A 2-d modeling approach for studying the formation, maintenance, and decay of Tropical Tropopause Layer (TTL) cirrus associated with Deep Convection

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07/28/2009

OUTLINE:

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- Recent Studies of the TTL
- UW-NMS
- Microphysics
- Preliminary Results
- Merging observational data sets
- Future Work
- References
- Questions/Discussion

INTRODUCTION

- **Cirrus located in the Tropical Transition Layer (TTL) have become a focal point much of research over the last decade. Understanding their role and contribution to the overall water vapor concentration in the stratosphere has drawn significant interest.**
- **Recent studies have been conducted to study the ice nucleation processes and role of aerosols during deep convective events as well comparing model simulations with in-situ observational data sets.**
- **Simulations in this study will utilize a new microphysical scheme that has been created called AMPS, which predicts multiple distributions of CCN and IN, liquid and ice mass spectral.**
- **The ice scheme called SHIPS is unique in that ice particle properties (such as size, particle density, and crystal habitats) are explicitly predicted in a CRM (Hashino and Tripoli, 2007, 2008).**
- **A new radiative transfer model to handle ice particles with arbitrary density and shape was developed for AMPS.**
- **Strong tool that effectively enables the explicit modeling of the TTL cloud microphysics and dynamical processes.**

What is the TTL…?

- The Tropical Tropopause Layer (TTL) is the layer between the level of zero net radiative heating which is found typically around 15 km (Gettelman et al., 2004) and the cold point tropopause at 17 to 18 km.
- The TTL layer represents the layer between approx. 14 to 18km alt. through which tropospheric air enters the stratosphere. It is characterized by high vertical gradients in water concentration and a local minimum in temperature (Garrett et al., 2006).
- This layer is characterized by slow ascent and forms the source region for the stratospheric Brewer-Dobson circulation (Immler et al., 2008).

TTL Cirrus Formation

Two general classes of tropical cirrus

- 1.) Formation related to detrainment of particles and water vapor from deep convection (Pfister et al., 2001).
- 2.) In-situ formation: TTL cirrus formation related to vertical propagating Kelvin and gravity waves (Boehm and Verlinde, 2000) while Pfister et al. (2001) argued that they could form through synoptic scale ascent along isentropic surfaces.

- Formation of Cirrus by direct injection from convective systems into the TTL most likely moistens the air by evaporation of the particles (Nielsen et al. 2007)
- In situ formation of Cirrus in slowly ascending air will most always lead to dehydration (Jensen and Pfister, 2004; Immler et al. 2007)

IMPORTANCE…?

- Cirrus play a role in the maintenance of the water vapor distribution in the Tropics. In the vertical region bounded by the detrainment layer of deep convection and the stratosphere, tropical cirrus help regulate the water vapor concentrations entering the lower stratosphere in the Tropics (Jensen et al., 1996; Hartmann 2002: Dessler and Sherwood 2000; etc.)
- Up to 20% of the global Tropics are regularly covered by extensive cirrus systems (Liou, 1986).
- These cloud layers **can** reduce the solar radiation reaching the earth's surface due to reflection. These cloud layers also **can** absorb a portion of the upwelling IR radiation emitted by the surface and lower atmosphere and emit IR at a lower temperature (Mace et al., 2005)
- Net effect **can** be to reduce OLR and thus heating of the atmosphere

RECENT STUDIES

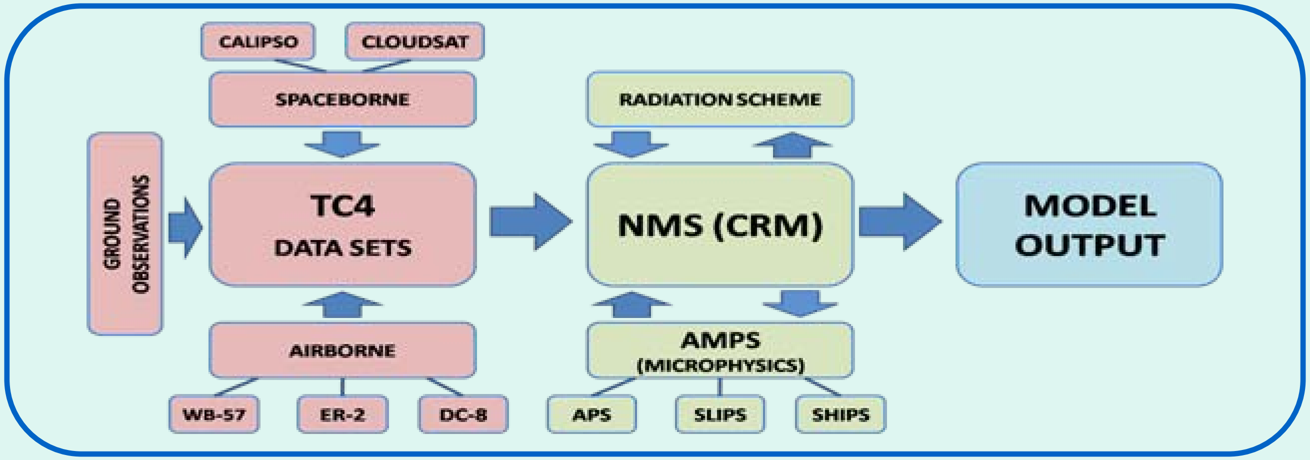
Recent Campaigns Related to the study of the TTL

- Cirrus Regional Study of Tropical Anvils and Cirrus Layers - Florida Area Cirrus Experiment (CRYSTAL-FACE), 2002, Jul, Key West, FL
- Tropical Warm Pool - International Cloud Experiment (TWP-ICE), 2006, Jan-Feb, Australia
- Costa Rica Aura Validation Experiment (CR-AVE) 2006,Jan-Feb, San Jose, Costa Rica
- Tropical Composition, Cloud and Climate Coupling (TC4), 2007, Jul-Aug, Costa Rica, Panama

These campaigns are crucial for the gathering of observational data in the TTL and validating remote sensed space borne observations

UW-NMS

- The **<u>U</u>**niversity of **<u>W</u>**isconsin **<u>N</u>**on-Hydrostatic **<u>M</u>**odeling **<u>S</u>**ystem is a non-hydrostatic cloud resolving research model used to investigate processes at a large range of scales, from hemispheric to micro- β.



<u>Key Features:</u>

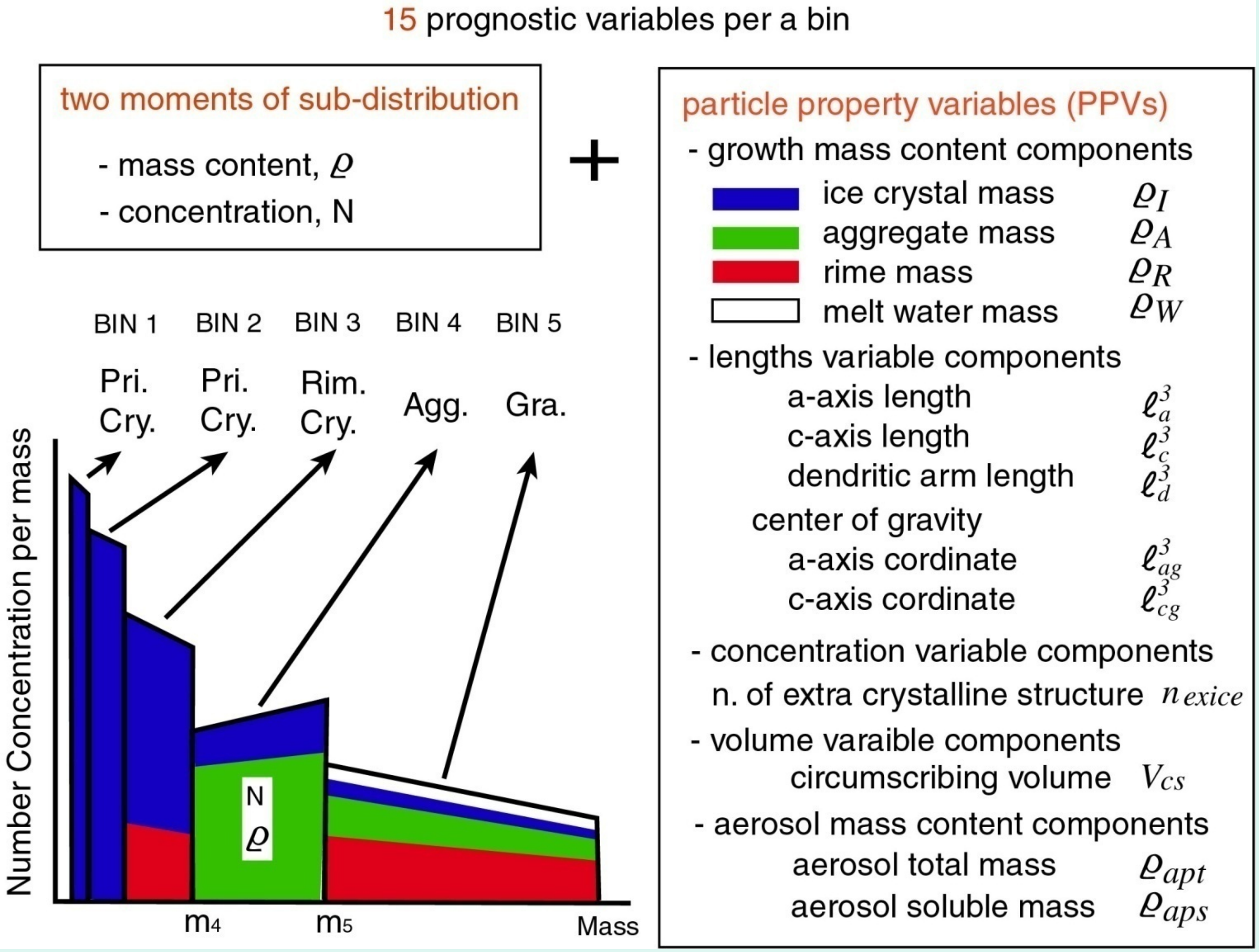
•Scalability in all directions (x,y,z), Two-way interactive grid nesting, Long and short wave radiation parameterization, and recently added the Advanced Microphysics Prediction System (AMPS)

✓Spectral Aerosol Prediction System (SAPS)
✓Spectral Liquid Prediction System (SLIPS)
✓Spectral Habit Ice Prediction System (SHIPS)

Advanced Microphysics Prediction System (AMPS) - liquid, ice, aerosol

Hashino and Tripoli (2007 and 2008)

Spectral Habit Ice Prediction System (SHIPS)



PPVs

- Integrated based on local conditions and history of particles
- Each bin has different properties of ice particles.
- The properties change in time and space.

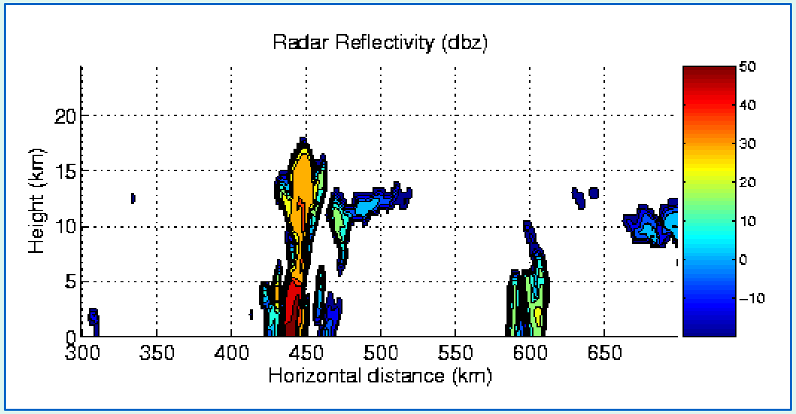
No use of categorization!

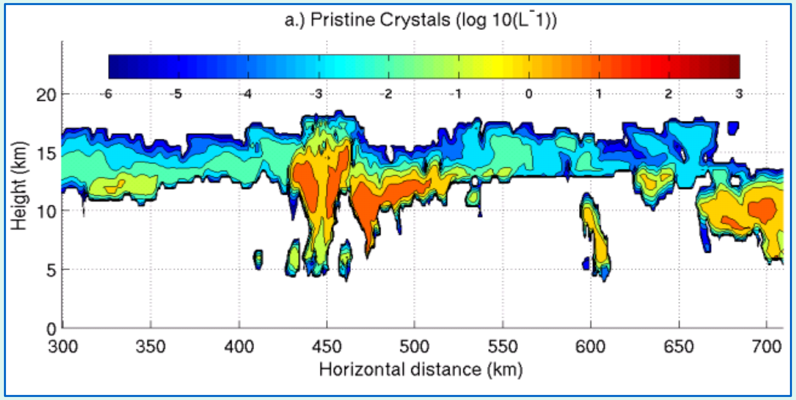
↕

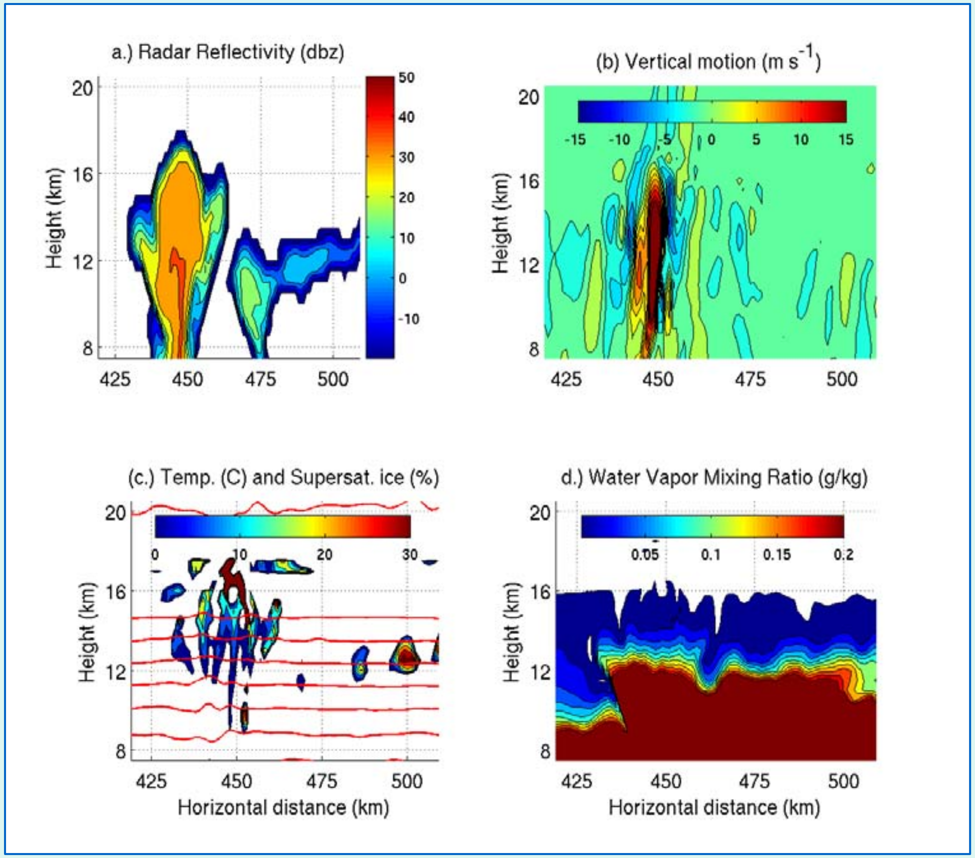
Bin model
Bulk micro. par.

Convective Case #1

- Rigorous Convective Updraft (developing stage)
- Overshooting top

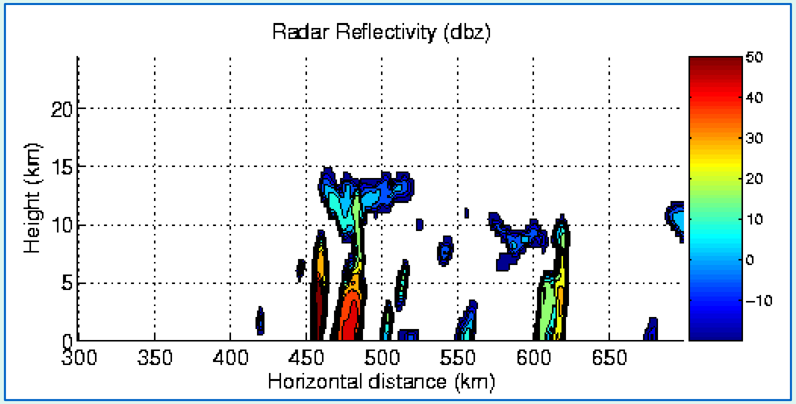


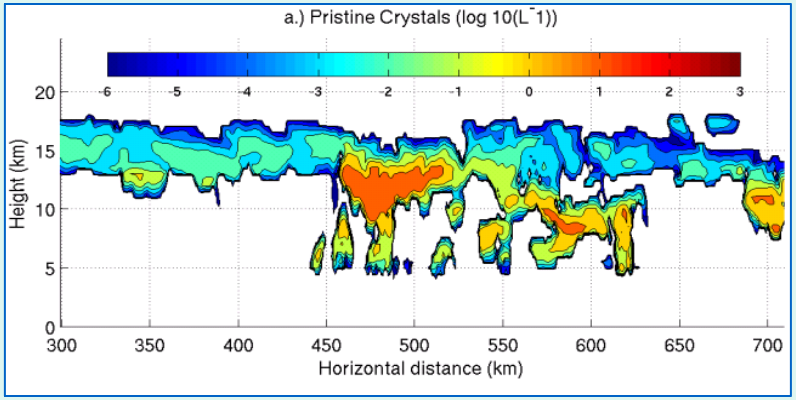


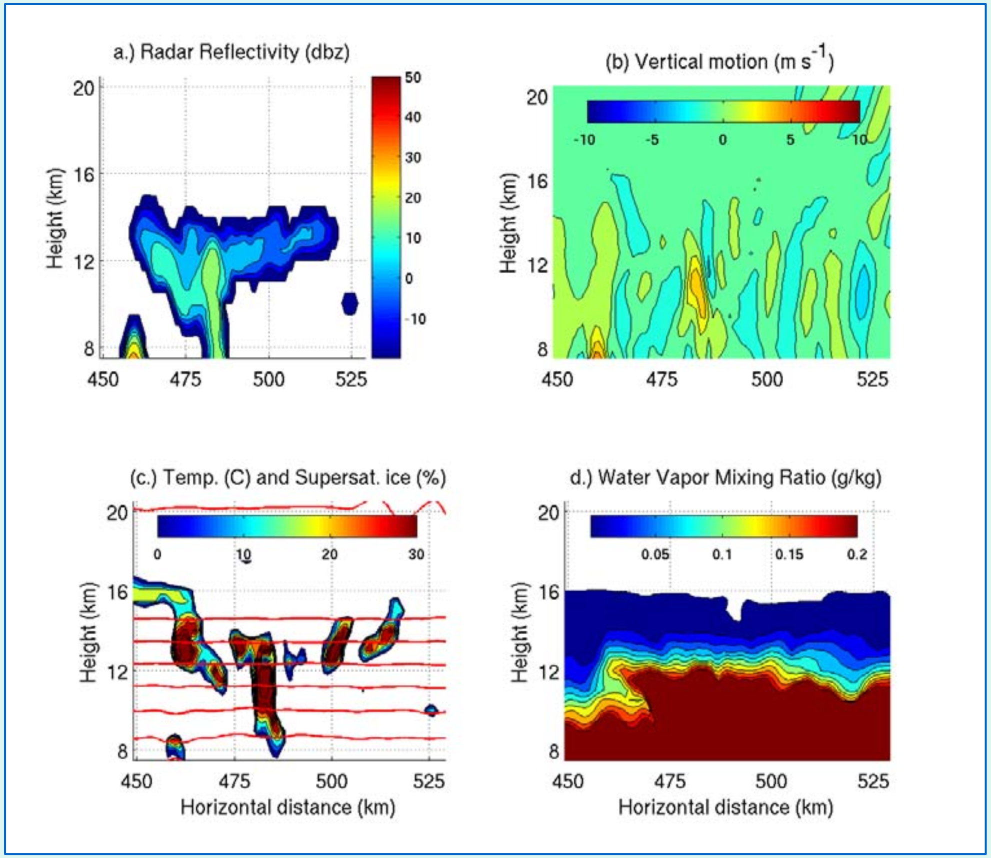


Convective Case #2

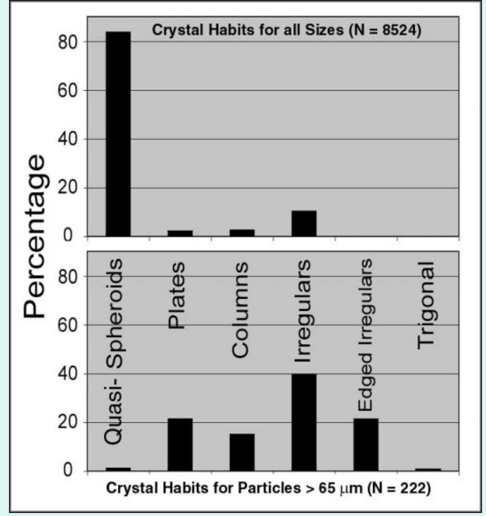
- Typical Convective tower (mature stage)
- Developed convective anvil







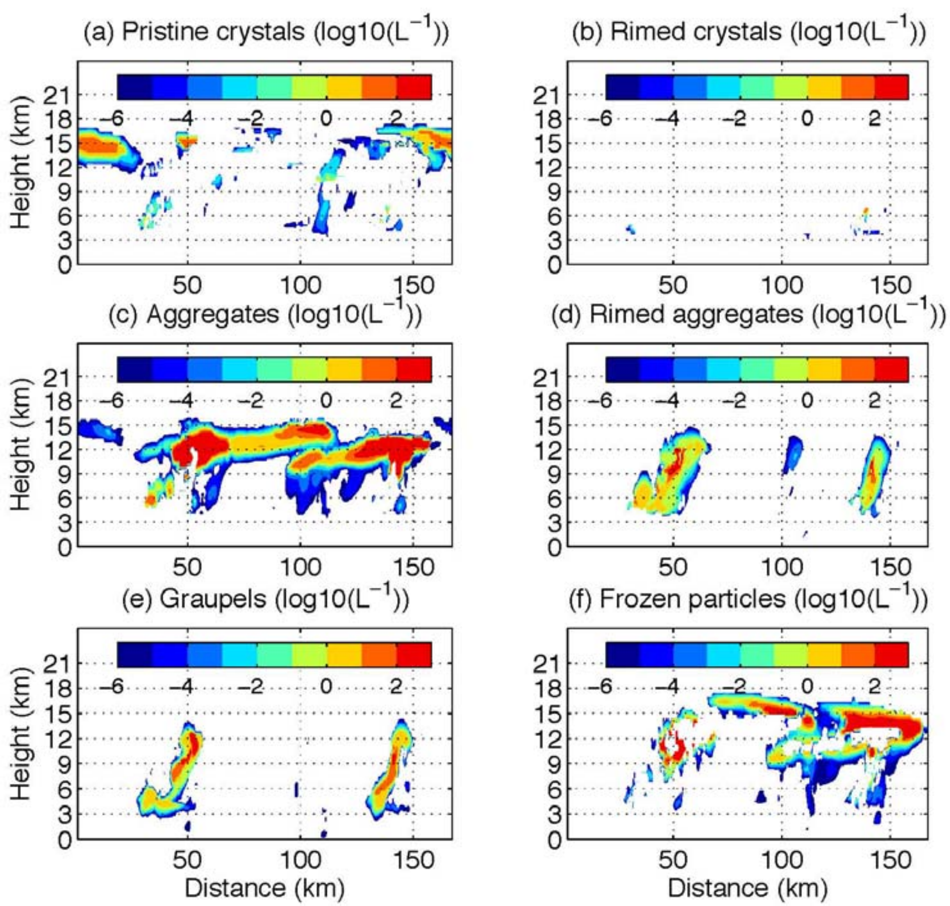
Predicted particle type and crystal habit for KWAJEX

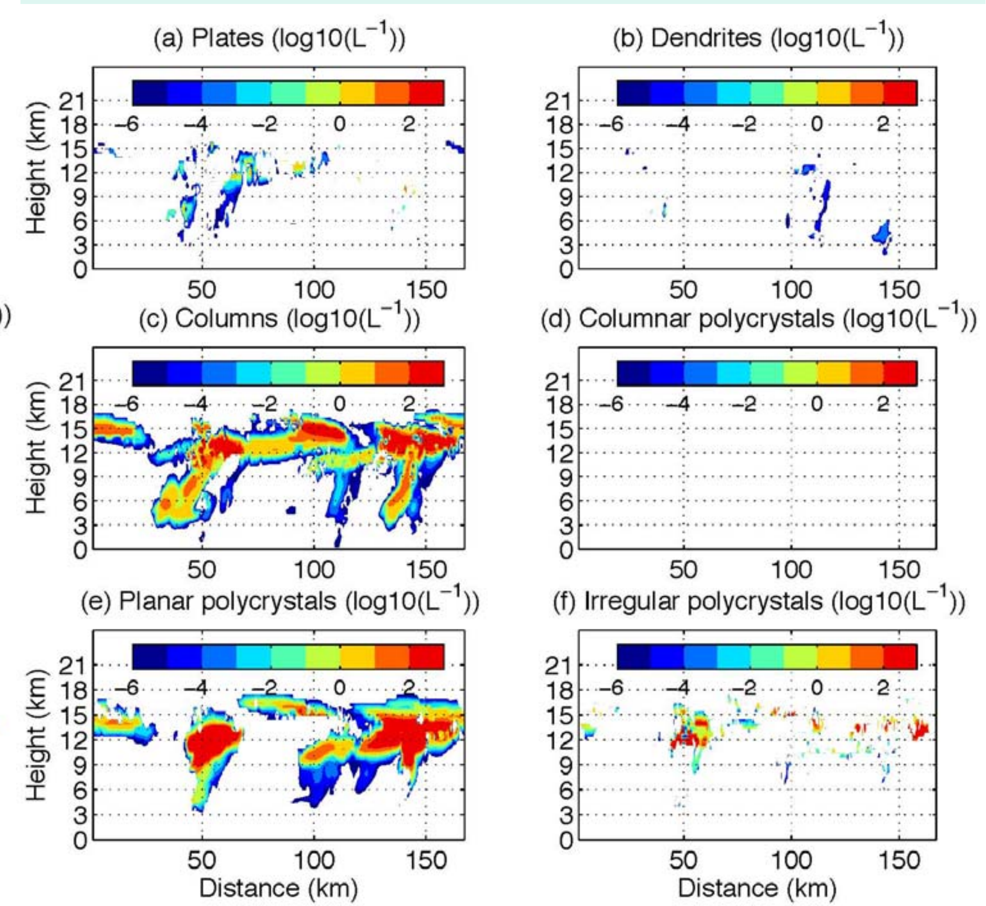


CPI observation during CR-AVE for subvisible cirrus (Lawson et al., 2008)

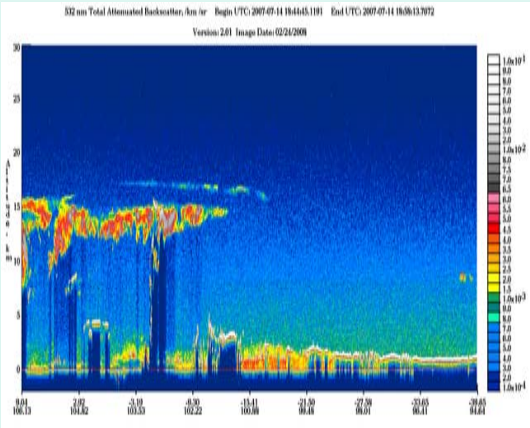
Type

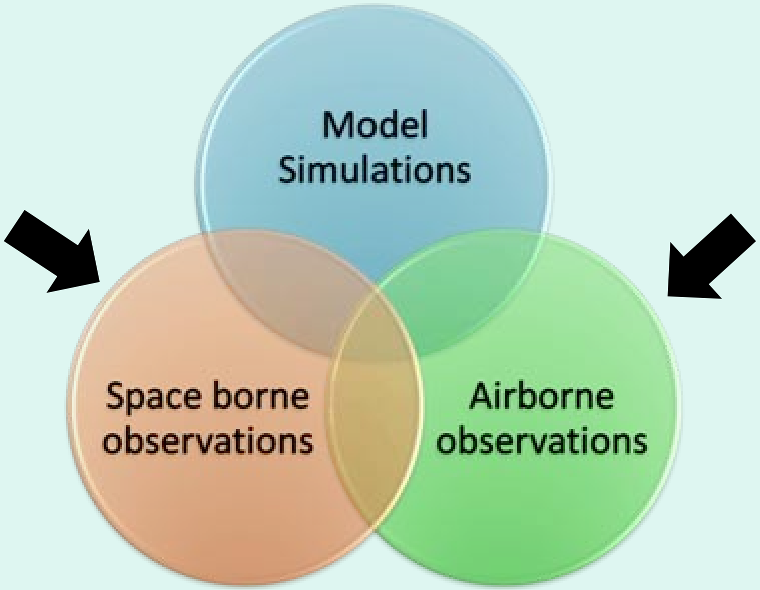
Habit

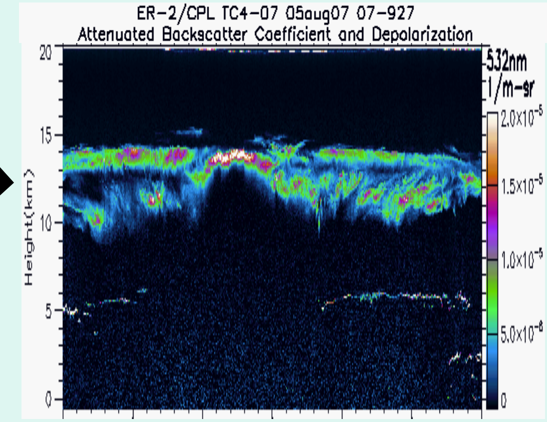




UTILIZING DIFFERENT OBSERVATIONS







We will be comparing the ice nucleation and aerosol properties simulated at the tropopause by NMS/AMPS model to the CloudSat and Calipso observations during the TC4 campaign as well as the in-situ and remote sensed ER-2, WB-57, and DC-8 aircraft observations.

- Information: layer optical thickness, number concentration,
- Vertical distribution particle size and aerosols, etc.
- Recognition of the limitations associated with the data sets

ONGOING WORK...

- Full simulation of the TTL using the NMS-AMPS system and TC4 observational data
- High-resolution simulation of local cloud processes for case study dates to determine cirrus cloud development, maintenance, and dissipation dynamics.
- Aerosol studies to determine the role of sulfates on ice crystals in the TTL
- Validation of high-resolution simulations through collected data.

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QUESTIONS…?

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