Accounting for gravitational attraction and loading effects from land ice on altimeter data

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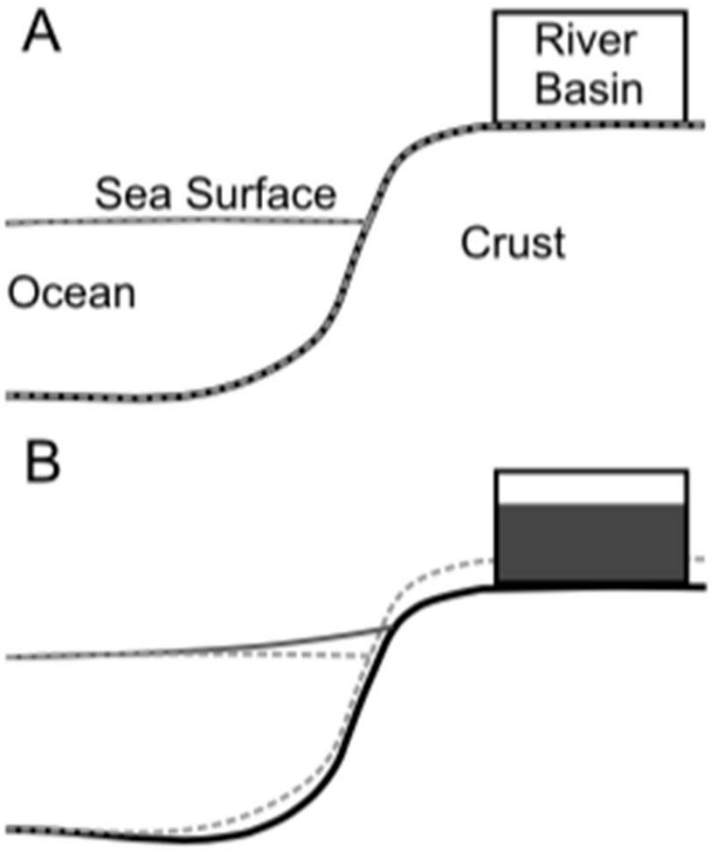
Ocean Surface Topography Science Team Meeting

Splinter on "Quantifying Errors and Uncertainties in Altimetry Data"

Gravitational and loading effects



Tamisiea et al. (2010, JGR)

- **Changes in the mass field over land, even without involving mass transfer to the oceans, affect sea level through the physics of gravitational attraction and loading (GAL):**
  - **Surface atmospheric pressure and distribution of air mass over land**
  - **Terrestrial water storage**
  - **Land ice (glaciers and ice sheets)**

Motivation and outline

At monthly and longer time scales, response to gravitational forcing associated with GAL effects is expected to be nearly static in nature, i.e., gradients in sea surface height (SSH) caused by GAL carry no dynamic significance

- **One already provides long period tides and IB corrections with altimeter data, to remove respective static signals—should we do the same with GAL-related variability?**
- **How important are these static signals associated with GAL effects and what are potential problems for physical inference if not corrected for?**
- **Can one provide useful estimates of GAL effects on SSH and at what level of uncertainty?**

Examine long-term trends associated primarily with changes in land ice at high latitudes, possible benefits of GAL correction, in the context of error budgets for altimeter data

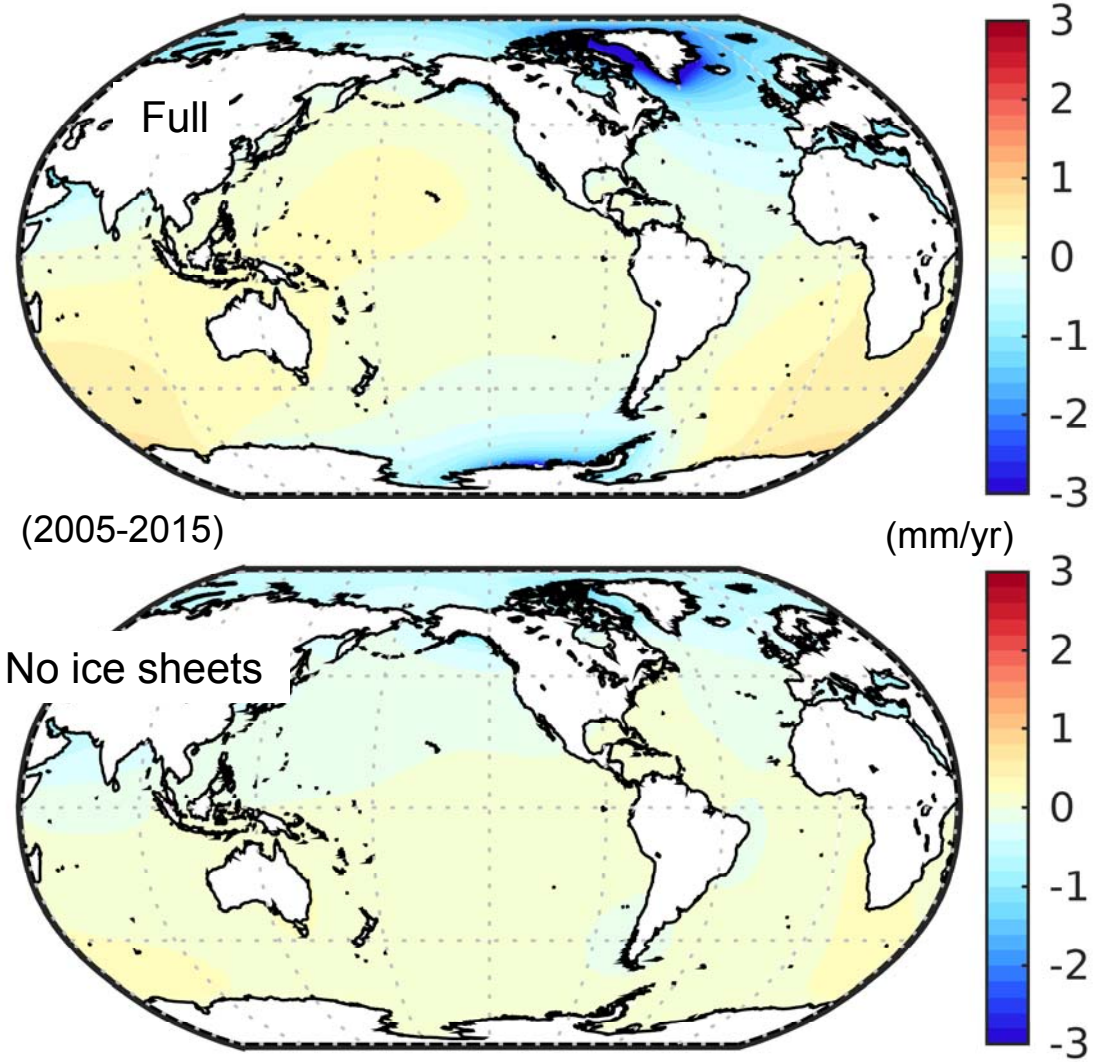
Methodology

- Effects of land hydrology/ice from GRACE data (JPL mascon solutions)
- Effects of atmosphere based on ECMWF fields
- Sea Level Equation including rotational feedback to estimate changes in SSH (or absolute sea level, as seen by altimeter)
- Steric sea level estimates from Argo data (Scripps gridded product)
- Altimetric 1x1 degree grids from CSIRO with IB and GIA corrections
- Other ancillary fields (bottom pressure, deep steric height) from ECCO ocean state estimates

Details on calculations and results provided in

Ponte, Quinn & Piecuch (2018, *J. Atmos. Oce. Tech.*)

GAL-driven trends in SSH

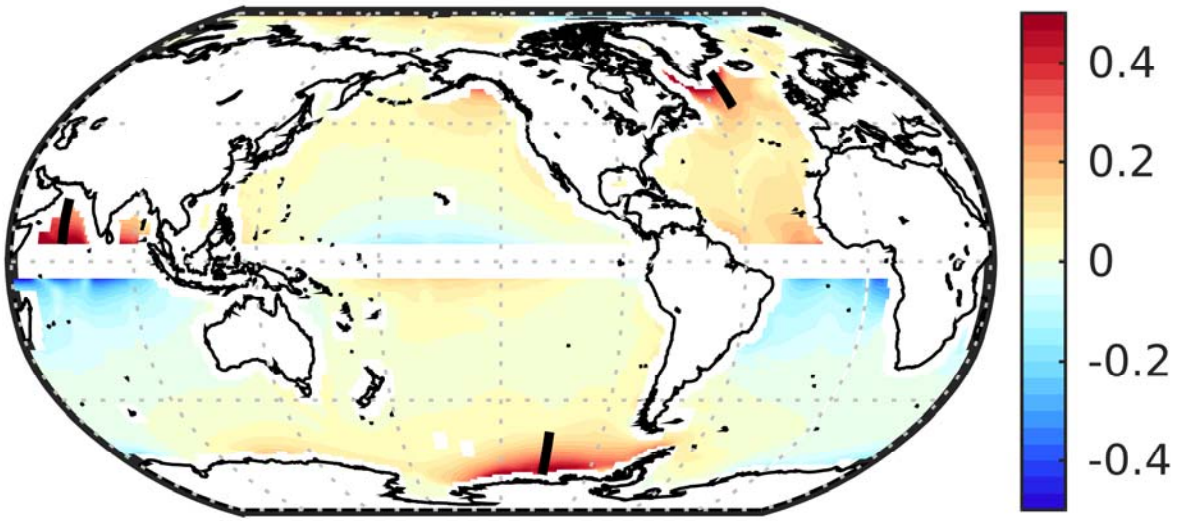


- **Typical effects of order 1mm/yr**
- **Larger (negative) trends near the ice sheets**
- **Strongest spatial gradients near Greenland**
- **Effects of atmospheric mass redistribution weaker (not shown)**

Implications for geostrophic transports?

Errors in geostrophic transports

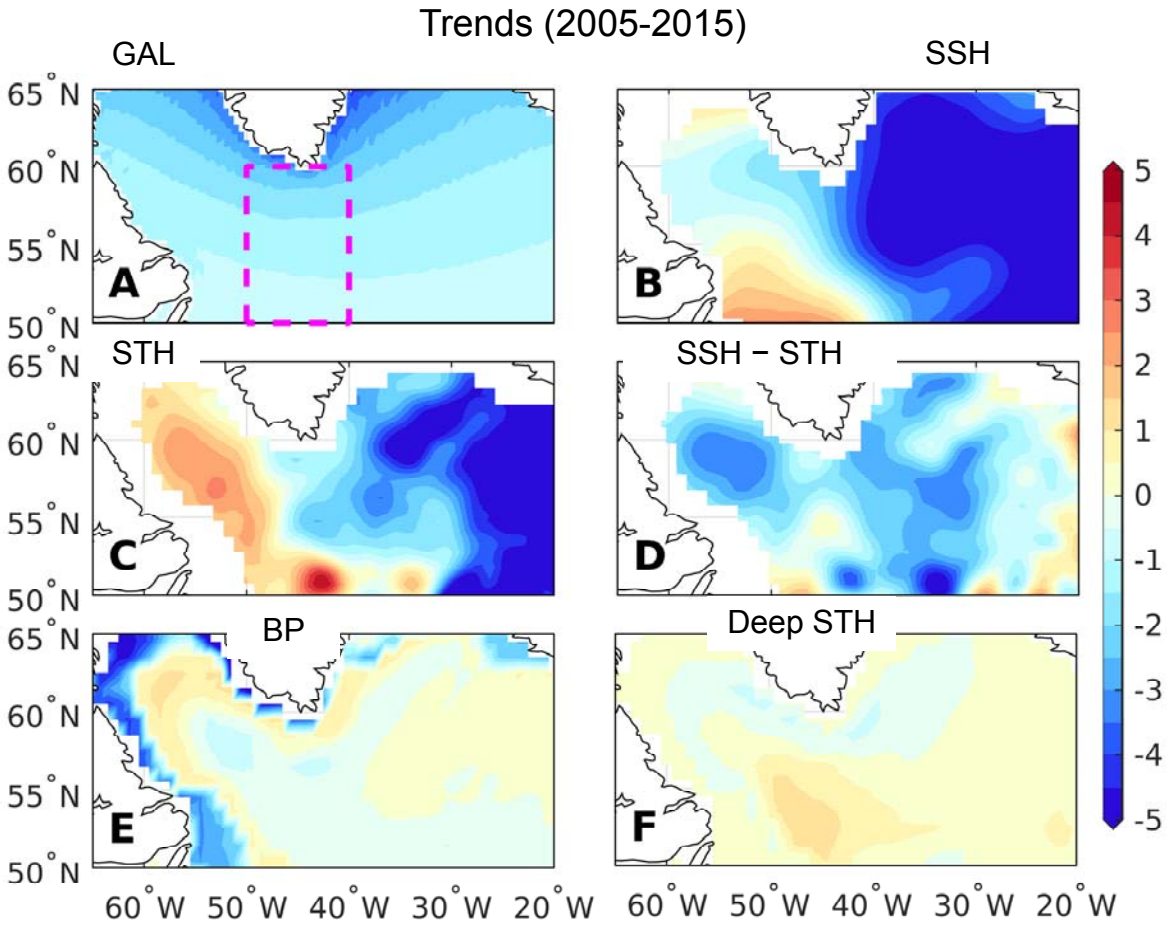
Decadal changes in zonal geostrophic transport per degree latitude (Sverdrups)



Based on SSH trends from GAL assuming they represent a depth-independent pressure gradient

- **Largest transport changes (~0.5 Sv) found near ice sheets and also in the tropics (e.g. Arabian Sea)**
- **Large spatial scales imply substantial accumulated errors (~ 5 Sv) across zonal sections in Southern Ocean, subpolar North Atlantic and Arabian Sea**
- **Magnitudes similar to decadal changes in circulation inferred from altimetric studies (e.g., Häkkinen and Rhines 2004; Hogg et al. 2015)**

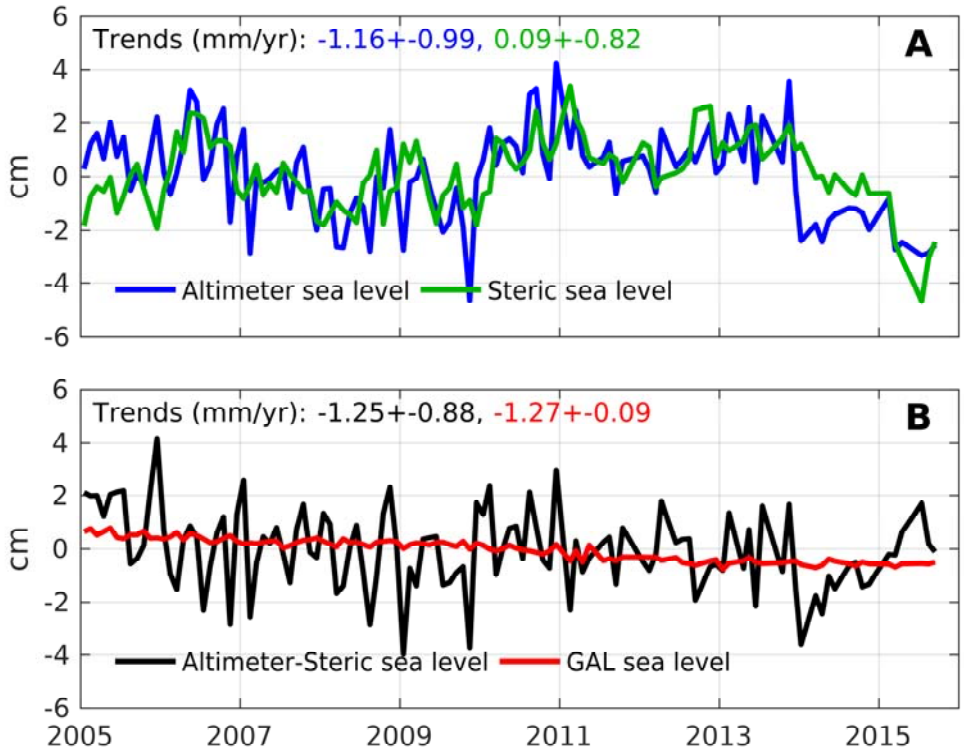
A closer look at subpolar NA



STH (steric height, Argo)
Deep STH (ECCO)
BP bottom pressure (ECCO)

- **Trends in altimeter minus steric height residual (SSH − STH) have magnitudes comparable to GAL trends, even in presence of considerable noise**
- **For mass, heat budget purposes, GAL trends are as large as deep steric or dynamic bottom pressure trends**

Time series in subpolar NA



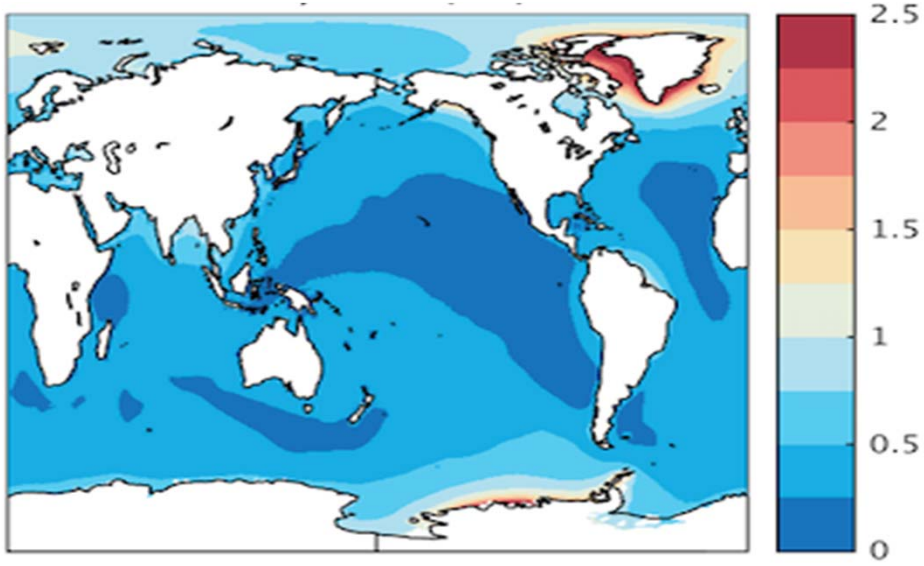
Time series of fields averaged over box south of Greenland (40-50W, 50-60N)

Annual cycles removed

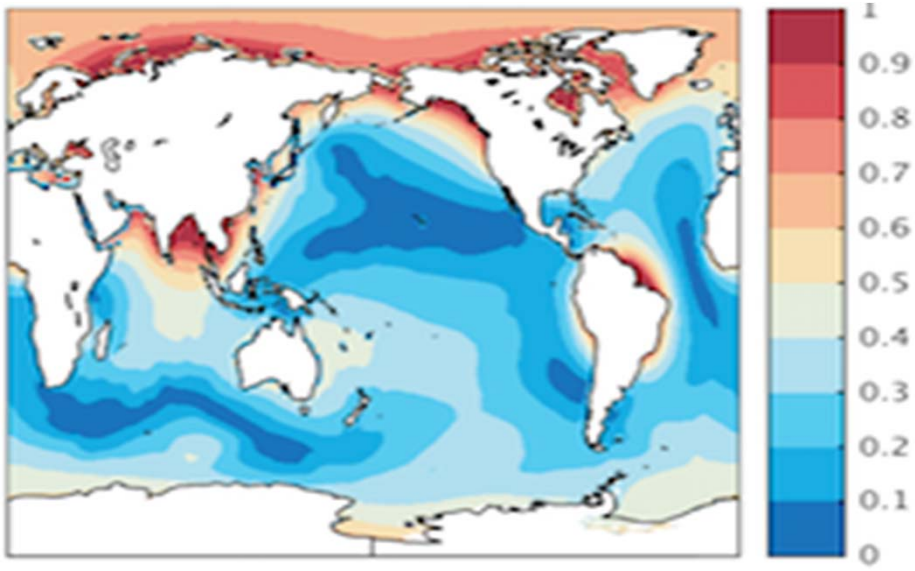
- **Trends from GAL effects important for correct interpretation of altimeter, steric height records and sea level budgets**
- **GAL effects at monthly time scales weak compared to other variability**

GAL (other variability)

Standard deviation (cm)



Annual amplitude (cm)



GAL correction?

- For appropriate studies of dynamics and sea level budgets using altimeter records, correcting for GAL signals (as done for IB) important for trends, possibly for seasonal variability as well
- Reliable, continuous estimates of mass loading over land needed for implementing a GAL correction
  - Satellite gravity (gaps, only since GRACE launch)
  - Hydrology models (omission errors)
  - Atmospheric effects weak but reasonably well determined
- Possible course of action
  - Calculate various estimates of GAL SSH variability (different input, model assumptions,…)
  - Compare and assess underlying uncertainty in GAL fields
  - At a minimum provide refined estimate of GAL variability, as a way of quantifying potential error in inferring dynamics, budgets from uncorrected SSH
  - Implement a GAL correction if warranted