Arctic Surface Radiation Budget, Clouds, and Sea Ice Extent

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The Arctic sea ice waxes and wanes in accordance with the annual cycle of solar radiation. Sea ice partly melts in the summer when days are long, and then grows back during the winter when sunlight is low or absent. One of the most important characteristics of sea ice is high albedo, causing sea ice to reflect more incoming solar radiation back to the atmosphere than the darker ocean water. Because of the large difference in albedo between sea ice and open water, any small change in the Arctic surface albedo would affect strongly the surface energy budget and thus, the extent of sea ice. This ice-albedo feedback has been regarded as a leading mechanism for the continuing sea ice loss in the Arctic. Nevertheless, the effect of Arctic clouds on sea ice cannot be underestimated. The Arctic is one of the cloudiest regions on the earth. Radiative properties of clouds are similar to ice, as both have high visible albedo and high longwave emissivity. Clouds have dual effects on surface radiation budget. On one hand, clouds reflect more solar radiation back to space and cause a decrease in the downwelling shortwave radiation at the surface. This cloud-albedo forcing tends to have a cooling effect on the surface. On the other hand, clouds trap heat emitted by the earth and re-emit some of that energy back to the surface, causing an increase in downwelling longwave. The increased downward longwave energy would increase the surface temperature until the longwave emission to space once again balances the incoming absorbed shortwave radiation. This cloud-greenhouse forcing tends to have a warming effect on the surface. Depending on the climate conditions such as surface albedo, clouds can either enhance (via longwave warming) or inhibit (via shortwave cooling) the initial surface warming signal in a feedback process known as the cloud-radiation feedback. However, despite the critical role of the clouds in the Arctic climate, polar clouds and their associated radiative interactions are poorly understood due largely to the lack of observations.

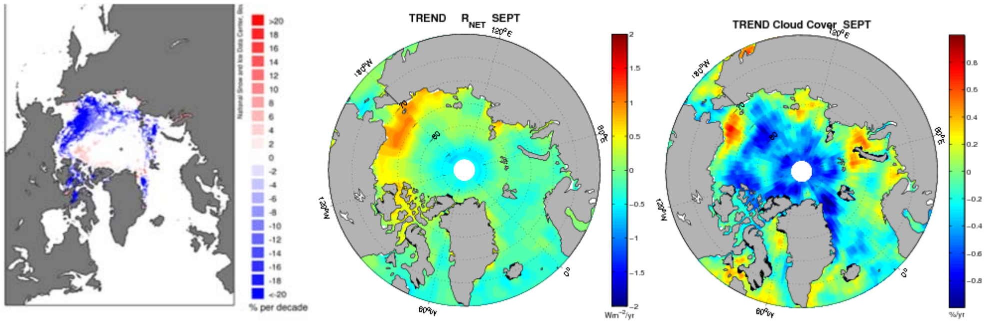

Figure 1. Linear trends in (a) sea ice concentration from National Sea-Ice Data Center, (b) Net downward radiation received at the surface (positive denotes an increase of downward radiation), and (c) cloud cover in September over the ISCCP period 1983-2009.

With support from The James M. and Ruth P. Clark Arctic Research Initiative, I processed the cloud and radiation archives from satellite radiation programs, including the International Satellite Cloud Climatology Project (ISCCP, from 1983 onward), the Global Energy and Water Cycle Experiment-

Surface Radiation Budget (GEWEX-SRB, from 1983 onward), and the Clouds and the Earth's Radiant Energy System (CERES, from 1998 onward) to examine the effects of the sea ice-albedo feedback and cloud-radiation feedback on the surface radiation budget over the Arctic Ocean. The study found that albedo, surface temperature, and clouds have intertwined in a complex manner in affecting the Arctic Ocean surface radiative fluxes, and that the seemingly dominant sea ice-albedo feedback mechanism may have been enhanced by the cloud-radiation feedback process (Figure 1).

I am grateful for the support from The Clark Arctic Initiative for making this research possible. At present, with funding support from NOAA, I am continuing to interpret surface radiation forcing changes in recent years obtained from different satellite sources and meanwhile continuing to develop surface radiative fluxes at high latitudes with improved accuracy.