Improving ECOSTRESS' Absolute and Relative Georeferencing for Optimisation of Crop and Irrigation Products

Agnieszka Soszynska[1], Jan Hieronymus[2], Darren Ghent[1]

1 University of Leicester, National Centre for Earth Observation   2 constellr GmbH

ABSOLUTE GEOREFERENCING

ECOSTRESS is currently the only source of high-resolution thermal imagery apart from ASTER (which is at its end-of-life). ECOSTRESS will continue to play a crucial role for the time before the future major thermal missions appear (LSTM, TRISHNA), delivering Land Surface Temperature (LST) operationally, and all the high-level derived products, such as evapotranspiration. Therefore, the scientific community as well as the emerging thermal remote sensing service industry rely heavily on ECOSTRESS imagery. However, ECOSTRESS imagery is affected by image-quality issues. One of the most crucial issues is an inaccuracy in the absolute georeferencing of the images. The standard georeferencing of ECOSTRESS images is based on matching to a static reference database and manages to successfully process approximately 38% of all the scenes (including cloudy scenes). In these cases, a small average error of 48 metres (< 1 pixel) is observed and a spread of 20 to 100 meters remains in the majority of the analysed scenes, as reported by NASA-JPL. If the matching fails (62% of the scenes), large errors are observed. Previous studies reported errors of 14 pixels (980 m) on average.

Histogram of Sentinel-2 scenes downloaded for the given ECOSTRESS image

Basemap mosaic of Sentinel-2 scenes covering the extent of ECOSTRESS scene.

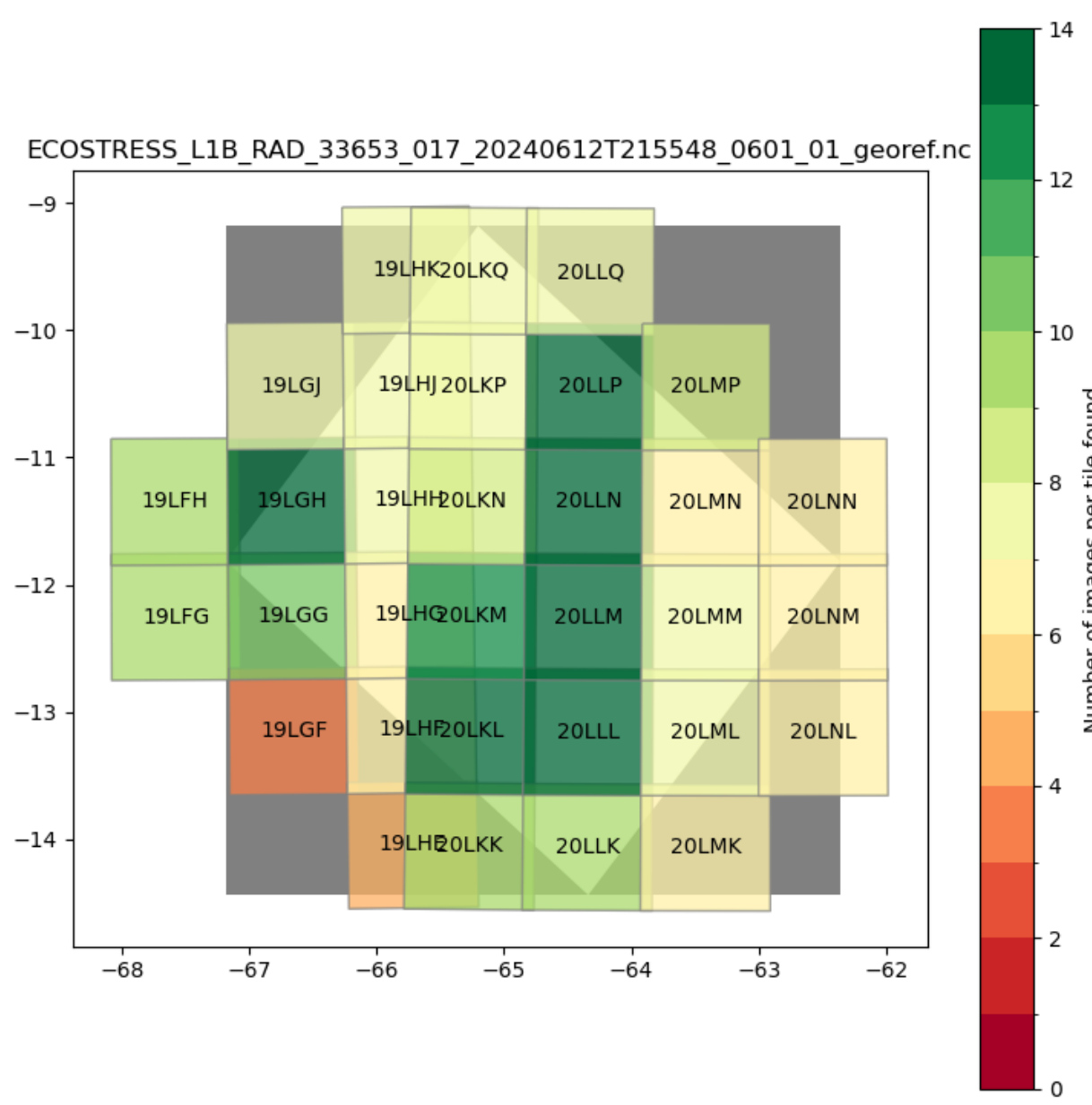**Creation of dedicated basemap from Sentinel-2 for each ECOSTRESS image**
- Using an up-to-date basemap accounts for dynamic land cover changes
- The method also saves storage space, as the basemaps are discarded, while the metadata is saved
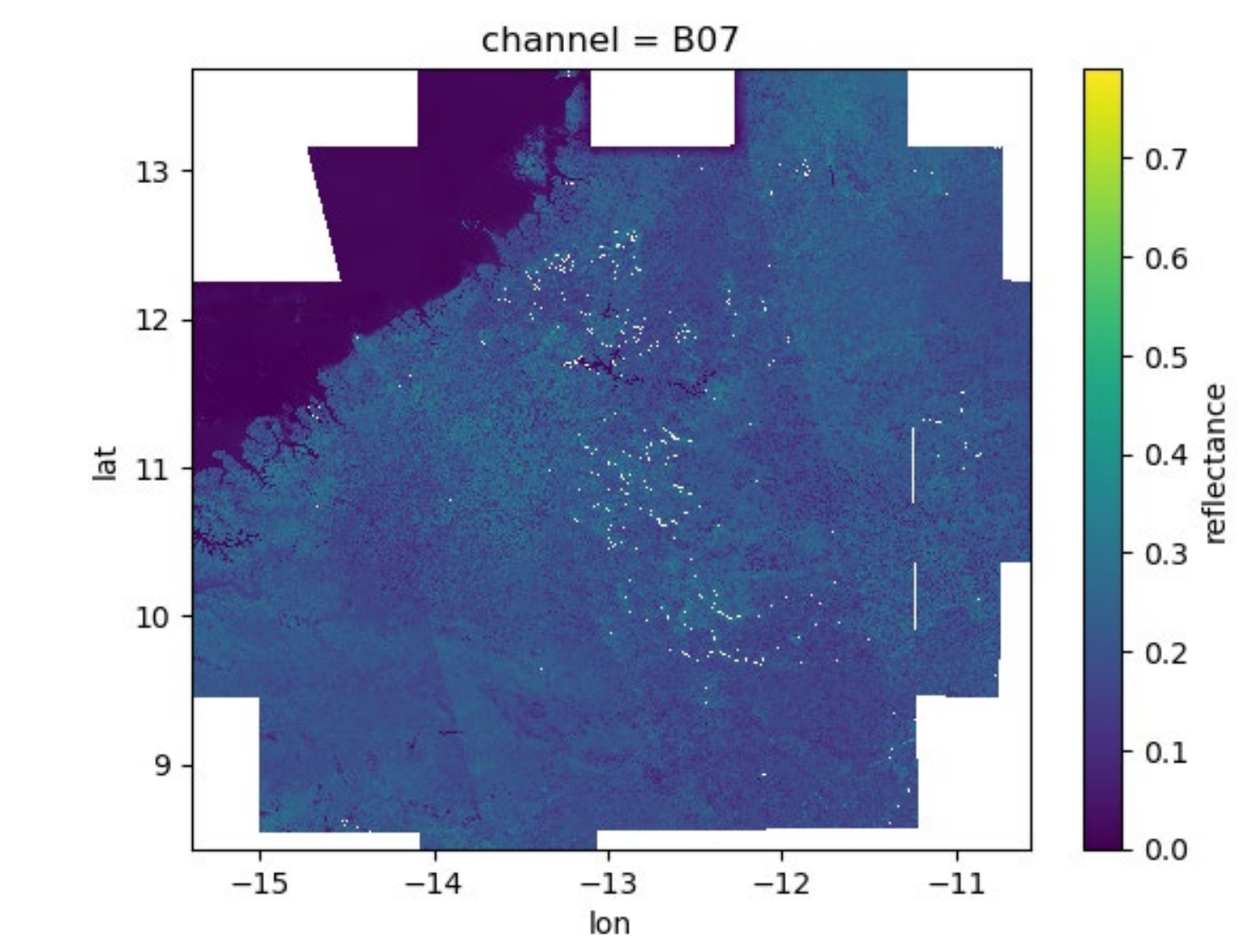
Matching ECOSTRESS image to the basemap
- Matching thermal image to an optical range image is challenging, as the difference in wavelengths causes differences in spatial patterns
- Selecting a method for feature extraction is paramount for the accuracy

Deriving transformation matrix parameters
- After matching, outliers are removed and transformation matrix parameters are fitted
- Transformation parameters are saved with each ECOSTRESS image

Water bodies are typically visible in both optical and thermal imagery. Their shape and form are unique and therefore they make good spatial patterns for matching between the basemap and ECOSTRESS image. From all the matching spatial patterns, a set of key points is created. The key point set is then analysed for consistency and outliers are removed. The remaining key points are used to fit transformation parameters to improve the absolute georeferencing of the ECOSTRESS image onto the basemap.
The accuracy of the fit depends on georeferencing accuracy of Sentinel-2 imagery as well as robustness of the outlier removal procedure.
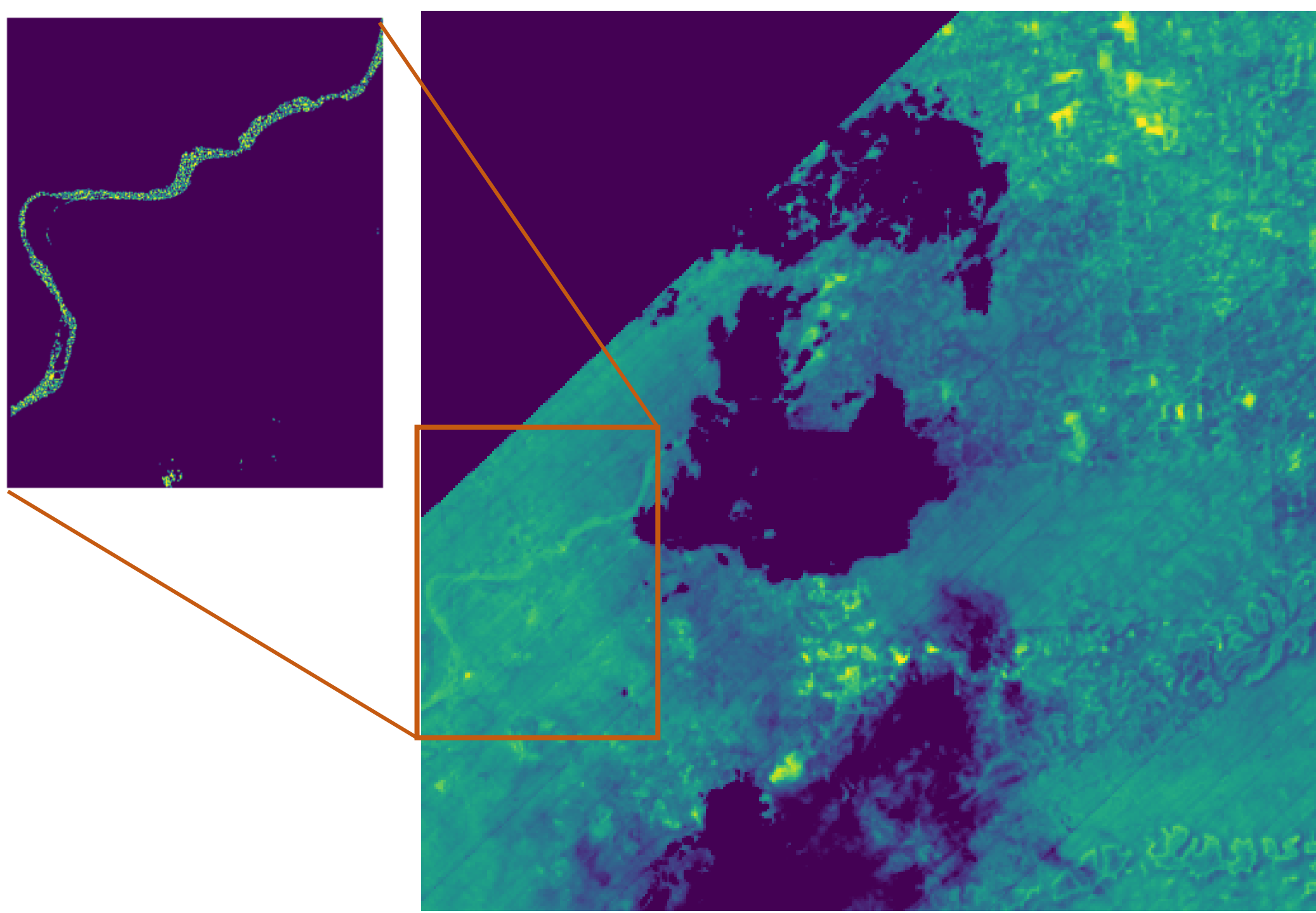
RELATIVE GEOREFERENCING

ECOSTRESS is a whiskbroom scanner that takes 44 scan lines with 128 x 5400 pixels per scene. The scanning mechanism contains a double-sided mirror that is constantly rotating. Consequently, adjacent scan lines are taken using different sides of the mirror. In level 1B of the standard image processing, each acquired pixel is assigned a geo coordinate on ground. When using this information to draw the acquired imagery onto a cartographic map, it becomes apparent that there are defects in the overlap region of adjacent scan lines. The standard image processing, which mixes the imagery from both adjacent scan lines by using nearest neighbour interpolation, results in a checkerboard pattern. Two main components contribute to this effect: 1. Residuals in radiometric calibration (not part of this poster). 2. Inconsistent annotation of geo coordinates for alternating scan lines. This poster explores how to arrive at this conclusion.
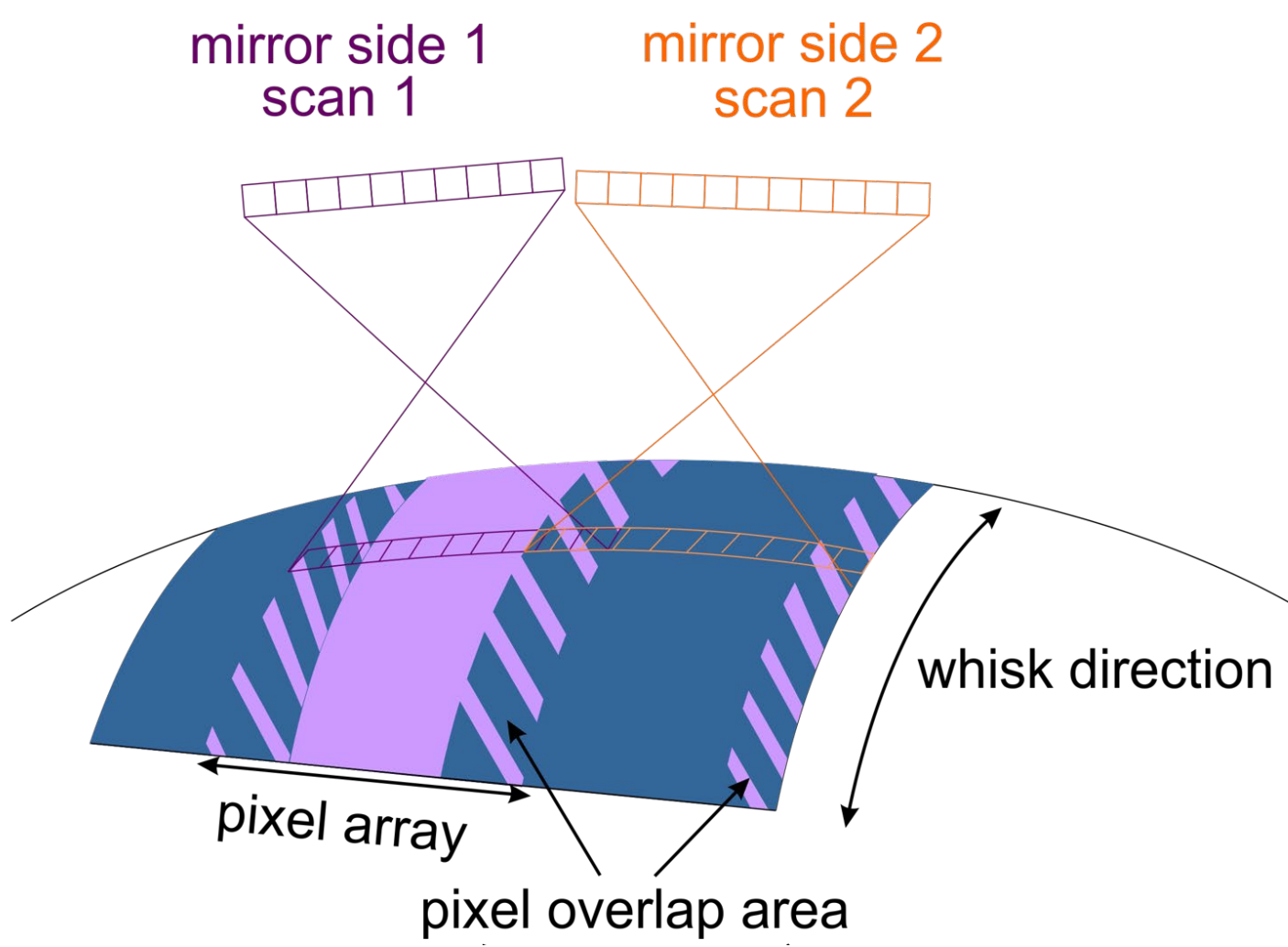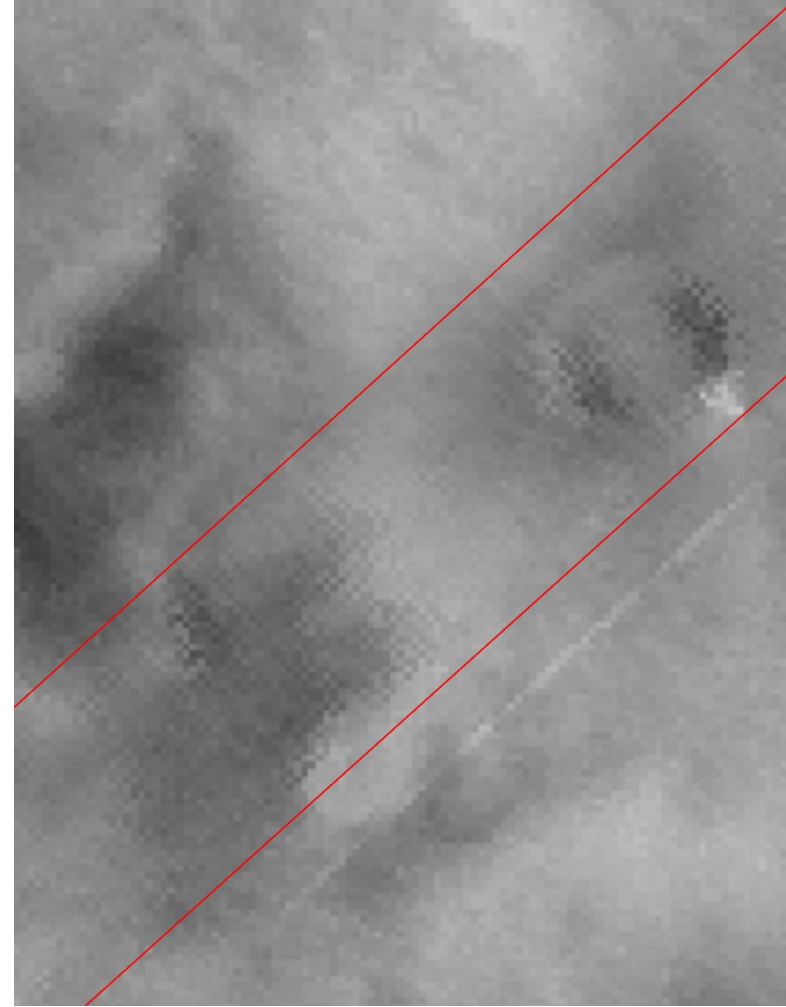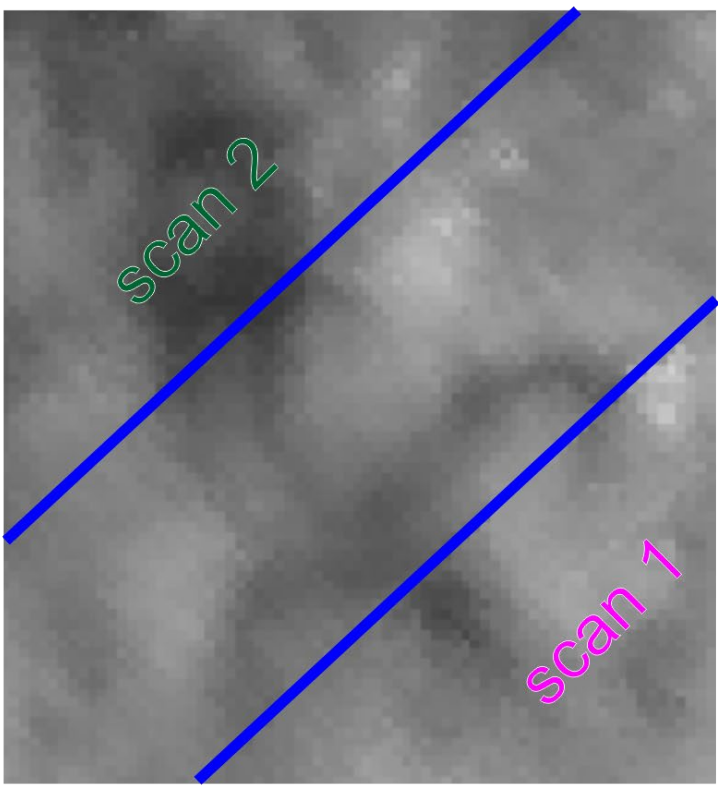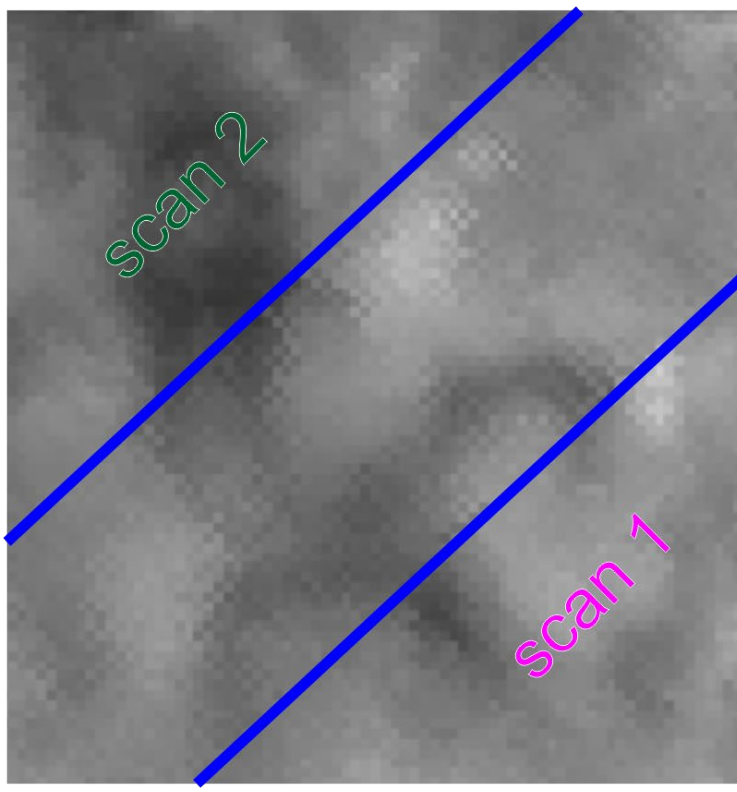

ECOSTRESS scan principle

ECOSTRESS image from 04.02.2021
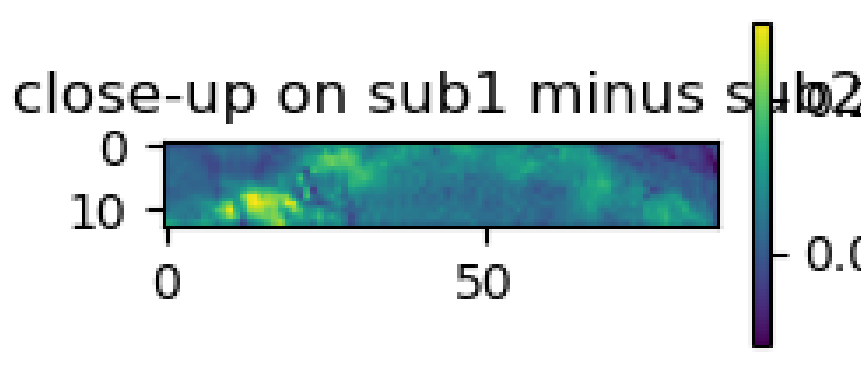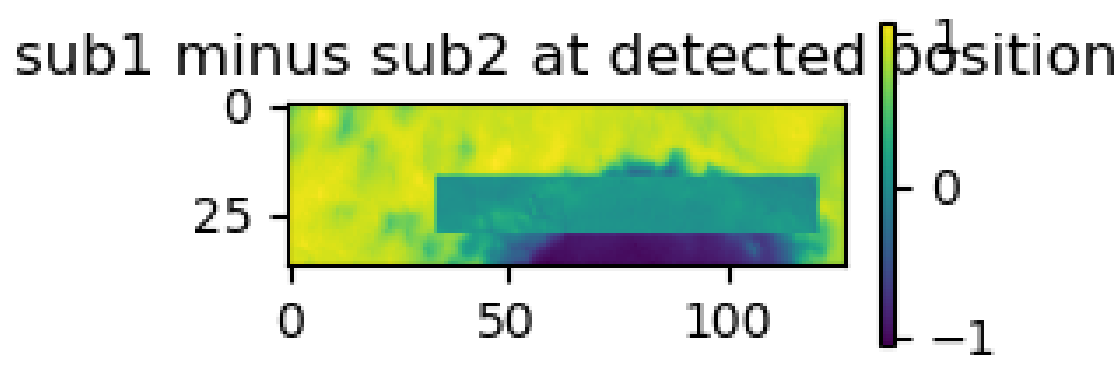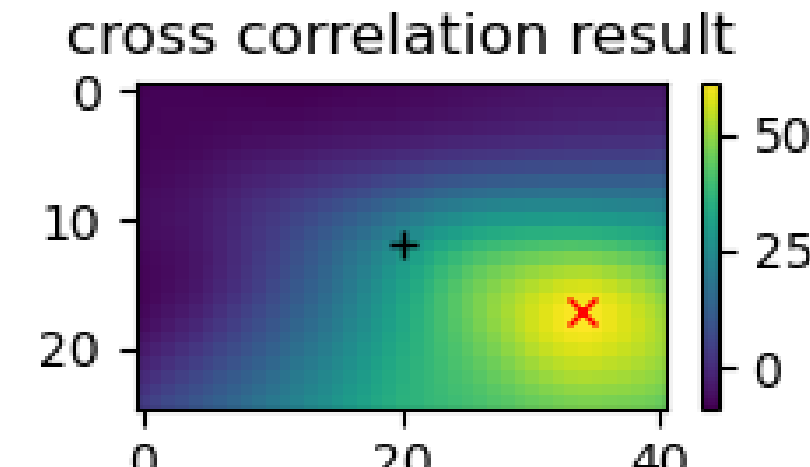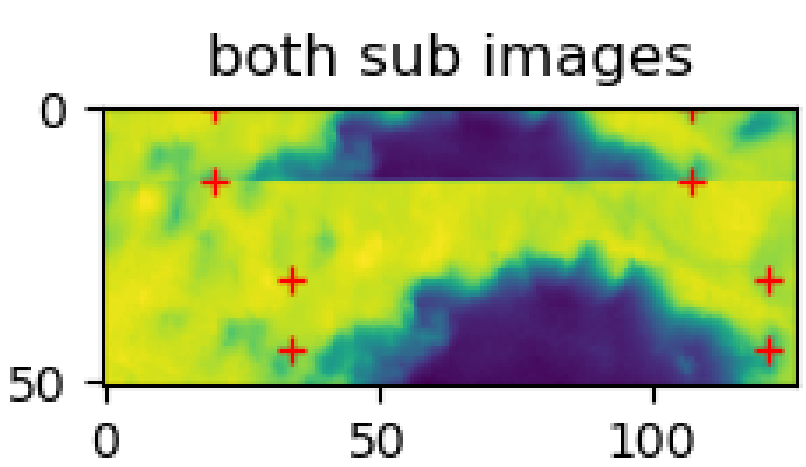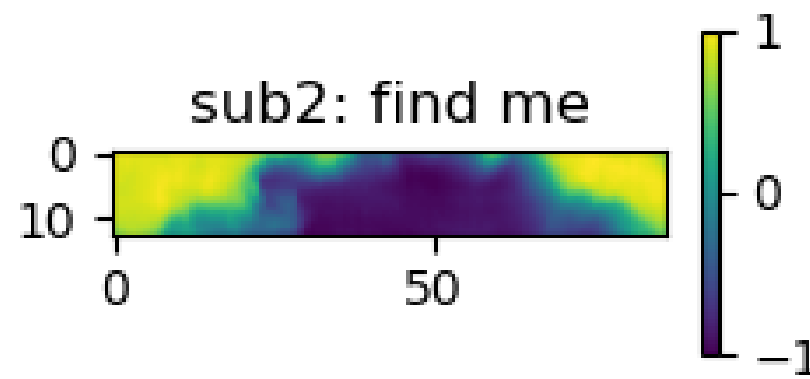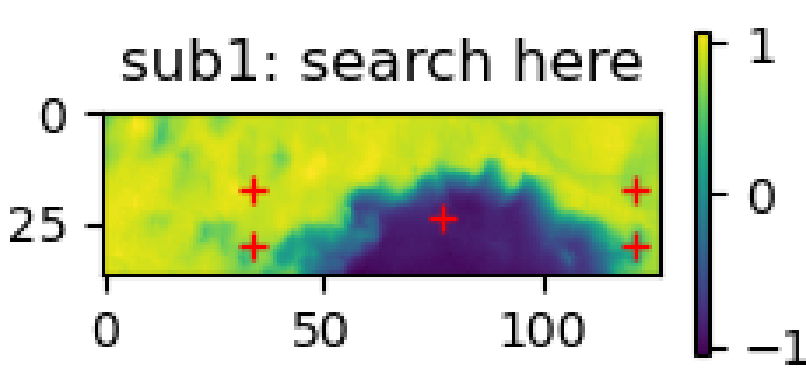APPEEARS processing — Single scan processing

ANALYSIS APPROACH

1. Find corresponding image fragments and map them for all 43 overlap regions, at 40 positions along each scan line pair
   a. Relative image shift in x and y, and Euclidian distance
2. Extract geo coordinates for corresponding image parts
   a. Difference in longitude and latitude, and Euclidian distance
3. Statistic analysis of image shifts and geo coordinate differences
   a. Note: ECOSTRESS scenes do not start always with the same mirror side. To compare them, the shift maps have been pre-processed such that all odd lines correspond to one mirror side, and the even to the other.
   Pre-processing: homogenise map, such that overlap region indices (y-axis) always correspond to them same mirror side
   b. Pre-processing: detect orbit direction and run analysis separately for ascending and descending orbits
   c. Average maps of 43x40 image fragment shifts and their corresponding geo coordinates for all available scenes
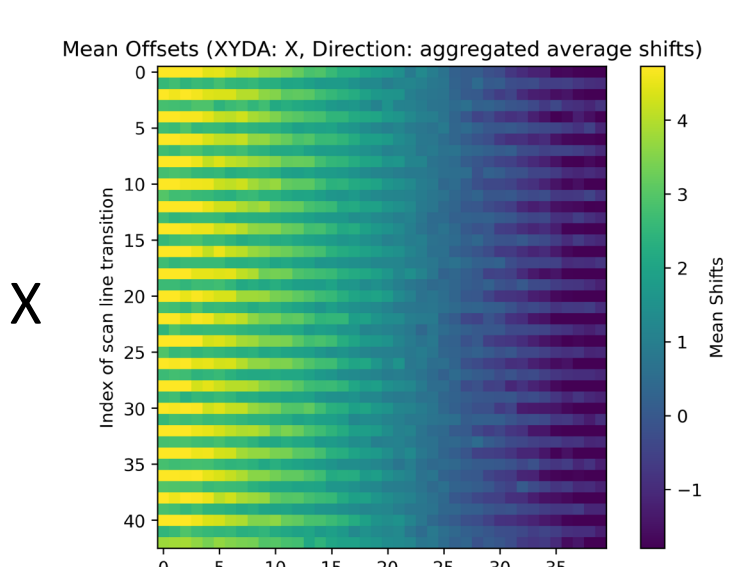
Finding Corresponding Image Fragments

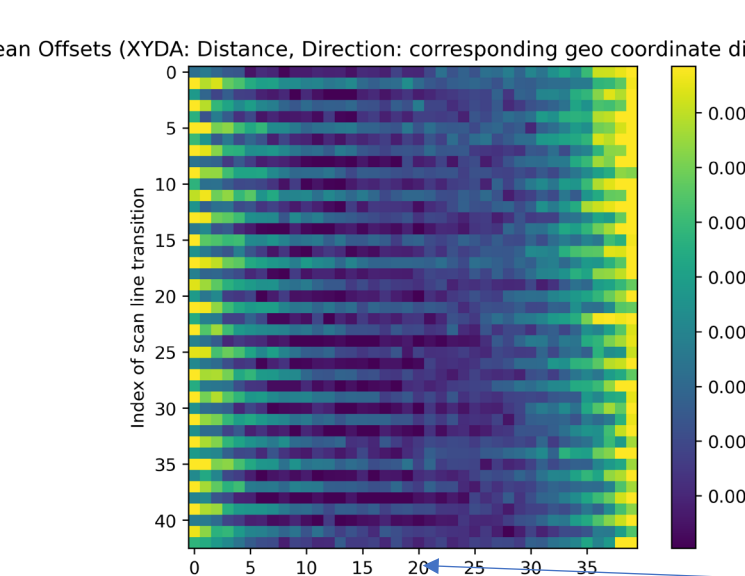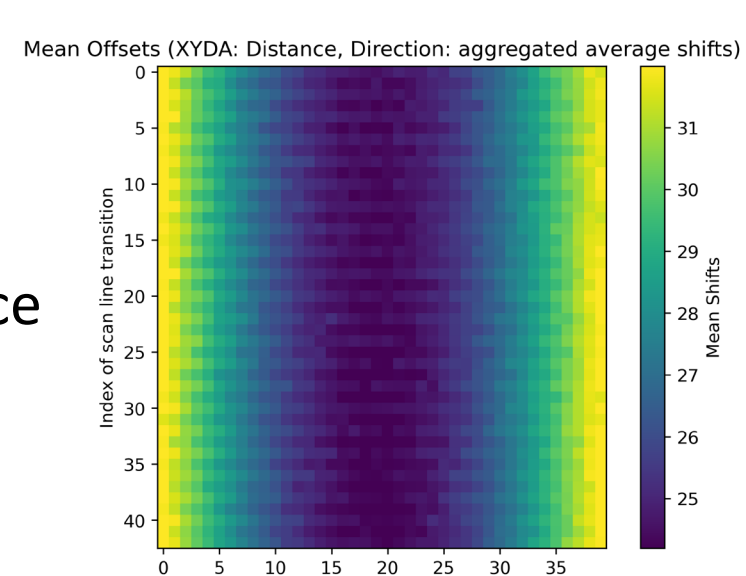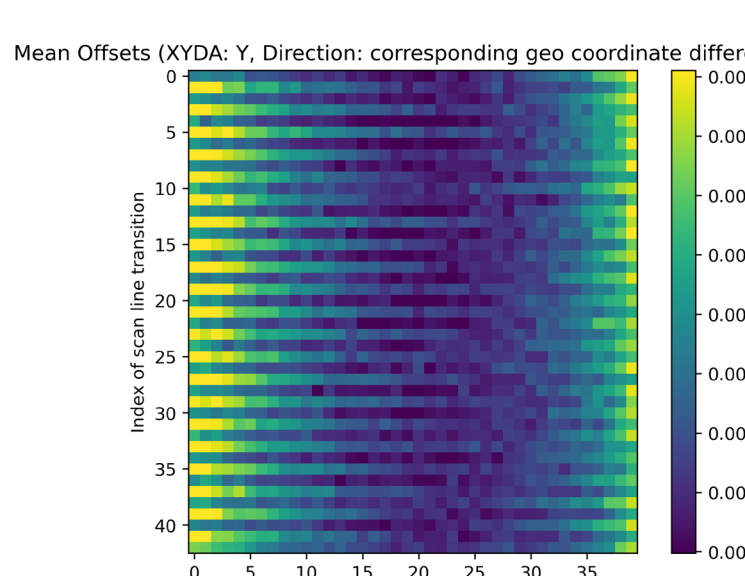pos: xy: 0512 | 4224 ; off +14 | +31 (dir:1) ; std: 0.74

sub1: search here — sub2: find me — both sub images — cross correlation result — sub1 minus sub2 at detected position — close-up on sub1 minus sub2

RESULTS
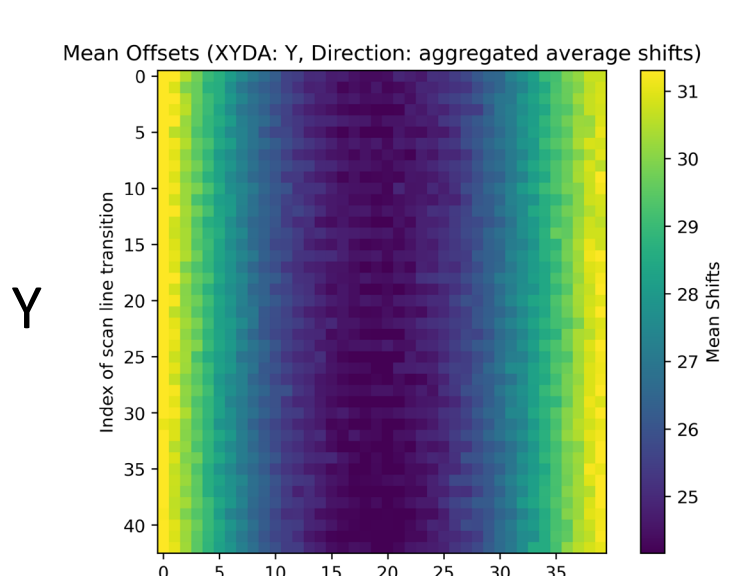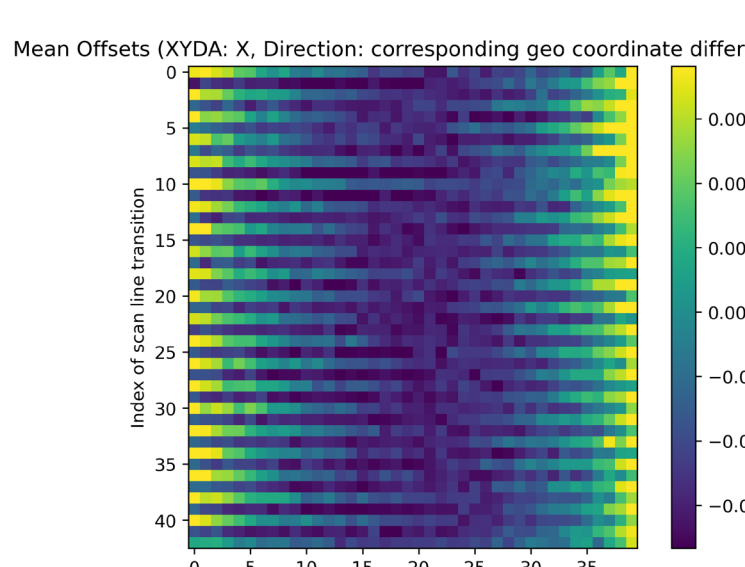
Averages over 600+ Scenes of Botswana

Ascending Orbit; 350+ Scenes — Descending Orbit; 200+ Scenes
Raw Image — Annotated Geo Coords — Raw Image — Annotated Geo Coords

One pixel is assumed to correspond to 0.000825°
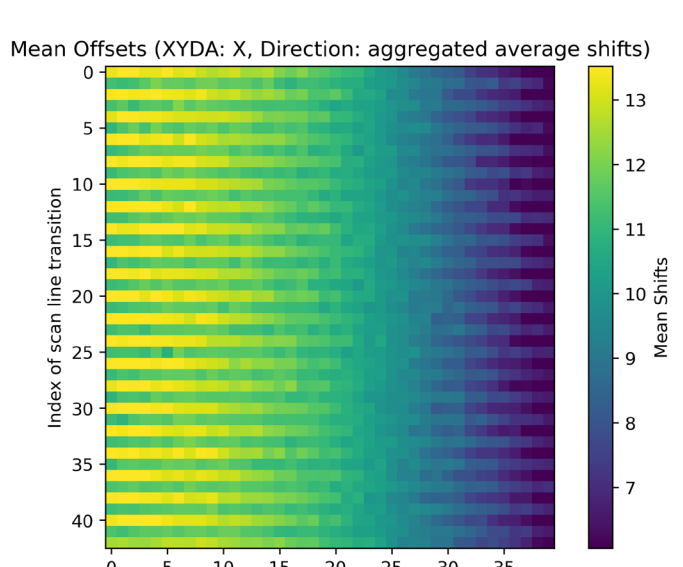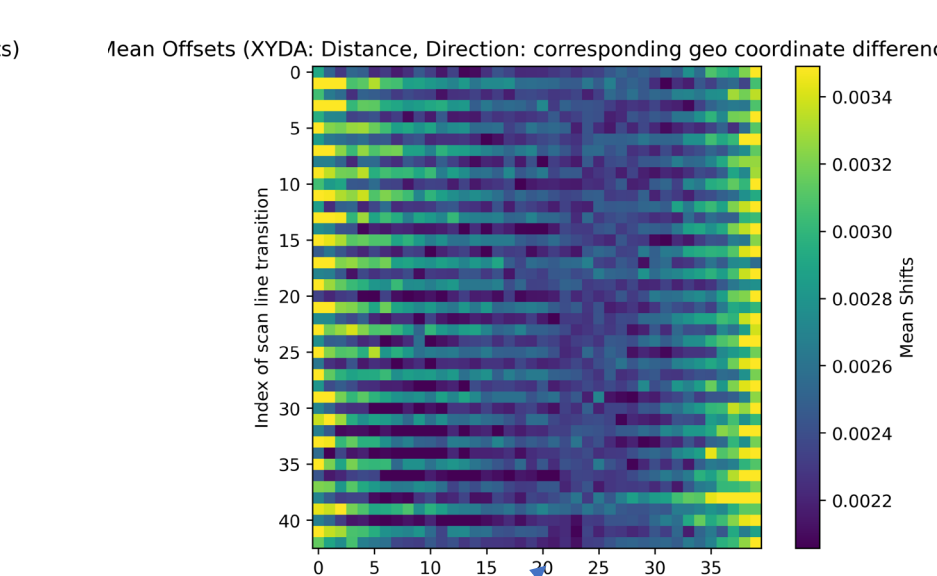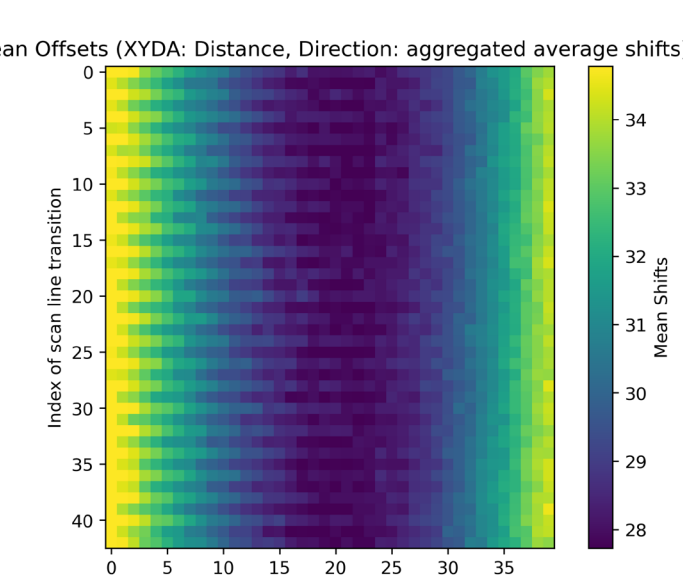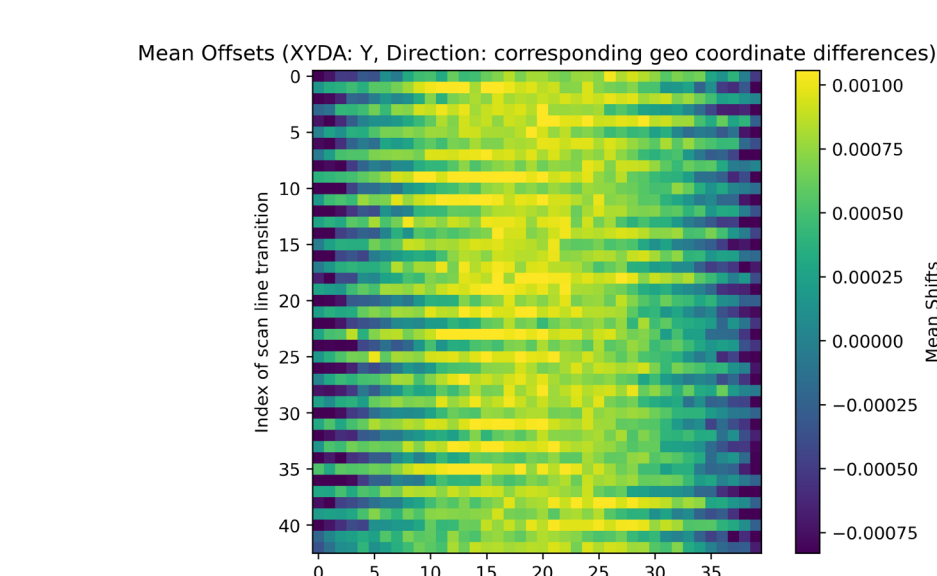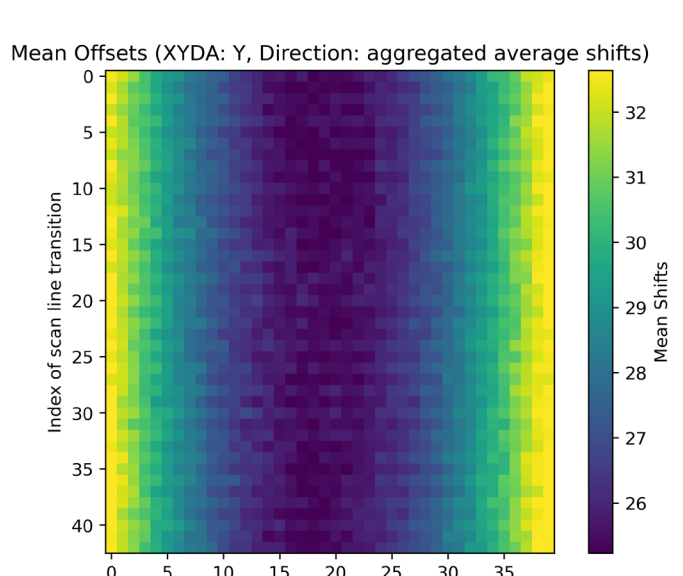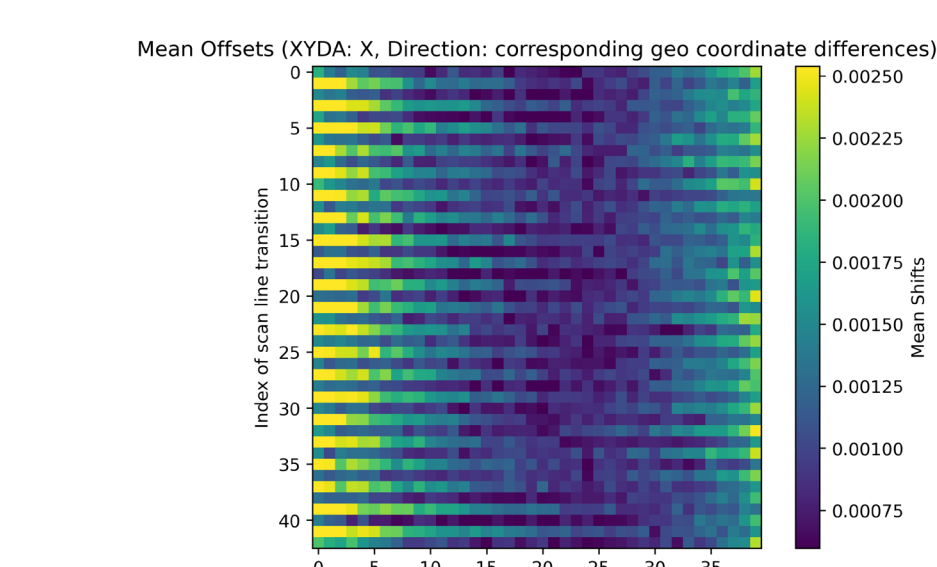
OBSERVATIONS

There is no significant change of the behaviour between the scans lines of a scene.
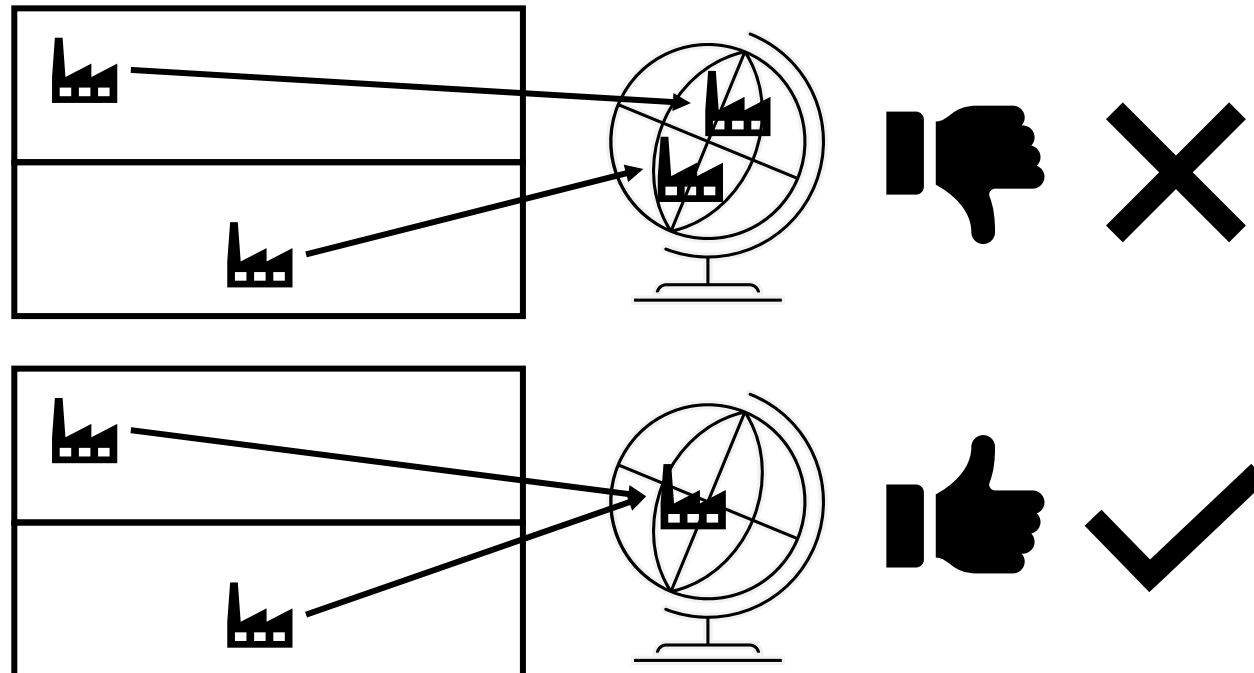The only change is along the whisk direction (x-axis)

CONCLUSIONS

The current findings concur that in the standard processing of ECOSTRESS imagery there is an offset between adjacent scan lines of 2.5 to 4.5 pixels (0.0022° to 0.0036°).
The offsets between adjacent scan lines change towards the edges of the scan in a non-linear fashion.

NEXT STEPS

Correction of the annotated geo coordinates.

These maps should be homogeneously zero, but they are not. That is the geometric origin of the checkerboard pattern.