GLOBAL GEODYNAMICS INVESTIGATIONS USING TOPEX/POSEIDON

B.F. Chao, R.D. Ray (NASA/Goddard Space Flight Center, USA)

Space geodetic measurements reveal variations in the Earth's rotation vector and the Earth's gravity field. Excepting precession and nutation, these variations must be caused by internal motions within the ocean, the atmosphere, and the solid Earth. Unraveling the ocean's role will be considerably clarified by the accurate sea-surface height measurements of TOPEX/POSEIDON.

Introduction

Aside from the intrinsic fascination of understanding millisecond, or even microsecond, changes in the length of day, the Earth's rotation is an important object of study, because it is a sensitive indicator of global-scale mass distribution changes in the Earth-ocean-atmosphere system. So too are variations in the Earth's polar motion and gravitational field. These and other geodynamic effects are (or will soon be) routinely monitored by space geodetic technologies, and the geophysical challenge is to sort out the causative mechanisms. T/P measurements, when combined with realistic modeling, should help us determine the ocean's role in these geodynamic effects.

Earth Rotation

Variations in the Earth's rotation at periods from several days to several years are caused primarily by the atmosphere, while variations at periods longer than a decade are caused primarily by the Earth's core [e.g., Lambeck, 1980]. Variations at daily and sub-daily periods are caused primarily by the oceanóspecifically by the ocean tides [Ray et al., 1994]. The accurate ocean measurements of T/P are allowing us to explore this phenomenon in great detail [Chao et al., 1996].

The Earth-rotation variations are induced by both ocean tidal heights, which modify the Earth's inertia tensor, and ocean tidal currents, which effect relative angular momentum exchanges between ocean and solid Earth. T/P-derived currents (strictly, volume transports) for the M2 tide are shown in Figure 1. They were deduced from the Schrama and Ray [1994] height solutions by use of the Laplace Tidal Equations.

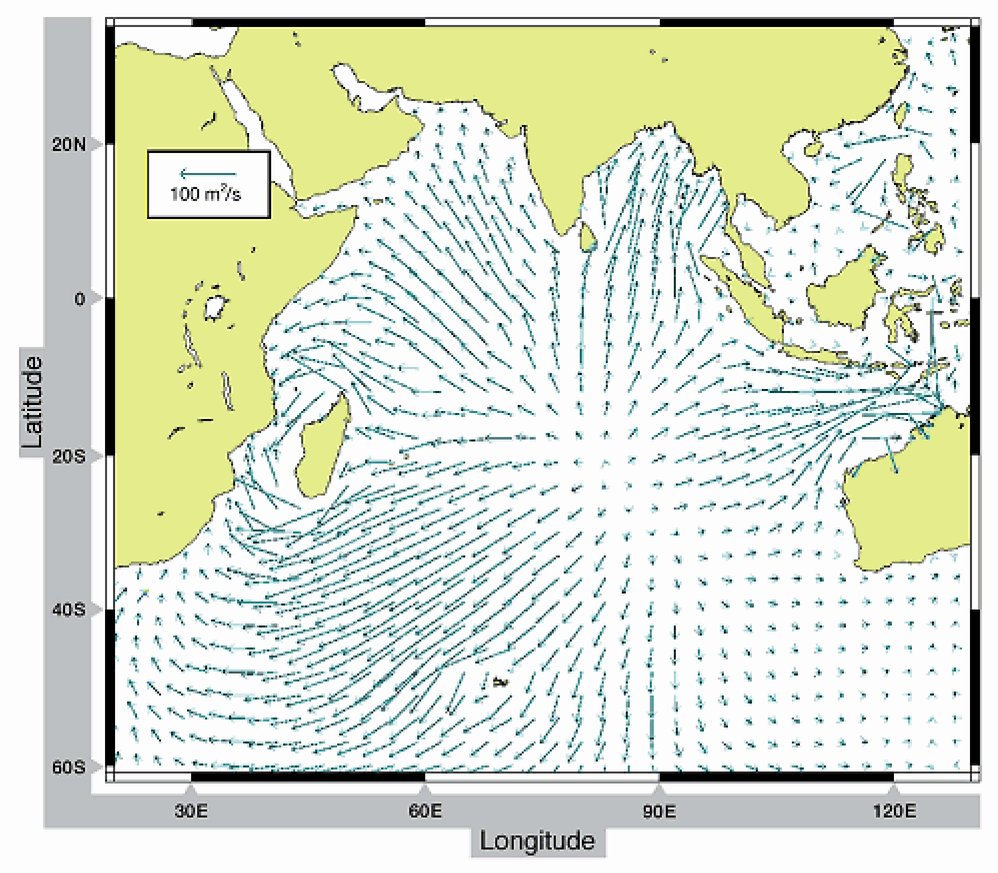

Figure 1

Tidal current transports (current velocity times ocean depth) for the principal lunar tide in the Indian Ocean, at the instant when the mean moon passes the Greenwich meridian. Within the central Indian Ocean, high tide occurred several hours earlier, and the water is now rushing away from that point. Flood tides are occurring in the Timor Sea and in the Bay of Bengal. These data were determined from TOPEX/POSEIDON altimetry.

Both momentum equations and continuity equations were solved to determine these currents, requiring solution of a large (150000 unknowns), sparse, least-squares problem. By invoking conservation of angular momentum, these height and current models allow the ocean tide's influence on Earth rotation to be calculated.

A comparison of model-predicted tidal variations in rotation rate with precise VLBI measurements is shown in Figure 2. The agreement is good, comparable to the measurement error bars, except for a few systematic discrepancies. Further work will refine both models and measurements, allowing the study of secondary effects such as atmospheric tides and Earth libration. A long-term goal is to use such refined data to determine the equatorial ellipticity of the Earth's core [Herring and Dong, 1994].

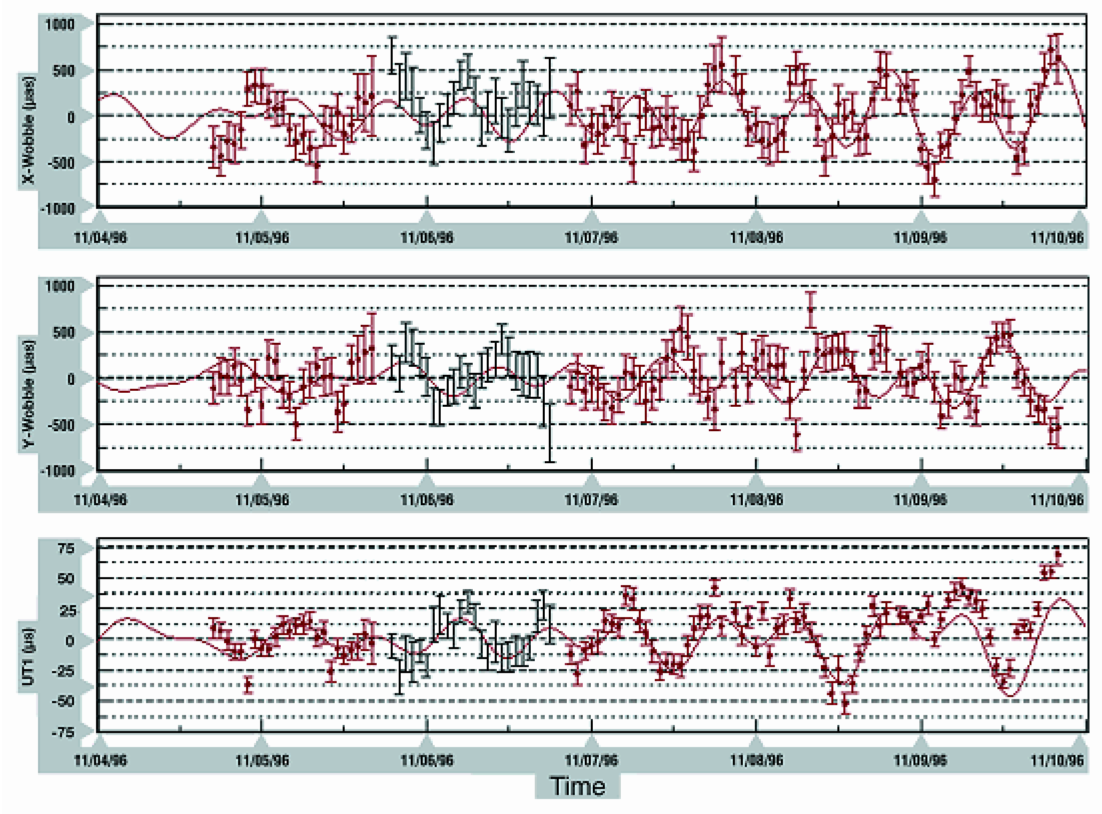

Figure 2

VLBI measurements (with error bars) and theoretical predictions (smooth curve) of the Earth's rotation, during the special intensive VLBI campaign in November 1996 called "Cont96." UT denotes Universal Time. "X-wobble" denotes the component of the polar motion along the Greenwich meridian; "Y-wobble" that along the 90°W meridian. Systematic deviations towards the ends are due to data artifacts at this time.

The ocean is also responsible for small, but important, rotational and gravitational effects at non-tidal frequencies, which T/P measurements will also help to determine. Significant progress in this direction was recently reported by Johnson et al. [1997], who use hydrodynamic ocean circulation models for predictions. Some work incorporating T/P observations in estimating ocean mass redistribution is also underway [Chen et al., Fall AGU, 1997].

Solid-Earth Q

Ray, Eanes, and Chao [1996] reported the first detection of tidal dissipation in the solid Earth at semidiurnal periods, based on the T/P oceanic tidal response and that observed by satellite tracking measurements (primarily laser ranging to Lageos). The (small) difference in the out-of-phase response is caused primarily by the tidal lag in the solid Earth, which in turn determines the solid-Earth tidal energy dissipation and the effective tidal Q at this frequency. Researchers had tried, unsuccessfully, to do this since at least the mid-1970's, but the ocean tide was too poorly known to permit it. It is only now, with sufficient T/P data in hand, that this detection of solid-Earth dissipation is possible. The present bounds on Q (200 to 600) are rather wide, but future improvements in tidal estimation from both altimetry and laser ranging should sharpen them.

References :

- Chao, B.F., R.D. Ray, J.M. Gipson, G.D. Egbert, C. Ma, 1996: *J. Geophys. Res., 101*, 20151-20163
- Herring, T.A. and D. Dong, 1994: *J. Geophys. Res*, *99*, 18051-18071.
- Johnson, T.J., C.R. Wilson, B.F. Chao, 1997: The role of ocean variability in the Earth's rotation and gravity field: geodetic applications for the parallel ocean circulation model. *AGU Spring Meeting*.
- Lambeck, K., 1980: The Earth's Variable Rotation, Cambridge U. Press.
- Ray, R.D., D.J. Steinberg, B.F. Chao, D.E. Cartwright, 1994: *Science, 264*, 830-832.
- Ray, R. D., R. J. Eanes, B.F. Chao, 1996: *Nature, 381*, 595-597.
- Schrama, E.J.O. and R D. Ray, 1994: *J. Geophys. Res.*, *99*, 24799-24808.