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Airborne Remote Sensing of Surface and Internal Wave Processes On the Inner Shelf

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LONG-TERM GOALS

To understand the role of surface and internal waves on inner shelf kinematics (mixing) and dynamics.

OBJECTIVES

The primary objectives of this proposal are to investigate the role of surface and internal wave processes on the dynamics, transport and mixing in the water column on the inner shelf and their measurement using airborne and autonomous surface platforms.



Figure 1. The MASS system on the bench at the Air-Sea Interaction Laboratory, SIO. It is flown on the Partenavia P68 light twin-engined aircraft and the Bell 206 L-III helicopter.

APPROACH

The approach has been to fly the Modular Aerial Sensing System (MASS, Melville et al. 2015) on a light twin aircraft (Partenavian P68) and a helicopter (Bell 206 L-III) (Figure 1) over the inner shelf using the components of the MASS system, including a waveform scanning lidar, visible and infrared (IR) and hyperspectral imagers, and a high precision GPS/IMU unit to measure surface waves, surface wave breaking, currents, surface-flow divergence and vorticity, SST, and SST signatures of internal waves (IWs). These data can be used to track the evolution of surface waves and the surface signatures of internal waves from offshore sources across the shelf until they are reflected or dissipated in the inner shelf. The data can also be used to measure along-shore currents and near-shore vorticity associated with surface and internal wave shoaling.

Key individuals are: Luc Lenain (Principal Development Engineer) and Nicholas Statom (Associate Development Engineer) who designed and built the MASS and serve as observer and operator for the system in flight.



Figure 2. Aerial views of Pt Sal. Note the foamy front extending from Pt Sal in the top left image. This was a common flow feature emanating from Pt Sal and other headlands (see bottom right image).

WORK COMPLETED

From June 24-July 2, 20215, seven fixed-wing (Partenavia) flights of the MASS were made during the Inner-Shelf Pilot Experiment in the area of Pt Sal, California. Figure 2 shows photos of the Pt Sal area.

The flights lasted from 1.5 – 5 hours at approximately 100 kts and their positions on time series of winds, significant wave height, H_s , and tides from NDBC buoy 46011 are shown in Figure 3 .

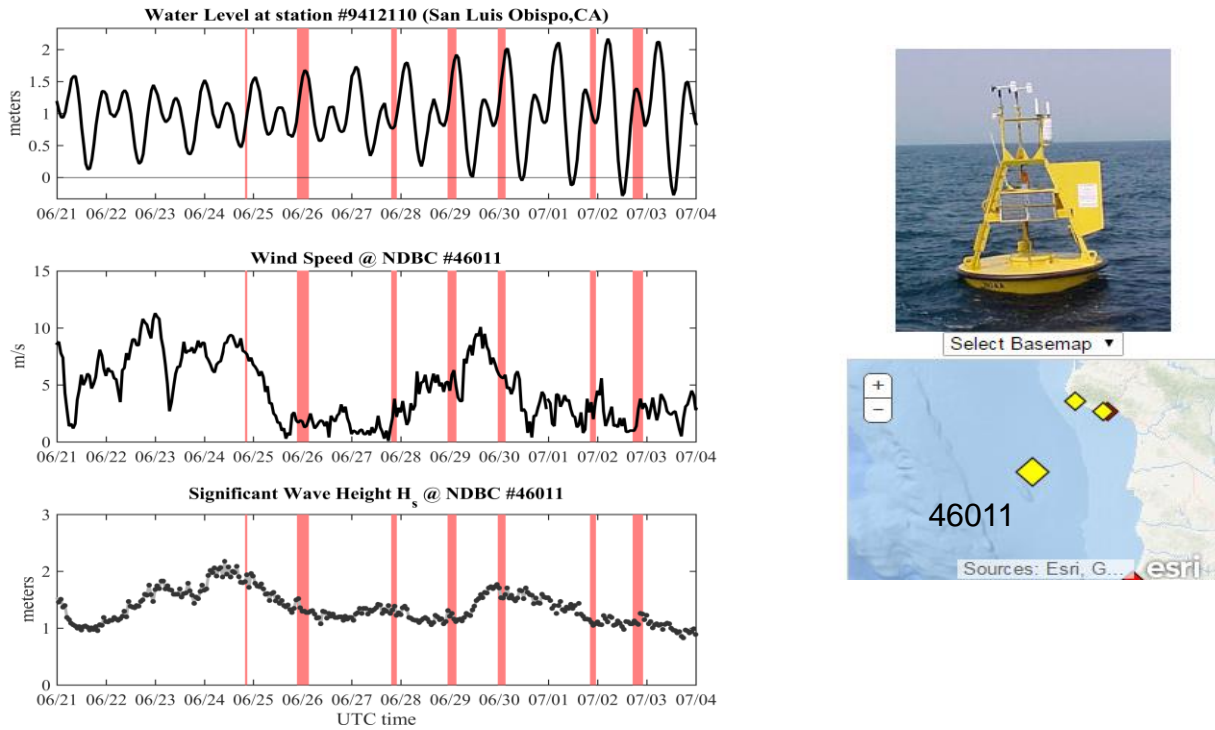


Figure 3. Timing of seven fixed-wind flights relative to tides, wind speed and significant wave height at NDBC buoy 460011 located SSW of Pt Sal.

Note that in addition to timing flights for high and low tide, they were also timed for maximum ebb and flow of the tide, corresponding to maximum tidal currents in the area.

RESULTS

While the official start date of the grant was May 1, 2015, funding was not available until the latter half of August, so there has not been much time for data analysis. However one prominent feature of the imagery and other data is the mixing and flow separation from Pt Sal itself, leading to a front, marked by foam generated at the Point, almost parallel to shore during some phase of the tidal currents extending northward as seen in the top left panel of Figure 1. Figure 4 shows that this visible imagery corresponds in some detail to the IR imagery of the sea surface, with arrows pointing out specific features. Note that Pt Sal itself is the site of significant mixing, presumably due to turbulence generated by the waves breaking on the rocky shoreline and the tidal flow past the point. This leads to colder surface waters to the north and south of the point that are clearly bounded by the visible foam. It is clear that headlands can be very important features leading to both across-shore *and* along-shore changes in the near-shore environment. So far we have just had time to look at the visible and IR data

but we expect that analysis of the hyperspectral data may provide further insight into whether sediment transport is also associated with headland mixing.

Given the importance of the kinematics around Pt Sal seen in the fixed-wing flights, we decided to install the MASS on a helicopter and made flights on July 31- August 1, 2015. This data is not analysed yet, but we are confident that the ability to hover over the point for long periods will be fruitful in analysing the surface signatures of mixing and transport at higher frequencies and wavenumbers.

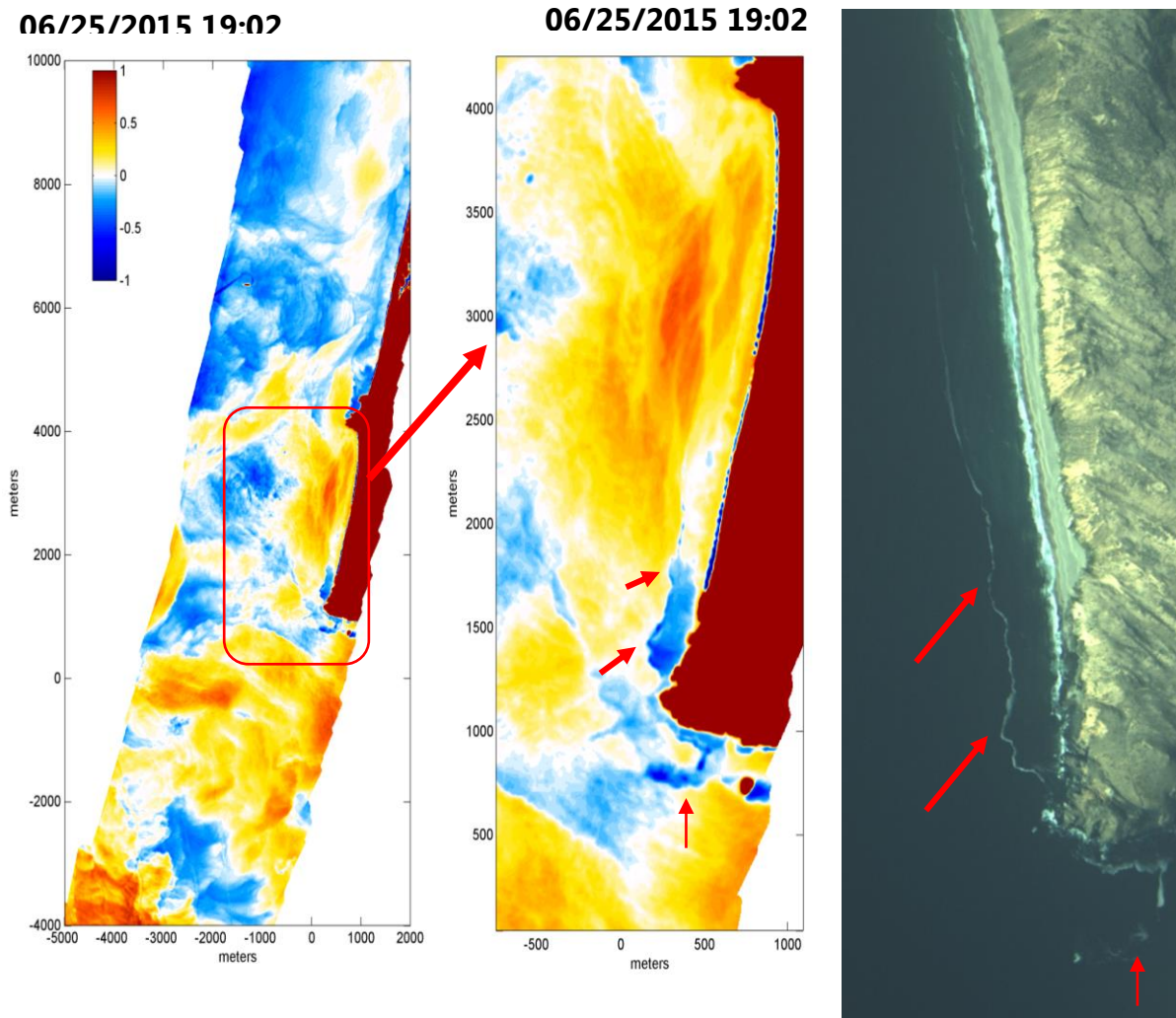


Figure 4. IR and visible imagery of the foam and colder surface waters associated with the flow around Pt Sal.

In summary, the primary result so far is recognition of the importance of mixing and transport at headlands leading to along-shore and cross-shore changes in the near-shore environment.

IMPACT/APPLICATIONS

Based on a quick look at the data we have already, there will be an impact on the scientific approaches to modeling near-shore environments. Furthermore, there will be a technological impact from the demonstration of the usefulness of airborne measurements using the MASS from both fixed-wing aircraft and helicopters.

TRANSITIONS

At the time of writing this report ONR Code 32 has just funded the development, construction and testing of a new Modular Aerial Sensing System (MASSII) for use in other ONR/Navy programs.

RELATED PROJECTS

The PI is also funded in the ONR Waves, Langmuir Cells and Upper Ocean Boundary Layer (“Languir”) DRI.

We expect that the knowledge gained in the Langmuir DRI will be helpful in better understanding the merger between the upper ocean boundary layer and the bottom boundary layer as we move from deeper water to the shallower water of the inner shelf.

REFERENCES

Melville, W.K., L. Lenain, D. R. Cayan, M. Kahru, , J. P. Kleissl, and N. Statom. (2015) The Modular Aerial Sensing System. *Journal of Atmospheric and Oceanic Technology* (in revision)