THE BACKGROUND TO THE MERIT/COTES RECOMMENDATIONS ON THE TERRESTRIAL AND CELESTIAL REFERENCE SYSTEMS

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ABSTRACT. The MERIT programme of international collaboration to monitor earth-rotation and to intercompare the techniques of observation and analysis has fostered the development of the use of space techniques. Earth-rotation parameters are now determined regularly with a precision that is better than 1 milliarcsecond (0".001) and the relative positions of the observing stations are determined to better than 1 decimetre (0.1 m). It is therefore necessary that the terrestrial and celestial reference frames be defined more precisely. The MERIT and COTES Working Groups have proposed that new conventional terrestrial and celestial reference systems be established and that the maintenance of these systems be the responsibility of a new International Earth Rotation Service. The new reference frames are to be based on the adoption of positions and motions of designated stations and extragalactic radio sources. Appropriate models and parameters will be associated with these frames to form reference systems so that observations can be used to determine the rotation of the terrestrial frame with respect to the celestial frame.

1. REVIEW OF ACTIVITIES

The IAU appointed in 1978 "a Working Group to promote the comparative evaluation of the techniques for the determination of the rotation of the Earth and to make recommendations for a new international programme for observation and analysis in order to provide high-quality data for practical applications and fundamental geophysical studies". This group has organised the MERIT programme of activities to monitor earth-rotation and intercompare the techniques of observation and analysis. The proposals were endorsed by the IAU and IUGG in 1979. The MERIT Short Campaign was held from 1980 August 1 to October 31; this served to stimulate the regular use of new observational techniques and provided a valuable test of new operational arrangements for data communication and analysis. The COTES Working Group was set up in 1980 "to prepare a proposal for the establishment and maintenance of a conventional terrestrial reference system". The two groups have since worked closely together and the MERIT Main Campaign, which was held during the period 1983 September 1 to 1984 October 31, was supplemented

J.-P. Swings (ed.), Highlights of Astronomy, 81–84.

by Intensive Campaigns in 1984 April to June and 1985 May to July that were aimed primarily at determining the relationships between the reference systems used in the six different techniques of observation (optical astrometry, satellite-Doppler, satellite and lunar laser ranging, connected-elements and very-long-baseline radio interferometry). The results of the MERIT campaigns were discussed at the Third MERIT Workshop and at the International Conference on Earth Rotation and the Terrestrial Reference Frame, which were held at Columbus, Ohio, on 1985 July 29 to August 2, and recommendations on the concepts and organisation of a new International Earth Rotation Service were developed. A summary report prepared jointly by the chairmen of the two groups (G A Wilkins and I I Mueller) is given elsewhere in this volume; it gives references to previous reports and is accompanied by the texts of the MERIT/COTES recommendations and by an account of their consideration at a Joint Meeting of IAU Commissions 19 and 31. Subsequently the IAU General Assembly adopted resolution B2 that endorsed the report and decided to set up the new service (Trans. IAU, 19B,).

2. THE NEED FOR NEW REFERENCE SYSTEMS

During the past seven years the MERIT and COTES programmes have stimulated the use of laser ranging and radio interferometry for the regular monitoring of the rotation of the Earth. These techniques have now largely replaced the use of optical astrometry and the Doppler tracking of satellites for the determination of universal time, length of day and polar motion; they are also contributing to the improvement of our knowledge of precession and nutation, which specify the motion in space of the axis of rotation. The earth-rotation parameters are now determined regularly with a precision that is better than 1 milliarcsecond (0".001). Correspondingly, the relative positions of the observing stations are determined to better than 1 decimetre (0.1 m). There are, however, significant differences between the results from the various techniques and even between different analyses for the same technique. These differences arise partly from inadequacies in the models used for the analysis of the observational data and partly from differences between the reference systems that are implicit in each of the techniques.

These considerable improvements in precision require that the relevant terrestrial and celestial reference frames be defined to a correspondingly higher precision. It would be appropriate to define the terrestrial reference frame so that positions may be specified globally with a precision of about 1 cm; it is essential that the definition takes into account the relative motions of points on the Earth's crust. Correspondingly the celestial reference frame with respect to which the rotation of the Earth is determined must be specified to a precision of about 0".0001. It is necessary to associate appropriate standard models and parameters with these frames to form conventional reference systems so that observations can be used to determine the rotation of the terrestrial frame with respect to the celestial frame.

3. THE TERRESTRIAL REFERENCE SYSTEM

It is not possible to specify directly with adequate precision the pole and prime meridian of a terrestrial reference frame. Instead these must be specified indirectly, as is now the case for the stellar reference frame, by the adoption of a catalogue of positions and motions of designated stations at which very precise observations are made regularly by space-geodetic techniques. (The positions may be specified by three rectangular coordinates or as an equivalent set of geodetic coordinates with respect to the international reference spheroid.) The positions of other points on the Earth's surface will then be determined from measurements relative to nearby reference points. The initial positions of the reference stations will be chosen so that the new reference frame will be in close accordance with the current reference frame. In particular, it is considered that the north pole should be as close as possible to the Conventional International Origin (CIO), as realized through the current BIH system; an alternative would have been to make the z-axis correspond to the principal axis of inertia of the Earth as specified by an adopted model of the gravity field. Similarly, the prime meridian should pass close to the Airy transit circle at the Old Royal Observatory at Greenwich, but this instrument will not be used to define the zero of longitude. The origin of the frame should be at the centre of mass of the Earth. The motions of individual stations are to be based on current observations of relative motions and on current models of tectonic motions. The arbitrary constants in the motions are to be chosen so that there will be no net rotation of the stations around the z-axis and no net translation with respect to the origin. In effect, the reference frame is to be tied to the crust as represented by the designated stations. An alternative would have been to try to tie the frame to the upper mantle as indicated by, for example, the positions of "hot spots". All points on the Earth's crust are subject to periodic motions due to Earth tides and to the tidally changing load of the oceans on the crust. A model of these tidal motions must be included in the specification of the conventional terrestrial reference system since their effects must be taken into account in the reduction of precise observations. Similarly, the periodic changes in the direction of the vertical must be taken into account in the reduction of astrometric observations that refer to the apparent direction of gravity.

4. THE CELESTIAL REFERENCE SYSTEM

The standard celestial reference frame is currently specified in terms of the mean equator and equinox of J2000.0 in the system of the FK5 catalogue of fundamental stars, which is not yet published. This is nominally the same as the reference frame used for the generation of the planetary and lunar ephemerides published in the Astronomical Almanac and most other national almanacs for 1984 onwards. These stellar and dynamical reference frames are not suitable for use for the monitoring of the rotation of the Earth since neither is directly accessible by either VLBI or SLR observations and since both may have a

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so far undetected rotation with respect to the "universe". The most appropriate choice for a "space-fixed" reference frame is provided by the system of distant galaxies as represented by the positions of quasars. This frame is directly and precisely accessible through VLBI observations which will be made regularly for monitoring the rotation of the Earth and for other studies. It will be specified by a catalogue of positions and motions (normally zero) of designated radio sources; the arbitrary constants will be chosen so as to give close accord with the frame of J2000.0. One of the tasks of the new International Earth Rotation Service will be to establish the relationships between the celestial frame represented by the radio sources and the frames represented by the FK5 catalogue and by the ephemerides of the planets and of the Moon and artificial satellites, such as LAGEOS, that are observed by laser ranging. The parameters that are now used to specify the orientation of the Earth are universal time and the angular coordinates of the 'celestial ephemeris pole' with respect to the BIH frame. (The celestial ephemeris pole is defined in such a way that it has no diurnal motion with respect to either the celestial frame or the terrestrial frame; it may be said to be in the direction of the 'axis of diurnal rotation', rather than of the axis of instantaneous rotation.) In effect the earth-rotation parameters at any instant (or 'date') specify the orientation of the Earth with respect to an intermediate celestial reference frame that is itself rotating slowly, but predictably, with respect to the space-fixed celestial reference frame. The rotation of the celestial reference frame of date is specified by the adopted theories of precession and nutation, which may be readily evaluated and which must be regarded as parts of the 'conventional celestial reference system'. It may be desirable to redefine universal time or to replace it by a more appropriate measure of the rotation of the Earth.

5. CONCLUSIONS

Although there appears to be general agreement about the form of the new reference systems it is clear that a great deal of work and consultation will be necessary before they can be formally adopted. It is important that the proposed specifications of the new systems be accompanied by full documentation that will show clearly and unambiguously how current terrestrial and celestial systems are related to the new systems. The new International Earth Rotation Service will need to establish appropriate arrangements to monitor these relationships and to propose, from time to time, modifications to the systems to ensure that they continue to meet future requirements for high-precision geodesy and astrometry.

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