WP4: Sensitivity Experiments and Hypothesis Testing

In this WP we will integrate results from other work-packages to develop numerical experiments designed to both test our developing understanding and identify observables that can help further constrain cloud feedbacks.

- *The work proposed in this package is broken into three tasks and several subtasks.*
- *Each sub-task is identified with a subtask leader.*

1. *Evaluate Unusual Behaviour (ECMWF, MPG)*
2. *Developing and Testing Parameterization Improvements (KNMI, ETHZ)*
3. *Establishing Observational Metrics (MPG)*

WP4: Sensitivity Experiments and Hypothesis Testing

1. A developing database and protocol for parameter and structural (numerical) sensitivity studies by others in the community (M24).
2. A study comparing the sensitivity of the models to the numerical structure of the computations (grid and time step) with the parameter sensitivity of the model. This study will also provide best practices for future use of the models, for instance recommendations for integrating diverse physical processes in time and space (M36).
3. A study identifying the utility of NWP based methods for identifying and narrowing sources of divergent behavior in cloud-climate feedbacks in models (M36).
4. New process representations that can be implemented in models and which will better rationalize (and hopefully narrow) the range of cloud responses by the models (M42).
5. A study evaluating the extent to which aerosol-cloud-climate effects depend on the representation of cloud processes (M48).
6. Process related metrics that can be used as model development and evaluation tools (M42)
7. Revised estimate, with uncertainty bounds, of climate sensitivity from EUCLIPSE ensemble (M8).

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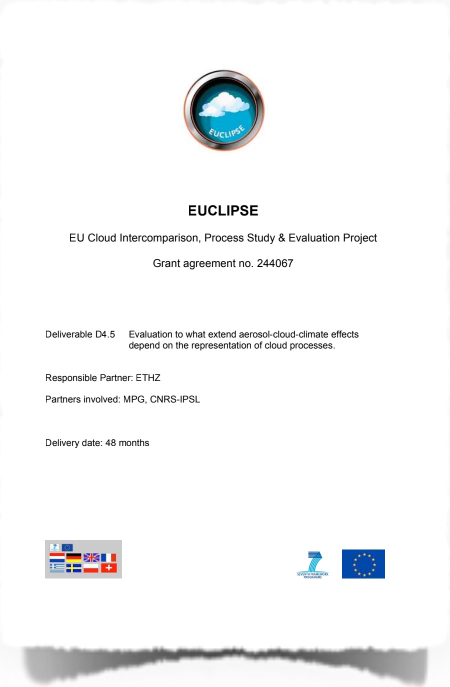
Deliverables



EUCLIPSE

EU Cloud Intercomparison, Process Study & Evaluation Project

Grant agreement no. 244067

Deliverable D4.5 Evaluation to what extend aerosol-cloud-climate effects depend on the representation of cloud processes.

Responsible Partner: ETHZ

Partners involved: MPG, CNRS-IPSL

Delivery date: 48 months

EUCLIPSE

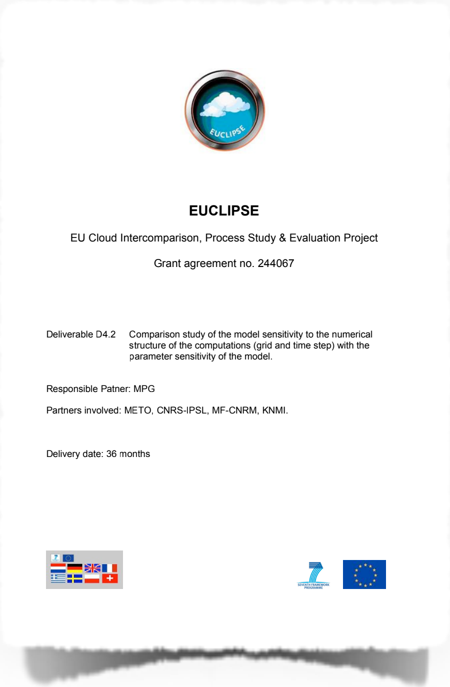
EU Cloud Intercomparison, Process Study & Evaluation Project

Grant agreement no. 244067

Deliverable D4.7 Revised estimates, with uncertainty bounds, of climate sensitivity from EUCLIPSE ESM ensemble.

Responsible Partner: MPG

Delivery date: 48 months



EUCLIPSE

EU Cloud Intercomparison, Process Study & Evaluation Project

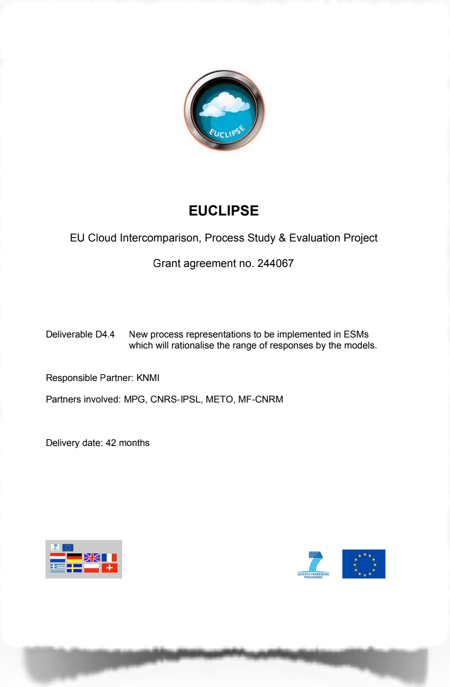
Grant agreement no. 244067

Deliverable D4.2 Comparison study of the model sensitivity to the numerical structure of the computations (grid and time step) with the parameter sensitivity of the model.

Responsible Patner: MPG

Partners involved: METO, CNRS-IPSL, MF-CNRM, KNMI.

Delivery date: 36 months



EUCLIPSE

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Deliverable D4.4 New process representations to be implemented in ESMs which will rationalise the range of responses by the models.

Responsible Partner: KNMI

Partners involved: MPG, CNRS-IPSL, METO, MF-CNRM

Delivery date: 42 months

EUCLIPSE

EU Cloud Intercomparison, Process Study & Evaluation Project

Grant agreement no. 244067

Deliverable D4.6 Process-related metrics that can be used as model development and evaluation tools.

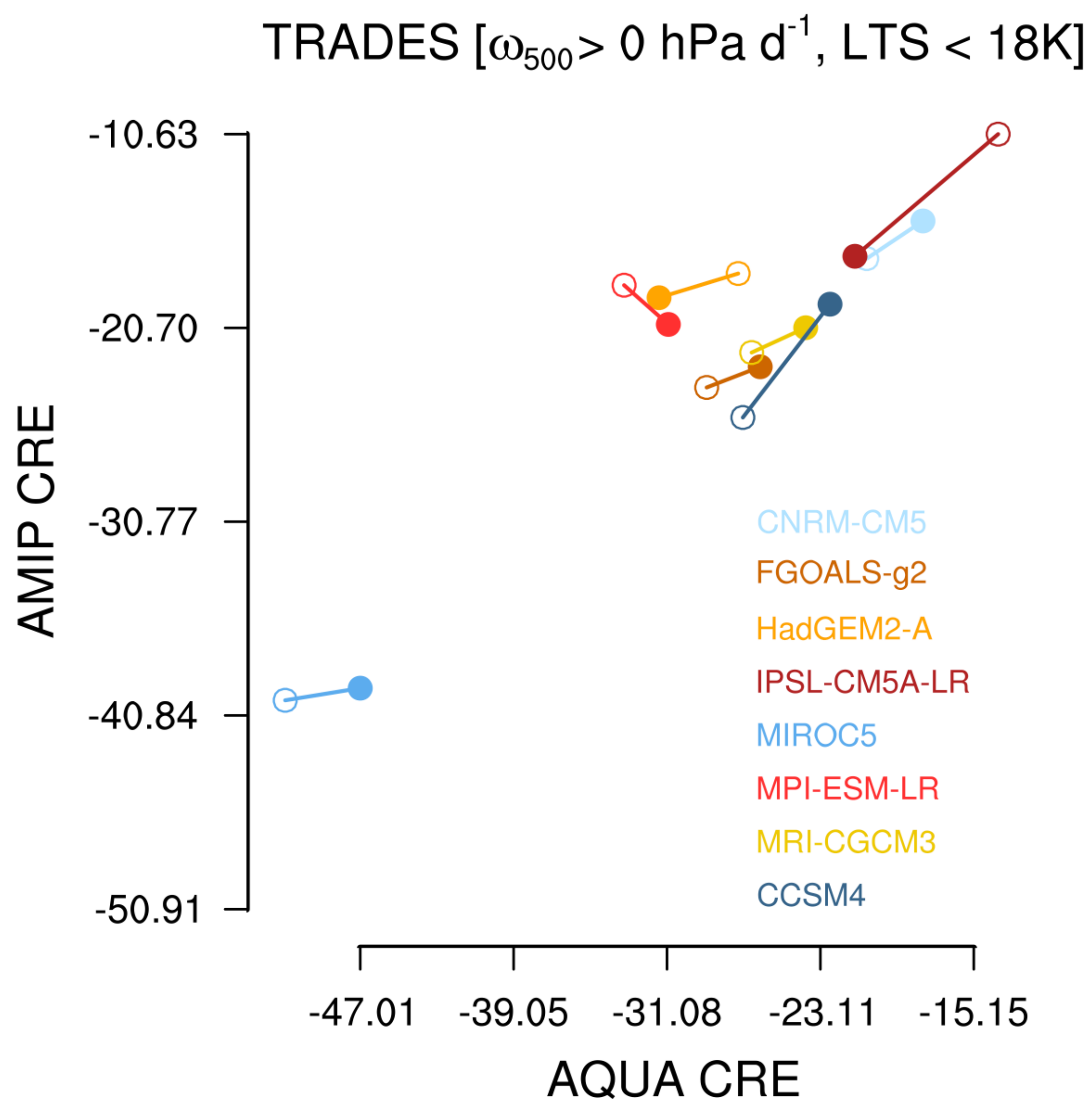
Responsible Partner: MPG

Partners involved: AA, CNRS-IPSL, METO, KNMI, ECMWF

Delivery date: 42 months

4.2 Comparison study of the model sensitivity to the numerical structure of the computations (grid and time step) with the parameter sensitivity of the model.

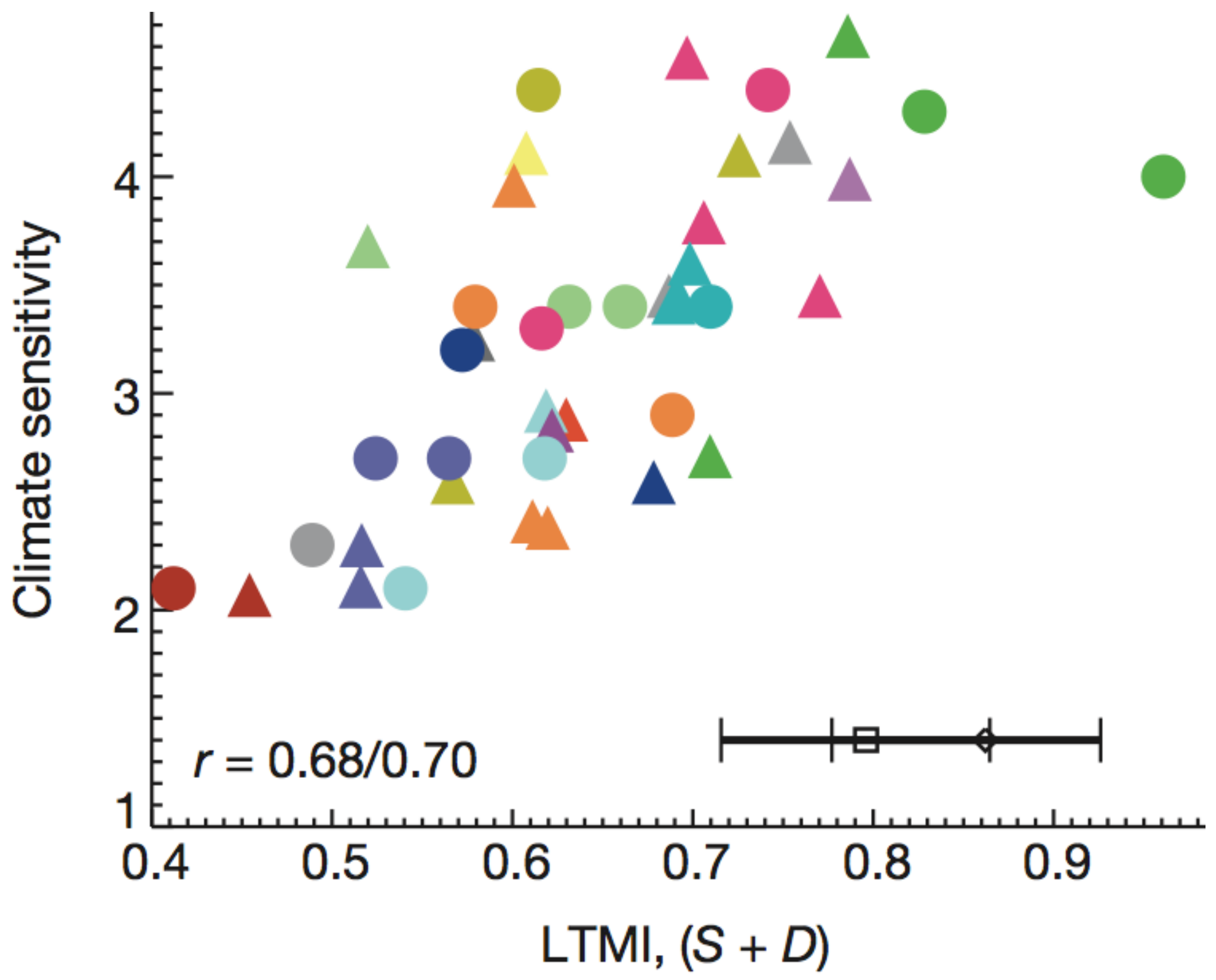
- Resolution studies showed modest effect on climate sensitivity, but links to parameterizations made these more difficult than we anticipated
- More successful in exploring the structure of the computation (parameter sensitivity studies, a number of these)
- Also the dependence on the structure of the computation, i.e., we made great use of the aquaplanets, and developed new frameworks (RCE)



Medeiros, Stevens, and Bony, *Clim Dyn*, 2014

4.4 New process representations to be implemented in ESMs which will rationalise the range of responses by the models

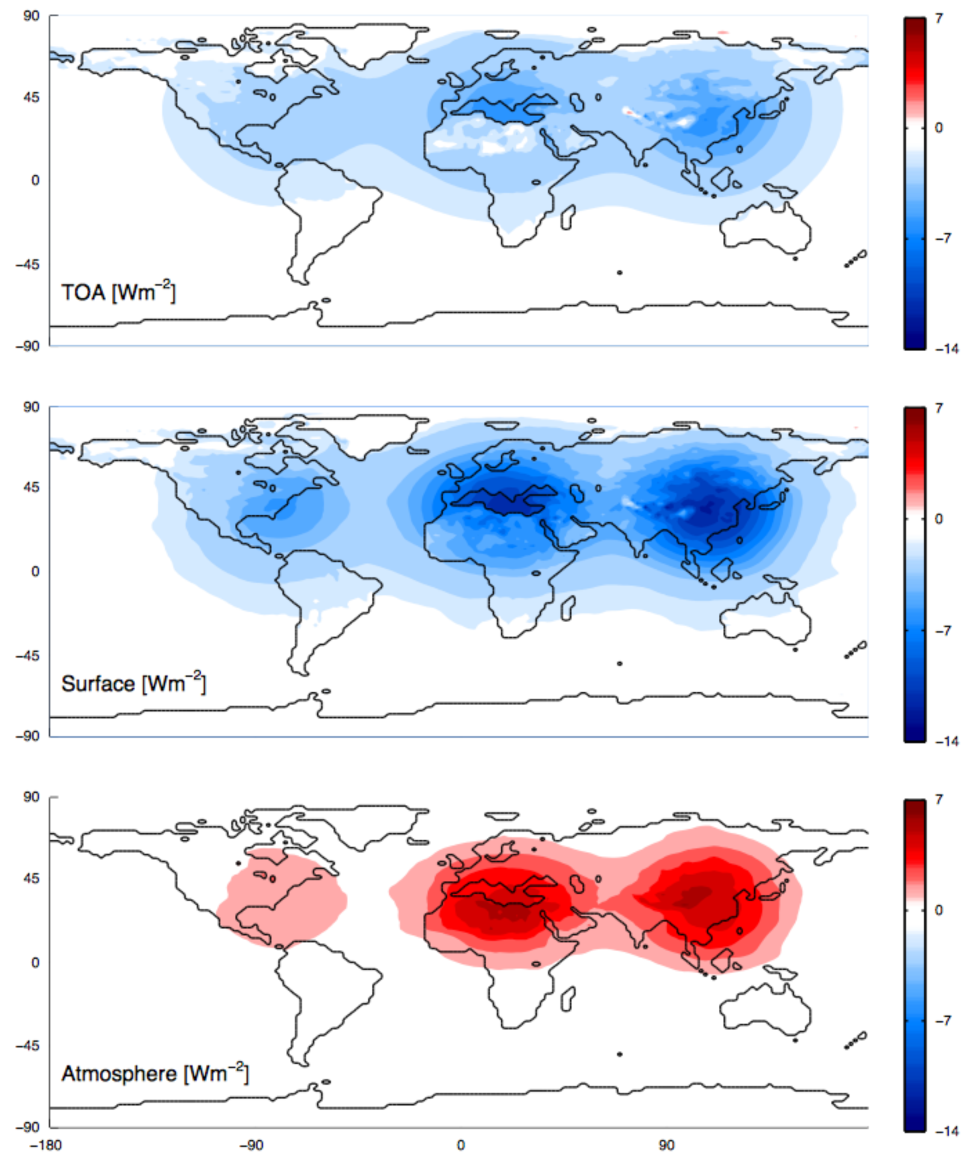
- Taking things out is easier than putting things in. An exceptions is Neggers and Siebesma, 2013.
- The beta feedback and cloud radiative effects, leading to COOKIE
- Stronger work on understanding the relationship between convective mixing and structure of the ITCZ.
- In the four SPOOKIE models, the range in global cloud feedback reduced by 40 % with the removal of parametrized convection.
- A variety of perturbed parameter experiments (Lacagnina et al., 2014)
- Much stronger physical understanding (Webb and Lock 2012)



Sherwood, Bony, and Dufresne, *Nature* 2014

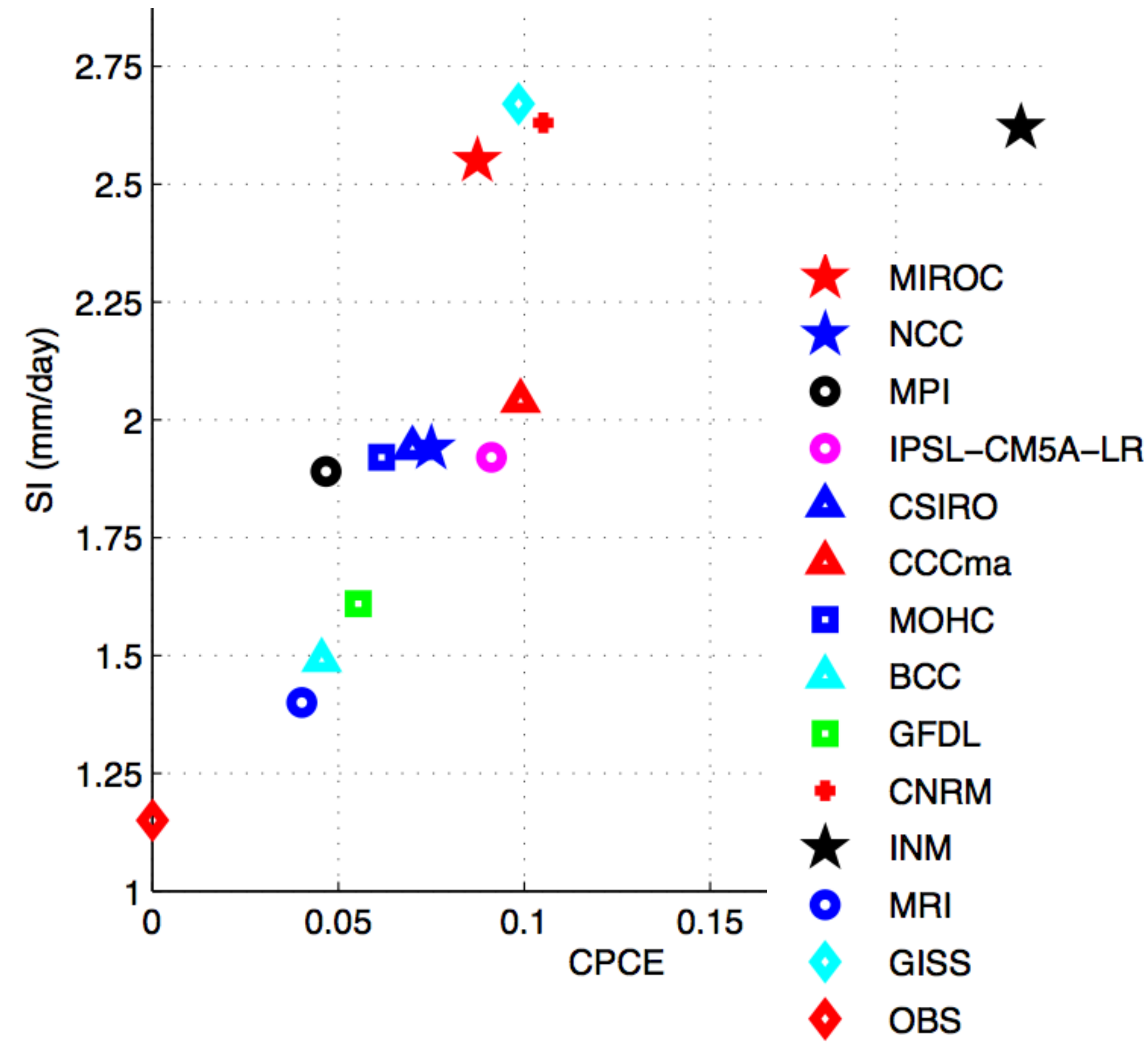
4.5 Evaluation to what extend aerosol-cloud-climate effects depend on the representation of cloud processes.

- Easy aerosol (right) introduced new ways to explore how (differing) large-scale changes in cloudiness mediate the response to aerosol forcing
- Response of the ITCZ to inter hemispheric albedo differences depends on representation of cloud radiative effects. (Voigt et al., 2014)
- Effective cloud fraction emerges as a key (poorly understood parameter) influencing aerosol effects.



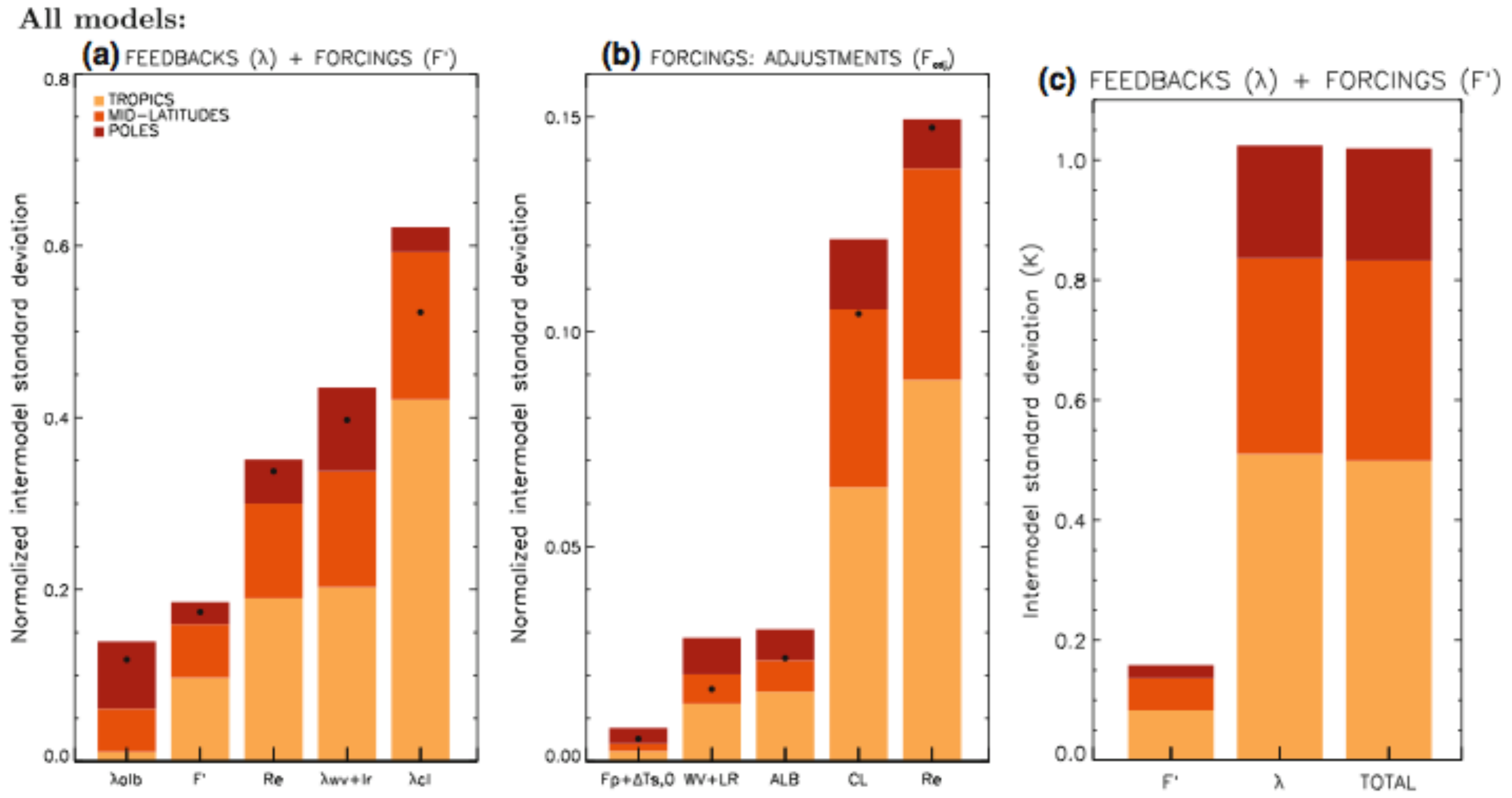
4.6 Process-related metrics that can be used as model development and evaluation tools

- MJO Index by Crueger et al., J. Climate (2012)
- Use of Transpose AMIP to study short term responses (ΔACRE vs ΔP, in dry regions, Fermepin and Bony, 2014)
- Combined Precipitation Circulation Index (Oueslati and Bellon, 2014) explaining strength of double ITCZ)
- Use of station data (and other diagnostics) advancing understanding of model representation of low clouds



Oueslati and Bellon, *Clim Dyn.* 2014.

4.7 Revised estimates, with uncertainty bounds, of climate sensitivity from EUCLIPSE ESM ensemble

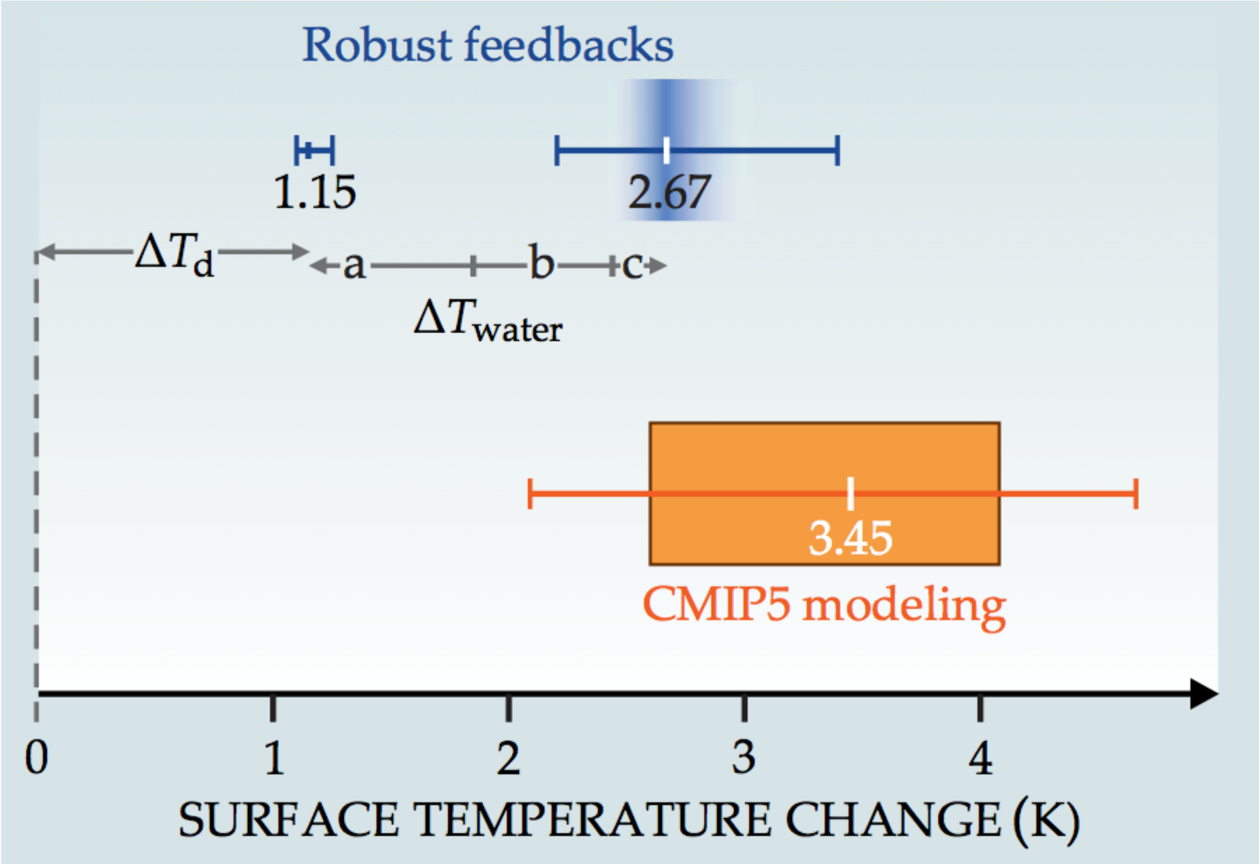


- Comprehensive analysis of CMIP models, reinforced previous findings, tropical low clouds in weak subsidence regions are crucial for feedbacks, e.g., seminal study of Vial et al., 2013.
- Introduced adjustments into framework for understanding climate responses.
- Explored lower bound on climate sensitivity (Mauritsen & Stevens, 2014)
- Divergent estimates of climate sensitivity. (more on that, next slide)

Vial et al., *Clim Dyn,* 2013

Climate Sensitivity

1. Some modelling work that suggests feedbacks between 2-3 K is a good null hypothesis
2. The lower sensitivities fit with revised estimates of aerosol forcing (Stevens, 2014) and observational inferences (Otto et al., 2013)
3. But emergent constraints seem to point to larger sensitivities.
4. What is our estimate?



Summary

1. We did an in incredible amount and advanced understanding fundamentally, for instance our picture of feedbacks is now very different … but improving the models is more difficult.
2. Much of the work emphasizes the different ways in which ***lower tropospheric mixing*** processes are crucial, but also … the manner in which ***cloud-radiative effects*** drive circulation changes.
3. Developed and developing new metrics for large-scale dynamics, and preliminary work on on low clouds (this is still coming together).
4. A story on climate sensitivity is emerging. Less than 2K is difficult to reconcile with understanding, above 4K difficult to reconcile with the data.
5. In many ways EUCLIPSE helped launch the WCRP Grand Science Challenge on Clouds Circulation and Climate Sensitivity.

Photo: Frédéric Batier (near Homestead Fl, USA)

Guidance to Parameterization Improvements

Max-Planck-Institut
für Meteorologie

Photo: Frédéric Batier (near Homestead Fl, USA)

If we learned one thing from EUCLIPSE

- lower tropospheric mixing and climate sensitivity
- the influence of changes in the lower tropospheric structure on hydrological sensitivity
- how convective mixing determines the ITCZ position, and this in turn modulates intra-seasonal variability

It is that convective mixing processes and their influence on the structure of the lower tropical troposphere is crucial in determining in the behavior of the general circulation and its susceptibility to perturbations.

But we learned (at least) two things from EUCLIPSE

- ITCZ position and strength as a function of high-cloud radiative effects.
- Effect of low-cloud radiative effects on circulations
- Modulating cloud feedbacks
- Intraseasonal variability, also decadal variability.

… cloud radiative processes are central to the structure of the atmospheric circulation.

Developed & advanced new frameworks

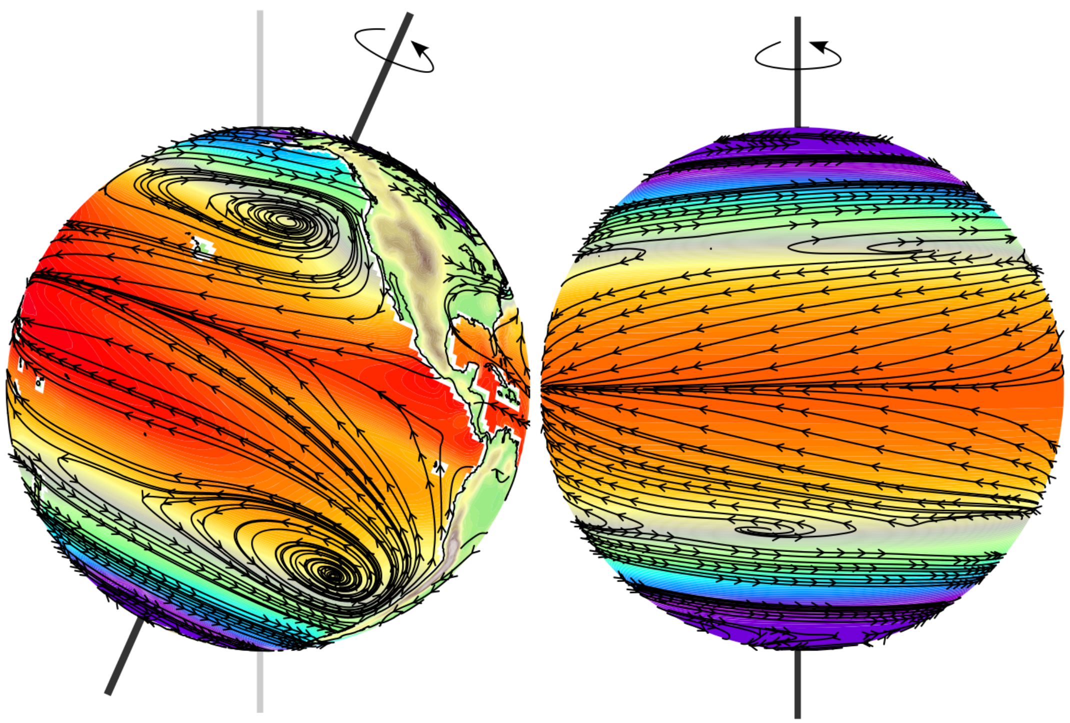


Fig. 2 Illustration of the *left* AMIP and *right* AQUA configurations. *Color shading* shows SST for ocean locations and topography for land locations; *streamlines* show the annual mean flow at 925 hPa

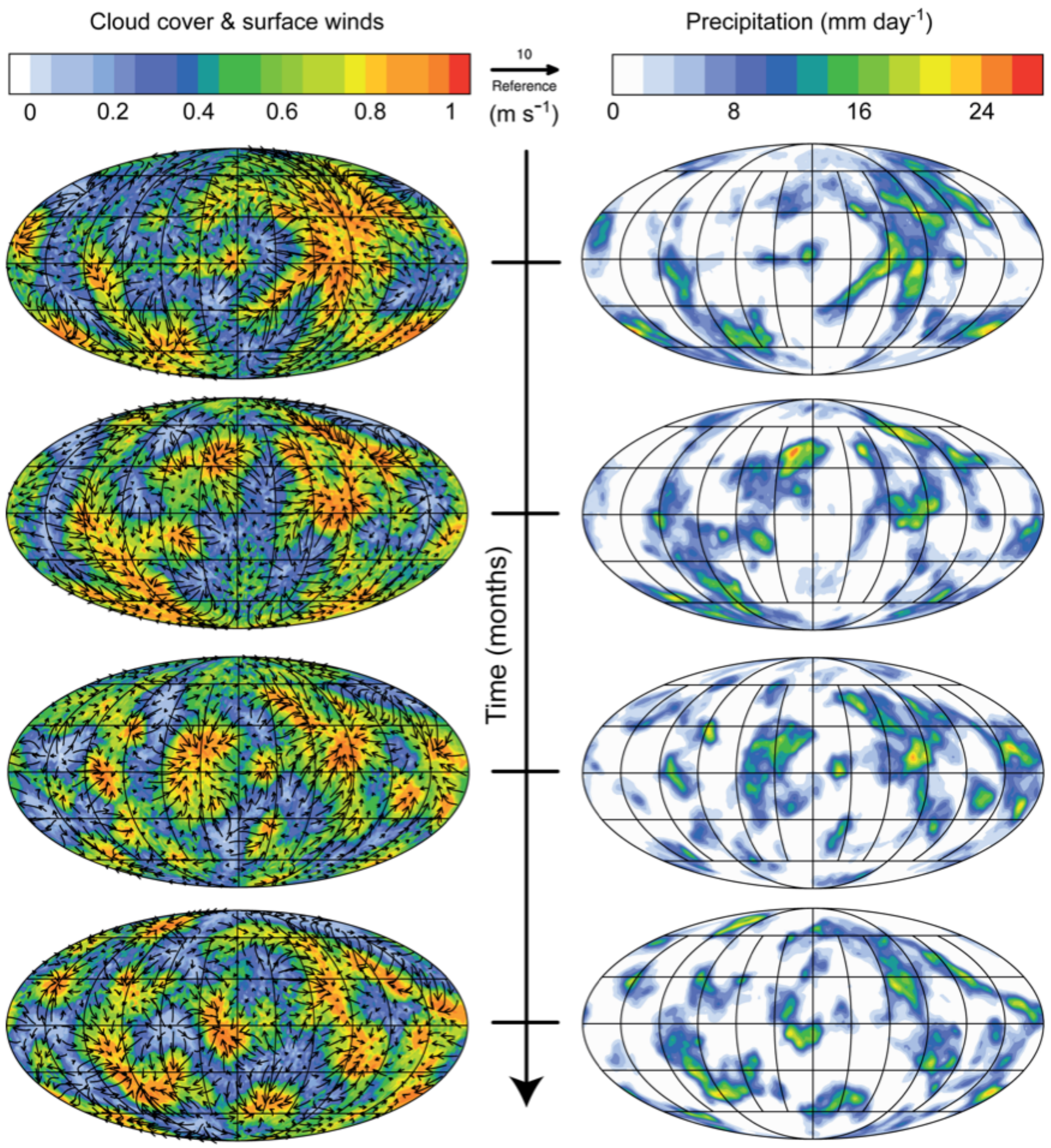


Figure 2. Four snapshots of consecutive monthly averaged (left) cloud cover in contours and surface winds as vectors and (right) precipitation. The RCE model is used with the Nordeng convection scheme.

What we know

- vertical structure and distribution of cloudiness is poorly represented by models
- interactions among parameterizations vary, and play a role in the response of models
- improving models is difficult, as it requires solving many problems at once
- progress is likely to be most lasting by working on simpler problems.

… what are the simpler problems, what is missing from our tool box …

The island problem

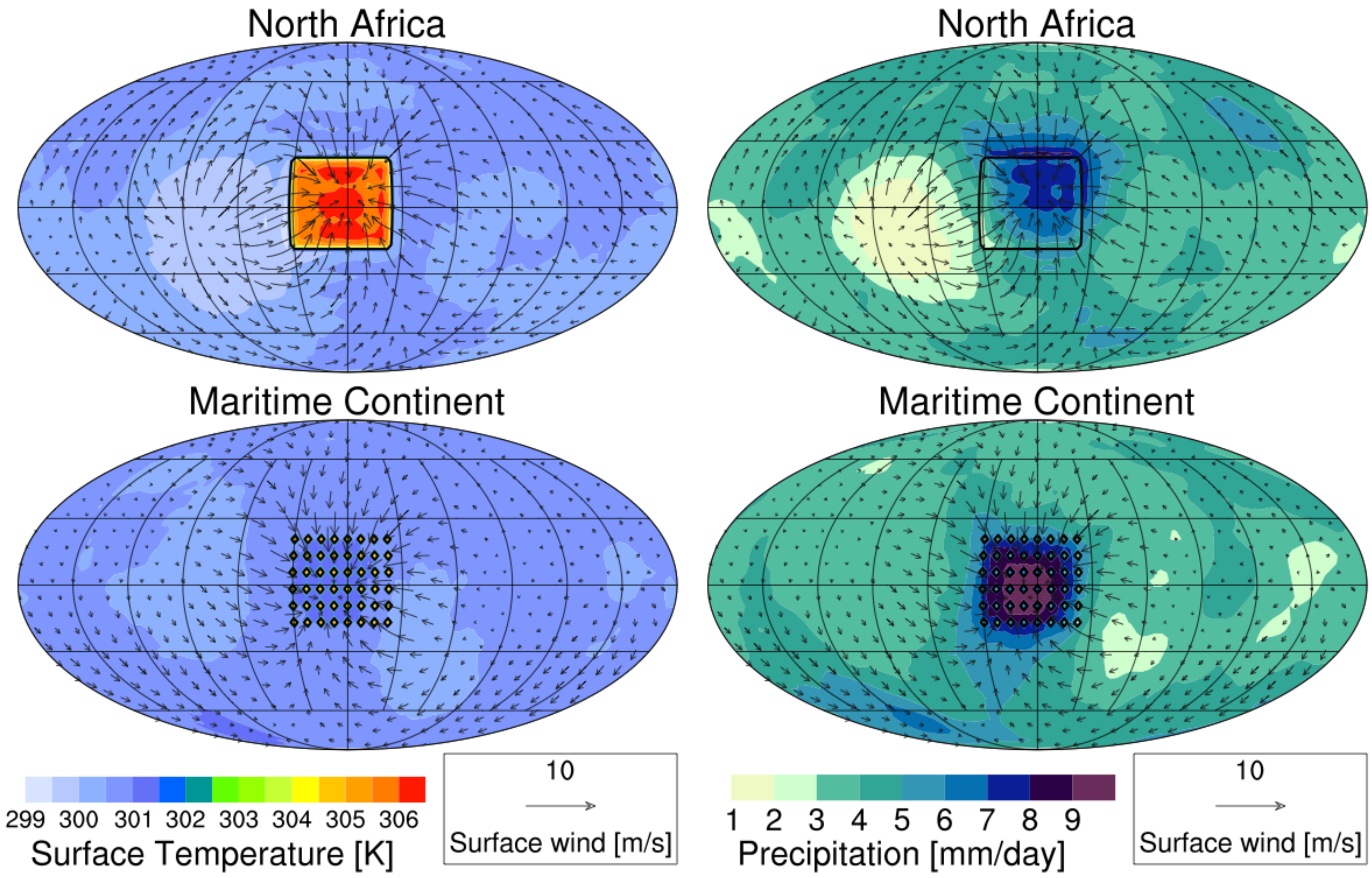
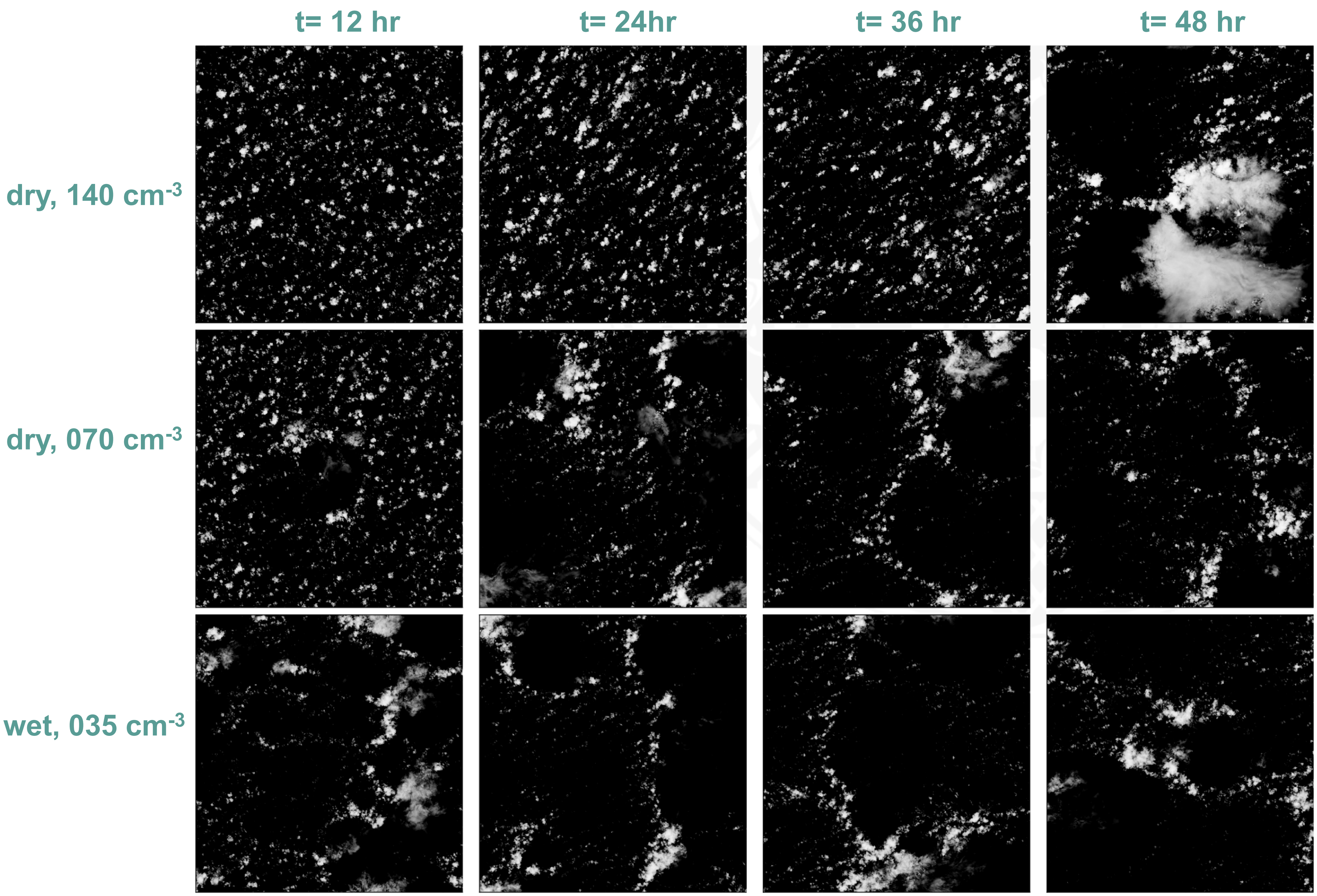


Figure 37: Mean field of surface temperature (left) and precipitation (right) together with the surface wind field for all time steps in equilibrium.

The role of organization



Albedo is controlled by an organizational transition induced by precipitation

See also Stevens and Seifert, *JMSJ* (2008).

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Photo: Bjorn Stevens (Central, Atlantic, around 20 °N)