Verifying the Accuracy of Geostationary Weather Satellite Image Navigation and Registration

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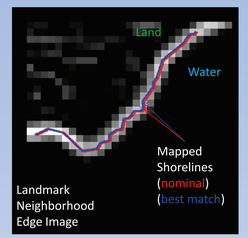
James L. Carr, Joseph Fox-Rabinovitz, David Herndon, and Sarah Reehl
Carr Astronautics • 6404 Ivy Lane, Suite 333 • Greenbelt, MD 20770

Product Monitoring (PM) in the Harris GOES-R Ground Segment measures Image Navigation and Registration (INR) Error in Advanced Baseline Imager (ABI) Products as Broadcast to Users.



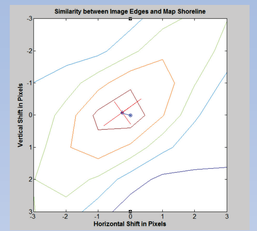
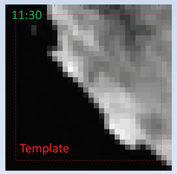


Image Navigation error is measured by comparing a Landmark Neighborhood with a Digital Map (Image-to-Map Matching). Shorelines are mapped into the geostationary fixed grid and shifted with respect to the neighborhood. The maximum similarity between the neighborhood edges and the shorelines defines the measured location of the landmark. The red points on the left are plotted for the nominal landmark location and the blue points are plotted at the location of the best match. A contour plot of similarity versus shift away from nominal is shown at the right. An iterative search algorithm walks the match from the initial first guess (blue circle at (0,0)) to the actual maximum (blue diamond) in sub-pixel steps. The cross shows the principal axes of curvature for the similarity surface at its maximum. It is desirable to have both axes approximately the same length so that the measured landmark location is constrained in all directions. Cloud masking is performed before matching and the cloudiness of the neighborhood is important criterion in an overall quality assessment of the measurement. Measurements are completely automatic in eight visible, near-infrared and thermal-infrared window channels. Valid measurements are retained for INR performance metric computations. The Image-to-Map Matching algorithms are an evolution of those in successful, continuous use in the legacy GOES ground system [1].



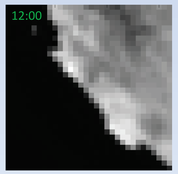
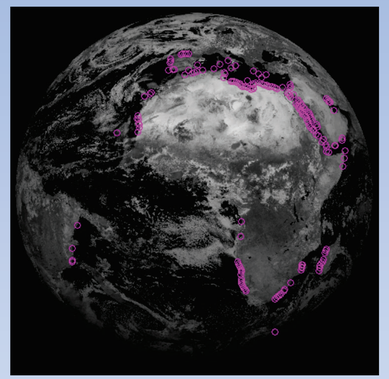


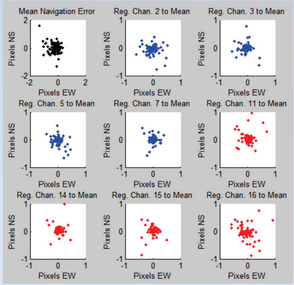
Image Registration error is measured by taking a template from a Landmark Neighborhood at one time, then searching for it and finding it in the same neighborhood at another time (Image-to-Image Matching). A correlation algorithm measures the shift of the template at integer resolution, with interpolation to achieve sub-pixel resolution. As long as the time difference is small and clouds are masked, the Image-to-Image measurements tell us how much fixed ground features have appeared to move, which is the registration between images.

[1] Madani, H., J. Carr, and C. Schoeser, "Image Registration using AutoLandmark", with, Proceedings of the 2004 IEEE International Geoscience and Remote Sensing Symposium, September 20-24, 2004.

Meteosat Second Generation (MSG) Proxy Data is Remapped into the GOES-R Fixed Grid to Drive PM Image-to-Map and Image-to-Image Matching Algorithm Verification.

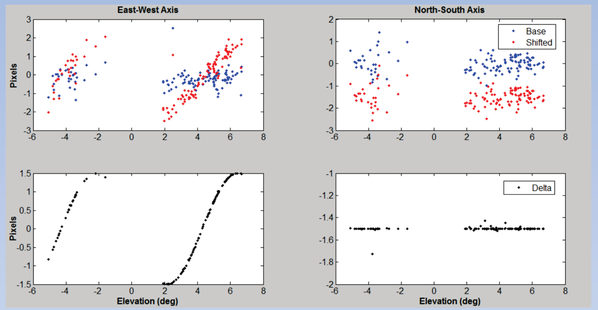


There are 102 landmark sites where an Image-to-Map measurement has been successfully made in all four reflective channels simultaneously, and 83 sites with measurements in all eight channels simultaneously, among those sites with at least one measurement (magenta circles) in the noontime image at the left. These sites have the most reliable information about INR performance (in this case for the MSG system). Many other sites in our demonstration landmark catalog are partially or totally cloud covered, as is often the case for landmarks in the tropics, and do not produce any valid matches. Landmarks will be produced for all scene types in eight channels. Peak rates of production are expected in daylight when the system is operating in Mode 4 (a Full Disk once every 5 minutes). Our PM system stores all valid Image-to-Map and Image-to-Image measurements and aggregates them over time to verify the INR performance metrics for image navigation, registration between successive scenes, and registration between channels. Satellite operators are made aware of out of limit conditions should they occur.

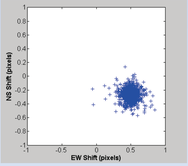


The nine bull's-eye charts at the left show measured INR errors in units of pixels at each of the 83 sites where a complete set of eight valid reflective and thermal channel measurements have been made. The average across all bands is plotted in the upper left subplot. The other eight subplots show the registration of a particular channel to the mean over all channels for each specific site. We note that the distribution of registration errors with respect to the mean is tighter in comparison to the distribution of mean navigation errors. This is as expected because all spectral channels are sampled within a small fraction of a second at each site. All bull's-eye plots are very nearly centered around a mean of (0,0), which confirms the fact that MSG INR quality is very high and is therefore an appropriate proxy.

PM Testing Demonstrates Sensitivity to Sub-pixel INR Errors, Enabling Accurate Verification of Challenging INR Performance Requirements.



Sensitivity to sub-pixel shifts in navigation error is demonstrated above. A sinusoidal error in the East-West axis and a constant error in the North-South axis was added to the digital map shorelines prior to matching. The top subplots show the base case (no errors added) and the shifted case (errors added) and the lower subplots show the differences. The error signature introduced is clearly recovered to sub-pixel precision.



The Image-to-Image Matching algorithm is similarly sensitive to sub-pixel shifts. At the left, an intentional shift of 0.5 pixels in the East-West direction and -0.25 pixels in the North-South axis was applied to simulated overlapping image fragments derived from MSG, and we measured their alignments using the Image-to-Image Matching algorithm. The bull's-eye plot shows the valid measurements at all sites. The correct mean is seen in the data and the standard deviation about this mean is 0.06 pixels in each direction. This demonstrates the capability of accurately measuring image-to-image relative registration at the tenth of a pixel level.

In conclusion, our test results demonstrate that the Product Monitoring (PM) capability being developed by Carr Astronautics for the Harris GOES-R ground segment is a precise tool for measuring sub-pixel INR errors. The GOES-R PM technology is derived from the legacy system currently operated by NOAA for the GOES-NOP mission and also developed by Carr Astronautics, with several enhancements introduced to improve accuracy and performance. The PM is capable of generating large INR verification datasets without human intervention, and will be an important part of the GOES-R Mission Management infrastructure.