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An integrated model for Jupiter's dynamo action and mean jet dynamics

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Data from various space crafts revealed that Jupiter's large scale interior magnetic field is very Earth-like. This is surprising since numerical simulations have demonstrated that, for example, the radial dependence of density, electrical conductivity and other physical properties, which is only mild in the iron cores of terrestrial planets but very drastic in gas planets, can significantly affect the interior dynamics. Jupiter's dynamo action is thought to take place in the deeper envelope where hydrogen, the main constituent of Jupiter's atmosphere, assumes metallic properties. The potential interaction between the observed zonal jets and the deeper dynamo region is an unresolved problem with important consequences for the magnetic field generation. Here we present the first numerical simulation that is based on recent interior models and covers 99% of the planetary radius (below the 1 bar level). A steep decease in the electrical conductivity over the outer 10% in radius allowed us to model both the deeper metallic region and the outer molecular layer in an integrated approach. The magnetic field very closely reproduces Jupiter's known large scale field. A strong equatorial zonal jet remains constrained to the molecular layer while higher latitude jets are suppressed by Lorentz forces. This suggests that Jupiter's higher latitude jets remain shallow and are driven by an additional effect not captured in our deep convection model. The dynamo action of the equatorial jet produces a band of magnetic field located around the equator. The unprecedented magnetic field resolution expected from the Juno mission will allow to resolve this feature allowing a direct detection of the equatorial jet dynamics at depth. Typical secular variation times scales amount to around 750 yr for the dipole contribution but decrease to about 5 yr at the expected Juno resolution (spherical harmonic degree 20). At a nominal mission duration of one year Juno should therefore be able to directly detect secular variation effects in the higher field harmonics.