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CMIP: A Study of Climate Models and Natural Climate Variability

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CMIP: A Study of Climate Models and Natural Climate Variability *

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Model simulations of the natural climate (without human-produced greenhouse gases and aerosols) can be compared with observations over the past century. Recent work concludes that an anthropogenic signal of global warming is emerging from natural variability "noise" (e.g., Santer et al., 1995). More careful and systematic examination of the model results seems warranted, however. Toward that end the World Climate Research Program has begun the Coupled ocean-atmosphere Model Intercomparison Project.

Like the Atmospheric Model Intercomparison Project (Gates, 1992), CMIP aims at a comprehensive study of model behavior, but there are important differences between AMIP and CMIP. Whereas AMIP examines atmospheric models run with prescribed sea surface temperatures—in essence fixing the climate near observations by imposing a boundary condition—CMIP deals with global coupled models of the atmosphere, ocean and sea ice. These are the models used to forecast global changes due to anthropogenic aerosols and greenhouse gases (IPCC, 1995). A second difference with AMIP is that in its initial stage, CMIP will examine existing model simulations rather than impose uniform external forcing (CO_2, solar "constant," etc.) and output standards on the models. This stage of CMIP will examine only so-called control runs of coupled models in which external forcing is constant. In a later stage, CMIP will consider the standardization of coupled model runs.

At the end of 1995, the CMIP Panel (part of CLIVAR Numerical Experimentation Group 2) sent invitations to all known coupled model developers. The Panel asked participants to supply from their output long-term means and standard deviations of some twenty climatic fields. These include precipitation, sea level pressure, zonal mean temperature and winds, and oceanographic variables such as zonal mean temperature, salinity and poleward heat transport. In addition, the panel requested a time series of surface air temperature. In terms of storage, the time series of surface air temperature constitutes the bulk of the CMIP data set.

At the time of writing this document, the Panel's deadline for receipt of CMIP output lies in the future, and many groups are actively preparing for participation. At the same time, we are evolving a strategy for quality-control and analysis of the data. What follows is only a preliminary discussion based on contributions received to date.

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So far we have focused our attention on model-simulated variability of surface air temperature. We have archived these data from eleven coupled GCMs (Table 1). Our analysis strategy is to proceed systematically through frequency bands, starting with the highest (and best-observed) frequencies of climate variations. We thus began by examining the models' simulation of the seasonal cycle. As shown in Figure 1, the models agree fairly well with observations. This is a nontrivial result. The cycle of the seasons is a climatic change driven by known forcing, namely changing insolation at the top of the atmosphere as a function of time and latitude. Note that about half the models examined refrain from using "flux correction" to move their results closer to observations (Table 1).

At longer time scales, substantial differences in variability appear among the models. Figure 2 shows power spectra of the globally and annually averaged surface air temperature from the four longest model runs received. Although model differences lie just within the 95% significance interval shown in the figure, two features are striking. At higher frequencies, the models shown—and nearly all the other models examined—fall below observations (Jones, 1994). At lower frequencies, observations are scarce, but we can note that the GFDL model has generally more variance than the other three. (For the ECHAM1+LSG run, we omitted the initial 300 years, which contained a long start-up transient, and thus found less low-frequency power than Santer et al. [1995].)

To repeat, CMIP has just begun. Contributions are still being received, and much more diagnosis of the model simulations is needed. This diagnosis will include many fields in addition to surface air temperature. For temperature variations, we plan to examine the geographical pattern and correlation structure of variations, and to compare the model output with high-resolution paleodata. Consideration of externally forced natural variability (e.g., from solar luminosity changes) is also required in order to assess the realism of the models' long-term variations.

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TABLE 1: CGCM Control Run Output Received for CMIP (20 March 1996)

Model	Flux Correction	Run Length [yr]	T time-series	Other fields
BMRC	none	108	√	
CERFACS	none	55*	√	
CSIRO	heat, water, momentum	300*	√	
GFDL	heat, water	1000	√	
GISS (Miller)	none	112	√	
GISS (Russell)	none	98	√	√
MPI (ECHAM1+LSG)	heat, water, momentum	1260*	√	
MPI (ECHAM3+LSG)	heat, water, momentum	560*	√	√
MPI (ECHAM4+OPYC)	heat, water, momentum	290+	√	√
NCAR	none	48	√	
UKMO	heat, water	75	√	

*Initial transient requires truncation of time series.

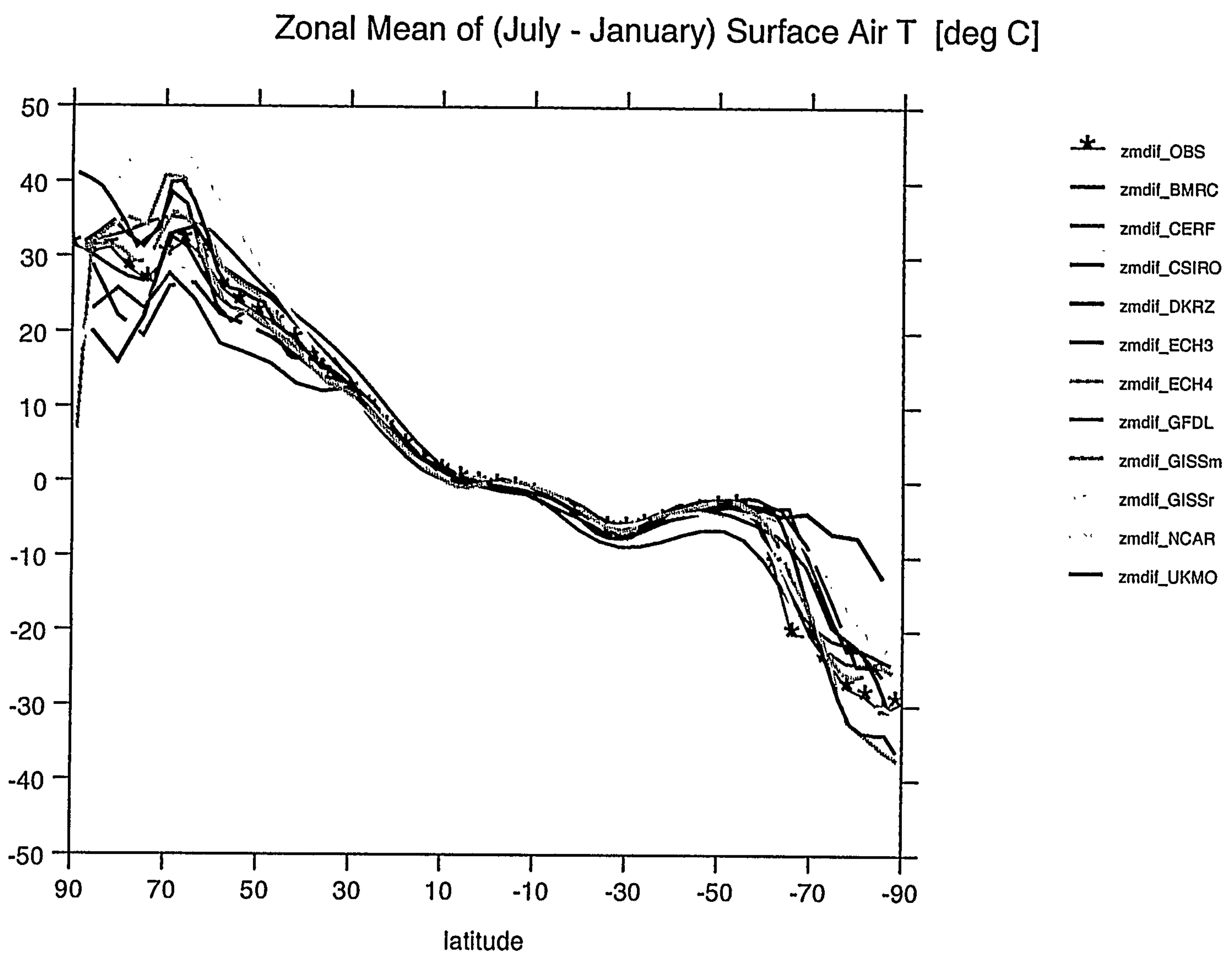
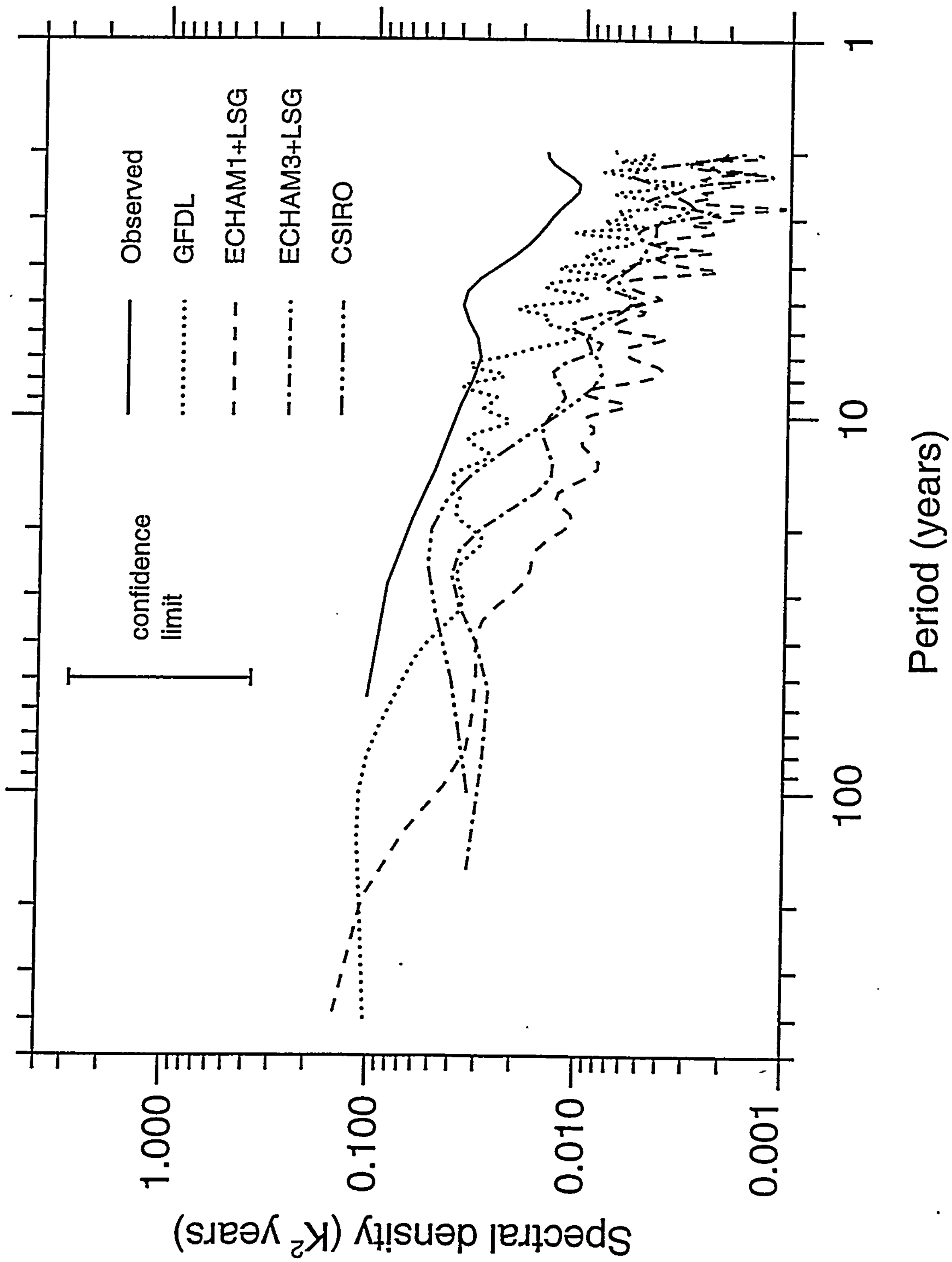

Zonal Mean of (July - January) Surface Air T [deg C]
50
40
30
20
10
0
-10
-20
-30
-40
-50
90
70
50
30
10
-10
-30
-50
-70
-90
latitude
zmdif_OBS
zmdif_BMRC
zmdif_CERF
zmdif_CSIRO
zmdif_DKRZ
zmdif_ECH3
zmdif_ECH4
zmdif_GFDL
zmdif_GISSm
zmdif_GISSr
zmdif_NCAR
zmdif_UKMO

Fig. 1

Fig. 2



Spectral density (K² years)
1.000
0.100
0.010
0.001
Period (years)
100
10
1
confidence limit
Observed
GFDL
ECHAM1+LSG
ECHAM3+LSG
CSIRO