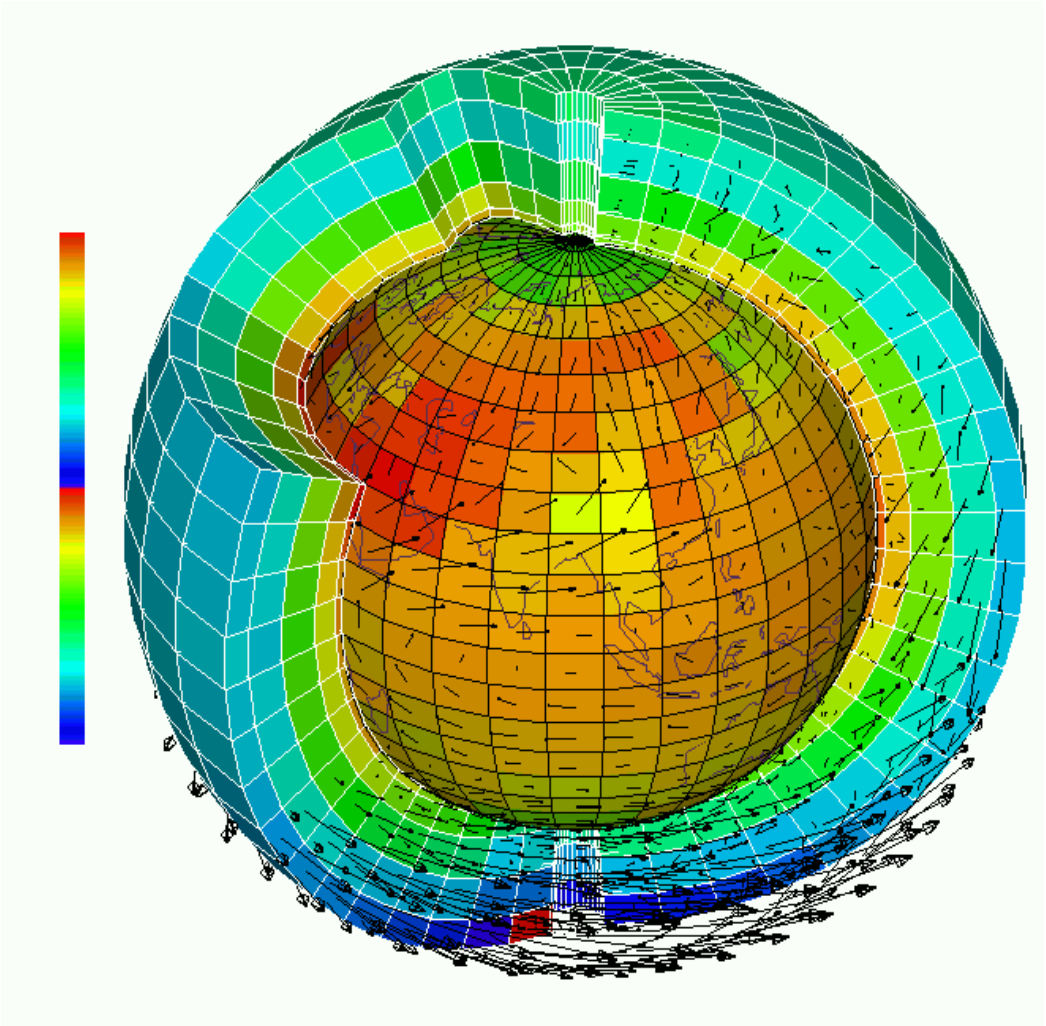
The WCRP Working Group on Coupled Models (WGCM)



Sandrine Bony & Jerry Meehl
WGCM co-chairs

28th WGNE meeting
Toulouse, Oct 2012

WCRP
World Climate Research Programme

WGCM Missions

- Review and foster the development of coupled climate models (AOGCMs) and Earth System Models (ESMs, i.e with a coupled carbon cycle, dynamic vegetation, chemistry, aerosols, etc.)

  Connect to :

  WGNE (processes and atmospheric model improvement),
  WGSIP (decadal climate prediction)
  IGBP AIMES (carbon cycle, ESM development),

- Coordinate model experiments and inter-comparisons:

  → better understand natural climate variability
  → predict the climate response to natural & anthropogenic perturbations
  → assess the climate predictability at the decadal timescale

  CMIP (with CMIP Panel in WGCM and many MIPs/partners),
  PMIP (with IGBP/PAGES), **CFMIP** (with GEWEX/GASS),
  Decadal Climate Prediction Panel (WGSIP/WGCM),
  Transpose-AMIP (WGNE/WGCM), **CORDEX** (JSC/WGCM)

· Promote and facilitate model validation and diagnosis of shortcomings, and understanding processes and feedbacks in the climate system

  → **Metrics panel** (WGNE/WGCM), Transpose-AMIP (WGNE/WGCM)
  → facilitating connections between modelling / observations / processes (e.g. CFMIP), Obs4MIPs

WGCM promotes balance between

simulation – evaluation – understanding

Some common interests between WGCM and WGNE

Outline

- CMIP5 : status, workshop, strengths, weaknesses, thoughts about the future
- WGNE/WGCM activities
- WCRP Grand Challenge on “Clouds, Circulation and Climate Sensitivity »

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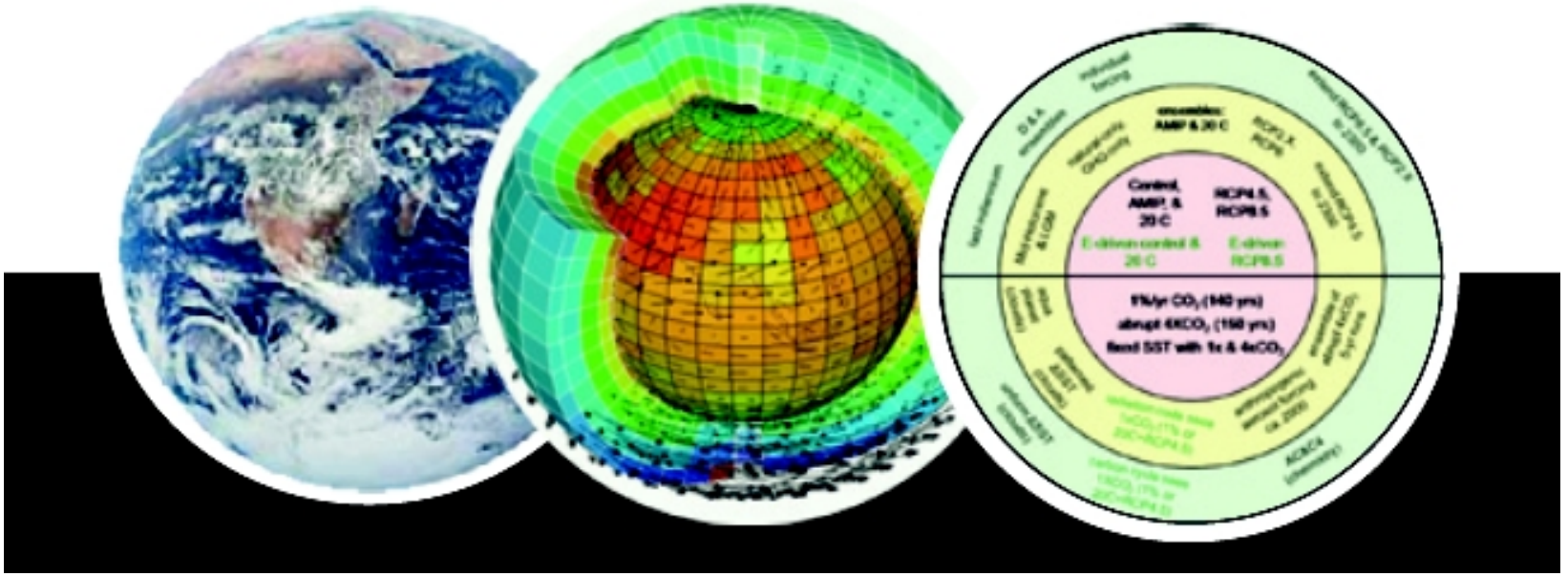
WCRP Coupled Model Intercomparison Project - Phase 5 - CMIP5 -



CLIVAR Exchanges, CMIP5 special issue (May 2011)

CMIP5 Status (as of today) :

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- Sept 2012 : 59 models from 24 modeling centers

CMIP5 participating groups 22 Sept. 2012:
59 models available from 24 groups

Primary Group	Country	Model
CSIRO-BOM	Australia	ACCESS 1.0, 1.3
BCC	China	BCC-CSM1.1, 1.1(m)
GCESS	China	BNU-ESM
CCCMA	Canada	CanESM2, CanCM4, CanAM4
DOE-NSF-NCAR	USA	CCSM4, CESM1 (BGC), (CAM5), (CAM5.1,FV2), (FASTCHEM), (WACCM)
RSMAS	USA	CCSM4(RSMAS)
CMCC	Italy	CMCC- CESM, CM, & CMS
CNRM/CERFACS	France	CNRM-CM5
CSIRO/QCCCE	Australia	CSIRO-Mk3.6.0
EC-EARTH	Europe	EC-EARTH
LASG-IAP & LASG-CESS	China	FGOALS- g2, s2, & gl
FIO	China	FIO-ESM
NASA/GMAO	USA	GEOS-5
NOAA GFDL	USA	GFDL- HIRAM-C360, HIRAM-C180, CM2.1, CM3, ESM2G, ESM2M
NASA/GISS	USA	GISS- E2-H, E2-H-CC, E2-R, E2-R-CC, E2CS-H, E2CS-R
MOHC	UK	Had CM3, CM3Q, GEM2-ES, GEM2-A, GEM2-CC
NMR/KMA	Korea / UK	HadGEM2-AO
INM	Russia	INM-CM4
IPSL	France	IPSL- CM5A-LR, CM5A-MR, CM5B-LR
MIROC	Japan	MIROC 5, 4m, 4h, ESM, ESM-CHEM
MPI-M	Germany	MPI-ESM- HR, LR, P, ESM-P
MRI	Japan	MRI- AGCM3.2H, AGCM3.2S, CGCM3, ESM1
NCC	Norway	NorESM1-M, NorESM-ME
NCEP	USA	CFSv2-2011
NICAM	Japan	NICAM-09
INPE	Brazil	BESM OA2.3

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- Participation : 48 models for historical simulations (20C),
  28 models for AMIP,
  18 models for decadal hindcasts/predictions,
  11 models for aqua-planets
  6 high-top models (at least)
  7 models for high-frequency pointwise outputs
  etc

- New system in place to access the data : http://pcmdi9.llnl.gov

- At least 260 publications submitted, in revision or published (http://cmip.llnl.gov/cmip5/publications/allpublications)

CMIP Coupled Model Intercomparison Project
World Climate Research Programme

U.S. DEPARTMENT OF ENERGY | Office of Science

Submit | Edit | View | Administration

Total Publications Count: 248

All Publications

Author	Article Title	Journal
?eparovi? L. , A. Alexandru, R. Laprise, A. Martynov, L. Sushama, ...	Present climate and climate change over North America as simulated by the fifth-generation Canadian Regional Climate Model (CRCM5); (Citation) (More Information)	Climate Dynamics
Ahlström A. , G. Schurgers, B. Smith	Robustness and uncertainty in terrestrial ecosystem carbon response to CMIP5 climate change projections; (Citation) (More Information)	Environmental Research Letters
Ahmed C. B. , S. Sensoy	Assessment of climate change effects on agriculture in the Mediterranean countries; (Citation) (More Information)	
Alan I. , M. Demircan, S. Sensoy	Trends in Turkey climate extreme indices from 1971 to 2004; (Citation) (More Information)	
Anav A. , P. Friedlingstein, M. Kidston, L. Bopp, P. Ciais, ...	EVALUATING THE LAND AND OCEAN COMPONENTS OF THE GLOBAL CARBON CYCLE IN THE CMIP5 EARTH SYSTEM MODELS; (Citation) (More Information)	Journal of Climate
Andrews T. , J. M. Gregory, M. J. Webb, K. E. Taylor	Forcing, feedbacks and climate sensitivity in CMIP5 coupled atmosphere-ocean climate models; (Citation) **Andrews T. , J. M. Gregory M. J. Webb K. E. Taylor null : " Forcing, feedbacks and climate sensitivity in CMIP5 coupled atmosphere-ocean climate models" , *Geophysical Research Letters* 39 , doi:10.1029/2012GL051607 , http://www.agu.org/pubs/crossref/2012/2012GL051607.shtml** (More Information) Experiments: abrupt4xCO2, piControl, sstClim, sstClim4xCO2 Models: CanESM2, CNRM-CM5, CSIRO-Mk3.6.0, GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, HadGEM2-ES, INM-CM4, IPSL-CM5A-LR, MIROC-ESM, MIROC5, MPI-ESM-LR, MPI-ESM-P, MRI-CGCM3, NorESM1-M Variables: land area fraction, surface temperature, toa incoming shortwave flux, toa outgoing longwave flux, toa outgoing longwave flux assuming clear sky, toa outgoing shortwave flux, toa outgoing shortwave flux assuming clear sky Keywords: WG1 (physical climate system), Abrupt change, Globe, Energy budget, Radiatiave forcing, Clouds, Radiation, Feedbacks, Climate sensitivity	Geophysical Research Letters

Publication Views

- All Publications
- By Journal
- By Publication Type
- By Publication Status
- By Publication Year
- By Model
- By Experiment
- By Variable
- By Keyword
- By Sampling Frequency

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  etc

- New system in place to access the data : http://pcmdi9.llnl.gov

- At least 260 publications submitted, in revision or published (http://cmip.llnl.gov/cmip5/publications/allpublications)

- CMIP5 research just beginning

- First lessons ?

First lessons from CMIP5
1. Data and infrastructure

Good :

- amazingly complex compared to CMIP3 but : worked out !
  (ex 1.7 Pb of data in CMIP5, 40 Tb in CMIP3)

- distributed data management system was a first !
  amazing accomplishment (although the complexity is not always well appreciated by users)
  + software effort from many different people
  + system in place extensible

Not so good :

- infrastructure funding initially underestimated, governance too informal
- capabilities not deployed in time
- modeling groups were late making data public (feb 2012 for most of them)
- model documentation (metafor) : lots of efforts, very little feebdack so far

First lessons from CMIP5
2. Science

CMIP5 Model Analysis Workshop
(IPRC, Hawaii, March 5-9 2012)
175 participants (230 abstracts submitted)

First lessons from CMIP5
2. Science

- **Spread of projections in CMIP5 AOGCMs comparable to CMIP3**, and first generation ESMs 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 ; **great value of idealized CMIP5 experiments.**

- Decadal prediction : challenging...

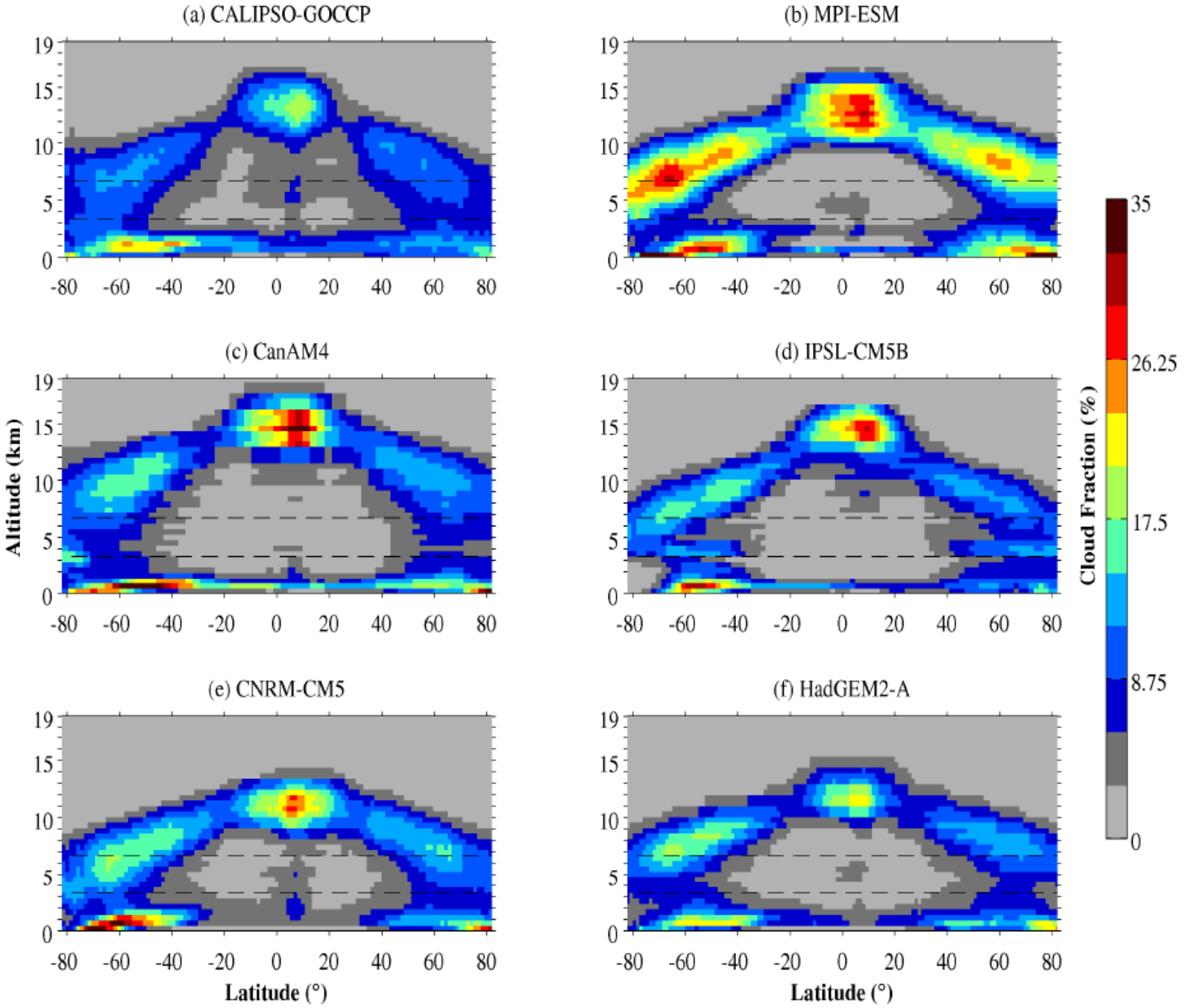
- RCPs may not sample the range of plausible pathways regarding aerosols and land-use.

- Model biases :

  * **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)

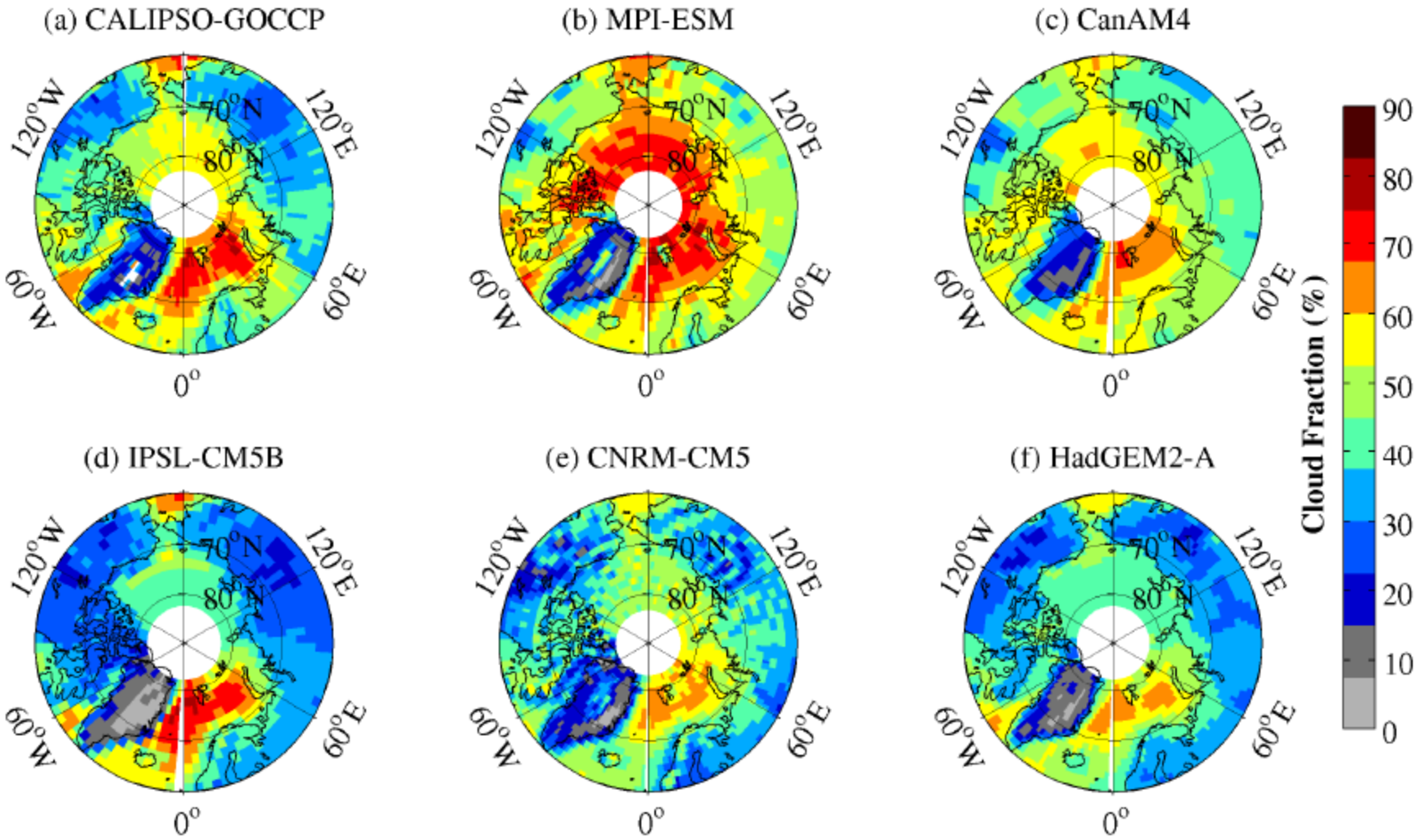
  *** many others have not significantly improved** (e.g. double ITCZ, Arctic clouds and circulation, Antarctic sea ice loss, southern ocean too warm, SPCZ too zonal..)

3D distribution of clouds (using COSP)



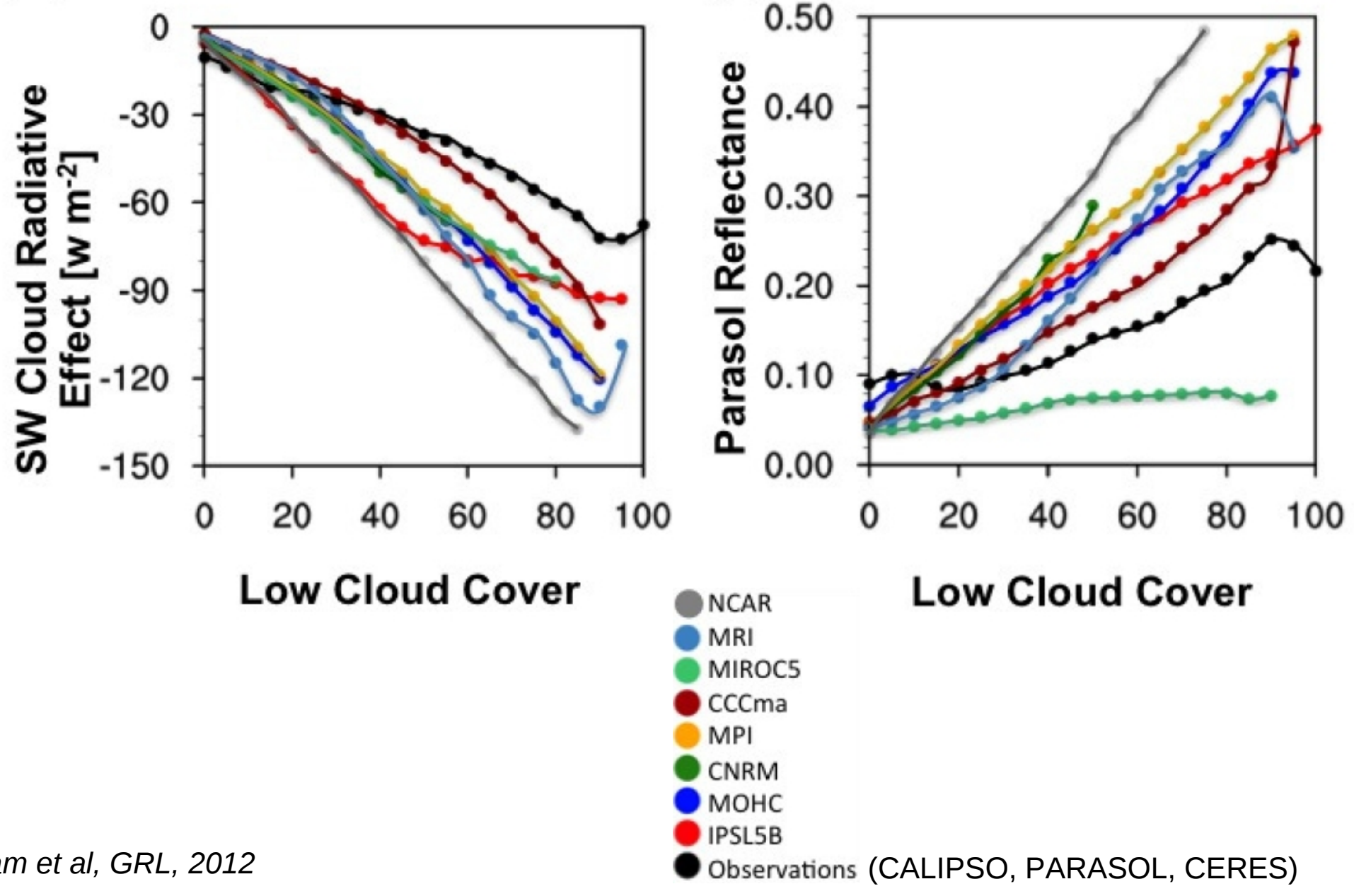
Cesana & Chepfer, GRL, 2012

Arctic low cloud cover (using COSP)



Cesana & Chepfer, GRL, 2012

Too few, too bright low-cloud problem

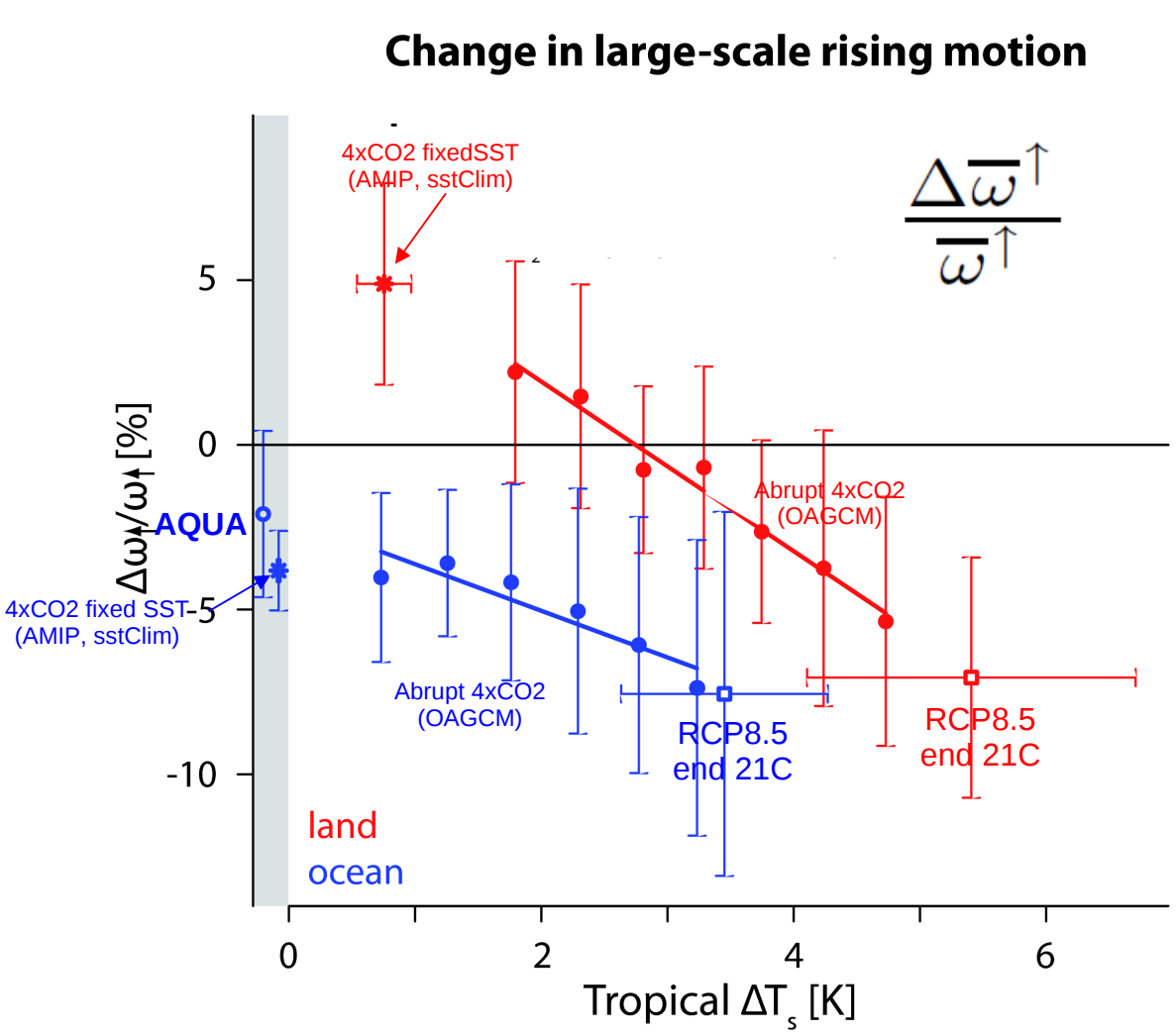


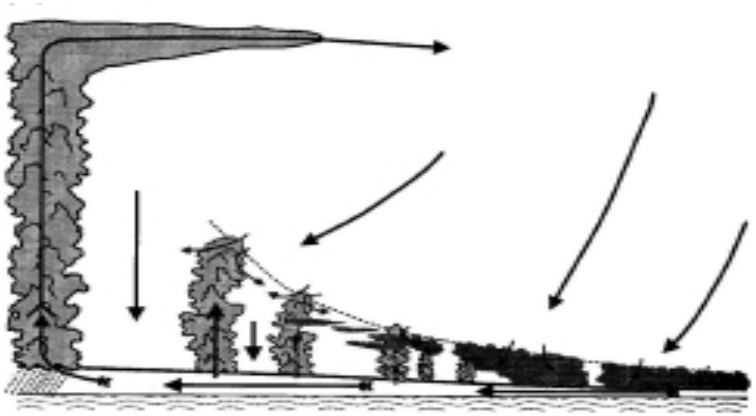
Nam et al, GRL, 2012

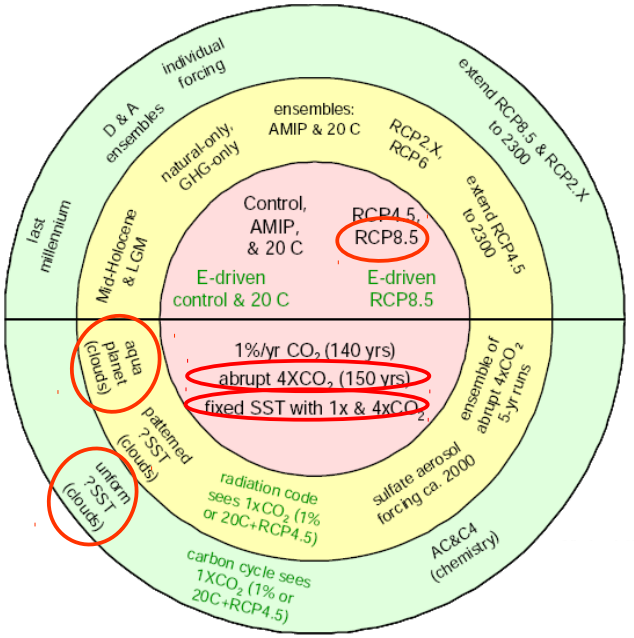
(CALIPSO, PARASOL, CERES)

Change in circulation predicted by CMIP5 models

... in multiple models, experiments and configurations



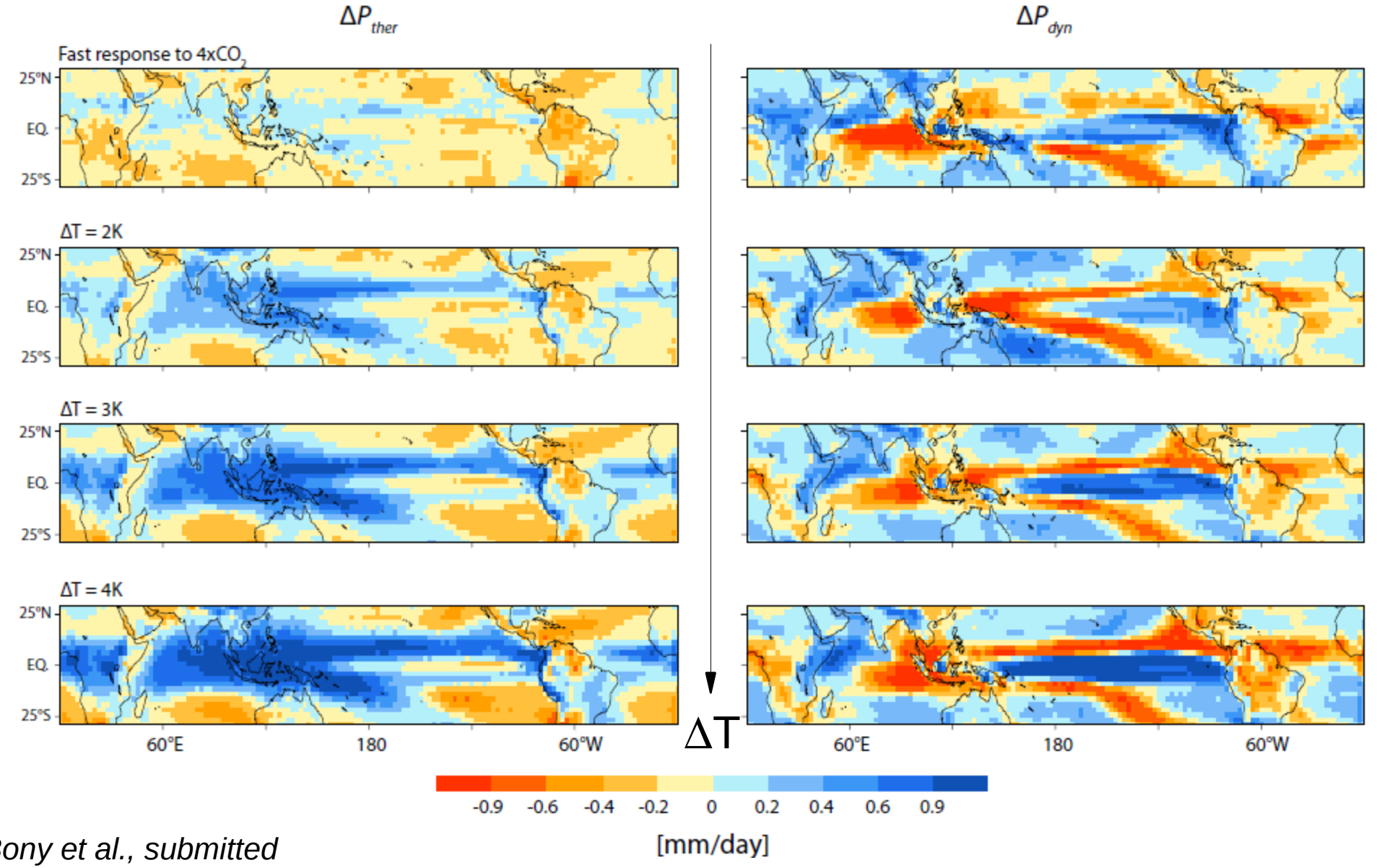




Bony et al., submitted

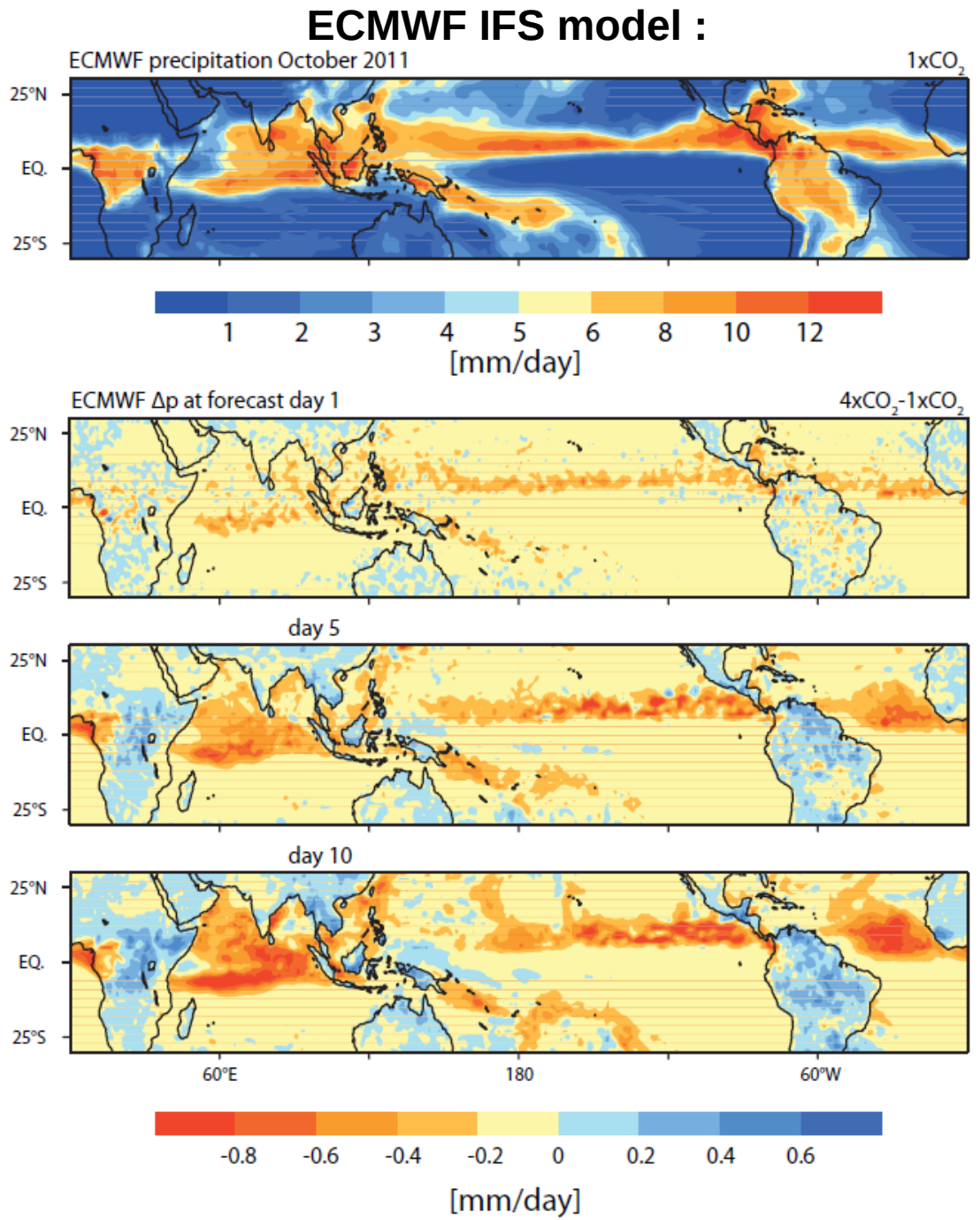
Change in tropical precipitation predicted by CMIP5 models

A significant part of regional rainfall changes due to the direct effect of CO2 rather than warmer surface temperatures.



Bony et al., submitted

Response of large-scale atmospheric dynamics and precipitation to CO2 controlled by very fast processes



4xCO2, Day 1

4xCO2, Day 5

4xCO2, Day 10

Bony et al., submitted

Next Steps

- Improve the governance and funding of the ESGF

- Conduct survey on CMIP5 (users, providers)

- Encourage all MIPs to follow CMIP5 standards

- Think about the articulation between CMIPs and model development
  → decouple the two ?
  → use CMIP variable names, file structure, ESGF, etc
  → leverage community efforts (e.g. codes for analysis and visualization)

- **Ask CMIP5 analysts some feedback about model shortcomings (and interpretation)**
  -> help from WGNE welcome !

- **Encourage the writing of synthesis papers about CMIP5 results (~2013/2014)**
  -> to be considered by WGNE ?

What would future CMIPs look like ?

- Continuity with CMIP5

- Core set of CMIP experiments + satellite MIPs ?
  Long-term and near-term experiments more integrated ?
  Subset of experiments decoupled from IPCC cycle ?

- Promote idealized experiments focused on science questions (cf GC)

- CMOR to become the standard protocol of our community

- Variable list to be revisited/prioritized based on CMIP5 survey

→ Exploratory workshop in 2013

→ Start planning CMIP6 (2014-2019)

Outline

- CMIP5 : status, workshop, strengths, weaknesses, thoughts about the future
- WGNE/WGCM activities
- WCRP Grand Challenge on “Clouds, Circulation and Climate Sensitivity »

Climate model coordinated experiments organized in parallel to CMIP5

- Many!

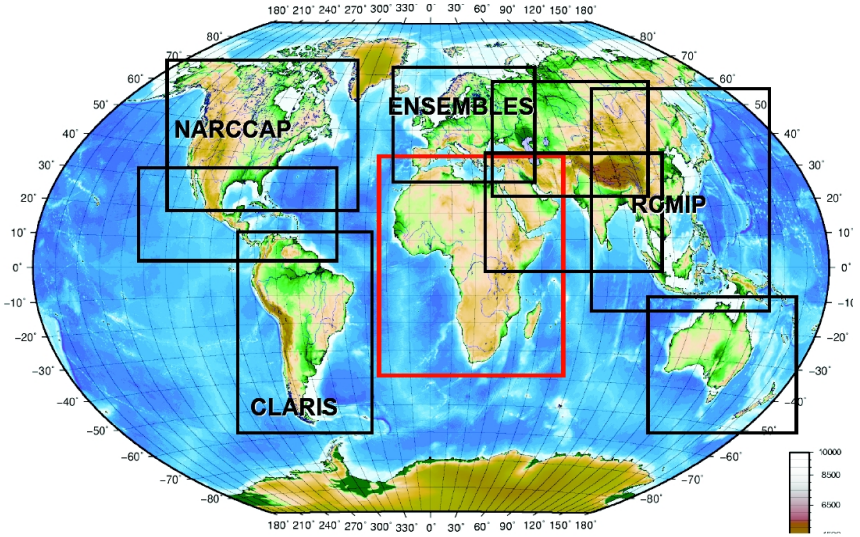
- Atmosphere-only experiments :

  - CORDEX (JSC Task Force on Regional Climate Downscaling) : regional climate modelling

  - CGILS (CFMIP-GASS Intercomparison of LES and SCM models) : cloud feedbacks

  - **Transpose-AMIP (WGNE/WGCM)** : evaluation of climate models in NWP mode

  - etc



What is Transpose-AMIP?

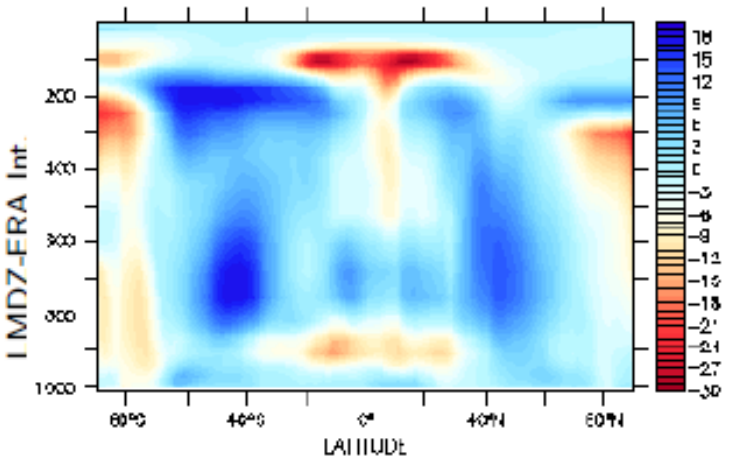
- Basically, running climate models in NWP mode.

- Core expt for Transpose-AMIP II is to run 64 hindcasts, each 5 days long, initialised from ECMWF YOTC analysis.
- Optional expt to repeat the same set of hindcasts with NASA MERRA re-analysis or own analysis.
- The hindcasts are spread through the annual and diurnal cycles during 2008/9 and were chosen to tie in with YOTC and coincide with some of the IOPs in:
  - VOCALS (SE Pacific stratocumulus)
  - AMY (Asian monsoon)
  - T-PARC (mid-latitude Pacific)
- Any global modelling centre (NWP or climate) can submit data. Those taking part in CMIP5 should use the same model as is being used for their AMIP simulation.
- **Jointly endorsed by WGNE and WGCM**.

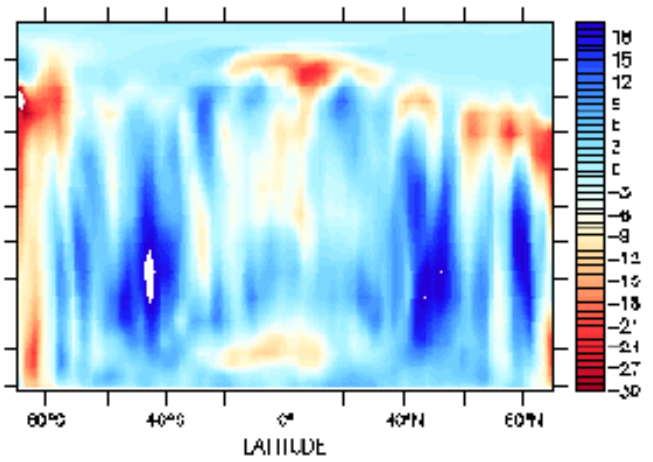
www.transpose-amip.info

An example: RELATIVE HUMIDITY errors in LMDZ, 15-Oct-2008

10-yr. October Climatology errors



day5-Forecast errors



Solange Fermepin (LMD/IPSL)

Status of experiments:

	Expt pledged	Expt run	Data converted	Data on ESG
EC-Earth (Frank Selten)	✓	In progress		
GFDL (Leo Donnor/student)	✓			
IPSL (Sandrine Bony/Solange Fermepin)	✓	✓	✓	✓
Met Office (Keith Williams)	✓	✓	✓	✓
Meteo France (Michel Deque)	✓	✓	✓	✓
MIROC (Masahiro Watanabe)	✓	✓	✓	✓
MPI (Bjorn Stevens)	✓			
MRI (Tomoaki Ose)	✓			
NCAR (Brian Medeiros)	✓	✓	✓	On NCAR node

www.transpose-amip.info

Proposed diagnostic subprojects:

- Relationship between short and long timescale model errors (PI: Shaocheng Xie)
- MJO dynamics in the Transpose-AMIP II hindcasts: (PI: Mitch Moncrieff)
- Water budget analysis (PI: Gill Martin)
- Comparison of methodologies (initial tendency using own analysis vs 5-day forecast using alien analysis) (PI: Mark Rodwell)
- Cloud regimes (PI: Keith Williams)
- Intense extratropical windstorms (PI: Peter Knippertz)
- VOCALS analysis (PI: Thomas Toniazzo)
- Timescale of tropospheric adjustment to increasing CO2 (Masahiro Watanabe)
- Comparison of current climate and NWP models (PI:TBD)
- Regional investigation into model tendencies (PI: TBD)
- 2009 SE Asian monsoon analysis (PI: TBD)

www.transpose-amip.info

Transpose-AMIP II description paper :

Williams, K. et al. (2012) : The Transpose-AMIP II experiment and its application to the understanding of Southern Ocean cloud biases in climate models. *J. Climate*, in revision.

- Transpose-AMIP permits detailed evaluation of climate models in a situation in which the large-scale dynamics is well constrainted

- A common bias of too little RSW is mainly associated with cold air side of cyclones/leading side of ridges.

- Cloud being too thin, as well as small cloud fractions, contribute to the bias.

- These situations appear very sensitive with a positive feedback between cloud thickness and BL structure easily developing in the models.

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WCRP Grand Challenges

GC concept (discussed at the JSC in October 2011) :

Identify critical areas of climate science where specific barriers are preventing progress and where targeted research efforts are likely to demonstrate significant progress over the next 5-10 years.

WCRP Grand Challenges :

1. Regional Climate Information (CLIVAR, WGRC, SPARC)

2. Regional Sea-Level Rise (CLIVAR)

3. Cryosphere in a Changing Climate (CLIC)

4. Clouds, Circulation and Climate Sensitivity (JSC 2012 -> WGCM)

5. Changes in Water Availability (GEWEX)

6. Prediction and Attribution of Extreme Events (GEWEX)

White Paper on WCRP Grand Challenge #4

Clouds, Circulation and Climate Sensitivity:

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

Sandrine Bony and Bjorn Stevens[1]

October 1st, 2012

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1 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 Mahowald, Teruyuki Nakajima, Jon Petch, Adam Scaife, Cath Senior, Philip Stier, Kevin Trenberth, Mark Webb and Steve Woolnough also helped sharpen and broaden the articulation of this grand challenge.

Why Clouds?

1. Clouds are largely responsible for the uncertainty in climate and precipitation sensitivity (how much warming and precipitation increase will come for a given increase in CO2)

2. Estimates of regional precipitation change vary widely between climate models to due poor representation of clouds in models

3. Changes in Climate Extremes (tropical cyclones, heat waves) are sensitive to the representation of clouds in models

4. The modeled response of climate to changes of aerosols is highly dependent on the representation of clouds

The Grand Challenge :

Barrier 1 : Inability to constrain the effects of clouds on climate sensitivity estimates

Barrier 2 : Lack of understanding of regional circulation and precipitation changes, especially over land

Barrier 3 : Unreliable representation of the coupling between cloud processes and large-scale dynamics

Opportunities for rapid progress :

- **CMIP5 and other MIPs** (CFMIP, PMIP, Transpose AMIP, GeoMIP, Aerocom..)
- **Qualitatively new types of models** (LES/CRMs over large domains, super-parameterizations)
- **A golden age of Earth observations**
- **Lessons from experience** (physical understanding gained through a spectrum of approaches, often through highly idealized frameworks)
- **An interconnected research community**

Initiatives :

We propose to develop targeted research efforts around 5 initiatives,

... each of them integrating expertise from theory, modelling from a hierarchy of models (conceptual, process, cloud-resolving to large-scale modelling), observations (space, ground-based, reanalyses), and weather prediction.

I1 : Climate and Hydrological Sensitivity

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

Focus : intensify on-going efforts to identify causes of inter-model differences in climate and hydrological sensitivity.

I2 : Leveraging the Past Record

Aim : targeting the exploitation of observations of the recent past, or proxies for changes over the more distant past, to improve understanding and assessment of climate sensitivity and precipitation projections

Focus : analysis of multi-decadal records of satellite and in-situ observations, improvement of paleo-climates reconstructions and syntheses, comparisons of past and future climate changes, facilitation of interactions between modelling and observations communities.

Initiatives :

I3 : Coupling Clouds to Circulations

Aim : tackle the parameterization problem through a better understanding the interaction between cloud/convective processes and large-scale dynamics,

Focus : interaction between diabatic heating and large-scale dynamics, dependence of cloud statistics on resolution, lessons from cloud-resolving modelling over large domains, analysis of new observations.

I4 : Changing Patterns

Aim : better anticipate how the large-scale atmospheric circulation will respond to anthropogenic forcing.

Focus : interactions cloud experts / large-scale dynamicists, CMIP5 analysis, understanding of the role of clouds and aerosols in circulation, understanding of local vs large-scale or remotely forced changes in driving regional changes, impact of model biases. Implications for the physical understanding of decadal climate predictability.

I5 : Towards more Reliable Models

Aim : improve models and understand how errors or shortcomings impact projections and predictions

Focus : indentification and reduction of errors in the representation of cloud and radiative processes, assessment of how model errors or shortcomings (physics, resolution) translate into climate errors, including climate projections and predictions. Ex : double-ITCZ problem + a few others TBD

Strategy of coordination and integration :

- **GC led by WGCM, in close collaboration with GEWEX/GASS, WGNE and SPARC.**

- **GC Joint Steering Committee to strengthen the coordination and integration**

of the different initiatives, including representatives of the key groups involved
and incorporating key expertise (climate, paleo, observations, processes, CRM, NWP..)
First goal will be to associate each initiative with a clear goal and a person to lead it.

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

Will make sure that workshops associated with these activities address the GC's goals.

- **Interaction with WMAC and WDAC**

- **First step will be to organize small-scale workshops to sharpen each initiative**,
and then present the GC to the community through an article in high profile journals.

Questions to WGNE :

- **Your feedback ?** (science, coordination)

- **Several initiatives strongly connected to GEWEX/GASS (and thus WGNE)**
  (e.g. cloud feedback processes, coupling clouds/circulation)

Last initiative (#5) focused on :

- Understanding how model errors or shortcomings impact projections and predictions
- Improving models

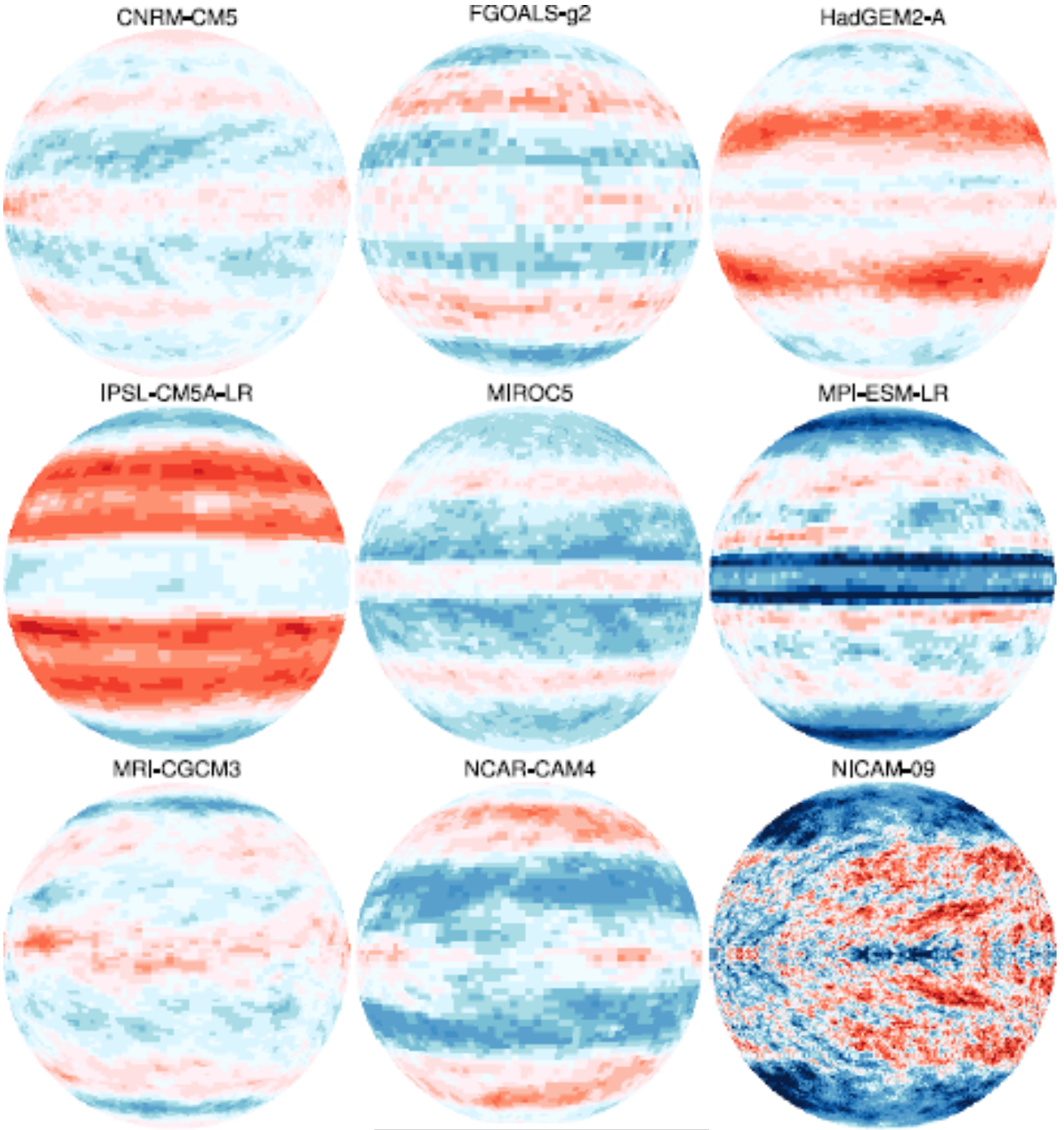
Can you help identify longstanding « model errors» that this GC should tackle in priority ?

- which are presumably related to cloud processes
- which matter both for climate, NWP and intraseasonal to decadal prediction
- for which there are opportunities and momentum

-> WCRP/WWRP survey on model evaluation and development to be exploited
-> plan some discussion at the WGNE workshop on systematic errors ?

Thank You - Questions ?

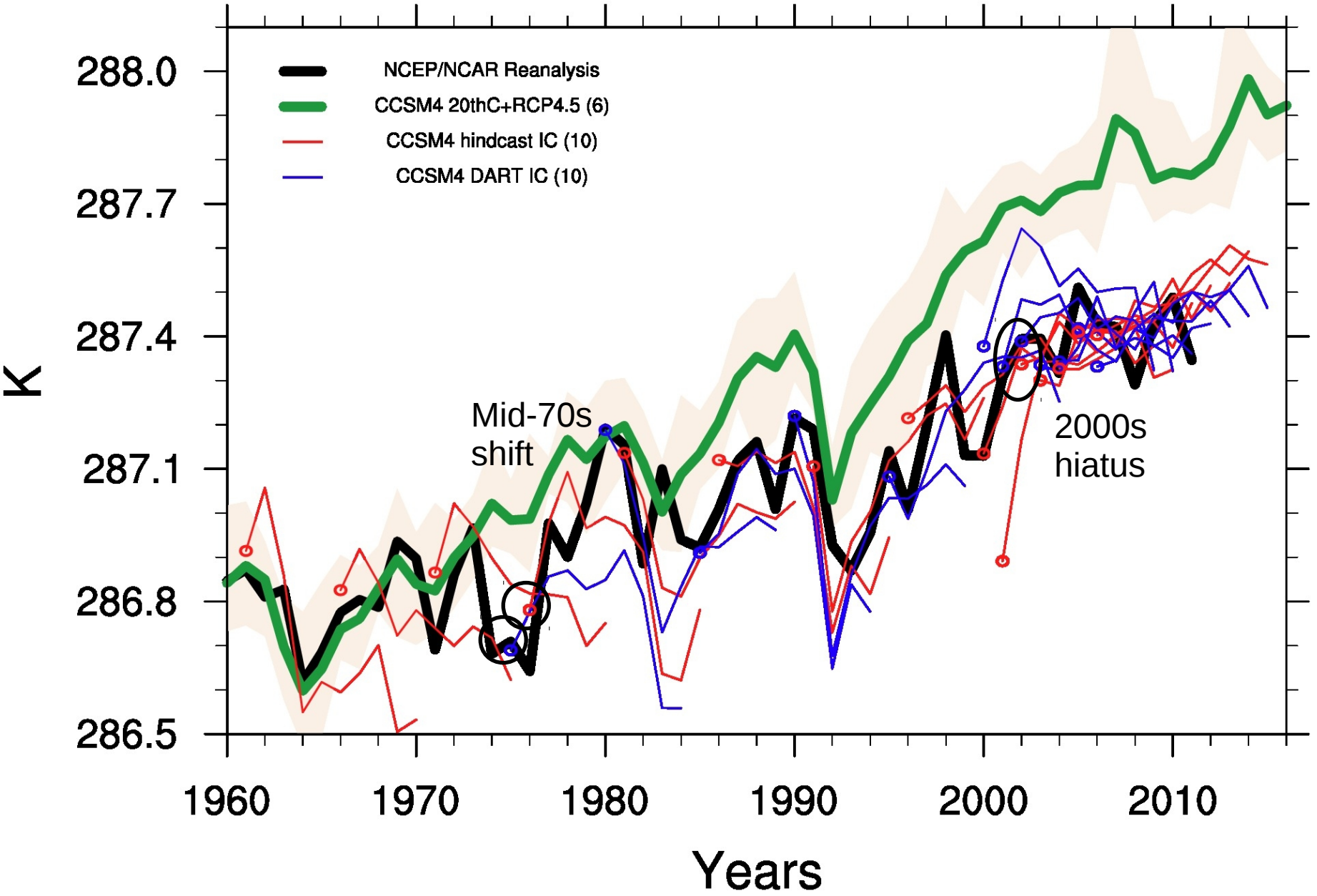
Aqua-Planets



NICAM (9 km)

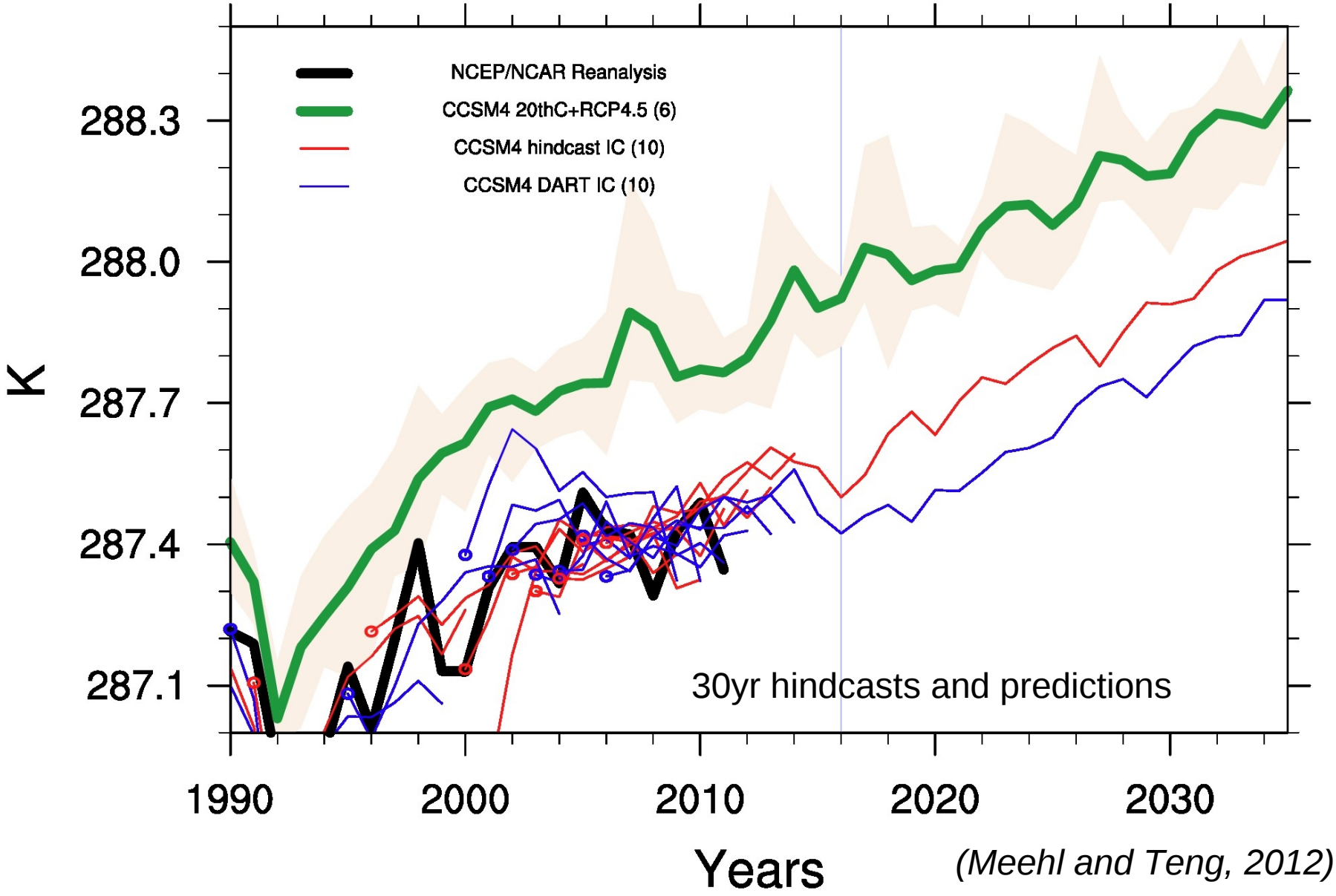
Courtesy Brian Medeiros

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)

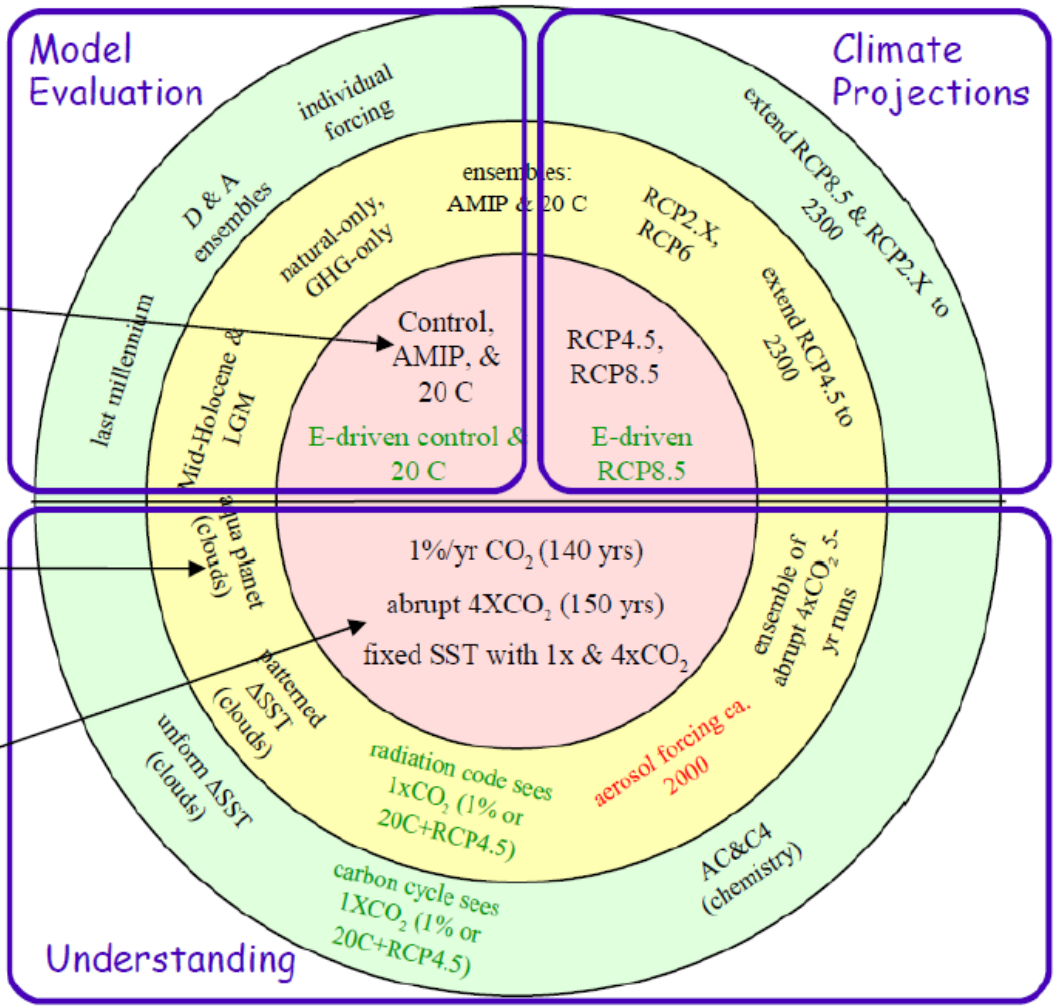
30 year bias-adjusted predictions using two initialization methods
(red and blue lines are ten member ensemble averages)

CFMIP in CMIP5

satellite evaluations & process diagnostics

aqua-planet & idealized expts

climate sensitivity & radiative forcing



CFMIP-Obs website :

ISCCP and CERES observations

A-Train observations consistent with COSP simulator outputs (e.g. Calipso, CloudSat, Parasol)

CLIMSERV

SERVICE DE DONNÉES ET DE CALCUL DE L'IPSL

Link available from www.cfmip.net

Institut Pierre Simon Laplace

CFMIP Observations

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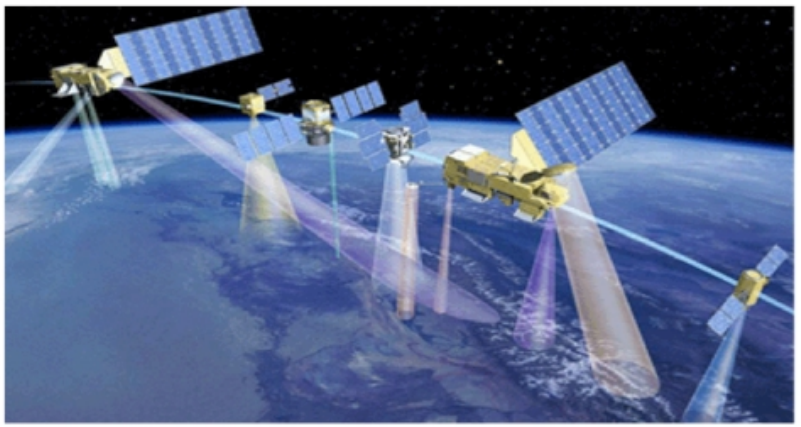
Observations for COSP, the CFMIP Observations Simulator Package

The Cloud Feedback Model Intercomparison Program has designed a protocol to evaluate clouds in climate and weather prediction models based on satellite observations (http://cfmip.metoffice.com/CFMIP2_experiments_March20th2009.pdf)

Index de l'article

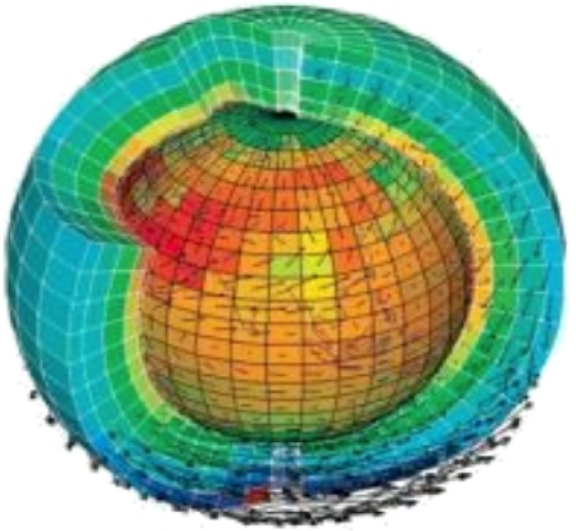
A-train :

CALIPSO/ CLOUDSAT / CERES / PARASOL



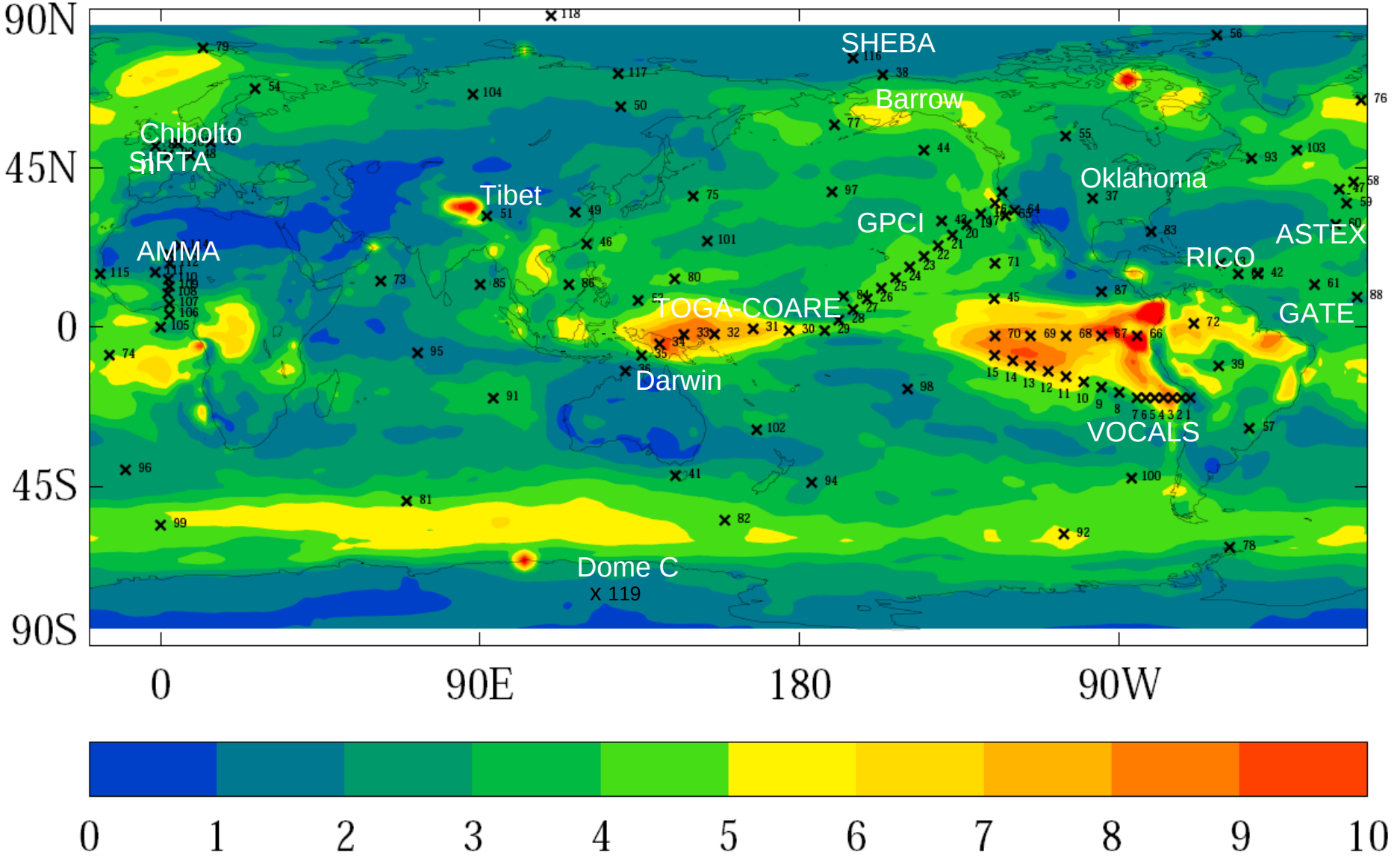
+ ISCCP + MISR

Climate Models



Part of the observations to be distributed to support the evaluation of CMIP5 simulations

CFMIP/GCSS/CMIP5 model outputs at selected locations
(119 locations, high-frequency, detailed cloud diagnostics)



- ARM, CEOP, CloudNet instrumented sites
- GPCI / Tropical West & South East Pacific / AMMA transects
- Field experiments / GCSS case studies
- Locations of large inter-model spread of cloud feedbacks (CMIP3)

"Long-term" experiments: output available, as of (March 3 and) Sept. 22, 2012

Experiment(s)	# of models
* Control & historical	(29) 48
* AMIP	(18) 28
* RCP4.5 & 8.5	(24) 40
RCP2.6	(21) 29
RCP6	(15) 22
RCP's to year 2300	?
* 1% CO2 increase	(21) 32
* Fixed SST CO2 forcing diagnosis	(10) 12
* Abrupt 4XCO2 diagnostic	(20) 30

Experiment(s)	# of models
Fast adjustment diagnostic	?
Aerosol forcing	(6) 9
*ESM cntrl, hist. & RCP8.5	(8) 13
Carbon cycle feedback isolation	(7) 10
Mid-Holocene	(11) 13
LGM	(4) 7
Millenium	(6) 7
CFMIP runs	(6) 10
D & A runs	(16) 17

* *Core simulations*

"Decadal" experiments: Output available, as of (March 3 and) Sept. 22, 2012

** Core simulations simulations*

Experiment(s)	Number of models
*Hindcasts and predictions	(14) 18
AMIP	(7) ?
Volcano-free hindcasts	(1) 2
2010 "Pinatubo-like" eruption	(1) 3
Initialization alternatives	?
Pre-industrial control	(12) ?
1% CO2 increase	(7) ?