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Global Climate Modeling of Saturn's Troposphere and Comparative Analysis with Cassini Observations

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Context The Cassini mission unveiled the intense and diverse activity in Saturn's troposphere and stratosphere: banded jets[1], eddies and waves[2], vortices[3], equatorial oscillations[4]. To better understand those phenomena, we built a new Global Climate Model [GCM] for Saturn[5,6], named the Saturn DYNAMICO GCM, by combining a radiative-seasonal model[5] tailored for Saturn to a hydrodynamical solver[7] based on a icosahedral grid suitable for massively-parallel architectures. Here we compare Cassini observations to high-resolution multi-annual GCM simulations of Saturn's troposphere and lower stratosphere. The study of Saturn's equatorial oscillations in the upper stratosphere is detailed in Bardet et al. (this conf.).

Thermal structure Our Saturn DYNAMICO GCM produces a satisfactory meridional and vertical thermal structure, and seasonal variability thereof, compared to Cassini CIRS measurements (Figure 1). The radiative-convective transition, between the neutral profile in the bulk of the troposphere and the stable profile in the upper troposphere and lower stratosphere, occurs around $500 - 600$ mbar as is observed[8]. The thermal signatures in equilibrium with jets (thermal wind $\partial\overline{T}/\partial y \leftrightarrow \partial\overline{u}/\partial z$) are of similar amplitude between modeling and observations, although the localization (i.e. latitude) of those thermal signatures is not compliant between models and observations, echoing the discrepancies in latitude between the observed and modeled jet structures.

Equatorial waves Fourier analysis on the temperature field simulated by our Saturn GCM at the tropopause is shown in Figure 2. Spectral mapping enables to evidence Rossby and Kelvin waves in the symmetric component accross the equator (and Yanai Rossby-gravity waves in the antisymmetric component, not shown). The Rossby wavenumber-2 signal in the tropics and mid-latitudes of Saturn's tropopause (130 mbar) detected by Voyager[10] is present in our our Saturn GCM DYNAMICO simulations. Our GCM results also indicate that other tropical Rossby modes (wavenumbers 3, 4, 5, . . .) are likely to be significant

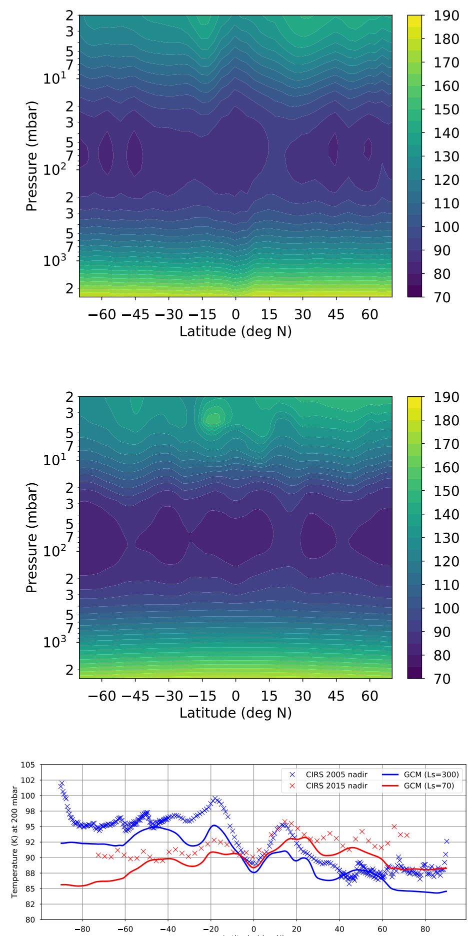

Figure 1: *Latitude-pressure section of zonal-mean temperature $\overline{T}$ [top] from Cassini/CIRS 2015 nadir retrievals[9] vs. [middle] from our Saturn DYNAMICO GCM in the 10th simulated year, $L_s \sim 70°$. [Bottom] Meridional profiles of upper-troposphere $\overline{T}$ at two opposite solstices, Cassini (crosses, CIRS nadir[8,9]) vs. GCM simulations (lines).*

within Saturn's tropics. This is compliant with Cassini CIRS observations[4] which show a complex structure at a pressure level of 150 mbar. The presence of both eastward and westward vertically-propagating equatorial waves in our Saturn DYNAMICO GCM simulations is crucial to explain equatorial oscillations.

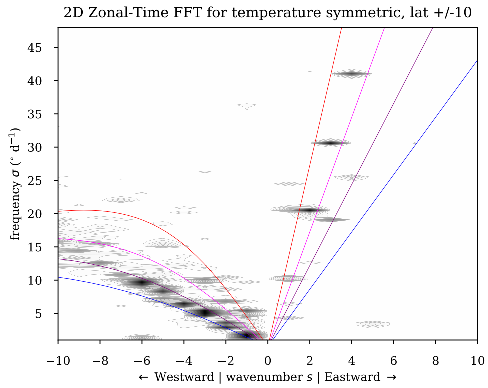

Figure 2: *Spectral analysis of the equatorial waves produced in our Saturn DYNAMICO GCM (in dynamical steady-state). The dispersion relations for equatorial waves are superimposed as colored lines.*

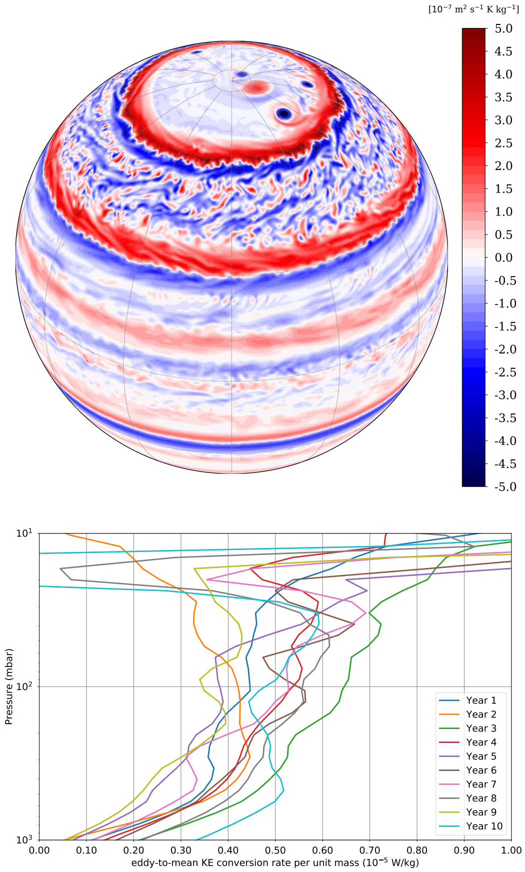

Figure 3: *[Top] View of simulated tropospheric jets, eddies and vortices by potential vorticity mapping. [Bottom] Rate per unit mass $\mathcal{C}$ in m^2 s^{-3} (or W kg^{-1}) estimating the conversion of eddy kinetic energy to zonal-mean kinetic energy. Vertical profiles of $\mathcal{C}$ are shown, anually-averaged and globally-averaged (60°S to N latitudes).*

Eddy forcing of jets Cloud tracking with Cassini ISS permits to calculate the conversion $\mathcal{C}$ per unit mass of eddy kinetic energy to zonal-mean kinetic energy[2]. The positive conversion rates $\mathcal{C}$ simulated by our Saturn DYNAMICO GCM (Figure 3) indicate that our model supports the conclusion that Saturn's zonal banded jets are, for a significant part, driven and maintained by eddies in the weather layer. Our model predicts $\mathcal{C} \sim 0.5 \times 10^{-5}$ m^2 s^{-3} at the tropopause, an order-of-magnitude match to the Cassini values, implying a typical timescale of replenishing the jets of less than a Saturn year. Nevertheless, the conversion rate $\mathcal{C}$ increases with altitude in our GCM simulation contrary to the Cassini observations. This probably indicates a lack of tropospheric eddy forcing e.g. latent heat release and convective motions associated with moist processes[11] in the current version of our GCM.

Perspectives Those results strengthen our Saturn DYNAMICO GCM as a useful tool to study Saturn's tropospheric circulations. Challenges remain to reproduce Saturn's powerful superrotating jet and hexagon-shaped circumpolar jet in the troposphere[6]. Our Saturn GCM is only a first step towards a GCM system able to simulate all giant planet environnements.

Bibliography

[1] F. M. Flasar, et al. Temperatures, Winds, and Composition in the Saturnian System. *Science*, 307:1247–1251, 2005.

[2] A. D. Del Genio and J. M. Barbara. Constraints on Saturn's tropospheric general circulation from Cassini ISS images. *Icarus*, 219:689–700, 2012.

[3] Harold Justin Trammell, et al. Vortices in saturn's northern hemisphere (2008–2015) observed by cassini iss. *Journal of Geophysical Research: Planets*, 121(9):1814–1826, 2016. 2016JE005122.

[4] S. Guerlet, et al. Equatorial Oscillation and Planetary Wave Activity in Saturn's Stratosphere Through the Cassini Epoch. *Journal of Geophysical Research (Planets)*, 123:246–261, 2018.

[5] S. Guerlet, et al. Global climate modeling of Saturn's atmosphere. Part I: Evaluation of the radiative transfer model. *Icarus*, 238:110–124, 2014.

[6] A. Spiga, et al. Global climate modeling of Saturn's atmosphere. Part II: multi-annual high-resolution dynamical simulations. *arXiv e-prints*, 2018.

[7] T. Dubos, et al. Dynamico-1.0, an icosahedral hydrostatic dynamical core designed for consistency and versatility. *Geoscientific Model Development*, 8(10):3131–3150, 2015.

[8] L. N. Fletcher, et al. Characterising Saturn's vertical temperature structure from Cassini/CIRS. *Icarus*, 189:457–478, 2007.

[9] S. Guerlet, et al. Saturn's stratospheric temperature and composition in 2015 from Cassini/CIRS limb observations. In *AAS/Division for Planetary Sciences Meeting Abstracts #47*, volume 47 of *AAS/Division for Planetary Sciences Meeting Abstracts*, page 311.17. 2015.

[10] R. K. Achterberg and F. M. Flasar. Planetary-Scale Thermal Waves in Saturn's Upper Troposphere. *Icarus*, 119:350–369, 1996.

[11] Y. Lian and A. P. Showman. Generation of equatorial jets by large-scale latent heating on the giant planets. *Icarus*, 207:373–393, 2010.