COST

European Cooperation in the field of Scientific and Technical Research - COST -

Secretariat

Brussels, 11 July 2006

COST 262/06

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MEMORANDUM OF UNDERSTANDING

Subject : Memorandum of Understanding (MoU) for the implementation of a European Concerted Research Action designated as COST Action 735'Tools for Assessing Global Air–Sea Fluxes of Climate and Air Pollution Relevant Gases'

Delegations will find attached the Memorandum of Understanding for COST Action 735 as approved by the COST Committee of Senior Officials (CSO) at its 165th meeting on 27/28 June 2006.

**MEMORANDUM OF UNDERSTANDING
FOR THE IMPLEMENTATION OF A EUROPEAN CONCERTED RESEARCH ACTION
DESIGNATED AS**

COST ACTION 735

'Tools for Assessing Global Air–Sea Fluxes of Climate and Air Pollution Relevant Gases'

The Signatories to this 'Memorandum of Understanding', declaring their common intention to participate in the concerted Action referred to above and described in the 'Technical Annex to the Memorandum', have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 400/01 'Rules and Procedures for Implementing COST Actions', or in any new document amending or replacing it, the contents of which the Signatories are fully aware of.

2. The main objective of the Action is to develop the tools for, and the production of, best estimates of global air–sea fluxes of compounds relevant to climate and air pollution.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at approximately EUR 60 million in 2006 prices.

4. The Memorandum of Understanding will take effect on being signed by at least five Signatories.

5. The Memorandum of Understanding will remain in force for a period of five years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Chapter 6 of the document referred to in Point 1 above.

COST ACTION 735

Tools for Assessing Global Air–Sea Fluxes of Climate and Air Pollution Relevant Gases

A. ABSTRACT

The exchange of mass at the air–sea interface is of critical importance to the regulation of the Earth's climate, and quantitative evaluation of these gas fluxes is an objective that will provide key information for improvement of our understanding of the Earth System. A collective assessment of these fluxes can be realised only by a concerted effort of a multidisciplinary and international assembly of the scientific community. This COST Action creates a framework for assessment of the global air–sea flux of climatically relevant trace gases and pollutants, and this evaluation will lead to improvement in our understanding of the processes responsible for the interfacial transfer of gases and toward improvements in our ability to monitor and predict future climate.

- The critical mechanism for this framework is the formation of three working groups of some of the brightest minds in the field to develop interpretable air–sea gas flux products, and this Action provides a unique system for development of the air–sea transfer products. This Action creates added- value in that the networking of European scientists and the integration of their data sets into a global framework of products adds up to a significantly greater result than the sum of individual national efforts. Further tools to be developed within this Action include the fostering and encouragement of young European scientists, the development of short-term scientific missions meant to target specific outstanding questions, and the creation of a series of symposia on topics of critical importance to the field of air–sea interaction.

Keywords: air–sea interaction, climate change, gas transfer, global assessment.

B. BACKGROUND

The oceans play a key role in regulating the composition of the Earth's atmosphere and are important in determining climate and air quality on a regional and global scale. The biological, chemical and physical processes that control the flux of climatically relevant compounds have traditionally been studied in an isolated manner. There is much to do to integrate and communicate previous work and to coordinate and plan future research on this critical component of the Earth System. Without such action, advances in our understanding of air–sea interactions will not adequately inform policy making on issues such as climate change, air quality, coastal eutrophication and acid deposition.

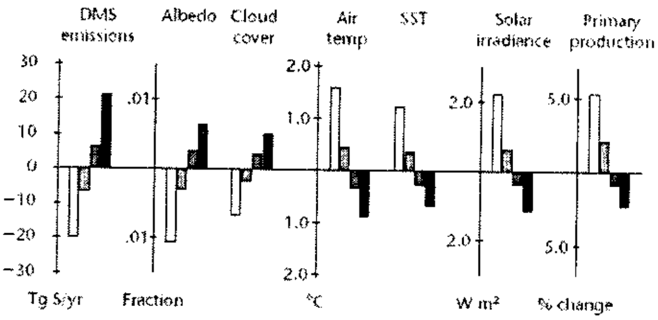

Figure 1. Global response to altering oceanic DMS emissions, showing sensitivity of climate to DMS as modelled in HadCM3

Simulations of future climate now incorporate biological and chemical feedbacks that arise as the atmosphere–ocean system changes in response to climate forcing (Figure 1). These simulations give divergent predictions, depending on how the feedbacks are modelled. Substantial changes in 'natural' sources and sinks of climatically active gases are probable once climate change effects become manifest. Carbon dioxide (CO_2) is the most closely studied example, but dimethylsulphide (DMS) and other chemically active trace species (e.g., organo-halogens) also have effects on air quality and oxidation capacity.

These deficiencies lead to uncertainties in the timing and magnitude of global change effects, the social and economic implications of which are profound, as adaptation strategies are highly dependent on time scales of climate change.

This COST Action is designed to address such issues, with the purpose of substantially reducing uncertainties in our predictions of the timing and effects of future global climate change.

Thus the Action will:

- Consolidate current knowledge of relevant air–sea interactions into a form that is accessible and useful to policy makers and climate modellers.
- Identify gaps in our knowledge and stimulate further research.
- Provide a framework into which new data and process-understanding can be assimilated to keep end-users up to date with our knowledge of air–sea interactions.

This Action encompasses a wide range of scientific topics and disciplines, but it focuses primarily on air–sea interaction and all the complex interrelationships therein. Given the high relevance of the science and expertise already assembled under the Surface Ocean Lower Atmosphere Study (SOLAS) project, a certain degree of synergy will be sought between this new COST Action and that project. However, this Action will remain autonomous with regard to any other international project.

Trace gases and biological feedbacks to global change

A broad range of gases are produced by biological and (photo)chemical mechanisms in the surface ocean. These gases cross the air–sea interface and can lead to considerable changes in the radiative environment by direct absorption or particle formation.

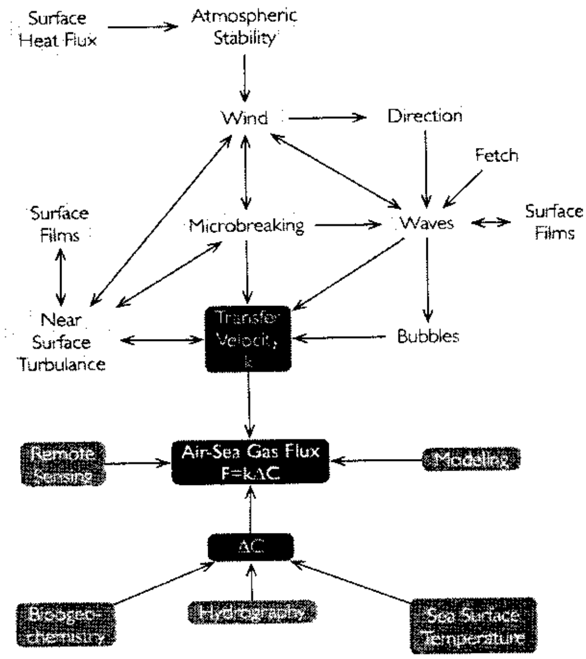

FIGURE 2. Key measured components to understand and extrapolate air–sea gas transfer to global and regional scales.

For example, the oceanic emission of reactive halogen compounds (Cl, Br, and I) is known to influence the ozone budget and the oxidation capacity of the marine atmospheric boundary layer in many marine regions. The bio/photogenic organo-halogen compounds CH_3Br and CH_3Cl contribute about 25% of chlorine equivalent to the stratosphere and, consequently, contribute significantly to the loss of stratospheric O_3. An increase of only 0.5 pptv (5%) in the atmospheric burden of CH_3Br would reverse the current downward trend in the atmospheric burden of ozone-depleting gases. Thus, climate-driven changes in biogenic production of organo-halogens, their emission fluxes, or their transport by deep convection could significantly impact stratospheric O_3.

Dimethylsulphide (DMS) emissions have received significant attention because of the landmark CLAW hypothesis, which postulated a feedback involving marine phytoplankton, sulphate aerosol formation, and cloud albedo that could stabilise the Earth's temperature. While some of the CLAW linkages have been demonstrated, (e.g., sulphate and cloudiness correlate with seasonal DMS flux cycles), many steps have not been verified. Process-based models of DMS give divergent predictions, and our knowledge of the oxidation and branching ratios of atmospheric DMS is incomplete.

Factors that control the emission of trace gases include wind speed, temperature, photochemistry and biological activity, which in turn depend on radiative, chemical and physical phenomena. Changes in any of these factors can be expected to vary trace gas emissions and feedback on the chemical condition of the atmosphere.

Despite recognition of the climatic importance of radiation-driven biogeochemical processes, most known photo-processes in the surface ocean are not well understood or treated in a quantitative manner in atmospheric models.

Physical processes regulating air–sea exchange

Gas transfer across the air–sea interface occurs by turbulent and diffusive transfer processes across the two fluid boundary layers and the interface separating them. Rates of transfer across the coupled boundary layers are controlled by a myriad of processes (Figure 2). Determination of the gas transfer velocity is critical for calculating the uptake of human-made CO_2 by the oceans, as well as the emission of the trace gases important for air quality and climate. Estimates of the oceanic CO_2 uptake can differ by as much as 200%, assuming the same wind field but different parameterisations of the gas exchange rate.

However, as well as tracer techniques developed by European scientists for measuring gas exchange rates at sea, there are a variety of methods using remote sensing and micrometeorological approaches which are beginning to yield reliable results. These new methods need to be developed and intercompared so that more robust parameterisations for use in air–sea exchange models can be developed.

Air–sea exchange of greenhouse gases

The ocean acts as a sink for anthropogenic carbon, absorbing 30% of fossil fuel CO_2 emissions. The associated net air-to-sea flux of CO_2 is controlled by solubility and the rate at which deep ocean waters are exposed to an atmosphere with elevated carbon dioxide relative to pre-industrial levels. This 'anthropogenic' flux is superimposed on a geographically and temporally varying pattern of large natural exchanges. These exchanges are determined by a variety of processes, including heating and cooling of surface waters, biological uptake and export of organic carbon from the surface layer, marine biocalcification and the upwelling of carbon-rich deep waters into the surface layer.

The local air–sea CO_2 flux can be estimated from measurements of the partial pressure difference across the interface, assuming knowledge of the gas exchange coefficient. Integration of local fluxes permits quantitative estimation of atmosphere–ocean fluxes on the global scale, and hence quantification of one of the two major inter-reservoir fluxes in the global carbon cycle.

Surface water CO_2 measurements collected over three decades have been extrapolated and interpolated in space and time to estimate the global distribution of the net flux of CO_2 between the ocean and the atmosphere. Climatologies of seasonal surface water oxygen partial pressures have also been compiled. This type of information can contribute directly to quantitative understanding of the contemporary global carbon cycle, including terrestrial biosphere processes, through atmospheric inversion modelling. However, despite considerable effort, the available surface water CO_2 data remain geographically and temporally sparse, and are compromised by variable measurement accuracy among the archived data sets employed.

Nitrous oxide (N_2O) has a global warming potential of several hundred times that of CO_2 and an atmospheric lifetime in excess of 100 years. However, in the climate change debate it has received significantly less attention than these properties indicate is appropriate. The fluxes are particularly large in organic-rich shelf and coastal areas, which are subject to increasing organic loadings from agricultural and urban developments. The situation in open ocean areas under foreseeable global change scenarios is potentially important.

Scope and relevance of this COST Action

This COST Action will coordinate an international effort to achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and the atmosphere, and how this coupled system affects and is affected by climate and environmental change. A COST Action is an appropriate tool to achieve these goals, as there exists a requirement to synthesise existing scientific findings, to bring together experimental, laboratory and model data sets, and to coordinate the considerable body of ongoing work in air–sea gas exchange and associated processes. Without a COST Action, this synthesis work is unlikely to occur, leaving the air–sea community without a global framework for interpretation of individual national efforts. Thus, the Action is truly timely and global in scope, and Europe will demonstrate significant leadership for it.

C. OBJECTIVES AND BENEFITS

The main objective of this COST Action is to develop the tools for, and the production of, best estimates of global air–sea fluxes of compounds relevant to climate and air pollution, including, but not limited to CO_2, DMS, halogenated hydrocarbons, nitrous oxide, trace metals and nutrients. The latter two are included as their flux to the ocean affects marine ecology and provides feedback to the production of trace gases. These estimates will be computed from a combination of available data and state-of-the-art model output.

This COST Action will:

- Compile existing data into a standards-based framework, in a format of use to climate modellers, interpolating sparse data and collapsing it to a 'virtual year'.
- Intercalibrate and compare different data sets and methods, and assess the errors within them.
- Compare the data products to model output.

Such a synthesis of data is critical for assessing the role of the oceans in regulating atmospheric concentrations of greenhouse gases, stratospheric ozone-depleting compounds and oxides of nitrogen and sulphur which form acid deposition. It will allow a determination of the ocean's influence on the oxidation capacity of the atmosphere, which regulates air quality and the lifetime of greenhouse gases.

Secondary objectives are:

- To implement the latest chemical and biological understanding of trace gas production into coupled models used for predicting regional and global climate.
- To assess the role that the oceans play in regulating air quality and the atmosphere's oxidation capacity.

- To synthesise our knowledge of the likely changes in air–sea exchange under various global change scenarios.

Such an initiative is timely because coupled GCMs (General Circulation Models) used to predict climate are now capable of incorporating biological feedbacks to global change (Figure 2). They are currently limited by a lack of data and understanding of how the chemical/ biological processes operate within our present climate and will operate in the future (Figure 3).

Finally, this Action will

- Develop fora for information dissemination, scientific synthesis and vigorous discussion.

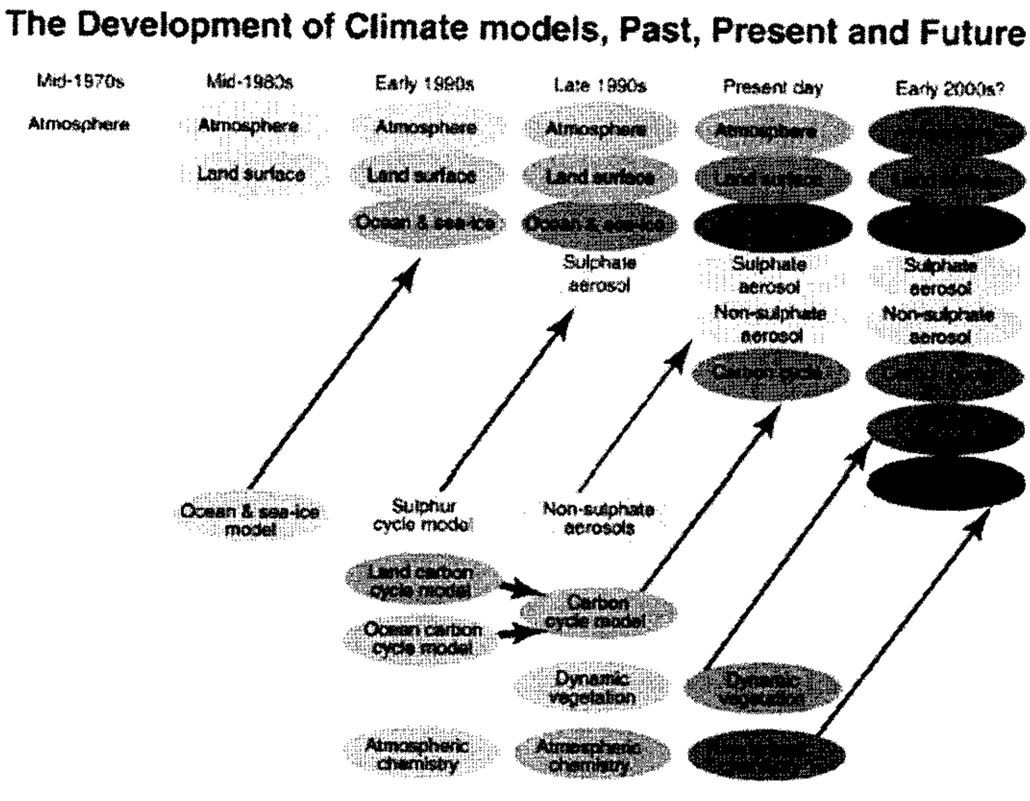

Figure 3. The development of climate models, past, present and future. (From WCRP Working Group on Numerical Prediction).

D. SCIENTIFIC PROGRAMME

Traditionally, scientific endeavour is funded at the national level, and many of the scientific efforts are focused on relatively local regimes (at a specific coastal area, within a particular region of a sea, focused on an isolated gas species, etc.). However, it is now widely recognised that addressing global issues (such as climate change, long range transport etc.) requires global integration and global points of view.

This Action represents a unique opportunity to create a network of European air–sea interaction scientists and to integrate their work to create data sets of a global dimension representing more than the sum of the parts. No other funding instrument exists to develop these data products, and it is likely that the work would not proceed under any national funding. Thus, this Action is critical for our understanding of the impact of air–sea gas exchange on global climate and of the effect of global change to air–sea transfer processes.

This COST Action will integrate activities of three working groups. A key element of the COST working groups (WGs) is that they be composed largely of younger scientists and those who are more apt to take part in short-term scientific missions (STSMs). This will ensure that the Action has a longer lasting impact and will foster the building of an international network and the development of intellectual capacity for young scientists.

The WGs will be complemented by a set of activities designed to engage a wider audience of European scientists. It allows the participation of Europeans in several symposia designed to present the work of the Action and stimulate further work on topics that will be identified by the WGs. This Action is designed to be scalable and to offer an open framework that is flexible to the level of participation. The scope and scale of the WGs, STSMs and symposia are flexible and will be managed adaptively as the Action progresses.

Working Groups

The Action consists of three working groups (WG). For conceptual ease, they are categorised each in association within three general air–sea interaction categories. However, it is emphasised that each of the WG's activities will intersect, providing full coverage from atmospheric processes, across the air–sea interface, through oceanic processes. Data policy and data management issues will be a priority item for discussion at the first meeting of each working group. Key tasks and products of each group are identified bellow.

Working Group 1: Short-lived trace gas production and biological feedbacks

For each short-lived trace gas of interest (e.g. DMS, $CHBr_3$, CH_3I, $MeNO_2$, isoprene, methanol), WG 1 will:

- Compile existing databases of relevant parameters into a framework to produce the definitive dataset of air–sea fluxes. The database is comprised of sea and air concentrations which can be combined with a gas transfer velocity to produce a flux estimate. This will allow the product to be updated to reflect progress in our understanding of transfer processes and concentration fields.
- Identify issues relating to calibration of different measurements, and develop and seek funding for intercomparison experiments where STSMs will not suffice.

- Examine the data products and compare them with modelling results.
- Depending on the skill of available models, the WG will include model results and global averages in the database.
- Identify gaps in the current data set and coordinate further research to address these.

WG1 compares and synthesises our understanding of the biological and chemical processes that regulate the concentrations of these gases in seawater, with particular emphasis on the effect of atmospheric inputs on these processes. To do this it requires collaboration with WG2 to develop estimates of atmospheric inputs to the ocean.

A compilation of data on the oceanic cycling of sulphur allows for an evaluation of the different models currently in use. A model intercomparison will be conducted and the outputs synthesised for a best estimate of ocean sulphur cycling. Oceanic DMS concentrations will be converted to air–sea fluxes using the gas transfer velocities developed by WG2. Once combined with a compilation of atmospheric measurements of the oxidation products of DMS, our knowledge of the oxidation pathways and branching ratios will be evaluated and best estimates for inputs to chemistry transport models provided. This work will allow sulphur cycling in coupled general circulation models (GCMs). A vital task of WG1 is to develop a dialogue between process modellers and those implementing diagnostic models within GCMs. For other short-lived trace gases, process models need to be developed and tested against data, global fluxes estimated and their importance to atmospheric chemistry evaluated.

Products:

- Global database of trace gas concentrations in the ocean and atmosphere (DMS, $CHBr_3$, CH_3I, $MeNO_2$, isoprene, methanol, etc.).
- Database of concentrations of oxidation products of DMS.
- Intercomparison of process and diagnostic models of air–sea sulphur cycling.
- Framework for modelling the air–sea flux of the other trace gases.
- Database of measurements of trace metals, nutrients and organics in marine aerosol.
- Database of all oceanic iron fertilisation experiments conducted to date. This information includes indicators of biological and trace gas response.

Working Group 2: The physical processes controlling air–sea exchange

This group will produce global estimates of gas transfer velocity, which allows a representation of air–sea gas exchange to be consistent in all global models. Individual estimates of gas fluxes diverge because different gas exchange parameterisations are employed. A widely accepted product of gas transfer will permit the intercomparison of flux estimate studies and is critical to the work of the other WGs.

The working group will also produce estimates of dry and wet deposition of material relevant for biogeochemical air–sea interactions. Global estimations of wet and particle deposition velocities can be combined with estimates of concentrations of the chemical species of interest to produce flux estimates. Such a scheme requires a synthesis of present measurements and a framework into which new measurements can be incorporated to improve the estimates.

Products:

- Global climatology of gas transfer velocity, dry and wet deposition velocities, atmospheric concentrations of trace metals in aerosol and soluble forms, and gas deposition
- Synthesis of the role of bubbles, surfactants rain and wind on gas transfer.

Working Group 3: The air–sea flux of long-lived climate active gases

The gases N_2O and CH_4 will be treated in a similar manner to the short-lived trace gases in WG1. However, one significant difference is the increased emphasis on coastal regions and the development of a typology for scaling up individual studies to estimate global fluxes.

Carbon dioxide fluxes in the coastal zone also take high priority. These fluxes are disproportionately large in relation to the spatial extent of coastal areas, because of the high productivity of such seas. Upscaling to global fluxes from regional budgets and individual studies is hindered by the heterogeneity of the coastal zone. Following the example of the LOICZ international programme, WG3 will develop a typology of coastal regions and net CO_2 fluxes, and populate this typology with available data. This will provide the mechanism for quantifying a significant unknown in the ocean carbon cycle.

WG3 takes on the task of interpolating and synthesising the open ocean CO_2 fugacity measurement database under development by various researchers. The resulting product of global pCO_2 can be converted into a flux using the transfer velocity products of WG2. An important part of WG3's work is to compare estimates of fluxes from observations with those from both atmospheric inversion and oceanic biogeochemistry models.

Understanding how the air–sea flux of CO_2 will change in the future is critical to simulations of climate. The ocean has taken up ~30% of the anthropogenic CO_2 released to date, but the future rate of intake is unknown. There is an urgency to coordinate experiments that simulate the behaviour of ocean ecosystems in a high CO_2 world. Europe leads the field in this activity with the mesocosm experiments (at the Bergen large-scale facility), and there are funding plans in the EU Sixth Framework Programme FP6 CarboOcean, in the United Kingdom and in Germany. However, this activity must expand to include the development of protocols for replication and intercomparison in a manner analogous with the terrestrial carbon community.

Products:

- Database of N_2O, CH_4 and CO_2 sea and air concentration measurements including representation of the coastal zone.
- Typology of coastal regions for scaling local to global fluxes.
- Protocol for mesocosm simulations of ocean ecology in high CO_2 conditions, and plans for long-term and large-scale ecosystem manipulations.

Capacity building: STSMs and symposia

To ensure that the Action has a long-term impact it will devote significant resources to networking and training young European scientists in the air–sea interaction field.

Short-Term Scientific Missions (STSMs) will be provided for young scientists to collaborate on experiments that are within the remit of the Action. Opportunities will be identified by the

WGs, primarily in the context of ongoing, nationally funded science programmes. Emphasis will be given to intercomparison and standardisation of the many measurement techniques used in air–sea interaction field work. STSMs also allow leading scientists in the field to work with the coordinator to develop databases.

To ensure that the Action databases and plans reach a broad community, international symposia will be scheduled. The titles provided below are provisional and subject to change, but between three and five symposia will be held during the term of this COST Action.

Some prospective symposia titles:

'Air–sea biogeochemical interactions in coupled climate models' will bring together scientists implementing such feedbacks with experimentalists and will be held early in the Action to allow conclusions to be incorporated into the design of databases.

'The influence of air–sea interactions on air pollution' aims to quantify the importance of air–sea exchanges on human health by following the impacts down the causal chain to influences on local air pollution and human health.

'Air–sea exchange in a double CO_2 world' will assess progress made during the Action and set out future research priorities.

E. ORGANISATION

The overall duration of the Action is five years.

During the first year, the Management Committee (MC) will plan the detailed implementation of tasks described here. Activities will include the establishment of working groups (WG) based on a survey of data, methodologies and activities to be considered within the Action. This development process will be conducted in conjunction with the three working groups. The participants will specify their individual contribution and goals through the Expression of Commitment scheme developed by the Technical Committee for Meteorology. The MC and WGs will generally meet twice a year, usually in conjunction with each other. Each WG will be coordinated by a chairperson who will report back to the MC. Coordinators will also be allocated for each sub-area of the WGs.

If required, external experts can be invited to some of the MC meetings to seek advice and/or enlarge the application basis of the Action (e.g. database managers). The MC will supervise the overall progress of work, coordinate WG activities, and will ensure wide dissemination of results.

A period of five years is required because of the diverse nature and wide scope of the Action. There are several large EU FP 6 projects that will have already begun work at the start of the Action (e.g., CarboOcean and a number of STREPS), as well as many national scientific activities, and the five-year duration will permit results to be incorporated into the products of the Action.

Broadly, the Action activities will have three phases; namely:

- Phase 1. Planning, operational arrangements, establishment of WGs and initial inventory (year 1).
- Phase 2. Main scientific work to be conducted by each WG (Years 2, 3 and 4).
- Phase 3. WGs conclude work with emphasis on reports and final publications (Year 5).

A dedicated preparatory phase will be implemented during the first year which will help to identify and compile the various data sets, parameterisation models and needs. Much of the compilation work will be conducted using the national networks of the Action's participants, the Internet, e-mail and questionnaires. The data gathering and synthesis will be directed by the WGs with the assistance of scientists on STSMs.

Links to other activities

Links will be made from each of the WGs to the new COST Action 729 Assessing and Managing Nitrogen fluxes in the Atmosphere Biosphere System in Europe, and will be explored at an early stage.

Links will be sought with the European Commission-supported Global Monitoring for the Environment and Security (GMES) programme. This programme represents a concerted effort to bring data and information providers together with users, with the intention to provide environmental and security-related information to the people who need it.

Links will also be sought with International SOLAS, as this programme has similar scientific interests to the COST Action. SOLAS is sponsored by IGBP, WCRP, SCOR and CACGP, and links will also be sought with other sponsored projects within these programmes (for example, IGBP: AIMES, IGAC, PAGES, LOICZ, IMBER; WCRP: WGSF; SCOR: CLIVAR, GEOTRACES; etc.).

Thus, the COST Action can be linked to a large framework of global change research, with ready-made connections to partner projects and other relevant organisations. For example, the Action will quickly establish links with the Global Emissions Inventory Activity (GEIA; an IGBP/AIMES activity) and the ACCENT Network of Excellence (under the European Commission's Sixth Framework Programme) to ensure that their terrestrial emissions databases and the existing air–sea emissions databases are fully integrated with this Action's air–sea flux products. The link to WCRP ensures that the WG products will be communicated to the physical climate modelling community and the data will be submitted to the IGBP/AIMES Earth System Atlas that is currently under development.

The outcome of the COST Action is the development of long-lasting high quality data products, and these products must be housed in a stable facility. This is where the structure and longevity of existing programmes (such as IGBP/AIMES, SOLAS, etc.) will provide useful resources, as they have developed data management plans which includes the use of existing large nationally funded data storage facilities (such as the British Oceanographic Data Centre; BODC, the Carbon Dioxide Information Analysis Center; CDIAC, etc.).

The MC and WGs will make an effort to develop links with other relevant air–sea programmes in Europe. Particular attention will be given to organisations that have the capacity to support the data products and database. The location and management of the database will be discussed and arranged by the MC in cooperation with the WGs.

The University of East Anglia has also sought and is nearing approval for a Data Integrator, funded by the UK Natural Environment Research Council (NERC). This Data Integrator, hosted by the University of East Anglia and the BODC, can work closely with the working groups, providing database support and data management for the Action. However, it is emphasised that the Action does not depend on the services of the Data Integrator, but that his/her support will enhance the Action's activities and provide long-term data management for the WG products.

Summary of anticipated resources for activities covered under this Action

- Travel, subsistence, and accommodation support for the three COST WGs to meet up to twice a year for three to four days to discuss actions and develop respective products as discussed above. Membership of the WGs is expected to be approximately 10-15 scientists. This activity also requires funding sufficient to cover expenses for meeting facilities, publications etc., all according to COST funding procedures.

- Support for operation of the STSMs. It is anticipate that younger air–sea interaction scientists will be able to take advantage of the short-term scientific missions to meet more senior peers and discuss the development of data sets, experimental design, and/or gas flux product development, as discussed above. The working time for these STSMs is anticipated to be approximately one to two weeks, and there may be as many as two STSMs per year under this COST Action.

- The proposed symposia outlined above are integrative activities that cut across experimental, modelling and laboratory work. Thus, they bring together many of the experts in each of these areas to discuss needs and products in a common format. These symposia will be held in Europe, perhaps at a fixed site, and support is required for travel, subsistence, and accommodation of the participants according to COST funding procedures. It is anticipated that a significant scientific synthesis paper (suitable for publication in elite journals such as *Nature* or *Science*) will be required output from each of these symposia.

F. TIMETABLE

Phase 1: Inventory (Year 1, 12 months)

- **MC**: Establish initial WGs and membership and define initial work. Identification of other related activities, planning and organisation of 1st symposium.
- **WG1:** WG1 will prepare an inventory of existing relevant data with detailed description. The group will identify gaps in the data and will make recommendations on how to close them.
- **WG2:** WG2 will prepare an inventory of parameterisations schemes and models with indication of strengths, weaknesses and uncertainties.

- **WG3:** WG3 will prepare an inventory of existing relevant data with detailed description. The group will identify gaps in the data and will make recommendations on how to close them.
- **WG1/2/3:** Report to the MC
- Development of web site with a description of activities, promotion of the Action, establishing links with other related activities and providing a working protected area for exchanging data sets and models and for internal discussions.

Phase 2: Development, Assessment, Applications, Evaluation (Years 2-4, 30 months)

- 1st symposium with proceedings and conclusions of the work for the Action.
- Prepare detailed plan of work based on outcomes of Phase 1.
- **WGs:** Meetings for planning, implementing, reviewing and synthesising the work.
- Report to the MC at least every 12 months on the progress of work.
- **MC:** Short Term Scientific Missions as appropriate.
- Preparation of 2nd symposium
- Monitor WG activities and advances in the field outside the Action

At the end of Phase 2 the following key achievements are expected (other deliverables are listed in section C):

- Report on the results of the model intercomparison exercise that also documents the present state-of-the-art in the field of the Action.
- Report on the availability, quality, coverage, representativeness of data sets for compounds of interest in this Action.
- Critical examination of the capabilities and the limitations of gas exchange models and parameterisations.
- Develop consensus on ranges of applicability, strengths and weaknesses of existing models of trace gas production and their implementation in GCMs.
- Identify necessary improvements of models for specific applications.
- Document guidelines for model intercomparison and evaluation

Phase 3: Synthesis and Dissemination of Action Results (Year 5, 12 months, overlapping with Phase 2)

- **WGs:** Finalisation of the expected outputs
- **WGs:** Contributions to the final report
- **MC:** Organisation of the final symposium
- **MC:** Completion of the final report
- **MC:** Dissemination of results through publications and participation in international conferences

Table 1 displays the overall time schedule for the Action.

Table 1. Schedule for the Action

		Year 1	Year 2	Year 3
MC meetings		set up WGs and Symposia		[illegible]
Working Groups	1. short lived gases	x	x	x
	2. Physical interaction	x	x	x
	3. GHGs	x	x	x
Symposia		Biological feedbacks in CCMs		[illegible]
STSMs		x x	x x	x x
Coordinator		x x	x x	x x
Summer School			x	[illegible]

* dependant on the timing of the Action

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Netherlands, Norway, Poland, Slovenia, Spain, Sweden, Turkey, and the United Kingdom.

On the basis of national estimates provided by the representatives of these countries, the economic dimension of the activities to be carried out under the Action has been estimated, in 2006 prices, at approximately EUR 60 million.

This estimate is valid on the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

It is expected that many of the participants in the Action (both the MC and the WGs) are already involved in air–sea research with funding at a national level. In order to communicate to a wider audience of air–sea interaction scientists, the Action will seek cooperation with existing international programmes such as SOLAS, IGBP/AIMES etc. which have existing networks throughout Europe. These networks will be used to distribute information and gather expertise to accomplish the COST Action. This Action will add expertise from many nations (Austria, Belgium, Bulgaria, Croatia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Lithuania, Netherlands, Norway, Poland, Portugal, Russia, Spain, Switzerland, Sweden, Turkey and the United Kingdom). This COST Action will expand and strengthen the network of air–sea research activities with other related activities such as IGBP, WCRP etc.

A communication strategy for the Action will be developed at an early stage. As an outline it includes the following:

Key audiences for the Action are:

1. Scientists participating in the Action or with data to contribute.
2. Modellers and other scientists who require the products of the Action.
3. Scientists involved in broader air–sea and Earth System research.
4. Policy makers on issues of climate and air quality.
5. Young scientists wanting to expand their knowledge and work to the air–sea domain.

Tools that will be used to engage these audiences are:

- A dynamic web site allowing the submission and retrieval of both the basic data and the products, (aimed at 1 & 2 above)
- An e-mail announcement list for the Action (1, 2 & 5)
- European and International e-mail lists (1,2, 3 & 5)
- Science highlights and announcements of new products in newsletters (for example, the *IGBP Global Change Newsletter*), and in an e-Bulletin (3, 4 & 5)
- Articles on a web site, such as International SOLAS, IGBP/AIMES, etc. (3, 4 & 5)
- International symposia arising from the Action (1, 2, 4 & 5)
- The STSMs (5)
- A final product of 'Science highlights' will be developed for a non-technical, policy-making audience (4); this will be based on the output of the symposia and the data products and could be published as part of the IGBP Science Series or a similar forum.

Users of the COST Action products will be required to acknowledge the Action in any peer-reviewed papers based on such data. These contributions will be catalogued and will provide a quantifiable indicator of the Action's success.

Acronyms

ACCENT	Atmospheric Composition Change: European Network of Excellence (FP6)
AIMES	Analysis, Integration and Modelling the Earth System project of IGBP
BODC	British Oceanographic Data Centre (a UK NERC-funded facility)
CACGP	Commission on Atmospheric Chemistry and Global Pollution (IAMAS)
CDIAC	Carbon Dioxide Information Analysis Center (a US Dept. Energy database)
CLAW	Charlson, Lovelock, Andreae and Warren
CLIVAR	Climate Variability and Predictability (a WCRP research effort)
DMS	Dimethylsulphide
FP6	Sixth Framework Programme (EU)
GCM	general circulation model
GEIA	Global Emissions Inventory Activity
GEOTRACES	Global marine biogeochemical cycles of trace elements and their isotopes (SCOR)
GMES	Global Monitoring for Environment and Security (Europe)
HadCM3	Hadley Centre coupled ocean–atmosphere general circulation model
IGAC	International Global Atmospheric Chemistry
IGBP	International Geosphere – Biosphere Programme of ICSU

IMBER	Integrated Marine Biogeochemistry and Ecosystem Research (IGBP project)
LOICZ	Land–Ocean Interactions in the Coastal Zone (core project of IGBP)
LOIS	Land–Ocean Interaction Studies (UK LOICZ)
MC	Management Committee
NERC	Natural Environment Research Council (a UK environmental research body)
NoE	Network of Excellence
PAGES	Past Global Changes
SCOR	Scientific Committee on Oceanic Research
SOLAS	Surface Ocean Lower Atmosphere Study (an IGBP core project)
STREP	Specific Targeted Research Project (EU)
STSM	short-term scientific mission
WCRP	World Climate Research Programme
WG	Working Group
WGSF	Working Group on Surface Fluxes (a WCRP WG)