Aquarius Pointing Assessment

Alex Fore
Overview

• We show the pointing error is stable over time to ~ 0.1 degrees.

• We show that the pointing errors can be represented well by the following biases:
  – B1: +0.45 Nadir; +0.5 Azimuth
  – B2: +0.25 Nadir; +0.2 Azimuth
  – B3: +0.40 Nadir; +0.2 Azimuth

• We show consistent results using both radar and radiometer data.
Coastal Crossing Analysis Method

• For every mixed ocean/land observation we:
  – Compute footprint heading relative (call this $\gamma$) to coast unit normal.
  – Bin data by *predicted* land fraction and $\sin(\gamma)$ or $\cos(\gamma)$.

• Only include data from [-55,55] degrees latitude.

• Do this for radiometer $T_H + T_V$ and scatterometer $\sigma_{HH}$.
  – Use $T_I := T_H + T_V$ since it is independent of Faraday rotation.
  – We use the antenna $T_f$, which has had RFI filtering applied.
Contour plot of smoothed land mask
Coast unit normal given by unit vector normal to contours
Relative Heading Angle ($\gamma$)

- $\gamma = 0^\circ$: $\cos(\gamma) = 1$; $\sin(\gamma) = 0$
  - Plots vs. $\cos(\gamma)$ are sensitive to along-track offsets.

- $\gamma = 180^\circ$: $\cos(\gamma) = -1$; $\sin(\gamma) = 0$

- $\gamma = 90^\circ$: $\cos(\gamma) = 0$; $\sin(\gamma) = 1$
  - Plots vs. $\sin(\gamma)$ are sensitive to cross-track offsets.

- $\gamma = -90^\circ$: $\cos(\gamma) = 0$; $\sin(\gamma) = -1$
POINTING ANGLE STABILITY
Radiometer $T_1$
Processed with Pre-Launch Pointing Angles
2011-238 to 2011-244

Y-axis is Scatterometer Land Fraction

Beam: 1 Avg. T1

Beam: 2 Avg. T1

Beam: 3 Avg. T1
Radiometer $T_i$
Processed with Pre-Launch Pointing Angles
2011-245 to 2011-251

Y-axis is Scatterometer Land Fraction
Radiometer $T_1$
Processed with Pre-Launch Pointing Angles
2011-252 to 2011-258

Y-axis is Scatterometer Land Fraction
Scatterometer $\sigma_0^{\text{HH}}$
Processed with Pre-Launch Pointing Angles
2011-238 to 2011-244

Y-axis is Scatterometer Land Fraction
Scatterometer $\sigma_0^{HH}$
Processed with Pre-Launch Pointing Angles
2011-245 to 2011-251

Y-axis is Scatterometer Land Fraction
Scatterometer $\sigma_0^{HH}$
Processed with Pre-Launch Pointing Angles
2011-252 to 2011-258

Y-axis is Scatterometer Land Fraction
POINTING ANGLE OFFSET
Radiometer T₁
Processed with Pre-Launch Pointing Angles

Y-axis is Radiometer Land Fraction
Radiometer $T_i$
Processed with Pre-Launch Pointing Angles

Y-axis is Scatterometer Land Fraction
Radiometer $T_1$
Processed with +0.1 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Radiometer $T_i$
Processed with +0.2 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Radiometer $T_1$
Processed with +0.3 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Radiometer $T_1$
Processed with +0.4 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Radiometer $T_1$
Processed with $+0.5\, \text{deg}$ Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Radiometer $T_1$
Processed with +0.3 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Radiometer $T_1$

Processed with +0.3 deg Nadir Angle Offset, +0.1 deg Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Radiometer $T_1$
Processed with +0.3 deg Nadir Angle Offset, +0.2 deg Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Radiometer $T_1$
Processed with +0.3 deg Nadir Angle Offset, +0.3 deg Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Radiometer $T_1$
Processed with +0.3 deg Nadir Angle Offset, +0.4 deg Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Radiometer $T_1$
Processed with +0.3 deg Nadir Angle Offset, +0.5 deg Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Scatterometer $\sigma_0^{HH}$

Processed with Pre-Launch Pointing Angles

Y-axis is Scatterometer Land Fraction
Scatterometer $\sigma_0^{HH}$
Processed with +0.1 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction

\[ B1; \sigma_0^{HH} vs \cos(\text{relhdg}) \]
\[ B2; \sigma_0^{HH} vs \cos(\text{relhdg}) \]
\[ B3; \sigma_0^{HH} vs \cos(\text{relhdg}) \]

\[ B1; \sigma_0^{HH} vs \sin(\text{relhdg}) \]
\[ B2; \sigma_0^{HH} vs \sin(\text{relhdg}) \]
\[ B3; \sigma_0^{HH} vs \sin(\text{relhdg}) \]
Scatterometer $\sigma_0^{\text{HH}}$
Processed with +0.2 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Scatterometer $\sigma_0^{HH}$
Processed with +0.3 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction

B1; Sigma0 HH vs cos(relhdg)

B2; Sigma0 HH vs sin(relhdg)

B3; Sigma0 HH vs cos(relhdg)
Scatterometer $\sigma_0^{HH}$
Processed with +0.4 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Scatterometer $\sigma_0^{\text{HH}}$
Processed with +0.5 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Scatterometer $\sigma_0^{HH}$
Processed with +0.3 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Scatterometer $\sigma_0^{HH}$
Processed with +0.3 deg Nadir Angle Offset, +0.1 Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Scatterometer $\sigma_0^{HH}$
Processed with +0.3 deg Nadir Angle Offset, +0.2 Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Scatterometer $\sigma_{0}^{HH}$
Processed with +0.3 deg Nadir Angle Offset, +0.3 Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Scatterometer $\sigma_0^{HH}$
Processed with +0.3 deg Nadir Angle Offset, +0.4 Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Scatterometer $\sigma_0^{HH}$
Processed with +0.3 deg Nadir Angle Offset, +0.5 Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction
Summary

• We show the pointing angle is stable to within 0.1 degrees over time.
  – We used both the radar and radiometer data.
  – Weekly analyses yield very similar results.

• We show that a radiometer and scatterometer give a consistent assessment of the best pointing offsets:

<table>
<thead>
<tr>
<th></th>
<th>Beam 1</th>
<th>Beam 2</th>
<th>Beam 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rad Delta Nadir</td>
<td>+0.4</td>
<td>+0.3</td>
<td>+0.5</td>
</tr>
<tr>
<td>Rad Delta Azi</td>
<td>+0.5</td>
<td>+0.2</td>
<td>+0.2</td>
</tr>
<tr>
<td>Scat Delta Nadir</td>
<td>+0.5</td>
<td>+0.2</td>
<td>+0.3</td>
</tr>
<tr>
<td>Scat Delta Azi</td>
<td>+0.5</td>
<td>+0.2 to +0.3 *</td>
<td>+0.2 to +0.3 *</td>
</tr>
</tbody>
</table>

Compromise Between Radiometer and Radar Best Fit Angles

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta Nadir</td>
<td>+0.45</td>
<td>+0.25</td>
<td>+0.4</td>
</tr>
<tr>
<td>Delta Azi</td>
<td>+0.5</td>
<td>+0.2</td>
<td>+0.2</td>
</tr>
</tbody>
</table>

*Hard to tell the difference
Possible Actions

- Adjust beams individually
  - B1: +0.45 Nadir; +0.5 Azimuth
  - B2: +0.25 Nadir; +0.2 Azimuth
  - B3: +0.40 Nadir; +0.2 Azimuth
  - Pros:
    - Improved land fraction computations will give better ability to correct for land contamination in both the radiometer and radar retrievals.
    - Reduced biases/errors when using incidence angle dependent model functions. (i.e. attributing an incidence angle error to a calibration error)
  - Cons:

- Leave the pointing angles as they are
  - Cons:
    - Reduced utility of the predicted land fraction.
    - Changing it in the future will require much more work than changing it now.

- Azimuth angle offset and time-tag errors are indistinguishable.
  - Both are along-track type of offsets.
BACKUP SLIDES
Pointing Angle Bias (Sensitivity Analysis)

- Simulated data with a constant 0.2 deg bias in yaw, pitch, and roll.
- We see beam center geo-location errors on the order of 2 km for a pitch and yaw bias.
  - Pitch bias results in a slightly varying offset which is almost the same for all beams.
  - Yaw bias results in a bias which is more different per beam.
- Roll bias results in the largest offset. (~4km)
- Beam footprint ~ 100km; these biases are a few percent of that.
Coast Heading

- We create a land fraction map using the simulator land mask which is posted at 1/128 degree.
- Create 1/12 degree grid; for each grid point:
  - Take random samples and average resulting land mask over 2000 (lon_mask, lat_mask) samples given by:
    - Lon_mask = lon_grid_point + 0.3 * n_0 / cos( lat_grid_point )
    - Lat_mask = lat_grid_point + 0.3 * n_1
    - Where n_0, n_1 are from Gaussian distribution with zero mean and unit variance.
    - $0.3 \text{ deg} \times \text{FWHM}(n(0,1)) \times 110 \text{ (km/deg)} = 76 \text{ km FWHM on ground.}$
  - Yields a very smooth land fraction
  - Take the gradient of this and arctangent of resulting gradient vector components to get a coast heading map. (coast heading points towards max increase in land fraction).
  - Note: we don’t use this land fraction map in analysis, only use the gradient for computing the beam heading relative to the coast normal direction.
Contour plot of smoothed land mask
Coast heading given by unit vector perpendicular to contours
Histogram of Relative Heading Angles
SEPARATE ANALYSIS PER WEEK
RADIOMETER
NOMINAL POINTING
Radiometer; 1 week starting 2011-238
Nominal Pointing
Radiometer; 1 week starting 2011-245
Nominal Pointing
Radiometer; 1 week starting 2011-252
Nominal Pointing
Radiometer; 1 week starting 2011-259
Nominal Pointing

Beam: 1 Avg. Tf 1

Beam: 2 Avg. Tf 1

Beam: 3 Avg. Tf 1
Radiometer; 1 week starting 2011-266
Nominal Pointing
Radiometer; 1 week starting 2011-280
Nominal Pointing
Radiometer; 1 week starting 2011-287
Nominal Pointing

Beam: 1 Avg. Tf I

Beam: 2 Avg. Tf I

Beam: 3 Avg. Tf I
Radiometer; 1 week starting 2011-294
Nominal Pointing

Beam: 1 Avg. Tf I

Beam: 2 Avg. Tf I

Beam: 3 Avg. Tf I
SEPARATE ANALYSIS PER WEEK
SCATTEROMETER
NOMINAL POINTING
Scatterometer; 1 week starting 2011-238
Nominal Pointing
Scatterometer; 1 week starting 2011-245
Nominal Pointing
Scatterometer; 1 week starting 2011-252
Nominal Pointing
Scatterometer; 1 week starting 2011-259
Nominal Pointing
Scatterometer; 1 week starting 2011-266
Nominal Pointing
Scatterometer; 1 week starting 2011-273
Nominal Pointing
Scatterometer; 1 week starting 2011-280
Nominal Pointing
Scatterometer; 1 week starting 2011-287
Nominal Pointing
SEPARATE ANALYSIS PER WEEK
RADIOMETER
NADIR ANGLE +0.3
Radiometer; 1 week starting 2011-238
Nadir Angle +0.3, all beams
Radiometer; 1 week starting 2011-245
Nadir Angle +0.3, all beams
Radiometer; 1 week starting 2011-252
Nadir Angle +0.3, all beams
Radiometer; 1 week starting 2011-259
Nadir Angle +0.3, all beams
Radiometer; 1 week starting 2011-266
Nadir Angle +0.3, all beams
Radiometer; 1 week starting 2011-273
Nadir Angle +0.3, all beams

Beam: 1 Avg. Tf I

Beam: 2 Avg. Tf I

Beam: 3 Avg. Tf I

Land Fraction

Cos γ

Sin γ
Radiometer; 1 week starting 2011-280

Nadir Angle +0.3, all beams
Radiometer; 1 week starting 2011-287
Nadir Angle +0.3, all beams