REPEAT STATIONS

Definition

Repeat stations are permanently marked sites where it is possible to make accurate observations of the Earth's magnetic field vector for a period of a few hours (sometimes a few days) every few years. Their main purpose is to track secular variation (see *geomagnetic secular variation* and *time-dependent models of the main magnetic field*) and, if accurate observational techniques and careful reduction procedures are followed, they can be a cost-effective way of supplementing observatory data for secular-variation modelling. Figure 1 shows a plot of repeat station locations. The distribution is somewhat uneven, being determined more by local need and resources rather than requirements to achieve global coverage.

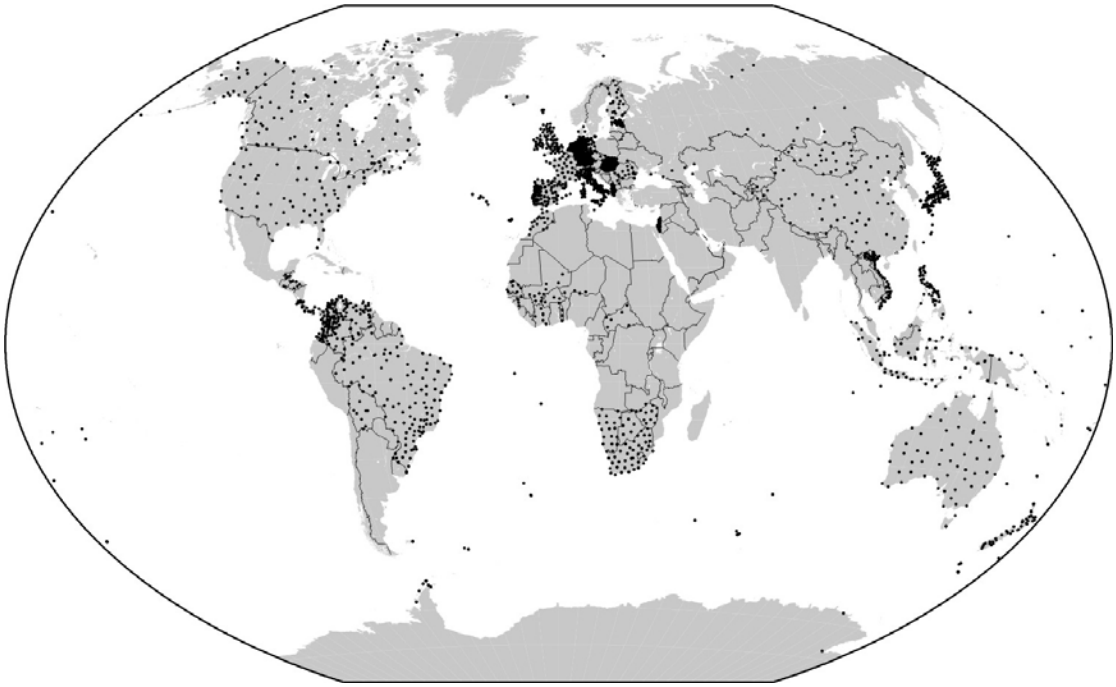

Figure 1 Locations of all known repeat stations visited more than once since 1975

History

One of the earliest repeat station networks was in the UK where 190 stations were established and measurements were made at each by Sabine and colleagues in the 1830s (see *Sabine. E.*). Many of these sites were reoccupied between 1857 and 1861. However, as the distribution of these stations was somewhat uneven and records enabling their further reoccupation do not seem to have survived, Rücker and Thorpe

established a new network between 1884 and 1888 comprising some 200 stations (Barraclough, 1995 and references therein). Some of these stations are still in use today although probably none are exact re-occupations. Elsewhere in the world, the Carnegie Institution of Washington Department of Terrestrial Magnetism (see *Carnegie Institution of Terrestrial Magnetism*) permanently marked sites to enable reoccupation during their excursions around the world starting in the early 20th century (see *Bauer, L.A.*) and many countries began to establish repeat station networks at around about this time.

.

Equipment

The instruments are usually the same as those used at magnetic observatories; a fluxgate theodolite to measure declination and inclination and a proton precession magnetometer (PPM) to measure field strength (see *observatory instrumentation*). At observatories fixed marks are usually already surveyed in but this is not always the case at repeat stations. Therefore additional instrumentation may be necessary for the determination of true north. This may be a gyro-attachment for the theodolite, eyepieces or sun filters and accurate timing equipment for sun or star observations, or separate geodetic-quality Global Positioning System (GPS) units. Also often necessary is a tent to provide shelter for the equipment and observer from the weather.

Procedures

Great care is taken to ensure that exact re-occupation of the site is made at each visit because, if there is an appreciable local gradient in the crustal field, any error in positioning the instruments will contaminate the resulting secular-variation data. At each visit a site survey with a PPM is usually done to check for magnetic contamination of the repeat station. An auxiliary station is established a few metres from the marked site and the difference in the total intensity of the field between these two sites is established using two PPMs running simultaneously. Depending on the method being used to determine true north the fluxgate theodolite or GPS unit may then be set up over the marked site. The fluxgate theodolite for observing declination and inclination is then set up over the marked site. The PPM at the auxiliary station logs data for the duration of the declination and inclination observations. Several rounds of observations are made over a number of hours, each round involving 4

circle readings to eliminate collimation errors between the theodolite telescope and the fluxgate sensor and within the theodolite itself.

An important aspect of the data reduction procedures is correction for the regular daily variation (see *periodic external fields*) and magnetic storms (see *storms and substorms*). When repeat stations are close to observatories, these variations are observed and corrected for using continuous observatory data. Elsewhere, especially for repeat stations in areas of complex external fields such as the auroral zones or remote from geomagnetic observatories, on-site variometers are sometimes run to monitor these variations.

A useful publication for guidance on repeat station survey procedures is that published under the auspices of IAGA (Newitt *et al*, 1996, see *IAGA*).

Use in modelling

Efforts to model the field over restricted regions of the Earth for the purposes of mapping rely on good local coverage of vector data such as that provided by repeat stations. Different approaches are used around the world depending on the extent of the area and coverage of data, but the most common is some form of spherical cap harmonic analysis (SCHA) (see *spherical cap harmonics*). As well as being applied in many individual countries to map the magnetic field, for example Canada, Spain, South Africa, SCHA has also been applied to European repeat station data to search for secular-variation anomalies. However the degree of success has been limited partly because of the high uncertainties associated with the data (Korte and Haak, 2000). Repeat station data have also been used in global modelling and help fill in some gaps in the observatory distribution.

Susan Macmillan

Bibliography

Barraclough, D. R., 1995. Observations of the Earth's magnetic field made in Edinburgh from 1670 to the present day. Transactions of the Royal Society of Edinburgh: Earth Sciences, Vol. 85, 239-252.

Korte, M. and Haak, V., 2000. Modelling European Magnetic Repeat Station Data by SCHA in Search of Time-varying Anomalies. Physics of the Earth and Planetary Interiors, Vol. 122, 205-220.

Newitt, L. R., Barton, C. E. and Bitterly, J., 1996. Guide for Magnetic Repeat Station Surveys. International Association of Geomagnetism and Aeronomy.