GEOHAB

Global Ecology and Oceanography of Harmful Algal Blooms

# OPEN SCIENCE MEETING:

# HABS AND STRATIFICATION

**UNESCO Headquarters**
**PARIS, FRANCE**

**5-8 December 2005**

International Council for Science

Scientific Committee on Oceanic Research

Intergovernmental Oceanographic Commission

UNESCO

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## AN INTRODUCTION TO THE CONFERENCE

# GEOHAB Core Project 4: HABs in Stratified Environments

The GEOHAB Core Research Project on Harmful Algal Blooms (HABs) in Stratified Environments must be comparative, interdisciplinary, and international. It will directly address the goal of GEOHAB of improved prediction of HABs by determining the ecological and oceanographic mechanisms underlying their population dynamics, integrating biological, chemical, and physical studies supported by enhanced observation and modelling techniques. The overall objective is to determine the factors underlying the development of communities related to HABs in sub-surface micro-layers and the real-time dispersion of these microlayers as a function of turbulent and advective regimes.

A feature common to nearly all oceanic harmful algal events is that the phytoplankton populations typically build up to the highest concentrations in subsurface layers. These layers are usually related to water column stratification. HAB populations may then be advected to the coast, where they cause harmful events. Stratified water columns may be encountered in upwelling systems, coastal embayments and estuaries, as well as in confinement zones. The temporal and spatial scales of thin layers (intermittent and less than 1 m thickness) pose problems for sampling and modelling of harmful bloom populations. Coupling physical effects (turbulence, shear, advection) and biological behaviour (migration, physiological adaptation) holds the key to understanding vertical distributions, bloom dynamics, and patterns of toxicity. Some of these physical processes are not yet defined at the proper scale, yet may be crucial in the formation of harmful blooms. It is in these areas where our knowledge is weakest.

Models have thus far been restricted by insufficient ability to gauge the interactions between the biology of algal taxa and underlying physical processes. As an example of chemically mediated interactions that may be very important in highly stratified systems, certain harmful species can produce exotoxins that may have an allelopathic effect on competitors for substrate, or even inhibit grazers. From the biological perspective, the relative importance of biological processes occurring within or at the interface of thin layers, such as species-specific adaptations for heterotrophy and the role of the microbial food web, are also poorly understood.

**Selected Scientific Objectives:**

- Determine groups of co-occurring taxa or assemblages within these highly stratified environments, and define functional groups in which HABs are present
- Identify the biological and life-history characteristics common to these HABs species
- Define the essential control factors that determine the population development of harmful species in relation to their community
- Quantify the role of small-scale physical processes in maintaining harmful phytoplankton in discrete thin layers
- Demonstrate the importance of density-driven coastal flows and limit-layer dynamics in the advection of populations of these harmful species into other regions of commercially important aquaculture activities
- Validate different models of growth and advection

Scientists working in physical, chemical and/or biological disciplines related to harmful algal research, and on the development of relevant instrumentation and models have been encouraged to participate in this meeting in order to discuss new findings, establish the “state of the art” and identify priorities for research.

The conveners welcome all participants to this Open Science Meeting

| | |
|---|---|
| Patrick Gentien<br>OSM Chairman | Grant Pitcher<br>Chairman, GEOHAB SSC |

## THE OPEN SCIENCE MEETING PLANNING COMMITTEE:

Patrick Gentien (France), Chair
Percy Donaghay (USA)
Thomas Osborn (USA)
Robin Raine (Ireland)
Beatriz Reguera (Spain)
Hidekatsu Yamazaki (Japan)

We gratefully acknowledge the support for the GEOHAB programme and for this Open Science Meeting received from the Scientific Committee for Oceanic Research (SCOR), the U.S. National Science Foundation and the Intergovernmental Oceanographic Commission (IOC).

In addition, the SSC and Planning Committee are grateful for the assistance of the following individuals in making this meeting possible:

Henrik Enevoldsen, IOC
Virginie Bonnet, IOC
Ed Urban, SCOR
Elizabeth Gross, SCOR

## About this Book

We hope you will find this book to be helpful, both as a reference during the Open Science Conference, and afterwards. The list of participants includes all those who completed registration for the conference before this book went to print on November 25, 2005. Similarly, the abstracts, both for speakers and the poster sessions, reflect the status of the programme for the conference on that date. Changes to the programme will be announced and posted at the conference and you are advised to look for these.

## Notes for Visitors to Paris

### Getting around:

The Paris Metro is very easy to use and, given the traffic congestion in Paris, is often much faster than taking a taxi. Pick up a Metro map at your hotel. The various lines are numbered and color-coded. You need to identify the number of the line and name of the station at the end of the line in the direction you wish to go so that you know which way to go in the station.

If you are going to be in Paris more than a few days, or are going to be traveling around the city for sightseeing, it is much cheaper to buy a "carnet" (pronounced car-nay), which is a bunch of 10 tickets, than to buy single tickets every time you use the Metro.

When you go through the turnstiles, you insert your ticket into a slot and it comes out on the other side. Be sure to take your ticket back and keep it with you until you leave the station at your destination – inspectors occasionally check riders for tickets.

The standard tip for taxi drivers is generally one to two Euros as much unless you have received unusual service – say with luggage.

### Personal safety:

As in any large city, be aware of situations where pickpockets may be a problem, especially in crowded places like some of the major Metro stations. In general, Paris is a very safe city.

### Eating in Paris:

Unless you want to eat surrounded by tourists, do not expect to eat dinner in France before 8pm at the earliest. Many restaurants do not even open before 7:30. If you want to eat early, a café is your best bet. They are also the best choice if you want to have lunch within the time allowed.

In a café, if you only want a coffee, drink and/or a light meal (e.g. sandwich), be sure to sit at a bare table or one with paper placemats. If you sit at a table with a cloth and more formal place settings, you will be expected to order a full meal.

A café is a great place to watch Parisian life go by. Order a coffee, beer ("pression" = draft) or wine and relax. The house wine in cafés is called "vin de la maison", or "vin du patron' (literally, the owner's wine). In a café, this is usually sold in 0.5 ("demi") or 0.25 ("quart") liter jugs, called "pichets" (pronounced pee-shay). Similarly, draft beer (see "pression" above) comes in the same sizes.

Restaurants and stores in France are often family enterprises. It is considered impolite not to say “bonjour” when you arrive and to say “merci, aurevoir” (thank you, goodbye) when you leave, whether it is a café, restaurant, or shop.

In almost all cases, the tip or service charge, is included in your bill in cafés and restaurants in France. In rare cases (or with large groups) you may see “service non compris” (service not included) on your bill. In this case, use the same guidelines as you would at home. Even when the tip is included in the bill, it is customary to leave a small amount of change as a bonus to your waiter if you have been well served.

A French menu is called “la carte”. Almost all restaurants offer you 2 options. You can order off the menu (“à la carte”), but you should always look at the front or back for “le menu”, the daily fixed-price offerings. For much less money you will get several choices for each course: an appetizer (called the entrée) main course (“le plat”) and a dessert or cheese. Sometimes wine is even included – “boisson compris”. The menu of the day is sure to include the specialties of the chef and to be made with the freshest ingredients.

Menus must be posted outside all restaurants, and many include rough English translations, so it is possible to check it out before you make a commitment and enter the place! See the following list for some personal favorites.

## RESTAURANTS IN THE AREA NEAR UNESCO AND LOCAL HOTELS

***L’Alchimie*** – 34, rue Letellier. One block west of the corner of rue de Commerce and the Boulevard de Grenelle. Tel: 01-45-75-55-95. A small restaurant with a young chef. Imaginative food at a reasonable price. Reservations suggested.

***Le Sept-Quinze*** - 29, av de Lowendal, 15$^{th}$ arrondissment, Tel: 01-43-06-23-06
Named because it sits near the boundary between the 7$^{th}$ and 15$^{th}$ arrondissements of Paris.

***Le Père Claude*** – 51 Avenue de Motte-Piquet. Tel: 01-47-34-03-05.
Traditional French food. Bouillabaise and rotisserie items are specialties of the house. Reservations a must.

***Swann et Vincent*** - West side of Bd.de Garibaldi between the Place de Cambronne and the rue Miollis. A small, popular bistro featuring Italian and French cuisine.

***La Fontana Rosa*** Within a few doors of Swann et Vincent. Has a nice outdoor courtyard and a lovely antipasto buffet. Classic Italian/Sicilian.

***Auberge du Champs de Mars*** - On the rue de l’Exposition, which also is home to several other nice little restaurants, especially around the courtyard and fountain where the rue de l’Exposition intersects the rue St. Dominique. The Auberge has always had one of the most affordable and enjoyable daily menus in this area of Paris.

***Le Fontaine de Mars*** - Also on the courtyard mentioned above. French country cooking.

***Le Square*** – 139 Boulevard de Grenelle. A good café, serving coffee and drinks all the time, with an excellent menu for lunch or dinner. The salads are a meal in themselves.

***Le Corsair*** – 110 Avenue de Suffren. Same owners and menu as the preceding café. This is the closest place to UNESCO to eat – just across the street. The "croques" are great for lunch.

***Café du Commerce*** - 51 rue du Commerce, 15th arrondissement Tel: 01-45-03-27. This is an historic Paris restaurant, over a century old; it was a former workingman's soup kitchen. Renovations have retained most of the old fittings and the waiters still wear the classic uniforms.

***Le Petit Niçois*** - 10, rue Amélie, 7th arrondissement. Tel: 01-45-51-83-65.
This is a seafood restaurant. It's a longish walk from the UNESCO area, but you can work up an appetite! The "soupe de poisson" (fish soup), paella and the bouillabaisse are classics.

***Bistro de Papa*** - 81 Av. Bosquet, 7th arrondissement. Tel: 01 47 05 36 15.
A casual brasserie, open most of the time. Warm atmosphere and reasonably priced.

***Le Troquet*** - 21 rue François Bonvin – go out the back door of the IOC building and up about one block. Basque regional cuisine. Open for lunch and dinner, except Sunday and Monday. Owner/chef.

***Le Suffren*** - At the corner of Aves de Suffren and Motte-Piquet. A "brasserie" - a good bet on a Sunday when many places are closed. If you are brave, try a "degustation" (sampling of various shellfish).

***L'Os à Moelle*** - 3, rue Vasco de Gama, 15th arrondissement Tel: 01.45.57.27.27.
Featured recently in an article about classic Parisian bistros in the Sunday New York Times magazine, I have not tried this one myself, but have heard from a friend that it is excellent. The prix-fixe menu is 38 euros and reservations are essential, possibly even a few days ahead.

***Vin et Marée*** – 71 Avenie de Suffren. Tel: 01-47-83-27-12.
An elegant fish and seafood restaurant, one of four in a chain in Paris. Reservations desirable.

## FACILITIES AT UNESCO

The UNESCO building contains many useful facilities for meeting participants:

- Automatic banking machine – on the main floor, near the Salle des Pas Perdue. There are also many bank machines on the streets in the area near UNESCO.
- Bank with exchange facilities - first floor, main building. Hours: Monday to Friday 09:30 - 12:15 and 13:15 to 17:15
- News stand, selling newspapers in many languages, to the right of the main elevators, near the main entrance
- Travel agency - first floor, main building
- Cafeteria, coffee bar with sandwiches and light snacks, and formal restaurant - 7th floor, main building
- Café/ bar with sandwiches and light snacks, lower level of the Conference Building.

- You may find cybercafés at the following nearby addresses. It is advisable to call to make sure they are still in operation as this list is a year old and these businesses tend to be ephemeral.

***Planet-Cyber café***
173 rue de Vaugirard
Tel: 01 45 67 71 14
10:30am – 8:00pm 6 days a week

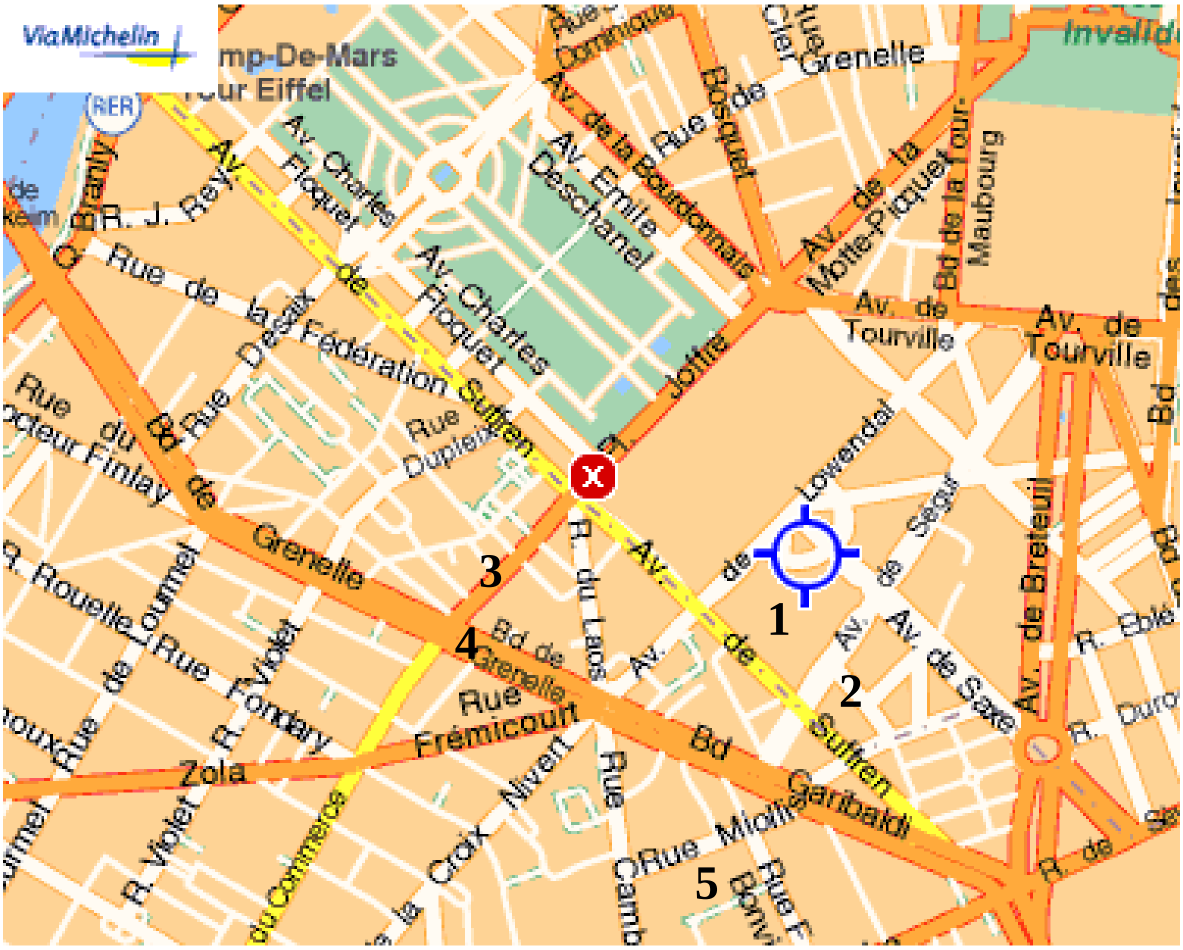
***skool@rena region***
199 Rue de Vaugirard
Tel: 01 44 49 02 03
24/7 closed Sunday 10:00-12:00

***9c.com***
83-85 rue de Javel
Tel **:** 01 56 77 14 00

***Cyber'Act***
32 rue des Volontaires
Tel: 01 53 69 10 60

***Cyberbase***
215 rue de Vaugirard
Tel 01 40 56 06 27

***Naninet CyberCafé***
43 rue Dutot
Tel 01 45 66 55 00

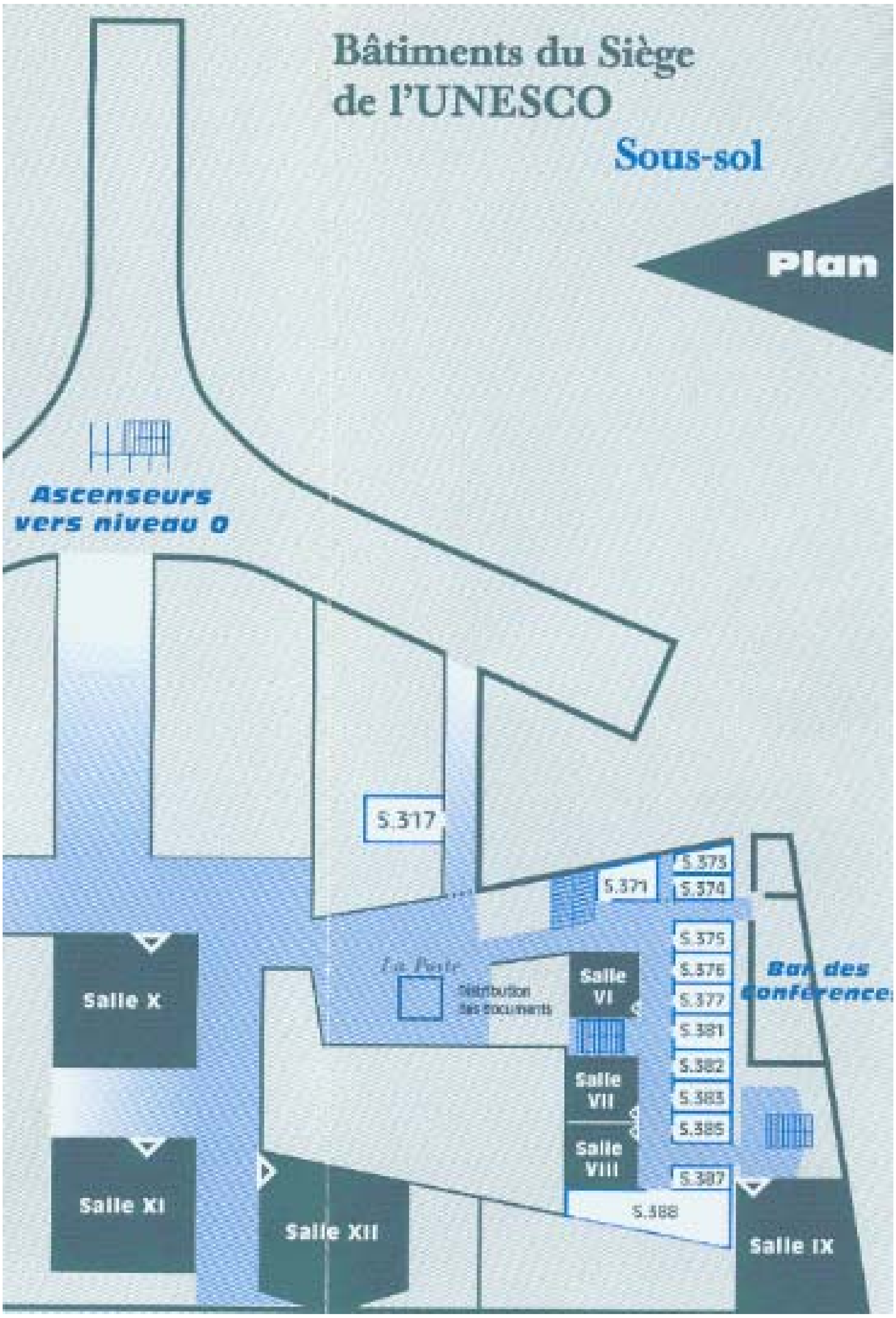



## The Area Around UNESCO

1 UNESCO Main Building
2 Segur Metro stop
3 La Motte Picquet Grenelle Metro stop
4 Cambronne Metro stop
5 UNESCO Annex Building, IOC offices

## PLAN OF THE LOWER LEVEL, UNESCO BULDING

Enter by the main entrance on Place de Fontenoy. Take the elevator, or the stairs behind the elevator, to level -1.



# PROGRAMME SUMMARY

| Monday<br>December 5 | Tuesday<br>December 6 | Wednesday<br>December 7 | Thursday<br>December 8 |
|---|---|---|---|
| 9:00 - 10:20<br>Plenary Session | 08:30 - 10:20<br>Plenary Session | 08:30 - 10:10<br>Plenary Session | 08:30 - 09:35<br>Plenary Session |
| 10:20 - 10:50<br>COFFEE BREAK | 10:20 - 10:50<br>COFFEE BREAK | 10:10 - 10:40<br>COFFEE BREAK | 09:35 - 10:00<br>COFFEE BREAK |
| 10:50-12:10<br>Plenary Session | 10:50-12:30<br>Plenary Session | 10:40-12:30<br>Plenary Session | 10:00 - 10:40<br>Plenary Session |
| 12:30 - 14:00<br>LUNCH | 12:30 - 14:00<br>LUNCH | 12:30 - 14:00<br>LUNCH | 10:40 - 12:30<br>Subgroup Meetings |
| 14:00 - 15:20<br>Plenary Session | 14:00-15:45<br>Subgroup Meetings | 14:00 - 14:20<br>Plenary Session | 12:30 - 14:00<br>LUNCH |
| 15:20 - 15:50<br>COFFEE BREAK | 15:45 - 16:15<br>COFFEE BREAK | 14:20 - 16:10<br>Subgroup Meetings | 14:00 - 14:30<br>Plenary Session |
| 15:50 - 17:00<br>Subgroup Meetings | 16:15 - 17:30<br>Subgroup Meetings | 16:10 - 16:30<br>COFFEE BREAK | 14:30 - 16:30<br>Subgroup Meetings |
| 17:00 - 18:00<br>Plenary Session<br>Subgroup Reports<br>Discussion | 17:30 - 18:15<br>Plenary Session<br>Subgroup Reports<br>Discussion | 16:30 - 17:30<br>Subgroup Meetings<br>Cont’d | 16:30-17:30<br>Plenary Session<br>Final Subgroup<br>Reports |
| Reception<br>Location TBA | | 17:30 - 18:00<br>Subgroup Reports | 17:30<br>End of Meeting |
| | | Dinner<br>Location TBA | |

# PROGRAMME FOR MONDAY, DECEMBER 5TH

0900-0910 **WELCOME OF THE PARTICIPANTS - PRACTICALITIES**
Henrik Enevoldsen

0910-0940 **THE GEOHAB PROGRAMME**
Grant Pitcher (Chair of the GEOHAB-SSC)

0940-1000 **INTRODUCTION : The key questions, Structure of the meeting, Structure of the report**
Patrick Gentien

1000–1020 **FINESTRUCTURE, THIN LAYERS AND HARMFUL ALGAL BLOOMS**
Thomas R. Osborn

1020–1050 ***Coffee Break***

1050–1110 **HABS IN THIN LAYERS – A CHALLENGE FOR MODELLING**
Wolfgang Fennel

1110–11h30 **OCEANIC TURBULENCE AND PHYTOPLANKTON DYNAMICS**
Hidekatsu Yamazaki

1130– 1150 **MIXING PROCESSES IN SEASONALLY STRATIFIED SHELF SEAS**
Tom P. Rippeth

1150–1210 **GENERATION OF SUBSURFACE ANTICYCLONIC EDDIES: NUMERICAL EXPERIMENTS**
Hongqin Xie and Pascal Lazure

1230– 1400 ***Lunch Break***

1400-1430 **CHALLENGES IN MEASURING AND MODELING THE FINESCALE INTERACTIONS CONTROLLING THE DYNAMICS AND IMPACTS OF THIN LAYERS OF HARMFUL ALGAL IN STRATIFIED COASTAL WATERS.**
Percy L. Donaghay

1430–1450 **DISSOLVED ORGANIC MATTER AND THIN LAYERS**
Timothy Wyatt

1450–1510 **A PRELIMINARY MODEL OF THE MECHANICAL EFFECTS OF PHYTOPLANKTON-DERIVED EXOPOLYMERIC SUBSTANCES ON THE DYNAMICS OF PYCNOCLINES**
Ian R. Jenkinson

1510–1520 **Assignments of Subgroups A & B**

**Subgroup A:** The layered environment and the population control factors: How do the physics and chemistry of stratified systems "condition" the environment for maintenance, advection and decay of some HAB species ?

**Subgroup B:** The layered environment and the species' intrinsic properties: Physiological and behavioural adaptations of some HAB species for life in stratified systems

1520–1550 ***Coffee Break***

1550–1700 **Separate Meetings of Subgroups A & B - Rooms to be assigned**

1700–1730 **Preliminary report of the two subgroups in Plenary Session, Room XI**

1700–1800 **General discussion**

1800 - **RECEPTION at UNESCO**

## PROGRAMME FOR TUESDAY, DECEMBER 6TH

0830-0900 **HABS AND STRATIFICATION - A BIOPHYSICAL AND ECOLOGICAL DEPENDENCE OR COINCIDENT SECONDARY EFFECT?**
Theodore J. Smayda

0900-0920 **FLUCTUATING ENVIRONMENTS AND COMPETITION BETWEEN TWO PHYTOPLANKTONIC SPECIES: INFLUENCE OF THE CELL TIME SCALE AND THE SURGE UPTAKE**
Jean-Claude Poggiale and Yves Lagadeuc

0920–0940 **HOW DOES PHOTOACCLIMATATION INFLUENCE PHYTOPLANKTON COMPETITION IN A VARIABLE TURBULENCE ENVIRONMENT?**
Myriam Bormans, Jean Braun and Yves Lagadeuc

0940–1000 **SWIMMING & SALINITY STRATIFICATION**
Rachel N Bearon, Rose Ann Cattolico, Daniel Grunbaum

1000–1020 **PHOTOSYNTHETIC RESPONSES OF A *GYRODINIUM ZETA* BLOOM DURING THE RELAXATION OF UPWELLING OFF THE WEST COAST OF SOUTH AFRICA**
Sophie Seeyave, Grant Pitcher and Trevor Probyn

1020-1050 ***Coffee Break***

1050–1110 **INFLUENCE OF HALOCLINE AND THERMOCLINE TO THE CYANOBACTERIAL BLOOM DEVELOPMENT AND INTENSITY IN THE GULF OF FINLAND (BALTIC SEA)**
Inga Lips and Urmas Lips

1110–1130 **DETECTION AND ENUMERATION OF HARMFUL ALGAL BLOOM SPECIES USING A CONTINUOUS IMAGING FLUID PARTICLE ANALYZER (FlowCAM®)**
Nicole J. Poulton, Harry Nelson, Lew Brown and Chris K. Sieracki

1130–1150 ***DINOPHYSIS ACUMINATA* AND WATER COLUMN STRATIFICATION**
Yolanda Pazos, Ángeles Moroño, Juan Maneiro, Laura Escalera and Beatriz Reguera

1150–1210 **STUDY OF *DINOPHYSIS* POPULATIONS UNDER DIFFERENT STRATIFIED SCENARIOS**
Reguera B., P. Gentien, S. González-Gil, M. Lunven, I. Ramilo and C. Bechemin

1210–1230 **MODELLING HYDRODYNAMIC AND BIOGEOCHEMICAL PROCESSES IN THE TAGUS ESTUARY AREA**
Mateus, M and Chambel, P.

1230–1400 ***Lunch Break***

1400–1545 **Separate Meetings of Subgroups A & B - Rooms to be assigned**

1545–1615 ***Coffee Break***

1615–1730 **Subgroups A & B meetings (cont'd)**

1730–1815 **Progress Reports from the Subgroups and General Discussion in Plenary Session, Room XI**

# PROGRAMME FOR WEDNESDAY, DECEMBER 7TH

0830-0850 **VERTICAL SCALES OF PHYTOPLANKTON PATCHINESS: THEORY, AND OBSERVATIONS USING A FREE-FALLING PLANAR LASER IMAGING FLUOROMETER**
Peter J.S. Franks

0850–0910 **CURRENT STATE OF ZOOPLANKTON SAMPLING.**
Gabriel Gorsky

0910–0930 **ECOPHYSIOLOGY OF PHYTOPLANKTON AT SMALL SCALE: INTERACTIONS WITH TURBULENCE**
Berdalet, Elisa and Marta Estrada

0930–0950 **MOTILITY AND AUTOTOXICITY IN KARENIA MIKIMOTOI**
Patrick Gentien, Pascal Lazure, Michel Lunven and Thomas R. Osborn

0950–1010 **STRATIFICATION, MODELLING AND SALINITY AND ITS IMPORTANCE TO *KARENIA MIKIMOTOI***
Fernand, L., A. Vanhoutte-Brunier, B.A. Kelly-Gerreyn, S. Lyons , F. Gohin, and Raine, R

1010–1040 ***Coffee Break***

1040-1100 **IS THERE A POLEWARD TRANSPORT OF *D. ACUTA* IN NW IBERIA?**
Moita, M.T., Reguera, B., Palma, S., Escalera, L., Cerejo, M. and Cabañas, J.M.

1100-1120 **SMALL SCALE RETENTIVE STRUCTURES AND *DINOPHYSIS***
Hongqin Xie, Pascal Lazure and Patrick Gentien

1120–1210 **ECOLOGICAL IMPORTANCE OF FRESHWATER PLUMES FOR TOXIC *ALEXANDRIUM TAMARENSE* BLOOMS IN THE ST. LAWRENCE ESTUARY (CANADA)**
Juliette Fauchot, Maurice Levasseur, Suzanne Roy, François J. Saucier and Réal Gagnon

1210-1230 **PLANKTON DISTRIBUTIONS, WITH PARTICULAR REFERENCE TO POTENTIALLY HARMFUL SPECIES, IN RELATION TO DENSITY-DRIVEN COASTAL JETS IN THE WESTERN ENGLISH CHANNEL**
Sandra Lyons, Robin Raine, Liam Fernand

1230–1400 ***Lunch Break***

1400–1420 **THE IMPORTANCE OF DENSITY DRIVEN COASTAL JETS IN THE PROMOTION OF HARMFUL ALGAL EVENTS.**
Robin Raine, Sandra Lyons, Glenn Nolan, Juan Brown and Liam Fernand.

1420–1610 **Separate Meetings of Subgroups A & B - Rooms to be assigned**

1610–1630 ***Coffee Break***

1630–1730 **Subgroups meetings (cont'd)**

1730-1815 **Progress Reports from the Subgroups**

## PROGRAMME FOR THURSDAY, DECEMBER 8TH

0830–0850 **SIMULTANEOUS MEASUREMENT OF VERTICAL MICROSTRUCTURE AND CHLOROPHYLL-A IN THE SETO-INLAND SEA OF JAPAN**
Nagao Masayuki, Yoshio Takasugi and Eisuke Hashimoto

0850–0915 **3D FLOW VISUALISATION IN THE COSTAL OCEAN**
Alex Nimmo Smith

0915–0935 **A NEW DEVICE FOR IN SITU VIDEO AND FLUORESCENCE ANALYSIS OF MARINE PARTICLES / APPLICATIONS TO PHYTOPLANKTON STUDIES.**
Michel Lunven, Michel Lehaître, Patrick Gentien, Roger Berric and Erwan Le Gall

0935–1000 ***Coffee Break***

1000-1020 **IN STRATIFIED ENVIRONMENTS, WHERE DO THE NUTRIENTS COME FROM ? OBSERVATIONS OF THE SECONDARY CIRCULATION AND IMPLICATIONS FOR NUTRIENT TRANSPORT, ASSOCIATED WITH A TIDAL MIXING FRONT ON EUROPEAN SHELF SEAS**
L. Fernand, K. Horsburgh, J. Brown, C. Chambers and S. Dye, G. Badin, D. Mills

1020–1040 **VIRTUAL ANTS FOR RETENTIVE STRUCTURES DETECTION**
Marc Segond and Cyril Fonlupt

1040–1230 **Discussions in sub groups**

1230–1400 ***Lunch Break***

1400–1430 **Plenary Session**

1430–1630 **Separate Meetings of Subgroups A & B - Rooms to be assigned**

1630–1730 **Final Subgroup Reports in Plenary Session, Room XI**

17h30 - **End of the meeting**

# FRIDAY, DECEMBER 9TH

The members of the organizing committee (P. Gentien, P. Donaghay, T. Osborn, R.Raine, B. Reguera, H. Yamazaki) will meet for the day in order to finalize the report of the OSM. Any extra contribution is welcomed.

# POSTERS

Any participant may present extra posters. The abstracts for these posters are included in the section that follows.

**STUDY OF PHYTOPLANKTON ALONG ABDA-DOUKALLA COASTAL AREA (MOROCAN ATLANTIC)**
Bennouna Asmae , El Attar Jaouad, Brigitte Berland, Omar Assobhei

**NEW ZEALAND RISK MANAGEMENT AND REGULATORY APPROACH FOR CYANOBACTERIAL BLOOM EVENTS**
Alexander Yu. Kouzminov and Michael E. U. Taylor

**VERTICAL DISTRIBUTION OF PHYTOPLANKTON COMMUNITIES AND RELATIONSHIPS WITH PHYSICO-CHEMICAL PARAMETERS RESOLVED BY A FINE SCALE SAMPLER.**
Lunven M, Guillaud J.-F., Youenou A., Crassous M.-P., Berric R, Le Gall E., Kerouel R., Labry C., Aminot A.

**ASTERIX : AN AUV FOR THE EXPLORATION OF PYCNOCLINE LAYERS**
Opderbecke J., Lemmin U., Osborn T.

# ABSTRACTS

All abstracts, including those for poster presentations, are arranged alphabetically by the name of the first author. This section includes all abstracts together, both for oral and poster presentations. If known, the name of the presenting author has been underlined

## STUDY OF PHYTOPLANKTON ALONG OF ABDA-DOUKKALA COASTAL AREA (MOROCAN ATLANTIC)

Asmae Bennouna (1) , Jaouad El Attar(1), Brigitte Berland(2), Omar Assobhei(3)

A study of phytoplanktonic population was carried out from january 1999 to december 2001 along of Abda- Doukkla costal water included Oualidia and Sidi Moussa Lagoons. Samples were taken bimonthly to weekly during the period of *Lingulodinium polyedrum* red tide. The aim of this study is the quantitative and qualitative evaluation. We have analysed phytoplankton in waters sampling and phycotoxins in shellfishs (mussels, clams and oysters) collected from the same areas. Potentially harmful species detected belong to *pseudonitzschia, Dinophysis, Alexandrium, Gymnodinium, Prorocentrum, Lingulodinium* genera. The *L. polyedrum* red tide accompagned by DSP in shellfish, occured when surface temperature water was 17-18 °C. The apparition of colored strips parallel to the coast is probably caused by phytoplankton aggregation generated by internal waves. Theses waves were created by constant moderate winds blowing in the same direction and with constant speed. The change of climatic conditions might also be the cause of the red tide dispersal.
*Alexandrium spp*. involved in production of PSP have presented a large spatio-temporel variability. At the equal threshold concentration ($10^3$ cell.$l^{-1}$) no PSP toxicity was noticed. *Dinophysis (D.acuminata, D.acuta, D.rotundata, D.caudata* and *D.sacculus)* were presents during all three years of study with a large spatio-temporel variability. Even if some *Dinophysis* densities values were over to the sanitary norms ($4.10^2$ cell.$l^{-1}$) without DSP toxicity, their low concentrations were enough to induct DSP toxicity. It was confirmed by HPLC analysis.

[1] Institut National de Recherche Halieutique (INRH), Station de surveillance de la salubrité littorale, Centre Régional d'Agadir. Agadir. [2] Centre d'Océanologie de Marseille. Station Marine d'Endoume. Rue de la Batterie des Lions. 13007. Marseille. [3] Université Chouiab Doukkali, Laboratoire MAB, Faculté des Sciences d'El Jjadida. El jadida.

## SWIMMING & SALINITY STRATIFICATION

Rachel N Bearon[1], Rose Ann Cattolico[2], Daniel Grunbaum[1]

The formation of toxic surface blooms of the motile raphidophyte Heterosigma akashiwo often occurs too quickly to be attributed to cell reproduction. Rapid appearance of surface blooms is more consistent with the hypothesis that a dispersed cell population aggregates at the surface due to a combination of physical factors and swimming behavior. Because of the frequent association of Heterosigma bloom formation with a decrease in surface salinity, we hypothesize that a layer of low-salinity water over a high-salinity layer will suppress near-surface vertical mixing and this halocline will enable up-swimming cells to rapidly aggregate at the surface. For this hypothesis to be viable, Heterosigma cells must be able to swim across salinity jumps of a sufficient magnitude to temporarily suppress vertical mixing. We tested whether this requirement is satisfied by using computerized video analysis to quantify swimming behavior and vertical distribution of Heterosigma within a vertical salinity structure. Swimming behavior is affected by the presence of a salinity jump and depends on the strength of the jump: cells stopped swimming upwards and aggregated below a fresh water interface; cells reduced upward swimming speed with a salinity jump from 28‰ to 8‰; and upward swimming speed was unchanged in cells encountering a salinity jump from 28‰ to 16‰. We used observed swimming behaviors to parameterize a model of a 2-layer stratified water column in which vertical mixing is suppressed at the halocline and modeled by eddy diffusivity within each layer. The model predicts rapid aggregation of cells to the surface layer. Experimental data verifies the formation of a surface aggregation in a fresher surface layer that overlays a well-mixed lower layer.

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## ECOPHYSIOLOGY OF PHYTOPLANKTON AT SMALL SCALE: INTERACTIONS WITH TURBULENCE

Berdalet, Elisa and Marta Estrada

Most phytoplankton species causing harmful blooms are smaller than (or very close to) the Kolmogorov length scale. At this small scale, many biological aspects are conditioned both by the viscosity and by the turbulent motion of the aquatic medium. At the same time, however, the size, shape and (motility) behaviour of the cells, along with their life-cycle characteristics, modulate their response to the physico-chemical properties of the water. This presentation will summarize the state of the art of these small-scale interactions between physics and biology, with the aim to shed light on our understanding of the dynamics and fate of harmful algal blooms.
Several examples of the direct effect of turbulence on the phytoplankton cell physiology obtained through experimentation in the laboratory will be illustrated. Namely, turbulence interacts with the transfer of molecules (such as nutrients) in or out of the cells, with the cell sedimentation and the contact rates among plankters, it may induce morphological changes, mechanical cell damage and alterations of cell division, growth, life cycle and toxin synthesis. Overall, dinoflagellates appear to be a specially sensitive group to small-scale turbulence, although the degree of response appears to be species-specific.
We will discuss how this available information should be critically considered before trying to extrapolate it to nature. Phytoplankton community and hence, HAB dynamics, result from the interplay among the described ecophysiological responses of the organisms, the environmental forcing and water circulation at a variety of spatio-temporal scales, and the interactions with other biological factors.

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**HOW DOES PHOTOACCLIMATATION INFLUENCE PHYTOPLANKTON COMPETITION IN A VARIABLE TURBULENCE ENVIRONMENT?**
Myriam Bormans[1], Jean Braun[2] and Yves Lagadeuc[1]

Many competition models between different phytoplankton groups have been developed over the last ten years including the role of turbulence and mixing on light availability, the availability of one or more nutrients, and the role of buoyancy. These models have usually been used with constant turbulence characteristics to simulate either a well mixed surface layer or a stratified upper layer.
On the other hand a number of models have represented the effect of photoadaptation on primary production and how mixing at different time scale (daily, wind induced or tidally induced) has influenced the vertically integrated production.
We have developed a Lagrangian model to simulate the effect of photoacclimatation on competition between phytoplankton species forced by a variable turbulence forcing.

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**CHALLENGES IN MEASURING AND MODELING THE FINESCALE INTERACTIONS CONTROLLING THE DYNAMICS AND IMPACTS OF THIN LAYERS OF HARMFUL ALGAL IN STRATIFIED COASTAL WATERS.**
Percy l. Donaghay

One of the major challenges in modeling the dynamics and impacts of harmful algal blooms is to determine the scales that control critical interactions, and then develop techniques to measure those processes and incorporate them into numerical models. This problem is particularly challenging for harmful algae that form layers that are substantially thinner than the multi-meter scales that are typically resolved in physical models or easily sampled from ships. Herein we will first use field data to evaluate the vertical sampling scales needed to resolve the finescale biological, chemical and physical structure of thin layers, and then use those data to evaluate the importance of finescale interactions in controlling the dynamics and impacts of such layers. In a final section we will consider how these processes might be incorporated into models.

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**ECOLOGICAL IMPORTANCE OF FRESHWATER PLUMES FOR TOXIC *ALEXANDRIUM TAMARENSE* BLOOMS IN THE ST. LAWRENCE ESTUARY**
Juliette Fauchot[1], Maurice Levasseur[2], Suzanne Roy[1], François J. Saucier[1] and Réal Gagnon[3]

An extensive research program, including laboratory, field and modeling activities, was conducted in the St. Lawrence estuary, in order to better understand the environmental factors controlling the bloom dynamics of the toxic dinoflagellate *Alexandrium tamarense* and the coincidence between these blooms and freshwater plumes. Estimation of the spatial and temporal variations of the growth rate during a red tide revealed that *A. tamarense* cells were not only physically confined to the Manicouagan and aux-Outardes river plume, but that their growth was also limited to that freshwater plume. Laboratory experiments showed that humic substances isolated from the Manicouagan river can enhance the growth rate of *A. tamarense*. We also observed that *A. tamarense* performed daytime and nighttime vertical migrations in the St. Lawrence estuary. This ability to reach the deep nitrate reservoir at night may allow *A. tamarense* to reach elevated biomass as observed during red-tide events, and could push this species toward phosphate limitation. Finally, the results from a first coupled physical-biological model of *A. tamarense* blooms in the St. Lawrence estuary suggest that the response of the freshwater plume to fluctuating wind forcing controls the spatio-temporal evolution of the bloom. The wind-driven dynamics of the plume could therefore partly determine the success of *A. tamarense* blooms in the St. Lawrence estuary by influencing the residence time of the blooms and the water column stability, which in turn affects *A. tamarense* vertical migrations and growth. Together, these results show that the relationship between dinoflagellate blooms and vertical stratification hides multiple interacting physical, chemical, physiological, and behavioral processes.

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## HABS IN THIN LAYERS – A CHALLENGE FOR MODELLING

Wolfgang Fennel

The talk addresses several aspects of the modelling of the physical biological interactions of HAB's which form thin layers. The requirements of the modelling of such systems are analysed starting from physical processes (vertical mixing, stratification, buoyant plumes), to aspects of food web interactions (cell responses, behaviour, toxin production). The attempt to model annual cycles of HAB's in thin layers reveals lack in understanding and highlights needs for specific interdisciplinary research.

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## IN STRATIFIED ENVIRONMENTS, WHERE DO THE NUTRIENTS COME FROM? OBSERVATIONS OF THE SECONDARY CIRCULATION AND IMPLICATIONS FOR NUTRIENT TRANSPORT, ASSOCIATED WITH A TIDAL MIXING FRONT ON EUROPEAN SHELF SEAS

L. Fernand, K. Horsburgh, J. Brown, C. Chambers and S. Dye, G. Badin, D. Mills

Abstract not available at time of printing.

**STRATIFICATION, MODELLING AND SALINITY AND ITS IMPORTANCE TO *KARENIA MIKIMOTOI***

Fernand, L[1]., A Vanhoutte-Brunier [2], B.A. Kelly-Gerreyn[3], S Lyons[4] , F Gohin[2], and Raine, R[4],

It is well recognized that *Karenia Mikimotoi* blooms are associated with stratified conditions, however, the importance of the contributions from solar heating, salinity and self induced warming are less well understood and are the focus of this paper.
In the summer of 2003 a massive Karenia bloom was identified in the western English channel, this bloom was anonymously large due to a combination of factors. This paper combines results from four projects, two field programs, RV cruises and an EU ferry box route, a satellite imagery program and a comprehensive modelling program.
The importance of the physical structure as a control mechanism to the growth of *K Mikimotoi* is discussed. Comparison between the observations and the model are presented and limitations in the model are discussed along with recommendations for future sampling and modelling. Many of the recommendations have general application beyond the modelling of *Karenia Mikimotoi*

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**VERTICAL SCALES OF PHYTOPLANKTON PATCHINESS: THEORY, AND OBSERVATIONS USING A FREE-FALLING PLANAR LASER IMAGING FLUOROMETER**

Peter J.S. Franks

There is evidence that many HABs initially form in relatively thin layers below the ocean's surface. The vertical extent of these features makes them difficult to sample, hampering our efforts to predict the occurrence and spread of HABs. Using a novel free-falling planar laser imaging fluorometer system, we have observed extensive layering of the phytoplankton on scales of 10's of cm to 10's of m. Thin (1 – 2 m) layers of unique cell types are common, though they often do not appear as maxima in chlorophyll fluorescence profiles. The spatial arrangement of fluorescent particles in our images is consistent with turbulence homogenizing cell concentrations over 10-20 cm scales, and biological processes creating vertical gradients over larger scales. The scales are determined by the strength of the turbulence, and the density stratification. This knowledge may help us to predict the scale of spatial gradients of phytoplankton from hydrographic measurements, and increase our understanding of the likelihood of HAB layer formation, and the scales of herbivore foraging in the ocean.

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**MOTILITY AND AUTOTOXICITY IN *KARENIA MIKIMOTOI***

P. Gentien, P. Lazure, M. Lunven and T. Osborn

Autotoxicity in *K. mikimotoi* was confirmed by the direct application of its synthesised toxin. Behaviour in batches of *K. mikimotoi* results from a trade-off between phototropic concentration of cells and the exploitation of hydrodynamic instabilities. Confinement of the population in the pycnocline results from another trade-off (growth conditions vs. mortality). The deduced growth equation reproduces the gross features of the development of *K. mikimotoi* on the Ushant front.
As this approach relies on intrinsic properties, it allows to reduce the number of parameters needed from several tens to 6, 4 of them being measurable experimentally. The ranking of control factors allows simplification of model formulation and therefore improvement of its robustness. The rate of cell lysis due to collisions should be considered as one of the major control factors of the population growth for this species.

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**CURRENT STATE OF ZOOPLANKTON SAMPLING.**

Gabriel Gorsky

Detectable changes in the abundance or species composition of mesozooplankton may reflect fundamental changes in the ocean environment affecting phytoplankton. In turn, changes in zooplankton communities can provide early indications of imminent changes in the food conditions for higher trophic levels. Because of their keystone trophodynamic role zooplankton should be included in any monitoring and biodiversity assessment network. Sampling, sample processing and data analysis of zooplankton has been addressed in detail a number of times. Different sampling gears and different approaches have different biases, rendering intercomparison of biodiversity between studies and over time difficult. An accurate observation is one with minimal bias that is one that does not contain a consistent over- or underestimate of the true abundance in nature (Cassie, 1968). This talk will deal with the following questions: what are the state and the perspectives of the zooplankton sampling technologies?

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**A PRELIMINARY MODEL OF THE MECHANICAL EFFECTS OF PHYTOPLANKTON-DERIVED EXOPOLYMERIC SUBSTANCES ON THE DYNAMICS OF PYCNOCLINES**

Ian R. Jenkinson

The thickness of a density discontinuity or pycnocline (PC) between an overlying and an underlying mixed layer is commonly modelled using the Richardson number,

$$Ri = \frac{g.\delta\rho/\delta z}{\rho.(\delta u/\delta z)^2} \qquad (1)$$

where $g$ is acceleration due to gravity, 9.8 m.s$^{-2}$, $\delta\rho/\delta z$ is change in density per unit depth across the pycnocline [kg.m$^{-4}$], $\rho$ is the mean density, $\rho$, and $\delta u/\delta z$ is the change in velocity of the water with unit depth (or horizontal shear rate [s$^{-1}$].

Equation (1) simplifies to

$$Ri = \frac{g.\delta\rho.\delta z}{\rho.(\delta u)^2} \qquad (2)$$

where $\delta\rho$ is the density difference and $\delta u$ the velocity difference across the PC (i.e. between its upper and lower faces), while $\delta z$ is the distance between these faces. Where *Ri* excedes a value of ~0.25, the PC is eroded by shear at its upper and/or lower faces, thus reducing $\delta z$, while if *Ri* is less than this value, turbulence occurs in the PC, thickening it by entraining water from the adjacent mixed layers.

Phytoplankton has been found to add shear-thinning viscosity to seawater through its secreted exopolymeric substances (EPS), and since phytoplankton frequently concentrates in PCs, I used an iterative model to investigate the effect of this extra viscosity on $\delta z$. With the equivalent of 1 million cells of *Karenia mikimotoi* /L, and within a normal range of oceanic conditions, $\delta z$ was found to iterate rapidly to zero while shear rate, $\delta u/\delta z$ decreased.

In the real world, however, it should be anticipated that processes and properties not modelled might produce unexpected supplementary effects. Such processes and/or properties might include: 1) vertical diffusion of EPS out of the PC; 2) the tendency of some phytoplankton to concentrate in (or avoid) the PC by swimming and/or buoyancy; 3) complex hydrological effects and their possible interactions with rheological properties of the EPS; 4) environmentally mediated reaction of phytoplankton, leading to production of different types and quantities of EPS; 5) interaction of exopolymeric thickening with the buoyancy effects of differential solar heating of phytoplankton. Furthermore I have not modelled length-scale and geometrical dependence on either rheological properties or turbulent structures but this should be done in future studies.

As the model has found major control of $\delta z$ by commonly found concentrations of phytoplankton, This suggests that PCs are ideal environments for plankton to easily carry out environmental engineering, and thus further their survival and reproduction. Where phytoplankton or EPS are present, the results of this preliminary model show that that there is little point in modelling or trying to understand PC dynamics without having measurements of their EPS-associated biorheological properties.

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**NEW ZEALAND RISK MANAGEMENT AND REGULATORY APPROACH FOR CYANOBACTERIAL BLOOM EVENTS**

Kouzminov, Alexander Yu. and Michael E. U. Taylor

Cyanobacteria bloom events are common seasonal phenomena occurring throughout New Zealand in fresh, estuarine and coastal waters, including those used for drinking-water supplies, recreation and stock-watering. The frequency, intensity, duration and geographic spread of cyanobacterial blooms are expected to increase if the current trends of increased warming and nutrient levels in New Zealand waters continue.
Cyanobacteria may have significant economic impacts from the significant increase in water supply treatment costs or the need to use an alternative source, and there are social impacts from the disruption of recreational use of water bodies.
This paper describes the national criteria for assessing the risk of toxic cyanobacteria in drinking-water supplies that the New Zealand Ministry of Health has developed. These criteria are part of an integrated management system for drinking-water. The main objective of this system is an improvement of the public health management of drinking-water supplies. The various components of this system complement and mutually reinforce each other. The aim of this integrated management system is to achieve an acceptable level of certainty about the water quality through the use of risk management principles to ensure that multiple barriers to cyanotoxins are in place and working properly and to provide a high degree of quality assurance in the safety of the water for all drinking-water supplies, whether these are large or small.

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**INFLUENCE OF HALOCLINE AND THERMOCLINE TO THE CYANOBACTERIAL BLOOM DEVELOPMENT AND INTENSITY IN THE GULF OF FINLAND (BALTIC SEA)**

Inga Lips [1] and Urmas Lips [2]

Nearly all harmful algal events benefit from the thermal stratification – high phytoplankton biomass occurs in the subsurface layer or in a thin layer in the thermocline. After concentrating to the near surface layer the HAB populations may be advected to the coastal areas where they could cause harmful effects. This is a case also in the Gulf of Finland (Baltic Sea) if considering the development of summer cyanobacterial blooms and their advection. While the formation of strong thermal stratification is important for development of dense surface accumulations, the salinity stratification is very important for creating pre-conditions for the formation of intense cyanobacterial blooms in the sea area under consideration. The strength of the permanent halocline at depths of 60-80m plays a key role in determining nutrient concentrations in the near bottom layer and nutrient transport to the upper layers. Strong halocline is one of the factors leading to occurrence of anoxic conditions in the near bottom layer and related release of phosphates from the sediments. Due to the winter convection high concentrations of inorganic phosphorus will be distributed over the whole water column. In summer several hydrophysical processes (upwelling, vertical turbulent mixing) will bring “excess” (low N:P ratio) phosphorus to the upper layers and thus are supporting the cyanobacterial bloom development and influencing its intensity. Since the strength of the permanent halocline in the Gulf of Finland indirectly depends on the irregular saltier water inflows from the North Sea to the Baltic Sea, the preconditions for the intense cyanobacterial blooms are settled for a relatively long period. However, that, whether an intense bloom is developed or not, is determined by the meso-scale processes and meteorological conditions in a certain year (summer).

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## VERTICAL DISTRIBUTION OF PHYTOPLANKTON COMMUNITIES AND RELATIONSHIPS WITH PHYSICO-CHEMICAL PARAMETERS RESOLVED BY A FINE SCALE SAMPLER.

Lunven M, Guillaud J.-F., Youenou A., Crassous M.-P., Berric R, Le Gall E., Kerouel R., Labry C., Aminot A.

Many studies in coastal areas have shown the existence of thin chemical and biological layers. Their thickness and vertical extension are mainly controlled by hydrological and physical forcing. An accurate description of the phytoplankton communities growing within these layers is difficult to obtain without a well-adapted sampling system. A new Fine Scale Sampler (FSS) has been designed in Ifremer in order to study phytoplankton distribution and associated dissolved properties in high stratified water column. This FSS consists in a vertical array of 15 sampling bottles, horizontally laid with 20 cm intervals. Data acquired from a CTD and Fluorescence probe provide a precise FSS positioning at the depth of highest density gradient or at chlorophyll a maximum. For two seasonal situations (spring and summer), the FSS allowed us to investigate micro-scale vertical distribution of phytoplankton species and relationships with physico-chemical parameters in the Loire estuary. For both situation, it was shown that the vertical distribution of phytoplankton communities was very variable. In summer conditions, the diatom *Chaetoceros sociale* was dominant in the phytoplankton peak located below the pycnocline and a thin layer of *Dinophysis acuminata* was detected 1 m above, in nutrient depleted conditions.

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## A NEW DEVICE FOR IN SITU VIDEO AND FLUORESCENCE ANALYSIS OF MARINE PARTICLES. APPLICATIONS TO PHYTOPLANKTON STUDIES.

Lunven M., Lehaître M., Gentien P., Berric R., Le Gall E.

A new video-microscope has been developed for in situ investigation on marine particles. A field of view is produced by a laser beam at 473 nm. Individual cells or particles that entered this field of view appear as individual diffraction-limited spots of light, which are resolved from the dark background. A mobile high-pass optical filter (610 nm) can be controlled and displaced in front of the CCD camera, allowing simultaneously imaging and discrimination between fluorescing and non-fluorescing particles. We have the possibility to add a band pass filter for phycoerytrin detection. The system allows white light visualisation of particles ranging from 10 µm to several millimetres, depending on the zoom magnification. With the 610 nm high pass filter, the light detected by the CCD is mainly due to chlorophyll fluorescence (phytoplankton). Image processing allows to extract information on the particle characteristics such as size, shape, number or movement trajectories. In coastal ecosystem studies, this new device is well adapted to the description of phytoplankton populations variability. Integrating this new technique on conventional profiler will make possible a new sampling strategy for toxic dinoflagellates study.

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**PLANKTON DISTRIBUTIONS, WITH PARTICULAR REFERENCE TO POTENTIALLY HARMFUL SPECIES, IN RELATION TO DENSITY-DRIVEN COASTAL JETS IN THE WESTERN ENGLISH CHANNEL**

Sandra Lyons[1], Robin Raine[1], Liam Fernand[2]

Two oceanographic surveys of the western English Channel were carried out during June and August of 2003. A high-frequency undulating towed-CTD coupled with traditional hydrocast water sampling at selected stations using a CTD rosette were employed. Measurements of the physical environment revealed strong bottom fronts to the west of Brittany and along the southern coast of England. Flows associated with these fronts were evidenced by the tracks of satellite tracked drifters deployed during the surveys. In the centre of the region the flows were weaker due to a combination of tidal and wind driven residuals.

Surface seawater in the western English Channel was visibly discoloured in late June/early July. Examination of water samples revealed that this was due to an exceptional bloom of the red tide-forming dinoflagellate Karenia mikimotoi, cell densities of which reached 3.8 million cells per litre. Surface chlorophyll levels associated with the bloom reached a maximum of 69 mg $m^{-3}$, and both underway measurements and satellite imagery revealed the bloom to be located in the central area of the Channel between 3 and 5° West.

Cell densities of K. mikimotoi were substantially reduced in late August, when blooms of the diatom Pseudo-nitzschia and the coccolithophore Emiliania huxleyi were observed. Multivariate statistical analyses (TWINSPAN and DECORANA) were used to summarise the phytoplankton data from both cruises.

Without doubt, the most important aspect of physical oceanography relevant to harmful events in the near-shelf/coastal region is the presence of density-driven coastal jets. The potential for a transport pathway for Karenia populations associated with these jet-like flows along the bottom density fronts from Ushant, across the English Channel and around the perimeter of the Celtic Sea is discussed, with particular reference to the historical distribution of exceptional blooms of this organism in this region.

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**MODELLING HYDRODYNAMIC AND BIOGEOCHEMICAL PROCESSES IN THE TAGUS ESTUARY AREA**

Mateus, M.[1] and Chambel, P.[2]

Over the last 20 years IST/Maretec research group and Hidromod (a small private company of former phD students of IST/Maretec) have been developing the MOHID numerical lab (http://www.mohid.com). Given its versatility and wide spectra of modelled processes for marine systems, the MOHID system is presently a basic tool in many scientific programs of various research fields. Over the years it has been used to evaluate the formation of nepheloid layers due to internal tide activity in submarine canyons (the Nazaré Canyon), to study the larvae transport along the Portuguese coast, to estimate the mussel production in places like Ria de Vigo (Spain, Galicia) and in Oosterschelde, and to study the biogeochemical processes in the Tagus estuary.

In the last decade the MOHID development team has focus its effort in modeling the main physical and biogeochemical processes in the Tagus system (the major Portuguese estuarine system). The exponential increase of questions about this particular system has lead to more monitoring programs and modelling effort. In this context, the MOHID model has been extensively used to test hypothesis about the underlying controlling mechanisms of the Tagus dynamics. In this framework, the MOHID model was developed to become an integrated modeling system.

Since 2002 a local operational system is being implemented for the Tagus estuary area, merging atmospheric, hydrodynamic and biogeochemical modeling results with field data campaigns, automatic data acquisition stations and remote sensing. This system has been running a 3D baroclinic hydrodynamic model daily since 2002 with a model domain covering the all Tagus interior and the adjacent coastal region of fresh water influence. In addition, a simple NPZ biogeochemical model for the Tagus interior has also been running.

In the framework of projects associated with IBIROOS task team of EUROGOOS, the MOHID model has been upgraded. One of the first planned steps is to run in a daily basis the new biogeochemical model reflecting the state-of-the-art in biogeochemical marine models (with several functional groups of producers and consumers, the microbial loop, explicit control of several nutrients in production, variable stoichiometry, myxotrophy, etc.). This model has already been implemented to the Tagus estuary interior but not to the coastal area.

The ability of the system to reproduce the main processes in the estuary interior and ROFI area has been confirmed with periodical validations. So far, the validation effort leads us to conclude that the model is able to reproduce the main variability forced by wind, tide and water masses exchange with the estuary. Also, the new biogeochemical model has been applied to the Tagus and was able to reproduce the major observable spatial and temporal patterns of nutrient concentrations and phytoplankton biomass and composition.

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**IS THERE A POLEWARD TRANSPORT OF *D. ACUTA* IN NW IBERIA?**

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*Dinophysis acuta* is a regular component of the phytoplankton in Iberian coastal upwelling waters but blooms normally occur between Cape Carvoeiro and Cape Finisterre, where stratification is enhanced by a wider and flatter continental shelf. Data from monitoring and oceanographic cruises in Galicia and Portugal between 1987 and 2004 were selected to compare upwelling conditions when record concentrations (up to 5 x $10^4$ cell $l^{-1}$) of the species were observed only in Portugal or extended to the whole region. The dynamics of *D. acuta* blooms seems to be regulated by upwelling. Intense upwelling pulses inhibit the species development. By contrast, upwelling relaxation/downwelling conditions favour the increase of *D. acuta* concentrations, both by *in situ* growth (*e.g.* thin layer formation) and/or physical accumulation (convergence areas). Years characterized by low upwelling conditions favour *in situ* growth along the whole NW Iberian coast. The DSP outbreaks associated with *D. acuta* occur firstly on the Portuguese coast, with an "epicentre" off Peniche-Aveiro where it is detected from May, reaching dense populations from July onwards. In autumn, with the end of the upwelling season and intensification of the poleward surface circulation, blooms occur further north in the Galician Rías Baixas, highlighting evidences for a northward transport of *D. acuta* blooms.

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**SIMULTANEOUS MEASUREMENT OF VERTICAL MICROSTRUCTURE AND CHLOROPHYLL-A IN THE SETO-INLAND SEA OF JAPAN**

Nagao, Masayuki ,Yoshio Takasugi, and Eisuke Hashimoto

Magnitude of vertical mixing in coastal region affects both physical and biological phenomena. Examples of physical phenomena include formation and disruption of stratification, vertical transportation of suspended particle, and transition of tidal front and stratified flow. And examples of biological phenomena include movement of marine plankton. Small eddies in the sea water with a length of from 1mm to 10cm determine magnitude of vertical mixing, and also should have great effect on life stage of marine plankton which has short body length. Therefore, if we can incorporate vertical microstructure of small eddies, another physical quantities, and movement of marine plankton into environmental diagnosis, investigation of the mechanism of environmental problem such as red tide may progress more than present. However, by comparison with the direct measurement of microstructure in the ocean, the microstructure measurement in the coastal region is more difficult because of the complicated variation of the oceanographic condition. For this reason, for the observation in the coastal region the different observation method from the ocean has been strongly desired. For this purpose we have developed a free-rising micro-scale profiler and conducted simultaneous measurements of vertical microstructure and chlorophyll-a several times in the Seto Inland Sea of Japan. In this paper we will outline some results of measurement in order to study correlation between vertical microstructure and movement of phytoplankton.

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**ASTERIX : AN AUV FOR THE EXPLORATION OF PYCNOCLINE LAYERS**

Opderbecke J., Lemmin U. and Osborn T.

Abstract not available at time of printing.

**3D FLOW VISUALISATION IN THE COASTAL OCEAN**

Alex Nimmo Smith

Turbulence in the coastal ocean affects the spread of pollution as well as the distribution of sediment and biological material. Turbulence is known to be generated intermittently close to the seabed in tidal flows, but there is still limited understanding of its structure and evolution through the water column. In situ observations using 2D Particle Image Velocimetry (2D-PIV) show that groups of coherent vortical structures play a key role in the transfer of energy from the mean flow to turbulence. Previous work has also shown the striking impact that coherent structures generated near the seabed have on the dispersion of oil and sediment once they have evolved to fill the entire water column. Here we present results from a novel submersible 3D Particle Tracking Velocimetry (3D-PTV) system which has been developed to elucidate the form and dynamics of the coherent vortical structures within the bottom boundary layer of the coastal ocean. The system uses multiple synchronised high resolution digital cameras (four 1004 x 1002 pixels, 30 frames/s, 8-bit), viewing a sample volume (20x20x20cm^3) from different angles, to locate and track naturally occurring suspended particles (sediment, plankton etc.) in three dimensions, and hence visualise the fluid motions. The submersible 3D-PTV system has now been deployed a number of times close to the seabed in Plymouth Sound, UK. Data were collected in 30s duration bursts at 25Hz, with auxiliary velocity measurements provided by a 3D ADV and shipboard ADCP. Time series of 3D distributions of velocity and vorticity reveal that the flow comprises of intermittently occurring coherent vortical structures, consistent with previous 2D-PIV observations. However, these new 3D observations provide unique insight into the form, scales and orientations of these important flow features.

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**FINESTRUCTURE, THIN LAYERS AND HARMFUL ALGAL BLOOMS**

T.R. Osborn

Finestructure is the label for meter scale features in temperature and salinity caused by the shearing motion of the flow. The motion includes both large scale, two-dimensional circulation and internal waves. Thin layers are driven by the same physical processes. However, thin layers are also forced by biochemical processes which interact and couple with the physical processes. While the coupling of processes may relate the biochemical layers to physical layers, it is the vertical shear of the horizontal currents in conjunction

with the horizontal gradients that have a major role in forming both thin layers and finestructure.

Since the background distributions of biological, chemical, and physical parameters differ significantly, there is no *a priori* reason for thin layers and fine structure features to be firmly locked together. Measurements must include the vertical profile of the horizontal velocity with resolution at the vertical scale of the thin layers in conjunction with the variation in horizontal and vertical distributions of the biological, chemical, and physical fields.

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## *DINOPHYSIS ACUMINATA* AND WATER COLUMN STRATIFICATION

Yolanda Pazos[1], Ángeles Moroño[1], Juan Maneiro[1], Laura Escalera[2] and Beatriz Reguera[2]

*Dinophysis acuminata*, the main agent of DSP events in Galicia (NW Spain), is present in the region throughout the year, and exhibits peaks and troughs between March and October. This persistence results in prolonged closures (up to 9 months in some areas) of shellfish harvesting in an area with an annual production over $250 \cdot 10^3$ t of mussels. *Dinophysis* spp. proliferations have been often related with stratification, but each species of *Dinophysis* have a suite of growth-favourable water column conditions that need to be quantified. In the Galician Rías, maxima occur associated with thermohaline stratification and with downwelling events. Thermohaline stratification inside the rías, from May until the end of August, can occur as a result of increased insolation and moderate upwelling pulses combined either with heavy runoff (temperature-salinity driven stratification) or just with heavy insolation during dry spells in July-August (thermally-driven stratification). Here we analyzed the weekly distribution of *D. acuminata*, between 1992 and 2005, in relation with water column stability estimated as the Brunt- Väisälä frequency (BV) from CTD readings. We chose one station (Bueu) in Ria de Pontevedra, within the 40 stations of the monitoring programme, as the station where DSP outbreaks are most severe. A dome-shaped relationship was observed between *D. acuminata* and the water column stability estimates. High numbers of this species ($> 10^3$ cell $\cdot$ $l^{-1}$) appeared distributed within a window of opportunity of 1-2 $s^{-1}$ BV. We discuss why values of BV above this window are not favourable for *Dinophysis acuminata*.

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## FLUCTUATING ENVIRONMENTS AND COMPETITION BETWEEN TWO PHYTOPLANKTONIC SPECIES: INFLUENCE OF THE CELL TIME SCALE AND THE SURGE UPTAKE

J.-C. Poggiale[1] and Y. Lagadeuc[2]

This work aims to propose a new approach of the well-known plankton paradox in the marine environment. Predation, spatial and temporal heterogeneities are commonly suggested as factors able to support the coexistence of two species on one resource, contradicting the competitive exclusion principle. We focused our analysis on the fact that phytoplankton cells are able to respond very fast to fast variations of food availability. In a chemostat, where the principle exclusion is often observed, the input of nutrient is usually almost continues and constant. However, in a natural marine environment, phytoplankton cells must face to the turbulence effects on food availability. In this case, the cells may receive an intermittent amount of nutrient, with fast variations. In this work, we proposed a simple model which takes into account the capability of cells to acclimate to rapid variations of nutrient (surge uptake). We provided an analysis of this model and exhibited on numerical simulations the effect of the surge uptake on the growth and on the competition between two species for one resource. We show that the competition may vary according to the way in which the resource is provided.

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## DETECTION AND ENUMERATION OF HARMFUL ALGAL BLOOM SPECIES USING A CONTINUOUS IMAGING FLUID PARTICLE ANALYZER (FlowCAM®)

Nicole J. Poulton[1], Harry Nelson[2], Lew Brown[2] and Chris K. Sieracki[2]

Phytoplankton detection, specifically of harmful algal species, has a requirement for continuous monitoring either at a stationary location (floating dock or laboratory) or aboard a ship. A major drawback of monitoring using standard microscopes for identification and enumeration in a laboratory or from field samples is the amount of time required for analysis. Fluid Imaging Technologies Inc. has developed an instrument for phytoplankton detection called a FlowCAM® (Flow Cytometer And Microscope). FlowCAM®, combines the capabilities of a flow cytometer with a digital-imaging microscope and automates phytoplankton detection and enumeration. Flow cytometry has been used to study the physiology and ecology of phytoplankton species that have unique sizes and pigments. However, larger size classes of phytoplankton, which include many toxic or harmful algal species, often cannot be discriminated from other phytoplankton species based on size and autofluorescence alone. Every particle or phytoplankton image captured by the FlowCAM® is saved for further identification. In addition to autofluorescence collection the length and width of each particle is also determined. Using a combination of specific aspect ratios (ratio of maximum length to maximum width), images and autofluorescence, different phytoplankton species including harmful algal species can be identified and enumerated in the laboratory and possibly environmental samples depending on the cell concentration in the field and depth of collection. The key benefits of this technology are the ability to analyze phytoplankton continuously not only from the surface but possibly from different depths, determine size (length and width), and most importantly the collection of digital images for further analysis in post-processing. A series of case studies shall be presented.

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**THE IMPORTANCE OF DENSITY DRIVEN COASTAL JETS IN THE PROMOTION OF HARMFUL ALGAL EVENTS.**

Robin Raine[1], Sandra Lyons[1], Glenn Nolan[1], Juan Brown[2] and Liam Fernand[2].

The seasonal development of thermal stratification promotes coastal jets along coastlines. These flows are found along parts of the English and Irish coastline. Although seasonal in nature, they provide an important transport mechanism for planktonic organisms including HAB species. Summer flows occur across the English Channel, along southern England, clockwise around the Celtic Sea and northwards along the Irish west coast. The flows have been measured using high resolution towed undulating CTD, satellite tracked drogues and moored current meters.

Evidence is presented linking the flows to occurrences of high cell densities of *Karenia mikimotoi* and *Dinophysis spp.* which are often observed in summer in these near shelf regions. These populations result in either exceptional surface blooms, which when advected onto the coast have been associated with mass mortalities of farmed finfish and shellfish, or contamination of shellfish with biotoxins respectively. The implications of density driven coastal jets in using transport models is discussed.

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**STUDY OF *DINOPHYSIS* POPULATIONS UNDER DIFFERENT STRATIFIED SCENARIOS**

Reguera, Beatriz [1], Patrick Gentien[2], Sonsoles González-Gil[1], Michel Lunven[3], Isabel Ramilo[1] and Christian Bechemin[2]

Production of lipophilic shellfish toxins. by dinoflagellates of the genus *Dinophysis*.that contaminate bivalves above regulatory levels, constitute the main threat to shellfish exploitations in South Western Europe. Nevertheless, the causative organisms occur, most of the year, in low concentrations (< $10^2$ cell · l-$^1$), or in very patchy distributions that render their study with conventional sampling methods an impossible task. Here we present two scenarios, with low *Dinophysis* numbers, that represented the wax and wane respectively of populations that caused prolongued bans of shellfish harvesting:–August 2003 in Ria de Vigo, with thermal stratification and a very moderate populations (< 5 · $10^2$ cell · $l^{-1}$) of *D. caudata* and *D. acuta*, and June 2005 in Ria de Pontevedra with a declining population of *Dinophysis acuminata* apparently embedded in a diatom-dominated community. With the aid of innovative instrumentation, such as the IFREMER-Particle Profiler and the IFREMER-Fine Scale Sampler, and size-fractioning of the population, it was possible to describe in detail: i) the vertical distribution of *Dinophysis* spp. and accompanying species in relation to microscale distribution of physical properties; ii) the identification of layers, where *Dinophysis* spp. populations exhibited their maximum division rate, of that just acted as retention layers under suboptimal circumstances for *in situ* growth. Additional experiments were carried out to test the response of *Dinophysis* isolates to different fractions of dissolved organic matter (DOM) concentrated by ultrafiltration. A critical review of the procedures their technical constraints is given.

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**MIXING PROCESSES IN SEASONALLY STRATIFIED SHELF SEAS**
Tom P. Rippeth

Water movement, the energy budget and the seasonal water column structure in most continental shelf seas is dominated by the barotropic tide. Although the barotropic tide essentially sets the extent to which seasonal stratification forms (ie. Simpson & Hunter, 1974; Nature, 250, 404—406) we will demonstrate that the across thermocline fluxes in these regions is largely a result of much less energetic phenomena such as the internal tide and wind driven near inertial oscillations. We will also describe the phenomenon of 'Strain Induced Periodic Stratification' (SIPS), which results from the interaction of the off-shore density gradient with the shear in the barotropic tidal current, and which produces a periodic switching of the water column between the mixed and stratified states on semidiurnal and monthly timescales.

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**PHOTOSYNTHETIC RESPONSES OF A *GYRODINIUM ZETA* BLOOM DURING THE RELAXATION OF UPWELLING OFF THE WEST COAST OF SOUTH AFRICA**
Sophie Seeyave[1], Grant Pitcher[2] and Trevor Probyn[2]

The West Coast of South Africa is regularly subjected to extensive Harmful Algal Blooms (HABs), typically during the late austral summer. Coastal accummulation of extensive dinoflagellate blooms are associated with the relaxation of wind- driven upwelling. It is thought that these blooms are initiated offshore, then advected inshore and transported poleward by an inshore counter current. The study presented here was carried out during a 2 week period (15-27th March 2001) at a monitoring station off Lambert's Bay. A bloom of the dinoflagellate *Gyrodinium zeta* was observed towards the end of survey, reaching a maximum surface chlorophyll concentration of 130µg $L^{-1}$. The productivity of the bloom was 184mgC $m^{-3}$ $h^{-1}$ and was mostly attributed to cells smaller than 20µm, as was the biomass. The temperature profiles showed that an upwelling pulse occurred prior to the bloom (20-21st March), then surface warming (from 11.5°C on the 21st to 15.5°C on the 27th) and stratification took place. High nitrate concentrations (~23µmol $L^{-1}$) were observed in association with the upwelling pulse, which were then rapidly depleted by the bloom (0.03µmol $L^{-1}$ on 27th). The photosynthetic parameters Pm*, α* and Ek all increased during the bloom. A multiple linear regression of surface α* versus Pm* shows a significant positive correlation ($r^2$ = 0.74), which suggests Ek-independent variability of Pm* and α* as a possible mechanism favouring growth and development of the bloom. Mean Pm* (n=5) was 7.2mgC$m^{-3}h^{-1}$ (±1.9) at the surface, and 4.6mgC$m^{-3}h^{-1}$ (±1.3) at 10-15m ; α* was 0.04 (±0.01) at the surface and 0.05 (±0.01) at depth ; Ek was 168 (±25) at the surface and 100 (±20) at depth. The difference was only significant (paired t-test, $p<0.05$) for Ek. This suggests that the water column was generally stratified, with a thin (~10m) surface layer favouring the growth of high light-adapted phytoplankton, and that increased stratification (as deduced from a greater disparity between surface and deep photosynthetic parameters) led to higher biomass.

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**VIRTUAL ANTS FOR RETENTIVE STRUCTURES DETECTION**

Segond, Marc and Fonlupt, Cyril

The presence and density of animal species in the ocean and coastal waters are often conditioned by the presence of physical structures, such as upwellings, temperature fronts, or vortices. In the case of the anchovy in the Gulf of Biscay, biologists from the IFREMER institute (French Institute for Exploitation of the Sea) want to investigate the relationship between the presence of such structures and fish demography. To verify this hypothesis, one difficulty is automatically and efficiently identifying such patterns in massive datasets, in order to match their presence against biologists' observations and fisheries statistics.
This problem is clearly difficult, since it partly relies on experts' advice on the significance of structures and thus it has no complete formal characterization available. Only local properties could be based on strong physical background, and these properties appeared too weak to correctly classify retentive structures: sensibility (true positive rate) is excellent, but specificity (false positive rate) is a lag behind. Moreover, due to the same cause, local based methods seem unable to accurately retrieve the global shape of structures. On the opposite, schemes based on the fusion of information at a more global level should prove more efficiency for outlining structure envelopes.
The ant algorithm used here was easily designed because it allowed an intuitive approach, as is often the case with artificial ants when the problem can be expressed in term of "optimal movements over a discrete structure".
The performance is very good, reaching 100% true positives for the lowest number of false positives. It should be noted that it is obtained by combining ten detections results, in a multi-start fashion that is familiar to practitioners of stochastic search. This is interesting since stochastic search was not favoured at first by oceanographers (for fear of the variability of results) and also because the problem appeared at first as oriented either towards machine learning or specialized physical method, whereas ant algorithms are seldom used besides the pure combinatorial optimization domain. This ant based software is in fact able to detect retentive structures in stream maps without falling into the classical tricks of this kind of detection, that is to say stream perturbations in coastal waters. This method has the advantage to be able to take in account both global and local information from the stream map to filter detection noise and focus on retentive structures as considered by the expert.

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**HABS AND STRATIFICATION - A BIOPHYSICAL AND ECOLOGICAL DEPENDENCE OR COINCIDENT SECONDARY EFFECT?**
Theodore J. Smayda

The paradigm that dinoflagellate HABs and red tides require a stratified water column for their blooms is analyzed applying experimental ecophysiological data and the recorded bloom dynamics of natural populations. The need to distinguish between the different types of dinoflagellate life-forms that bloom, rather than to assume uniform behavior when evaluating the HAB - stratification paradigm is demonstrated. Based on the relationships between temperature and cellular growth rate, and temperature and motility rate of representative HAB species established experimentally, it is demonstrated that sub-optimal temperatures often delay the seasonal appearance of many HAB species until a threshold temperature of approximately 15$^{o}$C is reached. This thermal threshold and period of seasonal warming usually occur after the spring diatom bloom terminates, accompanied by increased irradiance, day length, euphotic zone deepening and watermass stratification. Sverdrup' s critical depth concept successfully applied to spring diatom bloom initiation does not apply to dinoflagellate blooms. The experimental evidence that HAB taxa biophysically tolerate relatively high turbulence rather than require a vertically quiescent watermass is considered. From these various relationships, the conclusion is reached that the common restriction of HAB dinoflagellates and their blooms to stratified watermasses is a default consequence of their temperature requirements. That is, turbulence avoidance does not explain their seasonal bloom patterns, nor do most HAB species require watermass stratification, either biophysically or ecophysiologically, to occur, to complete their life cycle, or to bloom. In fact, most of these species are specifically adapted to exploit the nutrient, irradiance and other habitat conditions commonly associated with stratified habitats. The adaptive mechanisms resulting in blooms and used by the various HAB dinoflagellate species to exploit nutrient resupply in stratified waters, their nutrient uptake features, and the role of small scale turbulence and the characteristic microzooplankton grazer communities usually found then are considered. This analysis is carried out from the perspective of seeking to establish more firmly the ecological zone(s) of HABs depicted in Margalef's Mandala, and to help quantify why HABs are common in stratified waters, even when and where oligotrophic.

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**DISSOLVED ORGANIC MATTER AND THIN LAYERS**
Timothy Wyatt

A comparison can be made between metazoan tissues and the local environment surrounding phytoplankton cells in bloom conditions in thin layers. Macromolecules occupy between 5% and 40 % of intracellular space, which is therefore described as *crowded*. These polymers include both molecular machines and structural elements. Crowding, and the synchronization of metabolic activities, counteract the drawbacks of molecular diffusion and mass action. The high production rates of exopolymeric dissolved organic matter (DOM) by many bloom species, and their chemical characteristics, indicate their role may be to modify the intercellular environment, to alter dissipation rates, to manipulate the dictates of physical and chemical laws, and to reinforce the persistence of thin layers. If such arguments can be sustained, then thin layers can be viewed as external tissues, which provides a new window on the population dynamics of blooms. Key parameters in such arguments are the phase volumes of cells and DOM, both of which are at present poorly constrained.

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## SMALL SCALE RETENTIVE STRUCTURE AND *DINOPHYSIS*

Hongqin Xie[1], Pascal Lazure[1] and Patrick Gentien[2]

Despite its rarity, *Dinophysis acuminata* is in terms of economic impact, the first toxic algal species along the coasts of Western Europe. It is observed at low levels (< 20 cell.$l^{-1}$) all the year round but toxic events occur mainly in late spring and summer. *D. acuminata* ecophysiology is largely unknown due to the inability of culturing it. Therefore, standard biomass models based on inorganic nutrition are largely inadequate. Presently, any progress in describing the conditions of population growth of this species will be a step forward to prediction of harmful events at the coast.
Eddies selected on the basis of three basic rules (temperature threshold, minimum duration and subsequent advection to the coast) are directly involved in *Dinophysis* population dynamics. Examination of the hydrodynamic climate at the proper scale can support prediction of coastal events with a reasonable power as judged from a 12-years time series.
From this preliminary work, we conclude, eddy establishment in the coastal area is directly related with the *Dinophysis* season beginning in Baie de Vilaine, but with the *Dinophysis* early start in Baie de Quiberon Belle Ile, Lorient and Concarneau. From these results, we can draw the conclusion that *Dinophysis* population build up occurs in retentive zones and that hydrodynamical controls are essential.

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## GENERATION OF SUBSURFACE ANTICYCLONIC EDDIES: NUMERICAL EXPERIMENTS

Hongqin Xie and Pascal Lazure

Small-scale subsurface anticyclonic eddies are common in the Northern Bay of Biscay at scales matching the critical scales for phytoplankton. A sigma ($\sigma$)-coordinate three-dimensional ocean model is applied to study the formation processes of small scale anticyclone in the Bay of Biscay.
A small scale anticyclonic eddy is generated just offshore of the Vilaine Bay and usually localize in subsurface.
The geographic location of the eddies revealed by simulations is remarkably stable through the year: they should be topographically trapped. The anticyclones are suggested to form by baroclinic instability on sloping bottom, gaining energy from vertical sheared horizontal current.

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**OCEANIC TURBULENCE AND PHYTOPLANKTON DYNAMICS**
Yamazaki, Hidekatsu

Upper ocean turbulence is briefly reviewed. In order to compare the intensity of turbulence and planktonic swimming ability, a simple turbulence experiment is introduced. Because turbulence is not free from the law of physics, it is not a random motion. Organized structures in turbulence are important aspects to investigate. Marine particles can be aggregated by these structures. Intermittency is another important aspect of turbulence, because large shear region takes place in a limited space. The effects of intermittency for plankton dynamics are considered. Finally, a new data set obtained from free fall turbulence profiler (TurboMAP) is presented to show high-resolution (mm scale) fluorescence field in turbulence.

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