Consistency of Crustal Loading Signals Derived from Models and GPS: A Re-examination

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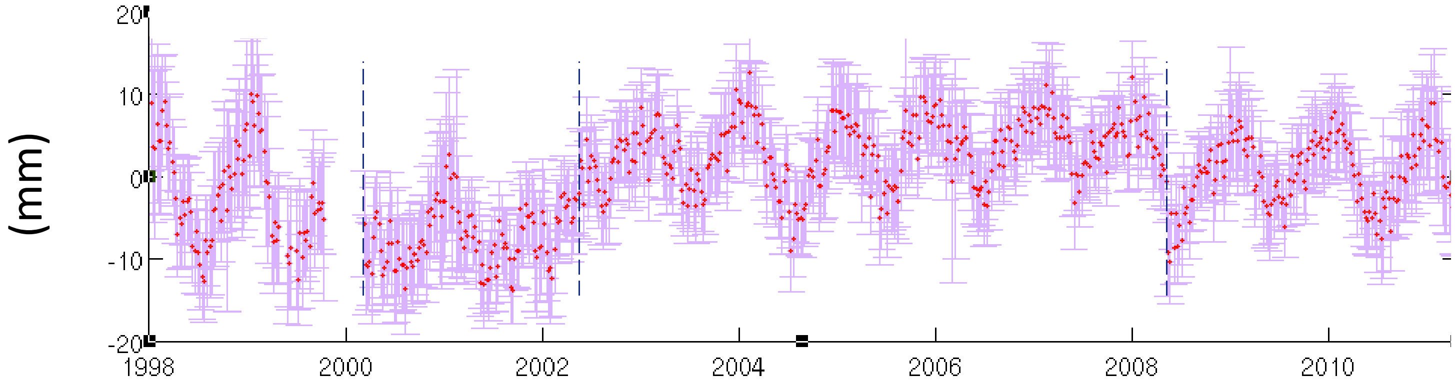
Acknowledgment: Daphné Lercier (IGN)

Introduction

Example of GPS station height time series : YAR2



Loading displacements + Other ground motion effects + Systematic errors + Noise

Discussed here

Friday: G51B-06, Ray et al.

Outline

- Loading effects and models
- Reprocessed GPS station position time series from the International GNSS Service (IGS)
- Comparison between both datasets in horizontal and vertical components

Loading model (1/3)

Elastic deformation of the Earth's crust due to mass transfer at the Earth's surface. <u>Only Non-tidal effect are discussed here</u>.

	ECCO	NCEP	GLDAS version 1
		+ 	+ 
Sampling rate:	12h	6 h	1 month
Space resolution	1 x 1	2,5 x 2,5	1 x 1

<u>Context:</u> •Many previous works studied these 3 effects. Here, we model the 3 effects and investigate the 3D displacements over a global network of 602 sites.

Loading model (1998.0 to 2010.0)

- Green's function approach. Earth model : Gutenberg-Bullen
- Reference Frame: Center of Figure (CF) of the Earth *(Blewitt, 2003)*

Loading model (2/3)

Non-tidal ocean loading (NTOL):

70% of MIT global GPS network height time series show a reduced scatter when this effect is corrected *(van Dam et al., Journal of Geodesy, submitted)*

- Boussinesq approximation generates erroneous trends in the predicted station displacement time series.

Non-tidal atmospheric loading (NTAL):

- Inverted barometer response of the ocean
- Use topographic corrections due to the spatial resolution of the NCEP load 2,5 x 2,5 *(van Dam et al., 2010)*

Non-tidal continental water loading effect (NTCWL):

Third order polynomial removed from the GLDAS (version 1) derived displacement time series to remove unrealistic signals.

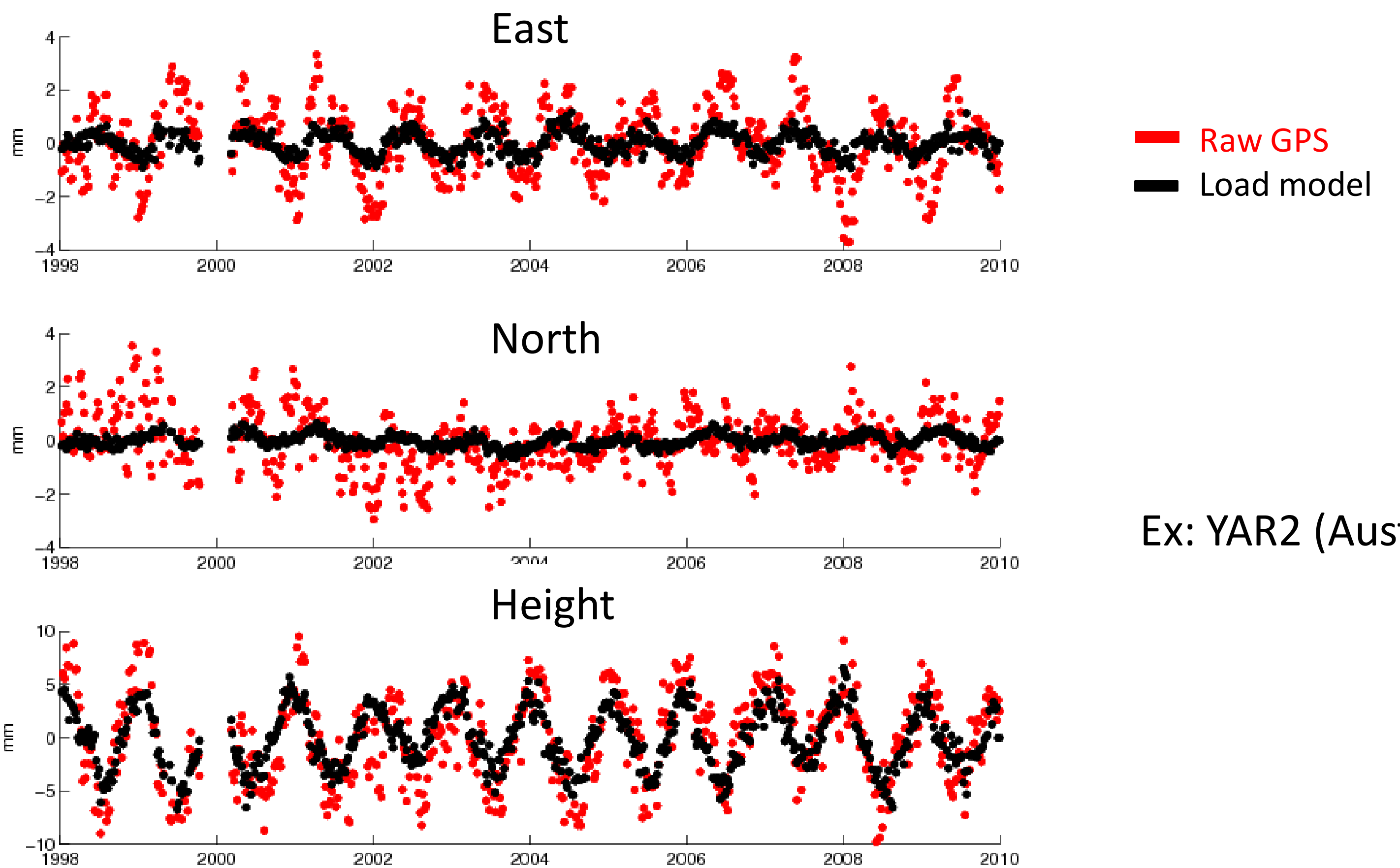
Better agreement with GPS once corrected:

Improvement of (0.1; 0.1; 0.5) mm in the GPS corrected time series WRMS in average.

Loading model (3/3)

3D-displacement of the 3 effects have been added

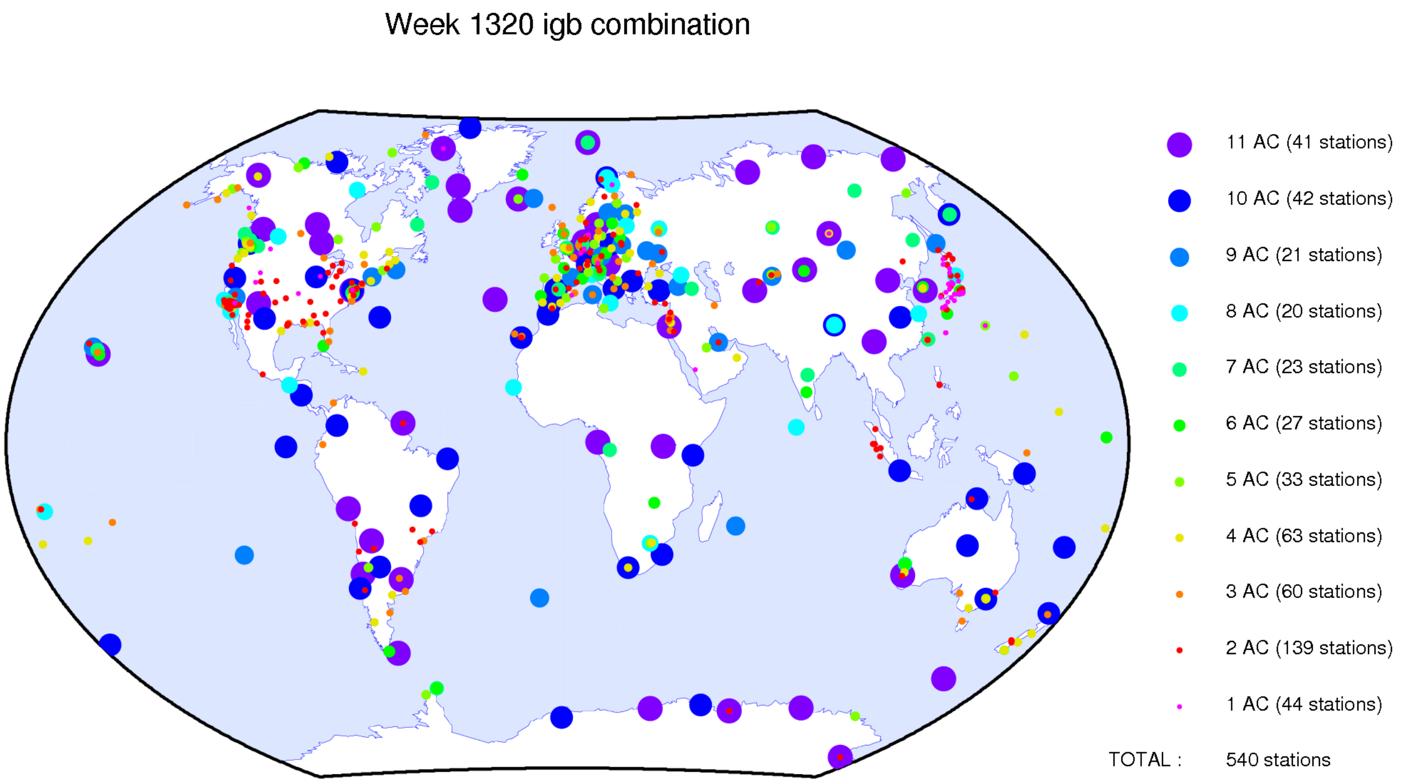
• Then averaged at a weekly sampling and detrended.



Ex: YAR2 (Australia)

GPS solution (1/4)

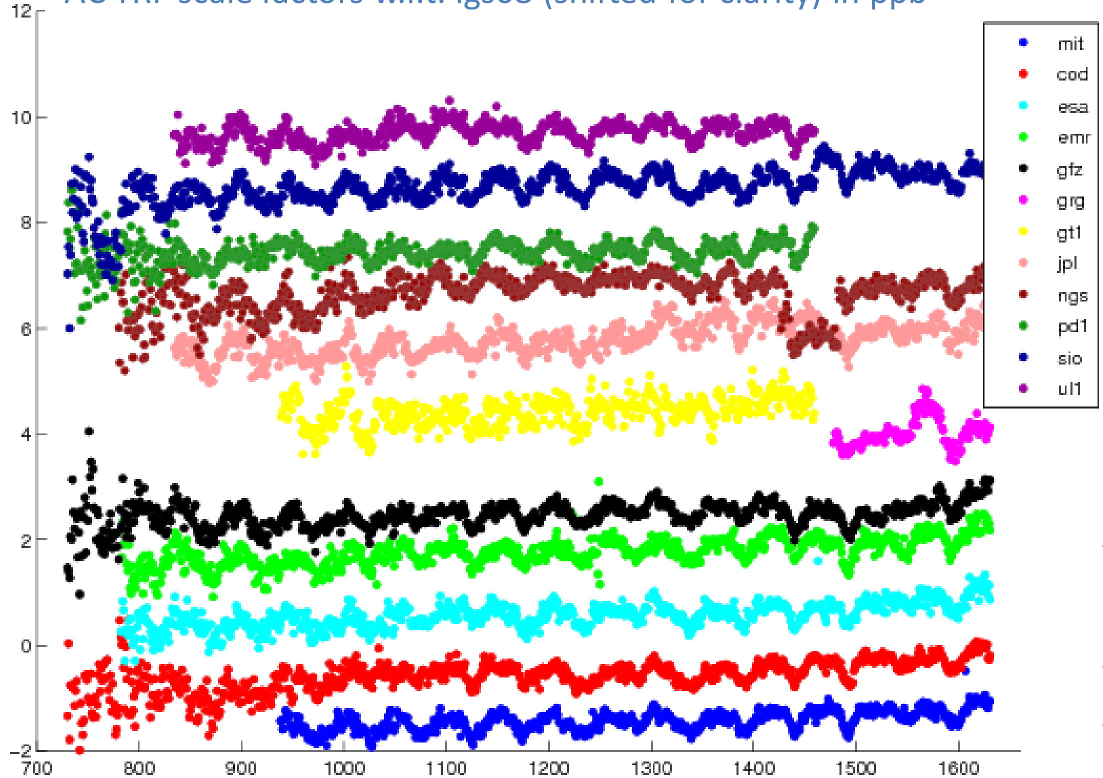
- GPS Analysis Center solutions submitted for repro1 (igs05 framework) have been recombined homogeneously with IGN combination strategy: “igb” weekly combined solutions.



○ All available stations included. More than 900 stations in total
○ 1994.0 - 2011.3. From 1998.0 to 2010.0 used here

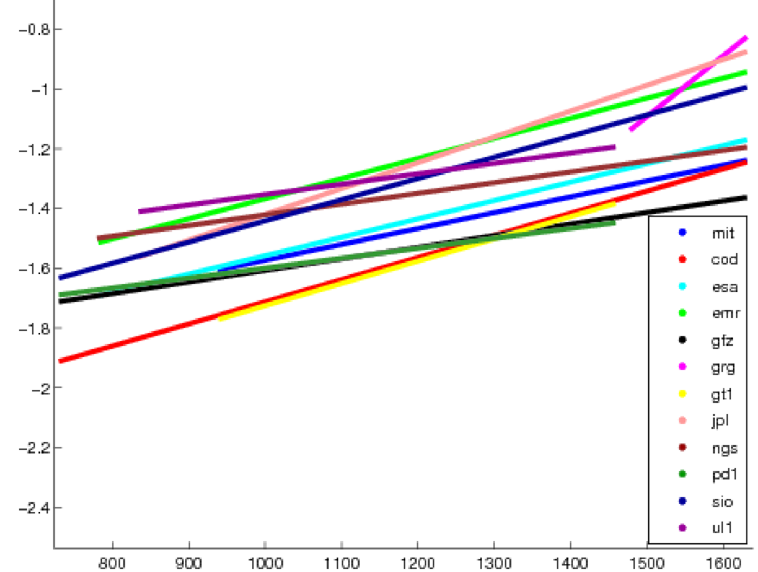
GPS solution (2/4)

AC TRF scale factors w.r.t. igs08 (shifted for clarity) in ppb



- Combined solution not projected into IGS05 reference frame as previous *ig1 weekly* combined solution.
- but GPS intrinsic origin and scale conserved

AC TRF scale factors linear change w.r.t. igs08 in ppb



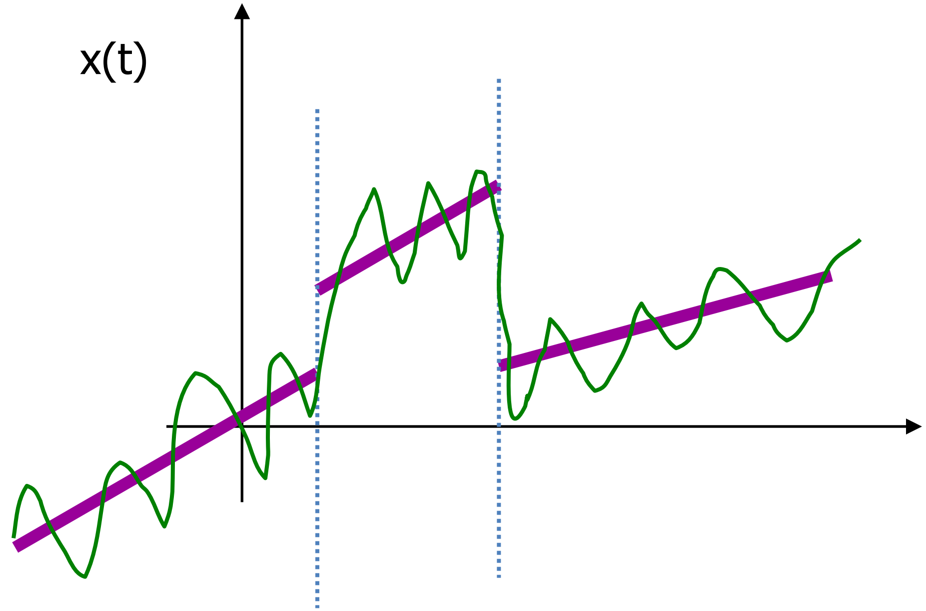
Origin and scale averaged for:
COD, EMR, ESA and GFZ

GPS solution (3/4)

Computation of station displacements

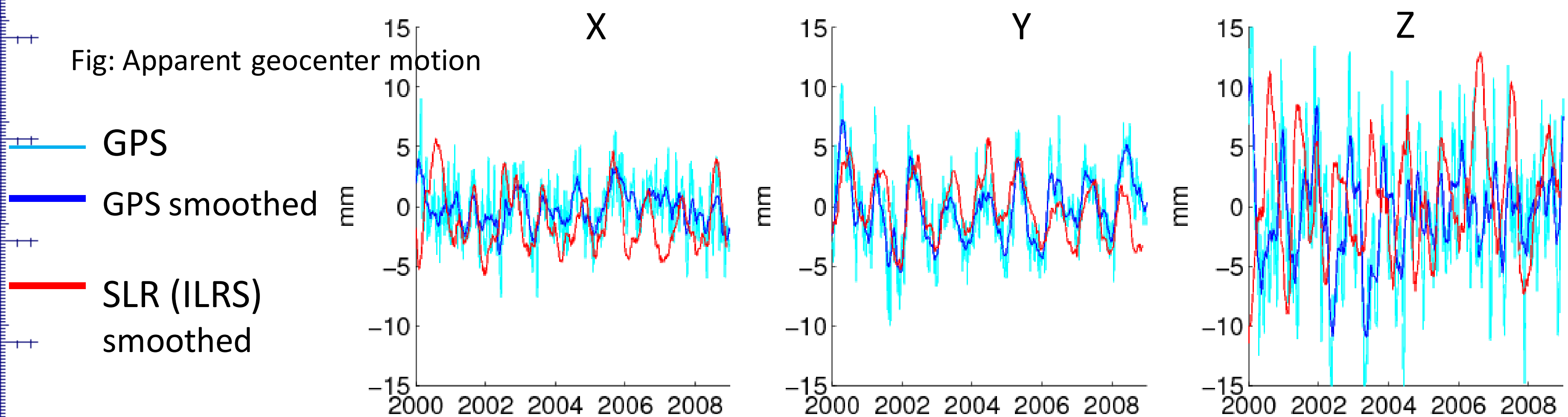
1) Long-term coordinates needed:

   - Segmentation of time series and empirical correction of the discontinuities



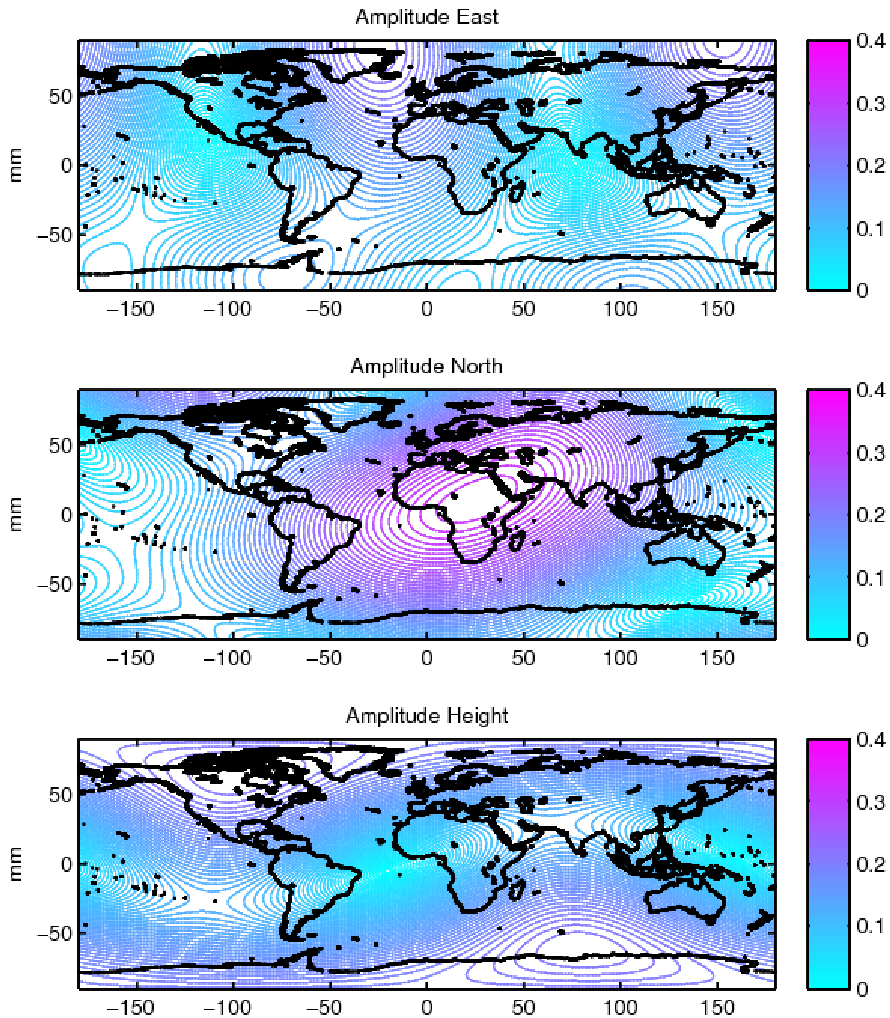
2) In order to approximate CF frame, we removed from the weekly positions:
   - long-term trends and offsets
   - GPS intrinsic geocenter motion information using a well distributed network of stations.

Fig: Apparent geocenter motion



GPS solution (4/4)

How well are GPS residual displacements expressed in the CF frame?



Cf. Collilieux et al., Journal of geodesy 2011

Fig. Difference between obtained annual loading residual displacement and annual loading displacement in CF. Shows remaining aliasing by loads.

Strategy used here:
* Height down-weighted by 3 in sigma
* IGS08 core network

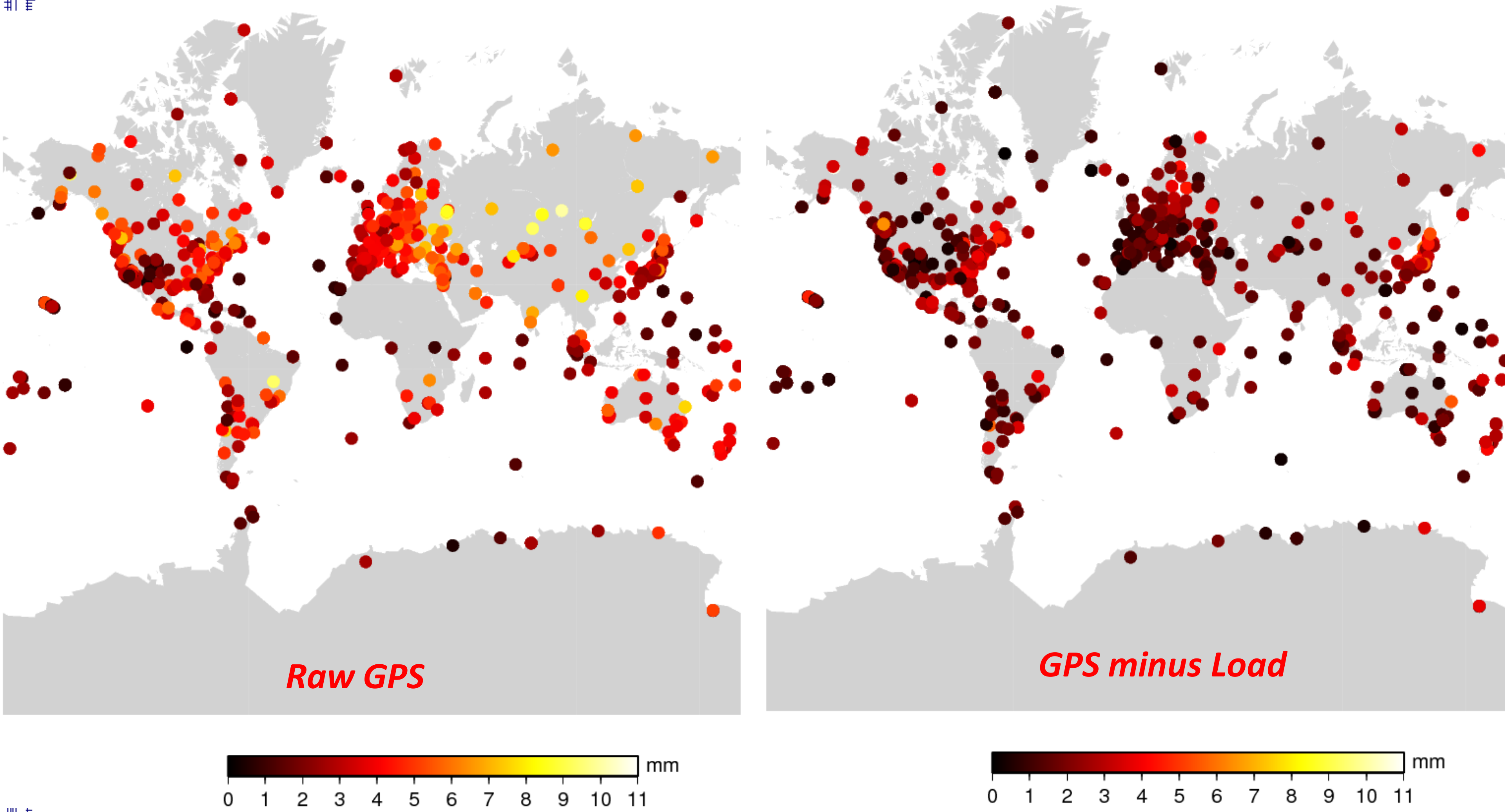
It is not possible to strictly access CF frame!

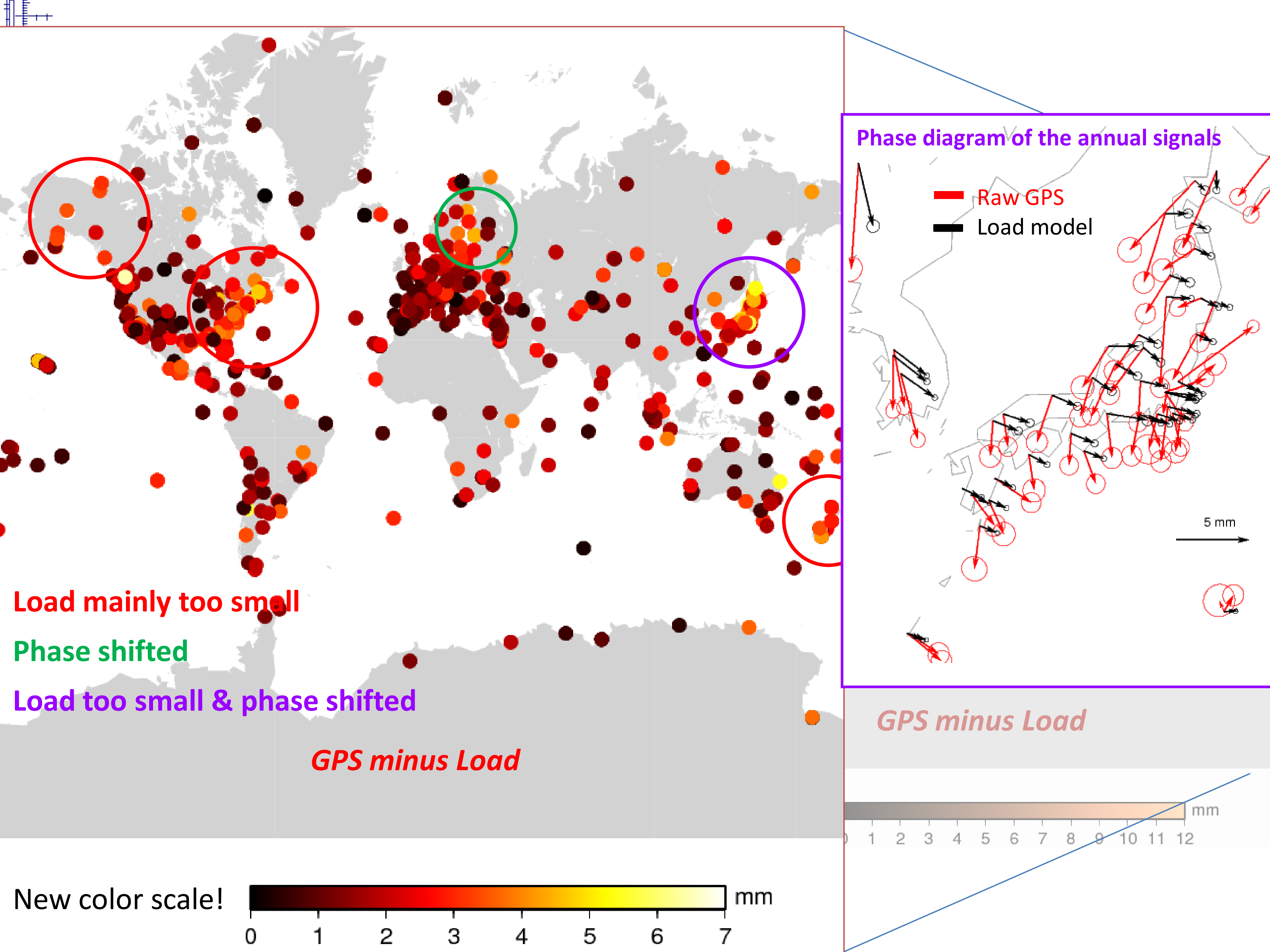
→ We correct for loading displacement before removing apparent geocenter motion.

Comparison (1/4)

Annual signal

Amplitude of the vertical annual displacement

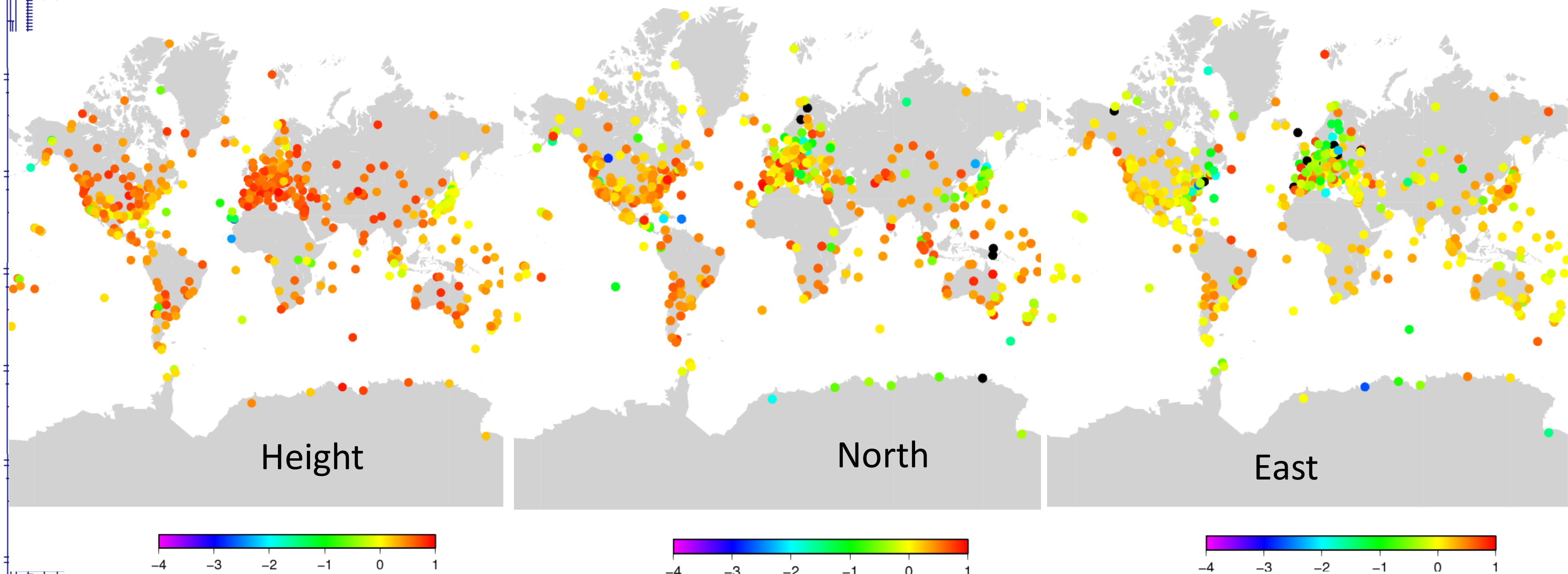



Phase diagram of the annual signals
Raw GPS
Load model
5 mm
GPS minus Load
mm
1 2 3 4 5 6 7 8 9 10 11 12
Load mainly too small
Phase shifted
Load too small & phase shifted
GPS minus Load
New color scale!
mm
0 1 2 3 4 5 6 7

Comparison (2/4)

How much of the signal is reduced by the loading model at the annual frequency?

$(A_{gps}-A_{load})/A_{gps}$?

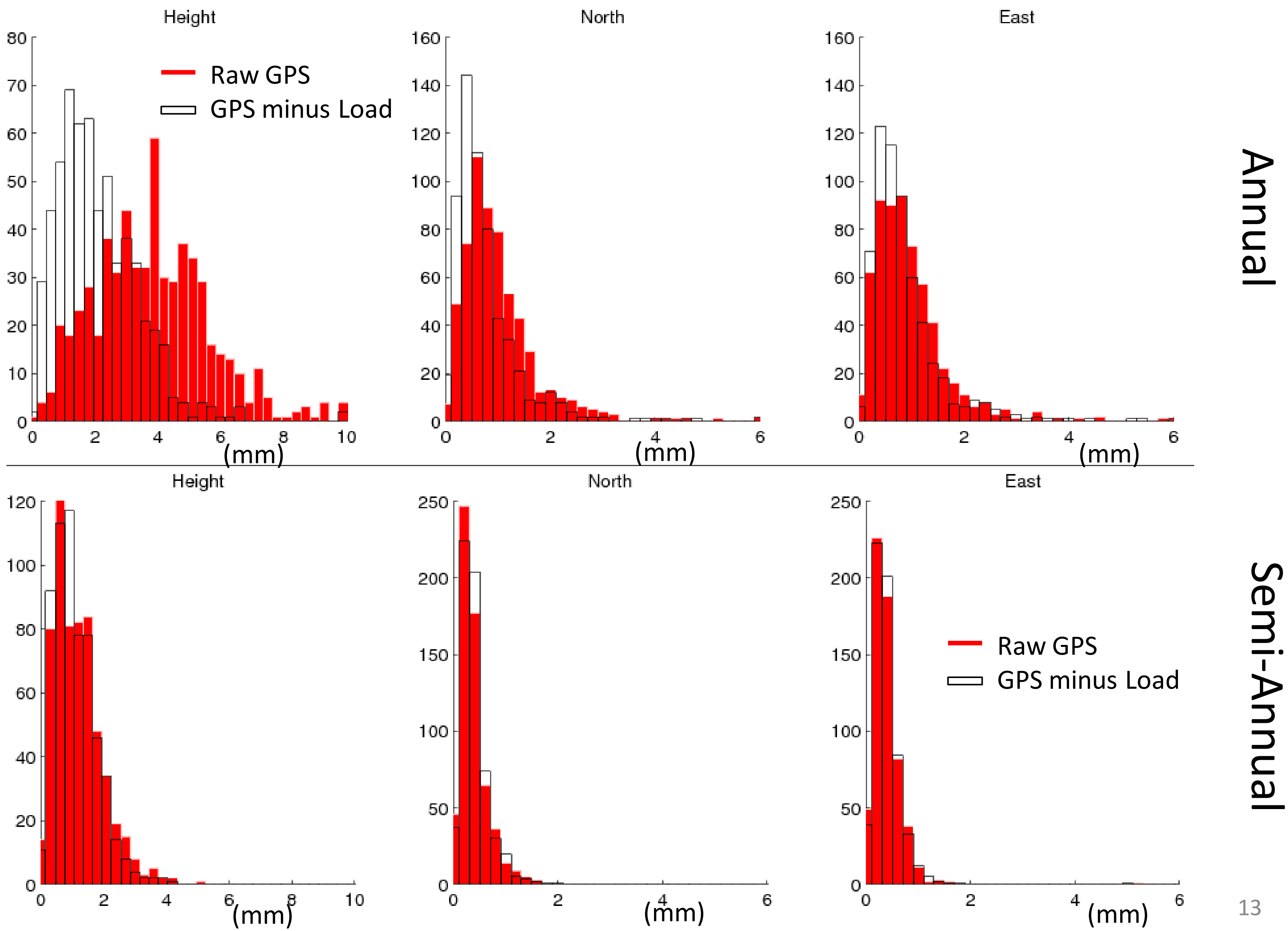


Worst agreement in the East component

For example in Europe (Tregoning et al., 2009)

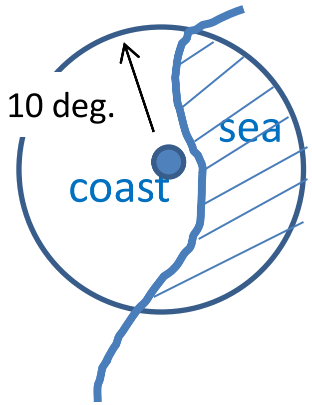
Comparison (3/4)

Distribution of seasonal displacement amplitudes

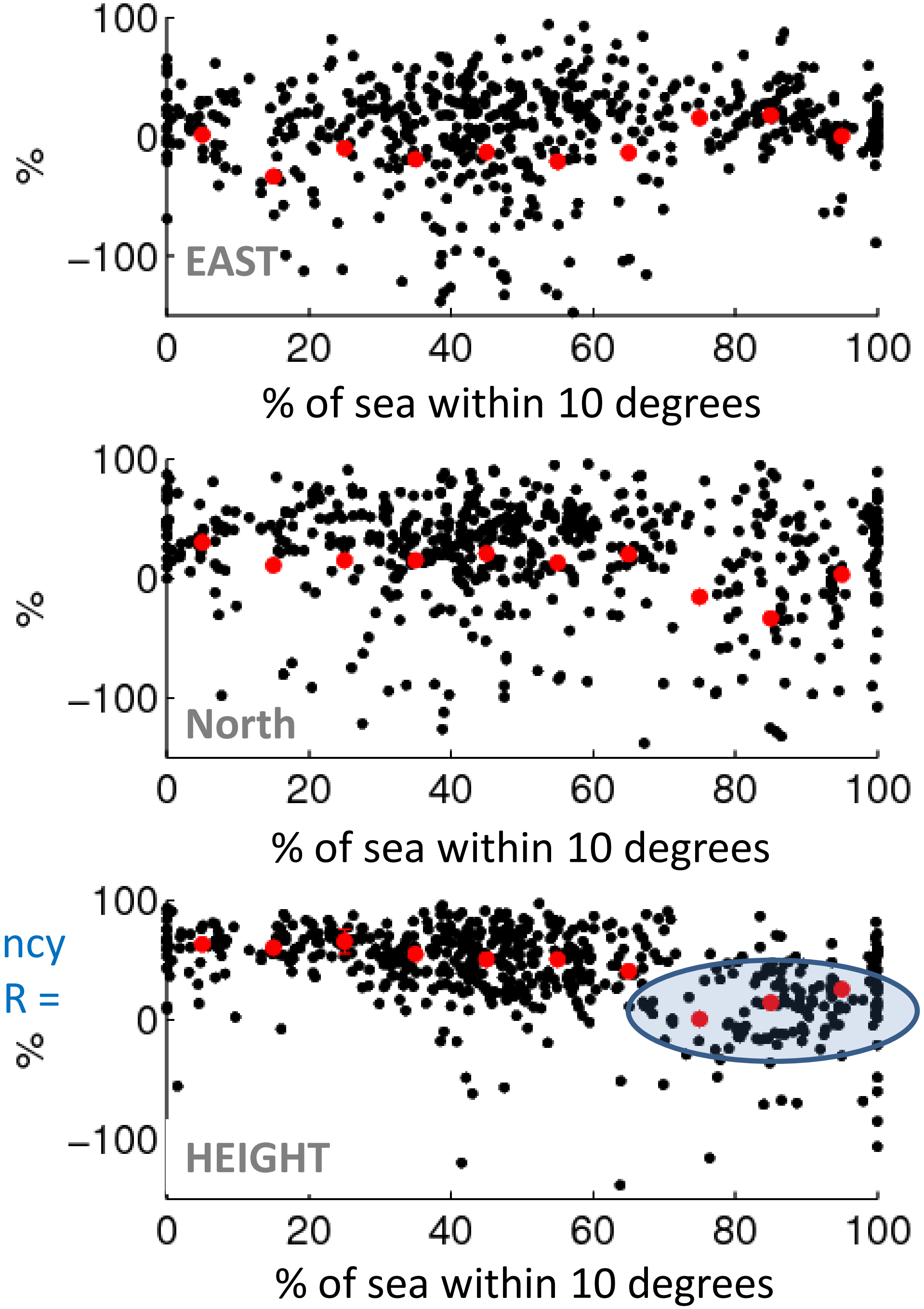


Comparison (4/4)

Percentage of explained annual signal by the loading model as a function of the percentage of sea within a radius of 10 degrees



Decrease in the load correction efficiency from about 70% of sea surface within R = 10 deg.



Conclusions

- Loading corrections decrease annual displacements for 63%, 76%, 88% of the 602 sites along East, North and Height. (47%, 44% and 57% for semi-annual)

- Still large discrepancies, especially in the East component

- Source of discrepancies?

Deficiencies in the loading model, Draconitic period *(Ray et al., 2008)*, thermal expansion of the ground *(Yan et al., 2009)*, local motion, troposphere modeling *(Gegout et al., 2009)*, ocean tide loading?