Lunar Observations of Changes in the Earth's Albedo (LOCEA)

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in collaboration with

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Motivation

Earth's global albedo (A) -- is known (0.29)

$$T_{eff}^4 = F(1\text{-}A)/(1\text{-}g)$$

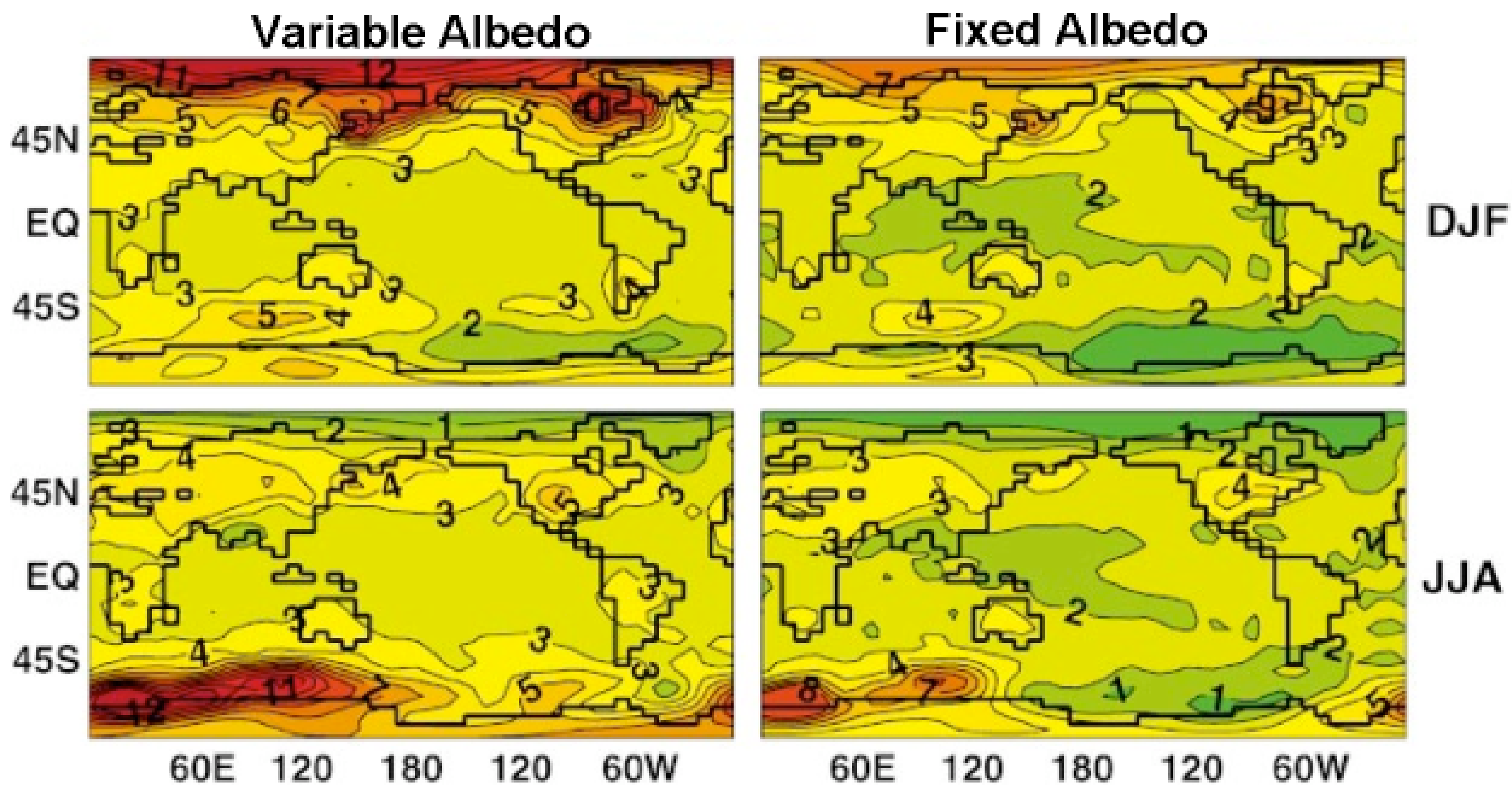
Deviations from global

-- included in most models as fixed distribution

-- $\delta A = 0.01$ changes the energy balance by 3.4 W/m^2, comparable to the impact of doubling CO_2 (Wielicki et al, 2005)

-- induced by changes in cloud cover (also due to CO_2!), and by aerosols, snow, ice, forest cover, etc.

Effects of Albedo Change



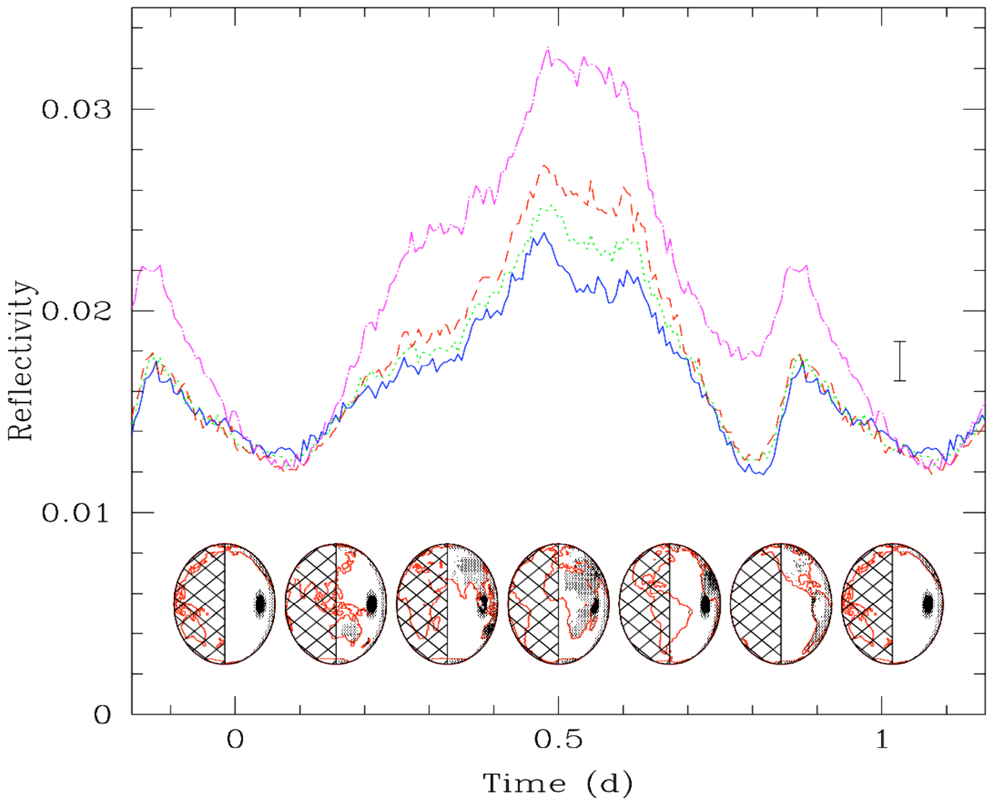
SAT (°C) doubling CO_2 run with fixed and variable (feedbacks) albedo distribution (Hall, 2004)

Expected Albedo Variations

Planetary scale north-south variations	-- 40%
Day-to-day Variations	--12%
Seasonal variations	-- 3%
Year-to-year variations	-- 2%

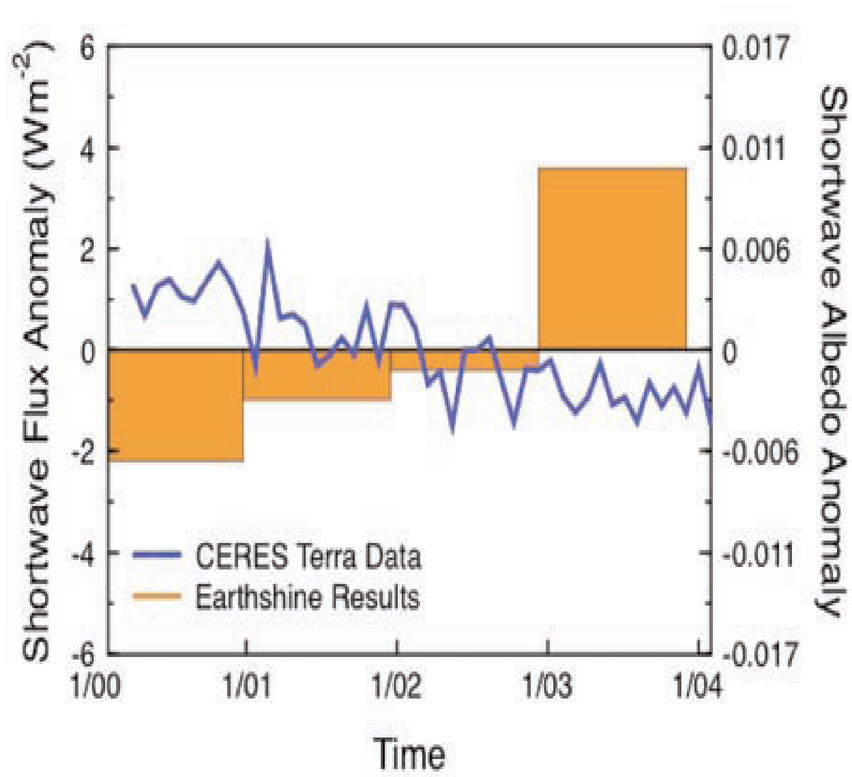
Pinatubo eruption (1991) changed albedo by 0.007
(2.5 extra W/m^2 for 2 years)

Modeled Albedo Changes



Modeled albedo of Earth's surface (no clouds, no atmosphere) at Sun-Earth-Moon phase angle = 90 deg *vs.* time for one rotation. The curves are for 750 nm (top), 650, 550, and 450 nm (bottom). Differences reflect the wavelength-dependent albedo of different components. Sahara desert sand causes a peak in the reflectivity curve.

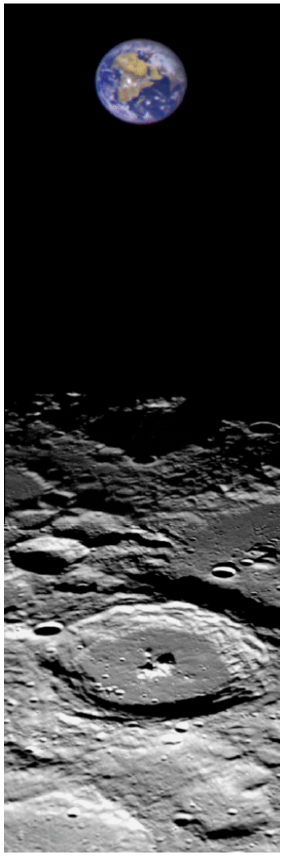
Current Measurements



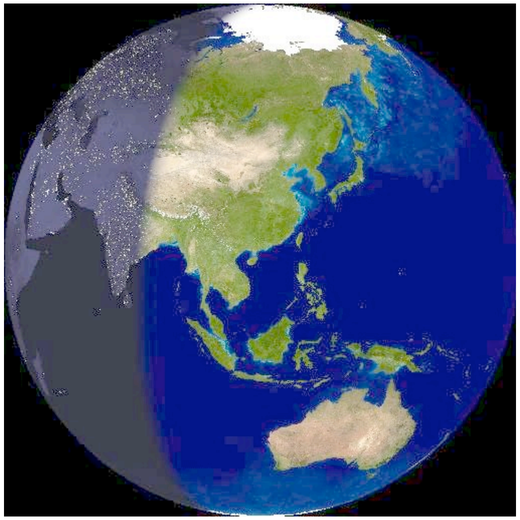
Measurements from LEO polar orbits (Nimbus 6&7, ERBE, CERES, MISR), GEO satellite (GERB), and ground (Lunar Earthshine) show different albedo changes.

Data are not uniform in time and spatial coverage. The main need is to observe reflected radiances from all Earth points at all angles.

Lunar Opportunity

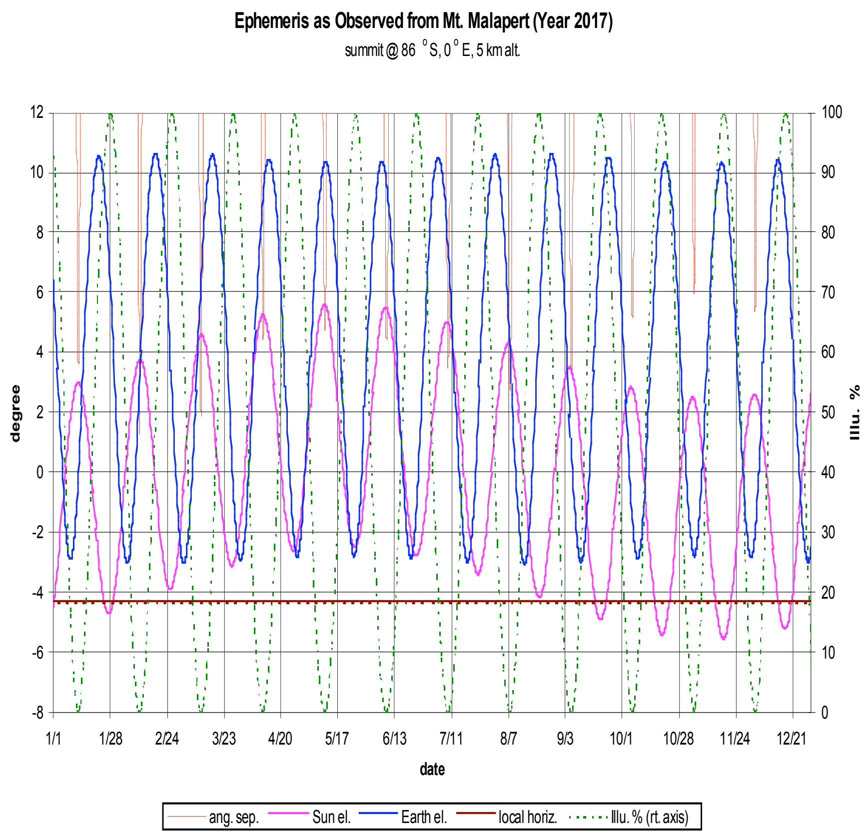


Clementine



The Earth viewed from the Moon (left) September 1, 2017 and (right) September 15, 2017. Images generated using J. Walker's code http://www.fourmilab.ch/earthview/vplanet.html

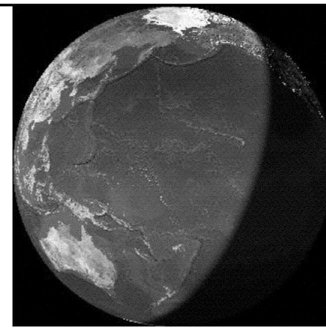
Observing from the Moon’s pole

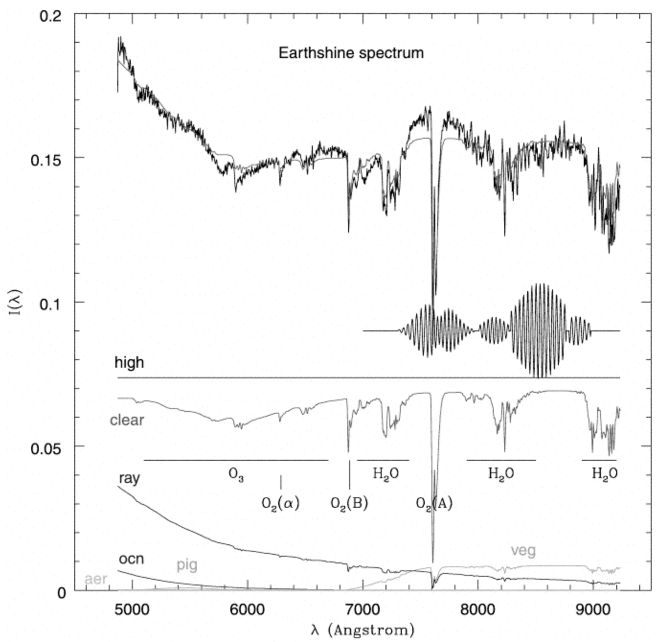


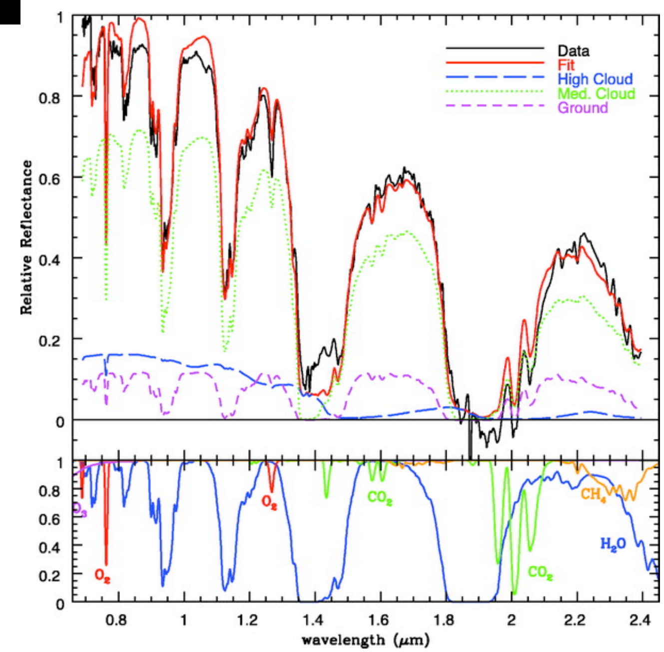
Example of elevation plots at Mt. Malapert near the Moon’s South Pole in 2017: lunar horizon (brown), the Sun (pink), the Earth (blue), the percentage of the Earth that is illuminated (green).

The Earth is always visible and the Sun is almost always visible.

Observables: spectrum, imaging







Visible spectrum (Woolf et al. 2002) fitted with 7 components: ‘clear’, high clouds, Rayleigh scattering, ‘vegetation’, ‘ocean’, ‘aerosols’, ‘pigments’ reflection.

Near-infrared Earthshine spectrum (Turnbull et al. 2006). Data and model are shown, including sea-level altitude surface, high land, and two types of cloud.

Benefits of Having LOCEA

- Homogeneous Longitude Sampling
- High temporal (hours) and spatial resolution (10 km)--separate cloud from surface contribution. Polar regions.
- Diurnal Cycle of the albedo
- Lifetime longer than any satellite’s; to monitor seasonal and interannual variability of the Earth's reflectance
- Calibration potential for great reliability in long- term measurements (a crucial factor in climate change studies, and the Achilles heel of satellite measurements)
- Low Cost

Instrument Requirements

- A stable platform pointed at the whole Earth. The ~±6° librations can be tracked with steering mirror in front of telescope
- Wavelength range -- 300 - 3000 nm
- Optics should capture light from the Earth seen as a 2° disk. Flux is large, 10^5 e/(s pixel) in visible
- For resolution of 100 x 100 $pixel^2$, 25 microns pixel, and the imaging beam is f/4, the telescope aperture be roughly 2 cm
- Calibration. Episodically measuring or getting solar flux.

Conclusions

- From *Lunar South Pole* LOCEA will measure changes in albedo with good coverage, short time resolution, and great calibration
- These measurements will be carried out for a much longer period of time than is possible with any instrument in orbit