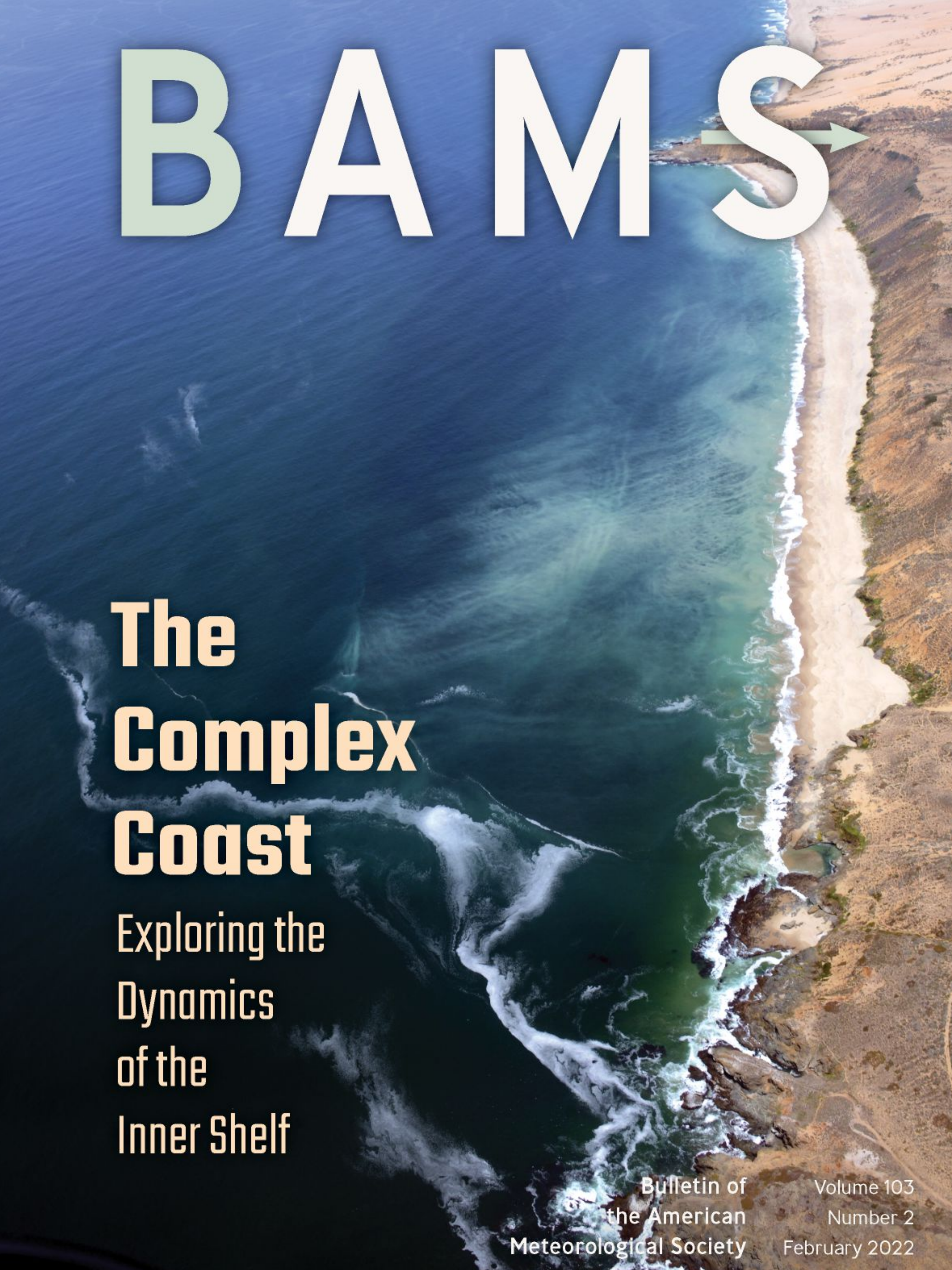

BAMS

The Complex Coast

Exploring the Dynamics of the Inner Shelf

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Examining the Inner Shelf

A Coastal Dynamics Experiment

Adapted from "The Inner-Shelf Dynamics Experiment," by **Nirnimesh Kumar** (Deceased; University of Washington), **James A. Lerczak, Tongtong Xu, Amy F. Waterhouse, Jim Thomson, Eric J. Terrill, Christy Swann, Sutara H. Suanda, Matthew S. Spydell, Pieter B. Smit, Alexandra Simpson, Roland Romeiser, Stephen D. Pierce, Tony de Paolo, André Palóczy, Annika O'Dea, Lisa Nyman, James N. Moum, Melissa Moulton, Andrew M. Moore, Arthur J. Miller, Ryan S. Mieras, Sophia T. Merrifield, Kendall Melville, Jacqueline M. McSweeney, Jamie MacMahan, Jennifer A. MacKinnon, Björn Lund, Emanuele Di Lorenzo, Luc Lenain, Michael Kovatch, Tim T. Janssen, Sean R. Haney, Merrick C. Haller, Kevin Haas, Derek J. Grimes, Hans C. Graber, Matt K. Gough, David A. Fertitta, Falk Feddersen, Christopher A. Edwards, William Crawford, John Colosi, C. Chris Chickadel, Sean Celona, Joseph Calantoni, Edward F. Braithwaite III, Johannes Becherer, John A. Barth,** and **Seongho Ahn**. Published online in *BAMS*, May 2021. For the full, citable article, see **DOI:10.1175/BAMS-D-19-0281.1**.

The Inner-Shelf Dynamics Experiment involved observing and numerical modeling of complex and influential geophysical interactions along the Pacific margin of California.

The coastal ocean spans the shoreline to the midcontinental shelf. These waters range from 0 to about 100 m deep, and the inner shelf, in particular, is dynamically complex. In this transition region between the surfzone and the midshelf, the evolution of circulation and stratification is driven by multiple physical processes.

We conducted an intensive, multi-institution field experiment to investigate the dynamics of circulation and transport in the inner shelf and the role of coastline variability in regional circulation dynamics. The experiment ranged from the midshelf through the inner shelf and into the surfzone off a 50-km section of central California, in the vicinity of Point Sal, during September–October 2017. We call this effort the Inner-Shelf Dynamics Experiment (ISDE). Coordinated by the Office of Naval Research, ISDE involved satellite, airborne, shore- and ship-based remote sensing, in-water moorings, and ship-based sampling, as well as numerical ocean circulation models forced by observations of winds, waves, and tides.

Coastal ocean circulation regulates the transport of tracers like nutrients, pathogens, and pollutants critical to maintaining healthy ecosystems. The circulation also controls lateral movement of heat and entrained gasses, resuspension of sediment, and advection and mixing of organic and inorganic particles contributing to variable optical clarity of coastal waters.

The surfzone extends from the shoreline to the offshore extent of depth-limited wave breaking, The midshelf, by contrast, is categorized by nonoverlapping surface and bottom boundary layers separated by a distinct interior. As the transition between these zones, the inner shelf is where the boundary layers can overlap.

For decades, the offshore extent and the dynamical definition of the inner shelf has remained somewhat ambiguous—it is dependent on the dominant processes driving the circulation in a particular coastal region. The inner shelf has been defined in the context of coastal wind-driven dynamics. In this context, the outer boundary of the inner shelf begins at the boundary layer overlap, which causes a divergence and eventual shutdown in Ekman transport.

The complicated dynamics within and immediately outside the inner shelf include surface waves, internal waves, wind, barotropic tidal processes, buoyancy, submesoscale eddies, and boundary layer–driven processes, all contributing to changing the circulation pattern and local stratification on frictional, rotational, and longer time scales.

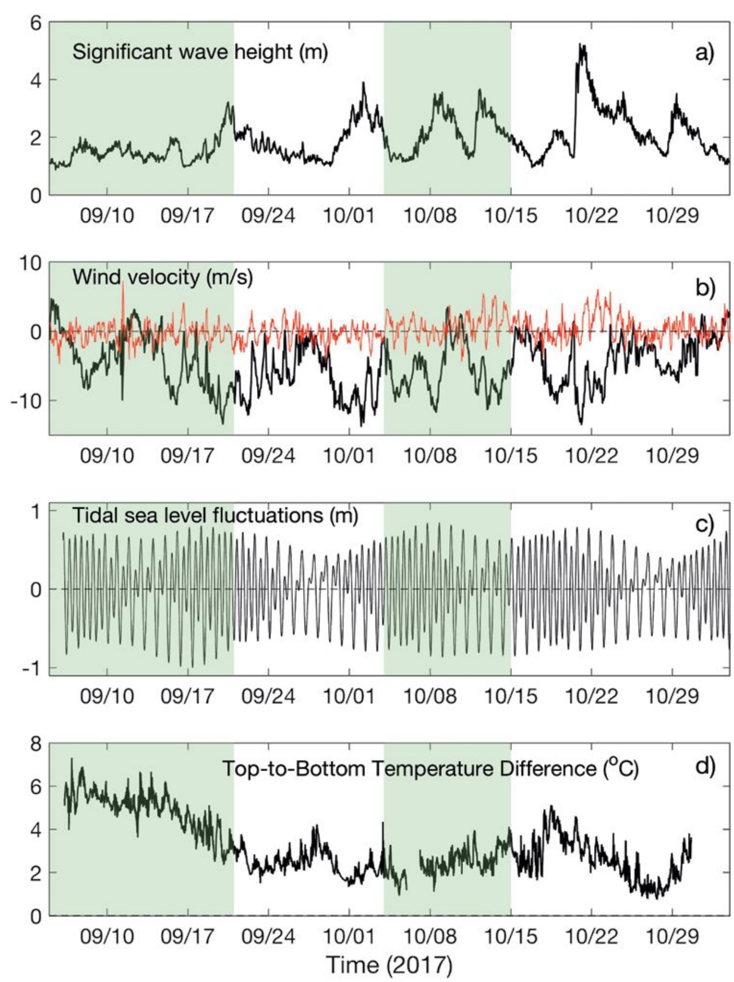
Previous studies targeting the inner shelf have documented the wind-driven and surface gravity wave–driven dynamics on simple coastlines and bathymetry, yet the role of complex coastlines in modifying inner-shelf dynamics on subtidal and shorter time scales have not been well understood. Furthermore, nonlinear interactions between wind, surface gravity waves, internal waves, surface heat fluxes, turbulence, and rip currents have yet to be quantified: prior studies generally treated processes like subtidal wind-driven circulation in isolation from other inner-shelf physical processes.

A defining feature of this field program is the capability to observe the complex superposition (and interaction) of multiple physical features. The project focused on quantifying circulation dynamics and stratification evolution and on understanding and predicting tracer exchange. The resulting high spatial and temporal resolution oceanographic measurements and numerical simulations provide a central framework for studies exploring this complex and fascinating oceanic region. ISDE allows for unprecedented investigations into spatial heterogeneity, and nonlinear interactions between various inner-shelf physical processes.

The article online has a supplemental animation of the phenomena observed and modeled in ISDE that can be found at 10.1175/BAMS-D-19-0281.2.

In the experiment, onshore-propagating nonlinear tidal bores and solitons often propagated through wakes. The dataset is rich with signatures of processes driving exchange between the surfzone and inner shelf. Fronts or internal waves were often observed in radar or airborne data to reach the surfzone edge (several hundred meters from the shoreline), sometimes appearing to “wrap around” rip-current plumes that extended up to several surfzone widths offshore (up to 1 km from the shoreline).

Among other insights, the dataset demonstrates that high-frequency elevation waves



(top) A 1-h temperature time series 5–30 m above the bed (mab) from a lander at 35-m depth shows a packet of high-frequency waves of elevation. (middle) East–west velocity profiles over the 3 mab (black box in the top panel) from a pair of up- and down-looking, pulse-coherent, high-resolution ADCPs showing strong near-bed velocities during the same time. (bottom) East–west velocity component from an ADV located roughly 1 mab (blue line in the middle panel) shows the amplitude of currents associated with the time scale (~12 min) of internal waves to be typically 4 to 5 times greater than the amplitude of currents associated with the time scale (~8 s) of surface gravity waves. The ADV and ADCPs logged for 20 min every half hour. The observed near-bed flows exceeded the critical threshold for sediment motion. Suspended particulates may not settle between internal waves within a packet.

generate bed shear stresses that exceed the critical threshold for sediment motion, and suspended particulates may not settle between internal waves within a packet (based on grab sample measurements of sediment size).

To complement observations, regional numerical simulations were used to identify the potential generation region of tidally forced internal waves.

Analyses and insights

Analysis of filtered temperature measurements from ISDE in water depths of 9–16 m reveals alongshore dependence in temperature variability in subtidal, diurnal, and semidiurnal frequency bands, with Point Sal being a location of strong changes in variability. Subtidal temperature variability was relatively uniform alongshore with a small gradient just south of

Primary Physical Processes of Inner-Shelf Transport: A Brief Overview

Seminal studies demonstrate at subtidal time scales the sensitivity of cross-shore transport to cross-shore, upwelling-favorable, and downwelling-favorable winds, strength of stratification and structure of mixing, alongshore pressure gradients, and the presence of cross-shore buoyancy gradients. In addition, Stokes drift by surface gravity waves outside the surfzone may be a dominant mechanism for cross-shore transport, and radiation stress gradients may be a potential leading-order term in the inner-shelf cross-shore momentum budget. Meanwhile, highly nonlinear internal tides and high-frequency internal waves in the inner shelf are responsible for large changes in stratification and strong cross-shore currents over short time scales and also transport heat from the inner shelf to the surfzone.

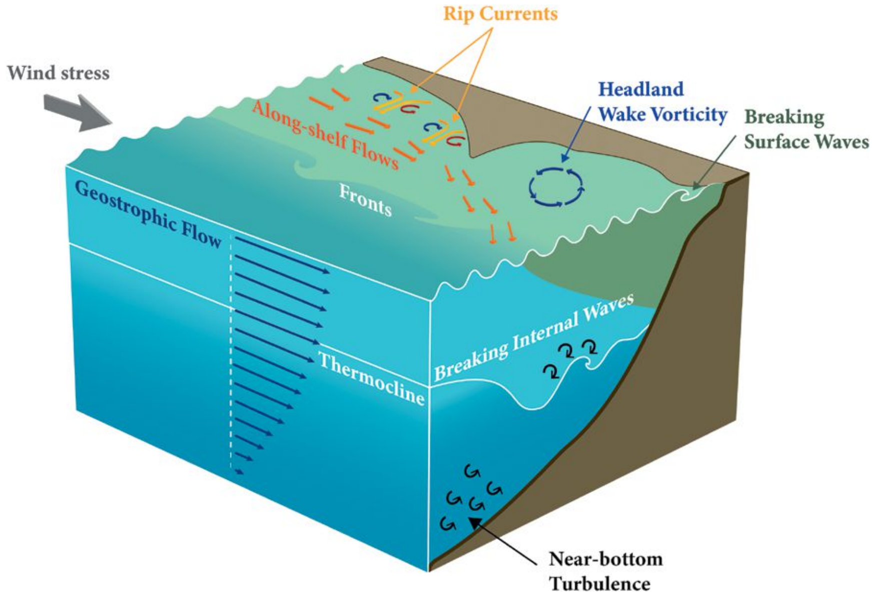
Internal waves also transport plankton and nutrients and can resuspend and transport sediment. Turbulence and mixing generated by internal wave dissipation lead to vertical fluxes of tracers and enhance stresses that may augment the surface and bottom boundary layer. Diurnal processes including heating and winds can also change currents and stratification.

Analogous to saturated waves in the surfzone, internal tides propagating into the inner shelf can reach a saturated state. The internal tide saturation region starts where the incident internal tide amplitude becomes comparable to the water depth. This typically occurred at water depths between 40 and 80 m during ISDE.

Mesoscale and submesoscale variability due to eddies, filaments, and fronts are dominant mechanisms for exchange between the continental shelf and open ocean, delivering nutrients to coastal ecosystems. Rip currents and surfzone eddies are the primary known mechanisms for cross-shore transport. Flow separation past abrupt bathymetry such as headlands leads to vorticity generation.

In addition, buoyancy-driven flows (e.g., river discharge) can dominate the inner-shelf circulation, and there are other inner-shelf processes not mentioned in this brief summary.

Inner-shelf processes in ISDE. ✱▶ **Surface waves become nonlinear and break, generating surfzone circulation like rip currents, which eject onto the shelf. Wind and tidally driven along-shelf flows separate from the coastline and generate eddies. Onshore-propagating internal waves also become nonlinear and lead to overturning and mixing. Additional mixing occurs at the bottom-boundary layer. The onshore-propagating warm bore was at least 10 m thick with 0.2–3-m s^{-1} onshore velocities.**

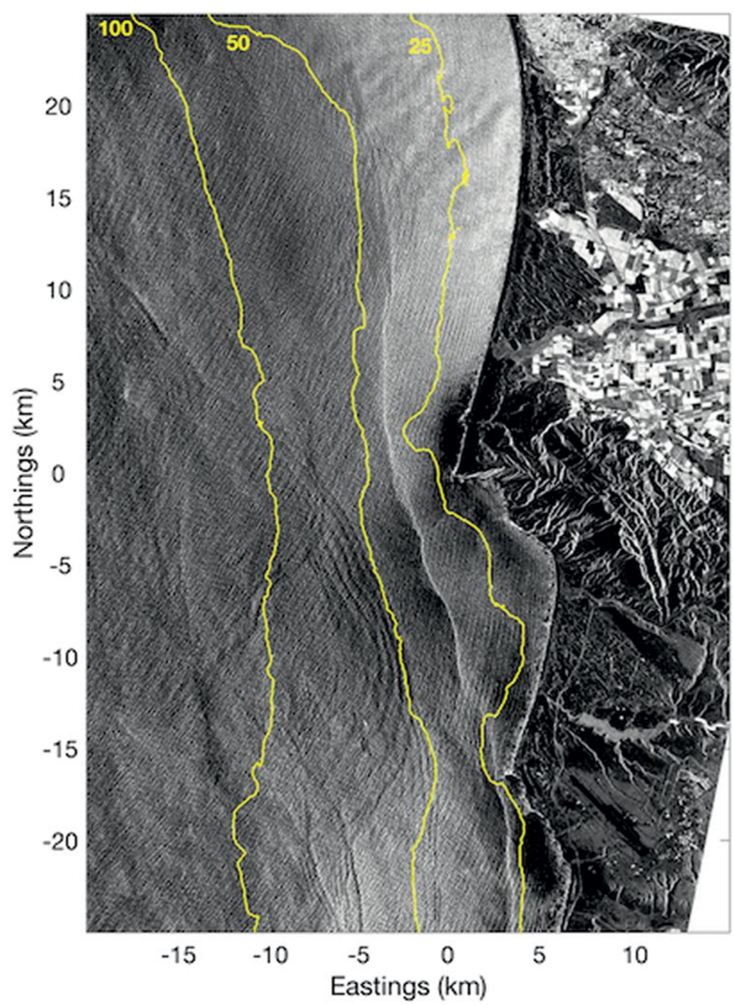


Point Sal. Diurnal variability was high north of Point Sal and was reduced south of Point Sal and Point Purisima. The same analysis reveals southward propagation of the diurnal baroclinic signal. Ongoing analysis including moorings from 9- to 50-m water depth also shows a consistent diurnal band variability on the length scales of tens of kilometers. Semidiurnal band temperature variability is found to be substantial, especially around the headlands. Variable stratification and Doppler shift associated with eddy activities might lead to this along-shelf inhomogeneity.

Spatial heterogeneity of the semidiurnal internal tide signals from the outer to the inner shelf have been investigated using both observations and numerical model simulations. Mean (September 2017) semidiurnal internal tidal energy fluxes at the 50- and 30-m isobaths are strongest adjacent to Point Sal, decreasing in magnitude both toward the north and south. The flux magnitude also decreases as internal tides propagate onshore and dissipate, a pattern that is also seen in the mean horizontal kinetic energy. Furthermore, internal tide properties, such as energy, amplitude, and frontal structure, are influenced by the spatial heterogeneity of stratification. For example, nonlinear internal bore fronts are found to be alongshore continuous *O*(10) km at the 50-m isobath and only *O*(1) km at the 25-m isobath.

The role of turbulence-enhanced mixing of mass and momentum as well as turbulence energy dissipation in controlling the inner-shelf subtidal cross-shelf circulation has been a poorly understood topic. ISDE allowed for the first comprehensive mapping of the turbulent dissipation rates over the inner shelf.

The distribution of depth-averaged dissipation rate over a portion of the inner shelf with smooth topography is enhanced in shallower regions decreasing smoothly from onshore to offshore. The enhanced dissipation rates in the shallower reaches of the smoother inner shelf may be associated with a variety of processes including surface-layer turbulence by wind and nonlinear internal-wave dynamics. Enhanced dissipation occurs at the headlands and complicated bathymetry of Points Sal, Purisima, and Arguello, with a more randomly distributed pattern with offshore distance.



Observed nonlinear internal waves (NLIWs) included steep bores, undular bores, and high-frequency waves of elevation and depression. Internal bores propagated into the region every 6 h and were detectable in both in situ and remote observations. Data from satellite SAR and land- and ship-based radar stations demonstrate that internal bores were alongshore-coherent of order tens of kilometers, with additional short-scale horizontal variability. This alongshore coherence decreased toward shore. As internal waves propagated into shallower water, their evolution depended on the shelf stratification and background shear. COSMO-SkyMed X-band synthetic aperture radar (SAR) satellite image at 0158:49 UTC 9 Sep 2017 shows surface signatures of multiple internal waves. Yellow contours indicate the 25-, 50-, and 100-m isobaths. COSMO-SkyMed Product Agenzia Spaziale Italiana (ASI) 2017 processed under license from ASI. All rights reserved. Distributed by e-GEOS.

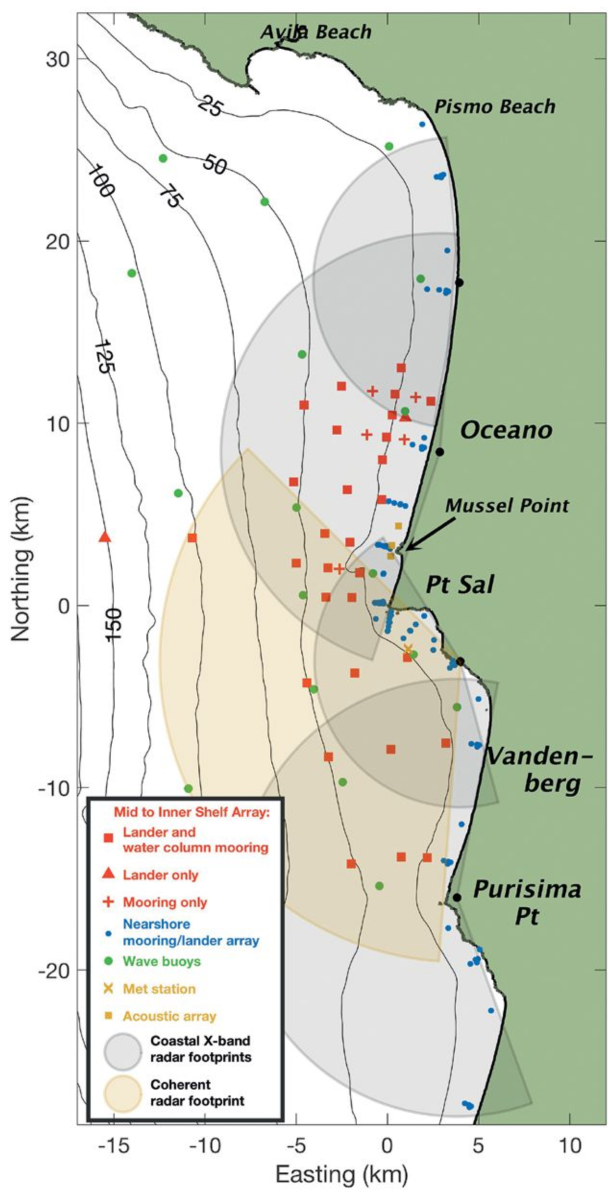
Sensors and Platforms

A total of 173 moorings and bottom landers were deployed during the experiment to measure temperature, salinity, current velocity, turbulence, surface gravity waves, and suspended sediment. Water-column temperature and salinity were measured along vertical mooring lines at 95 locations. Temperature sensors spanned the water column with vertical spacing of 1–5 m between sensors at the deeper locations and 1 m or less in shallow water. Sensor sample intervals varied from 0.5 to 30 s. Each lander had an upward-looking acoustic Doppler current profiler (ADCP) to measure current velocities. The vertical resolution ranged between 0.25 and 3 m. Most landers were also equipped with temperature sensors, programmed to sample at the same rate as the mooring sensors. In addition, high-precision pressure sensors (Ppods) were deployed on landers at five locations. Two of the landers were instrumented to observe near bed currents, turbulence, and seabed roughness using a suite of acoustic Doppler velocimeters (ADVs), high-resolution ADCPs (2 MHz), and high-frequency seabed imaging sonars. As noted above, some ADCPs resolved turbulent stresses. Temperature microstructure was measured along mooring lines and landers using χ pods. A newly developed instrument for this experiment, the GusT, was equipped to measure temperature and velocity microstructure as well as pressure and instrument orientation, pitch, roll, and acceleration. Approximately 80 GusT instruments were deployed on moored and shipboard platforms, providing greatly enhanced coverage of turbulence over the inner shelf.

Surface gravity wave directional spectra were measured using Sofar Spotter buoys at 18 locations and one miniature wave buoy near Point Sal. In addition, meteorological measurements were made from a mooring near Point Sal as well as from two locations on land.

In addition, there were drifters, land-based X-band radar, sUAS-based imaging, and along-coast surveys coordinated from as many as three ships (R/Vs *Oceanus*, *Sally Ride*, and *Robert Gordon Sproul*) and three small boats (R/Vs *Kalipi*, *Sally Ann*, and *Sounder*) with downward-looking ADCPs and profiling conductivity–temperature–depth (CTD) instruments.

Some ships also had echosounders, turbulence profilers (VMP-250, χ pods, and GusTs), fluorometers, and meteorological sensors. Bow-chains were deployed from the R/V *Sally Ride* and the R/V *R. G. Sproul* and measured temperature, salinity, and turbulence in the upper 20 m of the water column. The R/V *Sally Ride* conducted more than 5,100 vertical profiles using the VMP-250, while the R/V *Oceanus*—equipped with a towed CTD installed with a GusT probe, attached at the leading edge of the CTD—conducted more than 4,200 profiles. The R/V *R. G. Sproul* conducted more than 3,900 profiles with a towed CTD. Also, on 14 separate days, approximately 30 surface drifters were deployed from small boats on daily (or longer) missions designed to target specific processes—for example, along- and across-shore transport and dispersion flow around the headland (Point Sal). Most drifters measured surface temperature. Some were designed to directly measure surface vorticity. Others were equipped with sensors to measure surface shear and turbulence, wave statistics, and meteorological fields.



Contour lines show water depths in meters. A dense array of directional wave buoys (along the 100-m, 50-m, and 20-m isobaths) allowed for reconstruction of the regional mean wave field in real time.

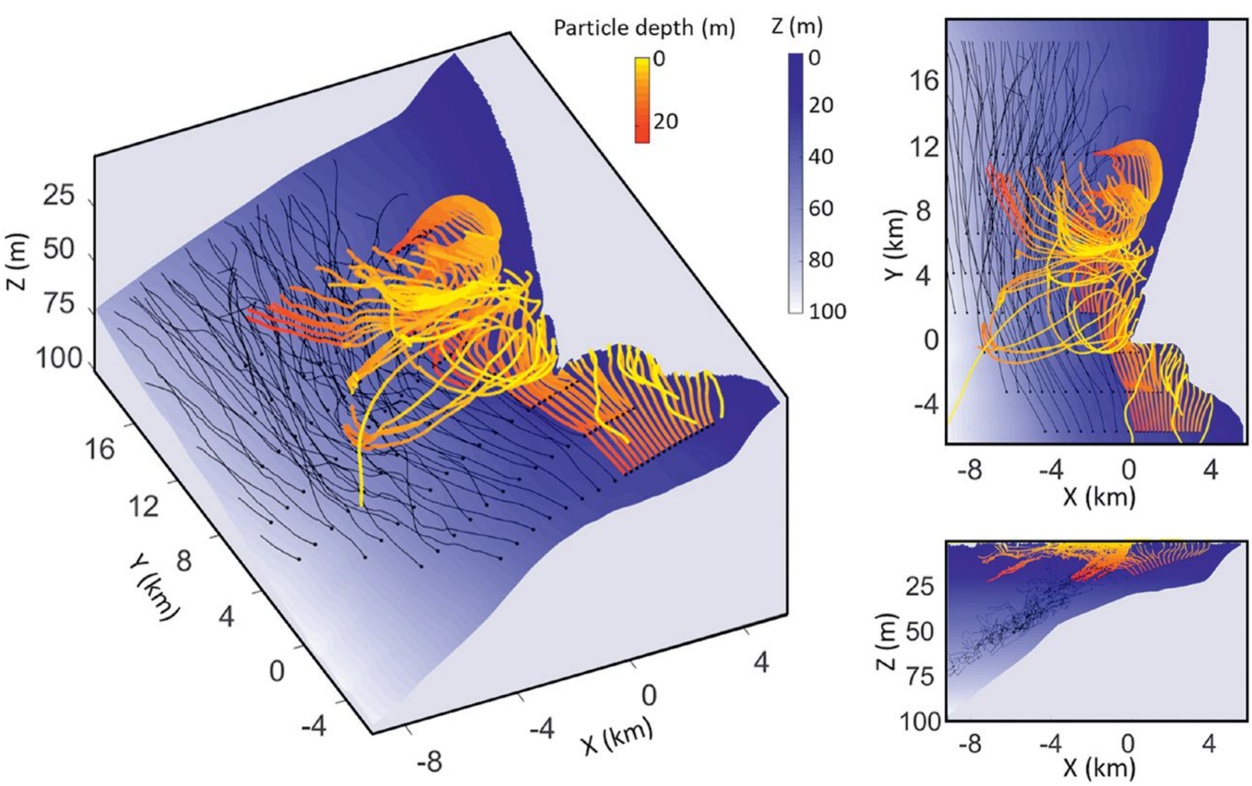
Elevated near-bottom dissipation from internal bores was also observed.

On the regional modeling scale, ISDE hindcast simulations suggest that the addition of remote baroclinic tides reduces the subtidal continental shelf stratification by up to 50% relative to simulations without tidal processes. A further analysis using passive particle dispersion in these simulations showed horizontal relative and vertical dispersion of three-dimensional drifters to be a factor of 2 to 3 times larger when including baroclinic tides.

Inner-shelf Interactions. Concurrent measurements of temperature, velocity, and turbulence at fixed-mooring locations supplemented by shipboard observations and numerical model results will allow for investigation of the interactions between inner-shelf physical processes. For example, mid- to inner-shelf stratification variability driven by synoptic variations in winds is expected to modify the propagation of semidiurnal internal tides.

One objective of the ISDE was to quantify the role of the surfzone as an onshore “boundary condition” to the shelf. In particular, it is not known how cross-shore exchange, or the magnitude of onshore or offshore material transport, varies along a complex coastline. The extent to which shelf and surfzone processes, including rip currents and internal waves, influence each other is poorly understood. X-band radar imagery in ISDE has suggested periods when nonlinear internal tidal bores interact with offshore-directed rip currents. These interactions have unknown consequences for exchange between the surfzone and the inner shelf and will be pursued in detailed analysis of observations supplemented by idealized modeling studies.

Form drag associated with coastline variability influences flow separation, wakes and eddies, and enhanced mixing. This is clearly



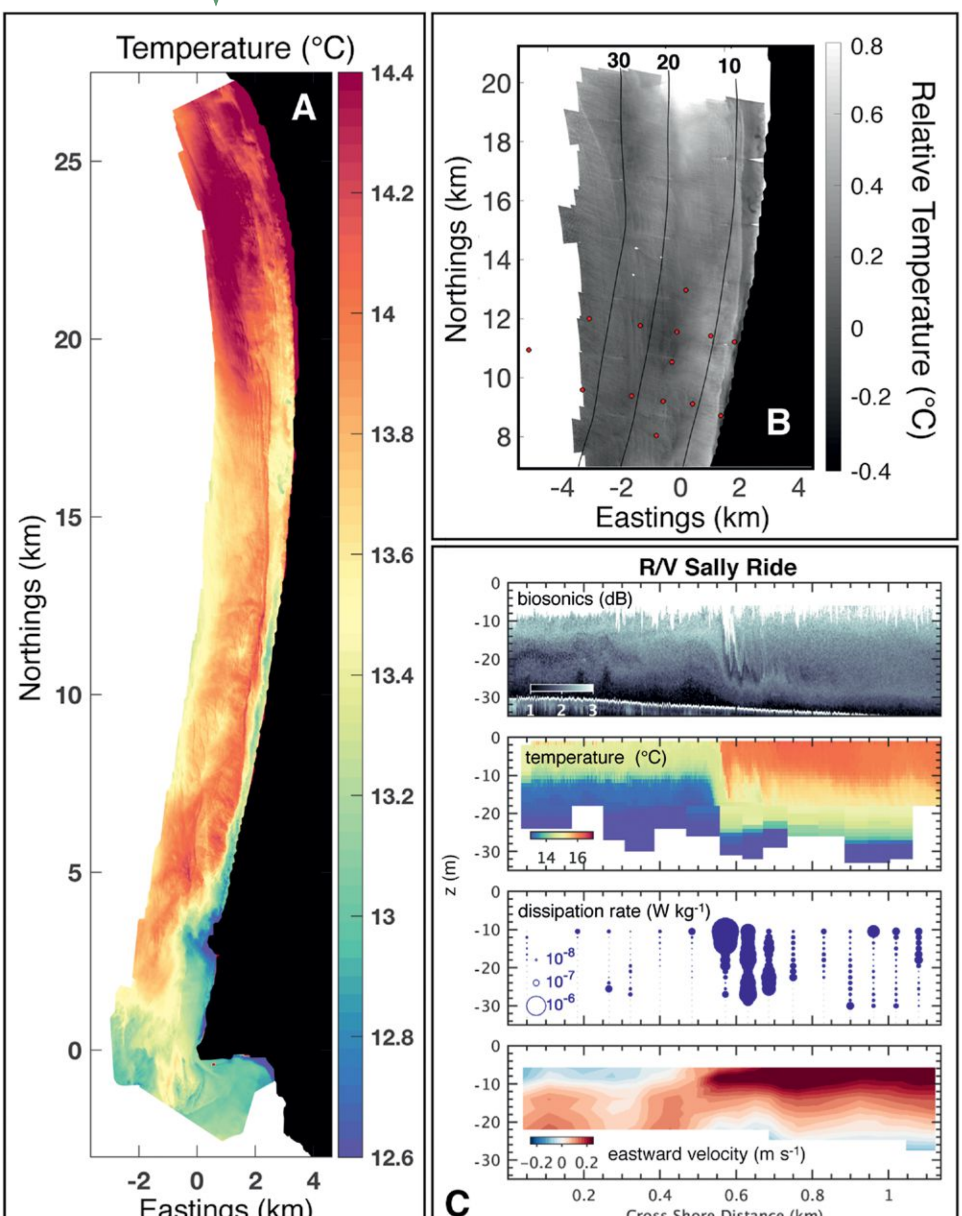
A modeling study with Lagrangian trajectories for particles launched offshore of Point Sal near the seafloor, at 80% of the water-column depth, along 15 cross sections during an upwelling event in 2015. Particles launched inshore of the 25-m isobath are colored yellow to red depending on their depth, and those released deeper are black. Racks are shown for 1.5 days. This model behavior agrees with the moored-array and shipboard observations: through interaction of the wind- and pressure-driven along-shelf flows, near-surface (20–25-m depth) water from the inner shelf is fluxed offshore at this promontory. This flow–topography mechanism is important for expelling upwelled water from the shelf.

exhibited by a rapid change in diurnal and semidiurnal variability in temperature around headlands. It is expected that the momentum transfer from mean flows into eddies and turbulence will be important to the along-shelf momentum balance. Detailed pressure measurements around Point Sal supplemented by mooring measurements and shipboard observations will facilitate further investigation of this problem. In addition, the eddies shed in the lee of the headland may interact with buoyancy fronts in the inner shelf, changing the circulation in thermal wind balance and inducing ageostrophic secondary circulations.

It has been known for a while that changes in vertical mixing as represented by an eddy

Aerial image of sea surface temperature from airplane-mounted longwave infrared (LIWR) camera reveals an internal wave front that extends ~20 km alongshore.

Nonlinear internal waves (NLIW) can drive strong thermal fronts in the inner shelf. Elevated turbulence behind the internal bore front suggests that NLIWs generate strong midwater-column mixing due to shear and/or convective instabilities.



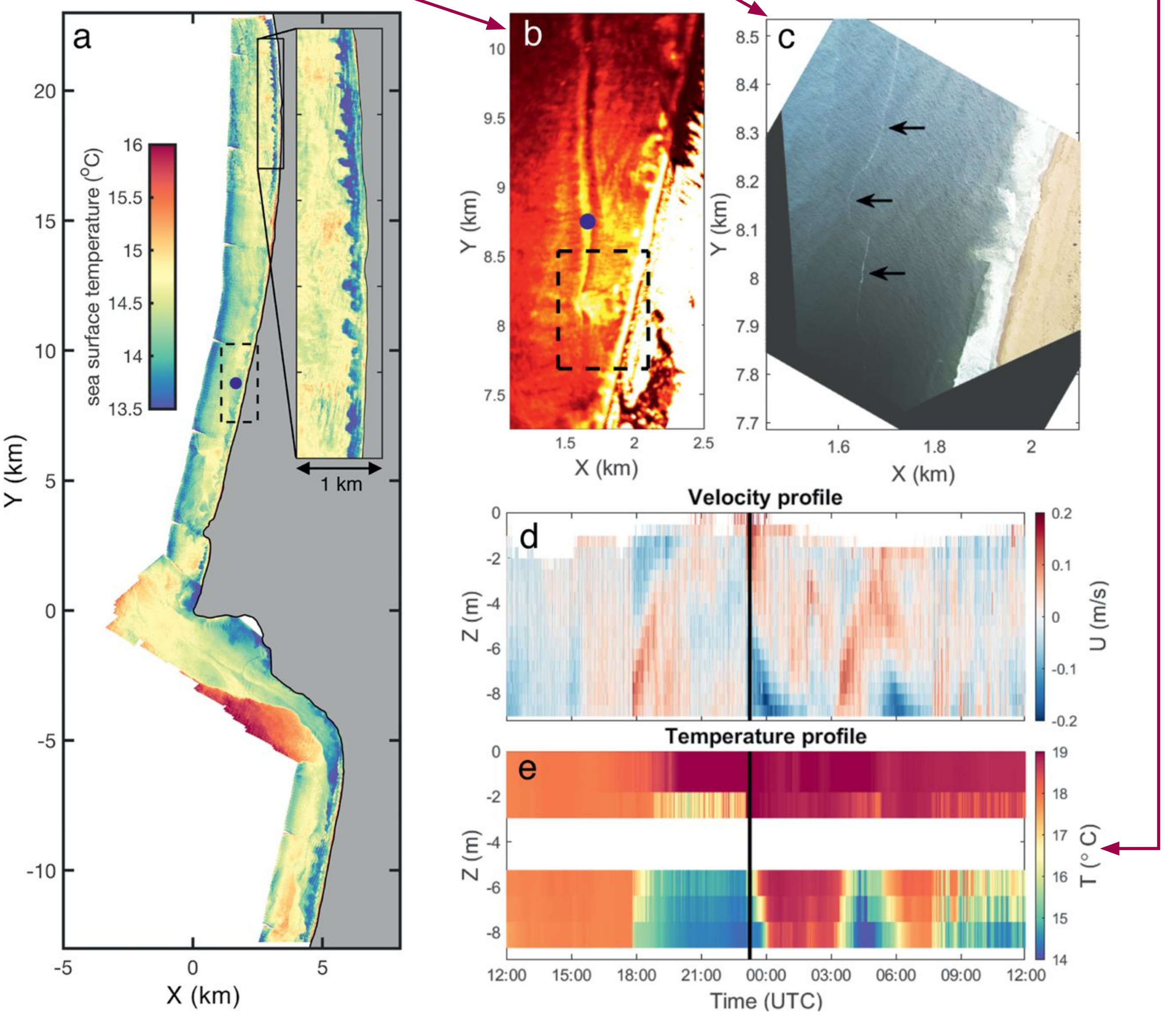
Relative temperature from the plane-mounted LIWR. The front is relatively warm (1°C) offshore of the front compared to the water inshore.

The NLIW temperature gradient is also evident from cross-front ship transects, which additionally show the internal bore vertical structure and elevated turbulence behind the front. (top to bottom) biosonics from the ship's echosounder; temperature data from a bow-chain temperature profiler (top layer) and a towed CTD (bottom layer); dissipation rates from a VMP-250; and eastward velocity from a pole-mounted, downward-looking ADCP.

A large rip current (high intensity feature at y = 8.1 km) appearing to interact with an onshore-propagating internal bore (alongshore bands of high and low backscatter in this X-band radar image).

A white foam line (indicated by arrows) carried by the internal bore as it bends around the rip current plume. The bright linear radar feature (transecting the blue dot) is collocated with the back face of a cold pulse at depth.

The cold pulse is 5°C cooler than the surface water and lasts around 6 h at the sensor location. These and other mooring data indicate that internal waves alter the stratification outside of the surfzone on relatively short time scales. This rapid stratification of an unstratified region is expected to influence offshore material transport by rip currents.



Particularly striking are events in which surfzone rip currents appear to collide with shoreward-propagating internal waves and fronts. (a) Airborne thermal infrared image (°C, calibrated with radiometer), taken on 15 Oct 2017 starting at 1639 UTC, composed of a mosaicked set of images from a continuous nearly 50-km along-coast transect centered at Point Sal (near y = 0 m). Cool "plumes" driven by rip currents (e.g., cool features emerging from the surfzone) with several-hundred-meter cross-shore scales at 0 < y < 22 km and −12 < y < −7 km are observed, along with signatures of fronts and internal waves (e.g., strong frontal signature at −4 < y < −6 km). In the southernmost half of the image, a strong front was observed to intersect with plumes in the surfzone. Inset shows zoom to 1 km × 5 km region with cool plumes. Dashed box in (a) shows the location of the radar image in (b) and the blue dot shows mooring location in both panels. (b) X-band radar. Dashed box in (b) shows the location of the sUAS image in (c). (c) Rectified visible image from sUAS. (d) Mooring time series of the east–west velocity profile. (e) Temperature vs depth time series for an event in which an internal wave [bright band in (b), white foam line in (c)] intersected with a rip current [plumelike feature in (b) and (c) near y = 8 km] on 12–13 Sep 2017. The time of the radar image is shown with a vertical line in the velocity and temperature profiles. The gap in the temperature profiles in (e) from approximately z = −3 to −5 m is due to the loss of two temperature sensors during the deployment period.

diffusivity can modify the wind-driven circulations. Recent work has analogously quantified the contribution that turbulent momentum fluxes make to the cross-shore and alongshore momentum budgets: episodic turbulence from passing bores and solitons dominates the long-term average of turbulent stresses over diurnal to seasonal time scales. The recent finding that the turbulent stresses play an order-one role in the cross-shore momentum budget at all depths pointed to the need to revise our conceptual model of dynamical balances offshore of the surfzone. Similarly, turbulence at the leading edge of an internal tidal bore may control the propagation (phase speed) and nonlinear evolution of subsequent bores. This question is being explored using mooring and shipboard measurements.

In Memoriam

Nirnimesh Kumar, 1984–2020

Nirnimesh (Nirni) was a coastal physical oceanographer at the University of Washington. He completed his Bachelor of Science in 2007 at the Indian Institute of Technology in West Bengal, India, where he studied ocean engineering and naval architecture. Following that, Nirni completed his M.Sc. and Ph.D. at the University of South Carolina under the supervision of George Voulgaris in 2010 and 2013. Before moving to Seattle, he was a postdoctoral scholar at the Scripps Institution of Oceanography, where he worked on a range of coastal-zone projects including becoming a leader on the ONR-funded Inner- Shelf DRI that this paper describes.

Technically deft and creative, Nirni was blossoming as a leader across a range of research topics. He valued scientific collaboration, and the exchange of ideas, and delighted in sharing achievements with others. He had an uncanny ability to develop and maintain collaborations across a wide range of coastal oceanographic regions, from the nearshore of Southern California to the high Arctic polar regions. Nirni was an enthusiastic scientist and an incredibly thoughtful mentor. His gregarious spirit brought an energy to our community that is irreplaceable. He will be remembered for his mischievous smile, his eagerness to help others, his deep scientific insights, and his rigorous work ethic.

This paper is dedicated to our friend, shipmate, and colleague Nirnimesh Kumar. We will miss you more than you can imagine.

Nirnimesh Kumar aboard the R / V *Sally Ride* during the Inner-Shelf Dynamics Experiment, 2017.

Sean Haney, 1987–2021

"The coexistence and intermingling of these two distinct features (gravity currents and internal bores) remind us that as students of turbulent flows we cannot restrict ourselves to the study of a single scale or type of ocean dynamics. This may be only one of many cases of intersections and interactions between nominally distinct phenomena that are yet to be appreciated."

—Sean Haney (Scripps Institution of Oceanography, University of California, colleague, coauthor), from his *Journal of Physical Oceanography* paper on ISDE research (DOI:10.1175/JPO-D-21-0062.1).

Sean Haney on the 2017 Inner Shelf DRI Cruise.

BAMS: What would you like readers to learn from this article?

James A. Lerczak (Oregon State University): *While many of the physical mechanisms that drive circulation, transport, and dispersion in the inner shelf have been identified, it is an exciting challenge to execute a large-scale and collaborative field and modeling experiment to understand when, where, and how these mechanisms interact. Such interaction results in drastically different circulation, transport, and dispersion patterns from what would be predicted by a particular mechanism in isolation, or the sum of the mechanisms considered without their interactions.*

Jaqueline M. McSweeney (Oregon State University): *The physical processes that determine the oceanic circulation and fate of material on the inner shelf are complex and intertwined. Trying to isolate the relative contribution of a specific process is challenging because it necessitates us to observe a very wide range of spatial and time scales. Even with the rich dataset collected through the inner-shelf dynamics experiment (ISDE)—one of the most resolved datasets in existence—there are processes that are difficult to adequately resolve or separate.*

BAMS: What got you initially interested in coastal physical oceanography?

JL: *I enjoy studying the complex, clearly observable, and immediate impacts of coastal ocean physical processes on ecosystems and humans. I am particularly fascinated by processes occurring on short time scales (tidal and shorter). You can go out on a small boat or a kayak for a day and make some interesting measurements while watching the sea change around you.*

BAMS: How did you become interested in the topic of this article?

JM: *I'm intrigued by the challenge of identifying the relative importance of multiple processes with overlapping spatiotemporal scales, and the inner shelf is a fascinating place to study for this exact reason! When I learned the scope of the ISDE project, I was ecstatic to take on such a complex topic and collaborate with this amazing team.*

BAMS: What surprised you the most about the work you document in this article?

JM: *I was especially surprised to find that internal waves are present approximately every 6 hours in this region. Based on previous work, we were expecting to observe internal waves approximately every 12 hours! I was also excited to discover that the complex spatial heterogeneity of each internal wave is different, dependent both on the low-frequency shelf conditions and the influence of the previous wave.*

Amy F. Waterhouse (Scripps Institution of Technology): *Every time we make measurements on the ocean, we always learn new and very unexpected things. As we develop new and better instruments, we will keep discovering new exciting physical processes. ISDE was special in that we were able to make oceanographic measurements on the inner shelf from almost all the oceanographic platforms available at an incredibly high resolution, on a part of the coast that is complicated and full of exciting physical dynamics.*

BAMS: What was the biggest challenge you encountered while doing this work?

JL: *This experiment involved many instruments and sampling methods. Working with colleagues to coordinate ISDE was an exciting challenge, from experiment design, construction of platforms, and executing a coordinated field plan to effectively centralizing the vast and diverse datasets to make them easily accessible and usable for the group, and now the entire science community. Fortunately, this group of creative and energetic scientists worked very well together.*

JM: *Trying to characterize and explain the variability in the internal wave field has been extremely challenging! There are many factors that influence the evolution and fate of an internal wave, and I found it insightful to evaluate those factors at an event scale (one wave at a time). However, scaling that analysis up to look at a 2-month dataset (with 4 internal bores per day) is really nuanced and time-consuming.*

AW: *There is so much interacting physics that we were able to observe on the inner shelf during ISDE. Trying to detangle all the various processes to understand what is really driving the cross-shelf exchange has been a fun, yet difficult, task.*