The Liquid-ice Partition in Arctic Mixed-phase Clouds Observed at the NSA Site

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Presentation Overview

- ***Introduction***
- ***Data***
- ***Temperature influence***
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- ***Large-scale vertical motion influence***
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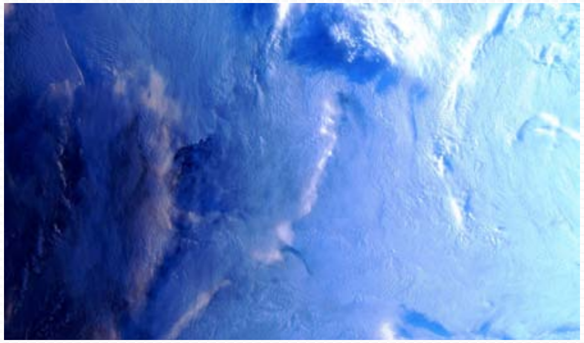


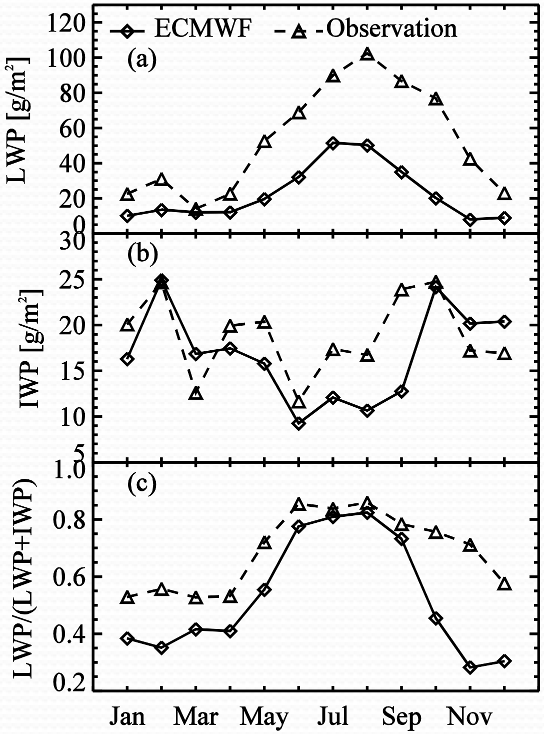
1. Introduction

1) Most frequent cloud type: ~70% of Arctic boundary layer clouds are mixed-phase.

2) Strong radiative effects on sea ice and snow-covered surface.

3) The cloud mass phase partition is important factor for cloud life time.

4)From our model comparison study, phase partition of the Arctic Mixed-phase clouds is poorly represented by the ECMWF model (Zhao and Wang, 2010).



Zhao and Wang, accepted by JGR

2. Data

1) Clouds: *(1999 to 2008 at the NSA Barrow site)*

- **Instruments**: MMCR, MPL, MWR, and SONDE.
- **Microphysical properties**

  Based on a new multiple sensor (MWR+MPL+ MMCR) approach (Wang, 2007):

  MPL+MMCR → ice water content and general effective radius profiles for **ice phase**.

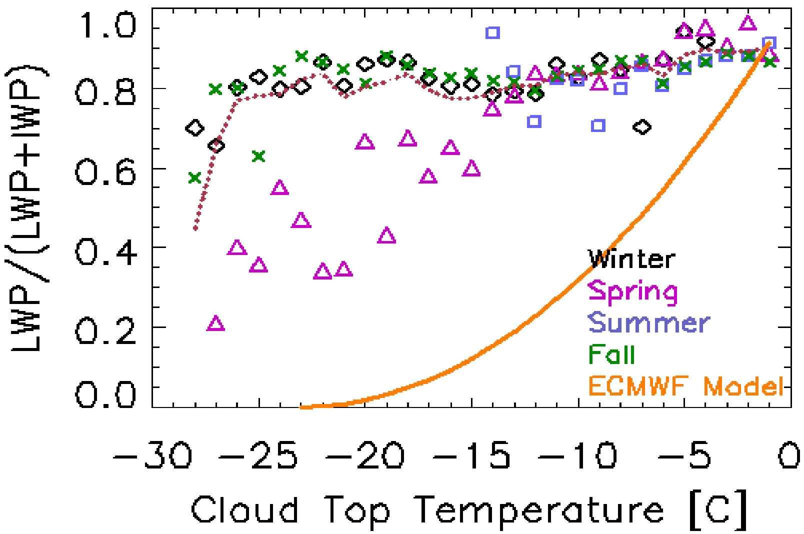
  MWR+MPL+ adiabatic cloud model → LWP and cloud effective radius for **water phase**.

2) Aerosol:

- **ARM MPL polarized data** → Aerosol depolarization ratio
- **ARM Aerosol Observing System (AOS)** → CCN
- **NOAA GMD Aerosol Data** → Extinction coefficient from Nephelometers

3. Temperature influence

1) LWF as a function of cloud top temperature



Klein et al. 2009: multi-model inter-comparison study on stratiform mixed-phase cloud simulations

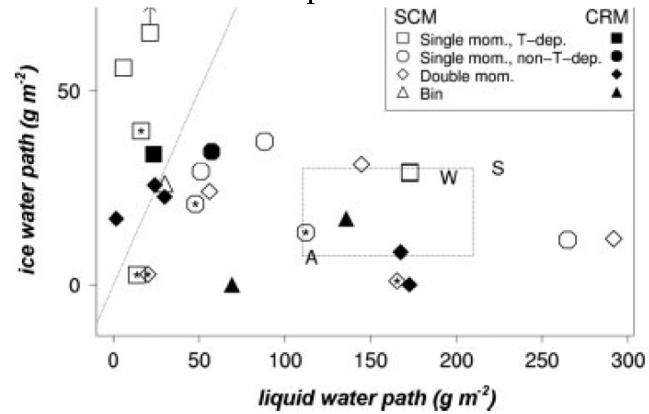


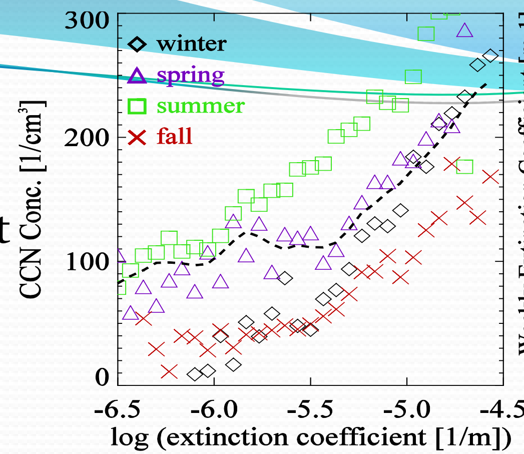
Figure 7. Scatter-plot of the median liquid water path and ice water path from observations (letters) and model simulations (symbols). The

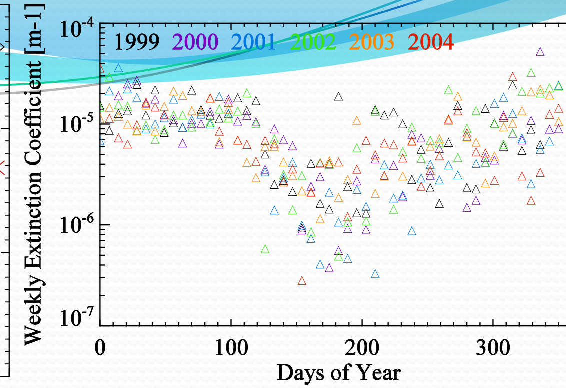
- Observed LWFs are noticeably different from model simulations.
- Observed LWF in spring is lower than in the other seasons when cloud top temp colder -15 ^{o}C.

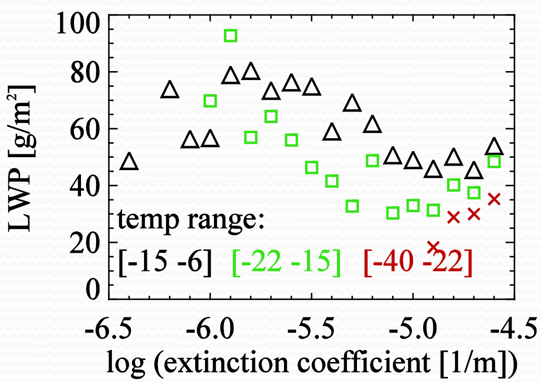
4. Aerosol influence

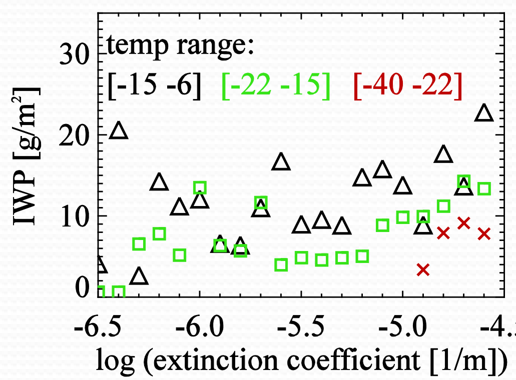
1) Aerosol loading:

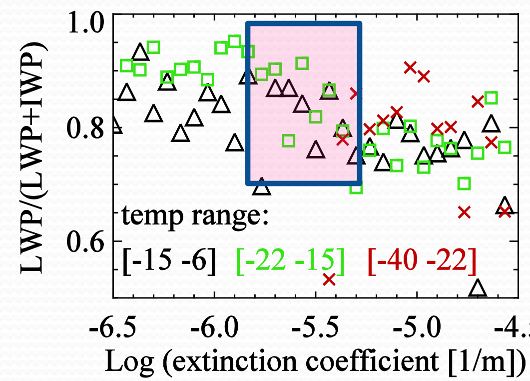
Extinction coefficient and CCN number concentration are positively correlated, but there are significant differences among seasons.











- LWP decreases with increase of aerosol loading.
- IWP slightly increases with increase of aerosol loading.
- LWF transits from a high value state to a slight low value state within the log(ext. coeff.) range of between -5.8 and -5.3.

2) Seasonal variation of aerosol depolarization ratio

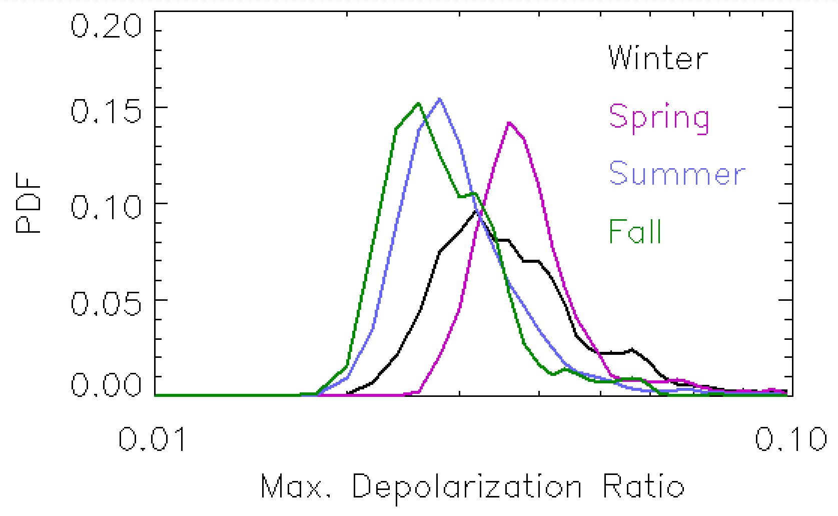
- ***Method*:**

1) The depolarization ratio:

x-pol/(co-pol+x-pol)

2) Layer mean and maximum depolarization ratios in 0.5 - 4 km

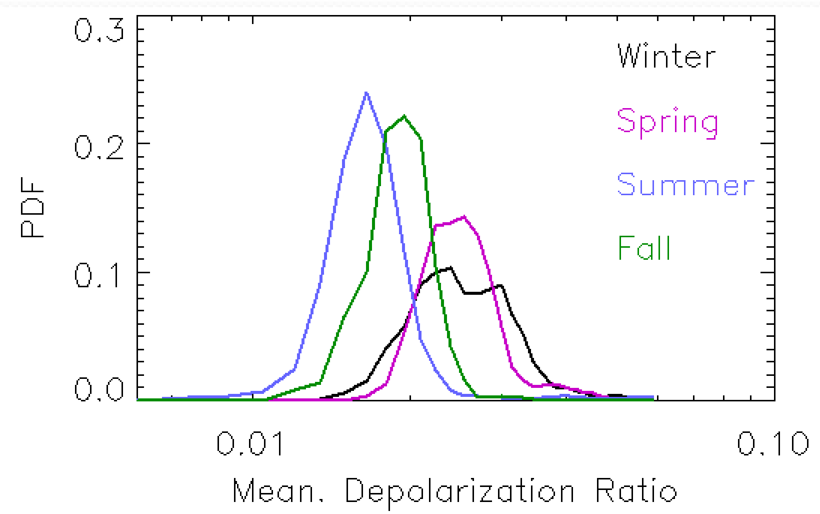
3) Cloud-free profiles only



- ***Statistical results:***

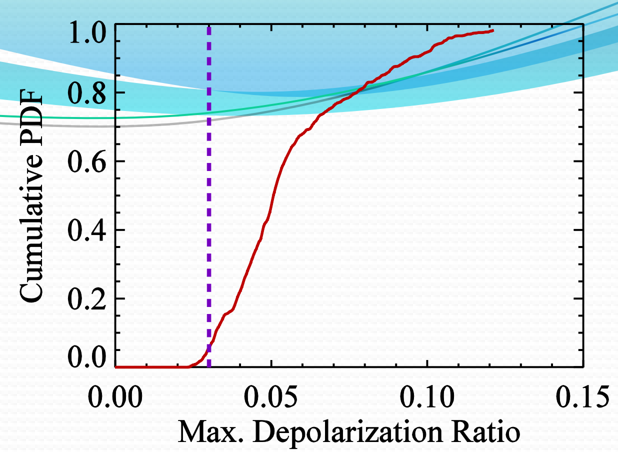
1) Probability density function (PDF) shows seasonal variation.

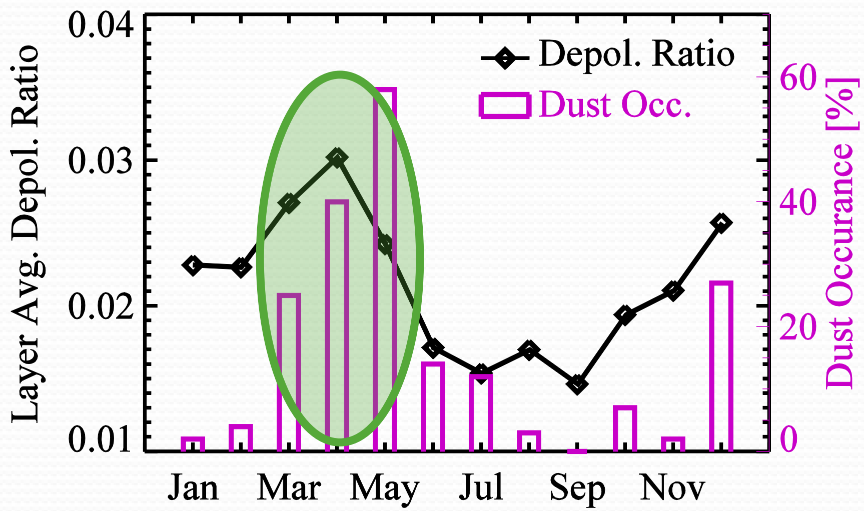
2) Larger depolarization ratio in spring is possibly due to Asian dust event.

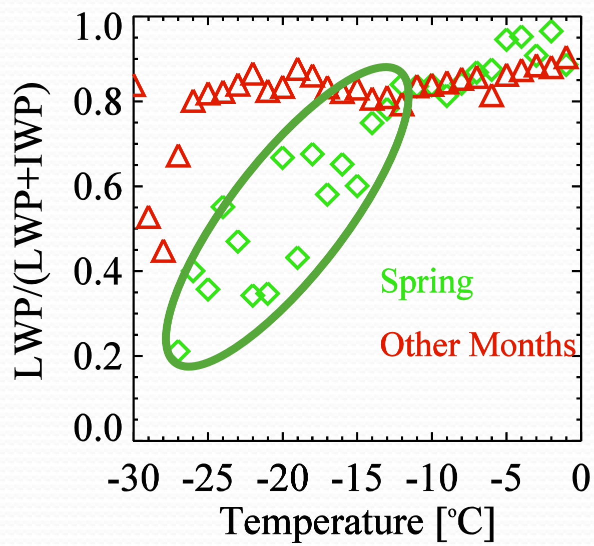


3) Dust impact

- Dust aerosols are effective heterogeneous ice nuclei.
- Max. depolarization ratio > 0.03 as threshold for identifying possible dust aerosol occurrence.

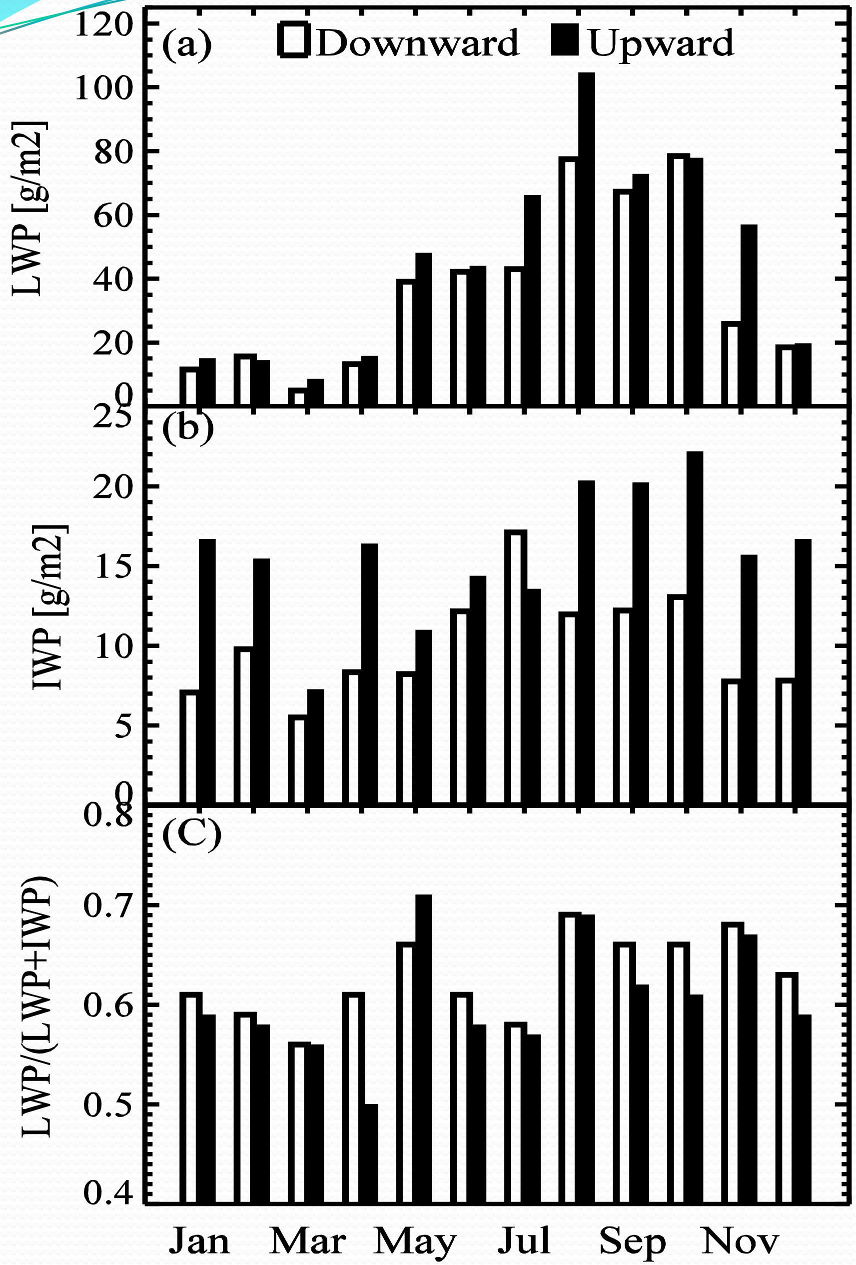






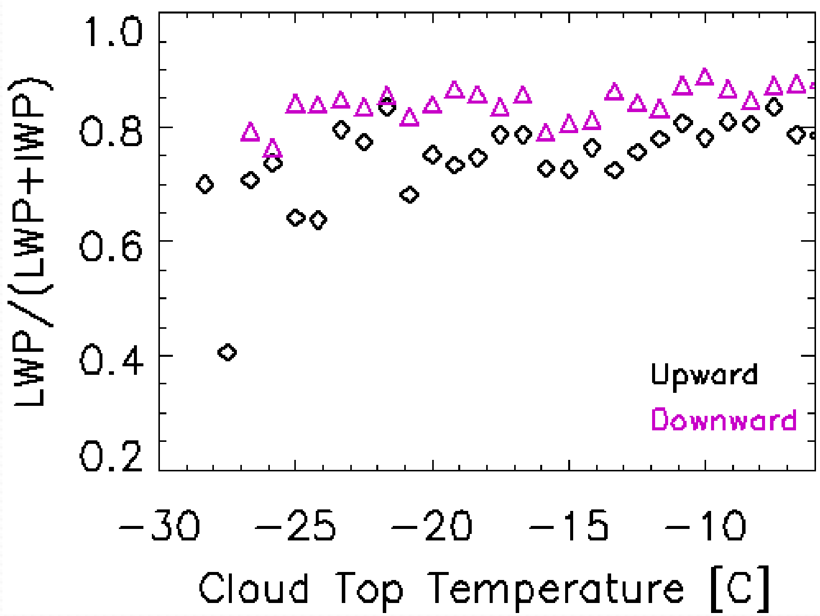
- Monthly mean layer-averaged depol. Ratio and dust occurrence show maximum value in Spring (*Dust occurrence is ratio of number of dust profiles and total number of cloud-free profiles*).
- Spring dust event is a possible reason to explain the observed lower LWF.

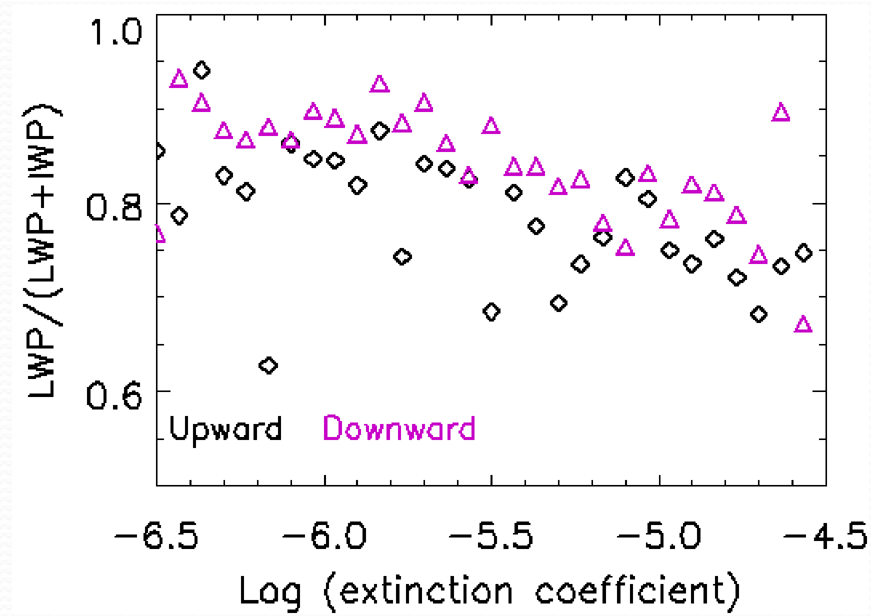
4. Large-scale Vertical Motion Influence



- Both LWP and IWP are larger under upward motion than under downward motion.
- Influence of large-scale vertical motion on IWP (57% difference between up and down) is more noticeable than on LWP (20% difference).
- LWF under upward motion is slightly lower than under downward motion except in May.

1) Dynamical influence on LWF as function of cloud temperature and aerosol loading

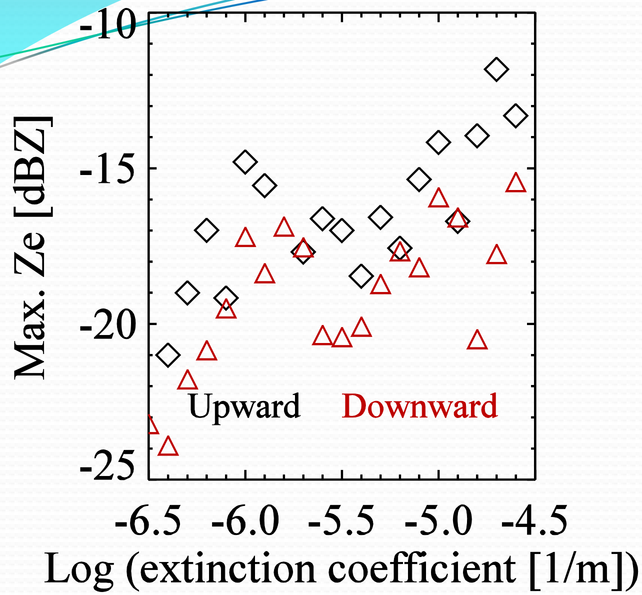




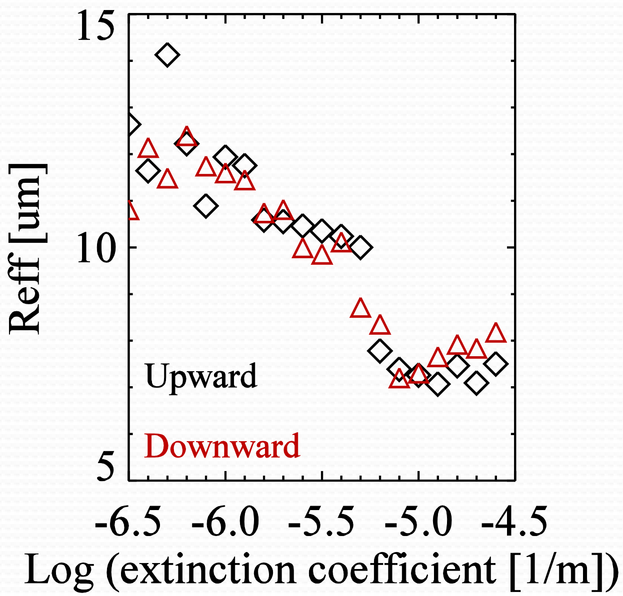
- At certain temperature/extinction coefficient, LWF is generally lower under large-scale upward motion than under downward motion.

- LWF difference (up-down)=0.15 top temp < -15 ^{0}C
  LWF difference=0.07 top temp > -15 ^{0}C:
  LWF difference =0.1, -6 < log(ext. coeff.) < -5
  LWF difference =0.06 log(ext. coeff.) > -5 or log(ext. coeff.) < -6

2) Dynamical influence on cloud microphysics



- Max. Ze within the mixed-phase layer is 3 dBZ larger under upward motion than under downward motion.



- The influence of large-scale vertical motion on R_{eff} is negligible.

Conclusions and Future Work:

Conclusion:

- In spring season, liquid water fraction (LWF) as function of cloud top temperature is lower than in other seasons when temp colder than -15 ^{0}C, which indicates:

-- Aerosol loading and aerosol type are other important factors to influence LWF other than cloud top temperature.

-- Lower LWF in spring is possibly due to Asian dust.

- Large-scale vertical motion is closely related to cloud liquid and ice properties. LWF is lower under upward motion than under downward motion.

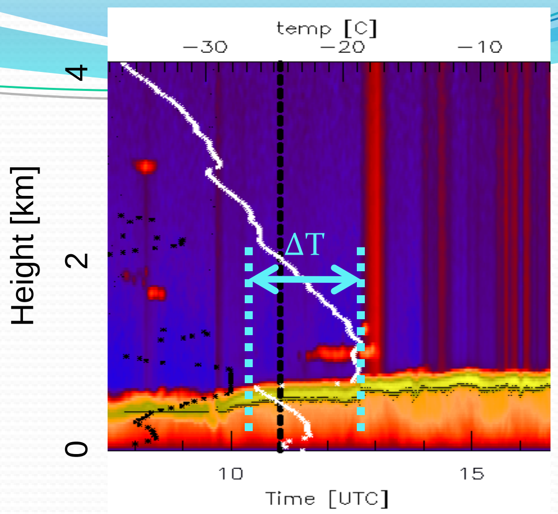
Future works:

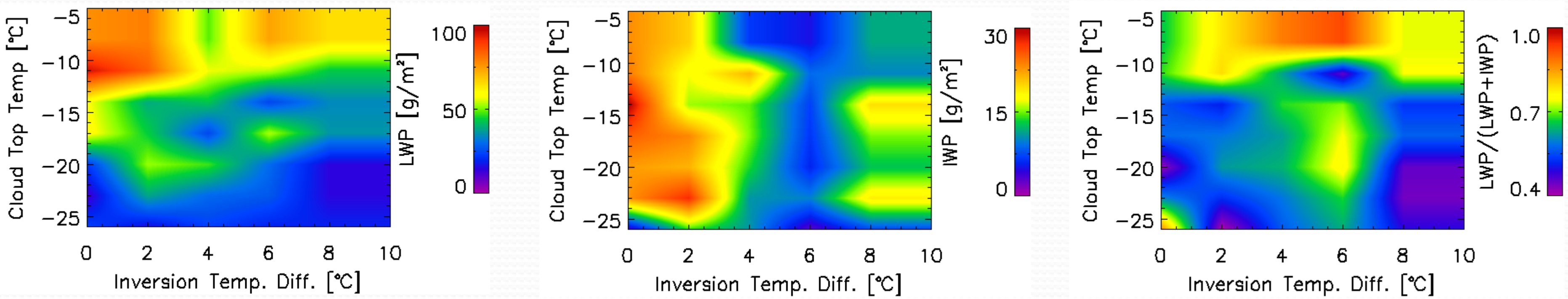
- Better understand dust influence on cloud ice formation and cloud microphysical properties.

2) Influence of temperature inversion

Temperature inversion strength (ΔT):
temperature difference between inversion base and inversion top.

Note: only inversions co-located with mixed-phase cloud layer are selected to do statistical analysis.





- Cloud liquid and ice paths are influenced by both cloud top temperature and inversion temperature difference.