Future CFMIP Experiments in CMIP6 and elsewhere

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Additional contributions: Timothy Andrews, Robin Chadwick, Hervé Douville, Peter Good, Alejandro Bodas-Salcedo and the COSP PMC
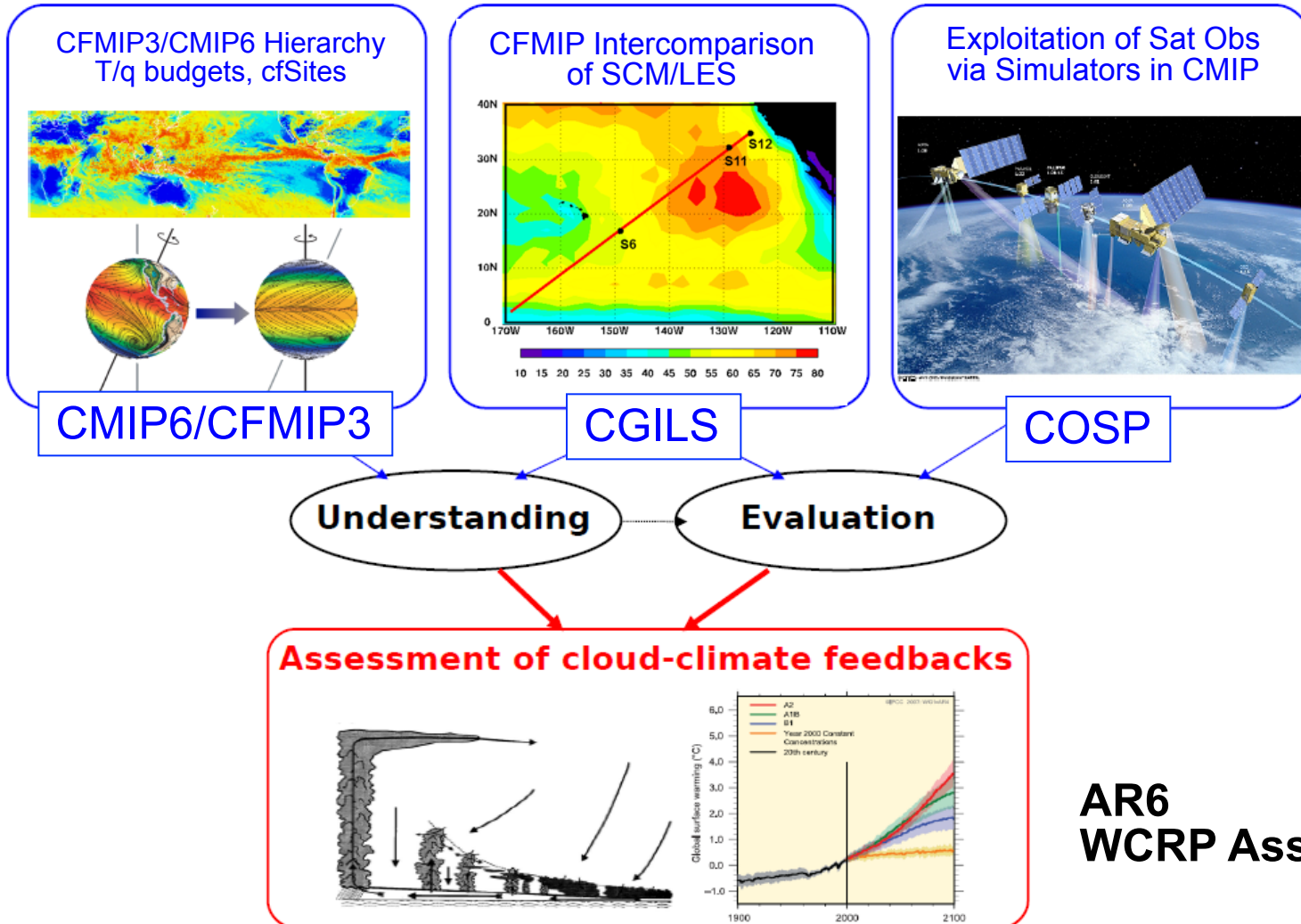
CFMIP Meeting, Monterey, June 2015

Met Office

Cloud Feedback Model Inter-comparison Project CFMIP3/CMIP6
http://www.cfmip.net

Objective 1: Inform improved assessments of climate change cloud feedbacks by:
   a) Improving our understanding of cloud-climate feedback mechanisms.
   b) Improving evaluation of clouds and cloud feedbacks in climate models.

CFMIP3/CMIP6 Hierarchy
T/q budgets, cfSites

CFMIP Intercomparison
of SCM/LES

Exploitation of Sat Obs
via Simulators in CMIP

CMIP6/CFMIP3

CGILS

COSP

Understanding · · · Evaluation

Assessment of cloud-climate feedbacks

AR6
WCRP Assessment

Cloud Feedback Model Inter-comparison Project CFMIP3/CMIP6
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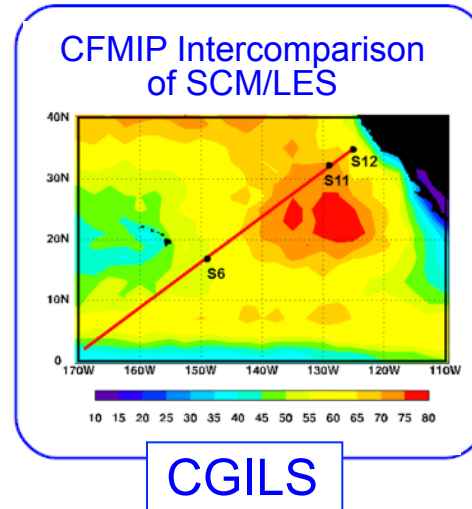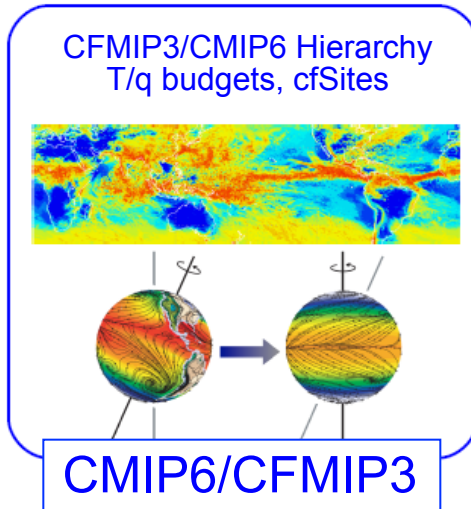 **b) Improving evaluation of clouds and cloud feedbacks in climate models.**

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Objective 2: To use the CFMIP experimental hierarchy and process diagnostics to better understand other aspects of the climate response, such as changes in circulation, regional-scale precipitation and non-linear change.

Three Categories of GCM Experiments relevant to CFMIP Phase 3

- **CMIP 'DECK' + CMIP6 Historical Experiments - AMIP, preindustrial control, 1% CO2, abrupt 4xCO2, CMIP6 Historical**

  - CFMIP/COSP PMC have proposed COSP + process diagnostics for these.

- **CFMIP experiments in CMIP6**

  - Various experiments proposed – soon to be endorsed by the CMIP panel?

  - Includes COSP + process diagnostics

  - Modelling groups participate via CMIP6 activity on CMIP6 timescales (2016-)

  - Hosted on the Earth System Grid as part of CMIP6 activity

  - Required Tier 1 experiments and optional Tier 2 experiments

- **Other CFMIP3 experiments outside of CMIP6**

  - Coordinated by CFMIP on a case by case basis

  - Hosted on Earth System Grid or via ad hoc data transfer/hosting

  - Can start at any time

  - May form pilot studies for future CMIP experiments

CFMIP CMIP6 Experiments (Tier 1)

A compact set of Tier 1 (entry level requirement) experiments are proposed address the question:

"What are the physical mechanisms underlying the range of cloud feedbacks and cloud adjustments predicted by climate models, and which models have the most credible cloud feedbacks?"

Tier 1 experiments retain CFMIP-2/CMIP5 idealized experimental hierarchy (amip, amip4K, amip4xCO2, amipFuture, aquaControl, aqua4xCO2 and aqua4K 174 yrs AGCM) Lead coordinator: Mark Webb

These experiments will continue to include outputs from the CFMIP Observational Simulator Package (COSP) to support quantitative evaluation of modelled clouds with observations and to relate cloud feedbacks to observed quantities.

Process diagnostics including 'cfSites' high frequency outputs at selected locations and temperature and humidity budget terms from radiation, convection, dynamics, etc. are also retained from CMIP5.

These support continuity with CFMIP-2/CMIP5 and application of the CFMIP approach to a larger number of models.

CFMIP CMIP6 Experiments (Tier 2)

Met Office

How do responses in the climate system due to changes in solar forcing differ from changes due to CO_2, and is the response sensitive to the sign of the forcing?
- Abrupt +/-4% Solar Forcing (abruptSp4 abruptSm4 300 yrs AOGCM)
- Chris Bretherton, Roger Marchand, Bjorn Stevens

To what extent is regional climate change per CO_2 doubling state-dependent (nonlinear), and why?
- Abrupt 2x and 0.5x CO_2 (abrupt2xCO2,abrupt0-5xCO2 300yrs AOGCM)
- Peter Good (NonLinMIP)

Are cloud feedbacks symmetric when subject to climate cooling rather than warming, and if not, why not?
- AMIP minus uniform 4K SST (amipMinus4K 36yrs AGCM)
- Mark Webb (Link to PMIP)

Are climate feedbacks during the 20th century different to those acting on long term climate change and climate sensitivity?
- AMIP with preindustrial forcing 1870-present (amipPIforcing 145yrs AGCM)
- Timothy Andrews

CFMIP CMIP6 Experiments (Tier 2)

How do regional climate responses (e.g. in precipitation) in coupled models arise from the combination of different aspects of CO_2 forcing and warming?
- Timeslice experiments forced with SSTs from preindustrial and abrupt4xCO2 (sstPi, sstPi4K, sstPi4xCO2, sstPi4xCO2Veg, sstPiFuture, sstPiTot, amipTot 156 yrs AGCM)
- Robin Chadwick, Hervé Douville

How do cloud-radiative effects impact the structure, the strength and the variability of the general atmospheric circulation in the present-day climate?
- Atmosphere-only experiments with clouds transparent to longwave radiation (offlwamip, offlwamip4K, offlwaquaControl, offlwaqua4K 92 yrs AGCM)
- Sandrine Bony

For full details see http://www.cfmip.net -> CFMIP Strategy and Plans

Satellite observations & simulators (COSP)
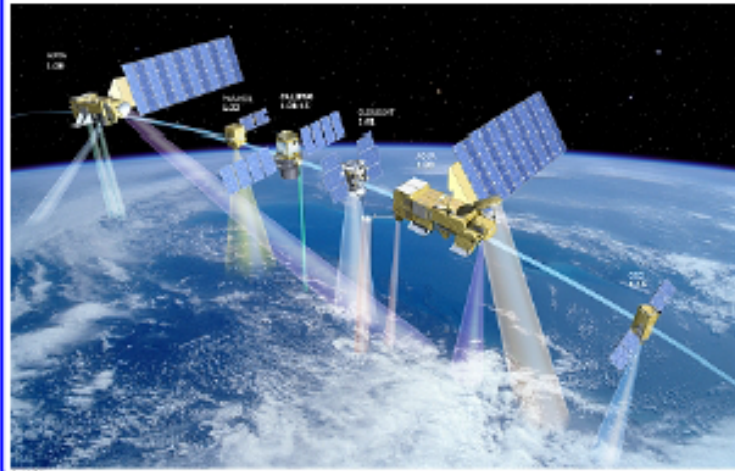
To evaluate present day clouds in the models, COSP simulator outputs for various instruments (ISCCP, CALIPSO, PARASOL, CloudSat, MODIS, MISR) and simulator inputs for one year (2008) are requested in the AMIP DECK experiment

A lighter set of ISCCP and CALIPSO simulator outputs are also requested to interpret and assess the credibility of cloud feedbacks:
PIcontrol abrupt4xCO2 1pctCO2 CMIP6Historical abruptSp4 abruptSm4 amip amip4K amip4xCO2 amipFuture aquaControl aqua4K aqua4xCO2 amipMinus4K offlwamip offlwamip4K offlwaquaControl offlwaqua4K

Use of Temperature and Humidity Tendency terms to understand cloud feedback mechanisms (e.g. Sherwood et al 2014)
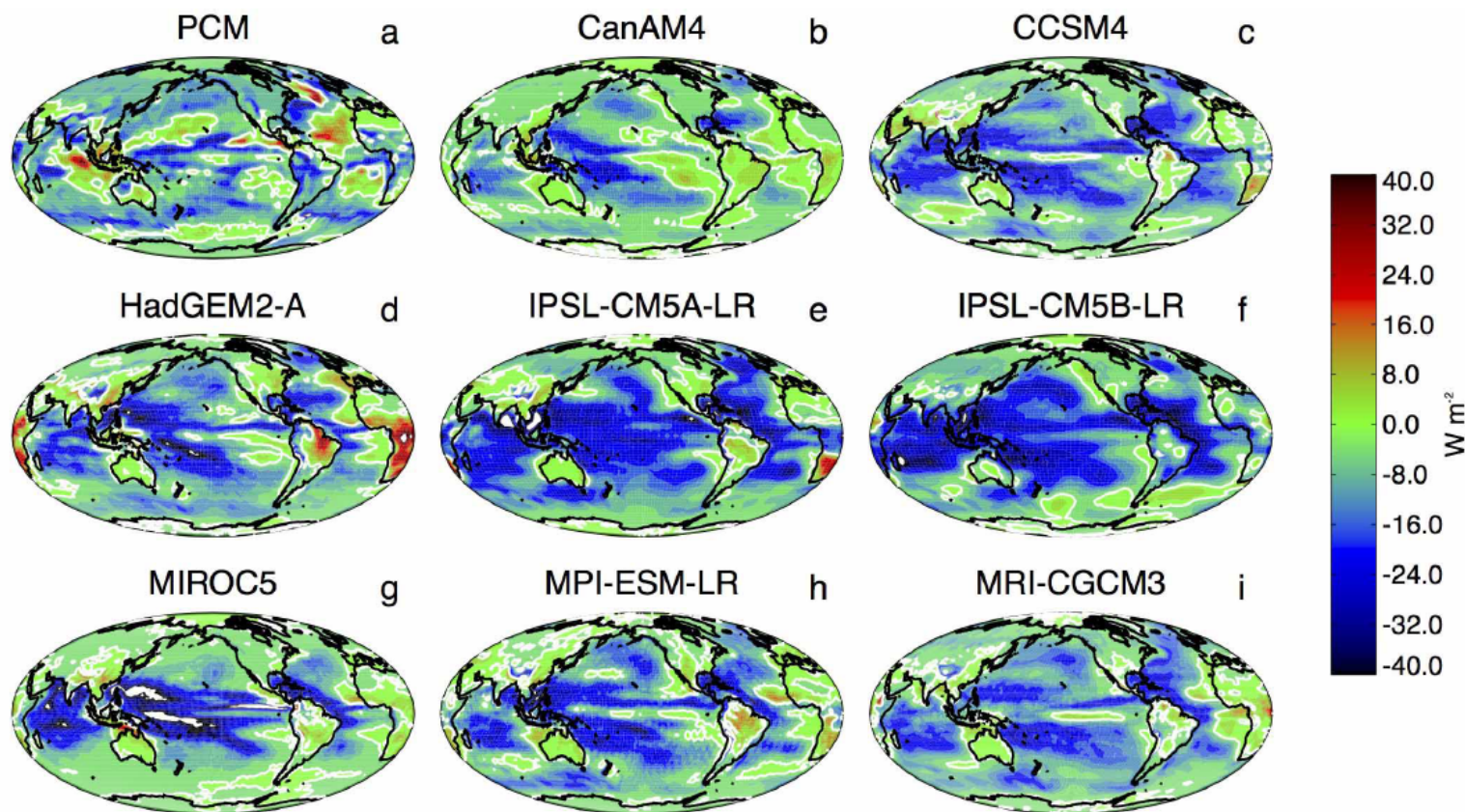

Extended Data Figure 5 | Response of small-scale, low-level drying to warming. Change in convective moisture source M_{small} below 850 hPa upon a +4 K warming in eight atmosphere models and one CMIP3 coupled model; units are W m^{-2}, with negative values indicating stronger drying near the surface. Zero contours are shown in white (a few off-scale regions also appear white). The models used for calculating M_{large} are the eight shown here plus two for which M_{small} data were unavailable: CNRM-CM5 and FGOALS-g2.

Proposed for Picontrol abrupt4xCO2 amip amip4K amip4xCO2 amipFuture aquaControl aqua4K aqua4xCO2 amipMinus4K abruptSp4 abruptSm4 offlwamip offlwamip4K offlwaquaControl offlwaqua4K

Instantaneous high frequency outputs at 'cfSites' locations
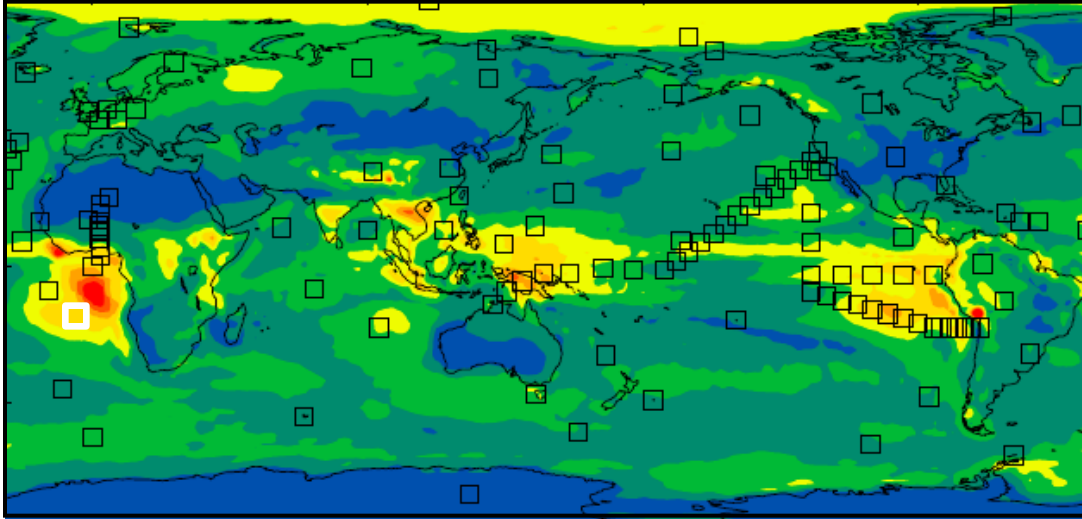
At the request of the US CLIVAR Eastern Tropical Ocean Synthesis Working Group we have added St. Helena to the increasing the total number of locations to 121.

cfSites will be requested in amip, amip4K and amip4xCO2

Possible CFMIP3 Experiments

What processes control the dependence of cloud and climate feedbacks on the pattern of SST change?
- amip4K experiments with different patterns + process diagnostics (amip4Kfast, amip4Kslow, amip4K20C - 108 yrs AGCM)
- Timothy Andrews

What processes contribute to inter-model spread in cloud feedback?
Further SPOOKIE experiments:
- Simplify PBL schemes?
- More targeted sensitivity experiments?
- Mark Webb

What role does convective aggregation play in cloud feedback?
- Non-rotating rotationally symmetric Radiative Convective Equilibrium experiments with varying resolutions up to cloud resolving
- aquaRCEcontrol, aquaRCE4K (2-10 yrs AGCM)
- Bjorn Stevens

Please contact CFMIP co-chairs if you have a proposal and we can put you in touch with the relevant modelling groups contacts.

Summary and proposed allocation to DECK, CFMIP/CMIP6 and CFMIP3 coordinated experiments

Proposal	DECK	CMIP6/CFMIP3	CFMIP3
Include COSP and temperature and humidity budget tendency terms in selected DECK / CMIP6 Historical runs.	X		
Retain amip,amip4xCO2, amip4K, aquaplanets with COSP+process diagnostics in CMIP6 (Lead Mark Webb)	X	Tier 1	
AMIP minus uniform 4K (Mark Webb)		Tier 2	
AMIP with pre-industrial forcings amipNoForcing (Tim Andrews)		Tier 2	
+/- 4% Abrupt solar forcing AOGCM experiments (Chris Bretherton/Roj Marchand/Bjorn Stevens)		Tier 2	
abrupt 4CO2 and 0.5 CO2 experiments to understand non-linear changes in precipitation (Peter Good)		Tier 2	
Timeslice experiments for understanding regional climate change (Rob Chadwick & Hervé Douville)		Tier 2	
COOKIE sensitivity experiments with clouds made transparent to radiation (PI Sandrine Bony)		Tier 2	
Sensitivity of atmospheric feedbacks to 'fast', 'slow' and 20C SST response patterns (Tim Andrews)			X
Develop SPOOKIE approach in CFMIP (Mark Webb)			X
Develop an inexpensive global RCE experiment (Bjorn Stevens)			X