Understanding the Liquid-ice Mass Partition in Stratiform and Convective Mixed-phase Clouds

Zhien Wang (zwang@uwyo.edu), Damao Zhang, Jing Yang, Tao Luo, and Min Deng
University of Wyoming

Summary

The liquid-ice mass partitions in stratiform and convective mixed-phase clouds are important in regulating cloud radiative properties, precipitation generation and their lifecycles, but it is still challenging to reliably simulate them. Remote sensing and in situ measurements are used to characterize the liquid-ice mass partitions in arctic stratiform mixed-phase clouds and tropical isolated convective clouds. These observation results provide important constraints for model simulations as well as for related process studies. This poster summarizes our recent activities and progresses. 1) An improved multi-year data set of arctic stratiform mixed-phase cloud properties including ice number concentrations is developed with multi-sensor observations at the ACRF Barrow site. The data set will be released as a PI product. 2) The dependence of liquid-ice mass partition on ice concentration and aerosol properties is explored with the multi-year data set at the Barrow site. 3) A new approach is developed to separate liquid and ice particles based on in situ 2D probe measurements, which allow us to quantify liquid-ice mass partition in tropical isolated convective clouds. 4) The systemic differences in the temperature dependence of liquid-ice mass partition between stratiform and convective clouds highlight the importance to understand ice generation differences between them.

Stratiform mixed-phase clouds

An advanced multi-sensor retrieval algorithm (Zhang et al. 2014)

Inputs: Cloud radar, MWR, lidar (MPL or HSRL), temperature profile

Outputs: **Ice phase**: IWC, general effective radius, and Ice concentration in the mixed-phase layer

Liquid phase: LWC, LWP, effective radius, and droplet concentration

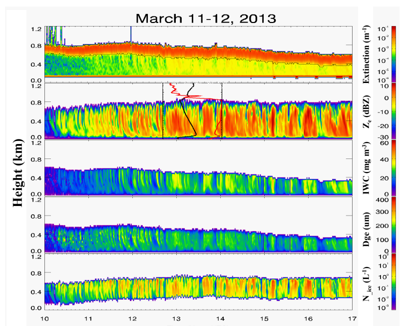


Fig. 1 An example of retrieved ice phase cloud properties .

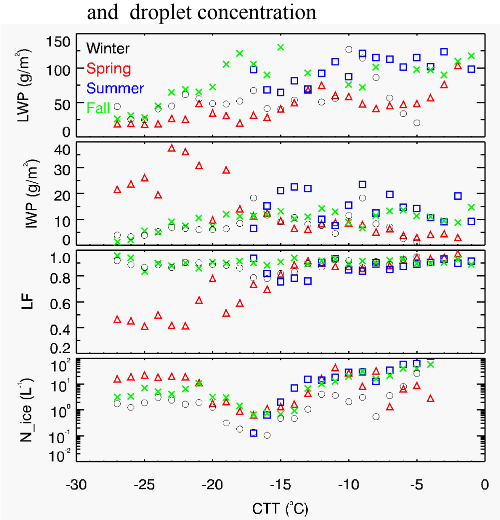


Fig. 2 Seasonal variations of temperature-dependent mixed-phase cloud properties observed at the NSA site.

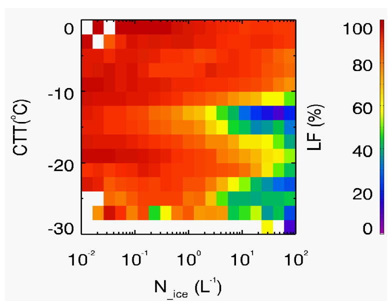
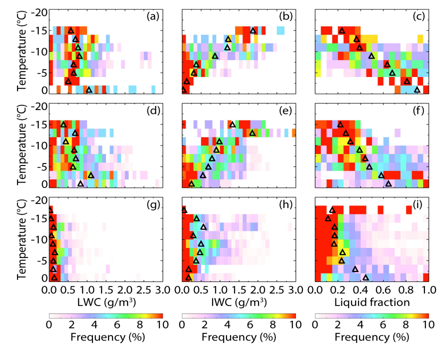


Fig. 3 Ice concentration together with cloud top temperature (CTT) controls liquid fraction (LF) in Arctic mixed-phase clouds.

Convective mixed-phase clouds

To overcome the challenges in study convective mixed-phase clouds with remote sensing measurements only, a new approach is developed to estimate LWC and IWC within convective clouds by combining measurements from 2D-C, 2D-P, CVI total water content, and King LWC measurements (Yang et al. 2015).



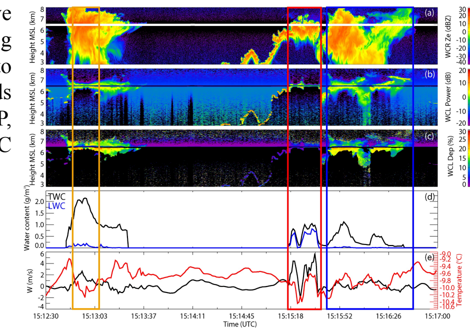


Fig. 4 (above). C-130 penetration of three convective turrets during their different life stages (red box - developing stage, orange box - mature stage, blue box - dissipating/remnants). From top are up and down cloud radar reflectivity, lidar power, lidar linear depolarization, TWC/LWC and flight level temperature/vertical velocity.

Fig. 5 (left). Temperature dependence of LWC, IWC and Liquid fraction for developing convective clouds sampled during NSF ICE-T experiment.

Comparison of liquid-ice mass partition in convective and stratiform mixed-phase clouds

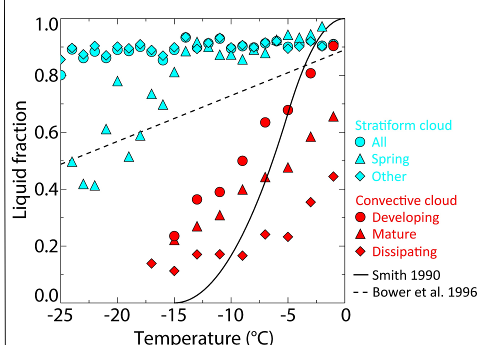


Fig. 6: Comparison of temperature-dependent liquid fractions between observations from arctic stratiform mixed-phase clouds and tropical maritime convective clouds.

For Arctic Stratiform Mixed-phase Clouds:

- Liquid fraction = LWP/(LWP+IWP), excluding ice below the mixed-phase layer.
- There are high dust occurrence during spring.

For tropical maritime convective clouds:

- Liquid fraction = LWC/TWC
- In situ data are from the ICE-T project conducted in July 2011 near St. Croix.

Key Points

- There are systematic differences in liquid fraction between stratiform and convective mixed-phase clouds.
- Ice generation is the controlling factor for liquid/ice mass partitions.
- Liquid/ice mass partition in convective clouds is strongly depend on convective cloud life cycles.

References

Zhang, D., et al.,, 2014: Ice Concentration Retrieval in Stratiform Mixed-Phase Clouds Using Cloud Radar Reflectivity Measurements and 1D Ice Growth Model Simulations. *J. Atmos. Sci.*, 71, 3613–3635.

Yang, et al., 2015: Liquid/ice mass partition in tropical maritime convective clouds. In prep.

Smith, R. N. B., 1990: A scheme for predicting layer clouds and their water content in a general circulation model. *QJRMS*, 116, 435-460.

Bower, K. and coauthors, 1996: A parametrization of ice water content observed in frontal and convective clouds. *QJRMS*, 122, 1815-1844.