Changes in Earth's Albedo Measured by satellite

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Earth's albedo

- The climate of Earth is determined by the balance between the absorbed solar radiation by surface and atmosphere, and the outgoing longwave radiation
- The former is depends on Earth's albedo and the latter is determined by the atmospheric content of gases and particles such as aerosol (dust) and clouds
- Whereas the theory of absorption by gases is well accepted, the observational and theoretical treatments of albedo, aerosols and clouds are still under the development

Earth's albedo (2)

- The albedo of Earth is the fraction of the global incident solar radiation that is reflected back to space
- The albedo can be changed with changes in Earth's cloud fractional coverage, aerosol amount, forest cover, or snow and ice cover
- The understanding the natural and anthropogenic changes in Albedo and the indirect or simultaneous observation of albedo with all diverse methods are important
- For determining climate state, the albedo change is as important as the change of the amount of greenhouse gases
- For example, the change of albedo of 0.01 is comparable to global energy balance change of 3.4 Wm^{-2} (average incident solar radiative flux is 341 Wm^{-2}) which is similar in magnitude to the impacts of doubling carbon dioxide in the atmosphere

Different methods to estimate Albedo

- The methods are (1) the measurement of earthshine reflected from the Moon (Wielicki et al., 2005) (2) the broadband radiometer data from low orbits around Earth (in this paper) and (3) surface radiometry (Pinker et al., 2005). All these methods require a theoretical model for relating the measured parameter to albedo, in which they are rely on different assumptions. Therefore, the comparison of the results from different methods is required to test the consistency
- Many different methods differ in their scattering geometrics, calibration accuracy, and spectral, space, and time coverage, in which the albedo is not directly measured
- Among these methods, the authors in this paper try to validate the data to support the decrease of albedo for 2000 through 2003 using the broadband radiometer data from CERES (Clouds and the Earth's Radiant Energy System) experiment

Major measurements objective for CERES and complementary imagers (EOS-AM, EOS-PM and TRMM) [Wielicki et al., 1996]

Output products	Comments
TOA radiative fluxes	SW, LW(up)
Angular-dependence models of solar and thermal infrared radiation	SW, LW, vary with surface and cloud condition
Cloud properties	Amount, height, thickness, SW and LW optical depth, particle size, particle phase
Atmosphere radiative fluxes	SW, LW (up, down, net)
Surface radiative fluxes	SW, LW (up, down, net)

Error budget (W m^{-2}) :

TOA net flux (1.25 lat/long)

[Wielicki et al., 1996]

Source of error	Monthly averaged global bias	Monthly averaged regional	Daily averaged regional
Angular sampling	0.9	1.2	3.5
Time sampling	1.1	2.3	8.1
Instrument calibration	1.6	1.6	1.6
Total	2	3	9
Science requirement	0.2-1	2-5	5-10

Large inconsistencies in change of albedo [Charlson et al., 2005]

Climate observations ad forcing	Equivalent change in albedo x 10^3
Enhanced greenhouse effect during industrial era	-7 ± 0.6
Anthropogenic aerosol forcing during industrial era	+4 ± 4
Albedo change estimated from earthshine data(2000 to 2004)	+16
Albedo change estimated from low-orbit satellite data(2000 to 2004)	-6
Change in irradiance at Earth's surface measured with satellites (1983 to 2001)	-8
Change in irradiance at Earth's surface measured at the surface (1985 to 2000)	-13
Change in irradiance at Earth's surface measured at the surface (1950 to 1990)	+20

Results from this paper

- This paper says that the decrease of ~2 Wm^{-2} in shortwave reflected flux or albedo decrease of 0.006 for 2000 through 2003
- Palle et al. say that increase of 6 Wm^{-2} in the reflected flux or increase of albedo 0.017 for same time period
- The authors state that the albedo should not increase because there is no record of the comparative large global cooling
- The authors state that the large increased albedo does not match with the increase of global ocean heat storage
- The authors state that there is no large cloudiness change that would be required to match the increased global albedo from 2000 to 2004

Implications

- The most fruitful validation is not simply the comparison of end results, but rather validation of underlying assumptions. For example, the authors in this paper more focus on comparing the end results (albedo) from the independent observations, such as Earthshine and CERES Terra satellite measurements.
- The fact that two different observations give totally different trends in the change of albedo implies that people need to put more efforts to not only qualify but also quantify the change in the albedo.
- The GCM type modeling analysis of the change in the albedo needs to be performed on the basis of the observations from various satellites, ground and aircraft measurements, in order to figure the effect of aerosol and cloud, and cloud feedback.