



# Introduction to the COSMOS Earth System Model



Marco Giorgetta

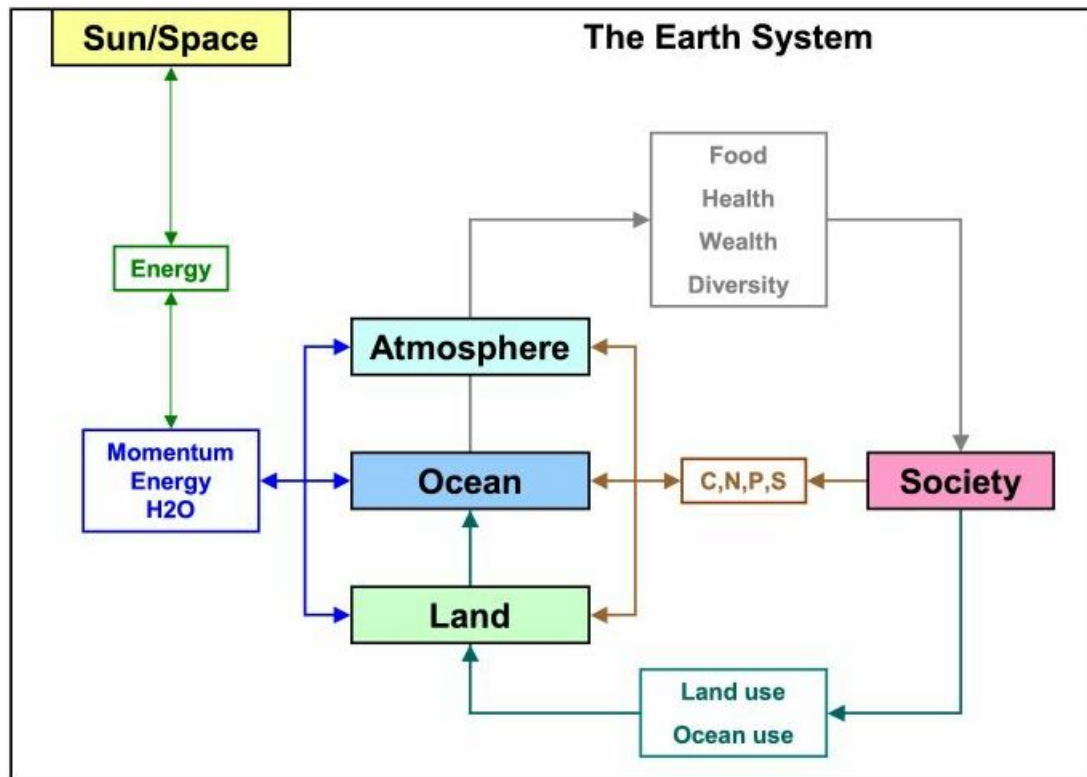




- Introduction
- Terminology
- The COSMOS model, what is it?
- Model configurations
- cosmos-asob
- Couplings
- Outlook



# Intro: Schematic view of the Earth system



- The physical part of the Earth system is driven by the flux of momentum, energy and water (incl. phase changes).
- Key substances (C, N, P, S) are important for the processes in atmosphere, ocean and land that influence the climate.
- Human activities influence the climate system, and the climate impacts on societal values.



- Observations
- A numerical laboratory
  - Experimentation with Earth is not practical
  - Numerical models of the Earth system allow systematic experimentation
  - Experimental design making optimal use of the flexibility of the model system under the practical limitations
  - Facilities to run experiments and store data
  - Diagnostic tools to evaluate the model data



# Terminology



- Coupled climate models, AOGCM, physical ESM  
= coupled atmosphere ocean model
- **ESMs** = model of the coupled atmosphere ocean system that includes further processes depending on substances other than water, e.g.:
  - Carbon/CO<sub>2</sub> → Carbon cycle models
  - Aerosols → Aerosol system models
  - Chemicals → Chemistry climate models
  - ...
- **ESMs are used** to study the interaction of physical, biological and chemical processes, and human actions with the climate **on time scales of typically decades to centuries**



## COSMOS: network and model



### COSMOS = Community Earth system modeling system

- COSMOS is a network for Earth system research of the Max Planck Institutes active in climate research and universities and research institutes in Germany and other European countries.  
→ <http://cosmos.enes.org/>
- The COSMOS model system provides an Earth system model based on atmosphere and ocean general circulation models of the Max Planck Institute for Meteorology
- Open source



# What is the COSMOS1 ESM in general



- COSMOS1 is an Earth system modeling framework that comprises numerical models for the different compartments: atmosphere, ocean and land
- COSMOS1 includes a standardized scripting environment for the configuration of different models:
  - Atmosphere + land
  - Ocean
  - Coupled atmosphere/ocean
  - Coupled atmosphere/ocean + carbon cycle
  - ...
- COSMOS1 includes a standardized scripting environment for the execution of experiments and the data storage and post-processing.
- COSMOS1 is a modeling system that (hopefully) facilitates scientific research with complex models.





# What is contained in the COSMOS package



- Models

- ECHAM5 = atmospheric GCM
- ECHAM5J = ECHAM5 + JSBACH  
JSBACH = vegetation+soil
  
- MPIOM = ocean GCM
- HAMOCC = marine biogeochemistry
  
- OASIS = coupler

- Standard environments

- For compiling (SCE)
- For running (SRE)



## Model configurations (SCE)

Specific model configurations are selected by keywords:

### Atmosphere w/o land vegetation and soil

- **cosmos-a** → ECHAM5 atmosphere
- **cosmos-as** → ECHAM5J atm. + vegetation/soil

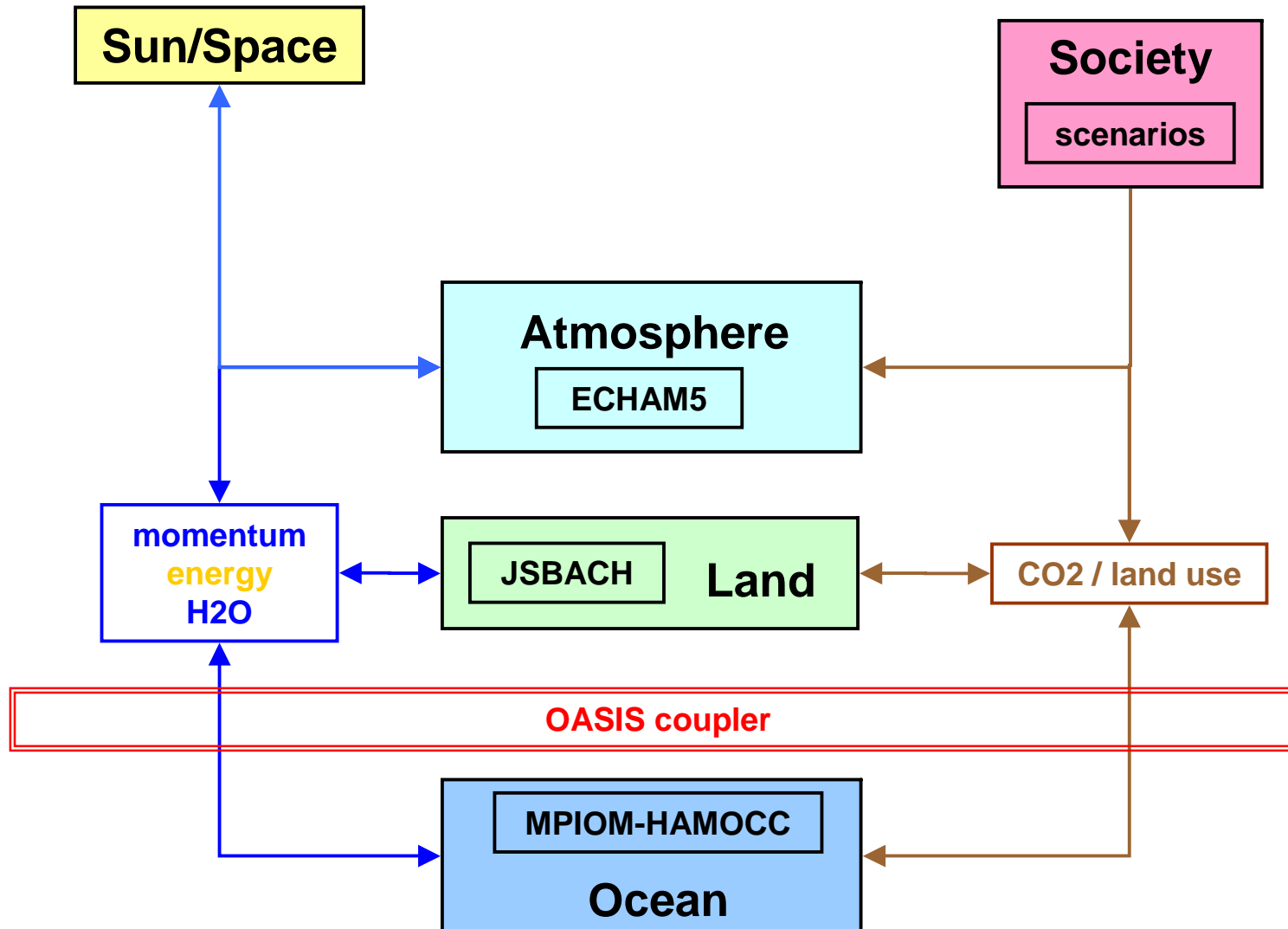
### Ocean w/o biogeochemistry

- **cosmos-o** → MPIOM ocean
- **cosmos-ob** → MPIOM-HAMOCC

### Coupled atmosphere ocean w/o carbon cycle

- **cosmos-ao** → ECHAM5/MPIOM
- **cosmos-asob** → **ECHAM5J/MPIOM-HAMOCC**

- ...





# How to make the cosmos-asob model

Get model package

... and modify the source code if necessary

Create compile scripts for all model components

```
cd ~/cosmos-issmes/util/compile/tools ./Create_COMP_cpl_models.ksh  
cosmos-asob --id <exp-id>
```

... and execute the compile scripts ...

Create setup for your experiment

```
cd ~/cosmos-issmes/util/running/tools  
./Create_TASKS.ksh cosmos-asob <exp-id>
```

... and edit the setup file if necessary ...

**Q: How would you create an atmosphere ocean model and setup?**





## Couplings in cosmos-asob



- Atmosphere ocean and land models are coupled, i.e. they exchange energy, momentum, water and CO<sub>2</sub>.
- The atmosphere model computes fluxes of:
  - Wind stress
  - Net heat flux
  - Net water flux (precipitation-evaporation)
  - CO<sub>2</sub> flux
- The ocean model must provide surface state:
  - Sea ice density and thickness
  - Surface temperature of water and ice
  - Surface velocity Q: where is it important?
  - Partial CO<sub>2</sub> pressure





## Couplings in cosmos-asob



- Atmosphere and land exchange fluxes every timestep
- Atmosphere and ocean coupling in intervals of 1 day
  - Fluxes are computed in the atmosphere, which has shorter timesteps than the ocean
  - Fluxes must be accumulated over GCM timesteps and averaged over the coupling interval
  - Fluxes accumulated in the atmosphere model in one coupling interval are passed to the ocean model in the next coupling interval.
- Questions:
  - Is a coupling timestep of 1 day a good choice?
  - Alternatives? 6 hourly? Every 5 days or longer?





## Couplings in cosmos-asob (continued)



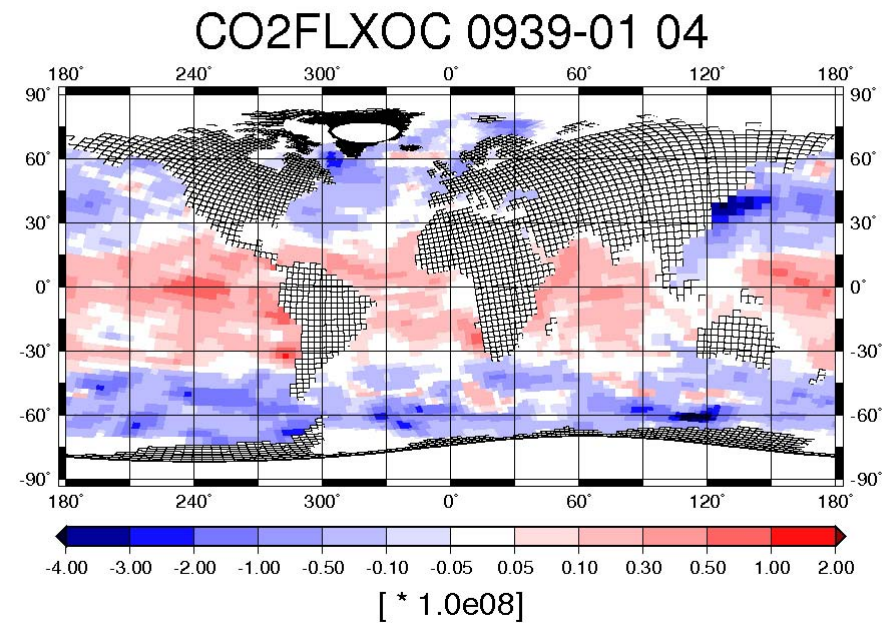
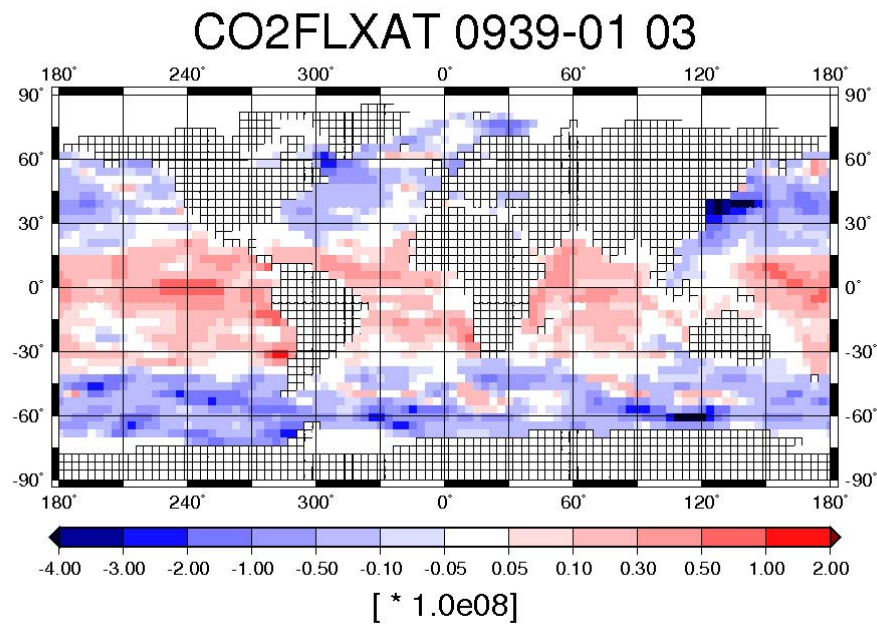
- Atmosphere and ocean models have different horizontal grids
  - Fluxes must be interpolated between grids
  - Difficulties at coastal points if flux quantity is different over land and sea, e.g. CO<sub>2</sub> flux
  - Fluxes are computed separately for open water and sea ice areas. Depending on the ice cover fraction, one or the other is used.
  - Interpolation errors must be corrected
  - Questions:
    - (a) to maintain global mean flux?
    - (b) to maintain globally integrated flux?



## Couplings in cosmos-asob (continued)



CO<sub>2</sub> fluxes (kg m<sup>-2</sup> s<sup>-1</sup>) on atmosphere and ocean grid





## Technical implementation of the coupling



- ECHAM5J contains atmosphere and land model  
→ direct coupling within the same model.
- ECHAM5J and MPIOM-HAMOCC are compiled as separate executables  
→ Separate coupler program necessary to receive and send data from and to the models.  
→ OASIS3 coupling program
- OASIS3 tasks at coupling timesteps (daily):
  - Receives data from atmosphere and ocean
  - Interpolates the data onto the grid of the other model
  - Sends data to both models



## Outlook



The COSMOS modeling system, as well as other ESMs, will be developed further to integrate more processes and feedbacks.

Q: Which processes are missing?



The COSMOS modeling system, as well as other ESMs, will be developed further to integrate more processes and feedbacks.

**Q: Which processes are missing?**

- Aerosols
- Atmospheric chemistry
- Dynamic vegetation
- Permafrost
- CH<sub>4</sub> in soils and wetlands
- N cycle
- Dynamic ice sheets
- ...



Thank you

