Overview Status CMIP6-Endorsed MIPs

SLIDES kindly provided by the Co-Chairs of each MIPs – THANKS!

Veronika Eyring

Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany

1-2 November 2016

WGCM-20

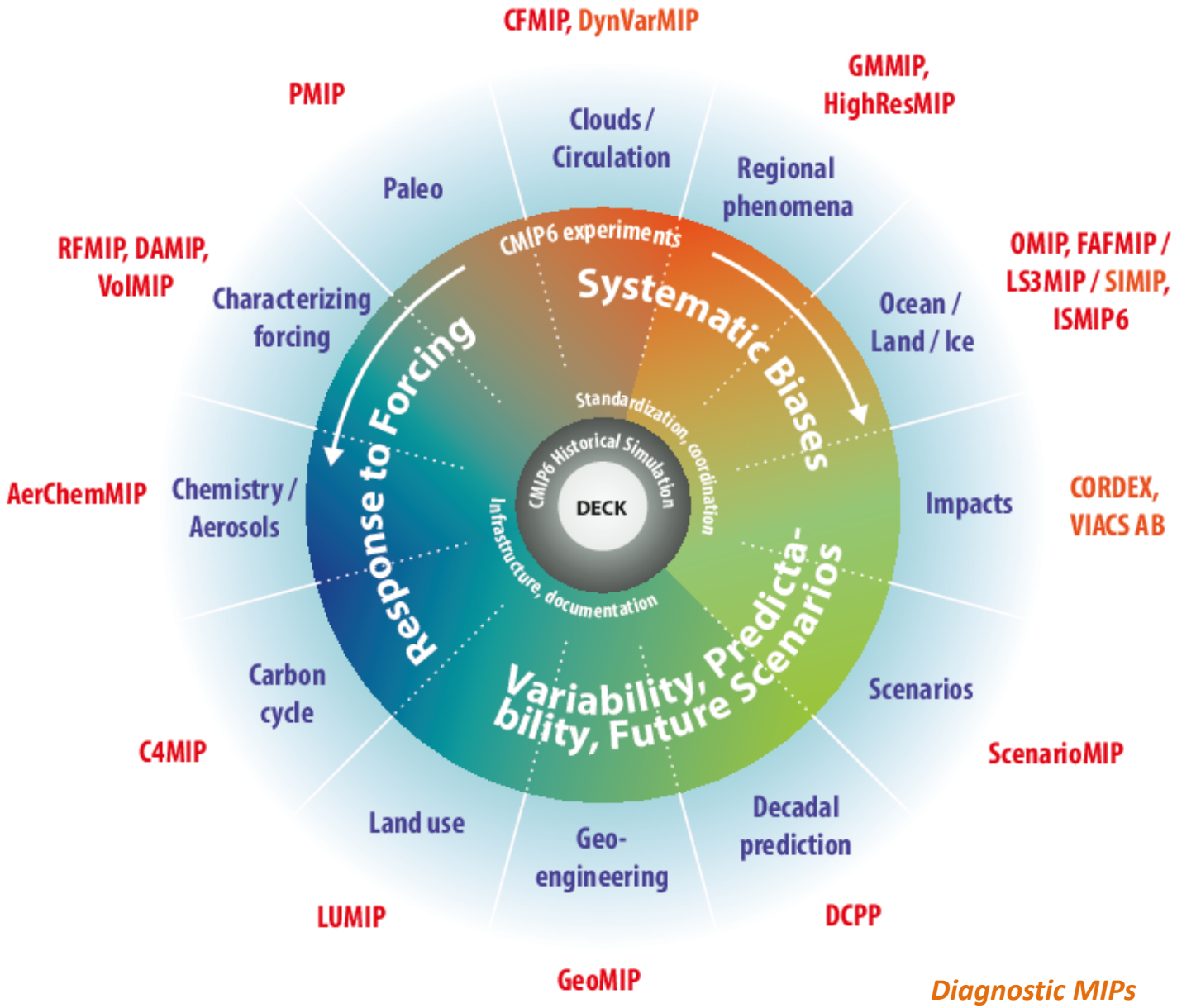
University of Princeton, USA

CMIP
The World Climate Research Programme's Coupled Model Intercomparison Project

DLR

21 CMIP6-Endorsed MIPs

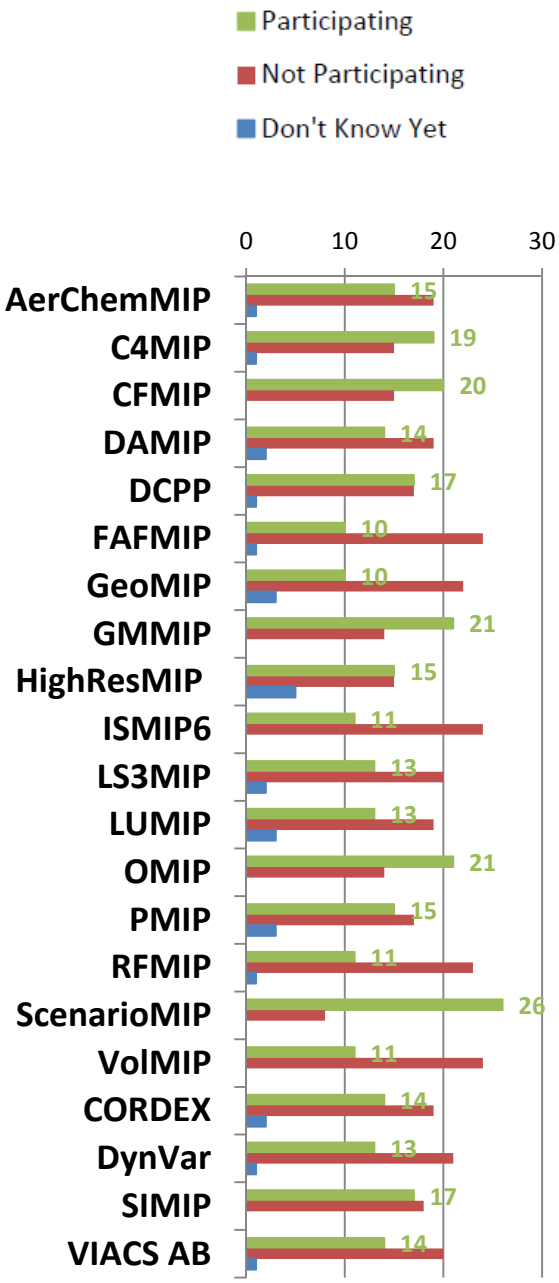
- All papers submitted ~on the agreed timeline (end of April 2016) to the CMIP6 Special Issue in GMD!
- Peer-reviewed by at least 2 referees
- Additional review of the majority of the MIP papers by the CMIP Panel.
- Additional comments from individual scientists.



Eyring et al., GMD, 2016

Model Groups' Commitments to participate in CMIP6-Endorsed MIPs

	Long Name of MIP (Short Name of MIP)	
1	Aerosols and Chemistry Model Intercomparison Project (AerChemMIP)	GMDD
2	Coupled Climate Carbon Cycle Model Intercomparison Project (C4MIP)	GMD
3	Cloud Feedback Model Intercomparison Project (CFMIP)	GMDDa
4	Detection and Attribution Model Intercomparison Project (DAMIP)	GMD
5	Decadal Climate Prediction Project (DCPP)	GMD
6	Flux-Anomaly-Forced Model Intercomparison Project (FAFMIP)	GMDDa
7	Geoengineering Model Intercomparison Project (GeoMIP)	GMD
8	Global Monsoons Model Intercomparison Project (GMMIP)	GMD
9	High Resolution Model Intercomparison Project (HighResMIP)	GMDDa
10	Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6)	GMDD
11	Land Surface, Snow and Soil Moisture MIP (LS3MIP)	GMD
12	Land-Use Model Intercomparison Project (LUMIP)	GMD
13	Ocean Model Intercomparison Project (OMIP)	GMD
	Biogeochemical OMIP	GMDD
14	Paleoclimate Modelling Intercomparison Project (PMIP)	GMDD
15	Radiative Forcing Model Intercomparison Project (RFMIP)	GMD
16	Scenario Model Intercomparison Project (ScenarioMIP)	GMD
17	Volcanic Forcings Model Intercomparison Project (VolMIP)	GMD
18	Coordinated Regional Climate Downscaling Experiment (CORDEX)	GMDDa
19	Dynamics and Variability Model Intercomparison Project (DynVarMIP)	GMD
20	Sea-Ice Model Intercomparison Project (SIMIP)	GMD
21	Vulnerability, Impacts & Adaptation and Climate Services AB (VIACS AB)	GMD



AERCHEMMIP

Co-chairs:
Bill Collins(UK)
Jean-François Lamarque (USA)
Michael Schulz (Norway)

OVERVIEW

University of Reading

AerChemMIP will quantify **composition, forcings**, **feedbacks** and global-to-regional climate **response** ($\Delta T, \Delta P$) from changes to:

- NTCF emissions (aerosols, O_3 precursors)
- Reactive GHGs concentrations (N_2O, CH_4, ODSs)

Experiments with interactive chemistry and/or aerosols.

Pairs of simulations:

Fixed SST -> ERF

Full ocean -> $\Delta T, \Delta P$

SCIENCE QUESTIONS

University of Reading

- CMIP6 Q1 “How does the Earth system respond to forcing?”.

1. How have anthropogenic aerosols and reactive gases contributed to global ERF and regional climate change over the **historical period**?
2. How will **future policies** (on climate/AQ/land use) affect the abundances of NTCFs and their associated climate impacts?
3. How can **uncertainties** in historical NTCF emissions be mapped onto pre-industrial to present-day changes?
4. How important are **climate feedbacks** involving natural NTCF emissions?

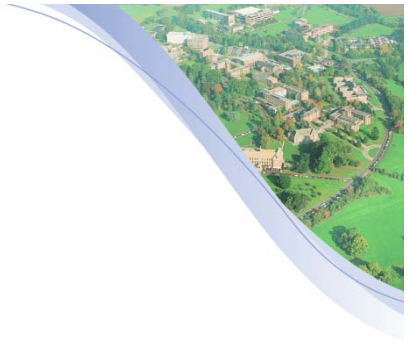
EXPERIMENTS

University of Reading

1. Historical transient contribution of NTCFs and ODSs to ERF and regional climate
2. Future policy effects on NTCFs and their climate impacts (SSP3-7.0 vs SS3-7.0_clean)
3. Timeslice anthropogenic ERFs
4. ERFs for natural emissions

DIAGNOSTICS

See latest excel tables on the wiki:
https://wiki.met.no/aerocom/aerchemmip/diagnostics
Not yet correctly included in CMIP6 data request
(…version was sent in may 2016 to BADC)



C4MIP Update

P. Friedlingstein, V. Arora, C.D. Jones

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In one slide

- C4MIP endorsed
- C4MIP paper published in GMD
- C4MIP variables in the CMIP6 data request
- C4MIP forcing finalized

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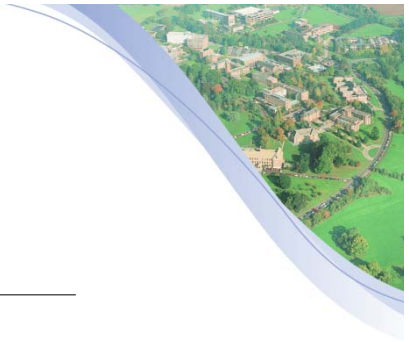
C4MIP Simulations



Category	Type of scenario	Emission or concentration driven	Coupling mode	Simulation years	Short name
Tier 1					
1 %BGC	Idealized 1 % per year CO_2 only, BGC mode	C driven	CO_2 affects BGC	140	1pctCO2-bgc
SSP5-8.5	SSP5-8.5 up to 2100	E driven	Fully coupled	85	esm-ssp585
Tier 2					
1 %RAD	Idealized 1 % per year CO_2 only, RAD mode	C driven	CO_2 affects RAD	140	1pctCO2-rad
1 %COU-Ndep	Idealized 1 % per year CO_2 only, fully coupled, increasing N-deposition	C driven	Fully coupled	140	1pctCO2Ndep
1 %BGC-Ndep	Idealized 1 % per year CO_2 only, BGC mode, increasing N-deposition	C driven	CO_2 affects BGC	140	1pctCO2Ndep-bgc
Hist/SSP5-8.5-BGC	Historical+SSP5-8.5 up to 2300, BGC mode	C driven	CO_2 affects BGC	165 85 200	hist-bgc, ssp585-bgc and ssp585-bgcExt
SSP5-3.4-Overshoot-BGC	SSP5-3.4-OS up to 2300 in BGC mode	C driven	CO_2 affects BGC	60 (from 2040–2100) 200	ssp534-over-bgc, ssp534-over-bgcExt

New simulation: Overshoot simulation SSP5-3.5-Overshoot in a **BGC mode**

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C4MIP forcing

- Emission driven
  - CO2 emissions (Fossil and Land-use, historical and SSP5-8.5
- 1% runs with Ndeposition
  - Ndeposition forcing (generated by C4MIP)
- Historical run
  - Atmospheric isotopic composition (13C and 14C) will be provided.

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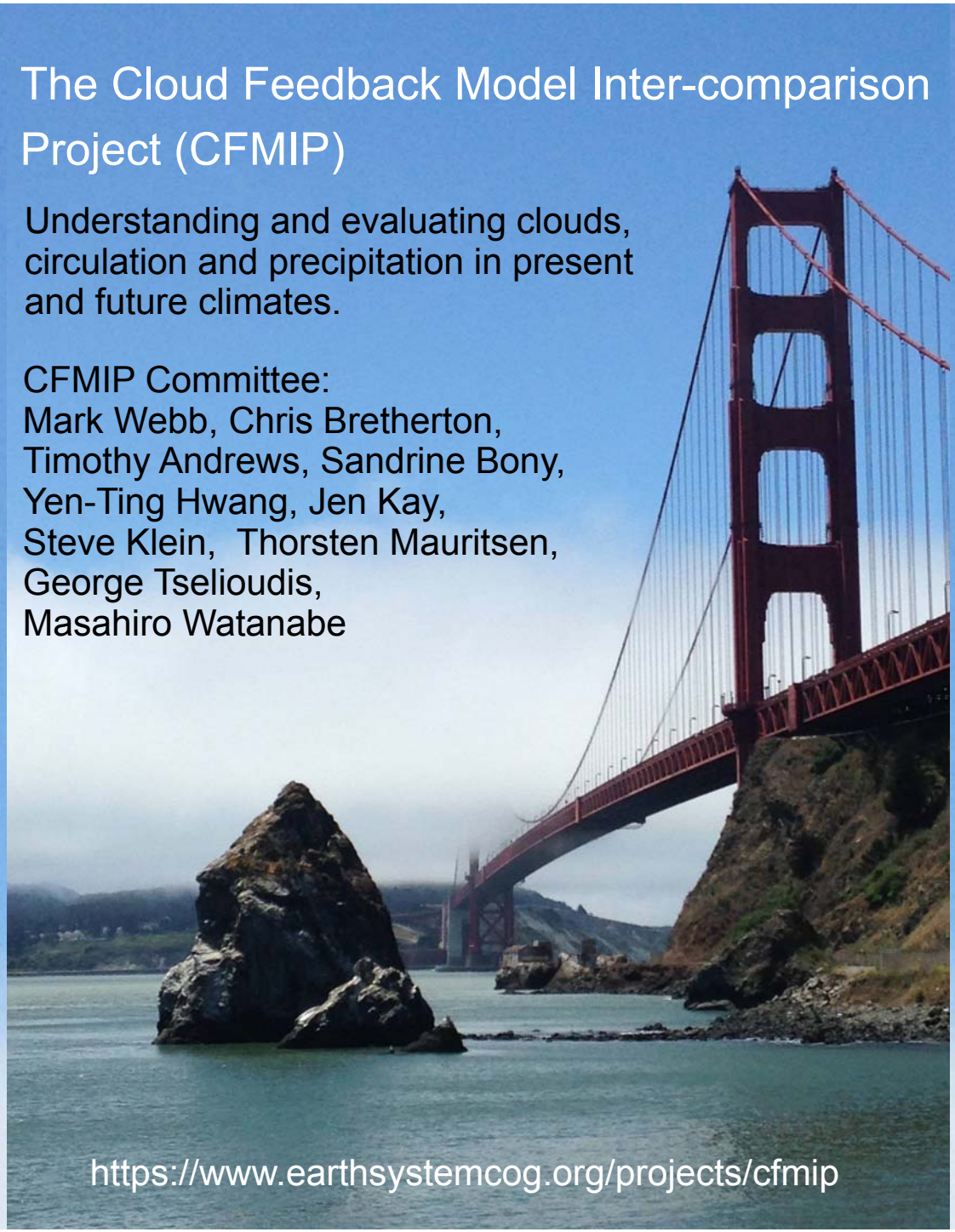
C4MIP data request

- Need to check with Martin Juckes

The Cloud Feedback Model Inter-comparison Project (CFMIP)

Understanding and evaluating clouds, circulation and precipitation in present and future climates.

CFMIP Committee:
Mark Webb, Chris Bretherton, Timothy Andrews, Sandrine Bony, Yen-Ting Hwang, Jen Kay, Steve Klein, Thorsten Mauritsen, George Tselioudis, Masahiro Watanabe



https://www.earthsystemcog.org/projects/cfmip

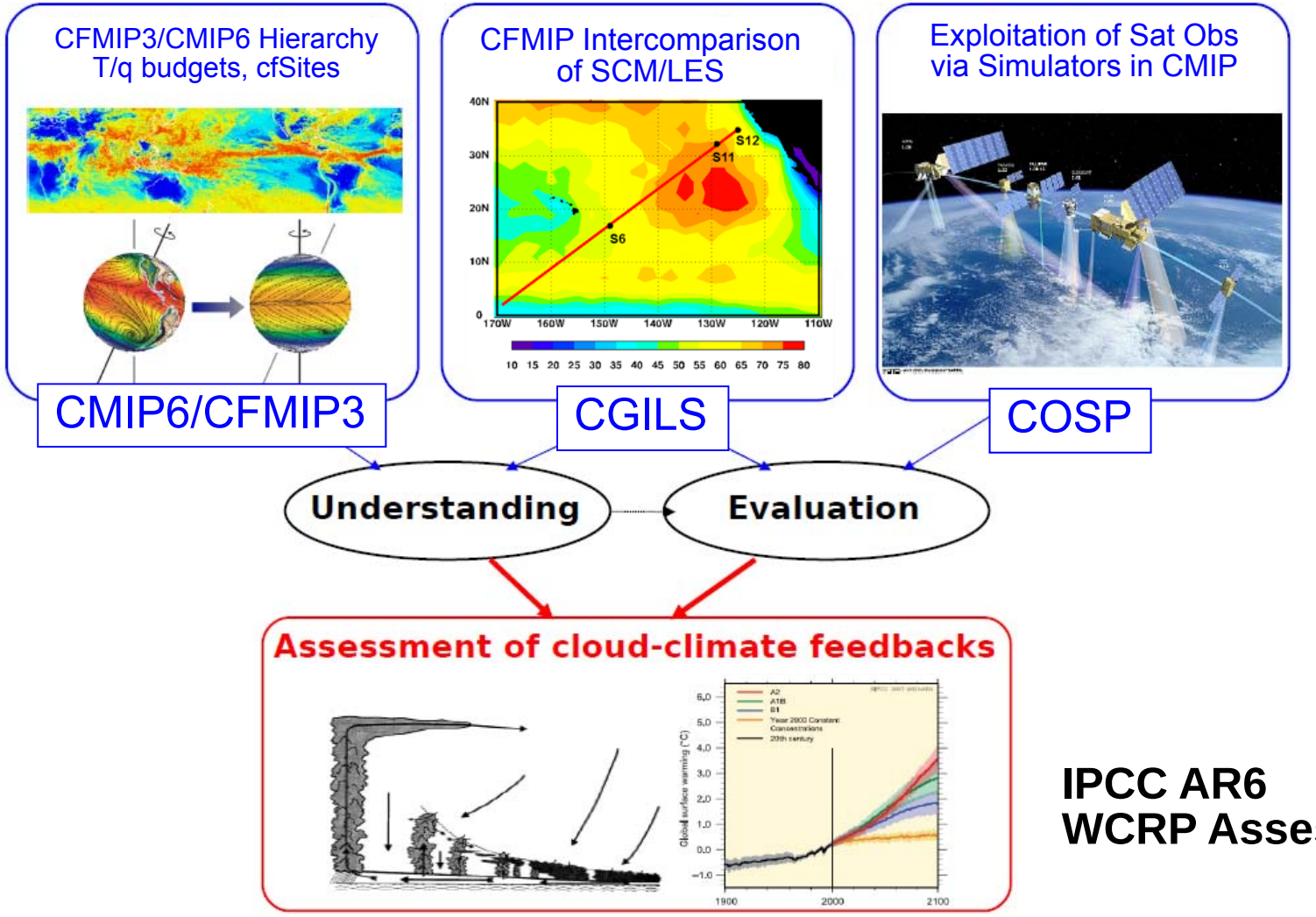
CFMIP/CMIP6 Status

- The CFMIP/CMIP6 experimental design is finalised and documented in the GMDD paper: http://www.geosci-model-dev-discuss.net/gmd-2016-70/
- The paper is accepted for publication in GMD as of 1st Nov 2016.
- The CFMIP submission to the data request was made in good time and is in good shape. Minor queries are coming up occasionally but are being addressed.
- CMIP6 release 1.4 of the CFMIP Observational Simulator Package (COSP) was released Nov 2013. A patch (1.4.1) is now available to allow some additional MODIS simulator outputs (optional).
- Modelling groups are making preparations to participate. Currently 20 models/groups have expressed interest:

  ACCESS, BCC, CAMS-CSM, CanESM, CESM, CESS-THU, CNRM, EC-Earth, FGOALS, GFDL, GISS, INM, IPSL, MIROC6-CGCM,NICAM, MPI-ESM, MRI-ESM1.x, NorESM, HadGEM3

Cloud Feedback Model Inter-comparison Project

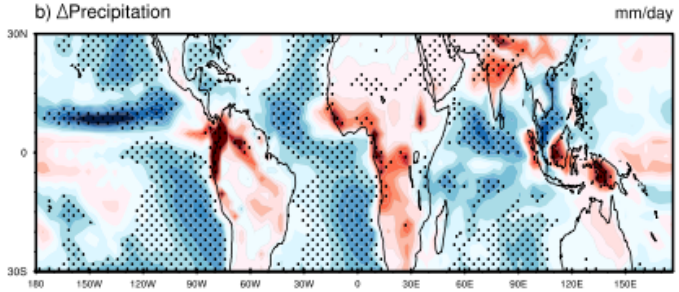
Objective 1: Inform improved assessments of climate change cloud feedbacks by:
a) improving our understanding of cloud-climate feedback mechanisms.
b) improving evaluation of clouds and cloud feedbacks in climate models.



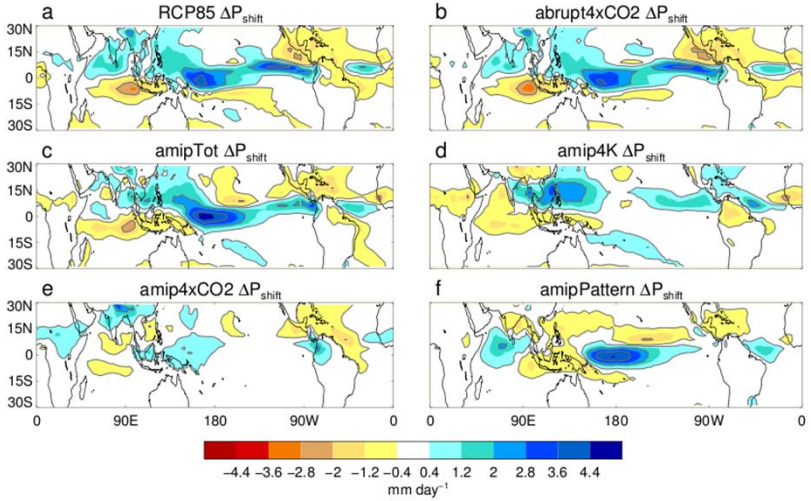
IPCC AR6
WCRP Assessment

Cloud Feedback Model Inter-comparison Project

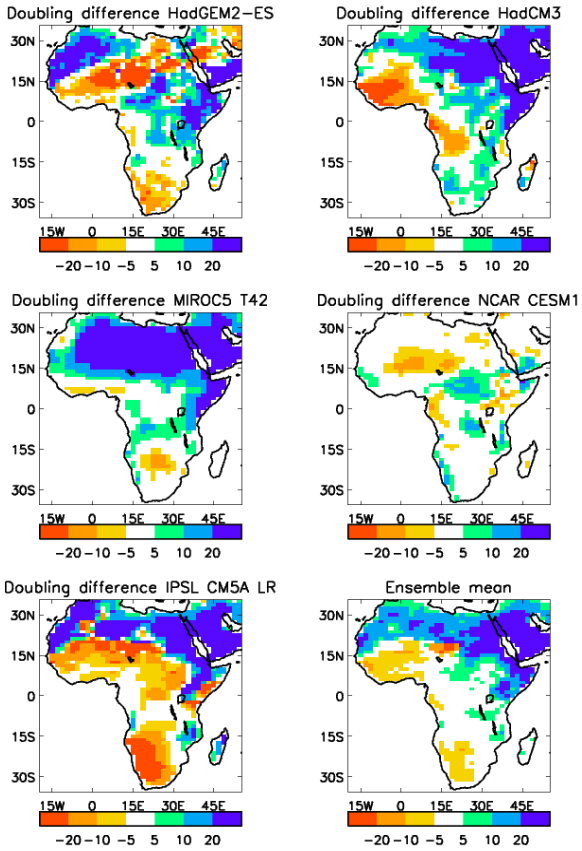
Objective 2: Use the CFMIP experimental hierarchy and process diagnostics to better understand other aspects of the climate response, such as changes in circulation, regional-scale precipitation and non-linear change.



Precipitation impact of PBL radiative effects: Fermepin and Bony 2014

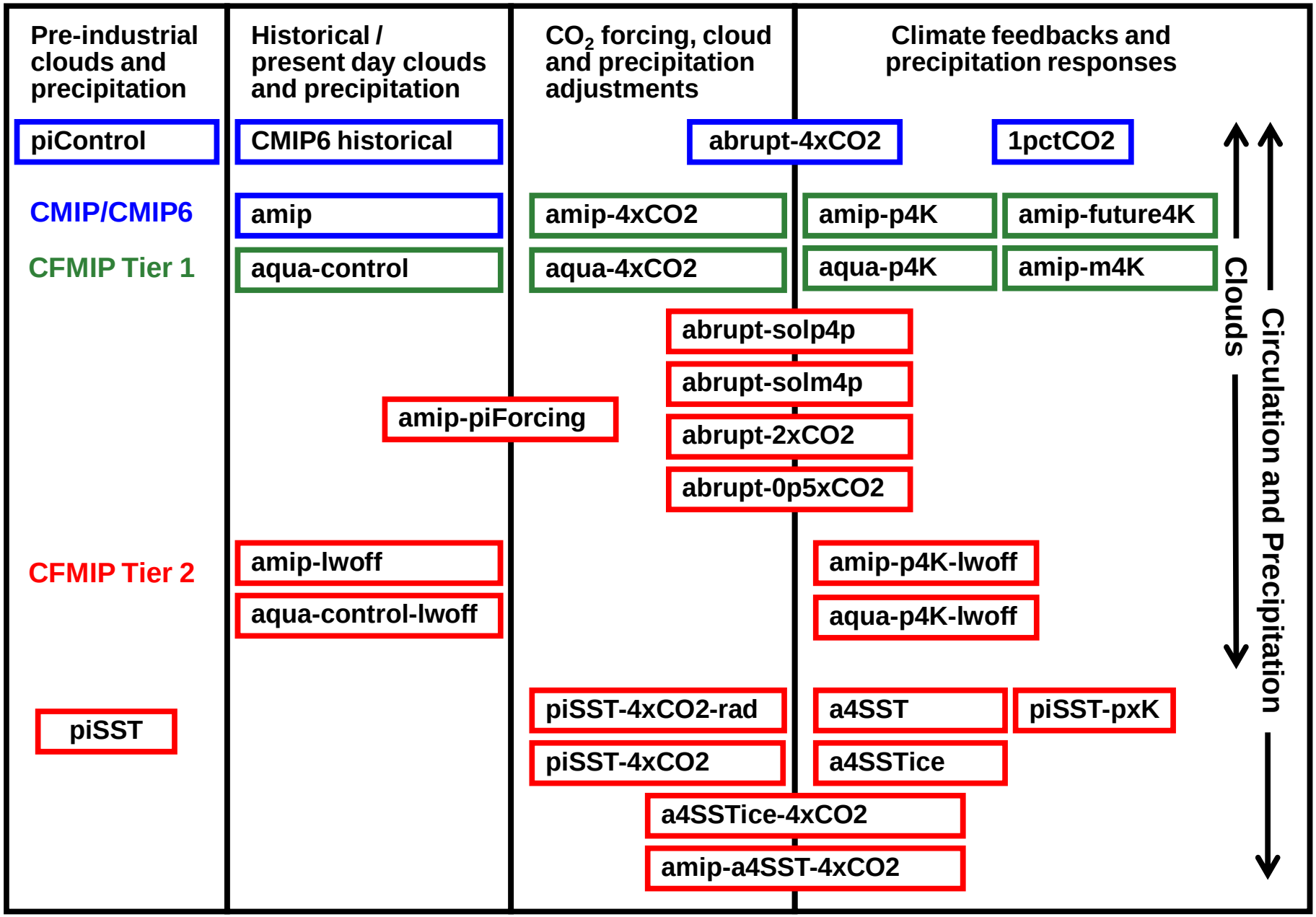


Precipitation response to CO_2 and SST pattern changes: Chadwick 2016

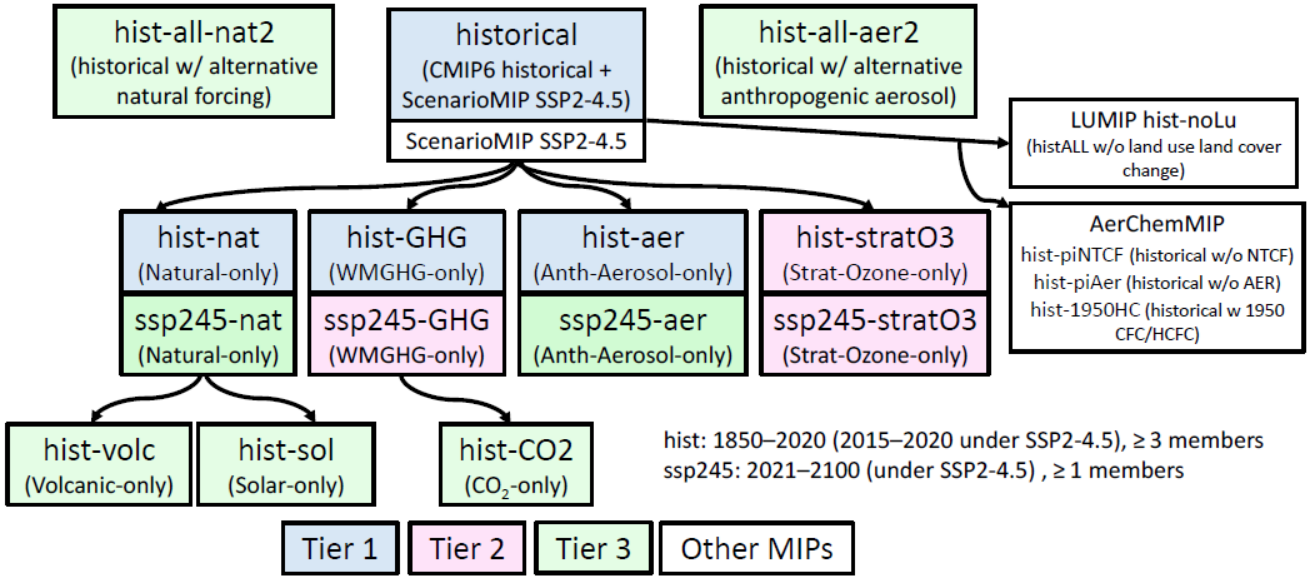


Effect of second doubling of CO2 on precipitation over Africa: Good et al. 2016 (NonLinMIP)

CFMIP CMIP6 Experiment Summary



Detection and Attribution MIP (DAMIP)



- GMD paper describing DAMIP now published (Gillett et al., 2016, http://www.geosci-model-dev.net/9/3685/2016/)
- Most simulations can begin as soon as CMIP6 historical and SSP2-4.5 forcings are available.
- Ongoing discussions with forcing groups to finalise hist-stratO3, ssp245-stratO3, hist-all-nat2 and hist-all-aer2 forcings.

The Decadal Climate Prediction Project

Overview

The term 'decadal prediction' encompasses predictions on annual, multi-annual to decadal timescales. The potential to make skillful forecasts on these timescales, and the ability to do so, is investigated by means of predictability studies and retrospective forecasts (termed hindcasts) using climate models and statistical approaches. Predictability and prediction studies have focused largely on temperature, and there is evidence of skill in the prediction of variations in annual means of temperature over much of the globe for several years, conditional on the initialization of the forecasts. As the forecast range increases initialized skill decreases but some skill is maintained due to external forcing from greenhouse gases, aerosols and volcanoes. There is currently less skill in predicting precipitation and other variables compared to temperature although progress is expected to be made as a consequence of the Decadal Climate Prediction Project (DCPP) and other projects and investigations.

Decadal Climate Prediction Project

Back to Modelling Overview

DCPP website is focus for the Project

Experimental Protocol

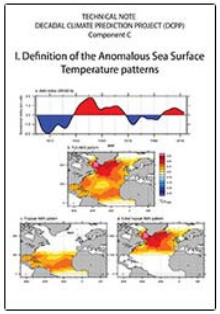
The experimental protocol for the Decadal Climate Prediction Project (DCPP) contribution to CMIP6 is described in detail in Boer et al. (2016). The paper is available here:

Geoscientific Model Development website

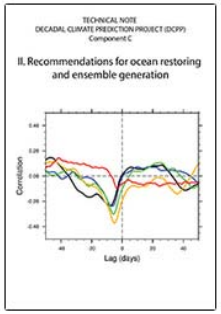
Or click the .pdf thumbnail below to directly access the article.

The Decadal Climate Prediction Project (DCPP) contribution to CMIP6
Geosci. Model Dev., 9, 1–27, 2016

There are two Technical Notes dealing with Component C experiments. They are available here:



I. Definition of the Anomalous Sea Surface Temperature patterns
TECHNICAL NOTE 1, DECADAL CLIMATE PREDICTION PROJECT (DCPP) - Component C



II. Recommendations for ocean restoring and ensemble generation
TECHNICAL NOTE 2, DECADAL CLIMATE PREDICTION PROJECT (DCPP) - Component C

Decadal Climate Prediction Project

Back to Modelling Overview

Some of the experiments in Component C of the DCPP make use of prescribed sea surface temperature (SST) patterns. These data will be available here soon:

- AMV SST data
- PDV SST data
- Pacemaker SST data

The CMIP6 Panel is coordinating the production of forcing datasets and the output data request. See the CMIP6 webpage for these links.

Questions and comments concerning the DCPP may be conveyed via the Decadal Climate Prediction Project (DCPP) Participant Forum.

Protocol and links

Summary

- First organized multi-model effort in decadal prediction for CMIP5 leads to the DCPP
- Broad interest in decadal variability and prediction across WCRP etc.
- DCPP proposed, adopts CMIP6 infrastructure, and becomes “endorsed” component
- Grand Challenge approved by JSC
- Active aspects for the DCPP component via CMIP6:
  - forcing specifications
  - finalize data treatment
  - foster participation and analysis
  - interaction via Forum
- DCPP website for specifications, interactions ….

Flux-anomaly-forced model intercomparison project (FAFMIP)

Steering committee: Jonathan Gregory (U Reading and Met Office), Stephen Griffies (GFDL), Detlef Stammer (U Hamburg), Oleg Saenko (CCCma), Johann Jungclaus (MPI)

The goal is to account for the spread in simulated ocean response to changes in surface fluxes resulting from CO_2 forcing, particularly the uncertainties in global ocean heat uptake and geographical patterns of sea-level change due to ocean density and circulation change.

Ten CMIP6 groups intend to participate. Several have indicated that they will run the experiments during 2017. We plan to hold a meeting at GFDL on 17-18 July 2017; the previous week a WCRP sea-level conference will take place in NYC.

The experimental design has been decided (though further additions might be made in the light of CMIP6 results). It requires 3x70 years of integration in tier-1, fairly minor code changes to A-O coupling, and the implementation of ocean process-based diagnostics.

The design has been tested by five groups using pre-CMIP5 AOGCMs. Some results of these experiments are described in the GMD paper on FAFMIP, which is now in press.

GeoMIP Status

- 36 peer-reviewed publications to date.
- Experiment description paper is published. Experiment descriptions and data requests are completed.
- Awaiting new versions of models and simulations of base scenarios (DECK and ScenarioMIP) to be completed.
- In the meantime, analysis of old simulations (CMIP5 output) is ongoing. Newly proposed simulations involving one or two models are progressing. These simulations will inform which experiments are included in future versions of GeoMIP.

Contact: Ben Kravitz (ben.kravitz@pnnl.gov) or Alan Robock (robock@envsci.rutgers.edu)

Status of GMMIP for CMIP6

Tianjun Zhou, Andy Turner, James Kinter III

The experiment design is finalized

- Tier-1: the SST forcing data is fixed to be HadISST.
- Tier-2: consistent with DCPP in SST nudging/restoring technique
- Tier-3: the design of orography sensitivity exp is fixed.

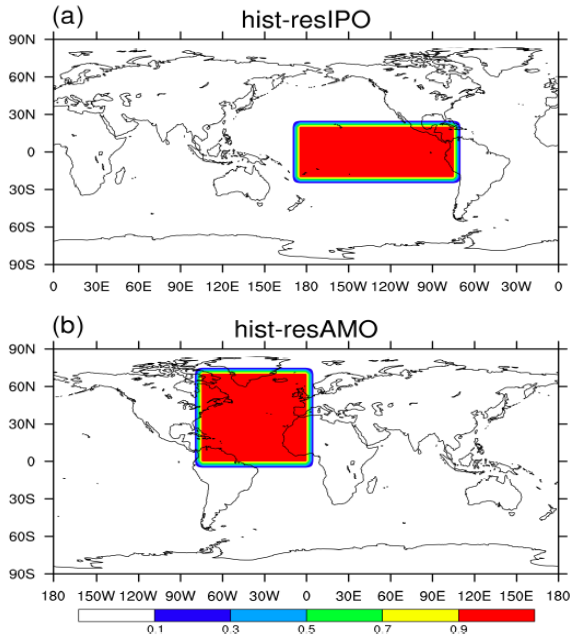


Figure 4. The restoring regions for tier-2 experiments **(a)** hist-resIPO and **(b)** hist-resAMO.

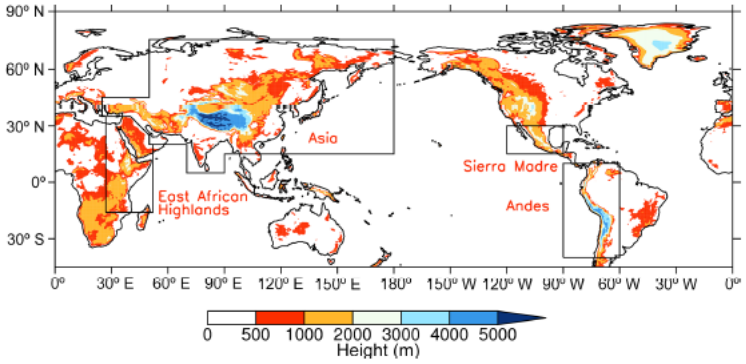


Figure 5. The orography regions specified for the tier-3 experiments for the Asia region (comprising the Tibetan–Iranian Plateau and Himalayas), the East African Highlands (adapted from Slingo et al., 2005), the Andes and Sierra Madre. Within each marked region, orography would be capped at 500 m height. Orographic data derived from a ∼30 km resolution (N512) boundary field of the Met Office HadGEM3 model.

The GMMIP paper is published in GMD

Geosci. Model Dev., 9, 3589–3604, 2016
www.geosci-model-dev.net/9/3589/2016/
doi:10.5194/gmd-9-3589-2016

Geoscientific Model Development Open Access EGU

GMMIP (v1.0) contribution to CMIP6: Global Monsoons Model Inter-comparison Project

Tianjun Zhou[1], Andrew G. Turner[2], James L. Kinter[3], Bin Wang[4], Yun Qian[5], Xiaolong Chen[1], Bo Wu[1], Bin Wang[1], Bo Liu[1,6], Liwei Zou[1], and Bian He[1]

[1]LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China
[2]NCAS-Climate and Department of Meteorology, University of Reading, Reading, UK
[3]Center for Ocean-Land-Atmosphere Studies & Dept. of Atmospheric, Oceanic & Earth Sciences, George Mason University, Fairfax, Virginia, USA
[4]Department of Meteorology, School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, Honolulu, Hawaii, USA
[5]Atmospheric Sciences & Global Change Division, Pacific Northwest National Laboratory, Richland, Washington, USA
[6]College of Earth Science, Graduate University of the Chinese Academy of Sciences, Beijing 100049, China

Correspondence to: Tianjun Zhou (zhoutj@lasg.iap.ac.cn)

Received: 30 March 2016 – Published in Geosci. Model Dev. Discuss.: 11 April 2016
Revised: 3 September 2016 – Accepted: 14 September 2016 – Published: 10 October 2016

Scientific Steering Committee, Working Groups and Funding

- On 17 September, the CLIVAR/GEWEX Monsoons Panel (MP) meeting was held in Qingdao, China.
- The progress of GMMIP has been reported.
- A Scientific Steering Committee of GMMIP will be established with the support from the MP.
- There are three working groups in CLIVAR/GEWEX MP, viz. Asian-Australian monsoon working group, African monsoon working group, and American monsoon working group. The analysis of GMMIP data will be coordinated by these three existing working groups.
- 3M RMB (~450K USD) funding from Chinese Academy of Sciences.

Coordinated analysis with other MIPs is under discussion

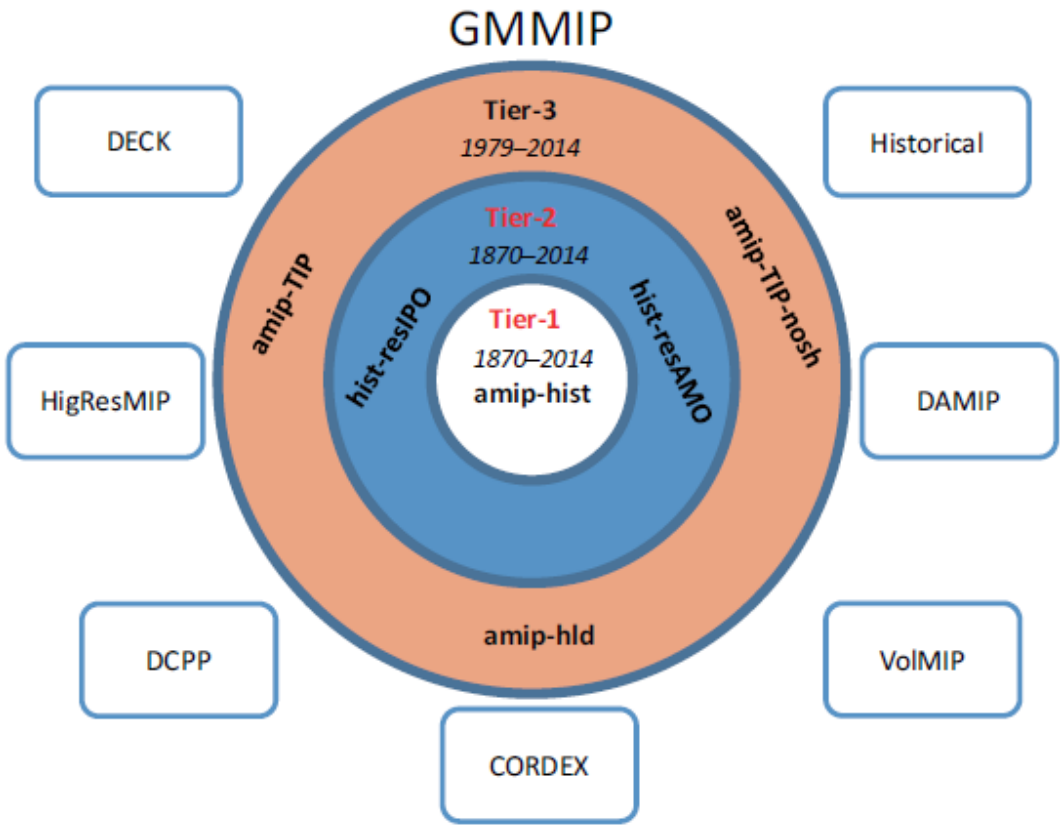


Figure 3. Three-tier experiments of GMMIP and its connections with DECK, historical simulation and endorsed MIPs.

HighResMIP

Rein Haarsma (KNMI) and Malcolm Roberts (Met Office)

HighResMIP protocol. Three Tiers

- Tier 1: AMIP 1950-2014
- Tier 2: COUPLED 1950-2050
- Tier 3: AMIP 2015-2050 (2100)

Motivation of these three Tiers

- Focus of HighResMIP is on the 1950-2050 period (Tier 2). This period includes significant past changes and the time horizon for the future is relevant for decision makers.

- The division of the AMIP runs in Tier 1 and Tier 2 is to enable that NWP centers can participate. Also to open the possibility for end of the century simulations .

2xresolution: Standard: Atmosphere ~100km km; Ocean ~1 degree
High: Atmosphere 20-50 km; Ocean ~0.25 degree

HighResMIP

Rein Haarsma (KNMI) and Malcolm Roberts (Met Office)

- Protocol paper accepted Oct 2016: Haarsma et al, 2016, GMD.
- All required forcing data now available
    - some MIP-specific datasets still need to be uploaded to PCMDI – e.g. daily, ¼˚ SST, sea-ice
- 6 European groups close to starting simulations
    - all part of EU-PRIMAVERA project
    - will start by the end of 2016
    - several international partners have obtained our forcing data and are close to starting
- Town Hall meeting convened at CLIVAR Open Science in Qingdao, Sept 2016
    - discussion about number of ensemble members, concern about data request and data volumes
    - making some links with CLIVAR panels – Dynamics, Atlantic and Southern Ocean all interested in HighResMIP output
        - working to coordinate analysis plans and early data access

HighResMIP

Rein Haarsma (KNMI) and Malcolm Roberts (Met Office)

Issues to raise

- Data volumes and enabling coordinated analysis
  - Volumes from HighResMIP (and CMIP6 more generally) becoming huge (many PetaBytes)
  - Impractical to download multiple ensemble members to local machine (even for DECK?)
  - How can we best enable data sharing and effective analysis
    - PRIMAVERA will use the CEDA JASMIN platform – from which the CMIP6 ESGF node is directly accessible
    - Central project platform for analysis
    - Intend to enable access for other international partners/collaborators (via mechanism being developed)
    - What is the international strategy – what prospects are there of equivalent platforms elsewhere?

Ice Sheet Model Intercomparison Project for CMIP6

Steering committee: S. Nowicki (USA), T. Payne (UK), E. Larour (USA), A. Abe Ouchi (JP), H. Goelzer (BE), J. Gregory (UK), W. Lipscomb (USA), H. Seroussi (USA), A. Shepherd (UK)

- ISMIP6 is a targeted activity of CliC and addresses the WCRP Grand Challenges *Melting ice and global consequence* and *Regional sea-level change and coastal impacts.*
- Primary goal: to estimate past and future sea-level contributions from the Greenland and Antarctic ice sheets, along with associated uncertainty.
- Secondary goal: to investigate feedbacks due to dynamic coupling between ice sheet and climate models, and impact of ice sheets on the Earth system.
- Experimental design uses and augments the existing CMIP6 experiments, with simulations for coupled AOGCM-ISMs and ISMs. The protocols are described in the CMIP6 GMD special issues.

Ice Sheet Model Intercomparison Project for CMIP6

More information:
http://www.climate-cryosphere.org/activities/targeted/ismip6

Since its start in summer 2014, ISMIP6 has organized 7 meetings, to promote community building:

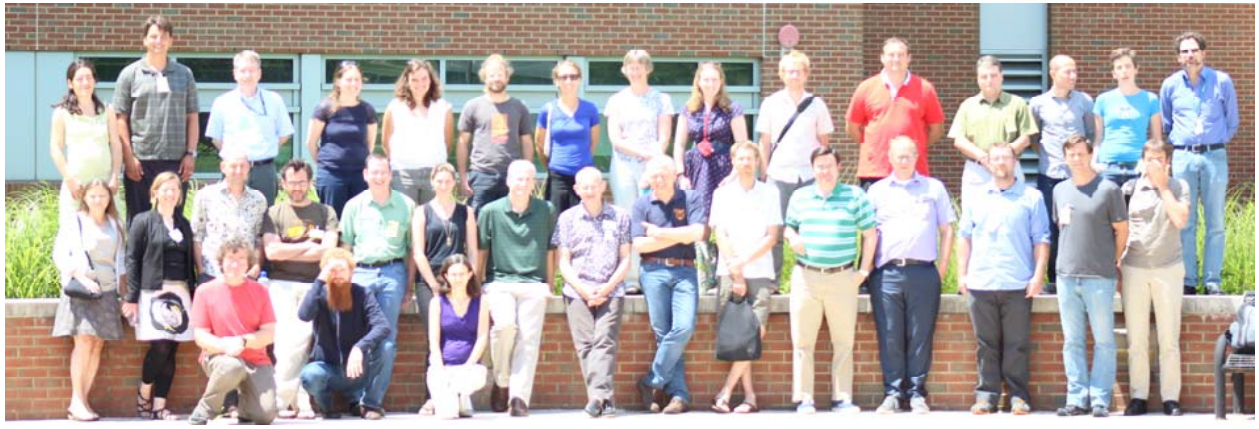
- Within ice sheet modeling
- Between ice sheet and climate modeling
- Between modelers and observationalists
- Connections with many community efforts, for example, ice-ocean (MISOMIP)

Participating Climate Modeling Centers:

CanESM (CA)
CESM (USA)
CNRM-CM (FR)
EC-Earth (SWE + 9EU)
GISS (USA)
INM (RU)
IPSL (FR)
MIROC-ESM (JP)
MPI-ESM (DE)
UKESM (UK)

Participating Ice Sheet Models (and hopefully more):

BISICLES (UK)
CISM (USA)
Elmer/ICE (FI + FR + JP)
f.ETISH (BE)
GISM (BE)
GRISLI (FR)
IcIES (JP)
IMAUICE (NL)
ISSM (USA, DE)
MPAS-Land Ice (USA)
PennState (USA)
PISM (USA, NZ, DE, DK)
PISM-PIK (DE)
SICOPOLIS (JP)
Ua (UK)
WAVI (UK)



CliC Climate and Cryosphere

ISMIP6 Ice Sheet Model Intercomparison Project for CMIP6

Current modeling activity, initMIP, targets standalone ice sheet models

- Goal 1: Understand impact of initialization method on ice sheet evolution and sea level projection
- Goal 2: Get ISM community ready for ISMIP6 projections (ie: file format, variable request, output grid…)
- initMIP Greenland: 15 different groups, 20 different initializations, results are being analysed
- initMIP Antarctica: launched in september 2016

Wiki: http://www.climate-cryosphere.org/wiki/index.php?title=InitMIP

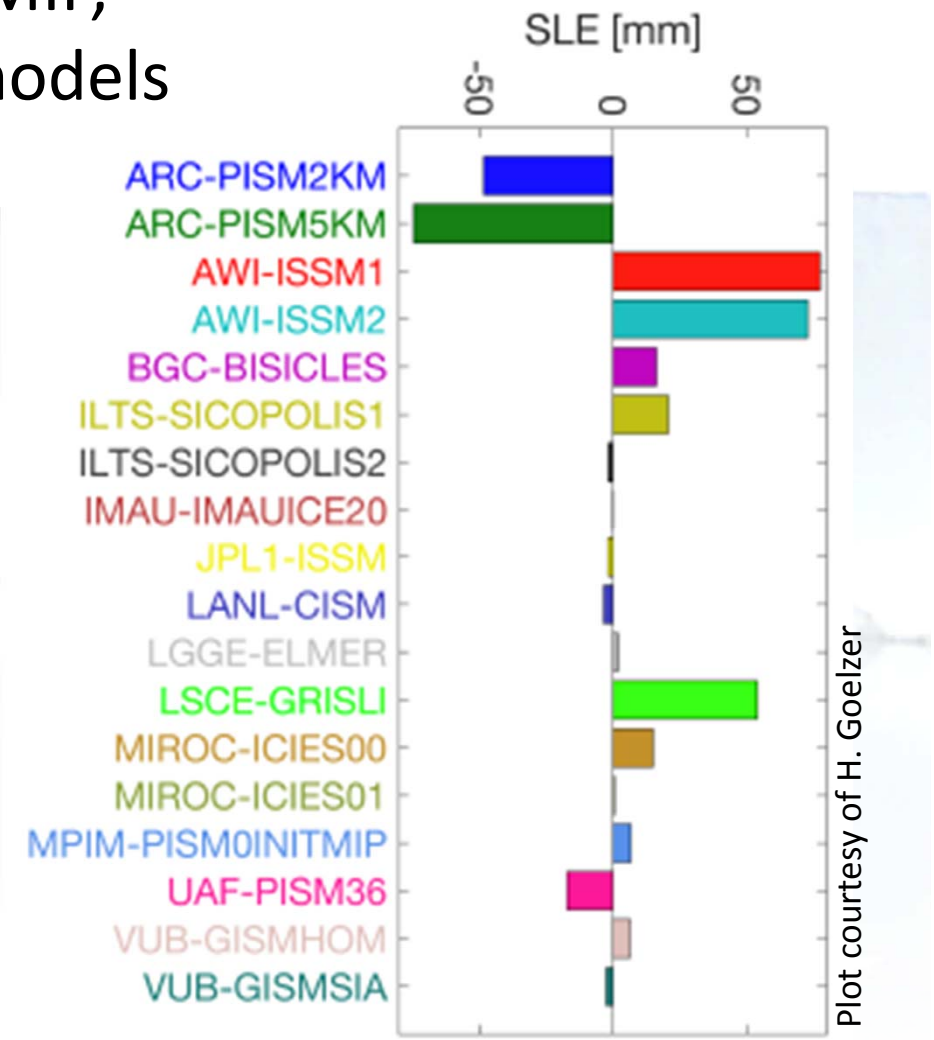


Fig: Centennial sea level background trend in control experiment due to model drift or transient initialization for the Greenland ice sheet.

Ice Sheet Model Intercomparison Project for CMIP6

Layout of LS3MIP

Bart van den Hurk (hurkvd@knmi.nl)
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Sonia Seneviratne (sonia.seneviratne@ethz.ch)
Chris Derksen (Chris.Derksen@ec.gc.ca)
Taikan Oki (taikan@iis.u-tokyo.ac.jp)
Hyungjun Kim (hjkim@rainbow.iis.u-tokyo.ac.jp)

Recently published

Geosci. Model Dev., 9, 2809–2832, 2016
www.geosci-model-dev.net/9/2809/2016/
doi:10.5194/gmd-9-2809-2016

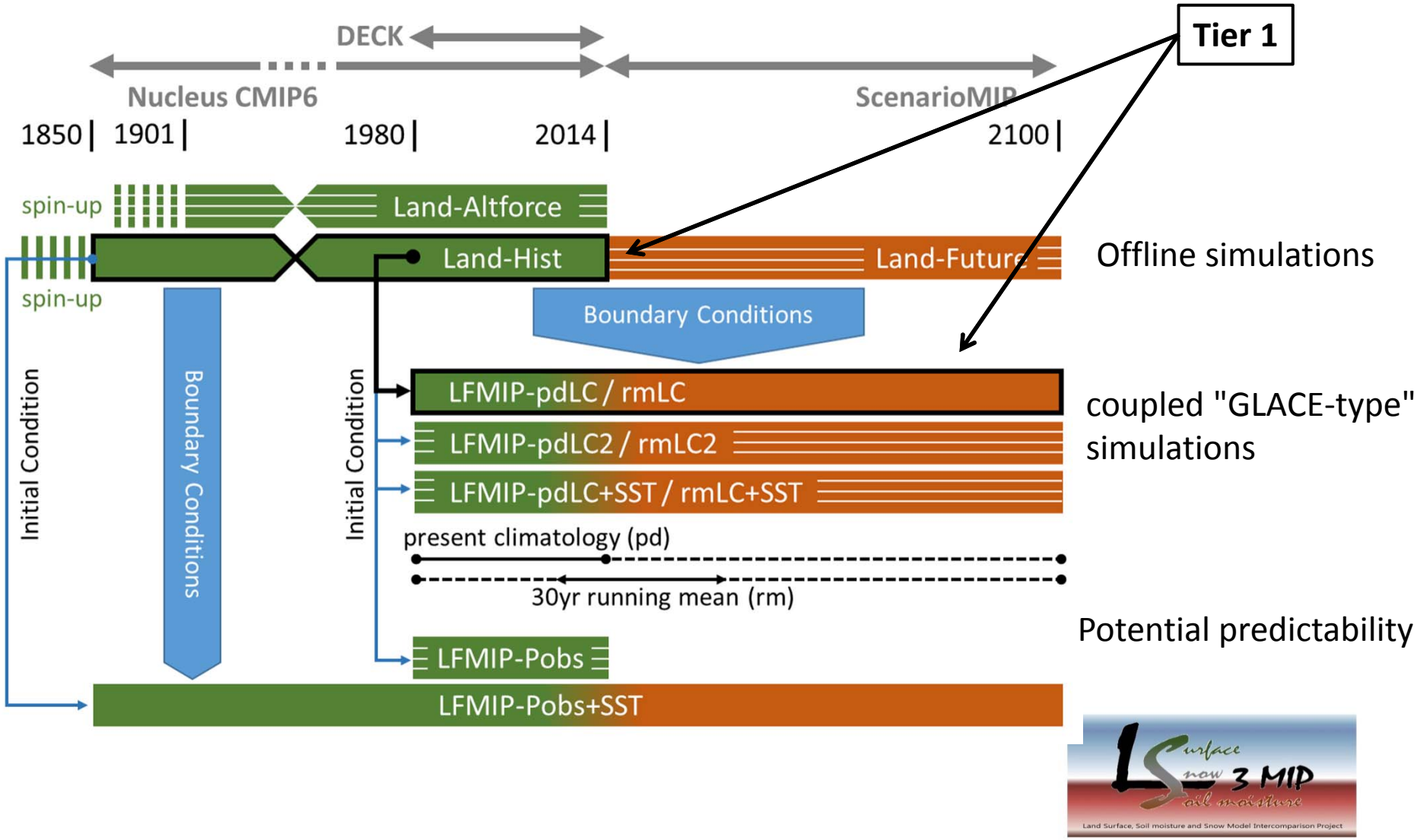
Geoscientific Model Development
Open Access
EGU

LS3MIP (v1.0) contribution to CMIP6: the Land Surface, Snow and Soil moisture Model Intercomparison Project – aims, setup and expected outcome

Bart van den Hurk[1], Hyungjun Kim[2], Gerhard Krinner[3], Sonia I. Seneviratne[4], Chris Derksen[5], Taikan Oki[2], Hervé Douville[6], Jeanne Colin[6], Agnès Ducharne[24], Frederique Cheruy[7], Nicholas Viovy[8], Michael J. Puma[9], Yoshihide Wada[10], Weiping Li[11], Binghao Jia[12], Andrea Alessandri[13], Dave M. Lawrence[14], Graham P. Weedon[15], Richard Ellis[16], Stefan Hagemann[17], Jiafu Mao[18], Mark G. Flanner[19], Matteo Zampieri[20], Stefano Materia[20], Rachel M. Law[21], and Justin Sheffield[22,23]

[1]KNMI, De Bilt, the Netherlands
[2]Institute of Industrial Science, the University of Tokyo, Tokyo, Japan
[3]LGGE, CNRS, Grenoble, France
[4]Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland
[5]Climate Research Division, Environment and Climate Change, Toronto, Canada

Experimental overview



Participants

- ACCESS
- BCC-CSM2-MR
- CanESM
- CESM
- CMCC
- CNRM-CM
- EC-Earth
- FGOALS
- GFDL
- GISS
- IPSL-CM6
- MIROC6-CGCM
- MPI-ESM
- MRI-ESM1.x
- NorESM
- UKESM

Status on LS3MIP

- LMIP
  - status of GSWP3 forcing is being tested in several modelling groups
  - full documentation of forcing still in preparation
  - GLASS panel discussed output list
  - synchronization with OMIP
  - some groups are gearing up
- Overall
  - working group on analysis prioritization formed
  - workshop with LUMIP/ISIMIP/C4MIP planned summer 2018
  - interaction with OMIP on shared data interest

The Land Use Model Intercomparison Project (LUMIP)

Advancing our understanding of the impacts of historic and projected land use in the Earth System

LUMIP
Land Use Change

Chairs: David Lawrence (NCAR) and George Hurtt (Univ of Maryland)

Status

- LUMIP protocol paper published in GMD: September 2, 2016
- LUH2_v2 dataset released: October 14, 2016
- LUMIP Kickoff Webinar: October 26, 2016
- Land-use subgrid tile output:
  - new variables and area_types submitted to CF-convention list
- Communication:
  - website – https://cmip.ucar.edu/lumip
  - Google Group – https://groups.google.com/forum/#!forum/lumip
- Developing protocol to check that land-use trajectory from LUH2 dataset is correctly implemented across models (asking groups to run historic land-only simulations first)

Ocean Model Intercomparison Project (OMIP)

Co-Chairs
Gokhan Danabasoglu (NCAR, USA)
Stephen M. Griffies (NOAA/GFDL, USA)
James Orr (IPSL, France)

Scientific Steering Committee

Physical Processes (CLIVAR Ocean Model Development panel (OMDP) & Collaborators)

C. Boning, E. Chassignet, E. Curchitser, H. Drange, D. Holland, Y. Komuro ,
W. Large, S. Marsland, S. Masina, G. Nurser, A. Pirani, A.-M. Treguier,
H. Tsujino, M. Winton, S. Yeager

Chemical and Biogeochemical Processes

L. Bopp, S. Doney, J. Dunne, F. Joos, G. McKinley, A. Oschlies, T. Tanhua, K. Lindsay

OMIP includes the previously separate Ocean Carbon Model Intercomparison Project (OCMIP). This merging of ocean physical, chemical, and biogeochemical efforts into a single project allows for efficient communication across these communities participating in CMIP6.

OMIP Overview and Scientific Goals

OMIP addresses the CMIP6 science question on investigating the origins and consequences of systematic model biases, by providing a framework for evaluating (including assessment of systematic biases), understanding, and improving ocean, sea-ice, tracer, and biogeochemical components of climate and earth system models contributing to CMIP6.

Among the WCRP Grand Challenges (GCs), OMIP primarily contributes to the regional sea-level rise and near-term (climate / decadal) prediction GCs.

Specifically, OMIP provides a framework:

- To investigate physical, chemical, and biogeochemical mechanisms that drive seasonal, inter-annual, and decadal variability;
- To attribute ocean-climate variations to boundary forced versus natural;
- To evaluate robustness of mechanisms across models and forcing data sets;
- To bridge observations and modeling by complementing ocean reanalysis from data assimilation;
- To provide consistent ocean and sea-ice states useful for initialization of climate (e.g., decadal) predictions.

OMIP

PART I

Diagnostic analysis of CMIP6 ocean components

- Physics
- Inert chemistry
- Biogeochemistry (BGC)

OMIP is independent of any particular CMIPX

PART II

Forced ocean – sea-ice hindcast simulations following the CORE-II protocol

TIER 1 (OMIP-A)

One 310-year simulation forced with the inter-annually varying CORE-II atmospheric datasets for the 1948-2009 period (5 repeat forcing cycles):

Path I: physics + chemistry

Path II: physics + chemistry + BGC

BGC fields are initialized from observations

TIER 2 (OMIP-B)

Same as Path II of Tier 1, except that BGC fields are initialized from spun-up fields

GMD CMIP Special Issue Papers

Geosci. Model Dev., 9, 3231–3296, 2016
www.geosci-model-dev.net/9/3231/2016/
doi:10.5194/gmd-9-3231-2016

OMIP contribution to CMIP6: experimental and diagnostic protocol for the physical component of the Ocean Model Intercomparison Project

PUBLISHED

Stephen M. Griffies[1], Gokhan Danabasoglu[2], Paul J. Durack[3], Alistair J. Adcroft[1], V. Balaji[1], Claus W. Böning[4], Eric P. Chassignet[5], Enrique Curchitser[6], Julie Deshayes[7], Helge Drange[8], Baylor Fox-Kemper[9], Peter J. Gleckler[3], Jonathan M. Gregory[10], Helmuth Haak[11], Robert W. Hallberg[1], Patrick Heimbach[12], Helene T. Hewitt[13], David M. Holland[14], Tatiana Ilyina[11], Johann H. Jungclaus[11], Yoshiki Komuro[15], John P. Krasting[1], William G. Large[2], Simon J. Marsland[16], Simona Masina[17], Trevor J. McDougall[18], A. J. George Nurser[19], James C. Orr[20], Anna Pirani[21], Fangli Qiao[22], Ronald J. Stouffer[1], Karl E. Taylor[3], Anne Marie Treguier[23], Hiroyuki Tsujino[24], Petteri Uotila[25], Maria Valdivieso[26], Qiang Wang[27], Michael Winton[1], and Stephen G. Yeager[2]

IN REVIEW

Geosci. Model Dev. Discuss., doi:10.5194/gmd-2016-155, 2016
Manuscript under review for journal Geosci. Model Dev.
Published: 18 July 2016

Biogeochemical protocols and diagnostics for the CMIP6 Ocean Model Intercomparison Project (OMIP)

James C. Orr[1], Raymond G. Najjar[2], Olivier Aumont[3], Laurent Bopp[1], John L. Bullister[4], Gokhan Danabasoglu[5], Scott C. Doney[6], John P. Dunne[7], Jean-Claude Dutay[1], Heather Graven[8], Stephen M. Griffies[7], Jasmin G. John[7], Fortunat Joos[9], Ingeborg Levin[10], Keith Lindsay[5], Richard J. Matear[11], Galen A. McKinley[12], Anne Mouchet[13,14], Andreas Oschlies[15], Anastasia Romanou[16], Reiner Schlitzer[17], Alessandro Tagliabue[18], Toste Tanhua[15], and Andrew Yool[19]

OMIP Datasets

The OMIP physics and BGC forcing datasets (along with all other CMIP and satellite MIP forcing datasets) will be hosted by the input4MIPs project at PCMDI. The datasets will likely require some formatting to allow the ESGF system to correctly index.

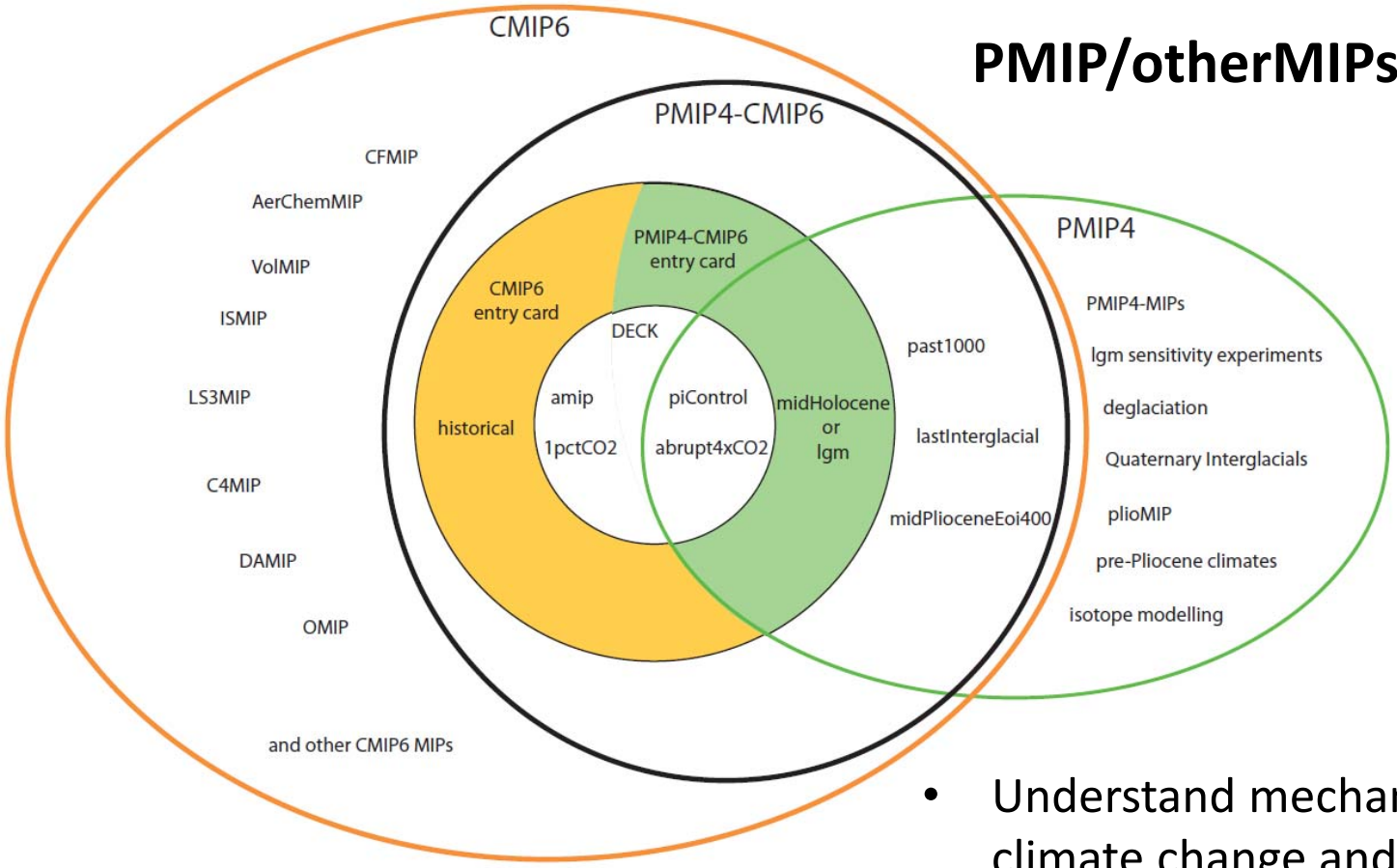
OMIP Diagnostics Spreadsheet

The BGC and chemistry requested variables are currently *in review* by the CF mailing list members – the new variables proposed can be viewed at http://cfeditor.ceda.ac.uk/proposals/1?status=active&namefilter=&proposerfilter=Durack&descfilter=&unitfilter=&yearfilter=&commentfilter=OMIP&filter+and+display=Filter.

The physics sheet requests are waiting review by Alison Pamment before being sent to the CF mailing list for formal review.

OMIP is undertaking this process before submitting requests to Martin. Once the CF review process is finalized, new variables as part of the OMIP-sponsored data request can simply be ingested into Martin's database.

Paleoclimate modeling intercomparison project : what is new in phase 4.



PMIP/otherMIPs in CMIP6

- Understand mechanisms of past climate change and climate feedbacks
- Evaluate the ability of climate models to simulate a climate different from that of today

Proposed experiments for CMIP6

Already in CMIP5 — New in CMIP6 — ★ Entry card

Period	Purpose	Imposed boundary conditions	# of years
Last millennium (850-1850CE)	a) observed variability (multi-decadal and longer time-scales.) b) Internal variability vs external forcing (volc, solar, LU) c) Longer-term perspective for detection and attribution studies	• Solar variations • Volcanic aerosols • Well mixed greenhouse gases • Land use • Orbital parameters	1000 (after spin-up period)
Mid-Holocene (6 kyr ago) ★	a) Comparison to paleodata for a warmer climate in the NH, with enhanced hydrological cycle (monsoons)	• Orbital parameters • Atmospheric concentration of well-mixed greenhouse gases	≥100 (after spin-up period)
Last Glacial Maximum (21 kyr ago) ★	a) Comparison to paleodata for an extreme climate, b) Attempt to provide empirical constraints on global climate sensitivity.	• Ice-sheet and land-sea mask • Greenhouse concentration of well-mixed greenhouse gases • Orbital parameters	≥100 (after spin-up period)
Last Interglacial (126 kyr ago)	a) Model evaluation for warm period, high sea-level stand b) Impacts of smaller ice-sheets/higher sea-level on climate	• Orbital parameters • Greenhouse concentration of well-mixed greenhouse gases	≥100 (after spin-up period)
PlioMIP 3.2 Ma	a) Evaluation of response to long term to CO_2 forcing analogous to that of the modern? b) Impact of smaller ice-sheets, higher-sea-level	• Ice-sheet and land-sea mask, topography (smaller ice-sheets) • Greenhouse concentration of well-mixed greenhouse gases • Orbital parameters	≥100 (after spin-up period)

Present status

Currently: 21 modelling groups, 26 models ; ~600 people on pmip_announce list.

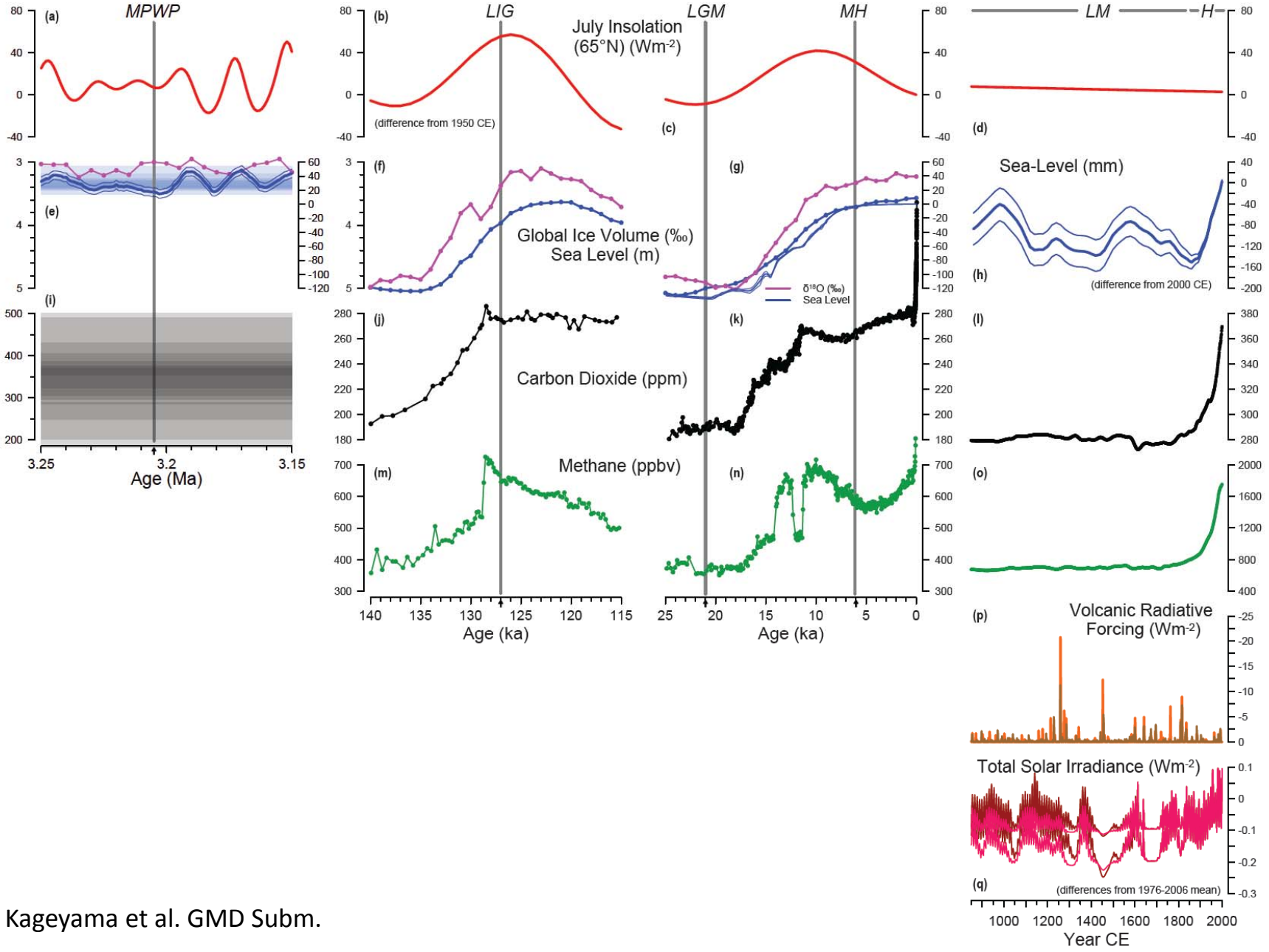
Scientific discussions organised with 11 groups:

- **5 on specific periods (MIPs):** past 2 millenia, Quaternary Interglacials, Mid-Pliocene, Pre-Pliocene climates, Last Glacial Maximum, Deglaciation
- **3 on model-data comparison or proxy-modelling**: isotopic modelling, paleo-data assimilation, ocean model-data comparison, benchmarking
- **2 cross-cutting across periods**: past2future, variability

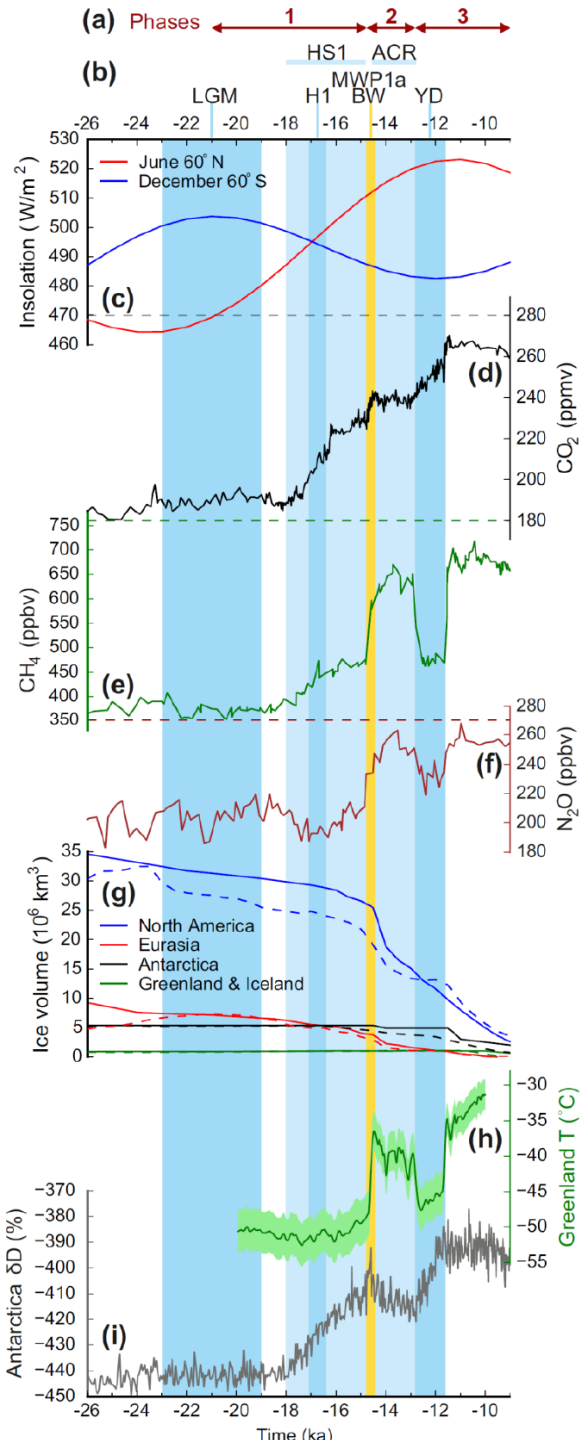
Last year : mostly working on PMIP4 protocols:

- PMIP4-CMIP6 overview paper : Kageyama et al. GMD, in revision
- PlioMIP protocol : Haywood et al. CP, 2016
- MidHolocene-Last Interglacial detailed forcings and rational : Otto-Bliesner et al. submitted
- Last Millennium detailed forcings and rational / Joungclaus et aL., to be submittec
- Last Glacial Maximum uncertainties in forcing and rational : Kageyama et al. to be submitted
- Also deglaciation protocol for PMIP4 : Ivanovic et al, GMD, 2016

Summary of period choice



Kageyama et al. GMD Subm.



The last deglaciation

A new PMIP group
See Ivanovic et al. GMD, sbm.

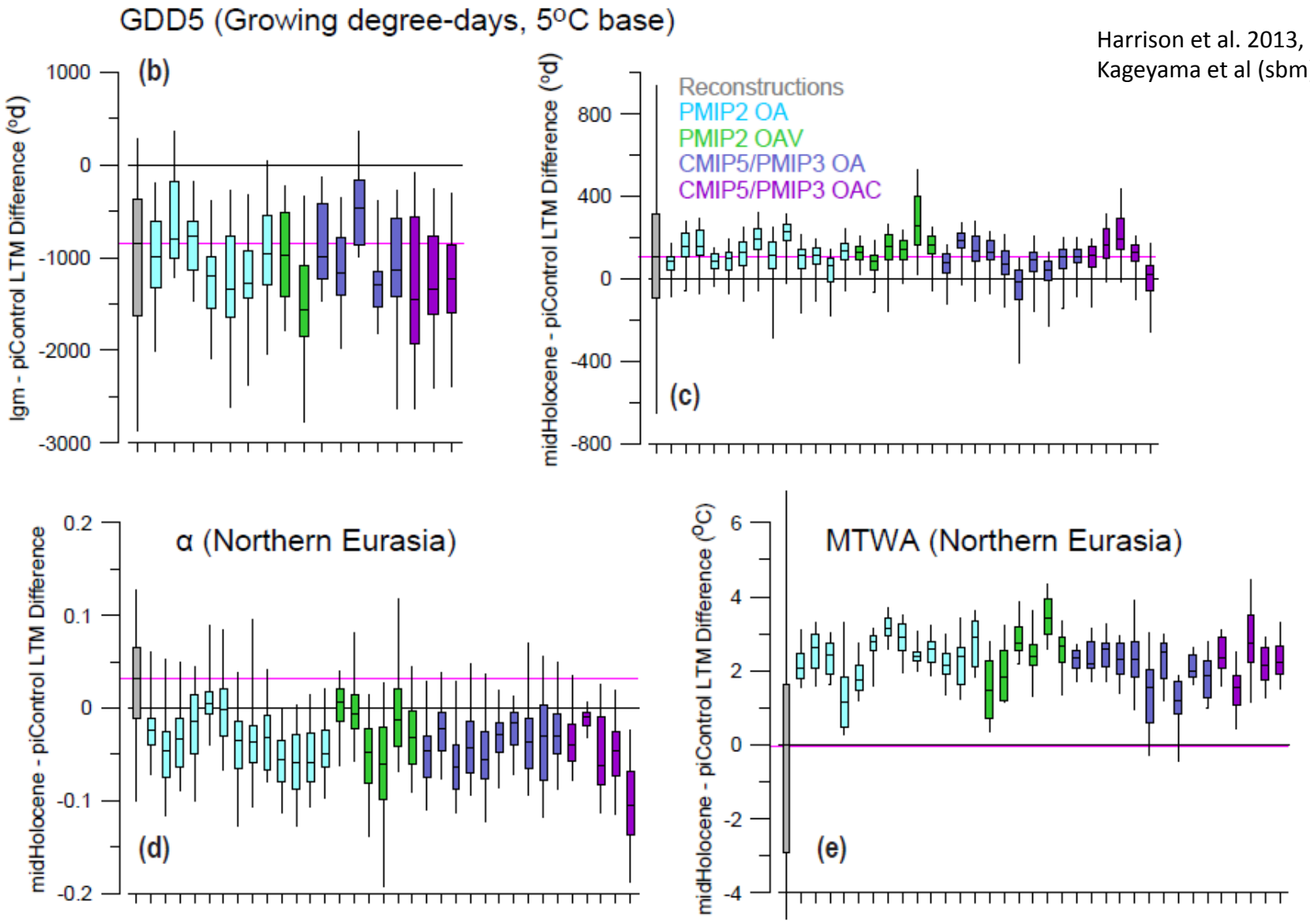
Forcing : insolation, trace gazes, ice-sheets (2 choices)
Initial state : PMIP LGM simulations

Focus on :

- Fresh water fluxes
- Timing of events
- Pace of changes

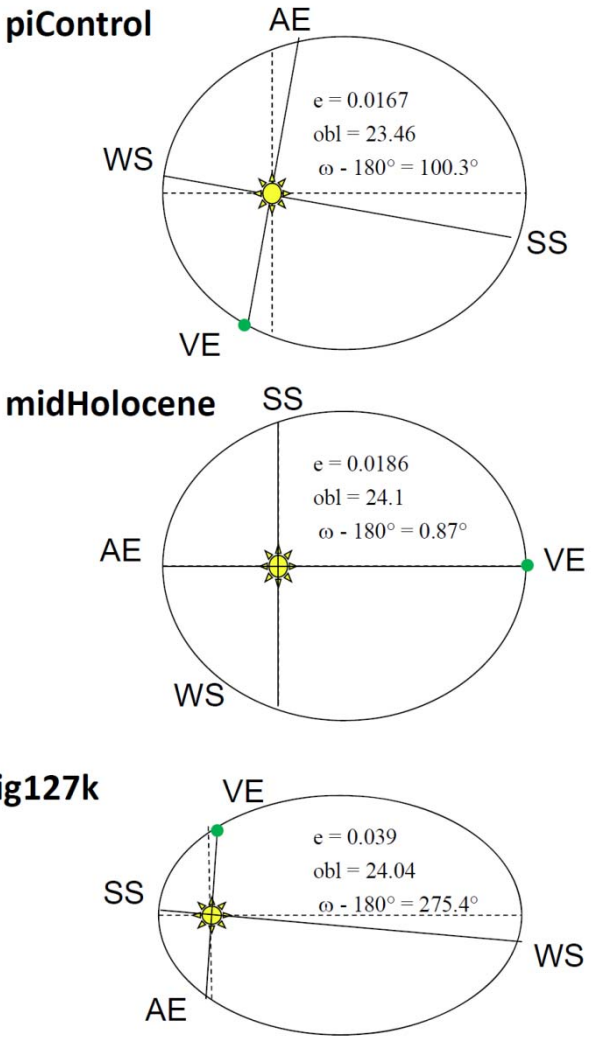
Towards long transient simulations with GCM

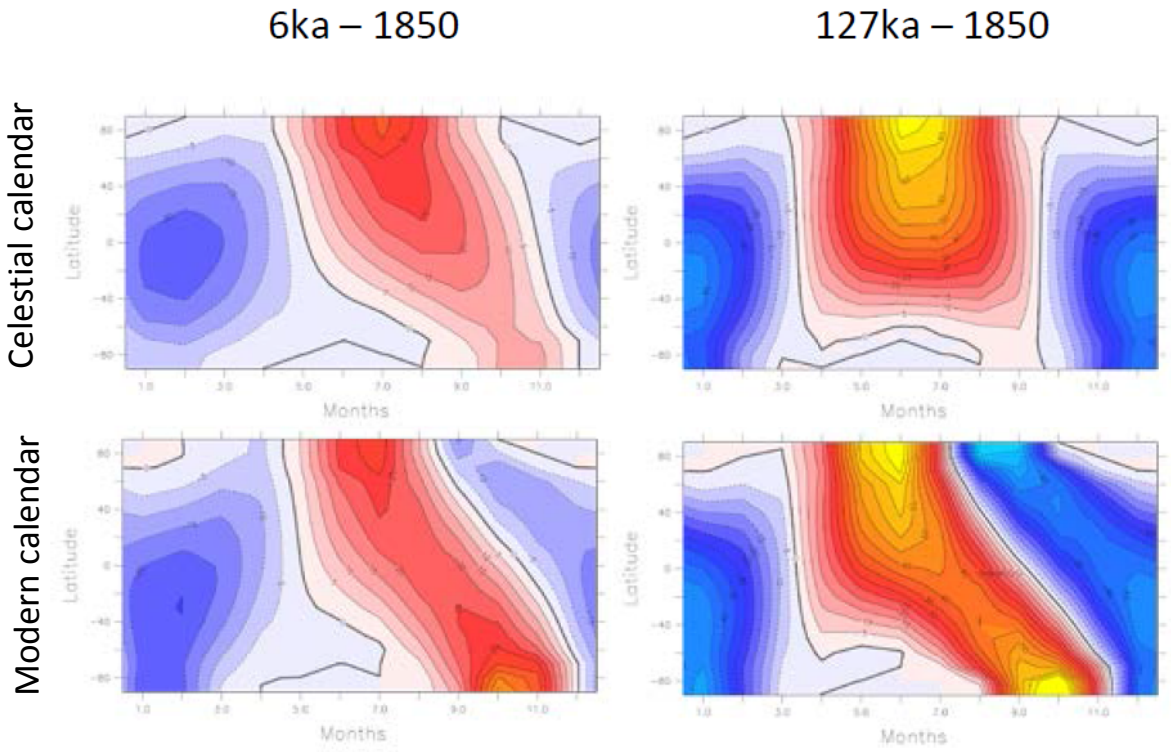
Entry card MH and LGM for systematic evaluation



Harrison et al. 2013, IPCC, 2013
Kageyama et al (sbm)

Insolation : interglacials



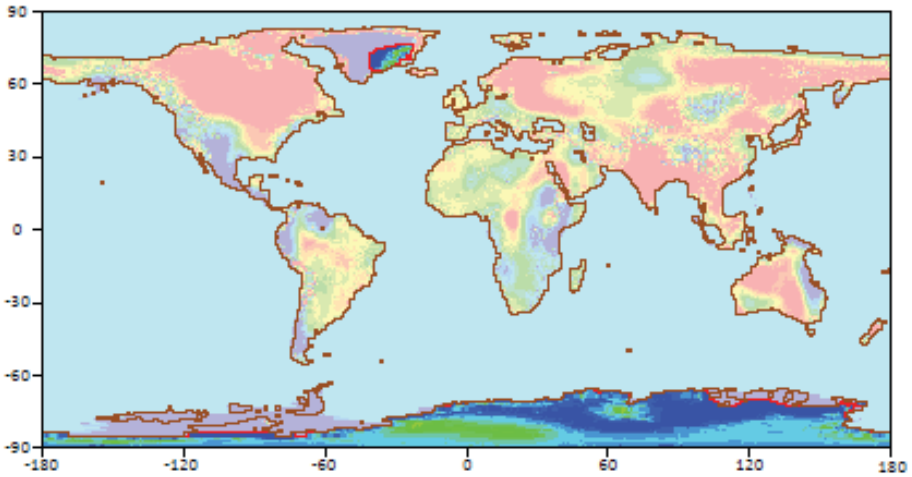


Warming in high latitudes
Increased NH monsoons

Do not forget calendar in mode-data and climate reconstruction from paleo archives

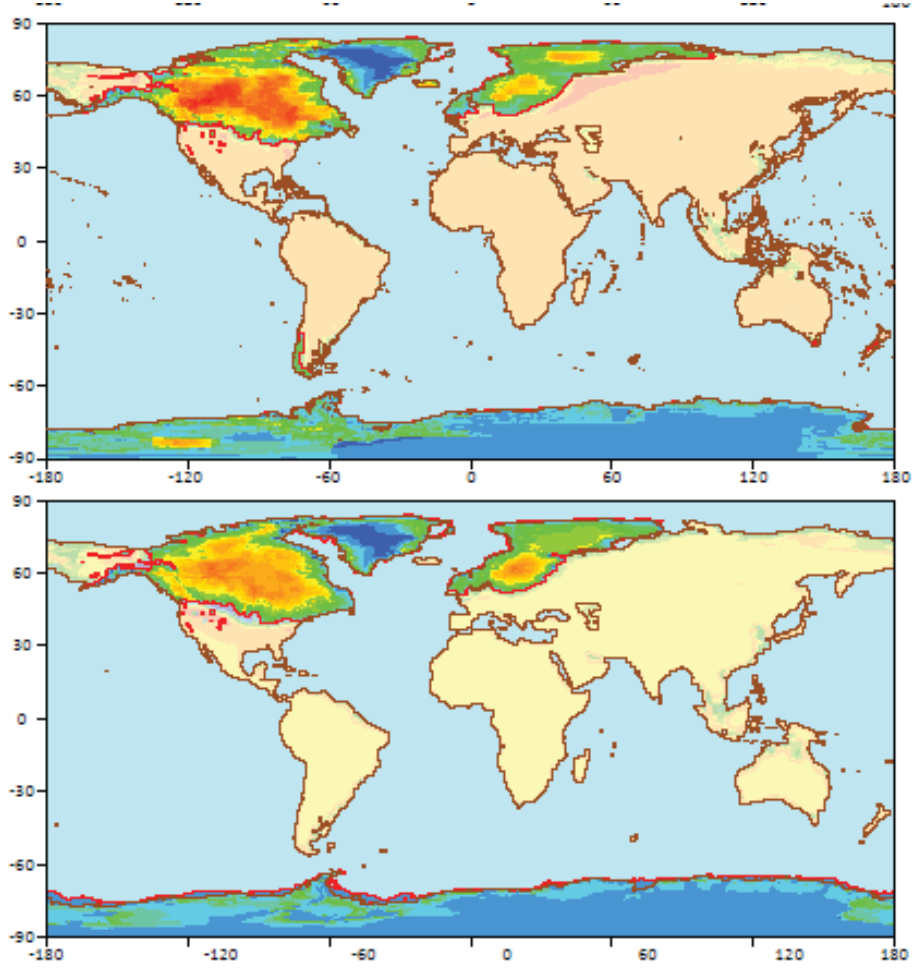
Ice sheet as boundary conditions :

Pliocene : 3.2 Ma

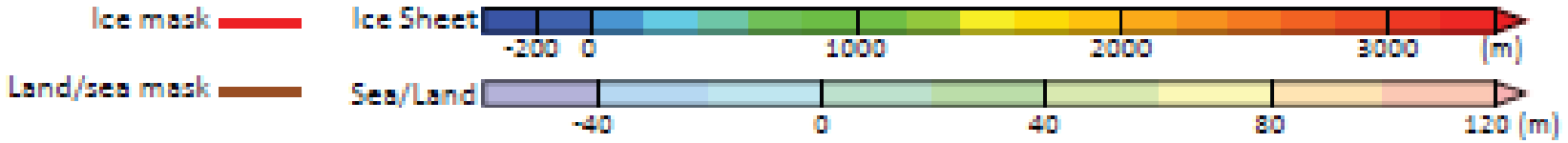


Haywood et al.

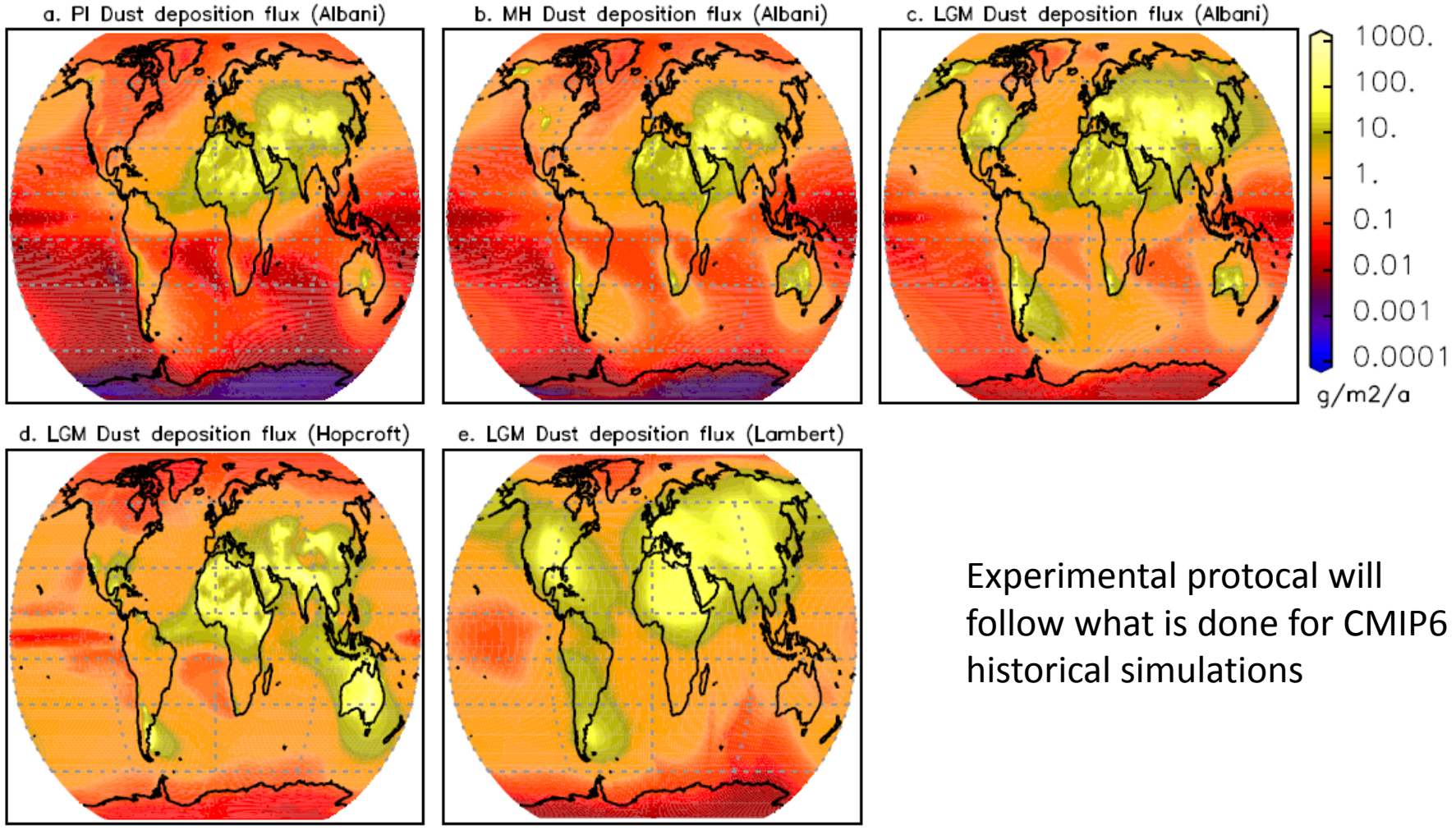
LGM : 21 ka



Ice sheet uncertainties ?
Implication on global and regional climates ?
Linkages with ocean fresh water forcing and sea level?



New feature : role of dust



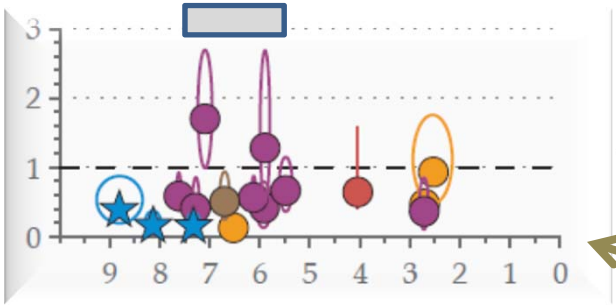
Experimental protocal will follow what is done for CMIP6 historical simulations

Kageyama et al. submitted from Albani et al, 2015, Thorncroft et al. 2015, Lambert et al. 2015

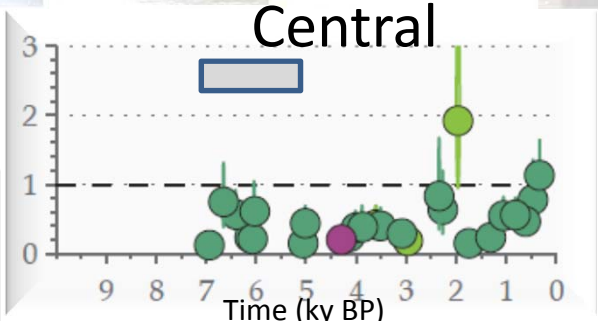
Interannual variability : Ex holocene

Std/std(0k)

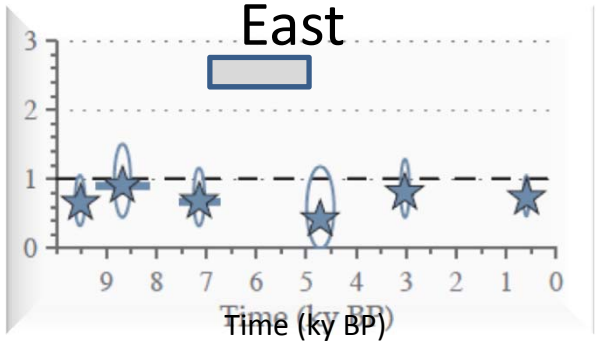
West

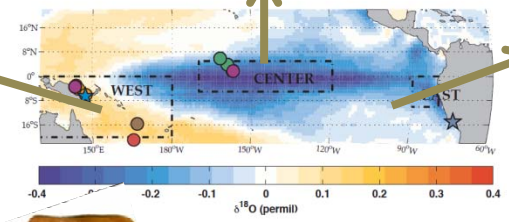


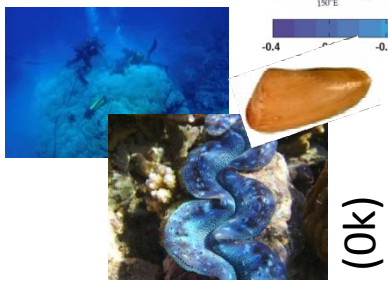
Central



East







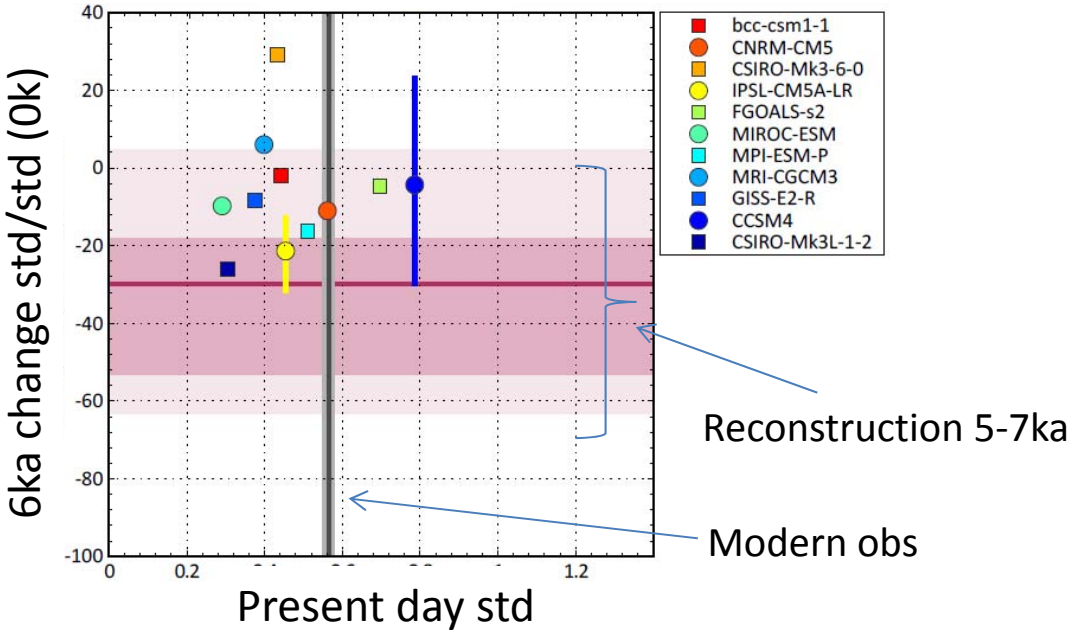
Emile Geay et al. 2015

Comparison with PMIP simulations

Using same filtering method

Niño 4 box

PMIP simulations



Conclusions

- Lots of new possibilities in PMIP4
- Data syntheses and analyses of uncertainties is an important point for model-data comparisons
  - Need to promote these aspects
  - Need to maintain strong linkages between PMIP groups and wider groups in PAGES or at national levels (ex PAGES 2k, QUIG, land surface6k, OSC3 etc…
- Model data base :
  - Follow international standard (ESGF, following CMIP6 recommendation)
  - Should provide taylored variables (but funding issue)
- Linkages with impact studies at regional scale, but also biodiversity (need to be organized)

Radiative Forcing MIP

RFMIP seeks to characterize effective radiative forcing for CMIP and understand how differences in this forcing arise between models

Atmosphere-only simulations to characterize effective radiative forcing.

Complementary efforts to understand parameterization errors in instantaneous radiative forcing for greenhouse gases and aerosols

Coupled simulations using CMIP6 specification of aerosol optical properties for hypothesis testing, detection and attribution

Coordinators: Robert Pincus, USA; Piers M Forster, UK; Bjorn Stevens, DE

Status, Oct 2016: Protocol published*, data request nearly final, forcing under review

(Protocol description in CMIP6 special collection is doi:10.5194/gmd-9-3447-2016.
*Small revisions to RFMIP-ERF since publication to better align with DAMIP.)

RFMIP-ERF

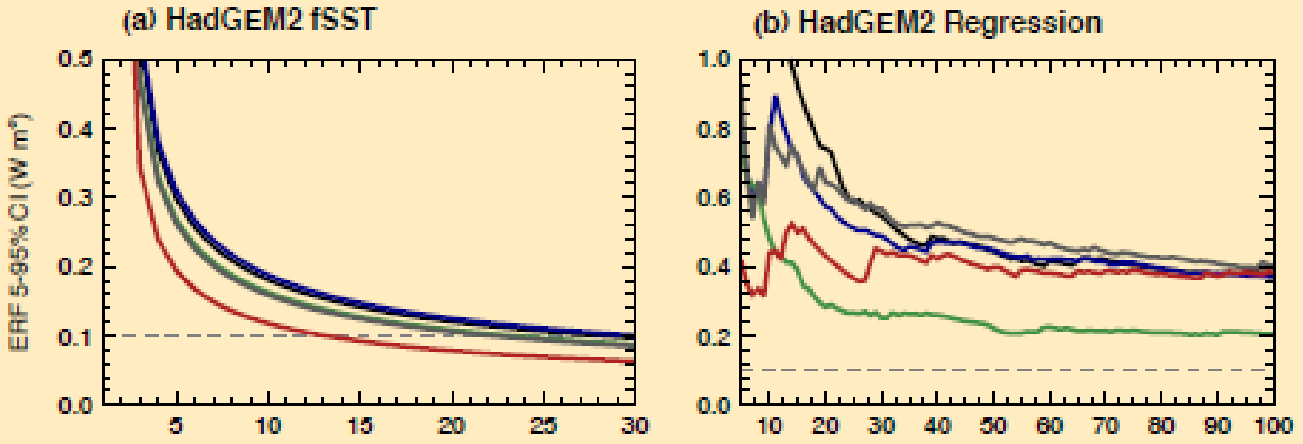
RFMIP uses fixed-SST simulations to diagnose effective radiative forcing

Recent publication doi:10.1002/2016JD025320 provides motivation vs. abrupt step changes in forcing agent

Protocol for generating SST and sea ice climatology is simple, adopted by CFMIP (AerChemMIP uses a more elaborate prescription)

RFMIP-light request is for 6x30 years — reliable forcing estimates rely on these!

Tier 2 is 4 x 251 years x 3 ensemble members to provide time-dependent forcing



ERF in HadGEM; fixed-SST vs. regression, doi:10.1002/2016JD025320

RFMIP-IRF

Lightweight but non-standard requests to diagnose parameterization error relative to reference line-by-line models

Errors in clear-sky greenhouse gas instantaneous radiative forcing rely on off-line radiative transfer calculations with specified atmospheric conditions

Using 100 carefully-optimized profiles present-day greenhouse gas instantaneous radiative forcing can be determined to within 0.05 W/m^2.

Forcing specification is under review, initial reference calculations to be reported in December

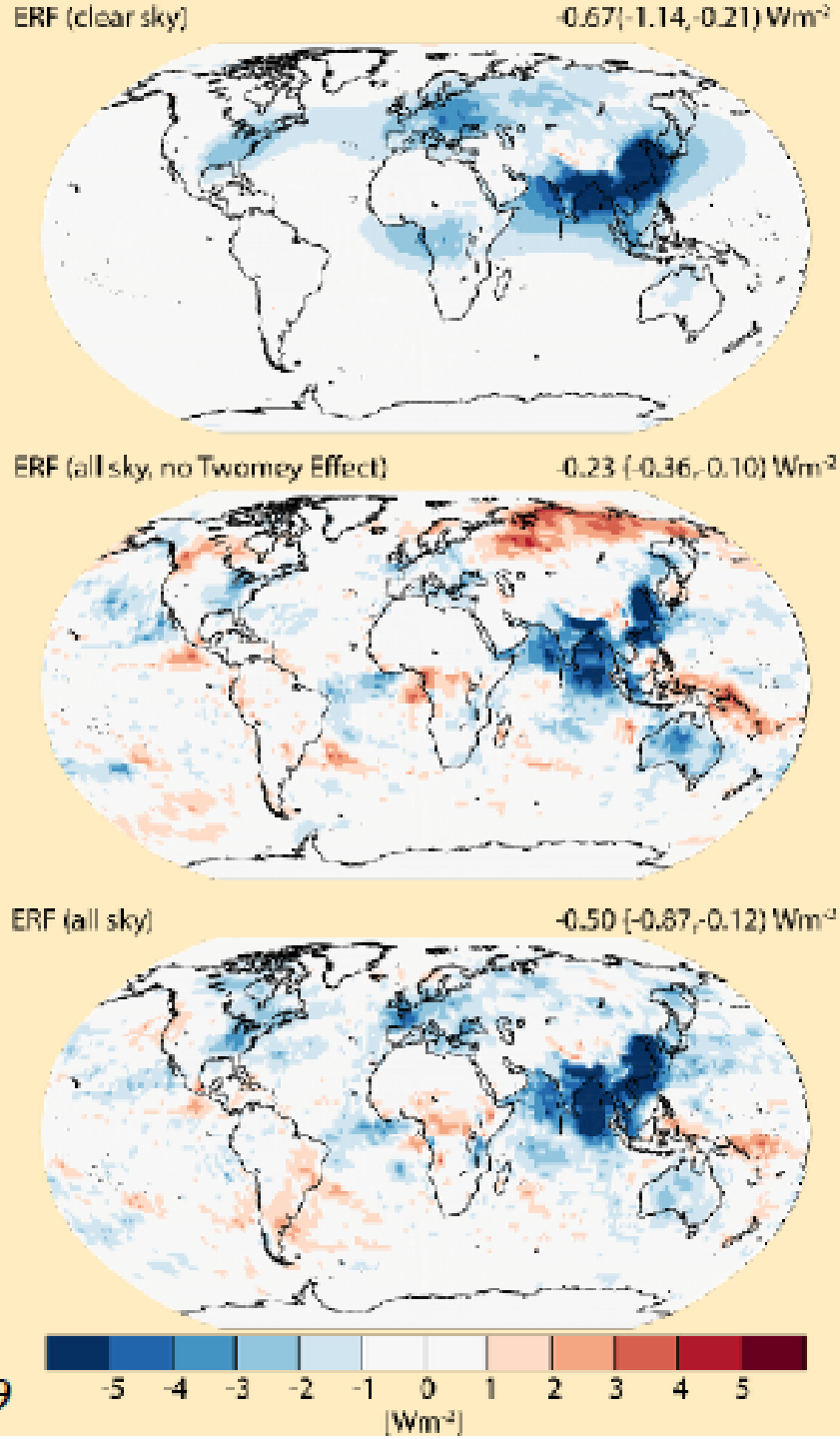
Errors in clear-sky aerosol instantaneous radiative forcing rely on detailed diagnostics on native model grid at 16 time slices (4 days in each of four years).

RFMIP-SpAer

We seek robust signatures of aerosols on climate via simulations with specified anthropogenic aerosol radiative properties - here the CMIP6 specification of direct and cloud-modifying effects. Models using the CMIP6 specification participate for free.

Tier 1 request is for coupled simulations of 165 years x 4 ensemble members. Tier 2 requests include another 165 years x 4 ensemble members to isolate aerosol impacts, plus atmosphere-only simulations to diagnose ERF. Simulations are linked to DAMIP.

Aerosol specification is under review (doi:10.5194/gmd-2016-189)



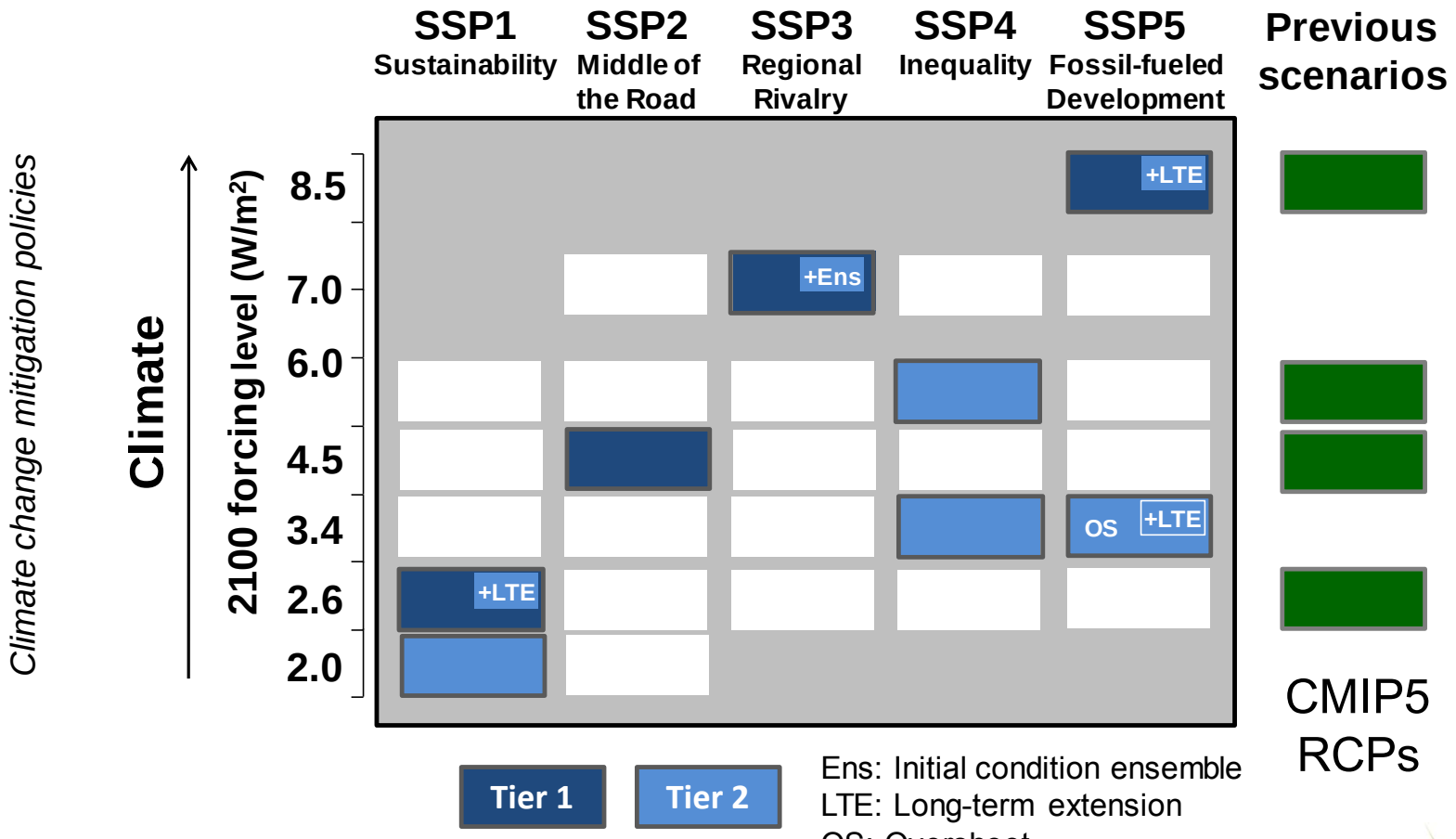
aerosol ERF in ECHAM, doi:10.5194/gmd-2016-189

The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6

Co-chairs: Brian O'Neill, Claudia Tebaldi, Detlef van Vuuren

SSPs: set of baselines, with future developments in absence of new climate policies beyond those in place today

Shared Socioeconomic Pathways



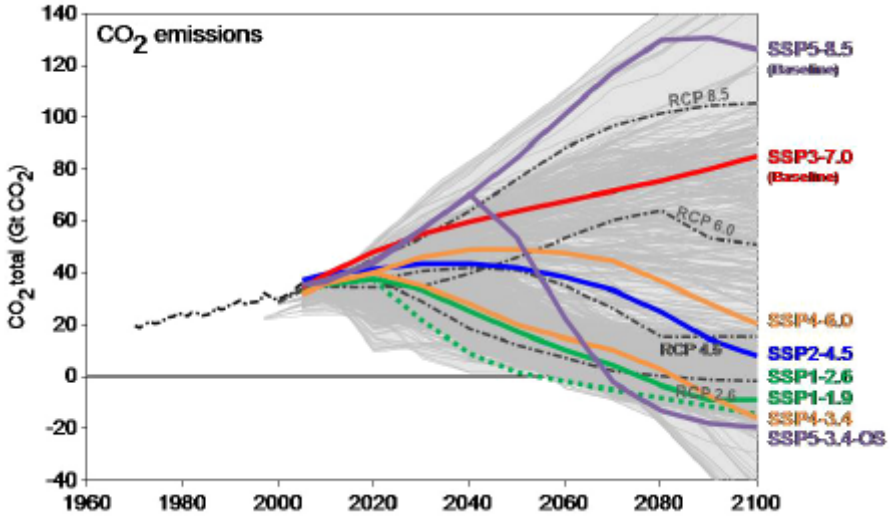
O'Neill et al., ScenarioMIP for CMIP6, GMD, 2016

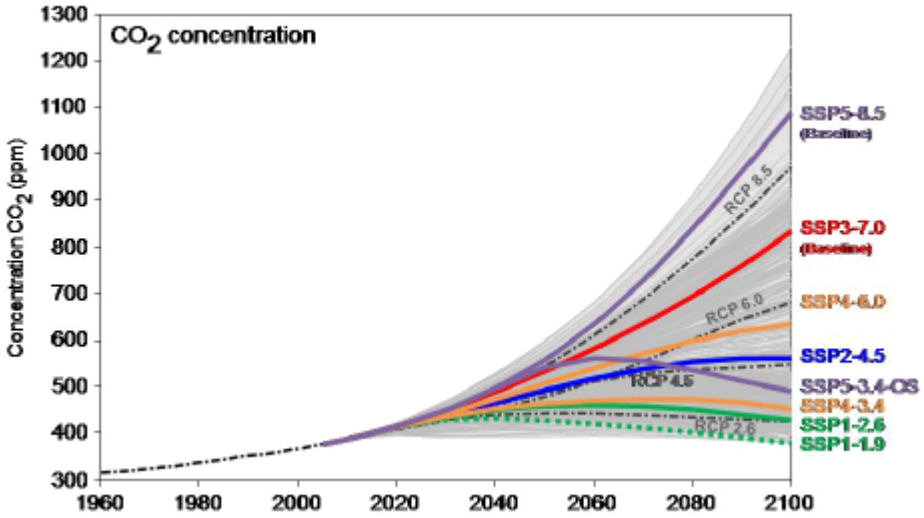
CMIP
The World Climate Research Programme's Coupled Model Intercomparison Project

SSP-RCP Scenario Matrix

Illustrating ScenarioMIP simulations, Results from Integrated Assessment Models

Gray areas: range of scenarios in the scenarios database for IPCC AR5

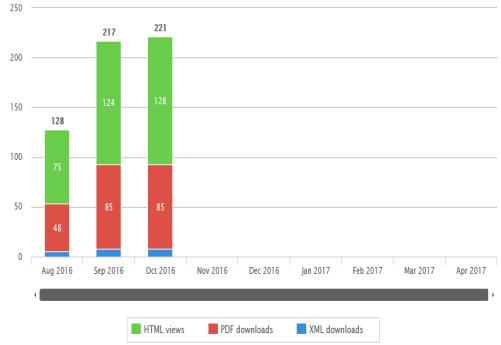




O'Neill et al., ScenarioMIP for CMIP6, GMDD, 2016

Figure reproduced from Riahi et al., Special Issue in Global Environmental Change, *2016*

The Model Intercomparison Project on the climatic response to Volcanic forcing (VolMIP): status, early October 2016



COORDINATING ACTIVITIES:

- **GMD paper published** on August 17th (>200 views and downloads).

- Started to inquire about a **VolMIP Special Issue** (joint ACP and Clim. Past)

- Applied to EGU sponsorship for the **first VolMIP meeting** planned for 2017 (*Programme Committee: Davide Zanchettin, Myriam Khodri, Claudia Timmreck, Angelo Rubino, Laureen Marshall, Alan Robock, Anja Schmidt, Matthew Toohey; anticipated location: Venice*)

- **Cooperation established and fostered** with other MIPs and non-CMIP projects (e.g., VICS, SPARC ISA-MIP)

- Definition and coordination of **working groups** interested in using the output of VolMIP experiments to investigate specific scientific questions: planned for within the next couple of months.

VolMIP: status, early October 2016

MODELLING AND ANALYSIS:

- **Status of VolMIP experiments**: MPI-M and IPSL are currently testing the final setup; production is expected starting from the first quarter of 2017.

- **Tambora ensemble** with chemistry climate models: analysis in progress, with a few related presentations at EGU 2016 and AGU 2016.

DISSEMINATION:

- The **website** www.volmip.org and the **mailing list** volmip@gwdg.de are active.

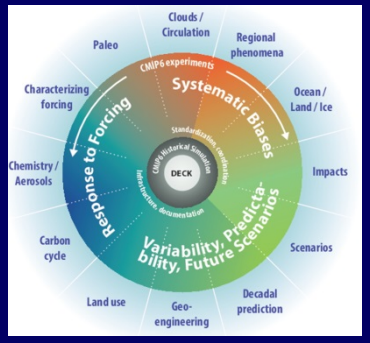
- VolMIP activities have been being presented at several **conferences and workshops**, as well as through **seminars** in different research institutes (including EGU, IUGG, PAGES-VICS, CLIVAR-DCVP, GFDL, University of Bergen, University of Cambridge, etc.).

CORDEX – A CMIP6 Diagnostic MIP

Primary CMIP6 Question Addressed:
How can we assess future climate changes given climate variability, predictability and uncertainties in scenarios?

Primary WCRP Grand Challenges/Issues Addressed:
1. Weather and climate extremes
2. Climate information for regions (evolving)

Coordination: ScenarioMIP, HighResMIP



CORDEX Scientific Vision

To advance and coordinate the science and application of regional climate downscaling through global partnerships

Goals:

- To better understand relevant regional/local climate phenomena, their variability and changes, through downscaling.
- To evaluate and improve regional climate downscaling models and techniques
- To produce coordinated sets of regional downscaled projections worldwide
- To foster communication and knowledge exchange with users of regional climate information

CORDEX – CMIP6 *GMD* Paper

☞ In press, part of *GMD* Special collection of papers on CMIP6

WCRP COORDINATED REGIONAL DOWNSCALING EXPERIMENT (CORDEX): A Diagnostic MIP for CMIP6

William J. Gutowski, Jr.[1], Filippo Giorgi[2], Bertrand Timbal[3], Anne Frigon[4], Daniela Jacob[5], Hyun-Suk Kang[6], R. Krishnan[7], Boram Lee[8], Christopher Lennard[9], Grigory Nikulin[10], Eleanor O'Rourke[10], Michel Rixen[8], Silvina Solman[11], Tannecia Stephenson[12] and Fredolin Tangang[13]

CORDEX – IPCC Interest

CORDEX Coordinated Output for Regional Evaluations (CORDEX CORE)

- In development
- Motivated by IPCC Workshop on Reg. Climate (Sept. 2015)
- Linked to CORDEX role as CMIP6 Diagnostic MIP

SPARC DynVar

Overview: DynVarMIP focuses on the interactions between atmospheric variability, atmospheric dynamics and climate change.

Reference:

Gerber and Manzini, The Dynamics and Variability Model Intercomparison Project (DynVarMIP) for CMIP6: assessing the stratosphere–troposphere system, Geosci. Model Dev., 9, 3413–3425, 2016, doi:10.5194/gmd-9-3413-2016 http://www.geosci-model-dev.net/9/3413/2016/

DynVarMIP key questions:

- How do dynamical processes contribute to persistent model biases in the mean state and variability of the atmosphere?
- What is the role of atmospheric momentum and heat transport in shaping the climate response to global warming and ozone depletion?
- How does the stratosphere affect climate variability at intra-seasonal, inter-annual and decadal timescales?

SPARC DynVar

Motivation:

The dynamics of atmospheric momentum transport is relevant to the tropospheric circulation response (measured by near-surface winds, at left, from Shepherd 2014) to global warming. For climate change projection of atmospheric dynamics there is low confidence.

Shepherd NG 2014, DOI: 10.1038/NGEO2253

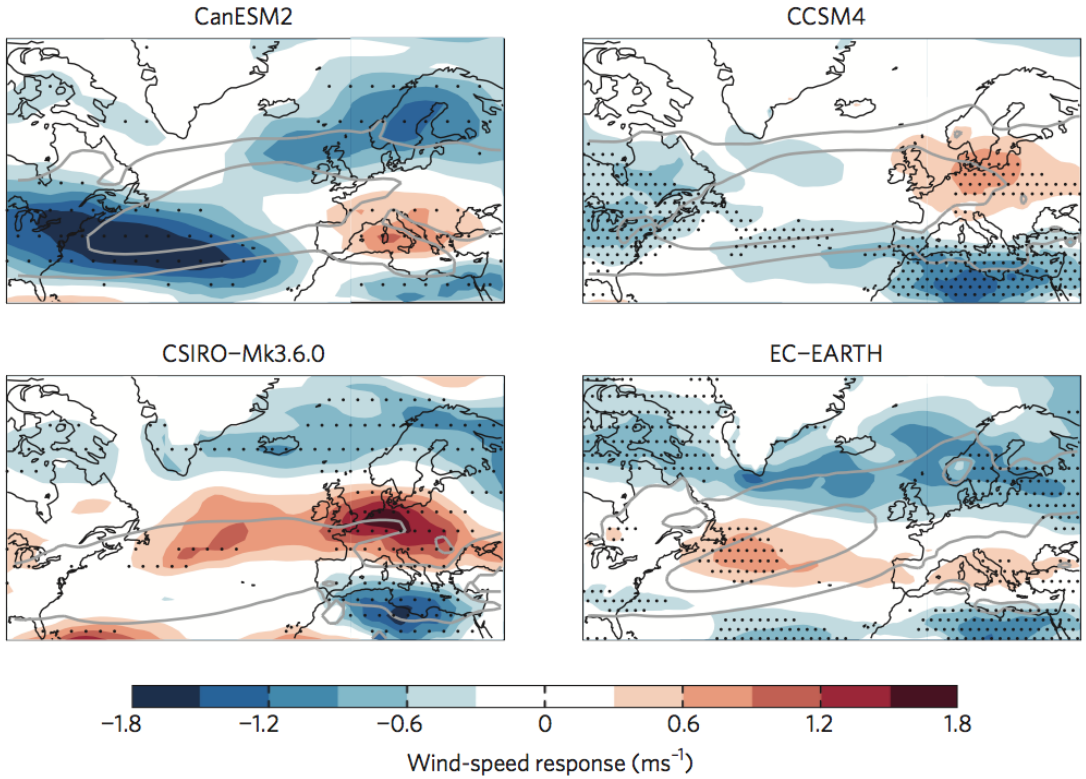
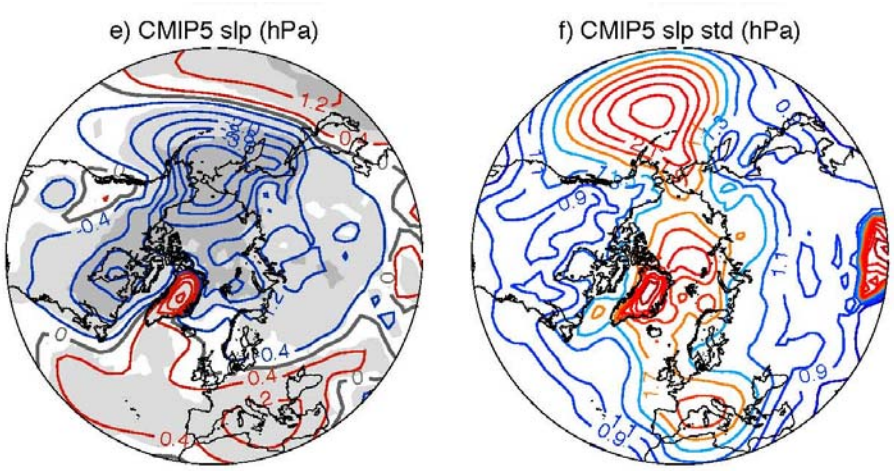


Figure 4 | Non-robustness of the predicted circulation response to climate change. Lower tropospheric (850 hPa) wintertime zonal wind speed (grey contours, 5 ms^{-1} spacing) over the North Atlantic, and the predicted response to climate change over the twenty-first century under the Representative Concentration Pathway 8.5 scenario (colour shading), from four different CMIP5 models, averaged over five members from each model ensemble (see Methods). Stippling (density is proportional to grid spacing) indicates regions where the climate change response is significant at the 95% level based on the five ensemble members. Figure courtesy of Giuseppe Zappa, University of Reading.

SPARC DynVar

Large inter-model spread in atmospheric dynamics, CMIP5 multi model ensemble:

Sea Level Pressure change, RCP8.5-historical (Manzini et al JGR 2014)

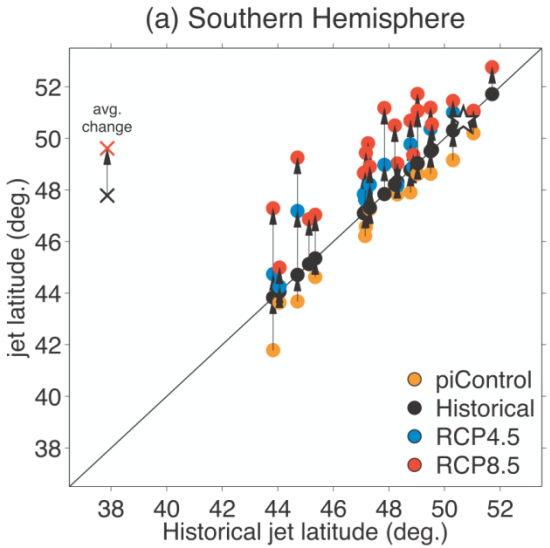


Multi Model Mean (MMM) change

Inter Model STD (spread) in the change

Spread in the change as large as (or larger of) MMM change => Uncertainty, why? Variability? Model formulations? Scenarios?

Mean jet position and its change (Barnes and Polvani JC 2013)



Mean jet position plotted against the historical jet latitude. Arrows connect scenarios for each model. Why such an inter model spread (~Δ8°) in jet position?

SPARC DynVar

The DynVarMIP is primarily focused on the DECK and the CMIP6 Historical Simulations.

DynVar analyses of the atmospheric circulation focus on:

- **DECK experiments:**
  - ❑ **AMIP, all years**
  - ❑ **Per-industrial control: 111–150 years after the branching point**
  - ❑ **abrupt4xCO2: years 1–40 and 111–150**
  - ❑ **1pctCO2: years 1–150 (monthly mean data only)**
- **the CMIP6 historical experiment (40 years, 1961–2000)**
- **the ScenarioMIP RCP8.5 experiments (40 years, 2061–2100)**
- **CFMIP AMIP experiments (amip-p4K, amip-future4K, amip-4xC02), all years (1979-2014)**

Note: Models need only commit to providing diagnostics to the DECK and the CMIP6 historical experiments to participate in DynVarMIP.

CMIP6 Sea Ice Model Intercomparison Project (SIMIP)

Co-chairs: Dirk Notz[1] and Alexandra Jahn[2]

[1]Max Plank Institute for Meteorology, Germany; [2]University of Colorado at Boulder, USA

Aim: To better understand the role of sea ice for the changing climate of our planet

Recent progress:

- Compiled consistent list of sea-ice state variables that allows researchers to analyse the heat budget, the mass budget and the momentum budget of sea ice
- This list of sea ice variables is represented in the CMIP6 data request, through the CMIP6 endorsed SIMIP (www.climate-cryosphere.org/simip)
- Description of data request published in CMIP6 GMD special issue:
  - Notz, D., A. Jahn, M. Holland, E. Hunke, F. Massonnet, J. Stroeve, B. Tremblay, and M. Vancoppenolle (2016), The CMIP6 Sea-Ice Model Intercomparison Project (SIMIP): Understanding sea ice through climate-model simulation, Geophys. Mod. Develop., 9, 3427-3446, doi:10.5194/gmd-9-3427-2016

CMIP6 Sea Ice Model Intercomparison Project (SIMIP)

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Aim: To better understand the role of sea ice for the changing climate of our planet

Next steps:

- Coordinate efforts to analyze CMIP6 sea ice model simulations (SIMIP)
- Focus on improved model evaluation through joint workshop(s) with providers of observational data
  - First workshop planned for 27-30th of March 2017 in Bremerhaven, Germany, in conjunction with Polar Prediction workshop

The Vulnerability, Impacts, Adaptation, and Climate Services (VIACS) Advisory Board for CMIP6

Building Bridges Between the Modeling and Applications Communities



Co-Chairs: Alex Ruane[1,2] and Claas Teichmann[3]
and the VIACS Advisory Board

[1]*NASA Goddard Institute for Space Studies, New York City*
[2]*Columbia University Center for Climate Systems Research*
[3]*Climate Service Center, HZG, Hamburg*

WCRP Working Group on Coupled Modeling
Princeton, USA, November 1st, 2016

VIACS Advisory Board - Overview

Designed to help form more coherent and productive link between the climate modeling community and users of CMIP6 outputs from the applications community.

- **Facilitates two-way communication around science and application goals:**
  - construction of model scenarios and simulations
  - informed use of model outputs
  - design of online diagnostics, metrics, and visualizations of relevance to society.

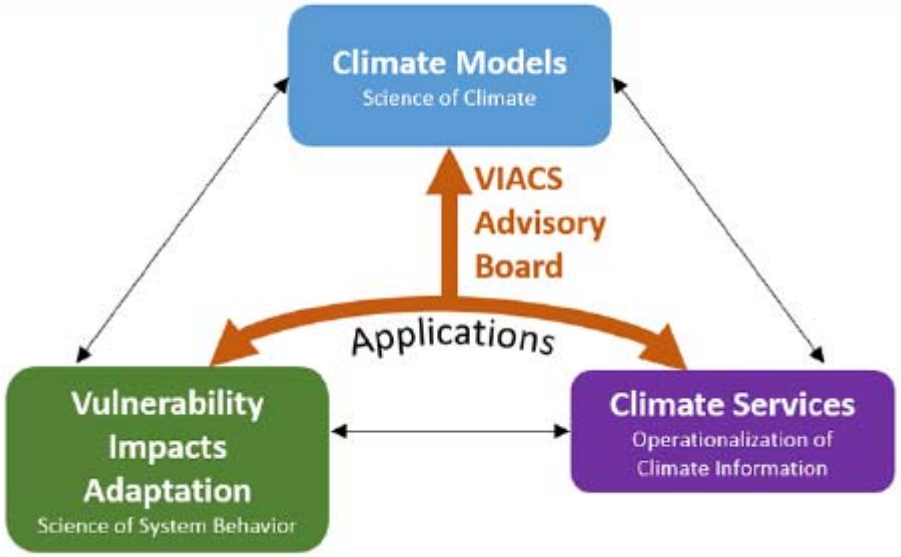
Anchored in the Program for Research on Climate Change Vulnerability, Impacts, and Adaptation (PROVIA)

PROVIA

VIACS Advisory Board – Activities

Previous and Ongoing Activities:

- Enhanced communication with VIACS communities
- Feedback on variables and experiments of interest for societal applications
- GMD Paper on VIACS Advisory Board and its role in CMIP6



Current Activities:

- Building web page to increase profile and reach
- Interested in working with MIP leaders to develop paper on guidance for application of MIP outputs
- Scoping out potential online metrics for CMIP6 data servers to increase VIACS relevance

Geosci. Model Dev., 9, 3493–3515, 2016
www.geosci-model-dev.net/9/3493/2016/
doi:10.5194/gmd-9-3493-2016

Geoscientific Model Development
Open Access
EGU

The Vulnerability, Impacts, Adaptation and Climate Services Advisory Board (VIACS AB v1.0) contribution to CMIP6

Alex C. Ruane[1], Claas Teichmann[2], Nigel W. Arnell[3], Timothy R. Carter[4], Kristie L. Ebi[5], Katja Frieler[6], Clare M. Goodess[7], Bruce Hewitson[8], Radley Horton[9], R. Sari Kovats[10], Heike K. Lotze[11], Linda O. Mearns[12], Antonio Navarra[13], Dennis S. Ojima[14], Keywan Riahi[15], Cynthia Rosenzweig[1], Matthias Themessl[16], and Katharine Vincent[17]