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Can an Adapted Betts-Miller Scheme Improve the Representation of Atmospheric Variability?

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Introduction

The parameterisation of moist convection is a necessary task for global circulation models to determine grid scale precipitation. However, there are various aspects of atmospheric variability which are not well represented in the models, which are sensitive to cumulus parameterisation and its tuning.

Of particular interest to this study is the tropical intraseasonal variability, such as the SAM and MJO, and the interactions with global circulation. Our goal is to improve our understanding of atmospheric variability, by breaking down a simple convection scheme, to investigate different fundamental aspects of the scheme separately.

To do this we first decouple the convective relaxation time τ, to form an intermediate scheme, in order to explore changes in enthalpy correction, relative humidity and precipitation.

The adapted moisture tendency equation, which is still under construction, which is sensitive to both the buoyancy and relative humidity of the environment, will be implemented into the simplified Betts-Miller scheme. This scheme has the potential to be more flexible than adjusting to a fixed relative humidity profile, as in the case for the simplified Betts-Miller scheme.

GFDL Aqua–Planet

The GFDL moist aqua-planet model will be used, as this model facilitates our investigation in a simplified environment.

The GFDL moist aqua–planet is a zonally symmetric model employing a slab ocean and with a grey radiation scheme. The model is run at T42 (resolution of $\approx 2.8^\circ \times 2.8^\circ$) with 25 vertical levels and using the SBM convection scheme of Frierson et al. (2007).

The SBM scheme is a convection scheme in the style of the Betts–Miller Scheme (BMS) of Betts (1986), Betts and M. J. Miller (1986), where by T and q fields are relaxed toward reference profiles.

The major difference between the BMS and the SBMS, is the calculation of the reference profiles. Where the moisture profile in the SBMS has a fixed RH_{SBMS} and the temperature profile is based on a virtual pseudoadiabat.

Convection Scheme

The intermediate scheme decouples the relaxation time τ, where τ_T and τ_q are introduced. An adapted scheme is also introduced for the moisture tendency, which is dependent on buoyancy and moisture, where A is a measure of CAPE.

BMS And SBMS

$$\frac{\partial \bar{T}}{\partial t} = -\frac{\bar{T}-T_R}{\tau} \qquad \frac{\partial \bar{q}}{\partial t} = -\frac{\bar{q}-q_R}{\tau}$$

Intermediate Scheme

$$\frac{\partial \bar{T}}{\partial t} = -\frac{\bar{T}-T_R}{\tau_T} \qquad \frac{\partial \bar{q}}{\partial t} = -\frac{\bar{q}-q_R}{\tau_q}$$

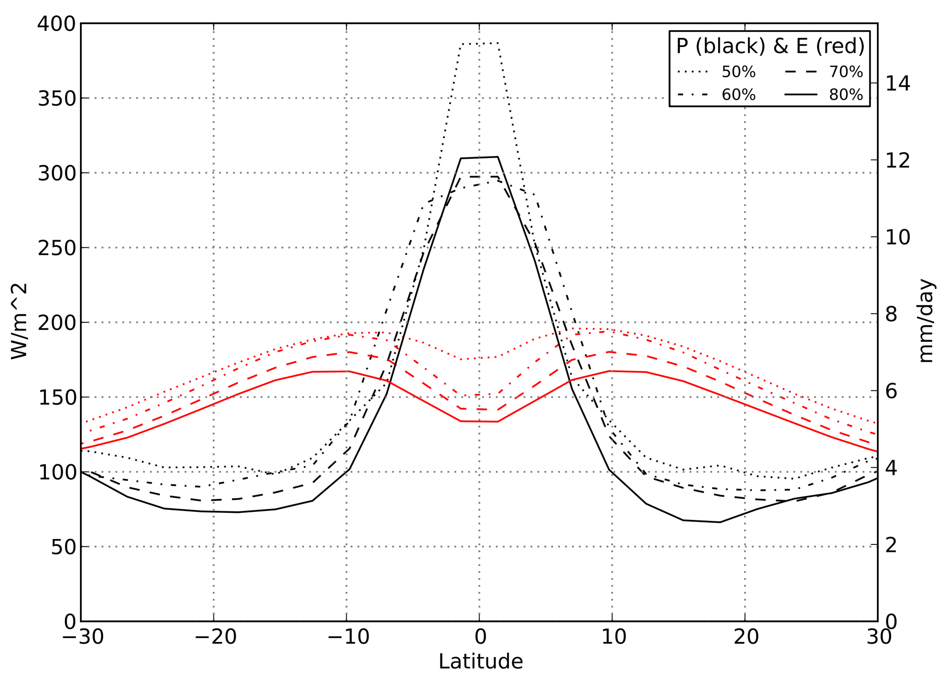
Adapted Scheme

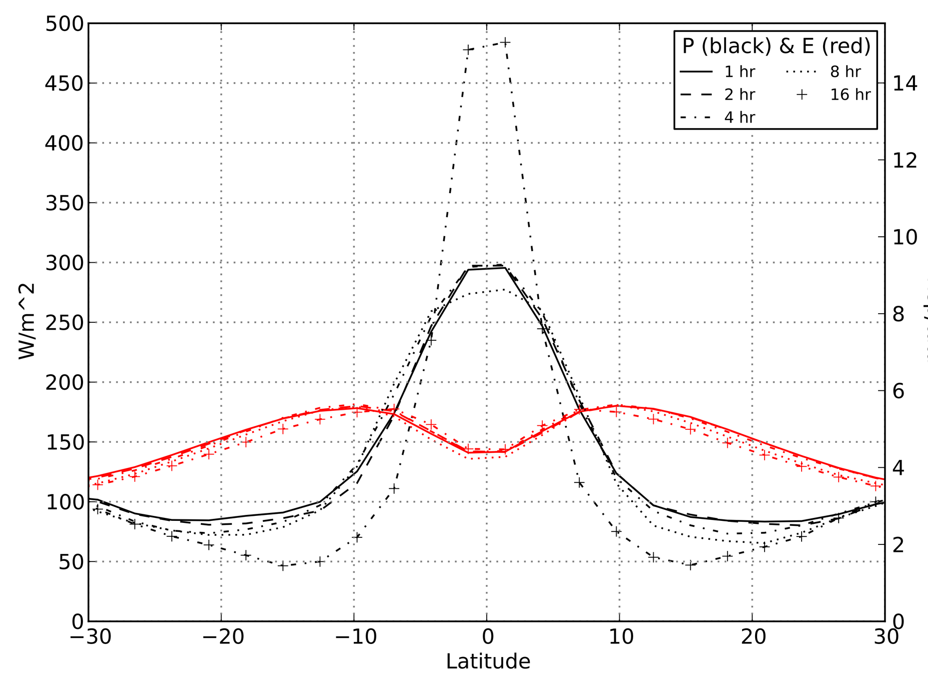
$$\frac{\partial \bar{T}}{\partial t} = -\frac{\bar{T}-T_R}{\tau} \qquad \frac{\partial \bar{q}}{\partial t} = -\frac{A^{\alpha}}{\tau}\frac{q_s^{1+\beta}}{(qs-\bar{q})^{\beta}}$$

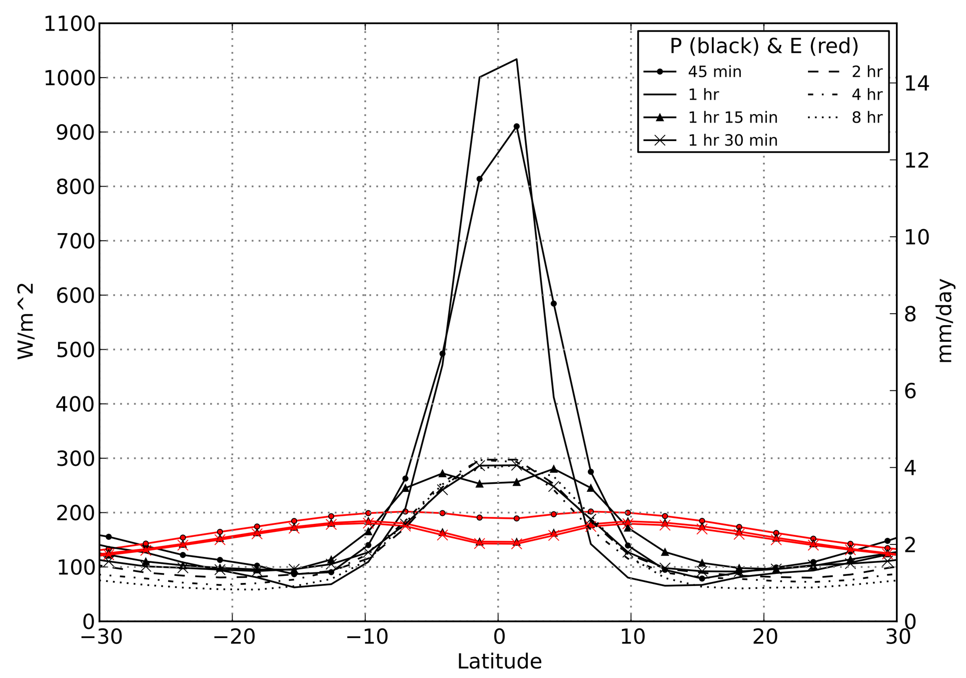
The SBMS scheme is used in the sensitivity testing of RH_{SBMS} and τ. The intermediate scheme is used for the decoupled τ experiments. The adapted scheme is currently under construction.

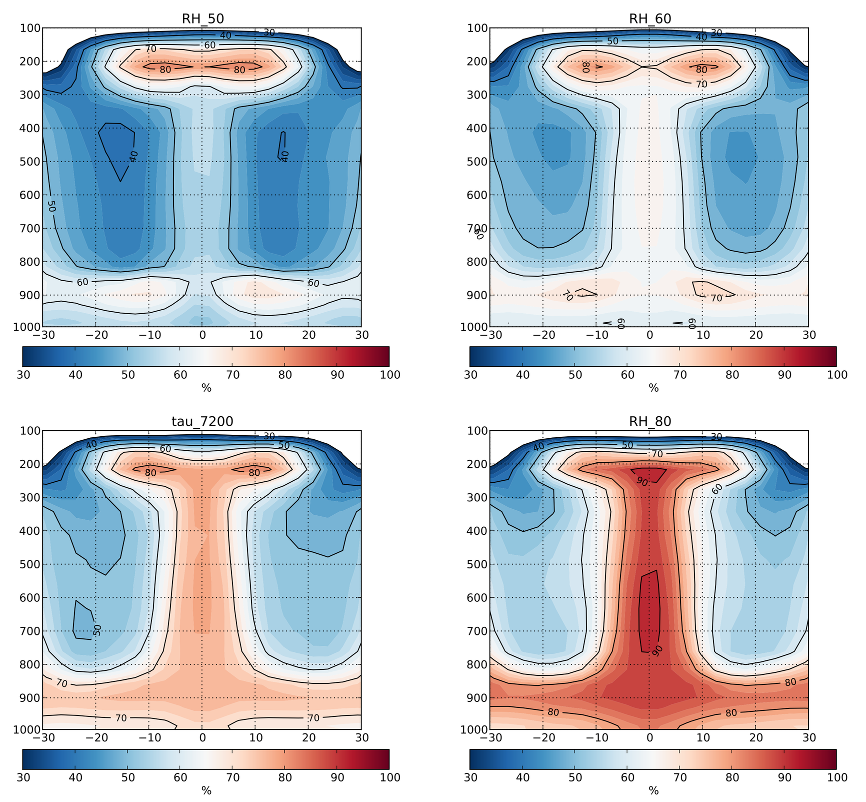
Deep convection in the SBMS operates in either a humidity–controlled or temperature–controlled regime, depending on the stability of the column. Maps in the decoupled τ experiment indicates the behaviour of the scheme.

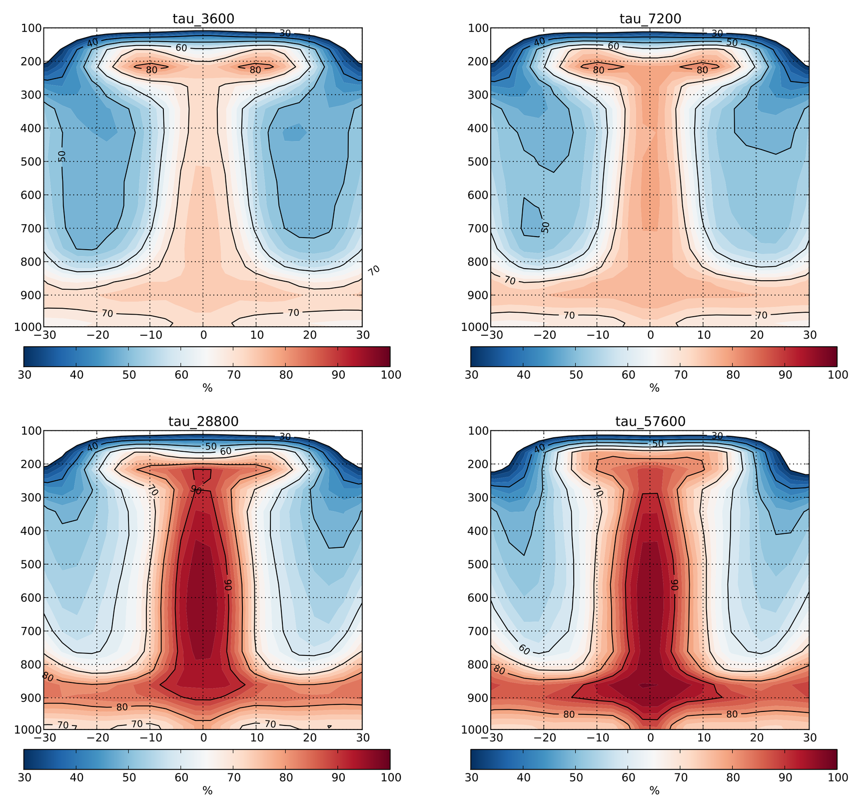
Model Validation and Preliminary Results

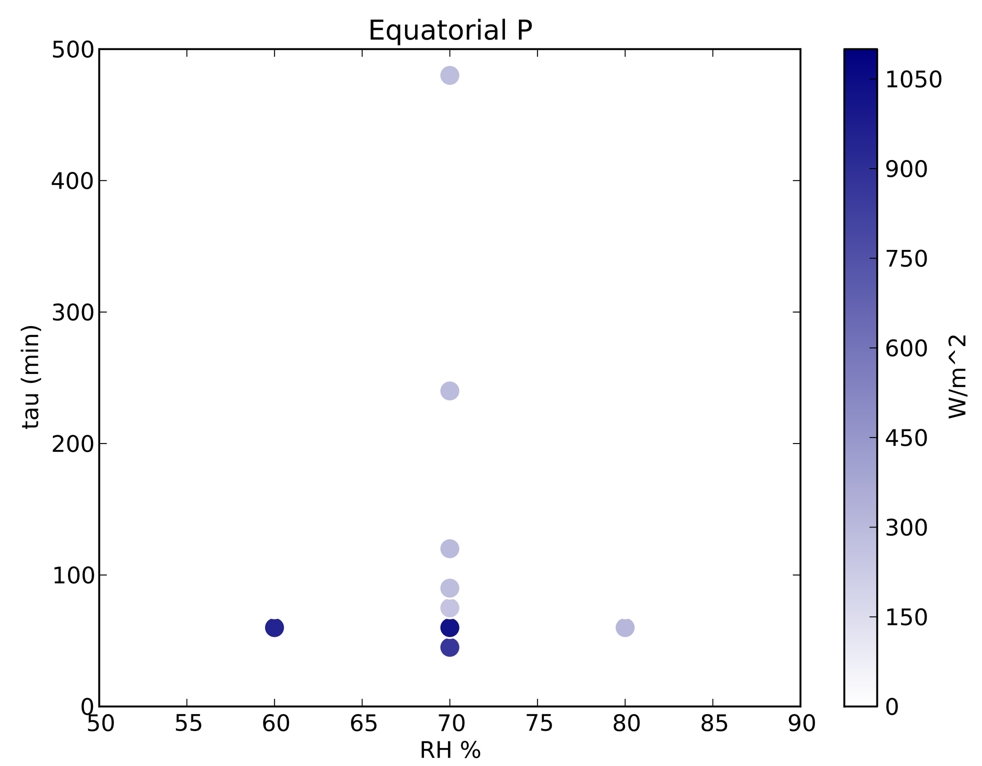


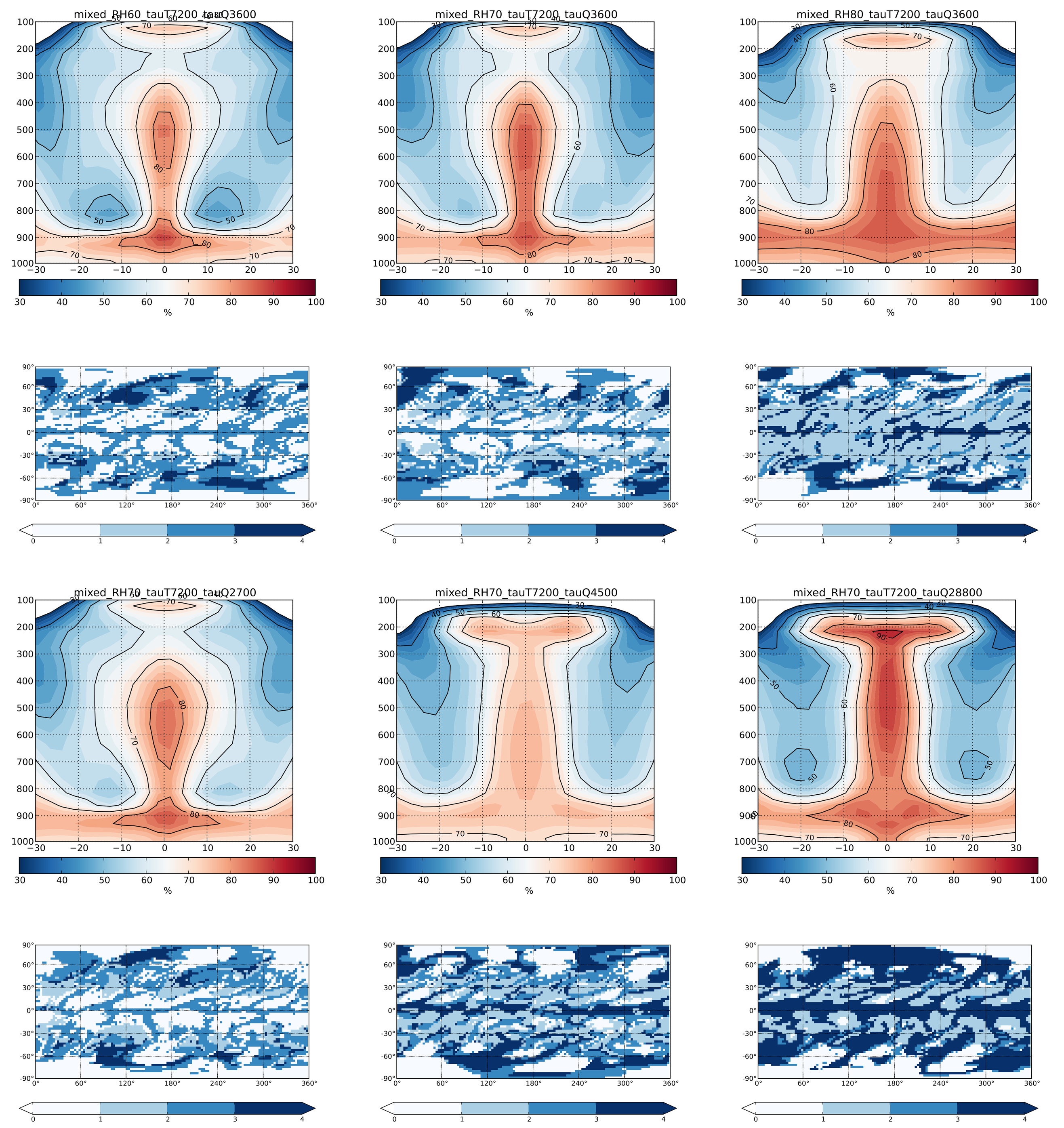


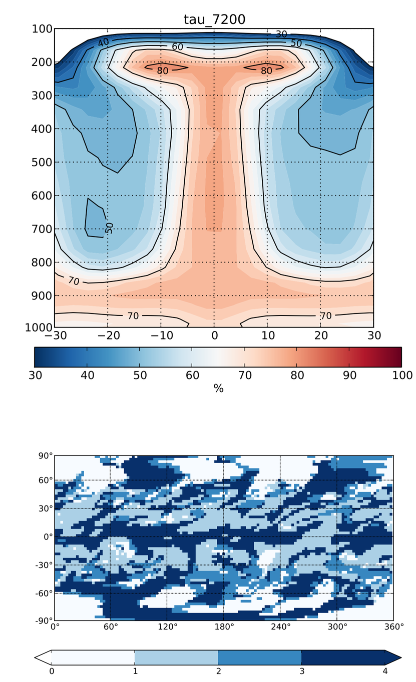












Sensitivity to RH_{SBMS}

- As reported by Frierson et al. 2007 as RH_{SBMS} is increased from 50, 60, 70 and 80% (τ=2hr) the zonal mean RH increases
- The equatorial zonal mean P is smallest for intermediate values, increasing at the lowest and highest RH_{SBMS}

Sensitivity to τ

- As reported by Frierson et al. 2007, as τ is increased from 1 to 2 hours, only minor changes to the zonal mean RH field are found (RH_{SBMS}=70%)
- τ needs to be lengthened to 8 hours before the zonal mean equatorial RH changes occur
- For τ=16 hours equatorial RH and P increase significantly

Decoupled τ

- RH_{SBMS} = 70%, τ_T=2hr and τ_q is varied from 45 mins up to 8 hours
- For small τ_q (45 mins and 1 hour), a large increase in P is observed, with only small increase in E
- This behaviour is also seen at 60% RH_{SBMS} but not at 80%

Sensitivity for decoupled τ

- Top: Zonal mean RH for τ_q=1 hour and RH_{SBMS} = 60, 70, 80%
- Second: Enthalpy correction, no convection (0), shallow (1), deep – q adjusted (2) and deep – T adjusted (3) for RH_{SBMS} = 60, 70, 80%
- Third: Zonal mean RH for RH_{SBMS} = 70%, with τ_q of 45 mins, 1 hr 15 mins and 8 hr
- Bottom: As in second but for τ_q of 45 mins, 1 hr 15 mins and 8 hr

Control

- RH = 70 %, τ_T = τ_q = 2hr con comparison to sensitivity for decoupled τ plots

Preliminary Conclusions

Decoupled τ experiments show:

- Short τ with intermediate RH_{SBMS} appear to increase the strength of the Hadley cell (work in progress), greatly reducing moisture content in the upper troposphere and shrinking the ITCZ
- There is a large increase in P at the equator, reduction in subtropical P and only minor changes to E
- For short τ_q the scheme is moisture–controlled, where for longer τ_q the scheme is temperature–controlled

Future Work

- Further investigation into why the scheme is over active for $RH_{SBMS} \leq 70\%$ and $\tau \leq$ 1hr
- Implement τ_q as a function of moisture where $\tau_q = \tau_T(1-RH)$ or similar
- Assess how changes to τ effect the strength and position of the subtropical jetstream, identify changes to the SAM and 'MJO like' signal
- Implement adapted scheme, as described in the convection scheme above

References

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