

Evaluation of GCM Simulated Arctic Mixed-Phase Boundary Layer Clouds Using the ARM M-PACE Data



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OUTLINE

- The ARM Mixed-Phase Arctic Cloud Experiment (**M-PACE**)
- Models: **ECMWF, NCAR CAM3, and GFDL AM2**
- Results
- Summary

The ARM NSA Mixed-Phase Arctic Cloud Experiment (MPACE): 00Z 05 October to 12Z 22 October, 2004



Barrow

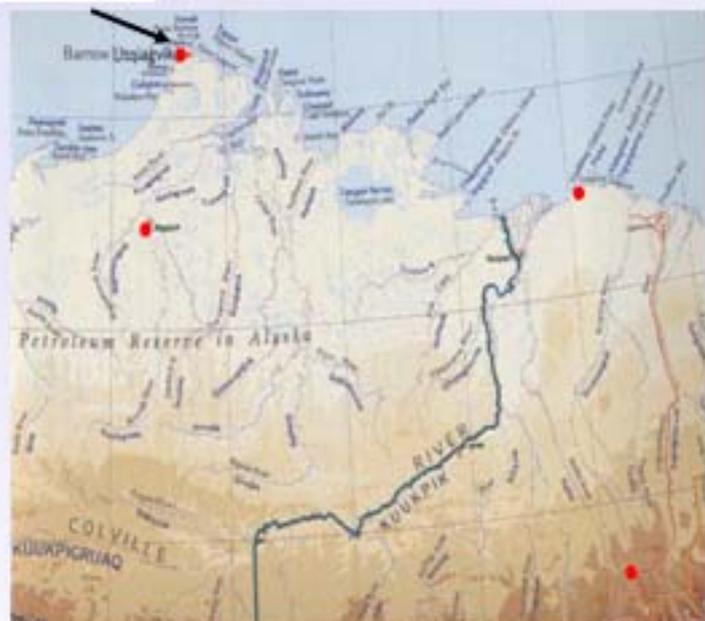


Figure 1 Experimental layout. The two ARM sites are located at Barrow and Atkasuk; the two supplementaries will be at Oliktok Point and the NSF Toolik Lake Field Station.

Measurements

Clouds and Cloud Microphysical Properties

Millimeter-wavelength cloud radar

Micropulse Lidars

Laser Ceilometers

Aircrafts

Microwave Radiometers

Surface Radiation

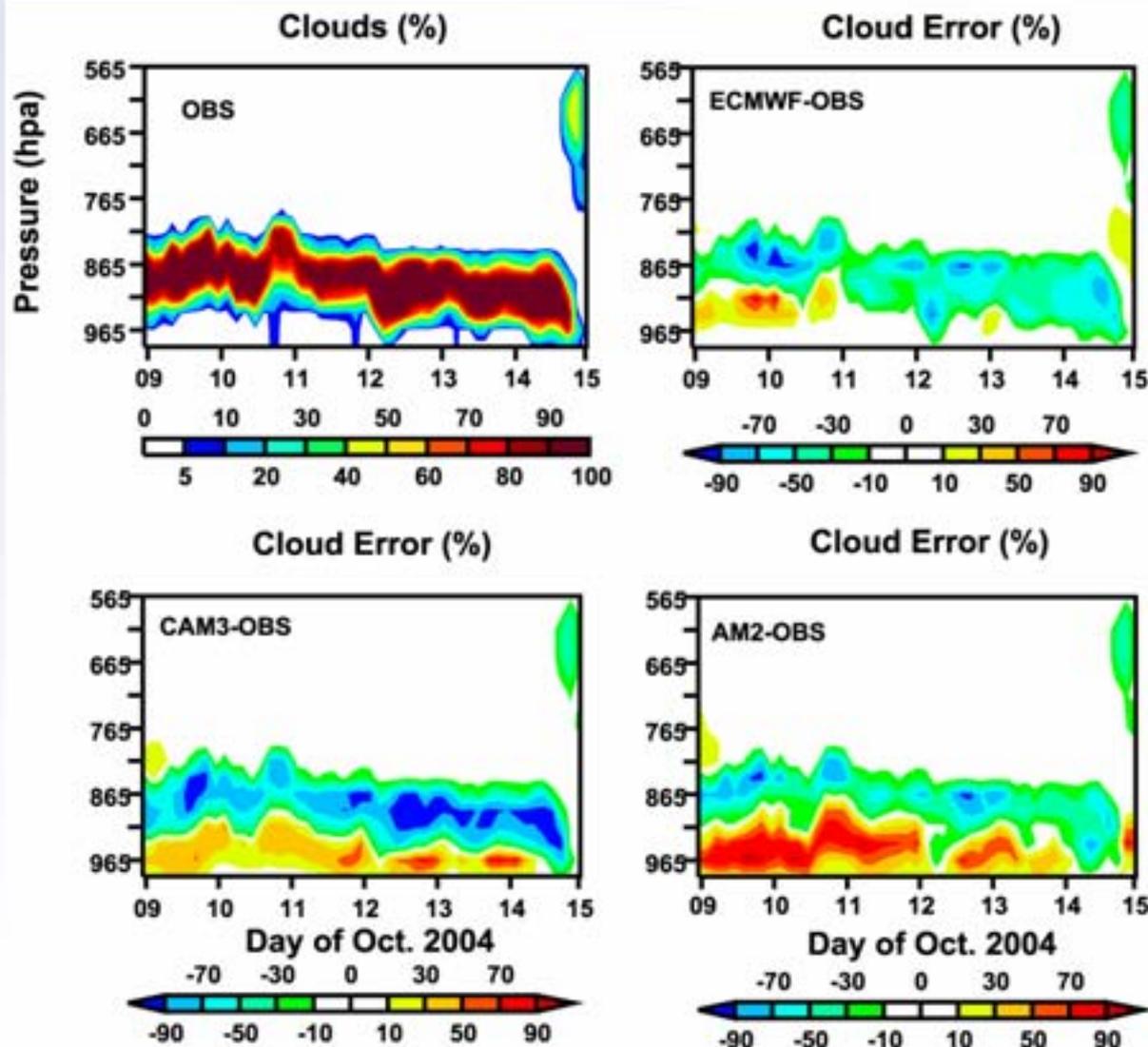
Radiometric Instrument Systems

TOA Radiation

NASA-Terra and NOAA-15, -16 Satellites

Data collected at **Barrow** were used in this study

Cloud Errors



- Underpredict clouds near cloud top and in the cloud layer
- Overpredict clouds below the cloud layer (**AM2 & CAM3**)

Models



- **ECMWF T511L60 Weather Forecast Model**

- Initialized with the ECMWF analysis at 00Z and 12Z every day
 - 0-12 hour forecasts

- **NCAR CAM3 T85L26**

- **GFDL AM2 2.5° x 2° 24 Levels**

- CAM3 and AM2 are initialized with analysis from NASA GSFC Data Assimilation System (DAO) at 00Z every day

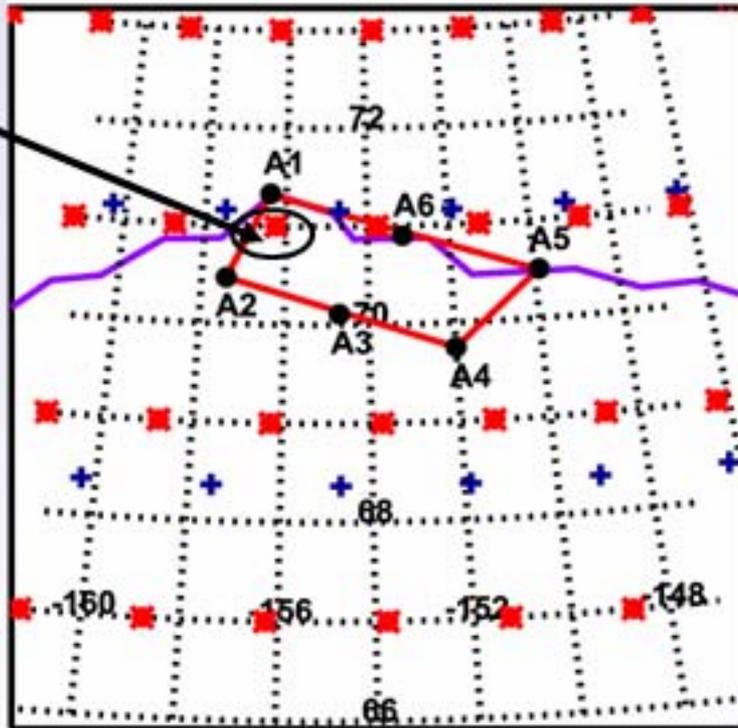
- 12-36 hour forecasts

Results at the model grid closest to the Barrow site are analyzed

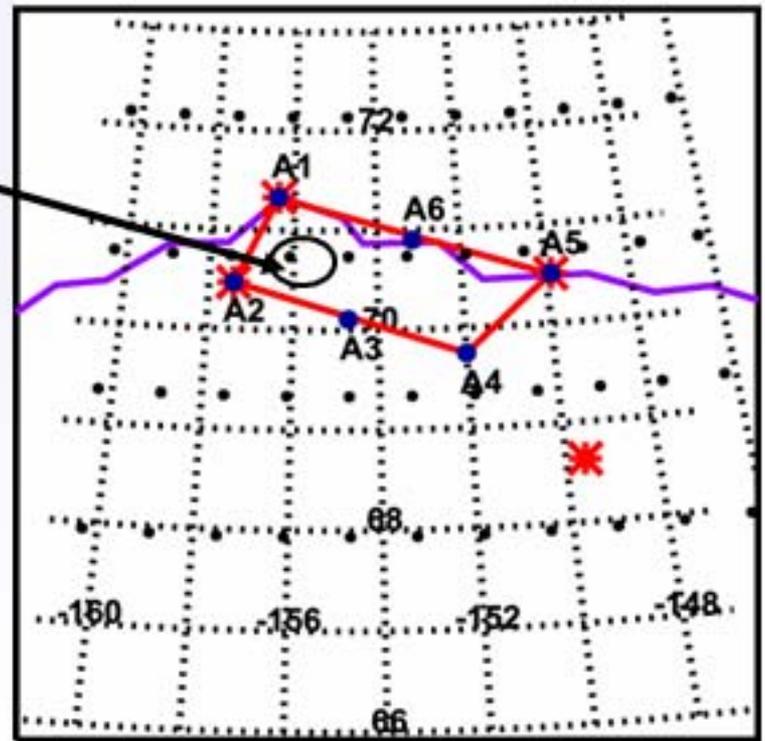
CAM3 and AM2 Grid points



AM2 (*) and CAM3T42 (+)

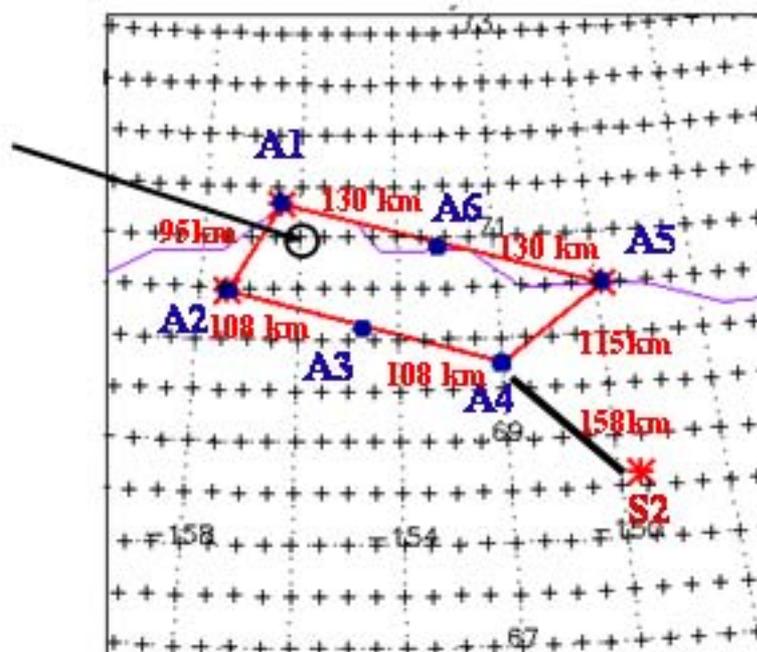


CAM3T85 (.)

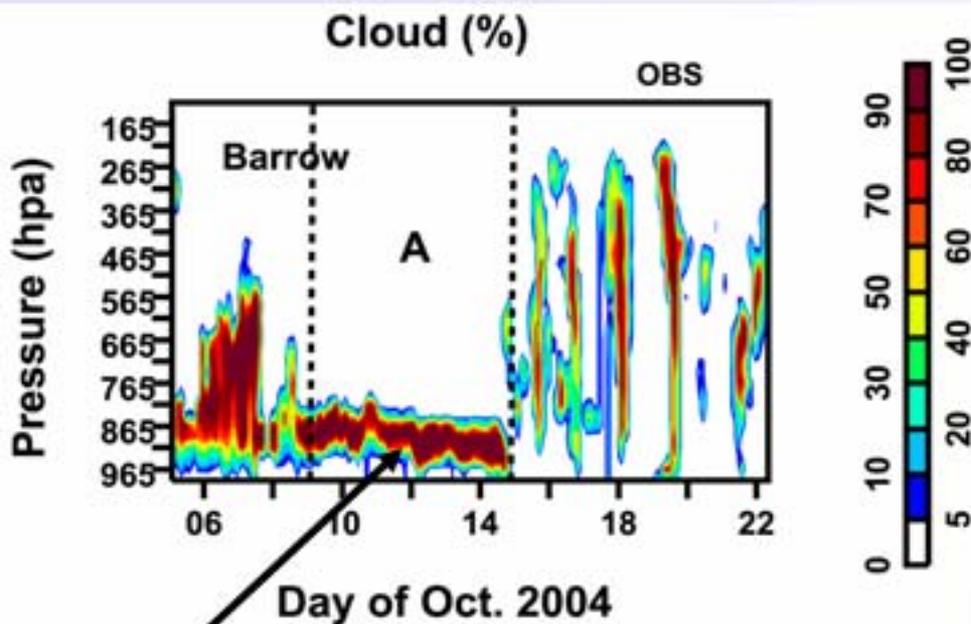




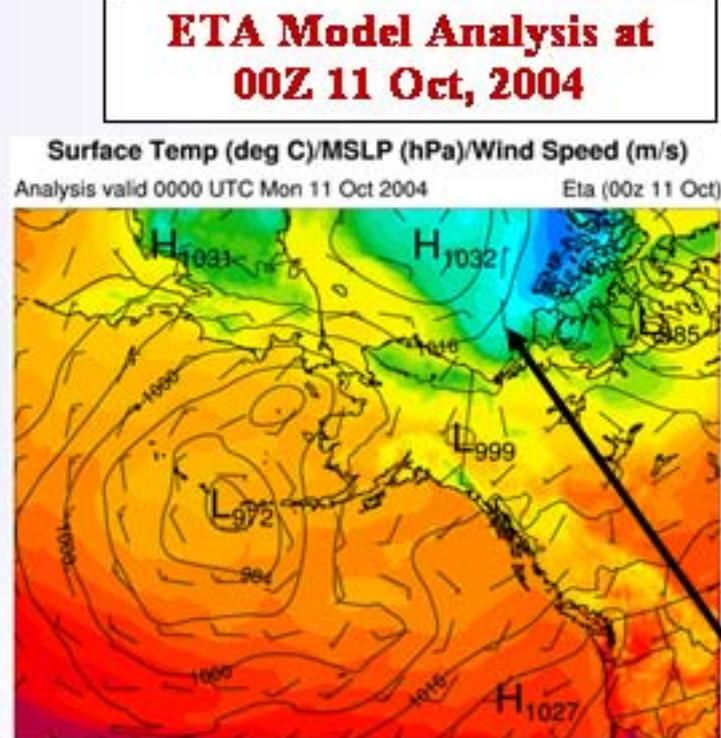
ECMWF Grid Points (+)



Radar Clouds



Persistent mixed-phase boundary layer clouds, formed over ocean and advected into NSA

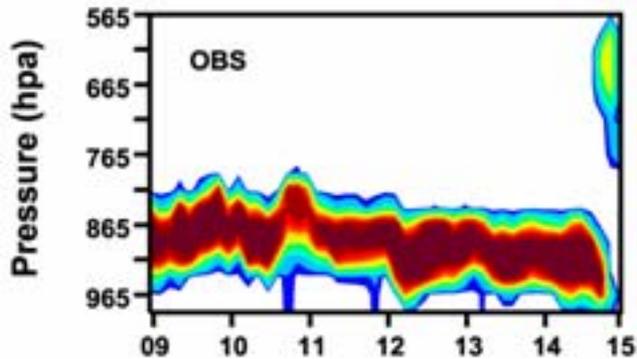


The NSA was mainly affected by a high pressure system centered to the northeast of the Alaskan coast

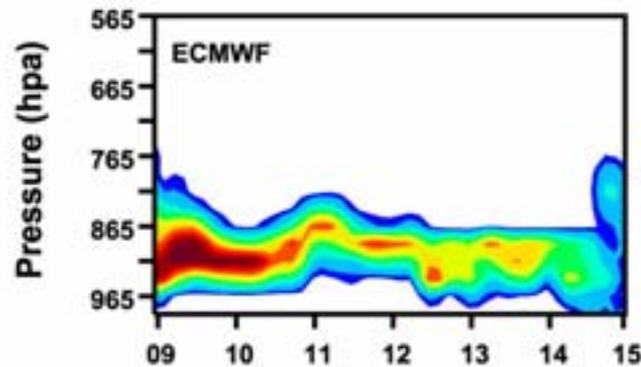
Simulated Clouds



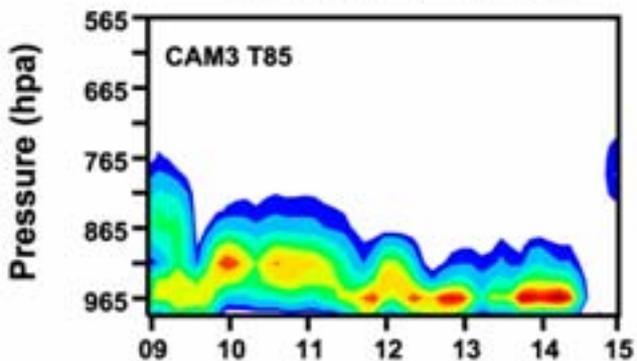
Clouds (%)



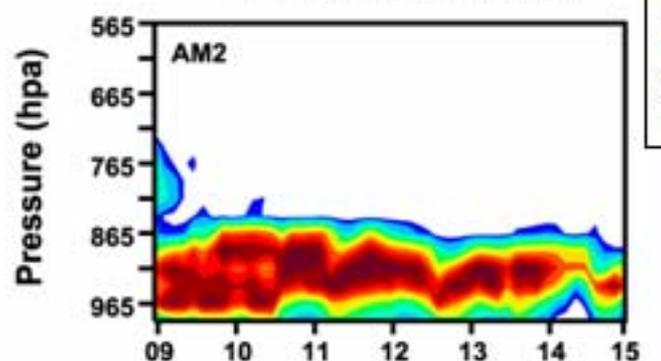
Simulated Clouds (%)



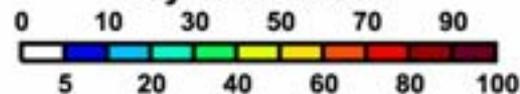
Simulated Clouds (%)



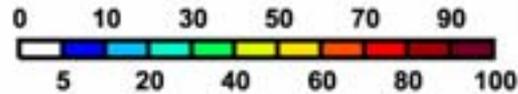
Simulated Clouds (%)



Day of Oct. 2004



Day of Oct. 2004



- All models are able to produce BL clouds
- Cloud bases are too low in CAM3 and AM2
- Cloud amounts are largely underestimated by ECMWF and CAM3

Aircraft Measured Cloud Water Content

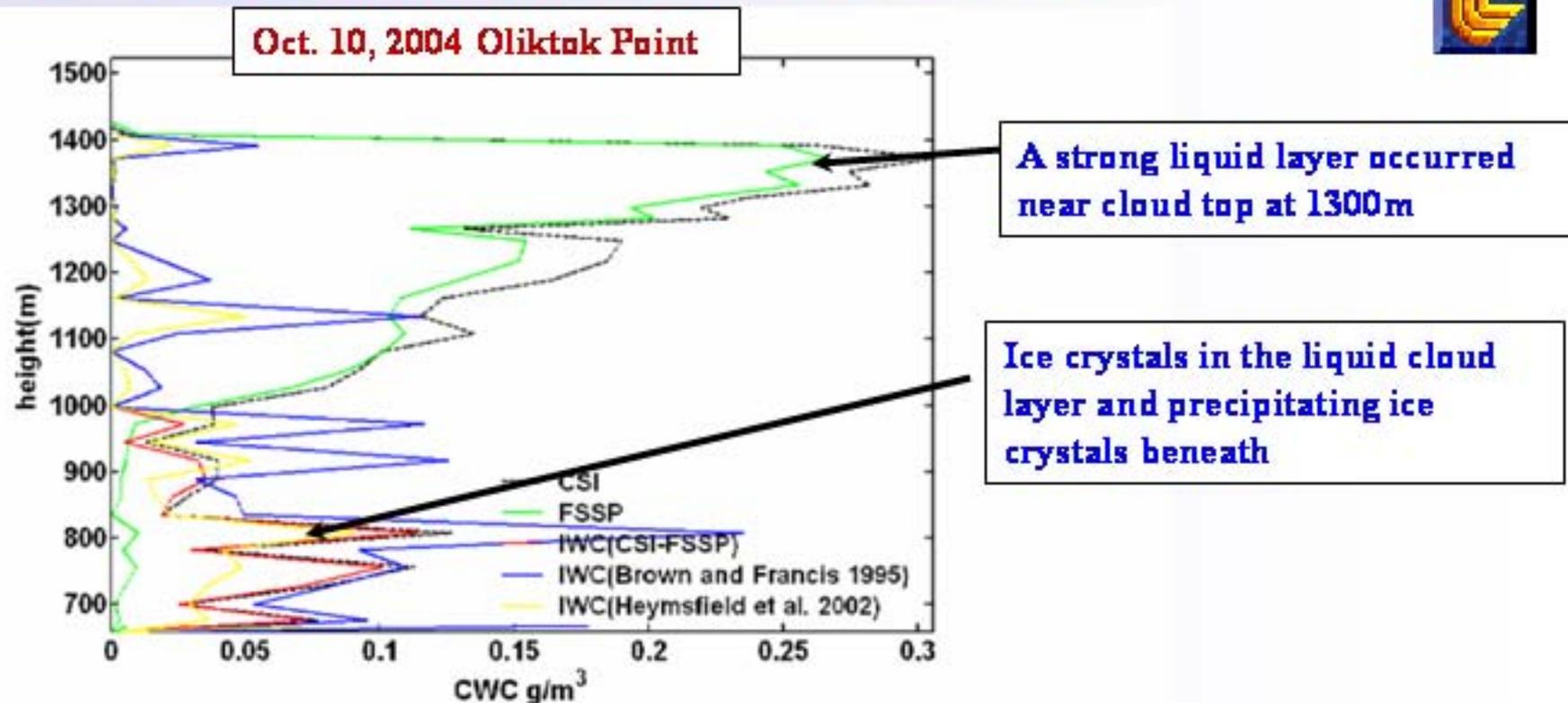


Figure 6 Comparison of bulk measurements of IWC (CSI-FSSP) against IWC estimated from 2DC using variety of habit identification and mass calculation techniques

(From G. McFarquhar et al. 2005)

- CSI**: Cloud Spectrometer and Impactor probe
- FSSP**: Forward scattering spectrometer probe
- 2DC**: two dimensional cloud probe

Summary

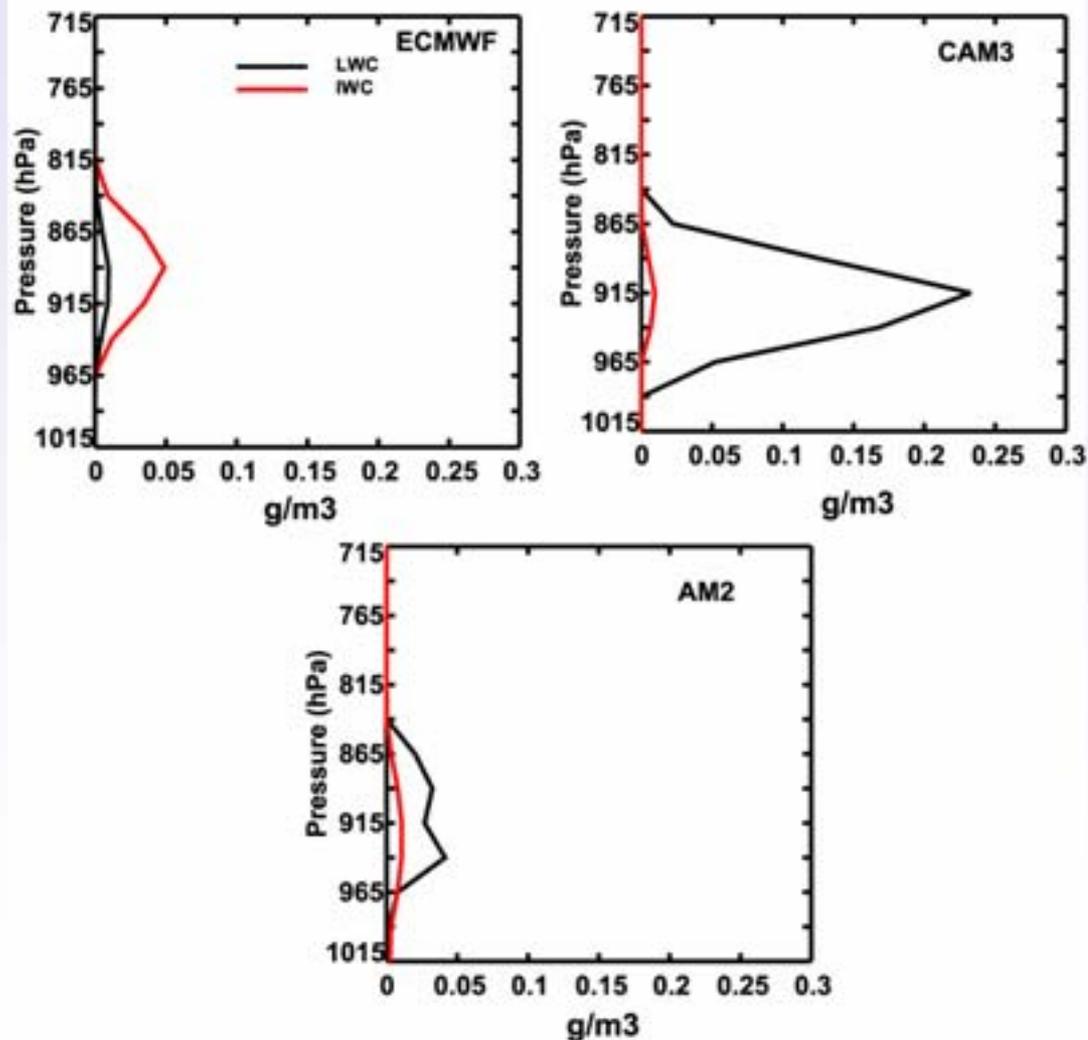


- *All models ==> produce the observed Arctic mixed-phase BL clouds*
- *All models ==>underpredict the cloud amount in the observed cloud layer*
- *Clouds in CAM3 and AM2 ==> too low, leading to an overestimation below cloud base*
- *Cloud properties: significant differences seen among the models and between the models and the observation*
 - *CAM3 produces a reasonable LWP while ECMWF and AM2 largely underestimate the observe value*
 - *Cloud fraction in CAM3 and AM2 is decoupled with cloud water*
- *All models overestimate the TOA OLR and CAM3 and ECMWF underestimate the surface downwelling LW, consistent with the problems in predicting the mixed-phase BL clouds*

Simulated LWC and IWC



Averaged over 10 October, 2004



- Significant differences in the cloud physical properties among the models
- The vertical distributions of LWC and IWC are significantly different from the observations

- ECMWF and CAM3: cloud phase dependent on T
- AM2: separate prognostic equations for liquid and ice

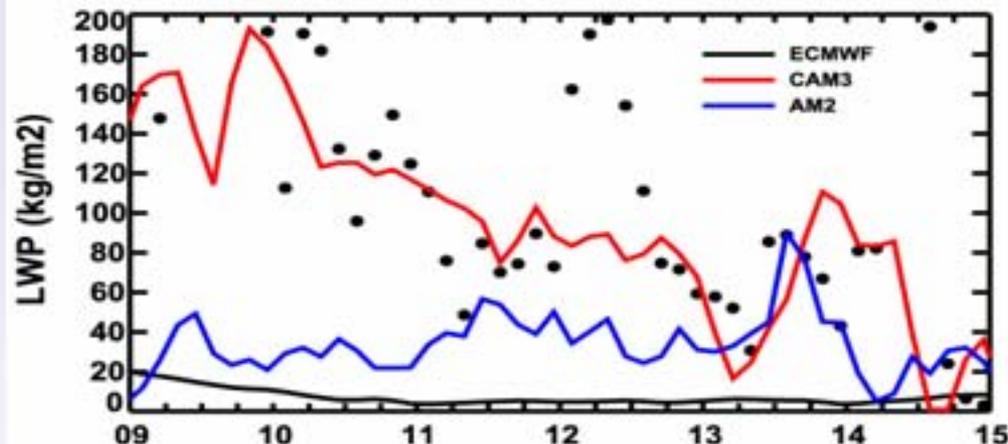
- Cloud fraction is decoupled from cloud waters, especially in CAM3 and AM2

Cloud fraction ~ RH

Cloud LWP/IWP



Cloud Liquid Water Path at Barrow

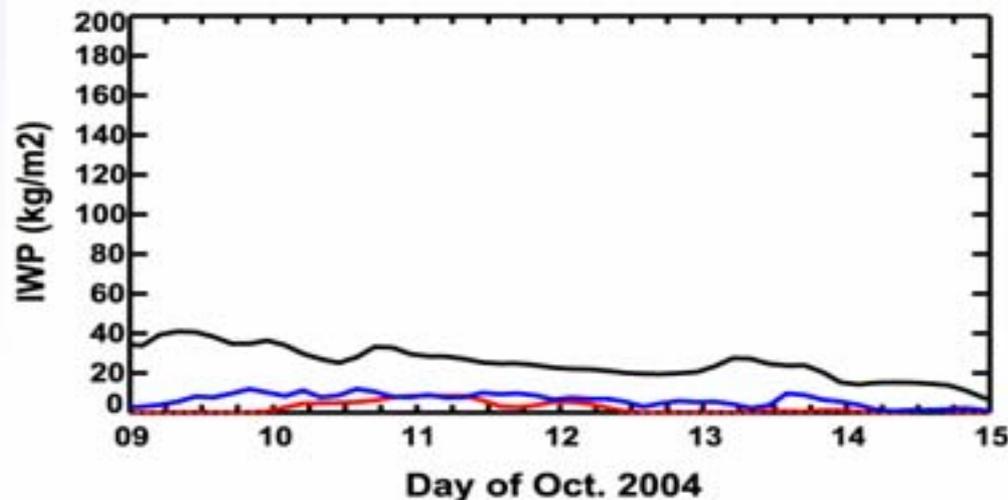


• Observations are from the ARM Microwave Radiometer (MWR)

LWP

- CAM3: surprisingly well
- AM2 & ECMWF: largely underestimate

Cloud Ice Water Path at Barrow



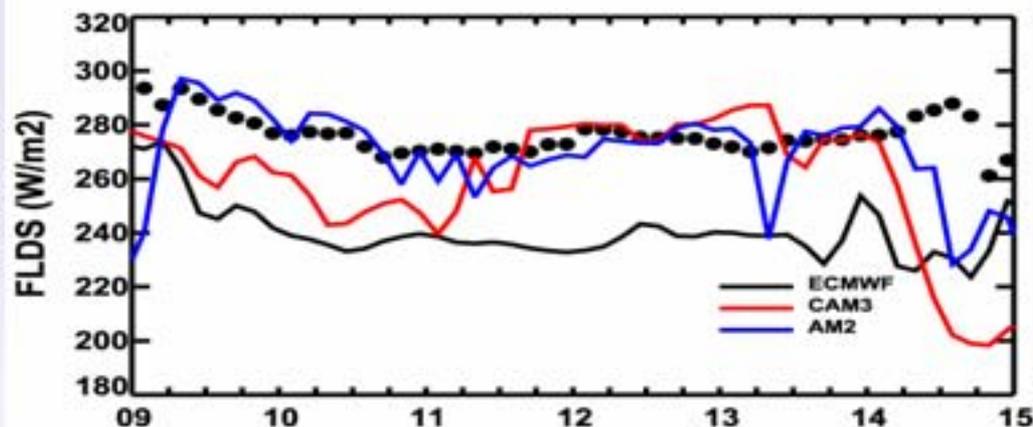
IWP

- CAM3 & AM2: seem too small

Surface Downwelling LW and TOA OLR



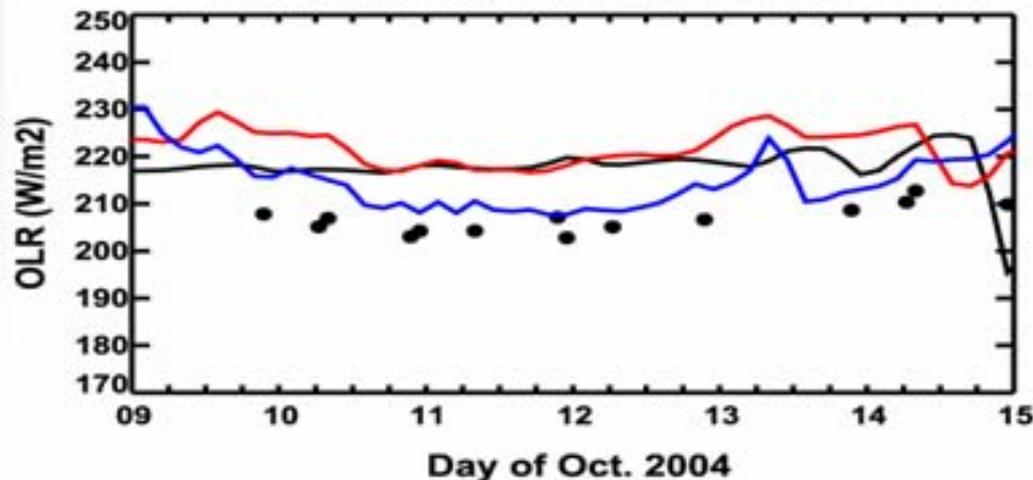
Surface Downwelling Longwave Radiation Fluxes



LWDS

- **ECMWF**: underestimate
- **CAM3**: good agreement Oct. 11-14 and underestimate during other periods
- **AM2**: good agreement due to lower cloud base?

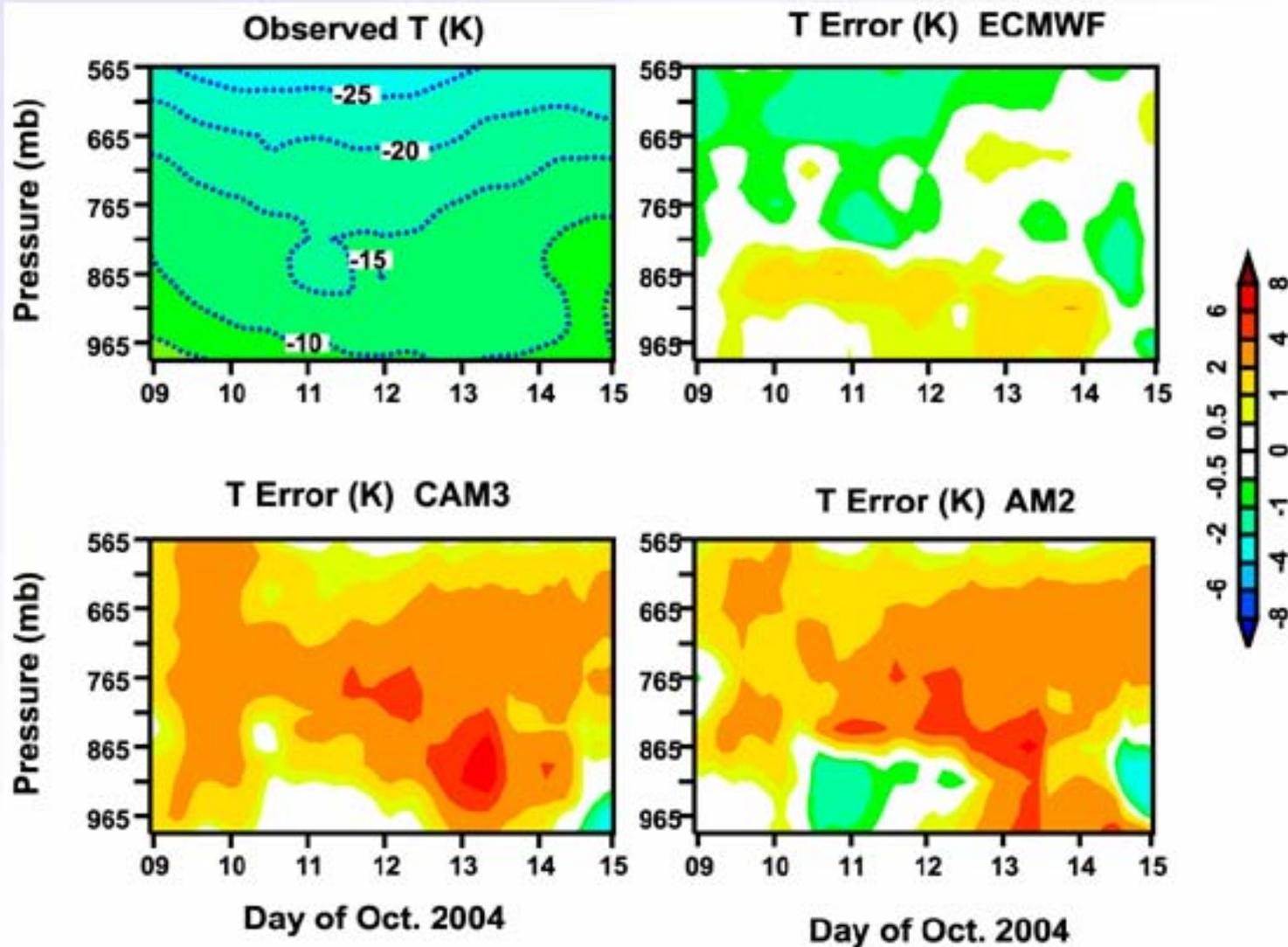
TOA Outgoing Longwave Radiative Fluxes



OLR

All models underpredict

Simulated Temperature





The End