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Simulation of near-surface dynamics for the interpretation of geodetic observations

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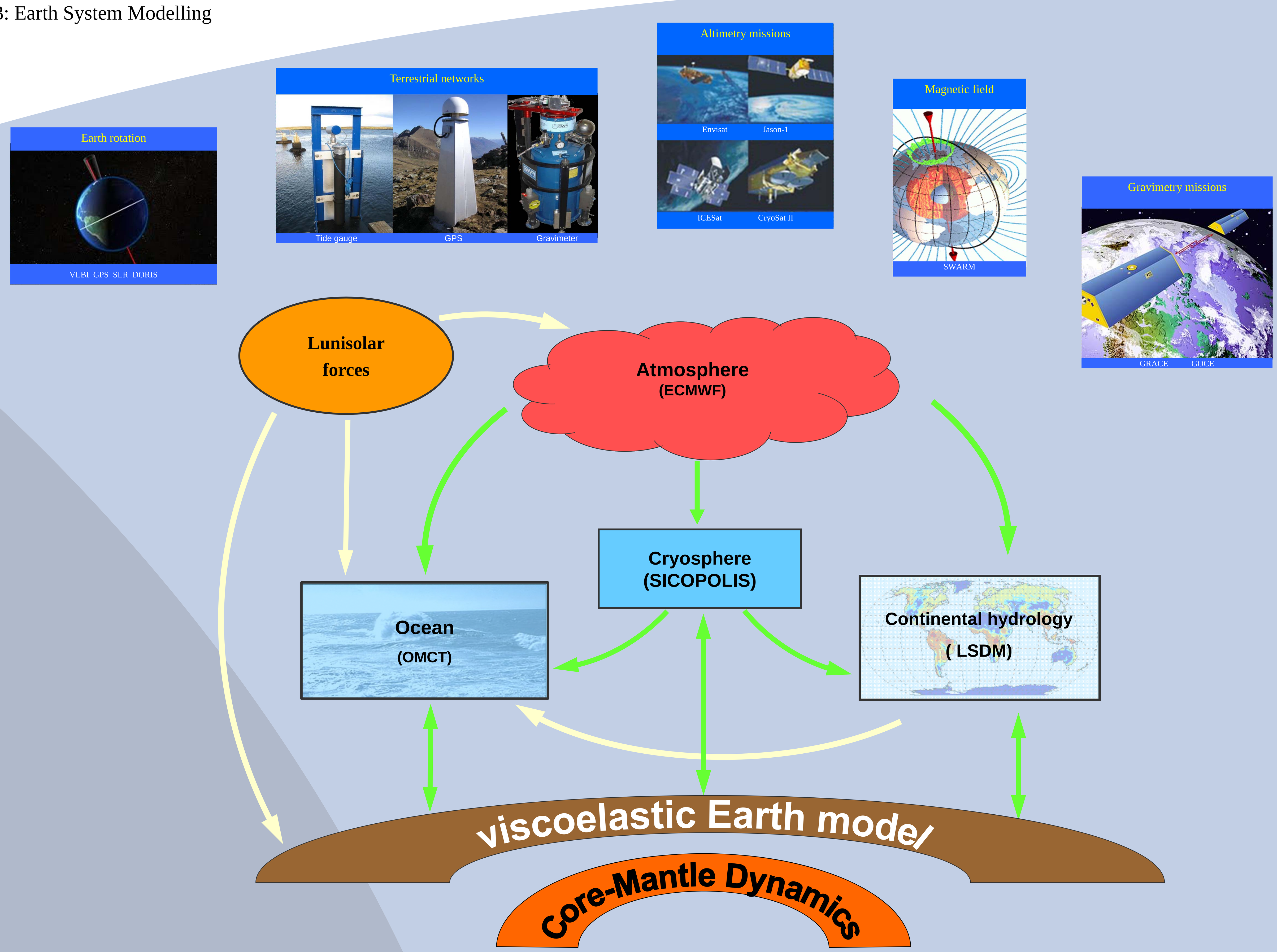
Introduction

Modern geodetic observations have greatly improved in accuracy and global coverage during the last decades, primarily due to advances in space-based techniques. Beside time-mean estimates of station positions, sea surface heights or local gravity, reliable estimates of temporal variations of these quantities have become available. In addition to tidally induced signals, which can be easily identified by their characteristic frequencies, variability in geodetic observations is also caused by transient mass re-distribution of geophysical fluids in the Earth system, i.e., the solid Earth, atmosphere, oceans, cryosphere, and continental hydrosphere. In order to properly interpret and successively correct for these signals, numerical models are required that describe the individual underlying physical processes and their interactions.



ECMWF atmospheric data

Global 1° fields with 6h temporal resolution from three atmospheric data-sets: (1) ERA-40 re-analysis, 1958 – 2001; (2) ERA Interim re-analysis, 1989 – 2011; (3) operational ECMWF analyses, from 2001 onwards.

LSDM terrestrial hydrosphere model

Continental water storage variations and discharge are simulated with the Land Surface Discharge Model (LSDM; Dill, 2008) on a 0.5° grid every 24h.

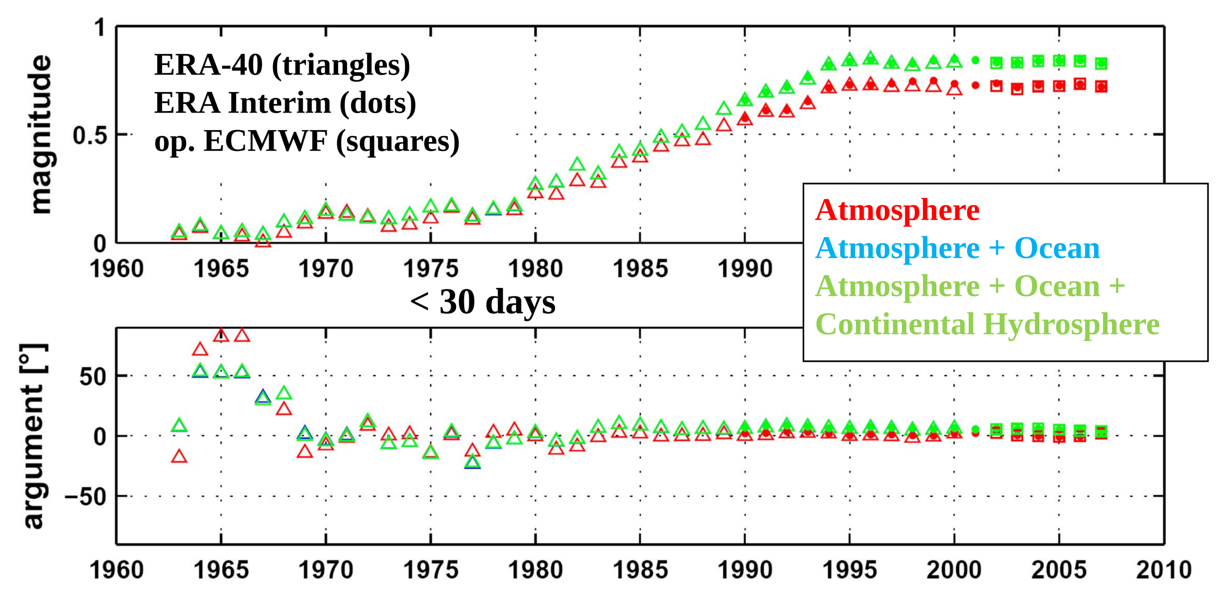
SICOPOLIS land ice model

Ice accumulation, melting, and calving for Greenland and Antartica is simulated with a dynamic polythermal ice-sheet model (SICOPOLIS) on a 20km x 20km grid at monthly time steps.

OMCT ocean model

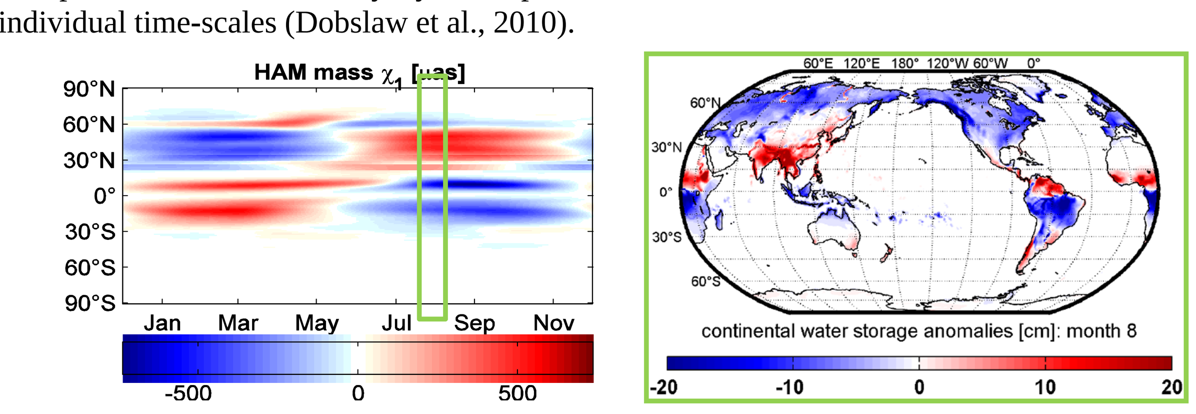
Ocean dynamics are simulated with the Ocean Model for Circulation and Tides (OMCT; Thomas 2002), discretized on a regular 1.875° grid. Ocean state variables are obtained every 6 h concurrent with ECMWF analysis times.

Seasonal variations in Earth rotation



Seasonal variations in the Earth's rotation are dominated by mass re-distributions in atmosphere, oceans, and the terrestrial hydrosphere. In comparison to EOP C04 series the effective angular momentum (EAM) functions from ECMWF, OMCT and LSDM are particularly reliable in the short-term band (<30 days) and after 1980, where both Earth orientiation observations and atmospheric analyses benefit from the advent of new observing systems.

Model data are subsequently used to relate globally integrated excitations to regional mass transports in order to identify dynamic processes that dominate Earth's rotation variations on individual time-scales (Dobslaw et al., 2010).



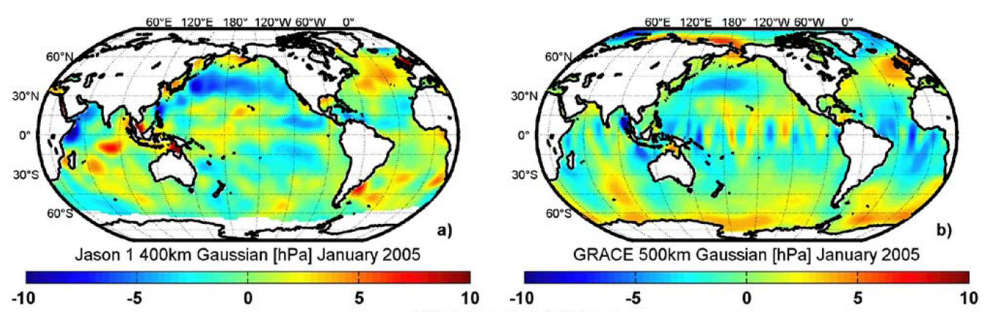
Short-term Earth rotation prediction

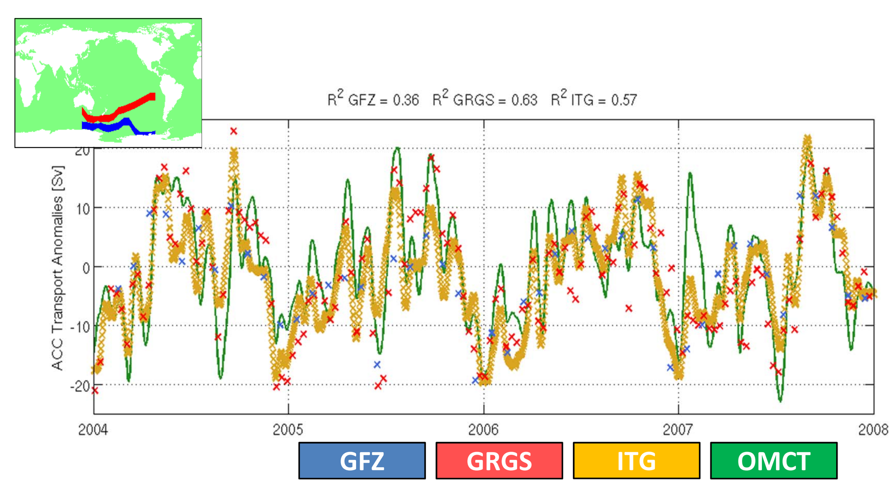
Standard deviation of MAE	bulletin A		model forecast	
	polar motion	UT1-UTC	polar motion	UT1-UTC
Day 10	± 2.95mas	± 0.40ms	± 1.95mas	± 0.31ms
Day 30	± 7.45mas	± 2.26ms	± 6.51mas	± 2.14ms
Day 90	± 16.02mas	± 3.47ms	± 17.61mas	± 3.17ms

EOP predictions based modeled EAM forecasts have been demonstrated to provide superior skill when compared to the current state-of-the-art forecasts published in IERS Bulletin A (Dill and Dobslaw, 2010).

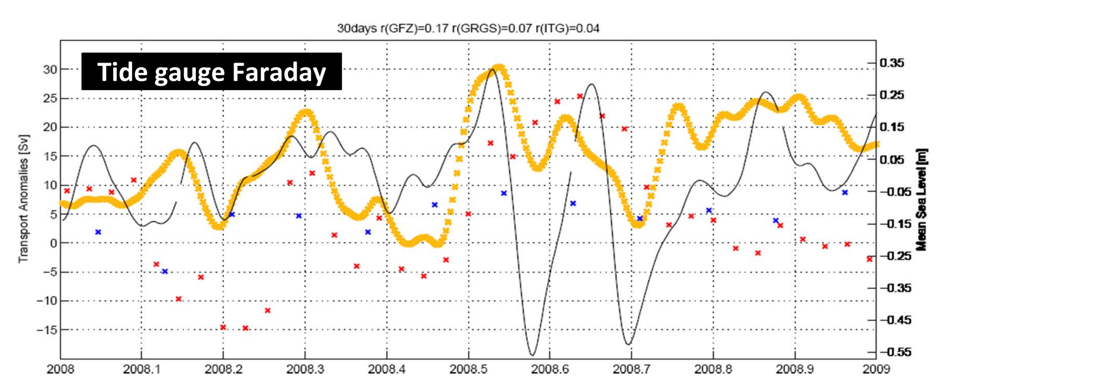
Ocean mass anomalies

Ocean mass anomalies from GRACE can be validated both against in-situ ocean bottom pressure gauges and sterically corrected satellite altimetry (Dobslaw and Thomas, 2007). Since regional mass anomalies are related to changes in barotropic currents, GRACE has been demonstrated to provide transport variations of the Antarctic Circumpolar Current (ACC). Today, improved time-variable gravity field products from GRACE additionally allow the assessment of high-frequency variations (Bergmann and Dobslaw, 2012):





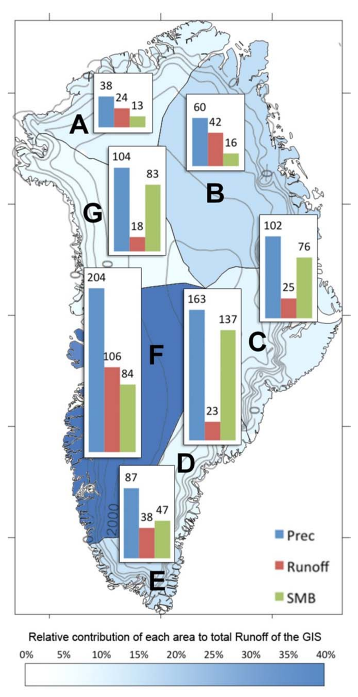
Since ACC transport variations are closely related to coastal sea-level variations at the Antarctic Coast via the Southern Mode, transport anomalies from GRACE have been contrasted with data from various tide-gauges augmented with permanent GPS stations.

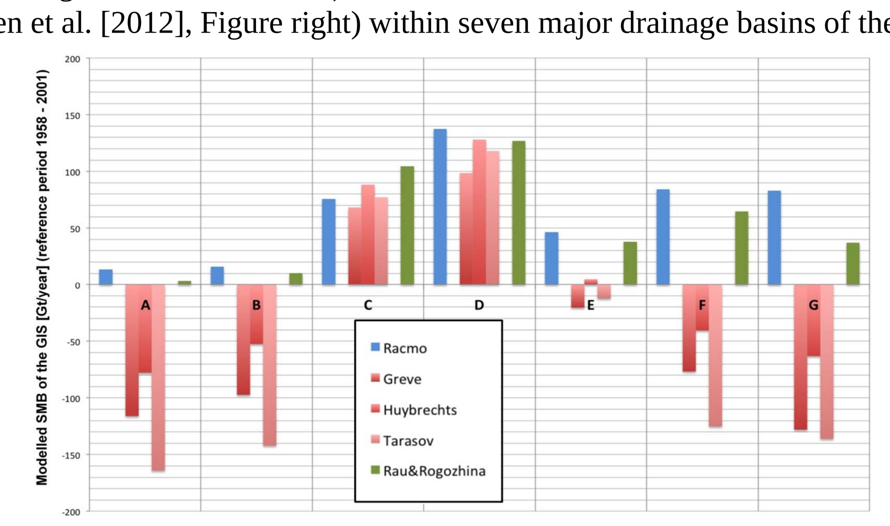


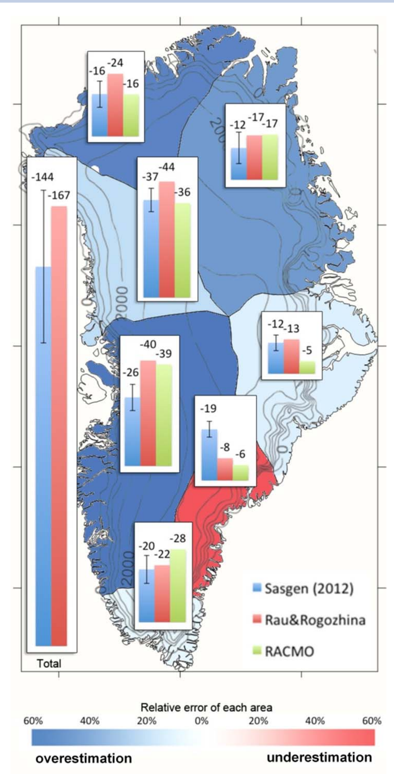
Together with observed ocean induced variations in Earth's rotation, GRACE-based ocean bottom pressure estimates are subsequently assimilated into OMCT within an Ensemble Kalman Filter framework (Saynisch and Thomas, 2012).

Greenland Ice sheet (GIS) surface mass balance

The results of transient simulations of the Greenland Ice Sheet (GIS) with the thermomechanical ice sheet model SICOPOLIS (Greve [1997], Rogozhina et al. [2011, 2012]) driven by the ECMWF climate datasets in the period of 1958 to 2010 are validated against high-resolution regional model results RACMO/GR (Ettema et a. [2009], Figures left and middle) and ice mass trends estimated from the GRACE and ICESat satellite data (Sasgen et al. [2012], Figure right) within seven major drainage basins of the GIS (A-G).







Left figure shows mean relative contributions of different regions to the total ice loss through surface runoff in the reference period (1958 to 2001) as derived from the regional model RACMO/GR (color map) along with major components of the surface mass balance (SMB), namely mean regional precipitation and runoff rates. The figure in the middle presenst modeled regional SMB values obtained from our new SMB parameterization (green bars; Rau and Rogozhina [in prep.]) versus the results of other existing SMB parameterizations (pink bars; Greve [2005], Janssens and Huybrechts [2000] and Tarasov and Peltier [2002]) and regional model RACMO/GR (blue bars). Finally the right figure carries out a region-to-region comparison of our modeled SMB trends (pink bars) in the observational period (2003 to 2009) with the estimates from satellite data (blue bars) and the results of the regional model RACMO/GR (green bars).

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