Troposphere delay modeling in VLBI and GNSS analysis

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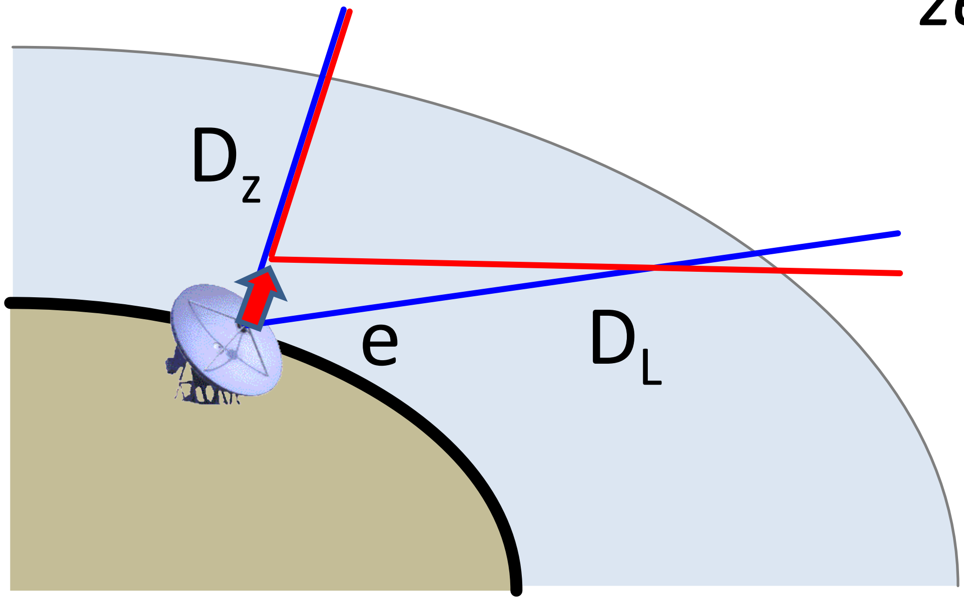
Zenith delay - clock - height

$D_L(e) = D_z \cdot m(e)$

$D_L(e) = D_z' \cdot m(e)'$



Partials:

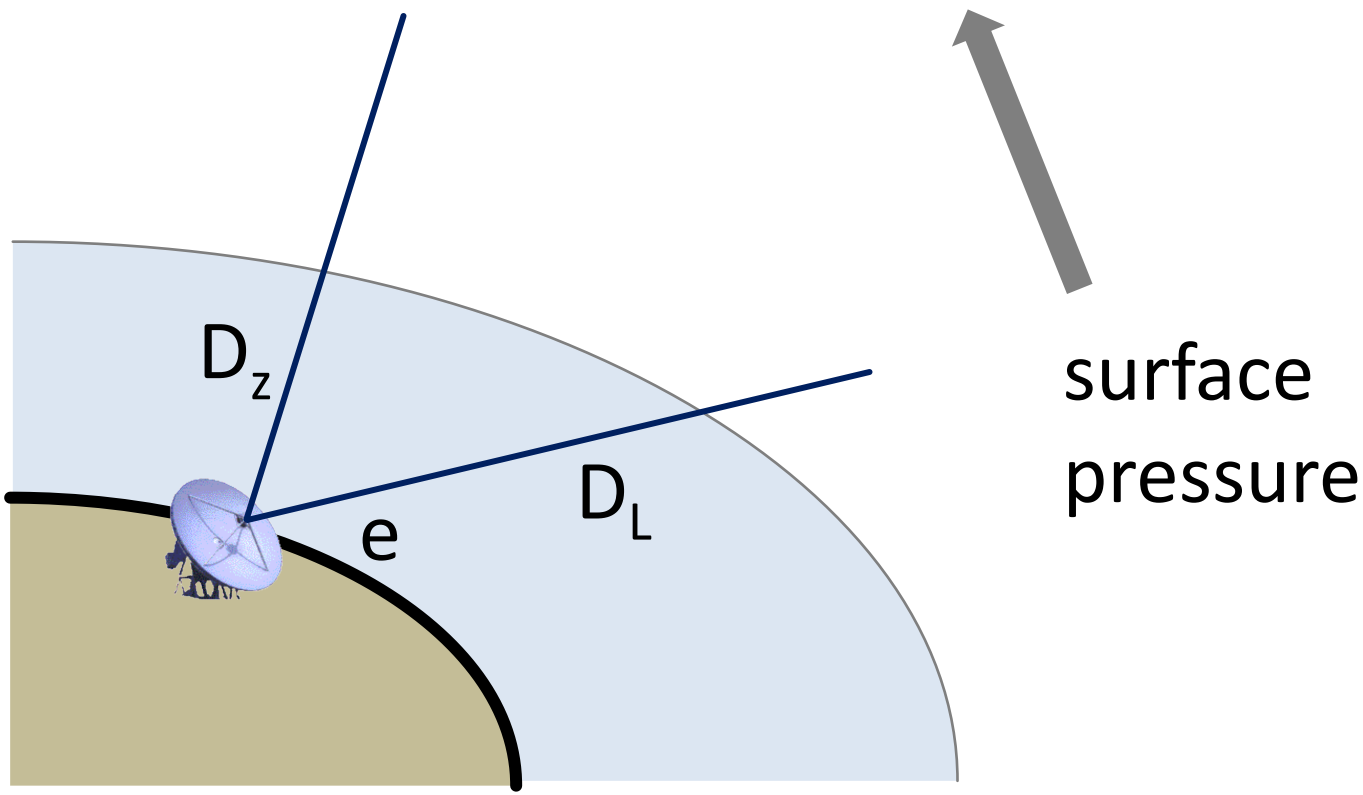
clock:	= 1
height:	= sin(e)
zenith delay	≈ m(e)

Rule of thumb

- The station height error is about 1/5 of the troposphere delay error at the lowest elevation (5°). (*MacMillan and Ma, 1994*)

IERS Conventions

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



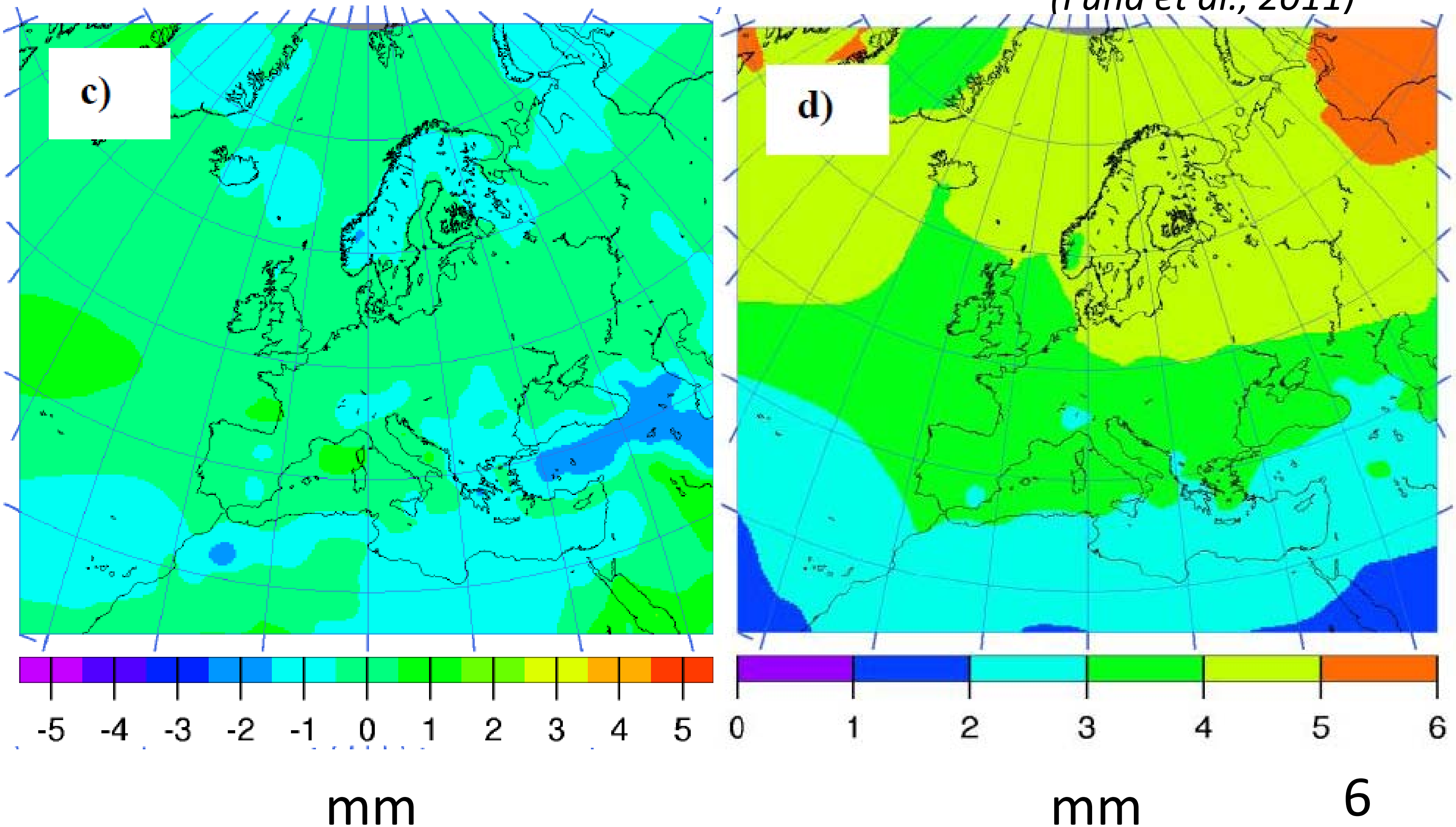
+ gradients

Mapping Functions

- empirical functions (doy, φ, λ, h)
  - GMF   Global Mapping Functions (Böhm et al., 2006)
- from numerical weather models (6-h time series)
  - VMF1   Vienna Mapping Functions (Böhm et al., 2006)

Height Changes: bias and std.dev. GMF vs. VMF1 (hyd.)

(Fund et al., 2011)

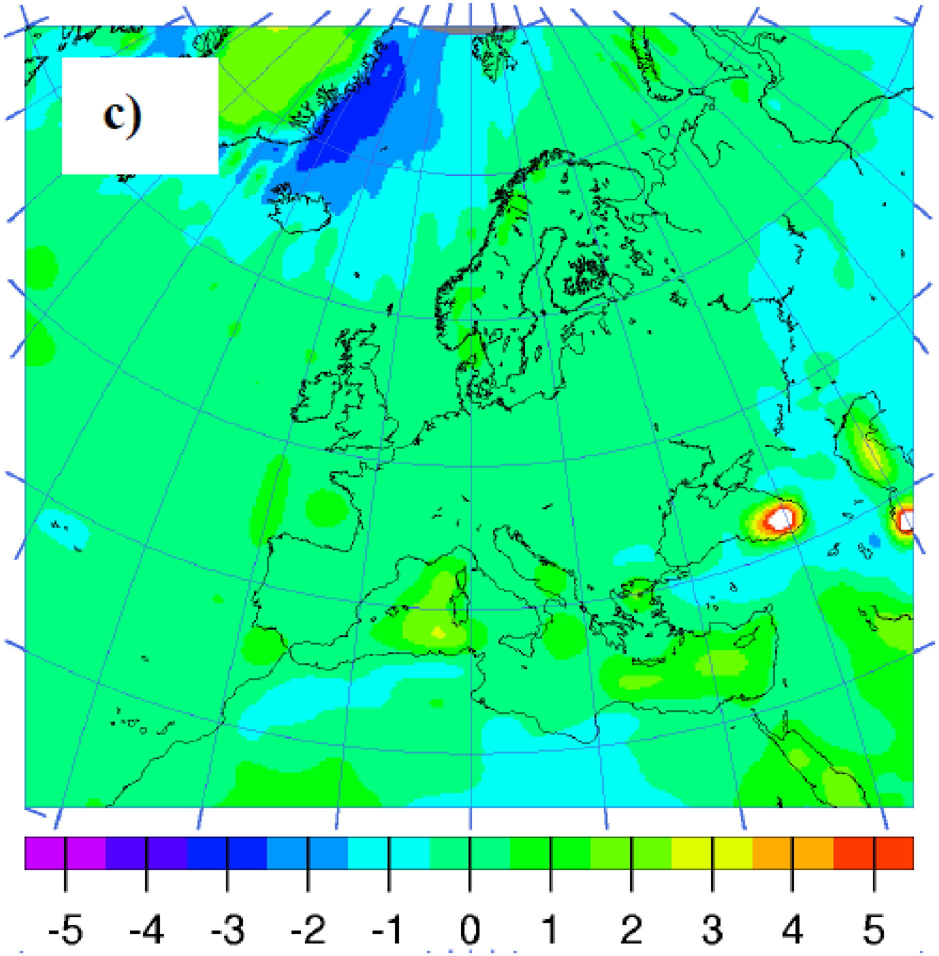


A priori hydrostatic zenith delay

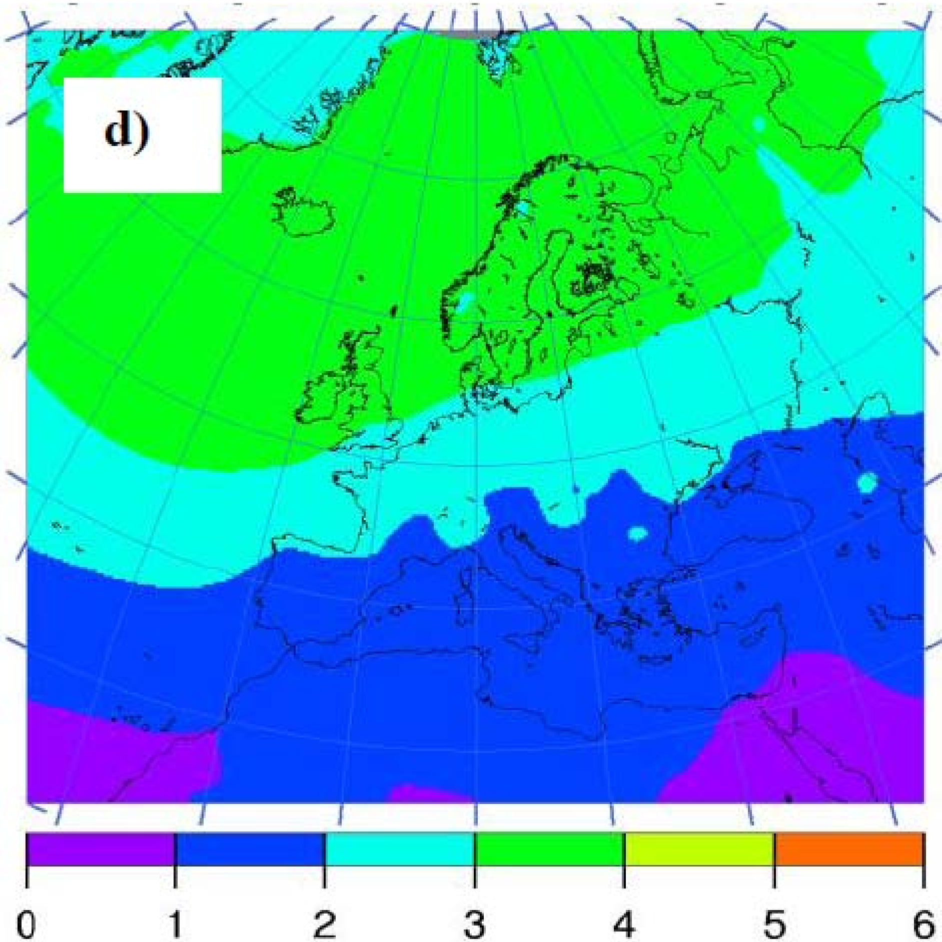
- observations
  - in situ measurements
  - numerical weather models (6-h time series)
- empirical functions (doy, φ, λ, h)
  - GPT Global Pressure/Temperature (Böhm et al., 2007)

Height Changes: bias and std.dev. GPT vs. ECMWF

(Fund et al., 2011)

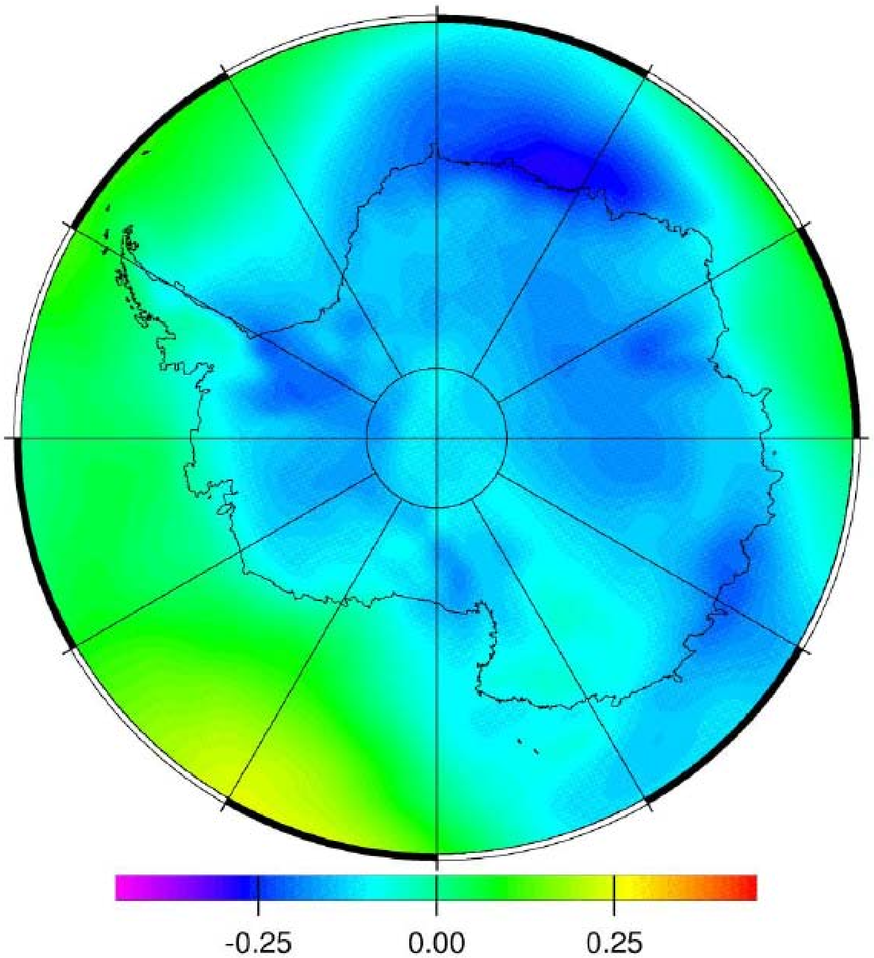


mm



mm

Height velocity in mm/year: GPT vs. ECMWF



(King et al., 2011)

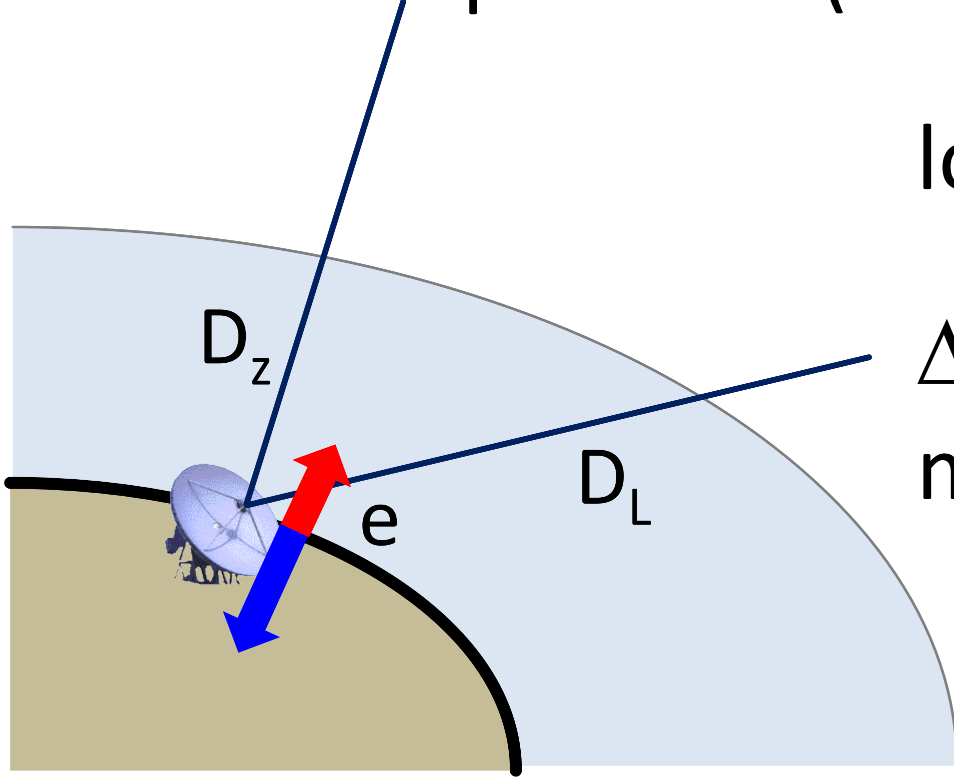
2003 - 2008

mm/year

Hydrostatic zenith delay errors

true pressure (ECMWF): 1020 hPa

reference pressure (GPT): 1000 hPa



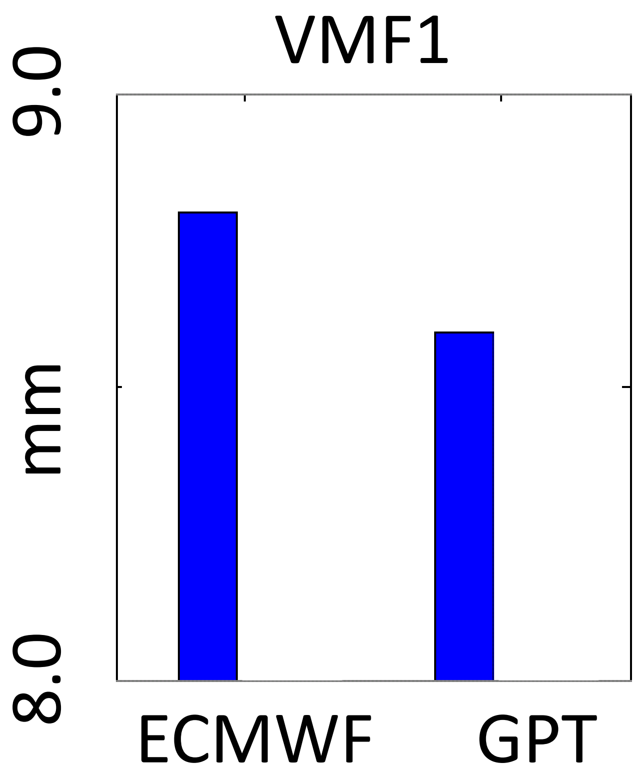
loading: 8 mm ⬇

ΔD_{hz}: –46 mm

m(e): +28 mm @5°

Δ height: 5.5 mm ⬆

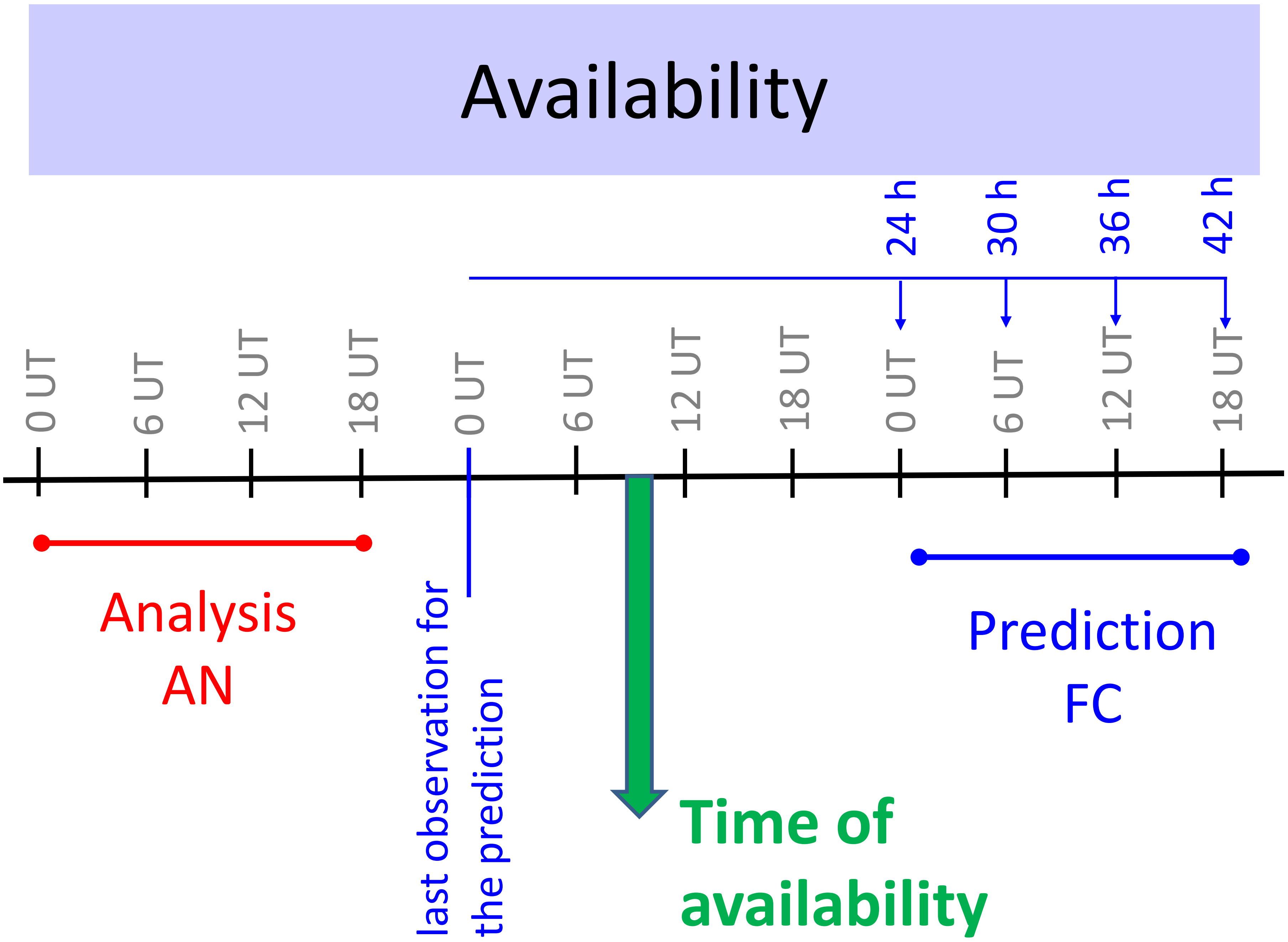
Repeatabilities of station heights



no atmospheric loading correction

a posteriori loading correction (L. Petrov)

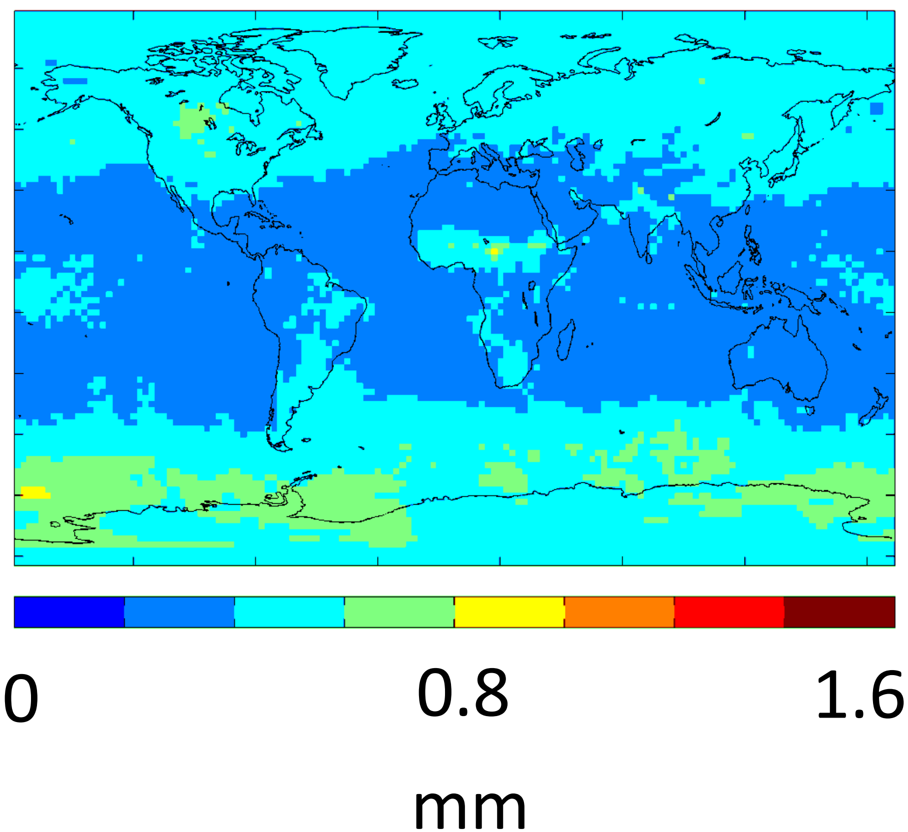
(Steigenberger et al., 2009)



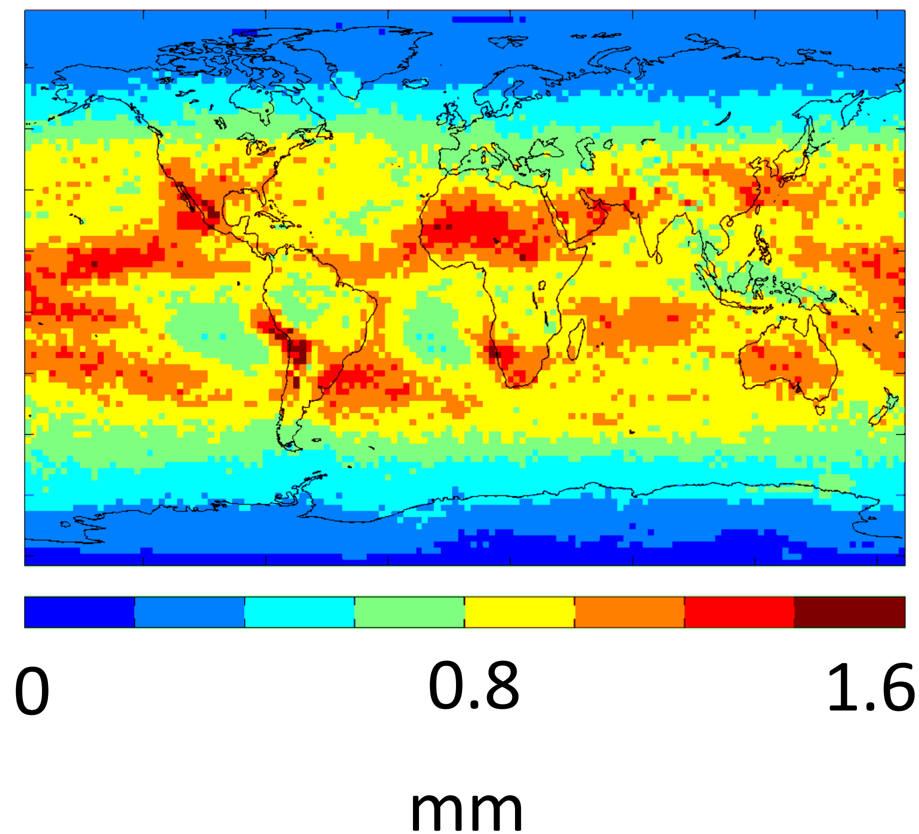
Availability
24 h
30 h
36 h
42 h
0 UT
6 UT
12 UT
18 UT
0 UT
6 UT
12 UT
18 UT
0 UT
6 UT
12 UT
18 UT
Analysis
AN
last observation for
the prediction
Time of
availability
Prediction
FC

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

VMF1 hyd.



VMF1 wet



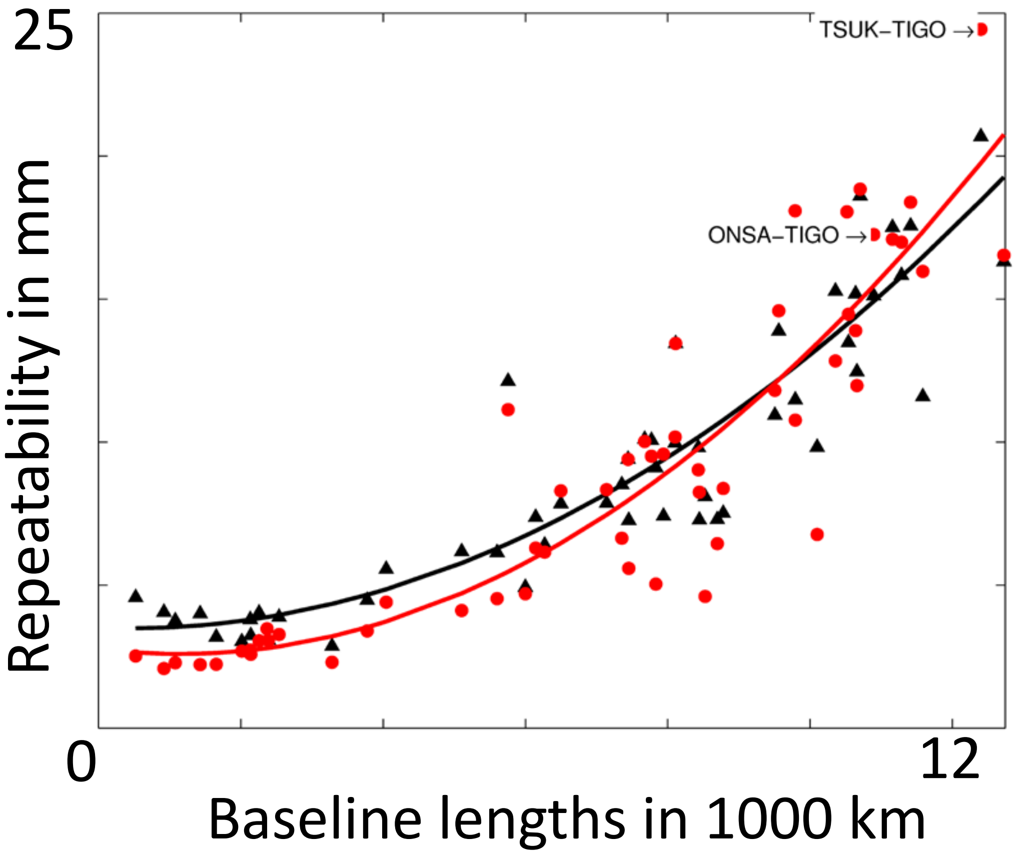
Recommendation

- It is recommended to use at least VMF1 and a priori hydrostatic zenith delays from numerical weather models if geophysical signals are to be investigated.
- ... or ...

Ray-traced slant delays

- Successful applications:
  - *(Hobiger et al 2008, EPS)* for PPP solutions w.r.t. GMF
  - *MacMillan/Petrov* for VLBI w.r.t. VMF1
  - *...*
- Estimation of residual zenith delays (and gradients) still necessary

CONT08 - Baseline length repeatabilities w.r.t. ECMWF/VMF1



Zenith delays estimated
No gradients estimated

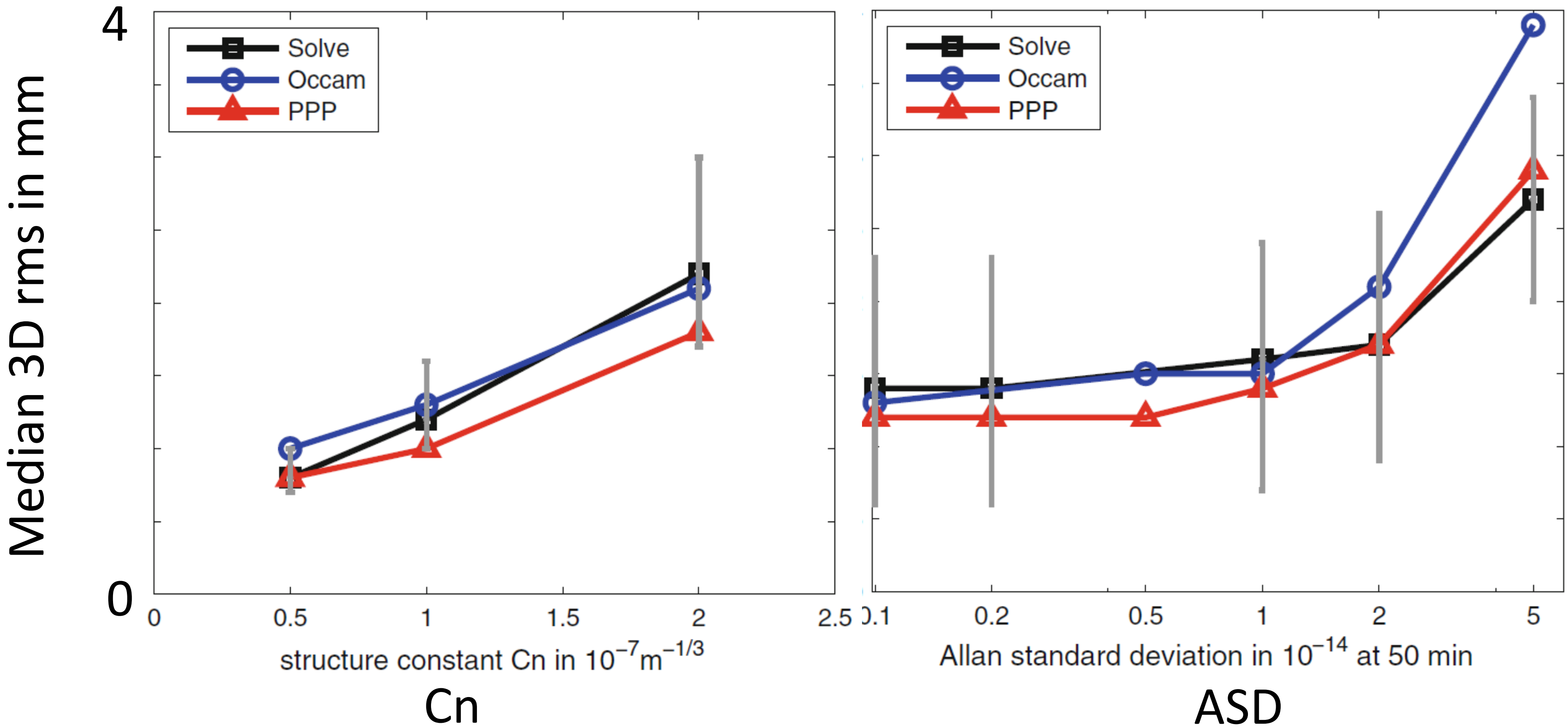
Ray-traced delays better for 33 baselines

ECMWF/VMF1 better for 19 baselines

More details this afternoon by Vahab Nafisi at 15:00 in Session G5.2/AS4.18!

VLBI2010 Simulations turbulence vs. clocks

(Pany et al 2009)



Conclusions (1)

- 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.

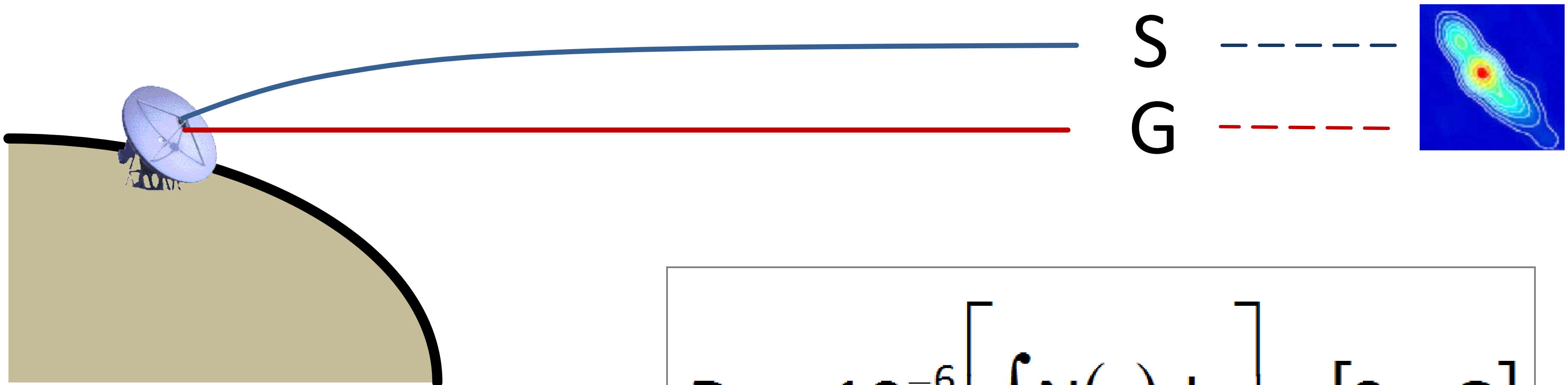
Conclusions (2)

- Ray-tracing through numerical weather models has shown some promising results, but NWMs are not yet accurate enough to solve all problems related to troposphere delay modeling.

Thanks for your attention!

Acknowledgement:
P 20902-N10

Troposphere path delays



$$D_L = 10^{-6}\left[\int_S N(s)\,ds\right] + \left[S - G\right]$$

Contents

- IERS Conventions
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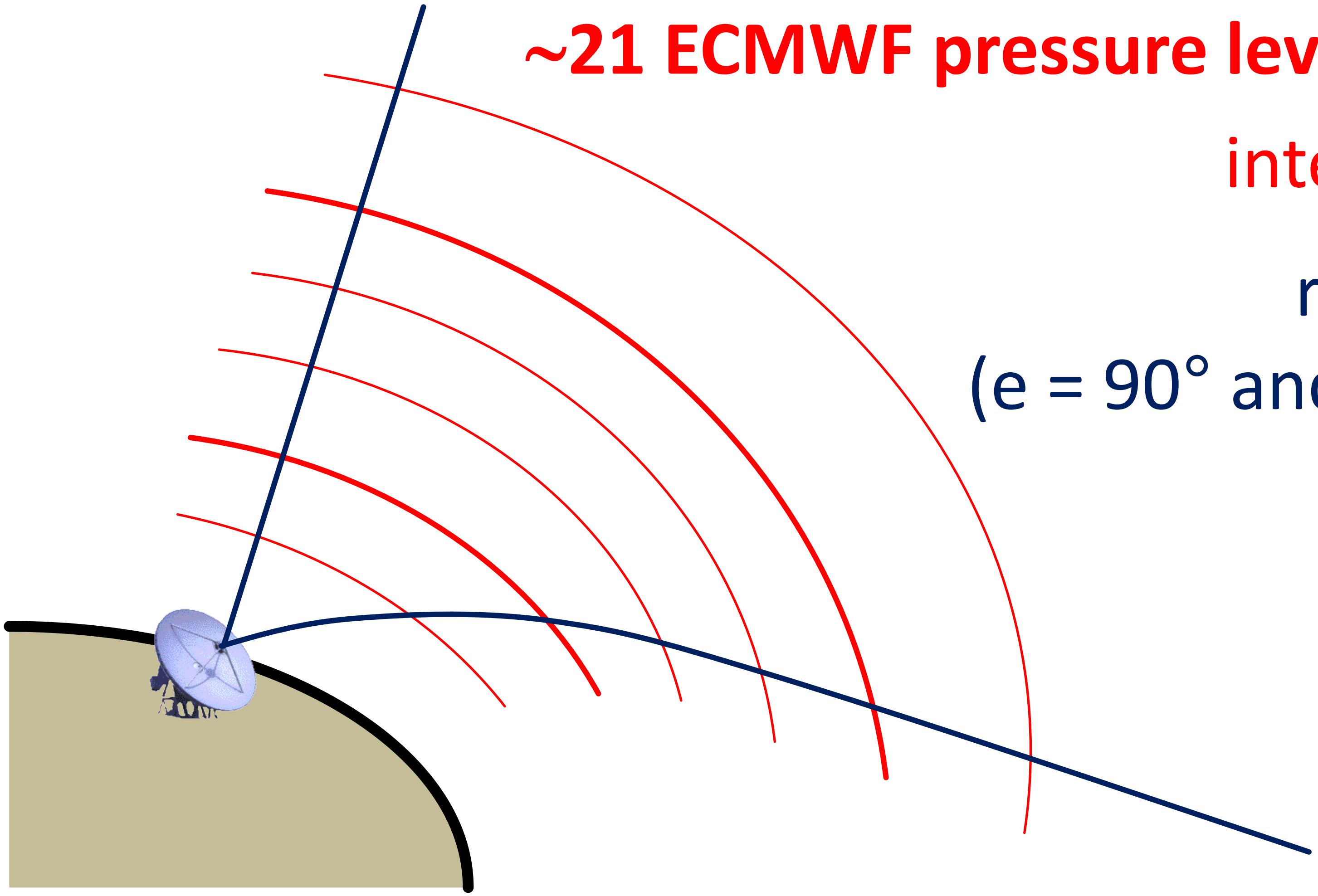
- Ray-traced slant delays for CONT08
- VLBI2010 Simulations
- Conclusions

Vienna Mapping Functions VMF1

~21 ECMWF pressure levels: T, e, h

interpolation

ray-tracing
(e = 90° and e = 3.3°)



Vienna Mapping Functions VMF1

$$m(e) = \frac{1 + \dfrac{a}{1 + \dfrac{b}{1 + c}}}{\sin(e) + \dfrac{a}{\sin(e) + \dfrac{b}{\sin(e) + c}}}$$

variable in time and space

ray-tracing

analytical functions