An Observatory for Ocean, Climate and Environment

SAC-D/Aquarius

MWR Geometric Correction Algorithms

Felipe Madero

7th Aquarius SAC-D Science Meeting
Buenos Aires – April 11-13, 2012
Geometric Processing Glossary

- Geometric Calibration: Activities done in order to tune the algorithms and models so as to obtain the expected geolocation results

- Geometric corrections: (Systematic) Processes applied to the sensor data, in order to:
  – Obtain knowledge of the geographic location of the measurements.
  – Solve geometric distortions introduced in the acquisition
  – Map the data to useful geographic reference systems

- Geolocation: (Systematic) Process applied to the sensor data in order to obtain knowledge of the geographic coordinates of the measurements
Geolocation Problem
Main reasons for having good geolocation accuracy for this sensor

- Radiometric calibration and retrieval algorithms development is heavily based in inter comparisons with data from other sources.

Secondary reason

- Provision of data of good quality to the end users
Geometric requirements for MWR

- Related to the expected location and extension of the swath, and to the geometric resolution of the measurements:
  - Individual footprint across-track < 54 km
  - Swath width of 380 km
  - Look and azimuth angle specifications

- Related to the expected geolocation accuracy:
- Pointing knowledge <= 0.03 degrees
mwr geometry from antenna pattern
Geolocation outputs

Geographic coordinates (geodetic latitude/longitude) for the center (maximum gain point) of the 8 horn measurements, for K H, Ka V, Ka H, Ka +45, Ka -45 bands.

Auxiliary geographic parameters associated to this positions (range to spacecraft, and zenith/azimuth angle to spacecraft, moon, and sun)

Geographic coordinates for selected points of the of the -3dB contour.

Geographic coordinates for parameters of the approximating ellipse of the -3dB contour.
Pre Launch
Pre launch measurements

- antenna pattern measurements at LaMA/CETT

- mechanical (3d robotic harm) alignment measurement between sensor parts, at INVAP installations

- optical sensor pointing alignment measurement, at LIT/INPE
Pre launch data to processors input data

- Obtain center (maximum gain point) for each beam
- Interpolation to get -3dB contour
- Sampling of -3dB contour to get selected points
- Fitting ellipse to -3dB contour to get ellipse parameters
- Conversion of alignment measurements to reference system used by processors
Geolocation Algorithms
Geolocation Algorithms development

- ATBD/prototype library developed at the same time

- Geolocation results cross checked with standard geolocation libraries

- Software replacement: library first developed and validated using Python language. Replacement of bottlenecks using c++ code. Last version expected to be mainly c++ code, with python as control code.
Developed Geolocation Libraries

- Time system transformations
- Coordinates systems transformations
- Generic interpolation and smoothing
- Attitude data validation and processing
- State vector data validation and processing
- Intersection of line of sight with earth models
- Generation of auxiliary geolocation parameters
Geolocation Steps: Input data from acquisition

- Validate and filter time data. Fix time measurement errors by fitting the data to a first order polynomial (sample number to time).

- Validate and filter attitude data. No fixing of attitude measurement errors. Quaternions Interpolation.

- Validate and filter state vector data. Fix state vector error measurements by fitting the data to a suitable order polynomial (time to state vector).
Geolocation Steps: Get intersection parameters

- For each sample (measurement of 1 horn per band):
  - Get spacecraft position in ECEF, by using time and state vector polynomial (J2000), and J2000 to ECEF transformation.
  - Get SENSOR2ECEF rotation matrix, by using calibrated SENSOR2PLAT rotation matrix, PLAT2J2000 rotation matrix from interpolated quaternions, and J2000 to ECEF transformation.
  - Apply SENSOR2ECEF rotation matrix to the line of sight of the center of each measurement included in the sample.
Geolocation Steps: Intersect line of sight with earth

- The spacecraft position in ECEF and the line of sight in ECEF defines a vector pointing to the earth, which is intersected to an earth model (WGS84), by solving a quadratic equation.

- The resulting intersection point in ECEF is converted to geodetic latitude/longitude (elevation=0 due to using earth model).
Geolocation Steps: Get auxiliary geolocation parameters

- Obtain moon and sun position in ECEF, by using standard tables, and J2000 to ECEF transformation

- Generate azimuth and elevation angles, between intersection point and spacecraft, sun, and moon, by using acquisition geometry
Optimal Interpolation
Product levels in relation to geometric correction

- L1B: geolocation parameters are included

- L1B3: along track optimal interpolation, with recalculated geolocation parameters

- L1B4: resampling to map projection (grid) by using standard techniques, based in L1B3, with recalculated geolocation parameters.

- L1B5: resampling to map projection (grid) by using optimal interpolation, Based in L1B, with recalculated geolocation parameters.
Optimal interpolation

- Along track superposition of 3 to 4 measurements, for -3dB contour, to be reduced to zero superposition, if possible, improving resolution.

- Convolution coefficients to be obtained by Backus/Gilbert, or SVD based reconstruction, in order to improve resolution.

- Simpler scheme of convolution coefficients, to avoid superposition, without improving resolution, to be used in some retrieval algorithms.

- Studying the possibility of gridding by using also optimal interpolation.
Geolocation Errors
Geolocation error from pointing knowledge requirement

- Pointing knowledge error: 0.03 degrees (max 3.1 km)

- Bias plus random
Bias geolocation error

- Error in alignment measurement from ST cube to ref cube: 0.005 degrees (max 180 mts)

- Cyclic (orbital) Thermoelastic deformation errors between ref cube and MWR reference system: 0.015 degrees (max 529 mts)

- Error in alignment between MWR reference system and antenna pattern measurement reference system: 0.0865 degrees (max 3 km)

- Goal to reduce it to 0 by post launch geometric calibration. Cyclic Thermoelastic deformation most difficult to correct.
Random geolocation error

- Error in attitude measurement: 0.011 degrees (max 388 mts)

- Goal is to have it as the final random error, after post launch geometric calibration.
### Expected final random geolocation error by beam

<table>
<thead>
<tr>
<th>Horn</th>
<th>Roll</th>
<th>Pitch</th>
<th>Yaw</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>176</td>
<td>290</td>
<td>136</td>
</tr>
<tr>
<td>2</td>
<td>204</td>
<td>388</td>
<td>167</td>
</tr>
<tr>
<td>3</td>
<td>199</td>
<td>272</td>
<td>136</td>
</tr>
<tr>
<td>4</td>
<td>232</td>
<td>363</td>
<td>165</td>
</tr>
<tr>
<td>5</td>
<td>227</td>
<td>249</td>
<td>136</td>
</tr>
<tr>
<td>6</td>
<td>267</td>
<td>335</td>
<td>165</td>
</tr>
<tr>
<td>7</td>
<td>263</td>
<td>219</td>
<td>138</td>
</tr>
<tr>
<td>8</td>
<td>309</td>
<td>302</td>
<td>166</td>
</tr>
</tbody>
</table>
Concluding
Known problems

- Invalid geolocation at high latitudes.

- Geolocation errors due to star tracker error from moon interference

- Current version of the processor uses Ka V antenna patterns to get Ka +45, Ka -45 geolocation info. Further work may be needed in order to estimate and apply suitable antenna patterns for this bands.

- Bugs in generation of sun and moon position in ECEF

- Reported geolocation error of 15 km (CFRSL, Tb Slope, Parabolic fit). To assess, repeat, and correct if needed.
Todo

- Known problems

- Complete post launch calibration

- Assess geolocation accuracy

- Optimal interpolation implementation

- Radiometric calibration and retrieval regressions may be needed to be revised after fine geometric tuning.