A review of GPS and GRACE estimates of surface mass loading effects

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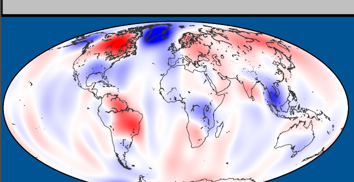
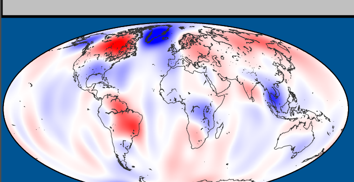


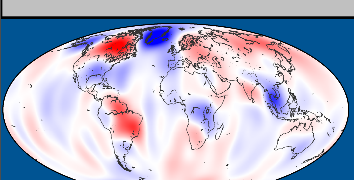
introduction

- variations in the distribution of surface mass displaces the Earth’s surface to an extent that can be observed with GPS, VLBI, and SLR
- this environmental loading signal is often a source of noise in geodetic data used for geodynamic or tectonic studies
- GRACE is sensitive to mass changes and provides observations of the global gravity field that can be converted into estimates of the associated surface displacements
- Can we use GRACE to remove the environmental loading signal, thereby improving our estimates of the long-term surface displacement fields?



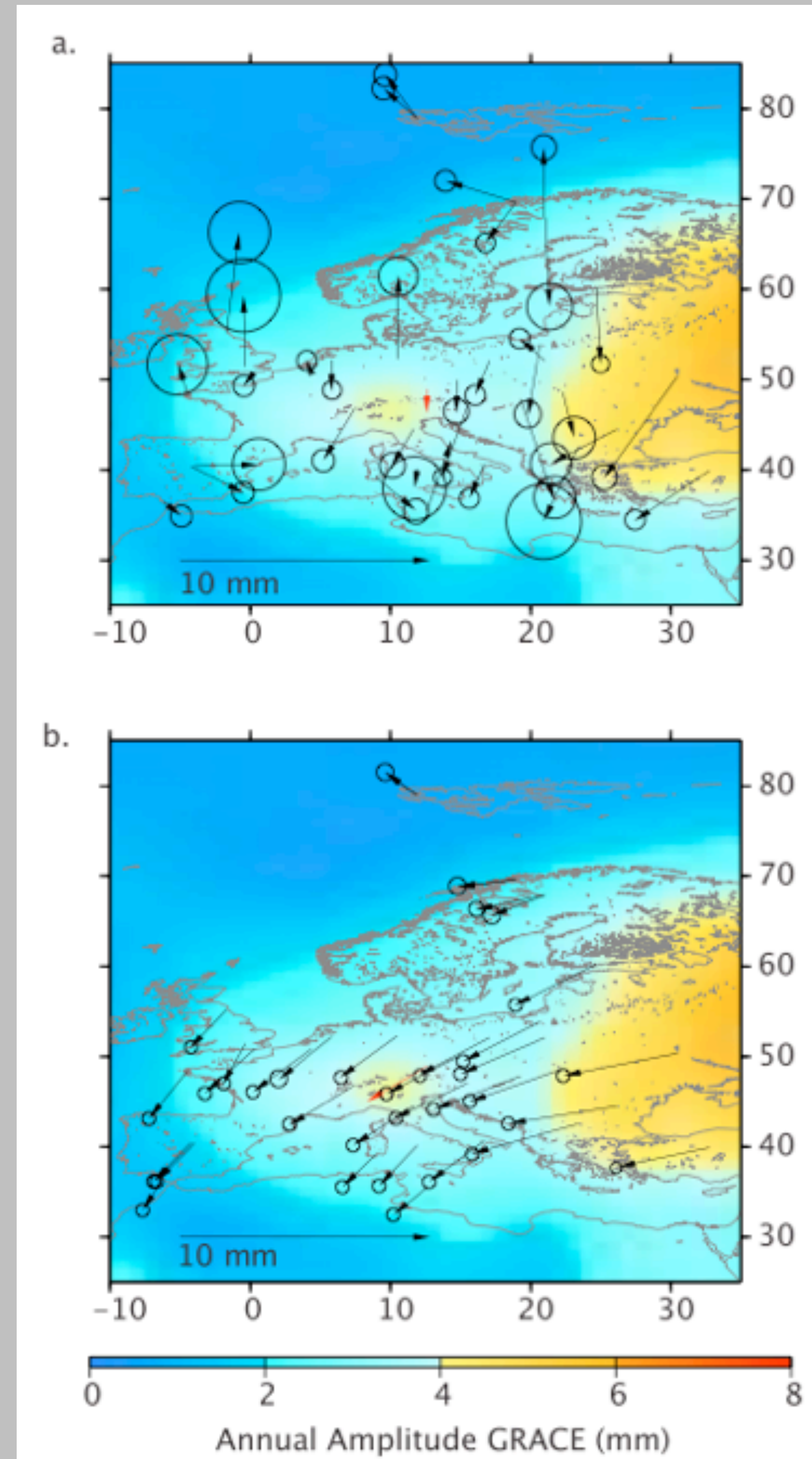
review

- the first comparison between GRACE estimates of surface displacements with observations, were only successful for the biggest signals
- *Davis et al.* [2004] compare the annual signal from GRACE with GPS heights from sites in the Amazon River Basin
- they found very good agreement between the signals
- annual amplitude in height is ~13 mm



review

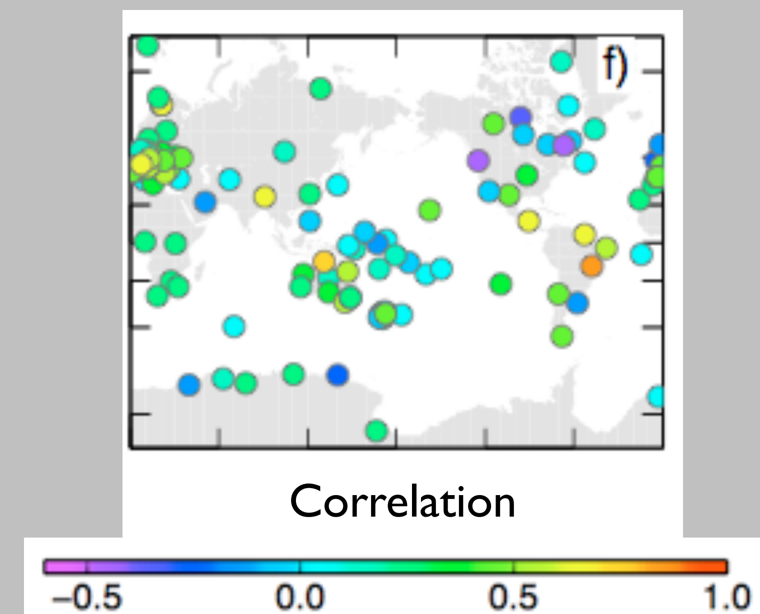
- *van Dam et al.* [2007] compared GRACE and GPS annual height variations over Europe
- GPS data from the IGS contribution to ITRF2005 [*R. Ferland et al., 2000*]
- found barely moderate agreement
- concluded that spurious signals in the GPS were primarily responsible for the disagreement



review

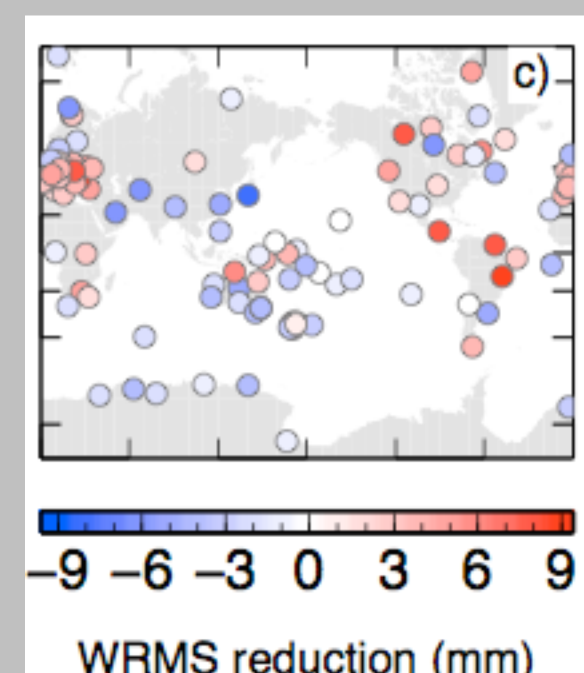
- *Tregoning et al.* [2009] found improved correlations between GPS and GRACE (over the results of *van Dam et al.*)

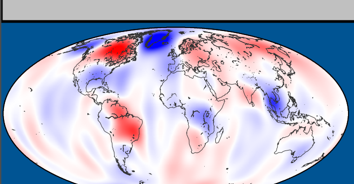
- *Tregoning* attributed the improvement to their use of a homogeneously reprocessed GPS time series



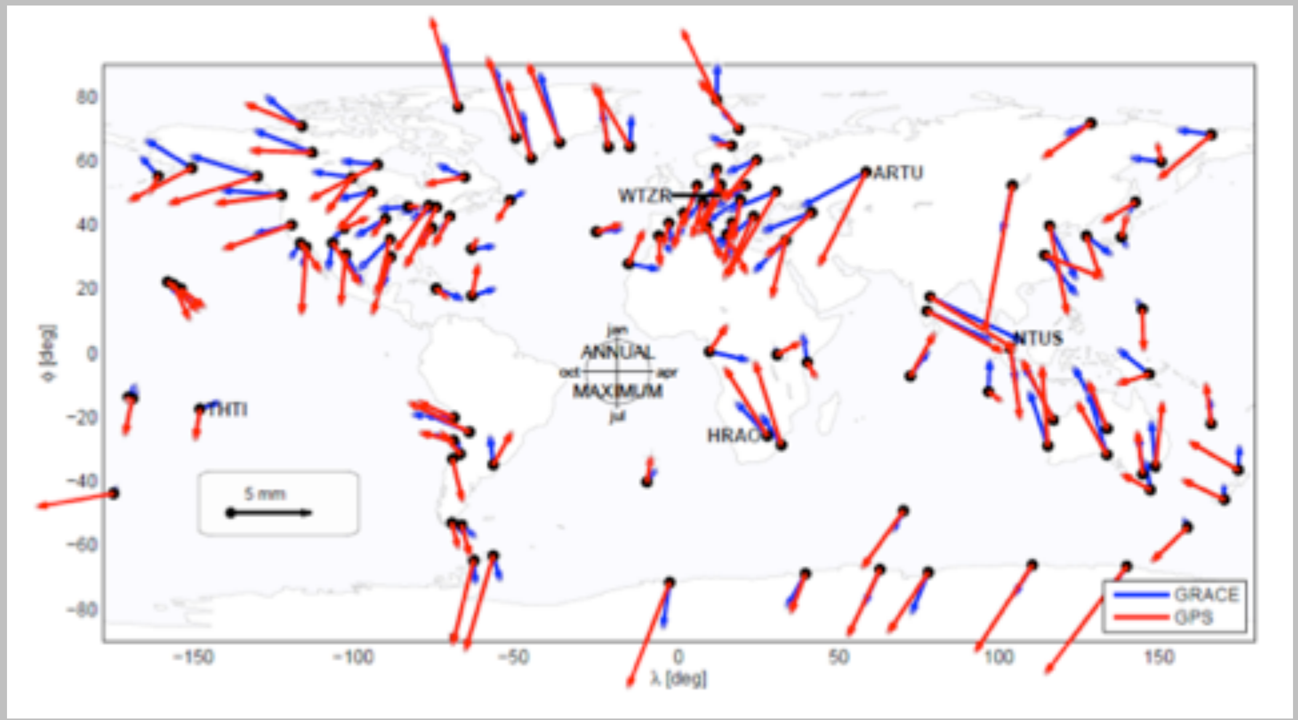
- removing the GRACE signal from the GPS heights still only reduced the WRMS of their GPS residuals on ~ 50% of their sites

- they concluded that local processes or site specific analysis errors dominated their GPS height estimates rather than the long-wavelength hydrological loading

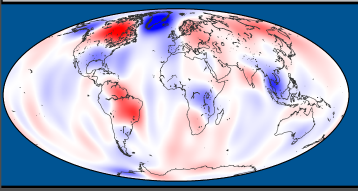




review

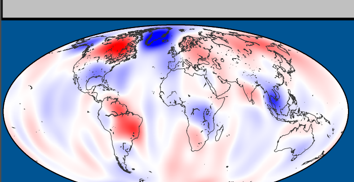


- *Tesmer et al.* [in press] also compared the GPS/GRACE annual signals
- they also used a reprocessed GPS data set
- they found an improvement over the results of *Tregoning et al.* [2009]
- improvement most likely due to their GPS site selection



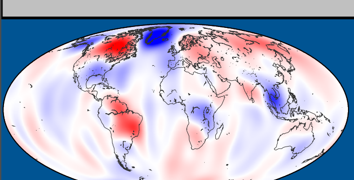
introduction

- in this presentation, we revisit the GPS/GRACE comparison; we evaluate the entire (versus annual) up-coordinate time-series from ~ 440 GPS stations
- we find slightly better correlations to those presented by *Tregoning et al.* and *Tesmer et al.*
- there is a strong correlation between the GPS and GRACE data at seasonal periods
- still, using GRACE data to approximate the environmental loading signal, must be undertaken with caution



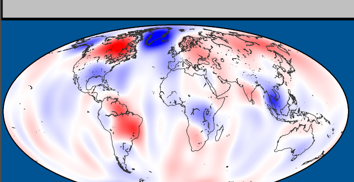
GPS Data

- non-linear height variations from the Massachusetts Institute of Technology reprocessed solution (mi1)
- secular positions and velocities for all the stations have been computed
- discontinuities were identified and modeled in the estimated secular frame
- non-linear variations are derived with respect to long-term secular frame by means of internal constraints
- transformation parameters are estimated between each weekly solution and the estimated secular coordinates of the epoch using a subset of well distributed stations in order to minimize aliasing errors



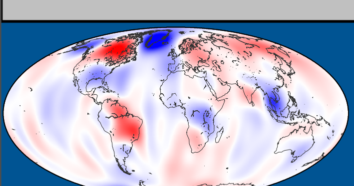
GPS Data

- we only use the up-coordinate time series with more than 100 weeks, leaving about 440 globally distributed stations
- GRACE data do not contain the effects of the atmospheric or ocean mass; GPS data must be corrected for atmospheric (atml) and barotropic (ntol) ocean loading to be consistent with the GRACE data
- ntol and atml are estimated using the GRACE AOD1B product described in [*Flechtner*, 2005]
  - 6-hourly Stokes Coefficients up to degree and order 100
  - GPS residuals are expressed in approximate centre of figure frame (CF)
  - AOD loads for each site determined in CF and averaged into weekly solutions centered on the GPS week
  - removing the AOD loads reduces the WRMS on 280 of the 440 files investigated (~ 63%)



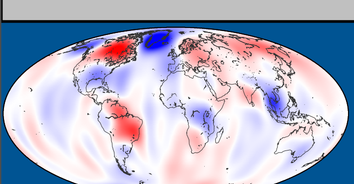
GPS Data

- GRACE data are generated from degree-2 and higher Stokes Coefficients, i.e. no reference frame
- to make the GPS data consistent with the GRACE data, we need to remove the degree-1 terms from the GPS data (or add degree-1 terms to the GRACE data)
- we use the GRACE+ocean model degree-1 [*Swenson et al.*, 2008] to determine degree-1 displacements at each GPS site in the CF reference frame
  - the ocean model is the Ocean Model for Circulation and Tides (OMCT)

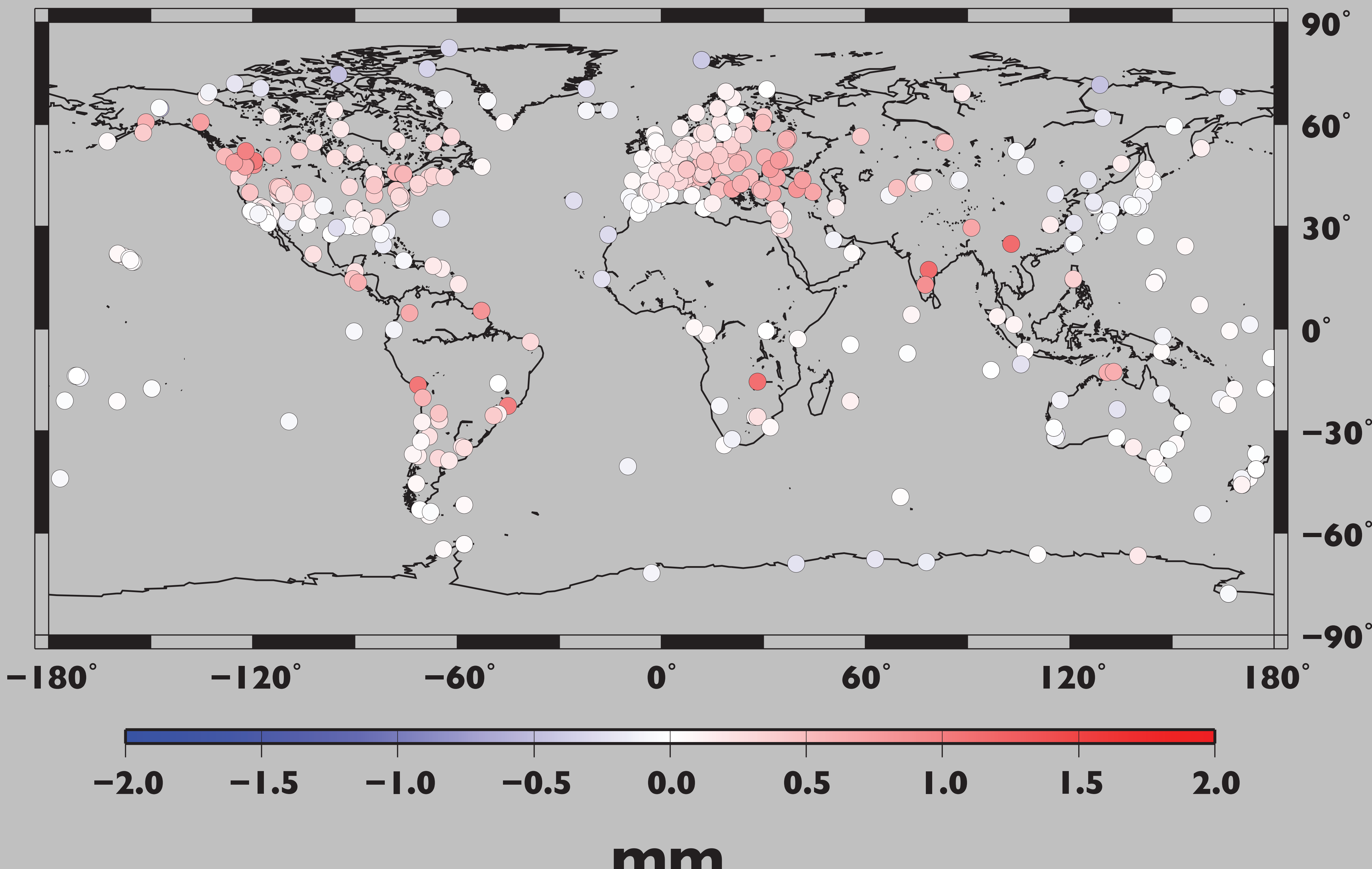


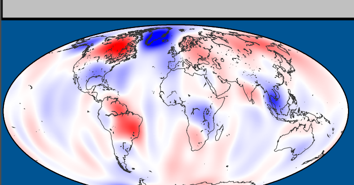
GRACE Data

- Results from the presentation of Tourian et al.," Long-range spatial correlations in GRACE products: a matter of S2-tidal aliasing?" Friday April 08 10:45 in the session: Determination of Mass Transport and Distribution in the Earth System
- GFZ release 04
- spherical harmonics 0-60
- Swenson and Wahr destriping [*Swenson and Wahr*, 2006]
- 500 km Gaussian smoothing



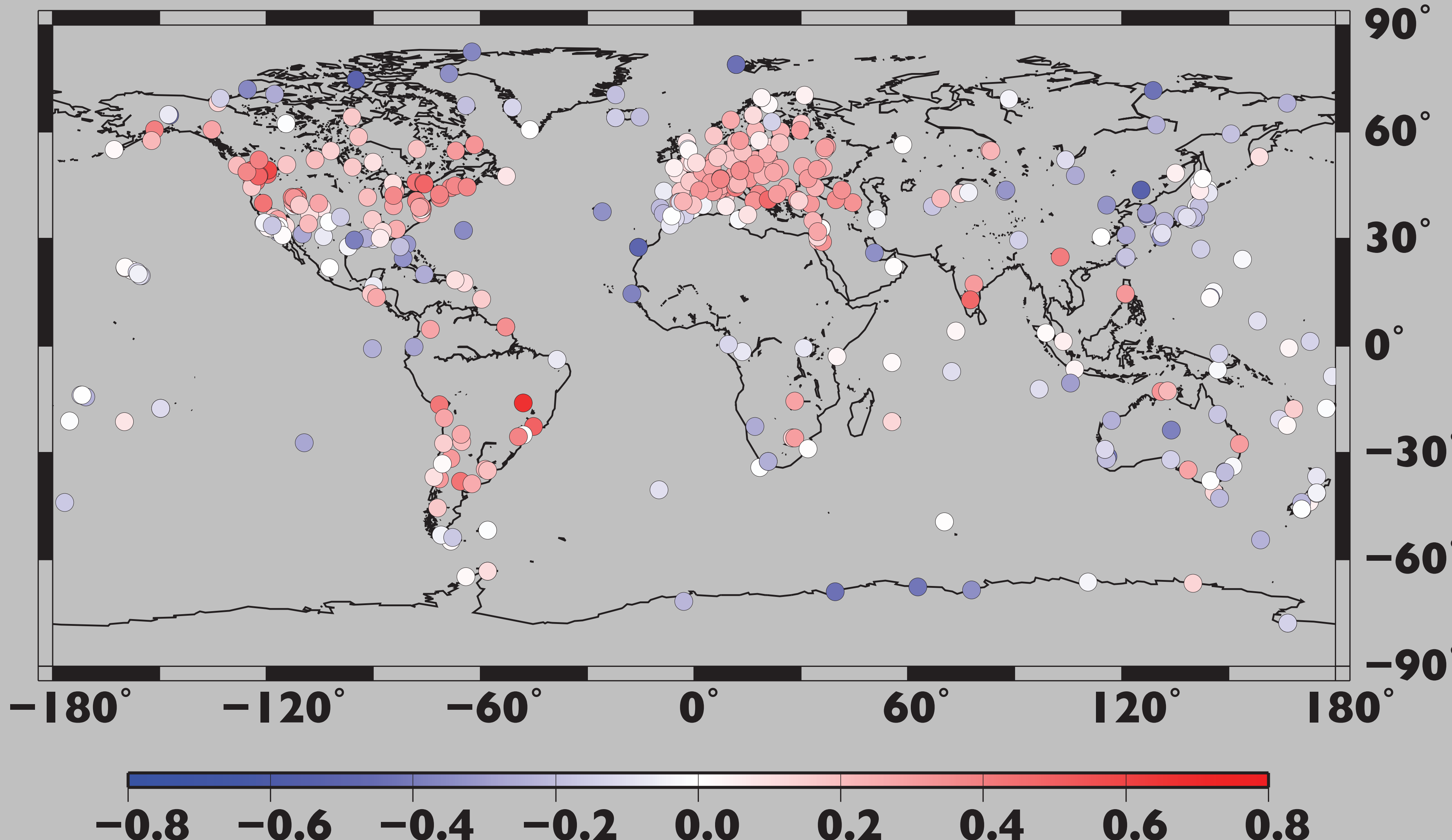
- removing the non-filtered GRACE loads from the GPS data, reduces the WRMS on 310 of the 442 files (70%)

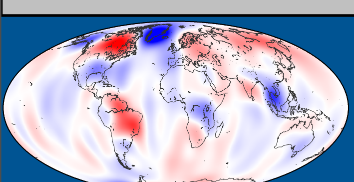




Correlations

- at 263 stations GPS observations and GRACE surface displacements are positively correlated (60%)





Conclusions

- the comparison with the non-filtered GRACE data and the mi1 data presented here is consistent with earlier studies, i.e. reprocessed GPS data and GRACE data are highly correlated
- the question we set out to answer is: "Can we use GRACE to remove the environmental loading signal (particularly the effects of water storage) from GPS data?"
- at stations where you expect the water storage signal to be large, yes.
- at other stations, you might be adding as much noise as the loading signal you want to remove