

WCRP Grand Challenge on Clouds, Circulation and Climate Sensitivity

Lead coordinators :

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with

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Steven Sherwood, Pier Siebesma, Adam Sobel, Masahiro Watanabe and Mark Webb

WCRP Grand Challenges

* Major research areas that are critical for climate science and for which targeted research efforts are likely to lead to significant progress over the next decade.

* 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
- Changes in Water Availability
- Prediction and attribution of extreme events
- **Clouds, Circulation and Climate Sensitivity**

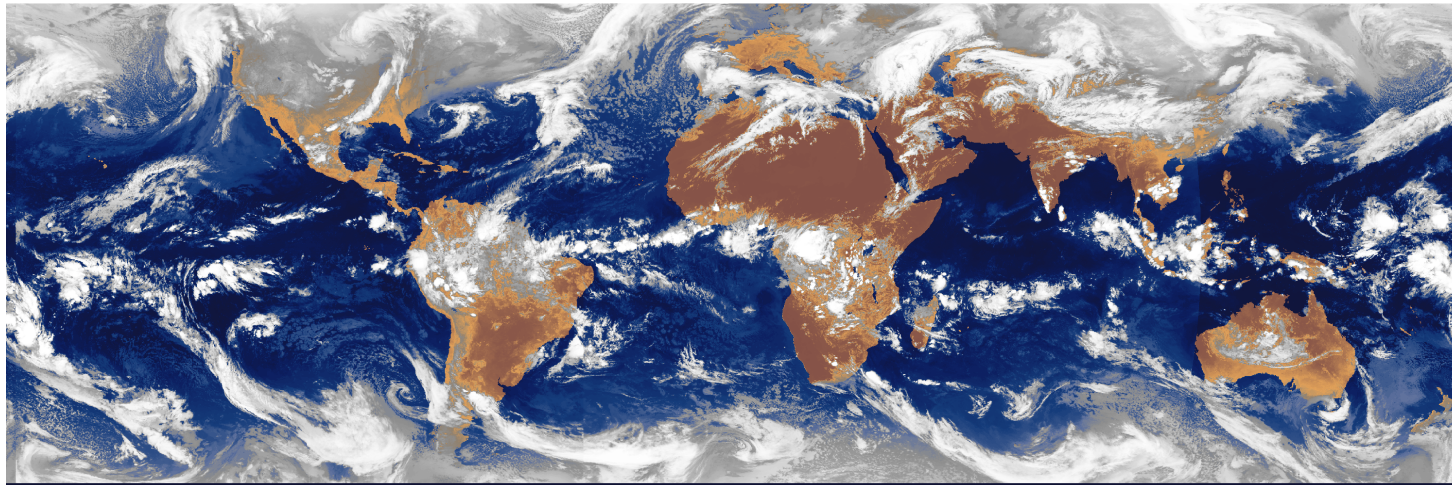
* More information on : <http://www.wcrp-climate.org/index.php/grand-challenges>

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

Led by WGCM, in collaboration with GEWEX, WGNE and SPARC



barriers ? opportunities ? initiatives ?

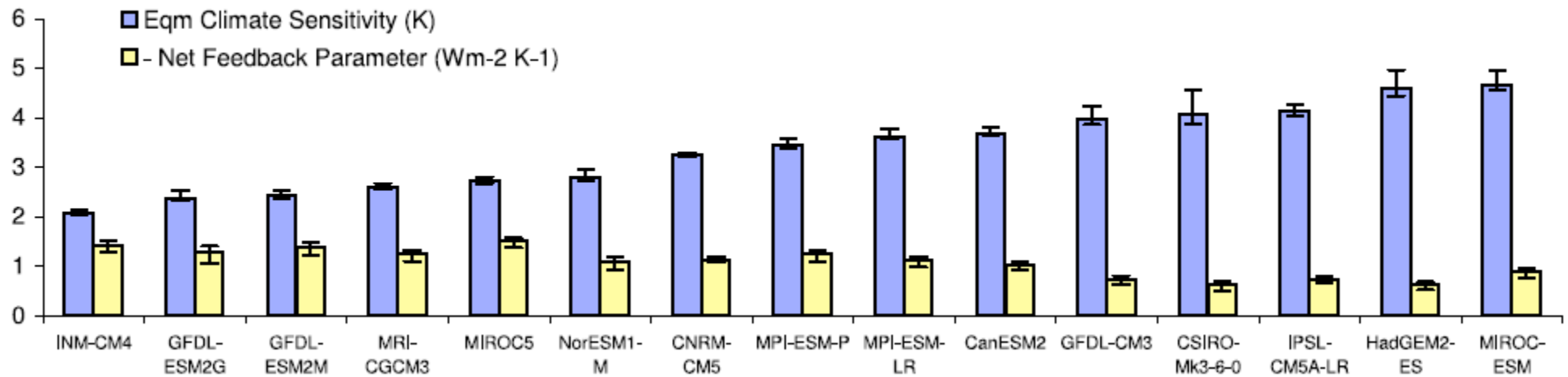
<http://www.wcrp-climate.org/index.php/gc-clouds>

* 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.

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

CMIP5 Climate Sensitivity Estimates



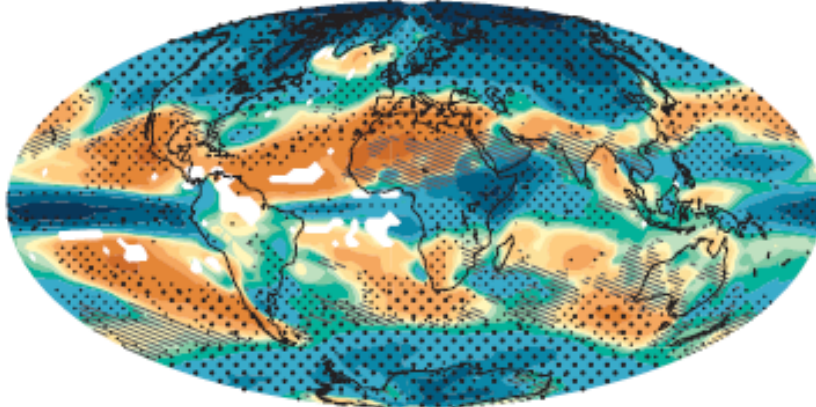
Range : 2 K – 4.6 K

Precipitation projections

CMIP5 (RCP8.5)

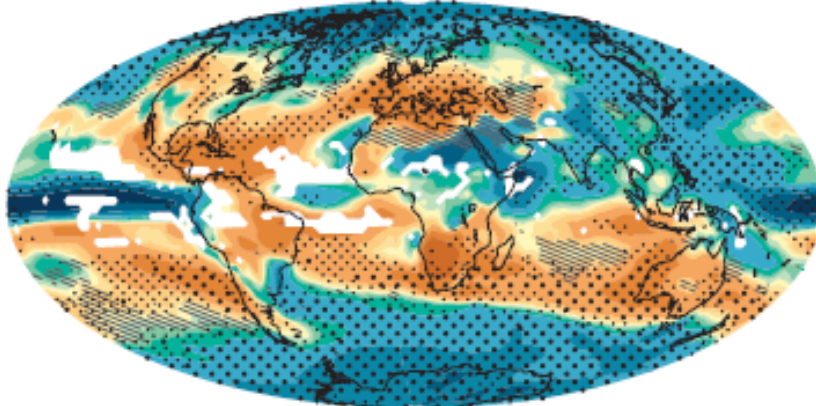
RCP85: 2081-2100

DJF



RCP85: 2081-2100

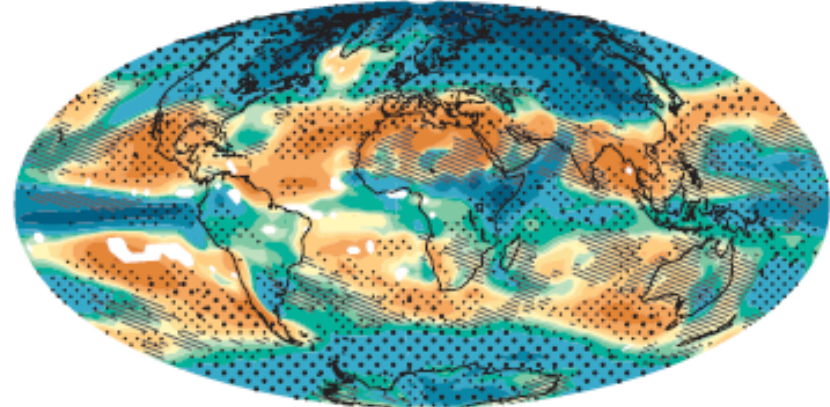
JJA



CMIP3 (SRES-A2)

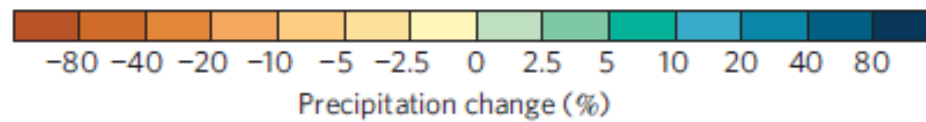
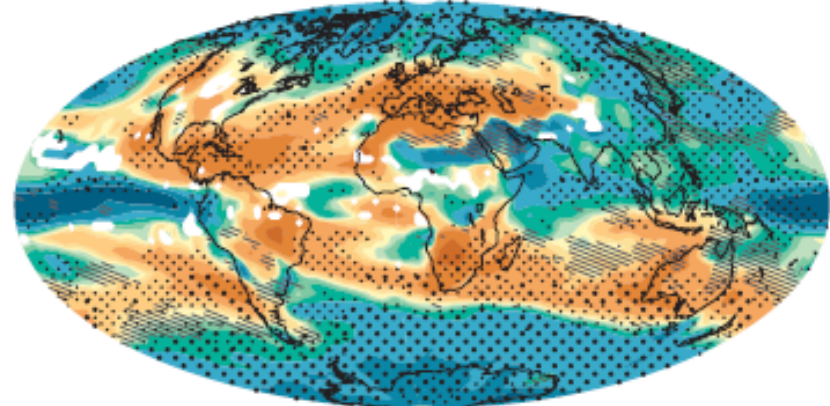
SRES-A2: 2081-2100

DJF

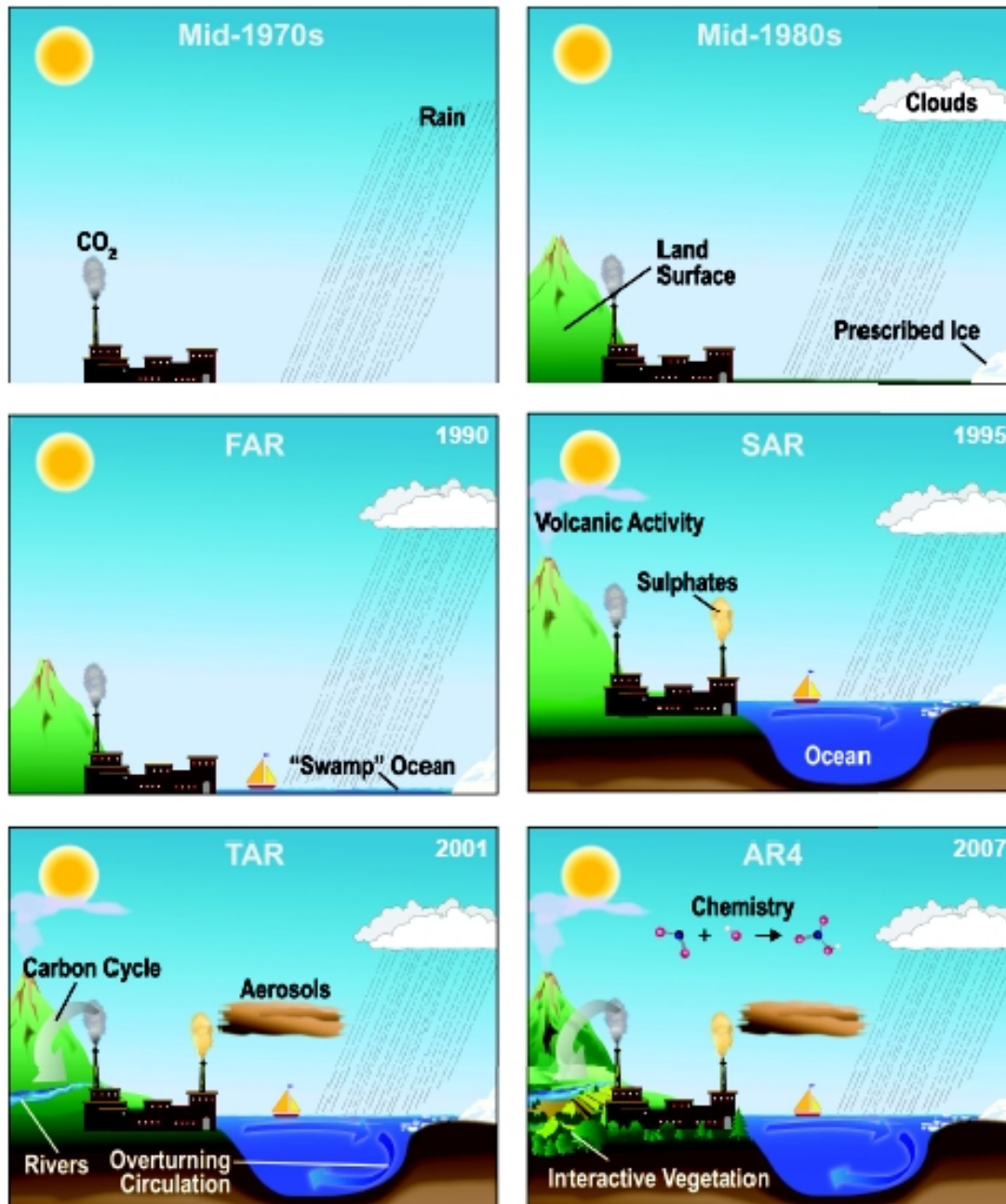


SRES-A2: 2081-2100

JJA



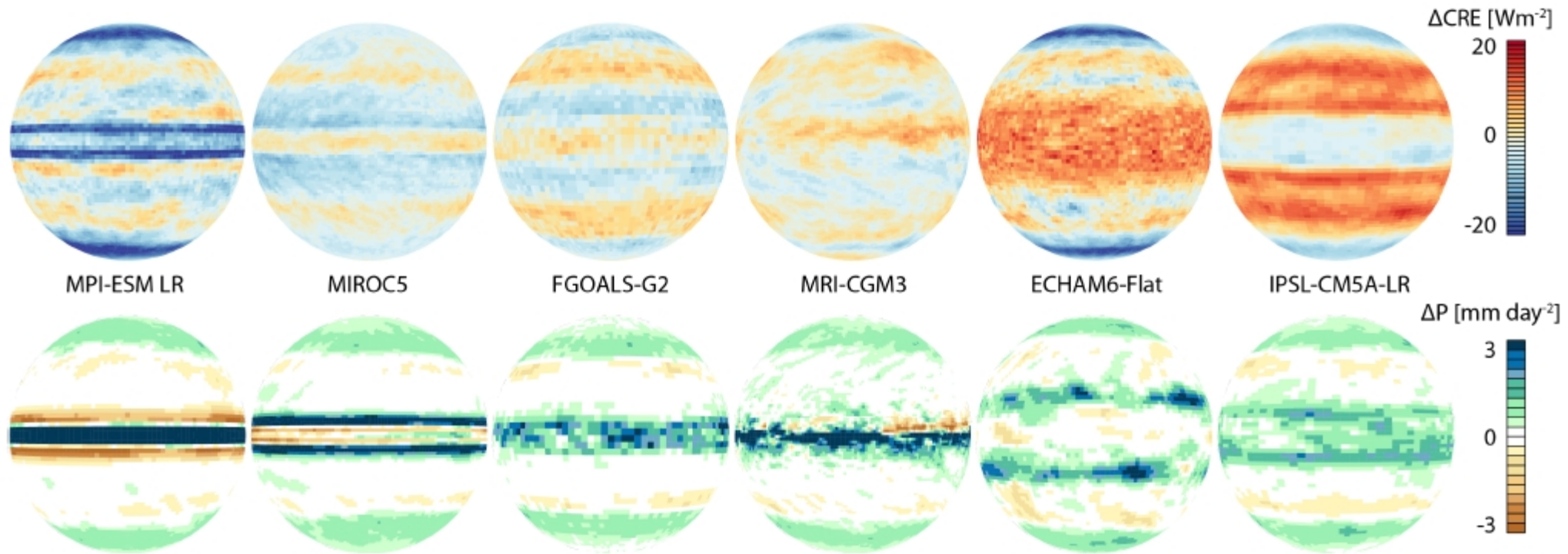
From GCMs to OAGCMs to ESMs...



- GCMs have become more and more complex (aerosols, interactive vegetation, carbon cycle, chemistry, etc)
- The drive to complexity has greatly extended the scope of questions that can be addressed with GCMs...
but has not reduced key uncertainties

Something aqua planets make painfully evident

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



- Uncertainties related to basic physical processes :
interactions atmospheric water / temperature / circulation
- Critical limitation for mitigation and adaptation studies

Interplay between
atmospheric water, temperature and circulation



**WCRP Grand Challenge on
Clouds, Circulation and Climate Sensitivity**

WCRP Organization

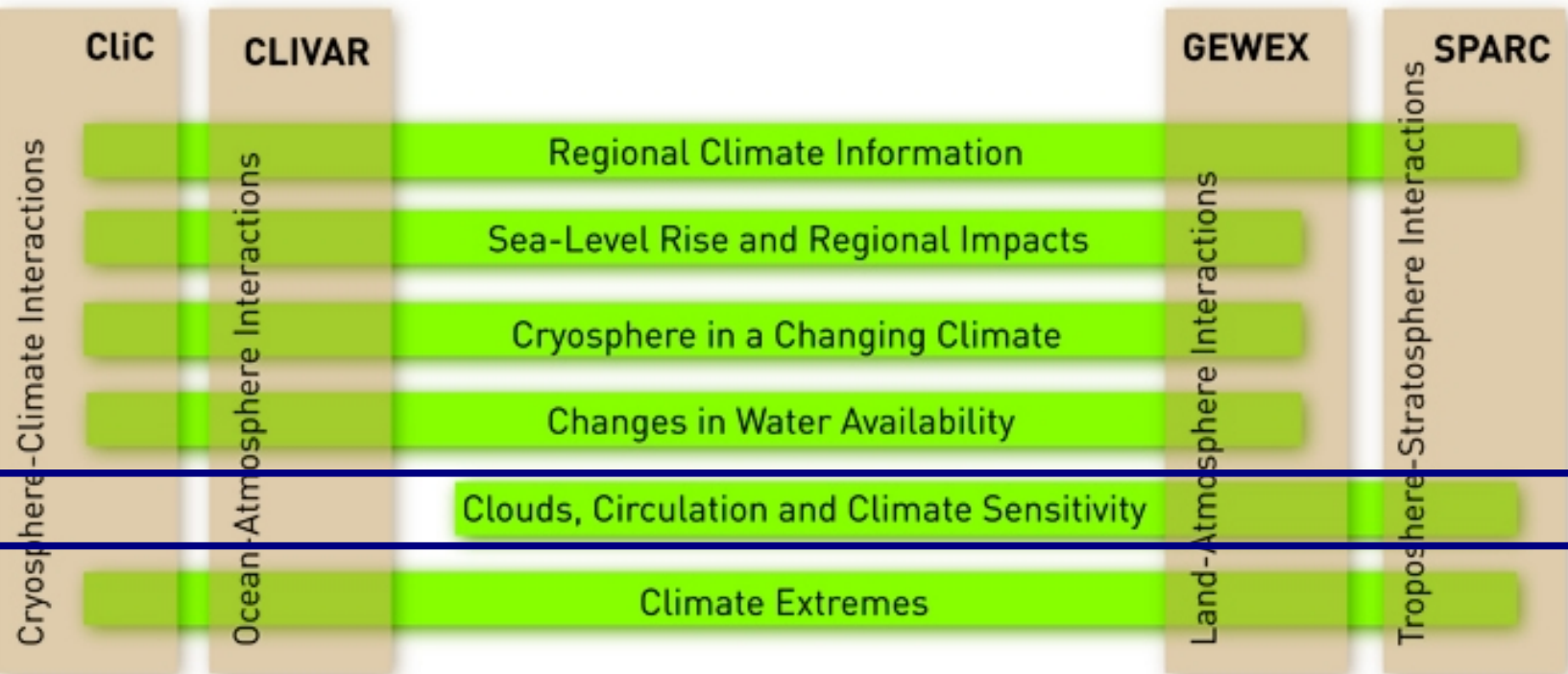
Joint Scientific Committee

Joint Planning Staff

Modeling Advisory Council

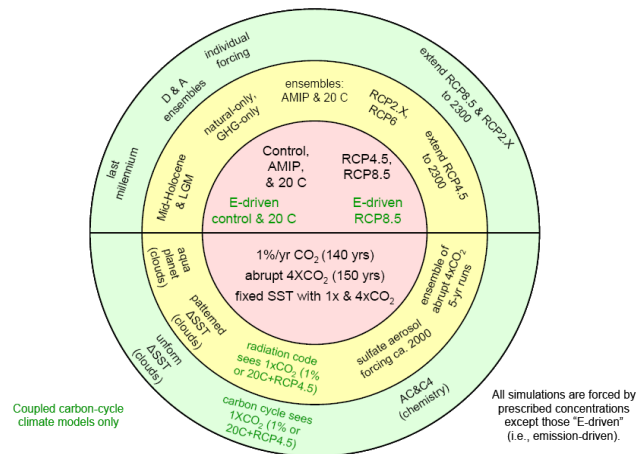
Data Advisory Council

Working Groups on: Coupled Modelling (WGCM), Regional Climate (WGRC), Seasonal to Interannual Prediction (WGSIP), Numerical Experimentation (WGNE)

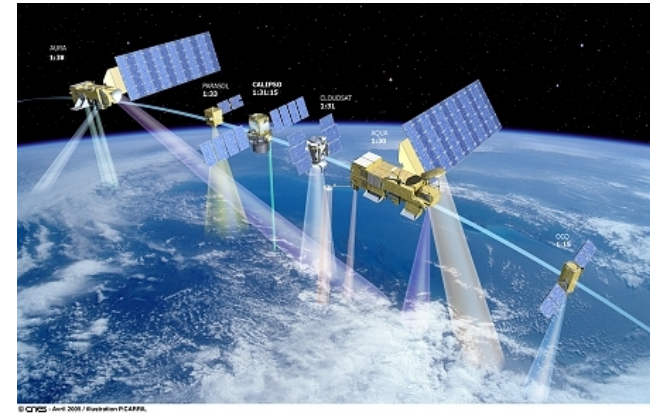


Opportunities

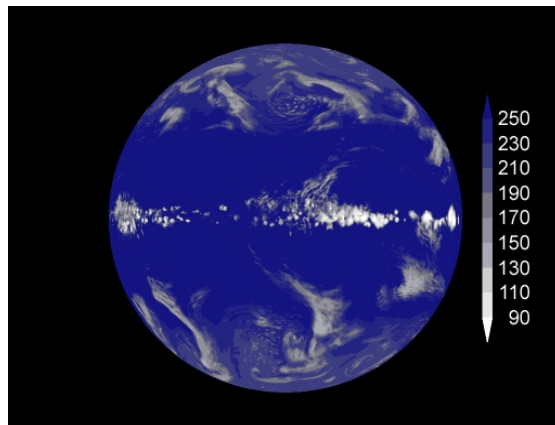
CMIP5 and associated MIPs



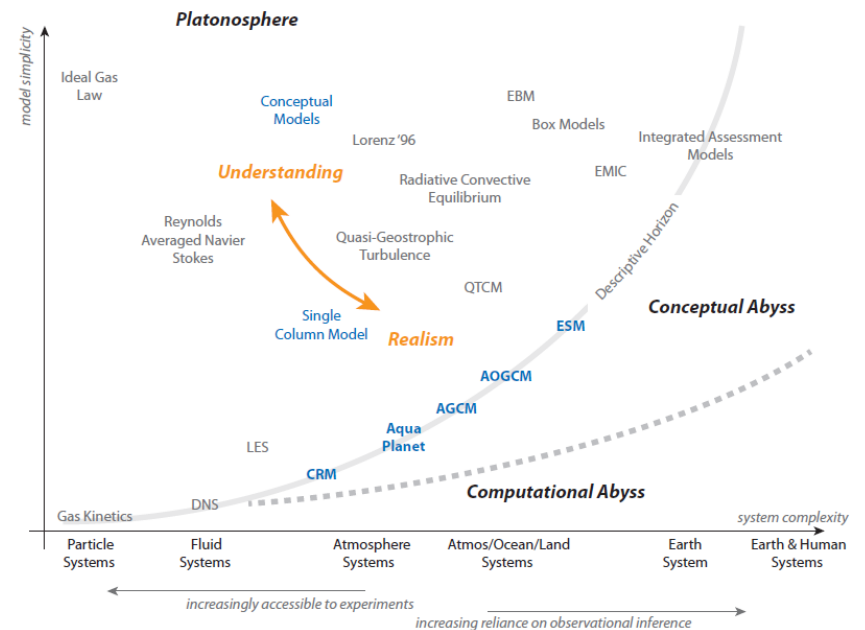
A golden age of Earth observations



Qualitatively new types of models



Lessons from experience



An interconnected
research community



WCRP Grand Challenge on Clouds, Circulation and Climate Sensitivity

Centered around five initiatives :

1. Climate and hydrological sensitivity
2. Coupling clouds to circulations
3. Changing patterns
4. Leveraging the past record
5. Towards more reliable models

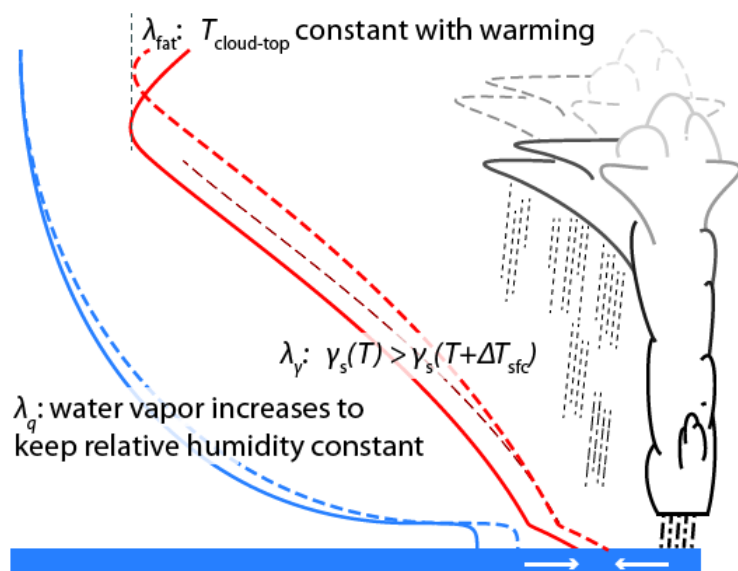
1. Climate and Hydrological Sensitivity

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

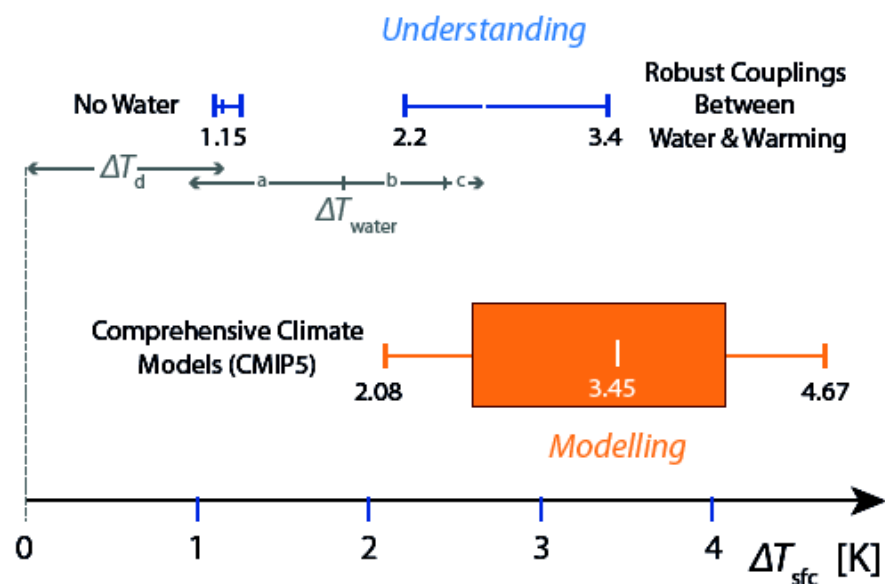
Aim : Design critical tests for climate models, whose application will help assess the most likely estimates of climate and hydrological sensitivity.

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

Connections : WGCM/CMIP5/CFMIP (e.g. CGILS), GEWEX/GASS, PMIP



Equilibrium Climate Sensitivity



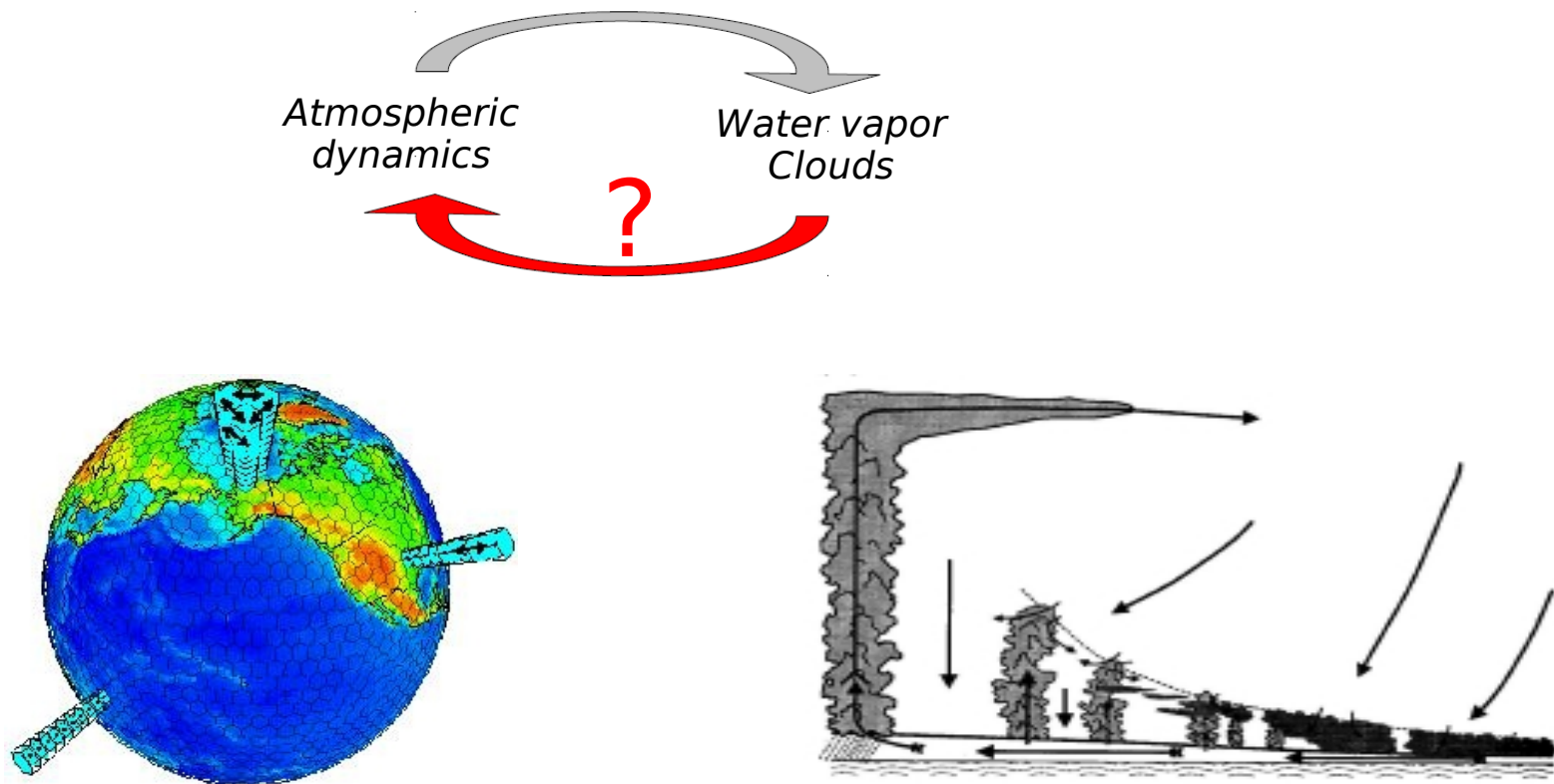
2. Coupling Clouds to Circulation

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

Connections : WGCM/GEWEX/WGNE (e.g. CFMIP, T-AMIP, global CRM/LES models),
WWRP/GEWEX/CLIVAR (MJO-diabatic), SPARC



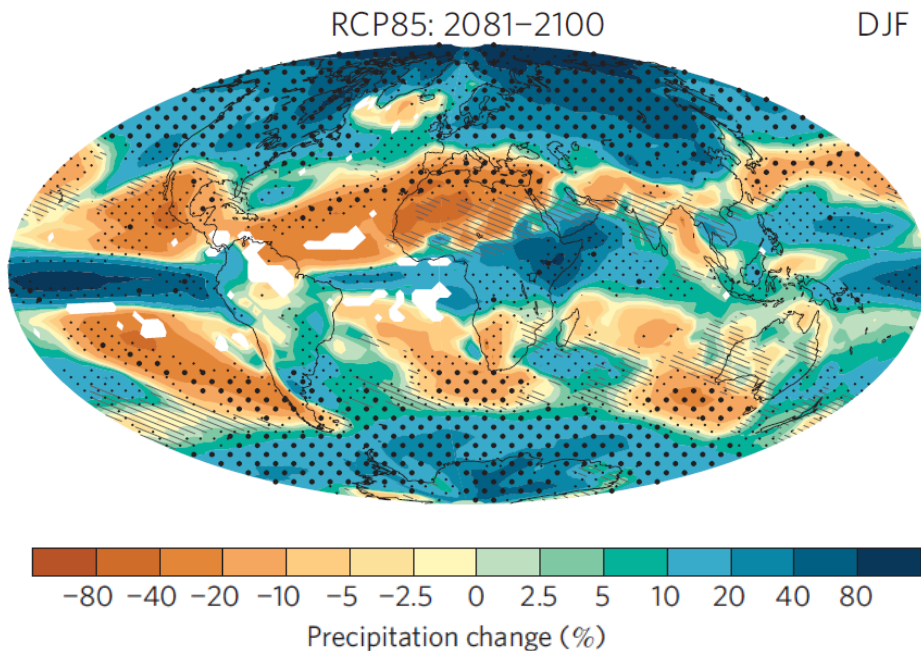
3. Changing Patterns

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

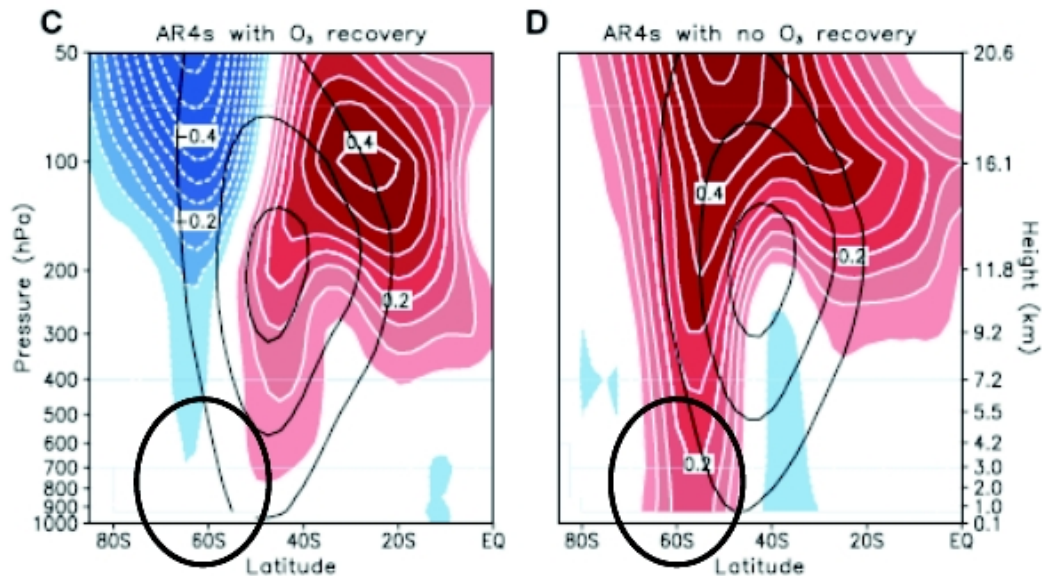
Aim : Better anticipate how the large-scale atmospheric circulation will respond to anthropogenic forcings (GHG, aerosols, ozone).

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

Connections : GEWEX/GASS (e.g. WTG), AEROCOM, SPARC



Knutti & Sedlacek (2012)



Son et al. (2008)

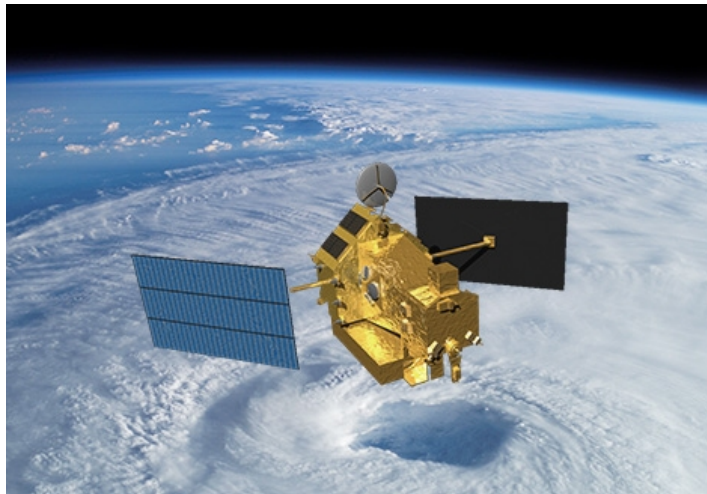
4. Leveraging Records of the Recent and Longer Past

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

Connections : GEWEX/GDAP, PMIP



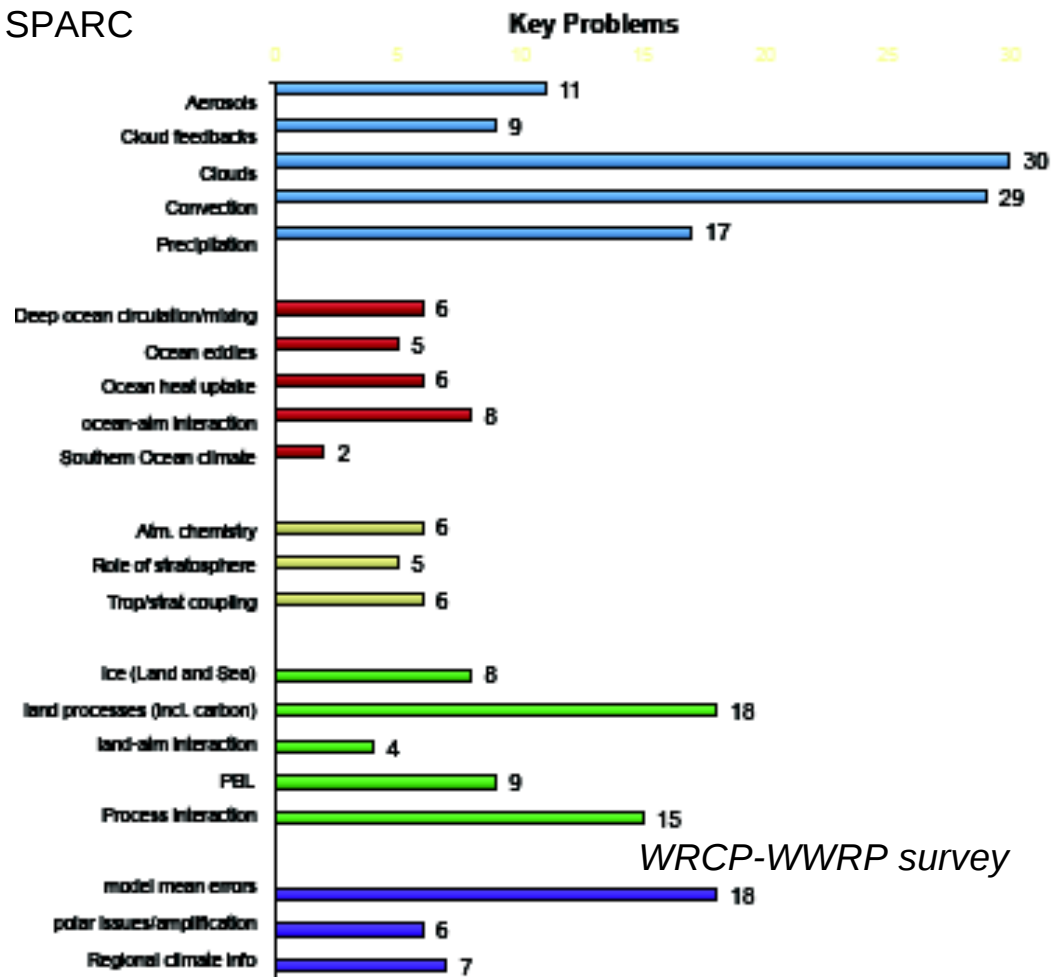
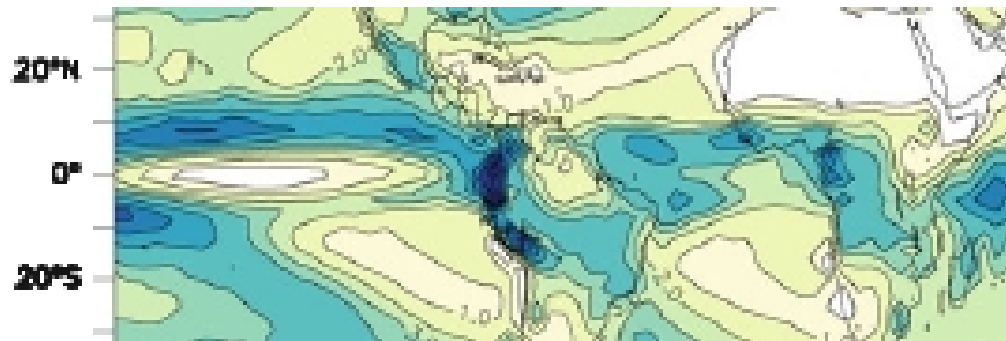
5. Towards more Reliable Models

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

Connections : WGNE, WGCM, GEWEX/GASS, SPARC



Next steps : an outline

Grand Challenge :

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

Next steps : an outline

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. For instance :

WGNE workshop on systematic errors (Exeter, Apr 2013)

-> encourage the development of diagnostic methods that are specifically aimed at linking dynamical and physical processes in models. A special workshop in this area might be helpful to organize the community.

ISCCP 30th Anniversary (New-York, Apr 2013)

-> identified key questions for our GC (with a particular focus on the observational component) such as :

- * How does convective organization influence to the large-scale circulation? What observational network would help investigate this issue ? Might convection organize differently in a warmer world ?*
- * How do clouds mediate the coupling between the atmosphere and the surface ? (land sfc temp, arctic sea ice)*
- * How do extratropical clouds interact with the general circulation (e.g. position and strength of the jets) ?*

CFMIP workshop (Hamburg, June 2013)

And soon :

How do aerosols affect large-scale atmospheric circulations ? (Aerocom workshop)

How robust is the large-scale circulation response to climate change ? (Royal Soc workshop)

Role of atmospheric water in circulation (Lorenz centre, MIT)

- But also organize new meetings

Next steps : an outline

Next :

**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, AEROCOM)
- * workshops
- * summerschools
e.g. « *On the role of clouds in climate* » (Les Houches, France, July 2013)
- * CMIP6 design
- * The identification of new projects

Passion, dreams and ideas welcome !

**What do you think are the most critical science questions
on which this Grand Challenge should focus?**