IGS Workshop 2012

July 23-27, 2012

University of Warmia and Mazury

in Olsztyn

International GNSS Service Workshop Symposium

23 – 27 July 2012, Olsztyn, Poland

Welcome

Welcome to the International GNSS Service Workshop 2012, held at the University of Warmia and Mazury in Olsztyn, Poland from 23 – 27 July 2012. The meeting is hosted by the Department of Astronomy and Geodynamics; the Honorable Patronage is taken by the Rector of the University of Warmia and Mazury in Olsztyn, Prof. Józef Górniewicz, President of Olsztyn, Dr. Piotr Grzymowicz and Chairman of the Committee of Geodesy of the Polish Academy of Sciences, Prof. Marcin Barlik. Over 200 participants from 20 countries registered for the symposium. Over 115 posters and 35 oral presentations will be given during the one-week meeting at the Kortowo campus.

The local organizing committee has been led by Prof. Andrzej Krankowski with effort from Ewa Kaim, Monika Biryło, Marcin Uradziński, Rafał Sieradzki, Leszek Błaszkiewicz, Tomasz Sidorowicz and others. The scientific program committee has been led by Dr. Shailen Desai (Jet Propulsion Laboratory) with substantial input from the rest of program committee, session chairs and the IGS Governing Board.

We would like to welcome you for an Ice Breaker Reception on Monday and the Workshop Dinner on Wednesday that is organized by INS and Leica Geosystems Poland at Hotel Park, respectively. On Tuesday and Thursday for those interested in events, the Town Hall of Olsztyn has organized a visit to the Astronomy Observatory and Planetarium, and sightseeing of Olsztyn's Old Town and regatta on the Ukiel Lake as well.

Lunch will be provided as a part of registration at the Mathematics and Computer Sciences building.

The local organizing committee is delighted to be hosting you during this one-week meeting. Please, do not hesitate to ask us, as we hope you will enjoy the meeting, events and time you spend in Olsztyn.

We wish you rewarding debates and an unforgettable stay in Olsztyn!

Prof. Andrzej Krankowski

Head of the Local Organizing Committee

SPONSORS

Workshop Dinner sponsor

- when it has to be **right**

Whether you want to capture airborne data for an agricultural area, of a city or to record changes in a disaster area, you need reliable measurements and solutions for your entire workflow. When it has to be right, more geospatial professionals turn Leica Geosystems to help them collect, analyze and present spatial information. From terrestrial and GNSS surveying solution, through GIS, 3D laser scanning, metrology and airborne sensors, to integrated software for measuring, analyzing and presenting spatial information in 2D and 3D, Leica Geosystems is trusted worldwide to deliver unmatched precision, seamless integration and superior customer support. For more information, see Leica's website at www.leica-geosystems.pl

Ice Breaker sponsor

INS Ltd. - Provider of GNSS systems.

Since 1995, INS has provided it's clients with the most sophisticated GNSS (Global Navigation Satellite System) technology. So far, we have delivered over 5200 systems for nearly 500 clients in Europe. Our extensive list of customers includes research centers, Universities, military and other governmental organizations in Poland. We also work with private business sectors. The received reference letters and other written testimonies confirm reliability, professionalism and the commitment with which we complete every project.

IFEN GNSS Software receivers SX-NSR and GNSS Simulators NAVX-NCS are used by the University of Warmia and Mazury in Olsztyn and the Air Force Institute of Technology for the analysis of new GPS, GLONASS and Galileo signals, investigation of interferences affecting satellite signals, and experimentation with new positioning algorithms.

SEPTENTRIO PolaRxS and JAVAD Sigma-G3T 100 Hz receivers installed in 2011 as the test bench at the Satellite Observatory in Lamkówko (LAMK) are connected to the rubidium atomic frequency standard and collect GNSS observations as well as ionospheres' parameters (TEC and scintillation parameter S4).

Events sponsor

Olsztyn is the largest city and the capital of region of Warmia and Mazury. In the city of 650 years history live over 170 thousand people. Most famous monuments of Olsztyn are gothic castle, Cathedral of Saint Jacob and Upper Gate located on the boarder of old city walls.

The biggest advantage of the city is its unique location among the forests and the lakes. 12 (and some people say that even 15!) lakes and City Forest – one of the biggest European park are located within the borders of Olsztyn. To accent those advantages, the vision of Olsztyn development extracts to the conception of city garden. The defensive architecture of the XIV-century's Warmia, unrepeatable XIX- and XX-century secession and interesting performances, concerts and exhibitions – all of that cause tourists, who want cameral atmosphere and tranquillity, to seek in Olsztyn the possibility of the escape from the daily routine's noise. Strolling through the streets of the Old City they may admire the rests of city walls, castle's massive construction or overlooking the buildings cathedral's copula. Facing the original astronomical plaque (totally unique hand-made by Nicolaus Copernicus!) they have a chance to feel the blow of the history and later discover its present "face" at Olsztyn's planetarium.

Nicolaus Copernicus is the most famous person in the history of Olsztyn, where he managed goods and defended the city from Teutonic forces. Here he carried out his great researches and wrote magnificent works. Today four Olsztyn's colleges maintain this science tradition. Over 45 thousands people study in the largest of them – University of Warmia and Mazury.

Olsztyn is worth visiting – genuinely "Naturally Garden!".

VENUE and REGISTRATION

Venue and registration will be held at building of FACULTY OF MATHEMATICS AND COMPUTER SCIENCES (RCI), University of Warmia and Mazury in Olsztyn, Słoneczna 54



ICE BREAKER RECEPTION and WORKSHOP DINNER

Ice Breaker Reception: Monday 23 July 2012, Meet at 7:00 pm at Hotel Park

Workshop Dinner: Wednesday 25 July 2012, Meet at 7:00 pm at Hotel Park


WORKSHOP EVENTS

Olsztyn sightseeing on Tuesday and Thursday, 5:30 pm. More information about these tours will be provided during the workshop. Registration for those interested in these events will be at the registration desk on Monday, 23 July.

In Olsztyn we recommend (see on appendix Olsztyn plan):

Malta Café

Olsztyn, Lelewela 6A St.

Przystań

Olsztyn, Żeglarska 2 St.

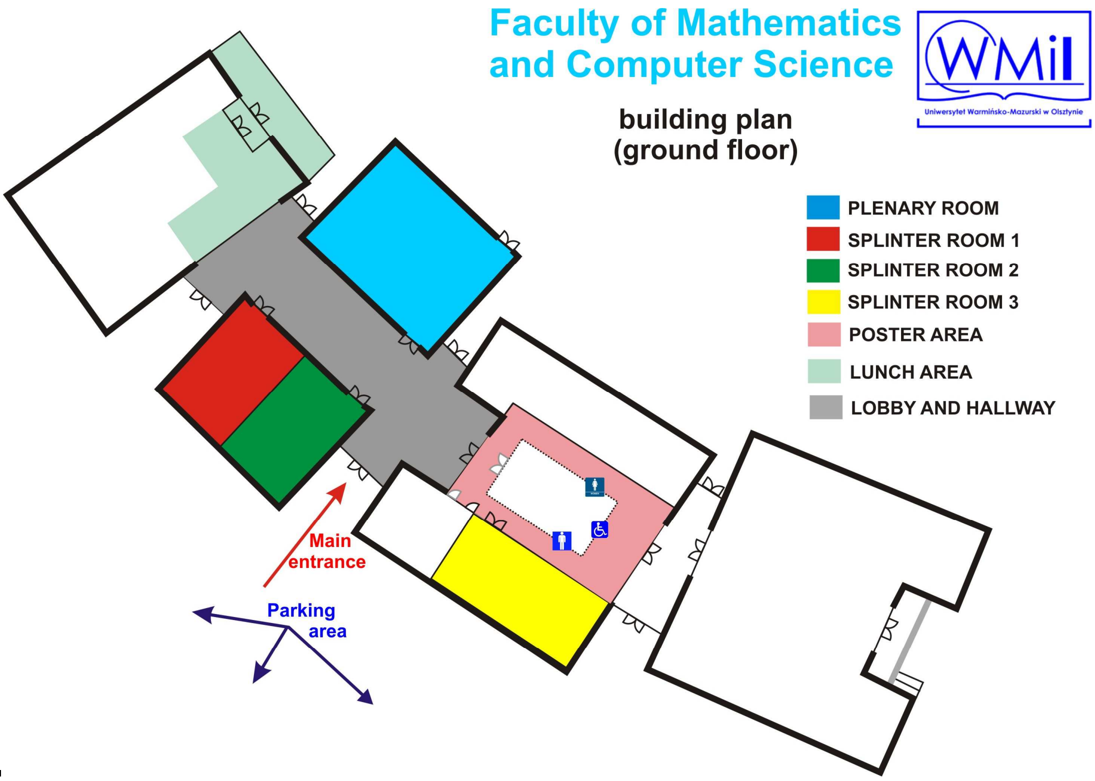
Karczma Jana

Olsztyn, Kołłątaja 11 St.

Highlander

Olsztyn, Stare Miasto 29/32

Plan of the FACULTY OF MATHEMATICS AND COMPUTER SCIENCES (RCI) building



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Splinter room 4 is on the first floor.

WIRELESS for VISITORS

Network : Goście/Guests

User name: igs2012@guests.uwm.edu.pl

Password: igs2012

Local Organizing Committee

Organizing Commitee Chair

Prof. Andrzej Krankowski

Organizing Commitee Members

BSc. Ewa Kaim

MSc. Monika Biryło

Dr. Marcin Uradziński

Dr. Rafał Sieradzki

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2012 International GNSS Workshop
July 23-27, 2012
University of Warmia and Mazury in Olsztyn (UWM)
Poland

Agenda

All posters on display Monday-Friday.

Monday, July 23, 2012– Morning

7:30-8:30 Check-in and Badge Pickup

8:30-10:00 Opening Plenary Session — R. Neilan
Plenary Room

8:30	UWM Welcome and Logistics	A. Krankowski
8:35	Official Welcome from UWM Rector	Prof. J. Gorniewicz
8:40	Welcome from Olsztyn President	Dr. P. Grzymowicz
8:45	IGS Welcome, Goals, Strategies, Objectives	U. Hugentobler
9:05	The International GNSS Service (IGS): The Secrets of a Success and the Challenges of the Future	G. Beutler
9:25	IGS Classic Products, Status and Towards the Future	J. Griffiths
9:45	IGS Products for GNSS Applications	T. Springer

10:00-10:30 Break

10:30-12:00 MGEX Campaign — R. Weber
Plenary Room

10:30	The IGS Multi-GNSS-Signals Tracking Campaign MGEX - Planning, Status, Perspectives	R. Weber
10:45	Challenges for Data Centers Supporting the Multi-GNSS Experiment	H. Habrich
11:00	MGEX Data Analysis at CODE - First Experiences	L. Prange
11:15	GNSS Bias Analysis at Shanghai Astronomical Observatory	J. Chen
11:30	Real-Time Stream Conversion to RTCM-3 MSM and RINEX-3 in IGS/MGEX Context	G. Weber
11:45	Discussion	R. Weber

12:00-1:30 Lunch (Mathematics and Computer Sciences building)

Monday, July 23, 2012 - Afternoon

1:30-3:00	**Network Infrastructure and Real-Time Plenary Room**	**C. Rizos**
1:30	The Real-Time Pilot Project and Transitioning to a New IGS Real-Time Service	M. Caissy
1:45	Data Flow and Format Issues to Support a Variety of Real-Time Services/Applications	G. Weber
2:00	Current State of the IGS Network	R. Khachikyan
2:15	Availability and Completeness of IGS Tracking Data	S. Lutz
2:30	IGS Network Challenges: Data Issues, Stations, Network, and Multi-GNSS	I. Romero
2:45	Discussion	C. Rizos
3:00-3:30	**Break**	
3:30-5:00	**GNSS Working Group Splinter Session Location : Splinter Room 1**	**R. Weber**
3:30-5:00	**Space Vehicle Orbit Dynamics Working Group Splinter Session Location: Splinter Room 2**	**M. Ziebart**
3:30-5:00	**Ionosphere Working Group Splinter Session Location: Splinter Room 3**	**A. Krankowski**
7:00	**Ice Breaker Reception Hotel Park**	

Tuesday, July 24, 2012 - Morning

8:30-10:00	**IGS and the Geodetic and Wider Community** **Plenary Room**	**U. Hugentobler**
8:30	The IGS: An IAG Service that Delivers	C. Rizos
8:48	The Interactions Between IGS and GGOS	M. Rothacher
9:06	What does FIG Surveyors Expect in Collaborative Partnership with IGS?	L. Hothem
9:24	Multi-GNSS Service Provision: The Role of the International Committee on GNSS and Possible Contributions from the IGS	D. Turner
9:42	The IGS Membership in the International Council of Science's World Data System	R. Neilan
10:00-10:30	**Break**	
10:30-12:00	**Multi-GNSS** **Plenary Room**	**R. Dach**
10:30	The International GNSS Service's Plans to Transition from RINEX 2.1X to 3.0X: Timeline, Procedures and Software Tools	K. MacLeod
10:45	Results from IGS Workshop on GNSS Biases, 18–19 January 2012 in Bern	S. Schaer
11:00	WHU's Developments for the GPS Ultra-Rapid Products and the COMPASS Precise Products	C. Shi
11:15	Development of a New Combination Software	E. Schönemann
11:30	Experience from Multi-GNSS Network Processing	A. Hauschild
11:45	Discussion	R. Dach
12:00-1:30	**Lunch (Mathematics and Computer Sciences building)**	

Tuesday, July 24, 2012 - Afternoon

1:30-3:00	**Poster Session** **Location: Poster Area at Mathematics and Computer Sciences Building.** **Presenters on attendance for following poster sessions**.. Session P1: The IGS Multi-GNSS Experiment (MGEX) Session P2: Space Vehicle Orbit Dynamics and Attitude Session P3: Ionosphere Observations and Modeling Session P4: Infrastructure and Data Centers	
3:00-3:30	**Break**	
3:30-5:00	**Infrastructure Committee Splinter Session I** **Location: Splinter Room 1**	**I. Romero**
3:30-5:00	**Bias and Calibration Working Group Splinter Session** **Location: Splinter Room 2**	**S. Schaer**
3:30-5:00	**Troposphere Working Group Splinter Session** **Location: Splinter Room 3**	**C. Hackman**
5:30	**Tour of Astronomy Observatory and Planetarium** **More information provided on first day of workshop.**	

Wednesday, July 25, 2012 - Morning

8:30-10:00	**Modeling Observations and Station Motion** **Plenary Room**	**J. Ray/T. van Dam**
8:30	Mitigation of Unmodeled Non-Tidal Atmospheric Pressure Loading into Parameters of a Global GNSS Solution	R. Dach
8:50	Summary of the 2012 Global Geophysical Center Workshop	T. van Dam
9:10	Analysis Effects in IGS Station Motion Time Series	P. Rebischung
9:30	Investigation of Non-Tectonic Signals at GPS Stations	C. Meertens
9:50	Discussion	J. Ray
10:00-10:30	**Break**	
10:30-12:00	**Atmospheric Delay Modeling and Applications** **Plenary Room**	**A. Krankowski/ C. Hackman**
10:30	GNSS Data and the Real-Time International Reference Ionosphere	D. Bilitza
10:45	Validation of GPS Signals During Geomagnetic and Ionospheric Disturbances	H. Rothkaehl
11:00	Recent JPL Advances in Ionospheric Specifications and Potential New Applications Using Ground on Space-Based GNSS Measurements	A. Komjathy
11:15	Modeling the Neutral Atmosphere Propagation Delay at UNB: Past, Present, and Future	M. Santos
11:30	Global Near-Real Time, Multi-GNSS and Ultra-Fast Troposphere Estimation at Geodetic Observatory Pecny	J. Dousa
11:45	GPS Meteorology With Single Frequency Receivers	Z. Deng
12:00-1:30	**Lunch (Mathematics and Computer Sciences building)**	

Wednesday, July 25, 2012 - Afternoon

1:30-3:00	**Poster Session** **Location: Poster Area at Mathematics and Computer Sciences Building** **Presenters on attendance for following poster sessions**. Session P5: Biases and Calibrations Session P6: Estimation and Application of GNSS-Based Troposphere Delay Session P7: Real-Time Services and Applications Session P8: Antenna Calibrations	
3:00-3:30	**Break**	
3:30-5:00	**Real-Time Working Group Splinter Session** **Location: Splinter Room 1**	**M. Caissy**
3:30-5:00	**Antenna Working Group Splinter Session** **Location: Splinter Room 2**	**R. Schmid**
3:30-5:00	**Data Center Working Group Splinter Session** **Location: Splinter Room 3**	**C. Noll**
7:00	**Workshop Dinner** **Hotel Park**	

Thursday, July 26, 2012 - Morning

8:30-10:00	**Space Vehicle Dynamics and Attitude, Clock Modeling and Time Scale Realizations** **Plenary Room**	**M. Ziebart**
8:30	Rotational Errors in IGS Orbit and ERP Products	J. Ray
8:50	GNSS Satellite Attitude Characteristics During Eclipse Season	F. Dilssner
9:10	Current Status of Non-Conservative Force Modeling and its Interface to REPRO2	M. Ziebart
9:30	GPS Timescale and Definition of IGS Timescale	K. Senior
9:50	Discussion	M. Ziebart
10:00-10:30	**Break**	
10:30-12:00	**Antenna Calibration Modeling and Errors** **Plenary Room**	**R. Schmid**
10:30	Three-Method Absolute Antenna Calibration Comparison	A. Bilich
10:45	Modeling and Correction of Carrier Phase Multipath Effects	C. Rost
11:00	Extension of the GPS Satellite Antenna Patterns to Nadir Angles Beyond 14°	R. Dach
11:15	Estimation of Azimuthal Satellite Antenna Phase Center Variations	F. Dilssner
11:30	The Geodetic Reference Antenna in Space (GRASP) – A Mission to Enhance the Terrestrial Reference Frame	Y. Bar-Sever
11:45	Discussion	R. Schmid
12:00-1:30	**Lunch (Mathematics and Computer Sciences building)**	

Thursday, July 26, 2012 - Afternoon

1:30-3:00	**Poster Session** **Location: Poster Area at Mathematics and Computer Sciences Building** **Presenters on attendance for following poster sessions**. Session P10: Analysis Combination Center and Reference Frame Session P11: Tide Gauge Benchmark Monitoring Session P12: General Geodetic and Geophysical Applications of IGS Products	
3:00-3:30	**Break**	
3:30-5:00	**Analysis Center Coordinator and Reference Frame Working Group Splinter Session** **Location: Splinter Room 1**	**J. Griffiths**
3:30-5:00	**Clock Product Working Group Splinter Session** **Location: Splinter Room 2**	**K. Senior**
3:30-5:00	**Tide Gauge Working Group Splinter Session** **Location: Splinter Room 3**	**T. Schoene**
3:30-5:00	**Infrastructure Committee Splinter Session II** **Location: Splinter Room 4**	**I. Romero**
5:30	**Tour of Olsztyn** **More information provided on first day of workshop.**	

Friday, July 27, 2012

8:30-10:00	**Geodetic Applications of IGS Products** **Plenary Room**	**G. Blewitt**
8:30	GNSS Analysis for Weather Applications Based on IGS Products	R. Pacione
8:48	Low-Latency Earthquake Displacement Fields for Tsunami Early Warning and Rapid Response Support	G. Blewitt
9:06	Strengths and weaknesses of the IGS contribution to the ITRF	Z. Altamimi
9:24	The Effects of Using Inconsistent Correction Models for PPP Users with IGS Products	T. van Dam
9:42	UNAVCO's Community Planning for Real-Time GPS in Earthscope's Plate Boundary Observatory Using IGS Products	C. Meertens
10:00-10:30	**Break**	
10:30-12:00	**Splinter Working Group Reports and Recommendations** **Plenary Room**	**U. Hugentobler**
10:30	Infrastructure Committee	I. Romero
10:37	Data Center Working Group	C. Noll
10:44	Real-Time Working Group	M. Caissy
10:51	GNSS Working Group	R. Weber
10:58	Bias and Calibration Working Group	S. Schaer
11:05	Ionosphere Working Group	A. Krankowski
11:12	Troposphere Working Group	C. Hackman
11:19	Antenna Working Group	R. Schmid
11:26	Clock Product Working Group	K. Senior
11:33	Space Vehicle Orbit Dynamics Working Group	M. Ziebart
11:40	Analysis Center Coordinator and Reference Frame Working Group	J. Griffiths
11:47	Tide Gauge Working Group	T. Schoene
11:54	Discussion and Closing Remarks	U. Hugentobler
12:00-1:30	**Lunch (Mathematics and Computer Sciences building)**	
1:30-5:00	**Governing Board Meeting** **Conference Room, Hotel Park** **Governing Board Members Only**	

Poster Sessions

Authors are requested to display posters by 8:30 am on Monday, July 23, and remove by 12:00 pm on Friday July 27. All posters should be on display for entire workshop**.** Authors requested to be available at their posters during assigned sessions.

Session P1: The IGS Multi-GNSS Experiment
Chair: R. Weber
Tuesday, July 24, 2012, 1:30-3:00 pm (Presenting authors available at poster)

P01-02	Performance Analysis of Compass Orbit and Clock Determination and Compass-only PPP	P. Steigenberger
P01-03	A COMPASS for Asia: First Experience with the BeiDou-2 Regional NavigationSystem	O. Montenbruck
P01-04	GFZ's Global Multi-GNSS Network And First Data Processing Results	M. Uhlemann
P01-05	A Single-Channel Validation Technique for All Available GNSS Observation Types	A. El-Mowafy
P01-06	Curtin and Delft Multi-GNSS M-GEX Stations: Infrastructure and Analysis Tools	N. Raziq
P01-07	A Data Center for Operation of Multi-GNSS Data	H. Habrich
P01-08	Precise Point Positioning for Characterization of GPS L5 biases UsingM-GEX Data	J. Tegedor
P01-09	Combined System Integrity Performance Analysis of Multi-Constellation Navigation	Xiaojun Duan
P01-12	GALILEO IOV Orbit Determination and Validation	S. Hackel
P01-13	MGEX Data Processing at CNES-CLS AC	S. Loyer
P01-15	MGEX Galileo Measurements Characterisations	F. Mercier
P01-16	Joint Reprocessing of GPS, GLONASS and SLR Observations - First Results	M.Fritsche

Session P2: Space Vehicle Orbit Dynamics and Attitude
Chair: M. Ziebart
Tuesday, July 24, 2012, 1:30-3:00 pm (Presenting authors available at poster)

P02-01	GPS-based Orbit Determination for LEO Satellites Using Double-Differenced Carrier-Phases	Z. Kang
P02-02	GNSS Orbit Validation Using SLR Observations at CODE	D. Thaller
P02-03	Analysis of the Usefulness of GRACE, NOAA and WGHM Models for the Flood Risk Assessment	M. Birylo
P02-04	Performance of the Selected Geopotential Models with theEmpirical Accelerations in the Aspect of GOCE SatelliteOrbit Computation	A. Bobojć
P02-05	Measuring the Extent of Error Gravity Anomalies Calculated from GRACE Data Within the Area of Poland	M. Birylo
P02-06	Orbit and Baseline Determination for Formation Flying Satellites Using Spaceborne Dual-frequency GPS	D. Gu
P02-07	Modeling and Characterization of the GPS Block II/IIA Attitude	J. Weiss
P02-08	Geocenter Coordinates and Polar Motion Estimated from a Combined Multi-GNSS Data Analysis	M. Meindl
P02-09	Adjustable Box-Wing Model for GNSS Satellites: Impact on Geodetic Parameters	C. Rodriguez-Solano

Session P3: Ionosphere Observations and Modeling
Chair: A. Krankowski
Tuesday, July 24, 2012, 1:30-3:00 pm (Presenting authors available at poster)

P03-01	On Traveling Ionospheric Disturbances Induced by Underground Nuclear Explosions and Earthquakes: Case Study	J. Park
P03-02	Generation of Hourly Global Maps of the Ionospheric Peak Electron Density and Peak Height from GPS_TEC Maps	T.L. Gulyaeva
P03-03	GNSS-Based Near-Real Time Ionospheric Monitoring over Europe Available On-Line	J.-M. Chevalier
P03-04	3-D ray Tracing of GPS Radio Occultation Paths	R. Norman
P03-05	Investigating the Quality of a New Regional Model of the Ionospheric Electron Content	N. Magnet
P03-06	The Occurence of the TEC Fluctuations at High Latitudes During Very Low Solar Activity.	R. Sieradzki
P03-07	GPS and Ionosonde Measurements at the Pruhonice Observatory	Z. Mosna
P03-08	Optimum Algorithms for Real-Time Ionospheric Scintillation Monitoring System	G. Nykiel
P03-09	Using of GPS TEC Observations and Radio Occultation Measurements for the Ionosphere's Monitoring	I. Zakharenkova
P03-10	Statistical Plasma Properties in Relation to Geomagnetic Activity Derived from Demeter Data	D. Przepiórka
P03-11	Ionospheric Drifts Estimated Using GPS Scintillation Data During Magnetic Storm on 5-6'th of April 2010	M. Grzesiak

Session P4: Infrastructure and Data Centers
Chair: I. Romero and C. Noll
Tuesday, July 24, 2012, 1:30-3:00 pm (Presenting authors available at poster)

P04-01	Improvement of the IGS station coverage in Latin America	L.Sánchez
P04-02	BRUX: A New EPN and IGS Reference Station in Brussels	W. Aerts
P04-03	CORSnet-NSW Adjustable Antenna Mount (CAAM) for GNSS CORS	R. Commins
P04-04	Availability and Completeness of IGS Tracking Data	S. Schaer
P04-05	Status and Plans for the NASA Global GNSS Network (GGN)	D. Maggert
P04-06	UNAVCO Development and Testing Activities in Support of the IGS GNSS Mission	F. Blume
P04-07	NASA's Next Generation Space Geodesy Network	S. Desai
P04-08	An Update on the CDDIS	C. Noll
P04-09	The ESA/ESOC GNSS Network Progress, Improvements and Planned Upgrades in the Station Network	M. van Kints
P04-10	The IGS Campaign to Measure Position Corrections for Un-calibrated IGSRadome Stations	I. Romero
P04-11	The Canary GNSS Center; An Effort to Promote Space Geodetic Data and Techniques for Africa	I. Romero
P04-12	GPS Data on CDAWeb	D. Bilitza

Session P5: Biases and Calibrations
Chair: S. Schaer
Wednesday, July 25, 2012, 1:30-3:00 pm (Presenting authors available at poster)

P05-01	GLONASS Inter-Frequency Code Biases and PPP Carrier-Phase Ambiguity Resolution	N. Reussner
P05-02	Monitoring of GPS-Galileo Inter-System/Signal Biases	D. Odijk
P05-03	Mitigation of Standing Multipath Based on Time-Frequency Analysis and Adaptive Filtering	J. Liu
P05-04	Wide-lane Bias and Fractional Phase-Bias Estimation for GIOVE and Galileo IOV Satellites	A. Hauschild
P05-05	Which IGS Products for PPP With Integer Ambiguity Fixing ?	F. Mercier
P05-06	Biases and Clock Modelling in the Frame of Ambiguity Resolution	E. Orliac

Session P6: Estimation and Application of GNSS-Based Troposphere Delay
Chair: C. Hackman
Wednesday, July 25, 2012, 1:30-3:00 pm (Presenting authors available at poster)

P06-01	Computation of the IGS Final Troposphere Product by the USNO	S. Byram
P06-02	Computation of Zenith Total Delay Residual Fields using Ground-Based GNSS estimates	B. Pace
P06-03	SUADA: Sofia University Atmospheric Data Archive	G. Guerova
P06-04	GNSS Research and Services at ROB to Support Meteorology and Nowcasting Applications	E. Pottiaux
P06-05	On the Use of the IGS REPRO1 Product for Climate Change Analysis: An IWV Inter-technique Comparison Study	E. Pottiaux
P06-06	An Evaluation of Real-Time, Near Real-Time and Post-Processed Zenith Total Delay Estimates	F. Ahmed
P06-07	Atmospheric Profiling using GPS Radio Occultation and Radiosonde Observations in the Australian Region	R. Norman
P06-08	IAG WG4.3.2 Inter-Comparison and Cross-Validation of Tomography Models – Aims, Scope and Methods	W. Rohm
P06-09	IGS Tropospheric Products - Quality Verification and Assessment of Usefulness in Climatology	M. Kruczyk
P06-10	The High Resolution Troposphere on the Area of GBAS System	J. Bosy
P06-11	Evaluation of Pressure Extracted from NCEP and CMC Global Numerical Weather Prediction Models Against In-Situ and GPT Pressure	M. MacAdam
P06-12	Tropospheric Products for Real-Time and Near Real-Time Applications	G. Moeller
P06-13	Fast-Static GPS Positioning with External Tropospheric Corrections Derived in Near Real-Time	J. Paziewski
P06-14	Advanced GNSS Tropospheric Products for the Monitoring of Severe Weather Events and Climate (GNSS4SWEC)	J. Jones

Session P7: Real Time Services and Applications
Chair: M. Caissy
Wednesday, July 25, 2012, 1:30-3:00 pm (Presenting authors available at poster)

P07-01	Technology of Reliable Rapid Static GNSS Surveying in Urban Area	M. Bakuła
P07-02	The CNES Real Time Integer PPP Demonstrator	D. Laurichesse
P07-03	On the Estimability and Reliability of Correction Models from CORS Networks	N. Lindenthal
P07-04	Generating UPD for IGS Combined Products for Ambiguity-Fixing of Real-Time PPP	M. Ge
P07-05	Real-Time GNSS Data Processing at the Technical University Vienna- Current Status and Upcoming Developments	F. Hinterberger
P07-06	BKG Ntrip Client (BNC) Version 2.6 – Recent Developments and Results	W. Söhne
P07-07	Control Methods of Real-Time Services of ASG-EUPOS	G. Nykiel
P07-08	Troposphere Model for PPP-RTK	J. Kaplon
P07-09	G-Nut Software Library for Implementing Various GNSS Applications	P. Vaclavovic
P07-10	Real-Time Operations at Natural Resources Canada, Geodetic Survey Division	M. Caissy
P07-11	Assessment of First Real-Time IGS Global VTEC Maps	M. Hernandez-Pajares
P07-12	Real Time Analysis Centre and AC Coordination Activities at ESOC	L. Agrotis

Session P8: Antenna Calibrations
Chair: R. Schmid
Wednesday, July 25, 2012, 1:30-3:00 pm (Presenting authors available at poster)

P08-01	Evaluation of Individual Antenna Calibrations Used in the EPN	Q. Baire
P08-02	Ray-Tracing Approach for Multipath Characterization Including Multiple Rays	M. Smyrnaios
P08-03	Current Research Activities at the IfE Antenna Calibration Facility	T. Kersten
P08-04	Absolute Antenna Calibration at the US National Geodetic Survey	A. Bilich
P08-05	Antenna Phase Center Calibration Effects on Sub-Daily and Daily Position Estimates	D. Sidorov
P08-06	Characterizing the GPS Satellite Antenna Phase- and Group-Delay Variations Using Data from Low-Earth Orbiters: Latest Results	B. Haines

Session P10: Analysis Combination Center and Reference Frame
Chair: J. Griffiths
Thursday, July 26, 2012, 1:30-3:00 pm (Presenting authors available at poster)

P10-01	First Combination of GNSS Solutions Submitted to IAG WG "Integration of Dense Velocity Fields in the ITRF"	J. Legrand
P10-02	GNSS-Based Processing at the USNO: Incorporation of GLONASS Observations	S. Byram
P10-03	IAG Dancer: Global Solutions for all Receivers in the World	H. Boomkamp
P10-04	Time Series Analysis of GNSS-SLR Co-located Stations	K. Sośnica
P10-05	Application of Wavelet Semblance Function to Comparison of Centre of Mass Time Series Determined by SLR, GNSS and DORIS Techniques	W. Kosek
P10-06	Activities at the CODE Analysis Center	R. Dach
P10-07	USNO Analysis Center Progress 2010-2012	C. Hackman
P10-08	The Stability and Dynamic Analysis of Chinese CGCS2000 CORS	Y. Dang
P10-09	Impact of Short Period Atmospheric Loading Signals	T. Herring
P10-10	Can We Decorrelate Geocenter Motion from Empirical Accelerations?	P. Rebischung
P10-11	Impact of Inconsistent Use of IERS Conventions on PPP results	H. Bock
P10-12	Current Status and Future Plans at the Natural Resources Canada (NRCan) Analysis Centre	B. Donahue
P10-13	GOP EUREF Permanent Network Reprocessing Using IGS05 and IGS08 Models	J. Dousa
P10-15	The JPL IGS Analysis Center: Status and Plans	S. Desai
P10-16	Incorporating Seasonal Variations Based on GRACE Measurements in Global andRegional TRF Models	R. Zou
P10-17	The ESA/ESOC Analysis Center Progress, Improvements and Planned Upgrades in the GNSS Data Processing	T. Springer

Session P11: Tide Gauge Benchmark Monitoring
Chair: T. Schoene
Thursday, July 26, 2012, 1:30-3:00 pm (Presenting authors available at poster)

P11-01	Towards a Vertical Datum Standardisation Based on a Joint Analysis of TIGA, Satellite Altimetry and Gravity Field Modelling Products	L. Sánchez
P11-02	The BLT IGS TIGA Analysis Center	F. Teferle
P11-03	An Evaluation of a Monte Carlo Markov Chain Method for the Statistical Analysis of GPS Time Series	G. Olivares
P11-04	The Potential of Persistent Scatterer Interferometry for Complementing GPS Installations at Tide Gauges – Experiences from the United Kingdom	L. Adamska
P11-05	The TIGA Data Assembly Centre SONEL: Recent Developments and Perspectives	M. Gravelle
P11-06	GPS Estimates of Vertical Land Motion for Altimeter Calibration	A. Santamaría-Gómez
P11-07	TIGA Network Coordination: Monitoring Data Fluxes and Providing Metadata	E. Prouteau
P11-08	Processing of a Regional EPN Sub-Network with Global IGS Sites at WUT EPN LAC: Experiences and Preliminary Results	T. Liwosz
P11-09	North Shields Tide Gauge: Local Ties Lessons	K. Palamartchouk

Session P12: General Geodetic and Geophysical Applications of IGS Products
Chair: G. Blewitt
Thursday, July 26, 2012, 1:30-3:00 pm (Presenting authors available at poster)

P12-01	Using IGS Products for Near Real-Time Comparison of UTC(k)'s	P. Defraigne
P12-02	A Focus on Estimated Coseismic Displacements using IGS Weekly Station Positions	D. Lercier
P12-03	Processing LEO Data and Gravity Field Determination at AIUB: A Status Report	U. Meyer
P12-04	Assessment of Single Epoch Integer Precise Point Positioning Performances	F. Fund
P12-05	Some Aspects of GBAS Application to Geodynamical Studies	J. Bogusz
P12-06	IGS Products in GNSS Time Transfer Using TTS-4 Receivers	A. Foks-Ryznar
P12-07	Atmospheric Loading Detection Using Regional GNSS Network: Case Study of Polish GBAS System	M. Rajner
P12-08	First Investigations on Using Galileo E5AltBOC for Time Transfer	M. C. Martinez-Belda

IGS Workshop 2012

Oral Presentation Abstracts

IGS Welcome, Goals, Strategies, Workshop Objectives

Urs Hugentobler

Technische Universität München, Munich, Germany

Abstract

The IGS Workshop is our opportunity to review the achievements and highlights in the past years and to discuss our focus areas, directions and challenges. The plenaries, poster sessions and splinter meetings cover all activities of the IGS with a special focus on the M-GEX experiment and real-time activities. The quality of data, products and services are continuously improved. IGS is transforming into a truly Multi-GNSS Service in the coming years. M-GEX focuses on the challenges of this transition in terms of understanding of equipment and signals, biases, data formats, and data analysis. IGS will issue a Real-time Service supporting public-benefit applications such as geophysical hazard monitoring and warning systems by providing openly available, global real-time GNSS products. This welcome presentation shall outline the objectives of the Workshop and address the goals of the IGS and strategies employed to expand the quality and reliability of its product portfolio in a changing GNSS landscape and growing interest in real-time applications.

The International GNSS Service (IGS): The Secrets of a Success and the Challenges of the Future

Gerhard Beutler

Astronomical Institute, University of Bern, Switzerland

Abstract

The essential stages of the development of the IGS, from the first plans at the IAG Scientific Assembly 1989 in Edinburgh to the start of the official service and the work since that time are briefly reviewed.

We then make the attempt to answer a few important questions: Why did the IGS becomea success? Why was it stable? Will it remain stable in future? Why was it not replaced by a more efficient commercial service?

What are the challenges of the future? Are multi-GNSS, real time orbit & clock determination, and LEO orbit & gravity field determinations the essential challenges? Has the IGS learned lessons, which would be important for the further development of GNSS? Does the IGS, e.g., have good arguments to ask for accelerometers and/or inter-satellite links on the next generation of GNSS satellites?

It will be challenging to address all these fascinating issues in just about 20 minutes. The attempt will be made.

IGS Classic Products, Status and Towards the Future

J. Griffiths and K. Choi

NOAA/NGS, Silver Spring, Maryland, USA

Abstract

The International GNSS Service (IGS) continues to provide satellite orbits and clocks, station clocks, Earth orientation parameters (EOPs), and terrestrial reference frame products. Currently, there are three product lines, namely the IGS Final, the IGS Rapid, and the IGS Ultra-rapid. These products are made available on a weekly basis, with a delay up to 13 (for the last day of the week) to 20 (for the first day of the week) days. These products are the basis for the IGS terrestrial reference frame and are intended for those applications demanding the highest internal consistency and best quality. The IGS Rapid products have a quality comparable to that of the Final products. They are made available on a daily basis with a delay of about 17 hours after the end of the previous observation day. IGS Ultra-rapid products are released four times per day with 3 hours latency—i.e., released at 03:00, 09:00, 15:00, and 21:00 UTC—making them available for real-time and near real-time use. Contrary to all other IGS orbit products, the IGS Ultra-rapid orbit files contain 48 hours of tabular orbital ephemerides, and the start/stop epochs continuously shift by 6 hours with each update. The first 24 hours of each IGS Ultra-rapid orbit are based on the most recent GPS observational data. The next 24 hours of each file are predicted orbits, extrapolated from the observed orbits. Normally, the predicted orbits between 3 and 9 hours into the second half of each Ultra-rapid orbit file are most relevant for true real time applications. All other orbit products contain only the 24 hours from 00:00 to 23:45 UTC.

The IGS generally aims to provide ~1 cm orbits and ~1 mm terrestrial frame products to meet the most demanding user needs. While the goal has not yet been met, the IGS has made good progress. Ray and Griffiths recently reported that the IGS GPS Final orbits have an accuracy better than 2.5 cm; the Rapids are of similar quality, with an inaccuracy of ~2.5 cm; and the 24h observed parts of the IGS Ultra-rapids have an accuracy of ~3.0 cm while the 24h predicted parts have an accuracy of about 5 cm. Inaccuracies of the IGS GLONASS orbits are about twice as large as for GPS. About half of the total error in the GPS orbits can be attributed to systematic time-varying rotational misalignment of the orbital frames (Griffiths and Ray, 2009; Gendt et al., 2010; Griffiths et al., 2012). Orbit mismodeling also contributes to these errors. Sub-daily alias and draconitic errors in the GPS orbits are largely caused by errors in the IERS diurnal and semi-diurnal EOP model (Griffiths et al., 2011). For most applications, the user of IGS orbit products will not notice significant differences between results obtained using the IGS Final and the IGS Rapid products. IGS weekly realizations of the combined terrestrial frame have accuracies of ~2 mm in each orthogonal horizontal component and ~5 mm in the vertical. The errors in the terrestrial frame probably arise mainly from inadequacies of the GNSS tracking stations, including the presence of uncalibrated radomes, near-field multipath effects and equipment changes, and mismodeling of tropospheric and ionospheric propagation delays. Many of these outstanding issues are indeed the focus of the IGS second reprocessing (i.e., IG2) campaign, the processing for which could be underway by early 2013. If all model changes intended for IG2 are in fact made, then the orbit and terrestrial frame errors should be reduced. However, there is currently no plan for a new IERS sub-daily EOP model or for mitigating inadequacies of the tracking stations, so one should temper their expectations for these aspects.

IGS Products for GNSS Applications

T.A. Springer

ESA/ESOC, Darmstadt, Germany

Abstract

The IGS is committed to providing the highest quality data and products as the reference for all Global Navigation Satellite Systems (GNSS) applications. The IGS serves a wide range of user communities, in particular Earth science research, multidisciplinary applications, and education. The IGS provides reliable, rapidly available, and highly accurate GNSS satellite orbit and clock solutions, convenient access to the International Terrestrial Reference Frame, and a number of other products including global ionosphere maps. The IGS products are in constant developments, the network is getting "bigger", the products are getting "better", and the delivery of the products is getting "faster". The key driver for the IGS has been, and still is, the "friendly competition", which is kept "alive" by the continuous IGS product comparisons and completely open availability of this quality control mechanism.

The IGS is faced with significant challenges in the near future! The GNSS world is developing very rapidly with the advent of the European Galileo, the Chinese Compass/Beidou, and the Japanese QZSS GNSS systems and the enhancements of the existing GPS and GLONASS systems. These developments will change the GNSS landscape dramatically. Consequently the IGS will be facing many challenges if it wants to successfully fulfill its mission of providing the reference for all GNSS applications.

We are convinced that the IGS is in an excellent position to face and address the challenges offered by the rapidly evolving GNSS landscape and we are confident that the IGS will remain able to respond to the ever increasing needs of its customers. But it implies that the IGS will have to take an active role in ensuring proper standardization of the huge amount of different observation types and corresponding products that will (have to) become available (MGEX campaign). This presentation gives a brief overview of the current status of the IGS product spectrum and the direction in which it will (have to) evolve to remain the reference for the future Global Navigation Satellite Systems landscape.

The IGS Multi-GNSS-Signals Tracking Campaign MGEX - Planning, Status, Perspectives

R.Weber

Abstract

Due to current modernization programs the existing Global Navigation Satellite Systems (GNSS) such as GPS and GLONASS already have, and will launch, new generations of satellites which provide additional signals to deliver better accuracy, reliability and availability of positioning. The Galileo system is currently represented by its first two IOV–satellites and will be upgraded by the scheduled launch of two more IOV–satellites planned in late 2012 as well as 14 FOC satellites until 2014/15. Furthermore, is China building up its own GNSS, known as COMPASS/BeiDou, which consists both of GEO and MEO satellites providing global as well as regional services. Japan's Quasi-Zenith Satellite System (QZSS) offers overlay services for the Asian-Oceania region, but with special focus on users in urban and highly masked areas.

The IGS is deeply involved in GNSS tracking, analysis and production of products for applications requiring the utmost accuracy. The Service provides the highest quality GNSS data and products in support of the terrestrial reference frame, Earth rotation, Earth observation and research, positioning, navigation and timing and other applications that benefit society. Up to now IGS operations have focused solely on signals provided by the GPS and GLONASS systems. In future IGS will take advantage of further satellite navigation systems. To facilitate this endeavor a test campaign has been launched in order to expand tracking capabilities and to support improved GNSS data analysis capabilities. This campaign shall encourage data analysts to investigate the quality of the measurements made using the new signals and the potential of processing multiple GNSS data sets. The campaign is also to be viewed as a means of fostering participation and cooperation with international space agencies and research organizations.

This presentation will review briefly the planning process of the Multi-GNSS-Signals Tracking Campaign MGEX and deal mainly with its current status. Furthermore perspectives concerning a potential prolongation of MGEX as well as the anticipated further outcome in terms of data analysis, benefits for already exiting and new IGS products and the mid term transition to a regular IGS multi-GNSS network will be discussed.

Challenges for Data Centers Supporting the Multi-GNSS Experiment

Heinz Habrich,Bruno Garayt, Carey Noll

Abstract

With the IGS Multi GNSS Experiment (M-GEX) there arise additional challenges for Data Centers (DCs) to support the new satellite constellations such as Galileo, COMPASS and QZSS that are going to be deployed in addition to the fully implemented GPS and GLONASS. With these new satellites, new signal types and frequencies arrive, which have not been considered in the legacy data format standards. The CDDIS, IGN, and BKG DCs are now supporting the M-GEX and must consider the requirements for M-GEX DCs, extending their operational structure, and developments required for data editing and quality control tools while maintaining their archives for users of the operational IGS data sets.

MGEX Data Analysis at CODE - First Experiences

L. Prange, R. Dach, S. Lutz, S. Schaer, M. Meindl, A. Jäggi

Abstract

The Center for Orbit Determination in Europe (CODE) is contributing as an analysis center to the IGS since many years. The processing of GPS and GLONASS data is well established in CODE's ultra-rapid, rapid, and final product lines.

In February 2012 the IGS has started its "Multi GNSS EXperiment" (MGEX), which is also supported by the CODE analysis center. Up to now about 30 IGS stations provide RINEX files in different versions containing not only data records of the well-established GPS and GLONASS but also of new GNSS currently being assembled. The analysis of MGEX data can be seen as a testbed for introducing the new GNSS into CODE's regular processing.

We will give a summary of the MGEX RINEX raw data monitoring at CODE and address some issues such as RINEX header inconsistencies and data format issues. Furthermore, the first results of a three-system (GPS, GLONASS, Galileo GIOVE and IOV) data analysis by a prototype for an operational rapid processing routine will be presented. The obtained GPS and GLONASS orbits will be compared to the CODE rapid products. GPS, GLONASS, and Galileo orbits will be validated by long-arc orbit fits and SLR measurements.

An outlook about CODE's future multi-GNSS activities (e.g., inclusion of further satellite systems, ambiguity resolution, handling of biases, extension to further product lines, adaptations of our Bernese GNSS Software) will be provided.

GNSS Bias Analysis at Shanghai Astronomical Observatory

Junping Chen, Haojun Li, Xiao Pei, Yibing Xie, Yize Zhang, Xiaogong Hu, Bin Wu

Shanghai Astronomical Observatory

Abstract

Since February 2012, the International GNSS Service (IGS) starts the IGS M-GEX (IGSMulti-GNSS Experiment), which focuses on tracking the newly availableGNSS signals and to determine intersystem calibration biases. As a participants of the IGS M-GEX, we combine the observations of COMPASS stations in China and the Multi-GNSS stations from IGS M-GEX. Multi-GNSS benefits user with more observing satellites, however, complicated bias issues have to be addressed in order to achieve improved Positioning, Navigation and Timing performance. This paper presents results of the inter system bias (ISB) between GNSS systems and the inter-frequency bias (IFB), including the newly L5/L2C frequencies, of GPS Block IIF satellites and COMPASS satellites.

The inter system bias is the hardware delay in multi-GNSS receivers, which varies with time. It is different for each receiver but appears to be similar in the same receiver groups. The inter system bias between GPS and GLONASS system is routinely analyzed at the GNSS Analysis Center at Shanghai Astronomical Observatory (SHAO) based on combined GPS/GLONASS solutions. We present the GPS/GLONASS inter system bias time series at each multi-GNSS station and derive empirical model for the prediction of the ISB. As a system status indicator, we derive also the time offsets (TOs) between GPS and GLONASS system in our routine GPS/GLONASS analysis. From the TO time series, long term and short term periodical signals are detected and a model for the prediction of TOs is presented. The precise prediction of GPS/GLONASS time offset and inter system bias have been applied to Multi-GNSS positioning. Positioning results using our ISB and TO products in kinematic and static mode confirmed the improvement of the positioning accuracy.

Using the data of IGS M-GEX, we determine the inter frequency clock bias (IFCB), which is defined as the difference of the two ionosphere-free (DIF) phase observation combinations (L1/L2 and L1/L5). Usingdata of 18 stations from the IGS network spanning 96 days (DOY 224 to DOY 319, 2011),IFCBs for the two GPS Block IIF satellites were determined. For the determination of COMPASS satellites' IFCBs, data of 5 stations spanning the whole year 2011 is analyzed. We study the IFCBsfeatures of GPS Block IIF satellites and COMPASS satellites. Periodical variations of the IFCBs of GPS PRN25, PRN01 and COMPASS GEO, IGSO satellites are discussed in detail. Empirical models are developed for the prediction of IFCBs.

Real-time Stream Conversion to RTCM-3 MSM and RINEX-3 in IGS/MGEX Context

Georg Weber[1], Gerhard Wübbena[2], Ken MacLeod[3], Leos Mervart[4], Oliver Montenbruck[5], Dirk Stöcker[6], Tomoji Takasu[7]

[1]BKG
[2]Geo++
[3]NRCan
[4]CTU
[5]DLR
[6]Alberding
[7]Univ. Tokyo

Abstract

When IGS decided in August 2011 for the Multi-GNSS Experiment (M-GEX), it was foreseeable that we would not have an RTCM Standard for GNSS stream formats in place. Instead we would have to handle streams in various proprietary formats, convert them following a draft for RTCM's Multiple Signal Message (MSM) streams, and translate these to RINEX version 3 files. In view of the approaching end of the M-GEX campaign which is scheduled for August this year, it is time to summarize our efforts.

Which agencies and reference stations participate in M-GEX with real-time GNSS streams? Which manufacturers and receiver types could be involved? Which proprietary stream formats are in use? Is getting proprietary stream format documentation a problem? Are there problems with the proprietary stream contents? What is the status of MSM developments in RTCM? What is the status of phase alignments in that? Besides Galileo, are observations from COMPASS and QZSS accessible? Which tools are involved in stream conversion? Which tools can be used to access M-GEX streams and where can they be picked up? The presentation will contribute to answering these questions based on latest experiences.

The Real-Time Pilot Project and Transitioning to a New IGS Real-Time Service

M. Caissy

Natural Resources Canada, Geodetic Survey Division

Abstract

The IGS Real-Time Working Group (RTWG) was established in 2001 with the goal to design and implement real-time infrastructure and processes for the delivery of real-time data to analysis centres, and the dissemination of real-time products to users. In June 2007, the IGS announced the Call for Participation in the IGS Real-Time Pilot Project (RTPP) with a three-year target to accomplish its goals. In December 2010 a new consolidated charter was adopted for both the RTWG and RTPP with new goals for the period 2011 – 2012. These goals are intended to demonstrate that the IGS has the capacity to offer real-time GNSS data and real-time GPS orbits and clocks as part of a new IGS Real-Time Service (RTS).

Under this joint framework, the pilot project has been demonstrating existing real-time capabilities while the working group has been focused on enhancing and extending these capabilities through the implementation of the recommendations from both the Miami (2008) and Newcastle (2010) workshops. The presentation will show the IGS's state of readiness to offer a RTS. The current plan that is in place for transitioning from pilot project to official service will be highlighted.

Data Flow and Format Issues to Support a Variety of Real-Time Services/Applications

Georg Weber[1], Martin Schmitz[2], Wolfgang Söhne[1], Gerhard Wübbena[2]

[1]BKG
[2]Geo++

Abstract

IGS announced the upcoming operation of a real-time GNSS service. In the beginning it will comprise the dissemination of precise satellite orbits, clocks and code biases. The intention is to maintain a service free from outages and outliers and deliver products in a standard format so that manufacturers can finally implement their usage in firmware, e.g. for Precise Point Positioning.

The presentation shortly describes the RTCM State Space Representation (SSR) stream format and the Ntrip stream transport protocol used to disseminate our products over the open Internet. It then introduces the real-time network of broadcasters dedicated to enable accessing them. The concepts in place to minimize observation and product outages in the data flow through redundant reference station and Analysis Center resources are explained.

Feeling confident about an uninterrupted IGS real-time service is one pre-condition for making it part of receiver firmware. Following an open data policy with access to products without registration is another one. The presentation shows that the data flow and data formats in place allow reliable world-wide product access with low latencies although based on best effort contributions in kind. The BKG Ntrip Client (BNC) and Tomoji Takasu's RTKLIB are Open Source tools that can be used for real-time PPP applications till broader firmware support of SSR messages is realized.

Future work may include real-time stations from IGS densification networks like Europe's EPN. Considering regional and local atmospheric conditions through additional SSR messages could in the end make PPP an optional alternative to Network RTK.

Current State of the IGS Network

Robert Khachikyan

JPL, IGS Central Bureau

Abstract

The IGS Network has increased with multiple new GNSS stations located at sparsely covered areas and a few decommissioned stations. This discussion will include the changes occurred over the past years, the issues and concerns with the network and how to work with the future of GNSS including real-time dissemination of data.

Availability and Completeness of IGS Tracking Data

S.Lutz[1], S.Schaer[2], M.Meindl[1], R.Dach[1]

[1]AIUB: Astronomical Institute of the University of Bern, Bern, Switzerland
[2]swisstopo: Swiss Federal Office of Topography swisstopo, Wabern, Switzerland

Abstract

Timely availability of consistent GNSS tracking data is a basic condition for the generation of best possible analysis products. Problems concerning availability and completeness of IGS observation files are highlighted. The steadily increasing number of observation types is monitored for each individual station (and each relevant GNSS). The statistics show among others that the homogeneity of the reported types is no longer ensured.

IGS Network Challenges: Data Issues, Stations, Network, and Multi-GNSS

Ignacio Romero

ESA/ESOC, Darmstadt, Germany

Abstract

The IGS products are based on stable continuous and reliable infrastructure elements such as data centers, station network, individual stations, data formats, etc. The Infrastructure Committee aims to assist the Governing Board and the Network Coordinator in analysing and making recommendations to ensure the IGS necessary infrastructure is improved and stays as current and useful as possible. This presentation will go through some of the important infrastructure challenges and how the IGS is addressing them.

The IGS: An IAG Service that Delivers

Chris Rizos

President of the IAG

Abstract

The International GNSS Service is one of the Services of the International Association of Geodesy (IAG). Since its establishment in 1994, the IGS has been a trailblazer in a number of respects. The IGS was the first of the technique-specific services, and therefore pioneered many of the things that we now take for granted in the operations of IAG services. These include a clear governance structure, a well-defined product range, strong support for important IAG activities, and provision of an invaluable service not just to science, but also to society in general. Furthermore, the IGS is an embodiment of the “virtues” or “culture” that the IAG is promoting: international cooperation, engagement with developing countries, open data policies, federated/distributed geodetic structures and analysis, increased support for ground observatory infrastructure, and cutting-edge research. The IGS is also critical to the IAG’s Global Geodetic Observing System (GGOS) because the IGS will generate the high quality products that can address the requirements for high accuracy positioning and International Terrestrial Reference Frame maintenance. However, the IGS does have challenges, similar to those of other geodesy techniques, in ensuring that its infrastructure, its capabilities and its products are upgraded to meet the stringent requirements of GGOS and the ever increasing demands of its user communities. The IAG is proud of what the IGS has achieved, and looks forward to the expansion of the IGS’s role in the coming years.

The Interactions between IGS and GGOS

Markus Rothacher

ETH ZurichInstitute of Geodesy and Photogrammetry

Abstract

Almost 10 years passed since the Global Geodetic Observing System (GGOS) was established as a pilot project during the 2003 IUGG General Assembly in Sapporo, Japan. During this time period the International GNSS Service (IGS) and GGOS were closely interacting. This presentation will give an overview of the status and future of GGOS, review the relationship and interaction between the IGS and GGOS, and try to answer questions such as what GGOS expects to gain from the IGS, what might be missing, and what GGOS can offer to the IGS in return.

What does FIG surveyors expect in collaborative partnership with IGS?

Larry D. Hothem[1] , Mikael Lilje[2], Robert Sarib[3]

[1] U.S. Geological Survey, Reston, Virginia, USA
[2] Geodesy Department, Gävle, Sweden
[3] Survey Services, Dept. Planning & Infrastructure, Darwin, NT, Australia

Abstract

The International Federation of Surveyors (FIG) represents more than 300,000 surveyors from more than 120 countries throughout the world. With access through the member associations as well as the national delegates to respective FIG commissions, it is possible for effective communication of technical information. FIG Commission 5, Positioning and Measurement, is the lead for FIG in maintaining an effective and successful working relationship with the International Association of geodesy (IAG) and the IGS. The activities of Commission 5 working groups share common interests with IGS such as special emphasis attached to the practical aspects of reference frames and in strengthening the global geodetic infrastructure. Normally, surveyors are interested in conducting geodetic positioning surveys with GNSS where the results are easily and rapidly produced. Critically important is that the produced coordinates meet required accuracies and are referenced to a definenational reference systemthat is aligned to aninternational reference frame. Surveyors require easy access to necessary information required to calculate the coordinates. To meet knowledge needs of surveyors, such as awareness of best practices, IGS has an important role in continuing collaboration with FIG, such as convening joint seminars and workshops, partnering in development of technical sessions at FIG conferences, and in cooperating with FIG with preparation of fact sheets, guidelines, and other appropriate publications.

Multi-GNSS Service Provision: The Role of the International Committee on GNSS and Possible Contributions from the IGS

David A. Turner[1]

[1]Office of Space &Advanced Technology, U.S. Department of State

Abstract

The International Committee on GNSS (ICG) has become an important venue for both system providers and representatives of many GNSS user communities to discuss important issues regarding the civil use of multiple satellite navigation systems. Foremost among these issues is the pursuit of improved service from multiple systems through both complementarity and interoperability. While many aspects of service improvement can be addressed through coordination among system providers and explotiation by the receiver industry, there is also a potential role for independent monitoring networks such as the IGS network. This possibility will be explored by the presentation, and additional background information on the ICG, its history, and its current activities will also be provided.

The IGS Membership in the International Council of Science's World Data System

Ruth Neilan[1]

[1] IGS Central Bureau, Jet Propulsion Laboratory

Abstract

The international Council of Science has reorganized its multi-disciplinary bodies over the past few years, resulting in the establishment of a new World Data System (WDS). This new body is an integration of scientific services, mostly within IAG, \'a0and world data centers. This talk will provide an overview of the WDS, the accreditation process for membership in WDS, why WDS is important, and \'a0the role of IGS and other IAG services. A brief historical context will be given and include links to other external bodies.

The International GNSS Service's Plans to Transition from RINEX 2.1X to 3.0X: Timeline, Procedures and Software Tools

Ken MacLeod, Loukis Agrotis, Ignacio Romero and Mike Schmidt

Abstract

RINEX 2.1X is currently the primary archival format used within the IGS and the GNSS industry. However, since RINEX 2.1X was designed in the mid 1990s, primarily to support GPS, it has proven difficult to extend RINEX 2.1X to support new GNSS constellations and signals. As a result of the shortcomings of RINEX 2.1X, RINEX 3.0x was designed to provide generic and systematic support for: GNSS constellations, signals and observations. Given the needs of the IGS community and the strengths of RINEX 3.0X, the IGS plans to support RINEX 3.0X.

It was understood by the IGS that the transition from RINEX 2.1X to 3.0x has to be done in partnership with the GNSS community. One of the first step in this transition occurred in 2009 when the IGS joined the Radio Technical Commission for Maritime services-Special Committee 104 (RTCM-SC104). The primary objective of joining RTCM-SC104 was to more effectively communicate the needs of the IGS community to the GNSS industry and receiver manufacturers in particular. Since joining RTCM-SC104 the IGS has contributed to the development of an open, generic, high precision and multi-GNSS binary observation format called RTCM-Multiple Signal Messages (RTCM-MSM). The RTCM-MSM format supports the creation of fully defined, phase aligned RINEX 3.0x observations files. In 2011 the IGS and RTCM-SC104 further agreed to jointly: manage development and document the RINEX 3.0X format. It is believed that the synergy derived by having RINEX within RTCM-SC104 will help both the IGS and the GNSS industry orderly and efficient transition to RINEX 3.0X. Further, to support the transition to RINEX 3.0X the IGS/RTCM-SC104 RINEX Working Group is encouraging and supporting the development of several open source software tools that will both convert RTCM to RINEX 2.1X and 3.0X formats and provide data quality control measures.

With RINEX 3.0X support established and growing it is now time for the IGS to define a multi-year plan that describes the steps that: station operators, data and analysis centers, analysis software developers and data users should plan for in the coming years.

Results from IGS Workshop on GNSS Biases, 18–19 January 2012 in Bern

Stefan Schaer[1,2]

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[2]AIUB: Astronomical Institute of the University of Bern, Bern, Switzerland

Abstract

An IGS Workshop on GNSS Biases was organized on behalf of the IGS Bias and Calibration Working Group (BCWG) from 18 to 19 January 2012 at the University of Bern, Switzerland. Nowadays, a multitude of any types of GNSS biases is considered relevant. We will give an overview (also referring to results from this workshop), specifically of:

- GNSS differential code biases (DCB),
- CODE's DCB specialties (e.g., DCB multiplier estimation)
- GLONASS interfrequency code biases (relevant to GNSS clock estimation, or PPP),
- intersystem code biases,
- DCPB crucial for GLONASS ambiguity resolution,
- intersystem phase biases (or drifts),
- uncalibrated phase delays (UPD) relevant to undifferenced integer fixing for PPP,
- GLONASS-GPS station-specific intersystem translations as considered in CODE's GNSS analysis,
- IGS ANTEX model,
- (GPS) quarter-cycle issue (still crucial).

WHU's Developments for the GPS Ultra-Rapid Products and the COMPASS Precise Products

C.Shi, M, Li, Q. Zhao, W. Tang, Y. Lou, X. Dai, Z. Hu, H. Zhang, M. Ge, J. Liu.

GNSS Research Center at Wuhan University

Abstract

We present an overview of the recent developments in the processing of global GNSS data including COMPASS data at the GNSS Research Center of Wuhan University (WHU). In the first part, we provide details of the changes to the models and strategies of the PANDA software for providing GPS ultra-rapid products to IGS, the new solution based on the combination of the 6-hour normal equation, including orbit, clock and ERP products, from Wuhan University are been evaluated by IGS AC coordinator since Feb 3rd,2012.

In the second part, the precise orbit determination of COMPASS Satellites with precise positioning will be introduced. The 11th COMPASS navigation satellite was launched successfully on Feb 25th, 2012, the initial navigation and positioning services in the Asian-Pacific region have already taken shape. Results show that the radial precision of the COMPASS satellite orbit determination is reach up to 10 centimeters. The RMS of the difference compared with GPS solution of the daily static PPP by only COMPASS system can reach several centimeters.

Development of a New Combination Software

Tim Springer, Rolf Dach, Erik Schönemann, Matthias Becker, Urs Hugentobler, Robert Weber, Adrian, Jäggi, Werner Enderle

Abstract

As the situation with two fully operational GNSS (GPS and GLONASS) shows, the contributions between the individual IGS analysis centers (ACs) are quite inhomogeneous regarding the included satellites and systems (GPS, GPS+GLONASS, GLONASS-only, all satellites, only healthy satellites). With the new systems this problem will increase.

In this context an update or very likely a renewal of the IGS combination software is unavoidable. The goal of this activity is a consistent multi-GNSS orbit and clock combination by maintaining the present standard of quality of IGS products. The principle for this development is the maintenance of present products, whilst developing and introducing new GNSS products, usable for arbitrary GNSS, frequencies and signals. In addition the development of quality checking procedures for static and kinematic positioning, including ambiguity-fixing aspects are aspired.

In particular the clock combination will need an extended bias handling. It must consider the degrees of freedom for the biases between systems, observation/tracking types (for each GNSS), and in case of GLONASS also the inter-frequency biases. An additional challenge will be the fact, that some of the ACs already today provides satellite clock corrections, that can be used for a PPP ambiguity resolution. A future clock combination algorithm should not destroy such a characteristic.

The presentation will expose the identified requirements for the next generation IGS combination software. Apart from the technical realization several scientific questions have been identified during our discussions for the concept. In a first study we will give an example, based on the processing strategies at ESOC and CODE ACs for the combined GPS/GLONASS products. The two solutions will be compared and used for a PPP to highlight the open questions and a potential strategy towards updated and new IGS combination products.

Experience from Multi-GNSS Network Processing

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Affiliations:

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Abstract

The presentation discusses the practical implications of multi-GNSS processing and provides a summary of results obtained from data of the CONGO network. The main focus will be on challenges and current limitations of processing new constellations such as GIOVE/Galileo, QZSS, and COMPASS. Open issues in current IGS formats and models will be discussed and needs for standardization identified to allow consistent processing across the IGS community.

Mitigation of Unmodelled Non-Tidal Atmospheric Pressure Loading into Parameters of a Global GNSS Solution

Rolf Dach[1], Peter Steigenberger[2], Johannes Boehm[3], Adrian Jaeggi[1]

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[3]Institute of Geodesy and Geophysics, Vienna University of Technology, Austria

Abstract

It is an on-going discussion already since a long time whether non-tidal atmospheric pressure loading (APL) corrections shall be applied during the processing of space-geodetic data or whether the obtained station coordinates are corrected afterwards by the mean effect. Both approaches have pros and cons.

This study investigates the propagation of unmodelled effects into the system of results obtained from a GNSS (Global Navigation Satellite Systems) data analysis in a global network scenario typical for the analysis centers of the International GNSS Service (IGS). This assumes the analysis of a global network of about 250~GNSS tracking stations. Apart from station coordinates station-specific troposphere parameters, Earth rotation parameters and GNSS satellite orbit parameters are solved in a Least-Squares Adjustment.

Two solution series have been compared one with and the other one without correcting for APL directly on the observations. During the processing all applied APL-corrections have been recorded which allows for a direct comparison of the differences in the obtained station coordinates with the sum of corrections.

As expected most of the APL-effect can be found in the differences of the station coordinates between the two solution series. But also the troposphere and even the resulting GNSS orbits differ between the solution series with and without applying APL-corrections during the data processing.

Summary of 2012 Global Geophysical Center Workshop

T. van Dam

Abstract

The International Earth Rotation and Reference Systems Service's (IERS) Global Geophysical Fluid Center (GGFC) provides the geodetic community with data and models of geodetic effects (rotation, gravity, and deformation) driven by the temporal redistribution of the Earth fluids, as well as information needed for geodetic observations that are reliant on the state of the fluids. These include fluid motions within the Earth, such as the core and mantle, as well as the motions of surface fluids, e.g. oceans, atmospheres, and continental water. Both tidal and non-tidal domains are considered.

The GGFC is composed of four operational entities: the Special Bureau for the Atmosphere (SBA, Chair, D. Salstein), the Special Bureau for the Oceans (SBO, Chair, R. Gross), the Special Bureau for Hydrology (SBH, Chair, J. L. Chen), and the Special Bureau for the Combination Products (SBCP, Chair, T. van Dam). In addition to the products provided by the Chairs of the Special Bureaus, valuable products generated by the community are also made available through the GGFC. There are currently 3 GGFC Operational Product Centers that also contribute to the GGFC store of data.

Every so often the GGFC organizes a workshop to allow an opportunity for the Special Bureau Chairs, the GGFC Product Centers, and the GGFC user community to review the structure and data holdings of the GGFC and to perhaps make suggestions for new products. The previous meeting was held in 2007 and led to a fundamental reorganization of the GGFC structure. A particular goal of this workshop was to focus on assessing the errors in current environmental models and to solicit ideas for overcoming these limitations so that the data could be reliably used in geodetic and geophysical data analysis.

Thirty scientists from the geodetic community attended the workshop with an agenda of 20 presentations! In addition to a few short presentations by the SB chairs, there were presentations 1) reviewing some of the newly proposed GGFC Provisional Products, 2) comparing models with geodetic observations, 3) geodetic observations driven by fluid redistribution, and 3) a statement of current issues and future challenges for the GGFC and geodetic community. The workshop program and copies of the presentations are available at: http://www.iers.org/IERS/EN/Organization/Workshops/Workshop2012.html

The highlights of the meeting are summarized in the following recommendations:

Special bureaux should investigate forming intra-fluid weighted combined products of available models (including forecasts), in part to investigate ways to quantify (relative) errors of each model. However, this might complicate efforts to from multi-fluid products with full internal consistency (see below).

The GGFC should promote the development and use of dynamic barometer models and products, especially for short-period (less than ~10 d) applications.

Greater availability of sub-daily product sampling should be sought for all surface fluids (down to 3 hr or shorter).

Special bureaux should consider ways to move towards adoption of common product formats (and delivery modes), at least for load grids.

Efforts should be made to reduce the latency of the availability of the products required for operational use (for example especially when oceanic forcing is used). This might be addressed by provision of suitable forecast products if their accuracy is sufficient.

The GGFC angular momentum components should lead a community effort to review and elaborate recommended procedures and algorithms to compute EOP excitations from geodetic time series, especially to ensure the best fidelity for the high-frequency regime.

Apparent large discrepancies in surface hydrology EOP excitations should be investigated in view of the relatively better performance of such models in computing local surface load displacements than for global angular momentum variations. It seems likely that large-scale time-variable biases in the hydrology models might degrade globally integrated products, like EOP excitations.

Working with the Technique Services and the greater geodetic community, the utility of load corrections in geodetic data reductions needs to be much better quantified and put on a sound statistical basis taking account of actual SNR values for the loads as a function of sampling intervals.

Global mass conservation is one of the biggest issues facing the community. Mass conserving system models (i.e. atmosphere+ocean +water storage) do not exist for geodetic applications. The current solution is to sum different models. This leads to inconsistencies. Recommendation: Only models (for example ocean and hydrology) that are forced by the same atmospheric model and consider continental discharge into the oceans should be combined to compute total effects.

At the same time, a much better understanding of the nature and magnitude of internal measurement errors by all the space geodetic techniques is needed, especially at short temporal samplings, if these are to be used to evaluate fluid-based load models.

It is our hope, that over the next few years the GGFC and its user community can make progress on many of these issues.

Analysis Effects in IGS Station Motion Time Series

Paul Rebischung, Xavier Collilieux, Tonie van Dam, Jim Ray, Zuheir Altamimi

Abstract

The Earth's loading deformations are an important cause of seasonal motions experienced by permanent GNSS stations. Part of non-linear station motion time series derived from the IGS reprocessed products can thus be modeled using a combination of NCEP atmosphere, ECCO ocean and LDAS surface water load models. However, loading-corrected station time series still show significant residual signals. We investigate here how signals related to the GPS draconitic year contribute to those residuals.

Another means of tackling unmodeled IGS station motions is to study inter-AC discrepancies (i.e. differences between AC and IGS combined weekly station positions). Geophysical signals should indeed cancel out in inter-AC discrepancy time series, leaving analysis related effects for interpretation. We will thus examine the spatio-temporal evolution of those discrepancies.

Investigation of Non-Tectonic Signals at GPS Stations

Charles Meertens, Henry Berglund, Christine Puskas, and Frederick Blume,

UNAVCO

Abstract

Differentiation of tectonic signals from those due to hydrologic loading, local site motions, multipath, and other near-field effects has been a long-term challenge. While regional effects of water and snow loads have been successfully modeled in the western United States, optimization of monumentation and site design to minimize noise and cost is a complex issue that has not been comprehensively addressed.

Much of the annual to interannual variability in the deformation signals observed in the 1,200 stations of the EarthScope Plate Boundary Observatory (PBO) can be attributed either to the effects of hydrological loading or to ground water level changes coupled with poroelastic effects. In order to characterize very local site effects (such as monument instabilities) at these longer periods it is first necessary to identify, and if possible model, these hydrologic effects. Where natural surface loading effects predominant, such as in mountainous areas, deformation can be modeled using the Global Land Data Assimilation System (GLDAS) and a variety of land surface models (NOAH, MOSAIC, VIC and CLM). However for stations in sediment filled valleys, the ground water variations from natural and anthropogenic are the primary hydrologic effect and are difficult to model without ancillary local ground water level data and an understanding of the poroelastic properties of the sediments. Examples of recent analyses from the PBO will be presented.

Effects of monumentation style, antenna height, and other local effects can be best identified at collocated stations where multiple antennas are permanently installed very close to each other. We present analysis of three such sites: the UNAVCO test facility in Marshall, Colorado, a Plate Boundary Observatory station on the eastern shore of the San Francisco Bay, and a USGS/SCIGN station in southern California. Each of these station clusters have multi-year time-series that demonstrate how processed positions correlate with noise such as multipath on varying time scales using different analysis techniques.

GNSS Data and the Real-Time International Reference Ionosphere

D. Bilitza

School of Physics Astronomy and Computational Sciences, George Mason University, USA

Abstract

The International Reference Ionosphere (IRI) is an international project of the Committee on Space Research (COSPAR) and the International Union of Radio Science (URSI). IRI was developed as the empirical standard for specifying the densities and temperatures of the Earth's ionospheric plasma and is recognized as such by the International Standardization Organization (ISO). IRI has been updated and improved as new ground and space data became available and as the dependencies on geophysical parameters became better understood. The latest version of the model, IRI-2012, introduces significant improvements and new model parameters. These advances will be briefly discussed. But the main topic of this presentation is the recently started effort of developing a Real-Time IRI and the important role played by GNSS data in this endavour. The standard IRI model provides monthly averages based on several solar and magnetic indices that are given as input parameters. The Real-Time IRI will rely on the assimilation of real-time data into the standard model to represent real-time conditions. GNSS TEC and radio occultation observations are one of the most important data sources for this purpose. We will review some of the existing algorithms and their results and discuss the path towards a Real-Time IRI. We will also make suggestions regarding potential IRI-related data products for the IGS Iono data distribution.

Validation of GPS Signals During Geomagnetic and Ionospheric Disturbances

Hanna Rothkaehl

Space Research Centre Polish Academy of Sciences, Warsaw, Poland

Abstract

The magnetosphere-ionosphere-thermosphere system is strongly affected by electric and magnetic fields, particle precipitation, heat flows and small scale interactions. The magnetised solar-terrestrial space plasma is a highly non-linear medium, which exhibits many different types of turbulence and instabilities. Those emissions are produced mainly by natural perturbations, but some of them also have anthropogenic origin. A study of mass, energy, and momentum transport in the solar-terrestrial plasma is directly related to the study of space plasma turbulence. The feedback between the radiation belt region and the Earth atmosphere can be very important, although it is still not fully understood.

Geomagnetic storms cause strong changes in ionosphere. During storm horizontal gradients and scintillations of GPS signals increase. Irregular ionospheric gradients can complicate phase ambiguities resolving and as consequence will worsen the accuracy of GPS positioning. Storm-time geomagnetic conditions may influence also on the estimation of satellite/ receiver biases. Rapid phase and amplitude scintillations lead to degrade GNSS network performance.

The aim of this presentation is to show manifestation of ionospheric boudar layers structures and dynamic diagnosed by various measuring techniques as: in situ wave and plasma diagnostics registered on board of DEMETER satellite, GPS observations collected at IGS/EPN network, GPS observation carried out at the Antarctic and Arctic IGS (International GNSS Service) stations used and the data retrieved from FORMOSAT 3/COSMIC radio occultation measurements. We would like also to discuss the limitation of presented diagnose techniques with respect to different geomagnetic condition and localisation in space.

Recent JPL Advances in Ionospheric Specifications and Potential New Applications Using Ground on Space-Based GNSS Measurements

Attila Komjathy

Abstract

The NASA Jet Propulsion Laboratory (JPL) and University of Southern California (USC) have jointly developed the Global Assimilative Ionospheric Model (GAIM) to monitor space weather, study storm effects, and provide ionospheric calibration for various customers including NASA flight projects. JPL/USC GAIM is a physics-based 3D data assimilation model using 4DVAR and Kalman filter approaches to solve for ion and electron density states and other key ionospheric drivers. The JPL/USC GAIM technologies, now operating in real-time and post-processing modes, can routinely accept as input ground GPS TEC data from 1200+ sites including streaming and hourly GPS stations, occultation links from CHAMP, SAC-C, COSMIC and C/NOFS satellites, UV limb and nadir scans. In the presentation, first we will discuss recent advances in our assimilating ground-based GPS, C/NOFS and COSMIC occultation measurements using our GAIM system characterizing the ionosphere in 3D. We will elaborate on our improved space-based bias estimation techniques to generate high precision calibrated TEC measurements to be assimilated into GAIM.

We will also demonstrate incremental algorithmic improvements in our JPL Global Ionospheric Mapping (GIM) and bias-estimation techniques including the introduction of the new 2D high-resolution (1 degree by 1 degree at 15-minute resolution) 'JPLI' IONEX product that may potentially be used by the IGS community for improved ionospheric calibrations.

We conclude the talk by demonstrating the benefits of adding GLONASS measurements to our GIM and GAIM processing technologies. New and upcoming applications and first results will be shown for estimating very high precision TEC perturbations using real-time and post-processed GNSS observations from GEONET and IGS networks. We will demonstrate initial steps on how to integrate this GNSS ionosphere-based technology into a global tsunami warning system. Additional potential applications might include the remote sensing of ionospheric TEC perturbations generated by other natural hazards such as earthquakes and volcanic eruptions and human-made events such as nuclear tests.

Modelling the Neutral Atmosphere Propagation Delay at UNB: Past, Present, and Future

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Dept. of Geodesy and Geomatics Engineering, University of New Brunswick, Canada

Abstract

Modelling the neutral atmosphere has been an effort that has crossed generations of space geodesists. The refinements of models and mapping functions have resulted in an increasing accuracy in modelling neutral atmosphere delay, so much so that what is left seems to be an elusive millimeter. This presentation overviews the past and current efforts towards modelling the neutral atmosphere at UNB, with emphasis on the family of UNB neutral atmosphere models and on the current effort towards a continuous generation of a VMF1-type product. There has been a family of UNB3 and related models and mapping functions (UNB3 proper, UNB3m, and UNBw.na), which have found use in various products and services, including satellite-based augmentation systems such as the Wide Area Augmentation System. The development of models and the assessment of their accuracy over North America will be discussed as well as plans to have refined UNB models for other continents. A recent effort deals with the generation of a gridded VMF1 and ray-traced zenith delays derived from the U.S. National Weather Service National Centers for Environmental Prediction datasets, which has been ongoing on a test basis. This model has been called UNB-VMF1. The benefits of providing a service based on this model would include: 1) a backup in the event of the European Center for Medium-range Weather Forecasts-based VMF1 or zenith delays being unavailable; 2) greater compatibility with other numerical weather model-derived corrections, such as atmospheric pressure loading; and 3) the availability of tropospheric delay products derived from an independent source and ray-tracing algorithms should provide more robustness for combination products, which use these models. A discussion on the structure of the service as well as the results of recent validation tests is presented. The UNB-VMF1 service has been recently accepted as a provisional product of the International Earth Rotation and Reference Systems Service's Global Geophysical Fluid Center.

Global Near-Real Time, Multi-GNSS and Ultra-Fast Troposphere Estimation at Geodetic Observatory Pecny

J.Dousa

Geodetic Observatory Pecny, Research Institute of Geodesy, Topography and Cartography, Czech Republic

Abstract

Geodetic Observatory Pecný (GOP) has long-term experience in the estimation of precise tropospheric parameters from GNSS permanent statations under limited conditions of near real time. More than a decade, the GOP zenith total delays (ZTD) contributed to various projects in Europe (COST-716, TOUGH, E-GVAP, E-GVAP II) and operational ZTD results flow via a meteorological observation network (GTS) to the end users worldwide. Currently, we are aware of its operational assimilation in Météo France and UK MetOffice at least. This presentation will be focused on new developments in three domains: a) global near-real time ZTD solutions, b) GPS+GLONASS vs. stand-alone GPS and GLONASS ZTD estimation and c) ultra-fast ZTD estimation.

The global solution has been evaluated over a year with reprocessed IGS ZTD, radiosondes and UK MetOffice numerical weather model and it has been switch from testing to operational mode are within the E-GVAP project on UK MetOffice's request. The muli-GNSS solution has been tested since 2009 together with developing GOP ultra-rapid GPS+GLONASS orbits, and at that time a specific bias between stand-alone GPS and GLONASS has been identified. This almost dissapeared after adopting IGS08 phase centre offsets and variations, which has proved much better consistency between GPS and GLONASS solutions. Since that time the GPS+GLONASS ZTD solution is running operationally in parallel at GOP (until end of 2011 off-line and afterwards in near real time) and has been evaluated over more then 8 months. The solution will be switched to the official one within 2012 and it will definitely replace GPS-only GOP contribution to the E-GVAP soon. Last, but not least, the ultra-fast ZTD estimation (sub-hourly or quasi real time) for severe weather monitoring is beein developed and its first implementation and results will be presented too based on IGS RT PP activities.

GPS Meteorology with Single Frequency Receivers

Zhiguo Deng[1], Michael Bender[1], Florian Zus[1], Maorong Ge[1], Galina Dick[1], Jens Wickert[1],Steffen Schön[2]

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Abstract

Atmospheric water vapor plays a significant role in atmospheric processes and shows a high temporal and spatial variability. Observations with a high density in space and time are required. GPSobservations provide information of the atmospheric state with high temporalresolution and a spatial resolution limited by the density of the receivernetworks. In order to increase the spatial resolution of troposphericGPS delays, existing GPS networks of dual-frequency (DF) receivers can bedensified with low-cost single-frequency (SF) receivers. TheSatellite-specific Epoch-differenced Ionospheric Delay model (SEID) wasdeveloped at the German Research Centre for Geosciences (GFZ) to derive theionospheric corrections for SF GPS receivers from the observations ofsurrounding reference stations equipped with DF receivers.

This approach is validated using SF and DF data from a very dense GPS network with about260 stations in Germany. The ZTDs and slant total delays (STDs)derived from the SF and DF observations are compared with independent data fromweather models and water vapor radiometers.After it is shown that the SF and DF products differwithin the precision of the DF data (about 3 mmRoot Mean Square in ZTD) the ZTDs and STDs are comparedwith model equivalents derived from a numerical weather analysis (ECMWF). In general good agreement betweenis found; for a period of 11 days in August 2007 the mean deviation is 0.2% and the standard deviation is 0.55%.The GPS observations ofone station could be compared to the slant integrated water vapor of a watervapor radiometer performing hemisphere scans at different elevations. Again, thedata are consistent within the uncertainty of the observation systems.The three validation studies show that the ZTD, STD and SWV products obtainedfrom SF data are almost of the same high-quality as those from the DF data.

However, there are situations where the spatial interpolation used by the SEIDmodel has some limitations, e.g. during medium-scale traveling ionosphericdisturbances (MSTID). The impacts of ionosphere variations on the scale of interstation distances of tens of kilometers is discussed.

GNSS Satellite Attitude Characteristics During Eclipse Season

F. Dilssner, T. Springer, J. Weiss, G. Gienger, W. Enderle

Abstract

The presentation focuses on the attitude characteristics of GNSS satellites orbiting the Earth whilst experiencing eclipses. It provides an overview of the various kinds of GPS/GLONASS noon-/midnight-turn maneuvers and demonstrates how the existence of a horizontal satellite antenna phase center eccentricity can be exploited to derive the instantaneous state of the spacecraft's yaw-attitude using the technique of "reverse" kinematic point positioning (PPP). The agreement between yaw-angle profiles generated by different institutions (ESA vs. JPL) using different GNSS software packages (NAPEOS vs. GIPSY) will be assessed. Outstanding issues like, for instance, attitude-related inconsistencies amongst the individual IGS Analysis Center (AC) clock solutions and how to deal with GPS Block IIA post-shadow maneuvers will be addressed here as well.

Rotational Errors in IGS Orbit and ERP Products

J. Ray[1], J. Griffiths[1], P. Rebischung[2], J. Kouba[3], W. Chen[4]

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[4]Shanghai Astronomical Observatory

Abstract

Ignoring mostly radial biases due to neglect of Earth albedo and antenna thrust accelerations (e.g., Rodriguez-Solano et al., 2009), about half of the time-varying inaccuracies in daily IGS GPS orbits involve systematic rotations of the satellite constellation (Ray and Griffiths, 2010). A large part of the rotational orbit errors come from deficiencies in the IERS conventional model for subdaily tidal variations in Earth orientation, which are absorbed directly into estimates of the nearly resonant orbit parameters as well as being aliased into longer-period signals near annual (or GPS draconitic), 3rd draconitic harmonic, and fortnightly periods (Griffiths and Ray, 2011). Some portion of the subdaily tide model errors also gets absorbed into the daily IGS Earth rotation parameter (ERP) estimates, affecting the same long-period bands as for the orbits. While the need for an improved IERS model is clear, progress has been slow due to the difficulty of the task.

Judging from orbit and ERP differences among IGS Analysis Centers (ACs), other sources of rotational error must exist also. Any rotational shift of an AC terrestrial frame realization should affect its orbits and ERPs similarly, which is the basis for the quasi-rigorous Final combination procedure adopted by the IGS in 2000 (Kouba et al., 1998).

However, it is clear that inter-AC rotational differences are much greater for orbits than for ERPs, an indication that full internal self-consistency is generally not achieved by most ACs. It is logical to suspect that AC modeling of the satellite solar radiation pressure (SRP) parameters is involved. Most IGS ACs have adopted variants of the Bernese empirical model, but operational implementation and usage of a priori constraints varies widely among ACs. These factors could, among other things, cause subdaily tidal errors to be partitioned differently among ACs into their solution parameters.

There are some worrisome indications that the quasi-rigorous IGS Final combination procedure is flawed with respect to rotational consistency and stability, possibly due to insufficient internal self-consistency by individual ACs. For instance, a 3-cornered hat decomposition of recent Ultra-rapid, Rapid, and Final ERP differences surprisingly implies that the Final ERP errors are largest overall. There is a low- frequency component (annual periods and longer) in the ERP differences that is either an artifact of the Finals or common to the both Ultras and Rapids. Subdaily tide model errors should be common to all and so not affect the ERP differences, assuming all ACs correctly implement the IERS model. A common-mode error in the Ultra and Rapid ERPs could potentially arise due to tightly fixing their terrestrial frames, whereas the Finals solve for

the terrestrial frame together with the other products. However, simulation of the two types of frame realization fails to explain the size of observed ERP differences (about 1 mm RMS of net surface motion). This observation, together with the intra-AC rotational inconsistencies mentioned above, suggests that AC effects might be important as a source of excess Final ERP error.

Determining which IGS polar motion series, Rapid or Final, is more accurate is exceedingly difficult as there is no other comparable, independent source for this information. (Comparison of IGS length of day measurements against VLBI UT1 + LOD series might possibly be useful, but this has not been studied yet.) Time series of atmospheric and oceanic angular momentum are simply too noisy, especially at annual periods and longer. Instead, we have examined the rotational stability of Rapid and Final PPP solutions for a global network of reference frame stations. (Equivalent PPP results for the observed half of the Ultras are highly scattered due to sub-optimal Helmert alignment of the AC orbits in the Ultra combination procedure, something that can be improved.) Spectra for the RX and RY components, which should be related to polar motion variations, show consistently more power for the Final PPP solutions for periods longer than about 7 to 10 d. This is especially true near the annual period, an observation that is consistent with the 3-cornered hat results but not conclusive. On the other hand, there is more RX instability in the Rapid PPP rotations over intervals shorter than ~10 d, a difference not seen in the RY rotations. Spectra for the axial PPP rotations are more similar for the two IGS product lines, though instabilities are greater for the Rapids at both high (<10 d) and low (~annual) frequencies.

Considering all the evidence, a lack of strict internal consistency in various AC submissions probably induces rotational errors in the combined IGS Final products to a small but non-negligible degree. The combination strategy relies on the assumption of AC solution consistency with no unremovable over-constraints, which is difficult to verify externally. Preliminary tests with the new daily Final submissions give hope that changes in AC procedures might incidentally improve the Final product consistency and rotational stability.

Current Status of Non-Conservative Force Modelling and its Interface to REPRO2

Marek Ziebart, Stuart Grey and Shawn Allgeier

University College London

Abstract

In this presentation I review the current approaches for space vehicle surface force modelling employed in the principal software tools that contribute to IGS orbit products.

I present the principal technical opportunities and barriers relevant to the study area in the context of REPRO2

I give an overview of research and testing carried out at University College London over the last 12 years developing various themes around non-conservative force modelling, and outline a funded research programme that will run over the next two years developing next generation models. In addition I explain existing parallel and complementary research in the field going on in other institutions.

I show that there is a range of existing models with some track record of success that have yet to be trialled by the IGS, and argue the point that, just as we would for the gravity field, it is logical to exploit the best available analytical models prior to developing an empirical parameterisation based on analysis of residuals and orbit quality metrics. I suggest that, both in the interests of science and operations, the issue of an appropriate empirical parameterisation be re-visited.

GPS Timescale and Definition of IGS Timescale

Kenneth Senior

Naval Research Laboratory

Abstract

Technologies for position and navigation have continued to evolve and improve over the past several decades. Increased tracking network densification, improved tracking techniques, improved geophysical and orbit modeling, and improved clock technologies have all led to marked increases in precision and accuracy of positioning, navigation, and timing applications. Improved algorithms for timescale formation and the clock models to support them are also necessary in order to keep pace with these technologies, specifically to support clock synchronization and prediction within the Global Navigation Systems themselves. This presentation briefly discusses some of the clock modeling issues necessary for timescale formation specifically for use by Global Navigation Satellite Systems

Three-Method Absolute Antenna Calibration Comparison

Andria Bilich, Martin Schmitz, Barbara Görres, Philipp Zeimetz, Gerald Mader, Gerhard Wübbena

Abstract

Antenna calibrations of receiving antennas are an essential component of GNSS data processing. Antenna calibrations provide measurements of carrier phase delay/advance introduced by the antenna components, and calibration models of the mean phase center offset (PCO) and direction-dependent phase center variations (PCV) are important for achieving mm-level positioning accuracy. Absolute antenna calibrations, where the calibration values are independent of a reference antenna, have been used in the IGS since 2006.

Several absolute calibration institutions exist, each implementing a different calibration method. Since 2000, Geo++ GmbH has conducted field calibrations using a robot with 5 degrees of freedom (DOF) and all-in-view GNSS signals, and was the first IGS-accepted absolute calibration institution. There are two other institutions in Germany with similar robot field calibration systems who also contribute to the IGS. The University of Bonn conducts multi-GNSS calibrations in an anechoic chamber with a 2-DOF robot, and began contributing to the IGS in 2010. The Bonn method uses a network analyzer to compute full GNSS calibrations. The US National Geodetic Survey (NGS) is the newest system, using a 2-DOF robot in the field with only GPS capability at the time of this abstract. Each institution uses a different set of model assumptions and data reduction methods to compute absolute calibrations.

If all of the above methods are to properly contribute to the IGS, it is important to establish that absolute calibrations from different institutions are compatible with each other. Towards that goal, we conducted calibration tests where identical antennas were calibrated by Geo++, Bonn, and NGS. We present results of the three-method comparison for several classes of geodetic antennas (e.g. chokering, groundplane, rover) and discuss the similarities and differences.

Because the NGS absolute calibrations are the newest and least-known, we also present an overview of the NGS method, with specific information on how this method differs from Geo++ and Bonn. Detailed information on the NGS method and results will be presented in the accompanying poster session.

Modelling and Correction of Carrier Phase Multipath Effects

Christian Rost[1], Lambert Wanninger[2]

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Abstract

Carrier phase based positioning with GNSS (Global Navigation Satellite System) is influenced by various measurement errors. The majority of these errors can be mitigated or eliminated by differential techniques, by forming appropriate linear combinations of multi-frequency observations or by estimating additional parameters. For station dependent errors, these options do not exist. In particular the influence from reflected or diffracted signals cannot be mitigated or eliminated by these techniques.

Carrier phase multipath causes range errors from several millimetres to a few centimetres. Their effect on the position estimates are about the same size but often more pronounced in the height component when compared to the horizontal components. Multipath effects deteriorate if the ionosphere-free linear combination is used and if tropospheric parameters have to be estimated. On the other hand, long-term static observations mitigate the influence of these fluctuating effects.

Over the years a variety of approaches for reducing or correcting carrier phase multipath effects have been developed and published. These techniques can be classified into site-specific (station selection), hardware-specific (receiver and antenna), data processing-specific (weighting schemes) and station calibration techniques. The first part of the presentation will cover carrier phase multipath theory and its influencing parameters. In the second part, we will give an overview on mitigation techniques with special emphasis on station calibration techniques.

Extension of the GPS Satellite Antenna Patterns to Nadir Angles Beyond 14°

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Abstract

The absolute antenna phase center model igs08.atx adopted by the International GNSS Service (IGS) in 2011 is based on robot calibrations for more than 200 terrestrial GNSS receiver antennas and consistent correction values for the GNSS transmitter antennas estimated from tracking data of the global IGS ground network. As the calibration of the satellite antennas is solely based on terrestrial measurements, the estimation of their phase patterns is limited to a nadir angle of 14°. This is not sufficient for the analysis of spaceborne GPS data collected by low Earth orbiting (LEO) satellites that record - depending on the missions' orbital altitude - observations at nadir angles of up to 17°.

We use GPS tracking data from the LEO missions Jason–1/2, MetOp–A, GRACE, and GOCE to extend the IGS satellite antenna patterns to nadir angles beyond 14° using different processing strategies and two different GNSS software packages (Bernese, NAPEOS). In order to achieve estimates that are consistent with the phase center variations (PCV) currently used within the IGS, GPS satellite orbits and clocks are fixed to reprocessed solutions obtained by adopting the IGS conventional values from igs08.atx. Due to significant near-field multipath effects arising in the LEO spacecraft environment, it is necessary to solve for GPS (nadir–dependent only) and LEO (azimuth– and elevation–dependent) antenna patterns simultaneously. We combine the results obtained with both software packages and derive the PCV extension proposed for igs08.atx.

Estimation of Azimuthal Satellite Antenna Phase Center Variations

F. Dilssner, T. Springer, W. Enderle

Abstract

Designed to provide constant signal strength for any Earth-located user regardless of the satellite elevation, the L-band transmitting antenna installed on every GPS/GLONASS spacecraft consists of twelve helical elements arranged in two concentric circles. The outer circle is composed of eight elements whereas the inner circle contains four radiators. Due to the particular array design, however, the antenna assembly exhibits small variations in its phase pattern as a function of the direction of the outgoing signal.

In this presentation we report on the estimation of satellite antenna phase center offsets (PCOs) and variations (PCVs) employing fully normalized spherical harmonic functions of maximum degree and order (8, 4). We particularly focus on azimuth-dependent variations as those are not yet considered in the current IGS antenna model (“igs08.atx”). Since we perform a combined processing of GNSS ground-station data together with GPS inter-satellite tracking data from low-Earth orbiting (LEO) space-borne receivers, we are able to retrieve the antenna PCVs for the GPS constellation down to a nadir-angle of 17°. Furthermore, as the network scale can be determined from the dynamical POD constraints imposed by the physical trajectory model of the LEO spacecraft, we do not have to adopt it from an external terrestrial reference frame solution in order to solve for the PCOs’ vertical components (“z-offsets”).

The Geodetic Reference Antenna in Space (GRASP) – A Mission to Enhance the Terrestrial Reference Frame

R. Steven Nerem, Yoaz Bar-Sever, and the GRASP Team

Abstract

The Geodetic Reference Antenna in Space (GRASP) is a small satellite mission concept, currently being proposed to NASA's Earth Venture 2 (EV-2) announcement of opportunity, that is dedicated to the enhancement of all the space geodetic techniques, promising revolutionary improvements to the definition of the TRF, its densification, and accessibility. GRASP collocates GNSS, SLR, VLBI, and DORIS sensors on a supremely calibrated and modeled spacecraft, offering an innovative space-based approach to a heretofore intractable problem: establishing precise and stable ties between the key geodetic techniques used to define and disseminate the TRF. GRASP also offers a solution to another difficult problem, namely, the consistent calibration of the myriad antennas used to transmit and receive the ubiquitous signals of the present and future Global Navigation Satellite Systems (GNSS). We will describe how errors in the TRF impact our ability to answer key science questions, such as mean sea level rise, and present new analysis of GRASP's capability to improve various aspects of the TRF.

GNSS Analysis for Weather Applications Based on IGS Products

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Abstract

Application of GNSS for Numerical Weather Prediction (NWP) is a well established technique in Europe. It started with the successful COST Action 716; in July 2002 six processing centres were processing an European network of 150 stations. At the present time, EUMETNET supports the operational exploitation of more than 1,600 continuously operating GNSS stations in the framework of the European E-GVAP project (http://egvap.dmi.dk). Current state-of-the-art GNSS meteorology is focused on the assimilation of hourly tropospheric delays into NWP. Currently, 13 GNSS processing centres deliver data with a maximum latency of 90 minutes and with hourly updates processing a regional European network. Furthermore 2 processing centres are delivering data of a global network for global NWP applications. Advancements in NWP models (such as the Met Office UKV 1.5km model) with rapid update cycles requires observations with improved timeliness and with greater spatial and temporal resolution than is currently available. IGS plays a key role to assure the full operation of the GNSS meteorological applications: all the E-GVAP hourly solutions, with only a few exceptions, are based on IGS Ultra-Rapid products. Recent achievements in IGS RT PP activities, whose product quality for the ZTD estimation will be assessed, could enable the use of the PPP strategy as very promising for future efficient GNSS-meteorology due to steadily increasing number of operational GNSS site. Long-term comparisons of hourly tropospheric estimates w.r.t. radiosonde data as well as IGS and EUREF tropospheric products will be presented.

Low-Latency Earthquake Displacement Fields for Tsunami Early Warning and Rapid Response Support

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Abstract

For offshore earthquakes, particularly for extreme earthquakes at near-coast faults, most fatalities originate from tsunamis. Tsunami early warning is key for reducing the number of fatalities. For most large earthquakes, more than 80% of the fatalities occur because of late response, which often is due to insufficient rapid damage assessments. Improved estimates of where the main damage occurred are a fundamental input for a more efficient response planning. Aftershocks are a danger for rescue teams and other helpers, and predictions of the location of aftershocks provide valuable guidance for the planning of search and rescue operations.

Time series of surface movements derived from Global Navigation Satellite Systems (GNSS) observations contain information on the static offset as well as the shaking of the ground during an earthquake. The strain field derived from the surface displacements can be used to understand the changes in the stress field, which determine the likely location of aftershocks. There is a trade-off between the latency of the time series, the temporal resolution, and the accuracy of the displacements. Currently, two main products are widely used: (1) highly accurate daily coordinates available with order ten days latency; (2) low accuracy, low latency (order 1 to 10 s) coordinates sampled with 0.1 s or 1 s. There are many other option between these two end points, and it is important to understand the requirements in terms of latency, temporal resolution, and accuracy in order to make an informed decision on the goals for observation system, rapid analyses, and rapid products.

For tsunami-early warning, the static displacement field (1) allows a better estimate of the tsunamigenic potential of an earthquake, and (2) serves as an input for tsunami propagation models. For (1), acceptable latencies are on the order of a few minutes in cases were the time from event to impact is on the order of 10 to 20 minutes (e.g., in the Mediterranean, the Cascadia fault, and many areas in the Indian and Western Pacific Ocean). However, since the tsunamigenic potential depends both on potential and kinetic energy transferred to the ocean water, in addition to the displacements field, estimates of the rise time would be very valuable. For (2), we note that tsunami propagation models are most helpful for predicting the locations of the delayed impact (from 30 minutes to several hours), while in most cases, they do not help very much for areas in the near-field with impact times of below 30 minutes. Considering that current minimal computational time requirements for propagation models not using pre-computed functions are on the order of several minutes to tens of minutes, a latency of 5 to 10 minutes for the displacement field is acceptable. Here, too, having a model for the rise time and any segmentation of the rupture process would improve the tsunami propagation modeling. Estimating the rise time and rupture segmentation from GNSS would require a dense network and high temporal resolution (1 s or better).

For rapid damage assessment, the most important information is the maximum shaking that occurred in a location. Damage assessments with available software (e.g., HAZUS) typically take one hour, and improvements of the input (shakemaps) can significantly refine the assessment. The static displacement fields can be used to rapidly provide an estimate of the rupture process, which then in turn help to improve seismic models for the computation of the shakemaps. Latencies of 15 minutes are acceptable for the shakemaps, thus, the static displacement field is required within 10 minutes after the initiation of the event. The static co-seismic displacement field and post-seismic deformation are a measure for changes in the stress field, and Coulomb stress derived from GNSS measurements help to constrain locations of aftershocks. For this application, the accuracy of the strain field is a key requirement, and latencies on the order of one hour are acceptable.

Comparison of time series with 1 s and 5 minutes temporal resolution shows that the accuracy of the 5-minutes series is almost an order of magnitude better than for 1 s. A lower temporal resolution has the potential to give better estimates of the static coseismic displacement field as well as slow postseismic changes in the strain field. A core limitation for the determination of the coseismic and postseismic displacement field is the lack of low-latency accurate satellite orbits and clocks. Making available a very low-latency continuous data stream with accurate satellite orbits and clocks would significantly improve the ability to provide more accurate low-latency station time series and displacement fields.

Strengths and Weaknesses of the IGS Contribution to the ITRF

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Abstract

The IGS GNSS contribution to the ITRF formation is fundamental given its major role of connecting the three other techniques (VLBI, SLR, DORIS) together at co-location sites. The drawback of this situation is that any GNSS related bias would propagate to the ITRF global parameters (e.g. origin and scale) or to individual station positions and velocities. This paper reviews the IGS GNSS contribution to the ITRF, focussing on its strengths and weaknesses. Results of data analysis of extended time series beyond the ITRF2008 time-span, including refined IGS repro 1 solutions, will be used to examine (1) the GNSS origin and scale consistency with SLR and VLBI, (2) the level of agreement between local ties and space geodesy, with an emphasis on the impact of uncalibrated radomes and discontinuities at some co-location sites on the ITRF parameters. Recommendations to IGS will be addressed for its future contribution to the next ITRF solution (ITRF2013), expected to be released in mid 2014.

The Effects of Using Inconsistent Correction Models for PPP Users with IGS Products

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Abstract

We mainly investigate the effect of using inconsistent Ocean Tidal Loading models on GPS coordinate solutions. We use up to a 6-year span of GPS data from 85 globally distributed stations to compare solutions using ocean tidal loading (OTL) corrections computed in different reference frames: center of mass of the solid Earth (CE), and center of mass of the Earth system (CM). We compare solution sets that differ only in the frame used for the OTL model computations, for three types of GPS solutions. In global solutions with all parameters including orbits estimated simultaneously, we find coordinate differences of ~0.3 mm between solutions using OTL computed in CM and OTL computed in CE. When orbits or orbits and clocks are fixed, larger biases appear if the user applies an OTL model inconsistent with that used to derive the orbit and clock products. Network solutions (orbits fixed, satellite clocks estimated) show differences smaller than 0.5 mm due to model inconsistency, but PPP solutions show distortions at the ~1.3 mm level. The much larger effect on PPP solutions indicates that satellite clock estimates are sensitive to the OTL model applied. The time series of coordinate differences shows a strong spectral peak at a period of ~14 days when inconsistent OTL models are applied and smaller peaks at ~annual and ~semi-annual periods, for both ambiguity-free and ambiguity-fixed solutions. These spurious coordinate variations disappear in solutions using consistent OTL models. Users of orbit and clock products must ensure that they use OTL coefficients computed in the same reference frame as the OTL coefficients used by the analysis centers that produced the products they use; otherwise, systematic errors will be introduced into position solutions. All modern products should use loading models computed in the CM frame, but legacy products may require loading models computed in the CE frame. Analysts and authors need to document the frame used for all loading computations in product descriptions and papers. We also discuss the effects if PPP users utilize inconsistent elevation cut-off angle and antenna calibrations models with what used for IGS products.

UNAVCO's Community Planning for Real-Time GPS in Earthscope's Plate Boundary Observatory Using IGS Products

David Mencin, Bill Hammond, Charles Meertens, John Langbein and Bob Woodward

UNAVCO

Abstract

Recent advances in GPS technology and data processing are providing position solutions with centimeter-level precision at high-rate and low latency. These data will have the potential to improve our understanding in diverse areas of geophysics including properties of seismic, volcanic, magmatic and tsunami sources, and profoundly transform rapid event characterization and warning. Scientific and operational applications also include glacier and ice sheet motions; tropospheric modeling; and space weather.

UNAVCO hosted an NSF funded workshop in Boulder,CO on March 26-28 that brought together 70 participants representing a spectrum of research fields, including geodesy, seismology, weather, space weather and natural hazards with participants spanning the Western Hemisphere. The goal of the workshop was to develop a community plan for the use of real-time GPS data and associated products within the UNAVCO and EarthScope community. IGS combined products play a key role in processing PBO real-time GPS data and UNAVCO is a participant in the IGS Real Time Pilot Project. Preliminary recommendations from this workshop and UNAVCO plans for real-time GPS in the Plate Boundary Observatory will be presented.

IGS Workshop 2012

Poster Abstracts

P01-02

Performance Analysis of Compass Orbit and Clock Determination and Compass-only PPP

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Abstract

The Compass constellation currently provides four usable satellites in geostationary orbit (GEO) and five satellites in inclined geosynchronous orbit (IGSO). Based on a network of Compass-capable receivers from the IGS Multi-GNSS EXperiment (MGEX) and the Cooperative Network for GIOVE Observation (CONGO) orbit and clock parameters of the Compass GEO and IGSO satellites are estimated. The quality of these orbits and clocks is evaluated by internal consistency tests and Allan variances. On the one hand, a sub-meter orbit precision could be achieved for the IGSOs. On the other hand, the orbit precision of the GEOs is significantly worse due to only small changes in the observation geometry.

Due to the sufficient amount of Compass satellites, a Compass-only Precise Point Positioning (PPP) is already possible today. Based on the orbit and clock products mentioned above, Compass-only station coordinates and troposphere parameters are compared with corresponding GPS-only products. Finally, first results of the two Compass satellites in Medium Earth Orbit (MEO) launched in late April 2012 will be presented if tracking data of these MEOs are available.

P01-03

A COMPASS for Asia: First Experience with the BeiDou-2 Regional Navigation System

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Abstract

Following GPS and GLONASS, COMPASS/BeiDou-2 is the first new navigation system enabling stand-alone positioning in at least a regional context. Even though the contents of the broadcast navigation message has not been publicly disclosed so far, a pre-operational status has been reached and the COMPASS/BeiDou-2 navigation signals can already be tracked by various commercial multi-GNSS receivers. This enables the determination of COMPASS/BeiDou-2 orbit and clock products independent of the control segment and paves the way for initial experimentation.

The presentation provides an overview of the current (April 2012) status of the regional component of the COMPASS/BeiDou-2 system, which is based on a total of nine satellites in geosynchronous orbits. The signal quality and tracking performance is described based on a small network of receiversin the Asia-Pacific region. Special attention is given to the availability of three frequencies, which enables advanced ambiguity resolution concepts. First results of COMPASS/BeiDou-2 based absolute and relative positioning are presented.

P01-04

GFZ's Global Multi-GNSS Network And First Data Processing Results

M. Uhlemann, G. Gendt, M. Ramatschi

GFZ

Abstract

GFZ is operating a global GNSS station network since many years. With recent developments in receiver technology and new upcoming navigation satellite systems like Galileo an upgrade of our stations was needed to track all GNSS. We will present the current status and setup of our station network and the plan for future upgrades. All modernized stations are presently contributing to the CONGO network (led by DLR) as well as to MGEX campaign. First results from data processing performed with GFZ's Multi-GNSS capable software package EPOS-8 will be shown. The data usage sticks mainly on CONGO network whereas the focus of analysis lies on precise orbit and clock determination of Galileo's Giove and IOV satellites. Quality assessments are given based on phase residual statistics, clock and inter-system bias stabilities as well as comparisons with solutions obtained by TUM. Additionally an independent validation of the orbits is derived through SLR measurements.

P01-05

A Single-Channel Validation Technique for All Available GNSS Observation Types

A. El-Mowafy[1], P.J.G Teunissen[1,2] and N. Raziq[1]

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Abstract

In this contribution, a flexible technique for quality control and validation of multi-GNSS observations is presented. In this approach, un-differenced data of each satellite are independently processed at each epoch, where processing is performed in parallel for all observed satellites and sequentially applied. A geometry-free observation equation model is used and validation is performed using the local Detection-Identification-Adaptation (DIA)method. The presented approach is applicable to data of any GNSS with any arbitrary number of frequencies, and for real-time or post-mission processing.

Software utilising this approach is used during the IGS M-GEX experiment to validate GNSS observations collected at Curtin’s continuously operating multi-GNSS observing station in Western Australia. Validation is performed for all satellites in view of GPS, Galileo, GLONASS, COMPASS and QZSS, and for all observation types (L1, L2, L5, E5a, E5b,E5a+b, E6, LEX, B1, B2, and B3). The poster presents examples on output results, data analysis and diagnostics for satellite observations from different systems. Performance of the method is demonstrated.

P01-06

Curtin and Delft Multi-GNSS M-GEX Stations: Infrastructure and Analysis Tools

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Abstract

The GNSS Research Centre at Curtin University and Department of Geosciences and Remote Sensing at Delft University of Technology are contributing as the Australian and Dutch data providers and as a joint Experiment Analysis Centre in the International GNSS Service Multi-GNSS EXperiment (IGS M-GEX) campaign. In this poster, we present the details of Curtin's and Delft's continuously operating multi-GNSS M-GEX stations, their data streams, and the analysis tools used in the experiment. The stations have several high-grade GNSS receivers capable of tracking all GNSS systems and observation types. The capabilities of these receivers and antennas, monumentation of antennas, data archival and real-time streaming regimes available to the IGS community are described and summarised in the poster. The developed multi-system GNSS data validation, conversion and analysis tools used in the experiment are also discussed. Access details for the real-time and archived data streams and the analysis products will be provided.

P01-07

A Data Center for Operation of Multi-GNSS Data

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Abstract

The package of various satellite navigation systems is also known as Global Navigation Satellite System (GNSS). New satellite constellations such as Galileo, COMPASS and QZSS are presently going to be deployed in addition to the fully deployed GPS and GLONASS. With the new satellites new signal types and frequencies arrive, which aren't considered in legacy data format standards. The GNSS Data Center (GDC) at BKG accepts the challenge and implemented the operation of new data formats, e.g., RINEX version 3. Galileo, COMPASS and QZSS tracking data are now publicly available at GDC, while ensuring that tracking data of long-term projects will stay unaffected. This was achieved by creating additional data directories. GDC also supports the IGS Multi GNSS Experiment (M-GEX) that has been launched at the beginning of February 2012 and an M-GEX project directory was set up accordingly. A new tool for editing and analyzing RINEX version 2 as well as version 3 files is under development. A draft program version is now applied at GDC to concatenate hourly RINEX version 3 files into daily files.

P01-08

Precise Point Positioning for Characterization of GPS L5 Biases Using M-GEX Data

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Abstract

The latest generation GPS-IIF satellites transmit the new civil signal on L5, allowing for the very first time triple-frequency Precise Point Positioning (PPP). The benefits of a new signal include better reliability and redundancy for navigation users. However, in order to fully exploit the new signal for accurate positioning, a detailed analysis of the new pseudorange and carrier phase observables is needed. Differential code biases need to be characterized for the new signals, in terms of stability and repeatability, among different receiver brands. Additionally, recent studies (Montenbruck 2011) show that the L1/L5 ionosphere-free observable shows variations when compared to L1/L2 ionosphere-free observable. Proper characterization of the L5 carrier-phase becomes then critical for high-accuracy applications, especially when ambiguity resolution is attempted. These challenges can be addressed now using the M-GEX network, which provides the scientific community with adequate access to the GPS L5 tracking, using state-of-the-art geodetic equipment.PPP can be applied not only for accurate navigation, but also for efficient bias determination. Therefore, the main purpose of this work is to demonstrate how to integrate the L5 observables with the traditional L1/L2 PPP, which at the same time will allow us to estimate adequately relevant biases between signals. This technique can be also extended to new GNSS constellations (i.e. Galileo and Compass) that are also being tracked by M-GEX. This will be assessed depending on the availability of adequate ephemerides data.

P01-09

Combined System Integrity Performance Analysis of Multi-Constellation Navigation

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Abstract

Integrity is the capability of sending the alarm to the users timely when the navigation system is out of use and it is a significant performance parameter of satellite navigation system. A user may receive signals coming from several different satellite systems in future. For local users, it is important to make full use of the whole integrity information of all the constellations. It is necessary to take advantage of the integrity information coming from multiple satellite constellations in order to prevent users from errors that might represent an excessive risk.

The Galileo system establishes a precise concept of the integrity different from GPS/SBAS system. In GPS/SBAS system, both HPL(Horizontal protection level) and VPL(Vertical protection level) are given. While in the implementation of Galileo system integrity, the integrity indicators SISA(signal-in-space accuracy), SISMA(signal-in-space monitoring accuracy), and IF(Integrity Flag), and the integrity indicators of users are investigated, including the computation of the Galileo system integrity risk and the calculation of the level of protection of Galileo system.

Nowadays, there are mainly three kinds of approaches to calculate the combined integrity for different satellite systems. (1) “One-System-Based Integrity”, uses only one kind of algorithm for all the systems with transformed same integrity inputs. (2) “Parallel Integrity”, which is based on the use of independent algorithms, provides a Bayesian-frame posteriori integration of the integrity results. (3)A “weighted RAIM(Receiver Autonomous Integrity Monitoring)”, is used to calculate combined integrity of the redundant satellites by monitoring the values assumed by both the Integrity Risk and the Protection Level, since classical RAIM algorithms are designed to protect user from a single satellite failure at a time. We consider “One-System-Based Integrity” method and the “weighted RAIM” method to analyze the combined integrity for a scenario of multiple navigation systems, including the GPS, Galileo and Beidou. We analyze the different synthesized integrity computation strategy for the combined GPS, Galileo and Beidou signals in future.

As for “One-System-Based Integrity” method, since GPS employs the protection level concept, while Galileo prefers to compute the integrity risk at the alarm limit. Also the Beidou uses the similar Integrity concept with GPS/SBAS system or Galileo integrity concept, this paper examines GPS and Galileo integrity concept separately first. Using both “GPS-Based Integrity” strategy and “Galileo-Based Integrity” strategy, corresponding different integrated integrity equations for combined integrity approaches using data from GPS and Galileo and Beidou are constructed, and their results are analyzed for comparison.

As for the “ Weighted RAIM” method, we study the critical characters of multi-constellation navigation satellite system. Considering the critical parameters of RAIM algorithm, missed detection probability is given using the information of satellite failure probability, missed detection probability and integrity risk, horizontal protection level and vertical protection level are reanalyzed both in theory and mathematical simulation. Results show that the receiver autonomous integrity monitoring performance based on multi-constellation navigation satellite system is much better than based on a single constellation system. Both the missed detection probability and protection levels are improved. The availability of RAIM algorithm is enhanced. The Combined integrity analysis with comparison of different strategies of GPS, Galileo and Beidou would provide support for the future choice of combining integrity for multiple navigation constellations.

P01-12

Galileo IOV Orbit Determination and Validation

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Abstract

On 21st October 2011, Europe's Global Navigation Satellite System (GNSS) Galileo has reached the in-orbit validation (IOV) phase through launch of the first two IOV satellites. This phase is aimed at qualifying the Galileo ground and user segments through extensive in-orbit/on-ground tests and operations of a core spacecraft constellation as well as the associated ground segment. Since 16th January 2012, both satellites are transmitting navigation signals.

The satellites are continuously tracked by the Cooperative Network for GIOVE Observation (CONGO), a global network of 19 tracking stations established by the German Space Operations Center (GSOC/DLR) and the German Federal Agency for Cartography and Geodesy (BKG) in cooperation with several agencies including the Technische Universität München (TUM). Moreover, various stations of the IGS Multi-GNSS Experiment (M-GEX) are tracking the IOV satellites. This allows the analysis of the IOV tracking performance within the stated networks, that will be presented within the poster.

Satellite Laser Ranging (SLR) observations of the IOV satellites are used as an independent validation for satellite orbits derived solely from IOV microwave observations. The quality of IOV orbits from single and multi-day solutions will be discussed and the performance of the Rubidium Frequency Standards as well as the Passive Hydrogen Maser will be assessed.

P01-13

MGEX Data Processing at CNES-CLS AC

Sylvain Loyer[1], Felix Perosanz[2], Flavien Mercier[2], Hugues Capdeville[1]

[1] CLS
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Abstract

The common CNES-CLS team joined the group of the IGS Analysis Centers in 2008. The main motivations are to propose an alternative software (CNES POD GINS), an alternative processing strategy and to participate in the improvement of combined IGS products. Since beginning of 2012, in the frame of the IGS-MGEX experiment, multi-gnss data in RINEX3 format are considered at the IGS analysis centers.

The paper focuses on the recent activities of the CNES-CLS Analysis Center. In parallel with the official products containing already GPS and GLONASS observations, we processed several weeks of data including recently available MGEX stations. One of the main aspects is the add of Galileo observations coming from newly installed receivers in our multi-GNSS approach. We describe the strategy we propose (un-differenced approach), from the data preprocessing to the generation of the combined and consistent multi-GNSS products.

P01-15

MGEX Galileo Measurements Characterisations

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Abstract

In the MGEX network there are various receiver types. Here we focus on the observables measured for the four Galileo satellites (GIOVE A et B, IOV 1 and 2). A dedicated test campaign is conducted in CNES Toulouse to characterise the different available commercial receivers, in order to be able to process in a consistent way the data from the REGINA network, which are also available in the MGEX network.

The test is a zero baseline measurement between receivers. The different pseudo range biases will be analysed (for example there are systematic biases between some IOV and GIOVE data). Then the satellite widelane biases will be studied for the complete MGEX network, and a possible set of biases will be constructed (as for GPS in the GRG solution). These informations are unsensitive to the knowledge of the satellite orbits, so this study can be conducted, even with few active stations, and without precise orbits.

Then, using the orbit/clocks determination, which will be conducted in the GRG analysis centre in the next months using MGEX mesurements, other biases will be characterized (for example inter-system biases between GPS and Galileo).

P01-16

Joint Reprocessing of GPS, GLONASS and SLR Observations - First Results

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Abstract

A joint reprocessing of GPS, GLONASS and SLR observations has been carried out at TU Dresden, TU Munich, AIUB and ETH Zurich. Common a priori models have been applied for the processing of all types of observation to ensure both consistent parameter estimates and the rigorous combination of microwave and optical measurements.

Based on the first results, we evaluate the impact of adding GLONASS observations to the standard GPS data processing. In particular, changes in station position time series and day boundary overlaps of consecutive satellite arcs are analyzed. Moreover, the GNSS orbits are validated independently by SLR range measurements. Corresponding residuals indicate a significant improvement compared to previous analyses results of this type. Finally, we address preliminary results obtained from the combined GPS/GLONASS clock processing.

P02-01

GPS-based Orbit Determination for LEO Satellites Using Double-Differenced Carrier-Phases

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Abstract

With the successful application of GPS-based Precise Orbit Determination (POD) for Low-Earth Orbiting (LEO) satellites, the accuracy of the orbits has increased due to improvements in both the dynamical and geometrical models, the observation accuracy and the methods for using both improvements.. In this presentation, we describe recent advances in GPS-based POD for LEO satellites. The results presented here demonstrate that better absolute orbit accuracy is obtained using high-low double-differenced (DD) carrier phases formed by two GPS satellites, one ground station and one LEO satellite; while better relative orbit accuracy can be achieved using high-high DD carrier-phases formed by two GPS satellites and two LEO satellites. If both high-low and high-high GPS DD observations are used for LEO POD, both the relative and absolute orbit accuracy is increased. In addition, the impact of ambiguity resolution on the LEO POD accuracy is investigated. The criterion for most current ambiguity fixing methods is based on based the variances of the estimated real-valued DD bias. A new approach, is discussed which is based on the difference between the estimated and adjusted DD ionosphere free phase biases based on the resolved wide-lane and narrow-lane integers. For our investigation, we utilized data from the GRACE (Gravity Recovery and Climate Experiment) satellites. The orbit accuracy was assessed using a number of tests, which include analysis of orbital fits, Satellite Laser Ranging (SLR) residuals, K-Band Ranging (KBR) residuals and external orbit comparisons. The results show that improved orbit accuracy for the GRACE satellites can be achieved through the combination of high-low and high-high GPS DD observations as well as the ambiguity resolution. The inter-satellite baseline accuracy is improved by factor of two and a half, from 5 mm to 2 mm.

P02-02

GNSS Orbit Validation Using SLR Observations at CODE

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Abstract

SLR observations to GNSS satellites provide an independent validation of the orbits determined from microwave observations, thus, allowing us to assess the quality of the GNSS orbits.

We have reprocessed GPS orbits for the time span 1994-2012 and GLONASS orbits for the time span 2003-2012 at hand which were generated with the latest models. The validation with SLR observations is shown.

Since about one year, a few SLR stations are tracking the full GLONASS constellation. This allows more detailed studies on issues related to the orbital plane.

P02-03

Analysis of the Usefulness of GRACE, NOAA and WGHM Models for the Flood Risk Assessment

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Abstract

In connection with the implementation of tasks arising from the Directive 2007/60/WE of the European Parliament and the Council on flood risk assessment and management, it is worth noting how models that are based on GRACE data can be useful in the implementation of tasks arising from this Directive.

Poland is characterized by large flows of water courses mainly in spring, and the smallest in autumn and winter months. Many years of observation showed that the greatest threats for Poland cause prolonged heavy rains in parts of the upper Vistula and the Oder, and depressive Zulawy areas. Comparison of models that are based on GRACE data to the results of many years of observation makes it possible to predict the potential flood hazards. For this purpose, the pre-processed data obtained from the computing center DEOS from TU Delft, the NOAA hydrological model and WGHM meteorological model were used. Time series of hydrologic phenomena in Poland in monthly intervals for the area covered by the flood of 2010 were created and calibration of NOAA and WGHM data was conducted. Next, GRACE model was compared with calibrated land hydrology models. The authors noted a high degree of correlation of the analyzed models.

During the analysis of time series of data filtered with ANS filter, it was found that in 2010 the trend intensified the occurrence of floods. It was because of high value of EWT in March.

Based on the survey, it can be very likely to say that observations based on GRACE data are very useful for monitoring climate. The climate monitoring can and should be used to monitor the flood periods and for the realization of tasks arising from the Directive.

P02-04

Performance of the Selected Geopotential Models with the Empirical Accelerations in the Aspect of GOCE Satellite Orbit Computation

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Abstract

In this work, the chosen geopotential models are used for modeling of the orbit of the Gravity Field and Steady-State Ocean Circulation Explorer Mission (GOCE) satellite. Selected gravity field models include, among other things, the recent models from the GOCE mission and the models such as EIGEN-51C, AIUB-CHAMP03S, ITG-Grace2010s, EIGEN-5C, EGM2008, EGM96, OSU91a. A main tool for orbital research is the Toruń Orbit Processor (TOP) system, which is based on the Cowell 8th order numerical integration method. The TOP software computes a satellite orbit in the field of gravitational and non-gravitational forces, also taking into account the relativistic and empirical accelerations. The 1-day orbital arcs were computed using various geopotential models and empirical accelerations for the absorption of modeling errors. The set of the root mean squares (RMS) of the differences between the satellite positions on the computed orbits and on the reference orbit was determined. The reference orbit was the 1-day arc of the reduced-dynamic Precise Science Orbit (PSO) of the GOCE satellite delivered by the European Space Agency (ESA). When comparing the computed orbits with the reference orbit, parameters of the empirical acceleration models were estimated in order to achieve the lowest RMS values. The linear and non-linear models of the empirical accelerations were used in the numerical tests. The obtained RMS values are a measure of sensitivity of the given geopotential models in the aspect of error absorption using the empirical accelerations, especially the radial acceleration. This sensitivity is smaller for the recent geopotential models, compared with the older models coming, for example, from the eighties and the nineties.

P02-05

Measuring the Extent of Error gravity Anomalies Calculated from GRACE Data Within the Area of Poland

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Abstract

International Center for Global Gravity Field Model, which is under the auspices of the International Association of Geodesy, offers on its website the possibility of obtaining archival and currently published GRACE observation data. In the present study, raw and processed data for several data centers (JPL, CSR, DEOS, GFZ) were obtained from ICGEM sites.

The aim of this study was to analyze the extent of error gravity anomalies designated by the calculation centers. For the analysis selected relevant data from the years 2008, 2009, 2010 for February, March, May and November were chosen. There were significant differences between the values of gravity anomalies. Geographical distribution of gravity anomaly differences for Polish territory was determined. All required data was derived from several data centers. The aim of this work was to see where there are values above the level of 1.1 mgal, which is a accuracy requirement of Polish technical standard G-2. Similar analysis were also conducted for the area of neighboring countries and Scandinavia.

The results showed that data for several data centers which were obtained from ICGEM sites differ significantly. In the area of south-eastern Poland, limit value of 1.1mgal was exceeded, what does not allow the use of this data for geodetic work.

P02-06

Orbit and Baseline Determination for Formation Flying Satellites Using Spaceborne Dual-frequency GPS

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Abstract

Spaceborne dual-frequency GPS observations are commonly employed nowadays on low-Earth orbit (LEO) satellites for high-quality orbit knowledge and precise relative positioning of formation flight. We study on the data processing methods which are crucial to meet the high precision demands ofboth single satellite orbit and formation flying baseline determination. We emphasize our strategies from the aspects of phase error modeling, differenced phase technique and formation flying relative positioning. Software is developed at NUDT and the solutions are verified by GRACE data.

1) We probe into the phase error modeling and its impact on precise orbit determination (POD) of LEO satellites.Limiting factors are mainly encountered with the in-flight phase error modeling. The phase error is modeled as a compound error of systematic part and random part which both depend on the direction of GPS signal reception. The systematic part and standard deviation of random part in phase error model are respectively estimated by bin-wise mean and standard deviation values of phase post-fit residuals computed by direct orbit determination. By removing the systematic part and adjusting the weight of phase observation data according to standard deviation of random part, the orbit can be improved by POD approach again. For the 31-day GRACE data processed by precise orbit improvement, the root mean square (RMS) values of phase post-fit residuals are reduced by about 3 mm, the 3-Dimensional (3D) magnitudes of orbit improvement for GRACE A and GRACE B are 0.0153 m and 0.0131 m respectively, the 3D RMS values of orbit comparison results with JPL precise science orbitsare reduced from 0.0553 m to 0.0527 m for GRACE A and from 0.0515 m to 0.0502 m for GRACE B, and the relative positions obtained by zero-difference GRACE orbits are significantly improved by 0.38 cm K-band standard deviation.

2) We study the reduced dynamic orbit determination using differenced phase in adjacent epochs for Spaceborne Dual-frequency GPS. This method not only overcomes the shortcomings that the epoch-difference kinematic method cannot be used when observation geometry is poor or observations are insufficient, but also avoids solving the ambiguity in the zero-difference reduced dynamic method. As the epoch-difference method is not sensitive to the impact of phase cycle slips, it can lower the difficulty of slip detection in phase observation preprocessing. In the solution strategies, we solve the high-dimensional matrix computation problems by decomposing the long observation arc into a number of short arcs. By GRACE satellite orbit determination and compared with GFZ post science orbit, for epoch-difference reduced dynamic method, the RMSof radial, transverse and normal components are 1.92cm, 3.83cm and 3.80cm, and 3D RMS is 5.76cm. The solution’s accuracy is comparable to the zero-difference reduced dynamic method.

3) We obtain 1mm level baseline determination for two satellites formation using GRACE formation configuration. The key technologies of 1mm level baseline determination for GRACE formation are presented, including spaceborne dual-frequency GPS data preprocessing, zero-difference reduced dynamic orbit determination for single satellite, double-difference (DD) reduced dynamic relative orbit determination for two formation flying satellites, DD integer ambiguity resolution and so on. Precise orbit determination software is developed, with which GRACE two satellites orbits are estimated, and the results show that the baseline determination precision for GRACE two satellites formation is 1.36mm compared to the K-Band Ranging (KBR) observations, and the average success rate of DD integer ambiguities resolution is about 85%.

P02-07

Modeling and Characterization of the GPS Block II/IIA Attitude

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Abstract

We characterize GPS Block II/IIA shadow and post-shadow maneuvers by way of “reverse” precise point positioning (PPP). This technique takes advantage of the non-zero antenna phase center offset, representing the vector from the satellite center of gravity (CG) to the antenna phase center, to estimate the spacecraft yaw attitude. We begin with a standard GIPSY-based precise orbit determination (POD) solution for the GPS constellation, and use the estimated ground station troposphere, clock, and position, as well as the reduced-dynamic GPS orbit solution as input to a follow-up estimation where the spacecraft body-fixed x, y, and z antenna phase center offset components relative the CG are estimated as unconstrained stochastic white noise parameters every 30 seconds. The spacecraft bodyfixed z-axis points towards the Earth, x points along the velocity vector, and y completes the righthanded coordinate system. The yaw angle is defined as the angle between the spacecraft velocity vector and the body-fixed x-axis, and is directly observed from the reverse PPP estimates.

In this presentation we utilize the outlined approach to characterize both shadow and post-shadow maneuvers of the GPS Block II/IIA spacecraft over a period of eight years. The results indicate that the reverse PPP yaw angle estimates are determined with an accuracy of a few degrees, with significant potential for smoothing to improve precision. We fit linear models to the yaw angle estimates during shadow (when the spacecraft traverses umbra) and compare the resulting yaw rate to estimates from standard GIPSY POD solutions. On average the yaw rate estimates from both techniques agree to 0.003 deg/sec. Comparisons of empirical yaw attitude to the standard model (Bar-Sever, 1996) furthermore show excellent agreement in the timing of noon and shadow maneuvers. In light of this, we use the reverse PPP technique to validate the subtle dependence of the yaw bias on the angle between the GPS orbital plane and the plane of the Earth's orbit around the sun (“beta” angle). We additionally characterize post-shadow maneuvers for which data are typically removed in POD solutions because the direction and duration of the yaw maneuver to recover nominal attitude are not straightforward to model. We analyze post-shadow maneuvers in terms of yaw angle versus time, the turn direction, and orbit beta angle. Based on the empirical results we test possible approaches for including post-shadow data in future orbit reprocessing campaigns.

P02-08

Geocenter Coordinates and Polar Motion Estimated from a Combined Multi-GNSS Data Analysis

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Abstract

GPS-only, GLONASS-only, and GPS/GLONASS combined time series of geocenter coordinates and (subdaily) polar motion parameters were computed based on four years (2008-2011) of GNSS observations from a global network of 92 stations. Special care was taken to keep the GPS and GLONASS solutions fully consistent and comparable, in particular where the station selection is concerned.

We demonstrate the presence of GNSS-specific artifacts in the geocenter time series as well as in the polar motion series. These artifacts are explained by perturbation theory.

P02-09

Adjustable Box-Wing Model for GNSS Satellites: Impact on Geodetic Parameters

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Abstract

Modeling of non-conservative forces is a key issue for precise orbit determination of GNSS satellites. Furthermore, mismodeling of these forces has the potential to explain orbit-related frequencies found in GPS-derived station coordinates and geocenter, as well as the observed bias in the SLR-GPS residuals. Several authors also found orbit-related frequencies in the EOP (e.g. x-pole rate). Due to the complexity of the non-conservative forces, usually they have been compensated by empirical models based on the real in-orbit behavior of the satellites. Recent studies have focused on the physical/analytical modeling of solar radiation pressure, Earth radiation pressure, thermal effects, antenna thrust, among different effects. However, it has been demonstrated that pure physical models fail to predict the real orbit behavior with sufficient accuracy.

In this study we use a recently developed solar radiation pressure model based on the physical interaction between solar radiation and satellite, but also capable of fitting the GNSS tracking data, called adjustable box-wing model. Furthermore, Earth radiation pressure and antenna thrust are included as a priori acceleration. The adjustable parameters of the box-wing model are surface optical properties, the so-called Y-bias and a parameter capable of compensating for non-nominal orientation of the solar panels. Using the adjustable box-wing model we study the impact on the geodetic parameters, derived from a multi-year GPS/GLONASS solution, like station coordinates, geocenter and length of day (LOD). Furthermore, we also study the impact of stacking the box-wing parameters over several days, profiting from the constant nature of the adjustable box-wing parameters.

P03-01

On Traveling Ionospheric Disturbances Induced by Underground Nuclear Explosions and Earthquakes: Case Study

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Abstract

The ionosphere responds to earthquakes, tsunamis, tropical storms, chemical explosions, underground explosions, and other geophysical activities. These phenomena can generate disturbances in the ionosphere, referred to as traveling ionospheric disturbances (TIDs). The TID can be extracted from the ionospheric delay of GNSS signals by eliminating the dominant trend from the solar diurnal variation. The aim of this study is to discriminate the specific TID wave generated by the underground nuclear explosion from other events such as earthquakes. This study focuses on the TIDs induced by an earthquake and underground nuclear explosion (UNE), and the unique characteristics of the waveforms created by these two types of events are demonstrated.

To discriminate the waveforms of TID induced by UNEs from those generated by earthquakes, the North Korean UNEs, detonated in 2006 and 2009 were compared to the TIDs from the earthquake of 2011 that occurred in Tohoku, Japan. For each event, the GPS data from the vicinity permanently tracking stations were collected. Using the dual frequency GPS signals, the ionospheric delay was extracted that was converted to the total electron content (TEC) to observe the TID. The small fluctuations in the regional trend of the TEC, caused by the specific local events, were extracted by taking the numerical third order horizontal 3-point derivatives. The significant derivative peaks were considered as the TID waveforms. In addition, the coordinates of the epicenter of the event were determined by the detected TIDs at multiple stations with varying distances from the event.

This study focused on exploring the characteristics of the TID waveforms. The TIDs detected by the 3-point derivatives of the TEC signal were independently verified by a wavelet de-noising technique. The correlation coefficients (CC) between the TID signals of the UNEs of 2009 and 2006 were significantly higher than their CCs with the TIDs from the Japanese earthquake. In addition, the related power spectra revealed that the TID waveforms from the earthquake had significantly lower frequency components than the UNE-induced TIDs. The results of this case study indicate that TIDs induced by different events can be readily discriminated based on their distinctive spectral properties.

P03-02

Generation of Hourly Global Maps of the Ionospheric Peak Electron Density and Peak Height from GPS_TEC Maps

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Abstract

Conversion of Global Ionospheric Maps, GIM-TEC, to the ionosphere global instantaneous maps of foF2 and hmF2 is produced daily in IONEX format at (http://www.izmiran.ru/services/iweather/daily/) from the hourly UPC-GIM maps provided at (ftp://cddis.gsfc.nasa.gov/pub/gps/products/ionex/). Since October 2010, UPC (one of the IGS centers that produce GIM) started to provide GIM on an hourly basis using Kriging interpolation. The globally acknowledged model of the ionosphere, International Reference Ionosphere extended to the plasmasphere up to the Global Positioning System (GPS) satellite height of 20,200 km (IRI-Plas) is used in assimilative mode of operation using the GPS-derived (GIM-TEC) as input. The paper discusses the outcome of proposed technique and highlights the prospects of providing the global maps of the ionosphere peak parameters on-line for modeling purposes and operational usage.

This study is supported by the joint grant from TUBITAK EEEAG 110E296 and RFBR 11-02-91370-CT_a.

P03-03

GNSS-based Near-Real Time Ionospheric Monitoring over Europe Available On-Line

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Abstract

With the beginning of the 24th Solar cycle, the increased Solar activity requires having a close eye on the ionosphere to better understand the Space Weather physics and its effects on radio communications and navigations. In this frame, near-real time ionospheric models over Europe are now routinely generated at the Royal Observatory of Belgium (ROB). These models are available to the public through new interactive web pages at the web site of the GNSS team (www.gnss.be) and the Solar Influences Data Analysis Center (www.sidc.be) of ROB. The models are ionospheric Vertical Total Electron Content (VTEC) maps estimated every 15 minutes on a 0.5°x0.5° grid. They are based on the high-rate Global Navigation Satellite System (GNSS) observations of the real-time stations of the EUREF Permanent Network (EPN) provided by the ROB NTRIP broadcaster. The maps are published on the ROB web site with a latency of 5-7 minutes with respect to the last GNSS measurement.

In a first step, this paper presents the processing strategy used to generate the VTEC maps: input data, parameter estimation, data cleaning and interpolation method. In a second step, the VTEC maps are compared with external ionospheric products and models such as Global Ionospheric Maps (GIM) and climatological models. Finally, the tools developed to further exploit the product are introduced (e.g. on-demand animated VTEC maps, statistics with respect to the 15 previous days, VTEC time series).

These new near-real time VTEC maps will allow any user within the geographical scope of the maps to estimate in near-real time the ionospheric delay induced along the signal of any observed satellite. In the future, the web site will continuously be updated in response to evolving user needs. This paper opens doors to discussions with the user community to target their needs.

P03-04
3-D ray Tracing of GPS Radio Occultation Paths

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Abstract

Simulation results of GPS L-band signals received by Low Earth Orbit (LEO) satellites, determined using a new 3-D ray tracing technique, are presented. This study investigates GPS signal variability as a function of time and position due to the refractivity gradients in the ionosphere and atmosphere. The 3-D numerical ray tracing technique involves synthesizing ray tubes and producing ray parameters such as the group path, phase path, angle of arrival and signal strength. The 3-D ray tracing technique has homing-in capability as is able to accurately determine the correct directional path to intercept the LEO satellite. The 3-D ray tracing technique also accounts for the birefringent nature of the ionosphere caused by the presence of the Earth's magnetic field and can trace the ordinary as well as the extraordinary refracted ray paths. The International Reference Ionosphere (IRI 2007) model is used to represent the refractivity in the ionosphere and the POGO 68/10 magnetic field Legendre model. Realistic refractivity gradients based on meteorological data are used to represent refractivity in the stratosphere and troposphere. Results showing 3-D ray paths will be presented, which are important as current Radio Occultation (RO) techniques rely heavily on the excess phase of the received signal and assume spherical stratification of the refractivity, ignoring magnetic field effects on the GPS signals.

The GPS to LEO satellite L-band frequency 3-D signal paths are simulated focussing on paths traversing atmospheric gradients and ionospheric anomalies where the refractive gradients are greatest. The effects of the Earth's magnetic field on the GPS RO signal are presented.

P03-05

Investigating the Quality of a New Regional Model of the Ionospheric Electron Content

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Abstract

The ionosphere is part of the upper atmosphere which affects electromagnetic waves by its ionization. The resulting propagation delay is frequency dependent, so it can be determined with dual frequency measurements. In case of single frequency users ionospheric models are used to correct the measurements.

At the Institute of Geodesy and Geophysics (Vienna University of Technology) a new ionospheric model, labeled Multilayer Model, is under development. It consists of nine horizontal equidistant electron layers within the height range of the F2 layer, where the maximum of the ionization can be found. The remaining ionospheric layers (e.g. the E-layers) are currently not considered. The electron content of each of the nine layers is obtained from a simple model with very few parameters, like the current maximum VTEC and weighting functions to account for the spherical distance between coordinates of the sub-sun point and the IPP-points of interest. All parameters are calculated with hourly time resolution from a combination of global (IGS-stations) and regional GNSS observation data. The Multilayer-Model focuses on regional densification of global ionosphere models (e.g. IGS VTEC SH models) by means of a small and easy predictable set of parameters.

The B-Spline Model is processed at the DGFI (Deutsches Geodätisches Forschungsinstitut) by Michael Schmidt et al. Within this model the electron density of the ionosphere is interpreted as a free-form surface, which is approximated by a one-dimensional B-Spline function. This B-Spline model is again well suited to describe the regional variations of the electron content.

In this presentation VTEC values calculated with the Multilayer Model are compared to the results of the B-Spline Model in order to evaluate the new model. The research is done within the project GIOMO (next Generation near real-time IOnospheric MOdels) which is funded by the Austrian Research Promotion Agency (FFG).

P03-06

The Occurence of the TEC Fluctuations at High Latitudes during very Low Solar Activity

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Abstract

During the last few years the number of the GPS permanent stations at high latitudes have been increasing systematically. Currently the networks of the GNSS receivers make possible to study of the ionospheric irregularities with high spatial and temporal resolution. Since 2010 at GRL/UWM laboratory near-real time online service of the TEC variability has been developed. In order to investigate the occurrence of the high-latitude TEC fluctuations, 30 second GPS measurements are used. Based on observations from more than 100 permanent stations daily map of the TEC fluctuations as a function geomagnetic local time are created.

In this work the variability of the high-latitude ionosphere during the last extended solar minimum is presented. Main goals of the studies were the calculations mean of TEC index rate (mean ROTI) at high latitudes during very quiet ionosphere. On the basis near-real time daily calculations for year 2010 and data postprocessing for years 2008-2009, the monthly average maps of the TEC fluctuations were created. The results in appropriate way show the temporal and spatial range of the intensive fluctuations for quiet conditions. The presented results should be a good background layer for next studies during the coming high solar activity.

P03-07
GPS and Ionosonde Measurements at the Pruhonice Observatory

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Abstract

Ionospheric measurement has been provided at Pruhonice station (50N, 15E) since 1957 using various types of ionosondes. These observations were complemented using the Topcon G3 receiver in year 2010. While GPS measurement are widely used to study the state of the ionosphere combination of the ionosonde and GPS measurement is relatively rare. First results are presented from both quiet and disturbed days. The advantage of using two such a different methods of ionospheric observations in one place is discussed.

P03-08
Optimum Algorithms for Real-Time Ionospheric Scintillation Monitoring System

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Abstract

Disturbances occurring in the atmosphere are one of the most important factors affecting the precision and accuracy of GNSS measurements especially during ionospheric storm. Therefore precise investigation of this subject is extremely important in the context of the conducting and developing of high frequency satellite measurements. This study was made to select the optimum method of detrending raw GPS data and calculating phase scintillation from real-time high-frequency GNSS measurements. Several methods of trend eliminations have been tested with the following methods of calculating phase scintillations: standard algorithm, method proposed by Biagio Forte and the algorithm called CHAIN. All calculations were tested on the example EPN site TRDS (Trondheim) using the data from the period between 8th and 10th March 2012 (ionospheric storm). Moreover, paper presents a brief analysis of the impact of ionospheric disturbances for determined position. The best method was implemented in the operating system, developed by the Center of Applied Geomatics at the Military University of Technology. The main element of the system is reference station equipped with high-frequency Septentrio PolaRxS Pro receiver. Computing center management system is located in the MUT where data acquisition, calculations, storage and presentation of results are carried out. The entire system is managed by specially designed and written computer application with database server. Atmospheric parameters are calculated based on 50Hz measurement data received from the reference stations. All the information collected in one place and available online allows continuous monitoring of the atmosphere and its impact on the determined coordinates.

P03-09

Using of GPS TEC Observations and Radio Occultation Measurements for the Ionosphere's Monitoring

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Abstract

The information about the state of the Earth's ionosphere is a very important for GNSS community. Different radio methods and techniques are applied in order to study the ionosphere variability and structure. Nowadays the majority of the ionospheric research activities in a global scale are based on the measurements of navigation systems signals. Data provided by ground-based GPS receivers allows to estimate values of vertical total electron content (TEC) up to the 20,200 km. GPS measurements onboard Low Earth Orbiting satellites provide possibility to study ionospheric electron density distribution on a global scale. This paper presents results of the joint analysis of GPS/GLONASS observations and FORMOSAT-3/COSMIC radio occultation (RO) measurements at the extended solar minimum of cycle 23/24 over mid-latitudinal regions. COSMIC RO data for different seasons corresponded to equinoxes and solstices of 2007-2009 were analyzed. All selected RO electron density profiles were integrated up to the height of 700 km (altitude of COSMIC satellites), the monthly median estimates of ionospheric electron content (IEC) were retrieved with use of spherical harmonics expansion. Monthly medians of TEC values were calculated from diurnal variations of GPS TEC estimates during considered month. Joint analysis of GPS TEC and COSMIC data allows us to extract and estimate electron content corresponded to the ionosphere (IEC) and to analyse redistribution of electron content between bottom and topside parts of IEC as well as PEC (plasmaspheric electron content) for different seasons of 2007-2009. Percentage contribution of PEC to GPS TEC over mid-latitudes indicates the clear dependence from the time and varies from a minimum of about 25-30% during day-time to the value of 50-60% at night-time of winter season. Contribution of bottomside IEC has minimal values during winter season in compare with summer season (for both day and night time). The obtained results were compared with TEC, PEC and IEC estimates retrieved by Standard Plasmasphere-Ionosphere Model (SPIM, http://ftp.izmiran.ru/pub/izmiran/SPIM/) that has the plasmasphere extension up to 20,000 km (GPS orbit).

According to this approach it was analyzed several cases of ionospheric disturbances as reaction to moderate geomagnetic storms during extended solar minimum period.

We acknowledge the University Corporation for Atmospheric Research (UCAR) for providing the COSMIC Data and IGS community for GPS permanent data.

P03-10

Statistical Plasma Properties in Relation to Geomagnetic Activity Derived from Demeter Data

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Space Research Centre, Polish Academy of Sciences, Poland

Abstract

We have analysed measurements collected by Demeter satellite. The aim of this study is to derive statistical plasma properties by discribing various electron populations, characterizing them and relating their occurance to different geophysical conditions, including deep solar minimum.

We have investigated electron temperatures and wave acitivity. In such a way we intend to assign each electron population to certain types of waves in plasma, describe spatial and temporal scales of plasma turbulence and find apparent physical mechanism lying behind it.

P03-11

Ionospheric Drifts Estimated Using GPS Scintillation Data During Magnetic Storm on 5-6'th of April 2010

Marcin Grzesiak, Andrzej Wernik

Space Research Center of Polish Academy of Sciences

Abstract

We have analysed the ionospheric drift pattern during disturbed geomagnetic conditions on 5-6'th of April 2010 at high geomagnetic latitudes (Hornsund). The stress in the analysis is put on drift dependence on scale size of underlying electron concentration irregularities. We compare also spectral and correlation methods of drift estimation.

P04-01

Improvement of the IGS Station Coverage in Latin America

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Abstract

After the strong earthquake of February 2010 in the Chilean Region Maule, a huge percentage of existing IGS reference frame stations in South America suffered an irreparable discontinuity in their time series. According to IGS, SIRGAS and national GNSS analysis centres in Argentina and Chile, this earthquake produced co-seismic displacements between 5 m at the Pacific Coast and 2 cm at the Atlantic Coast in Argentina and Uruguay. Additional movements due to the post-seismic relaxation during the first months after the main earthquake and its aftershocks are also evident in the station position time series. Thereby, the reliability of the recently launched IGS08 reference frame decreased considerably in South America and the affected stations are no longer usable as a basis for the GNSS data analysis or to guarantee the long-term stability of the ITRF in this region. Keeping in mind the achievements reached within the regional reference frame SIRGAS and the planned second reprocessing campaign of the IGS global network, a set of continuously operating SIRGAS stations was proposed to be included in this reprocessing with the main objective of improving the IGS station coverage in Latin America. Initially, the IGS Regional Associate Analysis Centre for SIRGAS (IGS RNAAC SIR), with the support of the national organizations responsible for the reference frames in the Latin American countries, made a selection of about 70 SIRGAS stations which satisfy the IGS requirements. This selection was evaluated by the IGS Reference Frame Working Group, and after some interaction with the IGS Global Analysis Centres, it was decided to include 40 SIRGAS stations not only in the IGS reprocessing but also in the present routine IGS processing. SIRGAS provided the IGS data centres with the metadata and all existing observations (historical data) of the selected stations by the end of January 2012. Present measurements (since the beginning of 2012) of the operational stations are directly provided by the responsible Latin American agencies to the IGS. The next step is to manage, together with the IGS Network Coordinator, the formal integration of these stations in the IGS network. Accordingly, this presentation shows the geographical distribution and main characteristics of the SIRGAS stations contributing to the IGS network and it should serve as an advertisement to promote routine computation and usage of these stations within the IGS community.

P04-02

BRUX: A New EPN and IGS Reference Station in Brussels

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Abstract

On Feb. 14, 2012, after more than 19 years, the Royal Observatory of Belgium (ROB) had to decommission its EPN/IGS station BRUS (Brussels, Belgium). A new station, BRUX, located about 100 m from BRUS, was installed in 2006 in order to replace the original station.

Compared to BRUS, BRUX has improved performance thanks to better visibility and equipment and enhanced multipath mitigation. In addition, its antenna has been calibrated by the University of Bonn. The tie BRUS-BRUX has been measured with both terrestrial measurements as GPS.

P04-03

CORSnet-NSW Adjustable Antenna Mount (CAAM) for GNSS CORS

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Abstract

Global Navigation Satellite System (GNSS) Continuously Operating Reference Station (CORS) networks are being built and expanded around the world, contributing to the definition and realisation of geodetic reference frames as well as providing reliable and accurate positioning infrastructure for a wide range of applications. Depending on the purpose of the GNSS station, CORS antenna monuments vary from concrete pillars anchored to bedrock to masts attached to buildings. An antenna mount is then used to connect the GNSS antenna to the monument. In all cases it is desired to orient the CORS antenna to True North in order to gain maximum benefit from GNSS antenna modelling. Other requirements generally include the unambiguous definition of the survey mark below the antenna (supporting a clear definition of the Antenna Reference Point, ARP), a zero or minimal antenna height above the monument, and the use of a truly vertical 5/8th Whitworth thread spigot. This poster introduces the CORSnet-NSW Adjustable Antenna Mount (CAAM), developed by NSW Land and Property Information (LPI) for CORSnet-NSW, LPI's rapidly growing GNSS CORS network covering the state of New South Wales, Australia. The CAAM was purposely designed to be incorporated into (rather than simply attached to) antenna masts located on buildings or free standing pole monuments but can also be used for pillar monuments. Being free of removable parts, it is adjustable in order to orient the antenna to True North without introducing an antenna height, thereby allowing a clear definition and maximum traceability of the survey mark and the ARP.

P04-04

Availability and Completeness of IGS Tracking Data

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Abstract

Timely availability of consistent GNSS tracking data is a basic condition for the generation of best possible analysis products. Problems concerning availability and completeness of IGS observation files are highlighted. The steadily increasing number of observation types is monitored for each individual station (and each relevant GNSS). The statistics show among others that the homogeneity of the reported types is no longer ensured.

P04-05

Status and Plans for the NASA Global GNSS Network (GGN)

David Maggert[1], Dave Stowers[2], Nic Flores[1], Chuck Meertens[1]

UNAVCO
JPL

Abstract

The Jet Propulsion Laboratory (JPL) and UNAVCO operate NASA GNSS infrastructure consisting of a network of 61 permanent GNSS stations called the Global GNSS

Network (GGN). These stations, operated in cooperation with many international agencies and groups, represent approximately 16% of the active stations that make up the IGS permanent station network. The GGN thus provides access to GNSS ground tracking data that contributes to precise GPS orbit determination and terrestrial reference frame control for a wide array of NASA missions as well as providing public data access through the IGS structure.

A number of long running GGN reference frame stations are planned to receive equipment upgrades; specifically antenna plus radome upgrades required to support the increase in GNSS satellites and signal types. Changes at these stations require precise and delicate modification in order to adequately account for position offsets due to such equipment upgrades. Nine reference frame sites continue to use an AOA chokering antenna, several with uncalibrated domes, and use an older method of mounting the antenna which precludes the direct installation of a calibrated antenna radome combination. Plans for upgrade of the network and installation of new GGN sites over the next few years will be presented.

P04-06

UNAVCO Development and Testing Activities in Support of the IGS GNSS Mission

Frederick Blume, Lou Estey, Henry Berglund, and Andrea Prantner

UNAVCO

Abstract

The UNAVCO Facility is actively investigating a number of details critical to the implementation and operation of next generation high-precision GNSS net- works. The addition of new GPS signals and new GNSS constellations to IGS stations will require that new hardware, infrastructure, data formats and software be carefully evaluated and modified. UNAVCO's Development and Testing group is evaluating the current offerings from leading GNSS hardware manufacturers. Detailed comparisons of technical features, usability, data quality, and overall performance will be presented. Findings regarding the impacts of critical factors such as near-band RF interference and earthquake ground-motion on tracking characteristics of new hardware will be highlighted.

Many global GNSS stations which are collocated with other space geodetic techniques such as SLR, and VLBI are in need of equipment upgrades, especially antenna and/or antenna/radome replacement. The data from these stations are used in the determination of the Global Geodetic Reference Frame, thus requiring delicate modifications in order to preserve sub-millimeter accuracy in positions. Suitable techniques will be discussed.

The high reliance of data flow on UNAVCO's teqc pre-processing software and the IGS push to embrace RINEX 3.xx have been at odds, as teqc has been limited RINEX 2.1X . Many new GPS signals and GNSS constellations cannot be handled with current RINEX 2 versions. We will present new options for future teqc development that will implement full GNSS translation, editing, and quality control of all GNSS observables using RINEX 3.XX or enhanced RINEX 2.XX formats. BINEX 7f-05 format enhancements for new observables are also under active development.

P04-07

NASA's Next Generation Space Geodesy Network

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Abstract

NASA's Space Geodesy Project (SGP) is developing a prototype core site for a next generation Space Geodetic Network (SGN). Each of the sites in this planned network co-locate current state-of-the-art stations from all four space geodetic observing systems, GNSS, SLR, VLBI, and DORIS, with the goal of achieving modern requirements for the International Terrestrial Reference Frame (ITRF). In particular, the driving ITRF requirements for this network are 1.0 mm in accuracy and 0.1 mm/yr in stability, a factor of 10-20 beyond current capabilities.

Development of the prototype core site, located at NASA's Geophysical and Astronomical Observatory at the Goddard Space Flight Center, started in 2011 and will be completed by the end of 2013. In January 2012, two operational GNSS stations, GODS and GODN, were established at the prototype site within 100 m of each other. Both stations are being proposed for inclusion into the IGS network. In addition, work is underway for the inclusion of next generation SLR and VLBI stations along with a modern DORIS station. An automated survey system is being developed to measure inter-technique vector ties, and network design studies are being performed to define the appropriate number and distribution of these next generation space geodetic core sites that are required to achieve the driving ITRF requirements.

We present the status of this prototype next generation space geodetic core site, results from the analysis of data from the established geodetic stations, and results from the ongoing network design studies.

P04-08

An Update on the CDDIS

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Abstract

The Crustal Dynamics Data Information System (CDDIS) supports data archiving and distribution activities for the space geodesy and geodynamics community. The main objectives of the system are to store space geodesy and geodynamics related data products in a central data bank, to maintain information about the archival of these data, and to disseminate these data and information in a timely manner to a global scientific research community. The archive consists of GNSS, laser ranging, VLBI, and DORIS data sets and products derived from these data. The CDDIS is one of NASA's Earth Observing System Data and Information System (EOSDIS) distributed data centers; EOSDIS data centers serve a diverse user community and are tasked to provide facilities to search and access science data and products.

The CDDIS data system and its archive have become increasingly important to many national and international science communities, particularly several of the operational services within the International Association of Geodesy (IAG) and its project the Global Geodetic Observing System (GGOS), including the International DORIS Service (IDS), the International GNSS Service (IGS), the International Laser Ranging Service (ILRS), the International VLBI Service for Geodesy and Astrometry (IVS), and the International Earth Rotation Service (IERS).

The CDDIS has recently expanded its archive to support the IGS Multi-GNSS Experiment (MGEX). The archive now contains daily and hourly 30-second and sub-hourly 1-second data from an additional 35+ stations in RINEX V3 format. The CDDIS will soon install an Ntrip broadcast relay to support the activities of the IGS Real-Time Pilot Project (RTPP) and the future Real-Time IGS Service. The CDDIS has also developed a new web-based application to aid users in data discovery, both within the current community and beyond. To enable this data discovery application, the CDDIS is currently implementing modifications to the metadata extracted from incoming data and product files pushed to its archive.

This poster will include background information about the system and its user communities, archive contents and updates, enhancements for data discovery, new system architecture, and future plans.

P04-09

The ESA/ESOC GNSS Network Progress, Improvements and Planned Upgrades in the Station Network

Mark van Kints, Jens Martin, Ignacio Romero, Werner Enderle

ESA/ESOC

Abstract

ESA/ESOC station network progress and upgrade plans. The ESOC station network is in the process of being upgraded to full GNSS receivers in an effort to continue to be a reliable provider of GNSS data for all the constellations.

P04-10

The IGS Campaign to Measure Position Corrections for Un-calibrated IGS Radome Stations

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[5]JPL, Pasadena, California, USA

Abstract

The IGS through the Infrastructure Committee, the Analysis Combination Center, the Antenna Working Group, the Reference Frame Working Group and the Central Bureau have organized a campaign to try to measure the unknown bias in the estimated position for co-located stations due to un-calibrated radomes over the GNSS antenna. The proposed approach of removing the un-calibrated radome for a significant number of weeks and then putting the radome back on in the exact same position, have been agreed by a number of relevant Station Operators. This poster presents the campaign approach, the participating stations and some initial results.

P04-11

The Canary GNSS Center; An Effort to Promote Space Geodetic Data and Techniques for Africa

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Canary Advanced Solutions, Telde, Canary Islands, Spain

Abstract

Africa is the continent with the least freely available good public GNSS data for long-term geodetic studies such as the ones promoted by the IGS. The Canary GNSS Center (CGC) is a non-profit effort based in the Canary Islands to offer a free Data Center to all organisations for their public GNSS data for the benefit of a worldwide community. The CGC's ftp and web presence represent the most complete African GNSS data repository serving as a benefit to researchers worldwide. This poster will summarise the CGC, the data holdings and some preliminary results in the context of the AFREF efforts.

P04-12

GPS Data on CDAWeb

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Abstract

NASA's Space Physics Data Facility (SPDF) at the Goddard Space Flight Center provides access to data from almost all of NASA's space physics satellite missions through its CDAWeb browse and plot web interface (http://cdaweb.gsfc.nasa.gov). The system is widely used in the space physics community as documented by acknowledgements in scientific journals (~20% of all JGR papers in 2011). Recently SPDF added the IGS-GPS data set of Total Electron Content (TEC) to its holdings because of the importance of TEC measurements for many of the other satellite missions. We will give a brief description of the CDAWeb system and an overview over recently implemented enhancements with a strong focus on the GPS TEC data and on other closely related data sets on CDAWeb.

P05-01

GLONASS Inter-Frequency Code Biases and PPP Carrier-Phase Ambiguity Resolution

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Abstract

The two fully operational GNSS GPS and GLONASS use different methods to make their signals distinguishable. GPS satellites broadcast their signals on the same frequencies but with different PRN codes (code division multiple access, CDMA). On the other hand, GLONASS satellites transmit their signals with the same PRN code but on slightly different frequencies in the two frequency bands L1 and L2 (frequency division multiple access, FMDA).

These GLONASS signals experience different code delays in the receiving equipment which affect both, the code positioning solutions and ambiguity resolution techniques which rely on the code measurements. Nevertheless, the carrier-phase is affected too, but the modelling and the correction of the carrier-phase inter-frequency bias (IFB) seems to be easier then the modelling and the correction of the code IFB or of combined carrier-phase/code IFB.

Precise Point Positioning (PPP) ambiguity resolution is based on a 2-step fixing algorithm. Usually, the first step involves the Melbourne-Wübbena linear combination to resolve the widelane ambiguities. This linear combination is a combination of carrier-phase and code and has the advantage that it is not affected by the atmosphere, orbit and clock errors. Hence the signal delays are a combination of the delays from carrier-phase and code. In the case of GLONASS, the frequency-dependent signal delays often prevent a successful ambiguity resolution since they are mostly receiver individual and sometimes even receiving channel individual.

As an alternative approach to fix widelane ambiguities a pure carrier-phase widelane ambiguity resolution can be used. Here, code observations are not directly involved and thus the frequency-dependent code delays do not affect this method. This approach, however, is affected by many other kinds of GNSS errors, with ionospheric refraction effects being the most prominent ones, and of course by the IFB of the carrier-phase.

Both methods to resolve widelane ambiguities have been implemented in our PPP analysis software so that we are able to compare their performances. We will present our latest results of GLONASS PPP ambiguity resolution and compare both methods.

P05-02

Monitoring of GPS-Galileo Inter-System/Signal Biases

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Abstract

Some GNSS systems, such as GPS and Galileo, have similar frequencies, i.e. the L1-E1 (1575.42 MHz) and the L5-E5a (1176.45 MHz) frequencies. These overlapping frequencies are beneficial for mixed RTK positioning, relying on integer ambiguity resolution. Instead of forming double-differenced phase and code observations for each GNSS separately (thereby choosing a pivot satellite for each system), with the overlapping frequencies it is possible to form the double differences with respect to the pivot satellite of just one system. As a consequence, additional parameters need to be estimated in the system of mixed observation equations: these are the differential Inter-System/Signal Biases (ISBs), accounting for the differential receiver hardware delay difference between the different systems' and signals phase and code observations on overlapping frequencies.

In this contribution monitoring results are presented of the differential ISBs between GPS and GIOVE, the two experimental Galileo satellites. The ISBs are estimated from data collected at Curtin University (Western Australia) and Delft University (Netherlands) in various zero-baseline setups and for different receiver types. The results indicate that the differential ISBs are stable in time, for both L1-E1 and L5-E5a phase and code. This stability may give rise for calibration of the Galileo double-difference (relative to the GPS pivot satellite) observations using the estimated differential ISBs. This would allow the Galileo data to be processed as if they were additional GPS data, thus strengthening the model as compared to a separate double differencing for each system.

P05-03

Mitigation of Standing Multipath Based on Time-Frequency Analysis and Adaptive Filtering

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Abstract

Geostationary (GEO) satellites have been used in satellite navigation systems such as Beidou and augmentation systems of GPS. Because GEO satellites are almost stationary relative to the earth, some multipath signals are varying very slowly. This will cause the so called “standing multipath”, which can dramatically decrease the accuracy of positioning. Multipath is corresponding to the characteristics of the signal, the processing method in the receiver, the antenna and signal receiving scenario. These complex factors make it quite difficult to eliminate the multipath errors.

Some approaches combined by radio frequency (RF) and post-processing methods have been proposed to mitigate the standing multipath. The post-processing methods can be classified into two types: the time-domain and frequency-domain processing. Bartone and Rizo’s frequency methods are based on the separability of different errors of GNSS data in frequency domain and multipath is mitigated by suppressing the corresponding frequency in Fourier of wavelet domain.While the frequency of multipath of the GEO satellite is much more lower, which may lap over those of ionosphere, troposphere and so on, and they are difficult to separate in frequency domain. Furthermore, it needs the data in one period at least to calculate its spectrum. For the multipath of one day period, the frequency domain method needs a whole day to initialization.The time domain processing can be done in two different ways. The first on is developed by exploiting the repeatability of multipath errors between successive sidereal days for a fixed-location receiver, and the multipath is estimated and cancelled with that one or several periods before. But because the repeatability is just some approximate, it is not entirely satisfy. The other one, code noise and multipath (CNMP), is proposed for real time processing in Wide Area Augmentation System (WAAS). Because multipath in the carrier-phase measurement is quite smaller, the multipath in pseudorange can be cancelled in the similar way as pseudorange smoothing. But unfortunately, in our experiments (see section 3) it is found that the smoothed code in CNMP still has some error left, which has the same periods as standing multipath. This paper, as an improvement of (CNMP) monitor, we proposed a coefficient-adaptive filter. The coefficients of this filter are estimated according to the modeling of standing multipath data by methods of time series analysis. A numerical verification was carried out by using WAAS data. The results indicate that the proposed method can significantly suppress the standing multipath and improve the rate of filtering convergence.

P05-04

Wide-lane Bias and Fractional Phase-Bias Estimation for GIOVE and Galileo IOV Satellites

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Abstract

Knowledge of satellite-dependent wide-lane biases and fractional carrier-phase biases are essential for precise zero-differenced ambiguity resolution techniques. These properties can now be obtained for GPS from different sources, but they are not yet available for new navigation satellite systems like the GIOVE and Galileo IOV, due to a lack of publicly available data and suitable processing software.

This poster provides estimates for the wide-lane biases and the fractional phase-biases for GIOVE and Galileo IOV satellites based on measurements from the CONGO network and the IGS MGEX network. It will furthermore discuss the effect of empirical corrections applied to reduce the GIOVE–A and –B differential code biases between the E1 and the E5a/b signals. Furthermore, the effect of different multipath mitigation techniques will be discussed.

P05-05

Which IGS Products for PPP With Integer Ambiguity Fixing?

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[1]CNES
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Abstract

Since November 2009, the GRG solution (CNES/CLS IGS analysis centre) delivers in sp3 and clk files specific clock products (phase clocks), which allow integer ambiguity fixing in PPP mode.

Currently, there is still an issue in these products concerning the translations of the reference network, which are not fixed relatively to ITRF as for the other IGS analysis centres. This is why the current GRG clocks are not used in the IGS combined clock product. Nevertheless the GRG orbits/clocks can still be used to solve for receiver positioning with ambiguity fixing (Integer PPP, IPPP).

This presentation summarizes the hypotheses used to construct the GRG phase clock solution (use of the widelane Melbourne-Wubbenna, iono-free pseudo-range and phase combinations).

The added or modified parameters necessary for ambiguity fixing in IPPP solutions are defined following the definitions given by J. Kouba in 'A GUIDE TO USING INTERNATIONAL GNSS SERVICE (IGS) PRODUCTS'. Various sets of parameters are possible to achieve the correct modeling (these paremeters are needed by the IPPP user). Many conventions are possible, either definitions close to the initial raw measurements (one bias for each observable), or definitions close to the solved expressions (widelane, pseudo-range and phase iono-free clocks).

The current PPP formulation in floating mode is close to the second approach while other igs products (P1P2 biases) remain close to the initial observations.

When the PPP user models are clearly defined, it is simple to combine different orbits/clocks/biases solutions in order to produce the best residual for the user.

P05-06

Biases and Clock Modelling in the Frame of Ambiguity Resolution

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Abstract

In the frame of the ESA project "Satellite and Station Clock Modelling for GNSS" we present a review of the code and phase biases in and between existing GNSS. The stability of these biases and opportunities for their modeling are investigated and compared to the requirements for successful ambiguity resolution on the zero- and single-difference levels.

Based on both simulated and real data, the track-to-track ambiguity resolution is investigated, with a special focus set on the impact of clock modeling.

P06-01

Computation of the IGS Final Troposphere Product by the USNO

Sharyl Byram and Christine Hackman

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Abstract

The United States Naval Observatory (USNO) serves as one of the International GNSS Service's (IGS) analysis centers (AC), producing solutions for the GPS constellation including the ultra rapid and rapid solutions for the GPS orbits, clocks, and the Earth orientation parameters which are submitted on a sub-daily and daily basis respectively. The USNO AC has been the provider of the IGS final troposphere product since July 2011 providing the estimates starting with day of year 107 of 2011.

Unlike other IGS products, the IGS final troposphere product is not a combination of solutions from the ACs which can be strongly affected by an individual AC changing estimation methods, the number of ACs contributing solutions, or an inconsistent set of common stations used among the contributing ACs. Prior to the USNO IGS final troposphere product processing, the processing of the IGS final troposphere product was performed by JPL. In a setup similar to the one used by JPL to ensure continuity in the product, the USNO computes final troposphere estimates of the zenith path delay and the East and North gradient components using a precise point position (PPP) approach to processing zero difference GPS observations directly from the RINEX files for approximately 300 stations world wide with the Bernese GPS software. This PPP processing of the troposphere product utilizes the IGS final orbits and clocks ensuring both consistency and the highest accuracy available for the GPS constellation inputs. The result is a set of troposphere estimates per station per day which provides internal consistency for the users of the troposphere products currently with a computed standard deviation of the zenith path delay in the range of 1-2 mm.

The IGS final troposphere estimates are processed daily with a three week latency as a result of using the IGS final orbits and clocks. The resulting station troposphere files are screened post processing for incomplete files and large standard deviation values to ensure quality troposphere estimate files are passed on to the user community.

This poster will provide an overview of the final troposphere product processing with a more detailed discussion of the methods and models used. Additionally, a comparison of the USNO created IGS final troposphere products to the ones previously created by JPL using the Gipsy-Oasis software will be made for clarity of the processing transition. Finally, this poster will also include a discussion of what is planned for the future of the IGS final troposphere product computation at the USNO.

P06-02

Computation of Zenith Total Delay Residual Fields using Ground-Based GNSS estimates

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Abstract

Tropospheric refraction is one of the major error sources in satellite-based positioning. The delay of radio signals caused by the troposphere ranges from 2m at the zenith to 20m at low elevation angles, depending on pressure, temperature and humidity along the path of the signal transmission. If the delay is not properly modeled, positioning accuracy can degrade significantly. Empirical tropospheric models, with or without meteorological observations, are used to correct these delays but they are limited in accuracy and spatial resolution resulting in up to a few decimeters error in positioning solutions. The present availability of dense ground-based GNSS networks and the state of the art processing techniques enable precise estimation of Zenith Tropospheric Delays (ZTD) with different latency ranging from real time to post-processing. We present a method for computing ZTD residual fields interpolating, through Ordinary Kriging, the residuals between GPS-derived and model-computed ZTD at continuously operating GNSS stations. At a known user location, ZTD value (hereafter site-ZTD) is obtained as the sum of site-ZTD residual and modeled-ZTD value. The performance of the method has been evaluated over 1-year period (January-December 2011) at 25 European stations belonging to the EUREF/IGS network. UNB3m [1] is used as reference model, which is capable of predicting ZTD with an uncertainty of 5cm under normal atmospheric conditions. An improvement of about 30% for the bias and 50% for the std is obtained when site-ZTD, rather then UNB3m-ZTDs, are compared w.r.t. IGS. This work aims at assessing that empirical models can be improved if tropospheric corrections got from ground-based GNSS network are taken into account, since it is not possible for an empirical model to emulate tropospheric delay variations exactly. Comparisons w.r.t radiosonde data and VLBI ZTD estimates are shown as well.

P06-03

SUADA: Sofia University Atmospheric Data Archive

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Abstract

The Sofia University Atmospheric Data Archive (SUADA, http://suada.phys.uni-sofia.bg/) has been developed to provide a framework for archiving Bulgarian atmospheric data on an ongoing basis. Currently, SUADA includes water vapour, derived from tropospheric path delay, at 31 ground based stations of Global Navigation Satellite Systems (GNSS) network in Bulgaria as well as radiosonde data for station Sofia for the period 1997-2012 and COSMO-EU model. The envisaged applications of the SUADA include:

(1) cross-validation of ground-based and satellite observations and derivation of systematic biases;

(2) study of the 2D water vapour distribution in Bulgaria/Southeast Europe;

(3) study convective storms development in Bulgaria/Southeast Europe;

(4) detection of long term water vapour trends in Bulgaria/Southeast Europe and links to heat waves, droughts and changes in the pathway of the Atlantic Cyclones.

P06-04

GNSS Research and Services at ROB to Support Meteorology and Nowcasting Applications

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Abstract

For more than a decade, the Royal Observatory of Belgium (ROB) has supported ground-based GNSS-meteorology, participating in European projects such as COST-716, TOUGH and the EUMETNET EIG Global Navigation Satellite System (GNSS) Water Vapour Program (E-GVAP). To this aim, the ROB developed and maintains an operational analysis centre providing meteorologists with hourly-updated 15-min sampled Zenith Tropospheric path Delays (ZTD) from a European network of about 190 GNSS stations. In the framework of the E-GVAP II program (2009-2013), these ZTD estimations are delivered hourly to a meteorological database at the U.K. Met Office and are assimilated operationally by the U.K. Met Office and Météo France.

At the end of 2011, the ROB developed a new hourly-updated GPS-based ZTD solution to enhance its current support to European Numerical Weather Prediction (NWP). In this poster we present the status of this new solution focusing on the assessment of the quality of our solutions in terms of precision, accuracy and latency. Particularly, we show that the new ZTD solutions improve the spatial density of the ZTD observations by including more than 320 GNSS stations (170% increase) while lowering the latency of the solution. We also show that our new ZTD solutions meets the NWP requirements in terms of precision and accuracy by comparing our results with in-situ measurements (radiosonde observations) and NWP data (background ZTD).

In addition, as a first step towards (quasi) real-time GNSS-Meteorology, the ROB is preparing a new solution to support rapid-update high-resolution NWP and nowcasting applications with sub-hourly processing of GNSS observations obtained from real-time NTRIP streams. We present first results obtained with this new solution. Finally, we present a method developed at the ROB based on krigging interpolation in order to map the wet tropospheric delay over Europe based on the contribution of the ROB to E-GVAP.

P06-05

On the Use of the IGS REPRO1 Product for Climate Change Analysis: An IWV Inter-technique Comparison Study

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Abstract

Being the most important greenhouse gas in the Earth's atmosphere, water vapour plays a key role in the climate change debate. However, observing the atmospheric water vapour over climatological timescales in an homogeneous and consistent manner is challenging. To this end, water vapour estimations derived from reprocessing campaigns of continuously-operating ground-based Global Navigation Satellite System (GNSS) observation networks are very promising. In particular, the IGS troposphere products from the REPRO1 campaign [Byun, S. H., and Bar-Sever, Y. E. 2009, 2010] provide climate researchers access to a world-wide dataset of continuous GPS-based Integrated Water Vapour (IWV) observations spanning over the last 15+ years. The AErosol RObotic NETwork (AERONET) also provides such long-term and continuous ground-based observations of the IWV performed with standardized and well-calibrated sun photometers.

The purpose of this study is to compare GPS-based IWV time series derived from the IGS REPRO1/final troposphere products with simultaneous IWV measurements from collocated ground-based (sun photometer), in-situ (radiosonde) and satellite-based (GOME/GOME2/SCIAMACHY) techniques (1) to evaluate the quality and the consistency between the techniques and (2) to assess the applicability of GPS-based reprocessed IWV data for time series analysis and climate trend detection.

Therefore, we compare the IWV measurements retrieved (at zenith) from these techniques, focusing on a selection of about 30 sites worldwide with colocation distances between techniques below 30 km. We show that ground-based and in-situ measurement techniques typically agree at the level of 0.3 mm +/- 2.2 mm of IWV. Comparisons with satellite-based techniques give rise to slightly higher biases and more variability (RMS of about 4 mm). Therefore, in a case study, we further investigate at the station Uccle (Brussels, Belgium) the influence of the clouds on the IWV inter-technique comparison and we compare the IWV values obtained from these instruments directly in the direction of the sun ("solar slant IWV"). Finally, we investigate the geographical dependency of the properties of the IWV scatter plots between all these different instruments.

P06-06

An Evaluation of Real-Time, Near Real-Time and Post-Processed Zenith Total Delay Estimates

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Abstract

Zenith total delay (ZTD) can be estimated in real-time, near real-time and post-processing modes using existing GPS processing strategies and each mode results in different accuracies for the estimates. The Bundesamt für Kartographie und Geodäsie Ntrip Client (BNC) can provide ZTD estimates in real-time using precise point positioning (PPP) without integer ambiguity resolution. Recently, the Centre National d'Etudes Spatiales (CNES) has released a modified version of BNC which produces ZTD estimates in real-time with integer-PPP, i.e. PPP with integer ambiguity resolution using their integer-recovery clock and widelane phase bias information. The University of Luxembourg in collaboration with the University of Nottingham operate hourly and sub-hourly near-real time GPS processing systems for estimating ZTD using the Bernese GPS Software v5.0 and double-differenced (DD) observations. The IGS Troposphere Working Group produces an official IGS ZTD product using the final satellite orbits and clocks, and Earth orientation parameter products.

In this study, we present a comparison of the ZTD estimates from the various processing systems. We investigate the effect of integer ambiguity resolution in real-time PPP on the ZTD estimates and assess the accuracies of the ZTD estimates from the real-time and near real-time processing systems using the official IGS troposphere product.

P06-07

Atmospheric Profiling using GPS Radio Occultation and Radiosonde Observations in the Australian Region

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Abstract

The GPS Radio Occultation (RO) technique uses GPS receivers onboard Low Earth Orbit (LEO) satellites to measure the received radio signals from GPS satellites so that atmospheric profiles, such as temperature, pressure, refractivity and water vapour, can be obtained using complicated atmospheric retrieval processes. The Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) was launched in April 2006. GPS RO data from this constellation of six LEO micro-satellites provides an atmospheric and meteorological observational data type. The GPS RO is now employed in operational meteorology, providing significant information on the thermodynamic state of the atmosphere with the demonstrated potential to improve atmospheric analysis and prognosis. The aim of this study is to determine the accuracy and limitations of the COSMIC GPS RO measurements. In this study COSMIC GPS RO temperature and pressure profiles are compared to those measured from radiosondes for the years 2006-2011 over the Australian region. The tropopause height and temperature are also investigated where GPS RO data are compared with radiosonde measurements.

P06-08
IAG WG4.3.2 Inter-Comparison and Cross-Validation of Tomography Models – Aims, Scope and Methods

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Abstract

The Global Navigation Satellite Systems (GNSS) signals transmitted from satellites are subjected to atmospheric delays since the signals have to propagate through different layers of the atmosphere before GNSS receiver receives them. Two major distinctive effects according to the nature of the impact on the signal propagation are the ionosphere which is a dispersive media and the troposphere which is a non-dispersive layer.

To analyse the lower part of the atmosphere the troposphere part of the delay could be utilized as observations for GNSS tomography models. The integrated measure of the delay into direction to satellite is converted into distribution of refractivity (total or wet), or directly water vapour using Radon inverse transform. The ill – conditionedess and ill-posedness of the equations set results in complexity of the problem. Currently there exist a couple of GNSS tomography models. In order to foster best practice, resolve main issues and benefit from different approaches, IAG in the frame of Sub-Commission SC 4.3 – "Remote sensing and modelling of the atmosphere", proposes to install the Working Group "Inter-comparison and cross-validation of tomography models".

This WG intends to address the main issues dealing with GNSS tomography. Promote the inter-comparison and cross-validation of different tomography models and approaches by using same data sets over same areas. Improve GNSS tomography by the integration of new GNSS measurements aiming at an enhanced reliability of tomography results, by increasing the number of observations and by incorporating cross-sectional observations. Promote the sharing of GNSS tomography technique data, results and software. Discuss the need of a "tomography service".

This paper presents initial participants, methods and aims of the WG. It is also a call for interested groups and individuals to help to further promote, use and develop GNSS tomography models.

P06-09

IGS Tropospheric Products - Quality Verification and Assessment of Usefulness in Climatology

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Abstract

Poster concentrates around two main questions.

First is multilevel conformity study of ZTD of IPW in IGS tropospheric products (combination till 2006, final and ultra-rapid solutions by JPL, USNO, CODE), EPN tropospheric combination and meteorological water vapour data sources. Water vapour data come from radiosoundings, global numerical weather prediction model GFS (operated by NCEP) and sun photometer CIMEL 318.

Next topic is information potential contained in IGS tropospheric products for climatology and aerology. Long time series of IPW (daily averaged) can serve as climate change indicator e.g.: relatively unique shape of such series in different climates. Long lasting changes in weather conditions - 'dry' and 'wet' years are also visible. The longer and more homogenous our series the better chance to estimate the magnitude of climatological IWV changes. The problems with GPS strategy and reference system changes can be solved by reprocessing (examples included). Next we adjust seasonal model to the series (LS method) for selected IGS stations. We apply two modes: sinusoidal and composite. Also two ways are tried: multi-year adjustment and every year separately (different are not only amplitudes but also phases). Even simple sinusoidal seasonal model of daily IPW values series clearly represents diversity of world climates. Residuals in periods up to 14 years are searched for some long-term IPW trend. For some stations & years such trends are quite clear, the following years not visible.

IPW from IGS tropospheric products can be treated also as information source for aerology: it demonstrates some clear physical effects evoked by station location (e.g. height and series correlation coefficient as a function of distance) and weather patterns like dominant wind directions. Also deficiency of surface humidity data to model IPW is presented for different climates.

P06-10

The High Resolution Troposphere on the Area of GBAS System

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Abstract

Global Navigation Satellite Systems (GNSS) are designed for positioning, navigation and amongst other possible applications it can also be used to derive information about the state of the atmosphere. Continuous observations from GNSS receivers provide an excellent tool for studying the neutral atmosphere, currently in near real time. The Near Real Time neutral atmosphere and water vapour distribution models are currently obtained with high resolution from Ground Base Augmentation Systems (GBAS), where reference stations are equipped with GNSS and meteorological sensors. The Poland territory is covered by dense network of GNSS stations in the frame of GBAS system called ASG-EUPOS (www.asgeupos.pl). This system were established in year 2008 by Head Office of Geodesy and Cartography in the frame of EUPOS project (www.eupos.org) for providing positioning services. The GNSS data are available from 130 reference stations located in Poland and neighbour countries. The ground meteorological observations in the area of Poland and neighbour countries are available from ASG-EUPOS stations included in EUREF Permanent Network (EPN) stations, airports meteorological stations (METAR messages stations), and stations managed by national Institute of Meteorology and Water Management (SYNOP messages stations). The first part of the paper present the methodology of NRT GNSS data processing for ASG-EUPOS stations for Zenith Total Delay (ZTD) estimation. The second part is covering analysis of meteorological parameters interpolation methods for determination of Zenith Hydrostatic Delay (ZHD). The last part concerns the modeling of water vapour distribution over the area of Poland.

P06-11
Evaluation of Pressure Extracted from NCEP and CMC Global Numerical Weather Prediction Models Against In-Situ and GPT Pressure

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Abstract

An earlier investigation by Urquhart et al (2011) demonstrated that ray traced hydrostatic zenith delays from NCEP's Re-Analysis I (NCEP) dataset proved to exhibit higher variability when compared to those from the Canadian Meteorlogical Centre's (CMC) Global Deterministic Prediction System (GDPS) and the European Centre for Medium Range Weather Forecasting (ECMWF). This investigation expands on the original by analyzing the variation of the zenith hydrostatic delay (as ray traced through the NWP) and the extracted pressure at the surface for 35 IGS reference stations for the entire year of 2010. Two NWP's were selected, NCEP's Re-Analysis I and CMC's GDPS. NCEP was selected since it forms the basis for the UNB-VMF1 service, and CMC's GDPS was selected due to availability. Both models have global coverage, but NCEP's grid resolution is 2.5x2.5 degrees as compared to CMC's (GDPS) 0.6x0.6 degrees. The location within the NWP is defined by the location of the IGS reference stations. The position of the reference stations are defined by the IGS weekly solutions where week 52's coordinate values for the year 2010 were used. The height was then adjusted by the defined meteorological sensor offset as defined the IGS stations's respective log. The investigation is based on the following comparisons: 1. Extracted Pressure from the NWP (NCEP and CMC (GDPS)) compared to measured pressure from the site, and also from pressure derived from GPT model. 2. Raytraced hydrostatic zenith delay compared to the Saastamoinen hydrostatic zenith computed from the measured site pressure. Results indicate good agreement between pressure extracted from the NWP and in-situ pressure and larger differences with respect to GPT.

P06-12

Tropospheric Products for Real-Time and Near Real-Time Applications

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Abstract

Atmosphere monitoring is a major scientific field of investigation at the Institute of Geodesy and Geophysics (IGG, TU Vienna) which is covered by both the Satellite Geodesy and the VLBI research group. For high precision analysis a mapping function (VMF1) was developed which is based on data from numerical weather models (NWM). It‘s coefficients, the wet and dry components of the signal delay on global grids and for selected sited are free available and updated every six hours. If the signal delay in the neutral atmosphere has to be known with highest accuracy, it should be derived from GNSS observations instead from NWM. Within the framework of the Project GNSSMET-AUSTRIA an automatic processing was set up which allows to estimate the tropospheric total delay in zenith direction (ZTD) over Austria with an accuracy better than 1 mm and a temporal resolution of 1 hour. Data referenced to tropospheric delays provided by the IGS Troposphere Working Group at nearby IGS stations. To obtain the zenith wet delay (ZWD), measurements from a nationwide meteorological network (TAWES) are used, which are available every 10 minutes. The ZWD converted into PW was assimilated into the numerical weather model ALADIN and a positive impact on upper air temperature scores and the intensity of precipitation could be observed. Tropospheric signal delays from 2011 are re-calculated to study its impact on the new numerical weather model AROME which is developed by the Central Institute for Meteorology and Geodynamics (ZAMG). In this presentation an overview of the research which is carried out at IGG is shown. In addition further research is addressed which will includes studies of the impact of upcoming Global Navigation Satellite Systems on ZTD estimation, new near real-time tropospheric products like north and east gradients and a 3D humidity model for applications in real-time.

P06-13

Fast-static GPS Positioning with External Tropospheric Corrections Derived in Near Real-Time

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Abstract

Nowadays the troposphere is considered as an ultimate accuracy limiting factor in geodetic applications of GNSS. Currently, the most popular solution in the state of the art applications is to estimate ZTD together with station coordinates in the common data adjustment. This approach requires long data spans, e.g., at least 30-60 minutes. However, in fast-static positioning when short data spans are available, this method in not feasible and the troposphere is very difficult to model. Therefore, fast-static positioning requires external tropospheric information in order to improve its accuracy. This can be achieved by a network of the reference GNSS stations (GBAS), where ZTD can be obtained in the adjustment of GNSS data or directly from the ground meteorological data in near real-time (NRT) and provided as an external supporting product.

The presented research are carried out in the frame of the “ASG+” project aimed at the development of NRT supporting modules for the ASG-EUPOS system. In this paper we present the analysis of the application of several ZTD modeling techniques to fast-static precise GNSS positioning ,namely:

(1) ZTD estimated in NRT from GNSS data from Polish GBAS system called ASG-EUPOS with IGS/EPN and IERS products, (2) NRT ZTD determination based on meteorological data collected in real time from ASG-EUPOS, METAR and SYNOP systems. These NRT strategies were compared with: (3) application of standard troposphere model and (4) ZTD obtained in postprocessing from the official solution of the ASG-EUPOS network. In order to assess the accuracy of these ZTD modeling techniques, test baselines of several tens of kilometers were processed in fast-static mode using in-house developed software - GINPOS. A 24-h data set was divided into 144 sessions, each of 5-minute long. Each session was processed independently and the obtained coordinate residuals were analysed.

The results show that NRT ZTD products can improve both the accuracy and the reliability of the fast-static positioning. The most noticeable effect is observed in the station height component. In some extreme cases, mismodelling of the troposphere may even disrupt ambiguity resolution and, therefore, prevents user from obtaining accurate position.

P06-14

Advanced GNSS Tropospheric Products for the Monitoring of Severe Weather Events and Climate (GNSS4SWEC)

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Abstract

Global Navigation Satellite Systems (GNSS) have revolutionised positioning, navigation and timing (PNT), becoming a common part of our everyday life. Aside from PNT applications, GNSS have proved to be an accurate sensor of atmospheric water vapour, the most abundant greenhouse gas and of crucial importance in weather forecasting.

The proposed COST Action will address new and improved capabilities from concurrent developments in both GNSS and atmospheric communities. It will stimulate the full potential exploitation of multi-GNSS water vapour data on a wide range of temporal and spatial scales, from real time severe weather monitoring to climate research. For the first time, the synergy of three GNSS systems (GPS, GLONASS and Galileo) will be used to develop new, advanced tropospheric products. The Action will also stimulate knowledge transfer and data sharing throughout Europe, particularly from West to East, and will promote the use of atmospheric data in satellite-based navigation services.

P07-01

Technology of Reliable Rapid Static GNSS Surveying in Urban Area

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Abstract

The research presents a methodology of reliable rapid static GNSS surveying for applications in urban areas where availability to satellites is limited. The technology is based on the use of three GNSS receivers positioned simultaneously in line on a special base at a distance of 0.5 m from one another. Given the possible gross errors of the determined baseline coordinates, the simultaneous application of three GPS/GLONASS receivers for a single point allows reliable determination of coordinates even in locations with severe obstructions. Presented technology can also be used for reliable RTK positioning, however post-processing procedures of rapid static can give much more accurate results. Based on presented practical results of survey and data processing methodology, reliable coordinates with accuracies expressed in sub centimeters during rapid static survey sessions can be obtained in the urban areas where obstructions caused by trees, buildings, power lines etc. limit satellite availability.

P07-02

The CNES real time Integer PPP demonstrator

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Abstract

Integer ambiguity resolution on undifferenced GPS phase data has been the object of a lot of attention in recent years. By combining pseudo-range and phase information, it is indeed possible to directly fix integer ambiguities on zero-difference phase measurements, for dual-frequency problems, without any atmospheric models. Phase measurement then become pseudo-range-like measurements with millimeter noise level.

Our complete method, adapted for dual-frequency problems, was presented for the first time at the ION GNSS 2007 meeting. Methods and results were refined and summarized in the Summer 2009 issue of Navigation.

The extension of our method to real-time applications has been developed in papers by the same author presented at the ION NTM 2008, ION ITM 2009, ION GNSS 2010 and ION GNSS 2011 meetings). The core of the real-time implementation is a Kalman Filter working in mixed-mode (with both real- and integer-valued phase ambiguities). The filter produces GPS constellation states (orbits and clocks) with the 'integer' property. Algorithms for user receivers were also introduced. Their performance in terms of real-time precision and convergence time was compared to standard RTK methods.

To demonstrate that this processing strategy is compatible with the latency constraints imposed by real-time applications and with the level of performance typical of common personal computers, CNES is developing a complete real-time 'integer PPP' demonstrator. This poster presents the goals and the architecture of this demonstrator, along with some actual results for both the system side and the user side.

The system side of the demonstrator collects network measurements, computes state-space products, and disseminates them over the net, using the tools that CNES uses in the frame of the Real Time IGS Pilot Project. On the user side, the demonstrator collects measurements from a local receiver, retrieves state-space data from the internet, and performs real-time kinematic 'integer PPP'. Several stations are monitored in real-time using this technique. Monitoring plots errors are generated on a real-time basis.

As part of this demonstrator, CNES proposes a free user test package that provides all the tools for users to perform their own PPP with ambiguity resolution. The test package includes an access to the CNES caster, and ICD to understand the nature of the ambiguity resolution quantities, and a PPP software. This PPP software is freeware and the source code is provided. All this material is available on a dedicated web site.

P07-03

On the Estimability and Reliability of Correction Models from CORS Networks

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Abstract

Continuously operating reference stations (CORS) are collecting observation data of different GNSS and are realizing global and regional GNSS networks. Besides the establishment and maintenance of reference frames, like e.g., the IGS frame, CORS are the basis for network real time kinematic (NRTK) applications and services, like e.g., the German Satellite Positioning System (SAPOS). The basic principle of NRTK is to derive appropriate correction models for the covered area. This enables users interpolating their individual distance dependent error corrections, like e.g., tropospheric corrections to achieve positioning accuracy of a few centimeters. According to the dimension of the reference stations network different parameterizations for the correction models are desired. From a user's point of view it is very important that the derived correction parameters by the provider are reliable and of high quality. To derive appropriate quality indicators for the correction parameters we started investigating the estimability and reliability of correction model parameters with a given scenario.

In this contribution, the influence of each single reference station within a network to a regional atmospheric correction model is presented. Based on the data resolution matrix which especially contains the station geometry we show the parameter's sensitivity to possible observation errors at a single reference station. Furthermore, we quantify the influence of single reference stations with and without outliers to arbitrary chosen rover positions within the network. Depending on the rover's position we can identify reference stations contributing strong or weak information to the error interpolation process used in the correction model.

P07-04

Generating UPD for IGS Combined Products for Ambiguity-Fixing of Real-Time PPP

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Abstract

The successful Real-Time Pilot Project is heading towards an official real-time Precise Point Positioning (PPP) service now. As is well known, integer ambiguity resolution of the real-time Precise Point Positioning (PPP) can significantly shorten the convergence time and improve the position accuracy as well. Therefore, ambiguity-fixing capability should be essential for the official service.

A number of studies are undertaken since years to overcome the uncalibrated phase delays (UPD) problem to recover the integer feature of the undifferenced ambiguities. Most of them are handling the UPDs in the clock estimation. Thus, the resulted UPDs are not always suitable for the IGS combined products due to possible inconsistency in models and algorithms.

In this contribution, we developed a new processing strategy to generate UPDs for IGS combined real-time products. After the combined products are made available, real-time PPP are performed for a large number of reference stations. Then the UPDs are estimated from the ambiguities of the PPP results in real-time and broadcasted at a certain update rate.

The algorithm is developed and running operationally for IGS combined products for validation and demonstration. PPP plus ambiguity-fixing with IGS official products and the generated UPDs are carried out with a number of IGS real-time stations. Fixing performance is compared with that using GFZ orbit and clock products and UPDs. The results confirm that the proposed strategy can efficiently generated reasonable UPDs for the combined products to enhance the official real-time PPP service by means of ambiguity resolution.

P07-05

Real-Time GNSS Data Processing at the Technical University Vienna - Current Status and Upcoming Developments

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Abstract

To meet the increasing demand of upcoming real-time (RT) applications the IGS (International GNSS Service) has initiated a real-time working group (RTIGS) to investigate the feasibility of real-time GNSS data distribution and the generation of derived products. Nowadays this real-time station network consists of approximately 80 stations. Scientific organizations and companies operating reference stations can participate in the working group either by delivering their data-streams via a central service or by providing real-time GNSS products such as precise clock and orbits corrections.

This presentation deals with the contributions of the Institute of Geodesy and Geophysics (IGG), Technical University of Vienna to the IGS Real-Time Working Group. IGG provides on a regular basis GPS- clock corrections and precise orbit solutions. Currently the processing scheme is subject to change to account for phase float solutions which will increase the accuracy of the satellite clock corrections by a factor of 2 compared to the current deliverables. Furthermore a recently started project with a duration of 2 years deals with the estimation of Uncalibrated Phase Delays (UPD) from regional network data, which shall be forwarded to user receivers to allow for zero-difference integer phase bias fixing.

P07-06

BKG Ntrip Client (BNC) Version 2.6 – Recent Developments and Results

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Abstract

The BKG Ntrip Client (BNC) was originally designed for collecting, synchronizing and streaming real-time GNSS data from real-time broadcasters to the real-time users. During the last years, BNC evolved to a very efficient and flexible tool in the real-time world, mainly because of its Precise Point Positioning (PPP) module. Being open source software, important features already implemented or under development are: multi-GNSS encoding/decoding, real-time GNSS orbit and clock combination, post processing capability, editing and quality control elements, especially for RINEX 3.

This poster presentation is reviewing the basic tags and tools of BNC and is highlighting several of the new features. Current results using the PPP module, e.g. from BKG's monitoring webpage, are completing the presentation.

P07-07

Control Methods of Real-Time Services of ASG-EUPOS

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Abstract

Differential corrections and services for real-time kinematic method (RTK) in many cases are used for support survey being base for administration decision. For that reason, services which allow to perform GNSS measurements should be constantly monitored to minimize the risk of any errors or unexpected gap in observation. System providing such control is the subject of the work carried out under a grant NR09-0010-10/2010 conducted by the Military University of Technology. This study was made to develop the concept of monitoring real-time services and the implementation of software providing users information of system accuracy. The main objectives of all concepts were: maximum use of existing infrastructure while minimizing the cost of installation of new elements, providing users calculation results via the ASG-EUPOS website. In the same time concept assume openness of the module that allow the successive development of applications and integration with existing solutions. This paper present several solutions which have been implemented and tested. It also consist some examples of data visualization methods.

P07-08

Troposphere Model for PPP-RTK

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Abstract

The PPP (Precise Point Positioning) method of determining the position requires the introduction of a'priori precise orbits and satellite clocks information to the equation system. Use of dual frequency GNSS receivers eliminates the first-degree influence of the ionosphere by means of using the linear combinations of the observations. Obtaining the highest accuracy of the technique requires the use of high quality products, since their errors directly affects the error of determined parameters. While GNSS data is post-processed, introduced a'priori models can be corrected during the estimation process, but when determining the position in real-time used models must be as precise as possible. An important problem is the introduction of reliable tropospheric delays for the PPP-RTK. The empirical models of troposphere, which are a function of atmospheric conditions (temperature, pressure and humidity), present the value of delay in the zenith direction (ZTD), which is converted to the slant delay (STD) in the direction to the satellite using the mapping function. Evolution of troposphere models is the increase of temporal and spatial resolution and the transition from standard atmospheric models to models of distribution of meteorological parameters, which can be derived from numerical models such as weather forecasts or reference station networks. Presented studies show the effect of using different models of ZTD derived from:

• the rapid solution of ASG-EUPOS network,• the near real-time solution of ASG-EUPOS network,• the Saastamoinen model computed with meteorological parameters (temperature, pressure, humidity) interpolated in near real-time from the meteorological stations, on the positioning accuracy and the initialization time of the receiver using the PPP, with comparison to solutions where the troposphere delay is an estimated parameter. Work includes also a qualitative assessment of the models used.

P07-09

G-Nut Software Library for Implementing Various GNSS Applications

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Abstract

The G-Nut software library is being developed at the Geodetic Observatory Pecny (GOP) since January 2011. The main goal of the new library is to support the development of various software packages fitting to specific applications such as GNSS observation and navigation data manipulation and quality checking, PPP-based processing for high-rate kinematic solution, precise ultra-fast or near real time troposphere estimation, satellite clock estimation or other products based on a network of stations and others in future.

All library models are designed for the processing of undifferrence multi-GNSS data. The core library structure supports both real-time (off-line, online) and post-processing modes via a unique input/output functionality and extensible containers of individual data/products elements providing a storage of a single epoch, more epochs or a daily batch. Various filtering techniques as well as the least-square adjustment have been implemented for various applications. The library is written in ANSI C+ taking a full advantage of object-oriented programming and currently supports linux and windows platforms. It is also strictly design for multi-threaded applications, which includes optional input-, model- and output-server (in specific threads) and thus simply supporting a single station processing as well as a network of stations. The basic configuration is via XML files. More details on the implementation of the library structure and intentions for future developments will be given. The first applications derived from G-nut library will be shown with some result examples, e.g. for PPP off-line/online kinematic positioning, ultra-fast troposphere estimation.

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P07-10

Real-Time Operations at Natural Resources Canada, Geodetic Survey Division

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Natural Resources Canada, Geodetic Survey Division

Abstract

Natural Resources Canada (NRCan), Geodetic Survey Division (GSD) has been operating GNSS stations in a real-time streaming mode since 1996 and has been generating Wide Area Differential GPS Corrections in a 24/7/365 production environment, since 2003. At present, GSD operates its core GNSS station network in a fully automated real-time streaming mode and is also generating high precision GPS corrections in support of its mandate and as a contribution to the IGS Real-Time Pilot Project.

This poster will present the current status and future work that is planned in a number of areas where GSD is currently conducting routine real-time operations. The following topics will be covered: network and station operations; data and corrections handling including formats; configuration of the high availability production environment; real-time clock and orbit accuracy (User Range Error); and real-time precise point positioning.

P07-11

Assessment of First Real-Time IGS Global VTEC Maps

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Abstract

The assessment of the first Real-Time (RT) IGS global VTEC maps computed by DLR and UPC, against JASON-1 (during 2011) and JASON-2 altimeter VTEC measurements (for 2012), is presented in this work.

Indeed, within the International GNSS Service (IGS), Associate Analysis Centres (ACC) produce specialized or derived products. Two examples of Real-time ACCs are the Universitat Politècnica de Catalunya (UPC) and the German Aerospace Center (DLR). They have participated in the IGS RTPP and continue to collaborate on the development of a combined global IGS RT-VTEC product. This collaboration is occurring under the umbrella of the IGS Ionosphere Working group currently lead by the University of Warmia and Mazury in Olsztyn, Poland.

RT-VTEC information is used to support earth observation missions and space weather monitoring and forecast. RT-VTEC information improves single-frequency positioning on a global scale and in smaller regions where the ionosphere may be well sounded, RT-VTEC information is known to improve RTPPP accuracy results for single-frequency users. Through the use of iono-geodetic techniques, phase quality dual-frequency RTPPP results are being improved by reducing the time it takes for phase ambiguities to converge.

The JASON comparisons are considered pessimistic for the overall global VTEC product accuracy because the land-based tracking stations are generally located quite far from the location of the Jason measurements. The importance of a reliable globally distributed and sufficiently dense real-time GNSS tracking network will be shown. Moreover the RT VTEC results are quite compatible with the rapid and final IGS VTEC maps for a significant fraction of time. These results suggest that it may be feasible to combine real-time VTEC products from several centres into a robust IGS real-time IONO product.

Additional work to compare both solutions is underway with the goal of finding optimal ways to assess and combine these products into an IGS RT-VTEC product. Future efforts will include working with RTCM to ensure that the IGS RT-VTEC product is compatible with ionosphere correction information proposed for the RTCM-SSR standard.

P07-12

Real Time Analysis Centre and AC Coordination Activities at ESOC

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Abstract

Over the last 10 years, ESOC has embarked on a program to build a Real Time GNSS software infrastructure. RETINA (system for REal TIme NAvigation) has been modelled after ESOC's experiences in Real Time satellite control systems and includes many of the elements for data processing, archiving and visualisation that are common to such systems.

The RETINA software has enabled ESOC to assume both the roles of Analysis Centre and Analysis Centre Coordinator in the IGS Real Time Pilot Project. With the launch of the new IGS Real Time Service, these roles will transition to parallel roles in the new service, requiring a high degree of robustness and reliability. This paper describes the operational environment for the generation and dissemination of IGS products for the new service. It also provides recent results of both ESOC and Combination products from the Real Time Pilot Project activities.

P08-01

Evaluation of Individual Antenna Calibrations Used in the EPN

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Abstract

The aim of this study is to evaluate the significance of the offset caused by using different receiver antenna calibration models on the station position. Using the PPP (Precise Point Positioning) technique, we first investigate the differences in positioning obtained when switching between individual antenna calibrations and type calibrations. We analyze the observations of the 53 EPN stations equipped with receiver antenna individually calibrated over the period covering from 2003 to April 2011 and we show that these differences can reach up to 4 mm in horizontal and 10 mm in vertical.

Secondly, we study the accuracy of the individual calibrations models and we evaluate the effect of different sets of individual calibrations on the positioning. For that purpose, we use the data from 6 GNSS stations equipped with an antenna which has been individually calibrated at two calibration facilities recognized by the IGS: Geo++ and Bonn institute. The influence of the calibration method can reach 3 mm in horizontal and 7 mm in vertical.

P08-02

Ray-Tracing Approach for Multipath Characterization Including Multiple Rays

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Abstract

Multipath propagation has a major contribution to the overall error budget of GNSS precise positioning applications. Although a lot of research has been dedicated to the understanding and modeling of this propagation error, during the last decades, only suboptimal solutions are derived. Site-dependent characteristics, unknown geometry, dynamic nature and the dependence on many other factors, like e.g. reflection/diffraction properties, weather conditions and antenna and/or receiver design make multipath mitigation very challenging. Furthermore, due to the above mentioned reasons and in order to overcome them, in most of the investigations presented in literature certain predefined assumptions are made and this may lead to only a partial characterization of the phenomenon.

In our study, the results of a novel ray-tracing approach are used for understanding and characterizing multi-multipath propagation process. Based on a 3D model of the physical environment of the antenna, measured by a terrestrial laser scanner, ray tracing simulations are performed. The rays that arrive at the receiving antenna by paths other than the direct are identified. Based on the geometric and electromagnetic characteristics of the identified rays, phase and code errors caused by superimposition of all rays are calculated. Our calculation showed that the 90° shift between code and phase errors, which occurs for errors caused by a single multipath component, is not valid in the case of multiple multipath components. It may be valid only when a dominate component exist. Furthermore, our simulation showed than constructions shorter and/or a few meters higher from the receiving antenna cause edge diffraction even from high elevation satellites. Last but not least, the impact of different relative amplitudes of the reflected and/or diffracted rays will be critically commented. Finally, first results of simulated DD measurements will be compared with real measurements.

P08-03

Current Research Activities at the IfE Antenna Calibration Facility

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Abstract

The Institut für Erdmessung (IfE) is an official IGS calibration institution, calibrating phase center variations (PCV) for receiver antennae routinely in the field, using the actual GNSS satellite signals in space. Current research activities focus on the antenna code phase calibration with the Hannover Concept of absolute antenna calibration. These effects may be critical for precise landing approaches and time and frequency transfer.

The receiving antenna as a part of a processing chain introduces systematic effects, currently known as Group Delay Variations (GDV), i.e. azimuth and elevation dependent code-phase delays. Depending on the used antenna design, GDV can degrade the code based accuracy.

In this contribution, we focus on the current investigations in the field of the receiver antenna GDV calibration. GDV from several antennae with different characteristics will be presented and critically discussed. It can be shown that for individual antennae, the determined GDV are a characteristical feature. The GDV were obtained using software developed at IfE. For the different types of antennae, tested at IfE Hannover, magnitudes of up to 0.3-0.5m for the P code for a typical geodetic antenna and +/- 1.7 m for the C/A code for a UBlox antenna can be obtained, mainly evoked by azimuthal variations. Different antenna calibration solutions with respect to repeatability and separability of estimable parameters will be discussed.

For the time and frequency transfer it was shown that GDV induce offsets in the link of up to 0.6 ns depending on the antennae used and the link length. The stablility of the link is not affected since the apparent noise introduced by GDV is below the code (for P3 time transfer) or phase noise (for PPP links).

P08-04

Absolute Antenna Calibration at the US National Geodetic Survey

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Abstract

NOAA's National Geodetic Survey (NGS) conducts antenna calibrations of receiving antennas in order to provide more accurate access to the National Spatial Reference System (NSRS), as an essential service for the surveying, mapping, and engineering infrastructure of the U.S. Antenna calibrations are an essential component of GNSS data processing and are used by both vendor- and university-supplied software as well as NGS' Online Positioning User Service (OPUS). It should be noted that NGS constituents use a much larger variety of antennas than are present in the IGS network. Therefore NGS is interested in providing calibrations for a wide variety of geodetic-grade antennas, from types in use at IGS reference stations to rover antennas not normally seen in the IGS network.

Since 1994, NGS has computed relative antenna calibrations for more than 350 antennas. In recent years, the geodetic community has moved to absolute calibrations - the IGS adopted absolute antenna phase center calibrations in 2006, and NGS's CORS group began using absolute antenna calibration upon the release of the new CORS coordinates in IGS08 epoch 2005.00 and NAD 83(2011,MA11,PA11) epoch 2010.00. Although NGS relative calibrations can be and have been converted to absolute, it is considered best practice to independently measure phase center characteristics in an absolute sense.

Consequently, NGS has developed and operates an absolute calibration system. These absolute antenna calibrations accommodate the demand for greater accuracy and for 2-dimensional (elevation and azimuth) parameterization. NGS will continue to provide calibration values via the NGS web sitehttp://www.ngs.noaa.gov/ANTCALwww.ngs.noaa.gov/ANTCAL, and will publish calibrations in the ANTEX format as well as the legacy ANTINFO format.

The NGS absolute system is located in Corbin, Virginia, and uses field measurements and actual GNSS satellite signals to quantitatively determine the carrier phase advance/delay introduced by the antenna element. In this poster, we intend to cover several topics of interest to the IGS community, by describing the NGS calibration facility and assumptions which underpin the setup and method discussing the observation models and strategy currently used to generate NGS absolute calibrations demonstrating that NGS absolute PCO and PCV values are consistent with other IGS-sanctioned absolute antenna calibration facilities outlining future planned refinements to the system discussing features of the NGS Calibration Policy and Procedures documents, which outline the relationship between NGS and its customers

P08-05

Antenna Phase Center Calibration Effects on Sub-Daily and Daily Position Estimates

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Abstract

In recent years, the number of absolutely calibrated GNSS antenna/radome combinations used within the global IGS network and other networks, for example, the EUREF Permanent Network (EPN), has increased considerably. Due to a number of reasons, including the fact that the individual calibrations for an antenna/radome combination show fairly consistent phase center offsets and variations across all combinations of the same type of antenna and radome, the geodetic community currently employs averaged ("type") rather than individual calibrations in high-accuracy GNSS data processing. As the individual calibrations for a specific antenna/radome combination do deviate from the type calibration, it needs to be investigated, if the use of individual rather than type calibrations could provide a significant improvement for geodetic and geophysical applications.

In this study we investigate the effect of using type and individual antenna/radome combination calibrations on the position estimates. We do this by analysis of position differences between precise point positioning (PPP) solutions employing both calibration models. Using four weeks of GPS observations we show that time series of sub-daily position differences contain periodic variations and systematic biases at the millimetre to centimetre levels. Using one year of GPS observations we show that for the time series of daily position differences the periodic variations seem less pronounced but the biases remain and are of similar magnitude to those in the sub-daily position differences. In general our preliminary results suggest that both sub-daily and daily position estimates are affected by the differences between the type and individual antenna/radome combination calibrations and require further investigation.

P08-06

Characterizing the GPS Satellite Antenna Phase- and Group-Delay Variations Using Data from Low-Earth Orbiters: Latest Results

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Abstract

Designed to support navigation, the L-band antenna arrays on the GPS satellites are significantly larger and more complex than the simple receiver antennas used in geodetic applications. The phase- and group-delay variations attributed to the GPS satellite antennas are difficult to model, and remain among the limiting sources of error for the most demanding GPS geodetic problems, such as determination of the terrestrial reference frame (TRF).

We have developed techniques for estimating the GPS satellite antenna phase and group delay variations using tracking data from low-Earth orbiters (LEOs). We describe updated estimates that are based on combinations of data from the GRACE (2002-present) and TOPEX/Poseidon (T/P, 1992-2005) missions. These satellites offer a number of substantial advantages for developing antenna calibrations. The scale (mean height) and origin of the orbit solutions are well determined (at the cm level or better) from dynamical constraints, thus obviating the need for a TRF constraint in solving for the antenna calibrations. In addition, there is no tropospheric delay to confound interpretation of the LEO measurements. In both cases, the multipath environment is also favorable: the GRACE receiver antenna is a choke ring embedded in the surface of a clean spacecraft with a simple profile, while the T/P antenna is mounted on a 4-m boom above the spacecraft bus.

Together, the T/P and GRACE missions provide a unique opportunity to observe and compare antenna calibrations for current as well as legacy GPS satellites. We provide updated comparisons of our antenna phase variation models to the International GNSS standard (based on ground data), and present new estimates of the antenna group-delay variations for use with pseudorange data. Finally, we apply our latest antenna calibrations in realizing the terrestrial reference frame from GPS alone. Current comparisons of our GPS-based TRF (1999-2011) with ITRF2008 show 0.3 mm/yr agreement in scale rate and better than 1 mm/yr agreement for origin rate. We discuss possible origins of a remaining scale bias.

P10-01
First Combination of GNSS Solutions Submitted to IAG WG "Integration of Dense Velocity Fields in the ITRF"

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Abstract

The IAG WG "Integration of Dense Velocity Fields in the ITRF" was created in 2011 as follow-up of the WG "Regional Dense Velocity Fields". The goal of the WG group is to densify the ITRF using regional GNSS solutions (submitted by the IAG regional reference frame subcommissions) as well as global solutions. This poster will give an overview of the different solutions submitted to the working group, evaluate their quality and the efforts made to homogenize them in preparation of a combination. Finally, first results of a preliminary combination will be shown.

P10-02
GNSS-Based Processing at the USNO: Incorporation of GLONASS Observations

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Abstract

As an Analysis Center (AC) of the International GNSS Service (IGS), the United States Naval Observatory (USNO) produces GPS-based estimates of satellite orbits, satellite- and receiver-clock time corrections, and earth-orientation parameters five times per day: once in a daily “rapid” process, and four times in an every-six-hours “ultra-rapid” process. Recently, USNO has begun testing incorporating GLONASS observational data into non-operational “rapid” processing. The inclusion of the GLONASS data presents an opportunity for improvement of the operational GPS-based rapids products and expansion of the GNSS product family available from the USNO. The stations which receive both GPS and GLONASS signals benefit from improved coverage with increased observations per epoch especially for stations in higher latitudes due to the higher inclination orbits of the GLONASS satellites. The incorporation affects both stations used in the network solution as well as in the PPP solution of the “rapid” product processing.

The resulting solutions from the GLONASS inclusion testing are compared to the USNO's existing GPS-based products as well as to the GPS-based combination products produced by the IGS. Comparison to the USNO operational product provides insight into the benefits and drawbacks of multi-signal based rapid products as well as what to expect as more GPS-like systems are available for inclusion, such as GALILEO and COMPASS/BeiDou-2. The IGS's rapid combination product gives an external source for comparison which allows for determining the quality of the multi-signal USNO solutions with respect to the operational USNO GPS-based rapid products.

The purpose of this poster is to illustrate the processing details and results of the incorporation of GLONASS observations. Additionally, it will provide analysis of the impact to estimated parameters that these additional observations make in comparison to the GPS-based estimates. Future directions for the USNO's multi-signal products will also be discussed.

P10-03

IAG Dancer: Global Solutions for all Receivers in the World

H. Boomkamp

ESA/ESOC

Abstract

The few hundred receivers that are routinely processed by IGS no longer represent a significant percentage of the permanent GPS sites in the world. Furthermore, GPS network operators tend to have strict requirements in the area of system integrity or availability that are not met by the “best effort” IGS products. Other operators cannot share their observation data with the IGS due to security constraints or contractual limitations. Normal GPS users do not have direct access to the ITRF either, but typically compute their position by mixing IGS orbits and non-ITRF regional reference frame coordinates. All these factors imply that the current ITRF solution for GPS has limited practical value.

The core objective of IAG Working Group 1.1.1 is to improve consistency of reference frames among the different space geodetic techniques. Because GPS is the only technique that does not even have an internally consistent ITRF solution among all reference stations, this problem had to be solved first. To this purpose, the IAG Dancer project develops software for global GPS analysis in the form of a grid computing scheme on the internet. The Dancer system separates a conventional batch least squares solution into identical tasks per receiver that run as a peer-to-peer process on the internet. Compared to the centralized approach of the IGS this offers a substantial increase in processing capacity per receiver, so that routine Dancer solutions can run at higher data rates and higher product rates than IGS. Furthermore, this processing capacity is scalable in the number of receivers so that new receivers can join without augmenting the workload for existing processes. The peer-to-peer implementation strictly avoids central elements like servers, data centres or analysis centres, and neither data nor products need to be shared with third parties. This also implies that global network operators do not depend on “best effort” third party systems. GPS end-users can join the Dancer network - without contributing to the global solution - to obtain local receiver products that are perfectly consistent with the Dancer ITRF.

The presentation summarizes the progress of the Dancer project since the Newcastle workshop and includes a call for participation in the global validation campaign. Demonstrations of the software can be organized on an ad hoc basis during the workshop.

P10-04
Time Series Analysis of GNSS-SLR Co-Located Stations

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Abstract

The 17-year time series of GNSS and SLR station coordinates are analysed using a new program of Bernese GNSS Software, namely FODITS (Find Outliers and Discontinuities In Time Series). In this program all statistically significant station events are detected i.e.: station discontinuities induced by technical and environmental sources; velocity changes (caused typically by earthquakes); outliers and periodicities (annual and semi-annual signals of coordinates’ time series). The positions of 60 SLR stations are derived using laser measurements to LAGEOS-1 and LAGEOS-2 for the time span 1994.0-2011.0, whereas positions of 595 GNSS stations are derived from GPS-only solutions for 1994.0-2002.0 and GPS-GLONASS combined solutions for 2002.0-2011.0. The analysis of the time series of GNSS-SLR co-located stations allows carrying out a multi-technique comparison between e.g. periodicities stemming from environmental sources (e.g. inaccuracies in loading displacement models), which are common for GNSS and SLR stations, and periodicities stemming directly from technological issues related to the particular technique of satellite geodesy, i.e. either SLR or GNSS.

The results presented here stem from SNF research project „Geodätische und geodynamische Nutzung reprozessierter GPS-, GLONASS- und SLR-Daten” jointly carried out by four universities: Technische Universität Dresden (TUD), Eidgenössische Technische Hochschule Zürich (ETHZ), Universität Bern, Astronomisches Institut (AIUB) and Technische Universität München (TUM).

P10-05

Application of Wavelet Semblance Function to Comparison of Centre of Mass Time Series Determined by SLR, GNSS and DORIS Techniques

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Abstract

Geocenter motion is the motion of center of mass with respect to the center of figure of the Earth. The geocenter time series can be now computed from the Satellite Laser Ranging (SLR), Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) and Global Navigation Satellite Systems (GNSS) observations with the sampling interval ranking from one day to one week. The time-frequency wavelet spectra computed from Morlet wavelet transform coefficients of these time series reveal seasonal and subseasonal oscillations in these data. The wavelet semblance function was applied to compute time-frequency correlation coefficients between these 3D time series projected as 2D complex-valued time series onto XY, YZ, and ZX planes of the Terrestrial Reference Frame. Additionally, the polarization functions computed from wavelet spectra enabled detection of common variations in the flattening and polarization of the relevant elliptic oscillations in these data. Next, these time series were transformed into time-scale domain using the discrete wavelet transform based on the Shannon wavelet functions. Such a transformation enables computation of the semblance functions between the wavelet transform coefficients of the considered time series determined by different techniques. Assuming a fixed semblance threshold, e.g. 0.1, zero values were assigned to discrete wavelet transform coefficients for which the semblance was below this threshold. The common signals in the compared center of mass time series were then computed using the inverse discrete wavelet transform of the coefficients for which the semblance exceeded the assumed threshold level.

P10-06

Activities at the CODE Analysis Center

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Abstract

Overview of the analysis activities at the Center for Orbit Determination in Europe (CODE). Specific issues relevant to the IGS are addressed and the most important new developments and model changes are presented.

P10-07
USNO Analysis Center Progress 2010-2012

C. Hackman, V.J. Slabinski, J.C. Tracey, S.M. Byram

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Abstract

The USNO has added new capabilities/responsibilities and strengthened existing ones since the 2010 IGS Workshop. New capabilities/responsibilities include assuming computation of IGS Final Troposphere estimates, chairing the IGS Troposphere Working Group, developing GLONASS processing capability, operationalizing sub-daily UTGPS estimates, and gaining memberships on the IGS Governing Board and IGS Associated Membership Committee. Existing capabilities continued/strengthened include 99-100% on-time submission of USNO Rapid and Ultra-Rapid estimates, with slight improvements made in orbit rotation, clock noise and EOP noise.

Further improvements are still needed in rapid clock and all rapid/ultra-rapid EOP noise. USNO will additionally assume Repro2 troposphere computation duties once Repro2 orbits/clocks/ERPs are being generated.

Two separate posters by Byram et al. will detail USNO IGS final troposphere computation and USNO GLONASS processing. This poster will provide an overview of new developments at the USNO analysis center, product precision/reliability, and future plans.

P10-08
The Stability and Dynamic Analysis of Chinese CGCS2000 CORS

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Abstract

There are more than 30 CORS stations included in Chinese GCS2000 geodetic coordinate system. 32 CORS stations data from 1999 to 2009 were collected and processed for analyzing their stabilities and the dynamic characteristics. The time series analysis for repeatability and non-linear periodic variation in horizontal direction were implemented by using spectrum and wavelet analysis, and HHT transform was used for trend term decomposition and periodic analysis. The analysis shows that most CORS stations have annual periodic change except few stations like URUM□XIAG. Some stations like CHUN□HRBN etc. have periodic characteristic in E direction, and some are not. The analysis result also shows that periodic characteristic in N direction is more obvious than in E direction.

P10-09

Impact of Short Period Atmospheric Loading Signals

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Abstract

Atmospheric pressure loading in a center of figure reference frame primarily affects the vertical positions of sites with the typical horizontal displacements being about 10 times smaller than the vertical ones. The high frequency part of the spectrum of the vertical displacements has strong peaks at the S1 and S2 tidal lines that arise from thermal atmospheric tides. However, in a center of mass reference frame, current models show that the horizontal displacements are comparable in size to the vertical ones and at the S1 and S2 tidal lines the horizontal signals are often large than the vertical ones at specific locations. In addition, the S1 and S2 tidal lines are of thermal origin and are not of constant amplitude and phase. When the current S1 and S2 center of mass system tidal loading corrections are applied to center of mass load calculations, there is typically still a large amount of power remaining in the loading signal at the S1 and S2 frequencies especially in the horizontal components. Most of this power arises from center of mass position changes relative to center of figure. In this analysis, we examine the magnitude of the residual S1 and S2 signals and assess the impact of these coherent signals and other sub-daily load variations on global GPS sites positions, earth orientation parameters and orbit determination. The more difficult question to answer will be the signal-to-noise ratio of both the tidal and non-tidal loading signals in the center of mass reference frame.

P10-10
Can We Decorrelate Geocenter Motion from Empirical Accelerations?

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[1]IGN/LAREG and GRGS
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Abstract

As a satellite-based technique, GNSS are theoretically sensitive to motions of the Earth's center of mass (CM). In particular, the net translations between the weekly solutions of the IGS Analysis Centers (ACs) and a secular frame such as ITRF2008 should approximate the non-linear motions of CM with respect to the Earth's center of figure. However, this sensitivity is limited by an insufficient knowledge of the non-gravitational forces acting on GNSS satellites which leads ACs to estimate them as empirical accelerations.

This presentation will focus on the correlations between the empirical acceleration parameters estimated by the ESOC Analysis Center and the position of CM. We will try to reduce them by appropriately constraining the empirical accelerations, and see if this helps to improve the determination of geocenter motion, while preserving the accuracy of the estimated satellite orbits and terrestrial frames.

P10-11

Impact of Inconsistent Use of IERS Conventions on PPP Results

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Abstract

The IERS Conventions define the standard reference systems realized by the International Earth Rotation and Reference Systems Service (IERS) and the models and procedures used for this purpose. State-of-the-art processing of space geodetic data requires, in principle, to adopt the latest version of the IERS Conventions, e.g., IERS 2010. This means, however, to frequently update analysis software packages accordingly, which cannot always be realized immediately due to several reasons, e.g., operational constraints. Small inconsistencies are an unavoidable consequence.

The impact of the use of inconsistent IERS Conventions is assessed by processing GNSS data from a global station network. Orbits and clocks from GPS and GLONASS satellites resulting from a reprocessing based on the IERS 2010 Conventions are used for a Precise Point Positioning (PPP) of the stations. On the one hand, the PPP is done with consistent IERS 2010 Convention models and on the other hand, the older IERS Conventions 2003 are used for the PPP. Results of kinematic and static analyses are compared and investigated to quantify and qualify the impact of an inconsistent use of the IERS Conventions.

P10-12
Current Status and Future Plans at the Natural Resources Canada (NRCan) Analysis Centre

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Geodetic Survey Division, Natural Resources Canada (NRCan)

Abstract

As an IGS Analysis Center (AC), NRCan has generated since the beginning of the IGS, GPS core products such as GPS satellite orbits, GPS satellite and station clocks, earth rotation parameters and station positions. NRCan has also been involved in the production and promotion of GPS Real-Time (RT) and Near Real-Time (NRT) products and services for more than 10 years. NRCan has more recently begun producing both rapid and final GLONASS orbits and clocks, and is currently working on the development of ultra rapid GLONASS orbits and clocks. Key products and services, like 1Hz GPS station data, 30 second GNSS station data, and GNSS Precise Point Positioning (PPP) continue to be refined and available to the global GNSS community. This presentation will summarize the current status of NRCan's core GNSS products as well as our near RT data, products, and services. It will also show NRCan's planned contribution and analysis strategy for the upcoming IGS repro2 campaign, initial results of NRCan's recently developed GLONASS ultra rapid products, as well as a description of NRCan's planned contribution to the final IGS ionospheric TEC grid.

P10-13
GOP EUREF Permanent Network Reprocessing Using IGS05 and IGS08 Models

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Abstract

Geodetic Observatory Pecny, Research Institute of Geodesy, Topography and Cartography, Czech RepublicThe GNSS re-processing (repro1) has been necessarily realized during the past years within the International GNSS Service (IGS) in order to provide homogenous parameter time-series according to the best models and products. The EUREF reprocessing has followed the IGS repro1, while the IGS orbit and clock products were kept fixed. The EUREF ITRF2008 densification is based partly on the EUREF reprocessed solutions and partly on operational solutions (since GPS week 1408) so that the consistent set of adopted models is provided. However, the ITRF2008 densifications is still a mixture of various analysis centres contributions, software packages, reprocessed and operational solutions etc. Although some problems were finally identified, the expected significant improvements of new ITRF2008 European reference frame densification were really achieved.

Firstly, GOP contributed to the EPN repro1 with its sub-network of about 70 stations. Secondly, GOP provided an independent re-processing of the whole EPN from GPS week 0836 to 1631 using both IGS05 and IGS08 reference frames (RF) and antenna phase centre offsets and variations (PCO+PCV) and their 1996-2011 combinations for velocity and discontinuity estimations. The GOP IGS05 solution was used to independently evaluate an official EUREF ITRF2008 densification, while helping to identify some issues with the EUREF repro1 campaign and providing recommendations for future repro2. Additionally, it has shown problems of the official ITRF2008 for some European stations. The comparisons of IGS05 and IGS08 solutions resulted in a very good agreement for all coordinates and velocities, however, a scale change of about 1ppb was identified (improves ~2ppb scale between the ITRF2008 its GNSS-based only European densification applying IGS05 models). Finally, GOP continued with the reprocessing from GPS week 1632 during which IGS switched from IGS05 to IGS08 RF and PCO+PCV models. This enabled us to assess an impact of such switch on the European cumulative densification, which necessarily mix IGS05 and IGS08 models in order to provide as much as up-to-date solution for end users after GPS week 1931.

P10-15

The JPL IGS Analysis Center: Status and Plans

Shailen Desai, Willy Bertiger, Bruce Haines, Christina Selle, Aurore Sibois, Anthony Sibthorpe, and Jan Weiss

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Abstract

We present an overview of the activities being performed by the Jet Propulsion Laboratory (JPL) in support of the International GNSS Service (IGS). The JPL IGS Analysis Center will contribute products from a reanalysis of global GPS data from 1993-present to the next IGS reprocessing campaign, using our GIPSY/OASIS software package. In particular, we will deliver solutions for the orbit positions and clock biases of the GPS constellation of satellites, Earth Orientation Parameters, daily SINEX files with station positions, troposphere observations, and yaw rates of the GPS satellites. Our clock products will include 5-minute solutions for the full reanalysis period, and 30-second solutions for 1996-present.

We present results from a first reanalysis of GPS data from 1993-present completed in mid-2012. This first reanalysis used the recently released IGS08 reference frame and associated antenna calibrations, IERS 2010 standards, and an updated solar radiation pressure model (GSPM10). We show that the precision of these new orbit and clock products improves by an average of 25 and 12 percent, respectively, compared to our products from the first IGS reprocessing campaign. More importantly, our most recent reanalysis also includes products that enable single receiver ambiguity resolved positioning for the entire duration (1993-present), which are automatically applied when performing positioning with the GIPSY/OASIS software. We show that 30-70% variance reduction in station repeatability is achieved from the cumulative effect of our improved orbit and clock products and the capability to perform single receiver ambiguity resolved point positioning. Typical east, north and up station repeatabilities of 2, 2, and 6 mm are achieved for daily static precise point positioning, and 6, 7, and 16 mm for unconstrained white noise 5-minute kinematic point positioning.

We conclude by presenting our plans for the minor adjustments that will be made prior to a second reanalysis from 1993-present for submission to the next IGS reprocessing campaign, and plans for the next release of the GIPSY/OASIS software, version 6.2.

P10-16

Incorporating Seasonal Variations Based on GRACE Measurements in Global and Regional TRF Models

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Abstract

Significant seasonal variations (especially in the vertical) are found in many GPS sites, but no such variations are assumed in the ITRF models. As a result, real seasonal variations at sites used for reference frame alignment may affect reference frame realization and coordinate time series at a seasonal timescale. Ignoring true seasonal variations will bias both the reference frame parameters and the coordinates of all sites in the transformed solution. In this study, we introduce a seasonal loading model based on GRACE measurements to model hydrological loading. In effect, this augments the ITRF by adding a seasonal componentto all sites (the amplitude of seasonal variations on many ITRF sites exceeds 5 mm). We then evaluate the use of both the original ITRF2008 and the seasonally augmented ITRF model for global and regional reference frame realization. We model the seasonal components using either annual and semi-annual terms or a non-parametric approach. When we applied a seasonal variation model, the WRMS misfit after 7-parameter transformation decreased for more than 70% of daily GPS solutions, relative to a baseline case using ITRF2008. In general, seasonal variations at all sites are slightly larger amplitude when we align daily solutions with the seasonally augmented ITRF model. However, the observed seasonal variations are more consistent with the GRACE-based model at more than 70% of the GPS sites that were NOT used in the frame alignment. We interpret these findings to mean that the use of ITRF2008 without seasonal terms causes the amplitude of seasonal variations in the coordinate time series to be damped down relative to the true loading deformation, and that the observed GPS time series are more consistent with a TRF model that includes seasonal variations. We have implicitly assumed that ignoring seasonal variations has not introduced any biases or distortions into the ITRF model itself, but that assumption should be verified.

P10-17

The ESA/ESOC Analysis Center Progress, Improvements and Planned Upgrades in the GNSS Data Processing

Tim Springer, Ignacio Romero, Florian Dilssner, Joachim Feltens

ESA/ESOC, Darmstadt, Germany

Abstract

ESA/ESOC continues to be an active IGS Analysis Center. This poster presents the recent improvements in our processing software Napeos, the increased quality and consistency of the ESA/ESOC products, and the plans for future improvements

P11-01
Towards a Vertical Datum Standardisation Based on a Joint Analysis of TIGA, Satellite Altimetry and Gravity Field Modelling Products

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Abstract

One of the most important problems of modern geodesy is the definition and realisation of a global vertical reference system, which unifies, with high accuracy, the existing classical height datums. Keeping in mind that the reference levels of these datums were realised by the mean sea level recorded at individual tide gauges during different time periods, their unification requires the accurate knowledge of the real mean sea surface at the definition time interval and the actual location (w. r. t. the geocentric reference system) of the tide gauge rod at the same epoch. This is only possible by deriving the corresponding vertical velocities from the combined analysis of GNSS series, tide gauge observations, and satellite altimetry data at common sites. The present contribution describes an approach for the combination of all these observables, including a detailed analysis of the error sources and the corresponding propagation, as well as the uncertainties caused by applying different models in the data processing, i.e. tides reference system, orthometric hypothesis, etc. As an example, the vertical datum standardisation at some South American height systems is presented.

P11-02
The BLT IGS TIGA Analysis Center

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Abstract

During 2011, the consortium consisting of the NERC British Isles continuous GNSS Facility (BIGF), hosted by the University of Nottingham, and the Geophysics Laboratory (GL), University of Luxembourg, was established as the BIGF-University of Luxembourg TIGA Analysis Center (BLT). The BLT proposes to contribute minimally constrained SINEX solutions computed using the new Bernese GNSS Software V5.2 (BSW5.2) to the TIGA Working Group. Over the past few years, the University of Nottingham (UNT) has carried out re-processing to generate its own homogeneous, satellite orbit and clock, and EOP products, for the period from 1998-2007, using an in-house modified version of the Bernese GPS software V5.0 (BSW5.0), which includes the Vienna mapping functions (VMF1). In preparation for the TIGA reprocessing campaign, BLT has produced a series of preliminary solutions using this modified BSW5.0 and processing of a global network based on double-differencing (DD). These solutions are based on the use of CODE repro1 products (co1), IGS repro1 products (ig1) and UNT products. In this study, we provide an evaluation of the UNT products, based on using the modified BSW5.0 in precise point positioning (PPP) mode, and an evaluation of the derived DD coordinate time series.

P11-03

An Evaluation of a Monte Carlo Markov Chain Method for the Statistical Analysis of GPS Time Series

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Abstract

The primary objective of the TIGA working group is to compute accurate geocentric velocities with realistic uncertainties for all continuous GPS stations located at or near a tide gauge. These velocities are generally computed by fitting a model consisting of a linear trend, periodic terms and discontinuities to the daily or weekly coordinate time series. It is now widely accepted that in order to compute realistic velocity uncertainties a comprehensive knowledge of the stochastic properties of the non-Gaussian noise within the time series is crucial, as it affects the parameter estimation and associated uncertainties. Currently, a number of methods have been described in the literature; these include, for example, optimization methods (maximum likelihood estimation (MLE) and least-squares) and empirical methods (Allan Variance). Although these methods provide more realistic uncertainties than those based on the assumption of Gaussian noise, they do not intrinsically provide a quantification of the error of the spectral index estimate nor of the correlation between the estimated parameters themselves.

We present a Monte Carlo Markov Chain (MCMC) method to simultaneously estimate the velocities and the stochastic properties of the noise in coordinate time series. This method allows to get a sample of the likelihood function and thereby, using Monte Carlo integration, all parameters and their uncertainties are estimated simultaneously. We assess this MCMC method through comparison with the widely used CATS software, which applies an MLE algorithm, using reprocessed daily GPS time series (British Isles continuous GNSS Facility (BIGF) level 2 product) from a global network of stations.

P11-04

The Potential of Persistent Scatterer Interferometry for Complementing GPS Installations at Tide Gauges – Experiences from the United Kingdom

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Abstract

Persistent Scatterer Interferometry (PSI) is a powerful technique for measurement and monitoring of vertical land movements (VLM) by the analysis of the time series of especially selected pixels in satellite imaging radar data. Contrary to other geodetic techniques, such as precise levelling and/or continuous GPS, which are used at tide gauge (TG) sites to monitor their stability, PSI is capable of providing estimates from a local to regional spatial extent. Over the past years, PSI has been successfully applied to the monitoring of urban and rural areas, as well as volcanoes and land slides, providing millimetre-level accuracy. However, the application of PSI to coastal areas and to monitoring TG sites has not been well investigated.In this study the suitability of the PSI technique using ERS1/2 and Envisat imaging radar data is investigated for the application to coastal areas and to monitor the stability of benchmarks and GPS installations at four TGs in the United Kingdom. We present results on scatterer identification under varying levels of urbanization and/or vegetation at TG sites and on ocean tide loading in PSI processing. The latter is routinely modelled in GPS analyses, but largely ignored in PSI.

P11-05

The TIGA Data Assembly Centre SONEL: Recent Developments and Perspectives

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Abstract

TIGA aims at processing and reprocessing GNSS data from permanent stations at or near tide gauges in order to provide robust estimates of their vertical land movement. Related important products are the weekly position time series, the offset discontinuities and the accurate average positions of the tide gauges in the latest ITRF. Since November 2011 SONEL (www.sonel.org) acts as the primary TIGA data centre. It therefore focuses on collecting, archiving and distributing observations from GNSS stations at or near tide gauges, but also from the IGS core stations to support each TIGA analysis centre (TAC) in its processing and reference frame alignment. It also aims at providing the above mentioned products. In this respect, we will present the new tools that are developed to display and provide the latest and previous GNSS solutions from each TAC in a standardized format, as well as the combined solutions from the TIGA Working Group. In the near future, the main page of the website will be restructured to highlight those products and its applications for climate-related studies, control of the satellite altimeter stability or unification of height systems. One of them builds upon the dynamic tool developed by the Permanent Service for Mean Sean Level (PSMSL) to calculate and display the rates of relative sea level change over different periods. The purpose in SONEL will be to provide the rates of absolute (geocentric) sea level change by correcting the PSMSL relative trends with the estimated GNSS vertical velocities.

P11-06
GPS Estimates of Vertical Land Motion for Altimeter Calibration

Alvaro Santamaría-Gómez[1], Médéric Gravelle[2], Xavier Collilieux[3], Mikael Guichard[2], Belén Martín Míguez[4], Pascal Tiphaneau[2], Guy Woppelmann[2]

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Abstract

Global Positioning System (GPS) data reanalyses are mandatory when aiming at the highest consistency of the estimated products for the whole data period. The University of La Rochelle Consortium (ULR) has carried out several GPS data reanalysis campaigns with an increasing tracking network, an improving processing strategy and the best available models. The main objective of this effort is to correct for long-term vertical land motions at tide gauges (TG) by estimating high-accurate GPS vertical velocities at co-located stations (GPS@TG), useful for long-term sea-level change studies and satellite altimeter drift monitoring. The latest GPS velocity field estimated at ULR (named ULR5) includes 326 GPS stations, fromwhich 201 are GPS@TG. The application of this velocity field is illustrated at worldwide TGs in order to appraise to what extent vertical land movements contaminate the estimates of satellite altimetry drifts. By taking into account the vertical land motion of the tide gauges, the impact on the altimeter-derived sea level trends was evaluated to be up to 0.6 mm/yr.

P11-07

TIGA Network Coordination: Monitoring Data Fluxes and Providing Metadata

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Abstract

This presentation aims to introduce the role of the TIGA network coordinator. This position was missing during the TIGA pilot project era (2001-2010) and only filled in 2011. The role is closely related to the TIGA data centre (TDC) activities which are carried out within the same institution at the University of La Rochelle. It requires monitoring the GNSS observations that are collected in the form of 24h/30s RINEX files and reporting on the status of the data actually made available. Nearly 700 station records are stored today at the TDC, out of which 503 are or were located at or near a tide gauge. The role also requires checking the availability and consistency of the associated metadata, which are mostly condensed in the so-called IGS station sitelogs.

These requirements are necessary for the TIGA analysis centers (TAC) to properly process the measurements and get accurate position time series and vertical velocities, in particular when a change has occurred to the station equipment or local environment. To fulfill these network coordination objectives, the SONEL database has been expanded and automatic procedures are developed based on mapping and web-based tools. Some of these tools still necessitate refinement or tuning, for instance to cope with the providers specific data latency in order to set accurate alerts.

In addition, we are developing web-based tools to support newcomers who are not familiar with the IGS or GNSS practices in order to enable them to commit to TIGA more easily (e.g., DOMES numbers request, submission of a compliant station sitelog). Only 112 out of the above 503 stations in the TDC are formally committed to TIGA. Technical support in RINEX conversion and quality control is also important for sea level agencies that are not processing GNSS data for their own purposes and thus may not notice when their observation files are corrupted. In this latter respect collaboration has been established between ROB and the University of La Rochelle.

P11-08

Processing of a Regional EPN Sub-Network with Global IGS Sites at WUT EPN LAC: Experiences and Preliminary Results

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Abstract

The poster presents initial experiences and results stemming from common GPS analysis of a regional EPN sub-network together with global IGS stations obtained by WUT EPN LAC. These analyses have been performed as a preparatory phase for WUT's contribution to EPN-Repro2 project which now includes a global extension of the EPN network. The EPN has become TIGA Analysis Centre in 2011. The WUT EPN LAC is one of 18 Local Analysis Centers of the EUREF Permanent Network (EPN).The analysis has been performed using Bernese GPS Software ver. 5.0 (possibility to apply GMF mapping function has been added). We processed _60 regional EPN sites together with _90 IGS global sites. Strategy used for GPS data analysis will be described on the poster. The comparison of time series of the common solution with regional only will also be presented for selected TIGA stations.

P11-09
North Shields Tide Gauge: Local Ties Lessons

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Abstract

The North Shields tide gauge is one of the core sea level measurement sites in the UK and contributes data to PSMSL. It has been providing measurements since 1895 with completeness of 93%. In the 1998 continuously operating GPS station NSTG was installed near the tide gauge and local control surveys between them were carried out regularly. Due to construction works the station had to be dismantled in 2009, the tide gauge moved and a new continuous GNSS station NSLG was constructed. Although there was a two week period of data overlap between these two sites, data quality appears to be substandard. In this presentation we share our experience in overcoming the data quality limitations in the process of establishing the ties between two GNSS site and the tide gauge.

P12-01

Using IGS Products for Near Real-Time Comparison of UTC(k)'s

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Abstract

The time-transfer technique based on Precise Point Positioning (PPP) has proved to be a very effective technique allowing the comparison of atomic clocks with precision at the level of hundred picoseconds, with latency of less than a few days. Using satellite orbit and clock information from the IGS ultra-rapid and real-time products, or from the NRCan Ultra Rapid products (EMU), it is now possible to compute very precise time transfer solutions in near-real-time mode (latency down to some minutes), using both code and carrier phase measurements in a PPP approach. Using the software tool named "Atomium" developed at ORB, we set up an operational service for the National Metrology Institutes, providing a near-real time comparison of their local realizations of UTC, named UTC(k)'s. The poster presents this application and a quantification of the quality of the clock monitoring so-obtained.

P12-02
A focus on Estimated Coseismic Displacements using IGS Weekly Station Positions

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Abstract

Given the large number of IGS stations and their global distribution, IGS network frequently records crustal deformations due to earthquakes. However, the weekly IGS products don't allow to estimate correctly coseismic offsets. For stations affected by recent great earthquakes, position residuals of individual Analysis Center (AC) solutions w.r.t IGS combined positions show clear differences in data editing and/or processing strategies. These differences can be generally explained by the exclusion of data by several ACs for specific days of the GPS week. Even if this problem will be partly solved with future daily solutions, every AC may exclude subsets of observations recorded a day of an earthquake so that final estimated positions may integrate different mixtures of preseismic, coseismic and postseismic data. In the future, verification of the ACs' epoch-block solutions before combination should be planned when seismic events are reported. In order to improve the quality of IGS combined solution, common AC processing strategies are necessary.

P12-03
Processing LEO Data and Gravity Field Determination at AIUB: A Status Report

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AIUB: Astronomical Institute, University of Bern, Switzerland

Abstract

The Astronomical Institute of the University of Bern (AIUB) has a well-documented record concerning the scientific analysis of Global Navigation Satellite System (GNSS) data with the Bernese GNSS Software. The Center for Orbit Determination in Europe (CODE) at AIUB generates the full IGS product line, in particular GNSS orbits and high-rate satellite clock corrections, which are available for spaceborne applications.

Spaceborne measurements of the Global Positioning System (GPS) are used at AIUB to determine precise kinematic and reduced-dynamic orbits for a variety of low Earth orbiting (LEO) satellites. So-called pseudo-stochastic orbit modeling techniques allow for efficient and flexible LEO precise orbit determination (POD) and have been used, e.g., to exploit CHAMP and GRACE GPS (and K-band) data for orbit and gravity field recovery. Currently, the POD procedures are used by AIUB to derive the precise science orbits for the GOCE mission.

We present LEO POD results based on undifferenced GPS measurements, and gravity field recovery using kinematic positions.

P12-04

Assessment of Single Epoch Integer Precise Point Positioning Performances

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Abstract

Recent improvements in Precise Point Positioning (PPP) including ambiguity resolution (Integer PPP; IPPP) make this technique a potential alternative to the classical differential approach. Single epoch positioning is a powerful method for geosciences applications, atmosphere monitoring, time transfer, and mobile tracking.

First, this study evaluates the current accuracy of single epoch IPPP derived from a global station network where each station is computed independently. After discussing the benefits of fixing ambiguities, we focus on remaining signal on time series.

We first review the problem of correlations between parameters derived from single epoch IPPP. Then, we quantify how remaining errors in observation equations and satellite products propagate on IPPP estimates. For such purpose, differential single epoch IPPP series obtained at close stations are compared to classical double differences solutions. We demonstrate the need to use consistent constraints with the expected signal. We show the benefits of constraints applied to positions and/or tropospheric estimates when single epoch IPPP is used for observing loading, co-seismic, post-seismic displacements, and mobile tracking. Finally, the impact is evaluated for time transfer applications.

P12-05
Some Aspects of GBAS Application to Geodynamical Studies

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Abstract

Originally augmentation of a global navigation satellite system (GNSS) is a method of improving the navigation system's attributes, such as accuracy, reliability, and availability, through the integration of external information into the calculation process. Each of the terms of Ground Base Augmentation System (GBAS) describe a system that supports augmentation through the use of terrestrial GNSS sites. Over time, it turned out that the ground stations can also be successfully used for scientific research in terms of geodynamics. Dense deployment of these stations allows to perform analysis of a local nature, including the creation of regional models of the recent neotectonic movements. Polish GBAS (ASG-EUPOS) consists of over 130 sites located at the area of Poland together with some incorporated sites from abroad. In 2010 the project aimed at creating supporting modules for ASG-EUPOS real-time services started and within this project the geodynamical module was incorporated. This poster presents results of joint processing of ASG-EUPOS observations together with EPN made in the Military University of Technology EPN Local Analysis Centre, studies on coordinate time series, determination of the local velocity field in both meaning (absolute and intraplate) as well as the first calculation of the local strain rates basing on information from Polish GBAS.

P12-06

IGS Products in GNSS Time Transfer Using TTS-4 Receivers

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Abstract

Presently the time transfer techniques used in the comparison of remote clocks for TAI computation are based on satellite signals. The majority of links in TAI time transfer network use GPS or GLONASS constellation for common-view (all-in-view) multi-channel or Precise Point Positioning techniques - the one-way techniques which are susceptible to orbit perturbations and atmospheric delays. A condition of reaching the uncertainty better than one nanosecond is the use of observation corrections. The Time Transfer System 4 (TTS-4) multi-frequency multi-constellation receivers were included to time transfer links in 2011. The poster provides the results of comparisons of the GNSS time transfer methods using raw data and with the use of the IGS products.

P12-07
Atmospheric Loading Detection Using Regional GNSS Network: Case Study of Polish GBAS System

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Abstract

The recent precision of satellite geodesy techniques allows to study subtle geodynamical phenomena. While the Earth crust cannot be regarded as rigid body anymore one has to deal with atmospheric loading (ATML) effects in GNSS results which can be as big as few centimetres for height component. In this work we examine the results of GNSS data collected within ASG-EUPOS system – polish national GBAS. We computed height time series of nearly hundred GNSS sites for almost one year time span. For this purpose we used Bernese 5.0 processing package utilizing the most recent models and IGS products. The coordinate variations were checked against the modelled atmospheric loading. We used the freely available data set provided by Leonid Petrov as well our own calculation. Our values were computed on the base of crustal properties (in terms of Greens functions) convolved along with global pressure field extracted from numerical weather models.

We found an overall good agreement for height component was found while for the horizontal component comparison is ambiguous. The distinct diminish of height time series is clear for majority of selected sites when ATML correction were applied. At some sites we do not see significant reduction of variance which can be even more robust indicator of site specific noise level then before applying ATML correction. This allows to easy pinpoint the problematic sites.

We also put a discussion of some problems of evaluating the global geodynamic signals in regional network. Some discrepancies between modelled and observed ATML can be attributed to the shortcomings of processing network with limited spatial coverage. Nevertheless this problem await for further investigations.

P12-08

First Investigations on Using Galileo E5AltBOC for Time Transfer

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Abstract

Measurements from Global Navigation Satellite Systems (GNSS) are used since the eighties to perform precise and accurate Time and Frequency Transfer. Using GPS measurements, the time transfer accuracy and precision are limited by the colored signature of the codes noise, mainly due to near-field multipath. This signature affects the medium-term (from some hours to some days) stability of the solution and induces possible discontinuities at the day boundaries, which can reach the nanosecond level for some stations, mitigating the quality of the results obtained by this technique.

The European Galileo system is under development, with currently two experimental satellites in operation, GIOVE-A and GIOVE-B and two operational satellites launched in October 2011. Galileo is planned to transmit in 3 frequency bands (E1, E5 and E6). In the E5 band, Galileo will use a PRN chip rate of 10.23 MHz and two subcarriers (E5a and E5b) spaced at 30.69 MHz, resulting in a 51 MHz wide signal bandwidth transmitted at the 1191.795 MHz carrier frequency, modulated with the alternate BOC(15,10) technique, denominated AltBOC. Thanks to this exceptional high bandwidth, the E5AltBOC code will, in addition, provide significant improvement of the noise and long-term multipath performance as compared to current GPS/GLONASS but also compared to E5a and E5B.

Some studies with GIOVE-A or GIOVE-B data already confirmed the high potential of Galileo code modulations, with code tracking noise improvement compared to GPS from dm-level to cm-level values, in particular for E5AltBOC. Further analysis also demonstrated the highest multipath suppression compared to other GNSS signals, down to values of about 20 cm. For these reasons, E5AltBOC is very promising for improving time transfer applications.

The aim of this study is to investigate new analysis procedures that take benefit of Galileo E5AltBOC (E5 hereafter) for time transfer. Combining the Galileo E5 code with another code in order to create an ionosphere-free solution would cause the loss of the properties of this very precise code, due to the noise of the second code used for the combination. This poster therefore discusses the possible use of the E5 code only, with different strategies to correct the E5 code for the ionospheric delays.