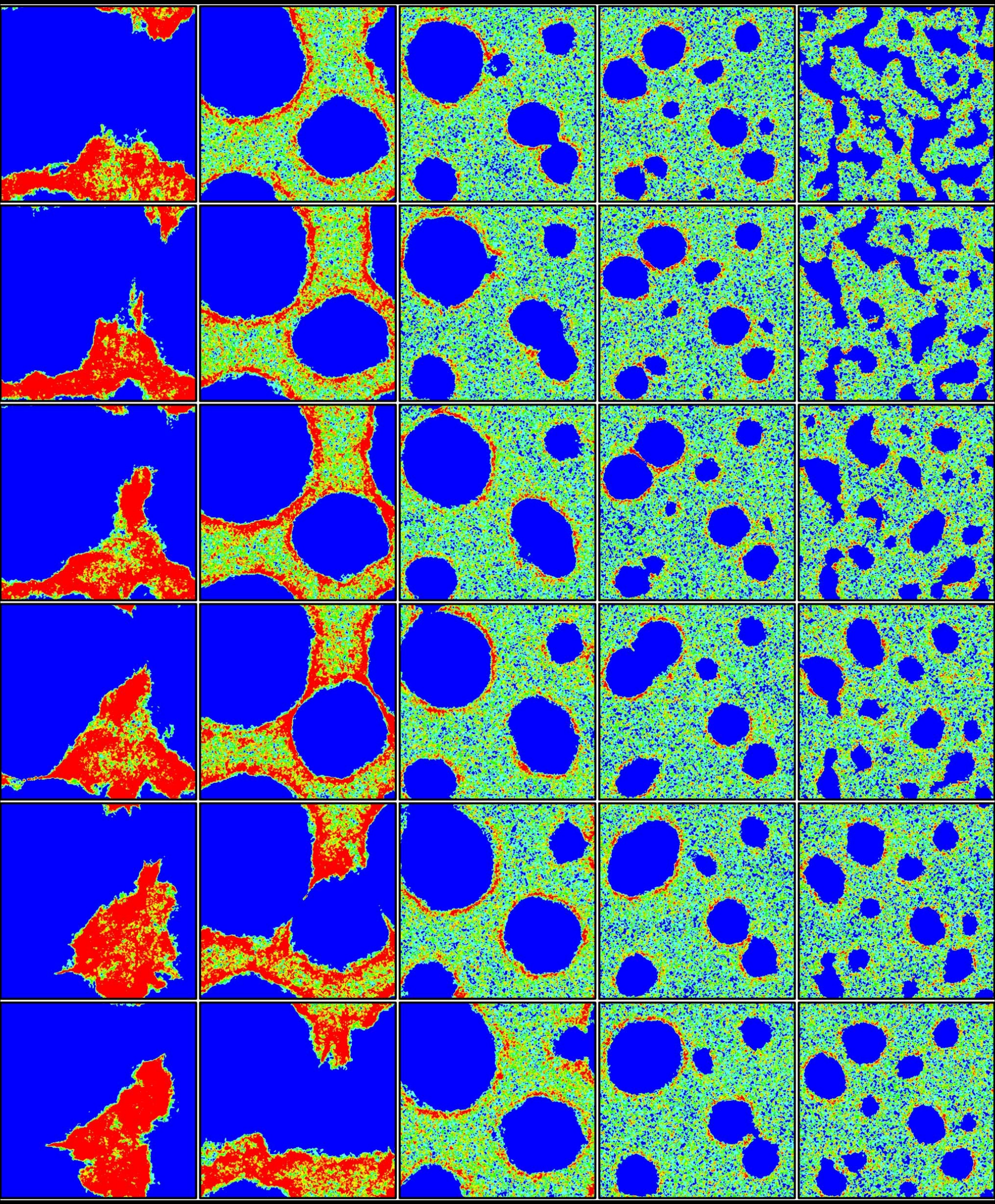
RCE (Cathy Hohenegger)



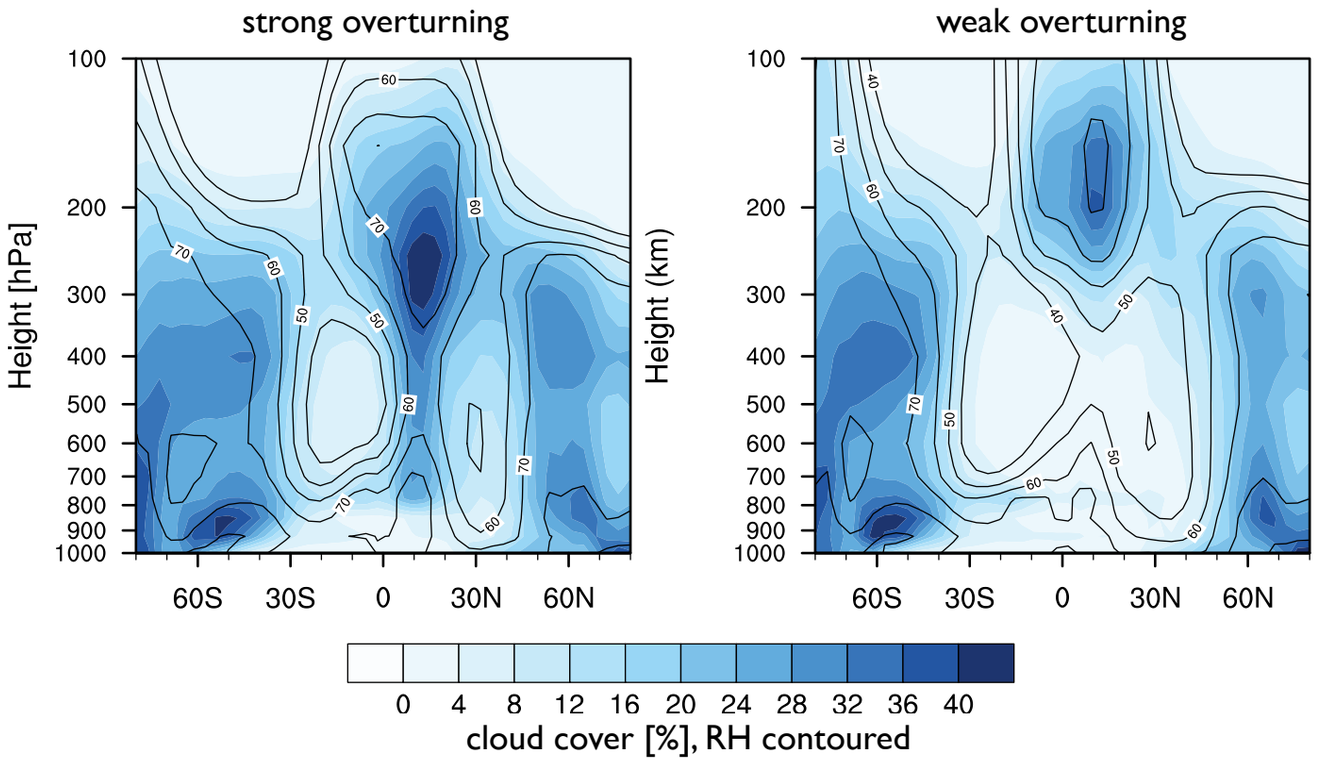
Radiative Convective Equilibrium (RCE)

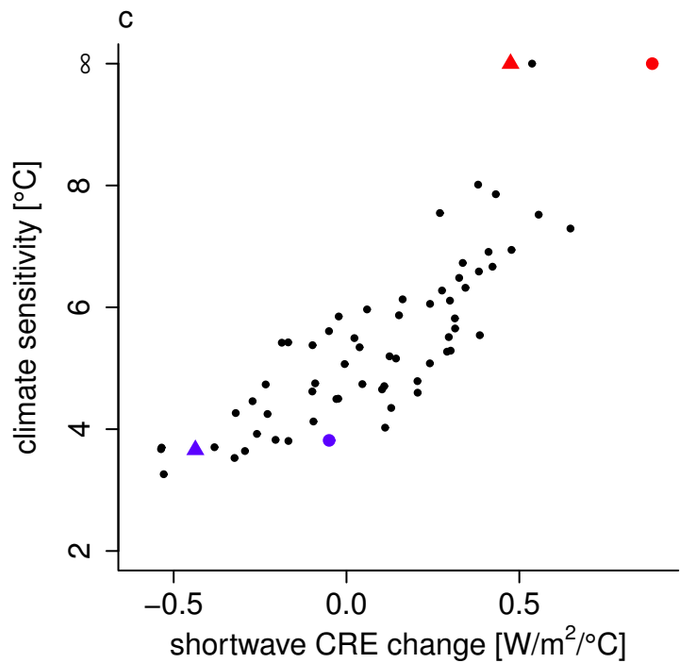
Bjorn Stevens

Max Planck Institute for Meteorology, Hamburg

(contributions from T. Becker, C. Hohenegger, D. Popke, A. Voigt)

Dominant Role of Convective Parameters





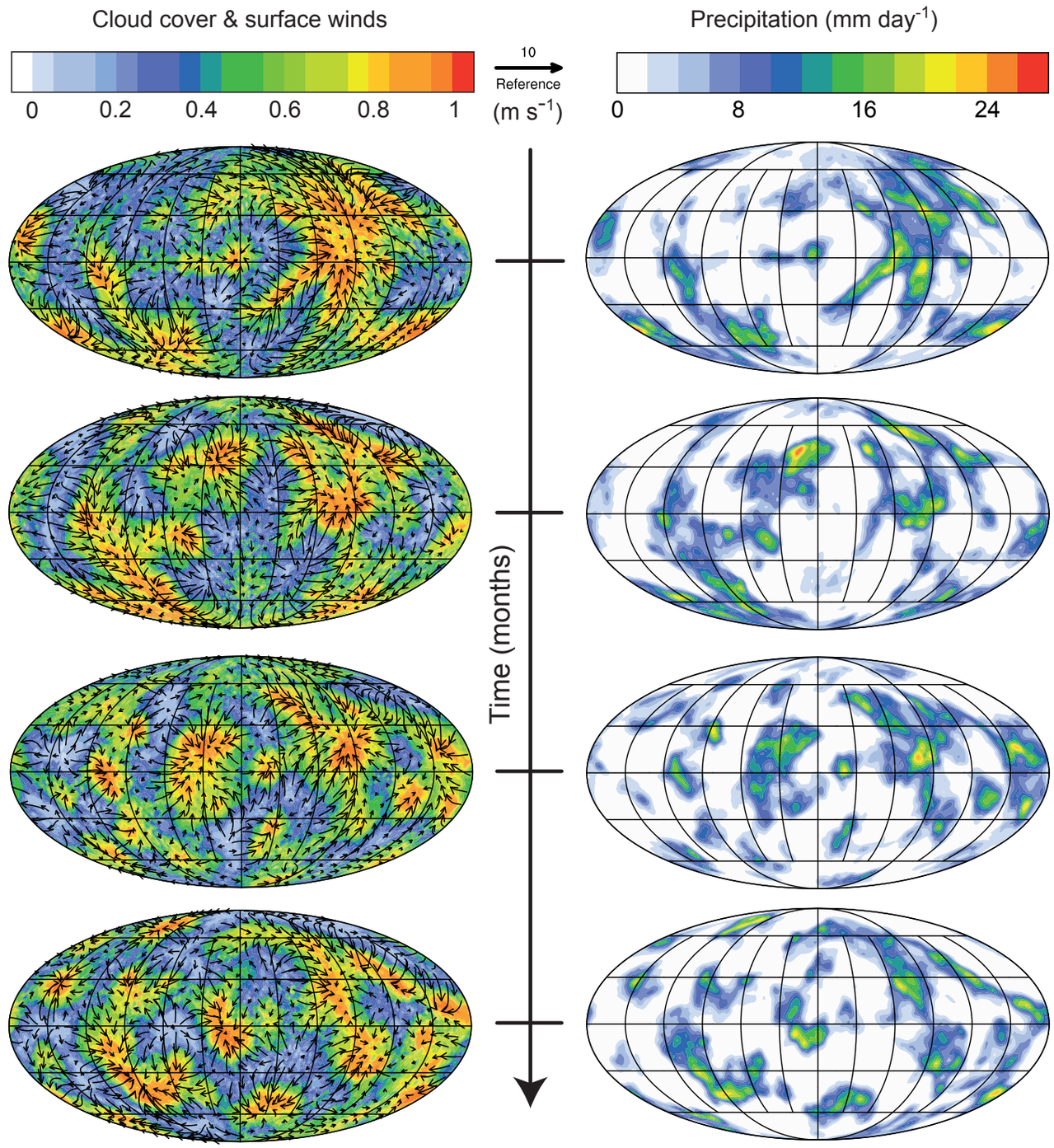
A coupled (MPI-ESM) model perturbed parameter ensemble shows that the model state is most influenced by parameters effecting mixing in the tropics. These parameters greatly influence:

- The atmospheric stability and strength of overturning;
- Tropospheric humidity;
- Cloud distribution and control temperature;
- Susceptibility of SW Cloud radiative effects and climate sensitivity.

Tomassini, Voigt and Stevens, *in prep*, 2014

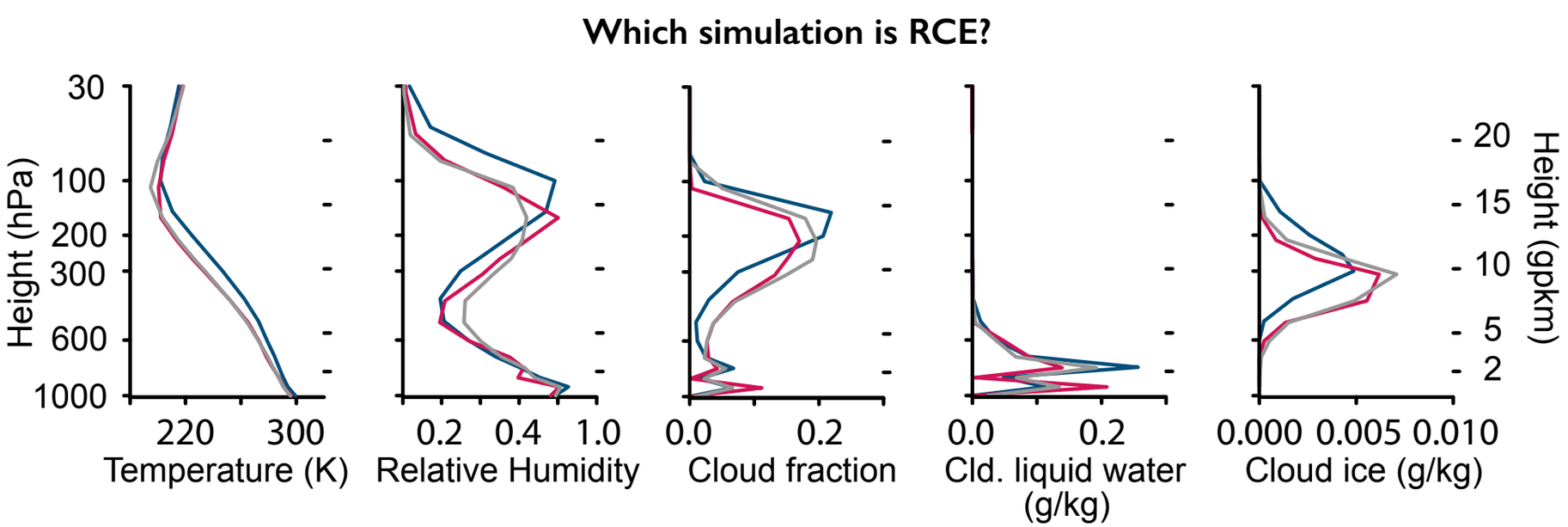
ECHAM6 (CMIP5 Version) RCE

- Uniform insolation;
- Diurnal cycle;
- No rotation;
- No continents;
- Slab 50 m ocean.



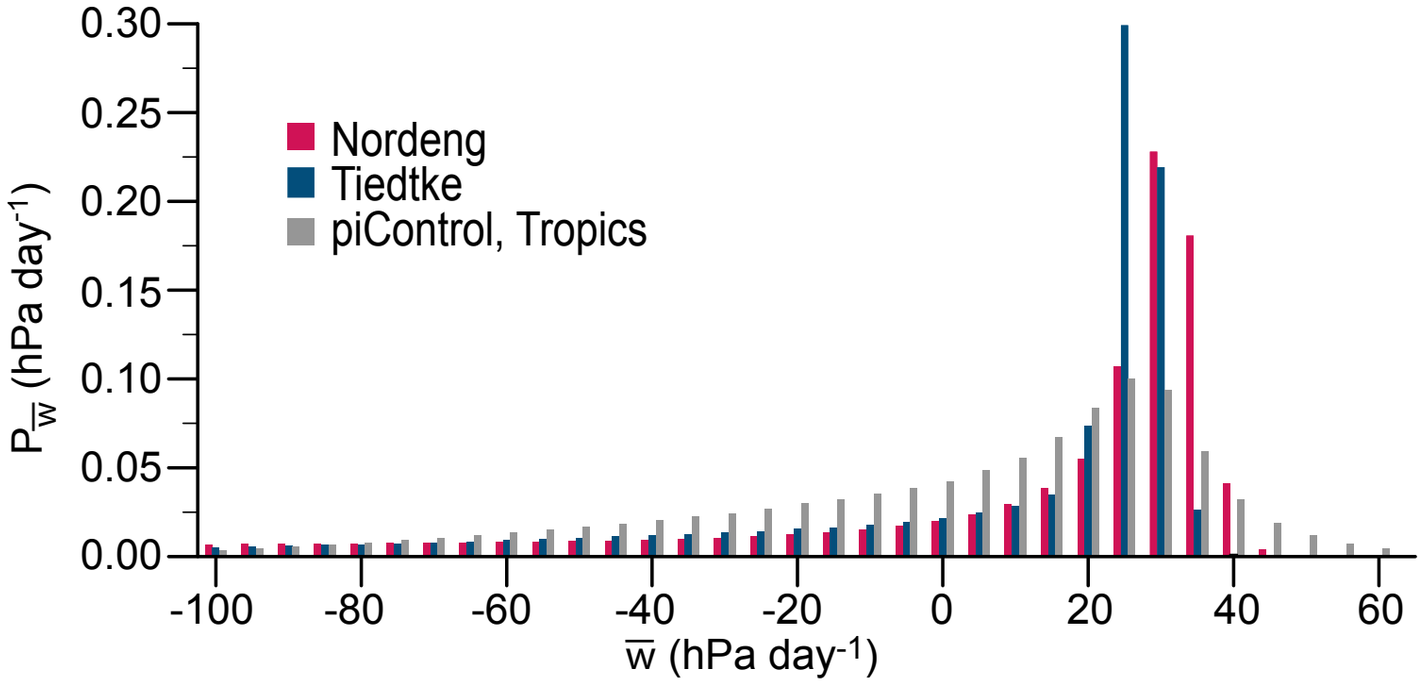
Popke, Stevens and Voigt, *JAMES*, 2013

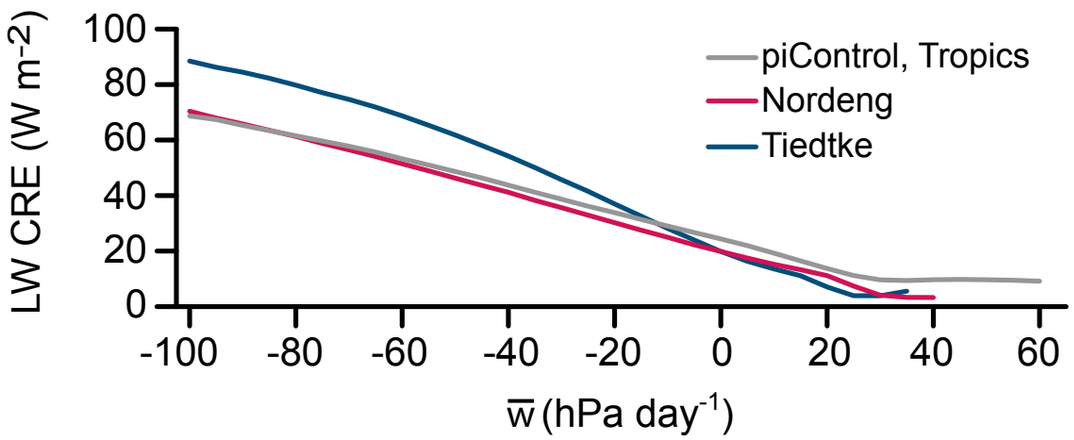
RCE as a surrogate for the coupled climate of the ESM

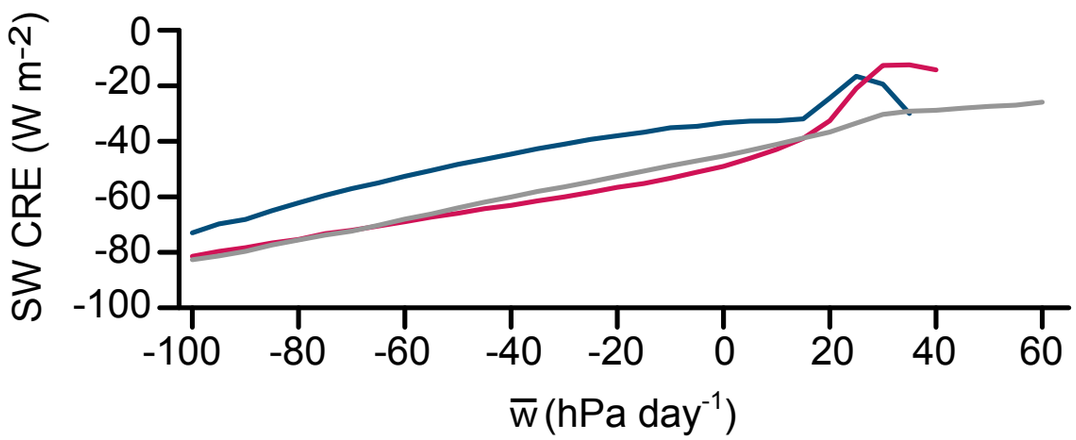


Popke, Stevens and Voigt, *JAMES*, 2013

RCE as a surrogate for the coupled climate of the ESM







Popke, Stevens and Voigt, *JAMES*, 2013

Questions: Effect of the surface boundary condition

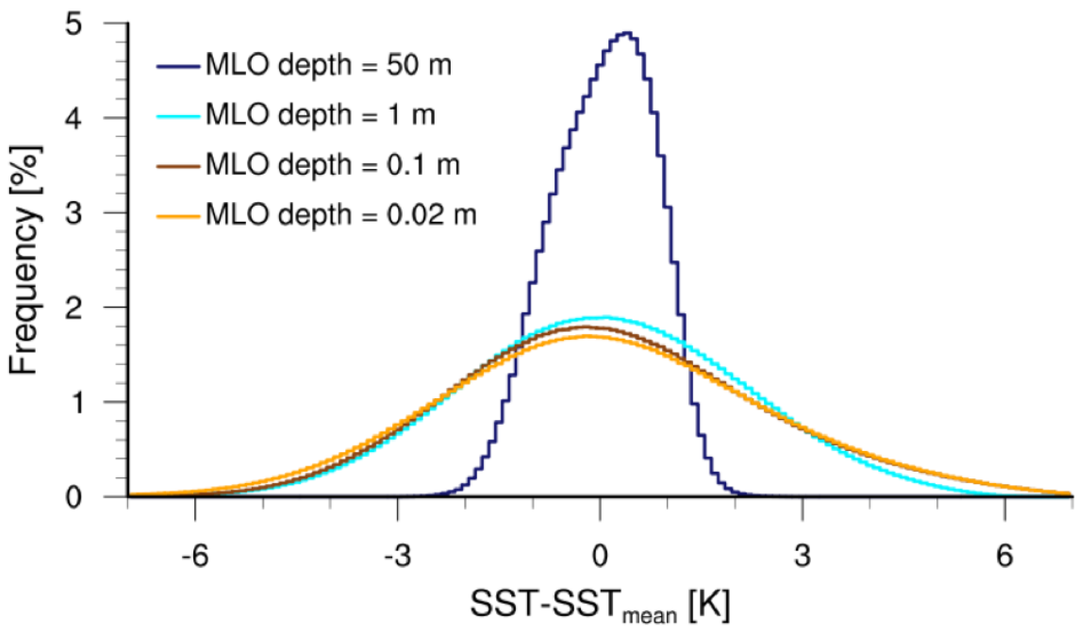
- How does the representation of the surface influence the coupling to the atmosphere?
- Does the equilibrium change on a land like planet? …. Specifically, is the climate sensitivity greater or smaller because of the restriction of moisture at the surface.
- Standard ECHAM RCE set up but conducted a series of experiments with:
  - progressively shallower mixed layer;
  - enhanced evaporative resistance;
  - a combination of both effects;
  - Islands big and small*.

The complex response of low clouds often dominate the behavior of the system – not necessarily in a way that inspires confidence in the modelling system

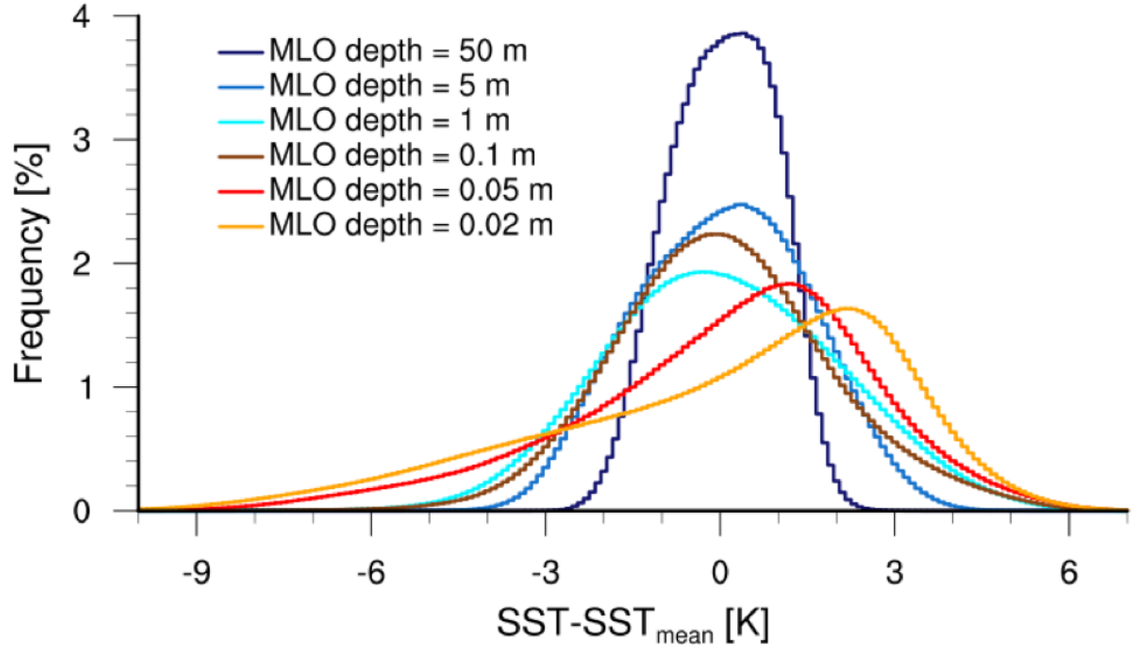
*See also work, using a more fundamental approach, by Tim Cronin (in audience)

Effect of surface coupling and the diurnal cycle

Simulations with no diurnal cycle

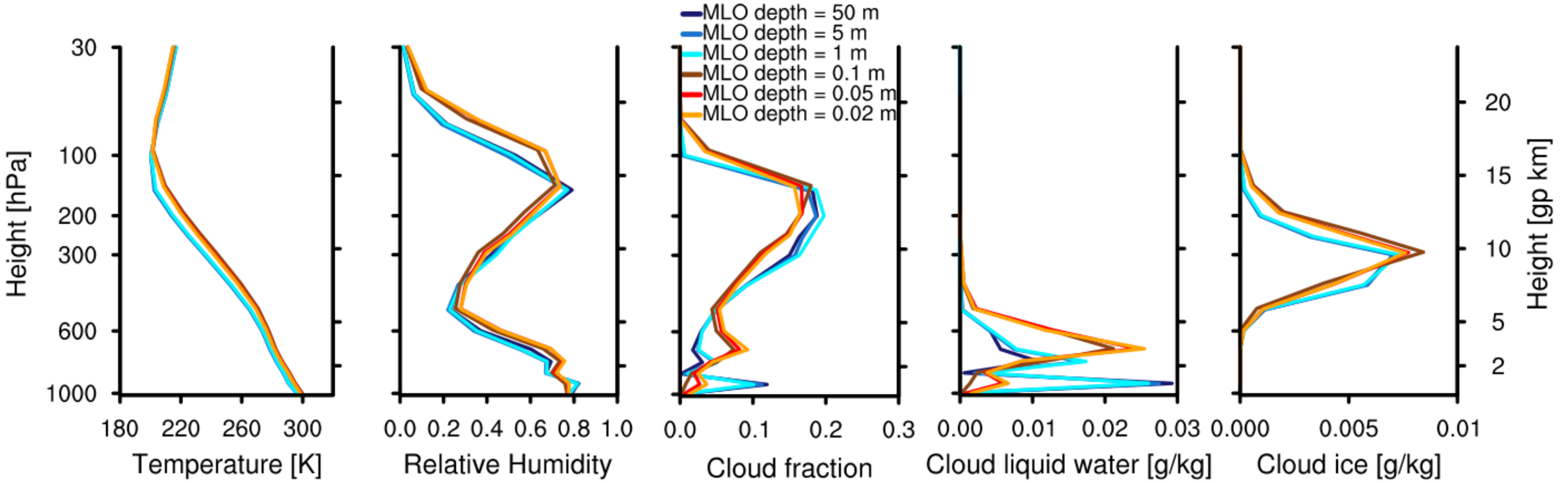


Simulations with diurnal cycle



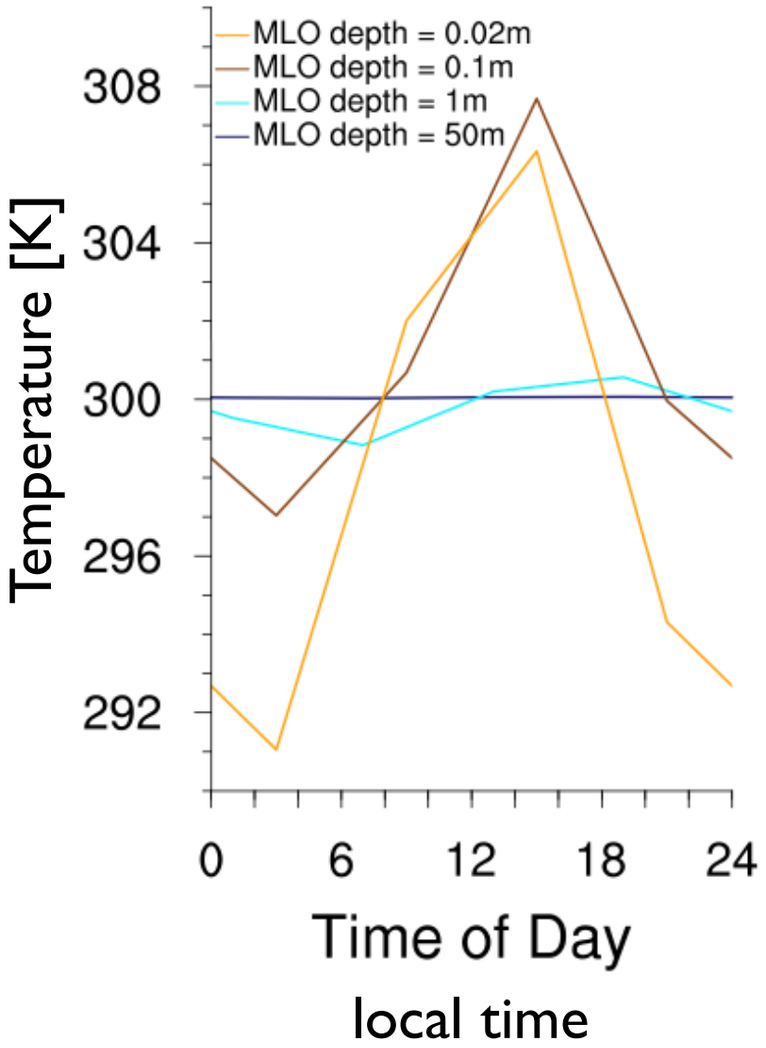
Effect of surface coupling is readily evident with and without a diurnal cycle, but the emergence of a diurnal cycle skews the distribution of surface temperatures.

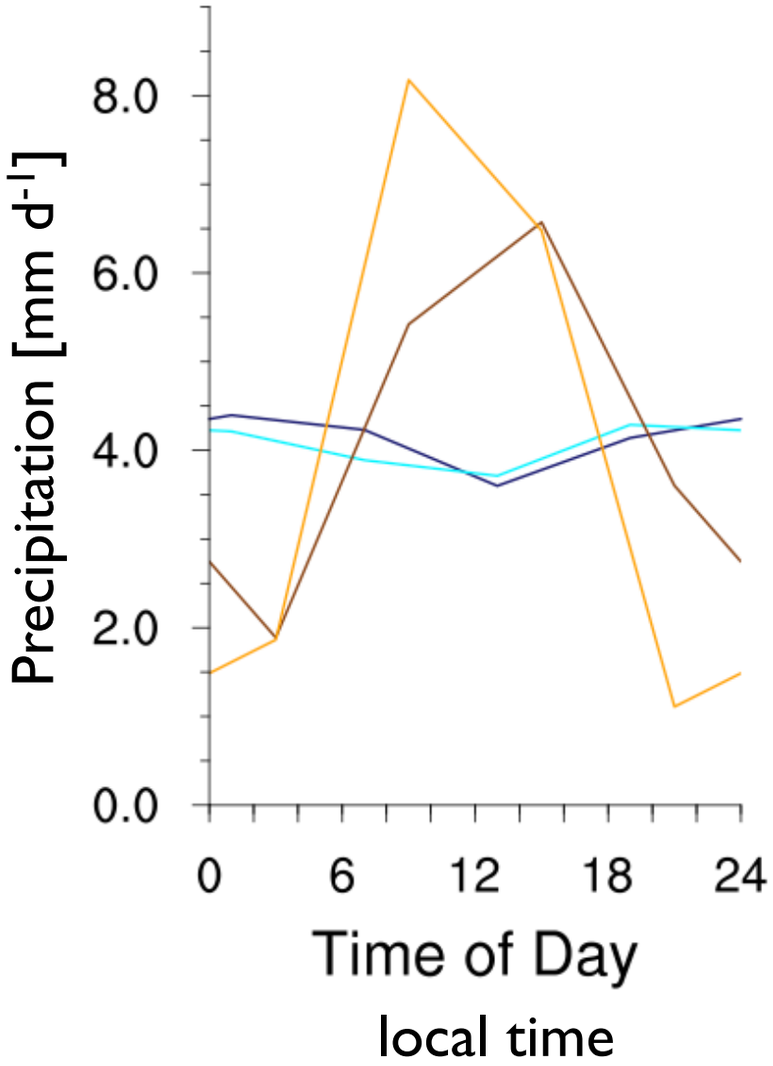
Diurnally coupled simulations on a warmer moist adiabat

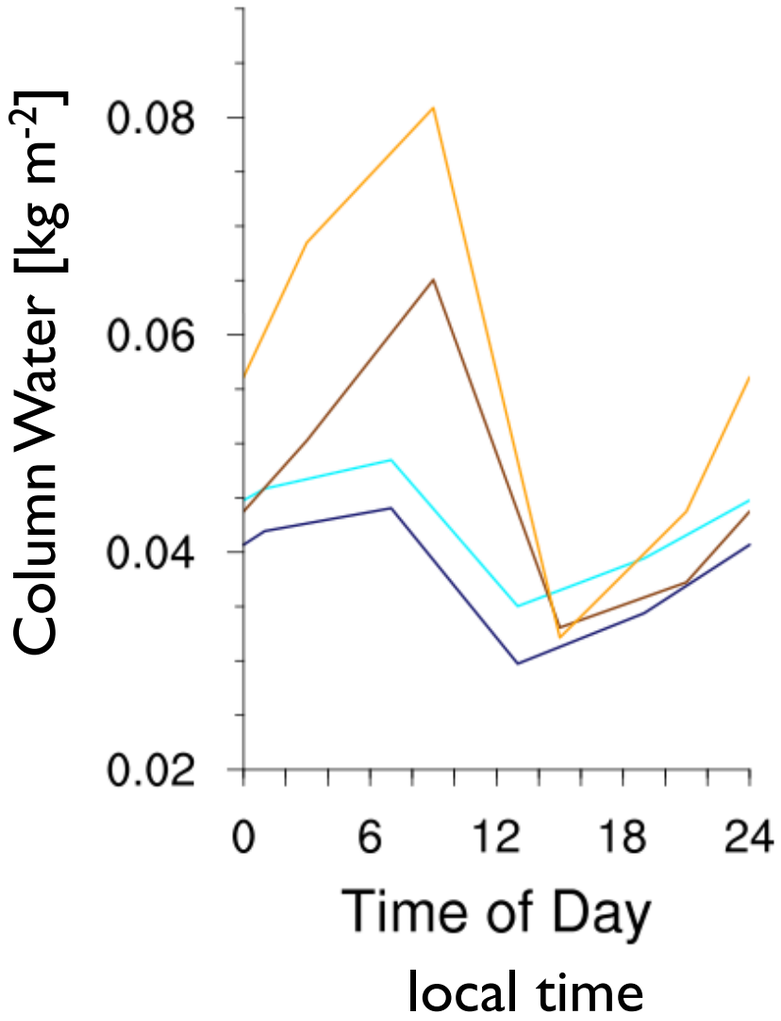


MLO depth	50 m	5 m	1 m	0.1 m	0.05 m	0.02 m
SST [K]	300.1	299.5	299.8	301.3	300.1	298.6
Precipitation [mm/d]	4.1	4.0	4.0	4.4	4.3	4.4

Diurnal Temperature Changes







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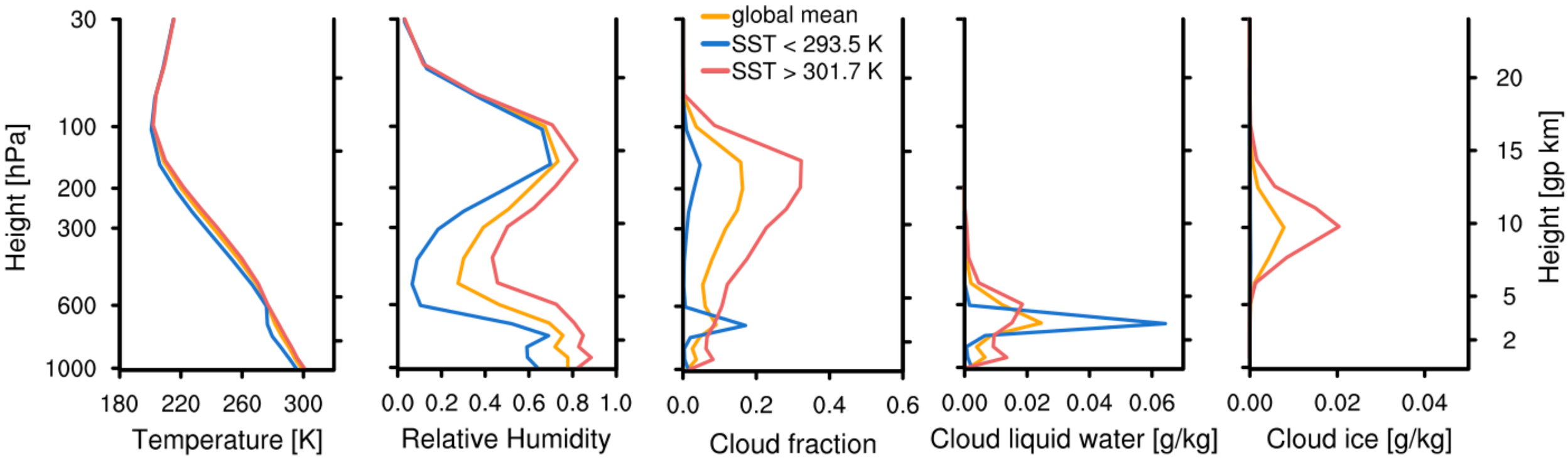
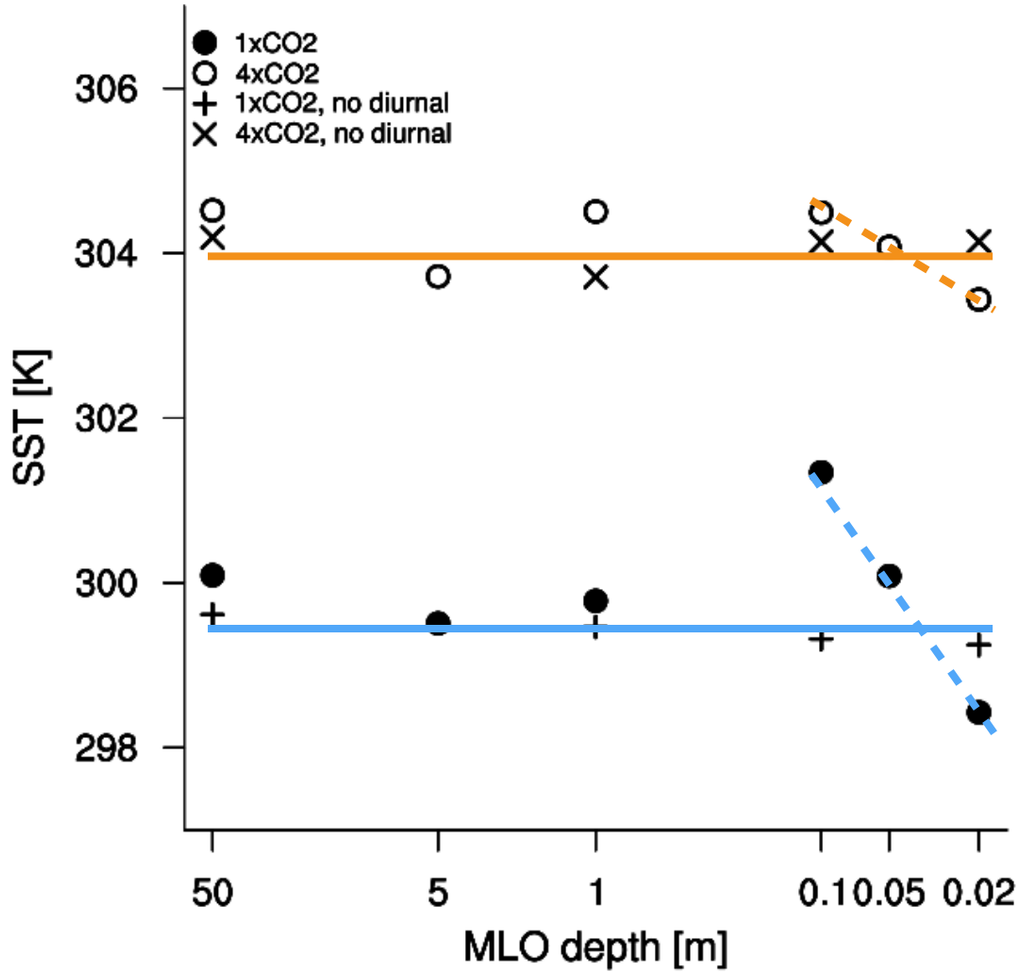
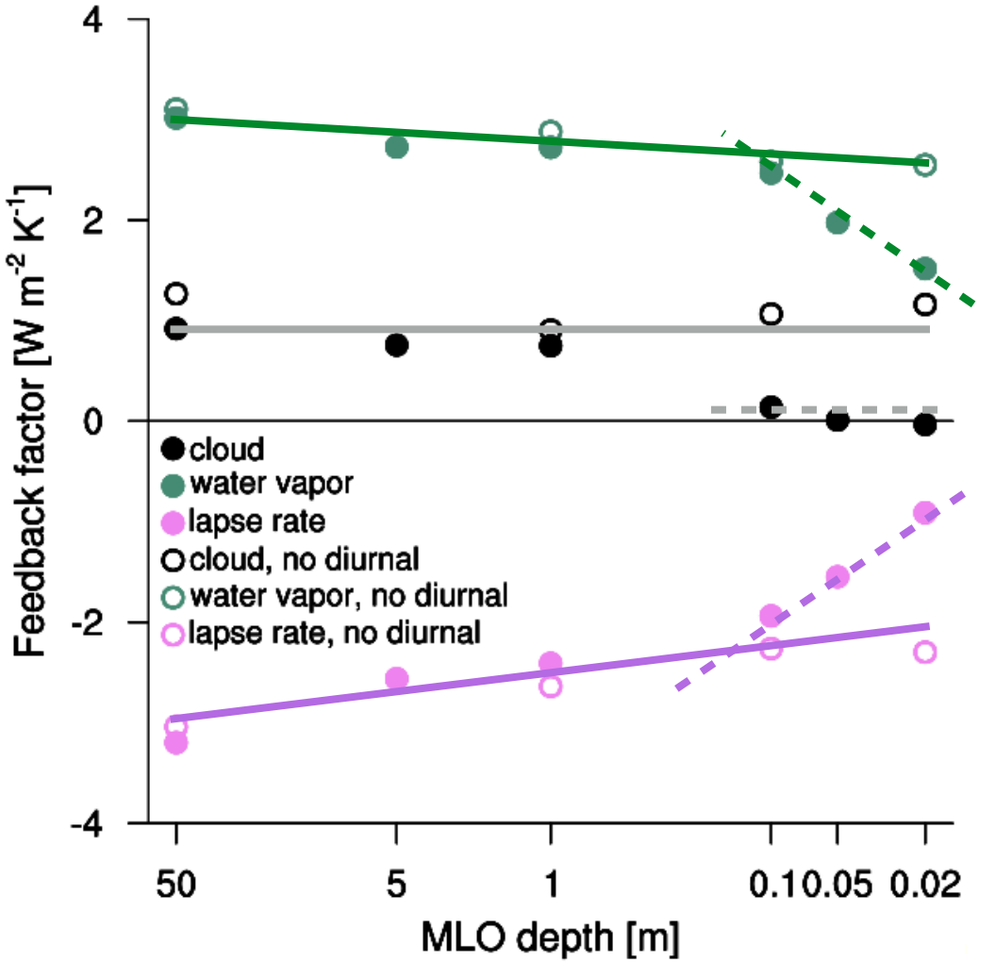
Becker and Stevens, in preparation 2014;
also Cronin and Emanuel, 2012.

Stratocumulus over cold surfaces (2 cm mixed layer)



Surface coupling effects on climate sensitivity



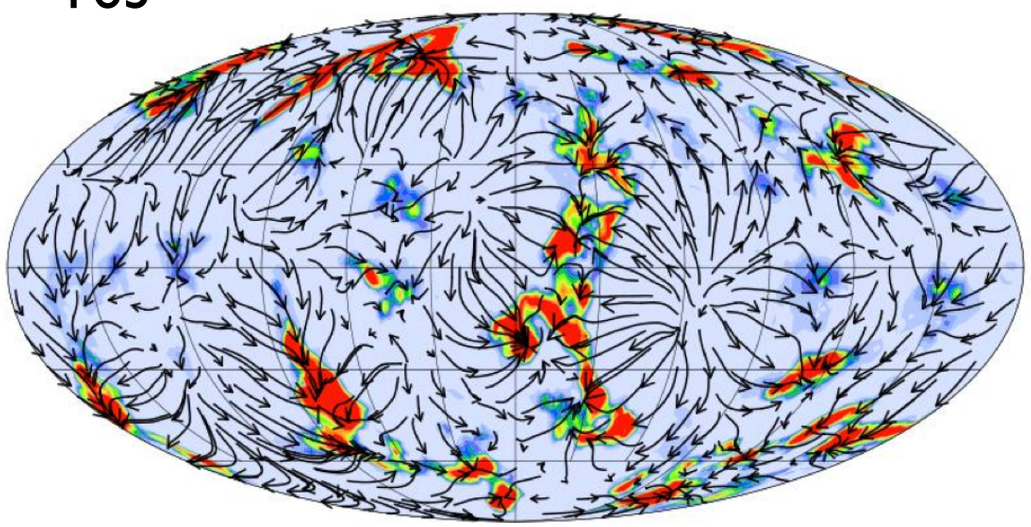


Summary

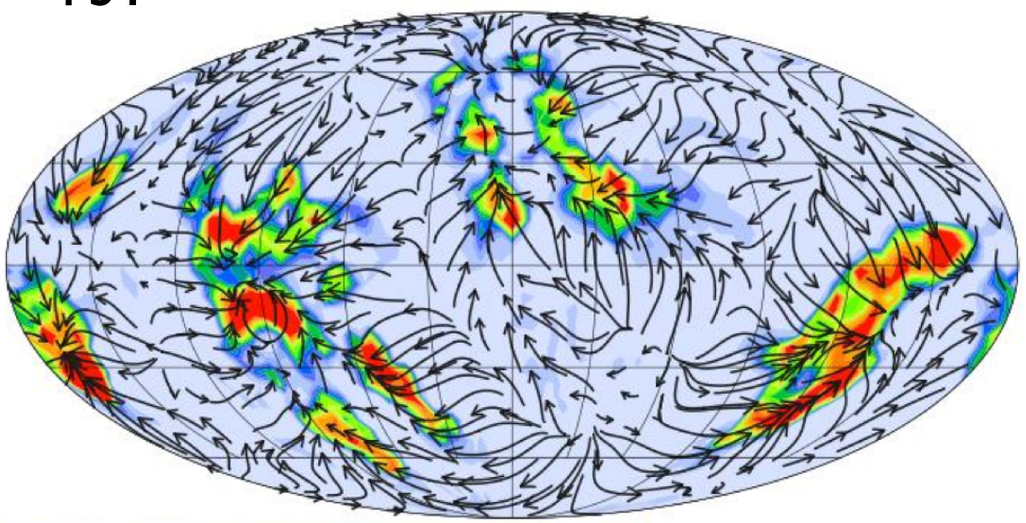
- Understanding RCE is relevant, and arguably necessary, for understanding climate — arguably more relevant than much of what we do when we say we are studying climate.
- RCE the first, and most important, problem that bridges the model hierarchy.
- RCE avails itself to a number of interesting sub problems which raise important issues in a conceptual way.
- One we looked at in more depth was the effect of the surface on the state and sensitivity of the system
  - surface coupling had no important effect on the climate of RCE
  - diurnal coupling with shallow mixed layers did, as understanding the base climate required an understanding of the diurnal cycle.
  - cloud feedbacks often dominated the behavior of the model, or transitions in the behavior, as low-clouds switched states in ways that often were I do not believe are physical.
- We are busy working on this problem in a great variety of contexts using the full hierarchy of models.

Larger clusters emerge at coarser resolution

T63



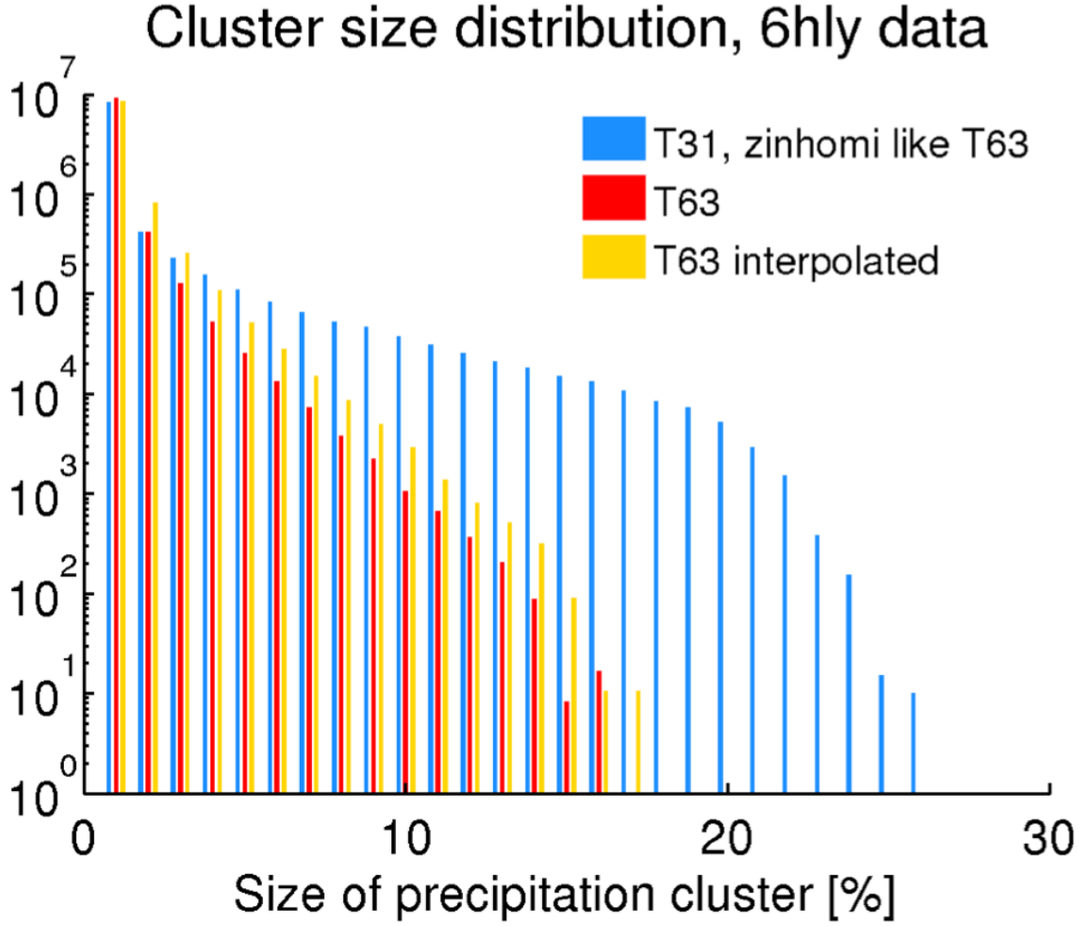
T31

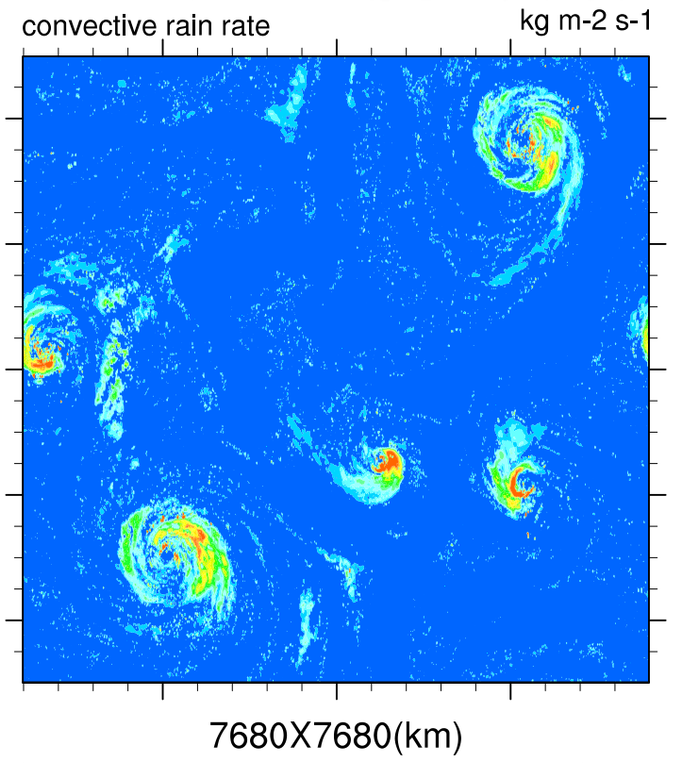


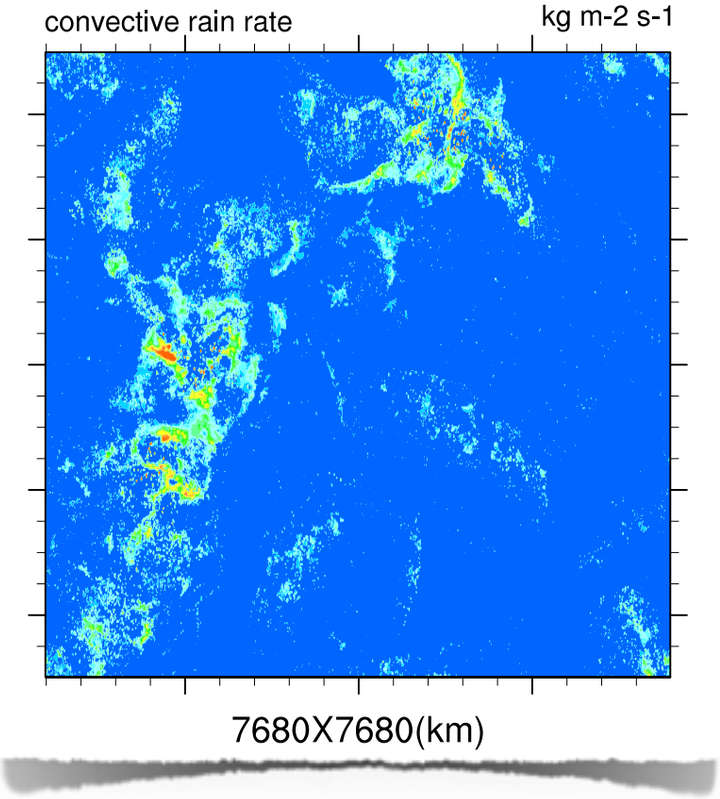
0 8 16 24

Precipitation [mm/d]

wind [10 ms^{-1}]




convective rain rate
kg m-2 s-1
7680X7680(km)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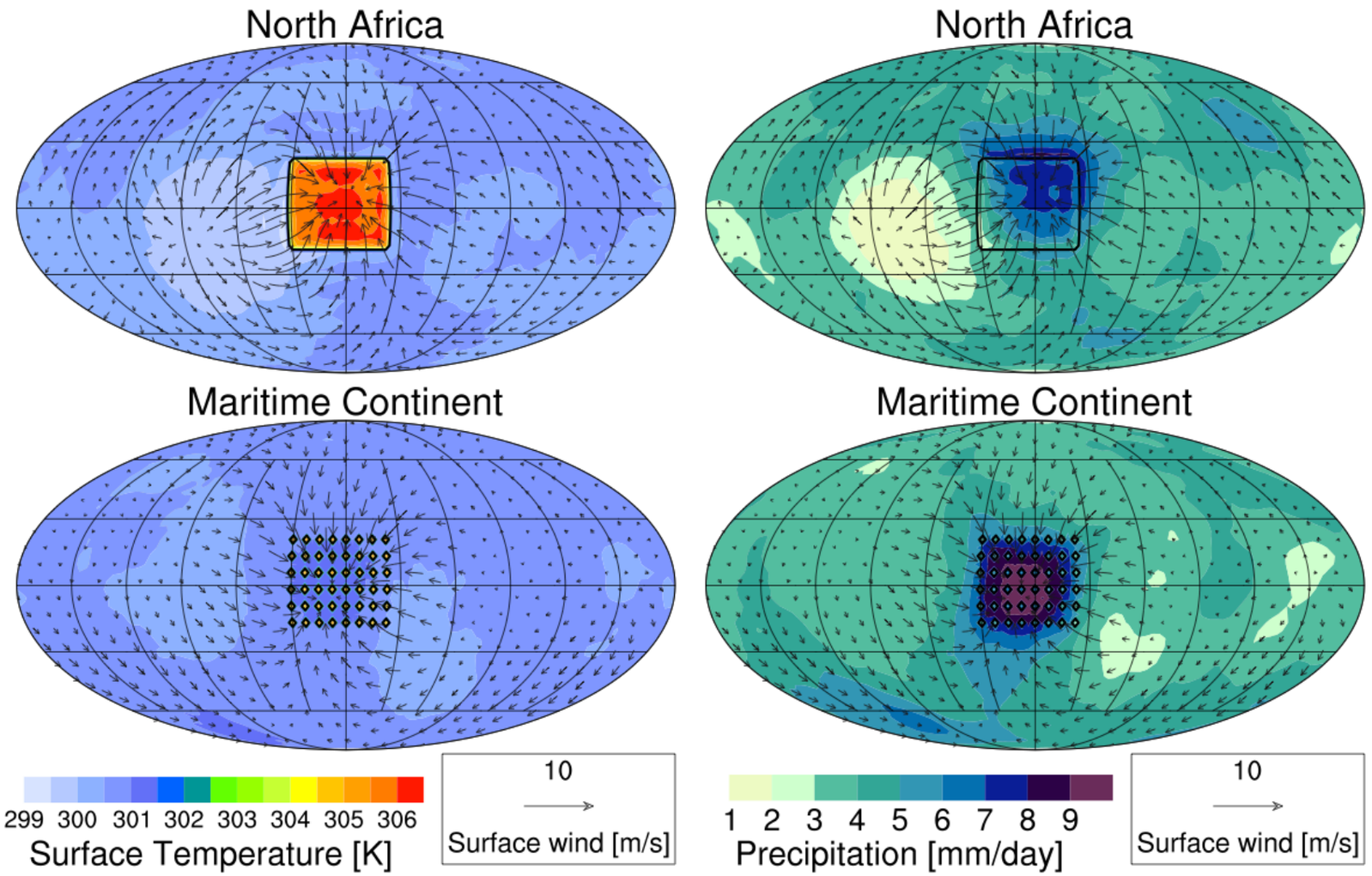
North Africa
Maritime Continent
North Africa
Maritime Continent
299 300 301 302 303 304 305 306
Surface Temperature [K]
10
Surface wind [m/s]
1 2 3 4 5 6 7 8 9
Precipitation [mm/day]
10
Surface wind [m/s]