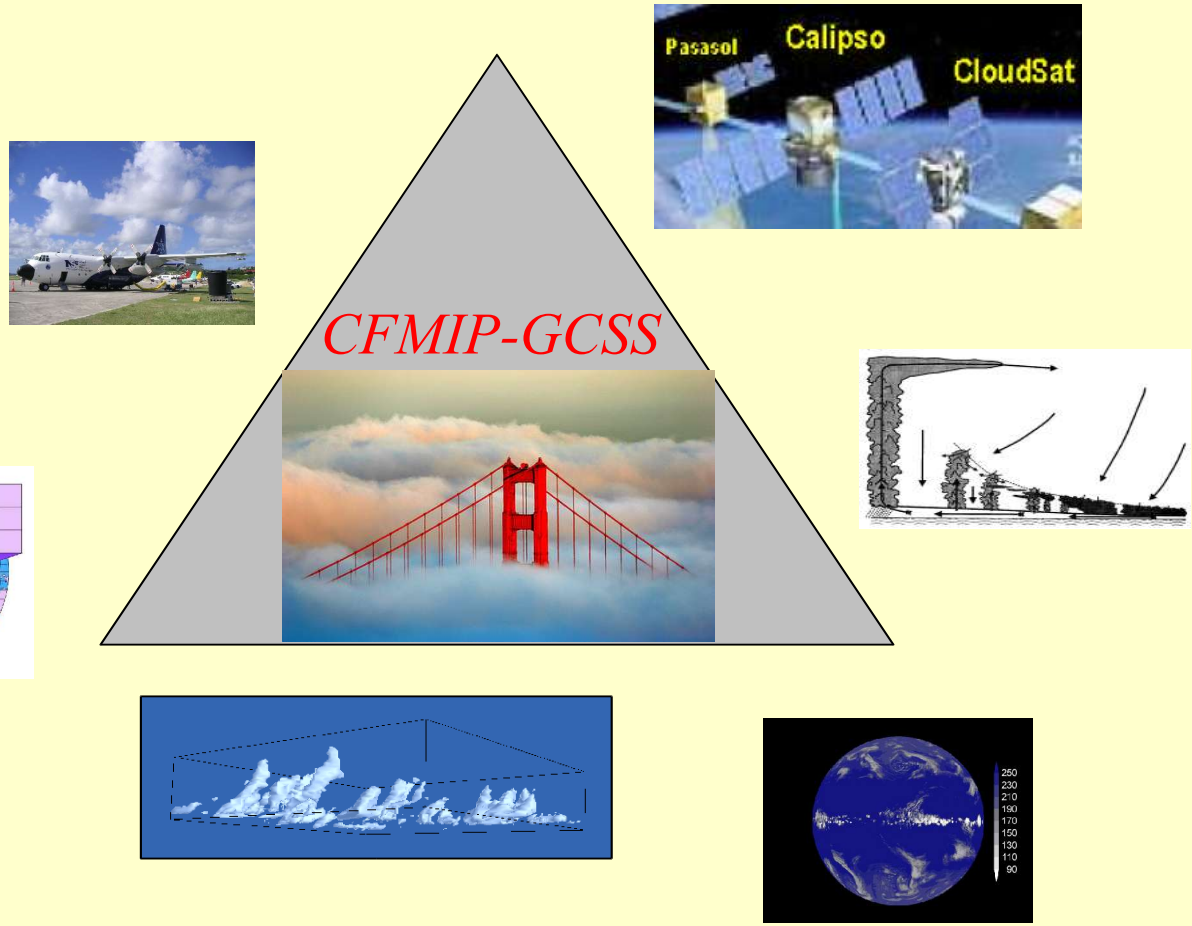
CFMIP-GCSS activities within the context of climate change modeling and CMIP5

Sandrine Bony (LMD/IPSL, CNRS, Paris)
on behalf of the CFMIP coordination committee

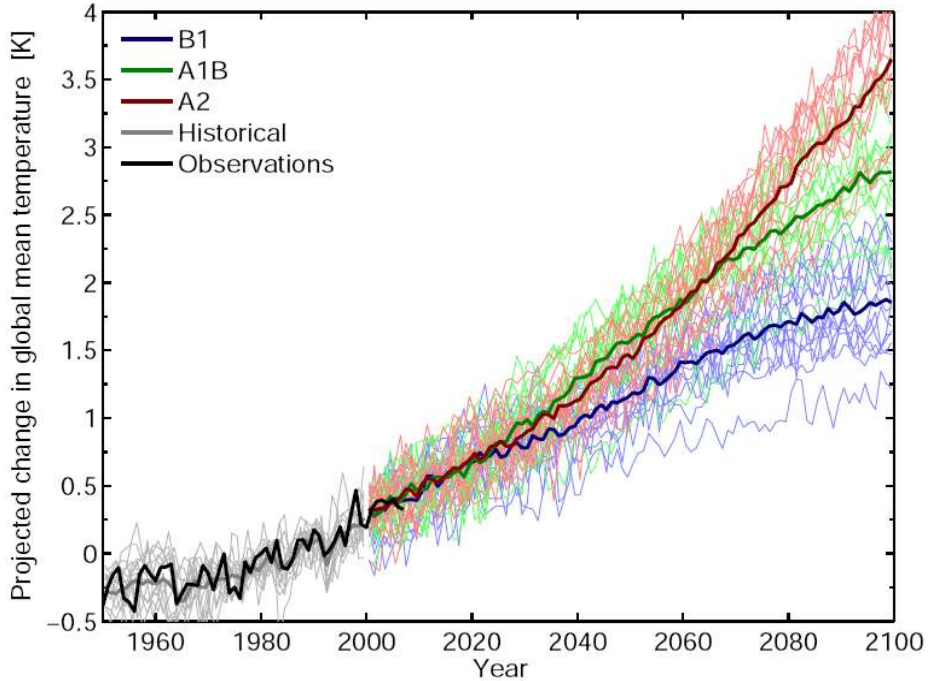


CFMIP/GCSS Workshop on Evaluation and Understanding of Cloud Processes in GCMs
Vancouver, June 8-12 2009

The climate change context

A changing paradigm for climate change modeling

Projections of anthropogenic climate change :

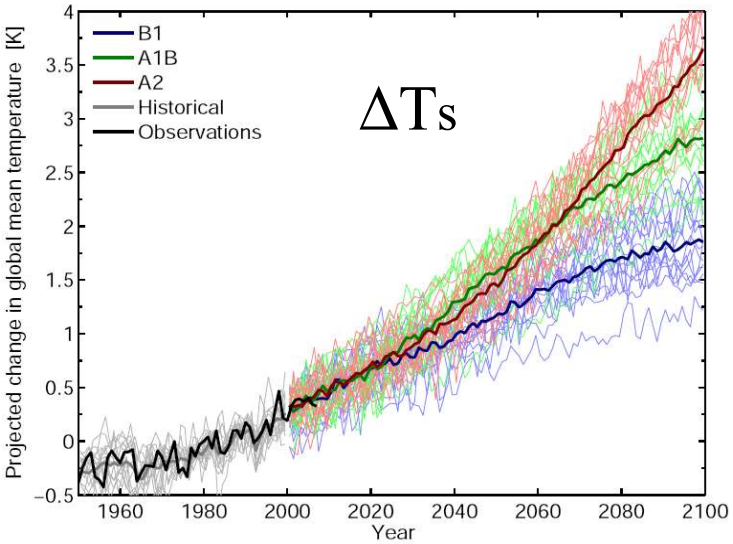


- further global warming inevitable over the next few decades
  → from “alarm” to “action”

- need to inform decisions about climate adaptation and mitigation
  → focus on two different time scales (near-term, long-term)

- the need to assess and to improve the reliability of climate model predictions and projections has never been so high !

Uncertainties in CMIP3 climate projections

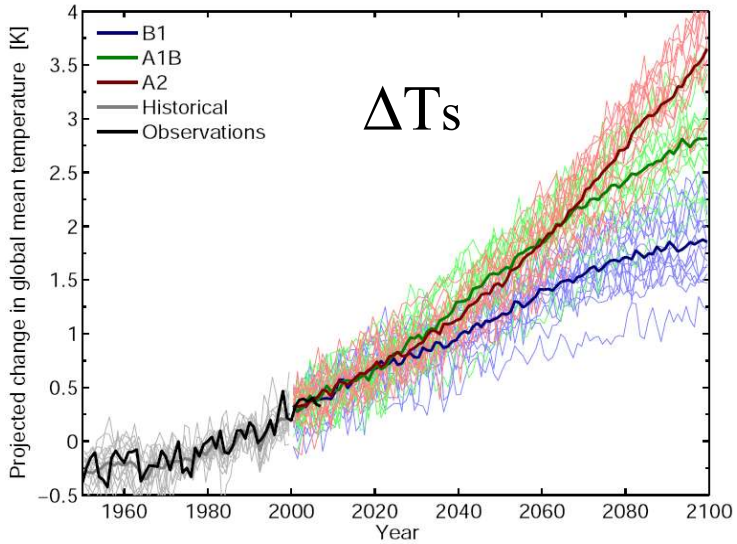


Three main sources of uncertainty :

- scenario
- model
- internal variability

(Hawkins & Sutton, 2009)

Uncertainties in CMIP3 climate projections

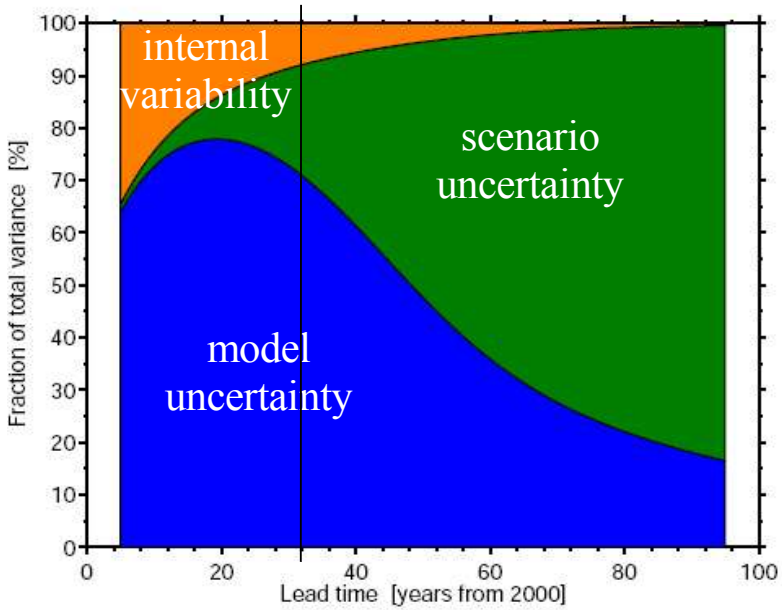


Three main sources of uncertainty :

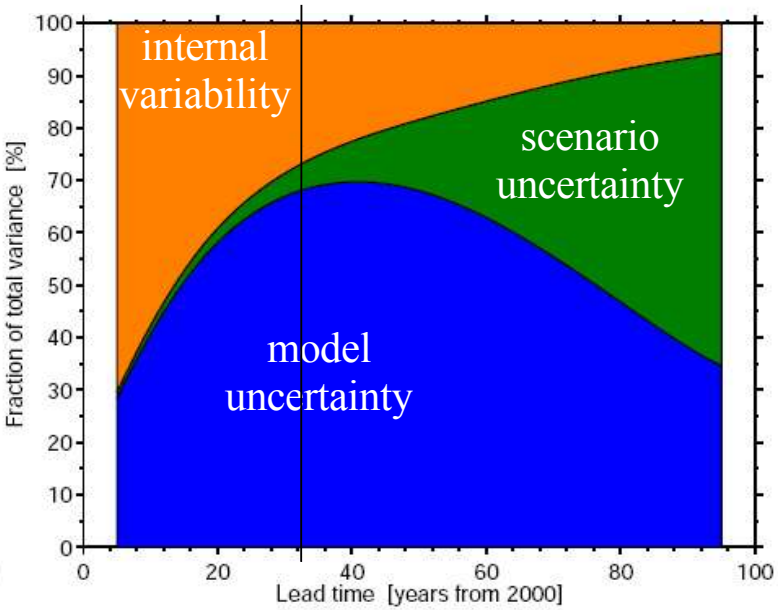
- scenario
- model
- internal variability

Fractional uncertainty (%) :

Global



British Isles



(Hawkins & Sutton, 2009)

Main focus & priorities over the next 5+ years within WGCM (the WCRP JSC/CLIVAR Working Group on Coupled Models):

- Near term (next 30 years) :
  - Regional information and extremes
  - Decadal predictability and prediction (initialisation of coupled models)
  - Using relatively high-resolution models (~ 50km)

- Longer term (mid-century to 2100+):
  - Climate sensitivity and physical feedbacks
  - Biogeochemical feedbacks (e.g. carbon-climate feedbacks)
  - 1st generation of Earth System Models (resolution ~ 200 km)

- Assessement of the uncertainty in model projections and predictions
  - Evaluation of GCMs
  - Understanding of inter-model differences

The CMIP5 framework (2008-2013)

(CMIP = Coupled Models Intercomparison Project)

This led to the formulation of CMIP5 :

- CMIP5 is an experimental design for a 5-year framework (2008-2013) for climate change modeling

- CMIP5 promotes a standard set of model simulations in order to:
  - evaluate how realistic the models are in simulating the recent past
  - provide projections of future climate change on two time scales
  - understand some of the factors responsible for model differences

- CMIP5 is not dictated by IPCC, but formulated by the climate science community

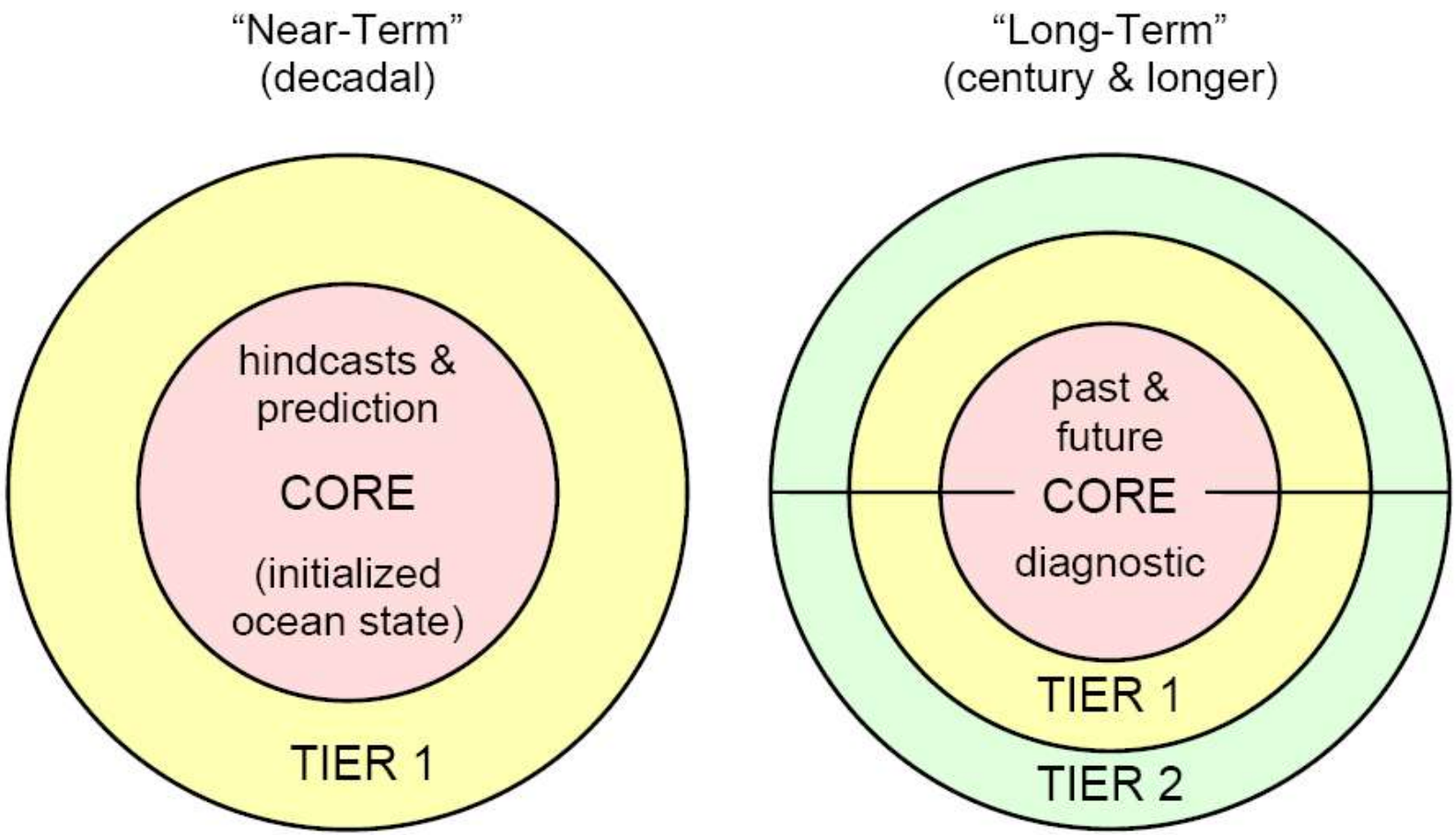
- Experiments completed by the end of 2010 will be assessed in the IPCC AR5

CMIP5 approved by WGCM (Paris, September 2008)

CMIP Panel : Stouffer (Chair), Meehl, Latif, Covey, Taylor, Mitchell, Stockdale

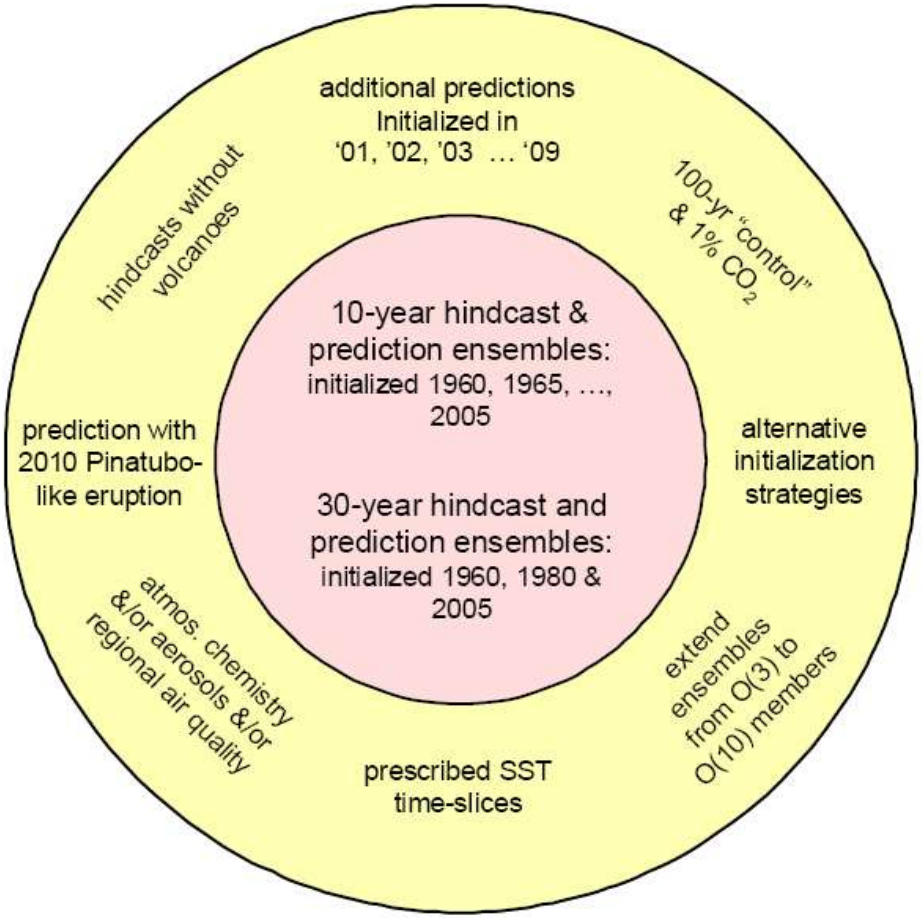
Taylor, K. E., R. J. Stouffer and G. A. Meehl, 2009:
A summary of the CMIP5 Experimental Design. http://www-pcmdi.llnl.gov/

Two classes of models for two timescales and two sets of science problems :



CMIP5 near-term experiments (to 2035)

Coordinated by joint WGCM/WGSIP contact group
on decadal predictability/prediction (Stouffer, Latif, Meehl, Stockdale, Boer)

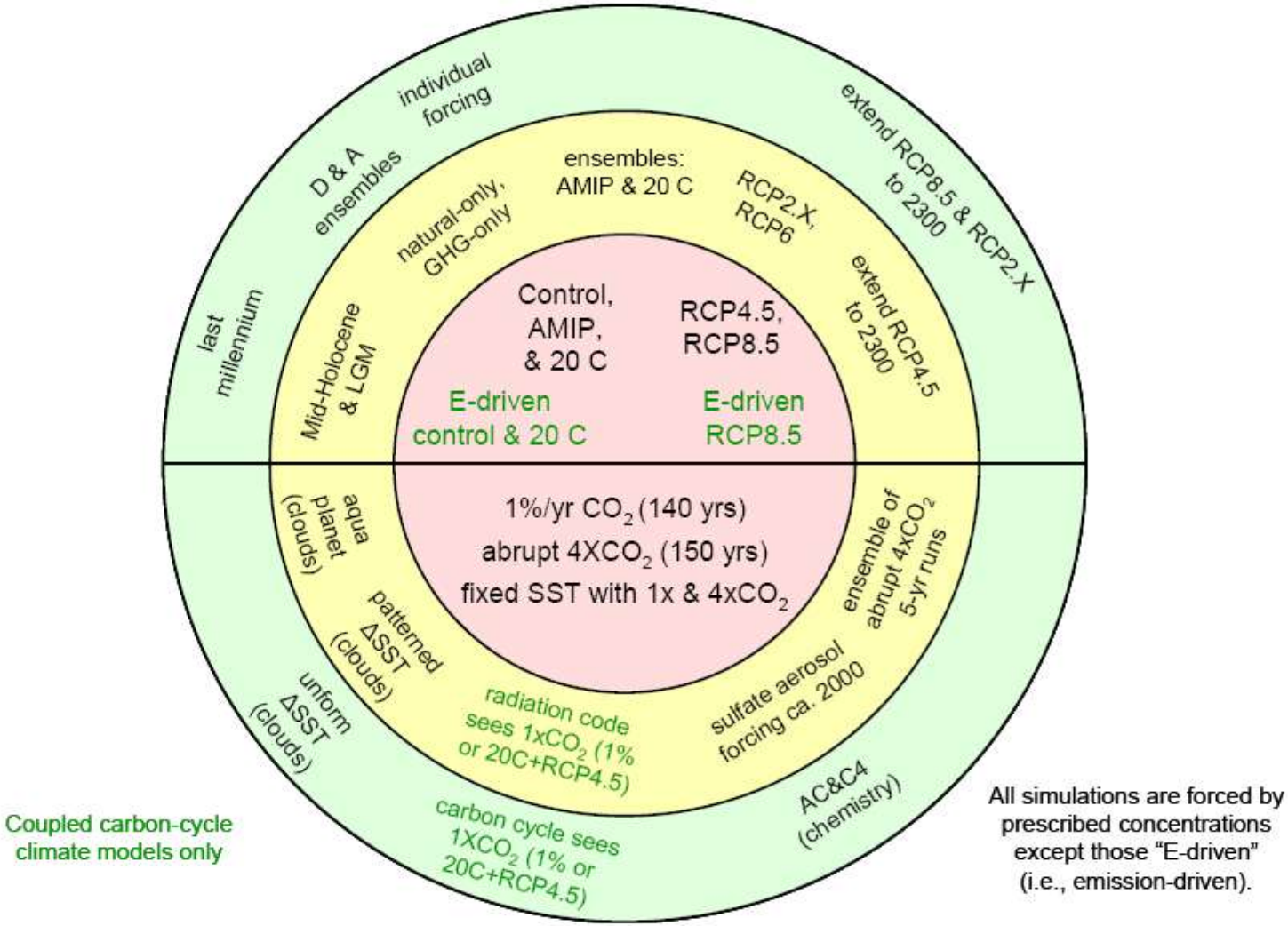


Core :
→ predictability of the climate system
→ model skill in decadal prediction

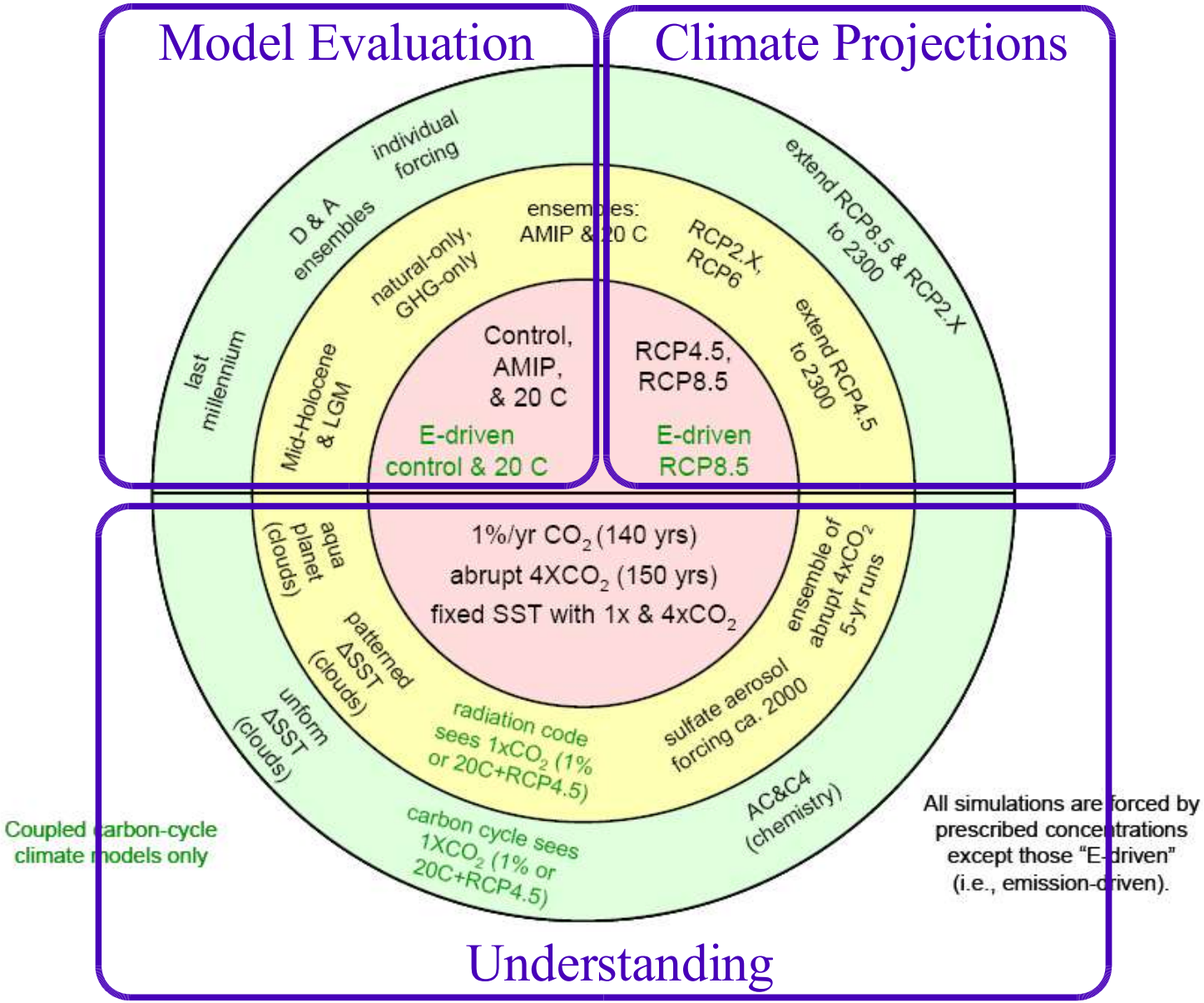
Tier 1:
→ impact of initialization methods
→ impact of the quality of the ocean initial state
→ impact of volcanic eruptions

Prescribed SST time-slices :
For models that require enormous computing ressources (very high resolution, chemistry, etc).
Time-slices: 1979-2008 + 2026-2035
→ atmosphere-only models
→ explore the impact of higher resolution
→ regional effects of climate change
→ air quality implications of climate change
→ extreme events

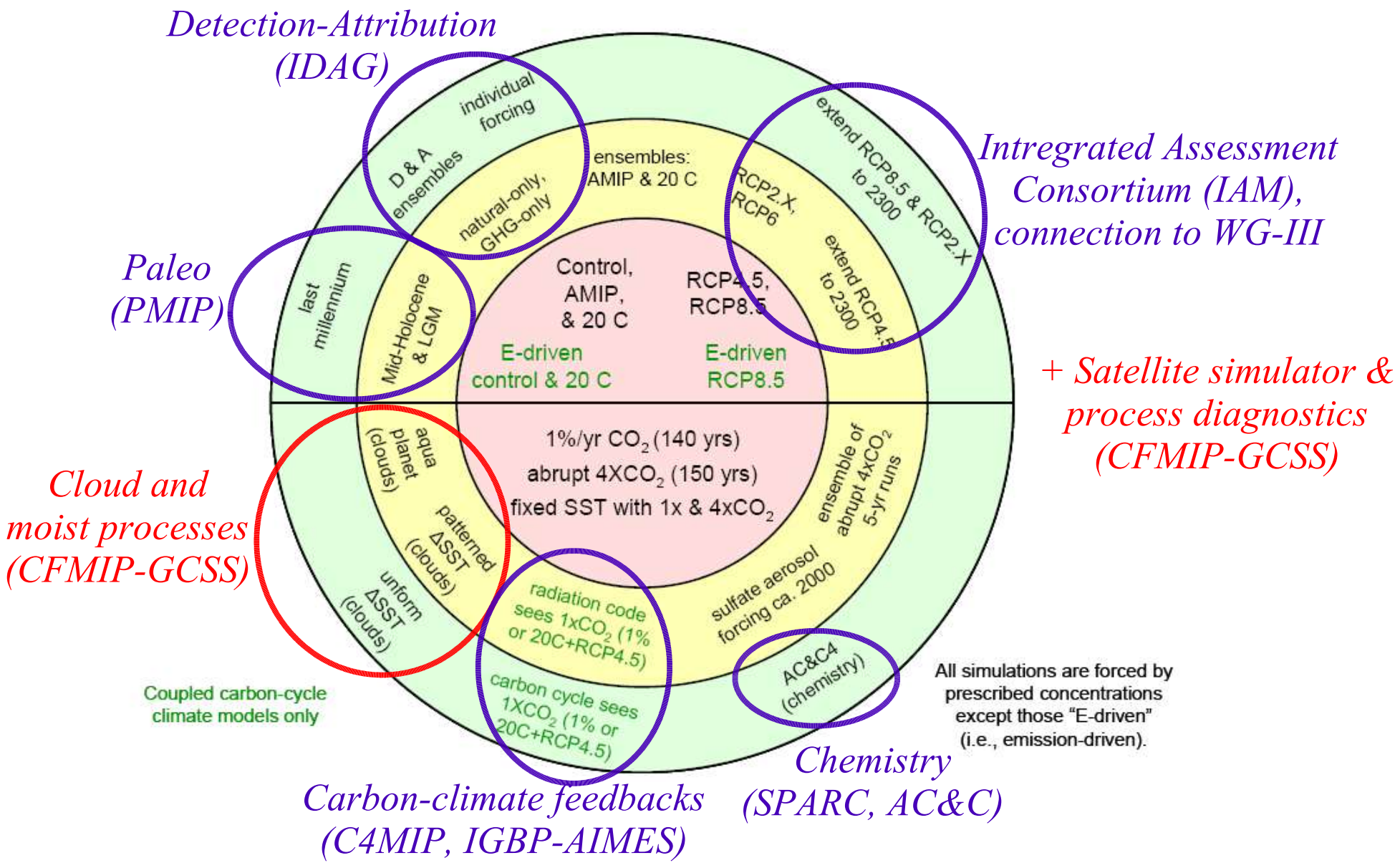
CMIP5 long-term experiments (to 2100 and beyond)



CMIP5 long-term experiments (to 2100 and beyond)

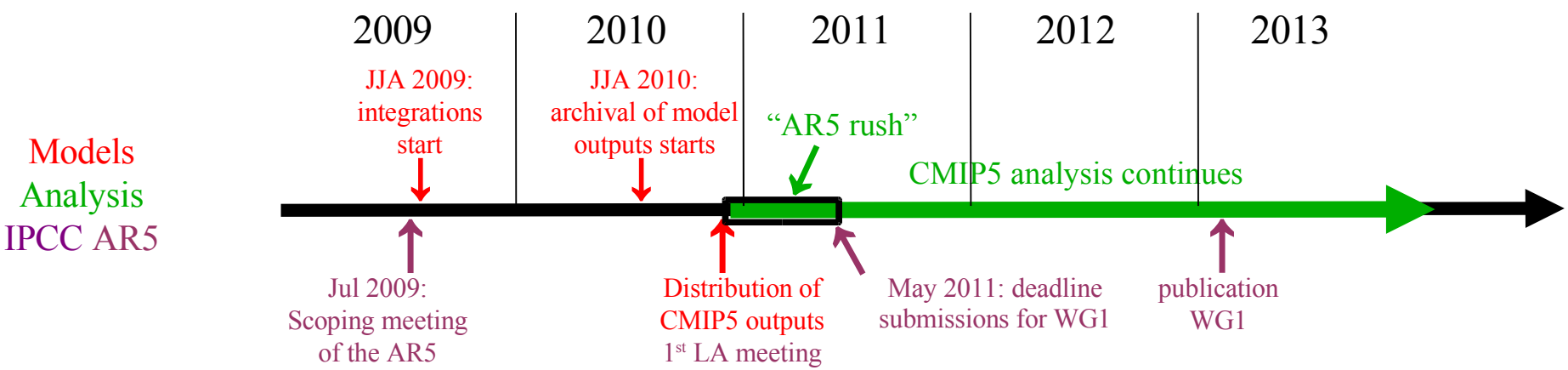


CMIP5 long-term experiments (to 2100 and beyond)



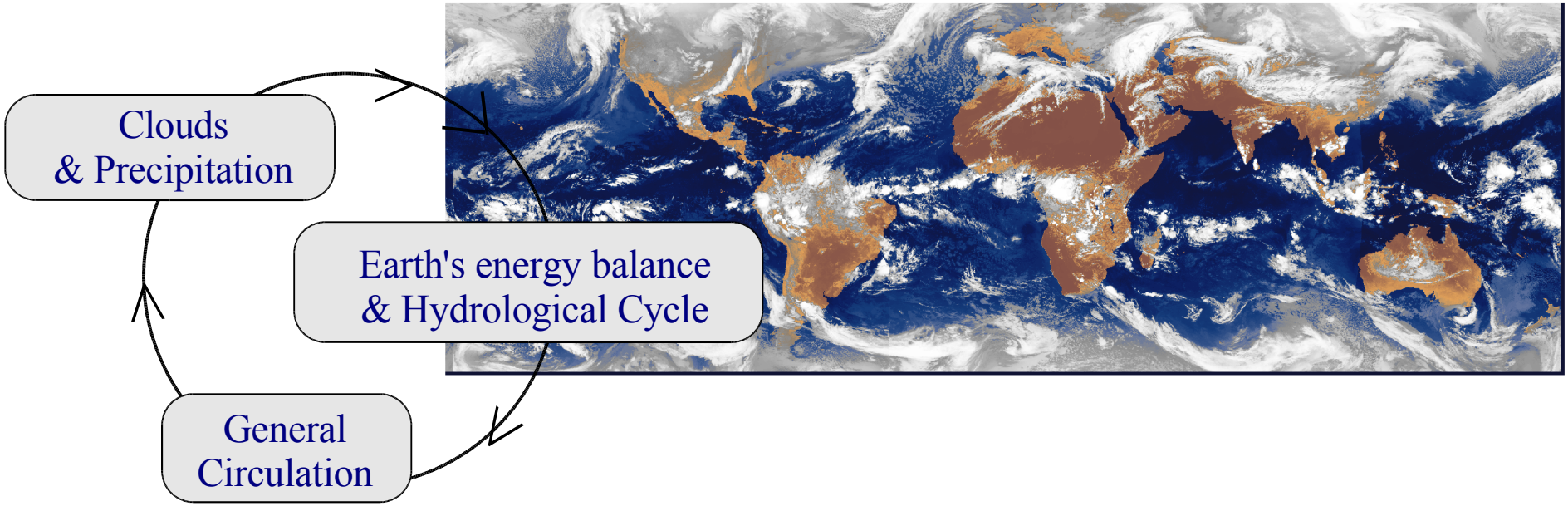
Status and Timeline :

- Modeling groups are finalizing new versions ; likely that about 5 groups will have 50 km class AOGCMs for decadal prediction, and at least 10 groups will have ESMs.
- Model simulations to be assessed in the AR5 completed in 2010
- PCMDI will begin to compile model data mid-2010 (distributed archive)
- Analyses of model data begins late 2010 and continues through 2013.
- Analyses to be considered by the IPCC AR5 will have to be submitted ~ by May 2011



Contribution of CFMIP-GCSS activities to the evaluation of climate models and to the understanding of model uncertainties

Cloud and moist processes at the origin of many model deficiencies



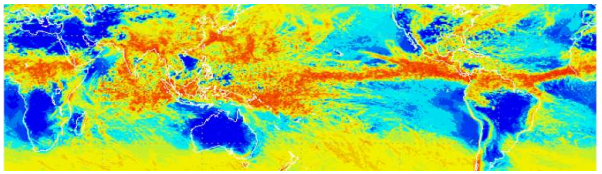
"It must be emphasized that the modeling of clouds is one of the weakest links in the general circulation modeling efforts." --- Charney et al. (NRC, 1979)

30 years later: the representation of cloud and moist processes remains highly critical for global climate modeling :

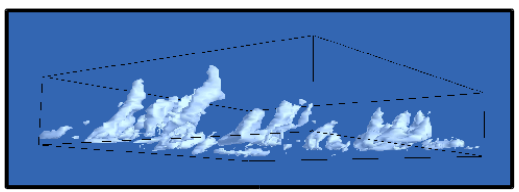
- current climate : large-scale circulation, regional climate patterns, modes of variability, etc
- sensitivity to external forcings (natural and anthropogenic): climate sensitivity, changes in precipitation and extremes, continental hydrology, carbon-climate feedbacks, etc

How to gain confidence in GCMs projections ?

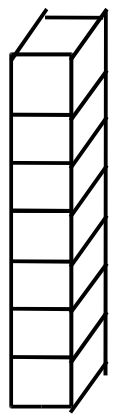
(1) Bottom-Up approach : evaluate and improve the physical basis of climate models through large-scale and process-scale evaluations



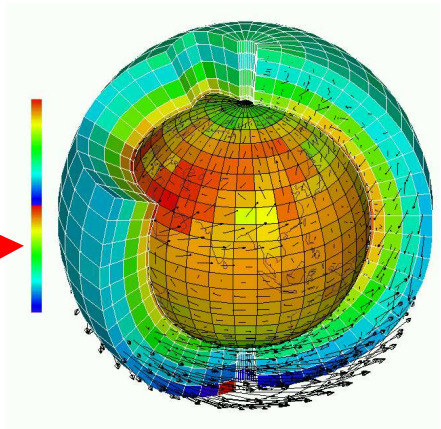
High resolution global models (global CRM, MMF)



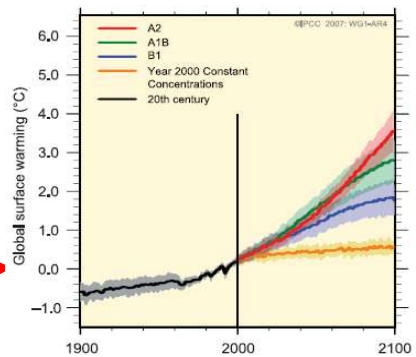
LES models Cloud Resolving Models



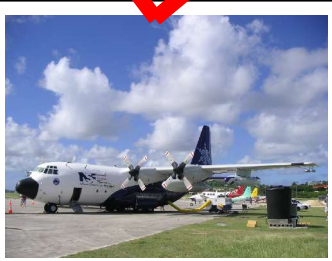
Single Column Models



3D-Climate Models NWP Models

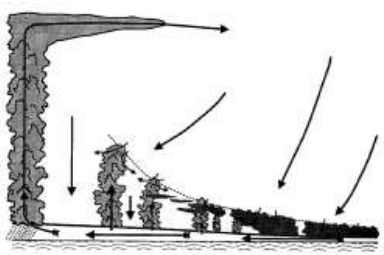


Model projections



Field campaigns & instrumented sites

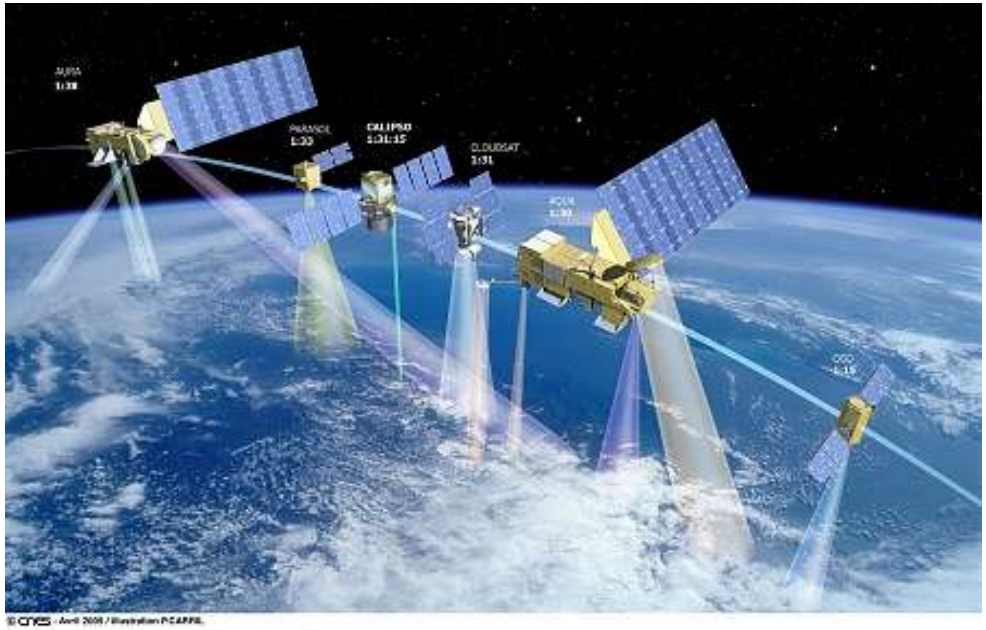
Global observational datasets



Analysis & Understanding cloud feedbacks

Bridging models, observations and processes to better evaluate cloud and moist processes in models

At the large-scale :



CFMIP Satellite Simulator (COSP)
to facilitate the comparison of model
outputs with satellite observations
(CloudSat, CALIPSO, PARASOL, ISCCP, MISR)

At the process scale :

Detailed model outputs at selected locations
where field experiments or
instrumented sites are available
(e.g. ARM, VOCALS, AMMA)

Bridging models, observations and processes to better evaluate cloud and moist processes in models

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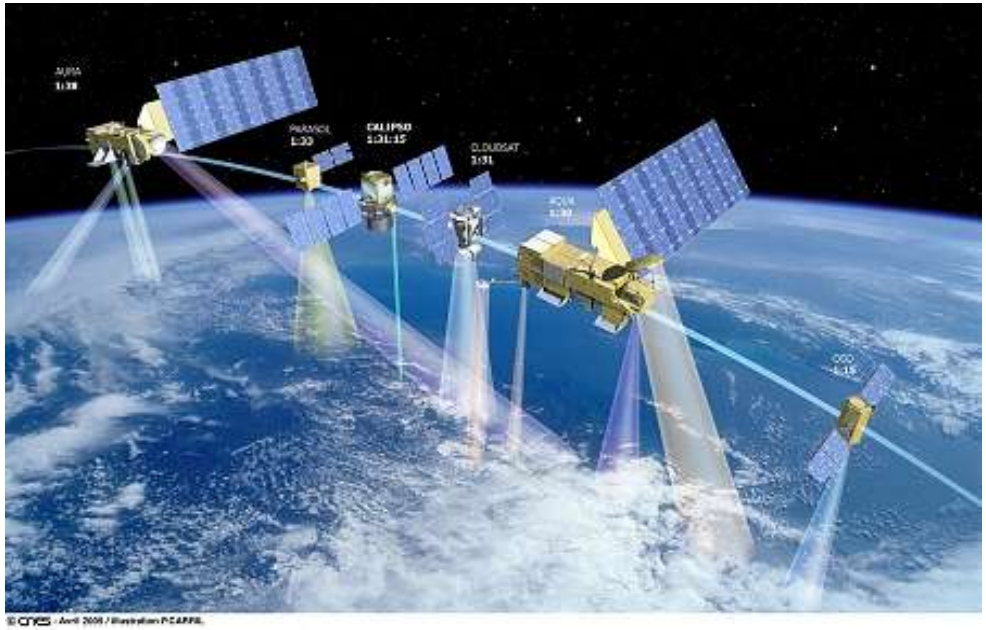


At the process scale :

CFMIP Satellite Simulator (COSP) to facilitate the comparison of model outputs with satellite observations (CloudSat, CALIPSO, PARASOL, ISCCP, MISR)

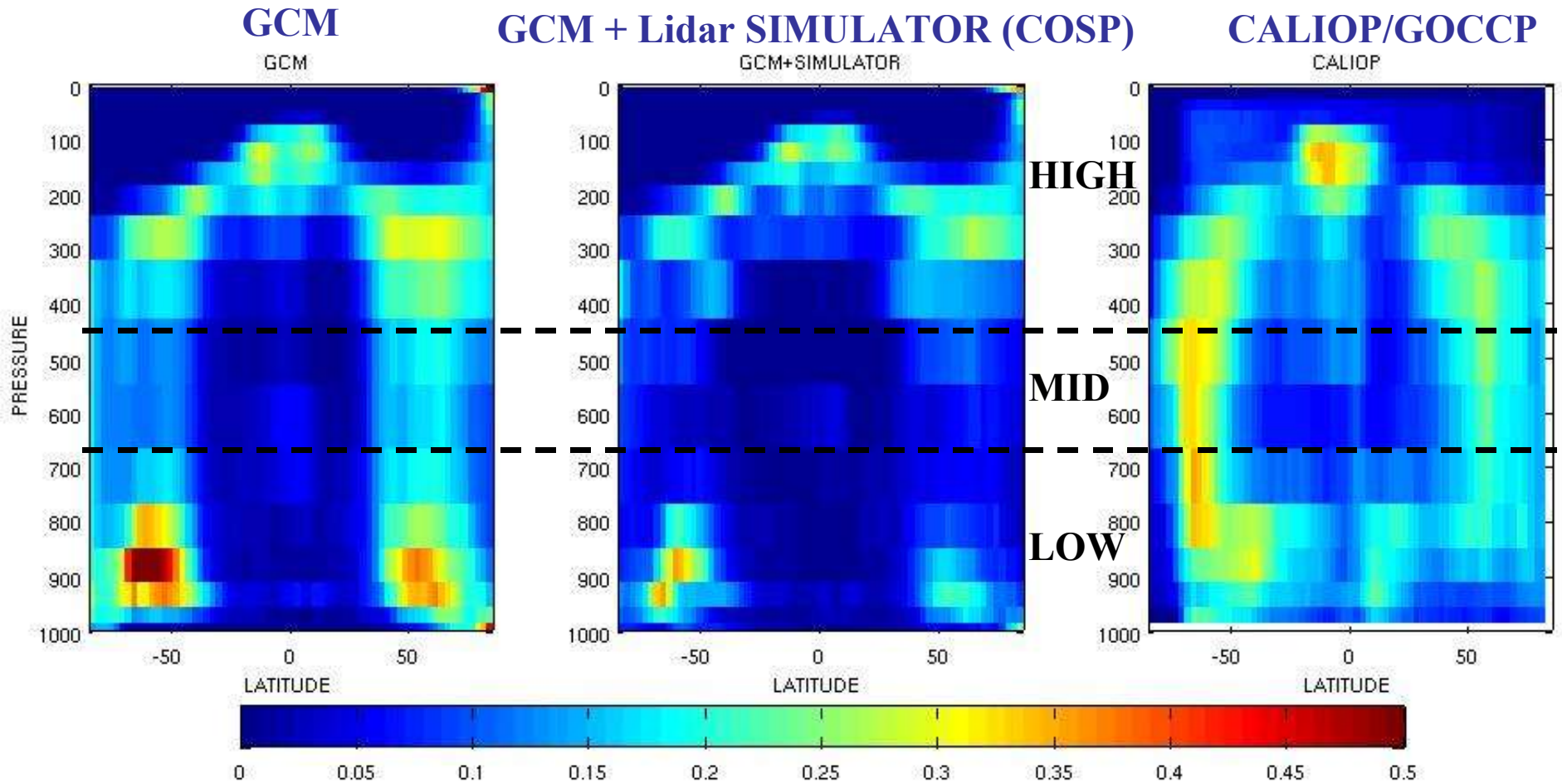
Detailed model outputs at selected locations where field experiments or instrumented sites are available (e.g. ARM, VOCALS, AMMA)

CFMIP-GCSS recommendations to WGCM (Sept 2008)

↓ Used in some CMIP5 experiments

↓ Part of CMIP5 outputs

Evaluation of the cloud vertical distribution using COSP

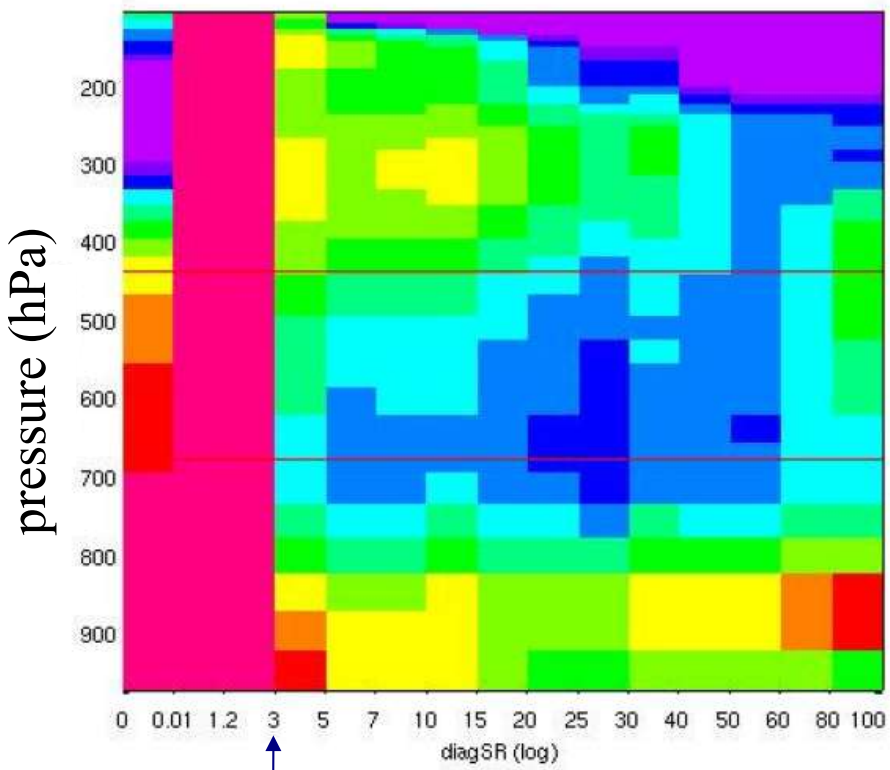


(Chepfer et al. 2008)

Use of COSP and CALIPSO-GOCCP observations to evaluate clouds along the GEWEX Pacific Cross section Intercomparison Transect (GPCI)

Histograms of the lidar scattering ratio as a function of height :

CALIPSO-GOCCP Observations



Lidar signal intensity (SR)

SR>3 : cloud

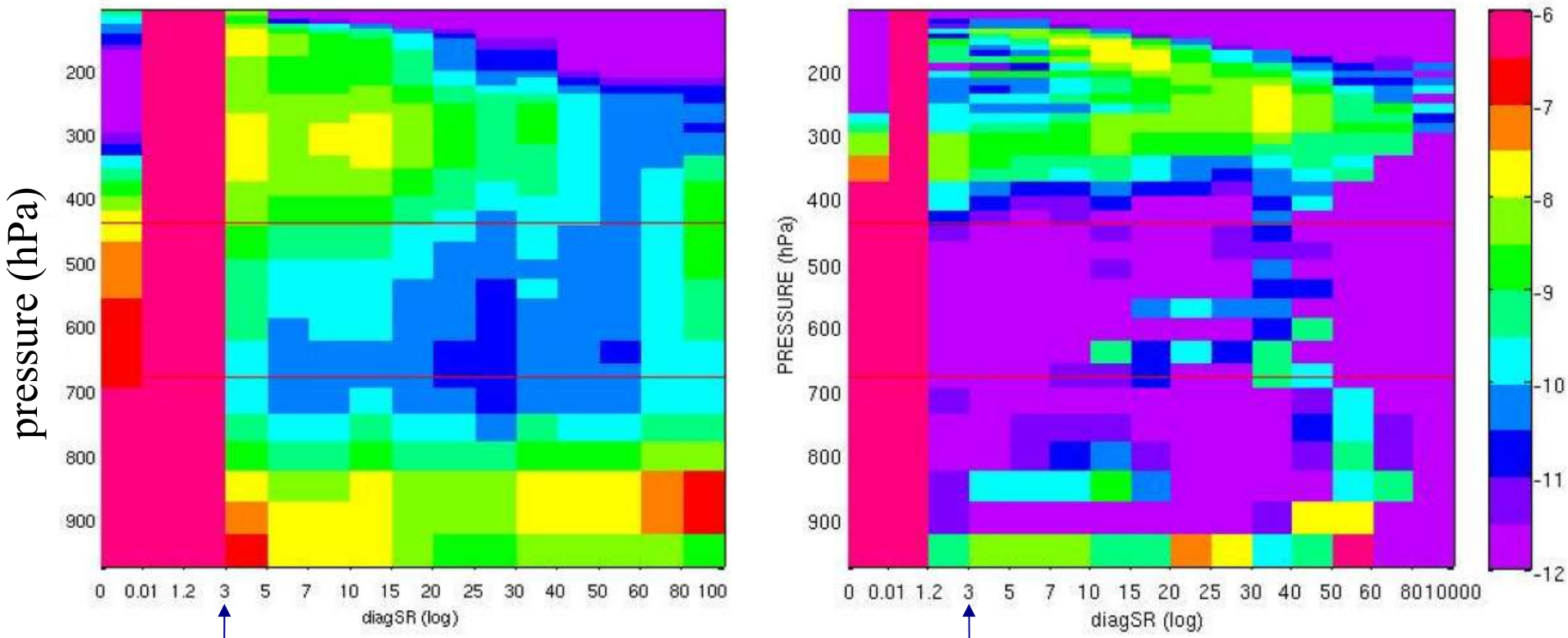
(Chepfer et al. 2009)

Use of COSP and CALIPSO-GOCCP observations to evaluate clouds along the GEWEX Pacific Cross section Intercomparison Transect (GPCI)

Histograms of the lidar scattering ratio as a function of height :

CALIPSO-GOCCP
Observations

LMDZ GCM
+ COSP simulator



Lidar signal intensity (SR)

SR>3 : cloud

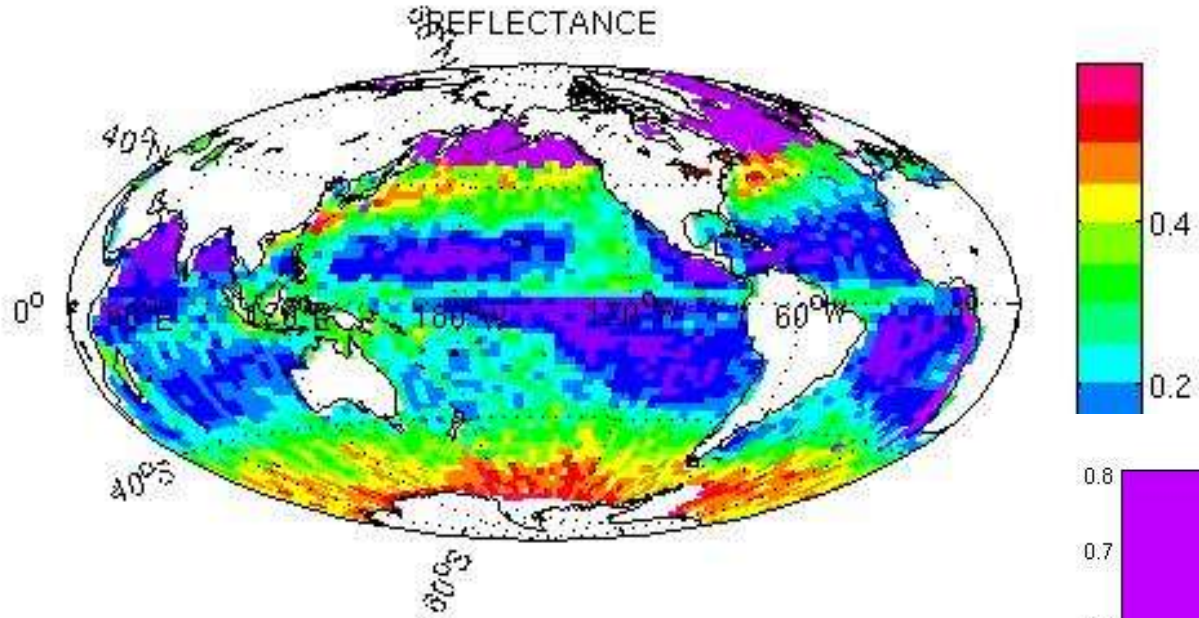
Lidar signal intensity (SR)

SR>3 : cloud

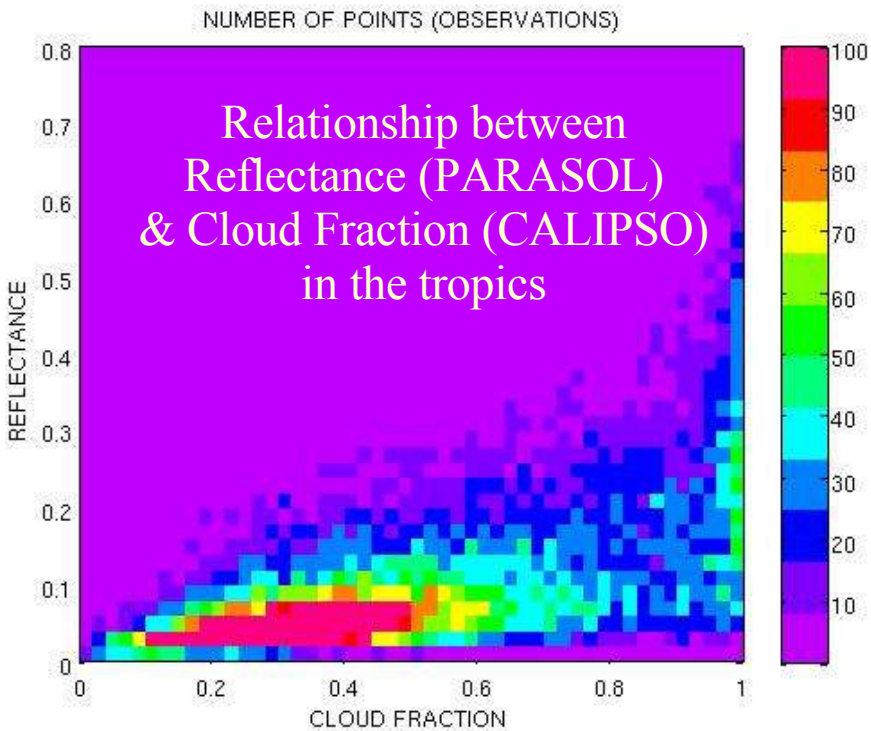
(Chepfer et al. 2009)

Use of COSP and PARASOL observations to evaluate the relationship between cloud fraction and reflectance

PARASOL



Diagnostics applied
to GCM outputs using COSP :
cf Hélène Chepfer's talk



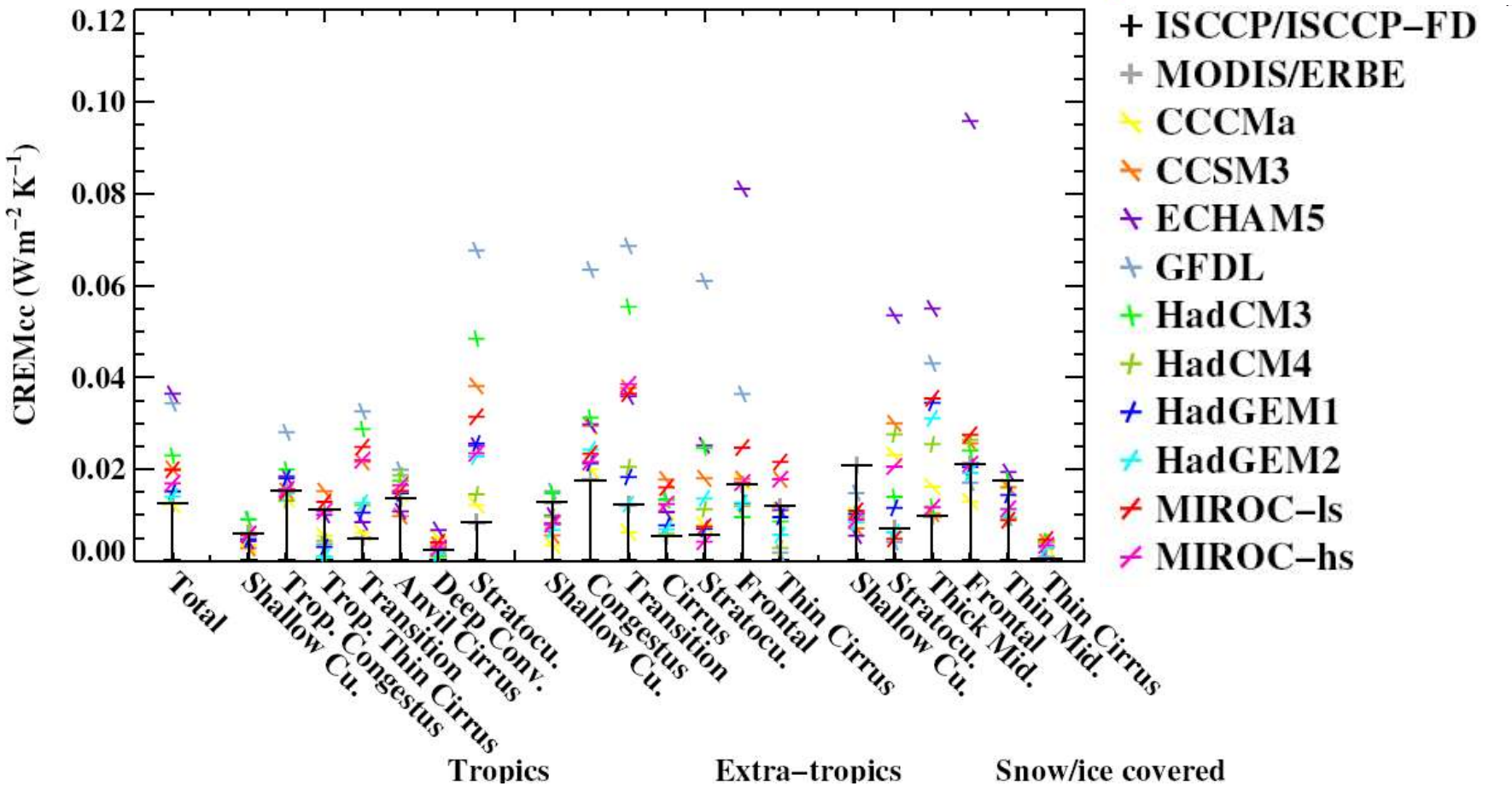
COSP simulator available at :

http://www.cfmip.net/COSP
(cf Alejandro Bodas-Salcedo's talk)

A-Train observational datasets consistent with
CALIPSO-PARASOL simulator outputs available at :

http://climserv.ipsl.polytechnique.fr/cfmip-atrain.html

Example of cloud regime error metric using the ISCCP simulator :



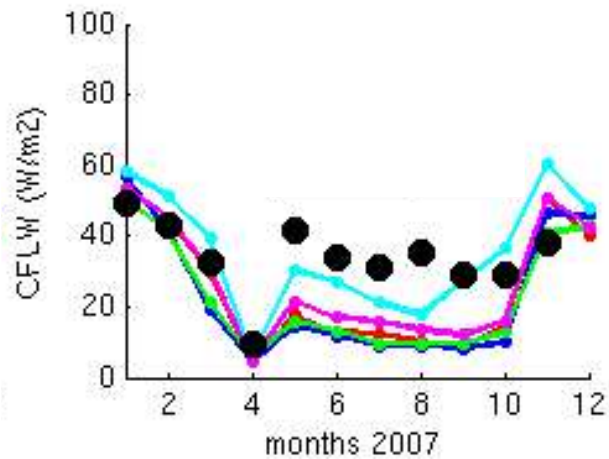
- Process-oriented cloud metrics
- Results quite different to climatological metrics
- Guide for parameterizations improvement (testing and development)

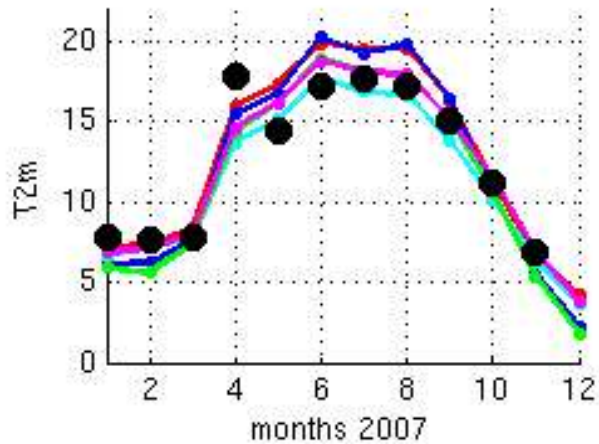
(Williams & Webb, Clim. Dyn., 2009)

Evaluation of model outputs at selected locations

Evaluation of seasonal variations of
surface meteorological and radiative properties
at SIRTA/Palaiseau (instrumented site near Paris)

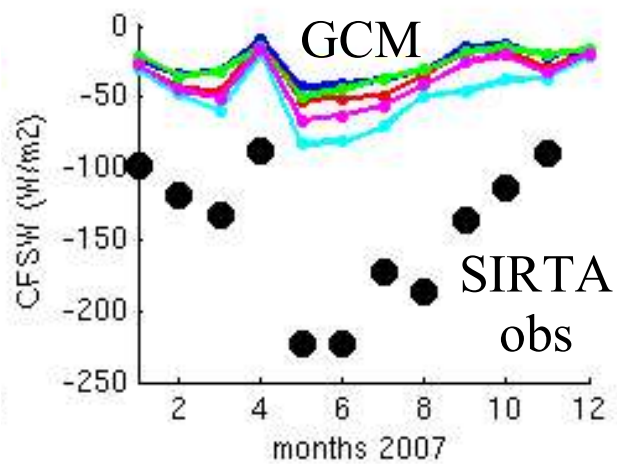
Surface LW CRF

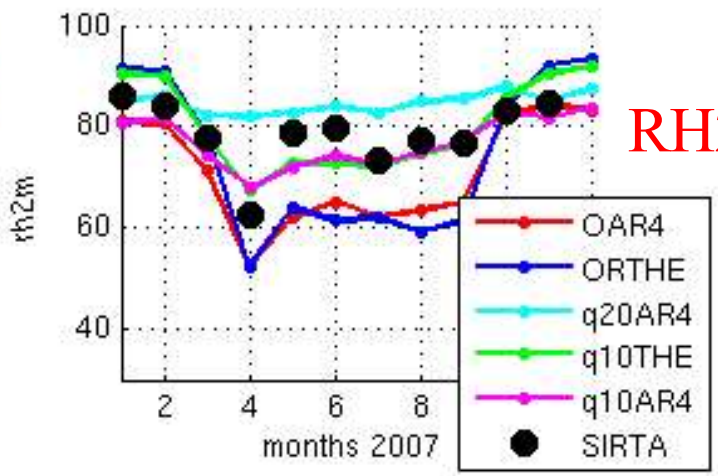




T2m

Surface SW CRF





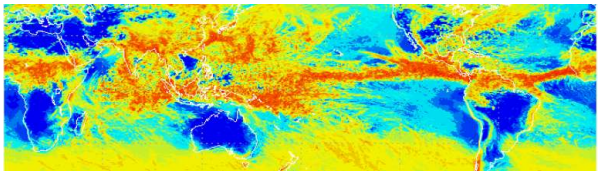
RH2m

Courtesy Frédérique Chéruy et al. (LMD)

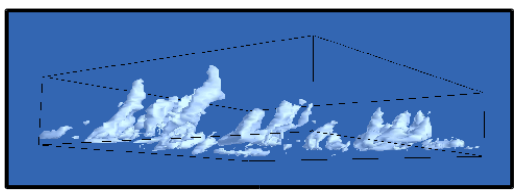
How to gain confidence in GCMs projections ?

(1) Bottom-Up approach : evaluate and improve the physical basis of climate models through large-scale and process-scale evaluations

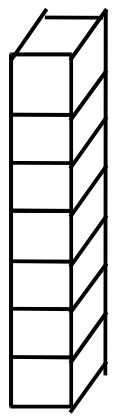
(2) Top-Down approach : understand the models' results & identify critical processes to provide guidance for specific observational tests/process studies



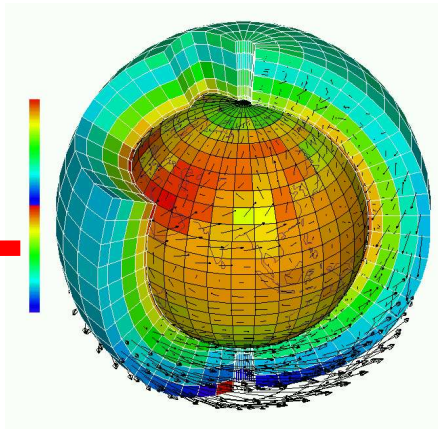
High resolution global models (global CRM, MMF)



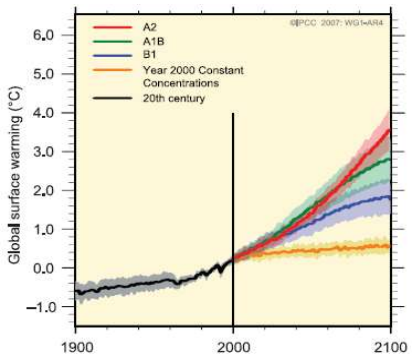
LES models
Cloud Resolving Models



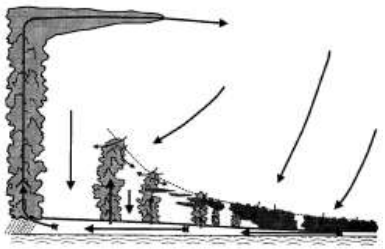
Single Column Models



3D-Climate Models
NWP Models



Model projections



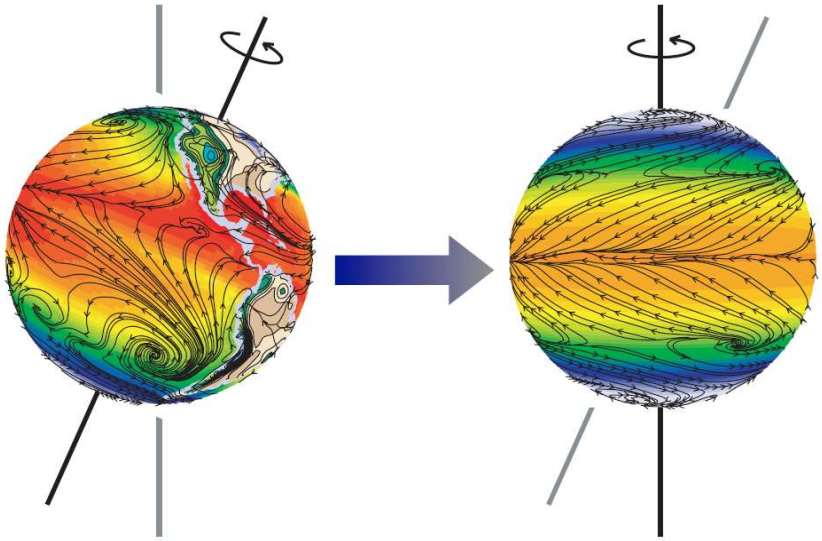
Analysis & Understanding cloud feedbacks

Field campaigns & instrumented sites

Global observational datasets

Understanding model differences and uncertainties

3D Idealized experiments :



(after Medeiros et al. 2008)

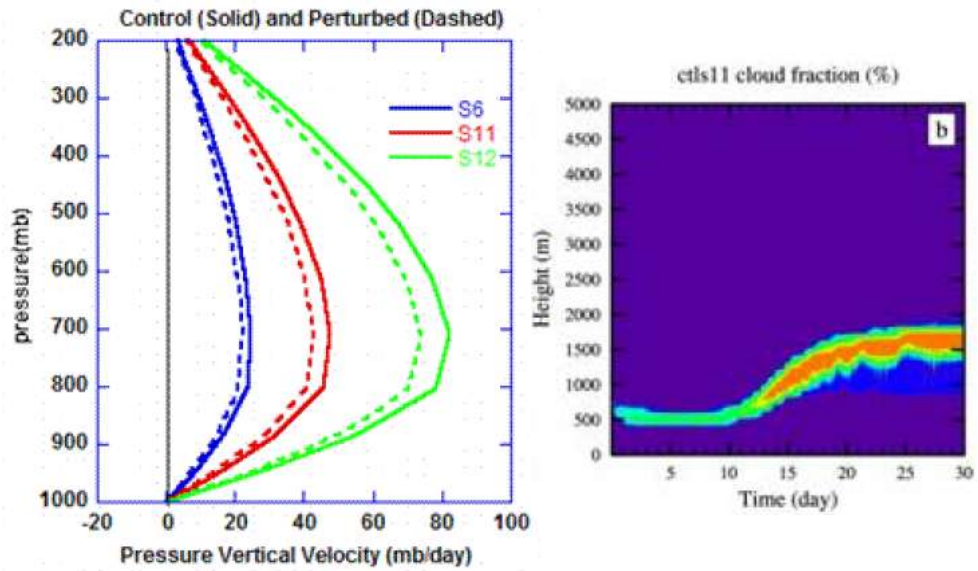
e.g. realistic/aqua-planet experiments with imposed SST distribution + SST/CO_2 change

CFMIP-GCSS recommendations to WGCM (Sept 2008)

↓

Part of CMIP5 experiments
(robustness of model results, interpretation of inter-model differences, etc)
Useful for many purposes (e.g. ITCZ, ISO)

Case studies of PBL cloud feedback mechanisms associated with an idealized climate change :



using LES/CRM/SCM models
(after Zhang & Bretherton 2008)

↓

Joint CFMIP-GCSS case studies

CFMIP-GCSS Activities within the context of climate change modeling

- Owing to the need to inform decisions about climate change adaptation and mitigation, the need to assess and to improve the reliability of climate model predictions and projections has never been so high.

- Increasing focus on climate models' evaluation and improvements within WCRP (WGCM, CLIVAR, GEWEX, WGNE).

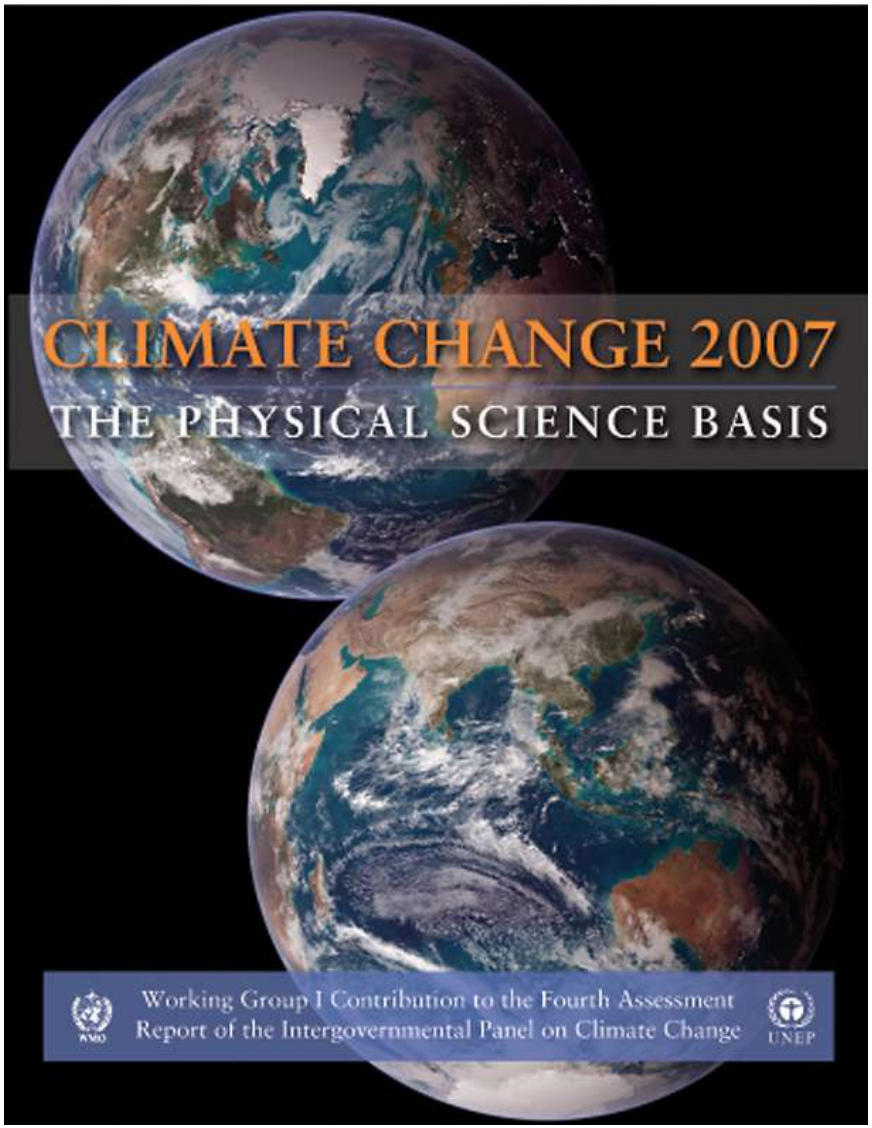
- Cloud processes and feedbacks being at the origin of many model deficiencies, the CFMIP-GCSS community has an important role to play.

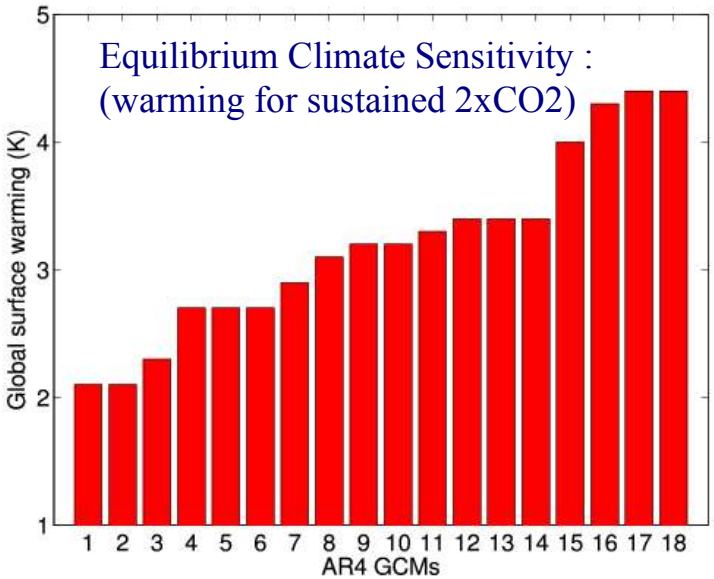
- Forming a “cloud modeling community” has allowed us to influence the design of CMIP5 experiments and outputs, so as to improve the assessment and our understanding of cloud processes and feedbacks in GCMs.

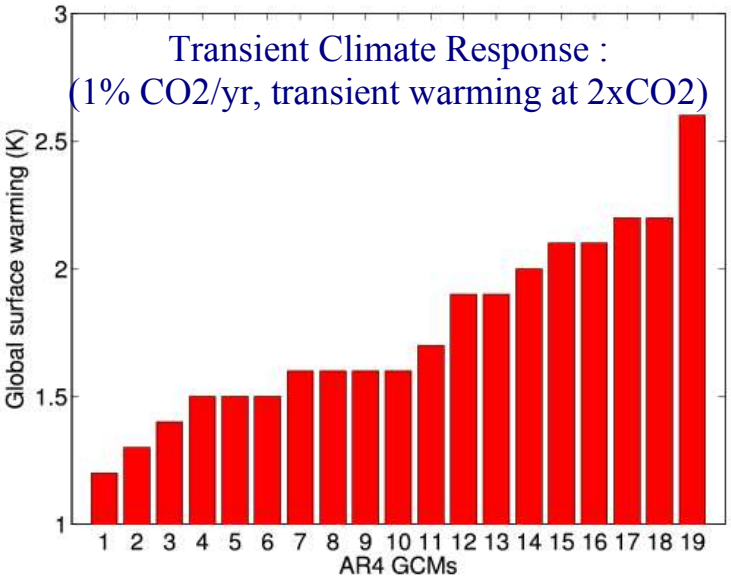
- A key role to play in the next IPCC Assessment Report
  and in the analysis of CMIP5 over the next 5+ years !


Thank You !

Climate Sensitivity Estimates from CMIP3 General Circulation Models :

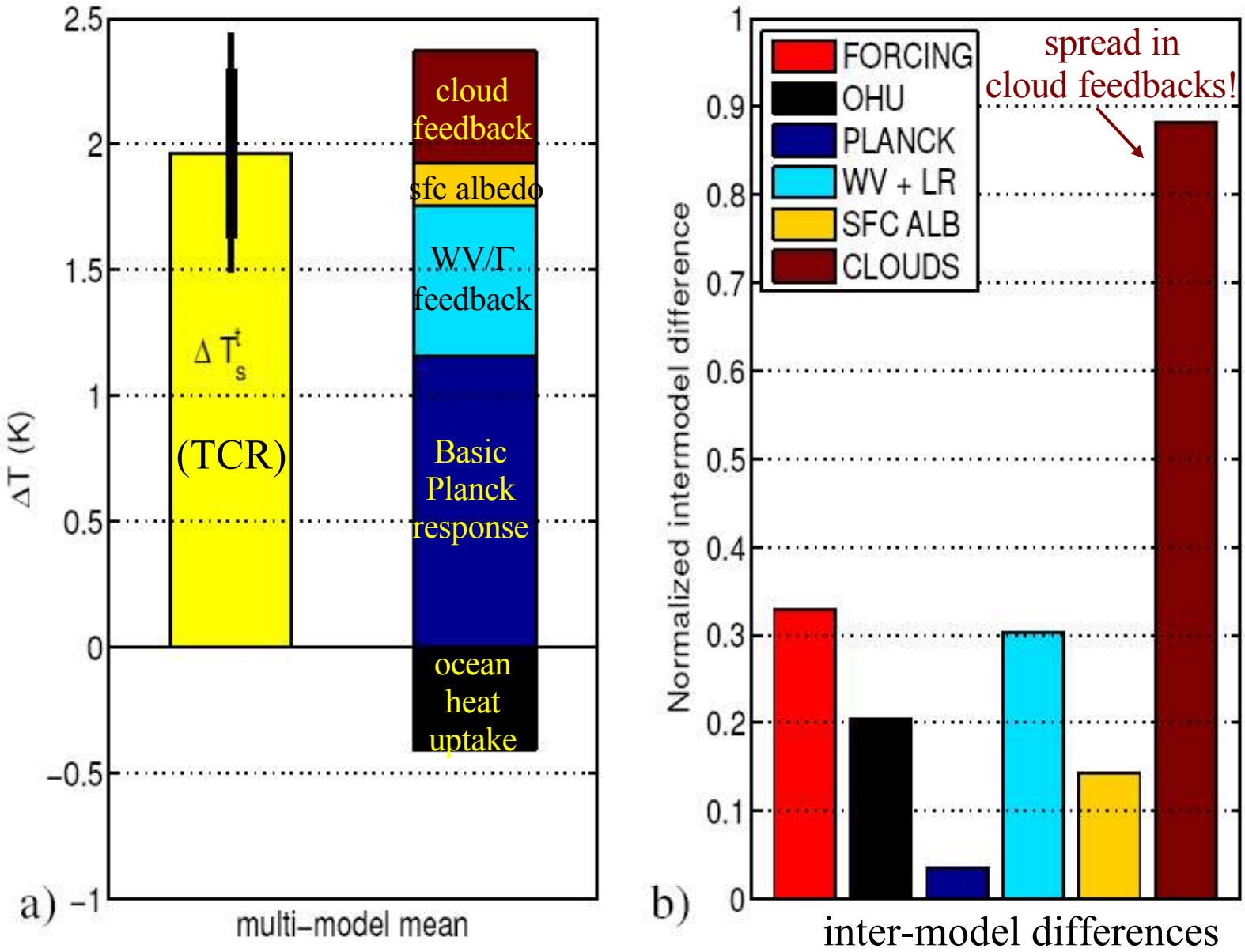






(Randall et al., AR4, 2007)

Contribution of Cloud Feedbacks to Climate Sensitivity in CMIP3 OAGCMs :



(Dufresne & Bony, 2008)

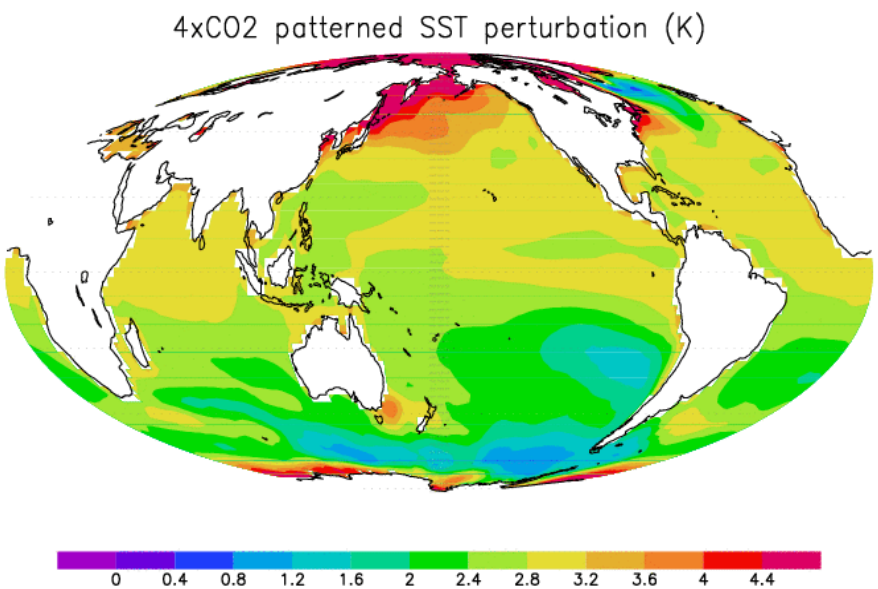
CFMIP2/CMIP5 idealized experiments :

Cloud response to an imposed change in SST (patterned or uniform +4K) or an imposed 4xCO2 in realistic (AMIP) or aqua-planet configurations.

→ to test the robustness of the cloud response to climate change

→ to assess the fast cloud adjustment to CO2 forcing and thus better evaluate radiative forcing and feedbacks

→ to better interpret inter-model differences



aqua-planet SST distribution