Topex/Poseidon, Gravity, and the Earth's Rotation: Investigating Mechanisms and Effects of Sea Level Change

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The objectives of this investigation arc to: (1) better describe, characterize, and understand the causes of global-scale variations in sea level occurring on subseasonal to interannual time scales through the use of complementary oceanographic and geophysical data sets; (2) study the impact of sea level change upon global geodynamic properties of the Earth such as its rotation and gravitational field and to thereby assess the degree to which past measurements of these global geodynamic properties can be used to investigate past sea level change; and (3) investigate the changing distribution of water in the atmosphere, hydrosphere, and cryosphere through its measured effect on sea level and the Earth's rotation and gravitational field.

The approach taken is to utilize Topex/Poseidon measurements of sea surface height in concert with Earth rotation and time-varying gravitational field measurements. The Topex/Poseidon altimeter provides measurements of the time-varying sea level which when assimilated into oceanic general circulation models provides improved estimates of the three-dimensional oceanic temperature, density, and velocity fields. The Earth's gravitational field will change as the mass distribution of the oceans varies, and, under the principle of the conservation of angular momentum, the Earth's rotation will change as the oceanic angular momentum varies due to oceanic current and sea level height fluctuations. The combined analysis of Topex/Poseidon altimeter data with Earth rotation and gravitational field determinations therefore provides a powerful means of investigating the mechanisms and implications of sea level change.

The first step in this investigation is to demonstrate that Earth rotation and time-varying gravitational field measurements are sensitive to the effects of oceanic current and sea level height changes. Results for the gravitational field have been reported by Gross et al. (1996), for the length-of-day by Marcus et al. (1997), and for polar motion by Gross et al. (1997). The polar motion results are summarized here. Atmospheric wind and pressure changes are known to be an important source of polar motion excitation on time scales of a few days to a few years. For example, during 1992-1994, the variance of the observed complex-valued SPACE96 polar motion excitation series is reduced from 1767 mas^2 to 957 mas^2 upon removing atmospheric wind and inverted barometer pressure effects computed from products of the NCEP/NCAR reanalysis system. Since the square of the mean uncertainty of the complex-valued SPACE96 polar motion excitation series during 1992-1994 is 172 mas^2, 785 mas^2, or nearly half, of the observed variance remains to be explained by mm-atmospheric excitation mechanisms, or by errors in the modeled atmospheric effects. Nontidal oceanic current and sea level height variations have been investigated as a possible source of the missing polar motion excitation. Two global ocean general circulation models have been used to compute the angular momentum of nontidal oceanic current and sea level height variations: (1) the Princeton Modular Ocean Model (MOM) having 22 vertical layers and a rigid lid, and (2) the Miami Isopycnic-Coordi nate Ocean Model (M ICOM) having 11 vertical layers with a mixed layer and a free surface. Both models were run on the same 2 degree longitude by 1 degree latitude grid spanning 80 S to 80 N latitude. Following a IO-year spin-up with climatological air-sea fluxes, both models were forced during 1992–1 994 with daily wind and heat flux from the NCEP operational analysis and sea surface salinity restoring to Levitus climatology. After correcting for the effects of mass non-conservation in these models, they are shown to predict similar effects on polar motion excitation of sea level height variations, but the effect of currents predicted by MOM is much larger than that predicted by MICOM. Upon removing atmospheric effects from the observed polar motion excitation series, the predicted effect of the sum of the current and sea level height variations of M ICOM are shown to reduce the residual polar motion excitation variance from 957 mas^2 to 723 mas^2, whereas removing the MOM results increases the residual variance to 1408 mas^2, indicating that the non-axial components of the angular momentum of the MOM currents are too large. Thus, during 1992– 1994, atmospheric effects modeled by the NCEP/NCAR reanal ysiss ystem, oceanic effects modeled by M ICOM, and polar motion excitation measurement uncertainty can account for 1216 mas^2, or 69%, of the observed 1767 mas^2 polar motion excitation variance. The remaining 551 mas^2, or 31%, of the observed variance remains to bc explained by errors in the atmospheric and/or oceanic models, and by other excitation mechanisms such as hydrologic effects.

The results for the length-of-day (Marcus et al., 1997) and the time-varying gravitational field (Gross et al., 1996) similarly show that measurements of these quantities are sensing oceanic current and sea level height changes. The next step in this investigation is to therefore decompose the total sea level change as measured by the Topcx/Poseidon altimeter into its steric and nonsteric components through the use of oceanic general circulation models to estimate the steric component by computing the effects of temperature ancl salinity changes. The effect upon the Earth's gravitational field of the resulting estimate for the nonsteric component will be computed and compared to measurements of the Eart h's time varying gravitational field (from which atmospheric effects have been modeled and removed). The effect upon the Earth's rotation of the modeled oceanic density and velocity changes associated with the measured sea level change will similarly bc computed and compared to Earth rotation measurements (from which atmospheric effects have also been modeled and removed). Since the predictions of any ocean model must be consistent with measurements of the Earth's rotation, gravitational field, and sea surface topography, the comparison between models and measurements of these effects will provide a powerful tool for the validation of the ocean models, including their use to decompose the measured total sea level change into steric and nonsteric components.

Acknowledg ments. The work described in this report was performed at the Jet Propulsion Laboratory, California institute of Technology, under contract with the National Aeronautics and Space Administration.

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