Aquarius’ Combined Active-Passive (CAP) SSS and Wind Retrieval

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• Introduction
• V2.0 Changes from V1.3 processing
  – Roughness dependence – wind and wave
  – CAP Wind speed/direction products
  – CAP SSS products
• Towards v3
• Summary
Aquarius CAP Products distributed through PO.DAAC

• Aquarius CAP (combined active-passive) product processed at JPL:
  – SSS
  – Wind speed
  – Wind direction

• CAP 2.0 products available at PO.DAAC in a days
  – http://podaac.jpl.nasa.gov/SeaSurfaceSalinity
  – Follow the FTP Data Access link for Aquarius data
Changes from V1.3 processing

• TB and sigma0 model functions updated and wave effects modeled
• The following effects corrected for retrieval
  – Significant wave height
  – Water dielectric constant (SST effect bias)
  – Galactic reflection (increase the effective wave slope)
• Constrain the wind speed retrieval near crosswind
• Constrain the wind direction retrieval at low-mid wind speed
• Added a rain flag by adding 10 to the cap_flag if the SSM/I rain >0
Two versions of GMFs are built

- AQ data, *SSM/I wind speed*, NCEP wind direction, NOAA WW3 SWH
- AQ data, *NCEP wind speed*, NCEP wind direction, NOAA WW3 SWH
Aquarius TB GMF
built using more than one year of data

- Match up with SSM/I wind speed

\[ \Delta e(w, \phi) = e_0(w) + e_1(w)\cos\phi + e_2(w)\cos 2\phi \]
Effects of SWH on Aquarius TB GMF Matchup with SSMI wind speed

• Match up with SSM/I wind speed for V-pol for 0 to 7 m NOAA WW3 SWH

\[
\Delta e(w, \phi) = e_0(w) + e_1(w) \cos \phi + e_2(w) \cos 2\phi
\]

• Impact of SWH on e0 is clear
• Impact of SWH on e1 and e2 inconclusive
Effects of SWH on Aquarius TB GMF Matchup with SSMI wind speed

- Match up with SSM/I wind speed for H-pol for 0 to 7 m SWH

\[ \Delta e(w, \phi) = e_0(w) + e_1(w)\cos \phi + e_2(w)\cos 2\phi \]

- Impact of SWH on \(e_0\) is clear
- Impact of SWH on \(e_1\) and \(e_2\) inconclusive
Interpretation of SWH Effects on Aquarius TB GMF

- SWH has **small** impact on \( \text{EH0} \) for SSMI matchup for light to mid-winds
- SWH has **positive** impact on \( \text{EH0} \) for NCEP matchup

SSMI \( \text{eH0} \)

NCEP \( \text{eH0} \)
Interpretation of SWH Effects on Aquarius TB GMF

- SWH has **negative** impact on EV0 for SSMI matchup for light to mid-winds
- SWH has **positive** impact on EV0 for NCEP matchup
Interpretation of SWH Effects of SWH on Aquarius Radar GMF

- SWH has small to negative impact on VV for SSMI matchup for light to mid-winds
- SWH has positive impact on VV for NCEP matchup

SSMI VV

NCEP VV
Interpretation of SWH Effects on Aquarius Radar GMF

- SWH has small impact on HH for SSMI matchup for light to mid-winds
- SWH has large positive impact on HH for NCEP matchup

SSMI-HH

NCEP-HH
Aquarius GMF for Roughness Effects

• Radiometer Model Function

\[ T_{Bp}(SSS, SST, w, \phi) = T_{Bp0}(SSS, SST) + SST \cdot [e_{p0}(w, SWH) + e_{p1}(w)\cos \phi + e_{p2}(w)\cos 2\phi] \]

• TBp0 evaluated using a hybrid of Meissner-Wentz and Klein-Swift dielectric models

• Scatterometer Model Function

\[ \sigma_p(w, SWH, \phi) = A_{0p}(w, SWH)[1 + A_{1p}(w)\cos \phi + A_{2p}(w)\cos 2\phi] \]
Aquarius Combined Active-Passive (CAP) Retrieval

- V1.3 - Combined Active-Passive (CAP) Algorithm (v1.3)
  - Retrieve SSS, Wind Speed and Direction Using Combined Passive and Active Data
  - Do not use NCEP winds for TB correction

\[
F_{\text{pol}}(SSS, W, \phi) = \frac{(I - I_m)^2}{2\Delta T^2} + \frac{(\sqrt{Q^2 + U^2} - \sqrt{Q_m^2 + U_m^2})^2}{2\Delta T^2} + \frac{(\sigma_{0VV} - \sigma_{0VVm})^2}{(k_p \sigma_{0VV})^2} + \frac{(\sigma_{0HH} - \sigma_{0HHm})^2}{(k_p \sigma_{0HH})^2}
\]

\[
Q = T_{BV} - T_{BH}
\]
\[
I = T_{BV} + T_{BH}
\]

Yueh and Chaubell, IEEE TGRS, April 2012

- V2.0: constrain wind speed retrieval at crosswind and direction retrieval for light-mid winds – \( \Delta W=1.5 \) and \( \delta=0.2 \)

\[
F_{\text{ap}}(SSS, w, \phi) = \frac{(T_{BV} - T_{BVm})^2}{\Delta T^2} + \frac{(T_{BH} - T_{BHm})^2}{\Delta T^2} + \frac{(\sigma_{VV} - \sigma_{VVm})^2}{k_p^2 \sigma_{VV}^2} + \frac{(\sigma_{HH} - \sigma_{HHm})^2}{k_p^2 \sigma_{HH}^2} + \frac{(w - w_{NCEP})^2}{\Delta w^2} + \frac{\sin^2((\phi - \phi_{NCEP})/2)}{\delta^2}
\]
• AQ CAP wind speed accuracy is about 0.7 m/s
  – Triple collocation analysis of Aquarius CAP Wind Speed, SSMI and ECMWF

<table>
<thead>
<tr>
<th></th>
<th>SSMI</th>
<th>ECMWF</th>
<th>CAP</th>
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<tbody>
<tr>
<td>Error (m/s)</td>
<td>0.714</td>
<td>0.935</td>
<td>0.700</td>
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</table>
SSS Bias and Std wrt Hycom vs SWH and Wind Speed
28 day average on 1x1 deg grids

**L2 V1.3.9**
- has systematic biases vs SWH and Wind Speed

\[ SSS_{L2} - SSS_{HYCOM} \]

- The systematic and std are reduced in CAP

\[ SSS_{CAP} - SSS_{HYCOM} \]

**CAP V1.3.9**
- Introduce the NOAA WW3 SWH as an additional model parameter for the GMF

\[ TB = TB(w, \phi, SWH) \]

\[ \sigma_0 = \sigma_0 \]

\[ (w, \phi, SWH) \]
SSS Bias and Std wrt Hycom vs SST and Wind Speed
28 day average on 1x1 deg grids

**L2 V1.3.9**
- has systematic biases vs SST and Wind Speed

**CAP V1.3.9**
- The systematic and std are reduced in CAP

Use the linear combination of MW and KS models
• CAP has a smaller bias than L2 V1.3.9, particularly for cold water and high wind speed
• CAP has a smaller standard deviation
  – L2: 0.285 psu
  – CAP: 0.250 psu – 14% better than L2
Aquarius and Hycom Differences
28 day global average on 100km grid

• The RMS error is under 0.25 psu from -40 to 40 deg latitude mostly
Towards V3.0

- Rain correction
- Improved galactic reflection correction
- Remove regional systematic bias in the scatterometer and radiometer model functions and retrieval
- Improved land contamination correction
• Develop TB and sigma0 model functions to model the rain effects
• Apply the CAP cost function for retrieval using the SSM/I rain rate as ancillary
• Current results of bias adjustment from the rain correction under rainy conditions
Distribution of SSS Bias & RMSE in Wind-Rain Domain (8/25/2011-9/19/2012)

Significant improvement from rain correction
Summary

• CAP is more accurate than the L2 product
  – Smaller bias with respect to SST, wave and wind speed
  – Smaller standard deviation

• The Aquarius salinity product (CAP) – about 0.25 psu RMS for 28-day average
  – There are systematic regional biases, which could be caused by rain, wave, galactic radiation, and so on.

• Aquarius CAP wind speed is highly accurate (0.7 m/s error) – slightly better than SSM/I
• Aquarius CAP (combined active-passive) product processed at JPL:
  – SSS
  – Wind speed
  – Wind direction

• CAP 2.0 products available at PO.DAAC in a days
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Rain correction for radar backscatter: $\Delta A_{0,p}(w,r)$

$$0_p(w, r) = A_{0,p}(w, swh) + A_{1,p}(w)\cos + A_{2,p}(w)\cos^2 + A_{0,p}(w, r)$$
Rain correction for radiometer emissivity: $\Delta e_p(w, r)$

$$e_p(\text{SSS, SST, } w, r) = e_p^{\text{flat}}(\text{SSS, SST}) + e_{0, p}(w, \text{swh}) + e_{1, p}(w)\cos + e_{2, p}(w)\cos^2 + e_p(w, r)$$