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Short-term variations in core surface flow resolved from an improved method of calculating observatory monthly means

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Monthly means of the magnetic field measurements taken by ground observatories are a useful data source for studying temporal changes of the core magnetic field and the underlying core flow. However, the usual way of calculating monthly means as the arithmetic mean of all days (geomagnetic quiet as well as disturbed) and all local times (day and night) may result in contributions from external (magnetospheric and ionospheric) origin in the (ordinary, omm) monthly means. Such contamination makes monthly means less favourable for core studies. We calculated revised monthly means (rmm), and their uncertainties, from observatory hourly means using robust means and after removal of external field predictions, using an improved method for characterising the magnetospheric ring current.

The utility of the new method for calculating observatory monthly means is demonstrated by inverting their first differences for core surface advective flows. The flow is assumed steady over three consecutive months to ensure uniqueness; the effects of more rapid changes should be attenuated by the weakly conducting mantle. Observatory data are inverted directly for a regularised core flow, rather than deriving it from a secular variation spherical harmonic model. The main field is specified by the CHAOS-4 model. Data from up to 128 observatories between 1997 and 2013 were used to calculate 185 flow models from the omm and rmm, for each possible set of three consecutive months. The full 3x3 (non-diagonal) data covariance matrix was used, and two-norm (least squares) minimisation performed. We are able to fit the data to the target (weighted) misfit of 1, for both omm and rmm inversions, provided we incorporate the full data covariance matrix, and produce consistent, plausible flows. Fits are better for rmm flows. The flows exhibit noticeable changes over timescales of a few months. However, they follow rapid excursions in the omm that we suspect result from external field contamination; this tends to cause more erratic flow speeds rather than a change in the flow pattern. We resolve temporal changes in flows derived from the rmm associated with two geomagnetic jerks that occurred around 2003.5 and 2004.5. Throughout the interval investigated, the band of westward flow straddling the equator in the hemisphere centred on the Greenwich meridian is well developed, and flows are considerably weaker beneath the Pacific Ocean. At most times, including at the start and end of our period of interest, an anti-clockwise gyre is seen beneath the southern Indian Ocean. These are the well-established long-term features of the flow. However, the gyre disappears and re-develops twice in the mid-2000s. These changes imply quite rapid and significant changes in length-of-day (assuming such changes set up torsional oscillations), which mimics changes thought to be associated with geomagnetic jerks. The bulk westward drift speed decreases throughout the interval, with oscillations superimposed. Sharp minima in 2003, 2006, 2009 and 2011 are at times Chulliat and Maus identified secular acceleration pulses at the core surface, with particularly prominent signatures at low latitudes.