Oceanic Excitation of the Chandler Wobble

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The Earth rotates about its axis once a day, but does not do so uniformly. Instead, the rate of rotation fluctuates by up to a millisecond per day, and the Earth wobbles as it rotates. Much like the wobble of an unbalanced automobile tire, the Earth wobbles because the mass of the Earth is not balanced about its rotation axis.

The wobbling motion of the Earth was first detected by Seth Carlo Chandler, Jr. in 1891 and has been under observation ever since. Analyses of these observations reveal that the Earth has, in fact, two dominant wobbling motions: (1) an annual wobble with a period of 12 months and an amplitude of about 3 meters, and (2) the Chandler wobble with a period of 14 months and an amplitude that varies between about 3 to 6 meters.

The annual wobble is a forced motion of the Earth that is caused largely by the annual appearance of a high atmospheric pressure system over Siberia every winter. The Chandler wobble on the other hand is not a forced motion of the Earth, but is rather a resonant motion that was first predicted by the Swiss mathematician Leonhard Euler in 1765. Euler studied the general translational and rotational motion of rigid bodies and, by applying his theory to the Earth, predicted that if the Earth's mass were not balanced about its rotation axis then the Earth should wobble as it rotates.

Despite numerous subsequent attempts by astronomers to detect this predicted wobbling motion of the Earth, it was not until 1891 that Chandler finally detected such a motion with a period of 14 months. Further analysis of the observations by Chandler revealed the additional presence of a wobble with a period of 12 months. The 14-month wobble is now known as the Chandler wobble in honor of the person who first detected the wobbling motion of the Earth.

Frictional forces associated with the wobble-induced deformation of the solid Earth would cause the Chandler wobble to freely decay with an exponential time constant of about 68 years if no mechanism or mechanisms were acting to excite it. Observations of the Chandler wobble taken during the past century show that there are times when its amplitude has actually increased. Thus, some mechanism or mechanisms must clearly be acting to excite the Chandler wobble. But despite the numerous studies that have been conducted since it was first detected, the primary mechanism responsible for exciting the Chandler wobble has only recently been discovered.

The recent availability of numerical general circulation models of the global oceans has allowed the impact of oceanic processes on the Earth's rotation to be studied. In particular, such models are used here to show that the change in the load on the oceanic crust due to changes in the weight of the overlying column of water associated with changes in the distribution of the oceanic mass is about twice as effective in exciting the Chandler wobble as is the changing atmospheric pressure over land. In fact, the sum of the changing atmospheric pressure over land and the changing ocean-bottom pressure can fully explain the excitation of the Chandler wobble.