Applying Spaceborne Gravity Measurements to Ocean Studies

"Gravity From Space" for Oceans, Land Ice, and Sea Level Rise; Hamburg, Germany, 29–30 September 2010

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Twenty-five scientists met at the University of Hamburg's KlimaCampus to discuss current analyses and future applications of spaceborne gravity measurements to studies of ocean circulation, cryospheric science, and sea level rise. The Challenging Minisatellite Payload (CHAMP), Gravity Recovery and Climate Experiment (GRACE), and Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) satellites, complemented with radar and laser altimeters, provide the necessary data.

Spaceborne gravity measurements provide two important quantities for ocean circulation studies: (1) the time-averaged geoid, which when subtracted from a time mean sea surface from radar altimetry yields the absolute surface dynamic topography and absolute surface geostrophic currents, and (2) time changes in ocean bottom pressure and total ocean mass. For sea level rise, the difference between the globally averaged trend from altimetry and that from GRACE is used to infer the top-to-bottom steric component (the component of sea level rise resulting from expansion of seawater due to temperature and salt), which is observable with data from the Argo system, a network of drifting probes that measure temperature up to 2000 meters in depth, and from expendable bathythermographs (XBT), temperature sensors deployed by ships.

Mean dynamic topographies have been created from the combination of geodetic and in situ oceanographic data; workshop participants expect these topographies to improve significantly at short wavelengths with the addition of GOCE data.

GRACE observes ice mass loss from Greenland, Antarctica, and glaciers in Alaska and Patagonia; much of this water enters the oceans. Trend retrievals depend critically on either using a model of glacial isostatic adjustment or estimating it together with the current mass loss; another complication noted by participants is the coarse "footprint" of GRACE, which mixes signals from neighboring areas.

In addition, participants pointed out that ocean bottom pressure signals (of the order of 10 millibars at high latitudes and 10 times smaller at low latitudes) are close to the noise level of GRACE and require special processing and filtering. Signals several hundred kilometers in extent match those obtained from in situ bottom pressure recorders in energetic regions and have been used to study the Antarctic Circumpolar Current, the Arctic, and interbasin mass exchanges. The data are now assimilated into numerical ocean models, although current models lack some of the physics measured by GRACE (loading and self attraction, mass conservation); the global ocean mean mass constrains the total freshwater flux in these ocean models.

In summary, time-averaged and time-varying satellite gravity data were demonstrated to be instrumental for physical oceanographic and sea level rise studies. The discussions centered on future processing, future applications of GRACE-like data, and future missions. Future missions include an expected GRACE continuity mission, which was strongly endorsed by the attendees, has been approved by NASA, and is under study in Germany for launch in 2016. The GRACE continuity mission is expected to close the gap between GRACE and missions under discussion for launch in the 2020s. From the improved processing and the future missions, scientists expect more accurate retrievals over smaller regions. Furthermore, ocean bottom pressure signals are small and require accurate removal of land signals, whether continental hydrology, strong earthquakes, or glacial isostatic adjustment. Participants believe that the addition of bottom pressure recorders at the Tropical Ocean–Global Atmosphere (TOGA) Tropical Atmosphere-Ocean (TAO) project locations (http://www.pmel.noaa.gov/tao/) would yield the overall ocean mass variability because the region is dynamically quiet. It is now timely to extend GRACE studies beyond the barotropic response of the ocean to wind.

The online supplement to this *Eos* issue (http://www.agu.org/eos_elec) contains a slightly expanded version of this report, including names of attendees, expertise, and references.

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