elasticity, one earthquake is not enough to cause a large wobble. If the wobble is not caused by one or two earthquakes, do quakes exert a cumulative effect?

"Since a big earthquake displaces a lot of mass, it is reasonable to think that this redistribution of mass will have some effect on the rotation of the earth, but the theoretical calculation comes out too small by a factor of two or three," says Edward Flinn, chief scientist of the National Aeronautics and Space Administration's geodynamics program. "Still, there is a distinct possibility that the continuous release of seismic energy would be enough to excite this wobble."

The wobble also perplexes scientists because it varies with respect to radius and, possibly, to period. One explanation for the variation is that different parts of the earth, for example the oceans or the liquid core, may wobble with different frequencies. Their interaction may cause the wobble to appear to vary with time when in fact it is two wobbles of fixed period — not varying with time at all. Chandler himself concluded that the 14-month period is complicated by a major peak at 428 days and a much smaller one at 436 days. Although his observations had once before proved correct in the august face of the "laws of dynamics" the scientific community again rejected his analysis because it conflicted with theory. This reaction still occurs.

"If you put two frequencies that close together you have a 'beat' phenomenon," J. Derral Mulholland, of the University of Texas at Austin told SCIENCE NEWS. "The frequencies 'beat' together so that sometimes they add together, sometimes they cancel each other out. If you look but don't know there are two frequencies, it looks like variable amplitude and variable period. People who look at geophysical theories can't imagine how that could happen. Observers say that it *does* happen and that the theory is wrong."

In the March 10, 1981 JOURNAL OF GEOPHYSICAL RESEARCH, William Carter of the National Geodetic Survey reports that his analysis of observational data shows a correlation between the magnitude of the polar motion and variations in the beat period — the time required for the pole to complete a cycle of the combined annual and Chandler motions. His conclusions echo Chandler's in 1901. The reason for the variation in frequency, Carter suggests, is that the oceans fail to respond quickly to the changing orientation of the axis of rotation to the solid earth. The frequency of the wobble decreases as the poles become further displaced.

The Chandler wobble also affects — and is affected by — the one-half to one-centimeter variation called the pole tide, the response of the oceans when the earth wobbles. The tide is small enough to inspire skepticism in some facets of the scientific community although, as Steven Dickman, a geophysicist at the State University of New York at Binghamton, explains, "From a theoretical point of view, it has to be there." In some locations, such as the North and Baltic seas, pole tides as large as three to five centimeters have been measured. "If the oceans respond more than people predict, it means the wobble is affected more than people predict," Dickman says. He suggests that the oceans are dissipating the energy as the waters, wobbling, rub against the sea floor.

To settle some of the controversies, better techniques of measuring polar motions and planet rotation are needed. In 1899, on the still-naive assumption that the wobble was of simple nature with a fixed period, the International Latitude Service (ILS) was established as a short campaign to monitor polar motion. The ILS, one of the oldest international efforts of scientific collaboration, operated five observatories around the world, all on the same latitude, to measure annual, semiannual, and random polar motions in addition to the Chandler wobble. While this work, expanded into the International Polar Motion Service, continues with support from NASA, the National Geodetic Survey (NGS) under the National Oceanic and Atmospheric Administration has embarked on a program to monitor earth rotation using space technology. An experimental, international program, 14 months long, will begin September 1983 to test observational methods. The most accurate method wins, becoming the vehicle of choice for a leap in the quality of observations of polar motions.

The techniques being tested include classical methods based on visual, photographic and photoelectric observations of stars, and modern methods such as doppler tracking of earth satellites, laser ranging using the moon or satellites and the method favored by the NGS — radio interferometry. The technique, called Very Long Baseline Interferometry (VLBI), uses extragalactic radio sources billions of light years from earth. Under a project called POLARIS the NGS uses three observatories to monitor the earth's orientation with respect to the extragalactic radio sources, primarily quasars. Where traditional methods track polar motion and the planet's rotation to an accuracy of about a meter, VLBI allows measurements accurate to five to 10 centimeters.

Study of tiny details of the planet's rotation is just one aspect of the effort to learn more about the earth's structure. Says Dickman: "It's one of the most specialized topics capable of telling us some of the most generalized information about the earth, such as properties of the core or the elasticity of the mantle. It presents an endless number of research problems, each of which can tell us a little more about the earth as a whole." □

BOOKS

BOOKS is an editorial service for readers' information. To order any book listed or any U.S. book in print please remit retail price, plus 50¢ handling charge for each book to **Book Order Service,** Science News, 1719 N Street, N.W., Washington, D.C. 20036. All books sent postpaid. Domestic orders only.

THE COLOR ATLAS OF HUMAN ANATOMY — Vanio Vannini and Giuliano Pogliani, Eds., translated and revised by Richard T. Jolly. Demonstrates with text, drawings, diagrams and photographs the complex wonders of our bodies. Helps to make clear to the general reader how muscles and nerves function, the course of food through the body and the other aspects of the ordinary yet miraculous body mechanics and chemistry that govern everyday existence. Crown, 1981, 107 p., color/b&w illus., paper, $6.95.

THE HEALTHY ADOLESCENT: A Parents' Manual — Barry Lauton and Arthur S. Freese. Describes the biological and chemical changes that the adolescent experiences. Shows how growth patterns are often uneven and how physical and sexual maturation leads to stresses and dangers that are all too often compounded by ignorance. Gives extensive medical information and advice about sex, including contraception, pregnancy and venereal disease. Scribner, 1981, 214 p., $11.95.

AN ILLUSTRATED MANUAL OF PACIFIC COAST TREES—Howard E. McMinn and Evelyn Maino. Includes the native trees growing within California, Oregon, Washington and British Columbia together with about 400 introduced species and varieties. One section by H. W. Shepherd lists trees recommended for various uses on the Pacific Coast. The second edition was published in hardback in 1980. U of Cal Pr, 1981, 413 p., illus., paper, $6.95.

THE OCEANS: Our Last Resource—Wesley Marx. Encourages us to re-evaluate both the real opportunities for preserving the oceans' resources and the false expectations for exploiting them. Explores ways to safeguard the resources of our seas. Sierra (Scribner), 1981, 332 p., $13.95.

THE RING OF FIRE — David Ritchie. This narrow band of intense earthquake and volcanic activity along the Pacific Ocean contains some 75 percent of all the active volcanoes in the world and has been the site of many destructive earthquakes and volcanic eruptions. From an earthquake in China in 1556 that is reported to have taken 800,000 lives to Mt. St. Helens's eruptions in 1980, the author discusses the famous disasters, including those caused by tsunamis. Explains the present thinking as to the causes of earthquakes and volcanic eruptions and looks to the future — new energy sources, earthquake prediction and the potential for catastrophe along the San Andreas Fault. Atheneum, 1981, 258 p., illus., $14.95.

THE TIGRIS EXPEDITION: In Search of Our Beginnings—Thor Heyerdahl. A 4,200-mile voyage aboard the reed ship *Tigris*. Retraces the trading routes of the ancient Sumerians in order to prove that the prehistoric civilizations of Mesopotamia, Egypt and the Indus Valley, long believed to have developed independently, had exchanged aspects of their cultures via their maritime trade. Doubleday, 1981, 349 p., color illus., $17.95.

USE AND MISUSE OF EARTH'S SURFACE: Readings from *American Scientist* — Brian J. Skinner, Ed. Pushed by the demands of ever-growing population, we are altering earth's air, land and water to an unprecedented degree. These articles demonstrate the kinds of environmental changes we know best—overpopulation, global and local pollution, the effects of changing the air, the water and the land and the impacts of communities of organisms. W. Kaufmann, 1981, 212 p., color/b&w illus., paper, $9.95.