Improved Modeling Approaches Towards the mm SLR

Erricos C. Pavlis
JCET/UMBC & NASA Goddard 698
and
Magdalena Kuźmicz-Cieślak and Peter Hinkey
JCET/UMBC

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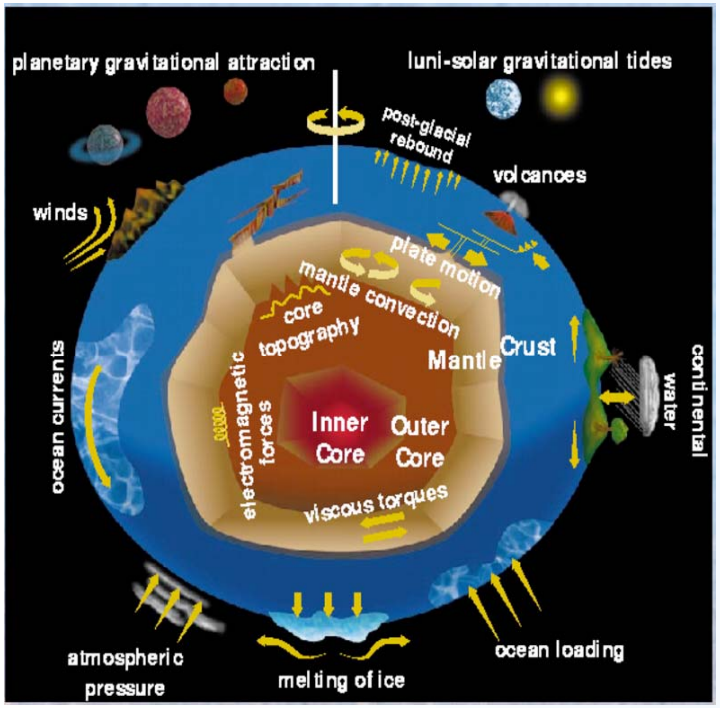
Outline

- **Motivation**
- **Proposed modeling improvements**
- **Examples of tested models**
- **Schedule of developing new products**
- **Summary and Future Plans**

We gratefully acknowledge the support of the ILRS and their network for making their SLR tracking data available to us for this work, as well as the GRACE Mission Project for the release of GSM products.

Motivation



Mass redistribution in Earth System monitored regularly by various remote sensing techniques.

Global fields with increasingly higher spatiotemporal resolution readily available to the analysts.

As LR data become more accurate we will soon face the limitation of our modeling standards, generally of 20th century vintage.

Future ITRF Accuracy Goal

- Future ITRFs* should exhibit consistently and reliably accuracy and stability at the level of:

<1 mm in epoch position, and

< 0.1 mm/y in secular change

*Current performance: ~ 10 mm and ~ 1 mm/y

Candidate Models

- Extended temporal gravity variations
  - NCEP or ECMWF (3 or 6 hr *t*-resolution, 0°.25,…)
  - GRACE-derived monthly fields & de-aliasing products
  - Other combinations
- Atmospheric loading (NCEP, ECMWF as above), hydrological loading (GLDAS)
- New ocean tides (GOT04.7 or more recent) with proper atmospheric tide treatment
- Atmospheric refraction from 3D ART to include gradients
- Albedo (e.g. higher degree-order seasonal model)
- …

Current Tests' Focus

- With ITRF being the primary customer of ILRS products and considering that the two LAGEOS are the prime targets for these products, the focus is on improving the LAGEOS POD at this point.

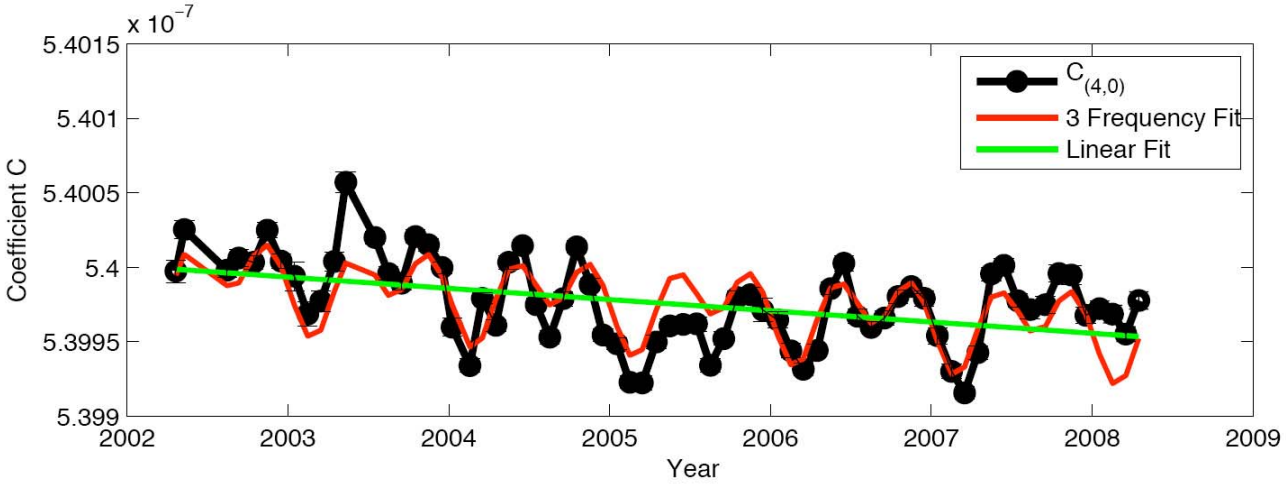
- In subsequent stage we will extend the most promising model improvements to LEO targets in an effort to make their contribution useful and of acceptable accuracy for inclusion in these products.

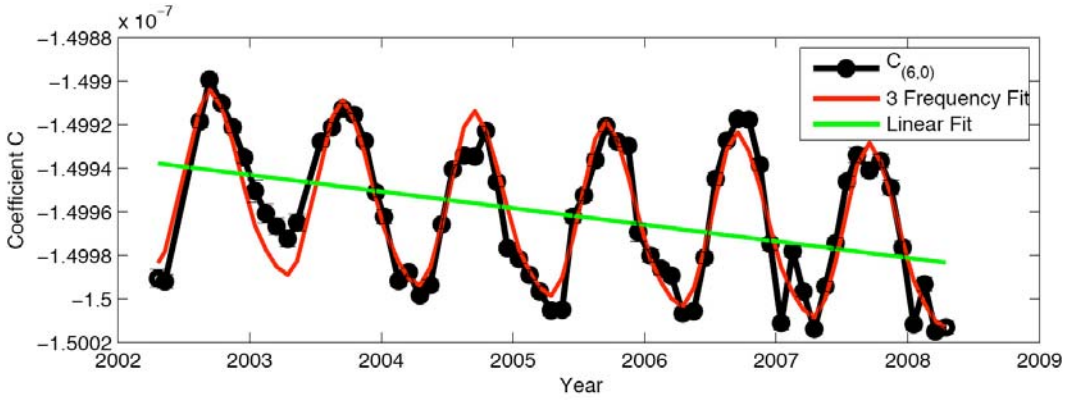
GRACE Monthly Gravity Models

- We used the six-year monthly series from CSR's release 4 (RL04) available from April 2002 up to present, along with the associated de-aliasing product and estimated a set of mean coefficients at epoch 2000.0, secular linear trends and annual, semi-annual and seasonal terms for the entire 60 x 60 field.

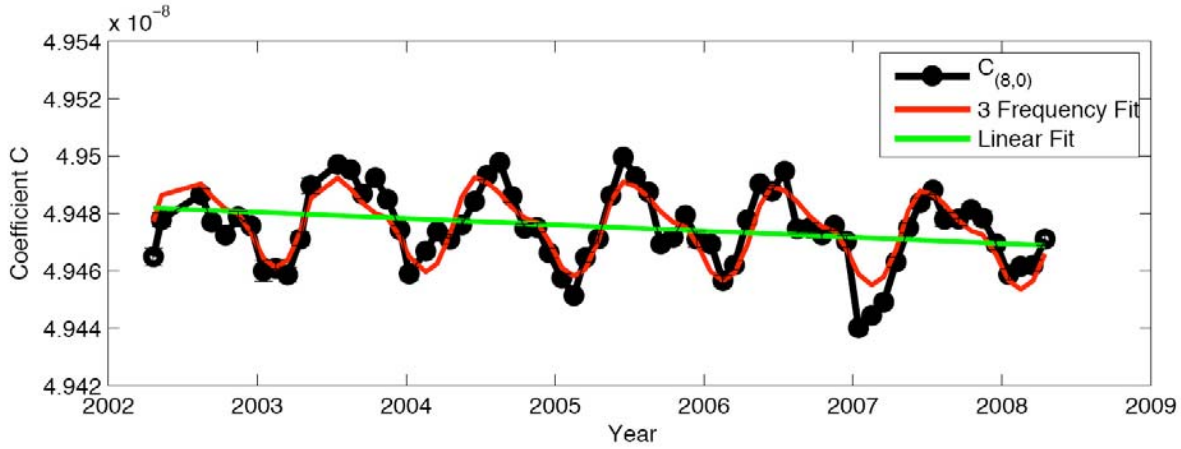
CSR RL04	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002												
2003												
2004												
2005												
2006												
2007												
2008												

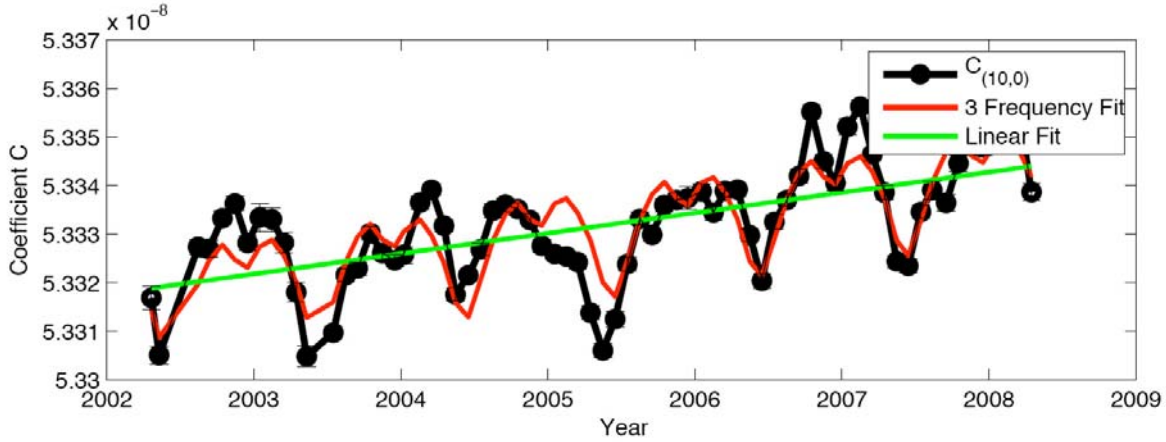
Zonals $C_{4,0}$ and $C_{6,0}$



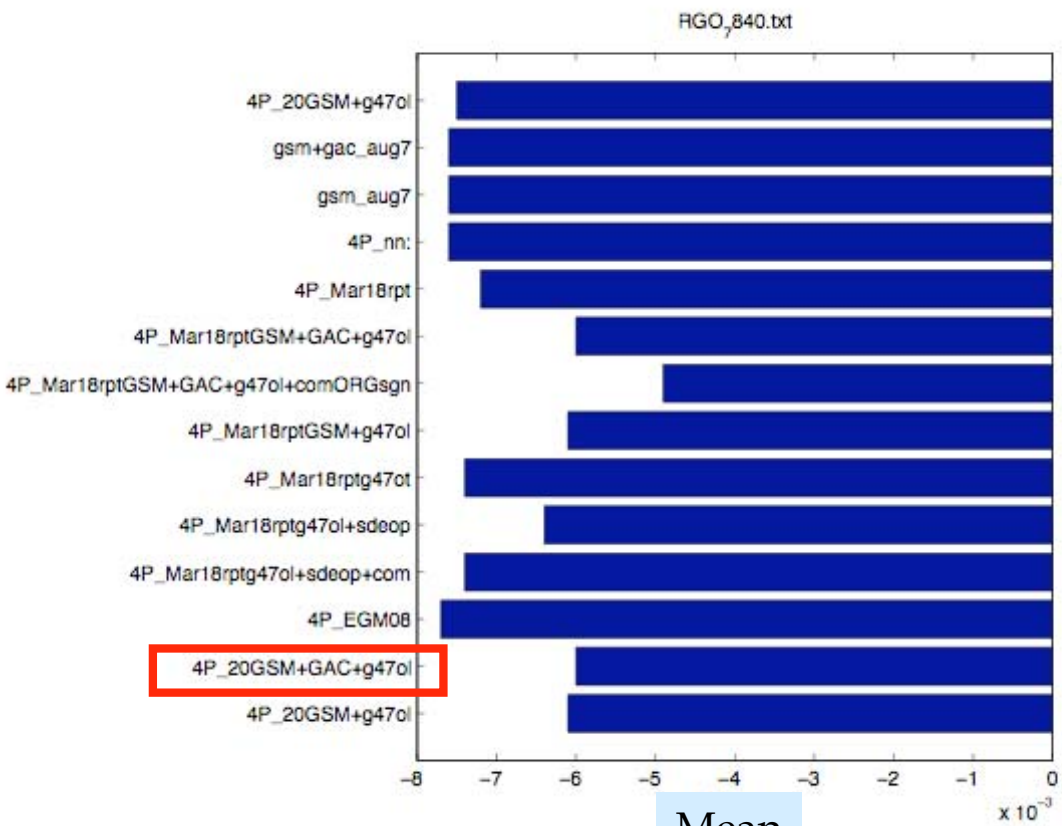


Zonals $C_{8,0}$ and $C_{10,0}$

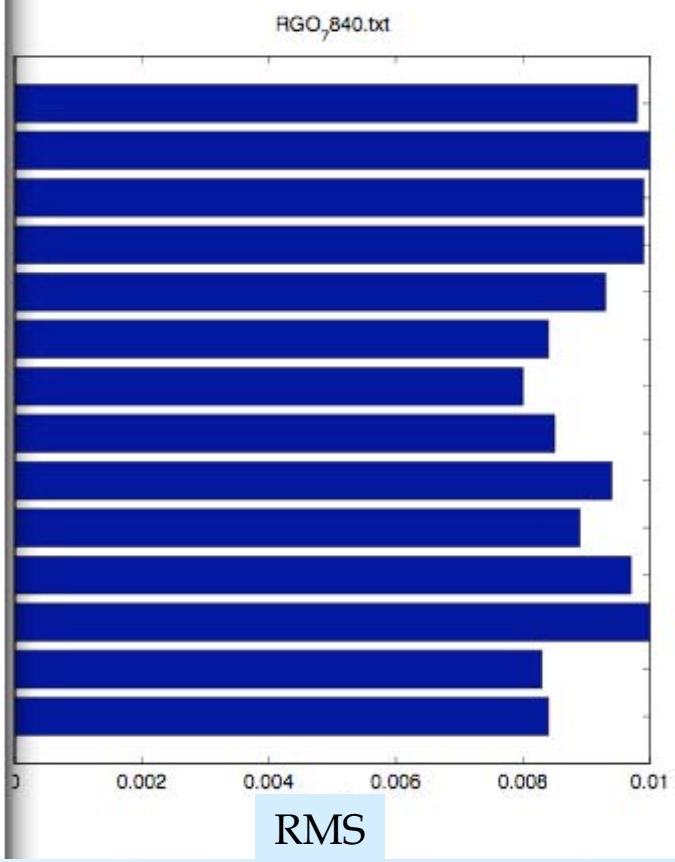




SLR Residual Statistics: RGO

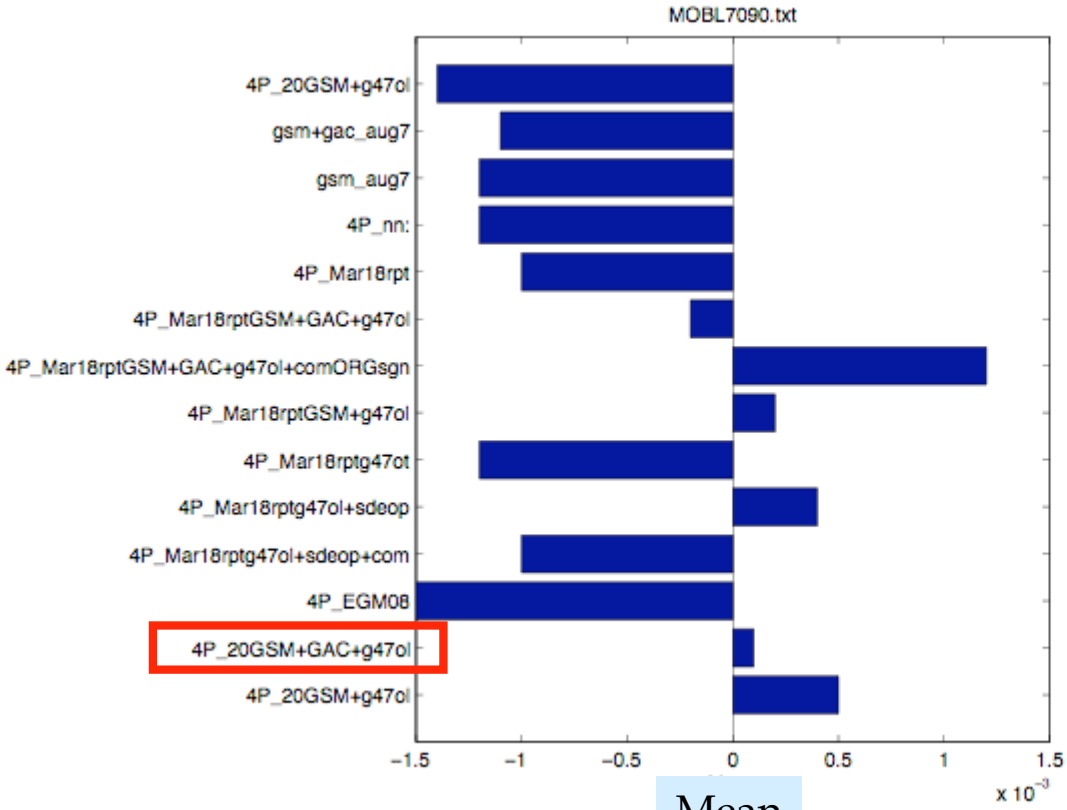


Mean

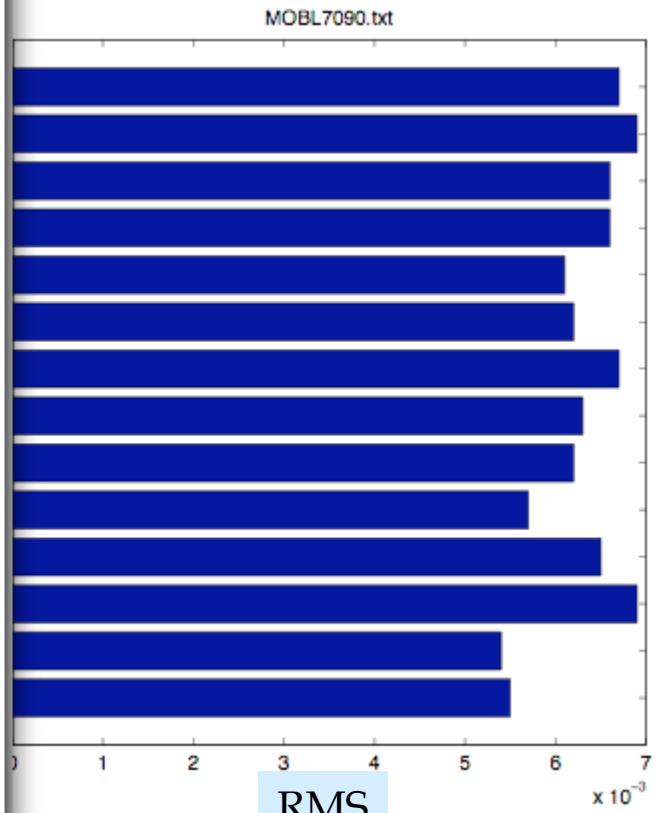


RMS

SLR Residual Statistics: Yarragadee



Mean



RMS

Atmospheric Loading (ECMWF)

Difference in the RMS of fit of weekly arcs of LAGEOS SLR for 2001 & 2006 and four Atmospheric loading treatments (one being NO loading)

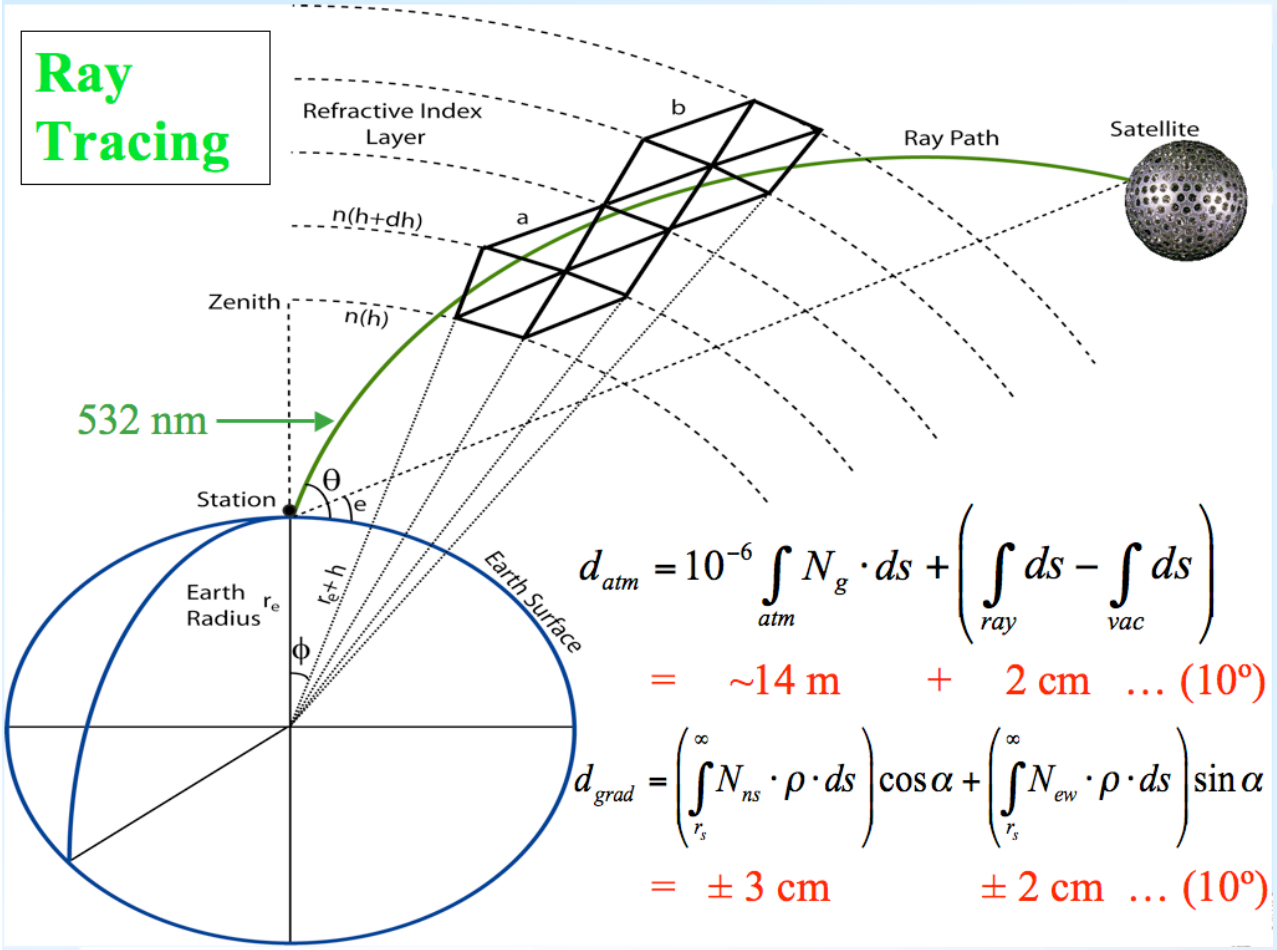
Variable	Points	Mean	Median	RMS	Std Deviatio
ΔRMS v0-NO	52	3.4	2.7	4.45	2.87
ΔRMS v1-NO	104	2.9	2.1	4.31	3.16
ΔRMS v2-NO	52	2.7	1.7	4.09	3.08
ΔRMS v1-v0	52	0.4	0.0	0.92	0.82
ΔRMS v2-v1	52	1.7	1.4	2.58	1.96

"v0": 1970/01 - 2002/08: ECMWF Reanalysis (ERA40), with a spatial resolution of 1.125 degrees

"v1": 2000/12 - 2006/12: ECMWF Operational, with a spatial resolution of about 0.350 degrees

"v2": 2005/10 - now: ECMWF Operational, with a spatial resolution of about 0.250 degrees

3D Atmospheric Ray Tracing (ART)



$$d_{atm} = 10^{-6}\int_{atm} N_g \cdot ds + \left(\int_{ray} ds - \int_{vac} ds\right)$$

$$= \quad \sim 14\ \text{m} \quad + \quad 2\ \text{cm} \quad \ldots\ (10^{o})$$

$$d_{grad} = \left(\int_{r_s}^{\infty} N_{ns} \cdot \rho \cdot ds\right)\cos\alpha + \left(\int_{r_s}^{\infty} N_{ew} \cdot \rho \cdot ds\right)\sin\alpha$$

$$= \quad \pm 3\ \text{cm} \qquad \pm 2\ \text{cm} \quad \ldots\ (10^{o})$$

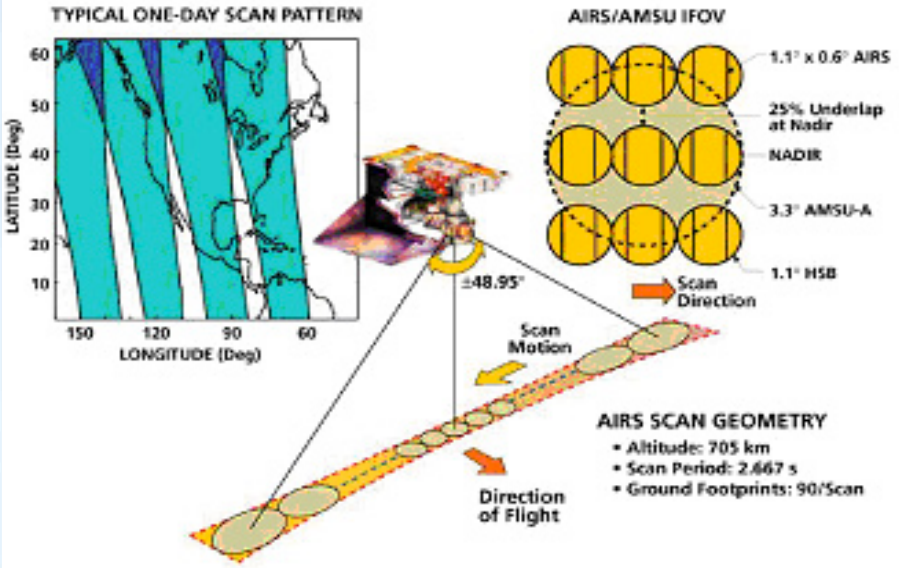
Hulley, G. C. and E. C. Pavlis, (2007), A ray-tracing technique for improving Satellite Laser Ranging atmospheric delay corrections, including the effects of horizontal refractivity gradients, *J. Geophys. Res.*, 112, B06417, doi:10.1029/2006JB004834, 2007.

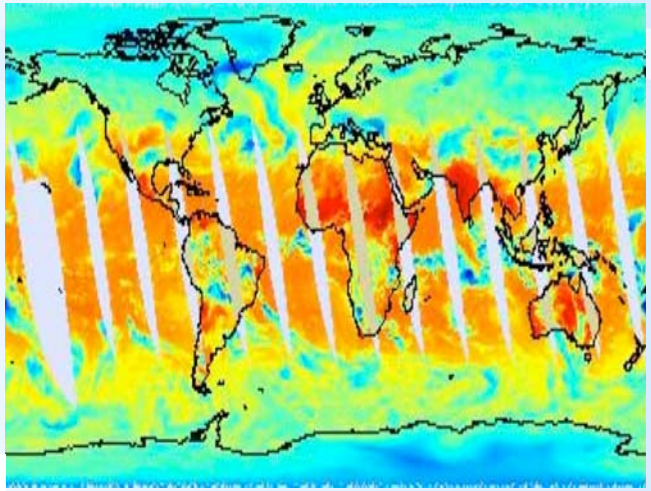
Pavlis, E. C., V. Mendes and G. Hulley, (2008), Tropospheric Model: Optical Techniques, in *IERS Conventions 2003*, G. Petit and B. Luzum *eds.*, IERS Technical 32, online version: http://tai.bipm.org/iers/convupdt/convupdt.html, Paris, France, 2008.

AIRS coverage

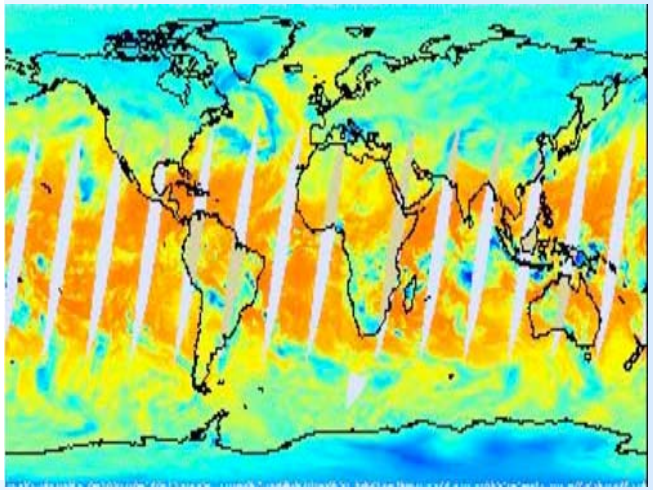
Granule:

- 1650 km x 2300 km
- ± 49.5° scan



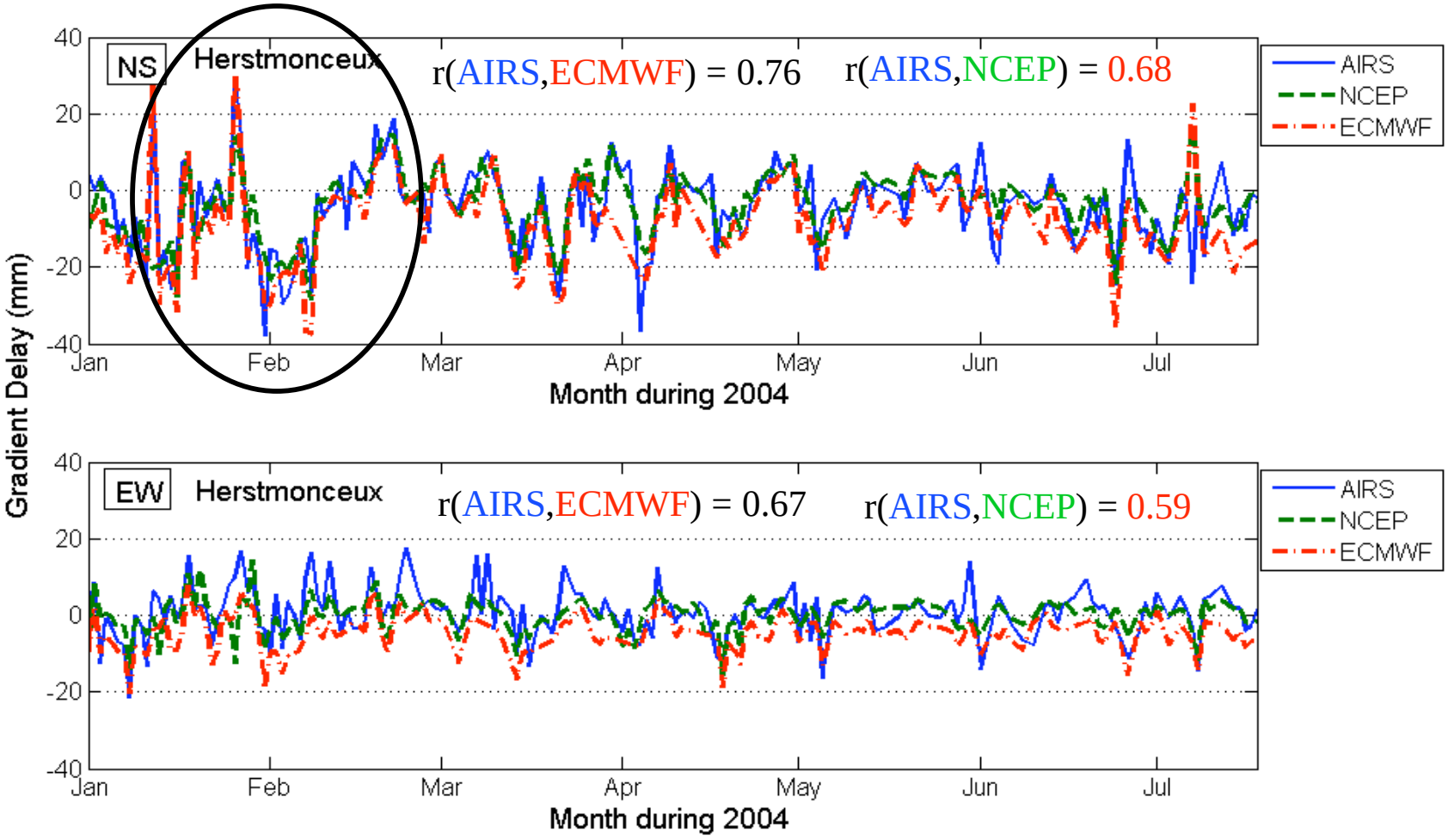


Ascending (day-time)



Descending (night-time)

AIRS/ECMWF/NCEP gradient comparison



Gradient-corrected SLR Residuals Statistics

Method	ΔBias (mm)	Δσ² (%)
AIRS		
RT_{grad}	0.3 ± 0.3	14.0
RT_{3D}	0.9 ± 1.1	24.8
ECMWF		
RT_{grad}	0.1 ± 0.5	10.8
RT_{3D}	0.6 ± 1.2	22.5

Schedule for New Products

- Complete tests of various models by end of this year (2008)
- Begin re-analysis of entire LAGEOS 1 & 2 data set from ~1983 to present in early 2009, to be ready by summer 2009
- Apply similar models with appropriate resolution to LEO satellites and reduce data over the same period by summer 2009
- Deliver combination SINEX products and SLR-only TRF solutions by autumn of 2009

Summary - Future Plans

- LR analysis needs to update its modeling standards despite the restrictions imposed by coordinated analysis requirements
- Several new, improved models exist already and resources for generating additional background and de-aliasing corrections are now available globally
- Some of the proposed improvements can be readily implemented and do not interfere with the agreed upon standards
- A demonstration of improved LR results will certainly help accelerate the transition of all techniques to the new and improved standards

The ILRS Network