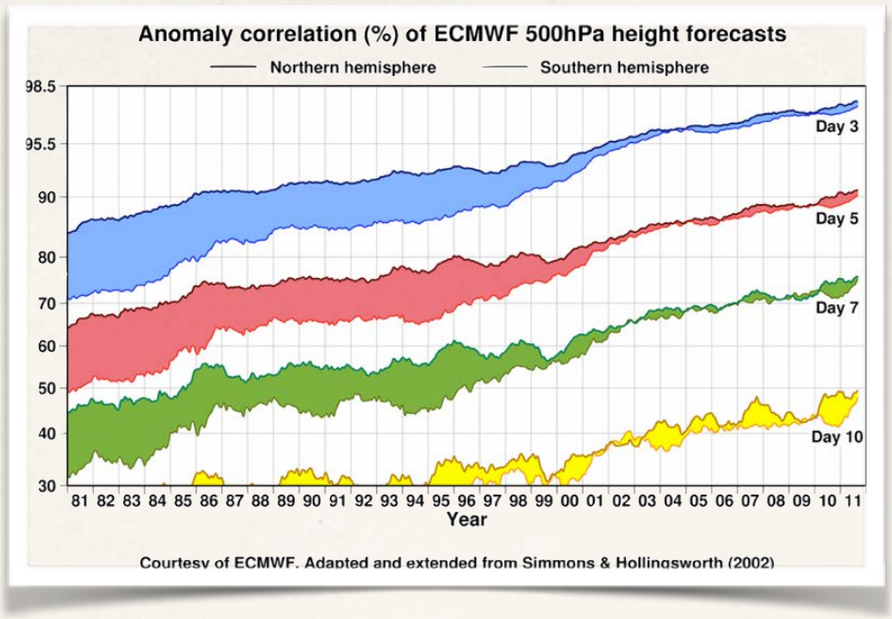
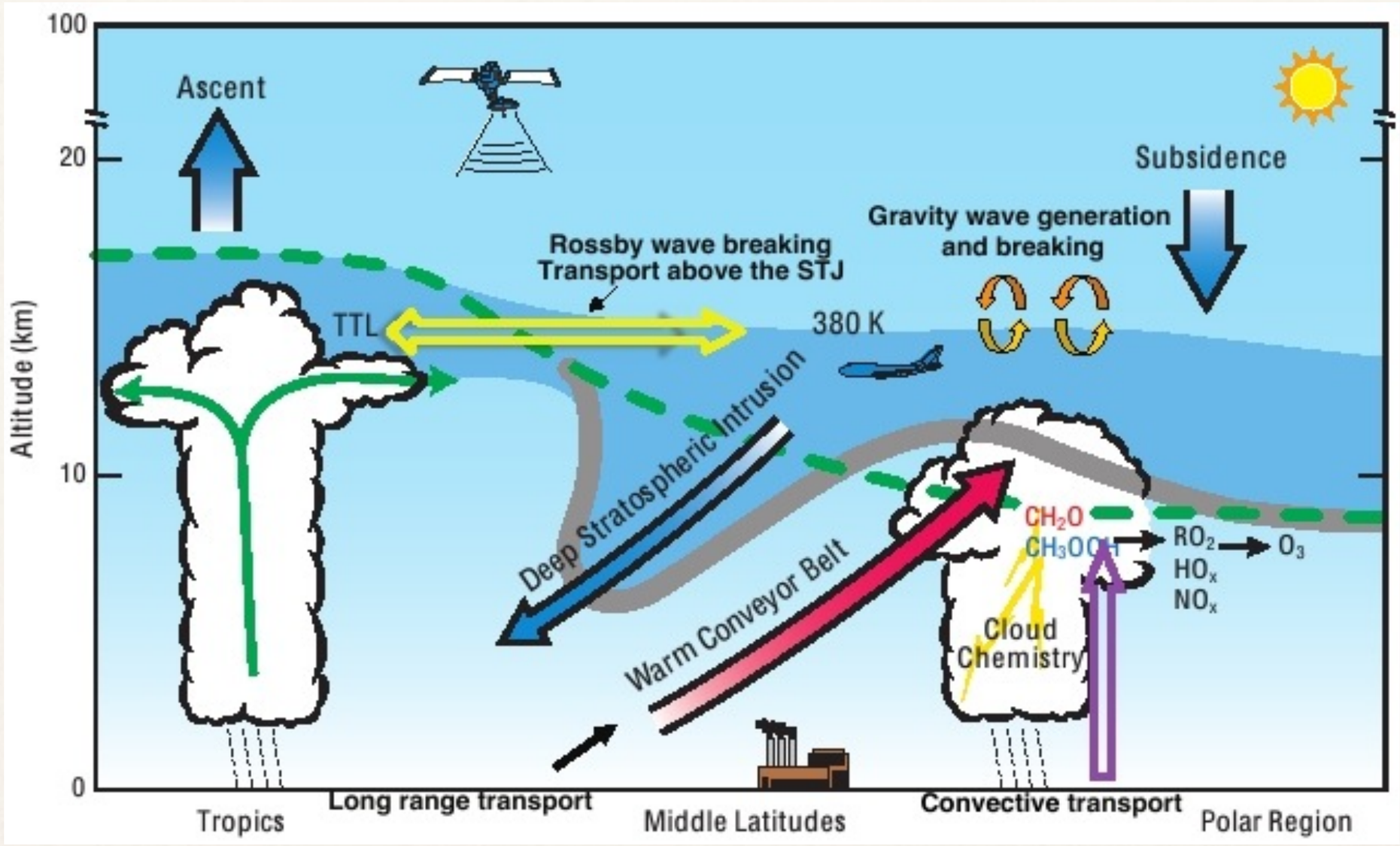


Long-standing errors in climate models - why might you care?

Christian Jakob, ARC Centre of Excellence for Climate System Science, Monash University, Melbourne, Australia

Special Thanks: My Friends And Colleagues On Ipcc Chapter 9

This is going to be a talk about water in the troposphere, so why would you care?



NCAR Atmospheric Chemistry Division

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All weather and climate predictions are based on models

$$\frac{du}{dt} - \left(f + u\frac{\tan\phi}{a}\right)v = -\frac{1}{a\cos\phi\,\rho}\frac{1}{}\frac{\partial p}{\partial\lambda} + F_\lambda$$

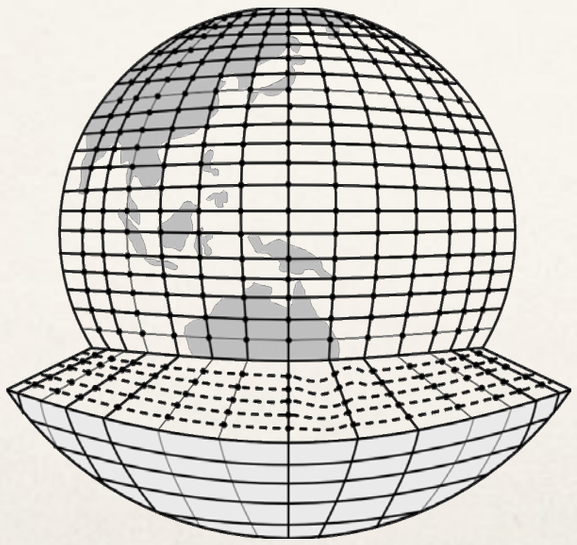
$$\frac{dv}{dt} + \left(f + u\frac{\tan\phi}{a}\right)u = -\frac{1}{\rho a}\frac{\partial p}{\partial\phi} + F_\phi$$

$$g = -\frac{1}{\rho}\frac{\partial p}{\partial z}$$

$$\frac{\partial\rho}{\partial t} = -\frac{1}{a\cos\phi}\left[\frac{\partial}{\partial\lambda}(\rho u) + \frac{\partial}{\partial\phi}(\rho v\cos\phi)\right] - \frac{\partial}{\partial z}(\rho w)$$

$$c_p\frac{dT}{dt} - \frac{1}{\rho}\frac{dp}{dt} = Q$$

$$p = \rho RT$$



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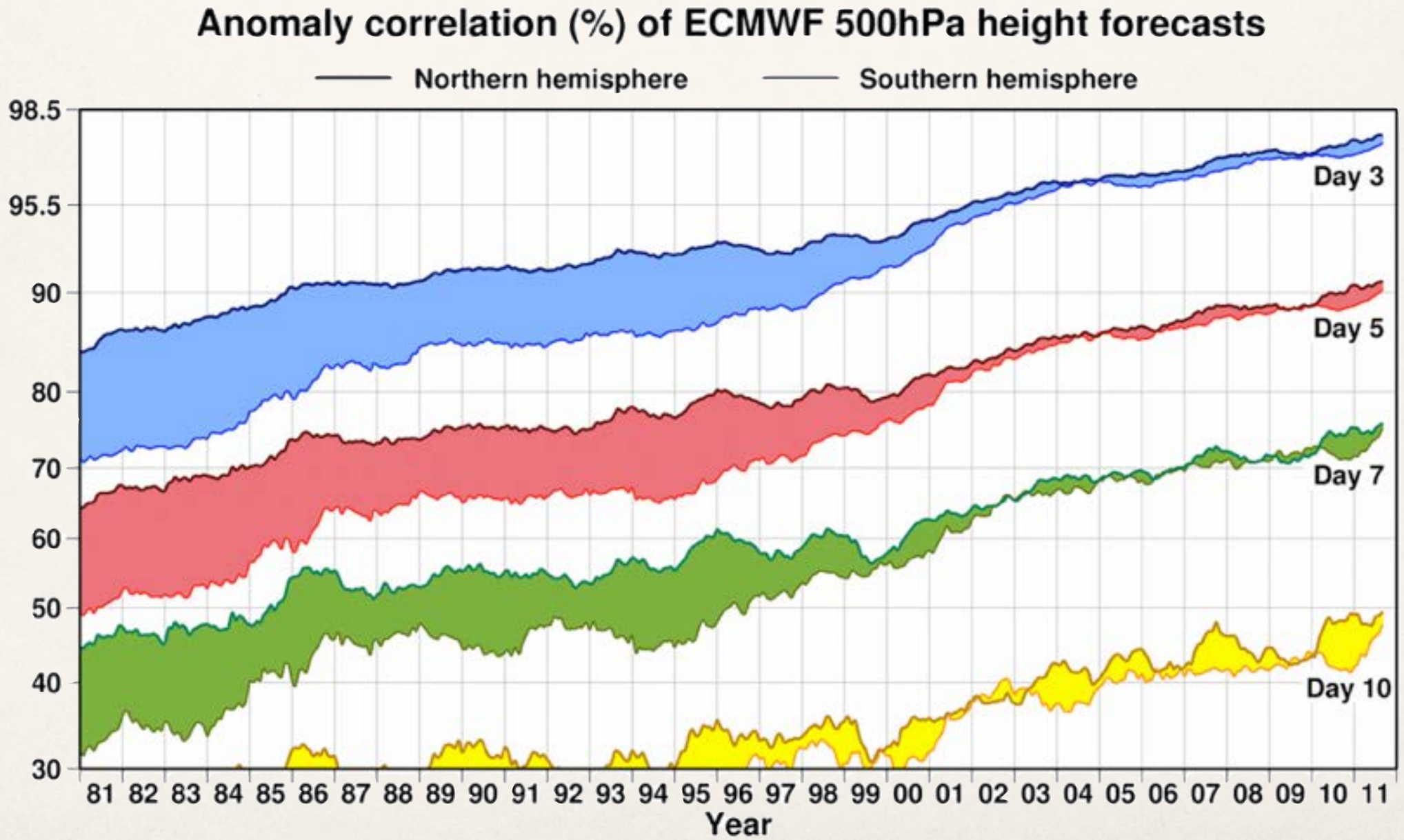
Weather and climate models constitute an unnoticed revolution



Courtesy of ECMWF. Adapted and extended from Simmons & Hollingsworth (2002)

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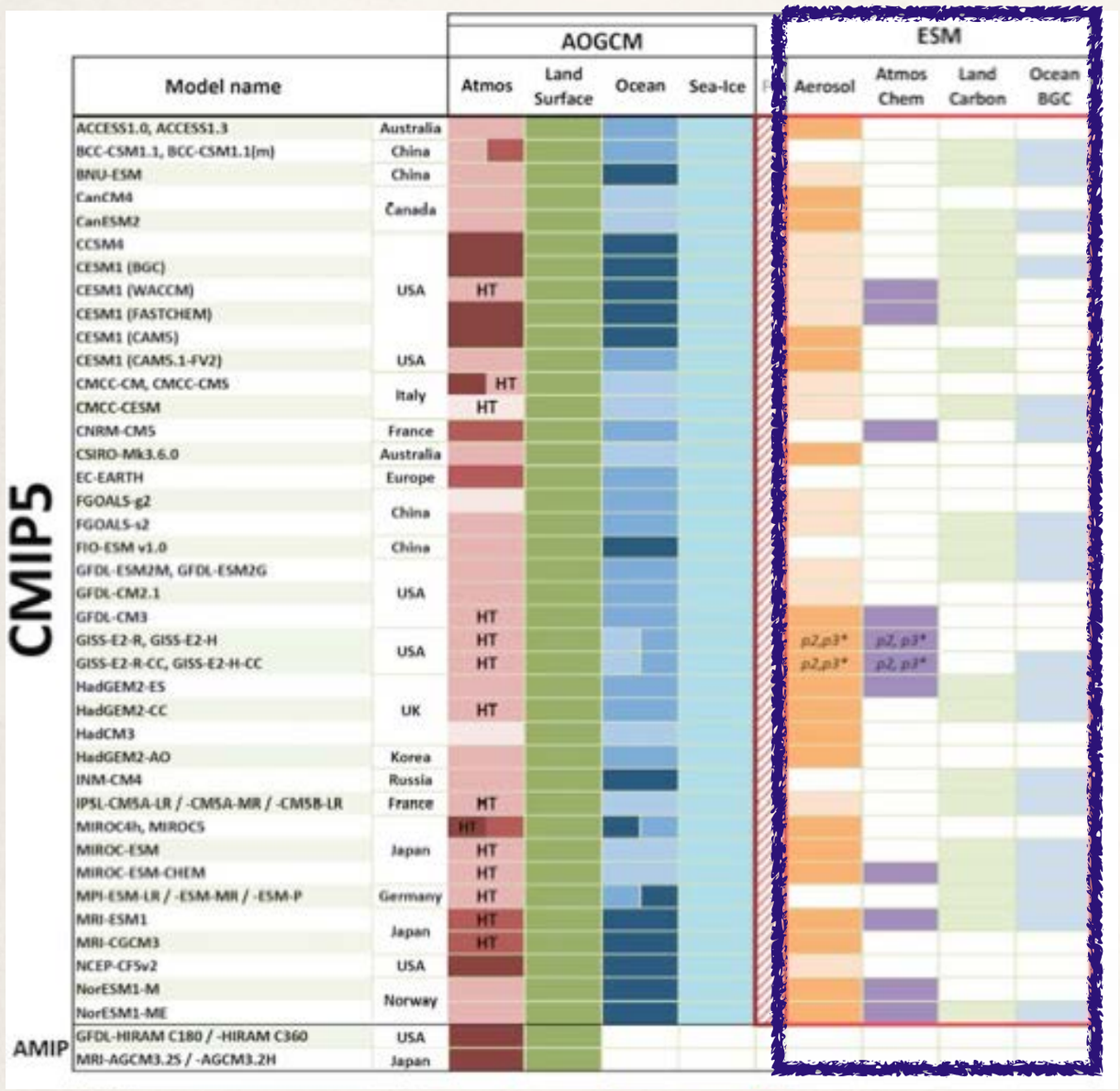
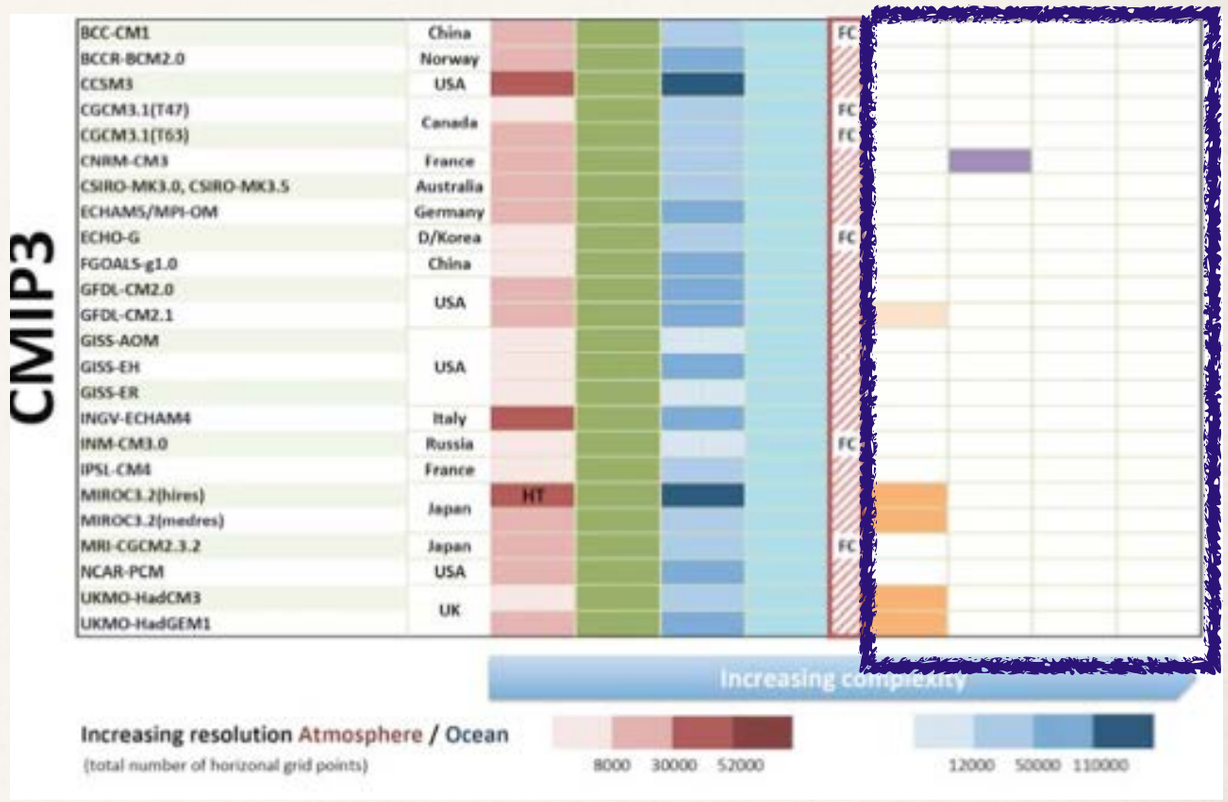
The models have become more complex extending their use

New components



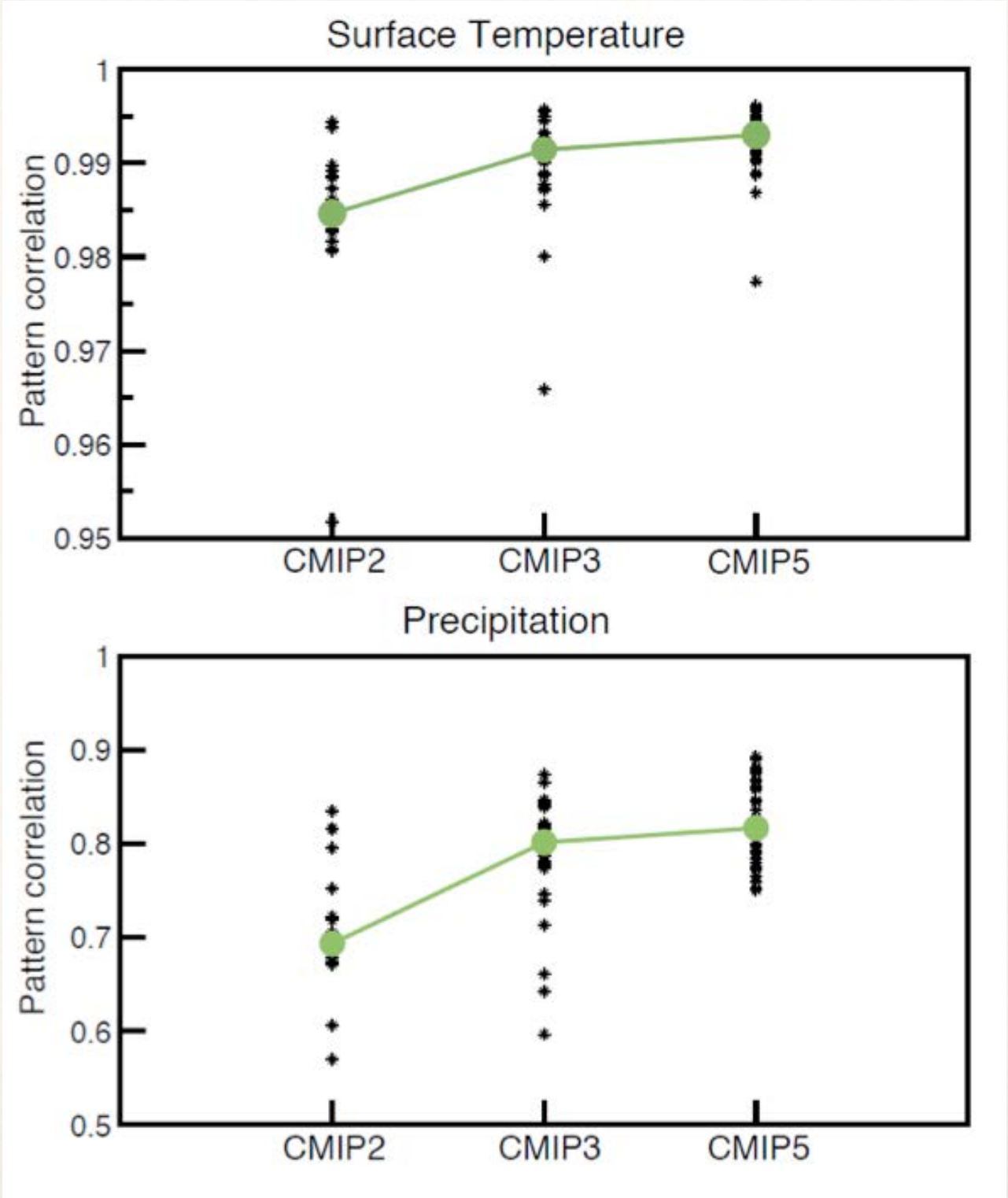
2013 models



2007 models

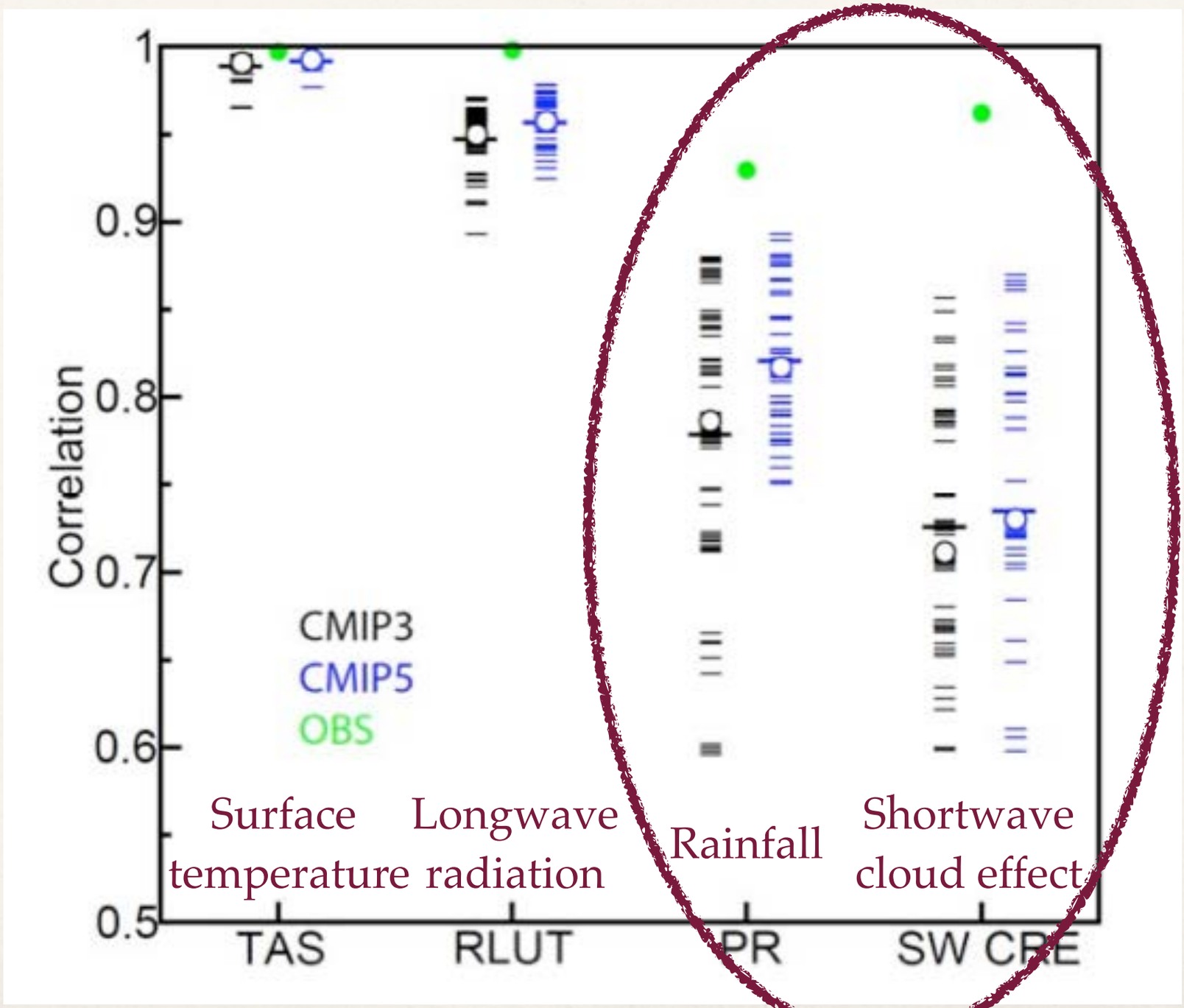
IPCC, 2013

The models are getting better



IPCC, 2013

The models are getting better, but water in the atmosphere remains a major challenge



IPCC, 2013

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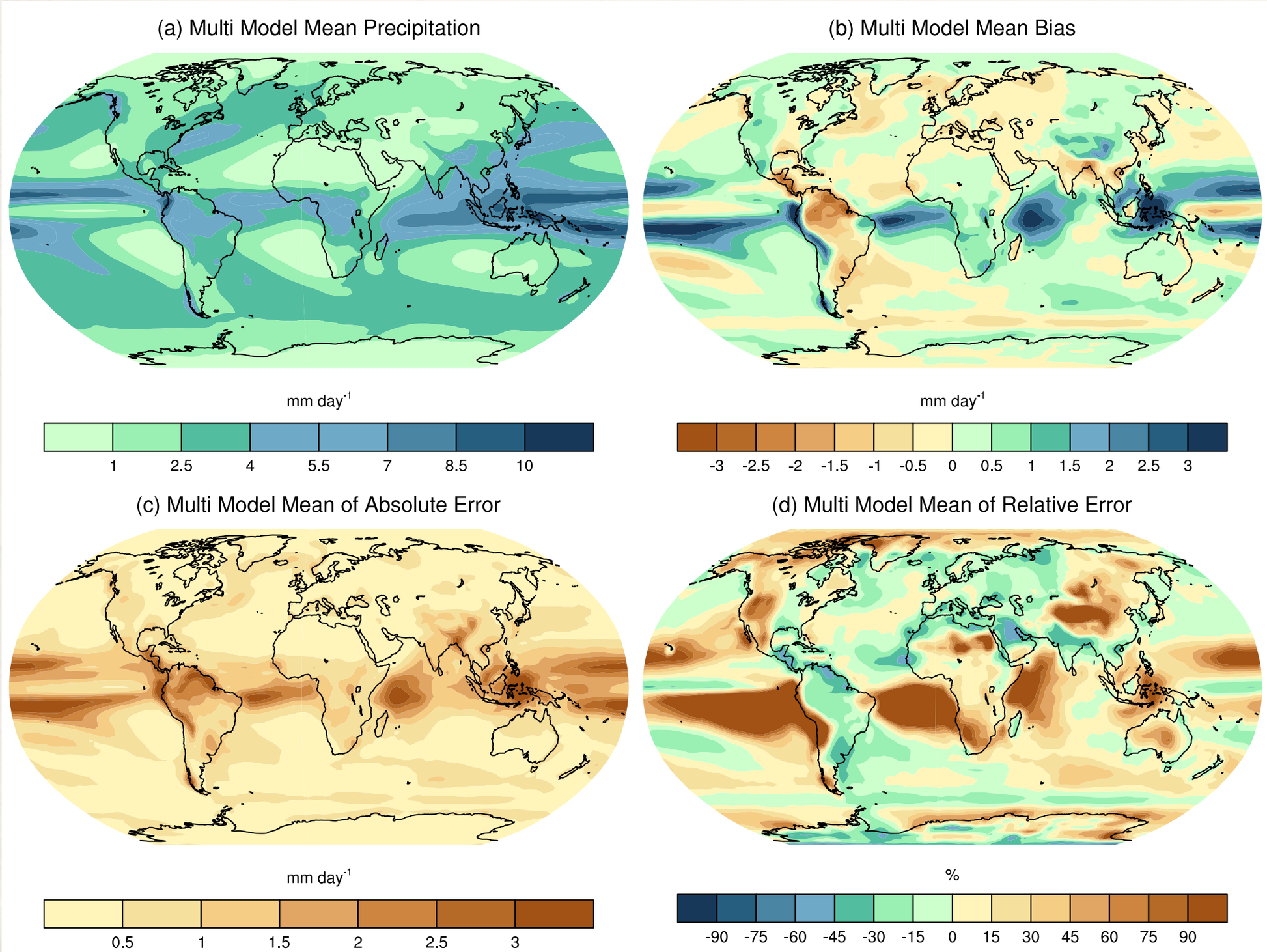
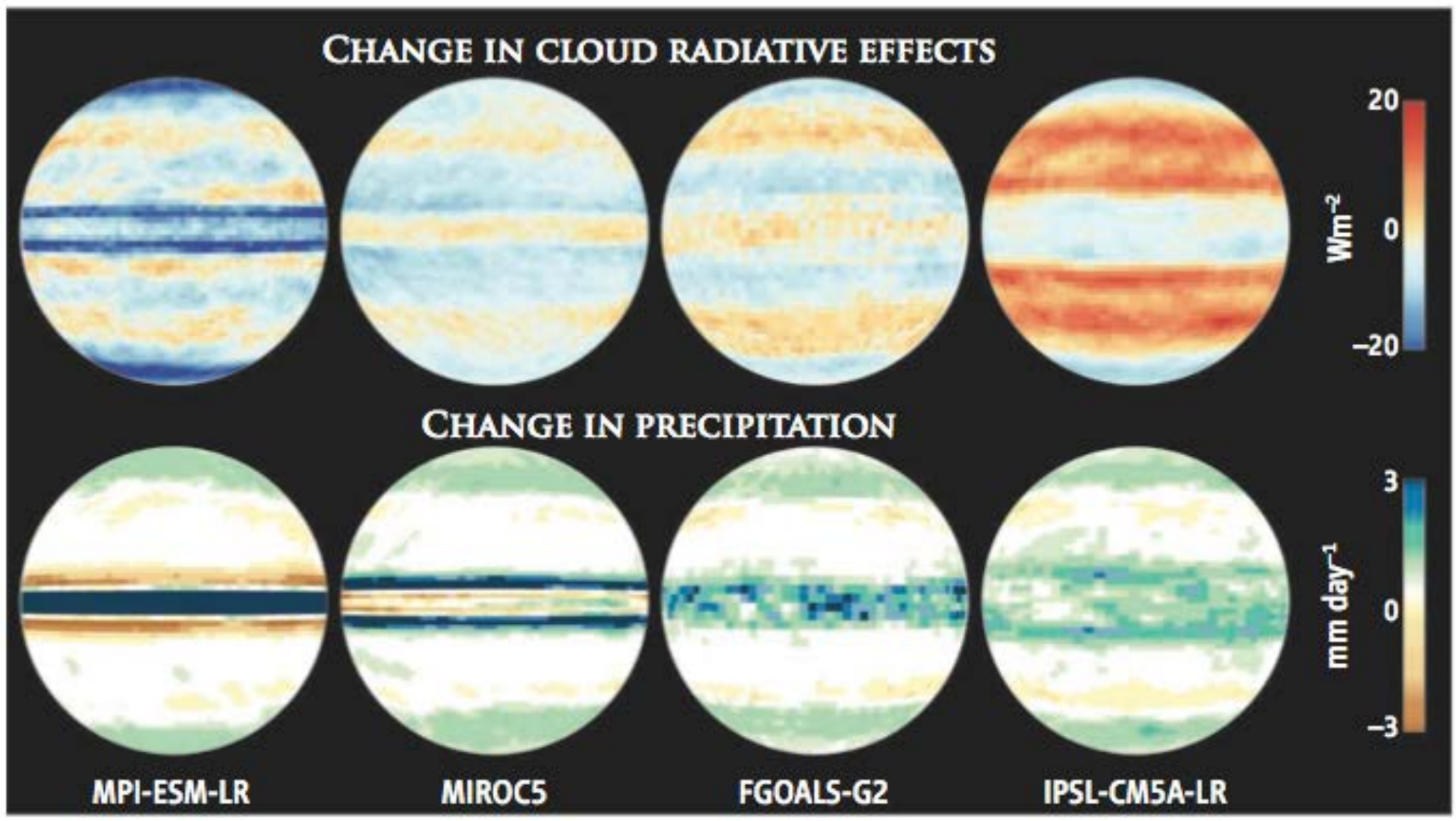
Clouds and precipitation remain a challenge



Precipitation CMIP5 multi-model mean

IPCC, 2013

Clouds and precipitation remain a challenge

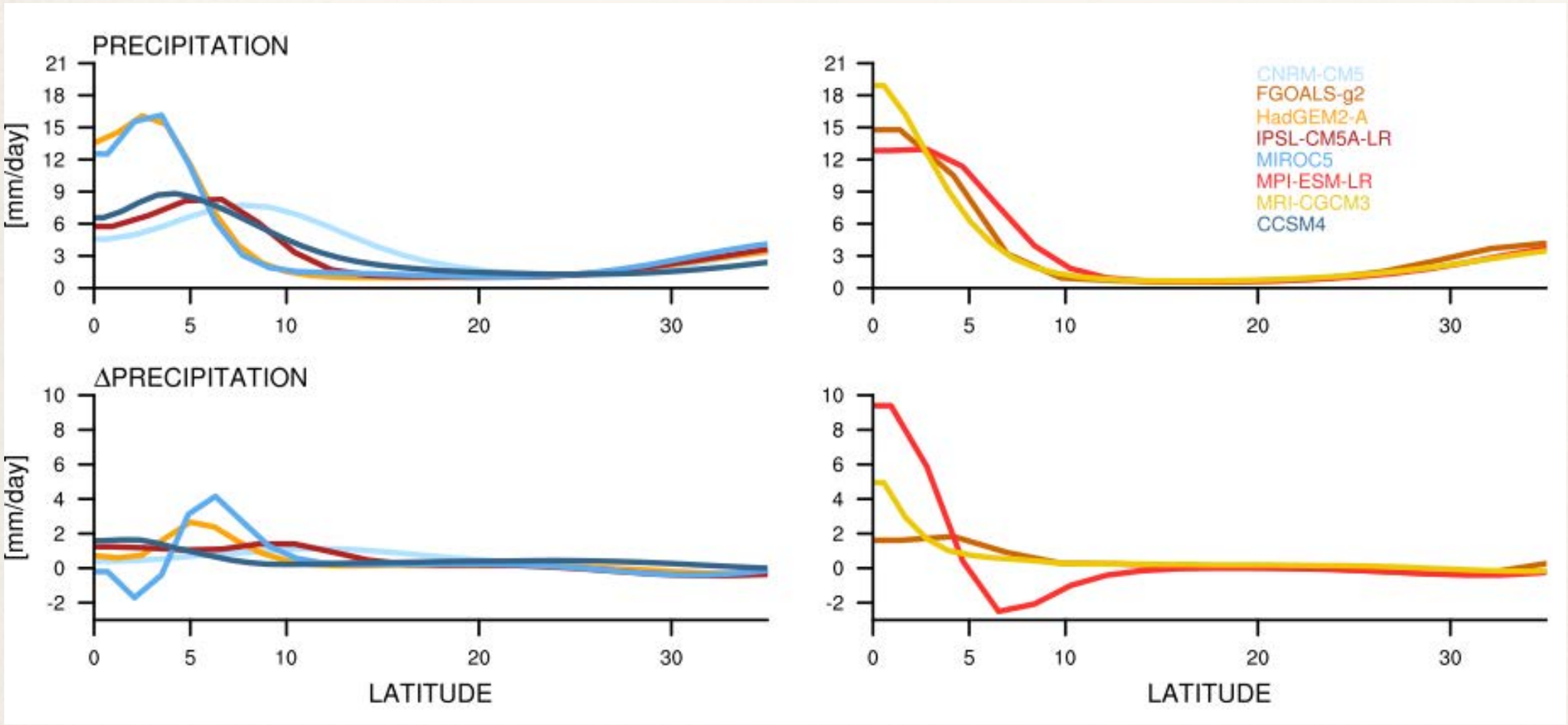


4 CMIP5 models run as a water planet

Response in cloud and precipitation to a 4^{o}C warming

Stevens and Bony, Science, 2013

The original model mean state is crucial for the response!

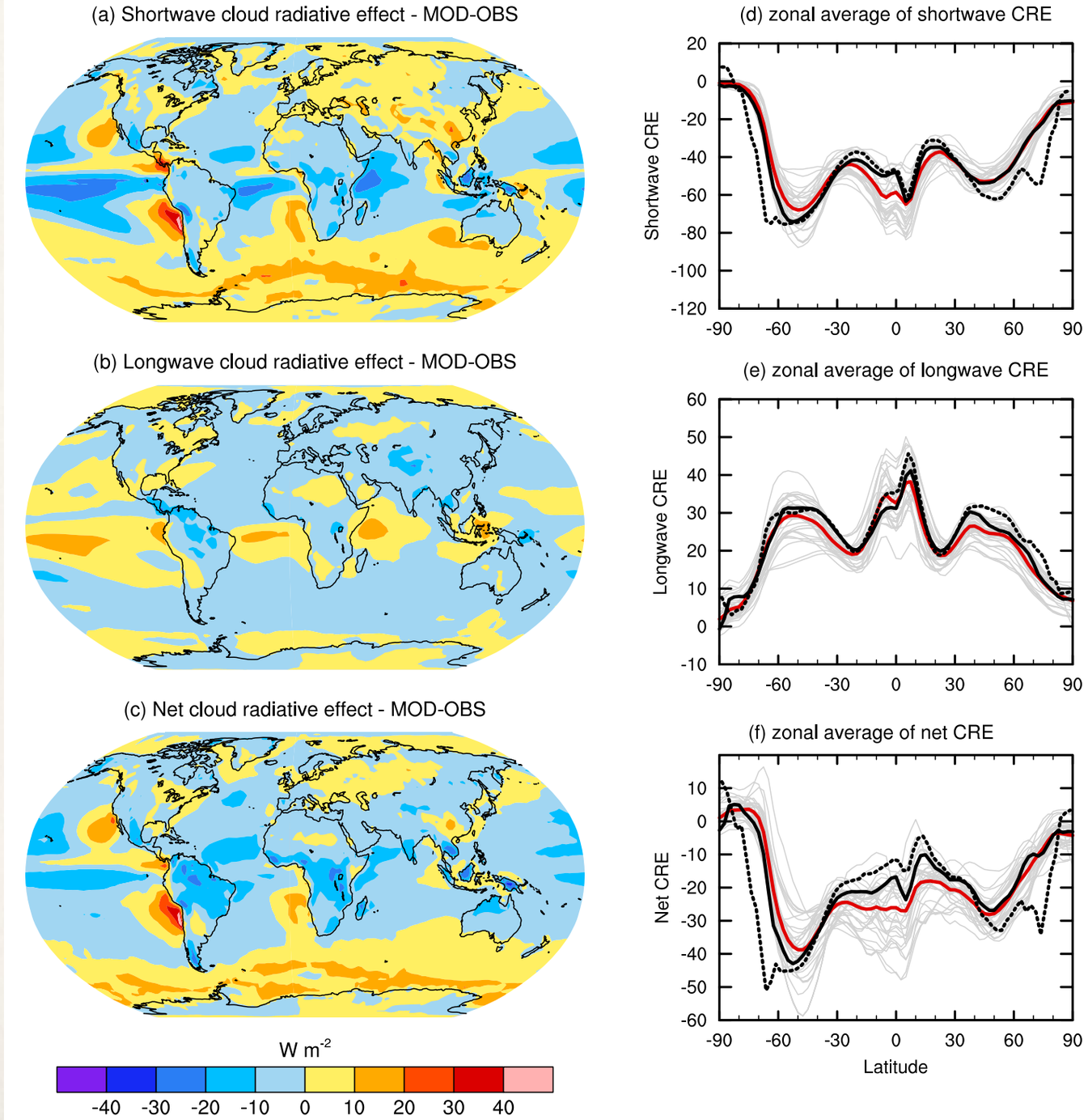


Control mean

+4K SST Response

Medeiros et al., 2014, submitted to Clim. Dyn.

Clouds and precipitation remain a challenge



CMIP5 multi-model mean cloud-radiative effects

IPCC, 2013

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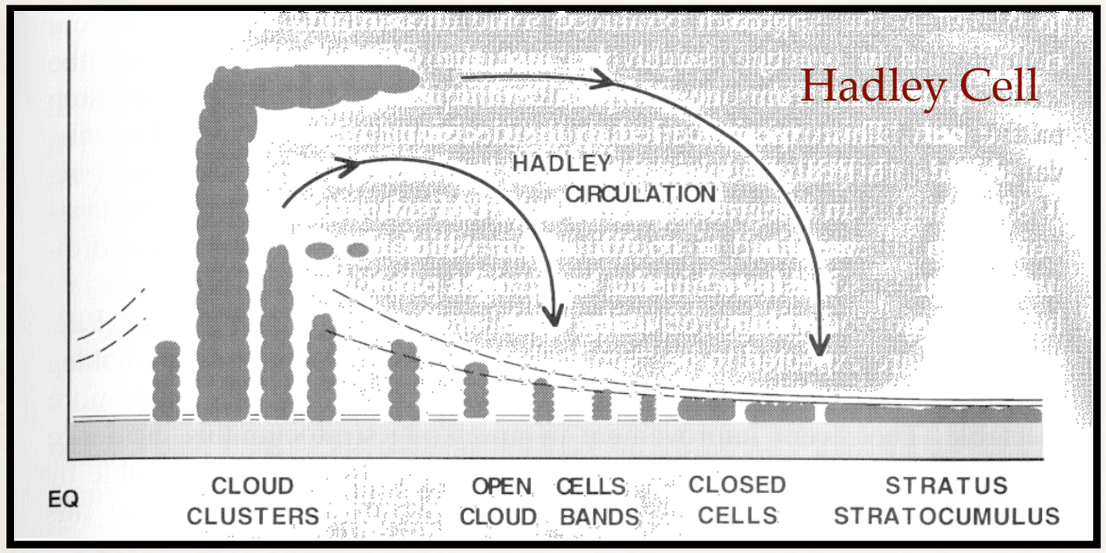
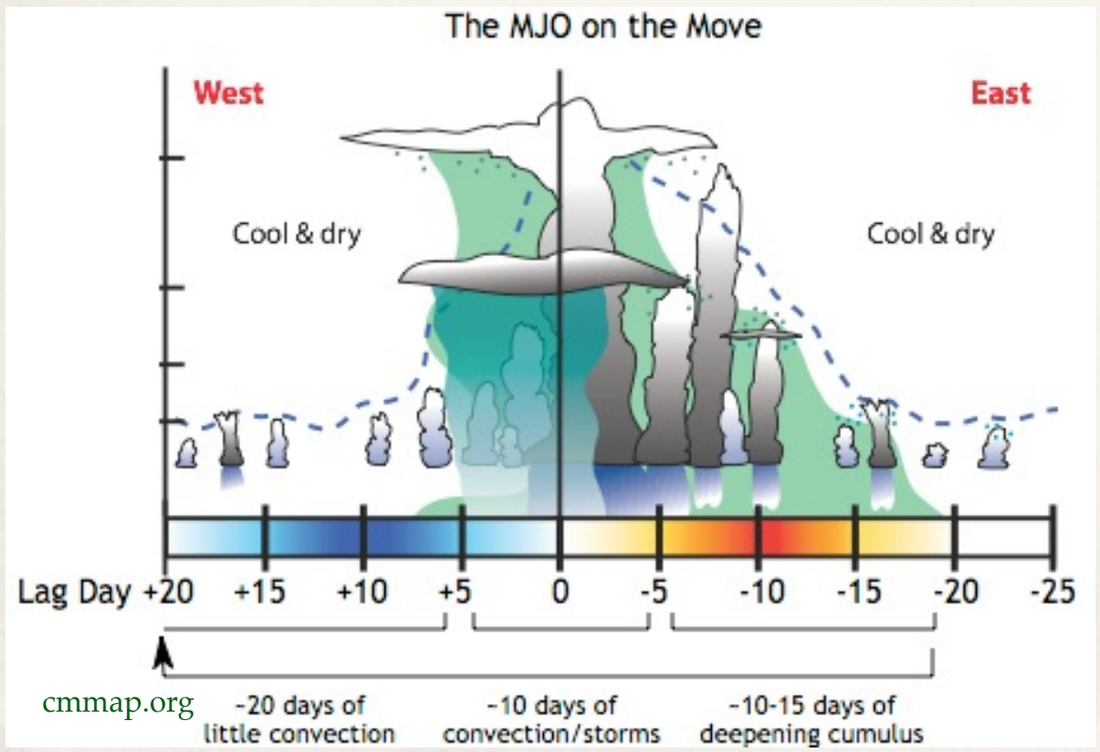
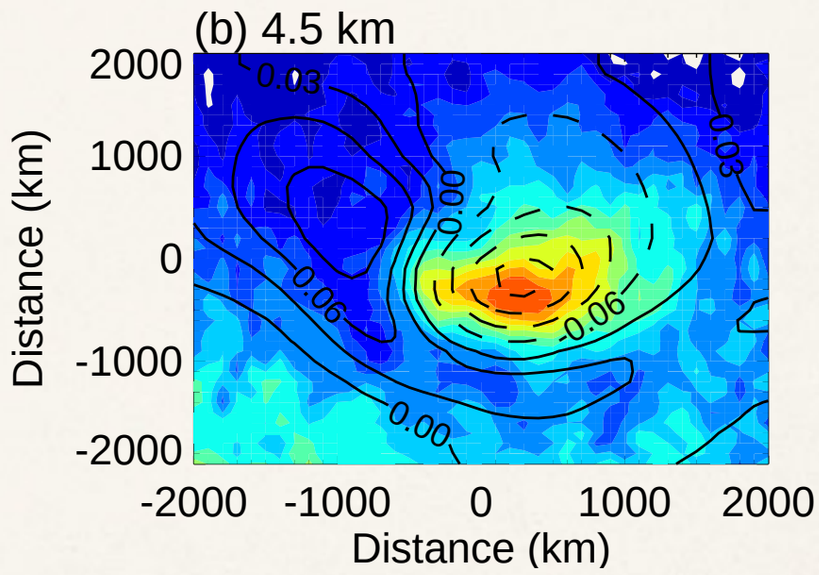
Water in the atmosphere couples to the circulation at many scales



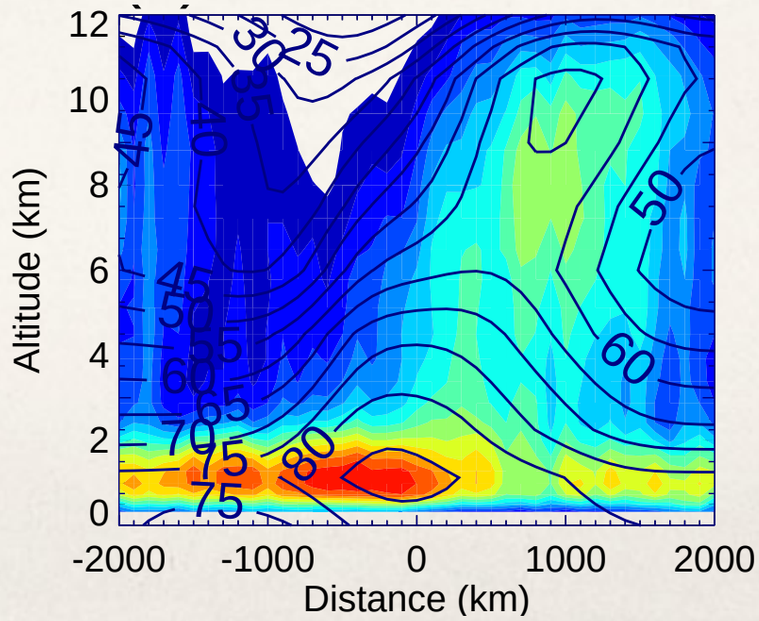
Hadley Cell



Clouds in Southern Ocean Cyclones



Cloud cover and vertical motion



Cloud cover and relative humidity

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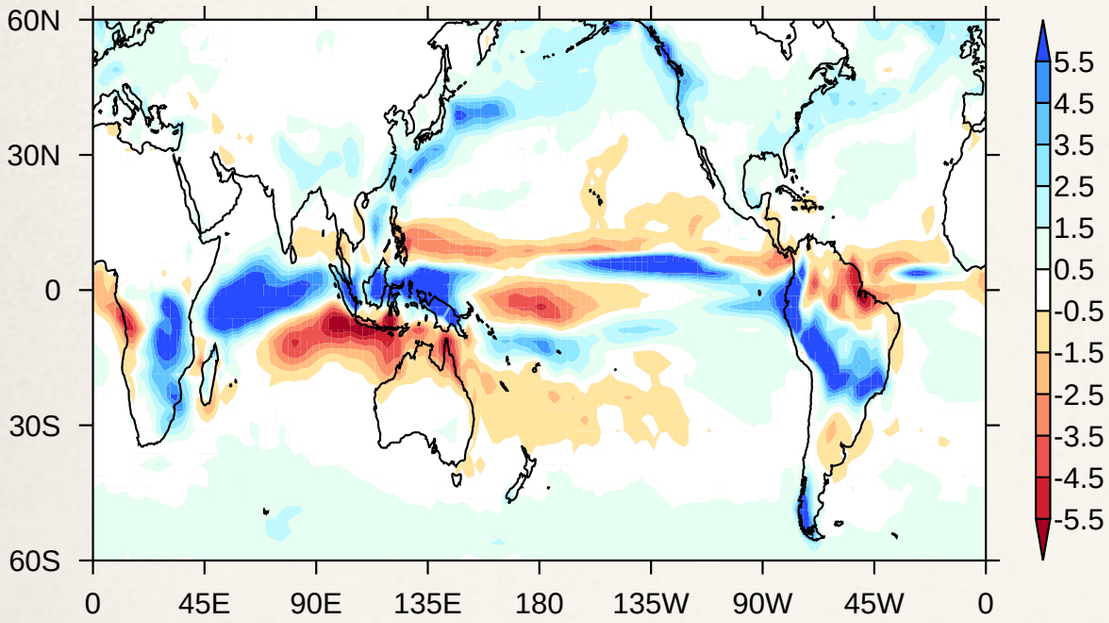
Large rainfall biases often coincide with large circulation biases

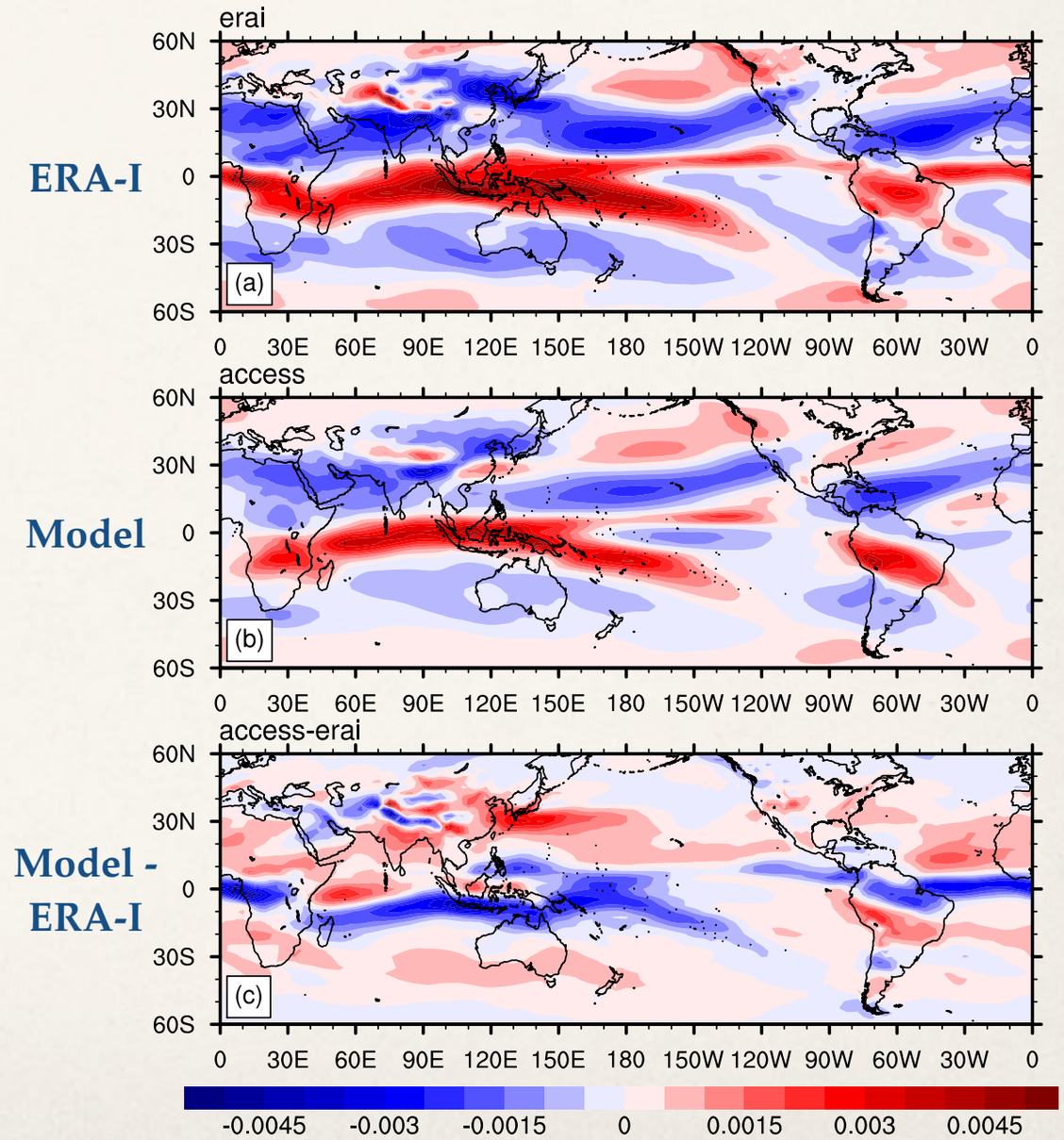
Model rainfall bias



From Duncan Ackerley and Juliane Schwendicke

see also Schwendicke et al., JGR2014

Local meridional overturning (Hadley) circulation



What to do?

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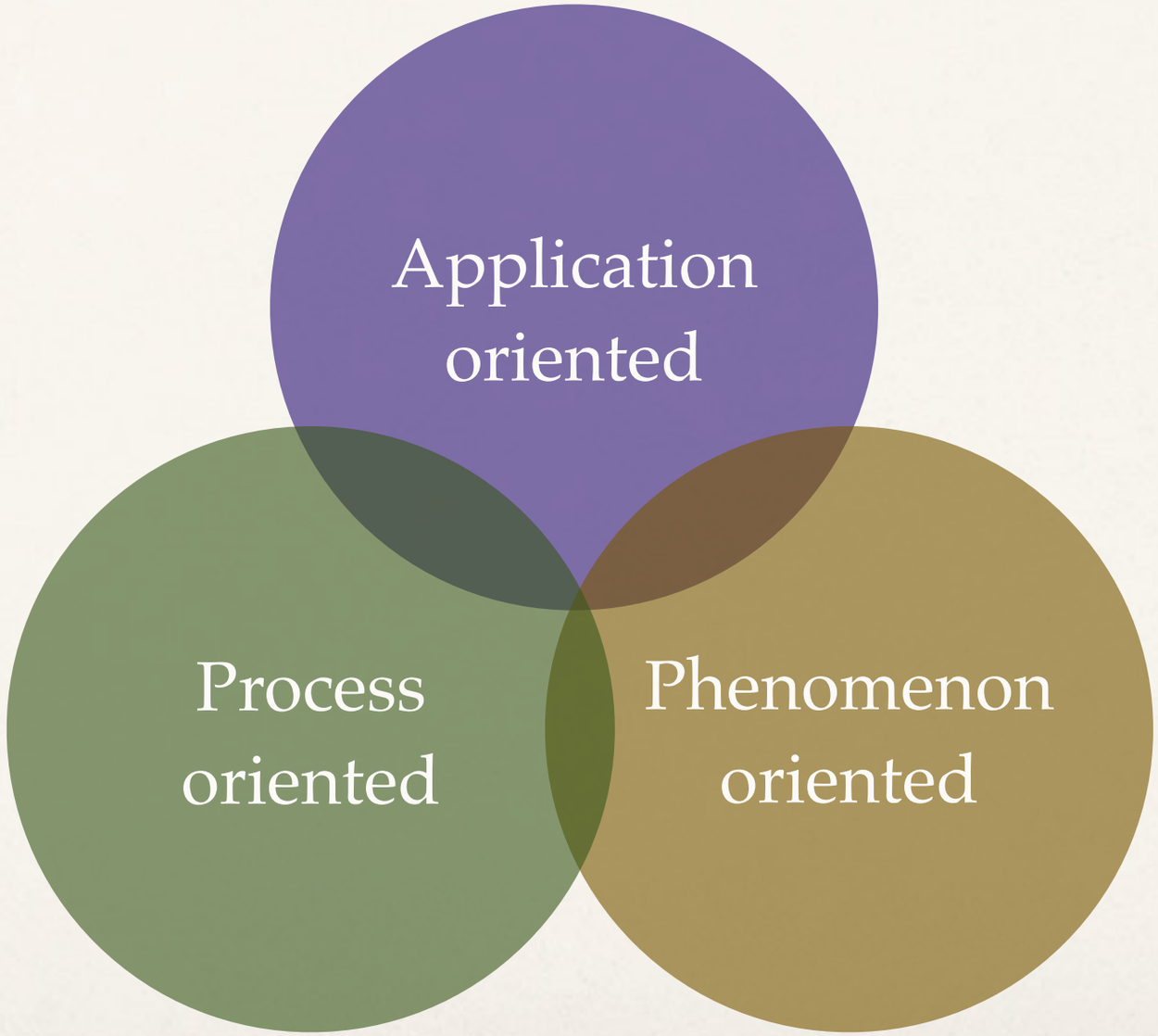
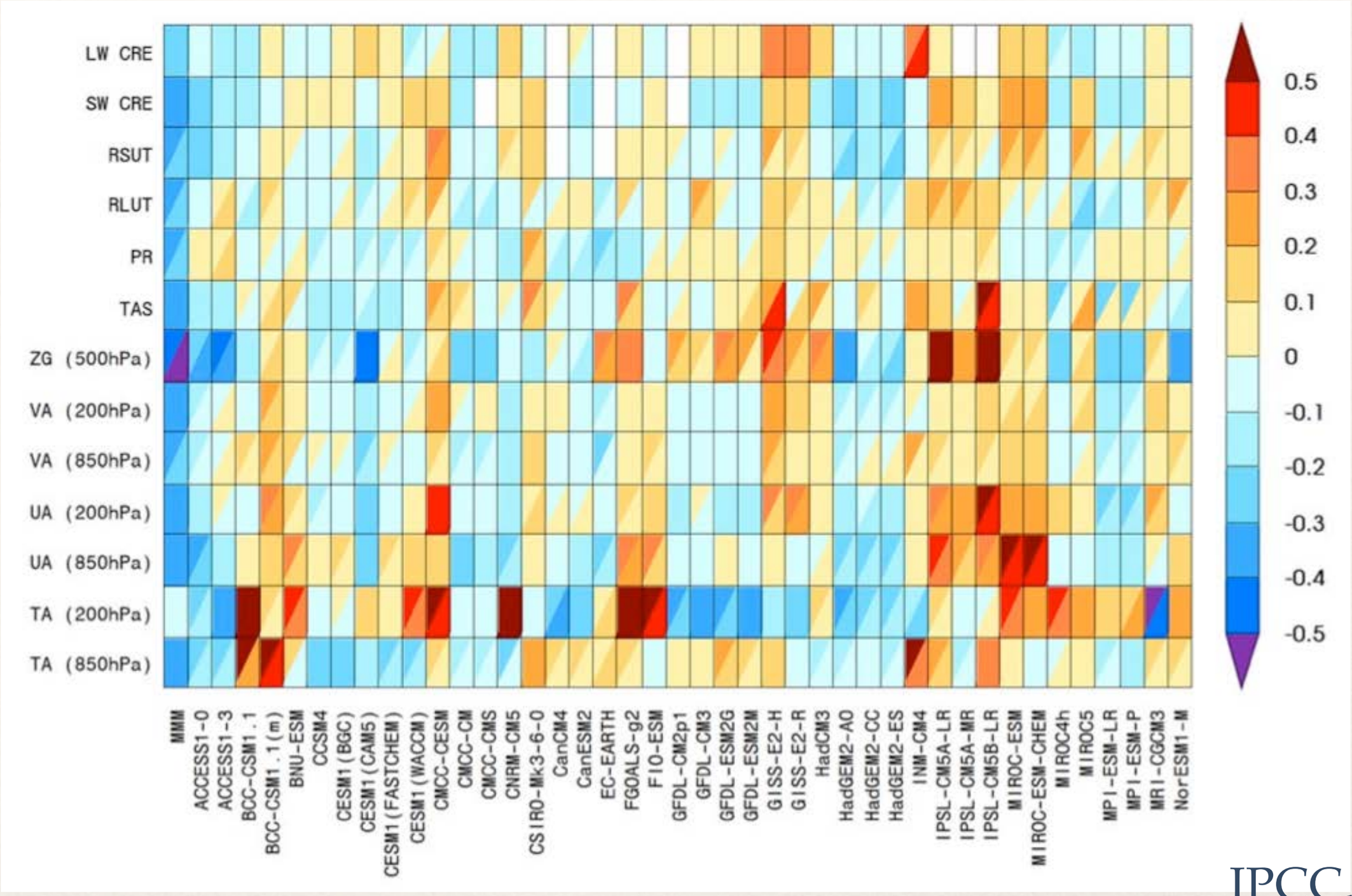
We must develop and employ more insightful evaluation techniques

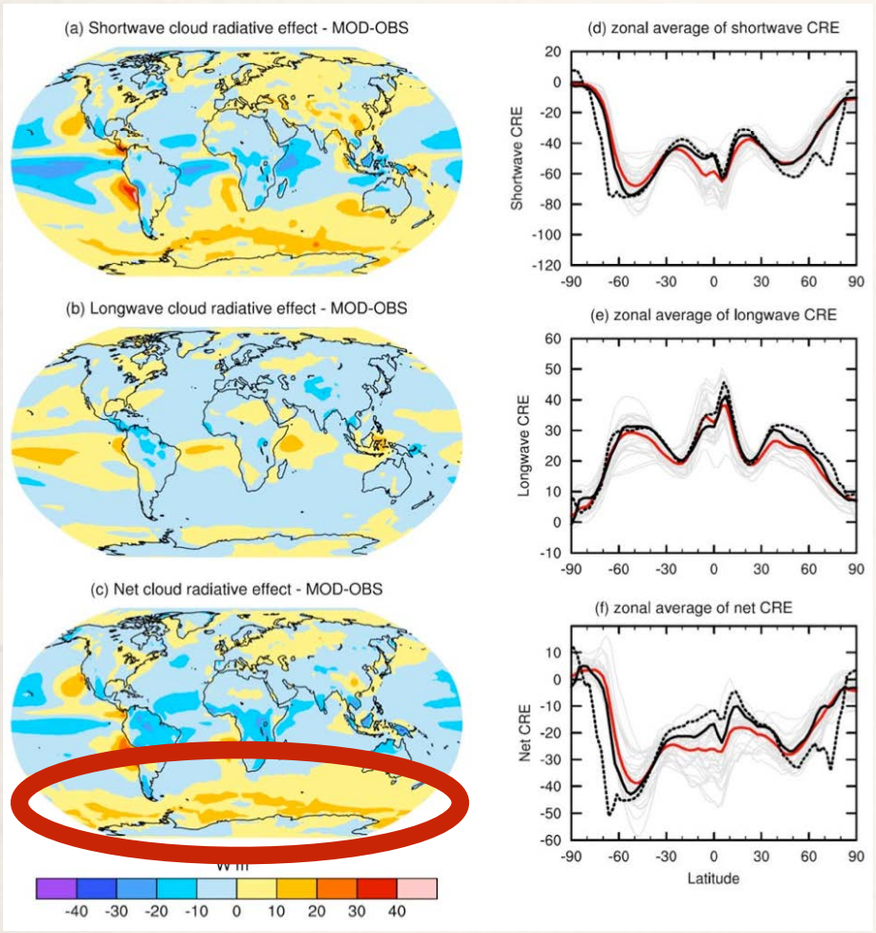


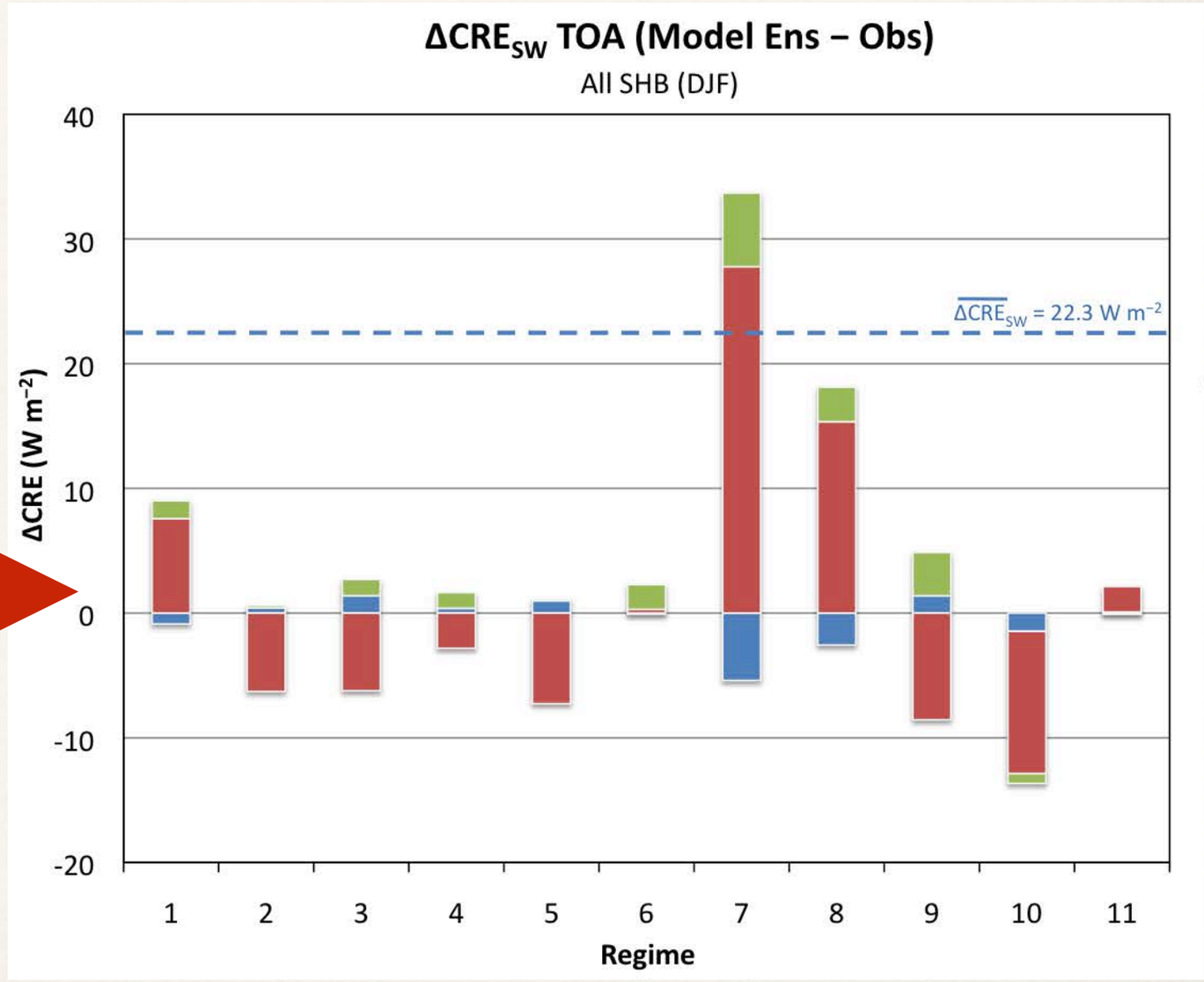
Application-oriented model evaluation sets the scene.



IPCC, 2013

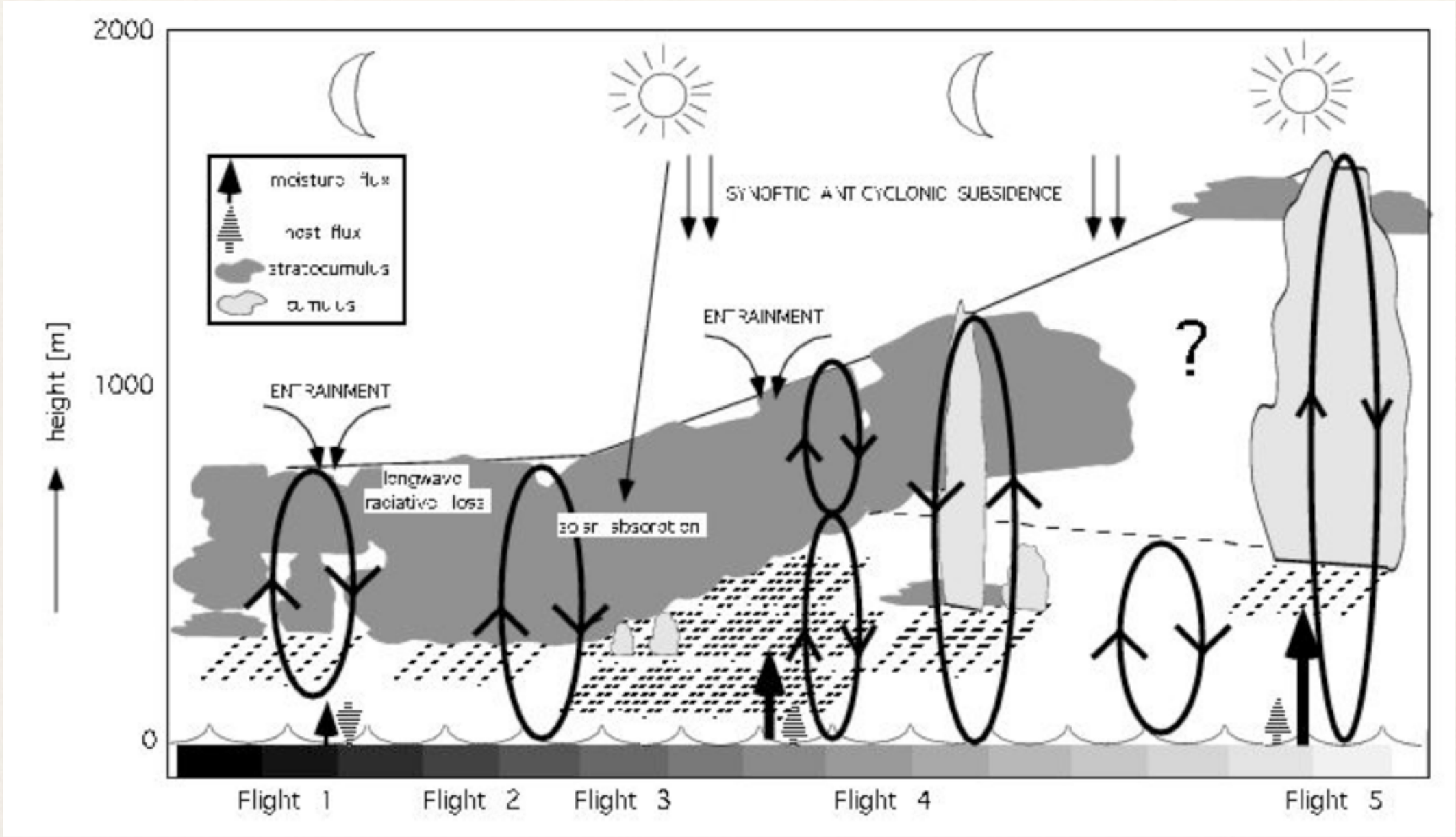
Regime-oriented approaches then allow for decomposition of model errors



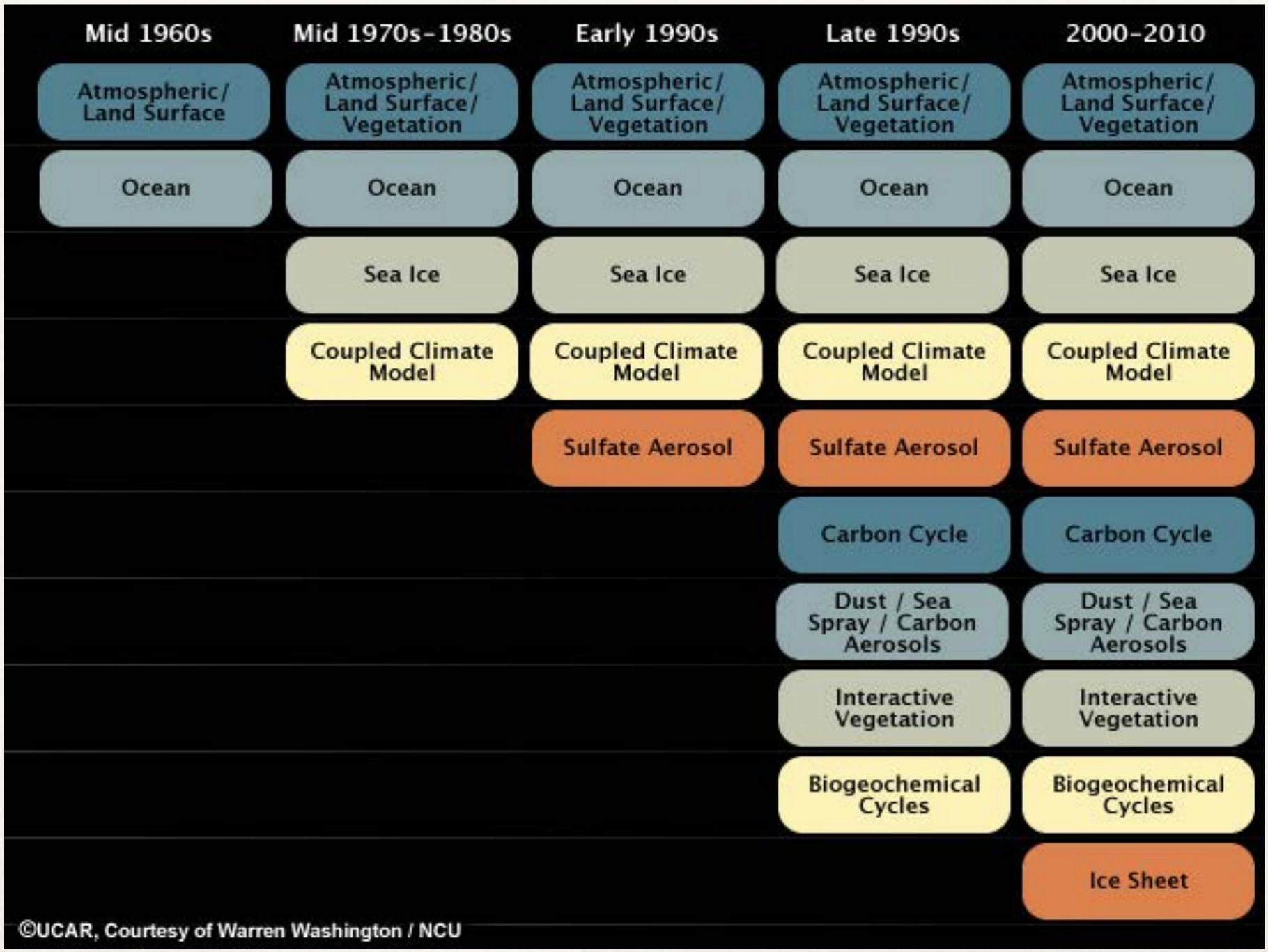


$$\Delta CRE = \sum_{r=1}^{11} RFO_r \Delta CRE_r + \sum_{r=1}^{11} CRE_r \Delta RFO_r + \sum_{r=1}^{11} \Delta RFO_r \Delta CRE_r$$

Finally process evaluation gets to the bottom of it all



Models are now more complex extending their use in principle



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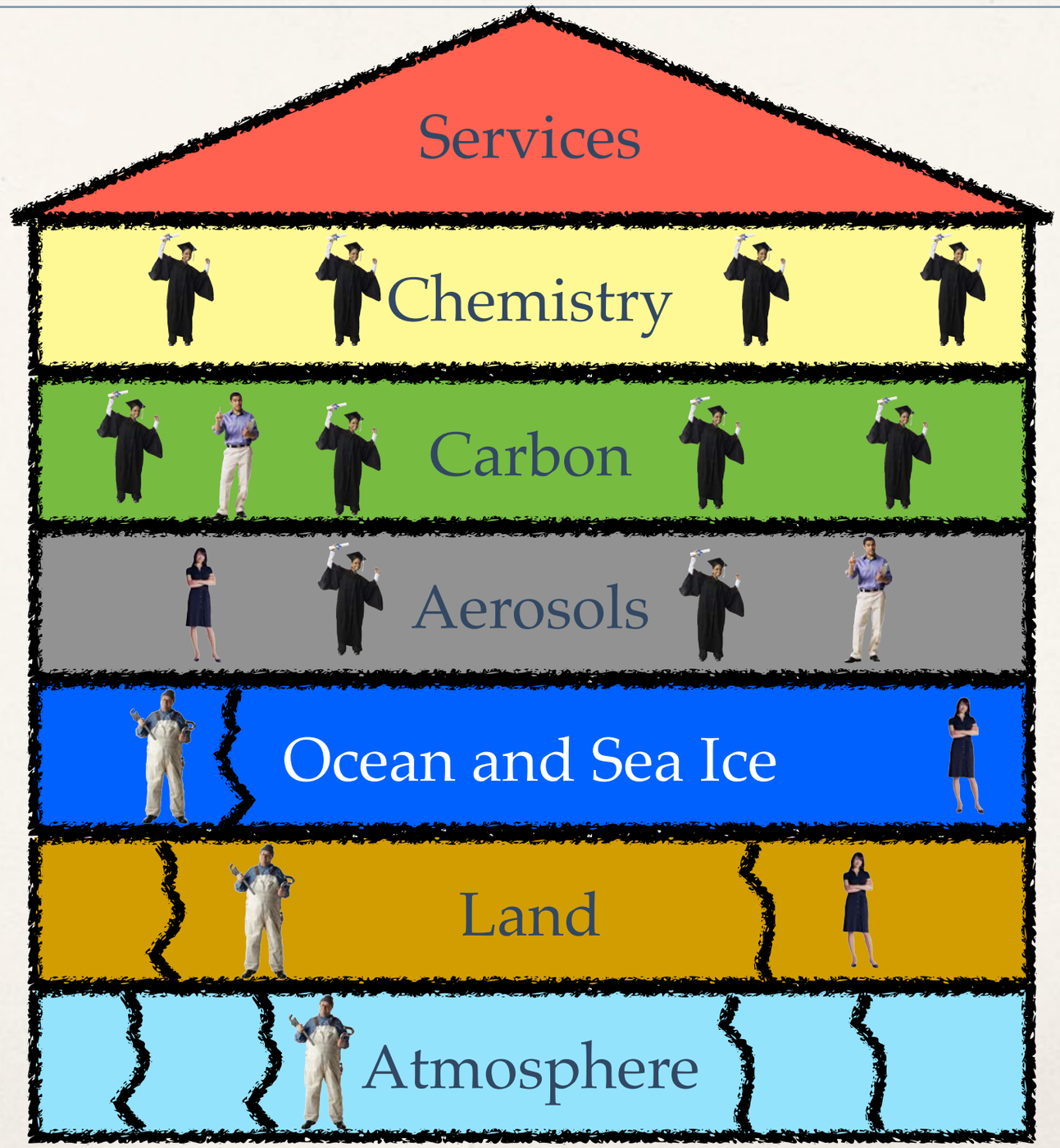
The climate model building - The foundations need more attention!

Today



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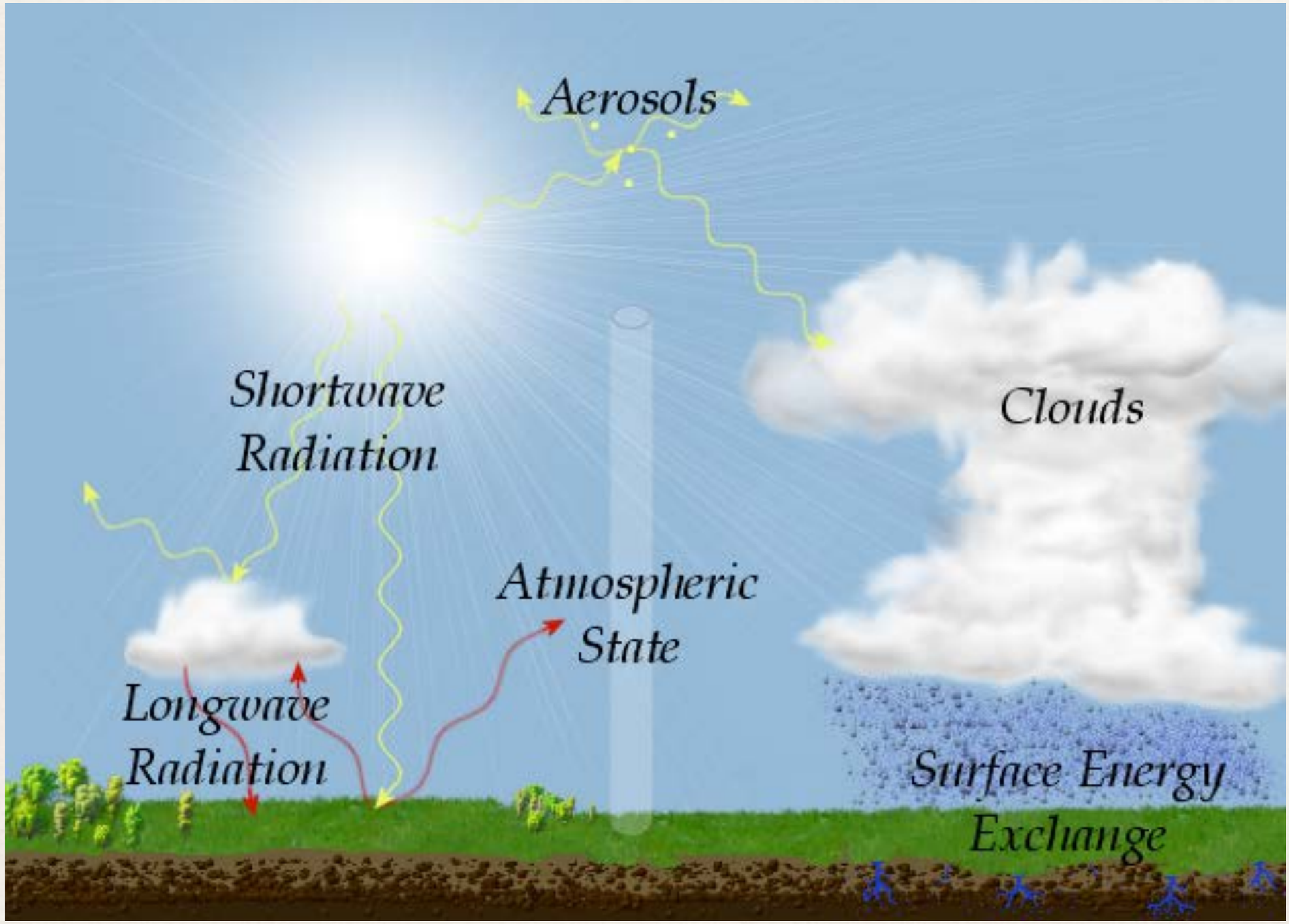
Improving the treatment of water and its link to circulations in the atmosphere is critical



Source: DOE ARM program

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Finding solutions requires concerted efforts in model evaluation and development

The World Climate Research Programme Grand Challenge on:

Clouds, Circulation and Climate Sensitivity

Bjorn Stevens (MPI) and Sandrine Bony (LMD)

Climate Sensitivity

Steve Sherwood (UNSW) and Mark Webb (UKMO)

Changing Patterns

Ted Shepherd (U Reading) and Adam Sobel (Columbia U)

Towards more reliable models

Christian Jakob (Monash) and Masahiro Watanabe (U Tokyo)

Coupling Clouds To Circulation

Dargan Frierson (U Wash) and Pier Siebesma (KNMI)

Leveraging the Past Record

Robert Pincus (NOAA) and Masa Kageyama (IPSL)

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Model developers are in short supply and the problem is hard - we need new people and better collaborative structures!

Modelling Centres

- Open the models to the community
- Change the rewards systems for model developers
- Involve model developers in model application projects
- Involve non-developers in model development projects

- Strong formal links between Centres and Academia
- Joint PhD to guaranteed Postdoc positions
- Strategic partnerships of Centres with Academic funding programmes
- MANY joint research activities

Academia

- Highly doted scholarships in model development - Rhodes scholars
- University chairs in model development
- Change the rewards system for model developers

Summary

- Weather and climate models underpin some of mankind's greatest endeavours. They save lifes. They save property. They affect all aspects of society.

- Improvements in predictions have been underpinned by improvements in models - Future improvements require renewed and increased investment in basic model development.

- Models have become increasingly complex, but some key issues have not been resolved. In particular the treatment of water in the atmosphere requires further improvements through focussed community efforts.

- We need the entire community to express this need and to contribute to finding solutions.