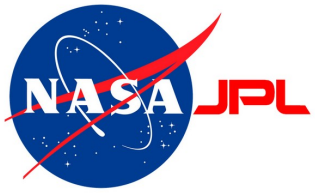

Simultaneously Invert PDMT and GIA From Multiple Data Sets – Simulation Results

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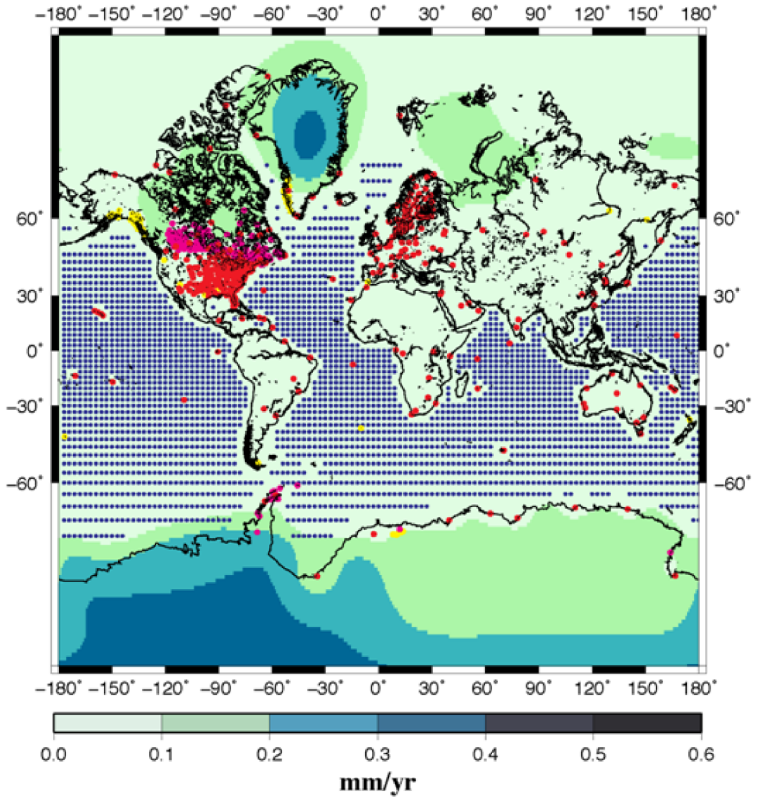
Jet Propulsion Lab,

California Institute of Technology

Inversion of Global Mass Transportation

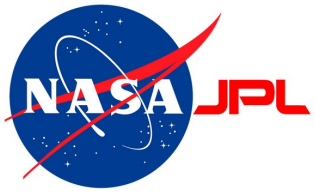


Wu et al., 2010

Earlier study (Wu et al., 2010) utilizing GRACE, GPS and OBP observations to invert simultaneously PDMT and GIA signals.

Inversion scheme worked very well. However, uncertainties in Greenland and Antarctica are larger due to lack of observations.

Motivation: how much uncertainties we can reduce by including ICESat observations.



ICESat Data and its Limitations

Pros:
Global data Coverage.
Direct measurement of ice mass change.
Satellite operation time are similar with GRACE (2003-2009).

Cons
Point measurements, with a footprint of 70 meters. Impossible to directly input in to our inversion code.
ICESat derived mass change are subject to several error sources.

ICESat Data and its Limitations

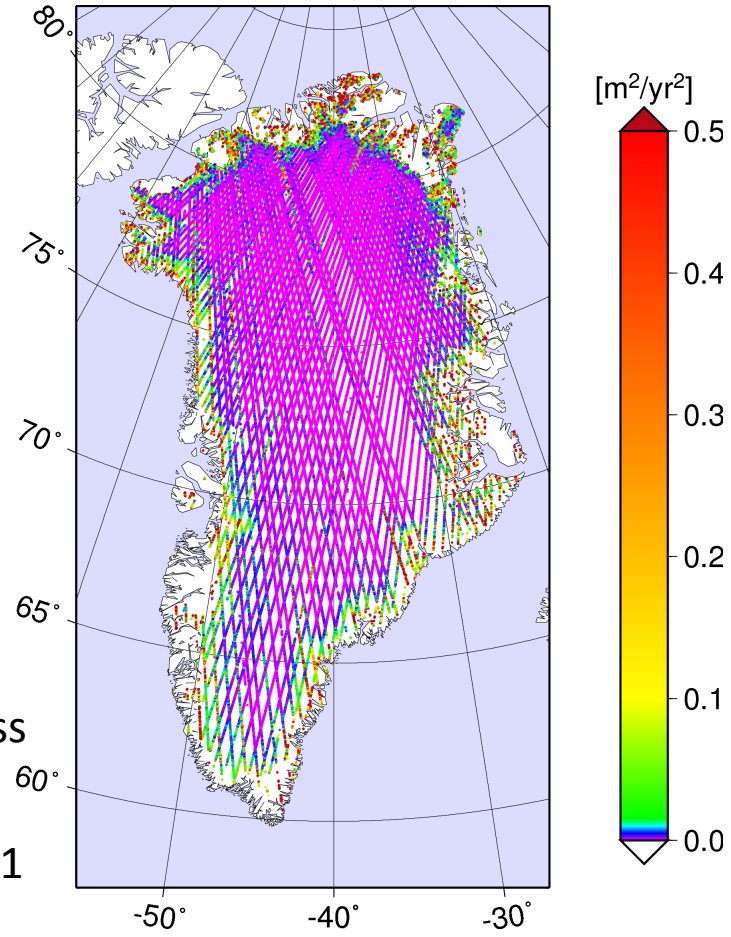
Errors associated with topographic changes

Imperfect DEM models

Under-sampling – severe at the edge of the ice sheet

Interpolation errors - point measurements to volume changes

dh/dt uncertainties are orders of magnitude larger at the edge of the ice sheet, where ice loss happens



Sorensen et al., 2011

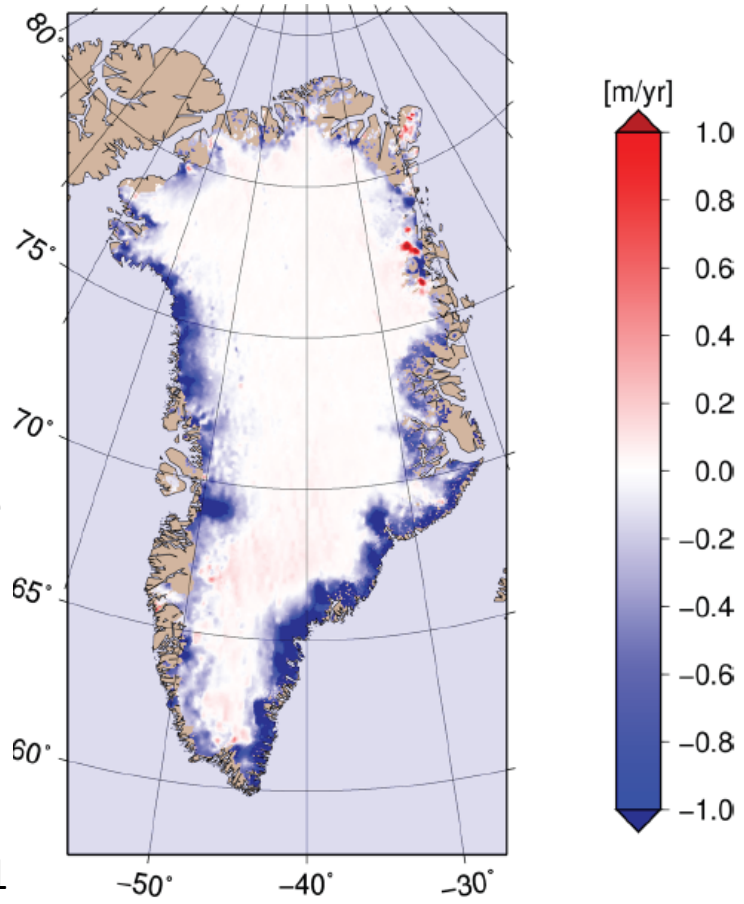
ICESat Data and its Limitations

Uncertainties when interpret from volume to mass

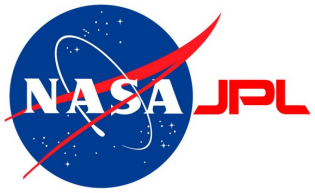
Firn compaction model uncertainty

Density profile uncertainty

Melting zones are narrow area at the edge of the ice sheet. Uncertainties of ICESat measurements in those areas are high due to topography and errors associated with climate models.



Sorensen et al., 2011



Inversion Strategy

ICESat data in Antarctica and Greenland will be used.

However, only part of the data will be used. Mass change data that subject to large uncertainties will be excluded from the inversion.

GIA will be determined in the center of Greenland and Antarctica use both GRACE and ICESat. GIA signal extrapolate to the narrow but fast melting edges.

ICESat measurements need to be preprocessed to be consistent in spatial resolution with the GRACE measurements.

Simulation Steps

Simulation focus on Greenland.

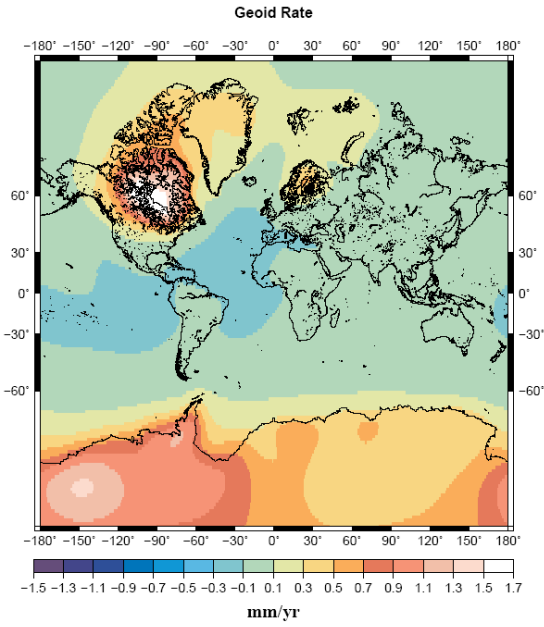
PDMT truth: arbitrarily made PDMT truth with strong melting on the edge of Greenland. Two PDMT truths with different spatial resolutions.

GIA truth: arbitrarily made.

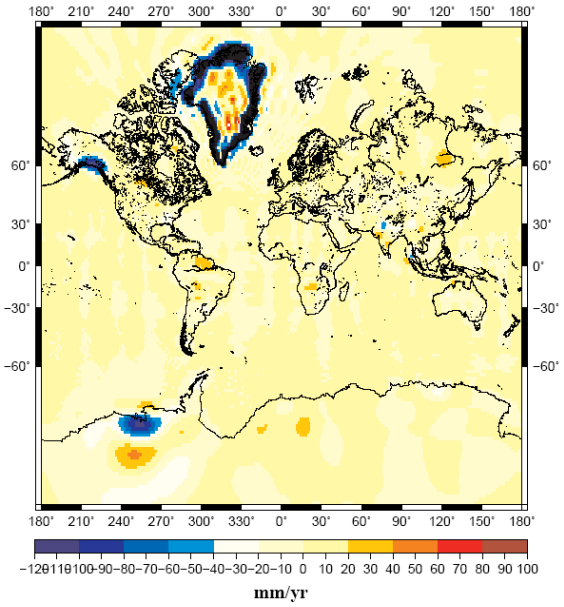
Simulated GPS, GRACE, OBP and ICESat data from both GIA and PDMT truth, assuming a reasonable earth structure profile and ice history.

GPS = elastic component + viscous component
ICESat = elastic component + viscous component + snow height change

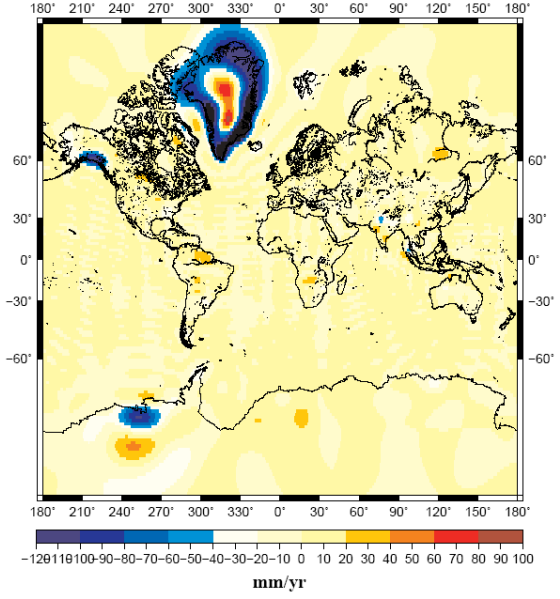
Simulation Steps



GIA geoid truth



180 degree PDMT truth



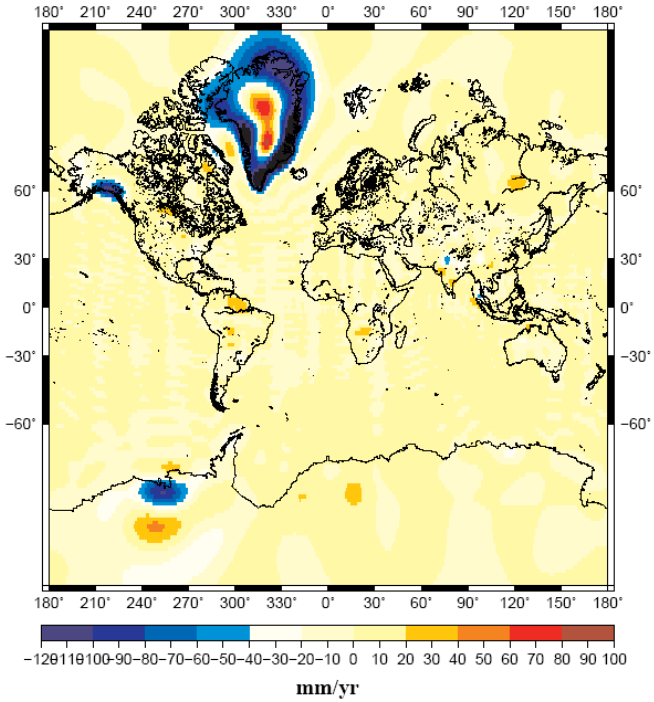
60 degree PDMT truth

Inversion Results use Simulated Data

When no noise presented….
Inversion with no altimeter data (Wu et al., 2010) recovers both truth (PDMT and GIA) with no bias.

GPS data are not critical to Greenland inversion, due to their sparse distribution (3-4 sites). Add more stations.

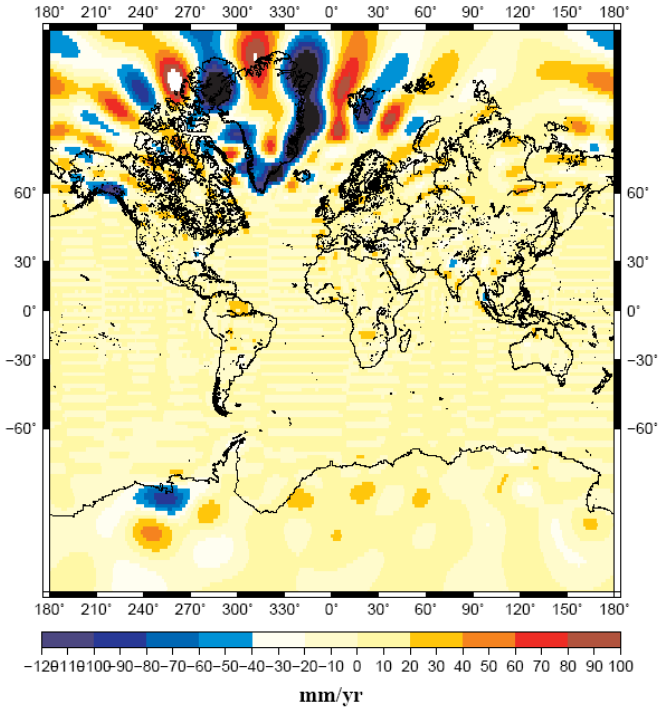
Inversion using ICESat data from 60 degree truth also recovers the truth



Inversion Results use Simulated Data

When higher degree ICESat data are used……

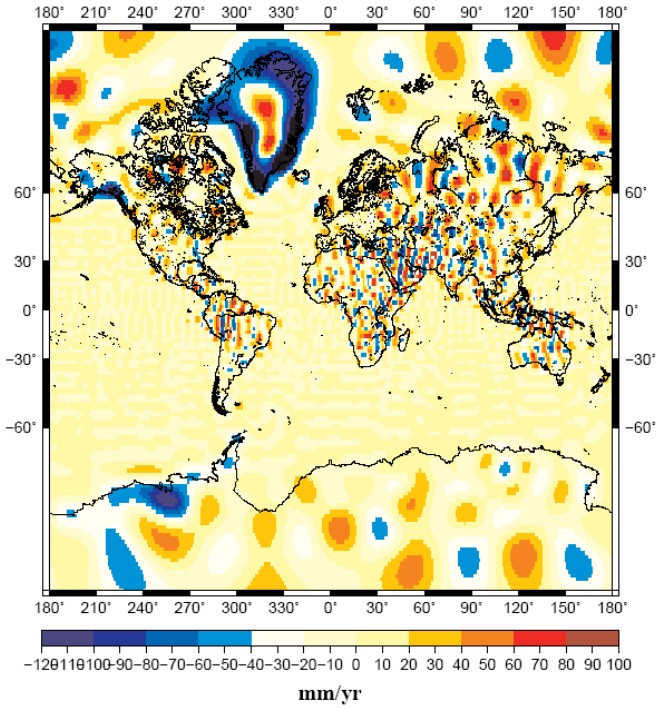
Possible reason: short wavelength deformation signals in ICESat data propagate into the results, bias both PDMT and GIA estimations



Inversion Results use Simulated Data

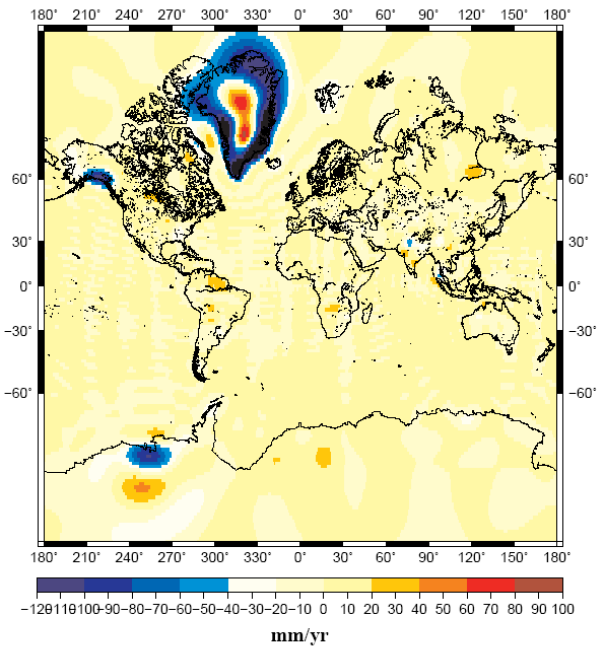
In the presence of noise.
White noises are added to the simulated data, with real uncertainties to account for noise.

Both cases recover the truth within uncertainties. By including ICESat data, we reduced the uncertainty by a factor of four (5GT vs 20GT) compare to inversion without ICESat data.



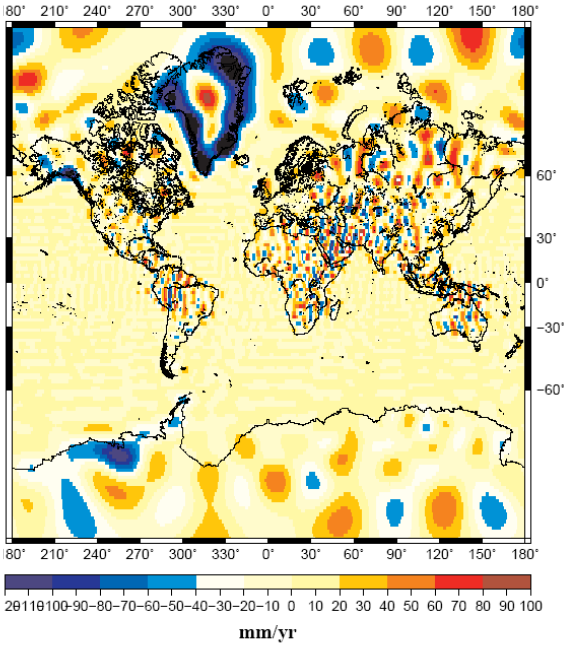
Inversion Results use Simulated Data

PDMT truth



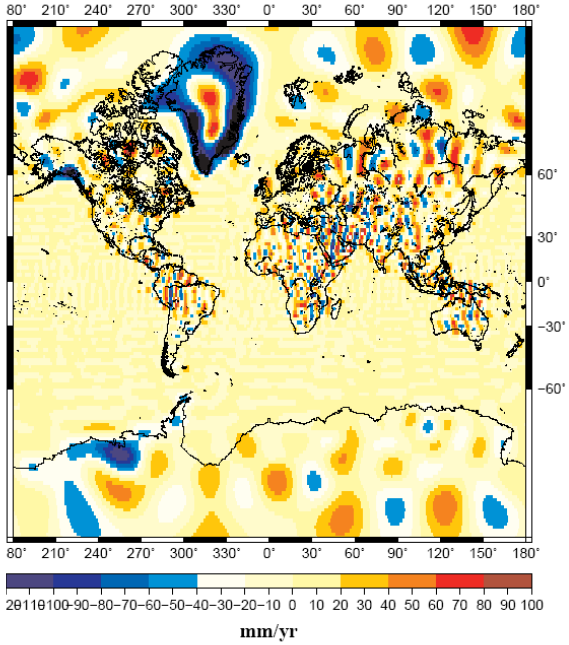
220 GT in Greenland

Without ICESat



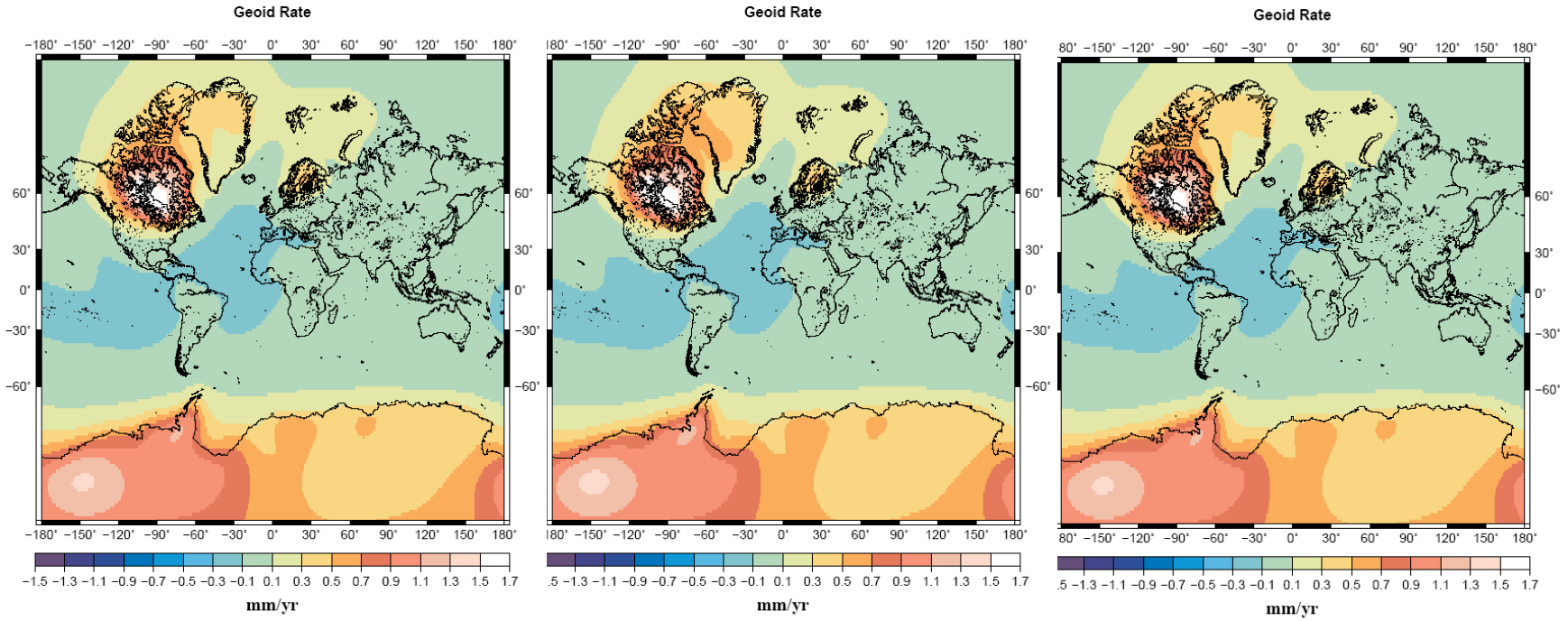
233 ± 20 GT

With ICESat



219 ± 5 GT

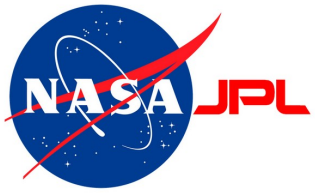
Inversion Results use Simulated Data



GIA Geoid truth

Without ICESat

With ICESat



Conclusions

Simulation results indicate the global kinematic inversion code worked well.

Direct use of ICESat measurements are erroneous due to different spatial resolution of GRACE and ICESat.

A factor of four improvement achieved by including ICESat data in Greenland.