Session 12

Two-Wavelength Tracking

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Zimmerwald Dual-Wavelength Operation

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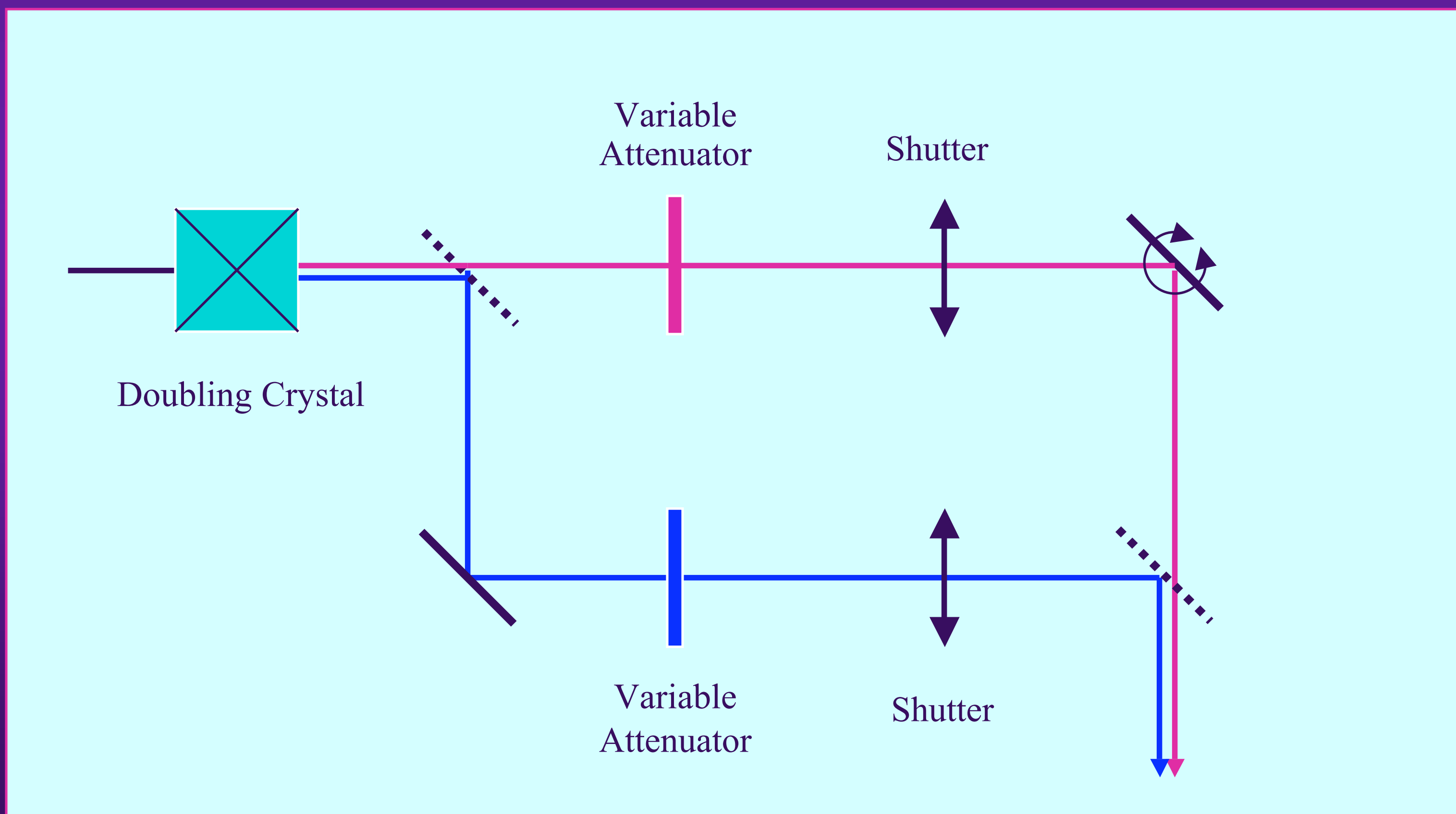
Kötzting

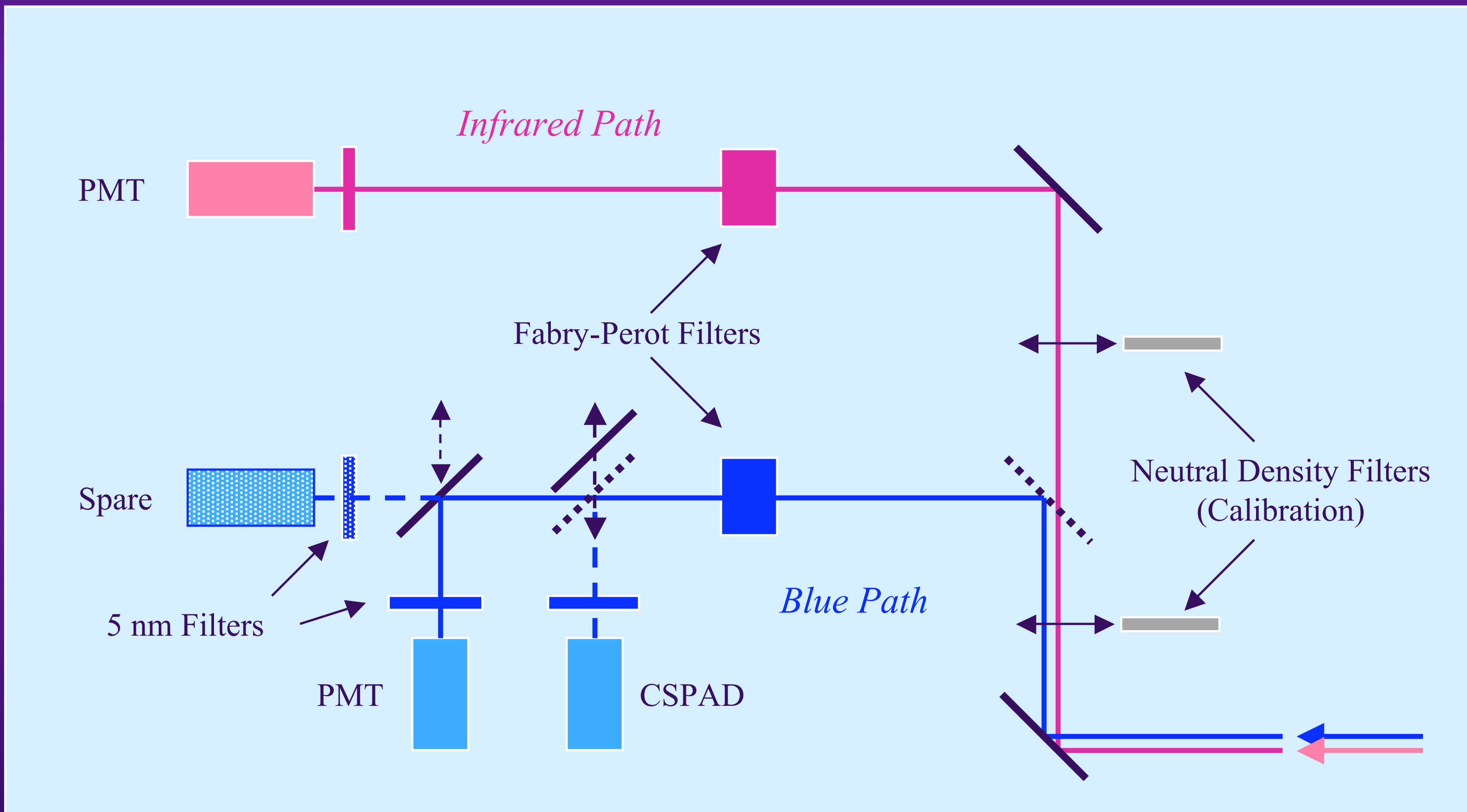
Two-Wavelengths Design

- Receivers
  - Blue (423 nm)
    - CSPAD: Single shot rms: 50 ps
    - Hamamatsu PMT
  - IR (846 nm)
    - Hamamatsu PMT: Single shot rms: 150 ps
- Beam attenuation
  - Transmitting beams
    - Separate rotating polarizer for each color
  - Receiving paths
    - Circular adjustable ND filters
    - Neutral density filters inserted for calibration

Transmit Path



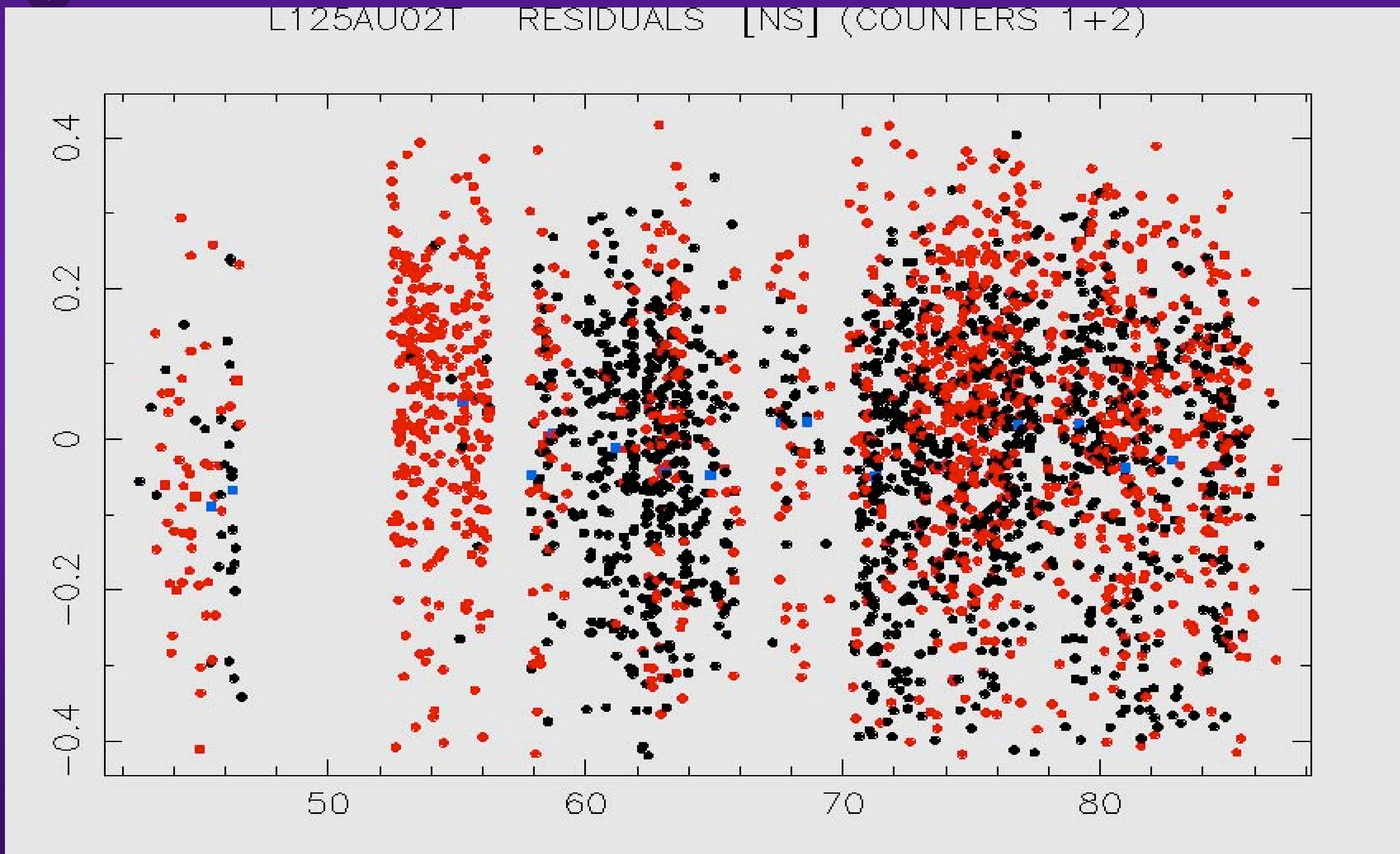
Receiving Path



Example: Lageos-1 Pass
25 August 2002, 19:40-20:30 UT

WavelengthSingle shotobservationsSingle shotRMSCalibrationRMSNumber of					

Lageos-1 Blue and IR Residuals (ns)



Experiences

- Beam alignment is rather critical
- Less noise in the infrared channel during daylight tracking
- Calibration RMS on IR larger by about 100 percents (180 ps vs. 90 ps)
- Average pass differences IR-blue (after M.M.-correction) < 0.08 ns

Conclusions

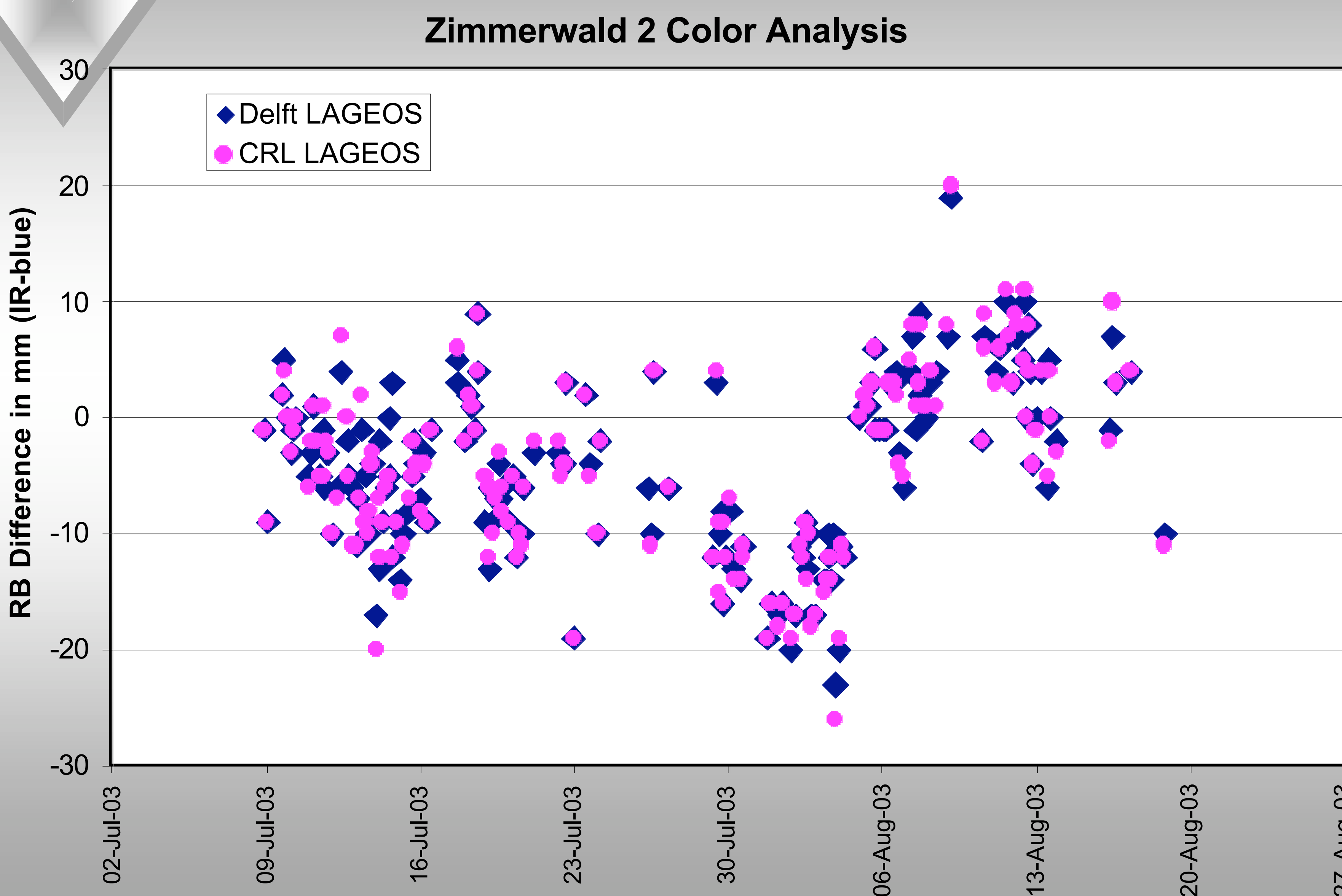
- Range biases between the two reception channels could still be in the system (a few millimeters?)
- Differences of the Marini-Murray refraction corrections at 423 and 846 nm obviously better than about 10 mm
- Is accuracy of the two wavelengths good enough for mapping function improvement?

Two-color Analysis Technique

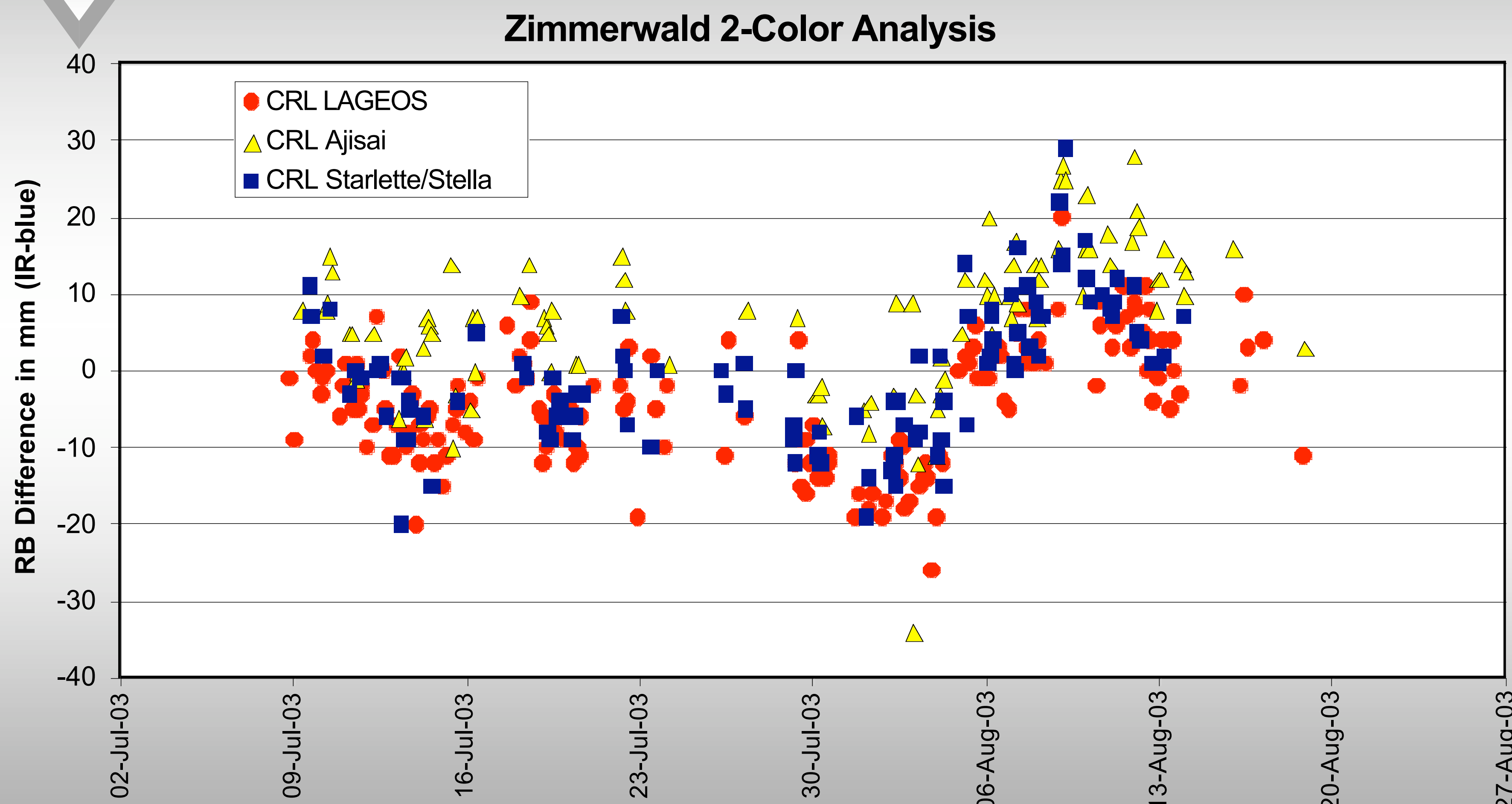
(Slides by Van Husson)

- Zimmerwald: Robust 2-color dataset in July – August 2003
- Zimmerwald 2-color configuration
  - **Blue (423nm): CSPAD**, SR620 #**0236**, **2.5** sigma
  - **IR (846nm):** PMT, SR620 #2282, 2.5 sigma
- In simultaneous passes, difference range biases (RB) from each color [i.e. IR(RB) – Blue(RB)]
- Uses RB results from Delft and CRL weekly reports

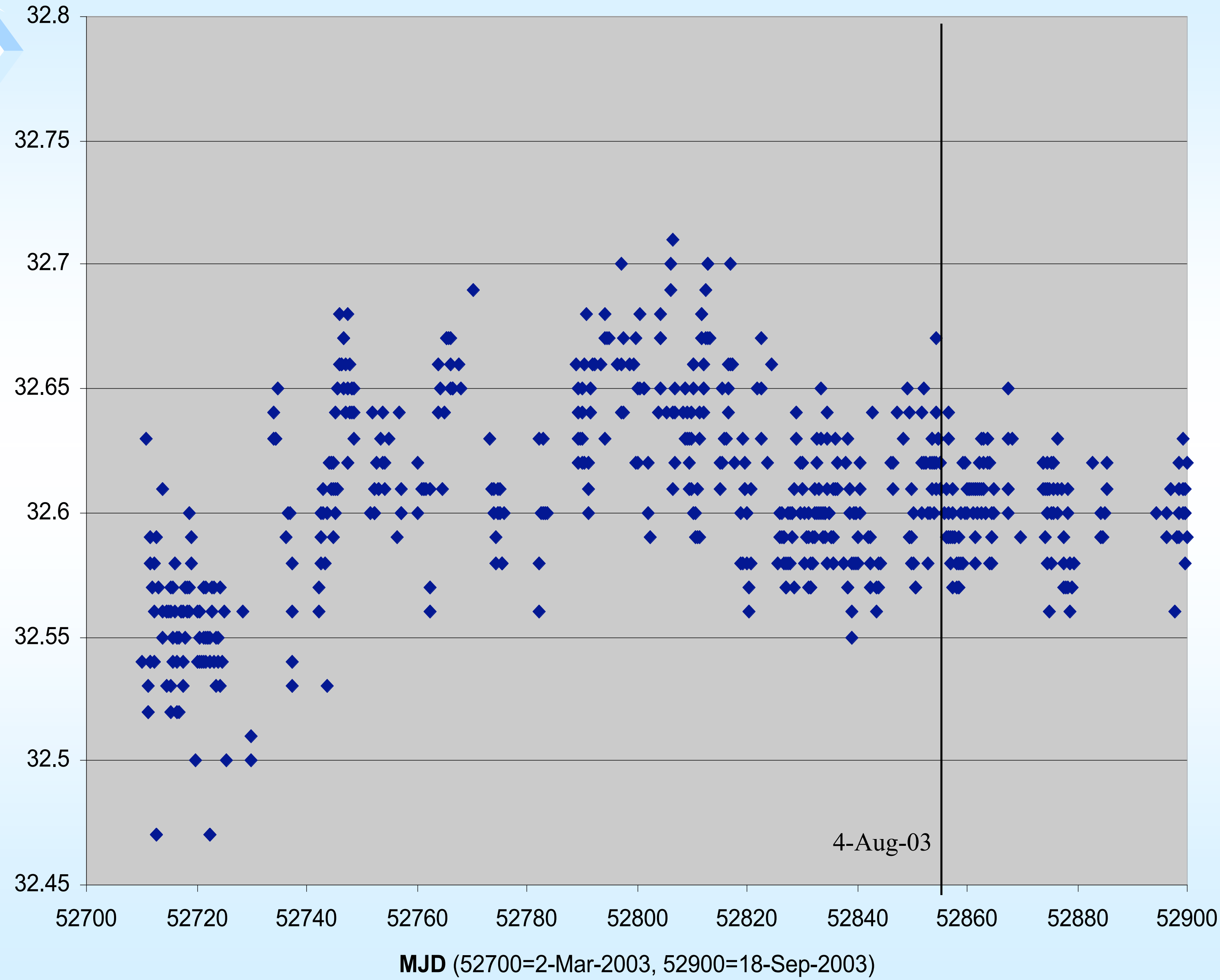
Zimmerwald 2-Color RB Differences



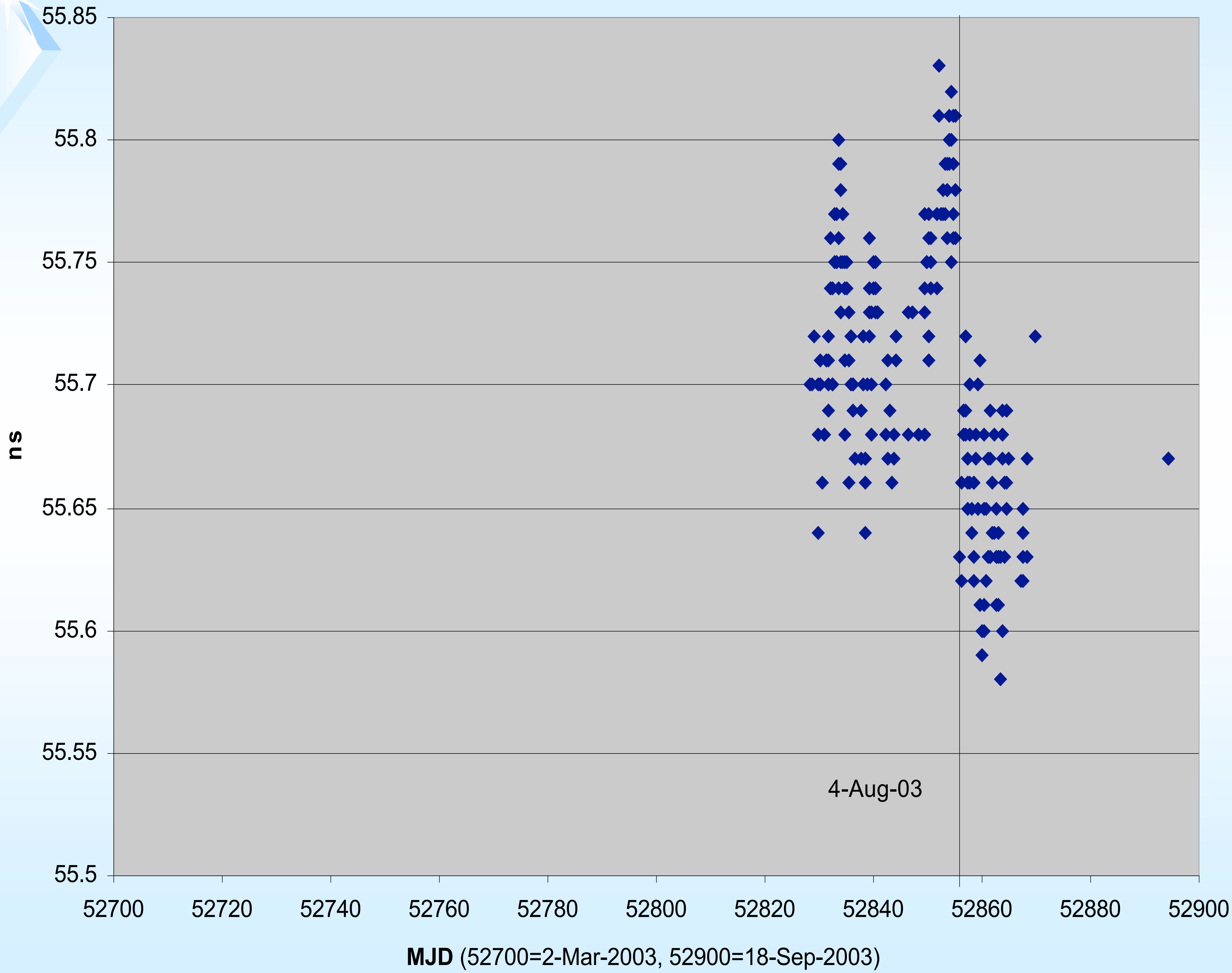
Zimmerwald 2-Color RB Differences



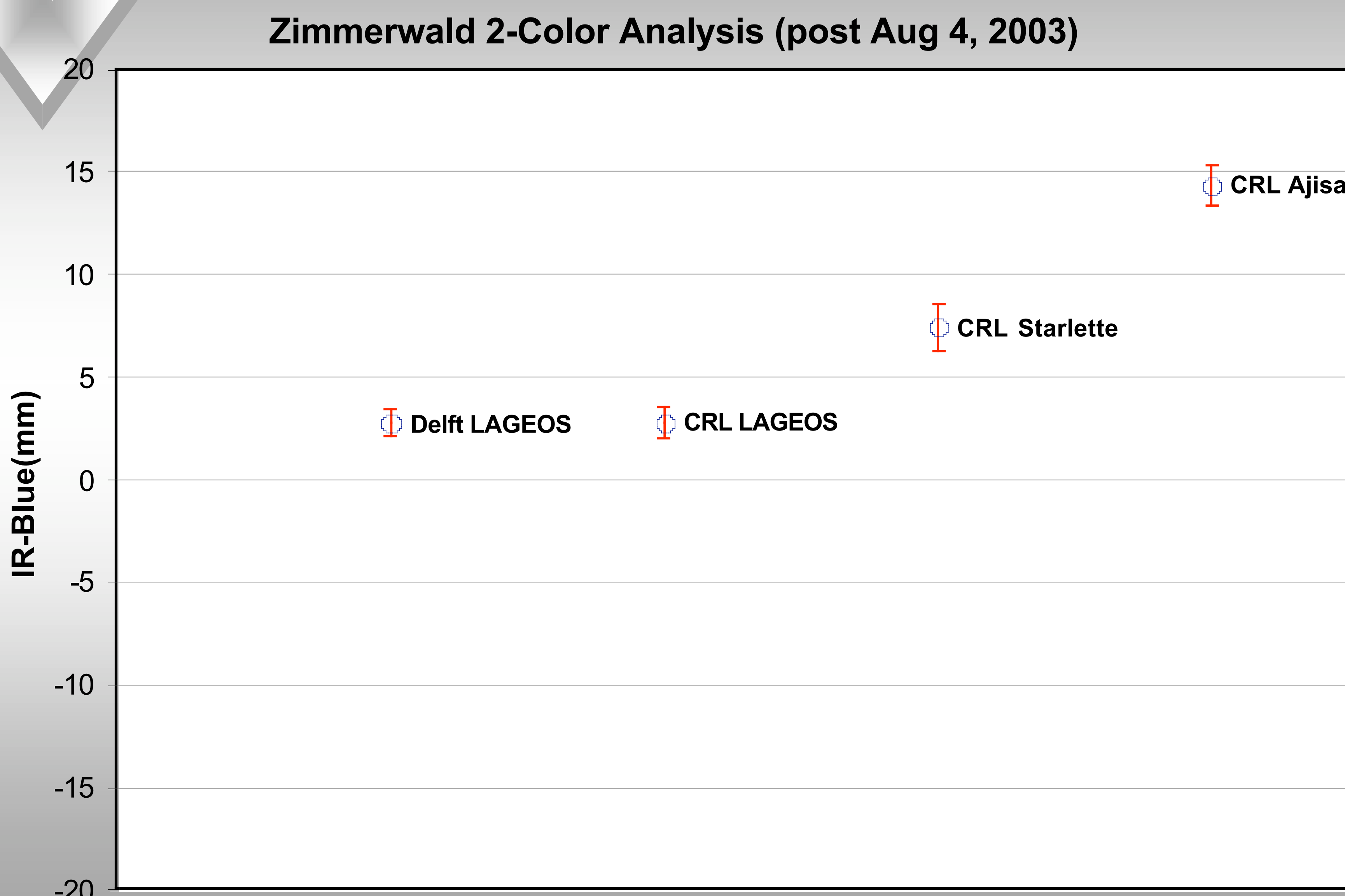
Calibration Values (SPAD)



Calibration Values (PM IR)



Zimmerwald 2-Color Analysis



Possible Source of Differences

- Refraction Algorithm
- CoM Differences
  - Detectors (CSPAD vs PMT)
  - Dual Wavelengths
  - Signal Strength
  - Polarization?
- System Calibration
  - Different SR620 Counter linearities
  - Signal Strength
  - Optical Path Differences?

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Dual Wavelength Data Analysis
423 & 846 nm

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2003 ILRS Workshop on Laser Ranging
October 28-31, 2003, Kötzting, Germany

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Description

- Analyzed data span 2001 to March 2003
- Data come from two sites:
  - **Zimmerwald (7810)** [PRIMARILY] , and
  - **Conception (TIGO)**
- Data are computed from already converged orbits and each wavelength is treated as an independent measurement at the same site

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Description, (cont.)

- Atmospheric refraction corrections were applied in two different ways:
  - standard Marini - Murray model **[MM]**
  - a variation of Ciddor's ZD model by Mendes and the new FCUL (Mendes et al.) mapping function **[MC]**
- Residual differences examined for bias and scale differences

Description, (cont.)

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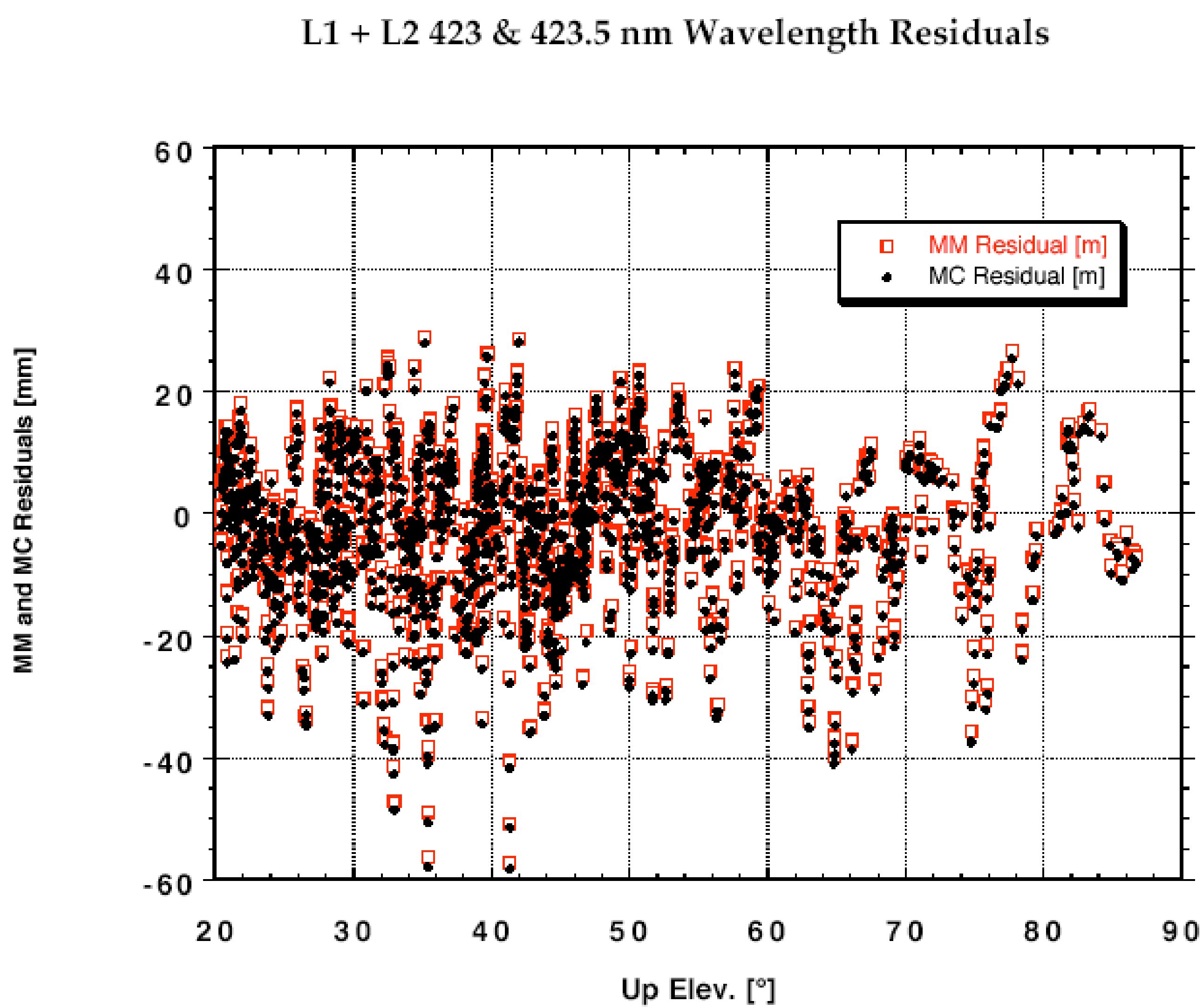
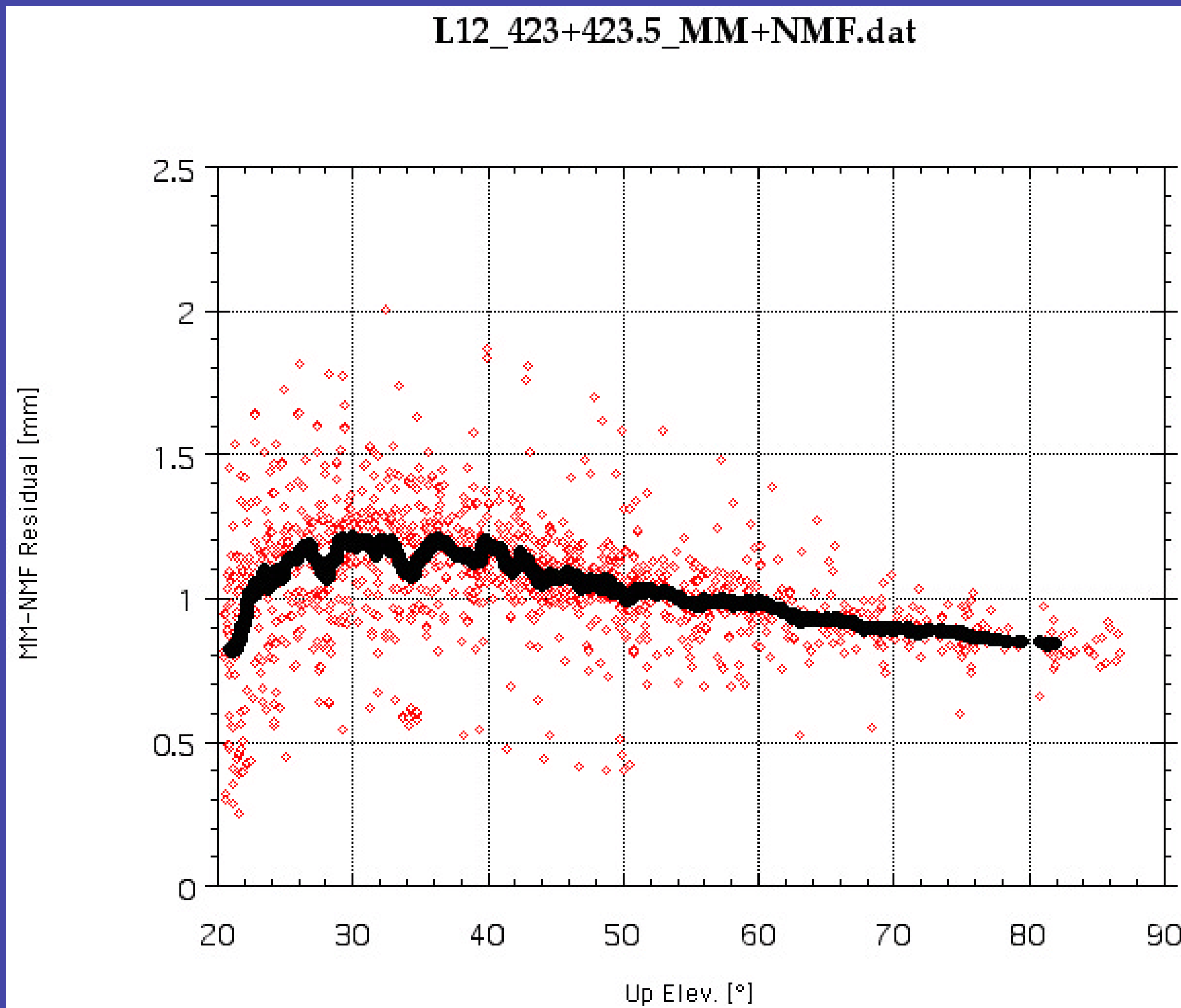
- Residuals grouped by "sign"
  - Positive-residual differences:
    - **$MM^{+} - MC^{+}$**
  - Negative-residual differences
    - **$MM^{-} - MC^{-}$**
- Residuals grouped in 10° elevation bands and regressed to investigate scatter variation correlated with dependence on elevation

Residual wrt Elevation



Erricos C. Pavlis

Residual Differences wrt Elevation



ZD Bias as a Function of Wavelength

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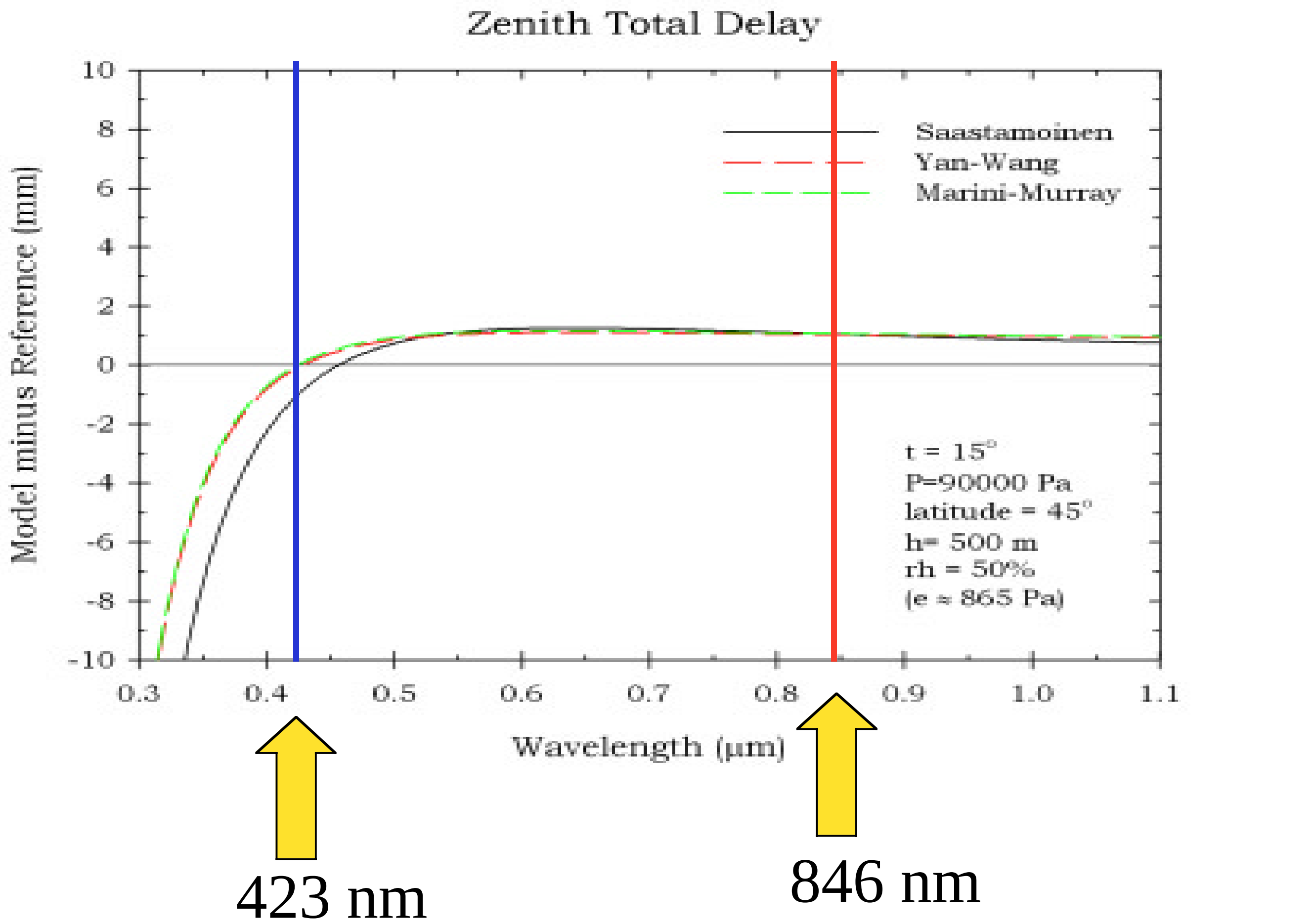

ZD Bias as a Function of Wavelength

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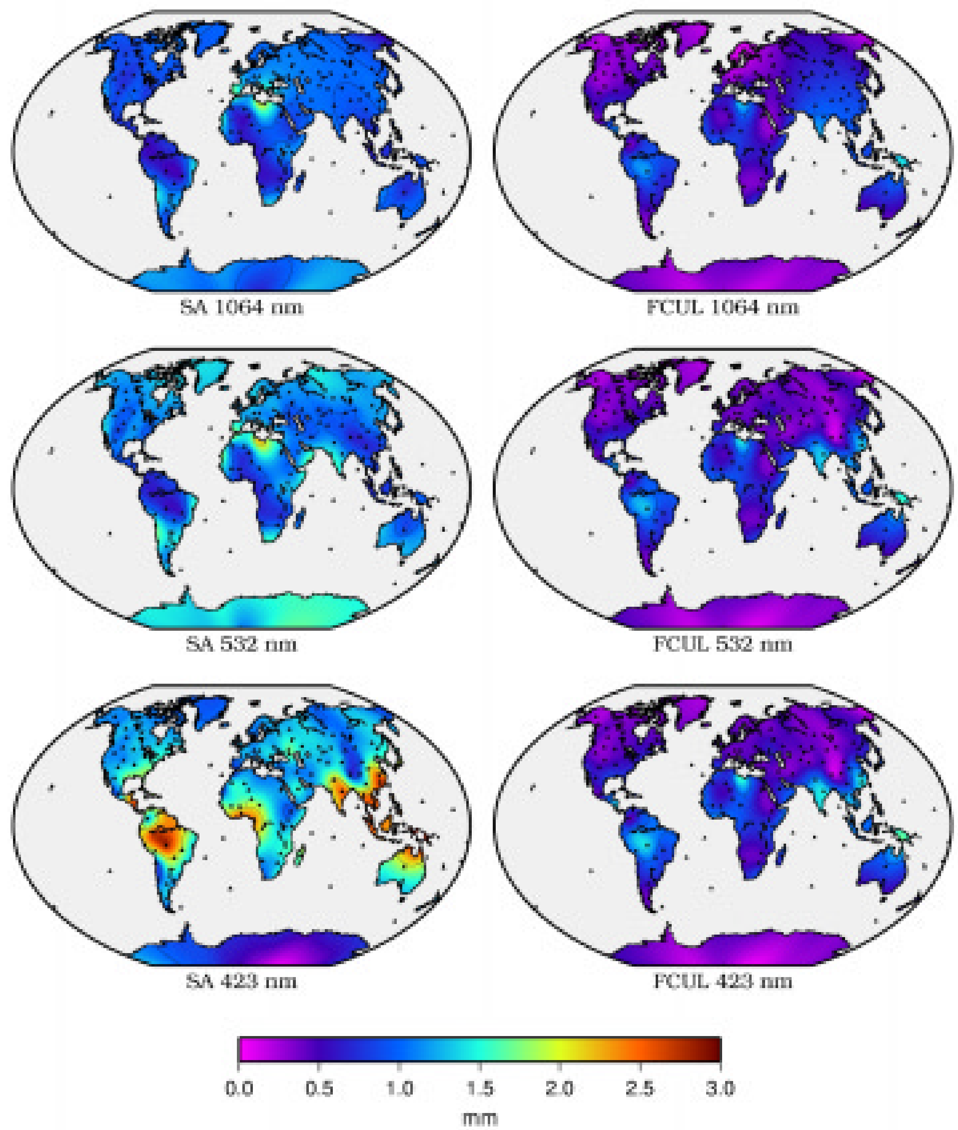
Saastamoinen

Ciddor-Mendes

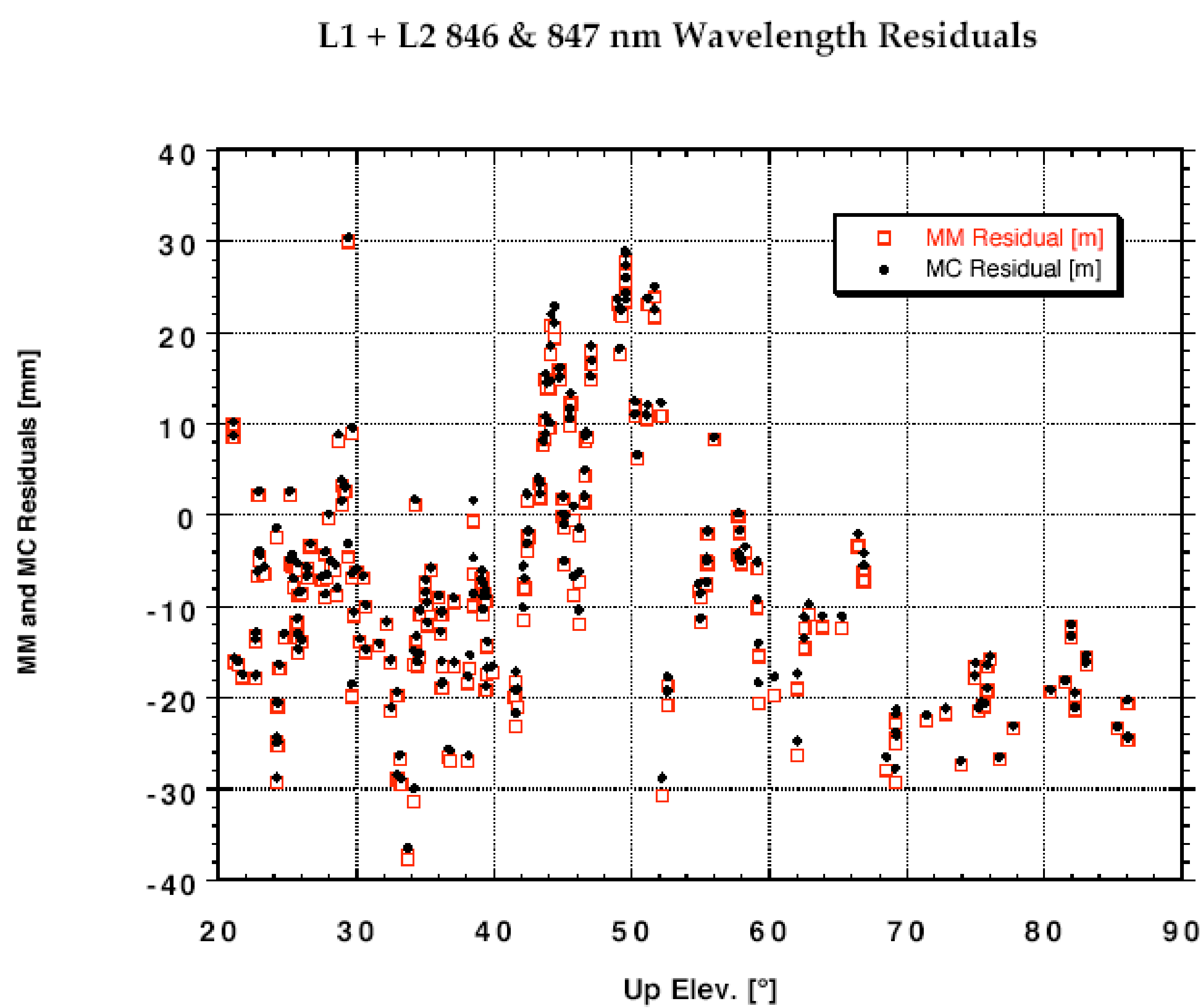
1064 nm | 1064 nm

532 nm | 532 nm

423 nm | 423 nm



Residual wrt Elevation



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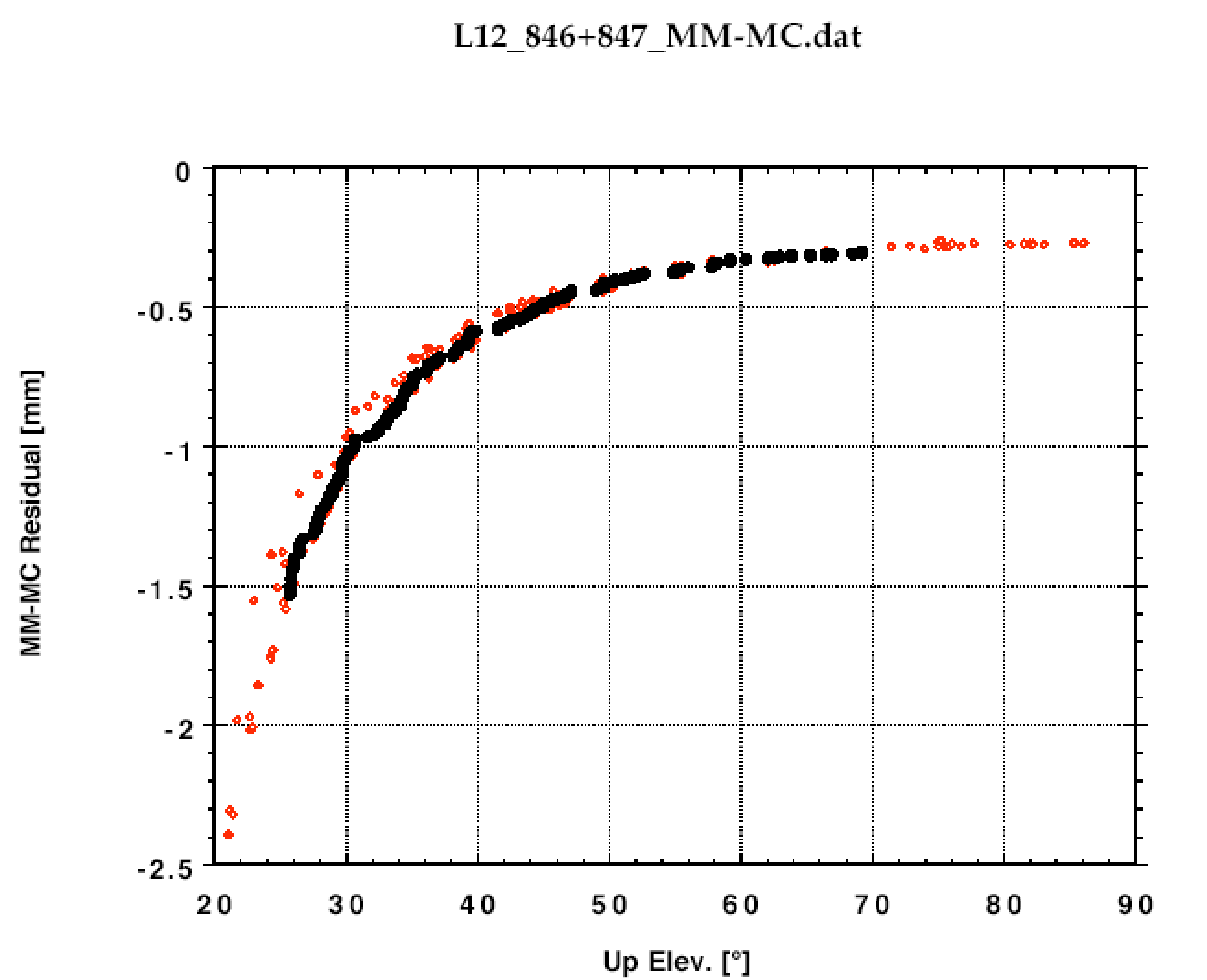
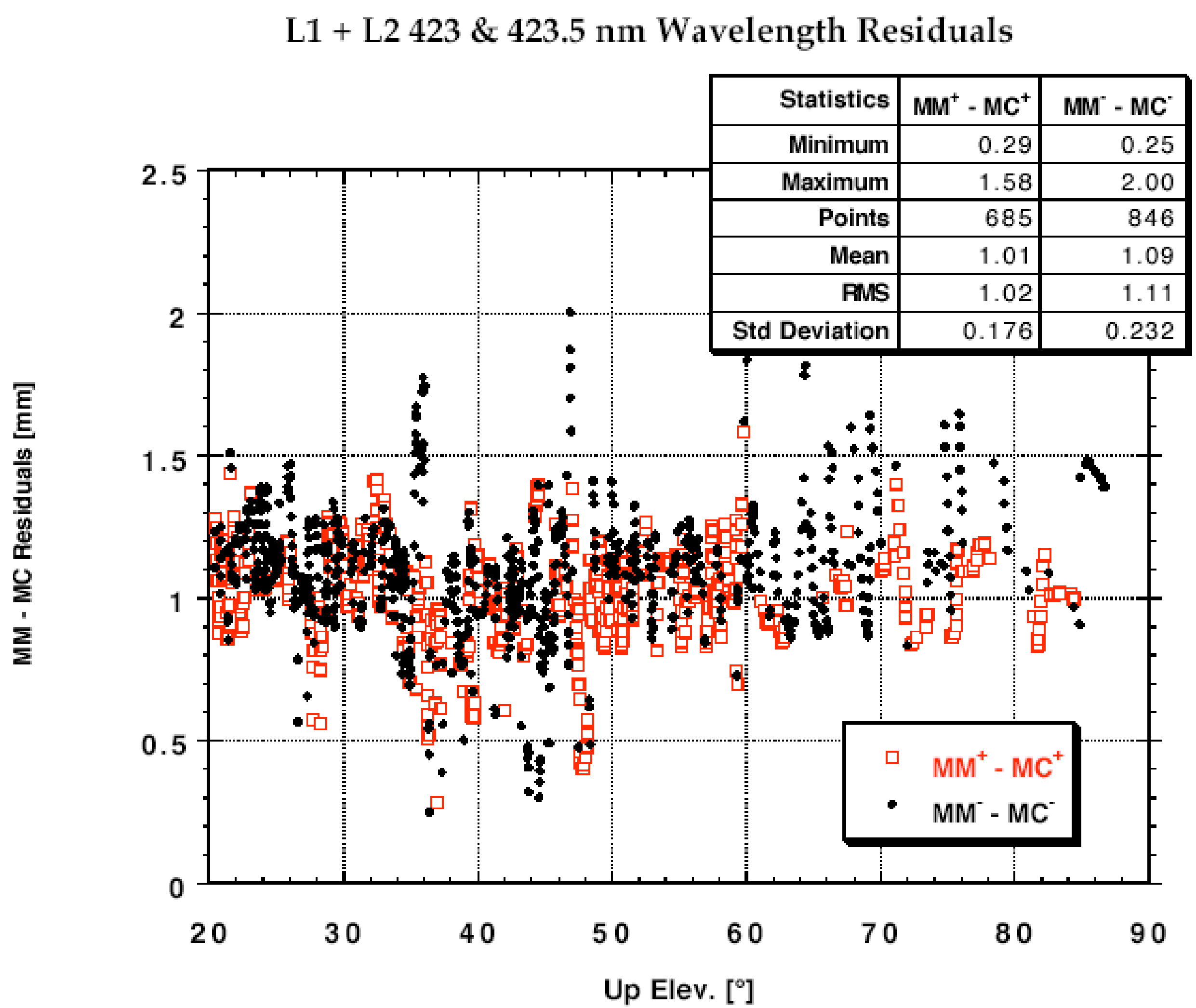
Residual Differences wrt Elevation

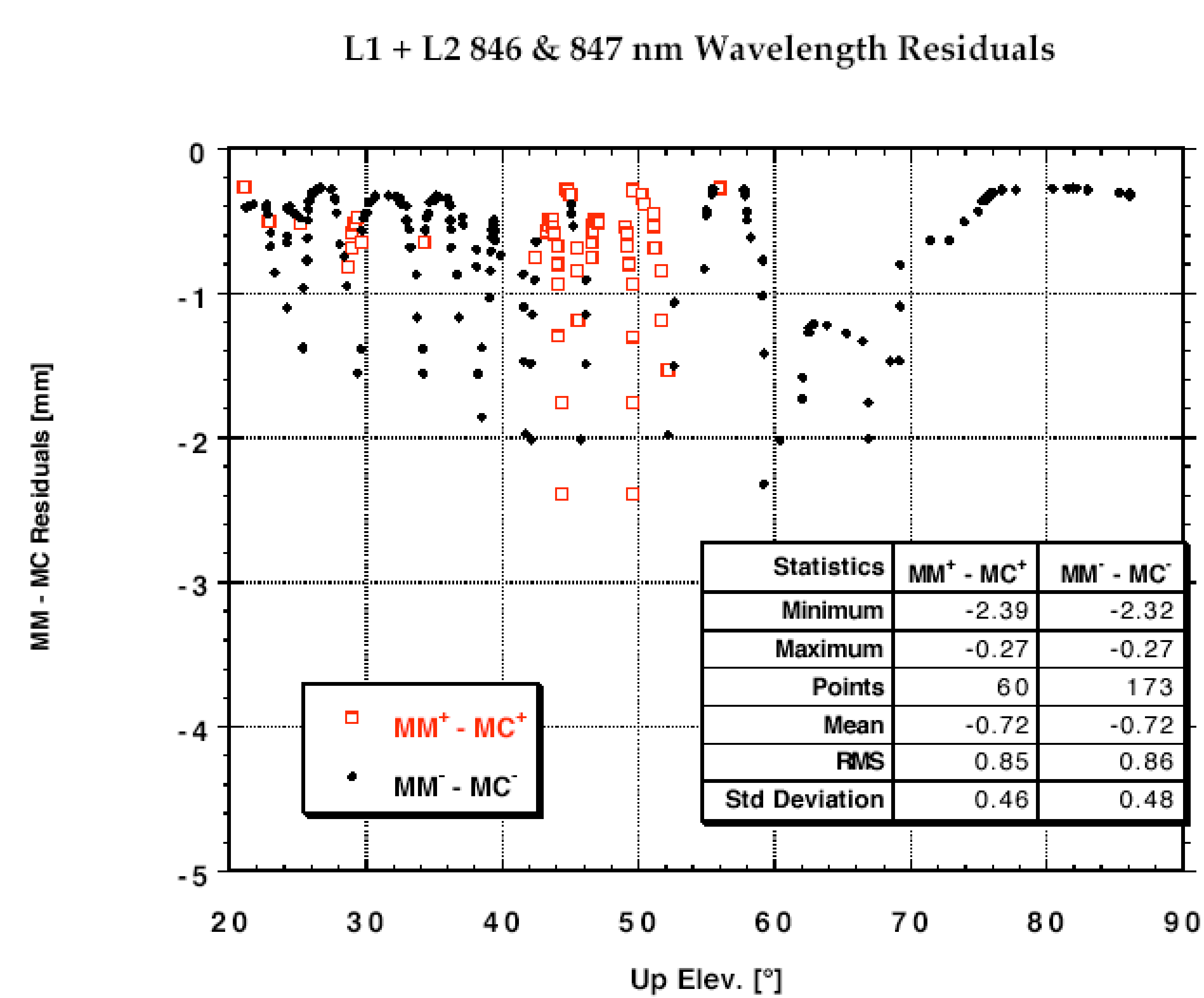


Residual Differences wrt Elevation

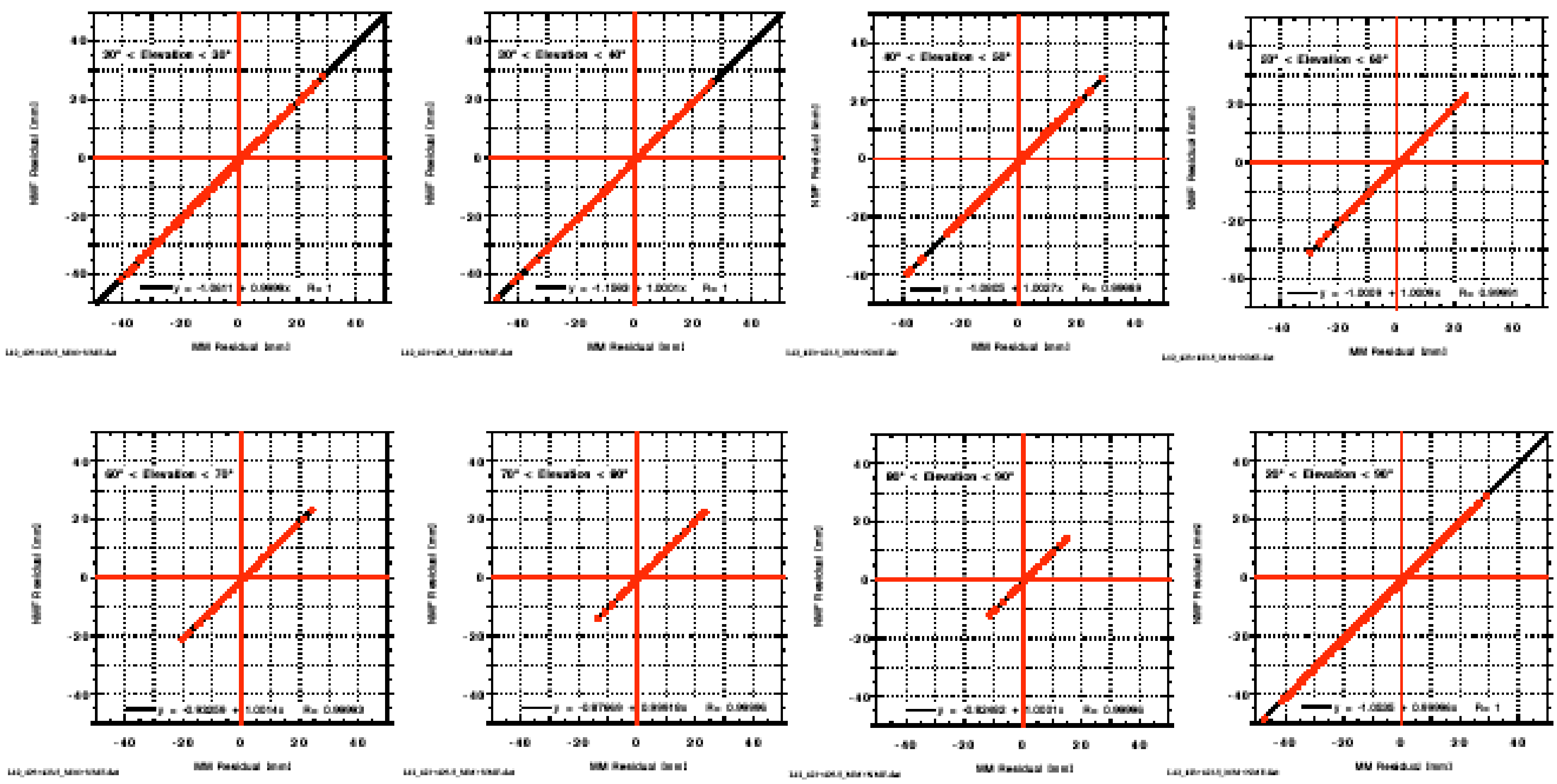


Statistics	$MM^+ - MC^+$	$MM^- - MC^-$
Minimum	0.29	0.25
Maximum	1.58	2.00
Points	685	846
Mean	1.01	1.09
RMS	1.02	1.11
Std Deviation	0.176	0.232

Residual Differences wrt Elevation



Residual Differences Regression
423 nm



Residual Differences Regression
846 nm

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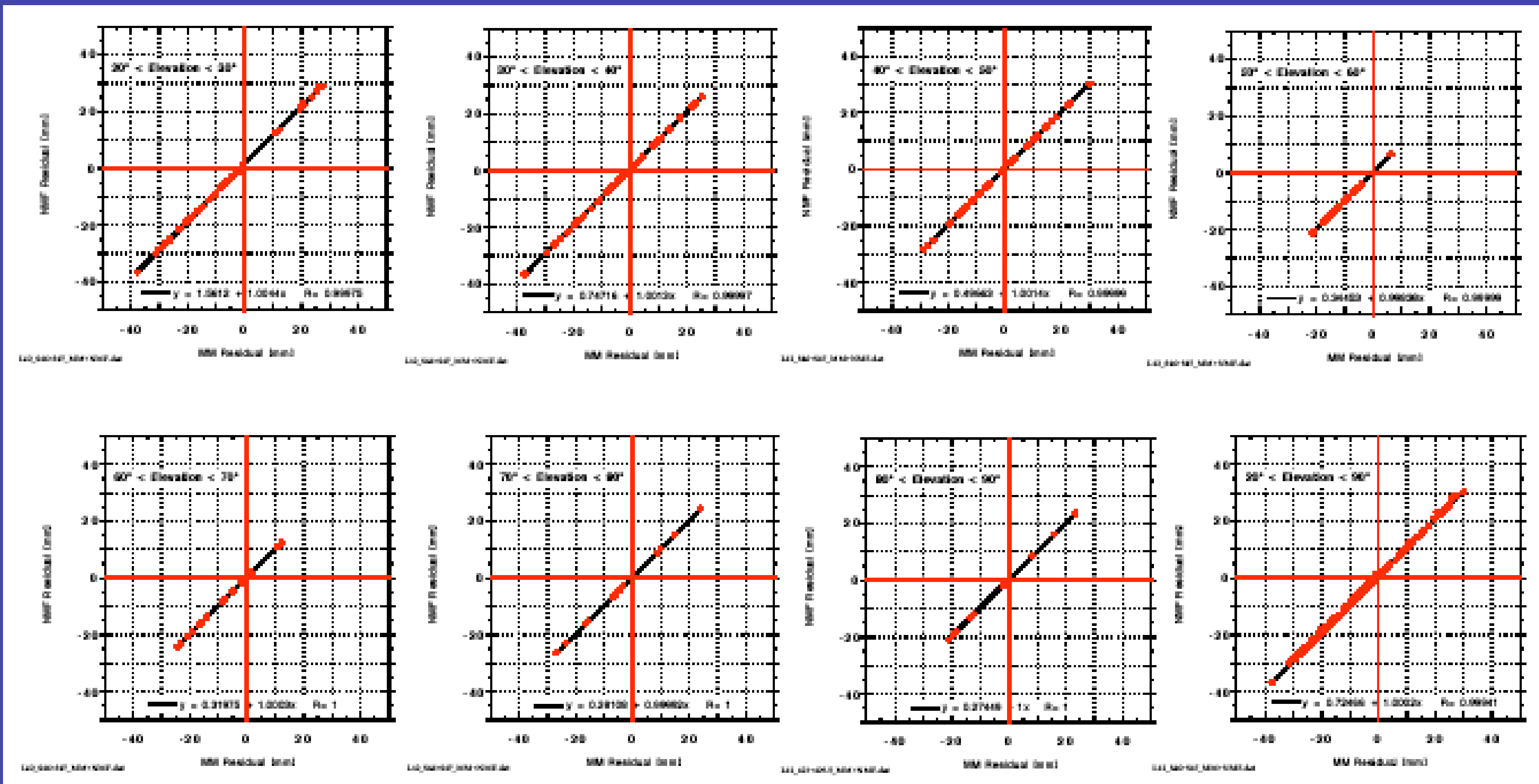
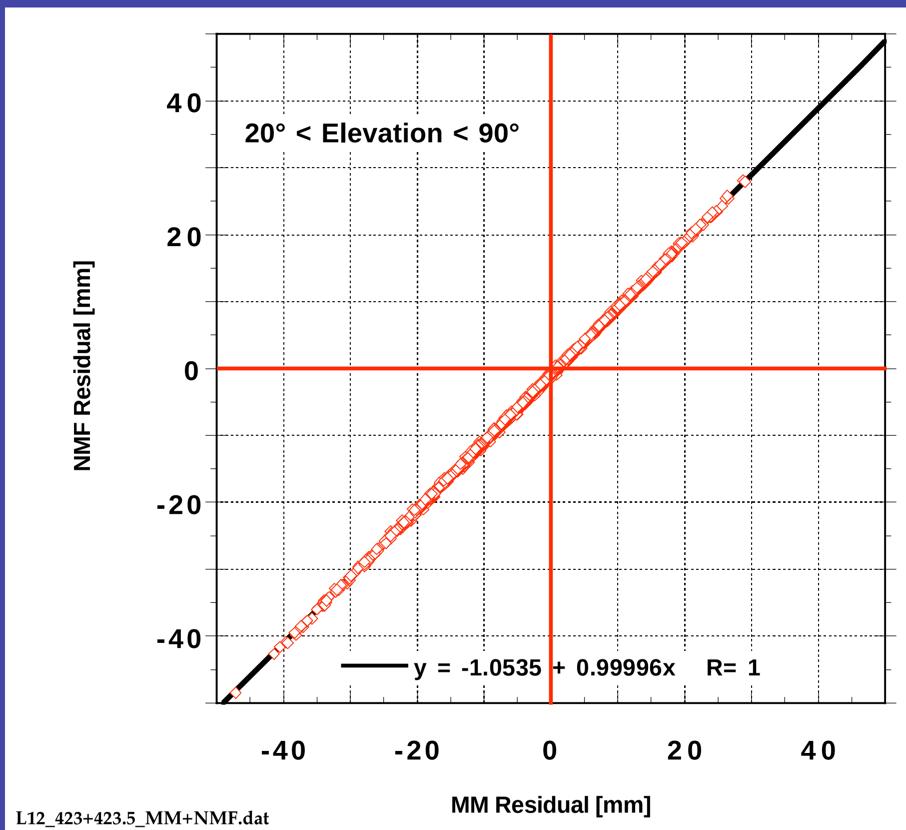
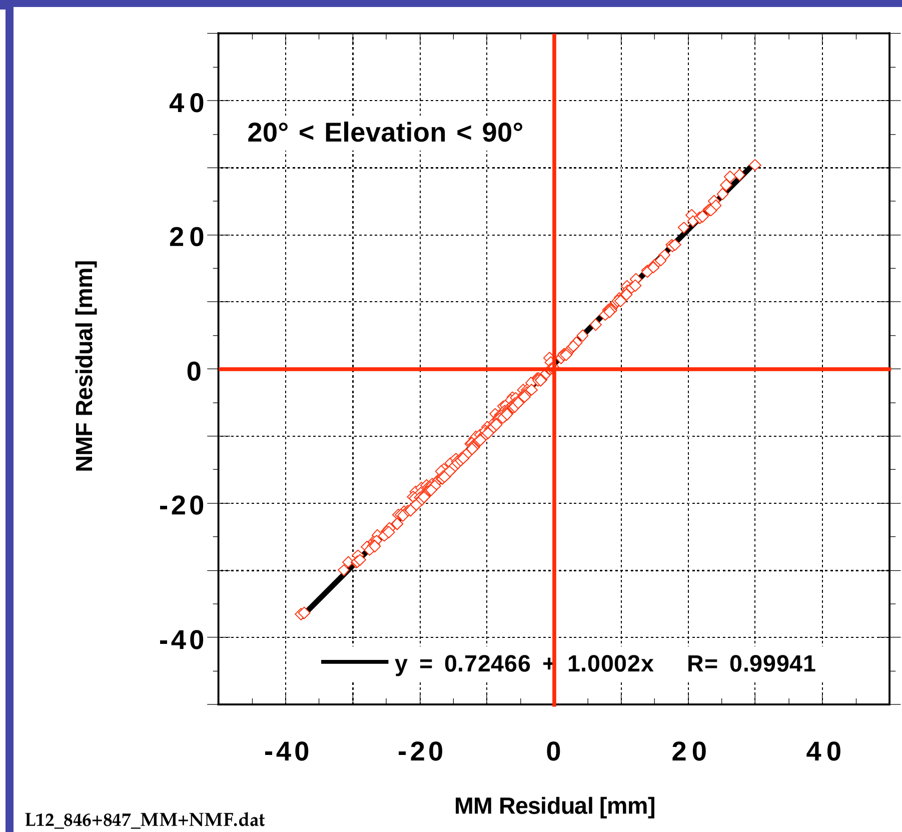


Residual Differences Regression
423 and 846 nm





Summary & Conclusions

- The residuals for either atmospheric correction model exhibit very similar scatter for ~1800 NPs so far examined:
  - @ 423 nm 12.26 mm
  - @ 846 nm 12.31 mm

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Summary & Conclusions (cont.)

- **@ 423 nm :**
  - Small bias (~ -1 mm) and a scale difference (0.99996) for M-M wrt Mendes - Ciddor
  - Current data set exhibits higher scatter at low elevation bands
  - Overall scatter about the mean is ~ 0.2 mm
  - The examined data set is small (~ 1500 NPs) so more robust conclusions can be obtained after the complete set of data is examined

Summary & Conclusions (cont.)

- **@ 846 nm :**
  - Small bias (~ +.7 mm) and a scale difference (1.0002) for M-M wrt Mendes - Ciddor
  - Most data are collected at elevations < 60° and exhibit lowest scatter at elevations:

$$50° < \varepsilon < 60°$$

  - Overall scatter about the mean is ~ 0.5 mm
  - The examined data set is very small (~ 230 NPs) so we can not reach any conclusions until after the larger set of data is examined

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Work in progress

- All of the data collected up to present (primarily from Zimmerwald) have now been processed and a more robust report will be compiled next month, with a simultaneous comparison of the data to atmospheric corrections derived from the revised Ciddor - Mendes model.

Preparing for Dual Wavelength SLR

- Once the differential delays become available routinely, we would like to compare them to model-derived delays:
  - The full precision formula of [Degnan, 93]
  - As well as the [Abshire and Gardner, 85] approximation

JCET

Comparison of the two approaches

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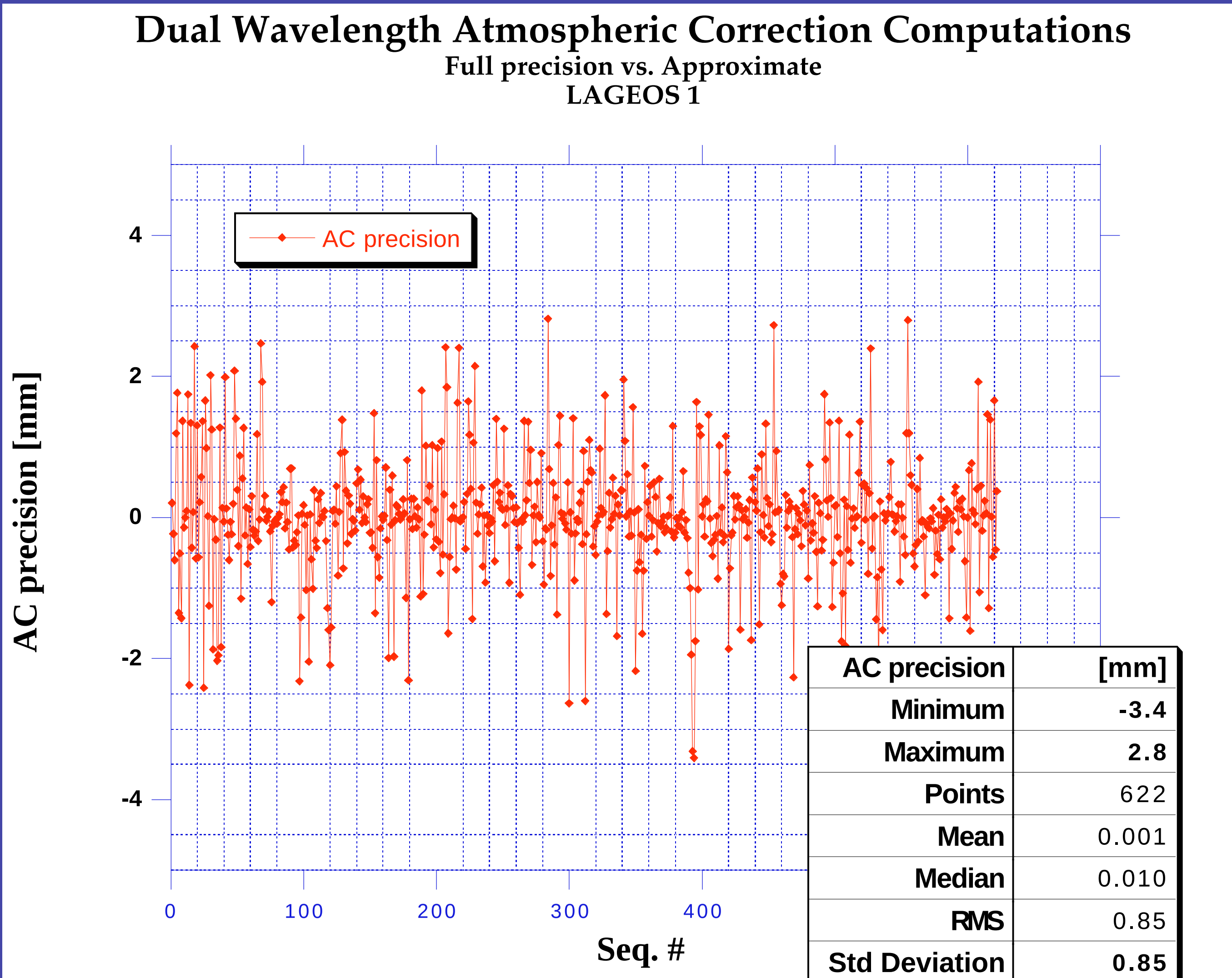
- We have used the latest Mendes-Ciddor formulation for the group refractivity indices for each wavelength
- The "*laser frequency factors*" f(λ) in the approximate [Abshire-Gardner] formula are obtained from the same formulation (i.e. Mendes-Ciddor), rather the suggested one used in Marini-Murray)
- We have used the LAGEOS data from the recent summer months to compare the two " γ " factors
- The examined data set indicates that we MUST use the full precision formula, if we want to maintain mm accuracy in our geodetic estimation problem

LAGEOS 1   July 10 - Aug. 21, 2003



AC precision	[mm]
Minimum	-3.4
Maximum	2.8
Points	622
Mean	0.001
Median	0.010
RMS	0.85
Std Deviation	0.85

LAGEOS 2 July 10 - Aug. 21, 2003

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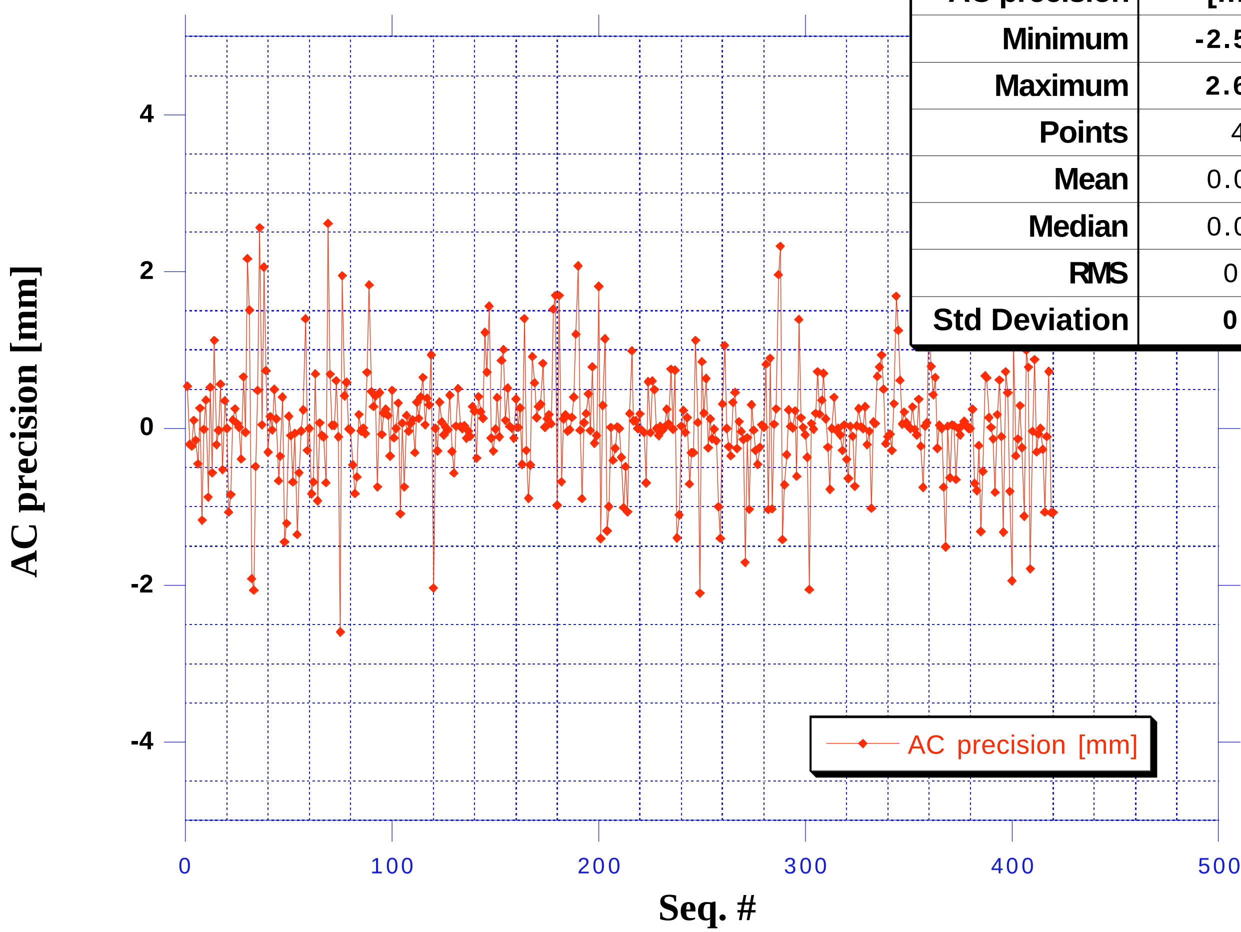
Dual Wavelength Atmospheric Correction Computations

Full precision vs. Approximate
LAGEOS 2

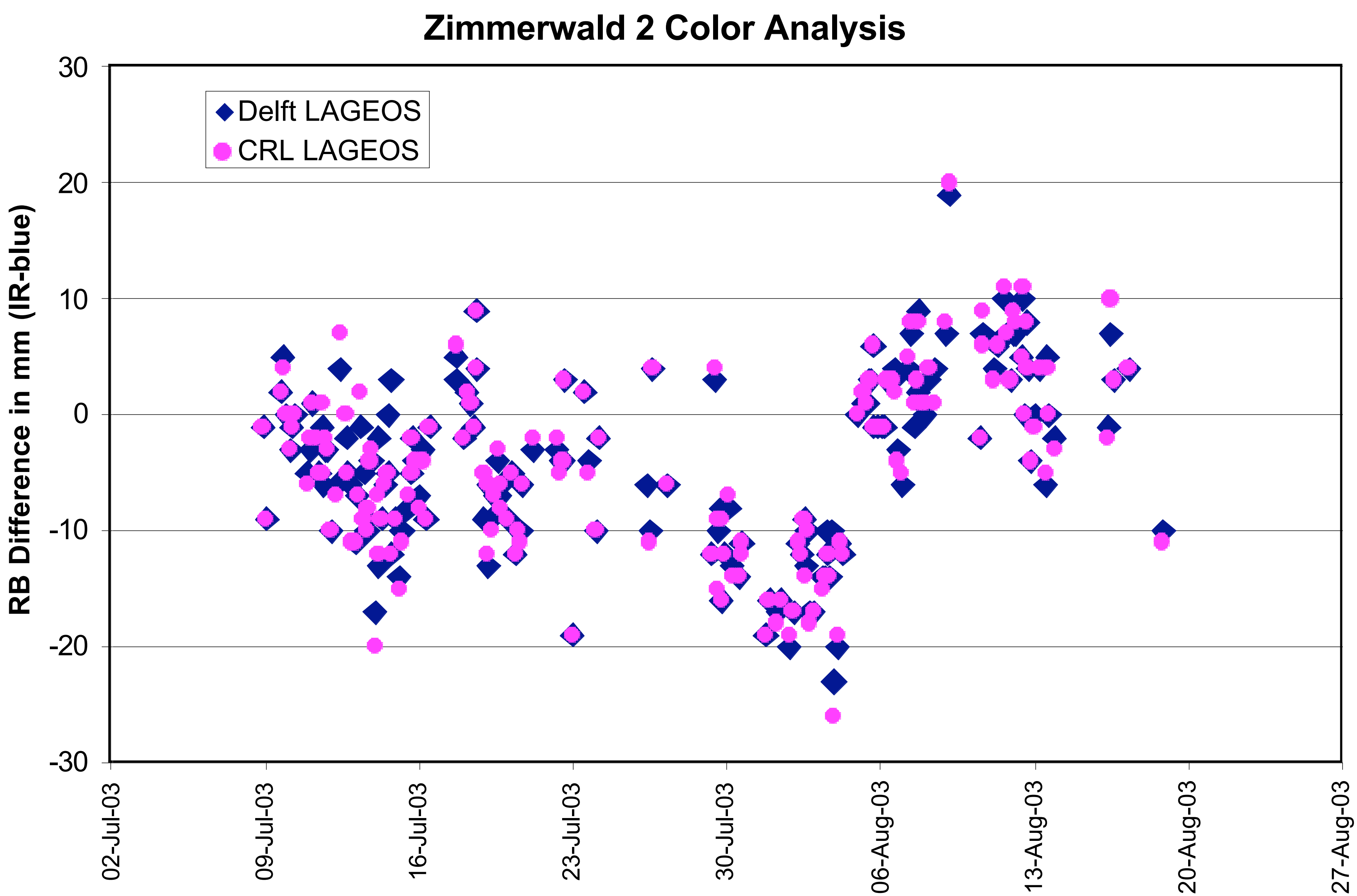


AC precision	[mm]
Minimum	-2.598
Maximum	2.613
Points	420
Mean	0.025
Median	0.015
RMS	0.72
Std Deviation	0.72

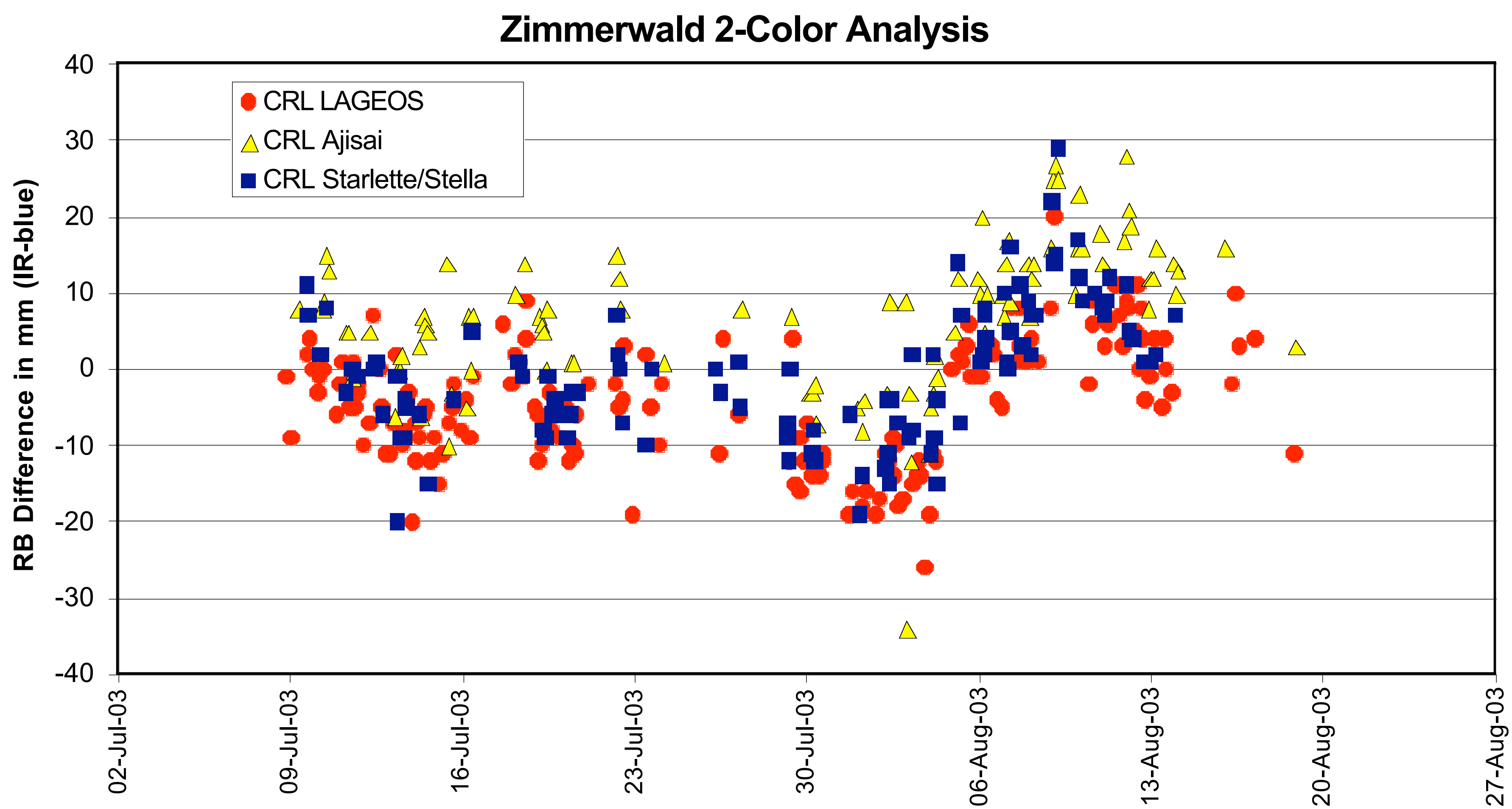
Two-color Analysis Technique

- Zimmerwald: robust 2-color dataset in July – August 2003
- Zimmerwald 2-color configuration
  - **Blue (423nm): CSPAD**, SR620 **#0236**, **2.5** sigma
  - **IR (846nm):** PMT, SR620 #2282, 2.0 sigma
- In Simultaneous passes, difference Range Biases (RB) from each color [i.e. IR(RB) – Blue(RB)]
- Uses RB results from Delft and CRL weekly reports

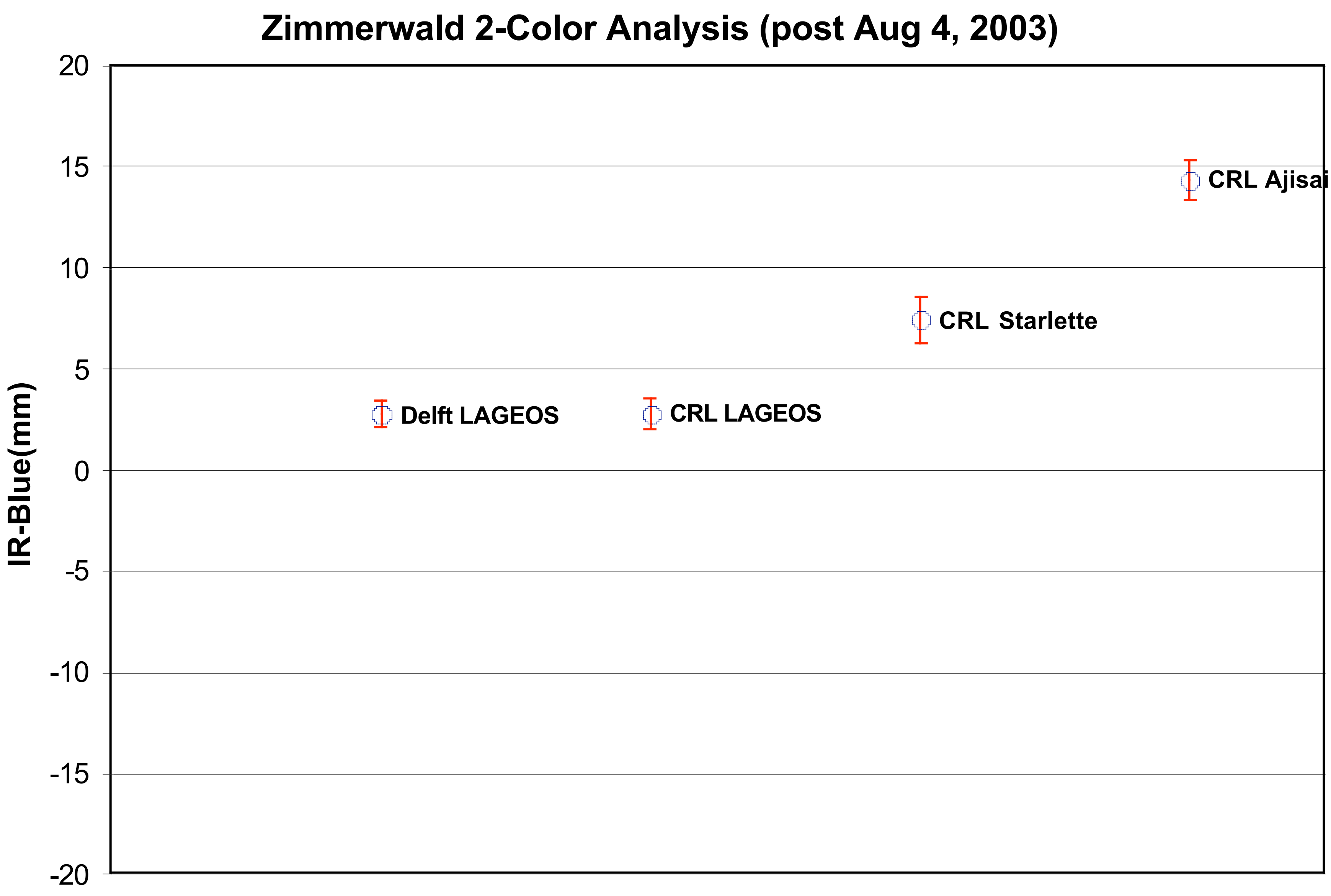
Zimmerwald 2-Color RB Differences



Zimmerwald 2-Color RB Differences



Zimmerwald 2-Color Analysis



Possible Source of Differences

- Refraction Algorithm
- CoM Differences
  - Detectors (CSPAD vs PMT)
  - Dual Wavelengths
  - Signal Strength
  - Screening Levels (2.5 vs 2.0)
  - Polarization?
- System Calibration
  - Different SR620 Counter linearities
  - Signal Strength
  - Optical Path Differences?