The effect of the second order GPS ionospheric correction on receiver positions

Sharon Kedar, George Hajj, ***Brian Wilson***, Mike Heflin

Jet Propulsion Laboratory

California Institute of Technology

Kedar, S. , G. A. Hajj, B. D. Wilson, and M. B. Heflin, The effect of the second order GPS ionospheric correction on receiver positions, ***Geophys. Res. Lett***., VOL. 30, NO. 16, 2003.

Bassiri, S., and G. A. Hajj, Higher-order ionospheric effects on the global positioning systems observables and means of modeling them, ***Manuscripta Geodetica***, 18, 280– 289, 1993.

Observables

$$P_i = \rho + \frac{q}{f_i^2} + \frac{s}{f_i^3} + \ldots$$

$$L_i = \rho + n_i\lambda_i + \frac{q}{f_i^2} - \frac{1}{2}\frac{s}{f_i^3} + \ldots$$

ρ = pseudorange (+receiver clock +wet troposphere delay)

f_i = carrier frequency (f_1 = 1.575Ghz; f_2 = 1.227Ghz)

λ_i = carrier wavelength (λ_1 = 19.0cm; λ_2 = 24.4cm)

$$q = 40.3 \times TEC$$

$$TEC = \int_L N \cdot dl$$

$TEC =$ Total electron content

$N =$ Ionospheric electron density

$L =$ GPS signal path

Faraday Rotation

$$s = \int f_g \cdot f_p^2 \cdot \cos\theta_B dl = 7527 \cdot c \int N \cdot B_0 \cos\theta_B dl$$

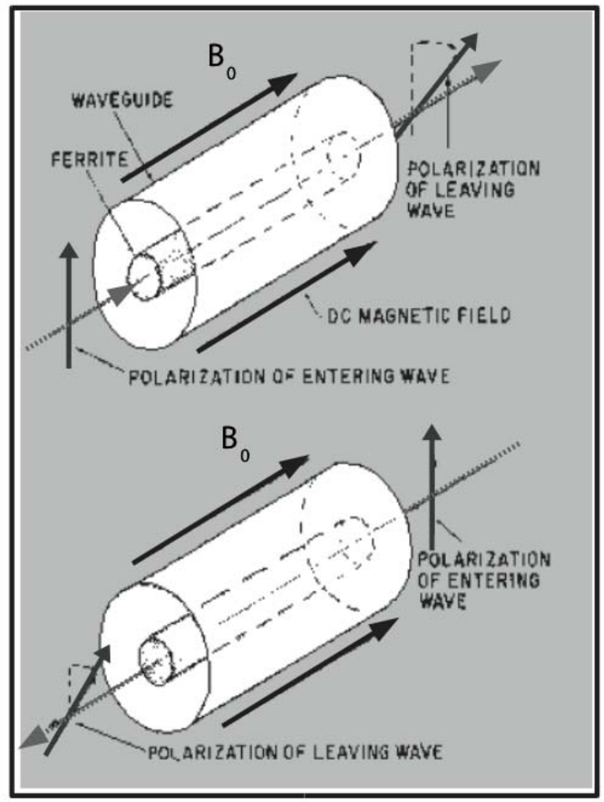
f_p = plasma frequency

f_g = gyro frequency

B_0 = Earth's magnetic field

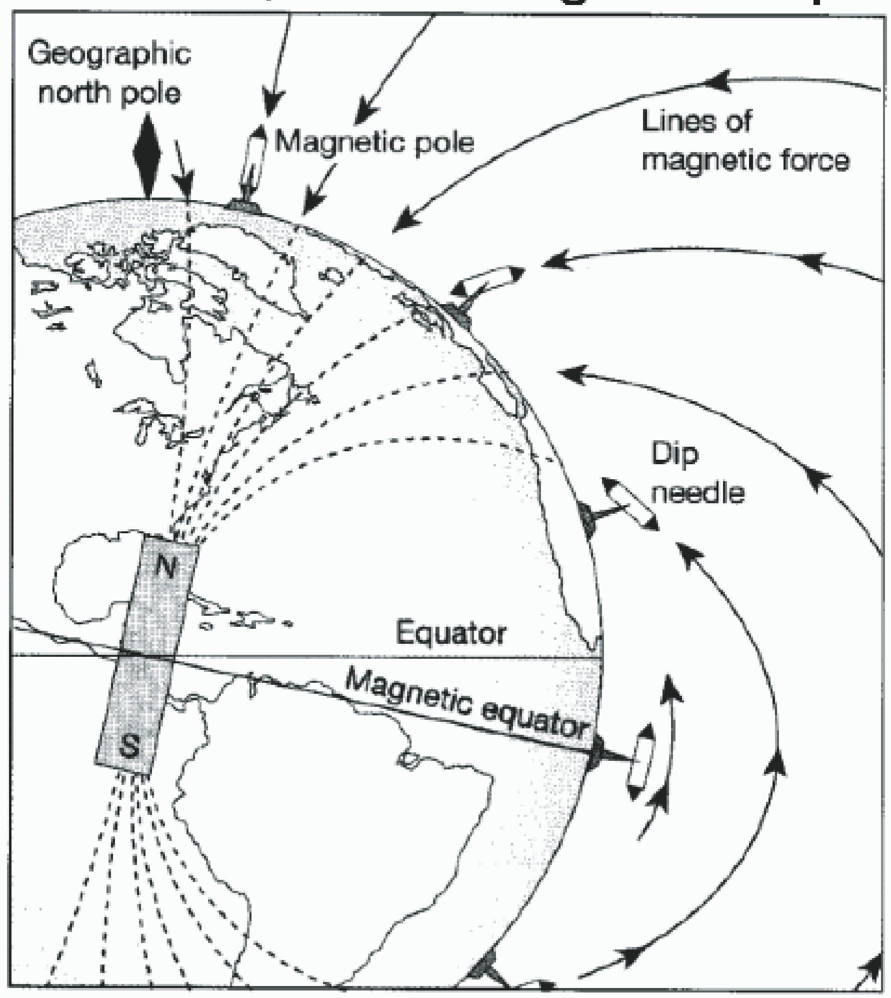
θ_B = angle between signal propagation vector and magnetic field

c = speed of light

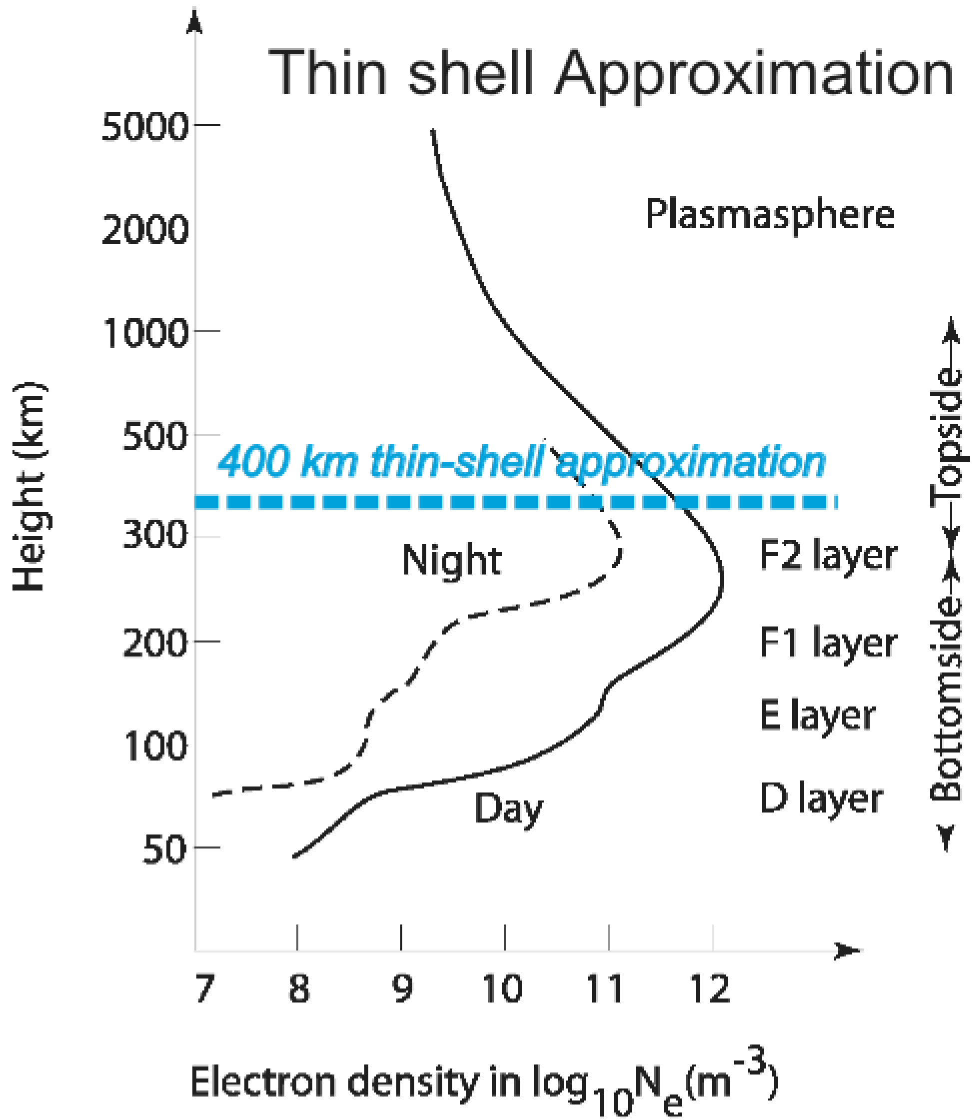


Approximations (I)

Co-centric, tilted magnetic dipole

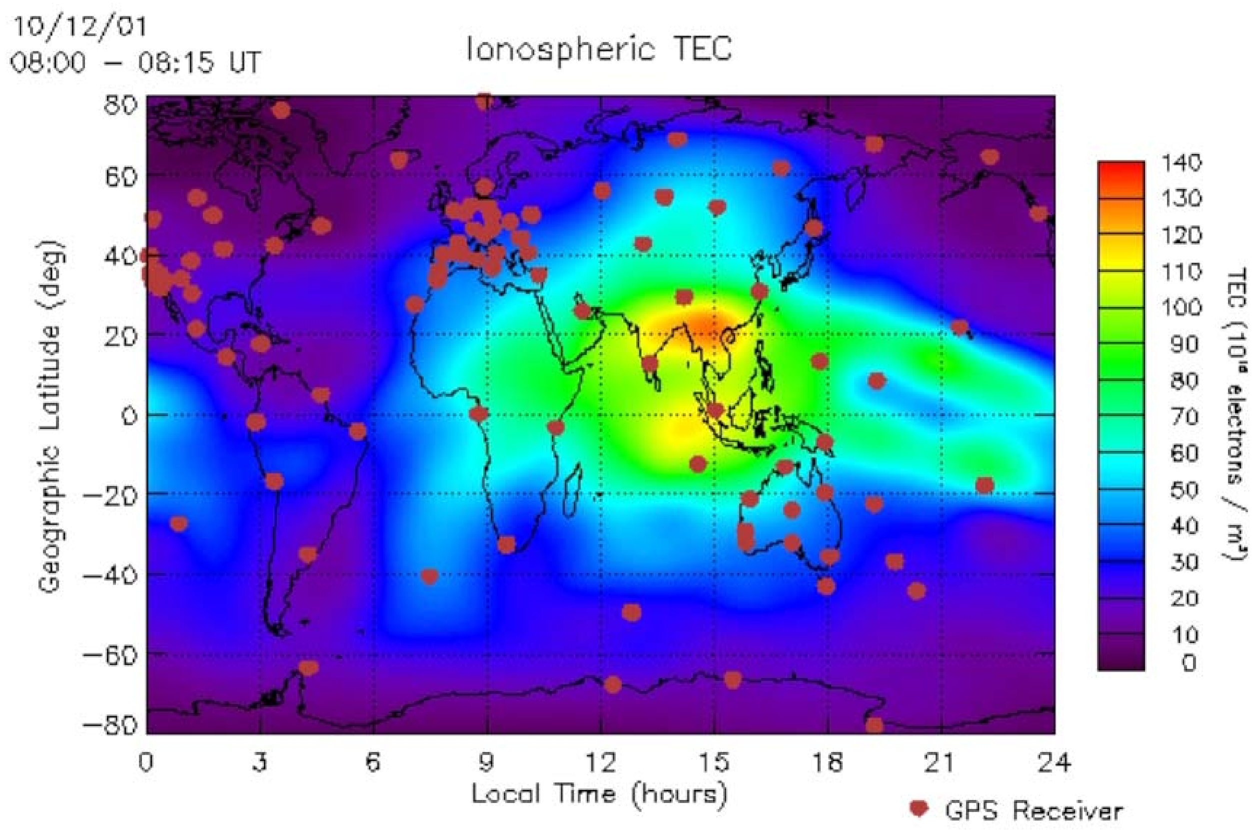


Approximations (II)

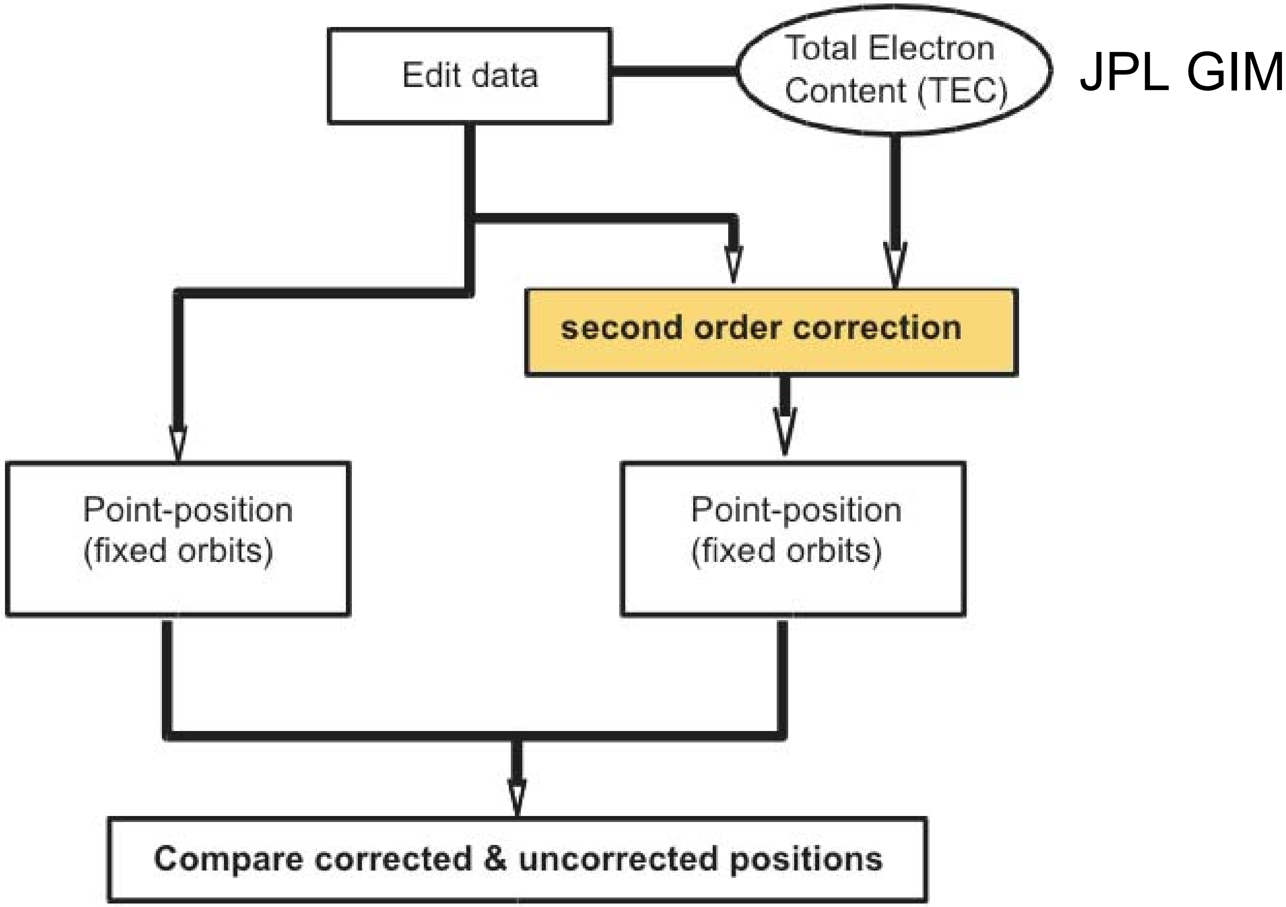


Calculation (I)

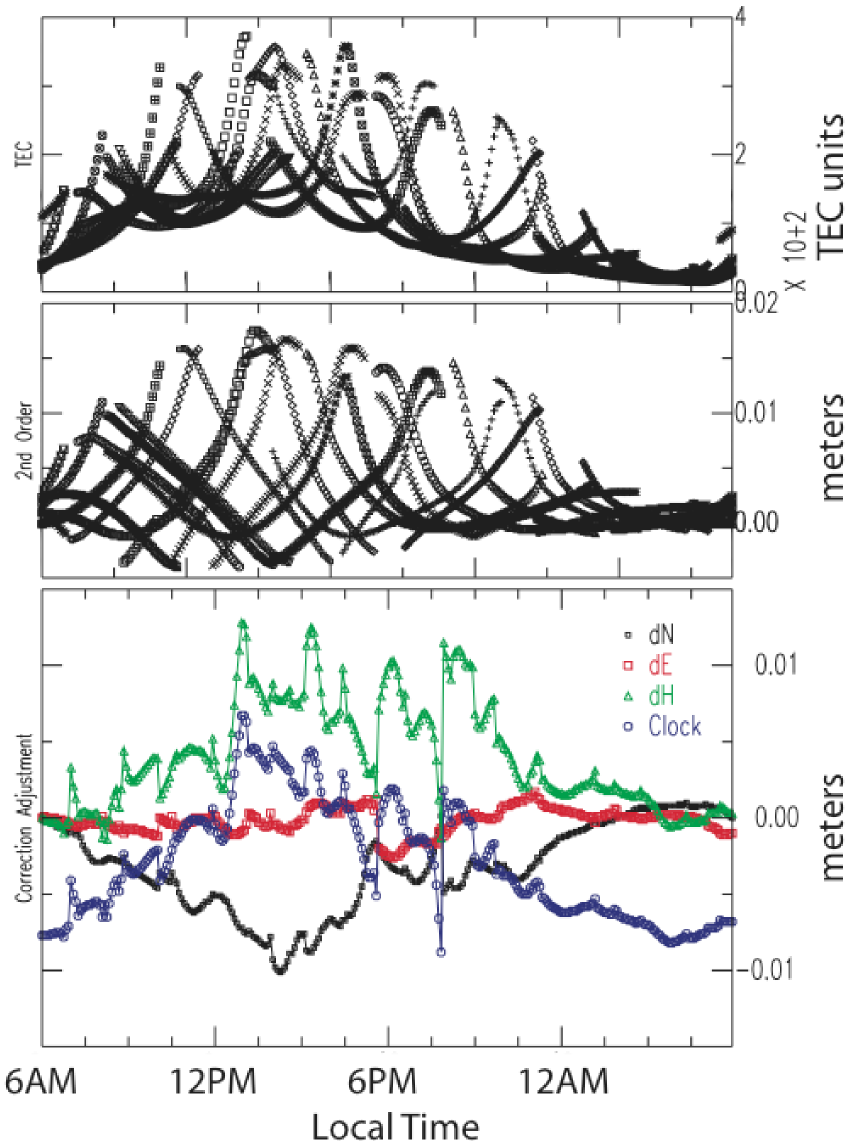
Typical geographical and temporal distribution of TEC



Calculation (II)



Diurnal Variation



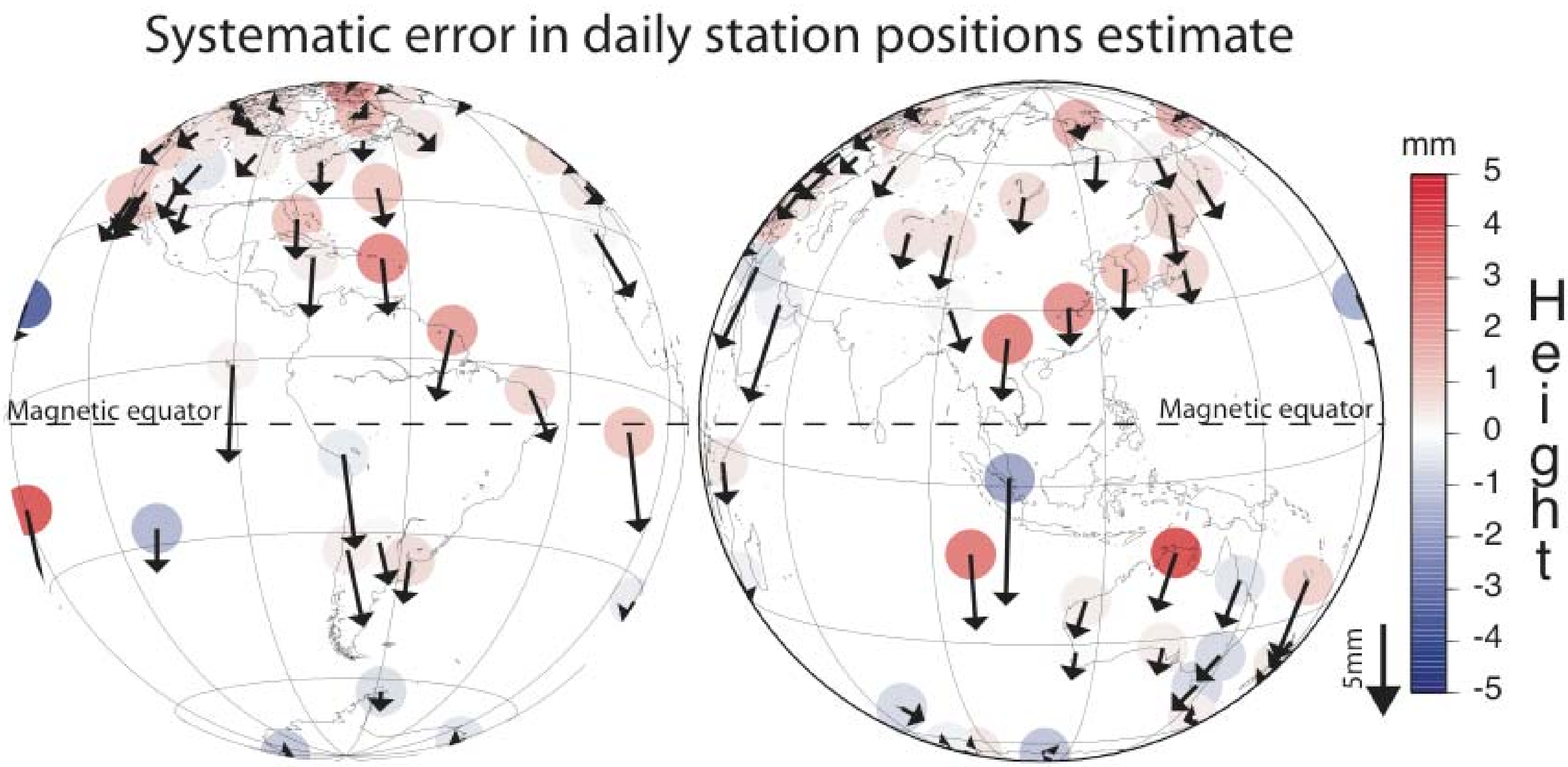
- Slant TEC values, 2nd-order ionospheric correction (to LC), and station position & clock correction at COCO (W. Australia, lat: 12.19), estimated every 5 minutes during April 2, 2000.

- Note strong correlation between station height correction dH and station clock correction d(Clock).

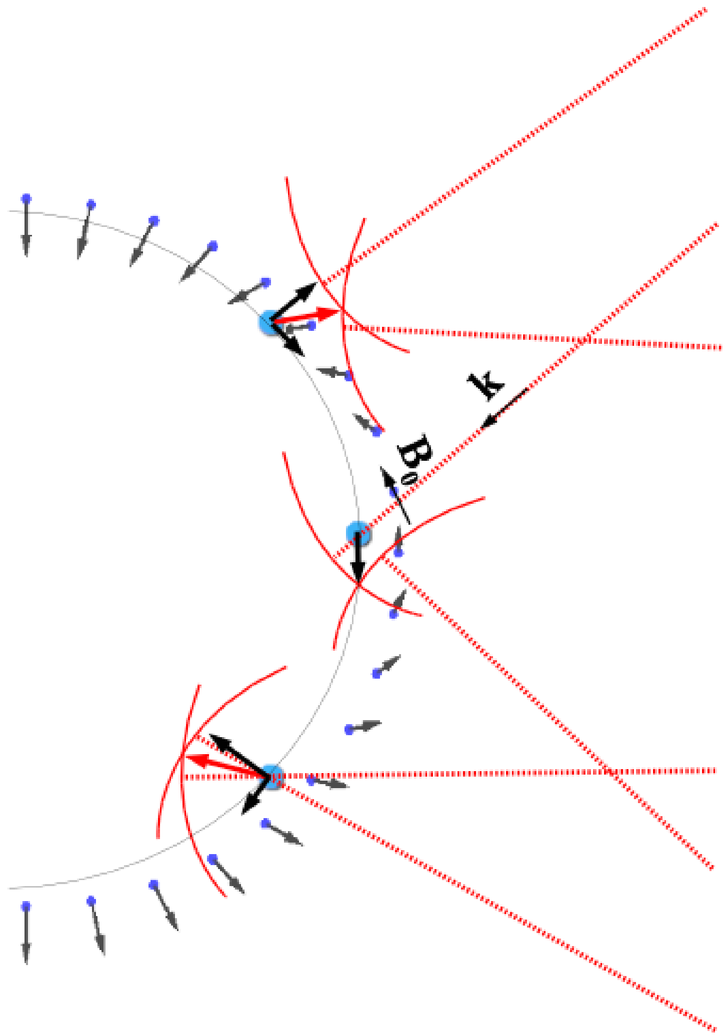
- dN < 0 (southward), dE = 0.

- Change in station latitude as much as 1 cm at peak TEC time.

Effect on station positions

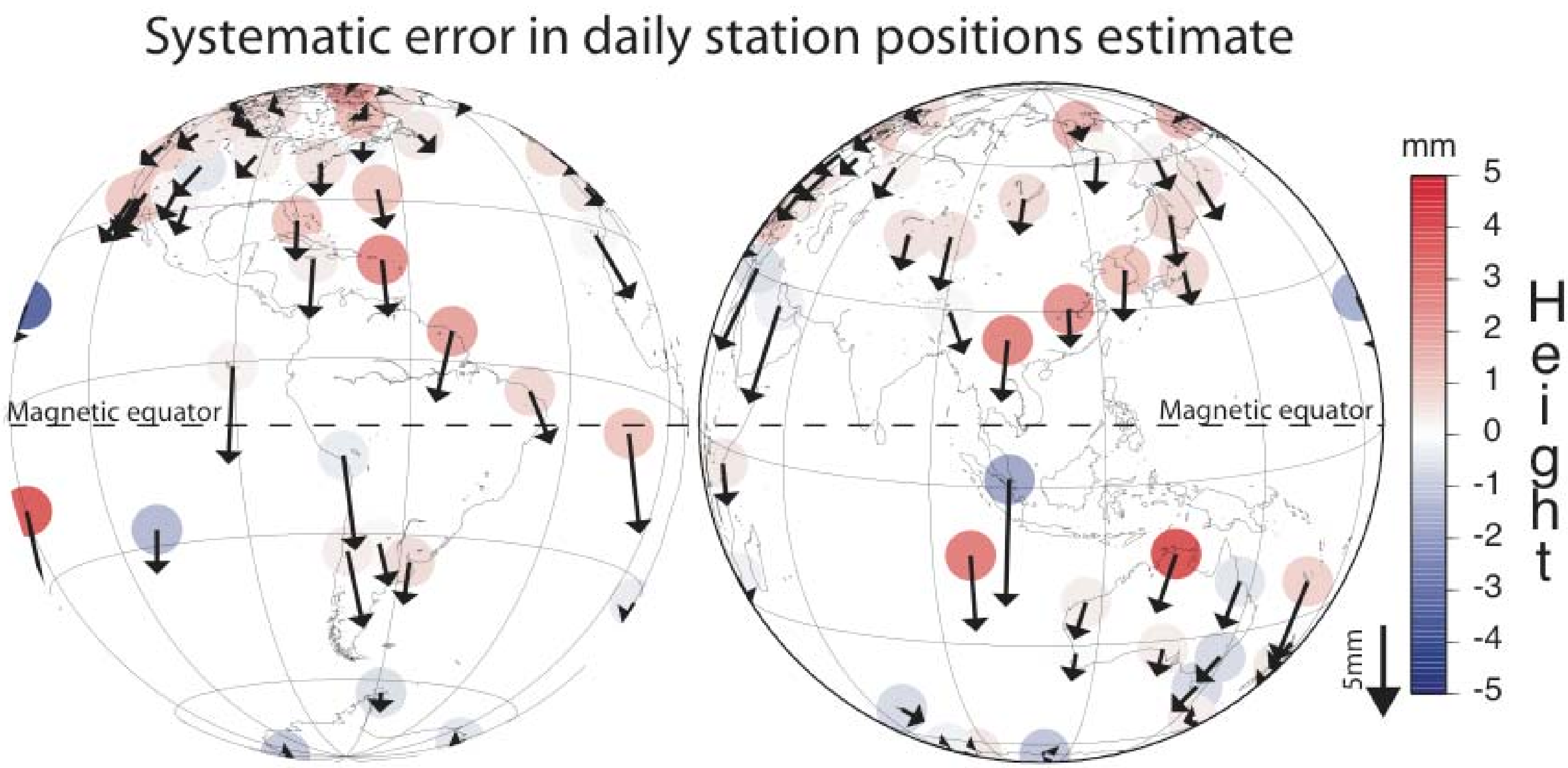


Interpretation

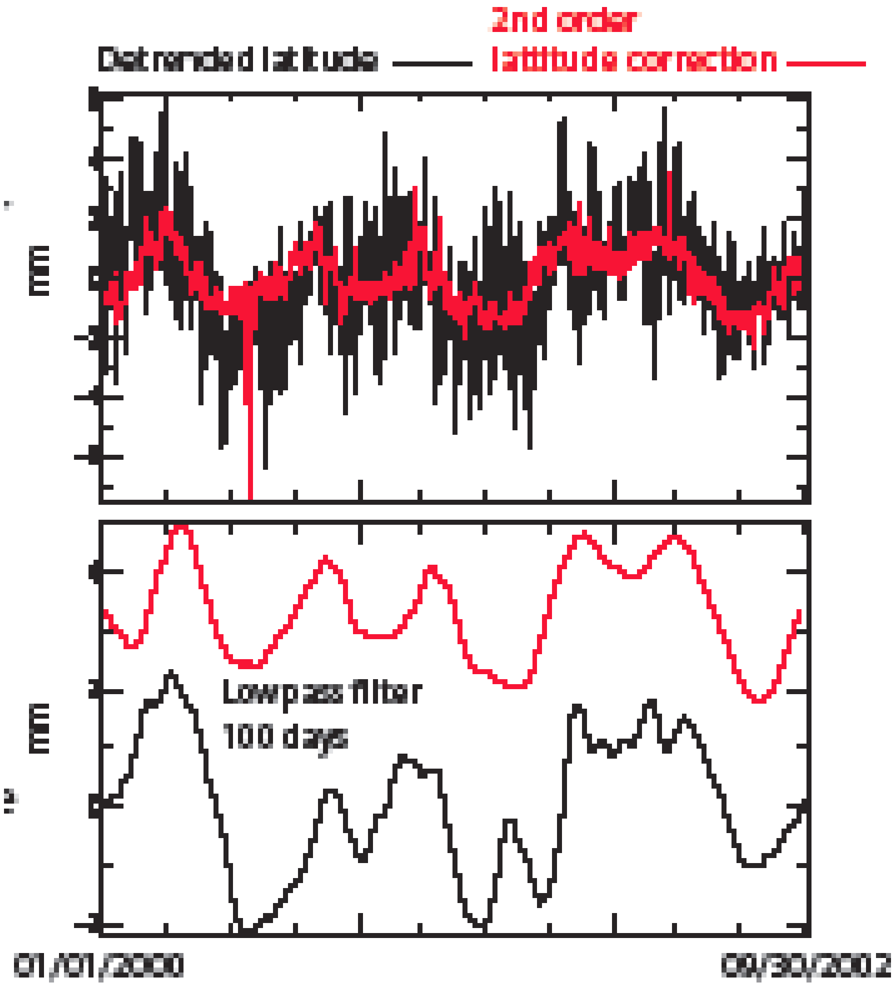


- Station position derived from phase range depicted by the intersection of two range arcs.
- **k** parallel to the magnetic field **B0** implies **LC** phase range is delayed. **k** anti-parallel to **B0** implies opposite.
- Not accounting for 2nd-order term when parallel (anti-) implies actual range is over (under) estimated.
- Geometrical intersection of corrected phase ranges shift station position accordingly.
- Position correction (red) is projected onto radial and horizontal planes.

Effect on station positions



Seasonal variation



- Compare time series of archived station positions to 2nd-order corrected positions.
- Average over 3 mag. equatorial sites (BAHR, COCO, GALA) to reduce non-coherent variations (multipath, tropo).
- When a linear trend removed, correlation between positions and correction observed.
- Semiannual cycle corresponds to high TEC values at equinox.
- Correlation indicates significant portion of semiannual latitude variation is due to imperfect elimination of the ionospheric effects.

Conclusions

- The effect of the 2nd-order ionospheric term is likely to improve global receiver positions repeatability.
- Not correcting for 2nd-order ionospheric effect introduces a seasonal variation of several mm into station positions.
- The 2nd-order correction may provide an explanation for small biases in GPS-derived geo-center estimate.
  - 3 mm Z-component bias relative to SLR & VLBI
  - 4 mm relative to ITRF2000
- A diurnal variation in station latitude and height of the order of 1 cm is introduced into the kinematic station position, if the 2nd-order correction is not applied.

Future Work

- Quantify the effects of the 2nd-order ionospheric on GPS orbit estimation.
- Introduce of a more accurate model of the Earth' magnetic field (such as the International Geomagnetic Reference Field).
- Use an ionospheric model which takes into account the vertical spread of ionospheric density with altitude.
- Incorporate the 2nd-order correction into GIPSY.
- References:

Kedar, S. , G. A. Hajj, B. D. Wilson, and M. B. Heflin, The effect of the second order GPS ionospheric correction on receiver positions, *Geophys. Res. Lett.*, VOL. 30, NO. 16, 2003.

Bassiri, S., and G. A. Hajj, Higher-order ionospheric effects on the global positioning systems observables and means of modeling them, *Manuscripta Geodetica*, 18, 280– 289, 1993.