LAPCOD VII

Meeting Program

Venice 2019

Jointly organized by the CoNISMa Local Research Units of the Parthenope and of the Ca' Foscari Universities

Table of Contents

lapcod.rsmas.miami.edu/2019-Venice

The LAPCOD portal, the abstract submission and handling, the building of the meeting program have been taken care of by Edward Ryan of RSMAS, University of Miami.

Meeting Announcement

We invite you to join us at the **7th Lagrangian Analysis and Prediction of Coastal and Ocean Dynamics** (LAPCOD) meeting. LAPCOD VII will take place in ***Venice, Italy, June 17-21, 2019*** in the splendid venue of ***Ca' Foscari University***. It will be four years after the last meeting, thus LAPCOD VII will be a good opportunity to assess the current status of Lagrangian-oriented approaches in (mainly physical, but also bio-, geo-, chemical) oceanography.

The city of Venice is a World Heritage Site, and needs no presentation. Many options for accommodation are available in Venice and Mestre. We will soon post suggestions, but be aware that early booking is strongly encouraged, since last minute reservations may be very expensive.

LAPCOD VII is being organized by the **Department of Environmental Sciences, Informatics and Statistics** of the **Ca' Foscari University of Venice** jointly with the **Department of Science and Technology** of the **Parthenope University of Naples**.

Best regards,

Angelo Rubino (Meeting Organizer)	Ca' Foscari University, Venice
Enrico Zambianchi (Meeting Organizer)	"Parthenope" University, Napoli, Italy

with:

Annalisa Griffa	Consiglio Nazionale Ricerche (CNR/ISMAR), La Spezia, Italy
Denny Kirwan	University of Delaware, USA
Arthur Mariano	RSMAS, University of Miami, USA
Anne Molcard	University of Toulon, France
Tamay Özgökmen	RSMAS, University of Miami, USA
Andrew Poje	City University of New York (CUNY), USA
Tom Rossby	University of Rhode Island, USA
Edward Ryan	RSMAS, University of Miami, USA
Enrico Zambianchi	"Parthenope" University, Napoli, Italy

Past LAPCOD Meetings

Ischia 2000	Ischia, Italy	October 2-6, 2000
Key Largo 2002	Key Largo, Florida	December 12-16, 2002
Lerici 2005	Lerici, Italy	June 13-17, 2005
La Londe-les-Maures 2009	La Londe-les-Maures, France	September 7-11, 2009
Miami Beach 2012	Miami Beach, Florida	June 11-15, 2012
Winter Harbor 2015	Winter Harbor, Maine	July 27-31, 2015
Venice 2019	Venice, Italy	June 17-21, 2019

Session A | Agenda | Monday, June 17th

Registration
9:30 am to 9:50 am

Welcome to the Venice LAPCOD Meeting
9:50 am to 10:00 am
Opening remarks by **Enrico Zambianchi**, *Universita' "Parthenope"*

Monday: A mix of talks from all of the Topics

Moderators:
Anne Molcard, *University of Toulon* (Morning)
Denny Kirwan, *University of Delaware* (Afternoon)

Morning Session: MoM1
10:00 am to 11:20 am

10:00 am	MoM11	Lagrangian simulations and influence of initial conditions on dispersion calculations *Francesco Enrile, Giovanni Besio, Alessandro Stocchino, Marcello G. Magaldi, Pierre-Marie Poulain*
10:20 am	MoM12	What have we learned about ocean velocity statistics from drifter experiments in Gulf of Mexico *Arthur Mariano*
10:40 am	MoM13	Scale-dependent dispersion and structure functions near a density front *Henry Chang, Helga Huntley, Denny Kirwan, Dan Carlson*
11:00 am	MoM14	Episodic strong convergence events in LASER drifter data *Andrew Poje, Angelique Haza, Tamay Ozgokmen, Rayan Ibrahim*

Short Break
11:20 am to 12:00 pm
Short Break (40 minutes), refreshments will be served.

Morning Session: MoM2
12:00 pm to 1:20 pm

12:00 pm	MoM21	Bridging the gap between physical and chemical approaches to ocean mixing and spreading *Thomas Rossby, Melissa Omand, Jakob Kuttenkeuler*
12:20 pm	MoM22	Machine learning ocean dynamics with lagrangian ocean drifters *Nikolas Aksamit, Themistoklis Sapsis, George Haller*
12:40 pm	MoM23	Kinematic Properties from single trajectories: Serendipity or Stupidity? *Denny Kirwan, Henry Chang, Helga Huntley*
1:00 pm	MoM24	Documentation and analyses of life cycle of mesoscale eddies on Lagrangian maps *Sergey Prants*

Lunch Break

1:20 pm to 3:00 pm (1 hr 40 min)

Afternoon Session: MoA3
3:00 pm to 4:20 pm

3:00 pm	MoA31	Do surface drifters accurately represent Eulerian turbulence statistics? *Jenna Pearson, Baylor Fox-Kemper, Brodie Pearson, Helga Huntley, Henry Chang, Denny Kirwan*
3:20 pm	MoA32	Particle trajectories in a model vortex Nathan Paldor, Yair Cohen
3:40 pm	MoA33	Kinematic Properties in the Alboran Sea: Results from Surface and Subsurface Drifter Observations and Numerical Analysis *Daniel Tarry, Sebastian Essink, Mara Freilich, Mathieu Dever, Ananda Pascual, Simón Ruiz, Pierre-Marie Poulain, Tamay Özgökmen, Luca Centurioni, Amala Mahadevan*
4:00 pm	MoA34	Lagrangian studies of particle sedimentation in the oceans: an analysis in the Benguela region *Cristóbal López, Gabor Drotos, Emilio Hernández-García, Pedro Monroy*

Short Break
4:20 pm to 5:00 pm
Short Break (40 minutes), refreshments will be served.

Afternoon Session: MoA4
5:00 pm to 6:20 pm

5:00 pm	MoA41	Rain Calms the Sea *Juan M. Restrepo, Alex Ayet, Luigi Cavaleri*
5:20 pm	MoA42	Surface connection between different areas of the Mediterranean Sea derived from drifter data *Paolo Celentano, Pierpaolo Falco, Enrico Zambianchi*
5:40 pm	MoA43	Integrating Lagrangian simulations of plastic pollution with chemical advection-diffusion processes to account for cetacean ingestion risk within the Pelagos Sanctuary *Federica Guerrini, Lorenzo Mari, Renato Casagrandi*
6:00 pm	MoA44	Seasonal, interannual and decadal variability of the Sicily Channel and southern Tyrrhenian Sea *Milena Menna, Pierre-Marie Poulain, Daniele Ciani, Andrea Doglioli, Marie-Helene Rio, Giulio Notarstefano, Riccardo Gerin, Rosalia Santoleri, Adam Gauci, Aldo Drago*

Registration
8:30 am to 9:00 am

Tuesday: A mix of talks from all of the Topics

Moderators:
Joe LaCasce, *University of Oslo* (Morning)
Tom Rossby, *University of Rhode Island* (Afternoon)

Morning Session: TuM1
9:00 am to 10:20 am

9:00 am	TuM11	Dispersion of Lagrangian isopycnal RAFOS floats deployed in the Atlantic Oxygen Minimum Zone *Tom Rossby, Don Rudnickas, Jaime Palter, Dave Hebert*
9:20 am	TuM12	Lagrangian Statistics from Surface Drifter Observations and Numerical Simulations in the Icelandic Basin *Thilo Klenz, Harper Simmons, Jonathan Lilly, Luca Centurioni*
9:40 am	TuM13	Greenland Ice Sheet Ocean Interactions gauged with backward Lagrangian simulations *Inga Monika Koszalka and multiple co-authors*
10:00 am	TuM14	Extraction of coherent eddy properties from individual particle trajectories, with application to the Gulf of Mexico *Jonathan Lilly, Paula Pérez-Brunius, Jeffrey Early, Julio Sheinbaum, Jorge Zavala, Julien Jouanno, Joao Azevedo, Sheila Estrada*

Short Break
10:20 am to 11:00 am
Short Break (40 minutes), refreshments will be served.

Morning Session: TuM2
11:00 am to 12:20 pm

11:00 am	TuM21	Can Lagrangian tracking simulate tracer spreading in a high-resolution Ocean General Circulation Model? *Patrick Wagner, Siren Rühs, Franziska Schwarzkopf, Inga Koszalka, Arne Biastoch*
11:20 am	TuM22	Coincident observations of dye and drifter relative dispersion over the inner shelf *Leonel Romero, Carter Ohlmann, Enric Pallàs-Sanz, Paula Pérez-Brunius, Nicholas M. Statom, and Stéphane Maritorena*
11:40 am	TuM23	Eddy Diffusivity Estimates from Lagrangian Trajectories Simulated with Ocean Models and Surface Drifter Data—A Case Study for the Greater Agulhas System *Siren Rühs, Victor Zhurbas, Inga Koszalka, Jonathan Durgadoo, Arne Biastoch*
12:00 pm	TuM24	Interannual and decadal variability of the Southern Pacific Ocean in response to the large scale climatic patterns *P. Falco, M. Menna, Y. Cotroneo, R. Di Lemma, P.-M. Poulain, G. Fusco, G. Budillon, E. Zambianchi*

Lunch Break
12:20 pm to 2:00 pm (1 hr 40 min)

Afternoon Session: TuA3
2:00 pm to 3:20 pm

2:00 pm	TuA31	Lagrangian geographies of the Gulf of Mexico *Philippe Miron*
2:20 pm	TuA32	Markov-chain-inspired search for MH370 *Philippe Miron*
2:40 pm	TuA33	Toward a dynamical-systems-based oil evolution prediction scheme *Maria J. Olascoaga*
3:00 pm	TuA34	Persistent transport patterns in the northwestern Gulf of Mexico *Maria J. Olascoaga*

Short Break
3:20 pm to 4:00 pm
Short Break (40 minutes), refreshments will be served.

Afternoon Session: TuA4
4:00 pm to 5:20 pm

4:00 pm	TuA41	Oil Spill Scenarios for the western Gulf of Mexico *Julio Sheinbaum and multiple co-authors*
4:20 pm	TuA42	Environmental processes that affect the 3D circulation pattern of oil spills and oil plumes. Sensitivity analysis of the contributing factors and a comparison with 2D only oil spill simulations *Konstantinos Kotzakoulakis, Julio Sheinbaum, Favio Medrano*
4:40 pm	TuA43	Larval flow among red gorgonian populations in the Ligurian sea unveils stepping-stone connections: implications for conservation practice *Roberta Sciascia, Katell Guizien, Lorenzo Bramanti, Mariana Padrón, Marcello G. Magaldi*
5:00 pm	TuA44	Fate and transport of giant kelp plants in coastal California waters *Carter Ohlmann, Jenny Dugan , Bob Miller, Kylene Cooley, Leonel Romero, Dave Hubbard, Kyle Emery, and Jessica Madden*

Session C Agenda Wednesday, June 19th

Wednesday: A day of interactions via a group social activity

Full day boat trip to the other islands of the Venice Lagoon: Murano, Burano, Torcello, including social lunch. Details of departure time and place will be given on the first day of the meeting.

Registration
8:30 am to 9:00 am

Thursday: A mix of talks from all of the Topics

Moderators:
Arthur Mariano, *University of Miami* (Morning)
Andrew Poje, *City University of New York (CUNY)* (Afternoon)

Morning Session: ThM1
9:00 am to 10:20 am

9:00 am	ThM11	Coastal submesoscale structures and variability from drifters and HF radar in the Ligurian Sea (Mediterranean) *Maristella Berta, Lorenzo Corgnati, Marcello G. Magaldi, Annalisa Griffa, Carlo Mantovani, Pierre-Marie Poulain, Paolo Oddo*
9:20 am	ThM12	Mass exchange of Atlantic Water with the Lofoten Basin derived from high-resolution Lagrangian simulations and Eulerian models *Johannes S. Dugstad, Inga Monika Koszalka, Knut-Frode Dagestad, Ilker Fer, Pål Erik Isachsen, Joseph Henry LaCasce*
9:40 am	ThM13	Anisotropy in Coastal Ocean Relative Dispersion Observations *Carter Ohlmann, Leonel Romero, Enric Pallàs-Sanz, Paula Pérez-Brunius*
10:00 am	ThM14	Circulation over the Inner-Shelf off the South Padre Island, Texas, USA *Enric Pallàs-Sanz, Leonel Romero, Carter Ohlmann*

Short Break
10:20 am to 11:00 am
Short Break (40 minutes), refreshments will be served.

Morning Session: ThM2
11:00 am to 12:20 pm

11:00 am	ThM21	Estimates of kinematic properties variability at the submesoscales from surface drifter measurements in the Gulf of Mexico *Maristella Berta, Annalisa Griffa, Helga Huntley, Andrew Poje, Tamay Ozgokmen*
11:20 am	ThM22	Lagrangian stability of the Malvinas Current *Francisco J. Beron-Vera*
11:40 am	ThM23	Preferential sampling of elastic inertial chains in the ocean *Francisco J. Beron-Vera*
12:00 pm	ThM24	A review on recent applications of the FSLE technique to Lagrangian dispersion studies in the Ocean *Guglielmo Lacorata, Raffaele Corrado, Federico Falcini, Rosalia Santoleri, Enrico Zambianchi*

Lunch Break
12:20 pm to 2:00 pm (1 hr 40 min)

Afternoon Session: ThA3
2:00 pm to 3:20 pm

2:00 pm	ThA31	Comparison of relative dispersion metrics in the inner shelf and continental slope of the western Gulf of Mexico *Paula Pérez-Brunius, and multiple co-authors*
2:20 pm	ThA32	Relative dispersion in quasi-geostrophic models of upper-ocean turbulence *Stefano Berti, Alexis Foussard, Guillaume Lapeyre, Xavier Perrot*
2:40 pm	ThA33	Lagrangian approaches to the analysis of cross-isopycnal tracer mixing *Jared Penney, Yves Morel, Peter Haynes, Francis Auclair, Cyril Nguyen*
3:00 pm	ThA34	Robust extraction of coherent regions in ocean flow from sparse, scattered, and incomplete trajectory data using transfer operators and the dynamic Laplacian *Gary Froyland*

Short Break
3:20 pm to 4:00 pm
Short Break (40 minutes), refreshments will be served.

Afternoon Session: ThA4
4:00 pm to 5:20 pm

4:00 pm	ThA41	The LTRANS-Zlev open-source Lagrangian ocean particle-tracking model: implementation and applications *Celia Laurent, Cosimo Solidoro, Stefano Querin, Donata Melaku Canu*
4:20 pm	ThA42	Lagrangian organization of phytoplankton assemblages *Clément Haëck, Marina Lévy, Roy El Hourany, Francesco d'Ovidio, Inès Mangolte*
4:40 pm	ThA43	Use of Lagrangian dispersion models to estimate distributions of plastic marine litter, observations planning and environmental risks assessment *Carlo Brandini, Bartolomeo Doronzo, Maria Fattorini, Massimo Perna, Stefano Taddei, Letizia Costanza, Chiara Lapucci*
5:00 pm	ThA44	Effect of Lagrangian flow properties on the distribution and composition of phytoplankton *Ismael Hernández-Carrasco, Alejandro Orfila, Vincent Rossi, Eva Alou, Veronique Garçon*

Session E Agenda Friday, June 21st

Registration
8:00 am to 8:30 am

Friday: **A mix of talks from all of the Topics**

Moderator:
Annalisa Griffa, *Consiglio Nazionale Ricerche (CNR/ISMAR)*

Morning Session: FrM1
8:30 am to 10:40

8:30 am	FrM11	TRACMASS - A versatile trajectory code for ocean and atmosphere general circulation models *Kristofer Döös, Joakim Kjellsson, Bror Jönsson, Sara Berglund, Aitor Aldama Campino, Dipanjan Dey*
8:50 am	FrM12	Two-point velocity statistics from ocean surface drifter observations in the Benguela upwelling system *Julia Draeger-Dietel, Dhruv Balwada and Alexa Griesel*
9:10 am	FrM13	Exchange Between a Deep Coherent Eddy and its Surroundings, studied with Subsurface Floats *Henrik Soiland*
9:30 am	FrM14	Using Lagrangian Transit Time Distributions to investigate eddy effects on carbon uptake in the ocean *Alexa Griesel, Manita Chouksey, Carsten Eden, Reiner Steinfeldt*
9:50 am	FrM15	A Lagrangian global dataset of Sea Surface Temperature *Shane Elipot, Rick Lumpkin*
10:10 am	FrM16	Lagrangian study of the water masses dynamics at the stations of the PEACETIME cruise in the Mediterranean Sea *Stéphanie Barrillon, Louise Rousselet, Anne Petrenko, Andrea Doglioli*

Short Break
10:40 am to 11:00 am
Short Break (20 minutes), refreshments will be served.

Morning Session: FrM2
11:15 am to 1:15 pm

11:15 am	FrM21	Ecosystemic connectivity from Lagrangian backtracking and bio-energetic modelling of small pelagic larvae in the Sicily Channe *Federico Falcini, R. Corrado, A. Cuttitta, G. Lacorata, M.C. Mangano, L. Palatella, B. Patti, R. Santoleri, G. Sarà, M. Torri*
11:35 am	FrM22	Integrating Lagrangian modeling with otolith analyses to quantify larval dispersal and locate spawning areas *Térence Legrand, Antonio Di Franco, Enrico Ser-Giacomi, Antonio Calò, Vincent Rossi*
11:55 am	FrM23	Vortex cores as barriers to the diffusion of vorticity in 2D turbulence *Stergios Katsanoulis , Mohammad Farazmand , George Haller*

12:15 pm FrM24 Topographic influence on currents and dispersion
Joseph LaCasce

12:35 pm FrM25 PDE-based Prediction, Estimation, Sampling, and Learning of Stochastic Lagrangian Transport
P.F.J. Lermusiaux, C. S. Kulkarni, A. Gupta, M. Doshi and A. Dutt

12:55 pm FrM26 The impact of vertical shear on horizontal dispersion
Sebastian Essink, Mathieu Dever, Amala Mahadevan

A Motion to Adjourn the Meeting

MoM11
Lagrangian simulations and influence of initial conditions on dispersion calculations

Francesco Enrile, Giovanni Besio, Alessandro Stocchino, Marcello G. Magaldi, Pierre-Marie Poulain
University of Genoa
(Abstract received 04/23/2019 for session A)

We assess the reliability of Lagrangian simulations based on HF-radar velocity fields upon drifter trajectories in the Gulf of Trieste, Italy. In particular, we carry out different types of simulations, such as single-particle tracking, lagrangian barrier identification and absolute and relative statistics. The analyses aim at evaluating how the former simulations compare with CODE drifter trajectories and the latter are influenced by initial conditions. Drifter simulations do present increasing errors when the quality of the HF-radar velocity fields deteriorates due to recording issues. However, the joint use of lagrangian barriers and single-particle tracking simulations could be an asset in increasing the quality of our predictions. Besides, initial conditions can influence the outcome of simulations since absolute and relative dispersion can vary up to one order of magnitude depending on the initial conditions set at the beginning of the calculations, i.e. their starting time. The dispersion regimes assessed through finite-size Lyapunov exponents do show such a dependence and some caution should be posed when employing such measures.

MoM12
What have we learned about ocean velocity statistics from drifter experiments in Gulf of Mexico

Arthur Mariano
U of Miami RSMAS
(Abstract received 03/28/2019 for session A)

Mean flows, ocean diffusivity, and relative dispersion are fundamental quantities that have been estimated from quasi-Lagrangian observations for over five decades. In the last three decades, a number of velocity statistics and diffusivity estimates have been calculated from ocean drifters and floats from larger and larger data sets. These studies have indicated that it is not a trivial exercise to estimate these quantities, even from large drifter sets such as those in the Gulf of Mexico. The large spatio-temporal variability in observed average velocities and diffusivity estimates indicates that classical theory, while elegant in the mathematical world, does not adequately describe the real world. These estimates and any climatological estimates are of little use for operational, real-time numerical simulations of ocean dispersion, given that the diffusivity is a strong function of dynamical features, wind forcing, and topography. Nevertheless, Taylor-based estimates can provide order of magnitude estimates of diffusivity. Mean velocity and dispersion estimates computed from drifter data sets suggest that a new paradigm is needed for ocean dispersion that does not depend on stationary flow in homogeneous domains and on the subjective decomposition into mean and fluctuating components, but accounts for different dynamical features and their interactions.

MoM13
Scale-dependent dispersion and structure functions near a density front

Henry Chang, Helga Huntley, Denny Kirwan, Dan Carlson
University of Delaware
(Abstract received 04/03/2019 for session A)

Density fronts are known to be areas in the ocean with high production and dissipation of kinetic energy (D'Asaro et al. 2011, McWilliams 2016). Here we investigate the associated dispersion and structure functions near a front from scales of tens of kilometers down to meters -- smaller than from previously reported open ocean observations. This is made possible through the analysis of small scale driftcard measurements resolved down to sub-meter and sub-minute scales, along with surface drifter trajectories, x-band radar velocity fields, and aerial infrared temperature fields, all obtained near the mouth of the Mississippi River in the northern Gulf of Mexico during CARTHE's LASER field campaign. These results are compared with statistics from an area without fronts and with classical results (i.e. Okubo 1971).

MoM14
Episodic strong convergence events in LASER drifter data

Andrew Poje, Angelique Haza, Tamay Ozgokmen, Rayan Ibrahim
City University of New York - CSI
(Abstract received 05/03/2019 for session A)

Buoyant materials in the ocean, such as plastics, oil and a variety of marine flora and fauna, are both dispersed and concentrated by the action of the fluctuating near surface velocity field. Sur- face dispersion takes place on all scales, while surface concentration,

requiring non-zero horizontal divergence, typically occurs at the ageostrophic submesoscales where horizontal density gradients produce significant downwelling velocities. Recent work by D,ÄôAsaro et al documents a dramatic case of organized clustering by sub- mesoscale motions during the 2016 Winter LASER field campaign where 100,Äôs of GPS tracked near-surface drifters initially arranged in a 10X10km array collapsed to within 100m of each other over the course of several days. The deployment in this case was specifically targeted to a strong cyclonic feature evolving along a sharp density front of Mississippi outflow. Questions remain about how prevalent such occurrence are, and what the relative importance of submesoscale surface clustering versus classical turbulent dispersion processes might be in any given pollutant release. To provide some quantification of this, we analyze the clustering behavior of drifter observations provided by other LASER launches, in particular a ,'randomly' positioned, near simultaneous launch of some 300 units. Various multi-point metrics indicate at least four specific episodes of strong clustering (the simultaneous convergence of multiple drifters to patches with length scales less than 100m) during the first 21 days after launch. In each case, drifter-based estimates of surface kinematic properties identify common features typically associated with submescale dynamics, namely cyclonic vorticity with magnitude several times Coriolis and associated convergence with similar inverse time-scales. Although the specific submesoscale features responsible for the observed surface convergence vary (small cyclonic eddies, apparent rapid roll-up of a front), comparison to available wind-wave models and observations suggest that the convergence events correlate with low wind periods following strong atmospheric frontal passages.

MoM21
Bridging the gap between physical and chemical approaches to ocean mixing and spreading

Thomas Rossby, Melissa Omand, Jakob Kuttenkeuler
Graduate School of Oceanography, University of Rhode Island
(Abstract received 04/04/2019 for session A)

Lagrangian techniques have proved effective at quantifying initial rates of relative dispersion using accurately tracked clusters of floats, both at the surface and at depth. At larger space and time scales chemical tracer techniques show where stuff spreads. The former provides insight into local eddy activity while the latter informs on how water masses eventually intermix. But what happens between the sub-mesoscale and the gyre scale? As particles disperse their relative motion soon becomes incoherent, but the subsequent trajectories may still be highly constrained. Obvious examples of this include shelf-breaks as barriers to lateral mixing, and topography that suppress interbasin exchange except at fracture zones.
Here we propose a further development of the RAFOS technology to enable studies of processes spanning these intermediate space and time scales. The floats will use the newly developed fishtag technology that allows for very energy-efficient acoustic reception; these also measure pressure and temperature. They will be small, ~ 5 kg in weight, and self-ballasting. We envision the basic unit cost to be well under 2 k$ in large numbers, but we are open to including other sensors such as for O2 and pH. Standard RAFOS sound sources provide acoustic navigation, but to save cost these may drift with the floats as SOFAR floats. Acoustic receivers on surfacing Argo floats would track the SOFAR floats. For applications that focus on the transition to geochemical applications at gyre scales high-resolution tracking can be replaced with occasional acoustic fixes to constrain their overall movements. An extreme Lagrangian challenge might to use floats to quantify mid-ocean abyssal drift.

MoM22
Machine learning ocean dynamics with lagrangian ocean drifters

Nikolas Aksamit, Themistoklis Sapsis, George Haller
ETH Zurich
(Abstract received 02/20/2019 for session C)

Transport barriers in the ocean influence the mixing of heat, salinity, debris, and the movement of complex mobile ecosystems. While their non-stationary boundaries can now be identified in a mathematically rigorous fashion, this identification relies on the availability of surface velocity fields at suitable temporal and spatial resolutions. A wealth of independent trajectory and velocity information from ocean drifters is also available but has remained largely unexploited in detecting transport barriers. The main difficulty in such a detection is the sparsity and intermittency of drifter data, which prevents constructing a sufficiently detailed drifter velocity field. Here we discuss how recent developments with deep neural networks enable the construction of such a drifter velocity field from observed drifter trajectories. This approach shows clear potential for uncovering the location of material transport barriers, such as fronts, eddies, and jets, from available drifter data, as well as for improving Lagrangian drifter models.

MoM23
Kinematic Properties from single trajectories: Serendipity or Stupidity?

Denny Kirwan, Henry Chang, Helga Huntley
University of Delaware
(Abstract received 04/02/2019 for session C)

Since the 1970s oceanic velocity gradients have been extracted from the differential motions of drifters in clusters. These algorithms rely either on a linear flow model based on a Taylor expansion of the drifter positions or velocities or on a generalized Stokes theorem integration around the convex hull of the cluster. An essential assumption is that the mean velocity and the velocity gradient components (the kinematic properties, or simply KPs) are constant over the area defined by the cluster. In recent years, as the density of drifter observations has increased dramatically, these methodologies have experienced a renaissance, including applications to deriving KPs from sea ice (Lukovich et al., Cryosphere, 2017).
This approach requires a minimum of 3 drifters. In a critique of various aspects of the paradigm, Kirwan (JGR, 1988) proposed an alternative method for estimating KPs, whereby the flow equations are solved analytically. In this approach, the critical assumption is that the KPs are approximately constant over the time between 3 consecutive position observations. The advantages of this approach are that the expansion region is localized to a single position instead of a cluster area, and the KPs can be obtained from just one drifter. The disadvantage is that the solutions involve transcendental functions, in which nonlinear combinations of the KPs are parameters in the function arguments. Consequently, Kirwan stated that this approach would be difficult to implement.
We show here that Kirwan was wrong, again. We obtain KP estimates following the basic assumption of that approach by application of linear algebra to individual trajectory data. Using data from recent CARTHE experiments we compare KP values obtained from the new paradigm with those from drifter triplets using the traditional approach. The analysis offers new insight into both the spatial regions and time periods over which Lagrangian estimates of the KPs are approximately constant.

MoM24
Documentation and analyses of life cycle of mesoscale eddies on Lagrangian maps

Sergey Prants
Pacific Oceanological Institute of the Russian Academy of Sciences
(Abstract received 02/12/2019 for session B)

A Lagrangian technique, based on computation of maps of specific indicators [1], is elaborated to document and study the life story of any mesoscale eddy in altimetric or numerically derived velocity fields. It allows us to visualize and analyse the main events in life cycle of ocean eddies: birth and formation, evolution, deformation, merger, splitting, erosion and decay. It is also shown how to identify origin of water masses inside eddies and to localize and date the events of entrainment and detrainment of water to and from the eddy [2]. We focus on mesoscale eddies distributed along the deep Japan, Kuril-Kamchatka and Aleutian trenches which are found to serve as a catching area for some Kuroshio rings, Hokkaido, Kuril, Kamchatka and Aleutian anticyclonic eddies. We identify those eddies which have a tendency to approach the trench and either remain quasi-stationary there or propagate along the trench axis even though the background flow has an opposite direction. By computing and inspecting altimetry-based daily Lagrangian maps from 1993 to the present time, we were able to identify all mesoscale trench eddies in the Northwest Pacific, to find the conditions for formation of specific eddies, to track their trajectories and monitor them from the birth to eventual decay.
1. S.V. Prants, M.Yu. Uleysky, M.V. Budyansky. Lagrangian oceanography: large-scale transport and mixing in the ocean. Berlin. Springer. 2017. 271 p.
2. S.V. Prants, M.V. Budyansky, M.Yu. Uleysky. J.Geophys.Res. V.123. P.2081 (2018).

MoA31
Do surface drifters accurately represent Eulerian turbulence statistics?

Jenna Pearson, Baylor Fox-Kemper, Brodie Pearson, Helga Huntley, Henry Chang, Denny Kirwan
Brown University
(Abstract received 02/18/2019 for session B)

Lagrangian instruments are frequently deployed throughout the global ocean to estimate regional oceanic statistics. Previous work paired with observations suggests that drifters tend to collect in convergent regions. This prevents drifters from sampling the entire velocity field, and may lead to biased statistics. Modeling work has confirmed that structure functions calculated with synthetic surface drifters are systematically different from Eulerian counterparts at scale separations below 10km in the Gulf of Mexico. In this study we use a series of surface drifter launches as well as X-Band radar in a comparable location to the modelling study to test for the presence of these biases in observations. We compare structure functions from coincident Lagrangian (drifter) and Eulerian (radar) data, and investigate whether differences are related to the local divergence and vorticity.

MoA32
Particle trajectories in a model vortex

Nathan Paldor, Yair Cohen
The Hebrew university of Jerusalem
(Abstract received 03/08/2019 for session B)

The Lagrangian dynamics of particles that move about in a time-independent circular symmetric geopotential field characterized by a single maximum at a particular radius is analyzed by transforming the Rotating Shallow Water Equations (RSWE) to an integrable,

two-degrees-of-freedom (2DOF), system. The two conserved quantities along each particle trajectory are the total (kinetic and potential) energy and the angular momentum. The azimuthal (tangential) angle and the angular momentum constitute one pair of the conjugate variables. The steady state of this pair occurs only when the vortex rotates as a solid body at a frequency of f/2 (f is the Coriolis frequency). An analysis of the steady states of the (u, r) (where u is the radial velocity and r is the radius) pair of conjugate variable shows that this subsystem has a unique and uniform steady state with u=0 at the radius where the geopotential attains its maximal value and that this steady state is independent of the value of the geopotential's magnitude. However, the nature of this steady state varies with the geopotential amplitude: For small geopotential amplitude this steady state is elliptic, and no additional steady state exists. In contrast, for large geopotential amplitude this steady state becomes hyperbolic and two additional, elliptic, steady states develop at larger and smaller radii. The pitchfork bifurcation at the radius of maximum geopotential that occurs when the geopotential amplitude is decreased has drastic consequences for particle trajectories in different heights of a hurricane-like vortex where the amplitude of the geopotential varies substantially with height, while the radius of this maximum changes only slightly. The net rate of azimuthal propagation (defined as the net change in azimuthal angle after the back-and-forth oscillations that result from the radial oscillation about the elliptic (u, r) steady state are averaged out) can also be estimated analytically and these estimates are validated by numerical solutions of the four non-linear RSWE. These results have important implications for the Lagrangian trajectories that can be expected to occur in different pressure levels in a hurricane and for the occurrence of outflows from the hurricane.

MoA33

Kinematic Properties in the Alboran Sea: Results from Surface and Subsurface Drifter Observations and Numerical Analysis

Daniel Tarry, Sebastian Essink, Mara Freilich, Mathieu Dever, Ananda Pascual, Simón Ruiz, Pierre-Marie Poulain, Tamay Özgökmen, Luca Centurioni, Amala Mahadevan
IMEDEA
(Abstract received 05/29/2019 for session A)

Tracing the three-dimensional pathways of water parcels and particles in the upper ocean is of importance from many perspectives. Observation, understanding and prediction of the three-dimensional pathways by which water from the surface ocean makes its way into the deeper ocean is the goal of this research.
During May of 2018 a pilot cruise in the framework of the CALYPSO ONR Departmental Research Initiative took place on the Alboran Sea in the Western Mediterranean Sea. This region is characterized by a strong semi-permanent front between the fresher Atlantic water that enters the Western Mediterranean at Gibraltar, and the more saline Mediterranean waters. It is populated by organized, time evolving features (jets, fronts, and gyres) that provide an ideal test bed for a dynamical systems-based Lagrangian analysis. During this cruise nearly a hundred drifters were deployed (between SVP, CODE and CARTHE drifters).
In this work we use a least square method to calculate the differential kinematic properties of flow, divergence, vorticity and lateral strain from a set of drifters. These values are obtained through the study of the evolution in time of a patch formed by a cluster of drifters. Results from drifters at different depths, surface and 15m, show different dynamics in these layers. To estimate the validity of the results, an numerical analysis is performed by advecting particles on a numerical model where the kinematic properties are known.

MoA34

Lagrangian studies of particle sedimentation in the oceans: an analysis in the Benguela region

Cristóbal López, Gabor Drotos, Emilio Hernandez-Garcia, Pedro Monroy
IFISC (UIB-CSIC), Institute for Cross-disciplinary Physics and Comples Systems, Palma, Spain
(Abstract received 02/18/2019 for session D)

Sedimentation of particles in the ocean leads to inhomogeneous horizontal distributions over the seafloor. We study this phenomenon considering a horizontal sheet of falling particles immersed in an oceanic flow, and determine how they spatially distribute when the particles sediment on the seabed (or are collected at a given depth by sediment traps).This is performed from a Lagrangian viewpoint attending to the oceanic flow properties and the physical characteristics (size and density) of typical biogenic sinking particles (for which we have previously discussed the proper equation describing their falling dynamics). Two main processes determine the distribution, the stretching of the sheet caused by the flow and its projection on the surface where particles accumulate. These mechanisms are checked, besides an analysis of their relative importance to produce inhomogeneities, with numerical experiments in the Benguela region. Faster (heavier or larger) sinking particles distribute more homogeneously than slower ones.

MoA41

Rain Calms the Sea

Juan M. Restrepo, Alex Ayet, Luigi Cavaleri
Oregon State University
(Abstract received 05/08/2019 for session D)

It is well known by mariners that intense rain can have a calming effect on rough seas. Reynolds and more recently, groups in Australia and in the US have been trying to eke out the mechanism by first recreating the phenomenon in the lab and then refining Reynolds original hypothesis that rain introduces turbulent motions that dampen waves. We suggest that a mechanism, that is by no means meant to be the exclusive explanation of the damping of waves originates in the entrainment of air by the rain. In this talk I will describe the phenomenon, and use homogeneisation ideas that were used to successfully upscale a micromechanics in comprehensive ocean oil spill model. In the oil spill the large scale dispersion is affected by the distribution of oil droplets in the water column. In the rain case wave damping is affected by enhanced dissipation.

MoA42
Surface connection between different areas of the Mediterranean Sea derived from drifter data

Paolo Celentano, Pierpaolo Falco, Enrico Zambianchi
Institute of Marine Sciences (ISMAR) - National Research Council (CNR), La Spezia, Italy
(Abstract received 04/10/2019 for session D)

The near-surface currents have been observed during last thirty years using Lagrangian drifter in the whole Mediterranean Sea. The Mediterranean Surface Velocity Programme (MedSVP) dataset collects all drifter data from various institutions and countries since 1986. The connection between the central Mediterranean and surrounding areas in the period 1986 ‚Äì 2016 has been studied by looking at the statistical properties of drifter trajectories.
In particular, we investigated the connection with a selected set of target boxes identified on the basis of:
a) Distribution of data, i.e. data coverage and density.
b) Surface circulation pattern, with a particular focus on the dynamic structures of interest (e.g. the Mid Ionian Jet in the Ionian Sea, etc.)
c) Socio-economic importance of the area, i.e. presence of AMPs, areas of tourist importance, etc.
An application of the connectivity methodology, has been applied for the Adriatic-Ionian Bimodal Oscillating System (BiOS) phases, showing their effect on the connectivity of the central Mediterranean Sea.

MoA43
Integrating Lagrangian simulations of plastic pollution with chemical advection-diffusion processes to account for cetacean ingestion risk within the Pelagos Sanctuary

Federica Guerrini, Lorenzo Mari, Renato Casagrandi
Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano
(Abstract received 04/12/2019 for session D)

The Mediterranean Sea is heavily impacted by anthropogenic activities. Under the Marine Strategy Framework Directive, marine litter (Descriptor 10) has been recognized as one of the principal causes of marine pollution, and plastics is raising concern about impacts on marine wildlife. We investigated the risk of ingestion of plastic debris by marine biota by interlacing a decade (2000-2010) of microplastic concentration fields obtained through Lagrangian simulations with a Habitat Suitability Model (HSM) for our target species Balaenoptera physalus, an endangered cetacean for which there is increasing evidence of impacts due to microplastic ingestion. We released particles on a wide area embracing the Pelagos International Sanctuary for the Protection of Mediterranean Marine Mammals (North-Western Mediterranean, between France, Italy and Monaco), which harbors the summer feeding grounds of the fin whale. Maps of species exposure were obtained by feeding the HSM with chlorophyll-a satellite data and then overlapped with maps of plastic litter distribution derived from our oceanographic modelling, to obtain a spatially explicit indicator of the risk of plastic ingestion for the cetaceans feeding in the Sanctuary. Plastics also act as vectors of pollutants, in terms of both additives used for their production and other chemicals sorbed from the environment they float in. Therefore we propose a coupling of Lagrangian simulations with chemical advection-diffusion processes to start developing an integrated framework that allows a comprehensive analysis of the multi-faceted problems related to plastic contamination in the Mediterranean Sea.

MoA44
Seasonal, interannual and decadal variability of the Sicily Channel and southern Tyrrhenian Sea

Milena Menna, Pierre-Marie Poulain, Daniele Ciani, Andrea Doglioli, Marie-Helene Rio, Giulio Notarstefano, Riccardo Gerin, Rosalia Santoleri, Adam Gauci, Aldo Drago
Istituto nazionale di Oceanografia e Geofisica Sperimentale, OGS
(Abstract received 04/29/2019 for session A)

The dynamics of the Sicily Channel and southern Tyrrhenian Sea is highly influenced by the seasonal variability of the Mediterranean basin-wide circulation, by the interannual variability of the numerous mesoscale structures present in the Channel, and by the decadal variability of the adjacent Ionian Sea. In the present study, all these aspects are investigated using in-situ (Lagrangian drifter trajectories and float profiles) and satellite data (Absolute Dynamic Topography, Sea Level Anomaly, Sea Surface Temperature, wind products) over the period 1993-2018. The availability of long time series of data and of high resolution multi-sensor currents (derived

from the merging of the satellite geostrophic currents and Sea Surface Temperature), allow us to add new details on the sub-basin and mesoscale features and on their driving mechanisms and to improve the recent results obtained by numerical model simulations. The combined use of all these datasets leads to overcome the main intrinsic limitations of each of them, provide the temporal variability of the main mesoscale structures, detect new permanent eddies not yet described in literature, describe how the external and/or internal forcings can modulate the strength of the mesoscale seasonal and interannual variability. The vertical structures and the hydrological characteristics of these mesoscale eddies are eventually delineated using the Argo float profiles when they are entrapped in these structures.

TuM11

Dispersion of Lagrangian isopycnal RAFOS floats deployed in the Atlantic Oxygen Minimum Zone

Tom Rossby, Don Rudnickas, Jaime Palter, Dave Hebert
Graduate School of Oceanography, University of Rhode Island
(Abstract received 04/04/2019 for session A)

The Eastern Tropical North Atlantic Oxygen Minimum Zone (OMZ) is a biogeochemically important area near the Cape Verde Islands. The low oxygen in this region is thought to be maintained by a balance between the slow mixing supply of O2 and its removal by respiration. We use data collected from 90 isopycnal RAFOS floats to characterize the mixing coefficients responsible for the supply of oxygen to the region. One group was ballasted to drift on the isopycnal where oxygen is at its minimum, and the other group about 300 m deeper. Using the record of the float positions at each 6-hr interval, we calculate the relative dispersion of a large number of pairs of floats. The time derivative of this dispersion provides a diffusivity coefficient that captures the net effect of eddy driven mixing along each isopycnal. With its sluggish mean circulation, the OMZ provided a study area in which this isopycnal mixing is observed with little interference by background advection. Relative dispersion of the floats in the OMZ area obeyed the canonical 4/3rds power scaling, representative of two dimensional turbulence. At the length scale of the maximum energy containing eddy, the effective diffusivity is 1400 ¬± 500 m2 s-1 in the zonal direction and 800 ¬± 300 m2 s-1 in the meridional. Within our quantification of error, the diffusivities on the two isopycnals are indistinguishable from one another. Synthesis of the diffusivity results suggest that meridional mixing across the large-scale O2 gradient is the leading supply term of oxygen to the OMZ.

TuM12

Lagrangian Statistics from Surface Drifter Observations and Numerical Simulations in the Icelandic Basin

Thilo Klenz, Harper Simmons, Jonathan Lilly, Luca Centurioni
University of Alaska Fairbanks, Fairbanks, AK, USA
(Abstract received 04/09/2019 for session A)

We investigate the relative dispersion and other time- and scale-dependent two-particle statistics of surface drifters in the Icelandic basin. The drifters, drogued at 15 m water depth, were released over the course of one week in May 2018 in a region of strong mesoscale activity. The release was carried out along the axis of a long-lived dipole of cyclonic and anticyclonic vorticity. The observed dynamics were heavily influenced by the mesoscale eddy field; multiple drifters remained within 100 km of their launch positions for up to 80 days, trapped inside an anticyclonic eddy. The relative dispersion exhibits the expected local and diffusive dispersion regimes for time scales between 2 - 20 days and more than 30 - 50 days, respectively. The non-local regime, while poorly resolved due to minimum initial separations of drifter chance pairs around 2 km, can be estimated to hold for approximately 1 - 2 days. Scale-dependent parameters reflect the scales of the largest eddies (50 - 100 km) that the drifters experience. High-resolution (2 km) hindcast simulations in ROMS are used to compare numerical and observed drifter statistics as well as evaluate the impact of the mesoscale eddy field and the mean flow on the relative dispersion and other parameters. Additionally, the Lagrangian velocity spectrum is analyzed directly for the observational and numerical datasets by performing a parametric fit to the turbulent background spectrum.

TuM13

Greenland Ice Sheet Ocean Interactions gauged with backward Lagrangian simulations

Inga Monika Koszalka and multiple co-authors
Department of Meteorology, Stockholm University
(Abstract received 04/09/2019 for session A)

More than 25% of global sea level rise is caused by mass loss from the Greenland Ice Sheet. A significant part of this mass loss is attributed to interactions between Greenland's marine terminating glaciers and the surrounding warm ocean waters. The latter were identified as Atlantic-origin water masses recirculating in the Nordic Seas and the Eurasian Basin and intruding on the East Greenland continental shelf through systems of troughs. As the Atlantic-origin waters in the subpolar North Atlantic and in the Fram Strait are observed to be warming, a prevailing hypothesis is that this warming signal propagates to the glacier termina and contributes to the increasing ice melt. In this contribution, I will present results from a couple collaborative studies using backward simulations of Lagrangian particles deployed in warm waters close to three major East Greenland glaciers (Sermilik, Kangerdlugssuaq and Nioghalvfjerdsbrae) and integrated using output from high resolution ocean models. These lead to a common conclusion that the far-field warming signal in Atlantic waters is obliterated before it reaches Greenland glaciers due to multiple and crossing oceanic pathways, mixing with Polar Waters, and modulation of the inflow on the shelf by wind forcing. I will put these results in a broader perspective concerning the application of Lagrangian techniques to track warming signals over large distances, hoping to trigger a vivid discussion.

TuM14
Extraction of coherent eddy properties from individual particle trajectories, with application to the Gulf of Mexico

Jonathan Lilly, Paula Perez-Brunius, Jeffrey Early, Julio Sheinbaum, Jorge Zavala, Julien Jouanno, Joao Azevedo, Sheila Estrada
Theiss Research
(Abstract received 04/11/2019 for session A)

The theory of extracting coherent vortex properties from individual Lagrangian trajectories is reviewed and is shown to exhibit excellent performance when applied to an idealized numerical model of an unstable nonlinear eddy on a beta-plane. The method is then applied to a set of 3310 surface drifter trajectories from the Gulf of Mexico. In addition to the anticyclonic Loop Current Eddies, two types of energetic cyclonic variability are observed. The first is associated with a persistent feature in the southern Gulf of Mexico, termed the Campeche Gyre. The second is small-scale, high-Rossby number events---with V/(fR) between 0.15 and 0.35---that are conjectured to originate in the intense cyclonic shear zone of the inflowing Loop Current, and that are observed in both the eastern and western portions of the basin. Strong anticyclonic activity in the northwest corner of the Gulf, seen in some numerical models, is not observed in the data. Comparison with several realistic numerical models serves to (i) further examine the method‚Äôs ability to accurately recover eddy structures and (ii) assess the models‚Äô performance at reproducing the observed eddy fields. Implications for eddy lifecycles, transport, and mixing are discussed.

TuM21
Can Lagrangian tracking simulate tracer spreading in a high-resolution Ocean General Circulation Model?

Patrick Wagner, Siren Ruhs, Franziska Schwarzkopf, Inga Koszalka, Arne Biastoch
GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany
(Abstract received 04/12/2019 for session A)

For modeling the spreading of tracers and water masses in the ocean, off-line Lagrangian simulations are a practical and commonly employed alternative to solving the advective-diffusive tracer equations. Differences between the two techniques raise a question whether the results are comparable. For example, Lagrangian simulations usually use model output subsampled or averaged in time, and are not subject to the subgrid and numerical diffusion which is included in tracer equations of ocean models. The vexatious question of the equivalence of the two methods has been addressed previously in studies using simplified models for ocean circulation, which showed that both methods yield similar results as long as the deformations scale dynamics is resolved and a sufficient amount of particles has been used. However, it has not been yet addressed using a high resolution ocean model. Our study fills this gap by comparing the spreading of an Eulerian tracer and a cloud of Lagrangian particles in an eddy-resolving ocean model of the Agulhas Current system. Tracer and particles were released below the mixed layer and integrated for 3 years. We find that horizontal spreading diagnostics are almost identical for the two methods and the diffusivity estimates are also consistent. Differences in vertical distributions are due to a combined effect of unresolved sub-daily variability of the vertical velocities and the vertical variation of the model vertical diffusivity. Reference: Wagner et. al., (2019), doi: https://journals.ametsoc.org/doi/pdf/10.1175/JPO-D-18-0152.1.

TuM22
Coincident observations of dye and drifter relative dispersion over the inner shelf

Leonel Romero, Carter Ohlmann, Enric Pall√†s-Sanz, Paula Perez Brunius, Nicholas M. Statom, and Stéphane Maritorena
Earth Research Institute, University of California Santa Barbara
(Abstract received 04/14/2019 for session A)

We present an analysis of relative dispersion over the inner-shelf off the coast of South Padre Island during the Inner-Shelf Dispersion Experiment (ISDEX). Coincident Lagrangian observations of coastal circulation with surface drifters and dye tracer were collected to better understand small-scale physical processes controlling transport. Patches of rhodamine dye and clusters of surface drifters at scales of O(100 m) were deployed in a cross-shelf array between 2 and 12 km from the coast and tracked continuously over a period of up to 5 hours with airborne and in situ observations. The airborne remote sensing system includes a hyperspectral sensor to track the evolution of dye patches, and a lidar to measure directional wavenumber spectra of surface waves. Supporting in situ measurements include a CTD with a fluorometer to inform on the stratification and vertical extent of the dye patches and a real-time towed fluorometer for calibration of the dye concentration from hyperspectral imagery. Experiments were conducted over a wide range of conditions with surface wind speed between 3 and 10 m/s, and varying sea states. Cross-shelf density gradients due to freshwater runoff resulted in active submesoscale flows. The airborne data allow characterization of the dominant physical processes controlling the dispersion of passive tracers such as freshwater fronts and Langmuir circulation. Langmuir circulation was identified in dye concentration maps during all sampling days except during a restratifying period. The observed relative dispersion is anisotropic with eddy diffusivities O(1 m^2/s). Near-surface horizontal dispersion is largest along fronts and in conditions dominated by Langmuir circulation is generally larger in the cross-wind direction. Surface convergence at fronts resulted in strong vertical velocities of up to -66 m/day.

TuM23

Eddy Diffusivity Estimates from Lagrangian Trajectories Simulated with Ocean Models and Surface Drifter Data,ÄîA Case Study for the Greater Agulhas System

Siren Ruhs, Victor Zhurbas, Inga Koszalka, Jonathan Durgadoo, Arne Biastoch
GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany
(Abstract received 04/11/2019 for session C)

One of the most common techniques of Lagrangian analysis is estimation of lateral eddy diffusivities (mixing rates) from spreading of floats or Lagrangian particles simulated with velocity output from ocean models. The relation between Lagrangian diffusivities and mixing rates employed in ocean models to parameterize the impact of unresolved turbulent processes is still poorly understood, however. In this work we flip this question and apply Lagrangian diffusivities to diagnose lateral turbulent transport from surface drifter trajectories and from Lagrangian particles released using output from a hierarchy of ocean models for the Agulhas Current system, known for its intense eddy variability. The models include an eddy resolving configuration (INALT01) with daily, 5-daily and monthly output, and noneddying configurations (ORCA05) with and without Gent and McWilliams parameterization. We find that INALT01 features different diffusive regimes for dynamically different regions, some of which exhibit strong suppression of eddy mixing by mean flow, and the model diffusivity estimates are consistent with the pattern and magnitude of drifter-based eddy diffusivity estimates. Using monthly mean velocities decreases the estimated diffusivities less than eddy kinetic energy, supporting the idea that large and persistent eddy features dominate eddy diffusivities. For a noneddying ocean model (ORCA05), Lagrangian eddy diffusivities are greatly reduced, particularly when the Gent and McWilliams parameterization of mesoscale eddies is employed. Reference: S. R√ºhs et. al., (2018): Eddy diffusivity estimates from Lagrangian trajectories simulated with ocean models and surface drifter data - a case study for the greater Agulhas system, doi: https://doi.org/10.1175/JPO-D-17-0048.1.

TuM24
Interannual and decadal variability of the Southern Pacific Ocean in response to the large scale climatic patterns

P. Falco, M. Menna, Y. Cotroneo, R. Di Lemma, P.-M. Poulain, G. Fusco, G. Budillon, E. Zambianchi
University of Naples Parthenope
(Abstract received 04/26/2019 for session A)

The surface interannual variability of the Pacific Sector of the Southern Ocean (PSSO) is related to the variations of the large-scale climatic patterns. Both the Southern Annular Mode (SAM) and El Nino Southern Oscillation (ENSO) influence the level of Eddy Kinetic Energy (EKE) in the PSSO and then the Antarctic Circumpolar Current (ACC) dynamical balance. Altimetry and drifter data depict two different possible responses of the EKE field during the period 1995-2017, showing positive/negative anomalies of the EKE when positive SAM values coincide with La Ni√±a/El Ni√±o events. Positive anomalies of the EKE are associated with increments of the meridional eddy heat fluxes both in southward and northward directions. Largest poleward fluxes are observed along the western boundary while largest equatorward fluxes involve the main meanders of the ACC latitudinal band. The PSSO results also linked to the decadal variability associated with the EKE and baroclinic transport time series derived from XBT and Argo float data. In the first decade (1995-2006) the prevalence of years with significant El Ni√±o events is reflected by a predominance of negative anomalies of EKE an almost constant value in the transport time series. In the second decade (2007-2017), the higher variability of indices and the larger contribution of significant La Niña events are reflected by a predominance of positive anomalies of EKE and by a sharp increase of the transport time series.

TuA31
Lagrangian geographies of the Gulf of Mexico

Philippe Miron
RSMAS, University of Miami
(Abstract received 03/26/2019 for session B)

Using trajectories from drifter and float trajectory data, we construct geographies of the Lagrangian circulation in the Gulf of Mexico at the surface and depth, respectively. A Lagrangian geography is composed of weakly communicating basins of attraction for almost-invariant forward attracting sets revealed from a spectral analysis of discrete transfer operators (transition matrices) computed using the trajectory data. We discuss implications of the resulting Lagrangian geographies for connectivity. (Joint work with F. Beron-Vera, M. Olascoaga, G. Froyland, P. P Perez-Brunius and J. Sheinbaum; support provided by CONACyT-SENER and GoMRI.)

TuA32
Markov-chain-inspired search for MH370

Philippe Miron
RSMAS, University of Miami
(Abstract received 03/26/2019 for session B)

Markov-chain models are constructed for the probabilistic description of the drift of marine debris from Malaysian Airlines flight MH370. En route from Kuala Lumpur to Beijing, the MH370 mysteriously disappeared in the southeastern Indian Ocean on 8 March 2014, somewhere along the arc of the 7th ping ring around the Inmarsat-3F1 satellite position when the airplane lost contact. The models are obtained by discretizing the motion of undrogued satellite-tracked surface drifting buoys from the global historical data bank. A spectral analysis, Bayesian estimation, and the computation of most probable paths between the Inmarsat arc and confirmed airplane debris beaching sites are shown to constrain the crash site in a largely unsurveyed area of the Indian Ocean. (Joint work with F. Beron-Vera, M. Olascoaga and P. Koltai.)

TuA33
Toward a dynamical-systems-based oil evolution prediction scheme

Maria J. Olascoaga
RSMAS, University of Miami
(Abstract received 03/26/2019 for session B)

Two tools from nonlinear dynamics recently advanced in oceanography, quasi-stationary Lagrangian coherent structures and time-asymptotic almost-invariant sets, are combined to diagnose the evolution of oil spills using climatological information of the state of ocean circulation in the Gulf of Mexico and of the oil degradation rate depending on its density. These represent the first steps toward developing a dynamical-systems-based oil spill prediction scheme. (Joint work with F. Beron-Vera and P. Miron; support provided by CONACyT-SENER.)

TuA34
Persistent transport patterns in the northwestern Gulf of Mexico

Maria J. Olascoaga
RSMAS, University of Miami
(Abstract received 03/26/2019 for session B)

Persistent Lagrangian transport patterns at the ocean surface are revealed from climatological Lagrangian coherent structures (cLCSs) computed from daily climatological surface current velocities in the northwestern Gulf of Mexico (NWGoM). The climatological currents are computed from daily velocities produced by an 18-yr-long free-running submesoscale-permitting NEMO (Nucleus for European Modelling of the Ocean) simulation of the Gulf of Mexico. Despite the intense submesoscale variability produced by the model along the shelf break, which is found to be consistent with observations and previous studies, a persistent mesoscale attracting barrier between the NWGoM shelf and the deep ocean is effectively identified by a hook-like pattern associated with persistent strongly attracting cLCSs. Simulated tracer and satellite-tracked drifters originating over the shelf tend to be trapped there by the hook-like pattern as they spread cyclonically. Tracers and drifters originating beyond the shelf tend to be initially attracted to the hook-like pattern as they spread anticyclonically and eventually over the deep ocean. The findings have important implications for the mitigation of contaminant accidents such as oil spills. (Joint work with M. Gough, R. Duran, F. Beron-Vera, J. Sheinbaum and J. Juoanno; support provided by CONACyT-SENER.)

TuA41
Oil Spill Scenarios for the western Gulf of Mexico

Julio Sheinbaum and multiple co-authors
CICESE, Physical Oceanography
(Abstract received 04/15/2019 for session D)

Several ocean circulation models and surface wind products are used to generate oil-spill scenarios for the western Gulf of Mexico. The oil-spill simulations are obtained using a fully comprehensive 3D oil-spill model as well as simpler 2D lagrangian and Markov chain models that include oil decay to parameterize weathering. A summary is provided with emphasis on the similarities and differences among model results and suggestions of possible products from the model ensemble that can provide useful information to decision makers.

TuA42
Environmental processes that affect the 3D circulation pattern of oil spills and oil plumes. Sensitivity analysis of the contributing factors and a comparison with 2D only oil spill simulations

Konstantinos Kotzakoulakis, Julio Sheinbaum, Favio Medrano
Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), Baja California
(Abstract received 04/18/2019 for session D)

Current state-of-the-art oil spill models can simulate a comprehensive suite of environmental processes which affect the fate and circulation of oil spills in the marine environment. The degree to which each process can affect the circulation pattern depends on a number of factors. These factors can be categorised in three groups.
1. The initial conditions of the oil spill/oil plume such as the oil type, release depth, leak flow rate, the environmental conditions and more.
2. The predictions of the oil spill model can also vary depending on the chosen hydrodynamic, wind, wave and biogeochemistry data or predictions to be used as inputs for the simulation.
3. The selected correlation to simulate a specific environmental process.
Due to the complexity of the transport and fate processes they are typically simulated by simplified theoretical approximations or empirical correlations which can vary significantly in their estimations and as a consequence alter the prediction of the oil spill model to a different degree. In this study we primarily tried to identify: a) the environmental processes that can potentially have the greatest effect on the 3D circulation pattern of the oil spill/oil plume, b) under which initial conditions these effects are pronounced, and c) how sensitive these predictions are to the variability of the initial conditions. We have also touched on the subject of variability due to the selected hydrodynamic and wind inputs as well as the different correlations to simulate a specific process, although we haven't reviewed all the available input combinations and process correlations. We present the effect of these processes on a single oil spill event and on maps produced by the processing of multiple simulations. Finally, since many of these processes such as the vertical diffusion, vertical advection, particle buoyancy and wave entrainment can only be simulated in 3D oil spill simulations, we compare the predicted 3D circulation patterns with those produced by 2D only simulations.

TuA43
Larval flow among red gorgonian populations in the Ligurian sea unveils stepping-stone connections: implications for conservation practice

Roberta Sciascia, Katell Guizien, Lorenzo Bramanti, Mariana Padrón, Marcello G. Magaldi
CNR-ISMAR, Italy
(Abstract received 04/19/2019 for session D)

Connectivity and migration between distant populations are considered essential for the resilience of marine populations. Moreover, connectivity patterns are regarded as a useful tool to guide marine protection and conservation measures.
Despite the increasing accuracy of ocean circulation models, the ability to model the connectivity of marine populations with dispersal larval stages is still limited. This is particularly true for sessile benthic species. Uncertainties arise from determining larval properties such as mortality and behavior (i.e. sinking, passive, swimming).
In the present work we use a high-resolution hydrodynamical model together with a Lagrangian transport model to simulate the dispersal of red gorgonian (Paramuricea clavata) larvae in the Ligurian and North Tyrrhenian seas (NW, Mediterranean Sea). Our goal is to assess the role of ocean currents and larval behavior in shaping the populations at regional and local scales.
We show that, when considering larvae with sinking behavior, the connectivity patterns are consistent with recent observations of gene flow among the red gorgonian populations in the Ligurian sea. Albeit local retention is found, larval transport is crucial for the resilience of the species and to this end, the populations in the central part of the Ligurian Sea are strategic for the regional persistence. Moreover, ocean currents and in particular the link between the Tyrrhenian and Ligurian Seas favor stepping-stone connections among the different red gorgonian colonies. These findings suggest new possible migration patterns within the basin and a trans-border approach to conservation practices.

TuA44
Fate and transport of giant kelp plants in coastal California waters

Carter Ohlmann, Jenny Dugan, Bob Miller, Kylene Cooley, Leonel Romero, Dave Hubbard, Kyle Emery, and Jessica Madden
University of California, Santa Barbara
(Abstract received 04/24/2019 for session D)

Trophic connections between ecosystems are key to understanding food webs and predicting their responses to a changing environment. The overall focus of this interdisciplinary study is quantification of trophic connectivity between the highly productive giant kelp forest (Macrocystis pyrifera; donor ecosystem) and the practically non-productive sandy beach (recipient ecosystem). Kelp forests export large amounts of drift kelp to sandy beaches. This beached kelp is necessary and sufficient fuel for a diverse and productive intertidal food web. The coastal ocean circulation, through its transport of kelp from forest to shoreline, is key to the health of sandy beach ecosystems. The transport of drift kelp from coastal ocean kelp forests to sandy beaches is being investigated in Southern California as part of the larger ecosystem study. Nearly 2000 kelp plants attached to the ocean floor were tagged with drift cards over a two-year period. The distribution of beached drift cards (tagged kelp plants) quantifies the connectivity between kelp forests and sandy beaches. A smaller set of kelp plants was tagged with GPS devices to quantify transport pathways (and transport times) from forests. GPS tracking allows trajectories of non-beaching plants to be quantified. Finally, transport pathways from kelp forests are quantified with trajectories computed from ocean circulation model results. Drift cards, GPS tracking and model trajectories all indicate that only about 25% of kelp plants removed from a forest land on beaches. The majority of kelp plants (~75%) move into open ocean waters where they presumably decay and sink. High levels of variability in loss of tag kelp plants and kelp

delivery to beaches are observed. First, there is a strong seasonal cycle in kelp removal from forests and deposition on beaches, with the majority of plants leaving forests during the winter months when surface gravity wave energy is largest. Second, the spatial distribution of beached kelp depends on the location of a forest relative to a curved coastline. Transport is directly shoreward from one forest. For another forest, initial transport is alongshore with subsequent deposition most often in the lee of headlands. The majority of kelp plants beach within ~5 km of their source forests. However, tagged kelp plants are observed to beach more than 100 km from their forests in both the upcoast and downcoast directions. The addition of Stokes drift to ROMS surface current solutions gives a significant improvement in kelp-transport compared with observations.

ThM11

Coastal submesoscale structures and variability from drifters and HF radar in the Ligurian Sea (Mediterranean)

Maristella Berta, Lorenzo Corgnati, Marcello G. Magaldi, Annalisa Griffa, Carlo Mantovani, Pierre-Marie Poulain, Paolo Oddo
CNR (Consiglio Nazionale Ricerche) ISMAR
(Abstract received 04/16/2019 for session A)

The presence and variability of coastal submesoscale structures, such as eddies and jets of the order of 1-10 km, is studied using drifters and HF radar data in the coastal Ligurian Sea. The presence of strong convergent areas and jets of a few kilometers are first investigated using drifter data, collected in the framework of the LOGMEC-17 experiment (September 2017). The time evolution of the structures is then studied using surface current velocity data from HF radar over a period of two months in October-November 2018. We focus in particular on the response to the wind during an extreme event occurred at the end of October, that caused extensive damage along the Ligurian coast. The submesoscale structures are characterized in terms of kinematic properties (KPs) such as vorticity and divergence. During the event, the current root mean square (rms) velocity is found to increase of approximately four times during the event, while vorticity and divergence are almost doubled. The deformation of the spatial structures suggests nonlinear interactions with the wind forcing, with local values of divergence greater than the Coriolis parameters f. This indicates significant submesoscale vertical velocity and consequent potential impact on the ecosystem in terms of transport of biological quantities, nutrients and pollutants in the water column.

ThM12

Mass exchange of Atlantic Water with the Lofoten Basin derived from high-resolution Lagrangian simulations and Eulerian models

Johannes S. Dugstad, Inga Monika Koszalka, Knut-Frode Dagestad, Ilker Fer, Pal Erik Isachsen, Joseph Henry LaCasce
Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Bergen, Norway
(Abstract received 04/17/2019 for session A)

The Atlantic Water in the Nordic Seas undergoes a substantial cooling and densification as it flows northwards towards the Arctic. The largest water mass transformation is observed to take place in the topographical depression west of the continental slope of Norway, the Lofoten Basin, due to a retention of relatively warm Atlantic Water which results in large surface heat losses. The Atlantic Water inflow to the basin has been previously attributed to mesoscale eddies that drift into the basin from the eastern continental slope. However, the spatial distribution, vertical structure and seasonal variations of the inflow has not been yet quantified. To address this issue, we first analyze historical surface drifter trajectories as well as volume and heat transport from an eddy-permitting ocean model (ROMS). We find that warm water is mainly entering the Lofoten Basin from the south at surface, while at deeper levels heat is transported into the basin by the help of eddy fluxes from the east. Next, we analyze a largest-to-date deployment of 2D and 3D Lagrangian particles in the region integrated using output from a dedicated high-resolution ROMS model simulation. We estimate key regions of the inflow, identify the typical characteristics of these water masses and study how these characteristics changes geographically around the basin. In addition, we compare how the vertical and seasonal signal is represented in the 2D and 3D simulations.

ThM13

Anisotropy in Coastal Ocean Relative Dispersion Observations

Carter Ohlmann, Leonel Romero, Enric Pallàs-Sanz, Paula Perez-Brunius
University of California, Santa Barbara
(Abstract received 04/18/2019 for session A)

Horizontal relative dispersion is investigated with Lagrangian drifter and dye tracer observations on relatively small scales (~100 to 850 m) in coastal waters. Anisotropy is quantified with an aspect ratio of the spreading in two orthogonal directions. Individual observations generally appear highly anisotropic. However, the ensemble mean computed in a coordinate system aligned with bathymetry indicates only weak anisotropy due to averaging highly anisotropic observations over a wide range of principal axis directions. The strong anisotropy is preserved when the mean is computed in a principle-axis coordinate system. In fact, the ensemble mean in principle-axis coordinates gives anti-dispersion or convergence in the minor-axis direction. This result suggests gradients in buoyant materials such as spilled oil and other contaminants are not necessarily smoothed as the standard eddy-diffusivity parameter suggests. Flow kinematics computed with clusters of four drifters indicate that approximately 72% of energy in the observed dispersing flows can be attributed to organized submesoscale structures.

ThM14

Circulation over the Inner-Shelf off the South Padre Island, Texas, USA

Enric Pallàs-Sanz, Leonel Romero, Carter Ohlmann
Centro de Investigación y Educación Superior de Ensenada (CICESE)
(Abstract received 03/14/2019 for session A)

The variability of the circulation over the inner-shelf off the South Padre Island is investigated with a combination of Eulerian (CTD casts) and Lagrangian (drifters) observations obtained during November 2016 and 2017 within 12km from the coast. In absence of atmospheric or larger scale forcing, typical stratification in the inner-shelf is cold and fresh upper layer due to inflow from Laguna Madre and warm and salty bottom layer (far field oceanic water). On November 8 2016 the passage of a cold front or Norte cooled down the atmospheric temperature by ~5¬∫C resulting in ebb tide outflow through the Port Isabel inlet of fresh but very cold water into the inner shelf. The fresh plume was ~2¬∫C cooler than the well-mixed nearshore waters found the day before. As a result, a retrograde front with isopycnals sloping downward towards the coast developed with a jet centered at roughly 8 km offshore on November 12. Light (dense) waters were found nearshore (offshore) driving a geostrophic southward flow in balance with the bottom intensified cross-shelf density gradients. Westward Ekman transport during downwelling regime drove onshore displacement of the outcropping retrograde front. During autumn-2017 experiment the opposite scenario occurred. The prevailing winds were northward (Suradas) favoring upwelling with offshore displacement of the frontal interface. Upwelled water was warm but saltier than that offshore leading to heavy (light) water nearshore (offshore) which triggers a surface intensified geostrophic current northward. The current jet was again centered at 8 km from the shore. We conclude that the inner-shelf off the South Padre Island is controlled by two main modes of along-shelf circulation driven by cross-shelf density gradients in qualitative agreement with the modeled inner-shelf circulation discussed in Austin and Lentz (2002; J. Phys. Oceanogr., 32). Two exceptions to these modes associated with plume-induced submesoscale instabilities are also shown.

ThM21
Estimates of kinematic properties variability at the submesoscales from surface drifter measurements in the Gulf of Mexico

Maristella Berta, Annalisa Griffa, Helga Huntley, Andrew Poje, Tamay Ozgokmen
CNR-ISMAR
(Abstract received 04/17/2019 for session C)

The transport and spreading of surface tracers at sea is relevant in many contexts, such as oil spills, search and rescue, marine litter, and biochemical properties. Dispersion in the ocean results from mechanisms acting simultaneously at different scales which can be difficult to disentangle. Geostrophic mesoscale dynamics (10 to 100 km, days to weeks) are globally monitored through satellite altimetry, but direct observation of the ageostrophic submesoscale (a few hundred meters to 10 km, hours to a few days) remains challenging, since it requires targeted experiments. In this study we focus on the submesoscale dynamics observed from massive drifter releases in the northern Gulf of Mexico, near the location of the 2010 Deepwater Horizon oil spill and home to many oil platforms. Drifter triplets are extracted from these releases to investigate the quasi-synoptic and scale-dependent characteristics of the flow. From the evolution and deformation of each triplet, the flow's kinematic properties (strain, divergence and vorticity) are computed at scales between 100 m and 5 km. The statistics of the kinematic properties estimated in winter during LASER is compared with that of kinematic properties calculated from the drifter observations collected in summer in the same area during the 2012 Grand LAgrangian Deployment (GLAD) experiment. In both seasons, kinematic properties increase in magnitude at decreasing scales. For winter flows, vorticity and divergence are of order f at scales of 1 km (further increasing at smaller scales), indicating ageostrophic flows capable of trapping flotsam and inducing vertical velocities. In summer, the ageostrophic submesoscales are weaker and smaller than in winter, of the order of 100-500 m, consistent with shallower stratification.

ThM22
Lagrangian stability of the Malvinas Current

Francisco J. Beron-Vera
RSMAS, University of Miami
(Abstract received 03/26/2019 for session B)

Deterministic and probabilistic tools from nonlinear dynamics are used to assess enduring near-surface Lagrangian aspects of the Malvinas Current. The deterministic tools are applied on a multi-year record of velocities derived from satellite altimetry data, revealing a resilient cross-stream transport barrier. This is composed of shearless-parabolic Lagrangian coherent structures (LCS), which, extracted over sliding time windows along the multi-year altimetry-derived velocity record, lie in near coincidental position. The probabilistic tools are applied on a large collection of historical satellite-tracked drifter trajectories, revealing weakly communicating flow regions on either side of the altimetry-derived barrier. Shearless-parabolic LCS are detected for the first time from altimetry data, and their significance is supported on satellite-derived ocean color data, which reveal shapes that quite closely resemble the peculiar V shapes, dubbed "chevrons" that have recently confirmed the presence of similar LCS in the atmosphere of Jupiter. Finally, using in-situ velocity and hydrographic data, conditions for symmetric stability are found to be satisfied, suggesting a duality between Lagrangian and Eulerian stability for the Malvinas Current. (Joint work with N. Bodnariuk, M. Saraceno, M. Olascoaga and C. Simionato; support provided by ONR Global.)

ThM23
Preferential sampling of elastic inertial chains in the ocean

Francisco J. Beron-Vera
RSMAS, University of Miami
(Abstract received 03/26/2019 for session B)

We consider the motion of chains of inertial particles interacting elastically near rotationally coherent Lagrangian vortices in quasigeostrophic flow. We find that, while cyclonic (anticyclonic) such vortices attract (repel) light (heavy) inertial particles and vice versa, sufficiently stiff elastic inertial chains are attracted by the vortices independent of the buoyancy of the chain particles and the polarity of the vortices. Our result provides a possible explanation for the observed tendency of \emph{Sargassum} mats to get collected inside mesoscale eddies in the ocean. (Support provided by CONACyT-SENER.)

ThM24
A review on recent applications of the FSLE technique to Lagrangian dispersion studies in the Ocean

Guglielmo Lacorata, Raffaele Corrado, Federico Falcini, Rosalia Santoleri, Enrico Zambianchi
Institute of Marine Sciences (ISMAR) - National Research Council (CNR)
(Abstract received 03/28/2019 for session B)

Recent applications of the Finite-Scale Lyapunov Exponent (FSLE) analysis of Lagrangian trajectory data will be described and discussed in the framework of transport and dispersion studies in the ocean upper layer. In particular, general characteristics of relative dispersion regimes observed from ocean drifter data will be outlined and a direct Lagrangian validation methodology of numerical trajectory simulations will be introduced and discussed.

ThA31
Comparison of relative dispersion metrics in the inner shelf and continental slope of the western Gulf of Mexico

Paula Perez-Brunius, and multiple co-authors
Ensenada Center for Scientific Research and Higher Education (CICESE)
(Abstract received 04/10/2019 for session B)

The need to better predict the impact of potential oil spills from deep water wells in the Gulf of Mexico has given rise to various drifter and subsurface float programs over the last decade. In the western Gulf of Mexico, a subsurface float program took place to study the circulation and dispersion at 1500m depth funded by the US federal agency BOEM (2011-2015), and more recently two drifter experiments designed to study dispersion over the inner shelf (ISDEX) and the continental slope (DWDE) were performed as part of the Gulf of Mexico Research Consortium (CIGoM), funded by the Mexican federal agencies SENER-CONACYT (2016-2018). These databases are used to compare and discuss relative dispersion metrics at various time and length scales between regions with very different dynamics: the inner shelf versus the continental slope, as well as the surface versus the bottom layer of the deep western Gulf of Mexico. In addition, the metrics from the observations are compared to those derived from the CIGoM numerical models used to produce oil spill scenarios, in order to evaluate their performance in reproducing the observed dispersion.

ThA32
Relative dispersion in quasi-geostrophic models of upper-ocean turbulence

Stefano Berti, Alexis Foussard, Guillaume Lapeyre, Xavier Perrot
Unité de Mécanique de Lille, Université de Lille, France
(Abstract received 04/14/2019 for session B)

Turbulent mixing in the ocean can be characterized through the relative dispersion of pairs of fluid particles. The relation between the observed dispersion behaviors and the statistical properties of the underlying turbulent flow, however, can be subtle and does not seem to be fully understood. To address this point, we numerically study relative dispersion in a class of generalized two-dimensional turbulent flows. The latter includes two systems that are relevant for ocean dynamics, the barotropic quasi-geostrophic (QG) model, corresponding to flows with energy concentrated at mesoscales, and the surface quasi-geostrophic (SQG) one, accounting for energetic submesoscales. All the considered dynamics are characterized by the conservation of an active tracer along the geostrophic flow with a direct cascade of tracer variance to small scales, but they theoretically possess different properties in terms of locality of spectral energy transfers. Aiming at exploring the relation between such Eulerian locality features and the statistical properties of the passively transported Lagrangian tracers, we examine relative dispersion in these flows, both as a function of time and as a function of scale, and compare it to predictions based on phenomenological arguments assuming the locality of the cascade. We find that dispersion behaviors agree with expectations from local theories when the dynamics are close to SQG ones and initial pair separations are small enough. Non-local dispersion is instead observed for the QG model, a robust result when looking at relative displacement probability distributions.

ThA33
Lagrangian approaches to the analysis of cross-isopycnal tracer mixing

Jared Penney, Yves Morel, Peter Haynes, Francis Auclair, Cyril Nguyen
Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS)
(Abstract received 04/25/2019 for session B)

This research examines diapycnal tracer mixing in Eulerian numerical simulations of stratified shear flow using techniques based on Lagrangian analysis. The first technique considers the use of quantitative density-tracer scatter plots, with their evolution providing a method of tracking the mixing of tracers across density ranges. The shapes of these scatter plots place constraints on the possible cross-isopycnal fluxes of a given tracer. For an initial layer of tracer in a typical stratified shear flow, it is observed that scatter plots tend to evolve toward a piecewise linear relationship. The second technique uses a variation of the Winters-D'Asaro-Nakamura effective density diffusivity formulation to predict tracer profile evolution. Individual fluid parcels are followed in the flow and cast to specific density classes to reconstruct a mean tracer profile. Geometric relationships between density and tracer gradients provide a forcing that affects the evolution of the mean tracer profile in smaller localized regions, while the bulk evolution of the profile is dominated by the effective density diffusivity contribution. The distribution of the final tracer profile is controlled primarily by the density diffusivity, the density range affected by mixing, and the tracer content within this density range.

ThA34
Robust extraction of coherent regions in ocean flow from sparse, scattered, and incomplete trajectory data using transfer operators and the dynamic Laplacian

Gary Froyland
University of New South Wales
(Abstract received 04/27/2019 for session B)

Transport and mixing properties of the ocean's circulation are crucial to dynamical analyses, and often have to be carried out with limited observed information. Finite-time coherent sets are regions of the ocean that minimally mix (in the presence of small diffusion) with the rest of the ocean domain over the finite period of time considered. In the purely advective setting (in the zero diffusion limit) this is equivalent to identifying regions whose boundary interfaces remain small throughout their finite-time evolution. Finite-time coherent sets thus provide a skeleton of distinct regions around which more turbulent flow occurs. Well-known manifestations of finite-time coherent sets in geophysical systems include rotational objects like ocean eddies, ocean gyres, and atmospheric vortices. In real-world settings, often observational data is scattered and sparse, which makes the difficult problem of coherent set identification and tracking challenging. I will describe both Markov chain-based and FEM-based numerical methods [3] to efficiently approximate the recently defined dynamic Laplace operator [1,2], and rapidly and reliably extract finite-time coherent sets from models or scattered, possibly sparse, and possibly incomplete observed data. A new, automatic method of extracting many coherent sets at once, based on sparse approximation [4], will also be presented. The methods will be illustrated on data arising from models, altimetry, and subsurface floats, from the mesoscale to the global scale.
[1] https://doi.org/10.1088/0951-7715/28/10/3587
[2] https://doi.org/10.1007/s00332-017-9397-y
[3] https://doi.org/10.1137/17M1129738
[4] https://doi.org/10.1016/j.cnsns.2019.04.012

ThA41
The LTRANS-Zlev open-source Lagrangian ocean particle-tracking model: implementation and applications

Celia Laurent, Cosimo Solidoro, Stefano Querin, Donata Melaku Canu
National Institute of Oceanography and Experimental Geophysics (OGS, Italy)
(Abstract received 04/30/2019 for session C)

We present LTRANS-Zlev, a new version of the off-line Lagrangian ocean particle-tracking model LTRANS, made compatible with a Z-coordinate (constant-depth layers) discretization of the hydrodynamic equations, in addition to the original sigma-coordinate (terrain following, variable-depth layers) configuration. Several additional features have been implemented in LTRANS-Zlev, including backward-in-time particle tracking, stranding at prescribed distances from the coast, customizable larval behavior and oil spill weathering using the OILTRANS module. The code is written in FORTRAN 90, parallelized with OPEN-MP directives and it is freely available under a Massachusetts Institute of Technology (MIT) license. LTRANS-Zlev has been initially tested by using the output of the Z-coordinate MIT general circulation model (MITgcm) for an idealized case-study describing a cyclonic gyre in a mid-latitude closed basin. Moreover, several other case-studies in the Adriatic Sea have been investigated simulating larval behavior, for connectivity analysis and oil spill modeling.

ThA42

Lagrangian organization of phytoplankton assemblages

Clement Haeck, Marina Levy, Roy El Hourany, Francesco d'Ovidio, Ines Mangolte
Laboratoire d'Océanographie et du Climat: Expérimentations et Approches Numériques (LOCEAN), Paris
(Abstract received 04/30/2019 for session D)

Phytoplankton assemblages exhibit strong variations at the mesoscale and sub-mesoscale. But the processes which govern this organization, and the influence of sub-mesoscale structures (front, eddies, filaments) are still not fully understood. This is in part due to the difficulty to retrieve synoptic taxonomic data on phytoplankton concentrations. A new method using a neural-network trained on in-situ data was recently developped (El Hourany 2018). It allows to retrieve the concentrations of different phytoplanktonic diagnostic pigments from satellite measurements and thus can provide a synoptic view on the phytoplanktonic assemblages. This method is used to compare observations from the Gulf-Stream with measurements obtained with a biogeochemical model of an idealized western boundary current. The variation in repartition of phytoplanktonic functional types and in diversity is studied. A distinction is made between frontal and background areas. Lagrangian diagnostic tools are applied along with surface velocity data in an effort to decouple the biologic response of the phytoplanktonic communities to a change in its environment and its horizontal advection by oceanic currents.

ThA43
Use of Lagrangian dispersion models to estimate distributions of plastic marine litter, observations planning and environmental risks assessment

Carlo Brandini, Bartolomeo Doronzo, Maria Fattorini, Massimo Perna, Stefano Taddei, Letizia Costanza, Chiara Lapucci
Consorzio LaMMA & Consiglio Nazionale delle Ricerche
(Abstract received 04/30/2019 for session D)

Lagrangian dispersion models are increasingly used to understand Plastic Marine Litter (PML) distribution from large to local scales, as well as to understand long period trends, or to find connections between sources and accumulation areas. Understanding PML distributions is crucial for the assessment of environmental risks, as plastic distribution significantly overlap with feeding areas of relevant marine species. The reliability of such distributions is strongly dependent on the quality of the hydrodynamic data used to force dispersion models, and this is particularly important in sea areas (eg in the Mediterranean) characterized by high seasonal and sub-seasonal variability as deduced by hydrodynamic observations and operational circulation models. Unfortunately PML observations shows a wide variety of values: although it is well known that such concentrations strongly depend on circulation, it is not clear which role have not permanent circulation features on such distributions. In this work we make a comparison, over the last few years (2015-2018), concerning the potential distributions of PML in North-Western Mediterranean (and in particular in the Pelagos Sanctuary area), deduced by lagrangian simulations. In this area marine debris observations are also available. Results are used to plan observation campaigns to characterize the presence of hot-spot and cold-spot areas for PML. Hydrodynamic models were also validated using available HF radars. Both the models and the observations show a significant degree of uncertainty and representativeness, that can be better represented in terms of probability distributions, in turn to be associated to environmental risk parameters.

ThA44
Effect of Lagrangian flow properties on the distribution and composition of phytoplankton

Ismael Hernendez-Carrasco, Alejandro Orfila, Vincent Rossi, Eva Alou, Veronique Garçon
IMEDEA (CSIC-UIB), Mediterranean Institute for Advanced Studies, Esporles, Spain
(Abstract received 04/30/2019 for session D)

Physical factors induced by the turbulent flow play a crucial role in regulating marine ecosystems. Here we show that the combination of complementary Lagrangian diagnostics provides an improved description of the flow geometry, which facilitates the interpretation of non-exclusive physical mechanisms affecting phytoplankton composition, dynamics and patchiness. The influence of small-scale dynamics (O(3.5-25) km, i.e. spanning upper submesoscale and mesoscale processes) on phytoplankton in surface waters derived from satellite chlorophyll-a (Chl a) is studied using Lagrangian metrics computed from High-Frequency Radar currents over the Ibiza Channel. Attracting small-scale flow structures are associated to filaments of accumulated negative divergence where particles and Chl a standing stocks cluster. Regions of accumulated positive divergence, representing large accumulated upward vertical velocities and suggesting accrued injection of subsurface nutrients, match areas with large Chl a concentrations. Furthermore, the influence of other accumulated dynamical properties of the flow on phytoplankton composition over a filament, originated in a region where Atlantic Water and resident Mediterranean Water are mixed, is studied combining in-situ observations obtained during the SHEBEX cruise (May 2015) and Altimetry-derived Lagrangian computations. We find that fluid parcels presenting high values of Lagrangian Turbulent Kinetic Energy and Vorticity are related to areas of large presence of diatoms as compared with the abundance of flagellates. Our findings suggest that an accurate characterization of the Lagrangian flow properties is necessary to comprehend bio-physical interactions in the ocean.

FrM11
TRACMASS - A versatile trajectory code for ocean and atmosphere general circulation models

Kristofer Döös, Joakim Kjellsson, Bror Jönsson, Sara Berglund, Aitor Aldama Campino, Dipanjan Dey
Stockholm University
(Abstract received 03/12/2019 for session A)

The latest version of the TRACMASS trajectory model will be presented.
TRACMASS calculates Lagrangian trajectories offline from General Circulation model's outputs for both the ocean and the atmosphere. A brief description of the numerical will be presented and why the trajectories can be associated with a mass or volume transport. We will show how model output frequency and spatial resolution affects the statistical behaviour of Lagrangian trajectories. We will also discuss how adding a recently developed parameterisation of sub-grid scale turbulence can reduce biases due to low temporal and spatial resolution of the GCM output. Instruction to how to set up the code, which has been greatly simplified, will be given. We will also provide support and help on how to set up the TRACMASS code during the LAPCOD meeting in case you have unix, fortran and netcdf installed on your computer.

FrM12
Two-point velocity statistics from ocean surface drifter observations in the Benguela upwelling system

Julia Draeger-Dietel, Dhruv Balwada and Alexa Griesel
Institut fuer Meereskunde, Hamburg, Germany
(Abstract received 04/30/2019 for session A)

Lagrangian trajectories from surface drifters in the ocean constitute a time evolving, highly non-uniform spatial grid. The drifter velocity observations can be treated as scattered point Eulerian measurements, albeit with potential bias with respect to convergent flow structures. These scattered measurements can be used to estimate the two-point velocity statistics, which can help in deducing the turbulent properties of the flow: e.g. the scale-dependent distribution of kinetic energy and spectral fluxes. Here we examine the probability distribution of relative longitudinal velocity, as a function of spatial separation, from surface drifters deployed in triplets at the boundary of a filament in the upwelling region off Namibia. For the drifters released at the northern boundary of the filament, close to the upwelling region, we find the PDF to be positively skewed (3rd order structure function) for relative separations. of 10 km - 80 km, supporting former findings of an inverse energy cascade (Richards scaling of pair separations). For the drifters released at the southern boundary, we find the 2nd order structure function (variance) follows a 2/3 power law for relative separations of 1 km - 800 km. We investigate dependence on filtering and compare our findings with the corresponding analysis of model-trajectories from a high resolution model of the region. We also perform a Helmholtz decomposition, to glean more into the dynamical origin of this scaling behavior.

FrM13
Exchange Between a Deep Coherent Eddy and its Surroundings, studied with Subsurface Floats

Henrik Soiland
Institute of Marine Research
(Abstract received 04/30/2019 for session A)

In recent years several studies have identified an area of intense anticyclonic activity in the central part of the Lofoten Basin in the Norwegian Sea. This is now recognized as the coherent Lofoten Basin Eddy (LBE). Recent ADCP and CTD surveys, subsurface float records, altimetry from the last 20 years and historical hydrography indicate that the LBE is a permanent feature. In the PROVOLO project [http://www.uib.no/en/rg/fysos/97330/provolo], a range of instrumentation, including CTD, VM-ADCP, LADCP and ocean microstructure profilers, was used at cruises in June 2016 and March 2017. The surveys confirmed that the LBE typically has maximum swirl velocities at 17-20 km radius, with peak velocities between 600 and 900 m depth. Here we will focus on the results from 24 neutrally buoyant acoustically tracked subsurface floats (RAFOS) That were deployed at different depths and radii in the LBE. The RAFOS floats deployed between 550 and 850 meter depth inside the radius of velocity maximum remained in the eddy for the duration of the deployment (5-14 months). At 200-300 m depth, RAFOS floats remained in the eddy up to 10 months. However, RAFOS floats deployed at 30-35 km radius remained in the eddy for only a few loops around the center before being expelled. These results show that there is very little exchange of water between the inner core and surroundings, whereas at larger radii the exchange is substantial. Overall, the exchange at shallower depths is enhanced compared to the deep (600-900 m) core.

FrM14
Using Lagrangian Transit Time Distributions to investigate eddy effects on carbon uptake in the ocean

Alexa Griesel, Manita Chouksey, Carsten Eden, Reiner Steinfeldt

CEN, Institute of Oceanography, University of Hamburg
(Abstract received 04/30/2019 for session A)

The ocean transports heat, salt, and also other tracers across huge distances by the mean flow advection, along-isopycnal eddy mixing, and across-isopycnal small-scale mixing. Of particular importance is the anthropogenic Carbon which is taken up and stored on long time scales by these interior oceanic transports. The distribution of such time scales at a single location is called the Transient Time Distribution (TTD) and is observed to reach decades at mid-depth to centuries in the deep ocean. The accuracy of such TTD estimates and in particular the role of the isopycnal eddy mixing in the process, however, remains poorly understood. We aim to estimate the TTDs from tracer distributions, such as CFCs, and from Lagrangian particle trajectories in a high-resolution eddying model and compare it to observations. This will aid in assessing the storage potential and possible changes in intermediate, deep, and bottom water masses of the global ocean, in particular the Southern Ocean, and the effect on the oceanic anthropogenic Carbon uptake.

FrM15

A Lagrangian global dataset of Sea Surface Temperature

Shane Elipot, Rick Lumpkin
University of Miami
(Abstract received 04/30/2019 for session A)

Sea Surface Temperature (SST) is the primary quantity by which the ocean forces climate processes in the atmosphere. It is thus crucial to not only gather observations of SST but also understand the dynamical processes controlling their time and spatial evolutions. The predominant in-situ observational system by which SST has been observed in the last decades is the global array of surface drifters from the Global Drifter Program (GDP). As the GDP has now nearly fully transitioned to tracking drifters by the Global Positioning System (GPS), the global dataset of high-frequency hourly estimates of drifter locations and velocities is increasing rapidly, and recently surpassed 148 million data points. To this high-frequency dataset we are working towards adding a companion dataset of hourly SST estimates with the goal of contributing to the understanding of the spatiotemporal variability of Lagrangian SST measurements. Preliminary results shows that the predominant diurnal variability can be partially linearly linked to local heat flux estimates from reanalysis products. Once this diurnal variability is removed, a global pattern of Lagrangian SST tendency associated with high eddy kinetic energy regions emerges.

FrM16

Lagrangian study of the water masses dynamics at the stations of the PEACETIME cruise in the Mediterranean Sea

Stéphanie Barrillon, Louise Rousselet, Anne Petrenko, Andrea Doglioli
CNRS
(Abstract received 04/04/2019 for session A)

Estimation of biogeochemical fluxes in the ocean requires measurements at stations for several days, where a key question is the impact of advection to the water sampling. The PEACETIME project assesses the processes occurring at the air-sea interface and in the ocean surface after dust deposition in the Mediterranean Sea, with the oceanographic cruise onboard the R/V ‚ÄòPourquoi Pas?‚Äô in the Western/Central Mediterranean Sea from May 10 to June 11, 2017. Three so called ‚Äúlong-duration‚Äù stations have been performed in the Tyrrhenian, Ionian and Algerian basins. Studies on the dynamics of the water masses during these stations are presented in order to determine the potential enrichment of the sampled water by rain events and the origin of an observed desalted water in one of the stations. The ARIANE package is used to predict the surface trajectories, origins and destinations of water particles, using the satellite data from Copernicus Monitoring Environment Marine Service (CMEMS) for surface geostrophic velocities and wind fields. The in situ Lagrangian drifters are used to validate the predicted trajectories. Results show the water masses direction and flushing at each station, the origin of the observed desalted water at the Ionian station, and a probable sampling of rain at the Algerian station. By directly addressing the concerns raised by the methodological aspects, this work intends to contribute to the design protocol of future multidisciplinary research cruises.

FrM21

Ecosystemic connectivity from Lagrangian backtracking and bio-energetic modelling of small pelagic larvae in the Sicily Channel

Federico Falcini, R. Corrado, A. Cuttitta, G. Lacorata, M.C. Mangano, L. Palatella, B. Patti, R. Santoleri, G. Sarà, M. Torri
CNR ISMAR
(Abstract received 05/07/2019 for session D)

Linkage networks and connectivity are extremely important in ecology and management of biological resources. Ecological spatial connectivity is recognised as one of the most important processes shaping coastal marine populations and ecosystems by determining their distribution, persistence and productivity. In the Sicily Channel (Central Mediterranean Sea), ichthyoplanktonic data showed dispersal of some of the most economically important species (e.g., European anchovy). Reconstructing spawning areas of small

pelagic species is, therefore, a fundamental tool for understanding ecosystems continuity and variability. Here we use Lagrangian back-trajectories to statistically identify spawning areas from an available ichthyoplanktonic dataset. In our analysis, otolith-derived ages of larvae give reliable ending conditions for back-trajectories. In parallel, environmental parameters, retrieved from remote sensing, constrain the success of each trajectory. We obtain a direct assessment of previously hypothesized spawning areas and we find new evidence of ecosystem connectivity between North Africa and recruitment regions off the southern Sicilian coasts. Results are then confirmed by outcomes produced by a bioenergetic model (based on Dynamic Energy Budget theory). By producing quantitative information on functional traits, the model can potentially predict species-specific responses to environmental changes. Our work promotes the need of incorporating climate and environmental variability effects into future marine resources management plans, strategies, and directives. It also supports the need of a "species-oriented" management of biological marine resources, which moves towards a more ecologically sound reframing of management when dealing with cross-border areas.

FrM22

Integrating Lagrangian modeling with otolith analyses to quantify larval dispersal and locate spawning areas

Térence Legrand, Antonio Di Franco, Enrico Ser-Giacomi, Antonio Calo, Vincent Rossi
Mediterranean Institute of Oceanography, Aix Marseille Univ., Marseille, France
(Abstract received 03/26/2019 for session D)

Assessing larval dispersal by ocean current is essential to understand the dynamics of marine meta-populations. However, crucial knowledge about early-life dispersal stages is sparse, and so are the scales and patterns of connectivity, impeding the localization of fish spawning areas. Indeed, the high spatio-variability and multi-scale character of the ocean circulation experienced during larval drift and the species-specific biological early-life traits engender a methodological challenge. We present an integrative framework which combines Lagrangian modeling, network theory, otoliths analyses and bio-geographical information to pinpoint and characterize the putative spawning areas and the induced connectivity patterns of coastal fishes. As a case study, we investigated here the larval sources of D. sargus and D. vulgaris juveniles sampled along the Apulian coast (Adriatic Sea). We found robust correlations between otolith analyses and Lagrangian model simulations that allow delineating spawning areas and assessing their relative importance for the larval replenishment of the Apulian coast. Our results evidenced that, contrary to D. sargus, D. vulgaris larvae could originate from both eastern and western Adriatic shorelines. We suggest then that the distances of dispersion and dispersal surfaces have different relationship with the PLD. Moreover, almost one third of D. sargus larvae and one tenth of D. vulgaris larvae could originate from Tremiti marine reserve, emphasizing the need for further enforcement. Beyond the present case-study, this flexible multidisciplinary framework, as it could be adjusted to any species and oceanic systems, is a powerful tool providing scientifically-based information useful for fisheries management and marine conservation.

FrM23

Vortex cores as barriers to the diffusion of vorticity in 2D turbulence

Stergios Katsanoulis , Mohammad Farazmand , George Haller
ETH Zurich
(Abstract received 04/29/2019 for session B)

Recent advancements have allowed for diffusion barriers to be identified as material surfaces that inhibit the diffusion of passive scalars more than neighbouring surfaces do. The objective (observer-independent) identification of such surfaces has recently been extended to uncover the material skeletons of diffusive tracer patterns in compressible flows. According to this new formulation, barriers to the diffusion of vorticity are constructed with and without constraining them on a specific initial vorticity distribution. Here, we describe a computational algorithm based on these new results. The algorithm offers a fully automated detection of conservative, constrained and unconstrained diffusive barriers without reliance on user input or fine-tuning of parameters, as other coherent-structure-detection algorithms typically do. We also introduce a publicly available Matlab graphical user interface (GUI) that implements all these results for general, two-dimensional unsteady flow data. We conclude by demonstrating the use of this GUI on a 2D decaying turbulence example.

FrM24

Topographic influence on currents and dispersion

Joseph LaCasce
University of Oslo
(Abstract received 05/13/2019 for session B)

The first EOF calculated from current meter velocities has a characteristic shape in many extratropical locations, decaying monontonically with depth to near zero at the bottom. This EOF often captures 80-90% of the variance of the horizontal velocities. The shape closely resembles the first baroclinic mode obtained over a rough ocean bottom. Such "surface modes" are shown to pertain over even weak topographic slopes, and thus over much of the world ocean. One consequence is that the deformation radius is larger than previously thought, which would explain why ocean eddies propagate westward faster than expected using the traditional first

baroclinic mode. In addition, topography suppresses baroclinic stability, favoring instead the generation of surface eddies. These results also have implications for mesoscale dispersion. They would explain why float dispersion at low latitudes and in the North Pacific is zonally anisotropic, if it were dominated by surface mode Rossby waves. However, dispersion in the Atlantic and at high latitudes is strongly steered by topography. This suggests the importance of a second mode ‚Äì topographic waves ‚Äì in these regions. In any case, it is more useful to think of mesoscale eddies in terms of surface modes and topographic waves than of traditional barotropic and baroclinic modes.

FrM25
PDE-based Prediction, Estimation, Sampling, and Learning of Stochastic Lagrangian Transport

P.F.J. Lermusiaux, C. S. Kulkarni, A. Gupta, M. Doshi and A. Dutt
MIT
(Abstract received 05/13/2019 for session B)

We present principled PDE-based methods for the probabilistic prediction, Bayesian estimation, optimal sampling, and machine learning of stochastic Lagrangian transport in geophysical fluid flows. We obtain super-accurate schemes for advective transport through flow map composition, achieving minimal errors and strong theoretical guarantees. We develop Bayesian data assimilation methods for dynamic Lagrangian fields and structures, and information-theoretic decision schemes for Lagrangian adaptive sampling. To characterize cohesion and mixing, we derive objective criteria that predict and classify sets of fluid parcels that remain most coherent/incoherent throughout an extended time interval. We finally develop generative learning methods to infer and predict Eulerian and Lagrangian fields from observational data. Results are presented for simulated geophysical flows and for real-time at-sea experiments with autonomous sensing platforms in diverse ocean regions and dynamical regimes.

FrM26
The impact of vertical shear on horizontal dispersion

Sebastian Essink, Mathieu Dever, Amala Mahadevan
MIT-WHOI Joint Program in Oceanography
(Abstract received 05/16/2019 for session B)

In the ocean, the vertical gradients in velocity can be orders of magnitude larger than the horizontal gradients in velocity. At submesoscale fronts, and in filaments, the vertical shear of the horizontal velocity is particularly large as it is in thermal wind balance with strong lateral buoyancy gradients ∇, which are continuously intensified by frontogenesis. Dye experiments and numerical simulations suggest that these vertical shears are efficient at dispersing tracers. In fact, due to the large magnitude of velocities differences, vertical shears are more potent at separating drifters than those due to horizontal shear. Conventional drifters, however, are not affected by the vertical velocity structure because they depth-keeping and, hence, will be ignorant to the associated dispersion. This modeling study provides insights into the characteristics of drifter dispersion by vertical shear. By deploying vertically-separated drifters in an eddying submesoscale flow field, we show that vertical shear leads to fast, ballistic pair dispersion that can be an order of magnitude larger than pair dispersion due to horizontal shear and strain. We find that filaments and fronts, where the vertical shear is largest, act as hot spots for pairs dispersion. These findings suggest that, particularly in the mixed layer, drifter-diffusivity might underesimate the diffusivity tracers encounter. And that turbulent dispersion regimes vary significantly in the vertical.

Author Index

R

S

T

W

Z

Attendees

Name	***Institution***
Aksamit Nikolas	*ETH Zürich*
Barillon Stephanie	*CNRS*
Beron-Vera Francisco Javier	*RSMAS*
Berta Maristella	*CNR-ISMAR*
Berti Stefano	*Unité de Mécanique de Lille, CNRS*
Celentano Paolo	*Institute of Marine Sciences (ISMAR) - National Research Council (CNR), La Spezia, Italy*
Chang Henry	*University of Delaware*
Draeger-Dietel julia	*Institute of Oceanography, Universität Hamburg*
Dugstad Johannes Sandanger	*Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Bergen, Norway*
Elipot Shane	*University of Miami*
Enrile Francesco	*University of Genoa*
Falcini Federico	*CNR-ISMAR*
Falco Pierpaolo	*Università di Napoli Parthenope and CoNISMa*
Froyland Gary	*University of New South Wales, Sydney*
Ghezzo Michol	*CNR ISMAR*
Griesel Alexa	*University of Hamburg, Institute of Oceanography*
Griffa Annalisa	*CNR-ISMAR*
Guerrini Federica	*Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano*
Haeck Clément	*LOCEAN*
Hernández-Carrasco Ismael	*IMEDEA (CSIC-UIB), Mediterranean Institute for Advances Studies*
Katsanoulis Stergios	*ETH Zürich*
Kirwan Jr Albert D.	*University of Delaware*
Klenz Thilo	*University of Alaska Fairbanks*
Koszalka Inga Monika	*Department of Meteorology, Stockholm University*
Kotzakoulakis Konstantinos	*Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)*
Krauzig Naomi	*Università di Napoli Parthenope and CoNISMa*
LaCasce Joseph	*University of Oslo*
Lacorata Guglielmo	*CNR ISMAR (Rome)*
Laurent Célia	*OGS*
Legrand Terence	*Mediterranean Institute of Oceanography*

Lermusiaux Pierre	*MIT*
Lilly Jonathan	*Theiss Research*
Lopez Cristobal	*IFISC, Palma de Mallorca*
Mariano Arthur	*U OF MIAMI/RSMAS*
Menna Milena	*OGS*
Miron Philippe	*University of Miami*
Molcard Anne	*University of Toulon, MIO*
Ohlmann Carter	*Earth Research Institute, UCSB*
Olascoaga Maria Josefina	*RSMAS-UM*
Paldor Nathan	*The Hebrew University of Jerusalem*
Pallas Sanz Enric	*Centro de Investigación y Educación Superior de Ensenada (CICESE)*
Pearson Jenna	*Brown University*
Penney Jared	*Laboratoire d'Etudes en Géophysique et Océanographie Spatiales*
Perez Brunius Paula	*CICESE*
Poulain Pierre-Marie	*CMRE and OGS*
Poje Andrew	*City University of New York - CSI*
Prants Sergey	*Pacific Oceanological Institute, Vladivostok*
Restrepo Juan	*Oregon State University*
Romero Leonel	*University of California*
Rossby Thomas	*GSO/URI*
Rubino Angelo	*Università di Venezia Ca' Foscari and CoNISMa*
Sciascia Roberta	*CRN-ISMAR*
Sheinbaum Pardo Julio	*CICESE, Physical Oceanography*
Søiland Henrik	*Institute of Marine Research*
Sybrandy Andrew	*Pacific Gyre*
Tarry Daniel	*IMEDEA*
Zambianchi Enrico	*Università di Napoli Parthenope and CoNISMa*