Studies of Multi-year Variability in Arctic Clouds

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Background

In recent decades there has been a general increase in global surface air temperature. The Arctic is the region of greatest warming with central and northern Siberia experiencing the most pronounced anomalies. Associated with the warming are other climate changes involving the hydrological cycle, cloud and aerosol variations, evolving ecosystems, and dynamical perturbations.

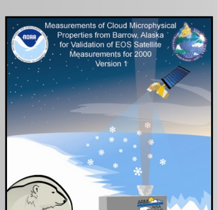
The primary goal of multi-parameter, long-term cloud variability monitoring will be to develop a cloud climate index based on the cloud properties that are shown to be most significant in changing the surface and atmospheric radiation budgets, and with the most potential for affecting, and being affected by other geophysical parameters. It is expected that by additionally quantifying the aerosol effects on changing cloud properties that it will be possible to distinguish anthropogenic effects from natural variability.

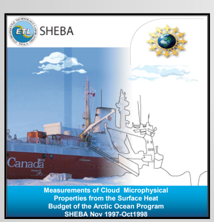
Studies in progress at ETL indicate that the amount of liquid water in clouds, and the related optical depth are likely to be the most important factors in influencing cloud-surface radiation interactions. These are more robust measures than the commonly used cloud amount, because cloud amount provides little information on the cloud radiative effect. Cloud water path and optical depth will therefore be the likely focus for preliminary development of cloud climate indices.

Existing Data Sets

At present, the most comprehensive continuous measurements of Arctic trophosphere variables are made near Point Barrow, Alaska. The combined Barrow facilities include a National Weather Service (NWS) station, the NOAA Climate Monitoring and Diagnostics Laboratory-Barrow Baseline Observatory (CMDL-BRW), and the Department of Energy Atmospheric Radiation Measurement North Slope of Alaska (NSA) site (DOE ARM/NSA). The combined programs provide data needed to understand the processes that determine the regional climate with a focus on how clouds and aerosols affect the surface/atmosphere radiation balance.

A new, recently released surface data set includes complete retrievals of cloud microphysical properties for the years 2000, 2001 and 2002 for Barrow, and Nov-1997 to Oct 1998 for the SHEBA ice camp that was deployed in the Beaufort Sea. In 2004, the NSA cloud data set will be extended to include 1998, 1999 and 2003, providing a 6 year record of cloud properties. (Contact: Taneil.Uttal@noaa.gov)



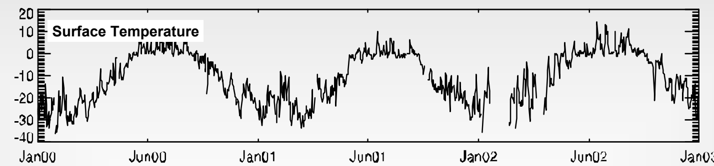


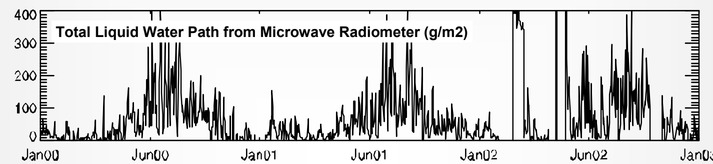
Additionally, satellite meteorological datasets now span two decades and can provide a pan-Arctic, long-term perspective. The primary Arctic cloud satellite dataset is the extended Advanced Very High Resolution Radiometer (AVHRR) Polar Pathfinder (APP-x) and the TIROS-N Operational Vertical Sounder (TOVS) Polar Pathfinder (Path-P) products. The APP-x is comprised of twice-daily composites of all-sky surface temperature and albedo, cloud amount, phase, temperature, effective radius, and optical depth, and radiation fluxes at a 25 km resolution for the period 1982-1999. (Contact: Jeff Key, jkey@ssec.wisc.edu)

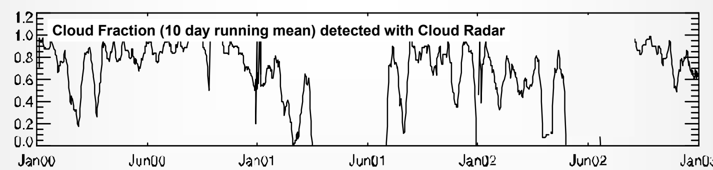
Alternative polar-specific clouds products are available from the TERRA and AQUA MODIS instruments. These are produced by the CERES Science Team. (Contact: Patrick Minnis, p.minnis@larc.nasa.gov)

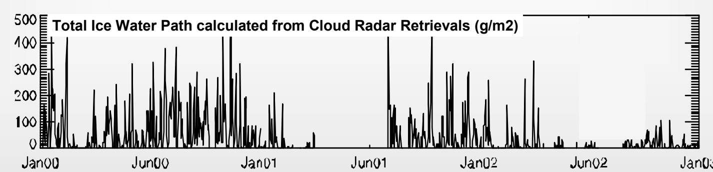
Comparing Multi-year Cloud, Radiation and Aerosol Data Sets

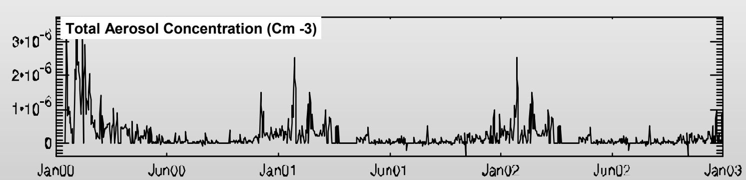
Three year (2000,2001 and 2002) time series are show below of surface temperature, total cloud liquid water path, cloud fraction (10 day running means), total cloud ice water path, and total aerosol concentration. The last panel shows two years (2001 and 2002) of broad band radiometric measurements. A preliminary inspection of data shows the strong annual cycle in surface temperature and cloud liquid water path. Annual variation in cloud amount is more difficult to assess because of gaps in the radar data in the spring/early summer of both 2001 and 2002. In general summers are very cloudy, with decreasing cloudiness through the winter, with a minimum around March. Total aerosol concentrations were higher in 2000 compared to 2001 and 2002 with some indication that there may be a relationship with annual averages in ice water path.



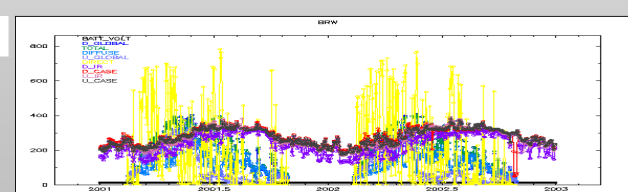








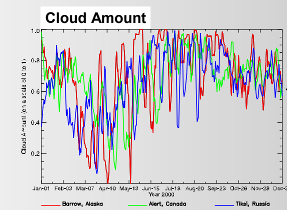
Radiative fluxes W/m2

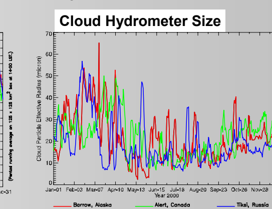


Analysis of Regional Cloud Variability

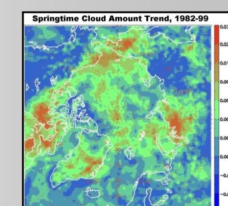
Surface data sets can be compared to satellite data sets to provide confidence in the satellite measurements. The satellite data sets can in turn can be used to "scale-up" the surface measurement and assess regional variability. It is likely that measurements in key regions to augment the Barrow, Alaska measurements will considerably enhance a combined surface-satellite observing system. The NOAA-SEARCH initiative is presently collaborating with Meteorological Services Canada to initiate cloud, aerosol and radiation measurements in Alert and/or Eureka Canada that will mirror the Barrow measurements. NOAA-SEARCH and the Russian academy of science are preparing a MOU that may allow implementation of a third site in Russia.

The figures below show how cloud amount and mean cloud hydrometeor size are compare between Barrow (Alaska), Alert (Canada) and Tiksi (Russia) for the year 2000 using the APP-X NOAA satellite data sets. Significant variations can be seen between the sites that will significantly impact cloud forcing. (Note that the annual trend of cloud amount agrees well with those detected by the cloud radar in Barrow).





Calibrated satellite data sets will provide the foundation for assessing decadal trends in clouds, cloud properties, and accompanying meteorological and surface changes. Trends in springtime Arctic cloud amount during the period 1982-99 based on the extended AVHRR Polar Pathfinder satellite data product are shown to the right..



Summary

The retrospective analysis of surface-based and satellite datasets will increase our understanding of spatial and temporal variability of Arctic clouds and aerosols, surface, and atmospheric properties on seasonal, inter-annual and decadal scales. A comparison of surface and satellite measurements will provide a quantitative assessment of the uncertainty in the satellite-derived quantities, thereby increasing their utility in the analysis of spatial patterns and trends over the Arctic Basin.

A coordinated set of intensive atmospheric measurements in Alaska, Canada, and Siberia that are coupled with an increasingly long satellite record will provide important observational records that will form the basis for understanding the processes that determine the climate of a vast region. Understanding these mechanisms will contribute substantially to improved predictions of future global climate.

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