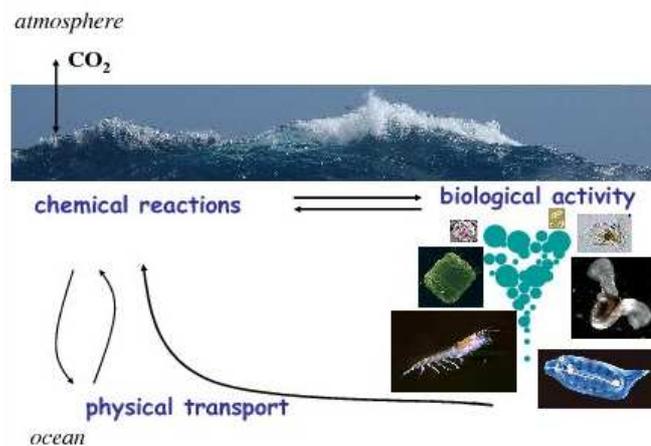


Marine Ecosystem Model Intercomparison Project (MAREMIP)

Report of the kickoff workshop, held in Cambridge on 28-30 October 2009.

Background:

Marine ecosystems (here referring to lower trophic levels) are the base of the marine food chain and exert a strong influence on the cycles of climate-relevant gases, particularly carbon dioxide (CO₂), nitrous oxide (N₂O) and dimethylsulfide (DMS). Marine ecosystems are made of individual organisms that play specific roles. Small plankton are efficient recyclers of organic matter, whereas large plankton consume smaller organisms and produce fast-sinking organic aggregates. There are many specific roles for individual plankton groups, such as the production of shell material by diatoms and coccolithophores which increases the sinking speed of aggregates, and



the production of precursors of DMS by *Phaeocystis* which influence climate. Changes in marine ecosystems will affect the primary and secondary production in the ocean, the plankton biomass and the availability of food resources for higher predators, ocean de-oxygenation and the production of N₂O, DMS emissions by the ocean, and export production and the associated drawdown of

CO₂ by the ocean (see sketch figure above). The impact on CO₂, N₂O and DMS can potentially provide important feedback with climate change.

In spite of the importance of marine organisms, little is known about their resilience to ocean acidification, climate and other environmental changes. Many studies have identified recent trends in marine ecosystems and changes in the efficiency with which the ocean absorbs CO₂ in some ocean regions. Models can greatly help to understand the observed change and to separate the contributions of physical, chemical and biological processes. The development of global models representing the activity of marine ecosystems and their impact on biogeochemistry started around the end of the 1980s with three parallel strands of work:

1. Diagnostic models are based on one macronutrient (P), which is restored to observations to obtain the fraction of primary production that sinks below the surface - the "export" (Najjar et al. 1992).
2. Biogeochemical models estimate export based on light, temperature, and a half-saturation constant for growth (Maier-Reimer et al., GBC 1990).
3. NPZD models represent the interactions between nutrient, phytoplankton, zooplankton, and detritus (Fasham et al. 1993).

The above strands of models have been successfully used to represent the basic interactions between marine ecosystems and ocean biogeochemistry. However their use is limited in several ways. Most importantly they do not capture the richness of

the interactions within ecosystems, the specific roles for individual plankton types, and their structure does not allow for the use of vast amount of metabolic rate data available to constraint the flow of matter within the ecosystem and between the ecosystem and the biogeochemical cycles. The most recent global ocean biogeochemistry models have moved towards the representation of several nutrients and of a wider range of phytoplankton and zooplankton, a strategy already widely used in regional ecosystem models. Some of the most recent models represent marine ecosystems by grouping plankton types with similar roles into Plankton Functional Types (PFTs), thus maximizing the flexibility of the modelled ecosystems at a limited (realistic) computational cost.

Considerable efforts have been made to put together the observations needed to constrain models based on PFTs. The validation of the ecosystem component of marine biogeochemical models is now possible because of the over 12 year of SeaWiFS satellite chl observations, recent breakthroughs in the use of satellite data to estimate the dominance of phytoplankton PFTs, and because of the important synthesis of observations for heterotrophic PFTs.

Rationale for MAREMIP:

There is a need for increased complexity in ocean biogeochemistry models, to progress towards the resolution of important scientific questions, such as:

- what processes control global and regional marine biomass ?
- what are the impacts of environmental changes on ecosystems ?
- are there multiple steady states in marine ecosystem distribution ?
- what is the role of biodiversity in the ocean ?
- what are the feedbacks to climate and the availability of food resources ?
- what observations are we missing ?

The recent advances in marine ecosystem modelling and the upsurge of observations provide a rich background context to start a new Marine Ecosystem Model Intercomparison Project (MAREMIP). There are many precedents of successful model intercomparison efforts. The Climate Model Intercomparison Project (CMIP) is now in its fourth phase. It provided a wealth of climate model results which have been extensively used by the Intergovernmental Panel on Climate Change (IPCC), not only to project future climate but also to assess the risk of extreme events, the recent fingerprints of human-induced climate change, and the impacts on ecosystems. The Ocean Carbon-Cycle Model Intercomparison Project (OCMIP) is closely relevant to MAREMIP. One of the activities of OCMIP was the comparison of the same diagnostic model implemented in several ocean general circulation models (Najjar et al. 2007). The specific goal of MAREMIP could be to:

- progress towards the resolution of important scientific questions,
- develop a community around ecosystem modelers,
- organise the synthesis of existing data,
- promote the development of targeted observations,
- link modellers with observationalists,

- document the evolution of marine ecosystem models.

25 scientists involved in the development of global biogeochemical models met in Cambridge during October 28-30 to define the priorities and time-scale for MAREMIP activities, identify the data needs, flag common projects, organise the associated work and explore funding possibilities. The list of participants and programme is included in Appendix A.

The workshop was funded by AIMES (Analysis, Integration and modelling of the earth system), OCB (Ocean Carbon & Biogeochemistry), IMBER (Integrated Marine Biogeochemistry and Ecosystem Research), and the NERC Quest and Marquest projects. Participants from Japan were self-supported. We thank our sponsors for their support, and Penny Goodearl, Glenda Harden and Clare Enright for help with the local organisation.

The workshop programme was organised as follows. During Day 1, the modelling group present explained their main interests, described their modelling strategy, and showed their most interesting results. During Day 2, we looked at global datasets and metrics available for model evaluation. The observationalist groups presented their findings and data efforts. We also discussed other previous/ongoing intercomparisons. Finally, during Day 3 we discussed the strategy for MAREMIP in the upcoming years.

Summary of discussions:

We recorded about ten global marine ecosystem models. The models differ principally by their focus, with some models specialising on the variety of nutrient sources or physiological developments, on the diversity of phytoplankton or of zooplankton types, or on the resolution and quality of the underlying physical model. Table 1 presents a short summary of the main focus of each model presented. Table 1 also shows the PFTs represented with the names used by individual model authors.

Table 1. Summary of the models, their author, PFT represented and main focus.

Model	Author	PFTs	Main focus
BEC	S. Doney & K. Lindsey	pico/nano, diatoms diazotrophs adaptive zooplankton	Primary production, carbon cycle, other biogeochemical cycles. Climate-biogeochemical feedbacks.
NOBM	Watson Gregg	diatoms chlorophytes cyanobacteria coccolithophores zooplankton	Phytoplankton phenology, primary production, carbon cycle
AusCom	R. Matear	silicifiers calcifiers N ₂ -fixers microzoo mesozoo	Use of parameter optimisations and size-based parameters. Interactions between the high-resolution ocean physics and biogeochemistry
TOPAZ	J. Dunne	small phytoplankton large phyto protists filter feeders	Phytoplankton physiology, such as development of optimal allocation theory & N:P cellular quotas.
MRI	H. Nakano	2 versions: NEMURO NPZD	Interactions between the high-resolution ocean physics and biogeochemistry
PISCES	L. Bopp	diatoms nanophyto microzoo mesozoo	Primary production, carbon cycle, other biogeochemical cycles. Climate-biogeochemical feedbacks. Adjoint version and high resolution physics.
PlankTOM	E. Buitenhuis & C. Le Quéré	silicifiers calcifiers <i>Phaeocystis</i> nanophyto pico-autotrophs N ₂ -fixers pico-heterotrophs protozoo mesozoo macrozoo	Ecosystem-climate interactions, particularly those involving zooplankton. Acclimation. Carbon cycle, other biogeochemical cycles. Climate-biogeochemical feedbacks.
ERSEM	I. Allen	diatoms dinoflagellates flagellates picophyto bacteria heterotrophs microzoo mesozoo	Biogeochemical interactions in the coastal ocean (upcoming global version). Complex interactions with sediment and microbial processes. Phytoplankton physiology (quota model). Interactions with fish.
BFM-PELAGOS	M. Vichi	diatoms flagellates picophyto large phyto bacteria heterotrophic nanopl heterotrophs microzoo carnivores omnivores	Carbon cycle, biological pump, and climate-biogeochemical feedbacks.
NEMURO	Y. Yamanaka & T. Hashioka	diatoms small phyto small zoo copepods euphausiids fish	Climate-biogeochemical feedbacks. Ecosystem interactions with coral reefs and fisheries.
DARWIN	S. Dutkiewicz & M. Follows	78 phytoplankton zooplankton	Flexible community structure and emergent properties. Ecosystem – climate interactions.

The models presented were evaluated with a variety of data and strategies. Common to all was the use of a visual comparison with surface chlorophyll data. Some looked at spatial mean only, or at seasonal cycles. Some looked at primary production from satellite or *in situ*, export, nutrients. Finally only few used sophisticated statistical analysis tools such as Taylor and Target diagrams. Regarding the data available for model parameterisations and evaluation, it was quickly recognised that there are a lot of data available, but that it is difficult to manage the information either because the data has not been compiled, units are not homogenised, or information is missing.

The MAREMIP community can greatly benefit from the experience of the Primary Production Algorithm Round Robin (PPAR; Friedrich et al. 2009), which included several global biogeochemistry models. In particular, MAREMIP could more extensively test the conclusion that more complexity in models appear to lead to more skill, and quantify the relative importance of physics versus biology for variables other than total chlorophyll.

Strategy

In order to meet the objectives of MAREMIP, the following actions were recognised as important (see full list in Appendix B). Some actions could be done in the months following the workshop with available resources, while other actions were more substantial and require targeted funding.

Action items from kickoff workshop:

Organise the available data. The participants among themselves shared many data products, which had been put together to address specific needs. For example, two databases of Fe concentration exist, which have substantial but not full overlap. The community would greatly benefit by making relatively small efforts to combine such databases and make them available to the community. We agreed that existing data products would be made available in a common web site. Where possible the data will be binned on the World Ocean Atlas grid.

Co-ordinate efforts to synthesize data. There are a lot of data on biomass and vital rates which exist, but has not been synthesized. Some data are in National Data Centers and repositories and are thus relatively easily accessible. A large fraction of the data however is with individual scientists. Much work is required to bring the data together in a common format with common units. We agreed to lead an effort to compile the biomass of the most important Plankton Functional Types recognised for the modelling at this date. We will initiate a special issue of Earth System Science Data to ensure that the data authors are recognised for their data contributions. We have identified ten lead authors for the chapters, as listed in Appendix C.

Determine a set of model experiments that can be archived and compared.

- Hindcast experiments (March 2010). We agreed to provide guidelines for common hindcast experiments. The experiments should be done with models forced by observed fields, and should run as long as possible. The analysis will focus on post-1980. There are several forcing products available (NCEP, ECMWF, JPL, MERRA, ECCO). We decided to not impose a common forcing field in the first phase because we have at the moment no dedicated

man-power and want to limit additional burden. The groups only need to focus on having experiments that matches reality as much as possible.

- Climate experiments (July 2010). Some groups were interested to do common climate experiments using climate output for AR5 runs. Climate anomalies will first need to be computed and shared.

The common model simulations include the following prescriptions:

- 5-day average for surface fields of nutrients, biomass for all PFTs, chlorophyll by PFT, integrated biomass, temperature, Mixed layer depth, light, salinity.
- monthly-averages for temperature, mixed layer depth, PAR, salinity, vertical velocity, primary production, export, air-sea gas fluxes (all gases), pCO₂.
- the output should be gridded on the World Ocean Atlas grid (x,y,z).
- common units and variable names need to be defined
- no constraints on spin up
- model results will be archived on a common server, tentatively hosted by L. Bopp at LSCE.

Determine a list of metrics that models need to reproduce, and a method to quantify model performance. As the model comparison progresses, it is important to identify at an early stage which are the key data products that the models need to reproduce, which are the key metrics (e.g. the date of the spring bloom), and what is the measure of performance. We had an extensive discussion on measures of performance, where we discussed Taylor and Target diagrams as well as the statistical tests that can be done (correlations, RMS errors, model bias, model efficiency, etc). In defining adequate metrics/measures, the representativeness of the data and data errors need to be taken into account. These issues will need to be re-viewed during the analysis of the first model results.

Define a benchmark experiment. It was recognised that the group needs to define a Benchmark experiment, which could be repeated during each phase of MAREMIP. This would be the equivalent to the 1% increase in CO₂ repeated by climate models, in order to monitor the evolution of the models through time. However there were no obvious experiments proposed, and it was generally felt that some targeted testing need to be done first by one group.

We agreed to move forward with MAREMIP activities on our own funding for the moment, and to minimize any extra work that MAREMIP activities would require from the participants. We agreed that anyone is encouraged to use the upcoming model archive for targeted analysis, but that the group needs to be first informed of the goal of each individual project to avoid overlap. Authorship should be discussed on a case-by-case basis, but it was generally agreed that the first few papers should be more encompassing of model authors, whereas subsequent analysis could have a more limited authorship. Yasuhiro Yamanaka kindly agreed to host the next meeting of MAREMIP in Japan around April 2011.

Report prepared by Corinne Le Quéré, January 2010.

Appendix A: Agenda and participant list

Wednesday 28nd October:

Please keep presentations to 10-15 min maximum to allow plenty of time for discussions.

9.00-10.30 Welcoming comments and Global DGOMs:

Chair:

- Introduction to MAREMIP (Corinne Le Quéré and Scott Doney)
- A history of ecosystem modelling
- Goals and desired outcome of this kickoff workshop

Global DGOMs

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- BEC (Scott Doney)
- NOBM (Watson Gregg)

10.30-11.00 Break

11.00-13.00 Global DGOMs (continue)

Chair:

- Richard Matear
- TOPAZ (John Dunne)
- MRI (Hideyuki Nakano)
- PISCES (Laurent Bopp)

13.00-14.30 Lunch

14.30-16.00 Global DGOMs (continued)

Chair:

- PlankTOM10 (Corinne Le Quéré)
- ERSEM (Icarus Allen)
- BFM-PELAGOS (Marcello Vichi)

16.00-16.30 Break

16.30-17.30 Global DGOMs (continued)

Chair: Corinne Le Quéré

- NEMURO (Yasuhiro Yamanaka)
- DARWIN (slides sent by Stephanie Dutkiewicz)

19.30 Conference dinner at the River Bar & Kitchen

Thursday 29 Oct:

Please keep presentations to 10-15 min maximum to allow plenty of time for discussions.

9.00-10.30 MAREMIP-0

Chair:

- Lessons learned from a regional marine ecosystem model comparison effort (Marjy Friedrichs)
- PFT niches in the global ocean (Meike Vogt)
- Seasonal distribution of PFTs (Taketo Hashioka)

10.30-11.00 Break

11.00-13.00 Global datasets

Chair:

- PFT from space (Séverine Alvain)
- Size class from space (Takafumi Hirata)

- Size class changes with depth (Bob Brewin)
- Ocean provinces (Nick Hardman-Mountford)
- Global dominance dataset (Watson Gregg)

13.00-14.30 Lunch

14.30-16.00 Global datasets (continued)

Chair:

- Bacteria and recycling (Richard Rivkin)
- Global biomasses and rates (Erik Buitenhuis)
- GloPad (Jill Peloquin)

16.00-16.30 Break

16.30-17.30 Global datasets (continued)

Chair:

- Global Fe dataset (Scott Doney)
- Southern ocean acidification: special concern for pteropods (Nina Bednarsek)

Friday 30th October:

Please keep presentations to 10-15 min maximum to allow plenty of time for discussions.

9.00-10.30 Short-term strategy

Chair:

- Time frame
- Forcing
- Spin up
- Individual projects
- Input to IPCC AR5 (by September 2012)

10.30-11.00 Break

11.00-13.00 Metrics for model evaluation (continued)

- Icarus Allen
- Scott Doney
- Databases and dataproducts (Stephane Pesant)

13.00-14.00 Lunch

14.00-16.00 10 year strategy

Chairs: Corinne Le Quéré and Scott Doney

- Long term plan (Corinne)
- Ideas for funding (Scott)

Participants:

1. Icarus Allen (Plymouth Marine Laboratory)
2. Severine Alvain (Université Lille 1, France)
3. Nina Bednarsek (British Antarctic Survey, UK)
4. Laurent Bopp (Laboratoire des Sciences du Climat et de l'Environnement, France)
5. Bob Brewin (Plymouth Marine Laboratory)
6. Erik Buitenhuis (University of East Anglia, UK)
7. Scott Doney (Woods Hole Oceanographic Institution, USA)
8. John Dunne (Geophysical Fluids Dynamic Laboratory, USA)
9. Clare Enright (British Antarctic Survey, UK)
10. Marjy Friedrichs (Virginia Institute of Marine Science, USA)
11. Watson Gregg (NASA, USA)
12. Nick Hardman-Mountford (Plymouth Marine Laboratory)

13. Taketo Hashioka (JAMSTEC, Japan)
14. Takafumi Hirata (Plymouth Marine Laboratory)
15. Keith Lindsay (UCAR, USA)
16. Corinne Le Quéré (British Antarctic Survey, UK)
17. Richard Matear (CSIRO, Australia)
18. Hideyuki Nakano (Meteorological Research Institute, Japan)
19. Jill Pelouin (ETH, Switzerland)
20. Stephane Pesant
21. Richard Rivkin (Memorial University, Canada)
22. Nick Stephens (Université Brest, France)
23. Marcello Vichi (Istituto Nazionale di Geofisica e Vulcanologia, Italy)
24. Meike Vogt (ETH, Switzerland)
25. Yasuhiro Yamanaka (Hokkaido University, Japan)

Annex B: Action items

Reporting on meeting:

- EOS paper (Scott and Corinne)
- Workshop report (Corinne and Scott)
- Talks on the web site (Erik)
- thank our sponsors

Project setup:

- email list (Scott)
- chasing up Dennis Mc. (Scott)
- Web site with model-friendly data and data efforts (Corinne and Erik)
- Model description (Meike and Marcello)
- Re-vamp web site (Meike)
- Model archive (Laurent)

Model intercomparison:

- Define model results to be archived (Corinne, John, Richard M., Laurent, Take)
- Hindcast experiments archived (all, March 2010)
- Compute climate anomalies from several models for 2000-2100 experiments (John, Corinne, Scott, Yasu, March 2010)
- Climate runs (July 2010)
- Test experiments to define benchmark (Greencycles II post-doc?)
- Model description on web site (Meike)

Data sharing and compilation:

- Erik to lead the special issue in ESSD
- Corinne/Erik to prepare web page with shared data products
- Erik/Keith to merge Fe dataset
- John to share DOC, DON, DOP etc
- Jill to share Chemtax product

Annex C: Chapters for special issue in Earth System Science Data (ESSD)

Editor: Erik T. Buitenhuis

Papers and lead authors:

1. Bacteria (Richard Rivkin (to be confirmed))
2. Picophytoplankton (Erik Buitenhuis)
3. N₂-fixers (Scott Doney)
4. *Phaeocystis* (Jill Peloquin and Meike Vogt)
5. Coccolithophores (Meike Vogt, Jill Peloquin and Moritz Heinle)
6. Diatoms (Karine Leblanc)
7. Nanophytoplankton (not identified)
8. Protozooplankton (not identified)
9. Mesozooplankton (Todd O'Brien)
10. Macrozooplankton (Róisín Moriarty)