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Rotation of the atmospheres of the Earth and planets

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The most striking features of the general circulation of the Earth's atmosphere are its average 'super-rotation' relative to the solid Earth at about 10 m s^{-1}, and the concentration of much of the motion in jet streams with speeds of about 30 m s^{-1}. Changes in the pattern of winds, and variations in the distribution of mass within the atmosphere produce fluctuations in the angular momentum associated with this 'super-rotation', namely, the axial component H_3 of the total angular momentum of the atmosphere H_i, $i = 1, 2, 3$, and also in the equatorial components H_1 and H_2. Fluctuations in H_3 during the Special Observing Periods of the recent 'First GARP Global Experiment' (FGGE, where GARP is the Global Atmospheric Research Programme) later have been investigated. They are well correlated with short-term changes of up to about 10^{-3} s in magnitude in the length of the day (allowing for lunar and solar tidal effects on the moment of inertia of the solid Earth), exhibiting pronounced contributions on timescales of about seven weeks and one year and they are consistent with the sum of H_3 and the axial component of the angular momentum of the Earth's crust and mantle being conserved on short timescales, without requiring significant angular momentum transfer between the Earth's liquid core and overlying solid mantle on such timescales. Fluctuations in H_1 and H_2 on timescales much less than the Chandlerian period (14 months) but rather more than a few days make a major contribution to the observed wobble of the instantaneous pole of the Earth's rotation with respect to the Earth's crust, which has a variable amplitude of several metres. A theoretical basis has now been established for future routine determinations of fluctuations in H_i for the purposes of meteorological and geophysical research, including the assessment of the extent to which movements within the solid Earth associated with major earthquakes (magnitude much greater than 7.9) and motions in the liquid metallic core might occasionally contribute to the excitation of the Chandlerian wobble.

Venus's atmosphere 'super-rotates' at an average speed of about ten times that of the underlying planet, which, owing to angular momentum exchange with the atmosphere, should (like the solid Earth) undergo detectable changes in rotation period. Each of the giant planets Jupiter and Saturn exhibits a sharply-bounded equatorial atmospheric jet stream moving at 100 m s^{-1} (Jupiter) or 400 m s^{-1} (Saturn) in a positive (i.e. eastward) direction relative to higher latitude parts of the atmosphere, the average rotation of which is close to that of the hydrogen-metallic fluid interior (as determined from radio-astronomical observations). The theoretical interpretation of these observations presents challenging problems in the dynamics of rotating fluids.

1. Introduction

Seven years ago the Royal Society held a lively discussion meeting on methods and applications of ranging to artificial satellites and the Moon (see Cook & King-Hele 1977). I was asked to contribute a paper on fluctuations in the Earth's rotation, with particular reference to manifestations of the exchange of angular momentum between the solid and fluid parts of the