Observing and Understanding Solar Eclipse Induced Global Spectral Reflectance from DSCOVR/EPIC

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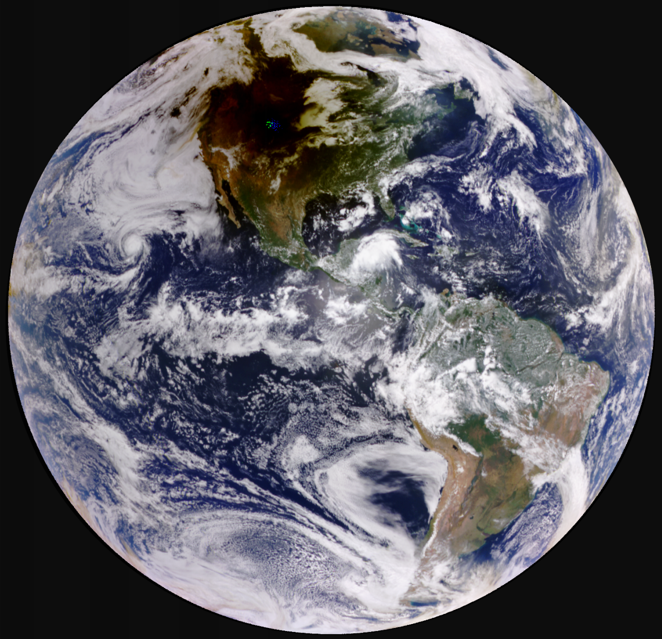
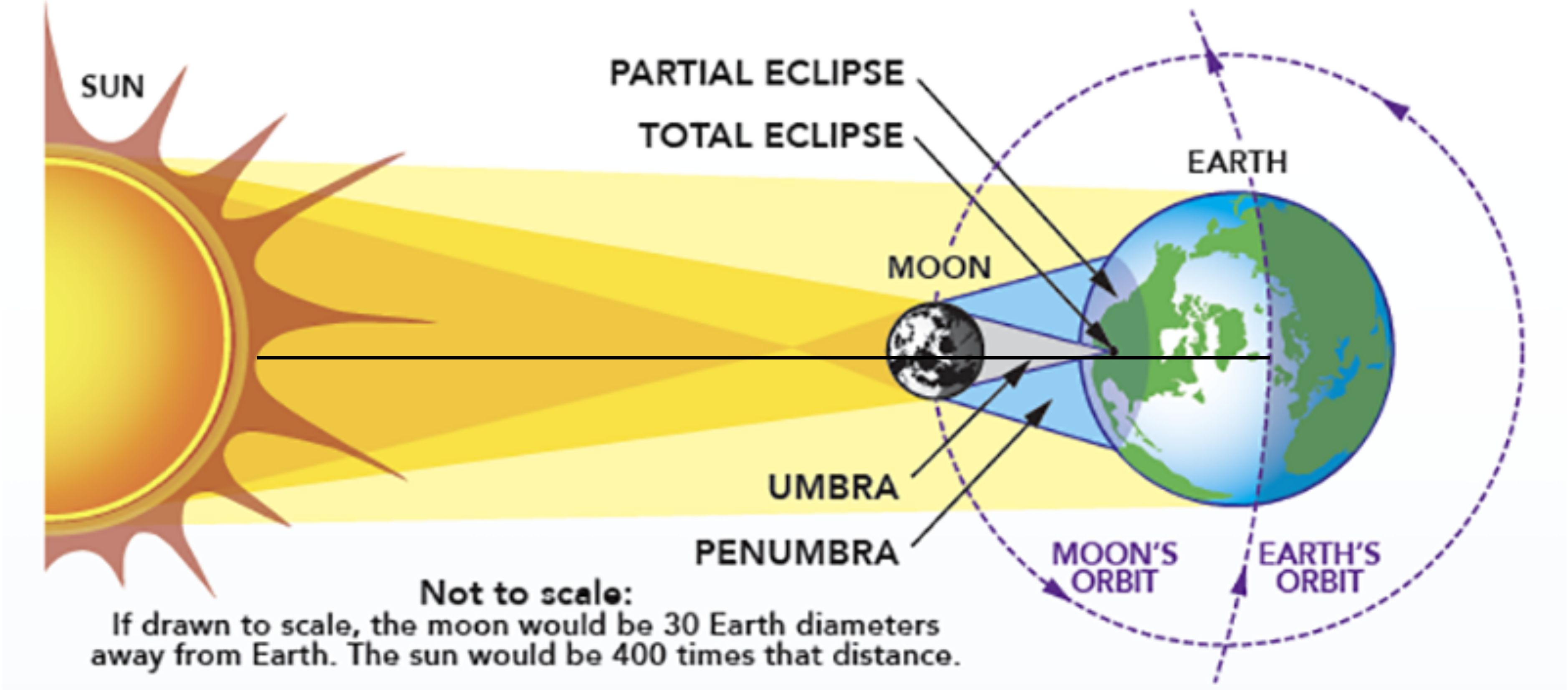
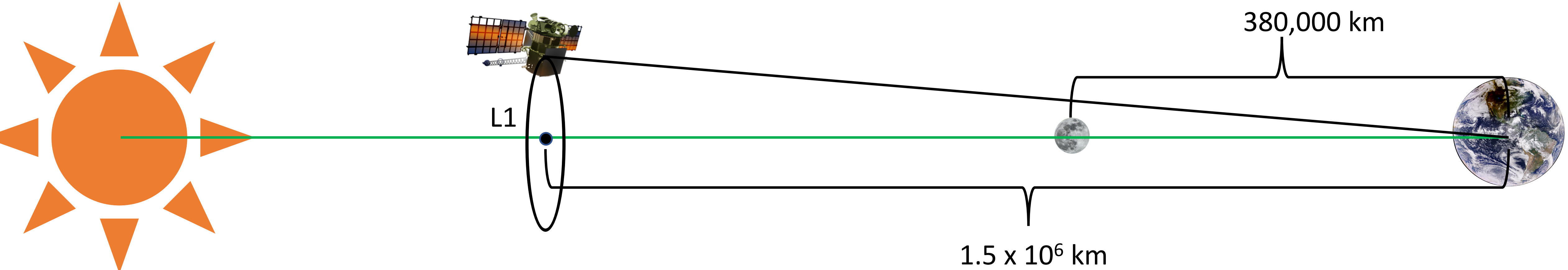


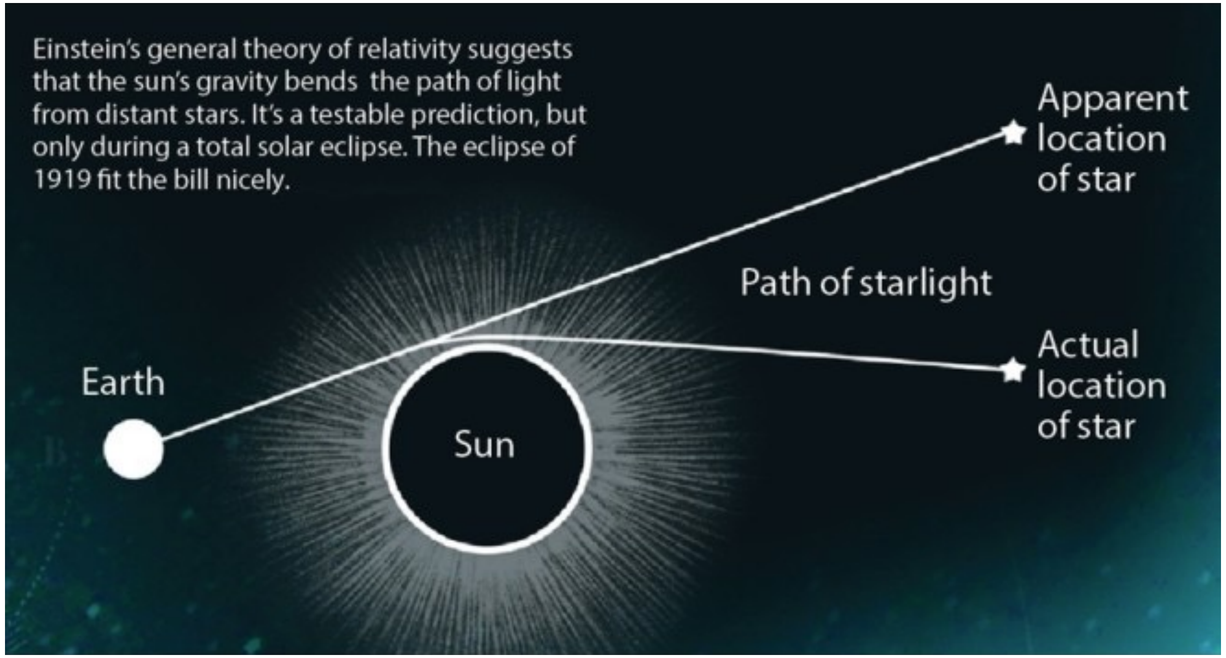
Eclipse Facts

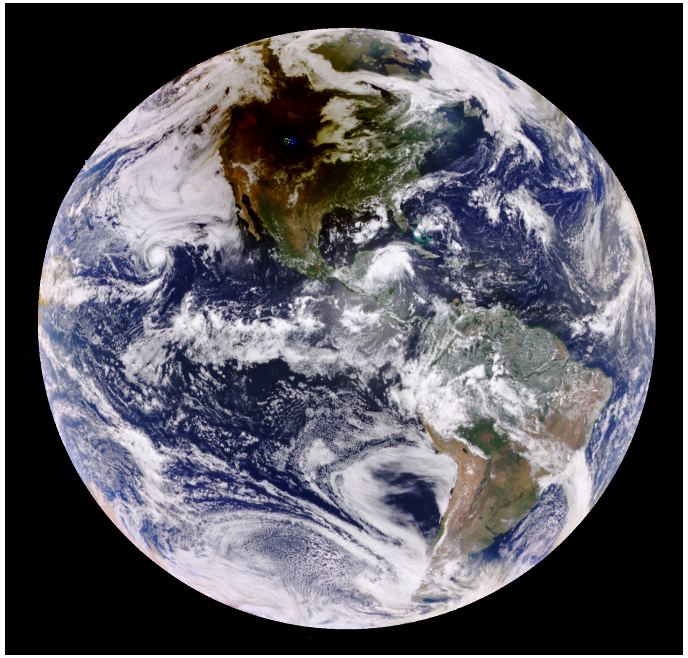




Solar Eclipses of Historical Interest

- **Corona part of Sun, 1724**
- **Identification of helium, 1868**
- **Confirmation of general relativity, 1919**
- **……**
- *Global reflectance reduction from EPIC, the 2017 Great American Eclipse*

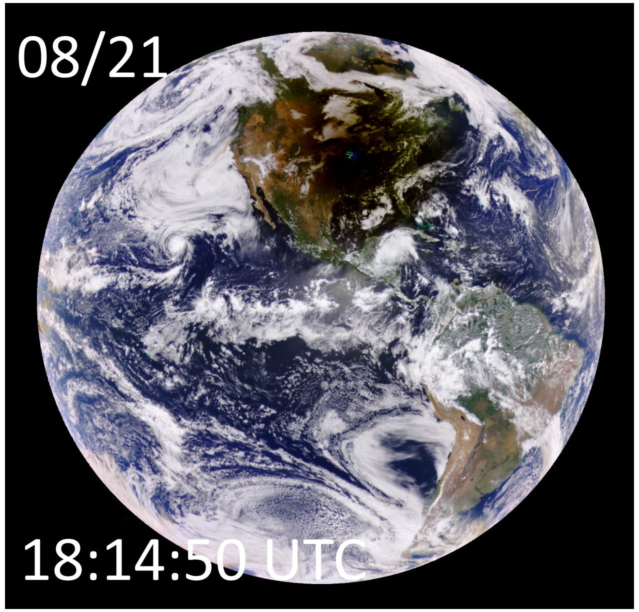


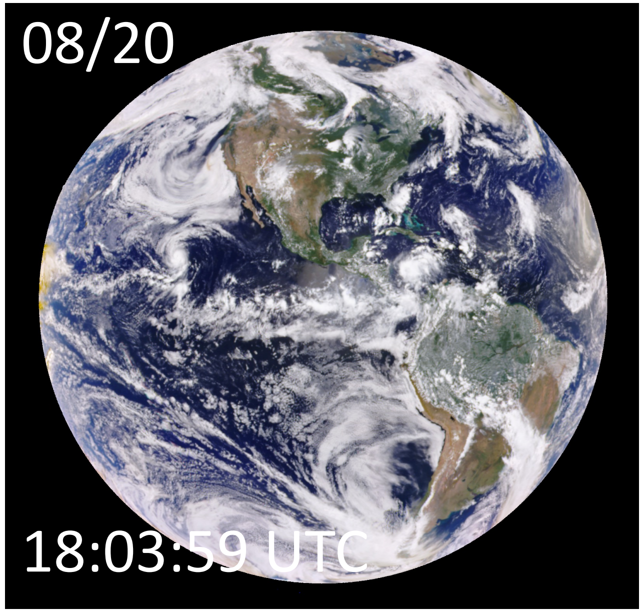


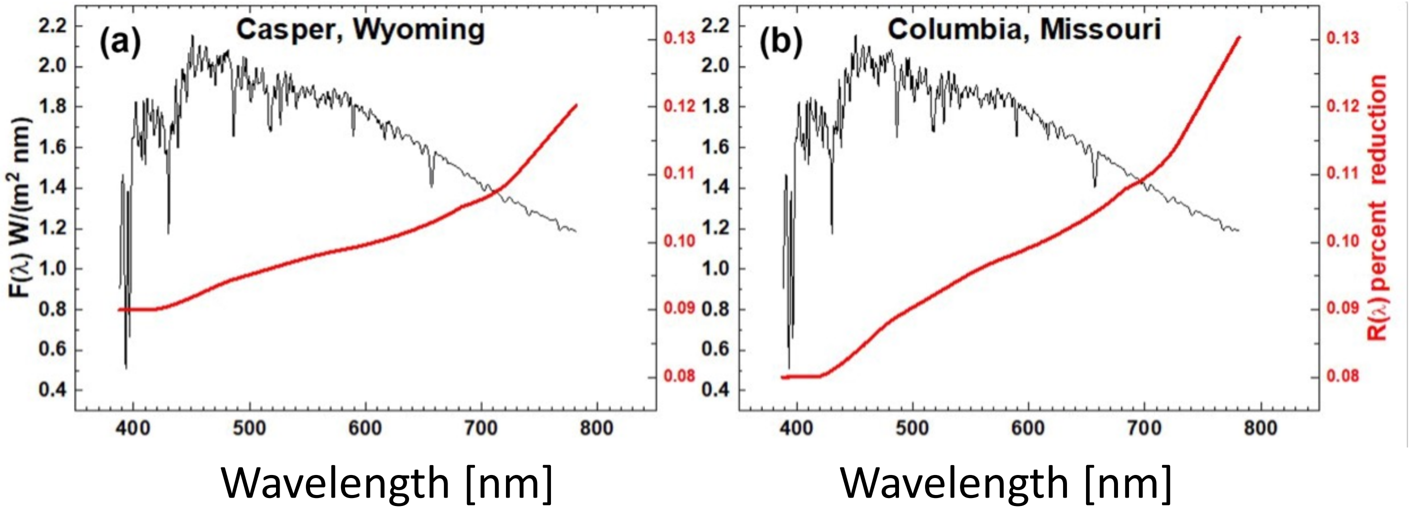
2017 Eclipse vs Non-Eclipse EPIC Images

- Day-to-day variabilities of EPIC image are small -> quantify the eclipse-induced global average reflected solar radiation (Herman et al., 2018).
- Need to understand the cause of the spectral reduction
- Need to derive EPIC image for non-eclipse conditions

Columbia, MO

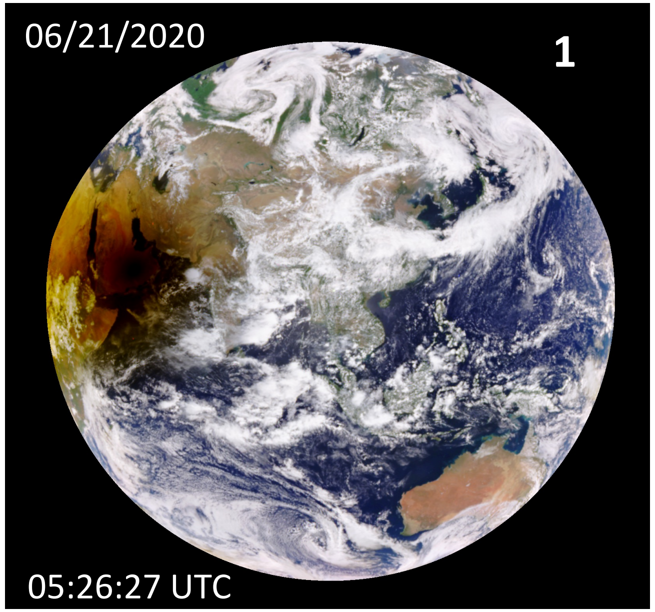


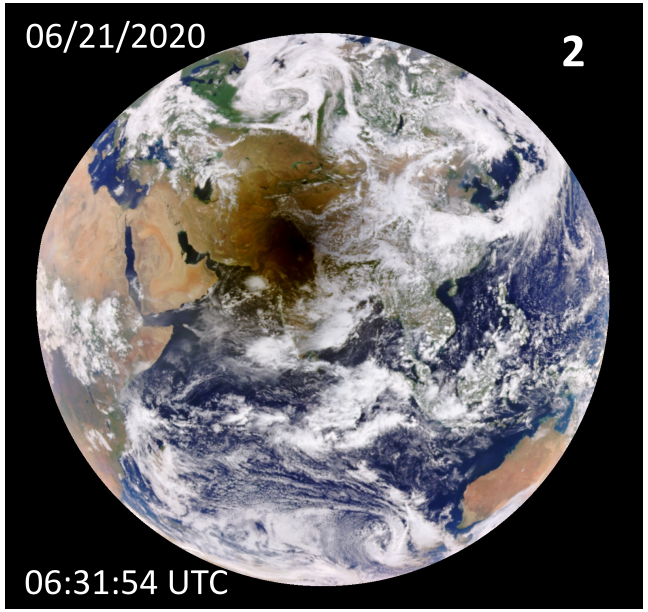


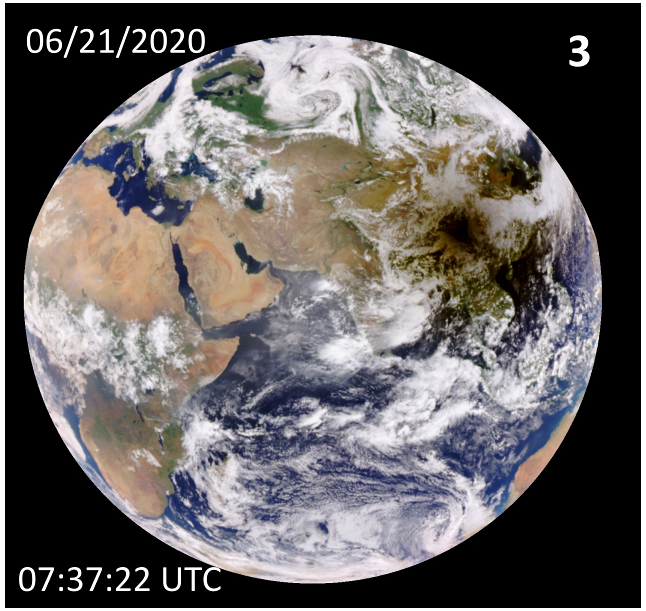


From Herman et al., 2018

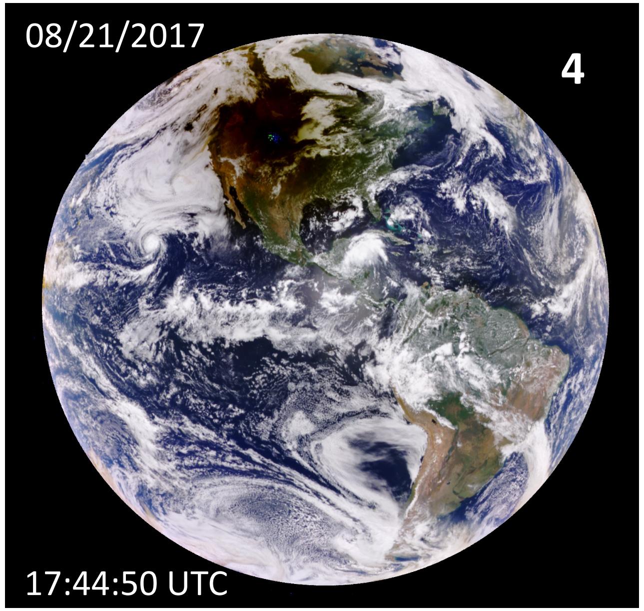
Reflectance Reduction Depends on Underlying Properties

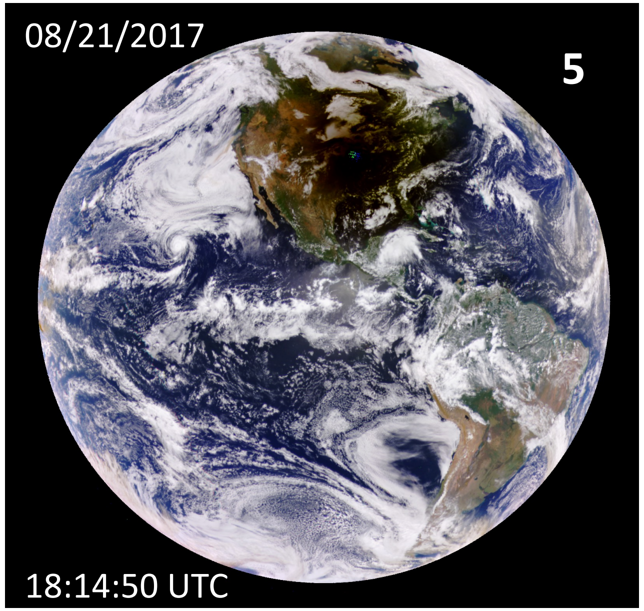




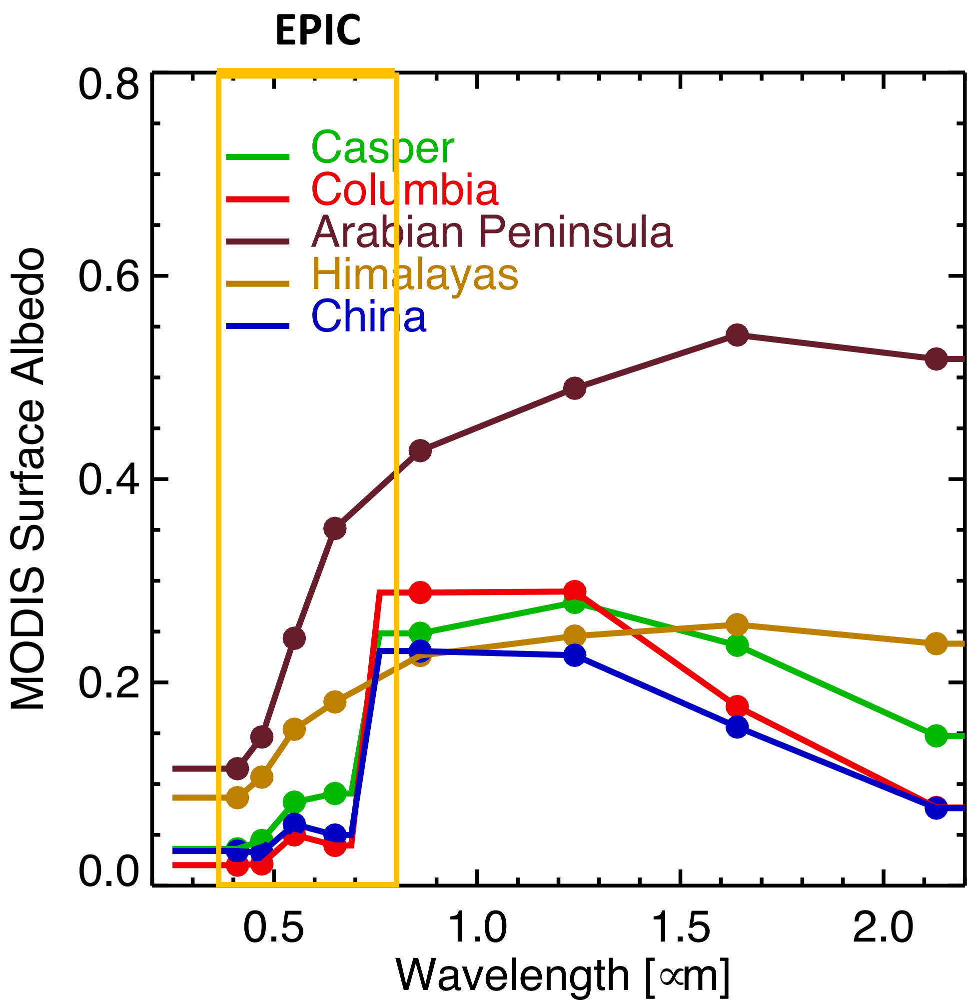


1. Desert, clouds, ocean
2. Land, clouds, ocean
3. Clouds, land, ocean
4. Clouds, land, ocean, vege
5. Clouds, land, ocean, vege





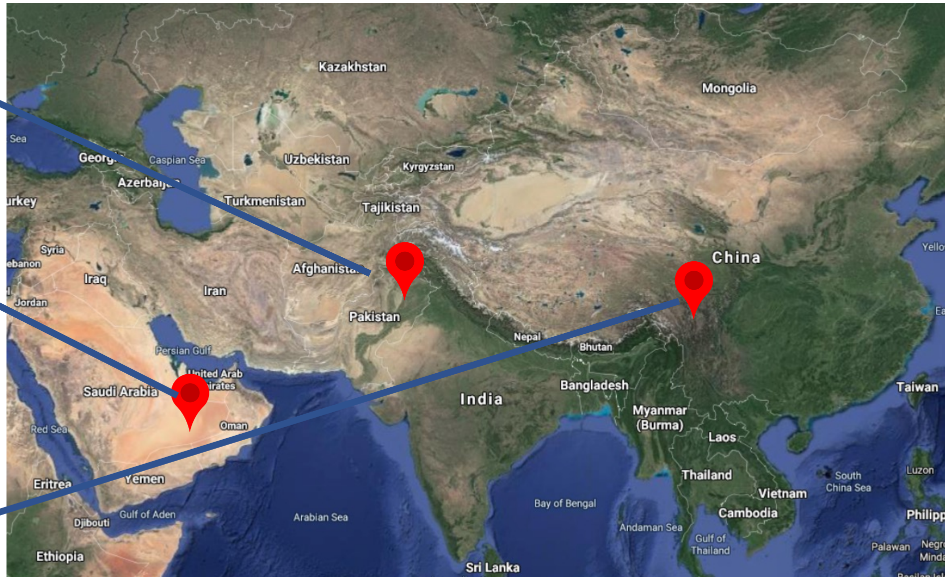
MODIS Surface Albedo and the Center of the Moon's Shadow



Himalayas
30.03°N, 76.94°E

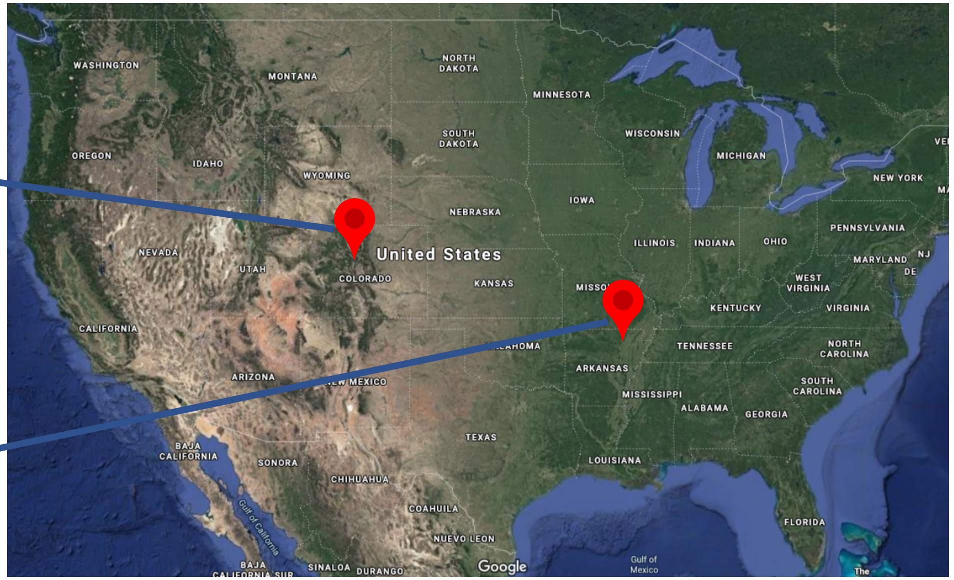
Desert
20.43° N, 53.55°E

China
29.73°N, 101.16°E

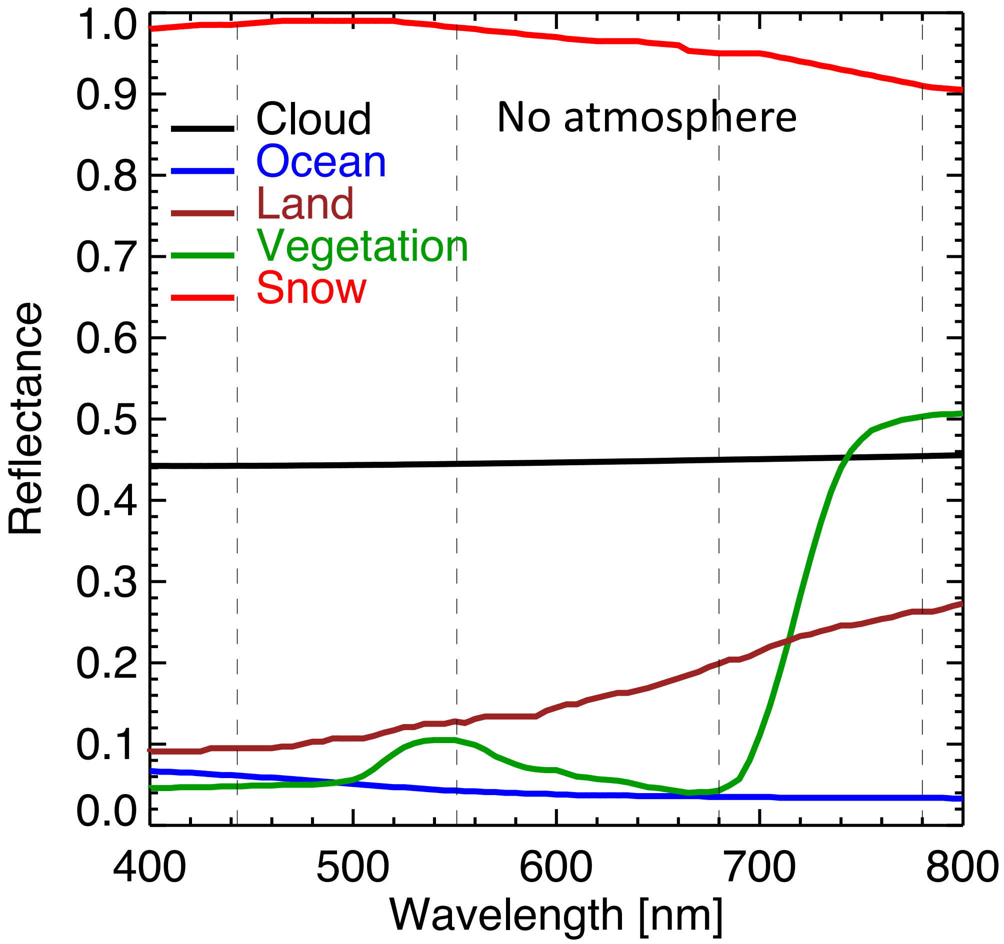


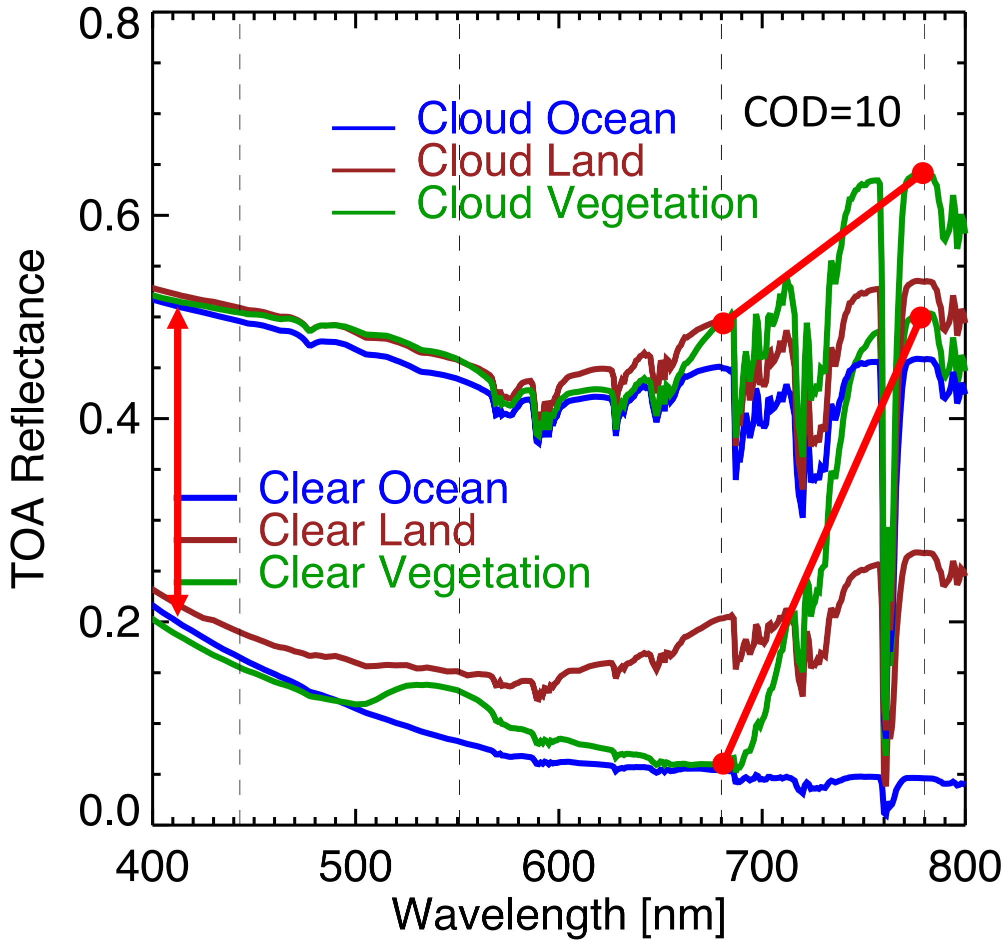
Casper, WY
42.87°N,106.31°W

Columbia, MO
38.95°N,92.33°W



Surface Spectral Albedo and TOA Spectral Reflectance



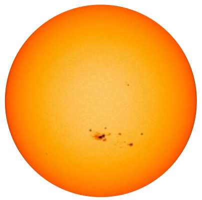


TOA spectral reflectance depends strongly on surface spectral albedo and cloud properties and the wavelength dependence of Rayleigh and aerosol scattering

Apparent and True Reflectance

For eclipse, we have apparent reflectance

$F_{0,\lambda}$



$$R_{e,\lambda}(i,j) = \frac{\pi I_\lambda(i,j)}{F_{0,\lambda}}$$

where $I_\lambda(i,j)$: eclipse radiance of pixel (i,j),

$F_{0,\lambda}$: incident spectral solar irradiance at TOA without eclipse.

For non-eclipse, the reflectance is

$F'_{0,\lambda}$

$$R_{ne,\lambda}(i,j) = \frac{\pi I_\lambda(i,j)}{F'_{0,\lambda}(i,j)}$$

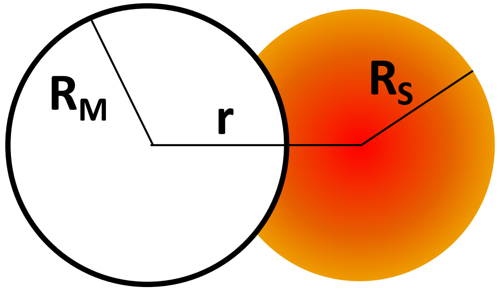
$F'_{0,\lambda}$: solar irradiance for uncovered solar disk

$$R_{ne,\lambda}(i,j) = \frac{R_{e,\lambda}(i,j)}{I_{norm,\lambda}(i,j)} \quad \text{and} \quad I_{norm,\lambda} = \frac{F'_{0,\lambda}}{F_{0,\lambda}}$$

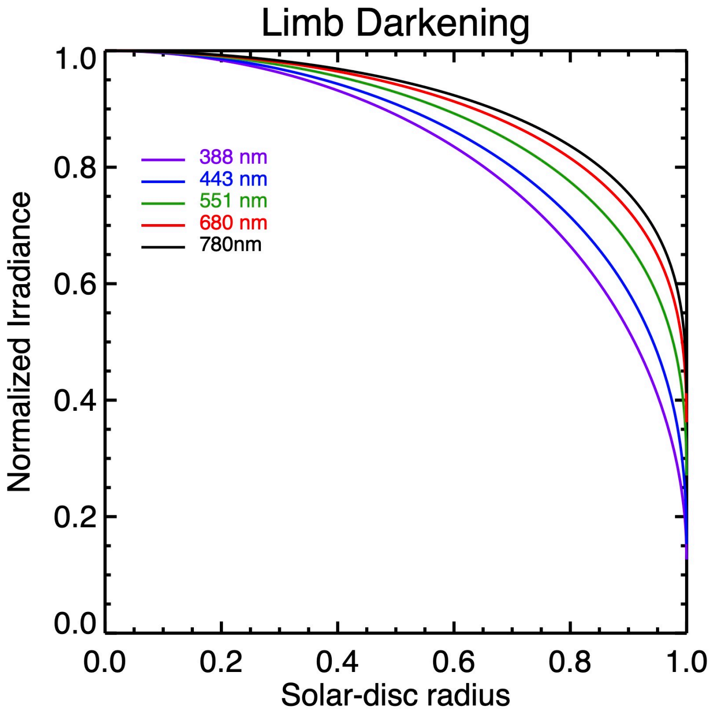
TOA Solar Irradiance

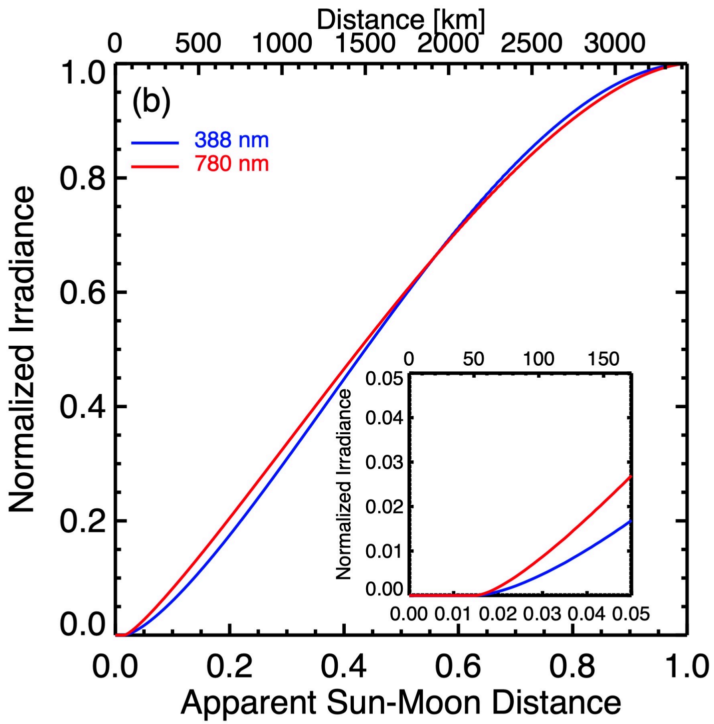
Reflectance reduction: $\Delta R_\lambda = (1 - I_{norm,\lambda})R_{ne,\lambda}$

Computing TOA Spectral Brightness



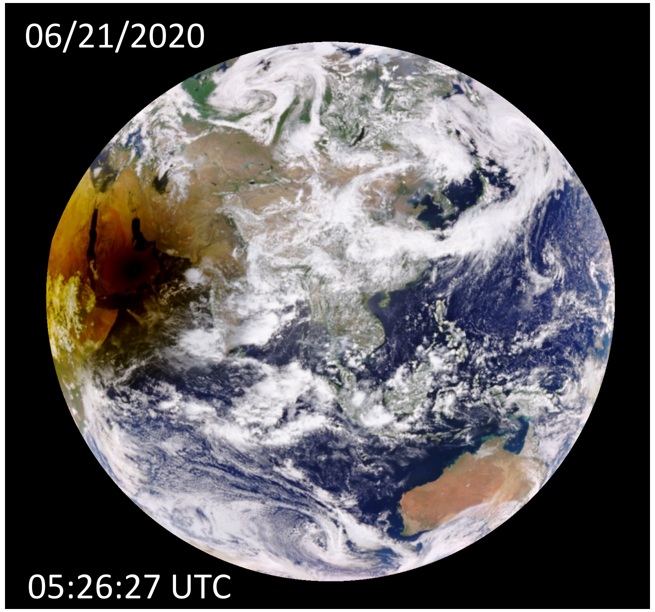
Sun-Moon Distance:
$X = r/(R_M+R_S)$

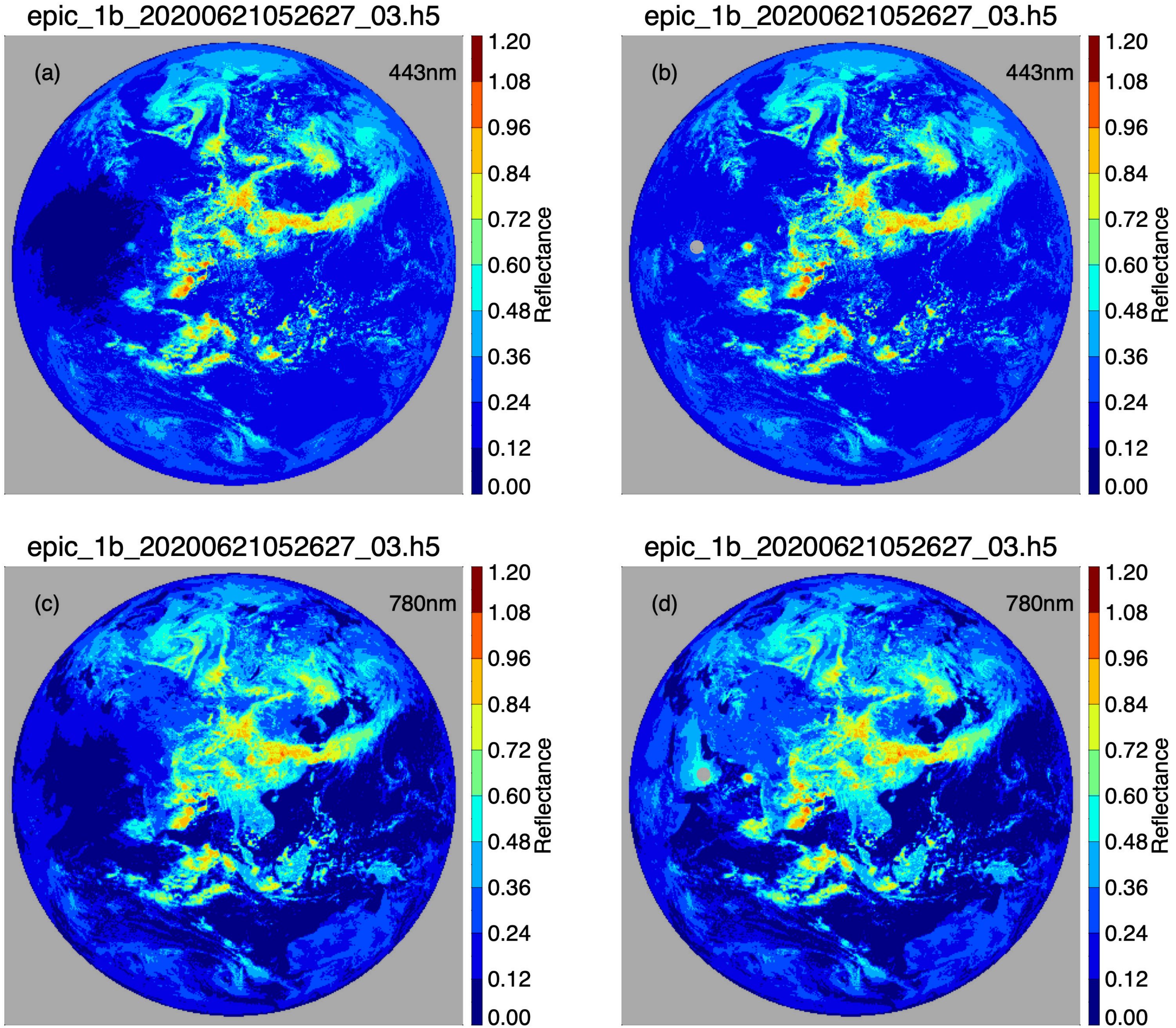




- Limb darkening: spectral solar irradiance decreases towards the edge of solar disk (wavelength dependent) (Neckel 2005).
- Integrate the uncovered part of Sun's disc to obtain the reduced brightness (Koepke et al, 2001).

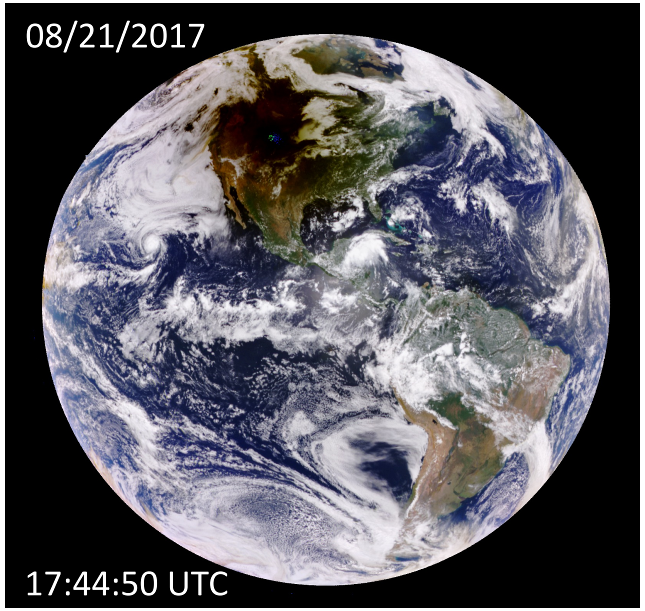
Recover Non-eclipse Images

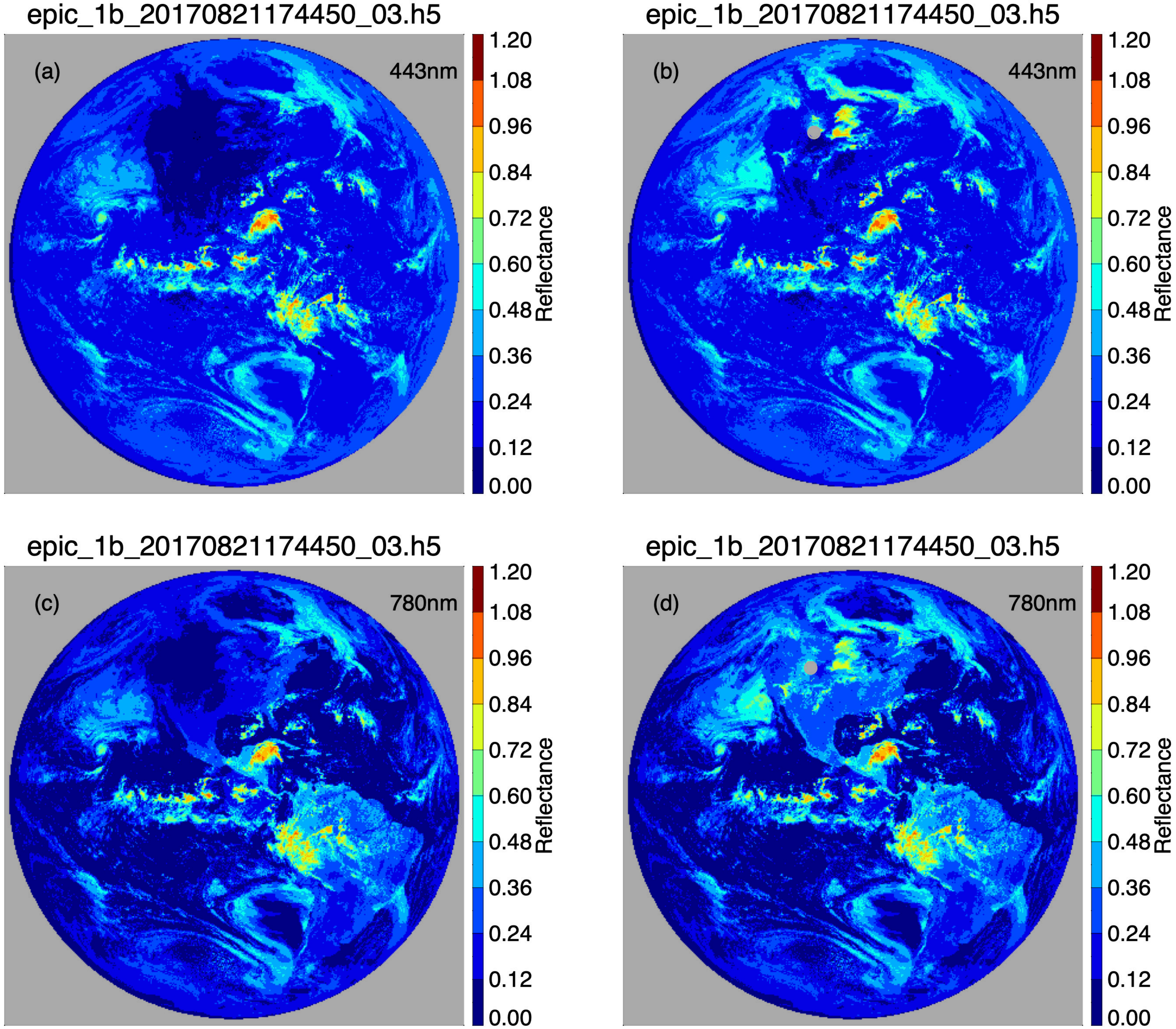




June 21, 2020 eclipse over the Arabian Desert

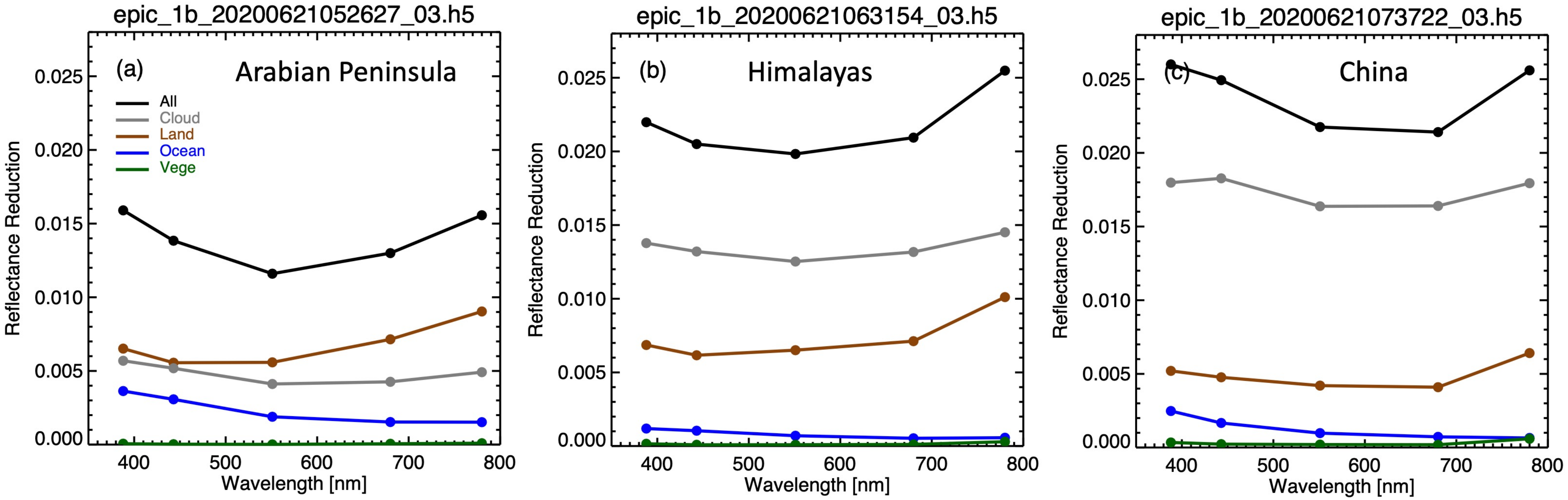
Recover Non-eclipse Images





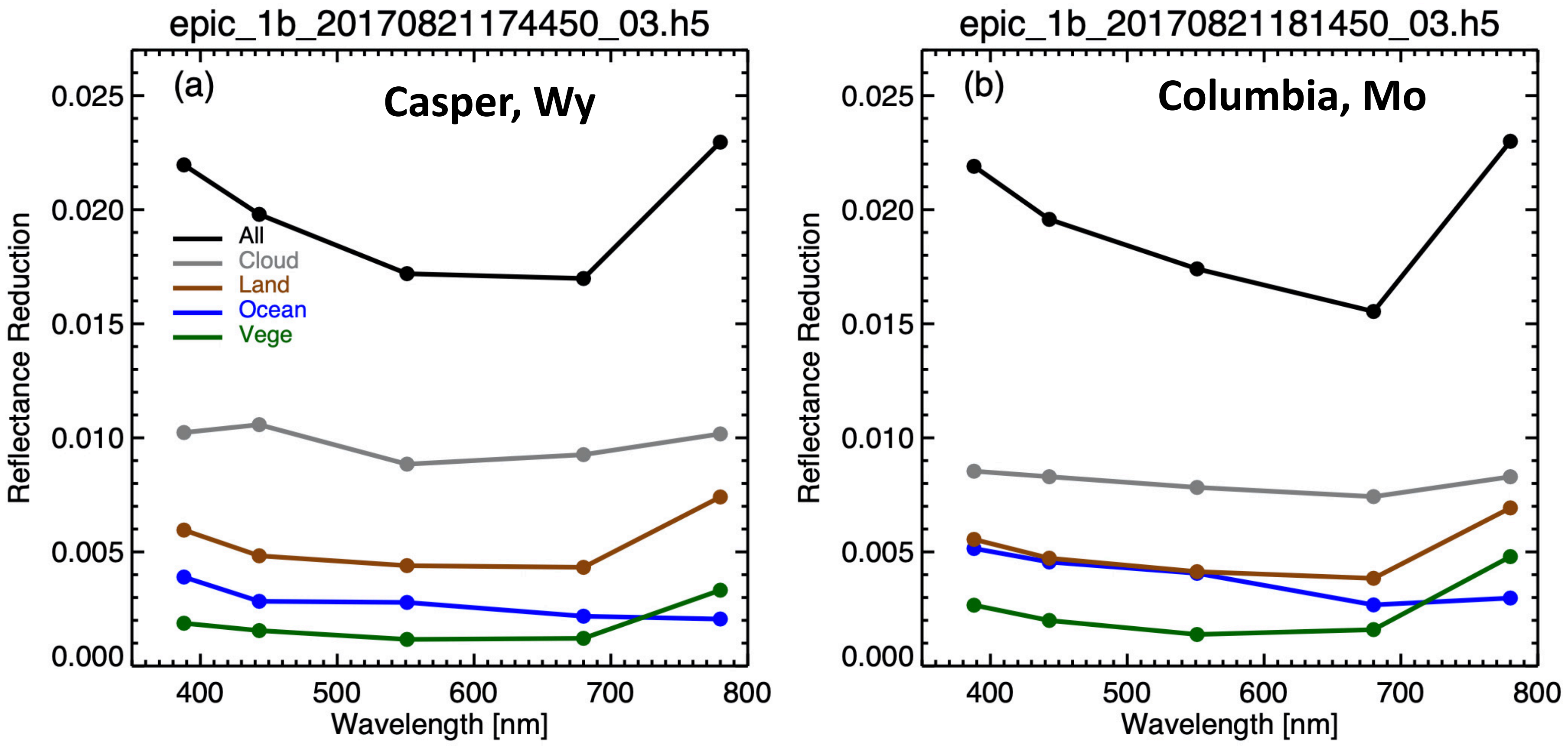
August 21, 2017 eclipse over Casper, Wy

Reflectance Reduction Contribution from Different Reflectors



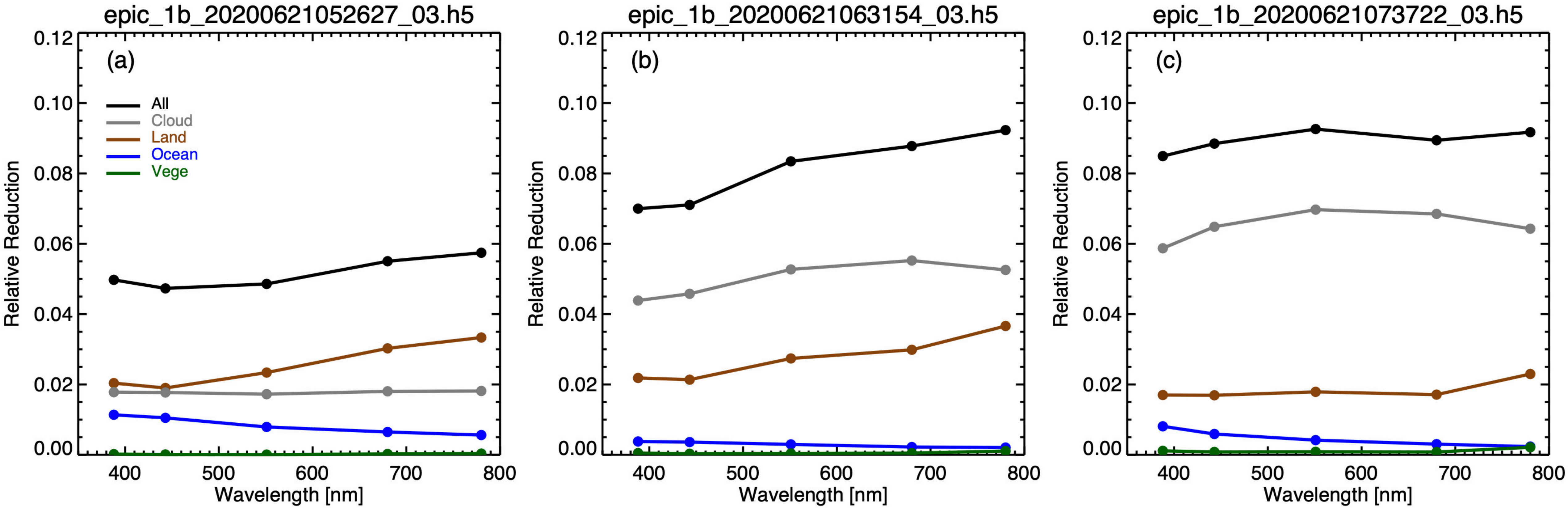
Reflectance reduction depends on surface properties and cloud fraction. The ERTI is used to classify different reflectors.

Reflectance Reduction Contribution from Different Reflectors



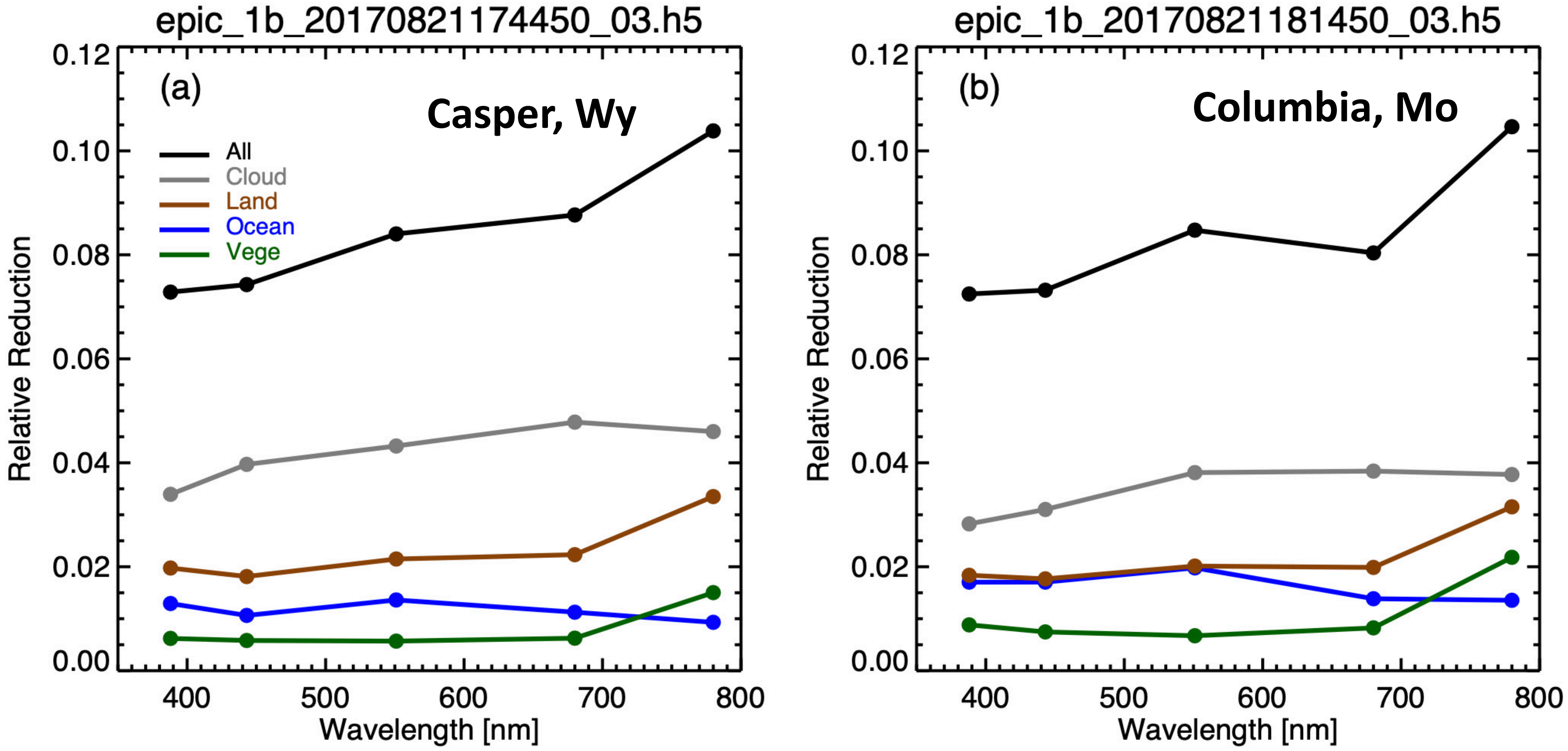
Spectral reflectance reduction depends on surface properties and cloud fraction.

Relative Reflectance Reductions



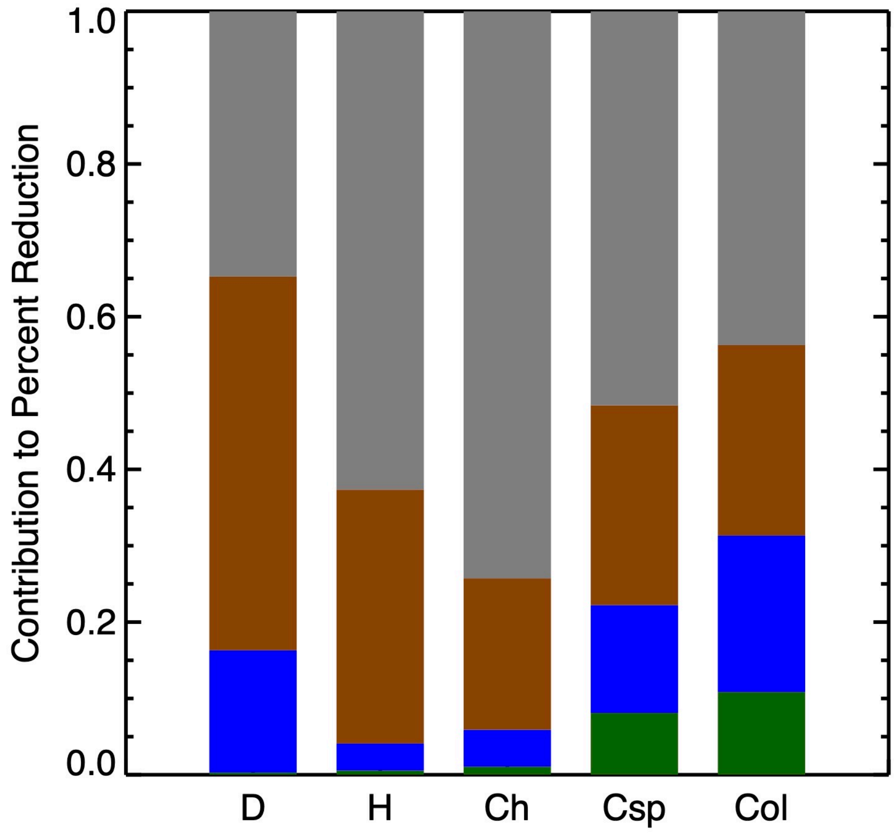
About 5%, 8%, and 9% reduction in global and spectrally averaged reflectance when the center of the Moon’s shadow is in Arabian Desert, Himalayas, and Southwest China during 2020 eclipse.

Relative Reflectance Reductions



About 8% reduction in global and spectrally averaged reflectance for 2017 solar eclipse

Summary of Relative Reduction



Reflectance reduction for the Arabian Desert (D), Himalayas (H), Southwest China (Ch), Casper, Wy (Csp), and Columbia, Missouri (Col).

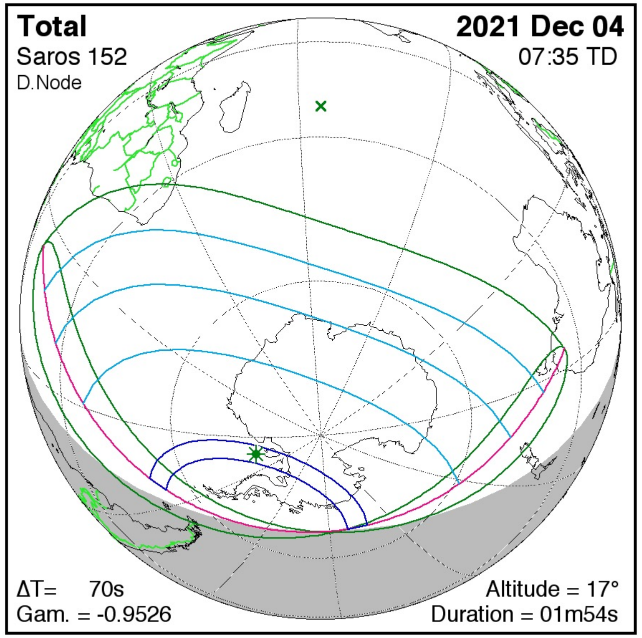
Summary

- **A method has been developed to recover image for *hypothetical* non-eclipse conditions**
- **Estimates of reflectance reduction for different surface conditions and cloud properties (mid-latitude: America, Desert, Himalayas, China)**
- **Understand the spectral dependence of the reduction**

Future Work

- **Study the impact of solar eclipse in Antarctica on December 4, 2021 on reflected spectral solar radiation from EPIC and broadband radiation from NISTAR (very rare event, next solar eclipse in Antarctica will be 2039)**
- **Study the eclipse-induced changes in *SW radiation budget* from EPIC and NISTAR**

www.EclipseWise.com/eclipse.html



Thousand Year Canon of Solar Eclipses
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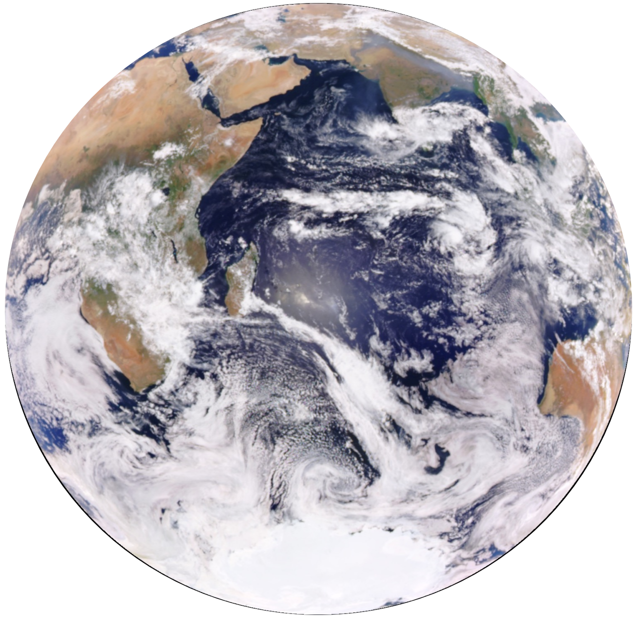

December 5, 2020