Combined Active / Passive Retrievals of Ocean Vector Wind and Sea Surface Salinity with SMAP
Alex Fore, Simon Yueh, Wenchui Tang, Bryan Stiles, and Akiko Hayashi
Jet Propulsion Laboratory, California Institute of Technology
alexander.fore@jpl.nasa.gov

Abstract
We outline the algorithms for a radar-only salinity product, a radar-only vector wind product, and a combined active/passive ocean vector and salinity product. We show how SMAP can provide ocean vector winds with accuracy approaching that from traditional scatterometers using both the active and passive instruments. We demonstrate the novel ability of SMAP to make higher-resolution salinity estimates as compared to Aquarius while having accuracy approaching it. Next we test some promising results using only the radiometer channels to retrieve extreme winds.

Introduction
The Soil Moisture Active / Passive (SMAP) mission is a combined active/passive L-band microwave instrument designed to measure the soil moisture over land at 9 km resolution with a revisit time of 8 days. To meet these requirements, SMAP has included an L-band radiometer (1.22 – 1.37 GHz) and radiometer (1.11 GHz) which share a 6 meter rotating deployable mesh reflector. The full footprint 1-way resolution is 40 km while the radar also operates in a range-sliced and Synthetic Aperture Radar (SAR) mode giving resolutions of 30x6 km and 1x3 km, respectively. Due to data downlink constraints the SAR mode is generally only available over land and within 1000 km of the coastline. While the mission goals of SMAP are solely over land, the similarities of SMAP to the Aquarius mission enable combined Ocean Vector Wind (OVW) and Sea Surface Salinity (SSS) measurements. Aquarius has paved the way of L-band combined active/passive estimations of ocean wind speed and salinity [2,3] and the conically-scanning nature of SMAP, similar to RapidScat and QuikScat, enables wind direction retrieval as well due to the addition azimuthal looks afforded by the measurement geometry.

Algorithm Overview
The first stage of the combined active passive (CAP) processing is the radiometer-only portion which entails a residual \( T_d \) bias estimation as a function of time and polarization. Next the data are binned into a typical scatterometer L2A swath grid and we perform two retrievals using the radiometer-only data. First a combined wind speed and salinity retrieval where we use the following objective function:

\[
E_{rad} = \frac{1}{N} \sum_{B=1}^{N} \left[ \frac{T_{BS} - T_{BS}^d}{NEDT} \right]^2 + \beta \left[ \frac{spd - spd_m}{\varsigma \sigma_{spd}} \right]^2
\]

Here \( T_{BS} \) is one of the four flavors of \( T_d \) (H-freq, V-freq, V-freq, V-freq), \( T_{BS}^d \) is the model value of \( T_d \) which is a function of wind speed, relative wind azimuth, sea surface temperature, significant wave height, and incidence angle. The second term serves to impose a prior on the wind speed keeping it near the NCEP wind speed otherwise the problem has a continuous family of solutions in the wind speed and salinity space. We use \( \beta = 1.5 \) m/s. For extreme winds we remove the prior term from the objective function and fix the salinity at the value from the ancillary data product. Then we retrieve wind speed and direction using algorithms developed for NCMAP, QuikScat, and RapidScat (i.e. Dirth [1]). After performing the radiometer-only processing we perform the radar-only processing, which is a direct application of algorithms developed for QuikScat and RapidScat to the SMAP data with the only significant change being in the model function used. Finally, the CAP processing stage combines the radiometer-only and radiometer-only retrievals to obtain the salinity and wind vector solution using the objective function:

\[
E_{cap} = \frac{1}{N} \sum_{B=1}^{N} \left[ \frac{T_{BS} - T_{BS}^d}{NEDT} \right]^2 + \sum_{B=1}^{N} \frac{\sigma_{spd} + \sigma_{spd_m}}{\sqrt{2 \varsigma \sigma_{spd}}}
\]

where \( \sigma_{spd} \) which is a function of wind speed, relative azimuth, and incidence angle. The CAP processing is an extension of the Dirth processing to include salinity retrieval as well as wind speed and direction.

Results

Salinity
Monthly SSS maps for ARGO (top-left), HYCOM (upper-right), Aquarius (lower-left), and SMAP (lower-right). This map illustrates the new level of detail that is now available from SMAP as able to provide, even as compared to Aquarius which was designed for SSS. The Amazon river outflow is much more striking in the SMAP map than in the HYCOM or ARGO map, both of which vastly underestimate the magnitude and size of the localized freshening that is occurring during the rainy season. We also see noticeable differences in the major river outflows in the gulf of Mexico, which are not detectable in the Aquarius map due to its larger antenna footprint size. In addition we can see higher-resolution features than in Aquarius, such as in the East Pacific, and swirling diffusion patterns in the Amazon freshwater plume. The SMAP \( T_d \) product can enable novel science even as compared to Aquarius due to the higher spatial resolution and resulting closer to land SSS estimation validity.

Ocean Vector Winds

Various Aquarius and SMAP biases (left) and STD (right) of monthly Level 3 (L3) SSS products as compared to APHRC ARGO data for May 2013. For Aquarius we show the project products as well as the CAP (JPL), produced salinity product. For SMAP we show two types of \( T_d \) only processing, one with an empirical \( T_d \) bias removal procedure and the combined radar/radiometer product. The legend of each shows the overall STD of SSS between 36°N latitude. The SMAP CAP product is not significantly better than the \( T_d \) only product due to the averaging criteria used to create the L3 data. The accuracy of the SMAP products is good; however, it is currently significantly worse than that from Aquarius and continues to be a huge issue at high-latitude.

Summary
• SMAP active/passive ocean vector wind estimates approach the accuracy from traditional scatterometers and may out-perform for winds above 12-15 m/s.
• SMAP radiometer-only data has sensitivity to ocean surface winds far past that from traditional scatterometers, perhaps as high as 70 m/s.
• SMAP can continue the time series of ocean surface salinity data from Aquarius.
• Higher resolution of SMAP allows for new science as compared to Aquarius.

References

Acknowledgements
This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.