Jet Regimes Induced by Stratification Changes in a Dry Dynamical Core Model

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Model Setup and Convective Adjustment

- Held-Suarez setup: radiation $\sim \frac{(T-T_{equ})}{\tau}$, T_{equ} is statically stable
- Our setup ($\sim$ Schneider & Walker 2006):
  - T_{equ} is convectively unstable
  - convective adjustment based on vertical heat exchange
  - lapse rate $\sim \gamma \cdot \Gamma$, $\gamma = [0,5,1]$, Γ = dry adiabatic lapse rate
- MESSy submodel EMIL (Garny et al. 2020)

Varying tropospheric lapse rates produces two circulation regimes: separated vs. joined subtropical and eddy-driven jets.

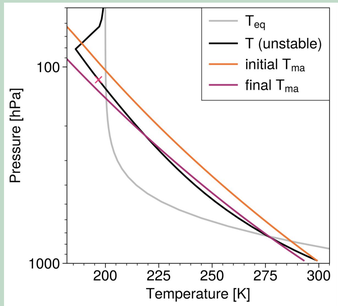

Fig. 1: Exemplary ambient tropical temperature profile (black), T_{equ} (gray), and moist adiabats (colored).

Separated vs. Joined Jet Regimes

Statistically steady simulations with different γ develop two types of regimes:

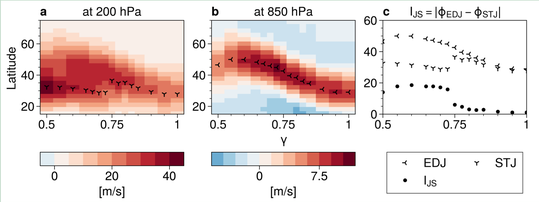

Fig. 2: Zonal mean zonal wind as a function of latitude and γ in the upper and lower troposphere.

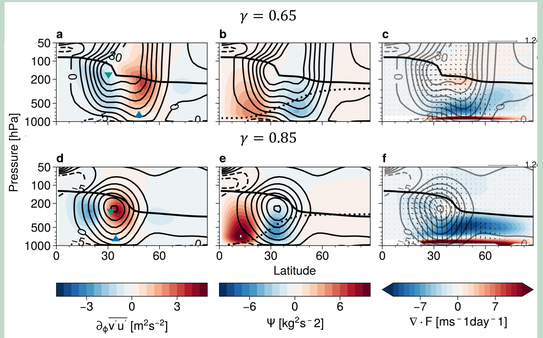

Fig. 3: Zonal mean climatologies for two exemplary simulations. The zonal mean zonal wind is overlaid as contours in all plots. The subtropical (green triangle) and the eddy-driven (blue) jet lie close together (a,b,c) or are clearly separated (d,e,f).

The two regimes have very different Rossby wave structures:

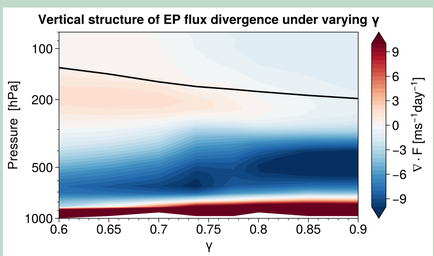

Fig. 4: EP flux divergence averaged over 40° to 60° latitude as a function of pressure and γ. The thermal tropopause is overlaid as black contour.

The upper atmospheric EP flux div. is most sensitive to changes in the convective lapse rate.

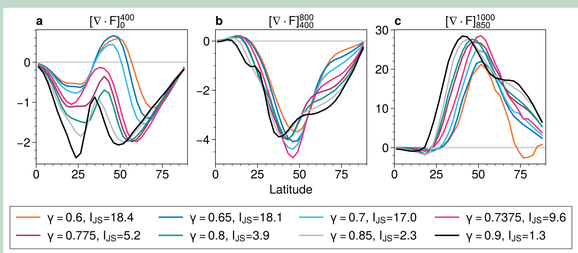

Fig. 5: EP flux divergence averaged over different pressure ranges. (c) is smoothed with a 5-point running mean. I_{JS} values are given in degree latitude.

References

- Garny, H., Walz, R., Nützel, M., & Birner, T. (2020). Extending the Modular Earth Submodel System (MESSy v2.54) model hierarchy: The ECHAM/MESSy IdeaLized (EMIL) model setup. Geoscientific Model Development
- T. Schneider, & Walker, C. C. (2006). Self-Organization of Atmospheric Macroturbulence into Critical States of Weak Nonlinear Eddy–Eddy Interactions. Journal of the Atmospheric Sciences

Forced Regime Transitions

Restart equilibrated run with different convective lapse rate γ.

$\gamma = 0.9 \rightarrow 0.6$

- stability increases
- wave activity suppressed
- slow adjustment to separated regime controlled by damping time scale

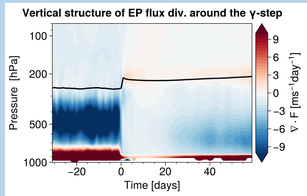

Fig. 6: EP flux divergence averaged over 40° to 60° latitude before and after the transition date. Composite over γ=0.9 → 0.6.

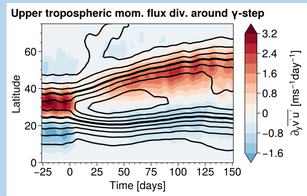

Fig. 7: Momentum flux convergence as shading overlaid with the zonal mean zonal wind as contours. Composite over γ=0.9 → 0.6.

$\gamma = 0.9 \rightarrow 0.6$

- stability decreases
- wave activity unleashed
- adjustment to new regime shows strong internal wave-mean flow fluctuations

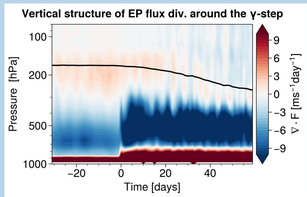

Fig. 8: Same as Fig. 6, but for γ=0.6 → 0.9.

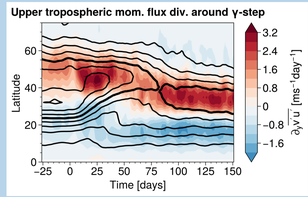

Fig. 9: Same as Fig. 7, but for γ=0.6 → 0.9.

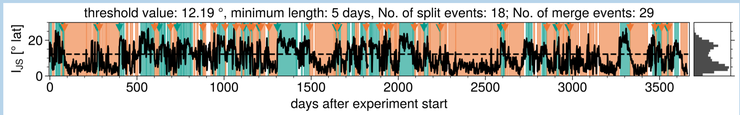

Fig. 10: Jet separation index over simulation time highlighting the regime changes used in the composite analysis in this box.

Internal Variability

- simulations near the regime threshold ($\gamma = 0.73$) feature transitions between the two regimes
- composites over these merge events show that variations in the EP flux convergence explain regime changes
- momentum flux convergence is the main contributor to this
- it is preceded by heat flux convergence variation
- similar characteristics in split events

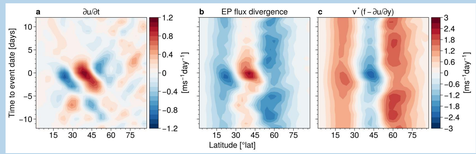

Fig. 11: Not negligible contributions to the zonal momentum balance averaged in pressure from 100 to 400 hPa.

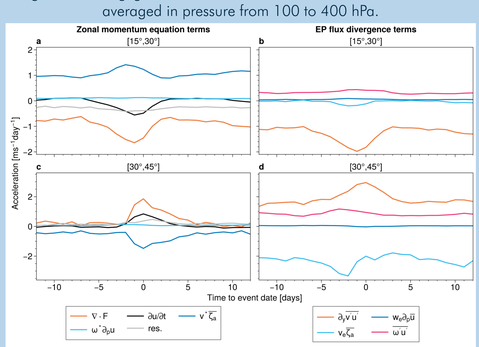

Fig. 12: Contributions to the zonal momentum balance additionally averaged in latitude in the subtropics (a,c) and in mid-latitudes (b,d).