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Land Based Remote Sensing of the Inner-Shelf

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LONG-TERM GOAL

The inner-shelf is a region of complex air-sea-land interactions that presents challenges to numerical ocean circulation forecast models, with the scales of the physical processes driving numerical models to operate at high resolution. Goals of the project are to observe variations in inner-shelf conditions as controlled by winds, internal and surface tides, waves, and remote forcing. Particular interest is the development and application of X-band and HF remote sensing techniques to study these phenomena.

OBJECTIVES

- Observe shelf physical processes using shore-based remote sensing techniques.
- Develop synthesis techniques for exploiting X-band radar.
- Generate high spatial and temporal data sets for validating ocean models.

APPROACH

An observational program applying a suite of in situ and shore-based remote sensing tools to study inner-shelf circulation is being conducted as part of the Defense Research Initiative "The Inner Shelf – Connecting the Coastal Ocean and the Surf Zone". Our study domain starts just outside the surf zone and extends approximately 5km in the offshore direction. Forcing terms of the coastal circulation are highly location and seasonal dependent and include winds, tides, and remote forcing. Gradients in the wind stress can be dramatic due to land-effects that lead to coastal wind jets in the offshore or alongshore directions, and differential heating can lead to diurnal land 'sea-breeze' effects. Barotropic tidal response will spatially vary due to changes in bathymetry and the overlying water column stratification. The propagation of coastal trapped waves will influence the sub-tidal conditions of the inner-shelf, and can lead to a significant signal of the ocean currents. The shallow water depths (100m or less) that characterize the inner shelf will have boundary layers that interact and span significant fractions of the water column. As a result of these complexities, models on the inner shelf are challenged as they need have both resolution in both the vertical and horizontal to resolve gradients, yet the model domain needs to span a large enough domain, or be coupled in a sophisticated manner to an outer-scale model, to propagate coastally trapped wave information (remote forcing) into the

forecast domain. Furthermore, the role and influence of surface waves in driving the oceanography increases as water depths become shallower, with the surf-zone introducing a complex boundary condition that is dominated by wave-driven circulation. Models operating adjacent to the surfzone must couple with a surf-zone model, and contain mechanisms for exchanges of heat, momentum, and currents. The inner shelf region is where the oceanic mesoscale and submesoscale interact, yet the scales and processes for fluxes of the energy are poorly understood. The 'Inner Shelf' Department Research Initiative (DRI) will address these processes to further our understanding of the oceanography in this poorly studied region of the ocean. Our observational effort will be to use shore-based remote sensing techniques (HF and X-band radar) to measure wind, waves, and currents; and to support those observations with in-situ measurements obtained with drifters and meteorological buoys.

WORK COMPLETED

Our study site for this program is the region of Pt. Sal, California extending south along the coastline immediately adjacent to Vandenberg Air Force Base. A pilot study was conducted in Summer 2015 that include the deployment of a) shore-based marine X-band radar configured to record maps of radar backscatter b) a meteorological buoy deployed in the footprint of the radar c) a GPS-based wave buoy in the footprint of the radar.

Figure 1 shows the placement of the Scripps radar van. The van has a retractable 10m tower that allows rapid and remote placement of the radar equipment. The system was configured to record raw backscatter, streaming data directly to a RAID array. Cellular modem connection to the van allowed for movement of summary data fields and remote control of the radar equipment. The equipment was located on a bluff nearby a decommissioned launch site at which power was available. During the course of the experiment, numerous brown outs occurred as a result of substandard power availability. Corrective actions will need to be taken in follow on experiments.

Figure 1. Deployment location of the Scripps radar van at Vandenberg AFB.

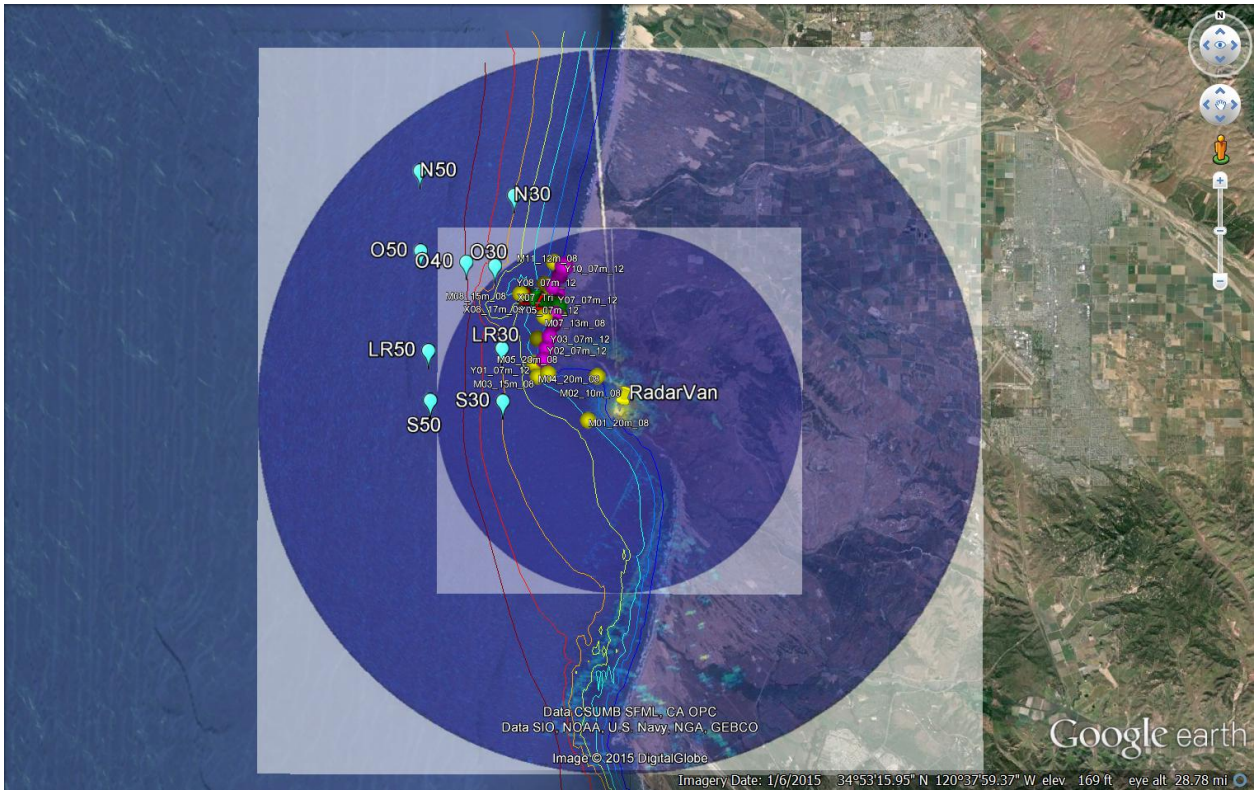

Figure 2. Radar coverage from the Scripps radar system when operating in high resolution and medium resolution mode. At high resolution, data was obtained at 7.5m range resolution out to distances of 8km. The radar scan rate was 42 RPM. Other symbols represent equipment deployed by Naval Postgraduate School PIs McMahon and Colosi.

In the field of view of the radar, approximately 3km offshore, a meteorological buoy was deployed that reported wind speed/direction, air temperature, barometric pressure, relative humidity, rain, location, and battery voltage. The system was configured to burst sample at 1Hz for 10 minutes every hour. Iridium communications provided reports of averaged values in near-realtime. The system operated continuously during the experiment, and a summary of the data is shown in Figure 4.

Figure 3. The field of view from the radar station. An Ethernet camera was mounted to the radar to provide realtime imagery of the environmental conditions.

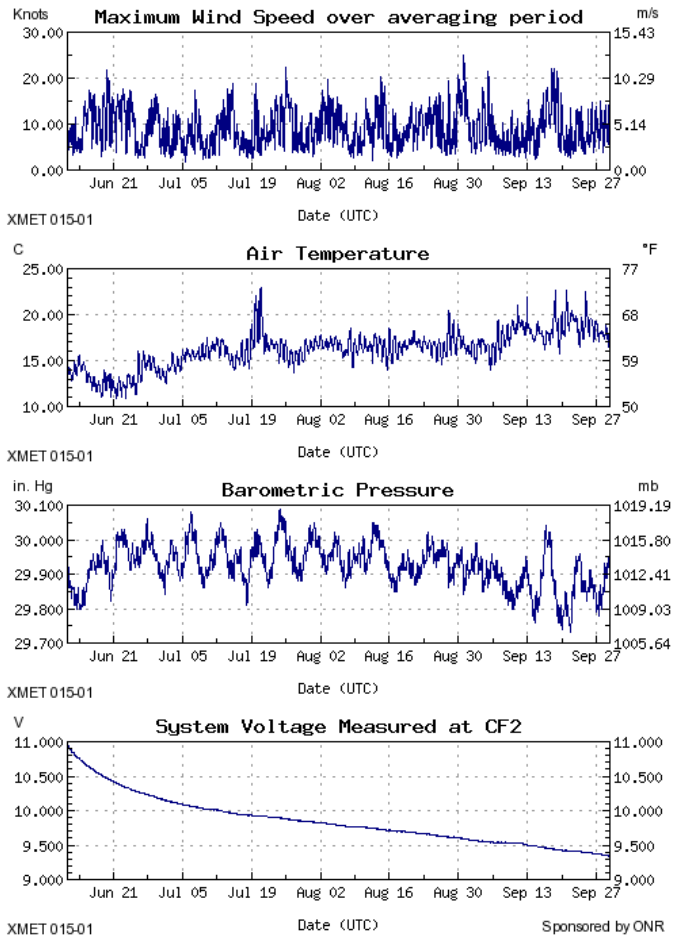

Figure 4. Summary of meteorological conditions during the 2015 pilot experiment.

Our initial analysis of the radar data obtained during the pilot study is to examine signals in the backscatter associated with fronts and internal waves. To accomplish this, the data is filtered in time to eliminate the wave signal (to be exploited later for wave inversions). As a result of wave-current interactions, areas of higher roughness or where breaking statistics are higher, result in a modulated backscatter signal. Both maps of the mean and variance of the signal can clearly identify where fronts are located. Figure 5. presents an example map generated on June 26, 2015 showing multiple trains of internal waves approaching the beach. Of particular interest is the modulation of the internal wave field by what we believe is the underlying bathymetry. The map shown in Figure 5 is for a period of low winds, and when the radar is operating in high resolution mode. Figure 6 is another example, but this time operating over a much larger range.

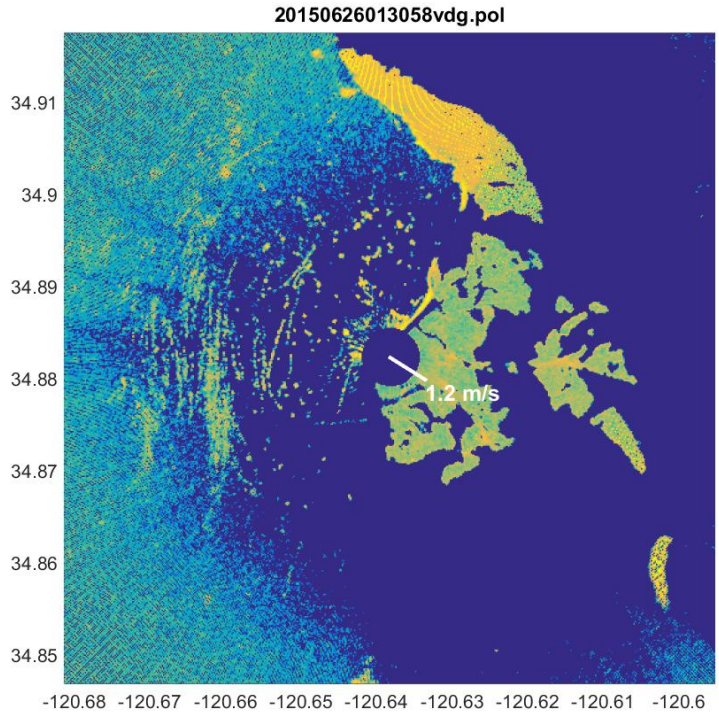

Figure 5. Example map of the variance of the radar backscatter computed over a 1 minute interval. The map clearly shows the location of internal waves propagating towards the coast. IWs are found to also be reflected.

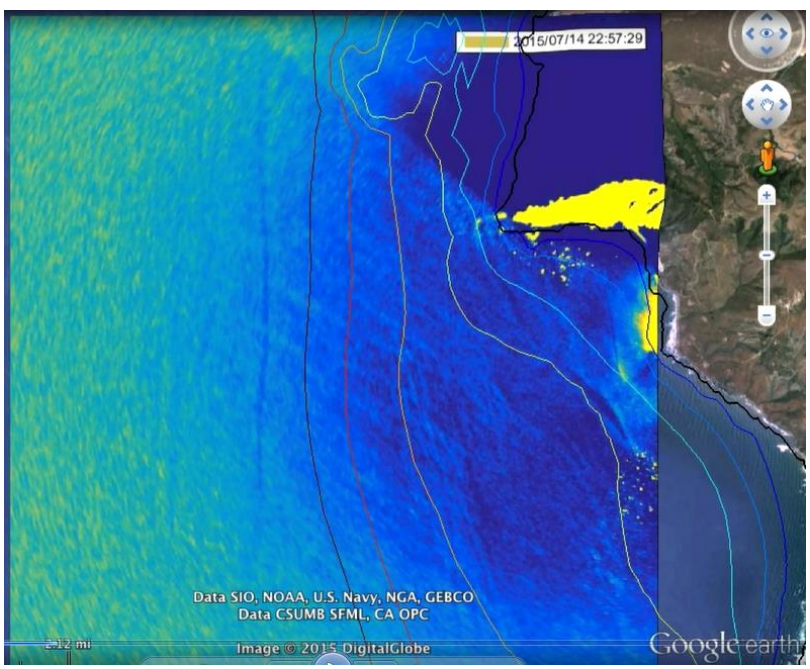

Figure 6. A map of radar backscatter, averaged to remove the surface wave signal, showing the location of internal wave fronts. At the offshore location, the IWs don't feel the bathymetry, but as they approach shallower waters, significant ray is observed.

RESULTS

Too early in the program to have results as this is the first year of a 5 year program, and has only been funded for 3 months.

IMPACT/APPLICATIONS

N/A

RELATED PROJECTS

N/A