Geocentric sea level rise from global tide gauges and GPS data reanalysis

Matt King[1], Ian Thomas[1], David Lavallee[2], Nigel Penna[1], Peter Clarke[1], Simon Williams[3], Pippa Whitehouse[4]

[1]Newcastle University, UK
[2]Delft University of Technology, The Netherlands
[3]National Oceanographic Centre, Liverpool, UK
[4] Durham University, UK

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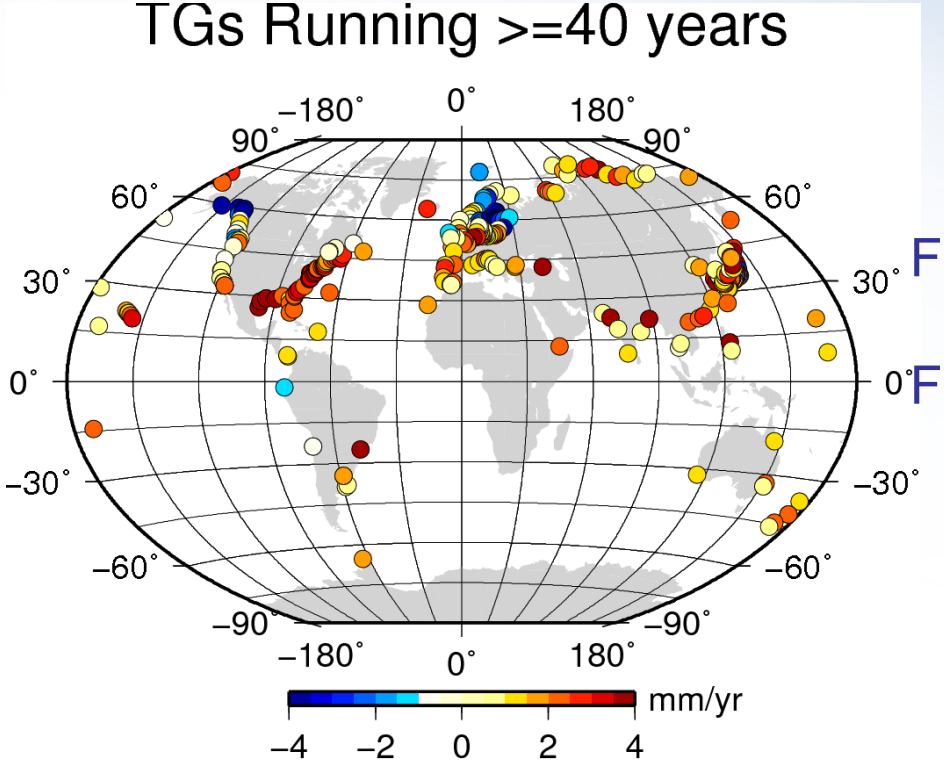
Tide Gauge Rates

Based on PSMSL RLR records with 85% completeness



Relative Sea Level

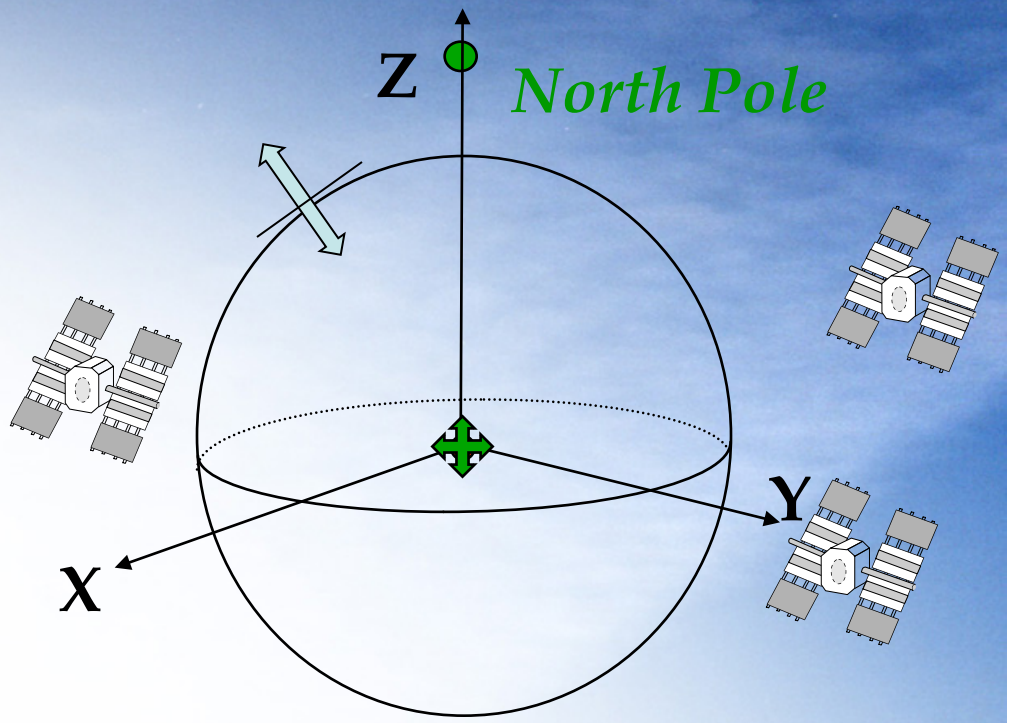
For coastal studies, this is somewhat sufficient (although point-based)

For process studies, we need Geocentric (Absolute) Sea Level

How well does the reference frame reflect the real world?

Reference frame accuracy

- All velocities measured are conceptually relative to the geocentre, but in reality are relative to a practical realisation – a reference frame



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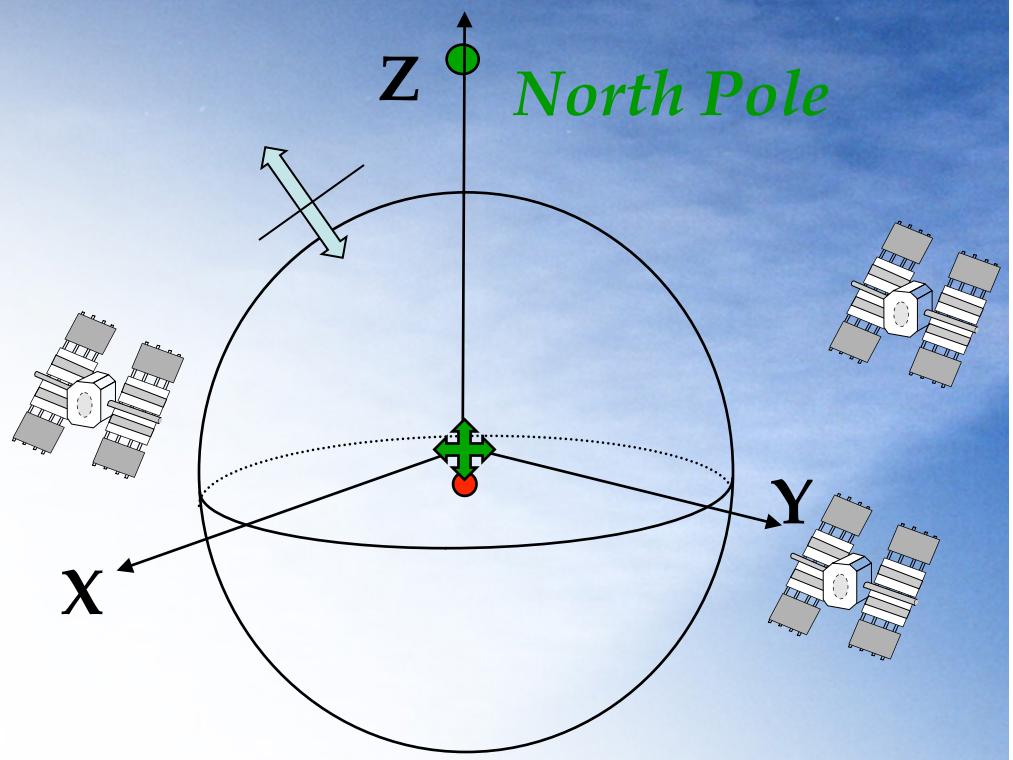

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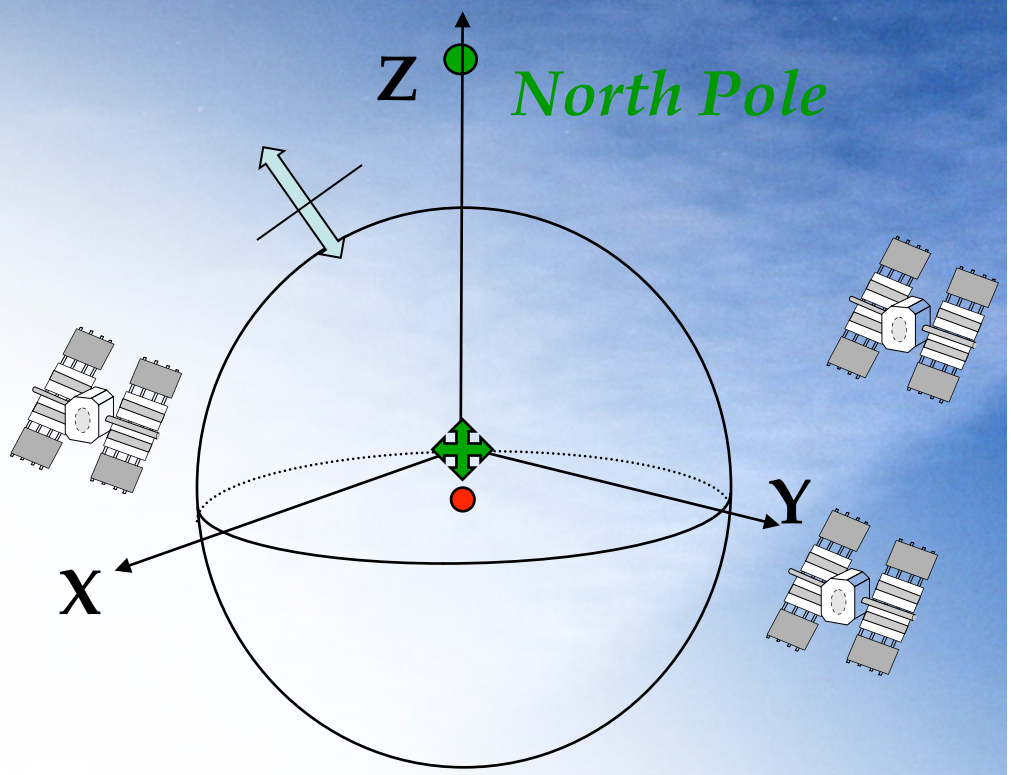

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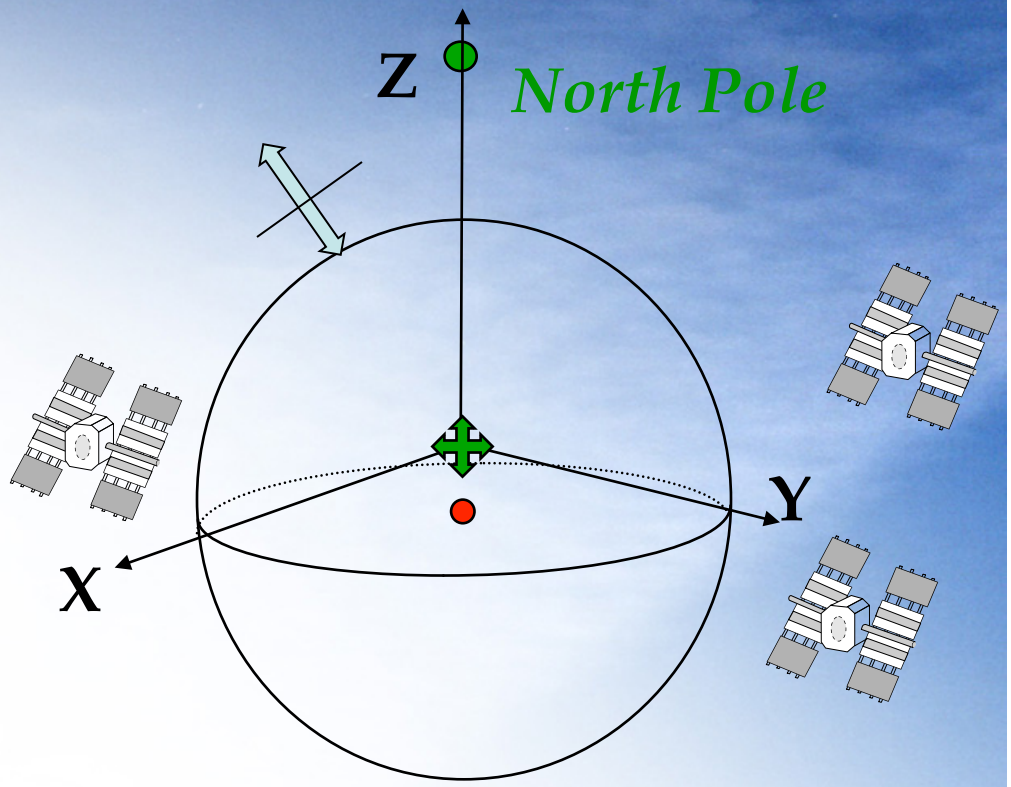

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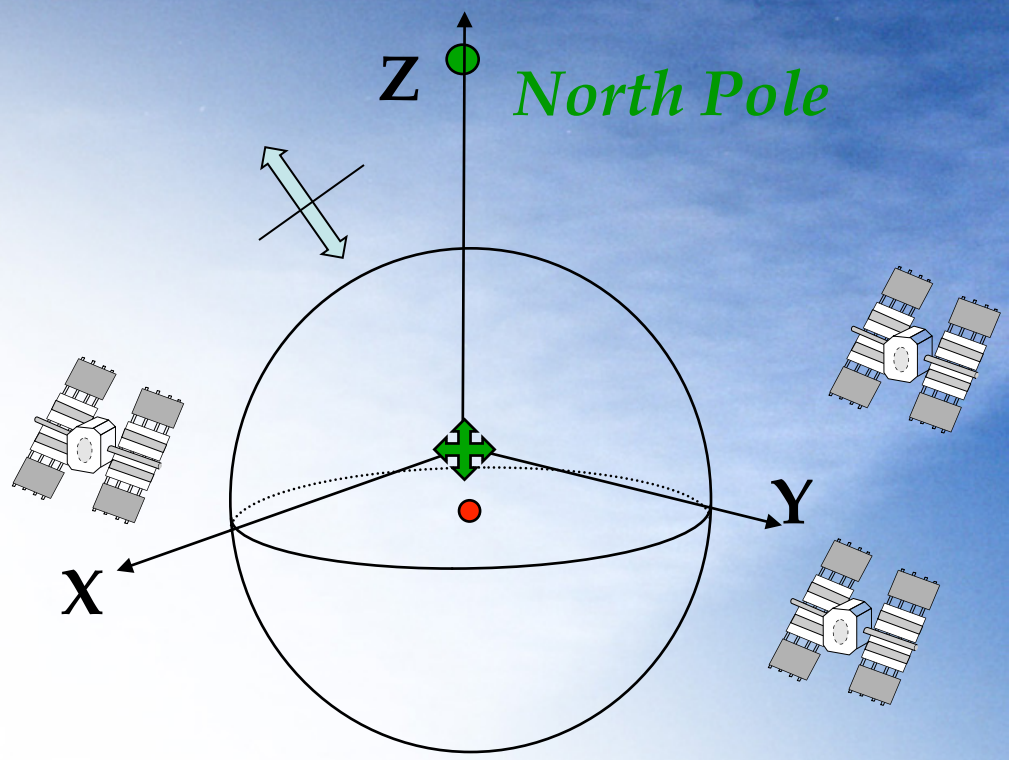

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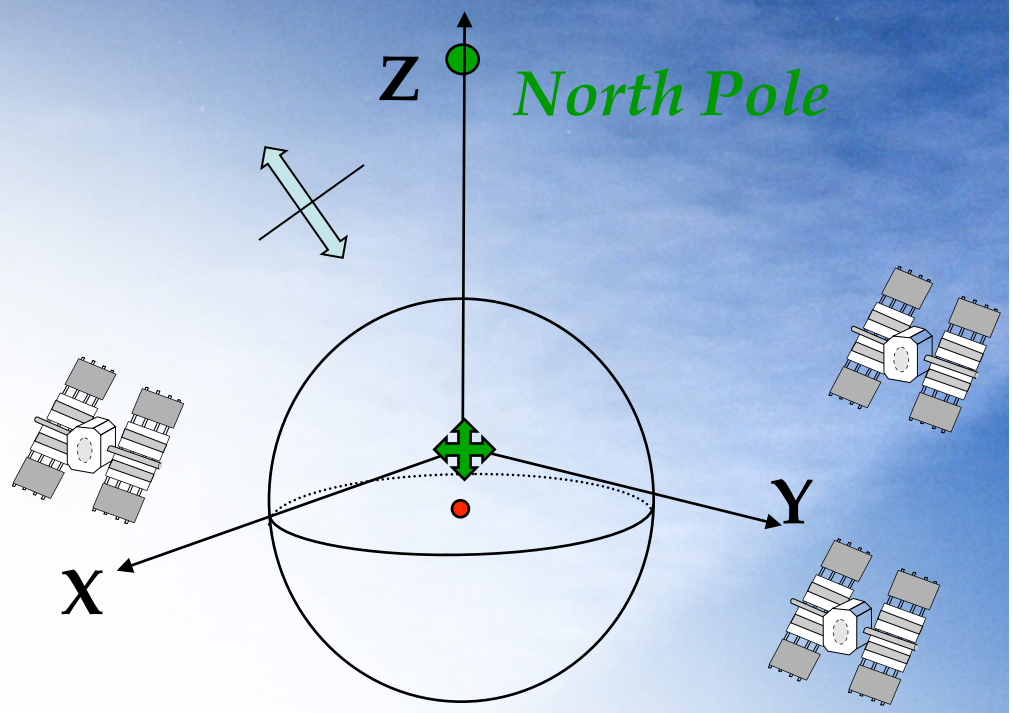
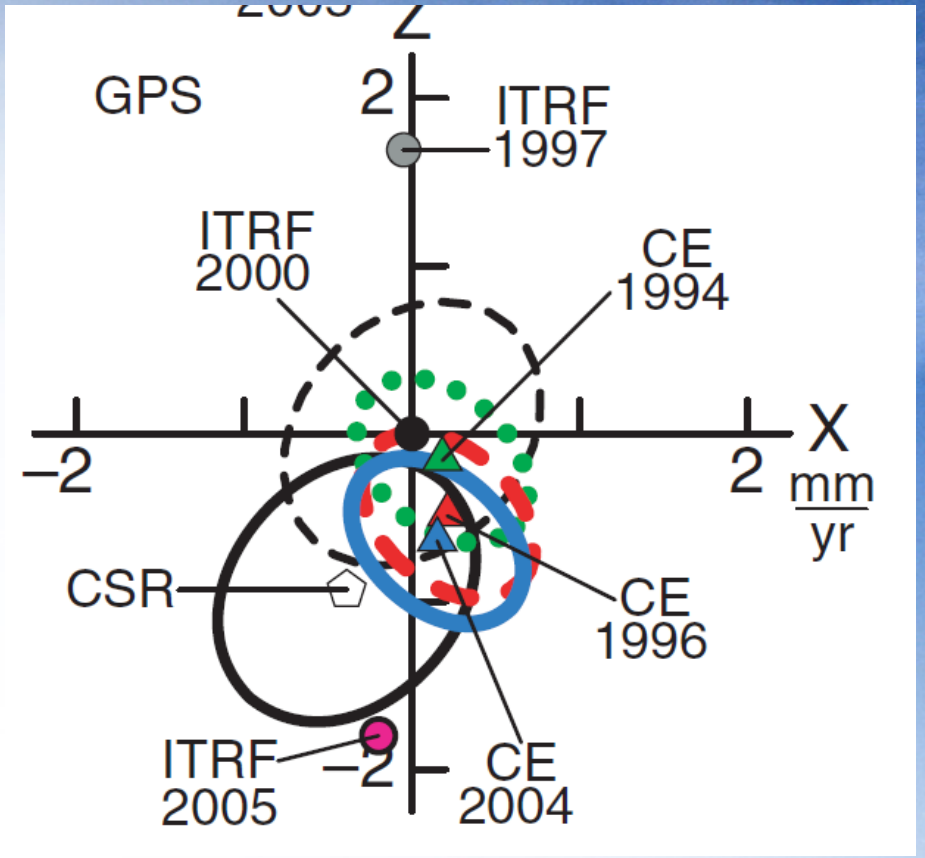


Confusion and Uncertainty

Confusion

- CE (most GIA models it seems…) vs CM (ITRF -> GPS, altimetry at secular times scales)
- It is an error to apply GIA predictions in CE to TGs for drift correction of altimetry in CM
- Difference is ~1.2mm/yr in Tz rate
- Tregoning et al. (EGU 2010) highlight that E Antarctic GPS sites are subsiding in ITRF2005 and prefer a geocentre rate closer to ITRF2000
- Teferle et al. suggest that GPS rates at UK TGs are biased high compared to Abs. Grav. and GIA models, but is it Tz dot or other?



Argus 2007

Confusion and Uncertainty

More Confusion

- In relation to comparison of GPS VLM and GIA models, some have presumed the predicted RSL from ICE5G on the PSMSL website to be equal to the VLM -> ignores the gravitational fingerprint, inundation etc.

Uncertainty

ITRF2000 and ITRF2005 difference in Tz dot by 1.8mm/yr.

- Used as a conservative estimate of the possible systematic

ITRF2005 and ITFR2008 agree to within <0.1mm/yr in Tz dot

- Same logic suggest no problem, but clearly there is – how big?

Our internal GPS-only frame differs from ITRF2005 by ~0.2-0.5mm/yr (in agreement with Rulke et al)

- Subject to orbit modelling errors?

We extend the results from Teferle et al by examining co-located GPS and AG rates in the UK(2), Fennoscandia(4) and Antarctica(1)

Reference Frame Issues

For each site turn (GPS minus AG) vertical rate into equivalent Tz rate bias

Site	GPS site	Lat	initial gdot/hdot	mean of Tz dot bias	computed gdot/hdot after bias removal
Newlyn	NEWL	50.10303	0.15	0.78	0.29
Lerwick	LERW	60.13914	0.16	1.05	0.21
Durmont d'Urville	DUM1	-66.6651	0.17	1.29	0.18
Kiruna	KIR0	67.8776	0.18	1.5	0.17
Martsbo	MAR6	60.5951	0.2	1.85	0.16
Metsahovi	METS	60.2172			
Skelleftea	SKE0	64.8792			

Used our GPS solutions transformed to ITRF2005

- Preferred Tz dot bias could reasonably range 1-1.5mm/yr
- Best fit is ~1.2mm/yr, closer to Argus (2007) value than ITRF2005
- Reduces velocities at positive lats and increases them at negative lats

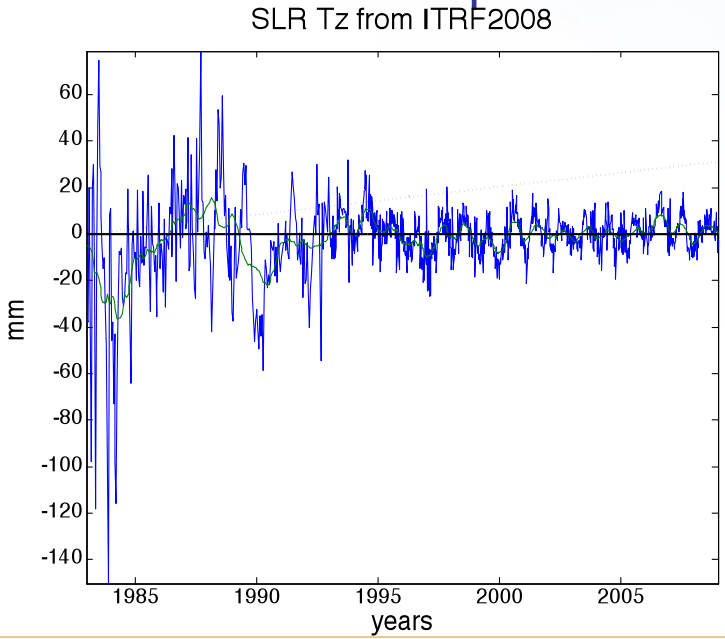
AG refs: Teferle et al (2010), Amalvict et al (2010) and Gitlein (2009). Thanks also to Holger Steffen

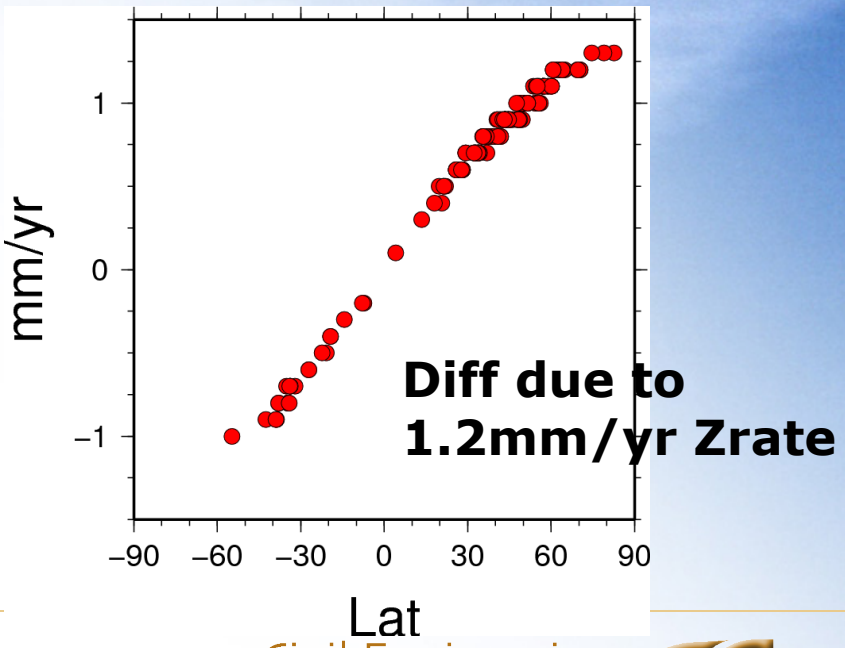
Reference Frame Issues

A quandary

- SLR systematic [seems very large]
- Limitations of Helmert Transformations?
- Missing physics?

Present range of results at extreme (ITRF2005 and ITRF2005_AG) and examine sea level pattern for further guidance





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Measuring VLM

Conventional to apply a GIA model

Measuring the actual TG motion is clearly preferred

- Global Positioning System (GPS) coordinate time series identified as a potential way forward since at least Carter et al. [1989]
- From 1989->2009 no reliable GPS-based rates published
  - Wöppelmann et al. [2009] found 1.55 ± 0.19mm/yr based on 28 TGs (across 10 distinct ocean regions)
  - Bouin and Wöppelmann [2009] found1.67 mm/yr based on 70

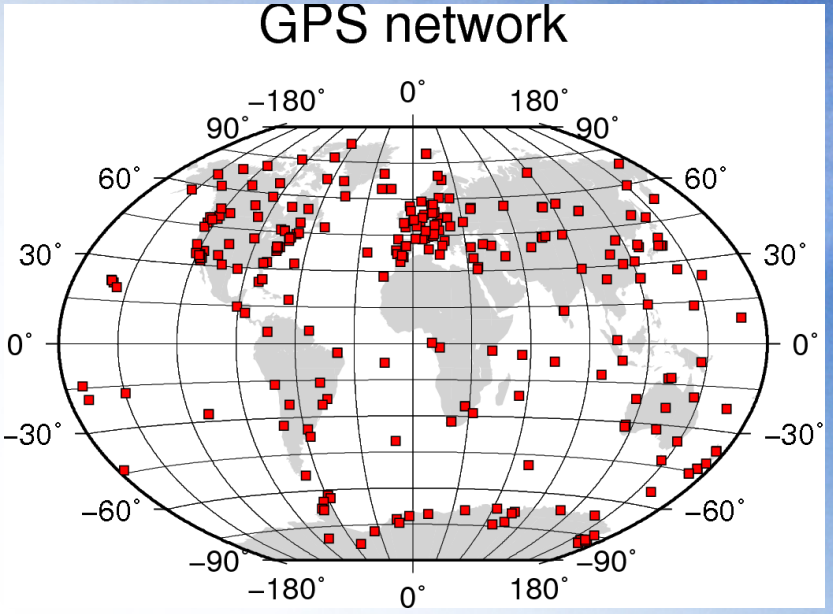
Land Motion Correction at the Tide Gauges	No Correction	GIA-Corrected ICE5G (VM2)	GPS-Corrected ULR 3
Scatter of the individual rates of sea-level change	2.05 mm/yr	1.49 mm/yr	1.15 mm/yr (0.98)
Scatter of the regional rates of sea-level change	1.37 mm/yr	0.98 mm/yr	0.62 mm/yr (0.60)

Wöppelmann et al. [2009]

Important: there is a limit to how low inter-regional agreements can go due to ocean dynamics and "fingerprints"

Our analysis

- We use raw GPS data to estimate site coordinates, satellite and earth orientation parameters in GIPSY v5
- State-of-the-art observation models (VMF1, ECMWF hydro zenith delay, subdaily ATML, 2nd order iono) + ambiguity fixing
- N/S hemispherically balanced global network with ~80 sites/day
- Data span 1997-2010.2
- PPPs for sites not used in global solutions (e.g., many TIGA sites)
- All solutions in ITRF2005



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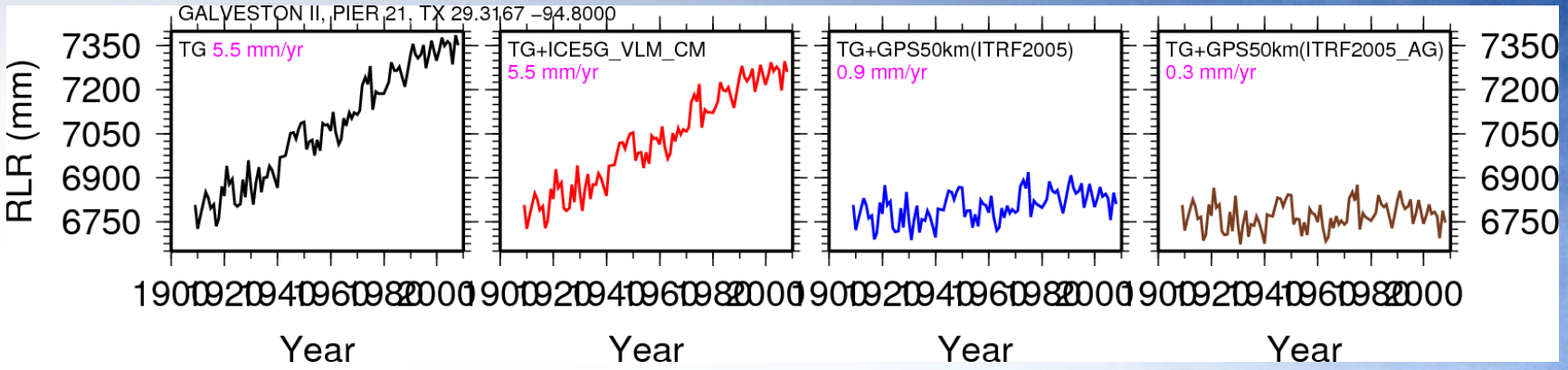
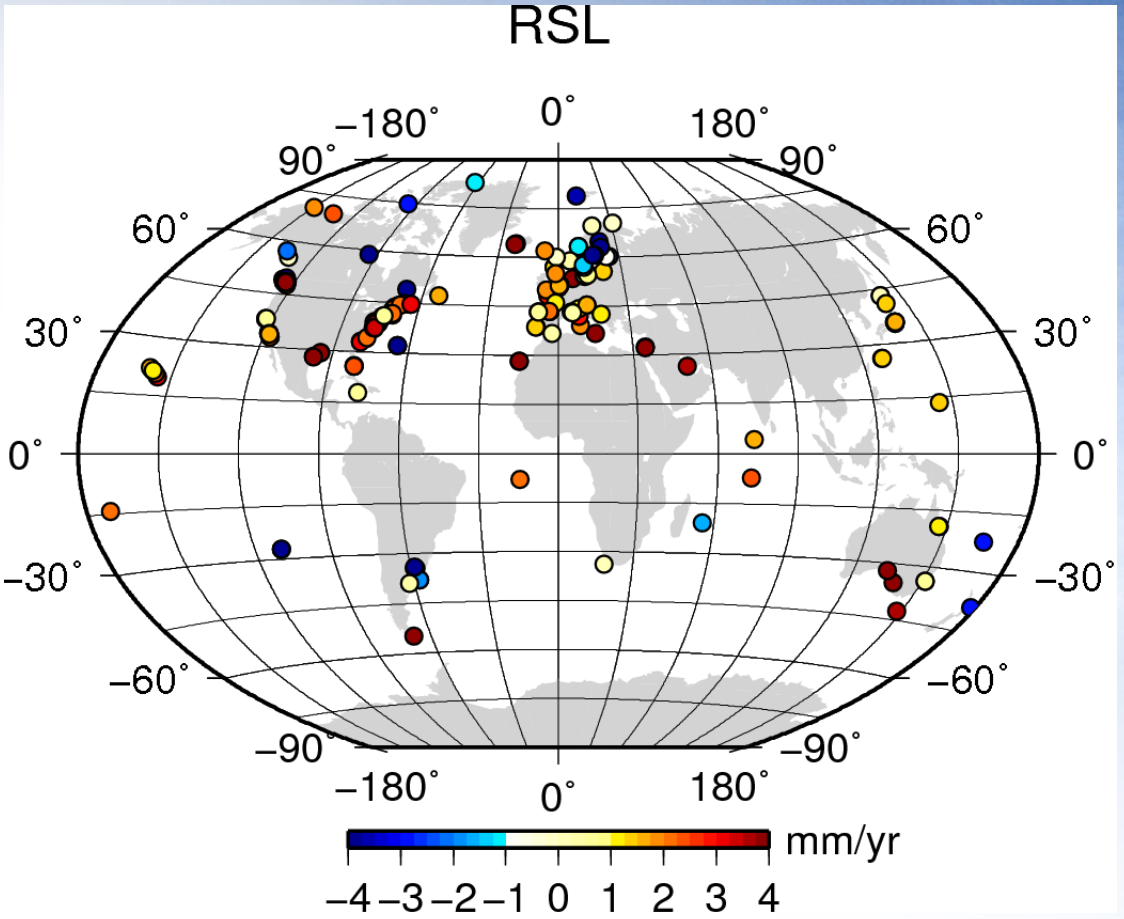
Corrected TG Time Series





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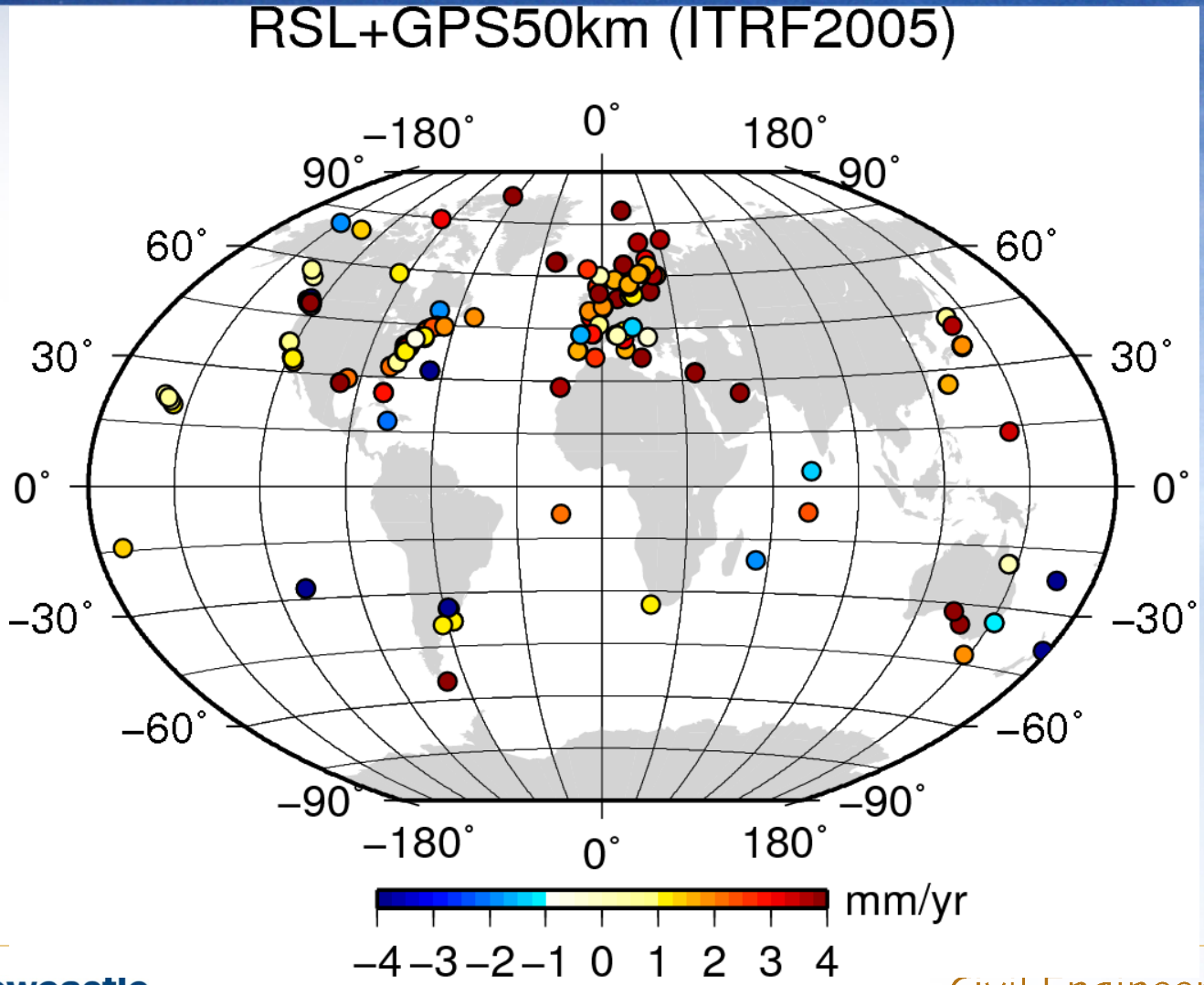

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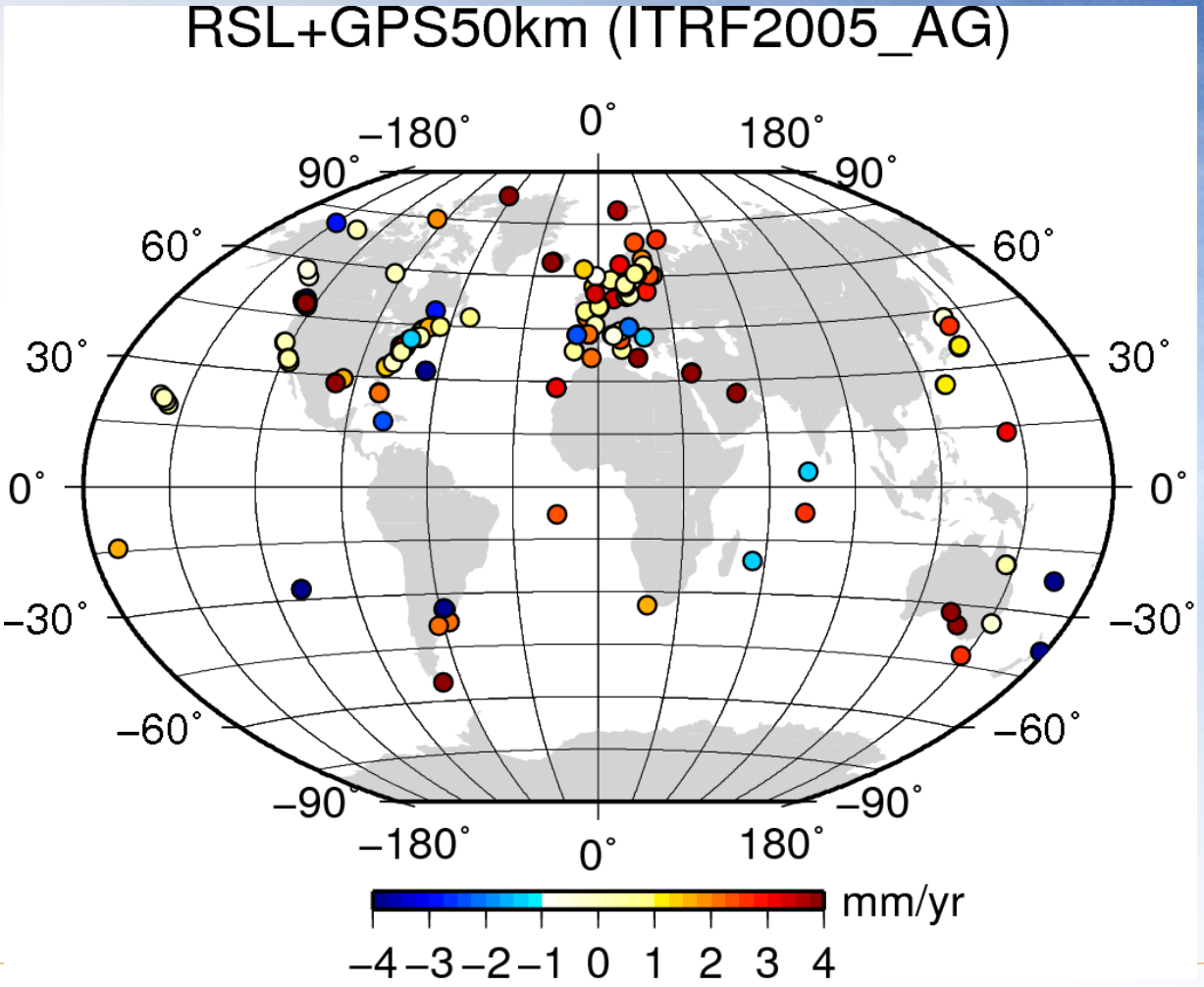

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Conclusions

Care must be taken in using GIA models, since typically in CE

Uncertainty in Zrate -> sea level obs and GPS-AG point to the need for a shift in Zrate from ITRF2005 defined by SLR of ~+1mm/yr