Simulations of the Common Era: from PMIP3/CMIP5 to PMIP4/CMIP6

& some thoughts on model-specific challenges regarding hydroclimate

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Outline

- Last millennium (past1000) simulations in PMIP3/ CMIP5
- past1000 simulations in PMIP4/CMIP6
- How good are CMIP5/CMIP6 models? including thoughts on hydroclimate

The PMIP3 “past1000” simulations

List of PMIP3/CMIP5 participants

Information as of April 22nd 2013

Up to date info: https://pmip3.lsce.ipsl.fr/wiki/doku.php/pmip3:database:status

Some P2P nodes: PCMDI IPSL DKRZ BADC

CMIP5 Errata: http://pcmdi-cmip.llnl.gov/cmip5/errata/cmip5errata.html

Models' documentation: http://q.cmip5.ceda.ac.uk/cmip5/publisheddocs/

	Institute	Country	0k *piControl*	6k *midHolocene*	21k *lgm*	LM *past1000 (1000 years)*	1 % CO_2 *1pctCO2 (140 years)*	CMIP5	PlioMIP	Last Interglacial	Holocene	Carbon cycle	Atm	Ocn	Model id	Term of Use	Data Node	Publish to (index node)	Extra Doc Errata etc...
1	AWI	Germany	Completed	Completed	Completed			No	Yes	Yes	No	Yes	96x48 x L19	120x101 x L40	*COSMOS-aso ?*		*DKRZ ?*	*ESG-WDCC ?*	
2	BCC	China	CMIP5 (500)	CMIP5 (100)		CMIP5	CMIP5	Yes	No	No	No	Yes	128x64 x L26	360x232 x L40	bcc-csm1-1	Unrestricted	BCC	ESG-PCMDI	
3	BCCR	Norway	Completed	Running Summer 2013	Complete	Running Summer 2013	Running Summer 2013	No	Yes	Yes	No	Yes	96x48 x L26	100x116 x L32	NorESM1-L	Unrestricted	*DKRZ ?*	*ESG-WDCC ?*	
4	CAU-GEOMAR	Germany	*PMIP3*	*PMIP3*	Starting		*PMIP3*	No	Yes	Yes	?	No	96x48 x L19	182x149 x L31	KCM1-2-2	Non-commercial	DKRZ	*ESG-WDCC ?*	
5	CNRM-CERFACS	France	CMIP5 (850)	CMIP5 (200)	CMIP5 (200)		CMIP5	Yes	No	No	No	No	256x128 x L31	362x292 x L42	CNRM-CM5	Unrestricted	CNRM	ESG-IPSL	Doc
6	FUB	Germany	PMIP3 (400)		PMIP3 (600)			No	No	No	No	Yes	96x48 x L19	120x101 x L40	COSMOS-ASO	Unrestricted	*IPSL (DKRZ later?)*	ESG-BADC	
7	NOAA-GFDL	USA	CMIP5 (470)		Starting avail. Fall 2013		CMIP5	Yes	No	No	No	Yes	144x90 x L24	360x200 x L50 360x210 x L64	GFDL-ESM2M GFDL-ESM2G	Unrestricted	GFDL	ESG-PCMDI	
8	NASA-GISS	USA	CMIP5 (7 x)	CMIP5 (100)	CMIP5 (2 x 10	CMIP5 (8 x 1000)	MIP5 151)	Yes	Yes	?	Yes	No	144x90 x L40	288x180 x L32	GISS-E2-R	Unrestricted	NCCS	ESG-PCMDI	Doc
9	IPSL	France	CMIP5 (1000)	CMIP5 (500)	CMIP5 (200	CMIP5	MIP5	Yes	Yes	Yes	Yes	Yes	96x95 x L39	182x149 x L31	IPSL-CM5A-LR	Unrestricted	IPSL	ESG-BADC	Doc
10	ICHEC (KNMI)	Netherlands	PMIP3 (40)	PMIP3 (40)				No	Yes	No	No	No	320x160 x L62	362x292 x L42	EC-Earth-2-2	Unrestricted	ICHEC	ESG-BADC	
11a	LASG-CESS	China	CMIP5 (900)	CMIP5 (100)	CMIP		MIP5		Yes	No	No		128x60 x L26		FGOALS-g2	Unrestricted	LASG	ESG-PCMDI	
11b	LASG-IAP	China	CMIP5 (501)	CMIP5 (100)		CMIP5	MIP5	Yes	No	No	No	No	128x108 x L26	360x180 x L30	FGOALS-s2	Unrestricted	LASG	ESG-PCMDI	
11c	LASG-IAP	China	Completed			CMIP5				No	No		72x45 x L26		FGOALS-gl	Unrestricted	LASG	ESG-PCMDI	Doc
12	LOVECLIM	Belgium France Netherlands	Completed	Completed	Compl d	Completed		No	No	Yes	Yes	No	32x64 x L3	122x65 x L20	LOVECLIM1-2	Unrestricted	IPSL	ESG-BADC	
13	MIROC	Japan	CMIP5 (531)	CMIP5 (100)	CMIP (100	CMIP5	MIP5	Yes	Yes	?	?	Yes	128x64 x L80	256x192 x L44	MIROC-ESM	Non-commercial only	DIAS	ESG-PCMDI	
14	MPI-M	Germany	CMIP5 (1156)	CMIP5 (2x100)	CMIP (2 x 10	CMIP5	MIP5	Yes	No	?	?	No	196x98 x L47	256x220 x L40	MPI-ESM-P	Unrestricted	DKRZ	ESG-WDCC	
15	MRI	Japan	CMIP5 (500)	CMIP5 (100)	CMIP (100	Running September 2013	MIP5	Yes	Yes	No	No	No	320x160 x L48	364x368 x L51	MRI-CGCM3	Non-commercial	DIAS	ESG-PCMDI	
16	NCAR	USA	CMIP5 (501)	CMIP5 (1x301 + 1x30)	CMIP (1x101 + 1)	CMIP5	MIP5	Yes	Yes	No	No	No	288x192 x L26	320x384 x L60	CCSM4	Unrestricted	NCAR	ESG-NCAR	
17	OSUVic	USA	Completed	Completed (400)	Runnin May 20		arting il 2013	No	No	No	No	No	128x64 x L10	100 x 100 x L19	OSUVic-0-3	Unrestricted	?	?	
18	CSIRO-QCCCE	Australia	CMIP5 (500)	CMIP5 (100)			CMIP5	Yes	No	No	No	No	192x96 x L18	192x192 x L31	CSIRO-Mk3-6-0	Non-commercial	NCI	ESG-NCI	
19a	MOHC (UK groups)	UK	CMIP5 (497)	CMIP5 (102)	Starting	Running Spring 2013	CMIP5	Yes	Yes	Yes	Yes	Yes	192x144 x L38	360x216 x L40	HadGEM2-ES	Unrestricted	BADC	ESG-BADC	Doc
19b	MOHC (UK groups)	UK	CMIP5 (240)	CMIP5 (35)				Yes	No	No	No	Yes	192x144 x L60	360x216 x L40	HadGEM2-CC	Unrestricted	BADC	ESG-BADC	
19c	UOED	UK	PMIP3 (1200)			PMIP3	CMIP3	Yes	Yes	Yes	Yes	No	96x73 x L19	288x144 x L20	HadCM3	Unrestricted	BADC	ESG-BADC	
20	UNSW	Australia	PMIP3 (1000)	PMIP3 (500)	Running June 2012	PMIP3	PMIP3	No	Yes	Yes	Yes	No	64x56 x L18	128x112 x L21	CSIRO-Mk3L-1-2	Non-commercial	IPSL *(NCI later?)*	ESG-BADC	Doc
21	UofT	Canada	Completed	Completed	Completed	Completed	Completed	No	No	No	No	No	256x128 x L26	320x386 x L40	UofT-CCSM3	Unrestricted	?	?	

Click for up-to-date exp check : piControl ? midHolocene ? lgm ? past1000 ? 1pctCO2 ?

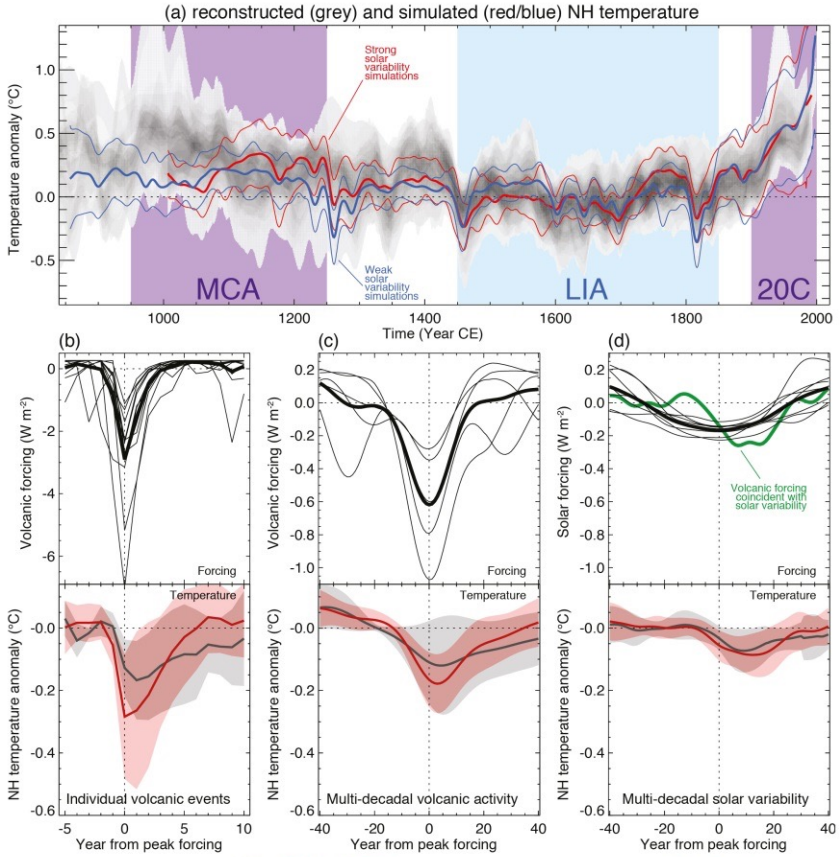
Legend

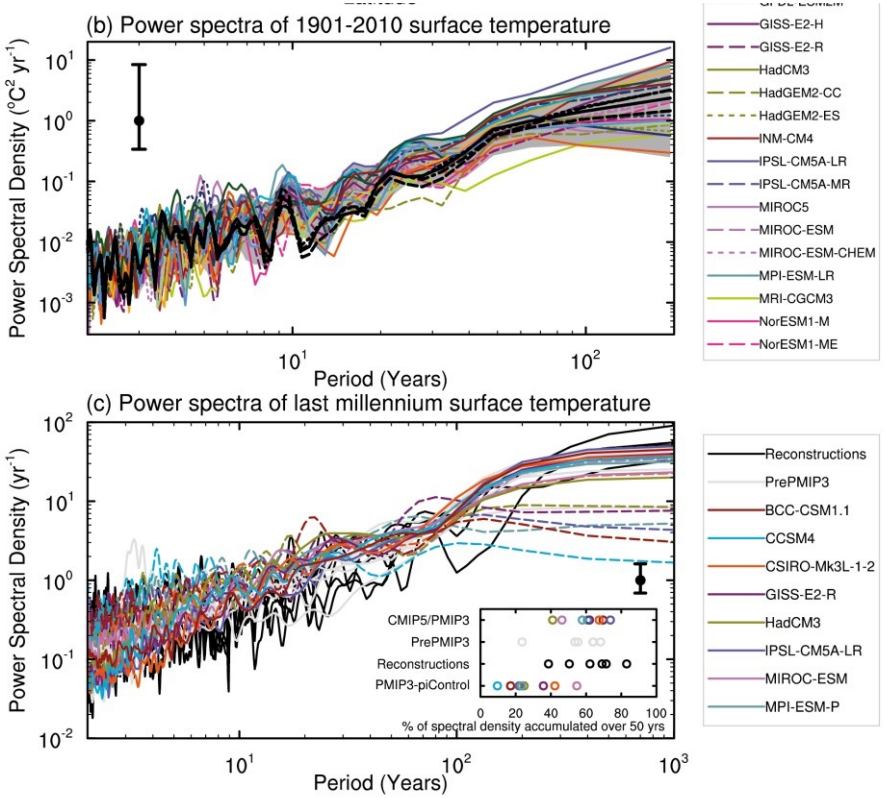
Status expected completion date	Available in CMIP5 DB (nb ens x nb years in CMIP5 DB)	Available in CMIP3 DB
No	Available in PMIP3 DB (nb years in PMIP3 DB)	
Yes		

PMIP3 PlioMIP groups: Note that the models used for PlioMIP are often not (exactly) the same as the ones used for PMIP3/CMIP5

PlioMIP only (not in the table): LPAP, UoM

Pre-PMIP3 and PMIP3 last millennium simulations in IPCC AR5

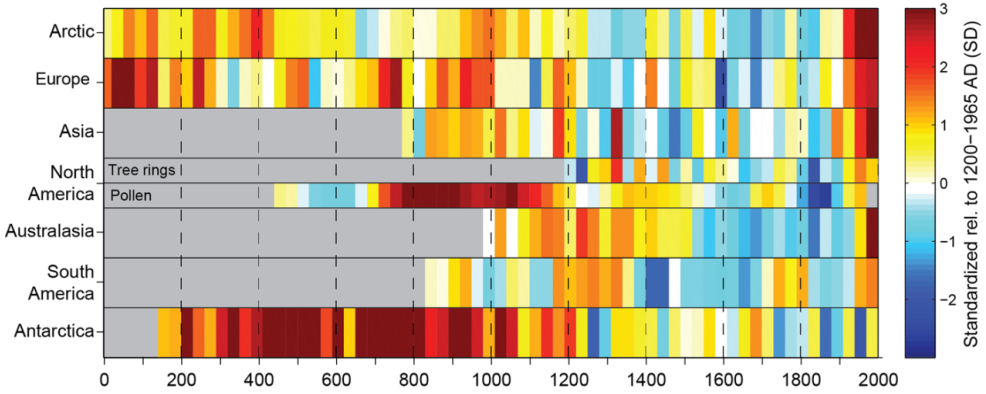




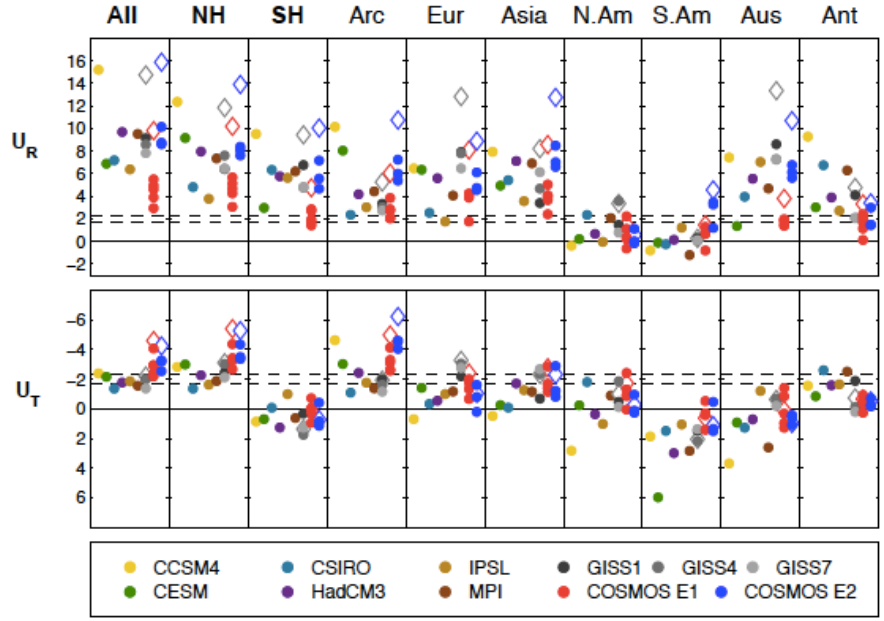
Ch5, Masson-Delmotte et al., 2013

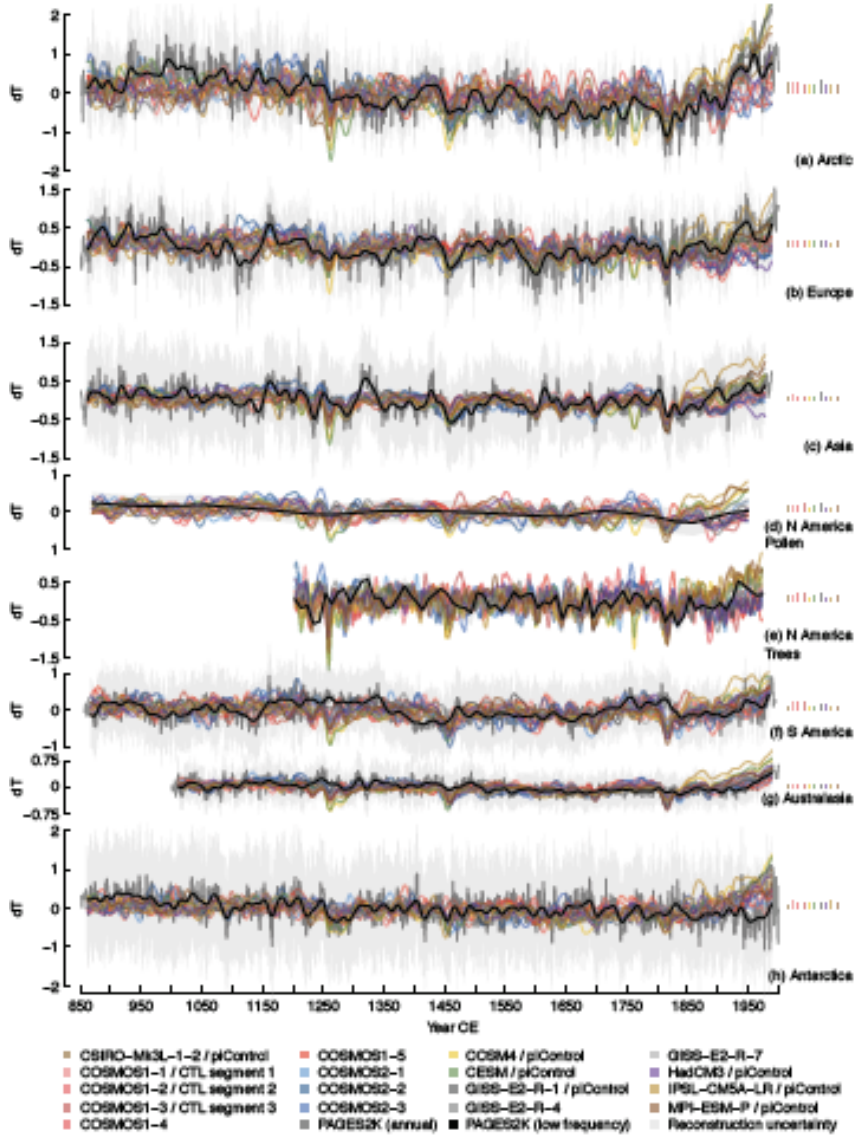
Ch9, Flato et al., 2013

PMIP3 last millennium simulations & PAGES2K



Ahmed et al., 2013





PAGES2k-PMIP3 group, 2015

PMIP3 last millennium simulations & PAGES2K

- Reconstructions and simulations agree that regional temperatures show response to ext. forcing. Some regions respond more to forcing than others. Solar impact acknowledged as comparatively smaller.
- Inter-regional correlations smaller in reconstructions
- New statistical methods and data assimilation can help to identify biases on regional scales and to improve understanding of mechanisms
- Model-based (pseudo-proxies) guidance in improving proxy-based analyses
- Improved process understanding (e.g. long-lasting effects of volcanic eruptions

The new PMIP4 “past1000” simulations

- PMIP conference Namur 2014: confirmed that *past1000* should be in the CMIP6 proposal
- past1000 should be 850-1849 CE (as in PMIP3) & mandatory “historical” experiment (1850-2014 CE)
- strong wish to encourage ensembles of simulations

PMIP proposal: LGM, MidHolocene, LastIG, Pliocene, past1000

Only **core** experiments are considered **CMIP6** experiments; all others, sensitivity experiments etc. are **PMIP4**

Documentation:

PMIP in CMIP6: Kageyama et al., GMDD, 2016

Past1000: Jungclaus et al., CP, in prep.

The PMIP4 “past1000” simulations

12 groups confirmed past1000 simulations

10 vs. 2 groups wish to have one set of forcing for the standard experiment

7 vs. 5 groups plan to run additional experiments with different forcing

6 vs. 6 plan to run multiple realisations

3 groups plan to run interactive aerosols or aerosol chemistry models (although no final confirmation on that)

The PMIP4 “past1000” simulations

Model id	Atmosphere resolution	Ocean resolution
CSIRO-Mk3L-1-3 (U. Tasmania)	64 x 56 x 18	128 x 112 x 31
NUIST-CSM	192x96x47	362x292x46
GISS-E2.1-R; GISS-E3-R	GISS-E2.1: 144x90x40; GISS-E3: Cubed sphere C90 x L96	360x180x32; 360x180x56
EC-EARTH3-LR, EC-EARTH3-CC-LR	320x160x62	362x292x75
MRI-ESM2	320 x 160 x 80	360 x 364 x 61
NorESM2-LM	1.9x2.5deg.x32	1deg.x53
INMCM48	180x120x21	360x318x40
UKESM-Io and/or HadGEM3	N96 = 192x145	ORCA1.0
MPI-ESM	192 x 96 x 47	256 x 220 x 40
AWI-CM	192 x 96 x 47	variable resolution, highest at coastal regions, 20 km near Greenland coast (details of the model grid will be submitted later)
FGOALS3	2 x 2 x 26	1 x 1 x 50
MPI-ESM-1.2	192x96x47	256x220x40
KCM2	2.8x2.8x31	182x149x31
CESM-2.1	288 x 192 x 32	320 x 384 x 60
IPSL-CM6-LR	144x142x79	1degx79L
iLOVECLIM1.2	5.6x5.6x3	3x3x20

The PMIP4 “past1000” simulations

Tier 1: The CMIP6 past1000 & historical experiment

- The official CMIP6 past1000 experiment covering 850 - 1849 CE followed by a mandatory CMIP6 historical experiment (1850 - 2014 CE). It applies the “consensus” forcing data set. Groups are encouraged to run multiple realisations (ensemble approach).

The PMIP4 “past1000” simulations

Tier 2: Additional PMIP4 past1000 experiments: Uncertainties and attribution

- Exploring uncertainty in forcing boundary conditions: Sensitivity experiments applying different flavours or differently derived forcing agents

- Attribution to individual forcings: Sensitivity experiments applying one forcing at a time (note that attribution may require multiple realisations owing to low signal-to-noise ratio).

The PMIP4 “past1000” simulations

Tier 2: Additional PMIP4 past1000 experiments:

- **VolcLong-Cluster:** Focus on volcanic forcing and climate change in the early instrumental period: An experiment carried out in cooperation with **VolMIP** (Zanchettin et al., 2016): An ensemble of 70-year long simulations starting from past1000 restart files in 1790 CE investigating the period of the Dalton Minimum and the Tambora eruption.

- The **PMIP4 past2k** experiment: same as the standard experiment, but starting in the year 0 CE. So far, four groups have expressed interest to extend to 2000 years.

PMIP4 “past1000” external forcing

Solar:

New TSI and SSI are based on updated reconstructions of most recent cosmogenic isotope data 14C (Usoskin et al., 2016) and 10Be (Baroni et al., in prep.).

PMIP4 provides:

CMIP6: (1) 14C -based data set (SATIRE_14C, N. Krivova, pers. comm.). Solar surface magnetic flux is reconstructed from the isotope data through a chain of physics-based models (Vieira et al., 2011; Usoskin et al., 2016).

(2) 10Be-based data set (SATIRE_10Be, N. Krivova, pers. comm.) using the same procedure as (1) to reflect uncertainty in the cosmogenic input data.

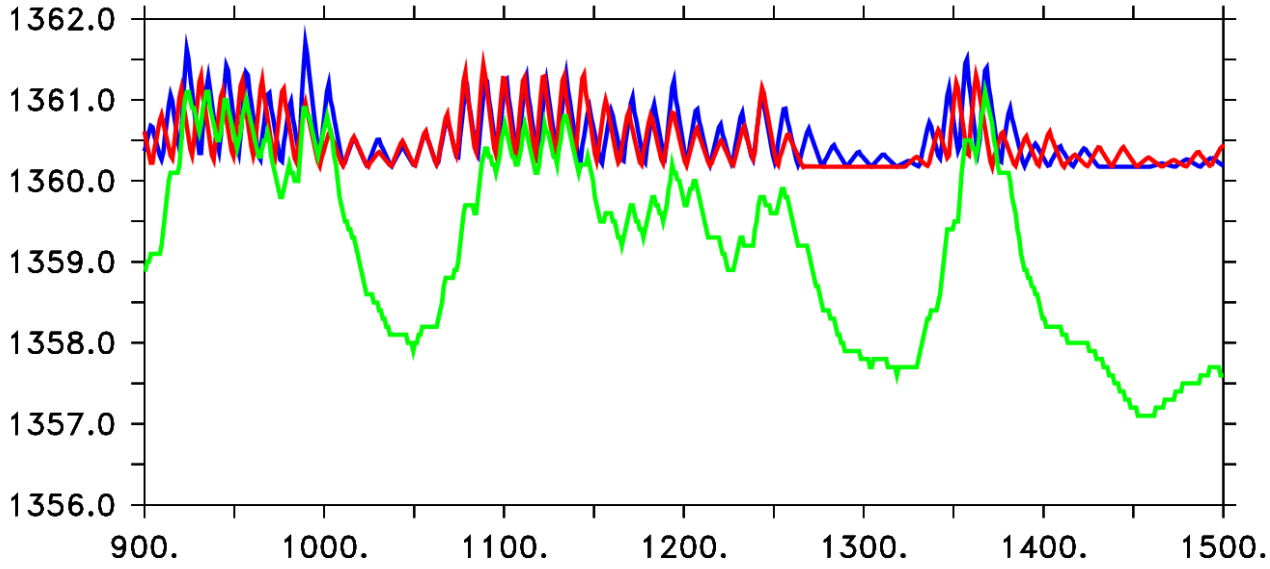
(3) 14C-based data data set (PMOD_14C) based on different assumptions for the long-term changes to reflect uncertainties in the magnitude of the secular variation Shapiro et al., 2011; Judge et al., 2012; Egorova et al., in prep.)

PMIP4 “past1000” external forcing

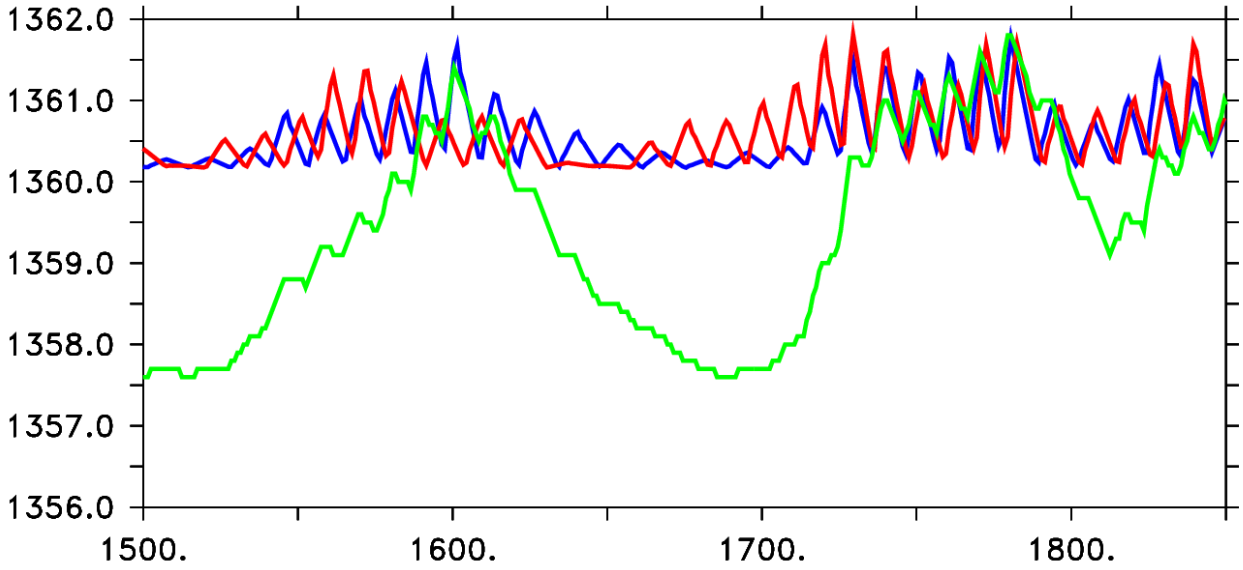
PMOD

SATIRE_C14

SATIRE_10Be



Time (years)



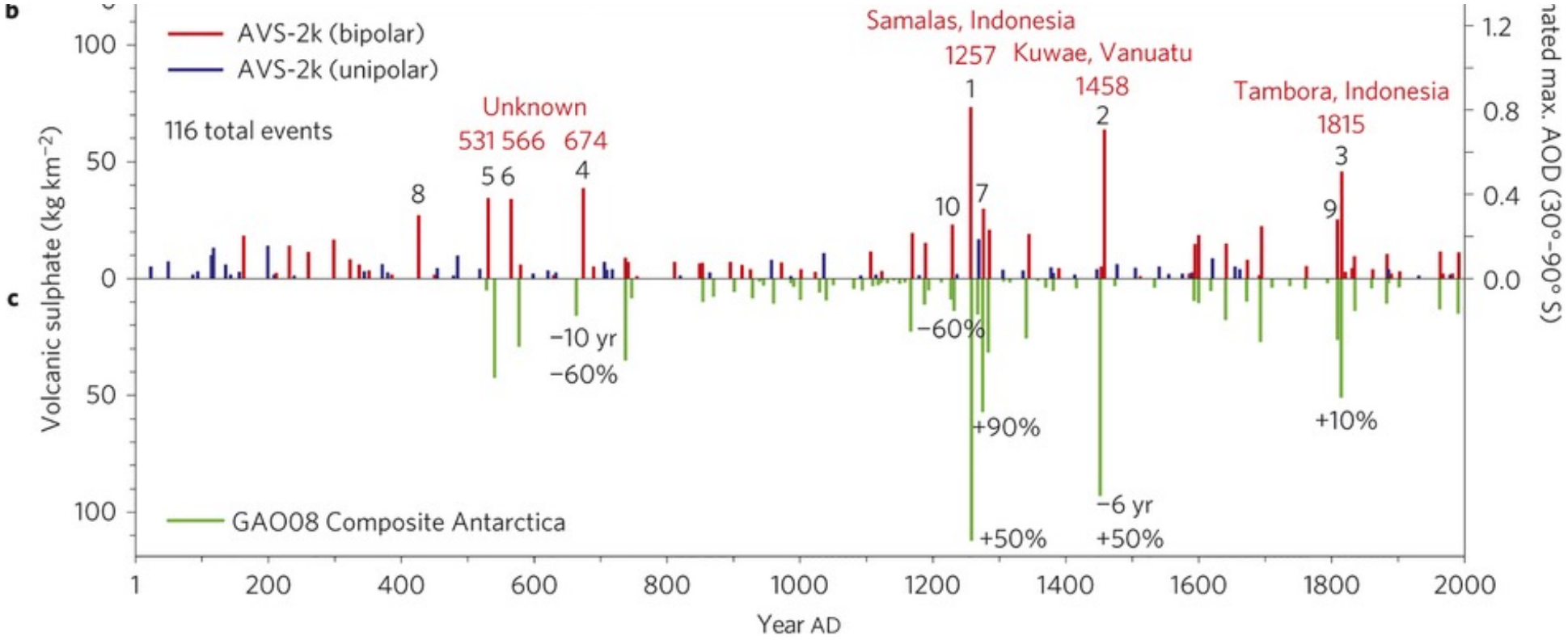
PMIP4 “past1000” external forcing

Volcanic:
New estimates of sulphur injections based on Sigl et al. (2014/15). Better constraints on timing and revises amplitudes of sulphur injections.

Groups using forcing based on aerosol optical properties (AOD, reff) are supposed to use the **Easy Volcanic Aerosol** (EVA) module (Toohey et al., 2016)

should be technically most compatible with CMIP6 historical data set

PMIP4 “past1000” external forcing



Sigl et al., 2014

PMIP4 “past1000” external forcing

Land-Use:
New historical land-use forcing covering 850 - 2005 CE based on HYDE3.2 (Klein-Goldewijk et al., in prep.) estimate of cropland, pasture, urban, and irrigation.
Grazing lands are split into managed pasture and rangeland categories, and crop type disaggregation.

Historical wood harvest is based on updated HYDE inputs and new historical estimates. High-/low estimates are provided in addition to the “best-guess” data set.

This comes as a continuous forcing 850 to 2014, provided by G. Hurtt et al.

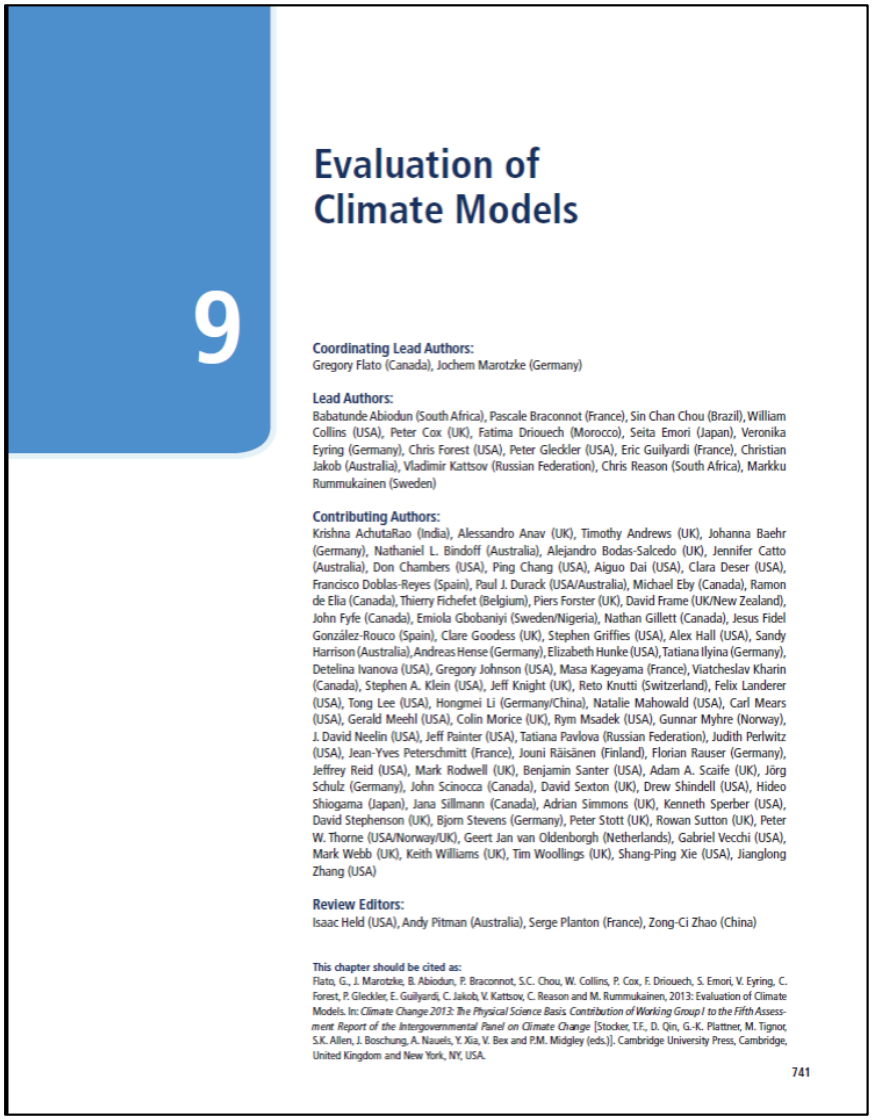
PMIP4 “past1000” summary

Models:
Models will be pretty similar to PMIP3, some go for higher resolution (ECEarth). Increase in computer resources can be used for multiple realisations (ensembles)

Forcings:
Some progress over PMIP3 (better time constraints for volcanic eruptions, Spectral solar irradiance), better integration of pre-industrial and historical forcing (although not achieved for all)

Experiments:
Standard past1000 & historical as part of CMIP6
Past2k: 4 groups
Additional experiments on specific topics (e.g. together with VolMip)

How good are climate models?



9

Evaluation of Climate Models

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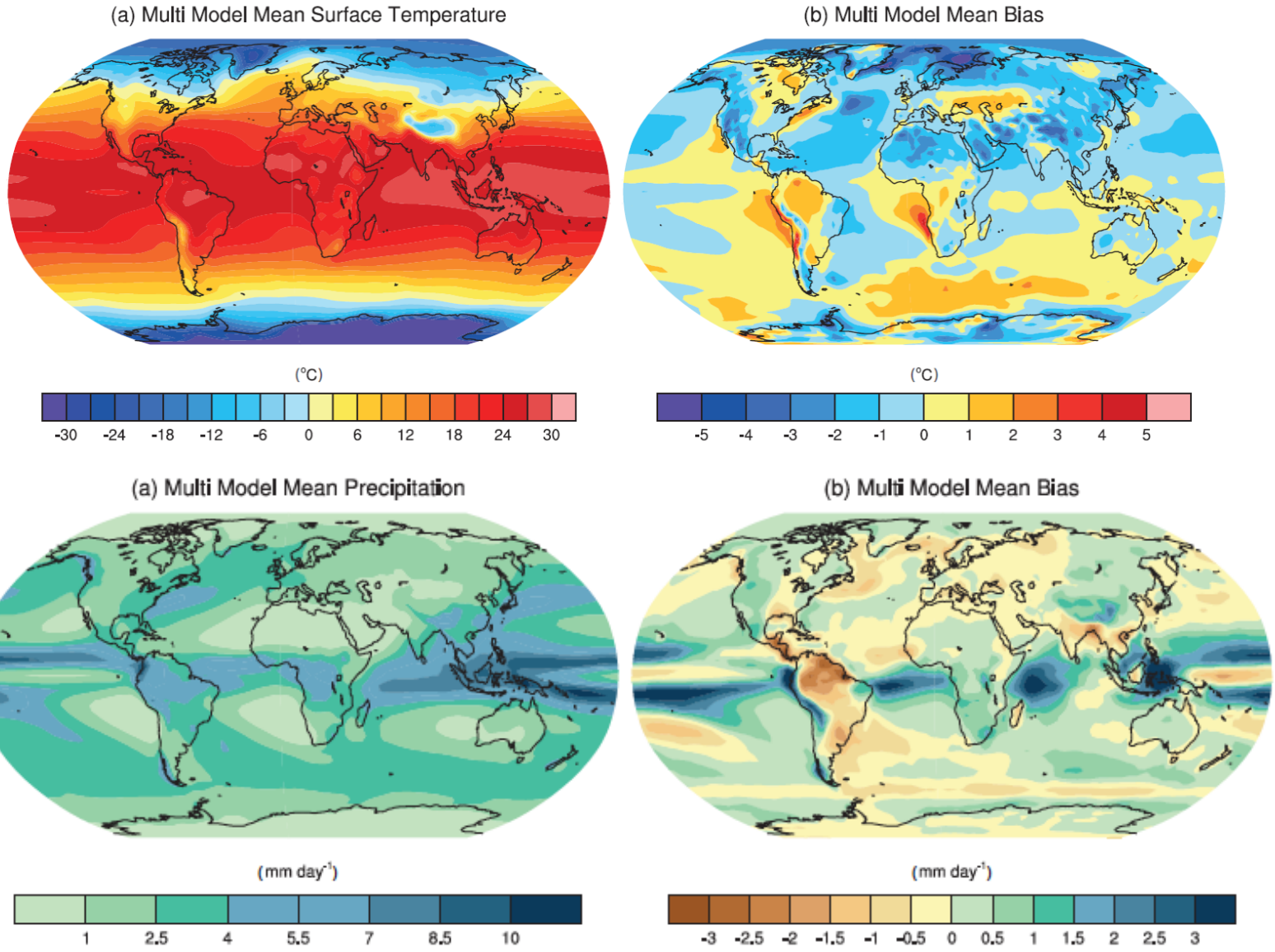
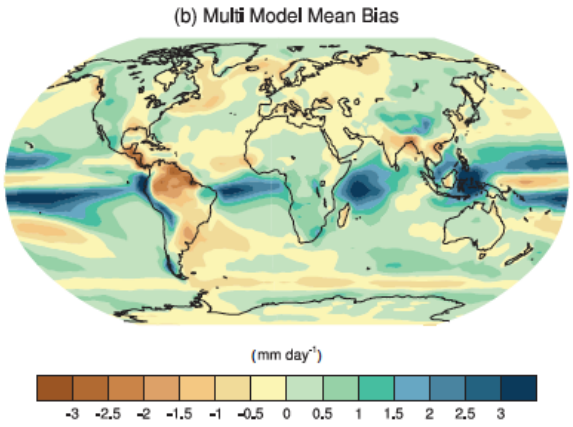
- Emphasis is on measures of performance, evaluation of CMIP5 vs. CMIP3, role of new “Earth system” components
- CMIP5 could draw on more models
- more Earth System Models including carbon cycle, sulphur, interactive aerosols etc.

How good are climate models?

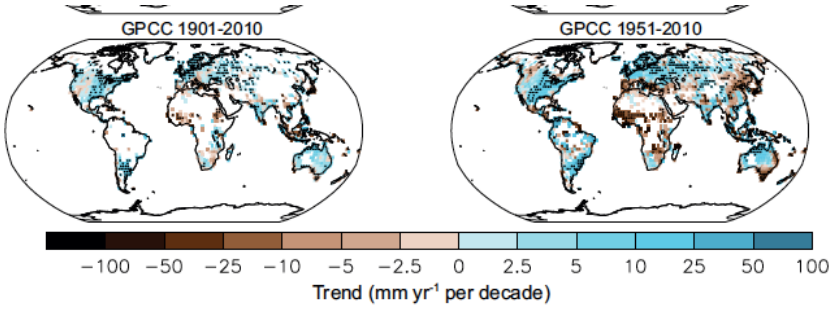


Flato et al., 2013

How good are climate models?



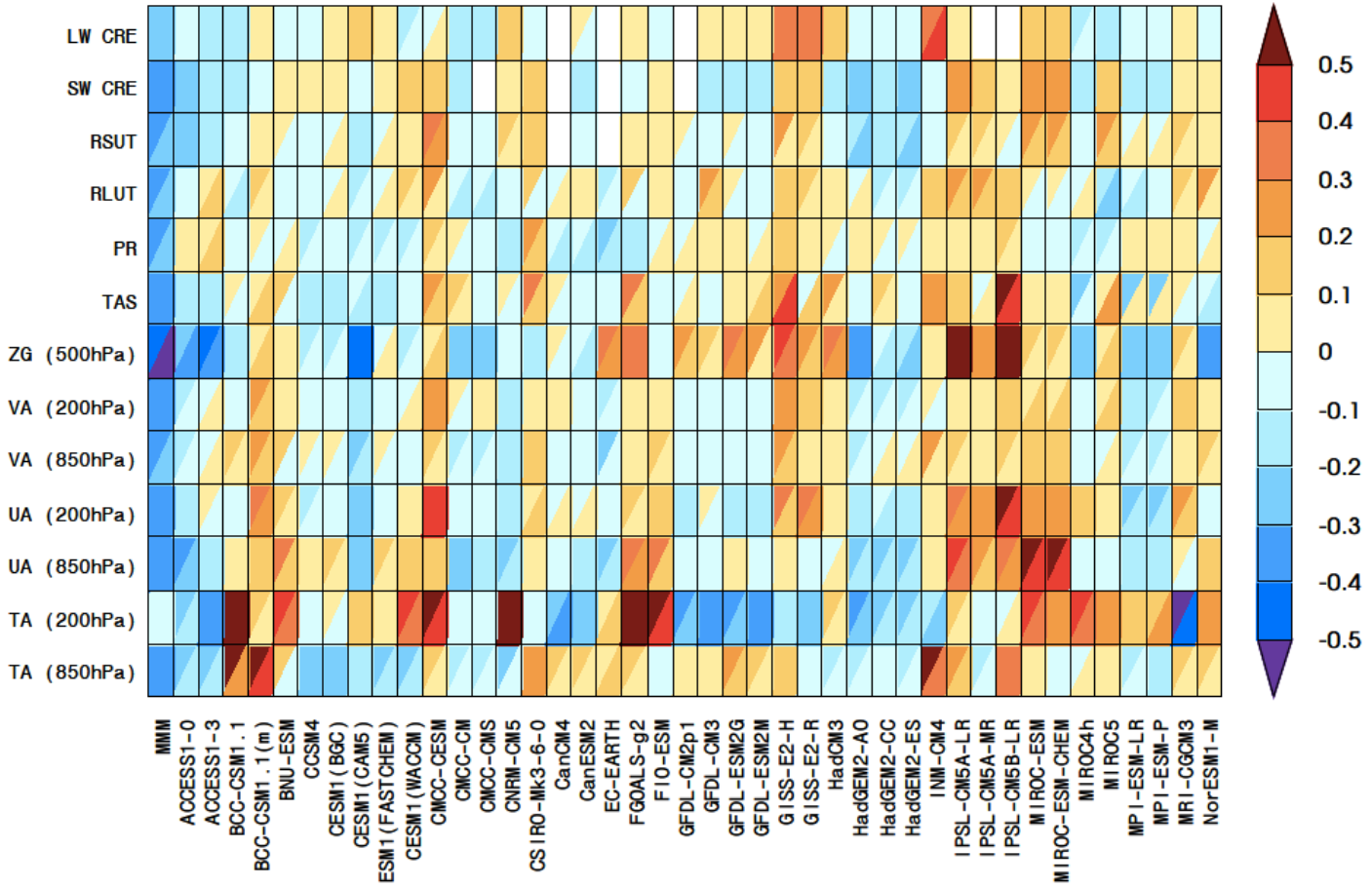
"A particular problem in simulating the seasonal cycle in the tropical Pacific arises from the 'double ITCZ', defined as the appearance of a spurious ITCZ in the SH associated with excessive tropical precipitation."



"There is *medium confidence* that models are correct in simulating precipitation increases in wet areas and decreases in dry areas on broad spatial scales in a warming climate based on agreement among models and some evidence that this has been detected in observed trends."

Flato et al., 2013

How good are climate models?

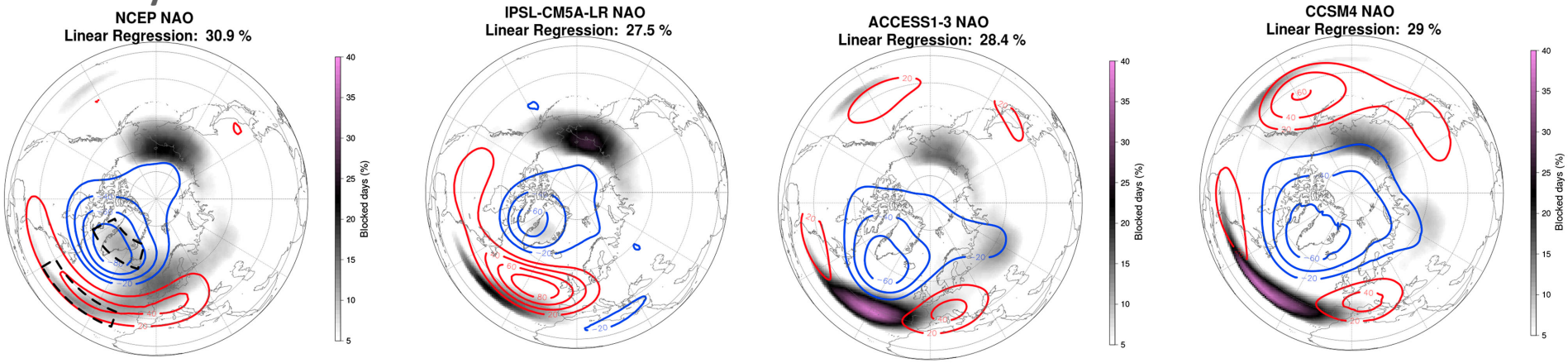


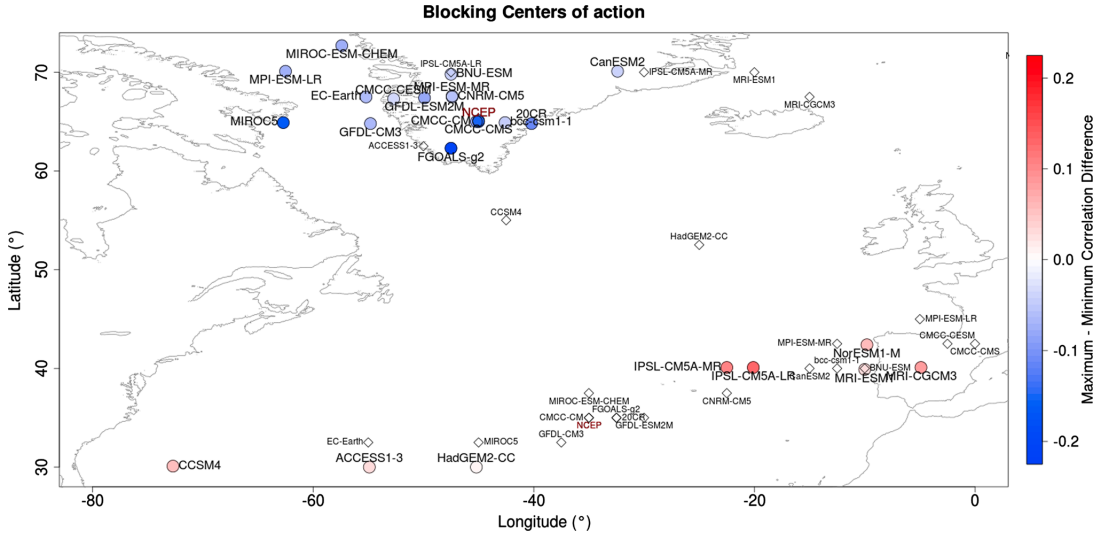
Metrics were developed to rank models and to compare overall performance…

Flato et al., 2013

How good are climate models?

Reanalysis





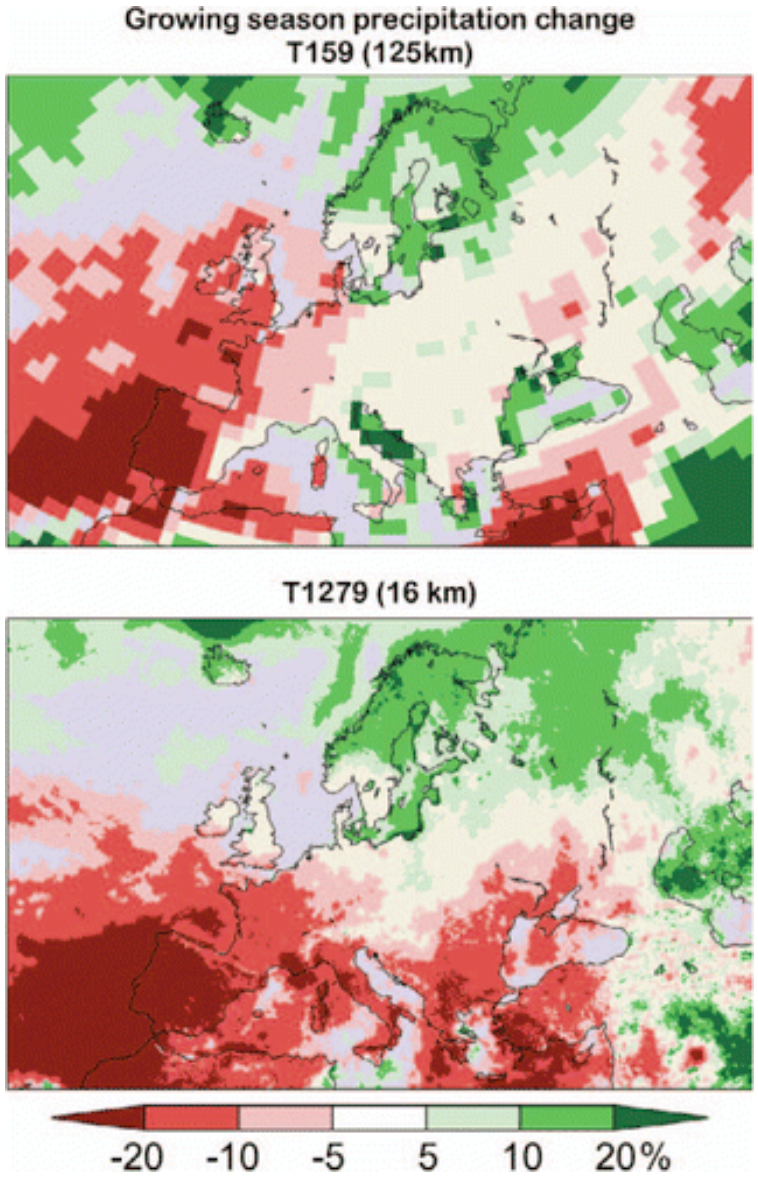
…however, model performance needs to be carefully analyzed for the specific purpose, e.g. NAO for European climate

Davini and Cagnazzo, 2014

How much does resolution matter?

ATHENA project:

"The outcomes to date suggest that, in addition to substantial and dedicated computing resources, future climate modeling and prediction require a substantial research effort to efficiently explore the fidelity of climate models when explicitly resolving important atmospheric and oceanic processes."

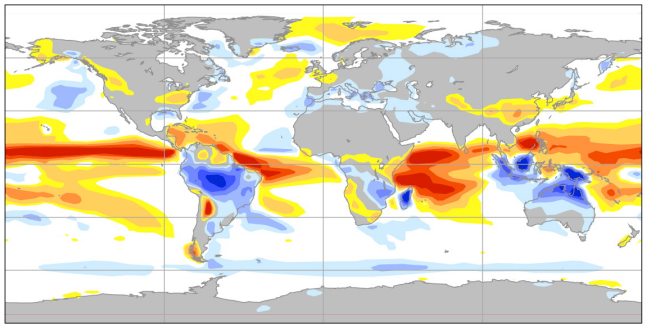


Kinter et al., BAMS, 2013

How much does resolution matter?

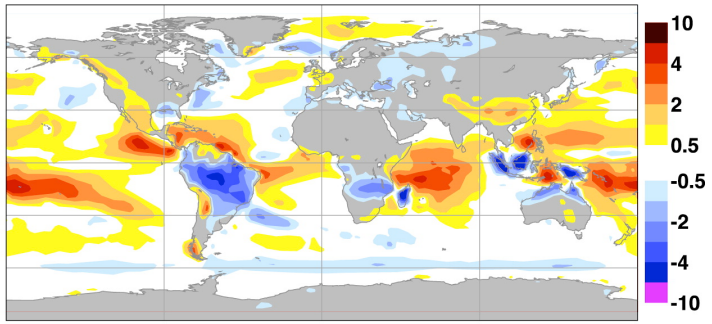
Precipitation bias in ECMWF IFS

a)



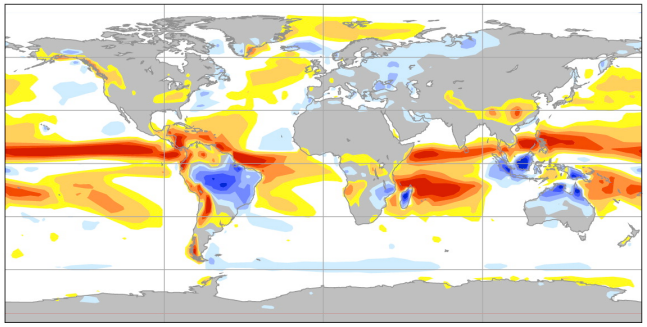
low resolution (T95)

b)



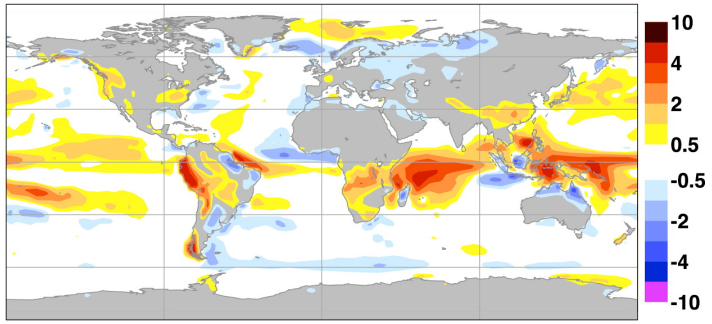
T95, stochastic subgrid para.

c)



high resolution (T511)

d)



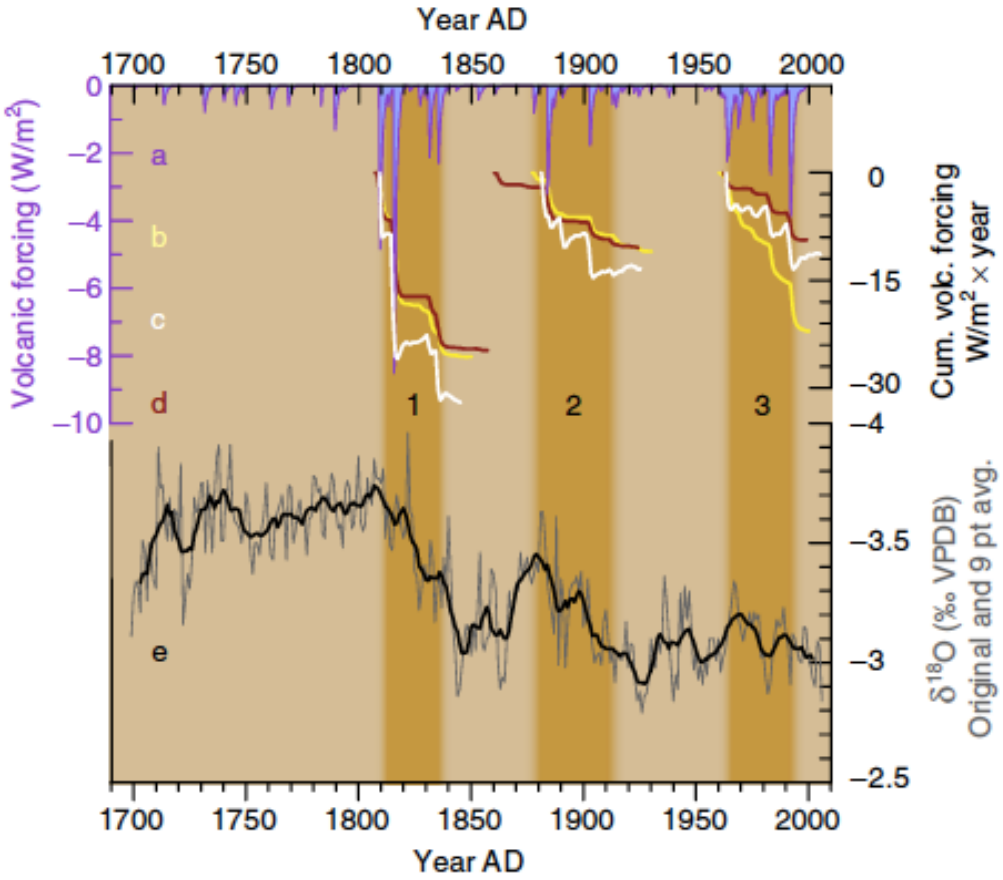
T95, improved physics

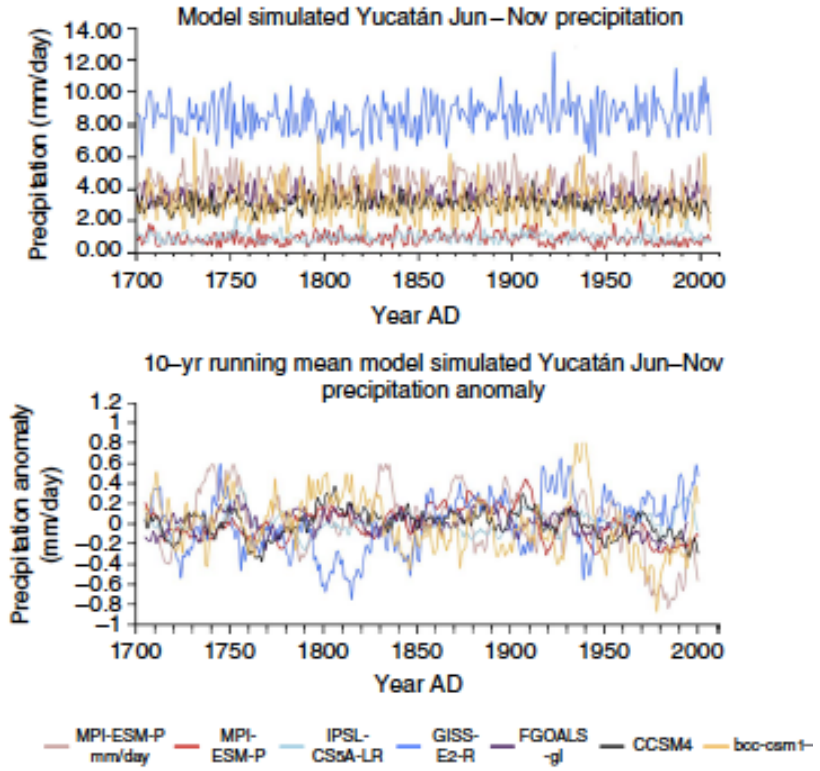
Higher resolution and improved parameterisations lead to better representation of circulation, e.g. Northern Hemisphere blocking, but does not solve problems in the tropics. More sophisticated parameterisations are needed to improve convectively coupled waves and tropical variability.

Berner et al., J. Clim, 2012

Forced responses in hydrolocical records

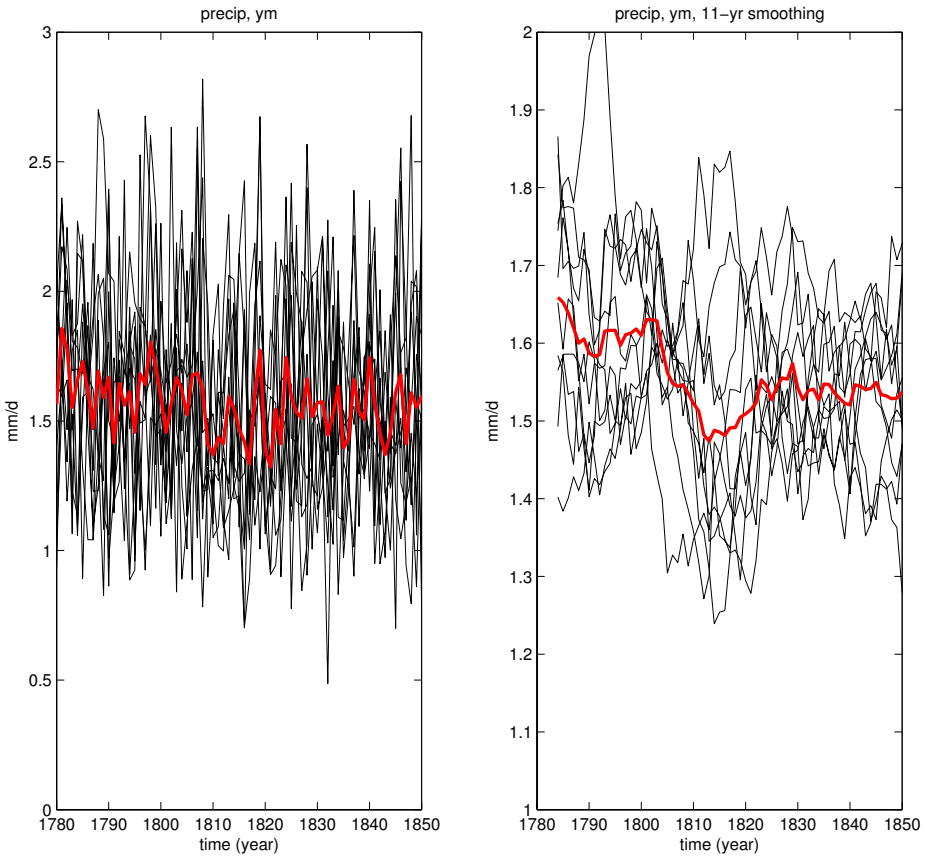
Winter et al. relate drying trends in Mesoamerica to volcanic forcing. No corresponding signal obvious in CMIP5 past1000 simulations





Winter et al., Nature Comm, 2015

Forced responses in hydrolocical records



….however, an ensemble of early-19th century simulation shows a corresponding drying as an average result.

Model-data comparison may be complicated by the low signal-to-noise ratio for hydroclimatic variables.

Davide Zanchettin, pers. comm.

Model biases in hydroclimatic variables seem to be more serious than temperature; more related to deficiencies in dynamics.

Stephens et al. (2010) diagnose “Dreary state of precipitation in global models” (even at much higher resolution than usually used in paleo simulations)

Gorman and Schneider (2009): “Changes in tropical precipitation extremes can not be reproduced; large model scatter owing to different parameterisations”

Thus, “comparing data and model estimates of hydroclimate variability and change over the common era” will be a difficult task and we need to carefully design our analyses.