Jet Propulsion Laboratory
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Revisiting the role of elastic deformation on GNSS observations of vertical land motion at tide-gauge locations

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Vertical land motion at tide-gauge locations

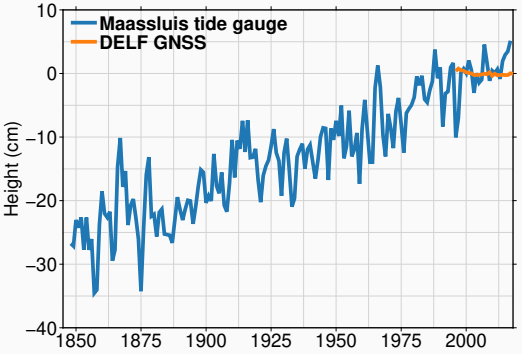
Vertical land motion at tide-gauge locations has seen a lot of interest:

- Improve global and regional sea-level reconstructions
- Isolate geophysical signals
- Study local subsidence
- Validate altimetry observations

IJmuiden tide gauge with GNSS receiver and InSAR reflector
(Source: gnss1.tudelft.nl)

Some open issues

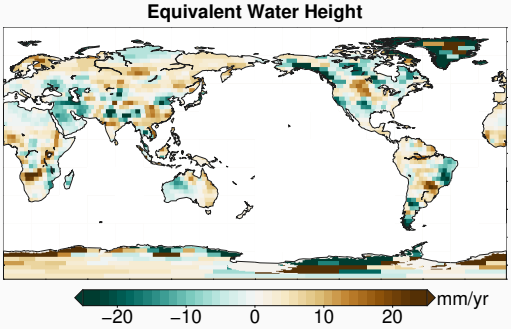
- Are the linear trends in GNSS time series representative for the TG record?
- GIA, sediment loading, compaction? **Probably yes**
- Deformation from surface loading? **Let's find out!**
- Geocentric sea-level change does **not** conserve ocean volume

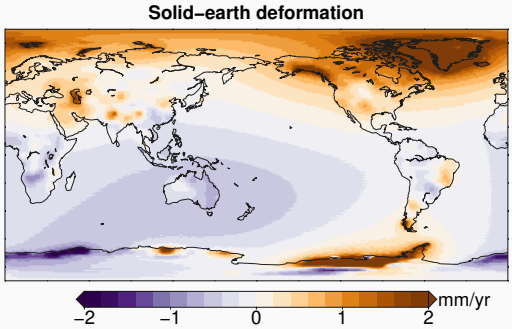


TG data: PSMSL, GNSS data: UNR, Blewitt et al., 2018

Mass redistribution from GRACE

- Mass redistribution causes elastic deformation
- Deformation can be computed from solving sea-level equation

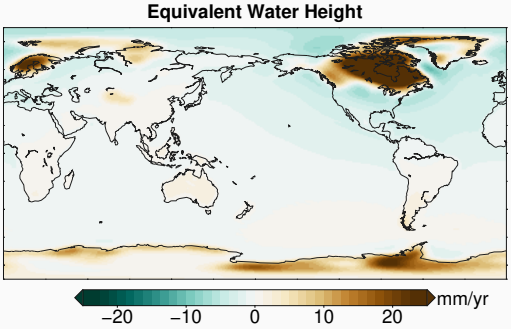


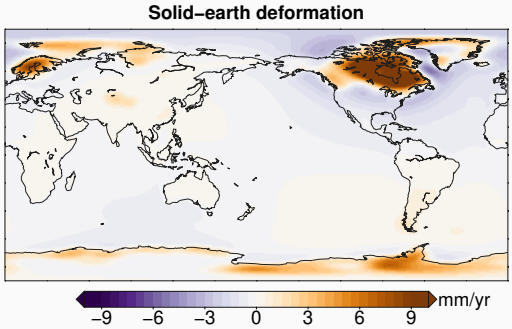


GRACE RL06 JPL Mascon, 2002.4-2017.6

The role of Glacial Isostatic Adjustment

- GIA affects GRACE observations and causes solid-earth deformation
- GIA has a considerable uncertainty

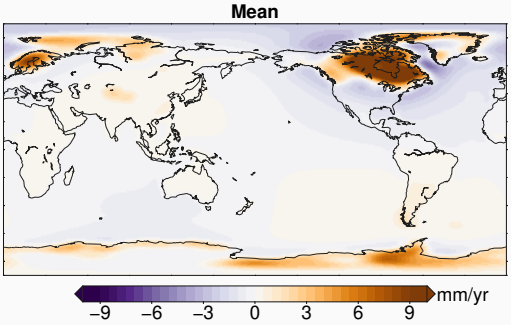


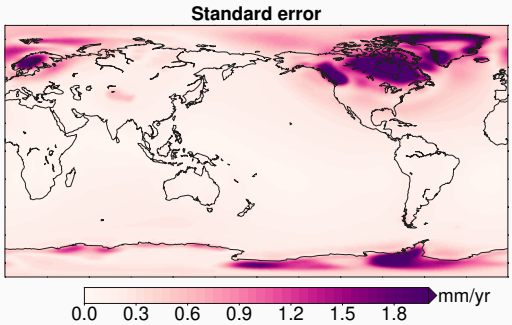


Source: Caron et al., 2018

Caron et al (2018): large ensemble of GIA models

- Quantifies GIA uncertainty by perturbing reology and ice history
- 167.000 GIA realizations with associated uncertainties





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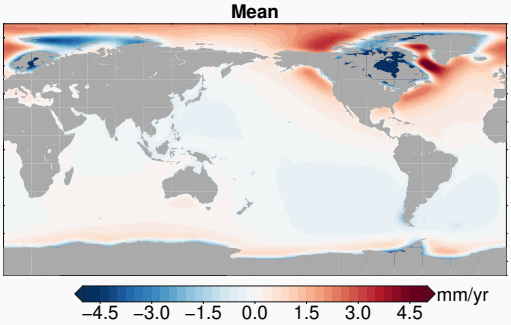
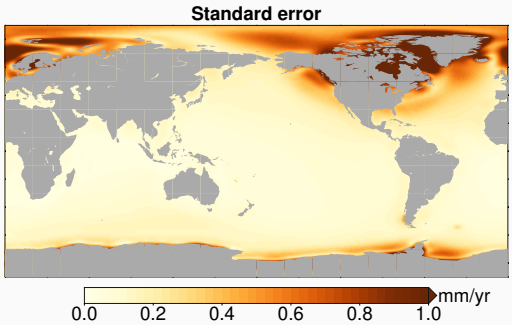




Source: Caron et al., 2018

Compute probabilistic estimates of present-day mass changes

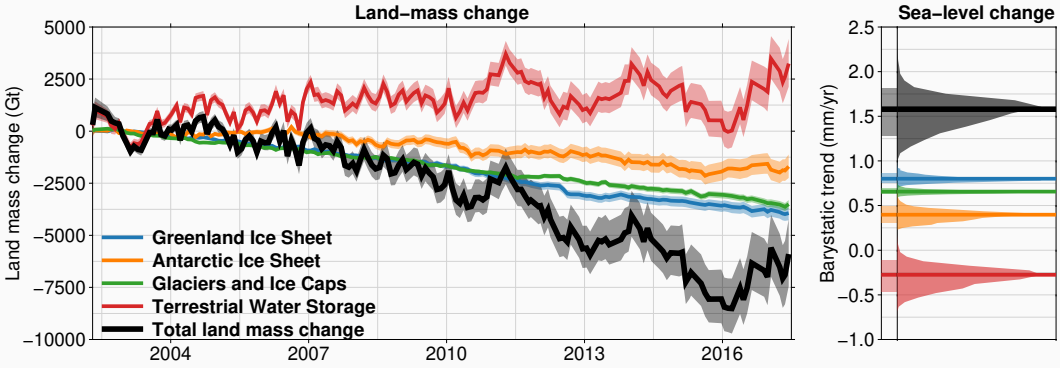
Consider two major sources of uncertainty in GRACE observations

- GIA uncertainty
- Measurement uncertainty
- We neglect some other sources (geocenter etc)

Generate large ensemble of perturbed GRACE solutions

Barystatic contribution

- GIA correction causes large uncertainty in land-mass changes
- Interannual variability in Terrestrial Water Storage

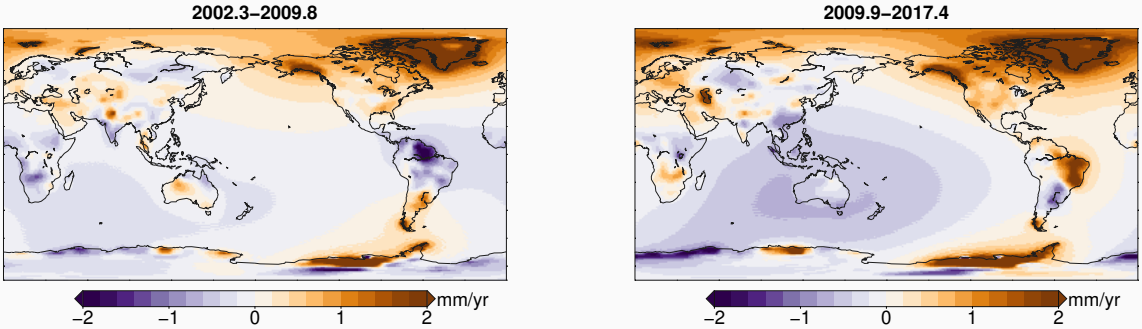


A large ensemble of fingerprints

Because GRACE estimates are uncertain, the resulting sea-level and deformation fingerprints are uncertain as well

- For each perturbed GRACE solution, solve sea-level equation
- This procedure gives a set of:
  - 5000 GIA model solutions
  - 5000 GRACE mass redistribution solutions
  - 5000 Sea-level and deformation fingerprints
- We can use this for Monte-Carlo estimates

Due to this variability, trends depend on time span



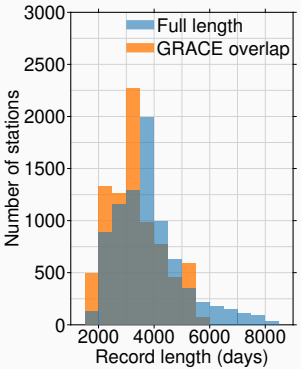
- Differences in near-field and far-field deformation
- Typical GNSS record length used to correct tide gauge is about 5-10 years

How to remove the elastic deformation from GNSS trends?

- Separate known and unknown contributors in the observed time series:

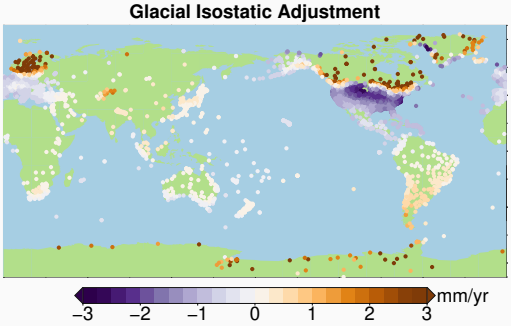
$$z_{\text{obs}}(t) = R_{\text{GIA}}(t) + R_{\text{Present-day}}(t) + z_{\text{residual}}(t)$$

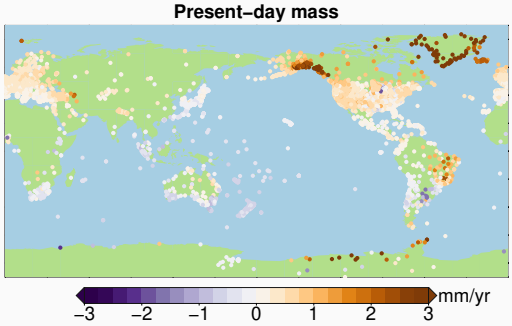
- Trends computed from MIDAS algorithm (Blewitt et al., 2016)
- Repeat these computations for each ensemble member to obtain robust uncertainty estimates



Source: UNR, Blewitt et al., 2018

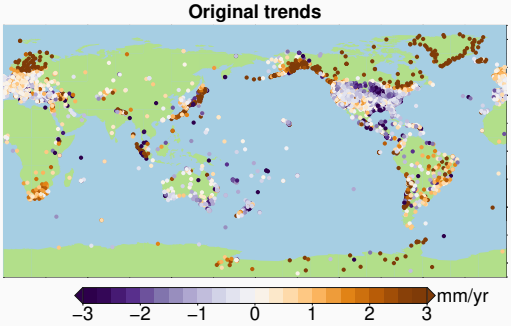
Modelled trends at GNSS station locations

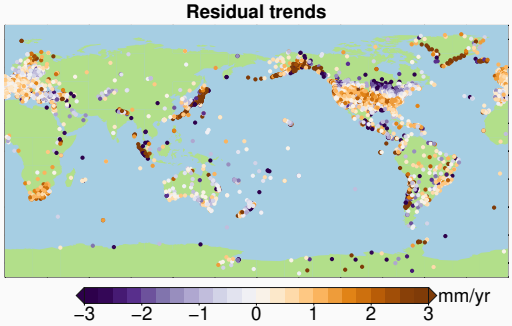




- Elastic deformation causes substantial trends: not only in cryosphere, but also due to TWS and far-field effects

Observed and residual trends

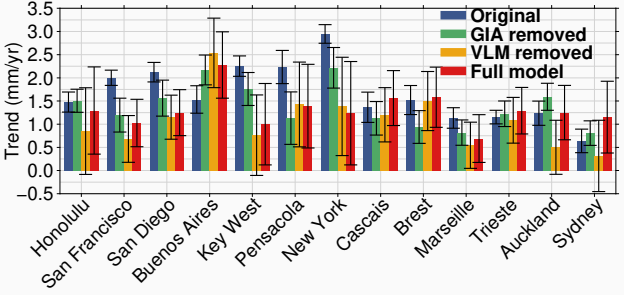




- Observed trends in South America and Australia coincide with modelled deformation

What is the impact of this correction on tide-gauge records?

- Sea-level trends from long tide-gauge records disagree with reconstructions
- Full model: correct tide gauges for GIA and residual VLM trend



mm/yr	Mean	Spread
Original	1.66	0.59
GIA removed	1.39	0.45
VLM removed	1.07	0.56
Full model	1.31	0.36

- Full model lowers disagreement with reconstructions and decreases spread between stations

Conclusions

- We computed elastic deformation resulting from GRACE mass changes
- A large ensemble of GIA predictions has been used to derive robust uncertainties
- Both GIA and elastic deformation have substantial impact on observed VLM trends
- Variability in elastic deformation leaks into trend estimates in shorter records
- Vertical land motion and deformation explains some discrepancies between tide-gauge records and reconstructions