RIVET II: Satellite Remote Sensing and Small Scale Wave Observations of the Columbia River Mouth

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LONG-TERM GOALS

The goals of this project are to utilize satellite remote sensing to understand the dynamics of inlets and river mouths, specifically the Columbia River. CSTARS has access to the new high resolution SARs like TerraSAR-X, Cosmo-SkyMed and RadarSat-2. We will utilize SAR images acquired at various frequencies, polarizations, incidence angles, and spatial resolutions to complement with similar high resolution EO imagery (e.g. EROS-B) to obtain a comprehensive picture of inlet and river dynamics, and phenomena that causes outflow patterns and interactions of ocean waves with river currents.

OBJECTIVES

Using satellite imagery to describe river mouth dynamics and wave-current interactions of the Columbia River.

a) To collect a comprehensive set of SAR and along-track InSAR images and EO images of the Columbia River mouth and selected upstream locations under a variety of current, wind, and wave conditions.
b) To estimate surface currents from interferometric pairs of SAR images.

c) To measure the cm-scale waves whose intensity variations are most visible in SAR imagery and to characterize their interaction with strong currents, horizontal and vertical current gradients and topography.

d) To measure the in-situ wind-stress that generates these short waves to determine the effect of peak wave refraction due to currents and topography on the local shear magnitude and direction.

e) To obtain an improved understanding of the physical mechanisms giving rise to observed SAR signatures of river plumes and fronts.

f) To develop improved methods for interpreting the SAR imagery in light of the observations to facilitate assimilation into coastal models.

g) To test a satellite-based monitoring of seasonal variations and long-term morpho-dynamic changes in selected test areas during a period of several months.

**APPROACH**

**RIVET-II: Columbia River Mouth**

A second experiment was carried out in May/June 2013 at the Columbia River Mouth (CRM). The CRM is much more energetic and dynamic, and therefore, making small scale physics measurements challenging from relatively stable platforms. We collected again a combination of SAR and EO images during the experimental phase. Our focus was much on aperture switching mode (ASM) collections to acquire small phase differences along-track interferometric pairs. Table 1 provides a summary of the satellite collections during the CRM.

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Mode</th>
<th>Resolution</th>
<th># of Collects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmo-SkyMed</td>
<td>SpotLight</td>
<td>1 m</td>
<td>31</td>
</tr>
<tr>
<td>TerraSAR-X</td>
<td>Aperture Switching Mode</td>
<td>3 m</td>
<td>11</td>
</tr>
<tr>
<td>RadarSat-2</td>
<td>SpotLight</td>
<td>1 m</td>
<td>6</td>
</tr>
<tr>
<td>EROS-B</td>
<td>Panchromatic</td>
<td>70 cm</td>
<td>4</td>
</tr>
<tr>
<td>TerraSAR-X</td>
<td>SpotLight</td>
<td>1 m</td>
<td>4</td>
</tr>
<tr>
<td><strong>TOTAL COLLECTION</strong></td>
<td></td>
<td></td>
<td><strong>56</strong></td>
</tr>
</tbody>
</table>

In order to acquire high resolution in-situ measurements in the river mouth and especially across the river plume as it emanated into the adjacent ocean, we utilized equipped the *R/V Point Sur*, a more severe wave conditioned vessel, with customized bowsprit and outriggers that included ultra-sonic elevation devices, IR and polarimetric cameras. On a mast we situated wind and wind stress sensors as well as air temperature and humidity instruments. The boat’s motion was recorded by a six-degree
motion pack on the bow for correcting all physical variables measured on the boat and then provides an earth referenced data set (Figure 1).

Figure 1: The R/V Point Sur (left) equipped with instrumentation and a meteorological mast (right) for the Columbia River Mouth experimental phase.

Shipboard Observations in the Columbia River Mouth (CRM)
The CRM offers significant challenges to making the high resolution short-wave and turbulence observations necessary to improve remote sensing in inlet regions. Most of the vessels are not robust enough for the high wave conditions of interest in the CRM. However, the measurement systems we used previously in the RIVET-I project were easily adapted to a larger vessel. An air-sea flux tower was mounted on the bow or above the top deck of the R/V Point Sur to place it outside the zone of vessel airflow disturbance. Surface roughness observations using polarimetric video and IR cameras as well as ultrasonic distance ranging were carried out from a boom deployed off the starboard bow. This was done so that the sensors can image the ocean surface outside the region of vessel disturbance. Critical to all of these observations was the motion correction provided by three-axis accelerometers and rate gyros mounted near key instrument platforms. All of the sensors to be used and the data acquisition system were successfully deployed on the smaller catamaran used in the RIVET-I program.

Satellite Data Acquisition and Products
The focus of acquisitions was at the river mouth where ocean waves and river currents interact. For example, Figure 2 shows the Columbia River mouth from a recent collection by Cosmo-SkyMed SAR on 27 September 2012 at 13:49 UTC. The image shows lots of obvious as well as subtle features. Off the river mouth internal waves and fronts related to the river plume are visible, whereas inside the river a front delineating quiescent waters strongly separates waters on the southern side of the river from fast moving, shear currents on the northern side. All images were downlinked and/or acquired, processed, and archived at the University of Miami's Center for Southeastern Tropical Advanced Remote Sensing (CSTARS).

From the various SAR and EO image data various products of the wind and wave conditions will be generated to produce an experimental climatology and validate the spatial fields with in-situ or limited range radar (marine X-band radar) observations. Time series from both EO and SAR images will be
useful to establish positions correlated with time of surface features such as fronts, plumes, shear, enhanced region of breaking, wet/dry line along beaches and river banks.

Figure 2: Columbia River mouth observed by Cosmo-SkyMed-1 stripmap image acquired on 27 September 2012 at 13:49 UTC. Interesting features are clearly visible both offshore the river mouth as well as inside.

Satellite Algorithm Development
Satellite data will be used to derive high resolution surface current and wave patterns, estimates of wave-current interaction intensities, and bathymetric maps. We will use conventional SAR, ATInSAR, and EO imagery. The analyses will be based on an existing numerical SAR / InSAR imaging model whose wave-current interaction part will be further refined and combined with available high-resolution 3-D flow models of project partners to relate the observed surface currents and surface current gradients to the bottom topography. As an innovative element, visible wave refraction patterns will be included in the analysis.

Within the two RIVET experiments at the New River Inlet (NRI) and the Columbia River Mouth (CRM), CSTARS has collected 19 TerraSAR-X along-track InSAR (ATI) images. At MRI, 29 COSMO-SkyMed SAR images and 14 EROS-B images were acquired as well. These were the first two experiments with full TerraSAR-X ATI data acquisition and processing through CSTARS. A sophisticated reprocessing technique has been developed to remove ATI-specific artifacts of the TerraSAR-X SAR processor from the data. As a result, the SAR amplitude images acquired in ATI mode are of a quality similar to standard SAR images from TerraSAR-X, and the interferogram phases that can be used for Doppler velocity and current retrievals are of very high possible quality, taking into account that the TerraSAR-X SAR system is not optimized for ATI acquisitions and that
TerraSAR-X ATI data will always suffer from a low sensitivity to scatterer velocities and a corresponding need to average over many pixels to obtain meaningful velocity estimates. Figure 3 shows an example of the processing steps needed to obtain phase difference for the TerraSAR-X ATI data.

Figure 3: Reprocessing steps of the TerraSAR-X ATI data for Columbia River Mouth. Left: Corrected amplitude image. Center: Coherence map of image. Right: Phase difference map. The area size is 11.7 km by 18.9 km.

WORK COMPLETED

The experimental phase of this project is completed and currently we are analyzing both space-based and ship-based remotely sensed data as well as the shipborne air-sea interaction measurements.

RESULTS

None.

IMPACT/APPLICATIONS

None.