11 September 2023

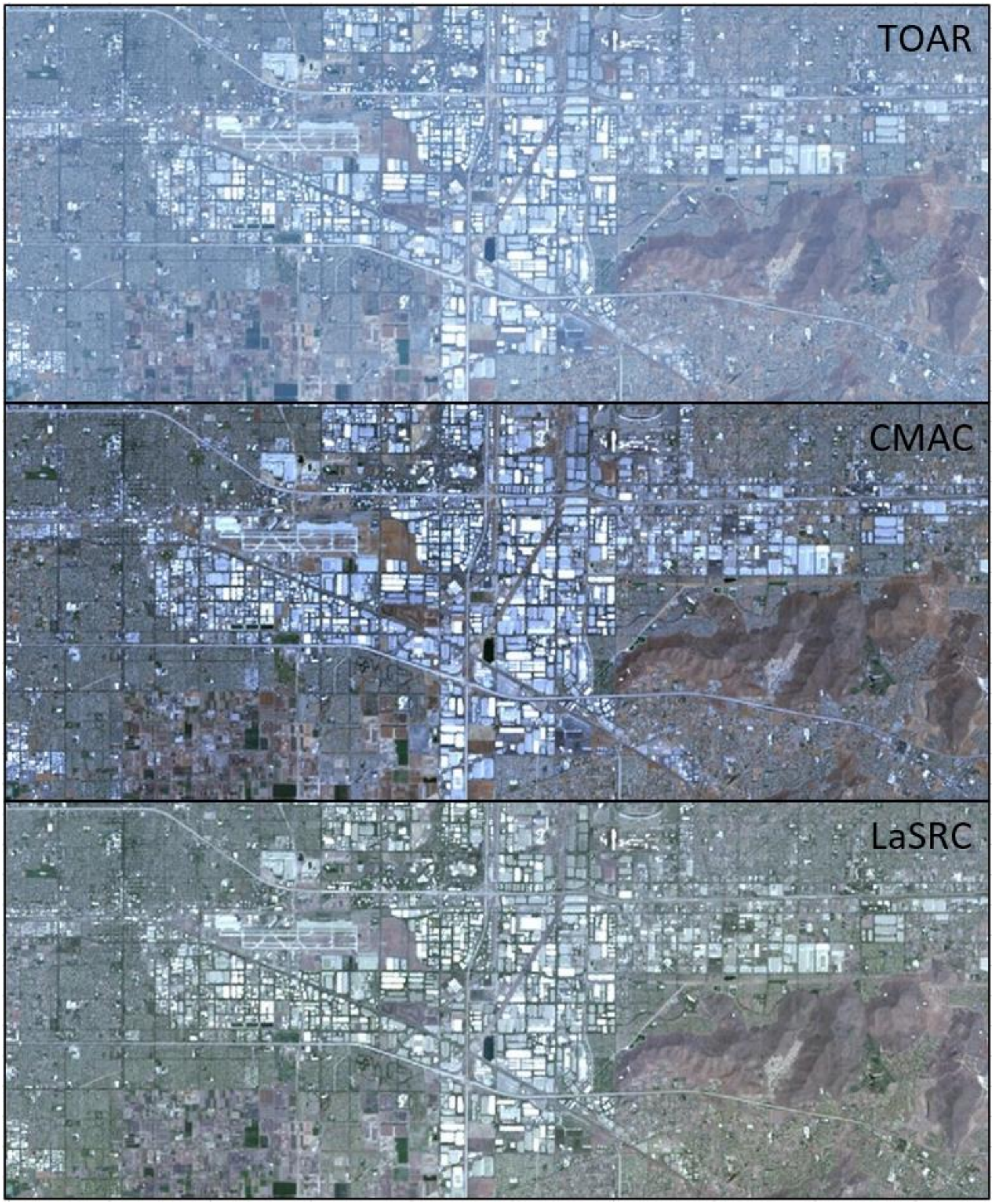
Image Gallery: Atmospheric Correction Challenges from Greater Atmospheric Effects

This paper was written to compare the results of the Closed-form Method for Atmospheric Correction (CMAC) to the state-of-the-art Landsat software, LaSRC for Landsat 8 and 9. LaSRC is the basis for current methods to be applied to smallsats. A recap of the findings:

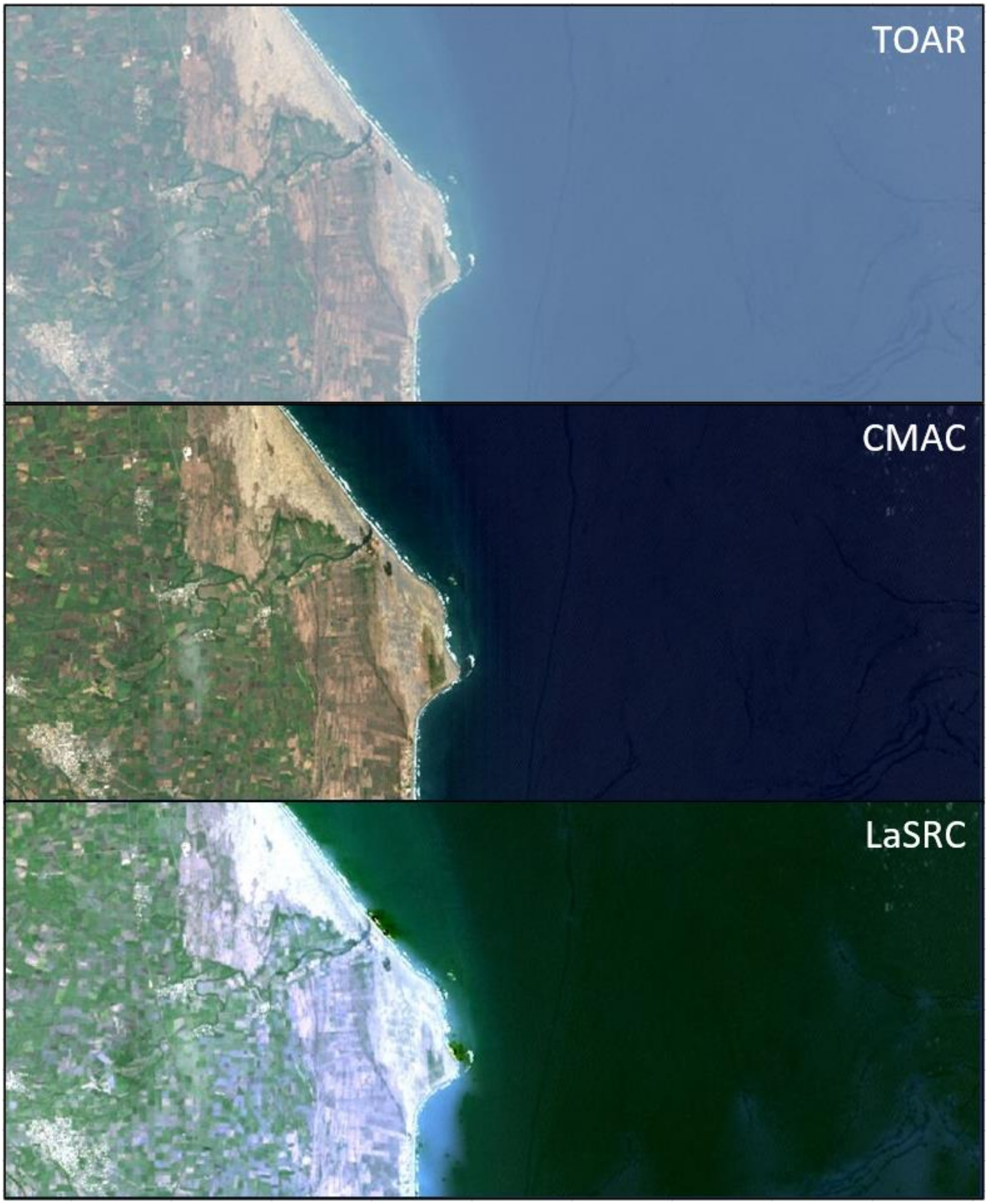
- LaSRC, requires ancillary data and this delays processing from one to several days waiting for data from another satellite, MODIS, of much lower resolution. CMAC processed each image for this paper in 60 seconds (desktop PC) and at higher granularity using scene statistics, alone. When adapted to reside in-satellite, CMAC is expected to correct images during collection and transmit them with latency of seconds.
- For images obtained through clear to low-moderate levels of atmospheric effect (883 to 1088 Atm-I) for five areas in Southern California, LaSRC and CMAC surface reflectance outputs agreed closely and shared virtually the same error profiles. Atm-I is the atmospheric index developed through CMAC R&D.
- LaSRC and CMAC performance was also compared for moderate to extreme levels of Atm-I in the form of calculated indices to test potential utility for machine analyses. CMAC results were stable (1%-3% error) and LaSRC was much less so (6%-20% error).
- For industry access to verify these results, the Supplemental Materials section contains a list of the images, a link to cloud-based image browsing, selection and CMAC correction, the python code, the shapefiles, and live spreadsheets to reconstruct these analyses.

In this gallery, six AC-processed images were selected that illustrate atmospheric correction issues with Landsat 8 and 9 data. Three treatments are shown as QGIS display screenshots with the default zero fill included that scales the color balance: top-of-atmosphere reflectance, and atmospheric corrections by CMAC and LaSRC. The images are presentated in order of their Atm-I, mapped by the CMAC software for scaling surface reflectance retrieval. The Landsat scene number is provided as are the satellite platform (L8 or L9), and the approximate Atm-I range measured across the screenshot. The image stretch includes the no data fill that sets zero reflectance – this is the most accurate method for image to image comparisons of haze. The image stretch that brightened or darkened the view. The same stretch was applied to the three views for each image. All but one image have the GIS default stretch applied, 2% to 98%, that removes the tails of reflectance distributions that would skew the visual presentation.

An important function of atmospheric correction is restoration of scene spectral statistics to surface reflectance. Removing atmospheric effects supports more competant machine analyses of all kinds, including AI. Visual interpretability is also important. For any level of atmospheric effect, as a first approximation, color balance and clarity of the corrected image provides confirmation that the results are close to surface reflectance. Of equal importance is that the corrections induce no artifacts. Retention of haze, obviously incorrect color balance, and induced artifacts confirm where surface reflectance retrieval is inaccurate.

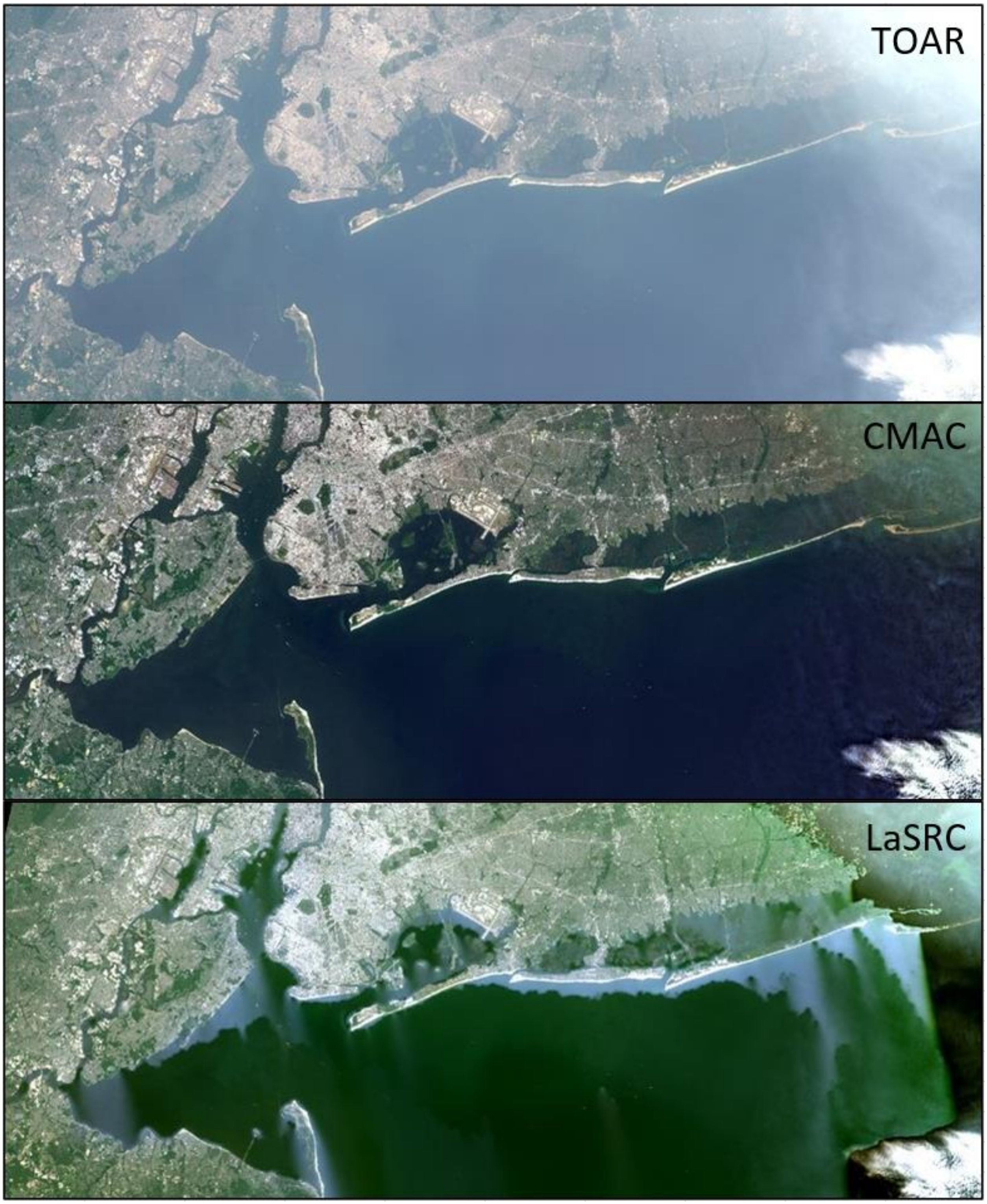


Ontario, CA, USA P024R047_20210715 (L8), Atm-I = 1051 to 1088 for QIAs, Image stretch 2% tp 98%
CMAC: This region was used to test CMAC and LaSRC responses for five quasi-invariant areas of stable suface reflectance that are clustered around the airport just left of center. The color balance reconstructs the hues visible in the uncorrected TOAR view.
LaSRC: This view is overly green, consistent with other LaSRC corrected scenes (and the only LaSRC comment here).



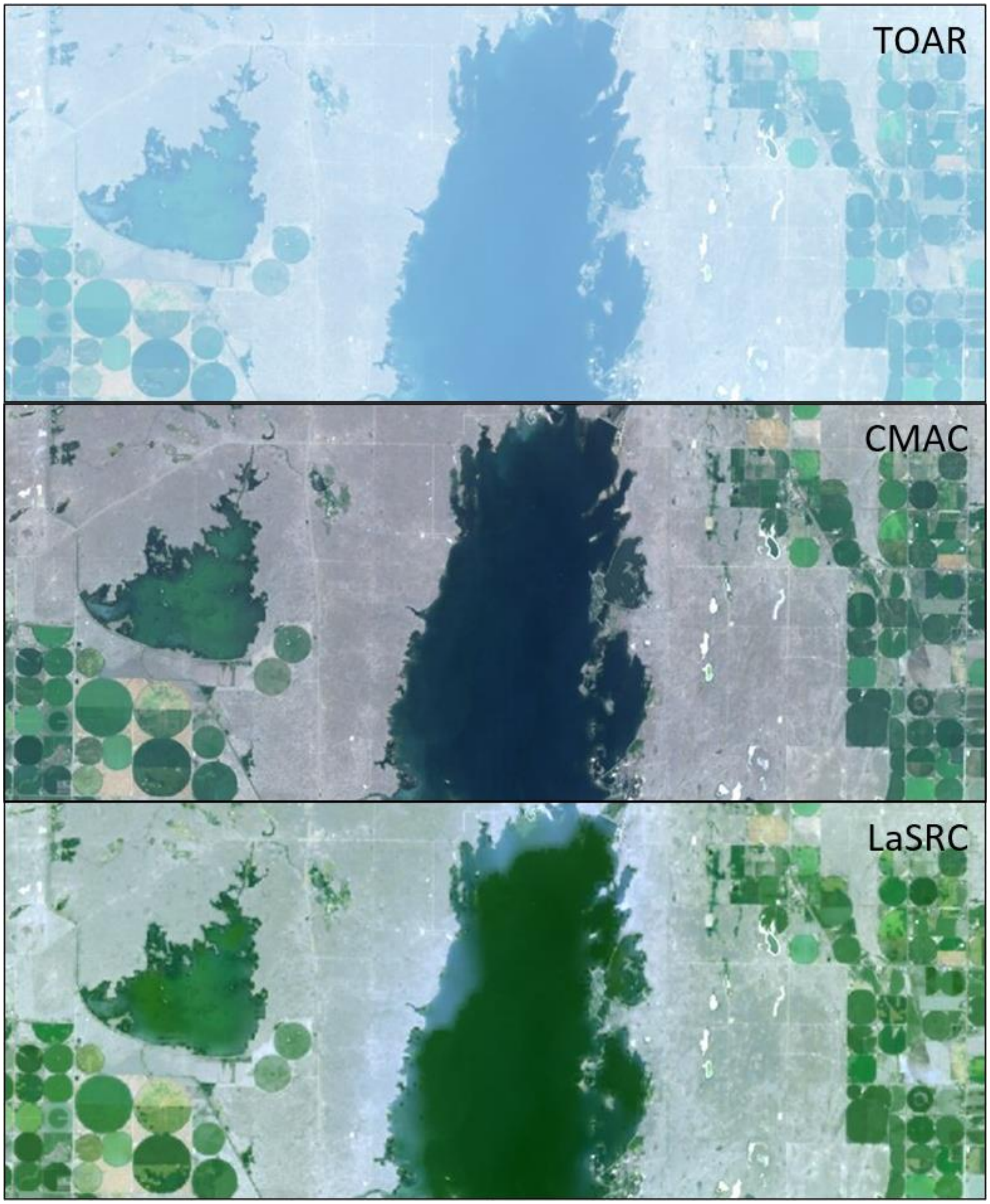
North of Veracruz, Mexico P024R047_20210512 (L8), Atm- = ~1075 to ~1300, Image stretch 2% -96%

CMAC: Water is a low spectral diversity environment. While the CMAC correction is competant here, additional work is necessary to assure that the dark-blue water-leaving reflectance is correct. This is, in part, a scaling issue for removal of specular reflectance from the water surface. A thin, undercorrected cloud over the land is due to the coarse pixelation of the L8 scene that forced the scale of Atm-I output to measure gross atmospheric features (between 300 and 600m).



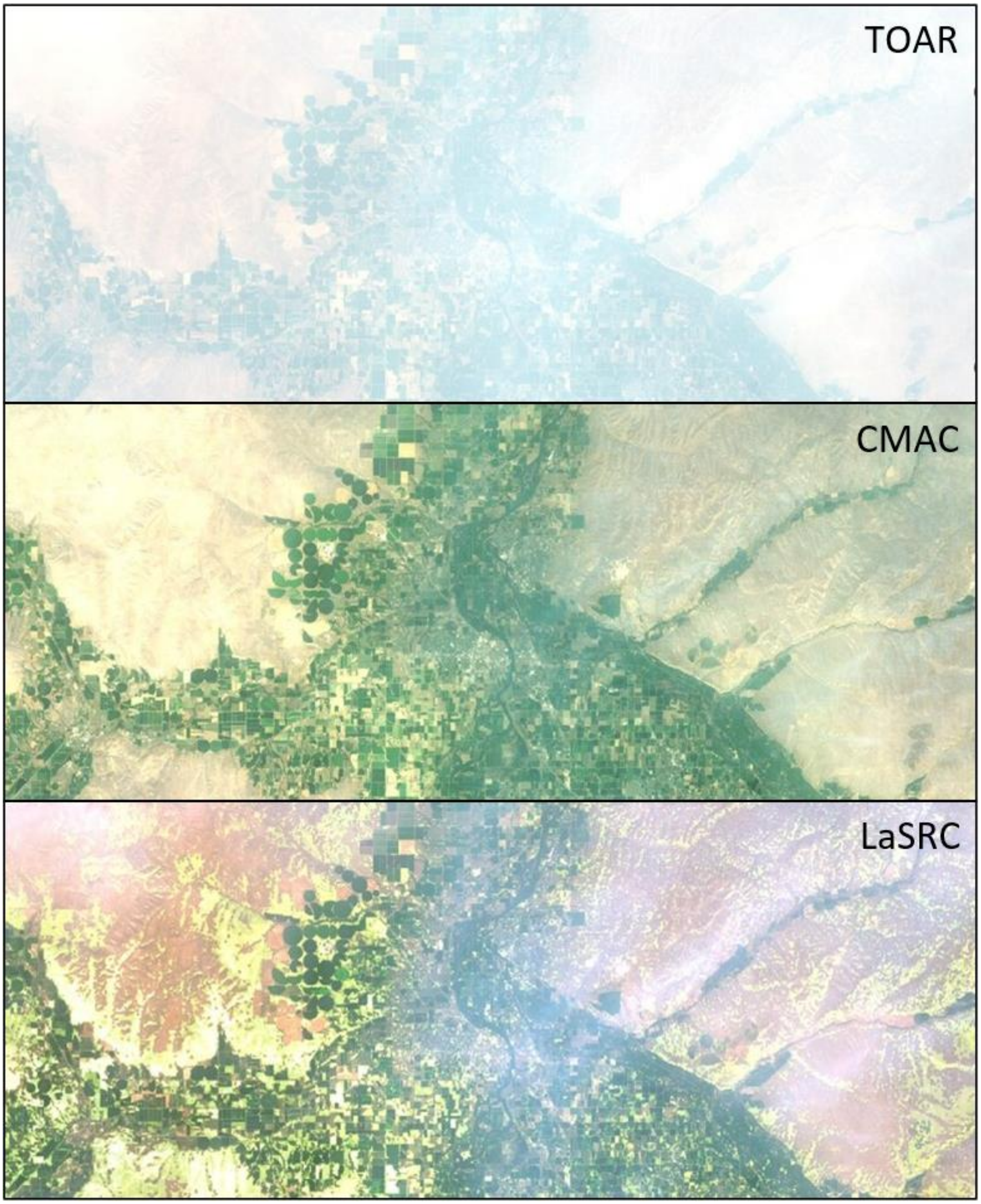
New York, New York, USA P13R032_20230606 (L8), Atm: ~1080 - >2500 (bright clouds), Image Stretch 2% - 98%.

CMAC: Again, the water may be overly dark. If so, this will be corrected after future R&D. Extreme levels of haze in the upper right corner were not corrected. Where correct, the hue of the CMAC version matches that of the TOAR.



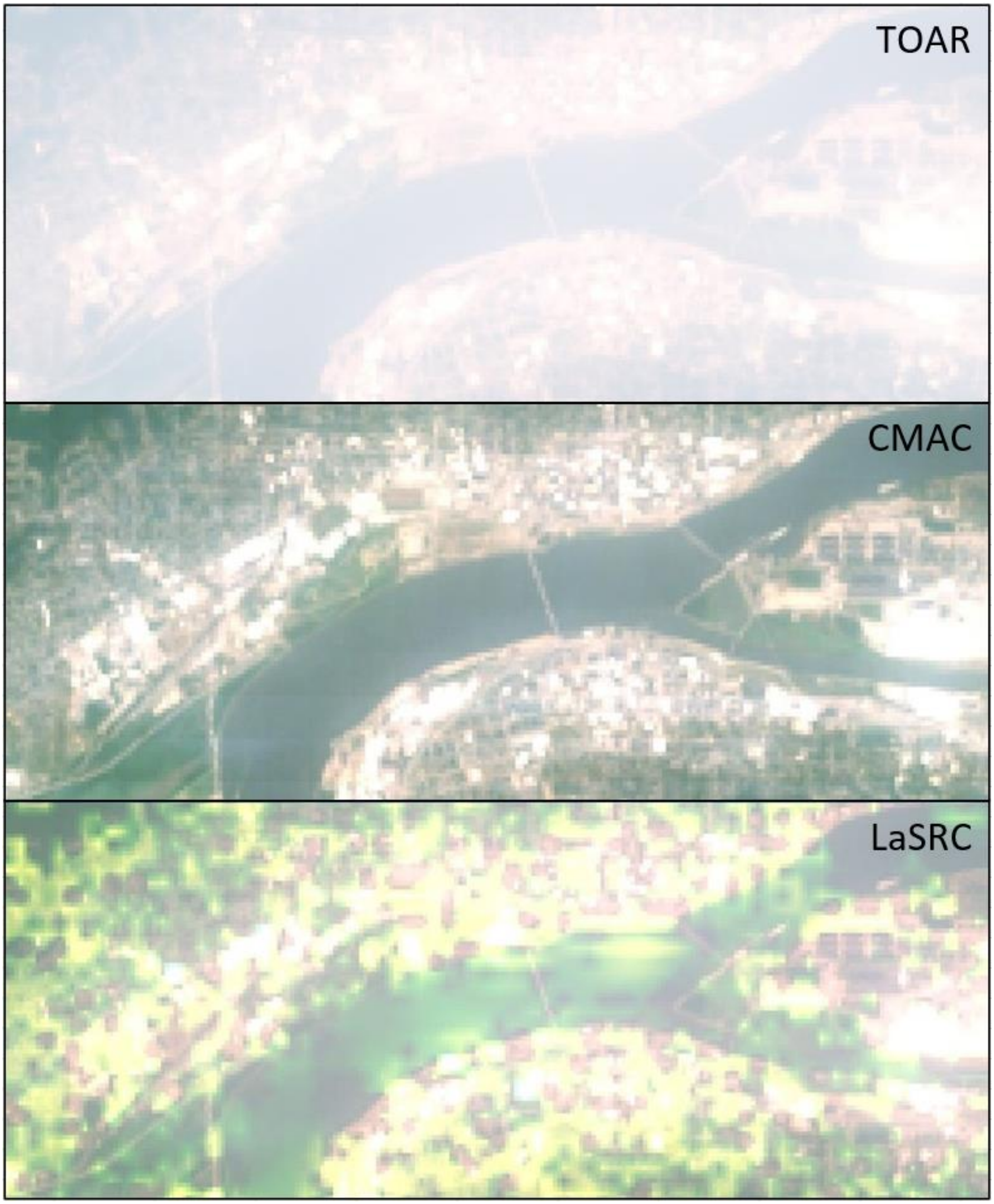
Lake Newell, Alberta, Canada P040R025_20210731 (L9), Atm-I ~ 1345 - ~1590, Image Stretch 2% - 98%

CMAC: The color is appropriate for the shortgrass prairie (warm gray-brown). The lighter colored features in Lake Newell at the north and far southwest are entrained sediments from drainages that can be confirmed through observation of Google Earth images.



Payette, Idaho, USA, P042R029_2021081 (L8) Atm-I: ~2095 - ~2455, Image stretch 2% - 98%

CMAC: This image exceeds current CMAC capability delivered by automated application alone. At these extreme levels of Atm-I, CMAC may not be appropriate to support automated analytics. A secondary applicaton of CMAC through a GIS-based plugin promises finer adjustment to retrieve image clarity for analyst-curated image preparation.



Davenport, Iowa, USA, P024R031_20230627 (L9), Atm-I: 2120 – 2330, Image Stretch 2% - 98%

CMAC: This result also exceeded CMAC automated capability but could be significantly cleared for viewing through a GIS plugin applied by an analyst. A secondary application of AI technology that is now used to recover blurred facial features is a promising addition for intelligence, surveillance and reconnaissance applications of images like these.