An overview of EUCLIPSE achievements on :

Evaluation & Understanding of Cloud-Circulation Couplings

Main EUCLIPSE contributors :

Gilles Bellon, Julien Cattiaux, Hervé Douville, Boutheina Oueslati,
Deepa Raveendran Pillai, Romain Roehrig (MF-France-CNRM, France)

Traute Crueger, Benjamin Möbis, Dagmar Popke,
Bjorn Stevens, Aiko Voigt (MPI-M, Germany)

Sandrine Bony, Florent Brient, Frédérique Chéruy, Jean-Louis Dufresne,
Solange Fermepin, Jessica Vial (LMD/IPSL, France)

Hugo Bellenger, Eric Guilyardi (LOCEAN/IPSL, France)

Sandrine Bony (LMD/IPSL, Paris)
EUCLIPSE/CFMIP Meeting on Cloud Processes and Climate Feedbacks
Egmond aan Zee, The Netherlands, July 8-11 2014

EUCLIPSE addressed two overarching questions :

How does the representation of cloud and moist processes influence :

- **simulations of the current climate :**
  - the mean tropical precipitation and large-scale circulation
  - the tropical variability at intra-seasonal and inter-annual timescales
  - temperatures over Europe

- **predictions of the climate response to external perturbations:**
  - Climate Sensitivity
  - Temperatures over Europe
  - Precipitation changes

→ **Evaluation & Understanding**

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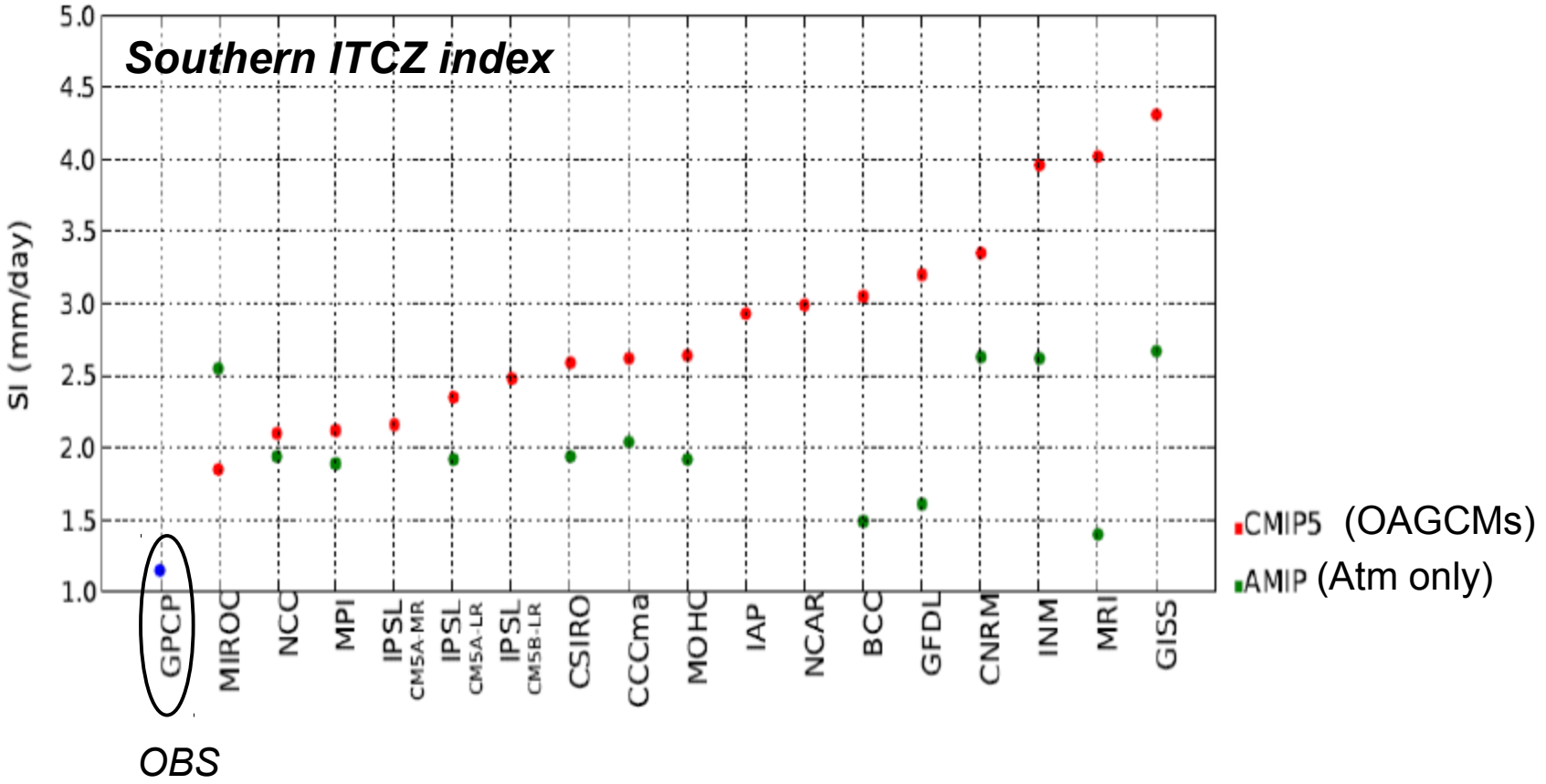
→ **Evaluation & Understanding**

Simulation of the ITCZ by CMIP5 models

Most CMIP5 models exhibit a spurious double ITCZ



Oueslati and Bellon, submitted

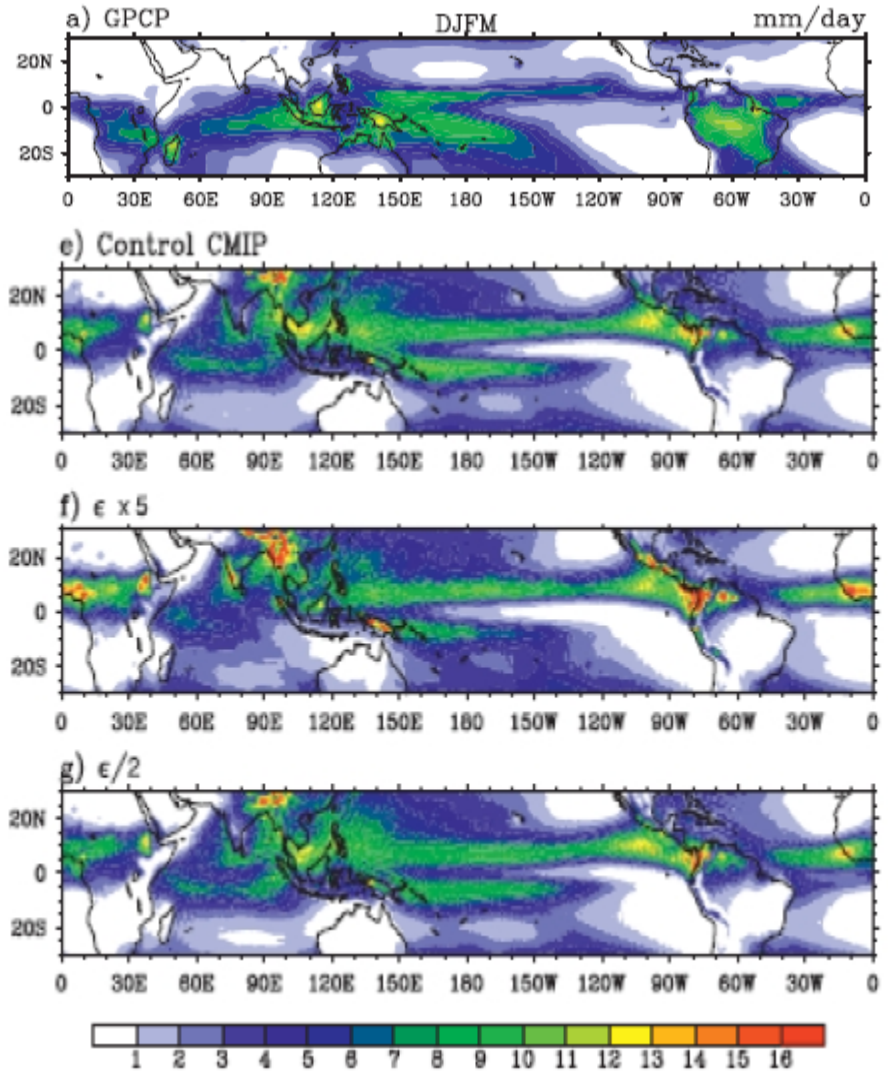
Impact of convective entrainment on the structure of the ITCZ

GPCP

control

increased entrainment

reduced entrainment

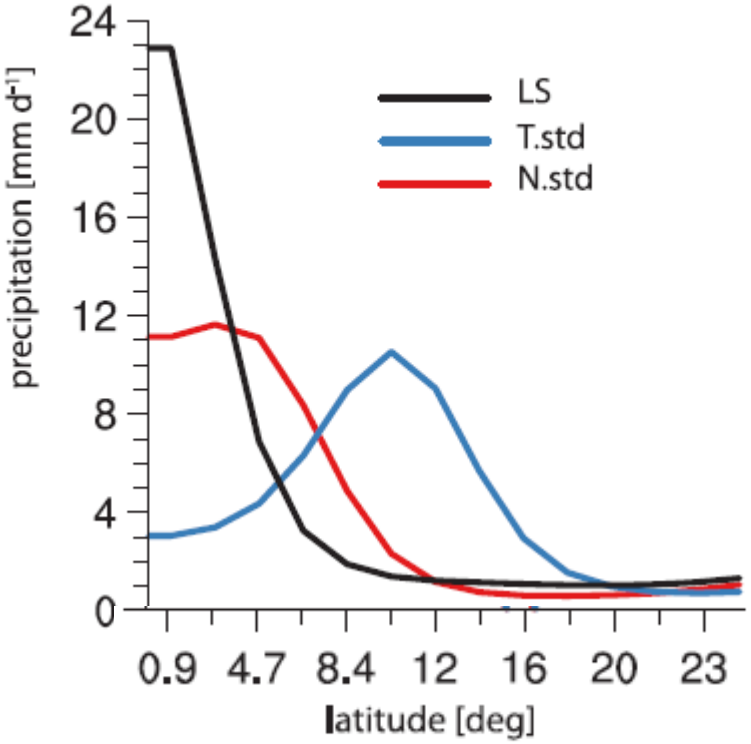


In the CNRM-CM5 model, the structure of the ITCZ is much improved when convective entrainment is increased

Oueslati and Bellon, J. Climate, 2013

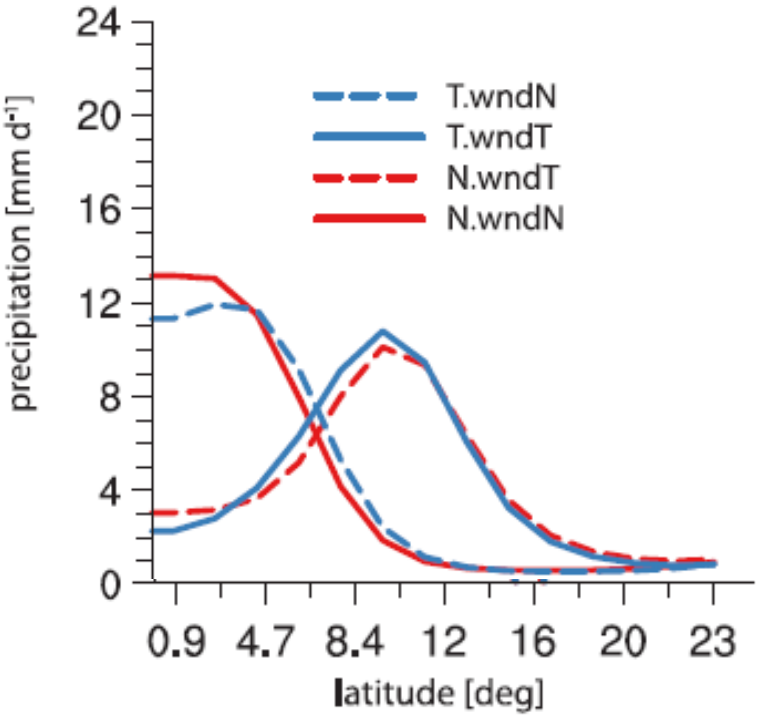
Impact of convective processes on the structure of the ITCZ

In ECHAM6, the structure of the ITCZ strongly depends on the representation of convection (entrainment, free tropospheric moistening):



Tiedtke vs Nordeng convection schemes

Much of this dependence relates to the coupling between convection and circulation (surface winds), which controls the PBL MSE

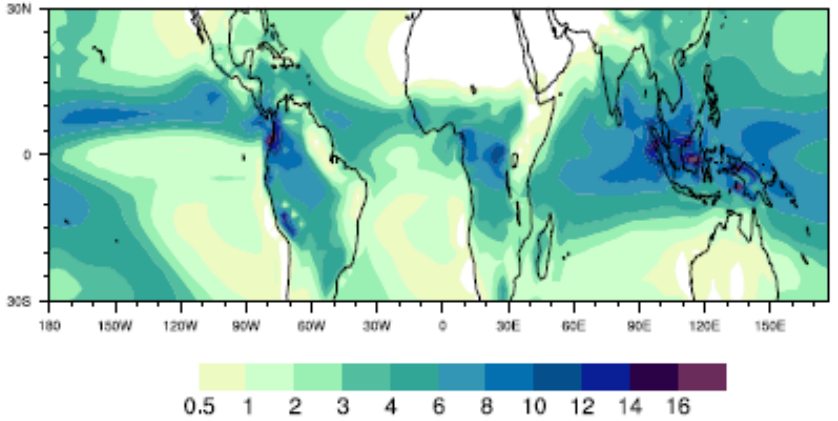


Surface wind imposed in surface flux calculations

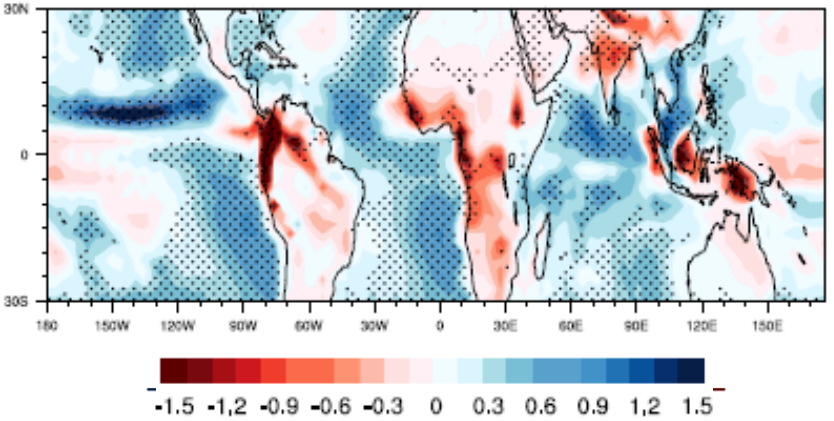
Möbis and Stevens, JAMES, 2012

Impact of low-cloud radiative effects on tropical precipitation and circulation

Precipitation climatology



Impact of low-cloud radiative effects



Low-cloud radiative effects :

- increase precipitation over ocean, both in convective and subsidence areas
- enhance surface evaporation
- strengthen the large-scale overturning circulation and surface winds

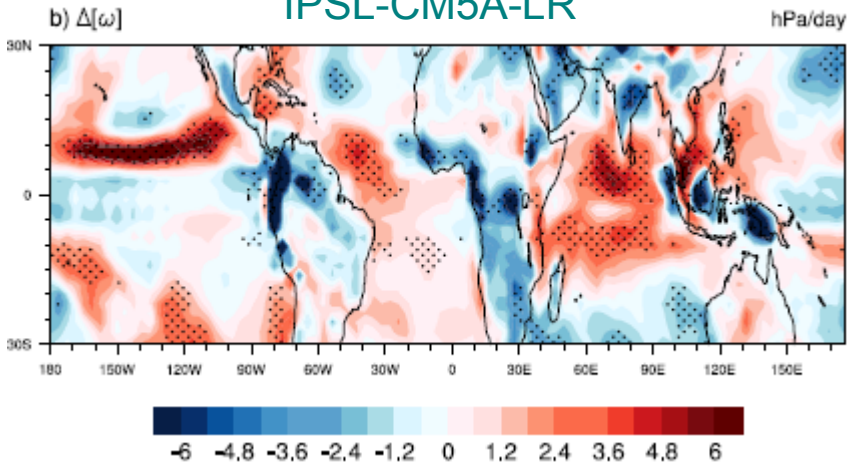
Interpretation (MSE budget analysis) :

- Primarily results from the coupling between low-cloud radiative effects and surface turbulent fluxes

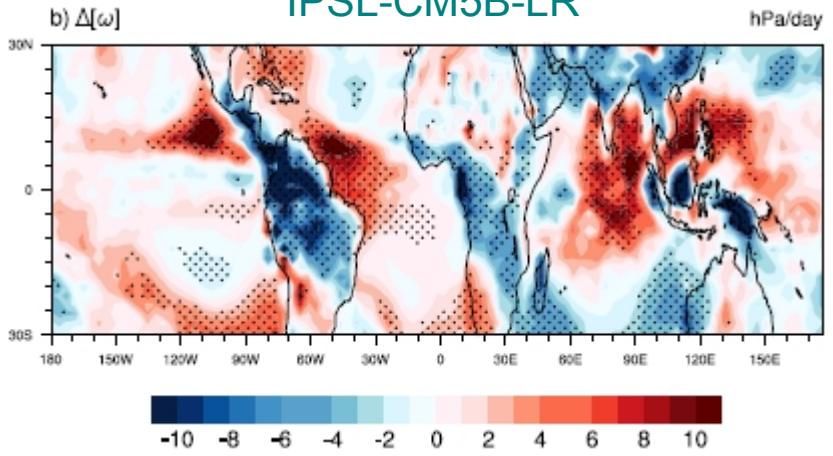
Fermepin & Bony, JAMES, 2014

Impact of low-cloud radiative effects on circulation robust across EUCLIPSE/COOKIE experiments

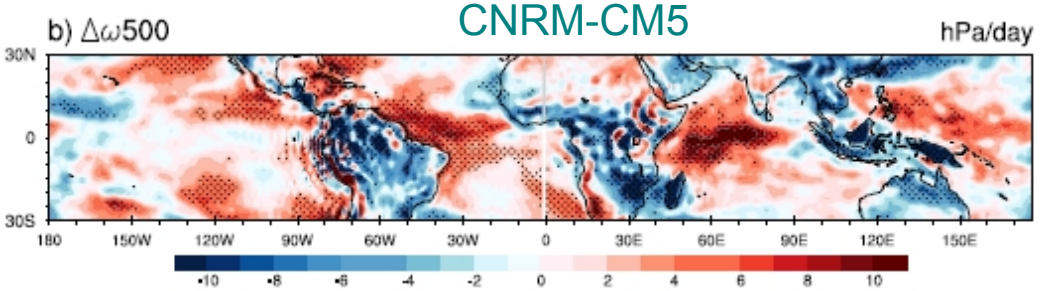
IPSL-CM5A-LR



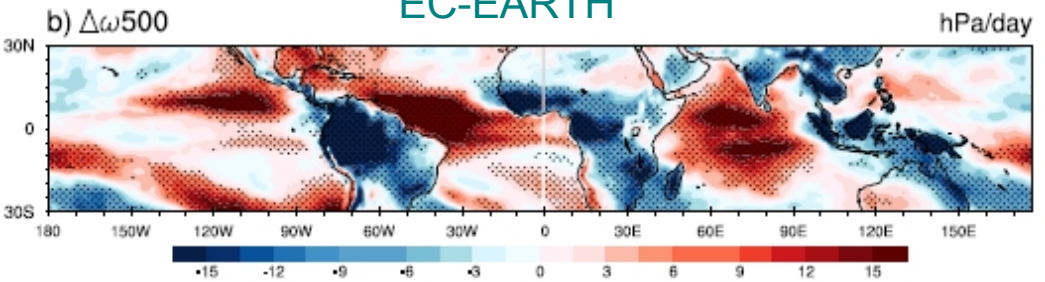
IPSL-CM5B-LR



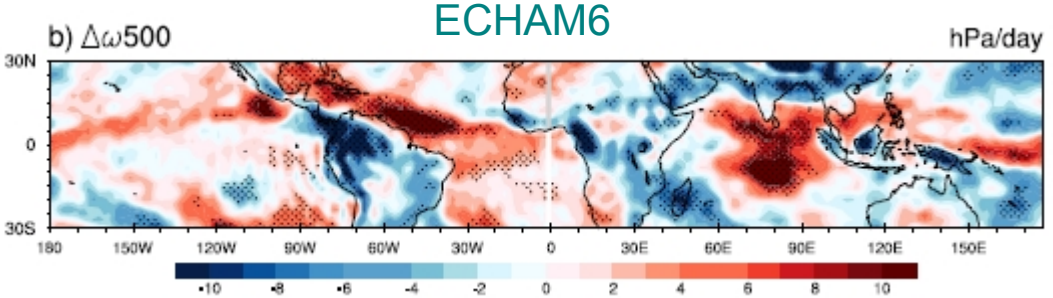
CNRM-CM5



EC-EARTH

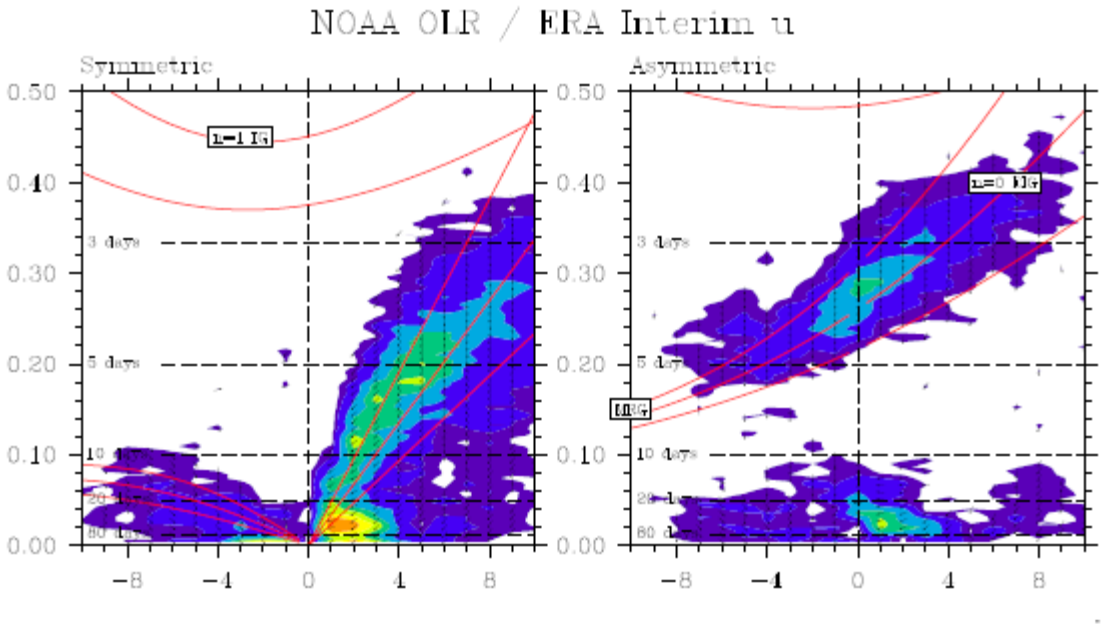


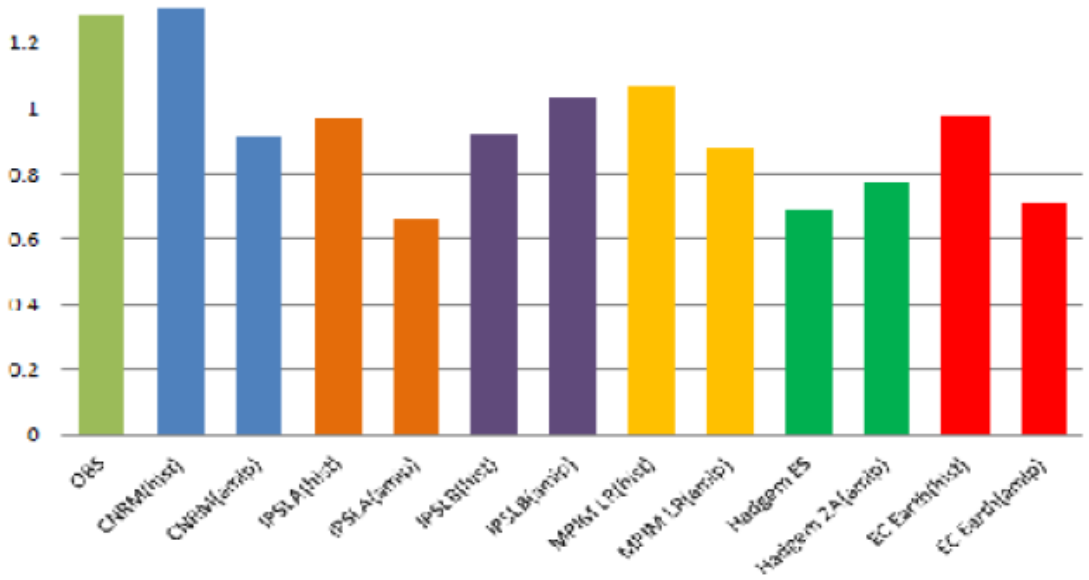
ECHAM6



PhD thesis S. Fermepin (LMD/IPSL)

Simulation of the tropical intra-seasonal variability (MJO) by CMIP5 models





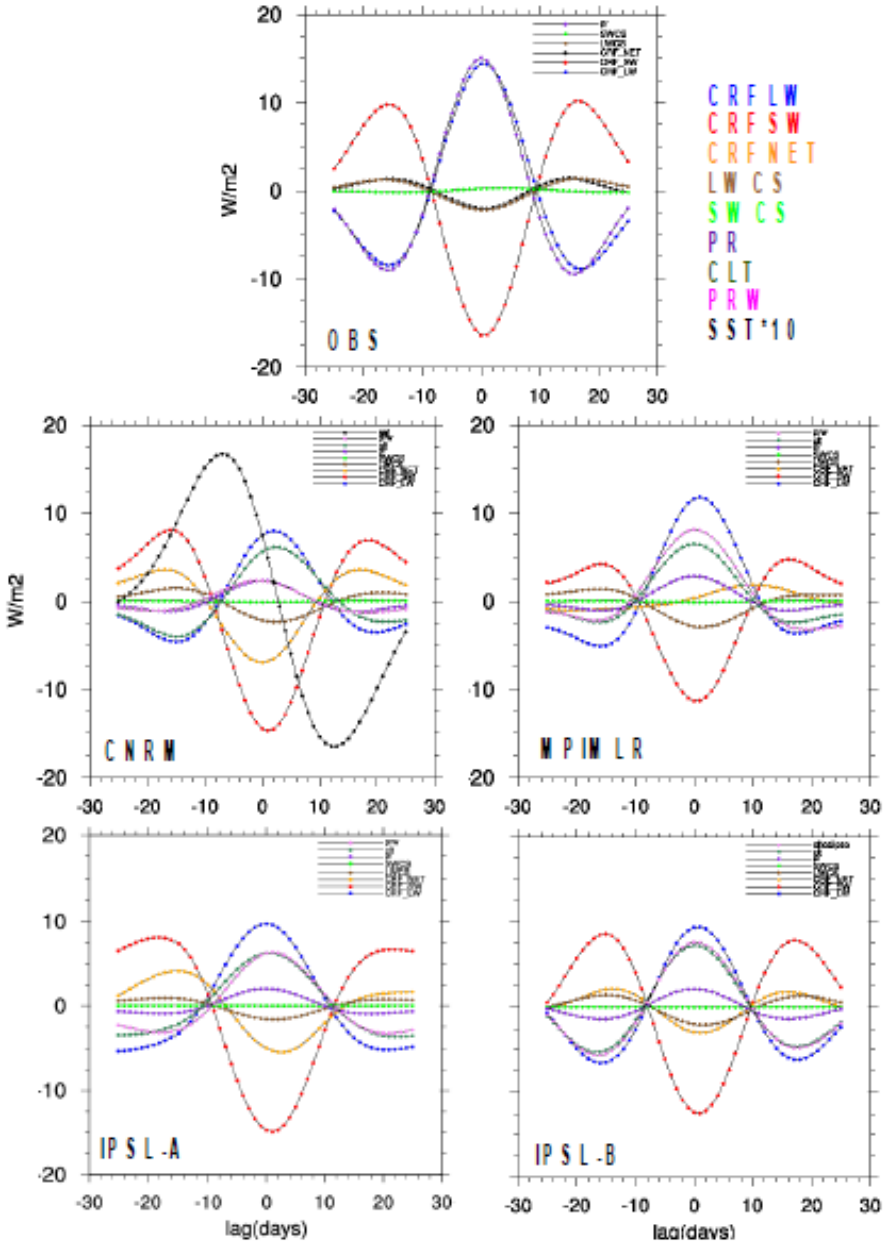
Tropical intra-seasonal variability is characterized by a spectrum with larger power of eastward propagating than westward propagating disturbances

Most models struggle to simulate more eastward than westward propagation.

Ocean-atmosphere coupling generally helps, but it is not systematic

Bellon et al, in preparation

On the role of cloud-radiative effects in tropical intra-seasonal variability (MJO)



Observations suggests that atmospheric radiative heating and precipitation are almost out of phase

Phase relationships between radiative heating and precipitation very variable across models

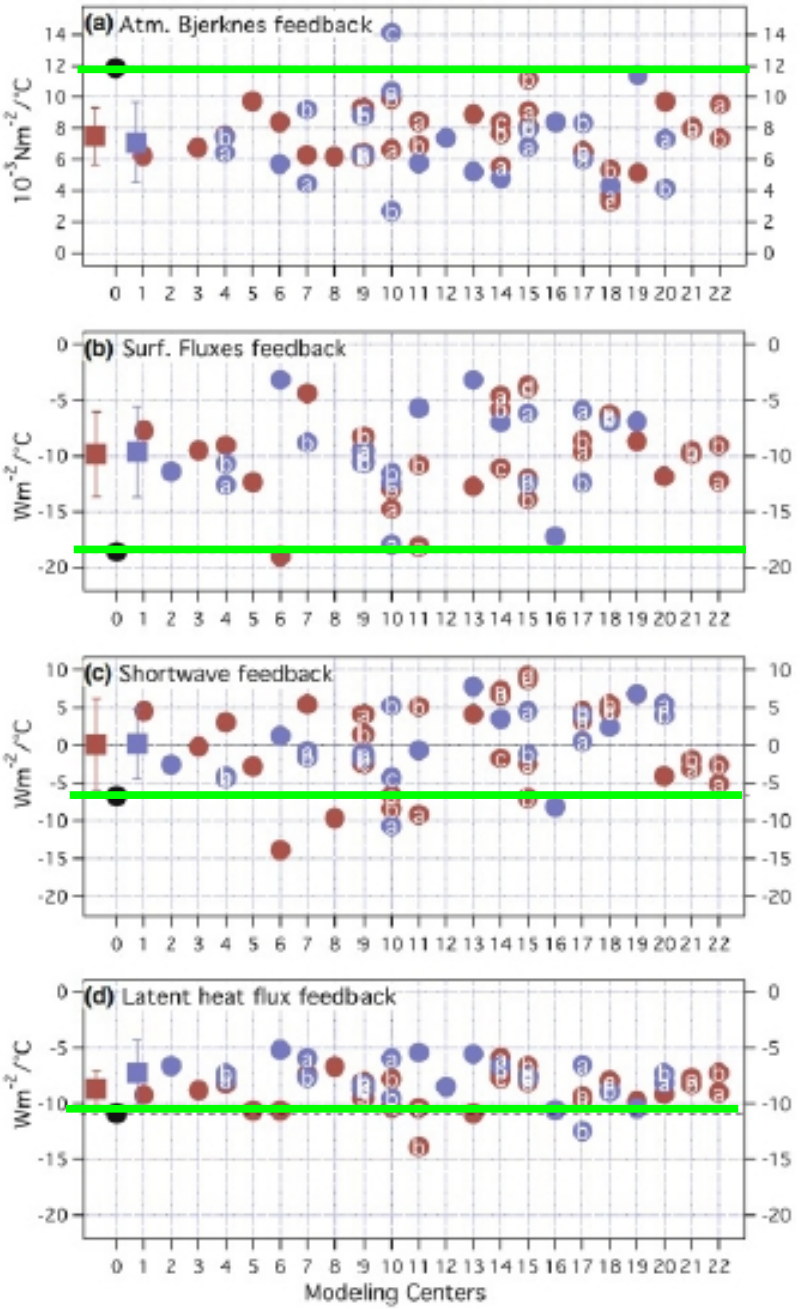
Model biases in radiation primarily due to cloud-radiative effects

Likely to explain part of the model biases, but no systematic link

Explored further using EULIPSE/COOKIE experiments

Bellon et al, in preparation
Crueger and Stevens, in preparation

Simulation of the tropical inter-annnal variability (ENSO) by CMIP5 models



Evaluation of atmosphere feedbacks during ENSO :

Bjerknes feedback (wind stress / SST)

Heat flux feedback (sfc heat flux / SST)
- total
- SW component
- LH component

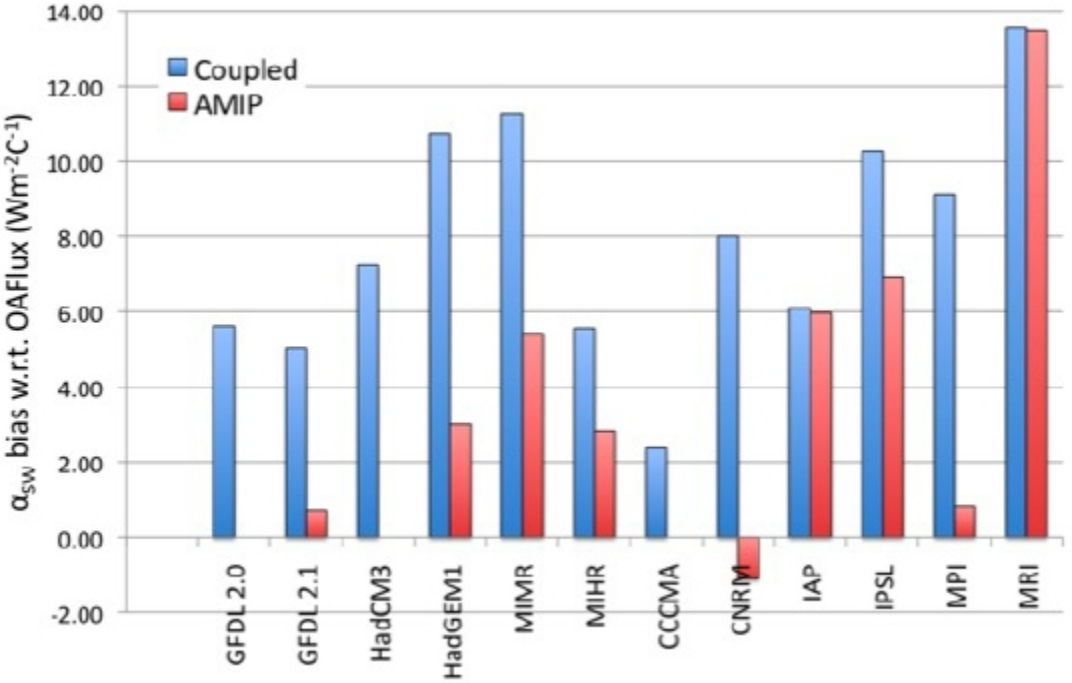
Observations / Ref dataset: green lines

Models under-estimate the dynamical response during El-Ninos.

Large biases in the SW cloud feedback

Bellenger, Guilyardi et al, Clim. Dyn., 2014

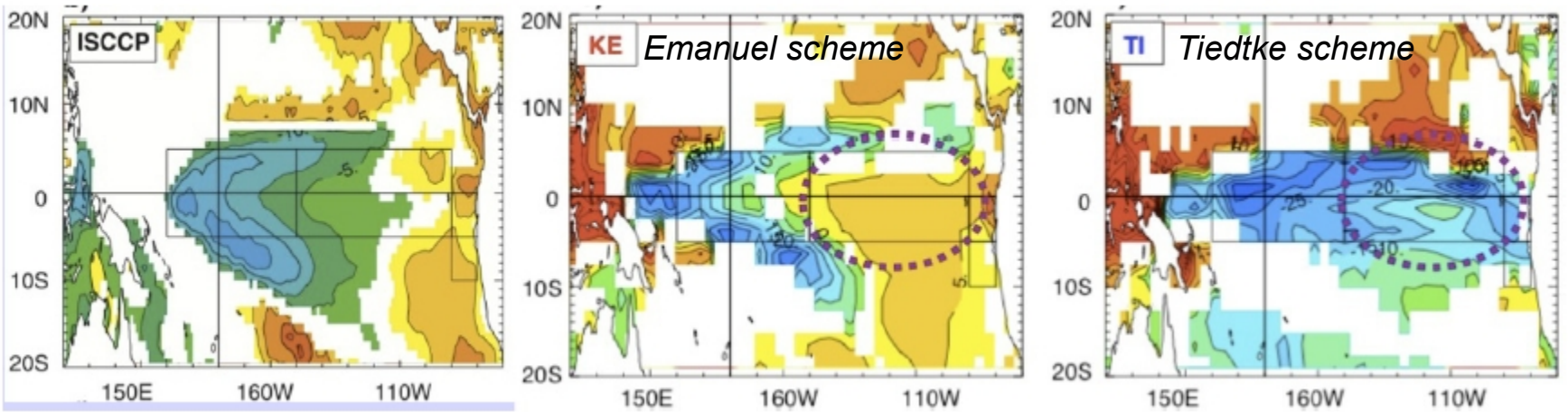
On the role of cloud-radiative effects in tropical inter-annual variability (ENSO)



Large biases in the SW component of the heat flux feedback.

Primarily related to a wrong shift in dynamical regimes with SST, and therefore to a wrong dynamical component of cloud changes.

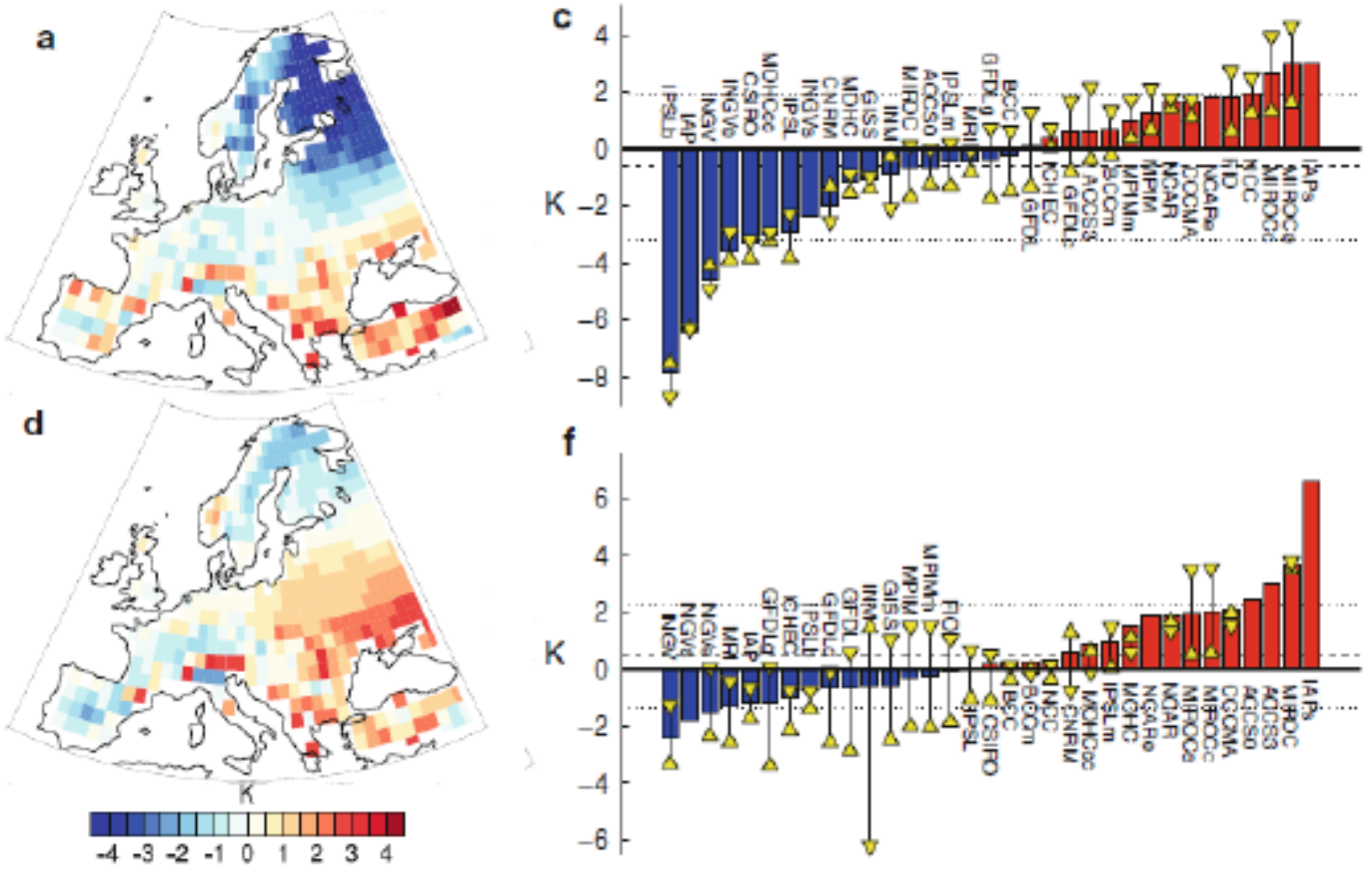
Strong dependence on the convection scheme :



Lloyd et al, Clim. Dyn, 2011
Guilyardi et al., J. Climate, 2009

Simulation of European temperatures by CMIP5 models

Significant biases in the simulation of present-day temperatures



Winter:
Cold bias in Northern Europe;
Large inter-model spread;
Not primarily a dynamical effect
(analysis of weather regimes)

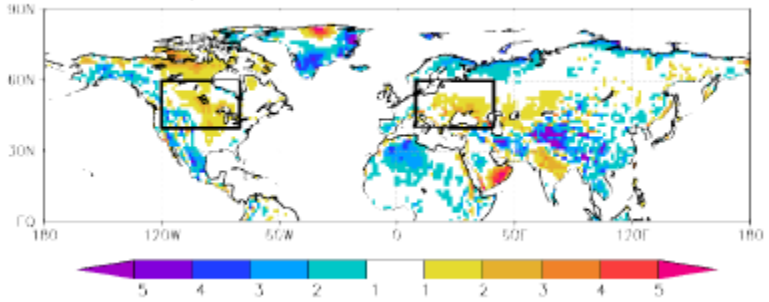
Summer:
Warm bias in Central & Eastern Europe

Cattiaux, Douville and Peings, Clim. Dyn, 2013

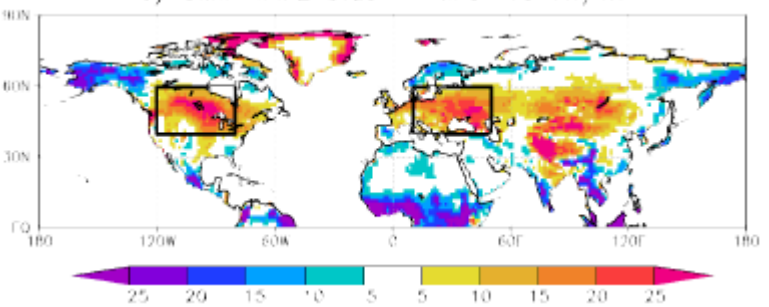
On the role of cloud-radiative effects in the simulation of European temperatures

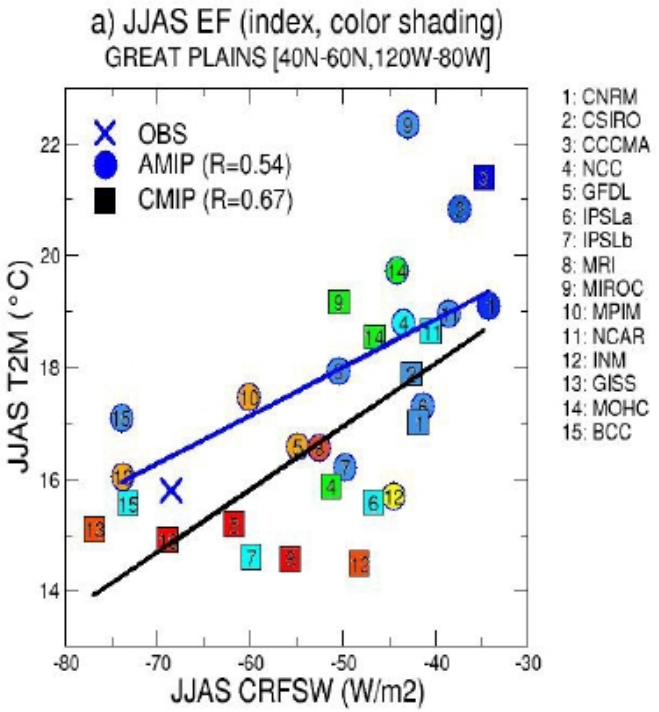
The higher the underestimate of the SW CRE amplitude, the warmer the bias

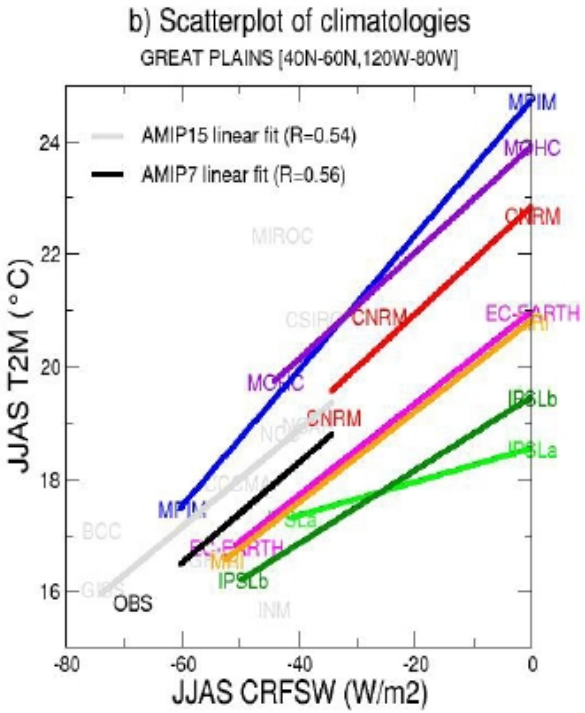
CMIP MME bias in temperature



CMIP MME bias in SW CRF







COOKIE experiments : confirmation of the major impact of cloud-radiative effects on European temperatures

Douville, Beau, Cattiaux, Tyteca, in preparation

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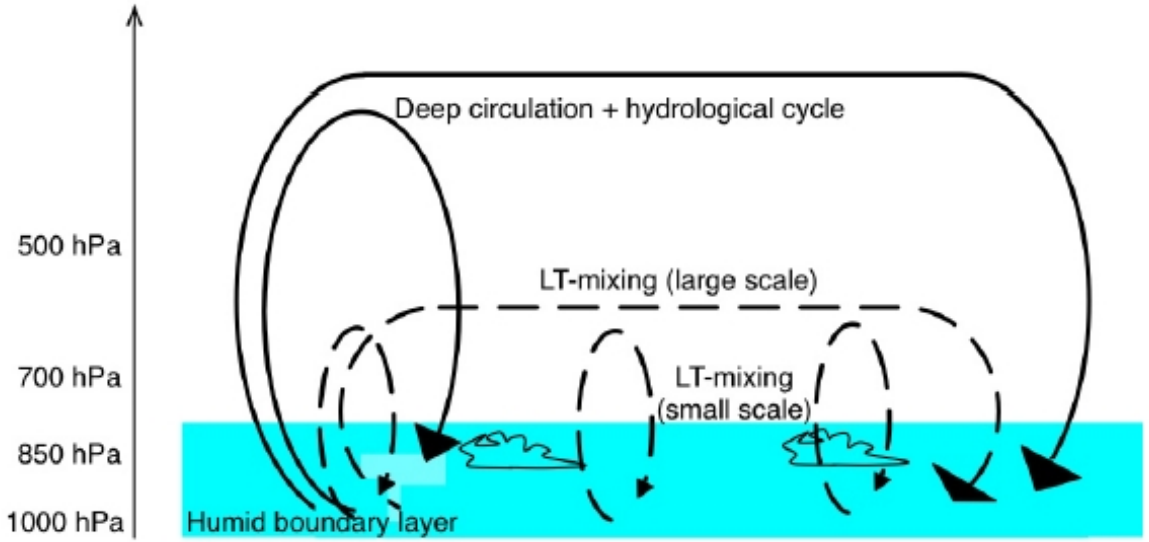
→ **Evaluation & Understanding**

Cloud-Circulation coupling & Climate Sensitivity

The coupling between clouds and circulation found to be critical for Climate Sensitivity



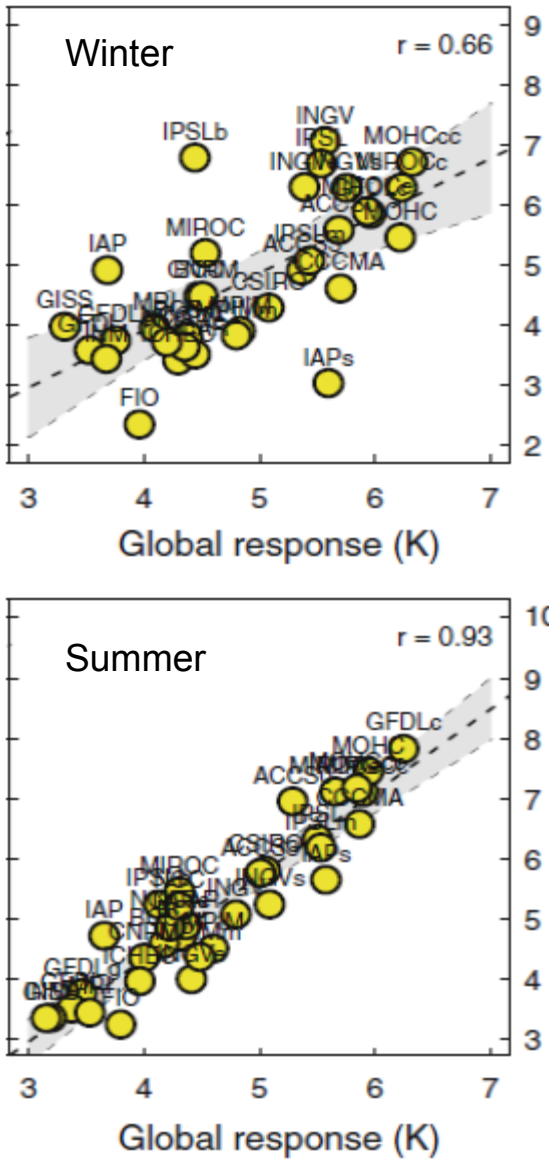
Transport of water vapour out of the low-cloud layer by shallow circulations found to play a critical role in low-cloud feedbacks

Suggests that models with more shallow circulation have higher climate sensitivity

cf Pier's talk

Sherwood, Bony and Dufresne, Nature, 2014

Changes in European temperatures under RCP8.5



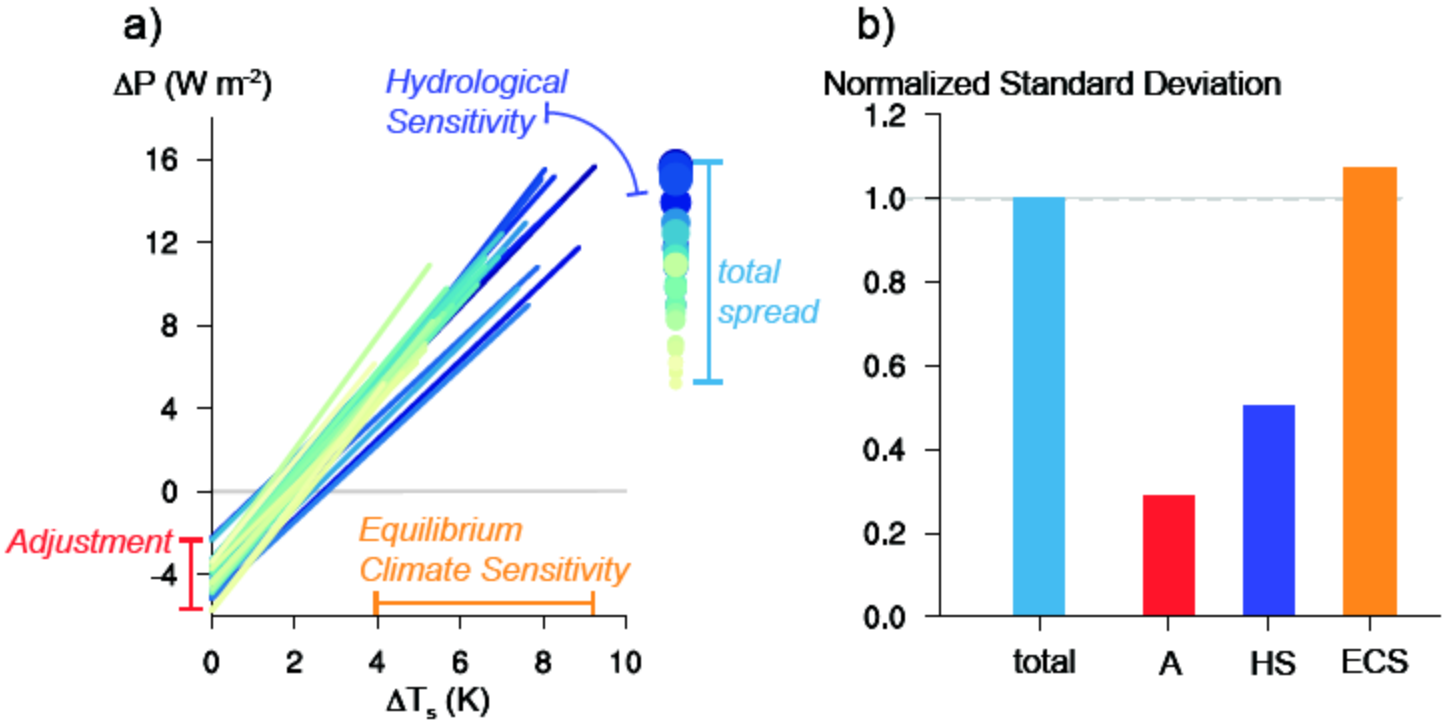
Strong relationship between European and global temperature changes, especially in Summer.

Constraining cloud feedbacks, and thus Climate Sensitivity, is probably the most efficient way to constrain regional changes in both mean and extreme temperatures.

Cattiaux, Douville and Peings, Clim. Dyn, 2013

Hydrological Sensitivity

Improved assessment and interpretation of the inter-model spread in global-mean precipitation changes under increased CO2



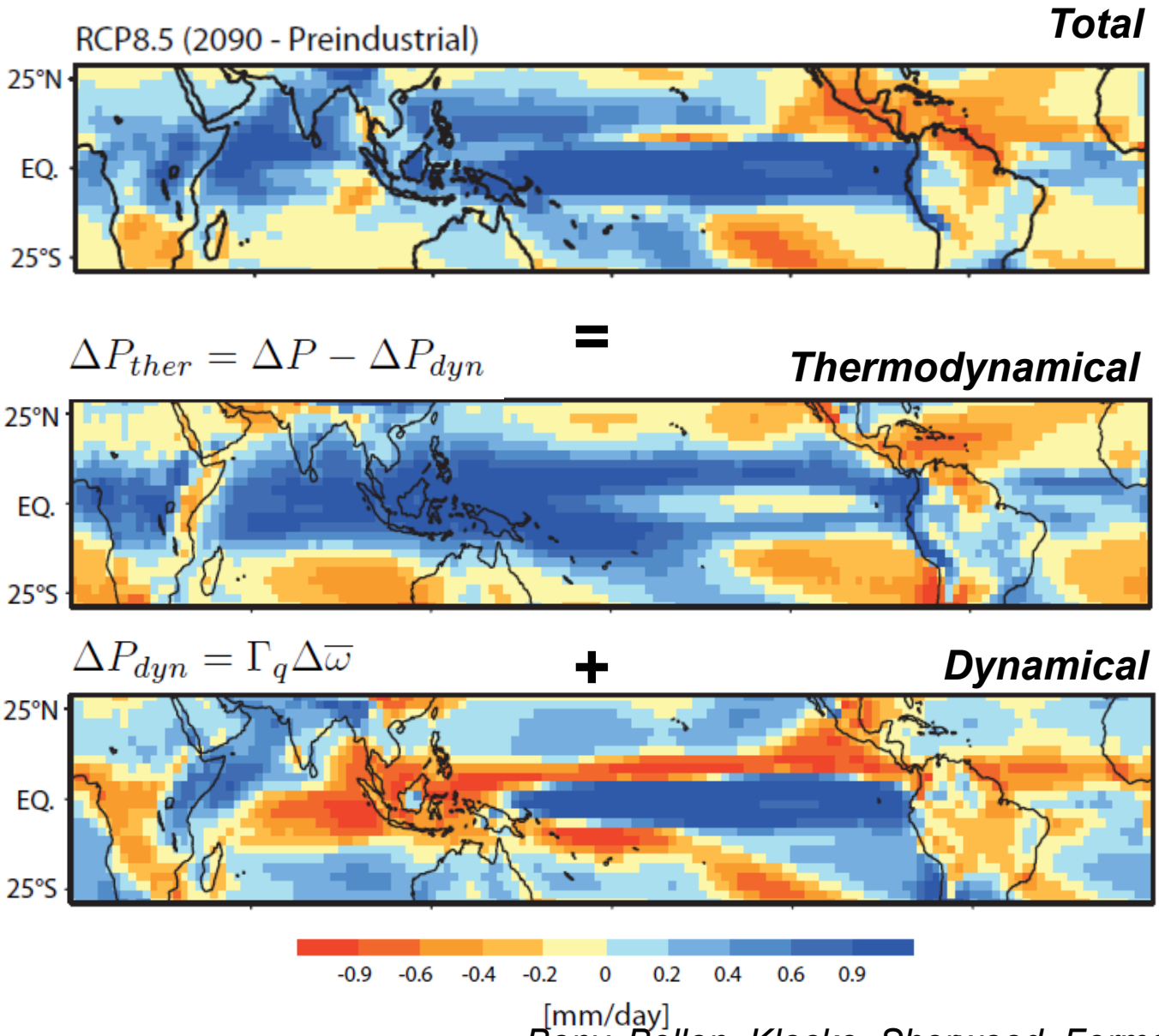
Spread in global-mean precipitation changes primarily due to the spread in ECS

Important role of lapse-rate, water vapor and cloud feedbacks in Hydrological Sensitivity

Popke, Mauritsen and Stevens, in preparation

Regional Precipitation Changes

Precipitation projections at the end 21C under RCP8.5



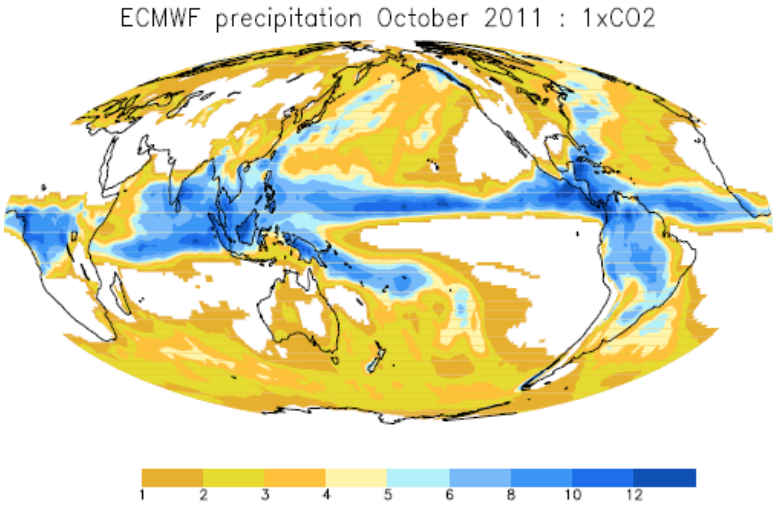
Decomposition of thermodynamical and dynamical component of precipitation projections

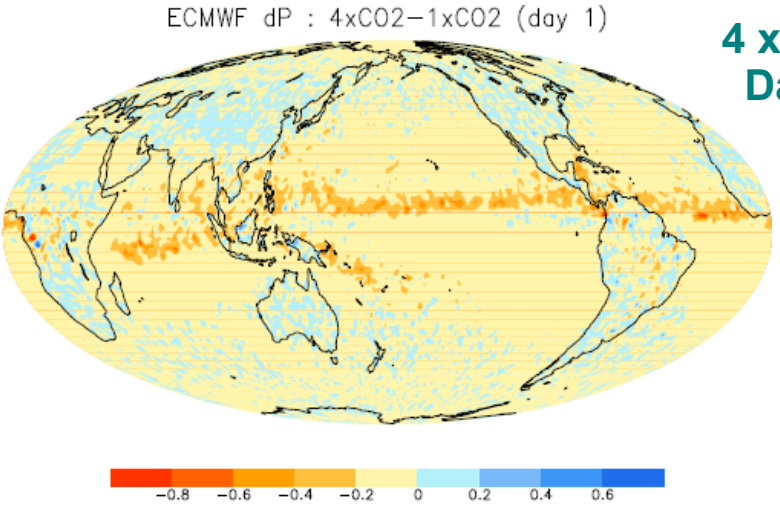
Most of the spread in regional precipitation projections arises from the dynamical component

Bony, Bellon, Klocke, Sherwood, Fermepin and Denvil, Nature Geosci. 2013

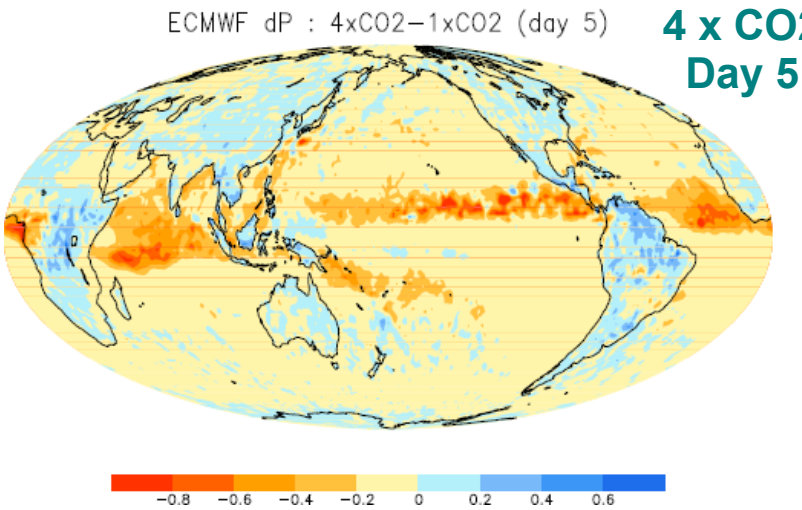
Direct (and fast) Effect of CO2 on Circulation and Precipitation

1 x CO2

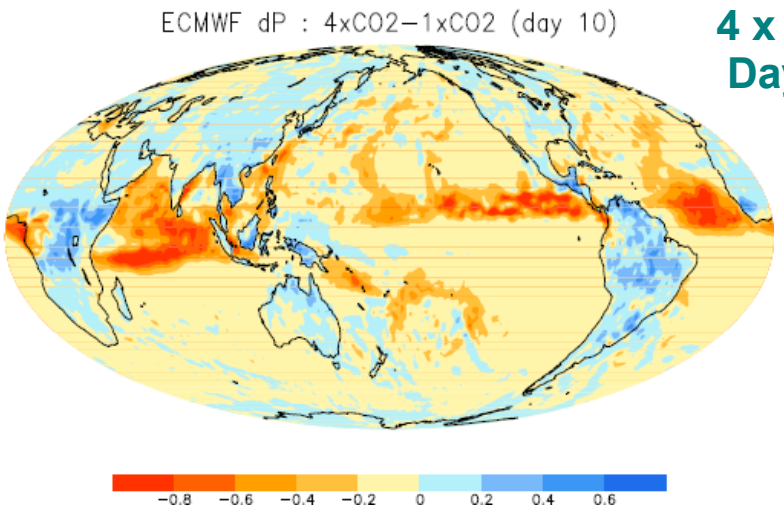




4 x CO2 Day 1



4 x CO2 Day 5

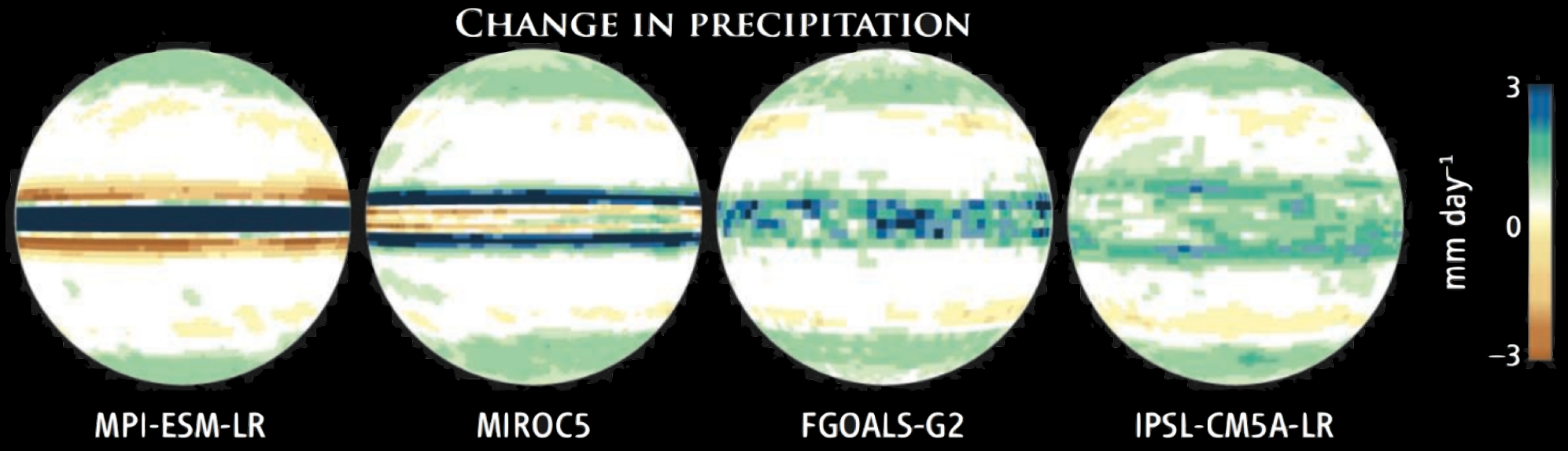


4 x CO2 Day 10

Bony, Bellon, Klocke, Sherwood, Fermepin and Denvil, Nature Geosci. 2013

Changes in tropical circulation and precipitation

CMIP5 Aqua-Planets (+4K - CTRL)

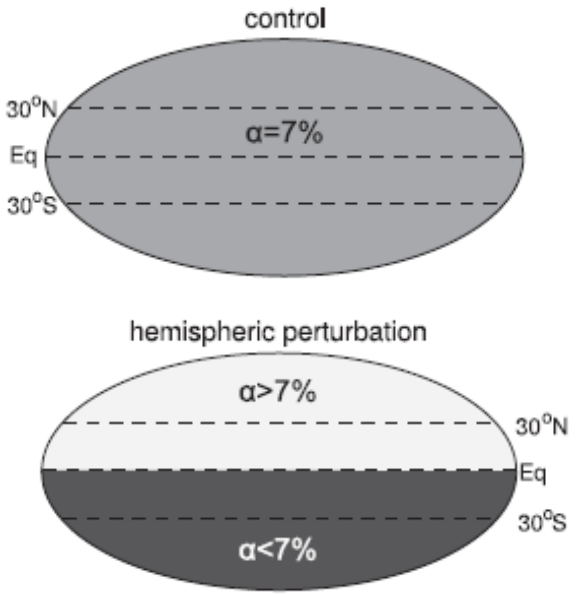


Critical role of cloud-circulation couplings in controlling patterns of precipitation response

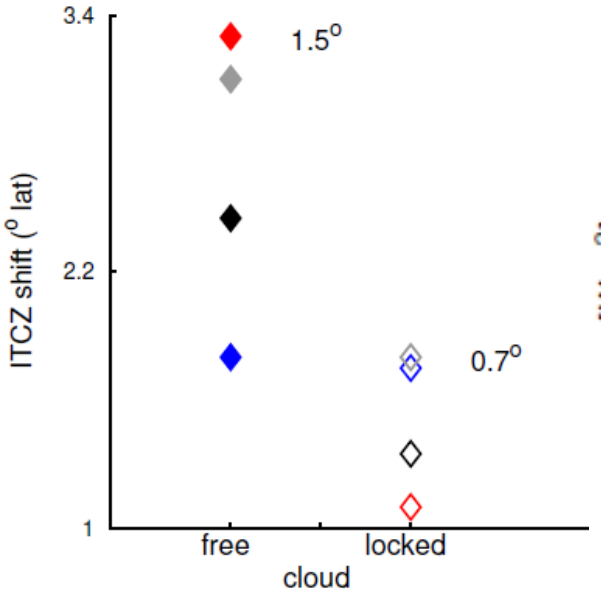
Stevens & Bony, Science, 2013
Medeiros, Stevens & Bony, Clim. Dyn., 2014

Changes in tropical circulation and precipitation

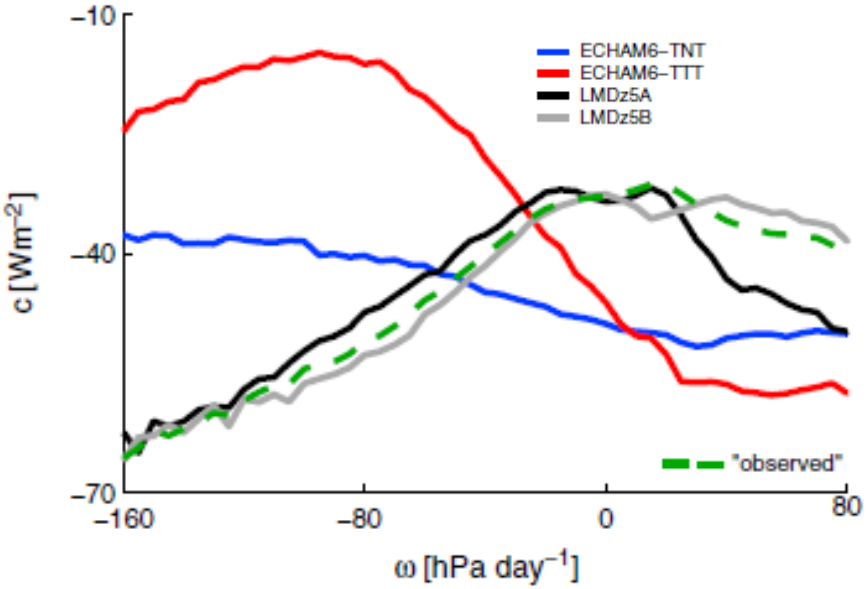
Shifts of the ITCZ induced by an external perturbation strongly depend on cloud-radiative feedbacks



ITCZ shift with/without cloud-radiative feedbacks



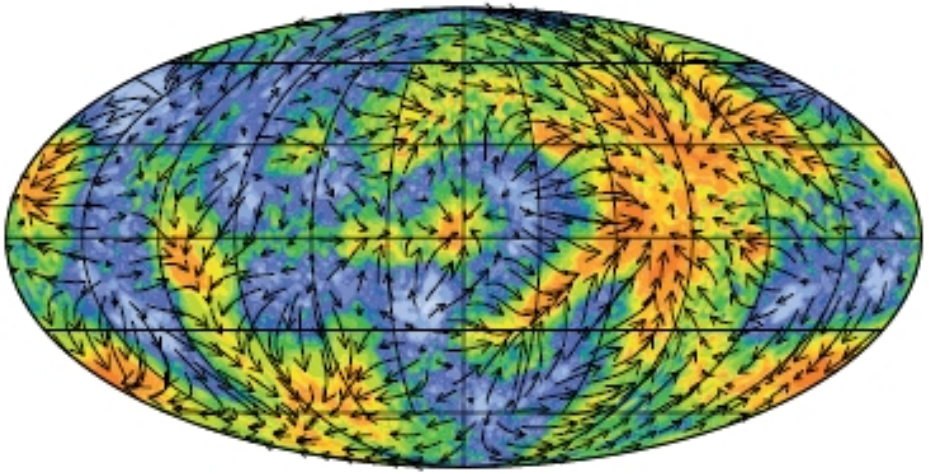
cloud-radiative effects vs circulation

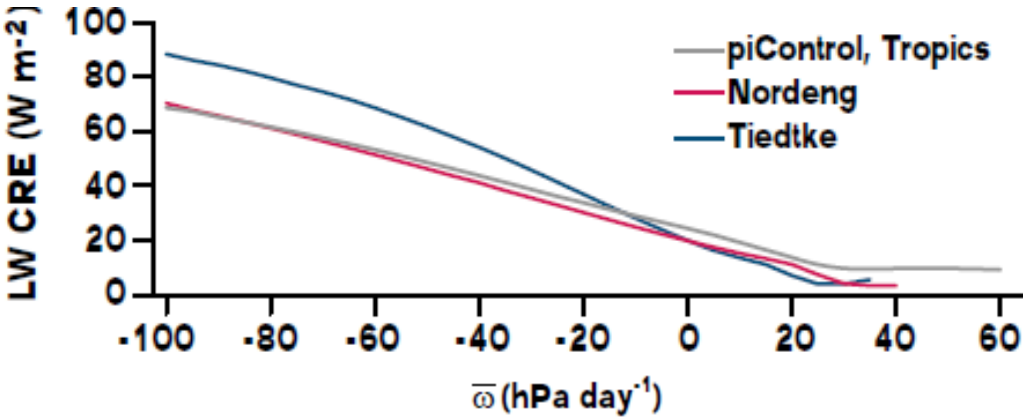


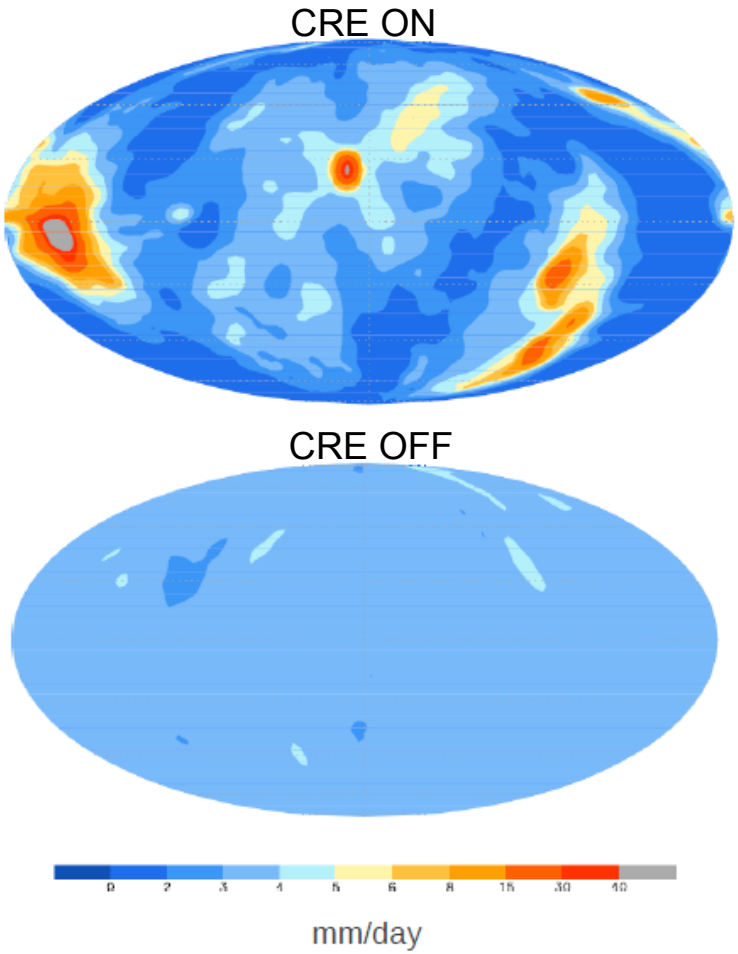
Voigt, Bony, Dufresne and Stevens, GRL, 2014
Voigt, Stevens, Bader and Mauritsen, J. Climate, 2014

Convective Aggregation, Circulation & Climate

Running GCMs in RCE configuration :
Great opportunity to study cloud-circulation couplings and their role in climate







Popke, Stevens and Voigt, JAMES, 2013
Mauritsen and Stevens, submitted
Coppin, Bony et al., in preparation

CONCLUSION

Significant contributions of EUCLIPSE to the evaluation and understanding of the large-scale atmospheric circulation, natural climate variability, precipitation and European temperatures in the present-day climate and in climate change.

EUCLIPSE has demonstrated that clouds and moist processes are not only critical for Climate Sensitivity, but also for many other fundamental aspects of the Earth system.

Continuing efforts on these issues will undoubtedly lead to substantial advances in the development of Earth System Models and in our assessment of robust responses of the Earth climate to natural and anthropogenic perturbations.

The focus of a next project ?