Effects of Immersion Freezing on Simulations of Mixed-Phase Stratus Clouds (Theory and Results)

Gijs de Boer

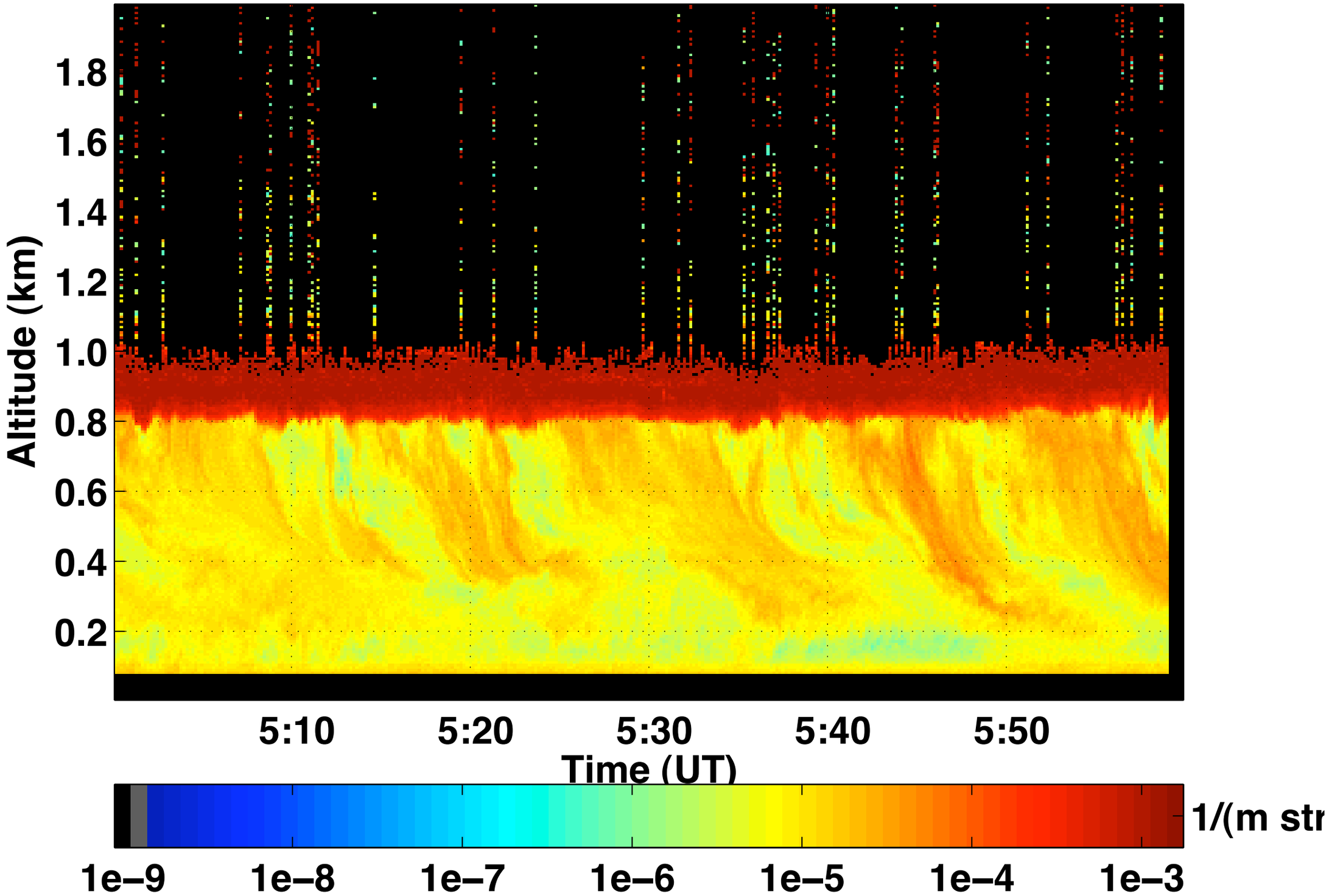
Tempei Hashino, Gregory J. Tripoli

THE UNIVERSITY of WISCONSIN MADISON

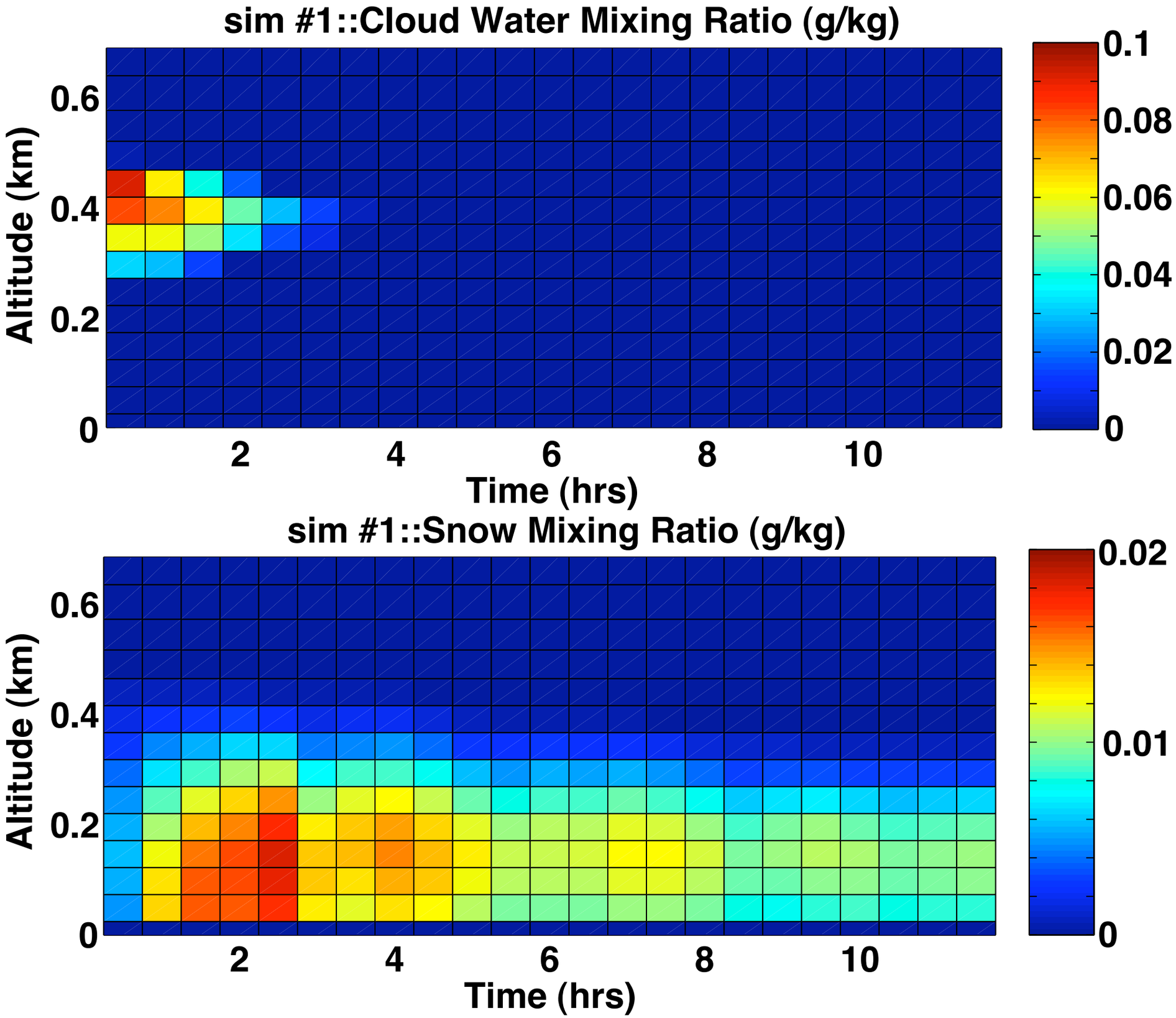
WMO Cloud Modeling Workshop, Cozumel, Mexico--14-17 July 2008

Introduction

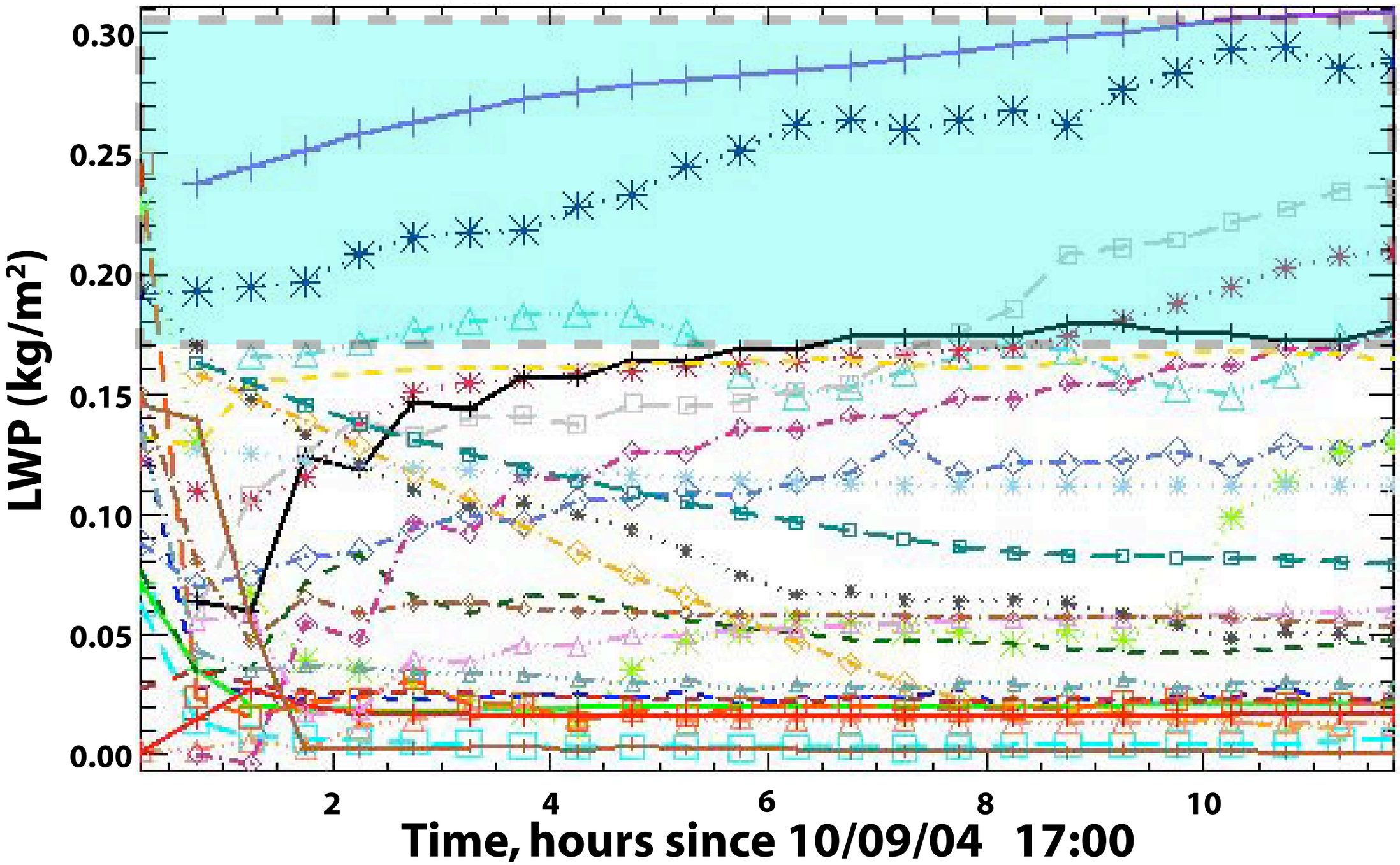
Lidar backscatter cross section (Masked values shown in black and white)



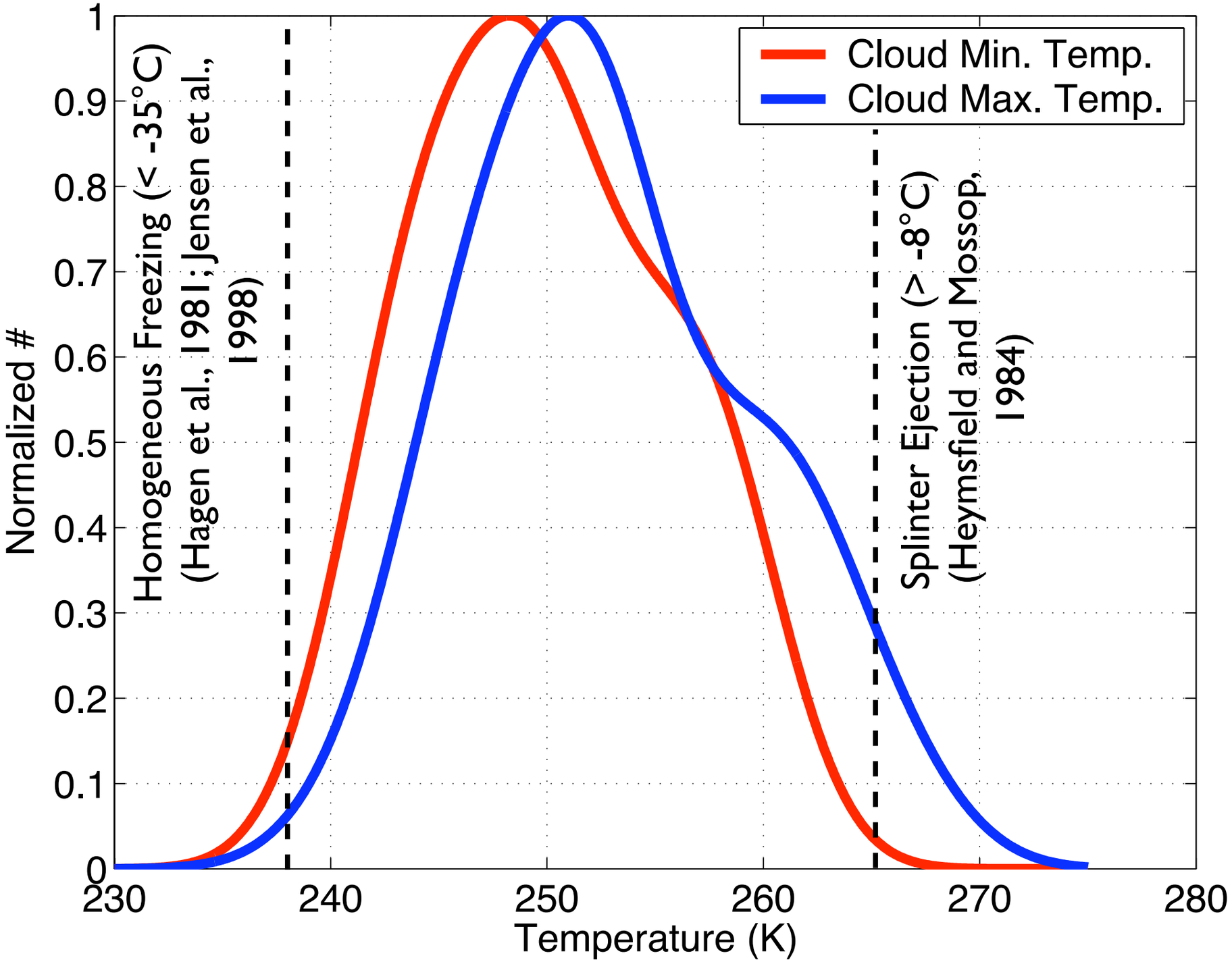
Introduction



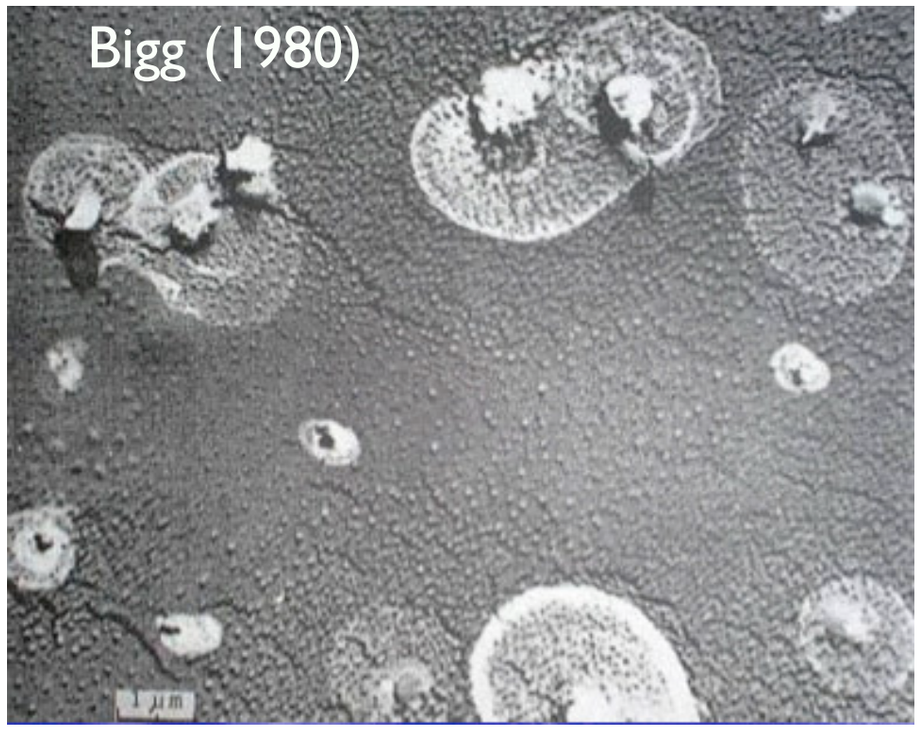
Introduction



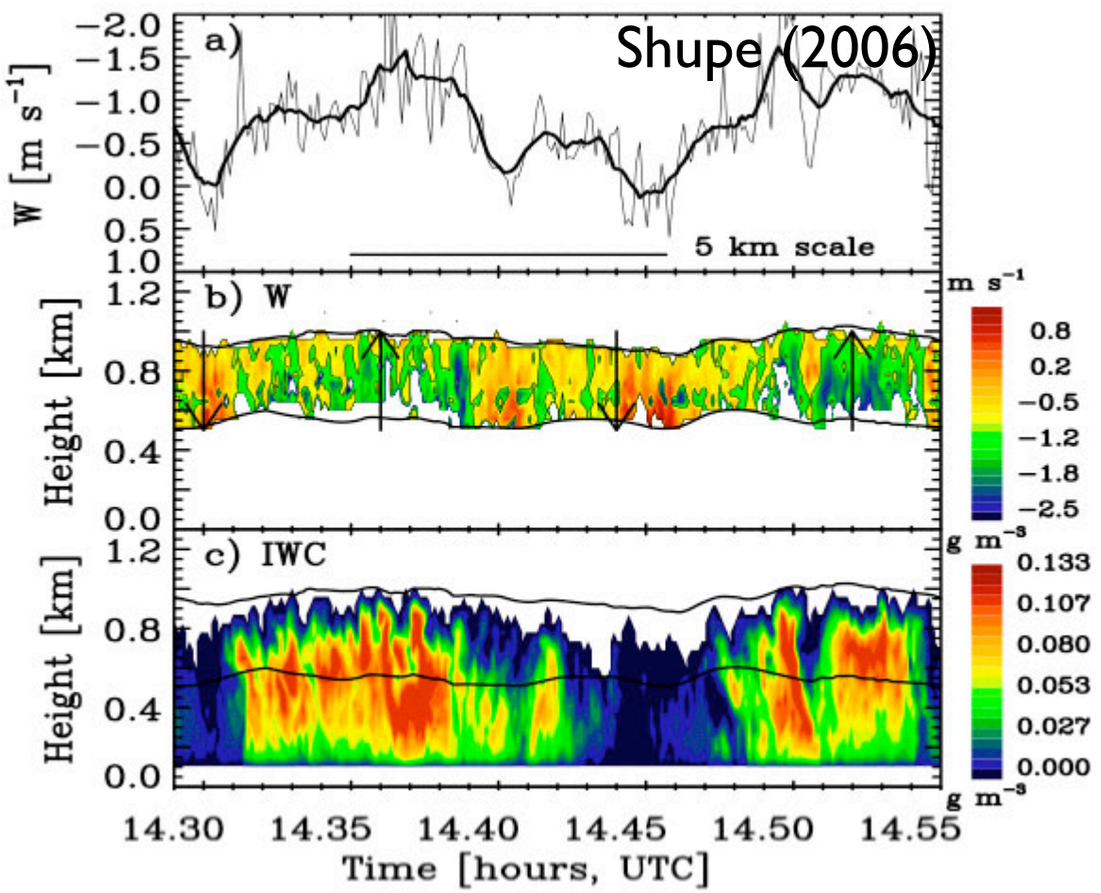
Introduction



Introduction



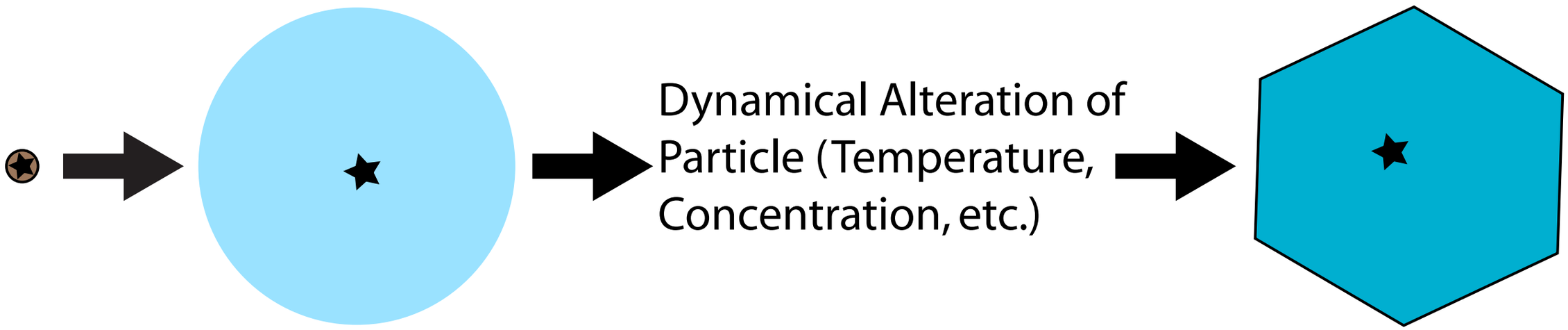
- Bigg (1980) observed sulfuric acid coating on aerosol particles during winter
- Sulfuric coating is water soluble, transforming possible IN into CCN.
- Blanchet (2007) hypothesizes that sulfur coating is a result of sulfur emissions from Siberia, and that resulting particles in Arctic have reduced ice nucleating ability.



From ground-based sensors:
- Large increases in IWC in updrafts
- Decrease in Liquid Fraction in updrafts

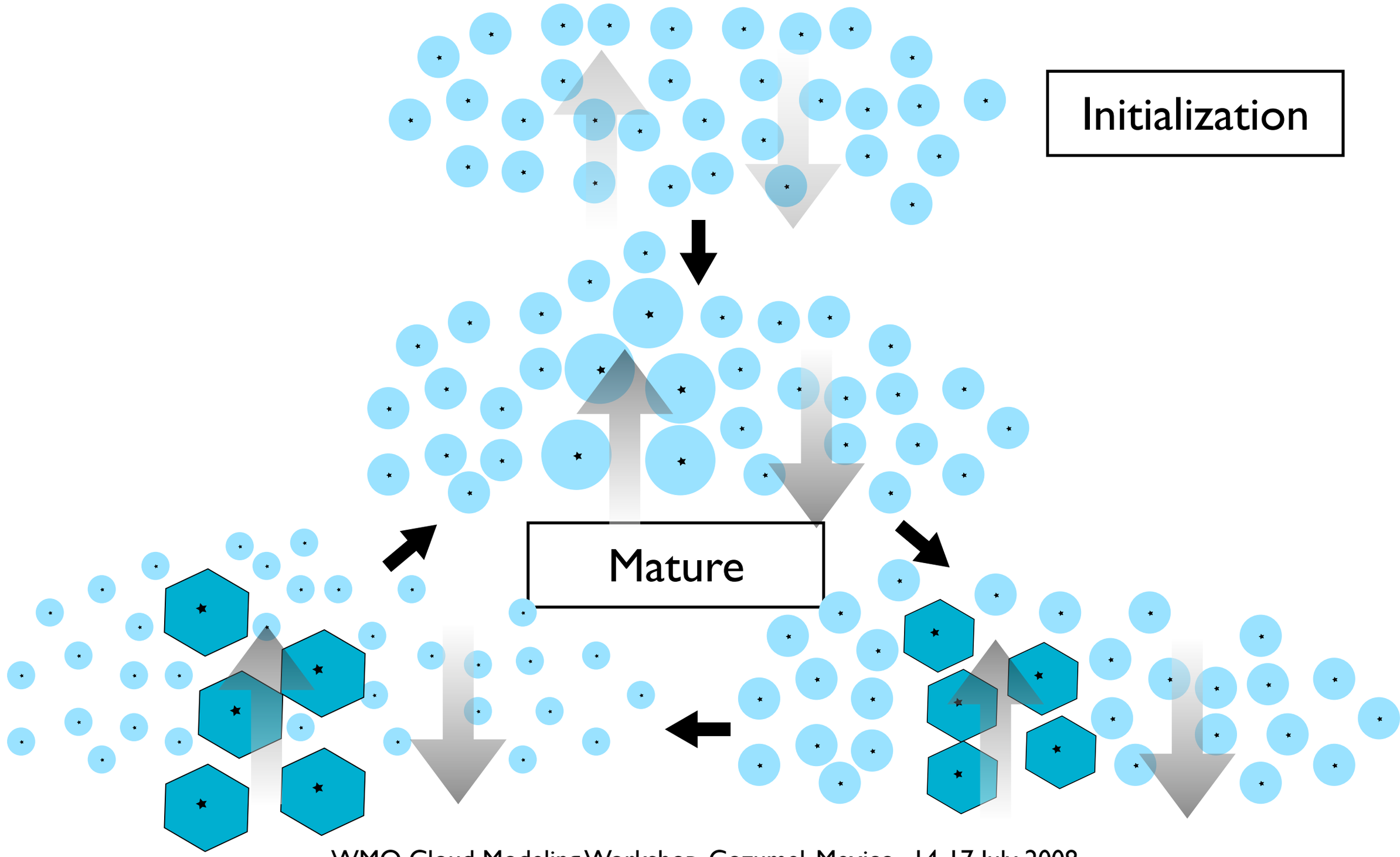
From in-situ measurements:
- Ice crystal concentrations strongly proportional to concentration of drops larger than 20 μm. (Rangno & Hobbs, 2001)

Immersion Freezing

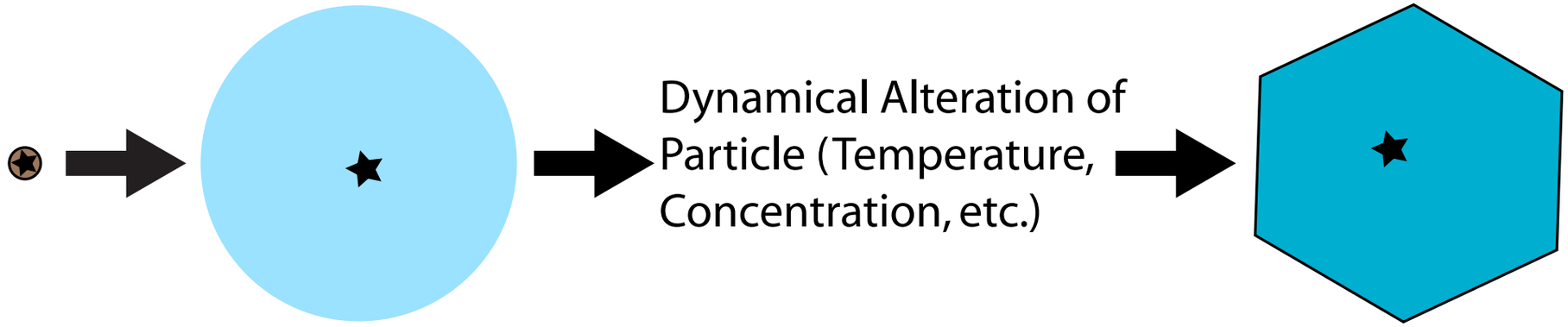


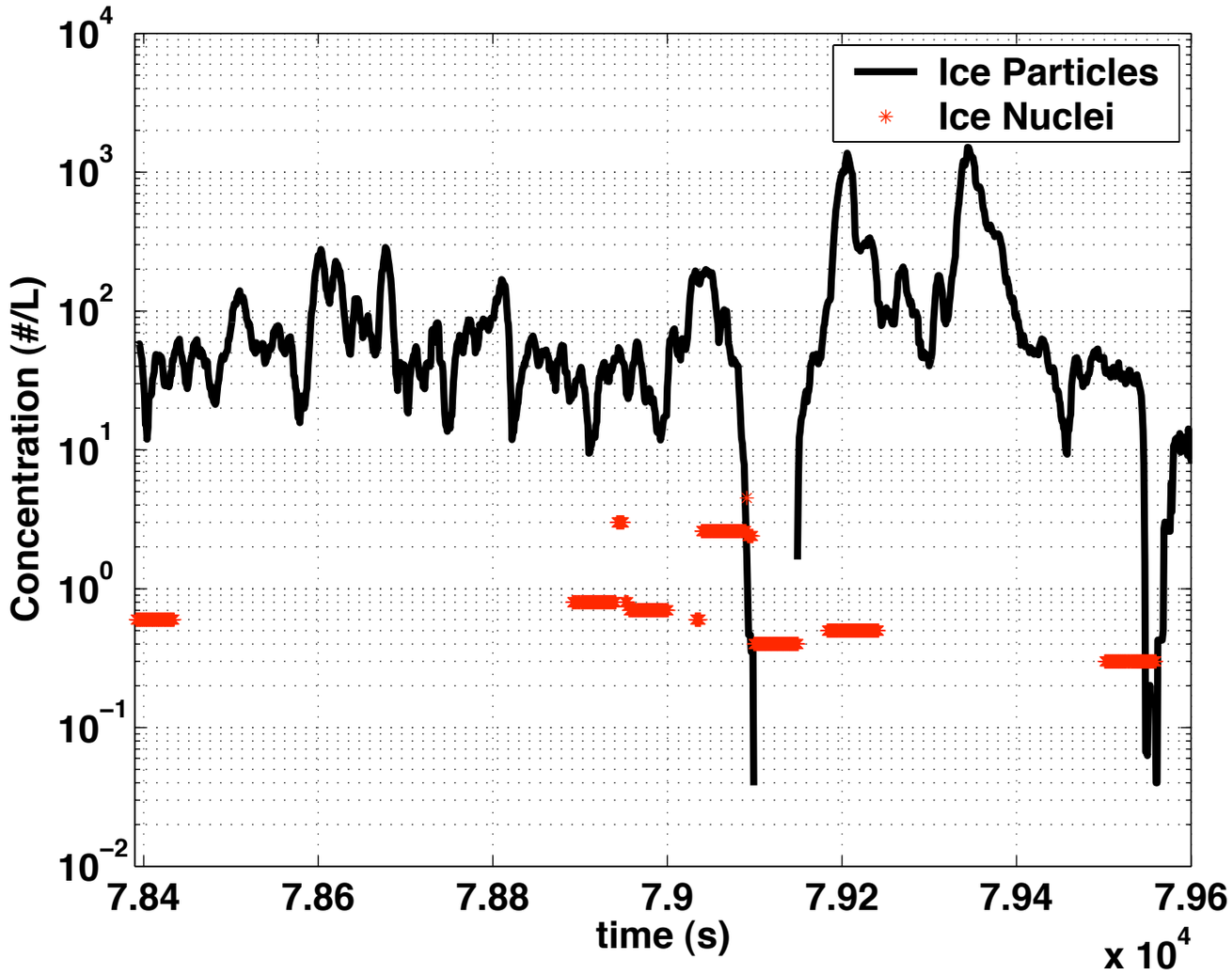
Immersion Freezing

Conceptual Model for Mixed-Phase Stratus

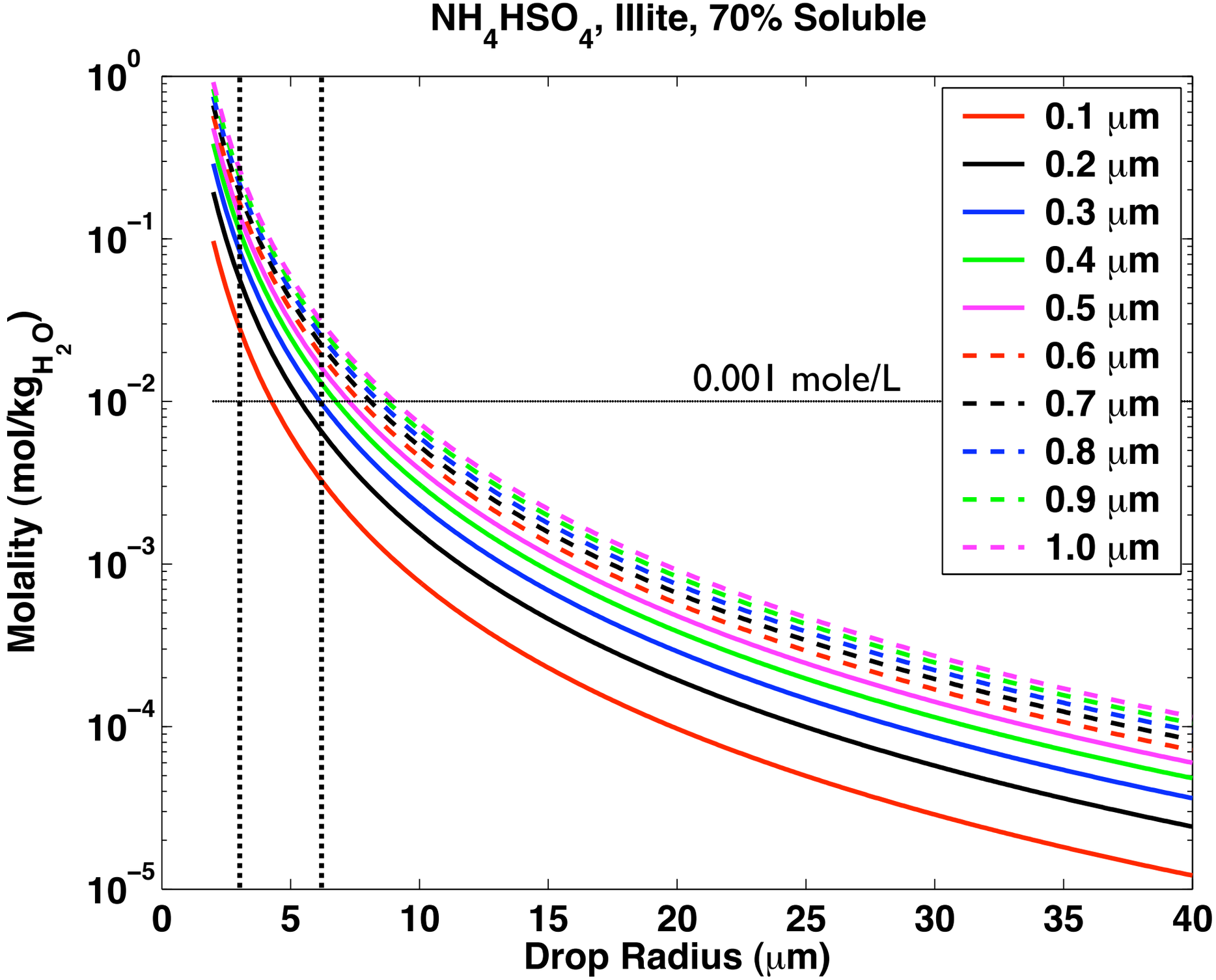


Immersion Freezing





Immersion Freezing



Simulations

2-D Simulations for the SHEBA mixed-phase case

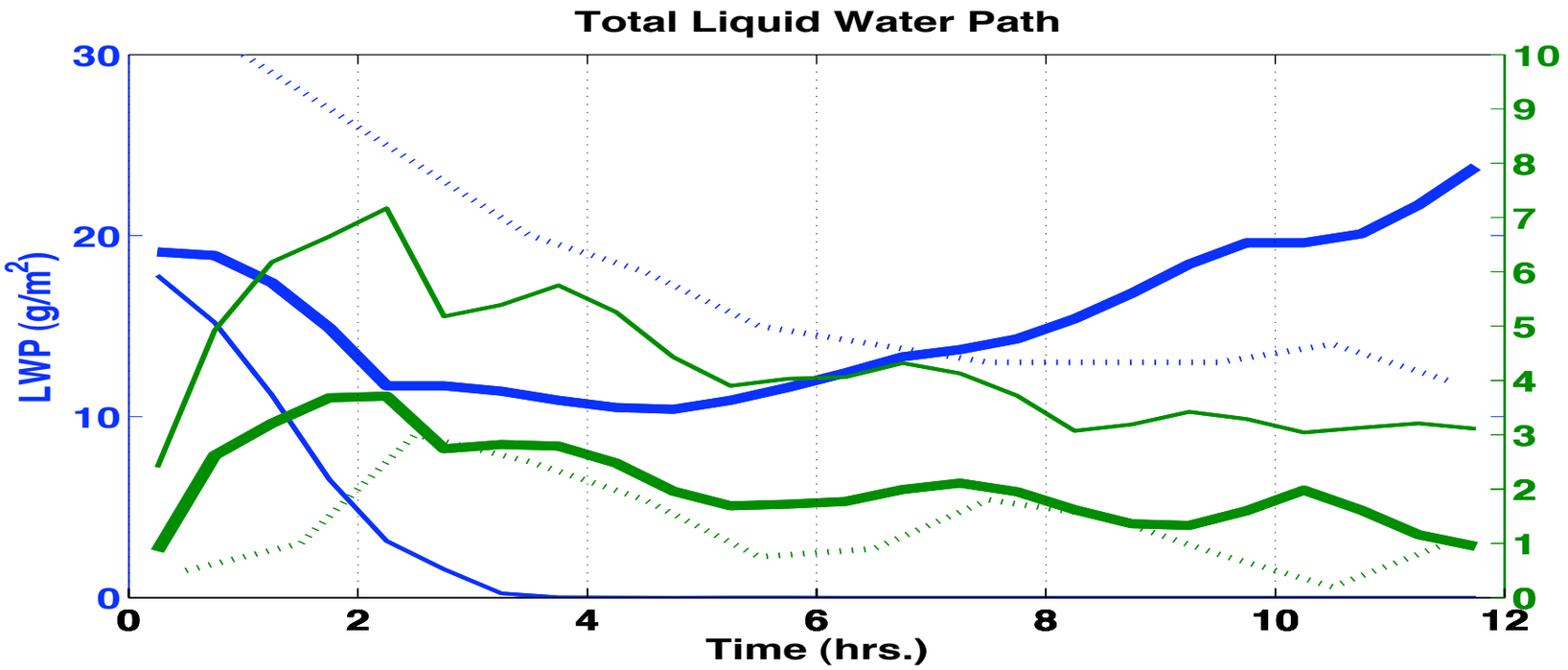
-- University of Wisconsin Non-Hydrostatic Modeling System (UW-NMS: Tripoli, 1992)

-- Advanced Microphysical Prediction System (AMPS: Hashino and Tripoli, 2007)

- Size-resolved liquid and ice microphysics with diagnostic aerosol (IN and mixed).
- Immersion freezing: Reisin (1996), and solubility effect from Diehl & Wurzler (2004)
- CCN: 70% soluble NH_4HSO_4 mixed particle

-- Resolution: 200 m horizontal, 50 m + vertical

Simulations



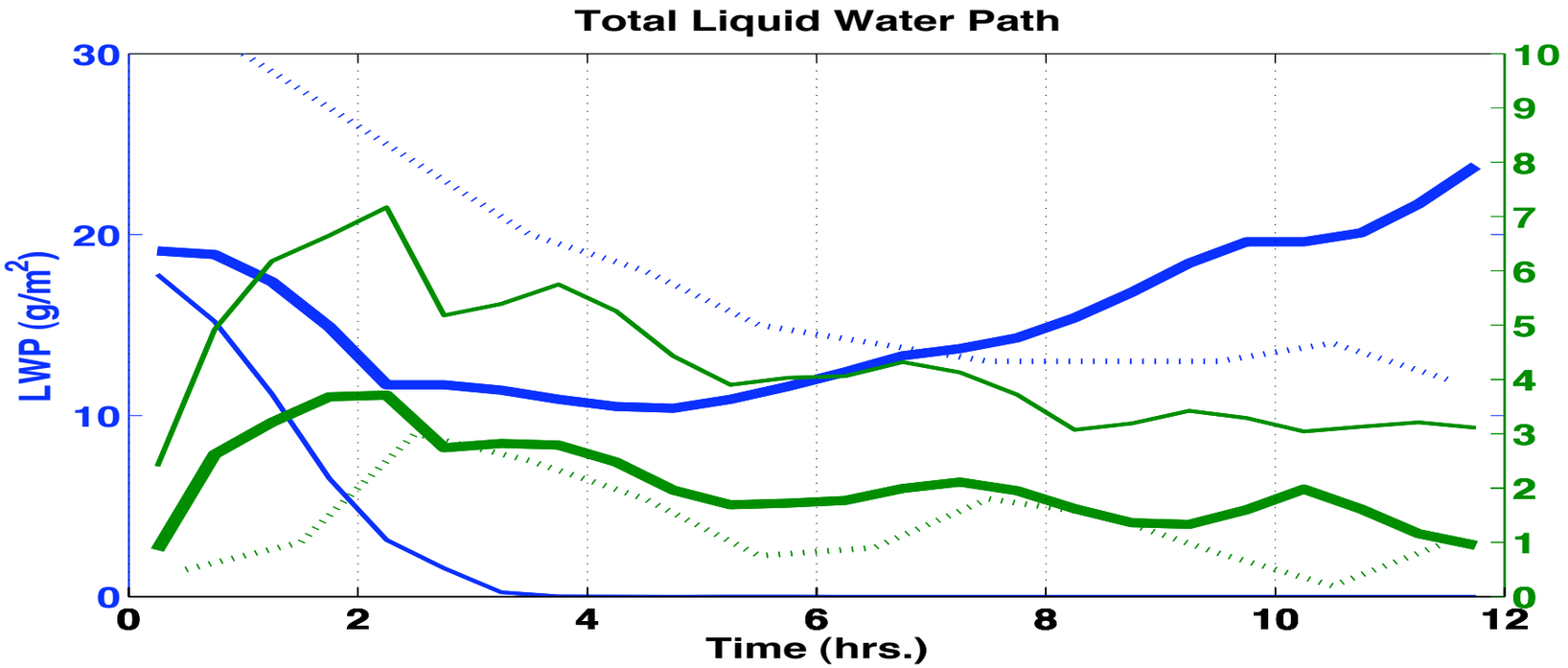
LIQUID **ICE**

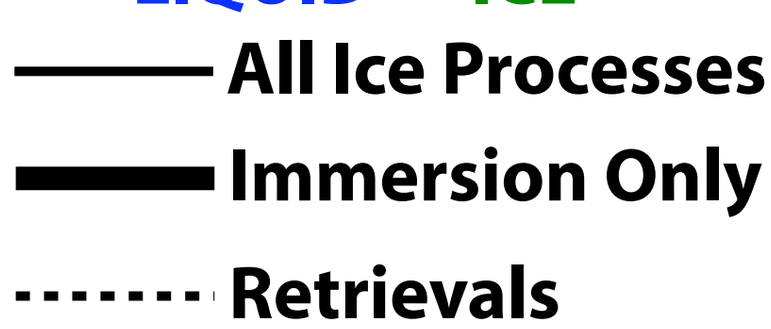
All Ice Processes

Immersion Only

Retrievals

Simulations

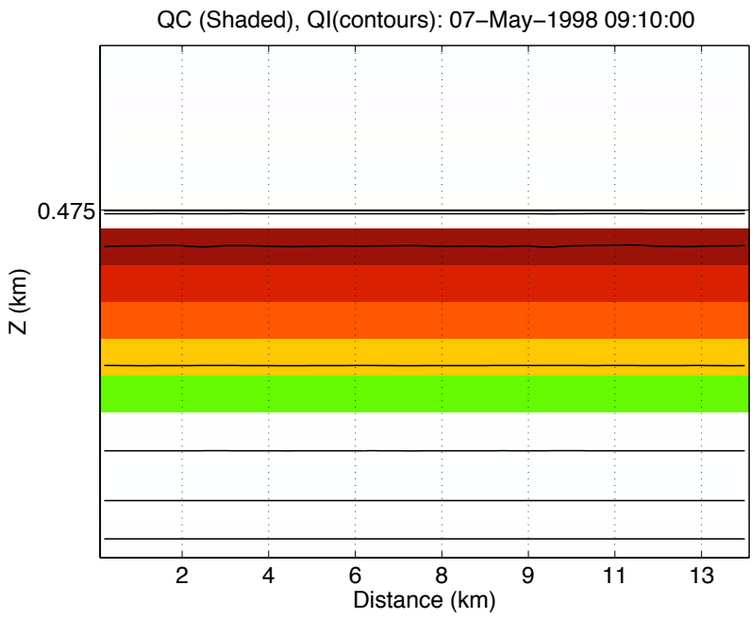


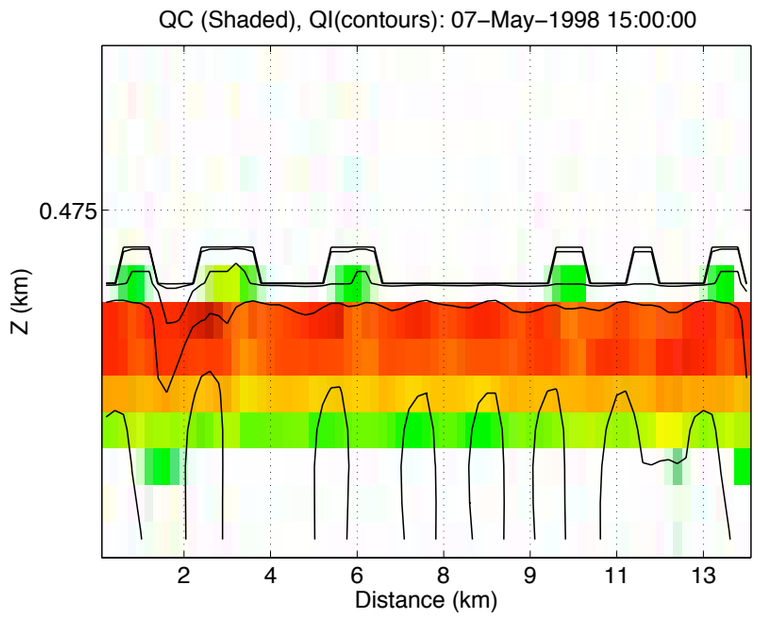


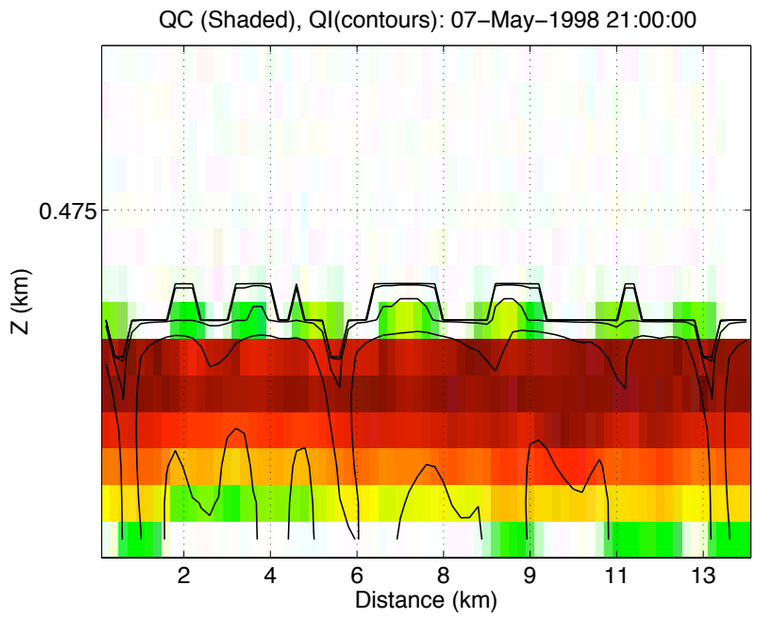
10 minutes

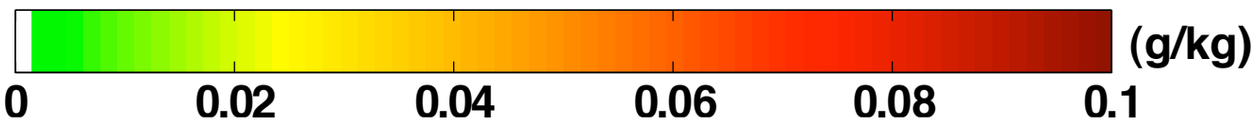
360 minutes

720 minutes



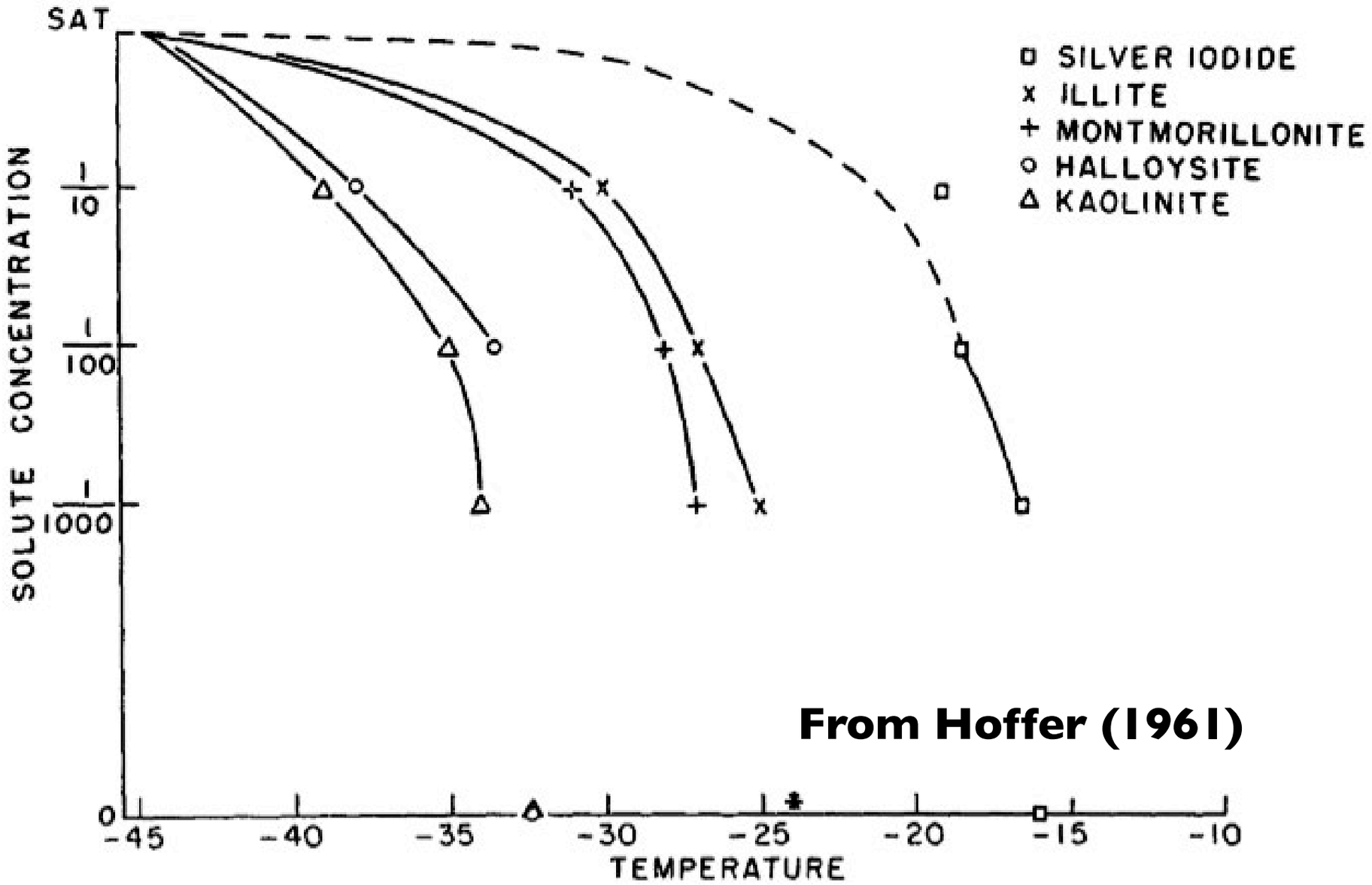






Simulations

Effect of Solution Concentration

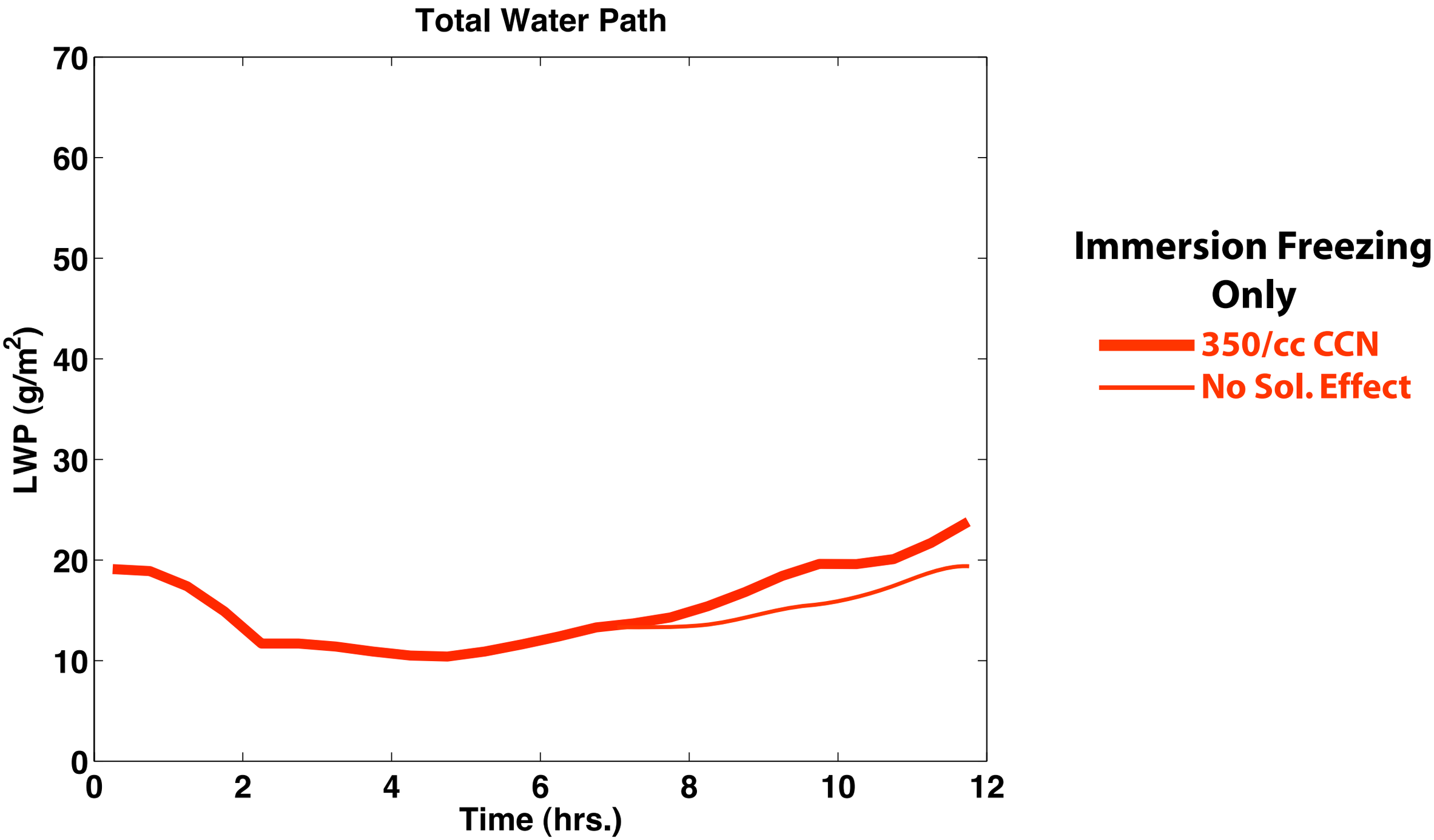


From Hoffer (1961)

FIG. 5. Median droplet freezing temperature for droplets of different solute concentration (100–120 microns diameter).

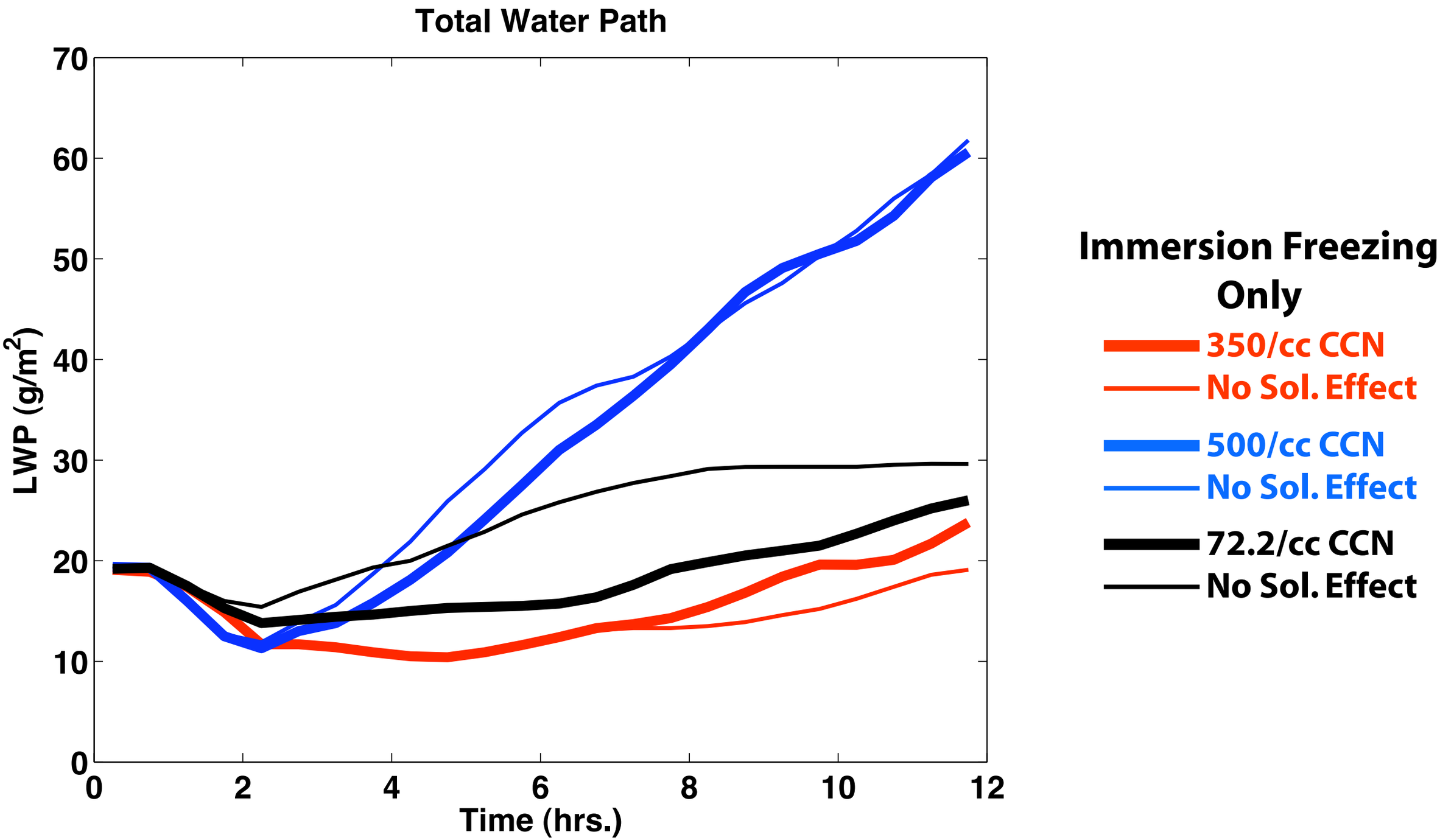
Simulations

Effect of Solution Concentration



Simulations

Effect of Solution Concentration



Summary

-- Understanding of ice nucleation mechanisms is key for understanding and modeling mixed-phase stratus lifetime.

-- Observation of IN involved with immersion freezing is uncertain at this time.

-- Simulations with only immersion freezing active produce approximately the correct amount of ice in high resolution simulation.

-- The freezing point depression due to presence of soluble material inside droplets significantly affects simulations, but pathways for these effects are not necessarily straightforward.