Cloud Feedback in an ensemble of general circulation model experiments of the Last Glacial Maximum

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The PMIP 2 project

Suite of AGCM, OAGCM and OAVGCM experiments for

- Control Pre-Industrial (0K)
- Mid – Holocene (6K)
- Last Glacial Maximum (21K)

using ECHAM5,IPSL-CM4-V1,ECHAM5,CCSM,MRI-CGCM1,FOAM, MIROC3.2,HadCM3M2, GISSmodelE, ECBILTCLIO

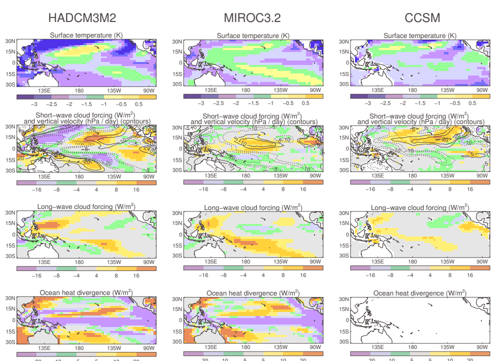
On this poster :

- Last Glacial Maximum
- 3 models : HadCM3M2, MIROC3.2, CCSM
- Beta-release of the database (!)

Experimental design :

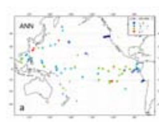
Ice sheets **ICE-5G** (Peltier et al., 2004)
Change in land-sea mask (lowered sea-level)
insolation of 21,000 years ago (astronomical forcing, Berger 1978)
reduced CO_2 (185 ppmv instead of 285 ppmv)
+ other GHG (CH_4, N_2O)
river routing modified (HYDRA)

The tropical Pacific



◄ Models simulate a spatially heterogeneous cooling in the tropical Pacific Ocean.. This may be related to a number of reasons, including change in short-wave or long-wave cloud forcings and in the heat divergence in the ocean. The contours are the variation in vertical velocity at 500 hPa.

The palaeoclimate data (Kucera et al, in press in Quaternary Science Reviews) support an eastward positive gradient of temperature differences between the Last Glacial Maximum and today ▼



Understanding the spatial variability of temperature anomalies

The tropical Pacific SSTs are regressed against the cloud forcing and the heat convergence of the ocean

$$\Delta T = \beta_0 + \beta_{CF}\Delta CF + \beta_{HD}\Delta HD$$

	Regression coefficients		
	β_0	β_CF	β_HD
HadCM3M2	-2.15	0.067	-0.0045
MIROC3.2	-1.76	0.062	0.0016
CCSM	-2.07	0.045	N/A

	Explained variability (%)	
	CF	HD
HadCM3M2	17.0	1.6
MIROC3.2	31.4	0.1
CCSM	26.9	N/A

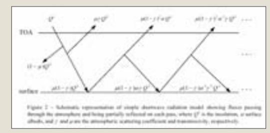
◄The regression reveals that a significant fraction (17 to 31 %) of the spatial variability in SST anomalies in the tropical Pacific may be explained by the cloud forcing, with a ratio of approximately 15 $W/m^2/K$.

Evaluation of forcing and response

K. E. Taylor et al, « Analysis of forcing, response and feedbacks in a paleoclimate modeling experiment », in Paleoclimate modelling intercomparison project, ed. P. Braconnot, WCRP-111 WMO/TD 1007, pp. 43-50 (2000)

I. Short-wave

principle:
diagnose μ, γ, α
to evaluate the impact of any individual component (snow, land-sea-mask, clouds etc.) on radiative balance



	[W/m2]										[K]
	TOTAL*	ALBEDO	(mask)	(ice)	(snow)	(other land)	sea-ice	CLOUD	CLEAR SKY	SOLAR	ΔT
HadCM3M2	-6.24	-5.59	-0.25	-3.79	-0.31	0.00	-1.23	-0.60	-0.28	0.06	-5.12
MIROC3.2	-4.36	-3.97	0.00	-2.83	-0.34	-0.09	-0.71	-0.16	-0.37	0.03	-3.69
CCSM	-5.23	-4.33	-0.35	-2.08	-0.29	-0.04	-1.57	-0.82	-0.18	0.05	-4.47

* TOTAL also includes non-linear terms not listed here

FORCING (mask, ice) — FORCING (SOLAR)

II. Long-wave

Forcing : estimate from GHG concentrations : –3.25 W/m^2

Response : calculated as « linear » (i.e., prop. to surface response), CLOUD AND CLEAR-SKY

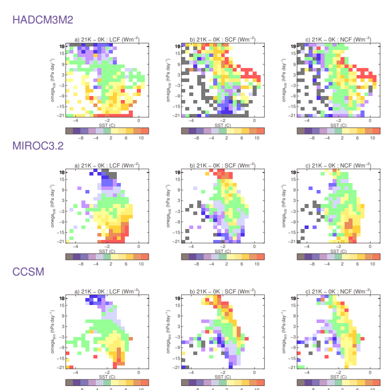
	[W/m2]				
	TOTAL	FORCING	LINEAR	CLOUD	CLEAR-SKY
HadCM3M2	6.08	-3.25	15.96	-2.89	-3.74
MIROC3.2	4.27	-3.25	12.02	-1.93	-2.57
CCSM	5.19	-3.25	N/A	N/A	N/A

IIi. Estimate gain and feedback parameters

		feedback factor (%)							
	GAIN_0	(snow)	(other land)	sea-ice	CLOUD (SW)	CLSKY (SW)	CLOUD (IR)	CLSKY (IR)	GAIN
HadCM3M2	0.32	1.9%	0.0%	7.8%	3.8%	1.8%	18.1%	23.4%	0.70
MIROC3.2	0.31	2.8%	0.7%	5.9%	1.4%	3.1%	16.1%	21.4%	0.61
CCSM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.23

▲ HadCM3M2 simulates the strongest global cooling, but CCSM is the most sensitive. Data are lacking for a complete feedback analysis of CCSM. MIROC3.2 and HadCM3M2 have similar sensitivities, with however cancelling differences as detailed in the table above.

Regime analysis (tropical Pacific)



▲ The grid-points of the tropical Pacific ocean are classed according to the SST difference simulated between the LGM and today (*x-axis*) and the difference in vertical velocity (*y-axis*). The variations in *(a)* short-wave *(b)* long-wave and *(c)* net cloud forcing are then plotted versus to these two variables. While,, taken separately, the shorw-wave and long-wave cloud forcings are stratified according to vertical velocity,, the net forcing is clearly correlated with surface temperature. This is due to cancellation of shortwave and longwave forcings in convective clouds

More on PMIP2

PMIP II is funded by the WCRP (CLIVAR) and the IGBP (WCRP). It is associated with the EU-funded MOTIF project. It involves modelling centres and palaeoclimate data laboratories.

PMIP II studies the role of climate feedbacks arising from the different climate subsystems (atmosphere, ocean, land surface, sea ice and land ice) and evaluates the ability of state of the art climate models to reproduce climate states that are radically different from those of today. Results from both coupled ocean-atmosphere models and ocean-atmosphere-vegetation models are considered.

Most of the runs are still being produced. Model data are archived at the LSCE (Gif-sur-Yvette, France) and will become of public domain.

PMIP 2 also fosters the development and improvement of paleo-environmental data sets. As in PMIP 1, analyses will focus on both model-model and model-data comparisons.

A certain number of analysis projects have been registered (« BIOME » simulations, high-northern latitude surface climates, role of vegetation feedback, bioclimatic parameters, sensitivity of large-scale forcing of eastern boundary current regions, cloud feedbacks, response of Atlantic Ocean, tropical interannual variability, Lagrangian analysis of Ocean circulation, tropical climates, estimating climate sensitivity from model-data comparisons, mid-Holocene climate variability, polar amplification of climate change, monsoon, influence of sea-ice on air masses etc.)

More details on the project may be found at ***http://www-lsce.cea.fr/pmip2/***

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