The Carbon Science in SOLAS and IMBER Joint Implementation Plan and the CARBOOCEAN project

http://www.gfi.uib.no/

http://www.bjerknes.uib.no/

Prof. Dr. Truls Johannessen
Geophysical Institute and the Bjerknes Centre for Climate Research, Allegaten 70, 5007 Bergen
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Outline:

• SOLAS and IMBER joint implementation group
• The CARBOOCEAN project
The Joint Implementation Plan between SOLAS and IMBER on carbon

A joint international effort between SOLAS and IMBER to coordinate international C-science

This will be done in close cooperation with IOCCP
Anthropogenic and natural forcing of the climate for the year 2000, relative to 1750

Global mean radiative forcing (Wm⁻²)

- **Greenhouse gases**
  - Halocarbons
  - N₂O
  - CH₄
- **Aerosols + clouds**
  - Black carbon from fossil fuel burning
  - Mineral Dust
- **Aviation**
  - Contrails
  - Cirrus
- **Solar**

**Cooling**
- Stratospheric ozone
- Sulphate
- Organic carbon from fossil fuel burning
- Biomass burning
- Land use (albedo only)

**Warming**
- CO₂
- Tropospheric ozone

The height of a bar indicates a best estimate of the forcing, and the accompanying vertical line a likely range of values. Where no bar is present, the vertical line only indicates the range in best estimates with no likelihood.

**Aerosol indirect effect**

**Level of scientific understanding**
- High
- Medium
- Medium
- Low
- Very low
- Very low
- Very low
- Very low
- Very low
- Very low
- Very low

SYR - FIGURE 2-2
PART 1 Global ocean inventories and fluxes

Support the establishment of surface ocean and atmosphere carbon observing systems (including associated data assimilation schemes) suited to constraining net annual ocean-atmosphere CO₂ flux at the scale of an ocean basin to <0.2 Pg C yr⁻¹.

Critically evaluate the performance of prognostic carbon cycle models against field observations of seasonal to centennial variability, in order to guide model development and gain insight into the impact of changed forcing.

Use observation-based estimates of air-sea fluxes and atmospheric inversion models to improve determinations of the magnitude and location of terrestrial carbon sinks.

Determine controls on carbon transformations and storage in the mesopelagic layer.

Determine the changes in uptake, transport and storage of anthropogenic CO₂ on decadal timescale to within 10%.

Determine the spatial and temporal scales of storage of carbon in the interior of the ocean.

Determine the sensitivity of the oceanic uptake of anthropogenic CO₂ to climate change.

Project future uptake of anthropogenic CO₂ given atmospheric CO₂ scenarios, with and without climate change. Years 2025, 2050, 2100, 2200", (this has to be consistent with IPCC report, targets, etc...).
PART 2 Future oceans and system sensitivities

Examine the existence and direction of feedbacks between projected changes in forcings and processes transforming carbon in the ocean (i.e. remove the question marks in Table 1). (Alternatively: Determine impacts of climate-induced changes through physical forcing and variability (changes in ocean temperature, circulation/ventilation/stratification, the ocean light environment, and frequency and intensity of extreme and episodic events).

Quantify the feedback on the atmospheric CO$_2$ reservoir (improve estimates of magnitude (in Pg C yr$^{-1}$) on decadal and centennial timescale) using the following three approaches:

- **Determine the effects of increasing CO$_2$ and changing pH on marine biogeochemical cycles, ecosystems, and their interactions.**
PART 3 Air-sea Flux of $N_2O$ and $CH_4$ and sensitivity of the sources

Determine the contribution of marine emissions, particularly from coastal regions, to the global $N_2O$ budget.

Improve understanding of factors regulating surface saturation of $N_2O$ and $CH_4$, including assessment of sensitivity to climate change and anthropogenic riverine input.
Strategic work in SOLAS and IMBER:

1. Process studies conducted in concert with observations

2. Manipulative experiments

3. Coupled biogeochemical – ecosystem models

Results

Projections of carbon transformations in the oceans

Projections of future forcing
CARBOOCEAN

Marine carbon sources and sinks assessment

"Integrated Project", European Commission
Contract no. 511176-2
MODELLING
hindcasting temp.
integration
prediction
DATA BASES
data assimilation
optimal interpolation
optimisation of obs.-systems

Society
knowledge about
CO2 sources/sinks
f (time, position, forcings, money)

runoff

sea ice

sea ice

ecosystem

pCO₂
measurements

intermediate/deep
ventilation

measurements of key variables

shelf filter
(non/depository)

estuarine filter

(fate of particles)

CaCO₃ sequestration mitigation

fate of particles

Society

knowledge about
CO2 sources/sinks
f (time, position, forcings, money)
CARBOOCEAN IP (= CarboOcean Integrated Project) aims at an accurate scientific assessment of the marine carbon sources and sinks within space and time. It focuses on the Atlantic and Southern Oceans and a time interval of -200 to +200 years from now.

CARBOOCEAN will determine the ocean’s quantitative role for uptake of atmospheric carbon dioxide (CO₂), the most important manageable driving agent for climate change. The ocean has the most significant overall potential as a sink for anthropogenic CO₂. The correct quantification of this sink is a fundamental necessary condition for all realistic prognostic climate simulations.

CARBOOCEAN will thus create scientific knowledge, which is essential to a quantitative risk/uncertainty judgement on the expected consequences of rising atmospheric CO₂ concentrations. Based on this judgement, it will be possible to guide the development of appropriate mitigation actions, such as management of CO₂ emission reductions within a global context (e.g., Kyoto Protocol, United Nations, 1997).

CARBOOCEAN combines the key European experts and scientific resources in the field through an integrated research effort. The effort complements other major research programmes on oceanic, atmospheric, and terrestrial carbon cycling and is linked to these programmes.
Range of temperature predictions from IPCC climate models for A doubling of CO₂ by 2100

(Source: Java climate model parameterizations, by Ben Matthews, Sarah Raper).
5 core themes structure the project work according to spatial, temporal, and topical aspects:

2. Detection of decadal-to-centennial Atlantic and Southern Ocean carbon inventory changes. (Doug Wallace)
3. Carbon uptake and release at European regional scale. (Helmuth Thomas)
4. Biogeochemical feedbacks on the oceanic carbon sink. (Marion Gehlen)
5. Future scenarios for marine carbon sources and sinks. (Christoph Heinze)

Cross cutting activities:
- data management
- dissemination

Consortium management

Training

Demonstration

47 participating groups (partners, associated collaborators)
Deliverable: Assessment with smallest possible uncertainties

5 Core Themes

Theme 1: North Atlantic and Southern Ocean CO₂ air-sea exchange
Theme 2: Detection of decadal-to-centennial Atlantic and Southern Ocean carbon inventory changes
Theme 3: Carbon uptake and release at European regional scale
Theme 4: Biogeochemical feedback on the oceanic carbon sinks
Theme 1: North Atlantic and Southern Ocean CO₂ air-sea exchange

3 overarching activities

Prediction
Long-term assessment
Short-term assessment
Objectives of CARBOOCEAN IP

Guiding sustainable Development management

Objective 5: Prediction, future assessment

Objective 1: Short-term assessment
System dynamics

Objective 3: Assessment of Regional European Contribution
Boundary conditions

Objective 2: Long term assessment

Objective 4: Assessment of feedbacks
Surface program, core theme 1
CO₂ observing system for the Atlantic
deep sections, core theme 2
<table>
<thead>
<tr>
<th>WP/Task</th>
<th>Title</th>
<th>Timing (month)</th>
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<tr>
<td>1</td>
<td>Prediction towards Sustainable Development (Overarching WP)</td>
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<td>2</td>
<td>Annual assessment (Overarching WP)</td>
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<td>3</td>
<td>Long Term Assessment (Overarching WP)</td>
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<td>Model performance assessment and initial fields</td>
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<td>Coupled climate carbon cycle simulations</td>
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<td>Feasibility study on purposeful carbon storage</td>
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- **Minor to normal work load**
- **High work load**
- **Intensive work load**

- Model performance with respect to observations assessed for present

- Kick-off meeting
- Atlantic observing system in place
- First improved basin wide pCO2 maps available
- 1st annual meeting

Models and data systems ready for phase II "understanding"
Indicators of the human influence on the atmosphere during the Industrial era

- **Carbon Dioxide concentration**
- **Nitrous Oxide concentration**
- **Methane concentration**
- **Sulfate aerosols deposited in Greenland ice**

SO$_2$ emissions from United States and Europe (Mt S yr$^{-1}$)
The Blue and Green Line show the difference between A2 and B2

Specific values are provided in the table below.

Equivalent CO2 Concentration (ppmv).

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Description of A2 and B2 scenarios

• The A2 scenario envisions population growth to 15 billion by the year 2100 and rather slow economic and technological development. It projects slightly lower GHG emissions than the IS92a scenario, but also slightly lower aerosol loadings, such that the warming response differs little from that of the earlier scenario.

• The B2 scenario envisions slower population growth (10.4 billion by 2100) with a more rapidly evolving economy and more emphasis on environmental protection. It therefore produces lower emissions and less future warming. Climate change results based on the A2 and B2 scenarios are also discussed in the IPCC Third Assessment Report.
Meridional Overturning Circulation (Schmitz, 1995) with NADW and AABW loops
Convection shut down? ESOP2 (1999)

\[
\overline{wA} \sim \frac{10^3 \text{m}}{10 \text{yr}} \cdot \pi \cdot (100 \cdot 10^3 \text{m})^2 = -0.1 \text{ Sv}
\]
Examples of Arctic ice cover at late winter (Feb 1999) and late summer (Sept 1999)
Climate: NAO, Bjerknes first to describe this system as well
NAO+ vs NAO−
Takahashi et al., 2002
Plankton development under past, present and future $CO_2$

(Mesocosm experiments in 2000 and 2003)

Large Scale Facilities, Bergen, Norway

$CO_2$ regulation
- 190 ppmV
- 370 ppmV
- 700 ppmV

95% PAR

$pCO_2$ (ppmv)

Sediment Trap

5m

10m

190 190 370 370 700 700
Mesocosm experiment Bergen 2000

Initial nutrient concentrations:
- $\text{NO}_3^-$: 15.5 mmol m$^{-3}$
- $\text{PO}_4^{3-}$: 0.51 mmol m$^{-3}$
- $\text{Si(OH)}_4$: ~0

$\text{NO}_3^-$ and $\text{PO}_4^{3-}$ exhausted on day 13

Emiliania huxleyi

B. Delille et al., in prep.
Some reflections

OCCC and CARBOOCEAN is more or less an echo of each other

There is a direct formalized direct link already through 5 active US partners in CARBOOCEAN

CARBOOCEAN has already approached SOLAS and IMBER to be an approved member

OCCC should do the same when formalized

There is a clear need for an office coordinating OCCC science and the same is true for SOLAS and IMBER internationally