Refraction - Modeling and Remote Sensing Approach

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Sounds which address the ear are lost and die
In one short hour, but these which strike the eye,
Live long upon the mind, the faithful sight
Engraves the knowledge with a beam of light
- Oliver Byrne

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Modeling Status

- Current network does not suffer from refraction modeling errors
- Mendes-Pavlis ensure sufficient (mm) accuracy above 20 degree elevation, according to validation by radiosound data
- Below 20 degee horizontal gradient effects are expected at the centimeter level
- Data volume below 20 degree is sparse

Modeling Improvements

- 3D Raytracing proposed for refraction correction
- Based on global meteorological grid data (ECMWF, AIRS, NCAR)
- Shows significant horizontal gradient effects
- Refraction Server to generate refraction corrected data product

Grid Data Refractivity Validation

- G.Hulley et.al., Model validation for improved atmospheric refraction modeling for Satellite Laser Ranging, IAG 2005
- Subcentimeter deviations above 30 degree elevation
- AIRS data shows huge variance due to surface data problem
- ECMWF not uniformly sampled
- Deviations of grid data wrt. station meteorological data

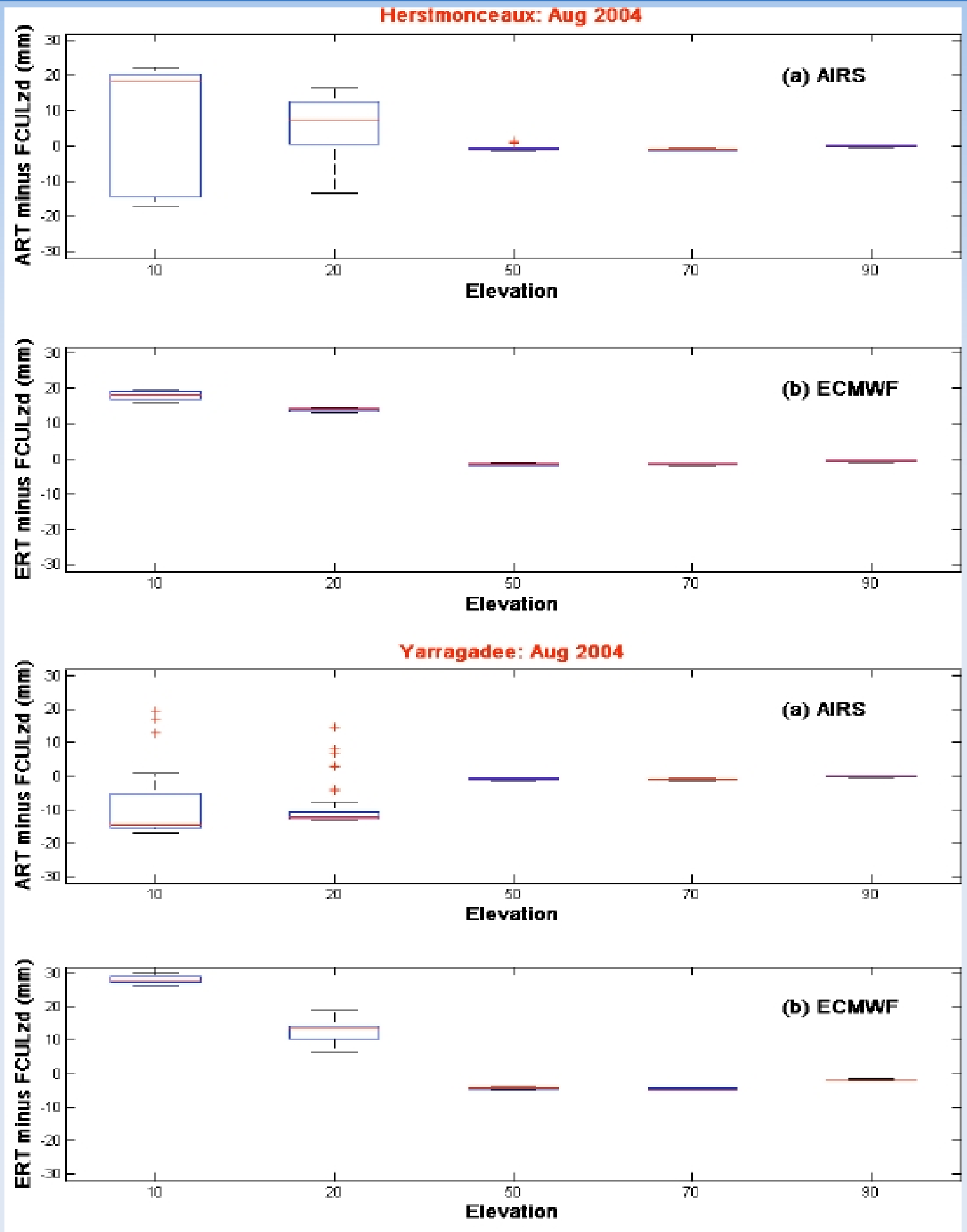


Fig. 3. Box-and-whisker plots showing the difference between the new model, FCULzd and (a) AIRS, (b) ECMWF ray-tracing for two stations during August 2004.

Refraction gradients from grid data

- G.Hulley et.al., Model validation for improved atmospheric refraction modeling for Satellite Laser Ranging, IAG 2005
- Amount up to +-5cm
- Temperature gradient at shore sites most dominant
- Long term average correction of few millimeters
- Larger rms during summer

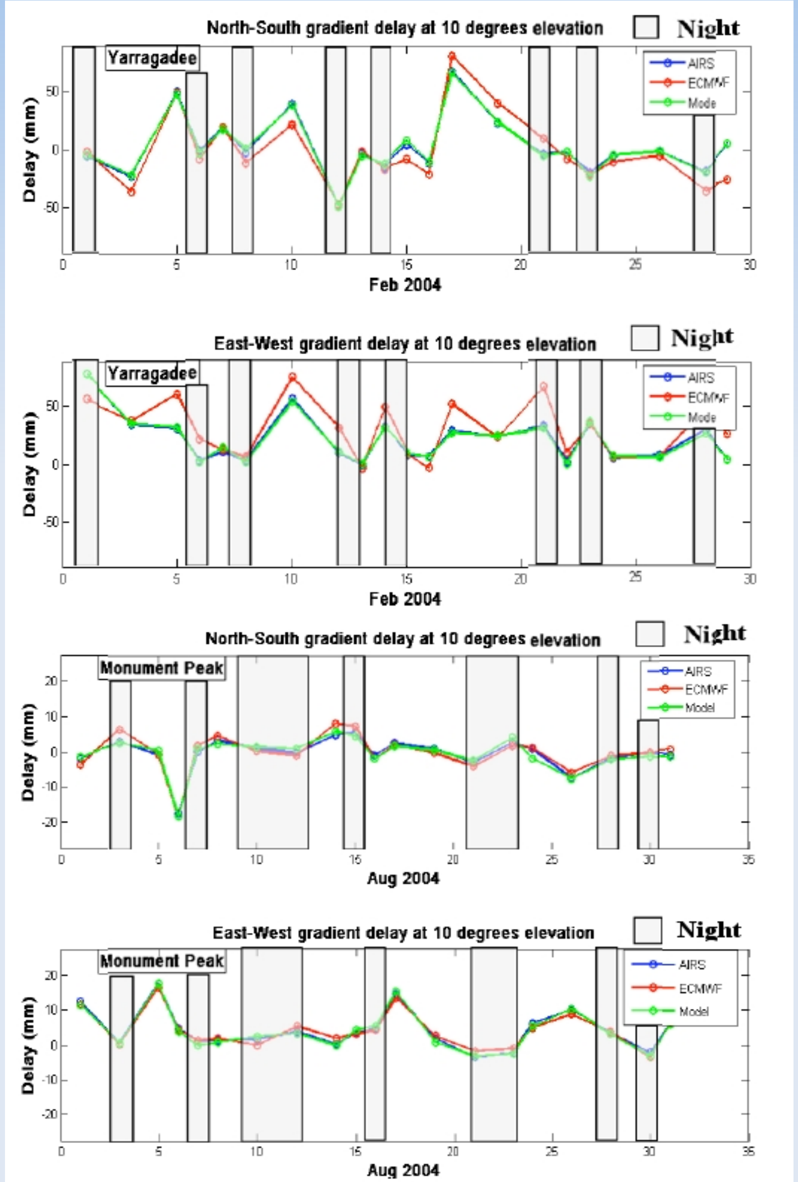


Fig. 4 Variations in North-South and East-West gradient delays during the course of one month for Yarragadee (top) and Monument Peak (bottom). Notice the sharp contrast in delays experienced at night and during the day.

Hardware Status – Ground Segment

- Currently 7405 only remaining two color capable station
- Operation optimized for infrared only due to the quest for GNSS data
- 100Hz DPSS upgrade in 2006 with SESAM modelocked TiSa-oscillator
- Capable for zenith delay remote sensing
- Required accuracy is still a challenge

Hardware Status – Space Segment

- Lageos most important since it serves for GM

  but: very difficult to model response function
- Grace and Goce are too fast for derivation of two color zenith delay, even at 100Hz repetition rate
- Starlette and Stella most suitable since:
  - nearly single retro target
  - two color observations down to 14 degree

Two color zenith delay regression

- Measurements carried out in strict single photon mode due to stringent accuracy requirement
- Projection onto zenith delay by regression function

$$R_i(\lambda_j) = m(\theta_i)\, f(\lambda_j)\, ZD(\lambda = 694\,\mathrm{nm}) + OrbCorrect$$

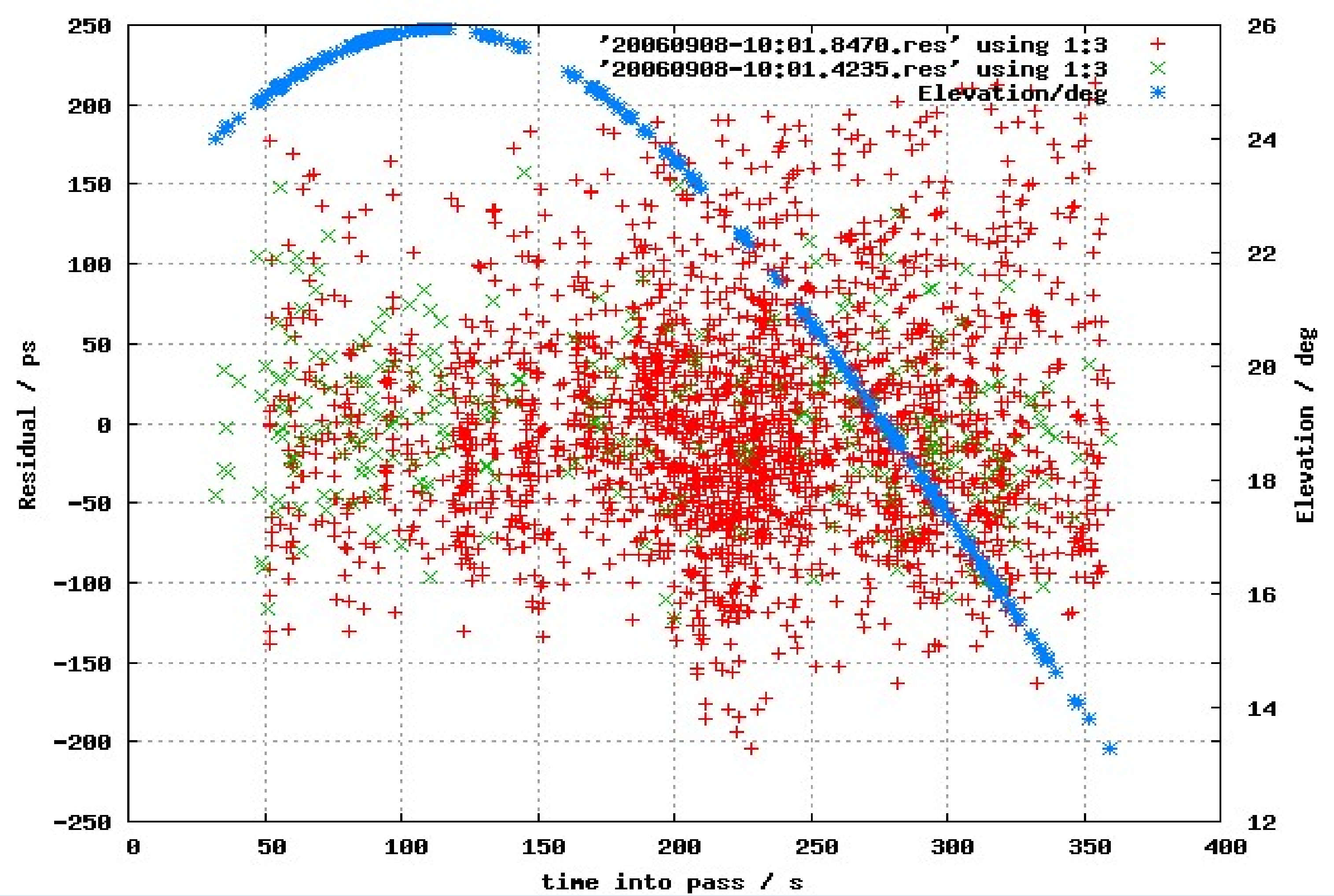
$R_i(\lambda_j)$: measured range at λ_j (423.5 nm, 847 nm)

$m(\theta_i)$: mapping function [illegible]

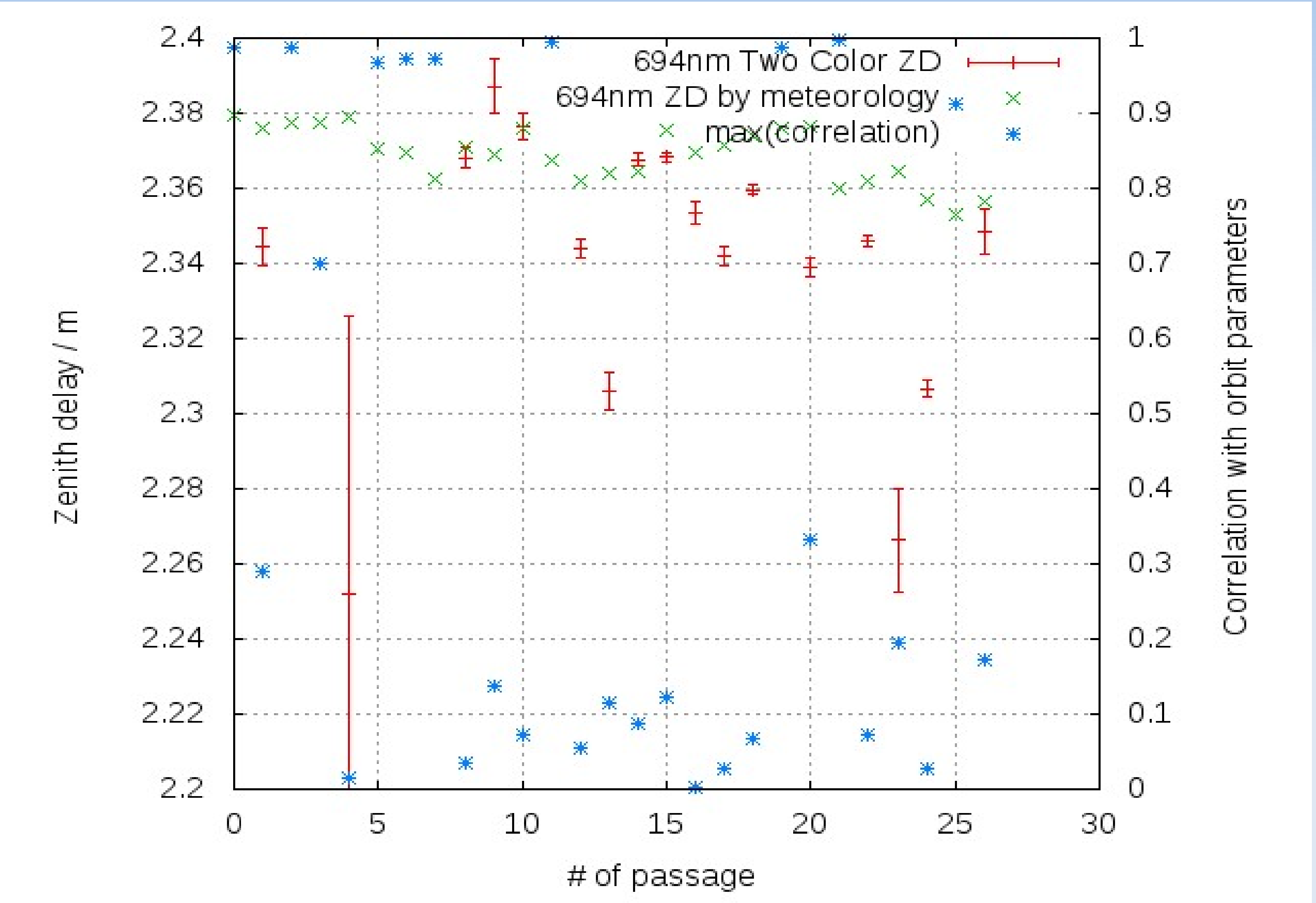
$f(\lambda_j)$: dispersion function

ZD: zenith delay at 694 nm

Two color measurement example

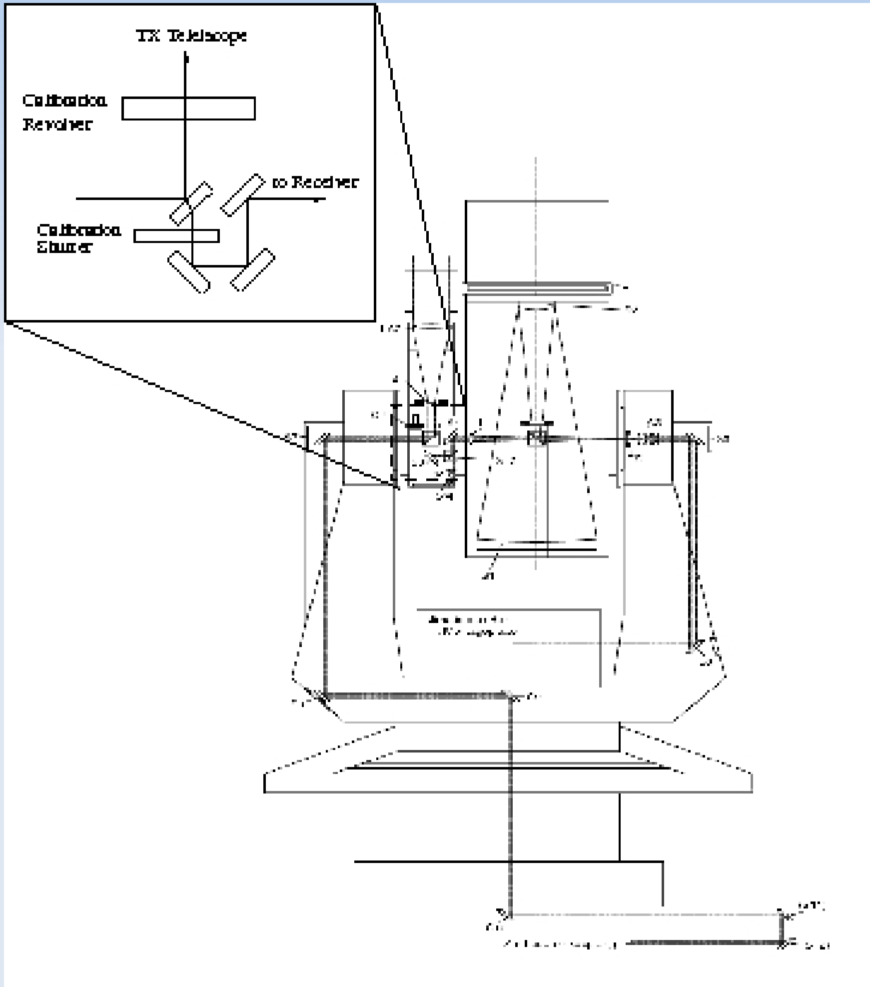


Zenith delay measurements by two colour ranging



Future Hardware - SOS-W

- 1kHz DPSS SESAM modelocked TiSa laser, 40ps, 1.5mJ
- 849.8nm and 424.9nm modulation capable
- Circular polarization in both wavelengths
- Bistatic telescope with TX/RX link
- Threefold calibration capability
- Activ Optics



SOS-W Timeline

- Start of project in 2004
- Laser, building and subsystems finished in 2007
- Telescope delivered in 7/2008
- Commissioning phase not finished due to receiver telescope instabilities
- Operability expected by end of year