Summary of the Polar Clouds Working Group

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Co-chairs

June 6, 2008, 4th Pan-GCSS meeting
Overview of the Breakout Sessions

• Review of current research related to polar clouds (13 talks)

• ~ 40 attendees

  o 4 talks on cloud observations, recent field campaigns
  o 2 talks on Arctic cloud-climate feedbacks
  o 2 talks on ice formation processes in mixed-phase clouds
  o 1 talk on parameterization development
  o 4 talks on modeling results from Mixed-Phase Arctic Cloud Experiment (MPACE)
• Description of 2 new case studies for model intercomparison
  o Kinematic 1-D microphysics tests (Ben Shipway)
  o Weakly-forced mixed-phase stratus from Surface Heat Budget of the Arctic Ocean (SHEBA) field experiment

• Discussion of the recently completed ARM/GCSS Mixed-Phase Arctic Cloud Experiment (MPACE) model intercomparison and other modeling studies
Mixed-Phase Arctic Cloud Experiment

• M-PACE took place at ARM’s Barrow site in October 2004 (Verlinde et al. 2007)

• M-PACE featured numerous aircraft flights that measured clouds and aerosols among other increased observations

• A variety of cloud types were observed

  A – multi-layer stratus
  B – boundary layer stratocumulus
  C – frontal clouds
• Focus on weakly-forced mixed-phase clouds
  o Prevalence in Arctic
  o Large impact on radiative forcing and surface energy budget
  o Climate and weather models have had difficulty correctly simulating them

% of clouds retrieved as mixed-phase during SHEBA

Shupe et al. 2006
Cloud and radiative flux differences (2007-2006)

CloudSat/CALIOP Cloud Fraction

Downwelling SW Radiation (W m\(^{-2}\))

Downwelling LW Radiation (W m\(^{-2}\))

Western Arctic: -16%

Western Arctic: + 32 W m\(^{-2}\)

Western Arctic: - 4 W m\(^{-2}\)

From J. Kay
Results from the ARM/GCSS MPACE model intercomparison

- First such model intercomparison undertaken by Polar Cloud Working Group

- Results for Period B and A (Klein et al. 2008, Morrison et al. 2008, QJRMS, submitted)

- Model participation:
  - Period B - 17 SCMs and 9 CRMs
  - Period A – 14 SCMs and 4 CRMs
Period B (single-layer cloud)

- Models tend to underestimate liquid water path, overestimate ice water path, but there is a lot of scatter (no consistent diff. between LES/CRM and SCMs).

Figure from G. De Boer
Figure from S. Klein

**Surface downward longwave radiation**

\[ (W \text{ m}^{-2}) \]

**Condensate water path**

\[ (g \text{ m}^{-2}) \]
Figure from S. Klein

**no-ice simulation liquid water path (g m⁻²)**

**control condensate water path (g m⁻²)**
Period A (multi-layer cloud)

• In contrast to Period B, models tend to overestimate liquid water path, underestimate ice water path, but again there is a lot of scatter.

• Results suggest differences in model’s ability to simulate low-level single-layer clouds versus deeper multi-layer clouds.

• Some evidence that increasing complexity of microphysics parameterization improved results in both Periods A and B, but lots of scatter and physical mechanisms for this are
• Importance of ice phase microphysics in weakly-forced mixed-phase clouds, especially ice initiation processes.

• Large discrepancy between observed ice nuclei and crystal concentration – not explained by any quantified ice formation mechanisms.
Early results from the April 2008 Indirect and Semi-Direct Aerosol Campaign (ISDAC)

PIs Greg McFarquhar, Steve Ghan, Hans Verlinde
(presented by M. Dubey)

• Most comprehensive set of in-situ microphysical measurements ever taken in Arctic clouds

• Goals are to provide new insights on ice formation and cloud-aerosol interaction in mixed-phase clouds
**M-PACE October 2004**

- Pristine Conditions
  - Open ocean
  - Few cloud droplets
  - Ice multiplication
  - Precipitation
- Measurements by ~10 instruments
  - aerosol properties
  - cloud microphysics
  - atmospheric state.

**ISDAC April 2008**

- Polluted Conditions
  - Sea Ice
  - Many cloud droplets
  - Ice nucleation
  - Little precipitation
- Measurements by ~40 instruments
  - aerosol properties
  - cloud microphysics
  - radiative energy
  - atmospheric state.
1-D kinematic mixed-phase microphysics test (Ben Shipway)

- Basic idea is to test microphysics schemes in a simplified framework with specified dynamics, allows for testing of microphysics in the absence of feedbacks with dynamics

- 1D column with specified vertically- and temporally-varying vertical velocity to mimic updraft/downdraft cycle of large eddy in stratocumulus
SHEBA mixed-phase stratus model intercomparison case

• Long-lived low-level mixed-phase stratus were observed during early May, focus is on May 7, 1998

• Several key differences from MPACE cases:
  o Colder temperatures (~ -22 C vs. -15 C)
  o Much smaller surface turbulent heat fluxes (ice-covered vs. open ocean)
  o More polluted aerosol
  o Much smaller amounts of cloud liquid water

• Intercomparison being conducted jointly with July 2008 WMO Cloud Modeling Workshop in Mexico
Broader outlook/questions

• Focus has been on mixed-phase clouds, future cases on ice-phase (diamond dust)?

• Bias toward evaluation of models based on point measurements in western Arctic - new satellite tools and observation ground sites