

2017-12-13

Earth reflectivity from Deep Space Climate Observatory (DSCOVR) Earth Polychromatic Camera (EPIC)

Wanjuan Song, Juri Knjazihhin, Guoyong Wen, Alexander Marshak, Guangjian Yan, Xihan Mu, Taejin Park, Chi Chen, Baodong Xu, Ranga Myneni. 2017. "Earth Reflectivity from Deep Space Climate Observatory (DSCOVR) Earth Polychromatic Camera (EPIC)." 2017 AGU Fall Meeting, New Orleans, Louisiana.

<https://hdl.handle.net/2144/27487>

"Downloaded from OpenBU. Boston University's institutional repository."

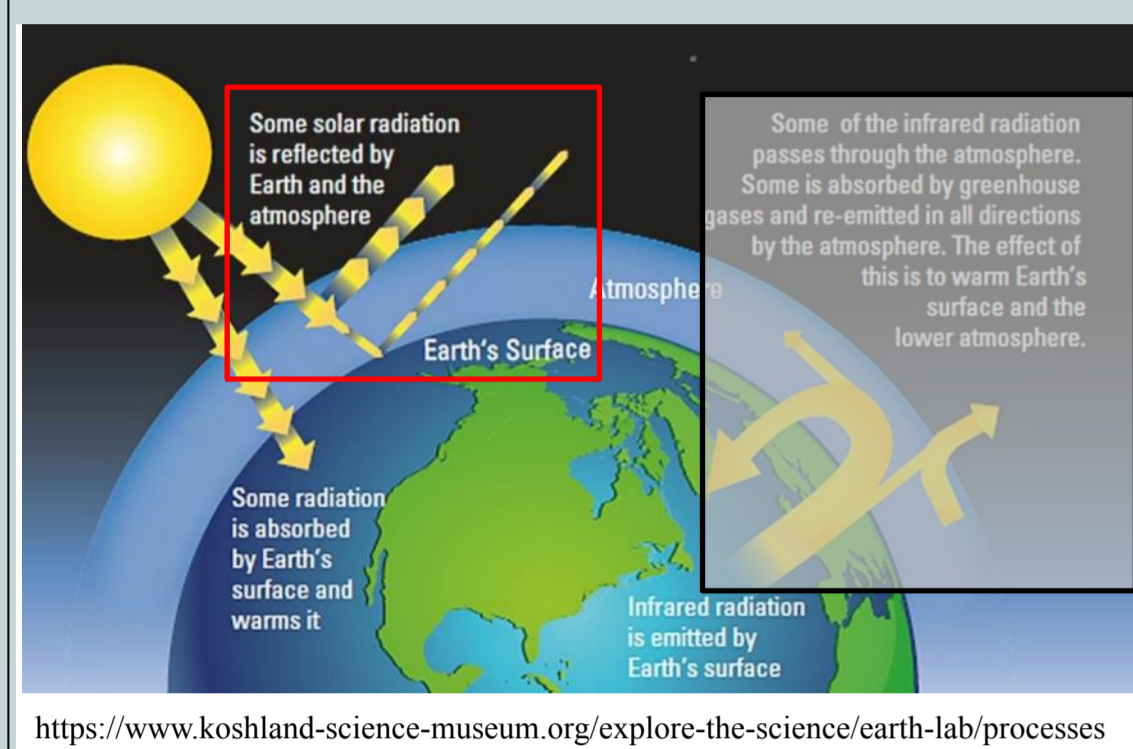
Earth Reflectivity from Deep Space Climate Observatory (DSCOVR) Earth Polychromatic Camera (EPIC)

Wanjuan Song^{1,2}, Yuri Knyazikhin¹, Guoyong Wen³, Alexander Marshak³, Guangjian Yan², Xihan Mu², Taejin Park¹, Chi Chen¹, Baodong Xu^{1,4}, Ranga B. Myneni¹

¹Boston University, MA; ²Beijing Normal University, China; ³NASA Goddard Space Flight Center, Greenbelt, MD; ⁴Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, China

Abstract. Earth reflectivity, which is also specified as Earth albedo or Earth reflectance, is defined as the fraction of incident solar radiation reflected back to space at the top of the atmosphere. It is a key climate parameter that describes climate forcing and associated response of the climate system. Satellite is one of the most efficient ways to measure earth reflectivity. Conventional polar orbit and geostationary satellites observe the Earth at a specific local solar time or monitor only a specific area of the Earth. For the first time, the NASA's Earth Polychromatic Imaging Camera (EPIC) onboard NOAA's Deep Space Climate Observatory (DSCOVR) collects radiance data of the entire sunlit earth at 8 km resolution at nadir every 65 to 110 min. It provides imageries in near backscattering directions with the scattering angle between 168° and 176° at 10 narrow spectral bands in ultraviolet, visible, and near-Infrared (NIR) wavelengths. We analyze temporal variation in the Earth reflectivity derived from DSCOVR EPIC observations and estimate uncertainties in Earth reflectivity due to sampling strategy of polar orbit Terra/Aqua MODIS and geostationary Goddard Earth Observing System-R series missions. We also evaluate contributions from ocean, clouds, land and vegetation to the Earth reflectivity.

1. INTRODUCTION



Definition:

Earth reflectivity, a.k.a. Earth albedo or Earth reflectance, is defined as the **fraction of incident solar radiation** reflected back to space at the top of the atmosphere. It is a key climate parameter that describes climate forcing and associated response of the climate system.

Measurements:

1. Presatellite Era

- model calculations based on solar radiative transfer in the atmosphere and surface
- earthshine observations (observations of the earth-lit Moon)

✓ *The results depend on model assumptions and vary between 0.29 to 0.89.*

2. Postsatellite Era

- Nimbus-7, NOAA-9/10, ENVISAT, Terra/Aqua, Aura, Metop...

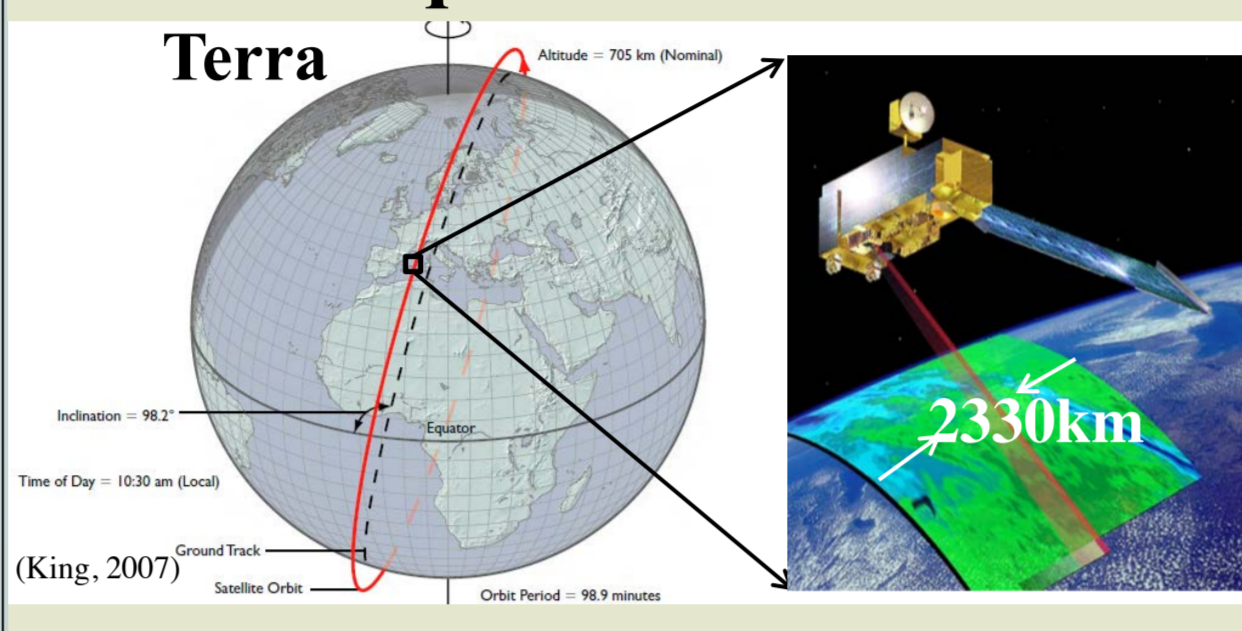
✓ *Earth reflectivity estimates came from low orbit observations.*

✓ *Satellites observe part of the Earth at a specific time.*

✓ *The results become stable at around 0.3 ± 0.02.*

2. SAMPLING APPROACHES

1. Terra/Aqua – MODIS

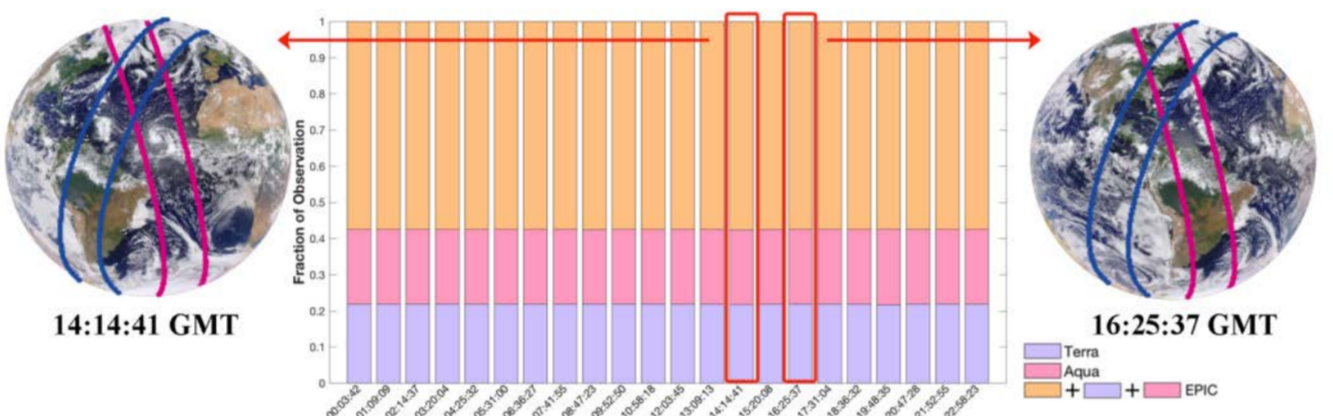
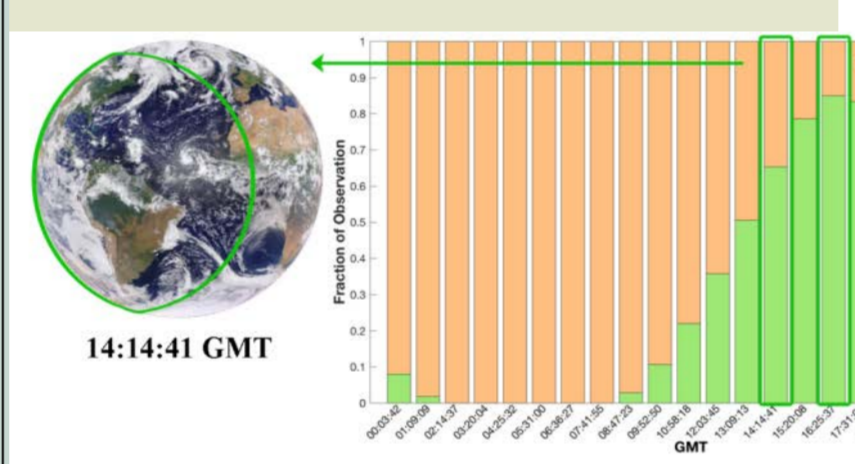


3. DSCOVR – EPIC



- For the first time, EPIC collects **simultaneously** radiance data of **the entire sunlit earth** every 65 to 110 min.
- It provides imageries in **backscattering directions** with the scattering angle between 168° and 176° at 10 narrow spectral bands (317nm~779nm).

✓ *Terra and Aqua Sampling areas is about 20% of the Earth disk.*

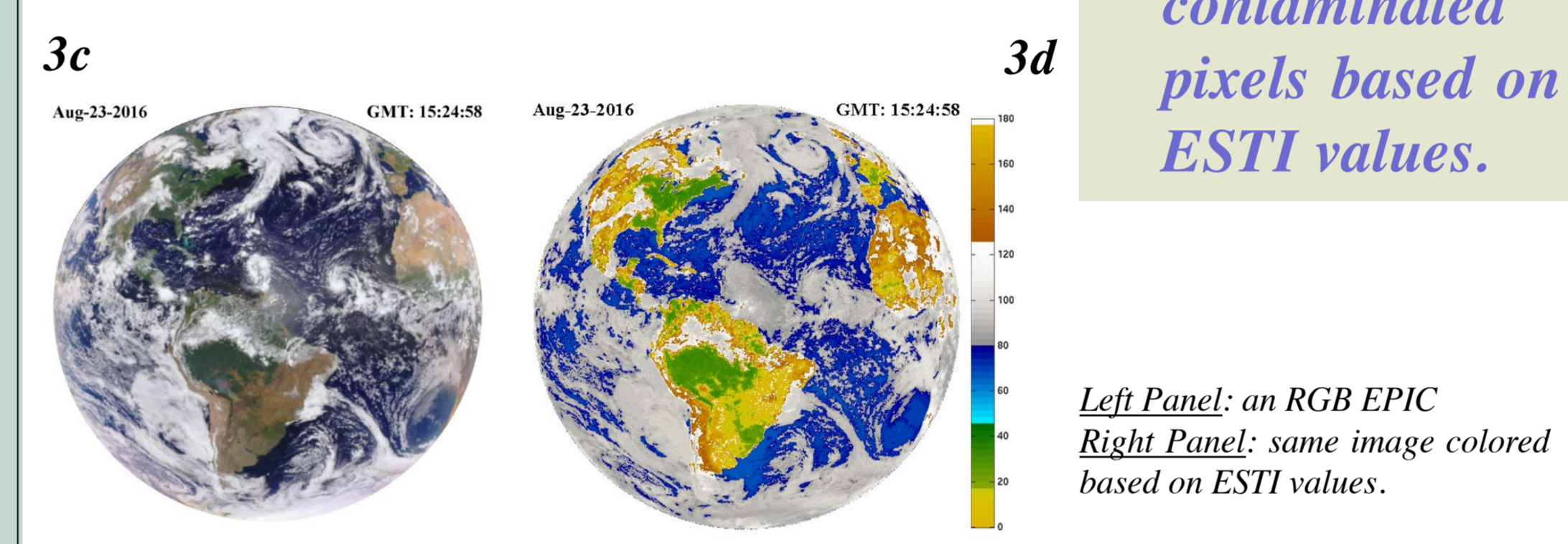
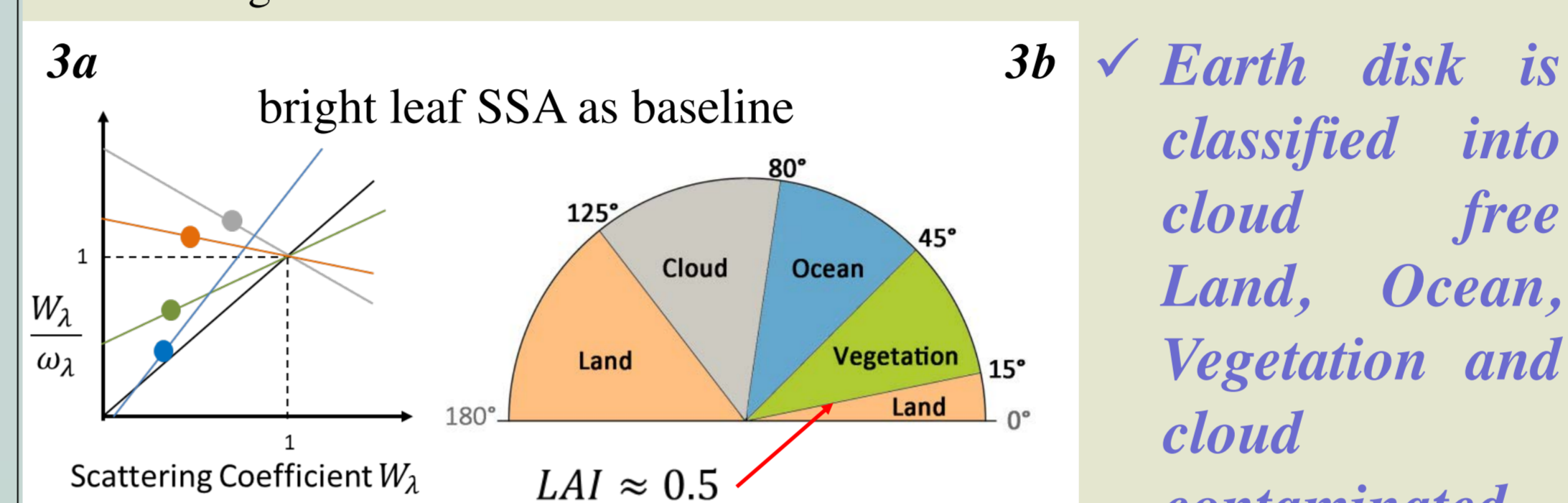


✓ *GOES Sampling area changes with time.*

3. EARTH SURFACE TYPE INDEX

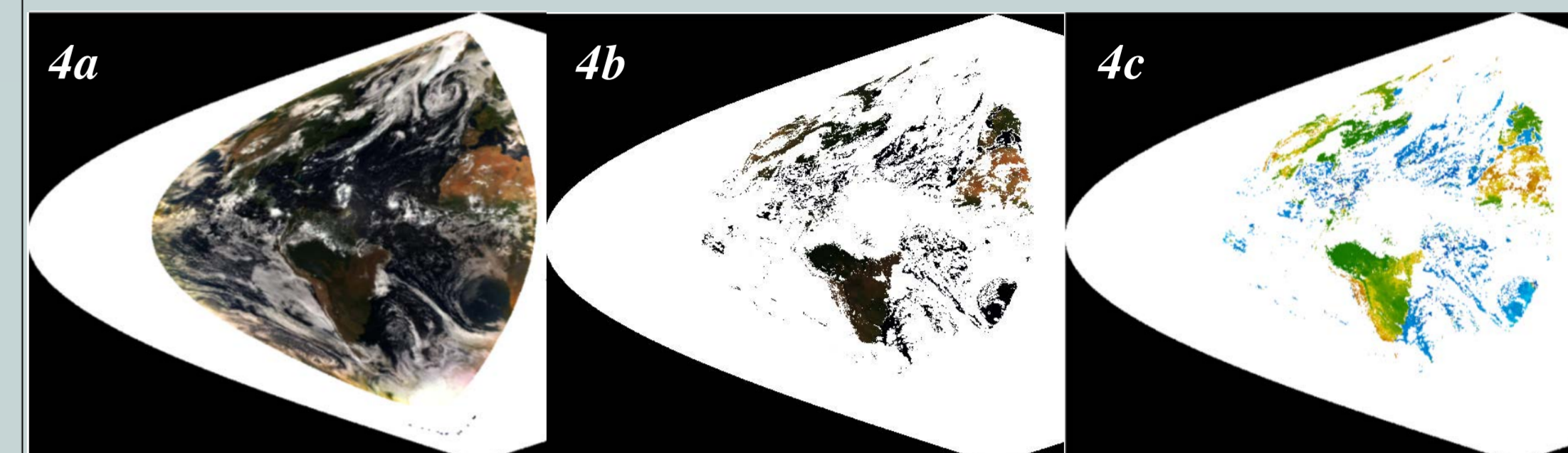
$$ESTI = \text{atan } p = \text{atan} \left(\frac{R_{NIR} - R_{GREEN}}{\omega_{NIR} - \omega_{GREEN}} \right) / \left(\frac{R_{NIR}}{R_{GREEN}} - \frac{\omega_{NIR}}{\omega_{GREEN}} \right)$$

The slope p of a line crossing points $(\frac{R_{GREEN}}{\omega_{GREEN}}, R_{GREEN})$ and $(\frac{R_{NIR}}{\omega_{NIR}}, R_{NIR})$ on the $R_{\lambda}/\omega_{\lambda}$ vs. R_{λ} spectral plane provides an estimate of the average recollision probability p . Here ω_{λ} is the albedo of brightest leaf (or the reference leaf albedo [1,2]). The Earth Surface Type Index (ESTI) defined as $ESTI = \text{atan}(p)$ takes values between about 15° and 45° only for vegetated surface. Its values for cloud contaminated, cloud free ocean and land pixels occupy different intervals within 0° to 180° range.

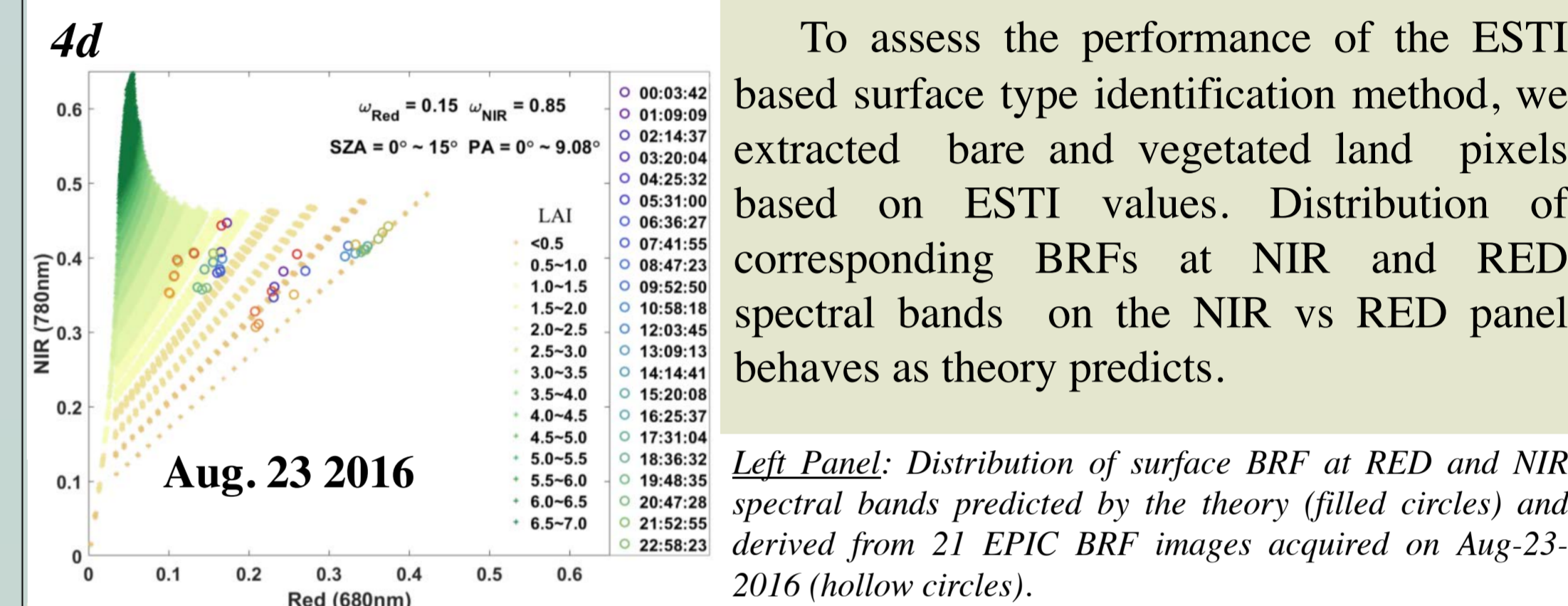


✓ *Earth disk is classified into cloud free Land, Ocean, Vegetation and cloud contaminated pixels based on ESTI values.*

4. REFLECTANCE IN NIR VS RED PLANE



The EPIC L2 surface Bidirectional Reflectance Factor (BRF) product is at 10 km sinusoidal grid. Panels 4a and 4b: Top of Atmosphere (TOA) and surface reflectance images. Panel 4c: Distribution of ESTI values derived from surface BRF data.



To assess the performance of the ESTI based surface type identification method, we extracted bare and vegetated land pixels based on ESTI values. Distribution of corresponding BRFs at NIR and RED spectral bands on the NIR vs RED panel behaves as theory predicts.

✓ *Vegetation reflectances behave as theory predicts;*

✓ *Land have LAI < 0.5 as defined;*

✓ *The ESTI is efficient for Vegetation Land classification with both TOA and surface BRF.*

5. SCATTERING INDICATRIX

1. EPIC Reflectance

The EPIC level L1B data products contain images in counts/second. The data should be multiplied by a calibration factor to get EPIC reflectance, $R_{E,\lambda}$ defined as [3]

$$R_{E,\lambda} = \frac{\pi I_{\lambda}}{F_{\lambda}} \quad I_{\lambda}: \text{the spectral radiance at the top of the atmosphere}$$

$$F_{\lambda}: \text{the spectral incident solar irradiance at wavelength } \lambda$$

2. Top of atmosphere BRF

$$BRF_{r,\lambda} = \frac{\pi I_{\lambda}}{F_{\lambda} \cos SZA} = \frac{R_{E,\lambda}}{\cos SZA}$$

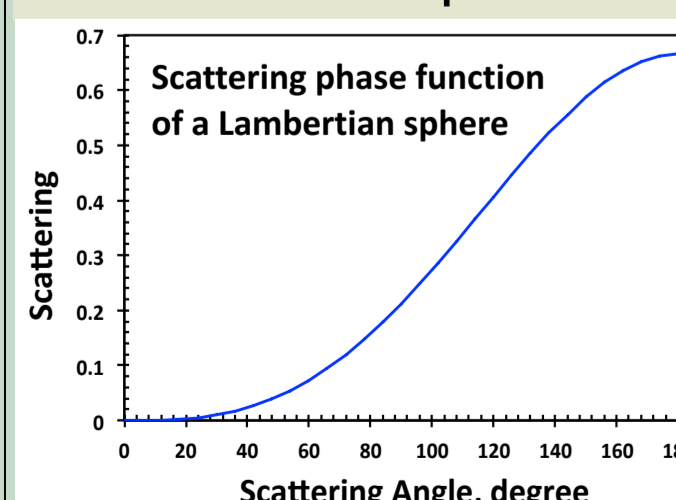
3. Earth scattering phase function

We idealize the Earth as a point. Its reflective property can be characterized by a scattering phase function defined as the ratio between radiances of scattered and incident solar radiation

$$\pi g_{\lambda}(\Omega_0, \Omega) = \frac{\pi I_{\lambda}(\Omega)}{F_{\lambda}} = \frac{1}{\pi} \int |\Omega_n \cdot \Omega_0| BRF_{r,\lambda}(\Omega_0, \Omega) |\Omega_n \cdot \Omega| \chi(\Omega_n; \Omega_0, \Omega) d\Omega_n$$

$$\approx \frac{\sum_{\text{pixel}} R_{E,\text{pixel},\lambda} \cos(VZA_{\text{pixel}}) \chi_{\text{pixel}}}{\sum_{\text{pixel}} \cos(VZA_{\text{pixel}})}$$

The indicator function of the Earth sunlit points, χ , takes the value 1 if $(\Omega_n \cdot \Omega)(\Omega_0 \cdot \Omega) < 0$ (i.e., sensor sees sunlit surface element) and 0 otherwise. We use this equation in our analyses.



In the case of a Lambertian sphere (i.e., $BRF_{r,\lambda} = \text{const} = \rho_{\lambda}$) the scattering phase function depends on the scattering angle γ and is given by equation

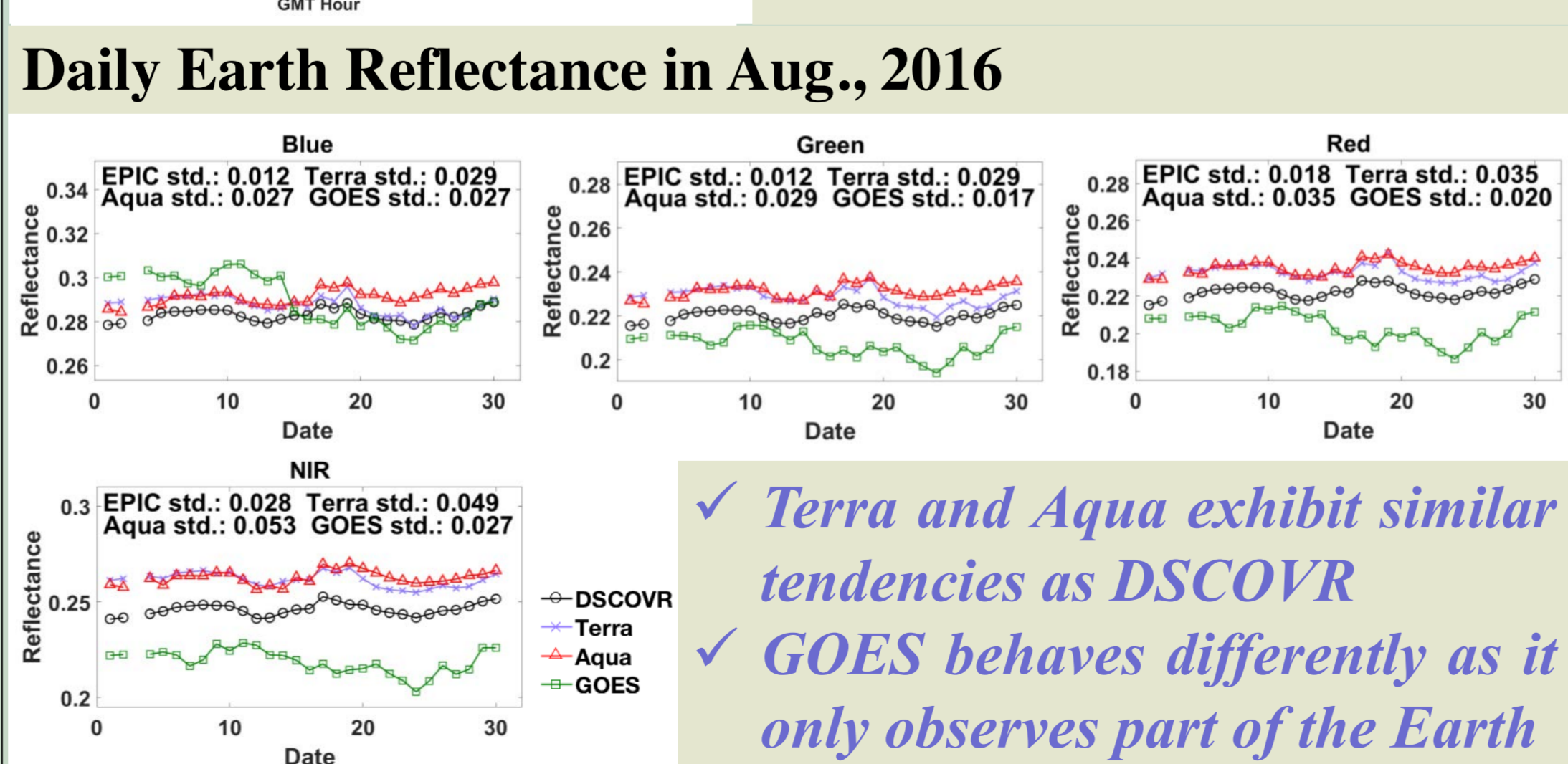
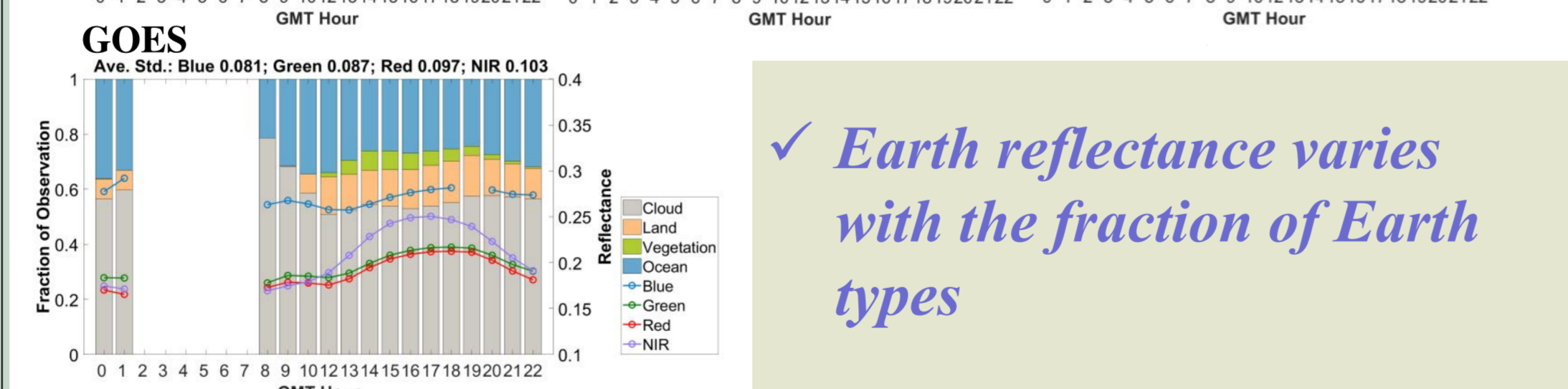
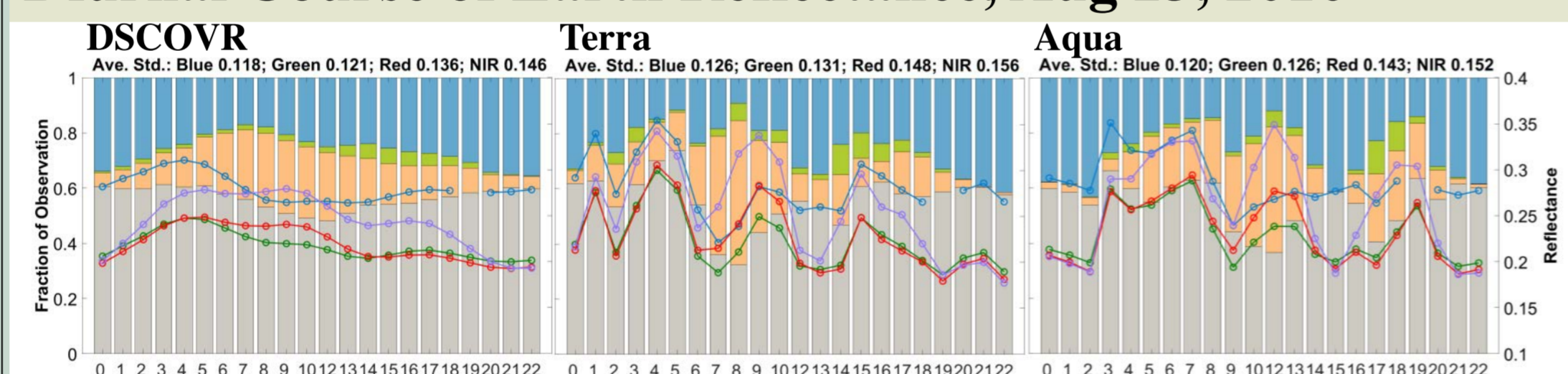
$$\pi g_{\lambda}(\gamma) = \frac{2}{3\pi} \rho_{\lambda} (\sin \gamma - \gamma \cos \gamma).$$

Left panel: shows phase function of an ideal Lambertian sphere, $BRF_{r,\lambda} = 1$.

✓ *The reflectance in block 6~8 is calculated as πg_{λ}*

6. EARTH REFLECTIVITY DISTRIBUTION

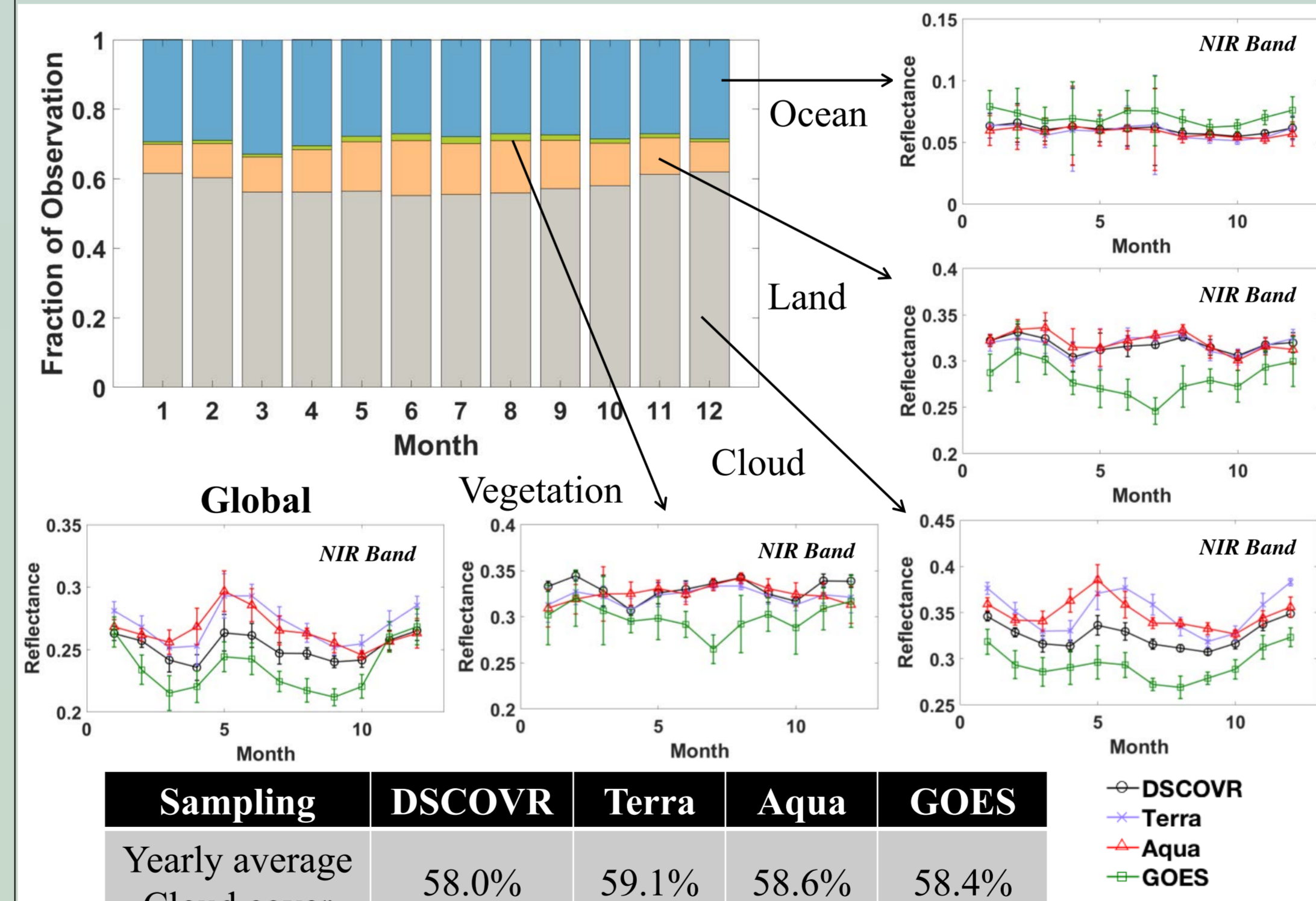
Diurnal Course of Earth Reflectance, Aug 23, 2016



✓ *Earth reflectance varies with the fraction of Earth types*

✓ *Terra and Aqua exhibit similar tendencies as DSCOVR*
 ✓ *GOES behaves differently as it only observes part of the Earth*

7. EARTH TYPE IMPACT

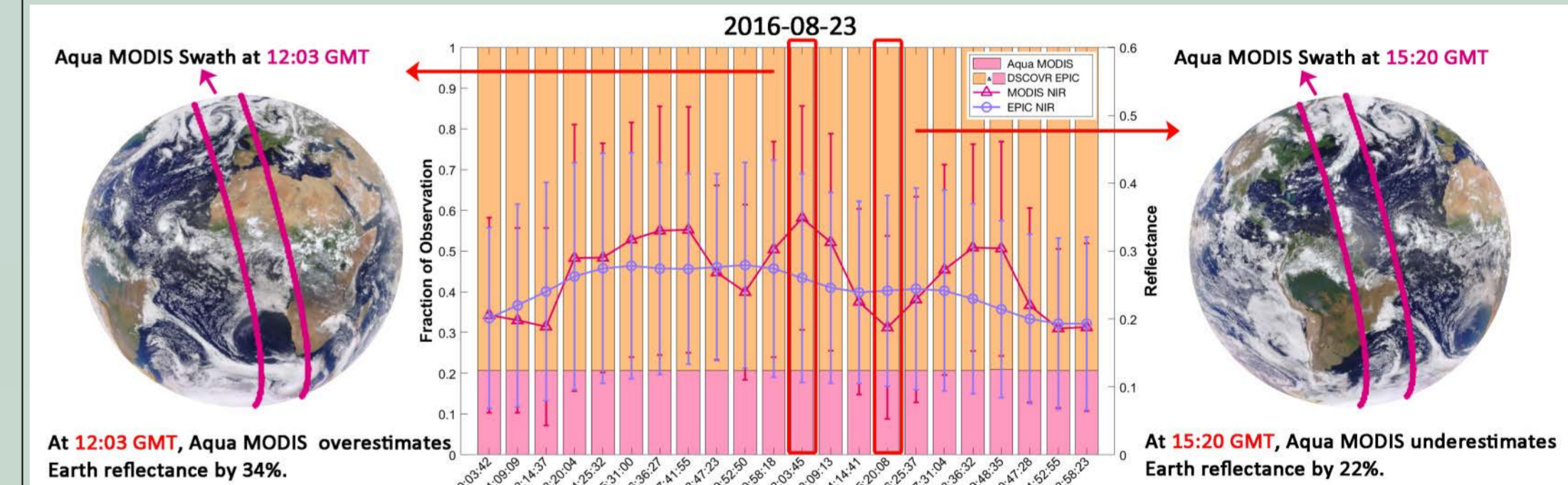


Sampling	DSCOVR	Terra	Aqua	GOES
Yearly average Cloud cover	58.0%	59.1%	58.6%	58.4%

*The average global cloud cover is 56% with clouds optical depth larger than 2^[4]

✓ *Clouds impact the Earth reflectivity, which varies significantly with cloud cover*
 ✓ *Impacts of Land and Vegetation have similar tendencies*
 ✓ *Ocean has the lowest reflectivity, and it makes the global reflectivity significantly lower than Clouds*

8. CONCLUSION



At 12:03 GMT, Aqua MODIS overestimates Earth reflectance by 34%. At 15:20 GMT, Aqua MODIS underestimates Earth reflectance by 22%.

In this example, Aqua MODIS sampling gives root mean square difference of 0.05 in daily average Earth reflectance.

1. *Sampling approach may impact estimates of Earth reflectivity. The average difference between DSCOVR and Terra reflectance is 5.7%, DSCOVR and Aqua is 5.0%, GOES and DSCOVR is 5.1%.*

	DSCOVR	Terra	Aqua	GOES
Blue	0.299	0.309	0.308	0.307
Green	0.233	0.246	0.243	0.226
Red	0.234	0.250	0.247	0.224
NIR	0.252	0.270	0.265	0.235

2. *A new Earth type classification method is involved to estimate contributions from cloud, land, ocean, and vegetation to the Earth reflectance. Different Earth types have different impacts on Earth reflectivity.*

DSCOVR	Cloud	Ocean	Land	Vegetation
Blue	0.380	0.182	0.213	0.157
Green	0.312	0.096	0.184	0.124
Red	0.320	0.071	0.210	0.107
NIR	0.326	0.060	0.318	0.331

REFERENCES

1. Y. Knyazikhin et al., "Hyperspectral remote sensing of foliar nitrogen content," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 110, no. 3, pp. E185-E192, Jan 2013;
2. P. Lewis and M. Disney, "Spectral invariants and scattering across multiple scales from within-leaf to canopy," *Remote Sensing of Environment*, vol. 109, no. 2, pp. 196-206, 2007;
3. A. Marshak and J. Herman. (2016). EPIC Calibration Factors. Available at <http://eosweb.larc.nasa.gov>;
4. C. Stubenrauch et al., "Assessment of global cloud datasets from satellites: Project and database initiated by the GEWEX radiation panel," *Bulletin of the American Meteorological Society*, vol. 94, no. 7, pp. 1031-1049, 2013.

POSTER ID: A33D-2387

2017 AGU Fall Meeting, New Orleans, Louisiana

AGU FALL MEETING

New Orleans 11-15 Dec 2017 What will you discover?

