



European Commission's 7<sup>th</sup> Framework Programme  
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Project acronym: **COMBINE**

Project full title: **Comprehensive Modelling of the Earth System for Better  
Climate Prediction and Projection**

Instrument: Collaborative Project & Large-scale Intergrating Project

Theme 6: *Environment*

Area 6.1.1.4: *Future Climate*

ENV.2008.1.1.4.1: *New components in Earth System modelling  
for better climate projections*

Start date of project: 1 May 2009

Duration: 48 Months

**Milestone Reference Number and Title:**

**M4.2 Complete coupled system of ESMs and ice sheet models of both Greenland and  
Antarctic ice sheets**

**Lead work package for this milestone: WP4**

**Organization name of lead contractor for this milestone: DMI**

**Due date of milestone: month 48 (April 30, 2013)**

**Actual submission date: May 31, 2013**

## M4.2 Complete coupled system of ESMs and ice sheet models of both Greenland and Antarctic ice sheets

Milestone M4.2 concerns the development of ESMs that include interactive ice sheet models for both Greenland and Antarctic. The new ESM systems follow the same coupling strategy as described in M4.1 (Prototype of coupling Greenland ice sheet models to ESMs using new coupling method), where the systems are energy and mass conserving at the ice sheet's interface for instance. Prototype model systems for both Greenland and Antarctic ice sheets have been established. Table 1 lists the details of the model systems developed by the partners. These systems are well tested for the Greenland ice sheet. However, the representations of the Antarctic ice sheet in the model systems are only preliminary and testing of the model systems is work in progress. In particular, the coupling between ice shelf and the underlying ocean, which is crucial for the mass balance of the Antarctic ice sheet, is not fully taken into account. This is because the involved technical problems are far more complex than anticipated, while the allocated resource for the task is limited. In addition the knowledge about the involved processes and their representation in comprehensive state-of-the-art climate models is still very limited.

**Table 1.** ESM-ISM coupled systems for ice sheets

Partner		CNRS	DMI	METO	MF-CNRM	MPG
ESM		IPSL-CM5	EC-EARTH	HadCM3	CNRM-CM5	MPI-ESM
ESM resolution	Atm.	96x95L39 or 144x143L39	T159L62	N48L19	T127L31	T63L47
	ocean		1°x1°L42	1.25x1.25°L20	1x1°L42	GR1.5L40
ISM		GRISLI	PISM	Huybrechts	GRISLI	PISM
ISM resolution		20 x 20 km	20 x 20 km	20 x 20 km	5 x 5 km	10 x 10 km
Representation of ice sheets		Greenland and Antarctic	Greenland and Antarctic	Greenland and Antarctic	Greenland and Antarctic	Greenland
Coupling method		PDD (first) then Energy Balance	Energy Balance	Energy Balance	PDD (first) then Energy Balance	Energy balance
Snow scheme over land ice		CROCUS multilayer scheme as used in SISVAT/MAR, including refreezing, percolation, snow aging, etc.	Single explicit snow layer scheme with liquid water reservoir and conductivity at ice/snow interface, etc.	Single implicit layer	CROCUS multilayer scheme as used in SURFEX surface scheme, including refreezing, percolation, snow aging, etc.	Explicit snow-layer scheme
ISM-Ocean interaction		Fresh water flux linked to melting	Fresh water flux due to surface and basal melt; Fresh water flux and heat transfer due to calving and direct ocean-ice interaction.	No	Fresh water flux linked to melting	Fresh water flux linked to surface and basal melting; Fresh water flux and heat transfer due to calving and direct ocean-ice interaction.