Quantifying the Dust Impacts on the Ice Generation in Supercooled Stratiform Clouds

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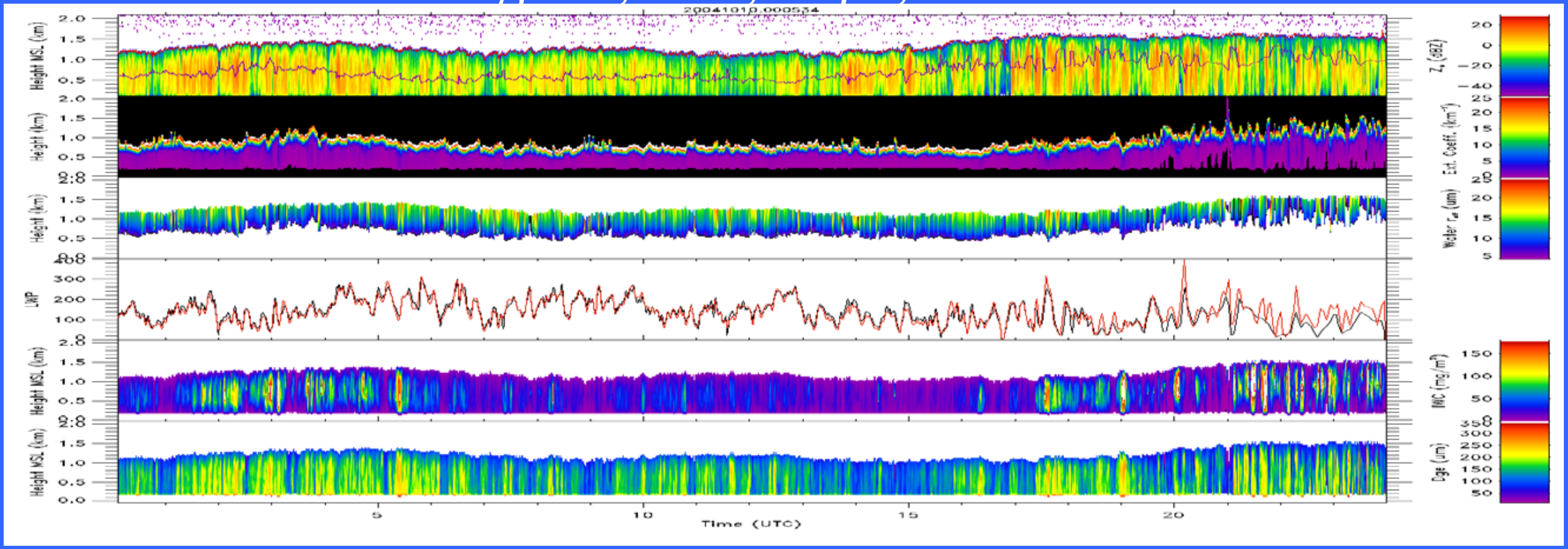
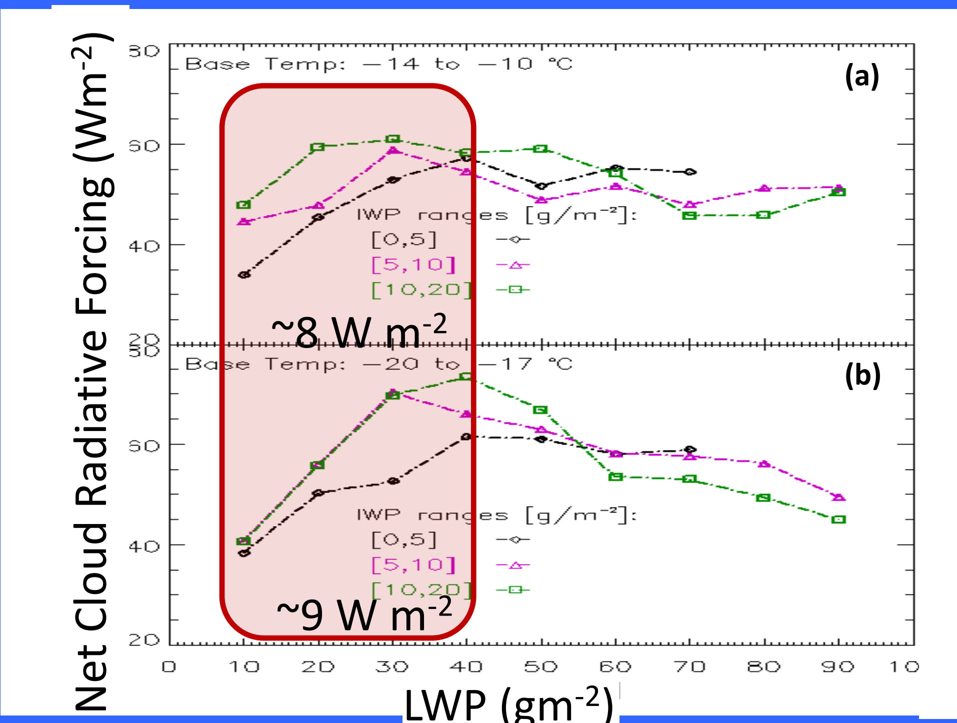
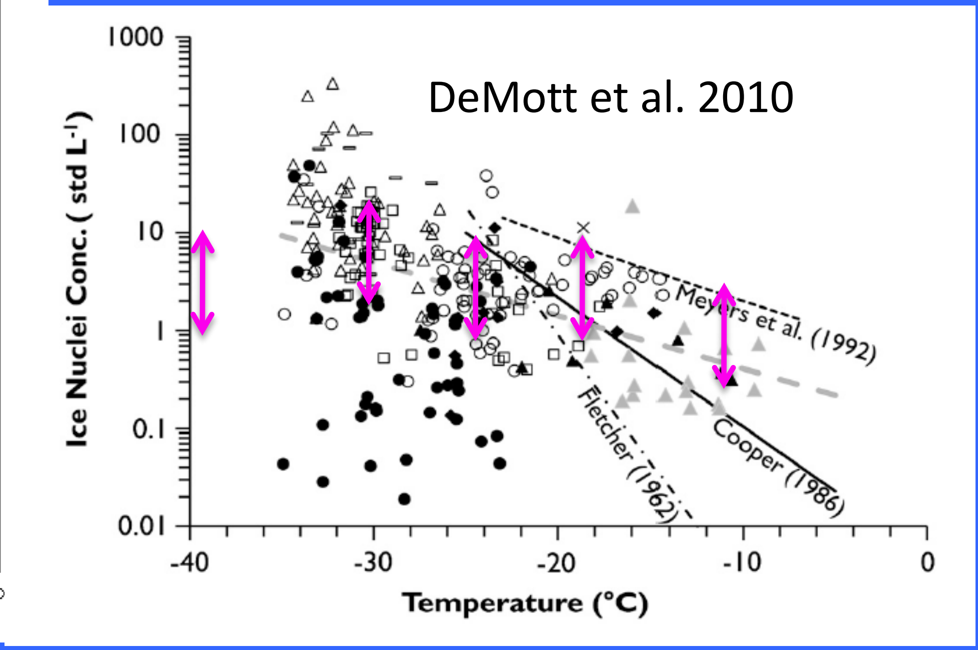


ASR Science Team Meeting, 2013

Motivations-1: The importance of heterogeneous ice generation





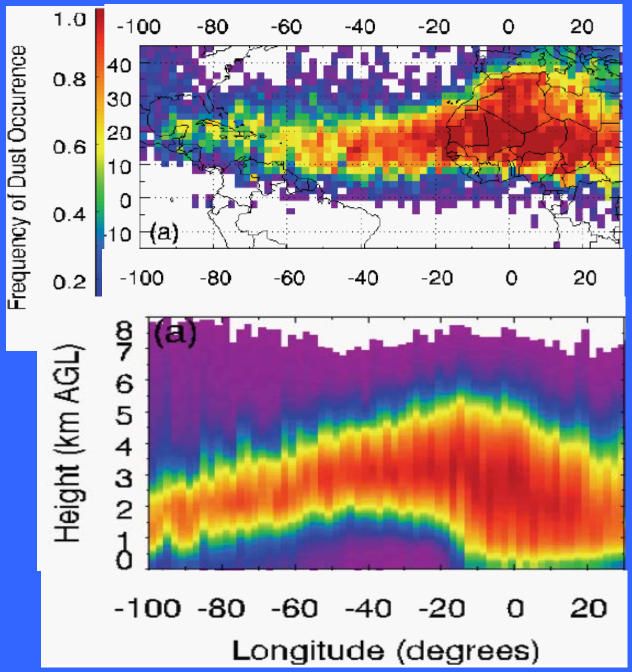
High impacts of IWPs on stratiform mixed-phase cloud radiative forcing

Results from multi-year results at the Barrow site.

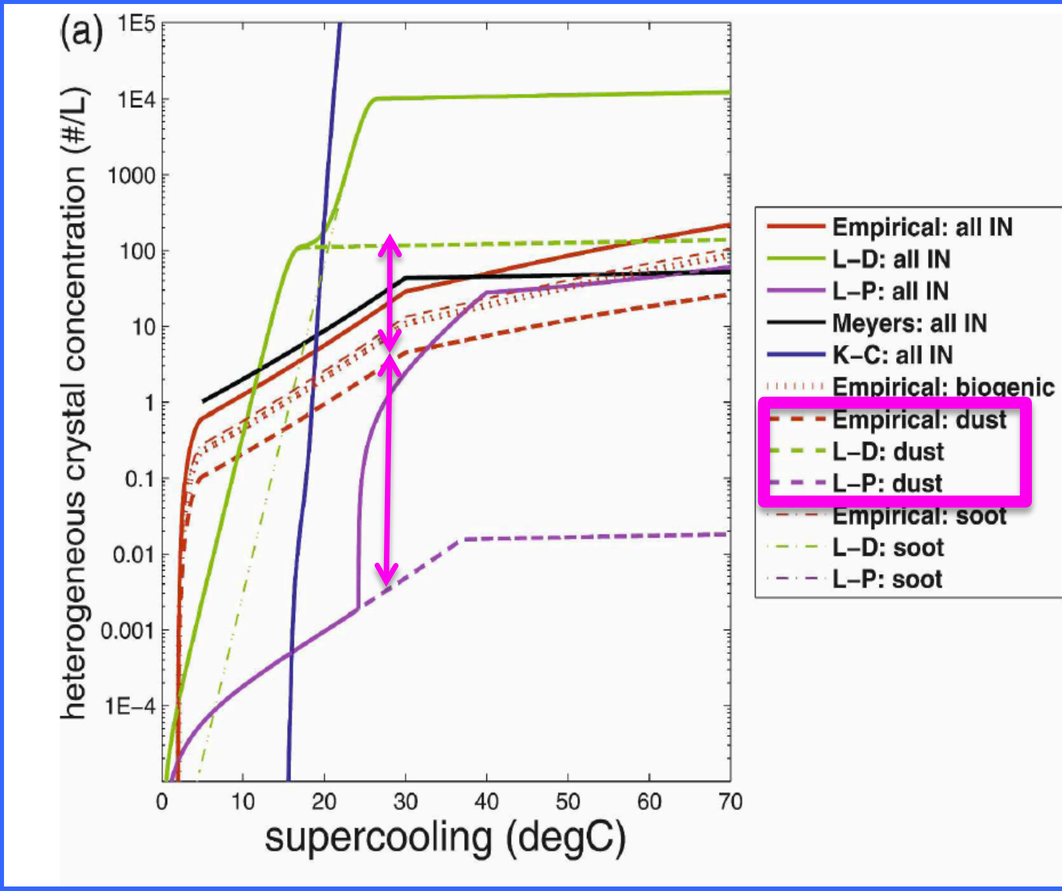
Big differences among many existing parameterizations! —***Which one is right?***

Motivations-2: Heterogeneous ice generation strongly depend on aerosol types!

- Dust aerosols are effective and important ice nuclei (IN).
- Big uncertainties in our knowledge base about dust as IN.



The JJA dense dust occurrence based on CALIPSO observations



From Fig. 10a, Phillips et al. 2008, JAS.

Our Research Goals

- **Using remote sensing to study ice generation in stratiform clouds**
  - Ground-based observations at the Barrow site
  - Global Satellite observations
- **Linking ice generation with aerosol properties**
  - Dust
- **Improve mixed-phase cloud parameterization**

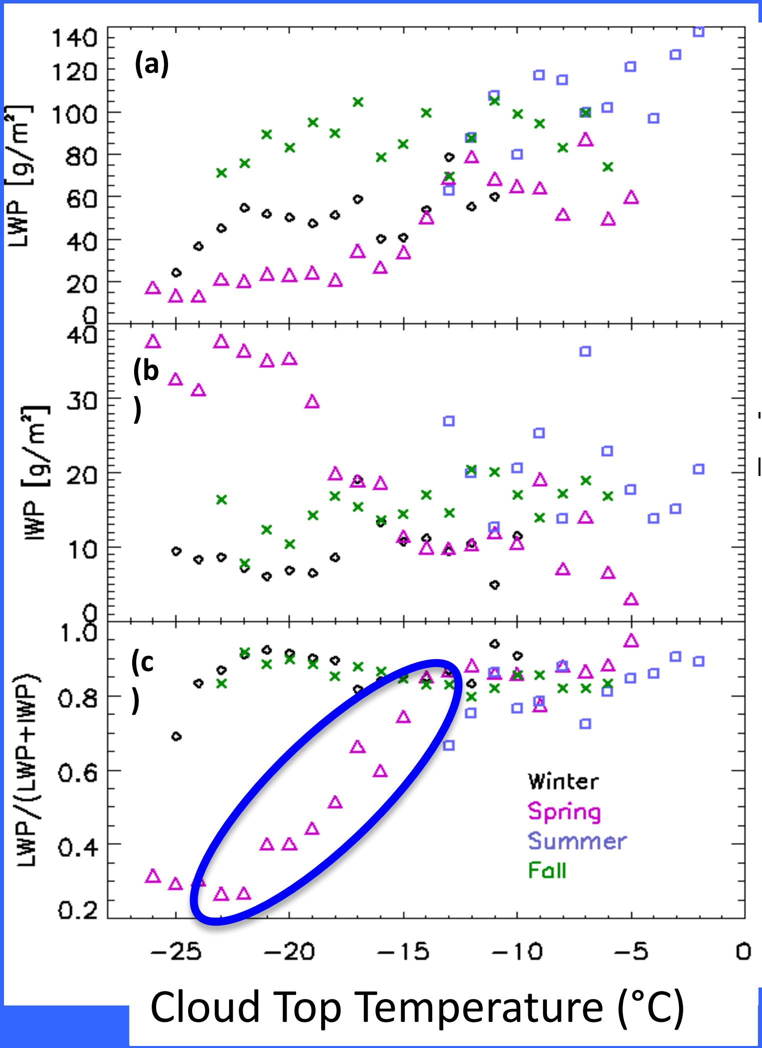
ACRF Observations at the Barrow Site

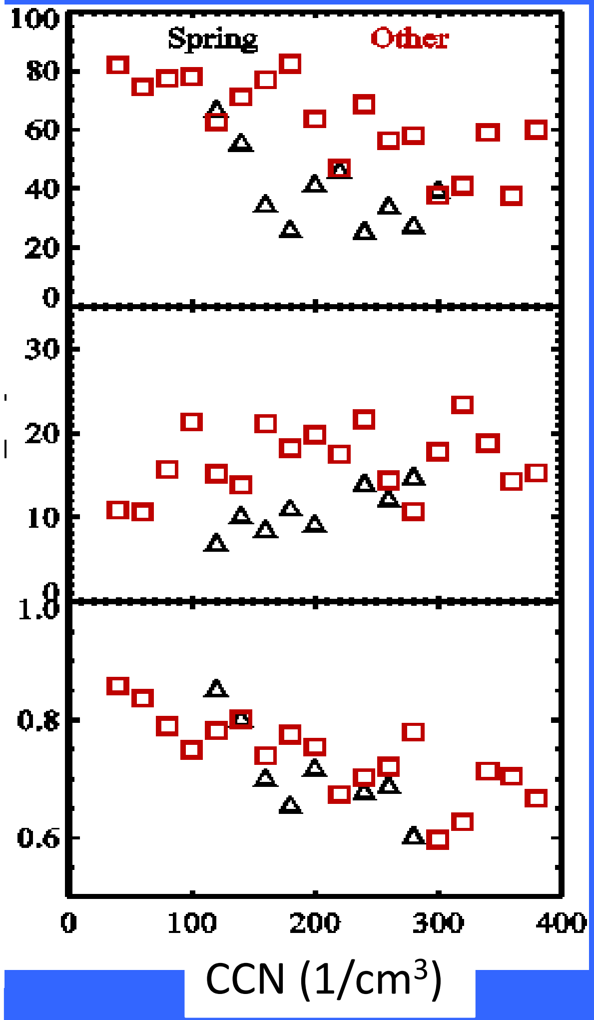
Liquid-ice partition in the Arctic Stratiform Mixed-phase clouds

LWP

IWP

$$\frac{LWP}{LWP + IWP}$$

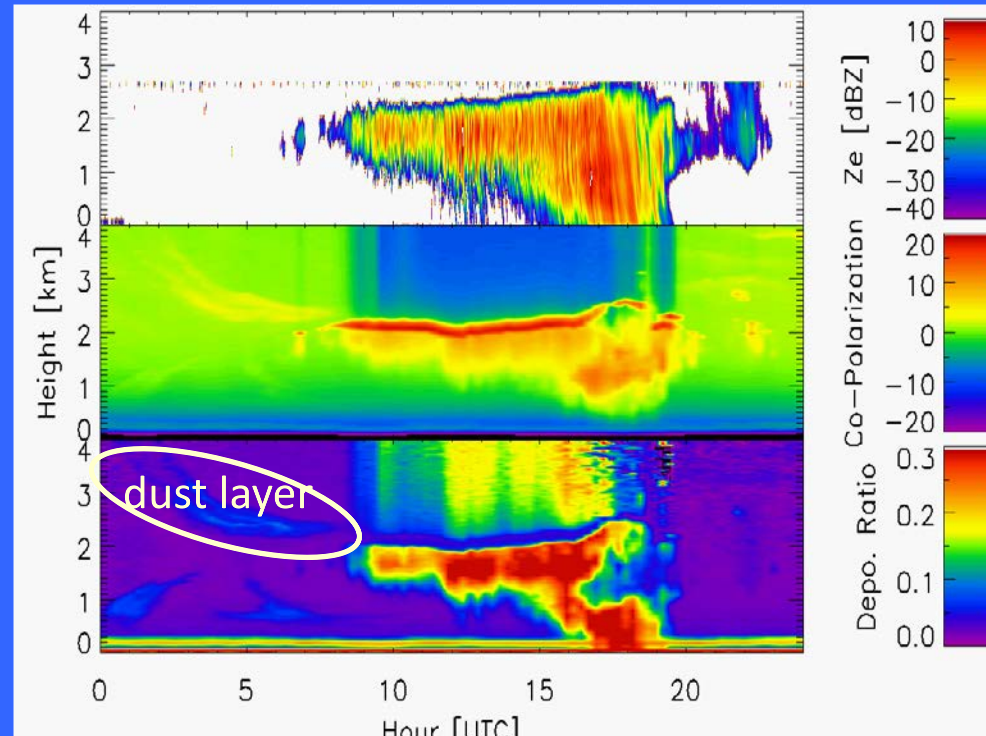




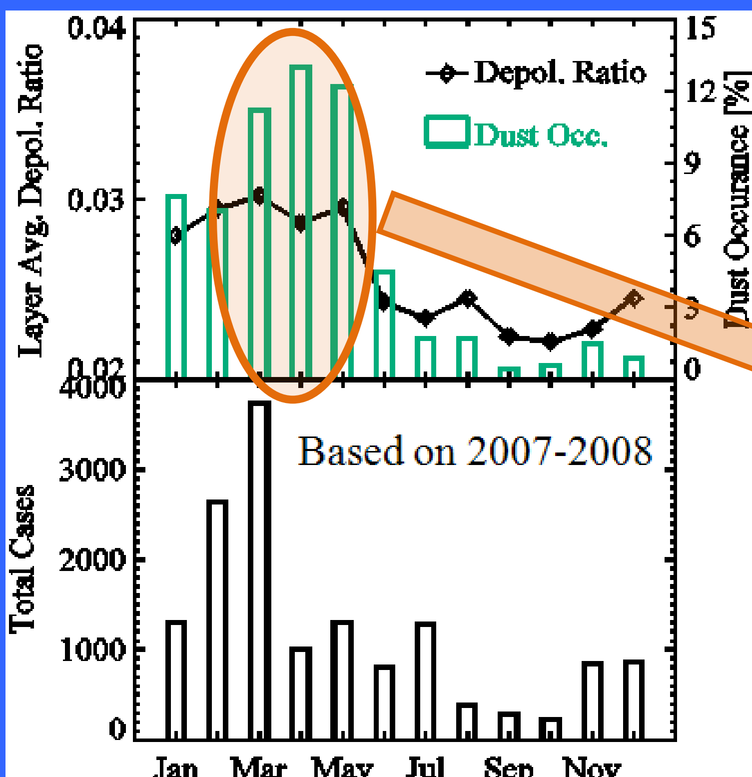
Distinct low liquid-ice mass partition during the spring time.

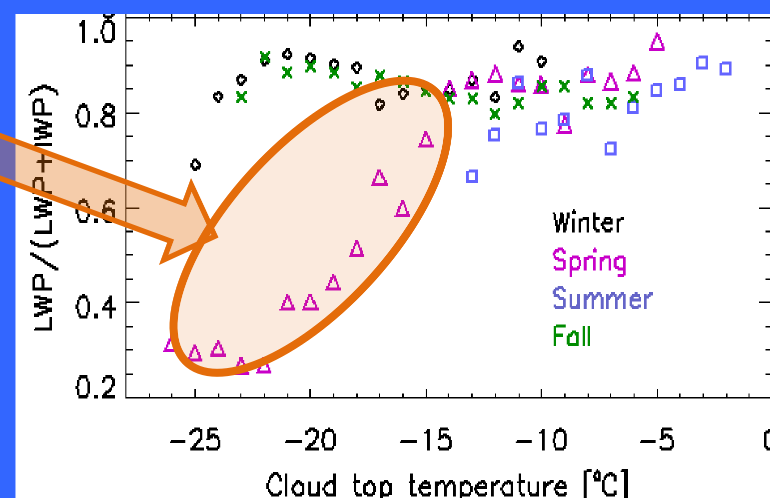
Spring time High Dust Occurrence is one of the potential reasons!

29 March 2008



(c)

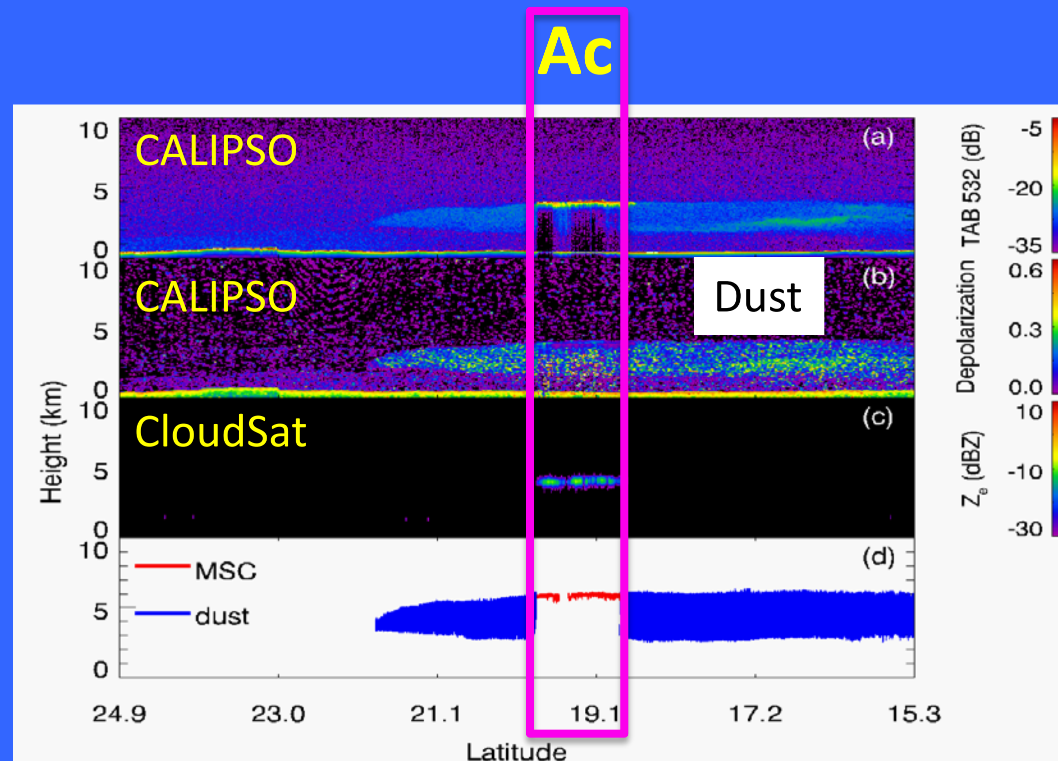




Dust Impacts from Satellite Observations

Use CloudSat radar and CALIPSO lidar measurements of mixed-phase altocumulus (Ac) to quantify dust impact on heterogeneous ice generation.

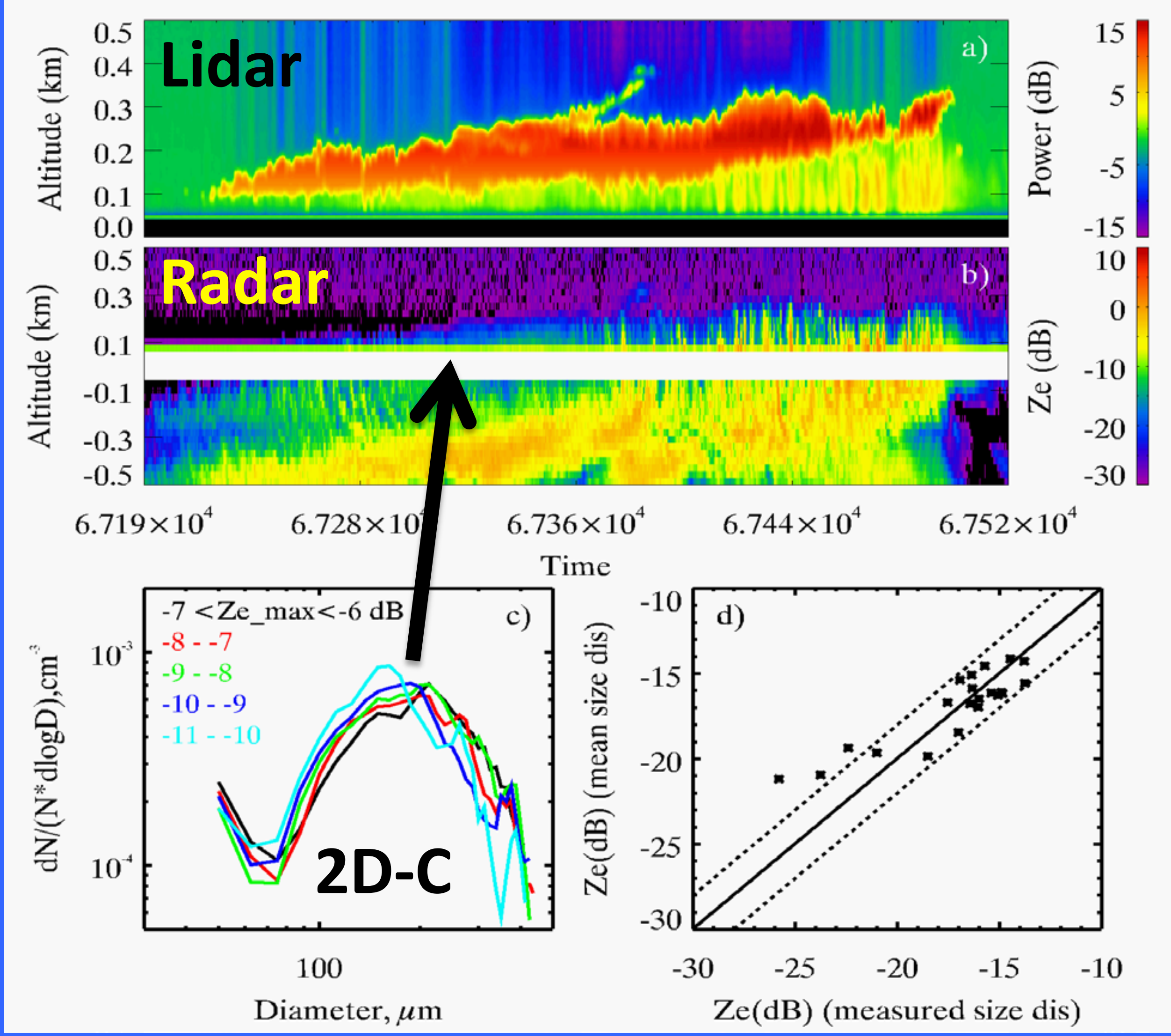
- CALIPSO → liquid properties + nearby aerosol information.
- CloudSat Z_e → ice properties.



But, we have to use **in situ** measurements and **modeling** results to develop these new potentials.

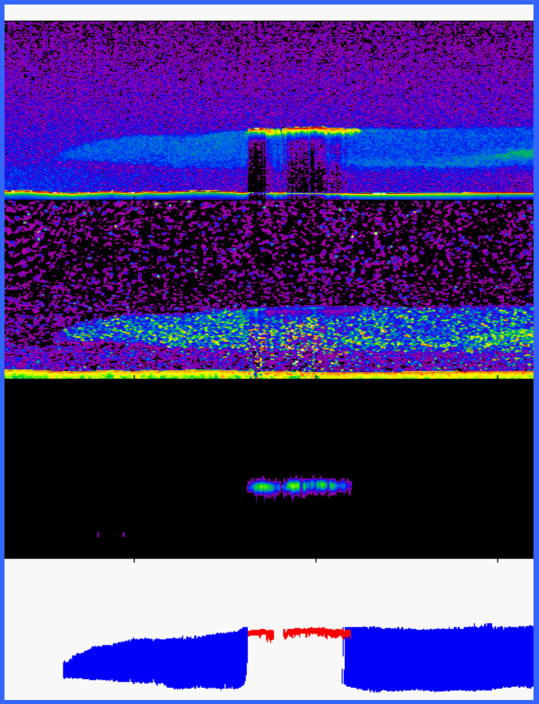
The Similarity of Ice Crystal Size Distribution in Similar Mid-level Stratiform Clouds

Similar clouds in terms of cloud top temperature (CTT) and LWP.

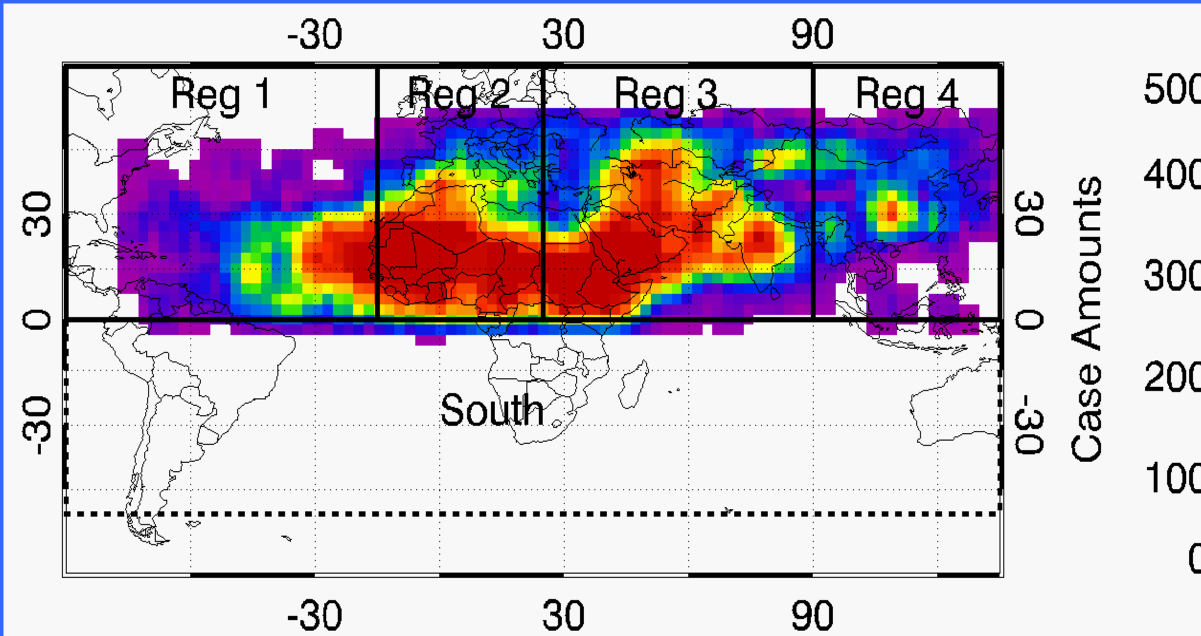


Dusty Conditions

1. Clouds within a dense dust plume – ***dusty***
2. Clouds over dust belt without clear dust layer – ***non-dusty***
3. The same lat and lon zone in the southern hemisphere – ***south***

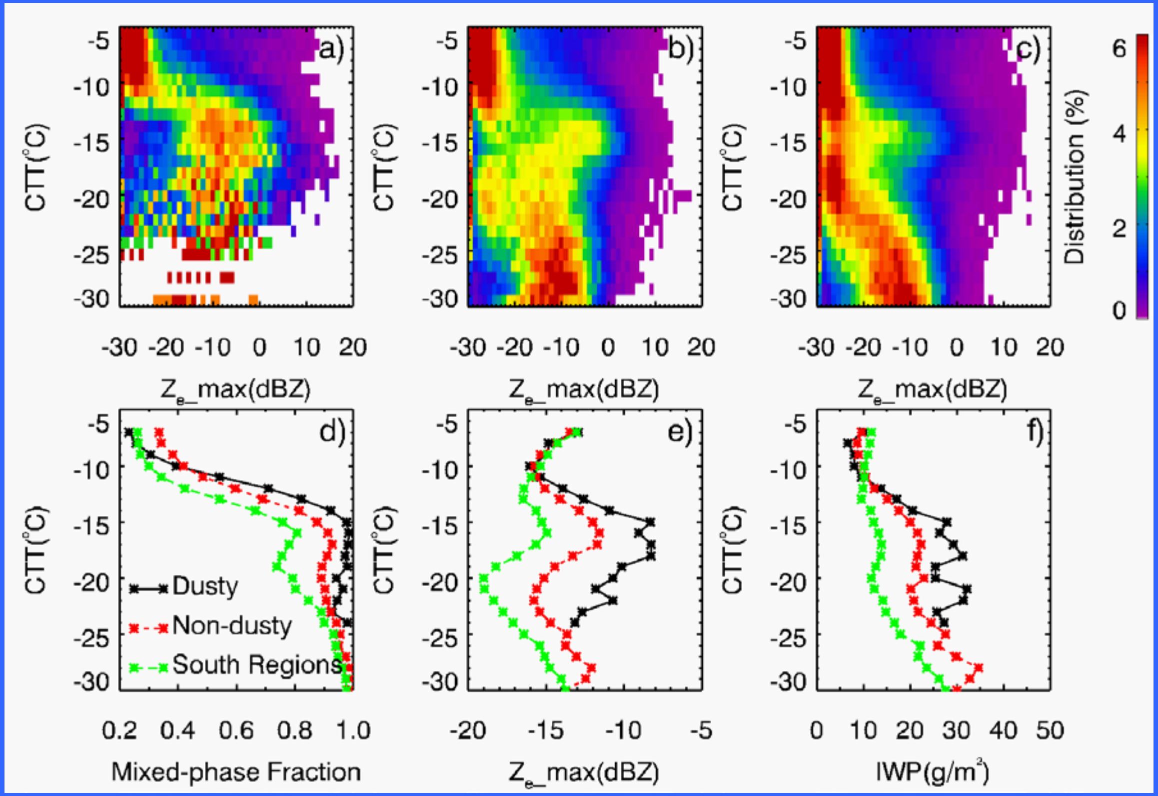


The dusty case distribution (4-year CloudSat and CALIPSO data)



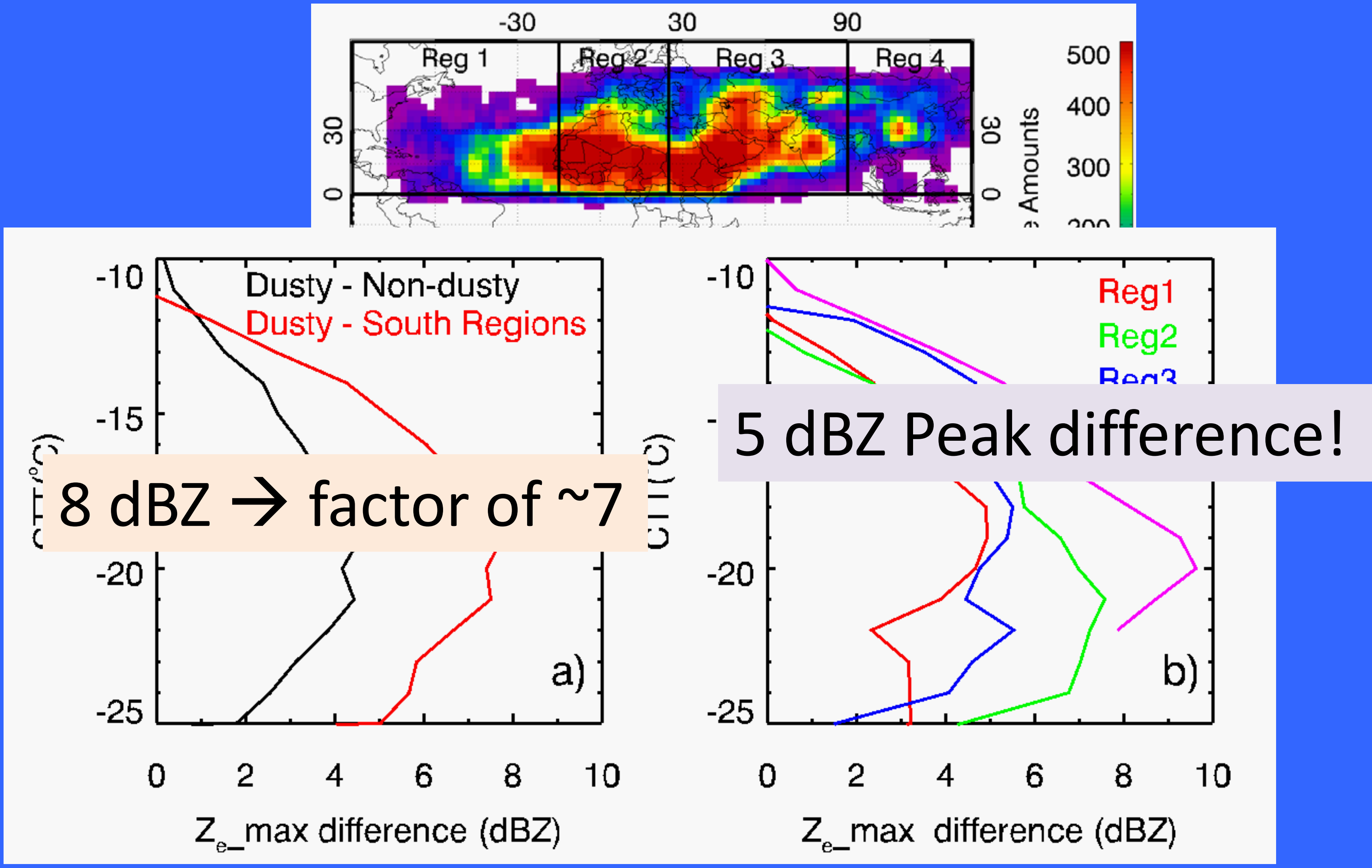
Dust impacts on heterogeneous ice generation

- Strong dust impacts on mixed-phase cloud occurrence, Z_e maximum, and layer ice water path.
- For Ac clouds with similar properties, ice crystal generation and growth in them are similar.
- Thus, Z_e differences among similar clouds in different regions reflect mainly ice number concentration differences.



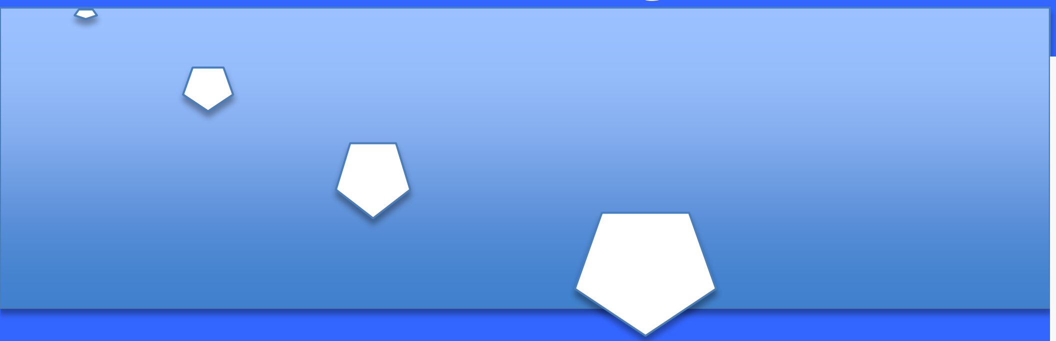
The distribution of supercooled Ac as a function of CTT and Ze_max (500 m within cloud top) for dusty and non-dusty cases with maximum total attenuated backscattering (TAB) within 0.37-0.51 km^{-1} sr^{-1} (a, b, c); d) mixed-phase Ac fractions, e) mean Ze_max, and f) IWP.

Regional Differences of the Dust Impact

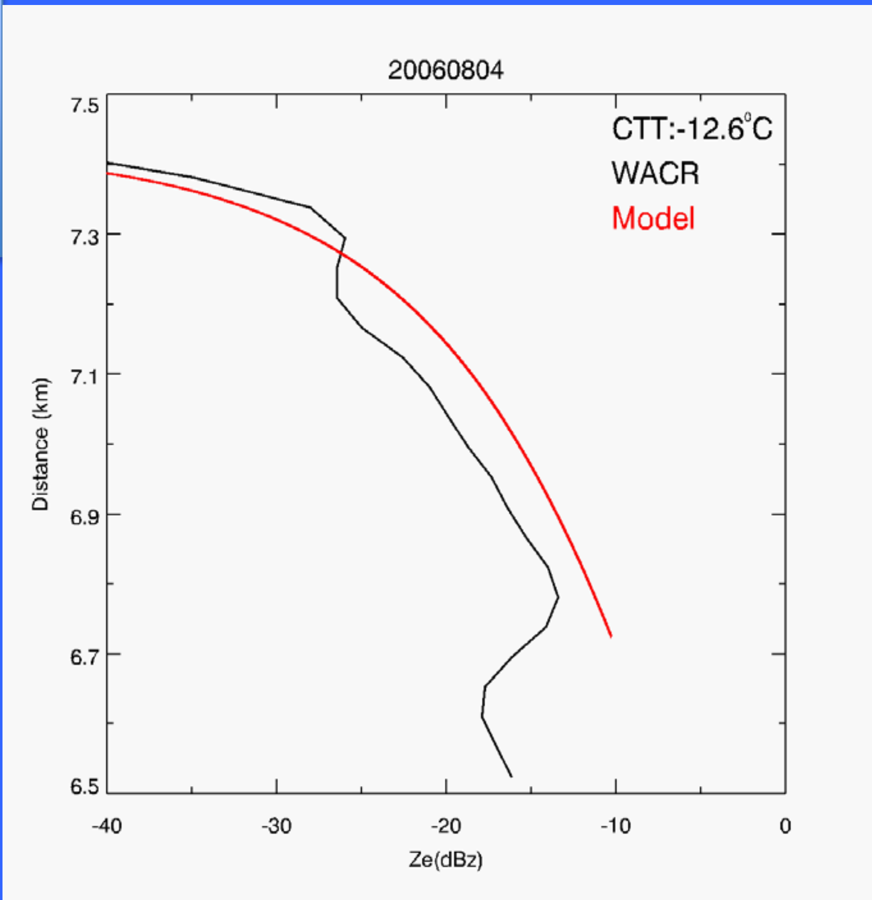


(a) Z_e_max differences between dusty, non-dusty and ‘South Regions’ MSCs in terms of CTT; (b) Z_e_max differences between dusty and ‘South Regions’ MSCs for the four sub-regions.

A simple ice growth model to establish *Z_e-N relationships*

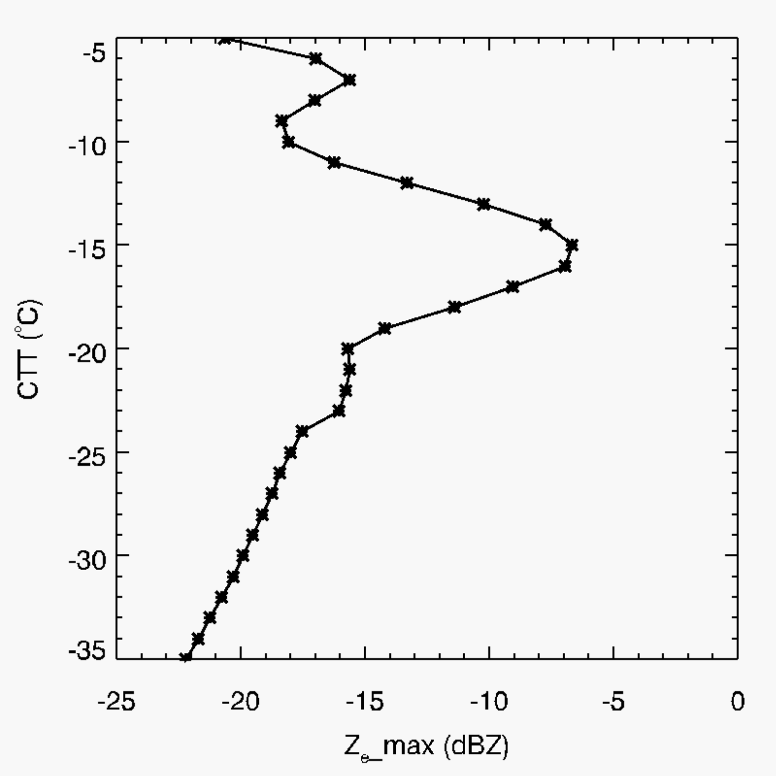


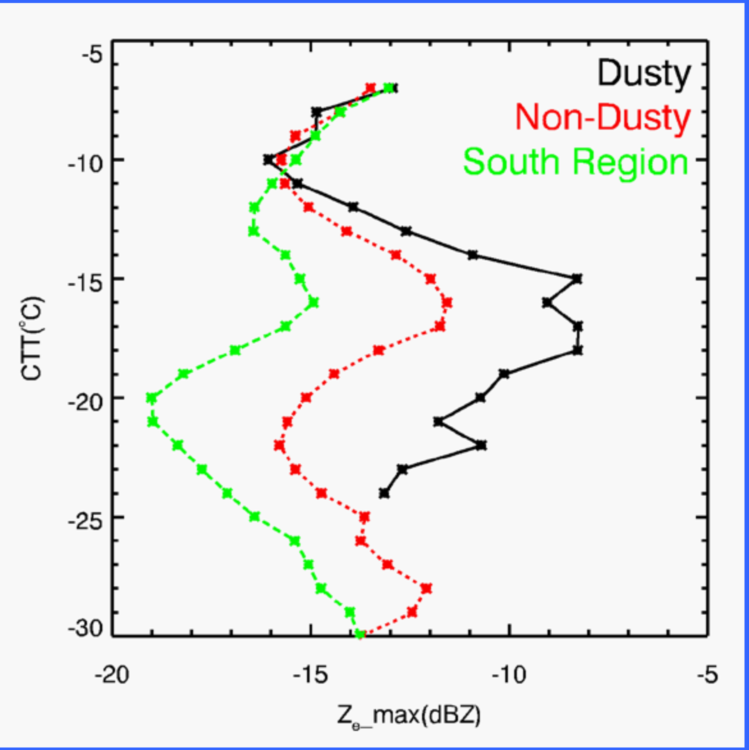
1. Given a cloud top temperature, a LWP, and turbulence features.
2. Ice crystals start near the cloud top, grow big and falls.
3. Z_e profile as a function of distance from the cloud top.



A comparison of observed and modeled Z_e profiles.

From Maximum Z_e to Ice Number Concentration





Modeled Z_e for 1 per liter ice concentration

+

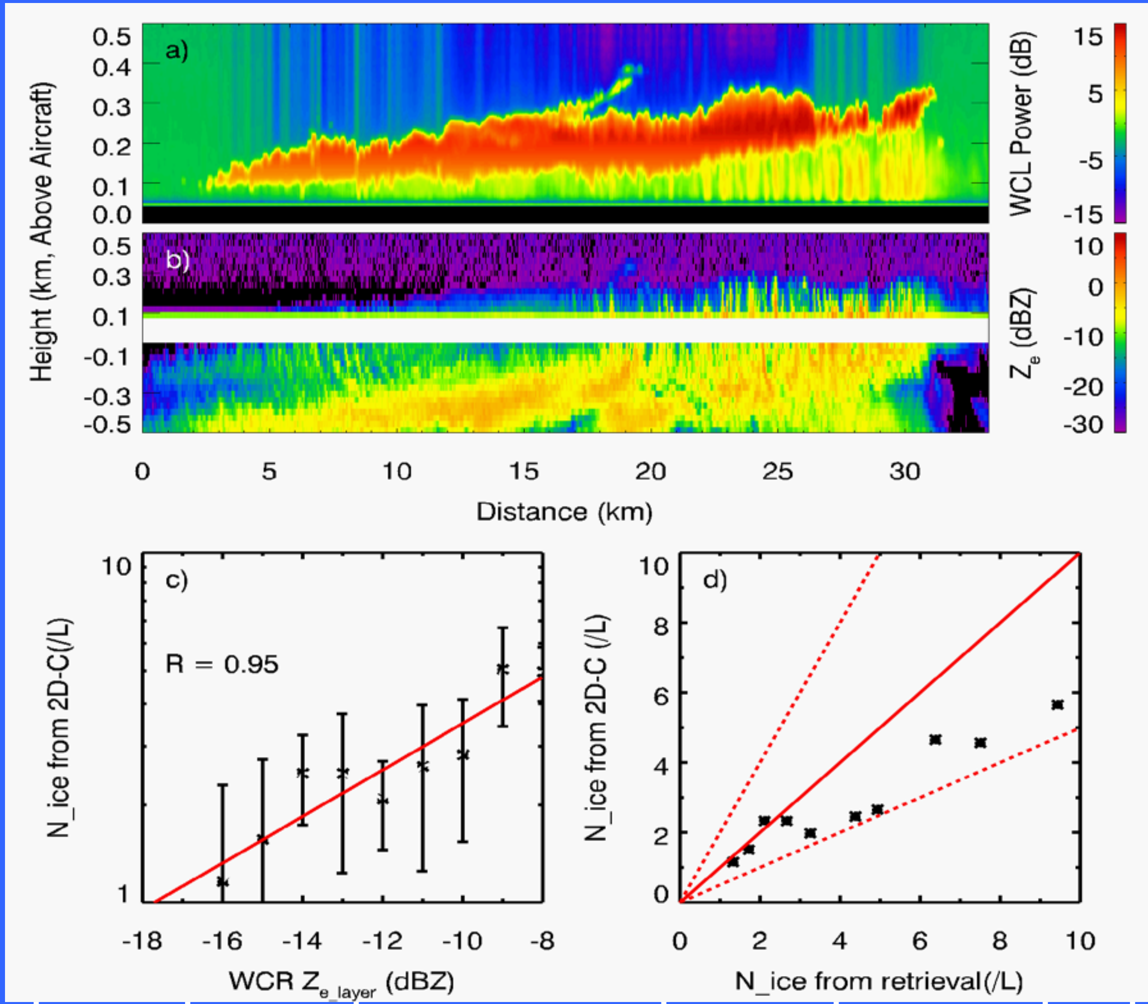
Observed Z_e

?

Global Ac ice concentration within -7 and -38 degree.

See the Poster by Damao Zhang et al. for more details.

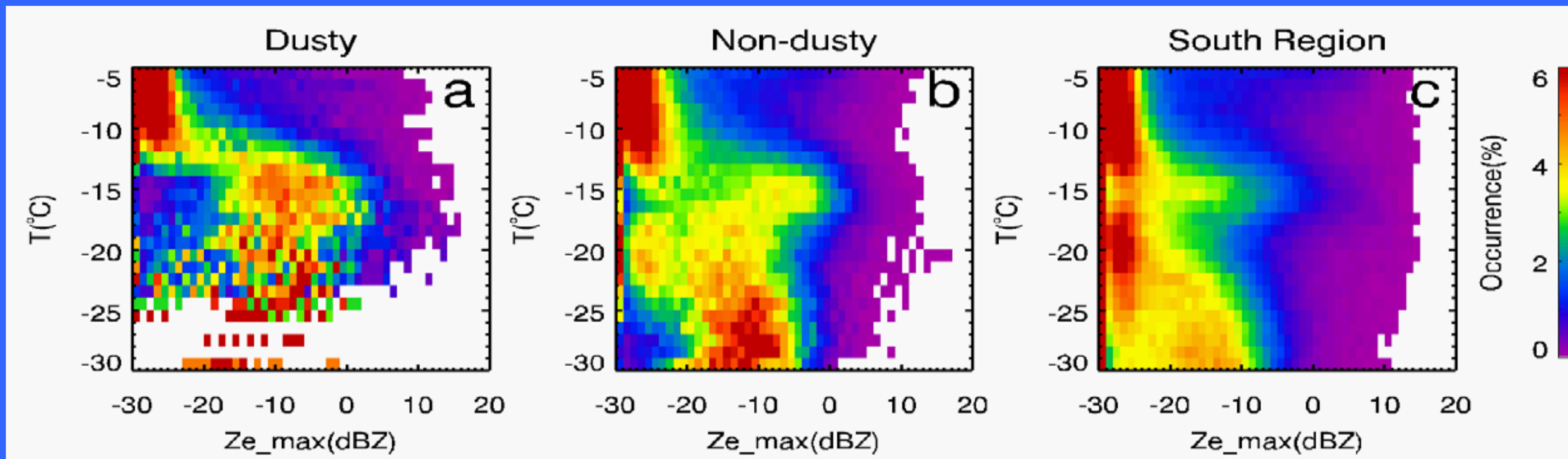
An in situ case for evaluation: -23 °C



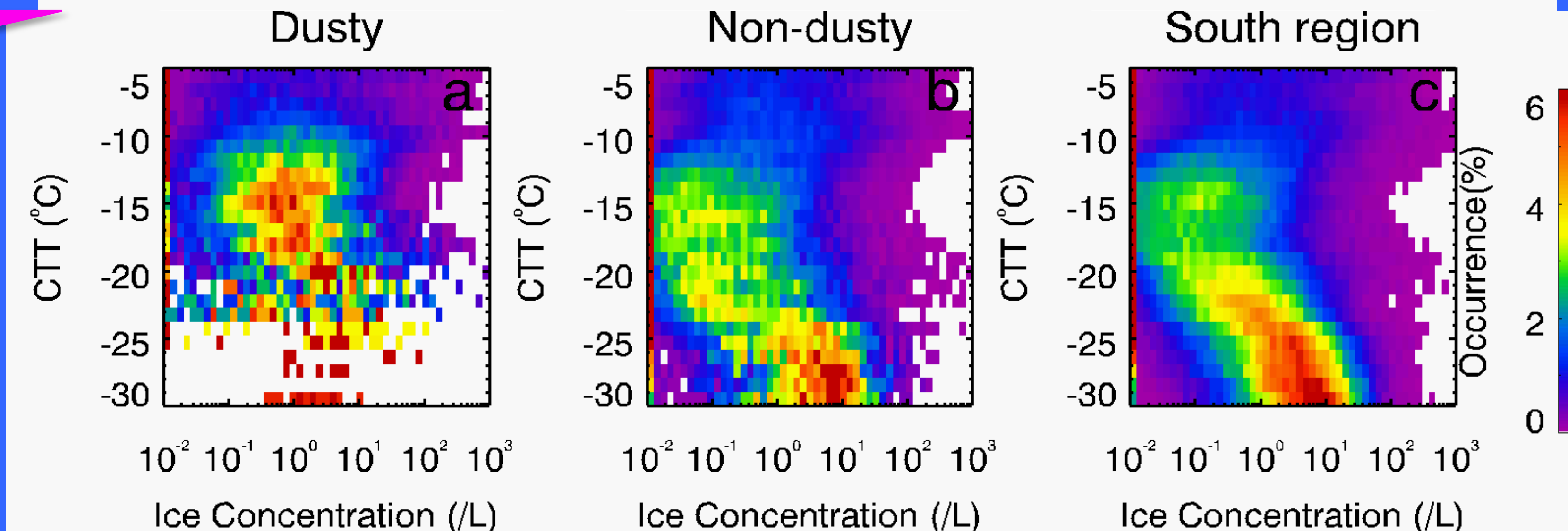
- Collocated in situ and remote sensing observations indicate that ice number concentration (N) is a strong function of Z_e max.
- Growth model estimated N agrees with observations within a factor of 2 statistically.

From maximum Z_e to N for ice in Stratiform Mixed-phase Clouds

Z_e

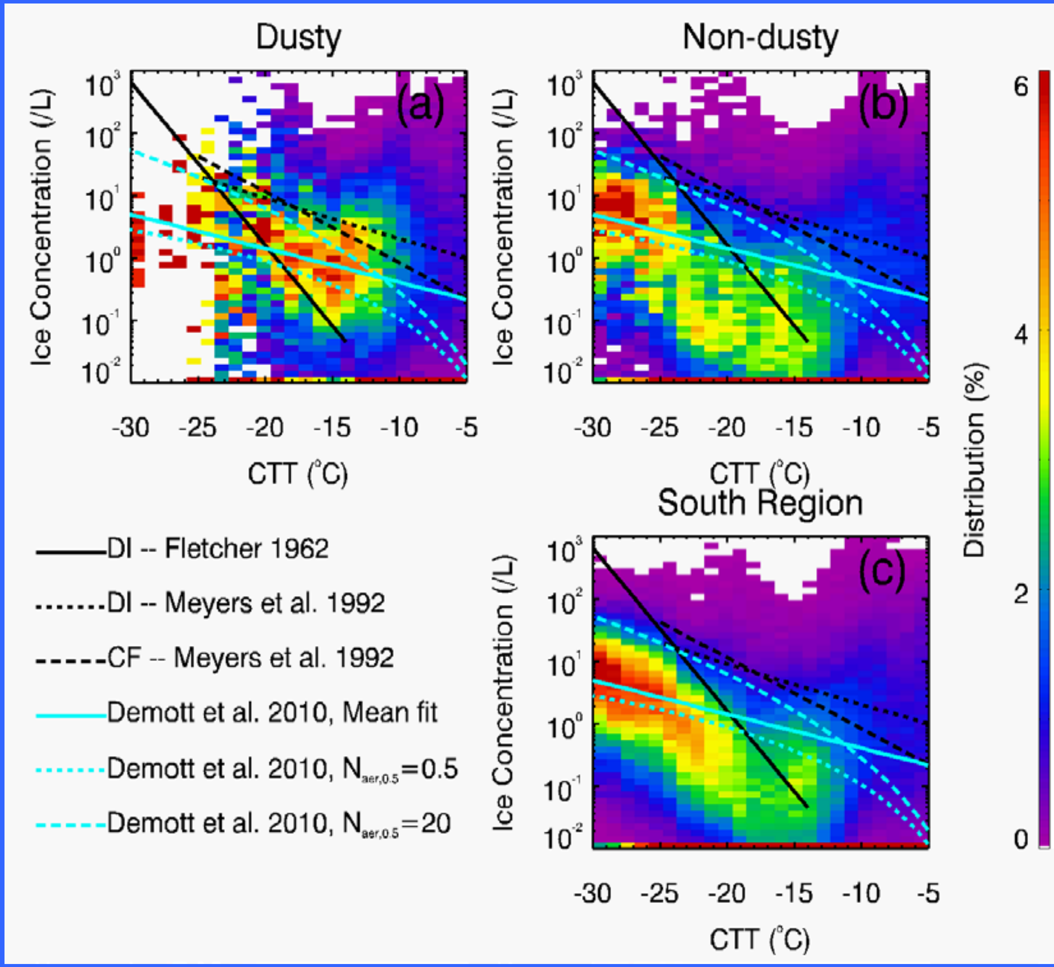


N



Dust Impacts In the Context of Different Parameterizations

- Large variations in ice concentrations.
- Old parameterization generally over estimate ice concentrations.
- Need a better understanding of ice concentration variations in association with aerosol property variations!

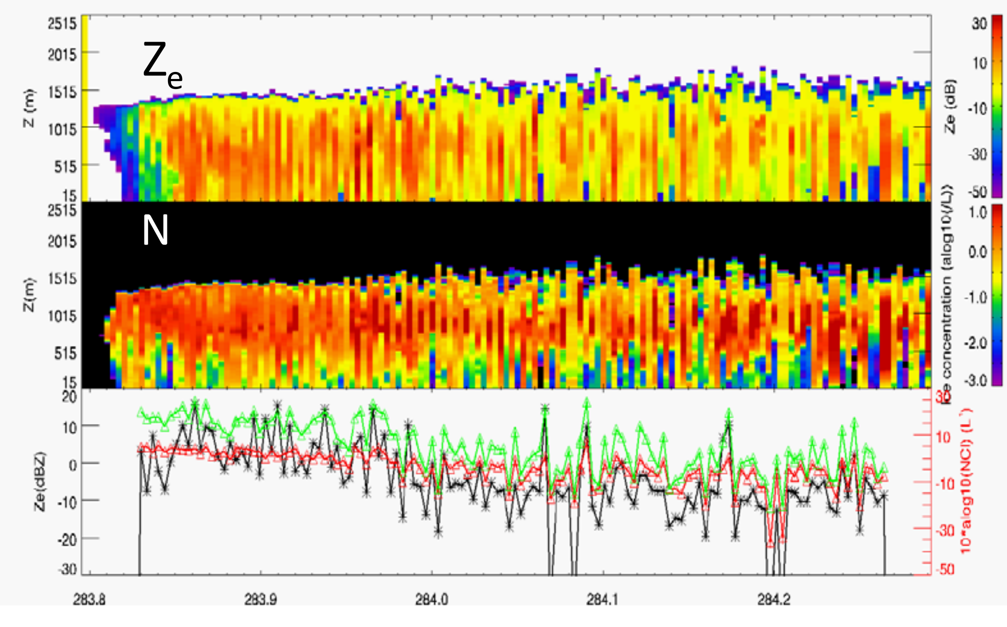


Summary

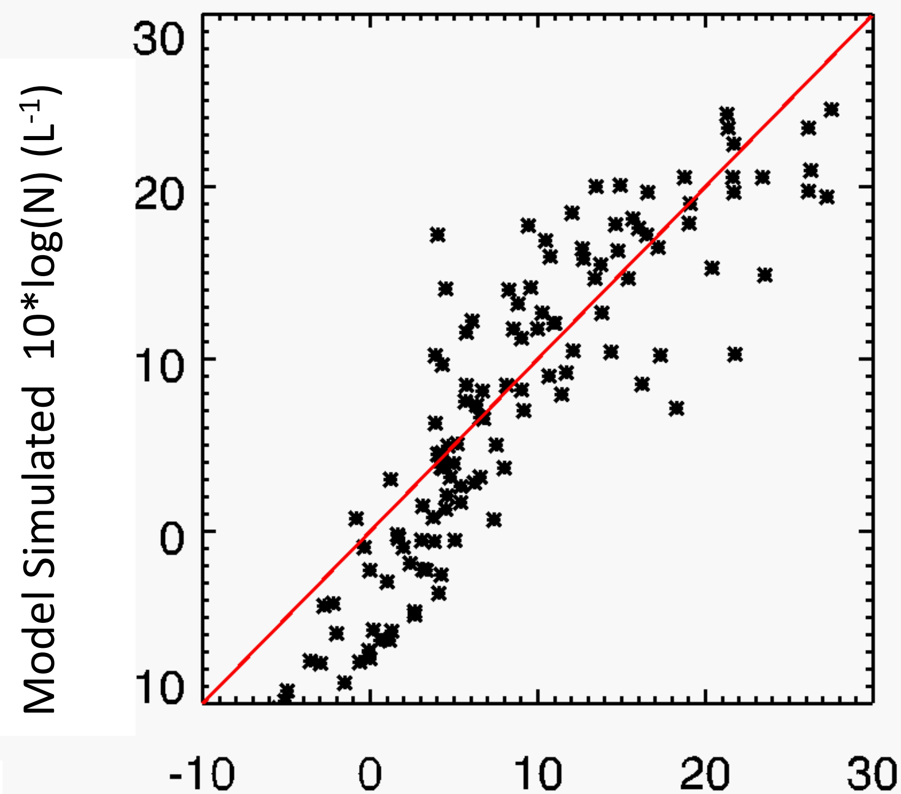
1. Remote sensing (lidar and radar) measurements are capable to estimate ice crystal number concentration in mixed-phase altocumulus clouds with uncertainties about a factor of 2 (statistically).
2. Dust aerosols can enhance ice number concentration in mixed-phase altocumulus clouds by **a factor 2 to 7**.
3. Remote sensing offers a new opportunity to refine our knowledge of heterogeneous ice generation, and **compliments with** lab and field IN measurements.
4. Ongoing work:
   - to refine the growth model (**see Zhang et al. Poster**),
   - to link ice concentration variations with dust properties-size, source, and concentration (see our report during the **ice nucleation section**).

3-D cloud resolving model with an explicit bin microphysics (Fan et al. 2009)

The time evolution (12-hr) of model simulated clouds



Time



The simple 1-D growth model performed quite well compared with 3-D CRM simulations.

An in situ case for evaluation: -15 °C