

# Clouds, Circulation and Climate Sensitivity

A Grand Challenge of  
the World Climate Research Programme  
for the next 5-10 years

Sandrine Bony (LMD/IPSL) & Bjorn Stevens (MPI)

With

Christian Jakob, Masa Kageyama, Robert Pincus, Ted Shepherd,  
Steven Sherwood, Pier Siebesma, Adam Sobel, Masahiro Watanabe, Mark Webb

# WCRP Grand Challenges

- \* Major research areas that are critical for climate science, hindered by specific barriers, and for which targeted research efforts are likely to lead to significant progress over the next 5-10 years
- \* Emerge from several years of consultation with scientists, sponsors and stakeholders
- \* **Six Grand Challenges will be promoted by WCRP :**
  - Regional Climate Information
  - Sea-level Rise and Regional Impacts
  - Cryosphere in a Changing Climate
  - **Clouds, Circulation and Climate Sensitivity**
  - Changes in Water Availability
  - Prediction and attribution of extreme events
- \* More information on : <http://www.wcrp-climate.org/index.php/grand-challenges> (in preparation)

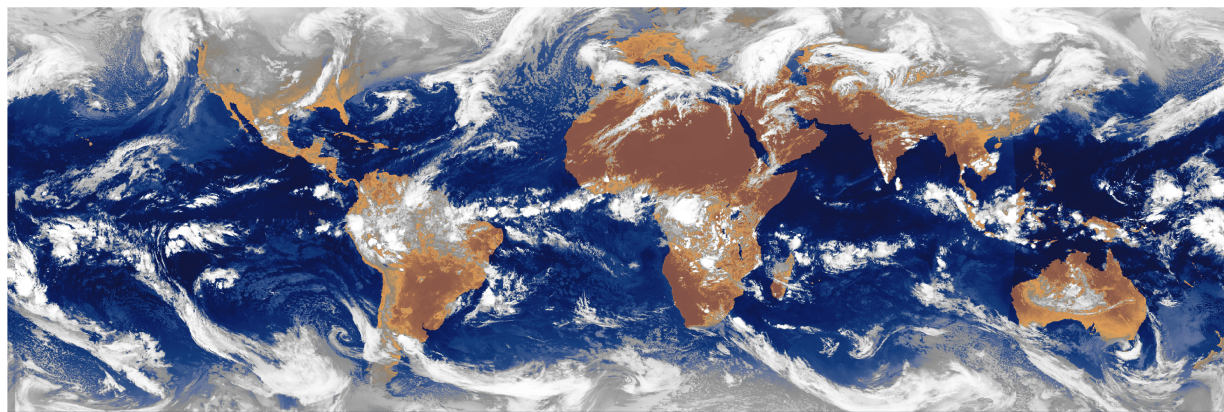


# WCRP White Paper

## Clouds, Circulation and Climate Sensitivity:

*How the interactions between clouds, greenhouse gases and aerosols affect temperature and precipitation in a changing climate*

Lead Coordinators\*: Sandrine Bony<sup>1</sup> and Bjorn Stevens<sup>2</sup>  
WGCM, in close cooperation with GASS, WGNE, SPARC



[http://www.wcrp-climate.org/images/documents/grand\\_challenges/GC4\\_Clouds\\_14nov2012.pdf](http://www.wcrp-climate.org/images/documents/grand_challenges/GC4_Clouds_14nov2012.pdf)

---

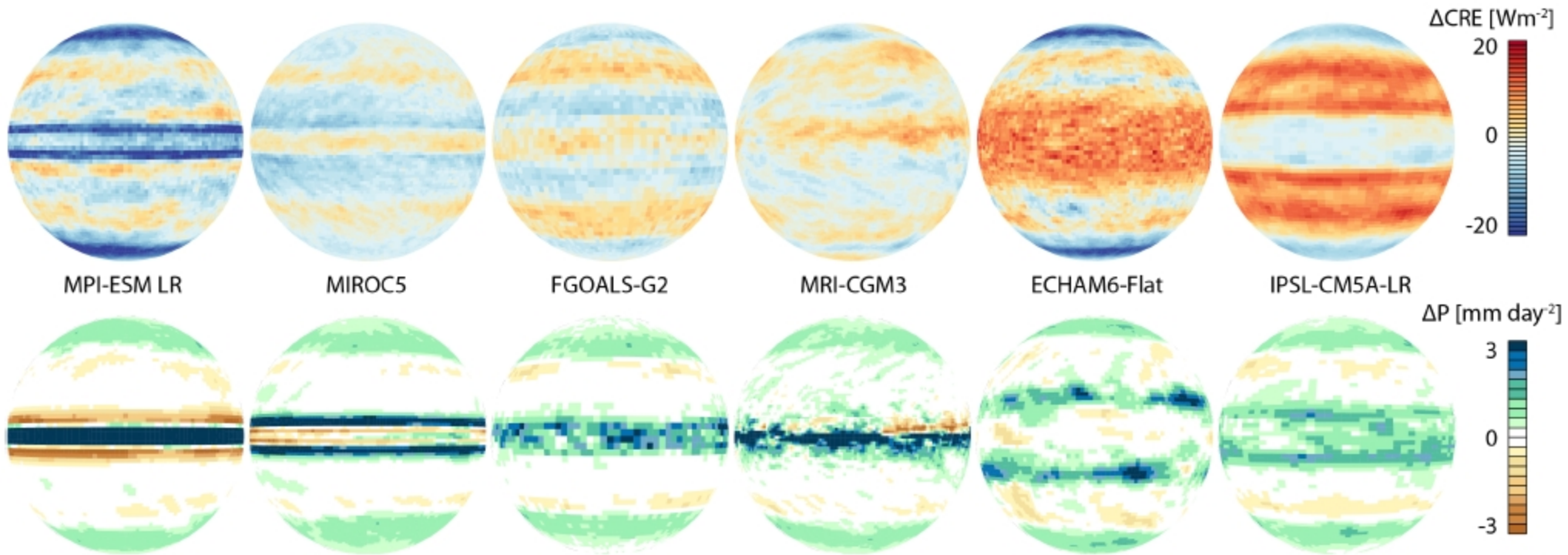
\* There are many WCRP groups and individuals who have contributed to this document. The authors wish to thank in particular the WGCM and GEWEX/GASS steering committees for their input and the WCRP Joint Scientific Committee for its support and encouragement. Specific and extensive comments from Alessio Bellucci, Pascale Braconnot, Christopher Bretherton, Veronika Eyring, Christian Jakob, Masa Kageyama, Stephen Klein, Natalie Maholwald, Teruyuki Nakajima, Jon Petch, William Rossow, Adam Scaife, Cath Senior, Ted Shepherd, Philip Stier, Kevin Trenberth, Mark Webb and Steve Woolnough also helped sharpen and broaden the articulation of this grand challenge.

<sup>1</sup> WGCM, LMD/IPSL (Paris, France), Email : bony@lmd.jussieu.fr

<sup>2</sup> WGCM, MPI for Meteorology (Hamburg, Germany), Email : bjorn.stevens@mpimet.mpg.de

# A (Really) Grand Challenge!

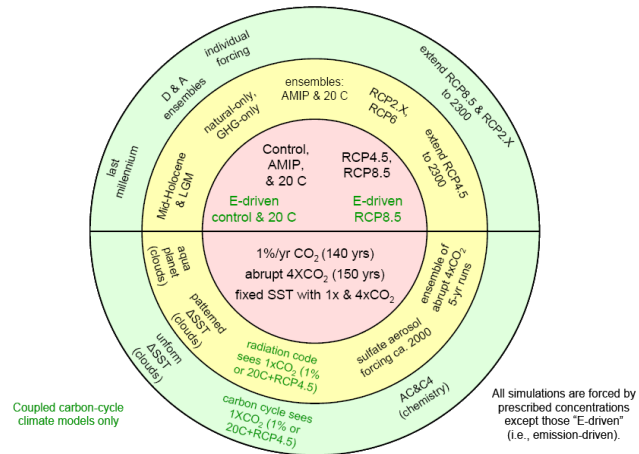
Response of Cloud Radiative Effects and Precipitation  
to a uniform +4K in **CMIP5 aqua-planets**



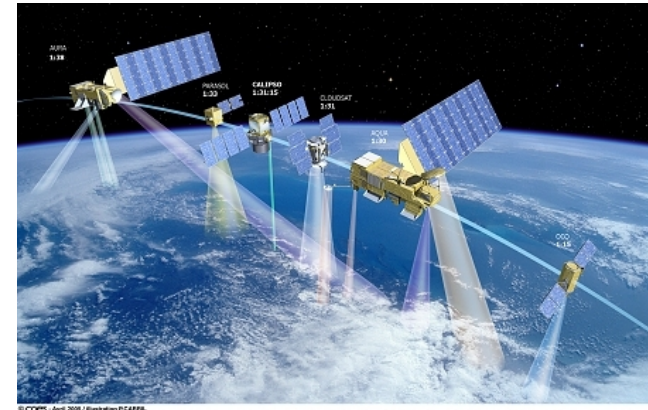
- Uncertainties related to basic physical processes
- Critical limitation for mitigation and adaptation studies

# Opportunities

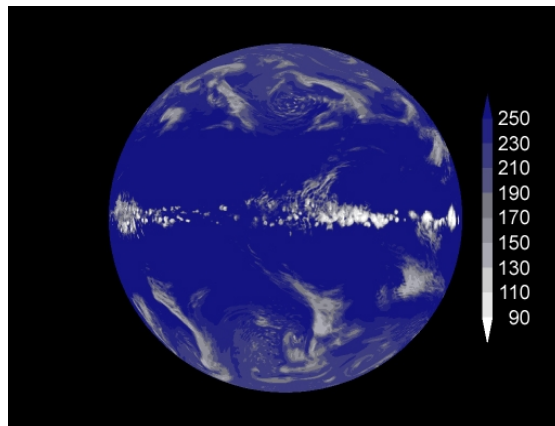
## CMIP5 and associated MIPs



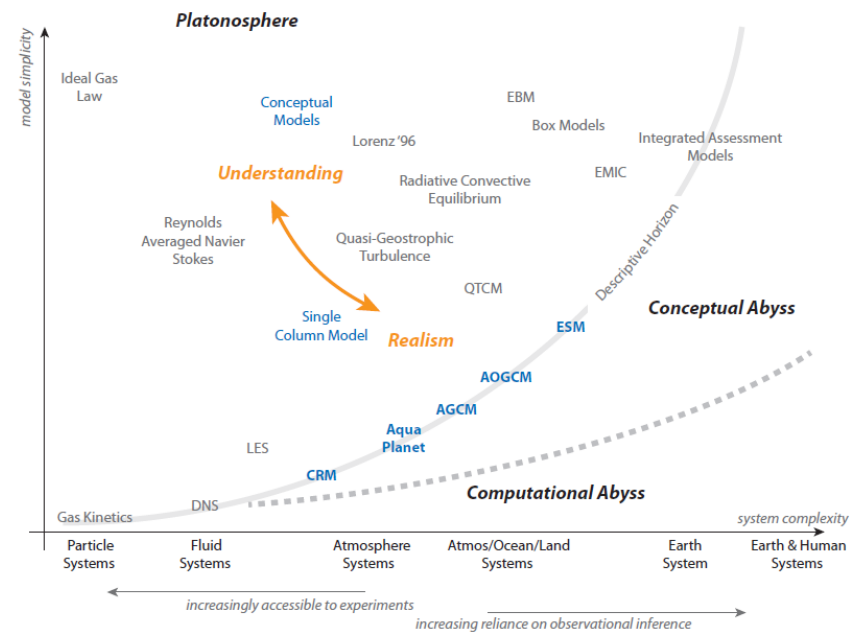
## A golden age of Earth observations



## Qualitatively new types of models



## Lessons from experience



An interconnected research community



# WCRP Grand Challenge on Clouds, Circulation and Climate Sensitivity

Will be articulated around five main Initiatives,  
complementary and closely coupled to each other:

- Climate and hydrological sensitivity
- Coupling clouds to circulations
- Changing patterns
- Leveraging the past record
- Towards more reliable models

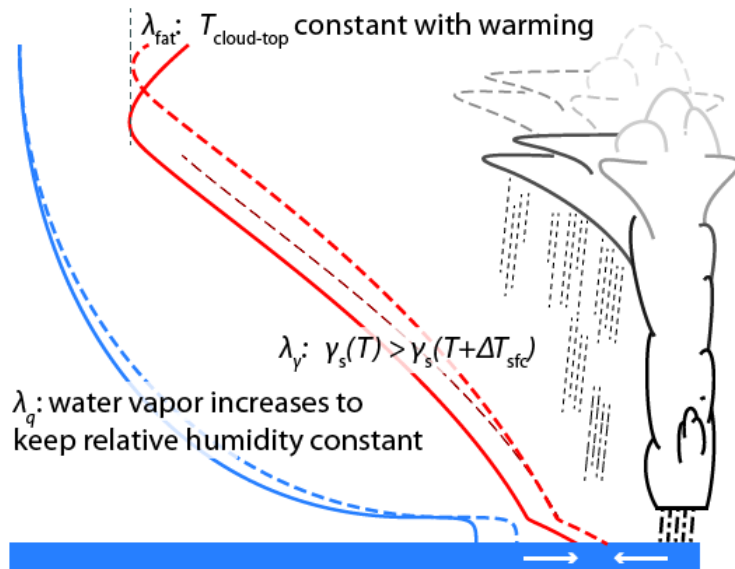


# Climate and Hydrological Sensitivity

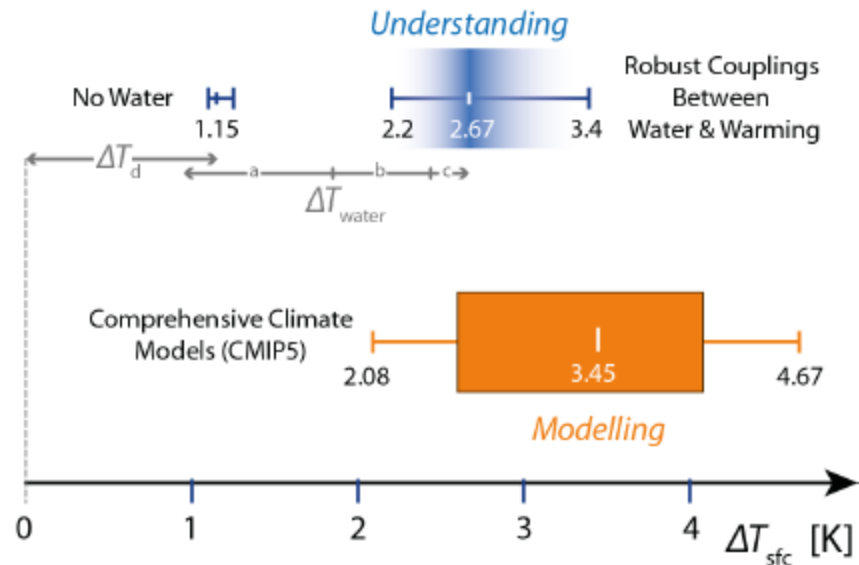
Led by Steven Sherwood (CCRC, Australia) & Mark Webb (MetOffice, UK)

**Aim :** Design critical tests for climate models, whose application will help assess the most likely estimates of climate and hydrological sensitivity.

**Focus :** Intensify efforts to identify causes of inter-model differences in sensitivity ;  
Interpret robust features ; Explain extreme behaviours ;  
Unravel uncertainties and propose strategies to tackle them



## Equilibrium Climate Sensitivity



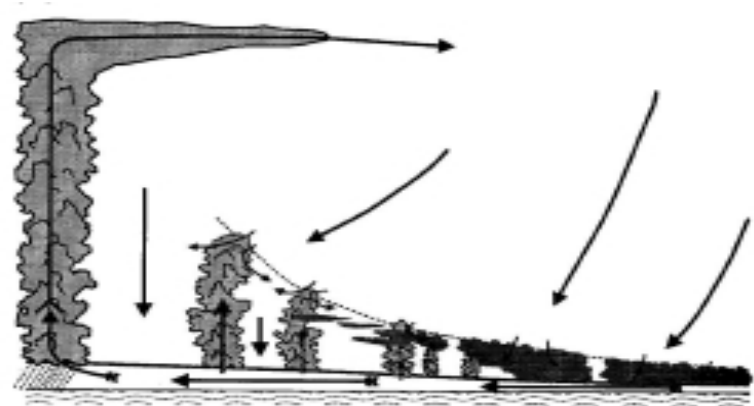
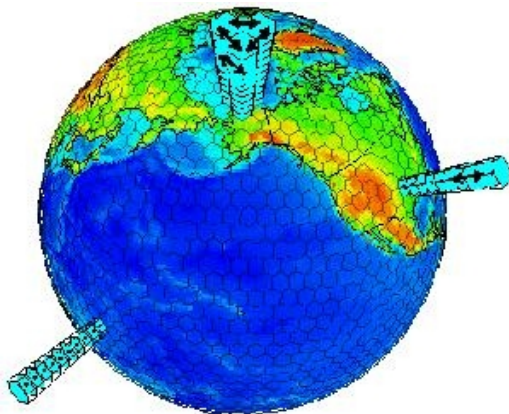
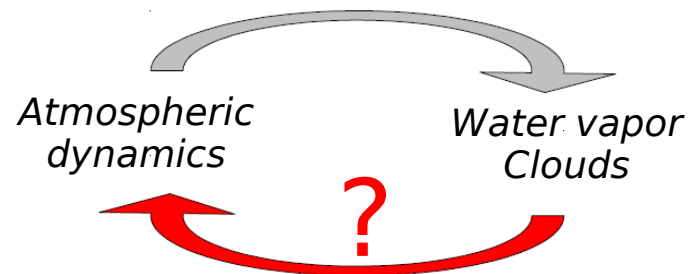
(Stevens & Bony, submitted)

# Coupling Clouds to Circulation

Led by Pier Siebesma (KNMI, Netherlands) & TBD

**Aim :** Tackle the parameterization problem through a better understanding the interaction between cloud / convective processes and circulation systems

**Focus :** Lessons from observations and cloud-resolving modelling over large domains ; Interaction between diabatic heating and large-scale dynamics



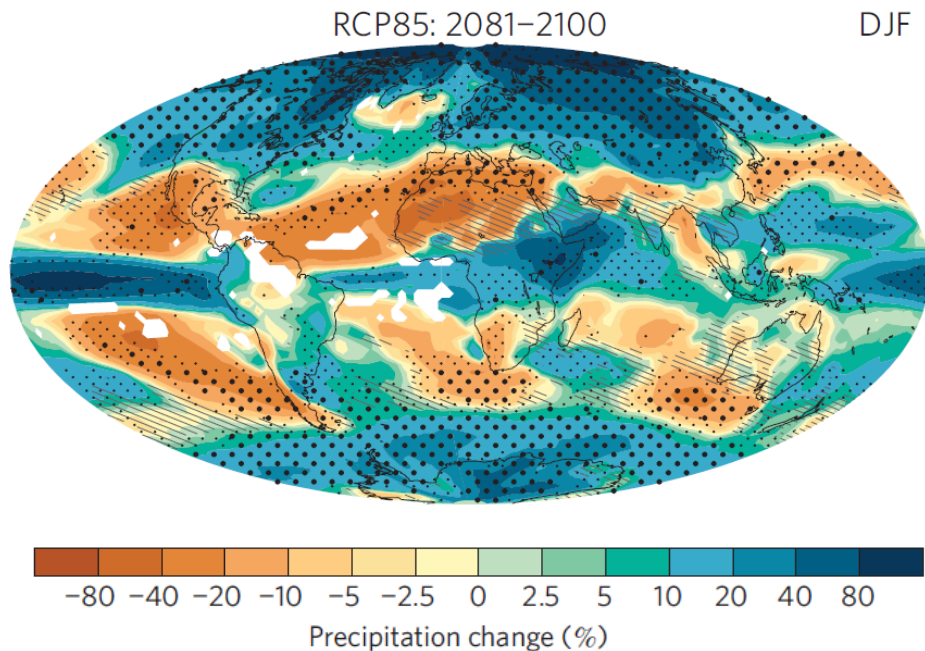


# Changing Patterns

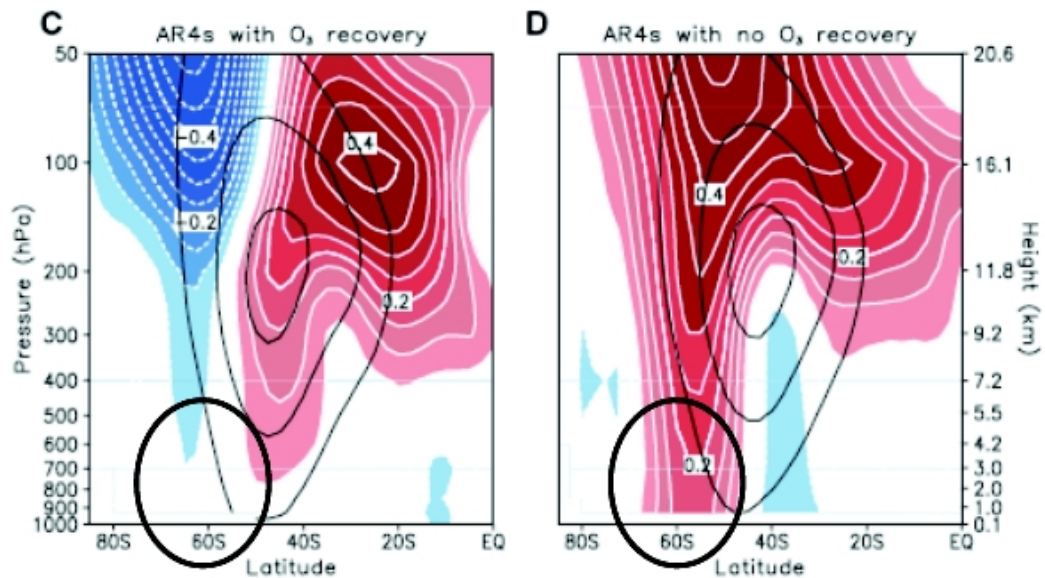
Led by Ted Shepherd (Univ. Reading, UK) & Adam Sobel (Columbia Univ., USA)

**Aim :** Better anticipate how the large-scale atmospheric circulation will respond to anthropogenic forcings (GHG, aerosols, ozone).

**Focus :** Role of local vs large-scale or remotely forced changes in driving regional changes ; Identify robust responses ; Interpret uncertain components ; Assess the impact of model biases or shortcomings on regional responses



*Knutti & Sedlacek (2012)*



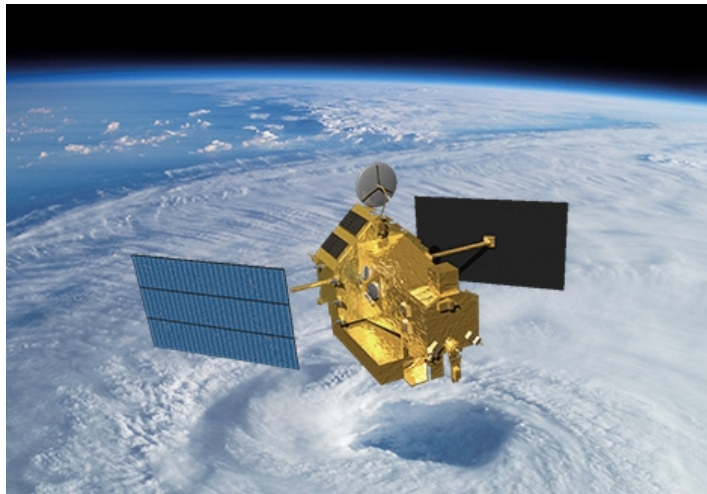
*Son et al. (2008)*

# Leveraging Records of the Recent and Longer Past

Led by Masa Kageyama (IPSL, France) & Robert Pincus (CIRES, USA)

**Aim :** Exploitation of observations of the recent past, or proxies for longer-term changes, to better constrain cloud processes and feedbacks

**Focus :** Analysis of decadal/multi-decadal records from satellite and in-situ observations; Improvement of paleo-climates reconstructions and syntheses ; Comparisons of past vs future changes

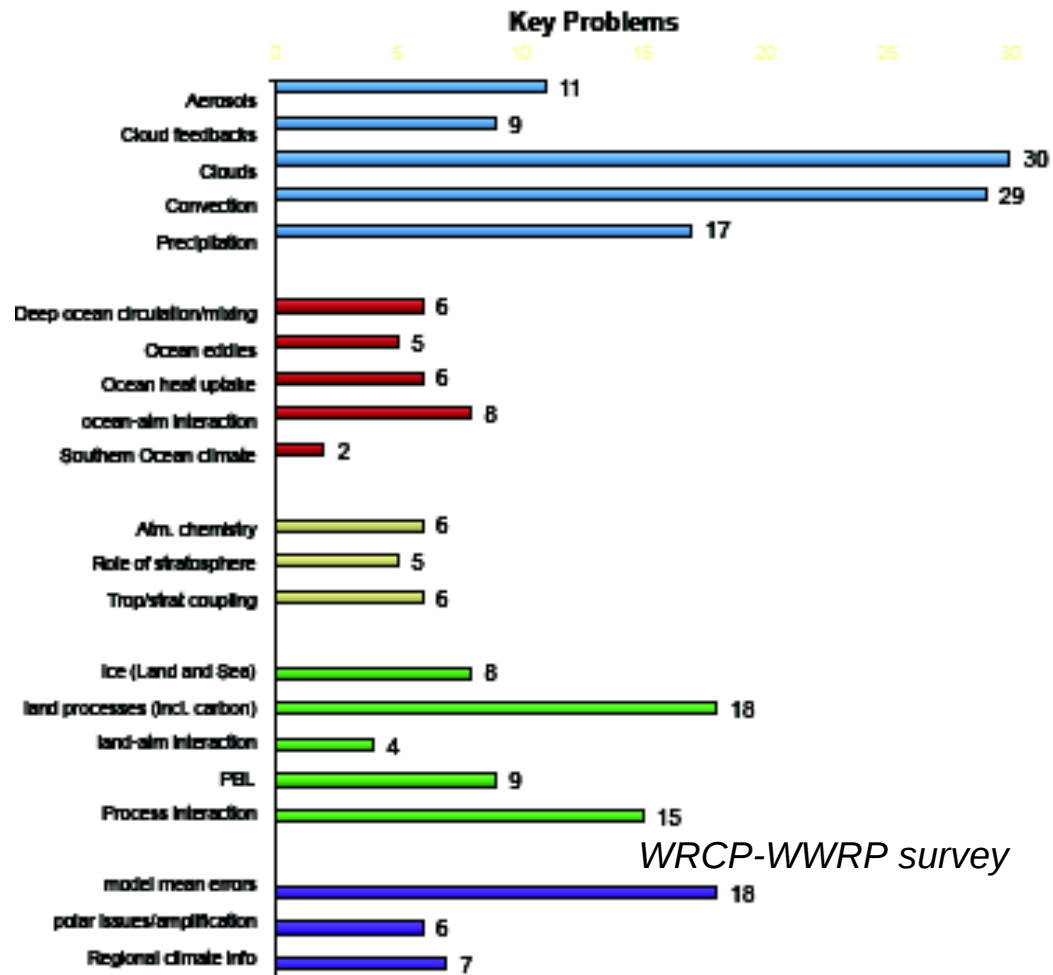
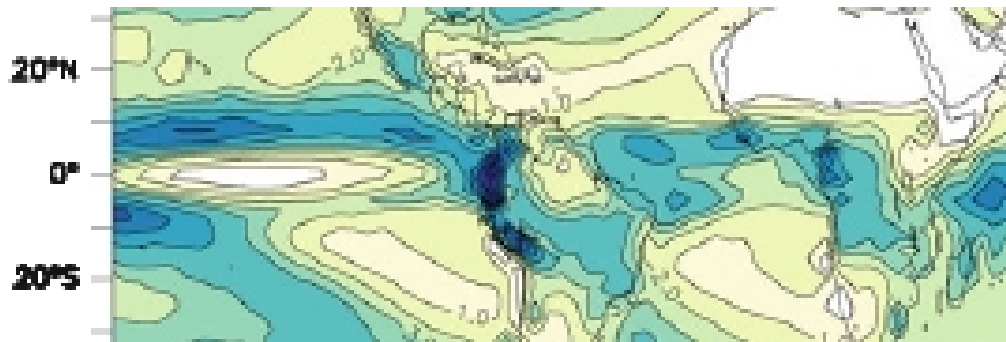


# Towards more Reliable Models

Led by Christian Jakob (Monash Univ., Australia) & Masahiro Watanabe (Tokyo Univ., Japan)

**Aim :** Interpret and reduce model errors to gain confidence in projections and predictions

**Focus :** Long-standing model biases (at least a few of them);  
Understand how model errors or shortcomings impact projections and predictions ;  
Gain physical understanding of the climate system through model development



# What's Next ?

## Grand Challenge :

Can help through collective priority setting, by maintaining focus on critical problems, by promoting activities within our community.

## First step (2013) :

- **To sharpen each initiative by highlighting key science questions**  
and by identifying opportunities (e.g. on-going projects) and gaps (e.g. missing connections)
- For this purpose, take advantage of (already planned) meetings :
  - e.g. are there key model biases that should be tackled in priority ? (WGNE workshop)***
  - how can observations help understand cloud-circulation couplings ? (ISCCP-30)*
  - how do aerosols affect large-scale atmospheric circulations ? (Aerocom)*
  - how robust is the large-scale circulation response to climate change ? (Royal Soc)*

## Then :

Motivate the community to work on GC initiatives (e.g. through high-profile papers), and implement them through :

- \* on-going projects (e.g. CFMIP/GASS, WGNE, SPARC, PMIP)
- \* workshops, summerschools
- \* CMIP6 design



**Ideas ? Suggestions ? Join the Grand Challenge !**



# Coordination

## GC led by WGCM, in close collaboration with GEWEX/GASS, WGNE and SPARC

Many of the initiatives leverage on-going or planned WCRP projects.

## GC Steering Committee

To ensure progress, coordination and integration of the different initiatives

Lead coordinators:

**Sandrine Bony** (France) & **Bjorn Stevens** (Germany)

Initiative #1: Climate and hydrological sensitivity

**Steven Sherwood** (Australia) & **Mark Webb** (UK)

Initiative #2: Leveraging the past record

**Masa Kageyama** (France) & **Robert Pincus** (USA)

Initiative #3: Coupling clouds to circulations

**Pier Siebesma** (Netherlands) & TBD

Initiative #4: Changing patterns

**Ted Shepherd** (UK) & **Adam Sobel** (USA)

Initiative #5: Towards more reliable models

**Christian Jakob** (Australia) & **Masahiro Watanabe** (Japan)