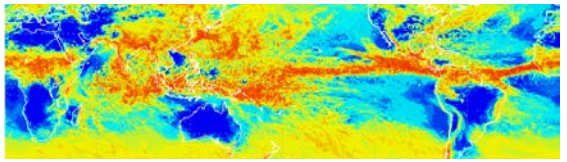
Cloud Feedback Model Inter-comparison Project Phase-2 (www.cfmip.net)

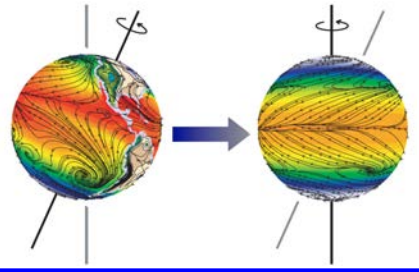
Co-Chairs :
Sandrine Bony & Mark Webb

Coordination Committee:
Chris Bretherton, Steve Klein, George Tselioudis,
Pier Siebesma & Minghua Zhang

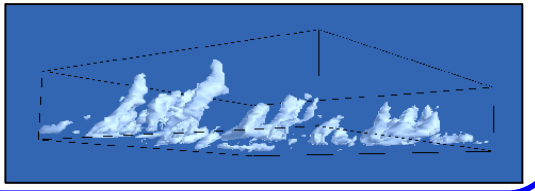
Cloud Feedback Model Inter-comparison Project Phase-2
CFMIP-2 (www.cfmip.net)

GCM analysis through a hierarchy of models

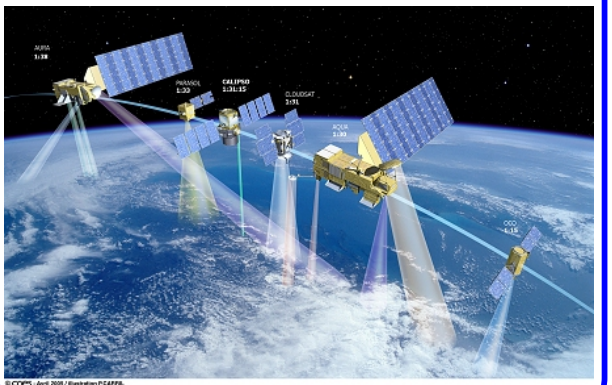




Process studies (in-situ obs, LES/CRMs)

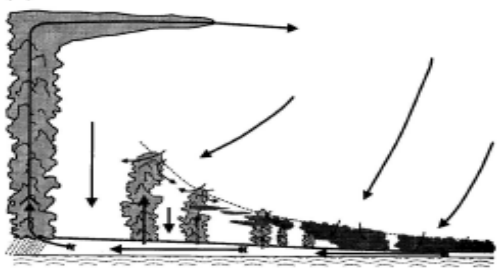


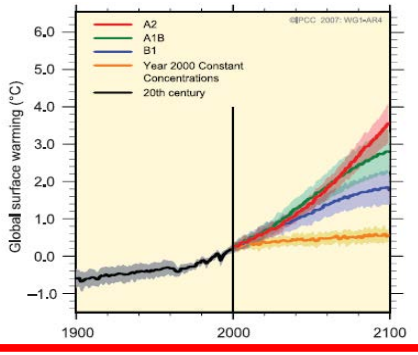
Satellite observations & simulators (COSP)



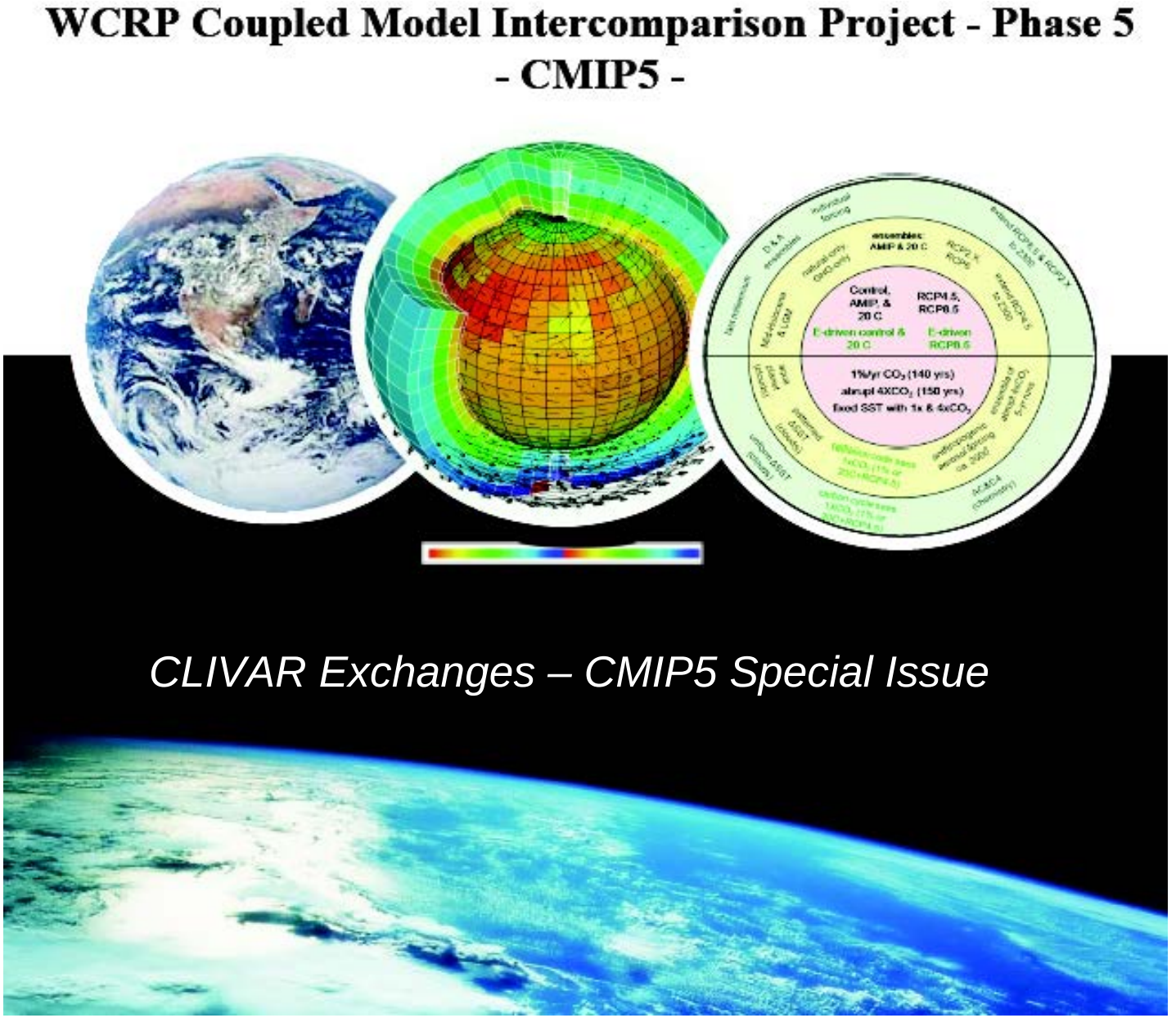
Understanding ⋯⋯▸ **Evaluation**

Assessment of cloud-climate feedbacks





CFMIP activities now closely coupled to CMIP5

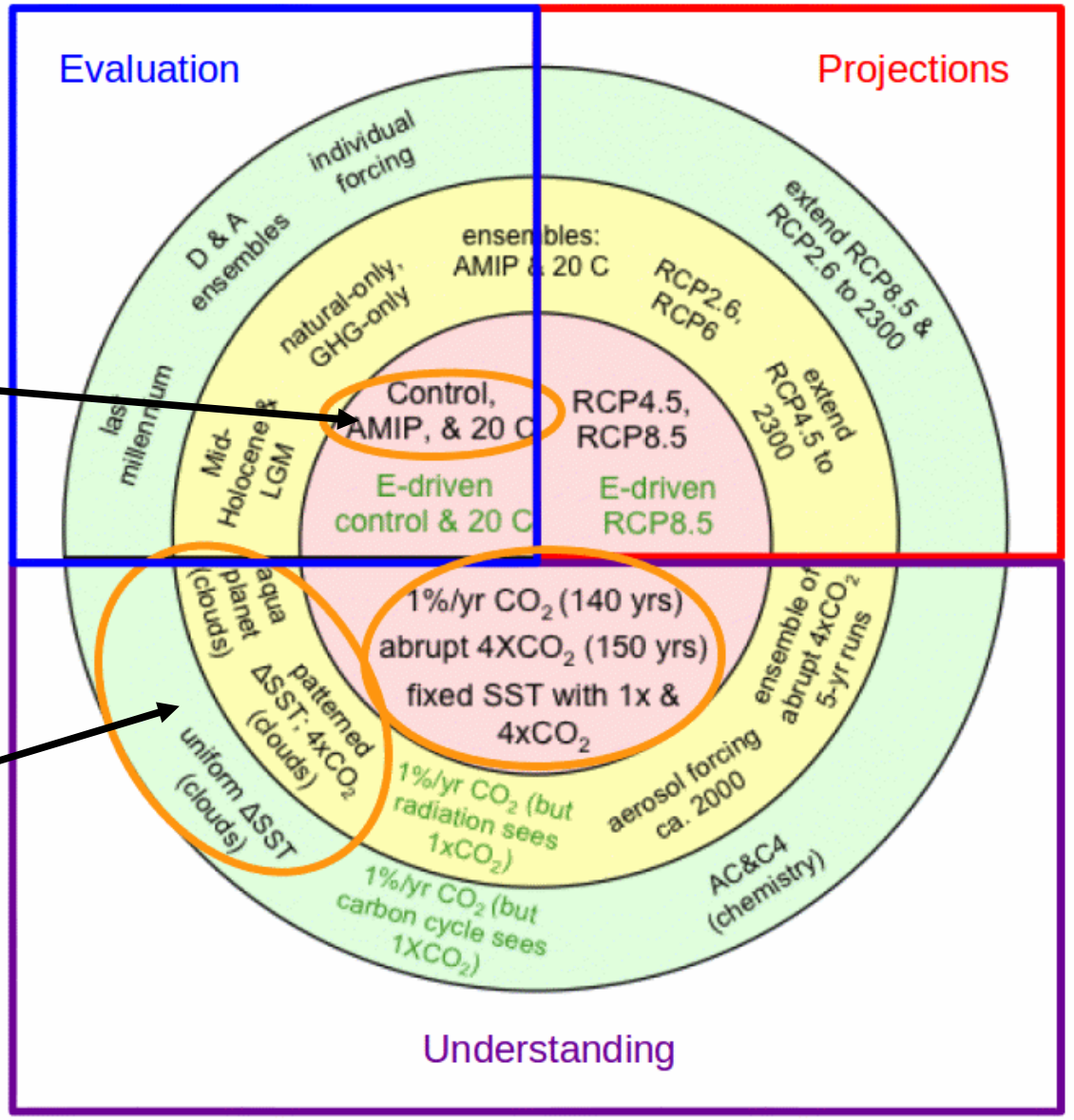


Bony, Webb et al., 2011: CFMIP: Towards a better evaluation and understanding of clouds and cloud feedbacks in CMIP5 models

CMIP5 “long-term” set of experiments

COSP outputs, process and radiative diagnostics, cfSites outputs

Idealized experiments (amip4xCO2, amipFuture, amip4K, aquaControl, aqua4xCO2, aqua4K)



Nb of models: CORE: 15-27, Tier1,2: 7-15
Mean Resolution: 2.1 deg (atm) ; 0.9 deg (ocean)

What's new since last year ?

Joint CFMIP / GCSS / EUCLIPSE meeting, Exeter, June 2011
(more than 100 participants)

-> COSP simulator useful for model development and evaluation

-> CFMIP/CMIP5 experiments (done or on-going) useful to understand cloud feedbacks (in individual models at least.. multi-model analyses are just starting)

-> CFMIP-GCSS collaboration works well

Plus :

- efforts to improve COSP management & development

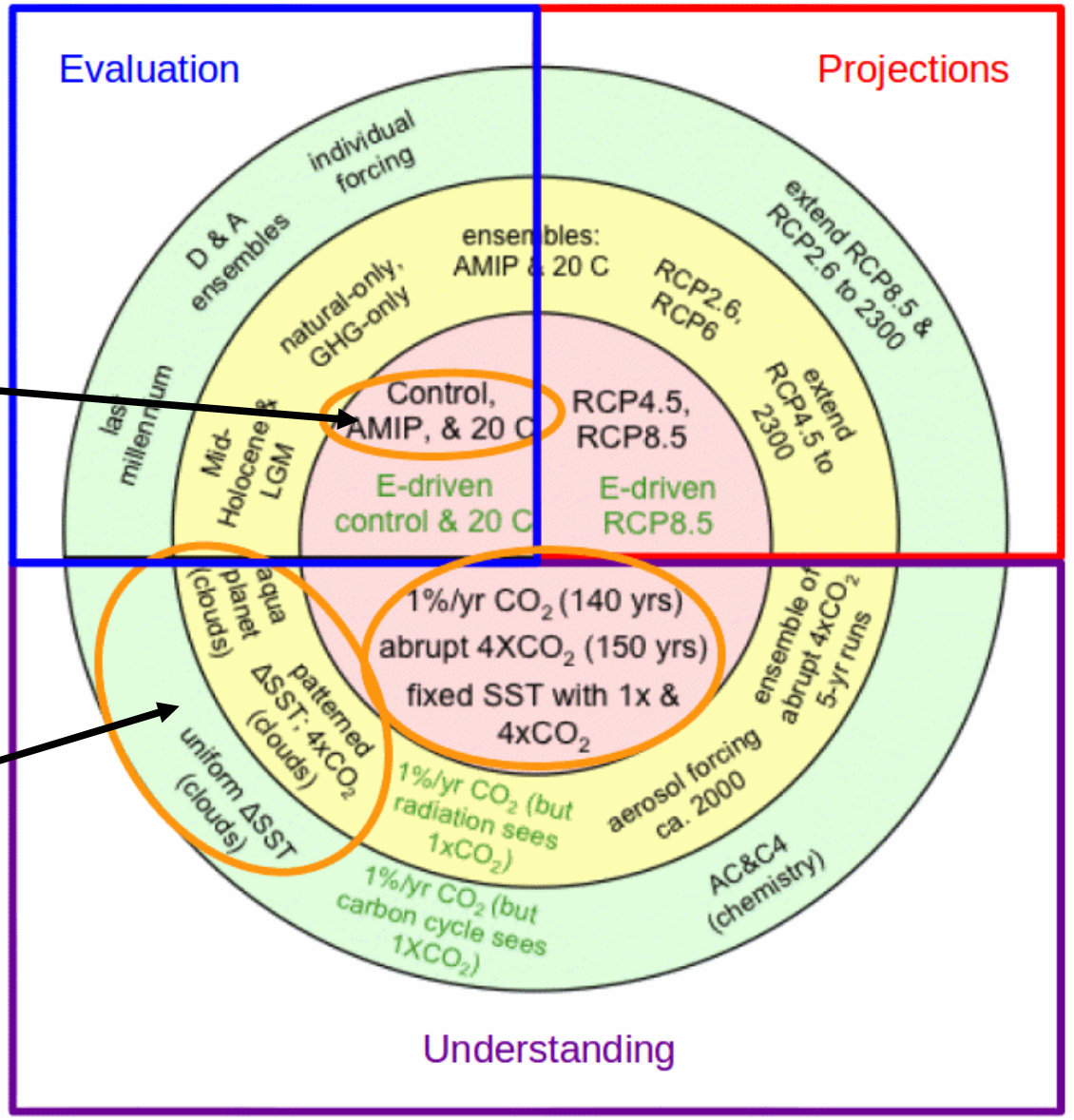
- efforts to collect and facilitate the access to observations useful to evaluate CMIP5 model outputs related to clouds (satellite data, ground-based data)

- **first analyses of CFMIP/CMIP5 outputs and experiments !**

CMIP5 “long-term” set of experiments

COSP outputs, process and radiative diagnostics, cfSites outputs

Idealized experiments (amip4xCO2, amipFuture, amip4K, aquaControl, aqua4xCO2, aqua4K)



Nb of models: CORE: 15-27, Tier1,2: 7-15
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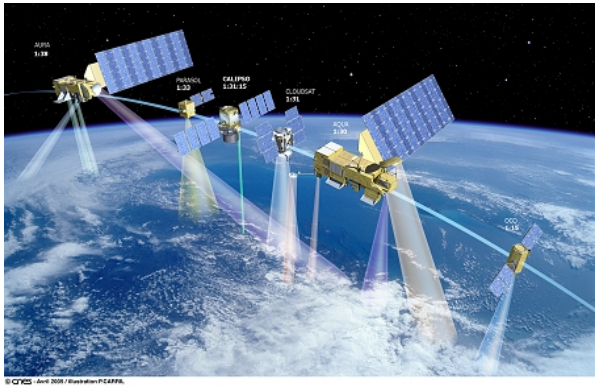
COSP : CFMIP Observations Simulator Package
(Bodas-Salcedo et al., BAMS, 2011)

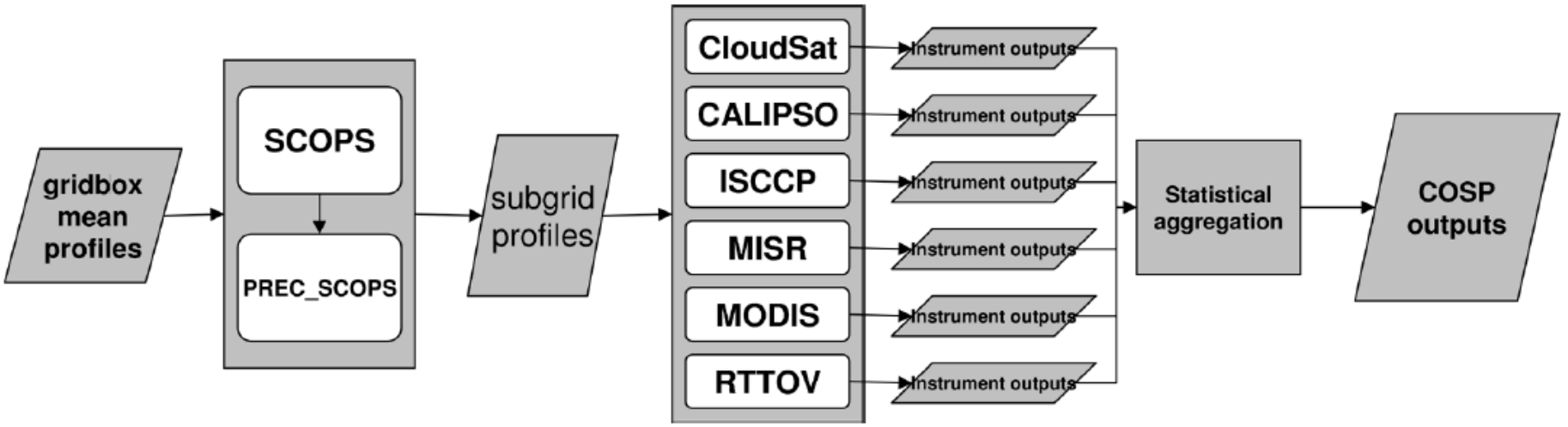


COSP

Satellite simulation software for model assessment

BY A. BODAS-SALCEDO, M. J. WEBB, S. BONY, H. CHEPFER, J.-L. DUFRESNE, S. A. KLEIN, Y. ZHANG, R. MARCHAND, J. M. HAYNES, R. PINCUS, AND V. O. JOHN

COSP is a multi-instrument simulator that enables quantitative evaluation of clouds, humidity, and precipitation processes in numerical models with observational satellite products by making consistent assumptions.



COSP

The CFMIP Observations Simulator Package

- Bodas-Salcedo A, M J Webb, S Bony, H Chepfer, J-L Dufresne, S A Klein, Y Zhang, R Marchand, J M Haynes, R Pincus, and V O John, BAMS, 2011 : ***COSP: Satellite simulation software for model assessment***

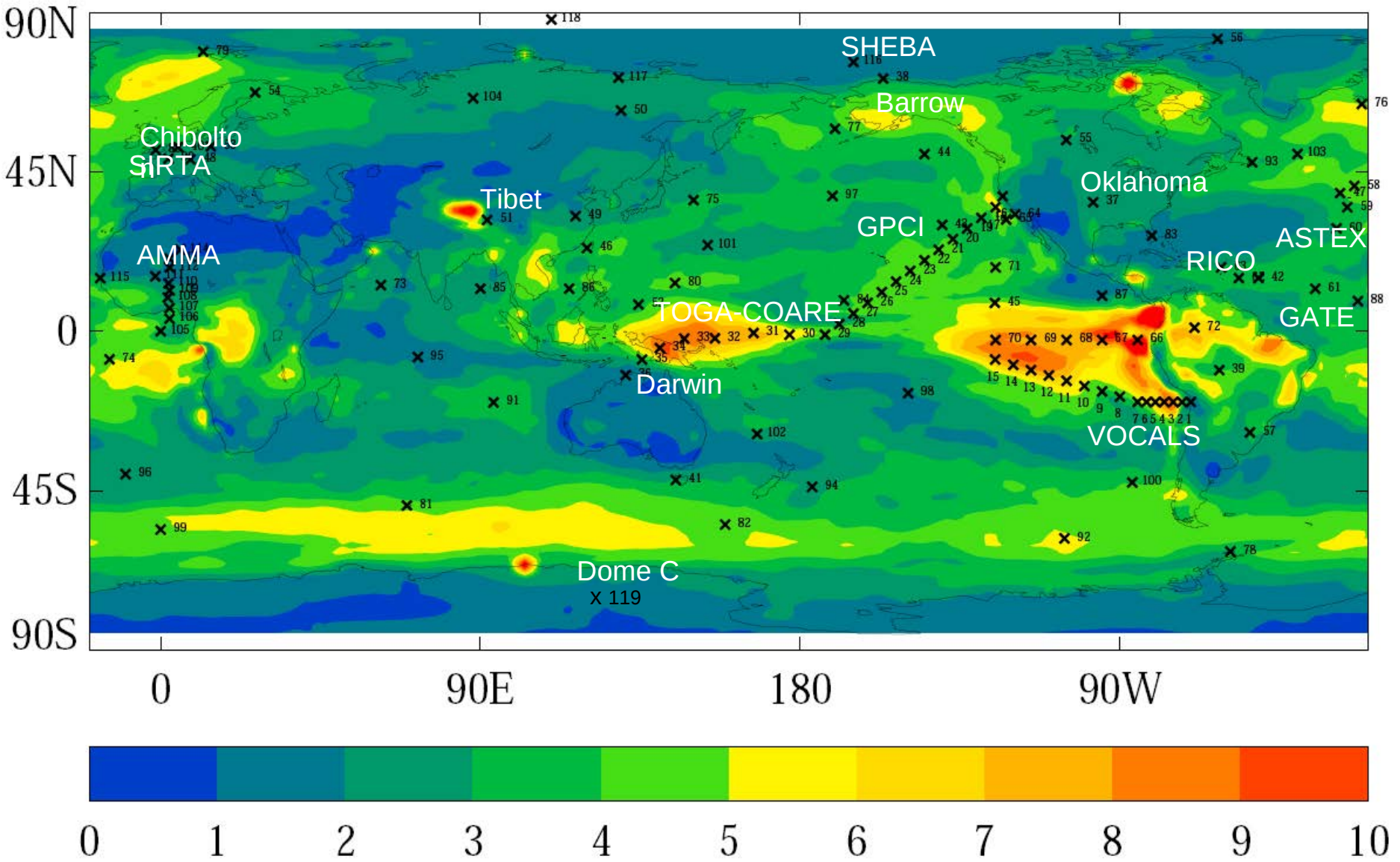
- Used in many CMIP5 models + some NWP and CRM models

- **Recent changes to COSP governance :**

  - Formal governance (meritocratic) model,
    with a Project Management Committee (PMC)
    co-chaired by Alejandro Bodas-Salcedo and Steve Klein

  - First activities undertaken by the COSP PMC:
    * Code moved to a SVN repository in Google code:
      http://code.google.com/p/cfmip-obs-sim/
    * User survey => discussion of future COSP developments:
      - new capabilities (e.g. new modules, new diagnostics)
      - software improvements (e.g. speed, documentation)

CFMIP/GCSS/CMIP5 model outputs at selected locations
(120 locations, high-frequency (half-hourly), 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)

CFMIP Observations for Model Evaluation

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

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CFMIP Observations for Model evaluation

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CFMIP Observations for Model evaluation

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)

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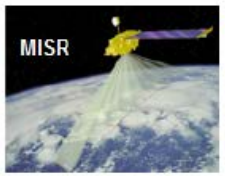
Satellite Observations



ISCCP

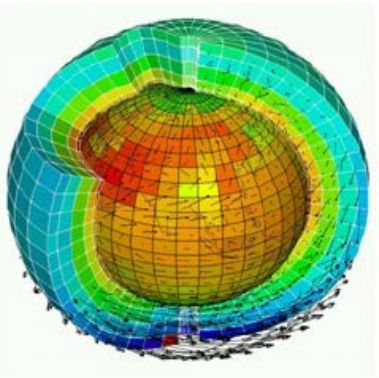
Ground-based Observations

ARM
CLIMATE RESEARCH FACILITY

Cloudnet

SIRTA
Site Instrumental de Recherche par Télédétection Atmosphérique

Climate Models



Thanks to all contributors !

A Subset of CFMIP-obs data is meant to be made available on the ESG as part of the "Obs for MIPs" initiative

CFMIP Observations for Model evaluation

ARM Climate Modeling Best Estimate

Description :

The Atmospheric Radiation Measurement (ARM) Climate Modeling Best Estimate (**CMBE**) [Xie, McCoy, Klein et al.] product is an ARM dati modelers for use in evaluation of global climate models. It contains a best estimate of several selected cloud, radiation and atmospheric

The data are stored in two different data file streams: **CMBE-CLDRAD** for cloud and radiation relevant quantities and **CMBE-ATM** for atmos one hour time intervals. Quick look plots and details can be found at http://science.arm.gov/wg/cpm/scm/best_estimate.html. See also ht

The data are available for the 5 ARM Climate Research Facility sites: **SGP.C1** (Lamont, OK), **NSA.C1** (Barrow, AK), **TWP.C1** (Manus Island (Darwin, AU) for the period when these data are available.

1. The **CMBE-CLDRAD** data file contains a best estimate of several selected cloud and radiation relevant quantities from ACRF observatic

- Cloud fraction profiles
- Total, high, middle, and low clouds
- Liquid water path and precipitable water vapor
- Surface radiative fluxes
- TOA radiative fluxes

2. The **CMBE-ATM** data file contains a best estimate of several selected atmospheric quantities from ACRF observations and NWP analy

- Soundings
- Surface sensible and latent heat fluxes
- Surface precipitation
- Surface temperature, relative humidity, and horizontal winds
- NWP analysis data

Reference : Xie, S., R.B. McCoy, S.A. Klein, R.T. Cederwall, W.J. Wiscombe, E.E. Clothiaux, K.L. Gaustad, J.C. Golaz, S.D. Hall, M.P. Jens McFarlane, G. Palanisamy, Y. Shi, and D.D. Turner, 2010: CLOUDS AND MORE: ARM Climate Modeling Best Estimate Data. *Bull. Amer. M*

Ground-based data from ARM stations (Atmospheric Radiation Measurement Programm)

- ARM Climate Modeling Best Estimate data

- ARM data tailored to climate modelers for evaluating global climate models

- selection of cloud, radiation and atmospheric quantities from ARM observations

- hourly data

- 5 ARM Climate Research Facility sites : SGP (OK), Barrow (AK), Manus Island (PNG), Nauru, Darwin (AU)

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EUROPEAN Ground

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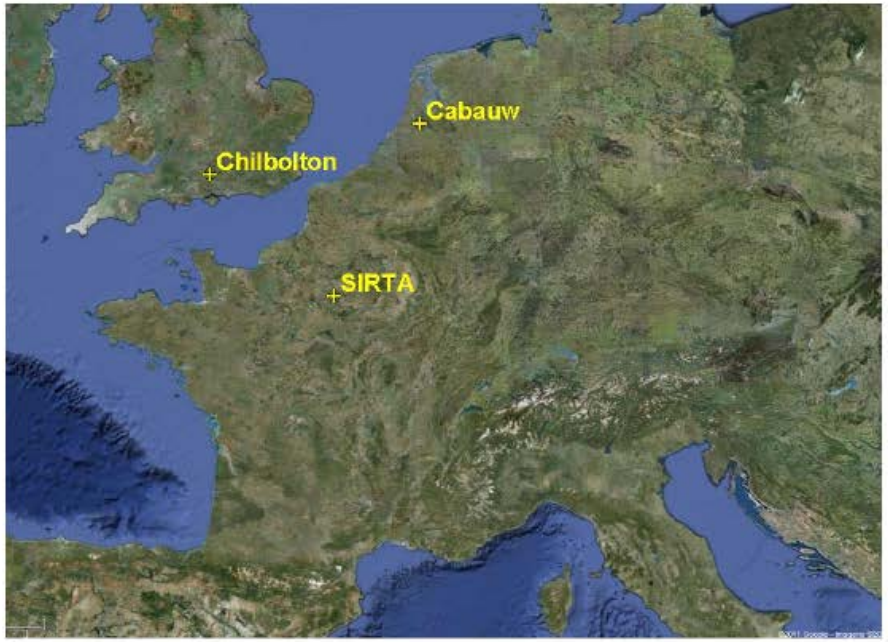
- ARM Ground
- CALIPSO-GOCCP sat
- CERES Sat
- EUROPEAN Ground
- CLOUDSAT Sat
- ISCCP Sat
- MISR Sat
- MODIS Sat
- MULTI-SENSORS Analysis Sat
- MULTI-SENSORS Sat
- PARASOL Sat
- References

CLIMATE TESTBED DATASETS FROM EUROPEAN RESEARCH OBSERVATORIES



The observation of the atmosphere based on passive/active remote-sensing and *in situ* measurements are mature to be exploited for the evaluation of models. Since many years, the ground-based atmospheric observatory such as the SIRTA (Site Instrumenté de Recherche par Télédétection Atmosphérique), Cabauw, and Chilbolton (all part of CLOUDNET) have been collecting many collocalized observations which can be used in order to analyse the interannual variability of the atmospheric column and to evaluate the parameterization included in models (objectives of the European project EUCLIPSE).

To make these data easily usable, important work has been implemented on their homogenization. All variables, their description, their quality flags, their spatiotemporal error-bars are written in a single file (NetCDF). Similar algorithms are applied to the three sites. Four files are produced: one by site (i.e. 3 files) for the EUCLIPSE time-period (January 2008 to April 2010) and variables required by CMIP-5, and one more file for the SIRTA with additional variables and a longer time-period (2002 to 2010, SCTD file).

Contributors: IPSL (LMD, LATMOS), KNMI, University of Reading

Project supported by: EUCLIPSE European project, Ecole Polytechnique

Contact:

- *Main contact:* M. Chiriaco (marjolaine.chiriaco@latmos.ipsl.fr)
- *Specific contact for SIRTA:* M. Haeffelin (martial.haeffelin@lmd.polytechnique.fr) and J.-C. Dupont (jean-charles.dupont@lmd.polytechnique.fr)
- *Specific contact for Cabauw:* P. Siebesma (Siebesma@knmi.nl) and H. Klein Baltink (baltink@knmi.nl)
- *Specific contact for Chilbolton:* E. O'Connor (e.j.oconnor@reading.ac.uk)
- *Technical contact:* Ludmila Kleno v (ludmila.klenov@lmd.polytechnique.fr)

Ground-based data from European CloudNet stations (Cabauw, Chilbolton, SIRTA)

- meteorological variables

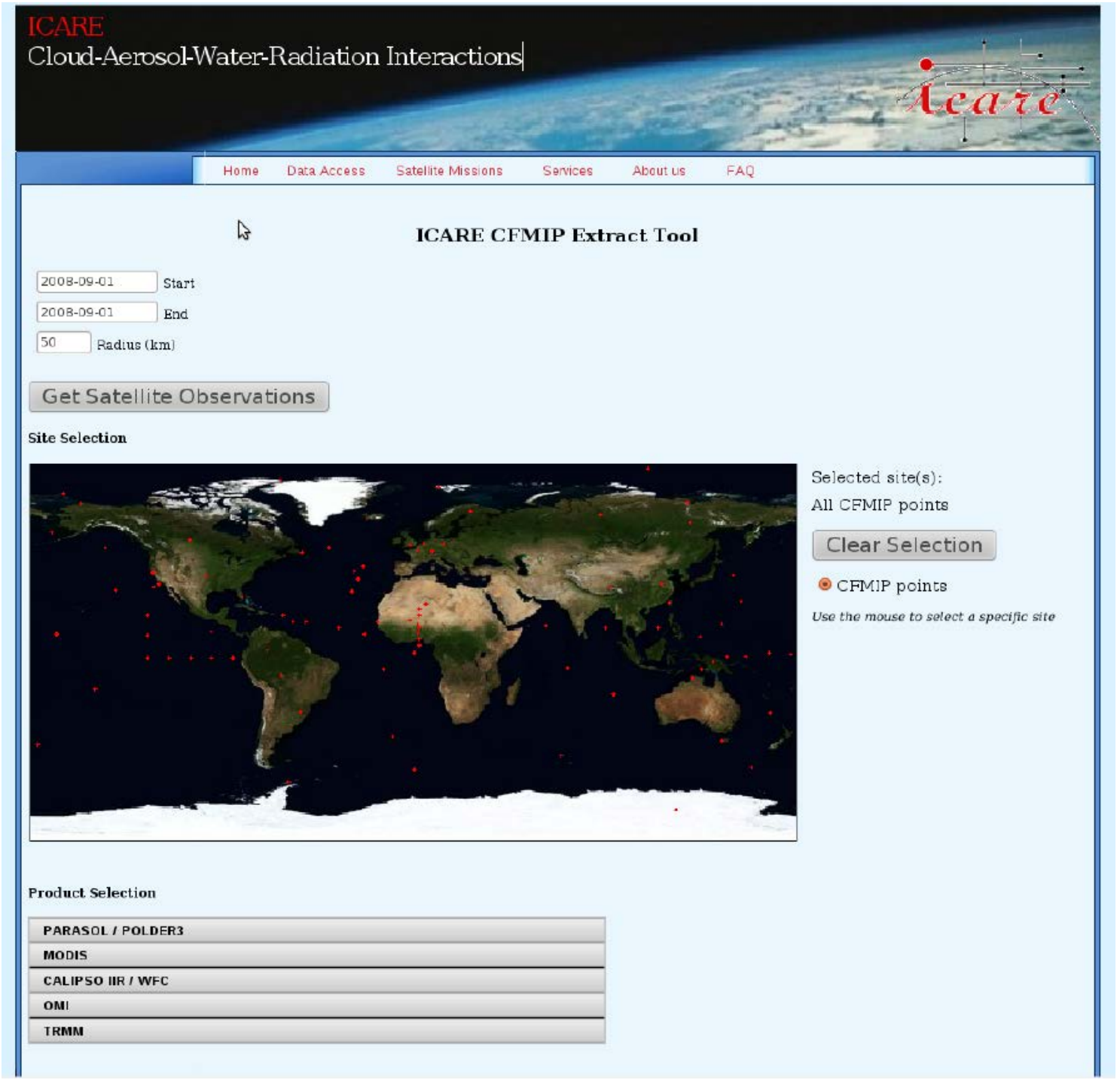
- clouds and radiation
(using the same cloud retrieval algorithm for all sites)

- hourly data

- CMIP5 variable names + CMOR format

- freely available on CFMIP-obs website
  + ESG in the future

EUCLIPSE



In preparation :

Extraction of multiple satellite observations + 3-hrly ERA-interim data over CFMIP stations

- instantaneous, full resolution over a domain of 1deg x 1deg centered around each station

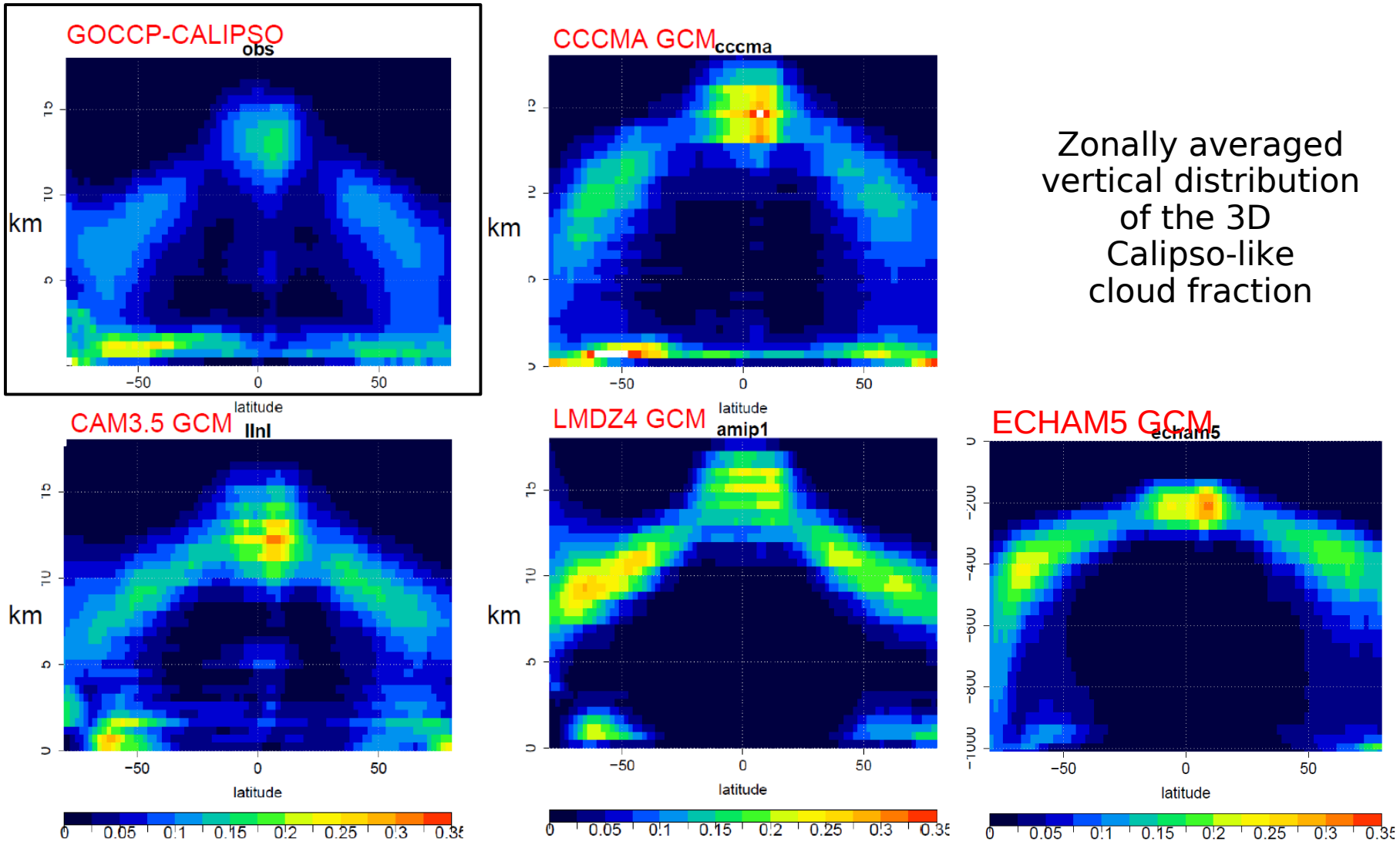
- to complete model evaluations using data from instrumented sites, field campaigns and COSP outputs

- netcdf, CMIP5 format (as much as possible)

- initial focus :
years 2008 & 2009
(coincident with T-AMIP and 3-hourly CMIP5/CFMIP outputs)

Courtesy ICARE (french data center CNES/Univ Lille/INSU)

Preliminary comparison of COSP model outputs with CALIPSO observations



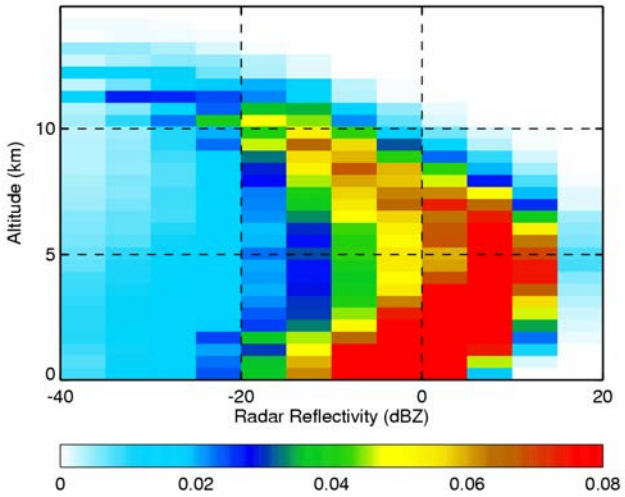
Zonally averaged vertical distribution of the 3D Calipso-like cloud fraction

Analysis of CMIP5 models : just starting...

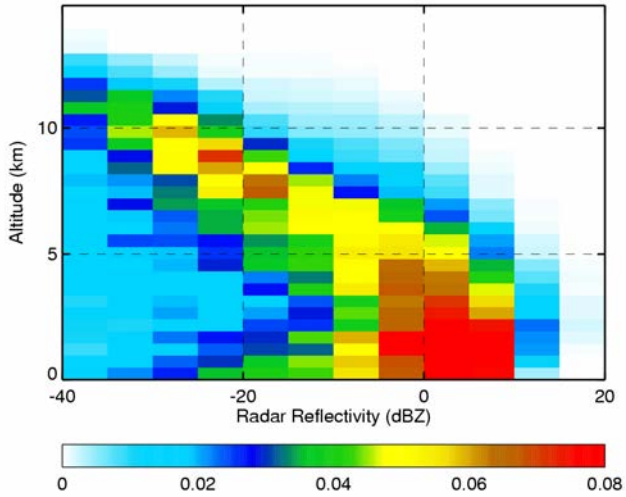
LMD/IPSL

Preliminary comparison of COSP model outputs with CloudSat observations
(height - radar reflectivity histograms over North Pacific)

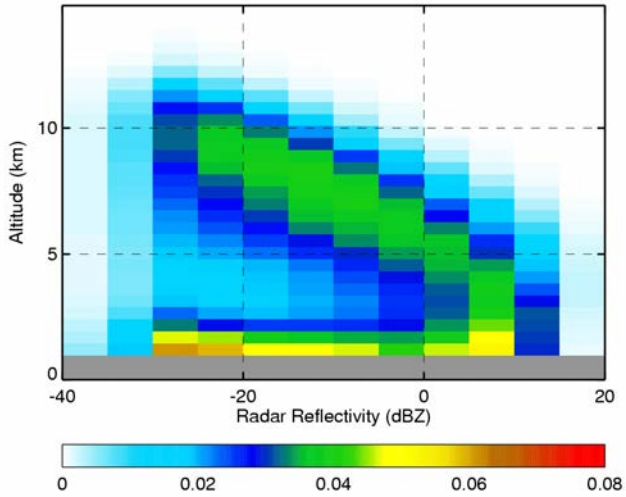
HadGEM1



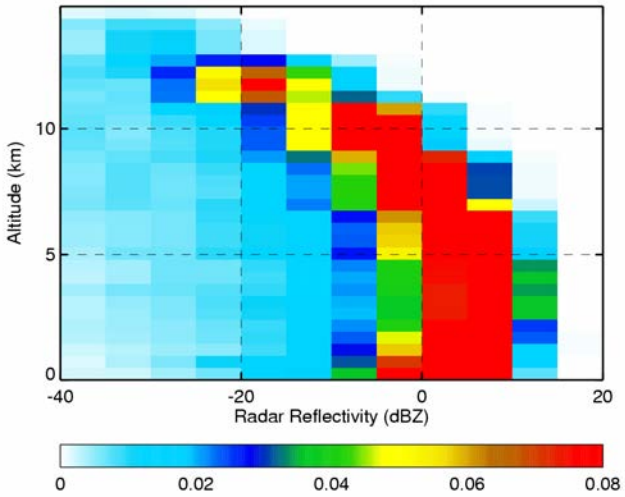
MMF 4km



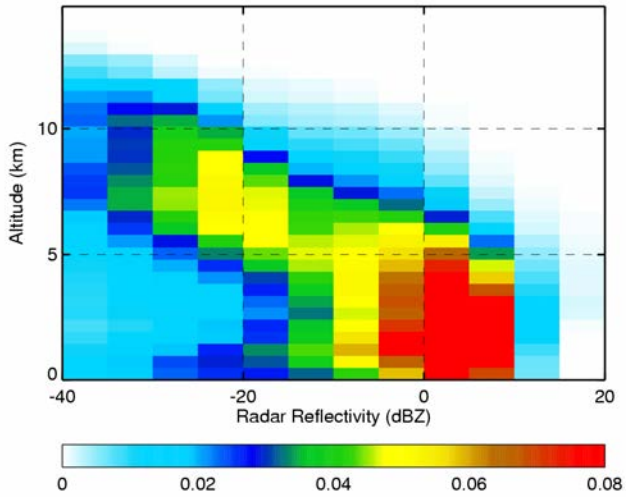
CloudSat observations



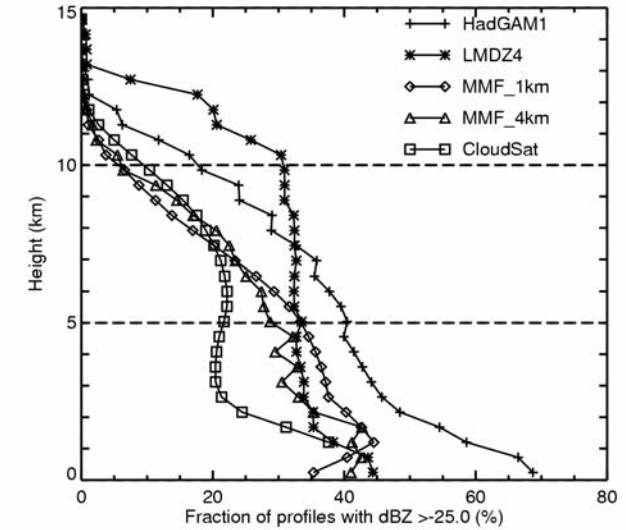
LMDZ



MMF 1km



dBZ>-25

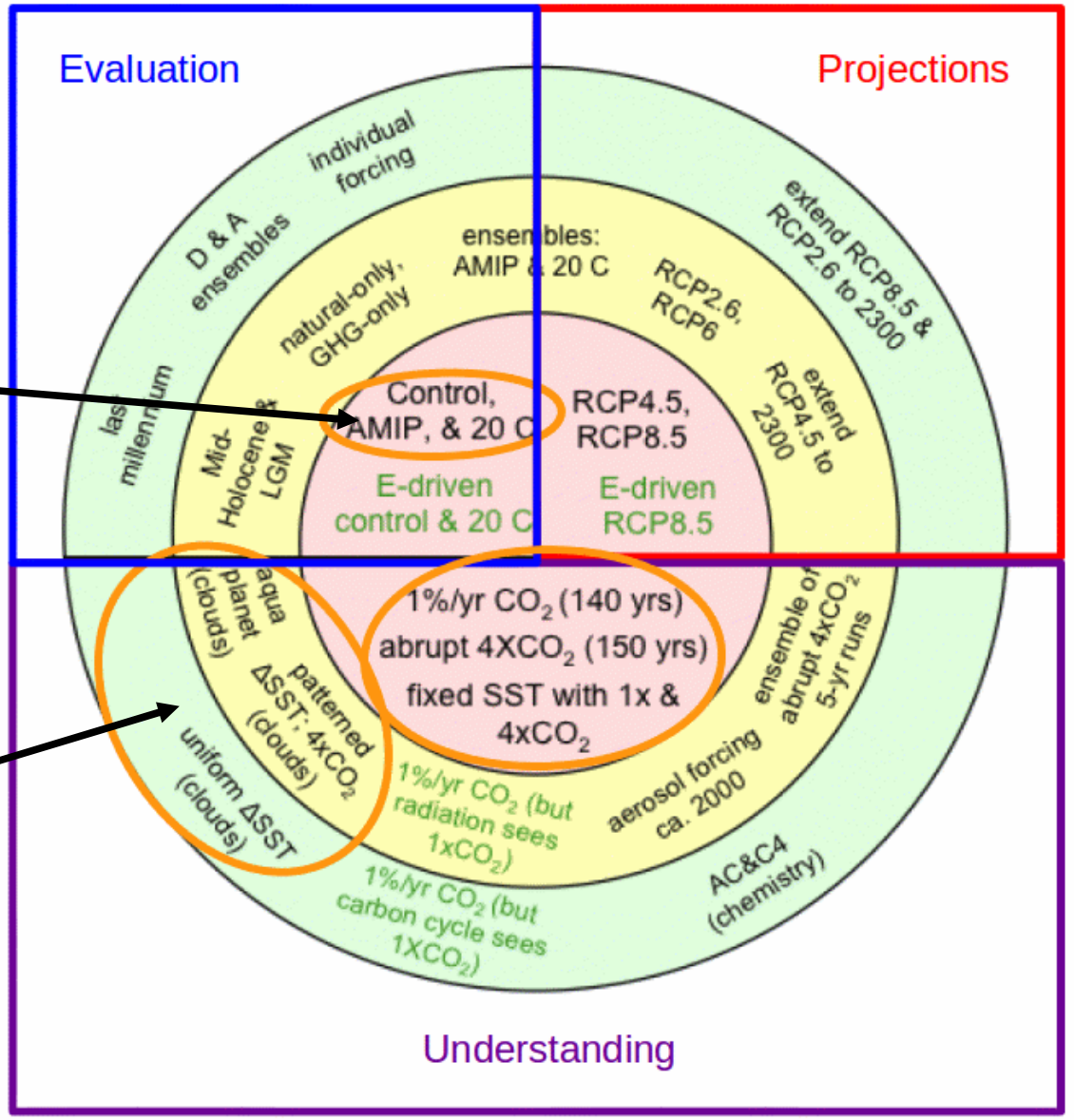


Bodas-Salcedo et al. (BAMS, 2011)

CMIP5 “long-term” set of experiments

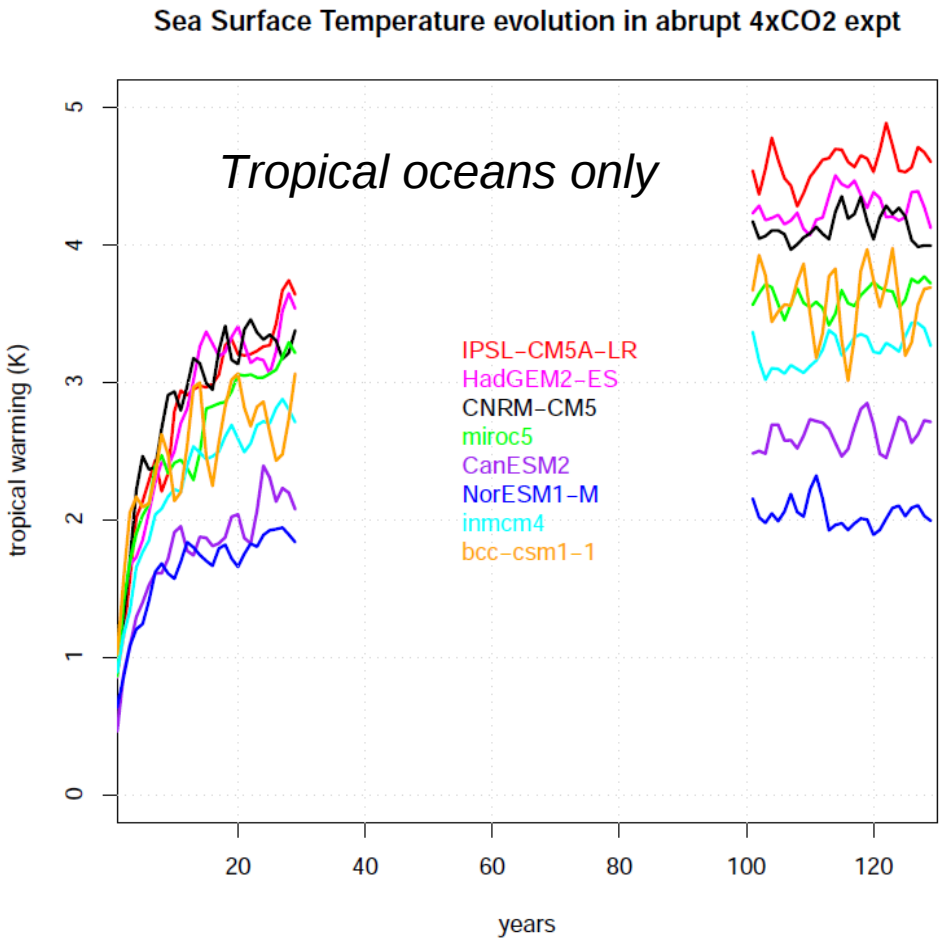
COSP outputs, process and radiative diagnostics, cfSites outputs

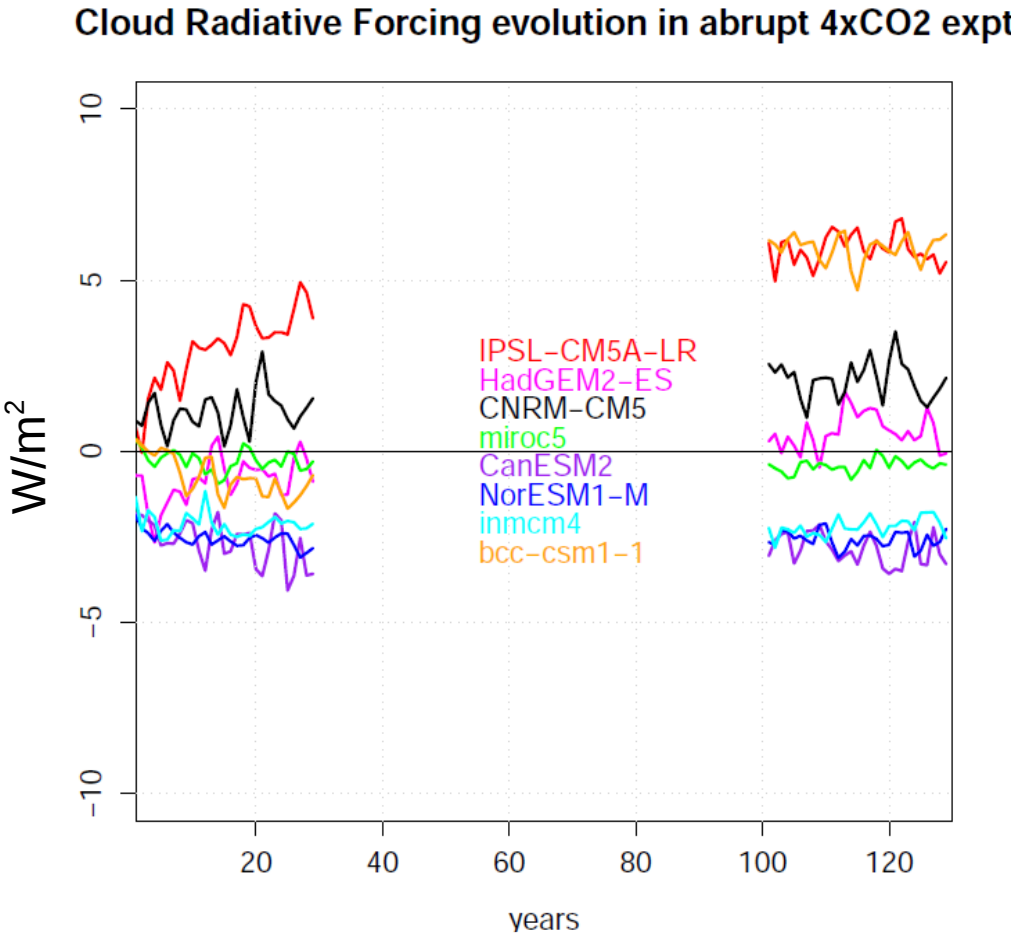
Idealized experiments (amip4xCO2, amipFuture, amip4K, aquaControl, aqua4xCO2, aqua4K)



Nb of models: CORE: 15-27, Tier1,2: 7-15
Mean Resolution: 2.1 deg (atm) ; 0.9 deg (ocean)

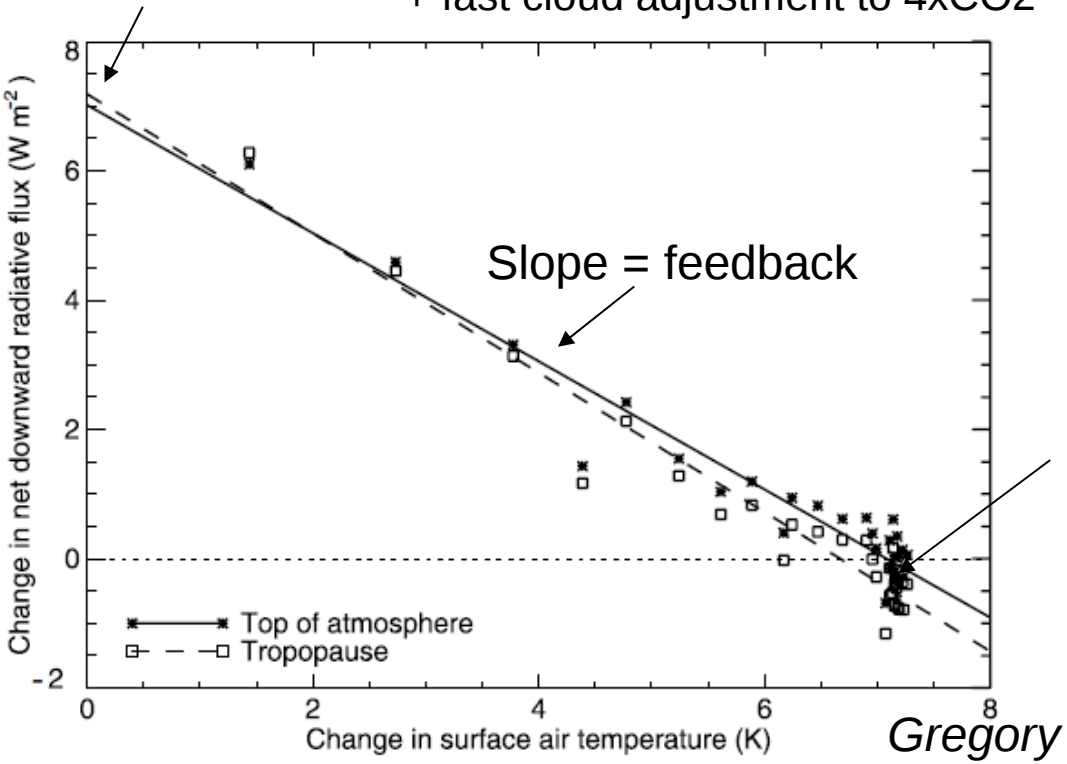
CMIP5


Sea Surface Temperature evolution in abrupt 4xCO2 expt
Tropical oceans only
tropical warming (K)
years
IPSL-CM5A-LR
HadGEM2-ES
CNRM-CM5
miroc5
CanESM2
NorESM1-M
inmcm4
bcc-csm1-1


Cloud Radiative Forcing evolution in abrupt 4xCO2 expt
W/m2
years
IPSL-CM5A-LR
HadGEM2-ES
CNRM-CM5
miroc5
CanESM2
NorESM1-M
inmcm4
bcc-csm1-1

Radiative Forcing, Feedback and Climate Sensitivity estimated from abrupt 4 x CO2 experiments using a regression method

Intercept = Forcing (x2) ; depends on CO2 radiative forcing
+ fast cloud adjustment to 4xCO2



Slope = feedback

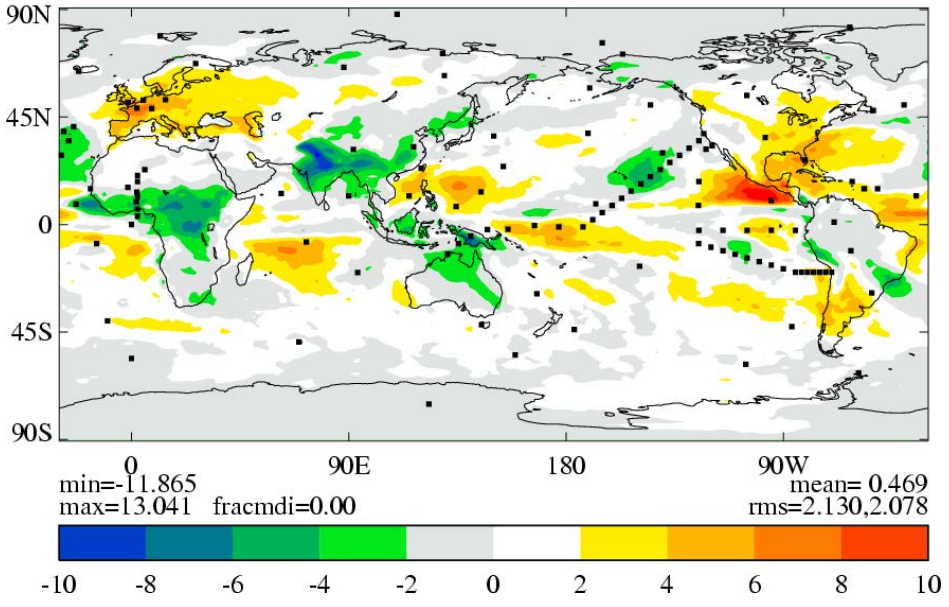
Climate sensitivity (x2)
(warming at N = 0)

Gregory et al. (2004)

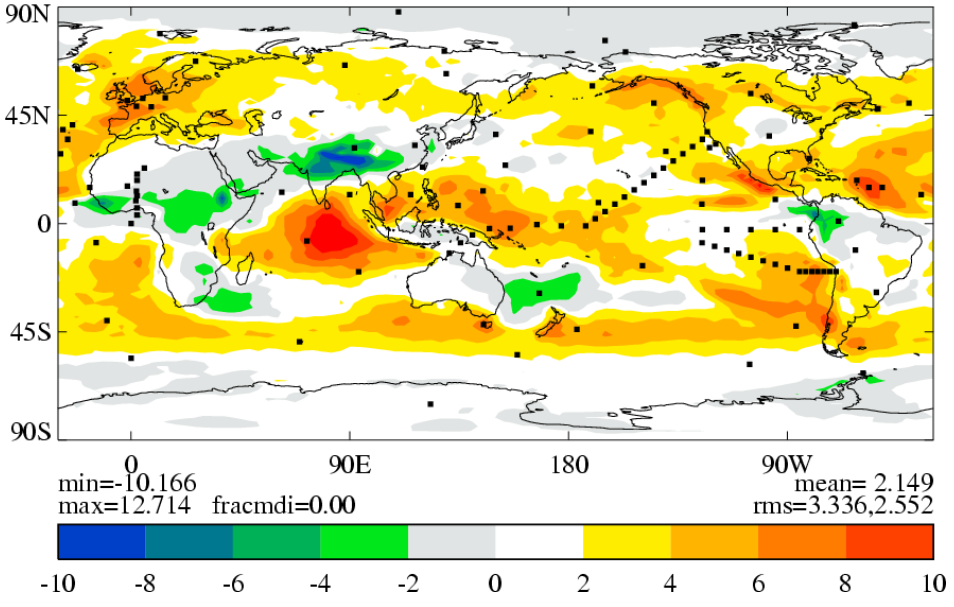
Possibility to quantify contributions to the inter-model spread in climate sensitivity :

- forcing (including fast cloud response to CO2 radiative forcing)
- feedbacks

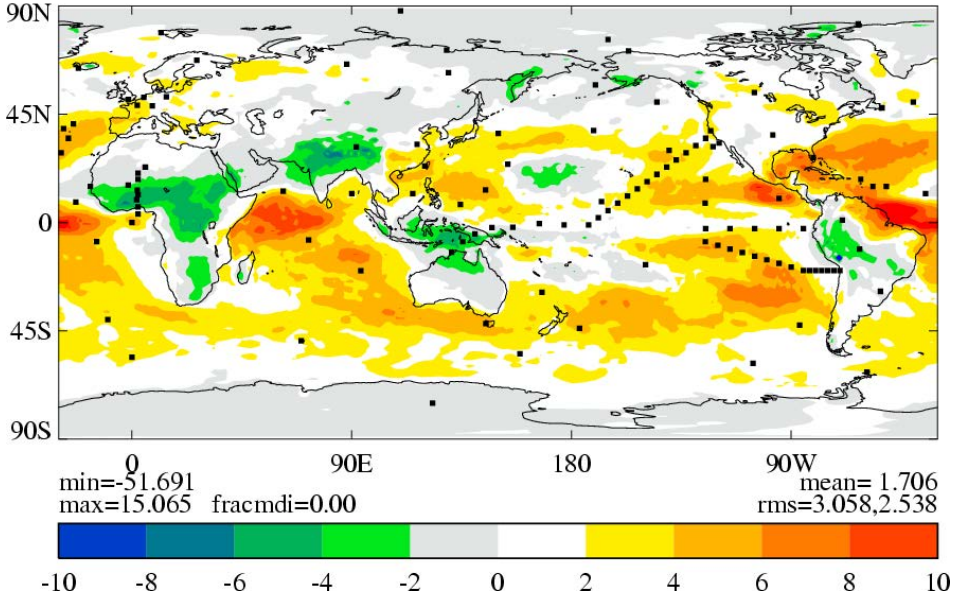
HadGEM2-A 4xCO_2 Fixed SST
SW CRE Response
Global 2xCO_2 Equivalent = +0.23 Wm-2



IPSL-CM5A-LR 4xCO_2 Fixed SST
SW CRE Response
Global 2xCO_2 Equivalent = +1.07 Wm-2



CNRM-CM5 4xCO_2 Fixed SST
SW CRE Response
Global 2xCO_2 Equivalent = +0.85 Wm-2

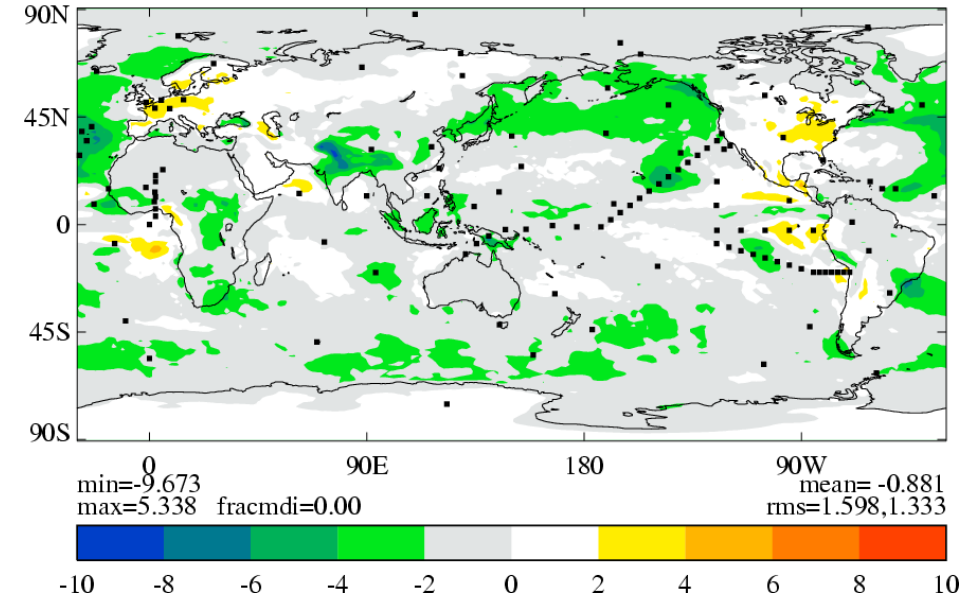


AMIP 4xCO2 - AMIP

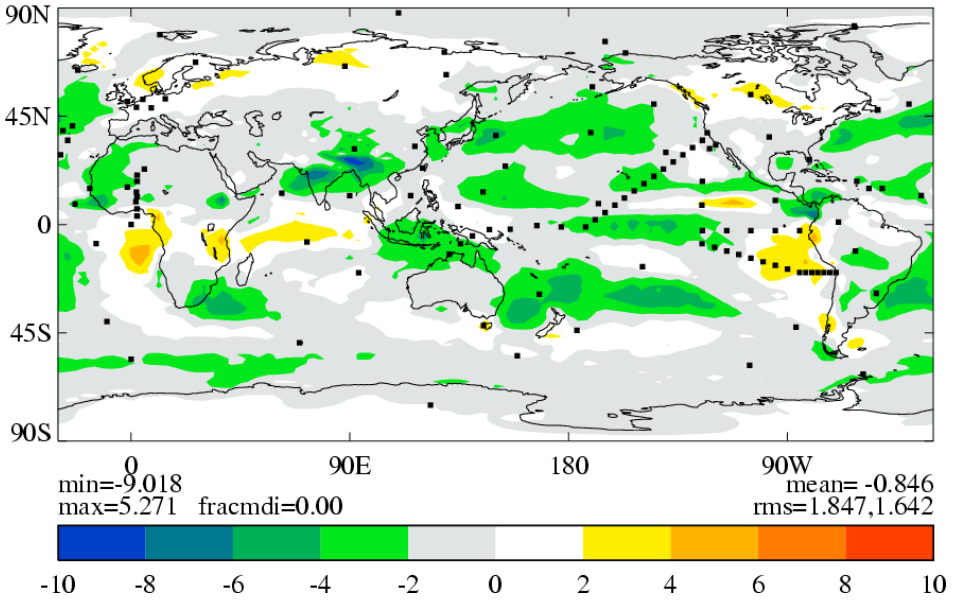
Early CFMIP-2 results show substantial positive shortwave cloud adjustments in CO_2 quadrupling experiments with fixed SSTs.

Mark Webb

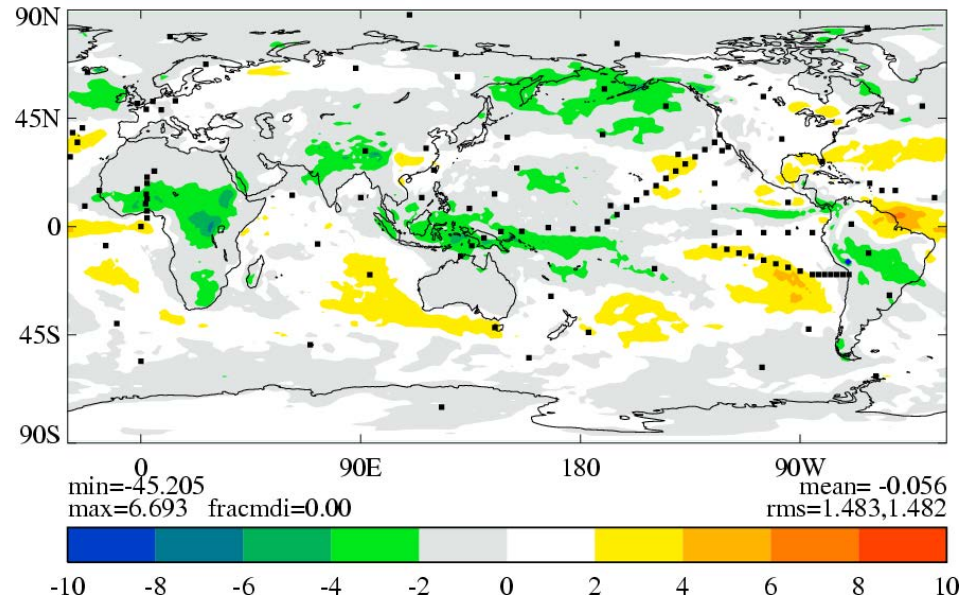
HadGEM2-A 4xCO_2 Fixed SST
Net CRE Response
Global 2xCO_2 Equivalent = -0.44 Wm-2



IPSL-CM5A-LR 4xCO_2 Fixed SST
Net CRE Response
Global 2xCO_2 Equivalent = -0.42 Wm-2



CNRM-CM5 4xCO_2 Fixed SST
Net CRE Response
Global 2xCO_2 Equivalent = +0.03 Wm-2

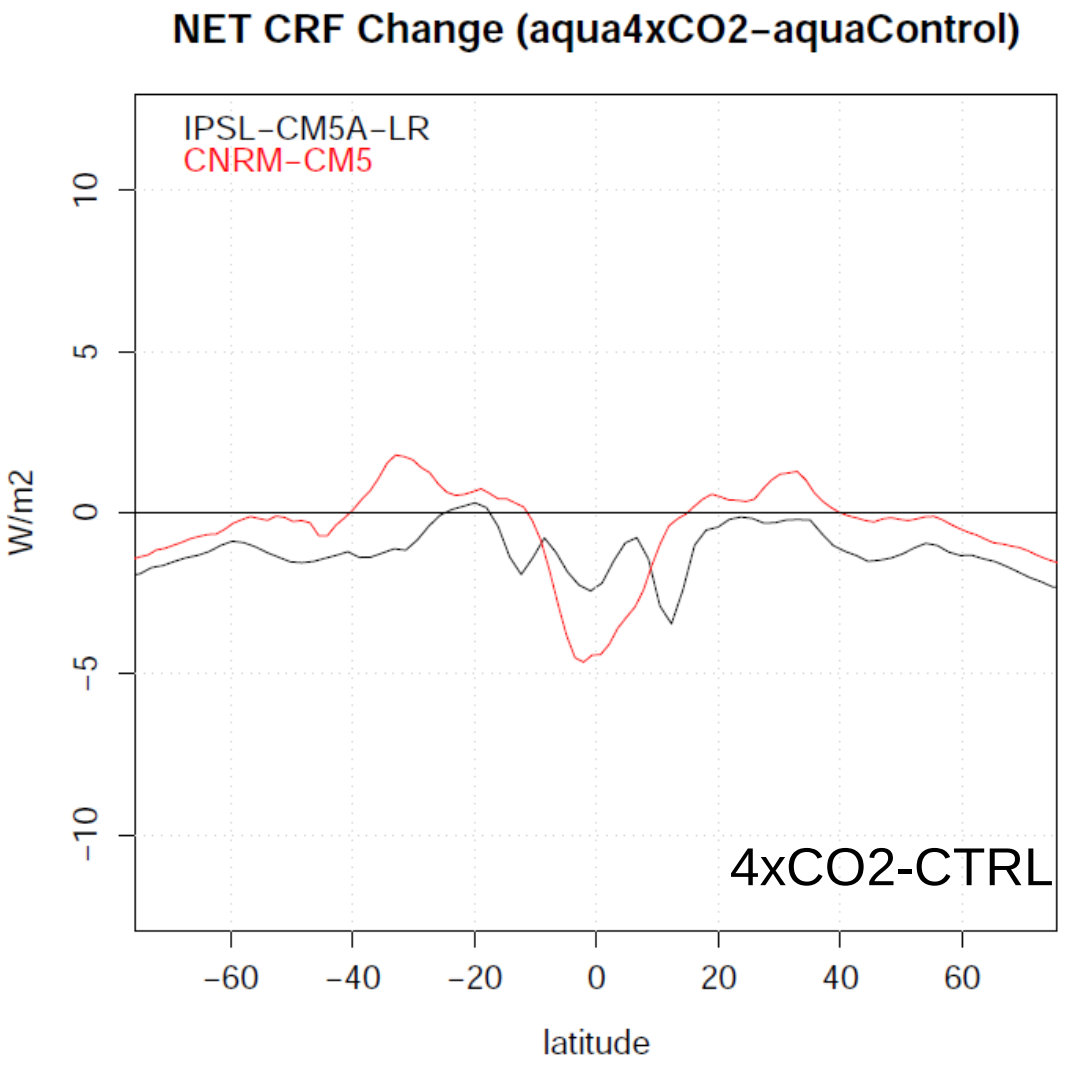


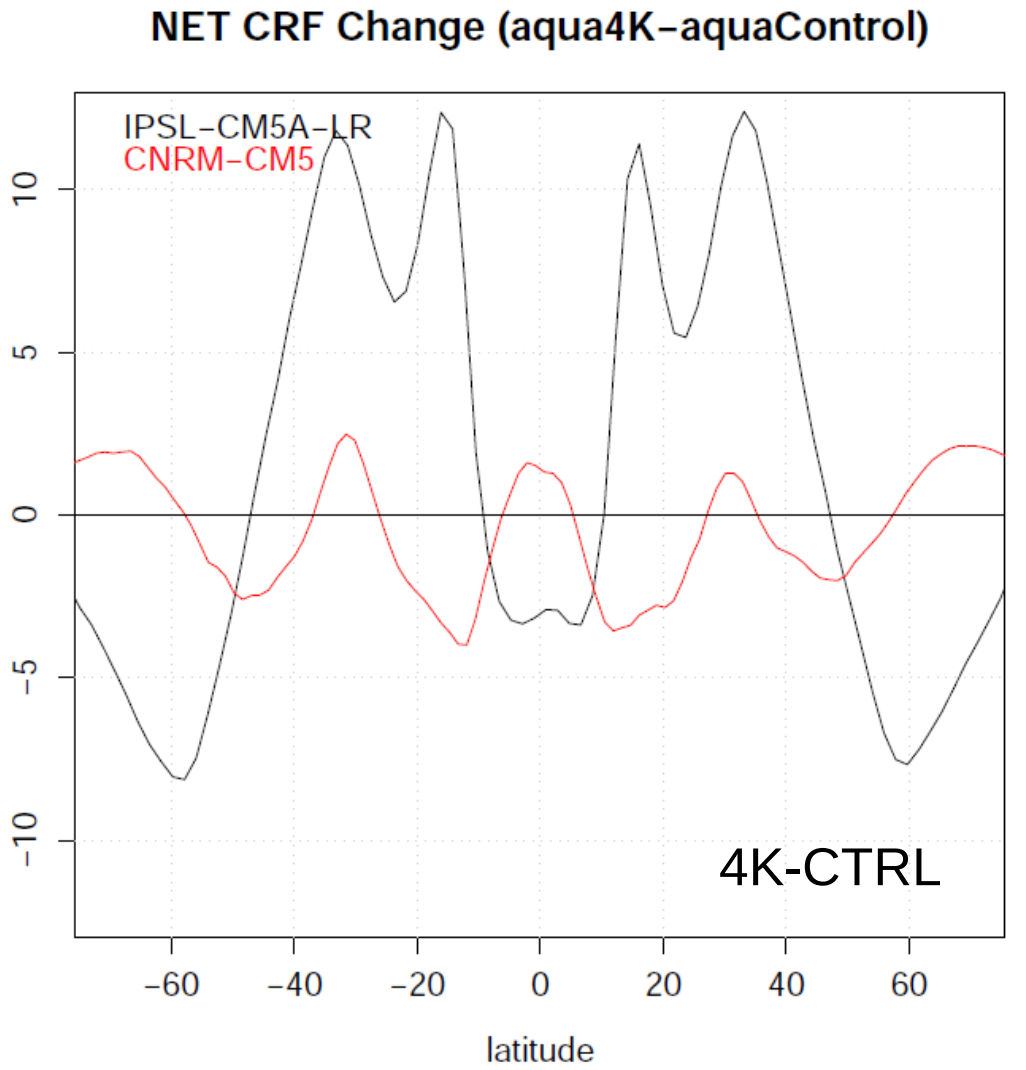
AMIP 4xCO2 - AMIP

Global mean Net CRE responses to CO_2 quadrupling with fixed SSTs are negative because longwave effects dominate (cloud changes and cloud masking)

Mark Webb

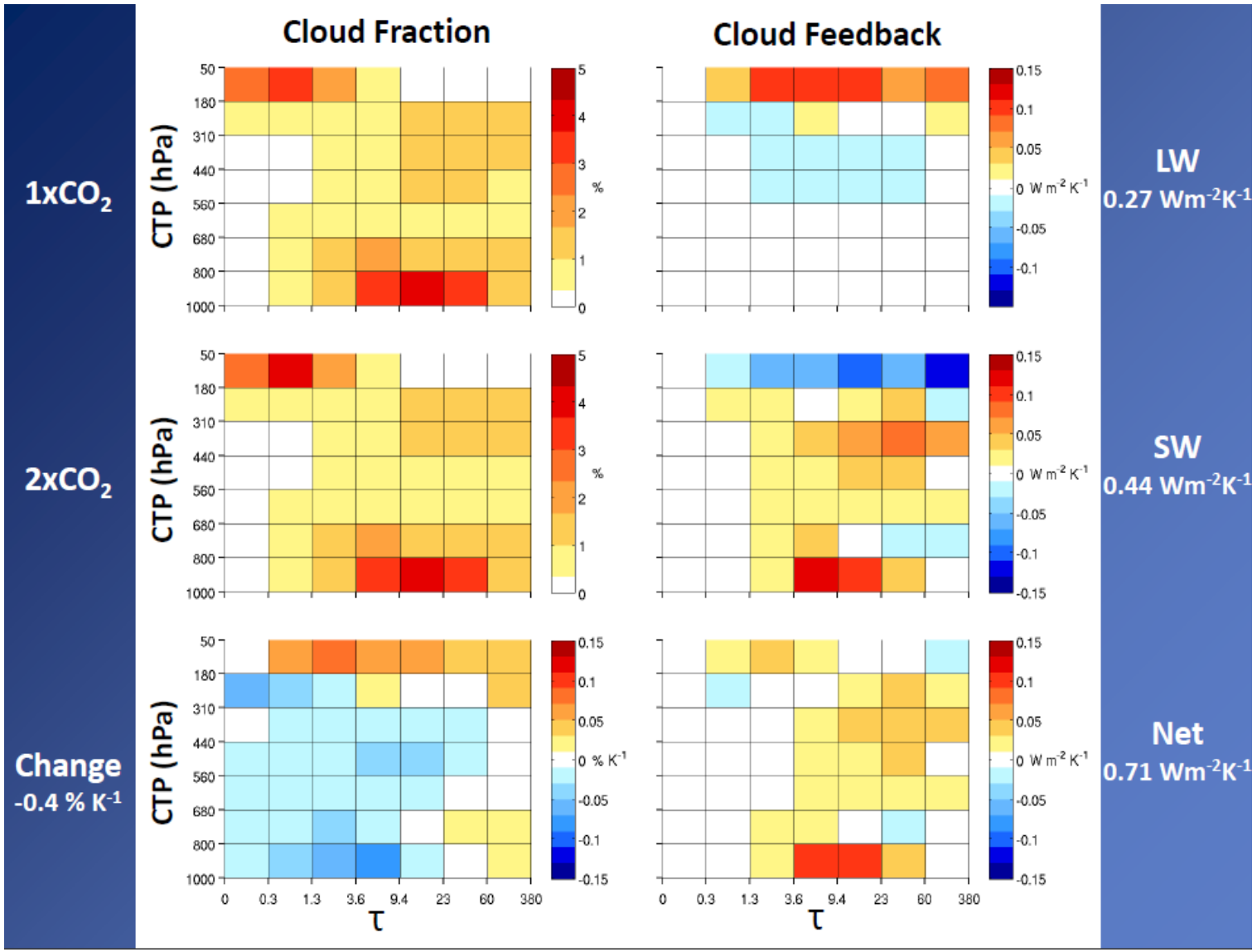
CMIP5 Aqua-Planet Experiments





A new methodology using ISCCP simulator outputs to diagnose cloud feedbacks

and quantify the contribution of different cloud types and different aspects of cloud changes (altitude, optical thickness, amount)



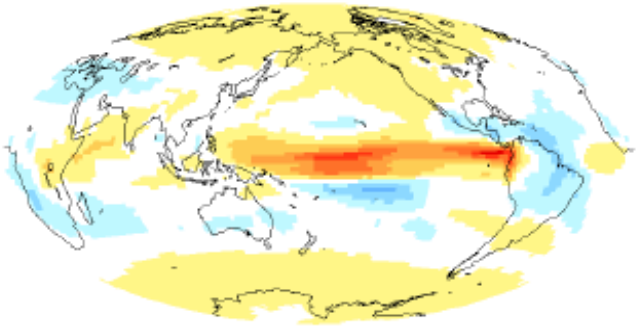
Global net cloud feedback positive

Inter-model spread due both to low clouds and high clouds

Mark Zelinka, Steve Klein and Dennis Hartmann (J. Climate, in rev)

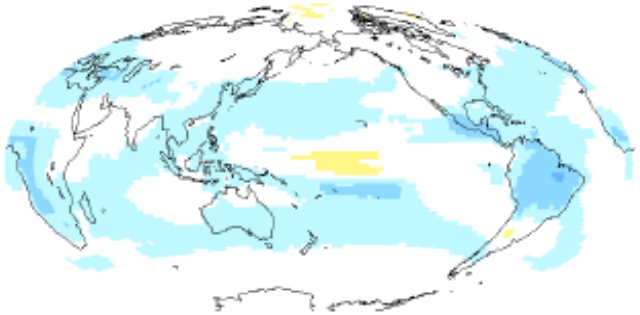
LW Cloud Feedback

0.26 W m^{-2} K^{-1}



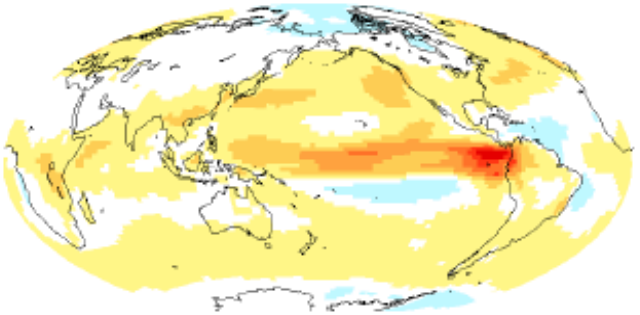
Amount

-0.30 W m^{-2} K^{-1}



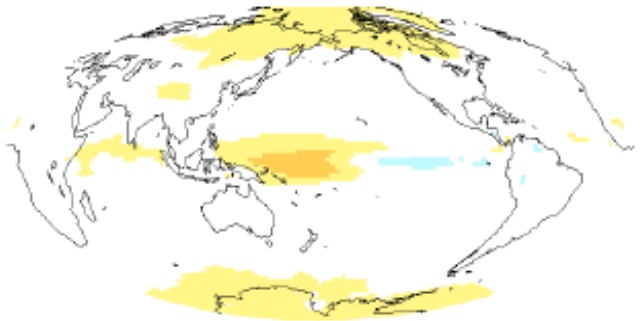
Altitude

0.44 W m^{-2} K^{-1}



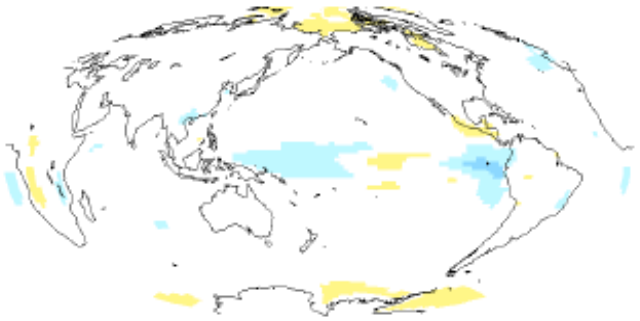
Optical Depth

0.16 W m^{-2} K^{-1}

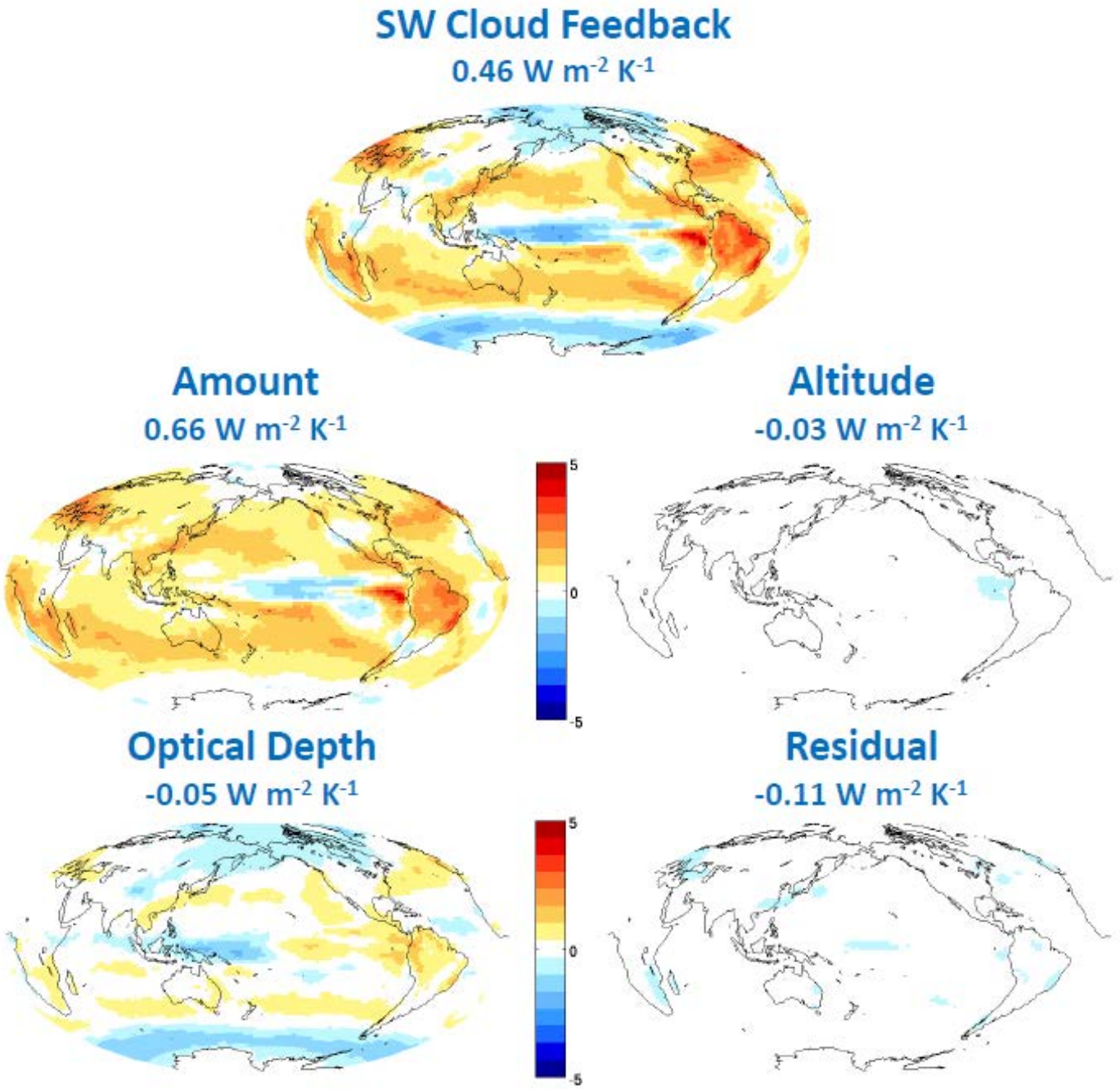


Residual

-0.04 W m^{-2} K^{-1}



Mark Zelinka, Steve Klein and Dennis Hartmann (J. Climate, in rev)

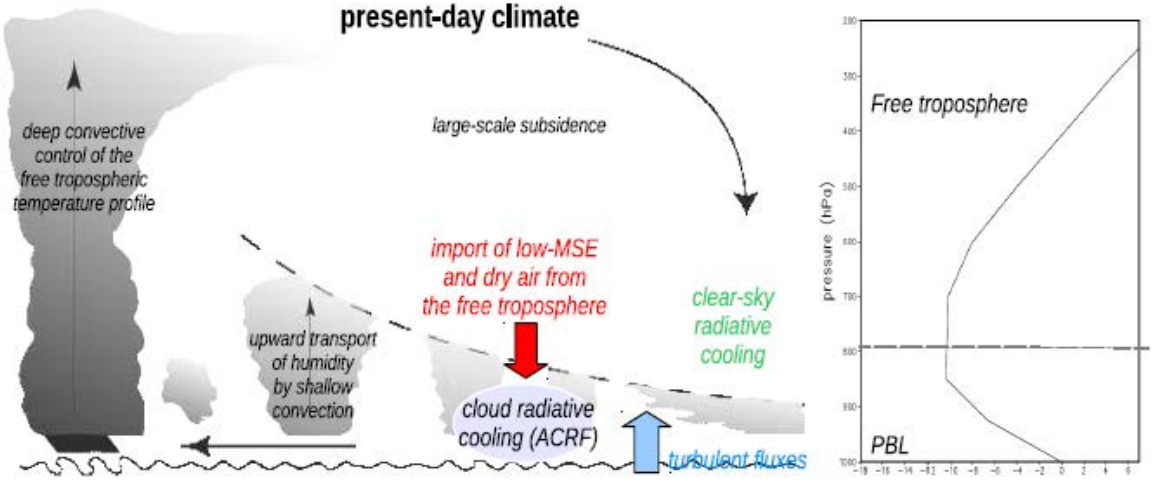


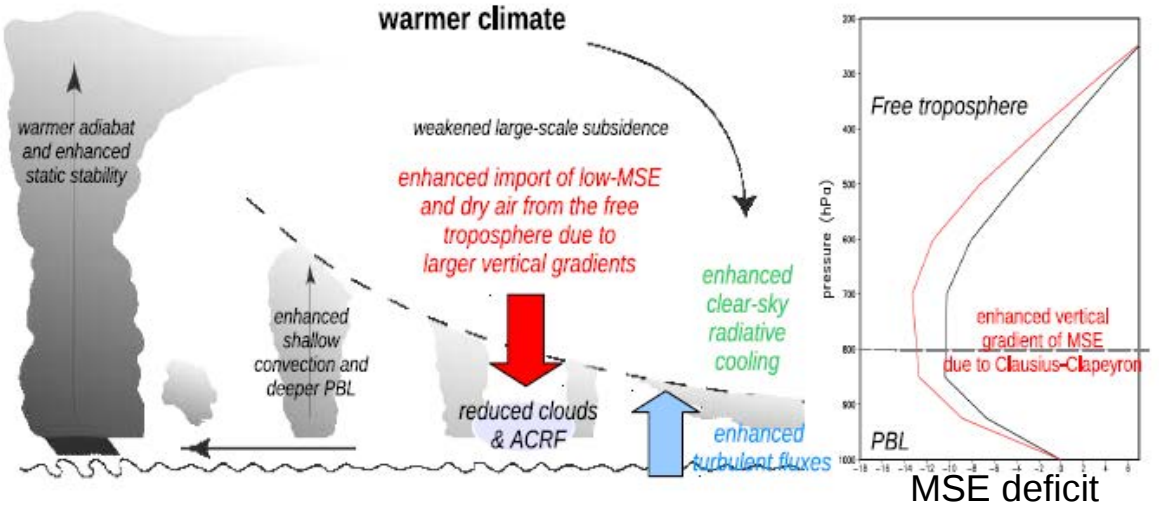
Mark Zelinka, Steve Klein and Dennis Hartmann (J. Climate, in rev)

Response of shallow cumulus clouds investigated through a spectrum of models

In a CMIP5 General Circulation Model (IPSL-CM5A)

- 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

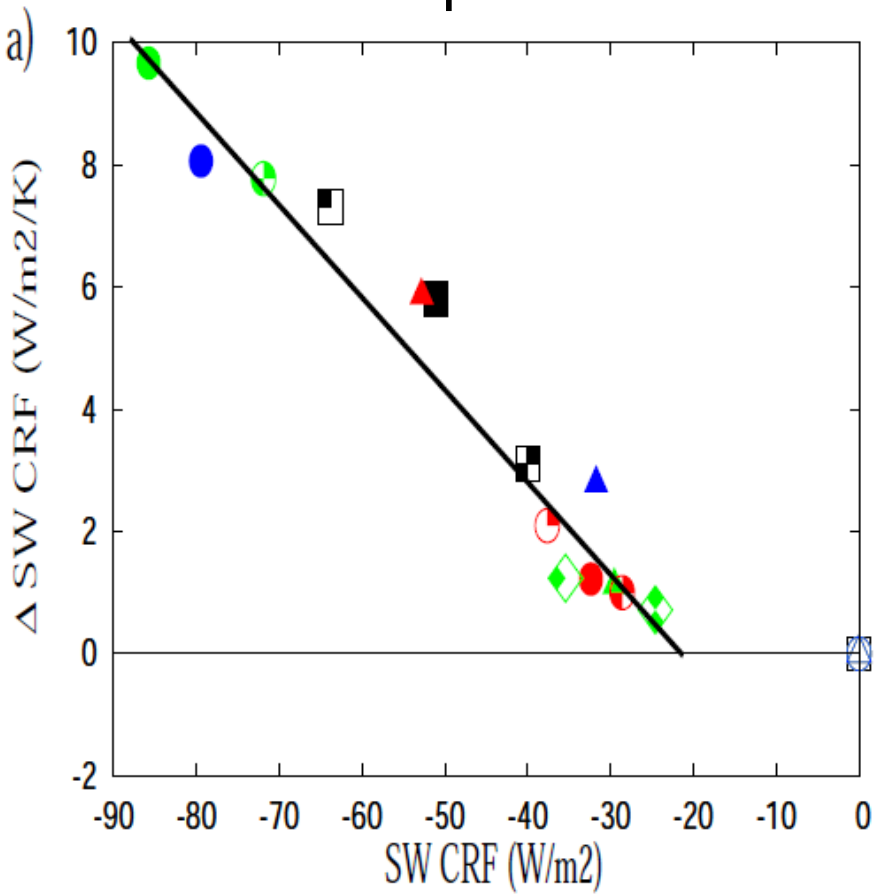




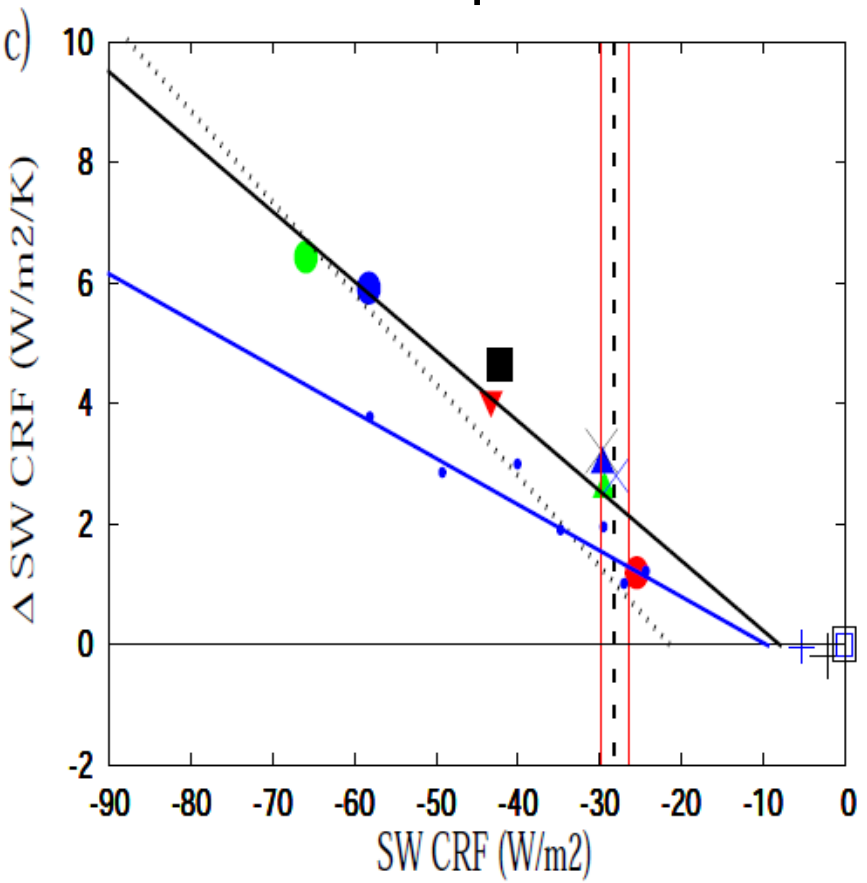
(Brient & Bony, Clim. Dyn, in rev)

Robustness of the shallow cumulus clouds response to tuning parameters in the IPSL-CM5 model

SCM experiments



GCM experiments

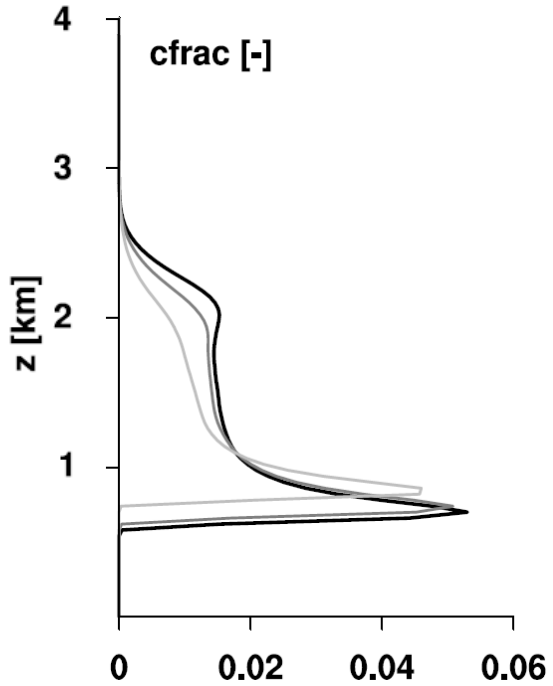


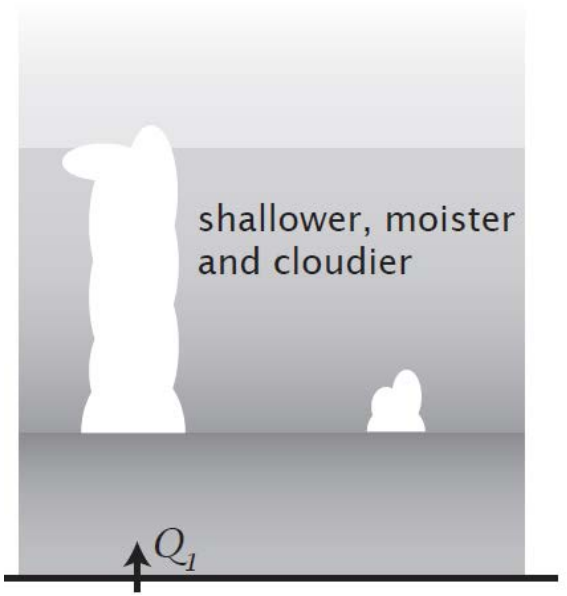
(Brient & Bony, in prep)

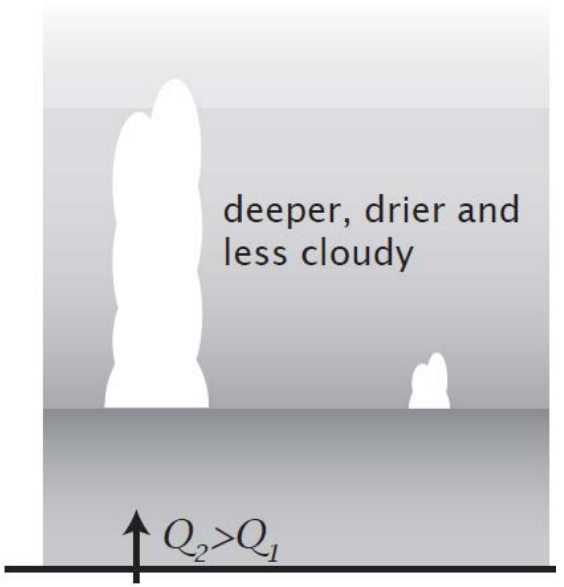
Response of shallow cumulus clouds investigated through a spectrum of models

In a Large-Eddy Simulation (LES) model

- Idealized experiment assuming a nearly unchanged relative humidity atmosphere







T_1 $T_2>T_1$

In this LES model :

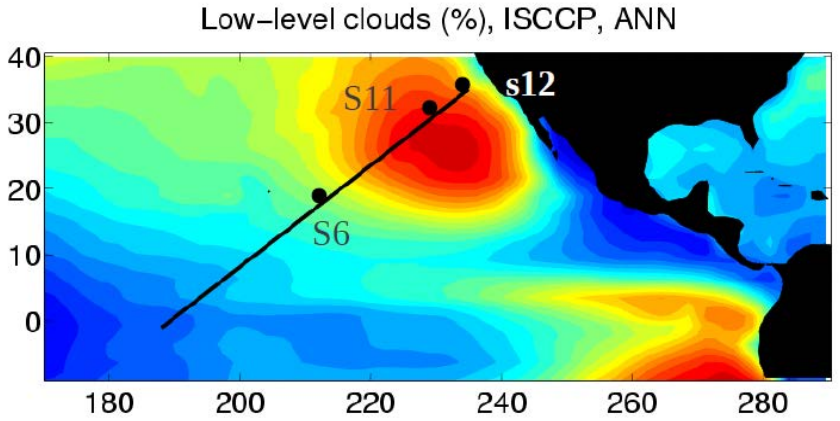
- deeper and drier planetary boundary layer
- decrease of the cloud fraction and water content
- positive low-cloud feedback

(Rieck, Nuijens and Stevens, submitted)

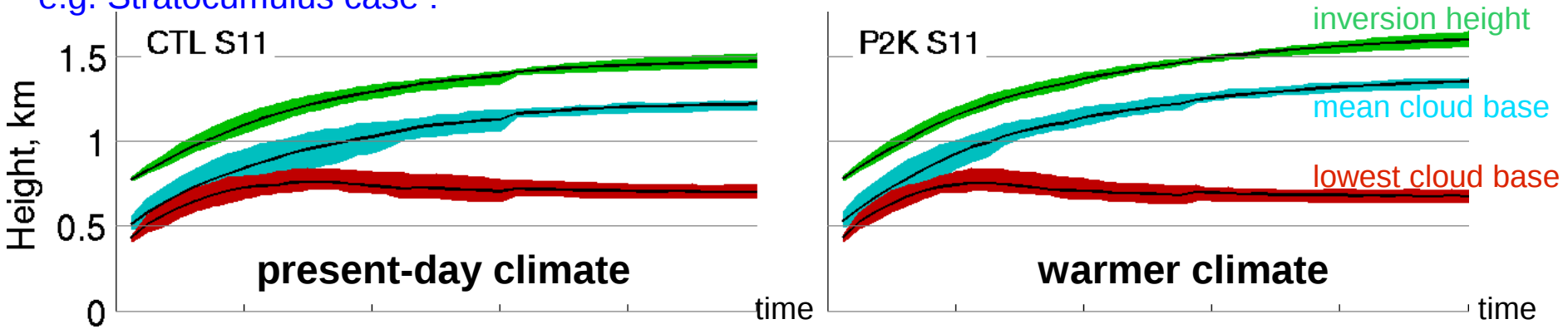
Response of low-level clouds investigated through a spectrum of models

CGILS project : CFMIP-GCSS Intercomparison of
Large-eddy Simulation models (LES) and Single column models (SCM)

- Focus on three types of low-level clouds
- Present-day and (idealized) climate change conditions
- Participation of 5 LES models and 16 SCMs
- Current LES results :
  - no consensus on radiative feedback
  - consensus on PBL structure changes



e.g. Stratocumulus case :



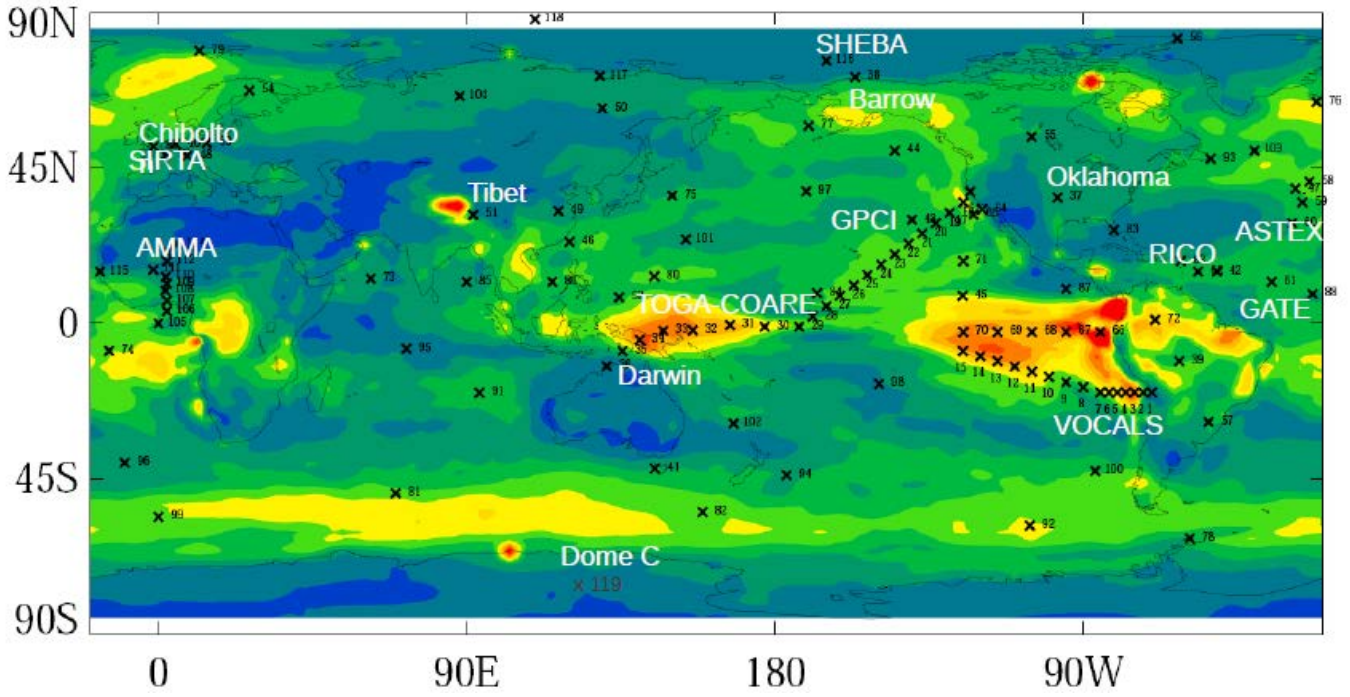
in warmer climate : deepening of the PBL and enhanced decoupling

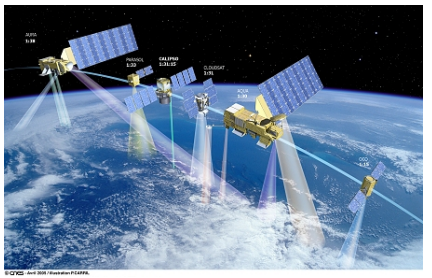
Courtesy Chris Bretherton, Peter Blossey, Minghua Zhang et al.

Improved Understanding of Cloud Feedback Mechanisms Should Help to Design Relevant Observational Tests

High-frequency (half-hourly) **detailed model outputs**
will be extracted from CMIP5 climate models
over **120 sites** where **cloud feedbacks** are particularly uncertain,
or for which **observations facilities** (ARM, CloudNet..), **field experiments**
and **satellite observations** are available

CFMIP sites with detailed CMIP5 outputs





A new generation of climate models is emerging ....

- Very high resolution climate models
- Super-parameterizations
- Global Cloud Resolving Models
- LES simulations over large domains ...

→ Is the climate change response different from that predicted by GCMs ?

→ Do GCMs miss (or mis-represent) processes critical for climate sensitivity ?

Issues of interest for CFMIP ...

Next CFMIP meeting :

Joint EUCLIPSE / CFMIP meeting

Paris, May 28 – June 1st 2012

Presumably organized around the following topics (at least) :
(very preliminary)

1. Cloud bias characterization in CMIP5 GCMs (focus on compensating errors) using satellite and ground-based observations.

2. Role of cloud processes in the current climate (ITCZ, MJO, ENSO, extremes) and impact of the representation of moist processes on the simulated climate (e.g. convection-dynamics interactions)

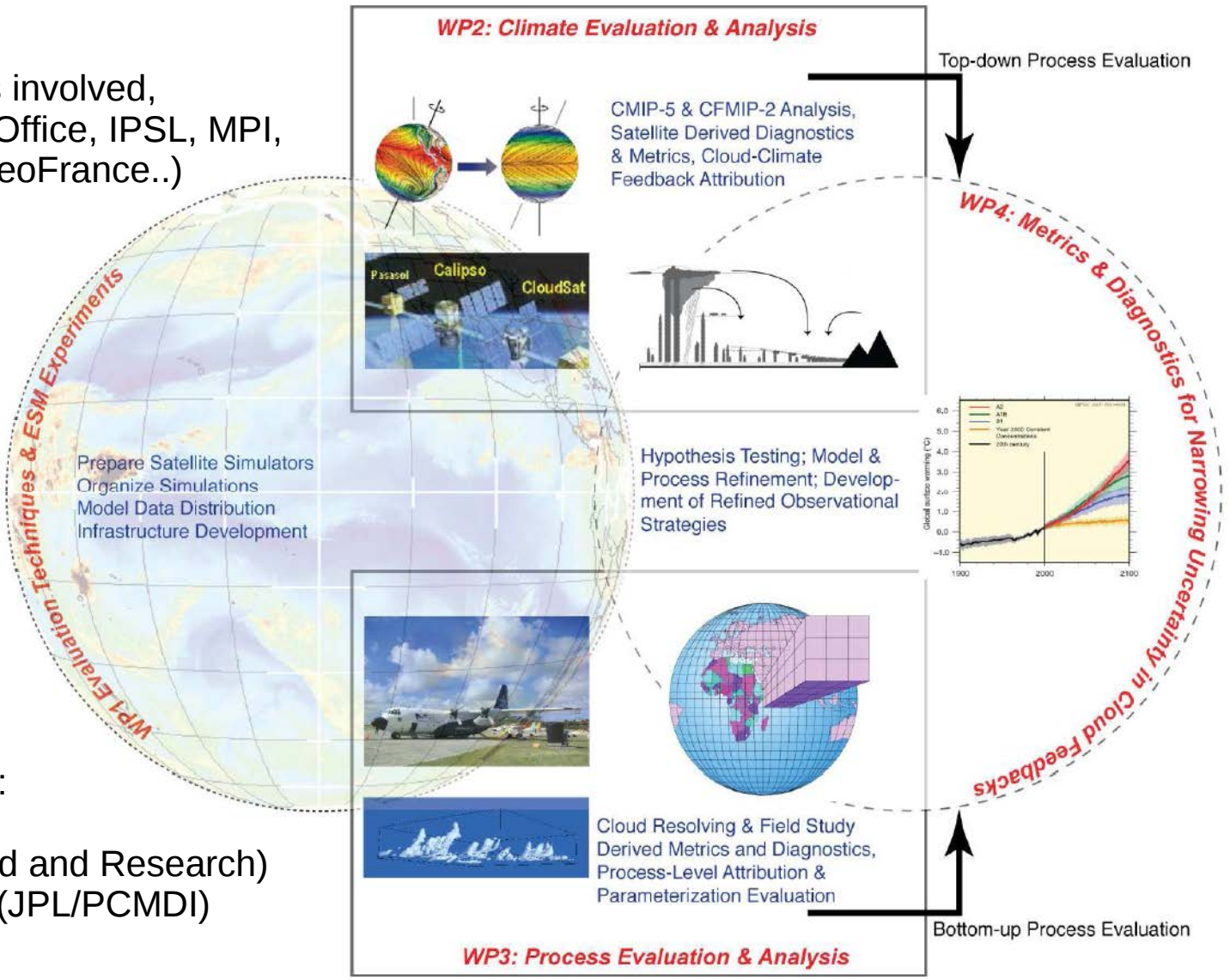
3. Climate change cloud feedbacks : understanding and assessment

European project EUCLIPSE (2010-2014)
EU Cloud Intercomparison, Process Study and Evaluation

- Focused on CFMIP / GCSS activities (satellite evaluations, process evaluations, cloud feedbacks)
  + WGCM / WGNE (CMIP5, Transpose-AMIP, Metrics..)

- PI: Pier Siebesma (KNMI)

- 13 european modeling groups involved,
  both climate and NWP (MetOffice, IPSL, MPI, KNMI, ECMWF, CNRM-MeteoFrance..)



· Opportunity for collaborations :
  e.g. FASTER in the US
  (Fast Physics System Testbed and Research)
  e.g. Observations for CMIP5 (JPL/PCMDI)