Observational plate tectonics

The latest report of the international radio-interferometric survey IRIS suggests that the direct measurement of plate movements lies just ahead.

THE exciting prospect that radioastronomers will be able, by the use of long-baseline interferometers, directly to measure the motion of tectonic plates, will be a little delayed, it seems. That is one cautious reading of the latest report on four years of work with the international network of geodetic observing stations operated under the title IRIS (for International Radio Interferometric Surveying), which is itself an outgrowth of the combined operation of the US project POLARIS (for Polar Motion Analysis by Radio Interferometric Surveying) and the West German geodetic radio telescope at Wettzell, Bavaria. In an account of observations to the end of November 1984, W.E.Carter, D.S.Robertson and J.R.MacKay of the US National Geodetic Survey (*J.geophys.Res.* **90**, 4577–4587; 1985) quote estimates of the rate at which two baselines are changing, but with errors that are still too great for comfort.

The idea that radio-interferometry might be used for checking on plate tectonics has been in the air ever since radio telescopes separated by a substantial distance were first used for the accurate measurement of the angular size of distant radio sources, quasars for example. But the technology of very long baseline interferometry (VLBI) is only now good enough, and the network of observatories enough, to bear on plate tectonics.

Schematically, the technique is simple enough. Several telescopes simultaneously observe the same distant radio source, recording their signals on magnetic tape (together with an accurate measure of time, most conveniently provided by a local hydrogen maser). In general, there is a time-lag between the receipt of the same waveform at one station and another which, when multiplied by the velocity of light, will be a simple measure of the separation of the two antennas along the line of sight. But given that the Earth rotates, the time-lag will change systematically with time, and in such a way that it should be possible to infer from the observations not merely the relative geometrical position of the two antennas, their baseline separation included, but also the instantaneous position of the axis about which the Earth is rotating.

Practice is, as always, more difficult. One heartfelt complaint by Carter *et al.* is that the sheer weight of the magnetic tape which has to be assembled at a comparator centre after a day's observation by a handful of stations may amount to several hundred kilograms, "a troublesome constraint limiting the growth of geodetic VLBI". Even so, the planners intend adding to the four core stations (Westford, Massachusetts, the Agassiz station in Texas, Richmond, Florida, and Wettzell) cooperation with the Kashima Observatory in Japan and the Shanghai Observatory on mainland China. Other radio telescopes in the United States and elsewhere join in the network as the opportunity arises; that at Onsala, Sweden, takes part for one day a month.

The most startling result so far seems to be that of the measurement of the Earth's pole position, which has been determined since the beginning of 1984 with an accuracy of 2 milliarc seconds (or 6 cm on the ground). This, at least, is the discrepancy between the VLBI measurements of the pole position and those obtained quite independently from satellite ranging, which confirms the accuracy of both sets of measurements. VLBI measurements every three or five days may be enough to keep track of this polar (Chandler) wobble to within a milliarc second.

For what it is worth, the 1984 observations put the position of the pole on a smooth arc destined to form a near-circle some 16.5 metres in diameter, not very different in amplitude from that measured in the previous year but more than twice as great as the amplitude of the Chandler wobble in the two earlier years. Because the VLBI measurements will be made in any case, and because they can be quickly reduced, they will quickly become the preferred way of tracking the wobble.

The data have also thrown up a wealth of detail about departures of the Earth's rotational speed as given by Universal Time (strictly, UT1). Departures from regularity leading to fluctuations of up to 6 milliseconds occur, with some excursions lasting for several months and others for only a few days. It should be possible to monitor the regularity of UT (or of the Earth's rotational speed) to within 0.1 milliseconds by means of a daily hour-long measurement along a single baseline. That is also a by-product well worth having. Daily monitoring may even make it possible to tell which fluctuations of rotational speed are attributable to what.

Other by-products include some information on the nutation of the Earth's rotation, which reflects displacements between the spinning core of the Earth and the outer solid hollow sphere. The Earth tides responsible for the rhythmic fluctuation of the altitude of the radio telescopes in the network are also evident in the data.

So what is there to be said about the baselines and their variation? It is obviously easier to extract from the measurements of the time-lags and their variation with time the quantities whose time-dependence takes a predictable form. This is one reason why fluctuations of the Earth's rotational speed can be monitored so easily; the time-lag between any pair of stations in the VLBI network will be a sinusoidal function of time whose frequency is that of the Earth's rotation.

By contrast, the baseline lengths appear as factors in the constants by which these variable quantities are multiplied, so that the accuracy with which they can be determined is no greater than that of the observations as a whole. Even so, baseline measurements are said to be repeatable to within about one part in 100 million, a mere centimetre or so of error for the longest baselines, for the time being those based in Europe and the United States.

This is the promise for plate tectonics. Many of the movements expected should be readily verified as further measurements of the baselines accumulate. Indeed, Carter *et al.* tantalize their readers with an estimate of the rate of change of the baseline between Westford (Massachusetts) and Onsala (Sweden) and that between Westford and the Texas station. The conclusion is that the trans-atlantic baseline is lengthening by 14 mm a year (with an estimated uncertainty of 3 mm) and that the baseline between Westford and the Texas station is shrinking by 8 mm a year (with an uncertainty of 1 mm).

The sense of these results, at least, is consistent with what plate tectonics would predict; the contraction of the US baseline, for example, is thought to be a consequence of compressional stress on the American plate at least in the region between the Appalachians and the Rockies (see D. I. Gough *et al. Nature* **305**, 619–621; 1983). The fly in the ointment is the suggestion of seasonal errors in the baseline measurements, implying a need for some refinement of the corrections for transmission through the ionosphere and atmosphere. The general interest now will be to see how quickly the VLBI collaboration will be able to accumulate further data. Another year's observations should make all the difference. **John Maddox**