Annex I

"Description of Work"

(Contract No. EVK2-CT2001-00100) ("ORFOIS")

1 PROJECT SUMMARY

This page about “adminstrative information”
will be added from the contract preparation forms and
the EU database after finalising the contract negotiations.

TECHNICAL PROJECT DESCRIPTION

Title of project:

"ORigin and Fate of biogenic particle fluxes in the Ocean and their Interactions with the atmospheric CO_2 concentration as well as the marine Sediment" (ORFOIS)

Problems to be solved:
The simulation of thoroughly backed up surface ocean pCO_2 distributions will narrow the uncertainties of carbon redistribution estimates within the earth system. This knowledge has direct economic consequences because it enables early political measures to react on and prevent undesired climate change evolutions. This knowledge enables a well planned procedure for fullfilling the Kyoto Protocol obligations of member states. Early planning on the basis of solid research results within this context has been shown to be of extreme economic value. The calculation of the fate of particles will be the foundation for valid estimates of removal and storage of hazardeous substances within the ocean (coming from land based sources through river runoff and atmospheric transport as well as from direct marine disposal). The consideration of near shore and shelf systems within a global BOGCM (biogeochemical ocean general circulation model) will provide a first global estimate of shelf/open ocean interaction and related water exchange time scales based on mechanistic modelling. The particle flux and sediment "community models" will provide a basis for future operational biogeochemical forecasting of environmental key variables. Thus these models will help to prevent marine areas around EU member states from environmental damage and foster sustainable use of these oceanic areas for fisheries.

Scientific objectives and approach:
The main scientific objectives of project **ORFOIS** are to identify and quantify globally the mechanisms underlying the transformation of biogenic particles to dissolved substances within the ocean water column in order to predict correctly surface ocean carbon dioxide sources and sinks; to develop a refined particle flux model for operational use in ocean general circulation models which realistically describes particle dynamics in the water column, deposition of material to the sediment, and the interaction with the carbon dioxide partial pressure (pCO_2); to provide a global closed carbon and nutrient budget for modern (preindustrial) conditions including the water column sediment interaction; and to estimate the changes in CO_2 sea surface source sink patterns and vertical redistributions of carbon as well as nutrients for future global change, climate change as well as carbon sequestration scenarios including the associated potential economic impacts.
The project's main technological objectives are to establish publically available community models for particle flux dynamics in the water column and early sediment diagenesis which are suited for use in general circulation ocean climate models and to establish data bases for marine carbon and nutrient cycling which will be easily publically available.
The methodology to achieve these goals is based on a combination of a comprehensive observational data base on marine carbon cycling to be collated with two BOGCMs.

Expected impacts:
The project will result in best estimates of sea surface CO_2 source sink patterns. Comprehensive observational data bases on surface ocean pCO_2 and marine carbon cycle data will be collated and made publically available through web access. Community models on marine particle flux dynamics and early diagenesis (top sediment zone) will be made publically available for use in any other ocean model. Estimates of socio-economic impacts of a better knowledge of sea surface CO_2 source sink patterns and particle flux dynamics will be provided for future climate change as well as carbon sequestration scenarios.

2 SCIENTIFIC/TECHNICAL OBJECTIVES AND INNOVATION

2.1 Scientific/technical objectives

The main scientific objectives of project **ORFOIS** are to:

- **Goal 1.** Identify and quantify globally the mechanisms underlying the transformation of biogenic particles to dissolved substances within the ocean water column in order to predict correctly surface ocean carbon dioxide sources and sinks.
- **Goal 2.** Develop a refined particle flux model for operational use in ocean general circulation models which realistically describes particle dynamics in the water column, deposition of material to the sediment, and the interaction with the carbon dioxide partial pressure (pCO_2).
- **Goal 3.** Provide a global closed carbon and nutrient budget for modern (preindustrial) conditions including the water column sediment interaction.
- **Goal 4.** Estimate the changes in CO_2 sea surface source sink patterns and vertical redistributions of carbon as well as nutrients for future global change, climate change as well as carbon sequestration scenarios including the associated potential economic impacts.

The project's main technological objectives are to:

- Establish publically available community models for particle flux dynamics in the water column and early sediment diagenesis which are suited for use in general circulation ocean climate models.
- Establish data bases for marine carbon and nutrient cycling which will be easily publically available.

Next to water vapor, carbon dioxide is the second most important greenhouse gas. The airborne fraction of carbon dioxide is determined by anthropogenic emissions and natural carbon redistribution processes between several reservoirs (atmosphere, land biosphere, ocean water, marine as well as lacustrine sediments, soils, and lithosphere). The world ocean (inorganic marine carbon cycle) and the terrestrial biosphere are the most important sink reservoirs for anthropogenic CO_2.

Compared to the atmosphere, the ocean contains a much larger standing stock of carbon (inorganically and organically dissolved as well as in particulate form). Turnover times of the marine carbon reservoir are shorter than those of the soil carbon pool. Therefore, small perturbations of the marine carbon cycle can induce significant alterations of the atmospheric CO_2 concentration. The CO_2 partial pressure in the ocean depends on the concentration of dissolved inorganic carbon and alkalinity (or pH value). The structure of dissolved inorganic carbon and alkalinity in ocean water is determined through ocean circulation and biogeochemical processes. These biogeochemical processes are mainly transfers of carbon from dissolved to particulate form and vice versa. These transfers are governed by biota (uptake of carbon, remineralisation by bacteria) and inorganic processes (dissolution) and are coupled to the nutrient cycles.

In large scale physical/biogeochemical models, the transformation from new biomass at the ocean surface back to redissolved forms in deeper waters up to now is performed through highly simplified quasi-exponential flux redistribution profiles. It has been shown in previous model experiments, that the oceanic CO_2 uptake or outgassing as well as the vertical nutrient distribution depend critically on the choice of these profiles (Najjar et al., 1992; Archer and Maier-Reimer, 1994; Heinze et al., 1999). In the real world, more complex particle dynamics processes are at work. These processes depend on factors such as wind stress, atmospheric dust loads, primary production, plankton composition, particle structure, trace substance composition, degree of saturation of seawater (for the respective substance), and oxygen availability.

For a reliable simulation of the time and space dependent CO_2 redistribution between ocean and atmosphere an appropriate time dependent simulation of particle dynamics processes is essential but has not been carried out so far. The major difficulties were the lack of suitable modules for particle dynamics and early diagenesis (in order to close the carbon and nutrient budget) in ocean general circulation models, and the lack of an understanding of biogeochemical processes, such as the partial dissolution of calcareous particles in oversaturated water.

The main target of the proposed project **ORFOIS** is to fill in this gap in our knowledge and prediction capability infrastructure.

We will achieve our goal step by step. At first comprehensive data bases (already existing data) of observations of relevance for the three major types of biogenic particles, organic carbon (POC), calcium carbonate ($CaCO_3$), and biogenic silica (BSi or opal), as well as for refractory particles of terrestrial origin will be collated and made publically available.

From these data base and process studies, model formulations and parameterisations for simulations of particle dynamics and particle degradation will be developed and formulated. These model formulations will be implemented in already existing "extended NPZD-models" of ocean circulation and ecology (NPZD="nutrient phytoplankton zooplankton detritus", "extended NPZD-models" = further developments of standard NPZD-models, to also include the silicon cycle, $CaCO_3$ production, and co-limitations of nitrate, phosphate, light, temperature, trace substances such as iron, and further factors). Specifically the following mechanisms will be addressed: Coagulation and disaggregation of particles, seasonality of particle production, settling velocity of particles, particle solubilities and redissolution kinetics dependent on particle structure and composition, change of particle size and settling velocity with wind mixing and aeolian particle deposition. The particle dynamics module will be applied in two different high end BOGCMs (Biogeochemical Ocean General Circulation Models). Both BOGCMs, I and II, include a full ocean physics component based on the Primitive Equations.

A closed nutrient and carbon budget will be established through equilibrium climate simulations for the preindustrial situation. This simulation includes a quantitatively correct simulation of the carbon and nutrient fluxes between the sediment and the water column. The simulation will be verified with the comprehensive data base developed before. The model set up will include "community models" of particle dynamics and sediment biogeochemisty (early diagenesis) which can be implemented in operationally running ocean climate models ("community models" = well documented and tested source codes of model components which can be shared by the entire scientific community). The surface ocean CO_2 source/sink pattern for the preindustrial ocean will be established.

External forcings as derived from global climate change scenarios will then be applied to the biogeochemical ocean circulation models. Aeolian dust flux and changes in atmospheric CO_2 content will be prescribed. The reaction of the water column processes and the resulting change in the surface ocean CO_2 partial pressure field will be established. Regions of highest variability (pre-anthropogenic/anthropogenically disturbed status) will be diagnosed. Changes in the intensity of particle fluxes and redistributions of matter within the ocean water column will be analysed. These biogeochemical redistributions have also implications for the fertility of the ocean and respective sizes of fish stocks. Finally, also the effects of marine carbon sequestration activities on the marine particle flux and pCO_2 will be investigated and potential economic impacts will be estimated.

2.2 Innovation

State of the art:

The major principles of the geochemical cycles governing the global carbon and nutrient fluxes are known (e.g., Delaney, 1998; Falkowski, 1997; Tréguer et al., 1995; Moore and Bolin, 1986/87; Degens et al., 1987) and can be described by models. For the ocean, comprehensive BOGCMs (Biogeochemical Ocean General Circulation Models) based on DOGCMs (Dynamical Ocean General Circulation Models providing velocity, sea ice, and thermohaline fields) are available (e.g., Palmer and Totterdell, in press; Fasham and Evans, 2000; Aumont et al., in press, 1999, 1998; Heinze et al., 1999; Sarmiento et al., 1998; Drange, 1996; Maier-Reimer, 1993). These models predict global or basin wide distributions of carbon tracers and nutrients, as well as air sea carbon fluxes. The models include biological modules of different complexity. The models were applied for studies concerning the regulation of the atmospheric CO_2 content in the present (e.g. Palmer and Totterdell, in press; Aumont et al., 1998; Drange, 1996; Maier-Reimer, 1993), past (Heinze et al., 1999; Archer and Maier-Reimer, 1994; Heinze et al., 1991), and future (e.g., Bopp et al., 2000; Sarmiento et al., 1998; Archer et al., 1997; Sarmiento and Le Quéré, 1996; Maier-Reimer et al., 1996) by marine processes.

All these models are based on strongly simplifying parameterisations of the real processes with biological primary production being a partial mirror image of the wind stress curl and the mixed layer depth - with high production rates in upwelling regimes and oligotrophic conditions in downwelling regimes. The respective space time pattern of simulated surface ocean carbon dioxide partial pressure (pCO_2) reflects the patterns of the biological carbon uptake by biota, the fate of the particles during their sinking through the water column, the vertical transport of carbon into the surface ocean (mainly through Ekman pumping), and surface hydrography (with enhanced marine storage of carbon in saline and cold waters). Surface ocean pCO_2 patterns can be reproduced qualitatively (a comparison of various biotic and abiotic models is under way using fixed ocean velocity fields in the OCMIP-2 study, http://www.ipsl.jussieu.fr/OCMIP/phase2/#simulations). **A rigorous comparison of BOGCM results with data sets of observed pCO_2 using time dependent model forcing also for the model physics, however, has not yet been carried out.**

The marine particle production is represented mostly through Michaelis-Menten kinetics. NPZD-models and more detailed extensions of them (e.g., Fasham et al., 1993; Six and Maier-Reimer, 1996) include besides phytoplankton and zooplankton also the microbial loop through detritus consuming organisms. For a parameterisation of the particle flux through the water column, all BOGCMs so far published - to the best knowledge of the proposal authors - employ exponential or quasi-exponential flux redistribution profiles. These profiles combine the two processes redissolution rate constant and particle settling velocity in one parameter (in exponential decay formulations in a number called "e-folding depth", the depth level at which the actual particle flux is reduced to 1/e of the export flux out of the euphotic zone). Fixed values for each of the three particle species POC, $CaCO_3$, and BSi are used (Volk and Hoffert, 1985; Najjar et al., 1992; Maier-Reimer, 1993; Heinze et al., 1999). Increasingly deep depth levels are chosen from POC to $CaCO_3$ to BSi (corresponding to higher settling velocities or lower redissolution rate constants). Besides the exponential profile, for POC, also the formulations of Suess (1980) (1/z-law) and Martin et al. (1987) (x^{-z}-law) are applied in BOGCMs (Najjar et al., 1992; Maier-Reimer, 1993; Heinze et al., 1999). It turns out that the vertical carbon and nutrient structure and hence the biological surface production and surface pCO_2 depend critically on the choice of these parameterisations. Moreover, it is shown from inverse modelling studies using adjoint modelling techniques, that spatially varying penetration constants have to be applied in order to match observations from the water column closely everywhere (Schlitzer, 2000). **Though being a key process for regulating the pCO_2, a more realistic detailed particle flux simulation has not yet been attempted in BOGCMs.**

The Martin et al. (1987) formulation for the POC flux through the water column is based on a best fit to sediment trap data and has been considered as the best guess for depth dependent POC degradation by many scientists. However it should be noted that the deep carbon flux is only poorly constrained by this curve because the lowest depth level of the traps used in Martin et al. (1987) is at 2000 m, far above the average ocean floor. The existing POC deposition map of Jahnke (1996) is not regarded as conclusive because it reveals a too strong coupling to bottom topography. **Even the order of magnitude of the deposition rate of biogenic material onto the ocean floor is not quantified and is only crudely estimated globally from budget considerations, but not yet determined locally in a synoptic approach.**

Advancement of state of the art by the project:

Time dependent global maps of surface ocean CO_2 partial pressure will be provided from improved BOGCMs which more appropriately describe the biogeochemical processes governing the marine carbon cycle. A detailed comparison between simulated and observed pCO_2 values will be carried out. Surface, sub-surface and ocean floor processes will be considered in a closed budget approach. State of the art "ecological models" and gas exchange formulations will be employed ("ecological models" = large scale ocean models of the NPZD type, but with extensions to include the marine biogenic silicon cycle and co-limitations of biological production by several factors such as nitrogen and phosphorous availability, radiation, temperature, and trace substance availability). The resulting pCO_2 maps will yield additional constraints for inverse atmospheric computations in order to reliably predict terrestrial as well as marine carbon sources and sinks. The improved BOGCMs will be run under time dependent forcing (including the physical forcing for computing respective time dependent ocean velocity fields) in order to establish interannually varying CO_2 fluxes between atmosphere and ocean. The verified model will be used under global warming future climate forcing in order to predict the change of carbon uptake/release areas in the world ocean.

In the proposed project, a more advanced particle dynamics module on the based on the work of Kriest and Evans (1999) will be employed in global BOGCM computations for the first time in order to more correctly simulate the degradation of biogenic particles in the water column and to establish realistic settling velocity values. Coagulation and disaggreation of particles in the water column will be simulated. New (still unpublished) findings from in situ and laboratory experiments will be used to establish significantly improved values for dissolution rate constants of biogenic matter (dissolution kinetics) and (apparent) solubilities. New geochemical findings concerning the degradation of $CaCO_3$ in oversaturated waters will be included in the model formulations. Dynamical changes of biogeochemical parameters due to microenvironments and organic/inorganic coatings of particle aggregates will be accounted for. The new particle flux model will contribute to a much more detailed prediction of the carbon redistribution in the water column and the surface ocean and thus enable a mechanistic (and not empirical) prediction of biogenic

pCO_2 regulation superior to state of the art capabilities. In addition, it will provide more quantitatively correct boundary conditions for the sediment early diagenesis model.

The model approach will include for the first time in global BOGCMs a time dependent realistic module of organic carbon degradation in the bioturbated sediment. Together with the early diagenesis modelling of $CaCO_3$ (inorganic carbon) and BSi, this simulation enables to present a closed budget for nutrients and carbon in the total model ocean system.

Within the global ocean approach, also the continental shelf regions will be considered. A first step of including shelf seas in a global BOGCM study will be tried through a crude parameterisation of retention of river load carbon and nutrients in shallow waters, shelf/open ocean carbon and nutrient exchange, as well as shallow water sedimentation (including a first order representation of anaerobic pore water chemistry). A correct representation of shallow water sedimentation processes is desirable in order to correctly quantify the amount of carbon and nutrients entering the open ocean from continental runoff loads. A correct simulation of sedimentary processes is vital for a correct prediction of local deposition rates and hence for a rigorous verification of the new particle dynamics module to be implemented. While particle flux measurements with sediment traps in the water column are extremely difficult, expensive, and associated with enormous systematic errors (though the traps give invaluable information concerning the timing of particulate fluxes), sediment pore water and solid sediment component data are more reliably and more widespread. A satisfying simulation of sediment processes in the bioturbated zone will be the clue for a verification of the particle dynamics model and the simulated deposition rates to the ocean floor. The improved sediment module furthermore will be the tool for evaluating the local and global impact of direct deep ocean sequestration of anthropogenic CO_2. To estimate the impact of deep release of CO_2, an appropriate simulation of the associated $CaCO_3$ dissolution dynamics from the ocean floor is essential for a thorough estimate of the consequences for deep ocean ecology and the efficiciency of the sequestering procedure.

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3 PROJECT WORKPLAN

(a) Introduction - explaining the structure of the workplan and the overall methodology used to achieve the objectives:

The workplan is structured into 10 main packages:

1. Data base compilation of observations.
2. Process parameterisations.
3. Community model development.
4. Compilation of model forcing fields.
5. BOGCM implementation.
6. Optimisation of the prognostic system.
7. Model application and demonstration.
8. Economic evaluation.
9. Dissemination.
10. Coordination.

Workpackages 1-6 (fundamental science batch) include fundamental science work and technological development of the projects's logistical infrastructure placing special emphasis on common use of data sets and computer programme source codes. Workpackages 7-9 (application batch) apply the deliverables to societal issues and disseminate the deliverables to the public. Coordination is an additional workpackage (package 10) to ensure smooth flow of the entire project.

During both, the basic science and the application batches, all participants work in parallel in a well defined network of tasks. It is planned to carry out the following meetings/workshops:

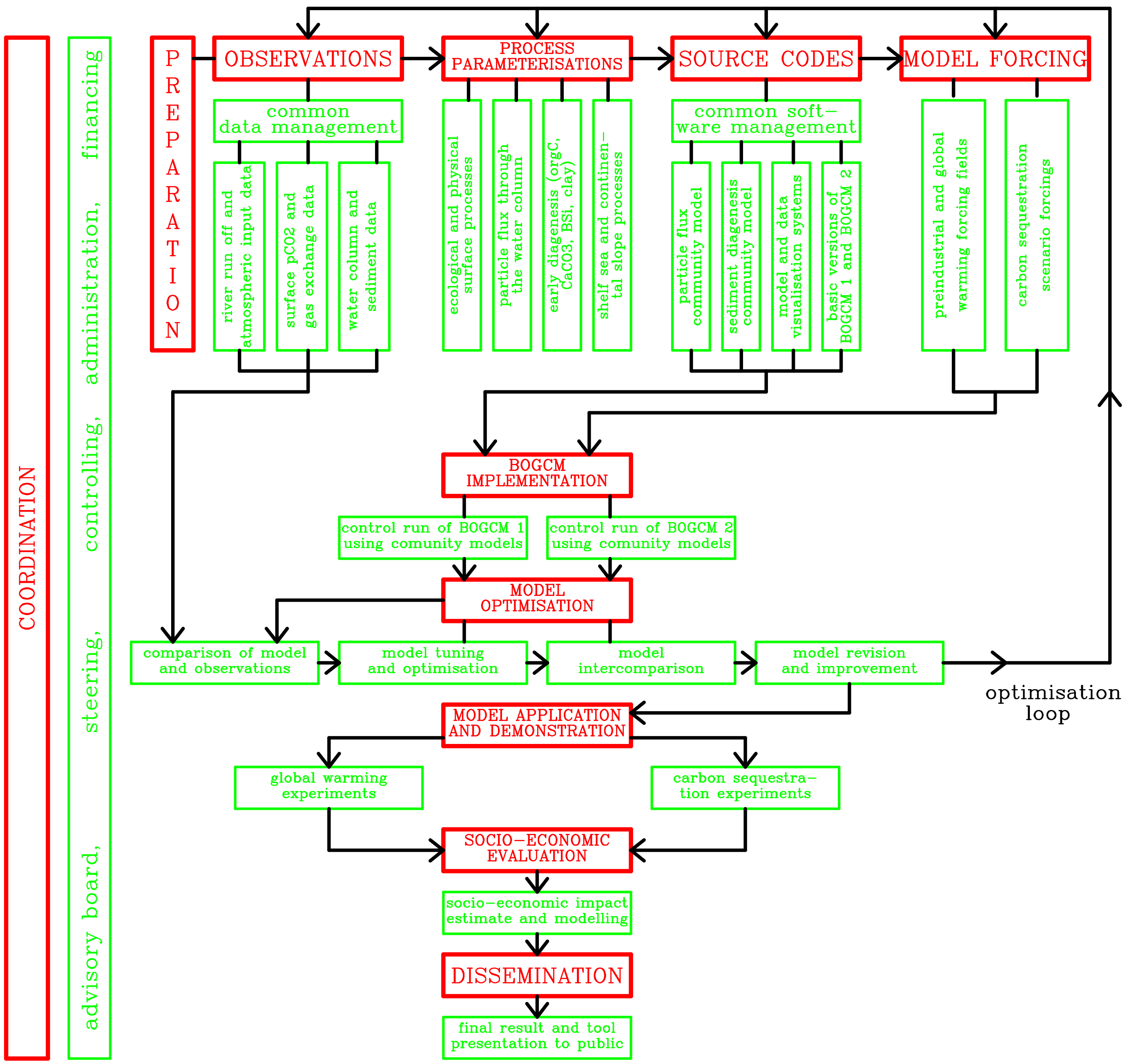
- Workshop 1 (kick-off meeting, start of project).
- Workshop 2 (implementation and optimisation, after 12 months).
- Workshop 3 (application, after 24 months).
- Workshop 4 (final workshop, after 36 months).

(b) Project planning and time table:

Time-work flow-chart:

Work-package no.	Workpackage name	year 1				year 2				year 3			
1	Data base compilation of observations	X	X	X	X	X	X						
2	Process parameterisations	X	X	X	X	X							
3	Community model development	X	X	X	X	X							
4	Compilation of model forcing fields	X	X										
5	BOGCM implementation			X	X	X	X						
6	Optimisation of the prognostic system					X	X	X	X	X	X	X	X
7	Model application and demonstration							X	X	X	X	X	X
8	Economic evaluation							X	X	X	X	X	X
9	Dissemination										X	X	X
10	Coordination	X	X	X	X	X	X	X	X	X	X	X	X

(c) Graphical presentation of the projects components (interconnection diagram):



Workpackages are indicated in red, contents of workpackages are in green. The optimisation loop iterates several times through the preparation and BOGCM implementation packages until the model and data bases are ready for the application and demonstration package.

(d) Detailed project description broken down into workpackages:

(d_1) Workpackage list (table WPL) and workpackage / partner manpower matrix (table WPM):

Table WPL workpackage list:

WPL WORKPACKAGE LIST						
Work-package No.	Workpackage title	Lead participant No.	Person-months	Start month	End month	Deliv-erable No.
1	Data base compilation of observations	3	63	1	18	1-4
2	Process parameterisations	4	73	1	15	5-10
3	Community model development	1	17	1	15	11, 12
4	Compilation of model forcing fields	1	4	1	6	13, 14
5	BOGCM implementation	2	19	7	18	15-17
6	Optimisation of the prognostic system	2	158	13	36	18-23
7	Model application and demonstration	1	21	19	36	24-29
8	Economic evaluation	5	8	29	36	30, 31
9	Dissemination	3	38	28	36	32-36
10	Coordination	1	3	1	36	37-49

Table WPM workpackage/partner manpower matrix, allocation of manpower to WPs:

Work-pack-age no.	PARTNER → WORKPACKAGE NAME	1	2	3	4	5	6	7	8	total
1	Data base compilation of observations	0	0	24	0	0	20	0	18	62
2	Process parameterisations	0	37.5	15	13	0	10	12	0	87.5
3	Community model source code development	8	4	0	2	0	0	3	0	17
4	Compilation of model forcing fields	2	2	0	0	0	0	0	0	4
5	BOGCM implementation	9	7	0	0	0	0	0	0	16
6	Optimisation of the prognostic system	15	12.5	36	18	0	30	17	14	142.5
7	Model application and demonstration	11	7	0	0	0	0	0	0	18
8	Socio-economic evaluation	0	0	0	0	9	0	0	0	9
9	Dissemination	4	6	9	3	1	6	4	4	37
10	Coordination	3	0	0	0	0	0	0	0	3
	TOTAL	52	76	84	36	10	66	36	36	396

(d_2) Deliverables list (table DL):

DL DELIVERABLE LIST, PART I (continued on next page)				
Deli-ver–able No.	Deliverable title	Deli-verable date, month	Nature	Diss-emina-tion level
1	Storage of data sets in online data base	18	Da	CO
2	CD-ROM with copy of online data base (basic version)	18	Da	PU
3	Project home page with references to the data sets (basic version)	18	Da	PU
4	Data extraction techniques	15	Me	PU
5	Parameterisation of particle flux dynamics (sinking velocity, coagulation, disaggregation)	15	Me	RE
6	Parameterisation of the dissolution rate of POC, $CaCO_3$, and biogenic silicate in the water column and in the sediment	15	Me	RE
7	Parameterisation of the conversion of biogenic silicate to other mineral phases in the sediments.	15	Me	RE
7a	Parameterisation of $CaCO_3$ dissolution.	15	Me	RE
8	1-D ecological/particle flux model	15	Me	RE
9	1-D sediment early diagenesis model	15	Me	RE
10	Coupled version of 1-D biogeochemical/particle flux and sediment model	15	Me	RE
11	particle flux dynamics module ready for coupling to BOGCM (community model)	15	Me	RE
12	sediment module ready for coupling to BOGCM (community model)	15	Me	RE
13	Preindustrial atmospheric forcing fields for BOGCM I and II	6	Da	PU
14	Atmospheric forcing fields for anthropogenic climate change scenarios (for BOGCM I and II)	6	Da	RE
15	Basic BOGCM I version with community model components running for preindustrial conditions	18	Me	RE
16	Basic BOGCM II version with community model components running for preindustrial conditions	18	Me	RE
17	Basic shelf regime parameterisation (BOGCM I)	18	Me	RE
18	Optimised data sets of observations including data coverage in key regions for BOGCM tuning, final CD-ROM with data bases	36	Da	PU
19	Optimised process parameterisations implemented within the community model components	36	Me	PU
20	Optimised community model source codes which can be coupled in a user friendly way to other models (1-D, 3-D)	36	Me	PU
21	Optimised preindustrial physical ocean forcing fields which are consistent with the ocean model physical fields	36	Da	PU
	(continued on next page)			

DL DELIVERABLE LIST, PART II (continuation from previous page)				
Deli-verable No.	Deliverable title	Deli-verable date, month	Nature	Diss-emina-tion level
22	Comparison between BOGCM I, BOGCM II, and observations	36	Si	PU
23	List of publications on the prognostic system	36	Re	PU
24	Distribution of surface ocean CO_2 sources and sinks and oceanic biomass for the preindustrial ocean	24	Si	PU
25	Closed carbon and nutrient balance for the preindustrial ocean including marine sediments	36	Si	PU
26	Distribution of surface ocean CO_2 sources and sinks and oceanic biomass for greenhouse gas induced warming conditions	36	Si	PU
27	Distribution of surface ocean CO_2 sources and sinks and marine biomass under Fe-fertilisation of HNLC regions	36	Si	PU
28	Distribution of surface ocean CO_2 sources and sinks and sediment coverage under deep-ocean disposal of CO_2	36	Si	PU
28a	Distribution of surface ocean CO_2 sources and sinks and sediment coverage for a glacial ocean scenario	36	Si	PU
29	List of publications on application of the prognostic system	36	Re	PU
30	Estimates of economic impact of changes in sea surface CO_2 source/sink patterns and changes in marine biomass	36	Si	PU
31	List of publications on economic evaluation	36	Re	PU
32	Public data sets including user manual	36	Re	PU
33	Public model source codes and model data	36	Re	PU
34	Presentation of the main steps and results for non-specialists	36	Re	PU
35	Electronic (online) presentation of the main steps and results	36	Re	PU
36	Invitation to final project workshop	33	Re	PU
37	management report to the EC after 6 months	6	Re	PU
38	management report to the EC after 12 months	12	Re	PU
39	management report to the EC after 18 months	18	Re	PU
40	management report to the EC after 24 months	24	Re	PU
41	management report to the EC after 30 months	30	Re	PU
42	management report to the EC after 36 months	36	Re	PU
43	scientific report to the EC after 12 months	12	Re	PU
44	scientific report to the EC after 24 months	24	Re	PU
45	scientific report to the EC after 36 months	36	Re	PU
46	Workshop 1 (kick-off)	1	Re	RE
47	Workshop 2 (implementation and optimisation)	12	Re	RE
48	Workshop 3 (application)	24	Re	RE
49	Workshop 4 (finish, open to the public)	36	Re	PU

(d_3_1) Workpackage description WP1. Data base compilation of observations.

(d_3_1.1) Workpackage number: 1
(d_3_1.2) Start date or starting event: month 1
(d_3_1.3) Participant codes: 3, 6, 8
(d_3_1.4) Person-months per participant: 24, 20, 18

(d_3_1.5) Workpackage description:	
(d_3_1.5.1)	**Objectives:** To provide a synoptic multi tracer data base of existing observations (stocks and fluxes) in surface water, water column, sediment traps, sediments, early diagenesis, and sediment pore waters including level of data access, meta-documentation and referencing information.
(d_3_1.5.2)	**Methodology and description of work including partner contributions:** • Online data extraction of publically available data from data centers; data compilation from the literature (partners 3, 6, 8). • Data acquisition from Principal Investigators around the globe including extensive travelling (partners 3, 6, 8). • Processing of analytical data and complementary meta-information by application of an advanced online data model which is already available (partner 3). • Data archiving in the World Data Center Europe (partners 3, 6, 8) • Data quality evaluation including consultation with their PI (partners 3, 6, 8). • Development of presentation software (GIS, 2-D plot, cross-section) (partner 3).
(d_3_1.5.3)	**Deliverables:** • Storage of data sets in online data base • CD-ROM with copy of online data base (basic version) • Project home page with references to the data sets (basic version) • Data extraction techniques
(d_3_1.5.4)	**Milestones:** • Month 12: home page, first data sets, data extraction techniques, interim CD-ROM (distribution restricted to the EU) • Month 18: updated home page, extended data sets, improved data extraction techniques, CD-ROM (as proof version restricted to the EU)

(d_3_2) Workpackage description WP2. Process parameterisations.

(d_3_2.1) Workpackage number: 2
(d_3_2.2) Start date or starting event: month 1
(d_3_2.3) Participant codes: 2, 3, 4, 6, 7
(d_3_2.4) Person-months per participant: 37.5, 15, 13, 10, 12

(d_3_2.5) Workpackage description:

(d_3_2.5.1)	**Objectives:** Development and calibration of 1-D biogeochemical model components of (1) a particle flux module which simulates particle interaction, modification and sinking speed (including a surface particle production formulation) and (2) an early diagenesis sediment model (including organic carbon chemistry). The model components simulate parts of the marine carbon, nitrogen and silicon cycles.
(d_3_2.5.2)	**Methodology and description of work including partner contributions:** • Coupling of an already existing ecological model (particle production, organic matter, $CaCO_3$, opal) to a particle dynamics module describing coagulation, disaggregation, and settling of biogenic particles (partners 2, 4). • Development of time dependent 1-D early diagenetic model describing the C, N, and Si cycles in the sediment (including bi-directional vertical sediment advection and anaerobic pore water chemistry) (partners 2, 3, 6, 7). • Coupling of 1-D ecological/particle flux and sediment diagenesis models as consistency check. Calibration with observations (partners 2, 3, 4, 6, 7). • Realisation of a well defined restricted number of laboratory experiments in order derive correct parameterisations (opal dissolution in the water column and the water/sediment interface, conversion of opal within the sediment mixed layer into other mineral phases) (partners 3, 6). • Laboratory experiments on calcium carbonate reactivity (solubility and dissolution kinetics (partner 2).
(d_3_2.5.3)	**Deliverables:** • Parameterisation of particle flux dynamics (sinking velocity, coagulation, disaggregation) • Parameterisation of the dissolution rate of POC, $CaCO_3$, and biogenic silicate in the water column and in the sediment • Parameterisation of the conversion of biogenic silicate to other mineral phases in the sediments • Parameterisation of $CaCO_3$ dissolution. • 1-D ecological/particle flux model • 1-D sediment early diagenesis model • Coupled version of 1-D ecological/particle flux and sediment model
(d_3_2.5.4)	**Milestones:** • Month 15: Standard 1-D models on particle flux and sediment diagenesis are available

(d_3_3) Workpackage description WP3. Community model development.

(d_3_3.1) Workpackage number: 3
(d_3_3.2) Start date or starting event: month 1
(d_3_3.3) Participant codes: 1, 2, 4, 7
(d_3_3.4) Person-months per participant: 8, 4, 2, 3

(d_3_3.5) Workpackage description:	
(d_3_3.5.1)	**Objectives:** To provide source codes for the model components on particle flux dymamics and early diagensis which can easily be coupled to various existing 1-D models as well as 3-D Biogeochemical Ocean Circulation Models.
(d_3_3.5.2)	**Methodology and description of work including partner contributions:** • 1-D Codes are modified to allow full vectorisation for use in 3-D models, which are run on high end supercomputers (partners 1, 2, 4). • Homogenisation of nomenclature; common mnemotechnical variable names are defiend from the very beginning of the project (partners 1, 2, 4, 7). • Development of coupling interfaces to BOGCM I and BOGCM II (partners 1, 2). • The community model source code development will be carried out through use of the ClearCase source code control software, which allows easy book keeping of changes made in the FORTRAN programmes as well as simultaneous work of different partners on one model component in parallel (partners 1, 2, 4, 7).
(d_3_3.5.3)	**Deliverables:** • particle flux dynamics module ready for coupling to BOGCM • sediment module ready for coupling to BOGCM
(d_3_3.5.4)	**Milestones:** • Month 15: Standard community models on particle flux dynamics and early sediment diagenesis available for coupling to BOGCMs and 1-D models.

(d_3_4) Workpackage description WP4. Compilation of model forcing fields.

(d_3_4.1) Workpackage number: 4
(d_3_4.2) Start date or starting event: month 1
(d_3_4.3) Participant codes: 1, 2
(d_3_4.4) Person-months per participant: 2, 2

(d_3_4.5) Workpackage description:	
(d_3_4.5.1)	**Objectives:** To provide climatological ocean forcing fields for the two BOGCMs in order to prepare the preindustrial model run. Compilation of time dependent forcing fields of climate change scenarios (with and without sulfate aerosol effect) for the climate change BOGCM runs.
(d_3_4.5.2)	**Methodology and description of work including partner contributions:** • Extraction of climatologies from preindustrial atmospheric general circulation model (AGCM) runs, which are available on model data bases (partner 1). • Extraction of time dependent ocean forcing fields from AGCM runs under anthropogenically perturbed conditions (climate change scenarios for the next 100 years, available on model data bases) (partner 1). • Interpolation of the forcing fields onto the ocean model grids of BOGCM I and BOGCM II (partners 1, 2).
(d_3_4.5.3)	**Deliverables:** • Preindustrial atmospheric forcing fields for BOGCMs I and II • Atmospheric forcing fields for anthropogenic climate change scenarios (for BOGCM I and II)
(d_3_4.5.4)	**Milestones:** • Month 6: preparation of physical model input to BOGCMs finished

(d_3_5) Workpackage description WP5. BOGCM implementation

(d_3_5.1) Workpackage number: 5
(d_3_5.2) Start date or starting event: 7
(d_3_5.3) Participant codes: 1, 2
(d_3_5.4) Person-months per participant: 9, 7

(d_3_5.5) Workpackage description:	
(d_3_5.5.1)	**Objectives:** Implementation of community models for particle flux and sedimentary reactions in BOGCMs.
(d_3_5.5.2)	**Methodology and description of work including partner contributions:** • Integration of the physical (dynamical) part of the BOGCMs into statistical equilibrium using the preindustrial forcing fields as compiled in WP4 (partners 1, 2). • Coupling of the community model versions for particle flux dynamics and sediment early diagenesis into BOGCM I and BOGCM II, including adjustment of the ecological modules already existing within BOGCMs I and II (partners 1, 2). • First test integrations of BOGCMs I and II using the same basic FORTRAN codes for the community models but with possibly different model parameter settings through application of the ClearCase source code control system (partners 1, 2). • Longer model integrations to provide basic preindustrial tracer and pCO_2 distributions (water column, sediment) as basis for the subsequent model optimisation (through application of burst coupling in order to accelerate the sediment equilibration) (partners 1, 2). • Rough comparison with observations as collated in WP1 in order to adjust model tracer distributions to correct order of magnitude (partners 1, 2). • Implementation and test of crude parameterisations of shelf sea processes (retention of nutrients and carbon loads entering the ocean from land, shelf/open ocean exchange, high shelf sediment accumulation regimes with anoxic pore water reactions) (partner 1).
(d_3_5.5.3)	**Deliverables:** • Basic BOGCM I version with community model components, running for preindustrial conditions • Basic BOGCM II version with community model components, running for preindustrial conditions. • Basic shelf regime parameterisation (BOGCM I)
(d_3_5.5.4)	**Milestones:** • Month 18: Basic BOGCMs I and II with standard community model components, ready for optimisation.

(d_3_6) Workpackage description WP6. Optimisation of the prognostic system.

(d_3_6.1) Workpackage number: 6
(d_3_6.2) Start date or starting event: month 13 (after workshop 2)
(d_3_6.3) Participant codes: 1, 2, 3, 4, 6, 7, 8
(d_3_6.4) Person-months per participant: 12.5, 36, 18, 30, 17, 14

(d_3_6.5) Workpackage description:

(d_3_6.5.1)	**Objectives:** To (a) provide optimised runs of BOGCMs I and II, (b) update the high quality data base of C, N, and Si cycling in the world ocean, (c) revise process parameterisations of the water column and sediment community modules, (d) set up corrected atmospheric forcing fields.
(d_3_6.5.2)	**Methodology and description of work including partner contributions:** • Comparison between BOGCMs outputs and observations, identification of the crucial disagreements to be removed (partners 1, 2, 3, 4, 6, 7, 8). • Tune BOGCMs optimally using an SVD technique (partners 1, 2, 4). • Fill in gaps in data coverage for model verification (partners 3, 6, 8). • Revise atmospheric forcing (e.g., for ACC strength adjustment) (partners 1, 2). • Quality check of the observations (partners 3, 6, 8). • Revise process parameterisations through 1-D modelling and feed these improvements into the community model components as used by BOGCM I and II (through use of the ClearCase source code control system including the test of the 1-D codes in selected case studies) (partners 2, 3, 4, 6, 7, 8).
(d_3_6.5.3)	**Deliverables:** • Optimised data sets of observations including data coverage in key regions for BOGCM tuning, final CD-ROM with data bases. • Optimised process parameterisations implemented within the community model components • Optimised community model source codes which can be coupled in a user friendly way to other models (1-D, 3-D) • Optimised preindustrial physical ocean forcing fields which are consistent with the ocean model physical fields • Comparison between BOGCM I, BOGCM II, and observations. • List of publications on the prognostic system.
(d_3_6.5.4)	**Milestones:** • Month 24: The entire prognostic system is mature enough to be applied to global change and carbon sequestration runs • Month 36: The entire prognostic system is refined, tested, archived, and documented.

(d_3_7) Workpackage description WP7. Model application and demonstration.	
(d_3_7.1) Workpackage number: 7 **(d_3_7.2) Start date or starting event:** month 19 **(d_3_7.3) Participant codes:** 1, 2 **(d_3_7.4) Person-months per participant:** 11, 7	
(d_3_7.5) Workpackage description:	
(d_3_7.5.1)	**Objectives:** To (a) provide an improved simulation of surface ocean CO_2 sources sinks and a closed biogeochemical budget for the preindustrial ocean, (b) assess modifications in surface ocean production patterns and associated changes in particle fluxes for climatic warming scenarios, (d) assess first order effects for anthropogenic carbon sequestration scenarios.
(d_3_7.5.2)	**Methodology and description of work including partner contributions:** • Final integration of the preindustrial reference runs with BOGCMs I and II using the optimised prognostic system (partners 1, 2). • Integration of greenhouse gas induced warming scenarios restarting from preindustrial conditions (partners 1, 2). • Integration of Fe-fertilisation scenario introducing additional iron input to areas with high preformed nutrient surface concentrations (restart from modern conditions, few hundred years) (partners 1, 2). • Integration of deep ocean CO_2 disposal scenario through CO_2 injection into selected $CaCO_3$ rich deep sea areas (partners 1,2). • Integration of glacial ocean scenario (partner 1). • Compilation of results for economic evaluation (partners 1, 2).
(d_3_7.5.3)	**Deliverables:** • Distribution of surface ocean CO_2 sources and sinks and oceanic biomass for the preindustrial ocean. • Closed carbon and nutrient balance for the preindustrial ocean including marine sediments. • Distribution of surface ocean CO_2 sources and sinks and oceanic biomass for greenhouse gas induced warming conditions. • Distribution of surface ocean CO_2 sources and sinks and marine biomass under Fe-fertilisation of HNLC regions. • Distribution of surface ocean CO_2 sources and sinks and sediment coverage under deep-ocean disposal of CO_2. • Distribution of surface ocean CO_2 sources and sinks and sediment coverage under glacial conditions. • List of publications on application of the prognostic system.
(d_3_7.5.4)	**Milestones:** • Month 24: Basic climate change and carbon sequestration scenarios are available • Month 36: Refined climate change and carbon sequestration scenarios are available

(d_3_8) Workpackage description WP8. Economic evaluation.

(d_3_8.1) Workpackage number: 8
(d_3_8.2) Start date or starting event:
(d_3_8.3) Participant code: 5
(d_3_8.4) Person-months per participant: 9

(d_3_8.5) Workpackage description:

(d_3_8.5.1)	**Objectives:** To (a) estimate regional emission reduction cost differentials for the optimised marine carbon cycle representation of WPs 6 and 7, (b) estimate regional climate change impact differentials for the optimised marine carbon cycle representation of WPs 6 and 7, (c) estimate the costs of sequestering carbon in the ocean, (d) estimate the economic impact of changes in marine biological productivity.
(d_3_8.5.2)	**Methodology and description of work including partner contributions:** • Use of already existing models of partner 5, which have been extensively used for similar purposes before (results published in the refereed literature and used for advice to climate change policy makers). • For obj. (a): Estimate differences in carbon fluxes due to the alternative representation of the marine carbon cycle and estimate impact on the costs of meeting certain emission reduction targets [such as the stabilisation of the atmospheric CO_2 concentration at 550 and 650 ppm, and continuations of the Kyoto-Protocol - marine CO_2 sinks/sources (1) equitably shared between all countries, (2) attributed to particular countries on the basis of geographic proximity] (partner 5). • For obj. (b): Estimate (based on previous step) (1) effects on atmospheric CO_2 concentrations, climate change and sea level rise, and (2) differences in the *impacts* of climate change and sea level rise (partner 5). • For obj. (c): Complementation of the impact estimates of marine carbon sequestration on carbon cycle and ecology of WP 7 with estimates of the costs of marine carbon sequestration (estimates available in the literature and in energy-engineering data bases for greenhouse gas emis--sion reduction (restriction here to collecting these data and making them internally consistent) (partner 5). • For obj. (d): Estimate the economic impact of changes in marine ecosystem productivity on fish prices, consumer surplus and fishery income. Development of empirical relationships between marine ecosystem productivity and fish harvests of the economically most important species (partial equilibrium model of harvest and price) (partner 5).
(d_3_8.5.3)	**Deliverables:** • Estimates of economic impact of changes in sea surface CO_2 source/sink patterns and changes in marine biomass • List of publications on economic evaluation
(d_3_8.5.4)	**Milestones:** • Month 36: Climate change carbon cycle and carbon sequestration scenarios are economically evaluated.

(d_3_9) Workpackage description WP9. Dissemination.

(d_3_9.1) Workpackage number: 9
(d_3_9.2) Start date or starting event: month 28
(d_3_9.3) Participant codes: 1, 2, 3, 4, 5, 6, 7, 8
(d_3_9.4) Person-months per participant: 4, 6, 9, 3, 1, 6, 4, 4

(d_3_9.5) Workpackage description:	
(d_3_9.5.1)	**Objectives:** To (a) provide all necessary tools for optimal use of and advertise the models (particle flux and early diagenesis community models, BOGCMs) and the data base of observations to the public. To (b) forward results of project to end users and the non-specialists.
(d_3_9.5.2)	**Methodology and description of work including partner contributions:** • Data base of observations including user manual: (1) on CD-ROM including documentation on data sets, and how to copy them, (2) electronic online publication on the Internet (partners 3, 6, 8). • Community model components (eclogical/particle flux dynamics and sediment early diagenesis modules): (1) Electronic online publication on the Internet within the pool of a leading climate research computing facility, (2) publication on paper as technical report in an established report series (direct distribution to libraries/subscribers) (partners 1, 2, 3, 4, 6, 7). • BOGCMs I and II plus output from preindustrial, climate change, and carbon sequestration runs: (1) Electronic online publication on the Internet at leading climate research computing facilities, (2) Publication on paper as technical report within an established report series (with direct distribution to libraries and other subscribers), (3) storage of model results in online data base and forwarding of meta information to European and overseas data centers (such as CDIAC, Oak Ridge, USA) (partners 1, 2). • Publication of results including economic evaluation as handout for the public (school, university, policy makers, fisheries agencies such as the ICES, energy and life science enterprises and other end users) (all partners). • Update of project's web page (partner 3, with contributions from all p.). • Final project workshop, which will be advertised to the scientific and end user community (partner 1, with contributions from all p.).
(d_3_9.5.3)	**Deliverables:** • Public data sets including user manual • Public model source codes and model data including user manuals • Presentation of the main steps and results for non-specialists • Electronic (online) presentation of the main steps and results • Invitation to final project workshop
(d_3_9.5.4)	**Milestones:** • Months 36: Results of the project are made available to the public and dissemination progresses.

(d_3_10) Workpackage description WP10. Coordination.	
(d_3_10.1) Workpackage number: 10 **(d_3_10.2) Start date or starting event: month 1** **(d_3_10.3) Participant codes:** 1 **(d_3_10.4) Person-months per participant: 3**	
(d_3_10.5) Workpackage description:	
(d_3_10.5.1)	**Objectives:** To ensure timely submission of deliverables, coordinate the project flow, compile the management and scientific reports for the EC, enhance communication between partners, organise work shops, keep in touch with the consultants, promote dissemination of results.
(d_3_10.5.2)	**Methodology and description of work including partner contributions:** • Contact partners early to receive results in time. • Gather contributions of participants for management and scientific reports and compile these reports for submission to the EC. • Contact participants regularly to discuss problems and solve them jointly. • Invite participants and consultants to workshops and meetings.
(d_3_10.5.3)	**Deliverables:** • Management report to the EC after 6 months • Management report to the EC after 12 months • Management report to the EC after 18 months • Management report to the EC after 24 months • Management report to the EC after 30 months • Management report to the EC after 36 months • Scientific report to the EC after 12 months • Scientific report to the EC after 24 months • Scientific report to the EC after 36 months • Workshop 1 (kick-off) • Workshop 2 (implementation and optimisation) • Workshop 3 (application) • Workshop 4 (finish, open to the public)
(d_3_10.5.4)	**Milestones:** • intermediate and final summaries/reports on project, final public workshop including all participants and consultants.

Possible risks: A glacial ocean sceanrio was added in WP7. Originally the project was not planned as a paleoceanographic study. What can be done in the application work package is the following: BOGCM I will be forced by an anomalous freshwater forcing which originally was derived for another ocean model (the LSG model from MPI in Hamburg). This change in buoyancy forcing is expected to yield a significant reduction in North Atlantic Deep Water production which is one of the features of the glacial ocean. As ocean models, such as the real ocean, act sensitively to slight changes in freshwater forcing, the HOPE-C model (BOGCM I) may react differently from the LSG model, and the associated deep water production effect may be exaggerated or diminished.

4 CONTRIBUTION TO OBJECTIVES OF PROGRAMME/CALL

The project contributes directly to Key Action 2 (Global Change, Climate and Biodiversity) of the Work Programme for Part A (Environment and Sustainable Development) of the Energy, Environment and Sustainable Development Programme for RTD under the 5^{th} framework. Through the model development, **ORFOIS** will provide tools for the study of global and regional environmental issues (marine CO_2 source/sink distribution and its spatial as well as temporal change, carbon nutrient redistribution in the water column and the sediment, atmospheric CO_2 partial pressure, see p. 16 of the Work Programme EESD, Part A). A correct knowledge and prediction of the CO_2 source/sink pattern is essential for a check of the Kyoto protocol targets. Atmospheric transport models are currently employed in inverse mode by several research groups in order to deduce carbon sources and sinks at the land and ocean surface. Especially the resulting terrestrial source/sink pattern is under heavy debate (e.g., Fan et al., 1998). **ORFOIS** aims at a proper quantification of surface ocean pCO_2 distributions which can be used to efficiently constrain these inverse models for a firm estimate of terrestrial carbon sources and sinks. The observational data bases as well as the community models for particle flux dynamics and early diagenesis will be made available on the Internet making use of up to date e-science technologies for data exchange as encouraged in the Work Programme (see p. 16 of the Work Programme EESD, Part A).

The project's targets are tied to item 2.2 (Actions to foster better understanding of terrestrial and marine ecosystems and their interactions) of the Work Programme, and address the central issues of RTD priority action 2.2.2. (Interactions between ecosystems and the carbon and nitrogen cycles): ORFOIS directly provides an improved quantification of the marine biospheric sources, sinks, and fluxes of carbon and nutrients (N, P, Si) which is one of the targets as stated in the Work Programme (see p. 18 of the Work Programme EESD, Part A). The temporal and spatial changes for carbon and nutrient redistributions within the ocean as well as between ocean and atmosphere under anthropogenically perturbed conditions will be established.

Moreover, the project is linked to topic 2.1 (Actions to understand, detect, assess, and predict global change processes) of the Workprogramme. ORFOIS will contribute to RTD priority action 2.1.1. (Atmospheric composition change). The project will provide best guesses for the preindustrial as well as future marine source/sink distribution for CO_2 at the sea surface and the associated fluxes of CO_2 out of and into the atmosphere. Also ORFOIS will be linked to RTD priority action 2.1.3. (Climate change and prediction scenarios). The project will help to reduce uncertainties of future evolution of the atmospheric CO_2 concentration through identifiying which marine regions will be amplified sources/sinks in a warmer climate in relation to biogeochemical processes in the water column and the bioturbated sediment.

5 COMMUNITY ADDED VALUE AND CONTRIBUTION TO EU POLICIES

The subject which will be addressed in **ORFOIS** is of wide European interest and strategic importance. The proposed work directly relates to obligations of the Member States to international treaties on environmental protection issues. These treaties are for the atmosphere the *Kyoto Protocol* (**KP**) on climate change, and for the ocean the *London Convention* (**LC**) (1972, plus protocol from 1996) on the prevention of marine pollution, the 1992 *OSPAR Convention* (**OC**) (replacing the earlier Paris and Oslo Conventions) for the protection of the marine environment of the North-East Atlantic, and also the 1992 *Helsinki Convention* (**HC**) on the protection of the marine environment of the Baltic Sea Area.

The establishment of reliable marine CO_2 source/sink distributions and their temporal and spatial prediction as well as research on carbon sequestration is part of the obligations of the Member States within **KP** (Articles 2.1.a.i., 2.1.a.ii, 3.3, 5.1, 9.1, 10.a, 10.b, 10.b.ii, 10.d, and 10.e). Exchange of information as well as cooperation on scientific and technical research on climate and carbon cycle issues are encouraged explicitly through **KP** Articles 10.c, 10.d, and 13.c..

Quantifying correctly marine particle flux dynamics and fluxes is necessary to predict reliably the fate of hazardeous substances in the marine realm. These substances are, e.g., heavy metals such as lead and radionuclides which are scavenged from dissolution to particles and finally are enriched within the sediment. The work in **ORFOIS** enables corresponding quantifications. The proposed project contributes to the objectives of **LC** (Articles I, II, and XII), of **OC** (Articles 1a,b), and of **HC** (Article 3). All three marine conventions demand joint collaborative research on environmental issues in order to protect natural resources (**LC**, Article IX; **OC**, Article 8; HC, Article 24).

The joint modelling of marine carbon sources and sinks will be of strategic importance for Europe. This additional constraint for atmospheric CO_2 transport inverse calculations will exclude biased sink propositions such as a highly unlikely North American carbon sink as suggested by Fan et al. (1998*Science*, 282, 442-446).

The establishment of precise temporal spatial surface ocean pCO_2 arrays and their prediction is too ambitious to be carried out on a national level alone. It is necessary to share experiences from the measuring, data analysing, and modelling community throughout Europe in order to make common use of expensive infrastructure (super computer resources, data base information systems).

6 CONTRIBUTION TO COMMUNITY SOCIAL OBJECTIVES

Project **ORFOIS** will contribute significantly to social objectives of EU Member States:

- The calculation of the fate of particles will be the foundation for valid estimates of removal and storage of hazardeous substances within the ocean (coming from land based sources through river runoff and atmospheric transport as well as from direct marine disposal). The consideration of near shore and shelf systems within a global BOGCM will provide a first global estimate of shelf/open ocean interaction and related water exchange time scales based on mechanistic modelling. The particle flux and sediment "community models" will provide a basis for future operational biogeochemical forecasting of environmental key variables. Thus these models will help to prevent marine areas around EU member states from environmental damage and foster sustainable use of these oceanic areas for fisheries.

- The simulation of thoroughly backed up surface ocean pCO_2 distributions will narrow the uncertainties of carbon redistribution estimates within the earth system. This knowledge has direct economic consequences because it enables **early** political measures to react on and prevent undesired climate change evolutions. This knowledge enables a well planned procedure for fullfilling the Kyoto Protocol obligations of member states. Early planning on the basis of solid research results within this context has been shown to be of extreme economic value (Nordhaus, W. D., and D. Popp, 1997, What is the value of scientific knowledge ? An application to global warming using the PRICE model, *The Energy Journal*, 18, 1-45; Peck, S. C., and T. J. Teisberg, 1993, Global warming uncertainties and the value of information: An analysis using CETA, *Resource and Energy Economics*, 15, 71-97).

- Within the proposed project young scientists will be trained for understanding and forecasting environmental systems. This qualification will contribute to recruite highly skilled personnel for the climate and global change tasks in the future (monitoring the environment, fulfillment of Kyoto Protocol obligations). Within the European science network these well educated people will be the most valuable human resource to guarantee a world leading position concerning scientific staff and ensure to keep Europe as a center of excellence concerning earth system science.

Furthermore, the specialists working together in **ORFOIS** have particular expertise on their fields which is not available at each national level in the same quality. E.g., three groups have the capability of carrying out BOGCM runs on high end supercomputers, while other groups have special expertise on selected marine processes and access to up to date observations. The results of the project will be "community models" of ocean particle flux dynamics and sediment modules which will be standardised for use in different model frame works. Comparable model components most probably will not be available from other places (e.g., the US side), providing a technological and scientific leading edge position for the EU.

7 ECONOMIC DEVELOPMENT AND S&T PROSPECTS

Dissemination of results for the consortium as a whole:

For the consortium as a whole dissemination of results will be carried out in a separate workpackage (WP 9). About 10 % of the project's manpower will be allocated to this workpackage.

The data sets which will be compiled will be made available to the public as CD-ROM as well as through the PANGAEA system online in electronic form. A user manual will document the history of this data set, quality issues, and how to retrieve data for individual user's purposes. The access to the data base will be facilitated through publication of access modes on the project's homepage on the world wide web (see below).

The community models for particle flux dynamics and early sediment diagenesis, as well as the updated BOGCMs I and II (the HOPE-C and the IPSL-OGCM) will be archived with all necessary files to run the models at MPG-IMET, which have a special model support group (M&D, Models and Data, successor of the scientific department of the German Climate Computing Center, see: http://www.mpimet.mpg.de/Depts/MaD/index.html, directed by Dr. U. Cubasch). Access to all these codes will be possible via the Internet. User manuals for all models/model components will be published online as well as on paper (as technical report in the MPG-IMET/DKRZ Technical Report Series ISSN 0940-9327). These reports are sent routinelly to world wide subscribers such as libraries, earth science research institutes, and individual researchers. BOGCM II will be additionally archived and maintained for further use at LSCE. BOGCM I will additionally be archived for further use at NERI.

Model results (especially the surface ocean pCO_2 data sets, but also threedimensional and time dependent data sets of further variables) will be stored in the CERA facility of the M&D-group (at MPG-IMET) for further exploitation in natural and economic sciences. Meta information about these data sets will be forwarded to other European and overseas data centers including the CDIAC (Carbon Dioxide Information and Analsysis Center, Oka Ridge, Tennessee, USA).

Besides publication of results in peer reviewed journals (not part of the dissemination per se), the model results will be reported on paper to the non-specialist. This brochure will also include details of the economic evaluation of the results which will be achieved. This brochure will be forwarded to end users for exploitation purposes (policiy makers, fisheries agencies such as the ICES, energy and life science enterprises such as BP) and for educational use (schools, universities).

All project results and products will be advertised on the project's homepage which will be mainly maintained by UBO (participant 3), who have year long experience in online publication (see the homepage of EU MAST-III project SINOPS, which has received awards, http://www.univ-brest.fr/IUEM/BIOFLUX/SINOPS/).

The advisory board of consultants will assist essentially to disseminate the results of the projects within the scientific and political community. Consultants will be invited to participate in the project workshops. The final project workshop will be announced well in time and will be open to the public. Individual invitations for this workshop will be sent to selected researchers and policy makers to ensure wide public use of the reults.

Exploitation of results for individual participants:

The individual user's will use the ruslts of the ORFOIS results as foundation for their further work. The data base compilations will allow a further evaluation of the biogeochemical data for a further statistical analysis, to identify major gaps in data coverage to be closed in future research cruises, and to crosscorrelate data of different variables in order to derive new advanced models of oceanic cycling of matter (especially for NERI, LSCE, UBO, NCMR, NIOO and UBO). The organisations running 3-D models (NERI, LSCE, MPG-IMET) will use the obervational data sets for further rigorous tuning of the models. The data sets will provide the backbone for systematic data assimilation into the BOGCMs with adjoint model codes which will be developed in the foreseeable future.

The model codes will be exploited for different purposes by the groups more specialised on 1-D process studies (such as UBO, NCMR, NIOO) and those more specialised in 3-D modelling (NERI, LSCE, MPG-IMET). The first group will exploit the models in 1-D mode for analysis of reasearch cruises, single stations, and time series deployments of sediment traps and other devices. The second group will use the BOGCM-versions in their quasi-operationally running 3-D model systems to address global and regional issues of climate change and environmental protection. It is planned to use the particle flux dynamics module (within the 3-D model framework) to study te export of hazardous substances out of the water column into the sediemnt. The first experiences with a parameterisation of shelf processes within the global 3-D model system will allow in future a more sophisticated representation of shelf seas within global marine budget computations.

Strategic impact of the proposal:

The project will join researchers from very different disciplines (earth sciences, biology, economy) an a common platform to address a question of vital interest to both: the society and the scientific community. Within the project, high end data sets, and high end model systems on the marine biogeochemistry will be developed and thoroughly archived for further exploitation. This exploitation is ensured by use of up to date e-technologies for (a) the data management (observations, model results) and (b) the model development and archiving (by use of the source code control system ClearCase). Observed and modelled data can be exchanged easily via the Internet between partners. The same is true for the models. We aim, in fact, on an easy exchange of model codes bewteen 1-D "process modellers" and 3-D "simulation modellers". This will ensure fast and smooth information flow on a European platform between scientists working on different scales. This will provide a further improvement of scientific-technical leadership of the consortium, a competitiveness based on cooperation, and the creation of new opportunities for the participants, in particular career opportunities for the PhD students and post-docs involved in this study.

8 THE CONSORTIUM

The consortium consists of 9 participating organisations (8 principal contractors and 1 subcontractor) from 6 different European countries:

participant no.	organisation short name	name of organisation	country
1	NERI	National Environmental Research Institute	Denmark
2	LSCE	Laboratoire des Sciences du Climat et de l'Environnement/CEA, UMR CEA/CNRS	France
3	UBO	CNRS/Institut Universitaire Européen de la Mer	France
4	MPG-IMET	Max Planck Institut of Meteorology	Germany
-	(MARUM)	(Center for Marine Environmental Sciences, subcontractor of MPG-IMET)	(Germany)
5	Uni-HH	University of Hamburg, research unit Sustainability and Global Change	Germany
6	NCMR	National Center for Marine Research	Greece
7	NIOO	Nederlands Instituut voor Oecologisch Onderzoek – Centrum voor Estuariene en Mariene Oecologie	The Netherlands
8	UEA	University of East Anglia, School of Environmental Sciences	United Kingdom

The data and process identification part of the project will mainly be in the hands of UBO, NCMR, UEA, and - as subcontractor - MARUM. The modelling section of **ORFOIS** will be taken care of mainly by NERI, LSCE, MPG-IMET, Uni-HH, and NIOO.

The particular tasks of the different partners are described in detail below.

- **Partner 1, NERI:**
  - NERI will coordinate the project (WP 10).
  - NERI will focus on the development and promotion of the community models for particle flux dynamics and early diagenesis (WP 3), the compilation of the model forcing fields (WP 4), and the model application and demonstration (WP 7) with BOGCM I (global warming runs, carbon sequestration runs, glacial scenario). BOGCM I is the "HOPE-C" model developed by Ernst Maier-Reimer (MPG-IMET), which is a coupled dynamical-biogeochemical ocean general circulation model ("HOPE-C" = Hamburg Ocean Primitive Equation model based on a C grid).
  - NERI will implement the community models into BOGCM I (WP 5) in close collaboration with MPG-IMET and NIOO.
  - NERI will optimise this model (WP 6) making use of the data base of observations mainly collated by UBO, NCMR, and UEA.
  - NERI will also take the lead for extraction of atmospheric forcing data from atmospheric model runs (of the ECHAM-AGCM version 4, results are published and made available by MPG-IMET) (WP 4).

- **Partner 2, LSCE:**
  - LSCE's main tasks are contributions to (a) the time dependent early diagenesis modelling (1-D) as well as the identification of particle redissolution processes within the water column and the bioturbated sediment including laboratory experiments on $CaCO_3$ reactivity (WP 2) and
  - (b) the implementation of the community models into BOGCM II (WP 5). This model is the "IPSL-OGCM", which is a coupled dynamical-biogeochemical ocean model ("IPSL-OGCM" = Institut Pierre Simon Laplace Ocean General Circulation Model) run by several groups in the Paris area.
  - LSCE will optimise this BOGCM and will also carry out corrsponding application experiments on greenhouse gase induced warming and carbon storage.
- **Partner 3, UBO:**
  - UBO is the focal point for observational data collection and archiving within the project (WP 1). The main flow of data storage into the data base and information system PANGAEA (maintaned by MARUM, subcontractor of participant 4 MPG-IMET) will run through UBO. UBO will take care of most of the open ocean data (except sea surface pCO_2), while NCMR and UEA will concentrate on shallow water diagenetic data and sea surface pCO_2 data resepctively.
  - During the optimisation phase (WP 6), UBO will fill in missing gaps of data coverage.
  - UBO will also contribute to WP 2 by 1-D modelling of BSi biogeochemistry in the water column as well as the sediment. Suggestions for parameterisations of diagenetic processes will directly feed into the work of NIOO in WP 2.
  - A limited number of laboratory experiments will be carried out by UBO within WP 2 in order to back up some concrete ideas for improved redissolution parameterisations (BSi).
- **Partner 4, MPG-IMET:**
  - MPG-IMET's focal work is on the process parameterisation of particle dynamics within the water column (WP 2). A corresponding community particle flux module will be established in close cooperation with NERI (WP3).
  - During the optimisation loop (WP 6) continuous refinements on the particle flux model will be made. These updates will be implemented by NERI and LSCE continuously into the 3-D models. The ClearCase server workstation for the source code development will be located at MPG-IMET, because this organisation has already experience with implementation and use of this system.
  - MARUM at the University of Bremen will be subcontractor of MPG-IMET and give technical support for the use of the data base system PANGAEA (the choice of MPG-IMET for taking care of this subcontracting is mainly for administrative reasons).
- **Partner 5, Uni-HH:**
  - Uni-HH will carry out the ecomomic evaluation (WP 8) in close collaboration with all participants, in particular with NERI and LSCE who will provide the input for this evaluation during WPs 6 and 7. Uni-HH has the appropriate tools and methodologies at hand. Easy communication between MPG-IMET and Uni-HH will facilitate the bridging of different disciplines (earth sciences, economics).

- **Partner 6, NCMR:**
  - NCMR's main task will be the identification of shallow water diagenetic processes of importance for the project (WP 2) as well as the collation of shelf sea data sets of observations (WP 1). NCMR will work directly together with UBO on WPs 1 and 2.
  - NCMR will give input to NERI in order to set up a first crude parameterisation for shelf sea processes and carbon and nutrient cycling suitable for BOGCMs.
  - During the optimsation phase (WP 6) NCMR will revise all shallow water aspects of the data sets and make suggestions for improvements of the diagenetic module which will developed mainly by NIOO (WP 2).
- **Partner 7, NIOO:**
  - NIOO's primary role is the development of the early diagenetic sedimentary model (WP 2) and its conversion into a community model (WP 3) under assistence of NERI and LSCE.
  - During the optimisation (WP 6), NIOO will revise and retune the 1-D version of the diagentic module with the data as collated by UBO and NCMR in WP 1. For the sedimentary process parameterisations NIOO will jointly work with all other participants, in particular, however, with NERI, LSCE, UBO, and NCMR.
- **Partner 8, UEA:**
  - UEA is the principal investigator for the collation of the sea surface pCO_2 (CO_2 partial pressure) data base (WP 1) which will be used by NERI and LSCE for model verification during WPs 6 and 7. UEA is the outstanding specialist for this difficult task.
  - During the optimisation phase (WP 6), UEA will test parameterisations of ecological and geochemical processes as used in the community models for selected case studies with good synoptic observational data coverage (local or regional multi-tracer data sets). Corresponding results will feed back immediately into the 3-D models and save ressources.

The dissemination (WP 9) of results through data bases, the Internet, and in joint work with the advisory board of consultants will be carried out by all partners together. UBO will play a leading role here for providing the dissemination of the observational data bases, while NERI, LSCE, MPG-IMET, and NIOO will take care of the modelling aspects of dissemination.

Consortium information table for partner 1 - NERI

personnel type (category)	number of staff involved	relevant expertise	tasks in the project
scientist	2	PhD in oceanography or related	WP 3-7, 9-10
technician	-	-	-
assistant	-	-	-
permanent staff (AC)	-	-	-

Consortium information table for partner 2 - LSCE

personnel type (category)	number of staff involved	relevant expertise	tasks in the project
scientist	5	PhD in oceanography or related	WP 2-7, 9
technician	-	-	-
assistant	-	-	-
permanent staff (AC)	-	-	-

Consortium information table for partner 3 - UBO

personnel type (category)	number of staff involved	relevant expertise	tasks in the project
scientist	1	PhD in earth sciences, data manager	WP 1, 6, 9
technician	1	physical/chemical lab techniques	WP 1, 6
assistant	2	Physical/chemcial lab techniques	WP 2, 6
permanent	3	PhD in oceanography or related	WP 1, 2, 6, 9
staff (AC)			

Consortium information table for partner 4 - MPG.IMET

personnel type (category)	number of staff involved	relevant expertise	tasks in the project
scientist	1	PhD in biological oceanography	WP 2-3, 6, 9
technician	-	-	-
assistant	-	-	-
permanent staff (AC)	1	PhD in oceanography, numerical modeller	WP 2-3, 6, 9
subcontractor PANGAEA scientist	1	PhD in earth sciences, database specialist	WP 1

Consortium information table for partner 5 - Uni-HH

personnel type (category)	number of staff involved	relevant expertise	tasks in the project
scientist	1	PhD in econonmics or related	WP 8-9
technician	-	-	-
assistant	-	-	-
permanent staff (AC)	1	PhD/Habilitation in economics	WP 2-3, 6, 9

Consortium information table for partner 6 - NCMR

personnel type (category)	number of staff involved	relevant expertise	tasks in the project
scientist	3	PhD in oceanography or related	WP 1-2, 6, 9
technician	-	-	-
assistant	-	-	-
permanent staff (AC)	-	-	-

Consortium information table for partner 7 - NIOO

personnel type (category)	number of staff involved	relevant expertise	tasks in the project
scientist	1	PhD in oceanography or related	WP 2-3, 6, 9
technician	-	-	-
assistant	-	-	-
permanent staff (AC)	3	PhD in oceanography or related	WP 2-3, 6, 9

Consortium information table for partner 8 - UEA

personnel type (category)	number of staff involved	relevant expertise	tasks in the project
scientist	1	PhD in oceanography or related	WP 1, 6, 9
technician	-	-	-
assistant	-	-	-
permanent staff (AC)	1	PhD in oceanography or related	WP 1, 6, 9

Advisory Board - List of Consultants

The following perons agreed to act as consultants of the project. Their input will be invaluable to improve the quality of the results. Consultants will be invited to participate in the project workshops.

consultant's name	special interest	organisation
Prof. Dr. Karin Lochte	pelagic-benthic coupling, benthos biogeochemistry	Institut für Meereskunde, Universität Kiel
Dr. Axel Michaelowa	climate politics, socio-economic impact of climate and of climate research	Hamburger Welt-wirtschaftsarchiv, HWWA
Dr. Olivier Aumont	large scale ocean modelling of physics and biogeochemistry	LODYC, Paris
Dr. Isabelle Dadou	oceanic biogeochemistry, satellite data, data assimilation methods	Laboratoire d'Étude En Geophysique et Océanographie Spatiales, Toulouse
Prof. Dr. Ulf Riebesell and Dr. Markus Pahlow	biological oceanography, micro-scale processes, marine ecology	Alfred-Wegener-Institut für Polar- und Meeresforschung
Prof. Dr. Gary Shaffer	biogeochemistry of organic carbon remineralisation	Danish Center for Earth System Science, University of Copenhagen

9 PROJECT MANAGEMENT

The project will be coordinated by Christoph Heinze from NERI (Roskilde, Denmark). The overall project management will be carried out also by Christoph Heinze. The major outlines of collaborations will be defined on the project workshops. Major information exchange between participants will be carried out through the Internet. A joint mailing list (orfois@dkrz.de, which was already established for the preparation of this proposal) will be the major information carrier between partners. A common **ORFOIS** home page will be established on the world wide web in order to facilitate exchange of results and to allow a tracing of the project's progress.

The data base compilation will be mainly managed by partner 3 (UBO), who will tightly work together with partners 6 (NCMR) and 8 (UEA) to ensure smooth transfer of observed data into the data base system. This system is the so called PANGAEA data base and information system, which was developed originally at AWI/Bremerhaven and which is maintained now by MARUM at the University of Bremen (Center for Marine Environmental Sciences, MARUM, University of Bremen, PI: Dr. Michael Diepenbroek, Klagenfurter Straße, D-28359 Bremen, phone: +49 421 218 3116, fax: +49 421 218 7765, email: mdiepenbroek@pangaea.de). MARUM will be sub-contractor of participant 4 (MPG-IMET, Hamburg, Germany) in order to provide the logistical data base infrastructure throughout the project. The PANGAEA system is one of the easiest to use, most versatile, and flexible data base systems available to date. It will also be used for dissemination of the observational data collated within the project.

The modelling part of the project will be mainly managed by partner 1 (NERI). The model source code development will be carried out using high end e-technology for source code development and administration. The development of the source codes for the 1-D models, the community model components, and the BOGCMs (including the interfaces to the community model components) will be realised with the ClearCase source code control system, which has successfully been used for developments of complex climate models. This control system allows simultaneous work of different authors on one model backbone, easy archiving of various source code releases, and easy swapping of codes between partners. The ClearCase server (a workstation) will be maintained by partner 4 (MPG-IMET), who has already experience with this system. Partner 1 (NERI) will survey the model development and ensure common use of one homogeneous nomenclature. He will assist the participants during the development and exchange of the source codes through regular briefings via phone and Internet.

Decisions on final releases for deliverables and milestones during the project flow will be made jointly, mainly during the project workshops. Consultants will be invited to the workshops and give external advice on most efficient progress and result preparation. The coordinator will ensure, that the time frame of the project will be maintained. The structure of the project workplan (see flow-chart in paragraph B6) was chosen so that the project's goals will be achieved in a most efficient way: In a comparatively short preparative phase, basic versions of the observational data sets and models will be provided. In the longer optimisation phase, optimal versions of all components of the predictive biogeochemical model and data system will be achieved iteratively.

Quality assurance for data collection will be based on previous experience. Jointly, standards for data accuracy will be established, and filters for clearly wrong data values will be provided by all participants. During the modelling part of the project, regular tests of compuational efficiency will be carried out (source codes will be swapped easily between 1-D and 3-D modellers using the ClearCase system). Only models and model components which are strictly mass conserving will be accepted. Mass conservation will be the standard quality assurance tool for the modelling part of the project.

An advisory board of external consultants will be established (see list under C7). These consultants will accompany the project and give independent input to steering and quality assurance of the project. The consultants will also assist the participants during the dissemination of the results and the preparation of the project's output for end users.