PDRMIP

Precipitation Driver Response Model Intercomparison Project

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Background

PDRMIP is a new climate model intercomparison initiative, and was launched in Oslo in November. In PDRMIP a number of different climate models will be used to explore whether differences in precipitation at present and future projections can be linked to differences in forcing mechanisms. The fact that various climate forcers (e.g., CO_2, BC, sulphate) have different influences on precipitation was explored in e.g., Andrews et al. (2010), Kvalevåg et al. (2013), Ming et al. (2010) and Wu et al. (2013). We will build upon these studies and seek to understand more of the differences in precipitation and extreme precipitation in the climate models, e.g., by the use of idealized experiments where the input data of each model will be nearly identical.

Seven modelling groups and climate models have confirmed participation in PDRMIP so far and we hope further groups will join in the challenge of understanding influence of different drivers on precipitation.

Confirmed participating models:

- National Center for Atmospheric Research (NCAR) Community Earth System Model CESM1
- Hadley Center Climate Model HadGEM2 & HadGEM3
- Goddard Institute for Space Studies (GISS) ModelE
- SPRINTARS
- IPSL-CM5
- NorESM

Participants and collaborators of PDRMIP:

Dr. Gunnar Myhre, Dr. Bjørn H. Samset, Dr. Øivind Hodnebrog and Dr. Jana Sillmann (CICERO, Norway), Prof. Piers M. Forster (University of Leeds, UK), Dr. Drew T. Shindell (NASA GISS, USA), Dr. Toshihiko Takemura (Kyushu University, Japan), Dr. Jimy Dudhia (NCAR, USA), Dr. Olivier Boucher (CNRS, France), Dr. Francis Zwiers (PCIC, Canada), Dr. Slava Kharin (CCCma, Canada), Dr. Jean-François Lamarque (NCAR, USA), Dr. Dirk Olivié (Norway), Dr. Alf Kirkevåg (Norway), Dr. Michael Schulz (Norway), Dr. Apostolos Voulgarakis (UK)

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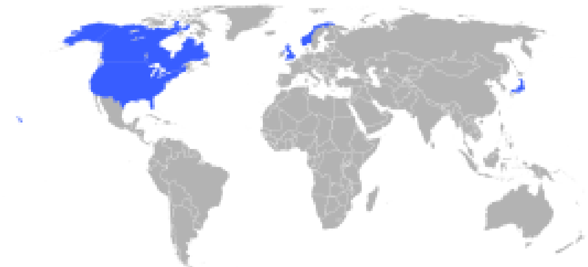

Motivation

A warmer atmosphere can carry greater quantities of water vapour; approximately 6–7% more is carried per degree K of warming near Earth's surface, as determined by the Clausius–Clapeyron relation (O'Gorman et al., 2012). However, recent studies show that the hydrological sensitivity in the climate system, i.e. the long term precipitation response to equilibrium temperature change, is closer to 2-3% K^{-1}. They conclude that the precipitation response to global warming cannot be explained by the availability of moisture alone (Andrews and Forster, 2010; Andrews et al., 2010; Frieler et al., 2011), but is constrained by the energy budget in the surface-atmosphere system (Allen and Ingram, 2002; O'Gorman et al., 2012).

The energy budget is altered by both natural and anthropogenic influences. Dependent on the physical properties of a climate forcing mechanism it causes either a fast response in precipitation, on a timescales of days to weeks, or a slower response on a timescale of years (Andrews et al., 2010; Ming et al., 2010; Frieler et al., 2011; Pendergrass and Hartmann, 2012). It has been shown that in several models at least in the global mean, fast atmospheric response correlates strongly with the atmospheric component of radiative forcing and the slower response with global surface temperature change (Andrews et al., 2010; Kvalevåg et al., 2013). A thorough investigation of differences in the effects of anthropogenic and natural drivers on precipitation will therefore lead to a reduction in uncertainties in global and regional predictions of both mean and extreme rainfall.

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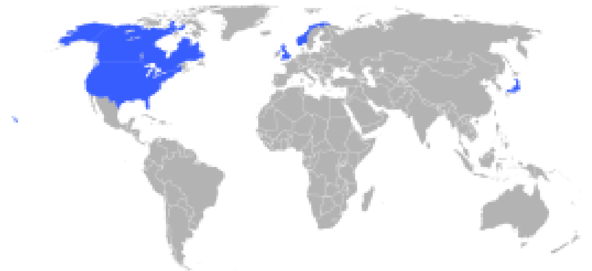

Extreme precipitation

CMIP5 studies (e.g., Kharin et al., 2013; Sillmann et al., 2013) indicate that extreme precipitation increases about three times as much as mean precipitation under different greenhouse gas emission scenarios. The scaling of extreme precipitation with temperature may be much more complex than is implied by the Clausius-Clapeyron relation, with considerable regional variations due to various dynamic and thermodynamic mechanisms (e.g., Caesar and Lowe, 2012; Westra et al., 2013). The estimated CMIP5 multimodel-average increase in annual extreme precipitation is about 6% K^{-1}, with a large inter-model range between 4%-10% K^{-1} according to Kharin et al. (2013). They also found considerable uncertainty in the model simulations representing the Clausius-Clapeyron relationship for extreme precipitation compared to mean precipitation. Thus, it is important to study whether different strength and representation of external forcing mechanisms included in a set of different GCMs may be a cause for the large difference in precipitation response apart from internal climate variability.

Relevance

Precipitation is arguably the most direct link between the climate and human society. We depend upon existing precipitation patterns for fresh water and food production, and global infrastructure is designed to withstand current precipitation extremes. Beyond changes in global and local mean precipitation, changes in rates and magnitudes of extreme rainfall events are also of high importance. Unless properly prepared for, extreme precipitation can cause devastating damage to infrastructure and society.

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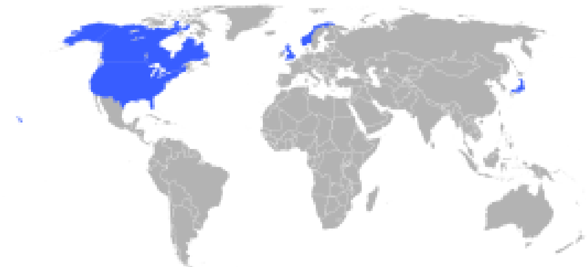

Experimental Design

PDRMIP consists of 1 base and 5 core experiments in addition to 6 additional simulations. The core experiments consist of simulations with a doubling of CO_2 concentration, strong increase in CH_4 concentration, changes in solar constant and 2 experiments on aerosols. The additional simulations are dedicated to regional changes in aerosols and ozone. Similar aerosol distribution will be implemented in all model simulations. Tools for implementing the aerosol fields into the climate models will therefore be provided.

Two sets of simulations are suggested with fixed SST simulations and fully coupled (or slab ocean) climate simulations.

The protocol for model output is described below and follows a subset of CMIP5 output (Amon plus some daily fields). Model results will be submitted and subsequently available for participating groups at a common server.

A brief description of simulations is given below. Full description and protocol will be provided in beginning of March.

Time line

- 1. Mar 2014: Distribution of protocol including aerosol distribution
- 1. Aug 2014: Completion of core experiment simulations
- 1. Oct 2014: Additional experiments
- Mid-late October: Next meeting in Leeds

AMON – Atmospheric monthly mean variables

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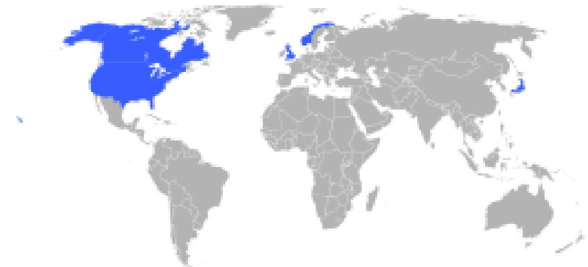
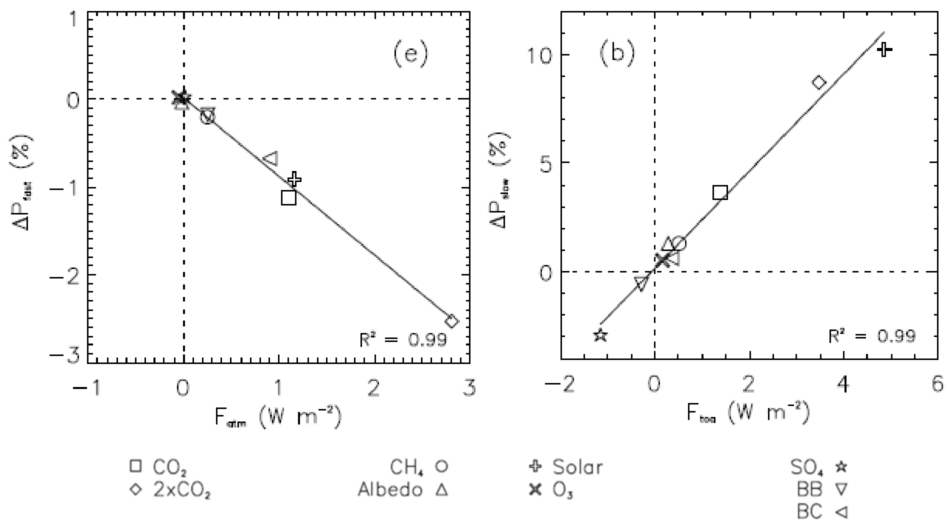
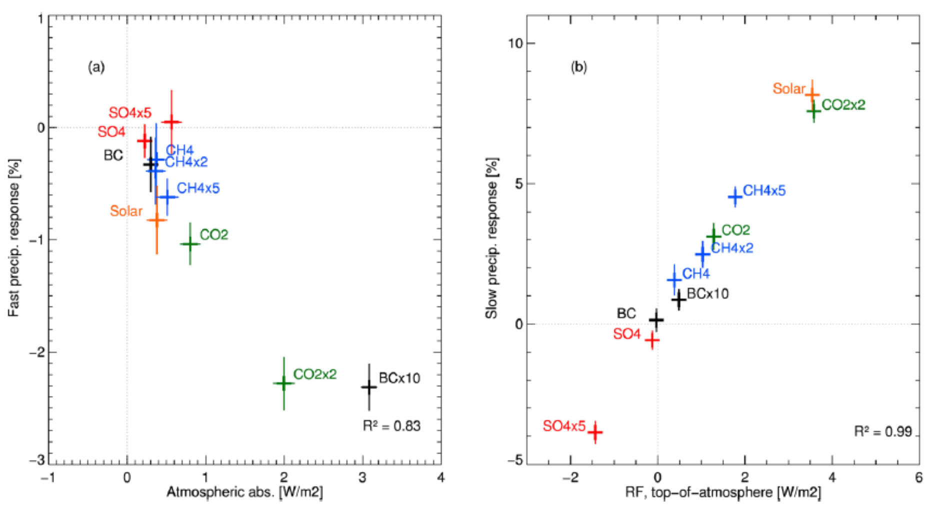


Andrews et al. (2010)



Kvalevåg et al. (2013)



PDRMIP will include several dedicated analysis including a better understanding of the drivers' importance for differences in precipitation changes, energy budget analysis and extremes related to precipitation.

Example analysis

- Fast precipitation responses to each forcing agent are diagnosed from fixed-SST runs, total responses from slab/full ocean runs.
- Radiative forcing is extracted at TOA and surface.
- HadGEM and CESM both show correlations between (left) fast precipitation response and atmospheric absorption, and (right) TOA forcing and slow (total-fast) precipitation response.
- Details for each forcing agent, underlying physics and total hydrological sensitivity differ between models.
- A similar analysis will be done based on PDRMIP results. Process level information will be used to understand intermodel differences also at the regional scale.

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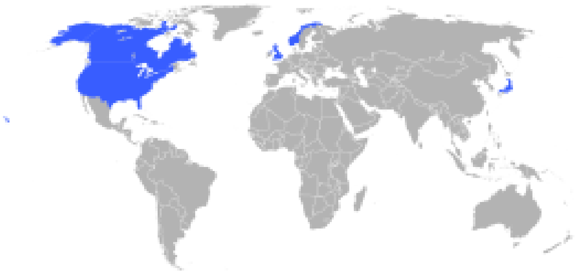

PDRMIP core experiments

Name	Description	Fixed-SST Nyears	Slab/full ocean Nyears (all output)
Base	Specified present day CO_2, CH_4, solar constant, aerosol concentration	15	100
CO2 x 2	CO_2 from PDC to 2xPDC	15	100
CH4 x 3	CH_4 from PDC to 3xPDC	15	100
Solar	Solar constant increased by 2%	15	100
Sul	Sulphate concentration from PDC to 5xPDC	15	100
BC	BC concentration from PDC to 10xPDC	15	100

PDC – Present day concentration

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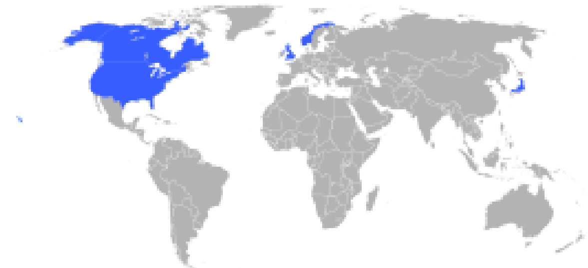

PDRMIP additional experiments

Name	Description	Fixed-SST Nyears	Slab/full ocean Nyears (all output)
Sulred	Sulphate concentration from PDC to PIC	15	100
Suleur	Sul multiplied by 10, Europe only	15	100
Sulasia	Sul multiplied by 10, but Asia only	15	100
BCasia	As BC, but Asia only	15	100
Sulasired	As Sulred, but Asia only	15	100
O3asia	Add O3, Asia only, comparable forcing to Sulasia	15	100

PDC – Present day concentration
PIC – Pre-industrial concentration

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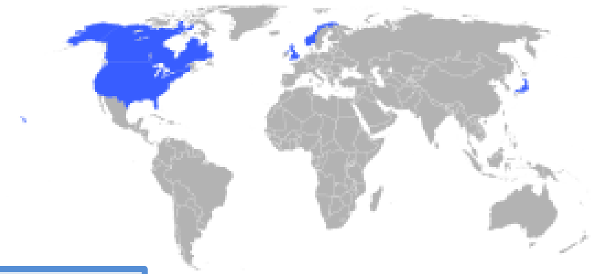

Regions, aerosol distributions and burdens

Aerosol distributions

For the experiments with altered aerosols, either:

1. Run with prescribed mmr or concentration fields. We will provide common mmr fields, regridded to your model resolution, based on AeroCom Phase II (see next slide). This is the prefered method, as aerosol impacts vary both across the globe and vertically.
2. Run with altered emissions, making sure to match the regions and global burdens in the common concentration files.

Region definitions:

Europe [-10,40]E, [35,70]N
Asia [60,140]E, [10,50]N

If you run with altered emissions, please perturb emissions within these region boxes such that you match the indicated global mean burden (see table).

Baseline conc.	Burden [mg m^{-2}]	Experiment	Burden [mg m^{-2}]	Experiment	Burden [mg m^{-2}]
BC PIC	0.06	SUL	11.5	BC	1.94
BC PDC	0.19	SULRED	1.25	BCASIA	0.62
BC PDCx10	1.94	SULEUR	2.79		
SO4 PIC	1.25	SULASIA	4.53		
SO4 PDC	2.30	SULASIARED	2.26		

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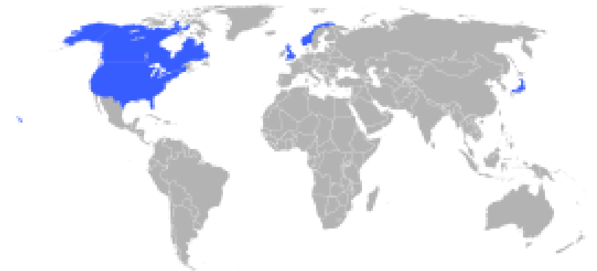
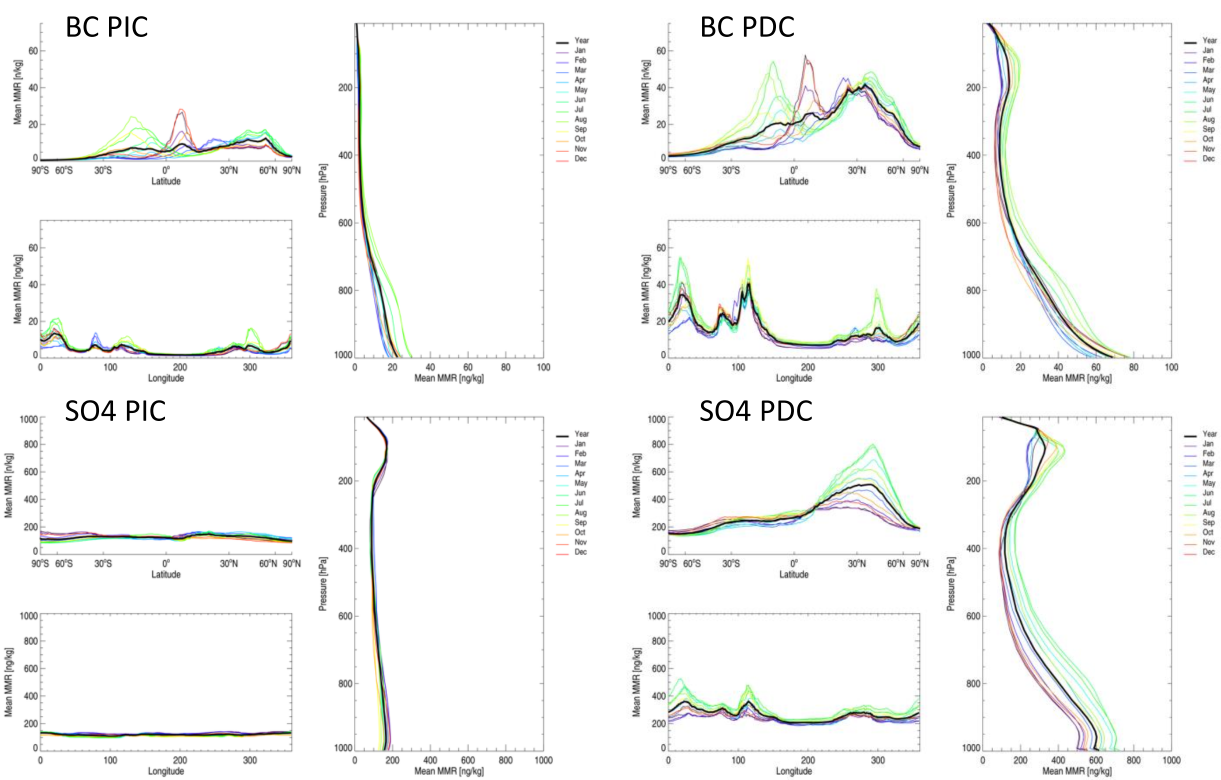


PDRMIP 3D aerosol distributions, based on AeroCom Phase II



- “Mean MMR” is the mean over the two other dimensions, e.g. for latitude it is the mean over longitude and altitude
- BC is based on 13 models, SO4 is based on 3 models
- Colored lines show seasonality

PDC – Present day concentration
PIC – Pre-industrial concentration

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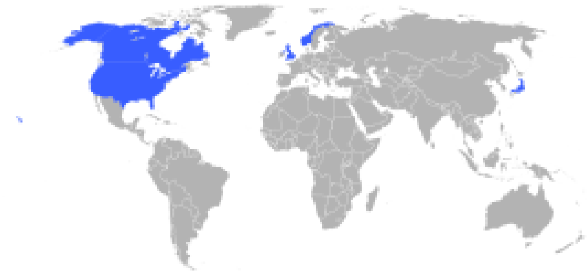
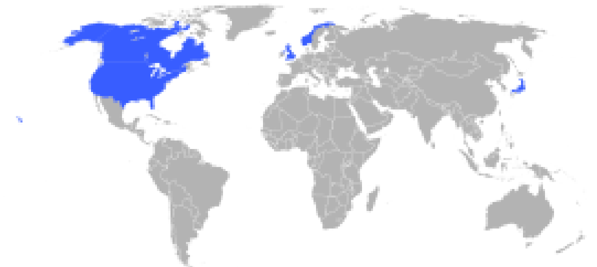


First results from CAM4, based on 40 years of slab ocean running

	Surface temperature change	Direct Radiative Forcing	Precipitation	Climate sensitivity	Hydr.sens.
	[K]	[W/m2]	[%]	[K/(W/m2)]	[%/K]
Sul	-1.42	-2.35	-3.78	0.60	2.66
Sulasia	-0.36	-0.70	-0.74	0.51	2.08
Sulred	0.29	0.34	0.83	0.85	2.84

- To participate in the aerosol experiments (BC and Sul cases), you will need the AeroCom-based 3D distributions
- These will be provided by the Oslo group, regridded to your model resolution.
- To allow us to do this, please provide a netcdf file with either a 4D matrix (lon,lat,lev,time) of your model level midpoints (in hPa) and/or the hybrid sigma information needed to recreate the levels (a, b, p0 and surface pressure).



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Contact

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