Quantifying the Radiative Influence of Clouds on Sea Ice Melting Rates

Gijs de Boer[1], Surabi Menon[1], William Collins[1], Elizabeth Hunke[2], Edwin Eloranta[3]

with additional contributions from: Sally McFarlane[4], Jim Boyle[5], Shaheen Tonse[1] and Mike Iacono[6]

(1) Berkeley Lab

(2) Los Alamos National Laboratory EST. 1943

(3) The University of Wisconsin Madison

(4) Pacific Northwest National Laboratory

(5) Lawrence Livermore National Laboratory

(6) aer Atmospheric and Environmental Research, Inc.

CCSM Polar Climate Working Group Meeting, 16 February, 2010, Boulder, CO

Introduction

Introduction

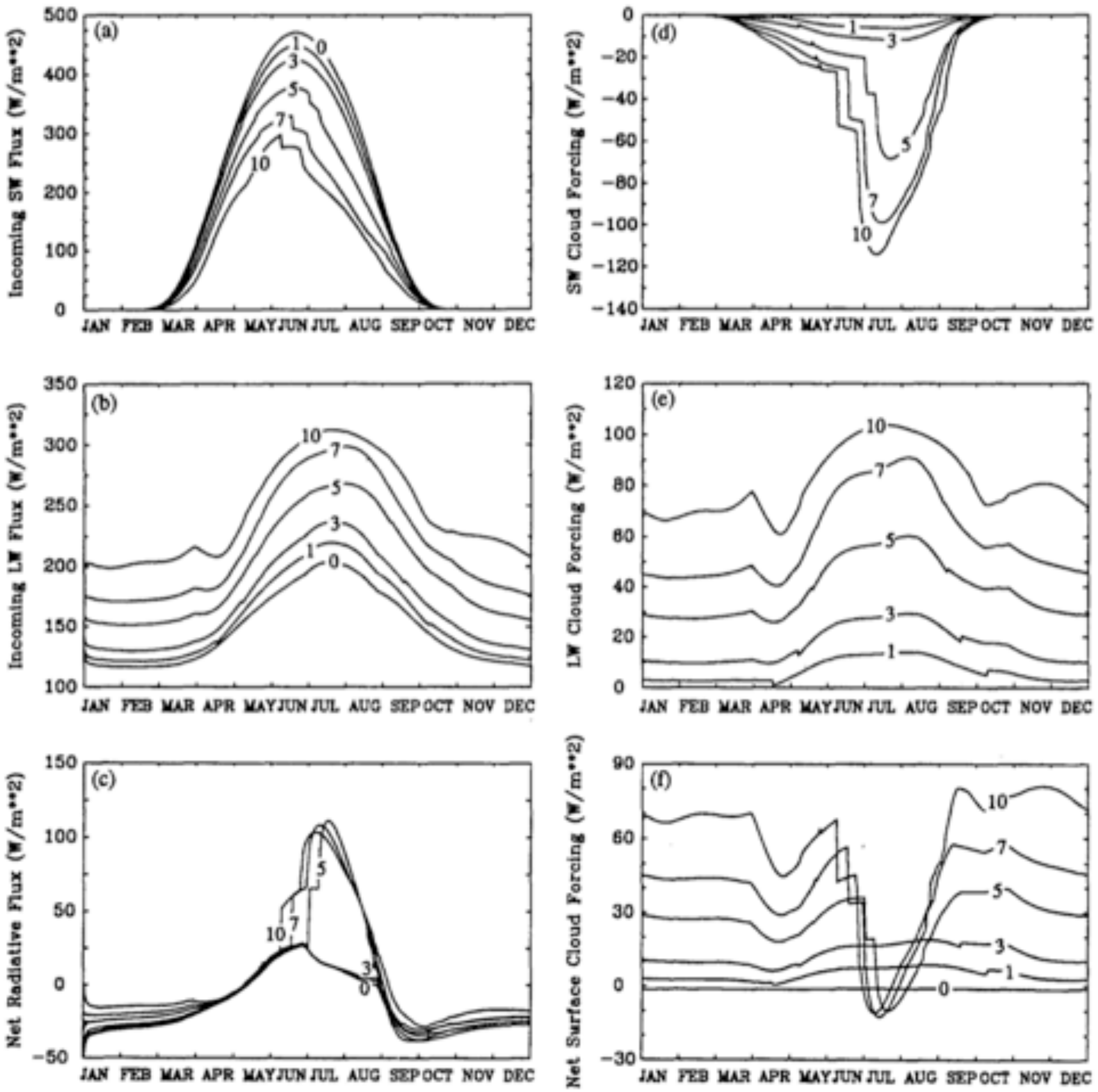


Fig. 4. As in Fig. 3, but for low cloud fraction and ice crystal precipitation

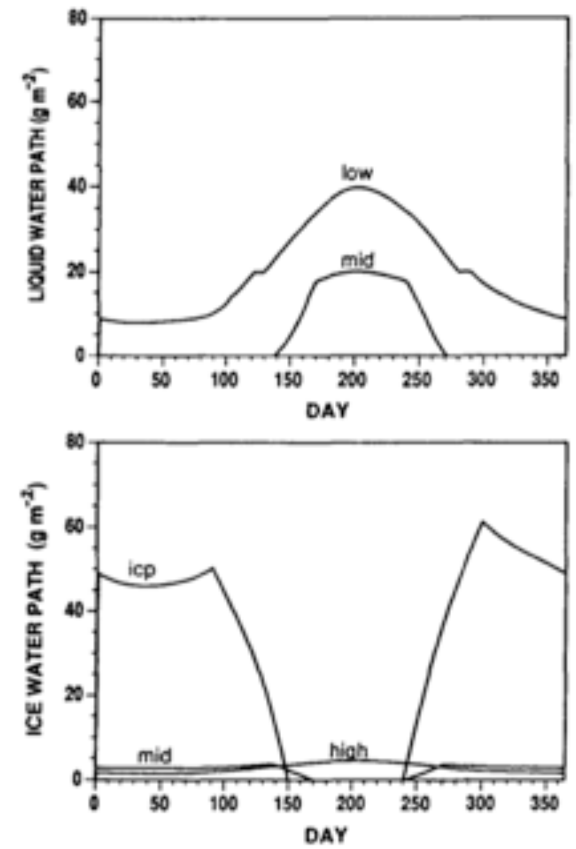


FIG. 2. Annual cycle of (a) liquid and (b) ice water paths for low, middle, and high clouds, as well as lower-tropospheric ice crystals (ICP) for current arctic climate.

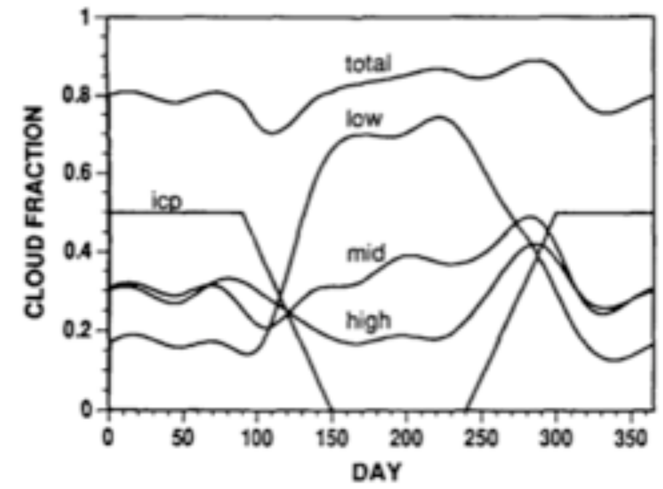


FIG. 1. Annual cycle of cloud fraction (after Huschke 1969), including lower-tropospheric ice crystal precipitation.

(Curry et al., 1993)

Column Model Study

- Clouds have net warming effect at the surface
- Low clouds have greatest impact on surface radiative flux
- Sea ice thickness decreases with increasing cloud fraction
- Based on parameterized seasonal mean cloud and surface properties

Introduction

Goals:

- Utilize a combination of surface-based remote sensors and CCSM modeling tools to derive quantitative estimates of the seasonal impact of clouds on sea ice melting/growth rates.
- Evaluate clouds and sea ice melting rates in global CCSM simulations using measurement derived profiles.

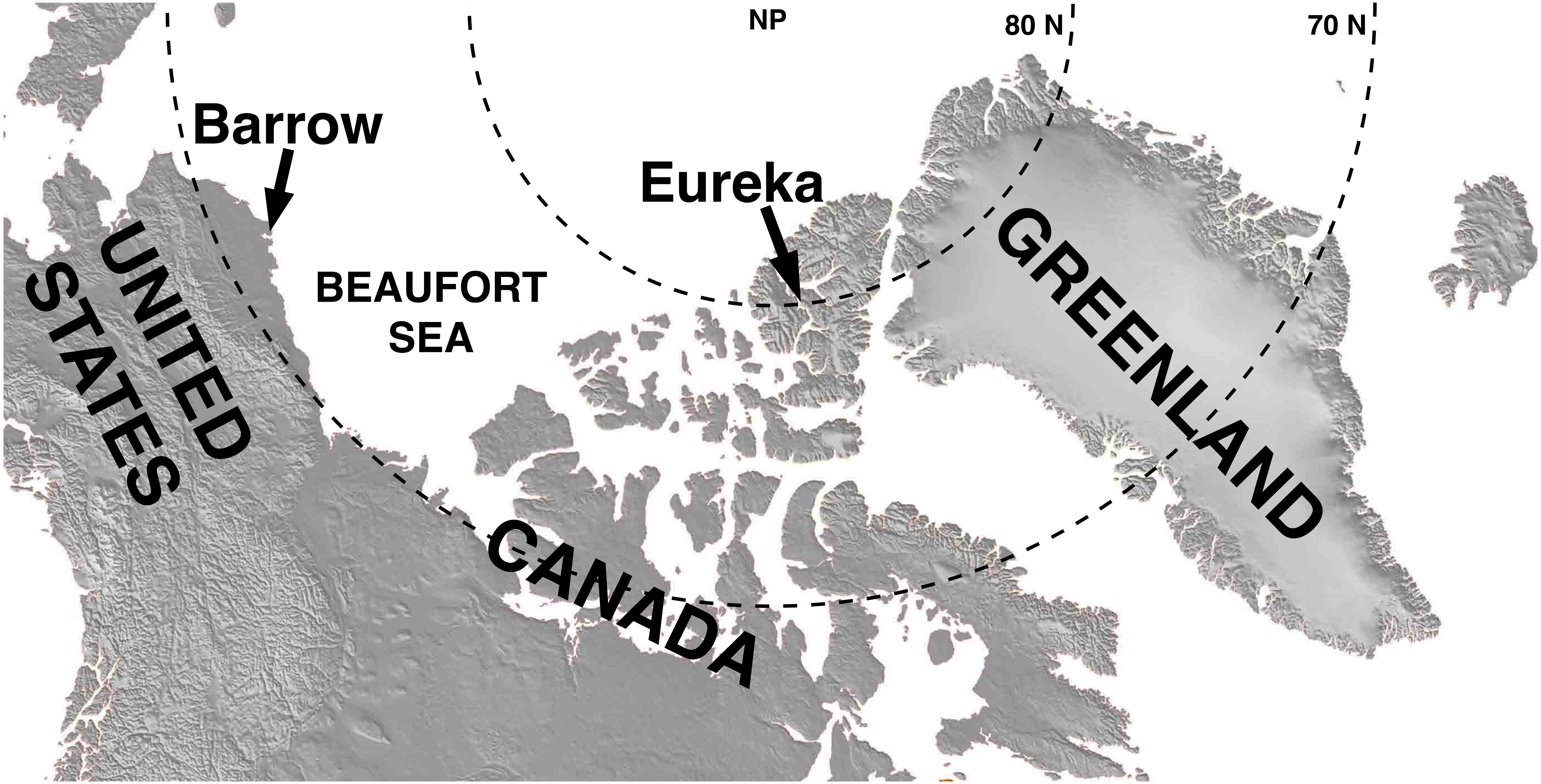
Tools:

- Surface-based lidar, radar, and radiometer measurements from arctic observatories, including the ASR Barrow NSA site.
- Routine radiosonde profiles.
- Rapid Radiative Transfer Model (RRTM) from CCSM.
- Los Alamos Community Sea Ice Model (CICE) from CCSM.

Central Collaborators:

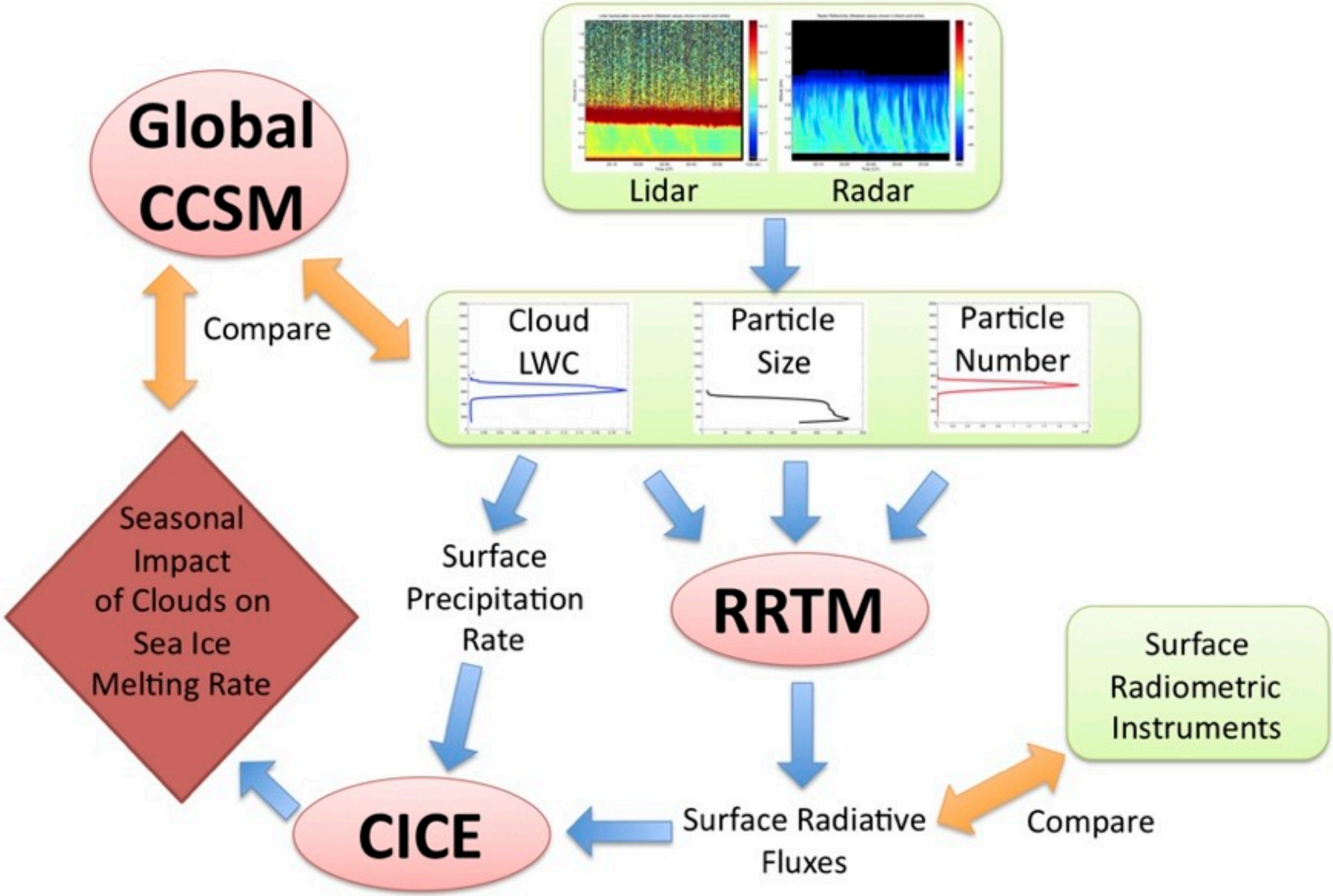
- Bill Collins (LBNL)
- Elizabeth Hunke (LANL)
- Edwin Eloranta (University of Wisconsin – Madison)
- Steve Klein, Jim Boyle (LLNL)

Introduction



High Spectral Resolution Lidar
Millimeter Cloud Radar
Radiosondes
Microwave Radiometer
(de Boer et al., 2009)

Plan of Action



Test Period: M-PACE

Table 2. Mixed-phase cloud properties, instruments used in their derivation, references for pertinent retrieval methods applied to mixed-phase clouds, and the conditions under which retrievals are applicable. SZA is the solar zenith angle.

Property	Instrument	Method	Conditions
Location, boundaries, thickness, persistence	Radar, lidar, ceilometer	Clothiaux et al. (2000)	All
Phase identification	Radar–lidar–MWR–radiosonde Doppler radar spectra	Shupe (2007) Luke and Kollias (2007)	All All
Ice water content/path	Radar Lidar–radar AERI Near-IR	Shupe et al. (2006) Matrosov et al. (2002) Donovan and van Lammeren (2001) Wang and Sassen (2002) Hogan et al. (2003a, 2006) Turner (2005) Daniel et al. (2006)	Ice-containing clouds Nonocculted, all-ice cloud volumes τ < 6, ice-containing clouds SZA ~<80°, ice-containing clouds
Ice particle size	Radar Lidar–radar AERI	Shupe et al. (2006) Donovan and van Lammeren (2001) Wang and Sassen (2002) Hogan et al. (2003a, 2006) Turner (2005)	Ice-containing clouds Nonocculted, all-ice cloud volumes τ < 6, ice-containing clouds
Liquid water content	Radiosonde, adiabatic Doppler radar spectra	Zuidema et al. (2005) Shupe et al. (2004) Verlinde et al. (2007)	Stratiform, liquid-containing clouds Mixed-phase cases with bimodal Doppler spectra
Liquid water path	MWR AERI Near-IR Radiosonde, adiabatic	Liljegren et al. (2001) Turner et al. (2007) Turner (2005, 2007) Wang et al. (2004) Daniel et al. (2006) Zuidema et al. (2005)	Liquid-containing cloud scenes, except rain LWP <50 g m^{-2}, liquid-containing clouds SZA ~<80°, liquid-containing clouds Stratiform, liquid-containing clouds
Liquid droplet radius	AERI Doppler radar spectra	Turner (2005) Turner and Holz (2005) Wang et al. (2004) Shupe et al. (2004) Verlinde et al. (2007)	LWP <50 g m^{-2}, liquid-containing clouds Mixed-phase cases with bimodal Doppler spectra
Optical depth, liquid	AERI Near-IR SW broadband Radiosonde, adiabatic	Turner (2005) Daniel et al. (2006) Portmann et al. (2001) Bernard and Long (2004) τ = 1.5 LWP R_e^{-1}	LWP <50 g m^{-2}, liquid-containing clouds SZA ~<80°, liquid-containing clouds SZA <80°, liquid-containing clouds Stratiform, liquid-containing clouds
Optical depth, ice	AERI Radar	Turner (2005) Matrosov et al. (2003) Hogan et al. (2003b)	τ < 6, ice-containing clouds Ice-containing clouds
Optical depth, total	Lidar AERI	Eloranta (2005) Turner (2005)	Nonocculted cloud volumes τ < 6, LWP < 50 g m^{-2}
Vertical velocity	Doppler radar spectra	Shupe et al. (2004, 2008b)	Liquid-containing cloud volumes
Turbulent dissipation rate	Radar	Shupe et al. (2008b)	All

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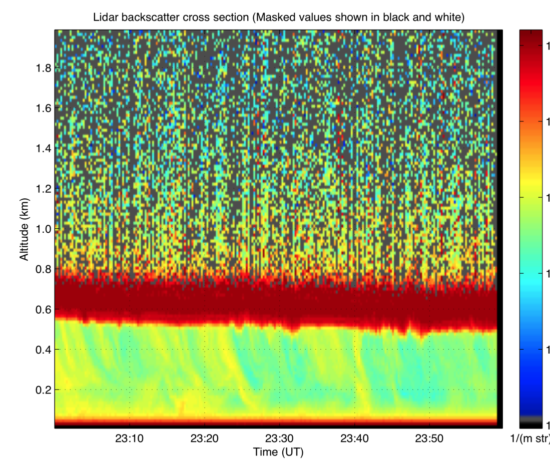
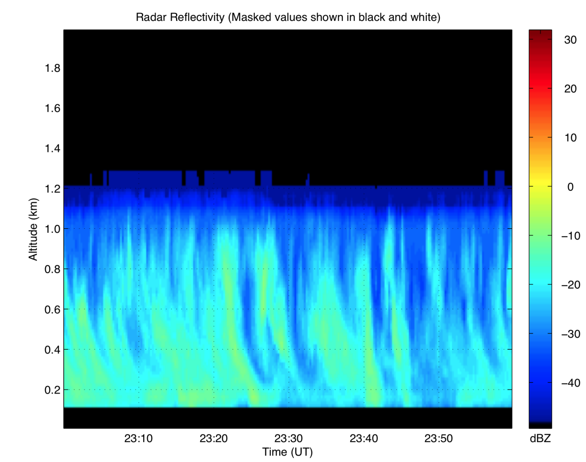
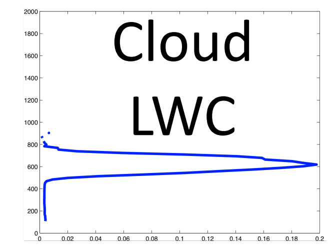
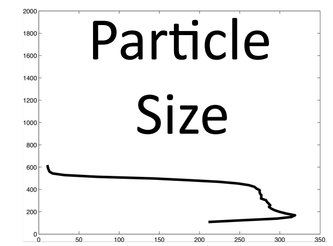
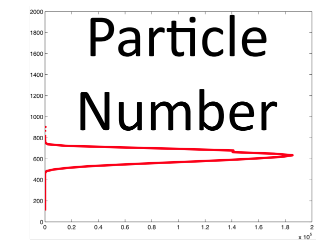
Follow retrieval guidelines from Shupe et al. (BAMS, 2008) for mixed-phase clouds











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Optical depth, total	Lidar AERI	Eloranta (2005) Turner (2005)	Nonocculted cloud volumes $\tau < 6$, LWP < 50 g m^{-2}
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Turbulent dissipation rate	Radar	Shupe et al. (2008b)	All

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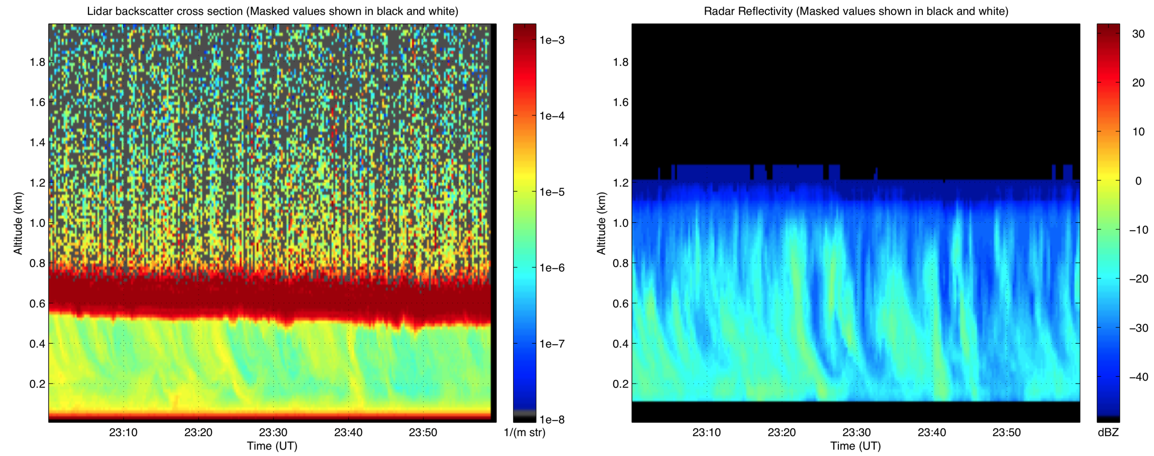
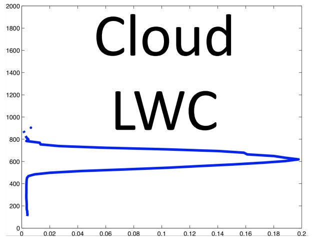
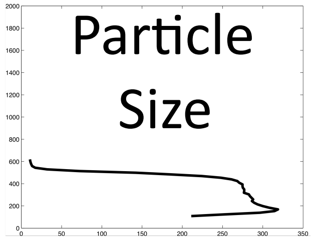
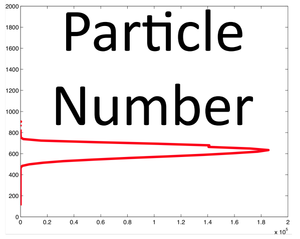




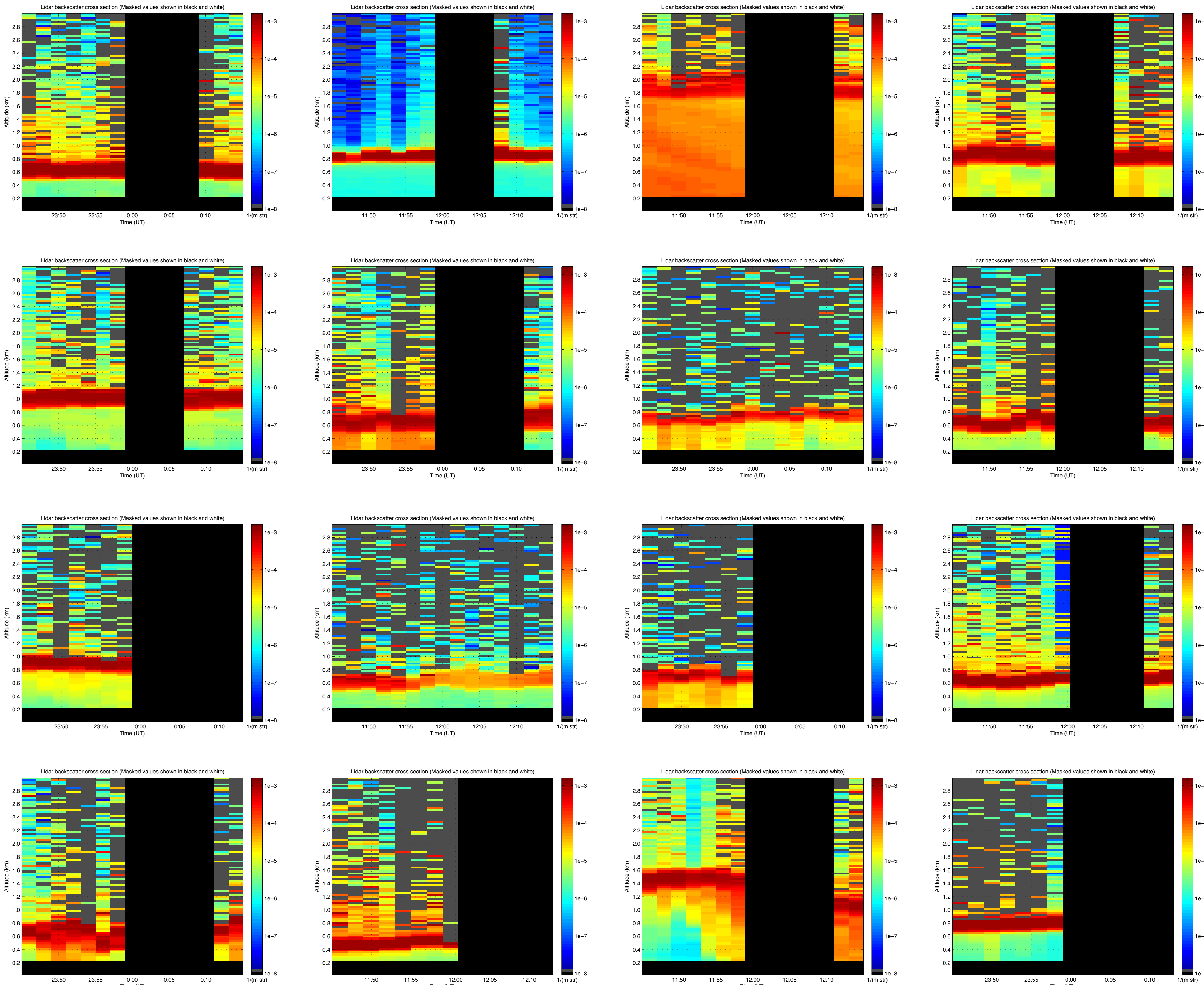




Test Period: M-PACE

- Mixed-Phase Arctic Clouds Experiment (Fall, 2004) at the NSA DOE ARM facility (Verlinde, et al., 2007)
- Validation available for surface radiation estimates
- Focused mainly on mixed-phase clouds

Test Period: M-PACE



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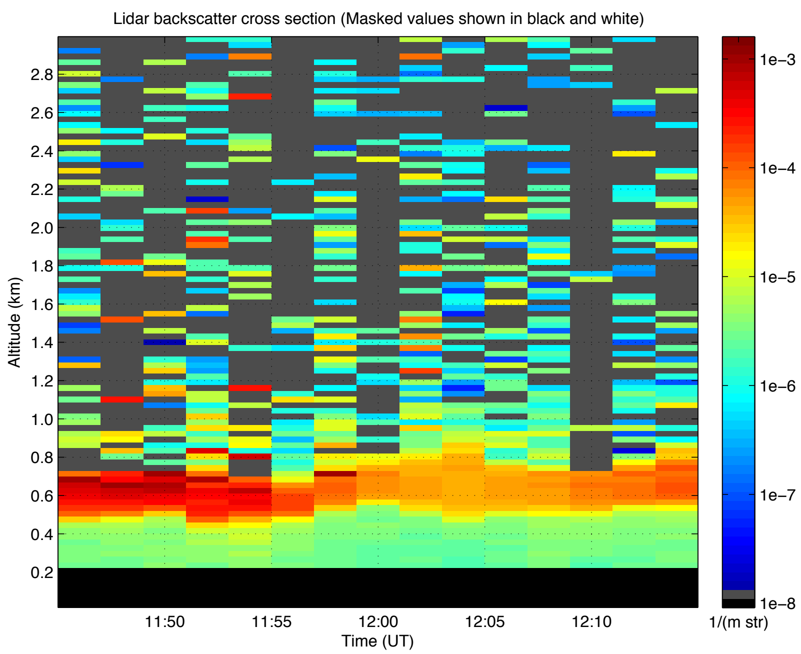
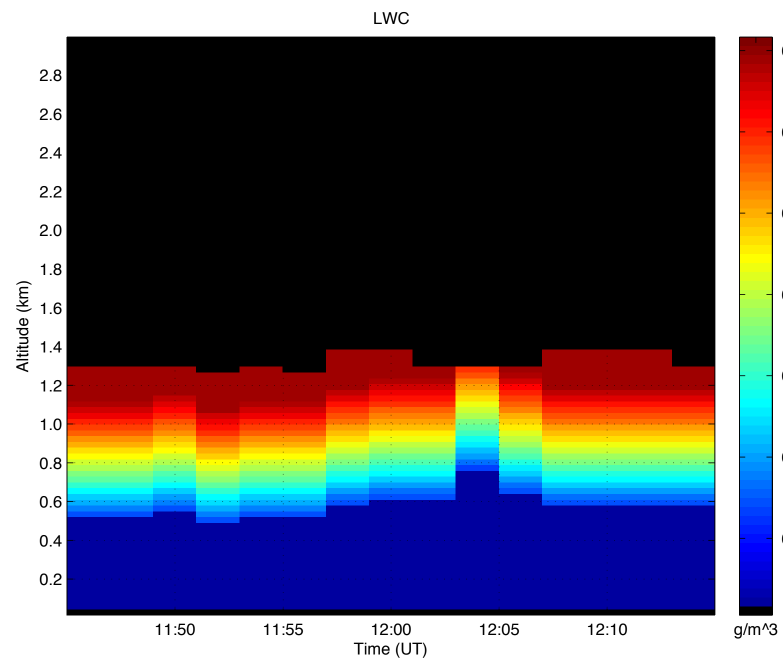
Test Period: M-PACE

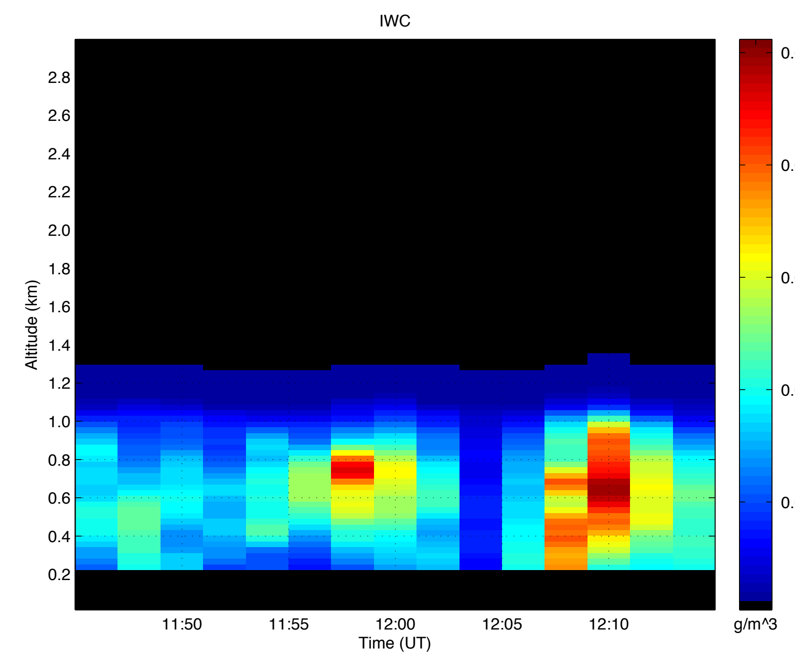
BSCS



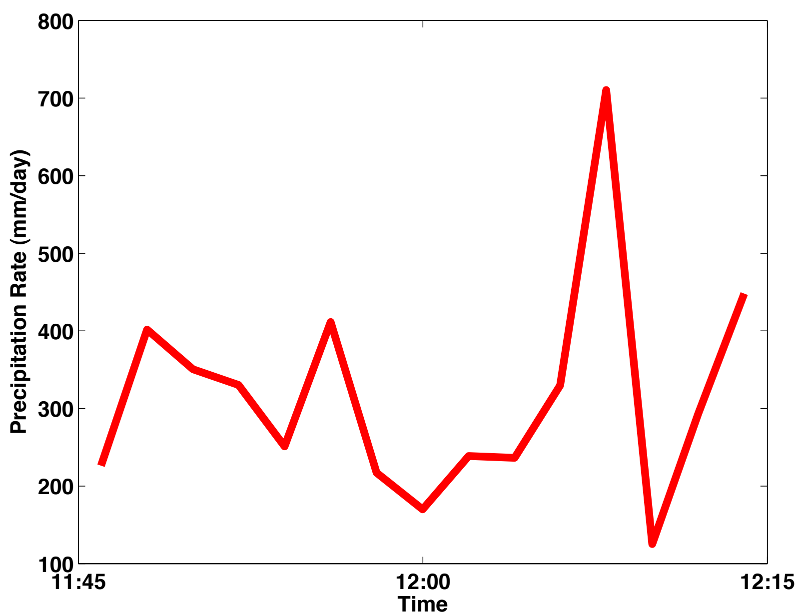
LWC



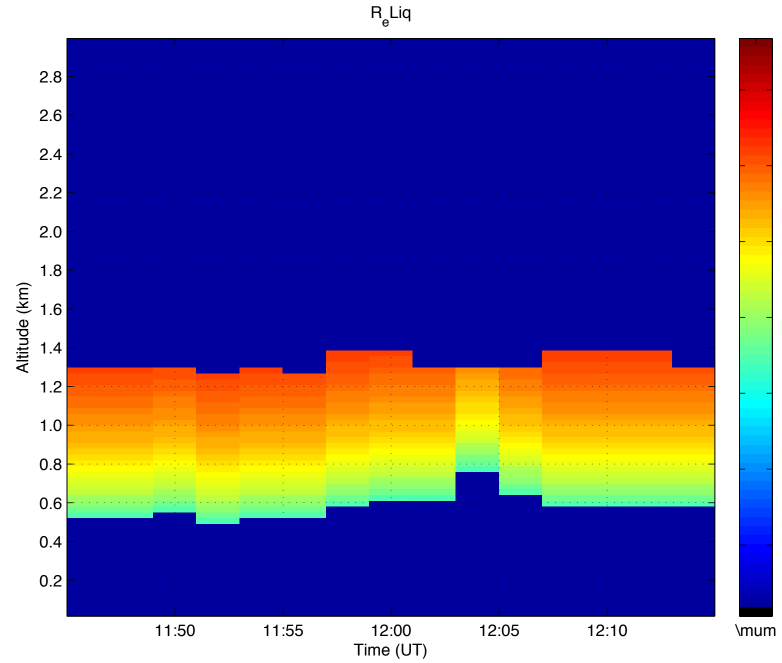
IWC



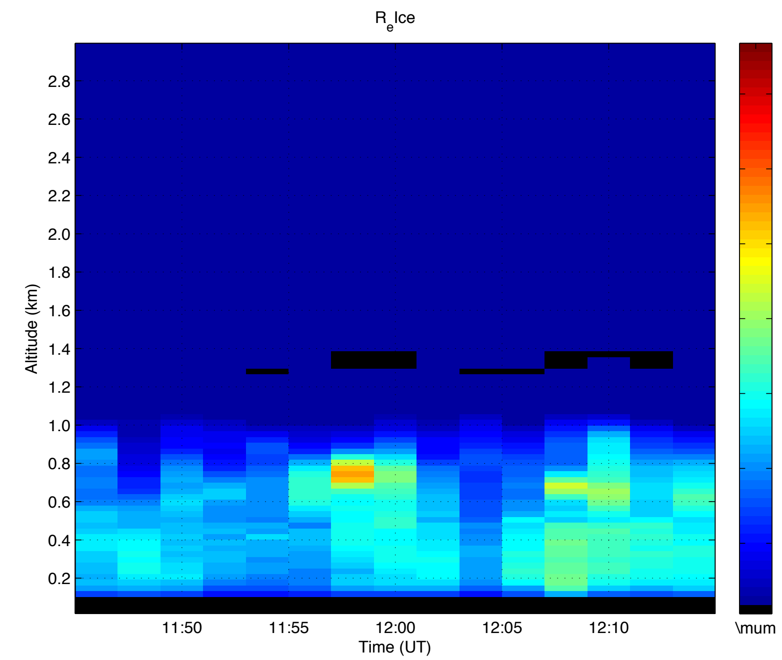
Surface Precip.



Liquid R_{eff}



Ice R_{eff}

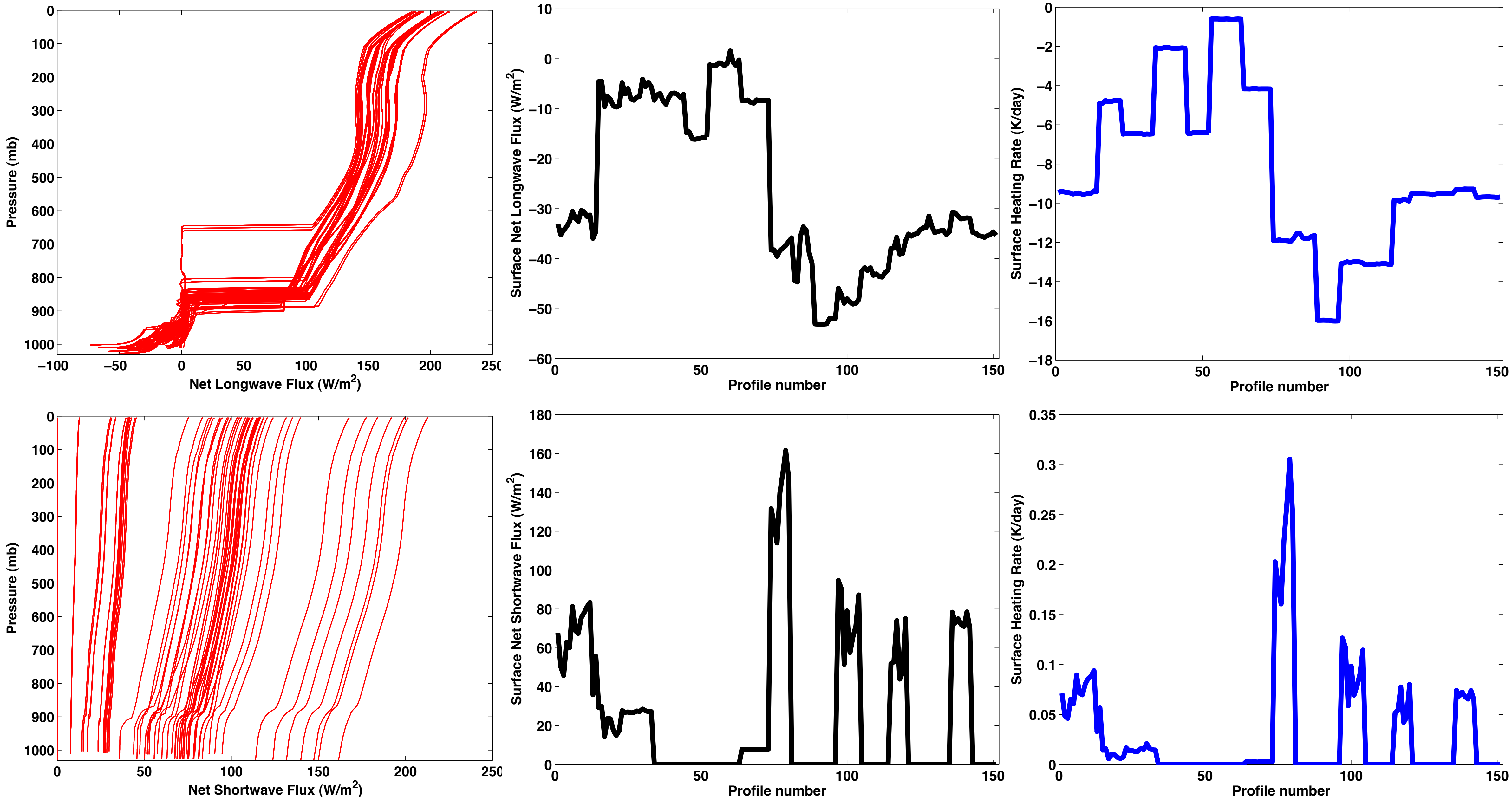


Test Period: M-PACE

Initial RRTM Runs

LW

SW



Compare with DOE ARM qcRad product from NSA

disclaimer: **VERY preliminary**

Test Period: M-PACE

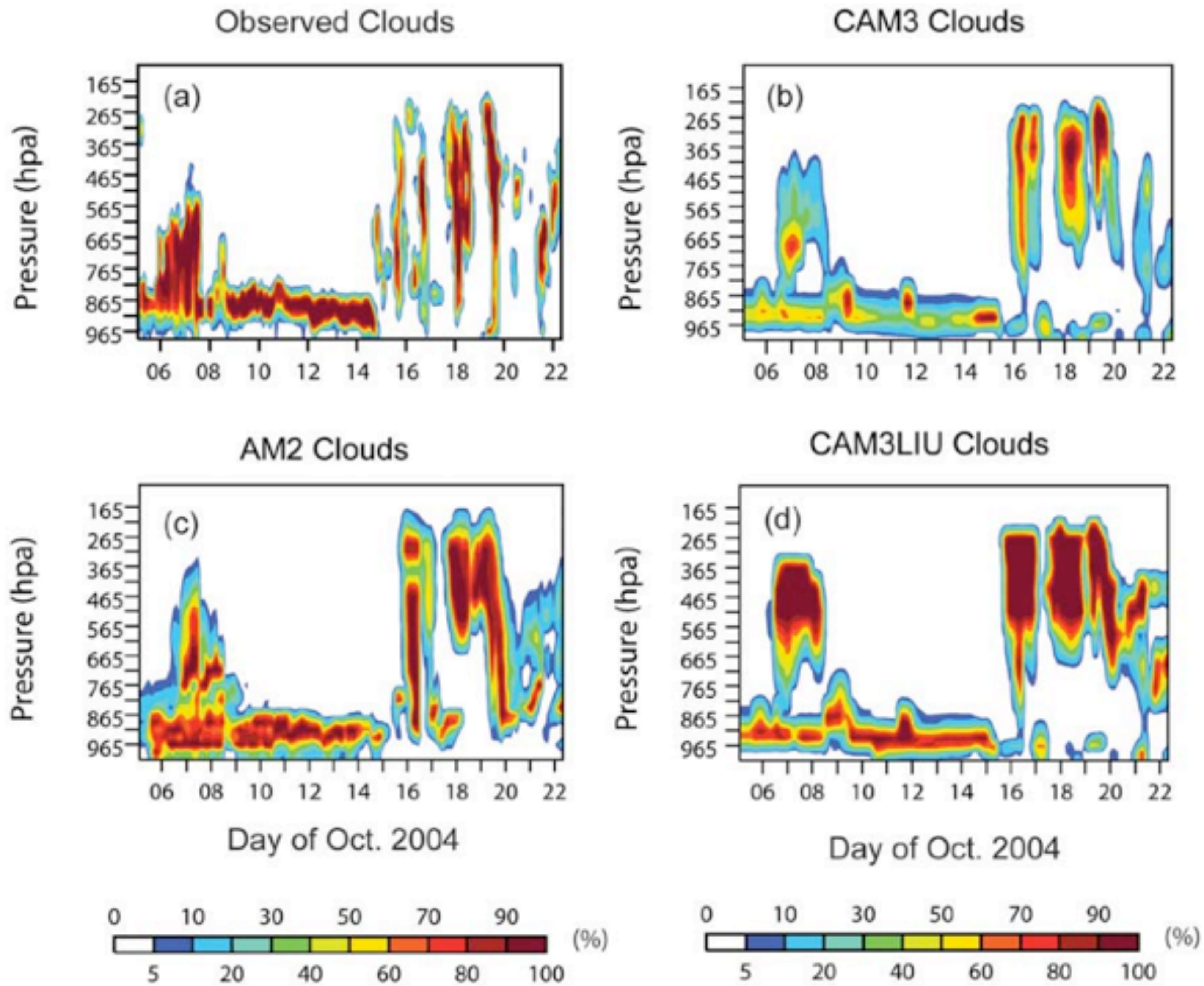


Figure 1. Time-height cross sections of (a) ARSCL cloud frequency and modeled cloud fraction (b) CAM3, (c) AM2, and (d) CAM3LIU at Barrow during M-PACE. The unit is %.

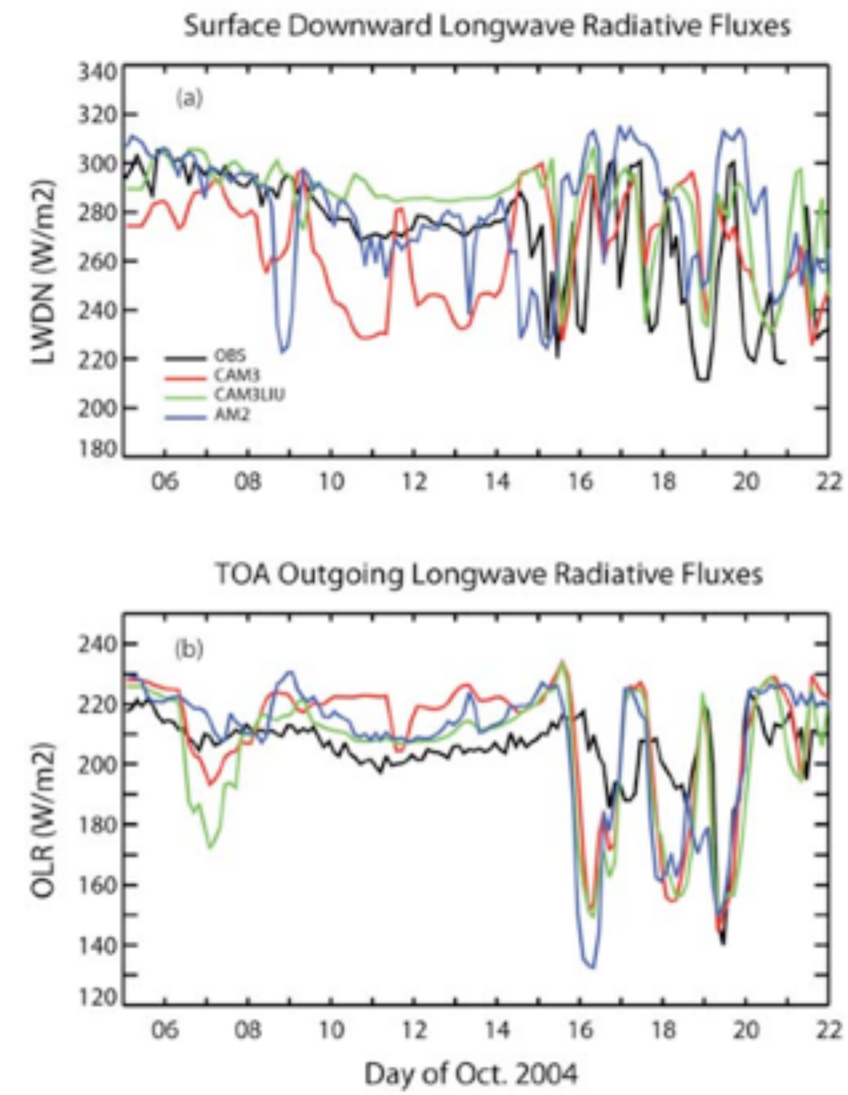


Figure 8. Time series of the observed and model-produced (a) surface downwelling longwave radiative fluxes (W/m^2) and (b) TOA outgoing longwave radiative fluxes (W/m^2). Black lines are observations. Red lines are for CAM3, green lines are for CAMLIU, and blue lines are for AM2.

(Xie et al., 2008)

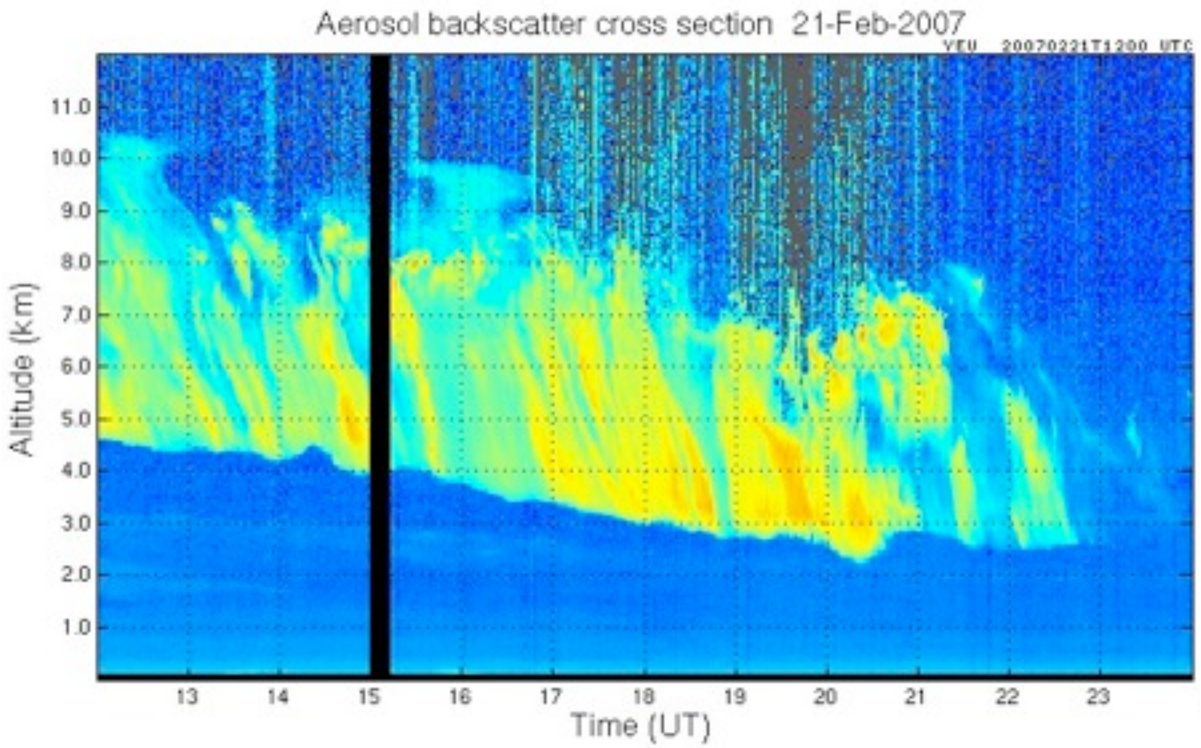
CICE

Drive column version of **CICE** using derived estimates of:
- Temperature
- Humidity
- Cloud Fraction
- Radiative fluxes (from RRTM)
- Precipitation

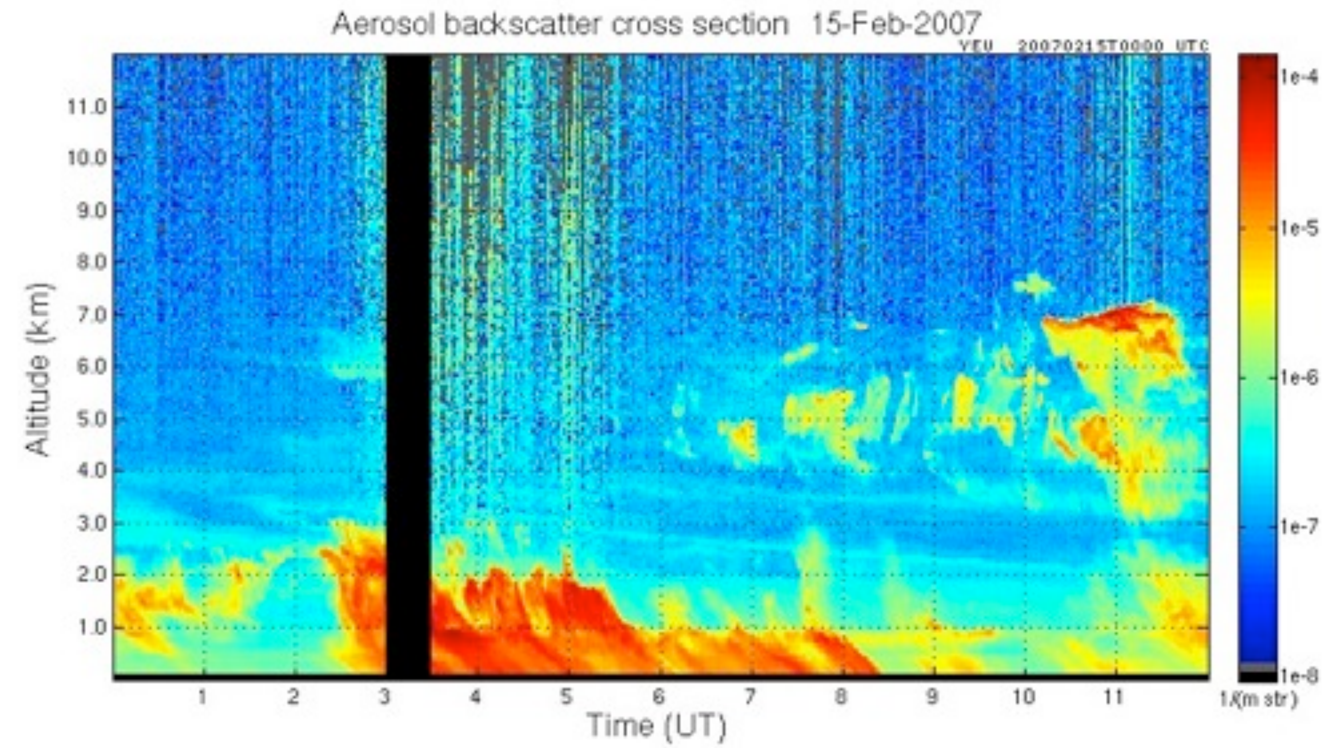
along with:
- Prescribed SST
- Prescribed salinity

to derive cloud impact on sea ice melting/growth rates

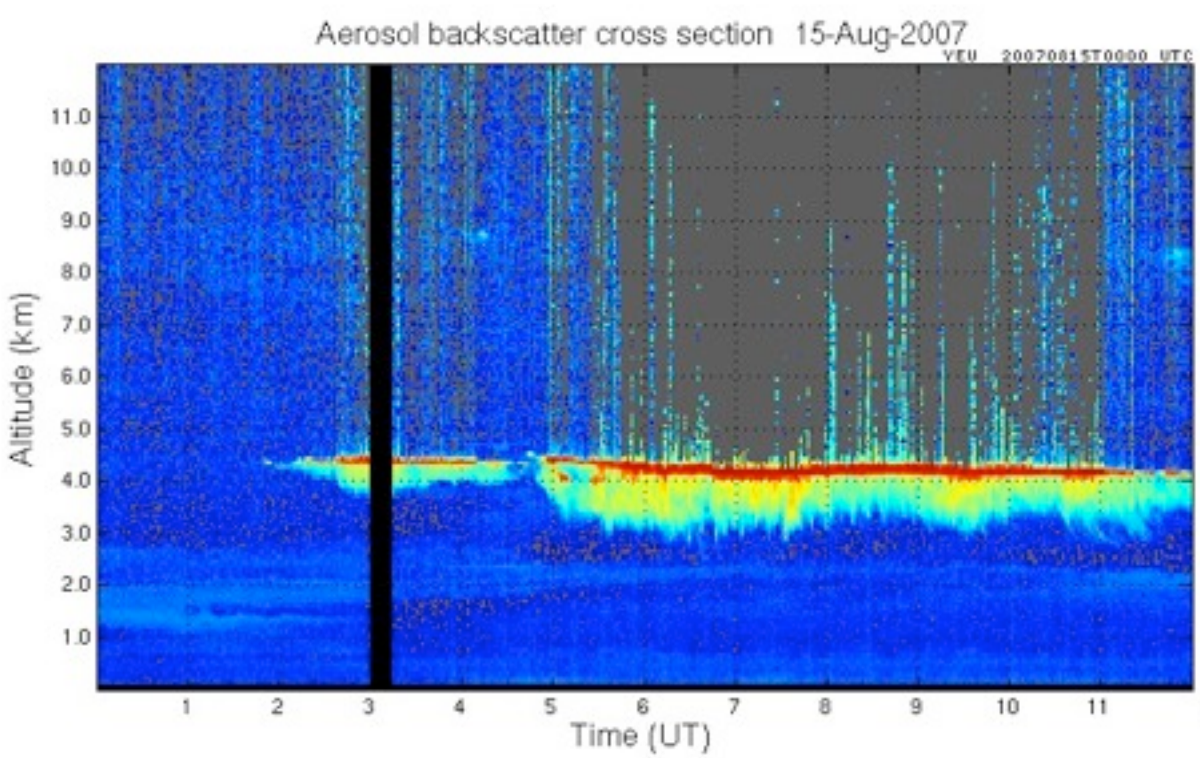
Other Cloud Types



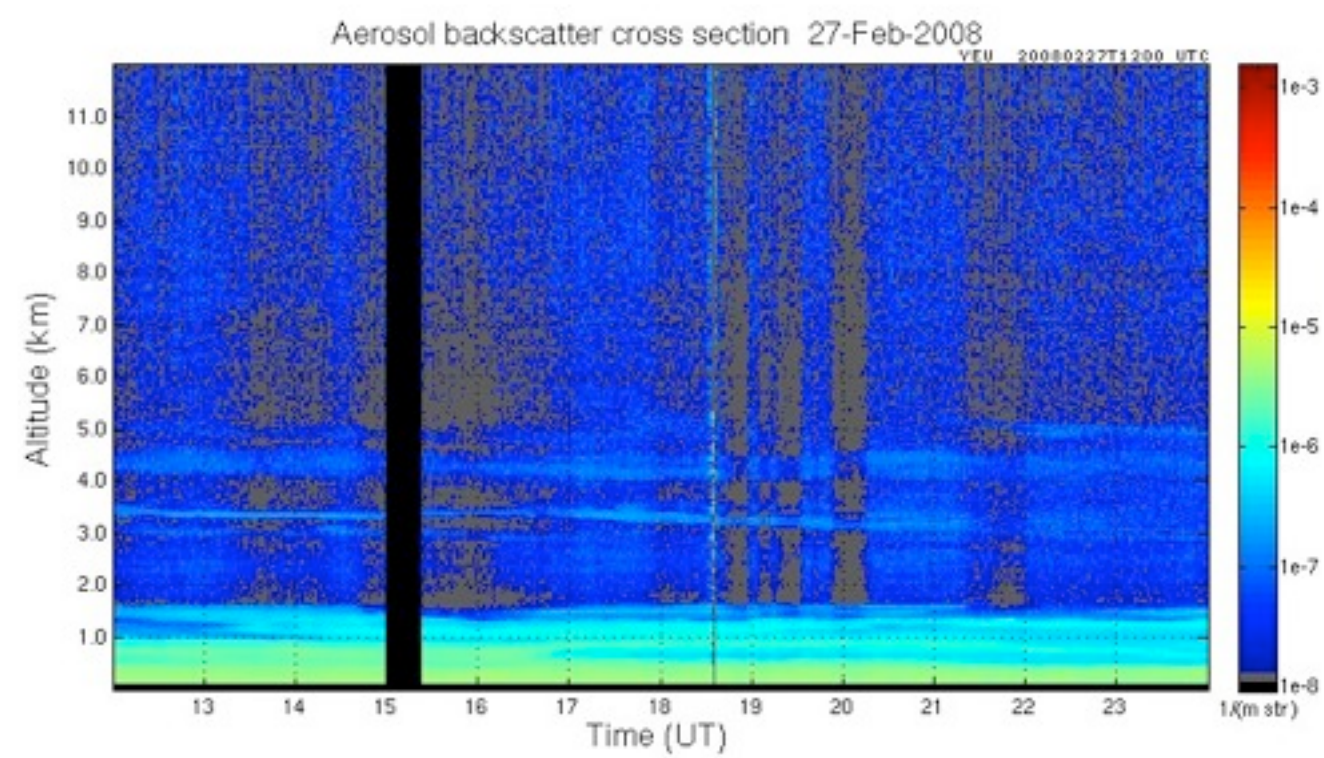
Cirrus



Diamond Dust



Liquid Clouds



Arctic Haze

Summary of Future Plans

- Test ability to accurately reproduce surface radiative fluxes using RRTM
- Compare radiative transfer with that from CAM simulations for same time period
- Utilize radiative fluxes along with temperature and precipitation information to drive column version of CICE
- Expand effort to include several years of measurements from Eureka
- Provide seasonal quantitative estimates of sea ice melting rates for mixed-phase stratiform clouds
- Expand study to other cloud types

Interest and Questions:

GDeBoer@lbl.gov
510-486-4556

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