OCI Geolocation Evaluation and Refinement using Landsat Control Points

Frederick S. Patt, Alex V. Semenov, Gwyn F. Fireman,
Thomas J. Owens, Corrine Rojas, John G. Wilding

NASA GSFC Ocean Ecology Laboratory
and Science Application International Corporation

September 18, 2024

Introduction

- The Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission launched February 8th, 2024.
- The Ocean Color Instrument (OCI) is the primary payload.
  - Global top-of-atmosphere (TOA) radiance measurements to support ocean color, aerosol and cloud studies
  - Hyperspectral coverage from 340nm to 895nm with multispectral coverage from 940nm to 2260nm.
  - Spatial resolution of 1 km at nadir
- OCI science data processing is performed by the PACE Science Data Segment (SDS).

Introduction (cont.)

- Geolocation processing is performed at SDS as part of Level-1B product generation.
  - “PACE OCI Calibration and Geolocation Operational Algorithm Description”, https://pace.oceansciences.org/docs/PACE_Vol_13_all_combined.pdf
- The geolocation accuracy requirement is 0.1 pixel (1 sigma).
- Geolocation evaluation has been performed postlaunch:
  - Determine errors with Earth View data.
  - Develop and implement processing corrections.
  - Monitor accuracy throughout the mission and determine whether further processing corrections are needed (e.g. seasonal effects).
- The method using Landsat control point “chips” (sub-images) was implemented before the PACE launch and tested with MODIS data.

Land Control Point Matching

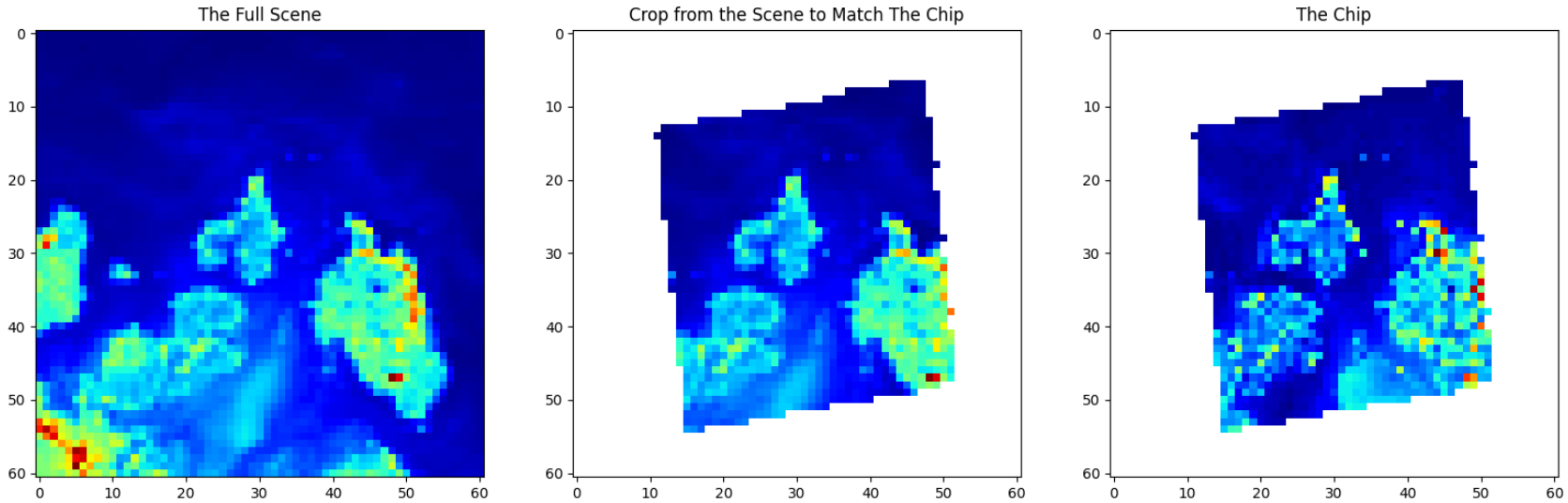
- The method of control point matching with features in Landsat data was originally developed for Terra MODIS.
  - “MODIS Level 1A Earth Location: Algorithm Theoretical Basis Document”
- The MODIS code and control point library were acquired from the GSFC Terrestrial Information Systems Laboratory.
  - The library currently contains ~2500 Landsat chips at 28.5m resolution.
  - The chips use 650 nm data to provide good land/water discrimination.
- The matching and error estimation method was recoded in Python.

Control Point Matching and Error Estimation

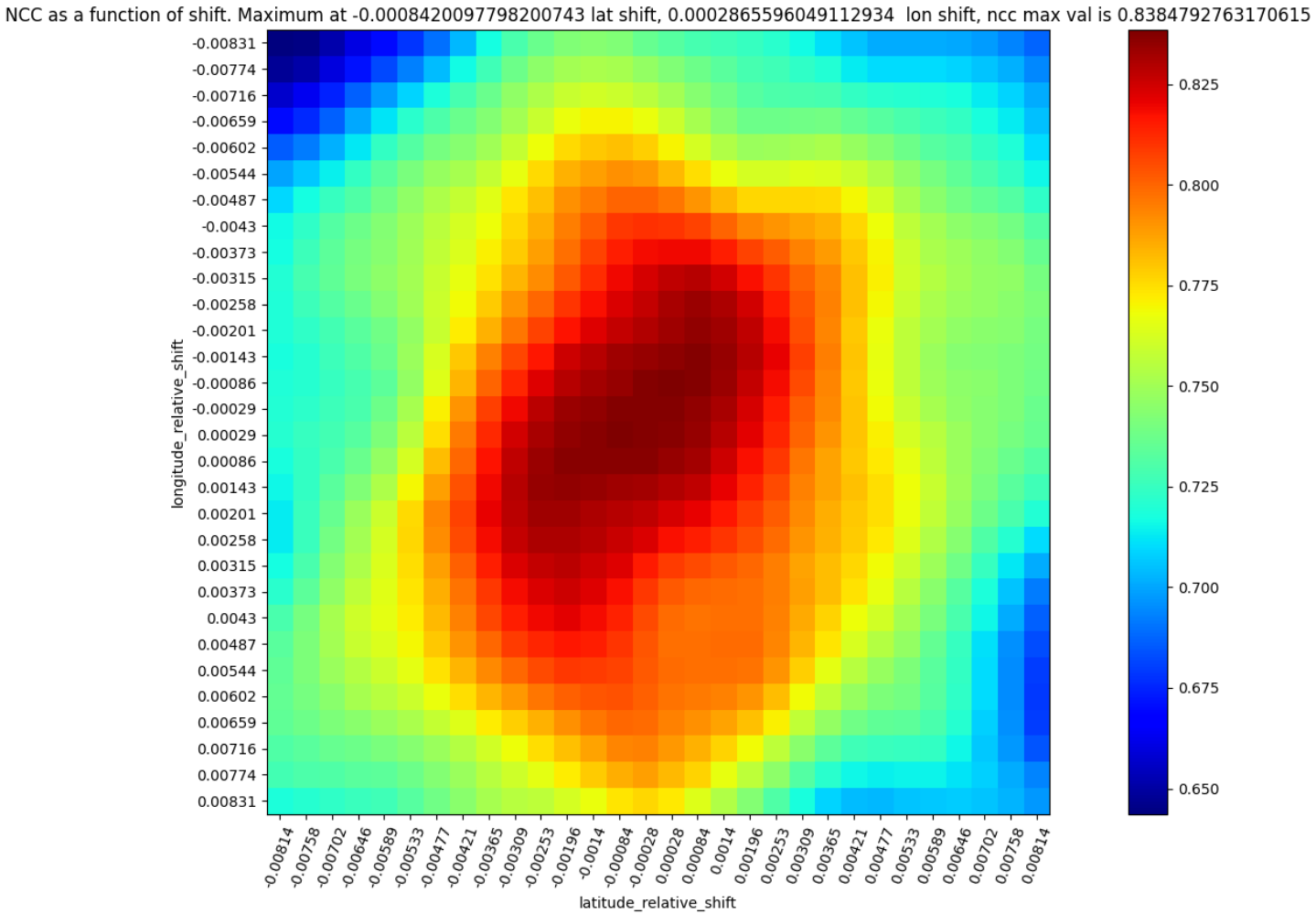
For each OCI Level-1B granule:

- Identify control point chips within bounds of OCI granule.
- For each chip:
  - Resample Landsat data to OCI resolution using geolocation from both sensors.
  - Compute normalized correlation coefficient.
  - Repeat by shifting Landsat data over a specified range of Landsat pixels and recomputing NCC.
  - The OCI error in latitude and longitude is computed from the 2-dimensional peak of the NCC.
  - If the NCC exceeds a threshold, the results are output.

Example of Landsat Resampling



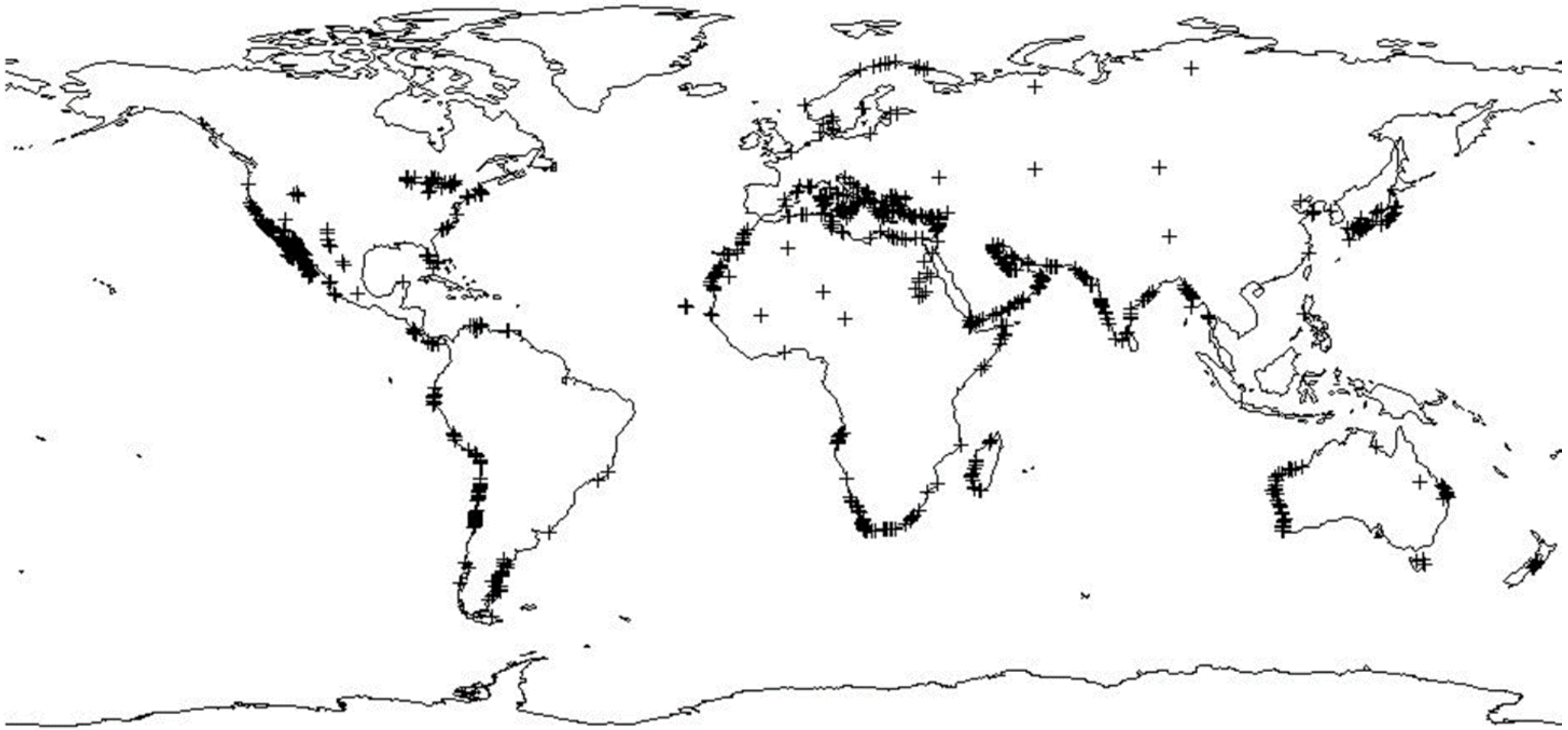
Normalized 2-D Cross-Correlation



Matchup Results

- Matchups are found for 20 to 35 granules per day.
  - Daily total of between 230 and 400 total matchups.
- Analysis has been performed typically for 10 days of matchups.
- This provides good global and geometric distribution.
  - Global distribution for April 1 – 10 on next page.

Global Distribution of Matchups for Typical 10-day Period.

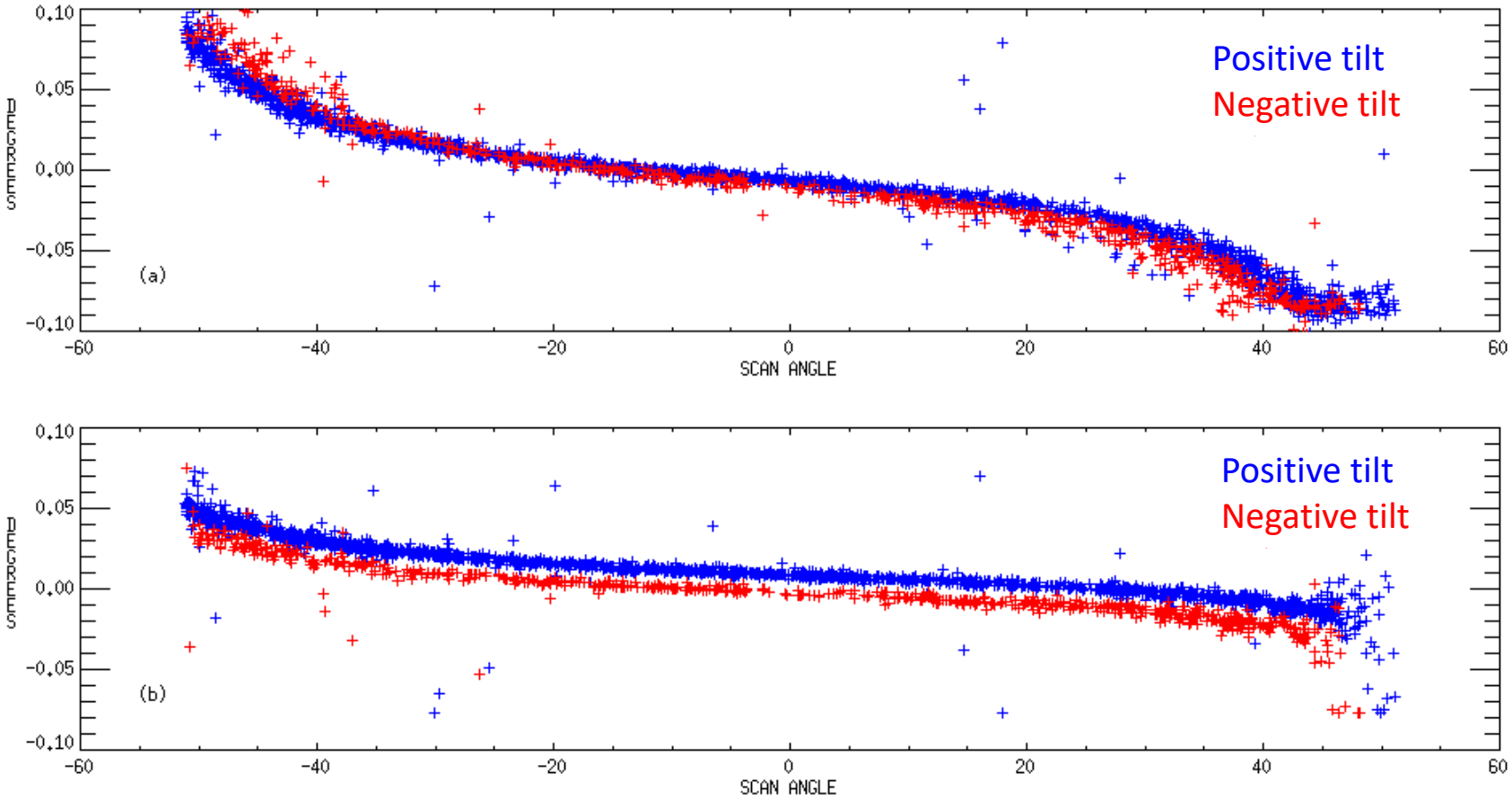


Sample OCI Control Point Matching/Correlation Results

scantime	granule	chip	feature_latitude	feature_longitude	delta_latitude	delta_longitude	pixel	confidence	tilt
1709089956	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20140107.p107r034.c01.v001.h5	36.8276412	140.80533	0.0040482	0.0037753	652	0.8335882	19.89972
1709089940	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20150110.p107r035.c01.v001.h5	35.6382099	139.939133	0.0090291	0.0024579	558	0.8879622	19.89972
1709089934	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20150110.p107r035.c02.v001.h5	35.3014413	140.4140763	0.0050418	0.0049202	587	0.814079	19.89972
1709089949	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20150110.p107r035.c05.v001.h5	36.2999248	140.5727589	0.011107	0.0062372	622	0.8601092	19.89972
1709089935	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20141209.p107r036.c02.v001.h5	35.1382228	139.1606587	0.0079613	0	488	0.8672203	19.89972
1709089933	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20141209.p107r036.c03.v001.h5	35.1371172	139.6769764	0.0060041	0.0012182	527	0.8788112	19.89972
1709089930	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20141209.p107r036.c04.v001.h5	34.9742806	139.753871	0.0060094	0.0060841	529	0.8312321	19.89972
1709089931	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20141209.p107r036.c05.v001.h5	35.134849	140.3184594	0.0060445	0.0049054	576	0.89098	19.89972
1709089929	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20141114.p108r036.c02.v001.h5	34.5945613	138.2304682	0.003942	0.004767	411	0.8517599	19.89972
1709089935	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20141114.p108r036.c03.v001.h5	35.017999	138.5157141	0.0059296	0.0012013	440	0.9112982	19.89972
1709089935	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20141121.p109r036.c04.v001.h5	34.6965958	136.9734998	0.0059641	0	333	0.9159652	19.89972
1709089940	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20141121.p109r036.c05.v001.h5	35.0008572	136.8009797	0.0039826	0.00121	329	0.8869314	19.89972
1709089940	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20140909.p110r036.c01.v001.h5	34.6086929	135.003054	0.0070975	-0.0012243	229	0.9010932	19.89972
1709089938	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20140909.p110r036.c05.v001.h5	34.3060689	134.246655	0.0040278	0.0024269	192	0.8881002	19.89972
1709089940	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20140909.p110r036.c07.v001.h5	34.6969111	135.3555087	0.0060654	-0.001224	247	0.8683588	19.89972
1709089924	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20140317.p110r037.c02.v001.h5	33.6680508	135.3301847	0.00708	0.0036289	229	0.8311204	19.89972
1709089929	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20140317.p110r037.c03.v001.h5	33.8384178	134.7429813	0.0030363	0	205	0.9254135	19.89972
1709089940	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20140409.p111r036.c04.v001.h5	34.259968	133.5905134	0.0060013	0.003614	166	0.9383523	19.89972
1709089943	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20140409.p111r036.c05.v001.h5	34.5966906	134.1337905	0.0060342	0	192	0.8647029	19.89972
1709089942	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20140409.p111r036.c06.v001.h5	34.5485635	134.2614786	0.0080562	0.0073026	196	0.8614092	19.89972
1709089943	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20140409.p111r036.c07.v001.h5	34.4417147	133.4741654	0.0059934	0.0048229	164	0.8868919	19.89972
1709089927	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20140324.p111r037.c07.v001.h5	33.4002949	133.3784362	0.0029955	0.0011905	147	0.8821803	19.89972
1709089927	PACE_OCI.20240228T031135.L1B.nc	LT08CHP42KM.20140324.p111r037.c09.v001.h5	33.5180172	133.7554512	0.007016	0.0107695	162	0.8493807	19.89972

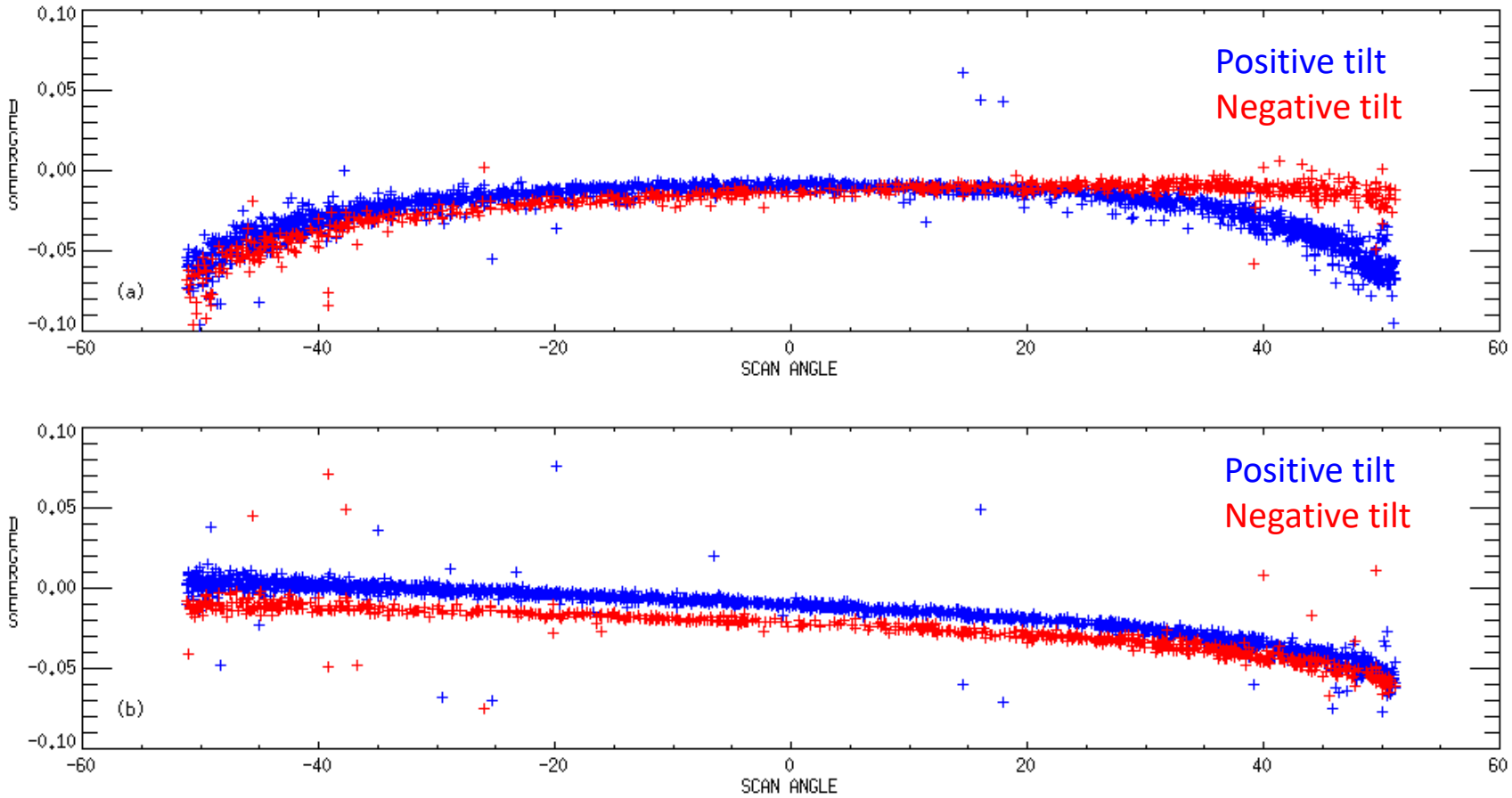
Initial Matchup Results

- A set of OCI L1B granules was selected for testing.
- Initial results showed large errors (up to 0.1 degree, ~10 km in longitude)
- This indicated that the planarity corrections from the prelaunch measurements had the wrong sign.
- The latitude results also showed differences between positive (blue) and negative (red) tilt.



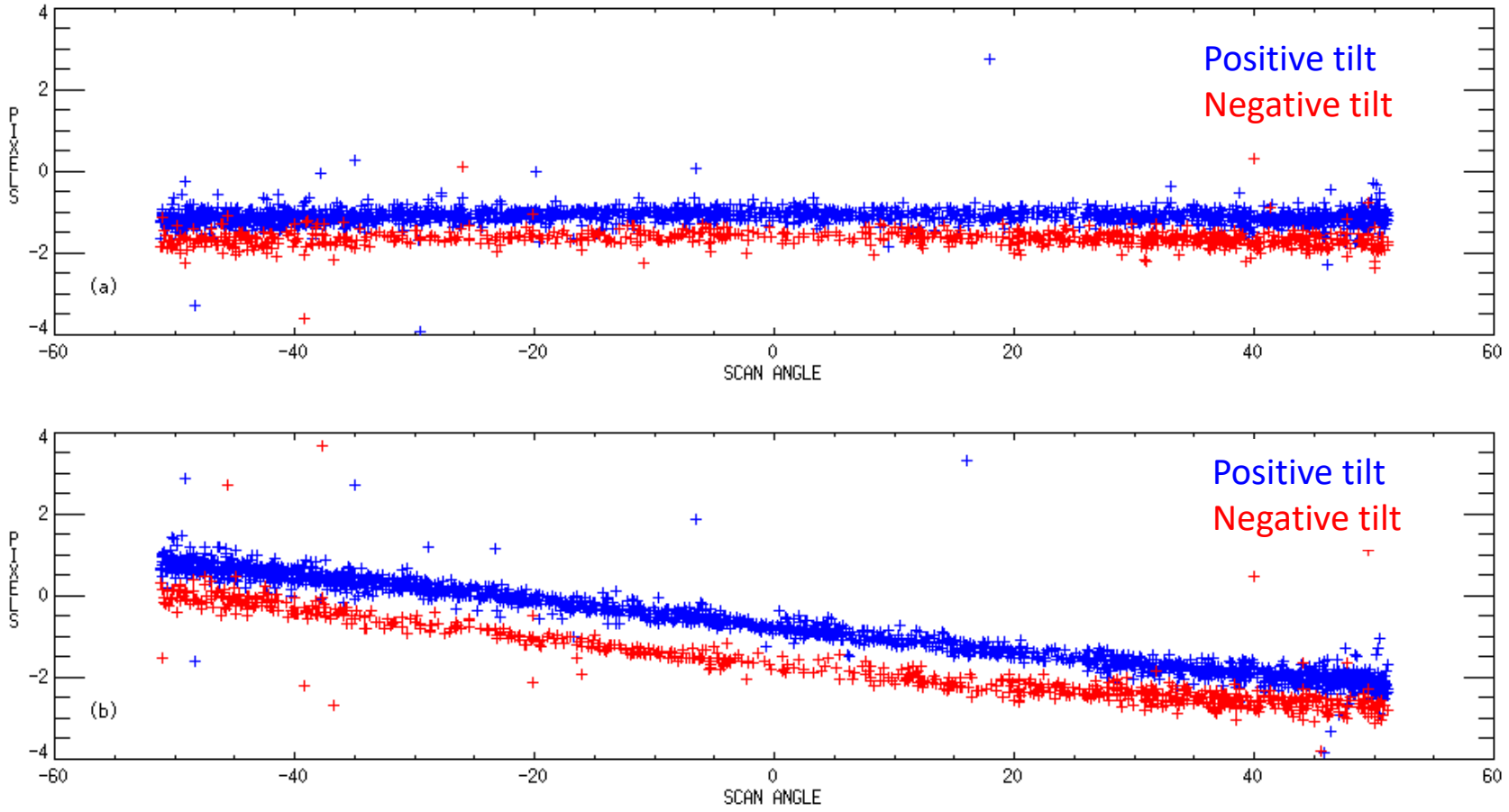
Results with Corrected Planarity Coefficients

- The large, monotonic trend in longitude was corrected
- Large, systematic errors remained in both latitude and longitude.



Matchup Results Converted to Pixel Units

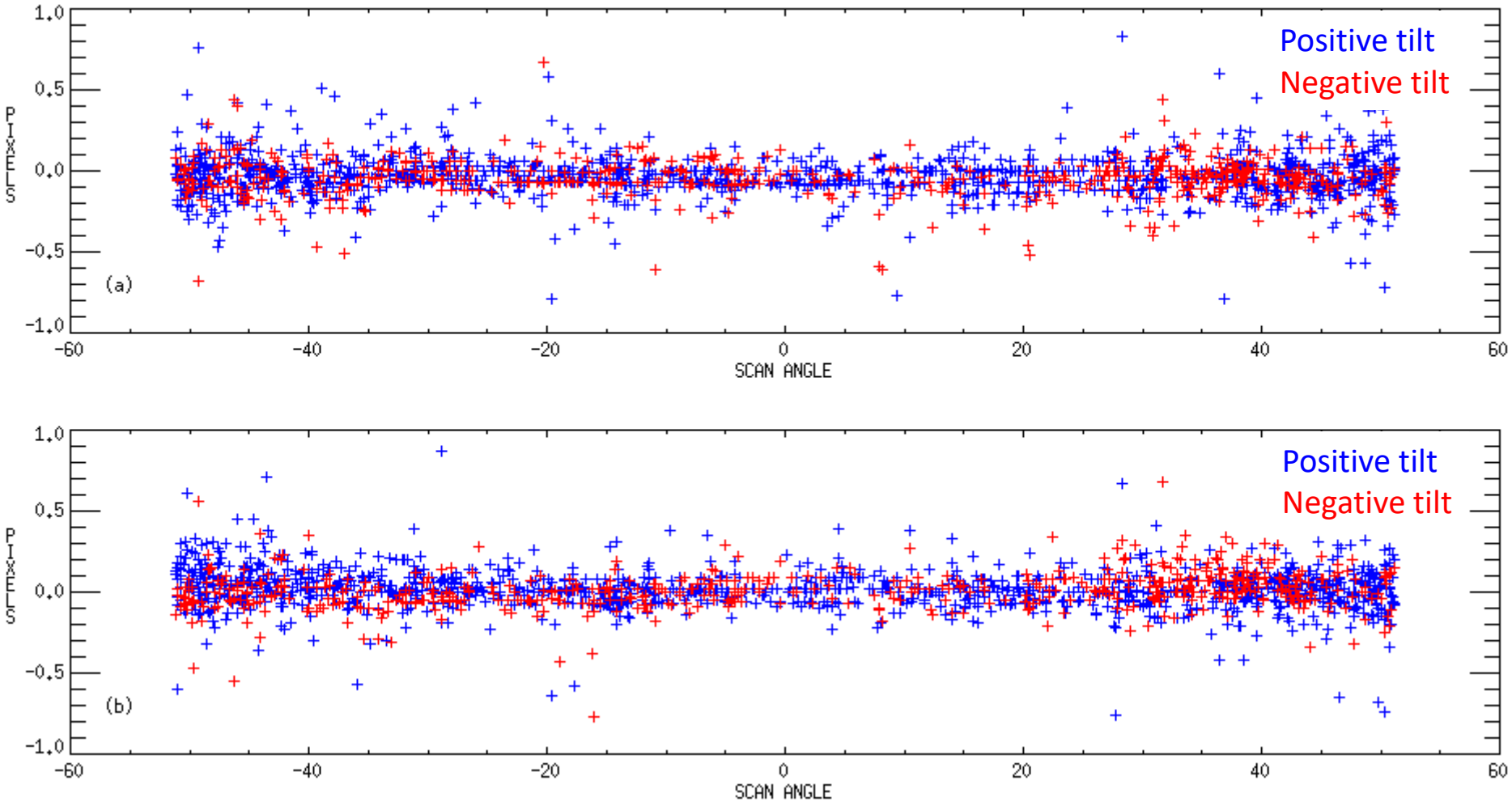
- The longitude and latitude errors were converted to along-scan and along-track errors in pixel units for comparison with the geolocation requirement.
- This illustrates more clearly the likely error sources: alignment and tilt angle/axis.



Geolocation Refinement Using Matchup Results

- The results were interpreted in terms of expected error sources, specifically misalignments between the spacecraft and instrument.
- This was accomplished using numerical partial derivatives and least-squares regression.
  - The alignments were computed separately for the forward and aft tilt.
- Based on these calculations, the following updates were made to geolocation processing:
  - Roll (+X) and yaw (+Z) components of the spacecraft-to-tilt alignment.
  - Tilt angles at the forward and aft position.
  - Tilt axis.

Matchup Results in Pixel Units with All Geolocation Refinements



Error Statistics in Pixel Units

- Statistics are computed separately at forward and aft tilt.
- The median and interquartile range (IQR) are used because they are insensitive to outliers.
  - The IQR is 1.33 times the standard deviation for a normal distribution.

Direction	Forward Tilt Median	Forward Tilt IQR	Aft Tilt Median	Aft Tilt IQR
Along-scan	-0.032	0.115	-0.044	0.108
Along-track	0.015	0.135	0.013	0.129

Conclusion

- The method for OCI geolocation evaluation using Landsat control point chips was implemented prelaunch and is run routinely during Level-1B processing at SDS.
- Initial results were substantially affected by an error in the planarity correction, and also by misalignment.
- The geolocation processing parameters have been refined using the matchup results.
- Geolocation accuracy is now at or close to the requirement.
- Matchup processing and analysis will continue throughout the mission for ongoing evaluation of geolocation accuracy and any further systematic (e.g., seasonal) error trends.

Acknowledgment

The authors wish to acknowledge the MODIS/VIIRS geolocation team of the NASA/GSFC Terrestrial Information Systems Laboratory for providing the Landsat control point matching code and chip library.