Ice Giant Global Circulation Patterns Inferred from Infrared Remote Sensing: Where To Target a Probe?

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Abstract

The extremely low atmospheric temperatures of Uranus and Neptune present a significant challenge for remote sensing. For Jupiter and Saturn, infrared spectro-spatial mapping has allowed us to directly relate the environmental conditions (temperatures, humidity, wind-shears, disequilbrium tracers and aerosol distributions) to contrasts in albedo and cloud colouration. This allows the indirect inference of meridional motions in the troposphere and stratosphere, from belt/zone contrasts to larger-scale, seasonally-variable transport as part of global circulation systems (Ingersoll et al., 2004; Fletcher et al., 2015; Showman et al., 2018). In contrast, our knowledge of the global circulation patterns in the ice giants remains in its infancy. In the upper troposphere, 25-50 μm spectroscopy from Voyager/IRIS revealed cool mid-latitudes (suggestive of upwelling) and warmer equators and poles (suggestive of subsidence) on both worlds (Conrath et al., 1998), with limited seasonal variability on Uranus (Orton et al., 2015), but a significant warm polar vortex emerging on Neptune's south pole by its 2005 summer solstice (Fletcher et al., 2014). In the deeper atmosphere, from the cloud decks to the interior, the circulation appears to be characterised by enhanced equatorial methane (Karkoschka and Tomasko, 2011; Sromovsky et al., 2014) and depleted gaseous abundances at the poles (Hofstadter and Butler, 2003; de Pater et al., 2014), indicating equator-to-pole flow. Stratospheric circulation patterns are almost completely unknown, with suggestions of a latitudinally uniform distribution of hydrocarbon species (Fletcher et al., 2014) and confirmation that Uranus' sluggish vertical mixing generates different chemical distributions compared to Neptune's enhanced activity (Moses et al., 2018). To date, inferring these ice giant circulation patterns from the limited data available has proven challenging. The entry site for a single descent probe must be carefully selected to minimise ambiguities in the resulting chemical and aerosol measurements, and the environmental conditions of the entry site should be characterised in advance. Sites of strong upwelling could maximise the chances of detecting trace species, but would also lead to a ground-truth that was not necessarily representative. Over the coming decade, upcoming observations from the James Webb Space Telescope (JWST) in the 1-30 μm range will provide significant reconnaissance of the circulation patterns that the probe will eventually encounter, revealing the tropospheric and stratospheric circulation patterns through sensitive reflectivity and thermal emission observations. We will review the key atmospheric observables for the carrier and probe (dynamics, meteorology, clouds, and chemistry), as discussed in Mousis et al. (2017).

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