Impact of Large-Scale Dynamics on ARM Arctic Cloud and Surface Radiation, and Early Snowmelt Events

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Objectives:

This study presents the monthly means of cloud fraction, Net Surface Radiation Budget (both clear and all skies), LWP, PWV, and NCEP reanalysis data collected from 1998 to 2007 at the DOE ARM NSA site. This comprehensive dataset allows us to investigate the following two scientific questions:

1) What is the seasonal variation of Arctic clouds and their impact on surface radiation budget, and how these local cloud and radiation properties associate with the large-scale dynamics?
2) To what extent do the large-scale dynamics play a role in controlling the early snowmelt events of 2002/2007?

Data and Methods:

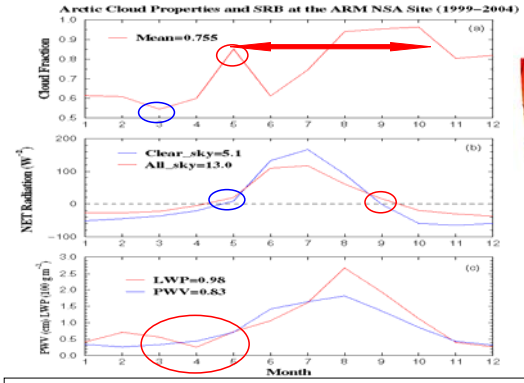
Cloud Fraction (CF): Derived from ARM radar-lidar observations

SW and LW net fluxes: Produced by Radiative Flux Analysis.

LWP and PWV: Precipitable water vapor (PWV) and cloud liquid water path (LWP) retrieved from microwave radiometer measurements.

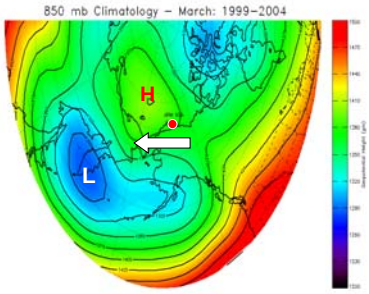
NCEP Global Reanalysis: 2.5° x 2.5° , 6 hourly, 17 levels, Ideally suited for diagnosing synoptic and mesoscale conditions over the ARM NSA site.

Question 1: What is the seasonal variation of Arctic clouds and their impact on the surface radiation budget? How do these local cloud and radiation properties associate with the large-scale dynamics?



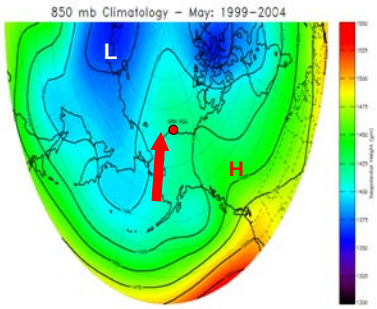
(a) More clouds during warm season (May-Oct.) than during cold season (Nov.-April).
(b) Arctic surface loses radiative energy during Oct. –April and gains radiative energy during May-Sept, and clouds tend to enhance snow melting in spring and impede the solidification of permafrost in autumn.
(c) From March to May, PWV increased from 0.32 to 0.71 cm (120%), and LWP from 56 to 73 gm^{-2} (30%), which is strongly associated with the large-scale dynamics.

March



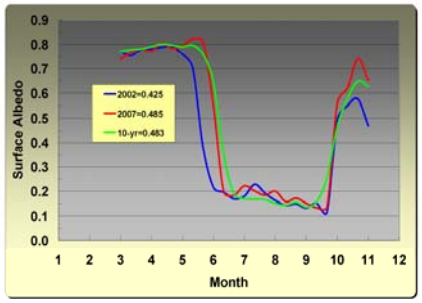
A high pressure located over North of NSA site with subsidence of dry/cold air and blocked Pacific air into Arctic ➔ min. CF in March

May



Predominant southerly airflow in May transports warm/moist air from North Pacific Ocean to NSA that enhances cloudiness there➔A peak CF in May.

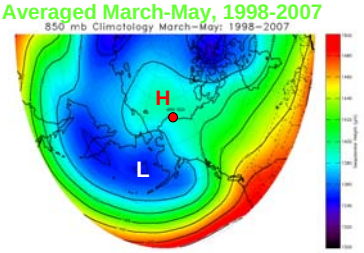
Question 2: To what extent do the large-scale dynamics play a role in controlling the early snowmelt events of 2002/2007?



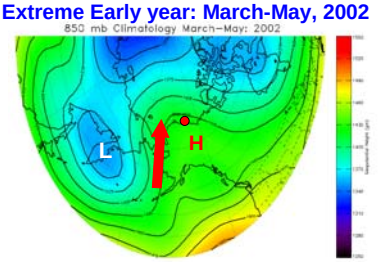
Normal years: Snowmelt from June 10-16 (R_{sfc}<0.3)
Extreme early 2002: Snowmelt from May 20-27
Mild early 2007: Snowmelt from June 1-7.

During the summer of 2007, Arctic sea ice extent reached a new record low.
(Stroeve et al., 2008; Gascard et al., 2008)

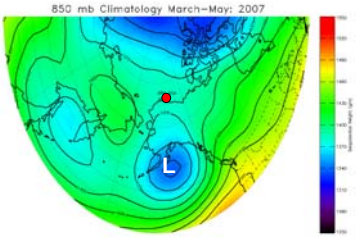
Averaged March-May, 1998-2007



Extreme Early year: March-May, 2002



Mild Early year: March-May, 2007



1. The averaged March-May synoptic pattern during the period 1998-2007 has a dipole pattern with Beaufort Sea High and Aleutian Low. The Beaufort Sea High blocks warm/moist Pacific air into Arctic region.
2. For the extreme early year 2002, the synoptic pattern turns clockwise 90° with a strong west-to-east pressure gradient, which is favorable for transporting more warm/moist Pacific air into Arctic region➔snowmelt earlier than normal years.
3. The mild early year 2007 falls between the 10-yr average and 2002.