Optimization of Tropospheric Delay Mapping Function Performance for High-Precision Geodetic Applications

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Motivation

- Neutral Atmosphere
  - Non-dispersive medium at radio frequencies
  - Effects:
    - ⇨ Propagation delay
    - ⇨ Ray bending
  - Troposphere accounts for most of the delay (hence the denomination ‘tropospheric delay’).
- Major modeling error for radiometric techniques, which affects the height component of position.
- Sea-level rise monitoring, postglacial rebound, earthquake hazard mitigation and other geodetic applications that require mm-level accuracy.

Tropospheric Delay

$$d_{trop} = d_h^z \cdot m_h(\varepsilon) + d_w^z \cdot m_w(\varepsilon)$$

Hydrostatic Zenith Delay

Hydrostatic Mapping Function

Wet Zenith Delay

Wet Mapping Function

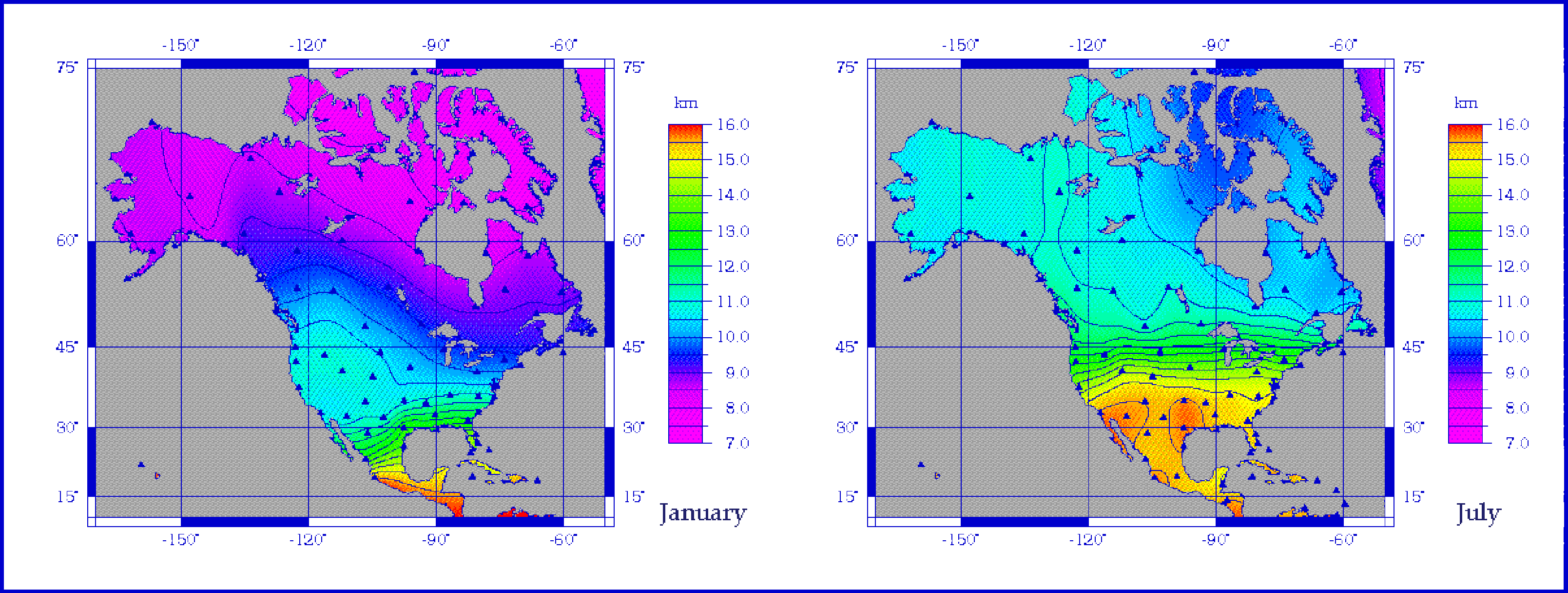
Temperature Profile Parameters

- **Nominal global values (based on a standard atmosphere)**
  - ☹ No latitudinal or seasonal variation accounted for.
  - Tropopause height: 11,231 m.
  - Temperature Lapse Rate: 6.5 °C/km
- **Predicted from tables**
  - ☹ In general, no seasonal variation accounted for.
- **Predicted from databases relative to a given station**
  - ☹ In general, available only for a limited number of sites.
- **Predicted from models**

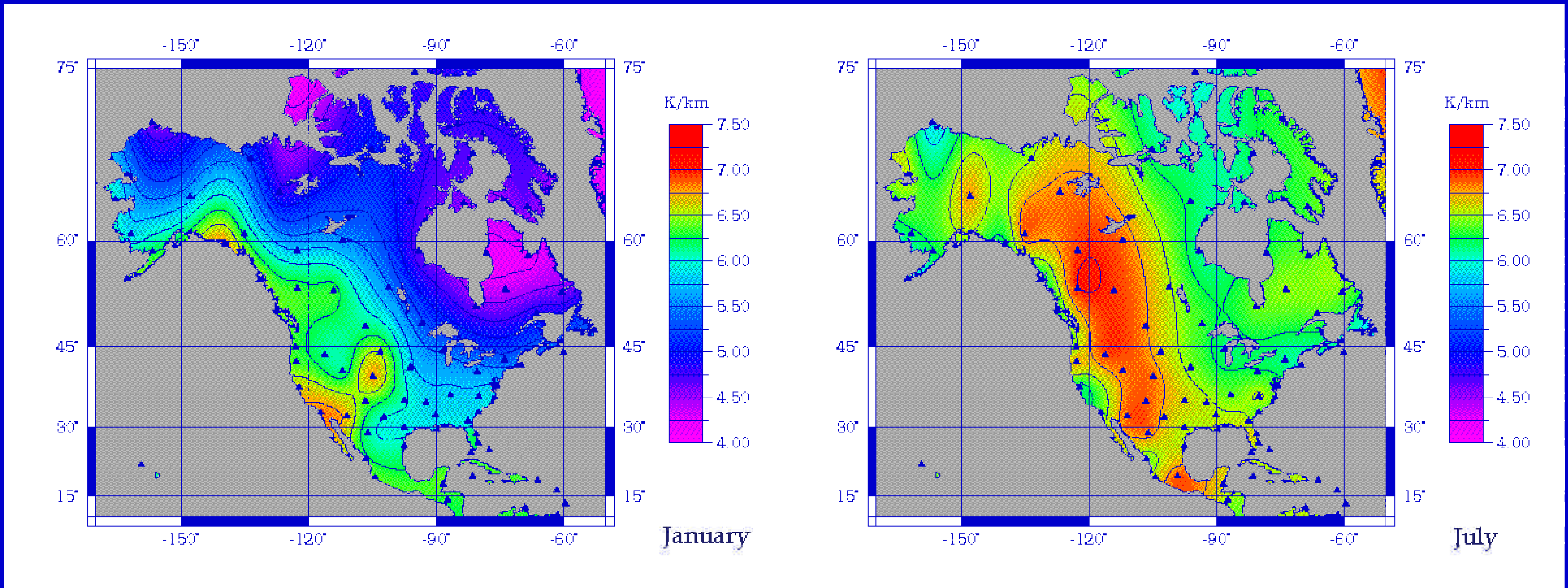
Mapping Functions

- **CfA-2.2** (Harvard-Smithsonian Center for Astrophysics)
  - Davis et al. (1985). *Radio Science*, Vol. 20, No. 6, pp. 1593-1607.
- **Lanyi** (Jet Propulsion Laboratory)
  - Lanyi (1984). TAD Progress Rep. 42-78, JPL, pp. 152-159.
  - Sovers and Jacobs (1996). JPL Publication 83-39.
- **UNSW931** (Shanghai Astronomical Observatory)
  - Yan and Ping (1995). *The Astronomical Journal*, Vol. 110, pp. 934-939.

North America
Tropopause Height Variability



North America
Lapse Rate Variability



Tropopause Height and Lapse Rate Prediction (UNB models)

UNB98TH1

$$H_t\,(\mathrm{km}) = 7.508 + 2.421\,\exp\left(\frac{t_s}{22.90}\right)$$

UNB98LR1

$$\alpha(°\mathrm{C}/\mathrm{km}) = 5.930 + 0.0359\,t_s$$

t_s = surface temperature (°C)

Parameter Settings (CfA and UNSW)

Version Code	α (K/km)	H_t (km)
CfA1	Mean†	Mean†
CfA2	6.5	11.231
CfA3	UNB98LR1	UNB98TH1
UNSW1	Mean†	Mean†
UNSW2	6.5	11.231
UNSW3	UNB98LR1	UNB98TH1

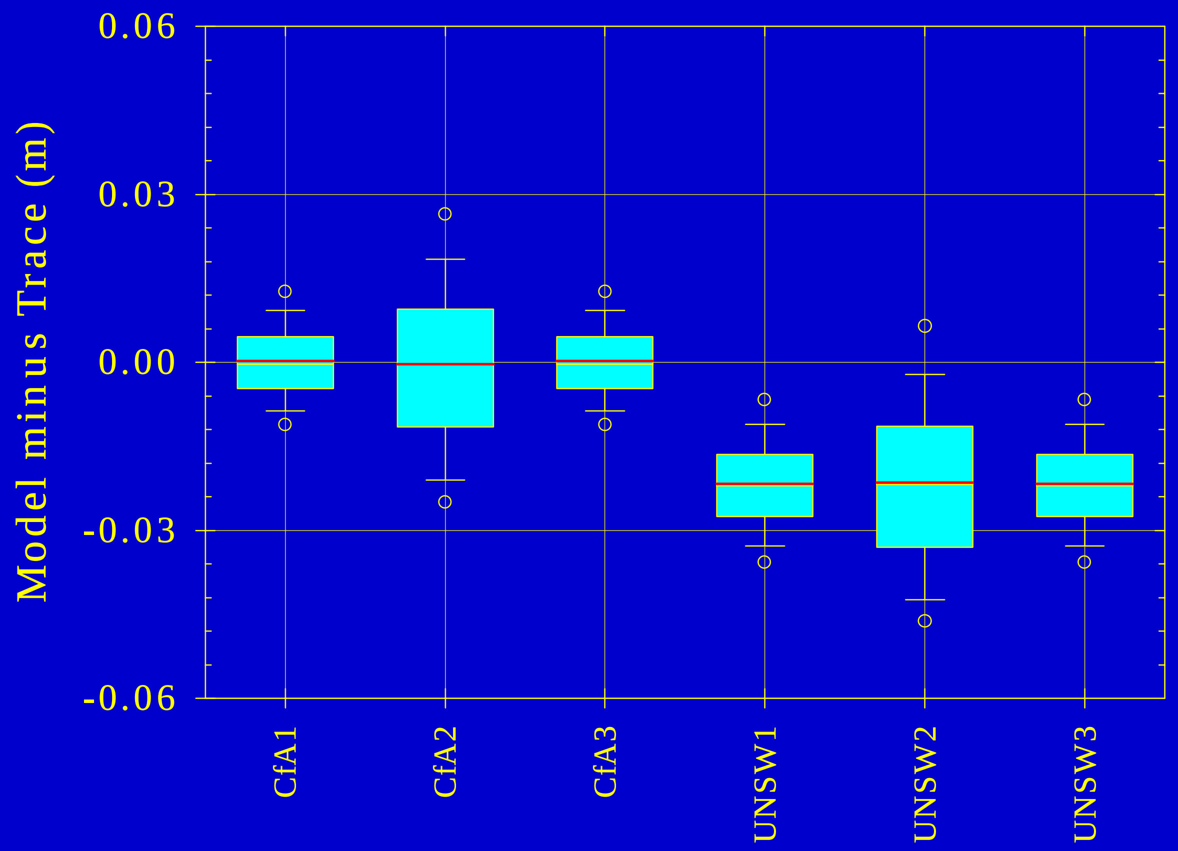
†monthly mean values based on radiosonde observations.

Parameter Settings (Lanyi)

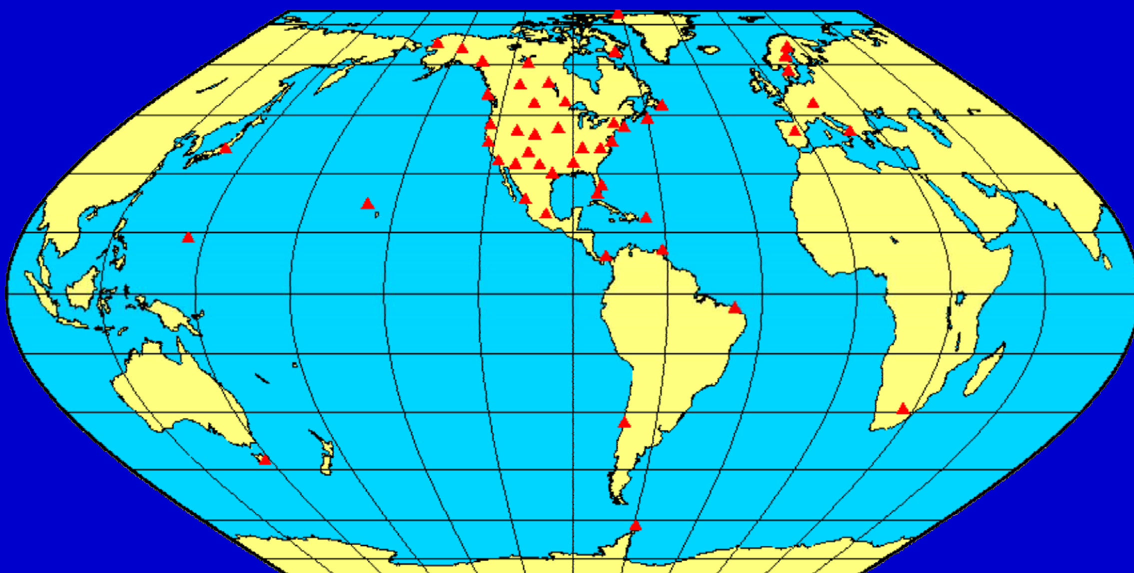
Version	S	P (hPa)	T (K)	α (K/km)	H_i (km)	H_t (km)
LA1	○	1013.25	292	6.8165	1.25	12.2
LA2	□	RAOB	SJ96	SJ96	0	SJ96
LA3	Δ	RAOB	RAOB	Mean	Mean	Mean
LA4	◇	RAOB	Mean	Mean	Mean	Mean
LA5	∇	RAOB	Mean	6.5	0	11.231
LA6	⬡	RAOB	Mean	UNB98LR1	0	UNB98TH1

RAOB – radiosonde observed values.
SJ96 – interpolation scheme by Sovers and Jacobs [1996].
Mean – monthly mean values based on radiosonde observations.

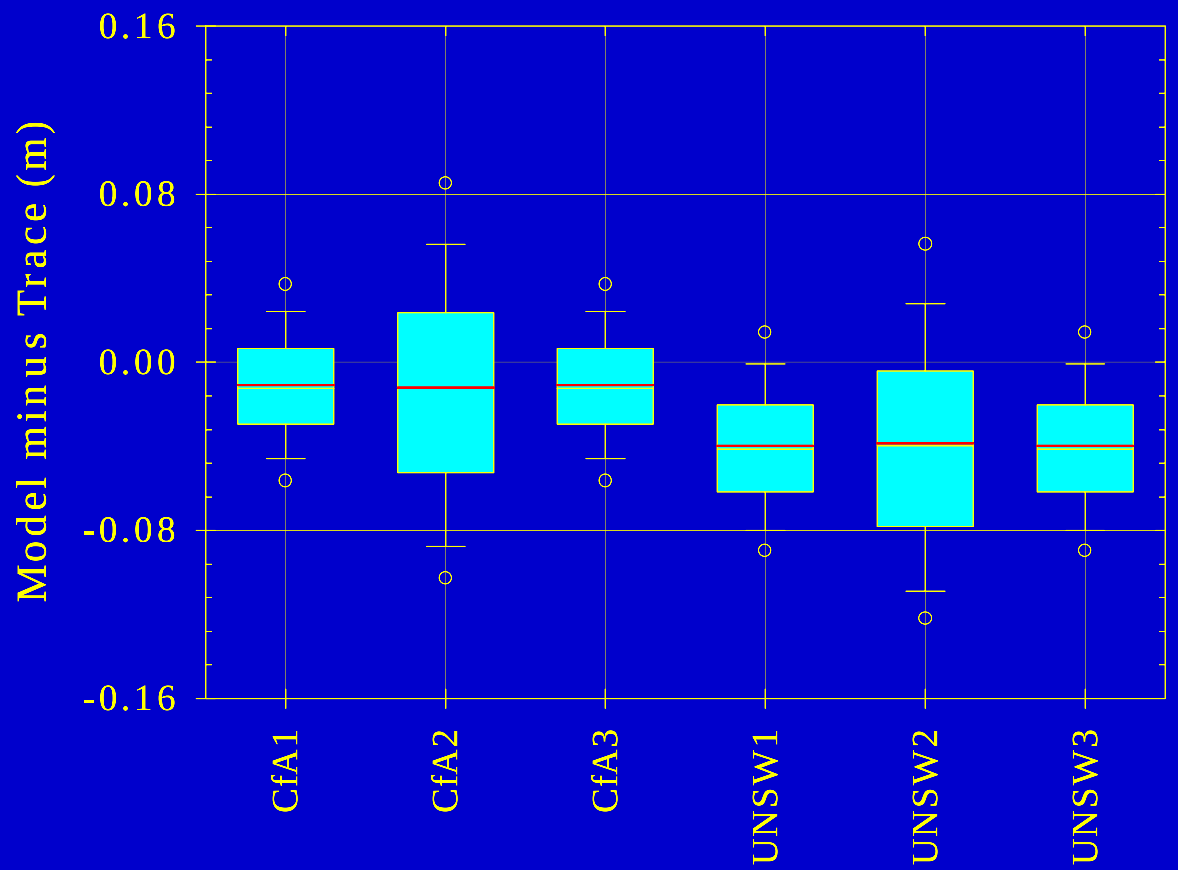
Assessment Results ($\varepsilon = 10°$)



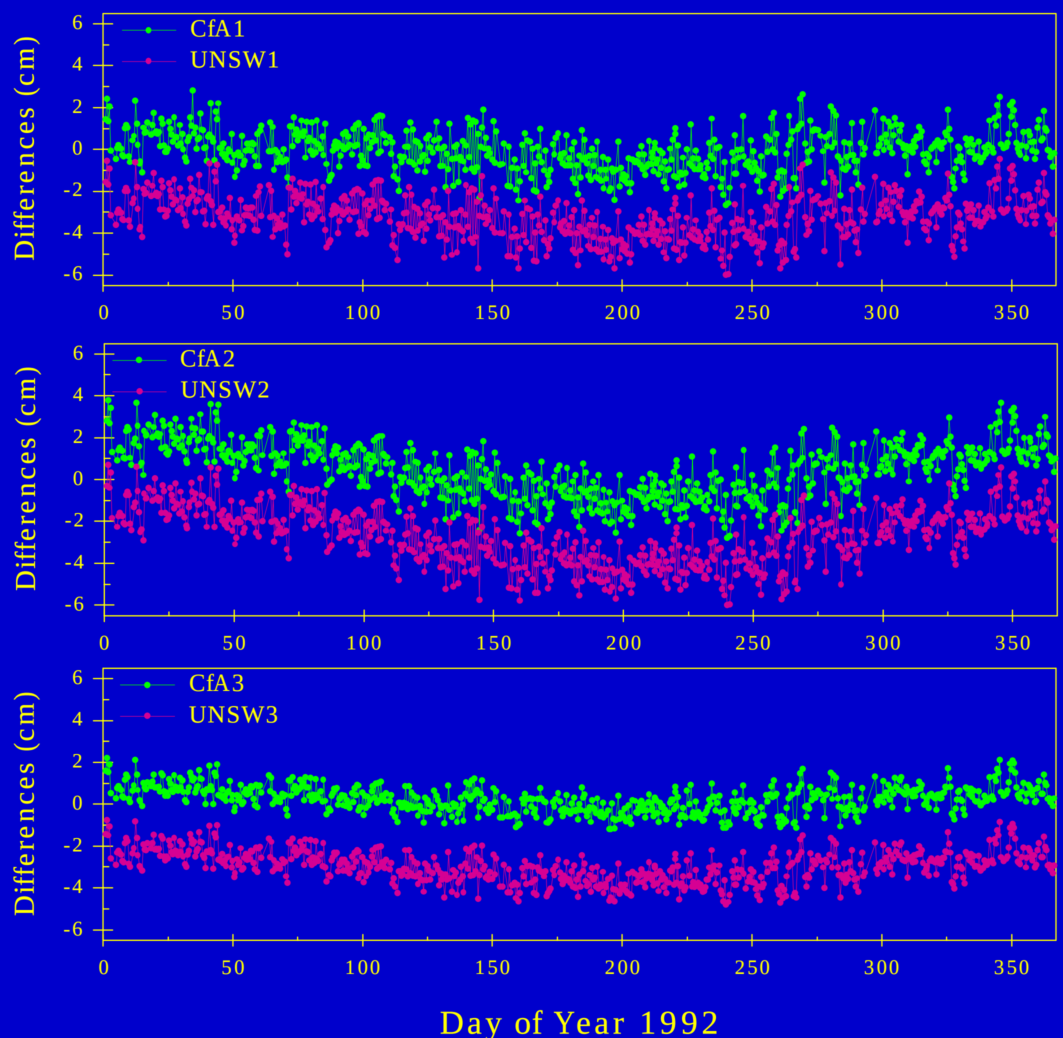
Locations of the Radiosonde Stations



Assessment Results (ε =6°)

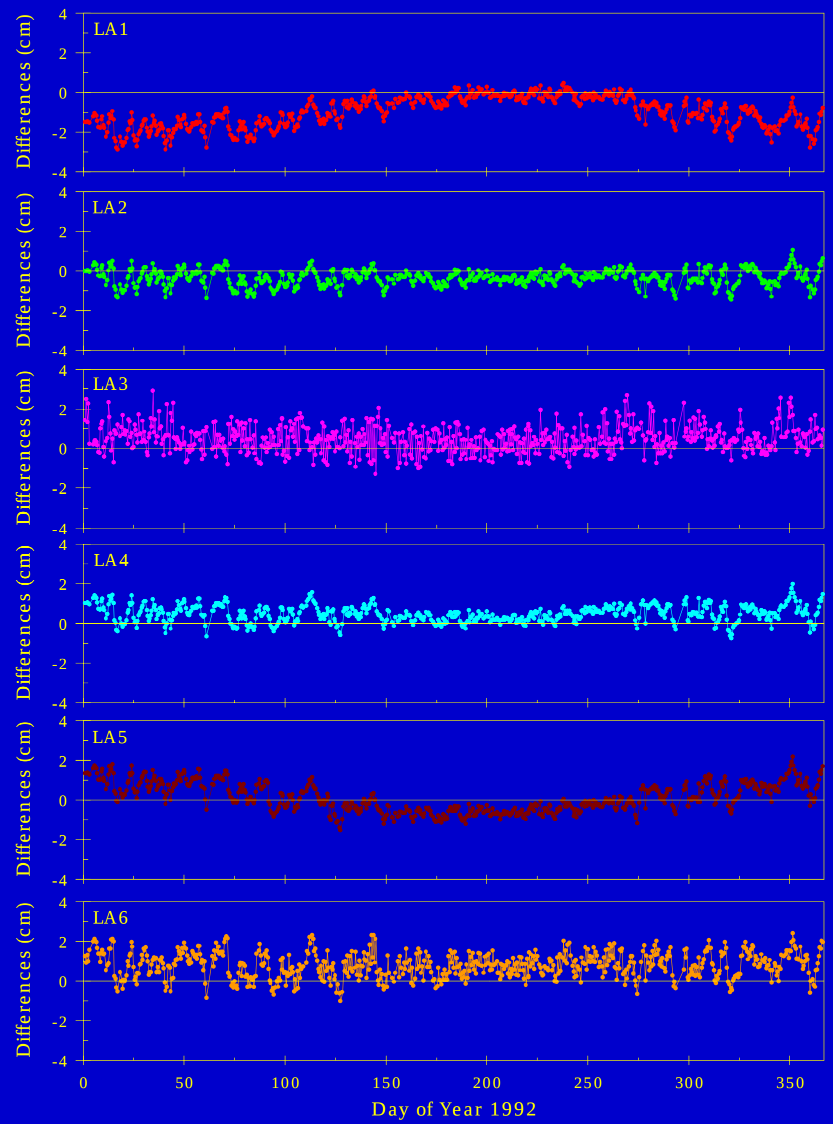


Results for Albany (ε = 10°)
(CfA and UNSW)



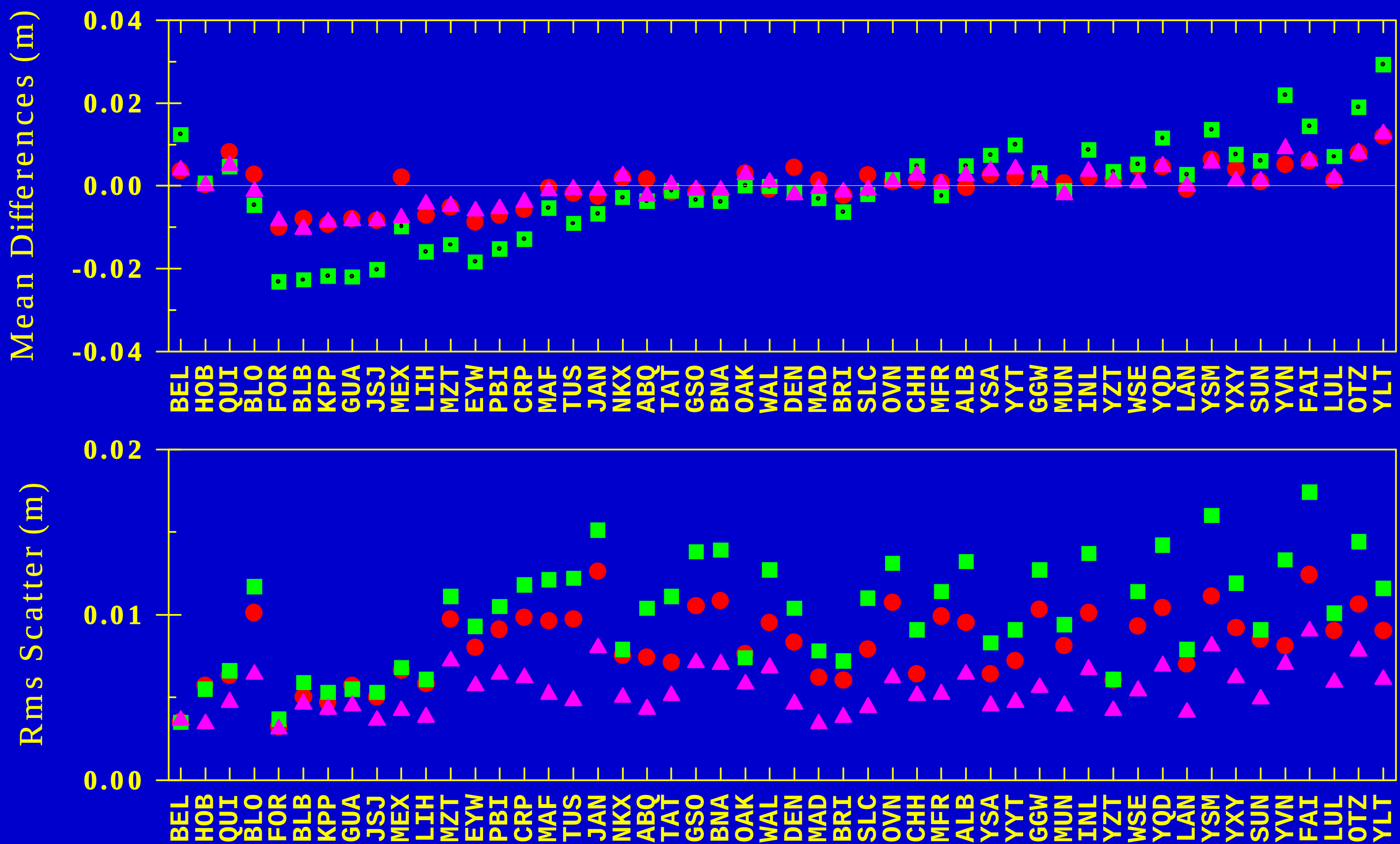
Note: Bias of -1 cm added to UNSW

Results for Albany (ε = 10°)
(Lanyi)



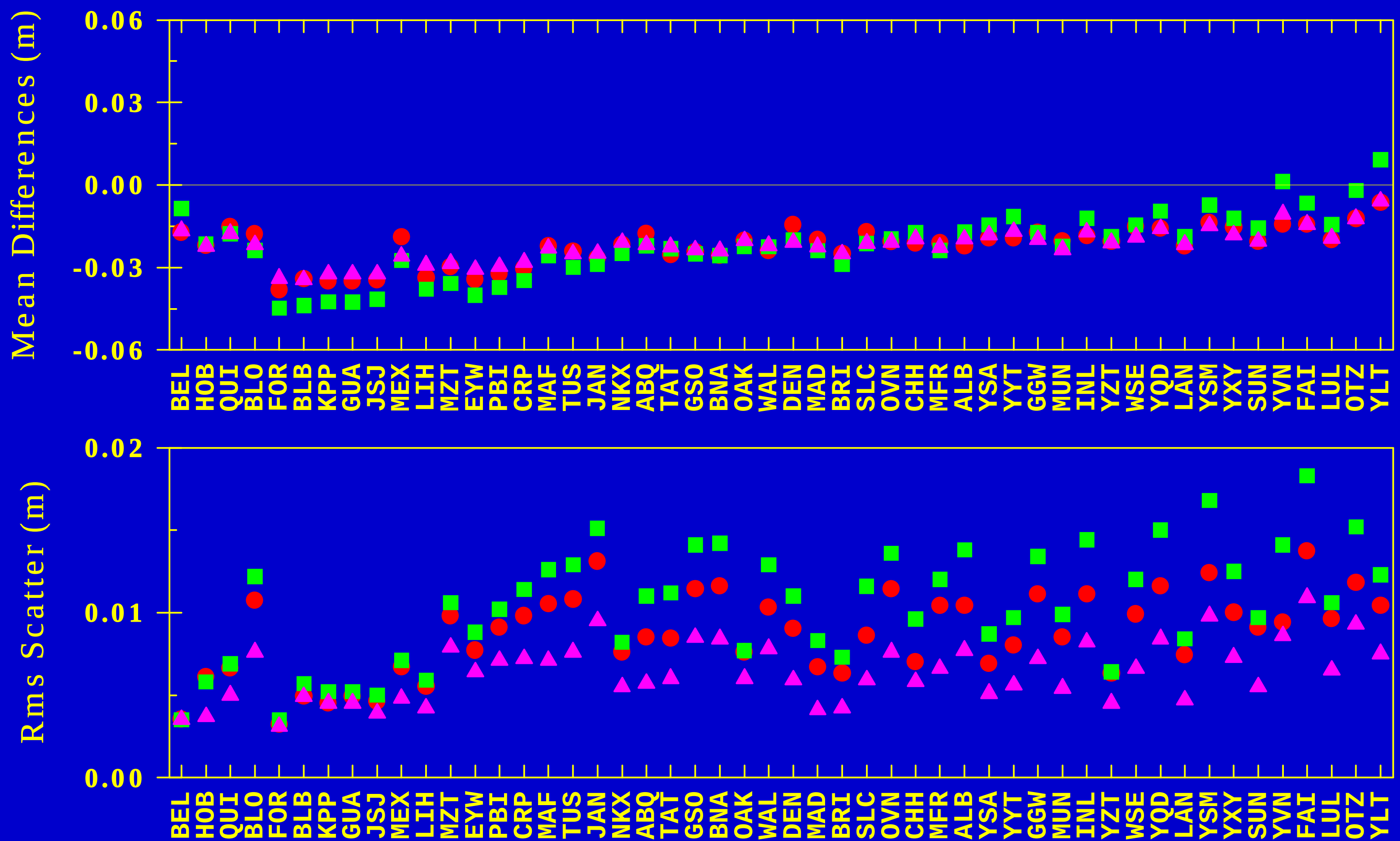
Statistics for CfA (ε = 10°)

(○=CfA1, □=CfA1, Δ=CfA3)

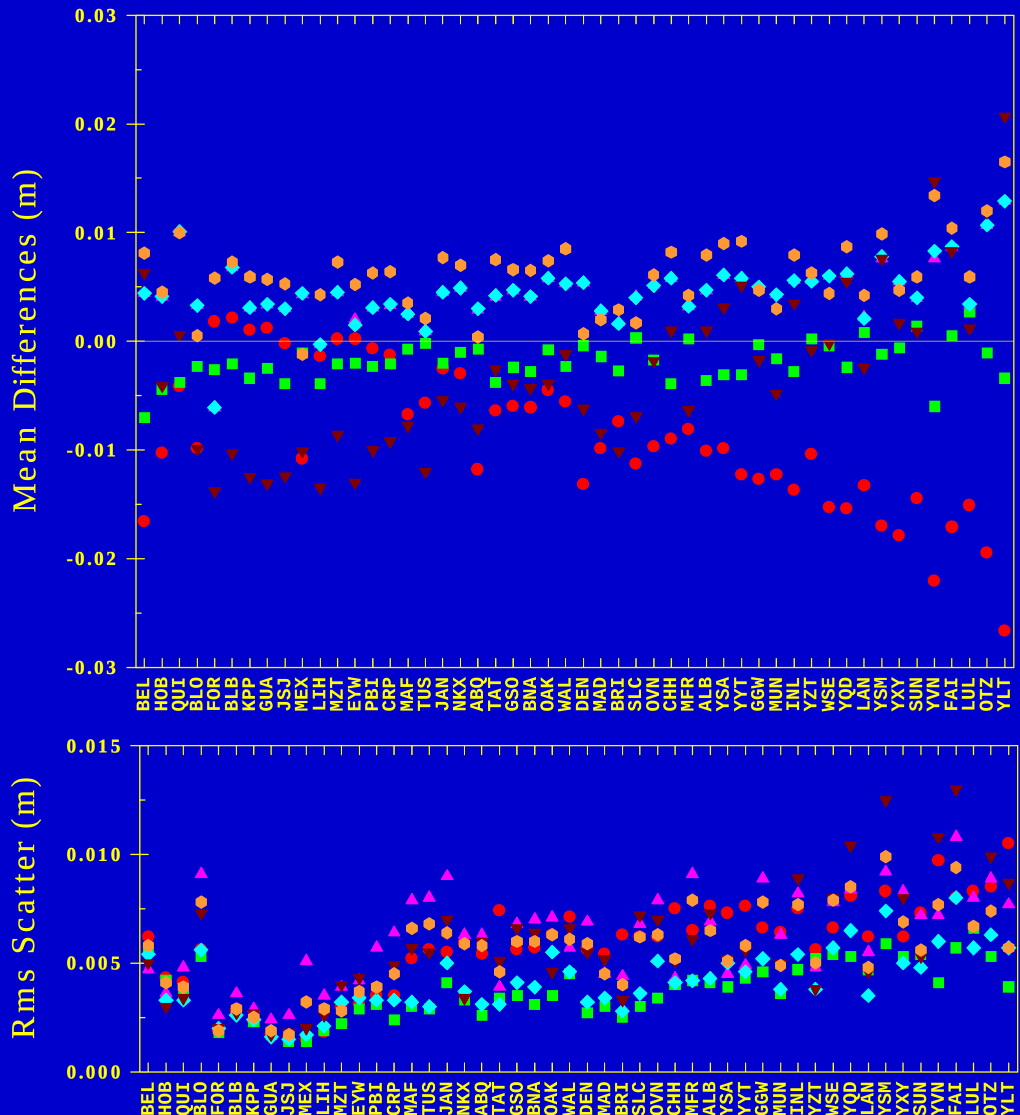


Statistics for UNSW ($\varepsilon = 10°$)

(○=UNSW1, □=UNSW1, Δ=UNSW3)



Statistics for Lanyi (ε = 10°)



Conclusions

- Use of nominal values for temperature profile characterization results in degradation in mapping function performance.
- Use of UNB models for tropopause and lapse rate prediction improves significantly the performance of CfA and UNSW.
- Lanyi behaves statistically better when driven by mean temperature profiles.
- The best solution for Lanyi corresponds to the use of UNB models driven by mean surface temperatures, as it improves the r.m.s. scatter.
- Inversion height information is essential to reduce the bias in Lanyi.