JUMP – Data collection.

Part I: Jets from a Global Climate Model

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Contents

We present data sets used in the paper Cabanes et al. (2020). Using the present data one can recompute the full statistical analysis with our open source numerical codes published on GitHub at: `https://github.com/scabanes/POST`

We use a high performance Global Climate Models (GCMs) to model the atmospheric circulation of gas giants with appropriate physical parametrizations for Saturn's atmosphere. The high-resolution model is named DYNAMICO and solves for 3D primitive equations of motion. We ran a Saturn simulation covering 15 Saturn years using the Saturn DYNAMICO GCM. Wind fields are output every 20 Saturn days at 32 pressure levels onto 1/2° latitude-longitude grid maps. Details on this Saturn reference simulation are given in Spiga et al. (2020). In addition, to diagnose the relevant 3D dynamical mechanisms in Saturn's turbulent atmosphere, we run a set of four simulations using an idealized version of our Global Climate Model devoid of radiative transfer, with a well-defined Taylor-Green forcing and over several rotation rates (4, 1, 0.5, and 0.25 times Saturn's rotation rate). Here, we present the open access data sets that are related to Cabanes et al. (2020).

1 Saturn Reference Simulation (SRS)

We deliver files to compute the full statistical analysis of our Saturn reference simulation. The data file contain latitude-longitude velocity maps and meridional cross sections from our Saturn reference simulation as shown in Fig. 1 and 2.

The velocity file:

uvData-SRS-istep-312000-nstep-50-niz-12.nc: is a netcdf file containing velocity fields for 12 pressure levels corresponding to the altitudes 34.9, 58.3, 82.3, 94.3, 106.3, 130.3, 154.3, 166.3, 178.3, 202.3, 226.3, 250.3 km, (with 0 km at the 3-bar level, which is the bottom of the model) and for 50 time steps between the simulated 12.7 and 12.84 Saturn years.

The file contain the following variables in m.s^{-1}:

- We note **u** and **v** the zonal and meridional velocity components respectively. The horizontal velocity fields are projected on a latitudinal-longitudinal grid. Grid space is of 0.5° and range in latitude from -89.75° to 89.75° and in longitude from 0.25° to 359.75°. Examples of horizontal maps are shown Fig. 1.
- We note **u_SMerid** and **v_SMerid** the zonal and meriodional velocity components sampled in a meridional cross section. The meridional cross section is at longitude 0.25° on known on 32 pressure levels from altitudes 0 to 375 km (with 0 km the bottom of the model). Examples of meridional cross sections are shown Fig. 2.
- the vector "dsteps" contains all time steps, with dsteps/24430 gives time in Saturn's year.

Statistical analysis files on GitHub:

Statistical analysis:

From file uvData-SRS-istep-312000-nstep-50-niz-12.nc on can compute the full statistical analysis using the Fortran 90 code statistical_analysis_JupObs_xyzt.f90 available on GitHub at `https://github.com/scabanes/POST`.

One has to set the appropriate parameters, excluding Taylor-Green Forcing ($Amp = 0$, $kf = 0$ and TGforcage = 0), and make compilation of statistical_analysis_JupObs_xyzt.f90, with:

```
real*8 :: Amp = 0., kf=0., ptimestep= 3805.2, radius = 58232000,
omega = 0.000165121, H = 375000
...
integer :: TGforcage = 0, NetcdefStatData=1, SavePhysicalFields=1,
SavePV=1, SaveSPA=1
```

When running statistical_analysis_JupObs_xyzt.f90, it results an output file StatisticalData.nc (an example of this file is given but can easily be recomputed) which contains the full statistical analysis described in Cabanes et al. (2020). This statisitcal analysis can be shown using the plots library that requires files filePTS.zono.temp, see below.

Plot library, parameters to set:

filePTS.zono.temp: contains information of the Saturn reference simulation and is required to use the plots library. The following variables need to be appropriately set for our Saturn reference simulation:

- omega_sat = 0.000165121 The planetary rotation rate in s^{-1}.
- R_sat = 58232000 planetary radius in m
- SatDay_s = 38052 Planetary day length in second
- Ck = 6 Kolmogorov constant of $ER(n) = C_k$ epsilon$^{2/3} n^{-5/3}$; $[Ck]$ = non-dim
- epsilon = 0.0000013 Energy transfer rate [epsilon] = m^2/s^3
- Cz = 0.2 Zonal constant of $EZ(n) = C_z \beta^2 n^{-5}$; [Cz] = non-dim
- H-atm = 59000 Planetary atmospheric height. $[H] = m$
- N = 0.01 Mean Brunt-Väisälä frequency. $[N] = s^{-1}$
- epsilon_f = 0.0000013 Energy transfer rate $<< f.u >_s >_T$ en m^2.s−3
- n_f = 0. unused
- tau_f = 0. Numerical time for physical package iteration. Don't have to be changed
- epsilon_i = 0.0000013 Energy transfer rate $<< f.u >_s >_T$ en m^2.s^{-3}

Note that all Energy transfer rate have to be at the same value.

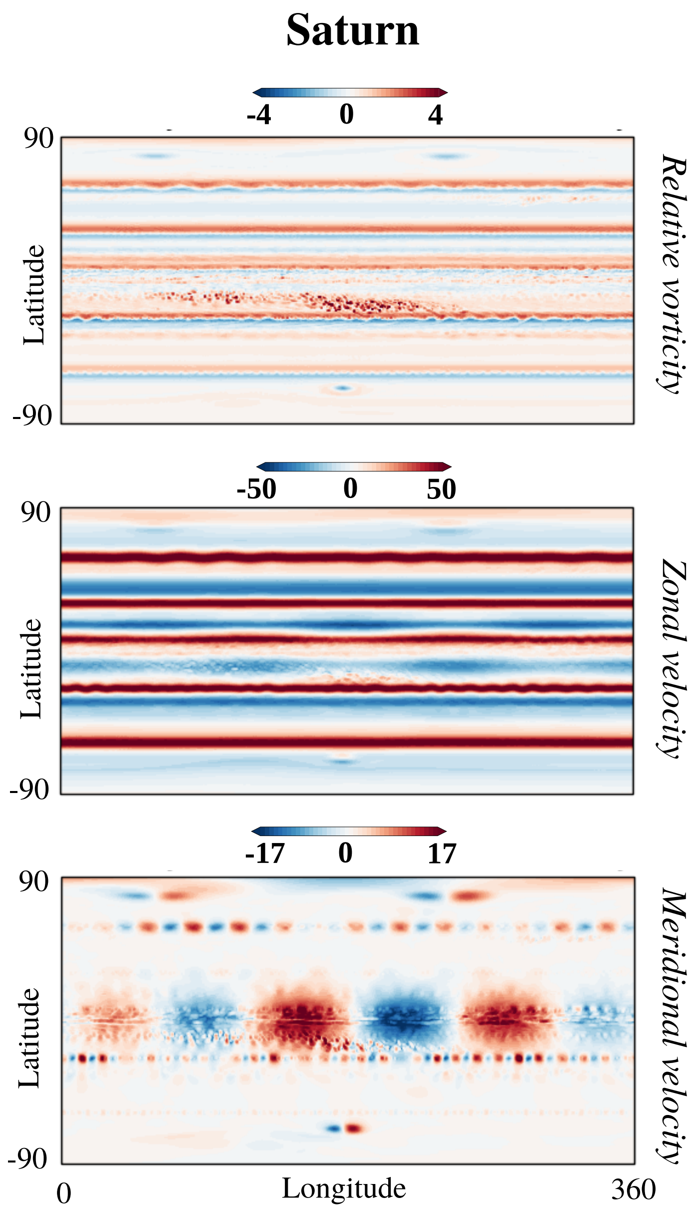

Fig. 1: **Saturn GCM fields. Top to bottom, relative vorticity is $\times 10^{-5}$ s^{-1}, zonal velocity and meridional velocities are in m s^{-1}.**

2 Idealized simulations

We deliver files to compute the full statistical analysis of our four simulations using the idealized version of our Global circulation model, see Cabanes et al. (2020). The data file contain latitude-longitude velocity maps as shown in Fig. 3 and meridional cross sections (not shown).

The velocity files:

uvData-Omega-X$_1$-istep-21026.0-nstep-20-niz-8.nc: is a netcdf file containing velocity fields for 8 pressure levels corresponding to the altitudes 46.3, 58.3, 70.3, 82.3, 94.3, 106.3, 118.3, 130.3 km, (with 0 km at the 3-bar level, which is the bottom of the model) and for 20 time steps after one simulated Saturn year. The value of X_1 is the rotation rate of the simulation, $X_1 = 4, 1, 0.5, 0.25$ with $X_1 = 1$ being the Saturn reference rotation rate.

The file contain the following variables in m.s^{-1}:

- We note **u** and **v** the zonal and meridional velocity components respectively. The hor-

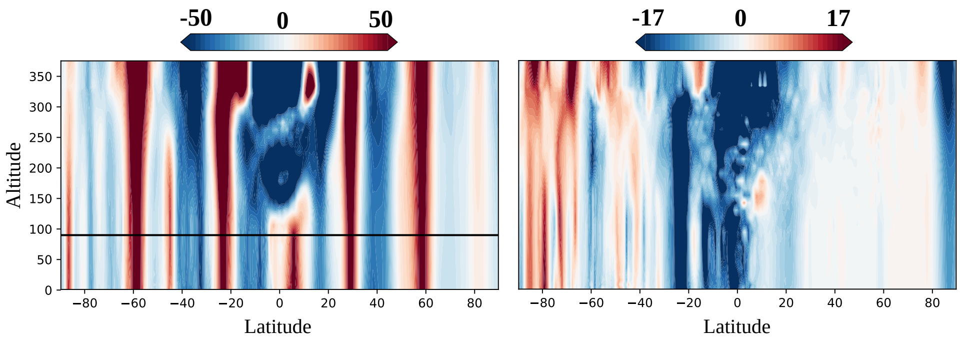

Fig. 2: **Instantaneous (altitude-latitude) meridional cross-section of velocity maps: zonal (left) and meridional (right) velocities ($\mathrm{m\,s^{-1}}$) at longitude $\lambda = 0°$, time $t = 12.5$ (bottom) Saturn years, as a function of latitude and altitude (in km, with 0 km at the 3-bar level, which is the bottom of the model). The solid line corresponds to the level at which horizontal maps are shown.**

izontal velocity fields are projected on a latitudinal-longitudinal grid. Grid space is of 0.5° and range in latitude from -89.75° to 89.75° and in longitude from 0.25° to 359.75°. Examples of horizontal maps are shown Fig. 1.

- We note **u_SMerid** and **v_SMerid** the zonal and meriodional velocity components sampled in a meridional cross section. The meridional cross section is at longitude 0.25° on known on 32 pressure levels from altitudes 0 to 375 km (with 0 km the bottom of the model). Examples of meridional cross sections are shown Fig. 2.
- the vector "dsteps" contains all time steps, with dsteps/24430 gives time in Saturn's year.

Statistical analysis files on GitHub:

Statistical analysis:

From file uvData-Omega-X_1-istep-21026.0-nstep-20-niz-8.nc on can compute the full statistical analysis using the Fortran 90 code statistical_analysis_JupObs_xyzt.f90 available on GitHub at `https://github.com/scabanes/POST`.

One has to set the appropriate parameters, including Taylor-Green Forcing (see below), and make compilation of statistical_analysis_JupObs_xyzt.f90, with:

```
real*8 :: Amp = 0.22, kf=56., ptimestep= 3805.2, radius = 58232000,
omega = 0.000165121, H = 375000
...
integer :: TGforcage = 1, NetcdefStatData=1, SavePhysicalFields=1,
SavePV=1, SaveSPA=1
```

When running statistical_analysis_JupObs_xyzt with the appropriate arguments, it results an output file StatisticalData.nc which contains the full statistical analysis described in Cabanes et al. (2020). This statistical analysis can be shown using the plots library that requires files filePTS.zono.temp, see below.

Plot library, parameters to set:

filePTS.zono.temp: contains information of the idealized simulations and is required to use the plots library. The following variables need to be appropriately set:

- omega_sat = 0.000165121 The planetary rotation rate in s^{-1}.

- R_sat $=58232000$ planetary radius in m
- SatDay_s $=38052$ Planetary day length in second
- Ck $=6$ Kolmogorov constant of $ER(n) = C_k$ epsilon$^{2/3} n^{-5/3}$; $[Ck]$ = non-dim
- epsilon $= 0.3e-06$ Energy transfer rate [epsilon] $=$ m^2/s^3
- Cz $= 0.2$ Zonal constant of $EZ(n) = C_z \beta^2 n^{-5}$; [Cz] $=$ non-dim
- H-atm $= 59000$ Planetary atmospheric height. $[H] = m$
- N $= 0.01$ Mean Brunt-Väisälä frequency. $[N] = s^{-1}$
- epsilon_f $= 0.3e-06$ Energy transfer rate $<< f.u >_s>_T$ en m^2.s-3
- n_f $= 56.$ Injection index of the Taylor-Green forcing
- tau_f $= 3805.2$ Numerical time for physical package iteration. Don't have to be changed
- epsilon_i $= 0.3e-06$ Energy transfer rate $<< f.u >_s>_T$ en m^2.s^{-3}

Note that all Energy transfer rate have to be at the same value.

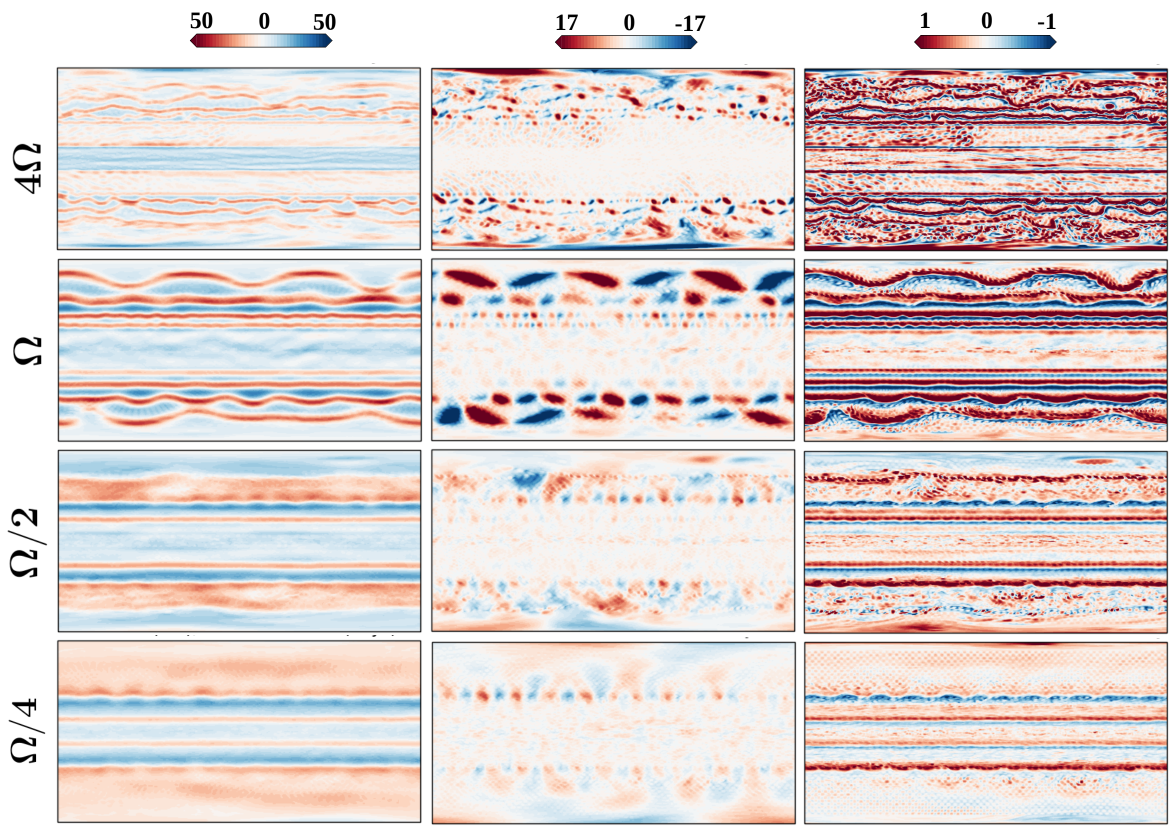

Fig. 3: **Instantaneous (latitude-longitude) velocity and vorticity maps: flow fields are shown for four idealised simulations with varying planetary rotation rate. (Left) zonal velocity (m s^{-1}), (middle) meridional velocity (m s^{-1}), and (right) vorticity (s^{-1}) at tropospheric depth 94.28 km above 3 bar.**

References

Cabanes, S., Aymeric, S., and Roland, M., B. Y. (2020). Global climate modeling of saturn's atmosphere. part iii: Global statistical picture of zonostrophic turbulence in high-resolution 3d-turbulent simulations. *Accepted to Icarus with minor revision, arXiv:2001.02473.*

Spiga, A., Guerlet, S., Millour, E., Indurain, M., Meurdesoif, Y., Cabanes, S., Dubos, T., Leconte, J., Boissinot, A., Lebonnois, S., et al. (2020). Global climate modeling of saturn's atmosphere. part ii: Multi-annual high-resolution dynamical simulations. *Icarus*, 335:113377.