SPEC inc

Secondary Ice Production in Cumulus Clouds

Paul Lawson, Colin Gurganus and Sarah Woods - SPEC Inc.
Roelof Bruintjes - NCAR

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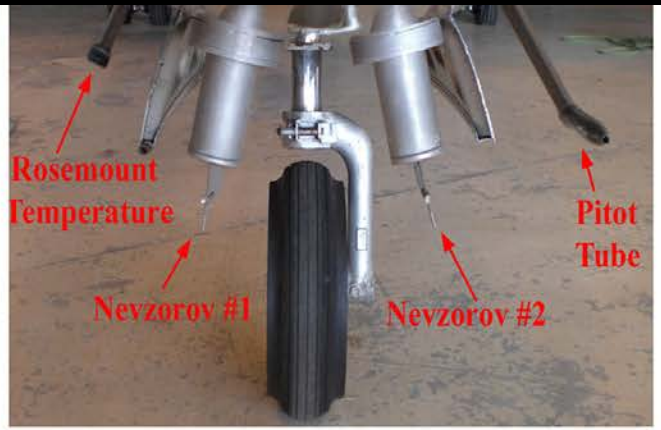
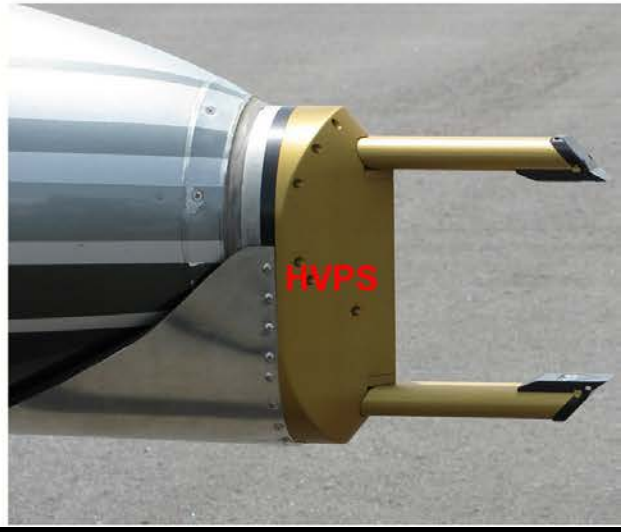
Learjet is Equipped with State-of-the-Art Microphyics and Air Motion Instrumentation

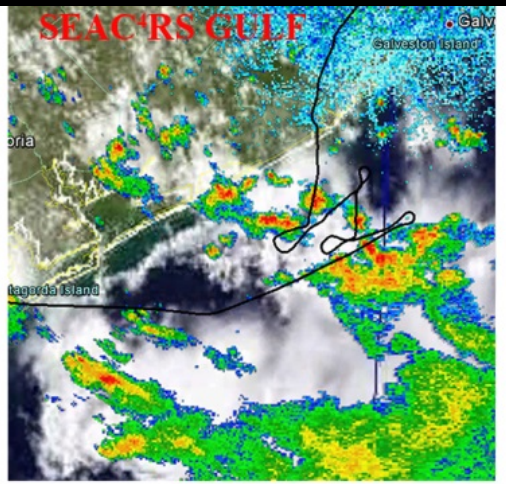


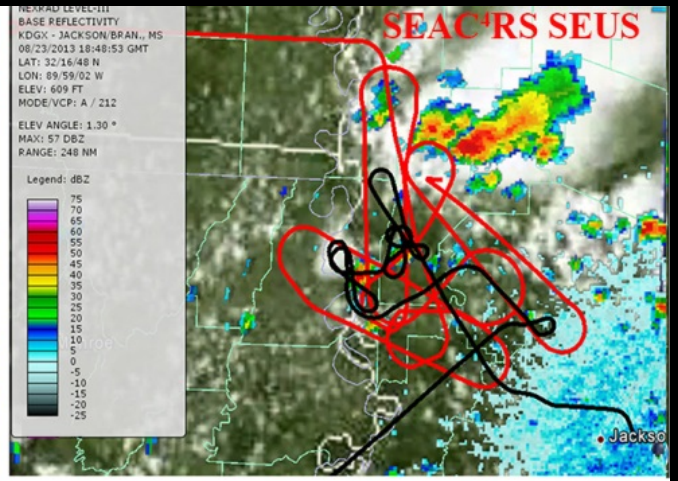


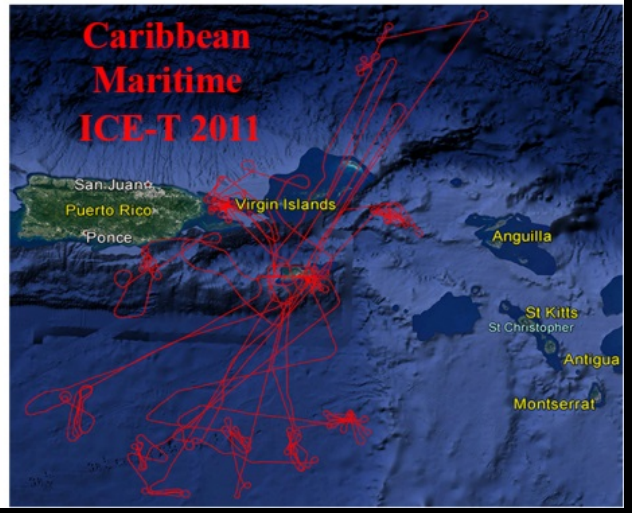
Learjet Participation in Four Field Campaigns: ICE-T, SEAC^{4}RS, Navy Icing and UAEREP

- Learjet made 137 Cumulus Cloud Penetrations in ICE-T (2011), 84 Penetrations in SEAC^{4}RS (2013), 90 Penetrations in Navy Icing (2014) and 108 Penetrations in UAEREP (2017)
- The Principal Role of the Learjet was to Penetrate new, Growing Turrets in the Region from -5°C to -10°C to Search for Ice Initiation, and then Climb with the Developing Turret up to -35 °C to Document Ice Development.

Learjet Flight Tracks







Hypothesis

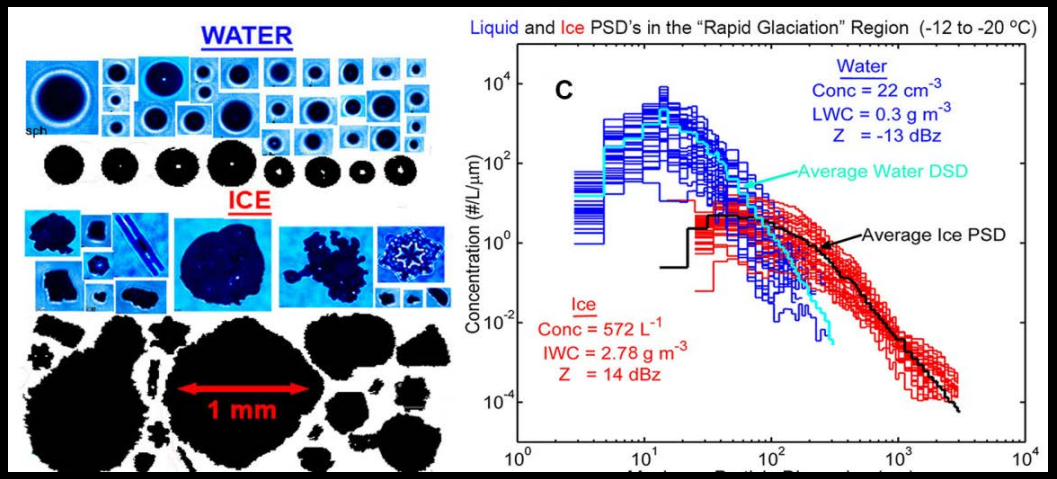
- Cumulus clouds that produce (~ millimeter-diameter) Supercooled Large Drops (SLDs) in sufficient concentrations rapidly glaciate via a Secondary Ice Process at T > ~ -15 °C.
- Cumulus clouds that produce only small diameter (< ~ 50 μm) drops do not produce secondary ice and substantial SLW is carried well above the – 15 ° C level.
- Some Cumulus clouds that do NOT produce SLDs may be stimulated via hygroscopic seeding to enhance the coalescence process and produce SLDs, potentially enhancing rainfall.

Question

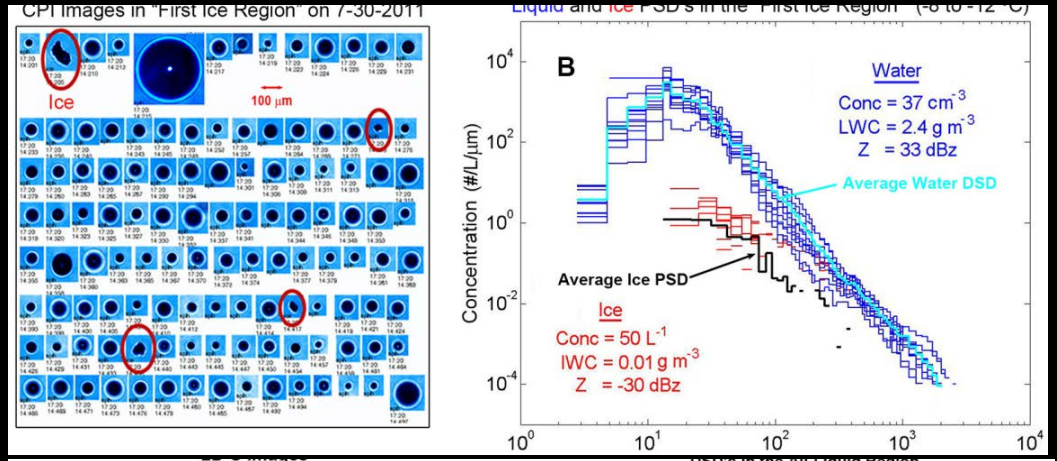
What are the characteristics of clouds that can be potentially stimulated to produce SLDs?

Rapid glaciation via Secondary Ice Production in (ICE-T) Tropical Clouds

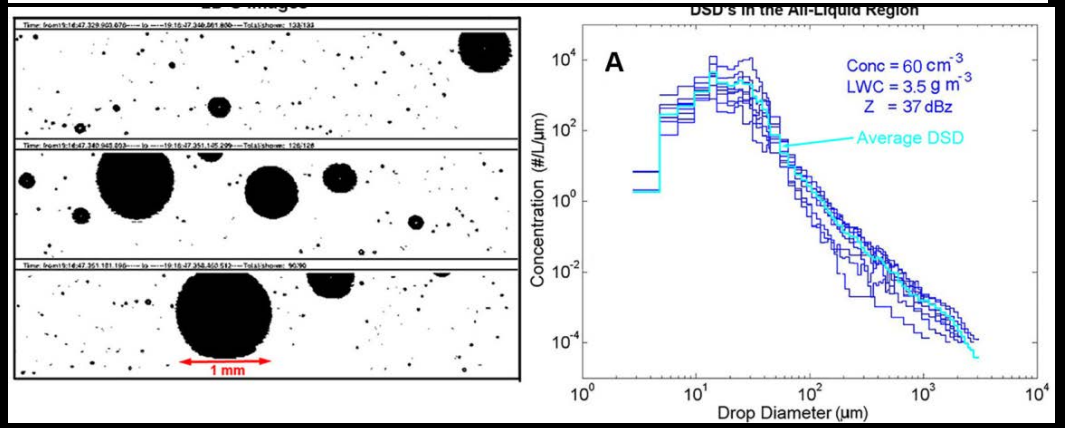
Rapid Glaciation



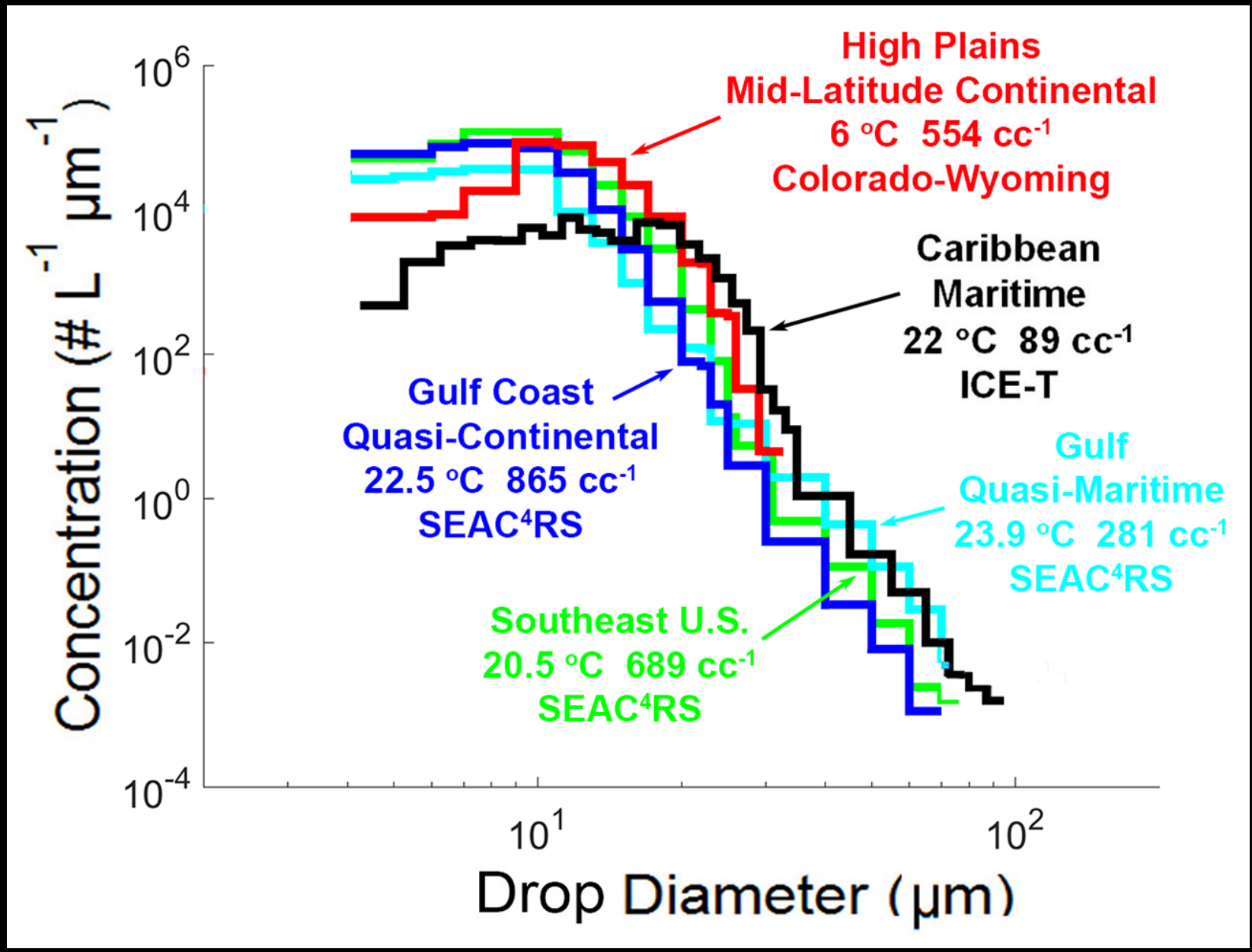
First Ice



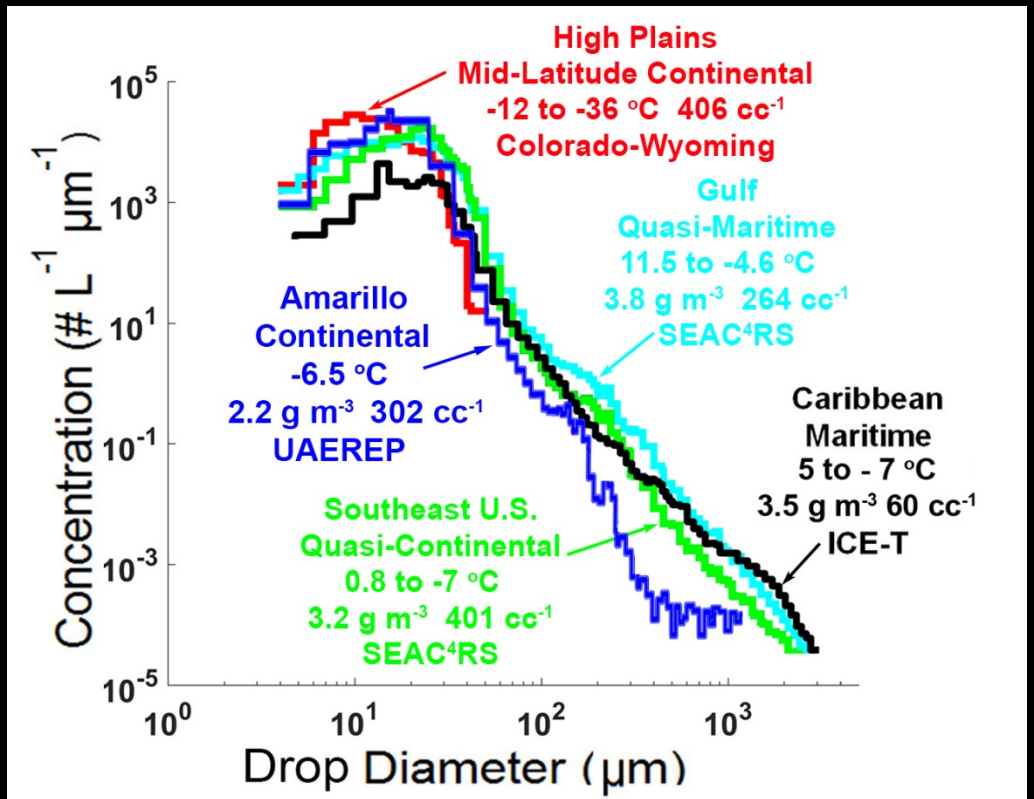
All Liquid with SLDs

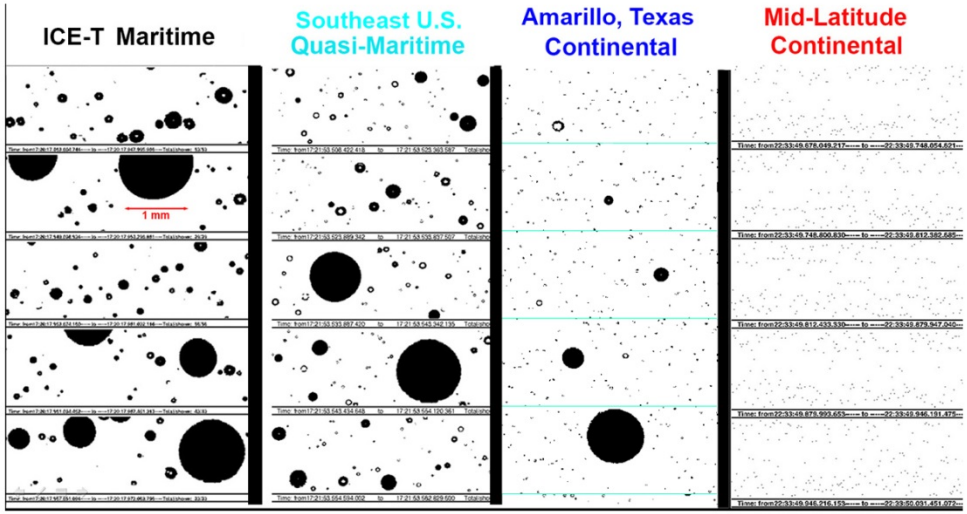


Cloud Base Drop Size Distributions as a Function of Cloud Base Temperature

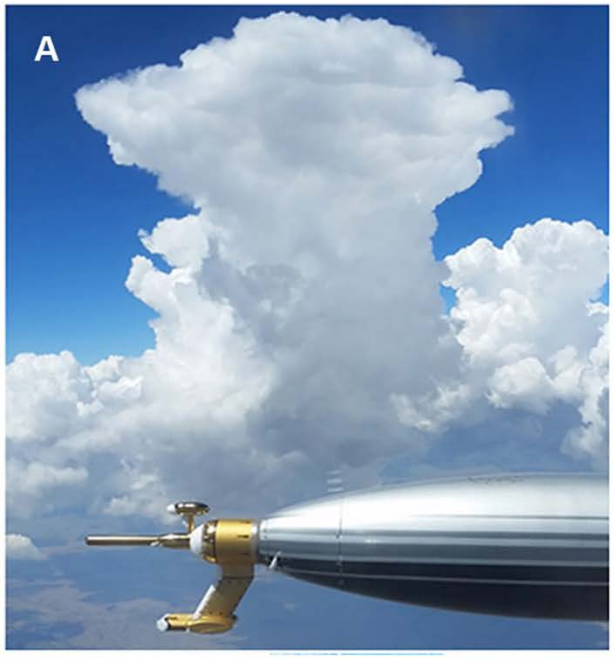


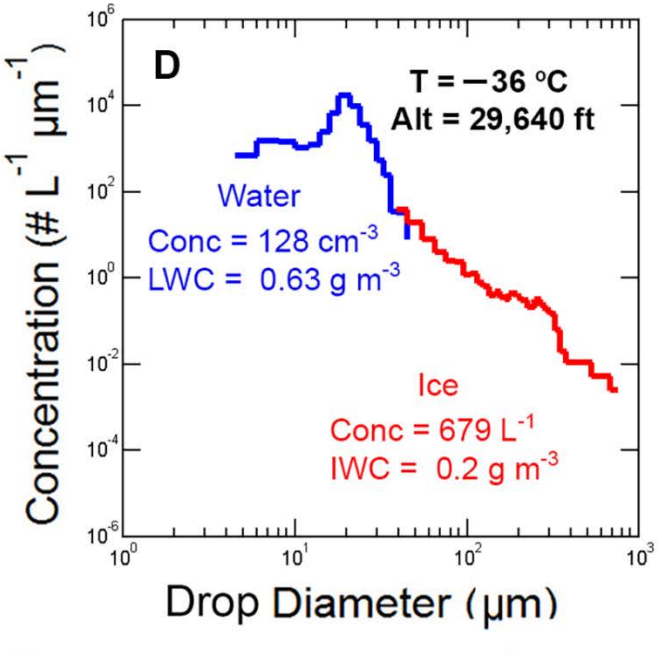
Drop Size Distributions in All-Liquid Cloud Regions

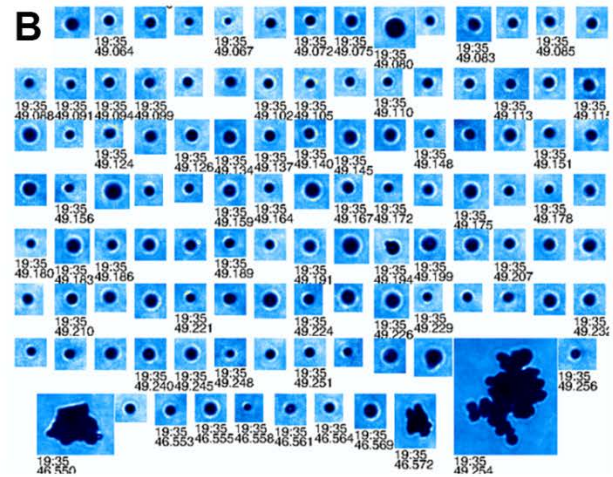


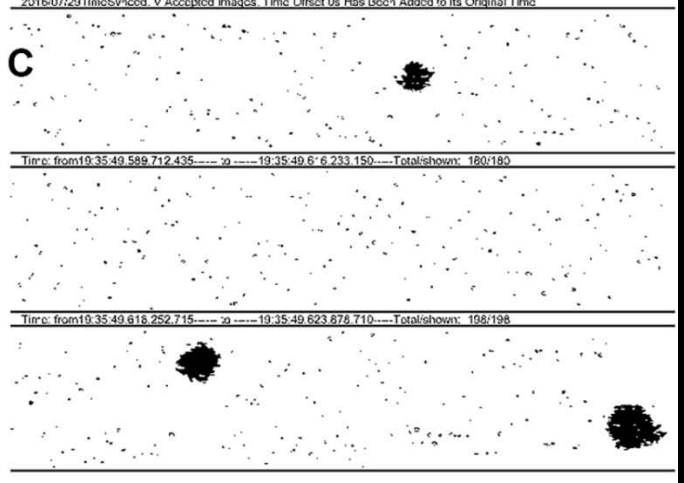


Supercooled Small Liquid Drops at -36 °C In Wyoming



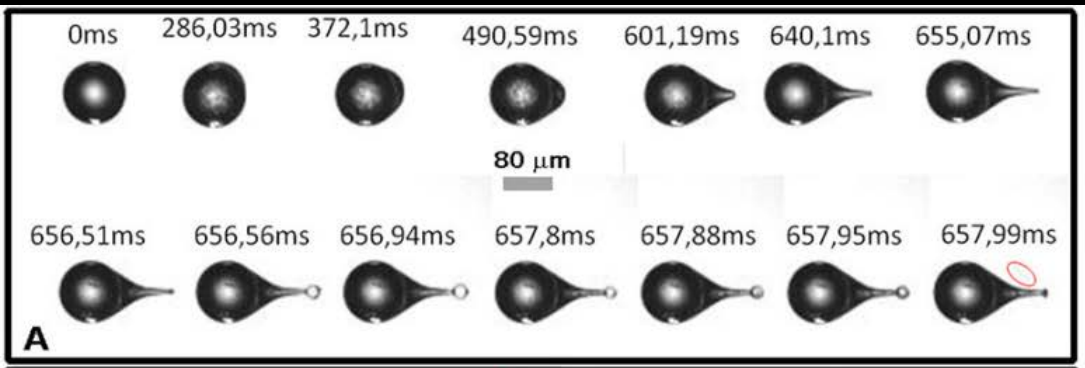


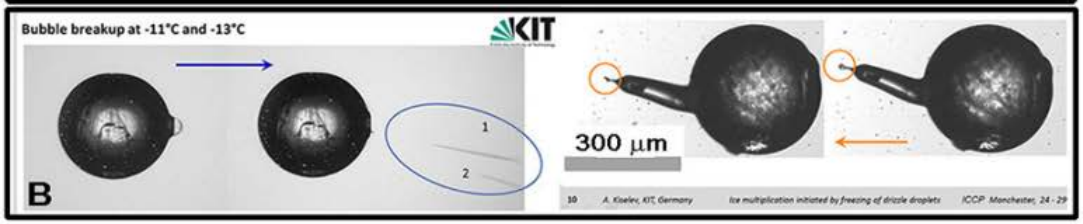


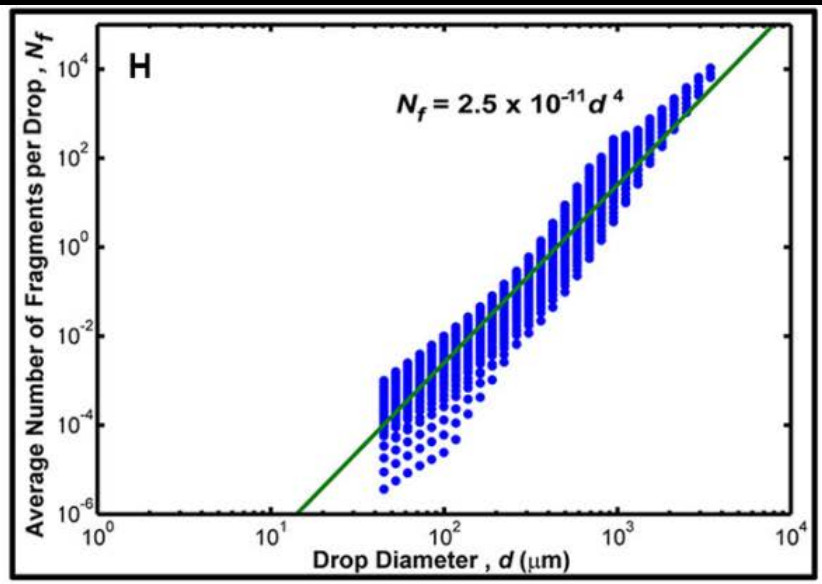


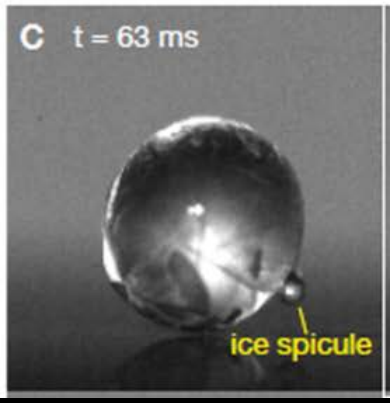
Why is there a correlation with SLDs and Secondary Ice Production?

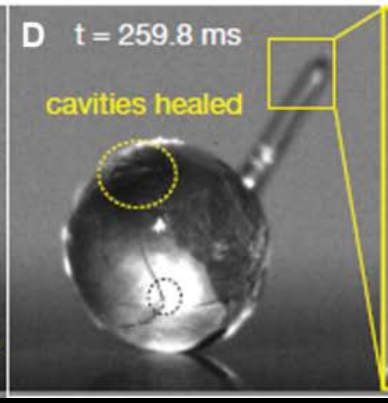
Laboratory Work of Leisner et al. (2014) and Wildeman (2017)

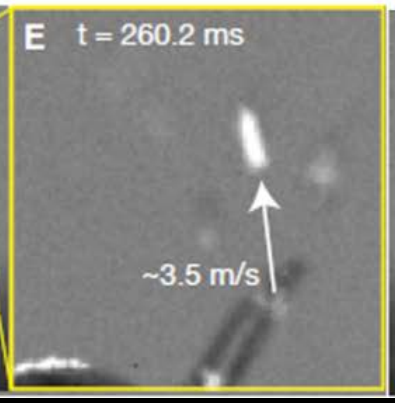


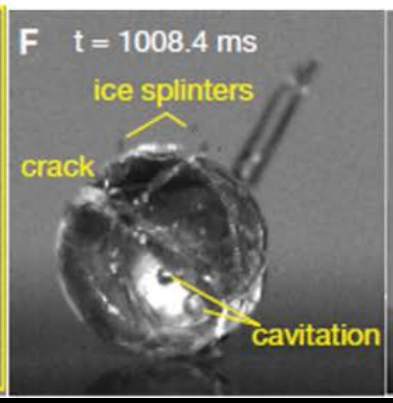


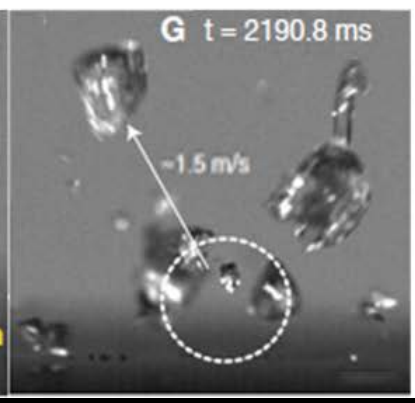




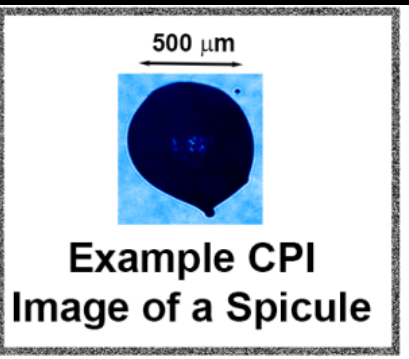


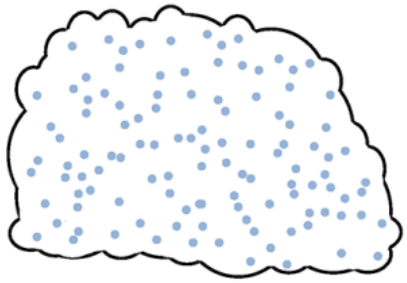




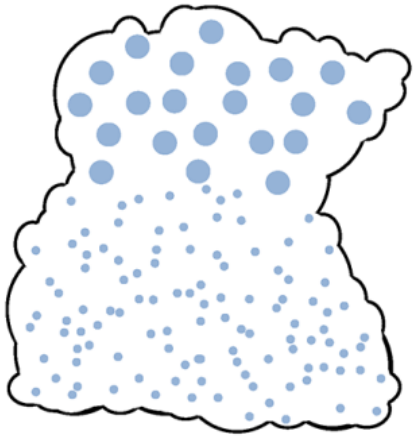


Cartoon Illustrating Secondary Ice Process in Clouds that Produce Supercooled Large Drops

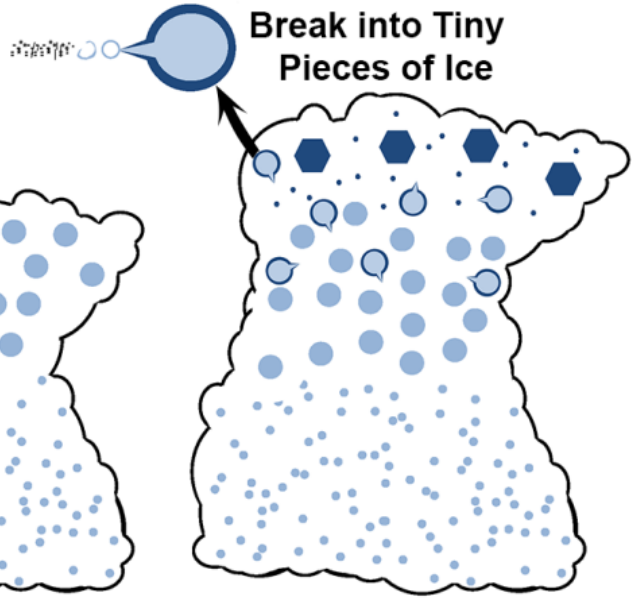




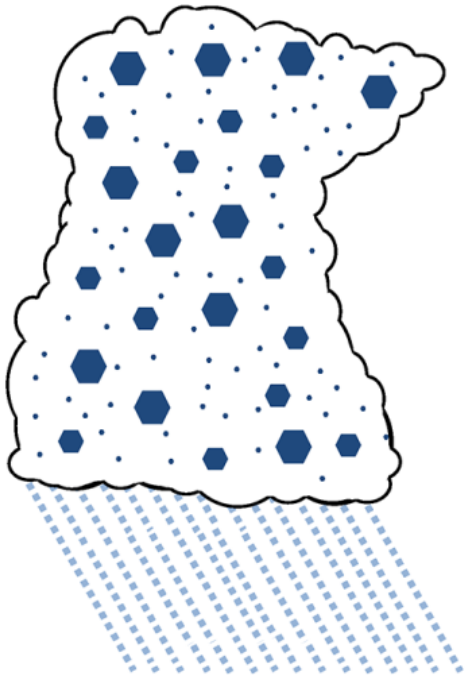
Liquid Cloud with Small Drops



Coalescence Produces Large Supercooled Drops



Large Drops Freeze and Produce Spicules



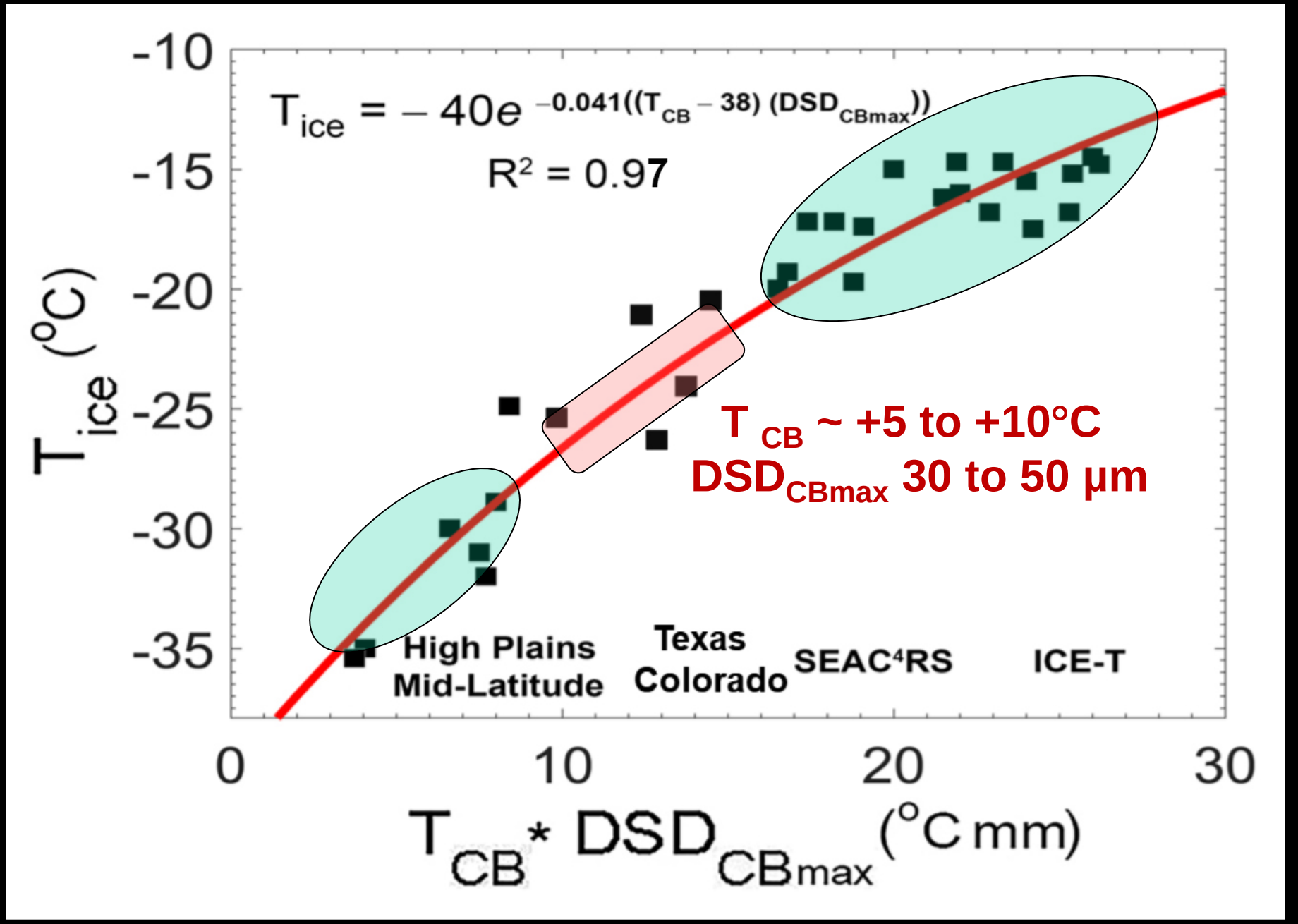
What is the Connection of Secondary Ice Production to Weather Modification?

- In some cumulus clouds it may be possible to simulate the coalescence process (by hygroscopic seeding at cloud base) to produce SLDs that would not be produced naturally.

- Freezing SLDs can fracture and emit small ice that will rapidly freeze other SLDs due to differential fall velocities.

- This will lead to an "Avalanche" process that rapidly glaciates the cloud (i.e., akin to glacionic seeding the entire supercooled updraft in a few minutes), with the possibility of enhancing rainfall.

Which Clouds are "Good" Candidates for Enhancement?



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Thank You