Tropical Climate Responses to Variations in Turbulent Drag

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How Does the Hadley Circulation Respond to Turbulent Drag?

- Turbulent drag in the lower atmosphere may be one important source of uncertainty in our understanding of and the ability to predict changes in the Hadley circulation

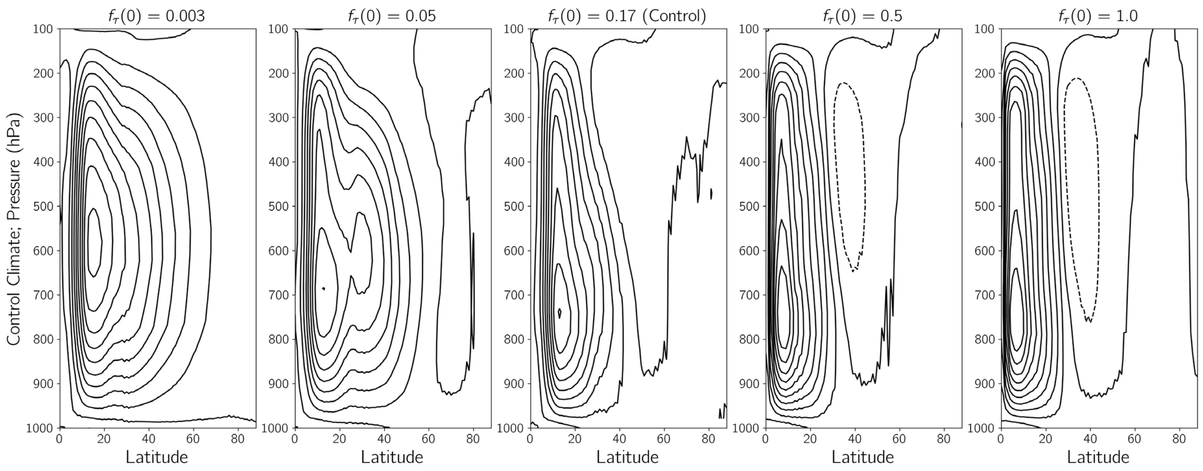

Fig. 1: Hadley circulation as mass stream function for representative drag simulations for the control climate, including the control drag simulation.

Regimes Emerge with Varying Drag

- Position and strength of the Hadley circulation divide into regimes with drag – low drag, transitional drag, and high drag regimes
- Greater drag associated with more equatorward Hadley cell edge, more equatorward ITCZ location, and a stronger, merged jet stream (not shown)
- Larger drag is consistent with position predicted from Held and Hou (1980), and variation of strength with drag also qualitatively consistent with HH1980 prediction

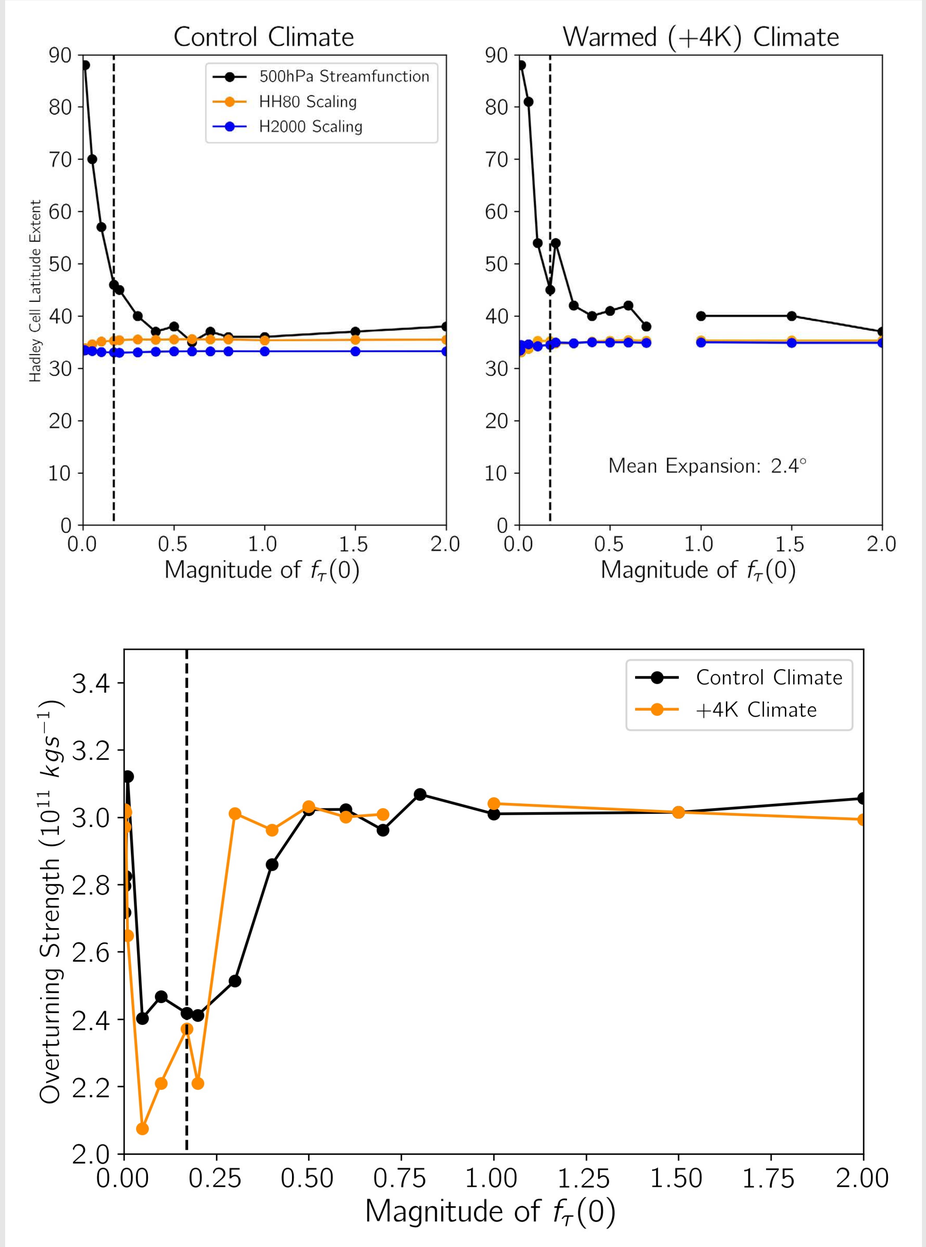

Fig. 2: (Top) Variation of Hadley cell poleward extent with drag for control climate (left) and warmed climate (right). (Bottom) Variation of strength of Hadley cell with drag. Vertical dashed line marks control drag simulation in all panels.

This work is funded by the ERC HighECS project (770765).

ICON Model Aquaplanet Simulations

- Explicit convection
- Qobs SST profile as lower boundary condition
- Hemispheric-, zonal-, and time-means to get climatology
- Turbulent drag varied from very small to very large values through tunable $f_t(0)$ non-dimensional stress parameter

Response Extends to Tropical Precipitation

- ITCZ location, latitudinal precipitation distribution, and how the precipitation distribution changes with warming divided into drag regimes similarly to circulation
- In general, “wet-gets-wetter” mechanism holds with warming though this is most straightforward for high drag

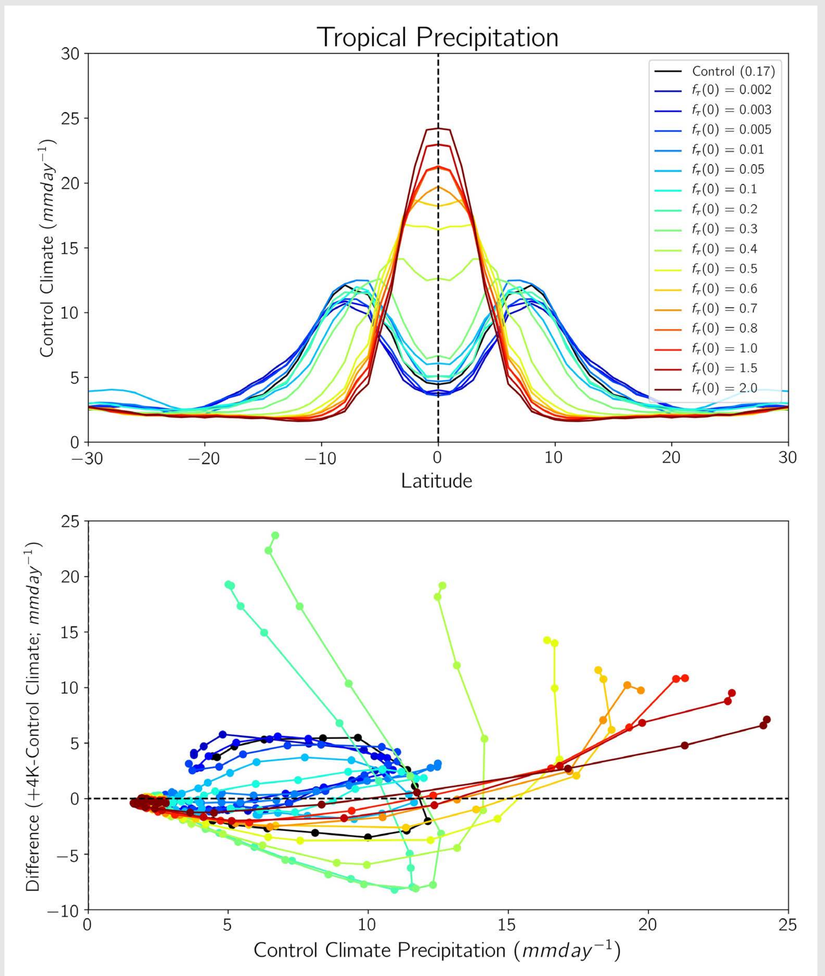

Fig. 3: (Top) Control climate tropical precipitation distribution color coded by drag. (Middle and Bottom) Change in precipitation with warming divided by drag magnitude.

Departure from HH1980 Expectation

- Variation of meridional heat transport with drag is in the opposite sense to that based on expectation
- Reasons remain unclear – due to lack of energetic constraints in HH80?

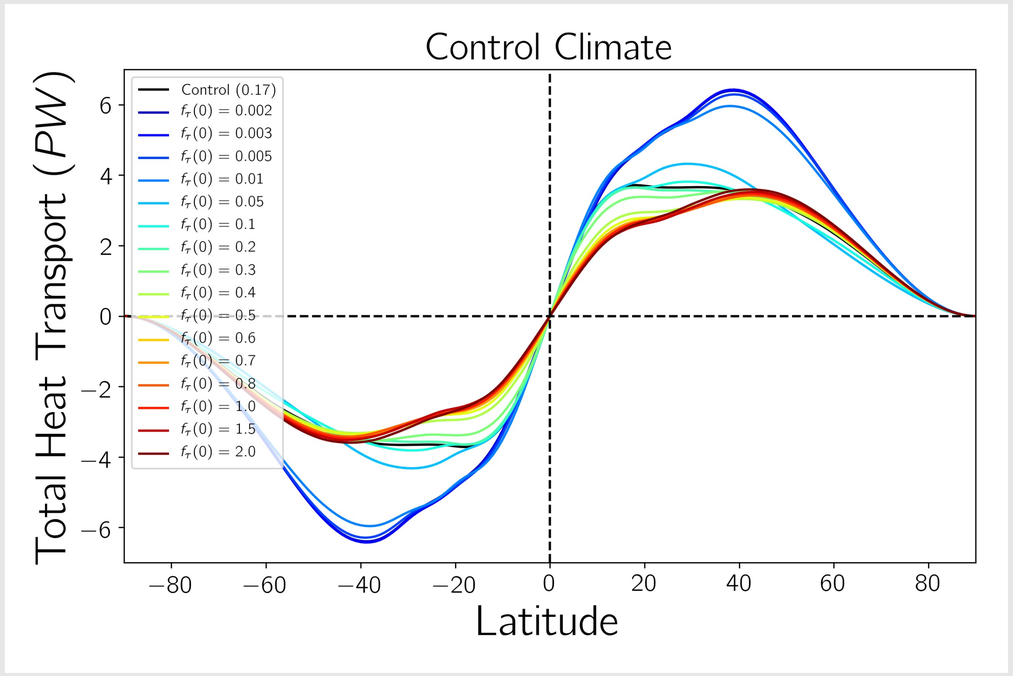

Fig. 4: Total meridional heat transport for the control climate color coded by drag.