CLIVAR WGOMD Workshop on Ocean Mesoscale Eddies: Representations, Parameterizations, and Observations

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1 Motivation and Goals for a Workshop on Mesoscale Eddies

The global ocean is a highly turbulent fluid, with scales of motion from the millimetre to global, on time scales from seconds to millenia. One of the most energetic scales is the mesoscale, where variability arises from the chaotic dynamics of geostrophic turbulence. The increasing power of satellite observations has confirmed that mesoscale eddies are a ubiquitous feature of the World Ocean (e.g., Chelton et al., 2007). Mesoscale eddies are critical for establishing ocean tracer properties; they affect the ventilation of heat, carbon, and other tracers; they support rich levels of biological activity; and they interact with smaller and larger scales.

A key weakness of nearly all global climate models used to study climate is the absence of an explicit representation of ocean mesoscale eddies, since their spatial scale is smaller than typical climate model grid meshes can resolve. Hence, the models rely on parameterizations. The most popular parameterizations originate from the tracer diffusion scheme of Solomon (1971) and Redi (1982) (i.e., neutral diffusion, as well as the eddy induced tracer stirring proposed by Gent and McWilliams (1990) and Gent et al. (1995). Many studies have shown that these parameterizations improve simulations relative to models run in their absence, prompting the parameterizations to be used by nearly all IPCC-class ocean climate models. Nonetheless, there remain many unresolved questions, both fundamental and practical, which support a very active research community aimed at providing more robust and flexible parameterizations of mesoscale eddies. In parallel to research aimed at understanding and parameterizing the mesoscale, the modelling community has steadily seen an increase in the numerical integrity of model codes, and the refinement of resolutions available for representing the ocean circulation. This effort has led to a few global, or near global, simulations with vigorous mesoscale eddy variability.

The intense level of research activities related to ocean mesoscale eddies prompted the CLIVAR Working Group for Ocean Model Development (WGOMD) to organize a three-day scientific workshop at the UK Met Office from 27-29 April, 2009. The main goals of the workshop were the following:

- To educate the research community regarding the importance of mesoscale eddies in theWorld Ocean, and correspondingly for establishing features of the ocean climate system;
- To identify best practices for parameterizing ocean mesoscale eddies in coarse resolution climate models, and to discuss various research avenues for improved parameterizations;
- To evaluate the ability of state-of-the-science numerical models to accurately represent the ocean mesoscale in eddying simulations.

In addition to these intellectual aims, the workshop was held to honour the seminal works of Gent and McWilliams (1990) and Greatbatch and Lamb (1990). After nearly 20 years, these works remain the touchstone for studies of mesoscale eddy parameterization and theory. Finally, the workshop represented a memorial to the tireless and intellectually penetrating work of Peter Killworth, who passed away in January 2008. Peter was a leader for more than a generation of physical oceanographers, whose work touched upon many aspects of observations, parameterizations, and modelling. He will be deeply missed.

2 The UK Met Office Workshop

The workshop consisted of six speakers per day, with each speaker presenting, in a pedagogical manner, different views on the state-of-the-science in ocean mesoscale eddies as seen through observations, simulations, and theory. The following workshop speaker list consists of a who's who in oceanography.

Day 1: Observing and simulating the ocean mesoscale

- CarlWunsch (MIT): Observations, simulations, and assimilations
- Dudley Chelton (Oregon State University): Global mesoscale eddy variability from satellite altimeters
- Matthew Hecht (Los Alamos): POP simulations in an eddying regime
- Steve Rintoul (CSIRO): Mesoscale processes in the Southern Ocean
- Malcolm Roberts (UK Met Office Hadley Centre): Impacts of the mesoscale on coupled phenomena
- Frank Bryan (NCAR): Tracer transport in eddy resolving global ocean simulations

Day 2: Parameterizing the mesoscale

- Peter Gent (NCAR): Gent-McWilliams with 20/20 hindsight
- Richard Greatbatch (IFM-GEOMAR): Interpretation of mesoscale eddy mixing
- Carsten Eden (IFM-GEOMAR): Parameterisation of mesoscale eddy mixing
- David Marshall (Oxford University): Parameterisation of geostrophic eddies: energetics, conservation
- and flow stability
- Trevor McDougall (CSIRO): Thermodynamic equation of state of seawater-2010
- John Marshall (MIT): The interplay between baroclinic instability, geostrophic turbulence and
- Rossby waves in the ocean (and routes to parameterisation)
- Raffael Ferrari (MIT): Lateral and vertical variations in eddy mixing

Day 3: At the frontier

- Michael Bell (UK Met Office): Forecasting the ocean mesoscale
- Mike Spall (WHOI): Eddies and deep water formation
- Andreas Oschlies (IFM-GEOMAR): Eddies and ocean biogeochemistry
- Baylor Fox-Kemper (University of Colorado): Submesoscale dynamics and parameterization
- Anne-Marie Treguier (IFREMER): Anisotropy, momentum fluxes: a few remaining challenges for parameterizations
- Jim McWilliams (UCLA): Eddy roles in the general circulation

Each speaker was given 70 minutes to delve in-depth into the chosen subject, and for questions and discussion with the 140 participants. Additionally, there was time during breaks, lunch, and evening socials to view more than 40 posters from students, post-docs, and senior scientists. The presentations and most of the posters are available on the meeting webpage http://www.clivar.org/organization/wgomd/meso/meso.php.

The organizers wish to thank the UK Met Office for hosting the workshop and NOAA, NASA and NSF for

generously awarding us additional funding that enabled us to provide travel support for thirteen young scientists who presented posters at the meeting.

3 Workshop Summary

It is difficult to summarize the content of a workshop such as this, where the variety of ideas discussed extend well beyond the number of speakers. Hence, to help in communicating certain of the workshop topics, the editors of Ocean Modelling, the journal founded by Peter Killworth, are planning a special edition in 2010. We have learned a tremendous amount in the 20 years since Gent and McWilliams (1990) and Greatbatch and Lamb (1990), and it is very satisfying to reflect on this deepening of understanding. It is in turn exciting to imagine how the next generation will continue to expand our knowledge of the ocean garnered from increasingly realistic global eddying simulations, the growing database of observations, and the continuing application of fundamental theoretical principles. The special edition of Ocean Modelling aims to provide a benchmark to document mesoscale eddy research of the past 20 years, and to promote many of the ideas that will be debated into the future.

We are entering an era where climate simulations with an eddying ocean will become common. Many of the assumptions and results arising from the non-eddying simulations will thus be tested. Do we need to resolve the mesoscale to obtain robust simulations of global climate, or can we rely on the parameterized coarsely resolved models? What does it mean to resolve the ocean mesoscale? Perhaps these questions will only be answered after a generation of researchers sufficiently digest eddying models to provide mechanistic interpretations of the huge amounts of information generated by the simulations. How do eddies impact climate variability, predictability, and stability? This question is of fundamental importance as the climate science community aims to realize the goals of CLIVAR by examining the potential for predicting climate phenomena at time scales extending out to the decadal, and to project climate for the 21st Century. These questions, and many more, motivate the science community to continue seeking an intellectual basis for describing the ocean and its role in climate, and to aim for realizing robust simulations of increasing realism. The discussions at this workshop indicate that the ocean mesoscale is at the heart of these goals, thus prompting an ongoing vigorous level of research forming a critical and stimulating area of climate science.

References

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