ATMS and CrIS Geolocation

Mark Esplin, Kris Robinson, Ben Esplin, Nephi Grant,
Deron Scott, and Likun Wang*

* University of Maryland

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- Summary of Suomi NPP sensors CrIS, ATMS, and VIIRS
- Geolocation methods
- Software optimization
- CrIS geolocation results
- ATMS geolocation results
- Conclusions

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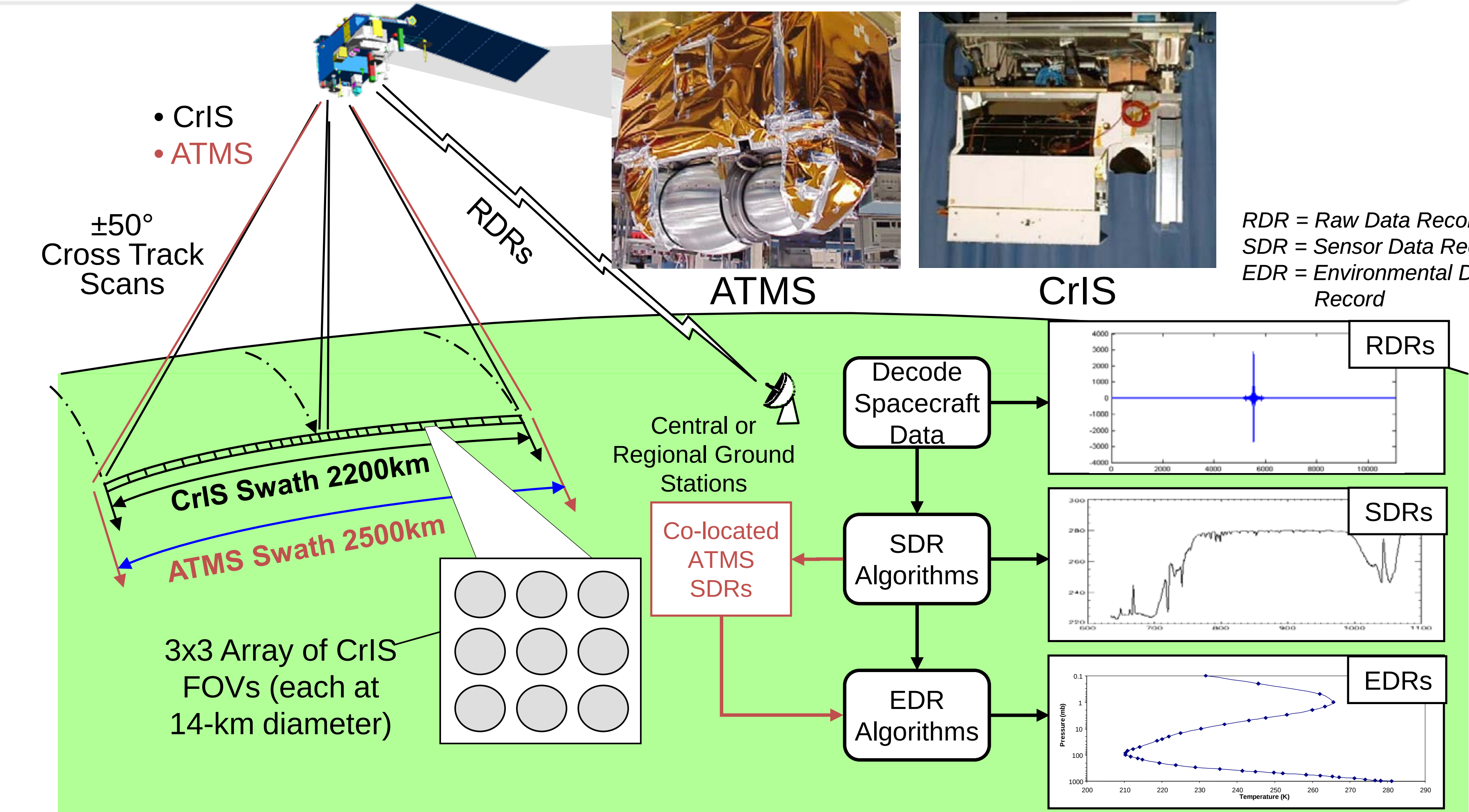
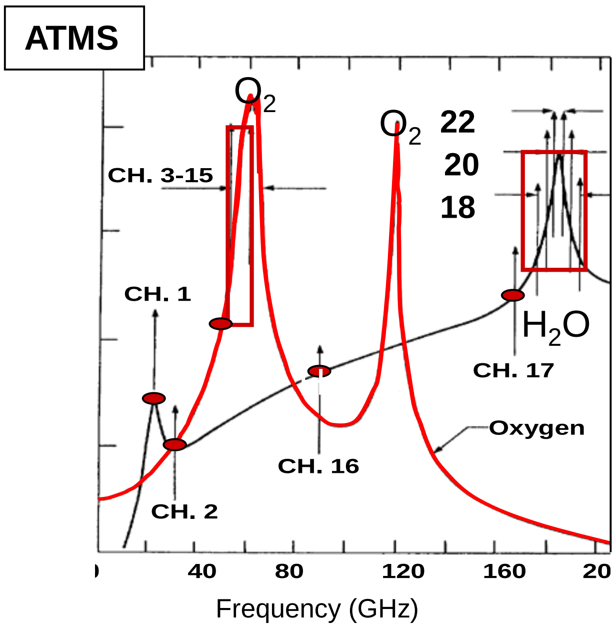
CrIS/ATMS Instrument Suite (CrIMSS)

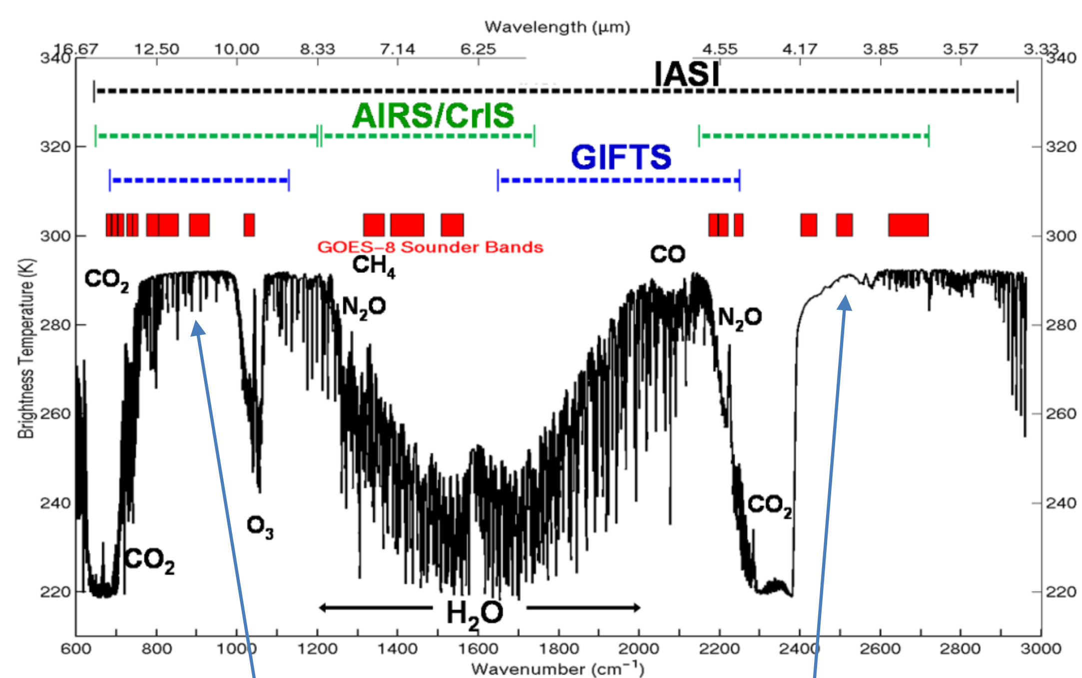


ATMS & CrIS work together to provide soundings in cloudy and clear conditions

Spectral Bands Used for Geolocation



ATMS channels used:
1, 2, 3, 16, 17



CrIS sub-bands used:
LWIR (907- 915 cm^{-1})
SWIR (2498 – 2535 cm^{-1})

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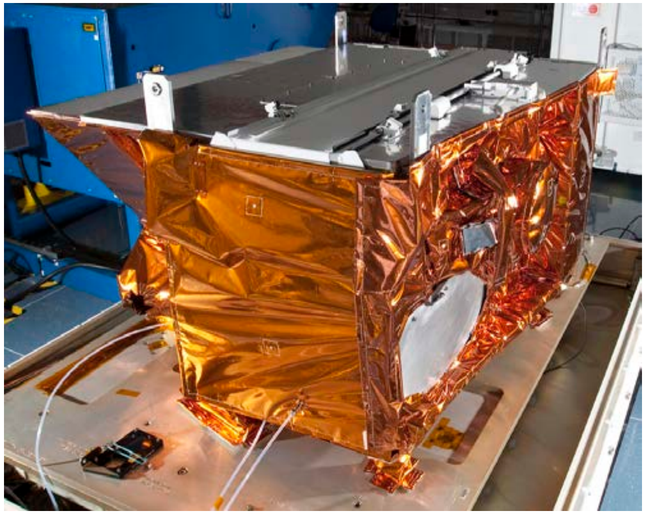
VIIRS Instrument Overview



Multispectral, cross-track-scanning, imaging instrument

22 spectral bands 0.4 – 12.5 μm

- Single ~20 cm diameter, rotating, all-reflective telescope
- Day-night band, VisNIR, S/MWIR, & LWIR focal plane assemblies
- Solar reflective and IR emissive on-board calibration sources
- 5 imagery bands at ~375 m nadir resolution
- 16 radiometric quality bands ~750 m nadir resolution
- 1 day / night band 750 m resolution

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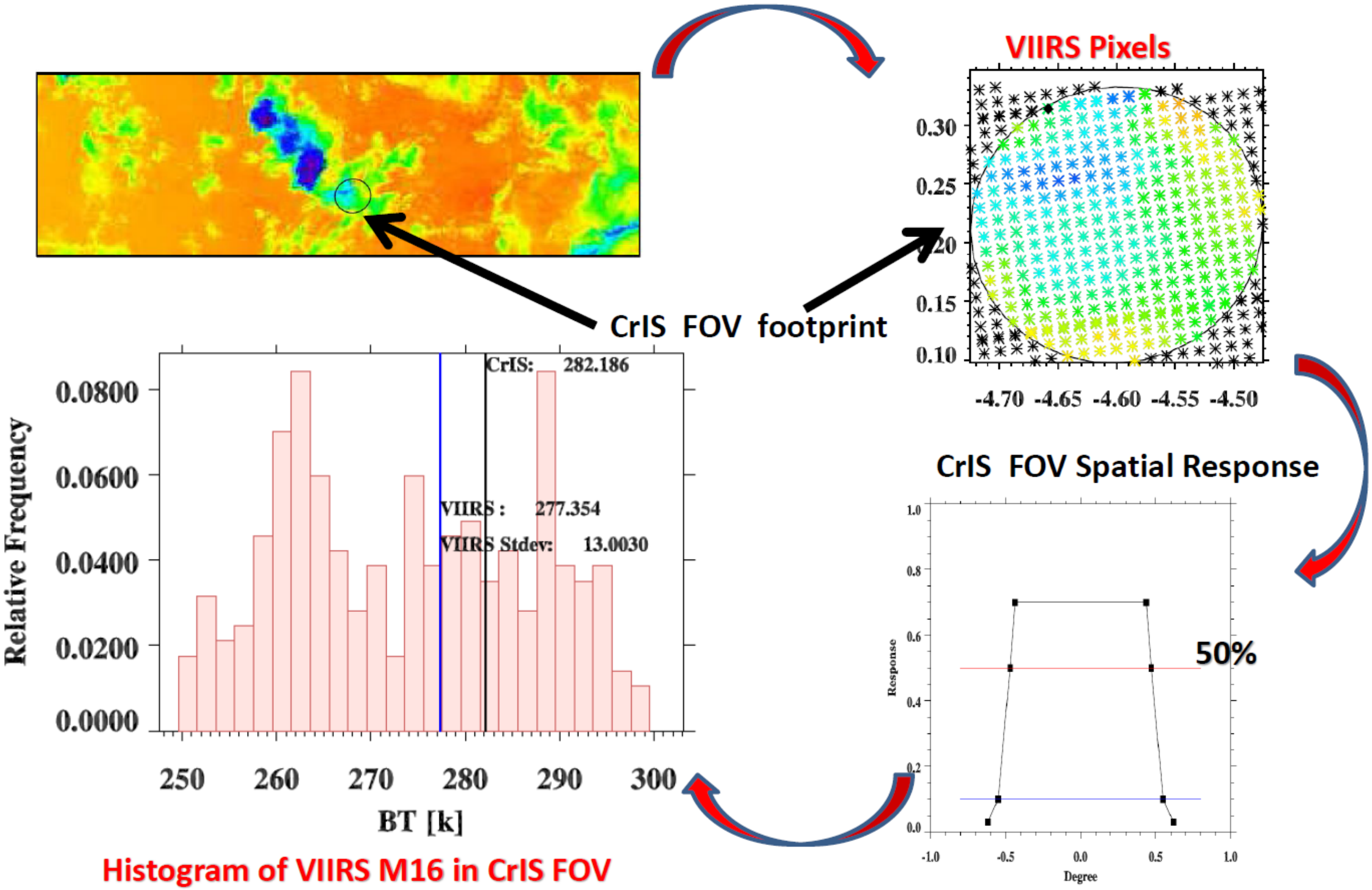
Three Geolocation Methods

- Cross Comparison Method (*Likun Wang NOAA/STAR)
  - Cross compare low spatial resolution sensor with high spatial resolution sensor
  - Shift high spatial resolution image to achieve best match with low resolution image
  - Requires availability of well calibrated, high spatial resolution sensor
- Shoreline Crossing Method
  - Fit a cubic polynomial to shoreline crossing points
  - Relies on contrast in radiance between land and sea
  - Inflection point is taken as shoreline crossing point
- Land-Sea Fraction Method
  - Determine fraction of land and sea in each pixel footprint using digital shoreline map
  - Model expected radiance from land/sea fraction in each sensor pixel
  - Use simple radiance model with a single temperature and emissivity for land and for sea

*Geolocation assessment for CrIS sensor data records by Likun Wang, et al., Journal of Geophysical Research: Atmospheres 11/2013; 118(22)

Cross Comparison Method



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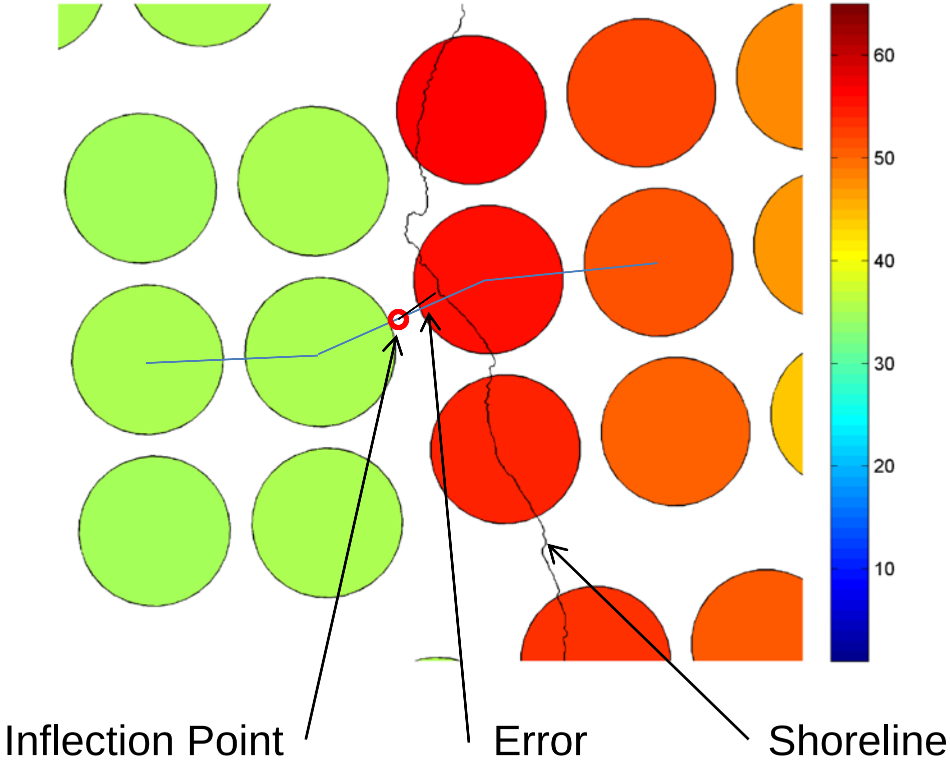
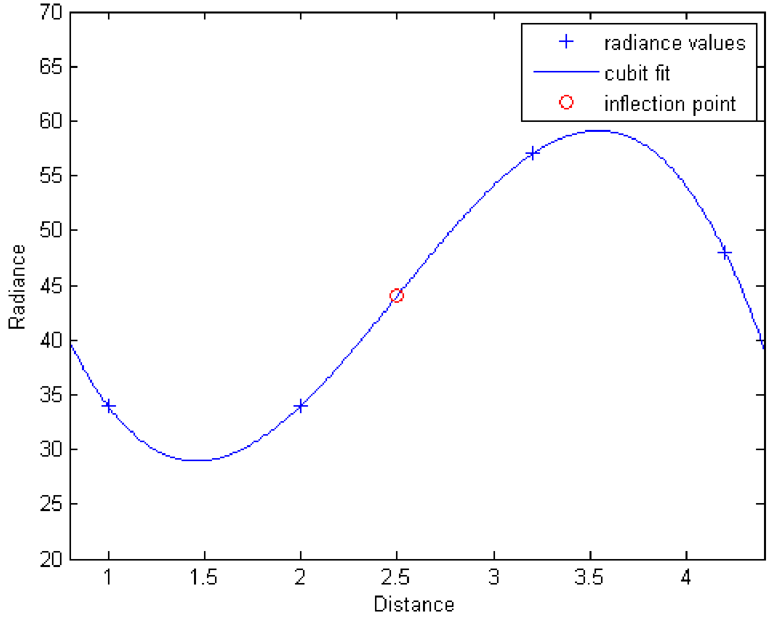
Shoreline Crossing Method





- Method Summary
  - Fit a cubic polynomial through four point in the in-track or cross-track direction
  - The inflection point is taken as the shore crossing point
  - Least-squares-fit to coastlines to minimize total error for scene

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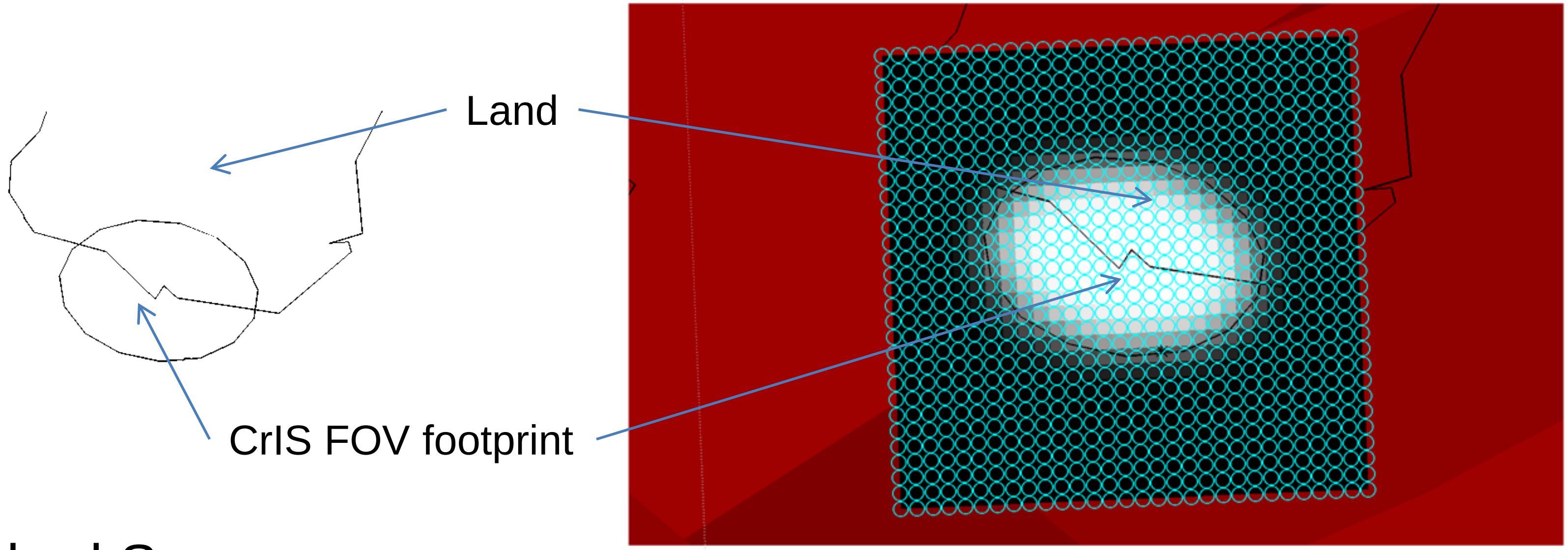
Land-Sea Fraction Method



- Method Summary
  - Place a rectangle around each CrIS FOV footprint
  - Divide the rectangle into a grid of equally spaced points
    - Points are represented by the small blue circles in the right hand panel (grid point spacing < 1 km)
  - Shift shoreline position used in calculation in x and y directions until differences between observed and modeled radiances are minimized

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Land-Sea Fraction Method Details

$$\chi^2 = \sum_{FOVs} (R_{CrISFOV} - R_{calFOV})^2$$

Minimize chi-squared for best fit

$$R_{calFOV} = (R_{land} - R_{sea})lfrac + R_{sea}$$

Linear radiance model

Where:

$R_{CrISFOV}$	=	Observed CrIS FOV radiance
R_{calFOV}	=	Calculated CrIS FOV radiance
$lfrac$	=	Land fraction in a CrIS FOV
R_{land}	=	Land radiance
R_{sea}	=	Sea radiance

Note: Shorelines from GSHHG (A Global Self-consistent, Hierarchical, High-resolution Geography Database)

Reference: Wessel, P., and W. H. F. Smith, A Global Self-consistent, Hierarchical, High-resolution Shoreline Database, J. Geophys. Res., 101, #B4, pp. 8741-8743, 1996.

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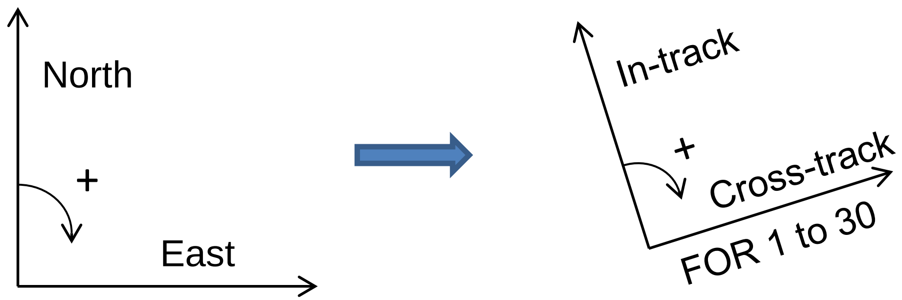
Coordinate System Convention



- North/east coordinate system used to measure error
- Geolocation errors expected to be constant in in-track/cross-track coordinate system
- Measured error rotated to in-track/cross-track coordinates through a rotation matrix
- Used for both shoreline crossing and land fraction method

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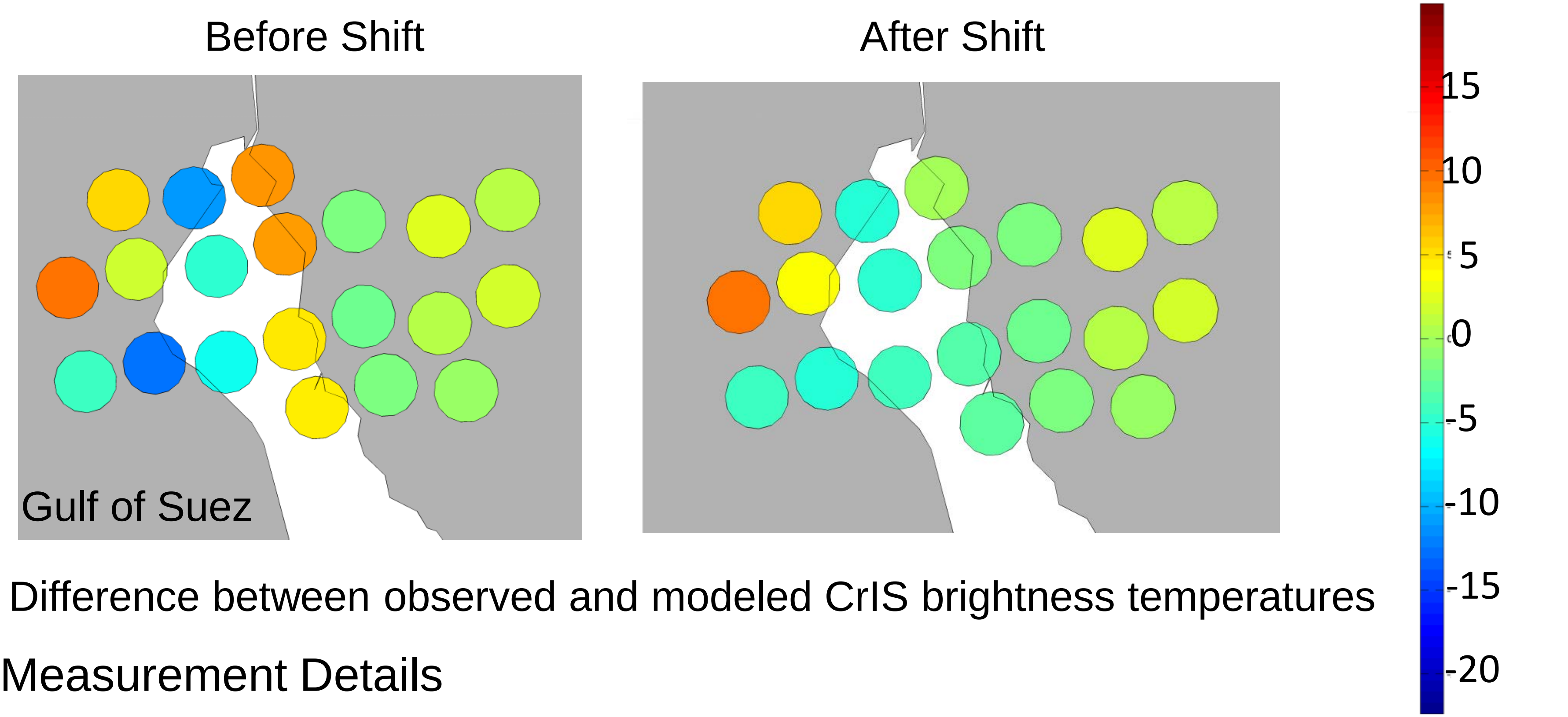
Land-Sea Fraction Method Example



Difference between observed and modeled CrIS brightness temperatures

- Measurement Details
  - 900 cm^{-1} (11 µm)
  - June 17, 2012 orbit 03307 IDPS SDRs
  - Coastlines from GSHHS (1 km) used to model shoreline
  - Improved coastline accuracy with more sensor pixels

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Method Comparison

- Cross comparison method
  - Results in highest accuracy
  - Can use any scene with spatial structure, not just coastlines
  - Not adversely affected by atmospherics effects (clouds, temperature gradients, indistinct coastlines, etc.)
  - Relies on other high spatial resolution sensor with matching bandwidth
  - Only applied to near nadir measurements
    - 30 degree off-nadir angle due to VIIRS imaging model (CrIS FORs 7 – 24)
- Shoreline crossing method
  - Doesn’t depend on details of footprint
  - Subject to problems with excessive coastline structure
  - Nearest coastline is not necessarily the correct coastline
- Land-sea fraction method
  - Works well on complex coastlines
  - Can be used off nadir
  - Depends on accuracy of land/sea model

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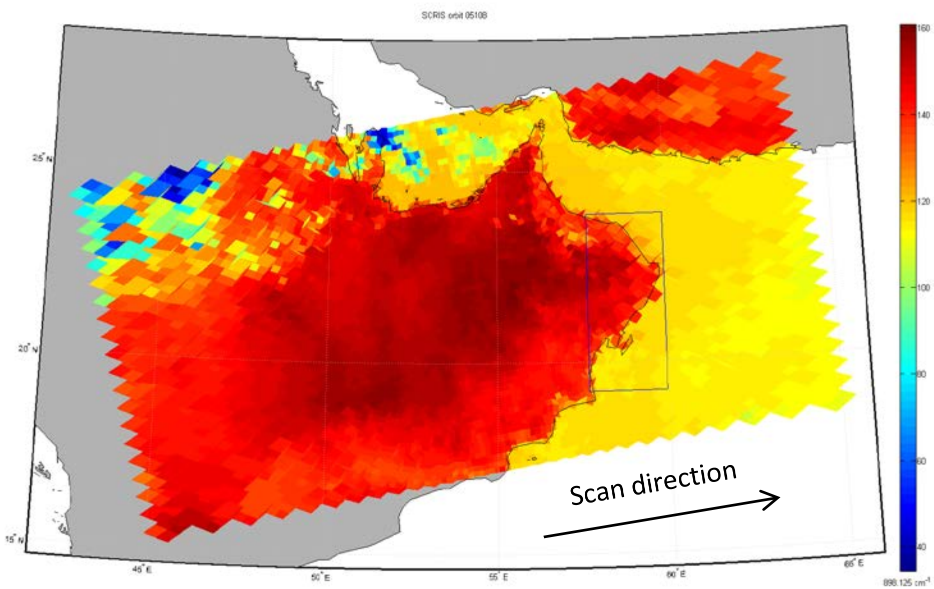
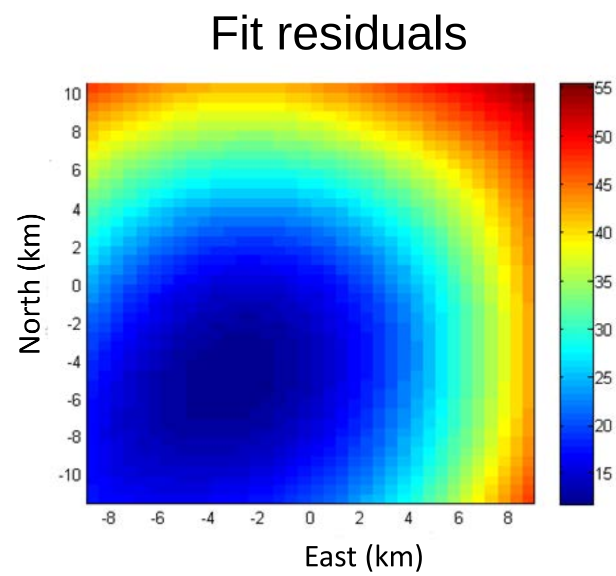
Oct 22, 2012 CrIS Example





- Box shows section used for geolocation case
- Box centered on approximately FOR 25 (FOR range 1 - 30)
- A ~4 km north and east shift required for consistent results between truth (GHHS) and reported (CrIS) results

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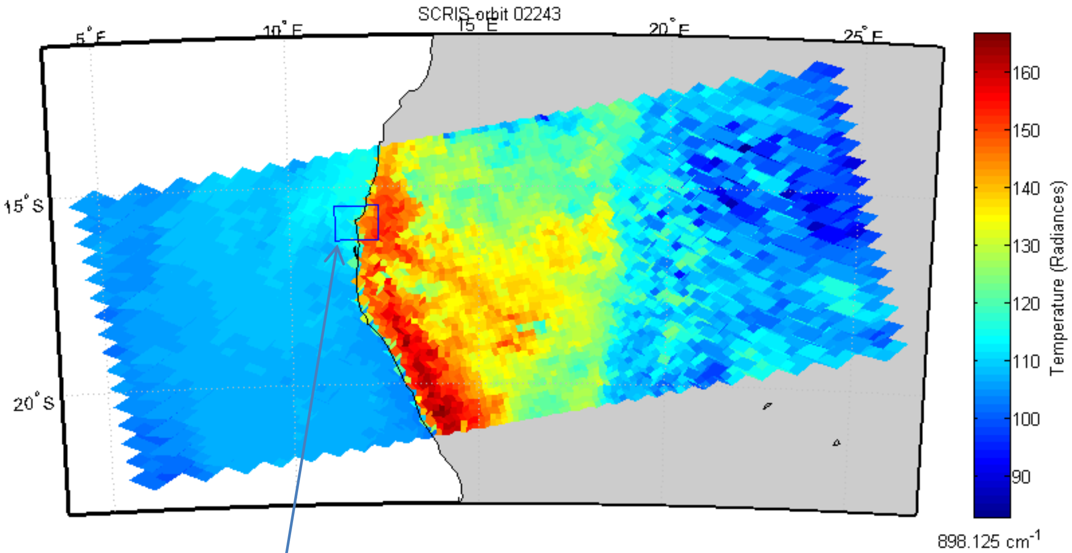
Software Optimization to Improve Efficiency

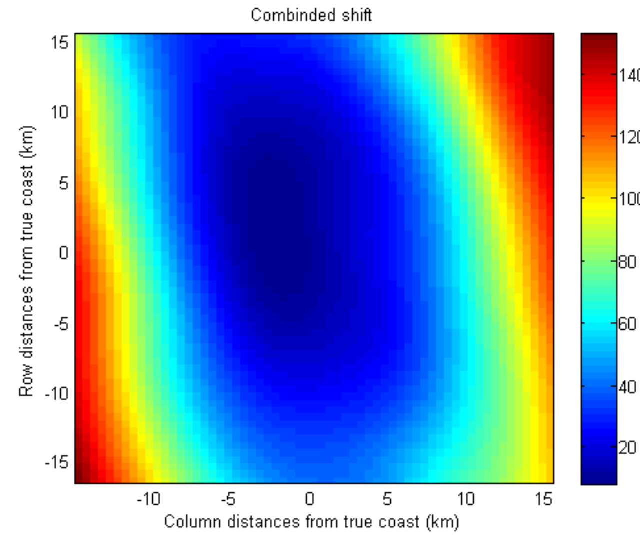
- Algorithm optimization
  - Optimize coastline gridding
    - Efficiently determine if given point is inside or outside a polynomial representing coastlines
  - Optimize regions of interest to keep sampling as small as possible
- Implemented selected function in C++
  - Optimized several functions using mex interface
  - Execution times dropped from hours to minutes per geolocation case
- Programming language efficiency
  - Marginal additional improvement in speed
    - Total C++ implementation vs. MATLAB (original implementation)

Execution times dropped from hours to minutes per geolocation case

Example of Poor Choice of Sampling Region



Small region used for test



Chi squared

- Vertical shoreline determination not well defined in this test
- Coastlines need structure for unambiguous fits
- Not easy to automate sampling regions

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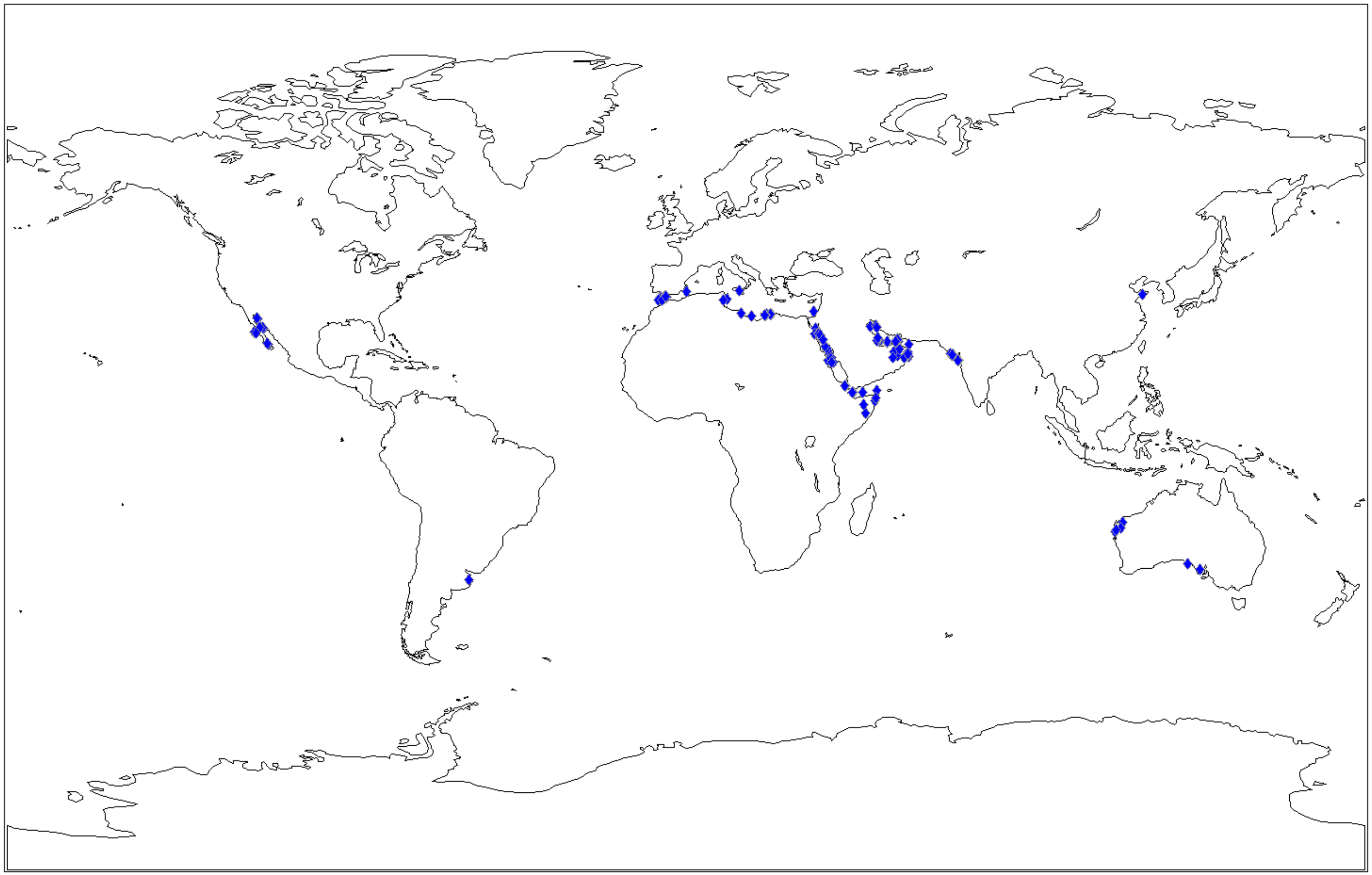
Location of CrIS Geolocation Scenes



- Coastlines by hot dry deserts generally work well

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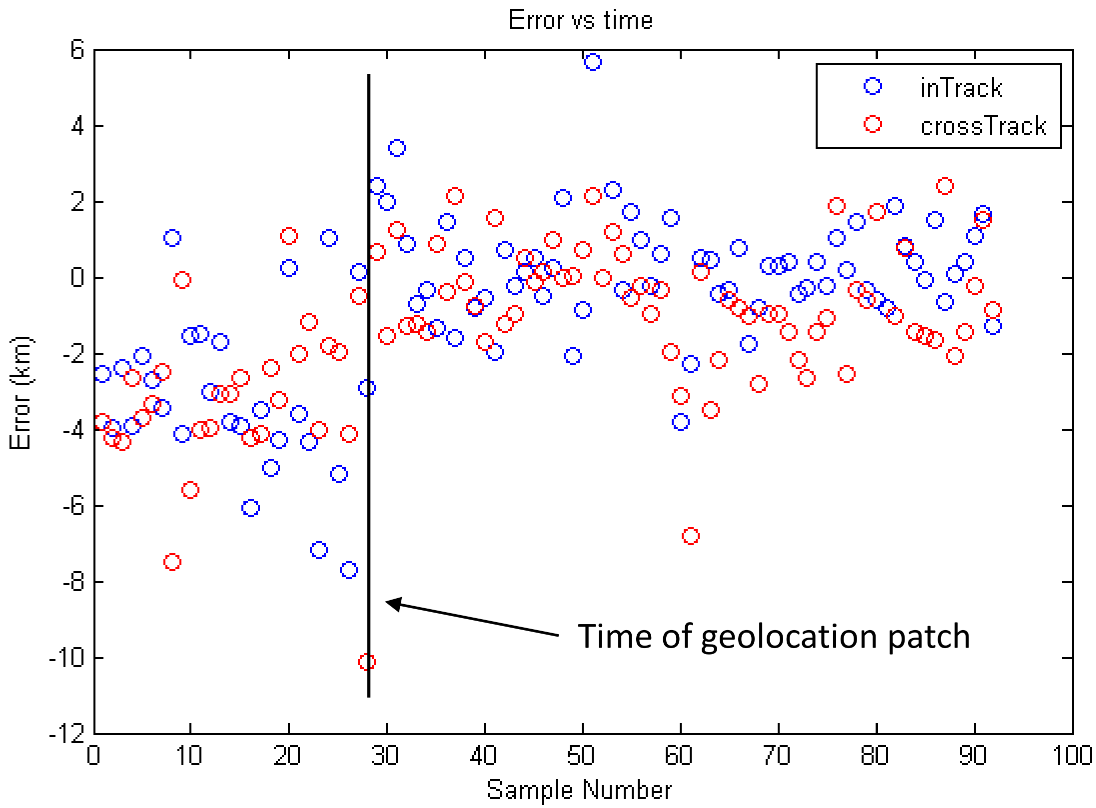
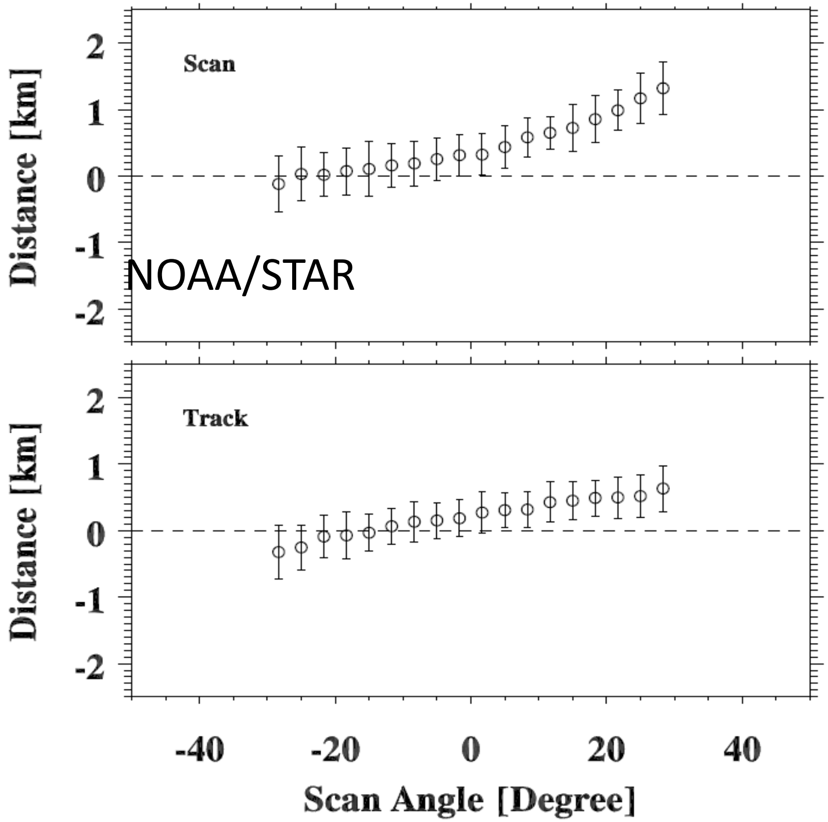
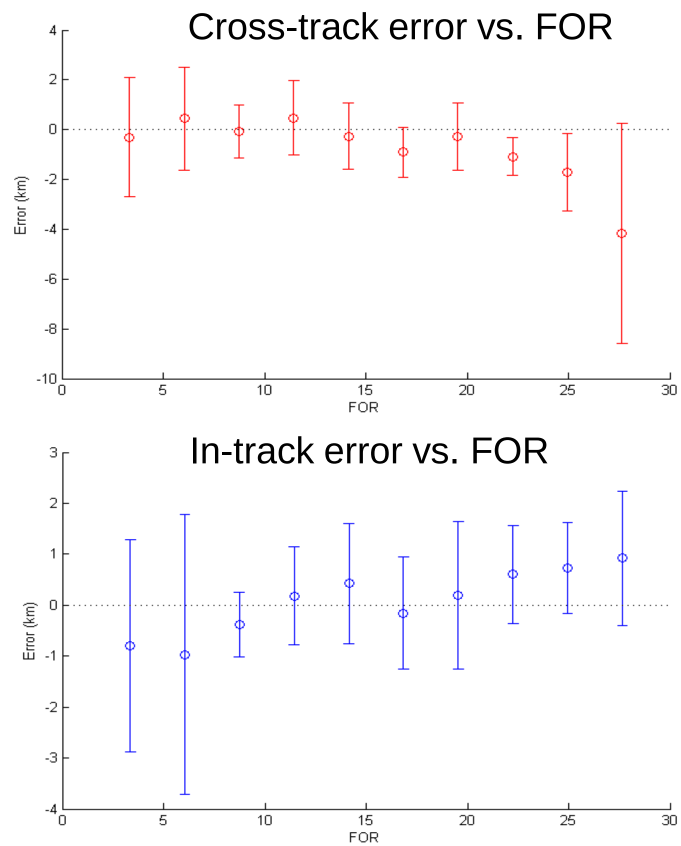
Effects of CrIS Geolocation Patch Detectable



- In October 2012 a bug was fixed in the CrIS SDR geolocation software
- Results are clearly seen

CrIS Results After Geolocation Patch





- Consistent results between organizations (SDL and NOAA/STAR)
- Opposite sign convention for cross-track error
- FORs 7-24

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CrIS Geolocation Summary

- Land-sea fraction method works better than shoreline crossing method for CrIS because of unequal ground footprint spacing
- Patch to geolocation software provides opportunities to verify software
  - Average cross-track location increased by nearly 4 km
  - Average in-track location increased by slightly more than 2 km
- Atmospheric window regions used for geolocation analysis
  - LWIR (907- 915 cm^{-1})
  - SWIR (2498 – 2535 cm^{-1})
  - No significant difference between results from the two bands
- Results consistent between different organization
  - Geolocation results consistent with NOAA/STAR results

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ATMS Geolocation

- ATMS has five bands with separate geolocation
  - K band – channel 1 – beam diameter 5.2 degrees
  - Ka band – channel 2 – beam diameter 5.2 degrees
  - V band – channels 3-15 – beam diameter 2.2 degrees
  - W band – channel 16 – beam diameter 2.2 degrees
  - G band – channel 17-22 – beam diameter 1.2 degrees
- Geolocation analysis performed for bands 1, 2, 3, 16, 17
- Bands 1, 2, 3, 16 are window bands
- Bands 17 is sensitive to water vapor but under dry conditions, shorelines are visible
- Accuracy specifications: 5.2° beams < 0.3 degrees, 2.2° beams < 0.2 degrees, and 1.2° beams < 0.1 degrees

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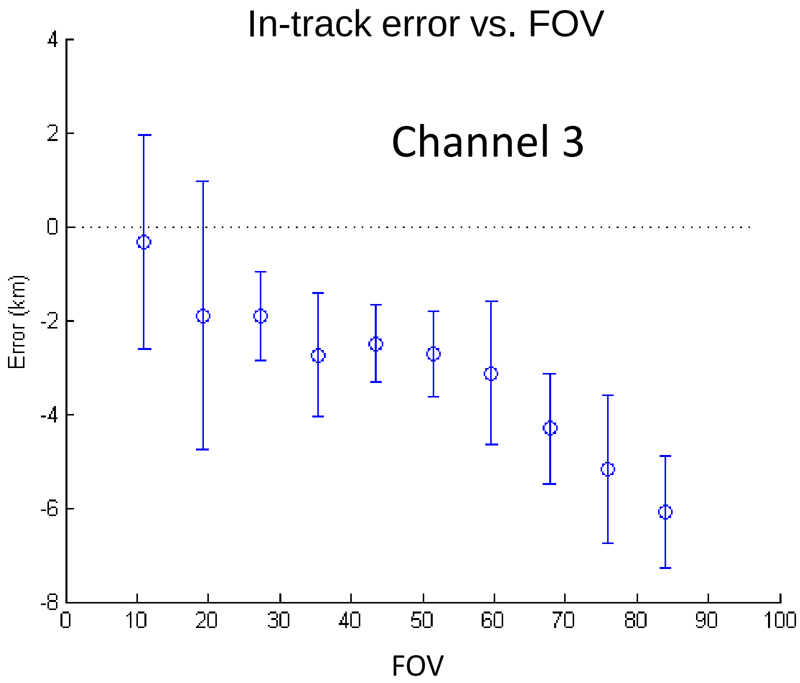
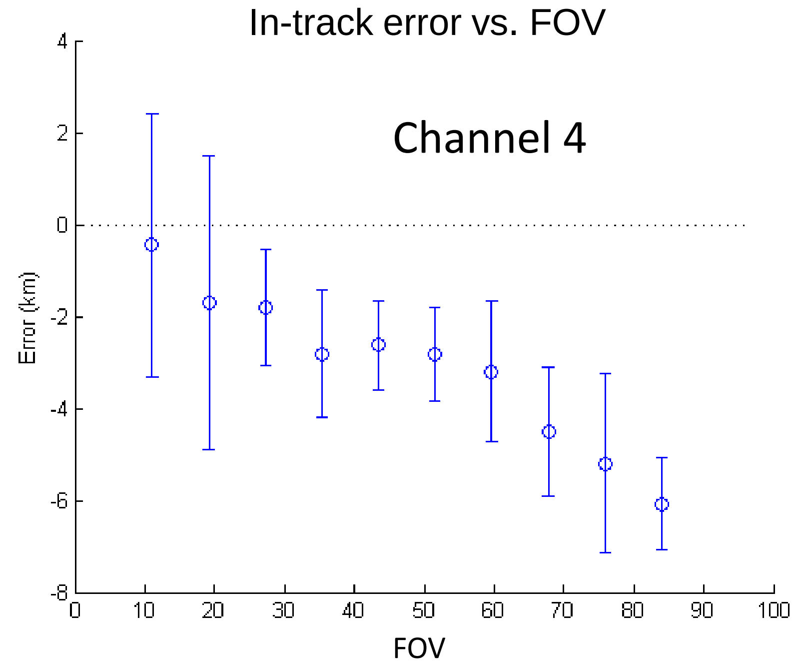
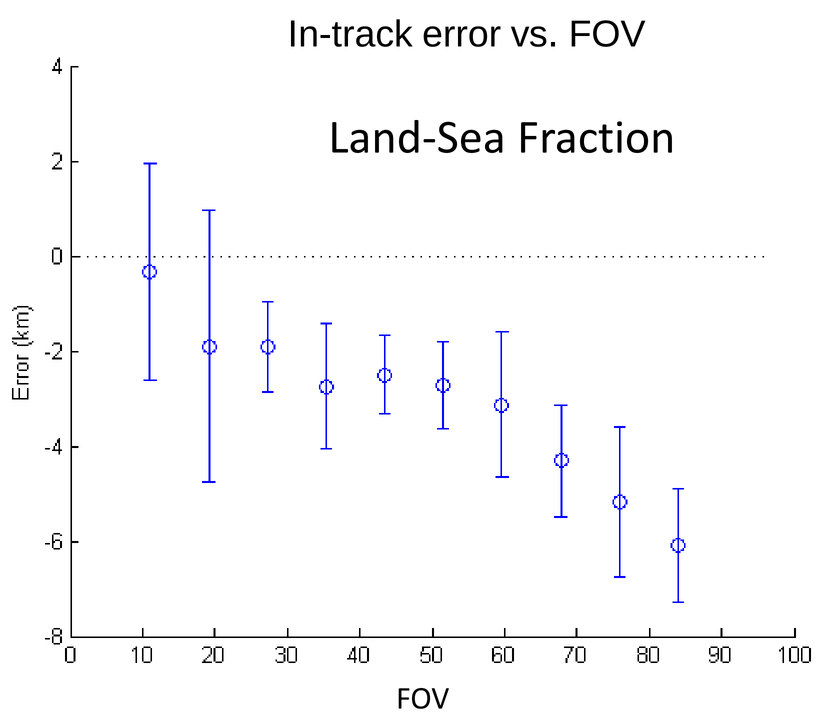
Test for Consistency

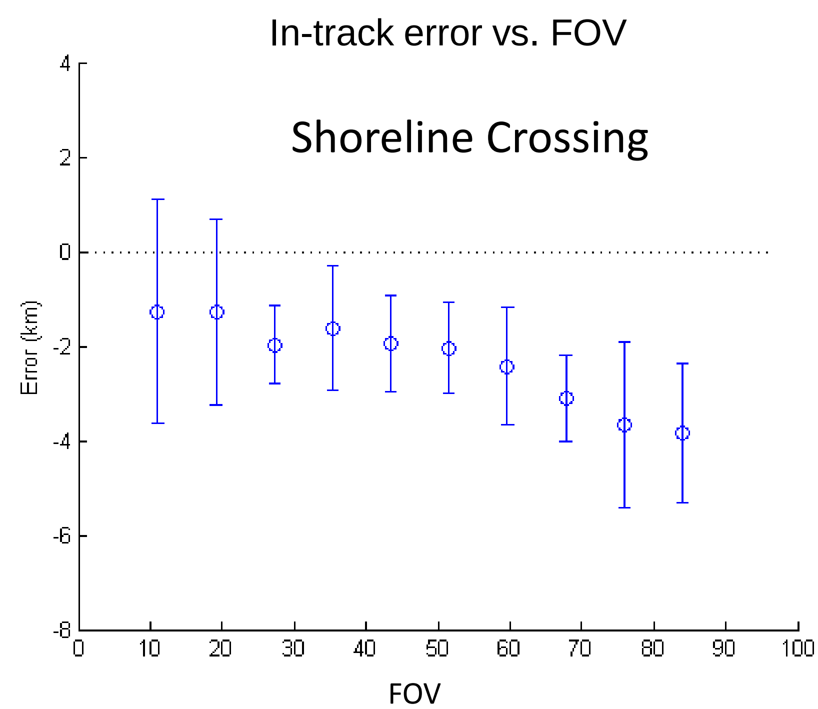




- Two channels that should give the same results were compared
- Both are V band window channels
- Land fraction method – 185 cases

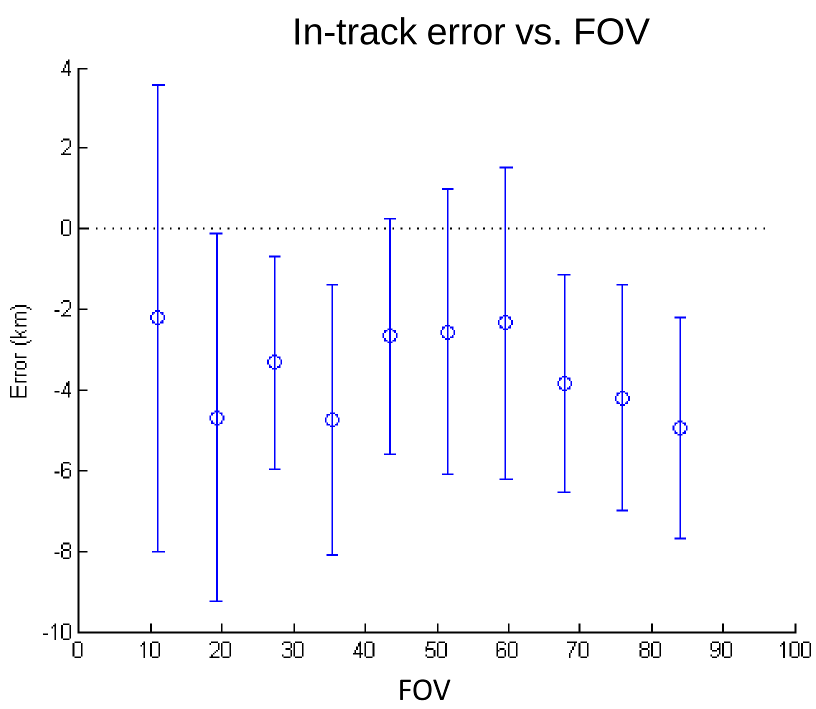
Land-Sea Fraction vs. Shoreline Crossing Method Comparison

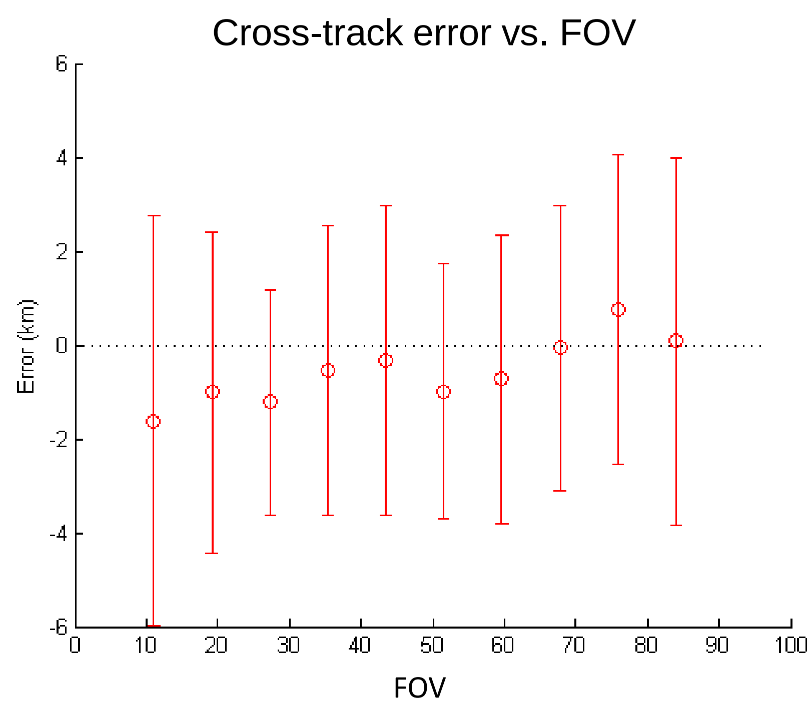




- Two methods in general give similar results
- Land fraction method shows larger geolocation error
- Land fraction method seems more consistent

Channel 1 Land-Sea Fraction Results





- Number of cases: 183
- In-track mean: -3.4 km, std: 3.8 km
- Cross-track mean: -0.6 km, std: 3.3 km

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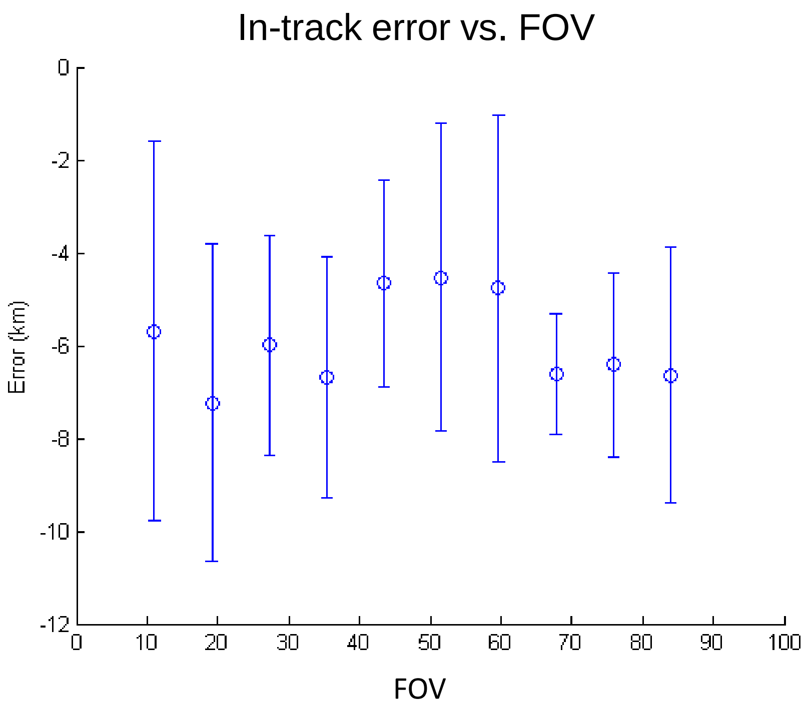
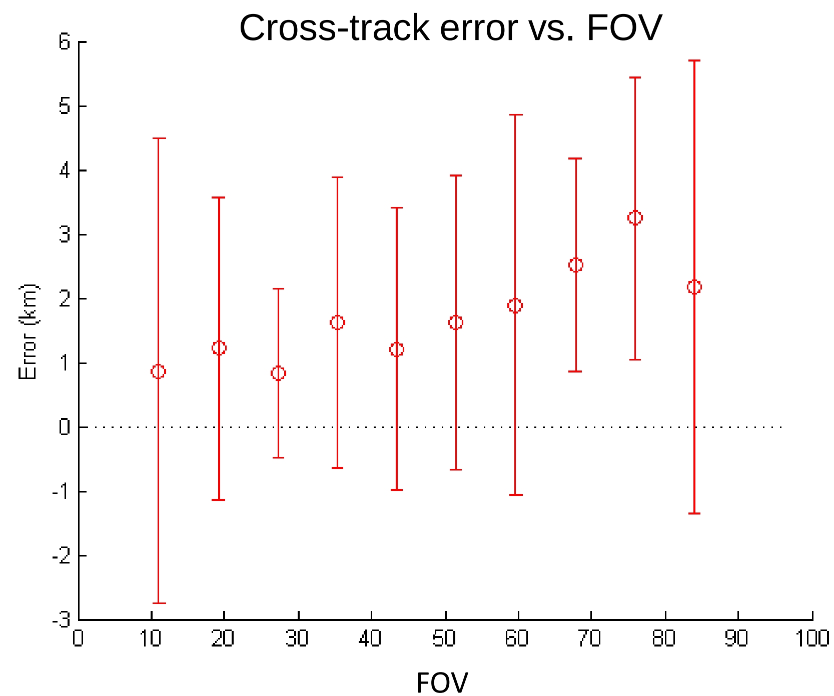
Channel 2 Land-Sea Fraction Results





- Number of cases: 185
- In-track mean: -5.8 km, std: 3.1 km
- Cross-track mean: 1.6 km, std: 2.6 km

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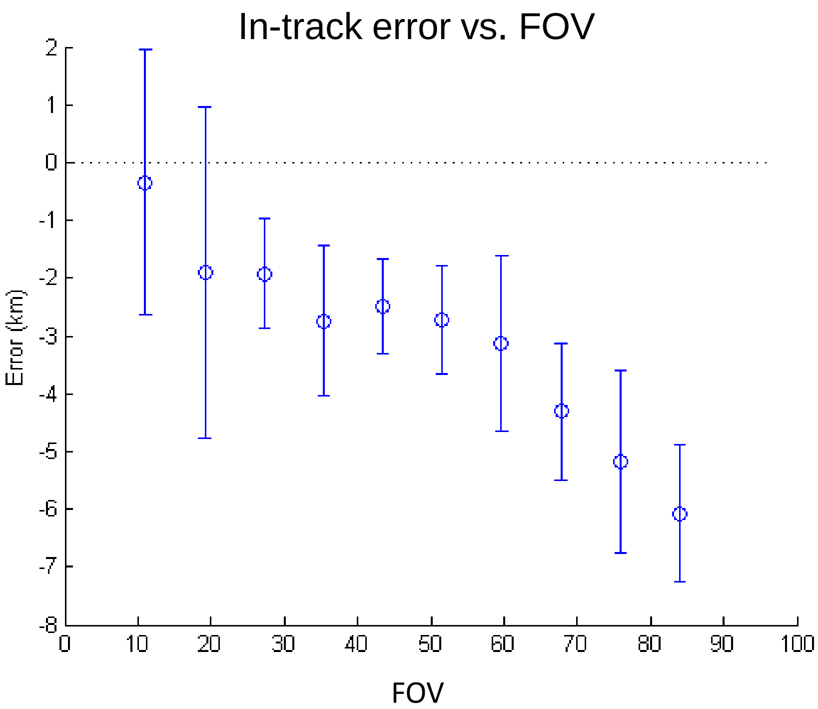
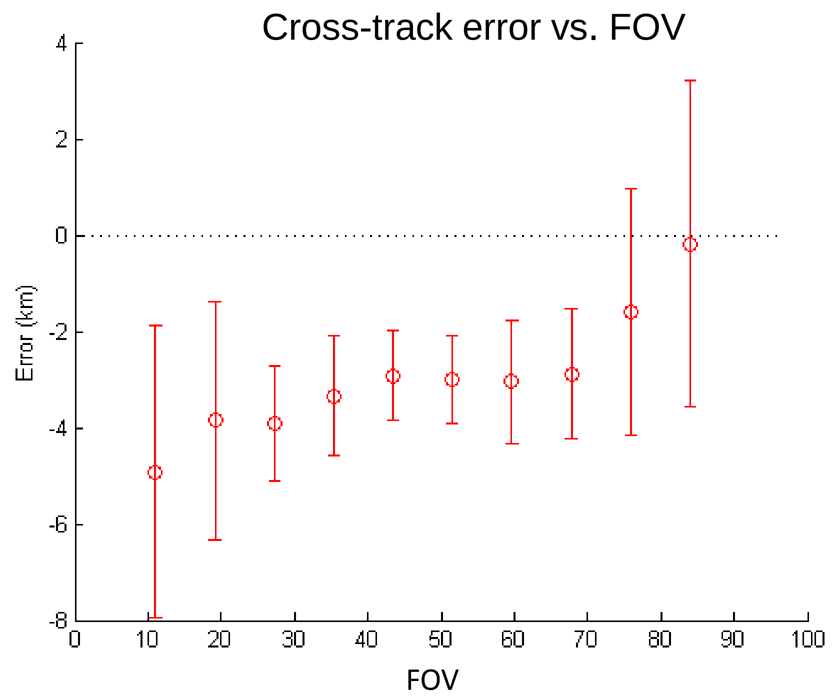
Channel 3 Land-Sea Fraction Results





- Number of cases: 185
- In-track mean: -2.8 km, std: 2.2 km
- Cross-track mean: -3.1 km, std: 2.2 km

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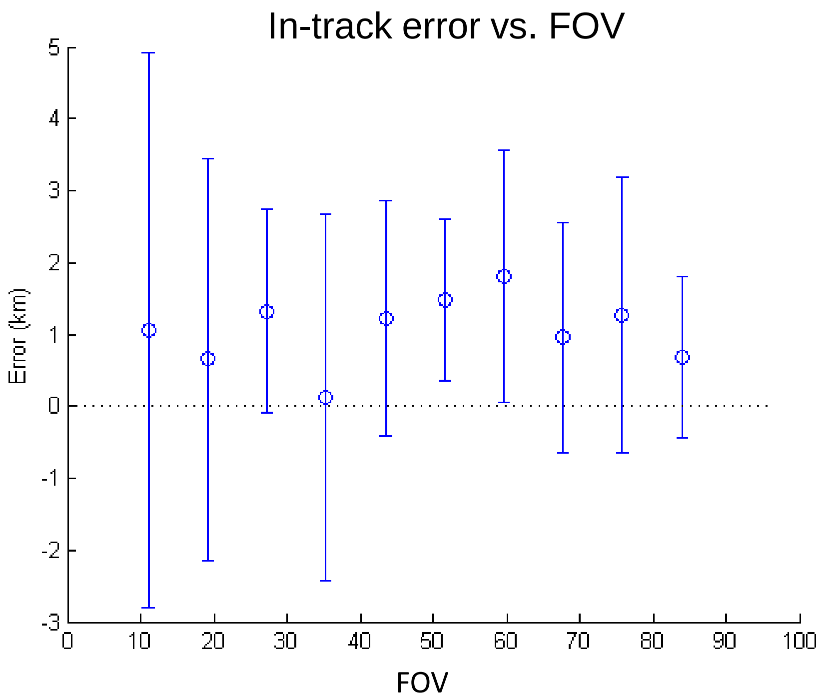
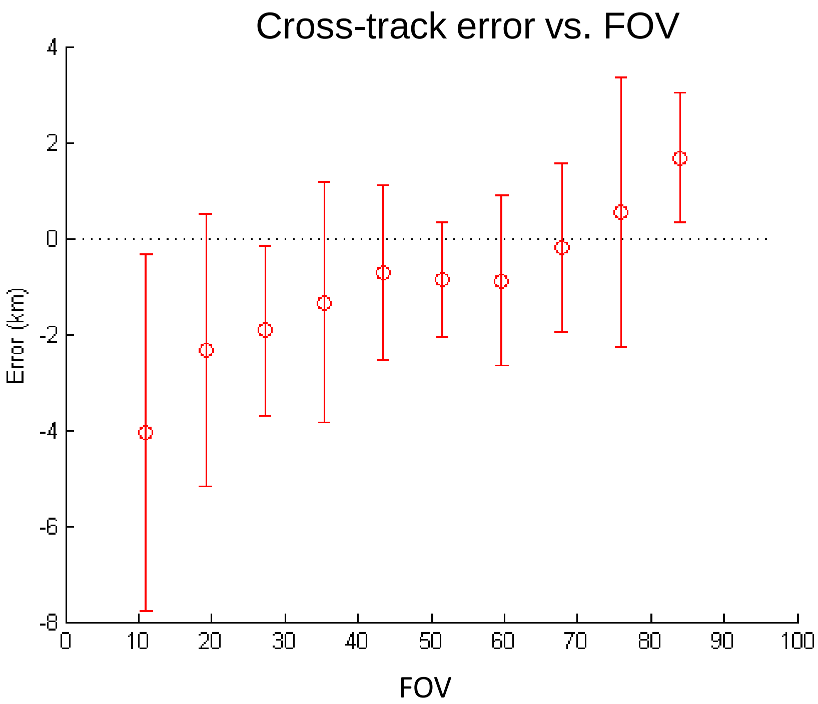
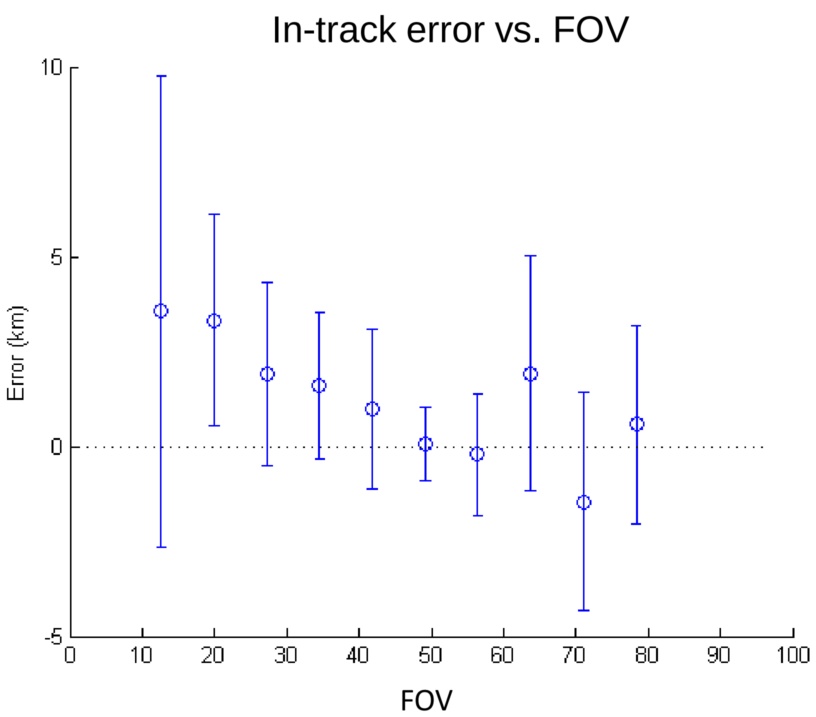
Channel 16 Land-Sea Fraction Results

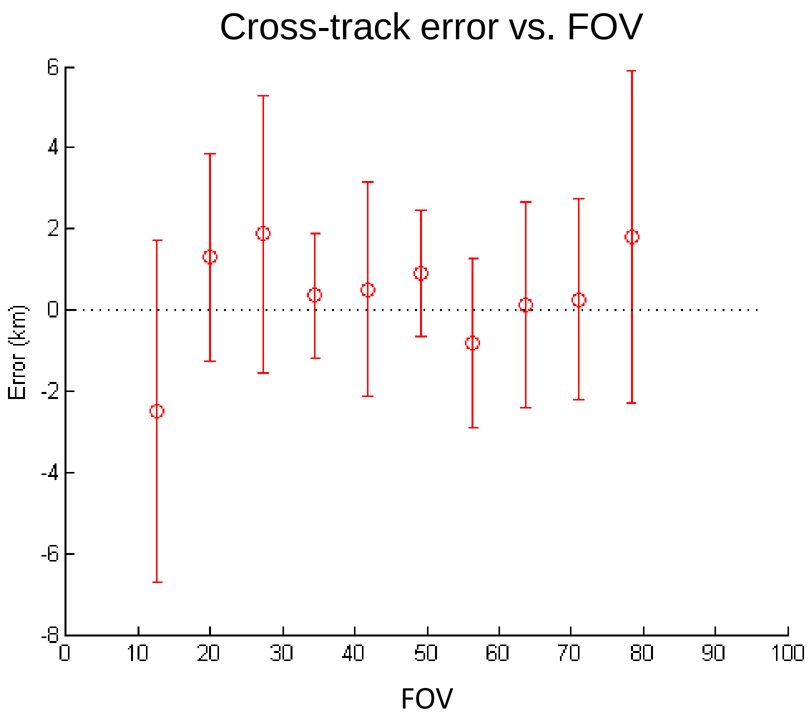




- Number of cases: 185
- In-track mean: 1.1 km, std: 2.2 km
- Cross-track mean: -1.2 km, std: 2.7 km

Channel 17 Land-Sea Fraction Results





- Only using cases with greater than12 K land/sea brightness temperature difference
- Number of cases: 84
- In-track mean: 1.1 km, std: 2.7 km
- Cross-track mean: 0.4 km, std: 2.6 km

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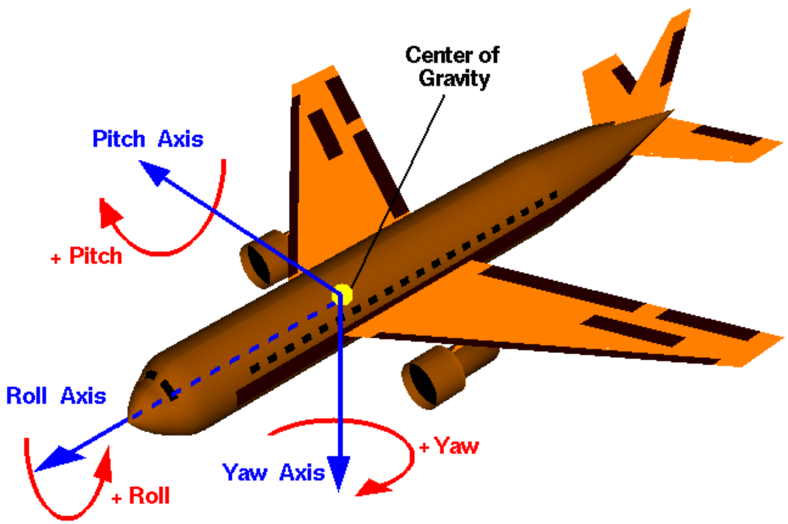
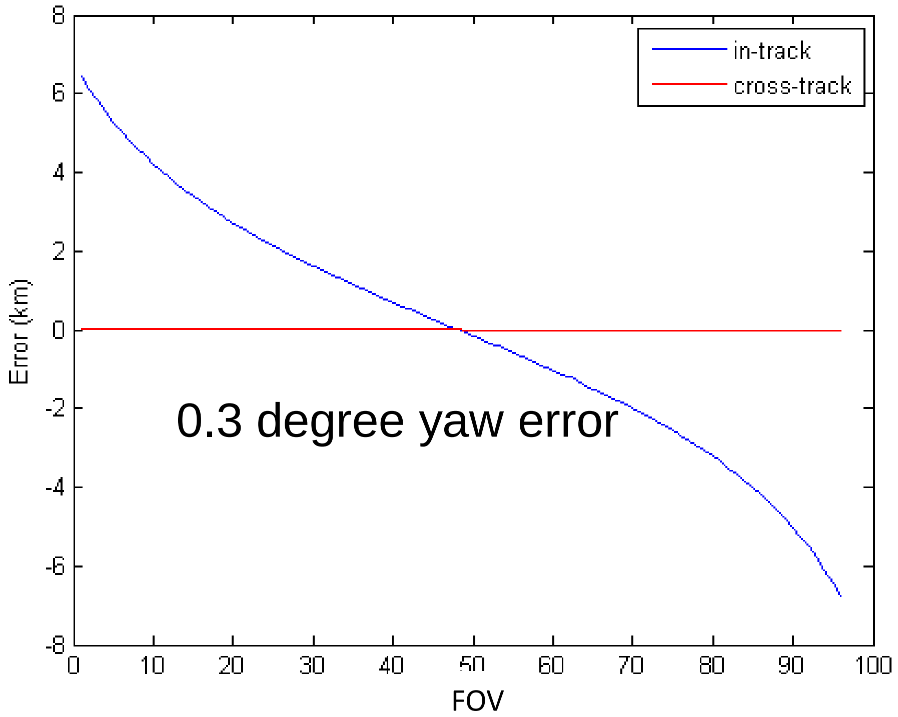
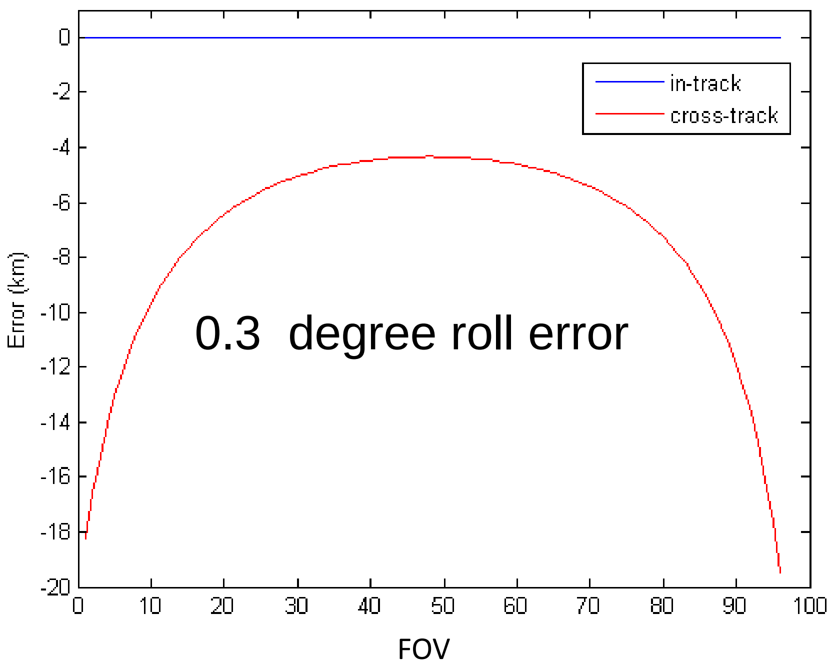
Simulated Effects of Sensor Alignment Error

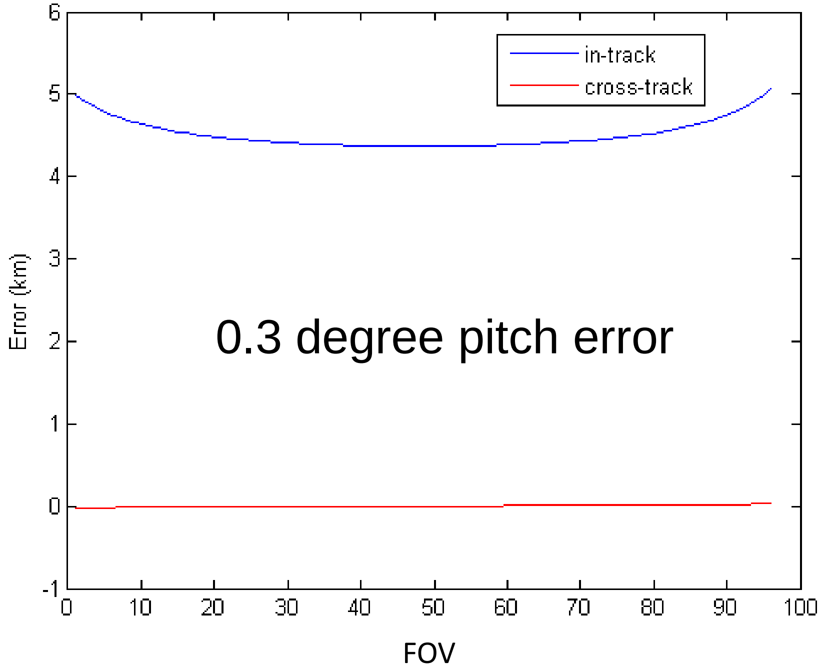




- Geolocation error simulation created from spacecraft and earth viewing geometry
- Yaw error affects in-track geolocation
- WGS 84 earth model

Simulated Roll and Pitch Error Sensitivity





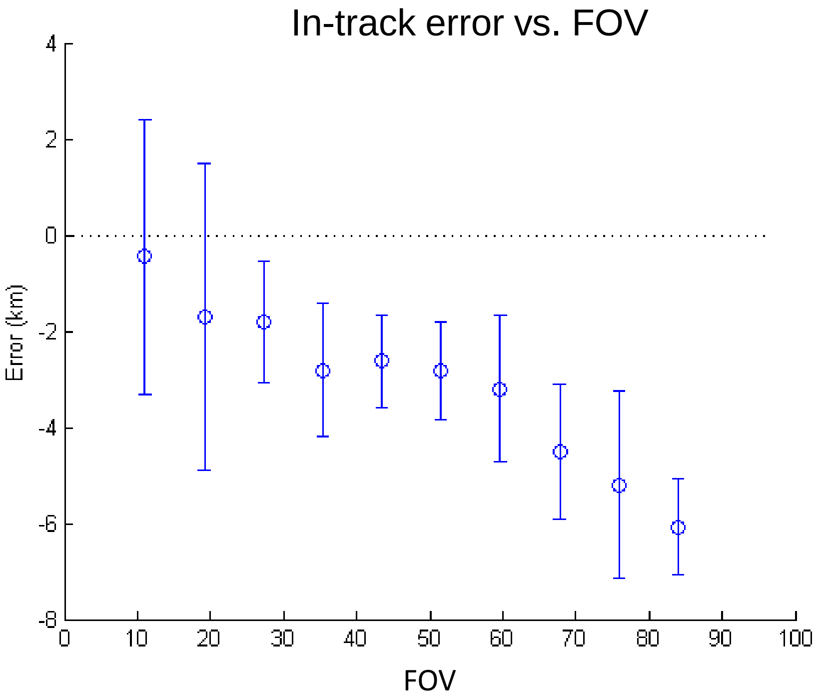
- Roll error affects cross-track geolocation
- Pitch error affects in-track geolocation
- Observed geolocation errors don't correspond to simple sensor rotations

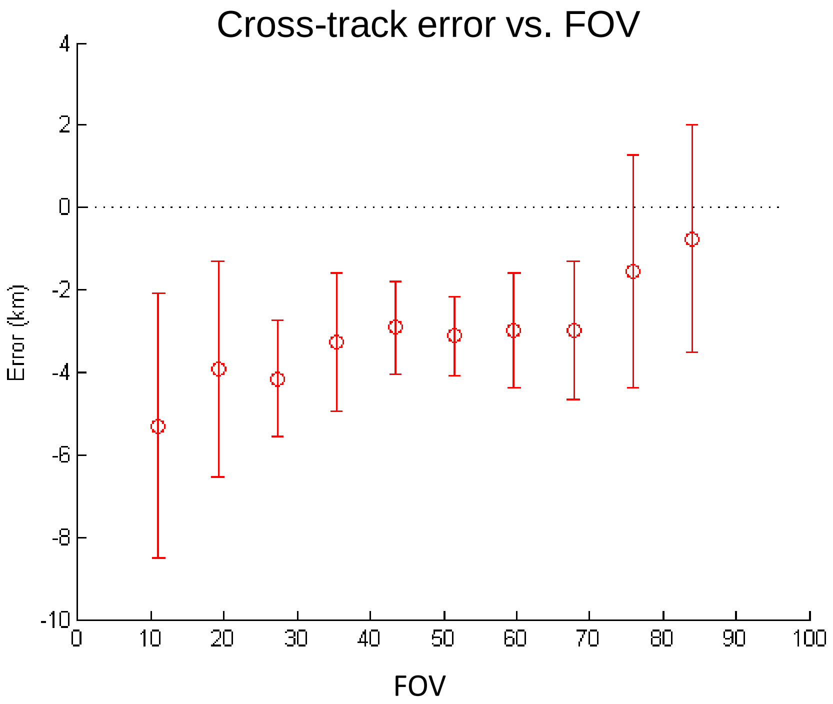
Conclusions

- Results consistent between multiple organizations
  - SDL CrIS results consistent with NOAA/STAR except for cross-track sign convention
- Geolocation results consistent between similar window bands
  - Scatter in geolocation results not due to sensor noise
- Shoreline crossing method produces smaller error than land-sea fraction method
  - Probably due to initial guess being zero
  - Additional analysis is needed
- Some adjustments to the ATMS pointing coefficients may be warranted
- More work needed on correlating ATMS geolocation errors with sensor alignment angles

BACKUP

Channel 4 Land Fraction





- Number of cases: 185
- In-track mean: -2.8 km, std: 2.4 km
- Cross-track mean: -3.2 km, std: 2.3 km

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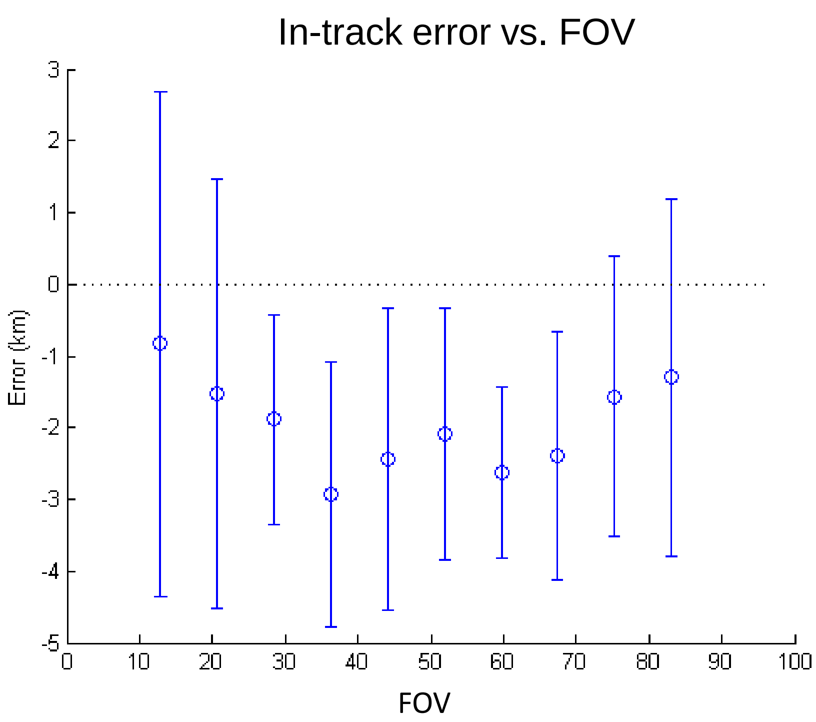
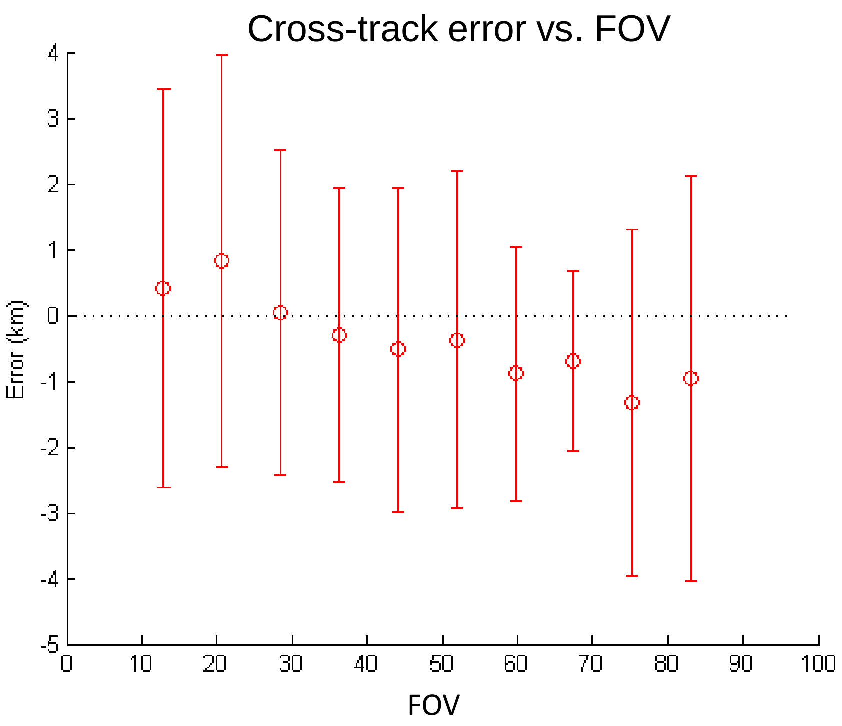
Channel 1 Shoreline Crossing





- Number of cases: 184
- In-track mean: -1.9 km, std: 2.3 km
- Cross-track mean: -0.3 km, std: 2.6 km

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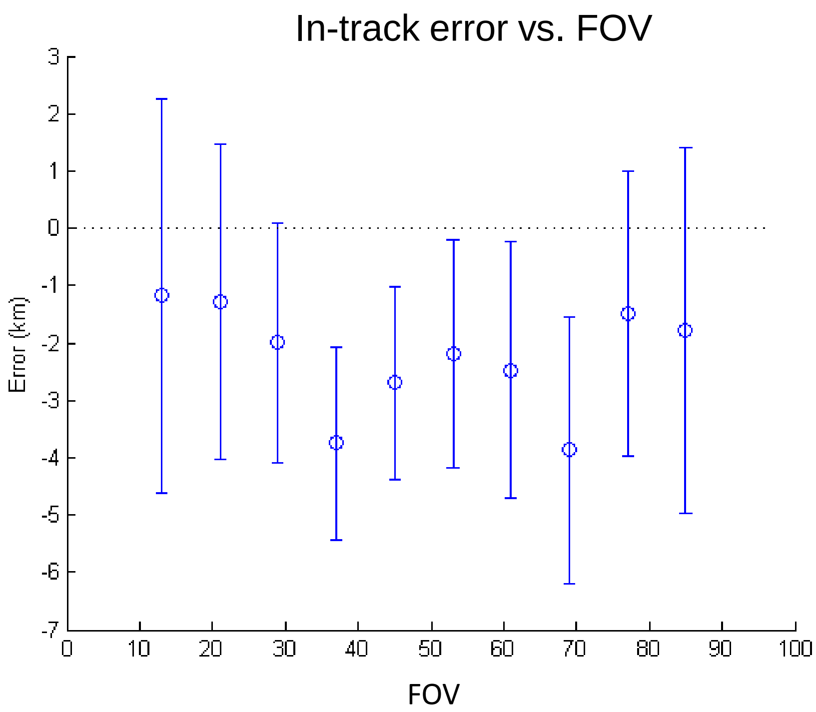
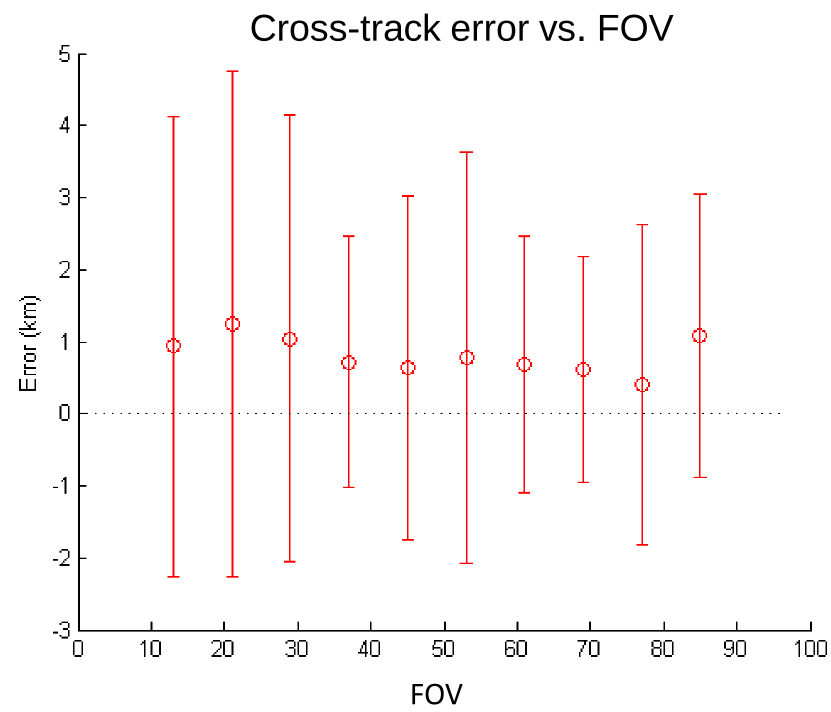
Channel 2 Shoreline Crossing





- Number of cases: 184
- In-track mean: -2.2 km, std: 2.6 km
- Cross-track mean: 0.8 km, std: 2.5 km

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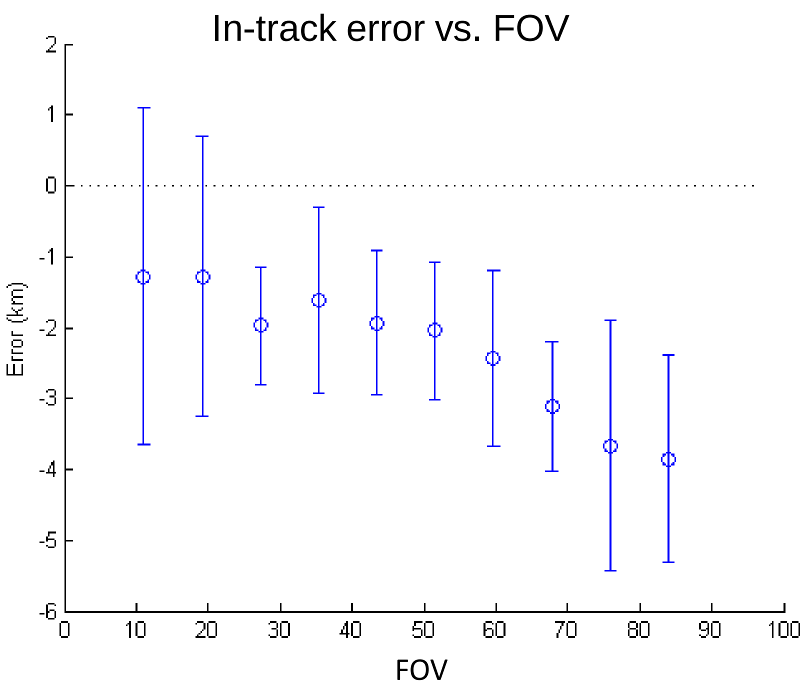
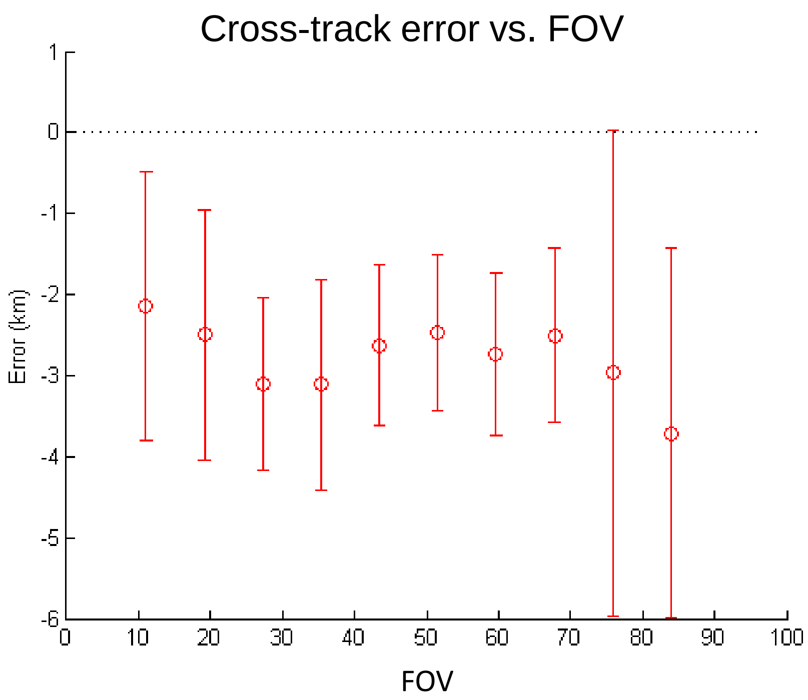
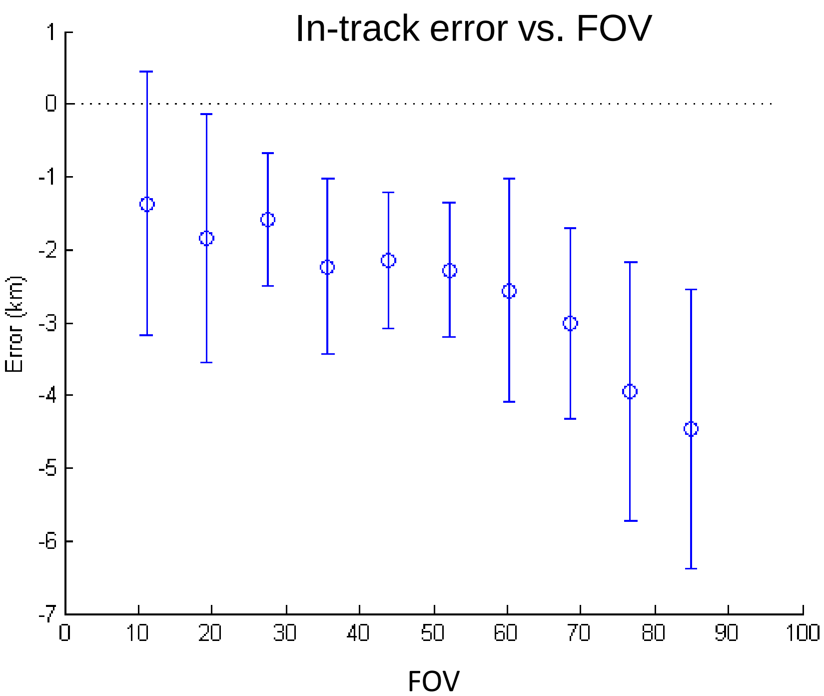
Channel 3 Shoreline Crossing

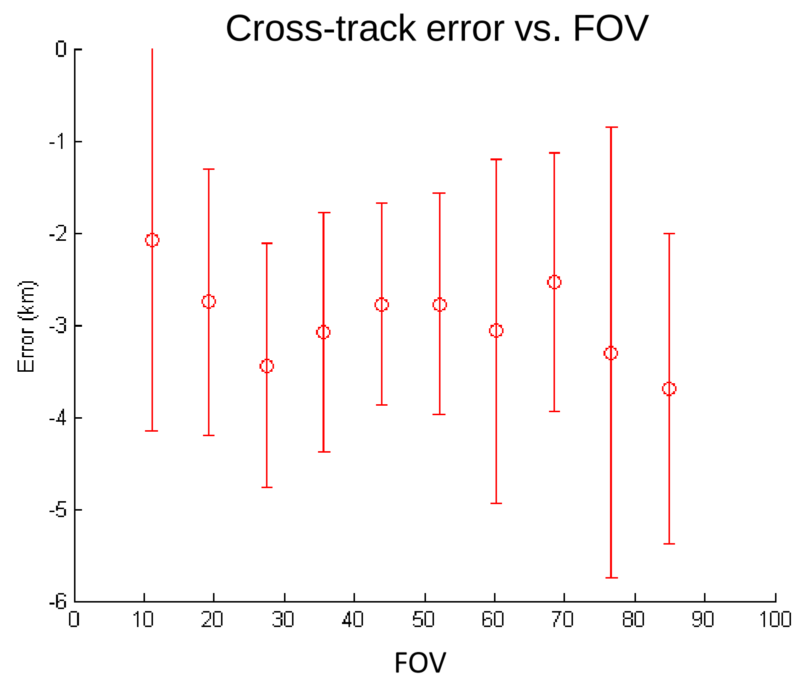




- Number of cases: 185
- In-track mean: -2.2 km, std: 1.7 km
- Cross-track mean: -2.7 km, std: 1.6 km

Channel 4 Shoreline Crossing





- Number of cases: 185
- In-track mean: -2.4 km, std: 1.6 km
- Cross-track mean: -2.9 km, std: 1.6 km

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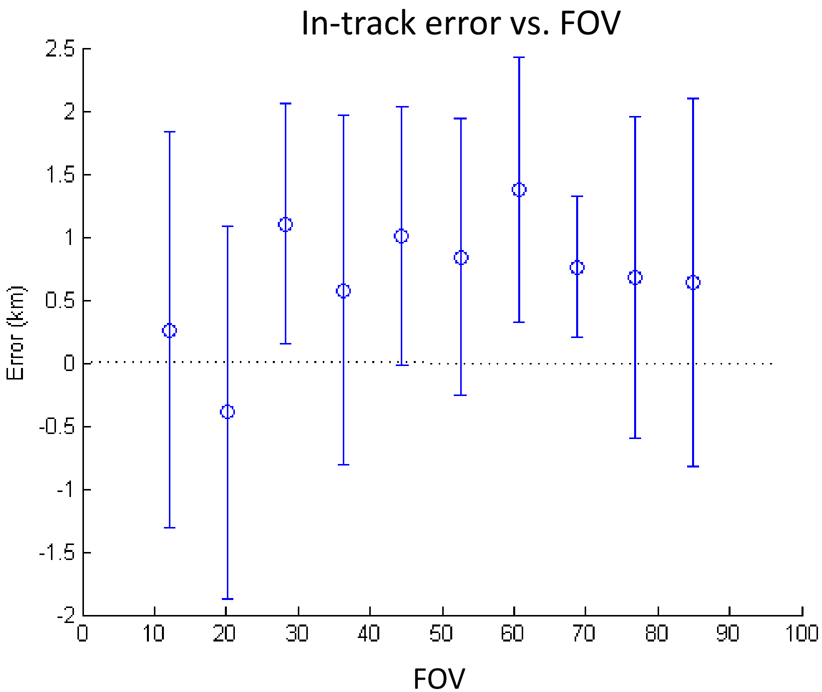
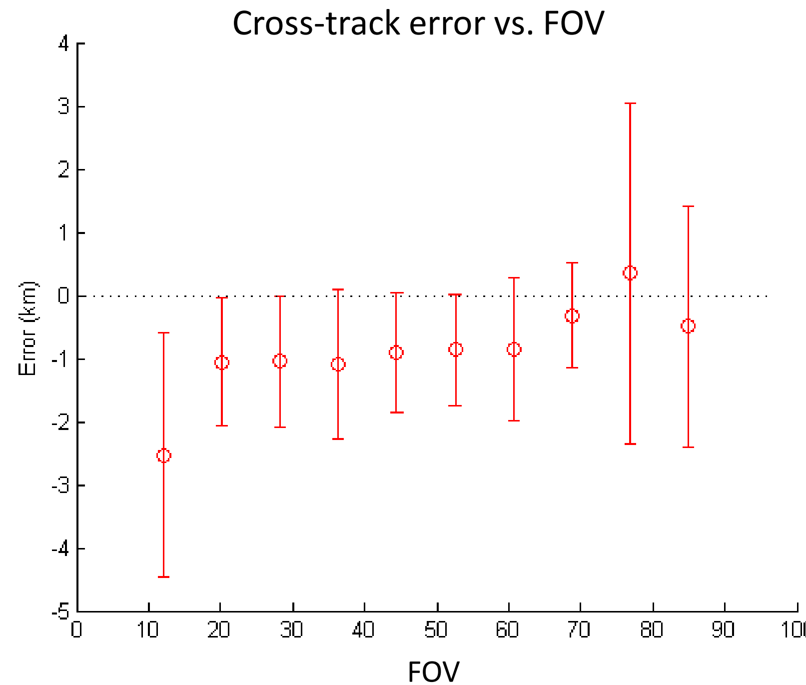
Channel 16 Shoreline Crossing





- Number of cases: 185
- In-track mean: 0.7 km, std: 1.3 km
- Cross-track mean: -1.0 km, std: 1.6 km

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