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Dependence of IMF - magnetosphere coupling on magnetospheric scale: Earth, Jupiter, Saturn

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One of the few things on which substorm specialists agree is that activity in the terrestrial magnetosphere depends strongly on the orientation of the interplanetary magnetic field (IMF). Various functional relationships have been proposed. Most of them suggest that magnetospheric responses (ionospheric current intensity, auroral activity, etc.) are proportional to some low power of sin(theta/2) where theta is the clock angle of the IMF relative to dipole north. For the purpose of this argument we will assume that the coupling varies as the square of sin(theta/2), consistent with the expectation that a southward-oriented IMF is critical to driving activity. At Jupiter and Saturn, auroral activity is believed to be driven dominantly by internal sources of momentum, but solar wind sources appear to contribute as well. Studies of auroral activity at Jupiter and Saturn are limited by the paucity of relevant solar wind data, but the few published analyses find little evidence of control by the north-south component of the IMF, concluding that auroral brightness responds principally to changes of solar wind dynamic pressure. In this presentation, we emphasize that the interaction of the solar wind with a magnetosphere is sensitive to the variability of relevant solar wind parameters, with a critical time scale, T, defined in terms of the length of the magnetosphere (L) as T = L /vsw. Only if solar wind parameters remain close to constant for times long compared with T can they impose effects on the global system. The critical time scale differs markedly for the magnetospheres of Earth and of the gas giants. We use Saturn as an example to compare with Earth. The nominal length of Earth's magnetotail (estimated as the distance from the nose at about 10 RE to the near-Earth neutral line) is about 30 RE, implying T is of order 7.5 min; for Saturn, where the nose of the magnetosphere is at 20 RS and the neutral line is no closer than 40 RS, T is of order 2.5 hr. Noting that terrestrial substorm growth phases last of order 30 min, one estimates that to be "geoeffective", solar wind parameters should remain close to constant for more than 4T, or for more than 10 hours at Saturn. Because the N-S component of the IMF has considerable power at frequencies below 1/4T at Earth but little power in the corresponding frequency band at the outer planets, the usual assumption linking activity with the N-S component is not valid for those magnetospheres. The azimuthal component, on the other hand, remains roughly constant for days at a time. At Saturn's solstice, assuming a dependence on the square of sin(theta/2), coupling with the dominant, relatively steady field component is smaller than coupling to a strictly northward field by only a factor of 0.44; the persistence of field orientation is expected to more than compensate for this reduction in coupling strength. (Here we have included the 27 degree tilt of the dipole from the planet-sun line.) Near equinox at Saturn, the role of the azimuthal component of the IMF should be even more important and there should be a strong dependence of activity on solar wind sector. Future studies of activity (SKR, aurora, etc.) at Jupiter and Saturn should consider whether the azimuthal component of the IMF can be linked to its variability.