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Inferring the depth of the atmospheric circulation on Jupiter and Saturn through gravity measurements by Juno and Cassini and an adjoint based dynamical model

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In approximately three years Juno and Cassini will both perform close flybys of Jupiter and Saturn respectively, obtaining a high precision gravity spectrum for these planets. This data can be used to estimate the depth of the observed flows on these planets. Here we use a hierarchy of dynamical models in order to relate the three-dimensional flow to perturbations of the density field, and therefore to the gravity field. The models are set up to allow either zonal flow only, or a full horizontal flow in both zonal and meridional directions based on the observed cloud-level winds. In addition, dynamical perturbations resulting from the the non-spherical shape of the planets are accounted for.In order to invert the gravity field to be measured by Juno and Cassini into the 3D circulation, an adjoint model is constructed for the dynamical model, thus allowing backward integration of the dynamical model. This tool can be used for examination of various scenarios, including cases in which the depth of the winds depend on latitudinal position.

We show that given the expected sensitivities of Juno and Cassini, it is possible to use the gravity measurements to derive the depth of the winds, both on Jupiter and Saturn. This hold for a large range of zonal wind possible penetration depths, from $\sim$100km to $\sim$10000km, and for winds depth that vary with latitude. This method proves to be useful also when Incorporating the full horizontal flow, and thus taking into account gravity perturbations that vary with longitude. We show that our adjoint based inversion method allows not only to estimate the depth of the circulation, but allows via iterations with the spacecraft trajectory estimation model to improve the inferred gravity field.