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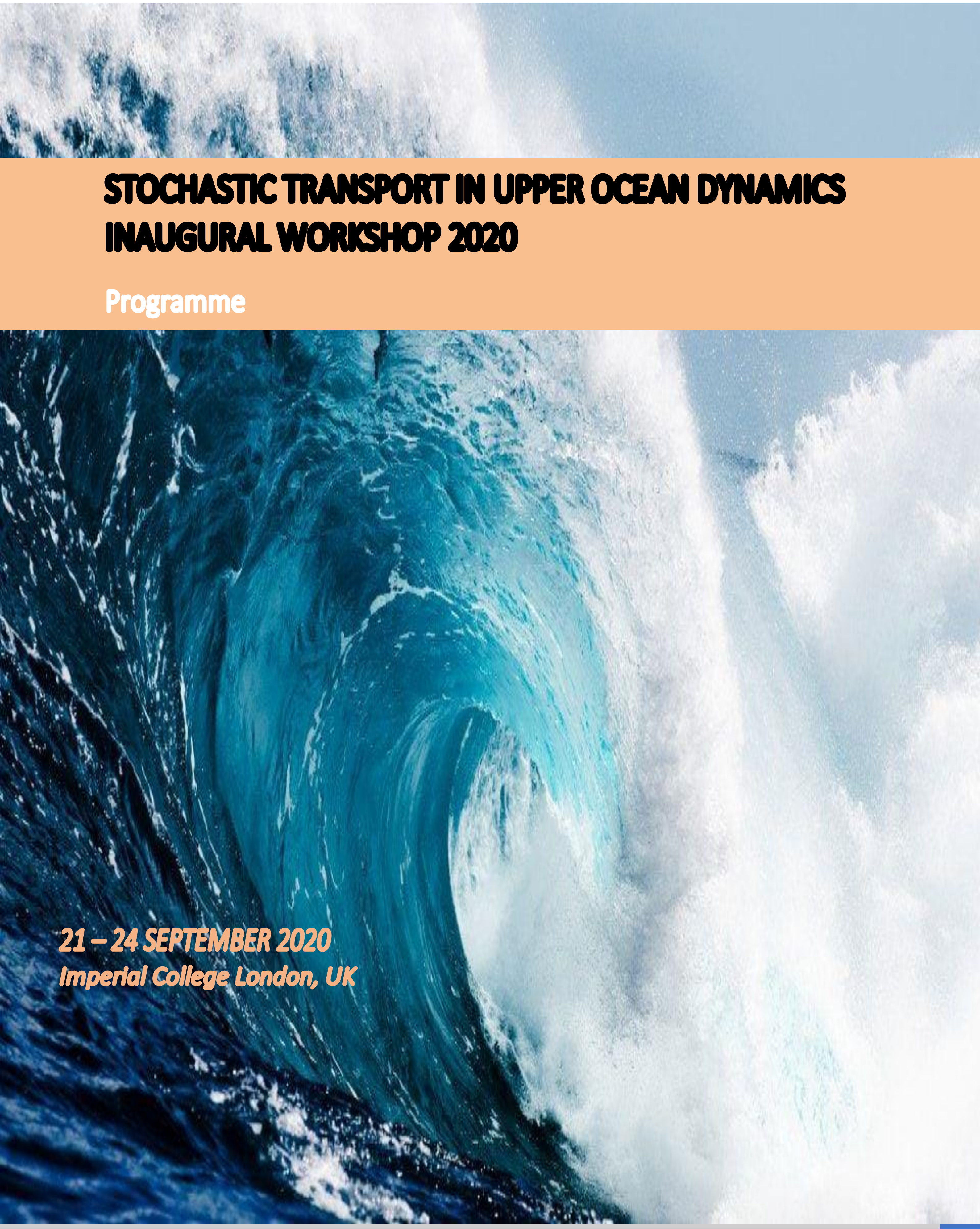
STOCHASTIC TRANSPORT IN UPPER OCEAN DYNAMICS INAUGURAL WORKSHOP 2020

Programme



21 – 24 SEPTEMBER 2020

Imperial College London, UK

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STOCHASTIC TRANSPORT IN UPPER OCEAN DYNAMICS
INAUGURAL WORKSHOP 2020

Workshop Organizers

Scientific Committee:

Prof Bertrand Chapron
IFREMER

Prof Dan Crisan
Imperial College London

Prof Darryl Holm
Imperial College London

Prof Ettiene Memin
INRIA Rennes Centre

Organizing Comittee:

Dr Anna Radomska
Imperial College London

Acknowledgments:

This seminar series is supported International Centre for Mathematical Sciences (ICMS) as part of the Virtual Forum for Knowledge Exchange in the Mathematical Sciences. Zoom is the online platform being used to deliver this seminar series.

Supported by the European Research Council

www.imperial.ac.uk/ocean-dynamics-

Stochastic Transport in Upper Ocean Dynamics (STUOD)

Welcome

Welcome to the Stochastic Transport in Upper Ocean Dynamics Inaugural Workshop held on 21 – 24 September 2020.

The event marks the launch of a newly established network focused on Stochastic Transport in Upper Ocean Dynamics.

The STUOD project is highly prestigious ERC Synergy Grant, led by Imperial College London (ICL), National Institute for Research in Computer Science and Automatic Control (INRIA) and the French Research Institute for Exploitation of the Sea (IFREMER). It aims to deliver new capabilities for assessing variability and uncertainty in upper ocean dynamics. It will provide decision makers a means of quantifying the effects of local patterns of sea level rise, heat uptake, carbon storage and change of oxygen content and pH in the ocean. Its multimodal monitoring will enhance the scientific understanding of marine debris transport, tracking of oil spills and accumulation of plastic in the sea.

The remote Inaugural Workshop aims at effectively rolling out project implementation and will feature:

- Discussions on the novel developments in fundamental and applied aspects of this research area.
- Distinguished national and international talent comprising senior and junior scientists.
- Global participation by leading scientists from academia, industry & government to consider and evaluate future directions and demands in the field.
- A relaxed, friendly and intellectually stimulating discussion forum for the free exchange of ideas for their implementation in a wider community setting.
- Several hours of excellent networking opportunities.
- Multiple sessions with oral presentations by an international faculty of senior & junior researchers (see confirmed speakers).
- Keynote talks by leading experts in the field.

The event will focus on a range of fundamental topic areas, including:
1. observations at high resolution of upper ocean properties such as temperature, salinity, topography, wind, waves and velocity;
2. large scale numerical simulations;
3. data-based stochastic equations for upper ocean dynamics that quantify simulation error;
4. stochastic data assimilation to reduce uncertainty.

Programme - Day 1

Monday, 21st September 2020	
9:45 – 10:00	*Welcome and Opening Remarks*
Session I	Presentation of the project and its objectives
Chair	Oana Lang (**Imperial** College London)
10:00 – 10:15	*WP 1: Multi-modal ocean data acquisition, analysis and interpretation* Bertrand Chapron (IFREMER)
10:15 – 10:30	*WP 2: Uncertainty representation and stochastic parameterization* Darryl Holm (Imperial College London)
10:30 – 10:45	*WP 3: Numerical schemes for stochastic fluid transport and diffusion* Etienne Memin (INRIA)
10:45 – 11:00	*WP4: Multiscale ensemble Data Assimilation and forecasting methods* Dan Crisan (Imperial College London)
Chair	Bertrand Chapron (IFREMER)
11:00 – 12:00	*Networking/Brainstorming session:* *Discussion on WP 1: Multi-modal ocean data acquisition, analysis and interpretation*
12:00 – 14:00	Break
Session II	Presentations by the AEB members part I
Chair	Darryl Holm (Imperial College London)
14:00 – 14:15	*ALDI: Geometry for discount inference* Sebastian Reich (University of Potsdam)
14:15 – 14:30	*Remarks on stochastic atmosphere-ocean modelling from a computational perspective* Peter Korn (Max Planck Institute for Meteorology)
14:30 – 14:45	*An operational ensemble Kalman Filter perspective on STUOD* Laurent Bertino (Nansen Environmental and Remote Sensing Center)
14:45 – 15:00	*Physics-based subgrid schemes in stochastic models* Baylor Fox-Kemper (Brown University)
Chair	Darryl Holm (Imperial College London)
15:00 – 16:00	Q & A Forum
End of day one	

Programme - Day 2

Tuesday, 22nd September 2020	
Session I	Work in progress presentations by PDRAs and PhDs part I

Chair	Anna Radomska (Imperial College London)
10:00 – 10:15	*Numerical scheme for thermal quasi-geostrophic equations (TQG)* Wei Pan (Imperial College London)
10:15 – 10:30	*Analytical properties for LU and SALT SPDEs* Oana Lang (Imperial College London)
10:30 – 10:45	*Stochastic modeling of oceanic mesoscale eddies* Long Li (INRIA)
10:45 – 11:00	*Title TBC* Jean-Francois Piolle (IFREMER)
Chair	Darryl Holm (Imperial College London)
11:00 – 12:00	*Networking/Brainstorming session:* *Discussion on WP 2: Uncertainty representation and stochastic parameterization*
12:00 – 14:00	Break

Session II	Presentations by the AEB members part II

Chair	Bertrand Chapron (IFREMER)
14:00 – 14:15	*Eddies, deterministic forcings, and the ocean mixed layer* Anne Marie Treguier (CNRS)
14:15 – 14:30	*Analysis of acoustic-gravity waves in a free-surface compressible and stratified ocean* Laurent Debreu (INRIA)
14:30 – 14:45	*Numerical methods for free surface Navier-Stokes equations: variable density flows and dispersive waves* Jacques Sainte-Marie (INRIA)
14:45 – 15:00	*Approximation-diffusion and fluid limits for (S)PDEs* Arnaud Debussche (Ecole Normale Supérieure de Rennes)
Chair	Bertrand Chapron (IFREMER)
15:15 – 16:00	Q & A Forum
End of day two	

Programme - Day 3

Wednesday, 23rd September 2020	
Session I	Work in progress presentations by PDRAs and PhDs part II

Chair	Wei Pan (Imperial College London)
10:00 – 10:15	*Machine learned 4DVar - a case study with the L63 model* So Takao (Imperial College London)
10:15 – 10:30	*Ocean response to Extreme Atmospheric events* Nicolas Reul (IFREMER)
10:30 – 10:45	*The thermal quasi-geostrophic (TQG) equations in ocean modelling* Erwin Luesink (Imperial College London)
Chair	Etienne Memin (INRIA)
11:00 – 12:00	*Networking/Brainstorming session:* *Discussion on WP 3: Numerical schemes for stochastic fluid transport and diffusion*
12:00 – 14:00	Break

Session II	In parallel

Chair	Sebastian Reich (University of Potsdam)	Erwin Luesink (Imperial College London), Nicolas Reul (IFREMER) and So Takao (Imperial College London)
14:00 – 15:00	*Closed EAB meeting*	*PDRAs and PhDs Q & A Forum*
15:00 – 16:00	*Feedback by the Chairman of the STUOD EAB*	
End of day three		

Programme - Day 4

Thursday, 24th September 2020	
Session I	Networking/Brainstorming session
Chair	Dan Crisan (Imperial College London)
10:00 – 11:00	*Discussion on WP4: Multiscale ensemble Data Assimilation and forecasting methods*
Chair	Sebastian Reich (University of Potsdam)
11:00 – 11:55	*Presentation on the STUOD strategic vision and future directions for engagement* Bertrand Chapron, Darryl Holm, Etienne Memin and Dan Crisan
11:55 – 12:00	*Closing remarks*
Workshop ends	

Bertrand Chapron
PI at the Centre IFREMER Bretagne

Research Interests:
Satellite Oceanography and Ocean-Atmosphere interactions

https://annuaire.ifremer.fr/cv/15870/

Bertrand Chapron

WP 1: Multi-modal ocean data acquisition, analysis and interpretation

To identify the changing regimes of uncertainty in geophysical fluid transport, we will calibrate the statistical properties of the upper ocean transport from multi-modal (sensor physics, time and space samplings) in situ and satellite data sets, test and assess dedicated analysis tools. This workpackage is essential in establishing the bridge between the observational data and the mathematical models developed and analysed in subsequent workpackages. The data analysis of the observation is used to calibrate the amplitude and the direction of the model noise as a function of location (hindcast). Following the exemplars treated in WP2 we will conduct a dedicated re-analysis of 25 years of data extracted from GlobCurrent, e.g., for the multidrifter 2016 Lagrangian Sea Experiment (LASER). This re-analysis will ensure that the data structures of the observations and the models mesh together coherently and are compatible. The data analysis in WP1 differs substantially from the data assimilation performed as part of WP4.

Darryl Holm

PI at Imperial College London

Research Interests:

Darryl's main research interests lie in nonlinear science – ranging from integrable to chaotic behavior, from solitons to turbulence, and then on to shape analysis. Most of his work is based on Lie symmetry reduction of Hamilton's principle, often by smooth invertible maps such as the relabelling invariance in Eulerian fluid dynamics. In these fields, he is particularly interested in emergent singular phenomena.

https://www.imperial.ac.uk/people/d.holm

Darryl Holm

WP2: Uncertainty representation and stochastic parameterization

The overall objective of the task is to devise methods to analyze and use satellite observations to complete stochastic mathematical models representing the effects of the computationally unresolvable scales of fluid motion on the resolved scales. The representation of the fine scale effects on the coarser scales of motion depends on the level of geophysical fluid approximation pertinent to the scale of motion of the data and the other physical processes involved, e.g., thermodynamics.
The versatility of the Holm-Mémin framework allows it to adapt to new requirements as the data analysis proceeds. The tasks in this work package are mainly aimed at making adjustments and developments of the theory, to ensure that we are position to contribute theoretical support responsively, as needed as the applications and data assimilation tasks proceed.

Etienne Mémin
PI at INRIA Rennes Centre

Research Interests:
Stochastic flow modeling, data assimilation, inverse problems.

https://www.inria.fr/en/etienne-memin

Etienne Mémin

WP3: Numerical schemes for stochastic fluid transport and diffusion

The success of the programme hinges on developing efficient and accurate numerical schemes for SPDEs arising in the Holm-Memin approach. These numerical schemes are the objective of this workpackage.

The tasks include:

- Numerical resolution of STUOD model.
- Stability and accuracy evaluation
- Schemes for Monte Carlo nested simulations
- Numerical schemes for stochastically coupled Ocean/Atmosphere models
- Implementation and demonstration using operational oceanic models

Dan Crisan
PI at Imperial College London

Research Interests:
Stochastic Analysis, a branch of Mathematics that looks at understanding and modelling systems that behave randomly.

http://wwwf.imperial.ac.uk/~dcrisan

https://www.imperial.ac.uk/people/d.crisan

Dan Crisan

WP4: Multiscale Ensemble Data Assimilation and forecasting methods

We will produce a new class of Ensemble based Data Assimilation methodologies adapted to work efficiently for STUOD models. The work package is divided into five tasks which we describe below. These tasks are interrelated. For example, we first will calibrate our methodology using the data obtained from the numerical models in WP1. Later, this calibration will produce realistic applications of our approach for WP4.

The STUOD models will be developed in WP2 and confirmed by data and calibrated to it as part of WP1. The process of calibration will be informed, modified and optimized by extensive tests involving uncertainty quantification. The uncertainty of the model will be numerically quantified. The overriding test will be to ensure that the Holm-Mémin stochasticity will provide ensembles/particles that are sufficiently spread to capture the true solution.

Talks summary

Wei Pan

Numerical scheme for thermal quasi-geostrophic equations (TQG)

In this talk, we present the pipeline of work (so far) that have gone into the implementation of TQG. More specifically, we discuss our choices for the numerical scheme, and discuss partial consistency and stability results. This work lays the foundation for the implementation and calibration of the SALT extension to TQG, with a view to apply our models to real satellite data assimilation.

Wei Pan
STUOD Research Assistant at Imperial College London
Research Interests

Research Interests:
stochastic analysis, geophysical fluid dynamics, data assimilation and scientific computing.

Oana Lang
STUOD Research Assistant at Imperial College London
Research Interests

Research Interests:

Oana's main area of research is Stochastic Analysis. In particular, she is interested in the theoretical and numerical analysis of nonlinear stochastic partial differential equations (SPDEs) that model the evolution of oceanic and atmospheric fluids, with direct applications in geophysical fluid dynamics. In addition to this, her research focuses also on nonlinear filtering problems which involve SPDEs driven by transport noise and stochastic data assimilation techniques for high-dimensional data.

https://oanalang.wixsite.com/oanalang

Oana Lang

Analytical properties for LU and SALT SPDEs

The intrinsic variability of the multi-scale processes which govern the oceanic dynamics is subject of intensive research. Two modern stochastic approaches have been developed in order to provide efficient strategies for encoding randomness into a priori deterministic models: Stochastic Advection by Lie Transport (SALT, Holm 2015) and Location Uncertainty (LU, Mémin 2014).

In this talk I will describe the analytical properties (existence, uniqueness, blow-up) for a couple of stochastic partial differential equations derived using these two approaches.

I will explain the well-posedness methodology as well as the technical differences between LU and SALT solution properties. In the last part of the talk I will present a data assimilation application where the signal is given by a SALT SPDE.

Long Li
PhD student in the Fluminance INRIA/IRMAR group.

Research Interests:
Stochastic modeling, uncertainty quantification, ensemble data assimilation

http://www.irisa.fr/fluminance/team/Long.Li.html

Long Li

Stochastic modeling of oceanic mesoscale eddies

In this work, a stochastic representation [1, 2] based on a stochastic trans- port principle is proposed to account for mesoscale eddy effects on the large- scale oceanic circulation. In particular, the modelling under location uncertainty (LU) scheme has been tested for the coarse-grid simulation of a multi- layered quasi-geostrophic circulation. In this talk I will show that the proposed stochastic model provide a marked benefit in improving the intrinsic variability and the energy transfer, compared to a classical coarse scale deterministic model. Such ability is of great importance for ensemble forecasting and data assimilation.

[1] Bauer, W., Chandramouli, P., Chapron, B., Li, L. and Mémin, E., 2020. Deciphering the role of small-scale inhomogeneity on geophysical flow structuration: a stochastic approach. Journal of Physical Oceanography

[2] Bauer, W., Chandramouli, P., Li, L. and Mémin, E., 2020. Stochasticrepresentation of mesoscale eddy effects in coarse-resolution barotropic models. Ocean Modelling

Anne Marie Treguier,
CNRS. LOPS,IUEM, Brest

https://annuaire.ifremer.fr/cv/17709/

Anne Marie Treguier

Eddies, deterministic forcings, and the ocean mixed layer

Mesoscale and submesoscale variability is found in the ocean at space scales of a few hundreds down to 1 km, and time scales from many months down to a day. Mesoscale variability is to a large extent driven by instabilities of the mean circulation, and is thus chaotic. However, mesoscale and submesoscale eddies coexist with more deterministic processes at the same space and time scales, such as the diurnal and seasonal cycles, or the tides. Moreover, surface flow is influenced by the bottom bathymetry through complex and often nonlocal processes.

In the first part of this talk, I present exemples of vortex generation mechanisms at play in the Nordic Seas (Lofoten vortex) and the subpolar Atlantic (Rockall Trough Vortex). These demonstrate remote dynamical influences from the continental slope to the interior, and from the deep layers to the surface layer.

A well-mixed layer is generally found in the surface layer of the ocean. The thickness of this layer varies on diurnal to seasonal time scales and can reach a typical depth of 1000m in winter in regions of deep convection, such as the Labrador sea. However, mesoscale and submesoscales have an imprint on the thickness of the ocean mixed layer, impacting the way the surface ocean transfers energy and properties from the atmosphere to the deep ocean. This is the subject of a new European project funded by the Joint Programming Initiatives Ocean and Climate, MEDLEY (MixED LayEr heterogeneitY). Scientific questions to be addressed in MEDLEY, which may be of interest for STUODS, are presented in the second part of this talk.

Laurent Debreu
National Institute for Research in Computer Science and Automation (INRIA)

https://team.inria.fr/airsea/en/laurent-debreu/

Laurent Debreu

Analysis of acoustic-gravity waves in a free-surface compressible and stratified ocean

Waves propagate in a free-surface ocean due to compressibility and gravity (and surface tension at much smaller scale). Analytical solutions have long been derived independently for acoustic and gravity waves, i.e., acoustic waves or internal-gravity rays in an unbounded ocean, surface-gravity waves in a free-surface-ocean, and acoustic or internal modes in a bounded ocean.

In the present study, capillarity waves and earth-rotation are neglected and a simple, unified model based on inner and boundary dispersion relations is derived for waves propagating in a compressible, stratified, free-surface ocean.

Wave solutions are identified and visually analyzed in phase-space. Taylor developments are then carried out with respect to small parameters describing stratification and compressibility and are compared with numerical approximations of the intersection of inner and boundary dispersion surfaces.

Finally, the model recovers the known approximations for swell, long-surface waves, internal-gravity rays, internal modes, acoustic waves or acoustic modes, and also provides modification of these solutions due to stratification and compressibility.

Jacques Sainte Marie
National Institute for Research in Computer Science and Automation (INRIA)

https://team.inria.fr/ange/team-members/jacques-sainte-marie/

Jacques Sainte Marie

Numerical methods for free surface Navier-Stokes equations: variable density flows and dispersive waves

Complex hydrodynamic regimes arise in oceanography. On the one hand, sophisticated methods are needed to approximate the free surface Navier-Stokes or Navier-Stokes-Fourier systems, on the other hand large time and space scales have to be considered requiring efficient numerical schemes.

We start this presentation with examples of simulations involving variable density flows and emphasizing the importance of accurate numerical techniques.

Then we show that, starting from the compressible Navier-Stokes system, it is possible to derive and approximate a model able to:

- capture acoustic-like waves propagation,
- capture non-hydrostatic effects and avoiding the costly resolution of an elliptic equation for the fluid pressure.

The proposed numerical methods are endowed with strong stability properties (invariant domain, well-balancing, discrete entropy inequality) and confronted with analytical test cases and experimental data.

The introduction of the stochastic aspects in the presented models and methods should be considered.

So Takao
STUOD Research Assistant at Imperial College London
Research Interests

Research Interests:
Stochastic PDEs,
Differential geometry,
Machine learning

So Takao

Machine learned 4DVar - a case study with the L63 model

The increased availability of raw data such as satellite images has led to a rapid development of data assimilation techniques to reconstruct the dynamics of a given state from sparse, noisy data. In particular, the 4DVar algorithm, in which the reconstructed state is obtained by minimizing a given cost function, has been shown to be particularly effective at this and is now a standard tool in the NWP community. Whereas 4DVar assumes that a predictive model is given a priori, recent progress in machine learning has seen the emergence of data-driven modelling, where the model itself can be learned from data. This is useful for instance when the model has several unknown parameters and requires tuning – the machine will take care of it automatically!

In this talk, I will present the results of a hybrid "data-driven-4DVar" assimilation algorithm, introduced in the recent work by Fablet et al. (2020)*, as applied to the L63 model, and discuss how we can use this approach to learn the initial conditions and unknown parameters of fluid PDEs accurately from sparse satellite images.

* https://arxiv.org/pdf/2007.12941.pdf

Erwin Luesink
MPE CDT Research Postgraduate

Research Interests:
Erwin's research interests lie in the intersection of stochastic geometric mechanics, geophysical fluid dynamics and numerical analysis. I am interested mainly in how methods from these three fields apply to ocean modelling.

Erwin Luesink

The thermal quasi-geostrophic (TQG) equations in ocean modelling.

Many of the models that are used in ocean modelling can be derived by means of a variational principle. Such variational principles help us to understand some of the geometric structure of the models and give us a framework for making approximations and introducing stochasticity.

The noise is introduced to give us an additional degree of freedom that can incorporate data and estimate uncertainty. We require that the noise does not change the underlying geometric structure. This can be guaranteed by using "stochastic advection by Lie transport" (SALT).

We follow along a branch of the tree of derivations outlined in [1]. We start with thermal rotating shallow water and identify thermal geostrophic balance. By applying asymptotic expansions around this balance, we pass through thermal L1, to arrive at thermal quasi-geostrophy (TQG). Thermal L1 is still variational, however, TQG is not. To overcome this difficulty, we adapted the formulation of TQG for applying SALT, by transforming TQG into a Hamiltonian theory.

[1]: Holm, D.D., Luesink, E. and Pan, W., 2020. Stochastic circulation dynamics in the ocean mixed layer. arXiv preprint arXiv:2006.05707

Contact Us

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