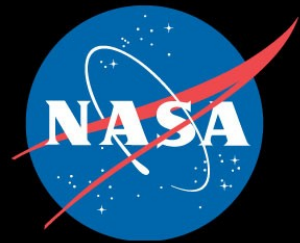




UCF CFRSL



SMART

SCIENCE, MATHEMATICS
& RESEARCH FOR
TRANSFORMATION

PART OF THE NATIONAL DEFENSE
EDUCATION PROGRAM

Engineering Evaluation of Multi-beam Satellite Antenna Boresight Pointing Using Land/Water Crossings

Catherine S. May

Master's Thesis Defense, March 20, 2012
University of Central Florida, Orlando, FL
Central Florida Remote Sensing Lab

Objective

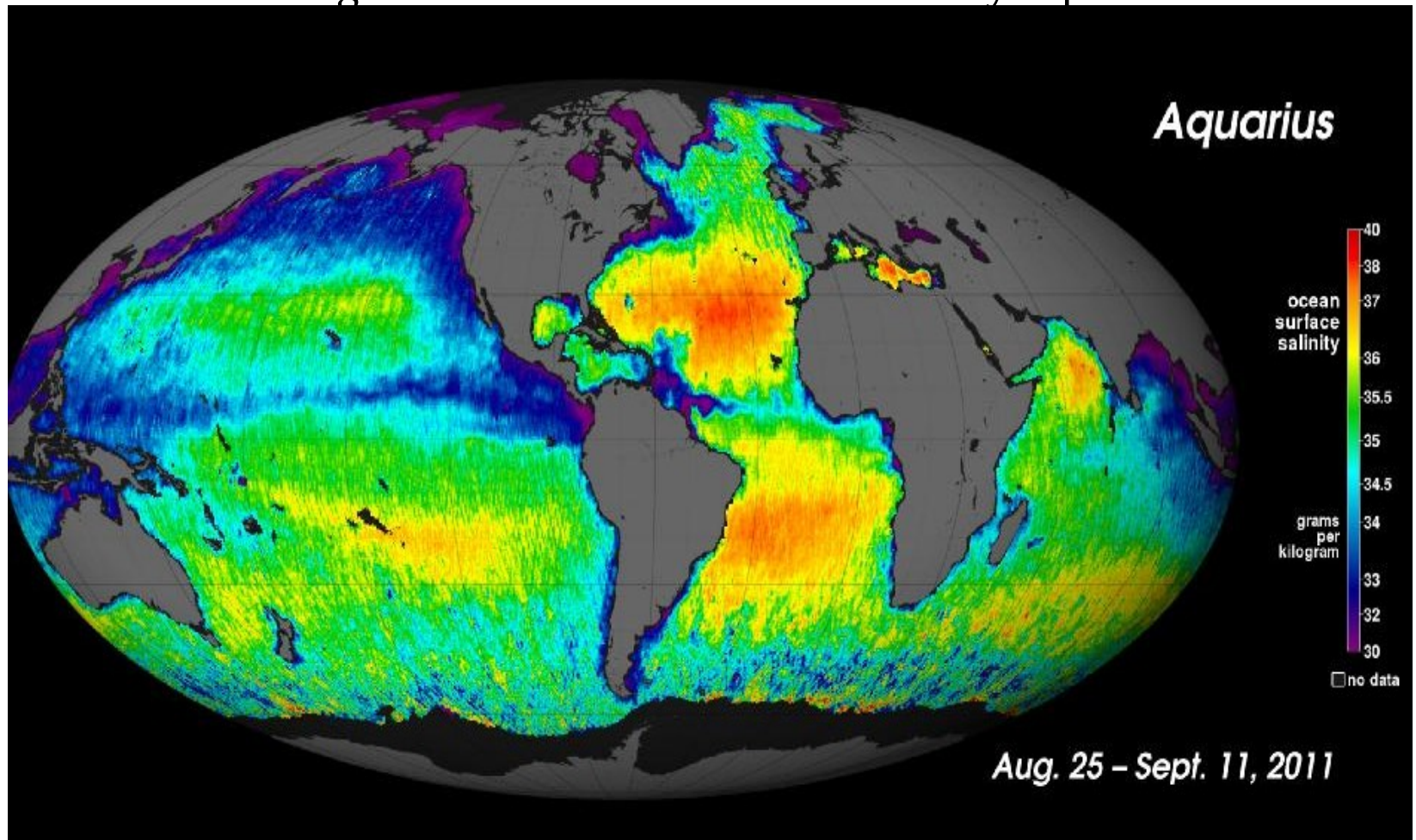
To validate the geolocation of satellite multi-beam antenna footprints on the Earth's surface

- Instantaneous field of view, (IFOV)
- For the Microwave Radiometer (MWR) on NASA's Aquarius/SAC-D mission

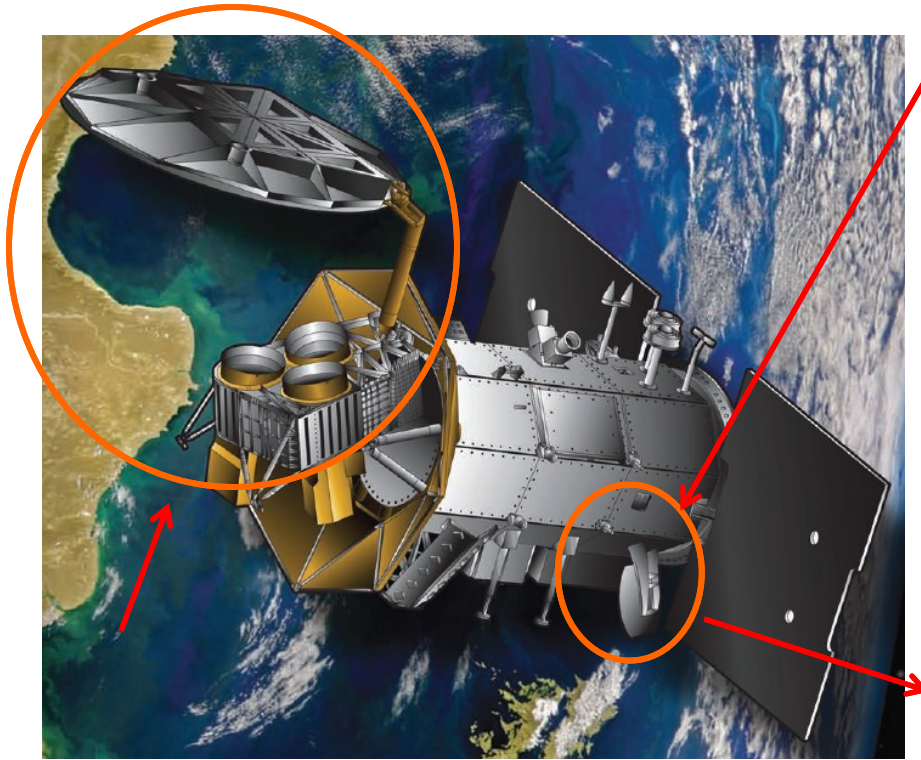
Aquarius/SAC-D Mission Overview

A mission of discovery by NASA and the Argentine Space Agency, (CONAE), to measure global Sea Surface Salinity (SSS)

First global SSS measurements made by Aquarius

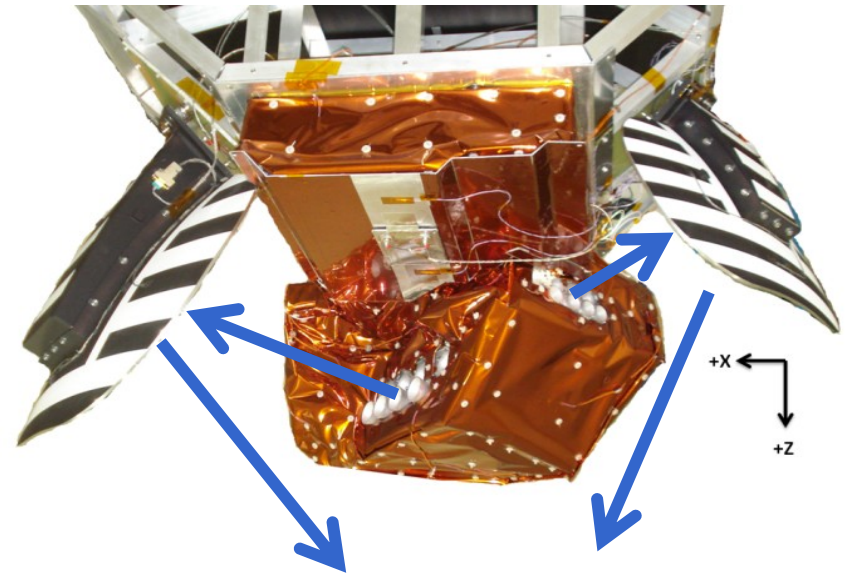


Aquarius and MWR Instruments



MWR Instrument

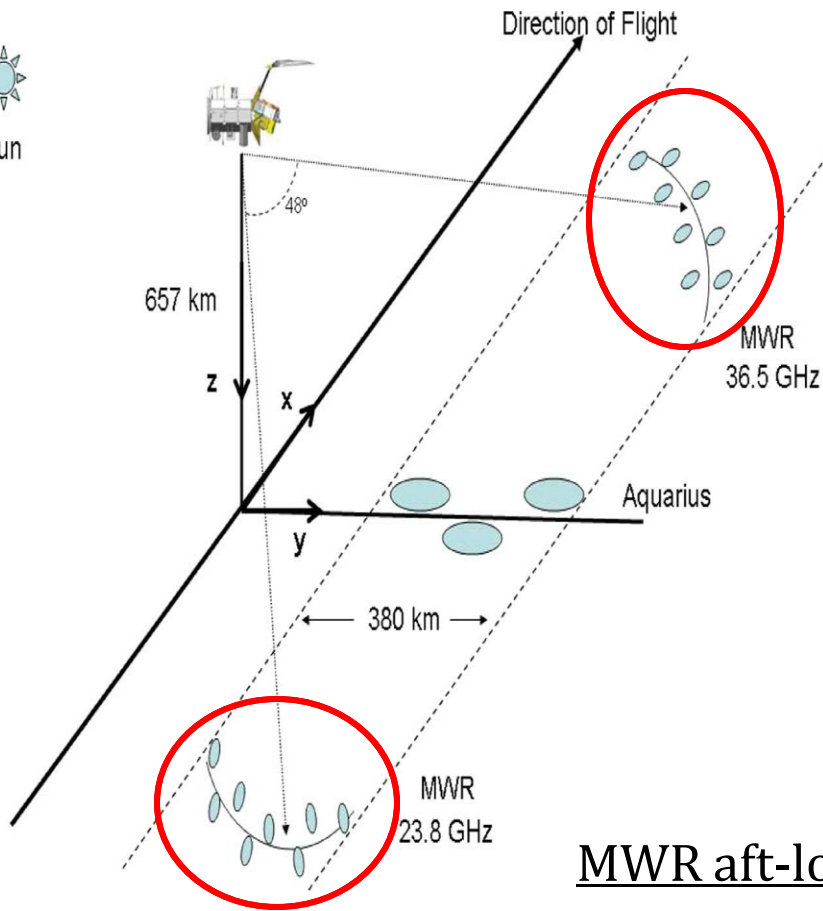
- K (H-pol) and Ka-band (V&H-pol)
- 8 beams forward (Ka-band), 8 beams aft (K-band)
- 380 km swath width
- Provides ancillary data to Aquarius



Aquarius/SAC-D and Instrument

- Radiometer/scatterometer
- 3 beams perpendicular to line of flight
- Sea Surface Salinity retrievals

MWR and Aquarius Geometry



MWR forward-looking beams

- 8 beams (Ka-band, V- & H-pol)
- Fixed beams on conical arcs
- Earth Incidence: 52° and 58°
- IFOV size range: $\sim 25 \times 50 - 30 \times 60$ km

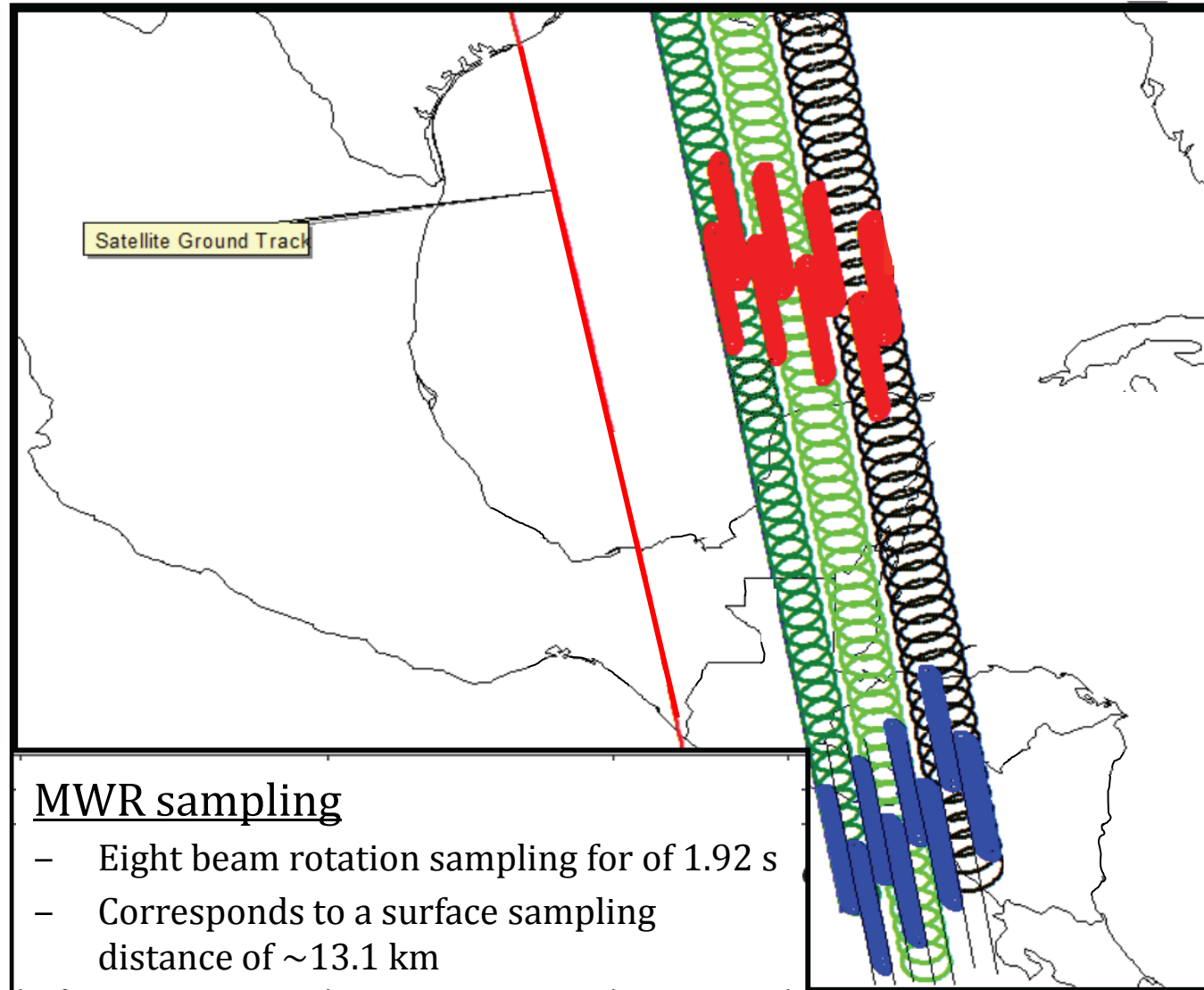
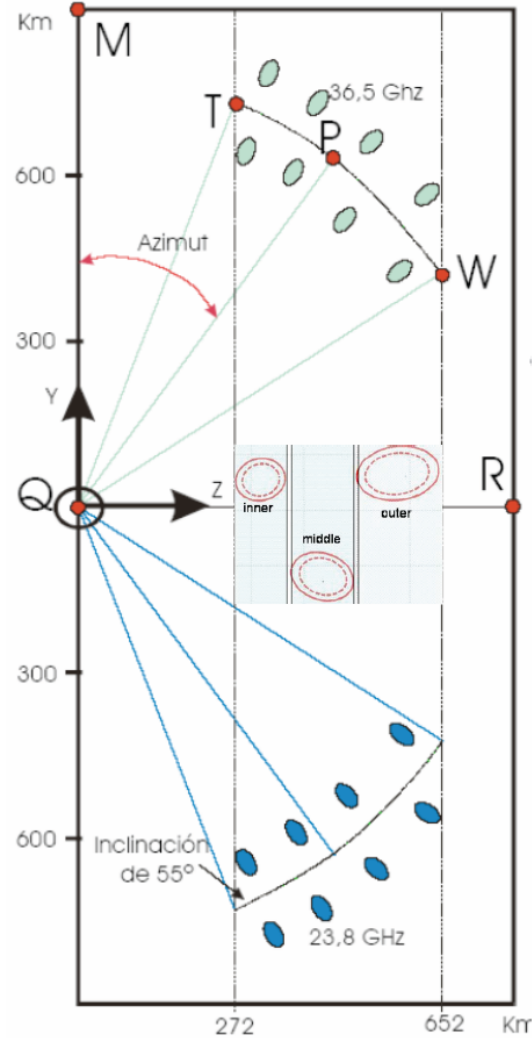
AQ beam geometry

- 3 Beams cross-track (azimuth 90°)
- IFOV size: 79×94 km – 96×156 km
- 380 Km swath

MWR aft-looking beams

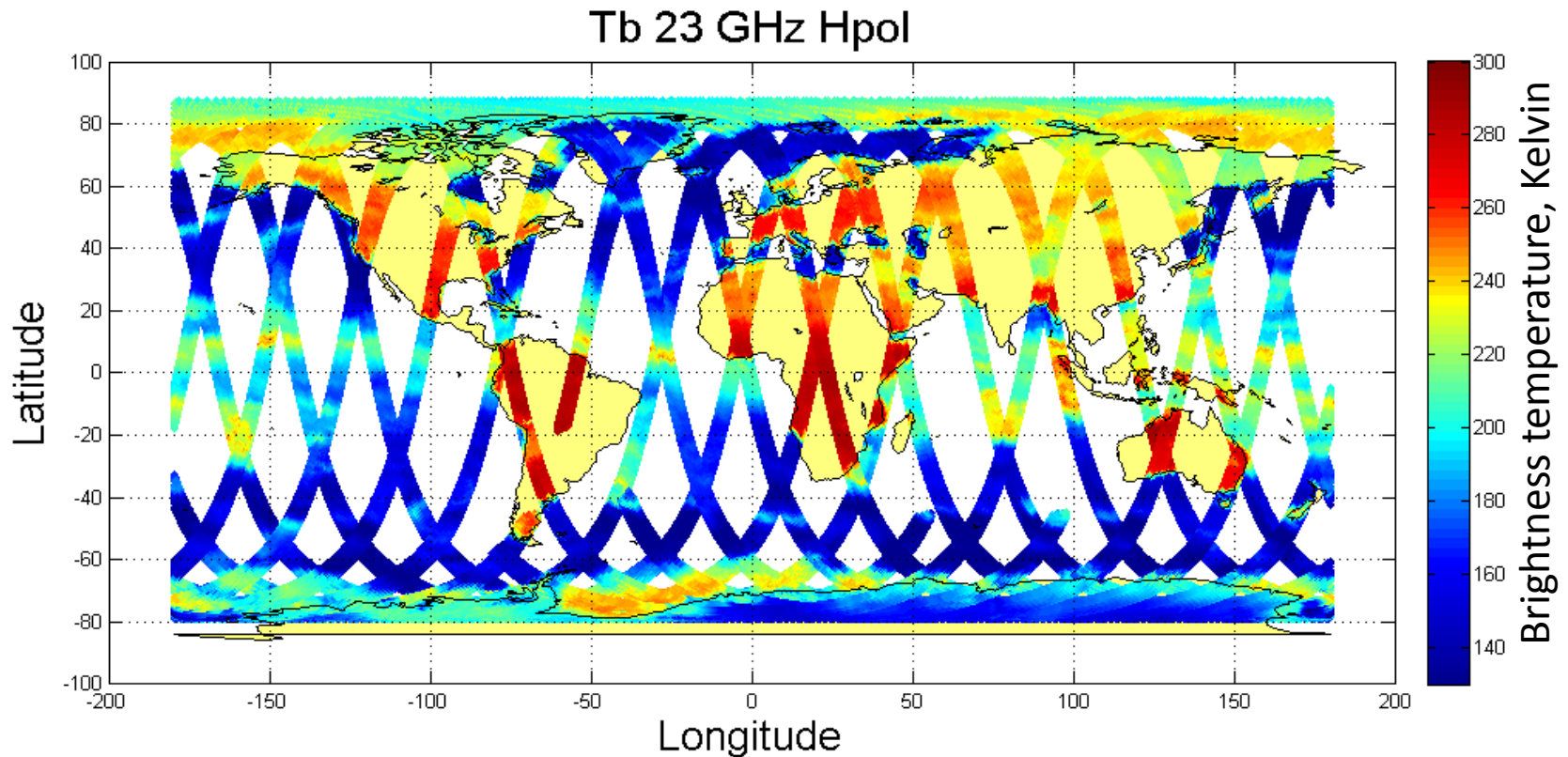
- 8 beams (K-band, H-pol)
- IFOV identical to forward beams

MWR Provides $>$ Nyquist sampling of AQ

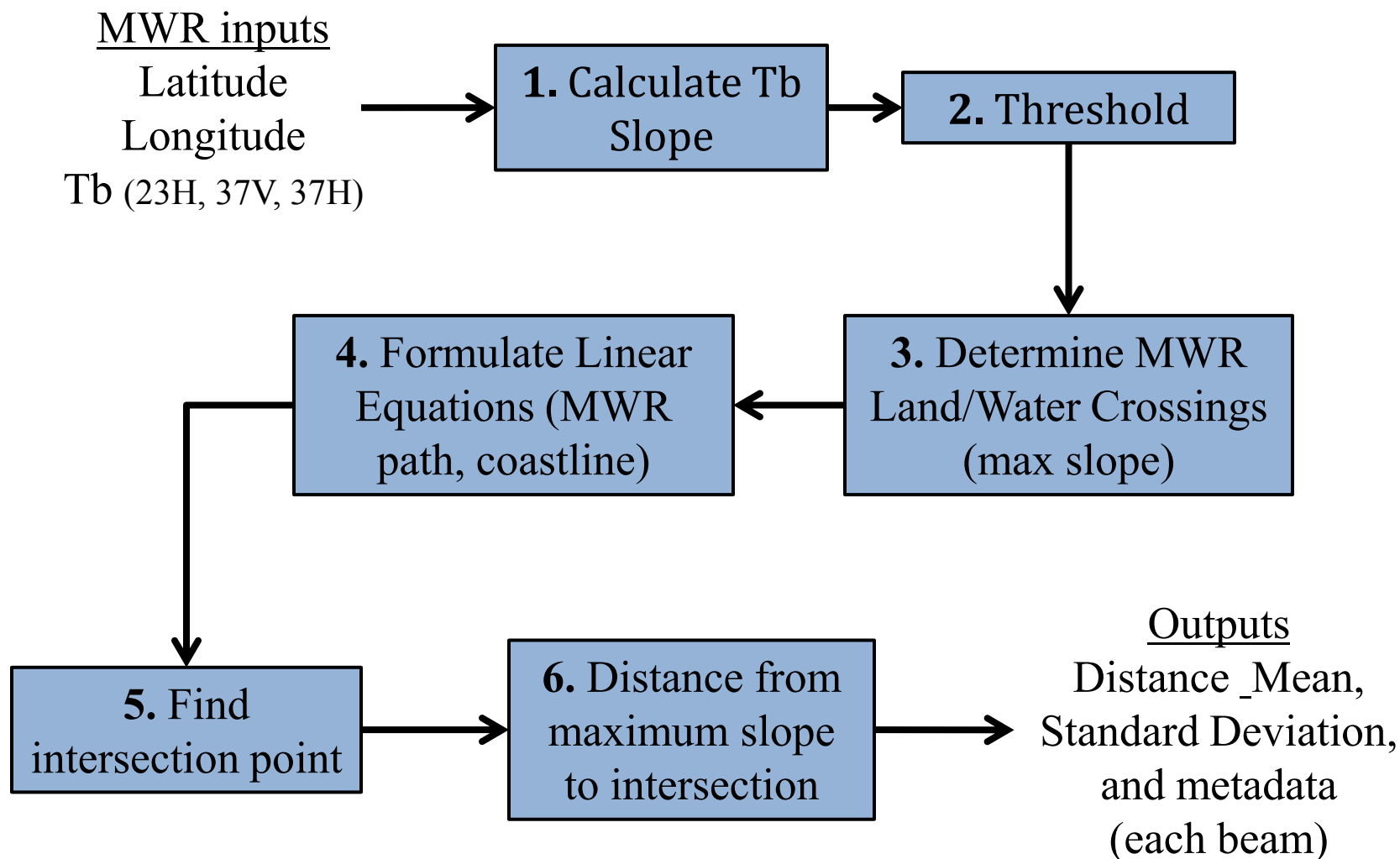


Geolocation Algorithm Approach: Compare MWR Tb Land Images to High Resolution Maps

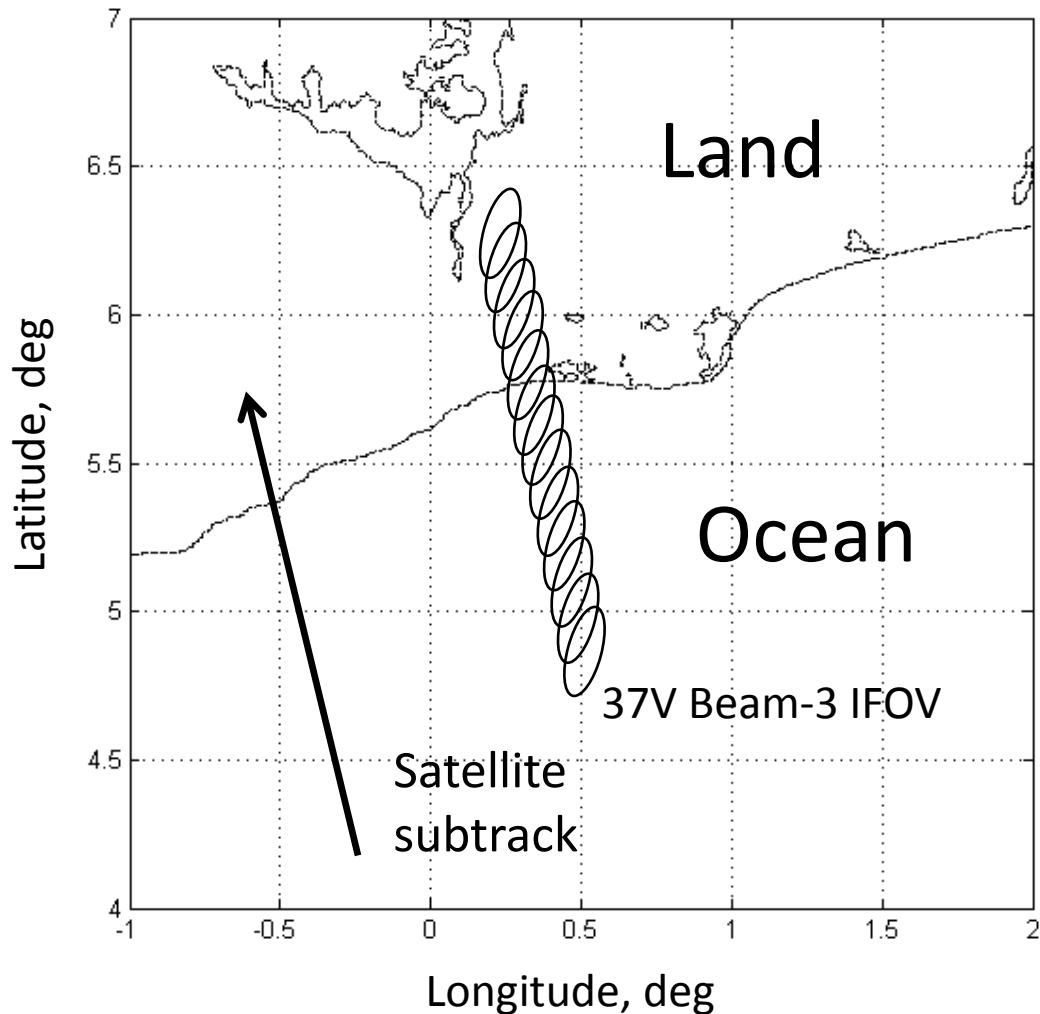
- High contrast brightness temperature (Tb) from ocean to land
- Maximum Tb slope occurs at coastline and indicates 'sensor observed' boundary



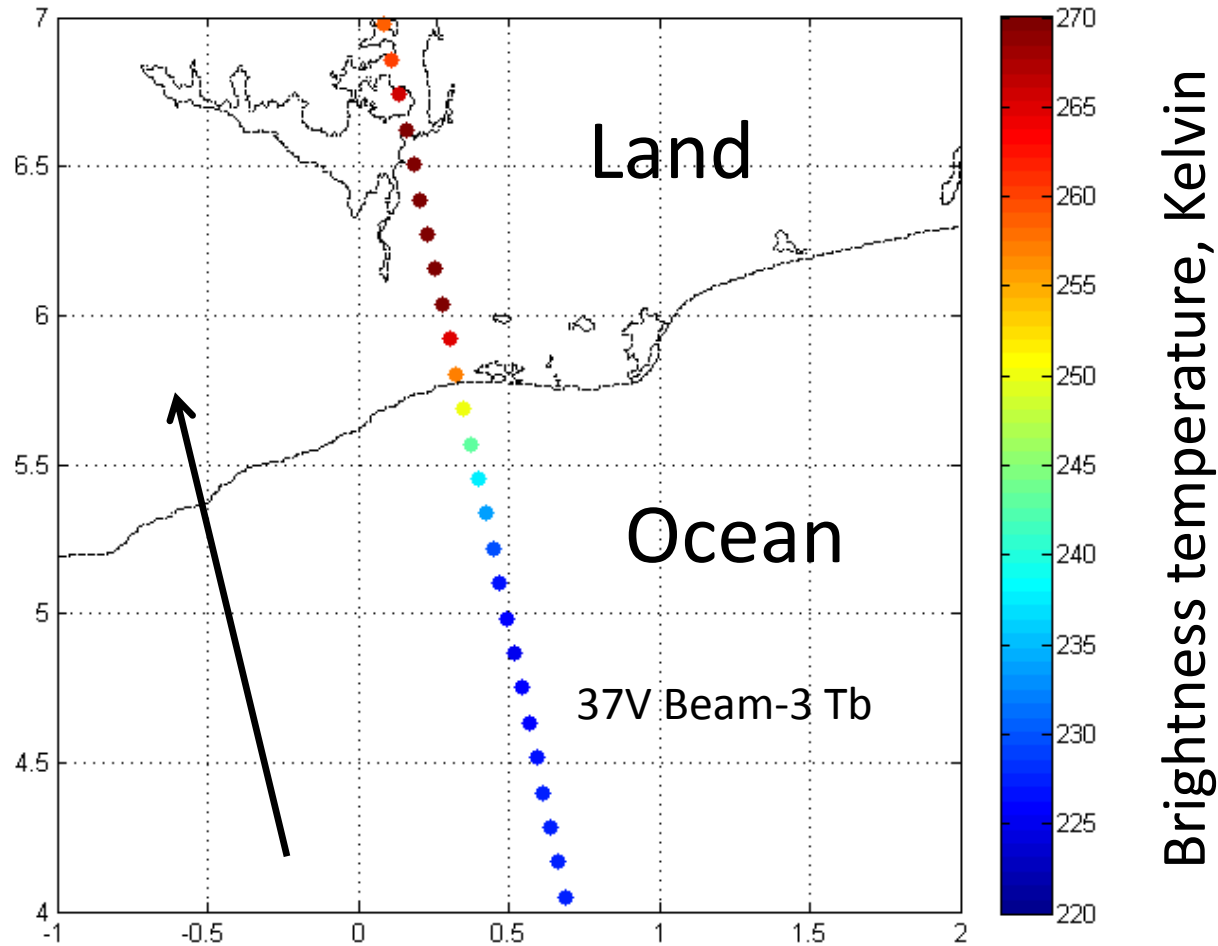
MWR IFOV Geolocation Algorithm



MWR Input: Overlapping Tb Measurements

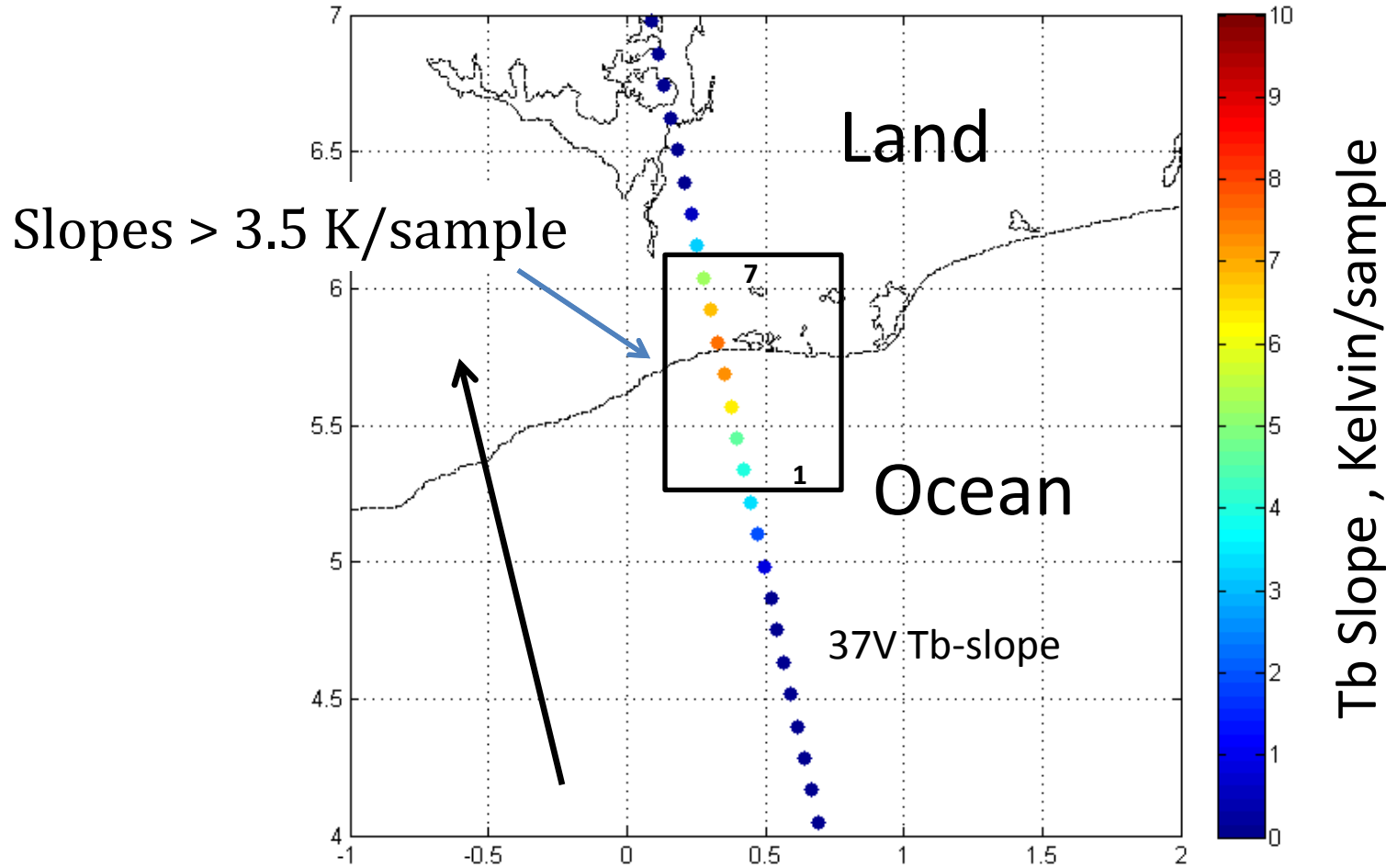


Algo Step 1: Calculate MWR Tb slope



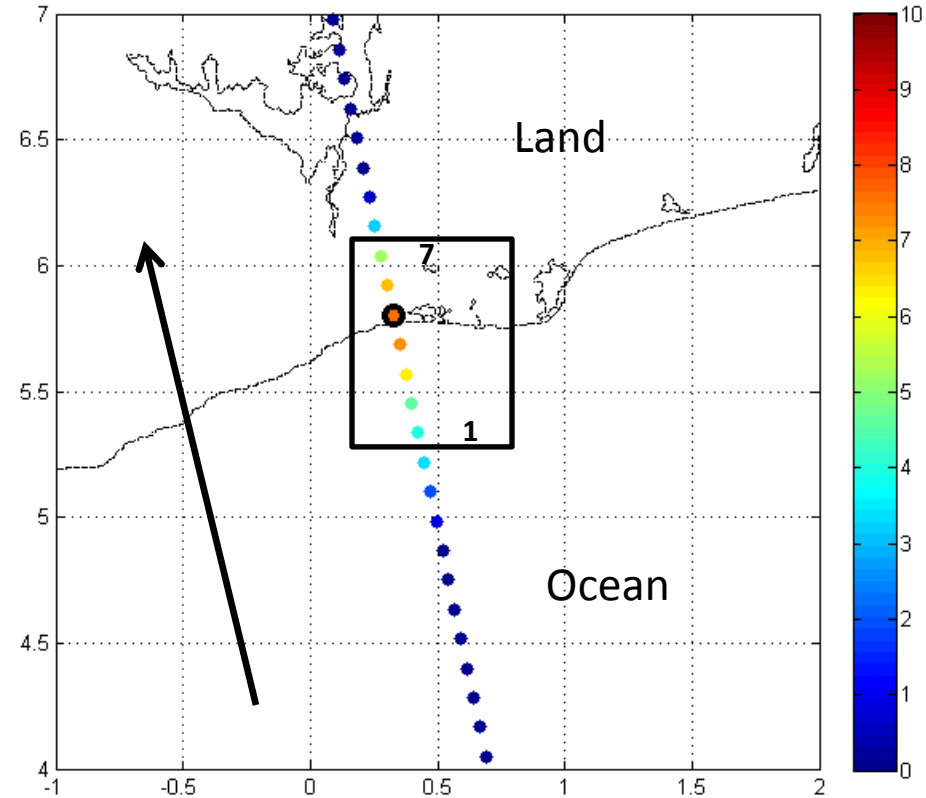
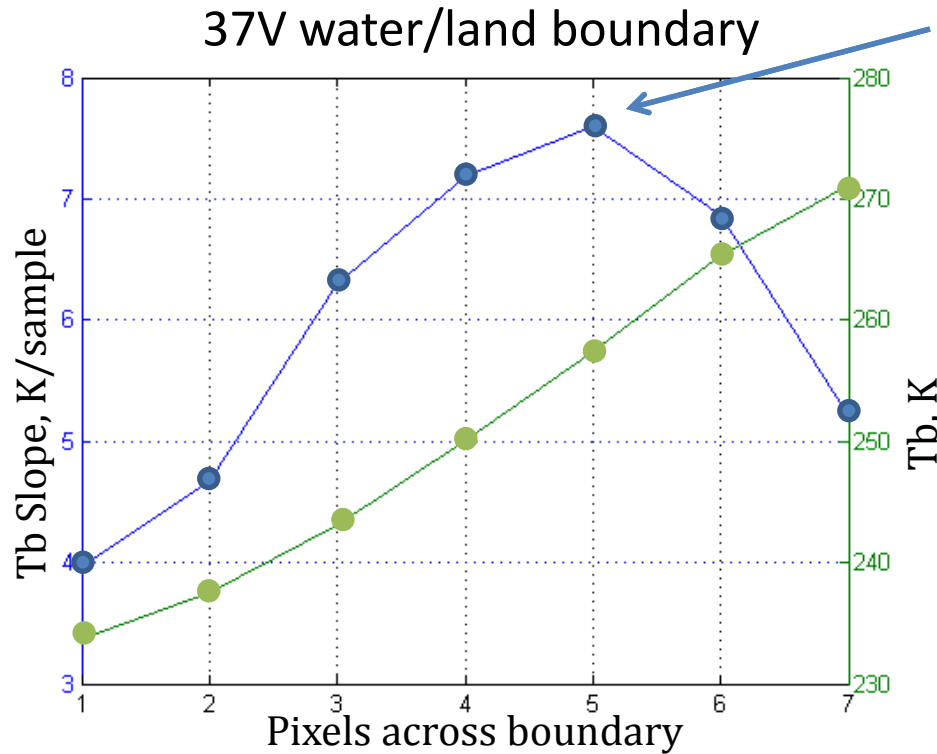
$$Slope_i = \Delta Tb / sample = (Tb_{i+1} - Tb_{i-1}) / 2$$

Algo Step 2: Find Land/Water Boundaries – Tb Slope > Threshold

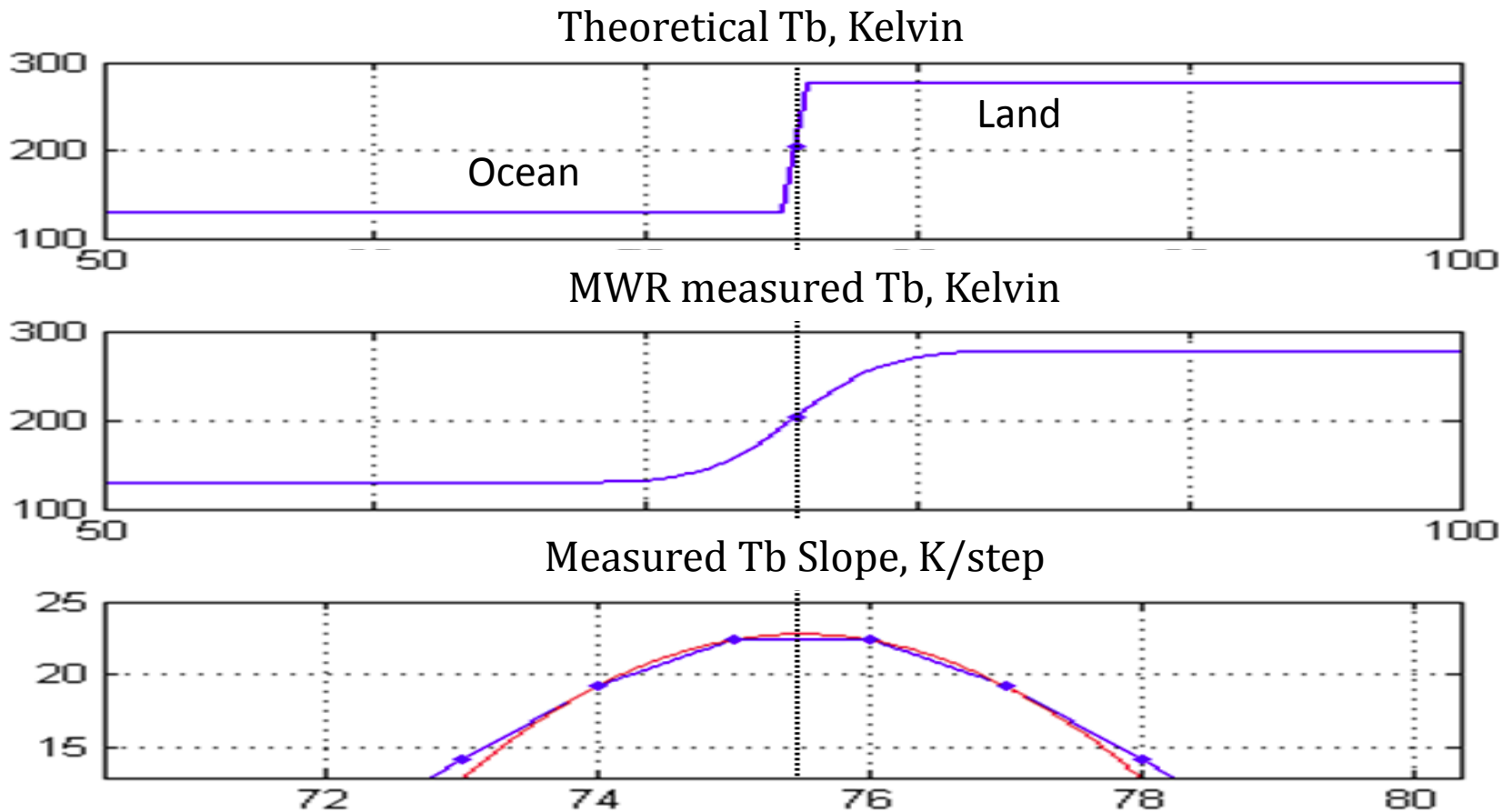


Step 3A: Find MWR Max-slope Location

- Iterative method to follow the threshold curve to the MWR sampled maximum

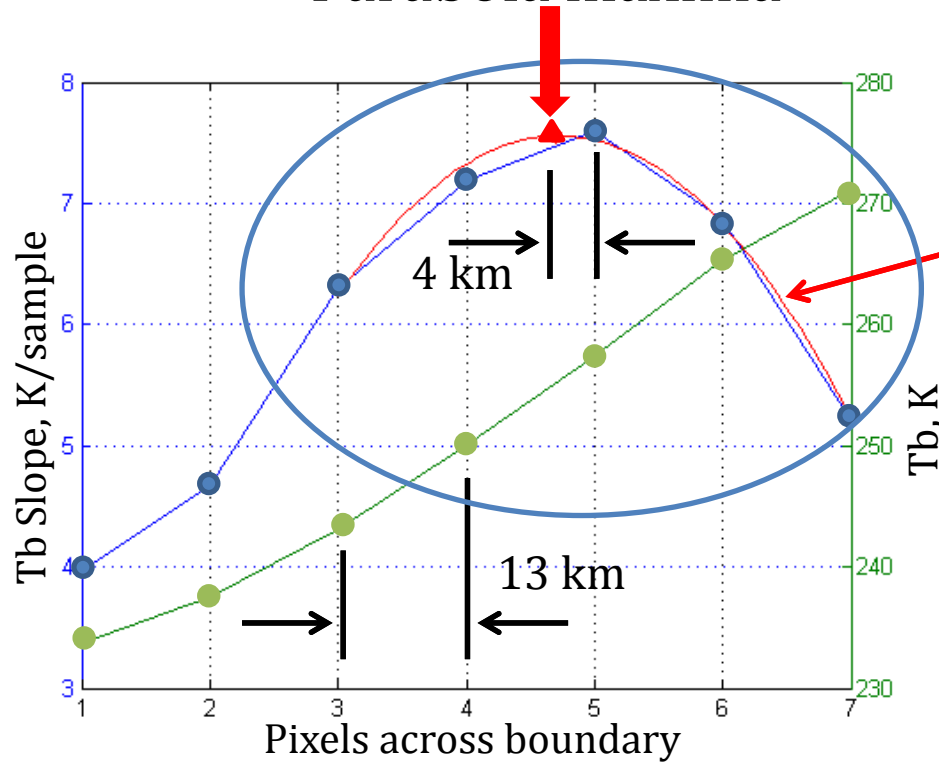


MWR Brightness Temp response to an Ocean/Land Transect

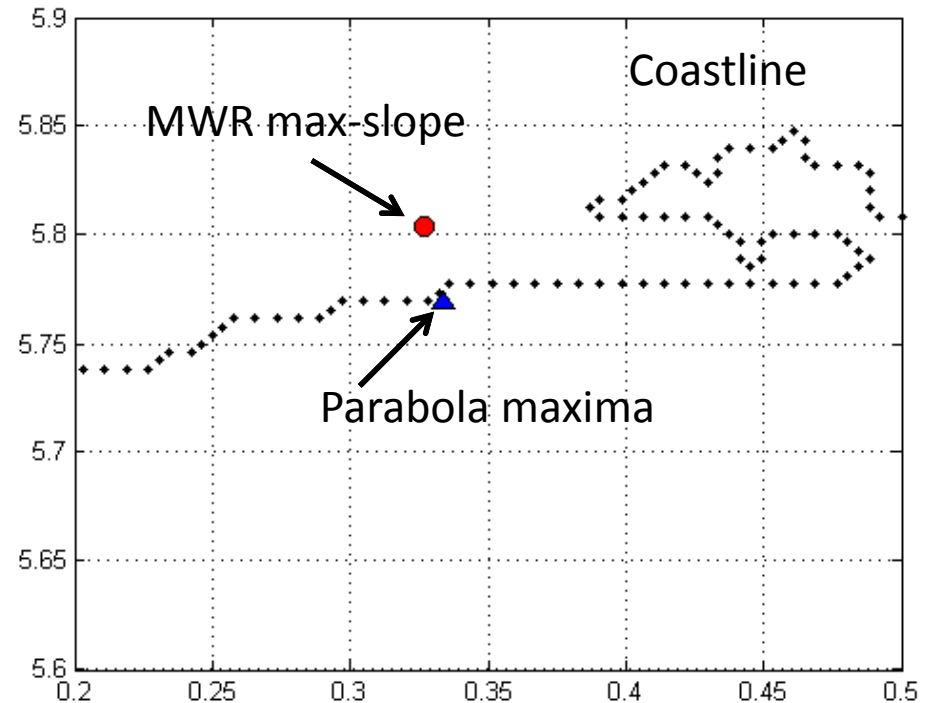


Step 3B: Find Best-fit Parabola Maxima (interpolated max-slope location)

Parabola maxima

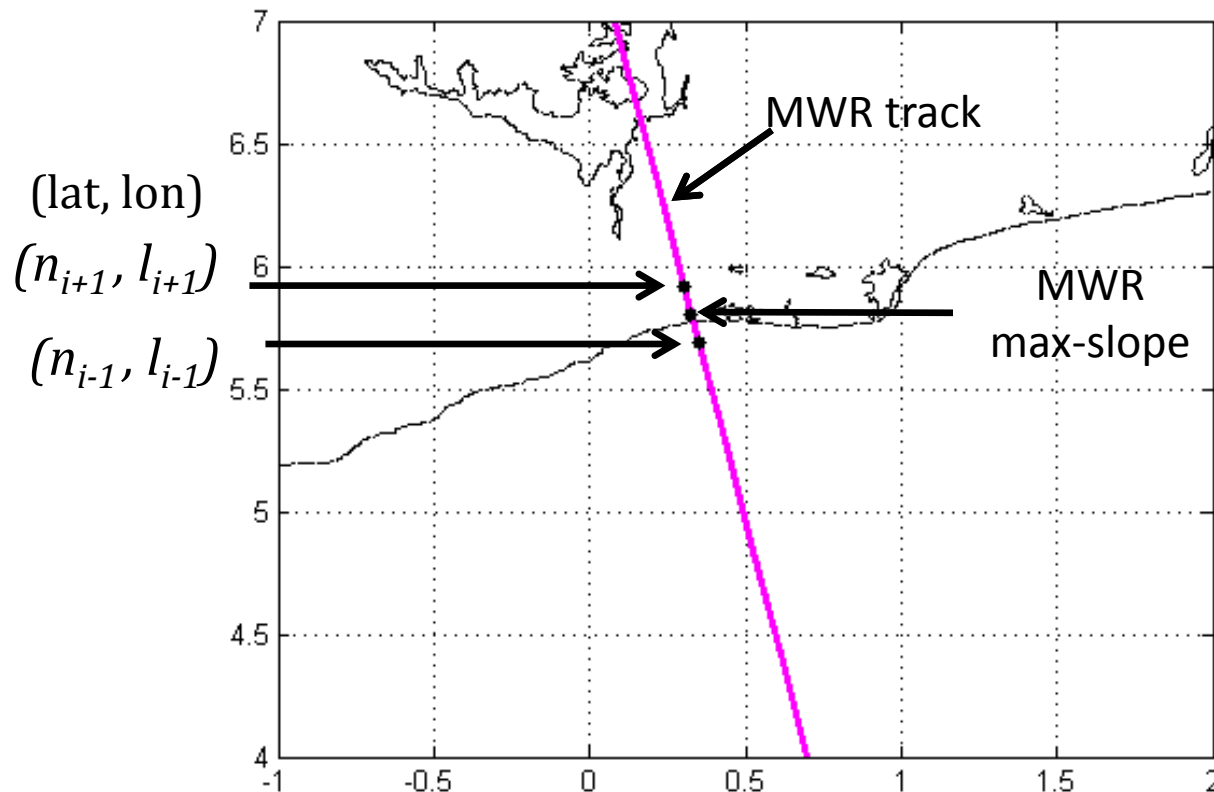


Parabolic curve-fit



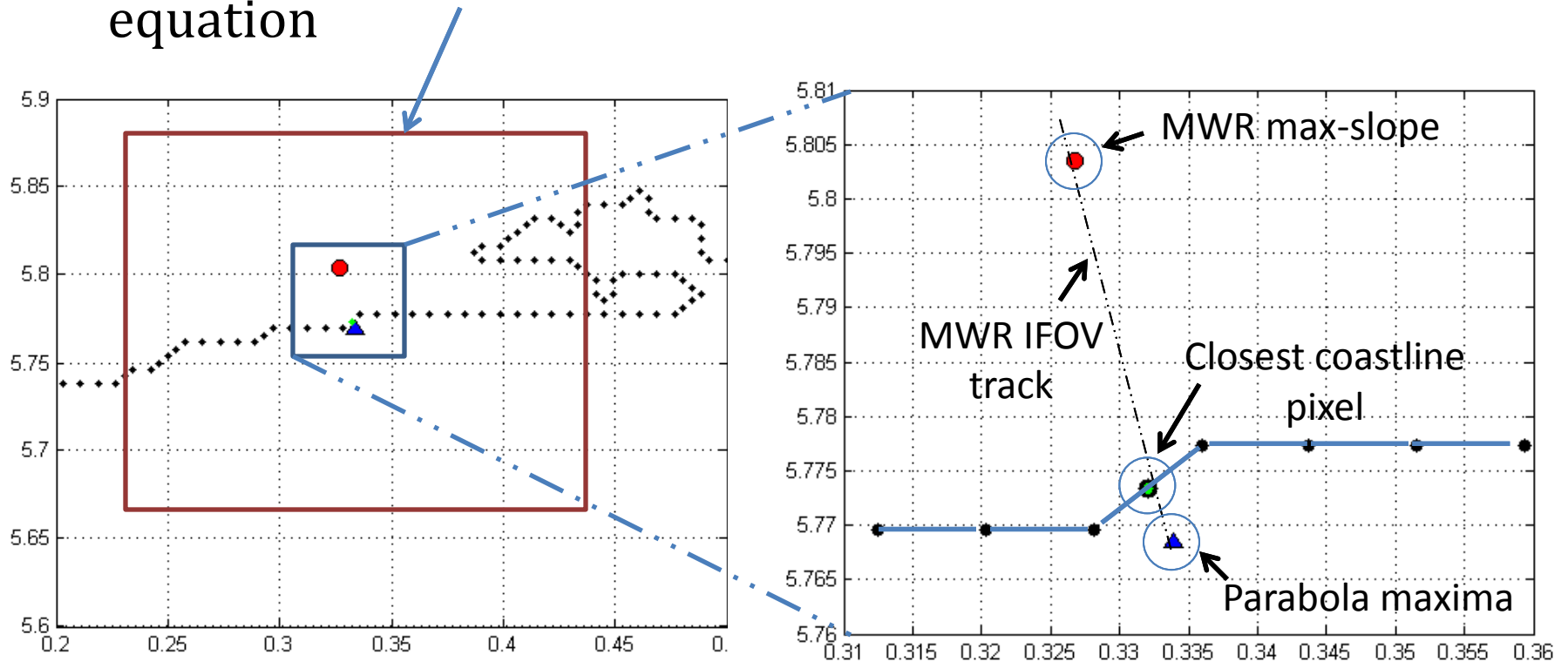
Step 4A: Linear Equation for MWR Track

$$Y = \underbrace{\left(\frac{l_{i+1} - l_{i-1}}{n_{i+1} - n_{i-1}} \right)}_{\text{slope}} X + \underbrace{\left(l_{i+1} - \left(\frac{l_{i+1} - l_{i-1}}{n_{i+1} - n_{i-1}} \right) n_{i+1} \right)}_{\text{offset}}$$



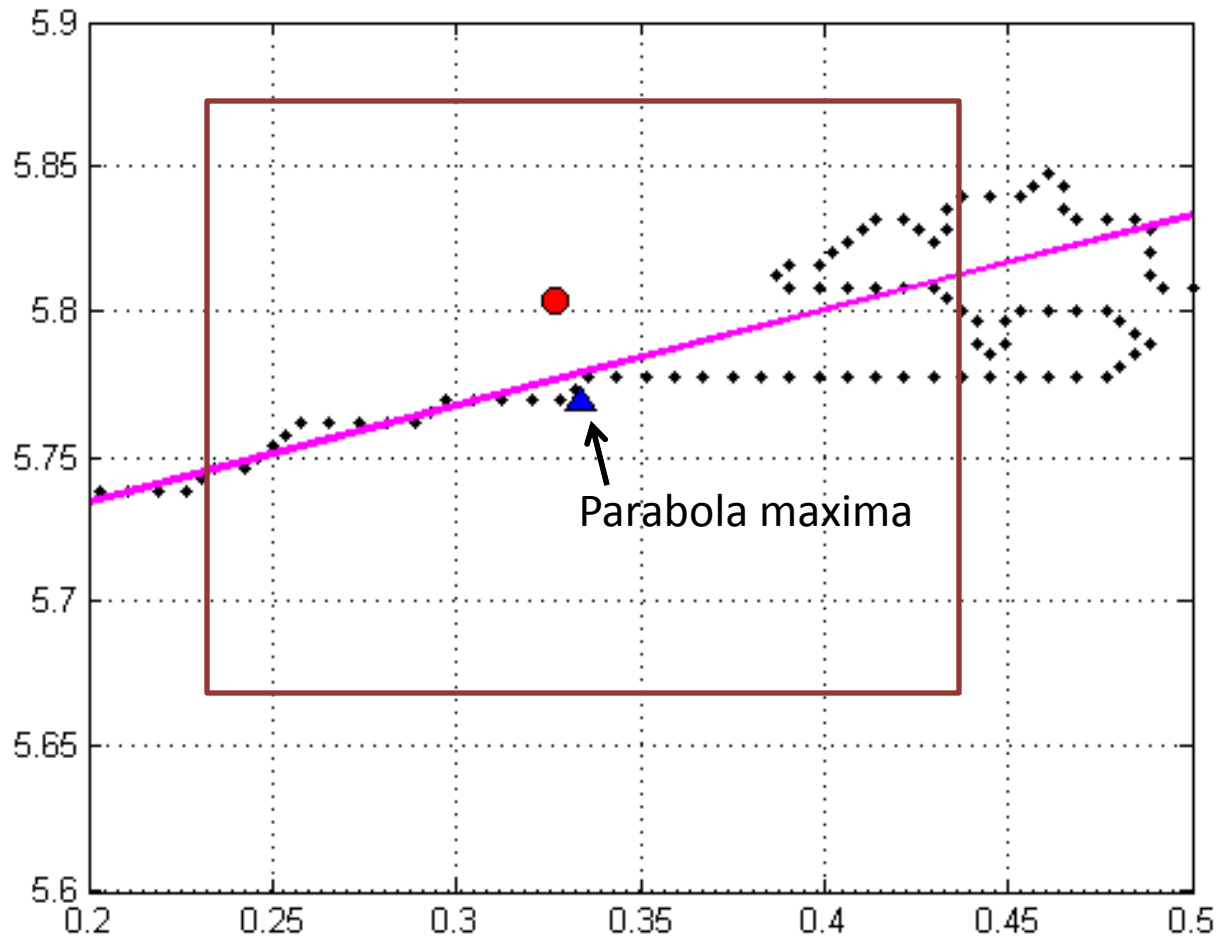
Step 4B: Find Coast Line Pixels

- Find closest coastline pixel to parabola maxima
- Construct ± 0.1 deg box of coast points for best-fit linear equation

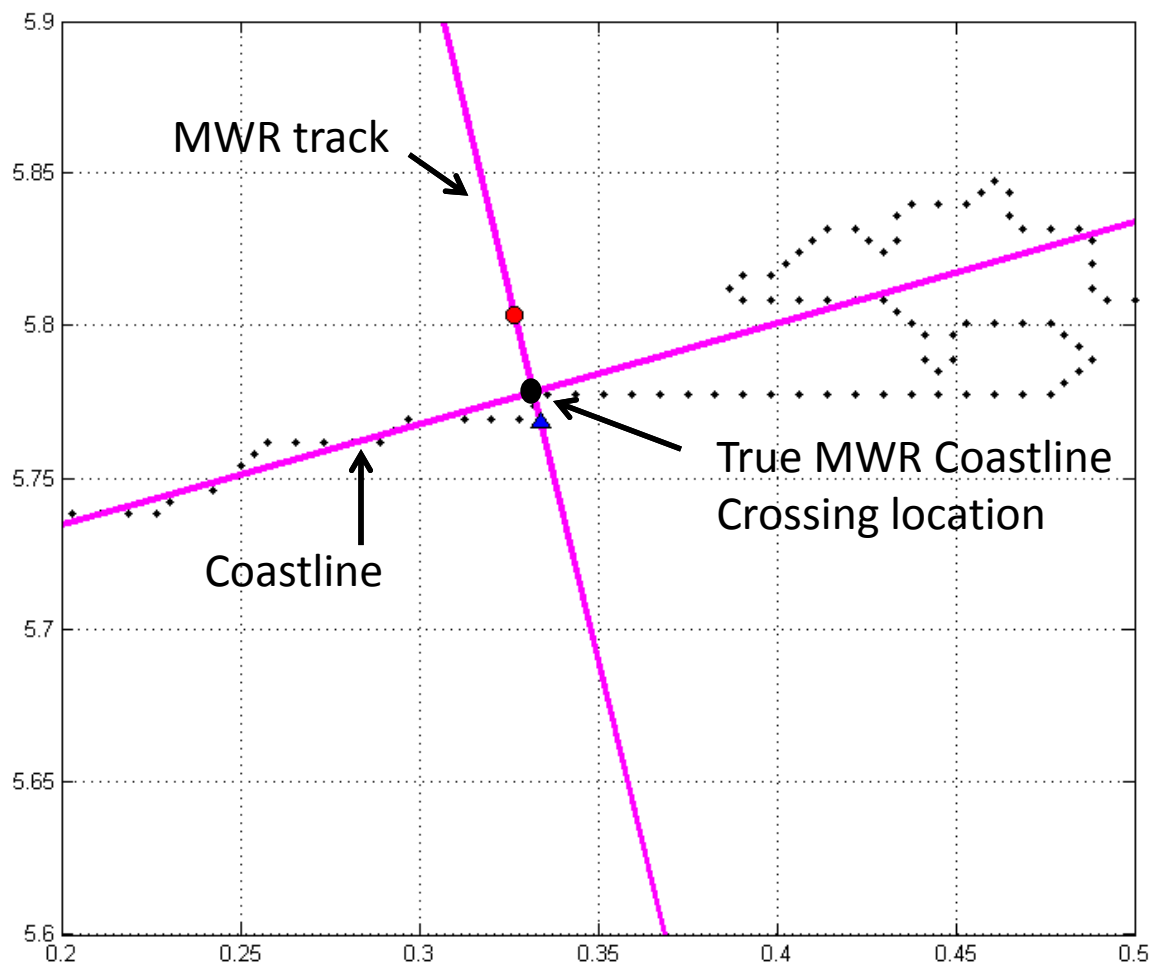


Step 4C: Best-fit Linear Coastline

- Within ± 0.1 deg box perform linear regression using coastline pixels

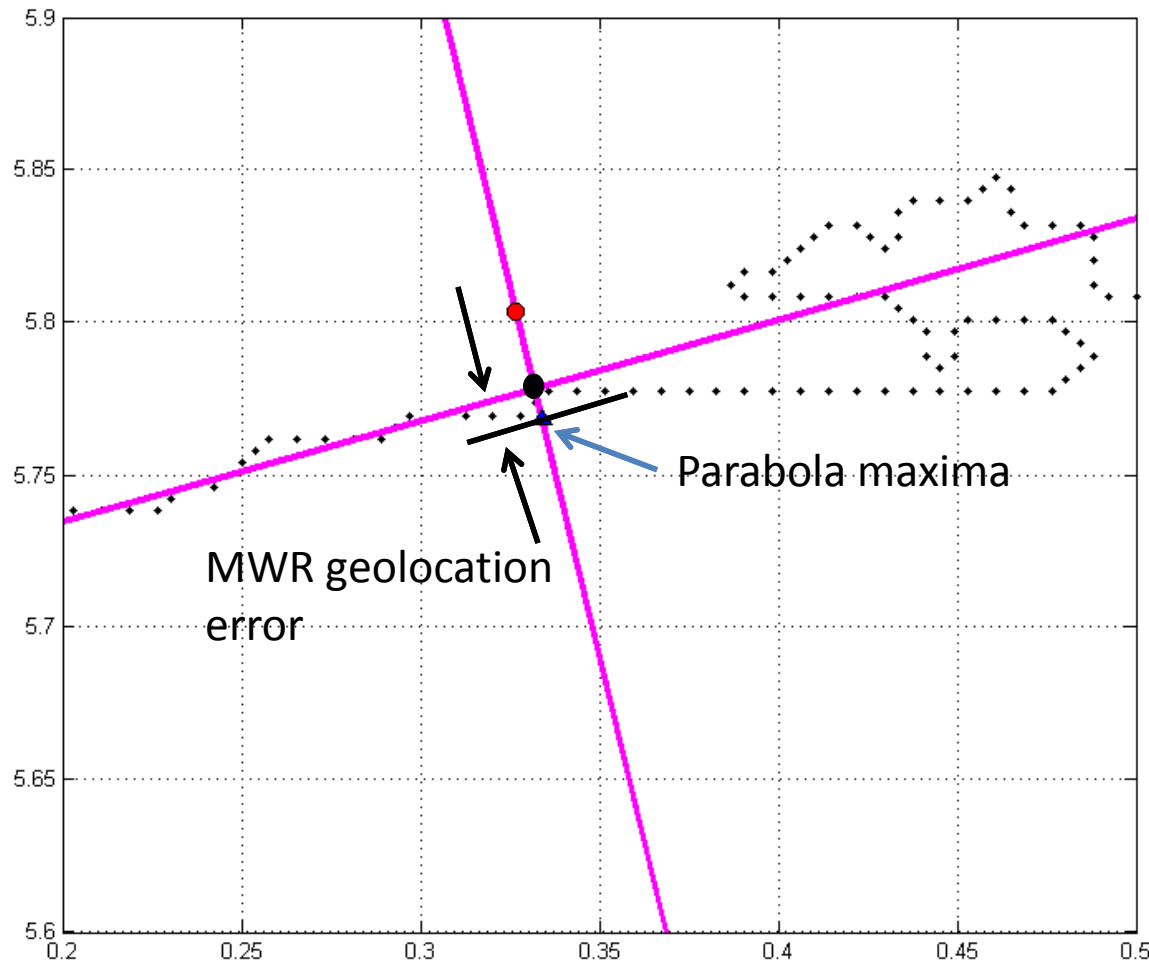


Step 5: Find MWR Coastline Crossing Location (Solve Simultaneous Linear Equations)

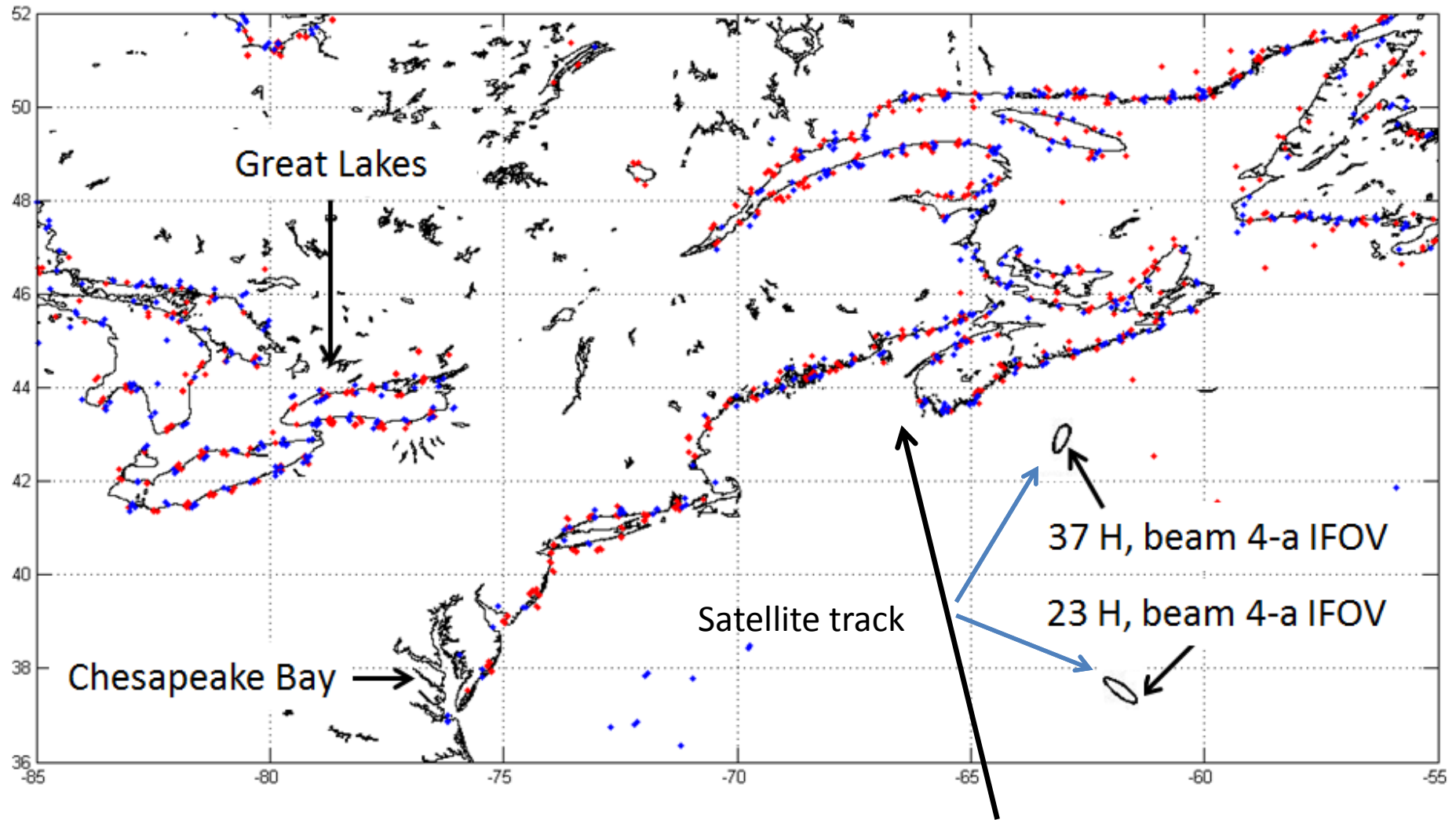


Step 6: Calculate Geolocation Error Distance

$$d = \sqrt{[(l_i - l_p) 111.12]^2 + [(n_i - n_p) 111.12 \cos\left(\frac{(l_i + l_p)}{2}\right)]^2}$$

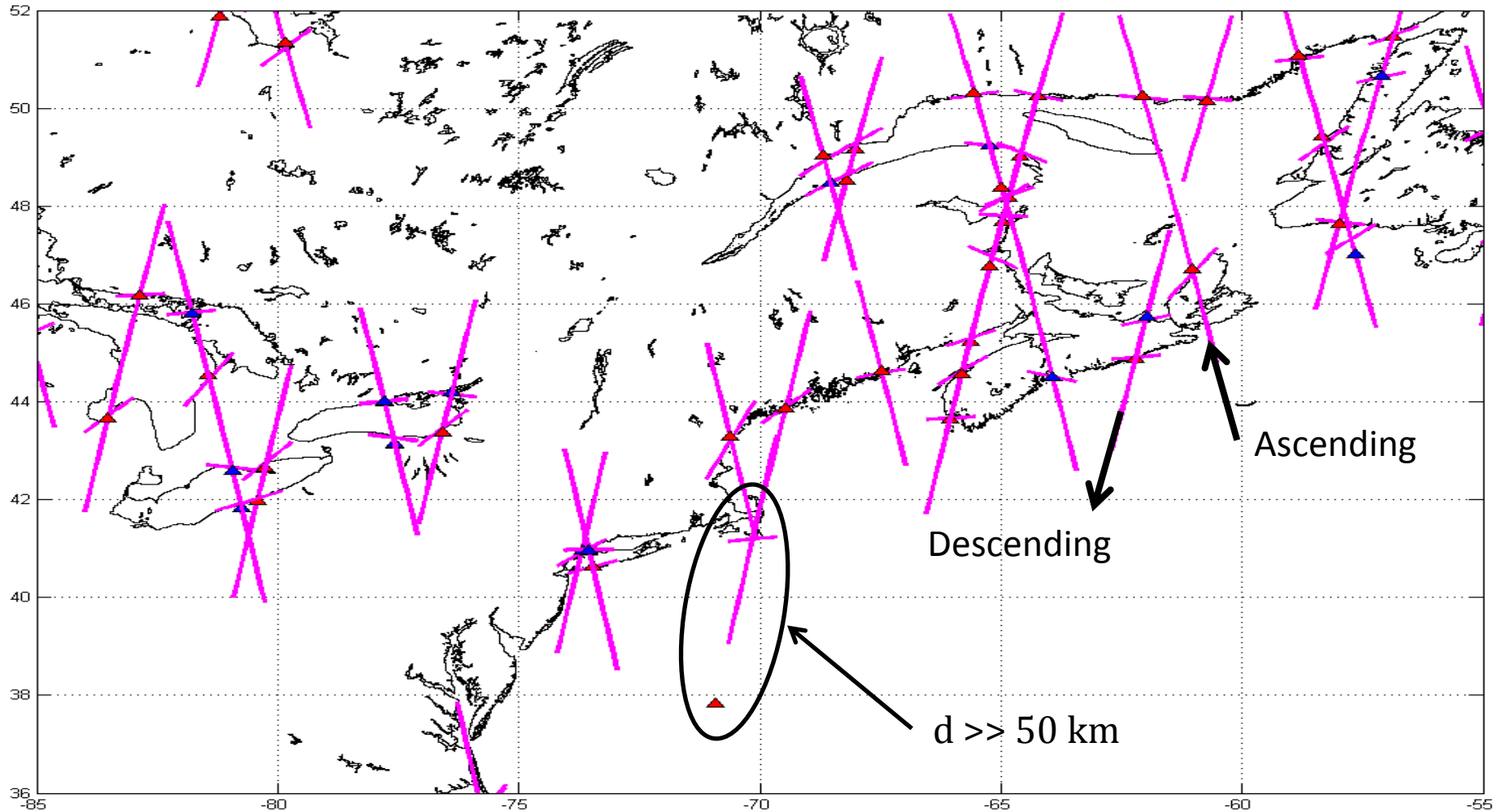


Land/Water Boundaries Observed – 7 days



Ascending/Descending Orbits Intersections

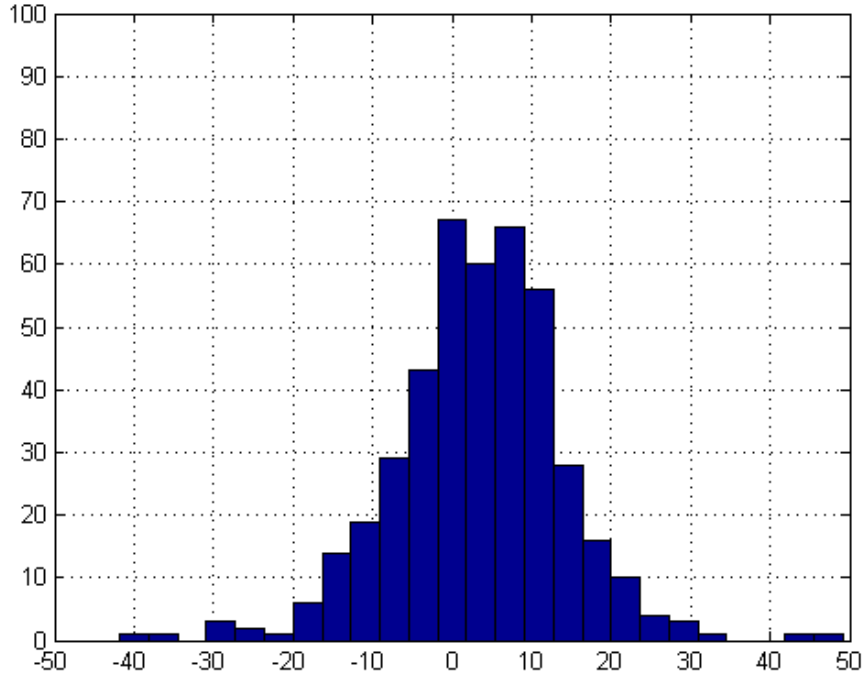
37V, beam 3 ascending and descending



Parabolic Fit Improvement

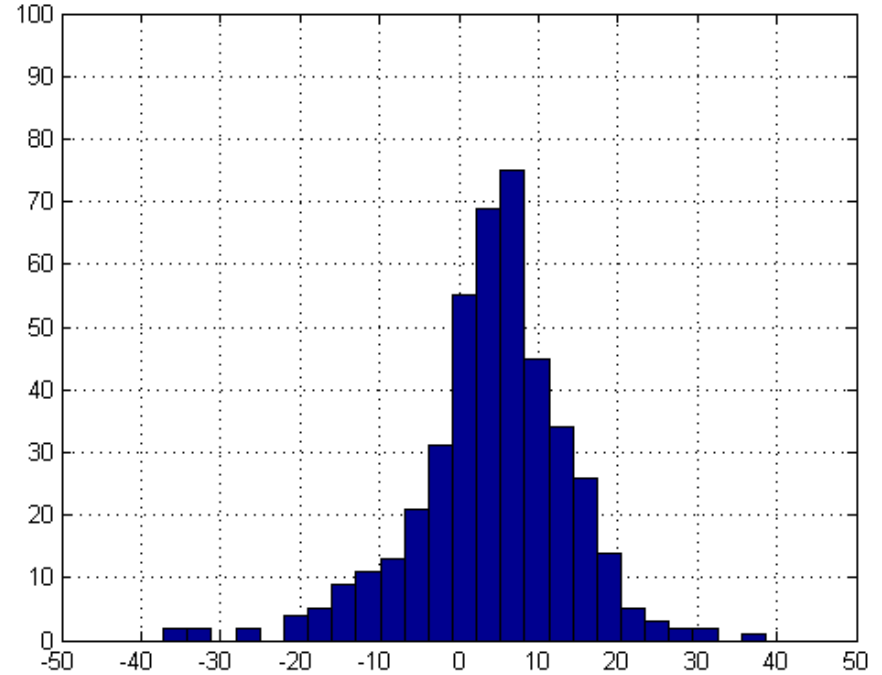
37V, Beam 1, Ascending

Error based on MWR max-slope



Mean = 3.3 km, StD = 10.7 km

Error based on Parabola maxima



Mean = 4.2 km, StD = 9.9 km

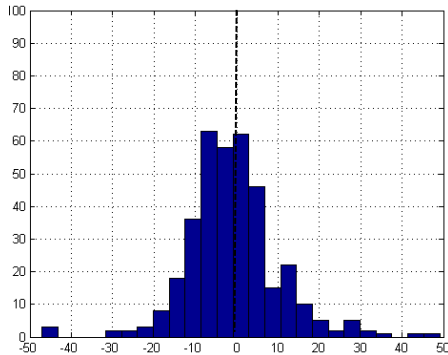
Error Analysis: Statistical Sorting by Parameters

- It is believed that geolocation should be independent of the following parameters:
 - Beam #
 - Ascending / descending passes
 - Water-to-land and land-to-water crossings
 - Latitude of crossing
 - Angle of intersection

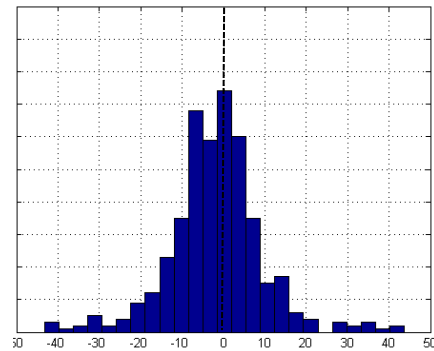
Geolocation Error by MWR Beams, 23 GHz

7-days, Descending Orbits

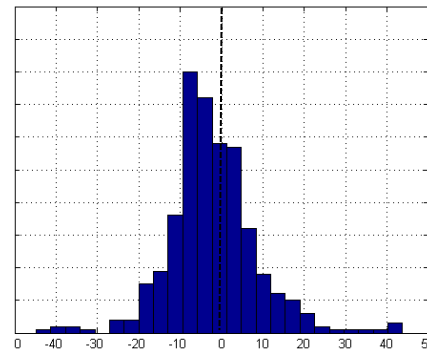
Beam -1



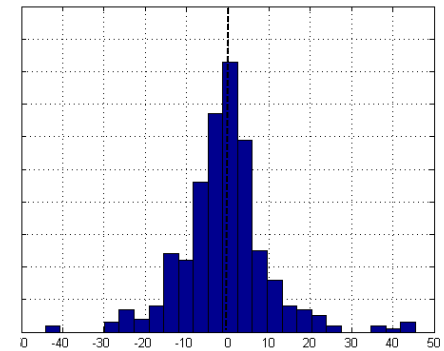
Beam -3



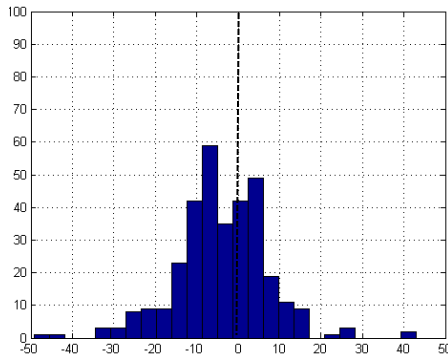
Beam -5



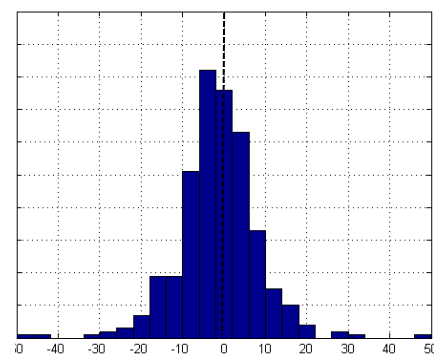
Beam -7



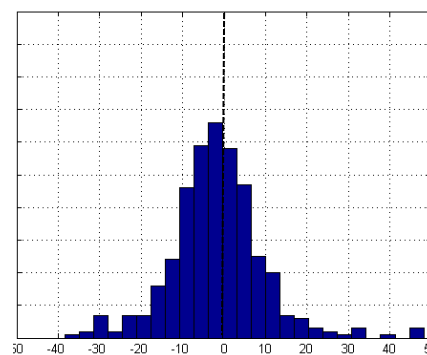
Beam -2



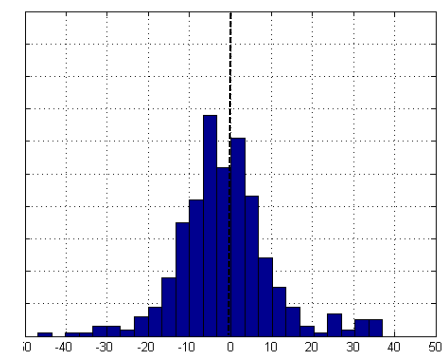
Beam -4



Beam -6

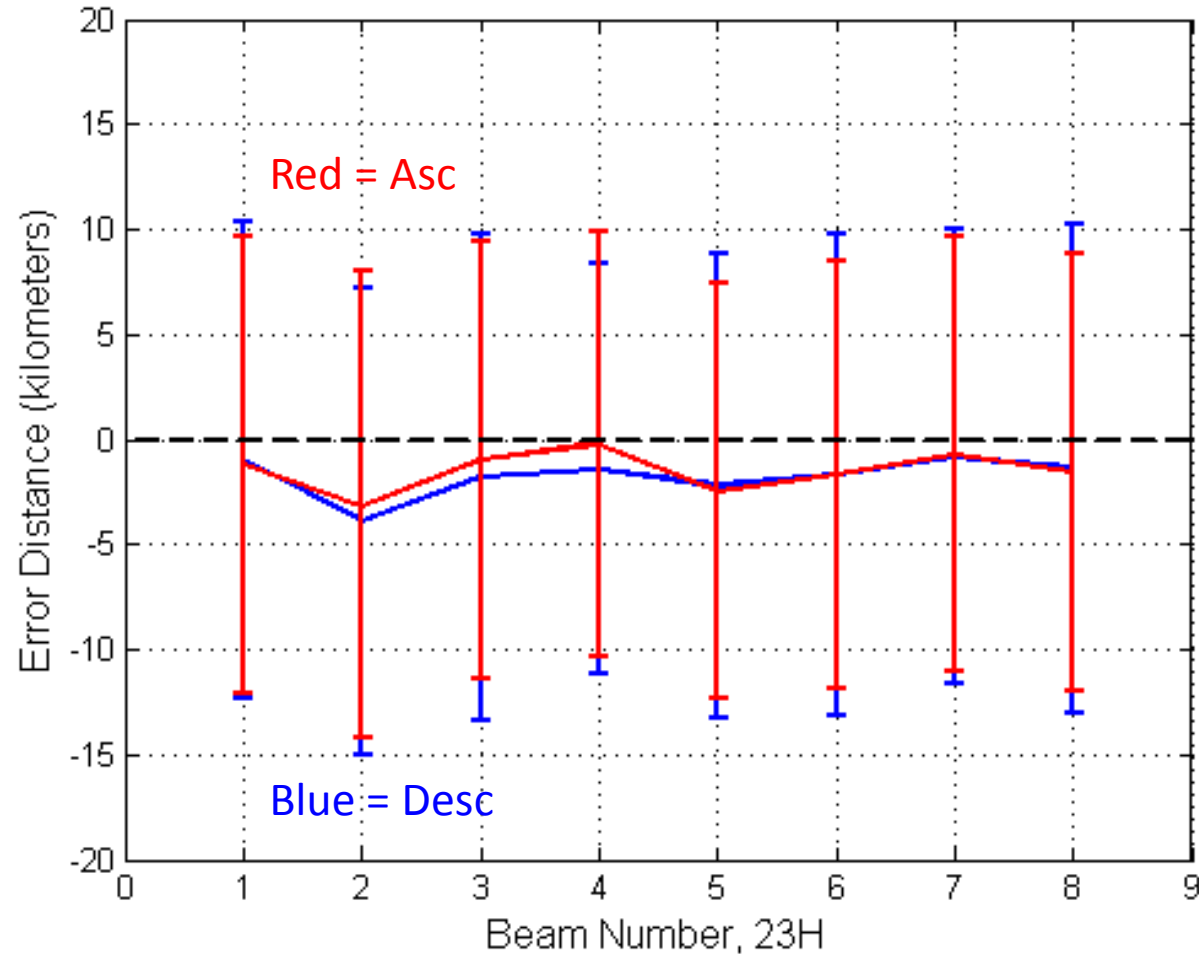


Beam -8



Geolocation Error Separately for Ascending/ Descending Orbits

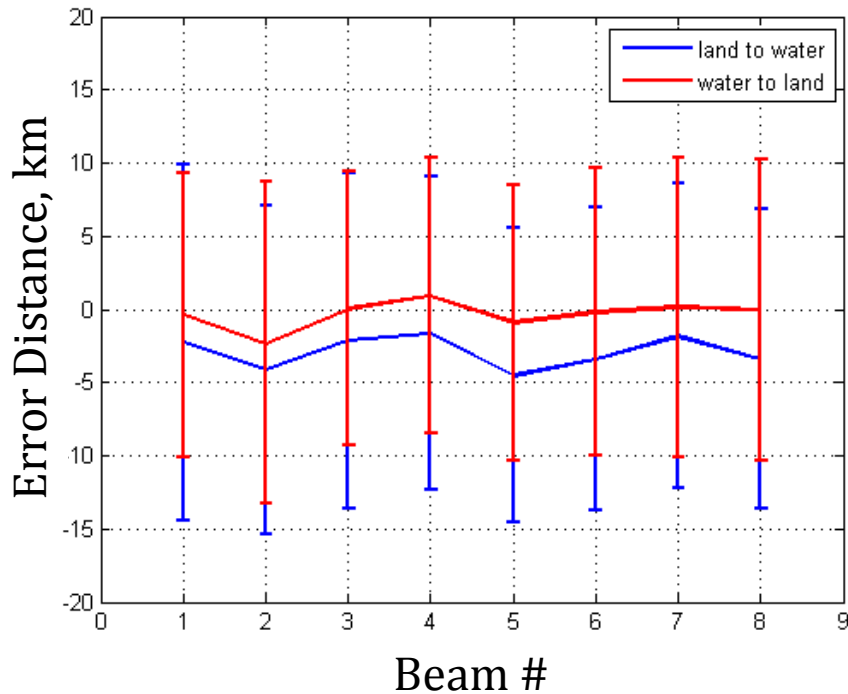
23 GHz Error Distance



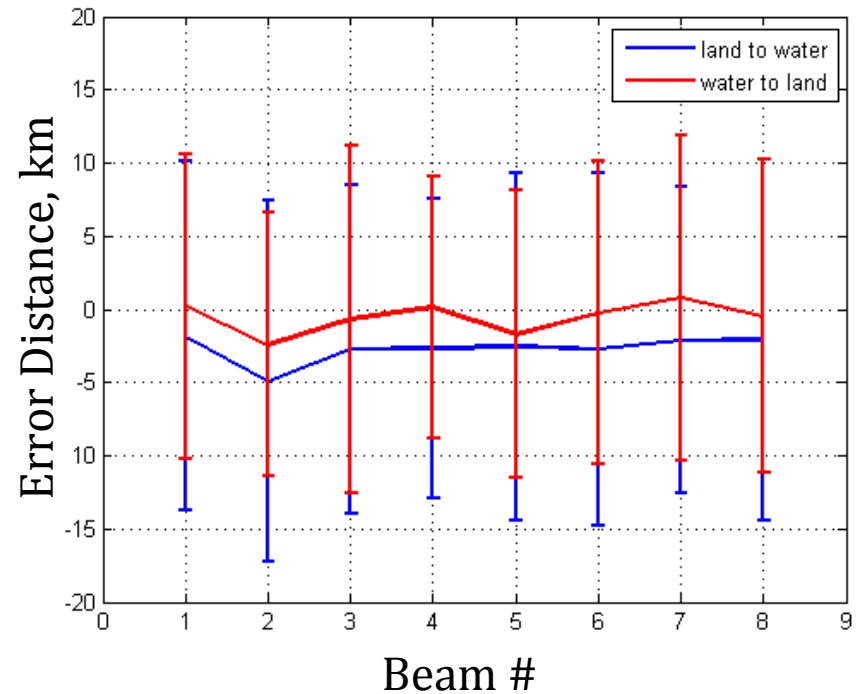
Geolocation Error Separately for Land-to-Water and Water-to-Land

23 GHz

Ascending



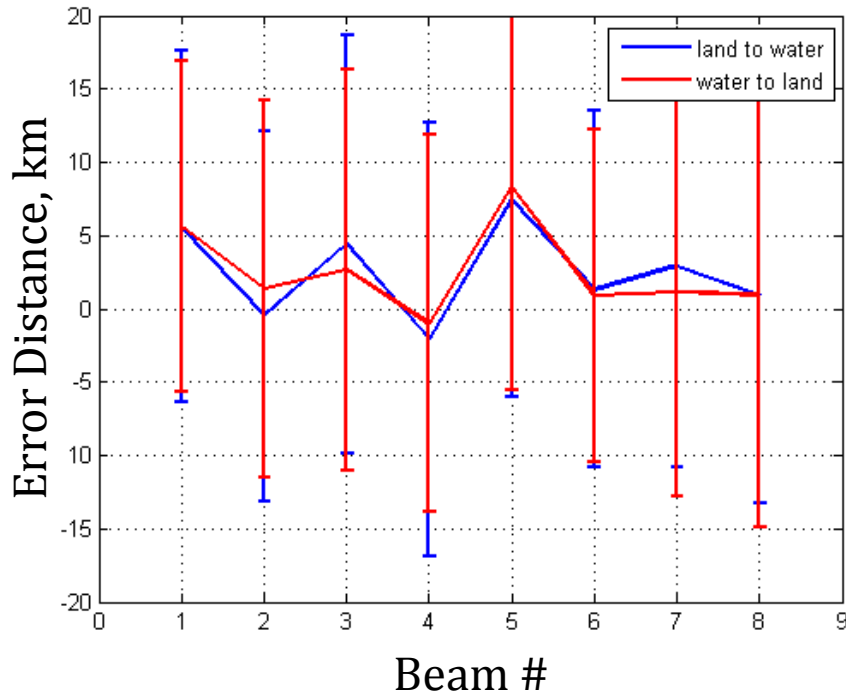
Descending



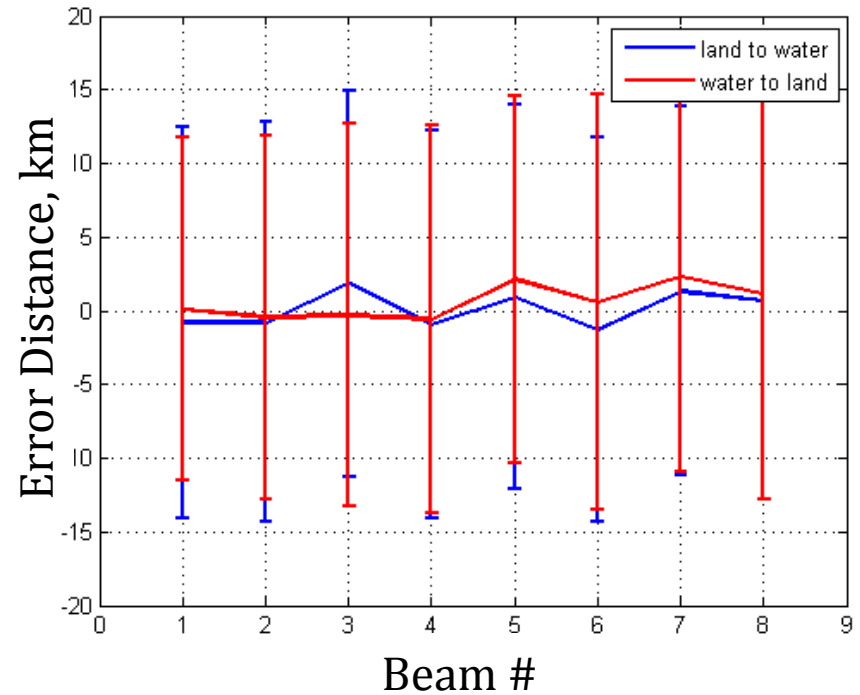
Geolocation Error Separately for Land-to-Water and Water-to-Land

Descending

37 V-pol



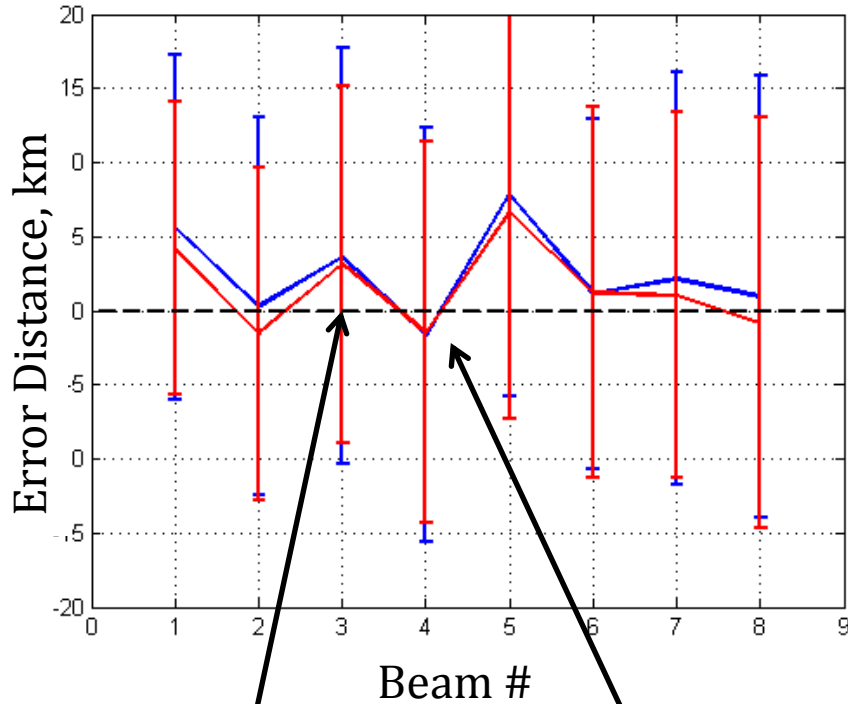
37 H-pol



Geolocation Error Separately for Even/Odd Beams

37 V&H Channel Pattern

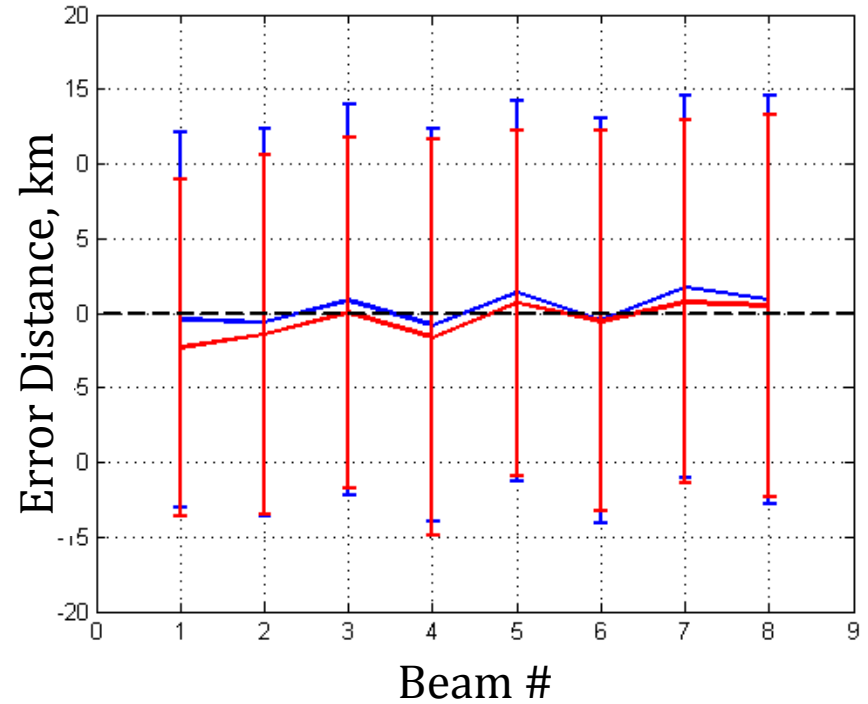
37 V-pol



Odd Beams
positive values

Even Beams
negative values

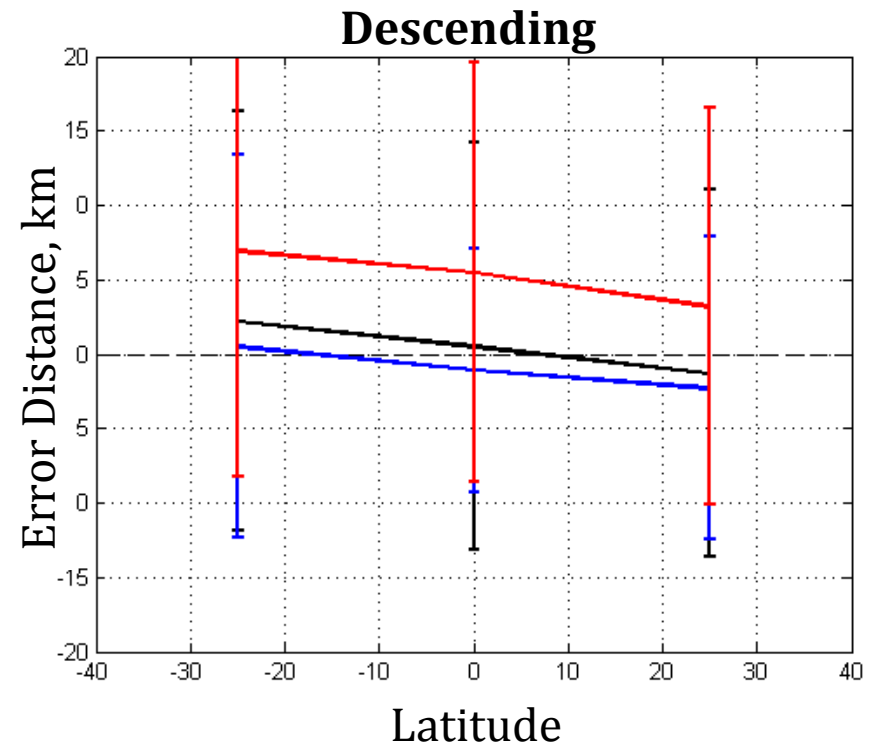
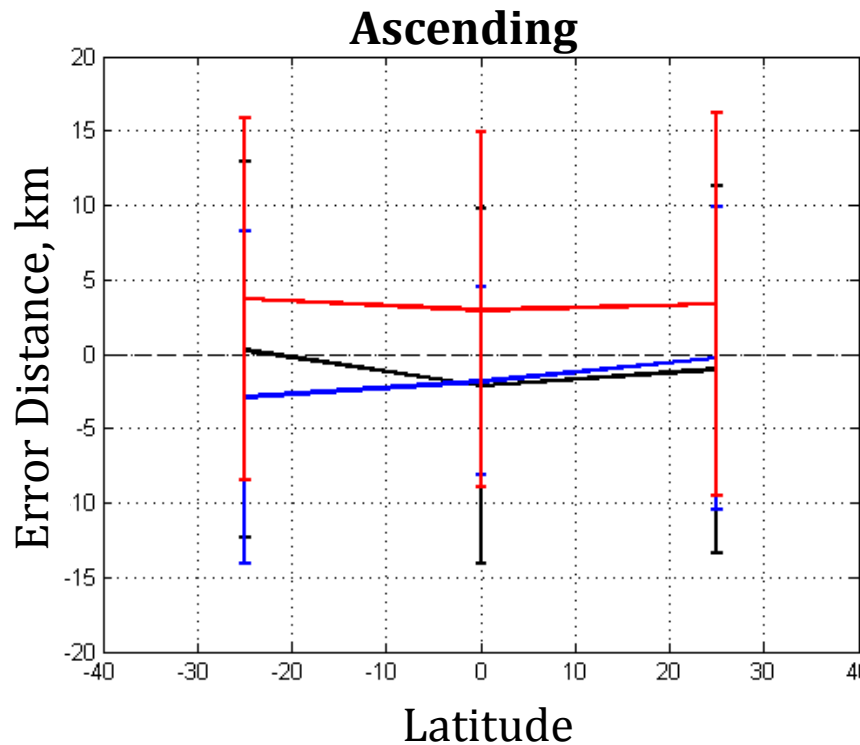
37 H-pol



Cannot combine all beams of the 37
V&H channels, bad assumption

Geolocation Error Latitude Dependence

Odd Beams



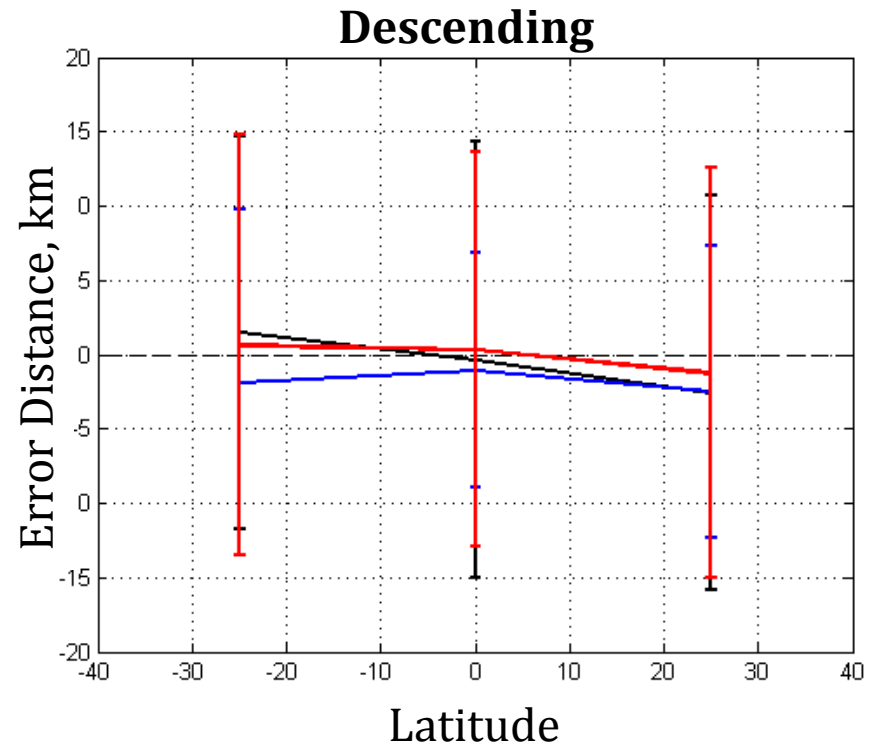
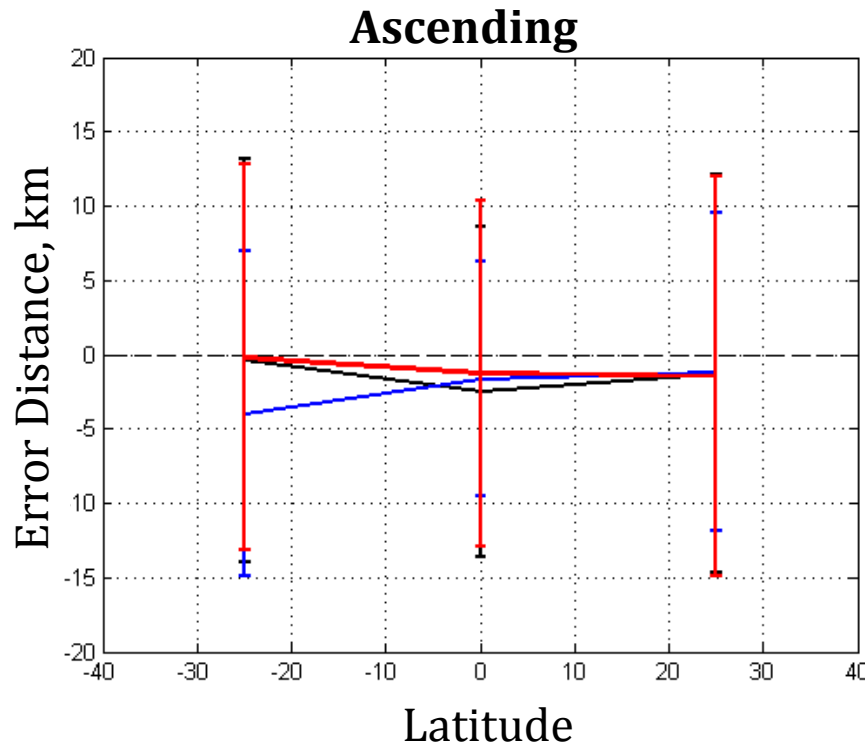
Blue - 23H

Red - 37V

Black - 37H

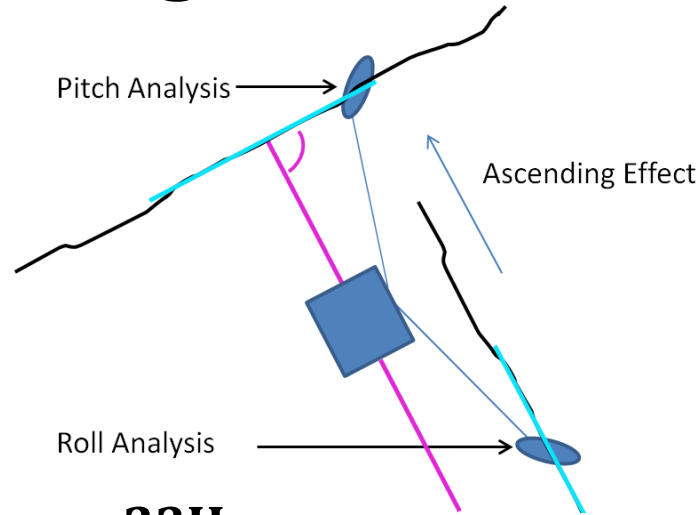
Geolocation Error Latitude Dependence

Even Beams

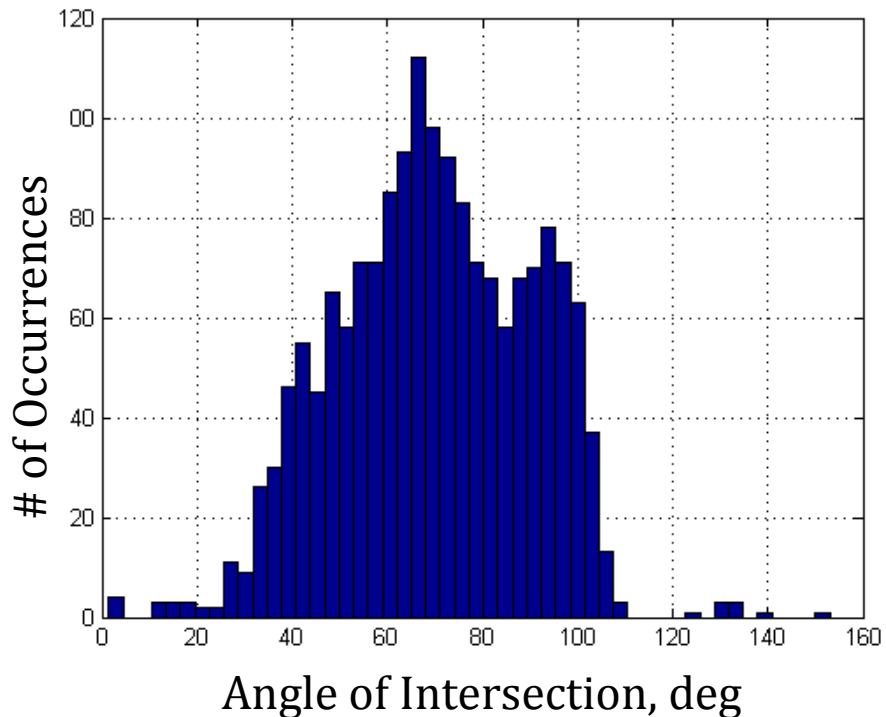


Blue - 23H
Red - 37V
Black - 37H

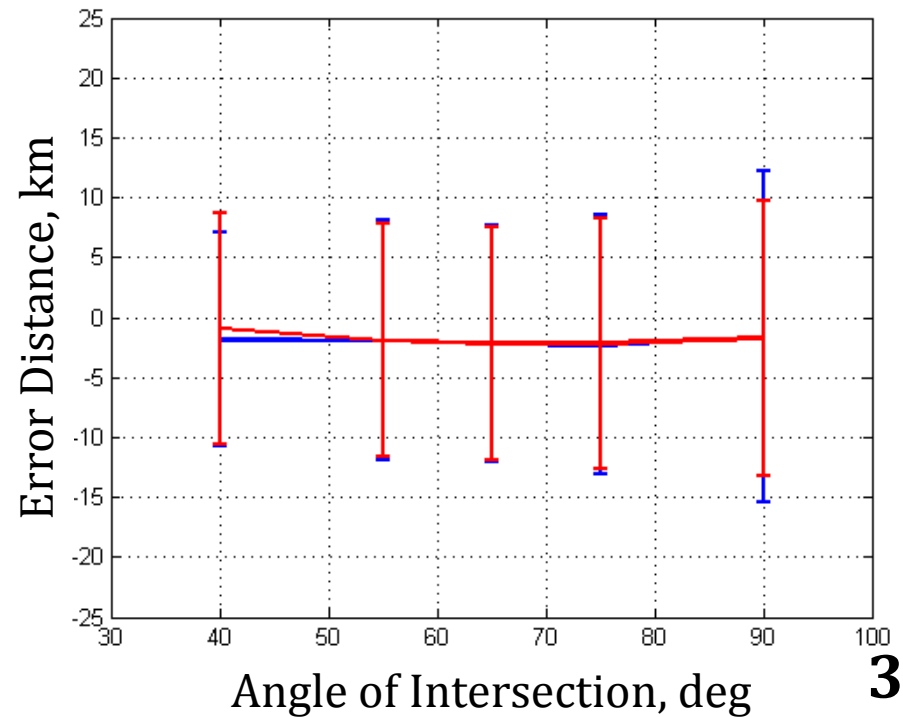
Angle of Intersection



Even beams, 23H



Even beams, 23H



Preliminary Error Analysis Summary

- Geolocation errors are small < 5 km overall
 - vs. Beam #
 - all beams 23H, even/odd 37V&H are similar
 - For Ascending / descending passes
 - No significant differences – as expected
 - Water-to-land and land-to-water crossings
 - Not consistent in all 3 channels – requires further investigation
 - Over latitude of land/water crossing
 - Some systematic differences for 37V channel
 - Angle of intersection with respect to coastline
 - Some minor differences – requires further investigation

Conclusions

- A data processing algorithm has been implemented in MatLab to assess the geolocation accuracy for the MWR multi-beam antenna Earth surface footprints
- MatLab script validated using simulated MWR observations and actual on-orbit Tb measurements
- Preliminary results will be presented at the Aquarius Cal/Val meeting (April)

Future Work

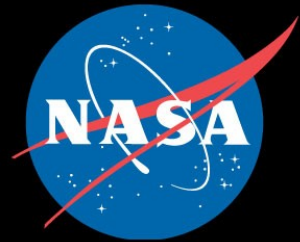
- Run more cases
- Improve quality control
- Perform detailed statistical analysis
 - Quantify systematic geoloc errors
 - Isolate attitude and sensor errors
- Write a technical report for MWR project
- Preliminary results will be presented at the Aquarius Cal/Val meeting (April)
- Submit paper to IEEE Geoscience and Remote Sensing Research Letters (May 2012)

Publications

- [1] **C. May**, L. Jones, “Engineering Evaluation of Multi-beam Satellite Antenna Boresight Pointing Using Land/Water Crossings,” presented at IEEE , Southeast Conf., Orlando, FL, Mar. 2012.
- [2] T. Miller*, M. James, J. Roberts, C. Buckley, E. Uhlhorn, P. Black, L. Jones, S. Biswas, **C. May**, C. Ruf, “Observations Of C-Band Brightness Temperature And Ocean Surface Wind Speed and Rain Rate In Hurricanes Earl And Karl (2010)”, presented at AGU Meeting, San Francisco, CA, Dec. 2011.
- [3] T. Miller, M. James, J. B. Roberts, L. Jones, S. Biswas, **C. May**, C. S. Ruf, E. Uhlhorn, R. Atlas, P. Black* “ High-altitude Hurricane Imaging RADiometer (HIRAD) microwave emissivity observations from surface winds and rain in Hurricanes Earl and Karl during GRIP (2010)”, presented at 66th Inter. Hurricane Conf., Charleston, SC, Mar. 2012.
- [4] L. Jones, E. Uhlhorn, S. Biswas, C. Ruf, C. Buckley, **C. May**, T. Miller, P. Black, M. James, “Wind Speed and Rain Rate Retrievals from HIRAD and Comparison with the Stepped Frequency Microwave Radiometer”,
- [5] L. Jones, S. Biswas, S. Alsweiss, Y. Hejazin, S. Farrar, Sh. Aslebagh, A. Santos-Garcia, P. Laupattarakasem, **C. May** J. Cruz Gallo, D. Rocca, M. Rabolli, J. Kuba, F. Madero, M. Colazo, S. Heredia, M. Marenchino, M. Labanda, S. Masuelli, H. Raimondo, “ SAC-D Microwave Radiometer (MWR) Preliminary Results “



UCF CFRSL



SMART

SCIENCE, MATHEMATICS
& RESEARCH FOR
TRANSFORMATION

PART OF THE NATIONAL DEFENSE
EDUCATION PROGRAM

Thank You Questions?