CNRS Summer School

Active transport in the Ocean: Turbulence, Chemistry & Biology

July 2nd - 6th 2018, Wimereux, France

Presentation

The spatio-temporal variability of chemical substances and microorganisms in the ocean is the result of the combined action of the turbulent dynamics of the carrying fluid flow and of a variety of processes taking place at sub-millimetric scales. One can think for instance of molecular diffusion, chemical reactions or the feeding and mating of microorganisms. Recent technological advancements on biogeochemical probes allow access to highly-resolved field measurements and makes oceanic active/reactive transport studies a fast developing domain. In this context there is a need for the development of theoretical and numerical modelling of the ocean biogeochemical variability at the smallest spatial and temporal scales.

The terms “active transport” correspond to quantities transported by the turbulence, where the concentration of the quantities can change due to chemical reactions or biological activities. This is potentially the case for all dissolved geochemical quantities, and also for living planktonic particles transported by the flow (bacteria, viruses, phytoplankton, zooplankton).

The aim of the present school is to offer an overview of the rich phenomenology of active transport and mixing in the ocean and at the same time to present the modelling tools that are currently in use, or can be adopted, to better understand biogeochemical dynamics. The one-week program is built around mini-courses (4:30 hours) and extended seminars (1:30 hours) delivered by specialists in the field. The lectures are intended to be pedagogical but will also give perspectives on open problems and present research challenges.

The school focuses on the three following main topics:

- Ocean turbulence: theory, modelling, experiments
- Ocean biogeochemistry: phenomenology and experiments
- Modelling complex flow systems from chemistry to microorganism population dynamics: theory and numerical approaches.

Organisation

The Summer School is organized by:

- **François G. Schmitt**, CNRS Research professor, Director of Laboratory of Oceanology and Geosciences, France
- **Stefano Berti**, Associate professor, University of Lille, Lille Mechanics Unit, France
- **Enrico Calzavarini**, Associate professor, University of Lille, Lille Mechanics Unit, France

Local organising committee:

- **Valérie Plouvin**, Administrative manager, logistic coordination, LOG CNRS, France
- **Lucdivine Bonnamy**, Financial manager, budget coordination, LOG CNRS, France
- **Himani Garg**, PhD student, Lille Mechanics Unit, University of Lille, France
- **Dario Canossi**, PhD student, Lille Mechanics Unit, University of Lille, France

With the support of:

- **CNRS**, Centre National de la Recherche Scientifique
- **Université du Littoral Côte d'Opale**
- **Université de Lille**
- **Région Hauts-de-France**
- **ERCOFTAC**, European Research Community on Flow, Turbulence and Combustion
- **LOG**, Laboratory of Oceanology and Geosciences UMR 8187 LOG - CNRS
- **UML**, Unité de Mécanique de Lille - J. Boussinesq - EA 7512 UML

Keynote speakers

Mini-courses (4h)

- **Peter Franks** (SCRIPPS, University of California San Diego, USA): **Oceanic turbulence from a planktonic perspective**
- **Emilio Hernandez-Garcia** (IFISC, CSIC-University of the Balearic Islands, Spain): **Ocean transport, coherent structures and their impact on chemical and ecological marine processes**
- **Catherine Jeandel** (LEGOS, CNRS, Toulouse, France): **Illustrating marine geochemistry**
- **John R. Taylor** (DAMPT, University of Cambridge, UK): **Ocean turbulence and mixing**

Extended seminars (1h30)

- **Yannis Cuypers** (LOCEAN, Sorbonne Université, France): **Turbulence observation in the stratified ocean**
- **Filippo De Lillo** (University of Torino, Italy): **Large and small scale clustering of phytoplankton in turbulence**
- **Guillaume Lapeyre** (LMD, CNRS, Paris, France): **Upper ocean turbulence at submesocale**
- **Aleksandra Lewandowska** (TZS, University of Helsinki, Finland): **The role of phytoplankton diversity in bloom formation**
- **Francesc Peters** (ICM, Barcelona, Spain): **Effects of turbulence on bacteria: can they be real?**
- **Federico Toschi** (Technical University of Eindhoven, The Netherlands): **Turbulence fundamentals**

Programme

Monday July 2, 2018

8:30	**Welcome, café**
8:45	**Stefano Berti** (Lille University, Mechanics Unit), **Enrico Calzavarini** (Lille University, Mechanics Unit), **François Schmitt** (CNRS, LOG, Wimereux) : **Introduction and presentation of the School**
9:00	**Federico Toschi : Turbulence fundamentals**
10:30	**Coffee break**
11:00	**John Taylor: Ocean turbulence and mixing I**
12:20	**Lunch** (buffet)
13:40	**Catherine Jeandel: Illustrating marine geochemistry I**
15:00	**Coffee break**
15:30	**Emilio Hernandez-Garcia: Ocean transport, coherent structures and their impact on chemical and ecological marine processes I**
16:50	**11 short talks of participants (10 min each)**
18:40	**End of the session**

Tuesday July 3, 2018

9:00	**Guillaume Lapeyre: Upper ocean turbulence at submesocale**
10:30	**Coffee break**
11:00	**Peter J.S. Franks: Oceanic turbulence from a planktonic perspective I**
12:20	**Lunch** (buffet)
13:40	**Catherine Jeandel: Illustrating marine geochemistry II**
15:00	**Coffee break**
15:30	**John Taylor: Ocean turbulence and mixing II**
16:50	**Emilio Hernandez-Garcia: Ocean transport, coherent structures and their impact on chemical and ecological marine processes II**
18:10	**End of the session**

Wednesday July 4, 2018

9:00	**John Taylor:** Ocean turbulence and mixing III
10:20	**Coffee break**
10:50	**Catherine Jeandel:** Illustrating marine geochemistry III
12:10	**Field trip to 2 Capes, lunch & visit of Cape Blanc-Nez and Cape Griz-nez**
20:00	**Gala dinner of the Summer School**

Thursday July 5, 2018

9:00	**Aleksandra M. Lewandowska:** The role of phytoplankton diversity in bloom formation
10:30	**Coffee break** **Discovery of the Art of the Region: free gifts to all participants of small paintings from the painter Hugues** http://www.hugues-artistepeintre.fr
11:00	**Emilio Hernandez-Garcia:** Ocean transport, coherent structures and their impact on chemical and ecological marine processes III
12:20	**Lunch** (buffet)
13:40	**Peter J.S. Franks:** Oceanic turbulence from a planktonic perspective II
15:00	**Coffee break**
15:30	**Franz Peters:** Effects of turbulence on bacteria: can they be real?
16:50	**Fillippo De Lillo:** Large and small scale clustering of phytoplankton in turbulence
18:20	**End of the session**

Friday July 6, 2018

9:00	**Yannis Cuypers:** Turbulence observation in the stratified ocean
10:30	**Coffee break**
11:00	**Peter J.S. Franks:** Oceanic turbulence from a planktonic perspective III
12:20	**Lunch** (buffet)
13:40	**End of the Summer School** **Departure of the participants**

Short presentations of participants

Nestor Aldea-Ramos	Estimation of the subduction of anthropogenic carbon in the Southern Ocean: contribution of large-imaging swath altimetry
Ingrid Angel-Benavides	High resolution observations of (small) submesoscale eddies : flow and mixing patterns inferred from optical tracers
Russel Arnott	The effect of convection-induced mixing on a phytoplankton population: a mesocosm experiment
Harshit Bhatia	Dynamics of micro swimmers in turbulent open channel flow
Matteo Borgnino	Buoyancy regulation of non-motile phytoplankton in a turbulent flow
Matthieu Caffin	Nitrogen budgets following a Lagrangian strategy in the Western Tropical South Pacific Ocean: the subordinate contribution of nitrate input by turbulent mixing (OUTPACE cruise)
Wanting Cheng	Sexual dimorphism of Oithona davisae (Copepoda, Cyclopoida) relative to foraging and feeding
Alexandre Delache	Irreversible mixing and energetic aspect of deacaying stratified turbulence
Ines Mangolte	Impact of external forcings on the diversity of phytoplankton: coexistence and intrinsic variability
Jared Penney	Redistribution of passive tracers by Kelvin-Helmholtz instabilities
Alessandro Sozza	Lagrangian models for the transport of phytoplankton in turbulence

Posters

Rebeca de La fuente Maranon	Flow network characterization of bilayers
Yvan Dossmann	Mixing induced by internal waves in long term experiments

Abstracts and outlines of the presentations

• **Yannis Cuypers** (LOCEAN, Paris, France)
Turbulence observation in the stratified ocean

We will review in this lecture the existing methods and parametrization to characterize the turbulence dissipation rate in the stratified ocean from usual fine scale (~1m resolution) observations of hydrology and currents to the more specific microstructure measurements (~1cm resolution).

Outilne :
- Introduction, turbulence in the stratified ocean, range of variation and important scales
- Estimation of the turbulent dissipation rate from temperature or shear microstructure measurements
- Estimating turbulence from fine scale measurements using dimensional scaling.
- Wave–wave interaction parameterizations of turbulence
- From turbulent dissipation rates to turbulent fluxes: the mixing efficiency

• **Filippo De Lillo** (Dipartimento di FIsica and INFN, Università di Torino, Italy)
Large and small scale clustering of phytoplankton in turbulence

Swimming and buoyancy may interact with oceanic turbulence and affect the small and large scale distribution of phytoplankton. At large scale, this interaction may be relevant for the formation of structures like thin phytoplankton layers. At small scale, the trajectories of transported microorganisms deviate from those of ideal tracers allowing for the emergence of non-trivial, fractal distributions. We discuss how numerical modeling can be used to investigate these phenomena.

Outilne :
1. Gyrotactic algae: mechanistic model and phenomenology in laminar flows.
2. Gyrotactic trapping as a mechanism for thin-layer formation. We discuss the effect in a laminar flow and in turbulent simulations.
3. Small scale clustering and preferential sampling in turbulence. We will discuss how chaotic advection can produce fractal clustering of motile plankton, as well as cause cells to preferably sample certain zones of the flow. We will first consider the ideal case of a population of identical cells and then consider how fractal clustering might appear to an experimental observer.

• **Peter J.S. Franks** (UC San Diego, Scripps Institution of Oceanography)
Oceanic Turbulence from a Planktonic Perspective

Turbulence is often invoked as an essential dynamic controlling the interactions among the plankton. However, oceanic turbulence is very weak. Furthermore, the statistics of turbulent properties are very skewed, with low probabilities of strong shears and vorticities. Plankton are largely Lagrangian, but most turbulence theory for plankton is Eulerian. It is time to incorporate a more plankton-centric view of oceanic turbulence into our understanding of plankton ecology.

• **Emilio Hernandez-Garcia** (IFISC, CSIC-University of the Balearic Islands, Palma de Mallorca, Spain)
Ocean transport: coherent structures and their impact on chemical and ecological marine processes

Ocean currents move, deform and mix fluid parcels. The way this occurs has profound impacts on biogeochemical processes occurring in the sea and shapes ecosystems. In this set of lectures I will review some techniques from Lagrangian fluid dynamics and dynamical systems suited to understand ocean transport and use them to characterize its biological effects at several scales.

Ocean transport, coherent structures and their impact on chemical and ecological marine processes (or simple dynamical systems tools to deal with oceanic transport)

Outilne :
Lecture 1: Introduction to Lagrangian fluid mechanics and chaotic advection. Lyapunov exponents. Open flows.
Lecture 2: Lagrangian coherent structures and their impact in biology. Networks of flow transport and marine provinces.
Lecture 3: Simple chemical and biological processes in flows. Fisher and excitable plankton waves. Filaments and filamental transitions

• **Catherine Jeandel** (LEGOS, CNRS, Toulouse)
Illustrating Marine Geochemistry: the oceanic REE cycle story

Researches in marine geochemistry are focused on quantifying the fluxes and processes that govern the chemical state of the ocean. With this aim, marine geochemists are developing trace element and isotope measurements in seawater and marine particles. This scientific approach will be illustrated by the story of the oceanic Rare Earth Element concentrations and neodymium isotope cycle, tracers of water mass circulation and mixing, dissolved-particulate processes and land-ocean exchange.

• **Guillaume Lapeyre** (Laboratoire de Météorologie Dynamique/IPSL, Paris)
Upper ocean turbulence at submesoscale

In this talk, I will present our new vision of the ocean circulation at scales 5-500km. In addition to mesoscale eddies (of typical diameters ~ 200km) that concentrate the horizontal kinetic energy, lies a sea of submesoscales (typical scales 5-50km) that concentrate vertical motions. I will discuss
transport and mixing associated with these structures.

Outline :
- Description of typical properties of a turbulent flow involving meso and submesoscales (3 to 500 km induced by large-scale currents
- Interior vs Surface dynamics. Link to QG and SQG theories
- 3d organisation of vertical fluxes and transport related to surface dynamics at meso and submesoscales

• **Aleksandra M. Lewandowska** (Tvärminne Zoological Station, University of Helsinki)
The role of phytoplankton diversity in bloom formation

The onset of the spring phytoplankton bloom depends on both water column mixing and trait combination of phytoplankton community. In this seminar, we will discuss how stratification and turbulent mixing affect phytoplankton community composition and which phytoplankton traits are crucial at the bloom onset.

Outilne:
- Sverdrup's critical depth theory and other theories to explain the onset of phytoplankton blooms
- Competitive interactions in phytoplankton and species coexistence
- Phytoplankton traits variability along environmental gradients
- Making predictions based on phytoplankton trait distribution

• **Franz Peters** (Institut de Ciències del Mar (CSIC), Spain)
Effects of turbulence on bacteria, can they be real?

Marine bacteria are smaller than 1 µm in size and live in a diffusion-limited nutrient environment. Under typical marine turbulent conditions, turbulent inertial motion should have negligible effects on the the diffusivity of solutes towards the cells and thus be unable to enhance uptake and growth. However, marine bacterial growth

often benefits from water turbulence treatments. I will elaborate on different aspects related to size and organic matter to explain such contradiciton.

Outline :
- Heterotrophic bacteria
- Turbulence and shear
- Kolmogorov and Batchelor scales
- Molecular diffusion, solute flux
- Direct and indirect effects of turbulence on bacteria
- Sherwood numbers, large molecular weight substances
- Bacterial aggregate formation

• **John Taylor** (University of Cambridge, UK)
Ocean turbulence and mixing. Ocean fronts and the surface boundary layer. Impact of turbulence on micro-organisms

I will give an overview of the sources and importance of turbulence in the ocean, introduce frontal dynamics and submesoscales, describe the interaction between small-scale turbulence in the upper ocean and submesoscales, and describe how all of these physical processes might influence ocean biology.

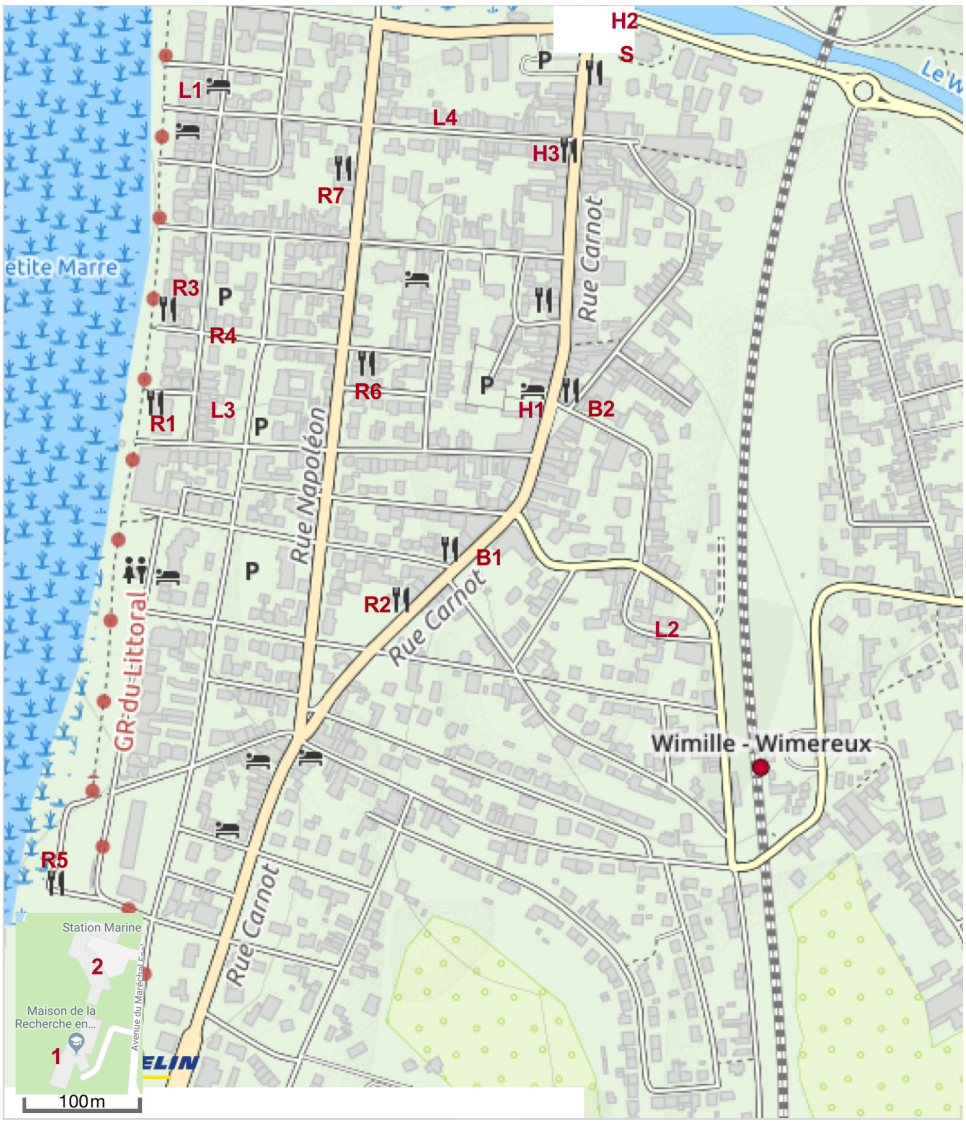
Outilne :
Lecture 1:
- Scales of ocean circulation
- Energy sources and sinks
- Boundary layer turbulence (Ekman layers and convection)

Lecture 2:
- Horizontal density gradients and frontogenesis
- submesoscale instabilities (specifically baroclinic instability and symmetric instability)
- Forward energy cascade from submesoscales to 3D turbulence
- mixed layer re-stratification

Lecture 3:
- Modulation of boundary layer turbulence by submesoscales
- Triggering of phytoplankton blooms through the critical turbulence mechanism
- Influence of submesoscales and turbulence on buoyant and dense material (time-permitting)

• **Federico Toschi** (Eindhoven University of Technology, Eindhoven, The Netherlands)
Turbulence fundamentals

In this lecture, we will review the basic fundamental properties of fluid dynamics turbulence with emphasis on both Eulerian and Lagrangian viewpoints.



1 : Location of the courses : MREN, 32 avenue Foch
2 : location of the lunches (Monday, Tuesday, Thursday, Wednesday) : Station marine, 28 avenue Foch

H1: Hôtel du Centre, 78 rue Carnot, Wimereux; +33 (3) 21 32 41 08
H2: Hotel Saint Jean : 1 rue Georges Romain, Wimereux; +33 (3) 21 83 57 40
H3: Hôtel Carnot : 12 rue Carnot, Wimereux; +33 (3) 21 32 41 04

L1: Lodging 1, Villa Rayon Vert : dam Michel Amiot
L2: Lodging 2, Villa Jean & Villa Estelle : 8 rue Amiral Gervais
L3: Lodging 3, Villa De Sonis : 21 rue Notre Dame
L4: Lodging 4, Maison Ferber : 28 rue du Capitaine Ferber

H1: Restaurant Hotel du Centre (good, little more expensive)
R1: Restaurant Cap Nord (sea food, dam sea view)
R2: Restaurant Le Ranch (good barbecue, grill meat)
R3: Restaurant L'Aloze-Atlantic (good food, little more expensive, dam sea view)
R4: Restaurant Esperanzo (good sea food)
R5: Restaurant LE 180° (sea view)
R6: Restaurant Chez yann (good food)
R7: Restaurant Le Pirate (pizza and brasserie)

B1: Bar Le Repère (night bar)
B2: Bar Bains de Minuit (night bar)

S: Small Supermarket

Mobile Homes: at Camping L’été Indien, 1.4 km from the course place.

Speakers

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