Dynamical Environments of Organised Deep Convection in Climate Models

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Introduction

Organised deep convection is a critical process in the climate system, providing half the rainfall in the tropics and often producing intense precipitation. As convection cannot be resolved in global climate models (GCMs), it has to be represented through parametrisation schemes, which do not explicitly account for convective organisation. Nonetheless, GCMs still produce high-topped and optically thick clouds, which in observation are a signature of organised deep convection. **Does the presence of these clouds imply that GCMs can represent organised deep convection?** To investigate this, we compare the precipitation rates and grid-mean vertical motion of these clouds between observation and GCMs.

Observation

- cloud regimes are an objective categorisation of ISCCP cloud fields at **2.5° daily** (Jakob and Tselioudis, 2003; Rossow et al., 2005)
- one regime, **CR1**, represents organised deep convection (Fig. 1)
- composite CR1 with **daily precipitation rates** (P) from GPCP and **grid-mean vertical motion** (ω) at **850 hPa**, **500 hPa** and **200 hPa** from ERA-Interim (similar to Tan et al., 2013)
- restrict to ocean-only grid boxes between 35°N/S and from 2004 to 2008

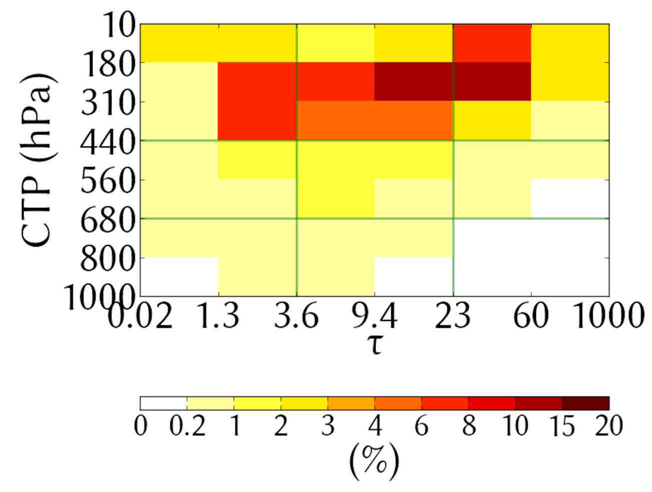


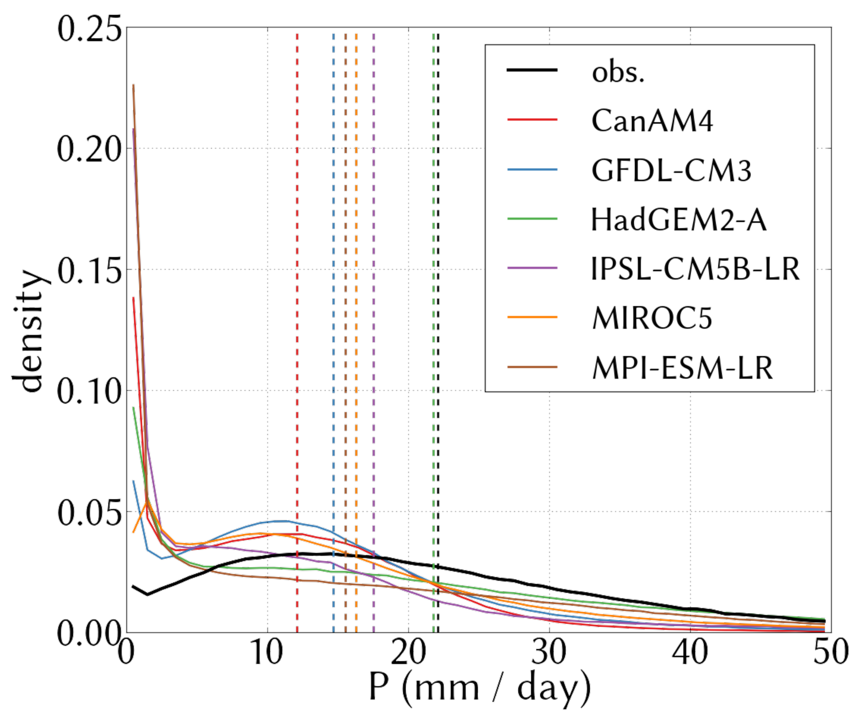
Fig. 1: Joint-histogram of the CR1 regime, which in observation represents organised deep convection.

Models

- use AMIP experiments in the CMIP5 database with the following variables:
  - **clisccp**: ISCCP cloud area fraction
  - **pr**: precipitation at surface
  - **wap**: omega
- GCMs: CanAM4, GFDL-CM3, HadGEM2-A, IPSL-CM5B-LR, MIROC5, and MPI-ESM-LR
- model regimes are defined following Williams and Webb (2008): assign clisccp cloud fields to observed regimes based on **mean albedo**, **mean cloud top pressure** and **total cloud cover**
- composite model CR1 with model variables similar to observation

Precipitation and Dynamics

- Fig. 2 shows the distributions of P and ω of CR1 in observation and in models
- all models **underestimate the mean daily precipitation rates** P of CR1 and **produce too much light rain** ($P < 5$ mm / day)
- all models except HadGEM2-A **do not produce enough heavy rain** ($P > 40$ mm / day)
- all models **overestimate ascending motion at 200 hPa**, predicting too negative an ω
- all models except CanAM4 **overestimate ascending motion at 500 hPa**
- majority of the models overestimate ascending motion at 850 hPa
- HadGEM2-A, best at reproducing observed P of CR1, overpredicts ascending motion at 850 hPa the most and at 500 hPa and 200 hPa second most
- CanAM4, worst at reproducing observed P of CR1, is closest to observed ω at 200 hPa and underpredicts ascending motion at 500 hPa and 850 hPa



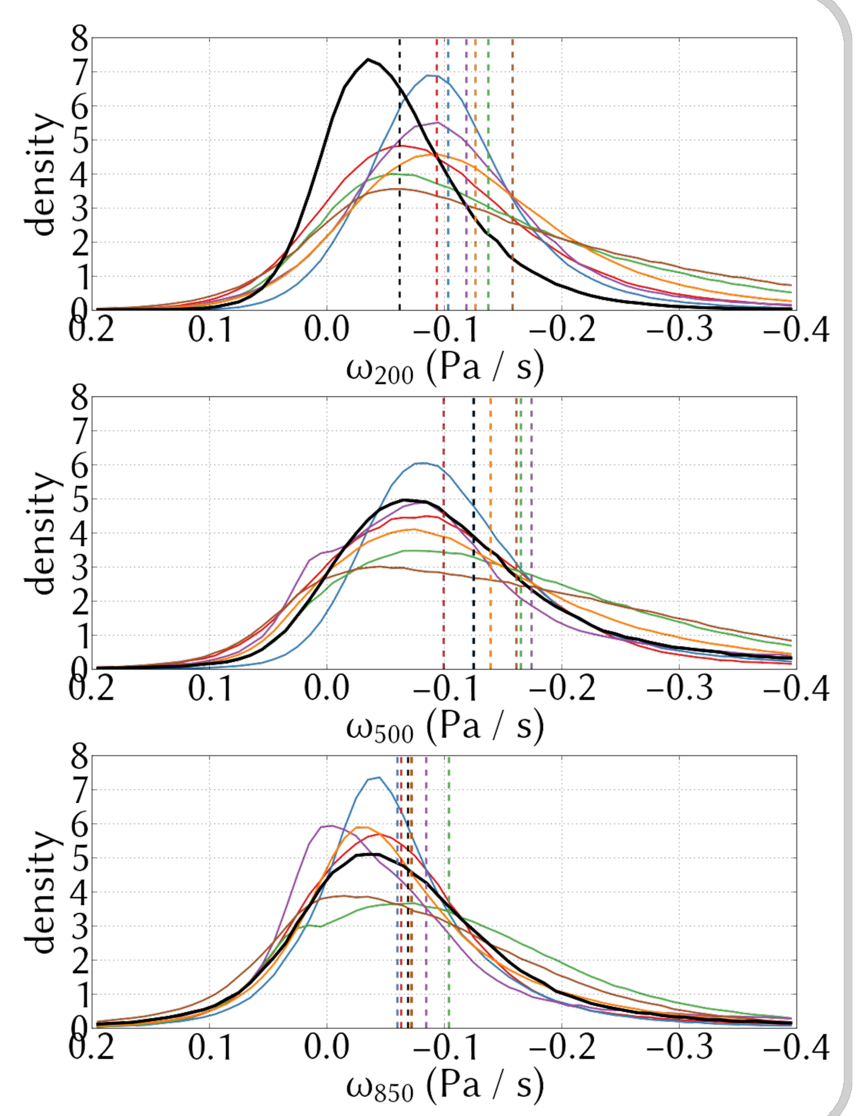


Fig. 2: distributions of the properties of the CR1 regime in observation (GPCP/ERA-Interim) and in GCMs. Above: daily precipitation rate P; top-right: grid-mean vertical motion ω at 200 hPa; middle-right: ω at 500 hPa; bottom-right: ω at 850 hPa. The dashed vertical lines denote the mean values.

Correlation of Errors

- errors in mean P are **negatively correlated** with errors in mean ω at all three levels (Fig. 3)
- therefore, when a model produces CR1, the associated environments are incorrect with correlating biases
- furthermore, models that overestimate the grid-mean ascending motion (ω too negative) tend to do better in P
- given that ω and P are variables closely related to convective parametrisation schemes, it is possible that these **high-topped and optically thick clouds** which in observations represent organised deep convection are in models **produced by a mechanism unrelated to convective organisation**
- this highlights the need to account for convective organistion in parametrisation schemes

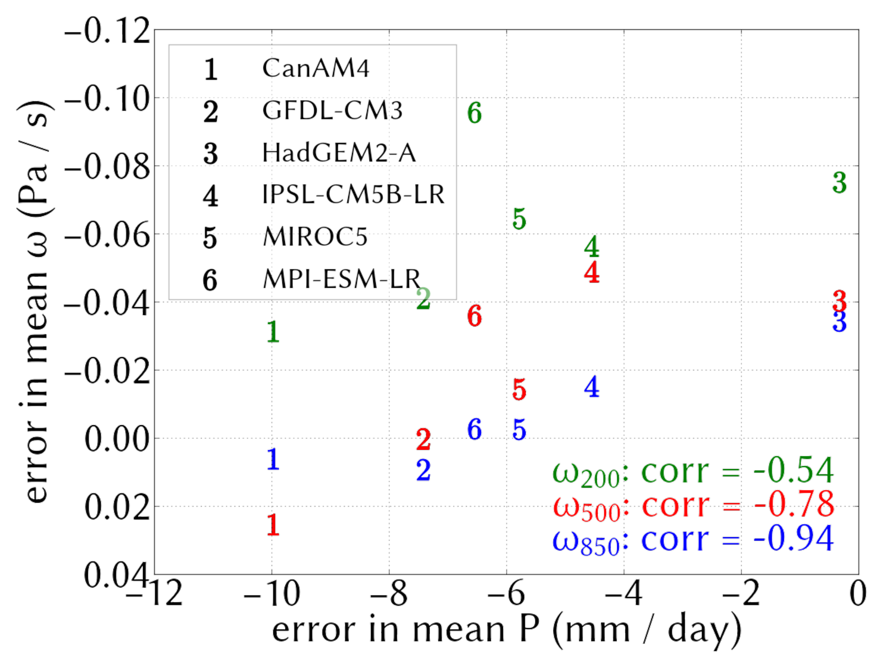


Fig. 3: scatter diagram between the mean errors in P against ω at various heights (green: 200 hPa; red: 500 hPa; blue: 850 hPa). Error = model − observation.

Conclusion

- GCMs produce the cloud regime **CR1**, which in observation represents **organised deep convection**
- however, the **precipitation rates** of CR1 in models are **too low** and the **grid-mean vertical motions** are **too strongly ascending**
- these errors are **moderately to strongly correlated**, with models that overestimate ascending motion doing less bad in precipitation
- this implies that **organised deep convection is poorly represented in GCMs** and parametrisation schemes need to account for organisation

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