Oceanography Committee **ICES CM 2003/C:15**

Report of the

Workshop on Real-time Coastal Observing Systems for Ecosystem Dynamics and Harmful Algal Blooms

Villefranche-sur-Mer, France
11–21 June 2003

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark

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1 INTRODUCTION AND TERMS OF REFERENCE

A Workshop on **Real-time Coastal Observing Systems for Ecosystem Dynamics and Harmful Algal Blooms** [WKHABWATCH] (Co-Chairs: M. Babin, France and J. Cullen, Canada) was held in Villefranche-sur-Mer, France from 11–21 June 2003.

The terms of the reference (2C16) for the workshop were to:

a) review real-time and near real-time sensing systems applicable for observation, modelling and prediction of plankton dynamics in coastal waters, including HABs;
b) present the underlying theory and review the possibilities together with the current issues and limitations, including:
    i) remote sensing of coastal waters;
    ii) *in situ* optical measurements, both passive and active;
    iii) automated methods for detection of plankton species or toxins;
    iv) integrated observation systems combining various kinds of detectors (optical, acoustic, chemical, hydrodynamical), including moorings and autonomous vehicles;
    v) continuous underway sampling systems (e.g., from ferries);
    vi) tools for characterising distribution of plankton in relation to physical and chemical properties;
c) elaborate guidelines for the development of strategic and rational use of optical sensors for specific HABs problems;
d) explore approaches for integrating data from various sensing systems to describe ecosystem processes in support of HAB research, monitoring and prediction (e.g., information systems);
e) review prognostic models designed to use real-time observations of variables related to coastal ecosystem dynamics and HABs; and
f) introduce and review data assimilation techniques.

Also, GEOHAB, GLOBEC and IOC-GOOS (COOP) were invited to participate in the workshop, and the organizers agreed to report for the attention of the Oceanography Committee by 31 July 2003.

2 BACKGROUND

There is a great deal of interest, throughout the world, in the installation of ocean observation systems to provide the data and knowledge needed to detect and forecast physical, chemical and biological changes in coastal and open-ocean ecosystems. Recent advances in instrumentation, communications and modelling capabilities have led to the design of prototype real-time observation and prediction systems for coastal ecosystems. Important phenomena in coastal waters include flooding and coastal erosion, oxygen depletion due to eutrophication, and harmful algal blooms (HABs). However, many of the new approaches are unfamiliar to potential users. Optical and chemical sensors are, for instance, increasingly used from various platforms. Effective use of these sensors does not necessarily require advanced technical training, but it does require knowledge of the underlying theoretical and technical principles, how to properly deploy these instruments, methods for processing data, approaches for interpreting the results within reasonable limits, and how such results can be incorporated into different kinds of predictive models.

It is for this reason that the "Workshop on Real-time Coastal Observing Systems for Ecosystem Dynamics and Harmful Algal Blooms" was convened at the Observatoire Océanologique de Villefranche and Citadelle of Villefranche-sur-Mer, France. The idea of this workshop initially emerged from the Working Group on Harmful Algal Blooms Dynamics (WGHABD) of ICES; the first stages of planning at a meeting in Dublin were critical. Major support from the European Commission made it possible for planning to proceed. Ultimately, the workshop received the following support:

Sponsorship: European Commission, IOC, SCOR, NOAA, NSF (U.S.), ONR, ONR IFO, Observatoire Océanologique de Villefranche, CNRS, CNES, ESA, Ifremer, and Research Systems.

Endorsements: GEOHAB, GOOS, ICES and PNEC (Programme National Environment Côtier).

The workshop was planned by the Organizing Committee: J. Aiken (UK), A. Cembella (CA), H. Claustre (FR), T. Dickey (USA), V. Fournier-Sicre (FR), P. Gentien (FR), B. Karlson (SE), J. Lee (CN), C. Roesler (USA). Lewis Conference Services International provided logistical support.

3 STRUCTURE

The Workshop was dedicated to an international audience with a broad range of backgrounds, and was intended to provide the participants with both the theory relevant to understanding the basic principles of real-time observation and modelling tools, and tutorials to allow the use of these tools. Participation was limited (89) to allow tutorials in small groups and to maximize interactions. Experts were invited to present overview lectures accompanied by peer reviewed chapters in a book. Others were invited to present demonstrations and tutorials. The remaining participants/contributors were selected from a large pool of applicants using criteria designed to favour students and potential end users of coastal observation systems. Industrial exhibitors were able to display, deploy and discuss their instruments and observation tools.

Interactions between participants were facilitated by providing midday and evening meals to all participants. This was widely regarded as a key factor in the success of the workshop.

4 CONTENT

The agenda was strongly consistent with the terms of reference for the workshop. The program and supporting materials are presented on the conference web site, www.habwatch.org, which will be maintained for a minimum of two years.

Plenary lectures provided the theoretical foundations for the workshop:

- *J. Cullen* (CA). Overview on observation and prediction of HABs
- *T. Dickey* (USA). Overview on physical and chemical dynamics of coastal ecosystems
- *O. Schofield* (USA). Overview of optical observation of biological variability
- *T. Dickey* (USA). Overview of chemical and physical sensors
- *A. Morel* (FR). Theory and state-of-the-art on optical properties of phytoplankton and other marine substances, with emphasis on HABs
- *C. Roesler* (USA). Description of the different methods for in situ measurement of inherent optical properties, and assessment of their potential for HABs detection
- *M. Babin* (FR). Theory and current literature on, and in situ measurement of the phytoplankton fluorescence, with emphasis on HABs
- *M. Lewis* (CA). Measurement of seawater reflectance and vertical attenuation coefficient, with emphasis on HABs
- *P. Franks* (USA). Overview on physical modelling
- *J. Jaffe* (USA). Acoustical detection and underwater imaging
- *C. Scholin* (USA) and *G. Doucette* (USA). Biosensors and toxin detection
- *H. Sosik* (USA). Characterizing seawater constituents from optical properties
- *K. Ruddick* (BE). Overview of ocean colour theoretical background, sensors, and applicability for the detection and monitoring of HABs (capabilities, limitations)
- *B. Karlson* (SE). Development and deployment of an instrumented mooring
- *G. Griffiths* (UK). Glider and AUV observation systems
- *T. Malone* (USA). Overview of observation networks
- *C. Compère* (FR). Overview on bio-fouling
- *J. Lee* (CN). Modelling of algal dynamics in sub-tropical coastal waters
- *D. McGillicuddy* (USA). Modelling blooms of *Alexandrium fundyense* in the Gulf of Maine
- *W. Fennel* (DE). Modelling coastal dynamics and HABs in the Baltic Sea
- *P. Bissett* (USA). The integration of ocean colour remote sensing with coastal nowcast/forecast simulations of Harmful Algal Blooms (HABs)
- *N. Pinardi* (IT). Theoretical bases of various data assimilation techniques
- *G. Pitcher* (ZA). The point of view of users
- *O. Schofield* (USA): Workshop retrospective

Contributed lectures were delivered by 17 participants as were 37 **Posters**. All are listed on the Habwatch web site.

Tutorials and demonstrations were conducted repeatedly for small groups, so participants were well exposed to instruments and techniques:

Inherent Optical Properties (IOPs):

- *In situ* absorption and attenuation meters (M. Twardowski, USA)
- Scattering and turbidity meters (C. Roesler, USA)
- Primary data processing (A. Barnard, USA)
- Data visualization (G. Chang, USA)

In vivo chlorophyll fluorescence:

- Conventional fluorometers for biomass estimation and assessment of phytoplankton physiology (J. Cullen, CA)
- Sun-induced fluorescence (Y. Huot, CA)
- Pulse Amplitude Modulation fluorometer (PAM) (M. Babin, FR)
- Fast Repetition Rate fluorometer (R. Geider, UK)

Apparent Optical Properties (AOPs):

- Underwater spectroradiometer (R. Davis, CA)
- In-water measurement of AOPs to estimate water clarity and phytoplankton biomass (J. Cullen, CA)
- Above-water spectroradiometer (K. Ruddick, BE; A. Morel and Y. Huot, FR and CA)
- Data post-processing (G. Chang, USA)
- Primary data processing (A. Barnard, USA)

Emerging technologies:

- Molecular probes for rapid identification of phytoplankton species (L. Medlin, DE and C. Scholin, USA)
- Rapid assays of biotoxins (A. Cembella, CA and G. Doucette, USA)
- Automated Submersible Flow Cytometry (H. Sosik, USA)
- FLOW Cytometer And Microscope (FLOWCAM) (M. Sieracki, USA)

Remote sensing (conducted at ACRI, Sophia Antipolis):

- Atmospheric corrections of satellite ocean colour observations over Case 1 waters (D. Antoine, FR)
- Atmospheric Corrections of satellite ocean colour observations over Case 2 waters (K. Ruddick, BE)
- Overview of Chl concentration retrieval approaches (S. Lavender, UK)
- Designing an operational remote sensing system (V. Fournier-Sicre, FR)
- Demonstrations of existing operational systems: SeaDAS based systems (S. Lavender, UK)
- Detection of surface accumulations of cyanobacteria in the Baltic using AVHRR images (B. Karlson, SE)
- Image analysis and the detection of HABs from satellite images: a practical tutorial with case studies (M. Kahru, USA)

Observational systems:

- International Observing Systems (T. Dickey, USA)
- Real-time Coastal Observing Systems for Ecosystem Dynamics and Harmful Algal Blooms (G. Chang, USA)
- The "BOUSSOLE" project (BOUée pour l'acquiSition de Séries Optiques à Long termE) (D. Antoine, FR)
- Validation of ocean colour remote sensing data using a moored databuoy; PlyMBODy, a case study of a low-cost bio-optical moorings for HABWATCH (J. Aiken, UK)
- Overview of the Gulf of Maine Ocean Observing System (GoMOOS) (A. Barnard, USA)
- Evolution of the New Jersey Shelf Observing System: Our Experience (O. Schofield, USA)

- Sampling thin layers (P. Donaghay, USA)

Modelling:

- A biologist's perspective on modelling (D. Anderson, USA)
- Biological Data Assimilation (D. McGillicuddy, USA)
- How to construct models with several functional groups (W. Fennel, DE)
- Real time observations in operational data assimilation systems (N. Pinardi, IT)
- Hydrodynamic and water quality models used in management (J. Lee, CN)
- The selection of model complexity (P. Bissett, USA)

5 PUBLICATION

New models of publication are being implemented. All lectures were presented using PowerPoint software with automatic voice recording. The presentations, including voice and animations, will be made available at the Habwatch web site and compiled in CD-ROMs. Visual materials from the tutorials and many of the posters will also be included.

In addition, chapters based on invited lectures will be published in a peer-reviewed volume of the UNESCO series "Monographs on oceanographic methodology", with Marcel Babin, John Cullen and Collin Roesler as editors. This volume should have a shelf life of up to 10 years, and it provides an excellent opportunity to review this rapidly developing field. Most of the chapters have been submitted and the reviewing process is underway.

The post-conference web site has been assembled, but will not be put in public view until the contents have been reviewed by the organizers and contributors. The site will also include a synthesis and list of recommendations that must be vetted by participants prior to publication.

6 DISCUSSION

As demonstrated by numerous testimonials, the workshop was an outstanding success. Experts in biology, ecology, new technologies in sampling and analysis, optical oceanography, remote sensing, physical oceanography, and several types of modelling interacted with each other and with students and potential users of coastal observing systems. All participants learned a great deal, and many remarked on the special opportunity the workshop provided to obtain detailed, "behind the scenes" information about observation and modelling systems. Students in particular seemed to benefit from the experience, and the seeds of many new collaborations were planted.

Although the workshop synthesis has not been finalized, it can be concluded that new technologies in coastal observation and prediction were very well received. Their strengths and limitations are now better understood by all participants, and the need for further interactions between experts in a broad range of fields is clearly recognized.

Although many challenges exist, the prospects for real-time coastal observing systems for ecosystem dynamics and harmful algal blooms are excellent. New initiatives are not being planned as a direct result of this workshop, but through the synthesis and recommendations, and interactions facilitated by the Habwatch web site, it is expected that participants will propose follow-on activities. In turn, the Habwatch organizers welcome suggestions from sponsors and endorsing groups, such as ICES (for example from the ICES/IOC Steering Group on GOOS): the Habwatch site can be used to promote activities related to real time coastal observing systems.