

EGU21-10553, updated on 29 Jan 2022

<https://doi.org/10.5194/egusphere-egu21-10553>

EGU General Assembly 2021

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Combined magnetic and gravity measurements probe the deep zonal flows of the gas giants

Eli Galanti and Yohai Kaspi

Weizmann Institute of Science, Rehovot, Israel (eli.galanti@weizmann.ac.il)

The strong zonal flows observed at the cloud-level of the gas giants extend thousands of kilometers deep into the planetary interior, as indicated by the Juno and Cassini gravity measurements. However, the gravity measurements alone, which are by definition an integrative measure of mass, cannot constrain with high certainty the detailed vertical structure of the flow below the cloud-level. Here we show that taking into account the recent magnetic field measurements of Saturn and past secular variations of Jupiter's magnetic field, give an additional physical constraint on the vertical decay profile of the observed zonal flows in these planets. In Saturn, we find that the cloud-level winds extend into the planet with very little decay (barotropically) down to a depth of around 7,000 km, and then decay rapidly, so that within the next 1,000 km their value reduces to about 1% of that at the cloud-level. This optimal deep flow profile structure of Saturn matches simultaneously both the gravity field and the high-order latitudinal variations in the magnetic field discovered by the recent measurements. In the Jupiter case, using the recent findings indicating the flows in the planet semiconducting region are order centimeters per second, we show that with such a constraint, a flow structure similar to the Saturnian one is consistent with the Juno gravity measurements. Here the winds extend unaltered from the cloud-level to a depth of around 2,000 km and then decay rapidly within the next 600 km to values of around 1%. Thus, in both giant planets, we find that the observed winds extend unaltered (barotropically) down to the semiconducting region, and then decay abruptly. While it is plausible that the interaction with the magnetic field in the semiconducting region is responsible for winds final decay, it is yet to be understood whether another mechanism is involved in the process, especially in the initial decay from the strong 10s meter per seconds winds.