Combination of VIIRS with CrIS toward Extending Data Utilization

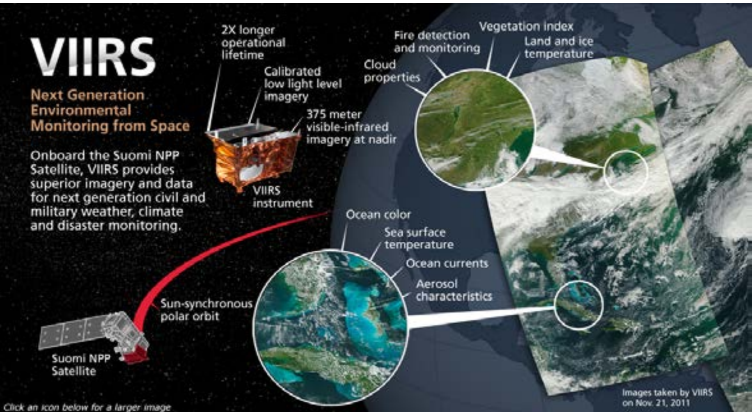
Likun Wang,

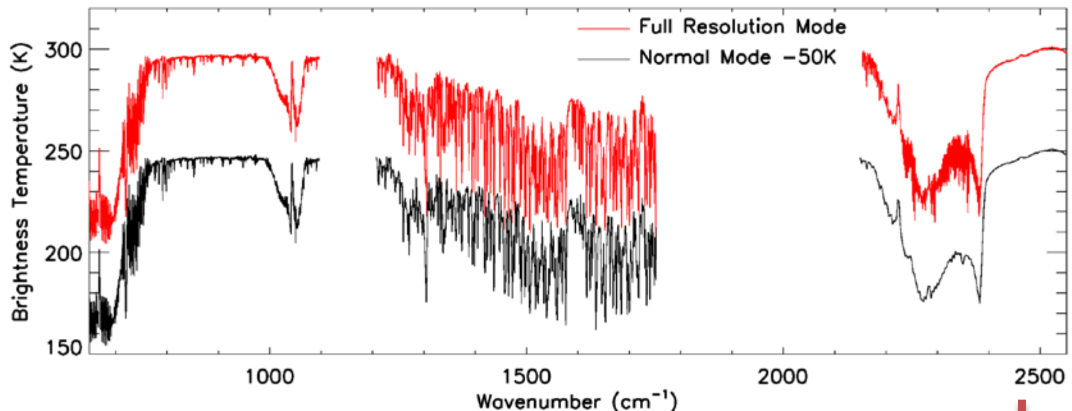
Yong Chen, Denis Tremblay, Yong Han

- ESSIC/Univ. of Maryland, College Park, MD; wlikun@umd.edu

Acknowledgment CrIS SDR Team

Motivation





land surface
cloud properties

Combination of CrIS Spectra and VIIRS Products

NWP Data assimilations
Geophysical parameter retrievals

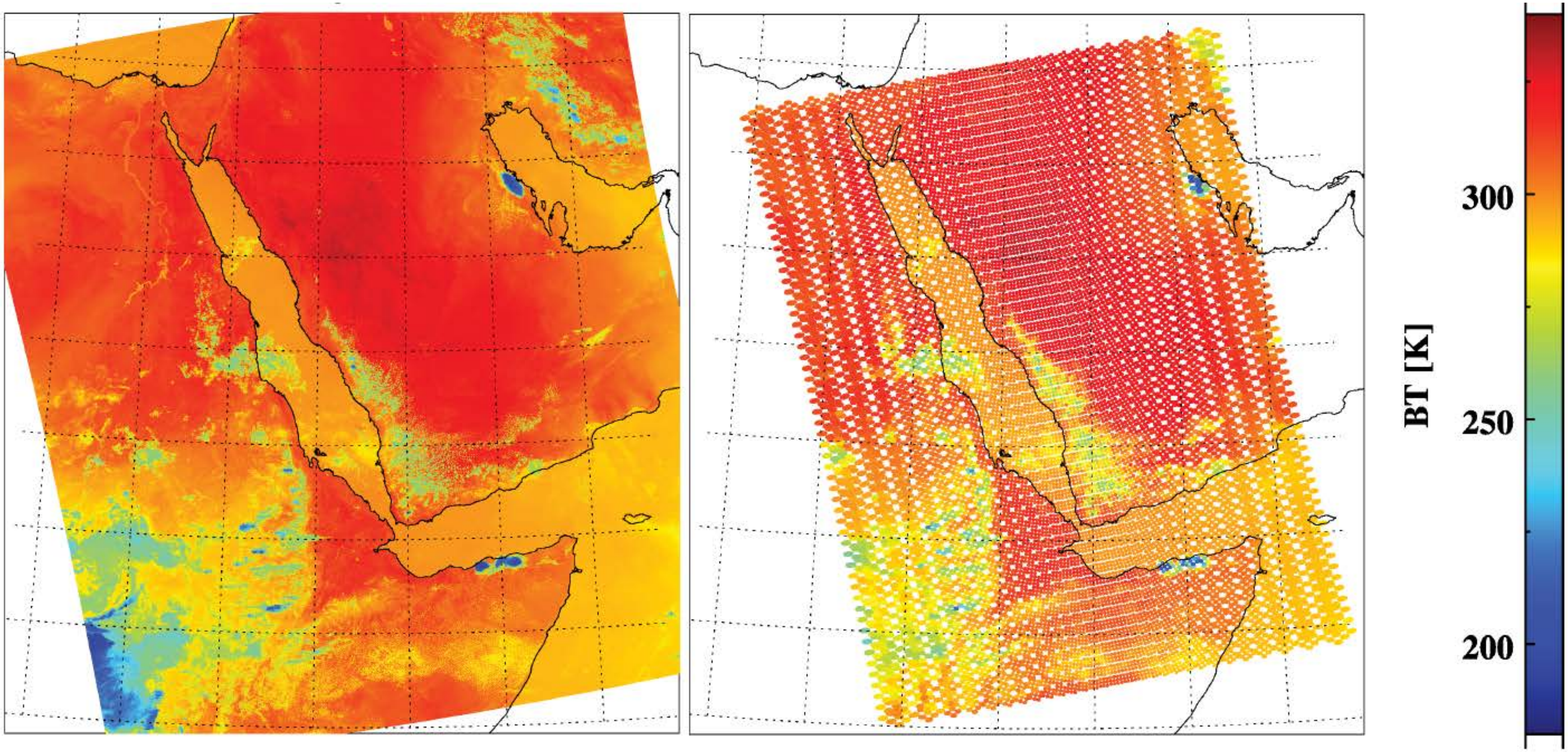
Purpose: Providing sub-pixel information for CrIS observations using collocated high-spatial resolution VIIRS radiances or products

Outline

- CrIS and VIIRS are two independent instruments, though on the same platform
  - Not like IASI and AVHRR on MetOp
  - No alignment requirements
  - Separate geolocation fields
- Fast and accurate collocation algorithm suitable for operational use
- Are CrIS and VIIRS perfect align together?
  - If not, collocated products can introduce errors and uncertainties, making applications even worse.
- Applications
  - Cloud detection
  - Effects of FOV size on the number of clear sky pixels
  - Cluster analysis (on-going)

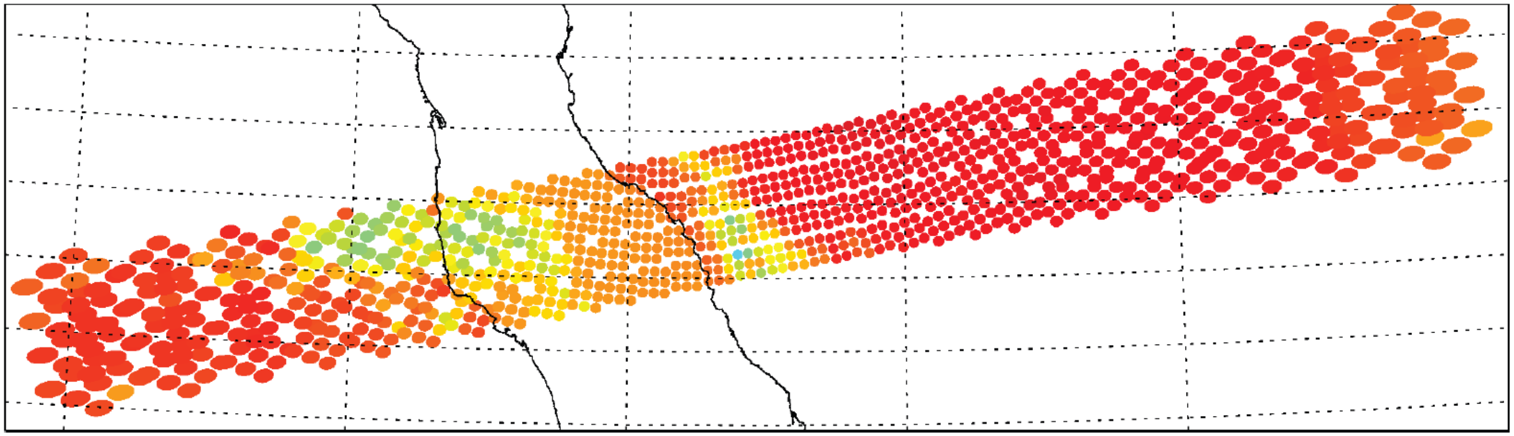
VIIRS vs. CrIS: Spatially

VIIRS I5 bands | CrIS at 900 cm^{-1}



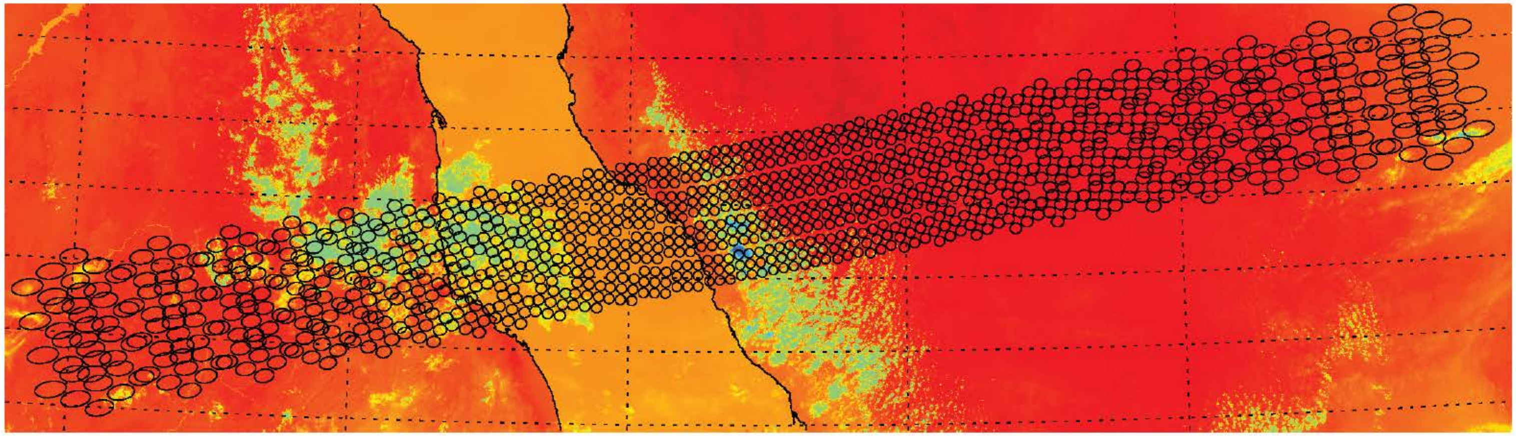
	VIIRS	CrIS
Resolution:	375m (I) or 750m (M)	14.0km nadir
Scan Angle:	58.3°	48.3 °
Sampling:	Continuous	Sub-sample

Collocation of CrIS with VIIRS



CrIS Footprints

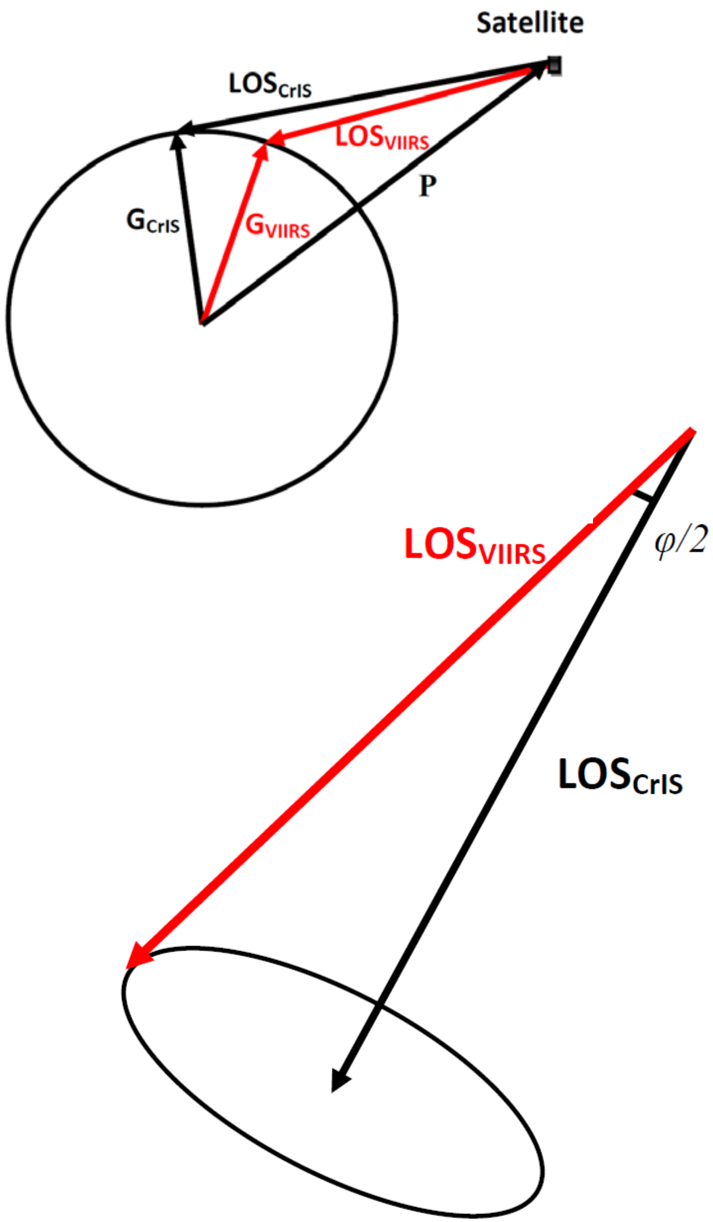
Collocation of the measurements from two satellite sensors (either on the same satellite platform or not) involves pairing measurements from two sensors that observe the same location on the Earth but with different spatial resolutions.



CrIS Footprints overlapped with VIIRS image

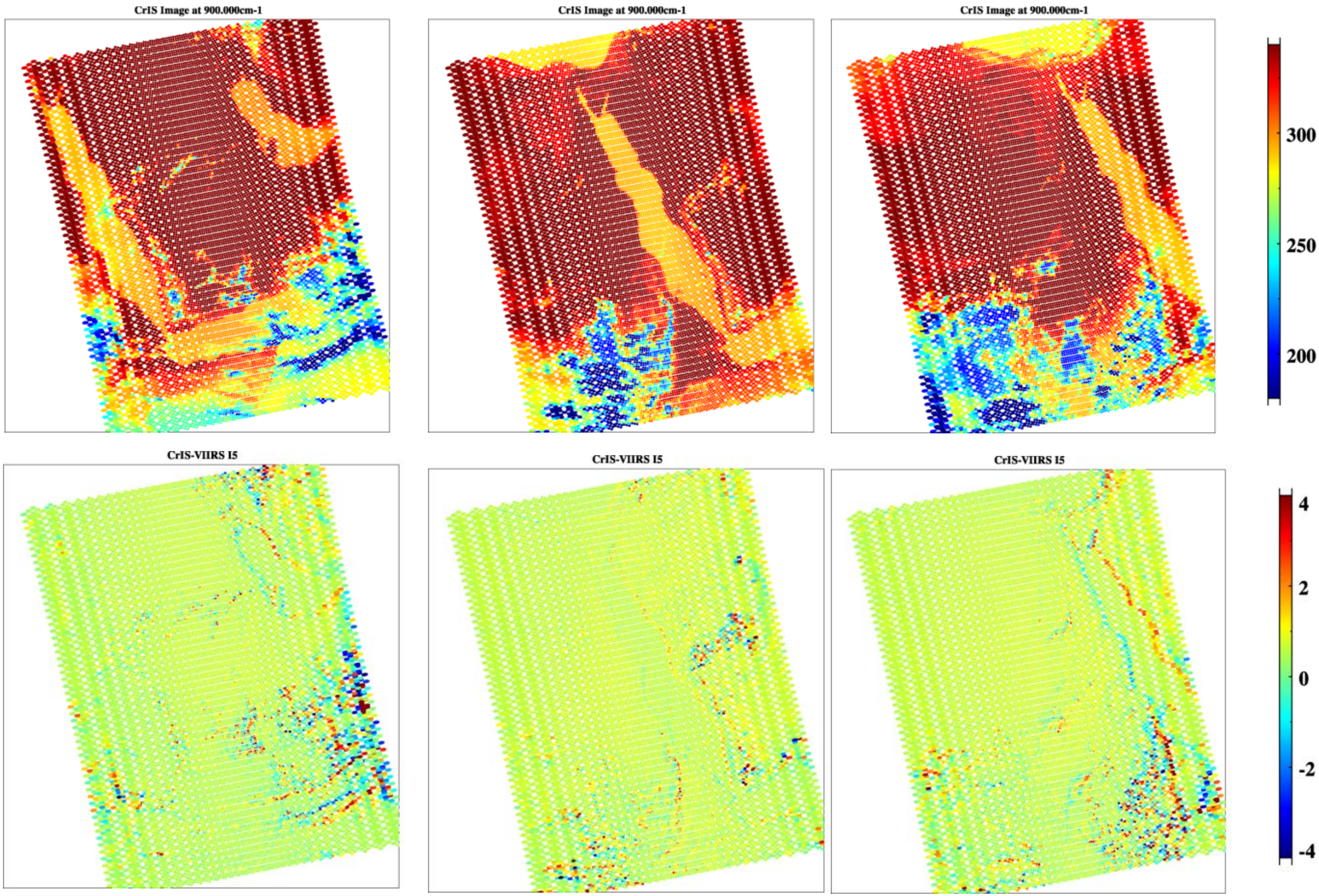
It is challenging to do it on the Earth Surface using latitude and longitude.
1) Footprint rotation and distortion off nadir; 2) Searching! Searching! Searching!

Collocation of CrIS with VIIRS Using line-of-sight vector

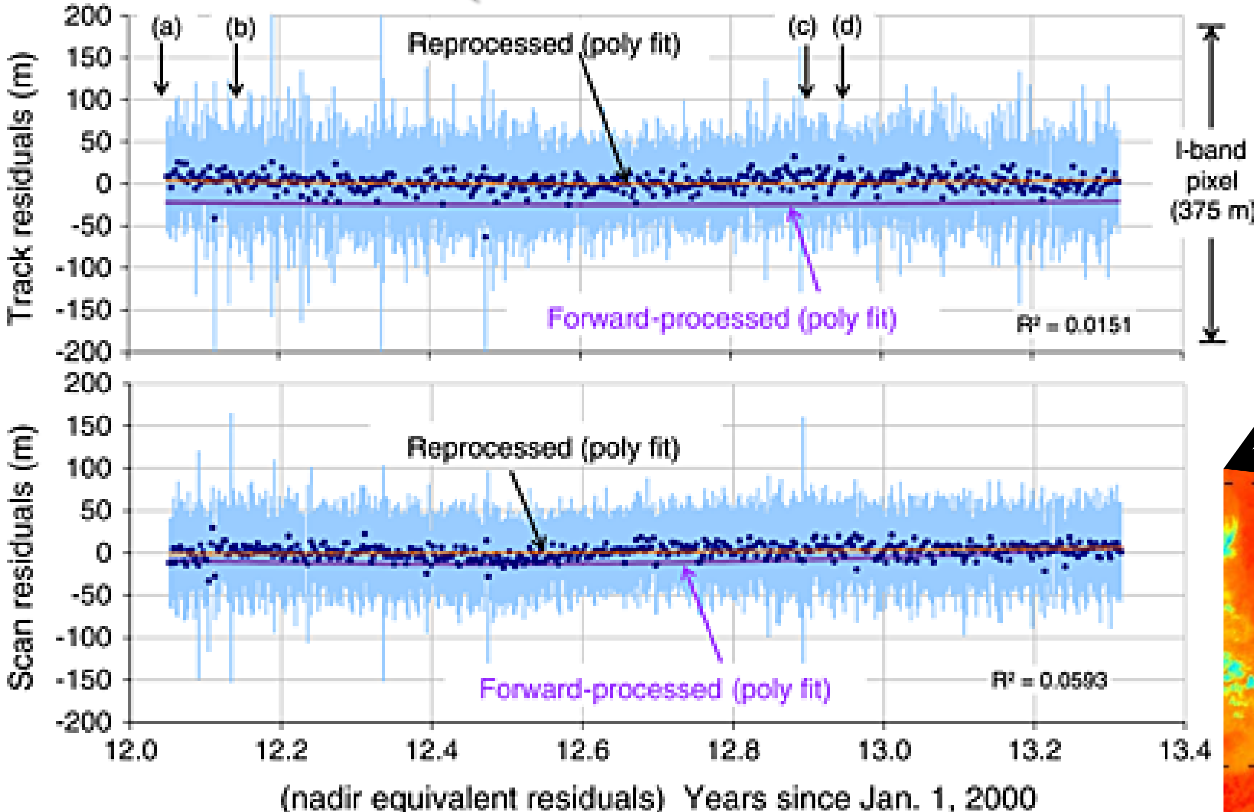


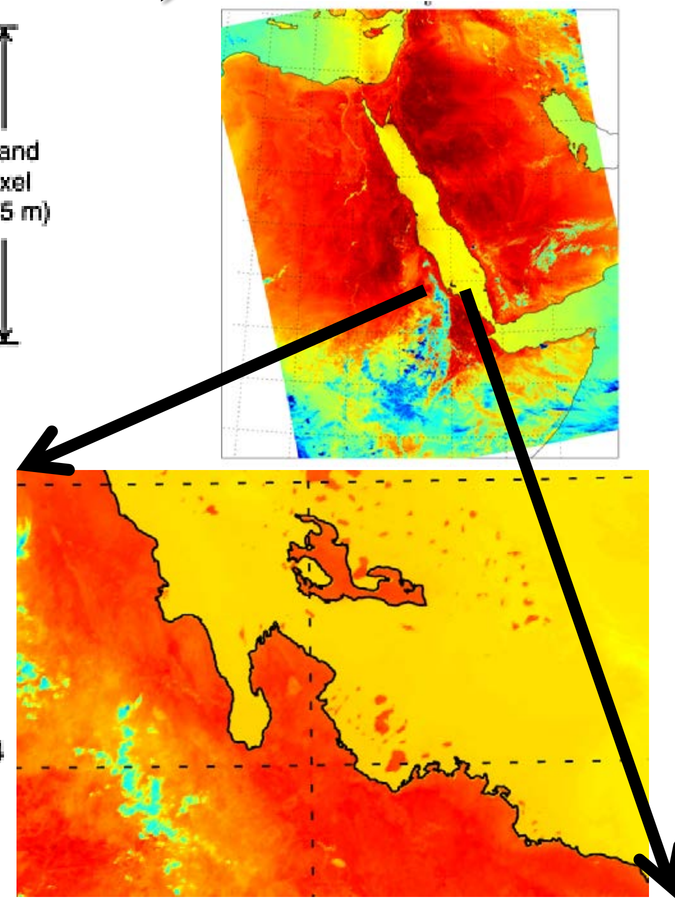
- It is better to collocate CrIS and VIIRS in space instead of on the Earth Surface
- If we can retrieve line-of-sight vector of CrIS and VIIRS
- The collocation of VIIRS and CrIS can be simplified as examining the angles between two vectors.
  - No worry about FOV distortion

Misalignment between CrIS and VIIRS at the end of scan



VIIRS Geolocation Very Accurate ! (I5 band: 375m resolution)





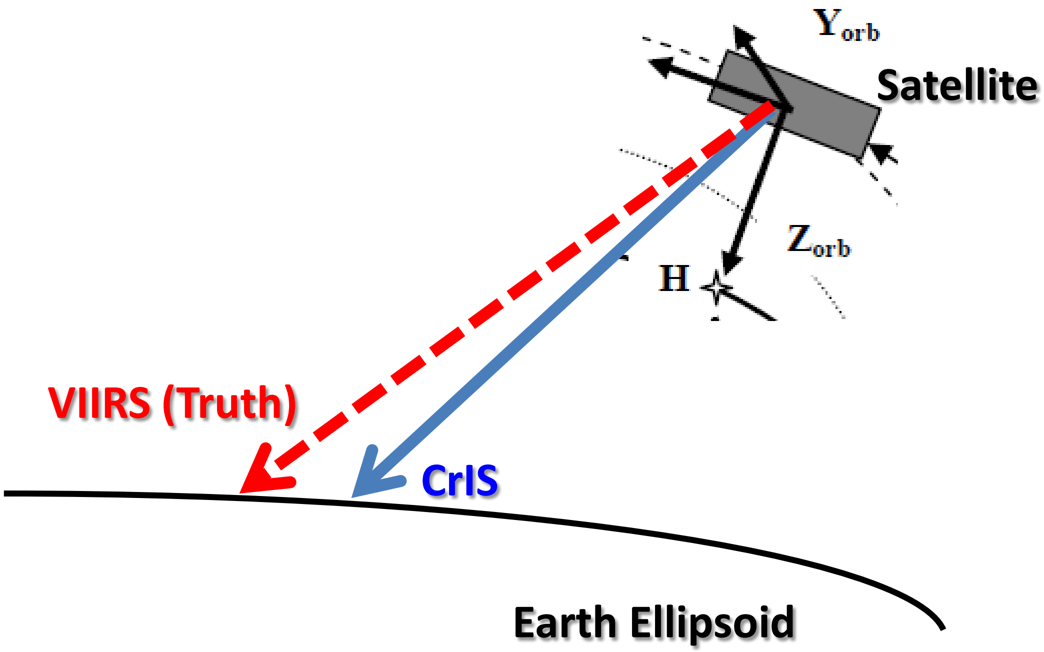
from Wolf et al. 2013

Table 2. VIIRS Geolocation Accuracy

Residuals	First Update	Second Update
	23 February 2012	18 April 2013
Track mean	−24 m, −7%	2 m, 1%
Scan mean	−8 m, −2%	2 m, 1%
Track RMSE	75 m, 20%	70 m, 19%
Scan RMSE	62 m, 17%	60 m, 16%

CrIS Geolocation Assessment Using VIIRS as a reference

- The misalignment between CrIS and VIIRS can be caused by the CrIS geolocation error.
- Can we use VIIRS as a reference to check CrIS geolocation accuracy?
- The purpose is to identify the error characteristics of CrIS LOS pointing vector by comparing them with the truth.
- Furthermore, if the systematic errors are found, a new set of co-alignment parameters should be retrieved based on assessment results to improve the geolocation accuracy.



Overview of NPP/JPSS Geolocation Algorithms

CrIS (or other instrument)

Coordinate transformation
- Interferometer
- SSM
- Sensor Isolation system
- Spacecraft

JPSS or any satellite

COMMON GEO
- Spacecraft
- Orbital
- ECI
- ECEF(ECR)
- Geodetic

Function call to common geo:
ellipIntersect(outPt,inst2SC,exitVec, dlat,lon,satazm,satzen,range)

Geolocate each FOV

feedback

GEOLOCATION ASSESSMENT

- GCP/Maps/Ground truth
- the other instrument measurements with enough geolocation accuracy
- Comparing the truth and CrIS Geo fields

ADCS

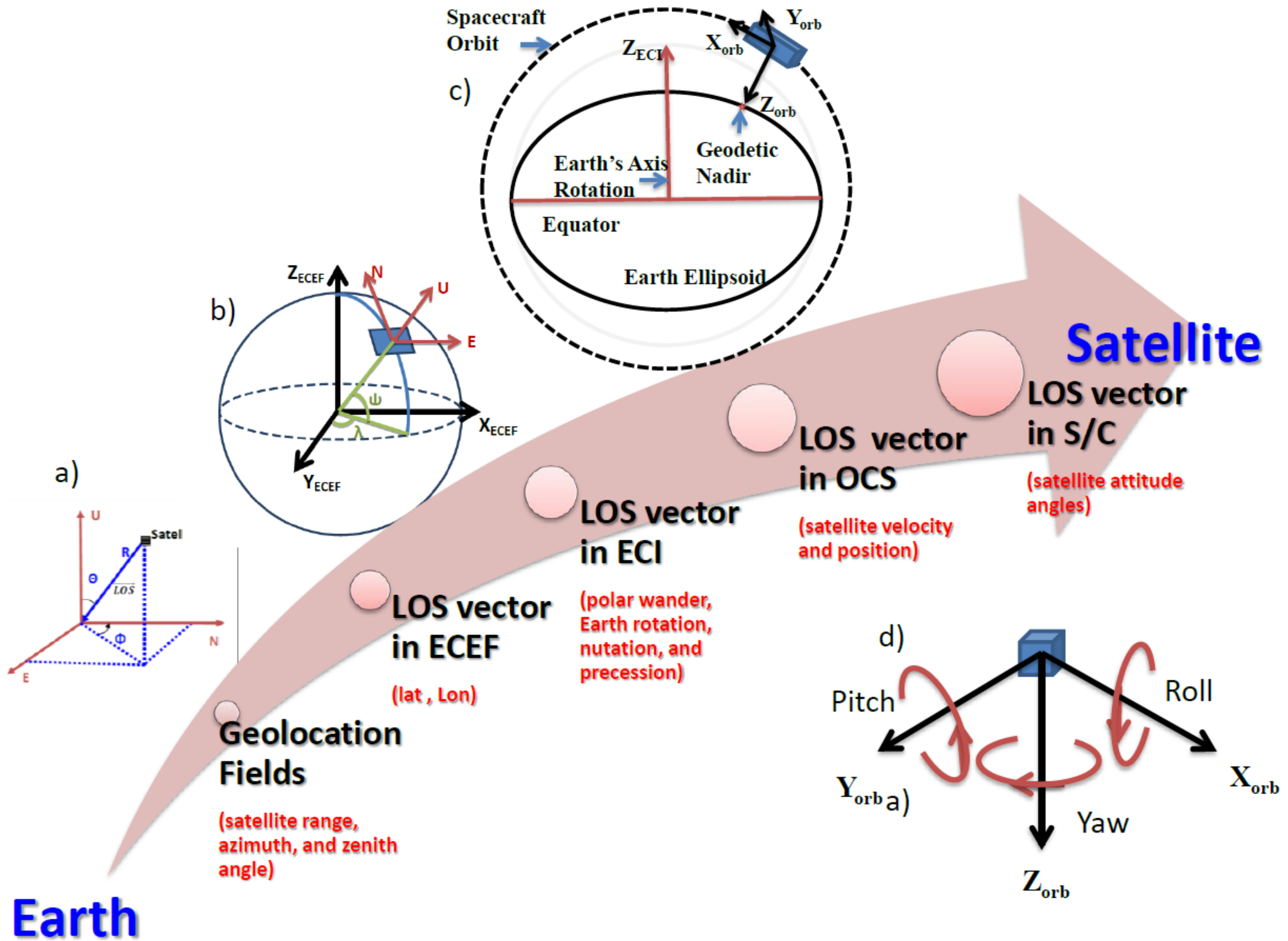
Pos/Vel/Quaternion (RPY)

Attitude Determination & Control System (ADCS)

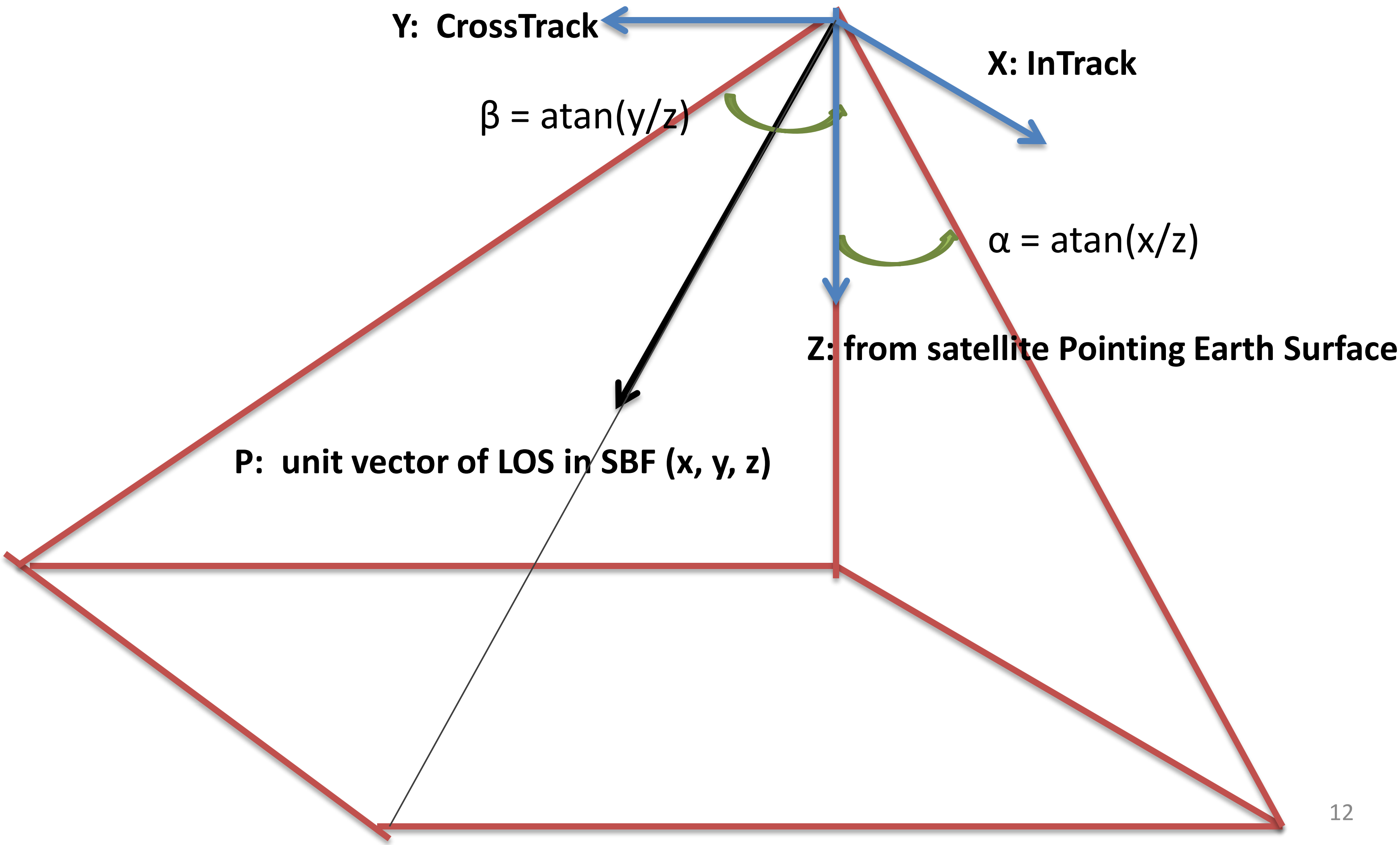
SGP4

Modified from C. Cao

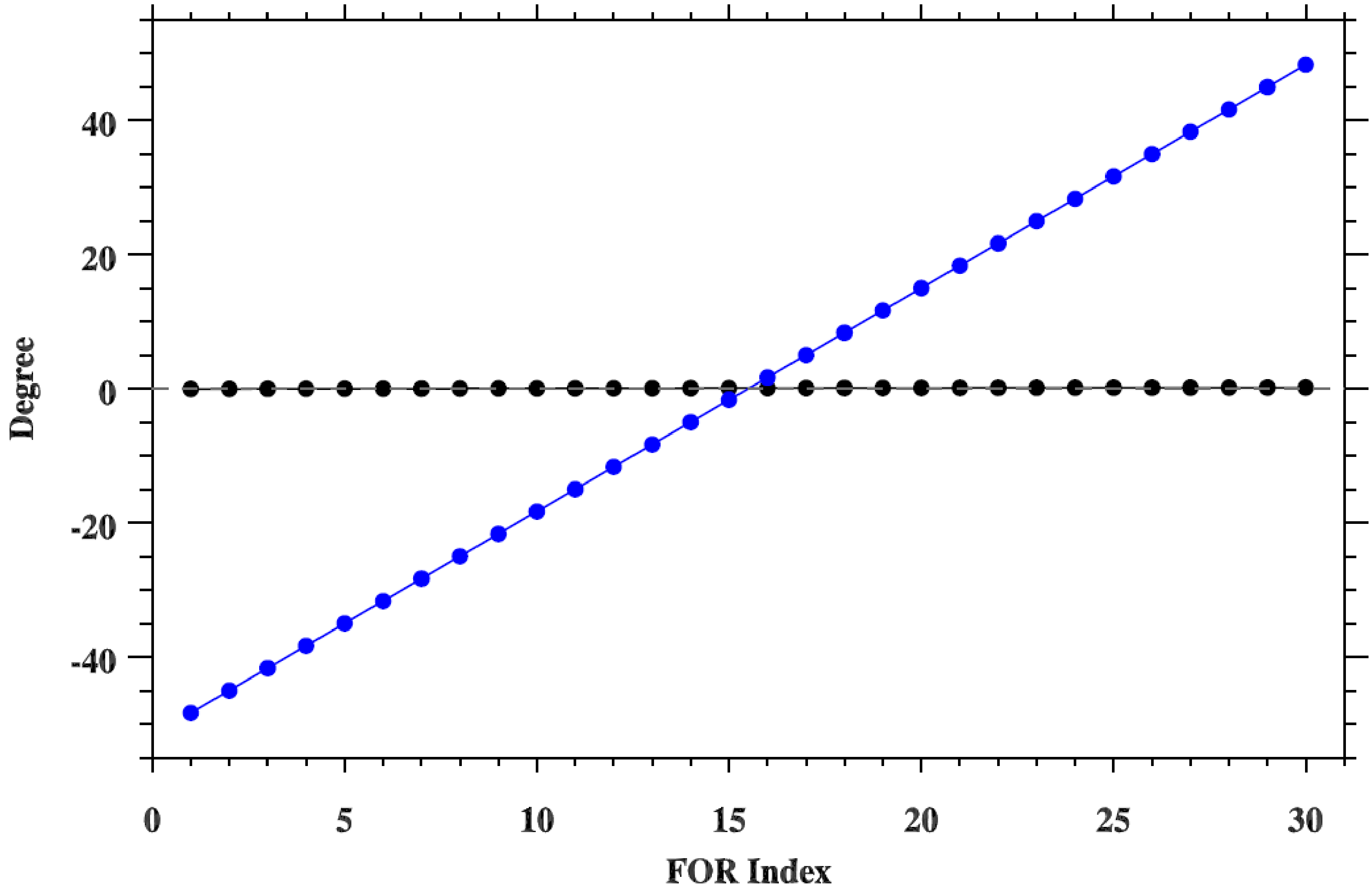
Inverse Geolocation Computation



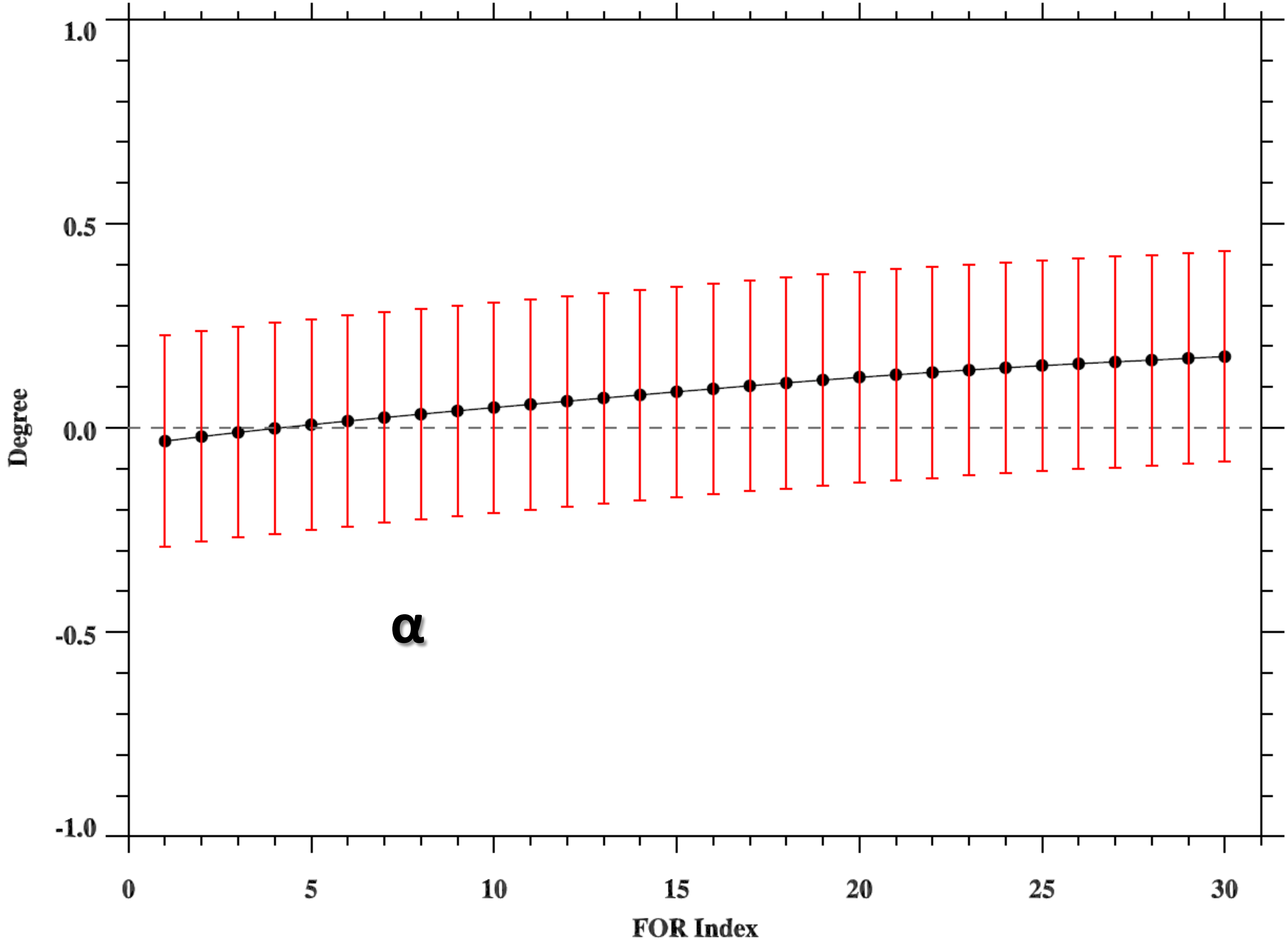
Defining α and β angles of CrIS LOS vector in Spacecraft Coordinate



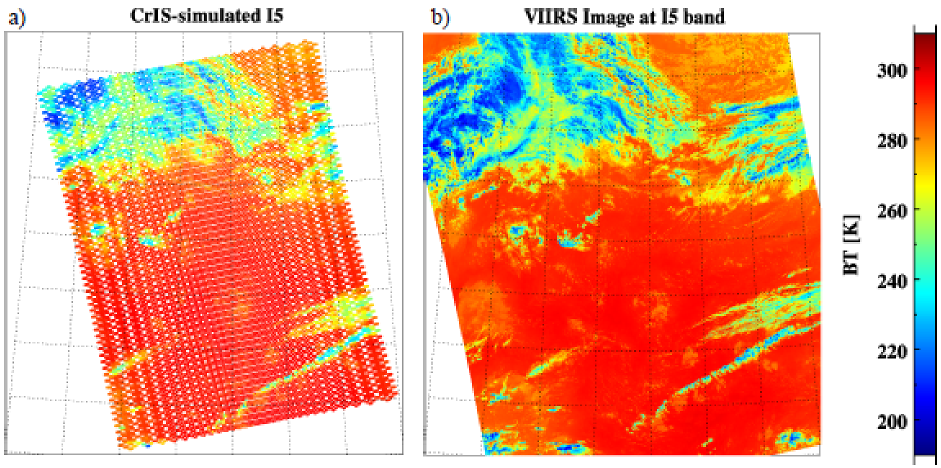
α and β Angles varying with Scan Position (FOV5)

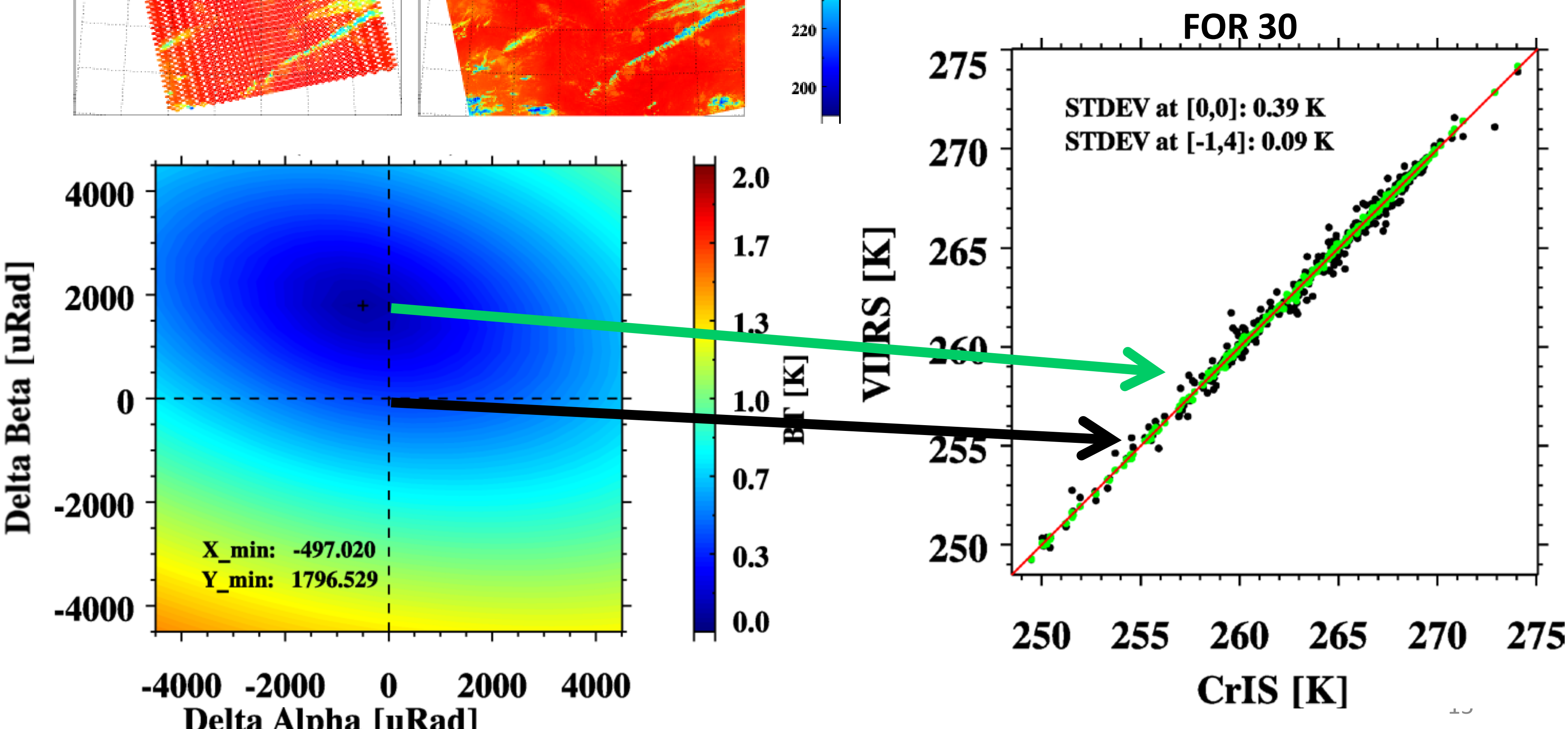


α and β angles are step-by-step perturbed by 21 steps with a angle of 375/833/1000.0

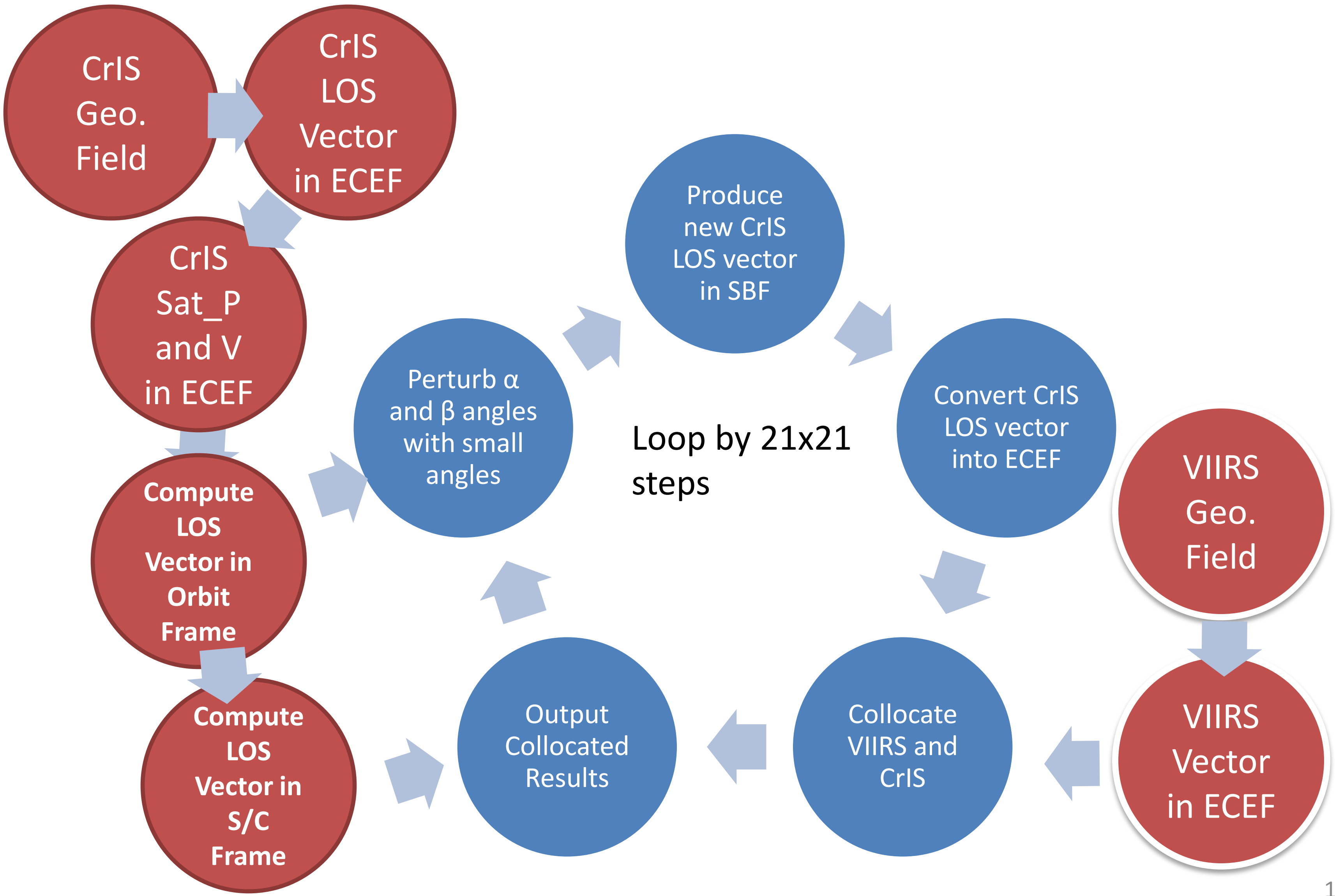


Using VIIRS to find best collocation position

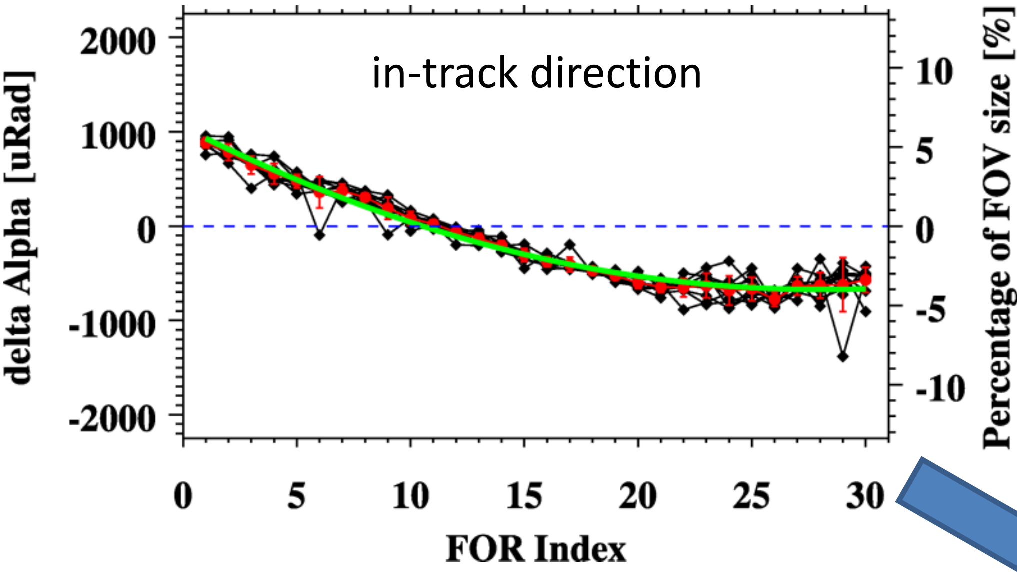


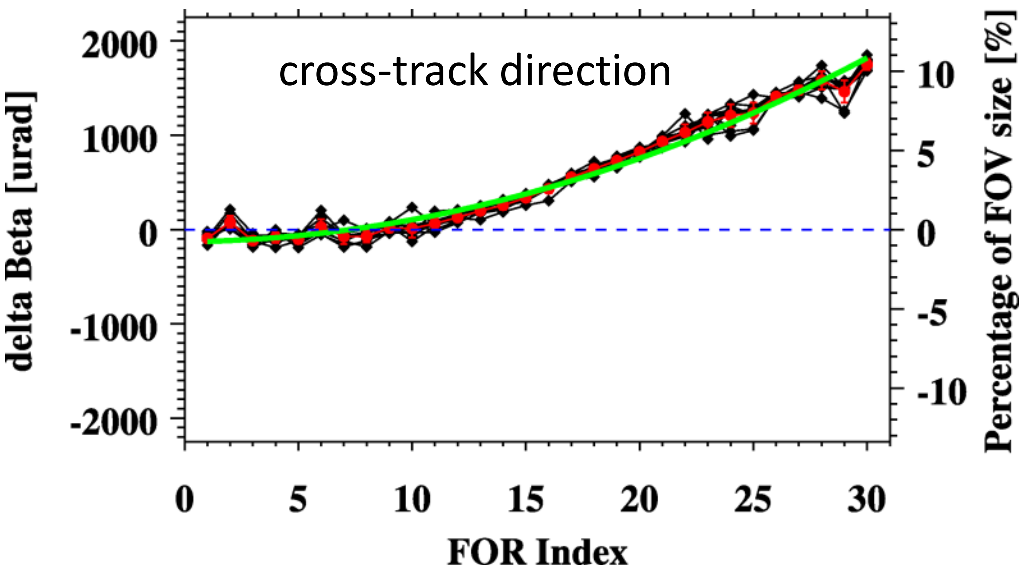


Flowchart for VIIRS-CrIS Alignment Check

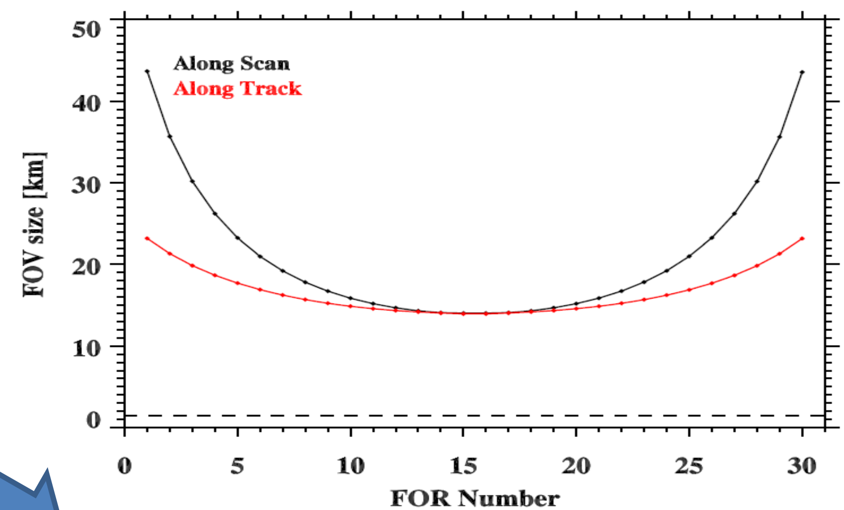


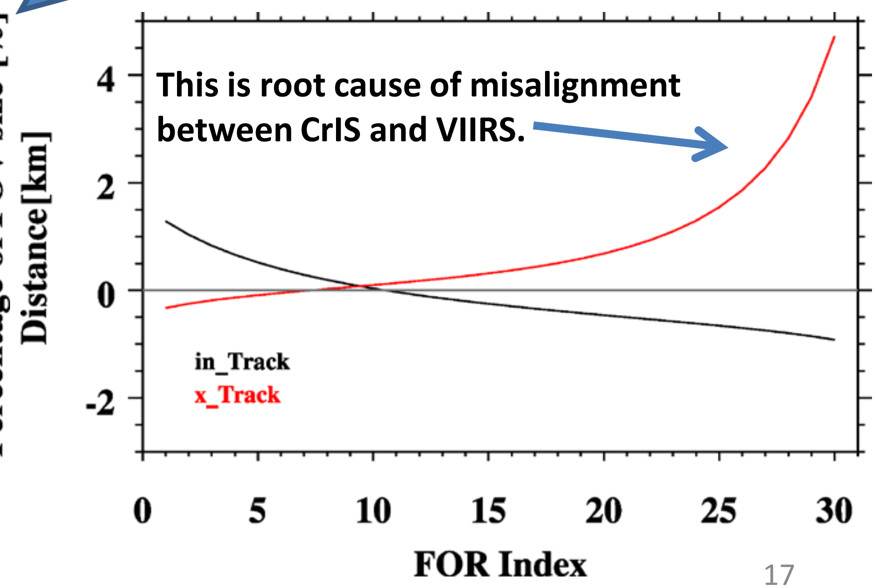
IDPS Data Geolocation Performance





CrIS FOV size in-track and cross-track direction





New Geometric Parameters

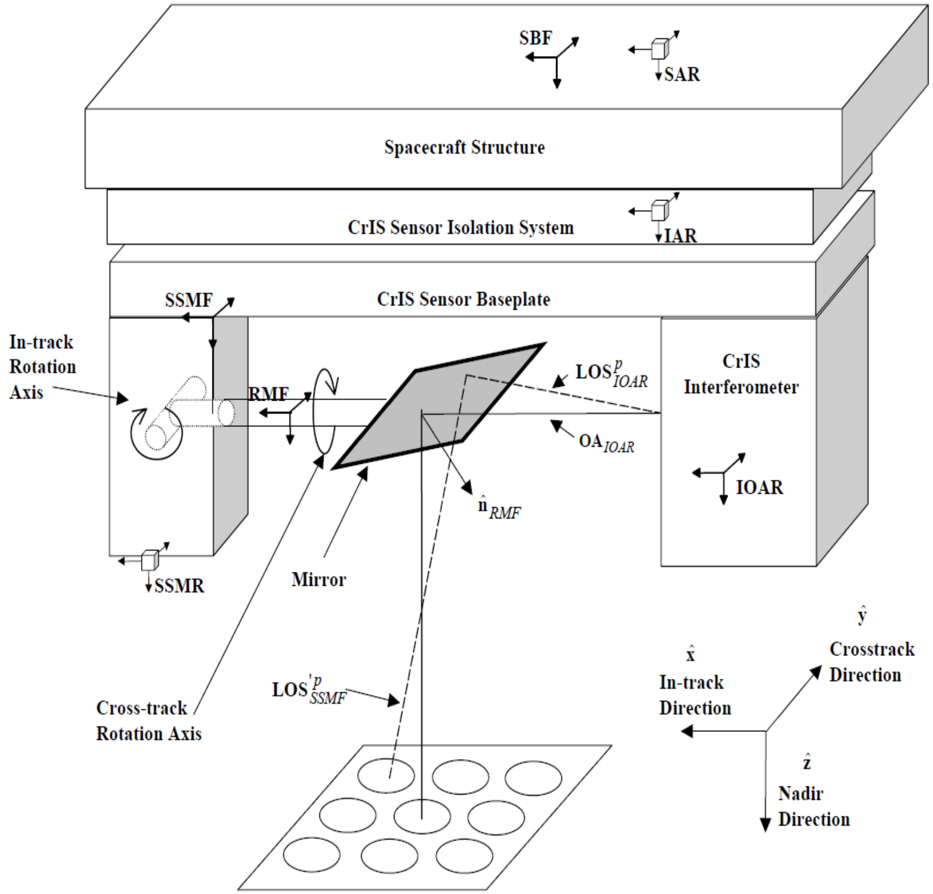


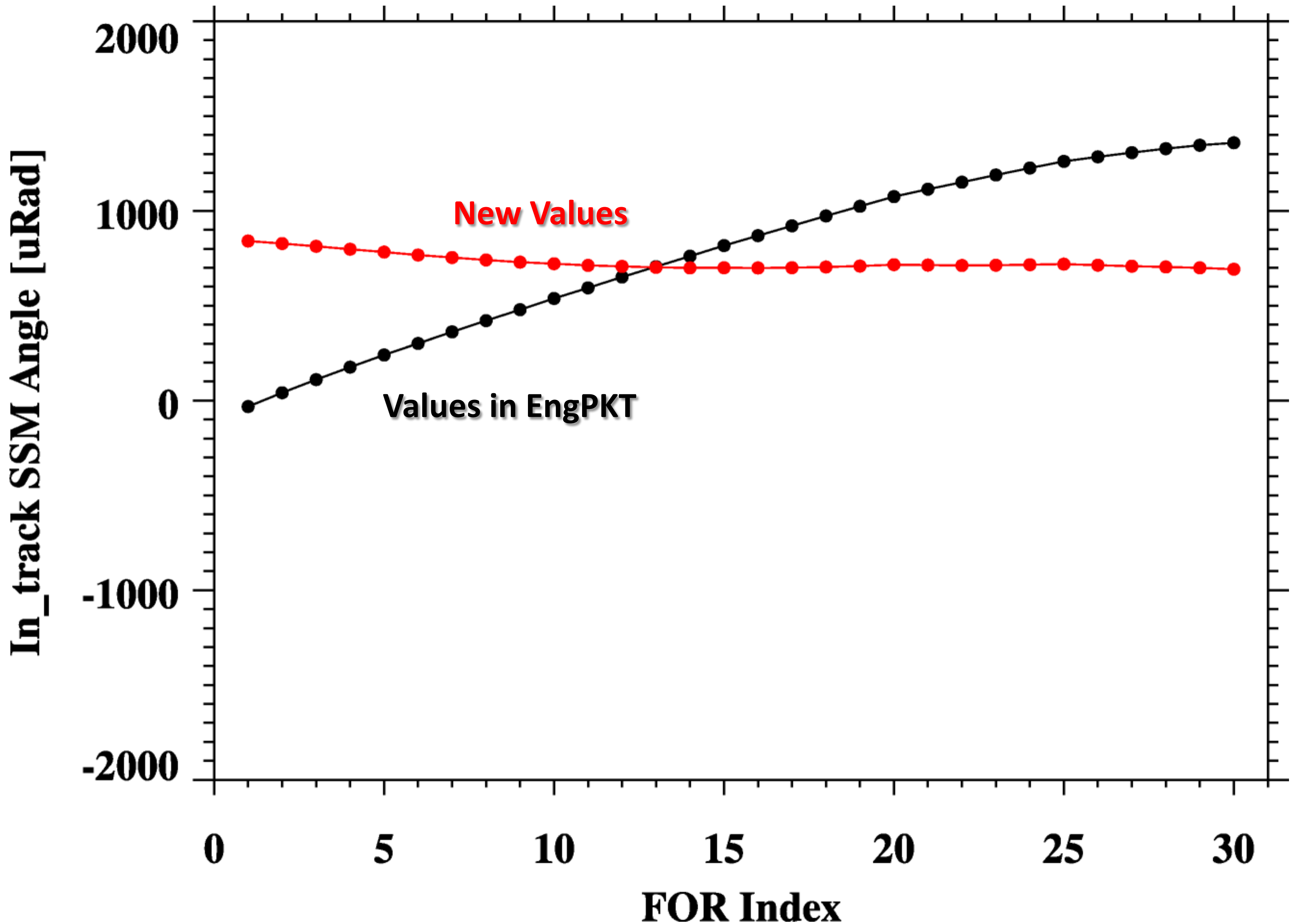
Figure 48: Sensor Algorithm Level Coordinate Systems

Given the assessment results with 60 angles, the best strategy is to retrieve 60 scan mirror rotation angles.

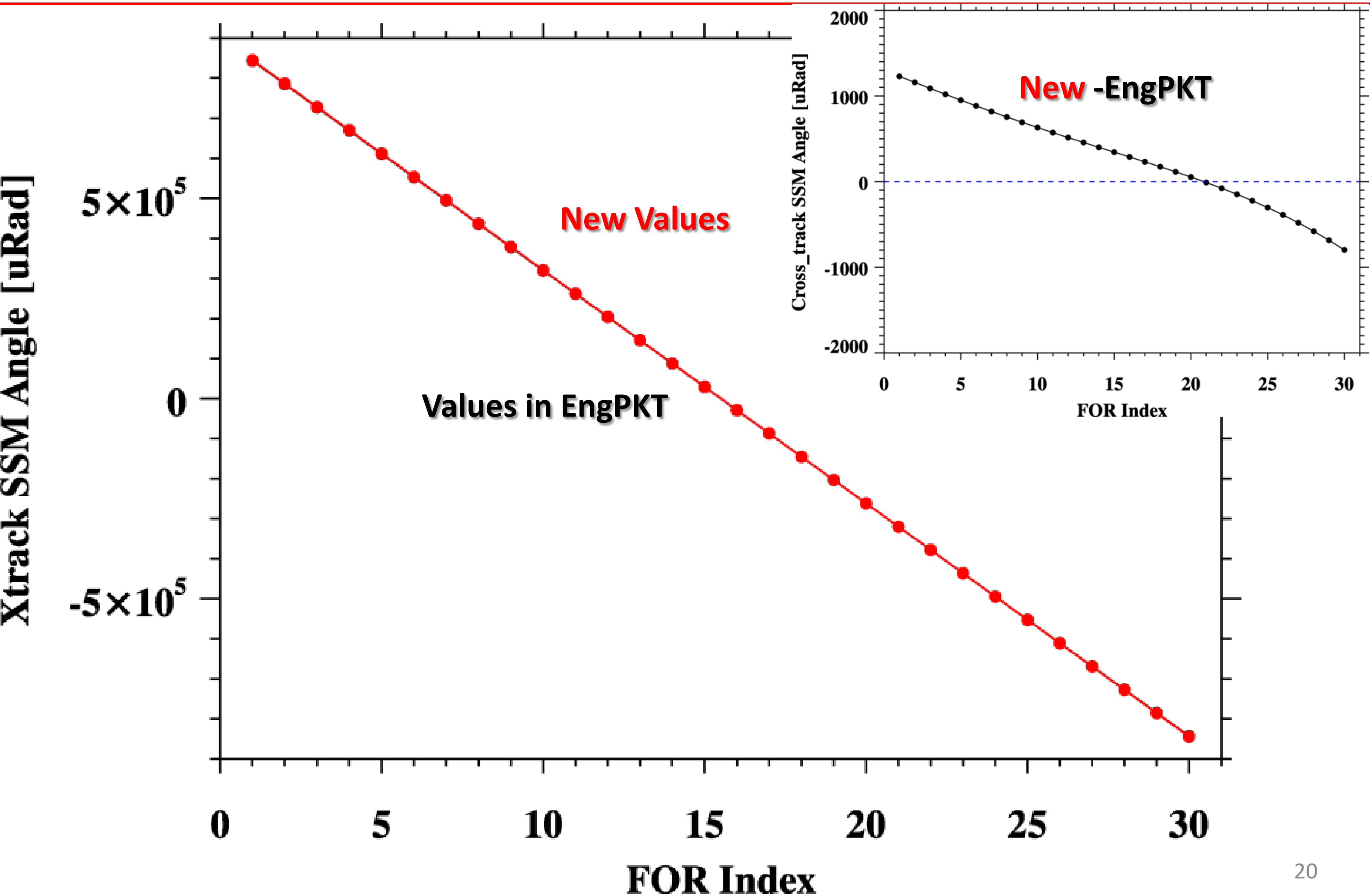
SDR Algorithm Process

1) LOS in IOAR coordinate = ILS parameters (3x3)
2) Convert from IOAR to SSMF coordinate **(2 angles)**
3) Compute normal to SSM mirror in SSMF (30 Scan Pos) **(60 angles)**
4) Apply SSM mirror rotation to get LOS in SSMF coordinate
5) Convert from SSMF to SSMR coordinate **(3 angles)**
6) Convert from SSMR to IAR coordinate **(3 angles)**
7) Convert from IAR to SAR **(3 angles)**
8) From SAR=> SBF coordinate **(0 angels)**
9) From SBF=> Spacecraft **(3 angles)**

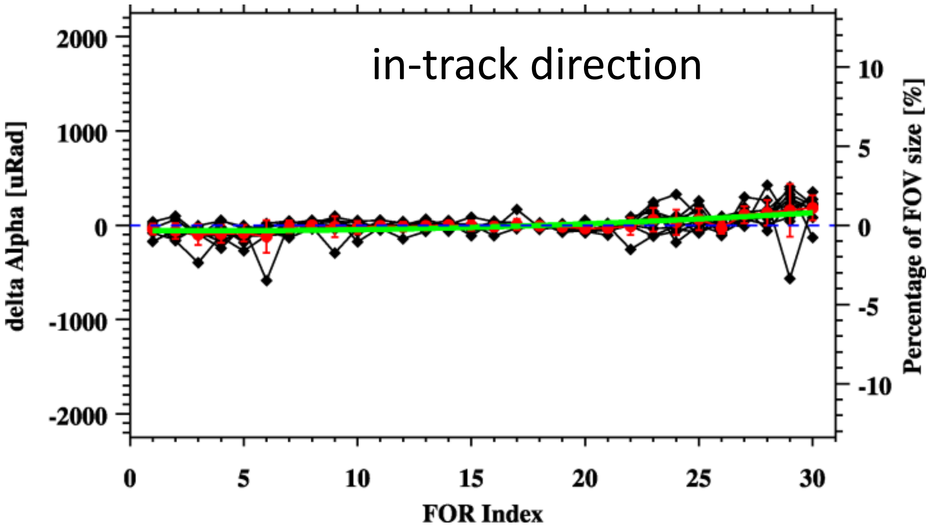
New SSMF In-track Angles

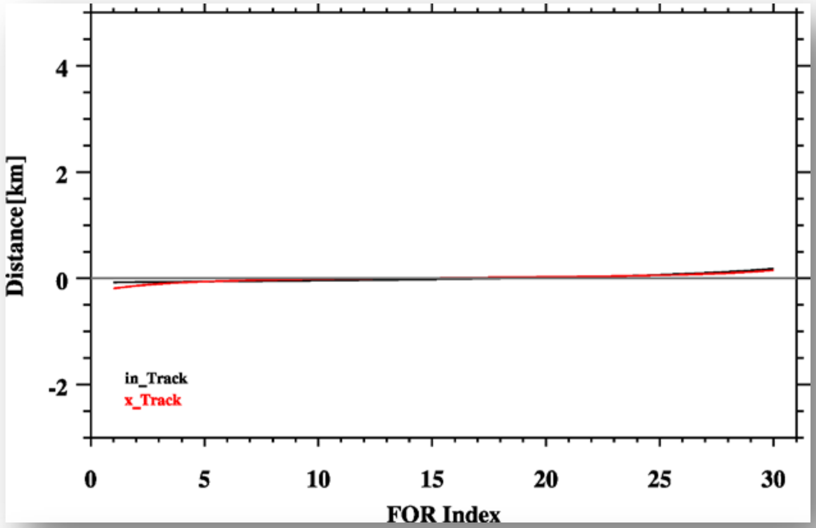


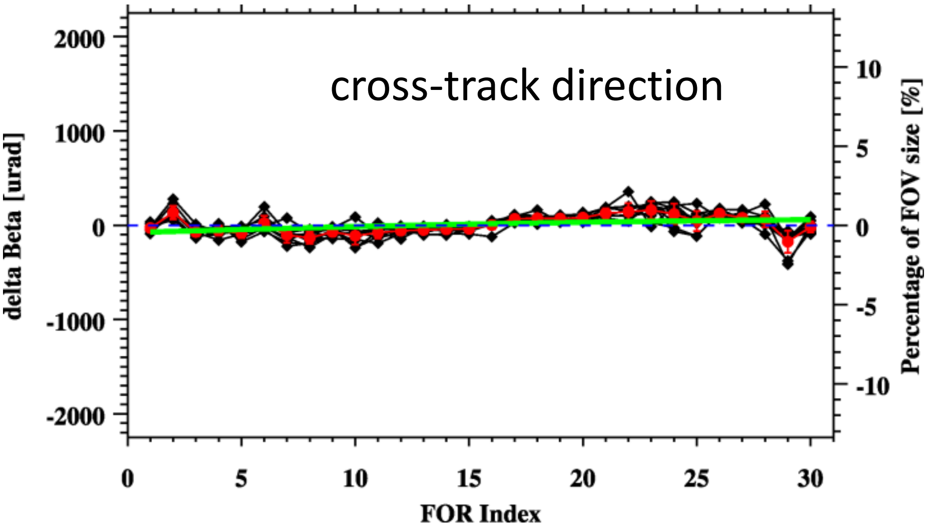
Retrieved SSMF Cross-track Angles

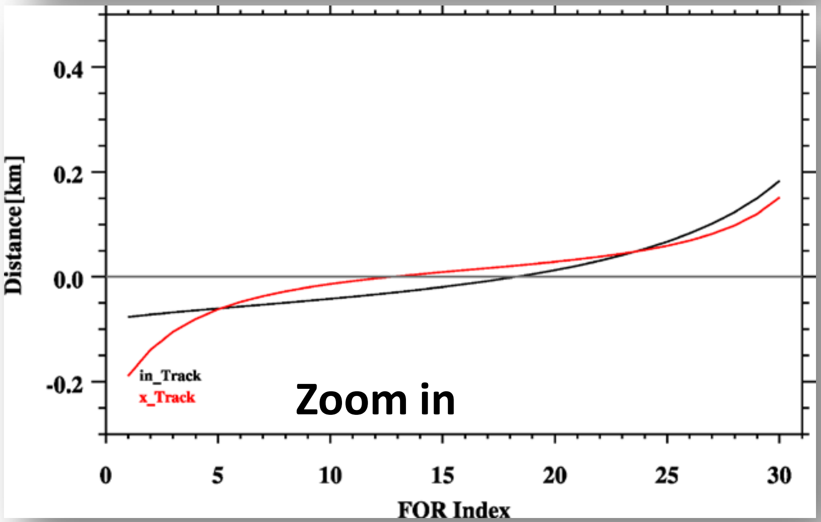


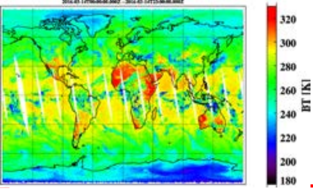
Geolocation Performance (New Parameters)



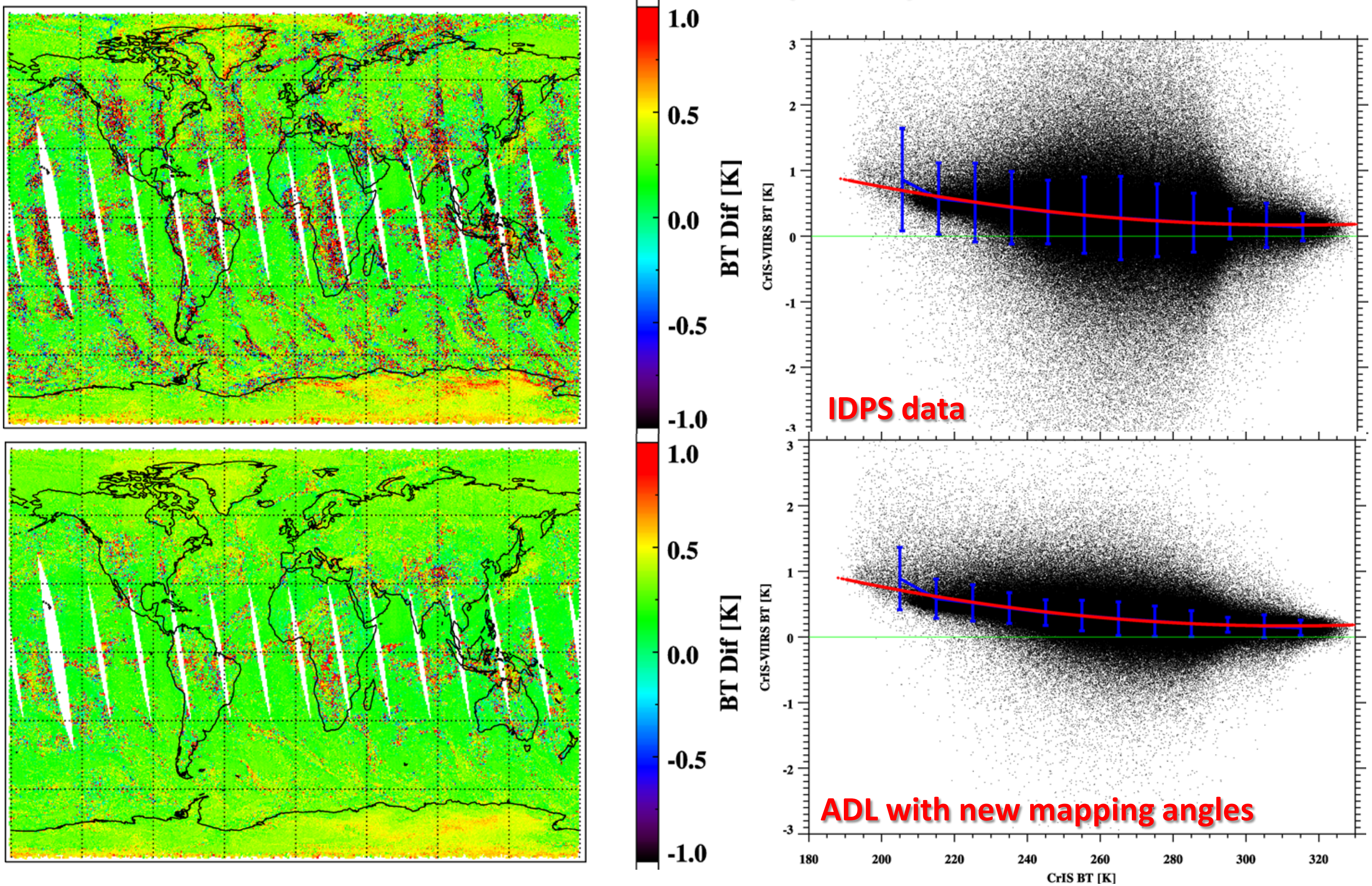




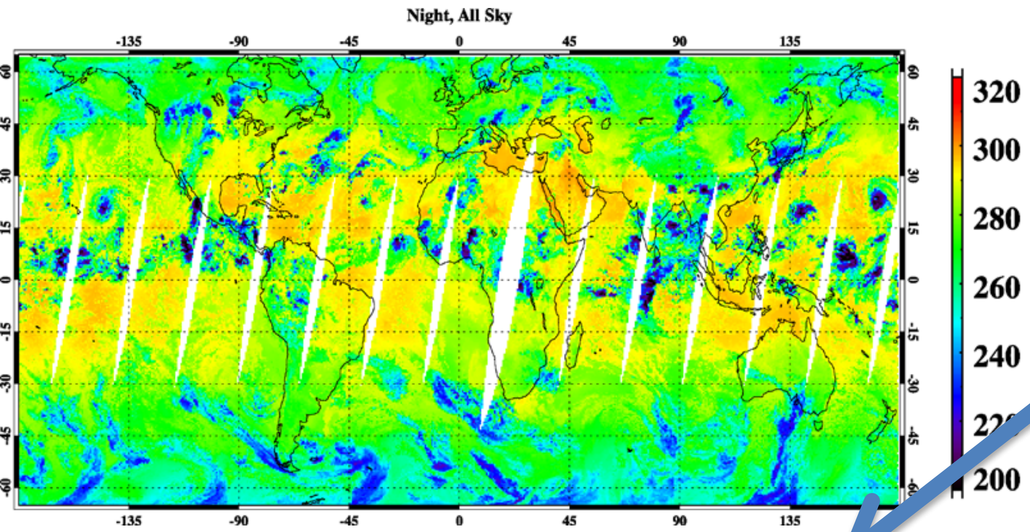




Effects of Geolocation Updates CrIS-VIIRS (M15)



Application (I)
Clear Sky Detection Comparison

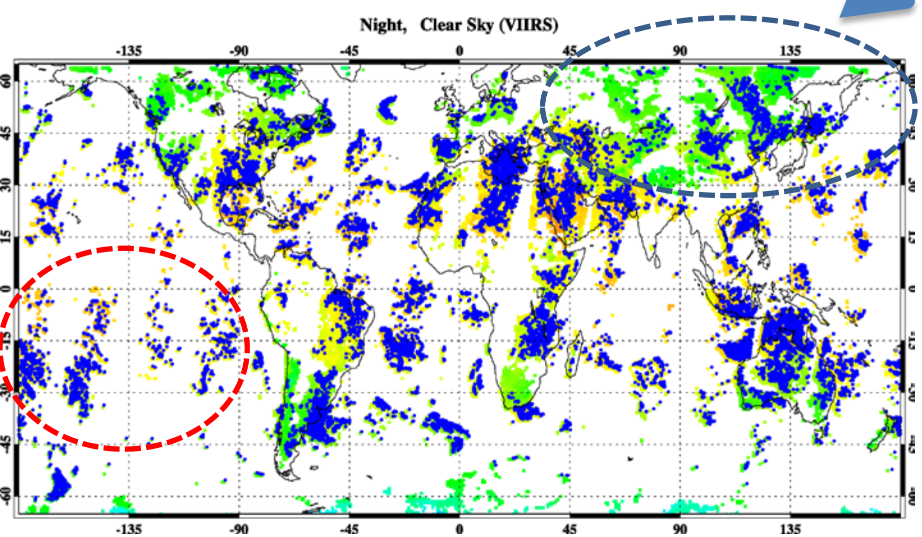


- Compared to NWP method, the VIIRS method represent the most conservative clear sky detection.

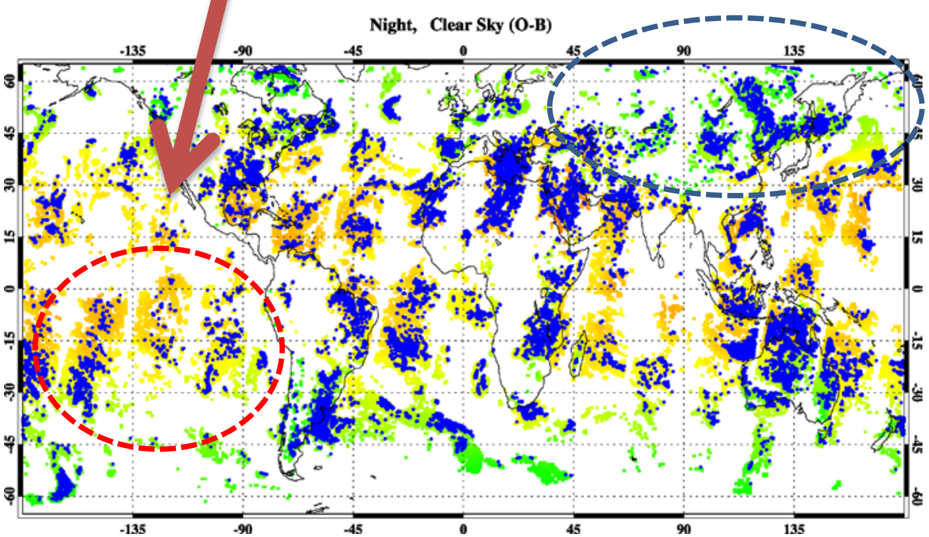
- Differences:

1Missed detection of clear sky observations over land by the NWP method

2. More clear sky observations over sea by NWP method



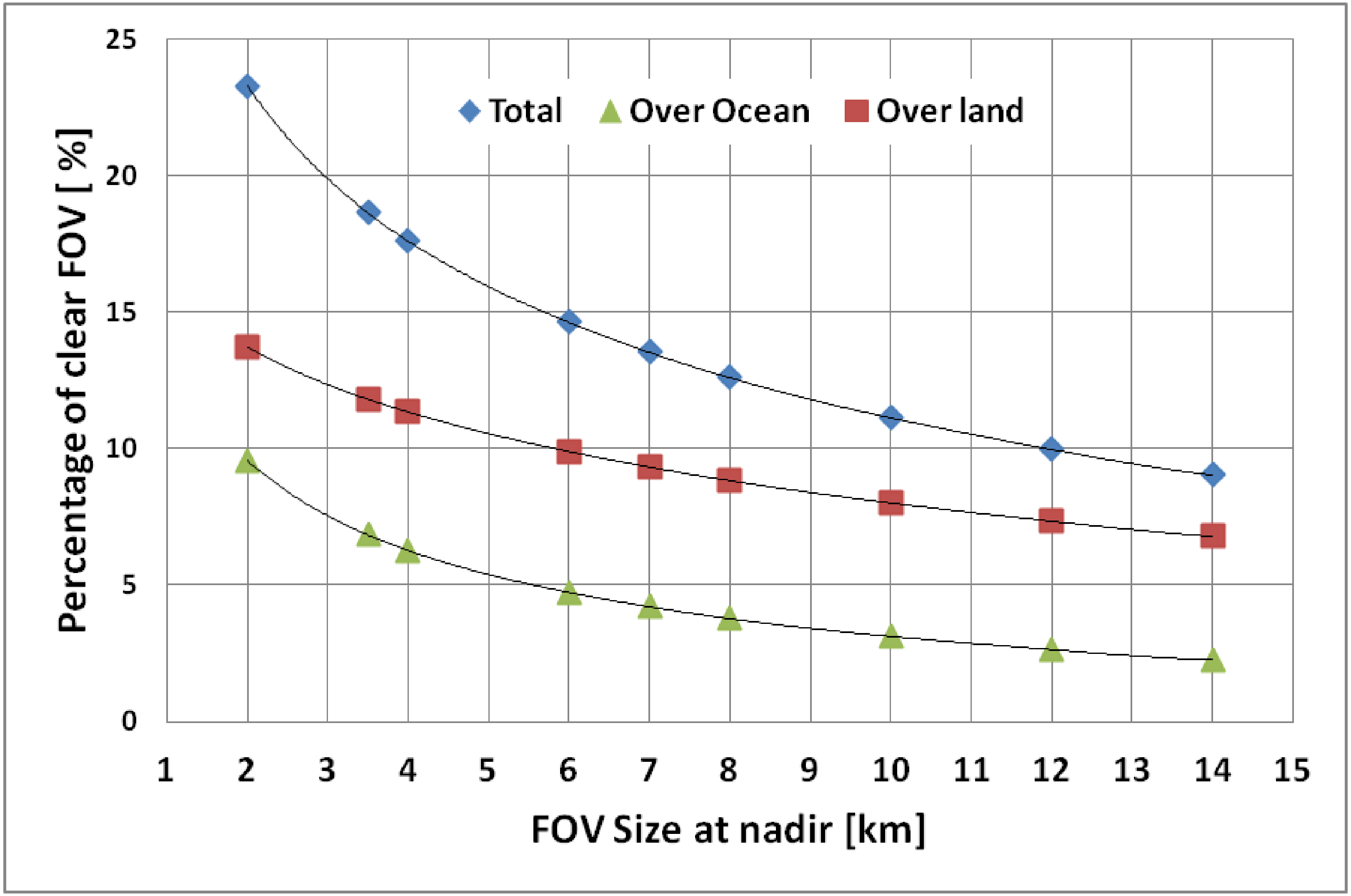
VIIRS method



NWP method

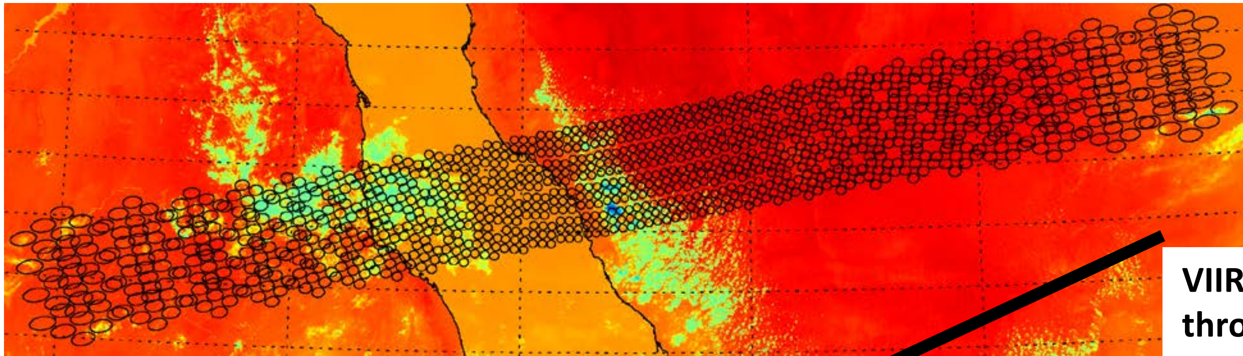
Blue dots represents the clear pixels identified by both methods

Application (II)
Clear Sky observations change with FOV size

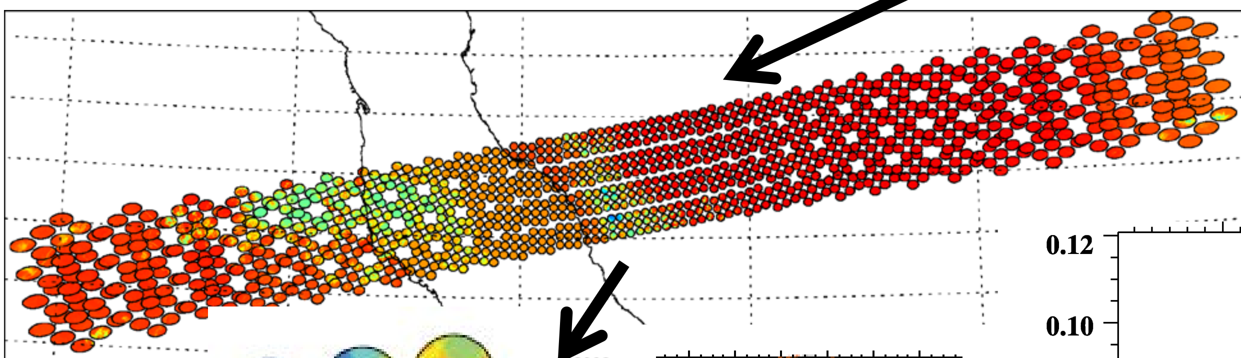


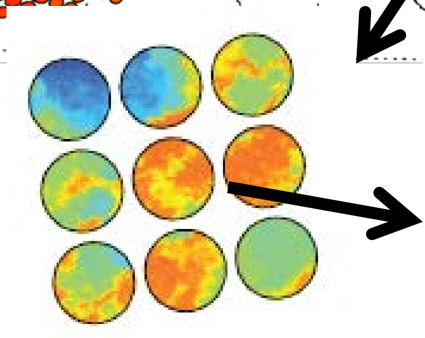
Application (III)

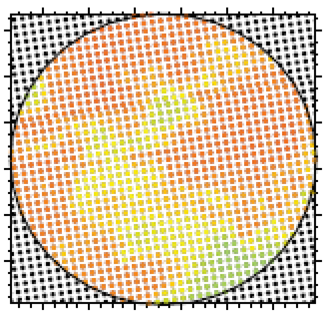
VIIRS radiance cluster analysis under CrIS FOV

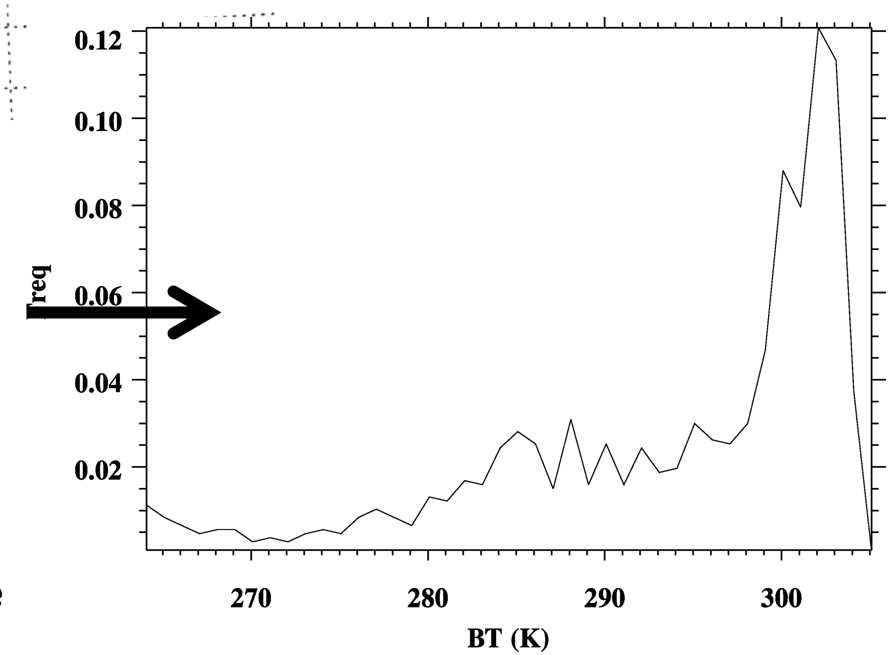


VIIRS can be collocated within CrIS footprint through fast collocation method









The collocated VIIRS pixels are then separated into several classes (7) based on cluster analysis; for each class, the fraction of CrIS FOV coverage, mean radiance value, standard deviation are provided.

Conclusion

- Fast and accurate collocation method of CrIS and VIIRS has been developed, which is suitable for operational use.
- CrIS geolocation has been adjusted to perfectly align with VIIRS.
- Accurate collocation VIIRS products shows some potentials for data assimilation and geophysical parameter retrivals.

Publication

- **Wang, L.**, D. A. Tremblay, B. Zhang, and Y. Han, 2016: Improved scheme for Cross-track Infrared Sounder geolocation assessment and optimization. Journal of Geophysical Research - Atmosphere (Submitted).

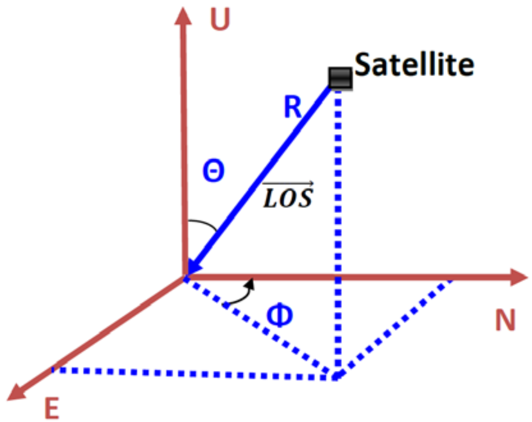
- **Wang, L.**, Y. Chen, and, Y. Han, 2016: Impacts of Field of View Configuration of Crosstrack Infrared Sounder on Clear Sky Observations, Applied Optics (In Print).

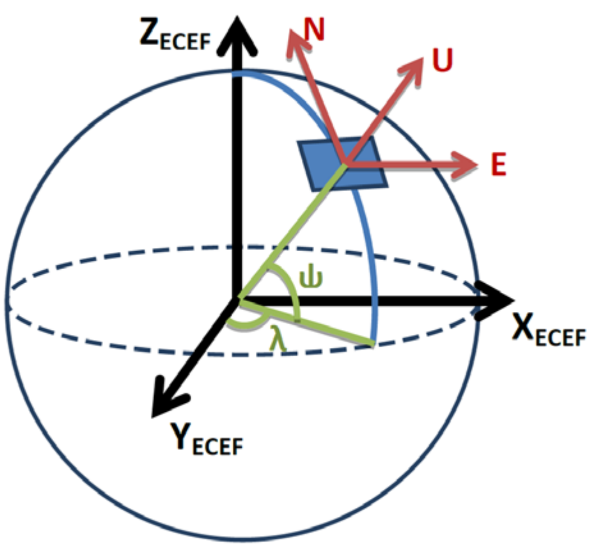
- **Wang, L.**, D. A. Tremblay, B. Zhang, and Y. Han, 2016: Fast and Accurate Collocation of the Visible Infrared Imaging Radiometer Suite Measurements and Cross-track Infrared Sounder Measurements. Remote Sensing, 8, 76; doi:10.3390/rs8010076.

QUESTIONS?

BACKUP SLIDES

Retrieve LOS Vectors





Azimuth, Zenith, Range in Local Spherical Coordinate

↓

(East, North, Up) in meter in Local East, North, Up (ENU) Coordinate

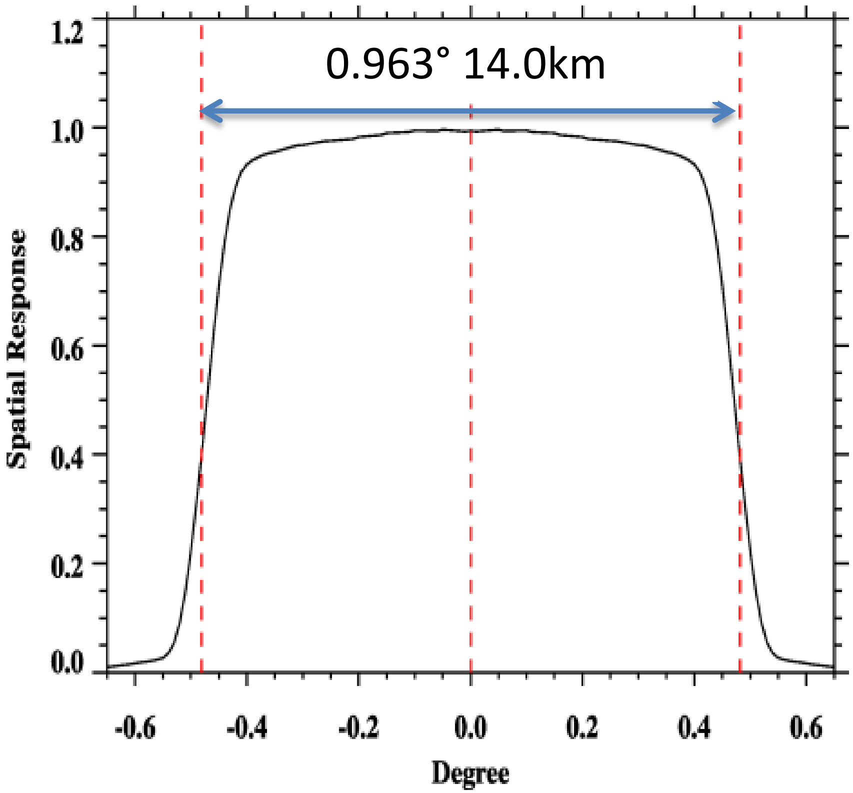
↓

Geodetic Latitude, Longitude, and Altitude (LLA) Coordinate

↓

Earth-centered, earth-fixed (ECEF) Coordinate

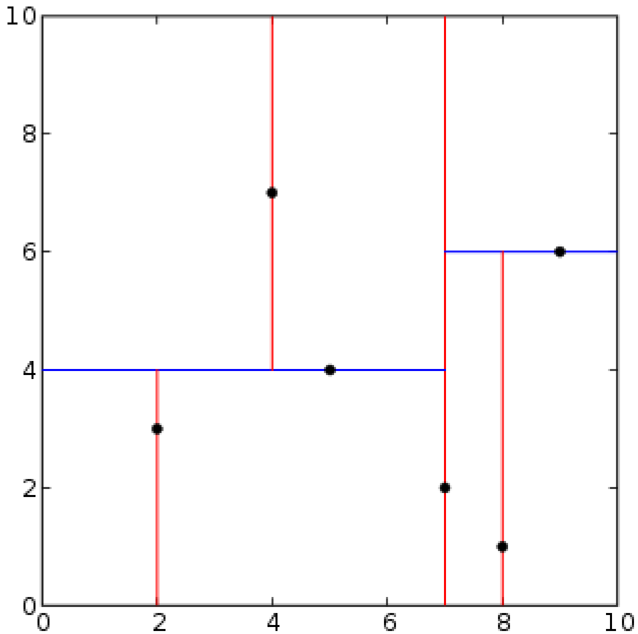
CrIS Spatial Response Function

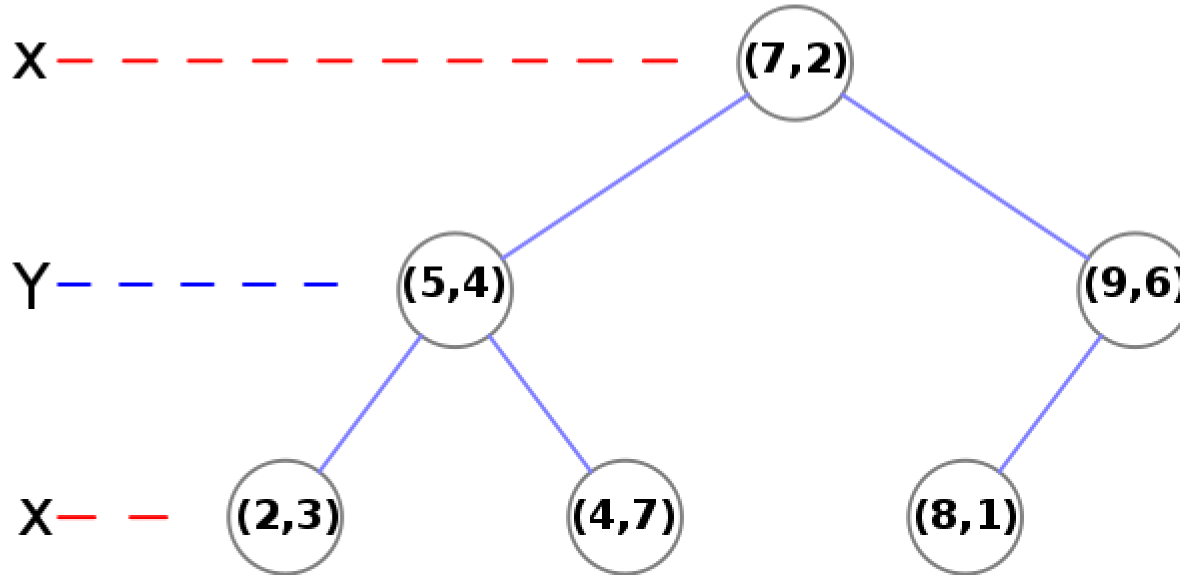


- Ideally, VIIRS images should be convolved with CrIS spatial response function.
- CrIS detector response function: a cutoff value of ±0.963°/2 (14.0 km at nadir) is about 41.19% to its peak value but already collects 98% of total radiation falling on the detector.
- The box-car spatial response is good enough to represent the real CrIS spatial response.

VIIRS (Box Car Average) - (Spatial Response Convolution): ~0.0023K

K-D Tree Search

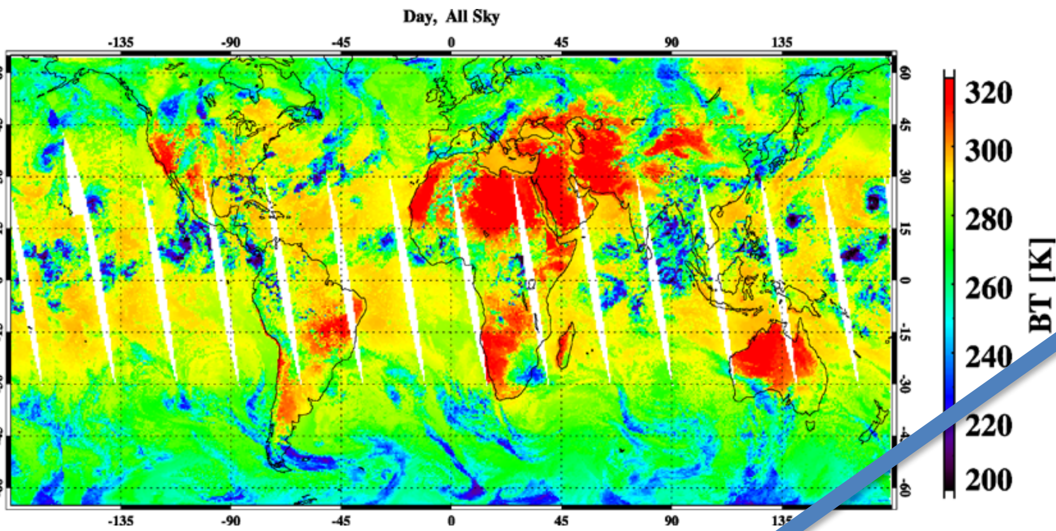




In computer science, a ***k*-d tree** (short for *k-dimensional tree*) is a space-partitioning data structure for organizing points in a *k*-dimensional space.

	Average	**Worst case**
Search	**O(log *n*)**	**O(*n*)**

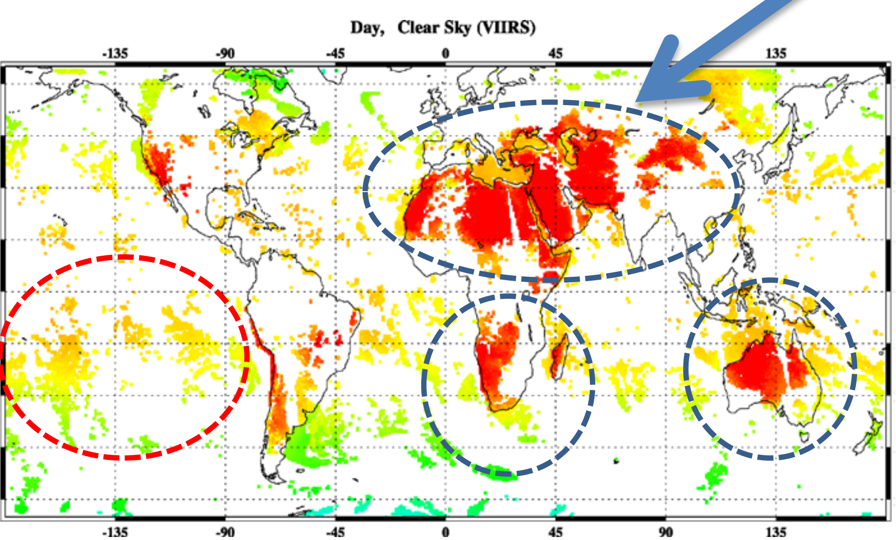
Clear Sky Detection Comparison (Day time)

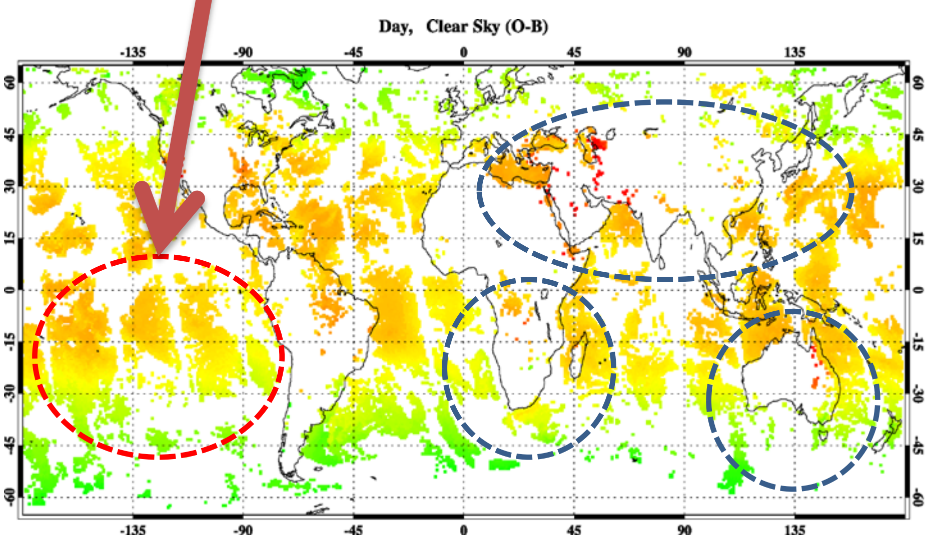


Two issues can be found that:

1) Land Surface temperate errors during day time make the RTM difficulty to simulate observations over land;

2) NWP method found more clear sky pixels over ocean. It seem warm clouds.

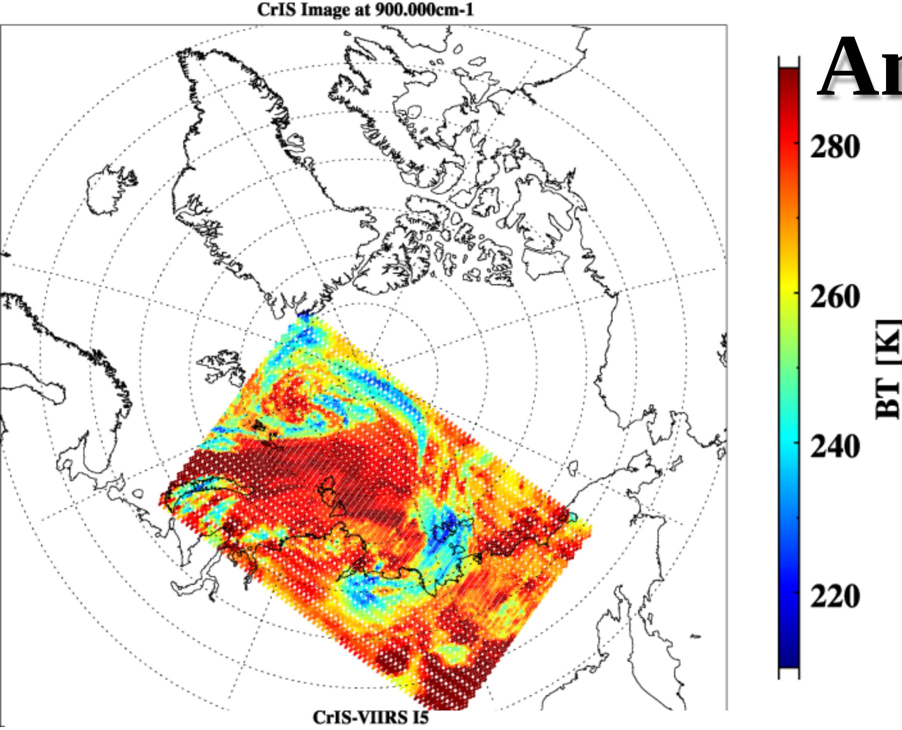




VIIRS method

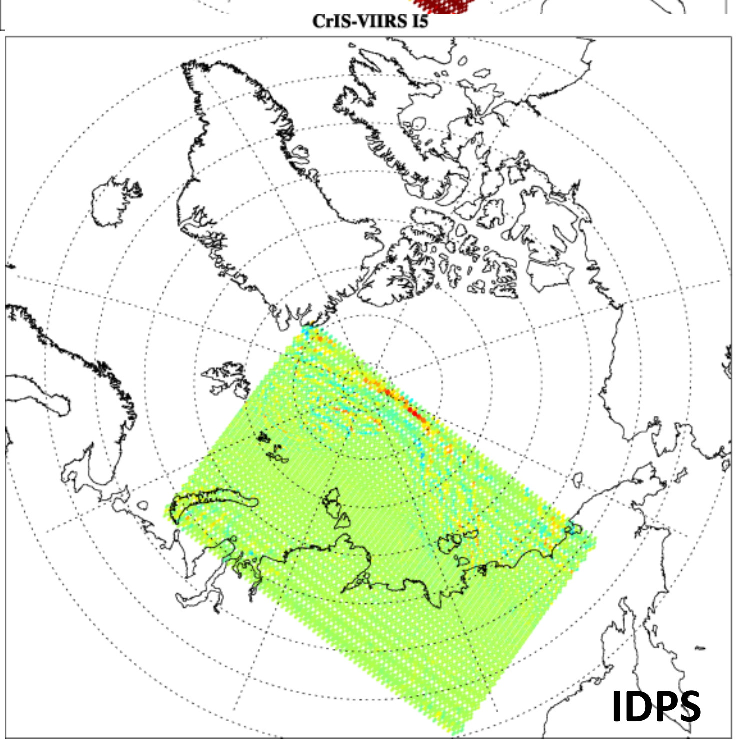
NWP method

Another Validation Case

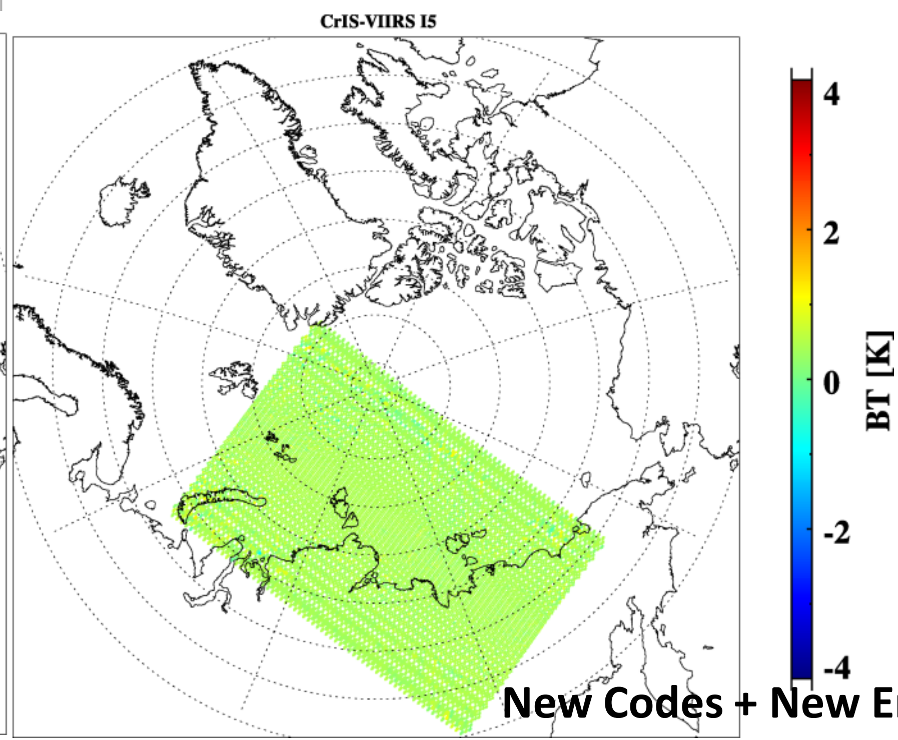


Polar Region

CrIS-VIIRS I5 image



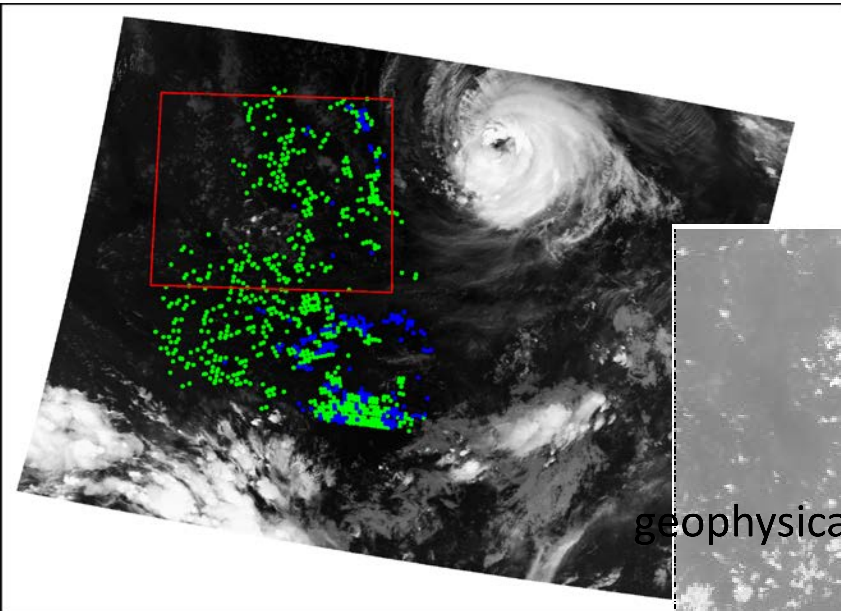
IDPS

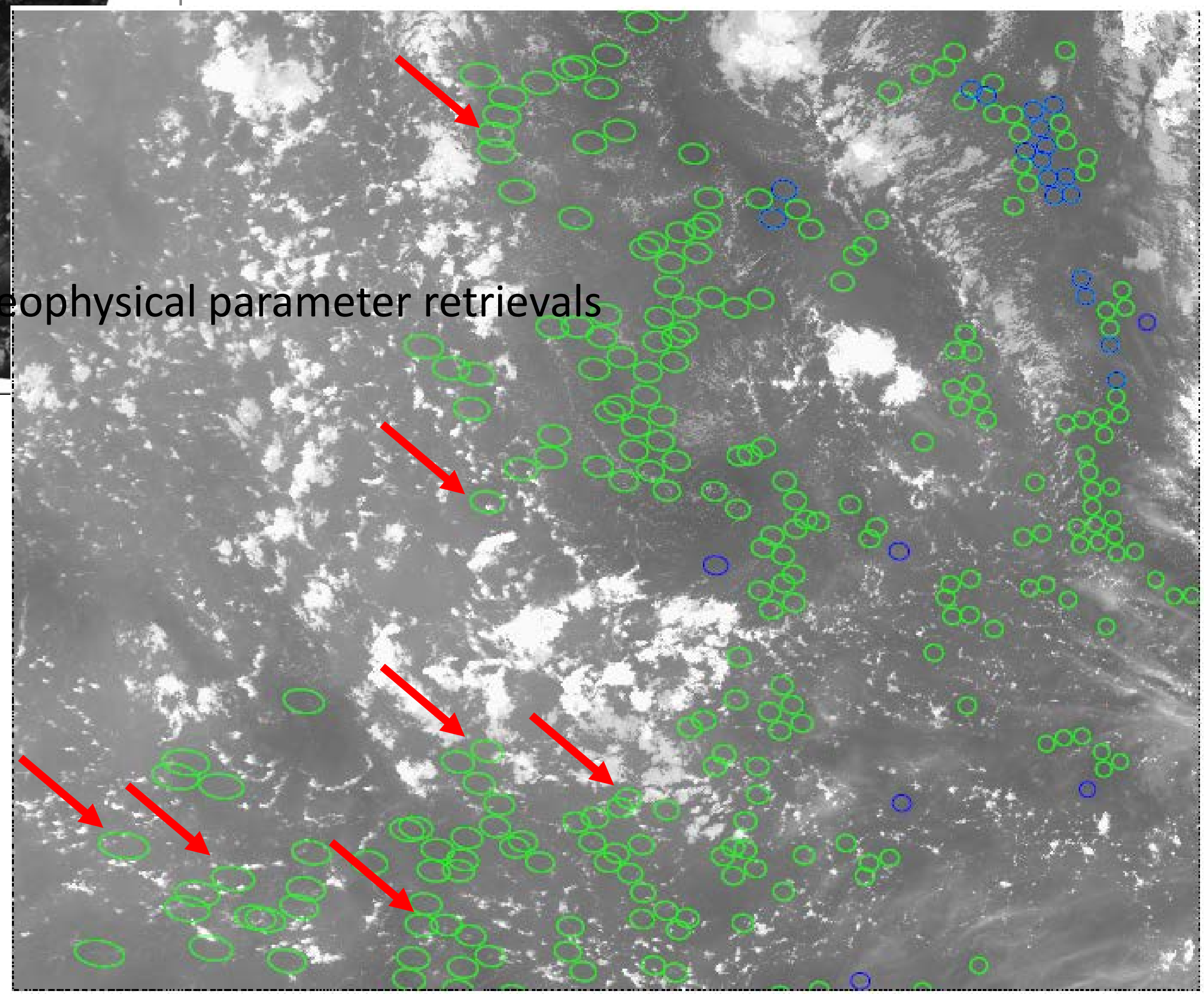


New Codes + New EngPkt

Zoom-in warm clouds

Some cloud contaminated observations are missed by NWP method.





geophysical parameter retrievals

NWP method
VIIRS method