A priori gradients in the analysis of space geodetic observations

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Session 2 - Strengths, weaknesses, modeling standards and processing strategies of space geodetic techniques

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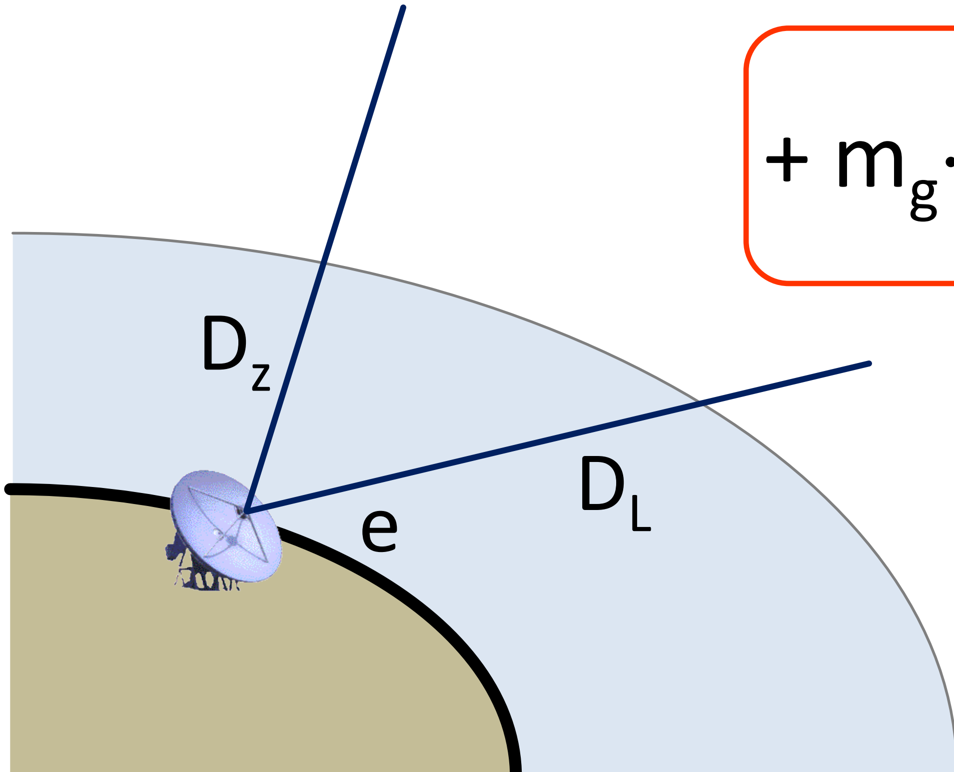
IERS Conventions

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

$$+ m_g \cdot [G_N \cdot \cos(a) + G_E \cdot \sin(a)]$$

gradients



Gradient mapping function

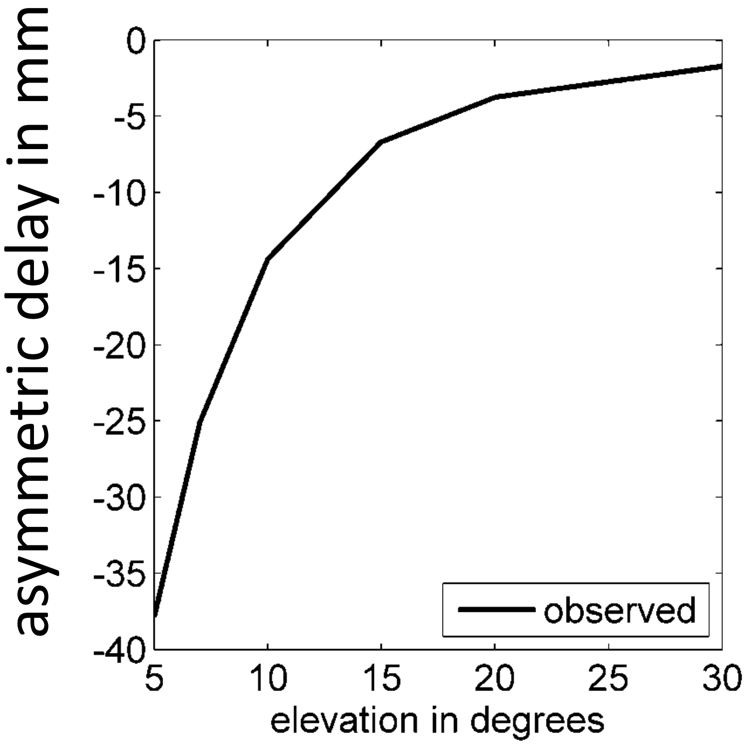
- MacMillan 1995
  - goes back to Davis et al. 1993 (“wet refractivity”)
  - **$\cot(e)\cdot mf_h(e)$** (←singularity at horizon)

- Chen and Herring 1997
  - **$1/(\tan(e)\cdot\sin(e) + C)$** **C = 0.0032**

	hydrostatic	*wet*
C	0.0031	0.0007
H	13 km	3 km

Examples with ray-traced delays

Wettzell, 1 January 2008
azimuth = 90°



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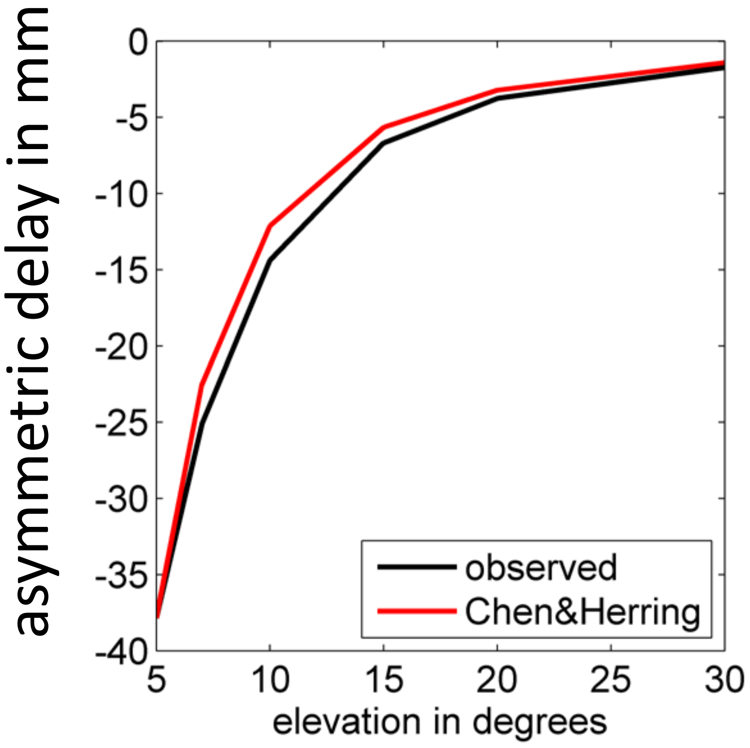

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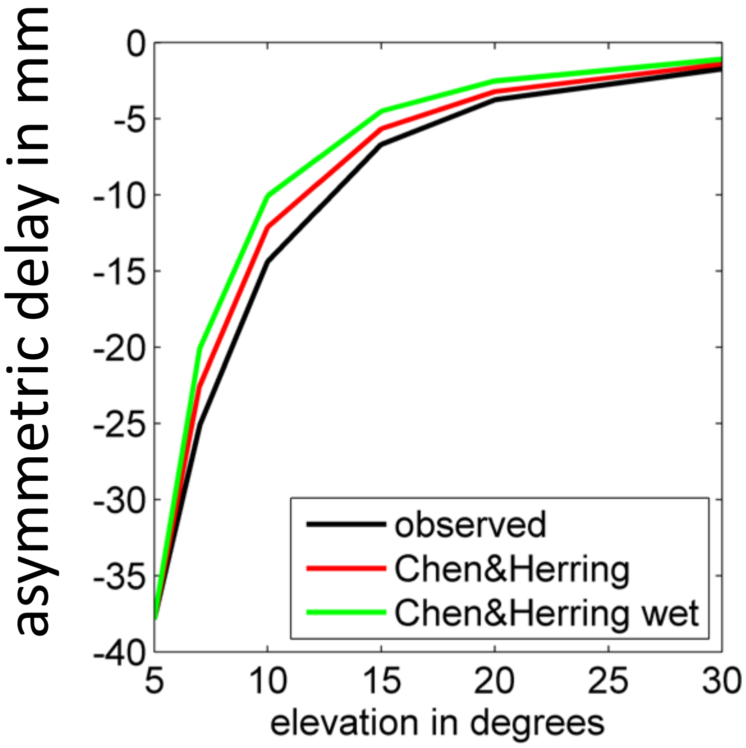

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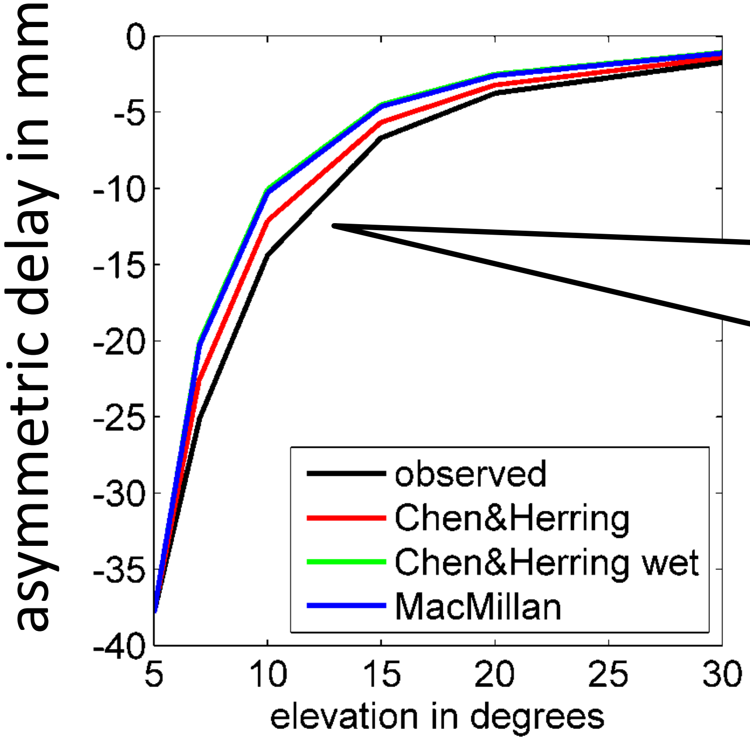
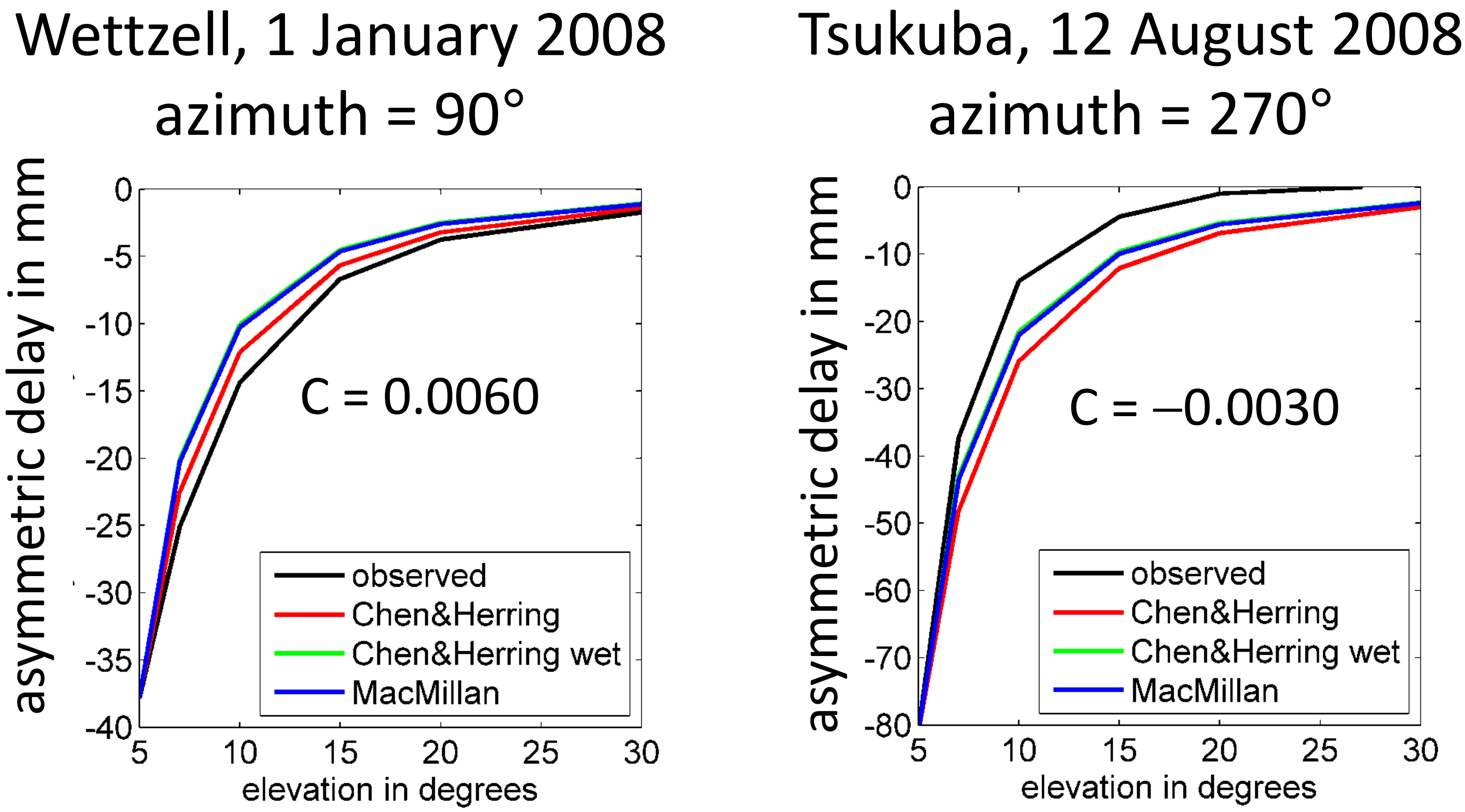


C = 0.0060
to follow the
observations

Examples with ray-traced delays



“Conventional” approach

- We recommend to use the model by Chen and Herring 1997 with the coefficient C = 0.0032.
  - There is no singularity at the horizon.
  - Easier to implement.
  - Allows the comparability of different solutions.

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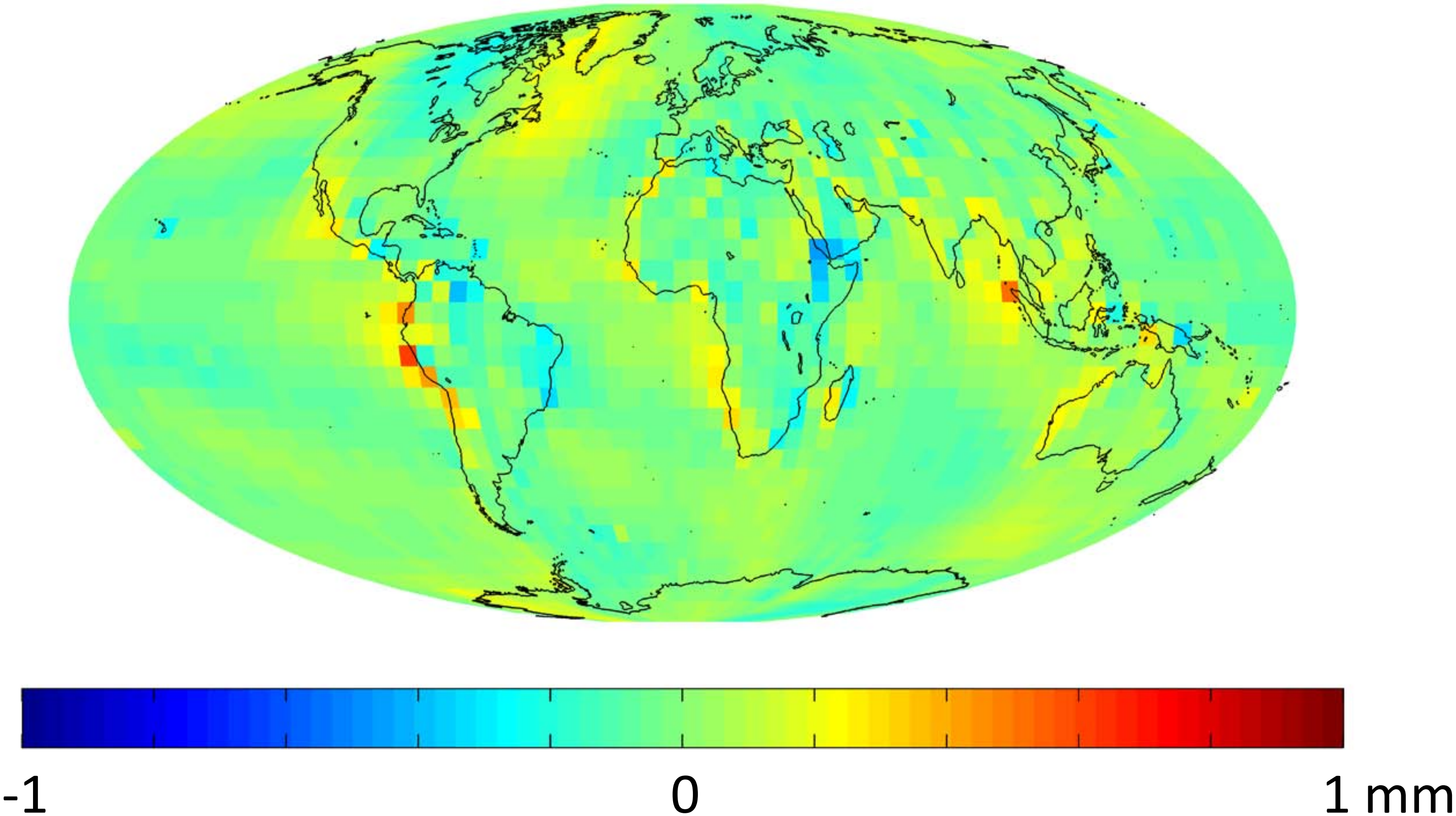
  - Allows the comparability of different solutions.

- ... until ray-traced delays or functions derived from ray-tracing are available globally.

A Priori **G**radient model **APG**

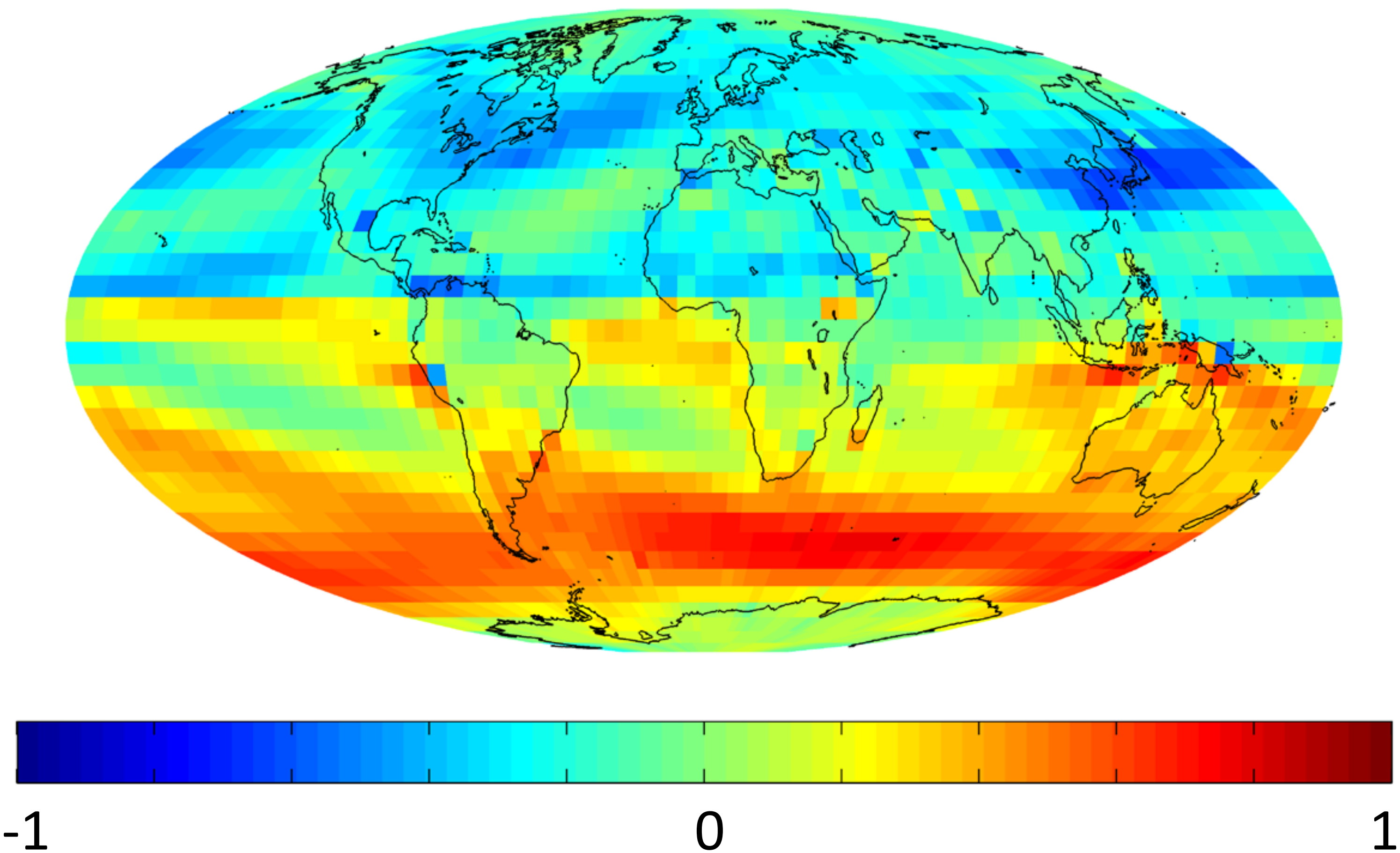
- ECMWF 40 Years Re-Analysis monthly mean pressure level data
  - horizontal resolution of 5°
- Asymmetric delays towards north/east at e=5°
  - determined by ray-tracing
- North and east gradients
  - using Chen and Herring with C = 0.0032
- Average over all 12 months

East gradients from the ECMWF
averaged over 12 months, 5° x 5° resolution



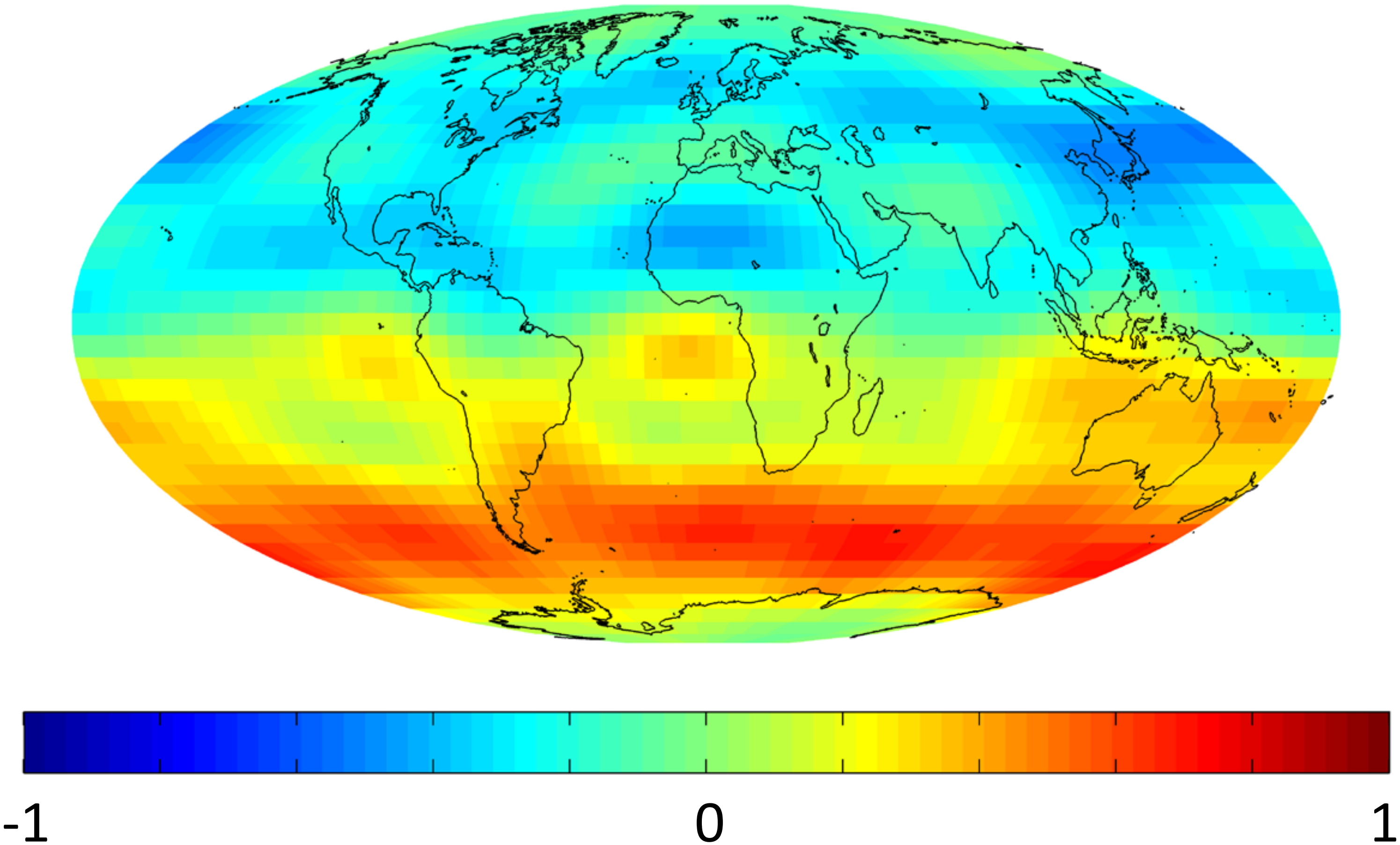
North gradients from the ECMWF

averaged over 12 months , 5° x 5° resolution

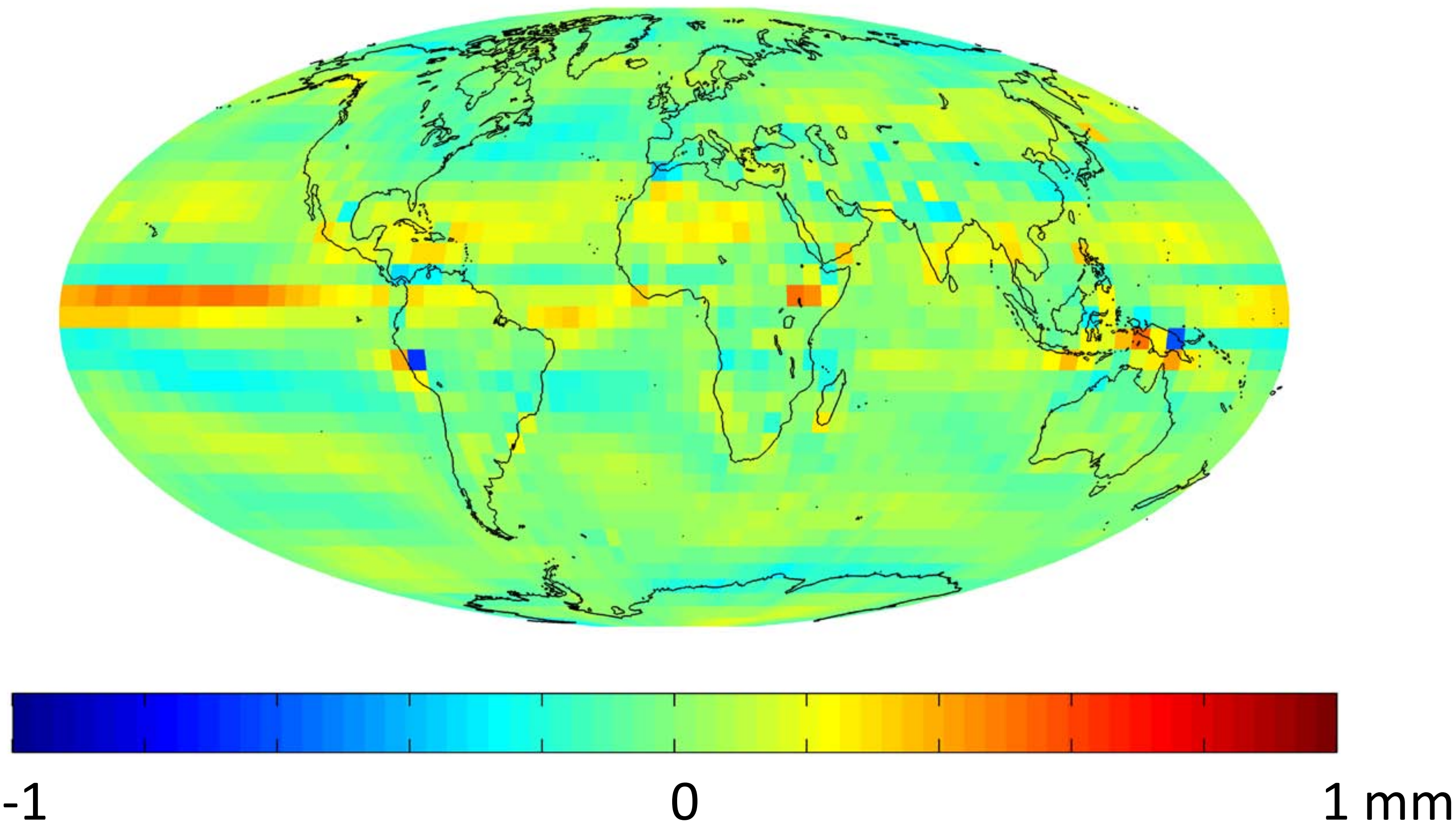


Spherical harmonic expansion
up to degree and order 9

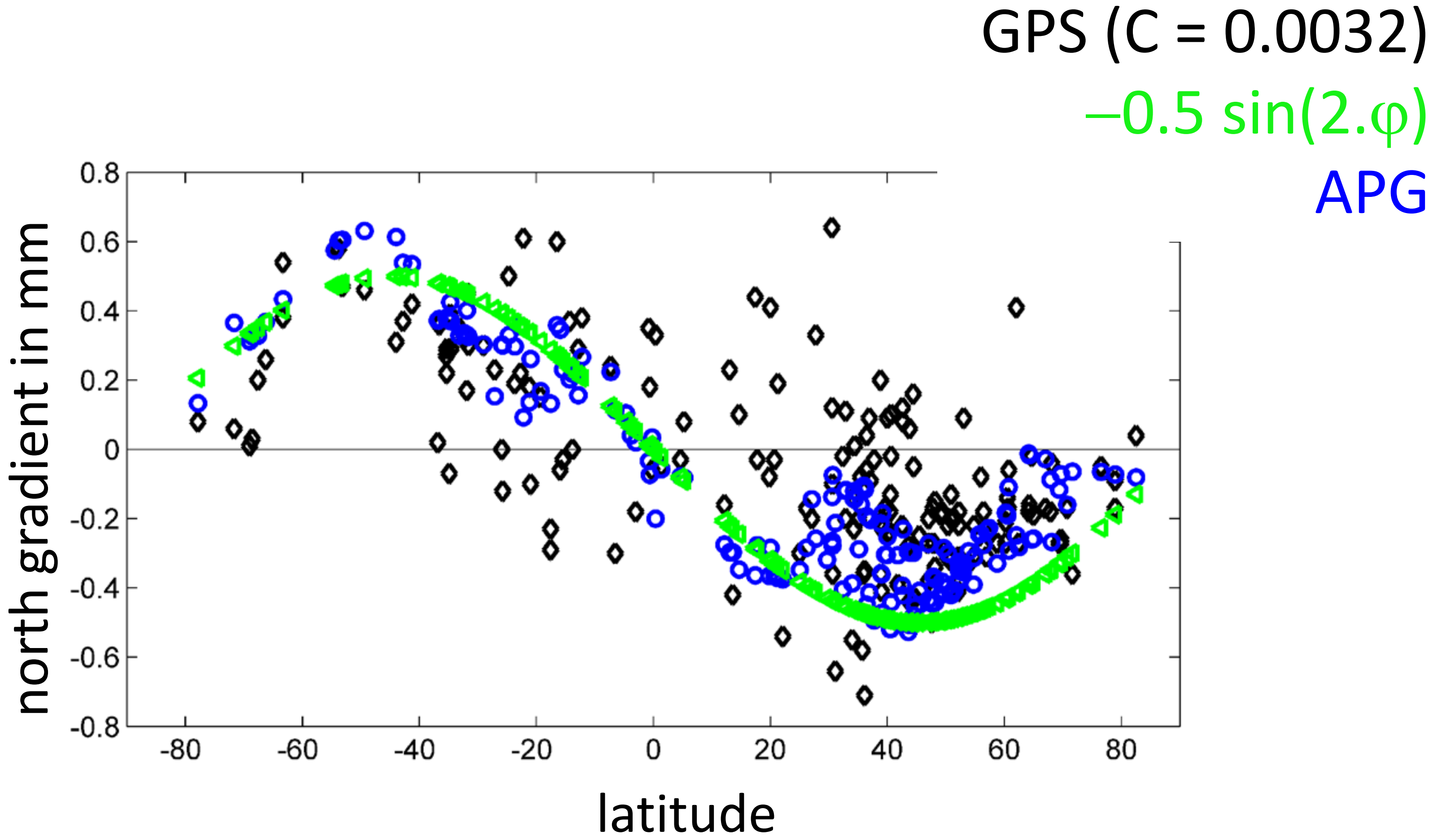
http://ggosatm.hg.tuwien.ac.at/



Residual north gradients



APG versus GPS-derived mean north gradients



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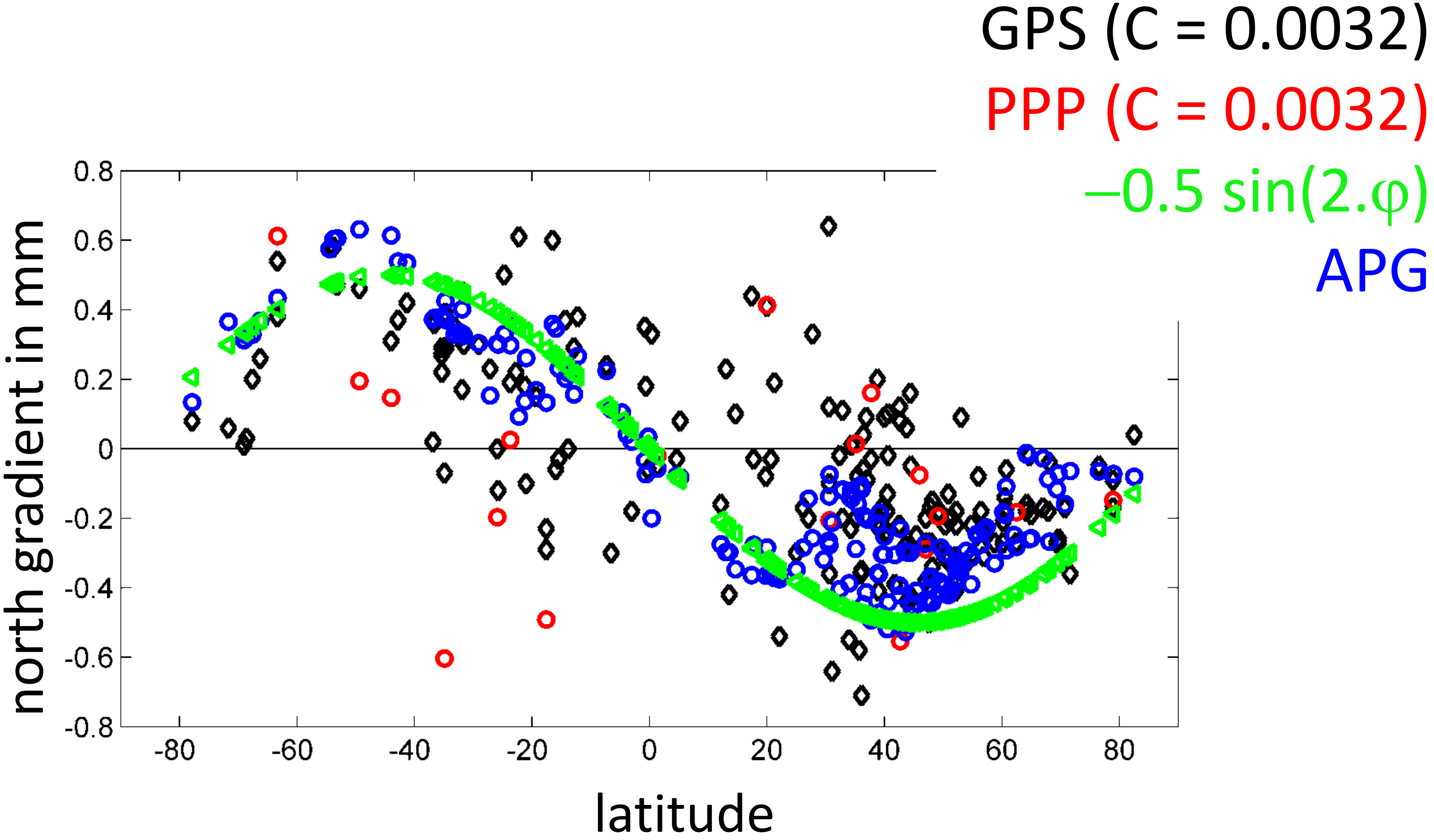

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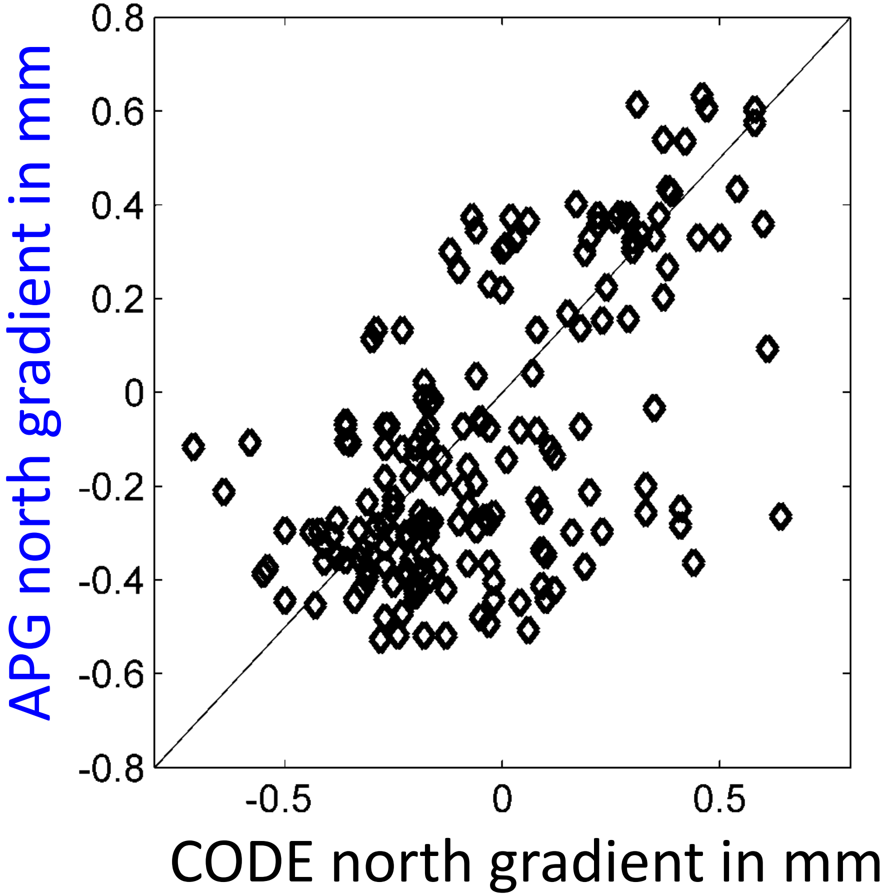


Consequences and questions

- APG are mostly larger than GPS-derived north gradients.
- Possible reasons:
  - C = 0.0032 is too large
    - (0.0007 helps only a bit, makes the gradients more “wet”)
  - Other effects on GPS gradients? Cutoff angle or down-weighting?
  - Error in NWM or ray-tracer?

GPS and VLBI analysis

- **With Chen and Herring (C = 0.0032) for the estimation of gradients (without constraints), there is no difference to not using APG!**

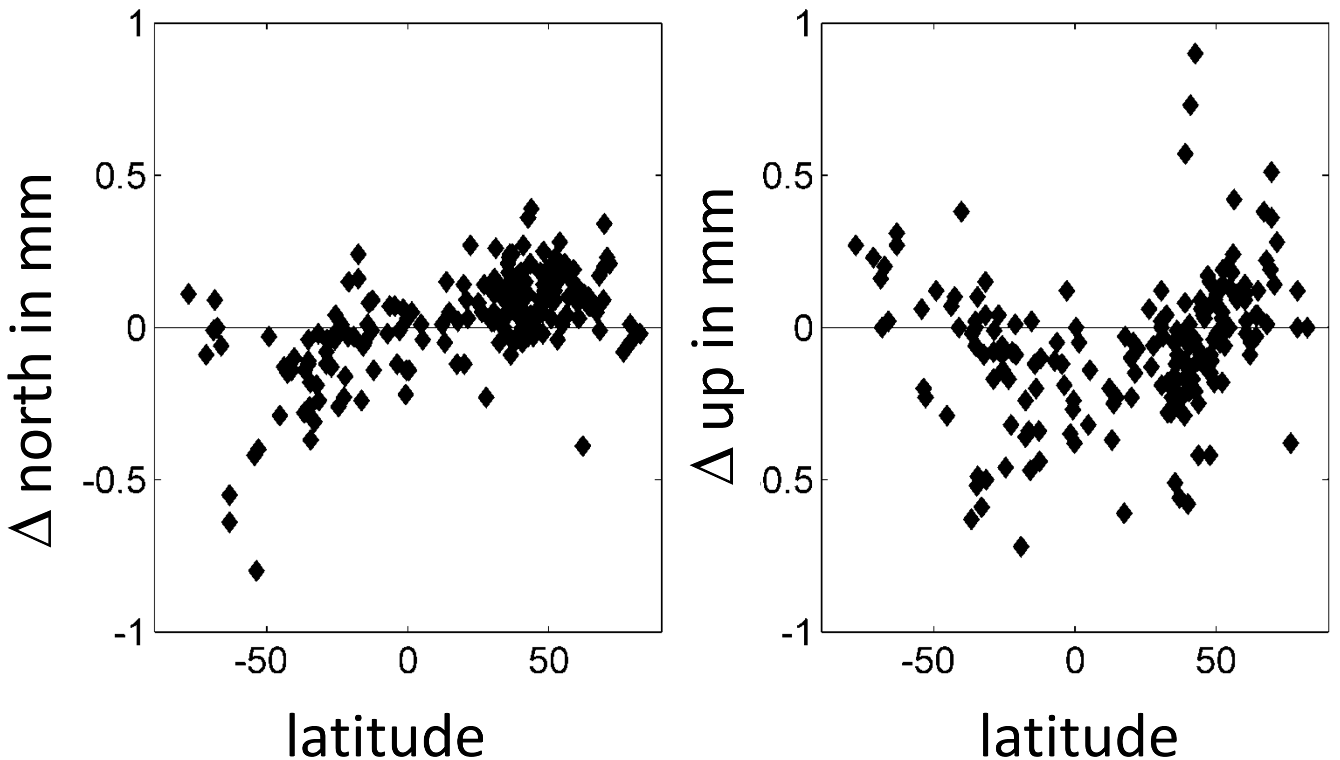
Station coordinates from GPS analysis

- **CODE**
  - Bernese network solution from 2007 to 2008
  - Orbits/EOPs/station coordinates estimated together
  - 3° cutoff elevation angle, down-weighting with $\cos^2 z$
  - No constraints on 24 h piecewise linear gradients
- **UNB**
  - Precise Point Positioning solution for 2008

GPS: mean coordinate differences

Different gradient mapping functions for estimation

	A priori gradients	Estimation
I.	no	MacMillan
II	no	Chen&Herring (C = 0.0032)



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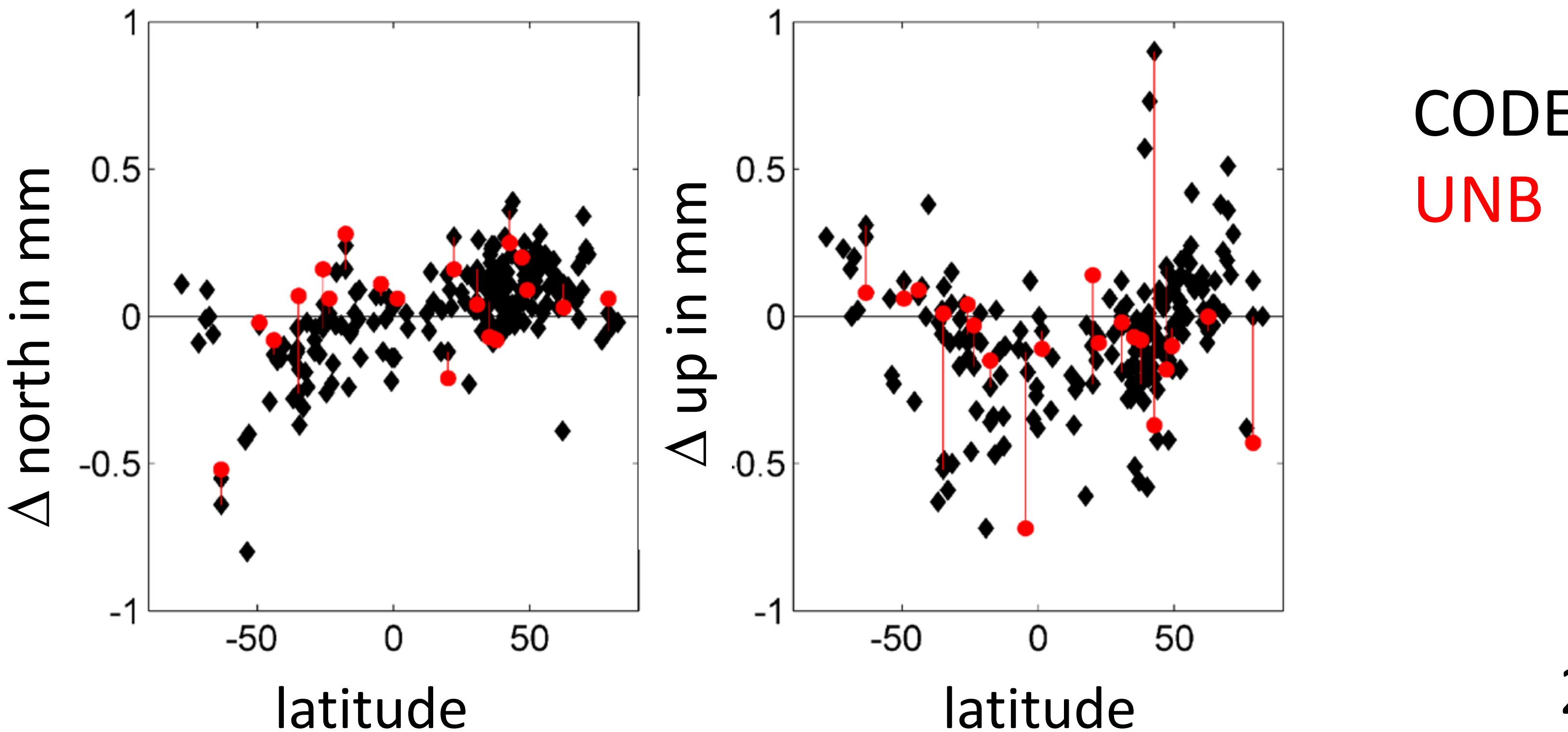

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With / without estimation of gradients

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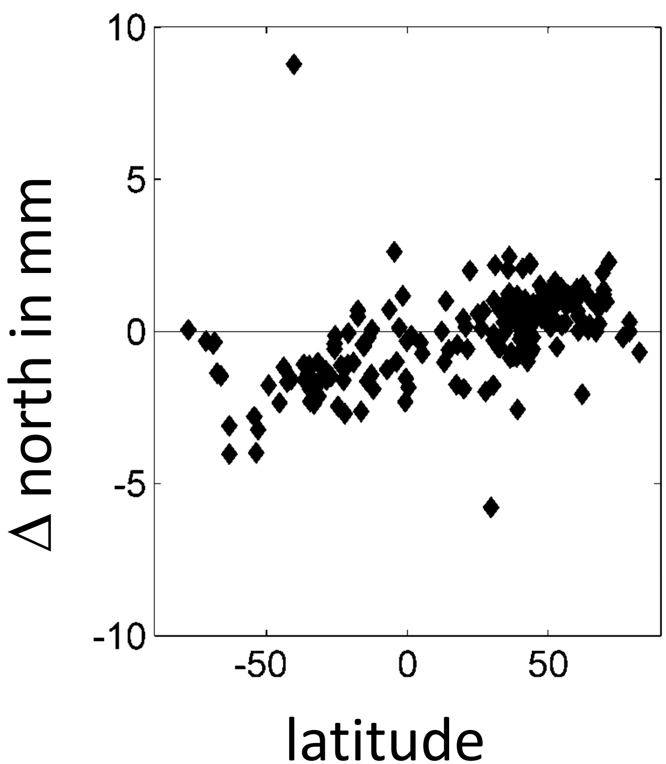

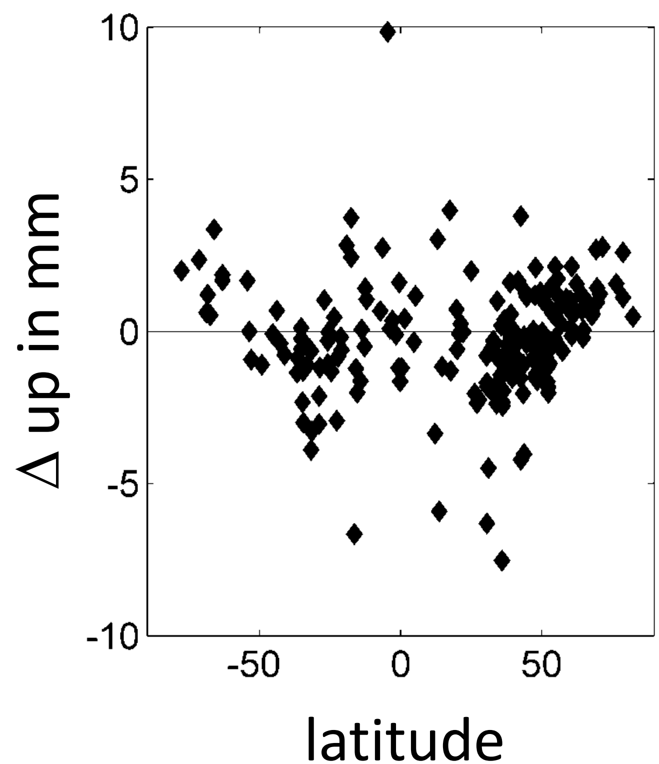

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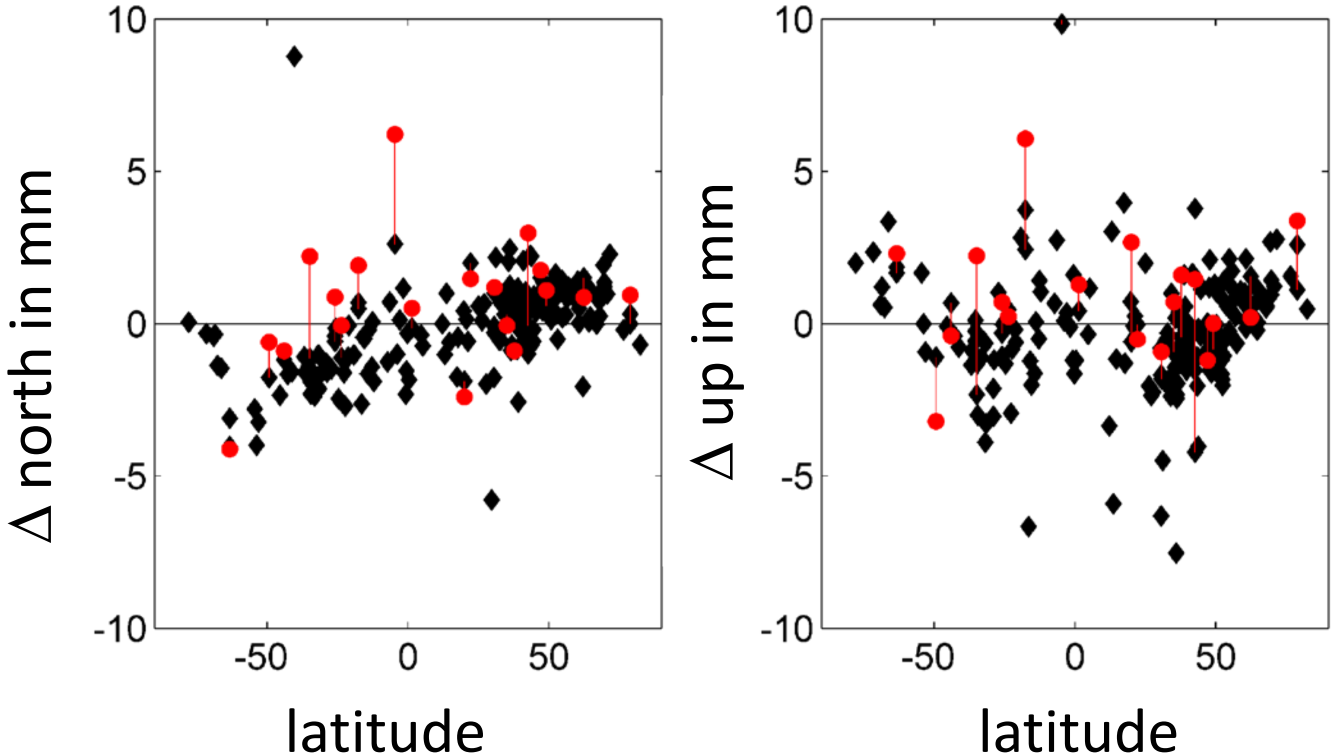

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Does APG help?

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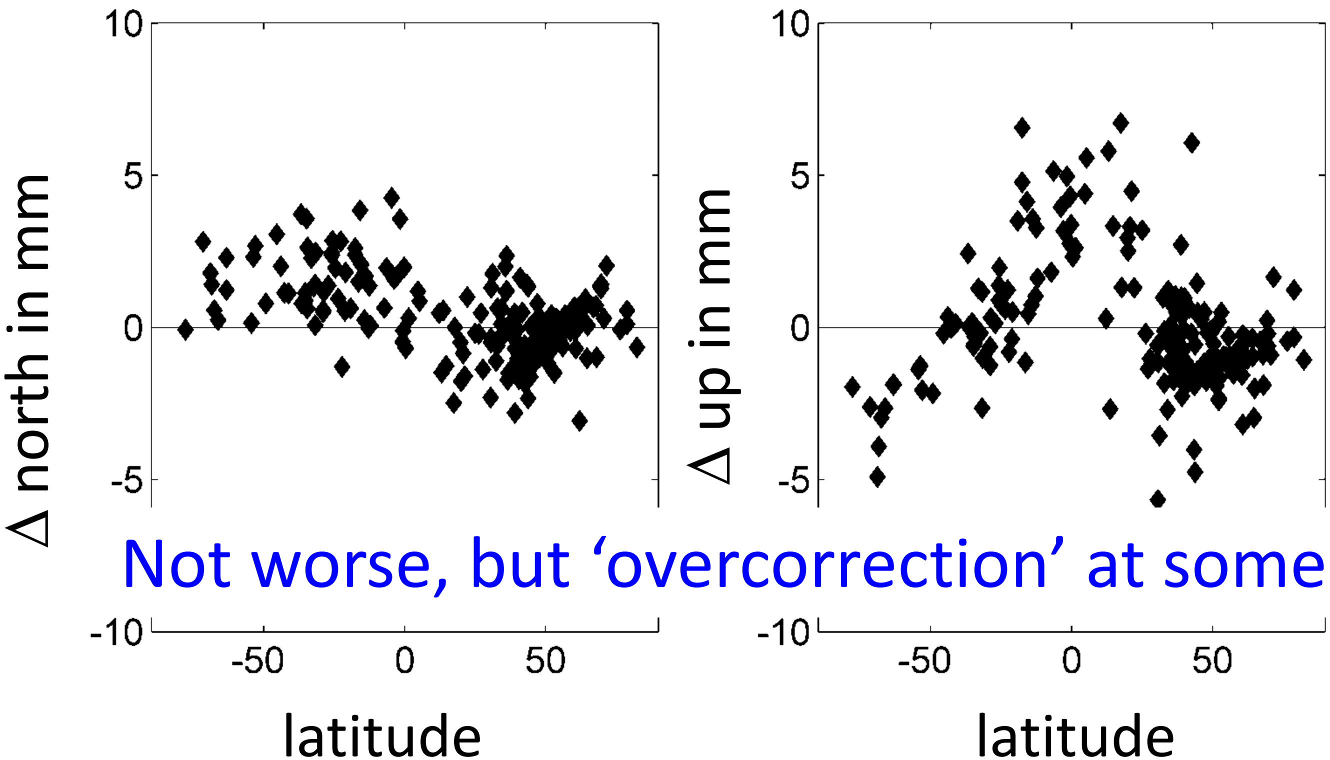

CODE

Not worse, but ‘overcorrection’ at some latitudes.

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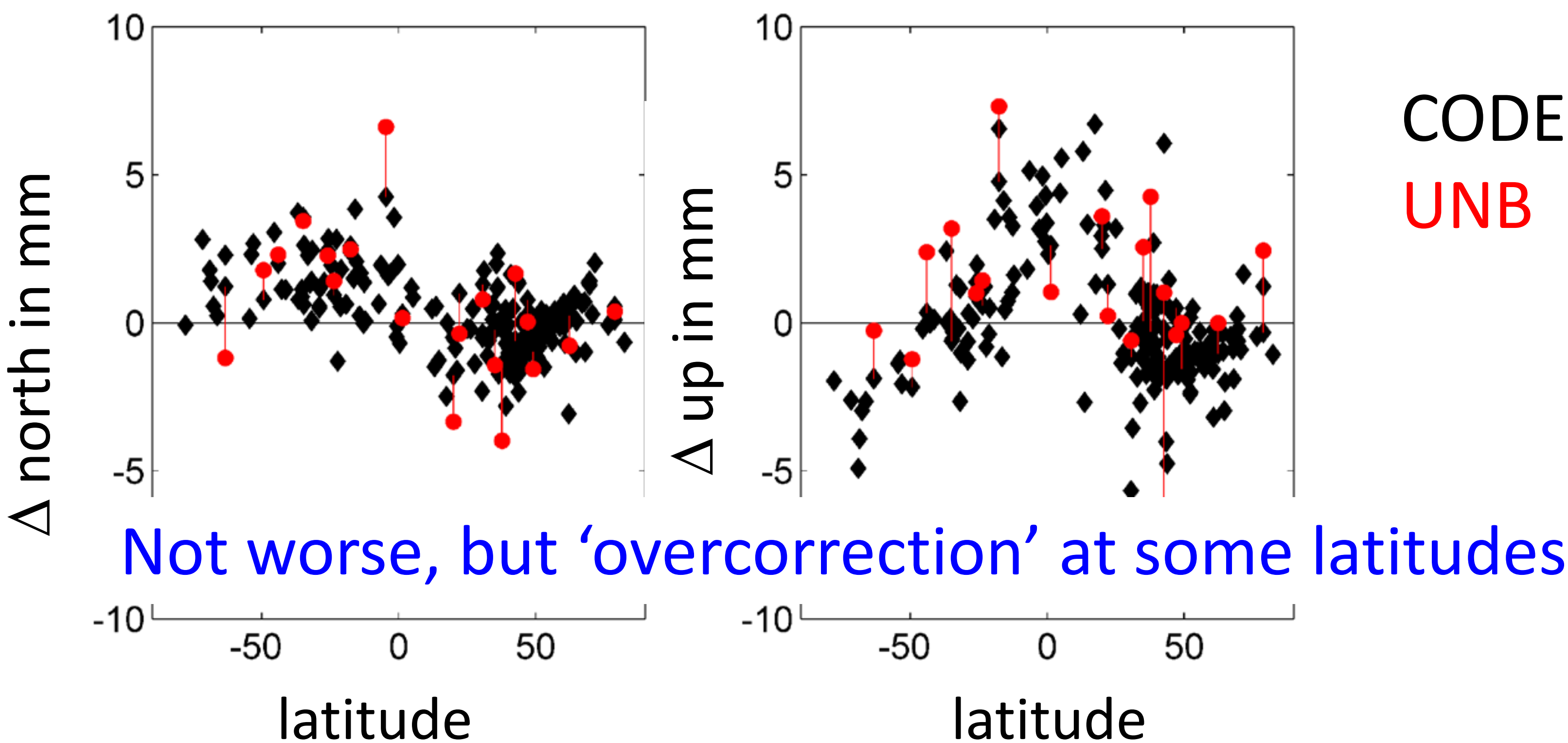

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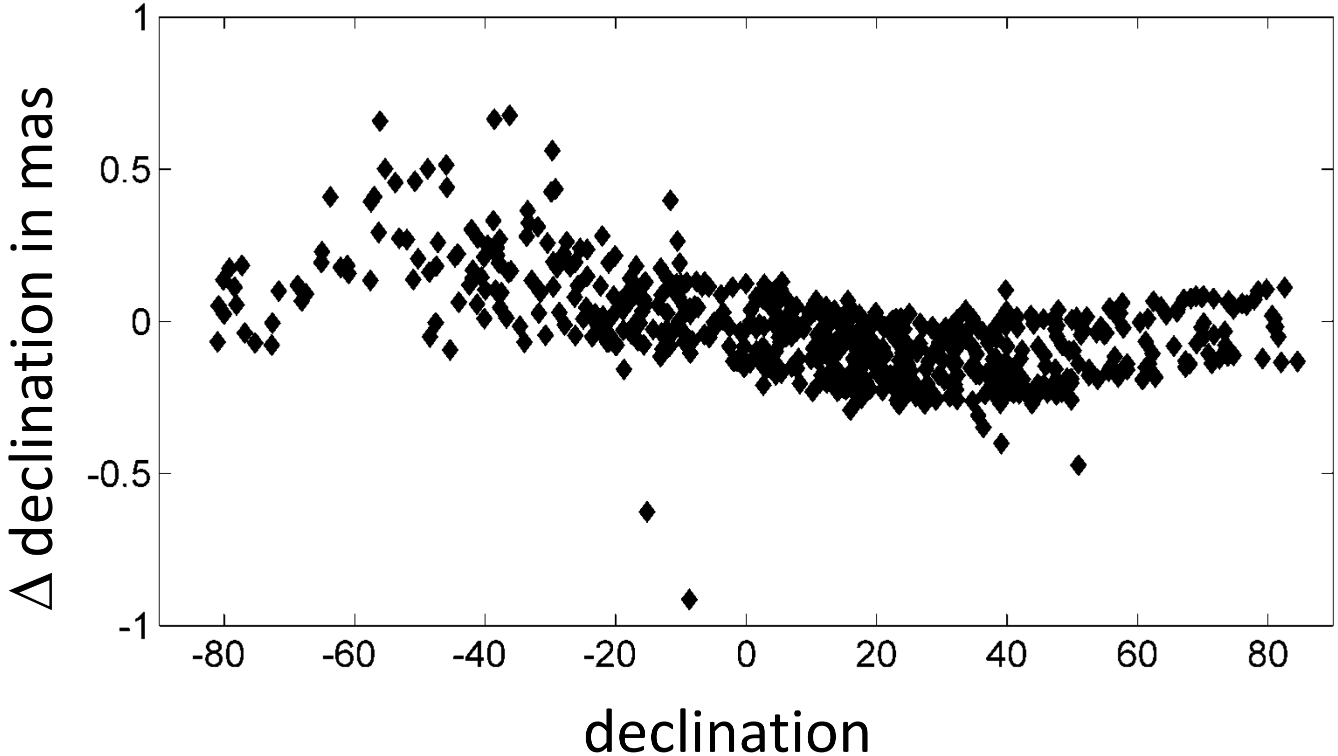
Source coordinates from VLBI analysis

- **VieVS**
  - **Simulation** for all R1/R4 sessions from 2002 to 2008
  - No cutoff elevation angle, no down-weighting
  - No constraints on gradients
  - 3 h piecewise linear offsets for gradients
- **DGFI**
  - Occam solution for all sessions from 1984 to 1990
  - relative constraints on gradients

VLBI: declination differences

Simulation: Influence of a priori gradients

	A priori gradients	Estimation
I.	APG	no
II	no	no



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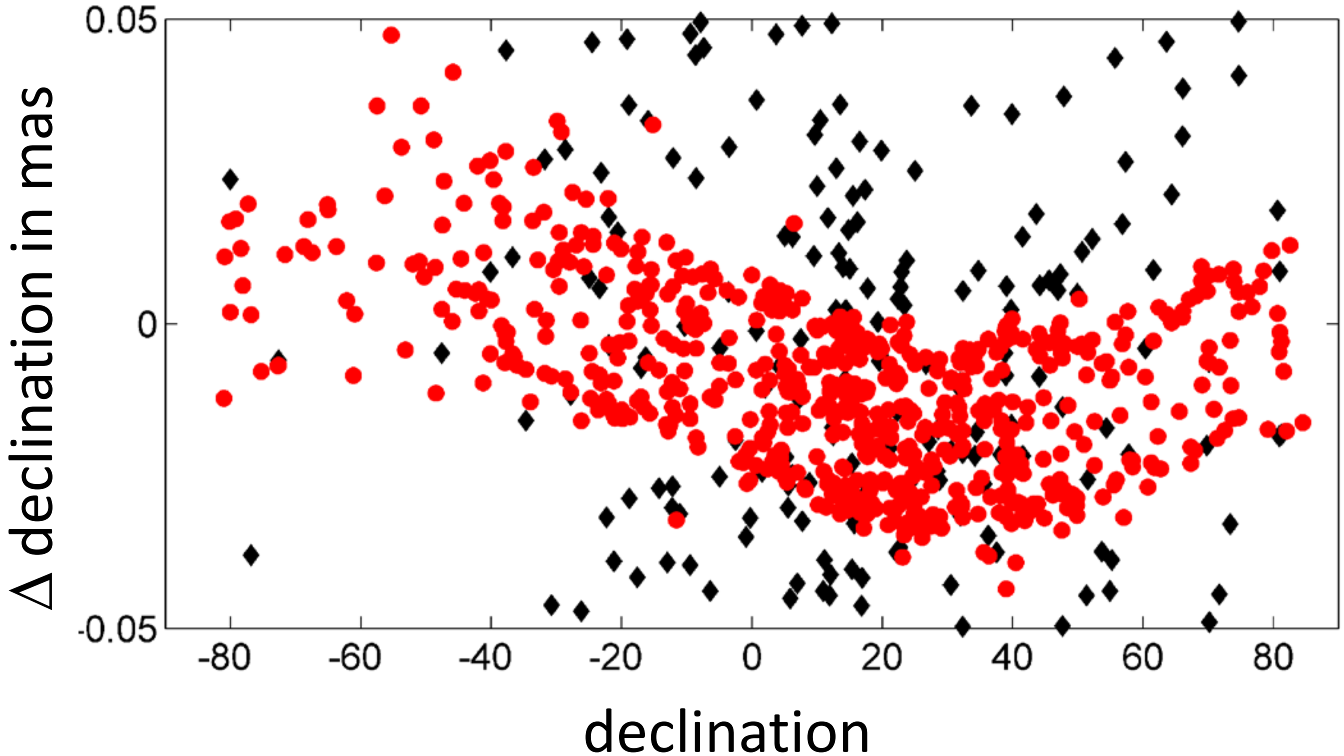

VLBI: declination differences

Occam

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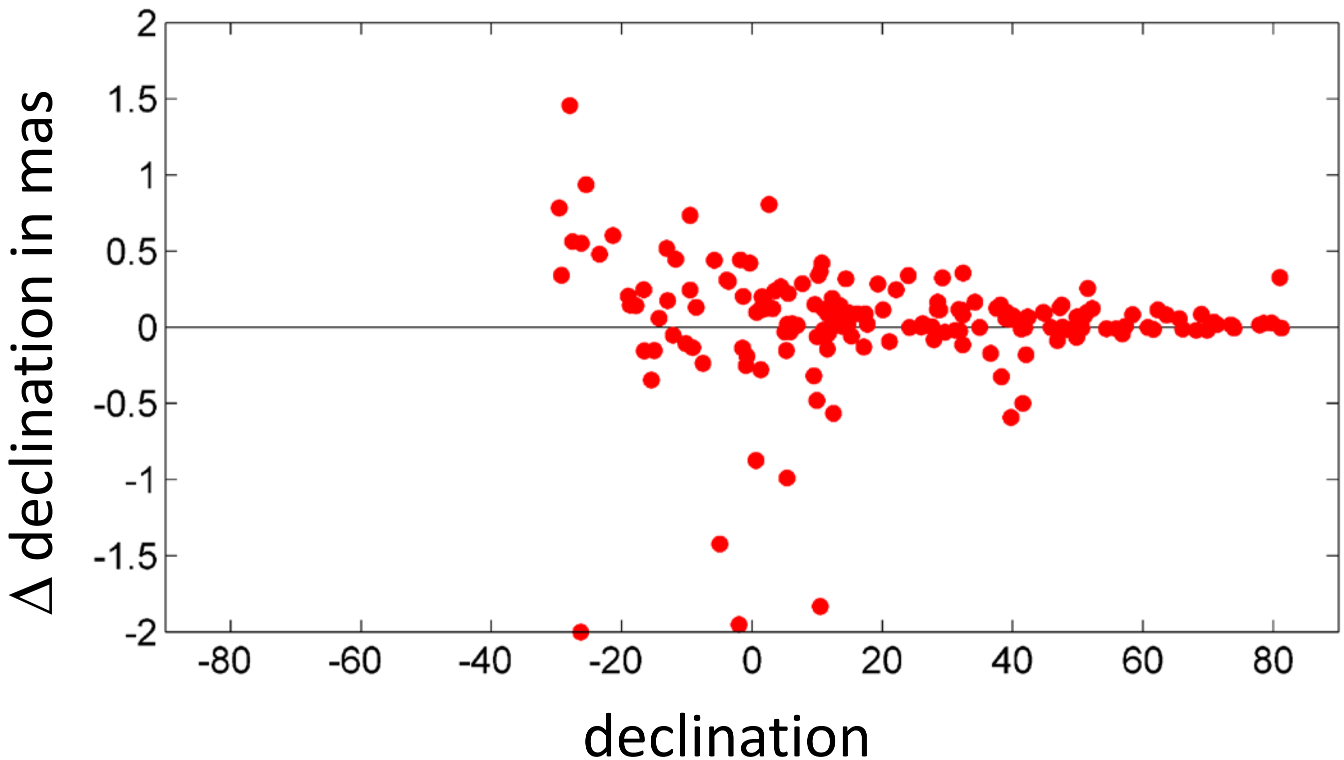

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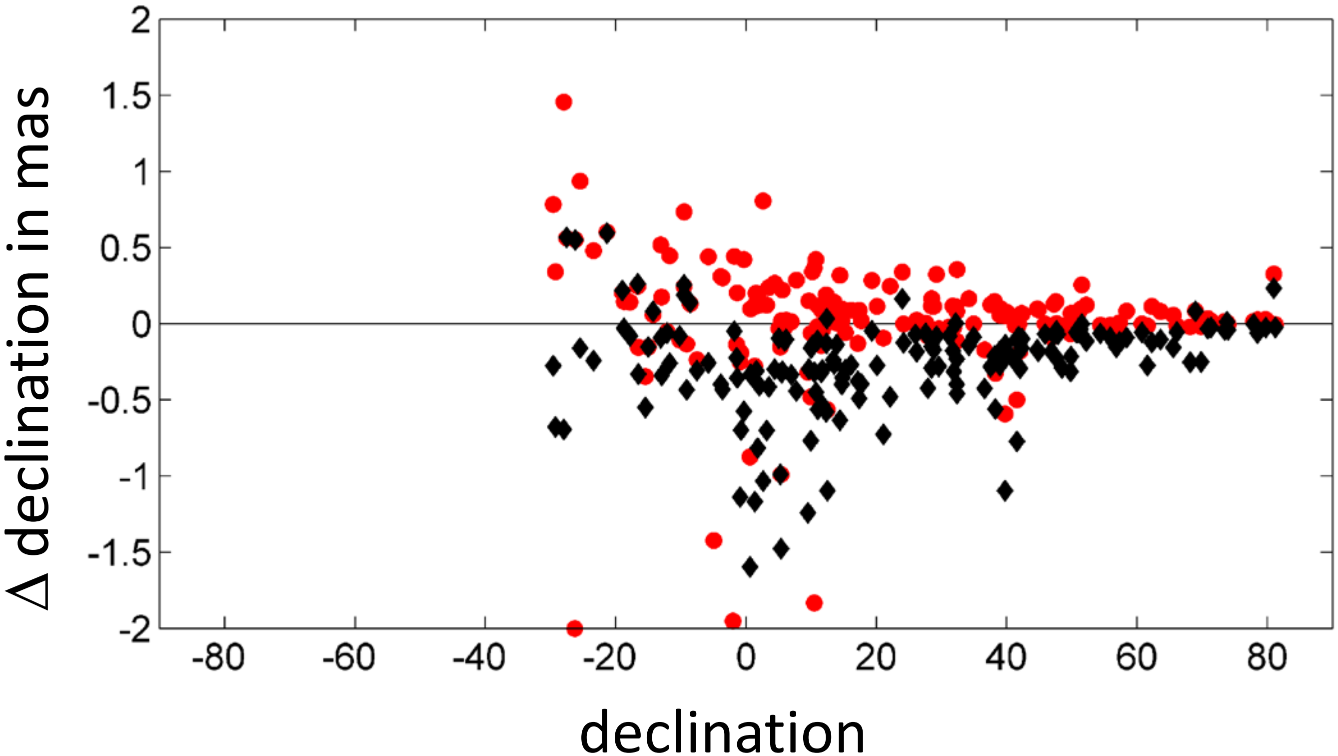

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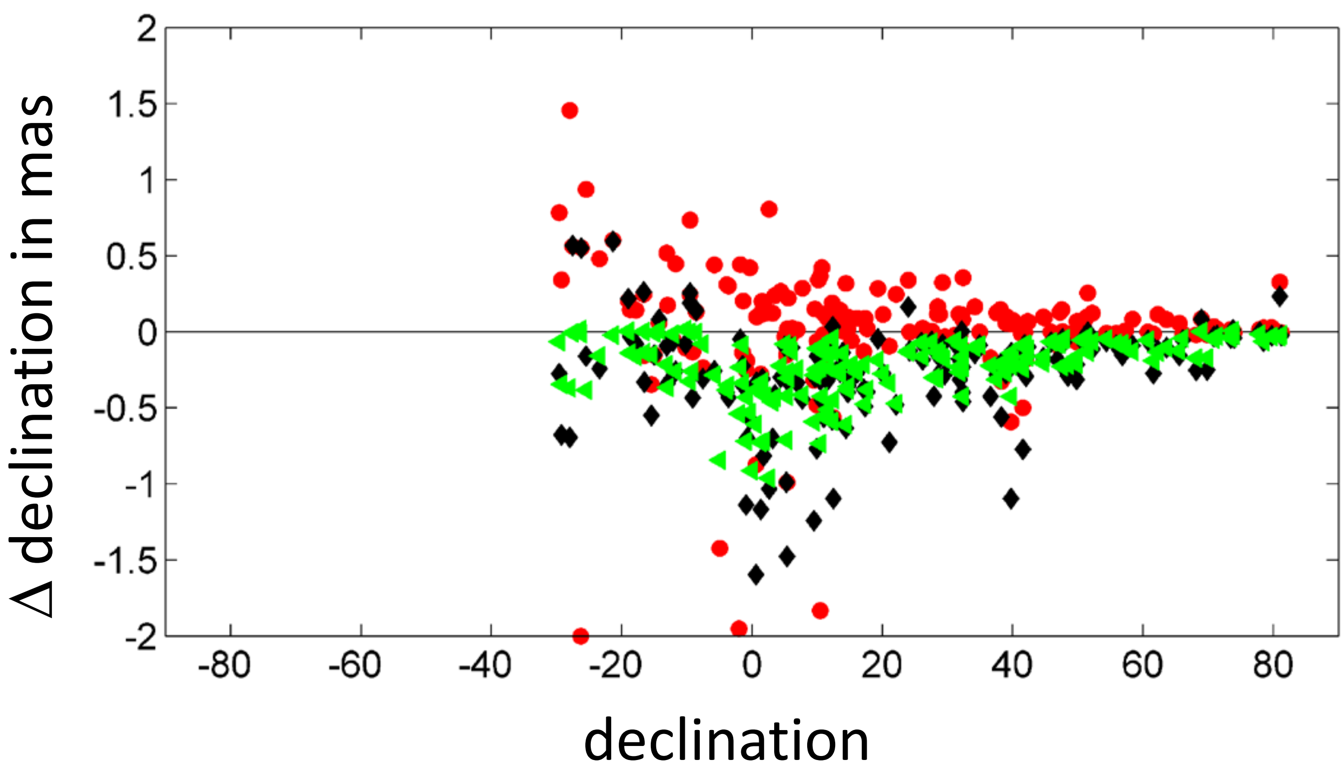

Summary and conclusions

- Mean GPS gradients are smaller than mean gradients derived from ECMWF data.
- Choice of gradient mapping function has a systematic effect at the 1 mm level on station coordinates.

Summary and conclusions

- We recommend to use the gradient mapping function by Chen and Herring with C = 0.0032 for the sake of consistency ...
- ... until more sophisticated methods (based on ray-tracing) are available globally.