Ice Giants winds and meteorology in unconstrained weather layers

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Abstract

Both ice giants have similar rotation periods, large orbital inclinations and similarly intense zonal winds. The structure of the winds differs from those of the giant planets and is similar to expectations of a solar driven circulation with zonal winds that flow to the West at low latitudes and to the East at mid and high-latitudes (see review by Sánchez-Lavega et al., in "Zonal Jets", Cambridge University Press, 2019). However the intensity of the winds remains a mystery considering the small energy budget available at the distance of the planets to the Sun. The global patterns of winds were first determined from images acquired by the Voyager 2 in the 80s (Smith et al., 1986, 1989; Limaye and Sromovsky, 1991; Karkoschka, 2015). More recent studies based on observations from the Hubble Space Telescope (Sromovsky et al., 1995, 2001; Karkoschka, 1998; Hammel et al., 2001) and Keck (Sromovsky, 2005; Hammel et al., 2005; Sromovsky et al., 2009; Martin et al., 2012) have resulted in significant variability for most short-lived features with large dispersions caused most probably from effects of vertical wind shears not well determined. However many large and long-lived atmospheric systems seem to follow closely the Voyagers wind profiles (Hueso et al., 2017).

Zonal bands and discrete bright clouds appear in both planets with Neptune also showing dark ovals with bright companion clouds (i.e., Smith et al., 1989; Wong et al., 2018). Neptune seems more active and variable than Uranus and its global brightness has been changing in time-scales of decades although whether this is due by differences in band patterns or other mechanism is not known (Hammel and Lockwood, 2007). The cloud observations used to track the winds are more sensitive to levels close to the troposause where clouds should be made of methane ice. A deep global cloud required to match results from radiative transfer models seems to lie at 1-2 bar level and could be made of either ammonia or hydrosulfuric acid. Below this layer thermochemical models predict the formation of additional cloud layers of ammonia, ammonia hydrosulfide and water. The depth and density of these hypothetical clouds are highly unknown since they should be related with the global amount of O, N, and C determined from formation processes (Hersant et al., 2004) coupled with atmospheric processes. Burning questions on these cold worlds are how deep their meteorological layers are taking into account the possible deep massive clouds and weak solar forcing.

In both planets ortho to para ratio of hydrogen can be a key measure of the degree of recent vertical mixing and convection. In this contribution we will review current knowns and unknowns in the circulation of the icy giants including the winds variability, vertical structure of the upper atmosphere, and the depth of the "weather layer".

Keywords: Atmosphere dynamics, global circulation, meteorology, cloud vertical structure

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