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TU WIEN GEO

Refined and site-augmented tropospheric delay models for GNSS applications

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Troposphere delay modeling

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

- ΔL^z : from IGS
- ΔL_h^z : calculated from p (measured or taken from models)
- ΔL_w^z : calculated via ΔL^z - ΔL_h^z
- mf_h, mf_w : from real-time mapping functions such as VMF1

BUT: Many applications without access to data from NWM or IGS

=> empirical troposphere models

GPT2w

Global Pressure and Temperature 2 wet (Böhm et al., 2015)

Empirical (blind) troposphere model providing:

a_h → mf_h

a_w → mf_w

p → ΔL_h^z

T

e T_m λ

$$\Delta L_w^z = 10^{-6} * \left(k_2' + \frac{k_3}{T_m}\right) * \frac{R_d e}{(\lambda + 1) g_m}$$

formula of Askne and Nordius (1987)

Can we improve the empirical ΔL_w^z by including in situ measured meteorological data?

Augmentation of ΔL_w^z

- no in situ measurements (= empirical only)

$$\Delta L_w^z = L_w^z{}_{GPT2w}$$

- in situ measurement of T:

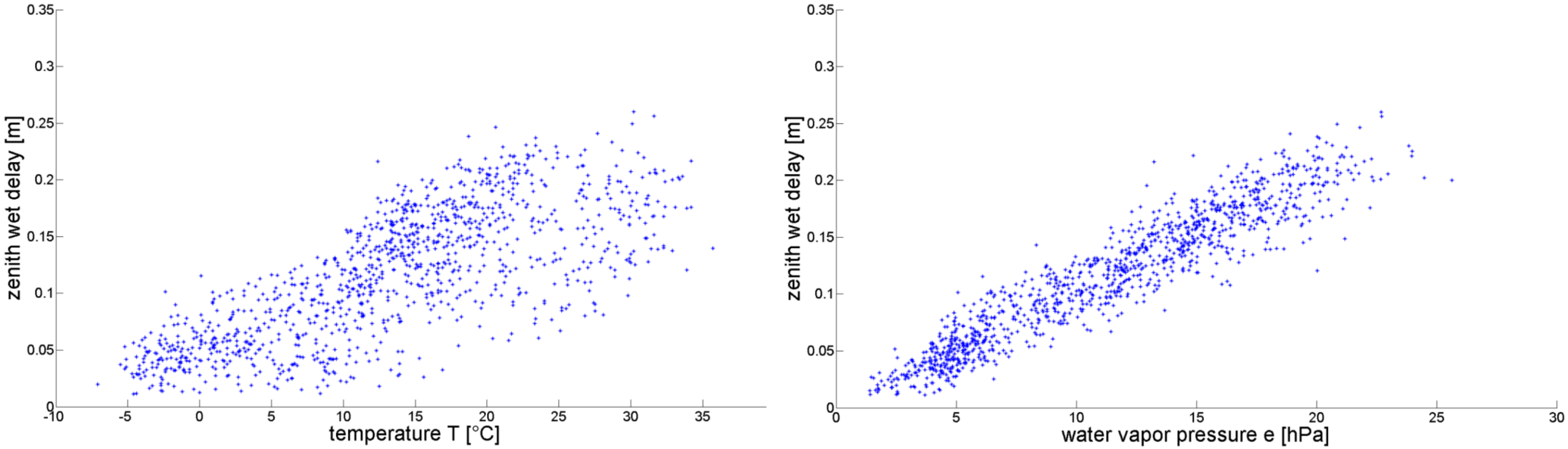
$$\Delta L_w^z = L_w^z{}_{GPT2w} + M * (T_{GNSS} - T_{GPT2w})$$

- in situ measurement of T and e:

a.) $$\Delta L_w^z = L_w^z{}_{GPT2w} + M_1 * (T_{GNSS} - T_{GPT2w}) + M_2 * (e_{GNSS} - e_{GPT2w})$$

b.) $$\Delta L_w^z = 10^{-6} * \left(k_2' + \frac{k_3}{T_m{}_{GPT2w}}\right) * \frac{R_d e}{(\lambda_{GPT2w} + 1) g_m}$$

Augmentation of ΔL_w^z



Correlation plots for BZRG

Overall correlations:
T with ΔL_w^z : 0.65
e with ΔL_w^z : 0.85

Universal, global coefficients M1, M2:
M1 = **5*10^{-4}** [m/°C^{-1}]
M2 = **0.0092** [m/hPa^{-1}]

If user measures T and e => improve ΔL_w^z :

$$\Delta L_w^z = L_{w\,GPT2w}^z + M_1 * (T_{GNSS} - T_{GPT2w}) + M_2 * (e_{GNSS} - e_{GPT2w})$$

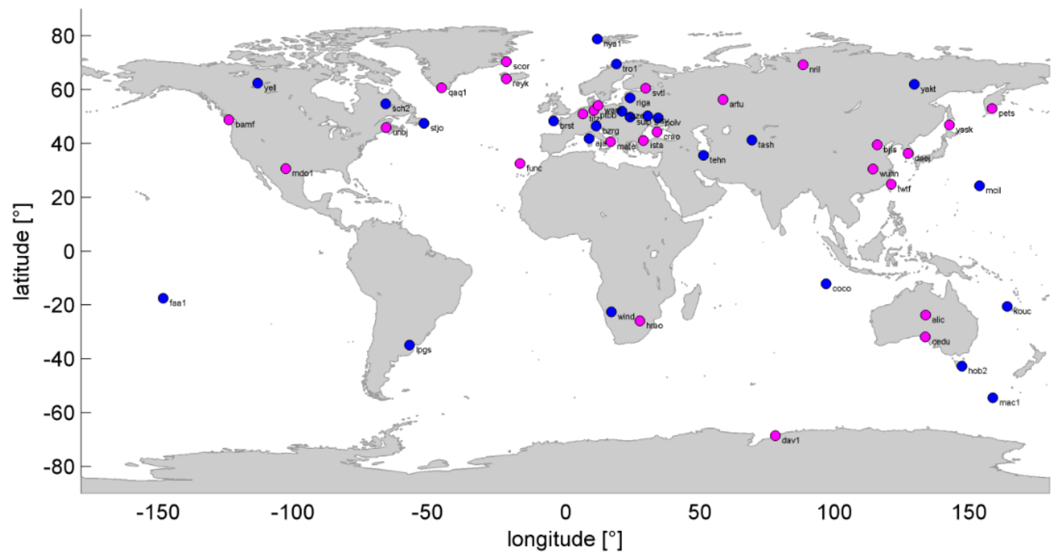
Data

GNSS Data:
- 55 globally distributed IGS stations
- 4 epochs per day in 2013
- zenith total delay (ΔL^z) from IGS final tropospheric SNX-TROPO

Meteo Data:

p, T, e from

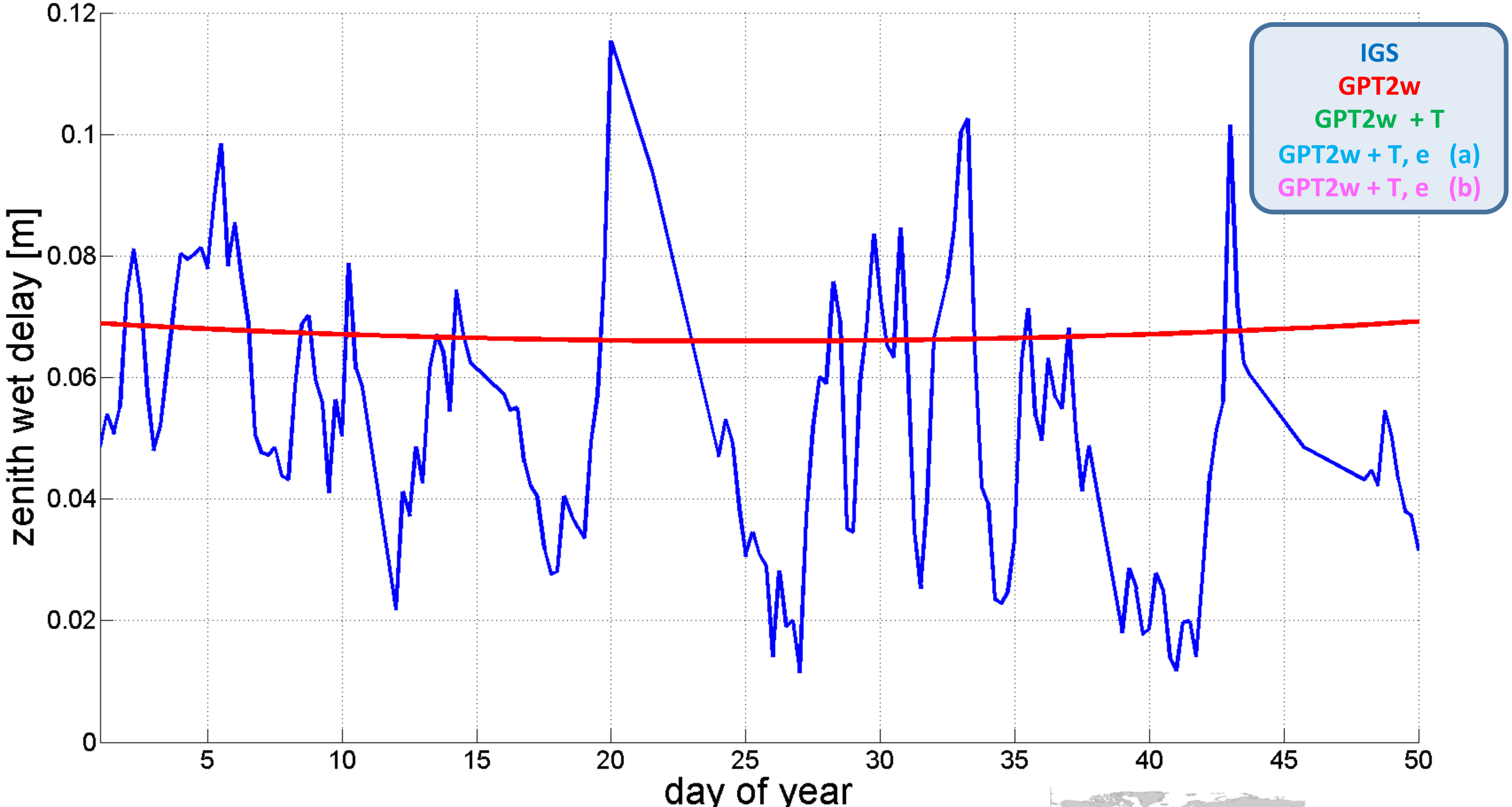
1) close-by weather stations (provided by ZAMG, blue dots)
   - max. 10km ↔ and 100m ↕ away
   - high quality
2) in-situ measurements (provided by IGS, pink dots)
   - moderate quality



p → Extrapolation / Saastamoinen → ΔL_h^z

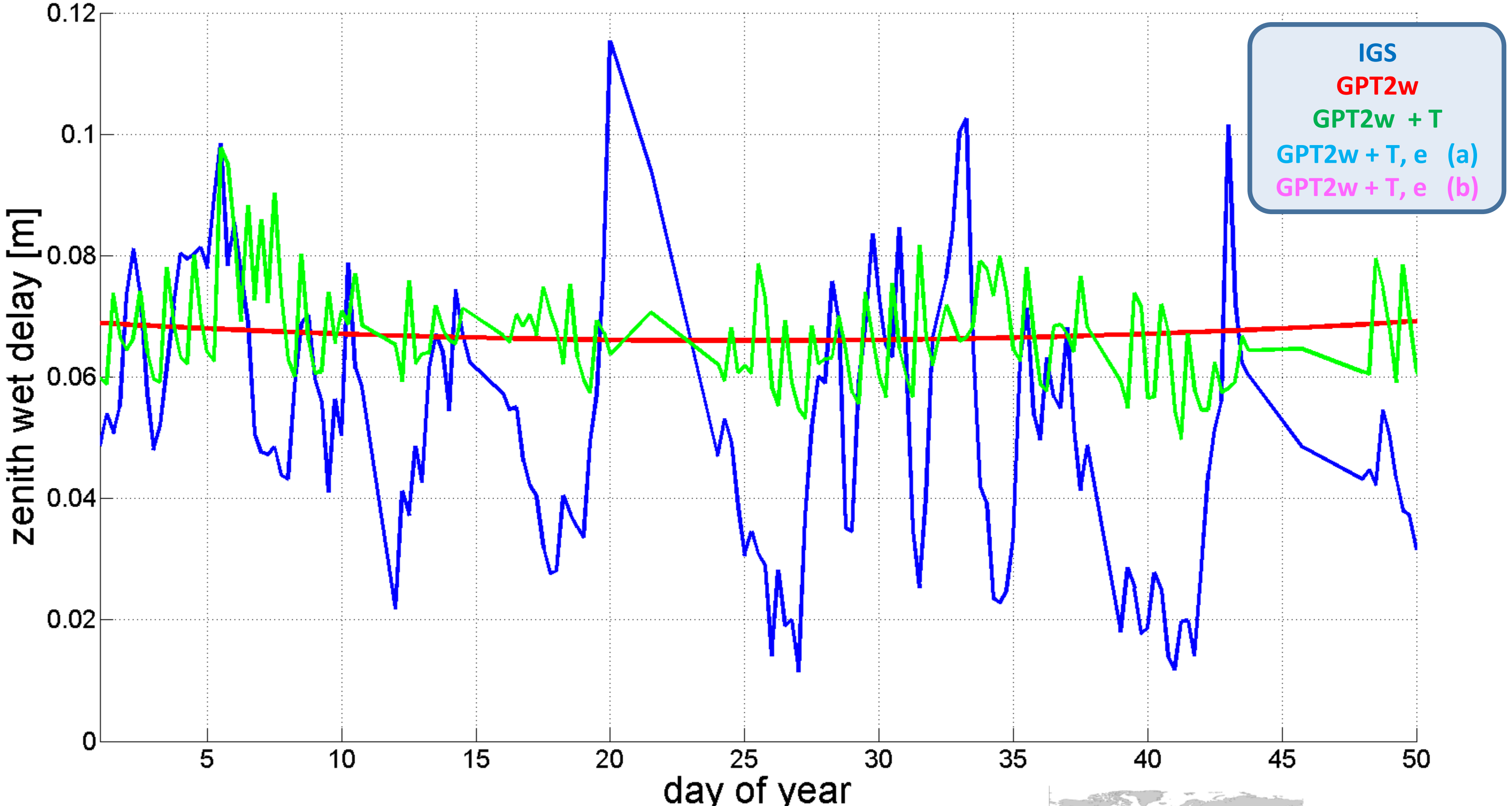
$\Delta L_w^z = \Delta L^z - \Delta L_h^z$ => Considered as „true“ values

Results



Comparison of ΔL_w^z for **BZRG**

Results



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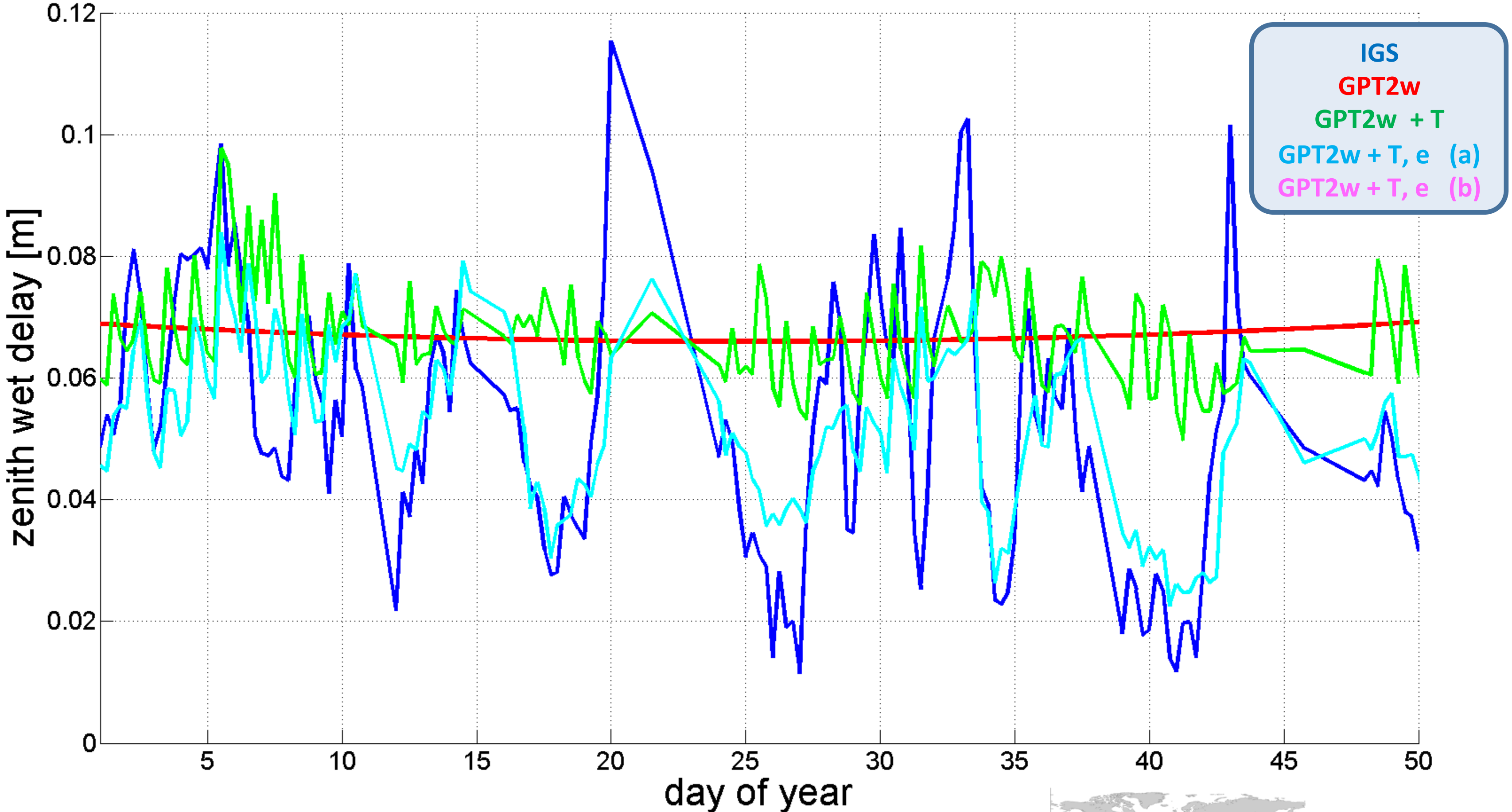
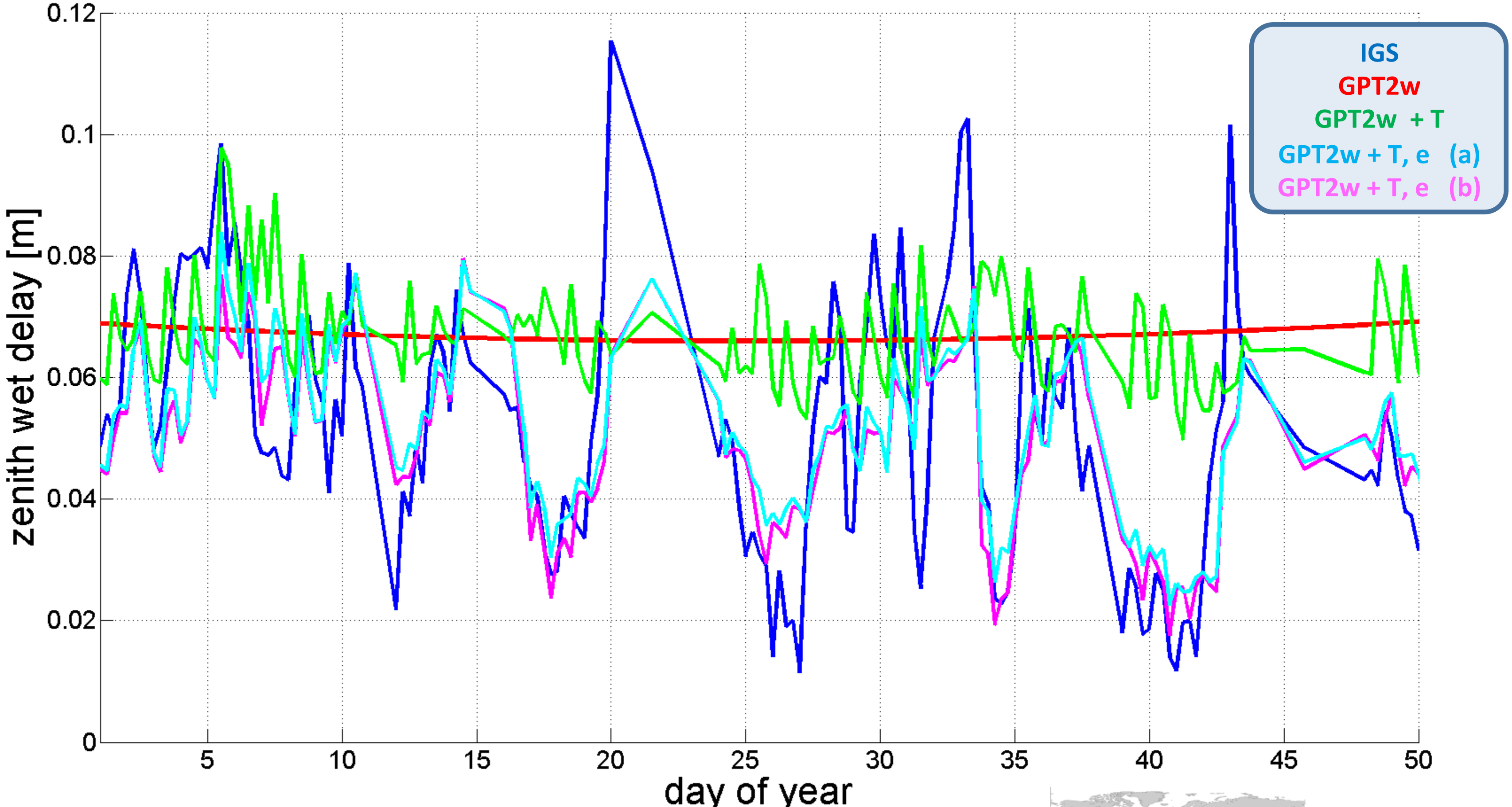


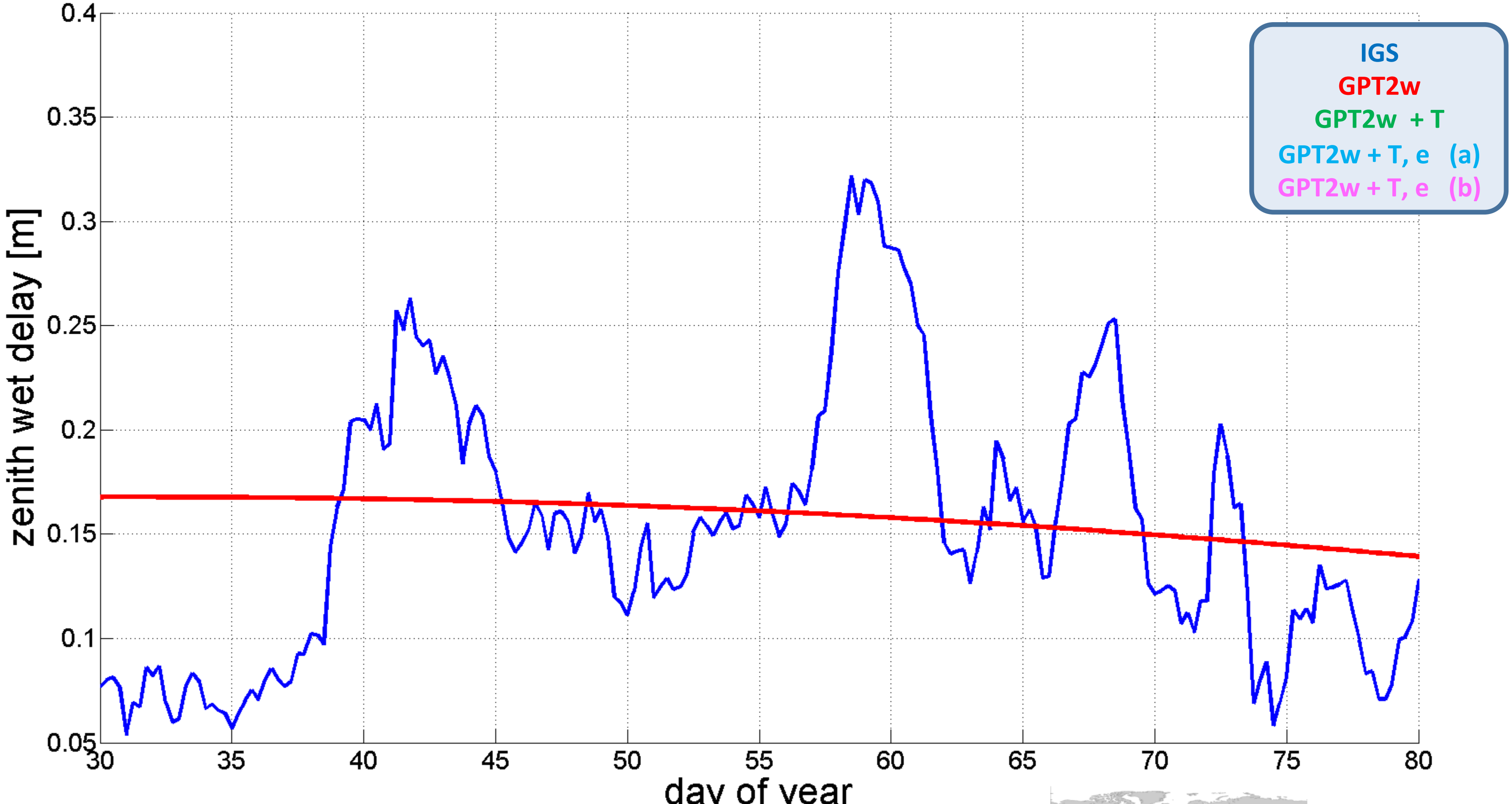
Comparison of ΔL_w^z for **BZRG**

Results



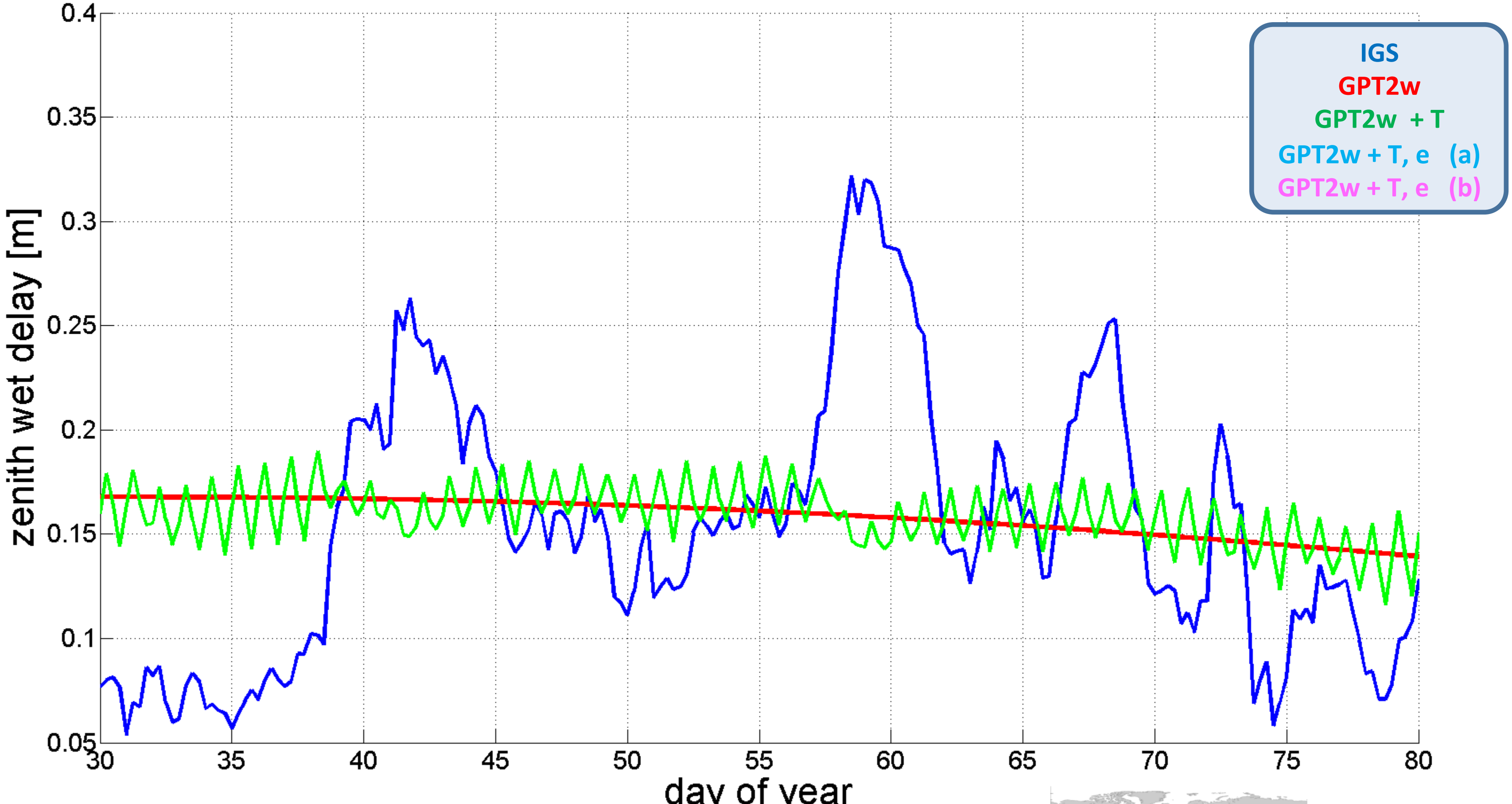
Comparison of ΔL_w^z for **BZRG**

Results



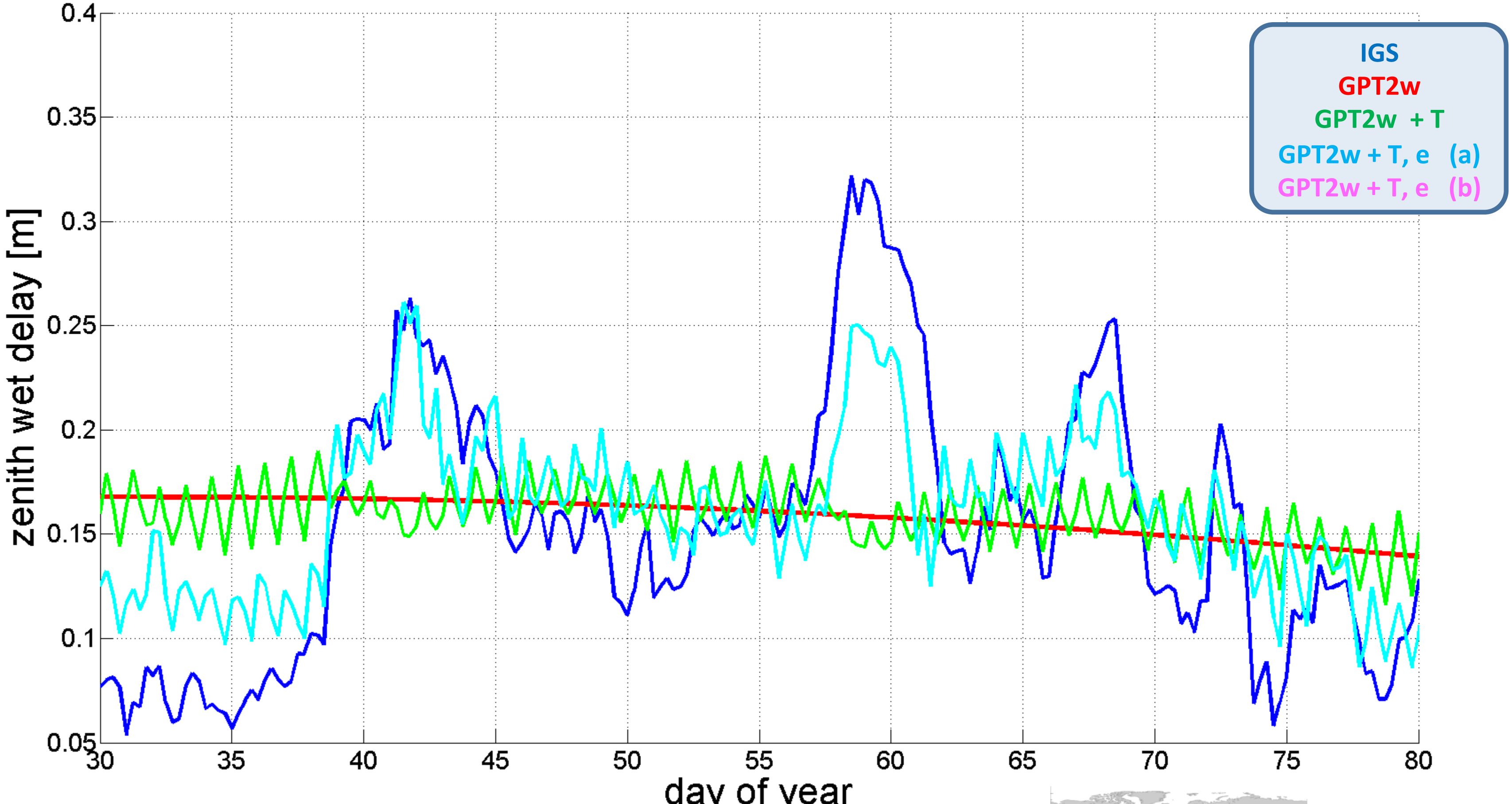
Comparison of ΔL_w^z for **ALIC**

Results



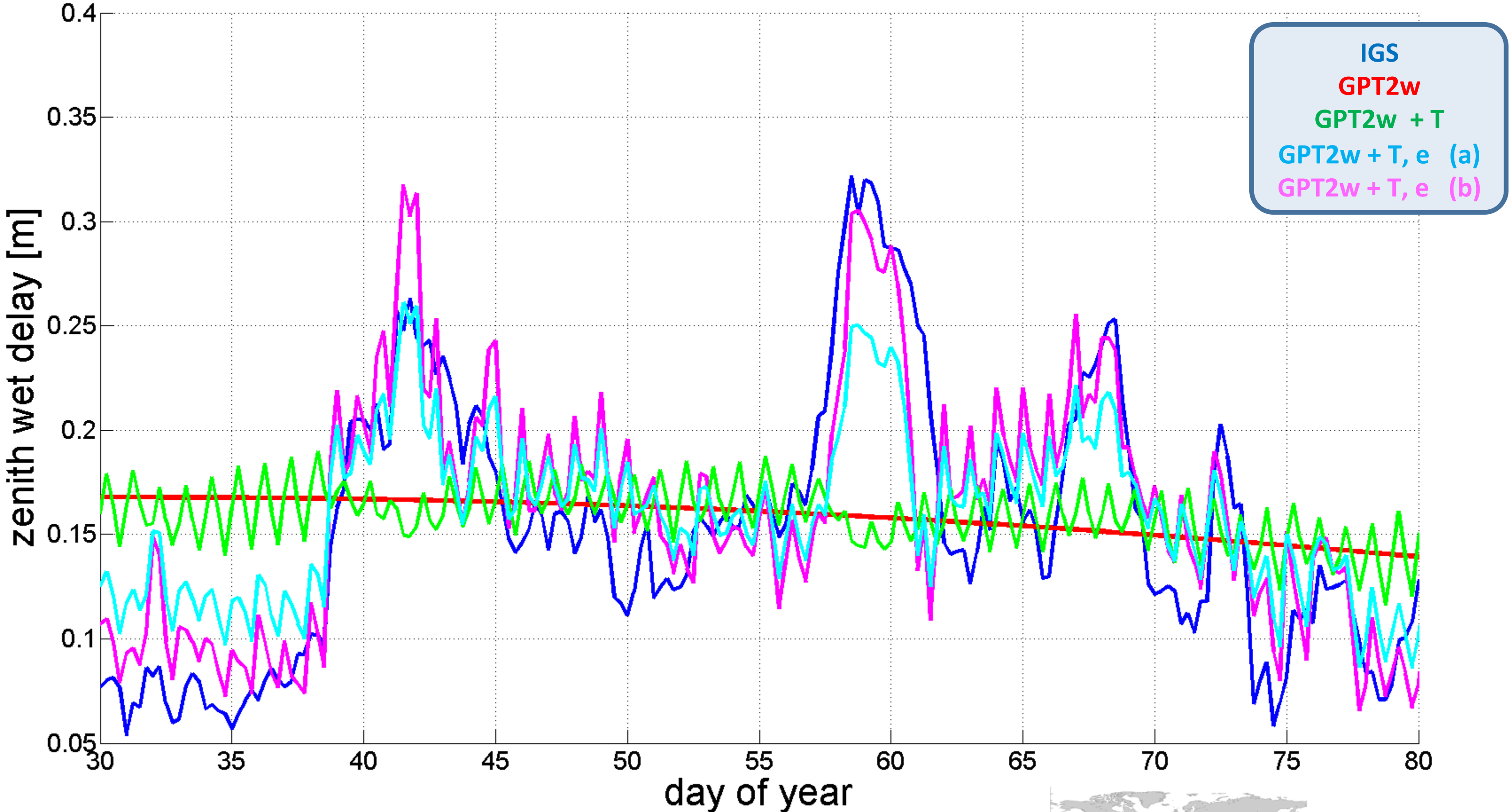
Comparison of ΔL_w^z for **ALIC**

Results



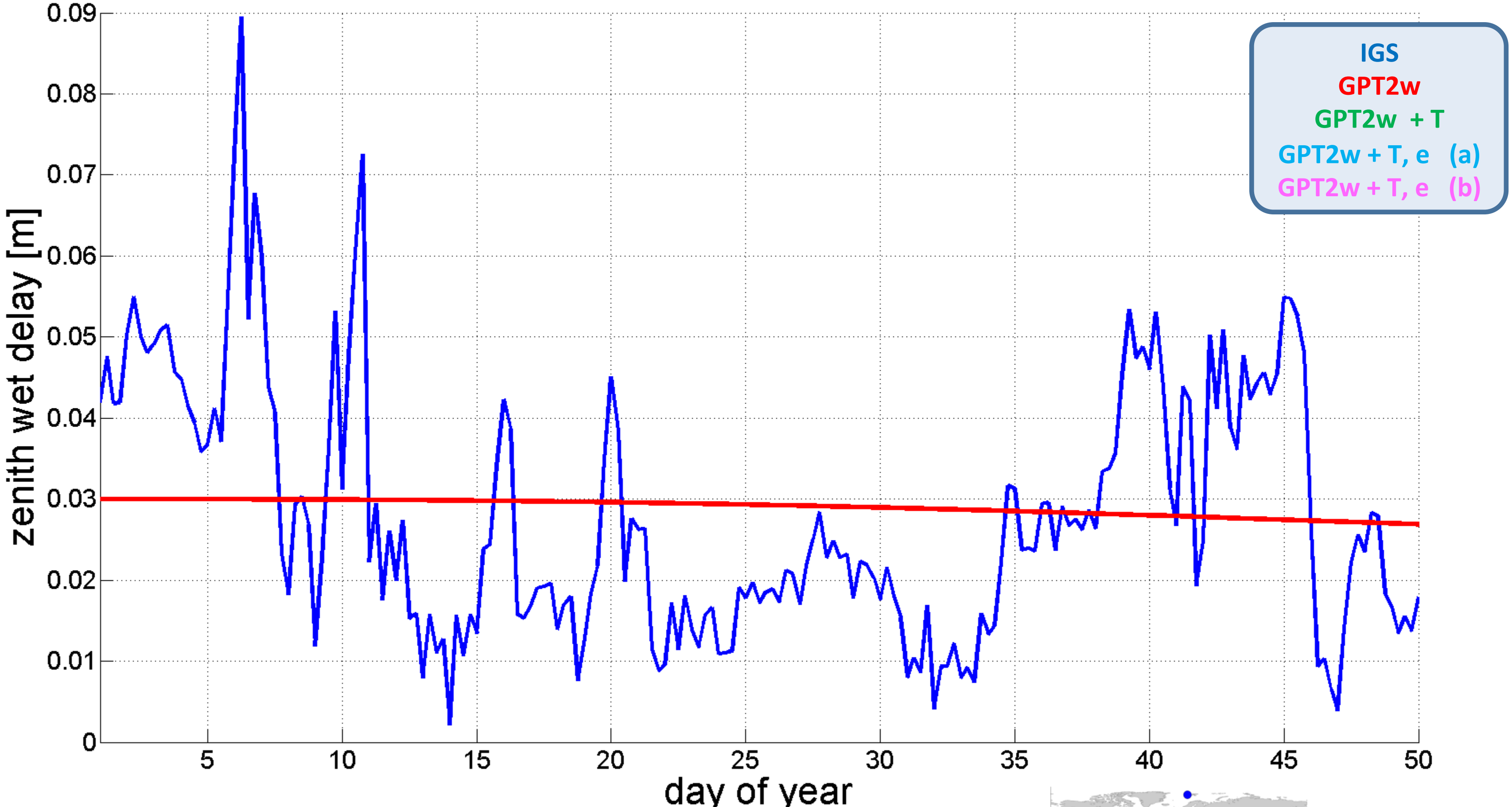
Comparison of ΔL_w^z for **ALIC**

Results



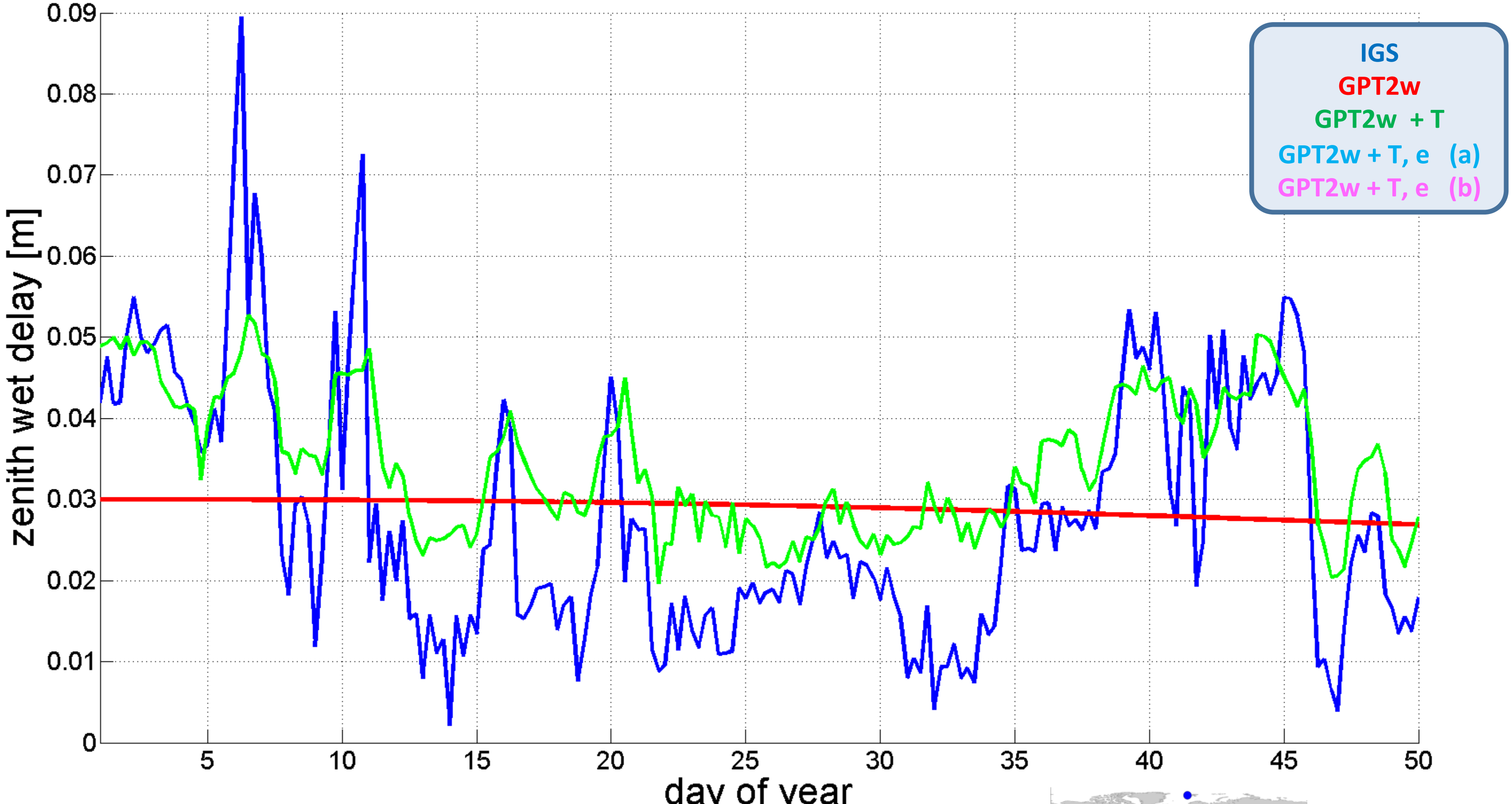
Comparison of ΔL_w^z for **ALIC**

Results



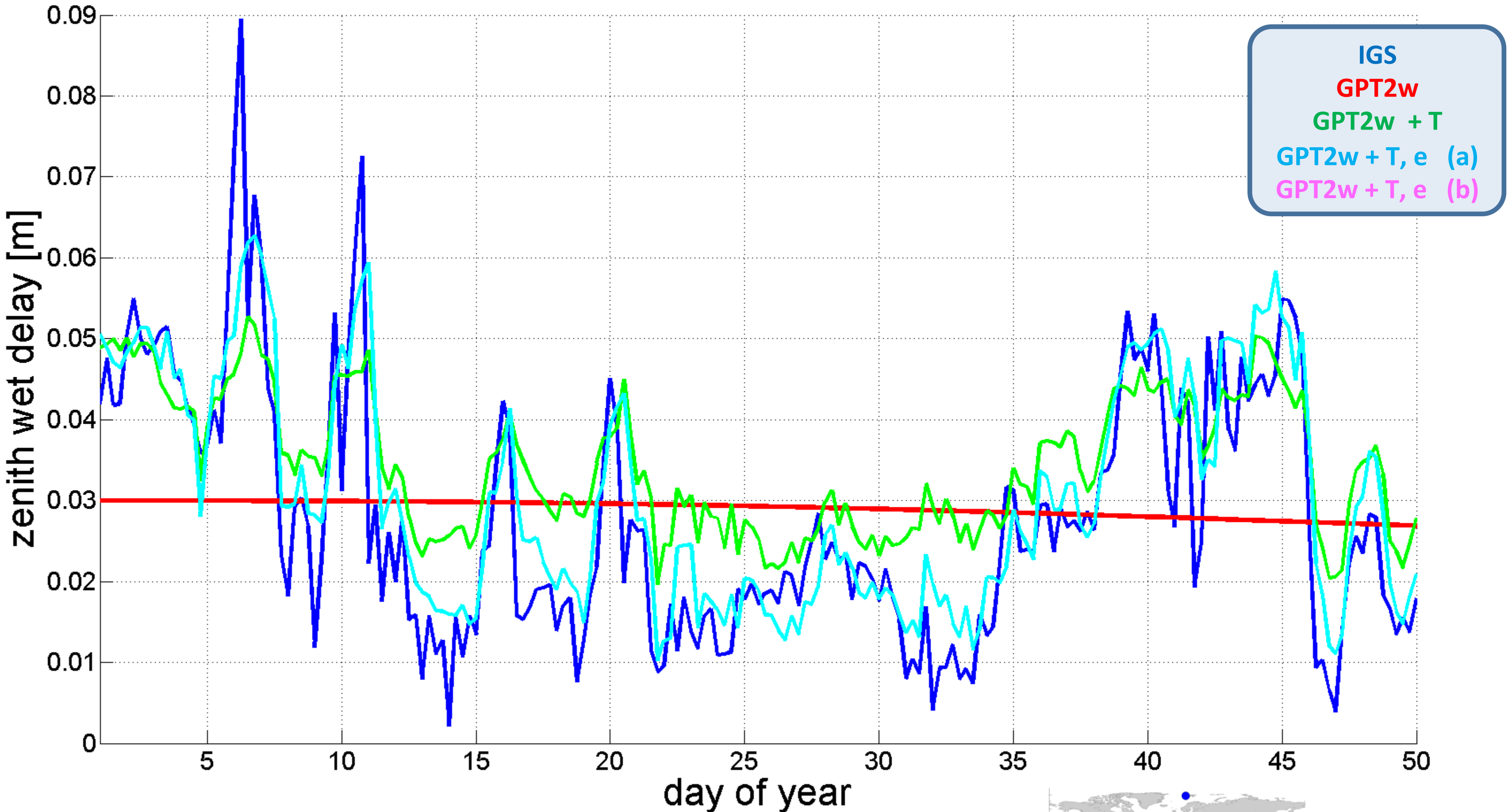
Comparison of ΔL_w^z for **NYA1**

Results



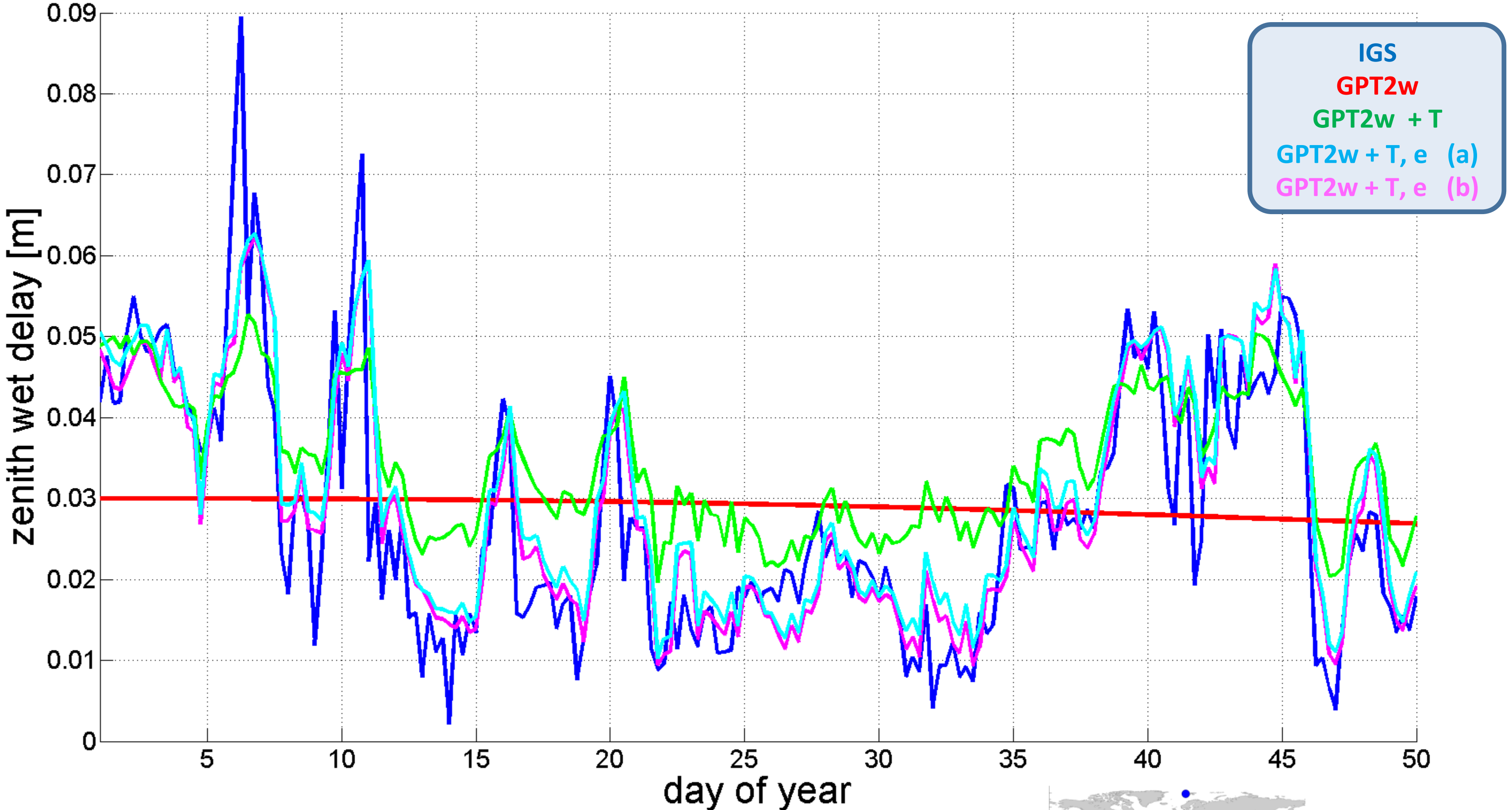
Comparison of ΔL_w^z for **NYA1**

Results



Comparison of ΔL_w^z for **NYA1**

Results



Comparison of ΔL_w^z for **NYA1**

Results

Comparison of "true" ΔL_w^z from IGS with reproduced ΔL_w^z :

- Mean absolute difference in ΔL_w^z (averaged over all stations and epochs)

	ΔL_w^z [cm] (1)	ΔL_w^z [cm] (2)
empirical only (= GPT2w)	2.8	2.8
empirical + T	2.7	2.6
empirical + T and e (a)	2.0	2.1
empirical + T and e (b)	2.0	2.1

$$(1) = mean(|\Delta L^z_{w\,IGS} - \Delta L^z_{w\,GPT2w}|)$$

$$= mean\left(|\Delta L^z_{w\,IGS} - \Delta L^z_{w\,GPT2w_{MOD}(2)}|\right)$$

$$= mean\left(|\Delta L^z_{w\,IGS} - \Delta L^z_{w\,GPT2w_{MOD}(3a)}|\right)$$

$$= mean\left(|\Delta L^z_{w\,IGS} - \Delta L^z_{w\,GPT2w_{MOD}(3b)}|\right)$$

- Correlation coefficient (averaged over all stations and epochs)

	Corr. Coeff. (a)	Corr. Coeff. (b)
empirical only (= GPT2w)	0.70	0.73
empirical + T	0.73	0.76
empirical + T and e (a)	0.86	0.86
empirical + T and e (b)	0.86	0.86

Conclusions

- GPT2w well suited for site-augmented approach using in situ measurements of T and e
- in situ measurement of T yields small improvement in zenith wet delay ΔL_w^z (~5%)
- additional in situ measurement of e yields significant improvement in zenith wet delay ΔL_w^z (~30%)
  => not much difference which formula is used for e
- In general, best performance of site-augmented GPT2w is achieved in dry regions

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