A Comparison of Spring and Fall Arctic Mixed-Phase Clouds:

Perspectives from the surface during ISDAC and MPACE

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Retrieval Methods

Analysis involves 6 weeks of single-layer, stratiform, mixed-phase cloud observations from the NSA site during MPACE (Sept-Nov 2004) and ISDAC (April-May 2008)

Cloud Boundaries – Cloud top identified using radar, cloud base identified using high spectral resolution lidar or ceilometer.
Phase Classification – Uses phase-specific signatures from radar, lidar, microwave radiometer, and radiosonde measurements (Shupe, GRL 2007).
Ice Microphysics (IWC and IWP) – Empirical radar reflectivity power law relationship and assumptions about particle size dist'n and mass-size relationship (Shupe et al., JAM 2005).
Liquid Microphysics (LWC and LWP) – Adiabatic liquid water profile using cloud boundaries and temperature profiles, scaled using a liquid water path derived from combined microwave radiometer and AERI measurements (Turner, JGR 2007).
Vertical Velocity (W) – From cloud radar Doppler spectra, assuming liquid water droplets are tracers for air motions (Shupe et al., JTECH 2008).
Turbulent Dissipation Rate (ε) – From time-variance of radar mean Doppler velocity measurements (e.g., Shupe et al., JTECH 2008).

Summary

❖ Similar structure and processes occur in Arctic stratiform mixed-phase clouds in both spring and fall seasons.
❖ Most differences that do occur are reasonably well linked to the balance of cloud forcing mechanisms:
➢ **Fall**: Surface forcing dominates radiative cooling, well-mixed boundary layer.
➢ **Spring**: Radiative cooling dominates surface forcing, cloud decoupled from surface.
❖ These differences lead to more vigorous motions in the fall, with more turbulence, thicker clouds, and more cloud liquid.

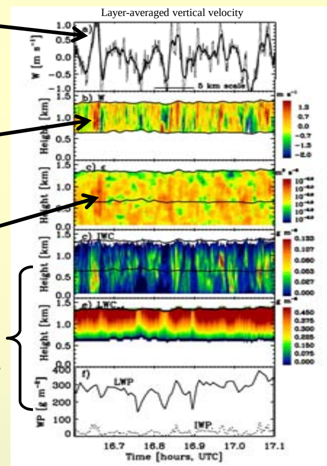
MPACE

Mixed-Phase Arctic Cloud Experiment

"Arctic Fall"

9 October 2004 Case Study

A characteristic Arctic fall mixed-phase stratocumulus case with ice crystals falling from a supercooled liquid cloud (Ttop ~ -15C). The case includes roll cloud structure caused by northeasterly flow off the sea-ice, over the "warm" ocean, and flowing to Barrow. Relatively low ice and cloud nucleus concentrations.

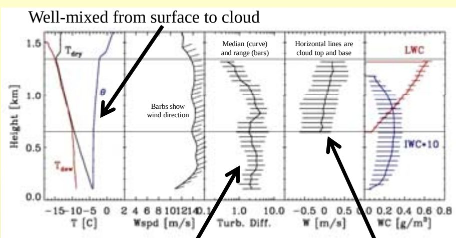


Cloud-scale variability on scales up to ~10 km

Vertically-coherent circulation structures

Increased turbulence at interfaces between strong up- and downdraft motions

Liquid and ice formation both occur in updrafts



Turbulence profile suggests that surface turbulent fluxes are important for cloud formation

Vertical velocity profile supports "bottom up" convection

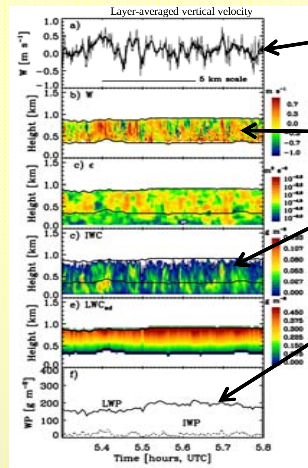
ISDAC

Indirect and SemiDirect Aerosol Campaign

"Arctic Spring"

27 April 2008 Case Study

A characteristic Arctic spring mixed-phase stratocumulus case with ice crystals falling from a supercooled liquid cloud (Ttop ~ -15C). This case is similar to the MPACE case with the same cloud top temperature, structure, and northeasterly flow. The primary differences are that in spring there is little influence from open water heat sources and there are higher ice and cloud nucleus concentrations.



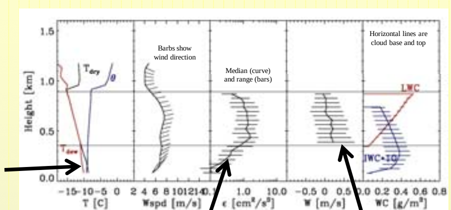
Cloud-scale variability on scales up to 2-3 km

Circulation are not vertically-coherent

Cloud ice forms during updrafts

Liquid water appears to be less sensitive to vertical velocity

Slight indication that cloud is decoupled from surface

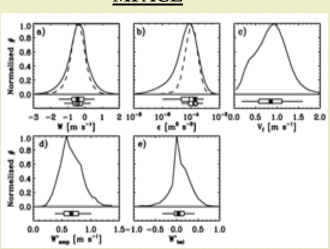


Turbulence profile suggests cloud top radiative cooling is most important for cloud formation

Vertical velocity profile supports "top down" convection

Comparing Dynamics (6 week data sets)

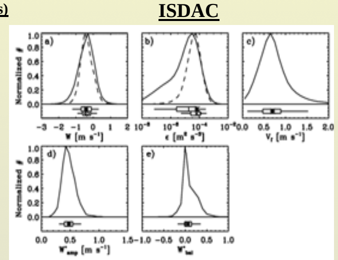
MPACE



Key Results

• Similar distribution shapes for most parameters.
• MPACE has a broader distribution of vertical velocities and typically a larger circulation amplitude (W_{amp}), indicating more vigorous motions.
• MPACE has more turbulence, on average, due to the presence of open ocean.
• ISDAC has smaller ice particle fall speeds (V_f) possibly because there are more ice crystals which then grow slower.

ISDAC

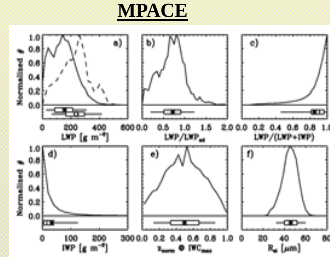


• ISDAC has less skewness to the vertical velocity distribution over ½ hour time periods.

Definitions
W_{amp} = variability of W in ½ hour window
W_{skl} = skewness of W dist'n in ½ hour window

Comparing Microphysics (6 week data sets)

MPACE



Definitions
LWP/LWPad = adiabadicity fraction
LWP/(LWP+IWP) = liquid fraction
Znorm @ IWC_{max} = fractional depth in layer w/ max IWC

Key Results

• Less liquid water during ISDAC compared to MPACE.
•Ice comparison is uncertain due to radar calibration issues.
• Clouds in both seasons are liquid dominated, although somewhat moreso during MPACE
•The height at which the maximum ice mass exists is higher within the hydrometeor layer during ISDAC than during MPACE

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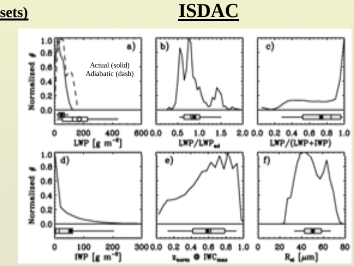

•Clouds during both seasons typically have liquid water paths that are 50-100% of the adiabatic value.