Outline for an Earth System Model

PUMA - LSG - HAMOCC - LPJ - Ice - ...

1 Scope

An Earth system model of intermediate complexity is developed for the study of climate dynamics on decadal to millennial time-scales. The main task is to identify the driving mechanisms and potential thresholds responsible for climate transitions. Emphasis is placed on the multiple states of the system and the interaction of the dominant pattern of atmospheric variability with the ocean and land surface. In contrast to conventional time-slice experiments, the present approach is not restricted to equilibrium states and is capable of utilising all available data for validation. Transient simulations for the past and future climate will examine feedback mechanism in the climate system.

The model explicitely resolves the three-dimensional atmospheric dynamics and is therefore conceptual different from statistical dynamical models (as e.g. CLIMBER). Pathways of orbital forcing into climate response reveal the understanding of climate records. The Earth system model shall have a modular structure with portable Fortran code. The modular structure of the model enables the user to modify model configurations according to the application. New schemes and model components can be included with a minimum of technical expense which is particularly useful for paleoclimatic applications.

At time-scale comparable to glacial-interglacial cycles, the importance of each Earth system component has not been estimated. At this early stage of exploration for the coupled system, it is necessary to be able to carry out a large number of sensitivity experiments. It is expected that, compared to e.g. scenario calculations for the next century, different processes will dominate Earth system interactions at such long time scales. This has to be accounted for a suitable modelling framework; it also requires cooperation between expert groups of different focus. Therefore, the knowledge and experience in different disciplines and institutes are required to construct the proposed Earth system model.

2 Description of the model components

The Portable University Model of the Atmosphere (PUMA) is derived from the Reading multi-level spectral model described by Hoskins and Simmons (1975). The model is based on the primitive equations with terrain following-coordinates in the vertical. The PUMA model in T21L5 resolution (Fraedrich et al., 1998) has been extended by relatively simple radiation and precipitation schemes. The model contains representations of subgrid scale fluxes over land, ice, and open sea. A snow model following Loth (1995) has been implemented. PUMA is designed to be as compatible as possible with the comprehensive GCM ECHAM, all common tools, statistical and graphical packages, can be applied on PUMA data in the same manner as on ECHAM data.

The atmospheric model has been coupled to the ocean model LSG (Maier-Reimer et al., 1993) designed especially for long-term climate studies (timestep of one month). This

Model		yr/h CPU	Memory	Δt	Reference

present model components

atmosphere	PUMA	7 yr	2 MW	1h, 1day	(Fraedrich et al., 1998)
ocean	LSG	200 yr	5 MW	1 month	(Maier-Reimer et al., 1993)
marine C-cycle	HAMOCC3	200 yr	10 MW	1 month	(Maier-Reimer, 1993)

planed model components

terr. biosphere	LPJ	200 yr	1 MW	1 day, 1 yr	(Sitch et al., 2000)
land ice	SICOPOLIS				(Greve, 1995)

model contains a parameterization for the bottom boundary layer (Beckmann and Döscher, 1997) which drastically improves the density-driven downslope flows (Lohmann, 1998) and is essential for the interpretation of paleoclimatic records (Lohmann and Schulz, 2000). The coupled atmosphere-ocean model does not require flux adjustments. Furthermore, the LSG model includes the HAMOCC carbon cycle model (Maier-Reimer, 1993). The model components have been extensively tested in studies of paleoclimate (Winguth et al., 1999), future climate change scenarios for the next century (Lunkeit et al., 1998), and storm track variability (Frisius et al., 1998).

First experiments exist for the terrestrial biosphere model LPJ (Lund-Potsdam-Jena, Sitch et al., 2000), which is forced with the PUMA-LSG climate. The LPJ model is a dynamic global vegetation model combining mechanistic treatments of terrestrial vegetation dynamics, carbon and water cycling. Vegetation population dynamics is updated annually and based on the productivity of the different plant functional types (PFT) but also on the mortality and establishment of PFT's. Terrestrial carbon is represented by three main pools: vegetation, litter, and soil. Fire plays a key role in both vegetation dynamics and global carbon cycle therefore a fire module (Thonicke et al., 2000) is implemented in LPJ.

3 Current computer resources

The required CPU time for the coupled atmosphere-ocean model is less than 8 min per year on the present Cray in Hamburg, i.e. approximate two orders of magnitude faster than complex GCMs. In the asynchronously coupled mode, where atmosphere and ocean model components take even parts in computing time, about 1000 years of model integration can be performed on one day. With its low computational costs, the model can be also used for sensitivity studies and ensemble integrations.

Model		Responsible	Institute

present model components

atmospheric model	PUMA	F. Lunkeit & G. Lohmann	MI, MPI Hamburg
ocean model	LSG	G. Lohmann	MPI Hamburg
marine carbon cycle	HAMOCC3	E. Maier-Reimer & A. Winguth	MPI Hamburg, Madison

planed model components

terrestrial biosphere	LPJ	M. Scholze & W. Knorr	MPI Hamburg, MPI Jena
Land ice	SICOPOLIS	R. Greve	TU Darmstadt

4 Applications

The model is flexible enough to turn various feedback processes off and on, to study the cause and relationships of the climate components.

- Process of Glaciation and Deglaciation
- Simulation of the last glacial cycle
- Interaction of vegetation, atmospheric dynamics, and the oceanic circulation (e.g. vegetation-snow feedback, vegetation distribution)
- Climate and CO_2: diagnostic and prognostic calculations of atmospheric CO_2 (including carbon isotopes) on long time scales
- Factorial analysis (e.g. orbital parameters, changing feedback mechanism) to understand main processes governing the global carbon cycle
- Interhemispheric synchronisation: Northern versus southern hemispheric forcing, teleconnections Atlantic-Pacific
- Does climate variability change with the background climate state?
  What are the characteristic patterns and time scales in atmospheric variability?

5 References

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