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Preface

33rd International Liège Colloquium on Ocean Dynamics

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The use of data assimilation in coupled hydrodynamic, ecological and bio-geo-chemical models of the ocean

The International Liège Colloquium on Ocean Dynamics is organized annually. The topic differs from year to year in an attempt to address, as much as possible, recent problems and incentive new subjects in oceanography.

Assembling a group of active and eminent scientists from various countries and often different disciplines, the Colloquia provide a forum for discussion and foster a mutually beneficial exchange of information opening on to a survey of recent discoveries, essential mechanisms, impelling question marks and valuable recommendations for future research.

The objective of the 2001 Colloquium was to evaluate the progress of data assimilation methods in marine science and, in particular, in coupled hydrodynamic, ecological and bio-geo-chemical models of the ocean.

The past decades have seen important advances in the understanding and modelling of key processes of the ocean circulation and bio-geo-chemical cycles. The increasing capabilities of data and models, and their combination, are allowing the study of multidisciplinary interactions that occur dynamically, in multiple ways, on multiscales and with feedbacks.

The capacity of dynamical models to simulate interdisciplinary ocean processes over specific space–time windows and thus forecast their evolution over predictable time scales is also conditioned upon the availability of relevant observations to: initialise and continually update the physical and bio-geo-chemical sectors of the ocean state; provide relevant atmospheric and boundary forcing; calibrate the parameterisations of sub-grid scale processes, growth rates and reaction rates; construct interdisciplinary and multiscale correlation and feature models; identify and estimate the main sources of errors in the models; control or correct for mis-represented or neglected processes.

The access to multivariate data sets requires the implementation, exploitation and management of dedicated ocean observing and prediction systems. However, the available data are often limited and, for instance, seldom in a form to be directly compatible or directly inserted into the numerical models. To relate the data to the ocean state on all scales and regions that matter, evolving three-dimensional and multivariate (measurement) models are becoming important. Equally significant is the reduction of observational requirements by design of sampling strategies via Observation System Simulation Experiments and adaptive sampling.

Data assimilation is a quantitative approach to extract adequate information content from the data and to improve the consistency between data sets and model estimates. It is also a methodology to dynamically interpolate between data scattered in space and time, allowing comprehensive interpretation of multivariate observations.

In general, the goals of data assimilation are to: control the growth of predictability errors; correct dynamical deficiencies; estimate model parameters, including the forcings, initial and boundary conditions; characterise key processes by analysis of four-

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dimensional fields and their statistics (balances of terms, etc.); carry out advanced sensitivity studies and Observation System Simulation Experiments, and conduct efficient operations, management and monitoring.

The theoretical framework of data assimilation for marine sciences is now relatively well established, routed in control theory, estimation theory or inverse techniques, from variational to sequential approaches. Ongoing research efforts of special importance for interdisciplinary applications include the: stochastic representation of processes and determination of model and data errors; treatment of (open) boundary conditions and strong nonlinearities; space–time, multivariate extrapolation of limited and noisy data and determination of measurement models; demonstration that bio-geo-chemical models are valid enough and of adequate structures for their deficiencies to be controlled by data assimilation; and finally, ability to provide accurate estimates of fields, parameters, variabilities and errors, with large and complex dynamical models and data sets.

Operationally, major engineering and computational challenges for the coming years include the: development of theoretically sound methods into useful, practical and reliable techniques at affordable costs; implementation of scalable, seamless and automated systems linking observing systems, numerical models and assimilation schemes; adequate mix of integrated and distributed (Web-based) networks; construction of user-friendly architectures and establishment of standards for the description of data and software (metadata) for efficient communication, dissemination and management.

In addition to addressing the above items, the 33rd Liège Colloquium has offered the opportunity to:

- review the status and current progress of data assimilation methodologies utilised in the physical, acoustical, optical and bio-geo-chemical scientific communities;
- demonstrate the potentials of data assimilation systems developed for coupled physical/ecosystem models, from scientific to management inquiries;
- examine the impact of data assimilation and inverse modelling in improving model parameterisations;
- discuss the observability and controllability properties of, and identify the missing gaps in current observing and prediction systems; and
- exchange the results of and the learnings from pre-operational marine exercises.

The presentations given during the Colloquium lead to discussions on a series of topics organized within the following sections: (1) Interdisciplinary research progress and issues: data, models, data assimilation criteria. (2) Observations for interdisciplinary data assimilation. (3) Advanced fields estimation for interdisciplinary systems. (4) Estimation of interdisciplinary parameters and model structures. (5) Assimilation methodologies for physical and interdisciplinary systems. (6) Toward operational interdisciplinary oceanography and data assimilation. A subset of these presentations is reported in the present Special Issue.

As was pointed out during the Colloquium, coupled biological–physical data assimilation is in its infancy and much can be accomplished now by the immediate application of existing methods. Data assimilation intimately links dynamical models and observations, and it can play a critical role in the important area of fundamental biological oceanographic dynamical model development and validation over a hierarchy of complexities. Since coupled assimilation for coupled processes is challenging and can be complicated, care must be exercised in understanding, modeling and controlling errors and in performing sensitivity analyses to establish the robustness of results. Compatible interdisciplinary data sets are essential and data assimilation should iteratively define data impact and data requirements.

Based on the results presented during the Colloquium, data assimilation is expected to enable future marine technologies and naval operations otherwise impossible or not feasible. Interdisciplinary predictability research, multiscale in both space and time, is required. State and parameter estimation via data assimilation is central to the successful establishment of advanced interdisciplinary ocean observing and prediction systems which, functioning in real time, will contribute to novel and efficient capabilities to manage, and to operate in our oceans.

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