What Controls Planetary Albedo and its Interannual Variability?

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1. Motivations

Determine the relative contributions of the surface and atmosphere to planetary albedo and its interannual variability at different locations

2. Data

ISCCP D-series cloud and flux data sets (1984-2000)

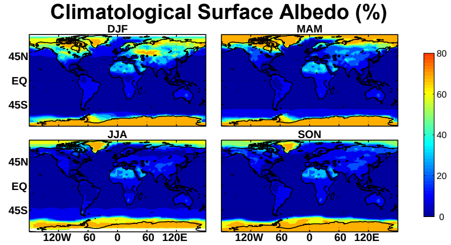
3. Climatological Planetary Albedo

$$\alpha_p = \alpha_a + T_{e^*}\alpha_s$$

Atmospheric effective transmissivity (T_{e^*})

Planetary albedo (α_p), Atmospheric albedo (α_a), Surface albedo (α_s)

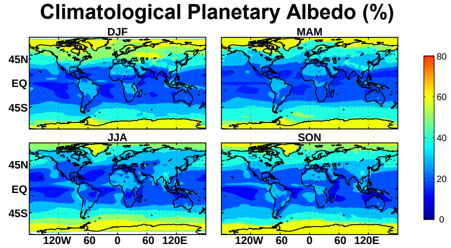
Climatological Surface Albedo (%)



(1) Highest in snow and ice-covered areas, lowest in ice-free oceans, and intermediate in Sahara and Saudi Arabia deserts.

(2) Displays large seasonal variations in NH extra-tropical land areas, Arctic and the circumpolar ocean.

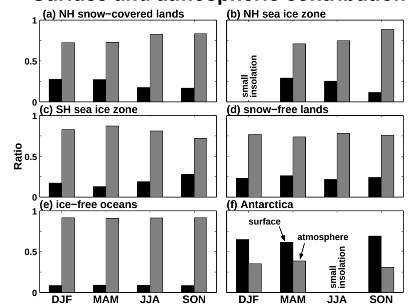
Climatological Planetary Albedo (%)



(1) Considerably higher in the cryosphere regions than elsewhere.

(2) Displays large seasonal variations in NH extra-tropical land areas, Arctic and the circumpolar ocean, consistent with seasonal variations in surface albedo there.

Surface and atmospheric contributions



(1) Surface contribution is much smaller than atmospheric contribution in nearly all regions with the exception of Antarctica. This can be attributed to relatively small surface albedo and the damping effect of the atmosphere on the surface contribution, represented by effective transmissivity.

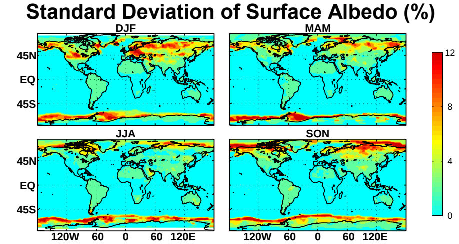
(2) In Antarctica, a relatively transparent atmosphere and large surface albedo are jointly responsible for the large values of surface contributions.

4. Planetary Albedo Variability

$$(\alpha'_p)^2 = (\alpha'_{ps})^2 + (\alpha'_{pc})^2 + 2(\alpha'_{ps},\alpha'_{pc}) + (\alpha'_r)^2$$

Planetary albedo variability ($(\alpha'_p)^2$); Surface contribution ($(\alpha'_{ps})^2$); Cloud contribution ($(\alpha'_{pc})^2$); Covariance between surface and cloud ($2(\alpha'_{ps},\alpha'_{pc})$); Residual term ($(\alpha'_r)^2$)

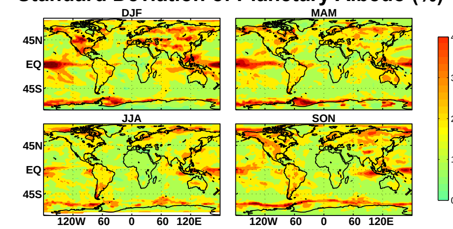
Standard Deviation of Surface Albedo (%)



(1) Shows large variations during all seasons due to snow variability on NH mass, though the pattern differ from one season to another.

(2) Shows significantly large variations in the Arctic and circumpolar ocean, consistent with the seasonal migration of the sea ice margins.

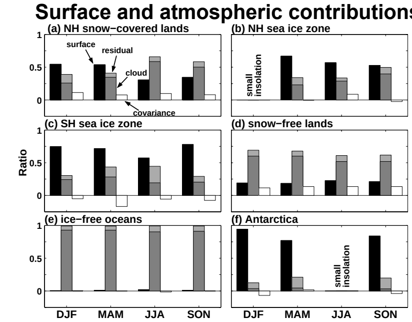
Standard Deviation of Planetary Albedo (%)



(1) Shows large values in the cryosphere and tropical oceans.

(2) Shows seasonal variations the cryosphere: NH land area, Arctic and circumpolar ocean.

Surface and atmospheric contributions



(1) The surface makes the dominant contribution to planetary albedo variability in snow and ice regions at nearly all times of year. This is because the surface albedo variability is significantly greater than cloud-induced planetary albedo variability in these regions.

(2) The cloud contribution overwhelms the surface contribution over snw-free lands and ice-fre ocean during all seasons.

5. Summary and implication

(1) With the exception of Antarctica, the atmosphere accounts for much more of climatological planetary albedo than the surface. This is mainly because the atmosphere attenuates the surface contribution.

(2) The surface accounts for more than 50% of planetary albedo variability in snow and ice-covered regions at nearly all times of year.

(3) This suggests if cloud fields do not change much in a future warmer climate, a retreat of snow cover, or sea ice would lead to a significant increase in net incoming solar radiation, resulting in an enhancement of high latitude cilmate sensitivity.

Reference

Zhang,Y-C., et al, 2004: Calculation of radiative flux profiles from the surface to top of atmosphere based on ISCCP and other global datasets: refinements of the radiative transfer model and the input data. Submitted to J. Geophys. Res.