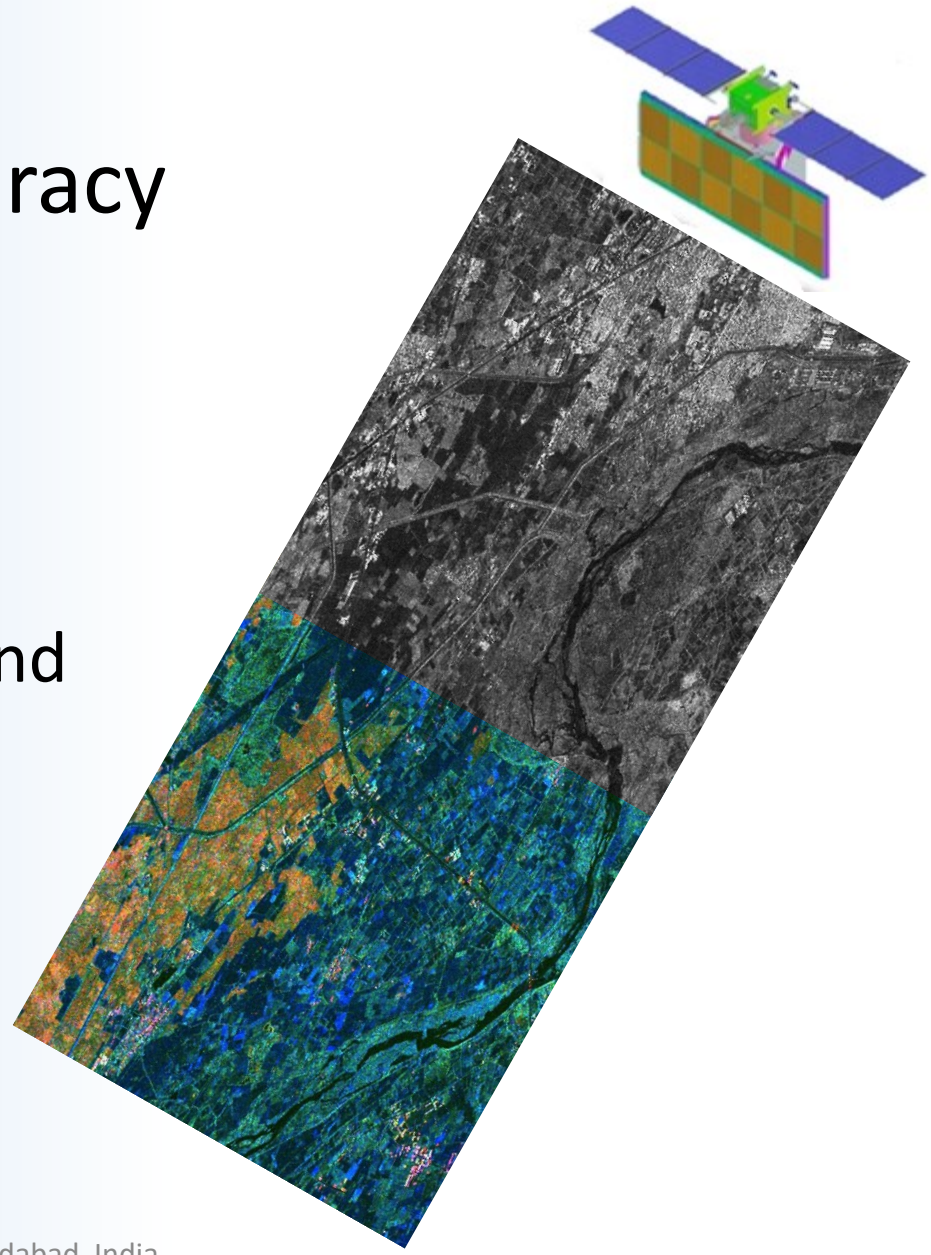
An Approach for Targeting Accuracy Evaluation for NISAR

Dr. Bhaskar Dubey

Microwave Data Quality Evaluation and

Calibration Division

DQCG/SIPA/SAC



What is Targeting Accuracy

- Targeting accuracy is regarded as the pointing inaccuracies in the look vectors of on-board sensors and it arises due to the platform's inability to orient the sensors in the commanded direction. Targeting accuracy quantifies the capability of the platform to target and record imagery of the commanded ground location.

- This deviation in pointing of the satellite from intended direction is termed as pointing accuracy of the satellite. The effect of the pointing error on earth surface results in the targeting error. It is further classified in along/azimuth and across/range track directions.

- After initial phase of satellite commissioning in the orbit, several calibration exercises of satellite sensors, e.g.(Pointing-Cal), are carried out to compensate for geometric errors . Following which it is desired that the satellite can be oriented precisely to a commanded location on the ground. within the predefined error limits.

- Thus, regular monitoring of targeting errors are required to ensure the satellite's targeting accuracy.

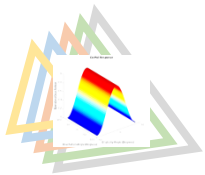
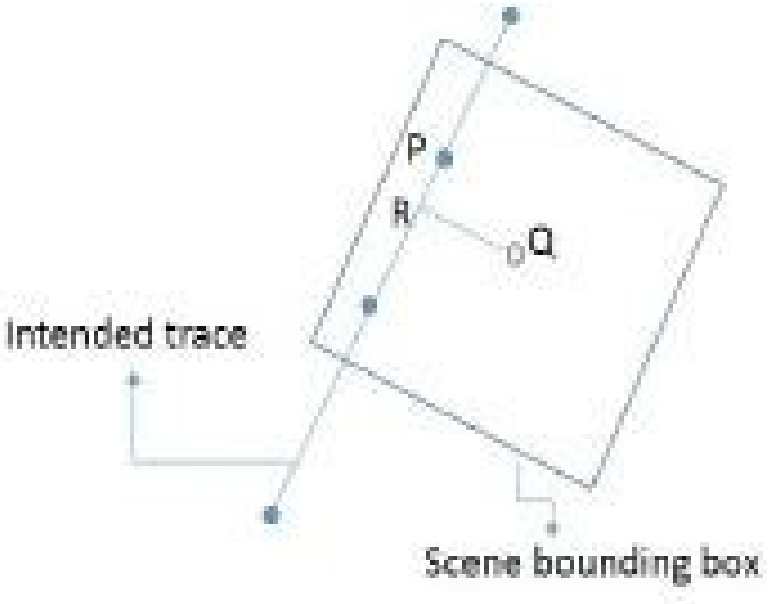


Illustration of Targeting errors



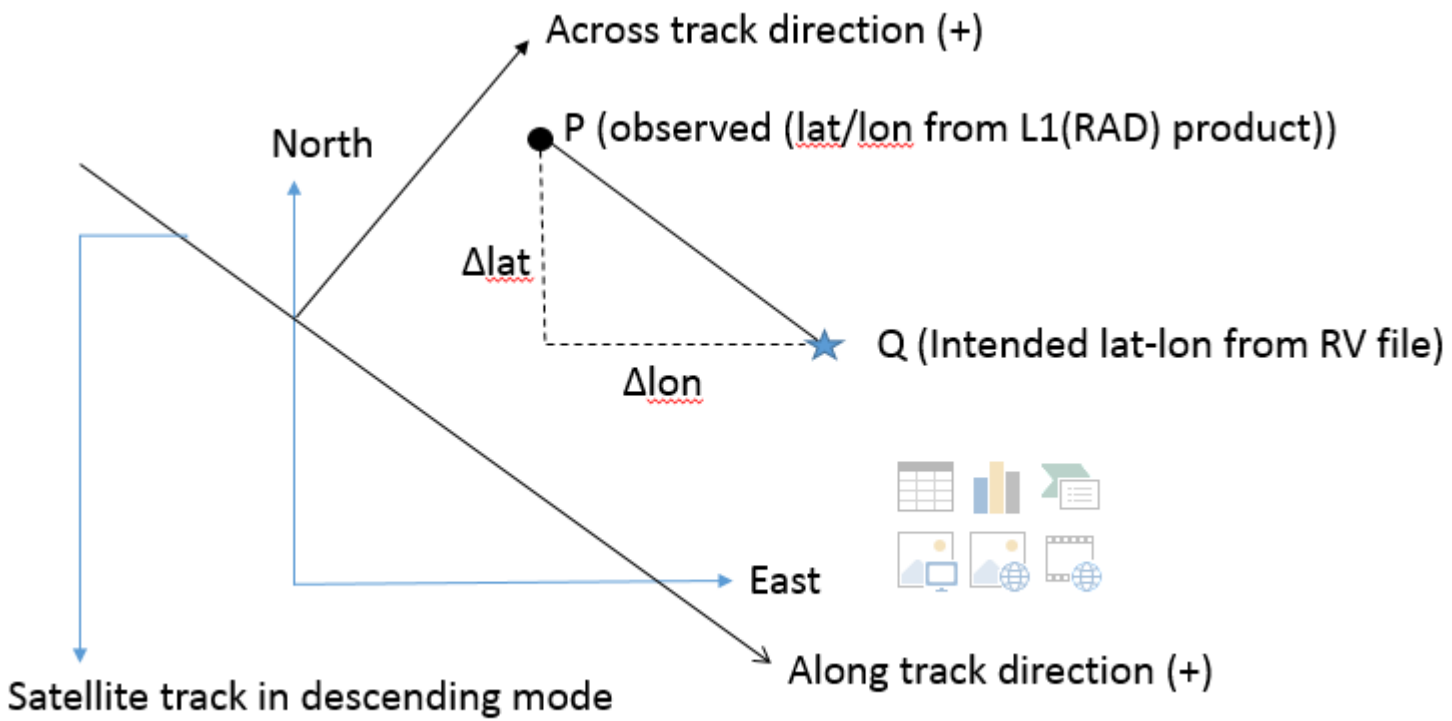
Along targeting error (MAP space): Let (P;Q) be the intended trace and observed trace pair of points. Let R be the foot of perpendicular from Q on piece-wise-connected-intended-trace.
Then the distance PR is defined as the along-track targeting error

Across-track targeting error (MAP space) The distance QR is defined as the across track targeting error.

These errors can also be defined in image space (SLC) by converting the intended lat./lon. to intended scan-pix, using independently obtained ground-to-image transformation.

Similarly ascending pass geometry can be illustrated.

Illustration of Targeting errors



In this example,
Δlat is non zero, however, across track error is zero. Moreover, along track error is equal to -|PQ| (observed –intended in rotated frame) which is more than Δlan.

Thus, simple differencing of lat-lon will not correctly represent the along /across track targeting errors.

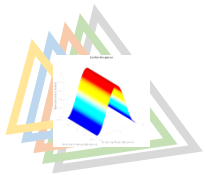
Similarly ascending pass geometry can be illustrated.

Factors affecting targeting accuracy

- Orbit and attitude/Doppler error
- Control error
- Modelling errors in generating intended attitude profile
- Error due to DEM in generating intended ground trace
- Satellite uncorrected drift and micro-vibrations
- Time errors

Importance of Targeting Accuracy

- Targeting accuracy is an important parameter that quantifies the platform performance by measuring the difference between commanded and acquired/observed location.
- Especially for high resolution missions it is one of the highly desired parameter.
- High cross-track error will cause the target to get missed in cross track directions.
- High along track error will cause the target to miss in time.



Translating targeting errors in SLC to residual Euler angles

A forward model:

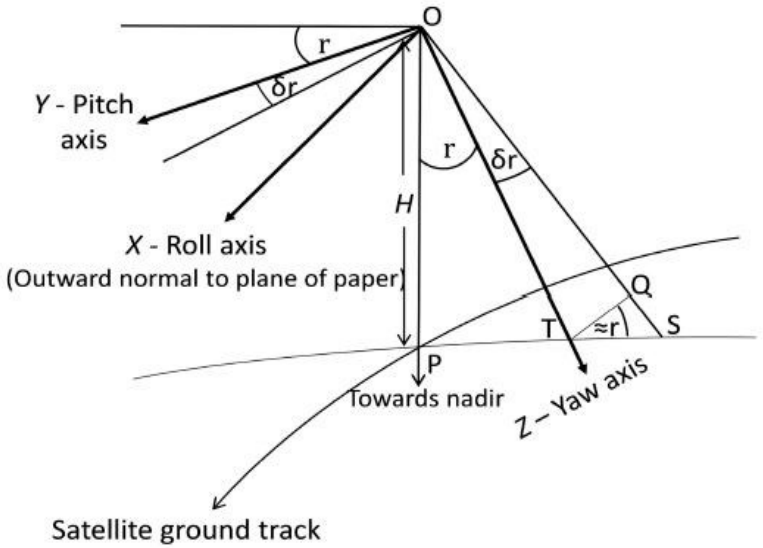
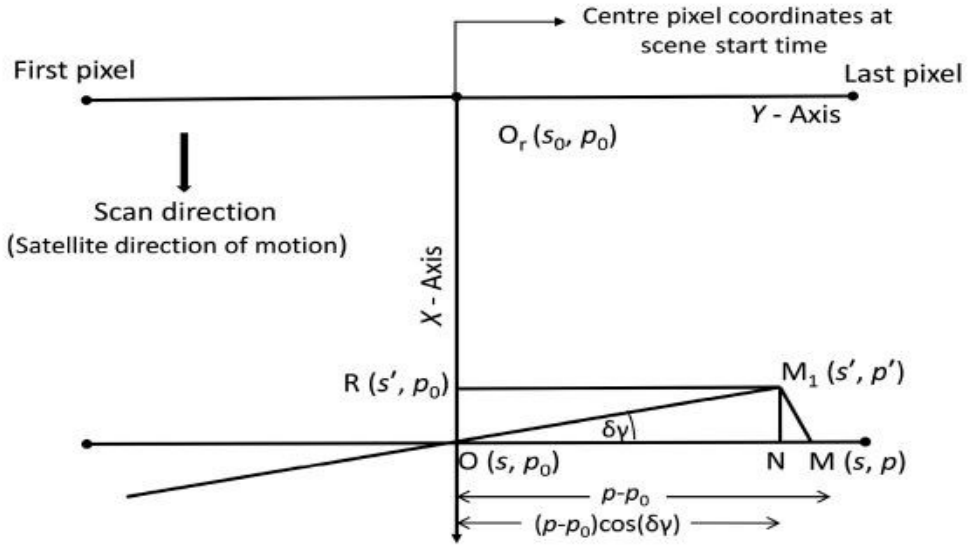


Illustration of Roll/Pitch effect on ground targets



Modelling of Yaw effect

$$\begin{bmatrix} s' \\ p' \end{bmatrix} = \begin{bmatrix} 1 & \sin(\delta\gamma) \\ 0 & \cos(\delta\gamma) \end{bmatrix} \begin{bmatrix} s + \mu\delta p \\ p + \mu\delta r \end{bmatrix} + \begin{bmatrix} -p_0 \sin(\delta\gamma) \\ p_0 - p_0 \cos(\delta\gamma) \end{bmatrix} + \begin{bmatrix} \eta^s(s,p) \\ \eta^p(s,p) \end{bmatrix}$$

The inverse model:

By minimising the square of residuals (η) we get an estimate of residual Euler angles. [A pure nonlinear minimization problem framework]

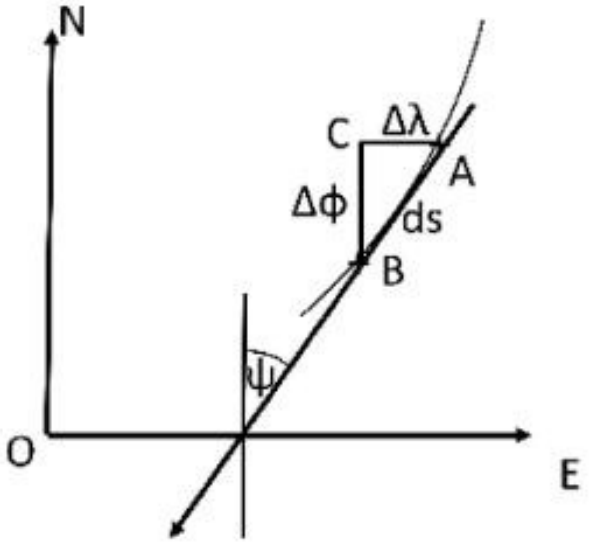
Translating targeting errors in GEO to residual Euler angles

•The RSLC image is rotated by heading angle to conform to GSLC

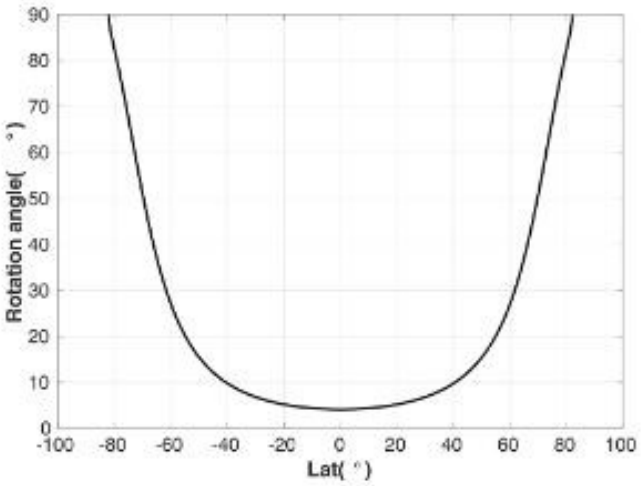
•First convert GSLC to equivalent RSLC then apply the previous approach.

A model of heading angle estimation as a function of latitude is given below

$$\frac{d\lambda}{d\phi} = \frac{d}{d\phi}\left(\sin^{-1}\left(\frac{b^2}{a^2}\tan(\phi)\cot(\theta)\right)\right) - \frac{\pi}{43{,}200v_g}\frac{d}{d\phi}\left(\int_0^{\phi}\frac{ds}{d\phi}d\phi\right)$$

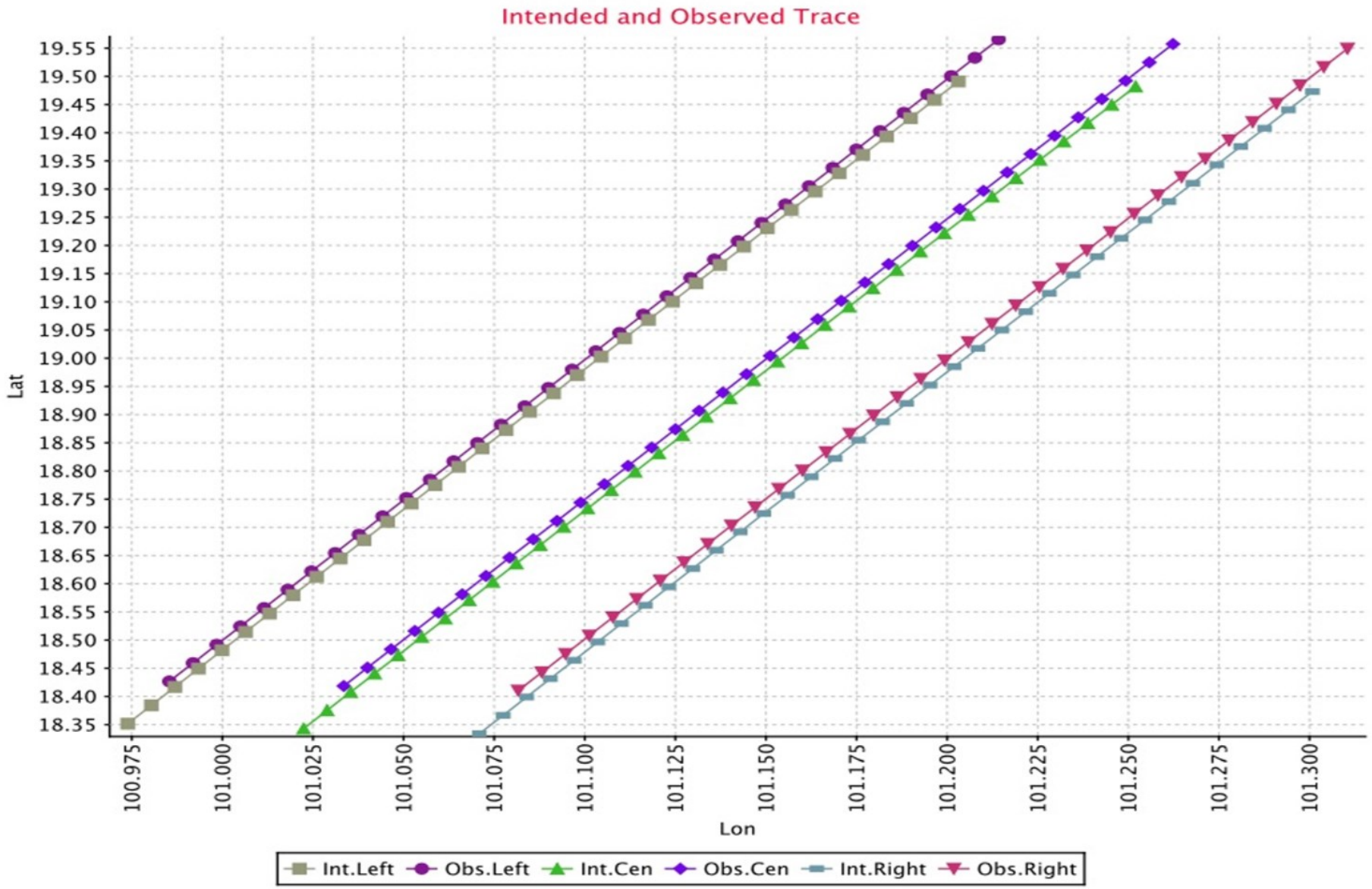


Rotation(heading) angle ψ

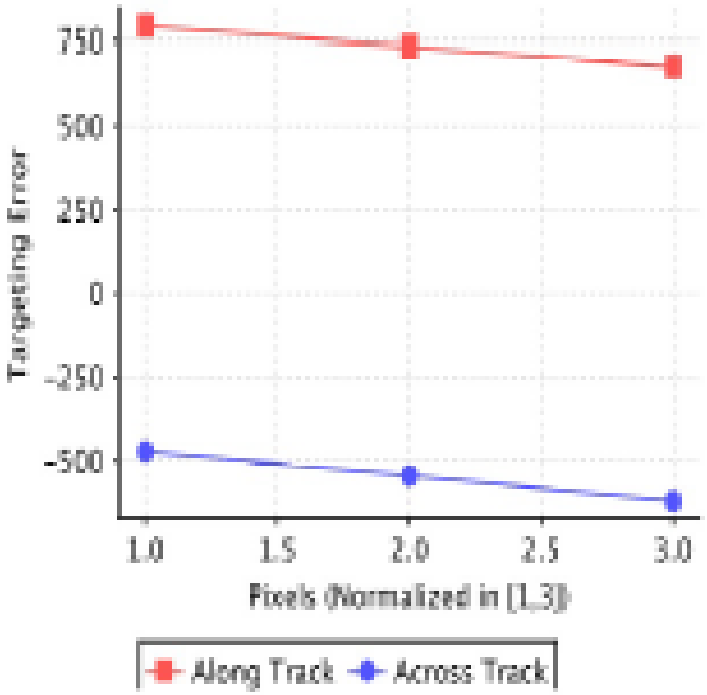


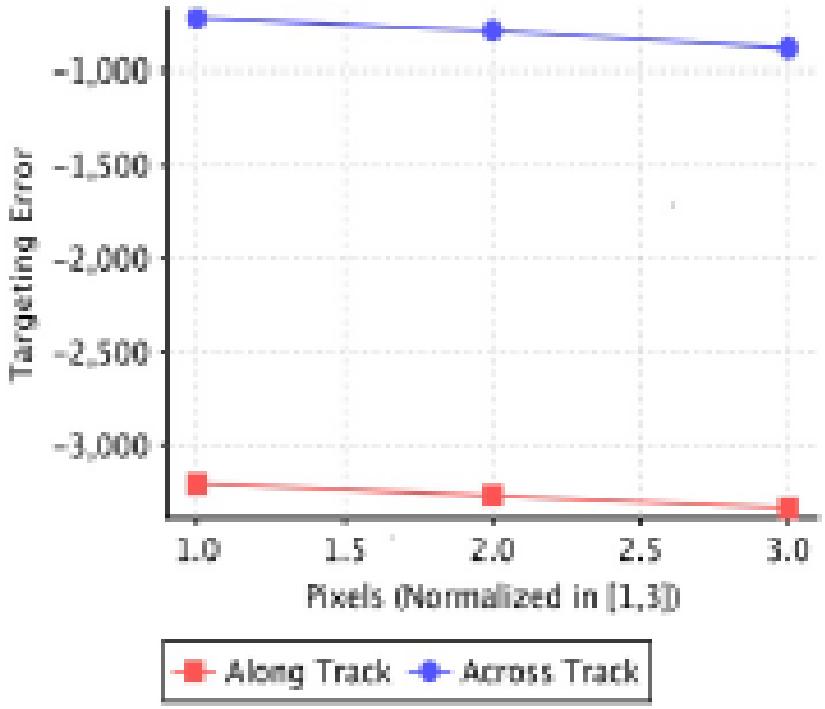
Variation of heading angle with latitude

Intended and Observed Ground Trace



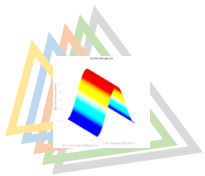
Targeting errors estimated during IOT



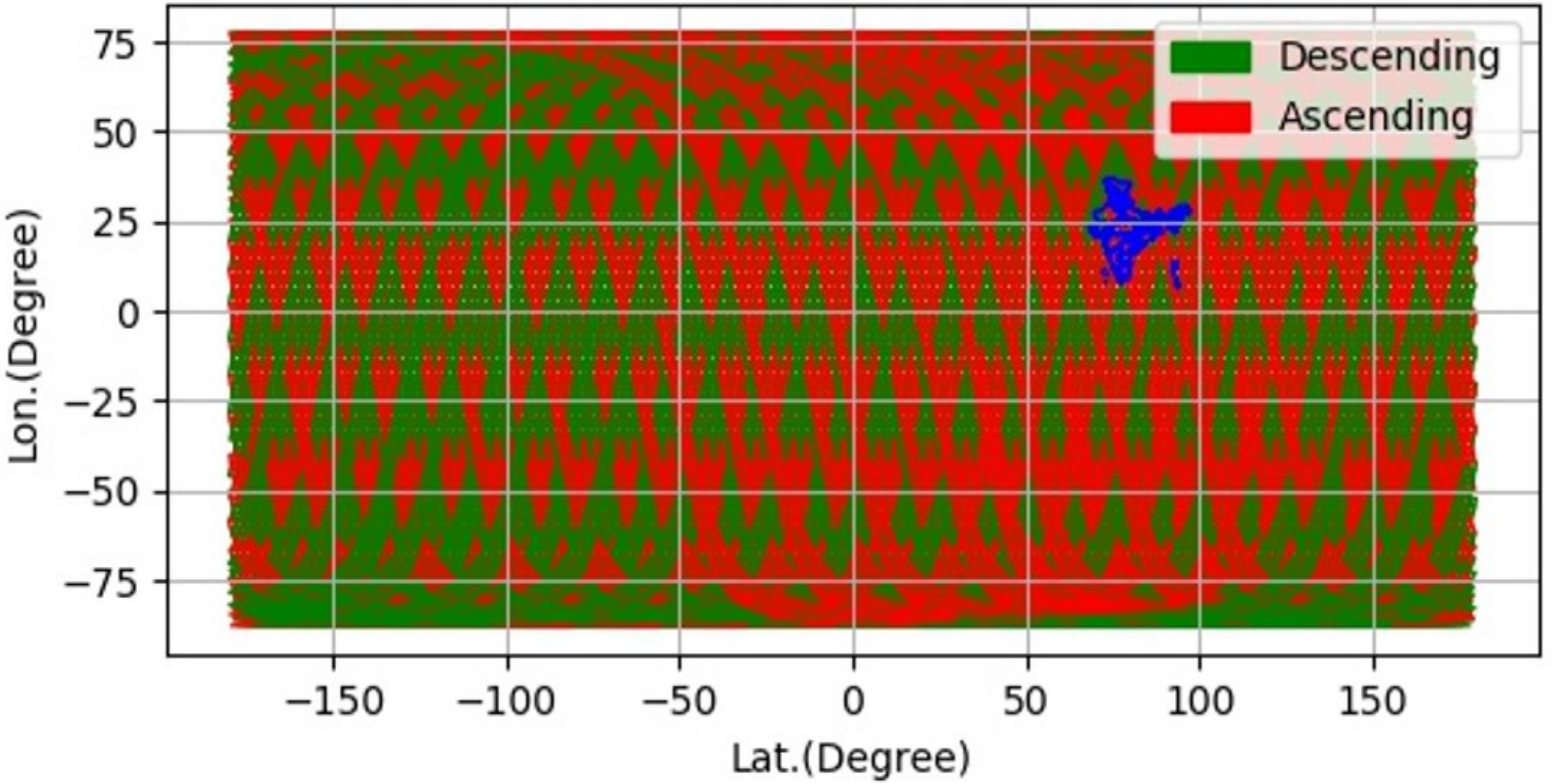


Reference Ground-Trace for NISAR

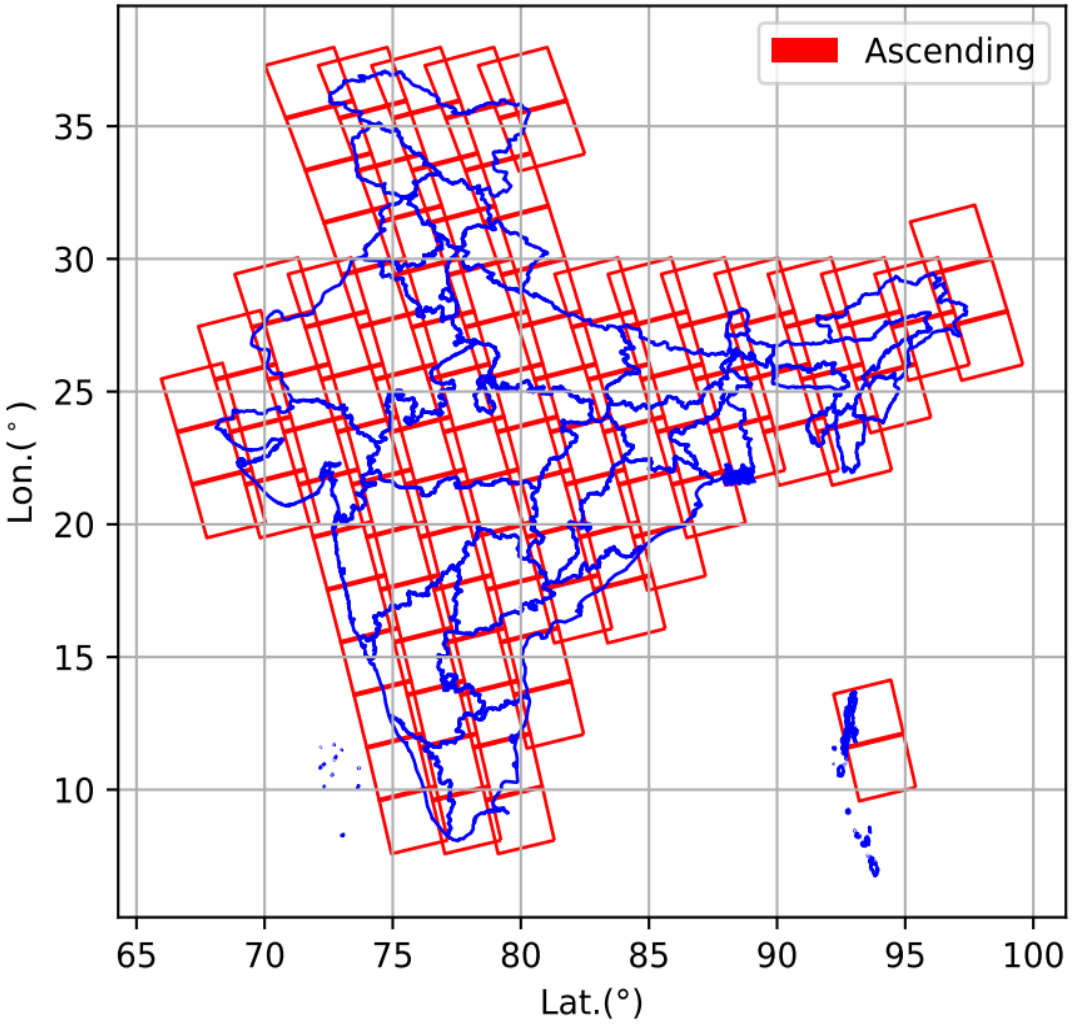
- Generally for IRS missions a range variation file containing a ground trace/ranges at first , centre and last pixel is provided.
- However for NISAR being very systematic science mission these files are not generated
- Instead of rangevarition files, NISAR's the track/frame polygons are provided with respect to reference orbit.
- We will use these track/frame polygons as the reference ground trace
- The errors will be analyzed at near and far ranges

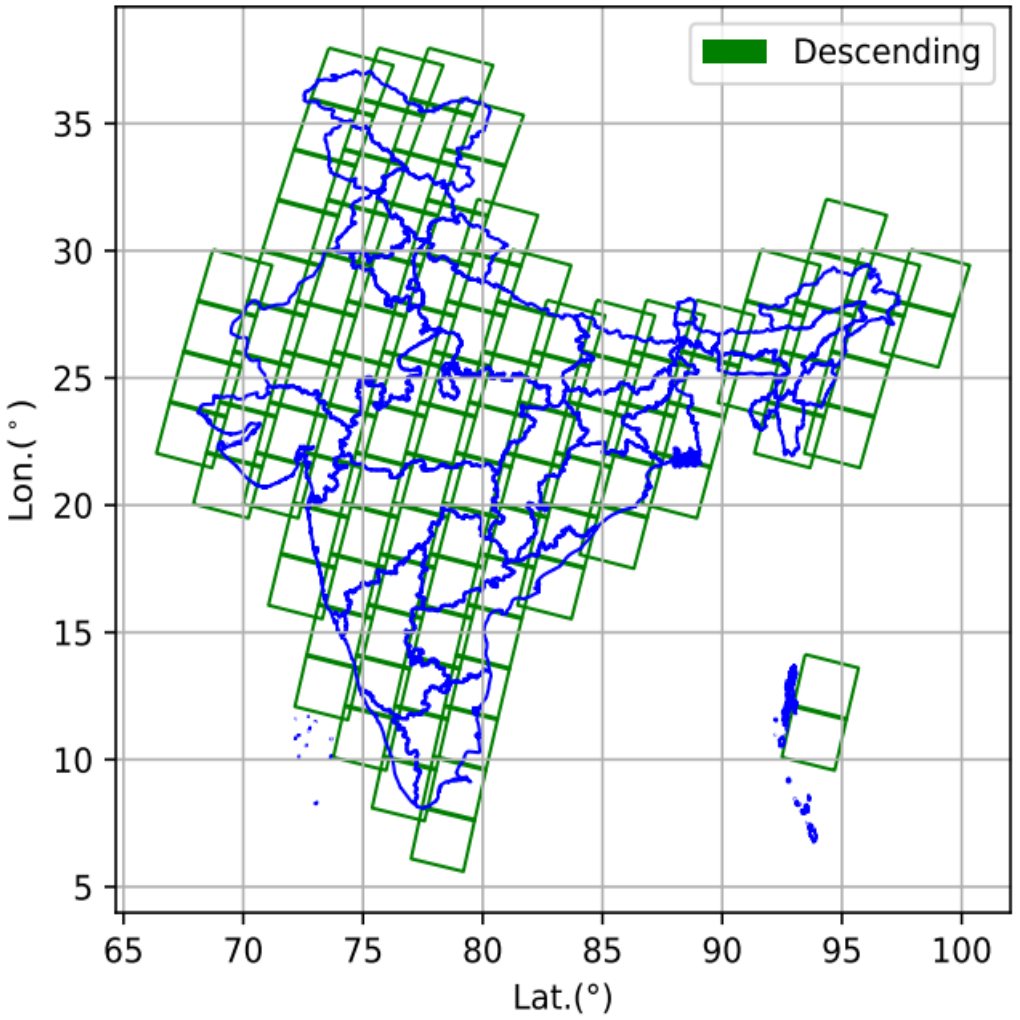


NISAR Reference Track/Frames world-wide

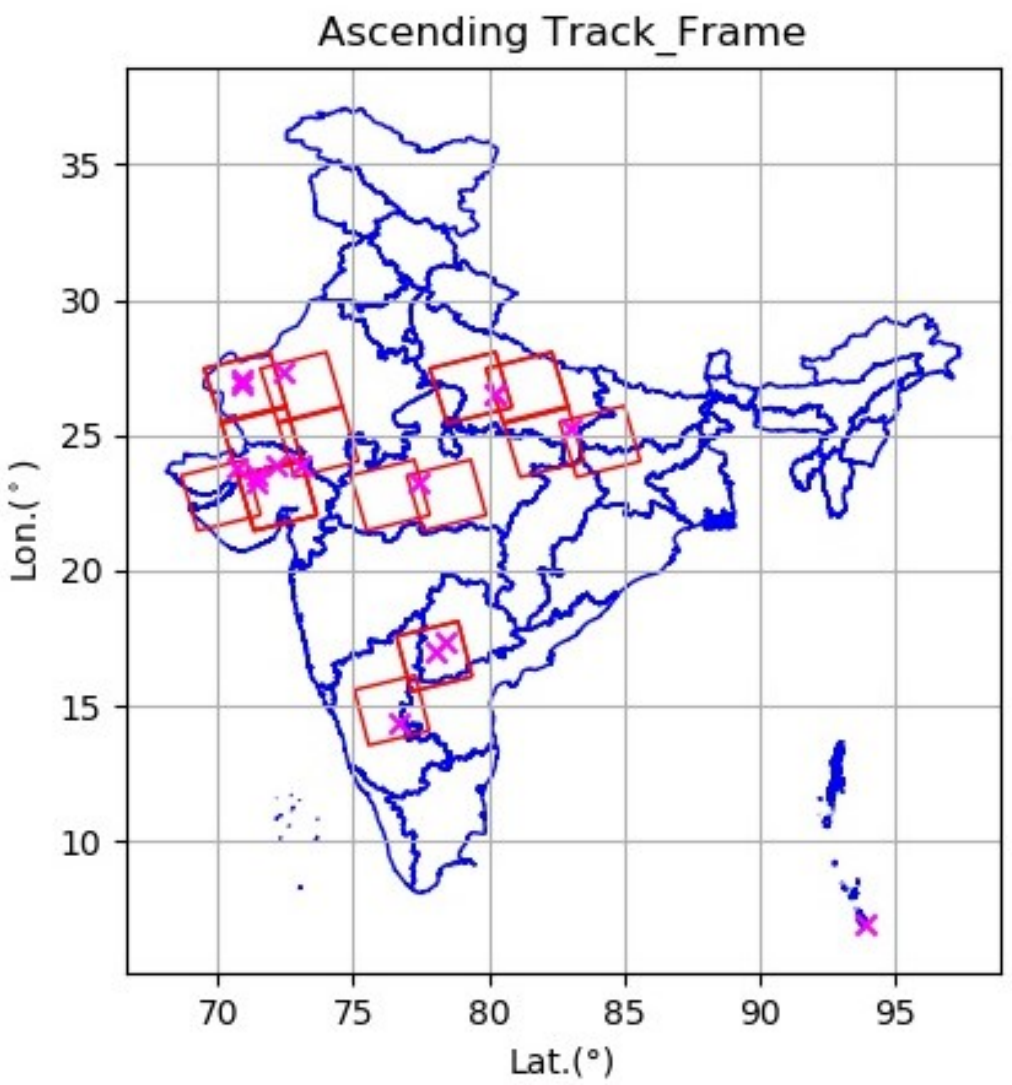


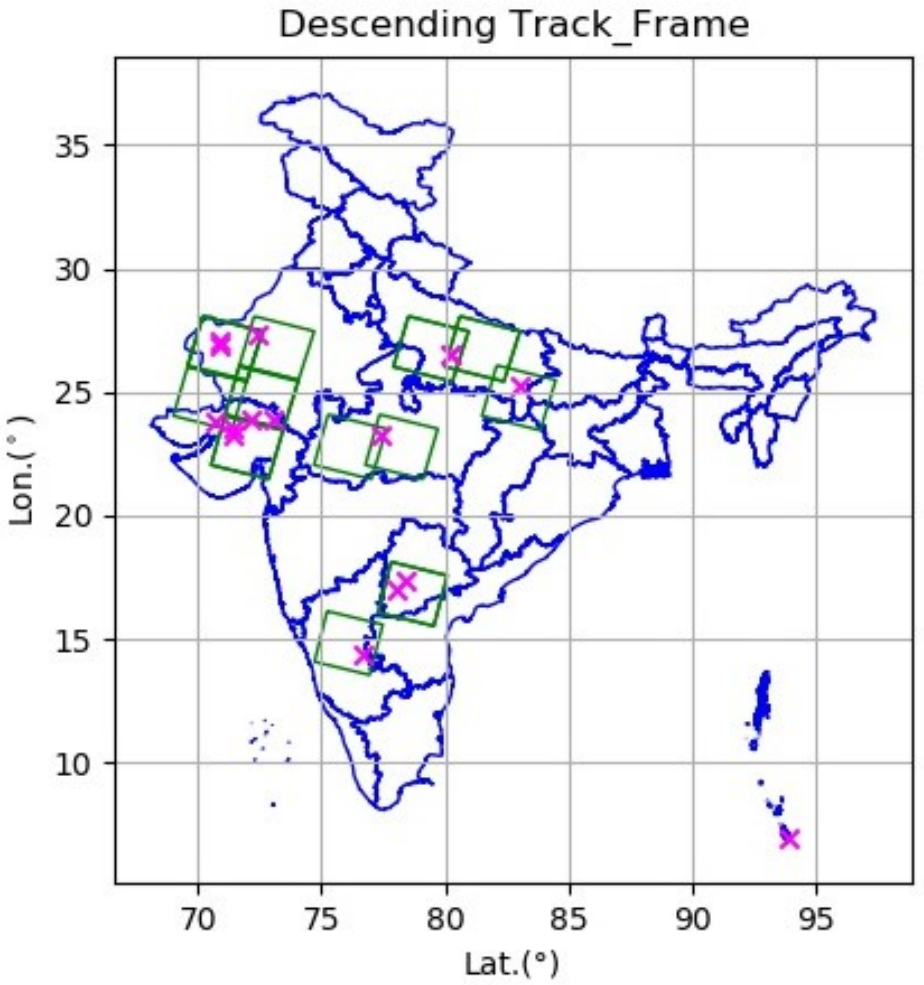
Ascending Track/Frame over India





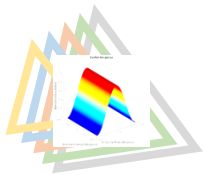
Track/Frame identification based on scene-center / known locations





NISAR Targeting Accuracy Evaluation Approach

- In NISAR, Targeting accuracy will be estimated using the reference track-frames and acquired RSLC products.
- For any given RSLC product corresponding track/frame number will be obtained from meta data.
- The corresponding track/frame's corner geo-coordinates will be obtained
- Using reference image SLC scan/pix to lat/lon (image-to-ground)mapping will be established.
- Using image-to-ground mapping the true lat/lon for each corner of the SLC image is obtained.
- Let (e_i,n_i): i= 1,2,3,4 be the corners of TRACK-FRAME in suitable projection system, e.g., UTM. Similarly,' let (e'_i, n'_i) be the true/acquired corners of the image.
- Direction cosines of the cross-track/along-track lines are obtained using track/frame corners (e_i, n_i).
- The above 2-D reference system is centered at each track/frame corner (e_i, n_i), and in this frame the co-ordinates of corresponding corner (e_i', n_i') of image is obtained. The x-coordinate is the cross-track targeting error and y-coordinate is the along-track targeting error.



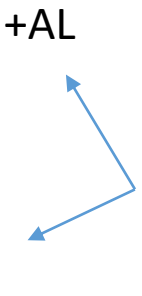
Targeting Simulation using NISAR Track-Frame Datasets

- A typical NISAR's ascending pass Track/Frame is selected and corresponding observed track/frame is artificially generated

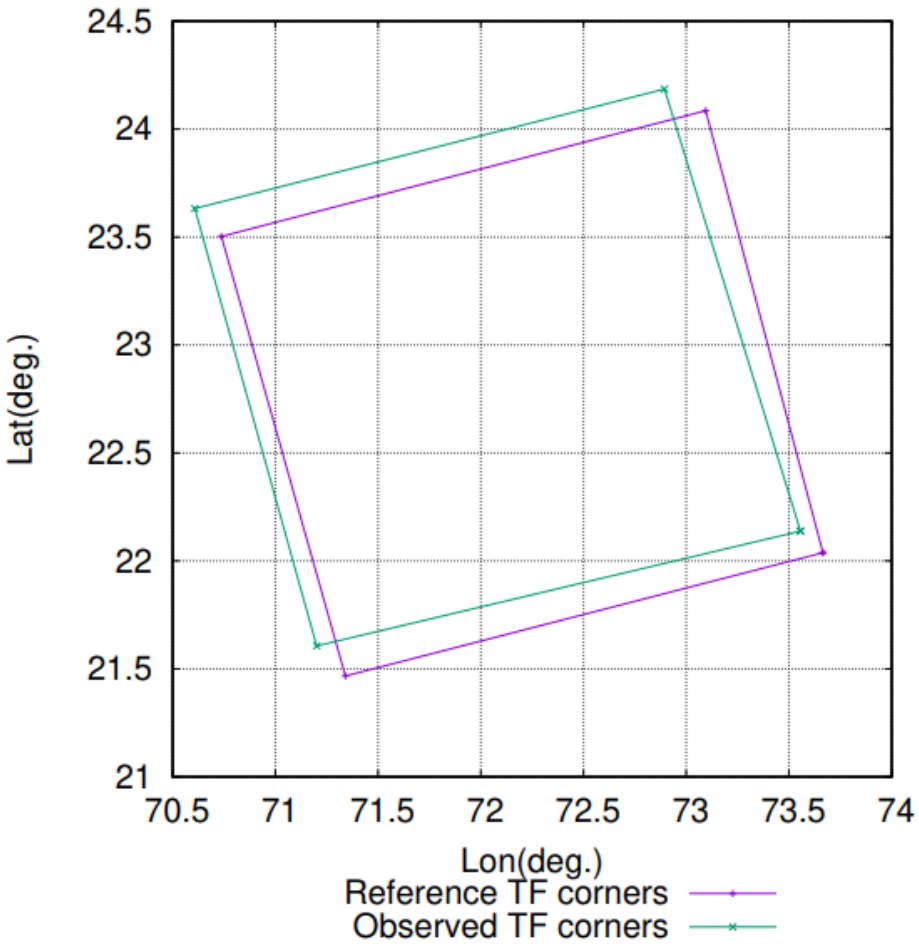
- DCS of +AC./ +Al lines are computed using ref. frame, and adjusted to make orthonormal to each other

- With respect to this frame the coordinate of the difference vector (observed - reference) is obtained for all the four corners.

- The average of the numbers obtained in step-3 (above step) will denote the along/across track targeting errors
- Positive time denote the +Al track and + Slant range denotes the +Ac track direction's. (Directions shown here are applicable only for ascending passes)



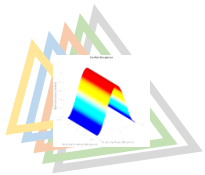
Al/Ac. Ref. Coordinate frame



A reference NISAR's Track/Frame with corresponding simulated corners shown as observed corners

Conclusions / Future scope

- We have developed a novel approach for NISAR targeting accuracy estimation using NISAR's track/frame database and the RSLC product and corresponding reference images for establishing the image-to-map transformations.
- The presented method can also be extended to compute the control errors by observing the corresponding location errors at the corners.
- The ac/al targeting errors can be translated to provide residual Euler angles or Qs.
- Using the along track errors deviations residual squint angle can be estimated.
- Deviations from intended/theoretical Doppler centroid estimates can also be obtained.



Thank you for your attention!