Testing cloud microphysical parameterizations in CAM5 with M-PACE and ISDAC observations

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Goal: Improve Climate Model Parameterizations

- **Tools: single column models (SCM) and DOE Cloud-Associated Parameterization Testbed (CAPT) (LLNL CAPT team)**

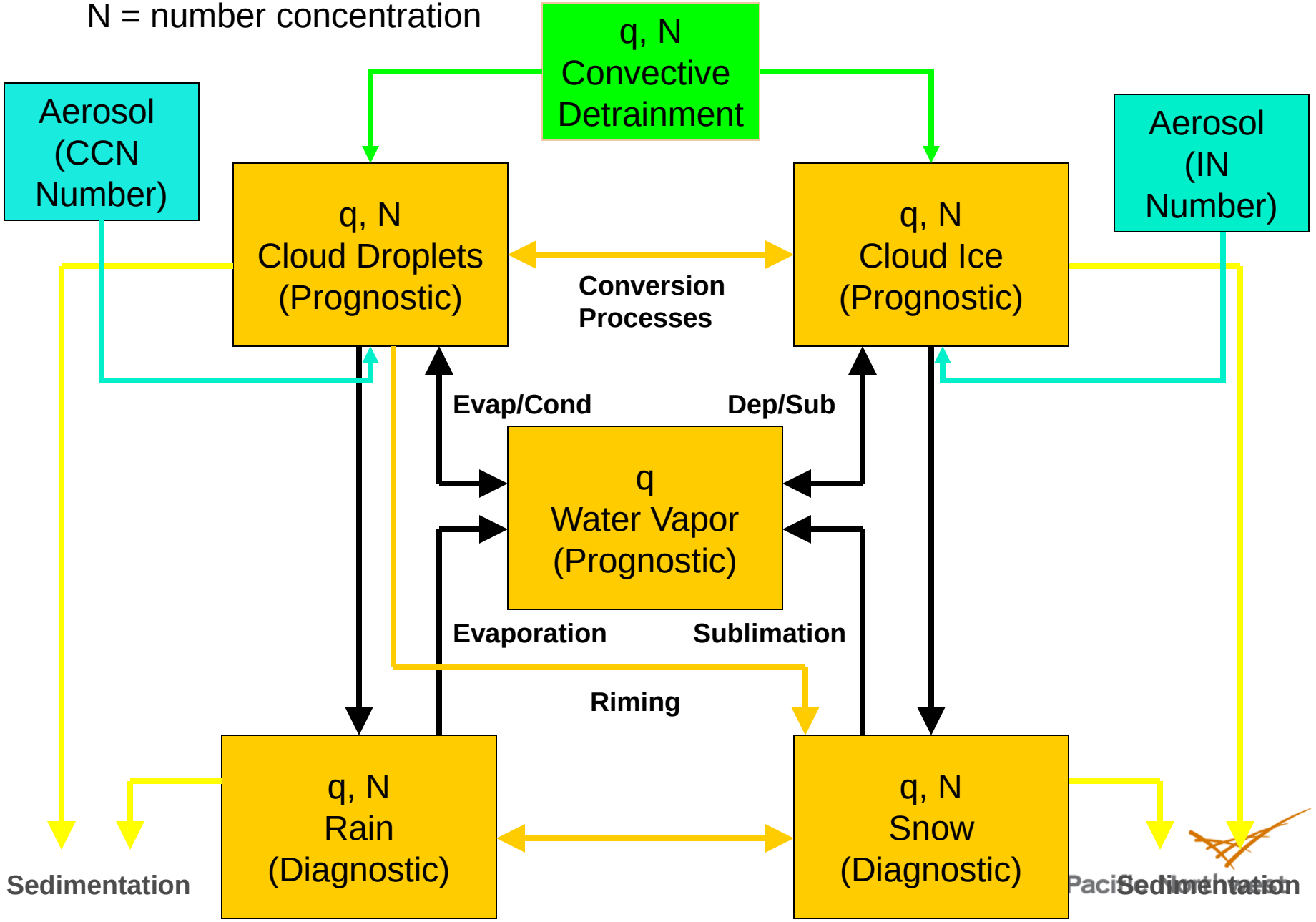
- **DOE ARM measurements provide unique data for model evaluation and guidance for parameterization improvement**

CAM5 Cloud Microphysical Scheme

- Two-moment stratiform microphysics (*Morrison & Gettelman 2008; Gettelman et al. 2010*)
  - Prognostic '*cloud mass*' and '*cloud droplet number*' (Γ-function size distributions)
  - Diagnostic 'precipitation mass' and 'precipitation droplet number'
- Cloud liquid droplet activation (*Abdul-Razzak & Ghan 2002*)
- Cloud ice crystal nucleation (*Liu & Penner 2005*; *Liu et al. 2007*)
  - Homogeneous freezing on sulfate & heterogeneous nucleation on dust in cirrus (ice) clouds
  - Meyers et al. (1992) for deposition/condensation in mixed-phase clouds

Morrison & Gettelman (2008)

q = mixing ratio
N = number concentration



CAPT Forecasts
(M-PACE, October 2004)

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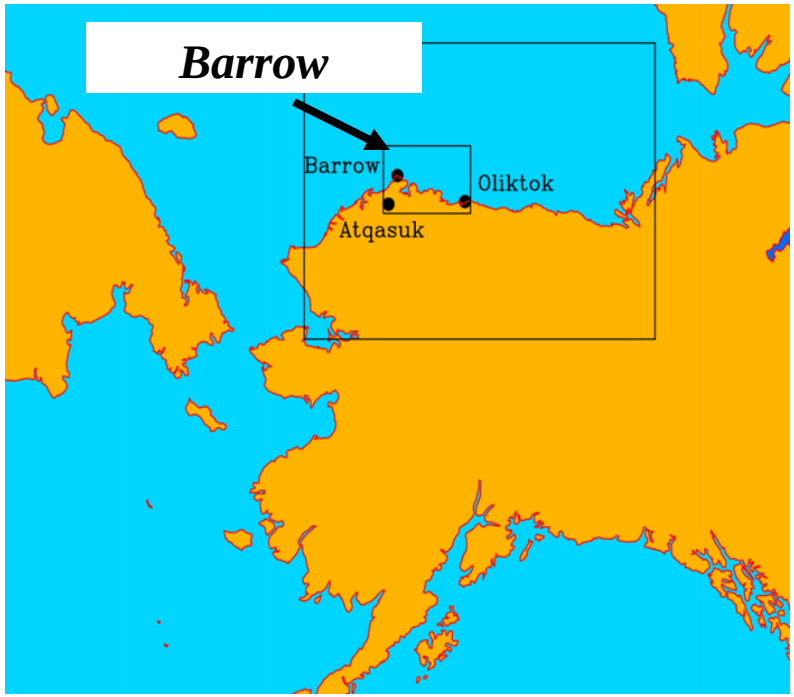
The ARM NSA Mixed-Phase Arctic Cloud Experiment (M-PACE)
October 5 to October 22, 2004



Measurements

Clouds and Cloud Microphysical Properties

- Millimeter-wavelength cloud radar
- Micropulse Lidars
- Aircraft
- 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

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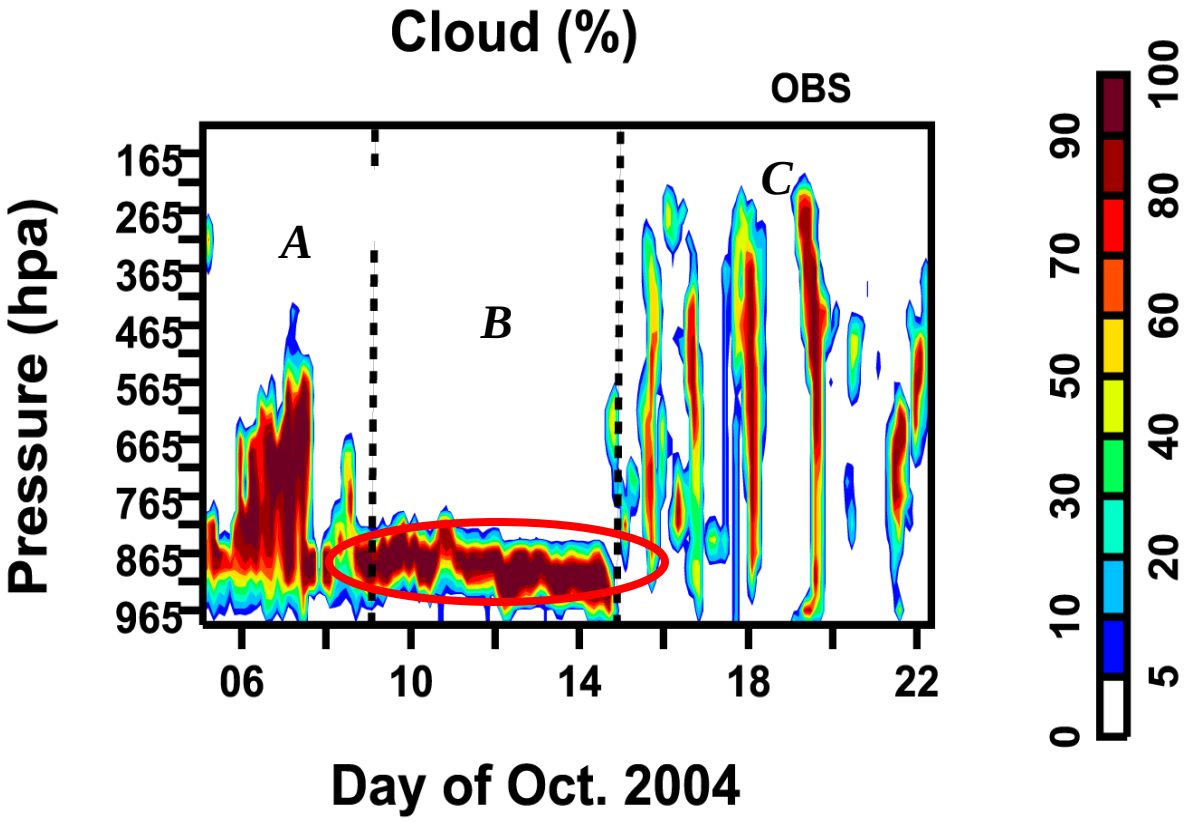
Radar Clouds at Barrow



A: Multi-layer clouds

B: Persistent mixed-phase boundary layer clouds

C: Deep frontal clouds

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Aircraft Measured Cloud Water Content

Oct. 10, 2004

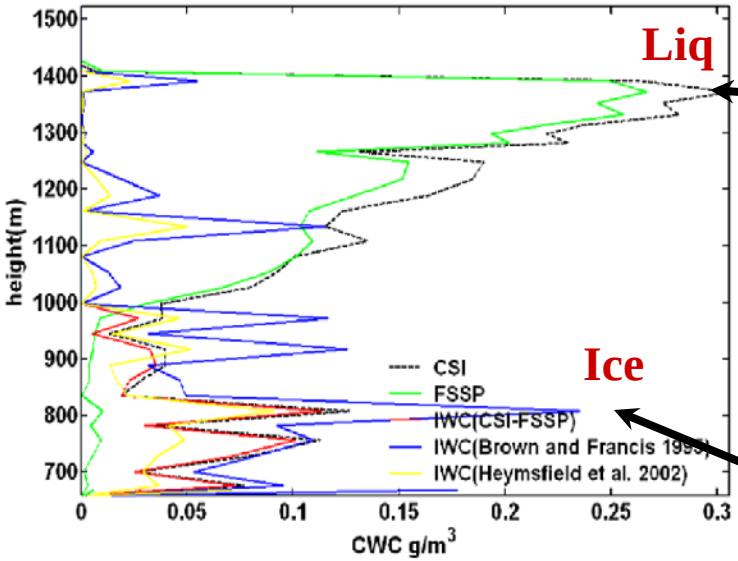

Figure 6 Comparison of bulk measurements of IWC (CSI-FSSP) against IWC estimated from 2DC using variety of habit identification and mass calculation techniques

(From G. McFarquhar et al. 2005)

A strong liquid layer occurred near cloud top at 1300m

Ice crystals in the liquid cloud layer and precipitating ice crystals beneath

For mixed-phase clouds, the range of cloud temp is from -5 C ~ -20 C

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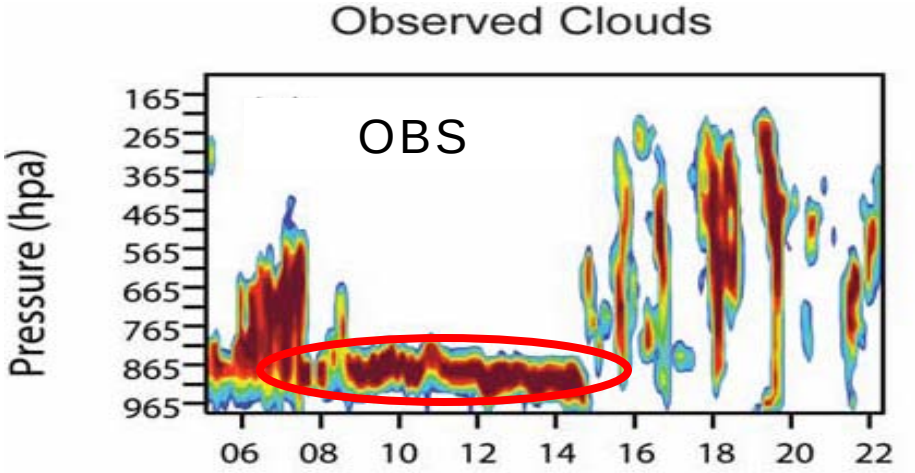
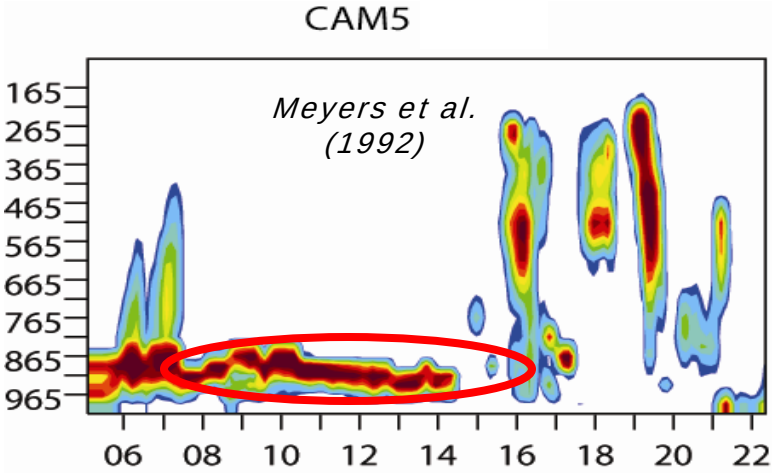
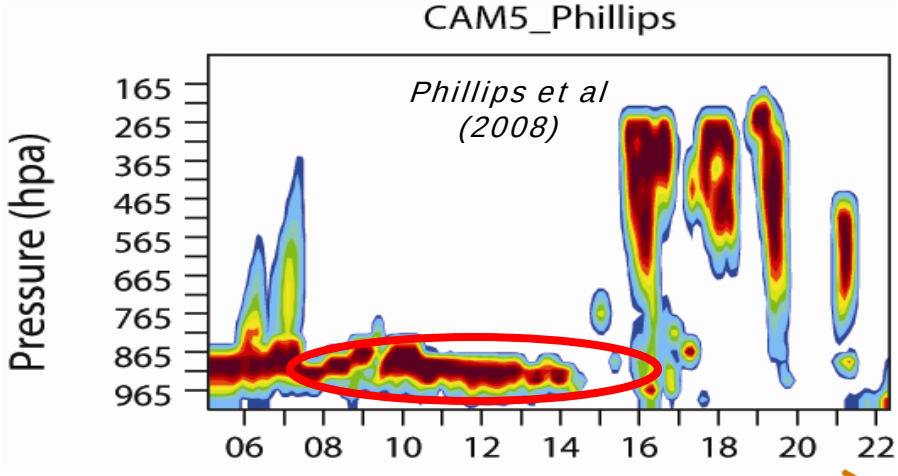
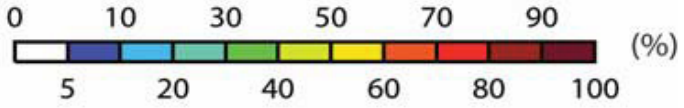
12-36hr forecasts: fewer IN → larger cloud fraction









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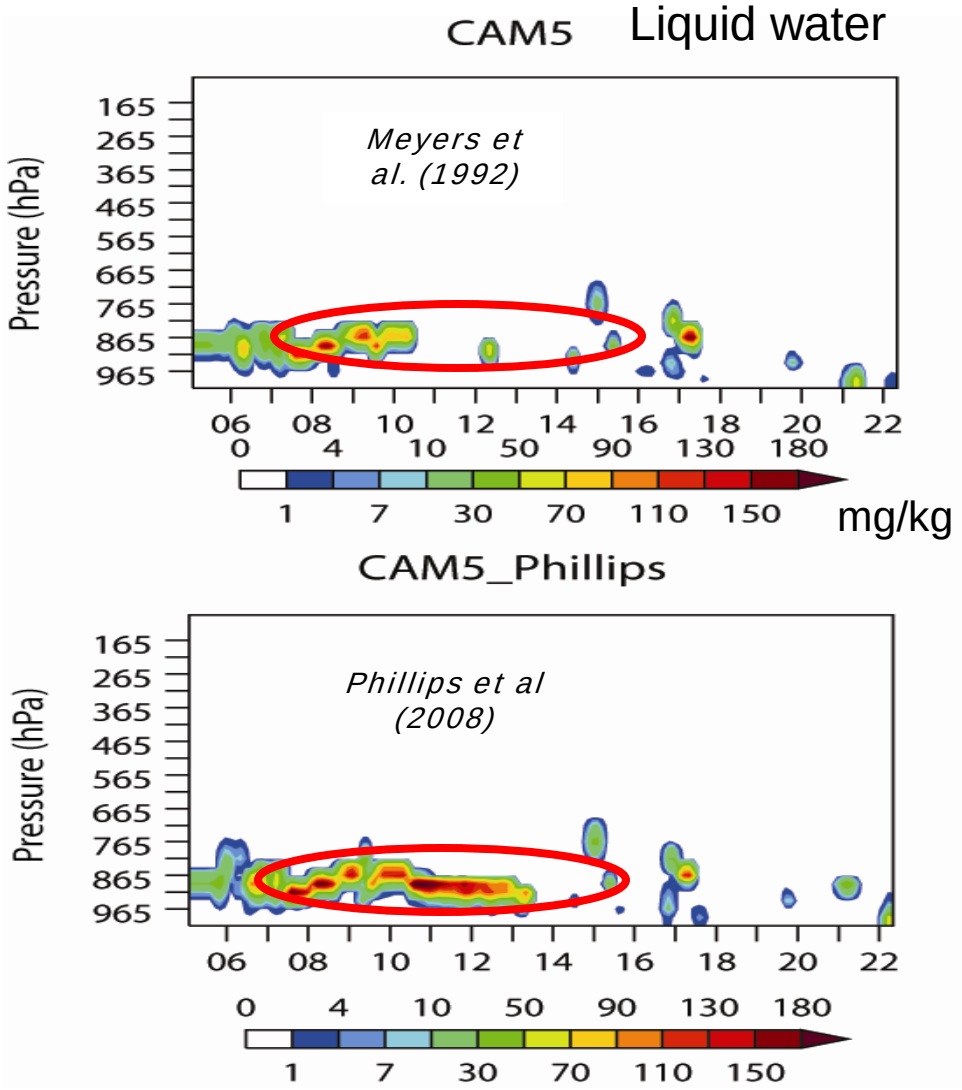
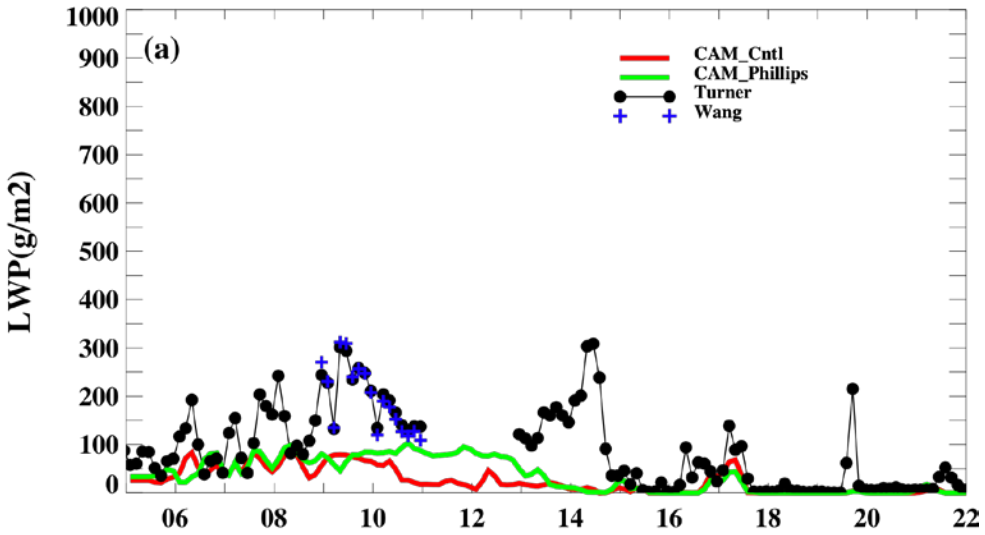
12-36hr forecasts: fewer IN → more Liquid



Fewer Ni → More Liquid

through slowing down the Bergeron process

Liquid Water Path



LWP averaged over 17Z 9 Oct – 05Z 10 Oct, 2004 (in g/m2)

TURNER: 211

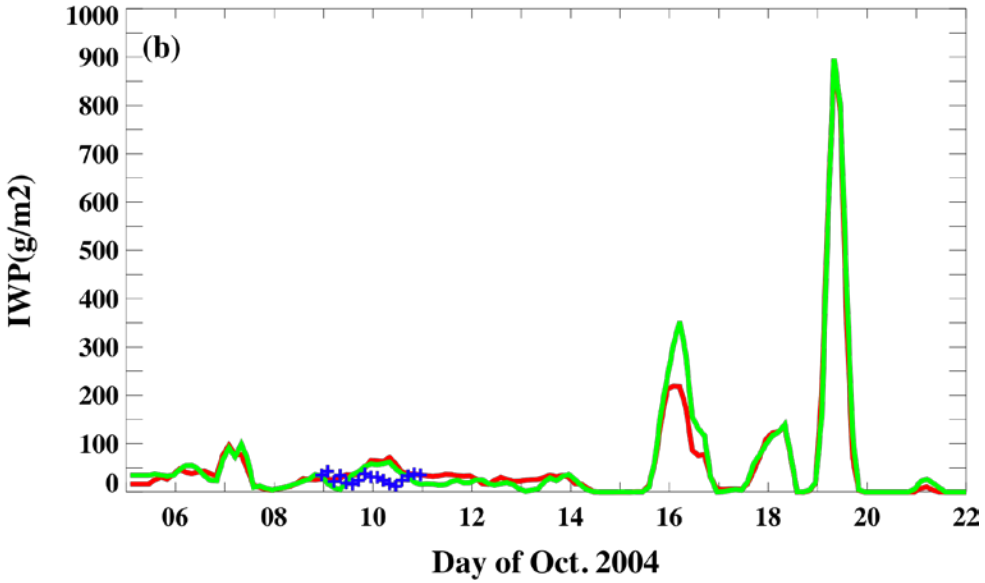
WANG: 204

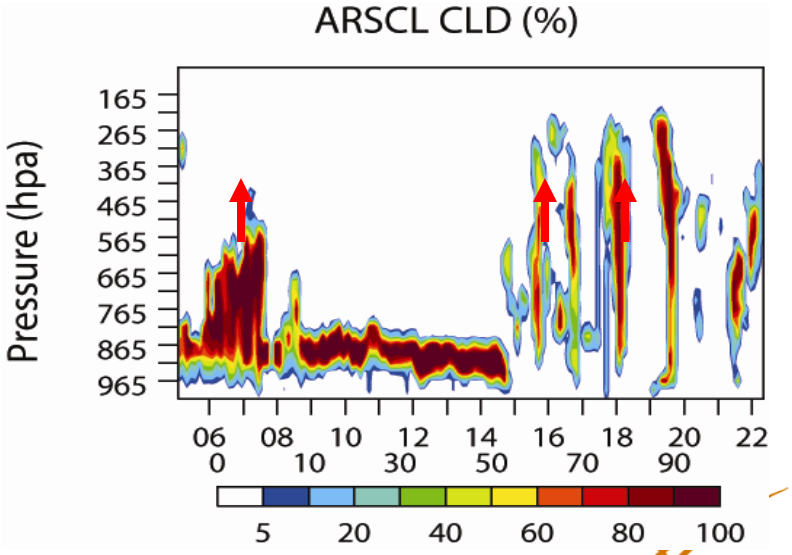
Aircraft: 120

CAM5_Meyers: 64

CAM5_Phillips: 83

Ice Water Path





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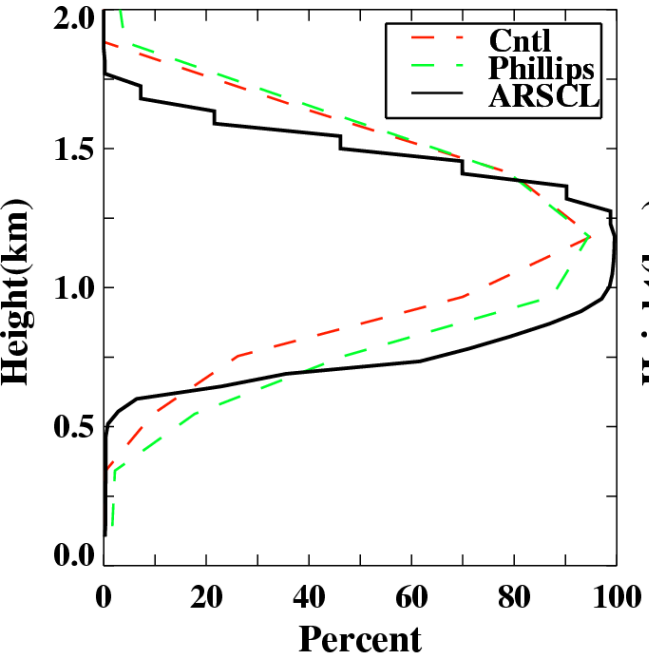
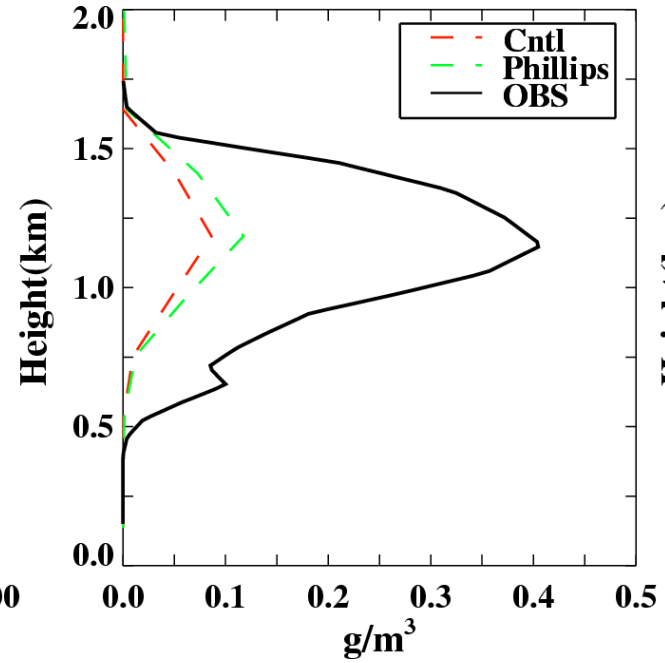
Single-Layer Mixed-Phase Clouds
(1200 UTC 9 October to 1200 UTC 10 October)

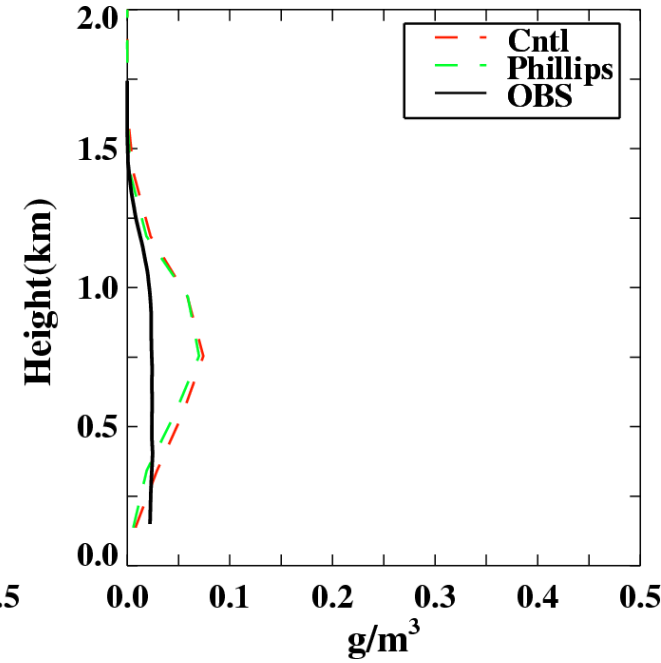
Cloud



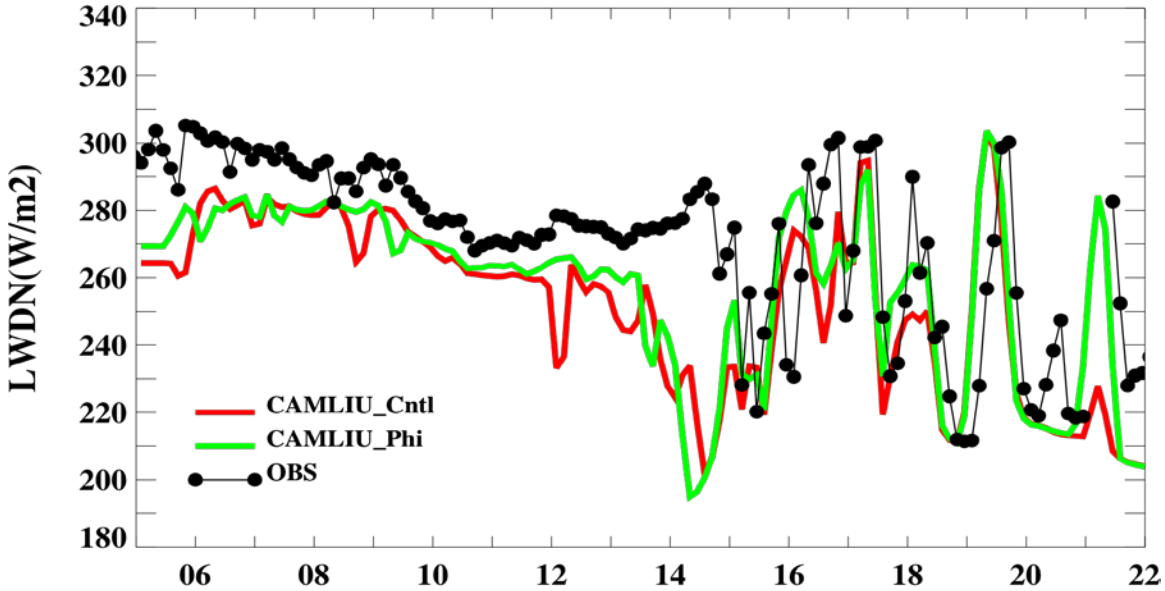
Liquid



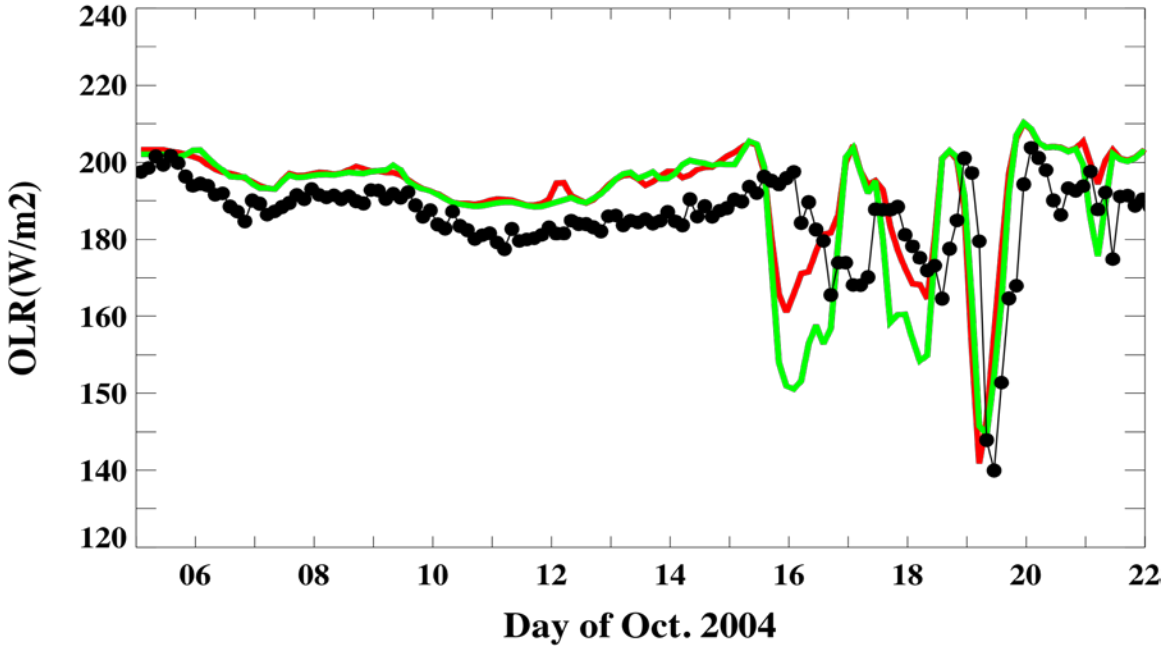
Ice



Impact on LW radiation



Downward LW



Outgoing LW

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SCAM Simulations of Mixed-Phase Boundary Layer Clouds (ISDAC, April 2008)

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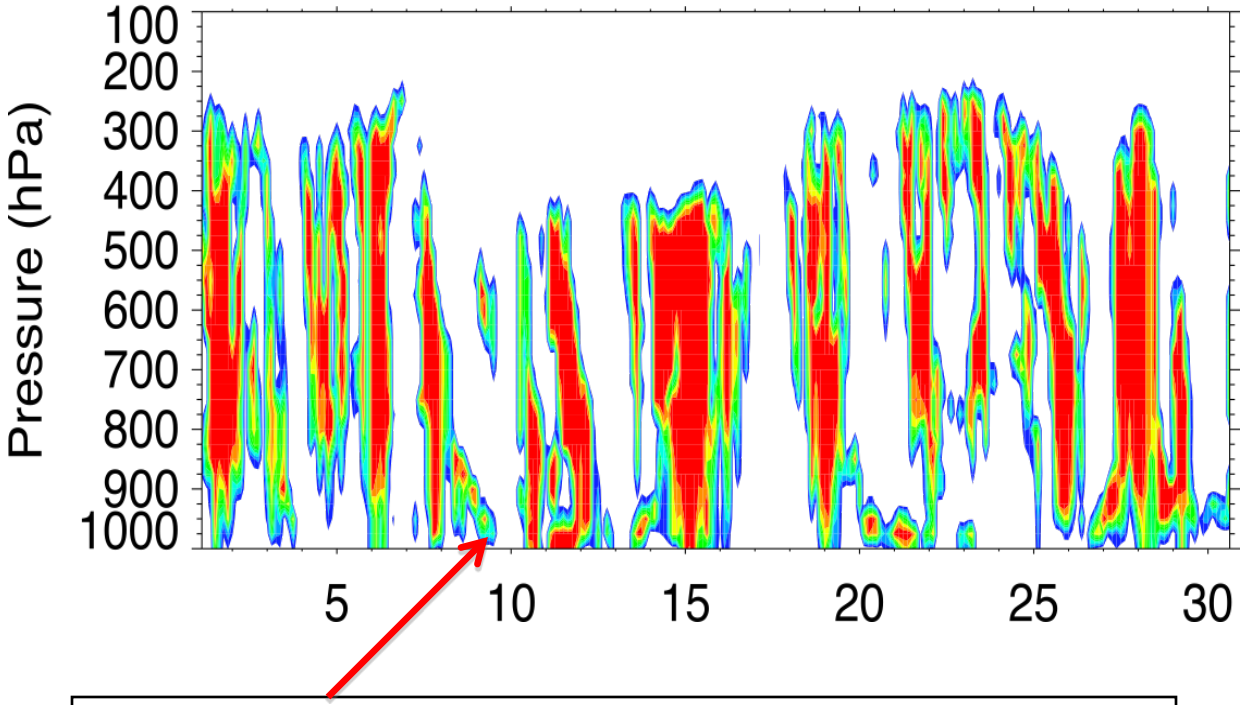
The ARM NSA Indirect and Semi-Direct Aerosol Campaign (ISDAC)
April, 2008

Radar Clouds at Barrow



April 8-9th : single-layer mixed-phase boundary layer clouds

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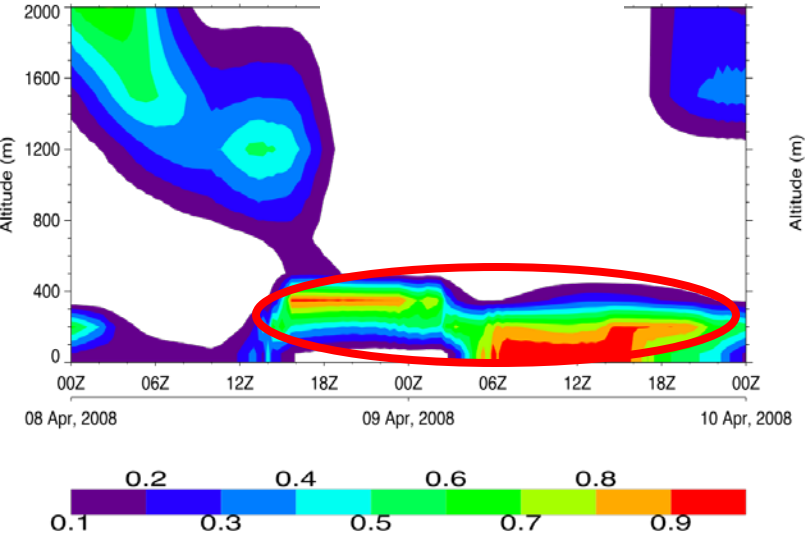
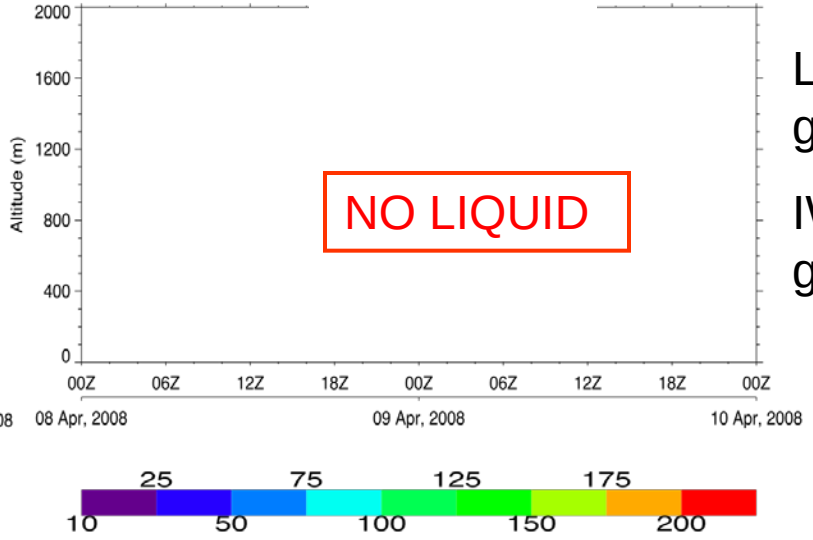
SCAM5 (April 8-9, 2008)

Cloud



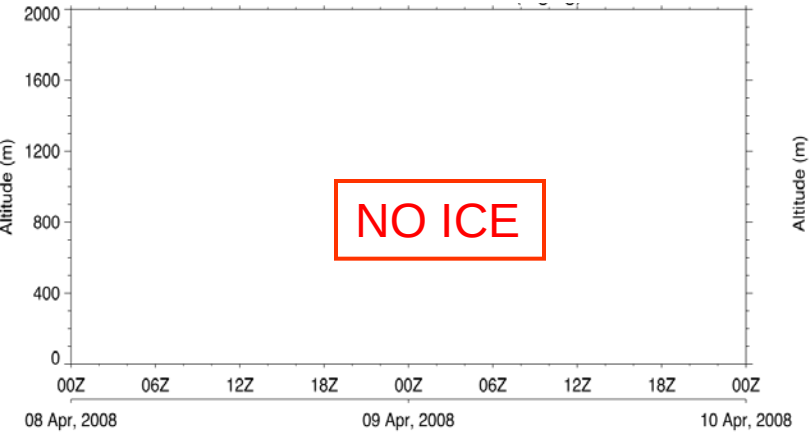
Liquid

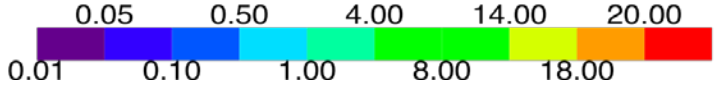


LWC: 0.05-0.4 g/kg (obs)

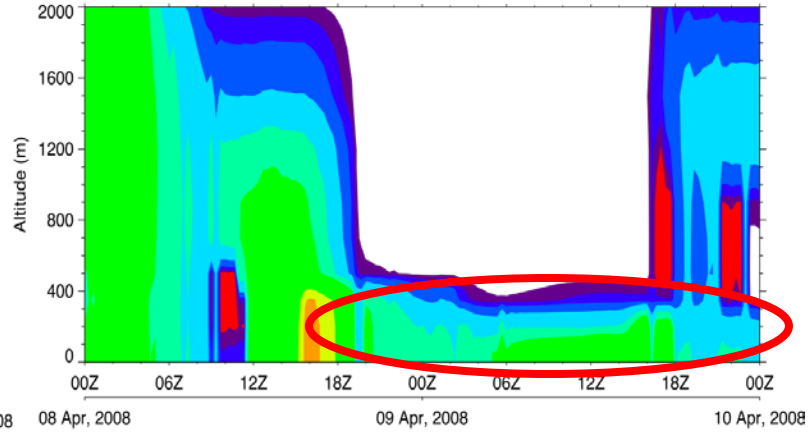
IWC: 0.02-0.05 g/kg (obs)

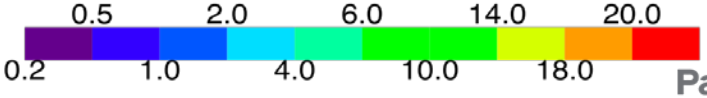
Ice





Snow





mg/kg

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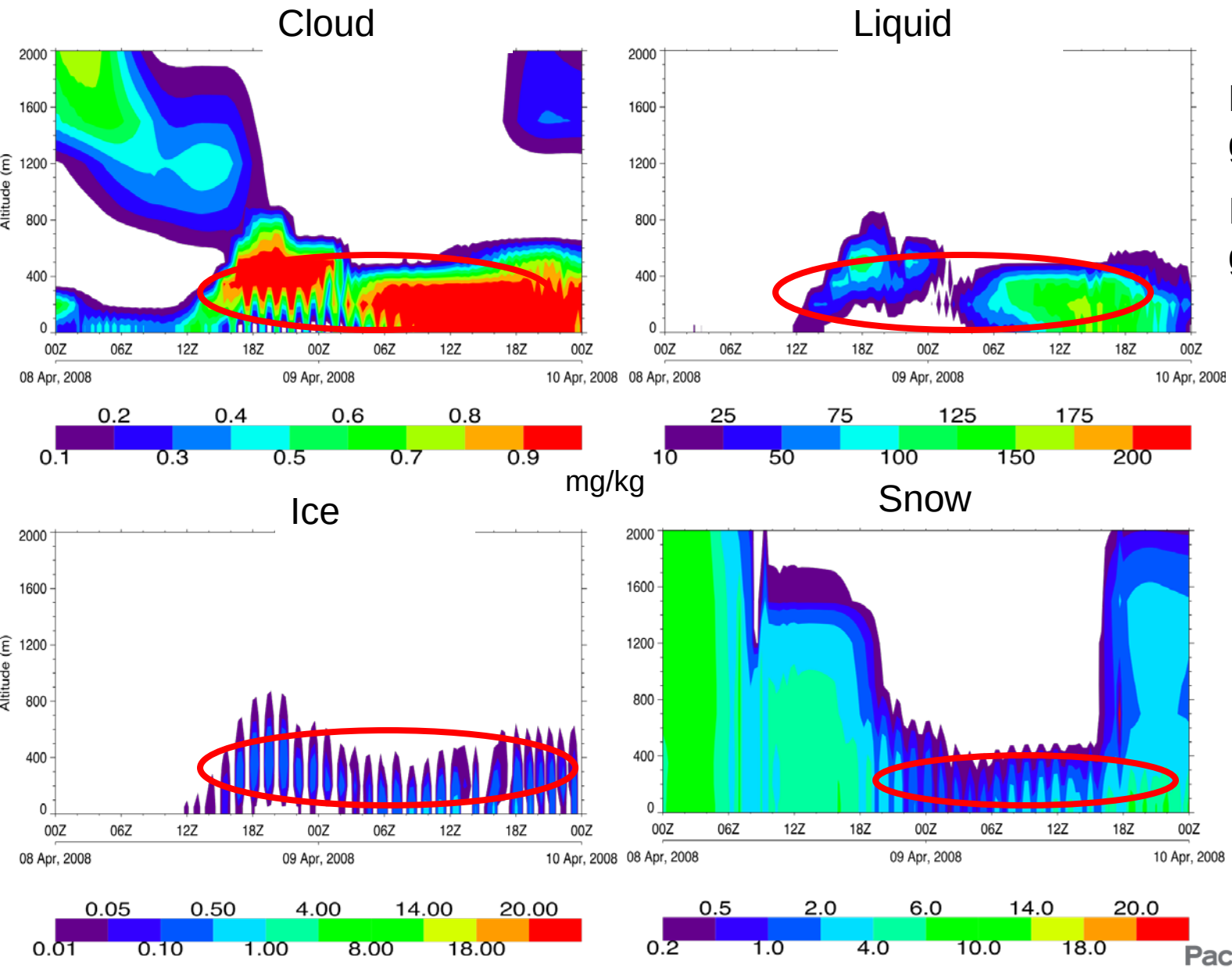
SCAM5 (Homogeneous Rain Freezing, HOMR at -40 C)



LWC: 0.05-0.4 g/kg (obs)

IWC: 0.02-0.05 g/kg (obs)

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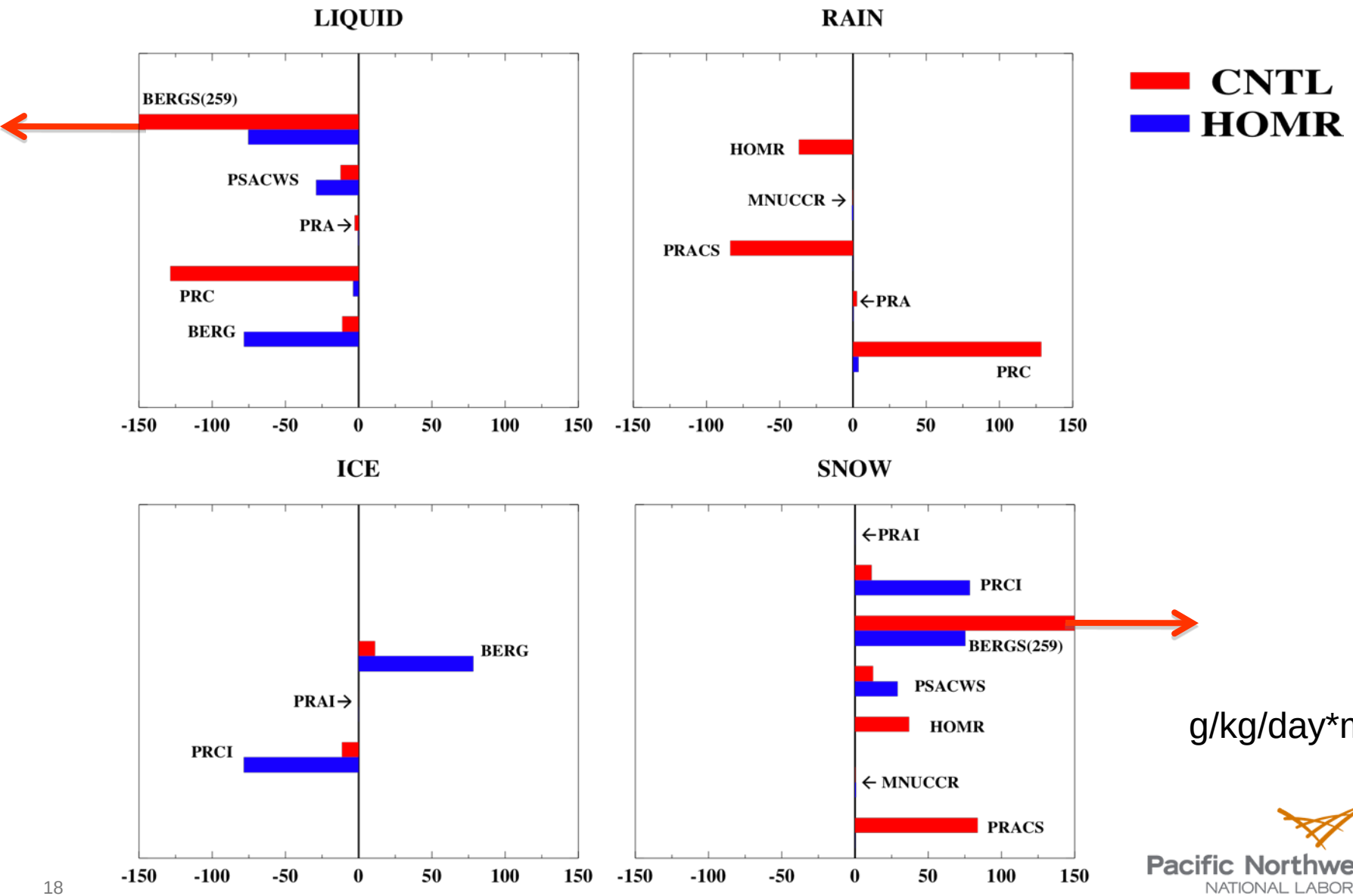
Budget of Cloud Microphysical Processes (0000 UTC 9 April to 1200 UTC 9 April)



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Summary

- **CAM5 simulates cloud fraction reasonably well and captures liquid/ice distribution in mixed-phase clouds. However, it underestimates LWC.**

  Downward LW flux at surface underestimated by 20 W/m2

- **Suggestion to improve LWC :**
  - **HOMR at -40 C (only regional and seasonal effects. Limited effects on global scale)**
  - **Ice nucleation (Phillips et al., 2008; DeMott et al., 2010)**
  - **Bergeron process for liquid (by snow and ice)**