Global modeling of cloud albedo biases from MODIS gridded cloud data

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Background facts

Level-3 daily MODIS gridded 1° products from aggregation of high spatial resolution liquid cloud retrievals of τ and r_e from are used as input to a BB RT algorithm in order to assess the *plane-parallel homogeneous (PPH) albedo bias* defined as the difference between PPH and ICA albedos:

$$B^R\left(\bar{\tau},\bar{r}_e,v_{\tau,r_e}\mu_0\right)=\mathbf{R}\left(\bar{\tau},\bar{r}_e,\mu_0\right)-\int\int\mathbf{R}\left(\tau,r_e,\mu_0\right)p(\tau,r_e)d\tau dr_e \qquad (1a)$$

where μ_0 is the cosine of the solar zenith angle, v is a measure of either τ or joint τ-r_e variability (e.g., a shape parameter of the 2-D probability density function $p(\tau, r_e)$), and $\mathbf{R}$ is the reflectance function (e.g., the analytical solution of the two-stream approximation). If the r_e spatial variability is neglected Eq. (1a) reduces to:

$$B^R\left(\bar{\tau},\bar{r}_e,v_\tau,\mu_0\right)=\mathbf{R}\left(\bar{\tau},\bar{r}_e,\mu_0\right)-\int\mathbf{R}\left(\tau,\bar{r}_e,\mu_0\right)p(\tau)d\tau \qquad (1b)$$

One can extend the PPH bias analysis to the SW Cloud Radiative Forcing ($SWCRF$) defined as the difference between clear and all-sky reflected TOA fluxes:

$$SWCRF=F^{clr}-F^{all-sky}=A_c(F^{clr}-F^{cld})$$

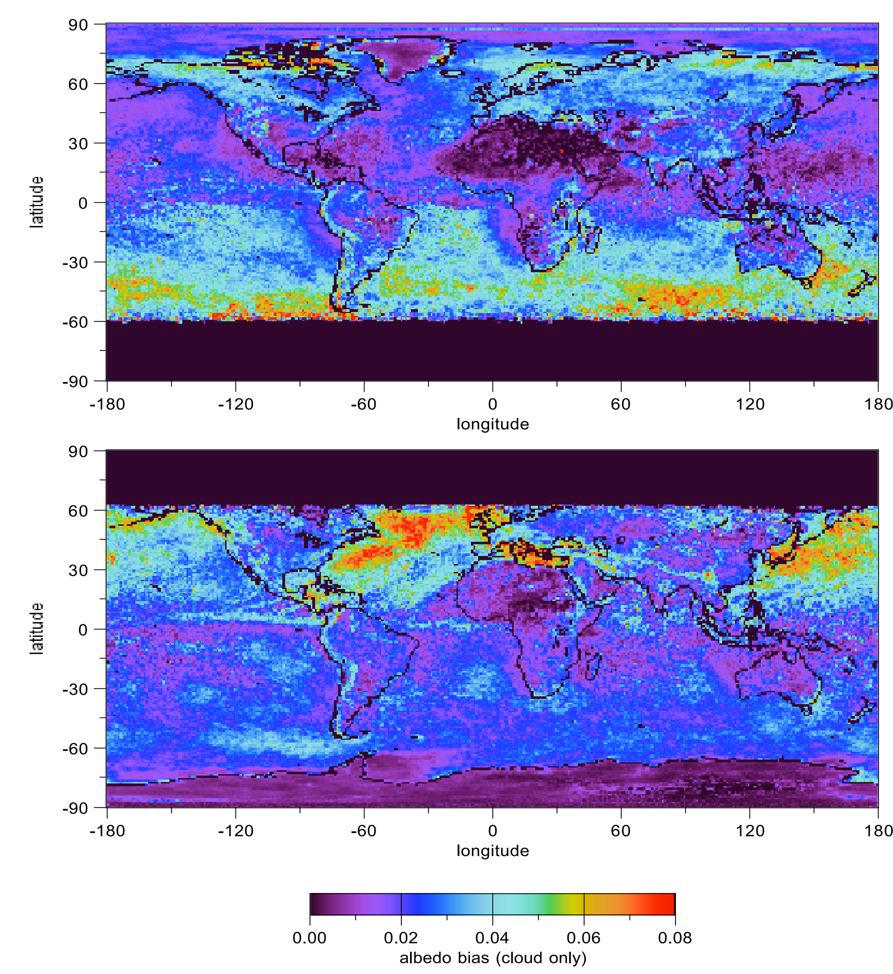
The bias in $SWCRF$ is simply:

$$B^{SWCRF}=SWCRF_{PPH}-SWCRF_{ICA}=-A_c(F^{cld}_{PPH}-F^{cld}_{ICA}) \qquad (2)$$

The RT calculations yielding daily atmospheric column albedo and $SWCRF$, are performed with a modified version of the SW Column Radiation Model used in Goddard GCMs. To isolate the albedo of the clouds themselves, one can easily switch off the atmosphere and surface (i.e., clouds in a vacuum). For full-column calculations, the values of surface albedo to diffuse incidence, and the concentrations of active atmospheric absorbers are required (aerosols are neglected in our calculations), and come from the same MOD43B3 and NCEP GDAS products used for the MODIS retrievals.

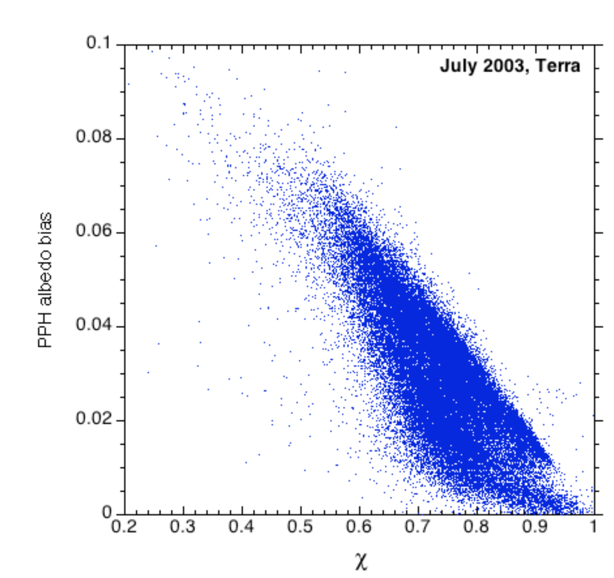
The albedo and $SWCRF$ bias calculations are performed for every day of the month in each gridpoint and are then averaged to monthly values. Due to the generally larger uncertainties in the retrievals and parameterization of wide-band optical properties of ice clouds, we restrict the current analysis to liquid water clouds only.

Geographical distribution

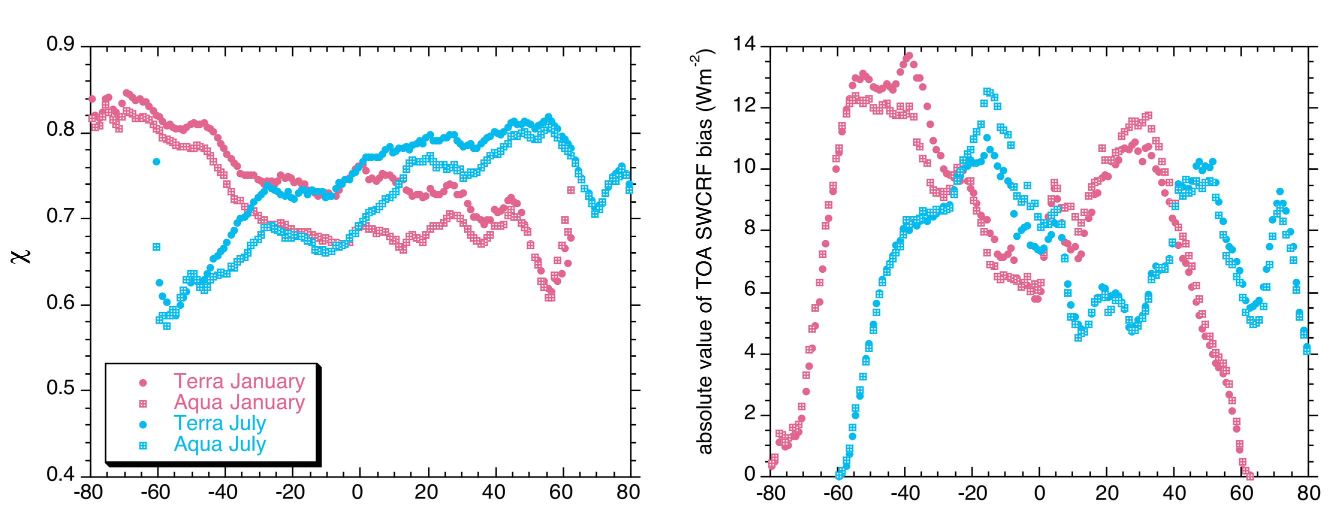


Monthly-averaged PPH albedo bias (Eq. 1b) for the portion of the MODIS Terra Level-3 1°x1° gridpoints filled with liquid clouds. Atmospheric and surface effects are included. Top panel is for July 2003 and bottom panel is for January 2004.

Relationship to cloud inhomogeneity



χ (ratio of logarithmic to linear mean, a measure of τ variability) correlates with PPH albedo bias, but there are other factors to consider (mean τ, SZA, sfc. albedo, averaging)

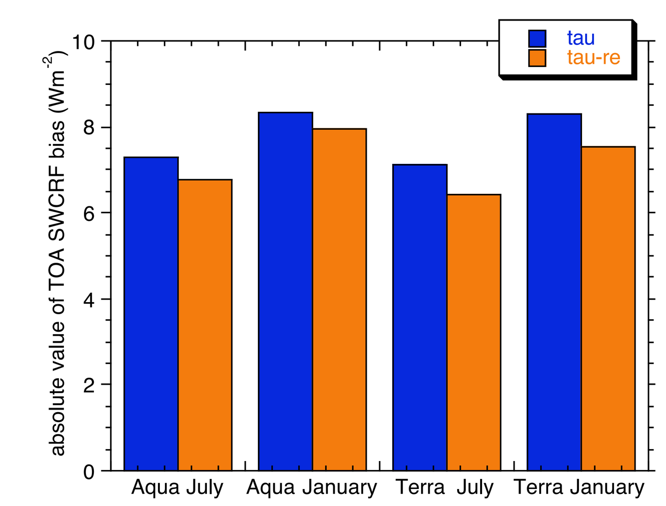


The amount of incident solar energy and the cloud fraction have a big influence on the values of the $SWCRF$ bias so there is no apparent (anti)correlation between the zonal patterns of bias and χ.

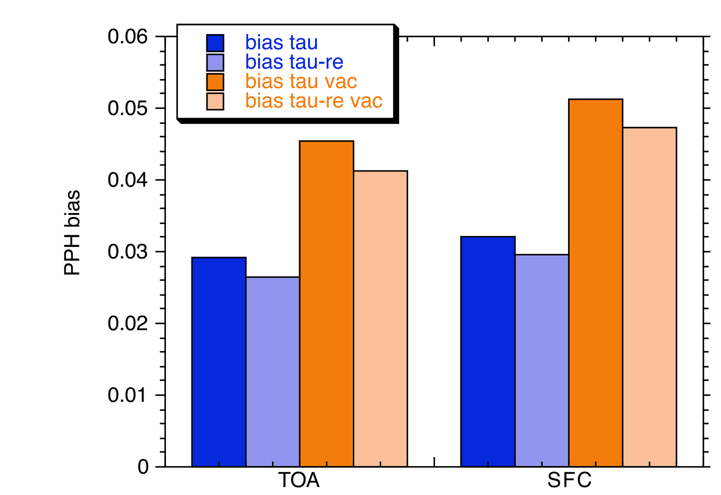
Relevance to global climate modeling

The substantial global magnitude of the liquid cloud $SWCRF$ bias when considers that $SWCRF \approx$ -50 Wm^{-2} globally, due to all types of clouds, stresses the importance of predicting subgrid variability in GCMs and accounting for its effects in cloud-radiation interactions. The results of this study along with those for cloud inhomogeneity derived from the same MODIS dataset (Oreopoulos and Cahalan, JCLI, 2005) constitute a useful validation dataset for GCMs implementing cloud schemes with subgrid prediction capabilities at spatial resolution similar to that of MODIS Level-3.

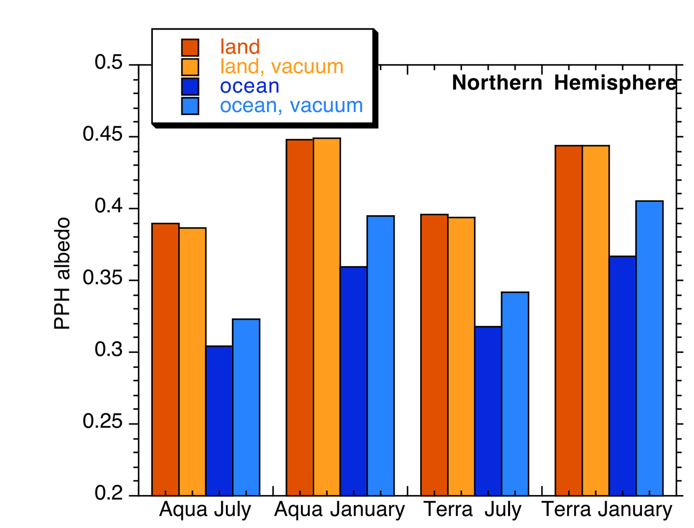
Global picture

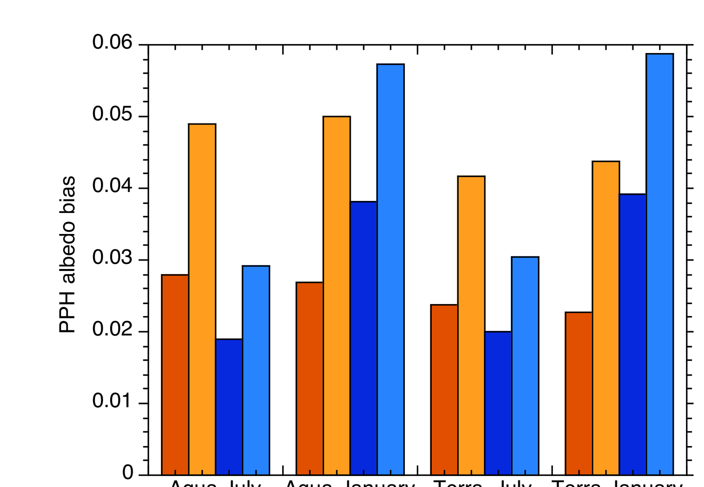


Global absolute values of $SWCRF$ bias. There is greater contrast between the two months than between morning and afternoon within the same month. Please note that since our albedo and insolation are calculated at the time of satellite overpasses which are close to local solar noon, our values, strictly speaking, are not proper diurnal averages, and may represent overestimates of the *SWCRF* bias.



Global albedo (TOA) and fractional absorptance at the surface (SFC) PPH bias. Including r_e variability and atmospheric/surface effects reduces the bias. The difference between TOA and SFC biases is the atmospheric absorptance bias.





Land-ocean contrast and the impact of including surface albedo and atmospheric absorption in the albedo and PPH bias calculations: Over land, an apparent cancellation between the brightening effect of surface albedo and the darkening effect of atmospheric absorption occurs. Over the dark ocean surface however, atmospheric absorption dominates and the full-column albedo is lower than the albedo of clouds in vacuum. Still, for both ocean and land, the PPH bias is smaller for full-column calculations. This simply reflects the fact that the contribution of clouds to the TOA albedo is smaller when atmospheric and surface effects are accounted for.