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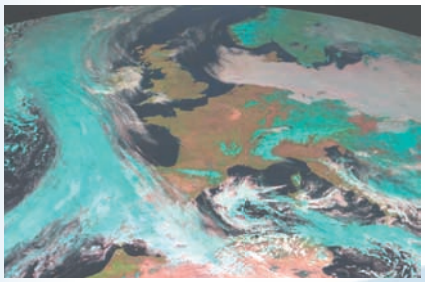
...Abrupt climate

ECOSPHERE

July 7th, 1992:
A group of scientists from Texas A&M University presents a report to IPCC (Intergovernmental Panel on Climate Change) about a phenomenon related to thermohaline shutdown that may cause a sudden change in climate. The controversial report has a mixed reception.



March 25th, 2005:
For Spain, Portugal, and Northern France, the forecast predicts a low of -25°C and a high of -15°C for today and tomorrow.

February 26th, 2009:
The last four winters are the coldest ones recorded in the last two centuries in Western Europe. Some eastern coastal areas of North America are affected with similar problems. Scientists around the world are still investigating the origins of this peculiar climatic change, but the consensus among experts is that thermohaline circulation is a major factor in the process.

July 17th, 2020:
A recent report shows that the GNP of most western European countries has decreased by more than 20% in the last two decades due to the thermohaline shutdown. Migratory movements towards southern countries are largely responsible for this economic slow down. Massive investments in the sectors of agriculture and fisheries have forced cuts in most military and public service budgets.

September 12th, 2025:
Most health care systems, public infrastructures and personnel are insufficient to manage the growing number of people in the southern areas of France, Spain and Italy due to massive migrations.

February 1st, 2026:
The Security Council of the United Nations creates the supra-national emergency organisation *Action Authority against Abrupt Climate Change*. This organisation provides struggling countries with the required financial support for basic public and health care services. It also provides international peacekeeping forces to help maintain their infrastructures and to ensure stability.

change...

ECOSPHERE

ECOSPHERE (Earth Climate Observation Systems Promoting Human Ecological Research and Education) is an international and interdisciplinary consortium of students, academics and professionals brought together by a common interest in the Earth's environment and a realisation of the major role space technology has in global monitoring.

Mission

To develop a framework to better understand the Abrupt Climate Change (ACC) phenomenon in the North Atlantic region through the application of space technology.

About Abrupt Climate Change

The futuristic scenario portrayed on the previous page is used to illustrate the importance and possible impacts of climatic events. This scenario is not meant to predict the future, but rather to present a series of possible events that could result from an abrupt change in climate.

Climate change is normally regarded as a gradual process. However, the Earth's climate has shifted abruptly in the past and it will do so again in the future. Changes in ocean circulation patterns in the North Atlantic could lead to an abrupt change in climate causing it to cross a threshold or move from one state to another in a strongly nonlinear response. An ACC occurs once the system has slowly been pushed beyond an equilibrium point; similar to that of applying an increasing pressure of a finger slowly on a light switch [Clark *et al.*, 1999].

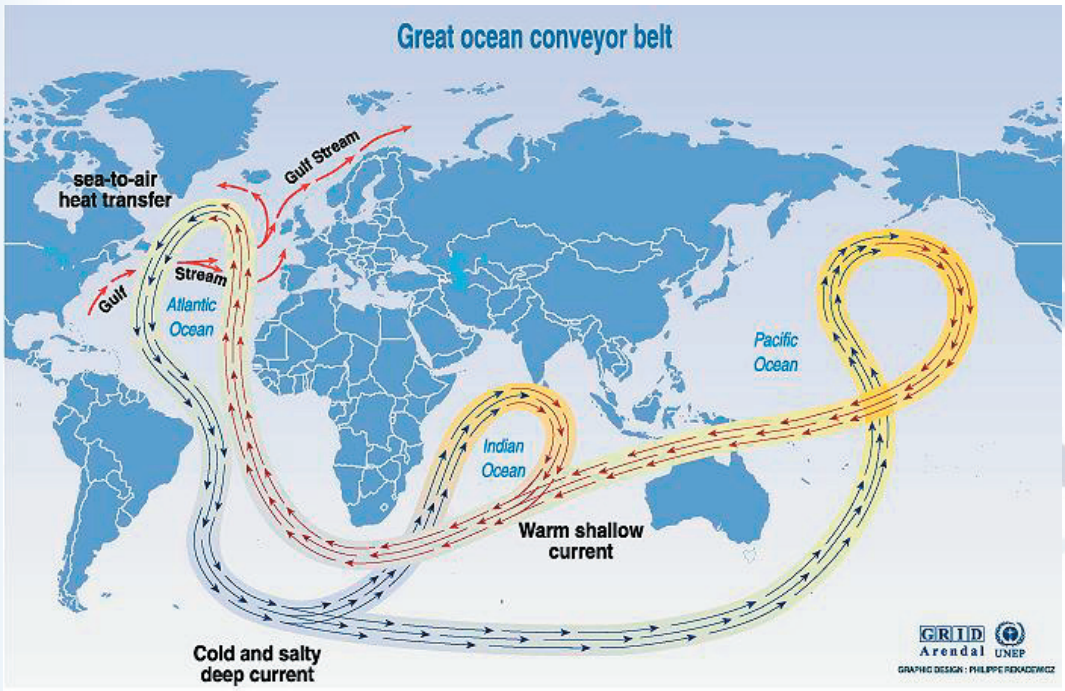
Paleoclimatic records and historical observations provide evidence that abrupt changes in the Earth's climate system have occured in the past in time scales as short as a few decades. Although accurate prediction of future climate changes is not possible, research into paleoclimatic records from ice and sediment cores and other sources enable past climatic changes, including abrupt events, to be characterised in terms of geographical patterns, timing, affected climate variables and resulting impacts [Rahmstorf, 2001].

...North Atlantic

Science

Thermohaline circulation and ACC

Considerable progress has been made in linking past abrupt changes in the North Atlantic ocean surface and atmospheric temperature with changes in deep ocean circulation [Clark *et al.,* 2002].



The North Atlantic ocean conveyor belt is a circulation system driven by temperature and salinity differences [Rahmstorf, 2001]. Warm tropical waters at the equator are drawn towards the poles and denser, salty water sinks in the north. As a result of prevailing winds, heat is carried eastward where it warms Europe. In a possible global warming scenario, an abundance of fresh water input (e.g. melting of sea ice) entering the North Atlantic could halt the flow, resulting in cooler climate conditions in North America and Europe. Major rearrangement of the North Atlantic thermohaline circulation could play an important role in triggering ACC and leads us to focus on this mechanism in our report.

Impacts of Abrupt Climate Change

Human and natural systems have survived ACCs in the past and may continue to do so. An improved understanding of possible ecological, economic and societal impacts of climate shifts will enhance our ability to adapt to such changes. Societies and ecosystems are better able to handle gradual or anticipated changes than abrupt and unpredictable changes in the climate system [NAS, 2002].

Studying Abrupt Climate Change

Numerical computer models of climate are the primary tools for studying ACC, but they have many limitations:

- Loss of model fidelity due to long model integration times with high temporal resolution
- Little understanding of several small scale physical processes in the oceans and atmosphere
- Lack of paleoclimatic data for model validation

Several scientific uncertainties exist in the study of ACC that need to be addressed before it can be well understood. The development of credible models for accurate simulation of ACC is highly dependent on the collection of observational data:

- Continuous remote sensing of ice thickness, ice sheet evolution and movement of sea ice in the future is required as part of a continuous quantitative analysis of freshwater flux into the oceans
- Increasing the geographic and depth coverage of measurements of ocean salinity and temperature
- More extensive collection of paleoclimatic data, such as ocean sediment

A Home for Abrupt Climate Change studies

ECOSPHERE recommends creating a programme within the European initiative GMES (Global Monitoring of Environment and Security) to focus on ACC, which can be used to justify policy for reactive and preventative mitigation strategies.

How ECOSPHERE Benefits From GMES	How GMES Benefits From ECOSPHERE
• ECOSPHERE's timely proposal will be delivered while GMES is in its initial period, thereby enabling ACC to be included within GMES' overarching policy and goals • GMES Shared Information System offers the infrastructure for international data-sharing, allowing industry experts, scientists and policy makers to work closely together • GMES has political legitimacy, and a good potential for funding due to its association with EU, ESA and EUMETSAT • GMES' regional focus is well-suited to a fledgling programme researching ACC	• GMES will benefit from proposals supporting its infrastructure in order to guarantee its viability and secure funding • The potential impacts of ACC fit with GMES' mandate to monitor environment and security globally but with a focus on Europe • GMES will gain global exposure by becoming a pioneer in ACC studies, and enabling it to make a significant contribution to a fundamentally global concern

ECOSPHERE's recommendations involve a proposal for a GMES integrated project dedicated to ACC studies. We believe that the GMES Steering Committee (GSC) is the best actor to recommend which agencies and experts should be involved in drafting the proposal. More specifically, we recommend that the proposal should be directed towards the 6th Framework Programme (FP6) in the thematic area of 'Sustainable Development, Global Change and Ecosystems.'

...application of

Architecture

The diagram illustrates the main system elements included in ECOSPHERE's proposed program as summarised below:

ACS key features

Autonomous Core Sampler

- Deep sea sediment core sample collection at pre-programmed sites
- Satellite link for system health-checks, collection of sensor data, mission logs, programming of missions/sample locations
- Autonomous navigation using GPS or GALILEO (from the surface) and Inertial Measurement Units (submerged)
- Fuel cell power source for long mission durations
- Operating down to a depth of 5000 m

THE ABYSS key features

ThermoHaline Explorer Autonomous BuoY Sea Submersible

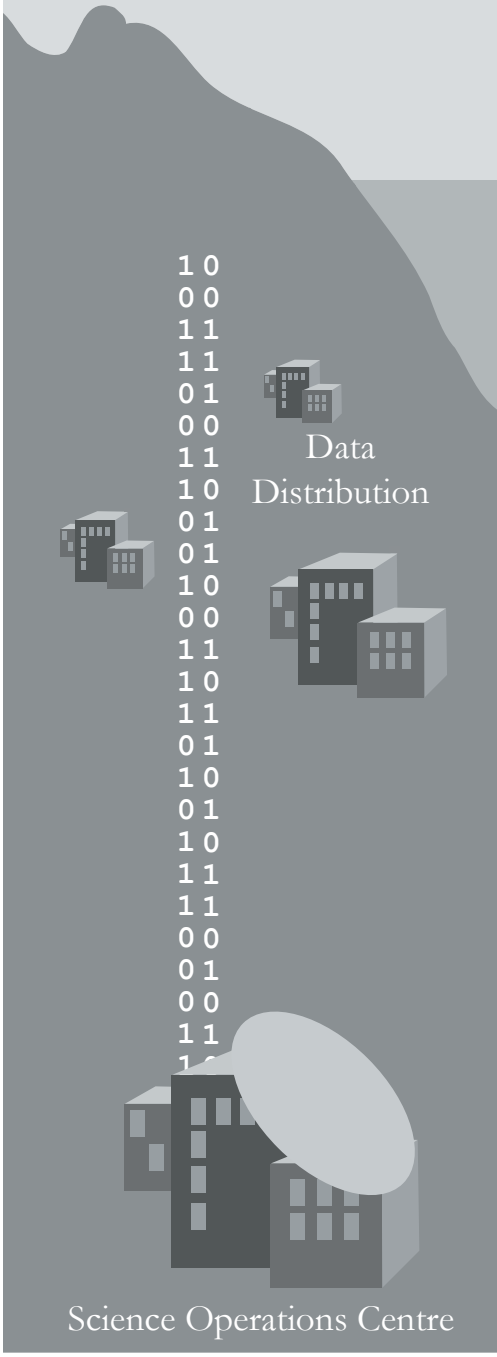
- Salinity measurements made over main depths of interest (0 - 5000 m)
- 10 day dive-drift-ascend cycle
- Relay of collected data measurements via satellite (S/Ka band)
- Key technologies: Fuel cells, water electrolysis, MEMS (Micro Electronic Mechanical System) technology
- Two versions proposed: COTS (Commercial Off The Shelf) probes using existing technology and OCEAN miniaturized probes using novel technology (diameter of only 1 cm)

Satellite key features

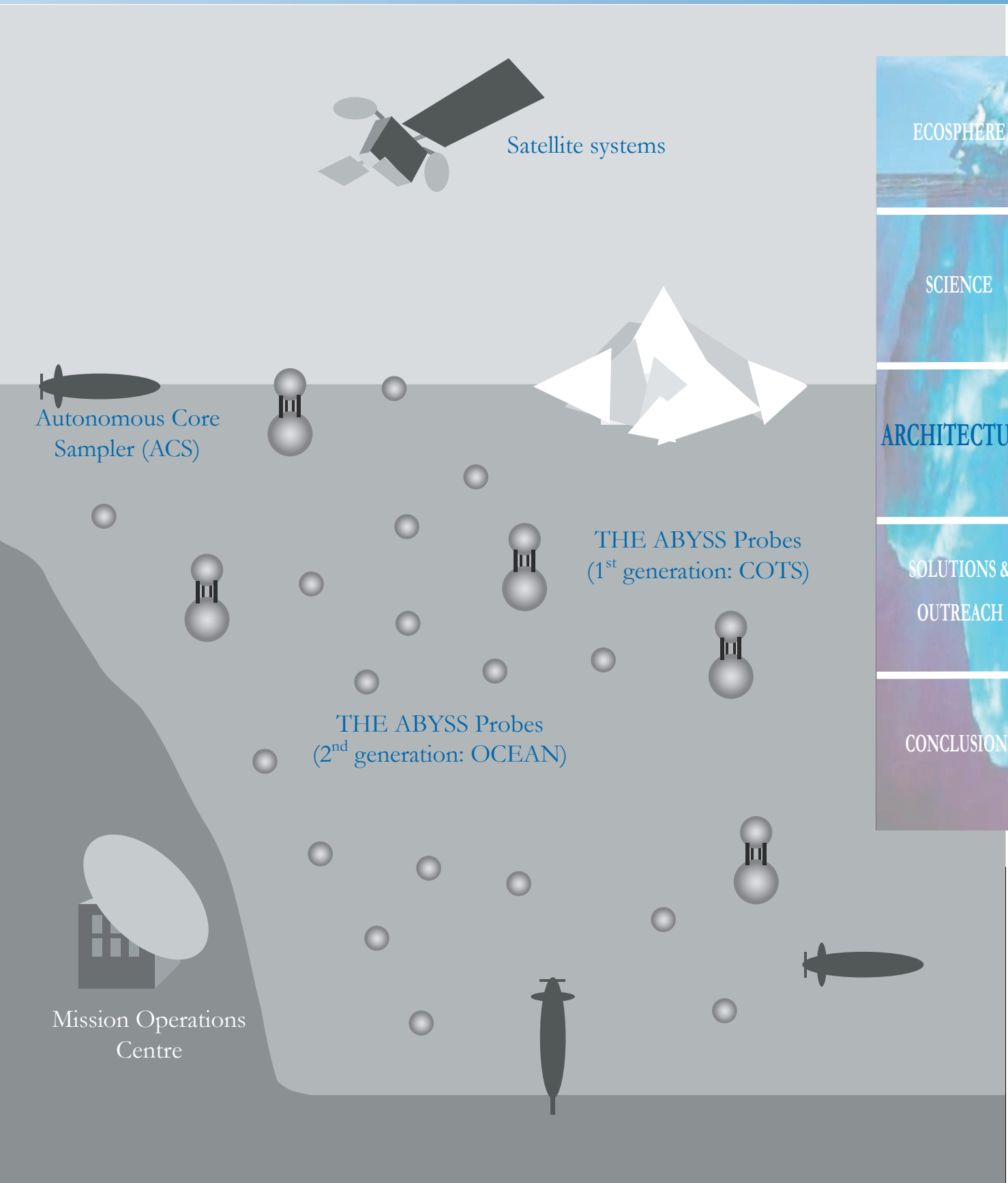
- Remote sensing payloads:
  - L-band radiometer for measuring sea surface salinity
  - Lidar for high resolution ice topography
  - ASAR (Advanced Synthetic Aperture Radar) for all weather ice topography
- Communications payloads to support ocean based systems
- Possible use of new satellite technology ('formation-flying' clusters/microsatellites) in order to sustain the ACC programme

Data sharing key features

- Operates under the GMES Shared Information Systems (SIS)
- Provides a means for good communication between industry, government agencies and academia to maximise efforts



space technology...



An integrated solution

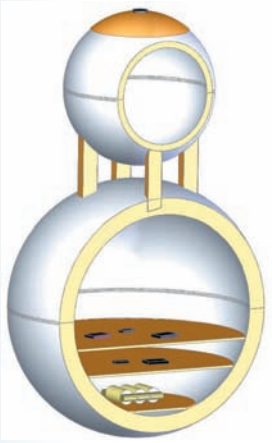
Ice and salinity monitoring from space

Current science indicates that the ice caps are melting, with the melted water flowing into the surrounding oceans, decreasing salinity. Monitoring and retrieving extensive measurements are essential to the creation of better models for predicting future climate.

To ensure continuous ice and salinity monitoring, ECOSPHERE proposes the following payloads to be carried on future satellites:

- Short term future (2 - 5 years)
  - Continuation of ice topography missions with current SAR and lidar instruments
  - S-band communication packages, which transfer data for the first generation deep-sea probes
- Long term future (6 - 10 years)
  - Next generation SAR, lidar and sea surface salinity instruments to improve accuracy and resolution of remote sensing
  - Ka-band communications packages, which transfer data for the second generation deep sea probes

Deep sea salinity and ocean current measurements



COTS probe

THE ABYSS is the solution that will be used to measure deep sea salinity and ocean flux.

The deep sea MEMS probes are to be deployed in large numbers in the regions of the ocean which constitute the Ocean Conveyor Belt shown earlier. The figure on the left shows the first version of the proposed probe (15 cm high).

Each probe will measure salinity to a preset depth and floating along with the current. Every ten days the probes will ascend to the surface and relay their stored measurement data via a satellite to a ground station. This cycle repeats itself throughout the probe's five-year mission lifetime.

Paleoclimatic ocean floor sediment sampling

The system proposed by ECOSPHERE is an autonomous core sample submersible vessel, based on proven technology: the ACS, which is a cigar-shaped vehicle, driven by an electric motor, and powered by a fuel cell. The ACS, aided by global navigation systems and an inertial measurement unit, takes samples at pre-programmed locations. The samples are stored on board before the vessel sets off to the next sampling site. After a mission is completed, the vessel is recovered by the mother ship, refuelled and redeployed. The total lifetime of a vessel is estimated at 10 years.

understand...

Outreach plan

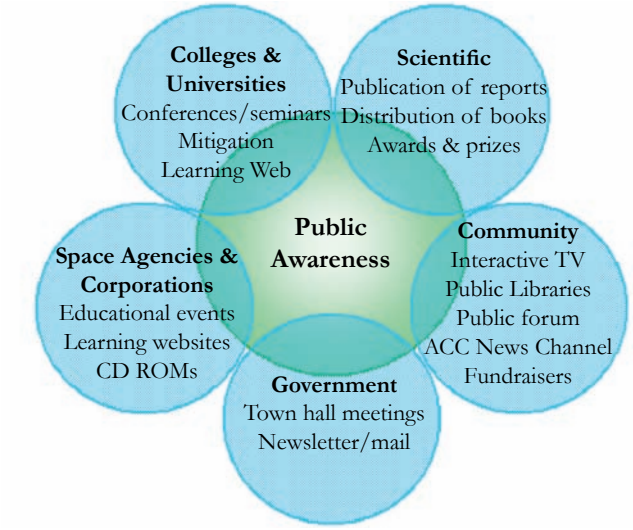
The public outreach plan aims to raise awareness about the potential effects of an ACC and provide a facility for education about its possible anthropogenic causes. The outreach plan proposed by ECOSPHERE has two main target groups:

- Government agencies, academia, industry representatives and policy-makers
- The general public

The proposed approach can be broken down into three phases of implementation as follows:

Phase 1	Develop a political and scientific infrastructure dedicated to ACC with a link to the public education system
Phase 2	Deploy a standard training approach in elementary schools, high schools and universities using posters, slides, CD-ROMs and the Internet
Phase 3	Expand to television media and interactive business software after assessment of public participation in phases 1 and 2

The outreach plan would provide educational institutions with the necessary information to properly educate students about the science and potential impacts of ACC, with research being funded by government or agency research grants at the university level. Conferences dedicated to ACC studies and adaptation policy are also proposed.



Mass media would be a part of the outreach program in ways such as:

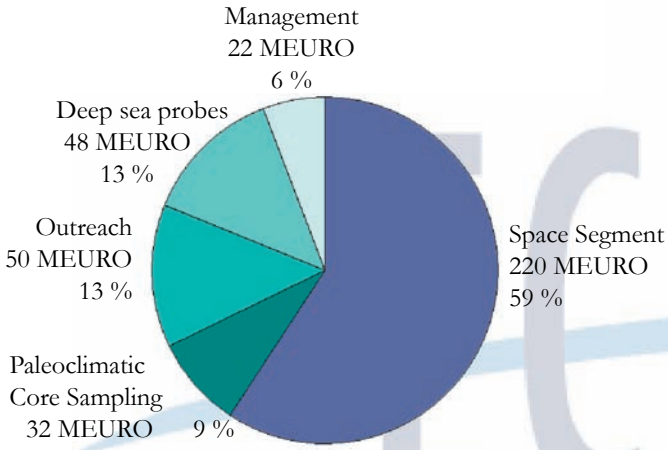
- A website providing users with real-time access to compiled ACC data and findings
- Documentaries addressing the possibility of ACC

A complete breakdown of the key components of the public outreach program can be seen on the left.

...to develop

Funding requirements

A breakdown of the estimated funding required to study ACC in the manner that ECOSPHERE has suggested can be seen in the figure below:



These fundings cover the time frame from 2005 through 2014. It is estimated that about 37.2 MEURO per year is required to fully study ACC, increase reliability of ACC prediction, educate the public about the phenomenon and prepare for adaptation. Considering the profound impact that ACC would have on European and global economies, this estimate is a reasonable budget and could fit within GMES' eventual funding levels.

Challenges

Implementation of our recommendations will face several challenges encompassing financial and technological limitations as well as policy, legal and social aspects:

- How to secure the funding required for ACC research within the GMES program where eventual budgets are still uncertain.
- The MEMS deep sea probes still require significant development. The availability of suitable technology could also be a problem for MEMS floaters possibly requiring five to ten years of work before they become fully operational.
- Constantly changing governments make it difficult to create a continuous and consistent approach towards ACC policy.
- Legal concerns may arise concerning the deployment of floaters and probes for environmental reasons, and if coastal countries object to devices in their territorial waters. The Argo system, however, has already been in use for several years and may provide precedence required to establish customary law.
- Creation of an effective curriculum that persuades the public that ACC is a real threat and needs to be put ahead of individual interests.

a framework...

Next steps

We suggest that, under the supervision of the GMES Steering Committee, ECOSPHERE's recommendations should be drafted as a proposal towards the 6th Framework Programme (FP6) in the thematic area of 'Sustainable Development, Global Change, and Ecosystems.' This integrated GMES project would focus on an ACC resulting from a potential shutdown of the thermohaline circulation in the North Atlantic region.

This proposal should contain:

- Monitoring of the evolution of land and sea ice with a focus on maintaining the continuity of ice measurements to measure fresh water balance in the North Atlantic
- Continuity in sea surface salinity observation by incorporating dedicated payloads on future satellite platforms
- An extensive system of deep ocean probes to derive vertical profiles of salinity and temperature in the ocean
- A system of autonomous core sample return submersible vessels for drilling the ocean-floor for ocean sediment collection and paleoclimatic studies
- Research to lead to the development of credible models for the scientific and policy-making communities
- An outreach program designed to inspire academic research, data sharing, industry support, technological developments and policy design to better understand ACC and to enable the implementation of preventative and reactive mitigation strategies

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