Global geodynamics investigation using TOPEX/POSEIDON and Jason-1 observations

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TOPEX/POSEIDON and Jason-1 missions altimetry data are utilized in combination with ocean general circulation model output, and global ocean surface temperature and atmospheric pressure data. The quantities to be estimated are the (non-tidal) oceanic angular and corresponding gravitational changes due to ocean mass transport. The results will be compared with space geodetic data of Earth rotation and time-varying gravity in order to better understand the observed geodynamic variations in terms of ocean mass transport, and the ocean dynamics, ocean-atmosphere interaction, and the dynamic behavior and response of the solid Earth.

Mass transport in global geophysical fluids has two distinct effects in global geodynamics, i) it changes the Earth's moment of inertia and relative angular momentum, which in turn changes the rotation of the Earth under the conservation of angular momentum, and ii) changes in the external gravitational field according to Newton's gravitational law [Chao et al., 2000].
These changes collectively will be referred to as the *geodynamic variations*.

The Earth's rotation changes slightly in both its speed (usually expressed in terms of the length-of-day LOD), and its orientation in the terrestrial reference frame known as the polar motion. These variations have been measured by the space geodetic techniques of satellite laser ranging (SLR), very-long-baseline interferometry (VLBI), and the Global Positioning System (GPS), to accuracies within 0.1 milliarcsecond on a wide range of time scales from sub-daily to decadal
(0.1 milliarcsecond corresponds to about 3 mm of distance on the Earth's surface). The gravitational field, on the other hand, is conventionally expressed in terms of the geoid spherical harmonic coefficients. Low-degree geoid harmonics have been observed by SLR to vary on the order of a few parts in 10^{10} (corresponding roughly to 1 mm of geoid height) on intraseasonal to interannual time scales. Future dedicated space gravity missions, notably GRACE, promise to deliver observations of gravitational changes much improved in accuracy, spatial and temporal resolutions [Tapley et al., 2000].

A major mass transport takes place in the atmosphere. Today its geodynamic effects are routinely computed based on general circulation models (GCM) that assimilate global meteorological data. [e.g., Salstein et al., 1993].
The next target of investigation is obviously the role of the ocean mass transport as an excitation source.
For example, the largest uncertainty in calculating the atmospheric excitation is due to our lack of knowledge in the pressure-driven dynamic inverted-barometer effect as a function of frequency, a fundamental interaction between the ocean and the atmosphere.
In fact, many of the well-determined geodynamic quantities await the ocean contribution to explain the residuals, essentially for all relevant time scales, between the observed and the atmospheric contribution.
Outstanding problems include the seasonal (primarily annual and semi-annual) LOD-AAM residual, the corresponding residual for J_2, and the excitation of the annual wobble and interannual polar motion including the Chandler wobble.
In another example, while atmospheric effect accounted for most of the anomalously large LOD variations (about 0.5 millisecond) during the strong 1982-83 and 1997-98 ENSO events, significant contributions must have come from OAM [Dickey et al., 1994].

In contrast to its atmospheric counterpart, the computation of oceanic mass transport and hence geodynamic effects has been hampered by the lack of in-situ data on a global scale. Recent effort has relied upon ocean GCMs, e.g., and the Parallel Ocean Climate Model (POCM) [Semtner and Chervin, 1992] [see, e.g., Johnson et al., 2000; 2001].

A complementary approach is to study ocean mass transport using ocean satellite altimetry data. With its accuracy, global coverage, and reasonably long (and growing) time series of data, TOPEX/ POSEIDON (T/P) and Jason-1 altimetry provides not only valuable data for advancing the sciences, but also a basis for evaluation and verification for ocean circulation models using the global geodynamics measurement as constraints.

These results will, of course, be limited by the T/P and Jason-1 temporal factors; but between the temporal resolution (10-day repeat cycle) and the total lifetime (multi-years) a wide range of temporal scales is covered. The spatial resolution poses little problem because we are mostly dealing with globally integrated phenomena. Another advantage of such real observational data is that any inverted-barometer (IB) behavior of the ocean surface in response to overlying atmospheric pressure changes need not be explicitly considered, as the ocean GCMs often do not include any pressure-driven effects. Combining altimetry-derived results with atmospheric effects computed under the "non-IB" option, in principle, accounts for the entire atmosphere + ocean mass distribution irrespective of what the (dynamic) IB response actually is [e.g., Fu and Pihos, 1994]. This eliminates a major uncertainty as far as global mass distribution is concerned.

On the other hand, the altimetry is, in a sense, an indirect observation for mass. One significant consideration is that it does not really yield the ocean bottom pressure field which is the physical quantity desired for computing the geodynamic effects. What it provides is ocean surface height, and to convert that into mass distribution, the steric (or thermal) part of the surface height change must first be removed because the latter does not involve any mass transport. Moreover, the altimetry does not provide the direct current velocity field that is needed to determine the "motion term" in the oceanic angular momentum. Only surface current velocity can be inferred from altimetry based on geostrophy, while the depth to which the inferred velocity resides is unknown. This is a drawback in the study of Earth rotation variation, but not for gravitational variation.

Thus, we will complement the altimetry data using independent, global oceanographic data of surface water temperature combined with those of the varying mixed-layer depth. This can be derived partly from satellite remote-sensing and partly from in-situ observations, or from ocean GCMs such as POCM.

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