Troposphere Delay Modeling

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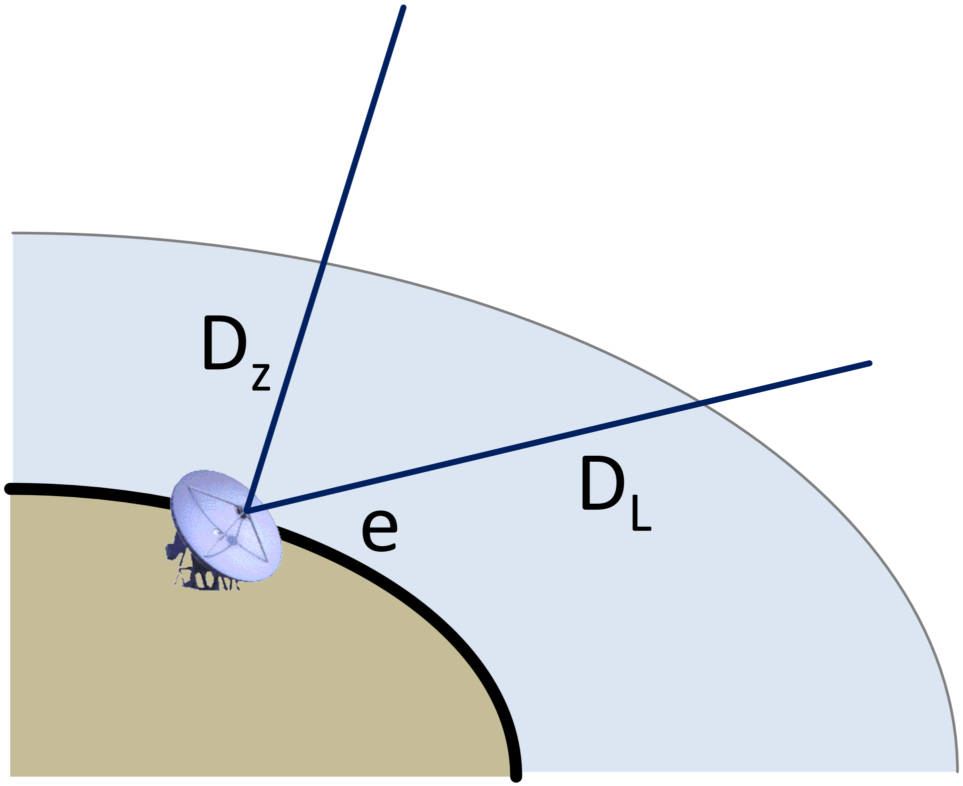
- Vienna Mapping Functions 1 – ECMWF, NCEP
- Ray-tracing

Troposphere delays

$$D_L(e) = D_z \cdot m(e) \qquad = D_{zh} \cdot m_h(e) + D_{zw} \cdot m_w(e)$$

+ gradients

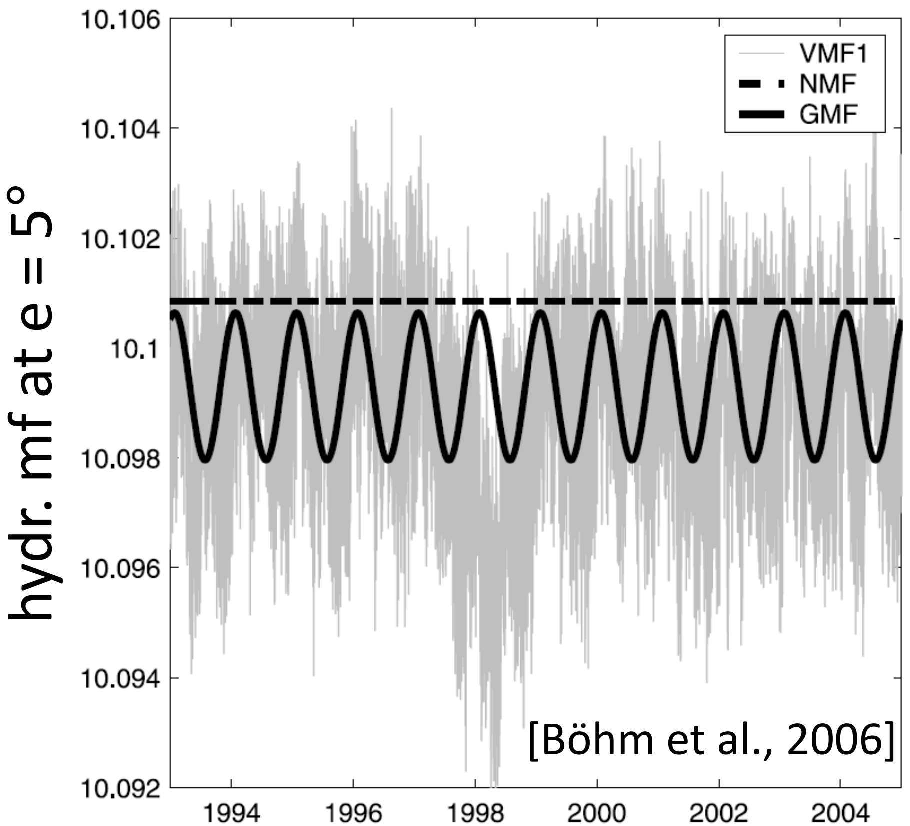


Mapping functions

Mapping functions

- Vienna Mapping Functions 1
  - from ECMWF data (6 h)
  - Böhm et al. (2006)
- Niell Mapping Functions
  - Niell (1996)
- Global Mapping Functions
  - ‘averaged VMF1’
  - Böhm et al. (2006)

Fortaleza (Brazil)

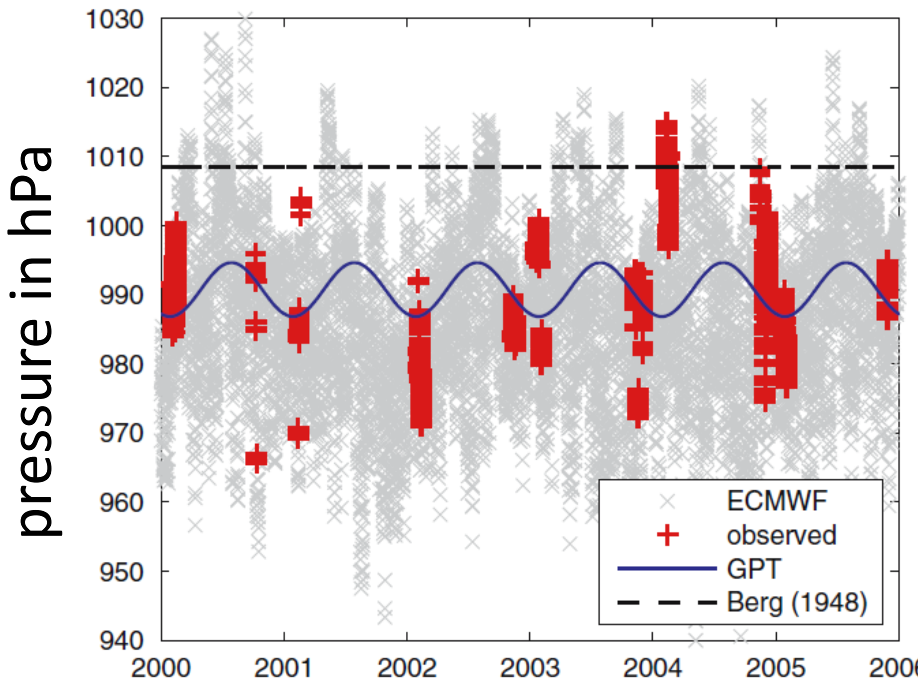


Hydrostatic zenith delays

Hydrostatic zenith delays

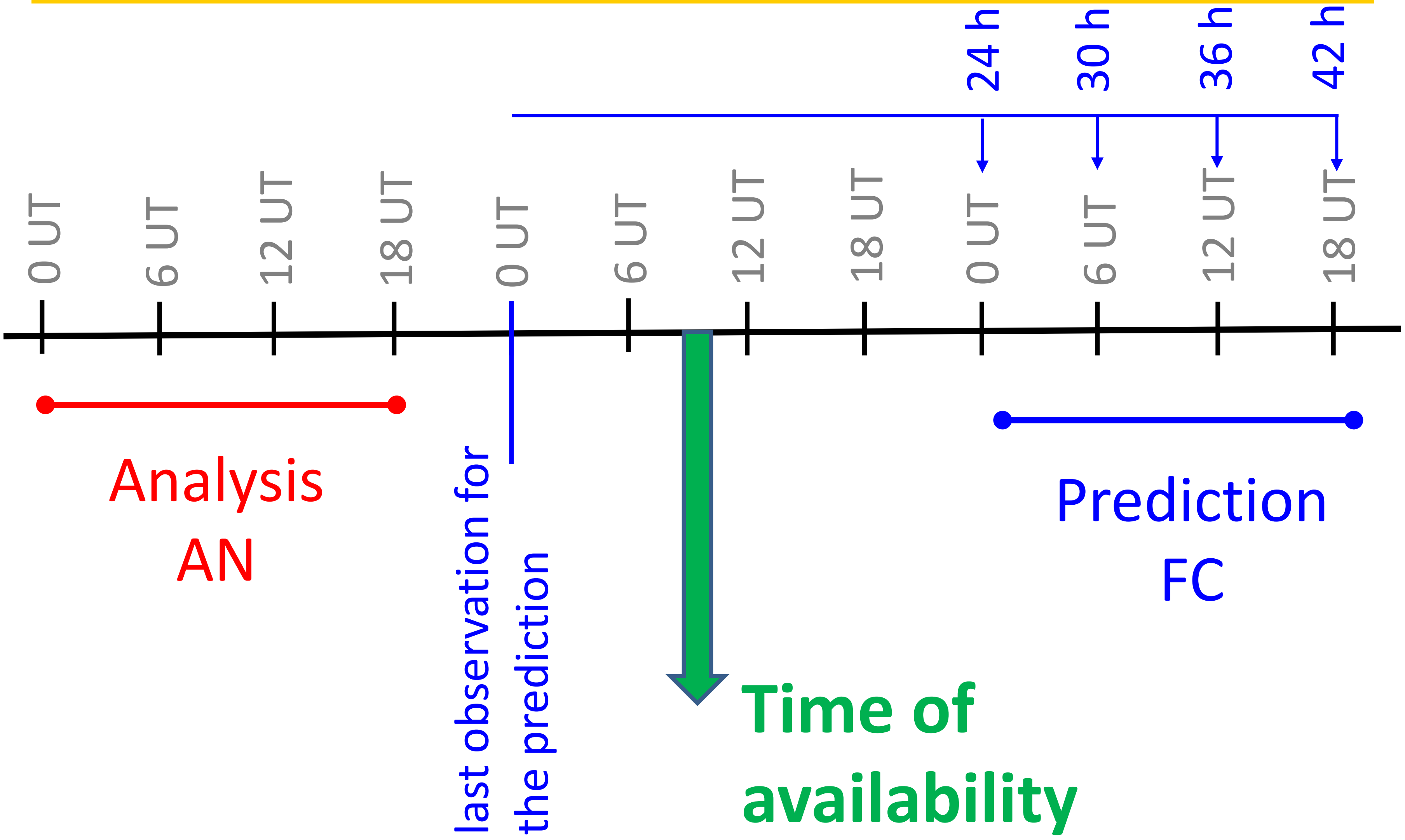
- pressure at the site
- numerical weather model
- Berg (1948)
- Global Pressure and Temperature (GPT)
  - Böhm et al. (2007)

O'Higgins (Antarctica)



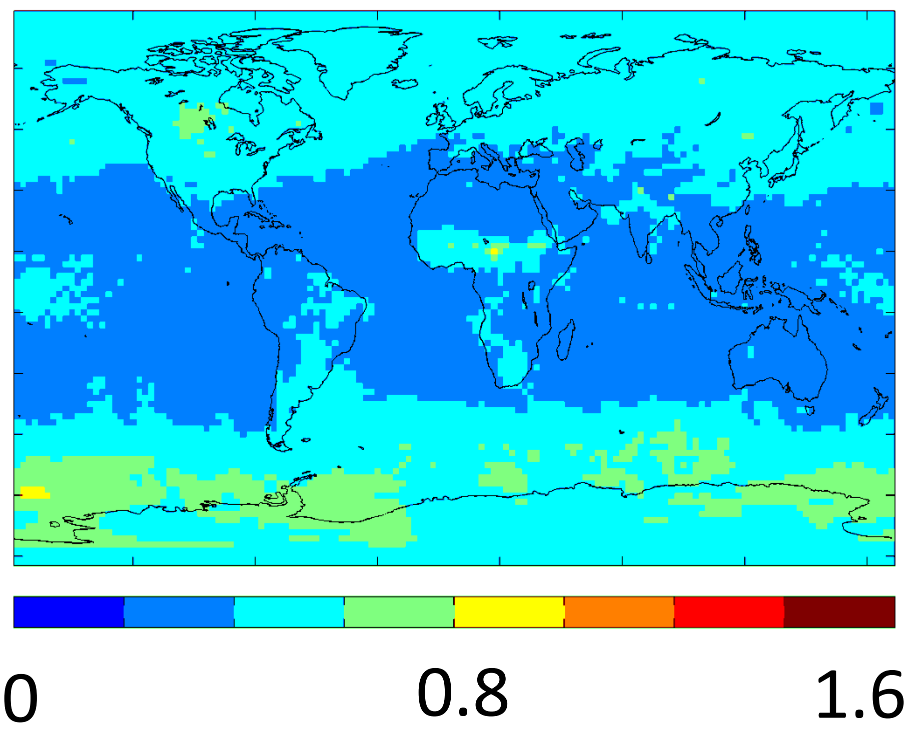
[Böhm et al., 2007]

Availability of VMF1

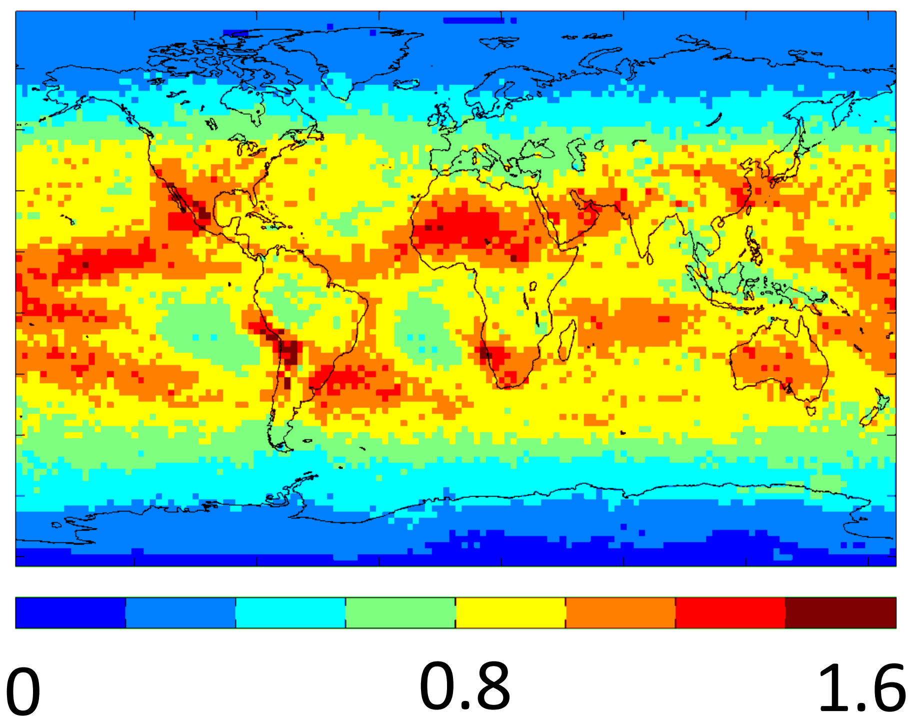


AN vs. FC
Height std.dev. after 42 hours

VMF1 hyd.



VMF1 wet

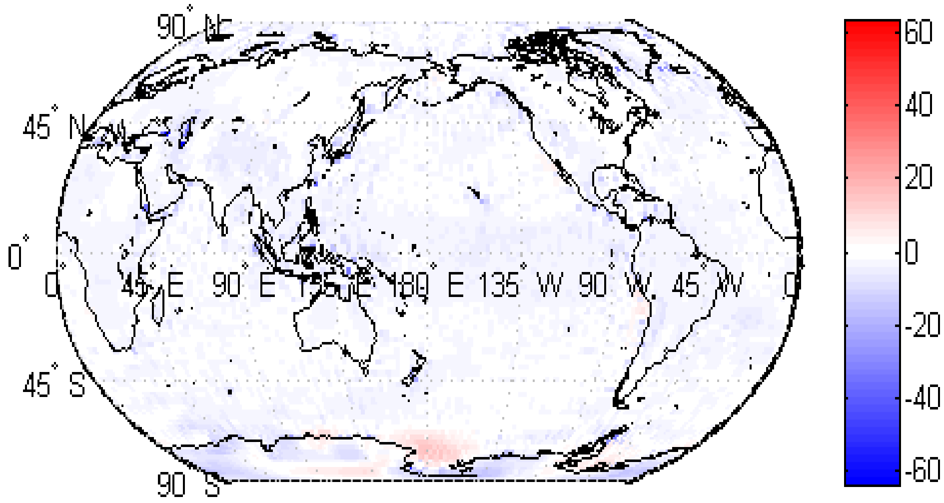


UNB realization of VMF1

- “VMF1-UNB”
- NOAA-NCEP re-analysis
- Available on 6-h basis and grids (2.0° x 2.5°)
- Independent ray-tracing algorithms
  - Nievinski (2009)

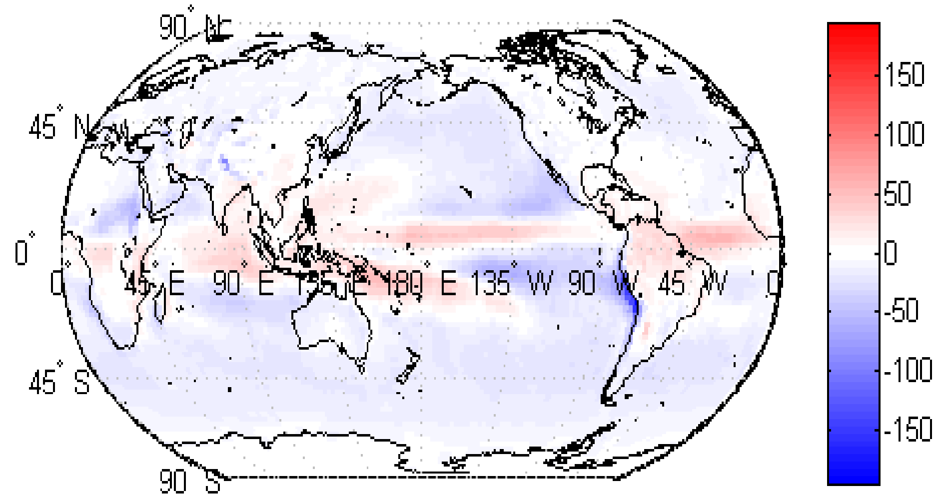
Zenith delay differences in 2010: ECMWF - NCEP

Hydrostatic in mm



- Overall: -2.4 ± 3.8 mm

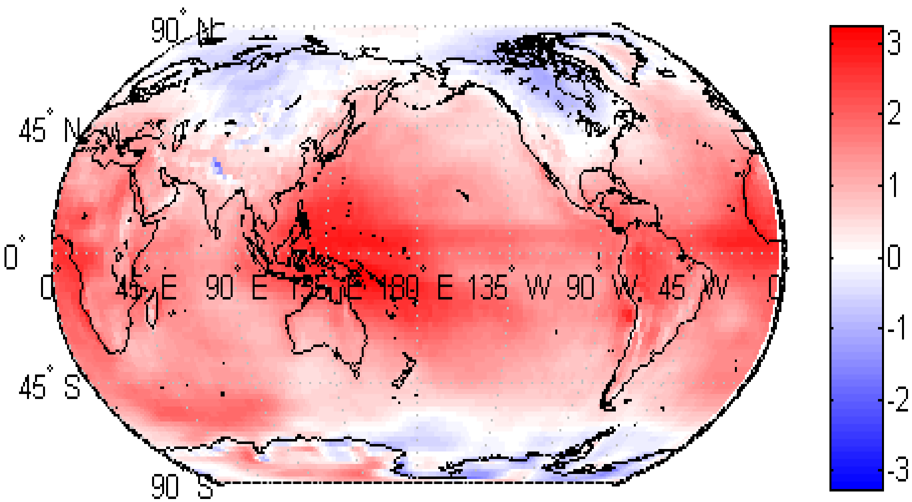
Non-hydrostatic in mm



- Overall: -6.3 ± 14.7 mm

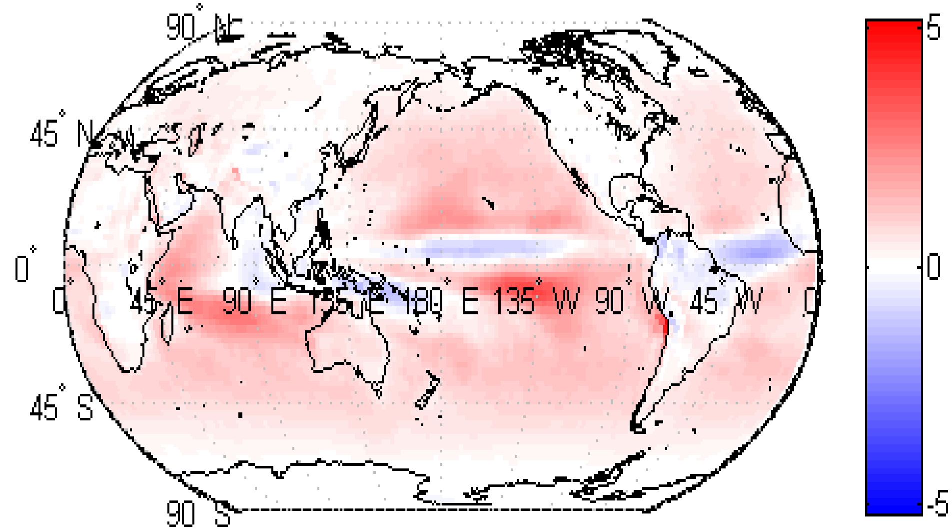
Height differences: VMF1 vs. UNB-VMF1

Hydrostatic in mm



- Overall: 0.79 ± 0. 89 mm
- Differences partly due to constant Earth radius with VMF1

Non-hydrostatic in mm



- Overall: 0.4 ± 0.58 mm

Conclusions/Recommendations

- Increase the number of realizations of
  - a priori hydrostatic and wet zenith delays (Dan)
  - (Vienna) mapping functions (UNB)
- Important to have alternatives (robustness, backup)
- Allows consistency with other parameters derived from e.g. NCEP data
- Check consistency with SLR

Conclusions/Recommendations

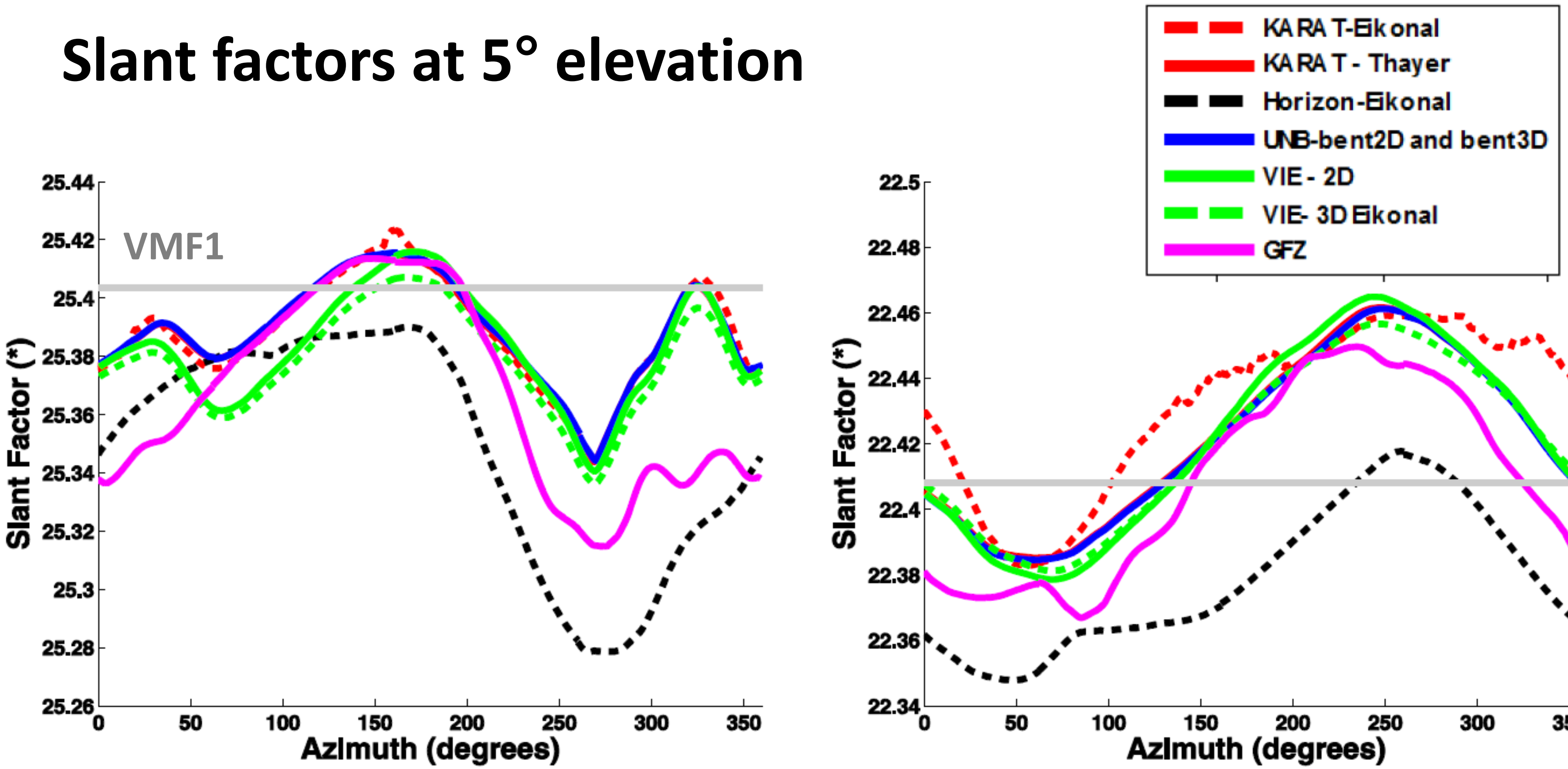
- Provide an improved GPT which is consistent with the reference pressure for atmosphere loading. This improved GPT should also contain semi-annual, S1, and S2 terms.
- However, it should only be used if real data is not available.

Ray-traced slant delays

- Applications:
  - Hobiger et al. (2008 EPS) for PPP solutions w.r.t. GMF
  - MacMillan/Petrov for VLBI w.r.t. VMF1
  - Böhm et al. (2010) for VLBI Intensive sessions
  - Gegout et al. (2011)
  - ...
- Estimation of residual zenith delays (and gradients) still necessary

Ray-tracing Comparison Campaign

Slant factors at 5° elevation



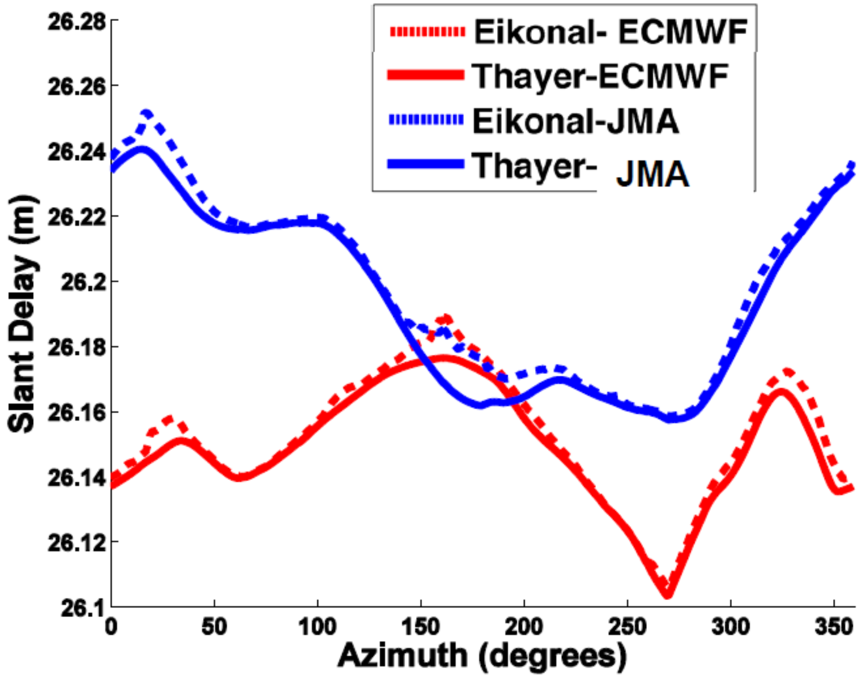
Wettzell

Tsukuba

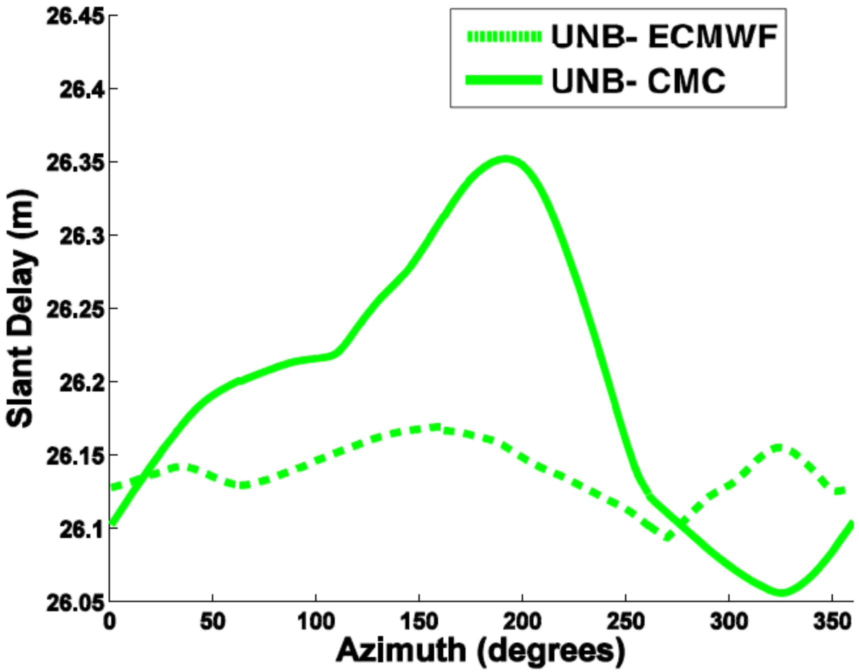
(Nafisi et al., 2011)

… different weather models

Slant delays at 5° elevation



Tsukuba



Wettzell

Conclusions

- Direct ray-tracing has shown some promising results, but NWMs are not yet accurate enough globally to solve all problems related to troposphere delay modeling.
- There will be an IAG IC SG chaired by Thomas Hobiger on coordinate systems in numerical weather models.

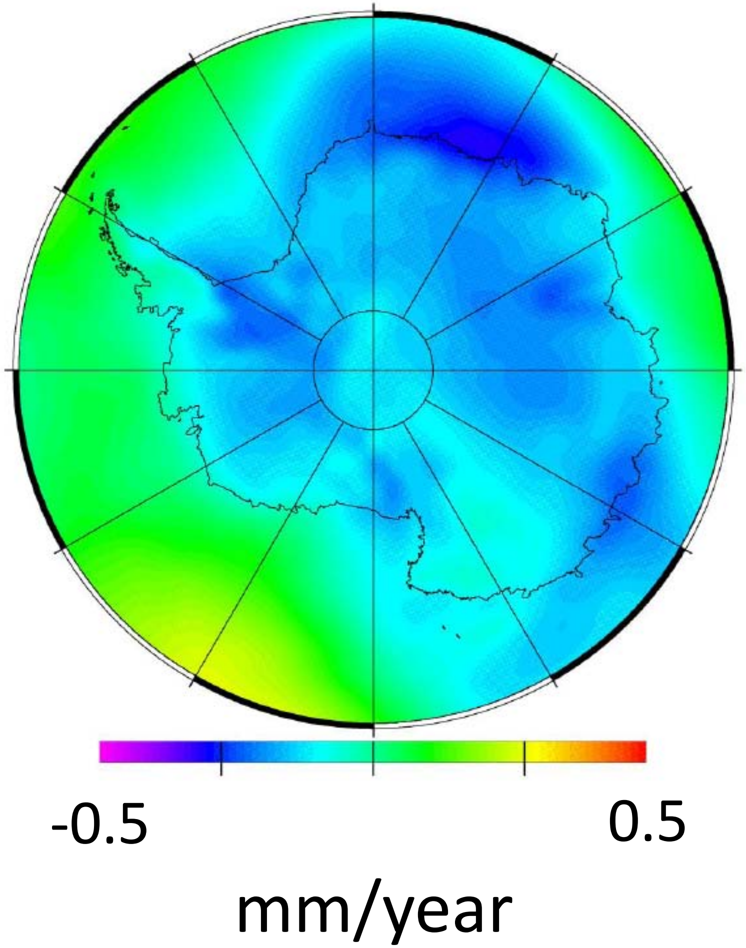
Conclusions

- Troposphere delay modeling is critical for the accuracy of space geodetic results ...
- and simulations based on turbulence show that it will stay the critical factor in future, at least for microwave techniques.

Thanks for your attention!

Acknowledgement:
P 20902-N10

Effect on height velocities



GPT - ECMWF

- Antarctica
- 2003-2008
- Importance for the determination of GIA
- (King et al., 2011)