- **PS52A:** How Do Submesoscale and Internal Wave Driven Mixing Matter on Global and Regional Scales? II

Ocean mixing processes driven by submesoscale dynamics (e.g. mixed layer instabilities, shear instability, etc), internal waves (e.g. nonlinear wave interactions, lee waves, etc), and the interaction between the two are known to have a significant local impact. However, less is known about the importance of these mechanisms on larger scales, including the effect on the water-mass transformation, buoyancy budgets, energy pathways, and subsequent biogeochemistry. This is due to the challenges of observing and modeling these processes accurately with regional and global coverage. This session welcomes abstracts that help investigate the influence of these small-scale processes (occurring at time scales of inertial periods and spatial scales below 10km) on the large-scale by use of observations, modeling, or parameterizations. We hope to initiate discussions that relate to the regional, basin, and global scale effects of submesoscales and internal waves on the physics and biogeochemistry of the ocean.

**Friday, February 16, 2018**

**10:30 AM - 12:30 PM**

- *Oregon Convention Center*
- *- B113-B115*

**Primary Chair**

- Mariona Claret
  - *JISAO/University of Washington*

**Co-Chairs**

- Caitlin Whalen
  - *Applied Physics Laboratory University of Washington*
- Tyler Hennon
  - *Scripps Institution of Oceanography*
- Cimarron Wortham
  - *NorthWest Research Associates*

- 10:30 AM**PS52A-01** A Unified Turbulence Spectrum for the Ocean and Atmosphere***Eric L Kunze**, NorthWest Research Associates Redmond, Redmond, WA, United States*

- Dimensional and dynamical scaling are used to argue for a unified turbulence spectrum above and below the Ozmidov lengthscale $(\varepsilon/N^3)^{1/2}$. The predicted horizontal wavenumber spectra for isopycnal slope and horizontal shear has a continuous slope of +1/3 while horizontal strain has slope –1. The predicted vertical wavenumber spectra for vertical shear has slope +1/3 above the Ozmidov wavenumber (isotropic turbulence regime), –1 below the Ozmidov wavenumber and above the wavenumber where horizontal shear is O(*f*) (gradient-wind), and +1/3 slope in the linear (thermal-wind) regime. Aspect ratios become increasingly anisotropic below the Ozmidov wavenumber until reaching ~O( *f/N*). The +1/3 slope spectral levels scale with cascade, or dissipation, rate ε while –1 slope spectral levels are invariant. These features are consistent with submesoscale horizontal and vertical measurements in the ocean and atmosphere, as well as published numerical simulations which indicate a forward cascade. A forward cascade suggests turbulence may be generated by horizontal rather than vertical shear instability, creating a much larger turbulent energy reservoir ($\varepsilon/f$ vs. $\varepsilon/N$) and so longer decay times ($f^{-1}$ vs. $N^{-1}$) for turbulence patches, as observed. Shear dispersion horizontal diffusivities are O(0.1 $m^2$/s) at lengthscales of 100 m and larger.

- 10:45 AM**PS52A-02** Patterns of Mixing from CTD-Chipod profiling on the GO-SHIP Repeat Hydrography Program Global Transects***Jonathan D Nash**[1], Andrew Pickering[1], Jim Moum[2], Jennifer A MacKinnon[3] and Amy Frances Waterhouse[3], (1)Oregon State University, Corvallis, OR, United States, (2)Oregon State University, College of Earth Ocean & Atmospheric Sciences, Corvallis, OR, United States, (3)Scripps Institution of Oceanography, La Jolla, CA, United States*

- With an aim to quantify mixing throughout the global ocean, we have deployed temperature microstructure sensors (chipods) and motion packages on standard shipboard CTD rosettes to obtain vertical profiles of small-scale temperature

gradient. Over the past four years, such chipod measurements have been made during 10 global repeat hydrography cruises spanning all major ocean basins. Here we begin by utilizing the turbulence database established through the Ocean Mixing CPT to determine the uncertainty and bias associated with our methodology, which assumes a relationship between the dissipation rates of temperature variance and turbulent kinetic energy to infer mixing rates. From our analyses, we establish that unbiased estimates of mixing rates can be determined from temperature microstructure in most regions of the global ocean. Regions where the methodology fails are found, and criteria to identify these established. Having confidence in the data and method, we then look at patterns of ocean mixing, which we relate to topographic variance, internal wave energy, and patterns of shear and strain; these are used to help us understand weaknesses in the less-direct methods. We suggest these measurements are a step towards constraining the spatial and temporal patterns of turbulent mixing across the world's oceans, and help us to better understand dissipative mechanisms and their role in ocean dynamics.

- 11:00 AM**PS52A-03** Large-Scale Impacts of the Mesoscale Environment on Mixing from Wind-Driven Internal Waves ***Caitlin Beth Whalen***[1]*, Jennifer A MacKinnon*[2] *and Lynne D Talley*[2]*, (1)Applied Physics Laboratory University of Washington, Seattle, WA, United States, (2)Scripps Institution of Oceanography, La Jolla, CA, United States*
- Mesoscale structures such as eddies and fronts are thought to alter the propagation, breaking, and subsequent turbulent mixing of wind-generated internal waves. However it is not known whether these processes are significant enough to affect the large-scale patterns, timing, and magnitude of turbulent mixing. Here we present the first basin-scale evidence showing that interactions between near-inertial waves and mesoscale features significantly enhances the turbulent dissipation due to either alone. This is accomplished by using internal-wave driven mixing estimates from Argo-profiling floats and a slab model to estimate the wind energy entering the internal wave field between 30-45 N in both the Atlantic and Pacific oceans. A seasonal cycle in turbulent mixing that extends to depths of at

least 2000 m is correlated with the energy flux from winds into internal waves. We find that the amplitude of this seasonal cycle is larger in the presence of strong mesoscale eddy kinetic energy. Additionally, when the energy flux from the winds is increased over regions of strong mesoscale eddy kinetic energy, mixing becomes significantly more elevated than for a similar change in winds above a quiet mesoscale. Our observations also support an elevated response in mixing when the geostrophic vorticity is anticyclonic and when the geostrophic velocity is large. These observations are then placed in the context of global patterns in turbulent mixing due to internal waves from a variety of energy sources.

- 11:15 AM**PS52A-04** Where Do Wind-Forced Inertial Waves Dissipate?***Ren-Chieh Lien**, Applied Physics Laboratory, University of Washington, Seattle, WA, United States, Eric Kunze, Northwest Research Associates, Redmond, WA, United States, Ryuichiro Inoue, JAMSTEC, Yokosuka, Japan and Shin-ichi Ito, Atmosphere and Ocean Research Institute University of Tokyo, Tokyo, Japan*
- Previous studies suggest that the strongest inertial wind power into the ocean occurs during fall storms in the western North Pacific. The energy pathway to dissipation of these storm-driven inertial waves is not well known. Studies based on mooring observations report that only 15–25% of inertial wave energy propagates away from the forcing field as low modes, suggesting that 75–85% of the inertial wave power dissipates in the nearfield. Observations were made in the western North Pacific during fall 2016 and fall 2017. Deployed in late August 2016, six microstructure EM-APEX floats collected nearly 5 months of measurements of water mass properties, horizontal current, and turbulence in the Kuroshio–Oyashio confluence east of Japan. Strong near-inertial waves propagate vertically to at least 1000-m depth and persist as much as one week after storm passages. In a weakly stratified surface layer, thermal diffusivity and turbulent kinetic energy dissipation rate increase nearly 50 and 10 times, respectively, from August 2016 to January 2017. This enhanced turbulent mixing is associated with increased inertial wind power from the passage of multiple fall tropical cyclones and lows, elevated upper-

ocean inertial wave energy and mixed-layer deepening. Surprisingly, turbulence in the pycnocline is not enhanced.

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- 11:30 AM**PS52A-05** Internal Waves, Vortical Mode and their Effects on Submesoscale Dispersion***Miles A Sundermeyer***[1]*, Cimarron Wortham*[2]*, Jeffrey J Early*[2]*, Marie-Pascale Lelong*[3] *and Eric Kunze*[3]*, (1)University of Massachusetts Dartmouth, New Bedford, MA, United States, (2)NorthWest Research Associates, Redmond, WA, United States, (3)Northwest Research Associates, Redmond, WA, United States*
- Interactions between internal waves and vortical mode and their relative contributions to diapycnal and submesoscale isopycnal mixing are examined using a fully nonlinear three-dimensional Boussinesq numerical model. A Garrett-Munk internal wave field is forced by tidal and near-inertial waves to achieve a statistically steady state. Simulations are run under a range of conditions, including varying buoyancy frequency *N*, Coriolis frequency *f*, internal wave and vortical mode energy levels, with/without nonlinear interactions, and in the presence/absence of vortical mode. The effects of nonlinear interactions and the presence/absence of vortical mode is examined in terms of its impact on the internal wave energy spectrum, kinetic and available potential energy, and the intensity and scales of internal-wave driven mixing events. Passive tracer and Lagrangian particles are used to determine diapycnal and isopycnal mixing rates under various scenarios, and to quantify the relative contributions of internal-wave vs. vortical-mode driven mixing processes, testing the null hypothesis that the internal wave cascade and lateral dispersion are dominated by internal-wave processes with little contribution from vortical mode. Results are used to identify parameter and/or forcing regimes where scaling predictions differ among the different processes, both to enable further observational testing and to improve subgridscale mixing parameterizations in terms of observable variables.

- 11:45 AM**PS52A-06** Diagnosing the Sensitivity of the Max Planck Institute Earth System Model with Regard to an Improved Parameterization of the Ocean Internal Wave Field***Nils Brueggemann**, University of Hamburg, Hamburg, Germany, Oliver Gutjahr, Max Planck Institute for Meteorology, Hamburg, Germany, Johann H Jungclaus, Max Planck Inst, Hamburg, Germany and Carsten Eden, University of Hamburg, Institute of Oceanography, Hamburg, Germany*

- In this study, we investigate the sensitivity of the Max Planck Institute Climate Model to a new parameterization of the internal wave field (Internal Wave Dissipation, Energy and Mixing - IDEMIX). In IDEMIX, internal wave energy is forced by wind, tides and the mesoscale eddy field. Dissipation of internal wave energy then feeds turbulent kinetic energy (TKE) which finally causes dissipation where TKE is dissipated. Therefore, IDEMIX enables to obtain a more consistent representation of the ocean energy cycle and diapycnal mixing. Previous studies showed that the circulation of an ocean model with IDEMIX is in better agreement with hydrographic observations compared to simulations without IDEMIX. However, the effect on other components of the climate system remains unclear. By using the Max-Planck-Institute-Climate-Model with and without IDEMIX in its ocean component, we diagnose the sensitivity of the coupled Max Planck Institute Earth System Model (MPI-ESM) with regard to the different representations of the internal wave field. A special focus lies on the feedbacks between the changed ocean circulation and other climate components.

- 12:00 PM**PS52A-07** Gauging the Impacts of an Observationally Derived Oceanic Diapycnal Diffusivity Increment***David S Trossman**, University of Texas at Austin, Institute for Computational Engineering and Sciences, Austin, TX, United States, Caitlin Whalen, Applied Physics Laboratory University of Washington, Seattle, WA, United States, Amy Frances Waterhouse, Scripps Institution of Oceanography, La Jolla, CA, United States and Thomas W N Haine, Johns Hopkins Univ, Baltimore, MD, United States*

- This presentation addresses the importance of modelling the diapycnal diffusivities more accurately than they are in state-of-the-art ocean models. It is shown how two different models, an ocean-sea ice-only re-run of a state estimate of the ocean (from ECCO v4r3) and a coupled Earth system model (NASA's GEOS-5 system), are impacted by using a more realistic representation of diapycnal mixing from Argo observations between 250-2000 meters depth. The simulated diapycnal diffusivities are adjusted to have the same time-average as the Argo-inferred diapycnal diffusivities where Argo observations exist (referred to as a "diapycnal diffusivity increment" hereafter) but are still allowed to vary in time as they do in the simulations without the diapycnal diffusivity increment. Assumptions about equating the Argo-inferred diapycnal diffusivity field with the re-run's diapycnal diffusivity field associated with either temperature or salinity are evaluated using a cost function analysis as well as basic ocean climate metrics, such as regional variability and transports. The primary effect of adding the diapycnal diffusivity increment in each model is an alteration of the thermocline depth and the stratification at mid-depth. One secondary effect of adding the diapycnal diffusivity increment to each model is a redistribution of sea ice. There is an atmospheric circulation response in the coupled model when the diapycnal diffusivity increment is applied. Physical mechanisms responsible for these secondary effects are discussed.
- **Plain Language Summary**
- The geography of the ocean's mixing field is not well-known on a global scale, but there are enough observations at least in the upper 2000 meters to be able to assess how our model simulations would change if we were to use a better representation of mixing across constant density surfaces. There are several different ways of doing this, which we present here. Changes in the way the ocean is stratified is the primary effect. Secondary effects include changes in the atmospheric circulation fields and in how sea ice is geographically distributed. Physical mechanisms behind these changes are discussed.

- 12:15 PM**PS52A-08** Mixing During Major Surface Cooling Events in the Equatorial Pacific’s Cold Tongue***Sally J Warner***, *Oregon State University, CEOAS, Corvallis, OR, United States and Jim Moum, Oregon State University, College of Earth Ocean & Atmospheric Sciences, Corvalis, OR, United States* he temperature of the Pacific equatorial cold tongue is intrinsically linked to atmospheric, climate and ENSO dynamics and is systematically modeled to be too cold in global climate models. From 9 years of data collected by moored mixing meters (χpods) on the TAO array at 0°, 140°W, we construct a climatology of turbulence dissipation and heat flux. These show that turbulence dominates the cooling of the cold tongue. Anomalies from the climatology are investigated in detail over two separate month-long periods when rapid cooling greater than 3°C per month occurred at the ends of the 2006–2007 and 2009–2010 El Niños. During January 2007, we observed depth-coherent fluctuations of temperature near the buoyancy frequency and high rates of turbulence dissipation, which we presume to be caused by shear instabilities. From mid-April to mid-May 2010, an upwelling Kelvin wave raised the thermocline closer to the sea surface and narrowband fluctuations of temperature were not observed at the depths of the χpods. In both cases, the cooling induced by subsurface mixing was sufficient to account for the observed mixed layer cooling. By understanding the role of mixing in regulating the sea surface temperature of the equatorial Pacific cold tongue, deeper insight into the onset and termination of El Niño can be gained.

- **PS53A:** How Do Submesoscale and Internal Wave Driven Mixing Matter on Global and Regional Scales? III

Ocean mixing processes driven by submesoscale dynamics (e.g. mixed layer instabilities, shear instability, etc), internal waves (e.g. nonlinear wave interactions, lee waves, etc), and the interaction between the two are known to have a significant local impact. However, less is known about the importance of these mechanisms on larger scales, including the effect on the water-mass transformation, buoyancy budgets, energy pathways, and subsequent biogeochemistry. This is due to the challenges of observing and modeling these processes accurately with regional and global coverage. This session welcomes abstracts that help investigate the influence of these small-scale processes (occurring at time scales of inertial periods and spatial scales below 10km) on the large-scale by use of observations, modeling, or parameterizations. We hope to initiate discussions that relate to the regional, basin, and global scale effects of submesoscales and internal waves on the physics and biogeochemistry of the ocean.

**Friday, February 16, 2018**

**02:00 PM - 04:00 PM**

- *Oregon Convention Center*

- *- B113-B115*

### Primary Chair

- Mariona Claret
  - *JISAO/University of Washington*

### Co-Chairs

- Caitlin Whalen
  - *Applied Physics Laboratory University of Washington*
- Tyler Hennon
  - *Scripps Institution of Oceanography*

- Cimarron Wortham
  - *NorthWest Research Associates*

**Moderators**

- Caitlin Whalen
  - *Applied Physics Laboratory University of Washington*
- Tyler Hennon
  - *Scripps Institution of Oceanography*

## Index Terms

- 4273 Physical and biogeochemical interactions
- 4544 Internal and inertial waves
- 4568 Turbulence, diffusion, and mixing processes
- 4572 Upper ocean and mixed layer processes

## Papers

- 02:00 PM**PS53A-01** On sampling of turbulent diapycnal mixing, its transition from interior to boundary, and the global implications***Ali Mashayek***[1]*, Raffaele M Ferrari*[2]*, Matthew H Alford*[1] *and Colm-cille Patrick Caulfield*[3]*, (1)Scripps Institution of Oceanography, La Jolla, CA, United States, (2)MIT, Cambridge, MA, United States, (3)University of Cambridge, BP Institute/Department of Applied Mathematics and Theoretical Physics, Cambridge, United Kingdom*
  - Ocean models use mixing parameterizations which assume upwelling of deep waters occurs through interior mixing by breaking of vertically propagating internal waves. Observation-based values of mixing, for example as expressed in terms of a diapycnal diffusivity, are also largely inferred based on a host of assumptions tuned to an internal-wave mixing mainframe. Recently, there has been an increasing evidence that non-propagating turbulent processes in the vicinity of ocean floor contribute significantly to deep mixing and upwelling. In this work we employ high resolution observationally-informed simulations of the Drake Passage region in the Southern Ocean, in addition to direct numerical simulations of sub grid-scale small scale turbulence, to address three issues: (I) the relative

contribution of boundary turbulence and interior wave-induced turbulence to the rate of dissipation of kinetic energy inferred from localized profiles, (II) the correlation between the rate of dissipation of kinetic energy and the buoyancy flux through of mixing efficiency which is finite in interior and must vanish at the seafloor, and (III) the appropriate time and space averaged buoyancy flux necessary for inferring correct rates of water mass transformation on regional scales, with implications for global mixing and lower branch of the circulation.

- 02:15 PMPS53A-02 Spatial Patterns and Temporal Variability of Mixing in a Shelf-Incising Submarine Canyon***Madeleine Marie Hamann***[1], *Andrew Lucas*[2] *and Matthew H Alford*[2], *(1)Scripps Institution of Oceanography, Physical Oceanography, La Jolla, CA, United States, (2)Scripps Institution of Oceanography, La Jolla, CA, United States*
    - Submarine canyons are common features of the coastal ocean. Their complex topographies host dynamical processes on a variety of scales – enhancing upwelling, forcing hydraulic jumps over abrupt bends, and focusing internal waves, to name a few. Many of these processes are associated with small-scale turbulence so that canyons are also “hotspots” of energy dissipation and mixing. Globally, these processes contribute to diapycnal transport 2-3 times that of the open ocean. Regionally, this mixing influences the distribution of tracers such as nutrients, oxygen, carbon, and heat.
    - In order to elucidate dynamics driving mixing in a shelf-incising canyon, a common but not well studied submarine canyon archetype, a suite of observations were undertaken beginning in September 2016 in the La Jolla Canyon System in San Diego. Eight cross-canyon sections were occupied with a towed body for 24-hours apiece revealing enhanced dissipation driven by both tidal and mean flows. Turbulence occurs both near the bottom and in mid-depth regions where stratification is stronger and resulting mixing can significantly modify water mass properties. Turbulent mean flow separation occurs on offshore lines where along-shore flow is not blocked by a southern headland. Most dissipation, however, is tidally driven.

- In addition to shipboard surveys, time series from 3 moorings along the canyon axis capture temporal variability of energetics and mixing patterns. Changes in stratification that occur over fortnightly timescales are linked to spring-neap cycles in energy and dissipation. These shifts alter the reflectivity of the system and thus the distribution of tidally driven mixing over the spring-neap cycle. The high-resolution, wave-powered WireWalker profiling mooring deployed at the head of the canyon has continued for the whole year, revealing dynamics and biogeochemical signals on seasonal, event, tidal, and higher frequency timescales and providing novel insight into the canyon's role in the environment on the adjacent shelf.

- 02:30 PM**PS53A-03** Benthic Frontogenesis, Production of Negative Potential Vorticity and Turbulence over the Northern Gulf of Mexico Continental Slope*__Kurt L Polzin__, WHOI, Woods Hole, MA, United States, Steven Francis DiMarco, Texas A & M University, College Station, TX, United States, Zhankun Wang, Cooperative Institute for Climate and Satellites, University of Maryland, College Park, MD, United States, Binbin Wang, Texas A&M University College Station, College Station, TX, United States, Angel Ruiz Angulo, Centro de Ciencias de la Atmosfera, UNAM, Mexico D.F., Mexico, Miguel Costa Tenreiro, CICESE, Physical Oceanography, Ensenada, Mexico and Christian Nygren, Texas A & M University, Oceanography, College Station, TX, United States*

- A unique set of vertical profiling and moored measurements was obtained in August of 2017 from the northern continental slope of the Gulf of Mexico. The measurements document turbulent dissipation rates thousands of times larger than background over vertical scales of hundreds of meters. The enhanced mixing is observed in conjunction with near bottom flows resulting in jet-like features on the rims of salt domes and over the Sigsbee Escarpment. The data will be discussed in the context of frontogenesis, negative potential vorticity production and form drag.

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- 02:45 PM**PS53A-04** Bridging the gap between Submesoscales and Turbulence: Investigating Drag, Dissipation and Mixing in Topographic Interactions of the Gulf

Stream*Maarten J Molemaker*[1], *Guillaume Roullet*[2], *Jonathan Gula*[2] *and Nicolas Ducousso*[2], *(1)UCLA, Los Angeles, CA, United States, (2)LOPS, IUEM, University of Brest, Brest, France*

- A recently developed, efficient, non-hydrostatic version of ROMS is used to quantitatively investigate submesoscale transitions towards turbulence. While ocean modelling has made great strides in recent years, processes at scales that are smaller than 1 km are typically outside the reach of realistic models. At these small scales, the aspect ratio of the flow is not guaranteed to be large and non-hydrostatic effects must be included. The scale range of O(10m-1 km) is challenging, not only due to the emergence of non-hydrostatic effects, but also due to the need to amend existing sub-grid scale parameterizations that are commonly used at coarser resolutions. Bridging the gap between submesoscales and turbulence, for the first time, allows for a numerical study of the emergence of submesoscale instabilities and the resulting turbulent cascades towards irreversible mixing and energy dissipation in a realistic oceanic environment.
- Using the new ocean model, we investigate the interaction of the Gulf Stream with the shelf break of the great Bahama bank. The topographic interaction provides a pathway for energy transfer from the geostrophic flow to submesoscale wakes through anticyclonic vertical vorticity generation in the bottom boundary layer. The submesoscale turbulence leads to elevated local dissipation and mixing in the interior. The resulting drag, form stress, and water mass transformation is important to the budgets of energy, vorticity, and tracers of the gyre scale circulation. Generation of anti-cyclonic vorticity, separation, and subsequent submesoscale centrifugal instability is generic for boundary slope currents that flow in the direction of Kelvin wave propagation. Based on the mean values of drag, dissipation and mixing that are explicitly resolved, the effects on the integral gyre scale balances will be estimated.

- 03:00 PMPS53A-05 Submesoscale baroclinic instabilities in the bottom boundary layer, a mechanism for enhanced turbulent vertical buoyancy fluxes***Jacob O Wenegrat*** *and Leif N Thomas, Stanford University, Stanford, CA, United States*

In this presentation we demonstrate the existence of a bottom-intensified submesoscale baroclinic instability mode over sloping topography, a bottom boundary layer (BBL) counterpart to surface mixed-layer instabilities. The instability results from the release of available potential energy generated during the spin-down of a current on a slope. A linear stability analysis suggests that the growth rates of the BBL instabilities are comparable to those of the surface mixed-layer mode and are relatively insensitive to topographic slope angle, implying the instability is robust and likely of broad importance in the global oceans. These BBL baroclinic instabilities are associated with large turbulent vertical buoyancy fluxes, which numerical simulations suggest can exceed fluxes associated with the breaking of internal waves over rough topography, underscoring the important role these instabilities may play in the global interior circulation. The small scales, and proximity to the bottom, of these BBL instabilities pose a challenge for observations and models, and the parameter dependencies of the eddy fluxes, and connections to the dynamics and properties of the interior ocean will be emphasized.

- 03:15 PM**PS53A-06** Numerical Simulations of Mode Water Formation involving Cabbeling and Frontogenetic Strain at Thermohaline Fronts***Leif N Thomas**, Stanford University, Stanford, CA, United States and Callum James Shakespeare, Australian National University,*

*Research School of Earth Sciences, Canberra, Australia*

Submesoscale-resolving numerical simulations are used to investigate a mechanism for sustained mode water formation via cabbeling at thermohaline fronts subject to a confluent strain flow. Unlike other proposed mechanisms involving air-sea fluxes, the cabbeling mechanism, in addition to driving significant mode water formation, uniquely determines the thermohaline properties of the mode water given knowledge of the source water masses on either side of the front. The process of mode water formation in the simulations is as follows. Confluent flow associated with idealized mesoscale eddies forces water horizontally in towards the front. The frontogenetic circulation draws this water near-adiabatically from the full-depth of the thermohaline front up close to the surface, where resolved submesoscale instabilities drive intense mixing across the thermohaline front, creating the mode water. The mode water is denser than the surrounding stratified fluid and sinks to fill its neutral buoyancy layer at depth. This layer gradually expands up to the surface and eddies composed entirely of this mode water detach from the front and accumulate in the difluent regions of the domain. The process continues until the source water masses are exhausted. The T-S relation of the resulting mode water is biased to the properties of the source water that has the larger isopycnal T-S anomaly. This mechanism has the potential to drive O(1 Sv) mode water formation, and may be important in determining the properties of mode water in the global oceans.

doi:10.1175/JPO-D-17-0001.1

- 03:30 PMPS53A-07 How much do submesoscale fronts modulate mixing in a typical upwelling regime?***Soeren Thomsen***[1]*, Daniel B Whitt*[2]*, Mariana Hill-Cruz*[1]*, Marcus Dengler*[1] *and Gerd Krahmann*[1]*, (1)GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany, (2)National Center for Atmospheric Research, Climate and Global Dynamics Laboratory, Boulder, CO, United States*
    - Submesoscale fronts are omnipresent in eastern boundary upwelling regimes and are thought to impact vertical advection of nutrients and carbon, for example, and thus impact biogeochemical cycles. Theory, models and a few observations suggest that fronts can also modulate diapycnal mixing rates in the upper ocean.
    - Observing mixing across submesoscale fronts with classical shipboard sampling is challenging due to their small spatial scales of O(1 km) and datasets are typically too small to capture the highly intermittent nature of turbulence. Here we use a huge glider-based microstructure dataset, which is not disturbed by the ship motion and thus allows us to quantify the effect of submesoscale fronts on mixing rates. During two deployments carried out off Mauritania in June 2014 various fronts were crossed by the gliders at a horizontal resolution smaller than 200 m and temporal resolution of about 10 min resulting in a dataset of about 2000 turbulence profiles. The observations are compared to large eddy simulations of idealized submesoscale fronts forced by observed buoyancy fluxes and wind stress.
    - In regions of strong lateral density gradients our observations reveal enhanced stratification in the lower half of the boundary layer and a less stratified pycnocline possibly due to enhanced entrainment. Additionally, a pronounced diurnal cycle of

stratification and turbulence in the surface boundary layer is observed associated with daytime warming and cooling at night. In frontal regions we find enhanced dissipation rates just above the pycnocline during the period of cooling and reduced stratification. Our observations suggest that submesoscale fronts modulate diapycnal mixing in a typical upwelling regime and furthermore interact with the diurnal cycle of turbulence in the surface boundary layer. This modulation might have large impacts on vertical fluxes of heat, nutrients and climate relevant gases in eastern boundary upwelling regimes.

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- 03:45 PMPS53A-08 Submesoscale Subduction and Ventilation in an Idealized Southern Ocean Model***Dhruv Balwada**, New York University, New York, NY, United States, K. Shafer Smith, New York University, Courant Institute of Mathematical Sciences, New York, NY, United States and Ryan Abernathey, Columbia University of New York, Palisades, NY, United States*

- The ocean's crucial role in influencing the climate system via heat, carbon, nutrient and oxygen exchange is well established. Upper-ocean tracer and heat transfers are influenced by a complex interplay between winds (Ekman pumping), air-sea fluxes, and the turbulent processes that naturally emerge. Recent modeling and observational research has pointed to the potentially large influence that the submesoscale flows might have on property exchanges between the surface and interior . This hypothesis is based on the anomalously large vertical velocities that are generally associated with these flows, which can influence the exchange of properties between the surface and interior ocean. However, one can easily envision that other factors, such as the vertical coherence of vertical velocities and the background tracer gradients, might also play an important role in influencing the ventilation.
- Here we present a set of MITgcm experiments, with progressively increasing resolution, that systematically address the role of the submesoscale dynamics in influencing the ventilation. The model setup is an idealization of the Southern Ocean, which is a hot spot of subduction and ventilation, with fluid in a channel that is forced by winds and heating at the surface. Idealized tracers are sourced at the surface, which simulate the anthropogenic carbon sources from the atmosphere,

and in the interior, which simulate the large reserves of nutrients in the deep. The model resolution is varied from low resolutions that barely resolve the mesoscale to highest resolutions that resolve the submesoscale. This variation of resolution leads to spontaneous emergence of turbulent dynamics at the submesoscale, which are the focus of this work. The role of the emergent small scale phenomena on tracer fluxes is quantified using large scale tracer budgets and cross-spectral tracer flux analysis. The cross spectral tracer flux analysis provides hints into the role played by different scales on the ocean ventilation. The influence of different boundary layer parameterizations, representing the smallest scale unresolved mixing, on influencing submesoscale driven tracer fluxes is also a focus of this work.

- **PS44B:** How Do Submesoscale and Internal Wave Driven Mixing Matter on Global and Regional Scales? I Posters

Ocean mixing processes driven by submesoscale dynamics (e.g. mixed layer instabilities, shear instability, etc), internal waves (e.g. nonlinear wave interactions, lee waves, etc), and the interaction between the two are known to have a significant local impact. However, less is known about the importance of these mechanisms on larger scales, including the effect on the water-mass transformation, buoyancy budgets, energy pathways, and subsequent biogeochemistry. This is due to the challenges of observing and modeling these processes accurately with regional and global coverage. This session welcomes

○

abstracts that help investigate the influence of these small-scale processes (occurring at time scales of inertial periods and spatial scales below 10km) on the large-scale by use of observations, modeling, or parameterizations. We hope to initiate discussions that relate to the regional, basin, and global scale effects of submesoscales and internal waves on the physics and biogeochemistry of the ocean.

**Thursday, February 15, 2018**

**04:00 PM - 06:00 PM**

- *Oregon Convention Center*
- *- Poster Hall*

**Primary Chair**

- Mariona Claret
    - *JISAO/University of Washington*

**Co-Chairs**

- Caitlin Whalen
    - *Applied Physics Laboratory University of Washington*
- Tyler Hennon
    - *Scripps Institution of Oceanography*
- Cimarron Wortham
    - *NorthWest Research Associates*

**Moderators**

- Mariona Claret
    - *JISAO/University of Washington*
- Caitlin Whalen

- *Applied Physics Laboratory University of Washington*
- Cimarron Wortham
- *NorthWest Research Associates*
- Tyler Hennon
- *Scripps Institution of Oceanography*

## Index Terms

- 4273 Physical and biogeochemical interactions
- 4544 Internal and inertial waves
- 4568 Turbulence, diffusion, and mixing processes
- 4572 Upper ocean and mixed layer processes

Papers

- **PS44B-2279** Extraction of Available Potential Energy from Geostrophic Fronts by Inertial-Symmetric Instabilities.***Nicolas Grisouard***, *University of Toronto, Toronto, ON, Canada*

- Submesoscale oceanic density fronts are structures in geostrophic and hydrostatic balance, which are more prone to inertial and/or symmetric instabilities. We argue in this article that drainage of available potential energy from the geostrophic flow is a leading-order source of their growth. We illustrate our point with two-dimensional Boussinesq numerical simulations of oceanic density fronts on the *f*-plane. A set of two-dimensional initial conditions covers the submesoscale portion of a three-dimensional parameter space consisting of the Richardson and Rossby numbers, and a measure of stratification or latitude. Because we let the lateral density gradient decay with depth, the parameter space map is non-trivial, excluding low-Rossby, low-Richardson combinations. Dissipation effectively selects the largest growing mode, and inertial-symmetric instability in a confined unstable region creates flow cells that recirculate outside the unstable region, disturbing isopycnal locations. As the ageostrophic flow grows in amplitude, isopycnals eventually get significantly displaced. Systematically, such isopycnal displacements correspond to a drainage of available potential energy from the geostrophic fronts to the ageostrophic perturbations. In the majority of our experiments, this energy drainage is at least as important as the drainage of kinetic energy from the front. Various

constraints, some physical, some numerical, result in our experiments to behave like inertial rather than symmetric instabilities. Our results depend very weakly on the Richardson number, and more on the Rossby number and relative stratification.

- *Image legend: Streamlines (solid lines, colour-coded by in-plane velocity, in mm/s), isopycnals (dashed black contours) and Ertel potential vorticity = 0 contour (solid magenta line, top panel only) at two different stages of the instability.*

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- **PS44B-2280** Overturning Circulation and Heat Transport: The Role of Background Diffusivity***Magnus Hieronymus****, Stockholm University, Farsta, Sweden, Jonas Nycander, Bolin Centre for Climate Research, Stockholm, Sweden, Johan Nilsson, Stockholm University, Department of meteorology, Stockholm, Sweden and Kristofer Döös, Stockholm University, Department of Meteorology, Stockholm, Sweden*

  - The coupled ocean-atmosphere model CM2G is used to investigate the dependence of the overturning circulation and the meridional heat transport on the background diffusivity used in the model. The background diffusivity is found to have a strong influence on the model's climate. The surface temperature as well as the volume mean temperature of the ocean is strongly influenced by the diffusivity, and so is the sea ice extent. The sea ice extent is found to decline with increasing diffusivities leading a weaker meridional temperature gradient, weaker zonal winds and therefore to a reduced Ekman transport in the Southern Ocean. The scaling of the strength of the meridional overturning circulation with diffusivity is found to agree reasonably well with earlier theoretical and numerical estimates, both for the AMOC and the Southern Ocean overturning. However, some reinterpretation of the diffusivity is needed since the theoretical scalings are based on the usage of a constant diffusivity. The heat transport due to individual streamfunction cells is also quantified, and it is found that the upper cells that exist only in the tropics tend to dominate the heat transport However, the changes in heat transport due to changes in diffusivity are larger for the deep cells.

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- **PS44B-2281** Strong turbulent mixing and nitrate flux in the Kuroshio across the Izu Ridge***Takahiro Tanaka***[1]*, Daisuke Hasegawa*[1]*, Ichiro Yasuda*[2]*, Hideyuki Tsuji*[3]*, Shinzou Fujio*[4]*,*

*Yasutaka Goto[5] and Jun Nishioka[6], (1)Tohoku National Fisheries Research Institute, Japan Fisheries Research and Education Agency, Shiogama, Japan, (2)Atmosphere Ocean Research Institute, University of Tokyo, Kashiwa, Japan, (3)Atmosphere and Ocean Research Institute, University of Tokyo, Japan, (4)Atmosphere and Ocean Research Institute University of Tokyo, Tokyo, Japan, (5)University of Tokyo, Bunkyo-ku, Japan, (6)Hokkaido University, Institute of low temperature science, Sapporo, Japan*

- Kuroshio / Kuroshio Extension region is an important nursery ground for major pelagic fish such as Japanese sardine, and the vertical turbulent nitrate flux is thought to be an important process for maintaining the biological and fisheries production in this region. Below the euphotic zone, the North Pacific Intermediate Water (NPIW) is considered to provide nutrient source to the Kuroshio via vertical mixing as suggested by Sarmiento et al. (2004). However, the spatial distribution of vertical mixing intensity, the physical processes involving vertical mixing, and the quantification of vertical turbulent nitrate flux along the Kuroshio / Kuroshio Extension has not been fully clarified on the observational basis.
- In this study, we conducted a series of simultaneous measurements of turbulence and nitrate near the Izu Ridge, where the Kuroshio flows over steep bottom topography. The mixing intensity was particularly elevated at about 100 m depth on the top and lee side of the ridge ($\varepsilon = O(10^{-7})$ [W/kg] and $K\rho = O(10^{-4})$ [m$^2$/s]). The mixing was also elevated where there was a large isopycnal heaving at about 26 – 26.6 $\sigma_\theta$ ($\varepsilon = O(10^{-7})$ [W/kg] and $K\rho = O(10^{-3})$ [m$^2$/s]). The energy dissipation rate was positively (negatively) correlated with the shear square (Richardson Number), suggestive of the occurrence of shear instability. The vertical turbulent nitrate flux, $F_{NO3}$, reached $O(10^{-1})$ [mmolNm$^{-2}$/day] which is more than 1 order magnitude greater than the background value. These results suggest that the Izu Ridge in the Kuroshio is a mixing hot spot which may provide large portion of the new production in the euphotic zone and may draw sufficient nitrate upward from NPIW to impact the downstream.

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- PS44B-2282 Observations of high-frequency internal wave generation by Langmuir circulation *Eefke Marijn van der Lee, Leibniz-Institute for Baltic Sea Research Warnemünde, Rostock-Warnemünde, Germany, **Frederic Cyr**, Fisheries and Oceans Canada, Northwest*

*Atlantic Fisheries Centre, St. John's, NF, Canada, Marc P Buckley, Helmholtz-Zentrum Geesthacht, Institute of Coastal Research, Geesthacht, Germany, Lars Umlauf, IOW, Warnemuende, Germany and Hans van Haren, Royal Netherlands Institute for Sea Research, Den Burg, Netherlands*

- While it is becoming increasingly recognized that Langmuir Circulation (LC) largely controls the depth of most of the ocean surface mixed layer, the exact mechanisms by which LC acts against stratification are still disputed. Using data from a moored velocity profiler and 150 fast-response temperature sensors equally-spaced over the bottom 30 m of the water column (i.e., 20 cm vertical resolution), we give a new look at the onset and development of Langmuir circulation. Such unprecedented vertical and temporal resolution suggests that the onset of the wind is rapidly followed by the generation of high-frequency internal waves near the buoyancy frequency. These internal waves are believed to rise from the LC cells impinging on the density interface of the two-layer system under observation. Although theoretically and numerically demonstrated in the past, this study is one of the few observational evidence of internal wave generation by Langmuir circulation. Observations also show that these waves participate to the erosion of the density interface and the deepening of the mixed layer. Implications of this finding are discussed in relation to Langmuir circulation theory and parametrization.

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- PS44B-2283 Low-to-High Frequency Energy Transfers in a Primitive Equation Channel Flow***David Straub****, McGill University, Department of Atmospheric and Oceanic Sciences, Montréal, QC, Canada and Stephanne Taylor, Department of Fisheries and Oceans, Halifax, NS, Canada*

- We consider flow in a primitive equation eddy-resolving channel forced with a combination
of steady and near-inertial winds. The high frequency forcing generates near-inertial waves, and
we examine their interaction with the underlying geostrophic flow. Reynolds stresses exerted by
the fast time scale motion provide a sink that accounts for up to 20% of the low frequency kinetic

energy dissipation. This balanced-to-unbalanced transfer extracts energy from a wide band of
sub-inertial frequencies and from wavenumbers centered in the mesoscale and is associated with a
larger downward transfer of kinetic energy and a deepening of the mixed layer. We also consider
the potential energy budget, and find that near-inertial motion also acts to extract potential
energy from low frequencies (transferring it to unbalanced, near-inertial frequencies). Finally,
we attempt to situate these results with a number of other recent studies that also focus on how
forced (or stimulated) near-inertial motion can damp balanced flow; that is, we situate our work
within the broader context of "Stimulated Loss Of Balance", or SLOB.

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- PS44B-2284 Increased turbulent dissipation rates by trapped near-inertial waves in the Lofoten Basin Eddy ***Ilker Fer***[1], *Anthony Bosse*[1], *Bruno Ferron*[2], *Pascale Bouruet-Aubertot*[3] *and Henrik Søiland*[4], *(1)Geophysical Institute, University of Bergen and Bjerknes Center for Climate Research, Bergen, Norway, (2)Univ. Brest, CNRS, IFREMER, IRD, Laboratoire d'Océanographie Physique et Spatiale, IUEM, Brest, France, (3)Sorbonne Universités- UPMC Univ. Paris 06- LOCEAN, Paris, France, (4)Institute of Marine Research, Bergen, Norway*

  - A long-lived, deep anticyclonic vortex (the Lofoten Basin Eddy, LBE) is frequently observed in the central part of the Lofoten Basin in the Norwegian Sea. Under the PROVOLO project, full-depth ocean microstructure profiles were collected from cruises in June 2016 and March 2017, to study the turbulent structure of LBE in summer and winter conditions. A set of two free-fall, deep vertical microstructure profilers (VMP5500 and VMP6000, Rockland Scientific Int.) and one loosely-tethered profiler (VMP2000) was utilized, supplemented by hydrographic and velocity measurements from the ship. Dissipation rate of turbulent kinetic energy was measured to a noise level of $10^{-11}$ W kg$^{-1}$, down to 50-100 m above the sea bed in 3200 m depth.

- The hydrographic and dynamic properties of the eddy during the cruises were typical of the average LBE, characterized by peak velocities at 600-900 m depth and 15-20 km away from the center of rotation, with intense cyclogeostrophic velocities ranging between 0.5 and 0.8 m/s, and core relative vorticity of -0.8f (f is the local Coriolis parameter). Dissipation rates from the energetic LBE environment exceeded the values from a reference station in the basin by up to two orders of magnitude between 750 and 2000 m depth. We observed a multi-layer core structure where 500-m thick well-mixed layers were separated by pycnoclines. While each pycnostad had negligible dissipation levels (< $3 \times 10^{-11}$ W $kg^{-1}$), the interfaces were associated with substantial background velocity shear and high dissipation rates reaching $10^{-8}$ W $kg^{-1}$. The negative vorticity core of the anticyclone imposes an effective Coriolis frequency, allowing for generation and propagation of near-inertial internal waves at sub-inertial frequencies. Downward propagating sub-inertial waves are thus trapped and amplified in the anomalous vorticity core, reflecting off the eddy boundaries at horizontal turning points, and stall in critical layers. We hypothesize that the source of energy to maintain the observed rates of dissipation of kinetic energy is the near-inertial energy trapped by the negative vorticity of the eddy.

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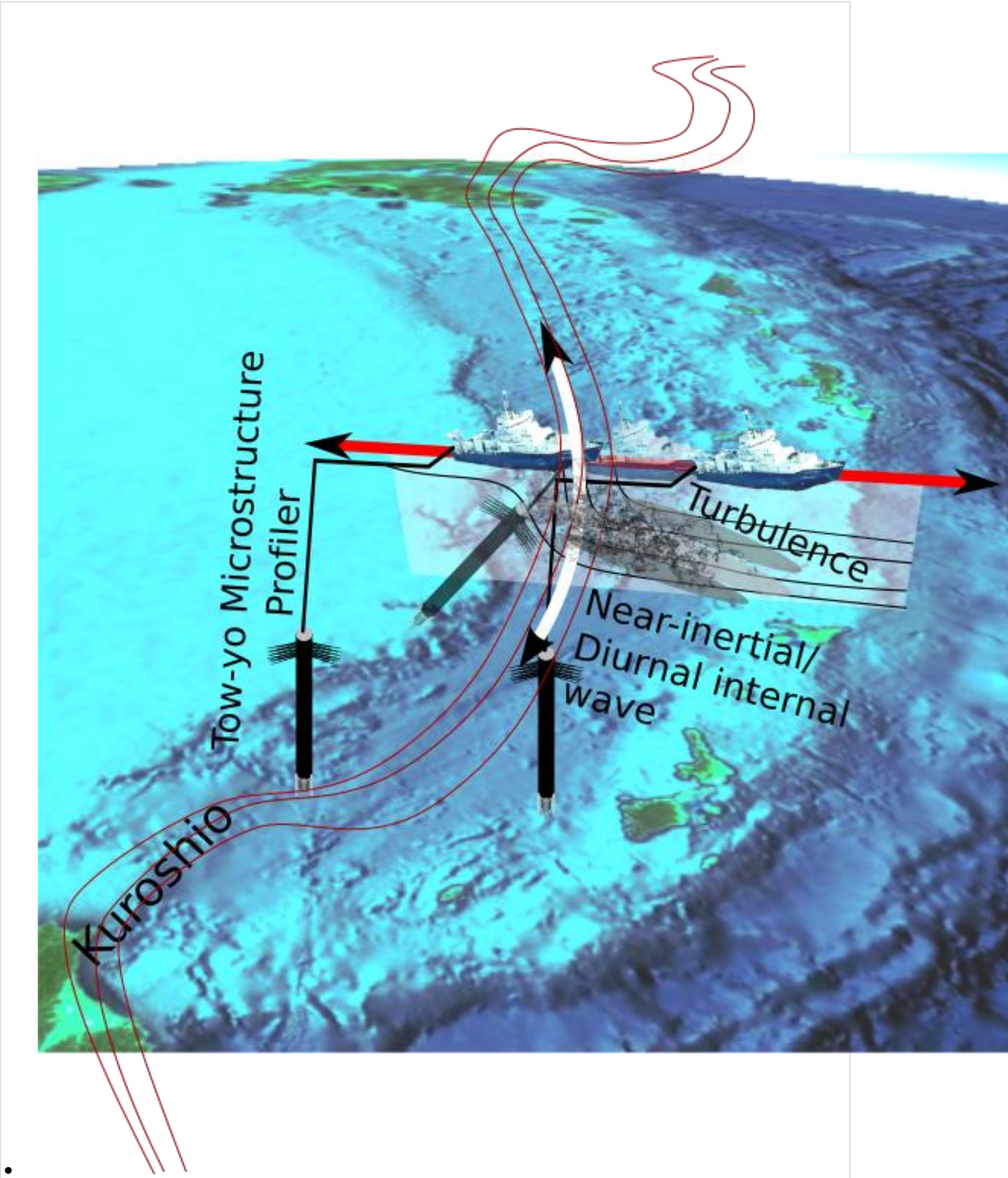
- PS44B-2285 Coherent Bands of Strong Turbulent Layers Associated with High-Wavenumber Near-Inertial Internal-Wave Shear in the Upstream Kuroshio ***Takeyoshi Nagai***[1], *Daisuke Hasegawa*[2], *Takahiro Tanaka*[2], *Hirohiko Nakamura*[3], *Eisuke Tsutsumi*[4], *Ryuichiro Inoue*[5] *and Toru Yamashiro*[6], *(1)Tokyo University of Marine Science and Technology, Tokyo, Japan, (2)Tohoku National Fisheries Research Institute, Japan Fisheries Research and Education Agency, Shiogama, Japan, (3)Kagoshima Univ, Kagoshima, Japan, (4)Kyushu Univ, Research Institute for Applied Mechanics, Kasuga, Japan, (5)JAMSTEC, Yokosuka, Japan, (6)Kagoshima University, Japan*

The upstream Kuroshio flows through Okinawa Trough and the Tokara island chain, the region near the continental shelf of the East China Sea and shallow seamounts, where the Kuroshio can induce strong mixing over the shallow topographies. Also, tidal currents over the rough topographies may produce internal tides, and associated turbulence. The previous observations show energetic high vertical wavenumber near-inertial wave shear in the Kuroshio thermocline, which implies strong turbulent mixing. However, direct turbulence measurements in this region are very scarce. Using high lateral resolution (1-2 km) direct turbulence measurements, we show here, for the first time, that strong turbulent layers form spatially coherent banded structures spreading over O(10 km) in the lateral direction associated with bands of near-inertial wave/diurnal internal tide shear of high vertical wavenumber in the upstream Kuroshio. The turbulent kinetic energy dissipation rates within these turbulent layers are >O($10^{-7}$ W $kg^{-1}$), and estimated vertical eddy diffusivity shows >O($10^{-4}$ $m^2s^{-1}$) on average. These results suggest that the high vertical wavenumber near-inertial waves propagating in the upstream Kuroshio could have large impacts on the watermass modifications, momentum mixing, nutrient supply, and associated biogeochemical responses in its downstream.



Tow-yo Microstructure Profiler
Turbulence
Near-inertial/
Diurnal internal
wave
Kuroshio

- **PS44B-2286** Submesoscale Dynamics of the Greater Agulhas Region in a Series of High Resolution Ocean General Circulation Models***René Schubert**, Arne Biastoch, Franziska U Schwarzkopf and Jan Harlass, GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany*

  - The Greater Agulhas Region is one of the regions with highest mesoscale activity in the world ocean. Here we use a series of nested high resolution ocean general circulation models (the INALT family with 1/10°, 1/20° and 1/60° resolution) to show that, in this region, the interactions of the mesoscale eddies drive energetic submesoscale dynamics in the surface boundary layer, when the model resolution is sufficiently high.
  - In the simulation with the highest resolution, the Agulhas Retroflection as well as the Southwest Indian Ocean Subgyre are associated with intense frontogenesis, frontal instabilities and the development of small eddies. In contrast, the Agulhas Ring path is found to be associated with only weak frontogenesis and more stable fronts due to the relatively small strain between the eddies. The small scale dynamics are found to have similiar characteristics as derived from previous studies for other regions.
  - In comparison to the lower resolution model runs we demonstrate that small scale instabilities energyze the smaller mesoscales and change the separation characteristics of the Agulhas Current. However, largescale transports of the Agulhas Current and the Agulhas Leakage are not found to increase significantly when the resolution is increased from 1/20° to 1/60°.

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- **PS44B-2287** Using New Approach to Quantify the Impact of Near-inertial Motions in the Gulf of Mexico***Chuan-Yuan Hsu**, Texas A&M University College Station, College Station, TX, United States, Jing Zhao, Texas A & M University, College Station, TX, United States; Ocean University of China - Qingdao, China, Ping Chang, Texas A & M Univ, College Station, TX, United States and Matthew Howard, Texas A & M University College Station, College Station, TX, United States*

- The effect of vertical mixing in the water column caused by the near-inertial motions on the Northern Coast of Gulf of Mexico during summer and winter season is investigated using a fully three-dimensional primitive equation model. Special attention is directed to the wind energy input to the surface near-inertial motions and subsequent change in the depth of mixed layer, seawater temperature, and the downward energy propagation into the deeper ocean. In addition, to quantify the NIWs impact, this study introduces a CW-CC approach to instead of the traditional 24hr temporal resampling approach. Several points can be concluded in this study. First, model results show the boreal summer near-inertial motions can be amplified significantly by the diurnal wind forcing in the northern Gulf of Mexico and propagate to levels 10 m or deeper, while the motions in wintertime are enhanced by the Gulf of Mexico winter storms. However, the intensity of wind power input is two to four times weaker than in the summer. Second, although the near-inertial motions are much powerful in summer, the summer stratification in the northern Gulf of Mexico is too strong to suppress the growth of the vertical mixing. On the other hand, although the winter stratification is weaker, since the near-inertial motions are weaker in winter, the ocean vertical structure is not only caused by the vertical impact of the near-inertial motions but also the advection. Third, by comparing with the two different ways to quantify the near-inertial motions, it is realized that the common 24-hr temporal resampling approach overestimated the results by, for example, up to 0.1°C in SST change as well as a change of approximately 1 m in the bottom base of mixed layer.

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- PS44B-2288 How a shallow sill cultivates the Kuroshio***Daisuke Hasegawa***[1], *Takeshi Matsuno*[2], *Eisuke Tsutsumi*[3], *Tomoharu Senjyu*[2], *Hirohiko Nakamura*[4], *Toru Kobari*[5], *Ayako Nishina*[6], *Naoki Yoshie*[7], *Xinyu Guo*[7], *Takeyoshi Nagai*[8], *Takahiro Tanaka*[1] *and Ichiro Yasuda*[9], *(1)Tohoku National Fisheries Research Institute, Japan Fisheries Research and Education Agency, Shiogama, Japan, (2)Kyushu Univ, Fukuoka, Japan, (3)Kyushu Univ, Research Institute for Applied Mechanics, Kasuga, Japan, (4)Kagoshima Univ, Kagoshima, Japan, (5)Kagoshima University, Aquatic Sciences, Faculty of Fisheries, Kagoshima, Japan, (6)Kagoshima Univ, Japan, (7)Ehime University, Center for Marine Environmental Studies, Matsuyama, Japan, (8)Tokyo*

*Univ.Mar.Science&Tech., Tokyo, Japan, (9)Atmosphere Ocean Research Institute, University of Tokyo, Kashiwa, Japan*

- The enhanced turbulent nitrate flux from deep to near-surface waters of the Kuroshio Current was observed in the Tokara Strait where the current encounters the multiple small islands and seamounts. For precisely quantifying the turbulent nitrate fluxes, we conducted simultaneous measurements of turbulence and nitrate by deploying a submersible ultraviolet nitrate analyzer (Deep SUNA V2 by Satlantic) attached on a turbulence microstructure profiler (TurboMAP-L by JAC) from *T/V Kagoshima-maru*; while drifting over a shallow (~100 m) sill between islands with the Kuroshio's flow. A continuous echogram from a bottom mount echo sounder (EK60 by SIMRAD) revealed how Kelvin-Helmholtz instabilities, hydraulic jumps and internal waves develop in the lee of the sill. A large turbulent dissipation rate of $O(10^{-5}$ W/kg at the maximum) was observed with the above-mentioned hydraulic features. The Nitrate flux caused by the strong turbulent mixing reaches to $O$(0.1 to 10 mmol $m^{-2}$ $d^{-1}$), which is high for a subtropical open ocean, and is comparable to the value in high productive areas.

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- PS44B-2289 Sectional Glider Measurements of Fine-Scale Hydrography of Frontal Jets and Mesoscale Eddies in the Japan Sea ***Taku Wagawa**, Japan Sea National Fishseries Research Institute, Japan Fisheries Research and Education Agency, Niigata, Japan, Yusuke Kawaguchi, Atmosphere and Ocean Research Institute, The University of Tokyo, Chiba, Japan, Yosuke Igeta, Japan Sea National Fisheries Research Institute, Japan Fisheries Research and Education Agency, Niigata, Japan, Naoto Honda, Japan Sea National Fisheries Research Institute, Japan Fisheries Research and Education Agency, Japan and Takeshi Okunishi, Tohoku National Fisheries Research Institute, Japan Fisheries Research and Education Agency, Shiogama, Japan*

- The region offshore of Sado Island, Japan (i.e., along the southern margin of the central Japan Sea) is characterized primarily by a surface-intensified jet with a lateral scale of $O$(10 km) and mesoscale eddies whose speeds exceeding 0.5 m $s^{-1}$. Large spatial/temporal variabilities of such mesoscale jets and eddies in this region cause perturbations of temperature and salinity, which raise serious concerns for the set-net fisheries and aquaculturists in the region. Although earlier studies have

investigated those synoptic-scale and mesoscale structures, their details remain unclear owing to insufficient in-situ data.

- We successfully completed a spatially high-resolution survey with an underwater glider off Sado Island from 20 April through 2 June 2016. The glider repeatedly profiled temperature and salinity with an along-track profile separation 2–3 km, which is sufficient to resolve the mesoscale structures. A total of 257 profiles were obtained during a two-round-trip observation (four transects; referred to as "Transects 1–4").
- We revealed a large intramonthly variability of mesoscale frontal/eddy structures and water properties from the glider observations. Mixing driven by internal gravity waves or double diffusions and its spatial/temporal variability within the mesoscale structures was also detected. A mixed-layer slab model predicted the generations of wind-induced near-inertial waves just before Transect 1 observations. High turbulent diffusivities estimated from spectral curves of strain were shown along Transect 1 trapped by a negative vorticity, representing possible evidences of the internal gravity waves. Along Transects 2–4, we observed the recognizable signals in the strain at depth right below the main pycnocline without the distinct wind forcing and negative vorticity. Transects 1–2, across the anticyclonic eddy, showed a diffusive-convection favorable vertical structure near the surface layer with colder and fresher water overlying subsurface layer. The counterpart of the cyclonic eddy was salt-fingering favorable.

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- PS44B-2290 High Vertical Wavenumber Structures Observed by an Intensive Survey of an Anticyclonic Mesoscale Eddy***Daiki Ito***[1], *Toshio Suga*[1,2], *Eitarou Oka*[3] *and Shinya Kouketsu*[4], *(1)Tohoku University, Graduate School of Science, Sendai, Japan, (2)JAMSTEC Japan Agency for Marine-Earth Science and Technology, Kanagawa, Japan, (3)Atmosphere and Ocean Research Institute University of Tokyo, Tokyo, Japan, (4)JAMSTEC, Yokosuka, Japan*

- Evolution of horizontal wavenumber (WN) of any tracer in a strain field is called frontogenesis/filamentogenesis and now studied in the framework of submesoscale currents. According to the 3D cascade theory developed by Klein et al. (1998), vertical WN of any tracer can grow by its product of horizontal WN and the vertical shear of the horizontal velocity. The main objective of our study is to investigate the distribution of submesoscale currents and examine how it corresponds with the 3D cascade theory. As part of the study, we conducted a high-resolution intensive survey at the periphery of an anticyclonic mesoscale eddy around the Kuroshio Extension.

- The intensive survey was carried out using XCTD and shipboard ADCP during the KH-16-3 cruise of R/V Hakuho-maru in June 2016. The XCTD stations were taken along 5 lines that were oriented along longitude, roughly perpendicular to the southern edge of the eddy. Each line has 16 stations. The distance between the stations was ~5.6 km and that between the lines was 10'.
- Low spiciness (π) water with the horizontal scale of several tens kilometers was at the edge of the eddy all the sections. Combined with ADCP data, it is suggested that the low π water represents a filament developed before/during first line survey. The developed filament surrounding the eddy is observed in other lines. High vertical WN structures of π were distributed associated with the filament. Since the filament is developed and distributed in the strain field around the eddy, high vertical WN structures are distributed more frequently in the strain field than other area.
- On the other hand, small patches of low π water were also distributed inside the eddy. They should be trace of filaments and they are also accompanied by high vertical WN structures. Its vertical scale is comparable to the scale of vertical shear of horizontal velocity, suggesting that not only developing filaments but also trace of filaments can cause high vertical WN structures.

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- PS44B-2291 Sensitivity of tidal mixing parameterization in quasi-global high-resolution oceanic simulation***Hideharu Sasaki***[1], *Shinichiro Kida*[2], *Hidenori Aiki*[3], *Nobumasa Komori*[4], *Ryo Furue*[1], *Toru Miyama*[5], *Bunmei Taguchi*[6], *Yoshikazu Sasai*[4], *Masami Nonaka*[1] *and Yukio Masumoto*[7], *(1)JAMSTEC Japan Agency for Marine-Earth Science and Technology, Kanagawa, Japan, (2)Kyushu University, Research Institute for Applied Mechanics, Fukuoka, Japan, (3)Nagoya University, Nagoya, Japan, (4)JAMSTEC, Yokohama, Japan, (5)JAMSTEC,*

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- Tidal motion over rough topography induces strong mixing, and then influences on oceanic field. The tidal mixing is one of key drivers of global thermohaline circulation and influences local oceanic field in marginal seas. Although we have been conducting a quasi-global hindcast simulation at a horizontal resolution of 0.1 degrees using the OFES (Masumoto et al. 2004), no tidal effects were included. To asses the impacts of tidal mixing, the tidal parameterization (St. Laurent et al. 2002) is implemented into the OFES.
  Two sensitivity simulations with and without the tidal parameterization show how the tidal mixing influences the oceanic fields. As expected by previous studies (e.g. Koch-Larrouy et al. 2007), the water mass characteristics in the Indonesian Throughflow are much improved by the parameterization. This local improvement is expected to modify the water characteristics in the subsurface Indian Ocean, which are unrealistic in the previous OFES simulation. We find the mass transport of the Indonesian Througflow to increase by about 0.7 Sv via the parameterization. The tidal mixing seems to provide more buoyancy to interior water in the Pacific Ocean than in the Indian Ocean, probably due to rough topography in the Pacific Ocean.

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- PS44B-2292 Impacts of submesoscale circulations on vertical dispersion. The case of the Gulf of Mexico

*ABSTRACT WITHDRAWN*

- PS44B-2293 Global Implications of Mixing by Internal Tidal Waves for the Supply of Nutrients to the Surface Ocean.***Jonathan Sharples***[1]*, Robyn E Tuerena*[2]*, Mattias Green*[3]*, Ric Williams*[4] *and Claire Mahaffey*[2]*, (1)University of Liverpool, Earth, Ocean and Ecological Sciences, Liverpool, L69, United Kingdom, (2)University of Liverpool, Earth, Ocean and Ecological Sciences, Liverpool, United Kingdom, (3)Bangor University, School of Ocean Sciences, Menai Bridge, United Kingdom, (4)Liverpool University, School of Environmental Sciences, Liverpool, United Kingdom*

- It is well established that internal tides over the steep topography of ridges and seamounts generate enhanced mixing in the deep ocean. We have recently found

that this enhanced mixing also affects the surface ocean, in particular increasing mixing in the base of the photic zone and so potentially affecting ocean biogeochemistry. Observations of turbulence and nutrients over the mid-Atlantic ridge show the diapycnal nitrate flux into the euphotic zone to be about 10 times greater than fluxes measured in the adjacent deep basin, with a marked spring-neap tidal variability in the fluxes over the ridge. Here we investigate the wider implications of this process and estimate the effects on nitrate supplies into the surface waters of the Atlantic and Pacific sub-tropical gyres.

- We calculate vertically integrated tidal dissipation from the TPXO8 database. We compute the associated vertical diffusivity by distributing the dissipated energy over depth assuming that the vertical distribution of the dissipation is proportional to the buoyancy frequency, making sure that the results are consistent with our observations of mixing into the photic zone over the mid-Atlantic ridge. Diffusivities are combined with local vertical nitrate gradients (World Ocean Atlas 13 v2) to yield maps of the diapycnal nitrate flux into the photic zone of the Atlantic and Pacific sub-tropical gyres at spring and neap tides. Nitrate fluxes over mid-ocean ridges and seamounts are 0.03 to 0.2 mol N $m^{-2}$ $yr^{-1}$, 5 – 20 times greater than over abyssal regions where fluxes are < 0.01 mol N $m^{-2}$ $yr^{-1}$. There is marked fortnightly tidal variability of fluxes over steep seabed topography, with fluxes at spring tides typically 2 – 3 times greater than those at neap tides. These fortnightly pulsed nitrate fluxes are likely to fuel additional primary production in locations over ridges and seamounts, perhaps adding 10 – 40% extra carbon fixation above the canonical 100 g C $m^{-2}$ $yr^{-1}$ for sub-tropical gyres.

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- PS44B-2294 Estimations of Diapycnal Diffusivities in the North Atlantic Upper Ocean from Shear-Based Spectral Method***Natalia Sukhikh****, University of Bremen, IUP/MARUM, Bremen, Germany, Tim Fischer, GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany, Maren Walter, MARUM/Institute of Environmental Physics, University of Bremen, Bremen, Germany and Christian Mertens, Institute of Environmental Physics, University of Bremen, Bremen, Germany*

- The North Atlantic Region plays an important role in the climate changes. The high-energy ocean processes occur here, between the polar regions and the tropics.

The energy of large scale ocean currents and eddies cascades to meso- and microscale structures. The upper ocean layer is influenced by atmospheric and hydrological processes. It is the intermediate layer between the wind-mixed ocean surface and the deep ocean.

- Ocean mixing is closely related to the large and small scale processes of ocean-atmosphere-sea ice interactions. The diapycnal mixing investigations give us an opportunity to describe the vertical exchange of water masses, induced by freshwater and heat fluxes. Ocean mixing itself belongs to small scale processes. Nevertheless, investigation of its variability over big water area allows us to estimate variability in large scales.
- Since 2003, the IUP/MARUM (Bremen University) have carried out active research of the ocean circulation in the North Atlantic. During 17 research cruises, data sets of sea currents, temperature and salinity structure of water masses and hydrochemical parameters were collected.
- In the current work, SADCP (Shipboard Acoustic Doppler Current Profiler) data is used to get estimates of diapycnal diffusivities in the upper ocean (20-1200 m) along a cross-basin transect at 47˚N. A shear-based spectral method is used to compute the internal waves' field parameters. The method includes the procedures of Wiener filtration, signal loss estimations due to SADCP configuration and its technical features and signal quality control. From the data, spatial distributions of mixing parameters as diapycnal diffusivity and energy dissipation are estimated.

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- **PS44B-2295** Combining seismic oceanography imaging with near-coincident in situ measurements to better assess the propagation and dissipation of internal wave dynamics in the Northwest Australian Shelf***Ana E Rice***[1], *Warren T Wood*[1], *Jeffrey W Book*[1], *Silvia Matt*[1], *Nicole L Jones*[2], *Cynthia Bluteau*[2,3] *and Scott R Smith*[1], *(1)U.S. Naval Research Laboratory, Stennis Space Center, MS, United States, (2)University of Western Australia, Crawley, WA, Australia, (3)Institut des Sciences de la Mer de Rimouski, Rimouski, QC, Canada*

- Seismic Oceanography (SO) is a an effective tool for imaging internal tides because the strong thermal gradients associated with their oscillations provide strong acoustic impedance contrasts for seismic observation. Furthermore, with horizontal resolutions of 100 m this technique can measure high-resolution internal tide spatial structure that cannot be typically measured with other methods. Here we present results from a unique analysis that combines the spatial information of seismic images with the time information of in situ measurements to provide new insights into patterns of propagation and dissipation of internal tide packets on a continental shelf.

- The unprecedented opportunity to combine SO and physical oceanographic (PO) measurements arose when 81 seismic lines of a 3D commercial SO survey from the Australian Northwest Shelf in spring 2012 overlapped in time and space with a comprehensive PO dataset acquired by NRL, UWA, the Australian Institute of Marine Science (AIMS) and the Integrated Marine Observing System (IMOS). The latter included moored and profile measurements of T, S, velocity and microstructure, in addition to glider observations. Independently, the PO data shows stronger internal tide energy on broad shelf locations, while more moderate internal tide energy on narrow shelf locations. These data also show the presence of strong non-linear internal tide wave packets at offshore mooring sites that become weaker at inner shelf sites, suggesting nearly complete dissipation over the span of the array. While preliminary results of SO data reveal poor seismic signals at PO mooring locations (depths) due to signal degradation caused by seafloor interference, the near-coincident SO data further offshore are nevertheless useable to characterize the spatial structure (wavenumbers and amplitudes) of wave packets as they propagate from their generation point at the shelf break to locations near the moorings. We use SO imagery to estimate mixing rates by tracing seismogram phase lines in space as a proxy for isopycnals, computing horizontal spectra, and then fitting with a combination of a Garrett-Munk spectrum for internal waves and a Batchelor model for turbulence. Results are compared directly with available microstructure data in the study area.

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- PS44B-2296 Revisiting the basics of internal waves: vertical modes, the Garrett-Munk spectrum, and particle dispersion***Jeffrey J Early**, NorthWest Research Associates Redmond, Redmond, WA, United States, Marie-Pascale Lelong, Northwest Research Associates, Redmond,*

*WA, United States and K. Shafer Smith, New York University, Courant Institute of Mathematical Sciences, New York, NY, United States*

- Modeling particle dispersion from internal waves with a Garrett-Munk (GM) spectrum would appear to be a simple affair, but numerous pitfalls arise that would cast any results into doubt. Here we revisit a few of the basic ingredients of this problem.
- First, we re-examine the eigenvalue problem for the internal wave modes and show that the standard numerical formulation using finite difference matrices produces modes with O(1) errors for all but a handful of the lowest modes. We show how spectral methods can be used to compute the vertical modes both faster and more accurately.
- Second, we show that the energy levels associated with the WKB scaled GM spectrum (typically used for observations) can differ by more than a factor of 2 from the exact formulation of GM spectrum (which is necessarily used in a model). The correspondence depends on the details of the stratification and the distance from the boundaries, but can be computed exactly, allowing for direct comparisons between model and observations.
- Finally, we examine the errors in measuring particle dispersion produced by discretization in the model and show that numerical diffusivity can easily dominate physical mechanisms. Using spectral methods to control the size of the numerical errors allows us to estimate particle diffusivity with a high degree of confidence.

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- PS44B-2297 Climatic Impacts of Parameterized Internal-wave Driven Mixing (Invited) ***Angelique Melet***[1]*, Robert Hallberg*[2]*, Sonya Legg*[1]*, Adrien Lefauve*[3]*, Caroline j Muller*[4]*, Maxim Nikurashin*[1]*, Alistair Adcroft*[2] *and Kurt L Polzin*[5]*, (1)Princeton University, Princeton, NJ, United States, (2)Geophysical Fluid Dynamics Laboratory, Princeton, NJ, United States, (3)University of Cambridge, DAMTP, United Kingdom, (4)CNRS, Paris Cedex 16, France, (5)WHOI, Woods Hole, MA, United States*

- n the ocean interior, breaking internal waves generated by the interaction of tides and geostrophic flows with the topography, or by wind events at the ocean surface are the main driver of diapycnal mixing. Internal wave driven mixing is patchy in time and space and occurs on scales too small to be explicitly resolved in ocean climate models. Physically based parameterizations of internal-wave driven mixing are therefore needed for realistic simulation of the ocean and for estimating how mixing might change in a changing ocean.

- In most ocean general circulation models (OGCMs, climate models), only the local dissipation of internal tides is currently parameterized, and a background diffusivity is used.
- Here, I will present parameterizations of internal-wave driven mixing for ocean models that have been developed as part of the US CLIVAR Climate Process Team on Internal-Wave Driven Mixing (http://www-pord.ucsd.edu/~jen/cpt/). A parameterization of diapycnal mixing induced by internal tides generated by small scale topography (abyssal hills) is introduced. Parameterizations of near-field and far-field internal-tide and of near-field lee wave driven diapycnal mixing have been implemented in NOAA/GFDL's climate model ESM2G. Climate simulations of 1000 years are used to assess the sensitivity of the ocean state to these parameterizations. I will especially focus on the sensitivity of the thermohaline circulation, ocean ventilation, temperature field and of steric sea level to these parameterizations.
- 10.1175/JCLI-D-15-0153.1, 10.1002/2014JC010598, 10.1175/JCLI-D-14-00432.1, 10.1175/JPO-D-13-072.1, 10.1002/2013JC009212, 10.1175/JPO-D-12-055.1

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- **PS44B-2298** Deep Coherent Vortices and their Sea Surface Expressions

*ABSTRACT WITHDRAWN*

- **PS44B-2299** Connecting Small-Scale Processes to Water-Mass Transformation and Nutrient Availability in the Coastal Pacific***Hayley V Dosser**, Hakai Institute / University of British Columbia, Victoria, BC, Canada, Jennifer Jackson, Hakai Institute, BC, Canada, Stephanie Waterman, University of British Columbia, Department of Earth, Ocean and Atmospheric Sciences, Vancouver, BC, Canada, Brian Hunt, University of British Columbia,* *Institute for the Oceans and Fisheries, Vancouver, BC, Canada and Charles G Hannah, Institute of Ocean Sciences, Sidney, BC, Canada*

- The coastal ocean off central British Columbia is characterized by alternating upwelling and downwelling regimes controlled by the prevailing winds. During the spring and summer, nutrient-rich upwelled water from the deep Pacific Ocean transits the continental shelf to Queen Charlotte Sound, one of the most biologically productive coastal regions on the planet, where it is crucial to phytoplankton productivity in the sunlit upper ocean. As it crosses the shelf, the upwelled water is modified by turbulent mixing driven by processes that are, at present, poorly understood. Here, the role of submesoscale processes and internal waves on regional water-mass transformation and subsequent nutrient availability in the near-surface ocean is examined using a combination of mooring and hydrographic profile data. Year-round velocity records from three moorings deployed in July 2016 are used to characterize flow pathways and to identify and quantify the physical mechanisms driving vertical mixing. Mooring data is examined in combination with over 40 years of hydrographic data - including biogeochemical and nutrient data from recent years - to provide information on regional and interannual variability of water mass properties and the strength of near-surface stratification. These results will guide direct turbulence measurements using an autonomous ocean glider equipped with a microstructure profiler, with the ultimate goal of improving predictions of future nutrient availability.

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- PS44B-2300 Numerical Computation of Instabilities and Internal Waves via the Viscous Taylor-Goldstein Problem***Qiang Lian**, Xiamen University, Physical Oceanography, Xiamen, China and William Smyth, Oregon State University, Corvallis, OR, United States*

- Normal mode perturbation theory is applied to a stratified, parallel shear flow in the presence of eddy viscosity and diffusivity. The result is an extension of the classical Taylor-Goldstein problem applicable to oceanic and atmospheric flows. Solutions with imaginary frequency describe shear and convective instabilities. Solutions with real frequency represent internal gravity waves, including barotropic and baroclinic normal modes. Application to large observational datasets can involve considerable computation and therefore require a compromise between speed and accuracy. We

compare several numerical methods to identify optimal approaches to various problems.

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- PS44B-2301 Observations of Scale Dependent Energy and Associated Stirring in the Gulf of Mexico and the Southern Ocean*Kevin Speer, Geophysical Fluid Dynamics Institute, Tallahassee, FL, United States,* ***Dhruv Balwada****, New York University, New York, NY, United States and Joseph Henry LaCasce, University of Oslo, Department of Geosciences, Oslo, Norway*

  - Lagrangian observations from surface drifters deployed as part of the Grand Lagrangian Deployment (GLAD) experiment and RAFOS floats deployed as part of the Diapycnal and Isopycnal Mixing Experiment in the Southern Ocean (DIMES) are used to estimate the second order velocity structure functions, which are a proxy for the kinetic energy, as a function of length scales. A Helmholtz decomposition was performed to obtain the rotational and divergent components of the velocity structure function, and also a wave- vortex decomposition was performed when observations of the buoyancy structure functions was available. Metrics, such as relative dispersion and finite scale lyapunov exponents, to characterize the associated stirring were also calculated
  - The GLAD data provided the first observational estimate of the energy distribution over 5 orders of length scales (10m - 1000km) in the ocean. The results reveal that the divergent component, compared to the rotational component, dominates at scales below 5 km, and the pattern is reversed at larger scales. The divergent component has a slope near 2/3 below 5 km, similar to an energy cascade range ($k^{-5/3}$). The third-order velocity structure function at scales below 5 km is negative and implies a forward cascade of energy to smaller scales. The rotational component shows similarity to the phenomenology of geostrophic turbulence.
  - The DIMES data provided the first direct observations of the scale dependence of the energy landscape in the mid-depth ocean over length scales of 5-1000km. The rotational component dominates over the divergent component at all the observed scales, with the two components becoming comparable in magnitude at length scales of 5km. The wave-vortex decomposition reveals that the wave component dominates over the vortex component at length scales smaller than 15km. The

stirring was observed to be local, contrary to the expectations of stirring from a geostrophically turbulent system. This result points at the potential impact of inertia-gravity waves on stirring in the mid-depth ocean.

- PS44B-2302 Elevated Mixing in the Periphery of Mesoscale Eddies in the South China Sea *Qingxuan Yang, Ocean University of China, Qingdao, China*

  - Direct microstructure observations across three warm mesoscale eddies were conducted in the northern South China Sea during the field experiments in July 2007, December 2013, and January 2014, respectively, along with finestructure measurements. An important finding was that turbulent mixing in the mixed layer was considerably elevated in the periphery of each of these eddies, with a mixing level 5–7 times higher than that in the eddy center. To explore the mechanism behind the high mixing level, this study carried out analyses of the horizontal wavenumber spectrum of velocities and spectral fluxes of kinetic energy. Spectral slopes showed a power law of $k^{-2}$ in the eddy periphery and of $k^{-3}$ in the eddy center, consistent with the result that the kinetic energy of submesoscale motion in the eddy periphery was more greatly energized than that in the center. Spectral fluxes of kinetic energy also revealed a forward energy cascade toward smaller scales at the wavelength of kilometers in the eddy periphery. This study illustrated a possible route for energy cascading from balanced mesoscale dynamics to unbalanced submesoscale behavior, which eventually furnished turbulent mixing in the upper ocean.
  - DOI: 10.1175/JPO-D-16-0256.1

- PS44B-2303 Mixed layer baroclinic and symmetric instability***Yisen Zhong***, *Shanghai Jiao Tong University, Shanghai, China, Qiangchang Ju, Institute of applied physics and computational mathematics, Beijing, China and Jiwei Tian, Ocean University of China, Qingdao, China*
    - The lateral gradients inside the mixed layer are unstable to both ageostrophic baroclinic instability (aka mixed layer instability) and symmetric instability. The spatial and temporal scales of the instabilities are within the ocean submesoscale range and hence they provide a route of forward energy cascade to the turbulent dissipition as evidenced in the in-situ measurements. The two instabilities are in fact of one kind but merely induced by along- and cross-front perturbation respectively. In this study, both of them were taken into account together by using Stone's (1966) non-geostrophic model but with a reduced-gravity bottom boundary condition representing a tilting mixed layer base. Growth rates of the two instabilities are derived analytically for various types of perturbations. The results show that the growth rate is a function of Richardson number, lateral buoyancy gradient, mixed layer base tilt and wave number. To testify the above linear theory and extend our analysis, an array of idealized nonlinear simulations were then performed to investigate the development of instabilities, the transition between them as well as their influence on the consequent turbulent mixing and mixed layer restratification.

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- PS44B-2304

Estimation of the parameterized dissipation rate from temporal variations in the internal wave continuum***Arnaud Le Boyer***, *Scripps Institut of Oceanography, MPL, San Diego, CA, United States, Coline Poppeschi, Scripps Institution of Oceanography, MPL, La Jolla, CA, United States and Matthew H Alford, Scripps Institution of Oceanography, La Jolla, CA, United States*

The magnitude and global distribution of internal wave (IW) driven turbulence is key for improving circulation models; yet, direct microstructure measurements are far too sparse to usefully constrain such maps. In the open ocean, IW-driven turbulence has been demonstrated by numerous authors to be well parameterized via the level of the wavenumber spectrum of shear and/or strain. These parameterizations allow, for example, maps of parameterized turbulence to be estimated from profiling floats and lowered ADCP profiles. We here explore an analogous method using the frequency spectrum of velocity from moored velocity records, which if the Garrett-Munk characterization of the internal wave spectrum is correct should be equivalent. Along the way, the relationship between the peaks (i.e., sources) and the continuum is investigated. We estimate the level of the continuum using rotary spectra computed in 30-day sliding blocks of 3157 moored time series. Continuum kinetic energy rises and falls as much as a factor of 5 at some locations and a factor of ten spatially, in sharp contrast with the spatially and temporally constant GM view. Relationships between sources and continuum are presented, and a comparison is conducted between our new moored estimates and extant estimates from lowered ADCP and ARGO profiles.

- PS44B-2305 Comparison of the Propagation and Dissipation of Internal waves in Two Distinct Ocean Basins: the Arctic and Indian Oceans ***Tamara Beitzel Barriquand**, Colorado College, Physics and Environmental Science, Colorado Springs, CO, United States, Jennifer A MacKinnon, Scripps Institution of Oceanography, La Jolla, CA, United States, Pascale Bouruet-Aubertot, Sorbonne Universités- UPMC Univ. Paris 06- LOCEAN, Paris, France, Yannis Cuypers, LOCEAN UPMC, Paris, France and Frederic Vivier, CNRS, LOCEAN-IPSL, Université Pierre et Marie Curie, Paris, France*

    - Internal waves are ubiquitous in all ocean basins, but their properties vary greatly from one region to another. High latitude internal waves have distinct properties due to their geolocation and ice cover, which reduces the wind forcing and leads to lower internal wave energy at high latitudes as compared to lower latitudes. This study looks at observations of internal waves at high latitudes, in the Storfjorden, a fjord in the Svalbard Archipelago just north of the Arctic Circle. At the latitude of these observations, the semidiurnal frequency is almost identical to the inertial frequency, so inertial waves at this latitude are almost indistinguishable from the internal semidiurnal tide. These high-latitude Arctic observations are compared to mid-latitude observations from the Southwest Indian Ridge in the Indian Ocean, an area of heightened mixing due to the rough topography of the region. These two distinct ocean basins provide an interesting comparison of internal wave propagation and dissipation in diverse conditions, and give some insight into how the ocean mixes in different regions around the world.

- http:// dx.doi.org/10.1016/j.csr.2015.10.001
- **Plain Language Summary**
- Inside the ocean, waves can travel between different density surfaces. These *internal waves* transport energy throughout the ocean, and when they break, they can dissipate energy as turbulence. This turbulence is responsible for mixing warm, less dense water in the tropics from the surface to greater depths in the ocean. The warm water is then convected in the Global Overturning Circulation to the colder poles, ensuring that our Earth does not burn up, nor freeze over. As global warming alters this circulation, the consequences could be dire. In order to predict the possible consequences of climate change, we need to understand the physical mechanisms that control ocean circulation. This study examines observations of internal waves from two distinct ocean basins: the Arctic and Indian Oceans, to compare how these waves travel and break in different parts of the world.