Paper # 10781-29

Evaluation of Geostationary Lightning Mapper (GLM) Navigation Performance with the INR Performance Assessment Toolset (IPATS)

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Outline

- GOES/Geospatial Lightning Mapper overview
- IPATS and INR evaluation overview
  - *General overview*
  - *GLM-specific challenges and optimizations*
- Post-processing quality filtering
- Example results and conclusions

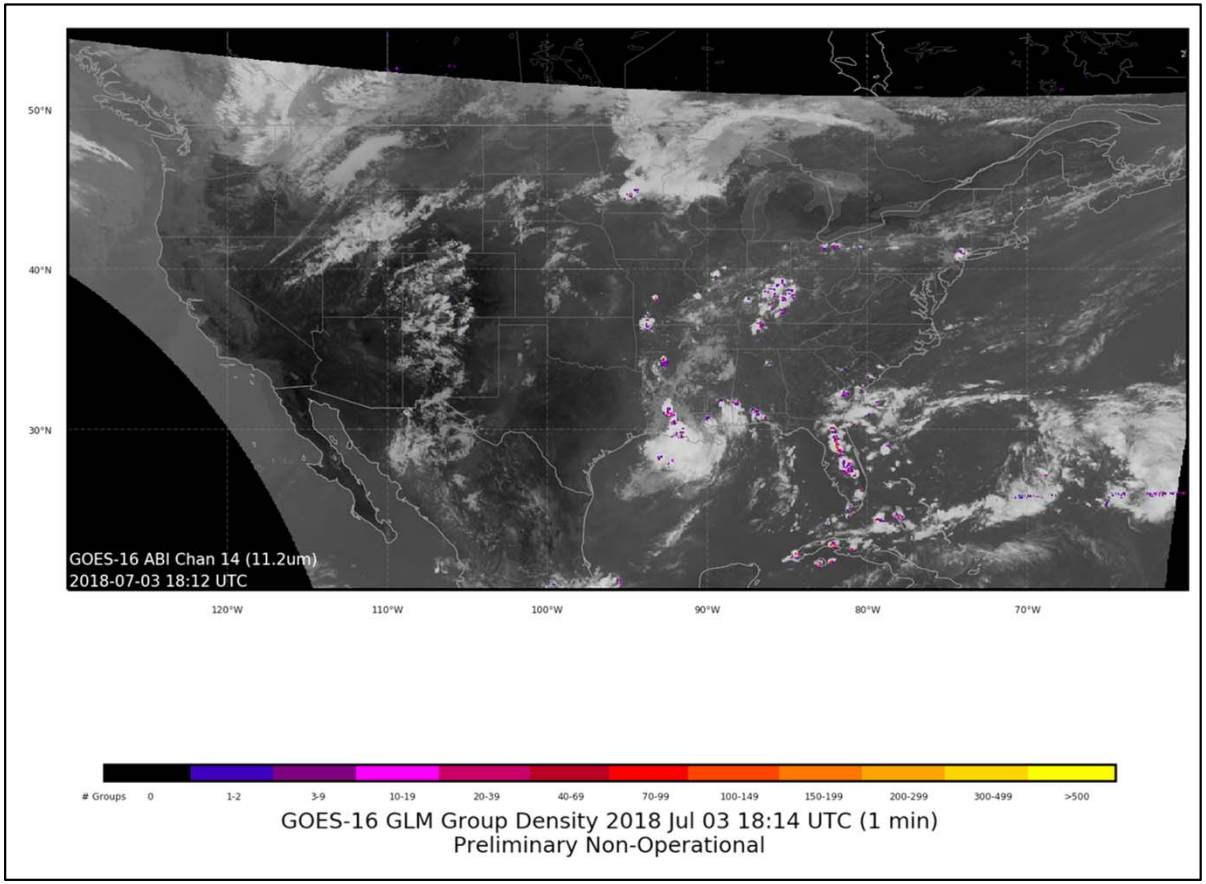
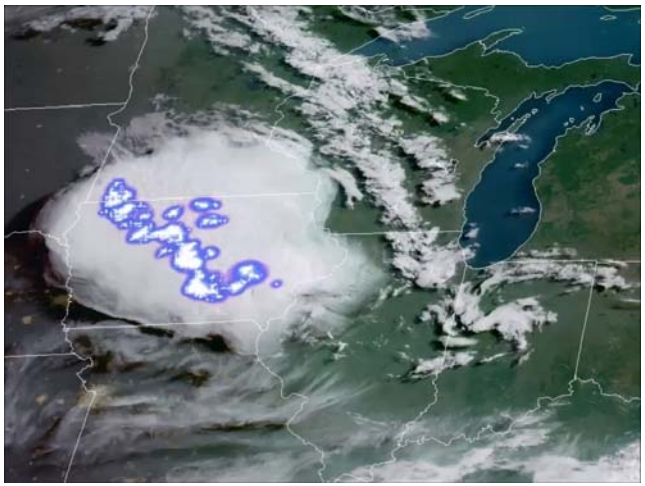


Image from NASA SPORT (Short-term Prediction Research and Transition Center; https://weather.msfc.nasa.gov/cgi-bin/sportPublishData.pl?dataset=goeseastglm&product=group&loc=conus

GOES-R series earth-observing payloads overview



ABI “GeoColor” image with GLM overlay from 6/14/18;
Animation from NOAA/NESDIS Regional and Mesoscale Meteorology Branch (RAMMB):
http://rammb.cira.colostate.edu/ramsdis/

	ABI – Level 1B	GLM – Level 1β
Spectral	16 bands, 0.4 μm to 14 μm	Single band (777 nm)
Spatial Resolution	Fixed Grid (FG) coordinate system with sample spacing of 14, 28, or 56 μrad (0.5, 1, or 2 km at nadir)	8 km at nadir, 14 km at edge of field
Coverage	• Full Disk (FD): 17.4 deg diameter centered at nadir • CONUS: Rectangular, 5000 km EW x 3000 km NS • Mesoscale: Rectangular, 1000 km EW x 1000 km NS	Near full disk
Temporal	FD: 5 or 15 min; CONUS: 5 min; Mesoscale: 30 sec	150 sec
Acquisition	Scan	Stare

GLM Level 1B product is navigated events; level “1 beta” “background images” acquired largely for calibration

GLM INR Assessment

- The formal GLM level 1B product is navigated lightning events
- Camera alignment errors are assessed using coastline matching (coastline identification in GLM background images, misregistration assessment between detected coastlines and coastline database)

Formal navigation

- Background images themselves do not have formal image navigation and registration (INR) requirements
- The GOES-R flight project performs independent verification and validation of the INR performance of ABI and GLM
  - *GLM INR is assessed via the background images after "downsampling" by the ground system*
  - *While the background images do not have formal INR requirements, their navigation accuracy is generally considered to be a helpful proxy for event navigation accuracy (i.e., background image INR accuracy is suggestive of event navigation accuracy but does not constitute a formal navigation accuracy validation)*

Informal assessment (IPATS)

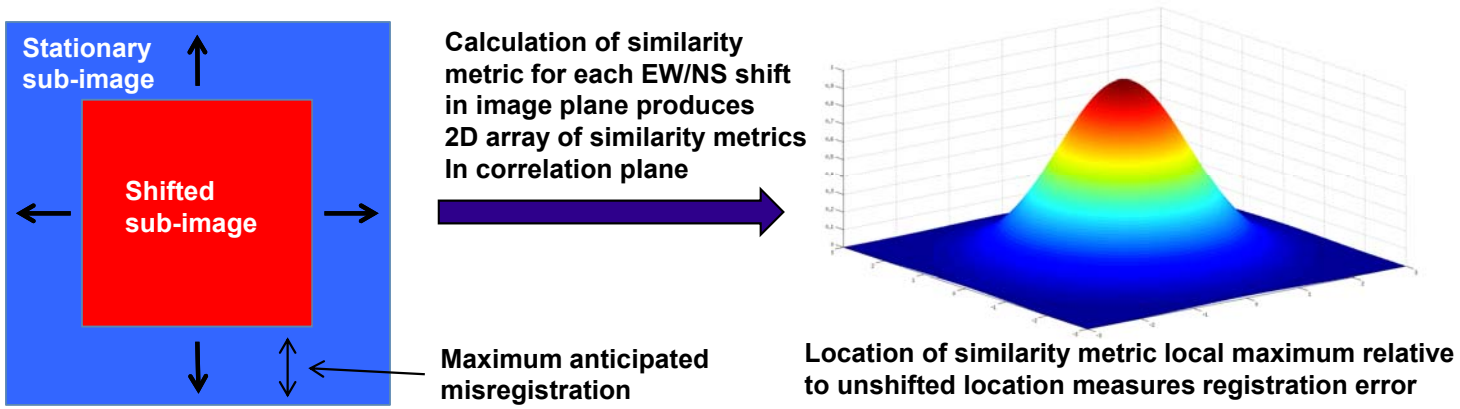
IPATS evaluation modes

- Navigation (NAV) error (ABI & GLM)
  - *Difference between location of pixel in data product and true location*

- Frame-to-frame registration (FFR) error (ABI)
  - *Relative navigation error of corresponding pixels of same band in consecutive images*
- Swath-to-swath registration (SSR) error (ABI)
  - *Relative navigation error of two neighboring pixels on opposite sides of image swath boundary*
- Channel-to-channel registration (CCR) error (ABI)
  - *Relative navigation error of corresponding pixels of different bands in the same frame*

- Within-frame registration (WIFR) error (ABI)
  - *Difference between radial separation of two pixels on the FG and their true angular separation*
  - *Computed from ABI NAV measurements*

IPATS image registration by correlation



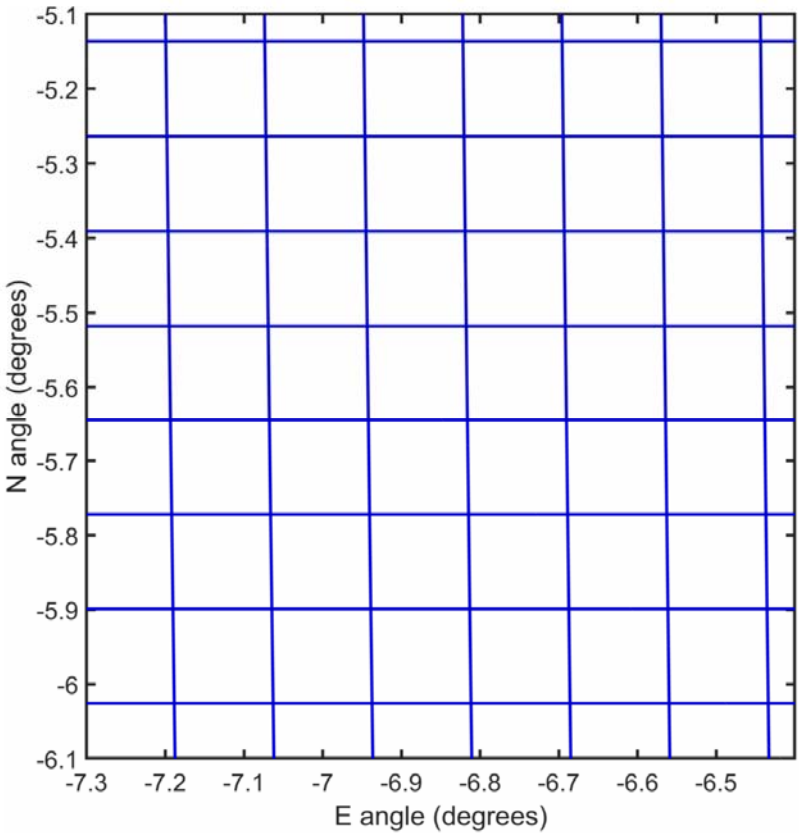
Modified from De Luccia et al., 2016

- For NAV, shifted sub-image is cropped from ABI or GLM image, stationary sub-image is truth map:
  - *High contrast Landsat 8 derived chip projected to FG for ABI NAV*
  - ***ABI image for GLM NAV**, with GLM background image resampled to fixed grid*
- For more detail on IPATS, see De Luccia et al., 2016, SPIE Asia Pacific Remote Sensing

Common error estimation concept for all evaluation modes except ABI WIFR

GLM-specific optimizations

- Downsampled GLM background images:
  - *Have very coarse resolution w.r.t. ABI images (~224 µrad vs 28 µrad for ABI B3)*
  - ***Lack regular pixel spacing***
- To perform navigation w.r.t. ABI data, the images must be on a common pixel grid
- IPATS has incorporated an irregular grid resampling algorithm
  - *GLM and ABI images are resampled to a common ("ABI-like") pixel grid at user-specified sampling; GLM NAV baseline resamples to native ABI resolution*
  - *Careful optimization of resampling factors and evaluation window size has been performed*



Irregular grid resampler concept: GLM grid (every 10 pixels illustrated)

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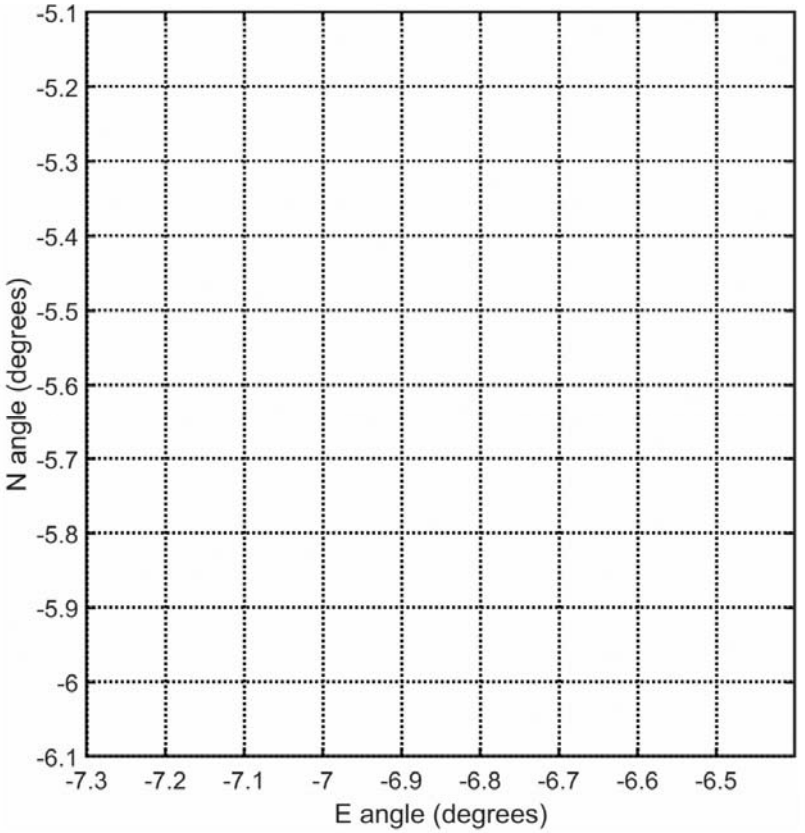

Irregular grid resampler concept: ABI-like (regular) grid

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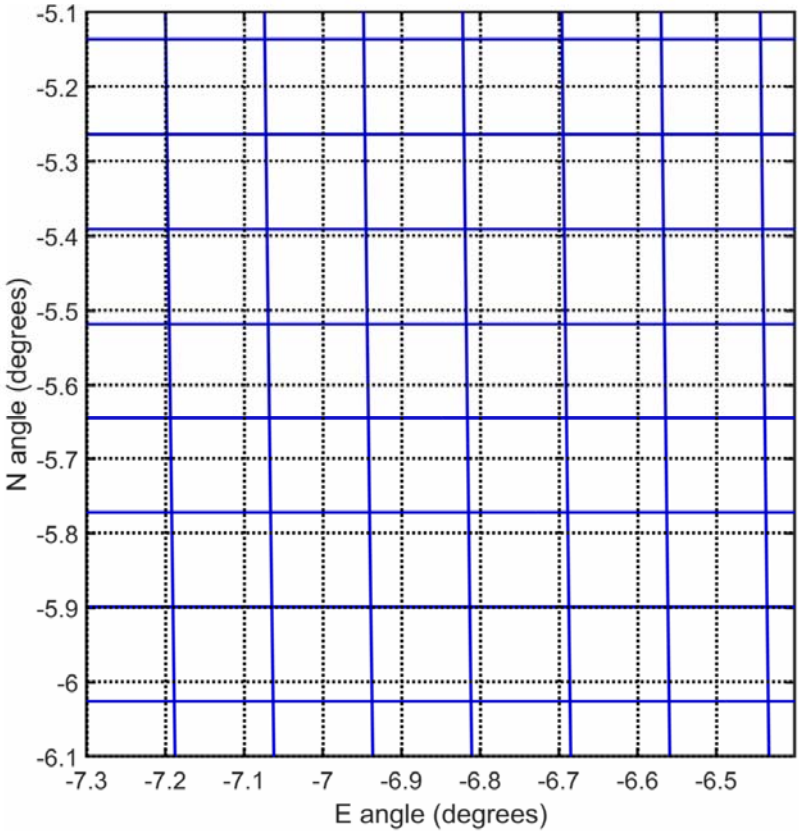


Irregular grid resampler concept. Solid blue lines represent GLM pixels, dotted black lines the regular ABI-like grid. A local search algorithm assigns GLM pixels to resampled pixels

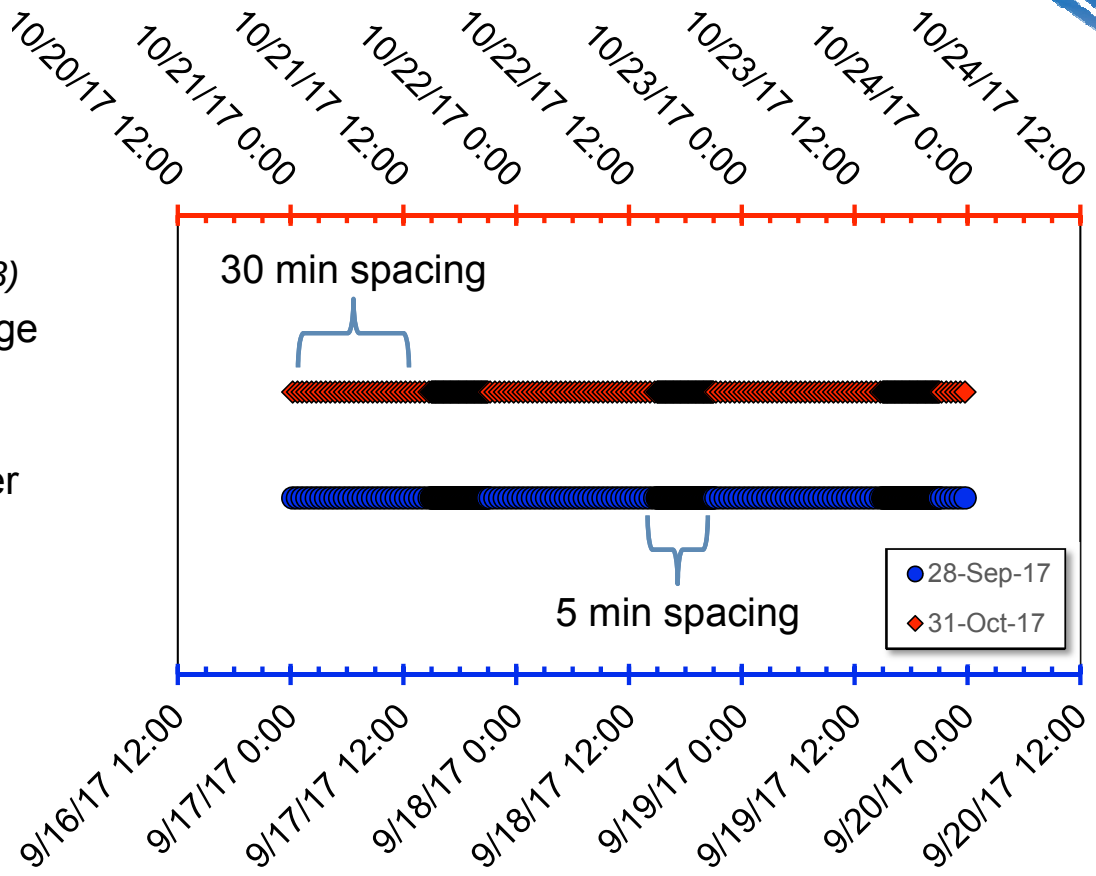
Distribution of IPATS correlation windows

- IPATS correlations are performed for a number of small image subsets (“windows”) across the image extents
- Windows drawn from the location of the Landsat-based chips used for ABI NAV and a regular grid of windows
- Windows are enabled and disabled for various evaluation modes
- GLM-specific optimizations included tailored window sizes, and disabling of windows over water and close to the edge of the disk/GLM field of regard

GLM evaluation windows for the 89.5° W “checkout” orbit.
Background image source: NASA

GLM Datasets

- 2 3-day sets, full 24 hours, denser sampling during illuminated periods
  - *28 Sep 2017: 2017, DOY 260-262 (9/17-9/19)*
  - *31 Oct 2017: 2017, DOY 294-296 (10/21-10/23)*
- Processed to downsampled background image format via offline process (Adam Milstein, MIT/LL, Donald Chu, NASA GSFC)
- 28 Sep 2017 is the training set for quality filter threshold tuning



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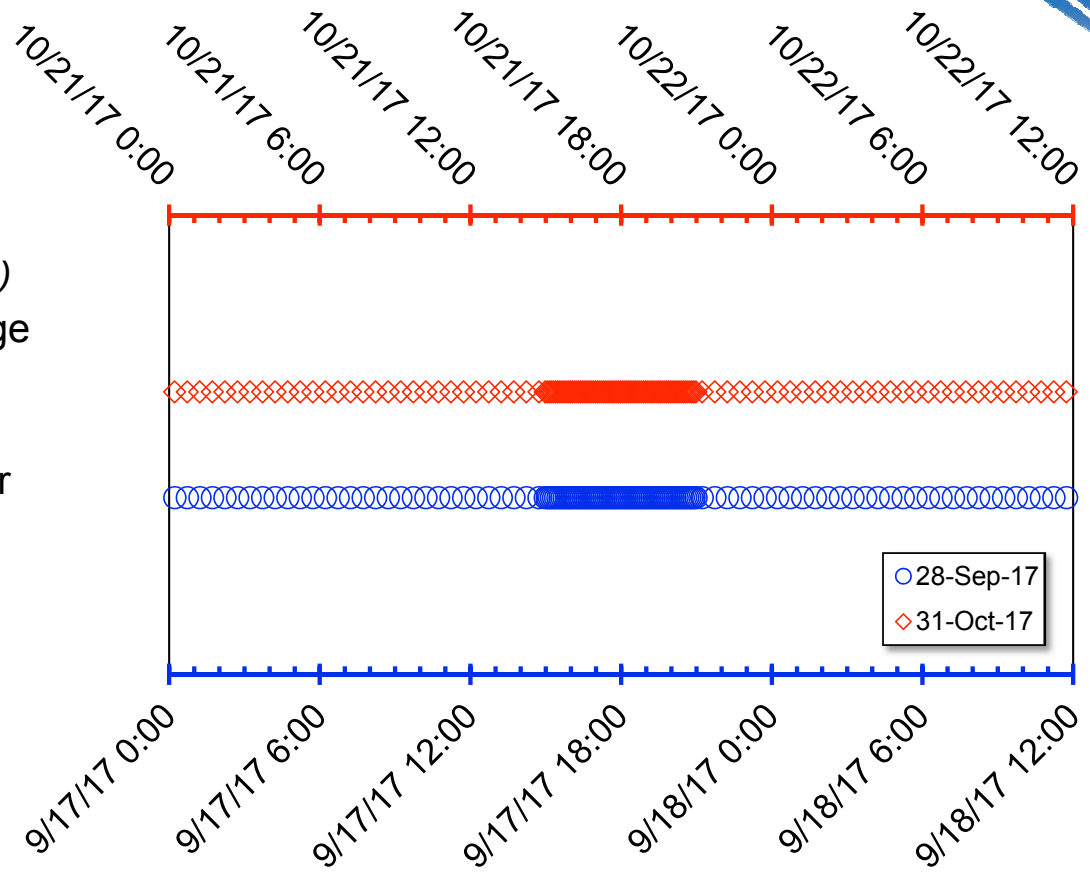
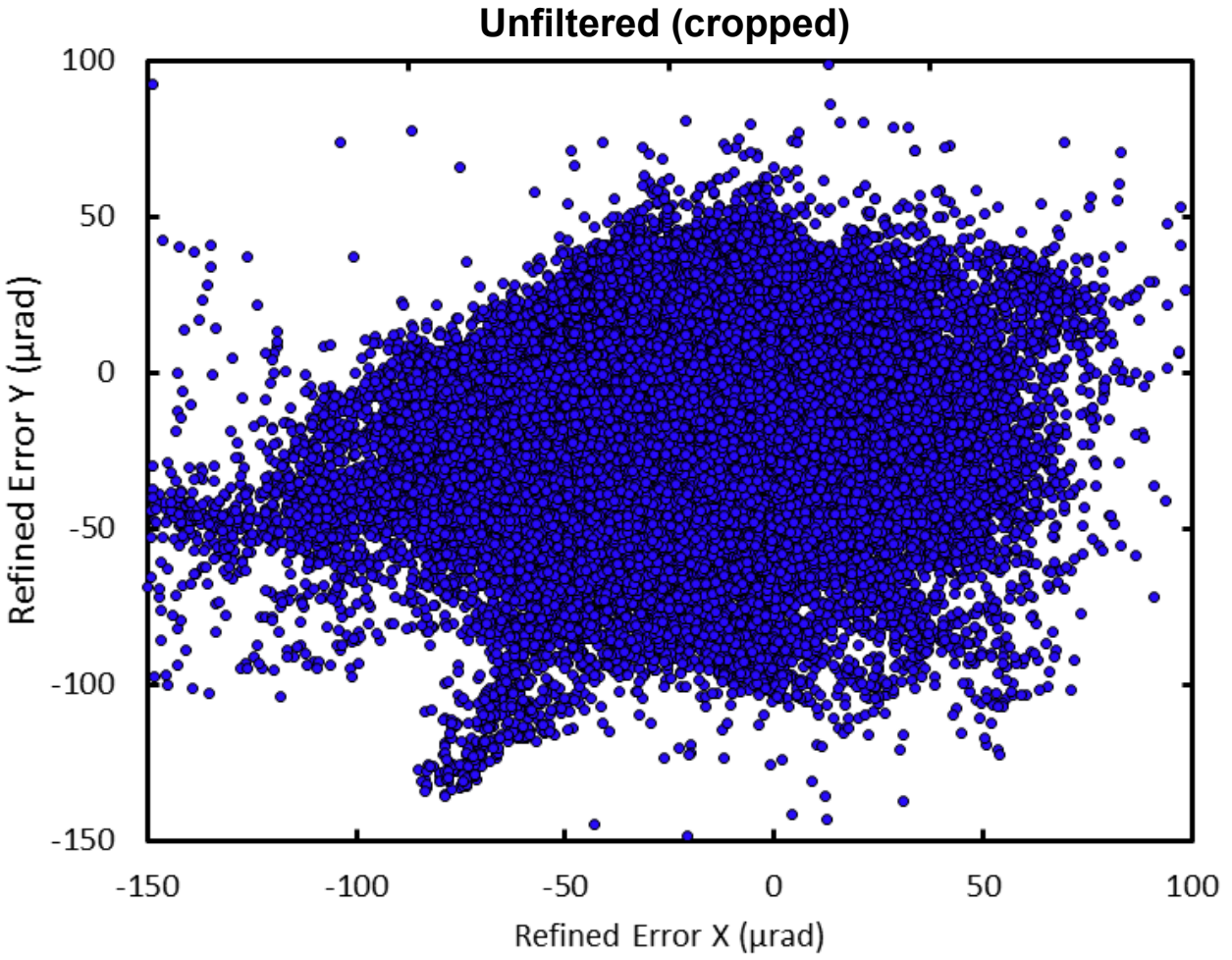


IPATS results quality filtering

- Correlation results from all windows span a range of “quality” levels
- Many windows exhibit reduced performance due to factors such as varied illumination conditions, variable scene content or cloud motion, errors in the correlation process, etc.
- Filtering in post-processing attempts to emphasize correlation results where misregistration is due to real navigation offsets as opposed to such other competing factors
- GLM NAV uses four parameters to perform quality filtering. The baseline configuration includes carefully tuned thresholds for each parameter; since GLM NAV is a relative assessment (no absolute truth), optimization trades reduced dispersion against sample size
  - *Solar zenith angle (reject low sun conditions); SZA*
  - *Analytic measurement uncertainty: parameterization of false misregistration resulting from noise sources described above for otherwise perfectly registered images; aMU*
  - *Clear sky ratio: Ratio of clear/probably clear to cloudy/probably cloudy pixels based on ABI level 2 cloud mask product; CSR*
  - *9*median absolute deviation extreme outlier rejection; MAD*

Progressive application of quality filtering: Unfiltered

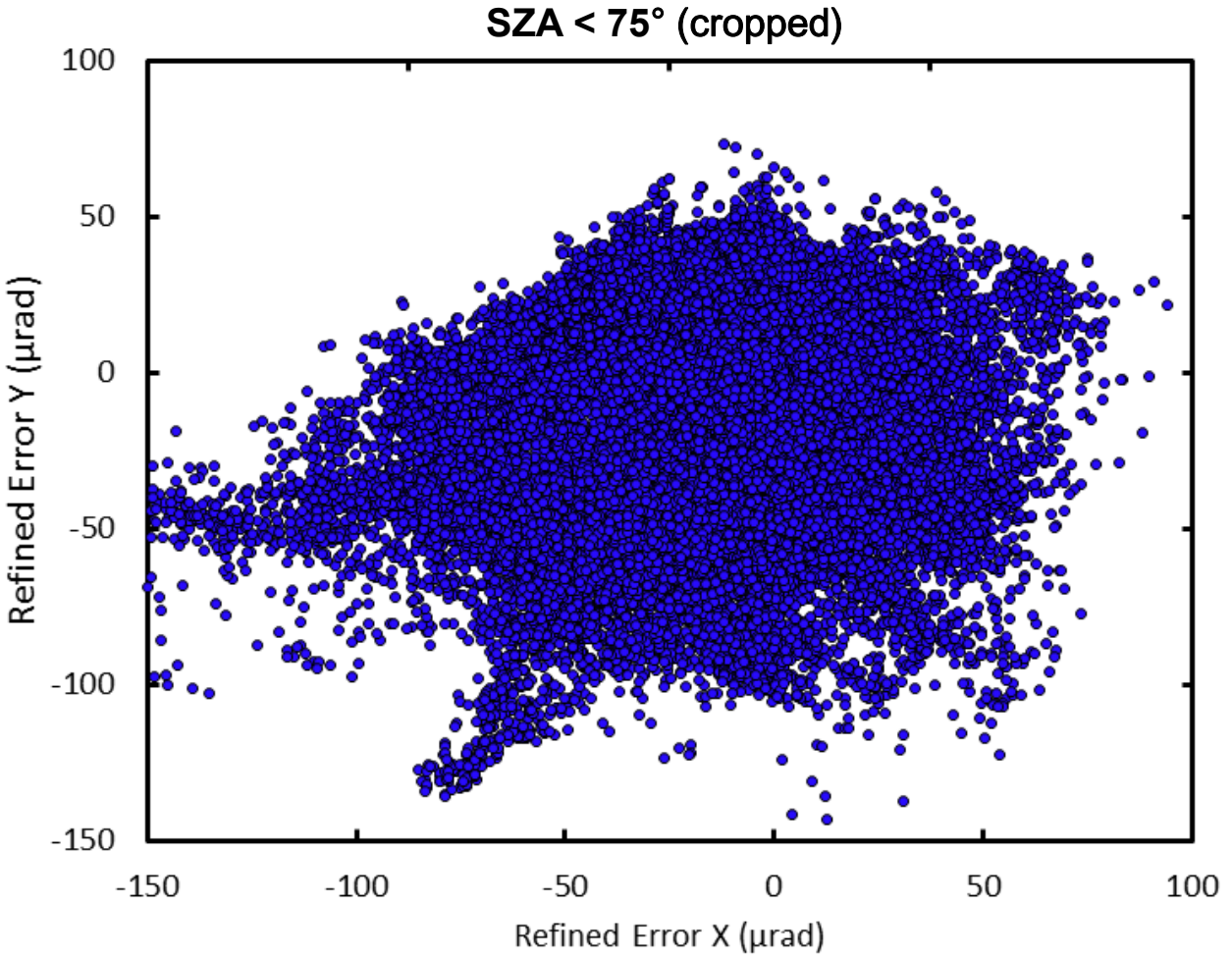
- Scatterplot of x vs y errors for the 28 Sep 2017 (training) set
- All correlations in the dataset surviving the indicated filter are illustrated
- Error indicates the relative NAV error for the GLM window w.r.t. ABI “truth”



n = 94949

Progressive application of quality filtering: SZA

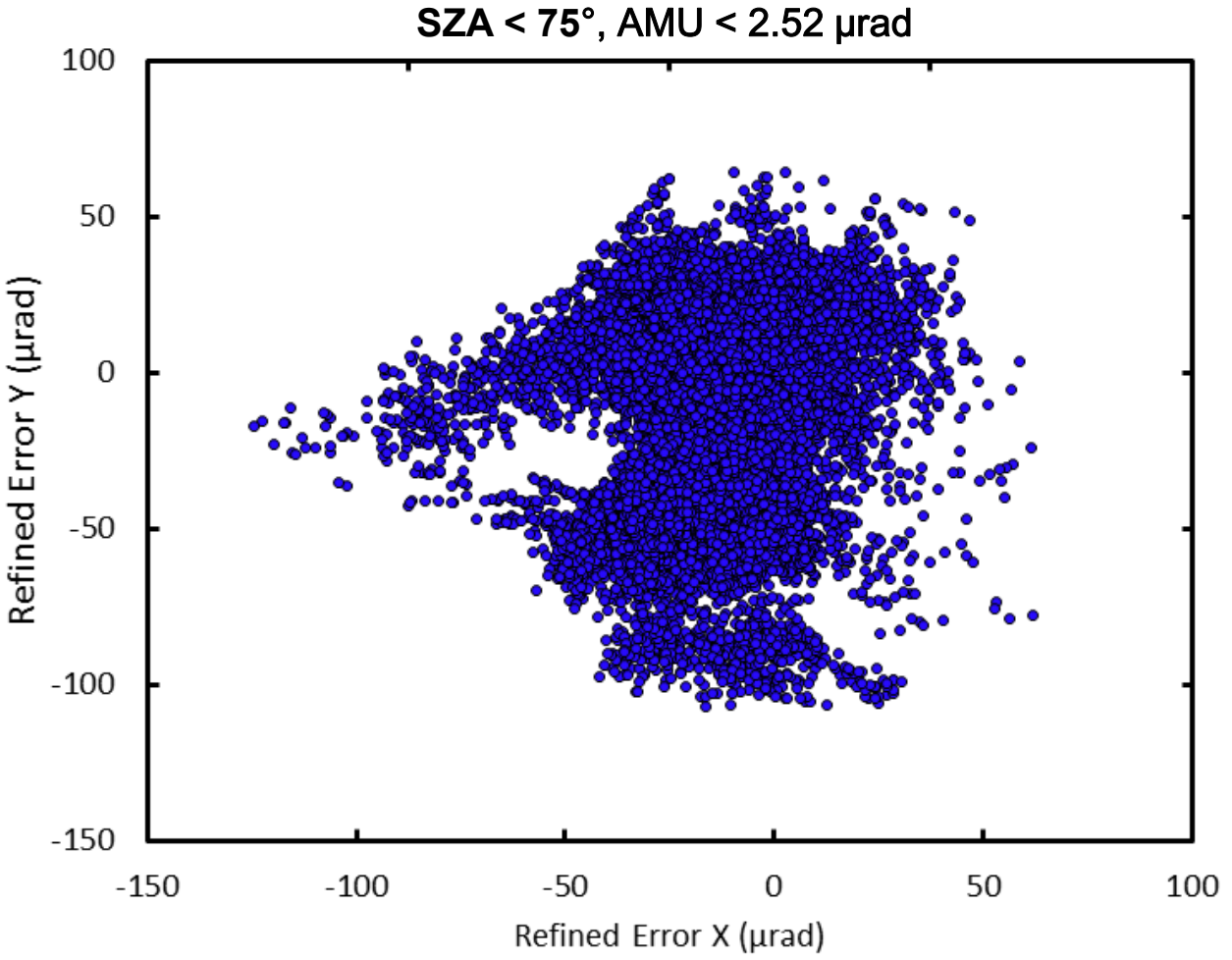
- Scatterplot of x vs y errors for the 28 Sep 2017 (training) set
- All correlations in the dataset surviving the indicated filter are illustrated
- Error indicates the relative NAV error for the GLM window w.r.t. ABI “truth”



n = 86825

Progressive application of quality filtering: SZA + AMU

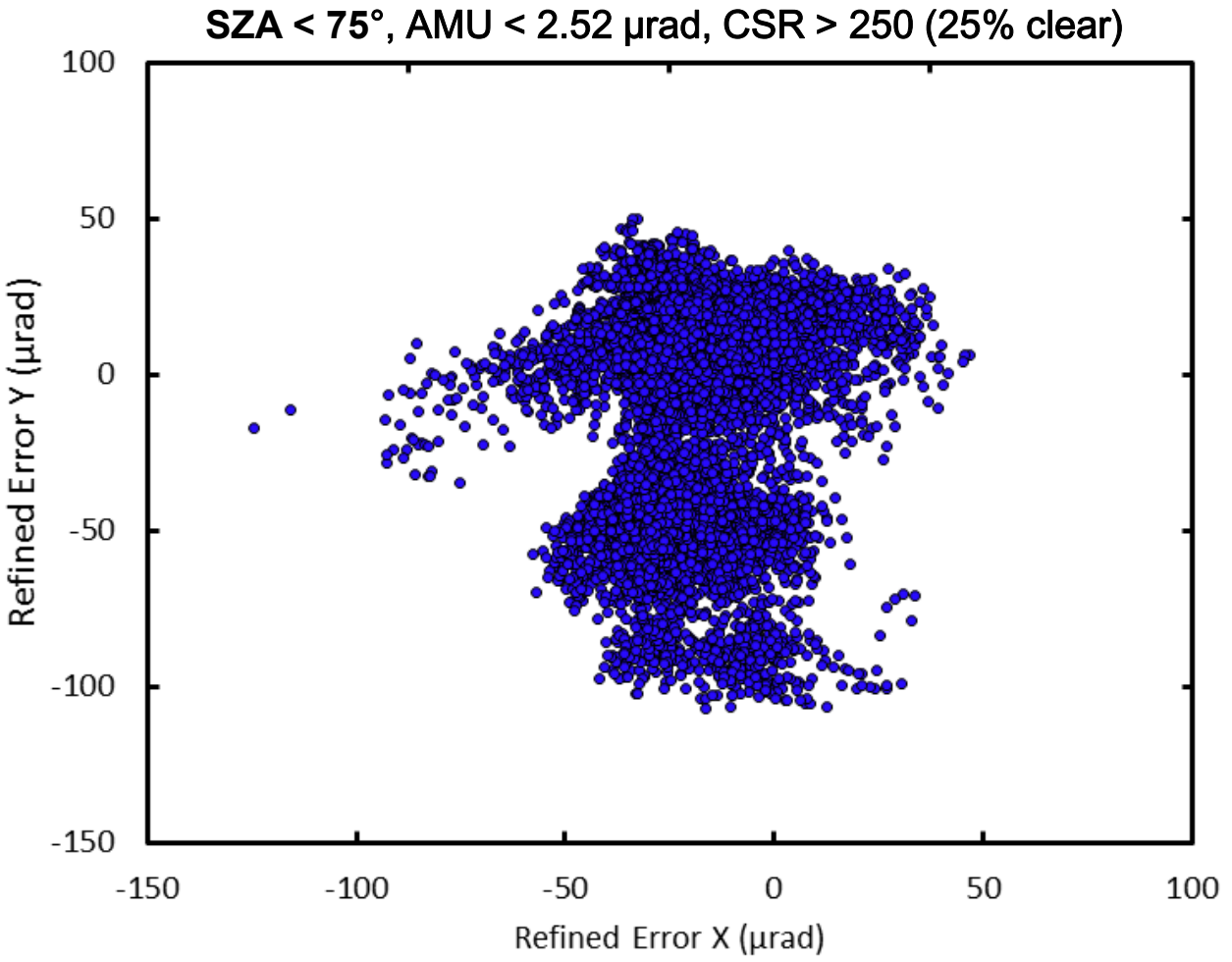
- Scatterplot of x vs y errors for the 28 Sep 2017 (training) set
- All correlations in the dataset surviving the indicated filter are illustrated
- Error indicates the relative NAV error for the GLM window w.r.t. ABI “truth”



n = 33168

Progressive application of quality filtering: SZA + AMU + CSR

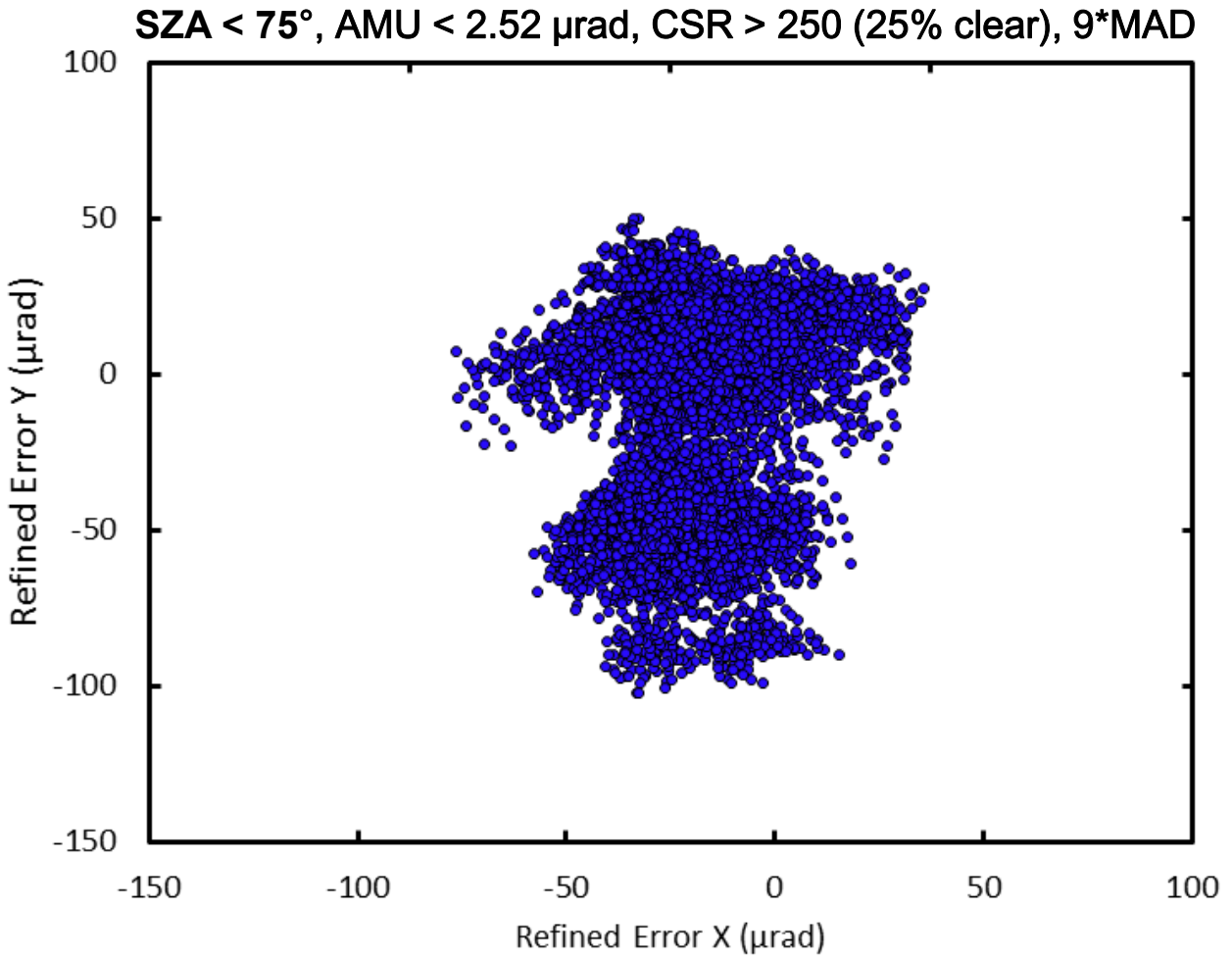
- Scatterplot of x vs y errors for the 28 Sep 2017 (training) set
- All correlations in the dataset surviving the indicated filter are illustrated
- Error indicates the relative NAV error for the GLM window w.r.t. ABI “truth”



n = 21308

Progressive application of quality filtering: SZA + AMU + CSR + MAD

- Scatterplot of x vs y errors for the 28 Sep 2017 (training) set
- All correlations in the dataset surviving the indicated filter are illustrated
- Error indicates the relative NAV error for the GLM window w.r.t. ABI “truth”



n = 21060

Bimodal distribution results from a known artifact of the GLM focal plane

Results for example datasets

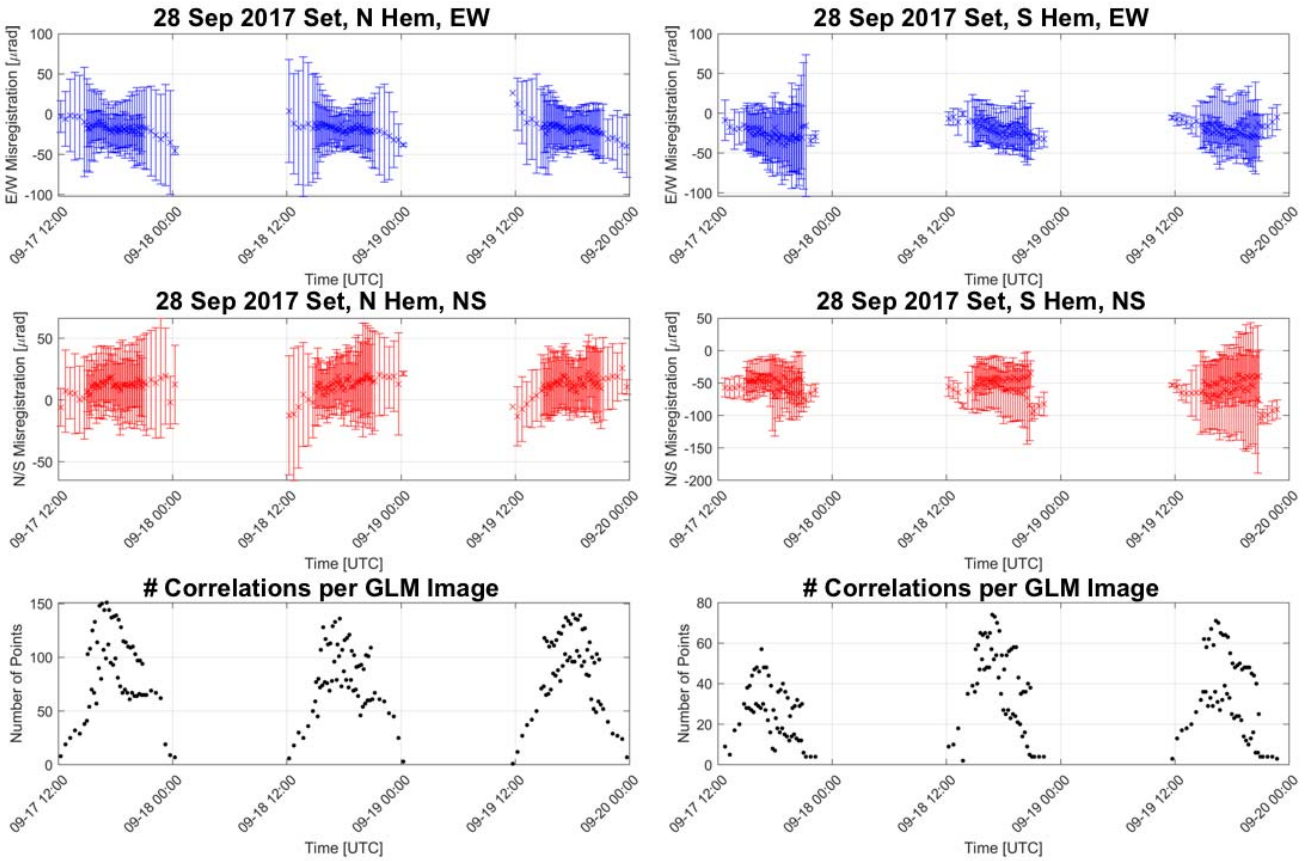
Summary results capturing properties of error distributions, as illustrated in previous charts

	28 Sep 2017 N Hem	31 Oct 2017 N Hem	28 Sep 2017 S Hem	31 Oct 2017 S Hem
σ_x	11.2	10.0	11.3	12.1
σ_y	9.5	9.5	15.4	14.3
Mean X	-18.1	-14.0	-22.4	-27.2
Mean Y	**12.7**	**11.4**	**-49.8**	**-54.1**
$\|\bar{X}\| + 3\sigma_x$	51.8	44.2	56.4	63.5
$\|\bar{Y}\| + 3\sigma_y$	41.2	39.8	96.0	96.9
n	15420	10322	5764	2062
# images	186	166	175	141

All shaded rows in units of microradians (μrad)
Results are after quality filtering and hemisphere stratification

Temporal trends

One point per GLM background image



- NAV estimates are relatively stable over the analysis period
- Expected trend in dispersion with sample size
- General correlation in sample size with illumination (time)
  - *Irregular nature likely due to variable temporal offset (inter- and intra-image) between ABI and GLM images*

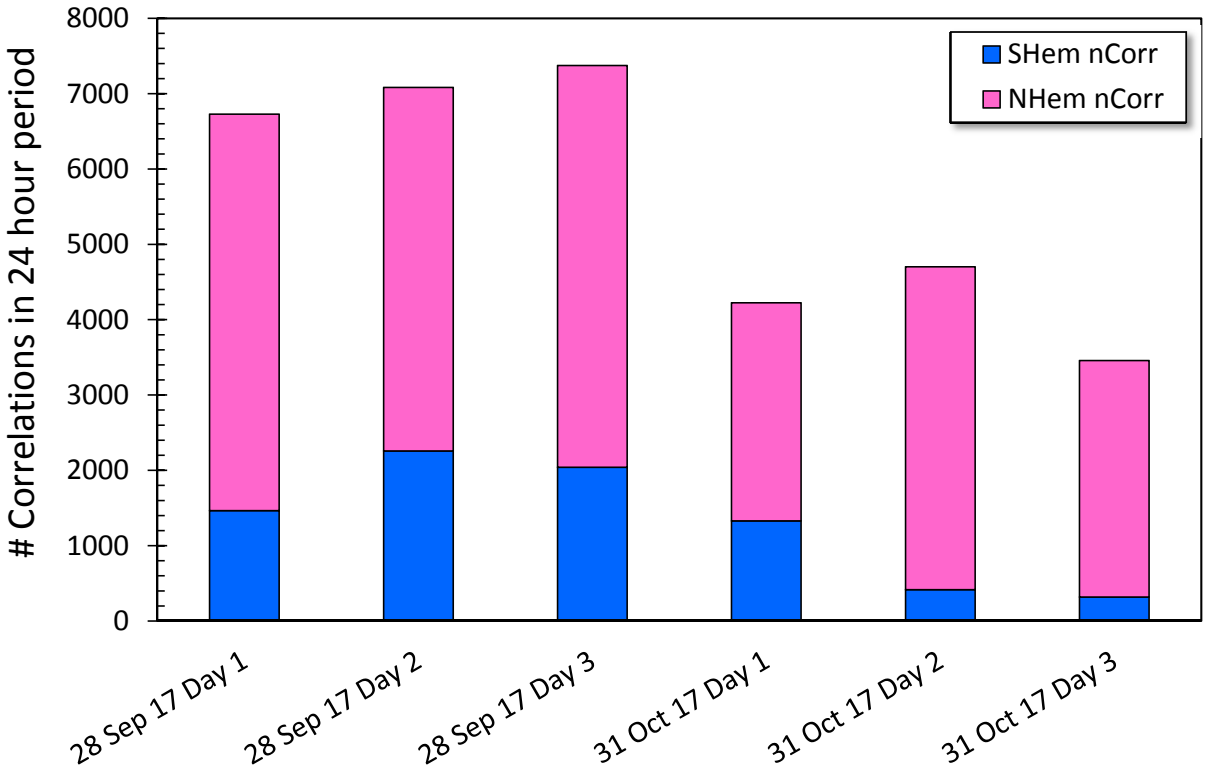
Discussion

- Error “metric” of mean + 3σ is ~40-50 μrad (~100 μrad NS in S Hem)
- Navigation accuracy requirement for navigated lightning events is 112 μrad
- IPATS NAV results for GLM background images are suggestive of NAV accuracy of lightning events
- Results suggest GLM NAV compliance with L1B requirement
- Sample size issues (note discrepancy between 28 Sep and 31 Oct sets) are likely due to cloud cover differences; sample size issues are a focus of ongoing research

	28 Sep 2017 N Hem	31 Oct 2017 N Hem	28 Sep 2017 S Hem	31 Oct 2017 S Hem
σ_x	11.2	10.0	11.3	12.1
σ_y	9.5	9.5	15.4	14.3
Mean X	-18.1	-14.0	-22.4	-27.2
Mean Y	12.7	11.4	-49.8	-54.1
$\lvert\bar{X}\rvert + 3\sigma_x$	51.8	44.2	56.4	63.5
$\lvert\bar{Y}\rvert + 3\sigma_y$	41.2	39.8	96.0	96.9
n	15420	10322	5764	2062
# images	186	166	175	141

Sample size issues

- Bars indicate total number of correlations per 24 hour period (ending 23:59 UTC) after quality filtering
- Fewer samples in S Hem are observed consistently
- Significant reduction in sample size for 31 Oct 2017 set
- Sample size issues are under active research; may be linked to cloud cover/distribution in this case



Insufficient sample size leads to poor statistical INR assessment

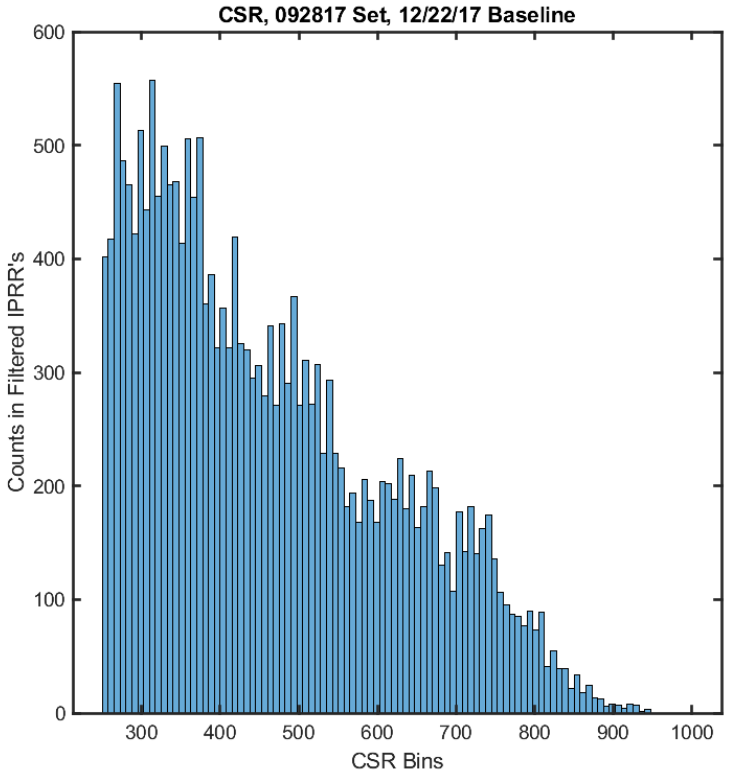
Conclusions

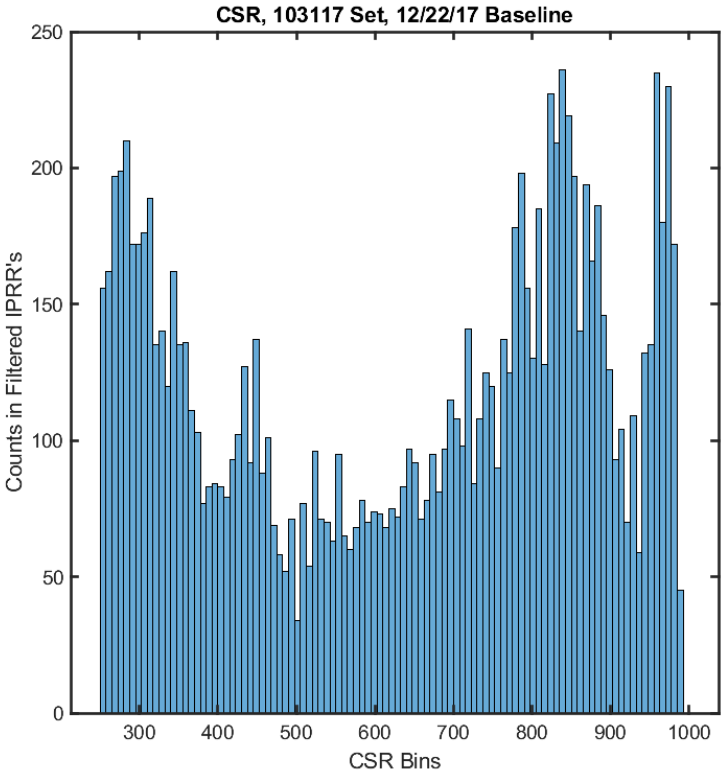
- Functional independent GLM NAV evaluation with IPATS has been demonstrated.
- Baseline quality filtering is effective at clarifying true INR performance.
- Filtered results from the two datasets considered herein suggest compliance with GLM NAV requirements.
- Sample size issues are the focus of ongoing research efforts.
- Analysis of GOES-17 GLM are forthcoming.


GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE-R SERIES
GOES R
NOAA ~ NASA
NOAA
NASA

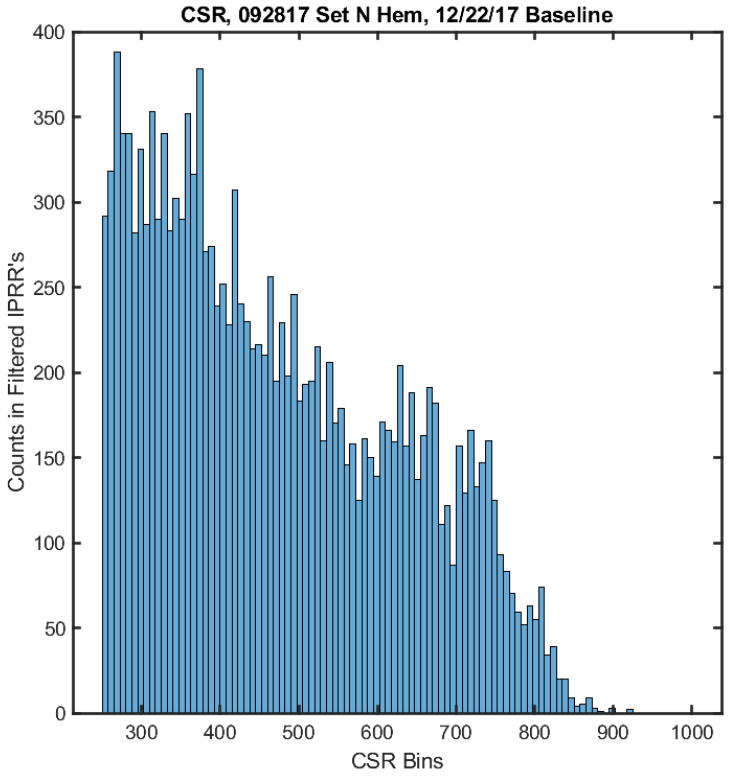
Backup Materials

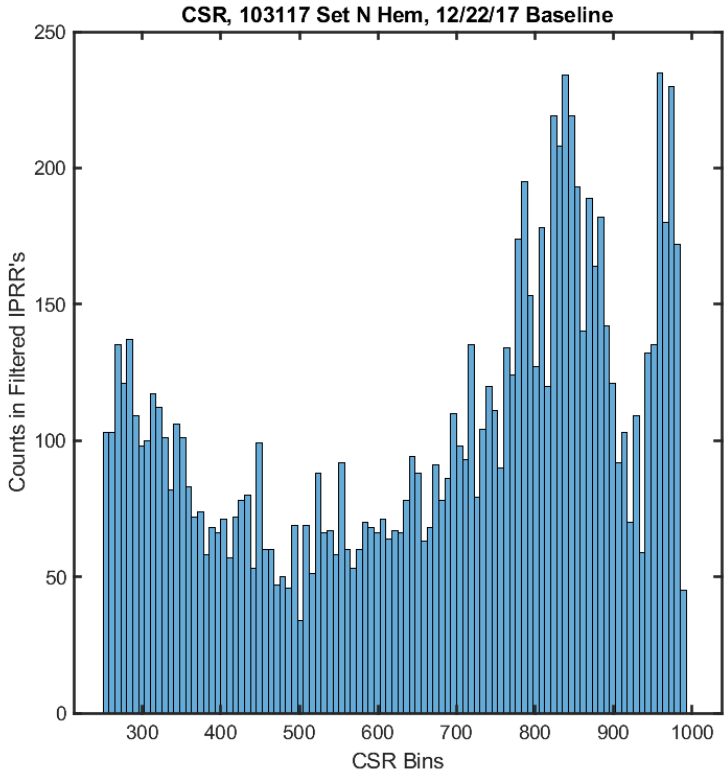
CSR Histograms





CSR Histograms, N Hem





CSR Histograms, S Hem