ILRS Governing Board

Chancellor Hotel
San Francisco, CA USA

December 14, 2009
07:00–09:30 p.m.

Agenda

1.	Opening Remarks (5 min.)	M. Pearlman
2.	Remarks by the New Chair	G. Appleby
3.	ILRS Status/Central Bureau Report (20 min.)	M. Pearlman/C. Noll
4.	WG Briefs and Recommendations (5-10 min each)	
	✦ Analysis (including status of data products)	E. Pavlis/C. Luceri
	✦ Missions (new missions/new missions approved/challenges)	G. Appleby
	✦ Data Formats and Procedures	C. Noll for W. Seemueller
	✦ Networks and Engineering (Stanford Counters, etc.)	G. Appleby
	✦ Transponders (incl. LRO)	J. McGarry
	✦ Lunar Laser Ranging	J. Mueller
5.	Task Force Reports (5 min. each)	
	✦ Communications	M. Torrence
	✦ Center-of-Mass Corrections	G. Appleby
6.	Normal Point Formulation (10 min)	M. Pearlman
7.	Status of the ITRF 2008 (10 min)	Z. Altamimi
8.	Report on the Metsovo Meeting (10 min)	E. Pavlis
9.	Retroreflector Issues (10 min)	M. Pearlman/G. Appleby
10.	ILRS Special Issue in Journal of Geodesy (5 min.)	E. Pavlis
11.	GGOS Activities (5 min.)	M. Pearlman
12.	New Business	
13.	Other Business	

All presentations will be posted on the ILRS website; please be concise
Coffee, tea, cold drinks, and cookies will be served

ILRS Governing Board 2008-2010

Director of the Central Bureau	Mike Pearlman (appointed)
Secretary of the Central Bureau	Carey Noll (appointed)
President of IAG Commission 1	Zuheir Altamimi (appointed)
IERS Representative	Bob Schutz (appointed)
EUROLAS Network Representatives	Giuseppe Bianco, Francis Pierron
NASA Network Representatives	David Carter, Jan McGarry
WPLTN Network Representatives	Yang Fumin, Ramesh Govind
Data Center Representative	Wolfgang Seemueller
LLR Representatives	Juergen Mueller
Analysis Representatives	Cinzia Luceri, Erricos Pavlis
At-Large Representatives	Graham Appleby*, Georg Kirchner

* Newly elected chair for 2010

ILRS Working Groups

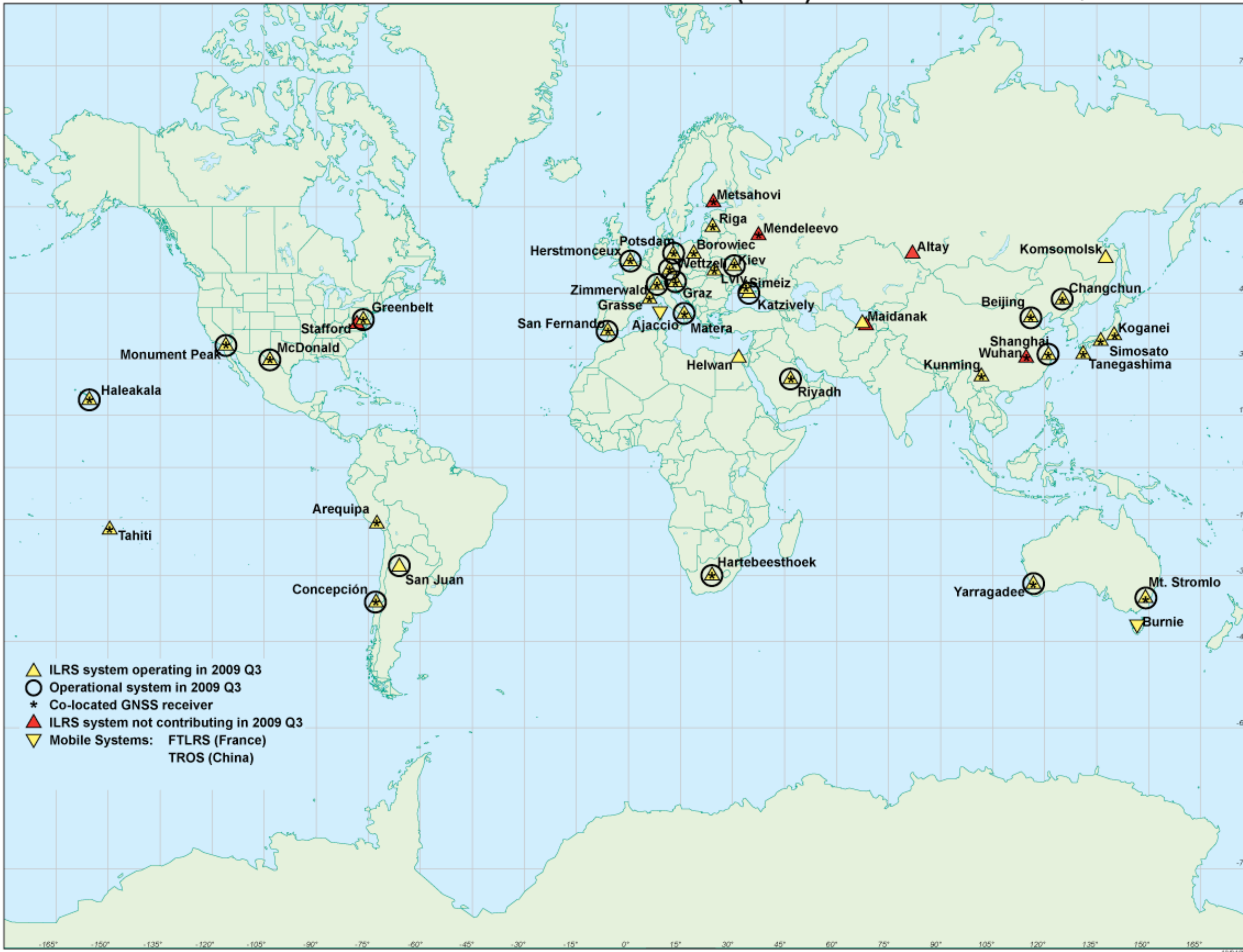
- Analysis
  - E. Pavlis/C. Luceri
- Missions
  - G. Appleby/S. Wetzel
- Data Formats and Procedures
  - W. Seemueller/R. Ricklefs
- Networks and Engineering
  - G. Kirchner/U. Schreiber
- Transponder
  - U. Schreiber/J. McGarry

Central Bureau Update

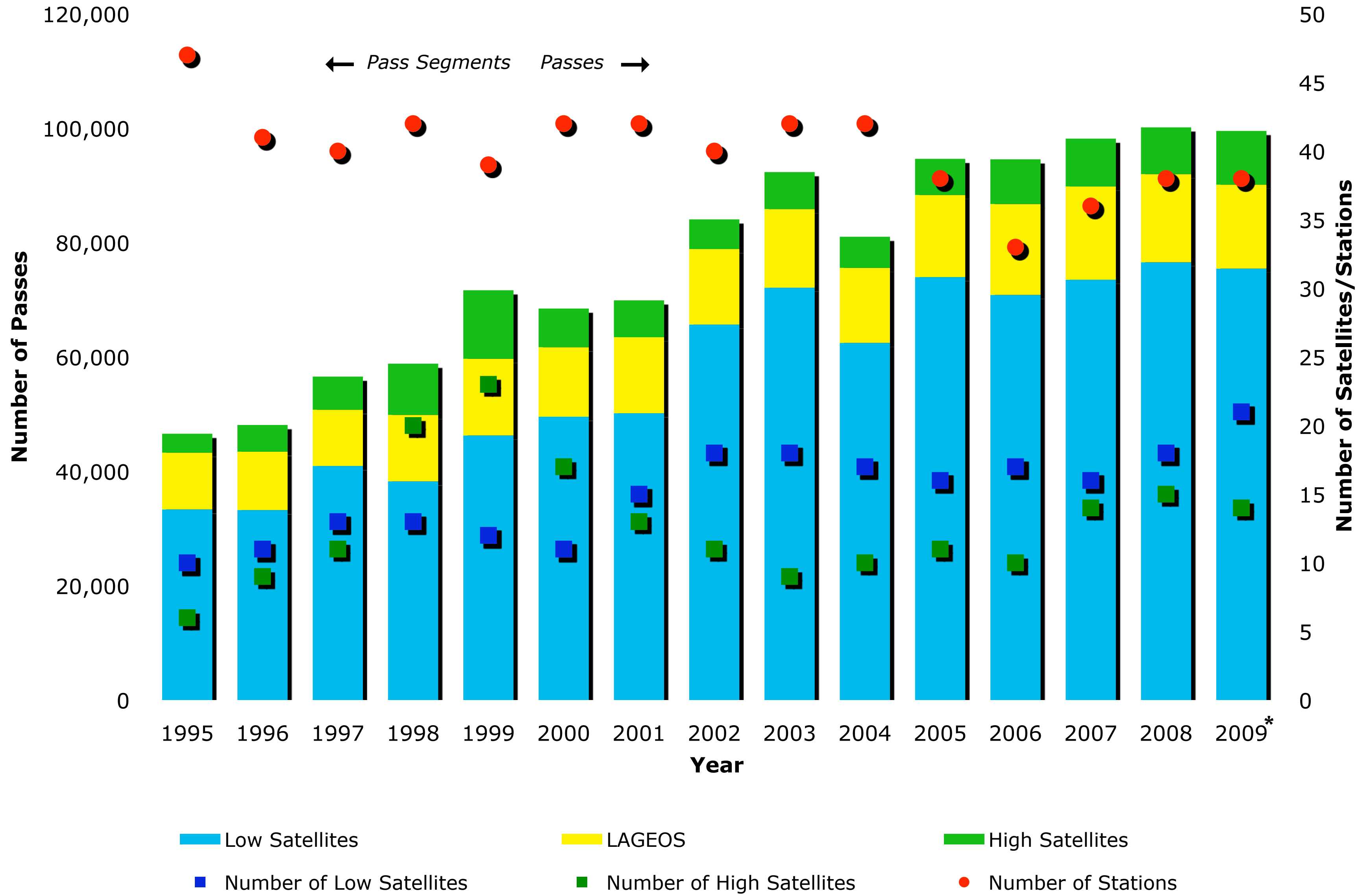
Network Status

- 38 stations providing tracking data in 2009
- Most productive stations are Yarragadee, Zimmerwald, Mt. Stromlo, Greenbelt, Changchun, Wettzell, San Juan, Graz, San Fernando, and Herstmonceux
- All MOBLAS systems (except Tahiti) and MLRS operating at 10Hz on low satellites
- Tahiti operational after visit by HTSI engineer; data under evaluation
- Arequipa not operational due to MCP failure
- Wettzell not operational due to mechanical issues with the telescope drive; staff hopes to bring new system (SOS-W) online shortly
- APOLLO lunar system to participate in LRO-LR and two-way ranging experiments in early 2010; need to resolve data transmission plans

INTERNATIONAL LASER RANGING SERVICE (ILRS) NETWORK IN 2009 Q3

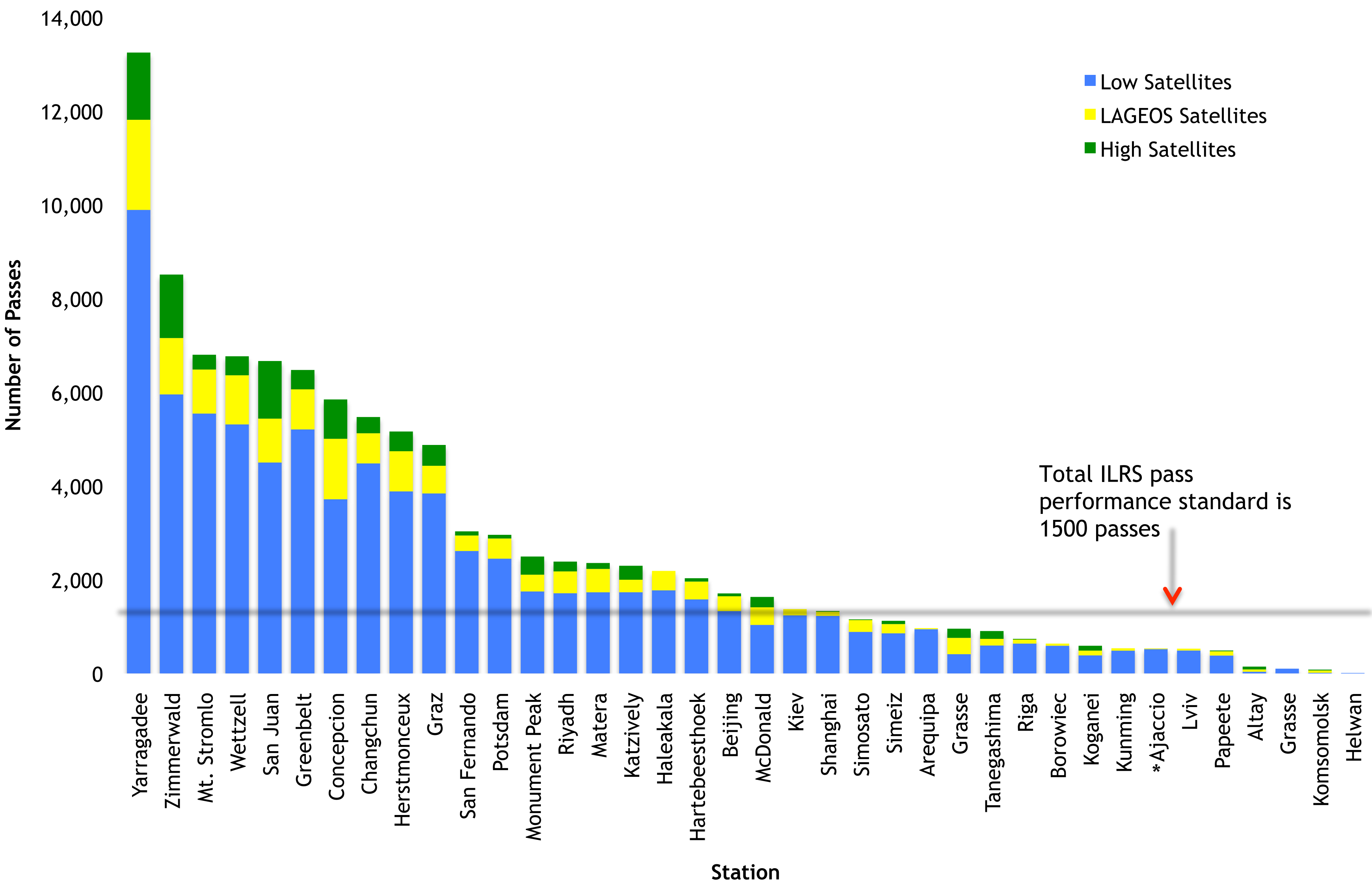


Annual Data Yield



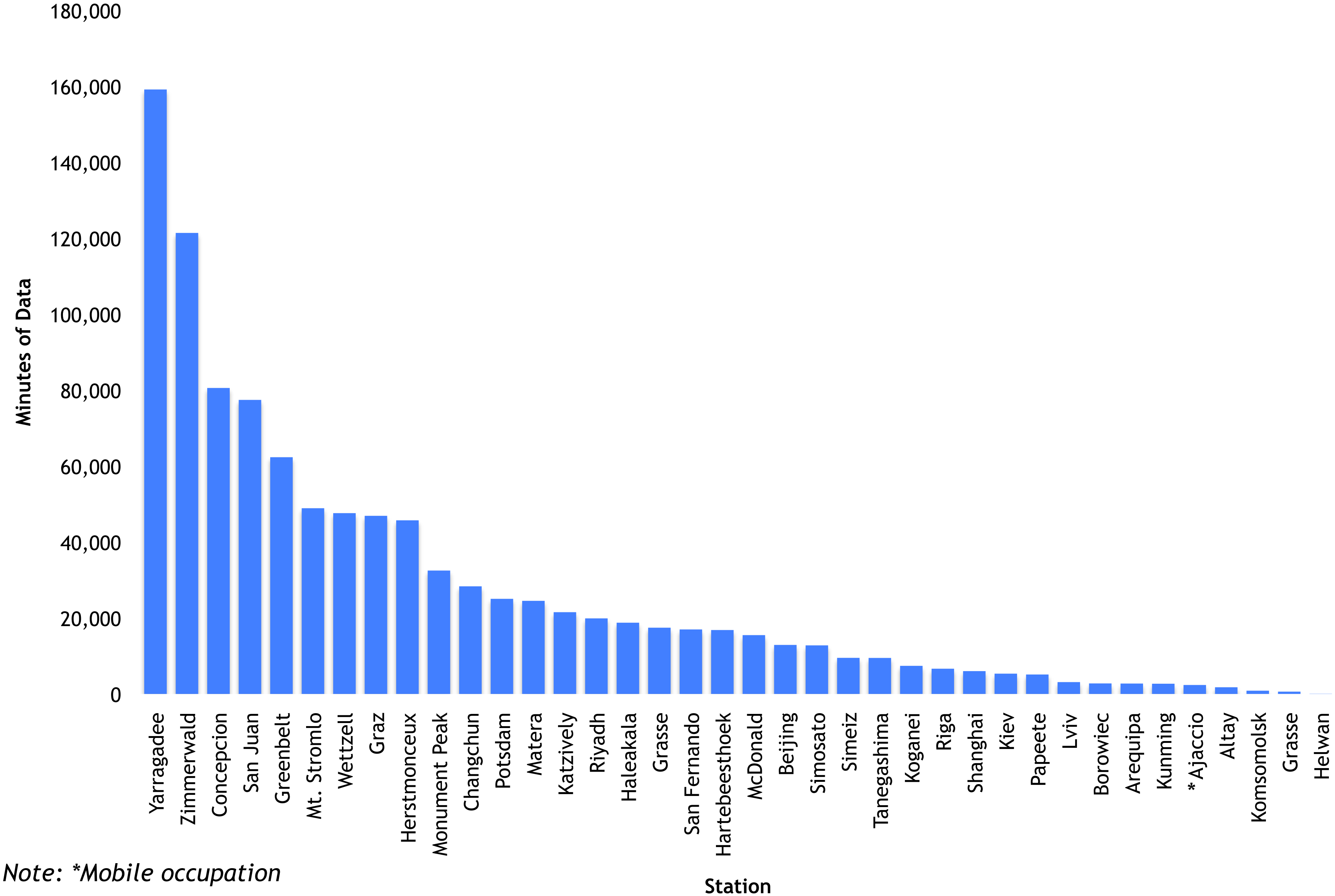
*Note: *statistics through 11/30/2009*

Station Performance
All Satellites (2009Q3)



*Note: *Mobile occupation*

Station Performance
Minutes of Data (2009Q3)

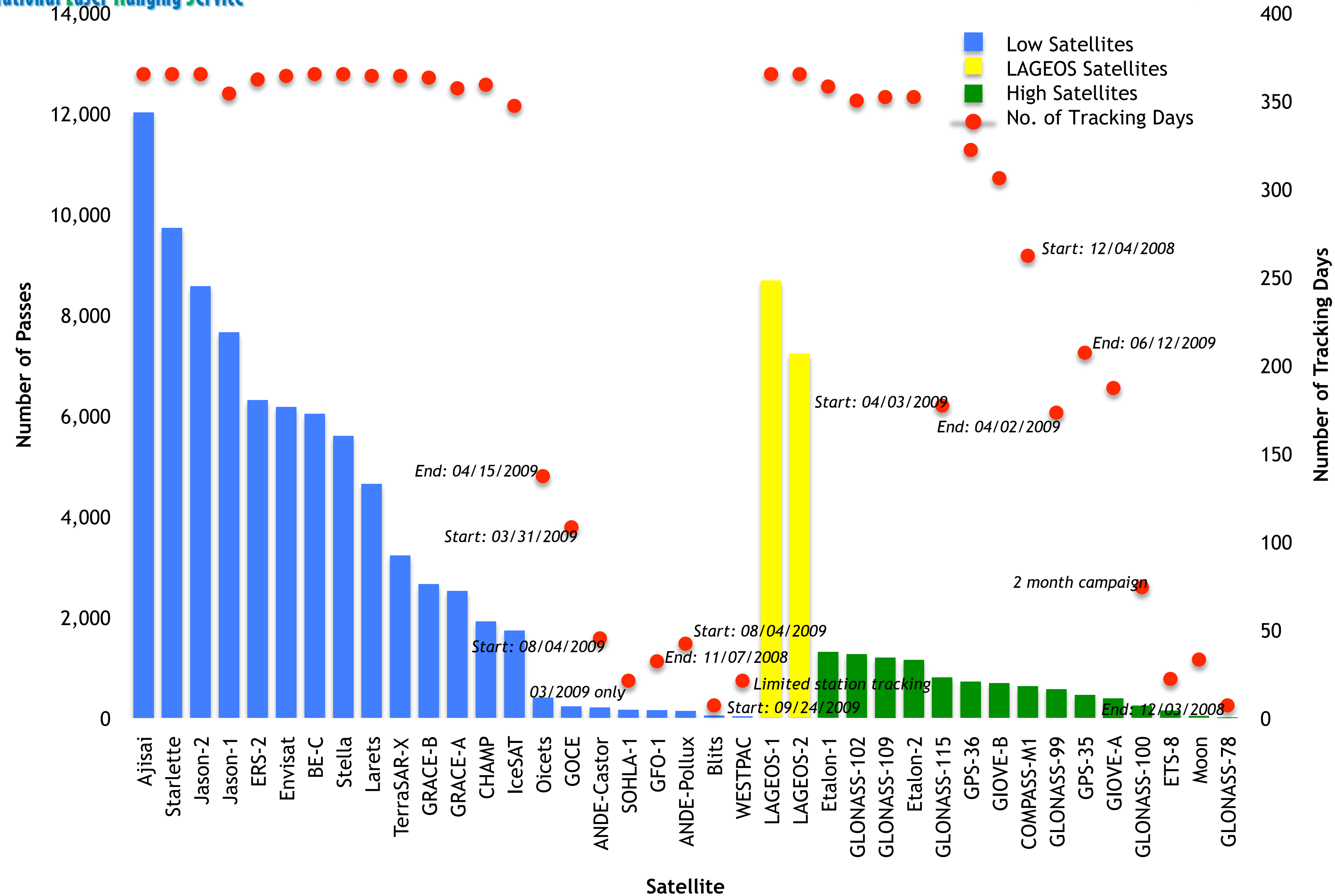


*Note: *Mobile occupation*

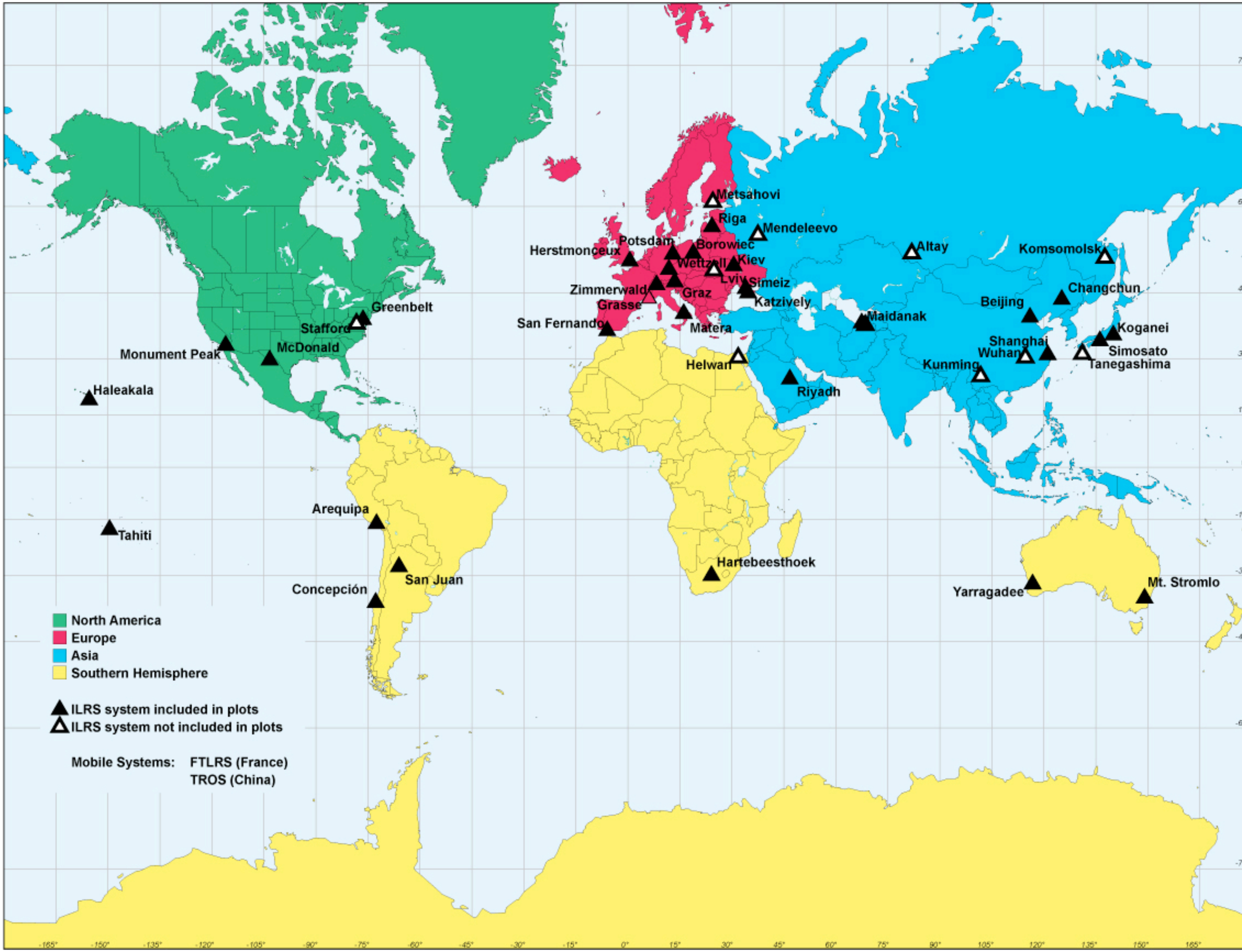
Mission Developments

- Currently supporting 27 missions and lunar tracking
- SOHLA-1 campaign in March, second campaign in fall possible
- GOCE tracking has improved mainly due to predictions generated by CODE from GNSS data
- STSAT-1 launch failure in April 2009
- Recent launches:
  - LRO: 30-Jun-2009
  - ANDE: 30-Jul-2009
  - Blits: 17-Sep-2009
- Upcoming launches of approved missions:
  - Proba-2 (ESA): 02-Nov-2009 (tracking in Jan-2010)
  - CryoSat-2 (ESA): 28-Feb-2010
  - RadioAstron (Russia): Dec-2009 (tracking by lunar-capable stations)
  - KOMPSAT-5 (KARI): 2009/2010 (in MWG for approval)
  - STSAT-2B (KARI): May-2010
  - TanDEM-X (DLR, GFZ, others): 2009?
  - QZS-1 (JAXA): 2009?
- Three new GLONASS satellites launched on December 14.

Satellite Tracking (2009Q3)

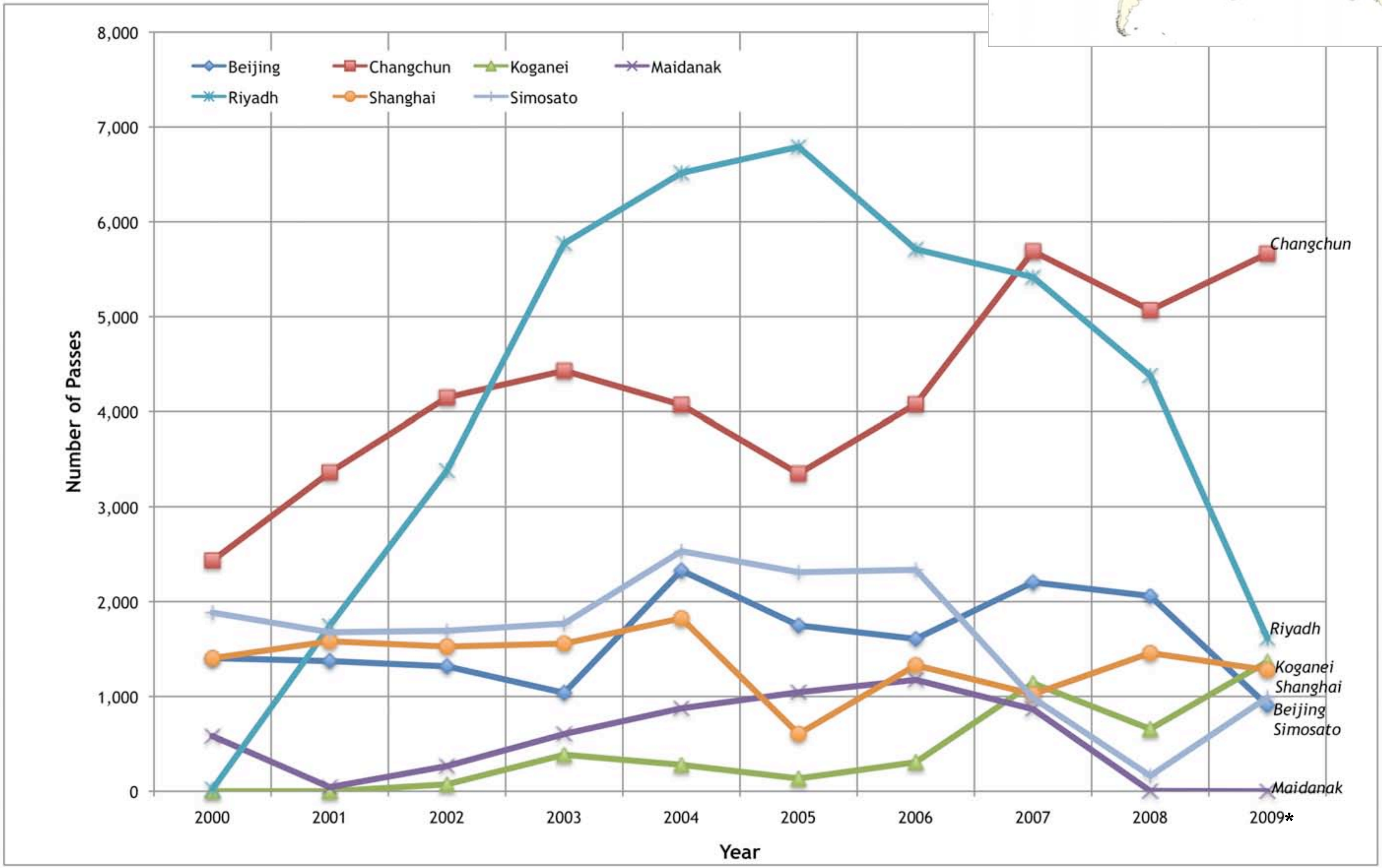


ILRS Network by Region



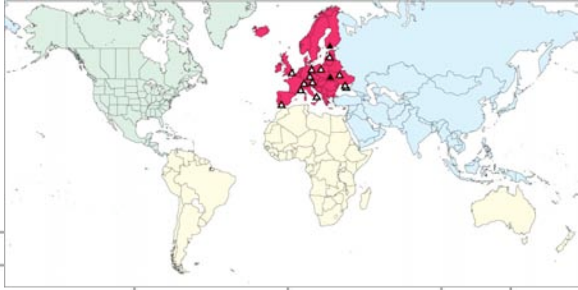
Yearly Pass Totals

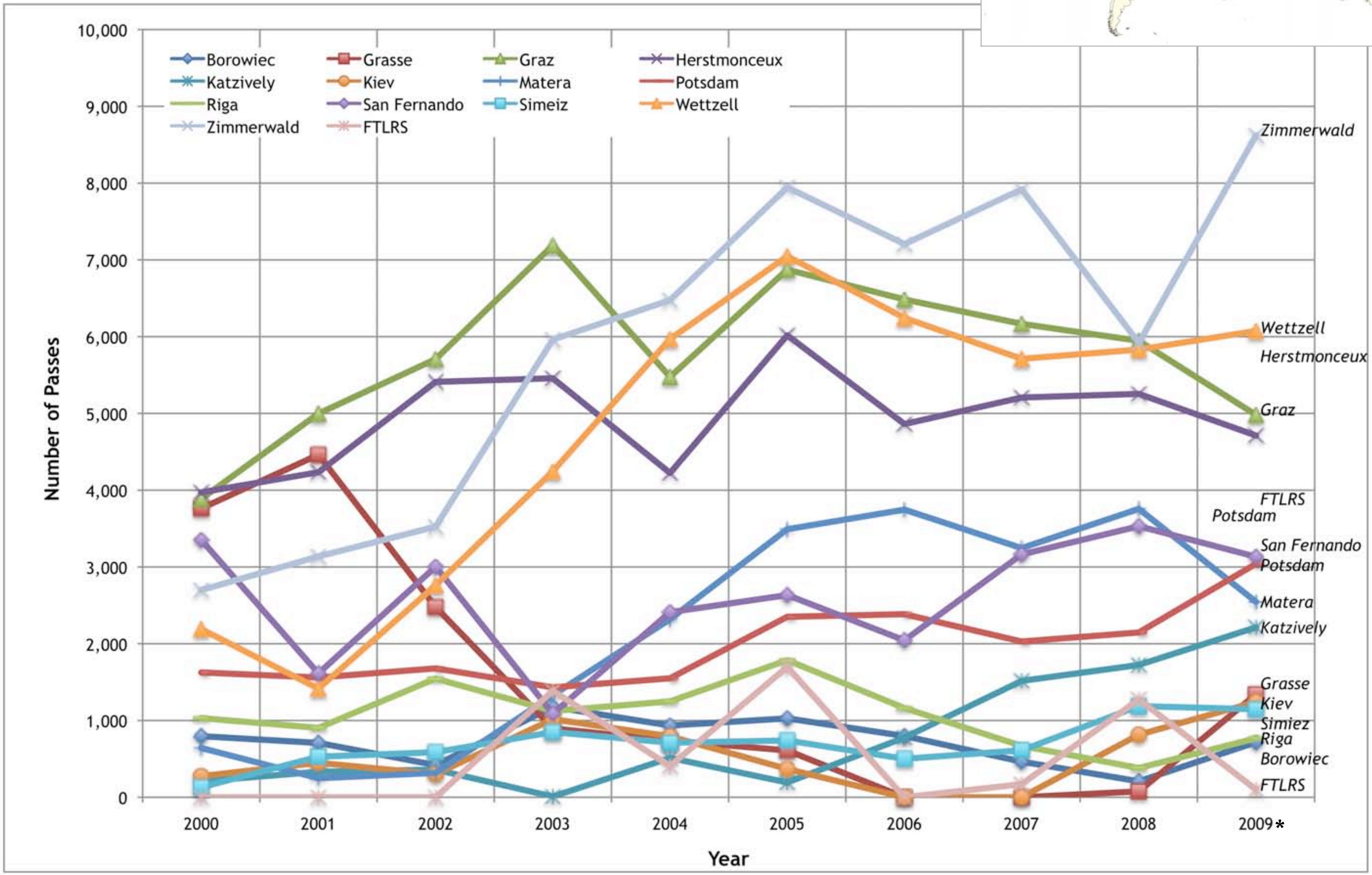
Asia



*Note: *statistics through 11/30/2009*

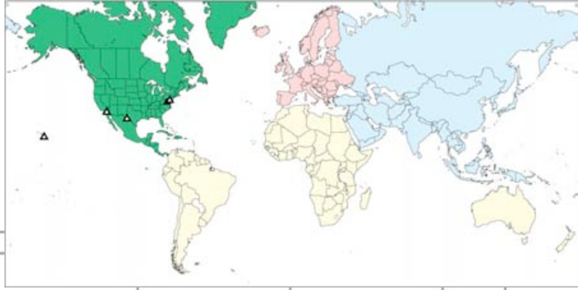
Yearly Pass Totals
Europe

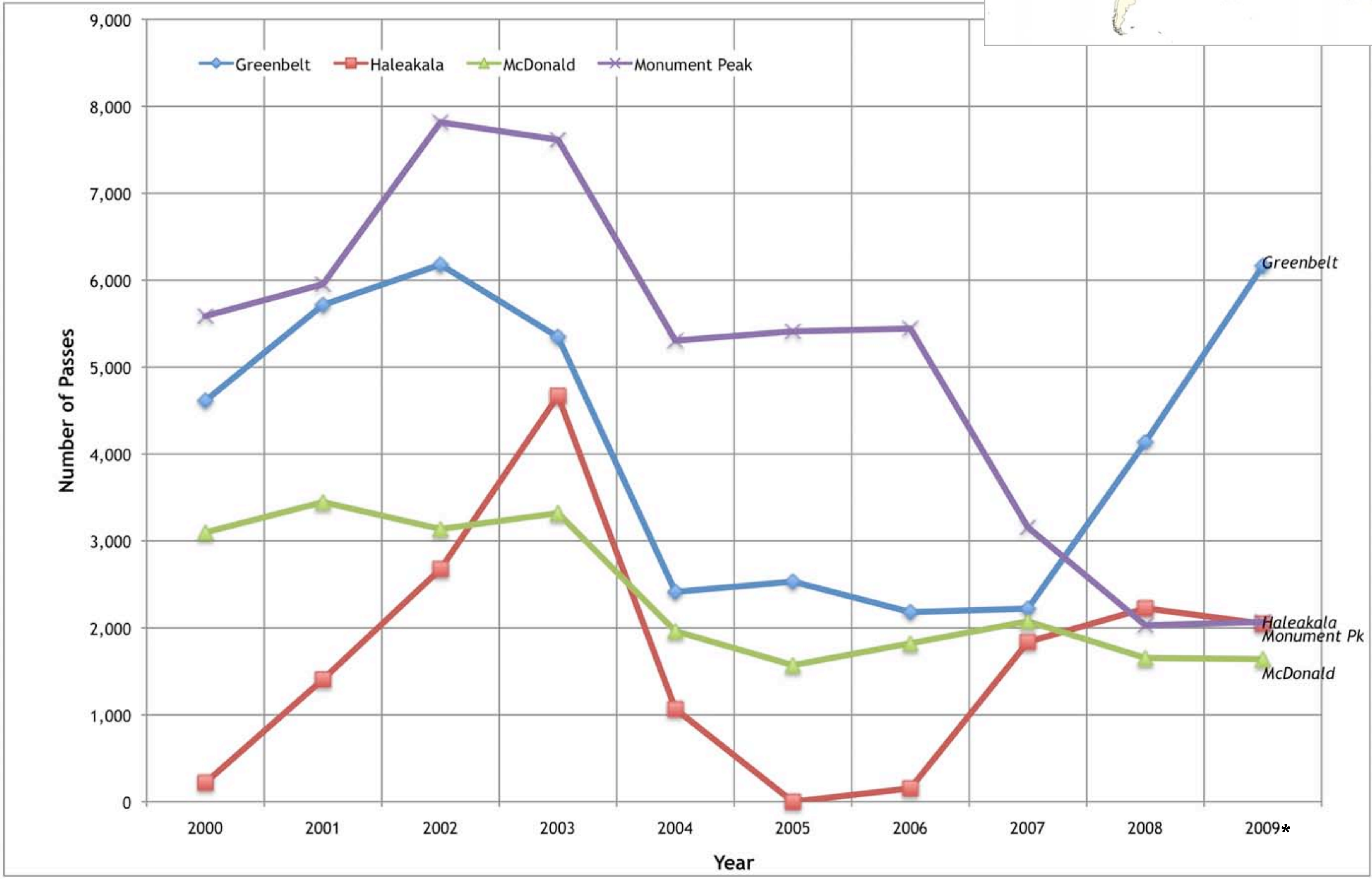




*Note: *statistics through 11/30/2009*

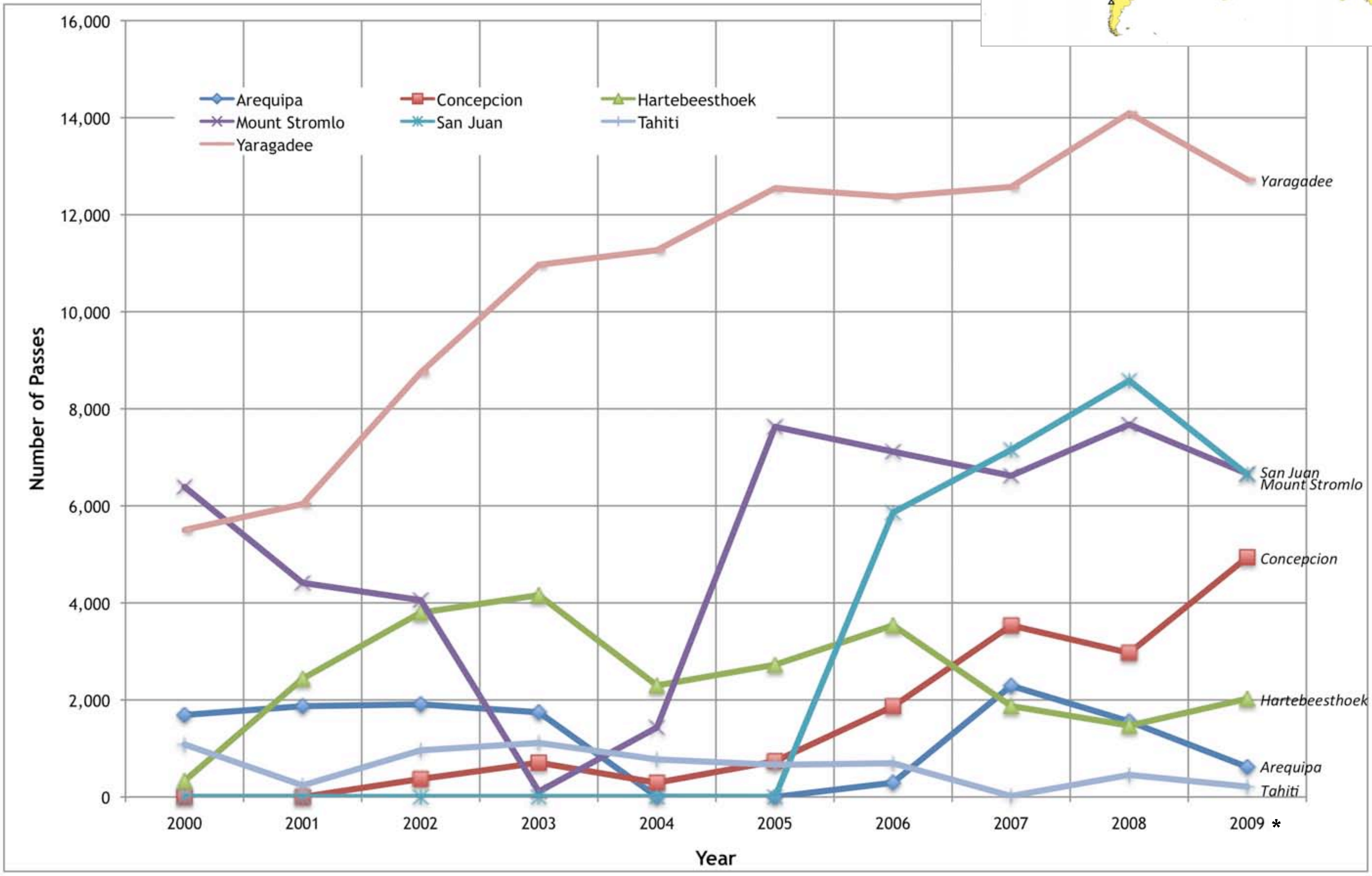
Yearly Pass Totals
North America





*Note: *statistics through 11/30/2009*

Yearly Pass Totals
Southern Hemisphere



Note: *statistics through 11/30/2009

Restricted Tracking

- Survey of stations distributed; 31 responses received
- 4 other productive stations have been queried repeatedly w/o response: Katzively (invalid email address), Changchun, Shanghai, and Riyadh
- Results (based on 31 responses):

Restriction	Automated Restriction	Manual Restriction	Automation Planned
Elevation	16	1	10
Go/No-Go Flag	15	2	11
Pass Segments	15	2	10
Power Level	2	2	9

CRD Format Development

- CRD testing performed in phases:
  - Station submits CRD to OCs (HTSI and EDC)
  - OCs perform format validation and new/old normal point comparison and verification
  - HTSI to perform test orbit validation with prediction orbit
  - ACs perform precise orbit validation
  - Station submits only CRD after validation (OCs convert to ILRS NPT format until completion)
- Current status:
  - 5 stations operational: MLRS, Zimmerwald, Herstmonceux, Matera, Wettzell
  - 7 stations have completed coding and OC validation; under review with ACs
  - 4 stations have completed coding and have submitted data for OC validation
  - 8 stations currently coding to generate CRD
  - 19 stations have not responded to inquiries; reminder sent
- Goal of January 2010 conversion needs to be extended
- Hourly distribution of CRD normal points converted to CSTG format is not yet occurring at EDC; 4 operational stations still send both old and new format
- CRD errata have been rolled into v1.01 of the CRD manual and sample code on ILRS website

Other CB Items

- Criteria for certification of new stations and requalification of stations after upgrading or significant downtime still needs to be addressed
- Simplified algorithm to encourage stations to better distribute tracking efforts perhaps using the real-time web facility at AIUB needs to be developed
- Stations contacted and encouraged to submit full-rate data; data centers will be able to accommodate full-rate data from kHz stations
- CDDIS and EDC data center structures supporting CRD-formatted data will be harmonized
- ILRS 2007-2008 Report now in final preparation
- Proceedings from 16th International Laser Ranging Workshop to be printed this month
- Website for both the 16th International Laser Ranging Workshop and Fall ILRS Workshop in Metsovo implemented

NGSLR Developments

- Still working to produce good system performance with ground calibrations that are stable to better than 1 centimeter over hour period. Not sure why this is proving so hard. Tom Varghese and Tom Zagwodzki are working this with John Degnan consulting.
- In parallel with above work (and with LRO-LR at NGSLR) we are working the completion of the automation and documenting the system.

LRO-LR Developments

- Have over 120 hours of successful laser ranging data to LRO.
- Seven stations have successfully ranged: NGSLR, MOBLAS-7, MLRS, Herstmonceux, Zimmerwald, Wettzell, and Hartebeesthoek.
- Monument Peak will start their ranging attempts next week and Yarragadee will follow shortly.
- Using LR and LOLA data the LOLA Science Team has been able to transfer time from the ground to LRO. Preliminary results suggest that using LR the LRO clock can be correlated to ground clock to at least a millisecond.
- Lots of good publicity for SLR from LRO-LR!

Meetings

- December 14-18, 2009: Fall 2009 AGU
  - GGOS Unified Analysis Workshop, Networks and Communications Bureau meetings
- May 01-07, 2010: EGU, Vienna Austria
- July 18-25, 2010: 38th COSPAR Scientific Assembly, Bremen Germany
- January 2011: 17th International Workshop on Laser Ranging, Concepción Chile
- June 28-July 7, 2011: IUGG General Assembly, Melbourne Australia

Analysis Working Group Report

ILRS Governing Board Meeting

San Francisco, CA, Monday, December 14, 2010

Erricos C. Pavlis & Cinzia Luceri
Analysis Coordinators

AWG News

- Eight AC: ASI (AC & CC), BKG, DGFI (AC & CC), GA, GFZ, GRGS, JCET, and NSGF
- Candidate AC/AAC: **BKG/AIUB**, **ESOC,** MCC and NCL
- Operational products (weekly & daily) are delivered routinely on time
- Re-analysis for 1993 to present by seven ACs:
  ASI, DGFI, GA, GFZ, GRGS, JCET, NSGF
- Historical data re-analysis 1983 to 1992 by six ACs:

  ASI, DGFI, GA, GFZ, JCET, NSGF
- Both CCs submitted combinations to ITRF2008

current ILRS AC solutions: weekly reanalysis pos+eop versions

ILRS-A

ILRS-B

ASI

BKG

DGFI

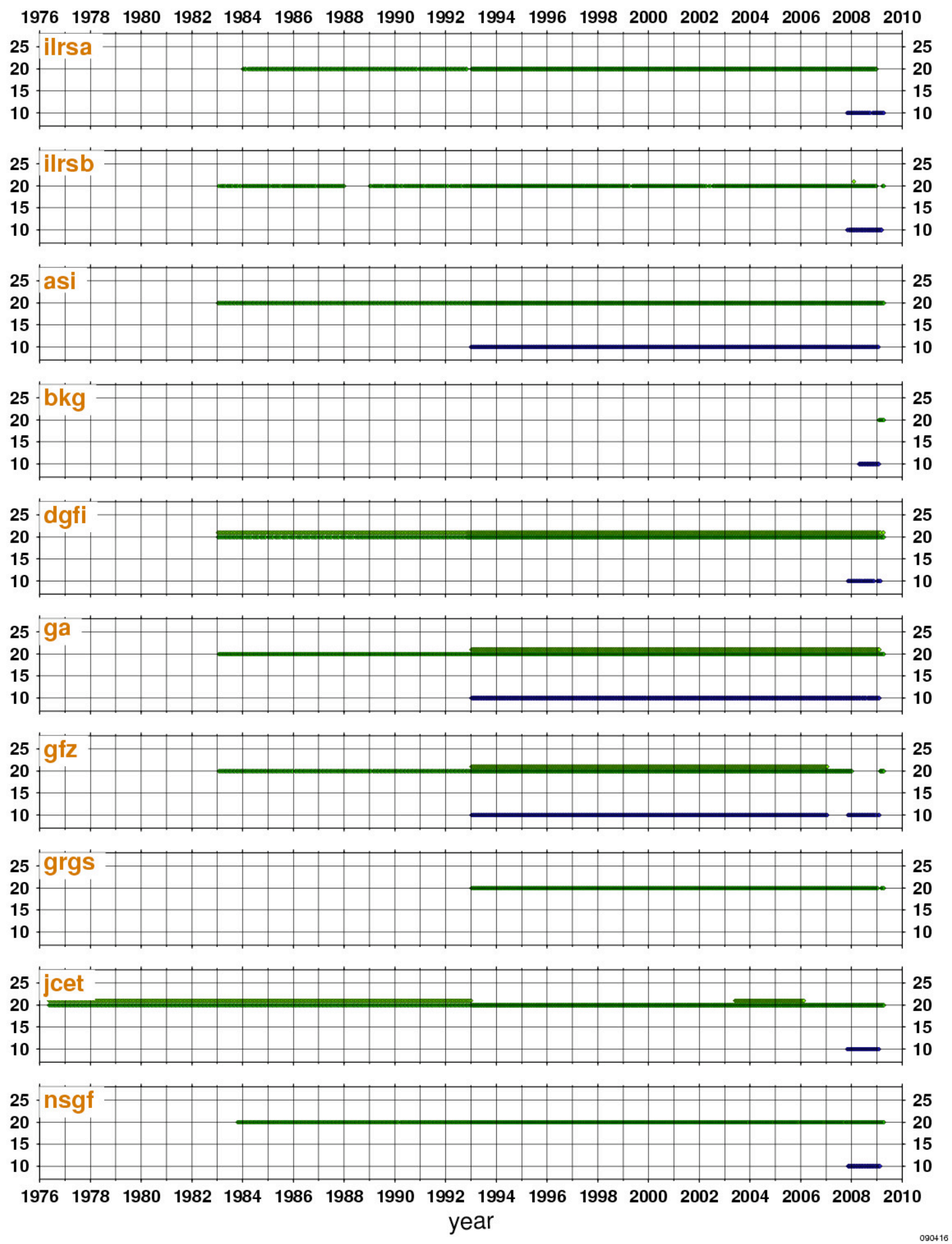
GA

GFZ

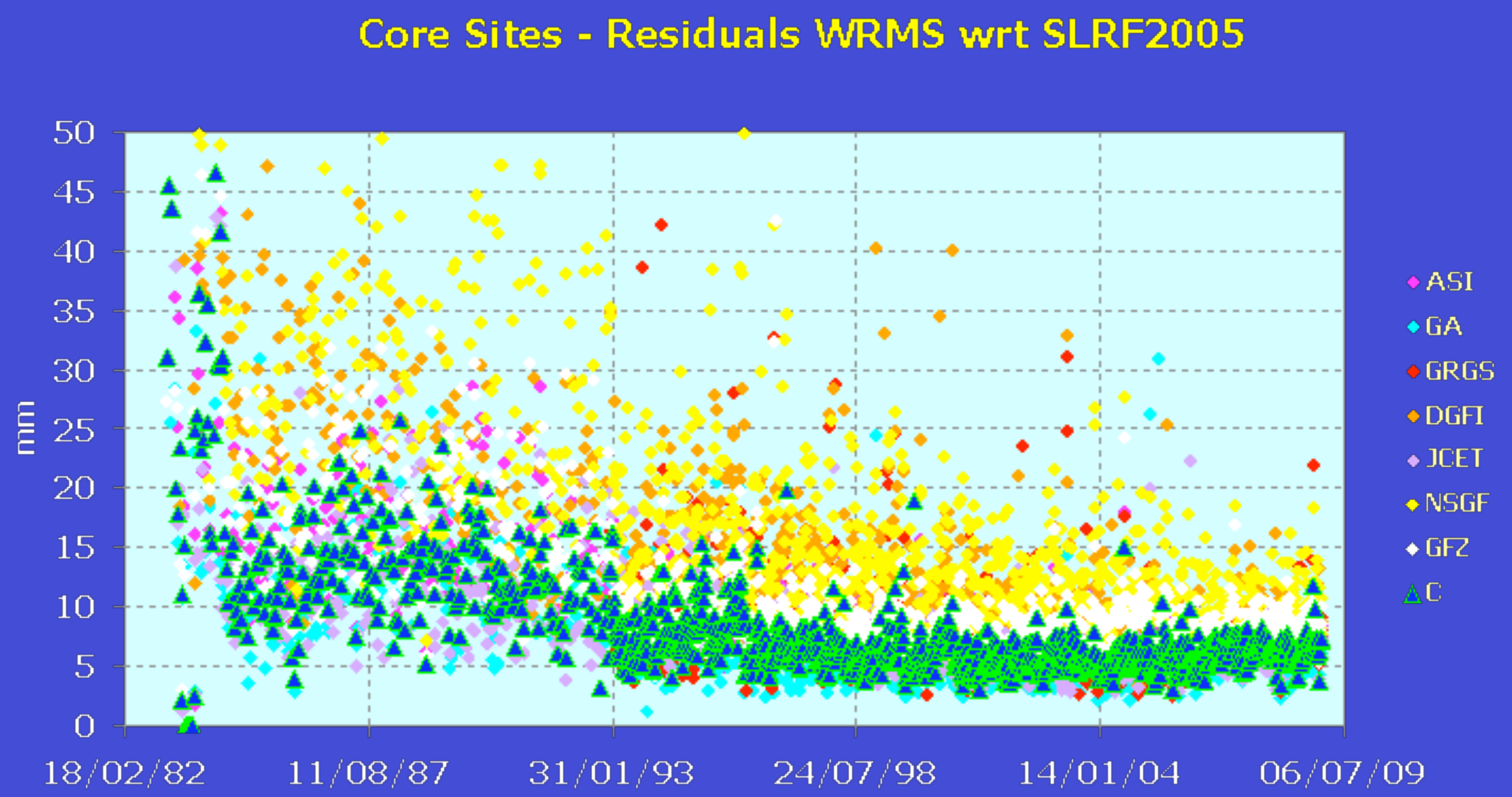
GRGS

JCET

NSGF



ILRSA solution overall quality



mm	ASI	GA	GRGS	GFZ	DGFI	JCET	NSGF	C
All Sites	13+/-8	8+/-6	15+/-9	16+/-9	26+/-30	11+/-7	22+/-12	13+/-18
Core Sites	10+/-6	7+/-4	8+/-4	11+/-7	16+/-20	8+/-5	17+/-10	8+/-6

ILRSA solution Reference Frame stability

Contributing Solutions

Tx	Tx_dot mm/yr	σ_Tx_dot mm/yr	WRMS (res) mm
asi	-0,35	0,02	5,37
dgfi	-0,57	0,03	6,27
ga	0,05	0,02	4,18
gfz	-0,49	0,03	5,46
grgs	-0,32	0,03	4,50
jcet	-0,18	0,02	4,19
nsgf	-0,41	0,03	6,70
C	**-0,29**	**0,02**	**4,16**

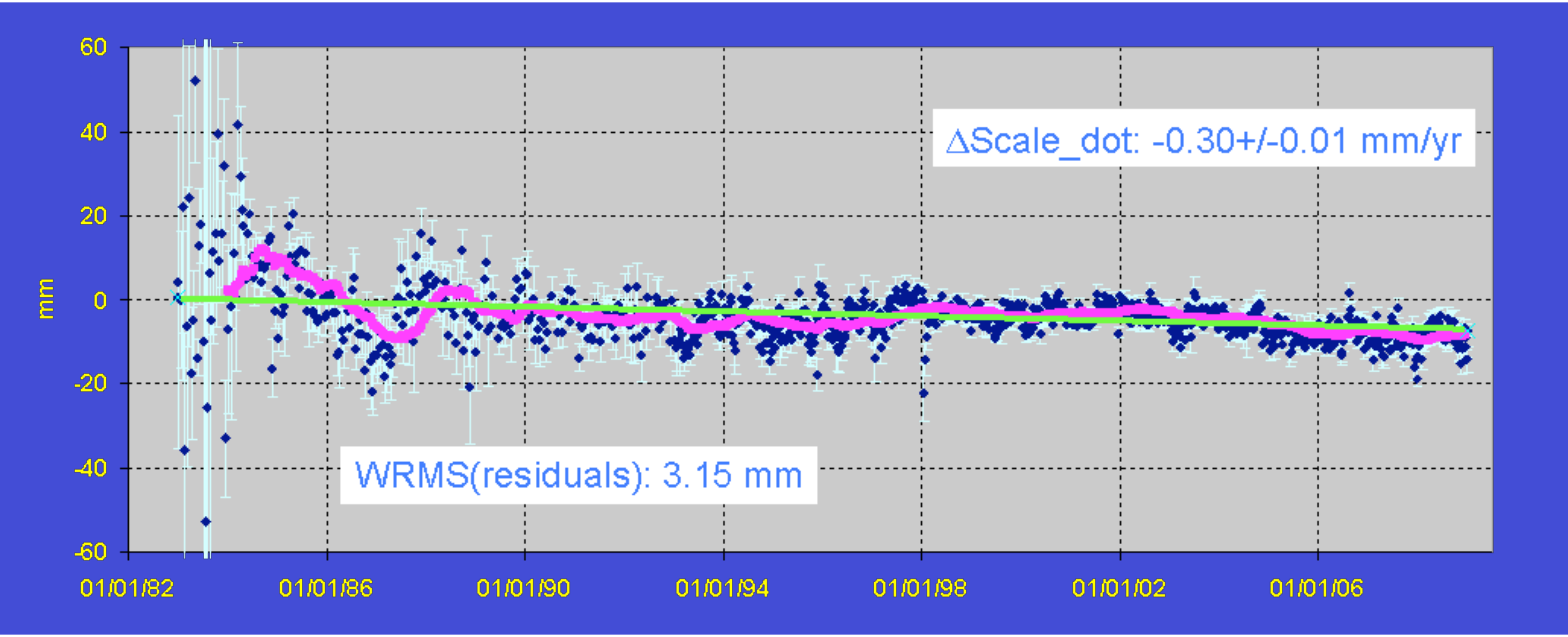
Ty	Ty_dot mm/yr	σ_Ty_dot mm/yr	WRMS (res) mm
asi	-0,12	0,02	4,50
dgfi	0,09	0,03	5,78
ga	0,17	0,02	4,29
gfz	0,11	0,02	4,98
grgs	0,04	0,03	3,71
jcet	0,10	0,02	3,99
nsgf	-0,08	0,03	7,26
C	**0,06**	**0,02**	**3,82**

Tz	Tz_dot mm/yr	σ_Tz_dot mm/yr	WRMS (res) mm
asi	0,24	0,06	10,38
dgfi	0,88	0,08	13,07
ga	0,83	0,04	8,58
gfz	0,36	0,06	10,89
grgs	0,06	0,02	7,11
jcet	0,25	0,04	8,32
nsgf	0,11	0,08	14,06
C	**0,38**	**0,03**	**7,45**

D_Sc	D_Sc_dot mm/yr	σ_D_Sc_dot mm/yr	WRMS (res) mm
asi	-0,31	0,02	4,26
dgfi	-0,48	0,03	4,98
ga	-0,22	0,01	3,64
gfz	-0,08	0,03	4,71
grgs	-0,46	0,02	3,34
jcet	-0,23	0,01	2,88
nsgf	-0,62	0,03	6,00
C	**-0,30**	**0,01**	**3,15**

ILRSA solution Reference Frame stability

Δ Scale



AWG New Projects

- **Projects currently in progress:**
  - *Orbit products (SP3C) -- 6 AC in testing (ASI, BKG, DGFI, GA, GRGS, JCET)*
  - *Daily solutions of 7-day arcs for 1^d EOP for NEOS (5 ACs + DGFI soon!?)*
  - *CRD data format station validation active ACs:* ***ASI, DGFI, GFZ,*** *and* ***JCET***
- **New Potential projects:**
  - ***Testing the application of atmospheric effects in ILRS products***
  - ***Generation of a "low degree ~2 harmonics" series (for CPP/GGOS)***
  - ***3-4 ACs to study the possibility of a new definition of NP generation procedure***
  - *Use of Starlette and Ajisai initially for EOP and eventually for TRF products with improved modeling (e.g. atmospheric effects)*
  - *Near real-time analysis of SLR data for "station health"/bias Rpts.*

CRD Implementation and Validation Schedule - 091201

SITE	ID	Code	Coding	Testing	OC Validated	AC Validated					Operational
						ASI	DGFI	GFZ	GRGS	JCET	
Golosiiv	1824	GLSL									
Lviv	1831	LVIV	X	X	P						
Maidanak 1	1863	MAID									
Maidanak 2	1864	MAIL									
Komsomolsk	1868	KOML									
Mendeleevo	1870	MDVL									
Simeiz	1873	SIML	X	X	P						
Riga	1884	RIGL									
Katsively	1893	KTZL									
McDonald	7080	MDOL	X	X	X	X	X	X		X	X
Yarragadee	7090	YARL	P								
Greenbelt	7105	GODL	X	X	X						
Monument Peak	7110	MONL	P								
Haleakala, HI	7119	HA46	P								
Tahiti	7124	THTL	P								
Wuhan	7231	WUHL									
Changchun	7237	CHAL	X	X	X					P	
Beijing	7249	BEIL									
Koganei	7308	KOGC	X	X	X					P	
Tanegashim	7358	GMSL									
Arequipa	7403	AREL	P								
Concepcion	7405	CONL	X	X	X	P	P			P	
San Juan	7406	SJUL									
Hartebeesthoek	7501	HARL	P								
Metsahovi2	7806	METL									
Zimmerwald	7810	ZIML	X	X	X	X	X			X	X
Borowiec	7811	BORL	X	X	P						
Kunming	7820	KUNL									
Shanghai	7821	SHA2	X	X	X						
San Fernando	7824	SFEL	X	X	P						
Mt. Stromlo	7825	STL3	X	X	X	P	P			P	
Helwan	7831	HLWL									
Riyadh	7832	RIYL									
Potsdam	7836	POTL									
Simosato	7838	SISL									
Graz	7839	GRZL									
Herstmonceux	7840	HERL	X	X	X	P	P			X	X
Potsdam	7841	POT3									
Grasse (MeO)	7845	GRSM	X	X	X					P	
Matera	7941	MATM	X	X	X		P	P		X	X
Wettzell	8834	WETL	X	X	X	P	P			X	X
FTLRS	--	--									
TROS	--	--									

Important Sites that MUST Accelerate CRD Implementation

Important sites where CRD implementation and validation is slow - 091201													
SITE	ID	Code	Coding	Testing	OC Validated	AC Validated					Operational
						ASI	DGFI	GFZ	GRGS	JCET	
Yarragadee	7090	YARL	P								
Monument Peak	7110	MONL	P								
Haleakala, HI	7119	HA46	P								
Tahiti	7124	THTL	P								
Beijing	7249	BEIL									
Tanegashima	7358	GMSL									
Arequipa	7403	AREL	P								
San Juan	7406	SJUL									
Hartebeesthoek	7501	HARL	P								
Riyadh	7832	RIYL									
Simosato	7838	SISL									
Graz	7839	GRZL									
Potsdam	7841	POT3									

AWG Meetings, Past/Future

- The AWG met twice so far in 2009:
  - *EGU 2009, Vienna, Austria*
  - *ILRS Tech. Laser Workshop, Sept. 2009, Metsovo, Greece*
- Next meetings:
  - EGU 2010, TUW, Friday, May 8, 2010
  - *???*
  - **17^{th} ILRS Int. Workshop**, Conception, Chile, Jan. 2011(?)

AWG Documentation

- All ACs and CCs have submitted online documentation (required by IAG/IERS/GGOS) describing the models and standards used in their routine analysis, only some AACs (*need to remind them often!*)

- A LR-dedicated special issue of the *Journal of Geodesy* to be compiled for better and wider documentation of ILRS (ground segment, space segment, **data analysis and interpretation**). *An initial TOC ready by Jan. 2010.*

J of G Guest EB

- *J of Geodesy Editor contacted*
- *Procedures and limitations imposed by JoG provided (no problem)*
- *ILRS Special Issue Editors:*
  - *Pavlis, Luceri, Pearlman*
- *Delayed due to higher priority for the development of the ILRS contribution to ITRF2008 (will be basis for this issue)*
- *Realistic time-table for soliciting papers: January '10*

ILRS Missions Working Group report to GB

Monday December 14th 2009, San Francisco

G Appleby, MWG coordinator

International Laser Ranging Service

Routine procedure for support recommendations

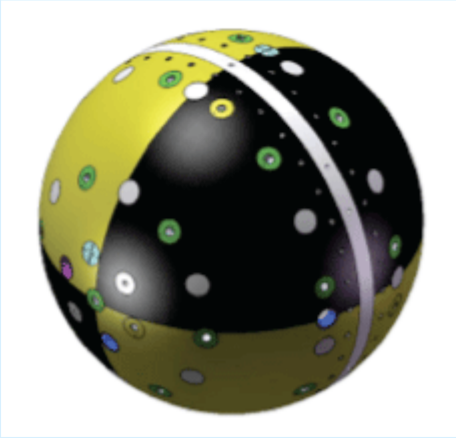
- As well as asking MWG members for comments:
- Use expertise in other Working Groups too:
  - Analysis WG regarding need for POD
  - Signal Processing for comments on LRA suitability
  - DFPWG and NEWG regarding operational issues (go-nogo flags, available CPFs, etc)
- Chairs of these WGs are ex-officio members of MWG

Missions approved for SLR and recently launched

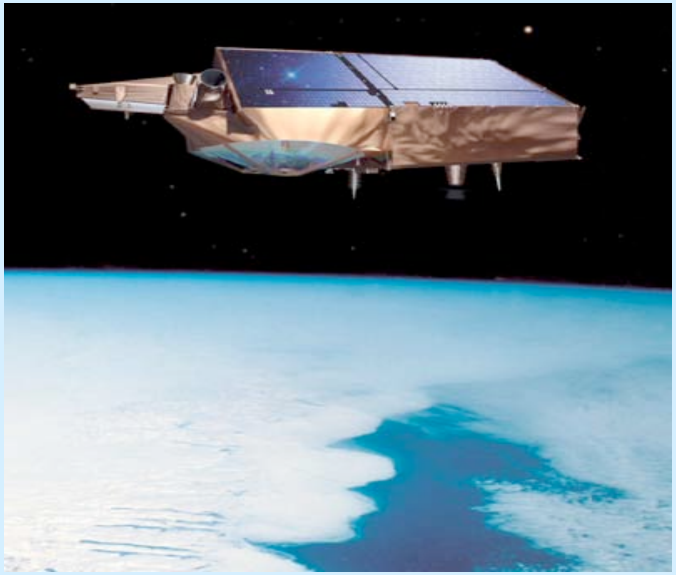
- BLITS – 17cm ball lens in Space - (IPIE) – approved. Useful discussion with IPIE regarding details of CoM correction.
  2009 Sept 17 launch.
  Good predictions and tracking (on-off)

Ready for testing

- ANDE (Castor & Pollux) - (NRL) – approved.
  2009 July 30 launch
  Predictions of variable quality (see NEWG report)



Missions recently approved for ILRS support



- CryoSat-2 – thickness of sea-ice and elevation of ice-sheets
- DORIS tracking with laser for altimeter calibration and additional POD support
- Due for launch 2010 Feb 28 into 750km polar orbit.
- No particular tracking issues.

Missions recently approved for ILRS support (2)

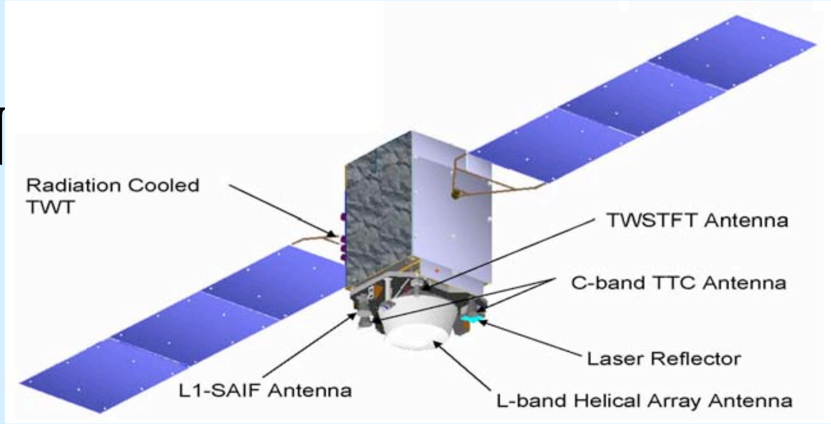
- RadioAstron – 10m VLBI dish in highly-elliptical orbit (0.96, 500-350,000km)
- Visibility of (100-cube) retro-arrays from Earth expected best at distances of 100-200 thousand km;
  - Realistic target only for LLR-capable systems
- MWG liaising – Matera, Wettzell expressed interest so far;
- Launch imminent (2009 December)

Missions recently approved for ILRS support (3)

- Quasi-Zenith-Satellite, QZS-1
- Japanese GNSS system, addition to existing GNSS
- To be launched late 2010 into 45^{o},

32,000-40,000km orbit

- Ranging from WPLTN



GLONASS

- Three new vehicles launched 2009 Dec 14
- MWG working with CODE to recommend which one of new vehicles to track:
  - Only 1 GPS now, so go for 4 GLONASS?
- Also, discuss whether to attempt more of the GL constellation;
  - Issue is more satellites, less data or less satellites, more data on each
  - SGF Herstmonceux running a test now to attempt all GLONASS – data to be submitted to CDDIS and EDC

Data Formats & Procedures Status

Report to ILRS Governing Board
14 December 2009
R. Ricklefs

CRD Format Implementation

- Operational: 5 stations - MLRS, Zimmerwald, Herstmonceux, Matera, Wettzell
- In Analyst Validation: 7
- In OC Validation: 4
- In Coding: 7
- No known activity: 20; A reminder has been sent
- Goal of January 2010 conversion needs to be extended
- Hourly distribution of CRD normal points converted to CSTG format is not yet occurring at EDC; 4 operational stations still send both old and new format
- CRD errata have been rolled into v1.01 of the CRD manual and sample code on ILRS website

Data Center “Harmonization”

- Applies to CRD formatted data only
- EDC and NASA/HTSI OCs' quality control and format verification procedures are under review for consistency
- File naming conventions identical; EDC has fixed problem with “allsat” naming.
- EDC is making directory naming consistent with CDDIS
- CDDIS is making contents of daily files consistent with EDC (contains all data taken on a given day)

Tracking Restrictions Questionnaire

- 31 stations have now responded after many queries
- 4 other productive stations have been queried repeatedly w/o response: Katsively (email returns!), Changchun, Shanghai, and Riyadh.
- Results:

Restriction	Automated Restriction	Manual Restriction	Automation Planned
Elevation	16	1	10
Go/No-go flag	15	2	11
Pass segments	15	2	10
Power level	2	2	9

Based on responses for 31 stations

ILRS Network and Engineering Working Group Report

Georg Kirchner
TU Graz
Ulrich Schreiber
TU Munich/Wettzell

ILRS Governing Board meeting 14th December 2009
San Francisco, USA

Summary for June-Dec 2009

- Main work was connected with GOCE (and partially with ANDE):
  - Pushing for better predictions,
  - exchanging TB information mails,
  - pushing stations;
  - encouraging them;
  - testing methods etc.
- Tracking GOCE now is pretty standard
  - Good achievement for ILRS

Summary for June-Dec 2009 (2)

- Similarly, we tried to push BLITS and ANDE TB info exchange
- BLITS successful
- ANDE still big TB differences preds/true
  - Realtime exchange via EUROLAS good
  - But TB predictions poor sometimes:

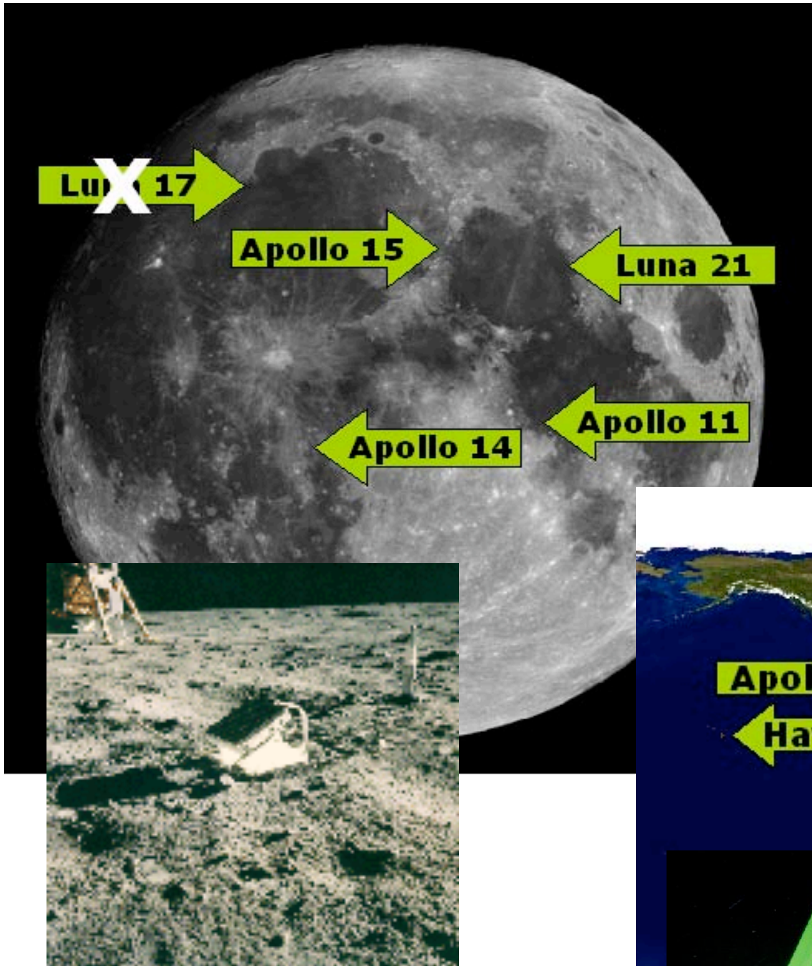
LLR – Status Report

Jürgen Müller

Institut für Erdmessung
(Institute of Geodesy)

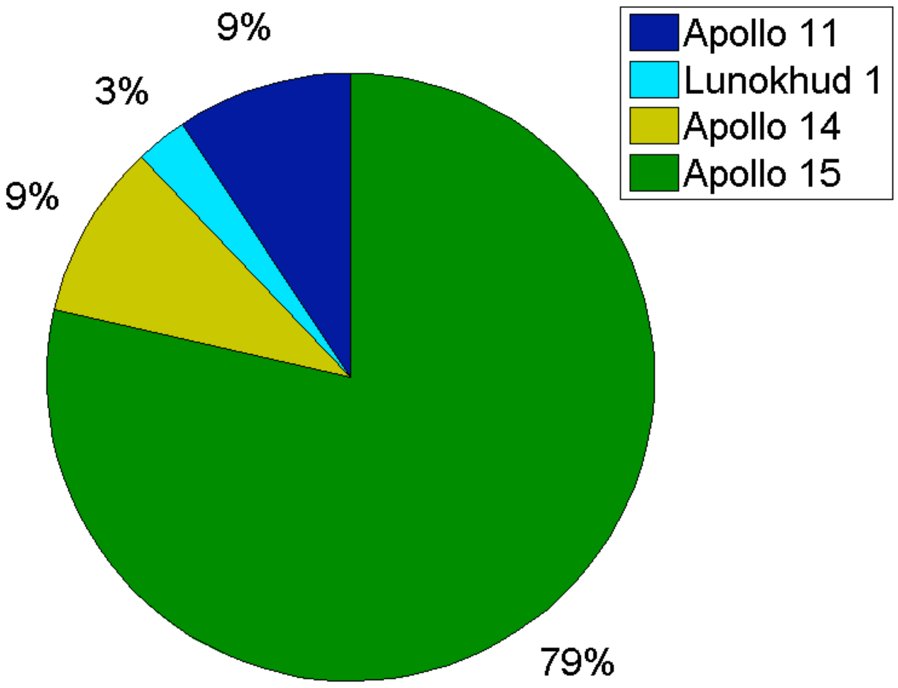
Leibniz Universität Hannover
(University of Hannover)

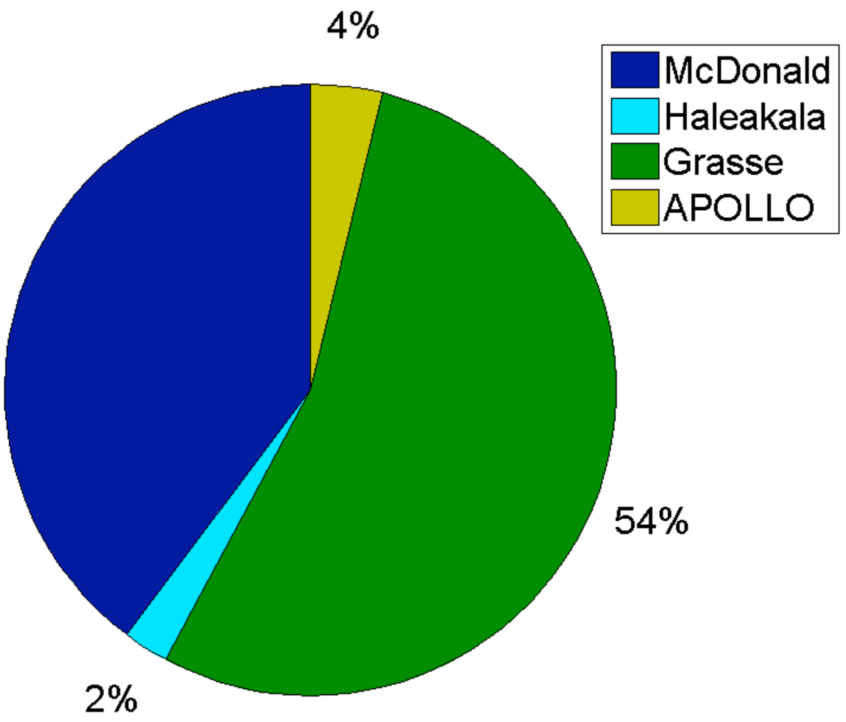
Retro-Reflectors and Observatories



- First reflector deployed on July 21, 1969 (Apollo 11)
- Continuous LLR observations for 40 years

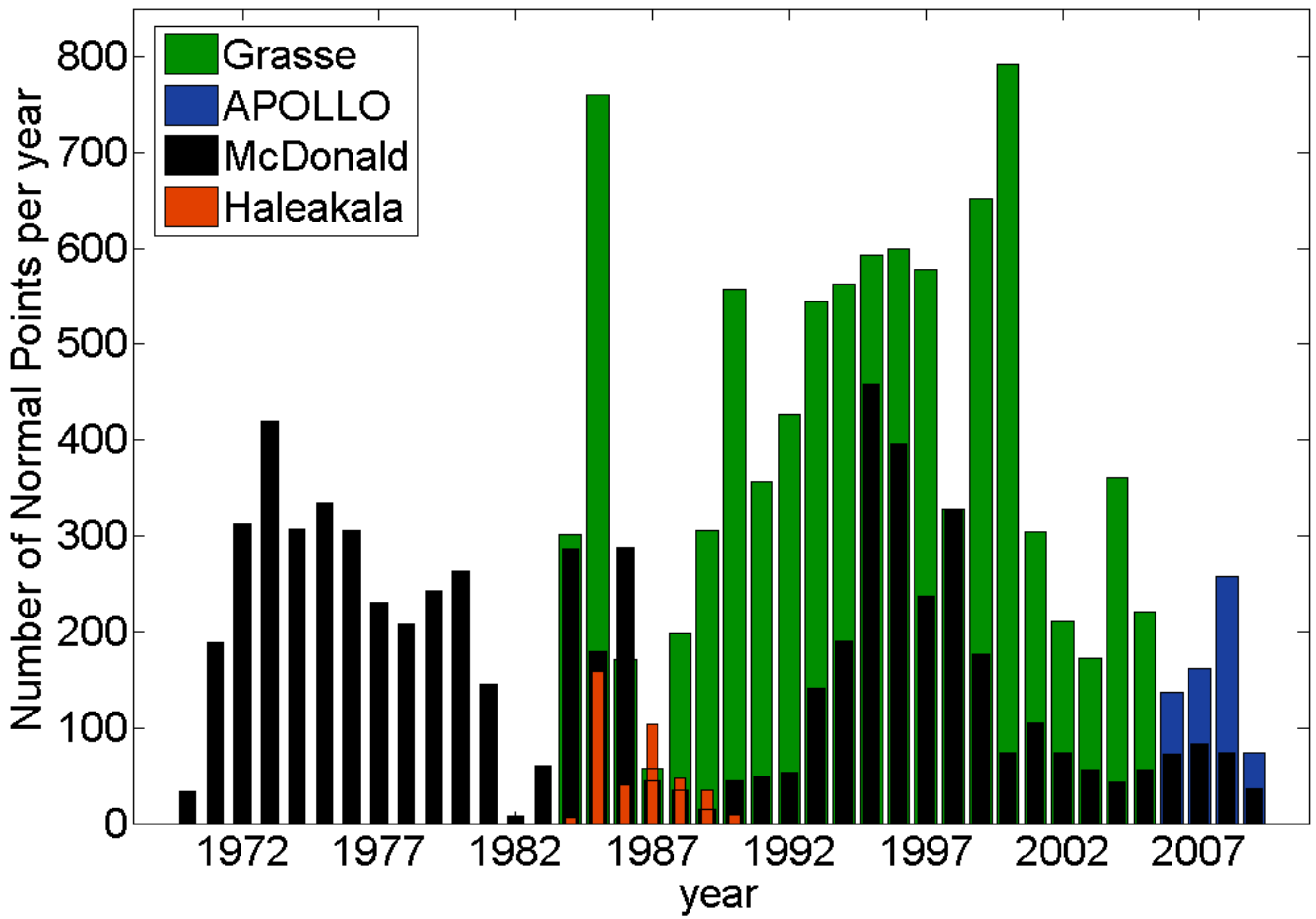
Statistics - Reflectors and Observatories





Number of Normal Points

- 1970 - 2009: ca.16,800 normal points



Main Research at Lunar Analysis Centers

- Jet Propulsion Laboratory (JPL):
  - lunar interior, lunar core
  - relativity
- Paris Observatory Lunar Analysis Center (POLAC):
  - libration theory
  - reference frames
- Institute of Geodesy (IfE):
  - Earth orientation
  - lunar interior
  - relativity
- others:
  - special topics

Status, Perspective

- McDonald will cease lunar tracking in February 2010, but LRO tracking
- APOLLO will also start LRO tracking
- Grasse with first new lunar normal points (end 2009)
- Matera plans to re-start LLR
- Wettzell plans to use old SLR system for lunar tracking …

- ISSI LLR workshop series: “Theory and Model for the New Generation of the Lunar Laser Ranging Data”
  - first workshop: 15.-19.02.2010 in Bern

Task Forces (TF)

At the October 2007 meeting of the ILRS Governing Board, the board decided to create two Task Forces to address concerns expressed during the 2007 Fall Workshop in Grasse:

1. Inadequate two-way communication between the stations and the analysis centers to provide (a) unambiguous, timely reports to the stations regarding data quality and bias information, and (b) timely reports to the analysis centers on configuration changes and other events that could affect system biases.

   Task Force 1 was set up with Mark Torrence (lead), Erricos Pavlis, Mike Pearlman, Geog Kirchner and Werner Gurtner to provide a plan for discussion by the 2007 Fall AGU in San Francisco on how to address the communications issue. Recent activities:
   - Meeting on 10/30/2007 (notes PDF)
   - Meeting on 12/10/2007

2. Large uncertainties in the spacecraft center of mass offsets, with particular concern on the geodynamic satellites.

   A task force was set up with Graham Appleby (lead), Toshi Otsubo, George Kirchner Mike Pearlman, and Dave Arnold to provide a plan for discussion at the fall 2007 AGU on how we should improve the precise computation of the spacecraft CoM offsets for given station-s/c configurations.

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http://ilrs.gsfc.nasa.gov/working_groups/taskforce_1/

CODE GNSS Analysis
Hitotsubashi University Analysis
NERC Analysis
Shanghai Analysis
Geoscience Australia Analysis
GSFC (T/P) Analysis
CERGA (T/P) Analysis

Quicklook Analysis Reports

Center	Satellite(s)	Arc Length *link is an analysis description*	Coordinates *link will open in a new window*	Contact
Chinese Academy of Sciences, Shanghai	LAGEOS-1,-2; Etalon-1,-2	LAGEOS (3-day); Etalon (7-day)	ITRF2000	HU Xiaogong or Wang Xiaoya
Mission Control Center (MCC)	LAGEOS-1,-2; GLONASS	LAGEOS (3-day); GLONASS (8-day)	ITRF2000	V Glotov or V Mitrikas
Joint Center for Earth Systems Technology, NASA Goddard & Univ. of Maryland, Baltimore County (JCET)	LAGEOS-1,-2; Etalon-1,-2; Ajisai; Starlette	LAGEOS (7-day); Etalon (14-day); LEOs (2-day)	SLRF2005	E Pavlis
Hitotsubashi University	AJISAI; STARLETTE; STELLA; JASON-1; ERS-2; ENVISAT; LAGEOS-1, -2; ETALON-1, -2; GLONASS	LAGEOS (7-day); GLONASS, Etalon (14-day); LEOs (2-day)	SLRF2005	T Otsubo
Deutsches Geodtisches Forschungs Institut (DGFI)	LAGEOS-1,-2; Etalon-1,-2	7-Day Arc	SLRF2005	H Mueller

A table comparing the parameterization used by the above centers will be available soon.

Analysis reports that are distributed via email, are accessible from the SLReport archives at both the EDC and the CDDIS. Some of the reports above are archived at the Data Centers for redundancy, click on the appropriate links below to gain access to these reports.

- MCC Weekly LAGEOS Analysis Report (CDDIS, EDC)
- Latest CODE combined range bias report
- NICT intensity dependence test (2001-02 and 2003-04)
- 3-Day Arc 2000-2001 LAGEOS-1,-2 rapid-analysis results from Geoscience Australia
- SLR Quarterly Global Performance Report Cards
- EDC Weekly Global Normal Point Data Volume
- CDDIS Weekly and Monthly Global Normal Point Data Volume

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http://ilrs.gsfc.nasa.gov/working_groups/taskforce_1/all_QKL_parameterization_D.html

Comparison of the parameterization used by quicklook analysis centers

	SHAO	MCC	JCET	Hitotsubashi	DGFI
Center Name	Chinese Academy of Sciences current as of January 1, 2008 V 01.01.2008	IAC/MCC, Information and Analysis Center of Navigation /Mission Control Center 141070, Russia, Koroliov of Moscow reg,Pionerskaya str. 4	Joint Center for Earth Systems Technology (JCET), NASA Goddard, Univ. of Maryland, Baltimore County, Baltimore, MD, USA	Hitotsubashi University 2-1 Naka, Kunitachi, Tokyo 186-8601 Japan	Deutsches Geodaetisches Forschungsinstitut, DGFIAlfons-Goppel-Str. 11 80539 Muenchen Germany
Contacts	HU Xiaogong or Wang Xiaoya	V Glotov or V Mitrikas	E Pavlis	T Otsubo	H Mueller
Software	SHORD-II	STARK, POLAR, developed by MCC	GEODYN-II, SOLVE	concerto ver 4.10	DOGS version 5.00
ILRS Products	global SLR station weekly solutions for range biases and time biases	mccwwwwd.sp3, mccwwww7.sum GLONASS ephemeris Daily EOP	Weekly solution for coordinates of global SLR stations and daily Earth Orientation Parameters (x,y-pole, LOD)(SINEX format)	Daily QC report for a number of satellites	Daily Bias reports for Lageos-1 and Lageos-2 (Etalon-1/2, Starlette and Ajisai in preparation) Weekly SP3C orbit for Lageos-1 and Lageos-2. Daily EOP's and station coordinates, on a weekly basis
Satellites					
	LAGEOS-1 LAGEOS-2 ETALON-1 ETALON-2	GLONASS, GLOSNASS-MLAGEOS-1, LAGEOS-2	LAGEOS-1, LAGEOS-2, ETALON-1, ETALON-2,Starlette, Ajisai	AJISAI, STARLETTE, STELLA, JASON-1, ERS-2, ENVISAT,LAGEOS-1, LAGEOS-2, ETALON-1, ETALON-2, GPS-35, GPS-36, GLONASS-95, GLONASS-99, GLONASS-102	Lageos-1, Lageos-2, Etalon-1, Etalon-2
Measurement Models					
speed of light (m/s)	299792458	299792458	299792458	299792458	299792458
Wavelengths (nm)	532.0, 423.0, 847.0 & 694.3	532.0, 423.0, 847.0 & 694.3	532.0, 423.0, 847.0 & 694.3	532.0, 423.0, 847.0 & 694.3	532.0, 423.0, 847.0 & 694.3
Elevation cutoff (degrees	10	0	3	not applied	0
weighting	5 - 100 mm by station	0.05 m to 1.0 m	1.0 m	5 cm to 2 m (4 levels)	1.0 m per AWG2000
range biases	estimated for selected stations	estimated for some stations	est/d for all sites	not modeled/estimated in orbit determination,pass-by-pass estimation in residual analysis	est/d for non-core stations
time biases	estimated for selected stations	not modeled/estimated	est/d for all sites	not modeled/estimated in orbit determination,pass-by-pass estimation in residual analysis	not modeled/estimated
troposphere biases	not modeled or estimated	not modeled/estimated	not modeled/estimated	not modeled/estimated	not modeled/estimated

Theoretical Values Computed from Provided Parameters

Sat.	Cross section	Range (0 deg.)	Signal strength	Range (45 deg.)	Signal strength
Lageos	15	5.8	1.000	6.8	1.000
Etalon	55	19.0	.032	20.5	.044
GPS	19	20.0	.009	21.5	.012
GIOVE-A	**45**	**23.9**	**.010**	**25.4**	**.015**
Galileo (0.8)	**175**	**23.9**	**.039**	**25.4**	**.058**
Galileo (0.0)	**201**	**23.0**	**.044**	**25.4**	**.067**
Glonass	80	19.0	.046	20.5	.065
Compass	80	21.0	.028	23.0	.041
ETS-8 (geosync)	140	36.0	.0063	37.6	.010

Parameters of LRA on satellites*

Satellite	Cube Number	Diameter (inch)	Coating	Dihedral Offset	Vendor
Lageos1	422	1.5	uncoat	1.25	Perkin-Elmer
Lageos2	422	1.5	uncoat	1.25	Zygo
Etalon	2140	1.06	coat	-	IPIE
GPS	32	1.06	coat	-	IPIE
GIOVE-A	76	1.06	coat	-	IPIE
Glonass	132	1.06	coat	-	IPIE
Compass	42	1.3	uncoat	0.6	SHAO
ETS-8	36	1.6	uncoat	0.5	ITE

* From David Arnold, private communication

NORMAL POINT CONSTRUCTION FOR OPTIMAL TRACKING

(To be reviewed and validated by the Analysis Working Group)

- Maximum normal point intervals (e.g. 2 minutes for Lageos) have been specified by the ILRS (see http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/index.html).

ASSUMPTIONS

- **The quality of a normal point depends only on the number of single shot contributors;**
- The normal point algorithm and choice of interval completely accommodates the accuracy, precision and ranging integrity requirements of accuracy, precision and ranging integrity for that satellite
- Assuming a Gaussian distribution, the normal point will depend on the distribution of the single shot contributors, so the first 100 shots (or any 100 shots taken within the appropriate maximum NP interval) are enough to define a normal point improving on the single shot precision by a factor of ten. Since modern SLR systems have full rate precisions in the neighborhood of 1 cm, normal points would have a precision of about 1 mm.

NORMAL POINT CONSTRUCTION
Assumptions Continued - 2

- **Any considerations of data distribution are limited to the choreography of normal points within a satellite pass.**
- This will be application dependent: orbit definition will require different (and less stringent) geometry than that for station positioning.
- Orbit definition can be satisfied with observations taken by any station as long as the tracking is continuous: the burden can be shared within the network.
- Accurate station location requires strong pass geometry from each station, but the normal points need not be regularly space in time during a pass.
- **The primary application of the SLR Network tracking LAGEOS I and II is station location.**
- Earth Orientation has similar requirements for time continuity as orbit definition, so the tracking requirements on ETALON can be relaxed for station location and leave the station location task to LAGEOS. ETALON would play an increased role in the determination of scale if the satellite CoM parameters are as accurate as claimed and if they are applied properly in the analyses.

Normal Point Construction
Assumptions Continued - 3

- **The primary application of the SLR Network tracking LAGEOS I and II is station location.**
- Earth Orientation has similar requirements for time continuity as orbit definition, so the tracking requirements on ETALON can be relaxed for station location and leave the station location task to LAGEOS. ETALON would play an increased role in the determination of scale if the satellite CoM parameters are as accurate as claimed and if they are applied properly in the analyses.
- **The primary applications of the SLR network tracking GNSS are (1) orbit definition and (2) reference frame definition (geocenter, scale and orientation) which has similar pass geometry requirements to orbit definition.**
- For some orbital requirements GNSS tracking could be shared by neighboring members of a regional network and allow each to multiplex tracking to other satellites with no degradation in GNSS orbit accuracy. This may not be applicable for the reference frame requirements.
- **Stations should strive for precision as close to one mm as possible for all applications of SLR data.**
- **Normal Point distribution during a satellite pass should be determined by the requirements of the most stringent application for that satellite.**

NP Recommendation

- A normal point should be terminated when 100 full rate data points have been accumulated or the maximum normal point interval (i.e. 2 minutes for Lageos) is complete, whichever comes first;
- Sequential normal points on a satellite pass should be separated by at least the maximum normal point interval; if the 100 data points applies and the normal point is terminated in less than the maximum normal interval, the station should move on to another satellite if available, or wait for the remaining time to lapse and resume tracking the same satellite for the next NP;
- Normal points should be spread over the satellite pass with at least 2 normal points for Lageos and 3 normal points for GNSS satellites near acquisition of signal, point of closest approach, and prior to loss of signal; (these numbers must be verified by the AWG).
- On LEO satellites, the stations should capture as much of the pass as possible within ILRS priorities and interleaving procedures.

Quality assessment of the ITRF2008

Still preliminary but close to final

Zuheir Altamimi
Xavier Collilieux
Laurent Métivier
IGN, France

Technique contributions

• IVS:	(1980.0 – 2009.0) :	Full EOP set	(84 sites)
• IGS:	(1997.0 – 2009.5) :	PM, PMrate, LOD	(492 sites)
• ILRS:	(1984.0 – 2009.0) :	PM, LOD	(89 sites)
• IDS:	(1993.0 – 2009.0) :	PM, LOD	(67 sites)

- New local ties since ITRF2005:
  - Tahiti : GPS SLR DORIS
  - Tsukuba: GPS VLBI
  - Herstmonceux: GPS SLR
  - Medicina & Noto : GPS VLBI
  - Greenbelt: VLBI SLR GPS DORIS
  - MAUI/Haleakala
  - San Fernando : GPS SLR

- Parallel analysis by IGN and DGFI

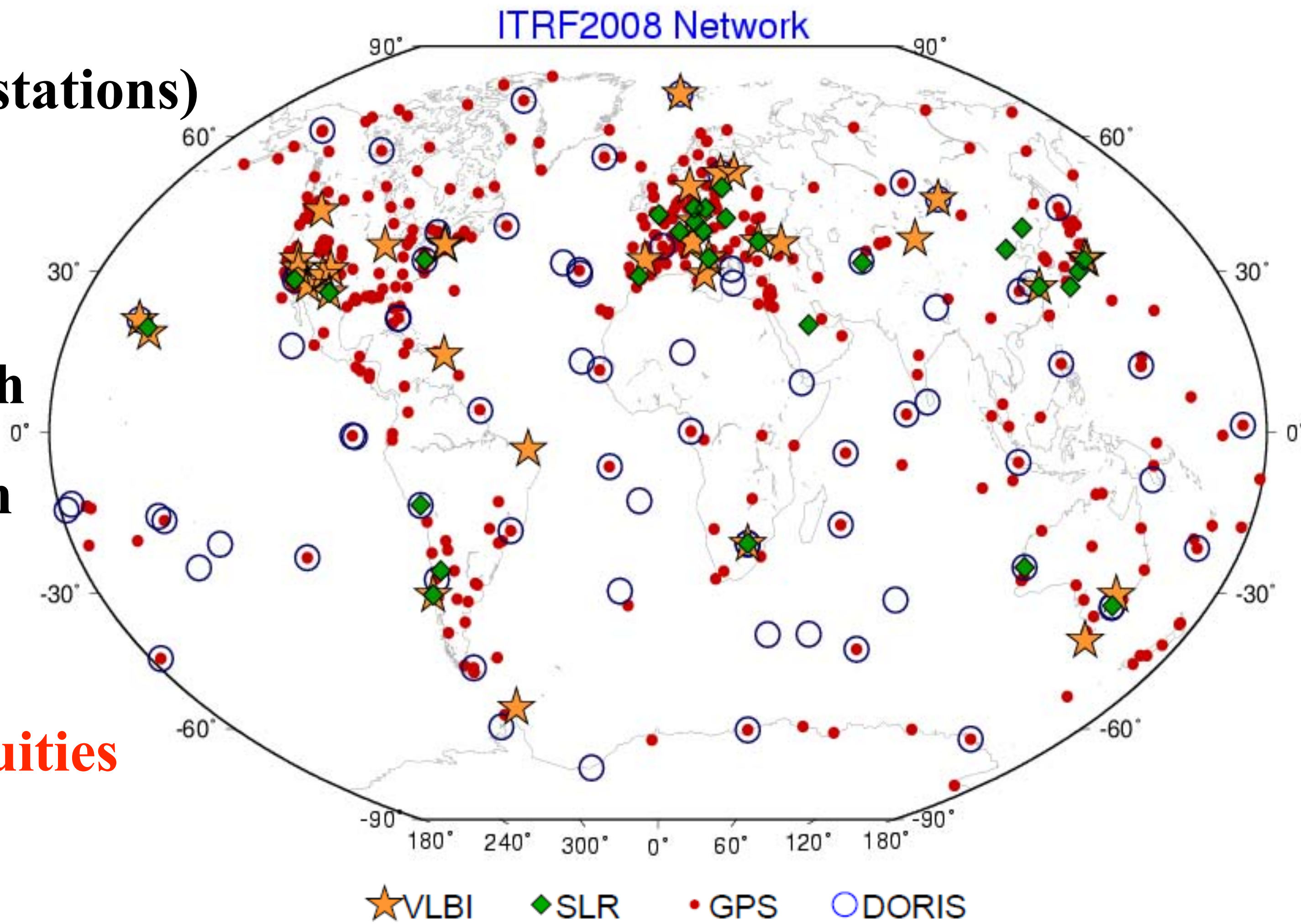
ITRF2008 Network

579 sites (920 stations)

461 Sites North

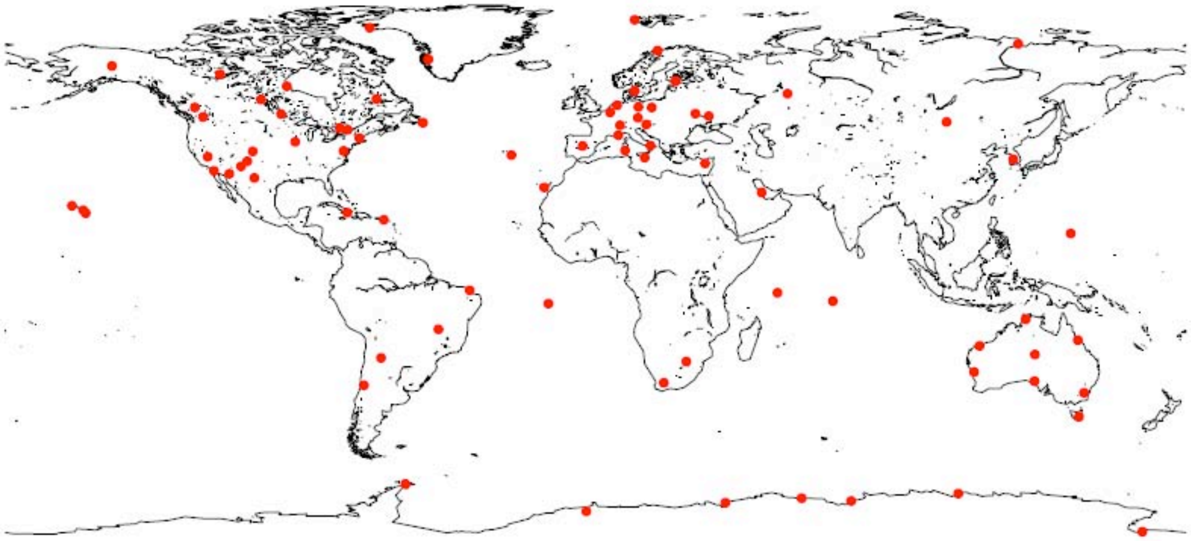
118 Sites South

584 discontinuities

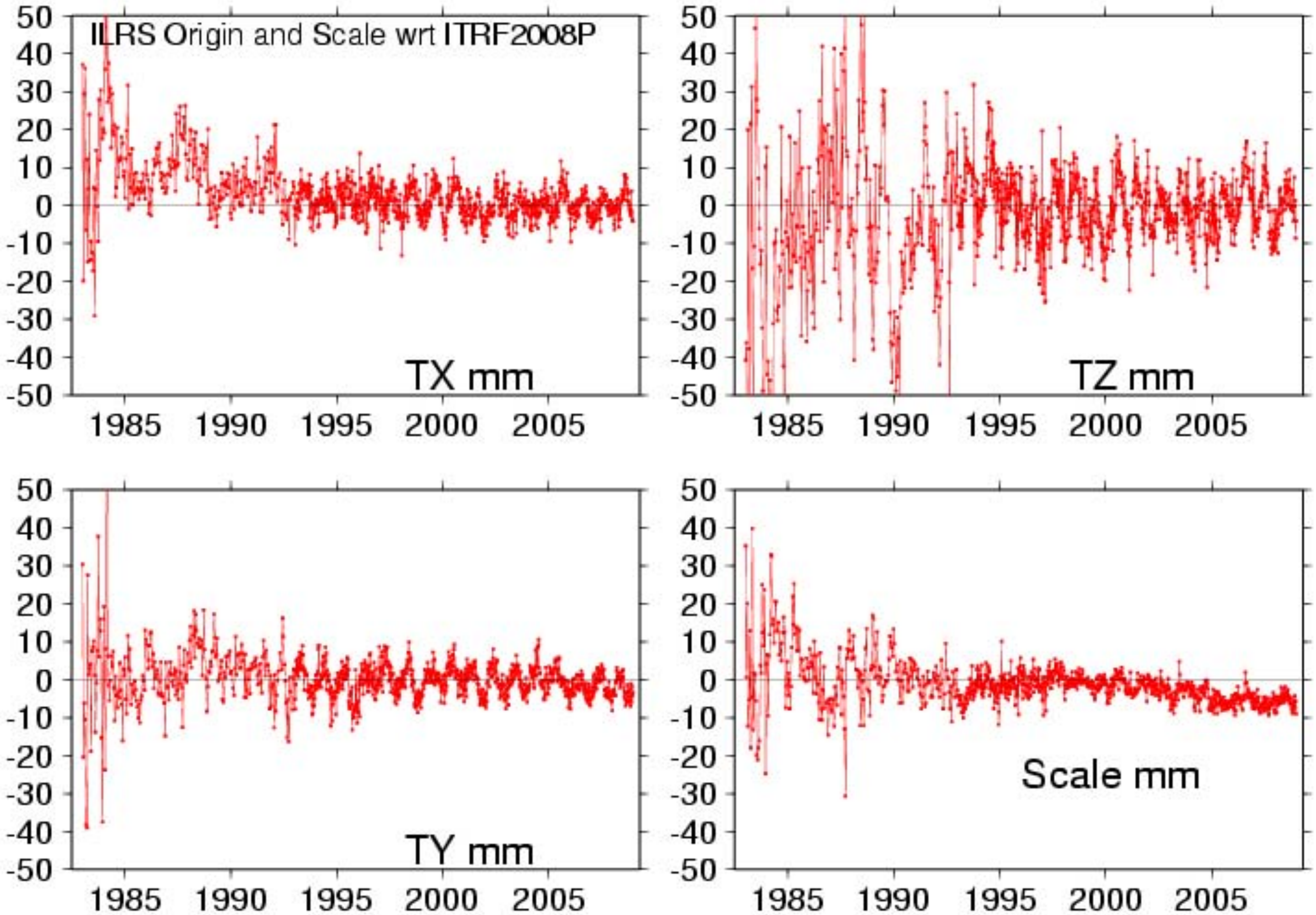


ITRF2008 Datum Specification

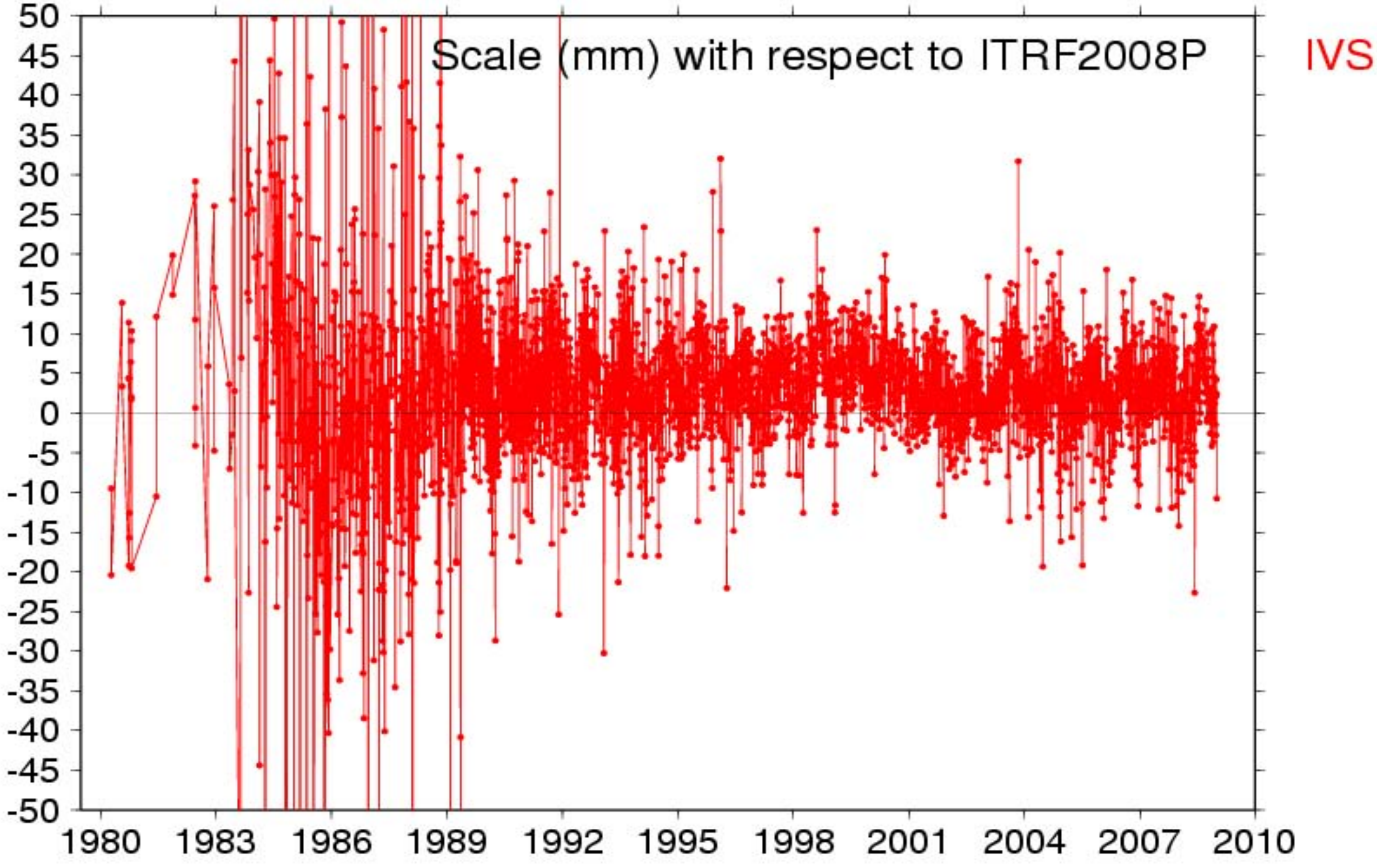
- Origin: SLR
- Scale : Mean of SLR &VLBI
- Orientation: Aligned to ITRF2005 (orientation and its rate) using 95 stations located at 79 sites:
  - 55 at northern hemisphere
  - 24 at southern hemisphere



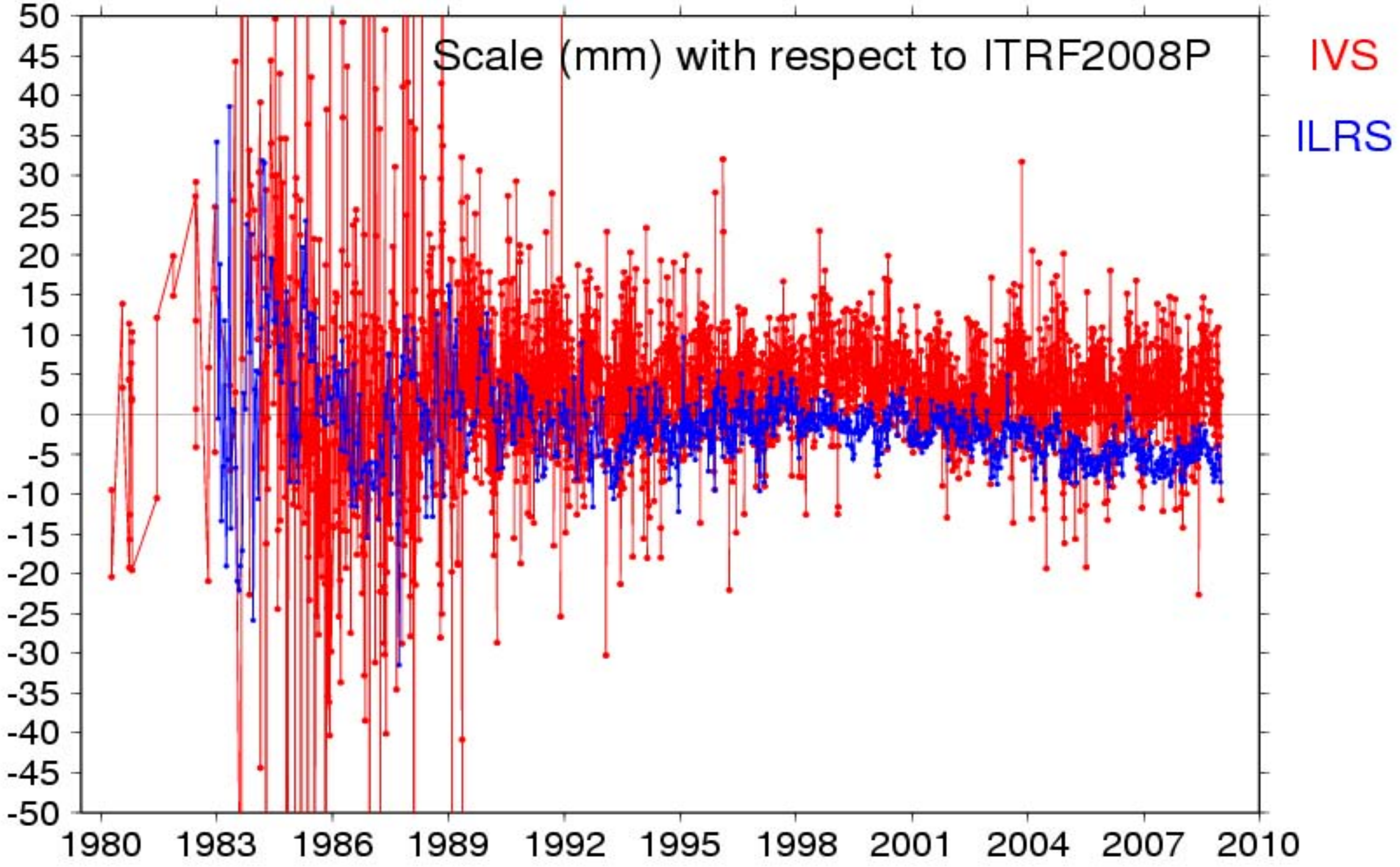
SLR/ILRSA24 Origin and Scale wrt ITRF2008P



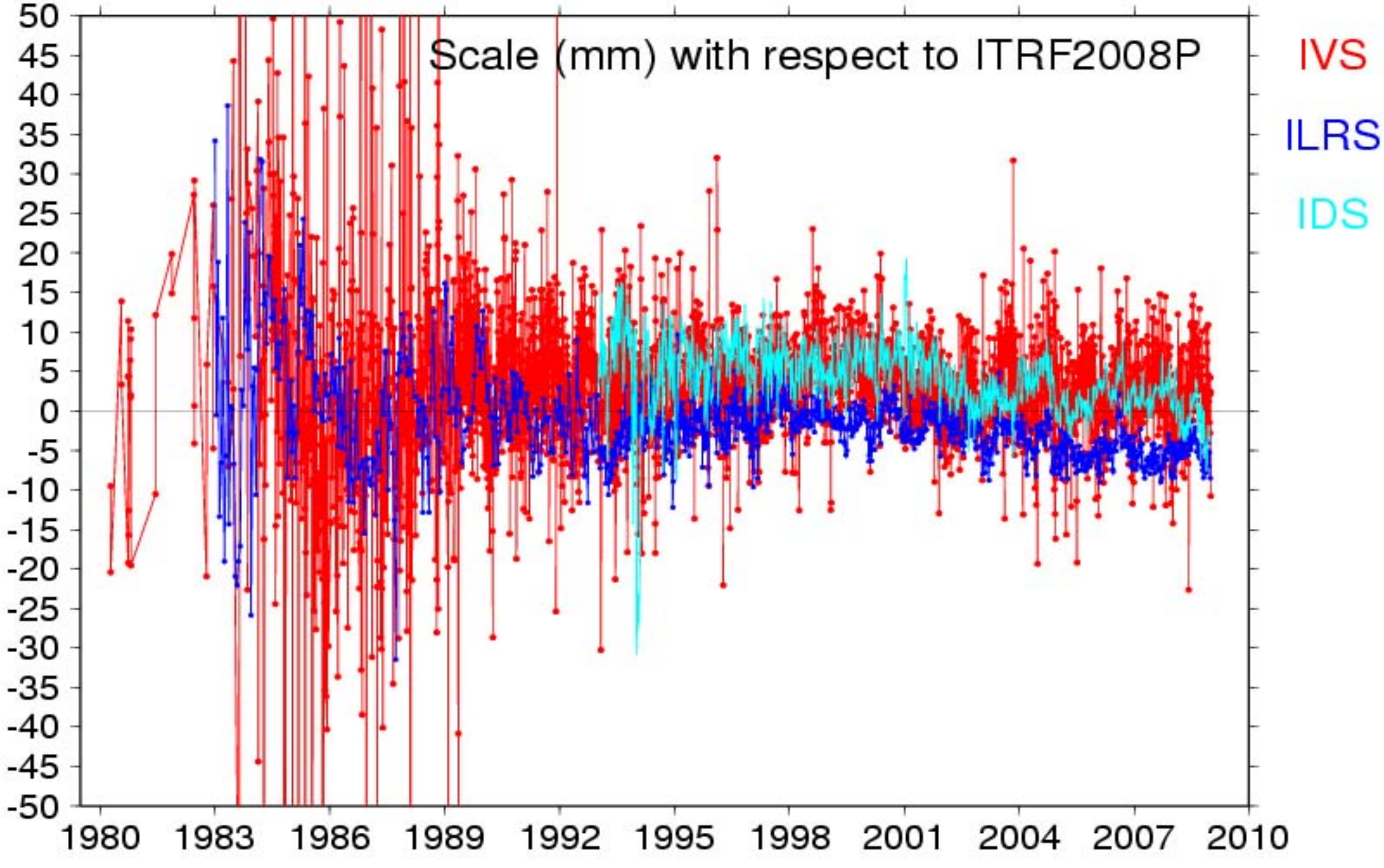
Scales wrt ITRF2008P



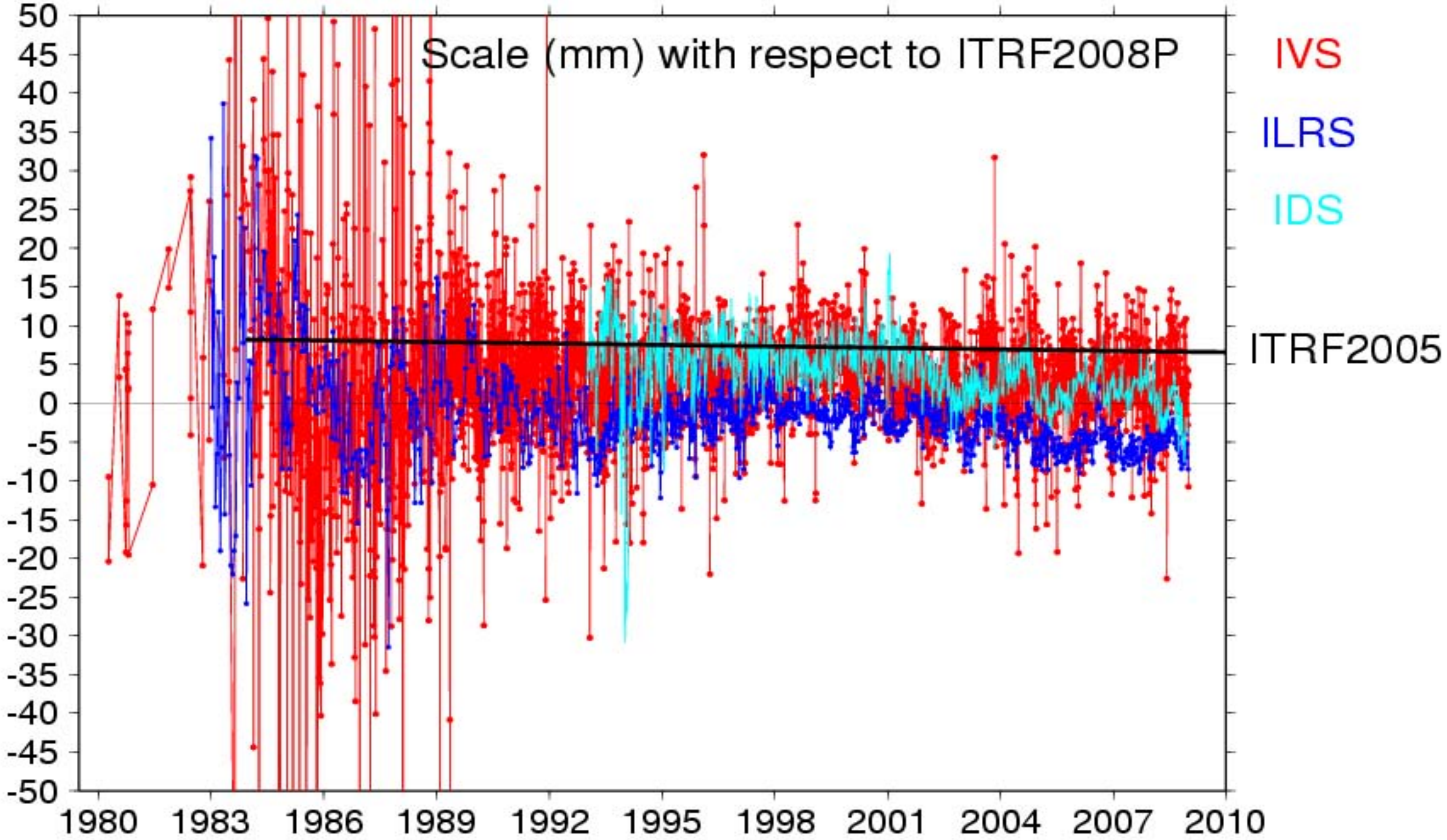
Scales wrt ITRF2008P



Scales wrt ITRF2008P



Scales wrt ITRF2008P



Scale FORMAL errors (1 σ) via ties to GPS

:·

	Scale ppb	Scale rate ppb/yr
VLBI	± 0.10	± 0.01
SLR	± 0.12	± 0.01
DORIS	± 0.20	± 0.03

Transformation Param Fm ITRF2008P To ITRF2005

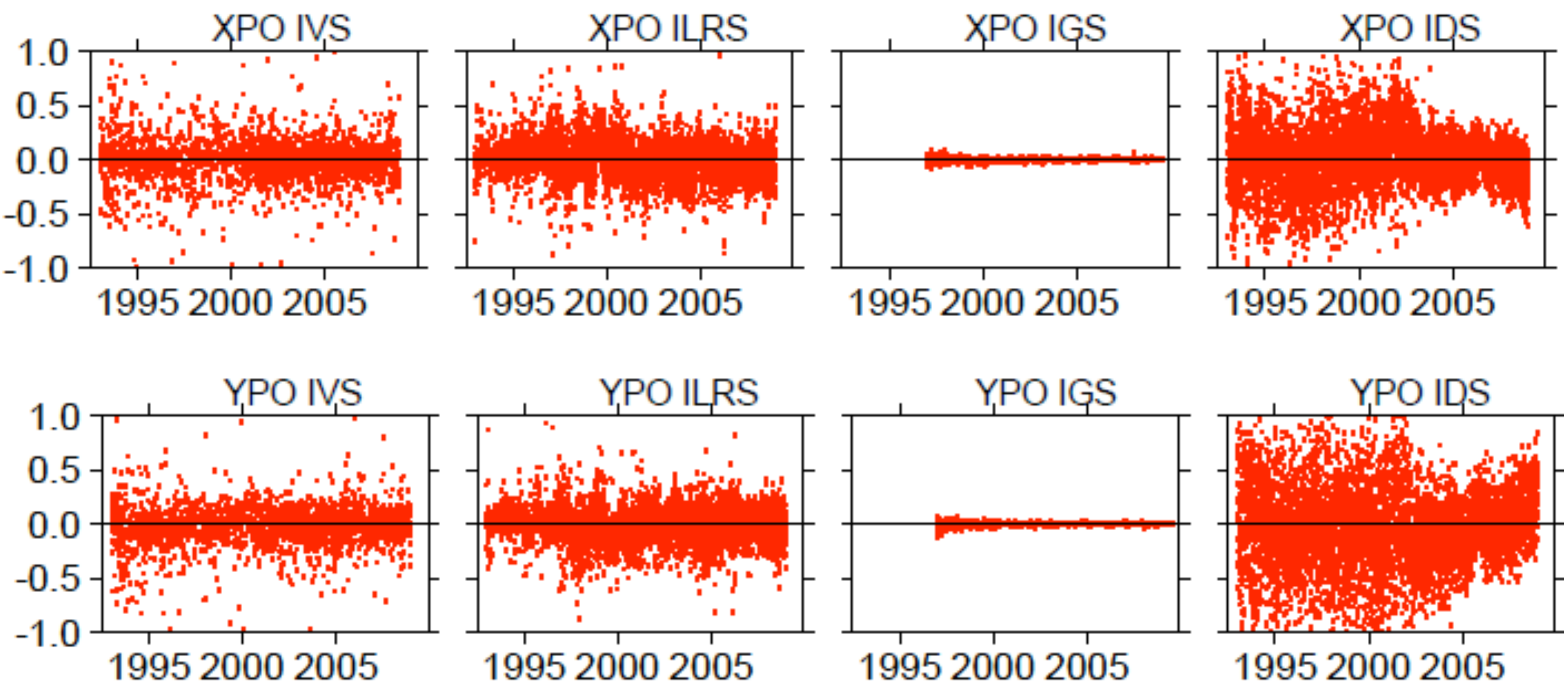
::

Tx	Ty	Tz	Scale	
mm	mm	mm	ppb	
-0.7	-0.4	-3.8	1.14	At epoch
± 0.5	± 0.5	± 0.5	± 0.10	2005.0

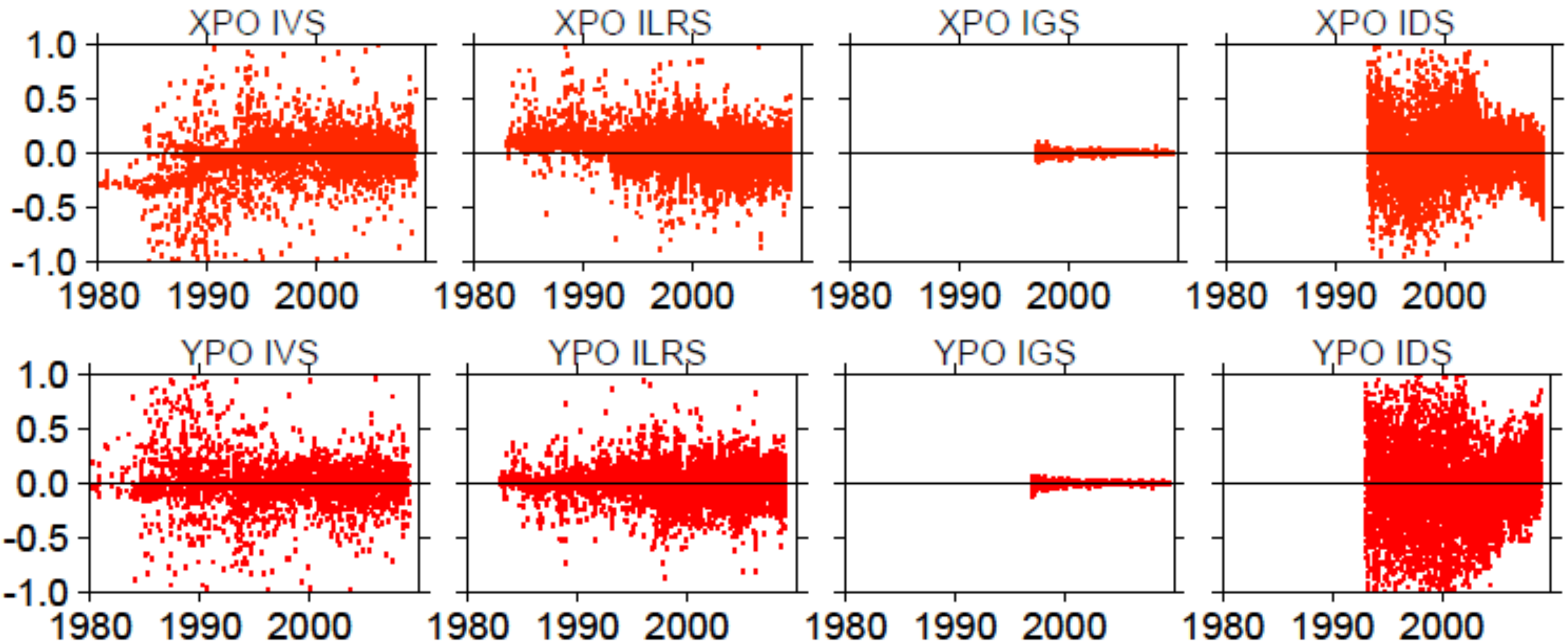
::

Tx rate	Ty rate	Tz rate	Scale rate
mm/yr	mm/yr	mm/yr	ppb/yr
0.2	0.0	-0.1	-0.01
± 0.1	± 0.1	± 0.1	± 0.01

ITRF2008P PM residuals



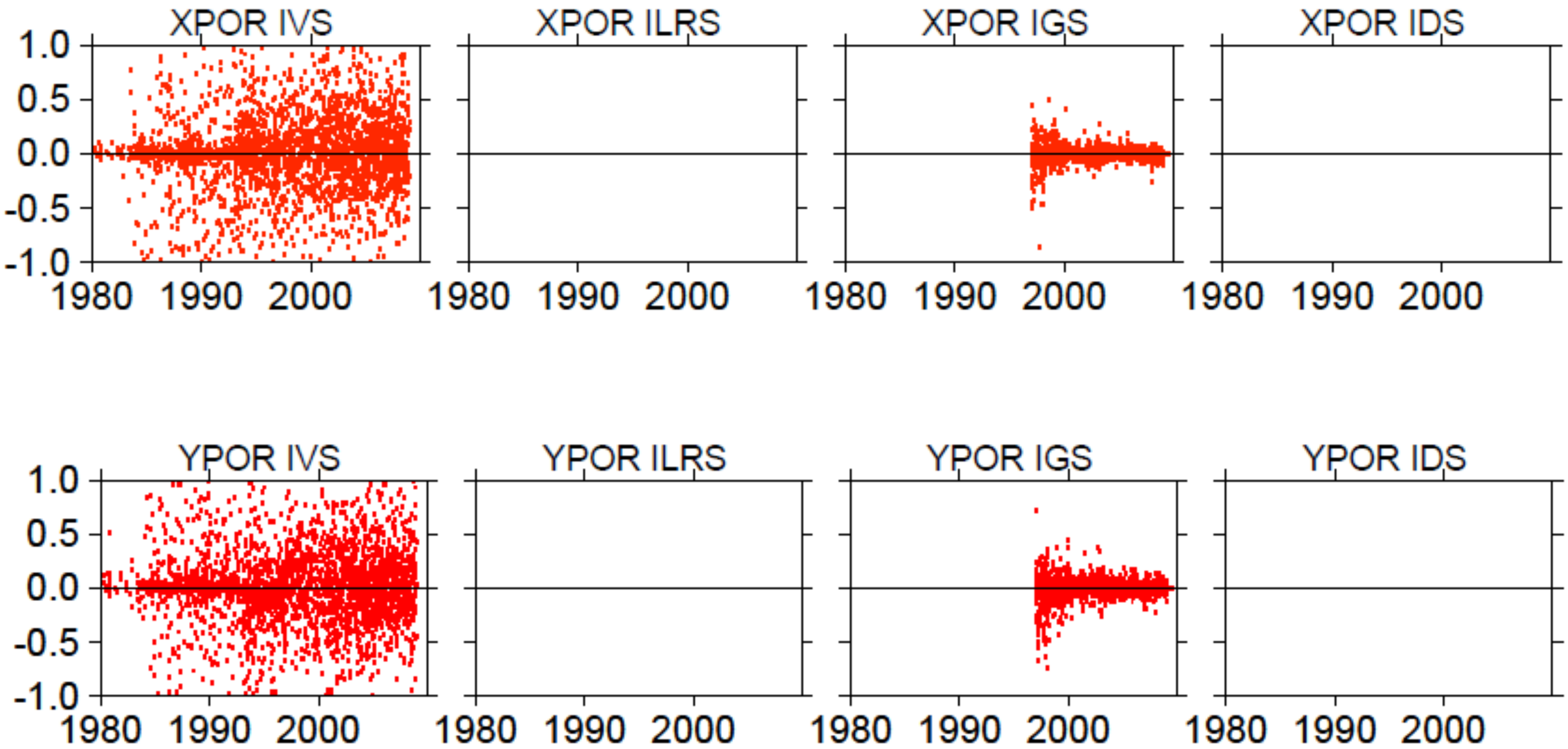
ITRF2008P PM residuals



WRMS in μas

	X-pole	Y-pole		X-pole	Y-pole
GPS	10	10	VLBI	142	120
DORIS	239	353	SLR	144	128

ITRF2008P PM rate residuals



Concluding remarks

- ITRF2008: independent combination from ITRF2005

- Origin: almost the same as ITRF2005:
    - 3.8 mm at epoch 2005.0 along Z-axis
    - 0.2 mm/yr along X-axis

- Scale: mean of VLBI and SLR
  - Agreement between VLBI and SLR:
    - 1.10 (± 0.13) ppb (at epoch 2005.0)
    - 0.06 (± 0.01) ppb/yr

    did we reach the limit of VLBI and SLR scale consistency ?
  - Diff (ITRF2005 – ITRF2008P):
    - +1.14 (± 0.10) ppb (at epoch 2005.0)
    - -0.01 (± 0.01) ppb/yr

GNSS Retroreflector Array Activities

- GNSS Standard established;
- Simulation studies to scope the network requirements for applications (E. Pavlis);
- Daylight ranging study underway (G. Appleby, M. Davis);
- Study in cornercube polarization effects (M. Davis, D. Arnold, and S. Della'Agnello)

ILRS Retroreflector Standards
(Revision September 28, 2007)

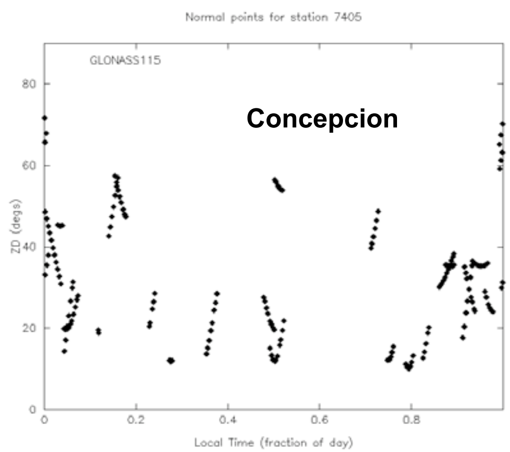
- Retroreflector payloads for GPS, GLONASS, and COMPASS satellites should have an "effective cross-section" of 100 million sq. meters (5 times that of GPS-35 and -36) for GNSS satellites;
- *Added Recommendation: Retroreflector payloads for satellites such as Galileo in higher orbits should scale the "effective cross-section" to compensate for the R**4 reduction in signal strength;*
- The parameters necessary for the precise definition of the vectors between the effective reflection plane, the radiometric antenna phase center and the center of mass of the spacecraft be specified and maintained with an accuracy of 2 mm.

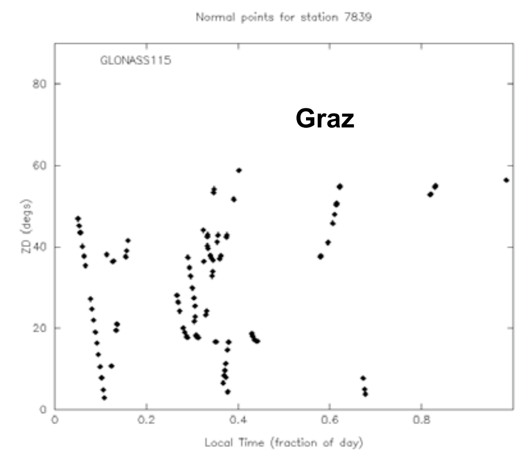
Retroreflector Arrays
on Lageos and HEO Satellites

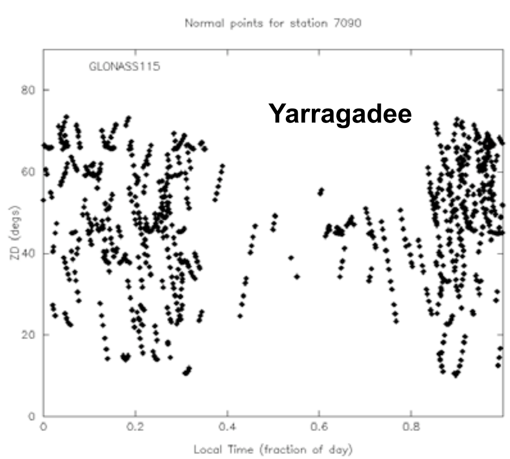
Satellite	**Altitude (MM)**	**Effective Cross Section (MSqM)**	**Relative Return Signal Strength**			
			Zenith	30 deg	45 deg	60 deg
Lageos1/2 *	5.8	15	1.0	1.0	1.0	1.0
Etalon1/2 *	19	55	.032	.037	.044	.058
GLONASS <115	19	80	**.046**	**.054**	**.065**	**.084**
GLONASS 115	19	131	**.076**	**.088**	**.107**	**.139**
GPS 35/36	20	20	.009	.011	.013	.018
COMPASS	21.5	80	**.028**	**.033**	**.041**	**.054**
GIOVE-A **	23.9	45	.010	.012	.015	.021
GIOVE-B **	23.9	40	.009	.011	.014	.018
ETS-8 ***	36	140	.006	.008	.010	.014

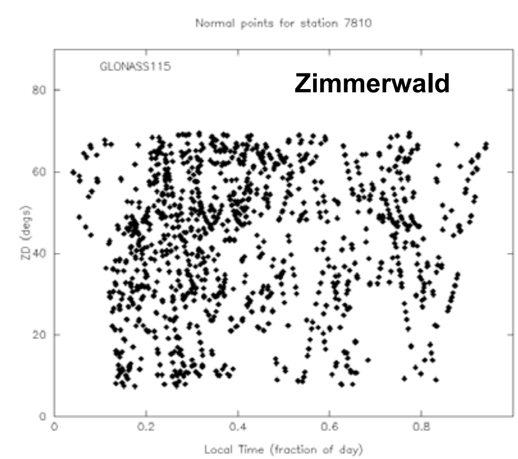
* Sphere ** Galileo Test Satellite *** Synchronous

GLONASS 115

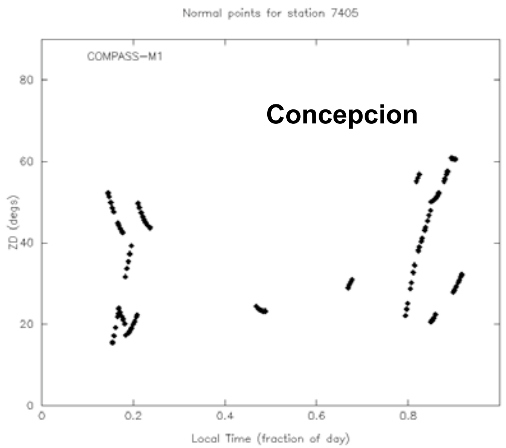

Normal points for station 7405
GLONASS115
Concepcion
ZD (degs)
Local Time (fraction of day)

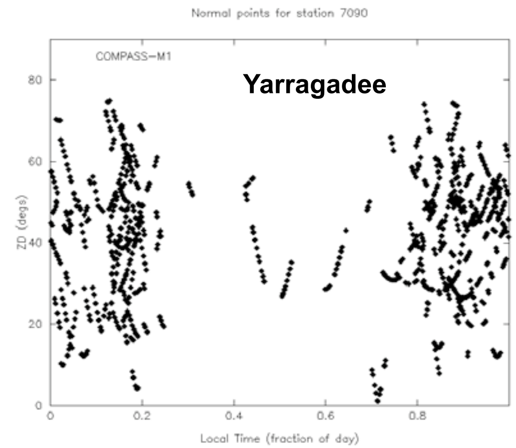

Normal points for station 7839
GLONASS115
Graz
ZD (degs)
Local Time (fraction of day)

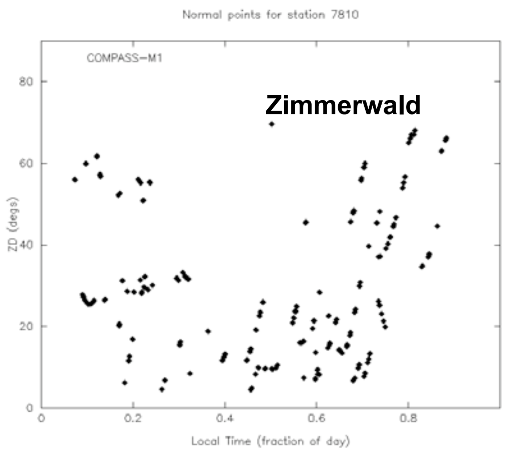

Normal points for station 7090
GLONASS115
Yarragadee
ZD (degs)
Local Time (fraction of day)

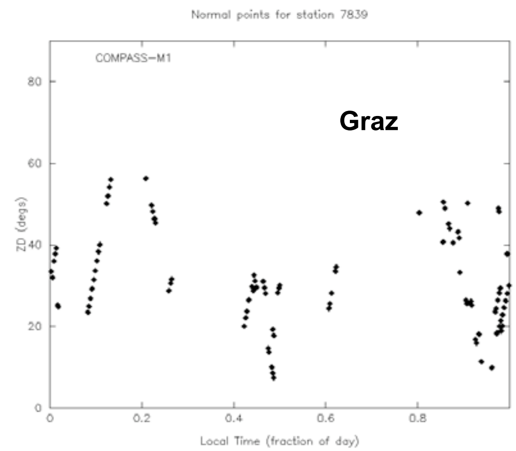

Normal points for station 7810
GLONASS115
Zimmerwald
ZD (degs)
Local Time (fraction of day)

COMPASS 1M


Normal points for station 7405
COMPASS-M1
Concepcion
ZD (degs)
Local Time (fraction of day)


Normal points for station 7090
COMPASS-M1
Yarragadee
ZD (degs)
Local Time (fraction of day)


Normal points for station 7810
COMPASS-M1
Zimmerwald
ZD (degs)
Local Time (fraction of day)


Normal points for station 7839
COMPASS-M1
Graz
ZD (degs)
Local Time (fraction of day)

A Possible Plan for Multiple GNSS Tracking

- Assumptions:
  - Satellites carry the enhanced array (factor of 5 increase in effective cross section);
  - Precise Center of Mass information including the change with fuel consumption required for all spacecraft;
  - Many network stations will be using enhanced systems (e.g. KHz ranging, improved detection,) in the 2013 timeframe for improved performance on weak targets;
  - Increased automation and data interleaving procedures at the field stations will increase ranging efficiency;
- Concepts for an Operational HEO Plan:
  - Support GPS, Galileo, and GLONASS; COMPASS; and possibly other;
  - Pointing predictions based on on-board GPS data and SLR data for improved pointing particularly in daylight using real-time communication;
  - Decrease Normal Point intervals (from 5 minutes) as data volume increases, thereby increasing tracking capacity;
  - Three segments per pass (ascending, middle, descending);
  - Data available for analysis immediately after each pass;
  - Network tracking roster organized for at least 16 GNSS satellites at a time (at least one satellite per orbital plane per system);
  - Tracking cycles set for 30 – 60 days (to cover all satellites within a 12 month period);
  - Greater stress on daylight tracking;
  - Flexible tracking strategies; organized in cooperation with the agencies involved and the requirements for the ITRF;

GGOS

- GGOS Structure
  - Bureau for Networks and Communications established (GSFC);
  - Bureau for Standards and Procedures established (DGFI);
  - Portal being developed (BKG, GSFC);
  - Proposal for a Coordination Center received (ASI)
  - Satellite Mission Working Group established (OSU)
- Publications
  - GGOS 2020 Book
  - Papers at IAG, EGU, AGU, etc
- Meetings
  - GGOS Science Workshop in Finland (June)
  - GGOS Science Session and Steering Committee Meeting at IAG in Buenos Aires (August);
  - Metsovo Workshop on GNSS/SLR synergy (POD, Reference frame, etc.)
  - Workshop on Intergovernmental/Interagency interface for GGOS at BKG in Frankfurt;
  - GGOS Unified Analysis Workshop, San Francisco, December 11 -12;
  - GGOS Bureau for Networks and Communications Meeting, December 16, Chancellor Hotel, San Francisco;
  - GGOS Retreat, Miami FL, February 2 – 4, 2010