Physical Oceanography Day @ HKUST

Thurs 20th June

Sponsors

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- Department of Ocean Science
- The Royal Society

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`https://github.com/maximelucas/AMCOS_booklet`

Timetable (Thursday, 20th June)

0925–0930	**Welcome remarks**		
0930–1015		**Xiaoming Zhai** UEA, Norwich	Cold anticyclonic eddies and warm cyclonic eddies in the ocean
1015–1045		**Tongya Liu** Second Institute of Oceanography, Hangzhou	Material transport induced by mesoscale eddies
1045–1115	**Break**		
1115–1145		**Qinbiao Ni** SMSEGL (Zhuhai)	Random movement and full-depth kinetic energy of mesoscale eddies in the global ocean
1145–1215		**Jin-Han Xie** PKU, Beijing	Impact of potential vorticity perturbation on geostrophic turbulence
1215–1400	**Lunch at China Garden G/F, HKUST**		
1400–1430		**Julian Mak** HKUST, HK	Scale-awareness in an eddy energy constrained mesoscale eddy parameterization
1430–1500		**Yan Wang** HKUST, HK	Bathymetry-aware mesoscale eddy parameterizations across upwelling slope fronts
1500–1545	**Break**		
1545–1615		**Xiaolung Yu** SYSU, Zhuhai	Mesoscale and submesoscale motions: kinetic energy transfers and their impact on the inertial chimney effect
1615–1645		**Qing Li** HKUST(GZ), Guangzhou	Ocean surface-wave driven turbulent mixing
1800–whenever	**Dinner at Paradise Dynasty, TKO**		

List of Abstracts

Cold anticyclonic eddies and warm cyclonic eddies in the ocean

Xiaoming Zhai

School of Environmental Sciences, University of East Anglia, Norwich

Anticyclonic and cyclonic ocean eddies are traditionally thought to be associated with positive and negative temperature anomalies, respectively. Our recent study found that about one-fifth of the eddies identified from altimeter data are surface cold-core anticyclonic eddies (CAEs) and warm- core cyclonic eddies (WCEs). Idealized numerical model experiments highlight the role of relative wind-stress-induced Ekman pumping, surface mixed layer depth, and vertical entrainment in the formation and seasonal cycle of these unconventional eddies in the tropical oceans. The abundance of CAEs and WCEs in the global ocean calls for further research on this topic.

Material transport induced by mesoscale eddies

Tongya Liu

Second Institute of Oceanography, Ministry of Natural Resources, State Key Laboratory of Satellite Ocean Environment Dynamics, Hangzhou

The methods used to identify coherent ocean eddies are either Eulerian or Lagrangian in nature, and nearly all existing eddy datasets are based on the Eulerian method. Millions of Lagrangian particles are advected by satellite-derived surface geostrophic velocities over the period of 1993–2019. Using the method of Lagrangian-averaged vorticity deviation, we present a global Lagrangian eddy dataset. We present the statistical features of Lagrangian eddies and compare them with those of the most widely used sea surface height eddies, focusing on generation sites, size, and propagation speed. A remarkable feature is that Lagrangian eddies are generally smaller than SSH eddies, with a radius ratio of about 0.5. Our eddy dataset provides an additional option for oceanographers to understand the interaction between coherent eddies and other physical or biochemical processes in the Earth system. Furthermore, a series of numerical experiments demonstrates that the isolated eddy can effectively carry initially enclosed water parcels, but in the presence of crowded eddies, significant water leakage occurs due to the ageostrophic motions. Our results indicate that, compared to eddy trapping, eddy stirring may contribute more significantly to material transport.

Random movement and full-depth kinetic energy of mesoscale eddies in the global ocean

Qinbiao Ni

Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai)

Mesoscale eddies are ubiquitous and energetic features of the global ocean circulation. Thanks to satellite and float observations, we have made significant progress in terms of eddy statistics, dynamics and energetics. However, our knowledge of mesoscale eddy movement and eddy kinetic energy (EKE) in the ocean remains incomplete. Using 20 years of satellite altimeter data, here we show that, in addition to the well-known westward propagation and meridional deflections, mesoscale eddies also move randomly in all directions at all latitudes. The speed of this random eddy movement decreases with latitude and equals the baroclinic Rossby wave speed at about 25° of latitude. The tracked eddies are isotropic at mid and high latitudes, but become noticeably more elongated in the zonal direction at low latitudes. The eddy energy diffusivity of such movement varies from over 1500 m^2 s^{-1} at low latitudes to around 500 m^2 s^{-1} at high latitudes. Furthermore, we estimate the EKE over the full depth of the global ocean by combining altimeter and Argo float data to infer the vertical profile of eddies. The inferred eddy profiles are surface-intensified at low latitudes and deep-reaching at mid- and high latitudes. They compare favorably to the first empirical orthogonal function obtained from current meter velocities. The global-integrated EKE estimated from the inferred profiles is about 3.1×10^{18} J. These findings have important implications for recently-developed energetically-consistent mesoscale eddy parameterization schemes which require solving the eddy energy budget.

Impact of potential vorticity perturbation on geostrophic turbulence

Jin-Han Xie

Department of Mechanics, College of Engineering, Peking University, Beijing

We study barotropic geostrophic turbulence under the impact of near-inertial wave (NIW) and bottom topography by modifying potential vorticity (PV). The two systems share a common feature: stronger small-scale PV perturbation induces larger downscale energy flux, which is absent in barotropic geostrophic turbulence. NIW centres in the anticyclones, which are associated with stronger wave-mean interactions and cyclone-anticyclone asymmetry. On a beta-plane, this effect leads to left-right asymmetric jets. The small-scale topography induces abnormal upscale energy flux, which generates condensation when geostrophic turbulence does not.

Scale-awareness in an eddy energy constrained mesoscale eddy parameterization

Julian Mak

Department of Ocean Science, HKUST, HK
National Oceanography Centre, Southampton

There is an increasing interest in mesoscale eddy parameterizations that are *scale-aware*, normally interpreted to mean that a parameterization does not require parameter recalibration as the model resolution changes. Here we examine whether Gent–McWilliams (GM) based version of GEOMETRIC, a mesoscale eddy parameterization that is constrained by a parameterized eddy energy budget, is scale-aware in its energetics. It is generally known that GM-based schemes severely damp out explicit eddies, so the parameterized component would be expected to dominate across resolutions, and we might expect a negative answer to the question of energetic scale-awareness. A consideration of why GM-based schemes damp out explicit eddies leads a suggestion for what we term a *splitting* procedure: a definition of a 'large-scale' field is sought, and the eddy-induced velocity from the GM-scheme is computed from and acts only on the large-scale field, allowing explicit and parameterized components to co-exist. Within the context of an idealized re-entrant channel model of the Southern Ocean, evidence is provided that the GM-based version of GEOMETRIC is scale-aware in the energetics as long as we employ a splitting procedure. The splitting procedure also leads to an improved representation of mean states without detrimental effects on the explicit eddy motions.

Bathymetry-aware mesoscale eddy parameterizations across upwelling slope fronts

Yan Wang

Department of Ocean Science, HKUST, HK

Mesoscale eddy buoyancy fluxes across continental slopes profoundly modulate the boundary current dynamics and shelf-ocean exchanges, but have yet to be appropriately parameterized via the Gent-McWilliams (GM) scheme in predictive ocean models. In this talk, I will present the prognostic performance of multiple GM variants in non-eddying simulations of upwelling slope fronts that are commonly found along the subtropical continental margins. The tested GM variants range from a set of constant eddy buoyancy diffusivities to recently developed energetically-constrained, bathymetry-aware diffusivities, whose implementation is augmented by an artificial neural network (ANN) serving to predict the mesoscale eddy energy based on the topographic and mean flow quantities online. In addition, an ANN is employed to parameterize the cross-slope eddy momentum flux (EMF) that maintains a barotropic flow field analogous to that in an eddy-resolving model. These tests reveal that non-eddying simulations employing the bathymetry-aware forms of the Rhines scale-based scheme and GEOMETRIC scheme can most accurately reproduce the heat contents and along-slope baroclinic transports as those in the eddy-resolving simulations. Further analyses reveal certain degrees of physical consistency in the ANN-inferred eddy energy, which tends to grow (decay) as isopycnal slopes are steepened (flattened), and in the parameterized EMF, which exhibits the correct strength of shaping the flow baroclinicity if a bathymetry-aware GM variant is jointly used. These findings provide a recipe of GM variants for use in non-eddying simulations with continental slopes and highlight the potential of machine learning techniques to augment physics-based mesoscale eddy parameterization schemes.

Mesoscale and submesoscale motions: kinetic energy transfers and their impact on the inertial chimney effect

Xiaolong Yu

School of Marine Sciences, Sun Yat-sen University (SYSU), Zhuhai

TBC

Ocean surface-wave driven turbulent mixing

Qing Li

Earth, Ocean and Atmospheric Sciences Thrust, HKUST(GZ), Guangzhou

The ocean surface boundary layer is distinct from its atmospheric counterpart by the presence of ocean surface-waves, which significantly modulates the behavior of boundary layer turbulence. The result is a different type of boundary layer turbulence known as the Langmuir turbulence, which has distinct features in its turbulence statistics than wind-driven shear turbulence and convective turbulence. In this talk I'm going to discuss the effect of ocean surface waves on the turbulent mixing in the ocean surface boundary layer by revisiting the Craik-Leibovich instability from a few different perspectives. The goal is to have a better understanding of the contribution of Langmuir turbulence to the so-called nonlocal tracer and momentum fluxes. Ideas and progress of incorporating such effects in an ocean turbulent mixing scheme will also be discussed.

Useful Information

Talks will be held in **classroom 4503 (lift 25/26)** of the Main Academic Building. Look for the Passion cafe, then head up to fourth floor (where the physics department is located).

Light refreshments will be provided during the **breaks**; some of us might go down to the Passion cafe.

The **lunch** will be somewhere on campus, while the dinner will be off campus in Tseung Kwan O (TKO). For those arriving on Wednesday, a dinner could be arranged; please get in touch at `jclmak AT ust.hk`.

How to get to the HKUST

Starting from Hong Kong International Airport, would first recommend getting an Octopus card (from a 7-11 or otherwise; need to put in a HKD 50 deposit), or there is also the Octopus app unless you plan to only use a taxi. Then, starting from the airport, you can either get

- a red taxi ($\sim$ HKD 350-400, cash is best),
- the A29 or E22A bus (I recommend the A29 because it winds around less) to Hang Hau or Tseung Kwan O, and make your way to the associated MTR station
- the Airport Express which is part of the Mass Transit Railway (MTR), get to the end probably, then either get to Choi Hung station (on the green line) or Hang Hau station (on the purple line)

If you are at Hang Hau MTR station (purple line), take either exit and look for the number 11M minibus (terminal station at HKUST north gate) or the 11 minibus (stops at HKUST south gate, more complicated, less frequent), or a taxi ($\sim$ HKD 50, both red or green taxis, but red taxi drivers have been known to refuse...)

If you are Tseung Kwan O MTR station (purple line), you can either take one stop to Hang Hau MTR and do as previous paragraph, or look for the 792M bus (but that bus comes every 20-30 mins), or a taxi ($\sim$ HKD 60-70, will probably only see red ones).

If you are at Choi Hung MTR station, take exit C and look for the number 11 minibus or the 91 or 91M bus, which will stop at HKUST north gate, or get a taxi ($\sim$ HKD 70-80, will only see red ones).