IGS INTERNATIONAL GNSS SERVICE

Tour de l'IGS

GNSS Processing based on IGS Products - Troposphere Modelling

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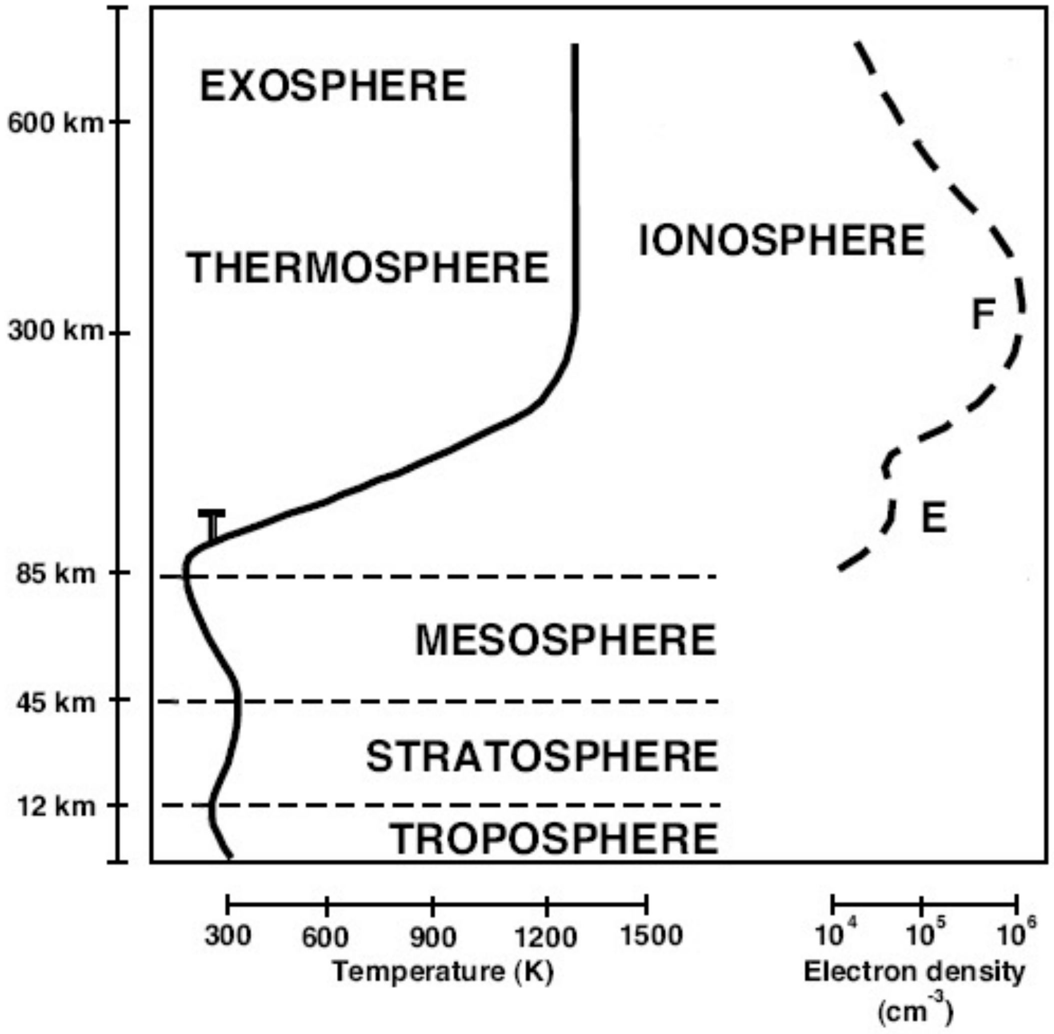
Neutral atmosphere

- "Troposphere delays"
  - strictly speaking delays in neutral atmosphere up to 100 km
  - Refractivity as function of pressure, temperature and humidity

$$N = (n-1) \cdot 10^6$$

  - Separation into hydrostatic and non-hydrostatic ("wet") refractivity

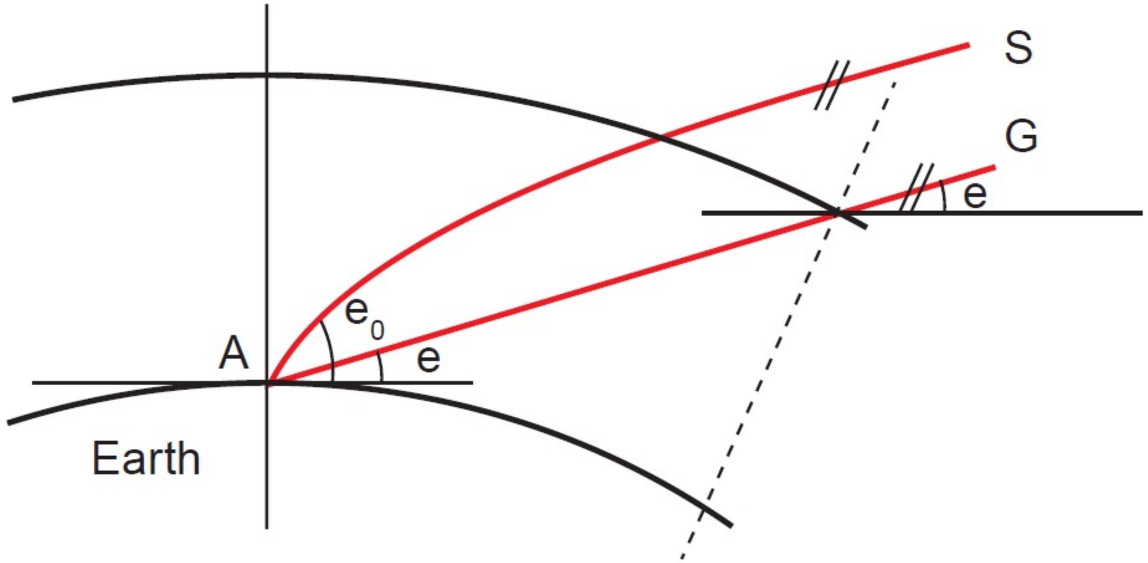


Wikipedia

Definition of tropospheric delay

- Electric path length L is minimized

$$L = \int_S n(s)\,\mathrm{d}s$$

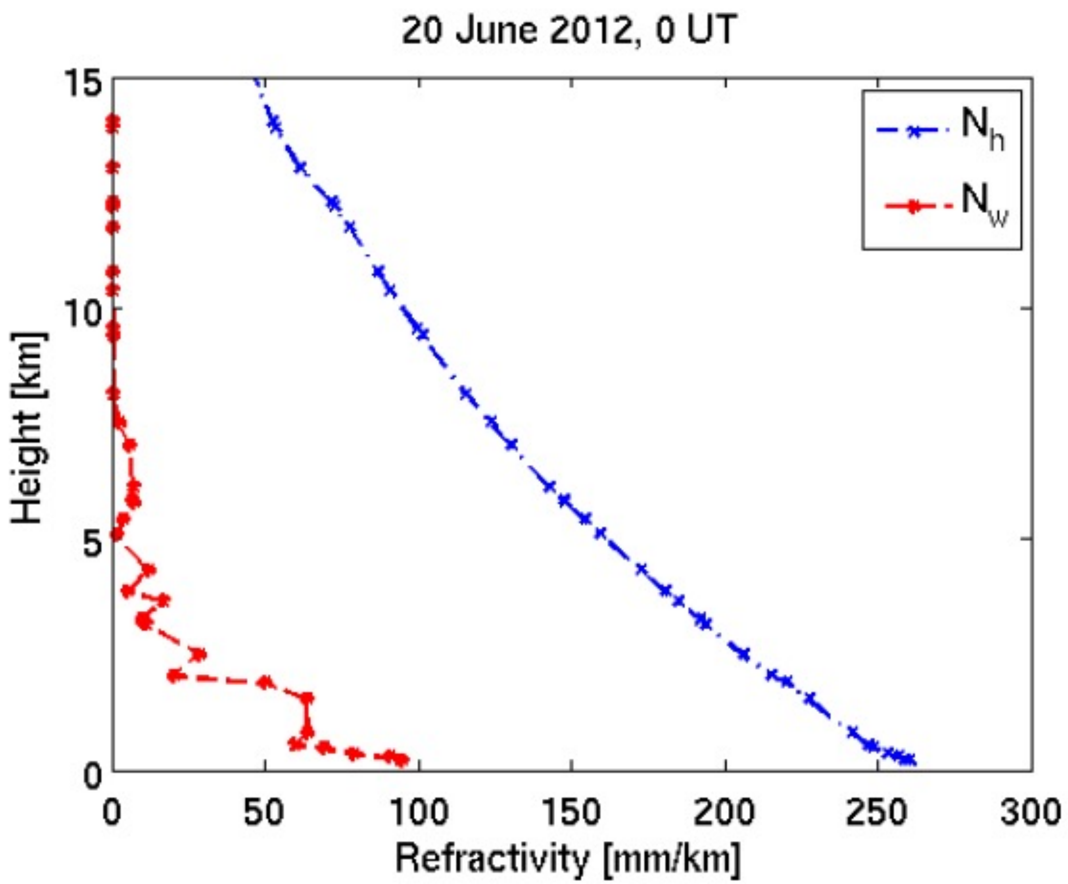


- Tropospheric delays: $\Delta L = L - G = \int_S n(s)\mathrm{d}s - G = \Delta L_h + \Delta L_w + S - G$

- Bending effect S – G about 2 dm at 5 degrees elevation (part of hydrostatic mf)

Hydrostatic versus wet refractivity

- Refractivity from radiosonde data



Hydrostatic refractivity N_h

Wet refractivity N_w

$$N = k_1 \frac{R}{M_d}\rho + k_2' \frac{e}{T} + k_3 \frac{e}{T^2}$$

hydrostatic — "wet"

Hydrostatic zenith delay

- Equation by Saastamoinen (1972)

$$\Delta L_h^z = 0.0022768 \frac{p_0}{f(\theta, h_0)}$$

≈ 2.3 m (8 nsec) at sea level

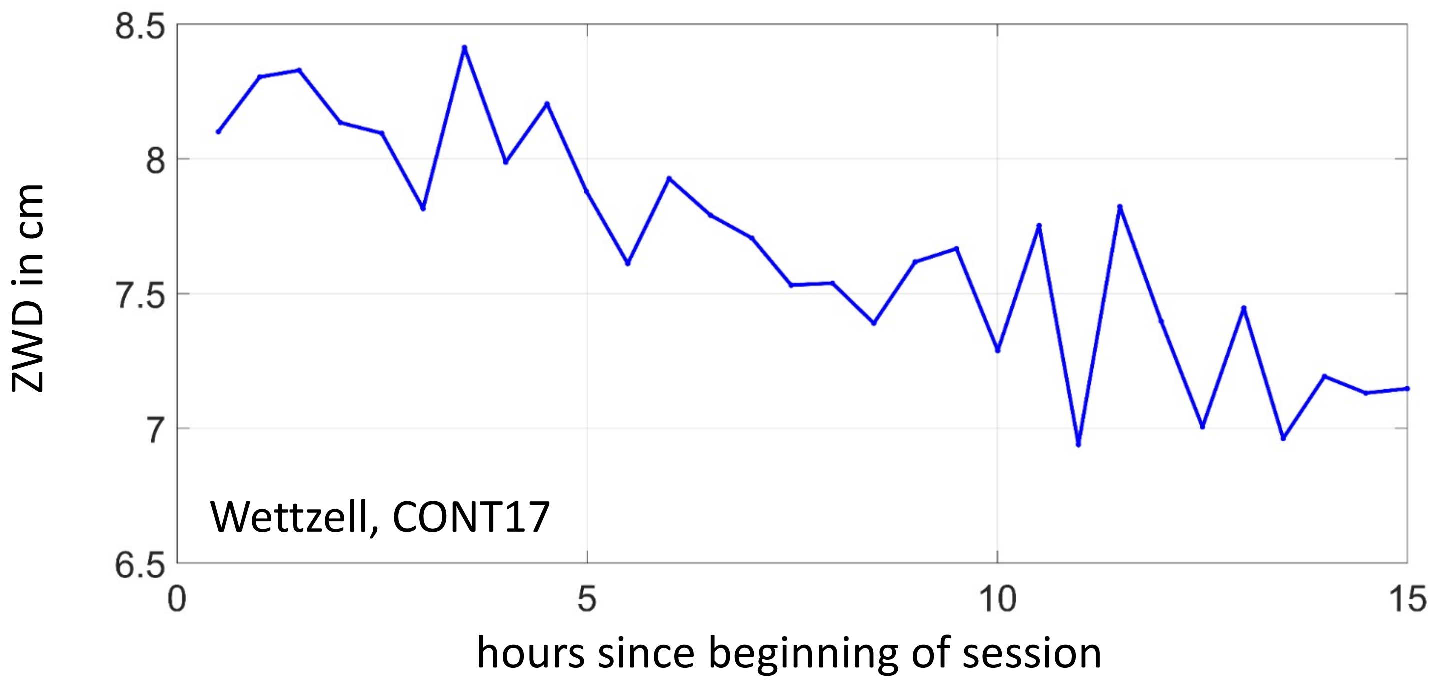
- We need the pressure at the site to determine the hydrostatic zenith delay very accurately
  - local recordings at the site (preferable if available)
  - gridded values from numerical weather models
  - empirical (blind) models like GPT2 etc
    - Caveat: do not use atmosphere loading corrections!

Troposphere delay modelling

- Mapping functions for a priori hydrostatic delay and estimating zenith wet delays

$$\Delta L(e) = \Delta L_h^z \cdot mf_h(e) + \Delta L_w^z \cdot mf_w(e)$$

- Zenith wet delays estimated every 20 to 60 minutes



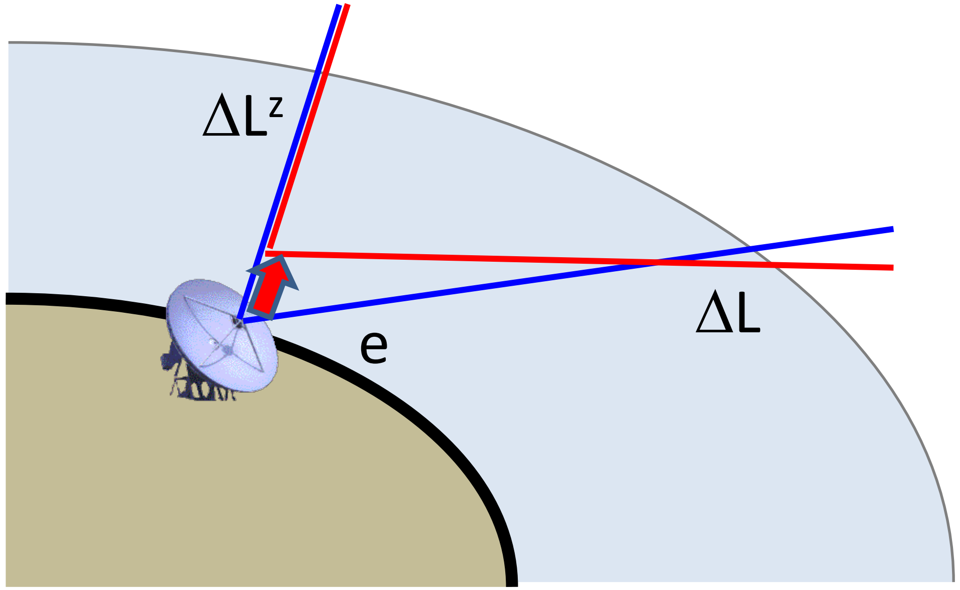
Mapping functions

- Correlation between height, clocks and zenith delays
- Partials are sin(e), 1, and mf(e)
  – Mapping function mf(e) not perfectly known, in particular at low elevations
  – Low elevations necessary to de-correlate heights, clocks, and zenith delays

- Errors via correlations also in station heights (and clocks)
- Trade-off $\rightarrow$ about 5 degrees cut off elevation angle
  – sometimes with down-weighting

Mapping functions

- The station height error is about 1/5 of the delay error at 5 degrees elevation



$\Delta L(e) = \Delta L^z \cdot mf(e)$

$\Delta L(e) = \Delta L^{z\prime} \cdot mf(e)'$

- The decrease of the zenith delay is about half of the station height increase

Mapping functions

- Continued fraction form (Herring, 1992)

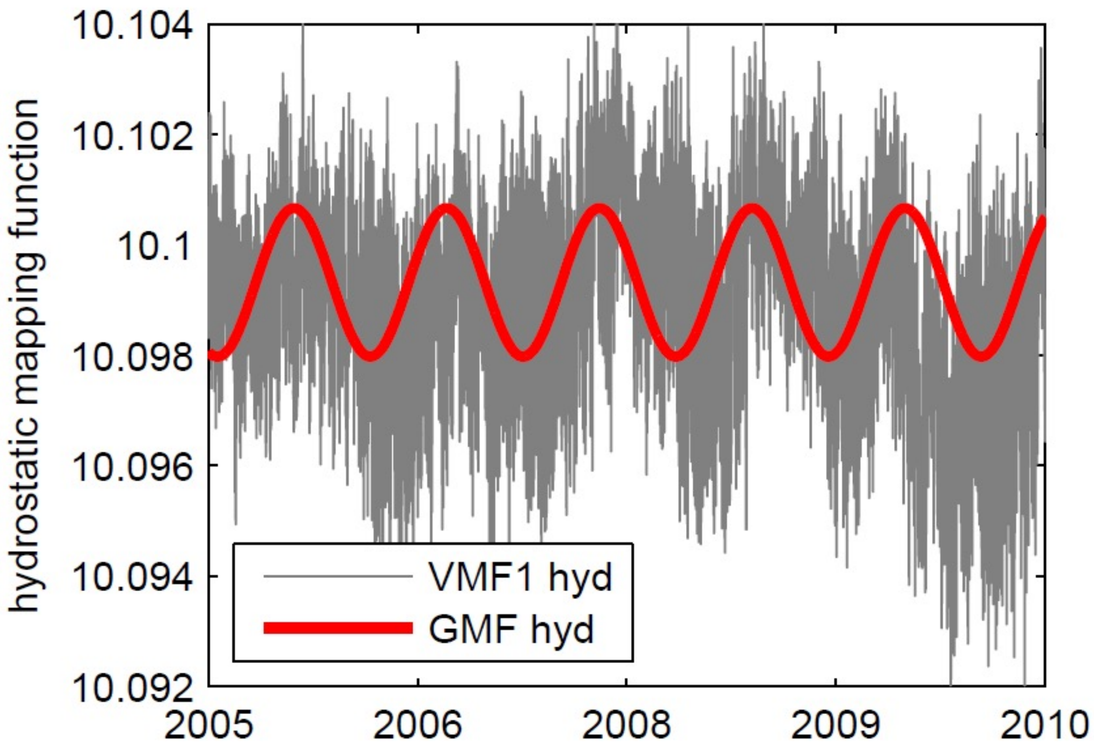
$$mf(e) = \frac{1 + \cfrac{a}{1 + \cfrac{b}{1 + c}}}{\sin(e) + \cfrac{a}{\sin(e) + \cfrac{b}{\sin(e) + c}}}$$

- Example Vienna Mapping Functions
  - Empirical functions for b and c coefficients
  - Coefficients 'a' by ray-tracing and inversion using 6h data of the ECMWF
  - Available for all IGS sites and on global grid

Mapping functions

- Global Mapping Functions GMF (GPT2, ..) is an averaged VMF

VMF1 versus GMF at Fortaleza (Brazil) at 5 deg. elevation

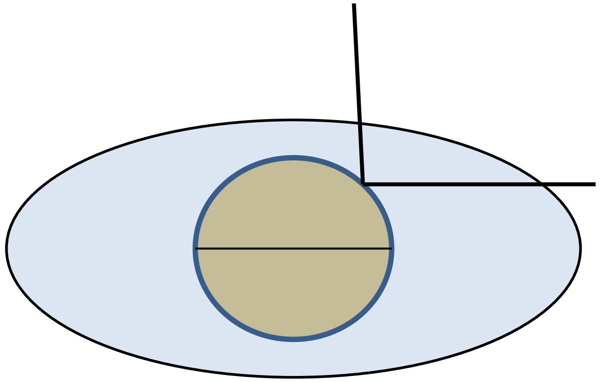


Tropospheric gradients

- Describe asymmetric delays

$$\Delta L(a,e) = \Delta L_0(e) + mf_g(e)(G_n \cos(a) + G_e \sin(a))$$

- Typical gradient: 1 mm (corresponds to 10 cm at 5 deg. elevation)
- Estimated, e.g., every 3 hours
- Caused by weather fronts, coastal situations, atmospheric bulge, ..



Regional and local networks

- In regional or local network solutions the troposphere parameters may get correlated to the satellite clock parameters and cannot be solved in an absolute sense.
  - In such a case, you may estimate troposphere parameters for all but one station.
  - Alternatively, you may introduce troposphere estimates from an external (preferable global) solution.

Regional and local networks

- In local network solutions, even a 100% correlation of the troposphere between the stations may occure.
  - If all receivers are located at the same station height, you don't need to estimated any troposphere parameters.
  - If there are significant height differences between the stations, a troposphere bias should be estimated.

Questions?

- Do not hesitate to contact Johannes.Boehm@tuwien.ac.at

Mapping function data

IGS INTERNATIONAL GNSS SERVICE

- http://vmf.geo.tuwien.ac.at/
- Vienna Mapping Functions coefficients (from analysis and forecast data)
  - including zenith hydrostatic (and wet) zenith delay
- Empirical mapping functions, e.g. GPT3
- …

- ftp://ftp.gfz-potsdam.de/pub/GNSS/products/gfz-vmf1
- Potsdam Mapping Factors @ GFZ Data Server

- UNB-VMF1