MULTI-SENSOR REMOTE SENSING OF UPWELLING NORTHEAST OF TAIWAN

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1. INTRODUCTION

Detection and monitoring of upwelling from space over the global oceans are very important as these regions are characterized by high productivity which offers us about half of the world's fisheries catch [1]. Upwelling dynamics also play a significant role in marine biogeochemical cycling of carbon and nitrogen, and have important implications to local surface property fluxes and weather. The upwelling region manifests itself not only as area with the drop of sea surface temperature (SST) but also with the increase of phytoplankton (chl-a concentration), which makes it detectable by satellite SST observations and ocean color sensors from space [2~4]. It also has a clear signal in altimetric sea surface height (SSH) anomaly [5]. As the enhanced atmospheric stability due to the drop in SST or the increased slicks due to the enhanced biological activity will both decrease the sea surface roughness, the upwelling can also be observed by satellite synthetic aperture radar (SAR) [6]. Because of its all-day and all-weather capability and high spatial resolution compared with visible and infrared sensors, SAR is becoming one of the most powerful sensors for remote sensing of the ocean.

This study aims at analysis of the coastal upwelling northeast of Taiwan using the synergy of different satellite observations. The upwelling in this region is primarily driven by interaction between the Kuroshio and the East China Sea along the western Kuroshio front [7].

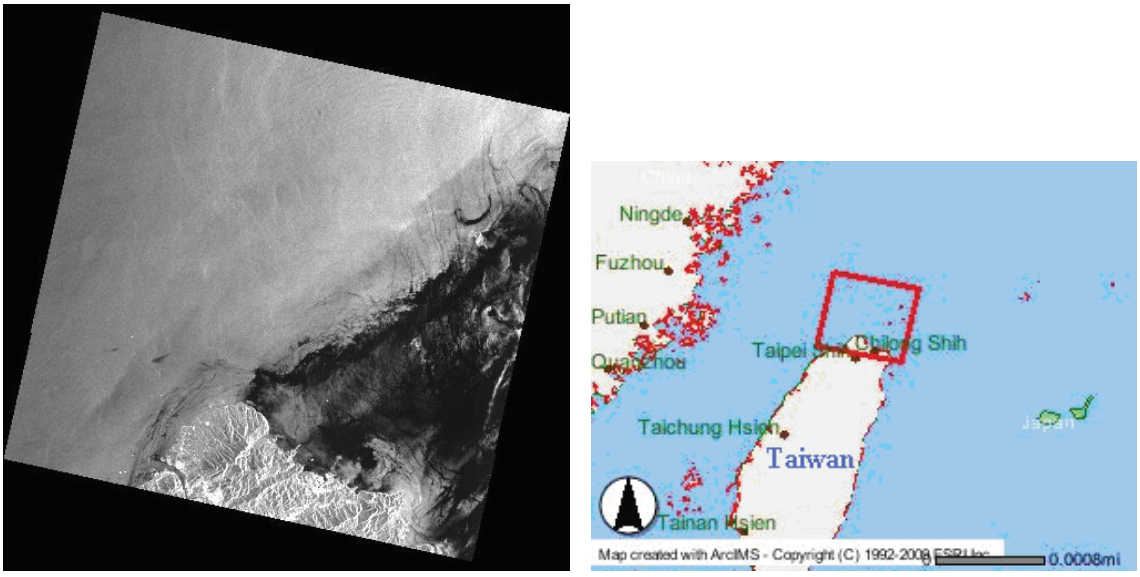
2. METHODOLOGY

In this study, several ENVISAT ASAR (Advance Synthetic Aperture Radar) images acquired in different seasons during 2006-2009 were collected. Detailed studies were carried out for cases when the upwelling area was detected by SAR and confirmed by GHRSST (The Group for High-Resolution Sea Surface Temperature, which

combined a variety of in situ and satellite SST data such as MODerate Resolution Imaging Spectroradiometer (MODIS), Advance Very High Resolution Radiometer (AVHRR) and Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) SST data, et al.) and satellite chl-a observations, as well as the SSH anomaly maps retrieved from Jason-1/ENVISAT altimeter. Base on the synergy of multi-sensor data, the time and space scales were evaluated to conclude the dynamics of upwelling events. In addition, ocean surface wind fields from QuikSCAT (Quick Scatterometer) were also analyzed to investigate the favorable environmental conditions for remote sensing of coastal upwelling.

3. RESULTS

As an example, Fig. 1 shows an ENVISAT ASAR image with a spatial resolution of 30 m off the northern coast of Taiwan acquired on Sep. 2, 2006. From the image we can clearly see the upwelling area northeast of Taiwan, which corresponds to the low backscatter region (i.e., dark area) on the image. Fig. 2 shows the GHRSST on the same date. SST northeast of Taiwan was about 1~2 ºC lower than adjacent background waters, which confirms the upwelling event detected by SAR. As shown in Fig. 3, at the time when SAR observed the area, the wind speed in the upwelling area was moderate at about 6 m s^{-1}.



(a) (b)

Fig. 1 (a) ENVISAT ASAR image near the northern coast of Taiwan acquired at 01:58 UTC on Sep. 2, 2006. (b) Location of SAR imaging area (red rectangular).

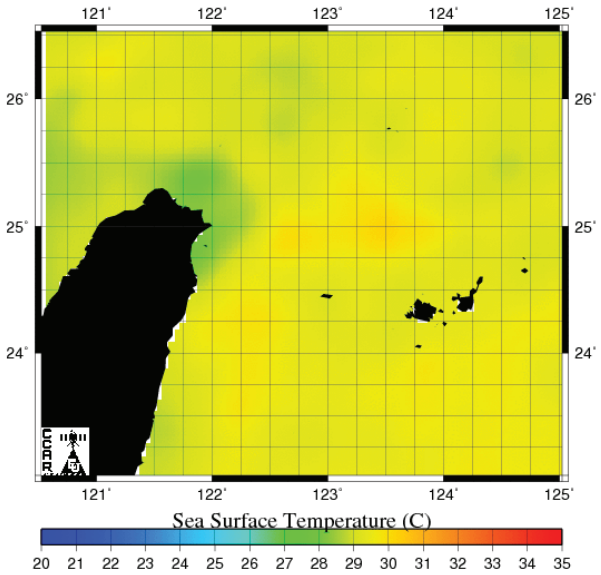


Fig. 2 GHRSST on Sep. 2, 2006.

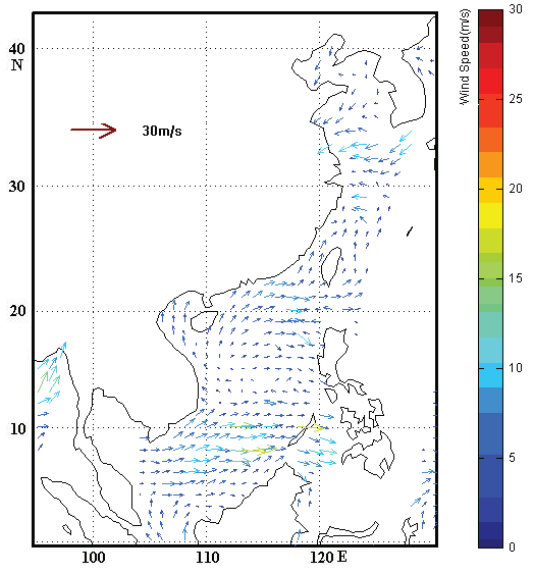


Fig. 3 Ocean surface winds in the China Sea measured by QuikSCAT at 10:42 UTC on Sep. 2, 2006.

4. CONCLUSION

Based on the synergic analysis of several upwelling events northeast of Taiwan during 2006-2009, we found that the coastal upwelling appears to be permernant. Influenced by the variability of Kuroshio and seasonal change of ocean surface wind, the area, intensity and evolution of the coastal upwelling change significantly. The favorable wind condition for SAR monitoring of upwelling in this region is less than 8~10 m s^{-1}. The results also demonstrate the utility of multi-sensor in observing the anomalous surface signals due to the upwelling processes. Since different natural factors will make different contributions to the SAR signature of coastal upwelling, more data including in situ measurements needs to be further analyzed to estimate their relative contributions.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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