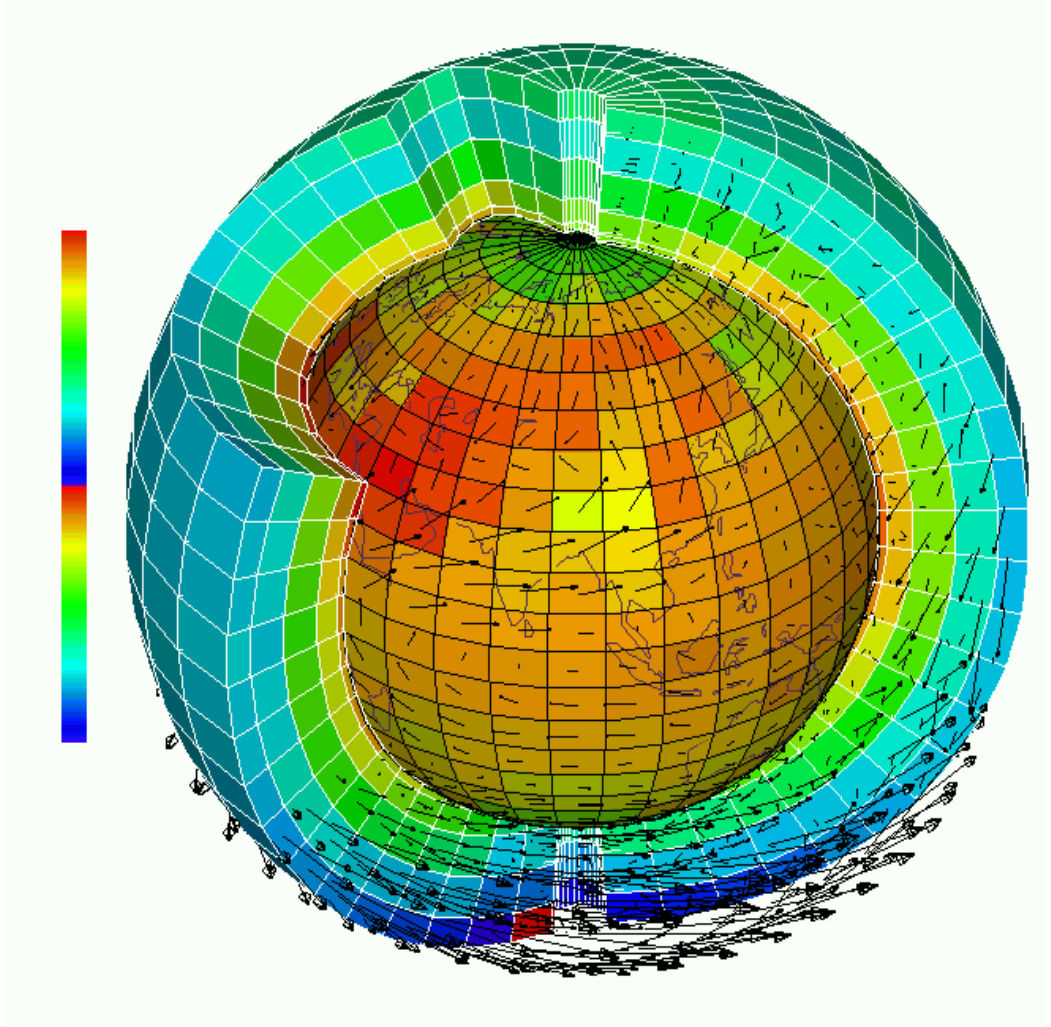
The Working Group on Coupled Models (WGCM)

Report to the JSC-33



Sandrine Bony & Jerry Meehl
WGCM co-chairs

Beijing, July 2012

WCRP
World Climate Research Programme

WGCM

- Review and foster the development and use of coupled climate models (and now ESMs)

- Representatives from international climate modeling groups, as well as other communities now connected to climate modeling (e.g. regional modeling, paleoclimate, IAMs, chemistry, carbon feedbacks, cloud processes and feedbacks)

Coordinate model experiments and inter-comparisons to:

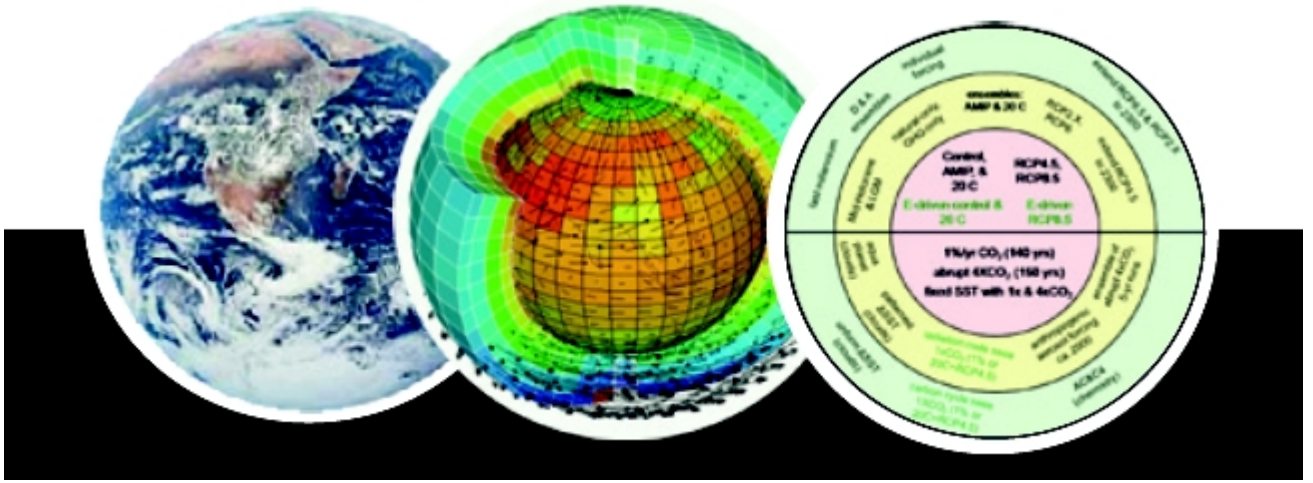
- better understand natural climate variability and predictability (decadal to centennial)
- predict and understand past and future climate changes

- Promote and facilitate model evaluation using observations and diagnosis of limitations to suggest where improvements can be made

Promote a balance between :

Prediction, Evaluation & Understanding

WCRP Coupled Model Intercomparison Project - Phase 5 - CMIP5 -

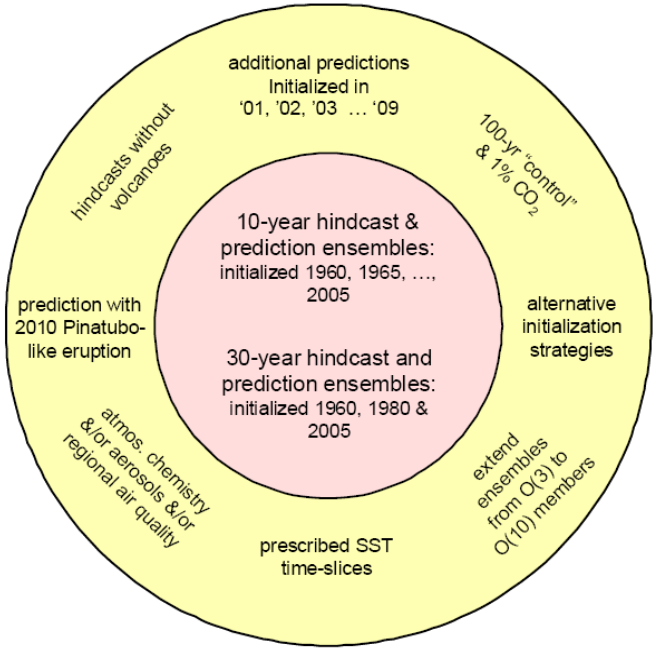


CLIVAR Exchanges, CMIP5 special issue (May 2011)

- The largest and most ambitious model inter-comparison ever organized (26 modeling centers, 53 models, many experiments & outputs)

CMIP5 is organized around several sets of simulations

“Near-Term” Experiments (decadal, up to 2035)

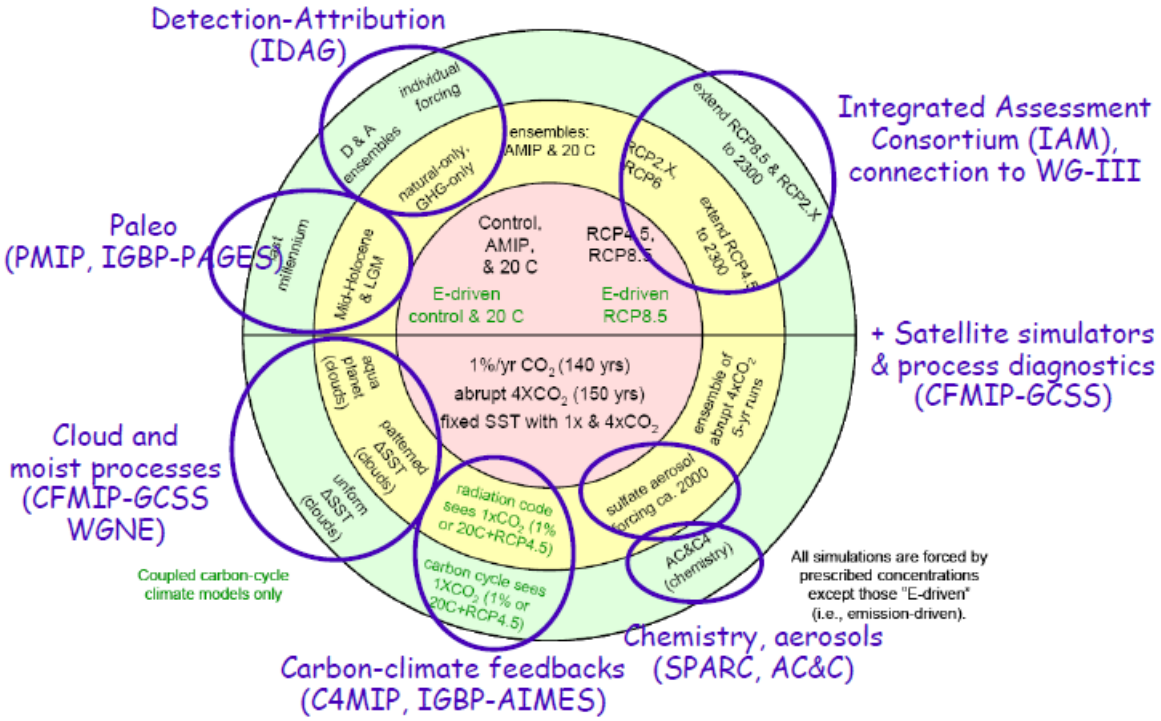


Designed and overseen by the WGCM-WGSIP Decadal Climate Prediction Panel

Up to 26 models (currently)

Mean Resol: 1.3 deg (atm); 0.8 deg (ocean)

“Long-Term” Experiments (century & longer)

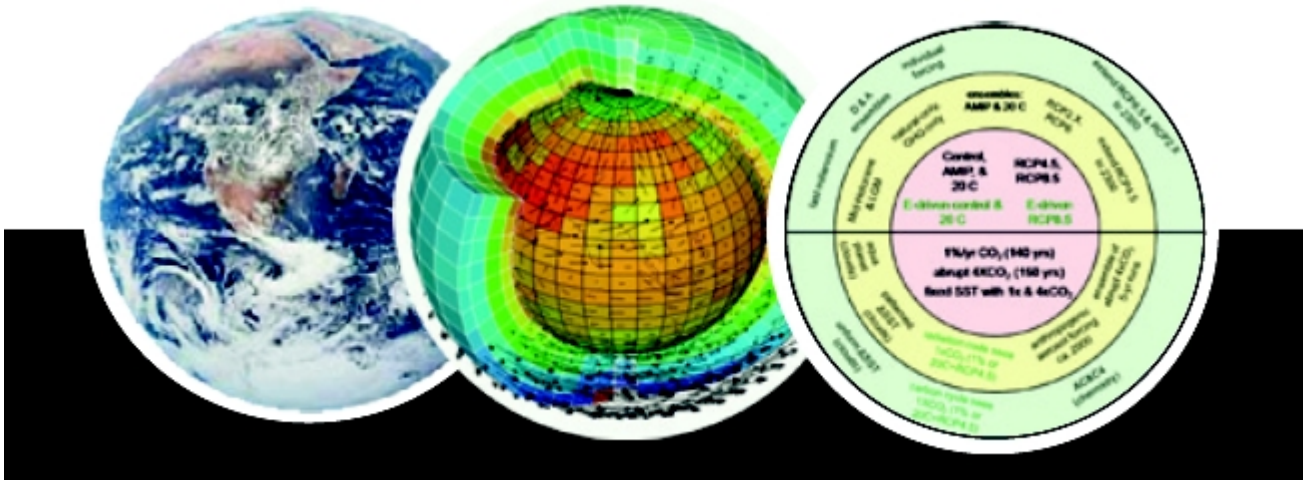


Designed in collaboration with many WCRP/IGBP partners

Up to 42 models (currently)

Mean Resol: 2.1 deg (atm) ; 0.9 deg (ocean)
+ a few high-resol global models (0.2-0.6 deg)

WCRP Coupled Model Intercomparison Project - Phase 5 - CMIP5 -



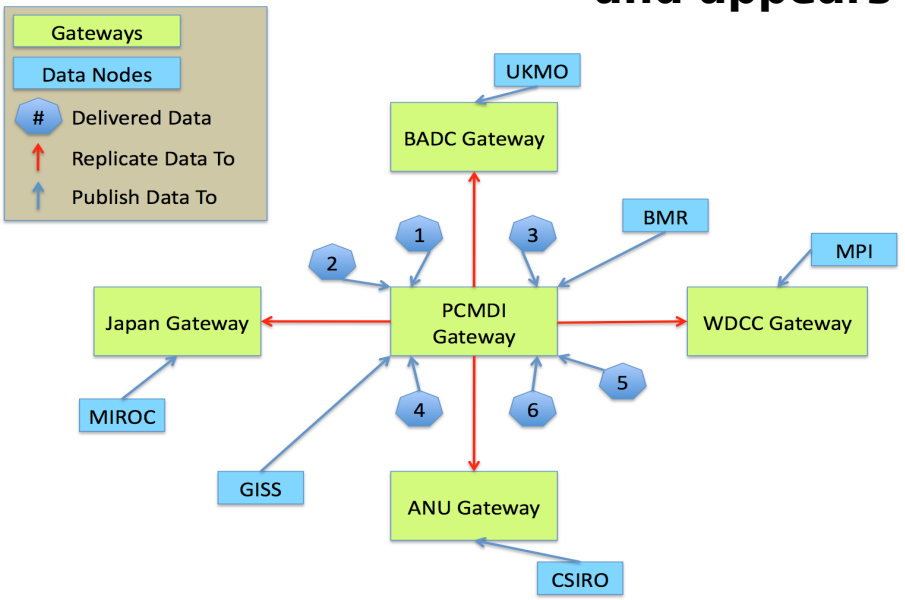
CLIVAR Exchanges, CMIP5 special issue (May 2011)

- The largest and most ambitious model inter-comparison ever organized
  (26 modeling centers, 53 models, many experiments & outputs)

- First lessons ?

Governance of the Earth System Grid Federation (ESGF)

CMIP5 model output is served by federated centers around the world and appears to be a single archive :



- Distributed archival and storage capability widely viewed as the future of accessing both model and observed data for a wide variety of applications in climate science

- PCMDI + other partners (BADC, DKRZ, NCAR, etc)

- **Governance structure of the ESGF needs to be improved** (e.g. decision-making framework or procedure accepted by the various ESGF institutions, interface with both our community and other communities)

→ **Role of WCRP in organizing it ? A new ESGF Working Group in WCRP ?**

CMIP5 Model Analysis Workshop

(IPRC, Hawaii, March 5-9 2012)

175 participants (230 abstracts submitted)

CMIP5 Model Analysis Workshop

(IPRC, Hawaii, March 5-9 2012)

First impressions from organizing committee (G. Meehl, S. Bony, K. Taylor)

• In spite of some delays in model availability and challenges in downloading model data, analyses so far usually could include between 15 and 22 AOGCMs, 4 to 8 decadal prediction simulation sets, about 6 high-top models, and 3 to 8 ESMs included in analyses, and there is **considerable interest and excitement in analyzing model data to learn new things** about the climate system.

• The concern that the spread of future projections from the new generation of AOGCMs with more complexity, or from ESMs with coupled carbon cycle, would be wildly greater than from the AOGCMs of CMIP3 appears to have been unfounded —**spread of projections in CMIP5 AOGCMs comparable to CMIP3**, and most first generation ESMs are well-behaved and produce **comparable first order results to AOGCMs**.

• However, CMIP5 offers the opportunity :

- to study climate change with **many additional capabilities**
  (carbon and chemistry, short-term climate change, comparison paleo/future, forcings and feedbacks diagnostics, high-resolution, high-frequency outputs, etc)
- to **better understand the spread and better assess the robustness** of model results

• Regarding model performance :

- **Some quantities show considerable improvement** (e.g. rate of sea ice loss in Arctic) or a decrease in model spread (e.g. AMOC, Nino3 standard deviation)
- **Others have not significantly improved** (e.g. double ITCZ, Arctic clouds and atmospheric circulation, Antarctic sea ice loss, southern ocean too warm, SPCZ too zonal, humidity in subtropical descent regimes too high)

Synthesis of CMIP5 results

- Hundreds (thousands?) of papers will be based on CMIP5 model output analysis
- **Growing need for community reviews and syntheses of CMIP5 analysis results**

→ An opportunity for WCRP

  - to sollicit a series of synthesis papers from its core panels, WG, expert communities
  - to make its activities highly visible..and more digestable by other communities
  - to facilitate IPCC assessments (ARs are not review papers..)

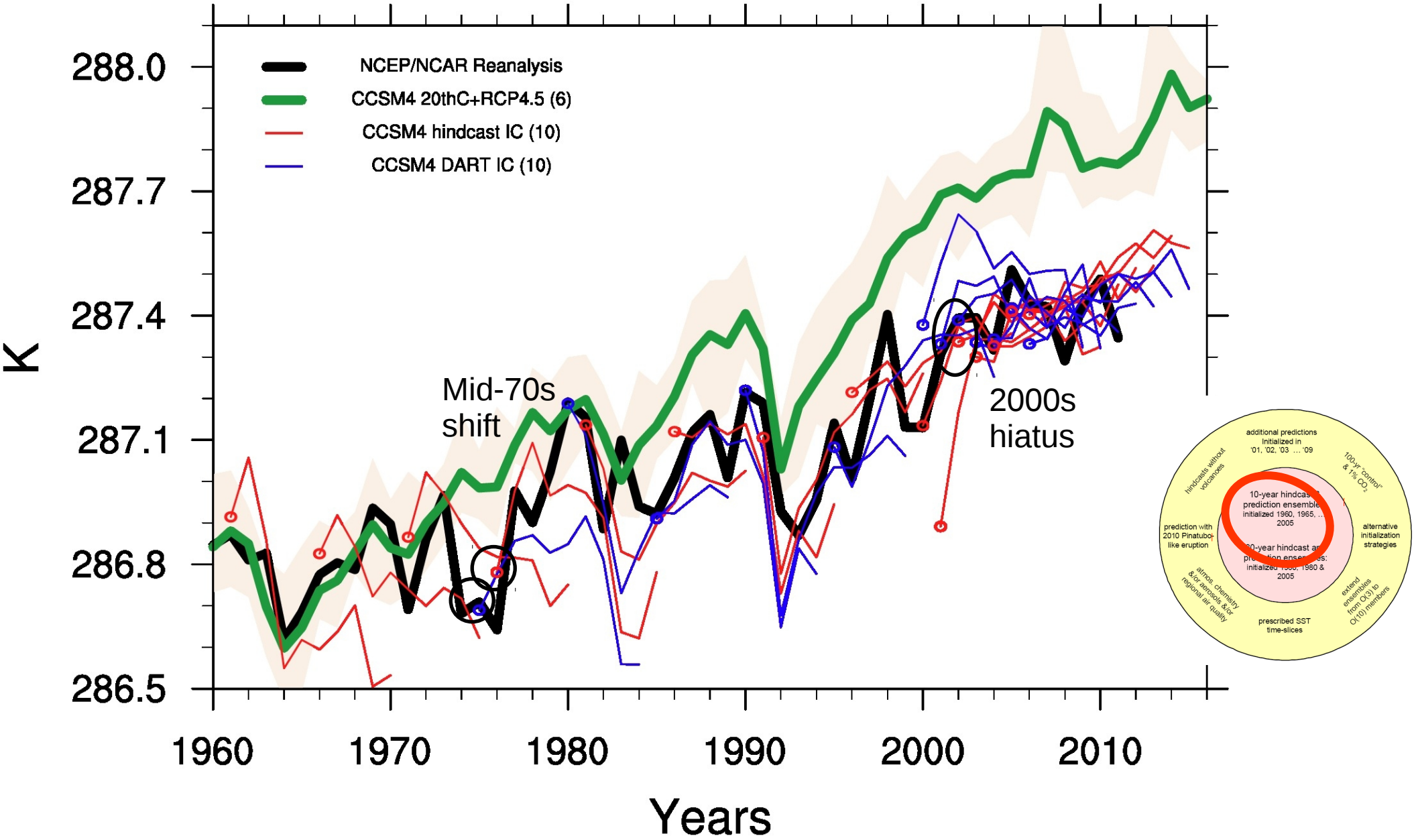
→ How to organize this activity in practice ?

What have we learned from CMIP5 so far ?

just a few early examples

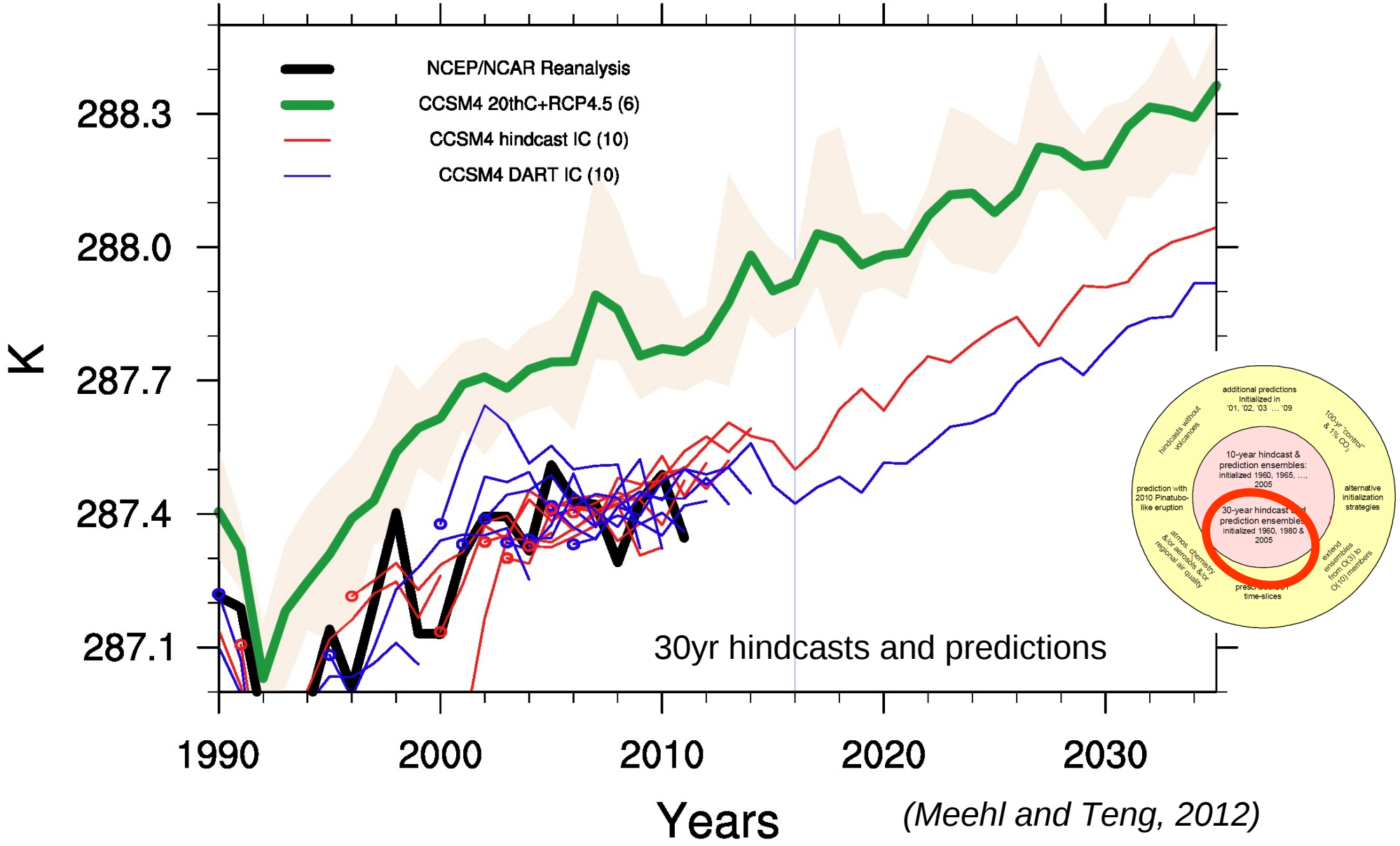
much more to come in the future !

Global Annual Mean Surface Air Temperature



Decadal ten year bias-adjusted hindcasts using two initialization methods (red and blue lines, ten member ensemble averages; circled initial states capture the mid-1970s shift and 2000s hiatus) *(Meehl and Teng, 2012)*

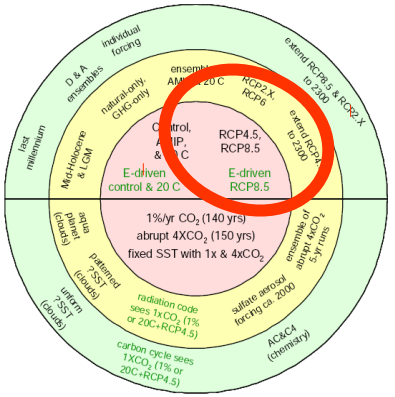
Global Annual Mean Surface Air Temperature



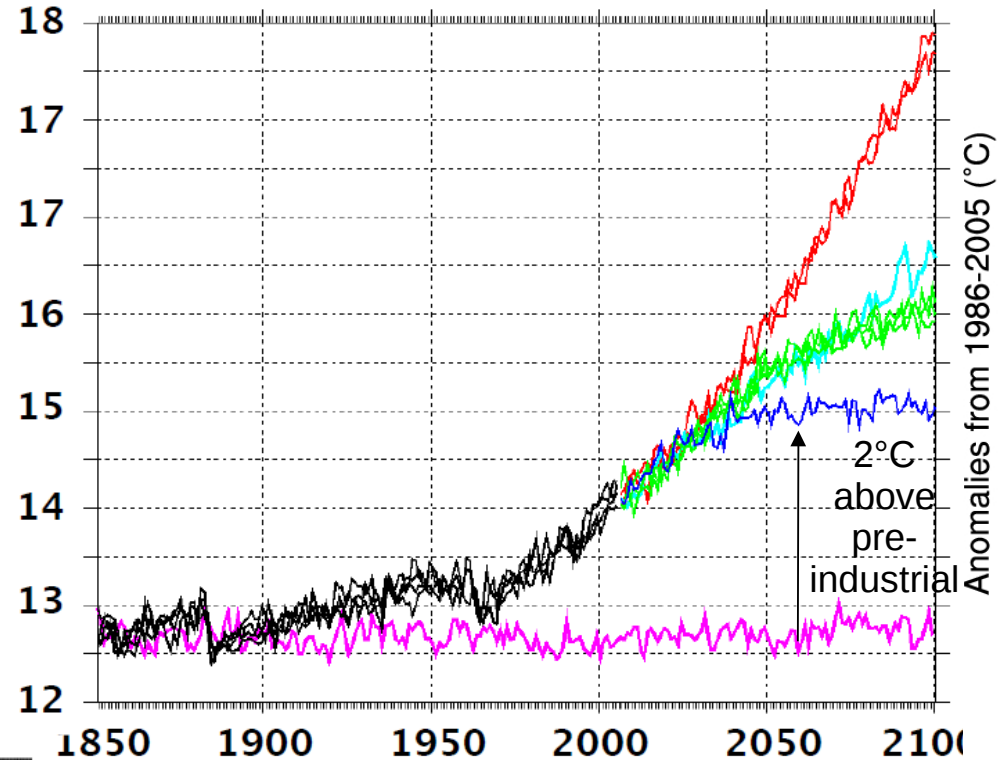
(Meehl and Teng, 2012)

30 year bias-adjusted predictions using two initialization methods
(red and blue lines are ten member ensemble averages)

Global warming predicted by 2 CMIP5 climate models for several RCP mitigation scenarios



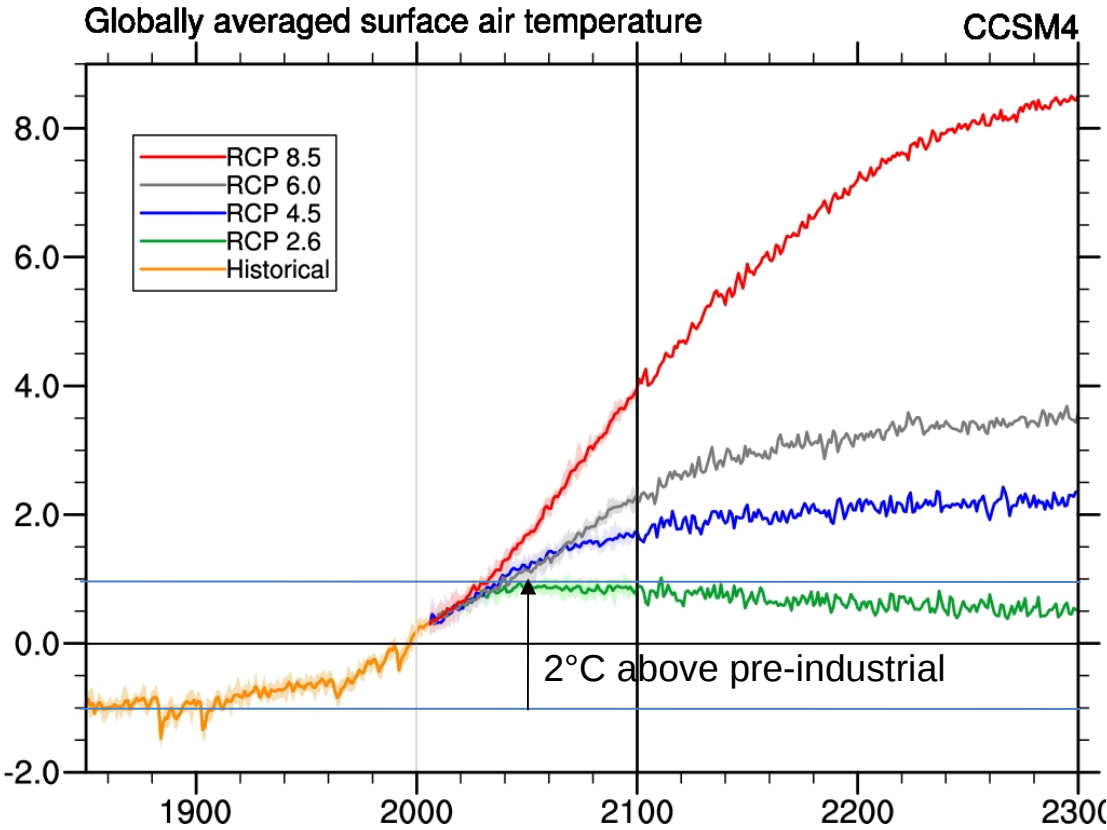
IPSL-CM5A



Dufresne et al. (2012)

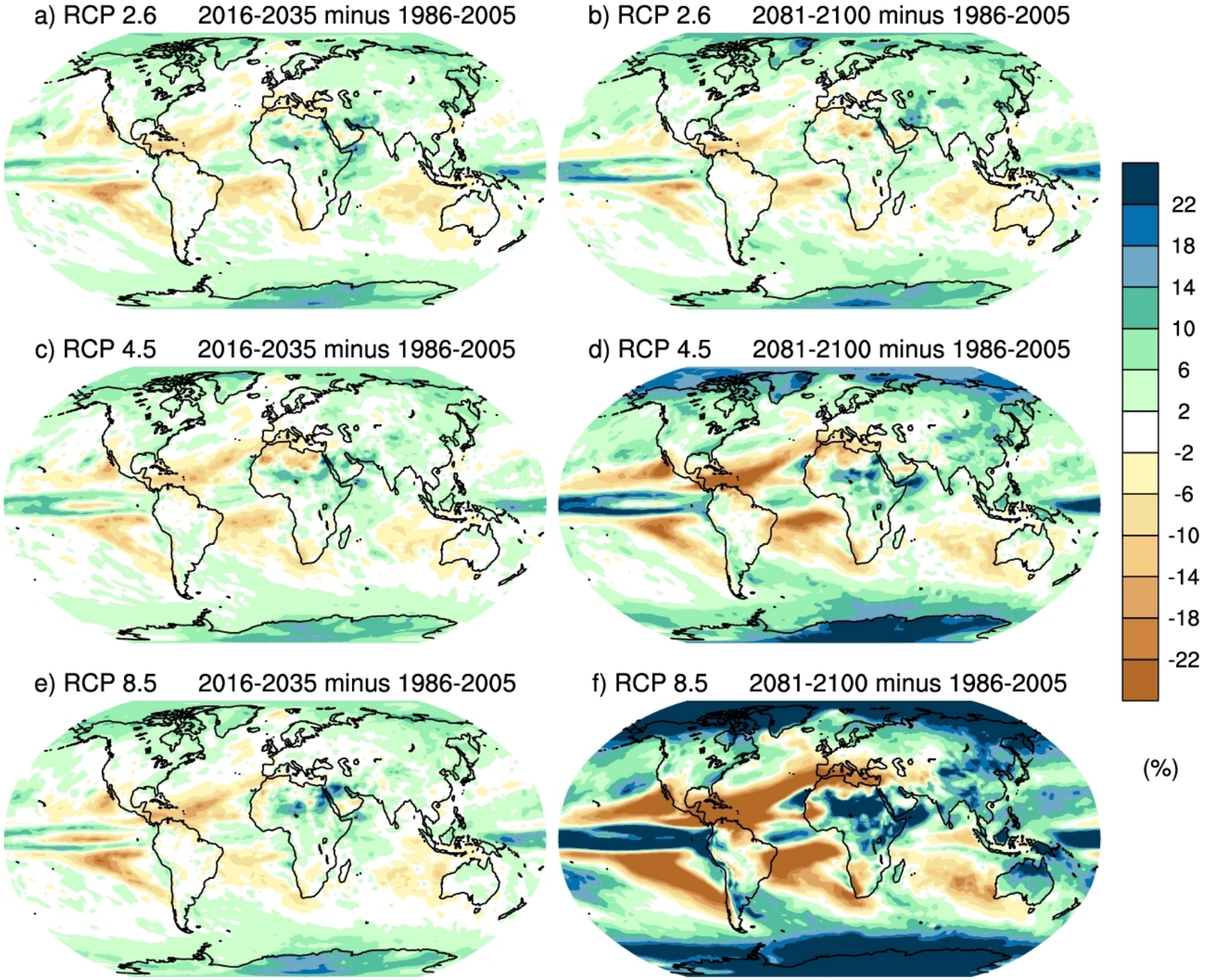
High-sensitivity model

NCAR CCSM4



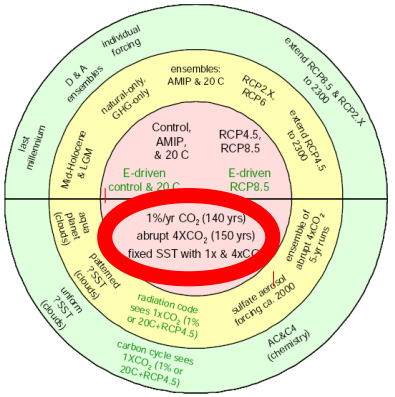
Meehl et al. (2012a)

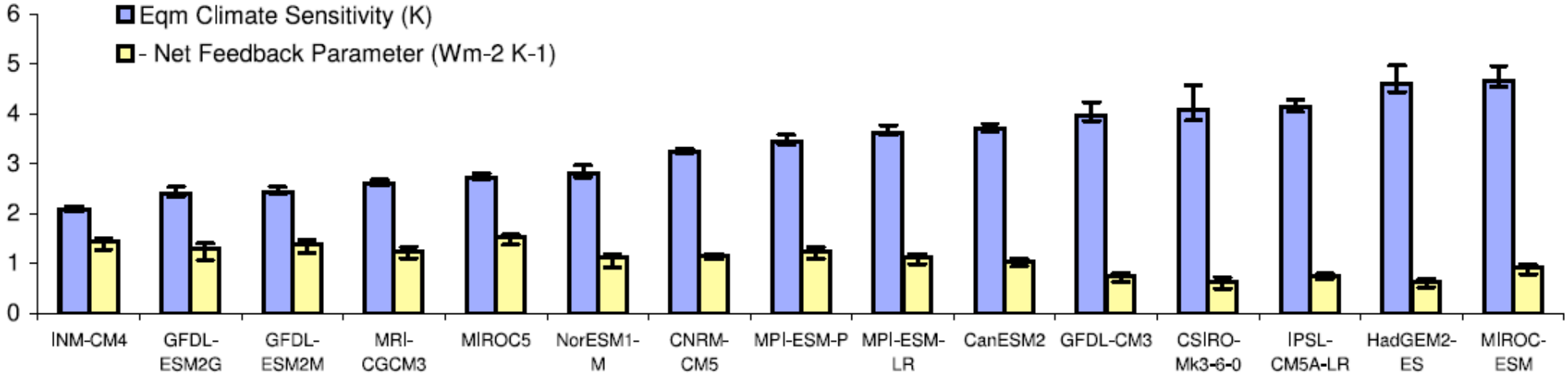
Low-sensitivity model



Meehl et al. (2012)

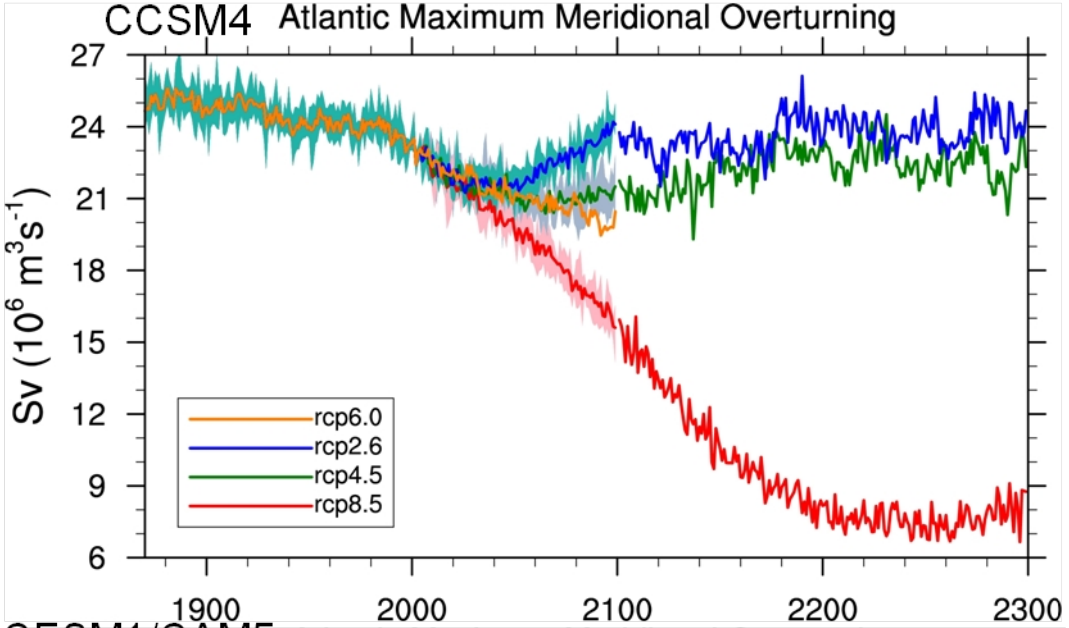
Still a large spread of Climate Sensitivity among CMIP5 models (similar to CMIP3)

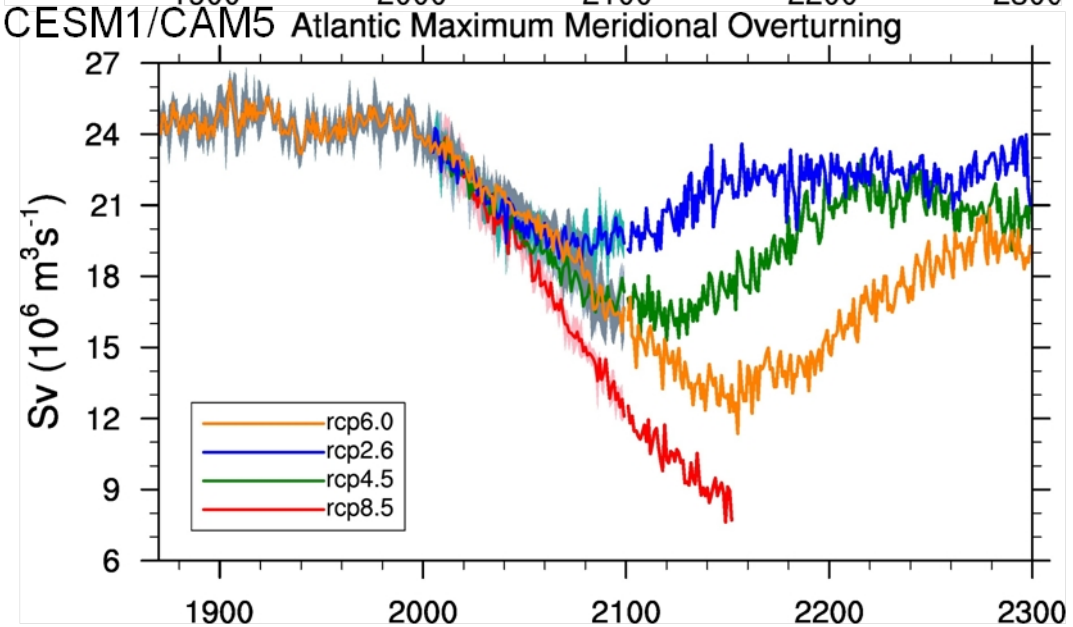


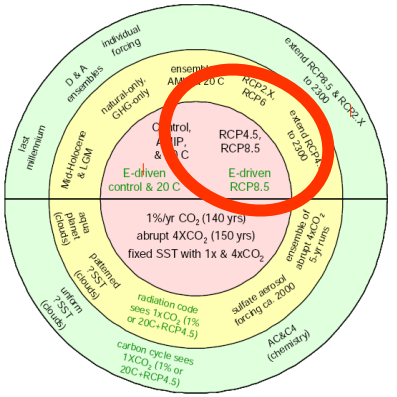


Andrews et al. (2012)

Dependence of the AMOC response on Climate Sensitivity







Future AMOC in two models with different sensitivities :

The more sensitive model (CESM1/CAM5) shows greater AMOC weakening and slower recovery in the mitigation scenarios than the less sensitive model (CCSM4)

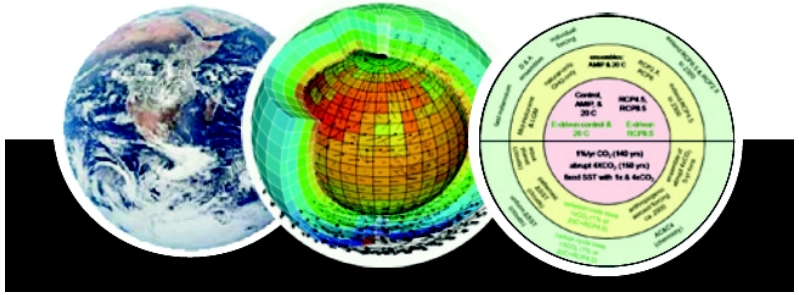
(Meehl et al., 2012b)

How may we improve
our assessment of future climate changes ?
(e.g. climate sensitivity,
large-scale circulation and precipitation changes)

&

How may WGCM contribute to these efforts ?
(in collaboration with other partners)

WCRP Coupled Model Intercomparison Project - Phase 5 - CMIP5 -

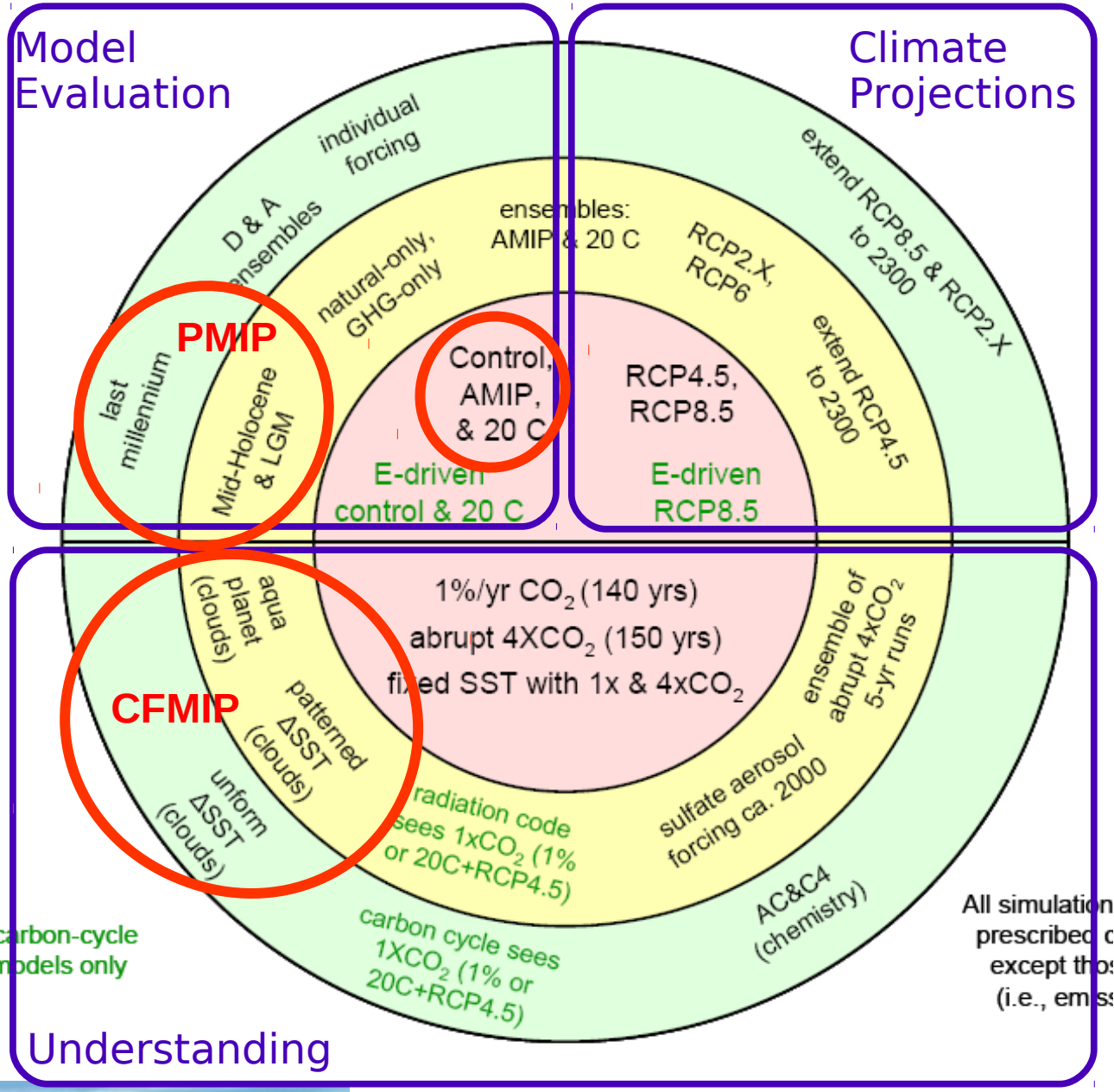


Paleoclimate Modelling

PMIP3

Intercomparison Project

Coupled carbon-cycle climate models only



CFMIP

Cloud Feedback Model Intercomparison Project

+ joint MIPs (e.g. T-AMIP, GeoMIP)

Paleoclimate Modelling

PMIP3

Intercomparison Project

Paleoclimate Modeling intercomparison Project

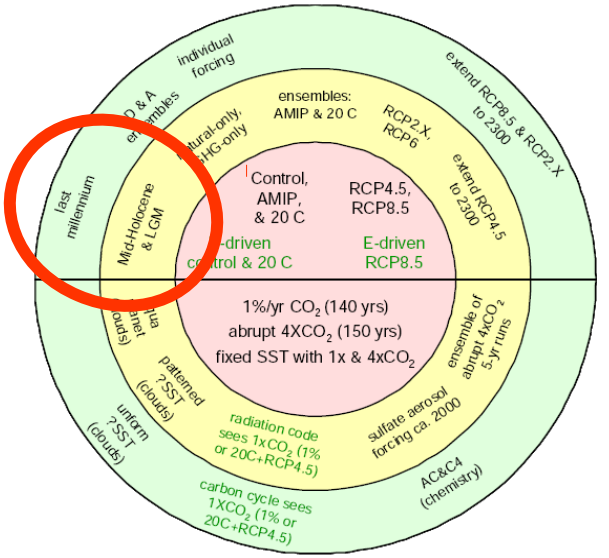
- Supported by WCRP/WGCM and IGBP/PAGES

  SC : *P. Braconnot (France); S: Harrison (UK), S. Joussaume (F), B. Otto-Bliesner (US), A. Abe-Ouchi*, (Japan), A. Haywood, P . Valdes, G.Ramstein, K. Taylor, P. Bartlein, M. Kucera, J. Jungclaus

- Objectives:
  - Understand mechanisms of past climate change
  - Evaluate roles of feedbacks from the different climate subsystems (atmosphere, ocean, land-surface, sea-ice …)
  - Evaluate the ability of climate models to simulate a climate different from that of today

- PMIP3 in CMIP5

CMIP5 : long term simulations
Taylor et al. 2009



- Other periods
  - Warm climates, abrupt events, transients….

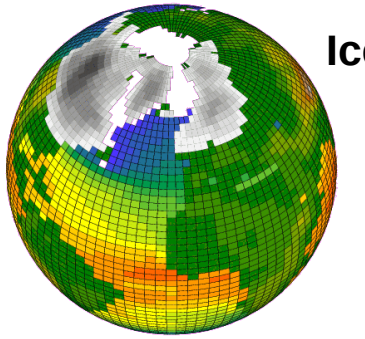
Paleoclimate Modelling

PMIP3

Intercomparison Project

Land-sea contrasts and polar amplification in past and future climates

Last Glacial Maximum main forcings

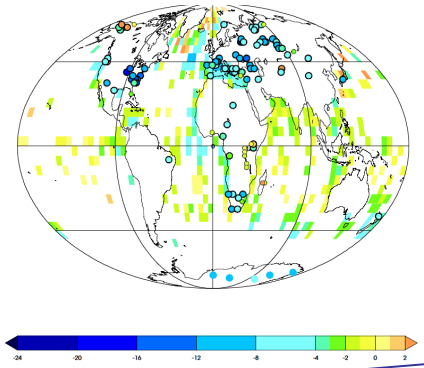


Ice-sheets

Greenhouse gases
CO2: 185 ppm,
CH4:350 ppb …

LGM climate reconstructions

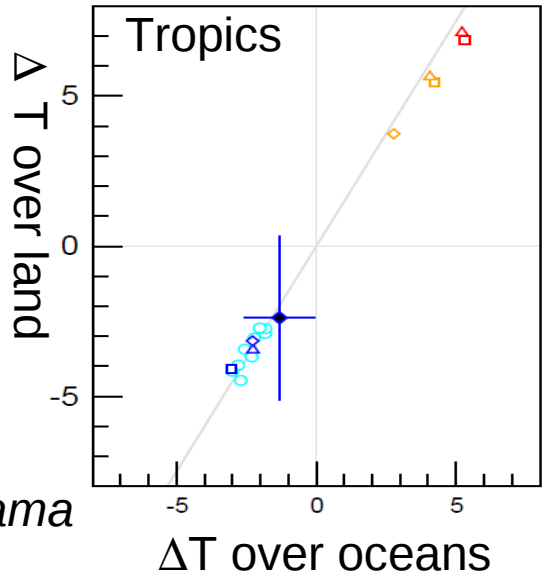
Land data
(pollen and plant macrofossils):
Bartlein et al, Clim Dynam 2011
Ocean data (multi proxy):
MARGO, NGS 2009
Ice-core data:
Masson-Delmotte et al pers. comm

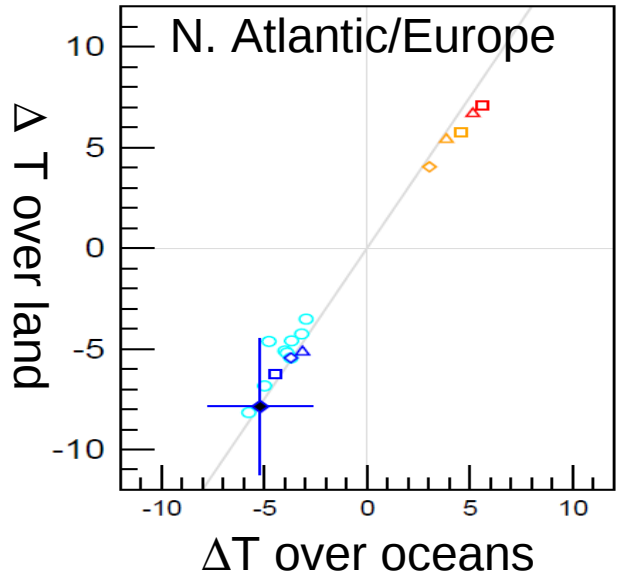


Relationships between LGM vs higher CO2 climates?
Are the large scale relationships stable? Can we evaluate them from paleodata ?

Example: Land sea contrasts

Courtesy Masa Kageyama et al





- 21k PMIP2
- IPSLCM5A-LR 21k
- MPI-ESM-P 21k
- NCAR-CCSM4 21k
- IPSLCM5A-LR 1pctCO2
- MPI-ESM-P 1pctCO2
- NCAR-CCSM4 1pctCO2
- IPSLCM5A-LR abrupt4xCO2
- MPI-ESM-P abrupt4xCO2
- reconstructions

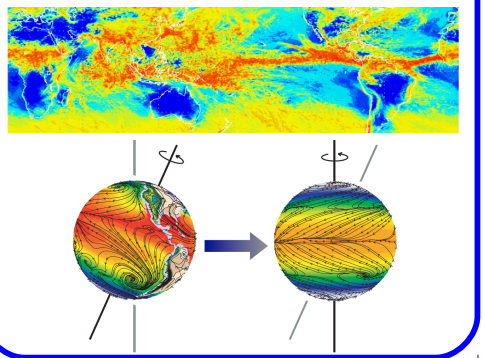
Note: all model averages calculated from grid points where LGM data is available

WCRP

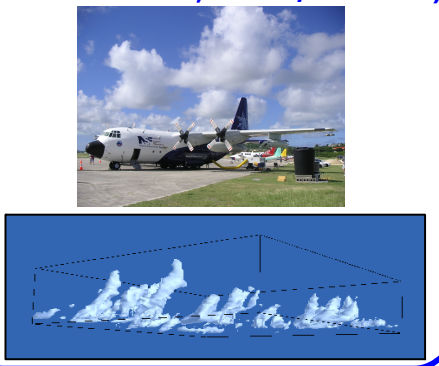
CFMIP

Cloud Feedback Model Intercomparison Project

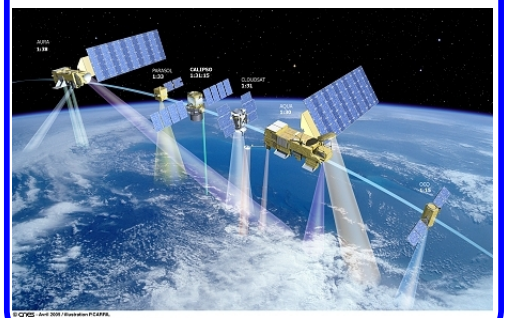
GCM analysis through a hierarchy of models



Process studies (in-situ obs, LES/CRMs)

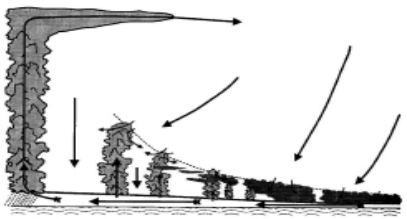


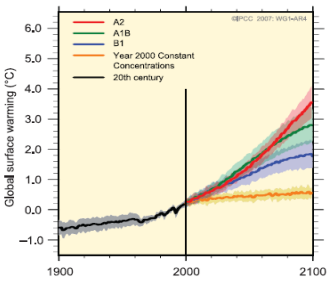
Satellite observations & simulators (COSP)



Understanding ⇢ **Evaluation**

Assessment of cloud-climate feedbacks

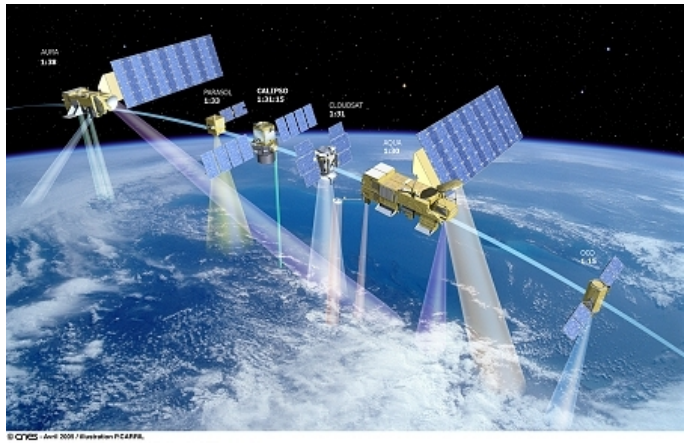




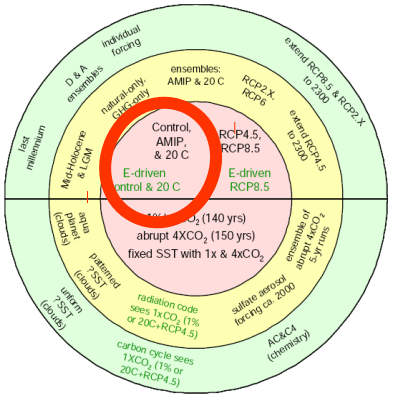
S. Bony & M. Webb
(CFMIP co-chairs)

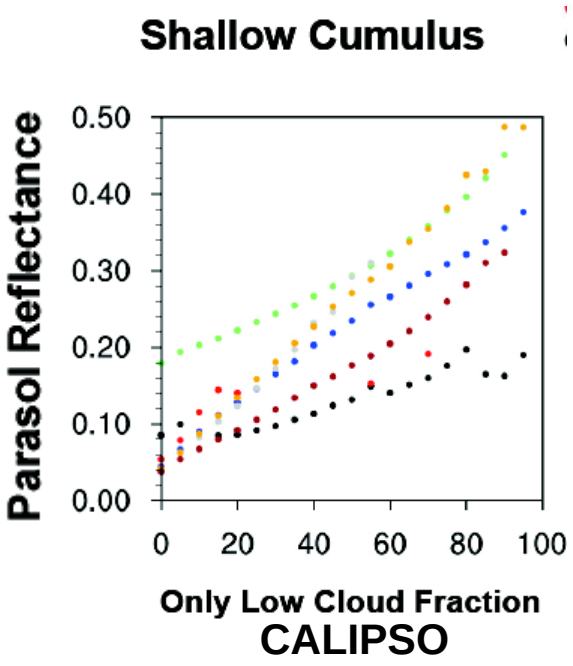
C. Bretherton,
S. Klein,
P. Siebesma,
G. Tselioudis,
M. Zhang
(CFMIP committee,
GEWEX GASS)

CFMIP meeting in Paris, May 29 - June 1 2012 (70 participants)



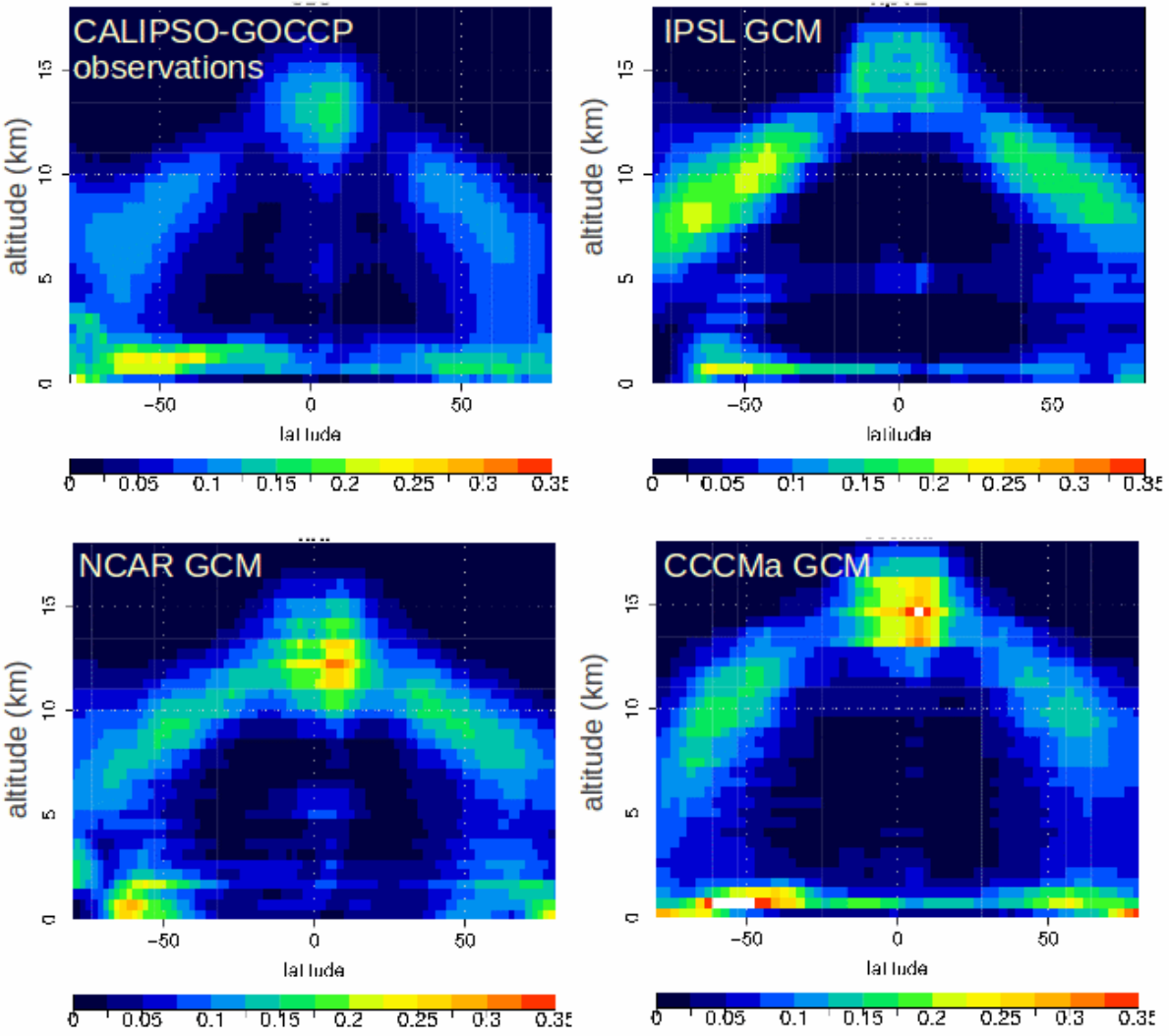
CFMIP / CMIP5
Evaluation of clouds simulated by CMIP5 models using A-Train satellite observations and the CFMIP satellite simulator (COSP), from the Tropics to the Poles





- CCCma
- MPI
- CNRM
- MOHC
- IPSL5B
- IPSL5A
- Parasol (2006-2008)

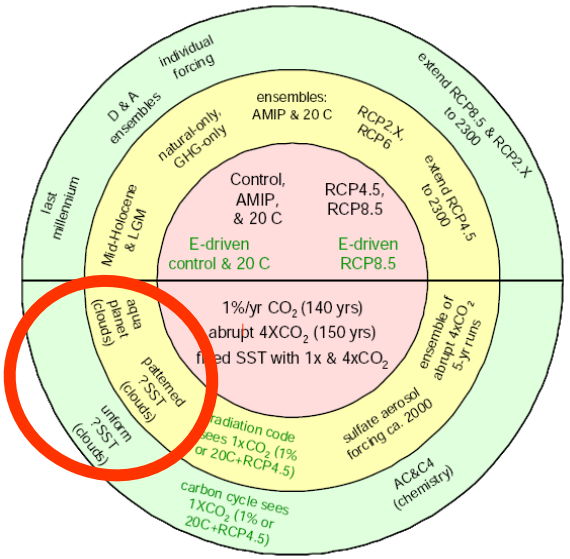
Courtesy C. Nam



Climate Sensitivity and Feedbacks in CMIP5 OAGCMs

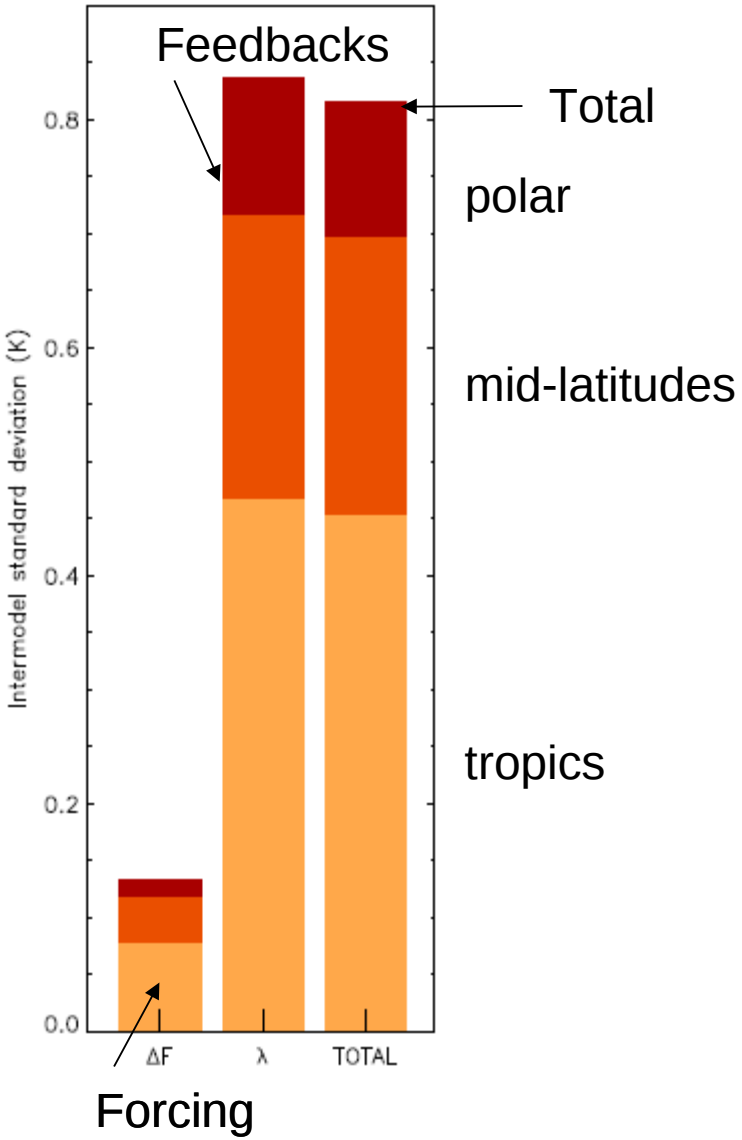
- CMIP5 experimental protocol allows us to diagnose forcings and feedbacks much more rigorously than in CMIP3.

- Radiative feedbacks remain the main source of uncertainty in climate sensitivity.



Courtesy J. Vial

Contributions to the spread of CS



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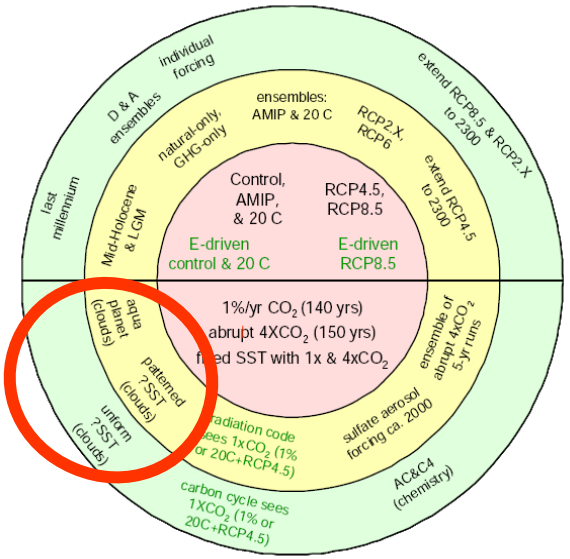
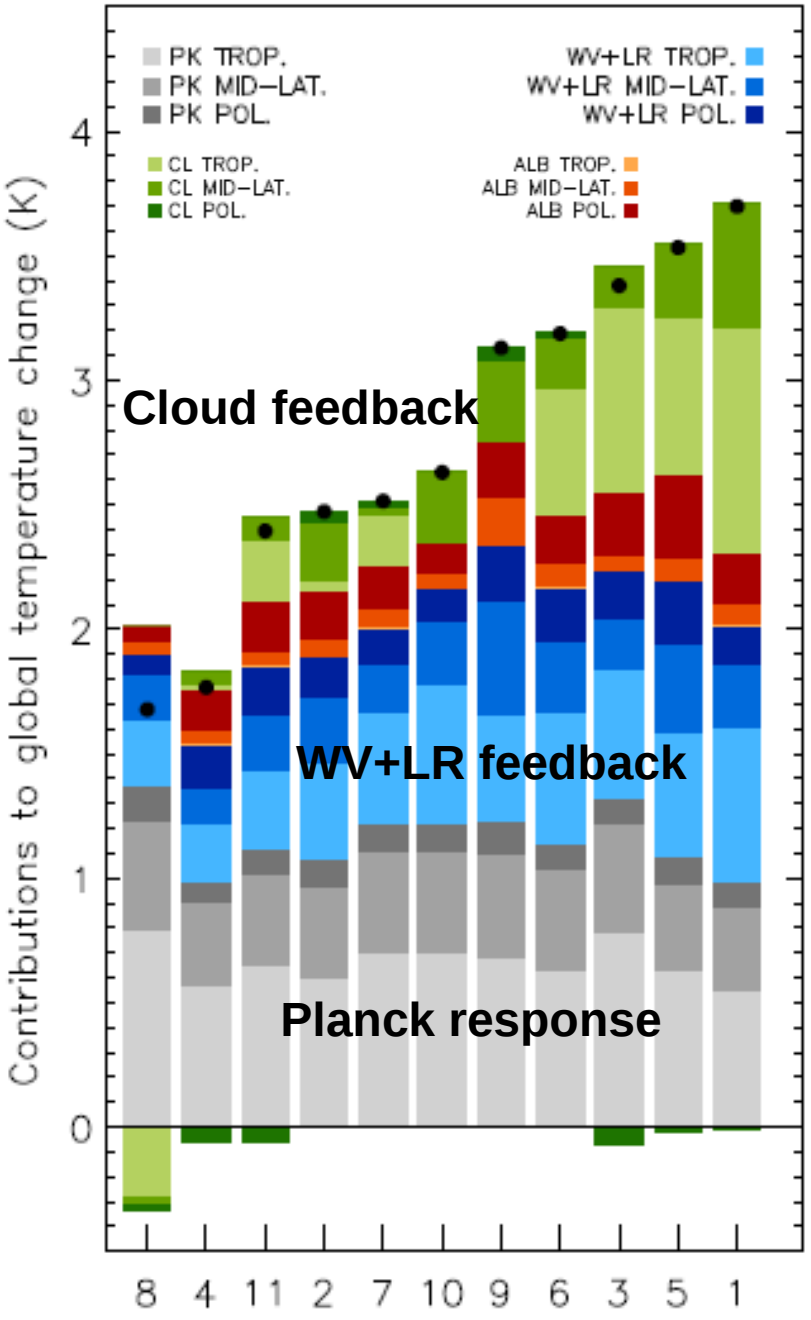


…. especially cloud feedbacks !

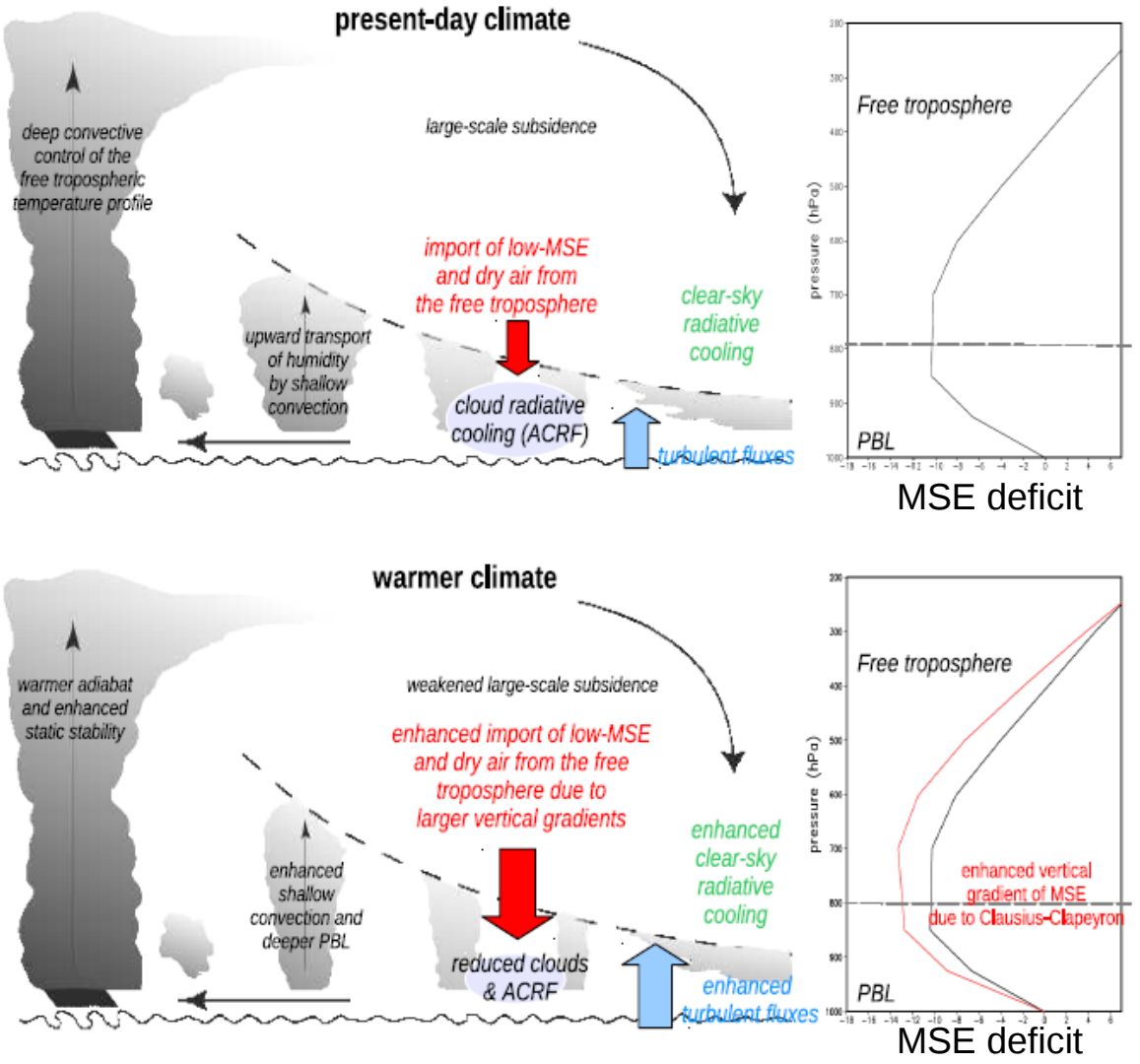


Courtesy J. Vial

CMIP5/CFMIP2 idealized experiments useful to unravel cloud feedback mechanisms in individual CMIP5 models

Example :
IPSL-CM5A GCM

- Positive low-cloud feedback
- Robust across CMIP5 experiments and configurations (1%CO2, AMIP, aqua-planet, 1D)
- Primary physical mechanism identified through a process and energetic analysis
- Role of the Clausius-Clapeyron relationship and of the deepening of the boundary layer in modifying the vertical gradients in moist static energy



(Brient & Bony 2012)

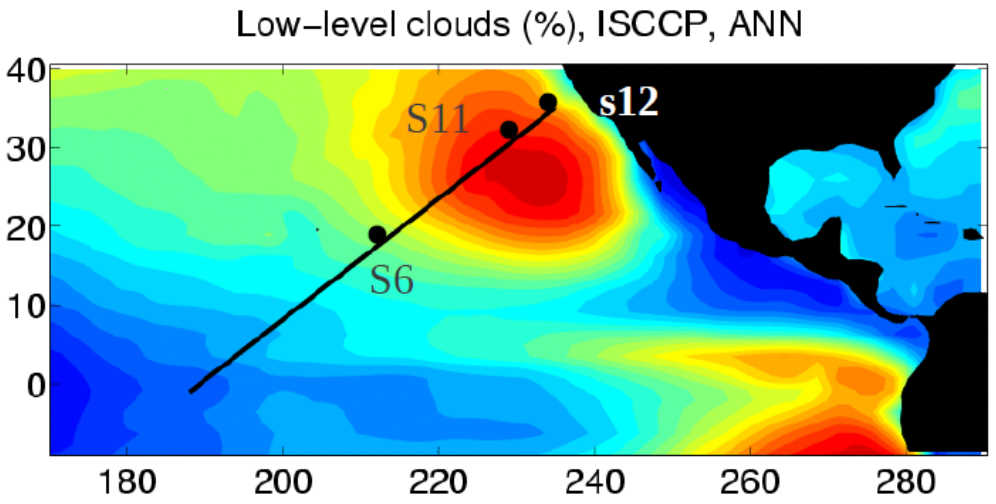
An opportunity to better understand and assess cloud feedback processes :

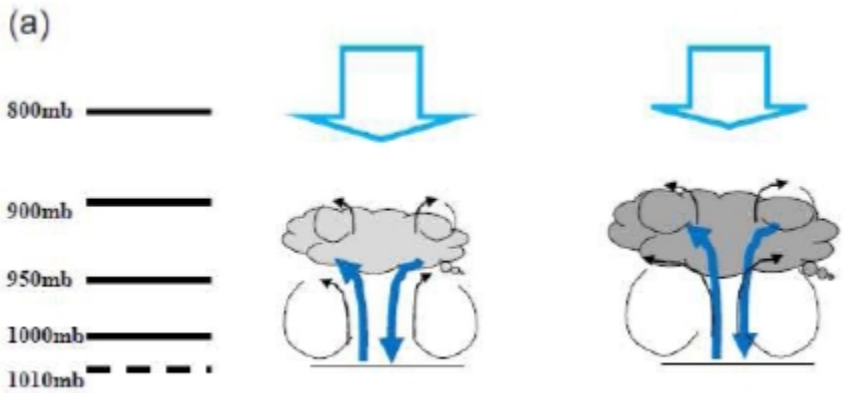
CGILS project (WGCM/CFMIP & GEXEX/GCSS)

CGILS: First Results from an International Project to Understand the Physical Mechanisms of Low Cloud Feedbacks in General Circulation Models

(to be submitted to BAMS shortly)

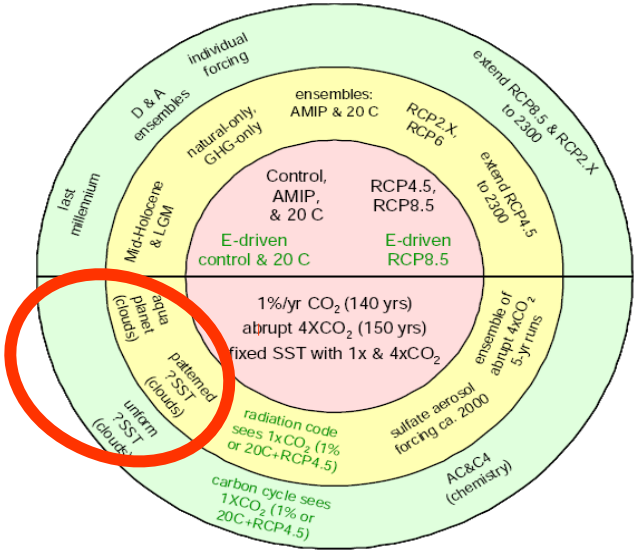
Minghua Zhang, Christopher Bretherton, Peter Blossey, Phillip Austin, Julio Bacmeister, Sandrine Bony, Florent Brient, Anning Cheng, Stephan de Roode, Satoshi Endo, Anthony Del Genio, Charmaine Franklin, Christopher Golaz, Cecile Hanny, Thijs Heus, Francesco Isotta, Dufresne Jean-Louis, In-Sik Kang, Hideaki Kawai, Martin Koehler, Suvarchal Kumar, Vincent Larson, Yangang Liu, Adrian Lock, Ulrike Lohman, Marat Khairoutdinov, Andrea Molod, Roel Neggers, Phillip Rasch, Irina Sandu, Ryan Senkbeil, Pier Siebesma, Colombe Siegenthaler-Le Drian, Bjorn Stevens, Max Suarez, Kuan-man Xu, Knut von Salzen, Mark Webb, Audrey Wolfe, Ming Zhao





→ Study and comparison of low-cloud feedbacks in 16 GCMs and 5 process models (CRM/LES)

An opportunity to better understand inter-model differences in cloud feedbacks :

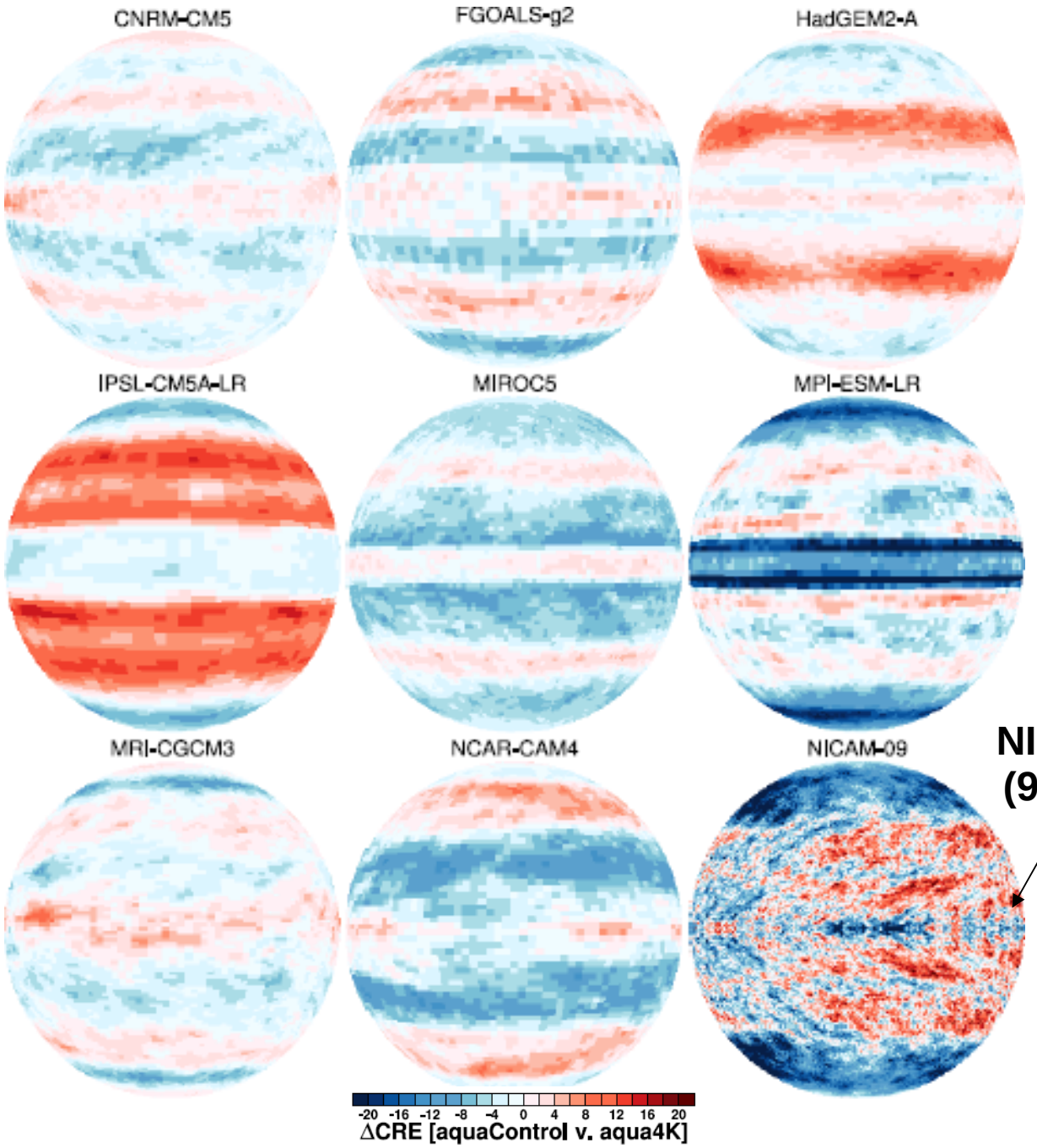


CFMIP / CMIP5 / WGNE
AMIP &
aqua-planets

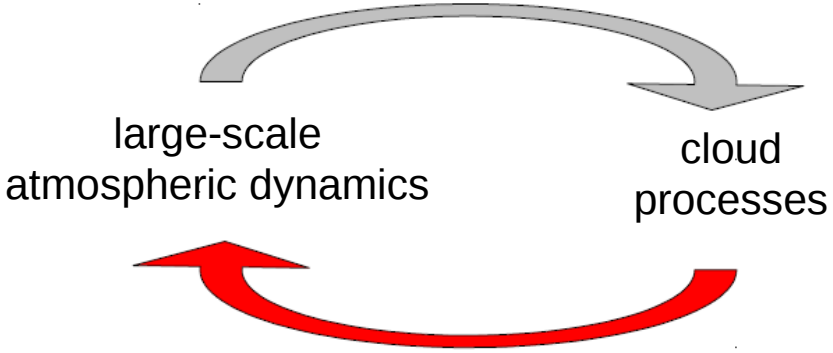
CTRL, 4xCO2, +4K

(AGCMs,
super-parameterisations,
global Cloud Resolving Models)

Courtesy B. Medeiros



Interaction between cloud processes and the large-scale circulation



Matters for :

- climate models biases

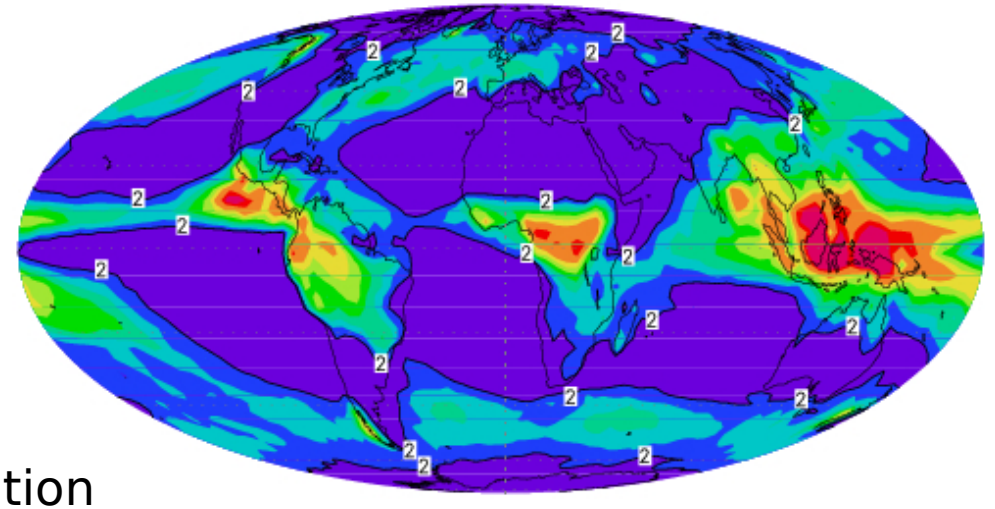
- large-scale circulation and precipitation changes in a warming climate

- regional climate changes

Partners :

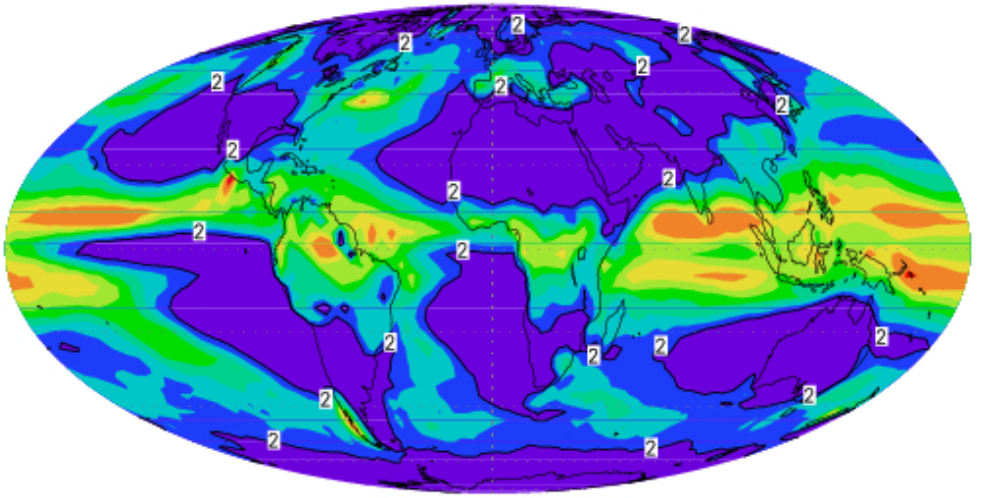
- WGCM (CFMIP)
- WGNE (Transpose-AMIP)
- GEWEX (GASS)

with cloud-radiative effects

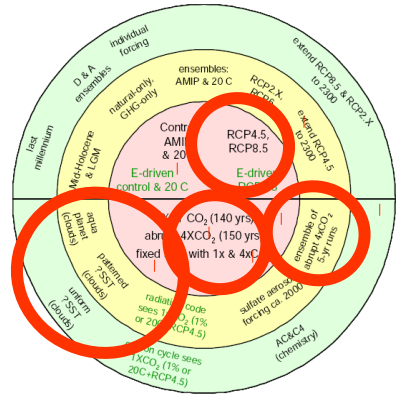


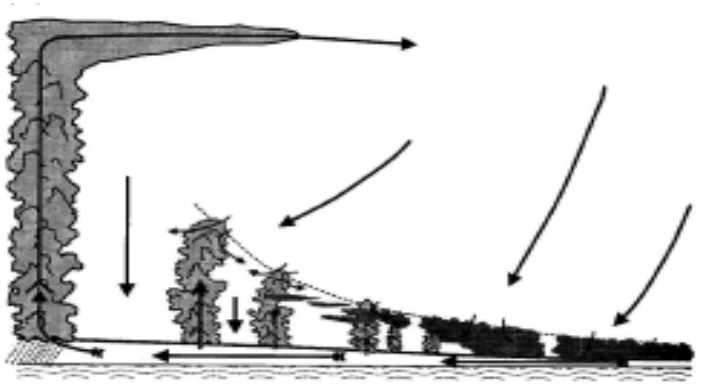
Precipitation (mm/d)

without cloud-radiative effects



Response of the tropical overturning circulation and rainfall to increased CO2 and surface warming

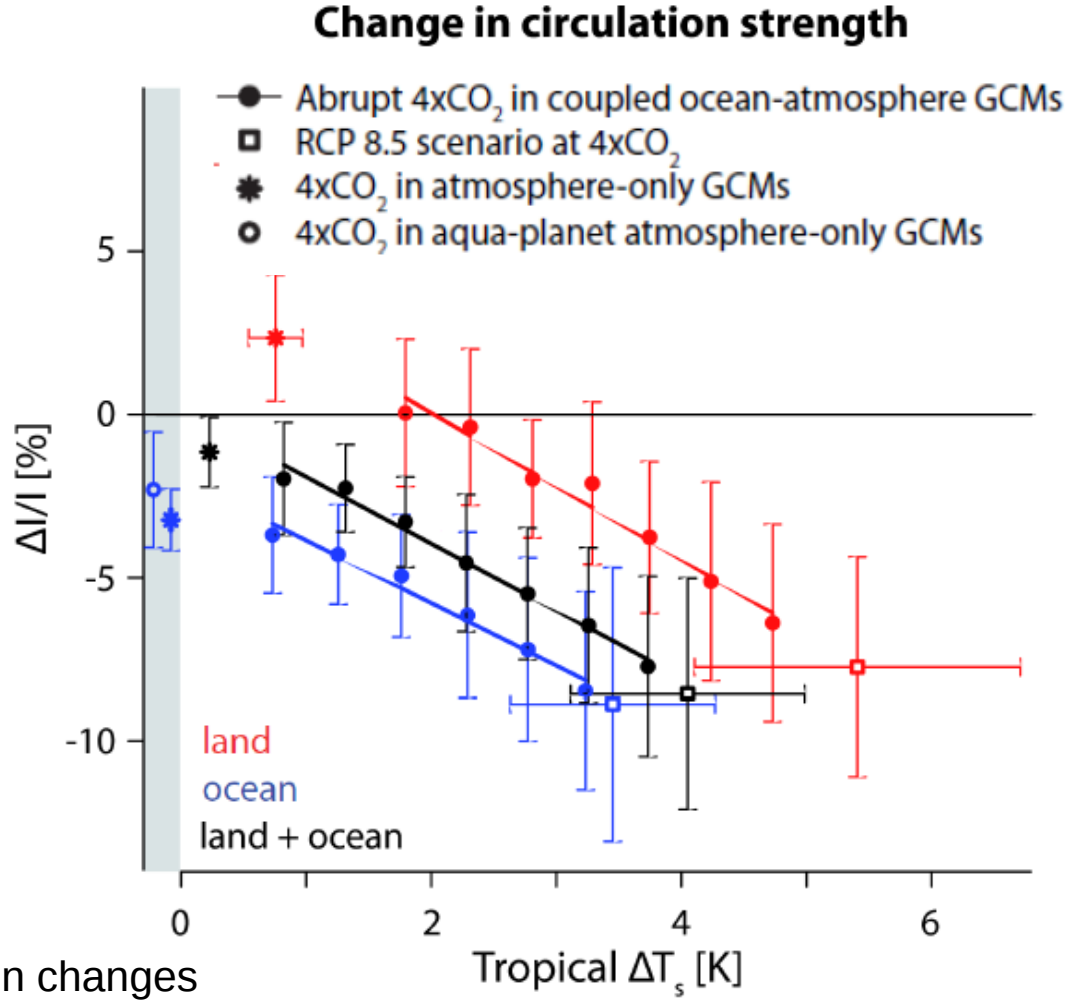




- Global warming weakens the overturning circulation and affects the distribution and intensity of tropical precipitation

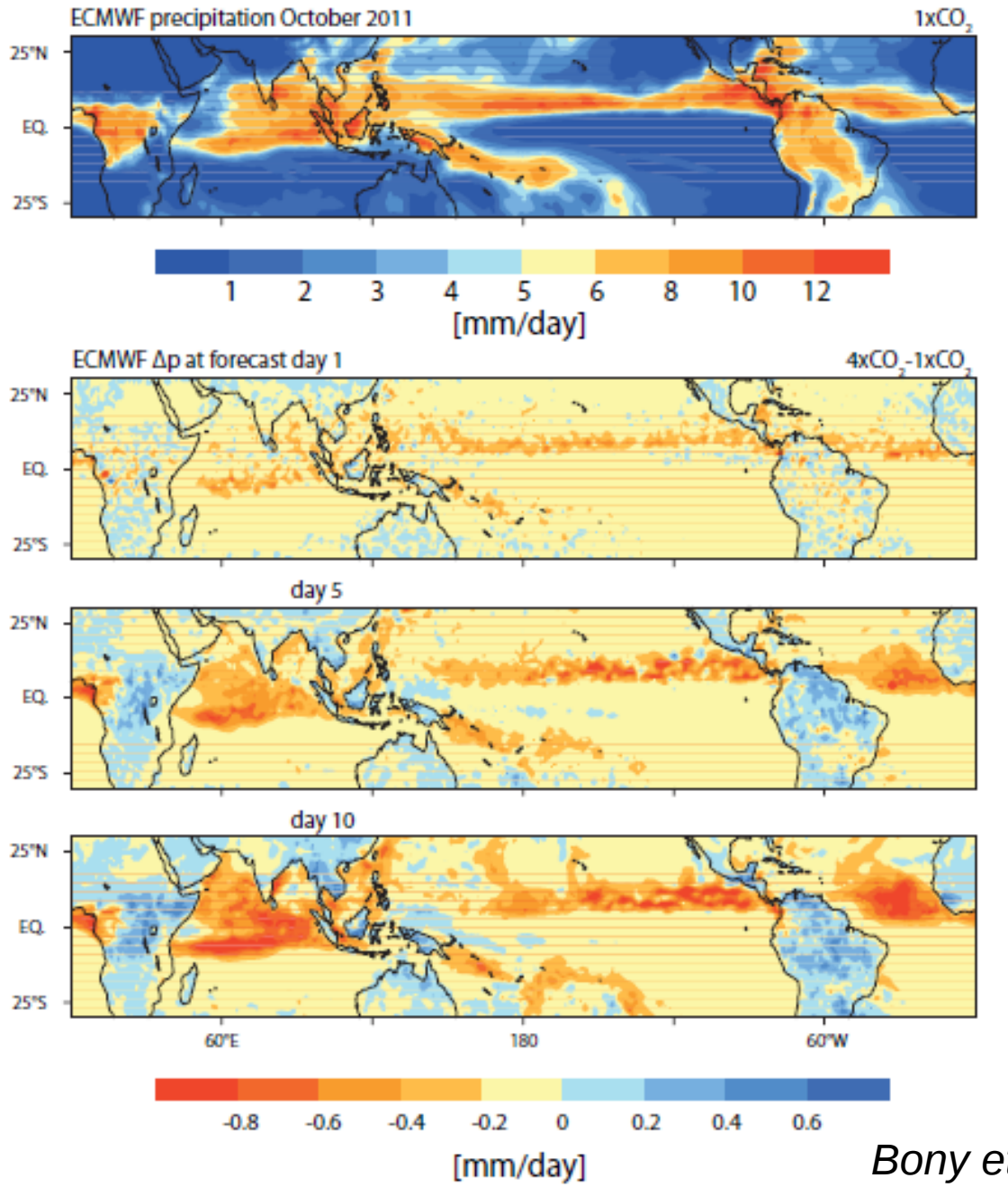
- In addition : direct effect of increased CO2 on the tropical overturning circulation
  - Controlled by very fast processes
  - Robust across models and configurations : OAGCM, AGCM, aqua-planet, 1D, ECMWF IFS forecast model

- Large impact on regional cloud and precipitation changes



Bony et al. (submitted)

Use of the ECMWF-IFS operational forecast model to understand an important component of the precipitation and circulation response to climate change



1xCO2

4xCO2
1-day forecast

4xCO2
5-day forecast

4xCO2
10-day forecast

Bony et al. (submitted)

How can WCRP improve our assessment of future climate changes ?

WCRP Position Paper on Long-Term Climate Change :

Carbon Dioxide and Climate : Perspectives on a Scientific Assessment

Sandrine Bony[1], Bjorn Stevens[2], Isaac Held[3], John Mitchell[4], Jean-Louis Dufresne[1], Kerry Emanuel[5], Pierre Friedlingstein[6], Stephen Griffies[3] and Catherine Senior[4]

« Climate sensitivity continues to be a centrally important measure of the size, and significance of the climate response to CO2. The aggregated impacts of climate change can be expected to scale superlinearly with climate sensitivity. »

« Promote research devoted to better understanding interactions between cloud and moist processes and the general circulation. »

→ **A Grand Challenge ?**

(WGCM – GEWEX – WGNE with connections to other projects)

« Understanding the role of clouds in climate,

especially in climate sensitivity and in the large-scale distribution of precipitation »

Some thoughts and remarks relative to the set-up of a Grand Challenge on clouds, precipitation and climate sensitivity :

- As funny as it sounds, the cloud community has started to wake up to the climate problem only a few years ago... and **we are on the cusp of real progress**.

- **Predicting the distribution of clouds and precipitation, and the large-scale circulation closely coupled to them, is one of the most important problems in climate.**

- **Our basic difficulties** (as the NWP community can tell) have little to do with aerosols at first order, including in climate projections, and everything to do with **how convection couples to the large-scale dynamics and with boundary layer processes.** These couplings are at the core of cloud and precipitation problems.

- Our understanding of the aerosol is limited by our understanding of clouds and precipitation much more than the other way around (rain removes aerosols far more efficiently than aerosol removes rain). So **improving our understanding of clouds and precipitation will be a way to foster progress in aerosol studies as well**.

- **In climate change, clouds and precip are strongly forced by warming and CO2**, and looking to the future, these are the forcings we need to focus on.

- **Clouds and precipitation are our Higgs Boson, and we have now new accelerators to takle the problem !** including CMIP5, new observations, Global Cloud Resolving Models, and a growing and motivated community behind all this. → WCRP should pounce on these opportunities and nurture it.

Issues for the JSC

- Governance of the ESGF

- Obs4MIPs (already addressed in WMAC and WDAC)

- Synthesis papers of CMIP5 model analyses : recommendations? suggestions ?

- Collaborations between WGCM and other modelling groups (in addition to WMAC) :

  → 3-year cycle for joint sessions with WGSIP, WGNE, IGBP/AIMES

  → Last WGCM meeting : Boulder, Oct 2011, jointly with WGNE

  → Next WGCM meeting : Hamburg, 24-26 Sept 2012, jointly with WGSIP

- Membership WGCM : several rotations planned in 2012 ; nominations proposed

- A Grand Challenge (primarily led by WGCM – GEWEX – WGNE) on :

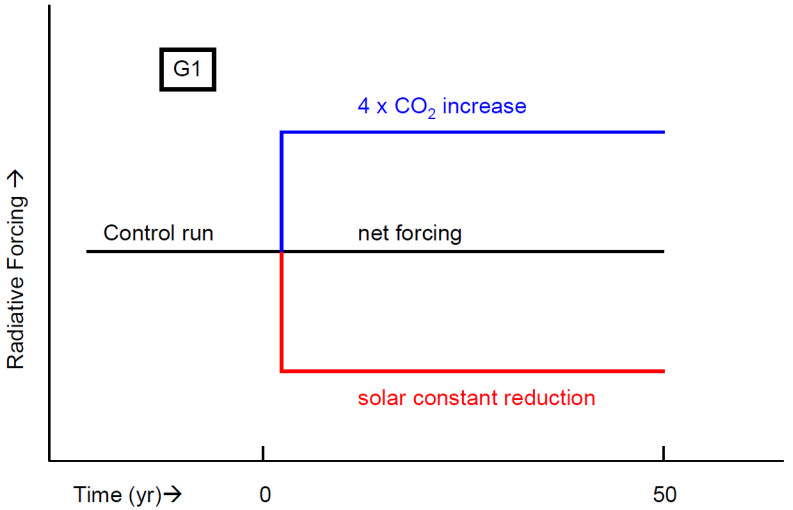
« Understanding the role of clouds in climate,
especially in climate sensitivity and in the large-scale distribution of precipitation »


Thank You

May solar irradiance reduction counteract climate change ?

The Geoengineering Model Intercomparison Project, GeoMIP
a WGCM-endorsed community coordinated experiment

(B. Kravitz, A. Robock, O. Boucher, H. Schmidt, K. Taylor, G. Stenchikov, M. Schulz)



Schmidt et al. (2012)