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Jupiter's thermal and moist convection: impacts of torsional oscillations on cloud activity

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Grand-based visible/infrared observations over many decades revealed Jupiter's weather layer exhibits quasi-periodic cycles of several years [e.g., 1, 2]. We recently proposed that the cloud-level variability could arise from the gas giant's internal dynamics, i.e., thermal modulations induced by torsional Alfvén waves, or torsional oscillations in the metallic hydrogen region [3], which is believed to host the global dynamo action of the planet. The excitation of the axisymmetric, rotation-controlled MHD waves [4,5] has recently been discussed in terms of NASA Juno's magnetic measurement too [6]. All this opens up novel questions: how indeed the deep internal dynamics couple with the near-surface and/or meteorological activity? This contrasts with a terrestrial planet like our Earth, in which the two dynamics are essentially disconnect by the presence of the rocky mantle.

To explore the coupling mechanisms, and in particularly whether/how torsional oscillations in the interior can impact the cloud activity, we perform two types of simple numerical simulations: (i) Rayleigh-Bénard thermal convection modulated by oscillating shear as a model for the outer envelope beneath the weather layer, and (ii) moist convection for simulating the tropospheric dynamics beneath the stratosphere. In the latter, the microphysics of three major cloud components on the gas giant, H_2O, NH_3, and NH_4SH, are taken into account [8,9].

We first confirm that temporally-modulating zonal flows at the bottom can influence thermal convection to yield oscillatory heat flux out from the layer, doubling the period; effects of the planet's rotation may hinder such a simple interpretation. We find that a few percent change in temperature of the deep atmosphere can influence cumulonimbus cloud activity on timescales of days to months, as depicted in Figure 1, and potentially give rise to their several-year changes in opacity. Here the thermal conditions at deep atmosphere crucially set the H_2O condensation, precipitation, and re-evaporation, and consequently its up-/down- drafts induce processes of H_2S/NH_4SH and NH_3; their responses are not very straightforward. This suggests the variability observed by visible/infrared measurements could indeed be triggered by torsional oscillations in the interior. Our results exemplify a role of the deep interior dynamics in ruling the near-surface weather layer dynamics in a gaseous planet.

References

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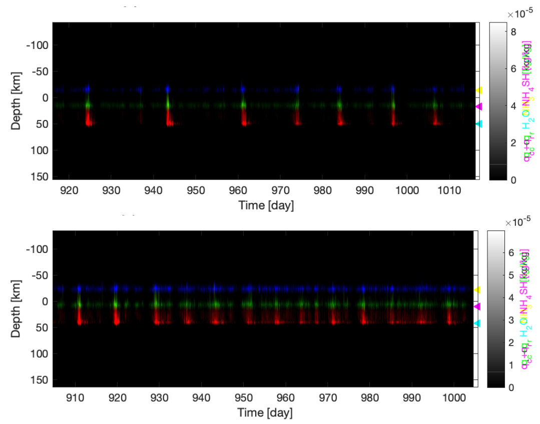

Figure 1. Time evolution of horizontally averaged mixing ratios of condensates when temperature of the deep atmosphere is by 3% lower (top panel) and higher (bottom), compared with a reference state. In both panels H_2O, NH_4SH, and NH_3 condensates are represented in red, green, and blue, respectively.