First Image Products from EcoSAR - Osa Peninsula, Costa Rica

Batuhan Osmanoglu, SeungKuk Lee, Rafael Rincon, Lola Fatoyinbo, Tobias Bollian, Jon Ranson
Biospheric Sciences Lab, Microwave Instrument and Technology Branch, NASA GSFC

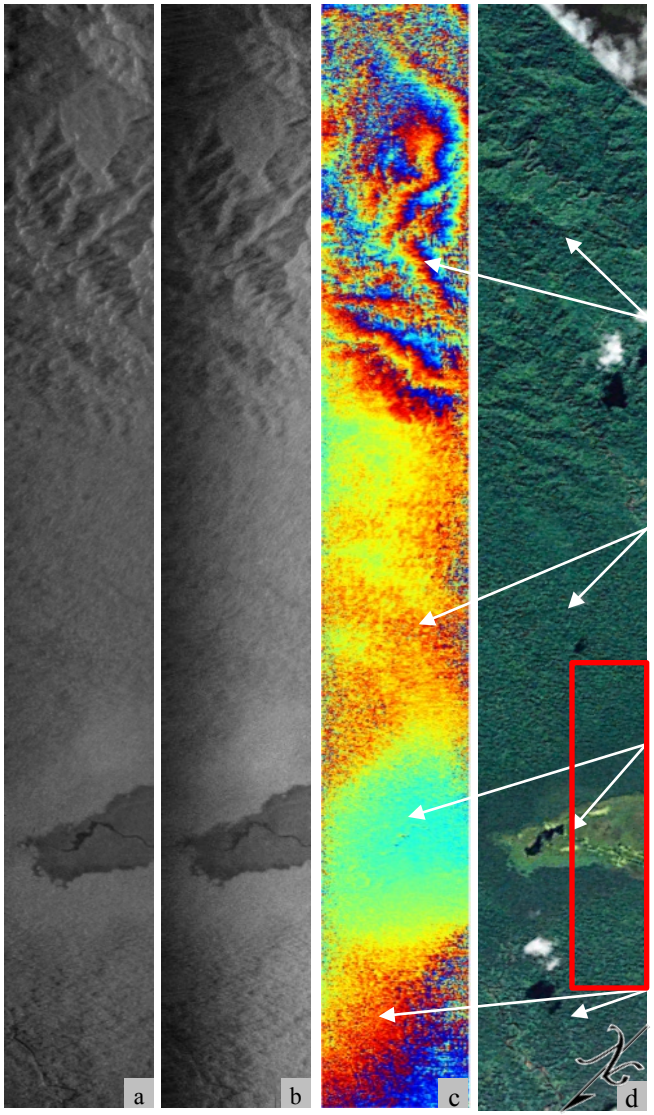


Figure 1

EcoSAR is an advanced airborne polarimetric and interferometric dual antennae P-band (435 MHz) SAR and provides two- and three-dimensional fine-scale measurements of terrestrial ecosystem structure including biomass of dense forest.

EcoSAR collected horizontal and vertical polarized data over a tropical forest area in Costa Rica in Spring 2014.

Preliminary analysis indicates good system performance as efforts focus on improving processing algorithms.

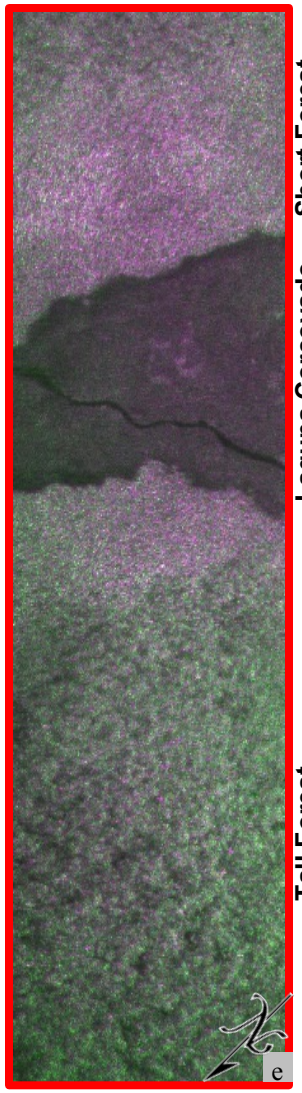


Figure 2

Name: Batuhan Osmanoglu, Biospheric Sciences, NASA GSFC
E-mail: batuhan.osmanoglu@nasa.gov
Phone: 301-614-6690

References:

1. Rincon, R.F., Fatoyinbo, T., Osmanoglu, B., Lee, S., Ranson, K.J., Sun, G., Perrine, M. and Du Toit, C., 2015, May. ECOSAR: P-band digital beamforming polarimetric and single pass interferometric SAR. In 2015 IEEE Radar Conference (RadarCon) (pp. 0699-0703). IEEE.

2. Cloude S. R., Pottier E., "A review of target decomposition theorems in radar polarimetry", IEEE Trans. Geosci. Remote Sens., vol. 34, no.2, pp.498-518, Mar., 1996

Data Sources: EcoSAR, Google Earth

Technical Description of Figures:

Figure 1 (a,b,c,d): EcoSAR [1] single pass InSAR image pair and topographic fringes are displayed from the *right antenna transmit and receive* (H_RH_R) master image and a *left antenna transmit right antenna receive* (H_LH_R) slave image intensity. Fringes from EcoSAR interferogram is shown on the third panel, where the colors indicate wrapped phase values due to topography. The cyan color indicates the extent of the swamp area (topographic low) while the mountains to the right create rapid color cycles due to sloping terrain. Areas of interest are shown with arrows: Tall Forest, Laguna Corcovado, Short Forest, Hills. a) Right antenna intensity b) Left antenna intensity c) Interferogram d) Google Earth.

Figure 2 (e): Pauli decomposition [2] of EcoSAR's polarimetric data shows the first polarimetric decomposition product generated from EcoSAR data using the Corcovado National Park dataset. Polarimetric (Pauli) decomposition are sensitive to forest structure. Detection of tall and short forests are possible.
Area for the polarimetric analysis is shown on Google Earth (d) with a red rectangle. In the figure green color denotes volume scattering, indicating *tall forest*, where red color indicates double bounce scattering, which mostly occurs with *shorter trees* in presence of water. The optical Google Earth and EcoSAR "see" *Laguna Corcovado* differently, even though the canopy-free open water appears dark in both figures. Optical imagery can not easily distinguish between the taller and shorter trees.

Scientific significance, societal relevance, and relationships to future missions:

Designed especially for forest ecosystem studies, EcoSAR employs state-of-the-art digital beamforming technology to generate wide-swath, high-resolution imagery. EcoSAR's dual antenna single-pass imaging capability eliminates temporal decorrelation from polarimetric and interferometric analysis, increasing the signal strength and simplifying models used to invert forest structure parameters. Antennae are physically separated by 25 meters providing single pass interferometry. In this mode the radar is most sensitive to topography. With 32 active transmit and receive channels, EcoSAR's digital beamforming is an order of magnitude more versatile than the digital beamforming employed on the upcoming NISAR mission. EcoSAR's long wavelength (P-band, 435 MHz, 69 cm) measurements can be used to simulate data products for ESA's future BIOMASS mission, allowing scientists to develop algorithms before the launch of the satellite. EcoSAR can also be deployed to collect much needed data where BIOMASS satellite won't be allowed to collect data (North America, Europe and Arctic), filling in the gaps to keep a watchful eye on the global carbon cycle. EcoSAR can play a vital role in monitoring, reporting and verification schemes of internationals programs such as UN-REDD (United Nations – Reducing Emissions from Deforestation and Degradation) benefiting global society. EcoSAR was developed and flown with support from NASA Earth Sciences Technology Office's Instrument Incubator Program.

A synthesis of the basal thermal state of the Greenland Ice Sheet

Joseph A. MacGregor *et al.*, Cryospheric Sciences, NASA GSFC

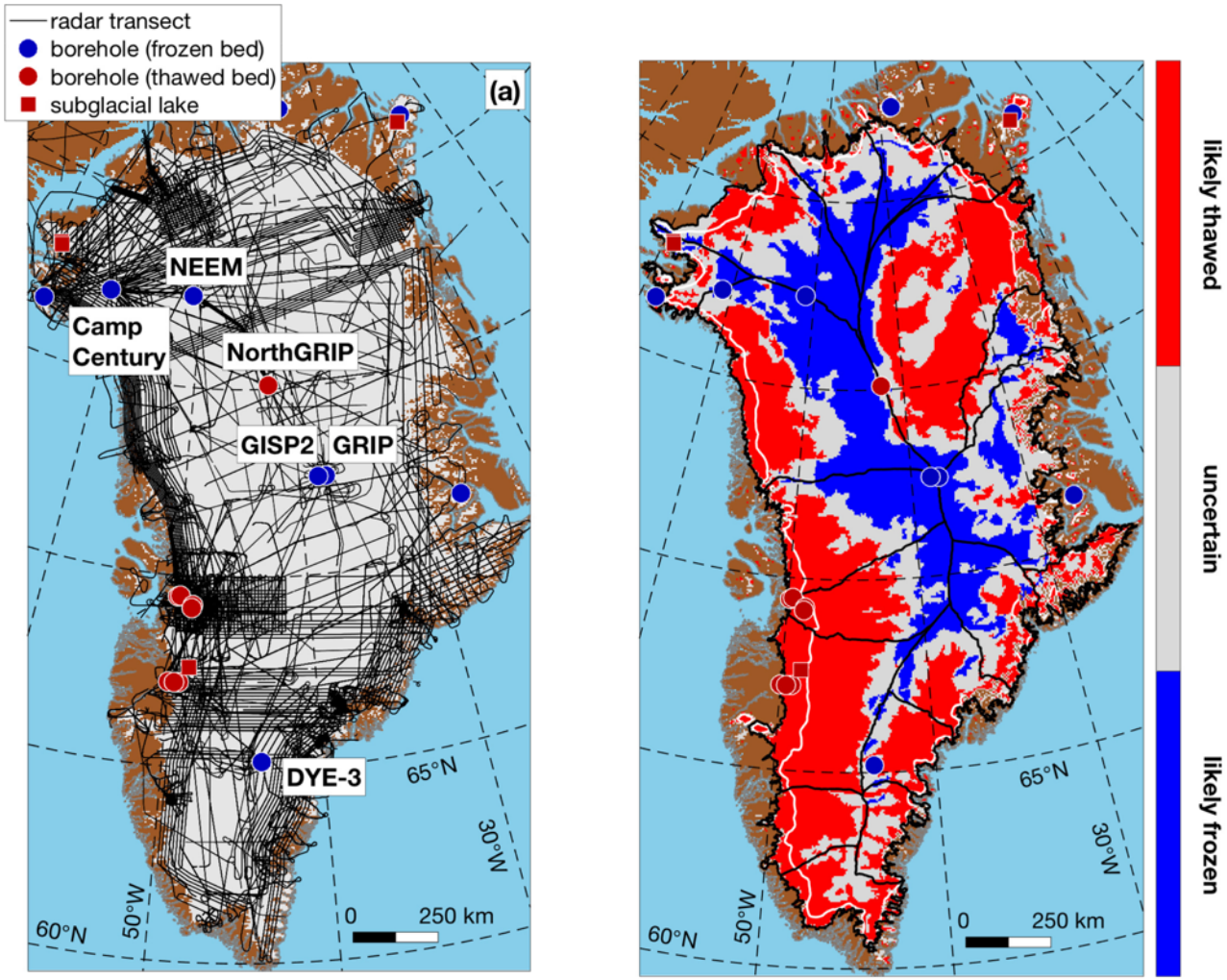


Figure 1

From a synthesis of models, airborne and satellite remote sensing, we found that 43% of the base of the Greenland Ice Sheet is likely thawed, 24% is likely frozen to the rock below, and the basal thermal state of the remainder is uncertain.

Name: Joseph A. MacGregor, Cryospheric Sciences Laboratory, NASA GSFC
E-mail: joseph.a.macgregor@nasa.gov
Phone: 301-614-5876#

References:

MacGregor, J.A., M.A. Fahnestock, G.A. Catania, A. Aschwanden, G.D. Clow, W.T. Colgan, S.P. Gogineni, M. Morlighem, S.M.J. Nowicki, J.D. Paden, S.F. Price and H. Seroussi, A synthesis of the basal thermal state of the Greenland Ice Sheet (2016), *Journal of Geophysical Research Earth Surface*, 121, doi:10.1002/2015JF003803

Data Sources:

- 8 SeaRISE ice-sheet thermomechanical models, including two NASA-supported models: ISSM (JPL) and PISM (UAF-GI)
- More than 400,000 km of PARCA and Operation IceBridge airborne radar-sounding surveys across Greenland
- 1995–2013 MEaSUREs InSAR surface velocity
- MODIS Mosaic of Greenland

Technical Description of Figures:

Figure 1*:*

- Left panel: Summary map of existing boreholes, known subglacial lakes and NASA airborne radar transects across Greenland.
- Right panel: Synthesis of the basal thermal state of the Greenland Ice Sheet, showing where the majority of the four methods agree on a particular basal thermal state, and where significant uncertainty remains.

Scientific significance, societal relevance, and relationships to future missions: Greenland's thick ice sheet insulates the bedrock below from the cold temperatures at the surface, so the bottom of the ice is often tens of degrees warmer than at the top, because the ice bottom is slowly warmed by heat coming from the Earth's depths. Knowing whether Greenland's ice lies on wet, slippery ground or is anchored to dry, frozen bedrock is essential for predicting how this ice will flow in the future. But scientists have very few direct observations of the thermal conditions beneath the ice sheet, obtained through fewer than two dozen boreholes that have reached the bottom. Our study synthesizes several independent methods to infer the Greenland Ice Sheet's basal thermal state –whether the bottom of the ice is melted or not– leading to the first map that identifies frozen and thawed areas across the whole ice sheet. This map will guide targets for future investigations of the Greenland Ice Sheet toward the most vulnerable and poorly understood regions, ultimately improving our understanding of its dynamics and contribution to future sea-level rise. It is of particular relevance to ongoing Operation IceBridge activities and future large-scale airborne missions over Greenland.

Evaluation of Current Planetary Boundary Layer Retrieval Capabilities from Space

Joseph A. Santanello, Jr.[1], Alexander J. Schaefer[2], John Blaisdell[3], and John Yorks[3]
[1]Hydrological Sciences Laboratory, NASA/GSFC; [2]University of North Carolina at Charlotte
[3]Mesoscale Atmospheric Processes Laboratory, NASA/GSFC

AIRS-based Temperature and Humidity Profiles vs. Radiosonde

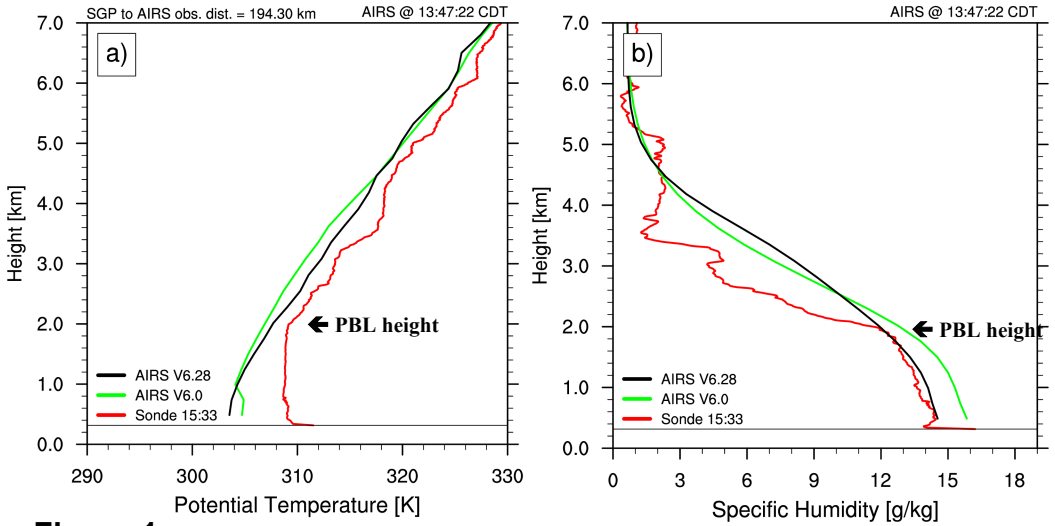


Figure 1

Properties of the planetary boundary layer (PBL), which are key to our understanding and prediction of the water cycle, can be monitored by NASA's satellite-borne CALIPSO (PBL height), CATS (PBL height), and AIRS (PBL temperature and humidity) instruments.

CALIPSO and CATS Backscatter Retrievals

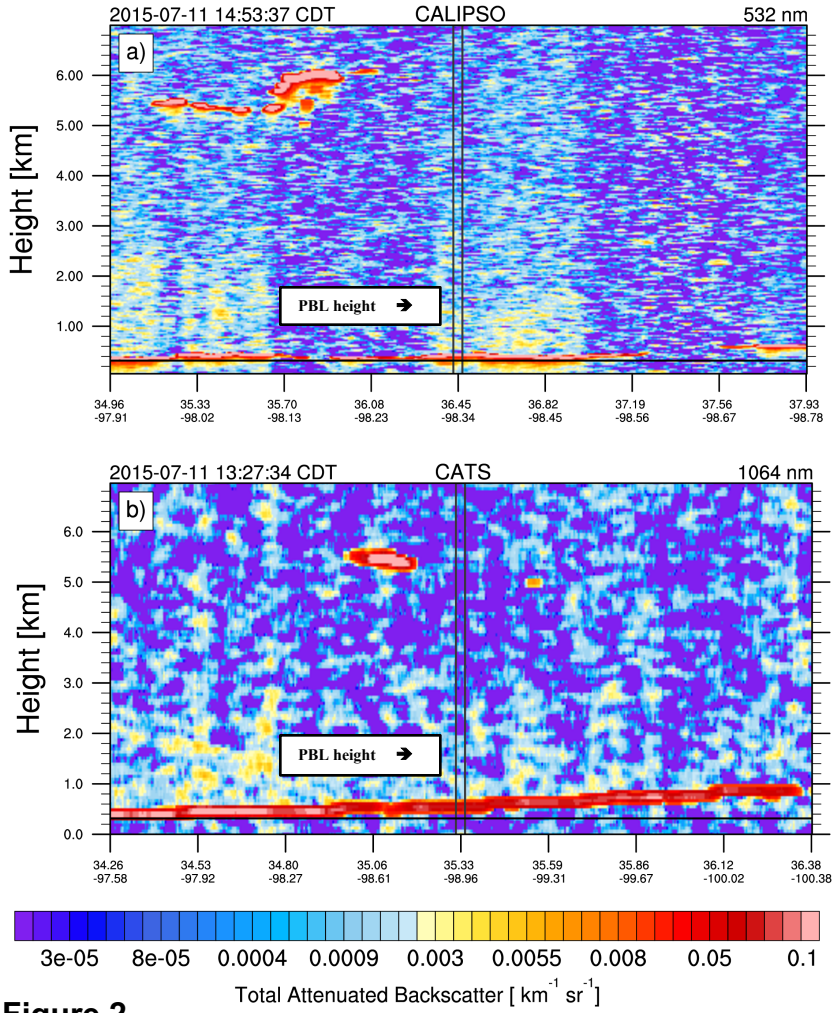


Figure 2

Goddard SPACE FLIGHT CENTER

Name: Joseph A. Santanello, Jr.,Hydrological Sciences, NASA GSFC
E-mail: Joseph.A.Santanello@nasa.gov
Phone: 301-286-7450

References:

Santanello et al., 2015: **The Importance of Routine Planetary Boundary Layer Measurements over Land from Space**. NRC Decadal Survey 2017-2027, Request for Information #1. http://sites.nationalacademies.org/DEPS/ESAS2017/index.htm
Santanello et al., 2016: **The Boundary Layer Gap over Land and Importance of Improved Retrieval from Space.** NRC Decadal Survey 2017-2027, Request for Information #2. http://sites.nationalacademies.org/DEPS/ESAS2017/index.htm

Data Sources:

AIRS: The Atmospheric Infrared Sounder (AIRS) instrument aboard NASA's AQUA spacecraft provides Level 2 profile retrievals (V6.0) to the public. Version 6.28 was obtained from J. Susskind's sounding team, and includes improved land surface emissivity, lower tropospheric channel selection sensitivity, and humidity treatments. The nearest granule to the Southern Great Plains (SGP) site was selected (~200km away).
CALIPSO: Level 1B backscatter (532 nm) data was acquired from the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite. A running average, 17 horizontal and 2 vertical bins, was used to smooth out excess noise in the horizontal transect shown, which covers approximately 300 km in length from SSE to NNW over the SGP domain.
CATS: Level 1B backscatter (1064 nm) data were obtained from the Cloud-Aerosol Transport System (CATS) instrument website. A running average, 27 horizontal and 3 vertical bins, was applied to smooth out excess noise in the horizontal transect shown, which covers approximately 300 km in length from SE to NW
In-situ: Hourly radiosondes were launched from the SGP facility in Lamont, OK as part of an IOP campaign (Co-I Santanello) in Summer 2015, as coordinated with CATS overpasses (J. Yorks) and hydrological regimes of interest.

Technical Description of Figures:

Figure 1: Mid-afternoon vertical profiles of **a)** potential temperature and **b)** specific humidity from AIRS V6.0, V6.28, and from the closest radiosonde launch at the SGP site in Lamont, OK on 5 July 2015. V6.0 and V6.28 fail to correctly identify PBL height (PBLh) with respect to potential temperature due to a lack of vertical resolution and inability to detect vertical gradients and the PBLh inversion layer. V6.28 indicates some overall improvement over V6.0 for correctly identifying the specific humidity profile in the lower troposphere, likely as a result of the modifications to the retrieval algorithm listed above.
Figure 2: Horizontal transect of total attenuated backscatter profiles from the **a)** CALIPSO and **b)** CATS lidar over the ARM-SGP domain on 11 July 2015 during the mid-afternoon. The black arrow indicates the radiosonde estimate of PBLh for the time nearest the instrument flyover. Yellow values show areas of higher aerosol concentrations and red/pink are areas indicative of clouds. The more consistent PBL depicted by CALIPSO also shows a sharp gradient from yellow to blue that indicates the PBLh. CATS depicts pockets of aerosols but lacks a distinct layer like CALIPSO due to reduced signal-to-noise ratios observed during daytime.

Scientific significance, societal relevance, and relationships to future missions: The PBL over land remains a significant gap in our water and energy cycle understanding from space. This work combines unique NASA satellite and model products to demonstrate the ability of current sensors (advanced IR sounding and lidar) to retrieve PBL properties and in turn their potential to be used globally to evaluate and improve weather and climate prediction models. While incremental progress has been made in recent AIRS retrieval versions, insufficient vertical resolution remains in terms of detecting PBL properties. Lidar shows promise in terms of detecting vertical gradients (and PBLh) in the lower troposphere, but daytime conditions over land remain a challenge due to noise, and their coverage is limited to ~2 week or longer return times.

From toes to top-of-the-atmosphere: Fowler Sneaker Index

Ben A. Crooke, Ocean Ecology, NASA GSFC and Sandy Spring Friends School, Lachlan I.W. McKinna, Ocean Ecology, SAIC, Ivona Cetinić, Ocean Ecology, GESTAR/USRA

Figure 1

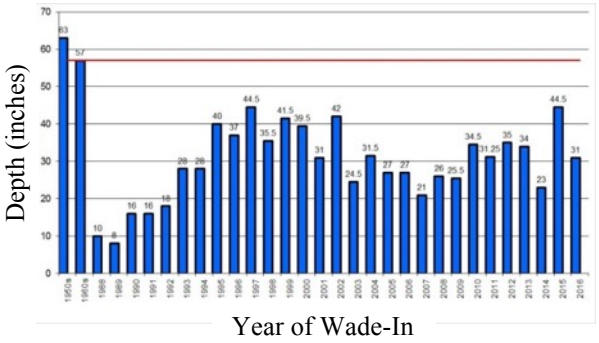


Figure 2

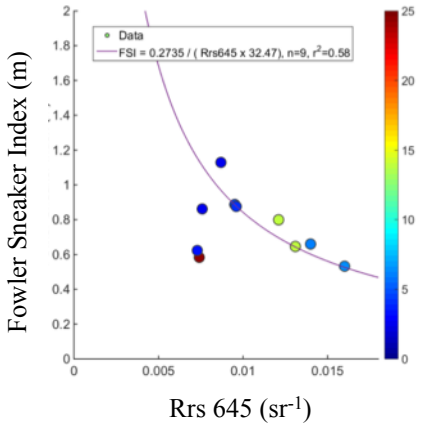
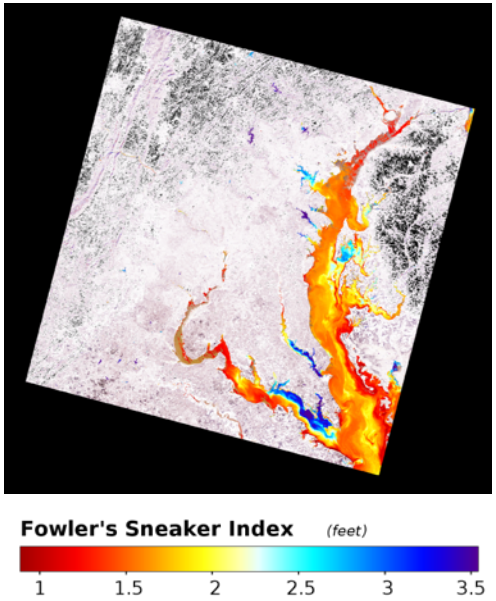


Figure 3



Fowler Sneaker Index (FSI), developed by a NASA summer intern, is a new Ocean Color application that facilitates continuous monitoring of environmental conditions in the Chesapeake Bay. It builds on three decades of citizen science data collected by former Maryland State Senator Bernie Fowler, during his yearly “Wade-ins in the Patuxent River”. FSI demonstrates how NASA’s Earth-observing tools, in combination with a concerned and engaged public, can take science from the tips of our toes to top-of the atmosphere and back.

Name: Ivona Cetinic, Ocean Ecology, NASA GSFC, GESTAR/USRA
E-mail: ivona.cetinic@nasa.gov
Phone: 301-286-1514

References:

B. A. Crooke, L. I. McKinna, I. Cetinić, "Toes to top-of-atmosphere: Fowler Sneaker Index" Optics Express (in prep)

B.A. Franz, S.W. Bailey, N. Kuring, P.J. Werdell, Ocean color measurements with the Operational Land Imager on Landsat-8: implementation and evaluation in SeaDAS. Journal of Applied Remote Sensing, 9(1), pp.096070-096070 (2015).

Data Sources: Maryland Department of Planning, MODIS Aqua, MODIS Terra, LANDSAT

Technical Description of Figures:

Figure 1: *Images taken from the Maryland Department of Planning website depict senator Bernie Fowler holding his sneakers that he uses to collect data regarding the visibility in the Patuxent River – shown in the bar plot in blue.*

Figure 2: *Relationship between visibility, which is determined during the annual Wade-Ins, and remote sensing reflectance as measured by MODIS Aqua and MODIS Terra, are used as a final FSI algorithm.*

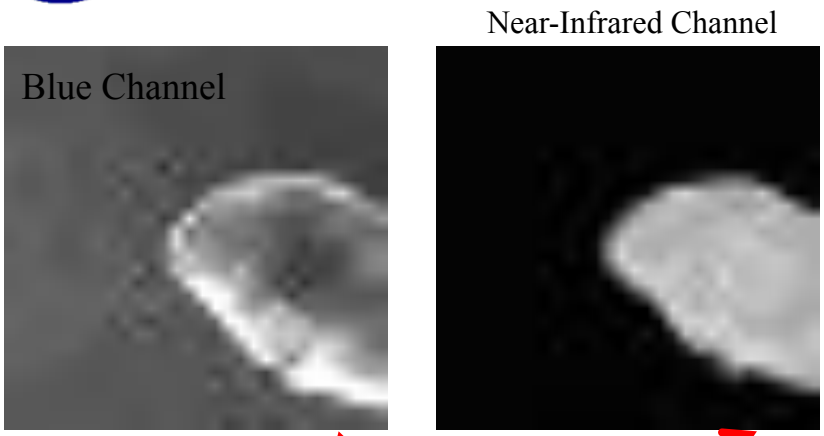
Figure 3: *FSI algorithm applied to a LANDSAT image demonstrating the applicability of this new Ocean Color product.*

Scientific significance, societal relevance, and relationships to future missions:

In recent years, citizen-collected data has started to assert itself as a powerful resource used by scientists worldwide to aid in understanding of Earth's natural variability. Although sometimes non-conventional, these datasets, such as Fowler Sneaker Index, present an opportunity through which NASA Earth observations can be used to address societal concerns locally and globally.

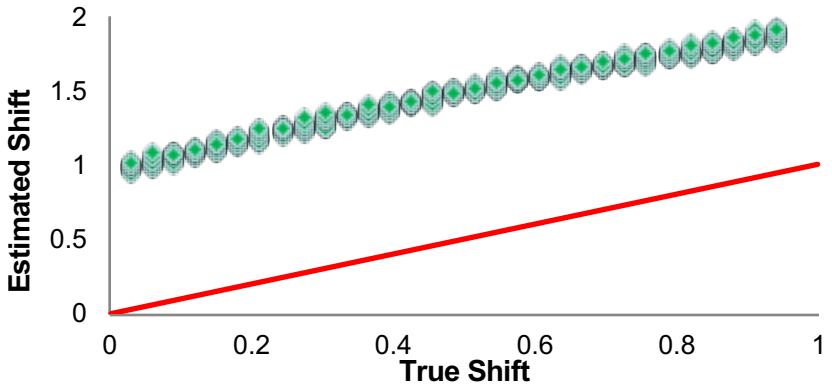
Cross Correlation versus Normalized Mutual Information on Image Registration

Bin Tan, James C. Tilton, and Guoqing Lin, Terrestrial Information Systems, NASA GSFC



Shoreline in Different Location in Blue and Near-IR band

Figure 1



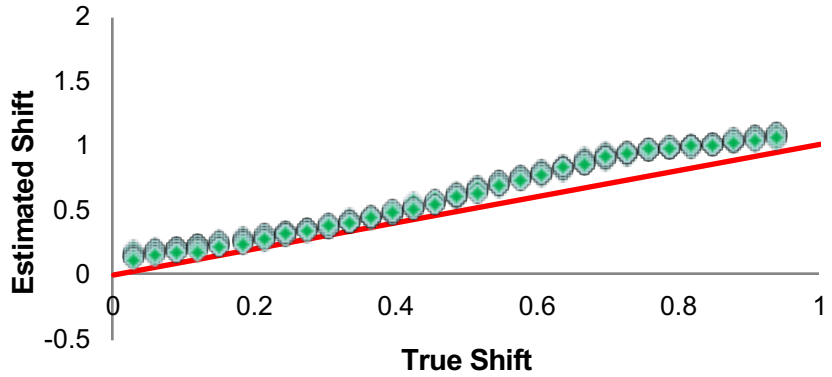


Figure 2

Normalized mutual information gives more accurate registration result than cross correlation when the edges of features are not aligned due to the spectral response differences between bands.

Name: Bin Tan, Terrestrial Information Systems, NASA GSFC
E-mail: bin.tan@nasa.gov
Phone: 301-614-5965

References:

[1] H. M. Chen, M. K. Arora, and P. K. Varshiney, “Mutual Information-based image registration for remote sensing data”, Int. J. Remote Sensing, vol 24, no. 18, pp. 3701-3706, 2013.
[2] G. K. Rohde, A. Aldroubi, and D. M. Healy Jr., “Interpolation artifacts in sub-pixel image registration”, IEEE Trans. Geosci. Remote Sens., vol 18, no 2, pp. 333-345, 2009.
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Data Sources: Landsat image from over Hadi collected on Dec 09, 2005 (L71009047_0472005120).

Technical Description of Figures:

Figure 1: Blue and Near-infrared band images. Shoreline extends further to the ocean in blue channel due to the spectral response difference at shallow water region. This difference is a “false signal” in image registration.

Figure 2: Plots of registered near-infrared band to blue band images. The sub-pixel shifts are introduced due to spectral response differences in shallow water. Both the cross correlation method and the normalized mutual information method are used to assess the shift between blue and near-infrared images. Upper/lower plots shows the estimated shift against the true introduced shift for the cross-correlation/normalized mutual information methods.

Scientific significance, societal relevance, and relationships to future missions: This is the first study to quantitatively assess and compare cross correlation and normalized mutual information methods used to register images in subpixel scale. The study shows that the normalized mutual information method is less sensitive to unaligned edges due to the spectral response differences than is cross correlation. This characteristic makes the normalized image resolution a better candidate for band to band registration. Improved band-to-band registration in the data from satellite-borne instruments will result in improved retrievals of key science measurements such as cloud properties, vegetation, snow and fire.