Quantifying Dust Impacts on Ice Generation in Supercooled Stratiform Clouds with CALIPSO and CloudSat Measurements

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Abstract

Dust particles is the major source of ice nuclei (IN) , however, there still are large uncertainties on the effectiveness of dust particles as IN at relatively warm temperatures. For the first time, the impacts of dust particles on the ice generation in Supercooled Stratiform Clouds (SSC) on global scale were quantitatively investigated by using four years collocated CALIPSO and CloudSat measurements (totally 626,521 dust impacted cloud profiles) together with a 1-D ice growth model.

Dusty SSC Identification

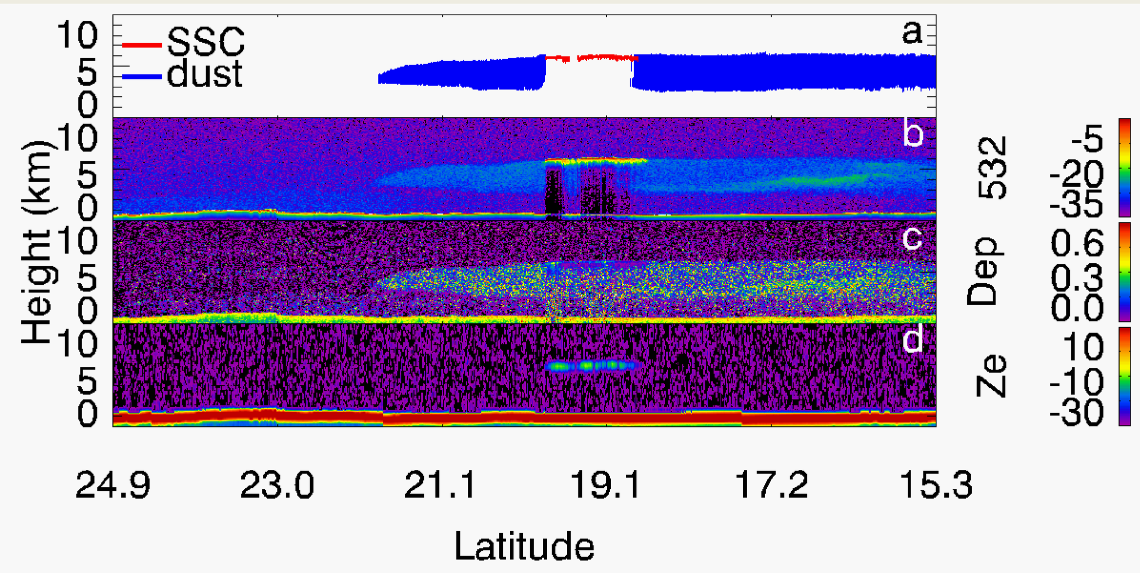


Figure 1 a) Identified dust layers with imbedded SSC ('Dusty SSC'); **b)** CALIPSO 532nm backscattering; **c)** CALIPSO 532nm depolarization; **d)** CloudSat radar reflectivity (Ze).

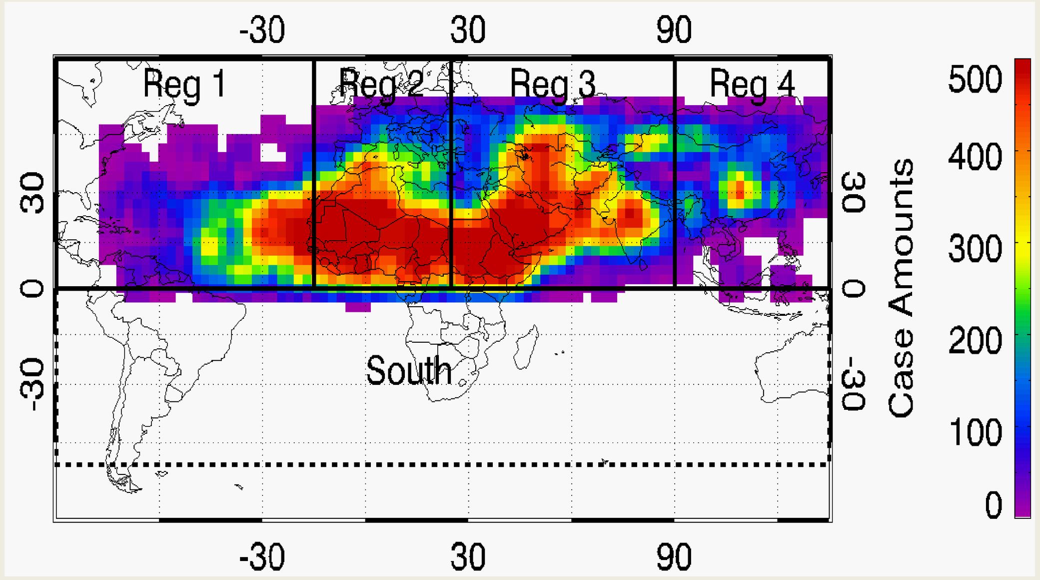


Figure 2 global distribution of dusty SSCs. SSCs without dust layer-'Non-dusty'. SSCs in the same latitude ranges in the southern hemisphere -'South region'.

Estimation of Ice Concentrations in SSCs

Maximum Ze within 500 m of cloud top (Z_e_max) was used to estimate the ice concentration (N_ice). 1-D ice growth model was developed to simulate the temperature-dependent ice growth and Z_e_max at given cloud top temperature (CTT) and liquid water path (LWP) .

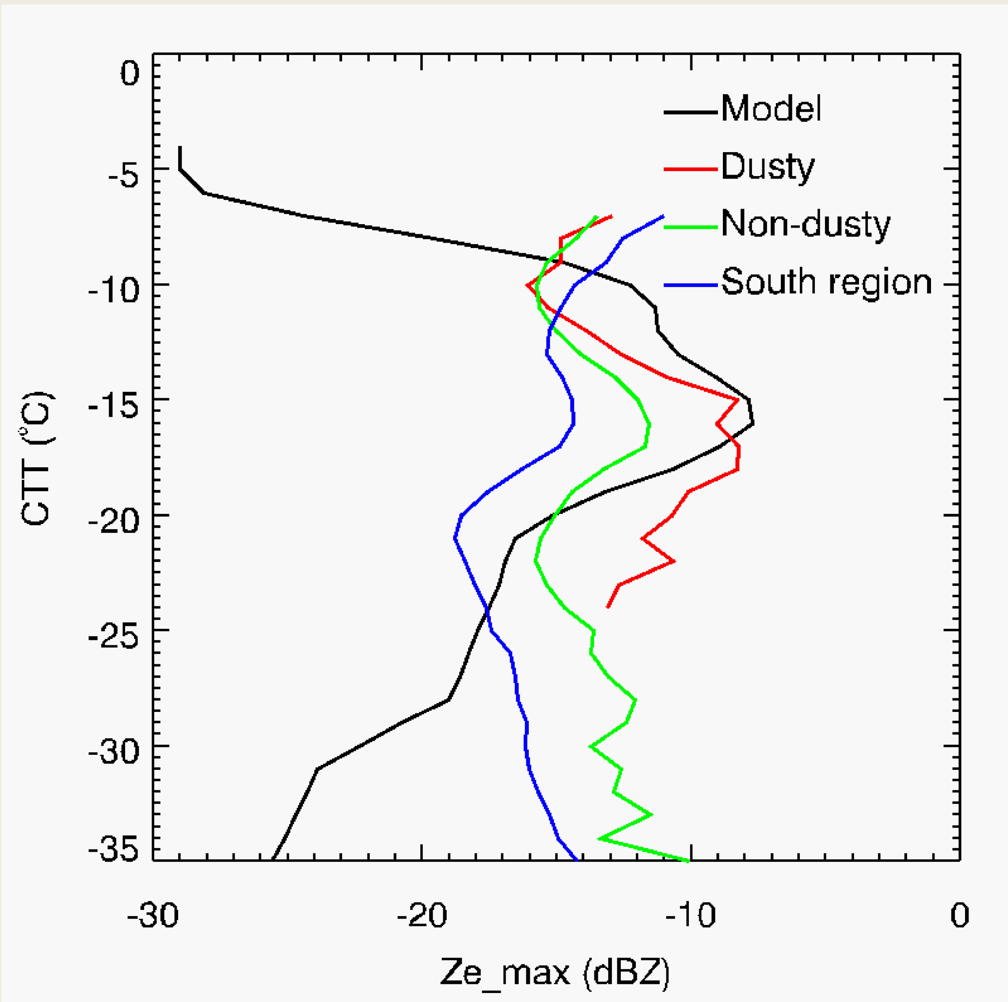


Figure 3. Comparison of Z_e_max obtained from 1-D ice growth model (assuming ice concentration of 1/L) and from CloudSat radar measurements. At the given CTT, the magnitude differences of Z_e_max reflects ice concentration difference.

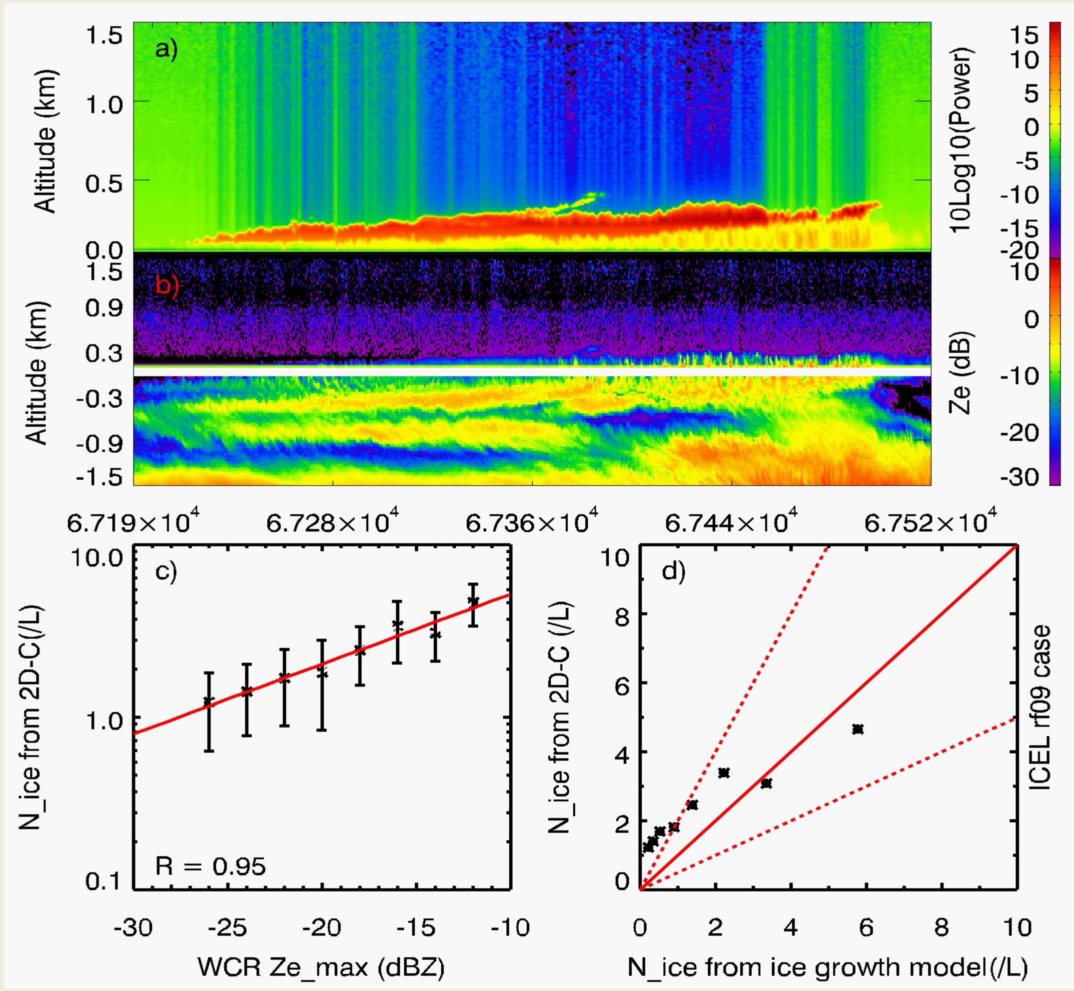
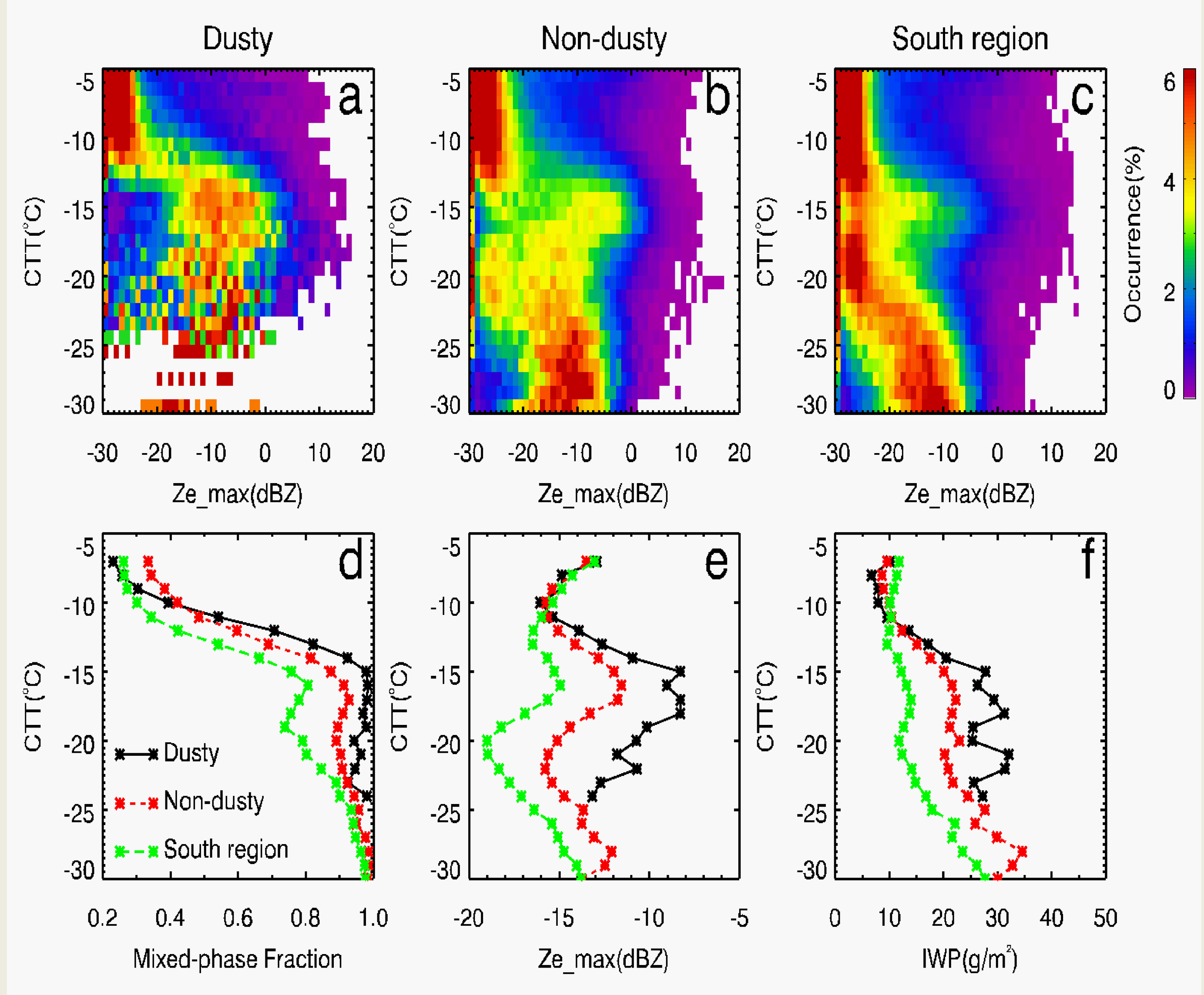


Figure 4. An airborne example of SSC during the ICE-L: **a)** Wyoming cloud lidar power, **b)** Wyoming cloud radar reflectivity, **c)** *in situ* 2D-C N_ice as a function of Z_e_max, and **d)** Comparison of N_ice from *in situ* 2D-C and estimated from Z_e_max.

Quantifying the Dust Impacts

Figure 5 a) the occurrence of dusty SSCs in terms of CTT and Z_e_max for dusty SSCs within the lidar backscattering value of 0.30-0.44 ($Sr^{-1}km^{-1}$). **b)** for Non-dusty SSCs; **c)** for 'South region' SSCs; **d)** Mean mixed-phase fractions for different groups; **e)** Mean mixed-phase Z_e_max; f) Mean ice water path (IWP).



- Ice particles are detected in SSCs when CTT colder than -7 °C.
- The mixed-phase fractions relative to all SSCs generally increase with supercooling increase for all cases.
- The dusty SSCs have higher mixed-phase fraction and IWP at similar meteorological conditions.

- N_ice in SSCs increases almost exponentially with supercooling.
- Dust can enhance N_ice by a factor 2 to 5 in SSCs.
- The N_ice based on DeMott (2010) parameterization is lied between dusty and non-dusty SSCs at given CTT, suggesting its underestimation of dust efficiency.

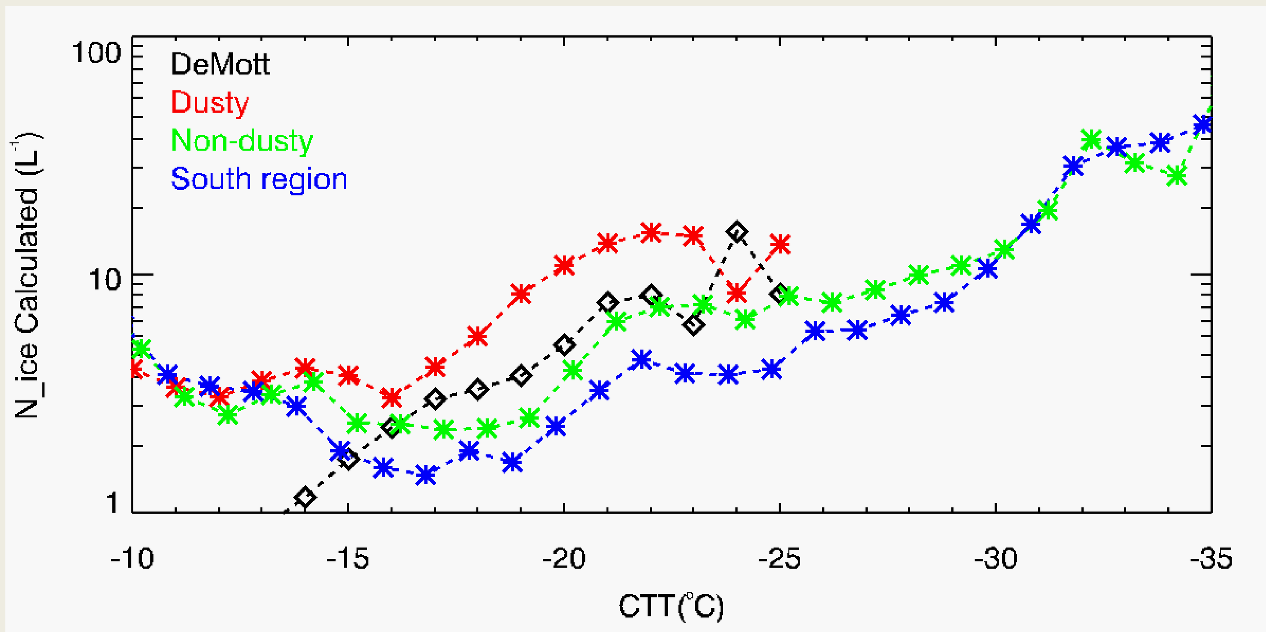


Figure 6. Temperature dependencies of N_ice estimated from combined Ze_max and 1D ice growth model for dusty, non-dusty and south regions and also from DeMott's (2010) parameterization by using dust concentration estimated from CALIPSO lidar measurements.

References

DeMott et al., (2010), Predicting global atmospheric ice nuclei distributions and their impacts on climate. PNAS. Vol. 107. no. 25. 11217-11222.

Zhang, D., Z. Wang, and D. Liu (2010), A global view of midlevel liquid-layer topped stratiform cloud distribution and phase partition from CALIPSO and CloudSat measurements, *J. Geophys. Res.*, **115**, D00H13, doi:10.1029/2009JD012143.