A Cloud-Precipitation Mission Concept for Studying Cloud and Precipitation Processes with Application to Climate Models

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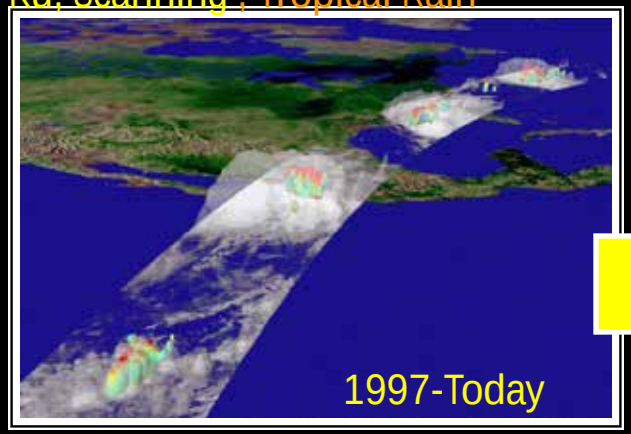
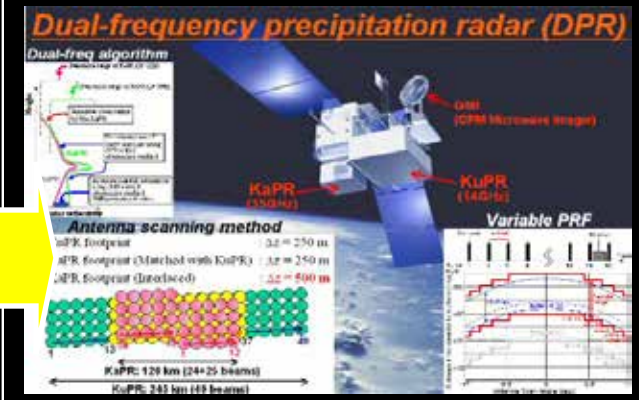
TRMM to Cloud+Precipitation Mission

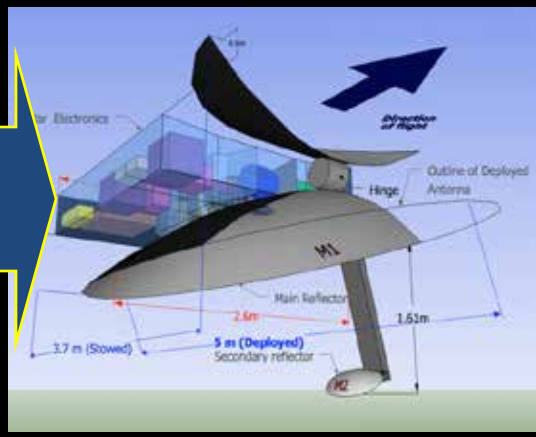
TRMM/PR – NICT/JAXA
Ku, Scanning , Tropical Rain



GPM/DPR – NICT/JAXA
Ku/Ka, Scanning, Precipitation

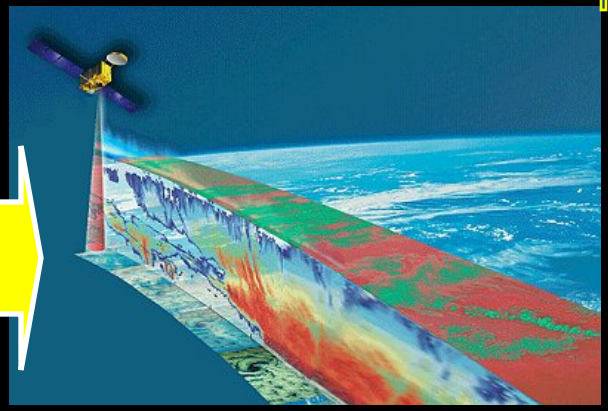


ACE Radar
W/Ka, Scanning,
Doppler

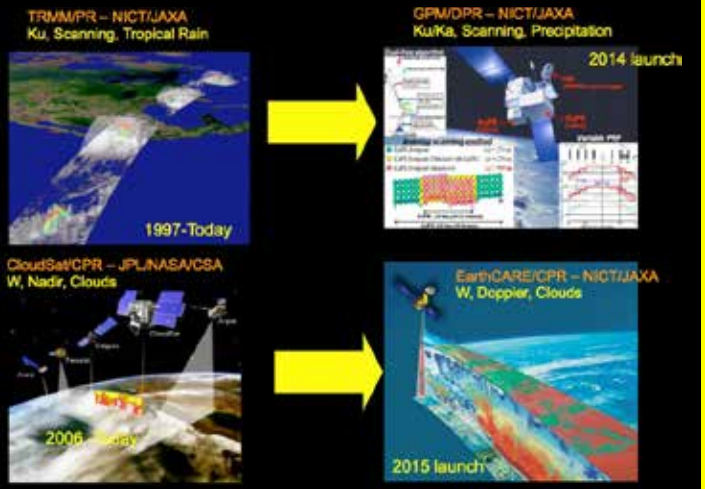


CloudSat/CPR – JPL/NASA
W, -30dBZ , Clouds

EarthCARE/CPR – NICT/JAXA
W, Doppler, Clouds

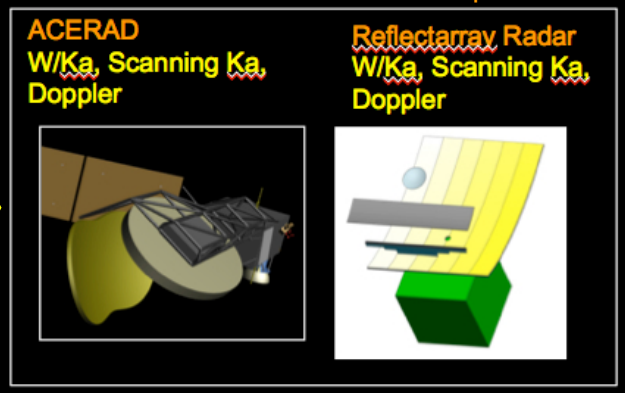


Visions Beyond GPM & EarthCARE Radars

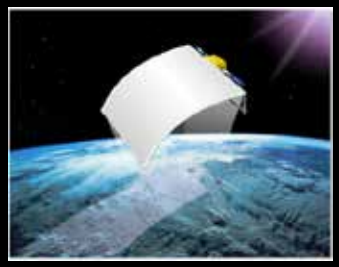


Examples of radar concepts under study by the international community

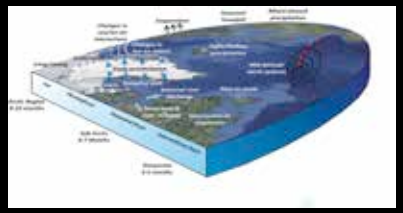
For US Decadal ACE meas. concept



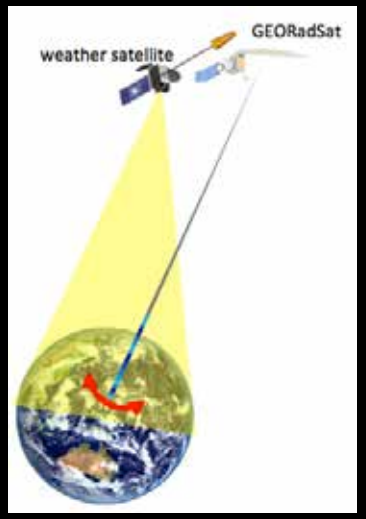
GPCM Radar Ku/Ka/W, Doppler, Scanning



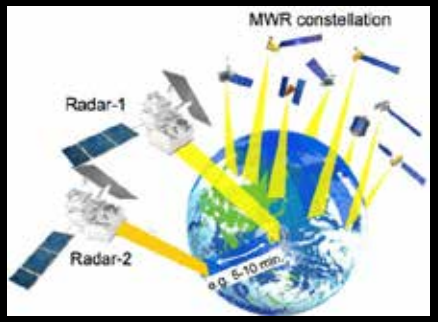
SnowSat / PPM
W/Ka, Doppler



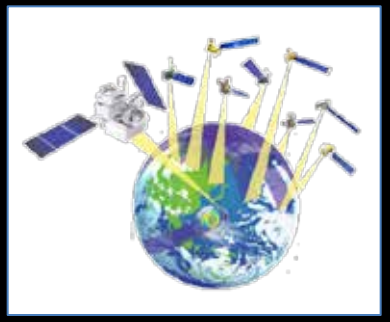
GEORadSat
W, Scanning, Doppler, GEO



GPM w/ Radar in Train Formation
Radar 1 & 2: Ku/Ka/W, Scanning



RadarGPM Constellation
Core S/C: Ku/Ka/W, Scanning
SmallSat: One freq radar

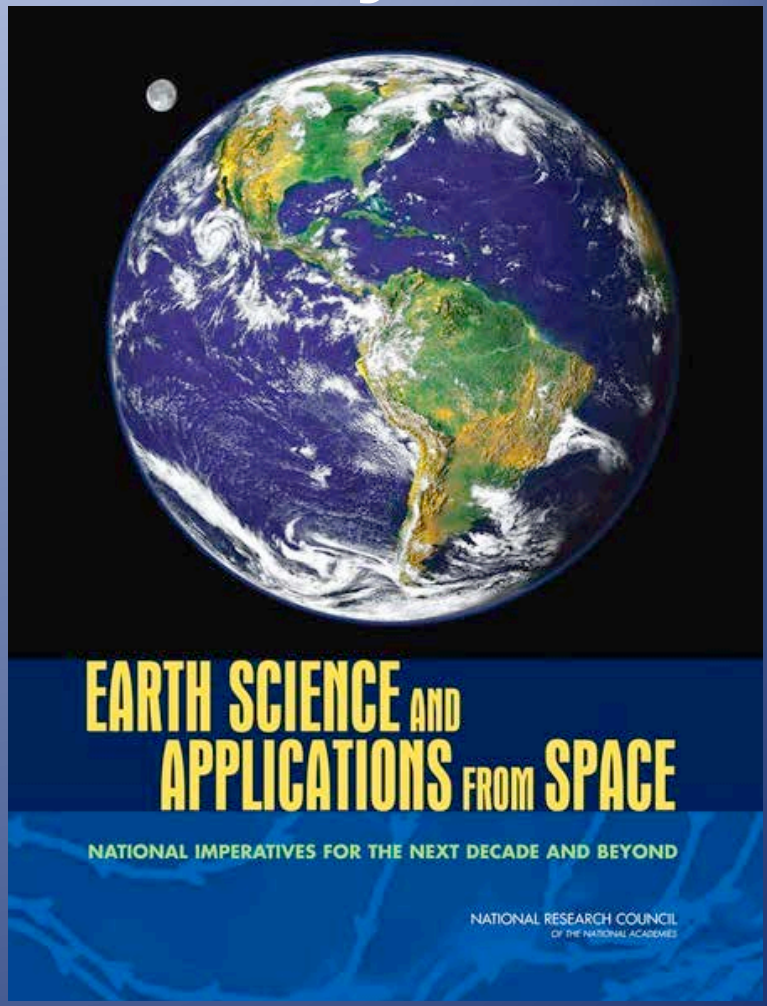


NEXRAD-In-Space
W/Ka, Scanning, Doppler, GEO

Courtesy Eastwood Im

NASA Decadal Survey

- **Decadal Survey:** NASA's Science Mission Directorate engages the science community to identify and prioritize leading-edge scientific questions and the observations required to answer them is through National Research Council (NRC) surveys.
- Previous Earth Science Decadal Survey published in 2007
- Decadal Survey inputs are expected to be requested in 2015



National Research Council. *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*. Washington, DC: The National Academies Press, 2007.

Overarching Question

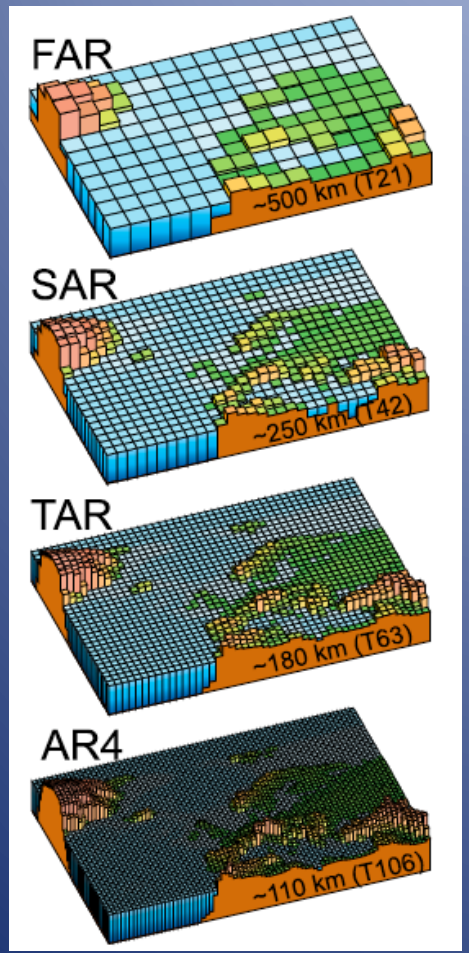
Cloud and Precipitation Processes Mission (CaPPM)

- Science Question: To what extent is *the character of precipitation* and variability of precipitation determined by the large scale controls exerted by the Earth's general circulation versus the cloud scale processes?

  - Which cloud processes lead to the onset of precipitation?
  - Which cloud processes lead to extremes in precipitation?

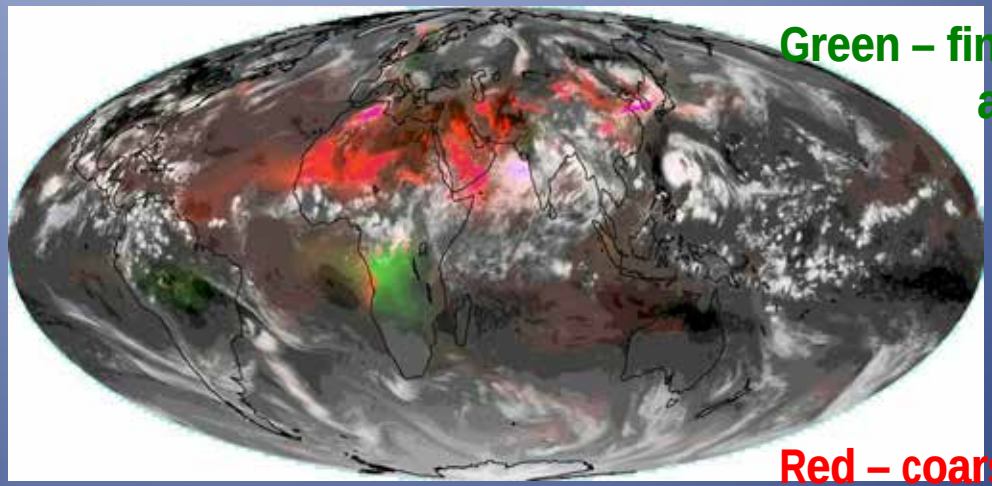
Model resolution, like entropy (and taxes) increases with time

I) Climate/earth system models



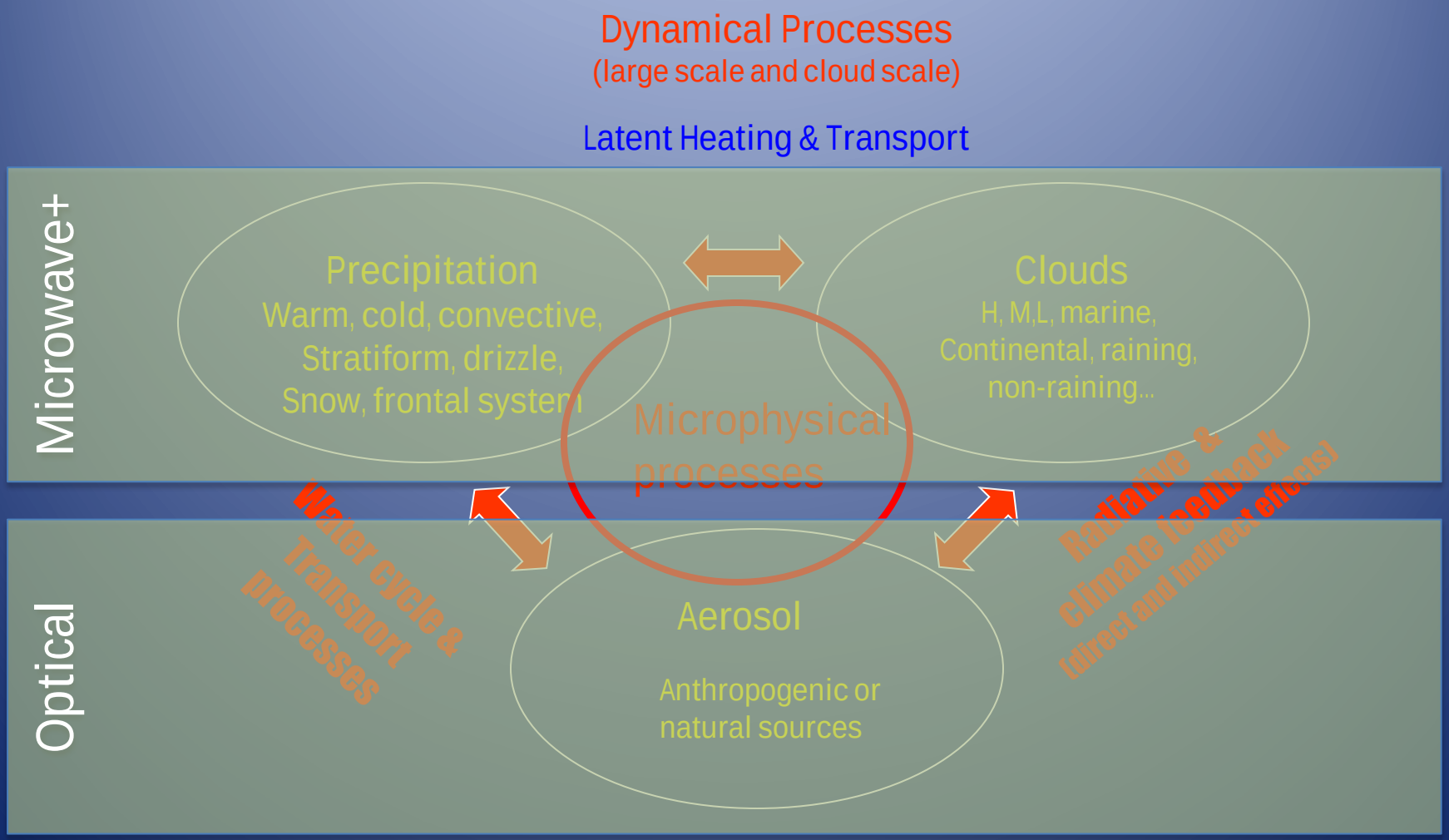
ii) TODAY Operational weather models, global 15km, regional @ 4km (and even 1 km)

iii) TODAY, Global Cloud resolving model @3.5km



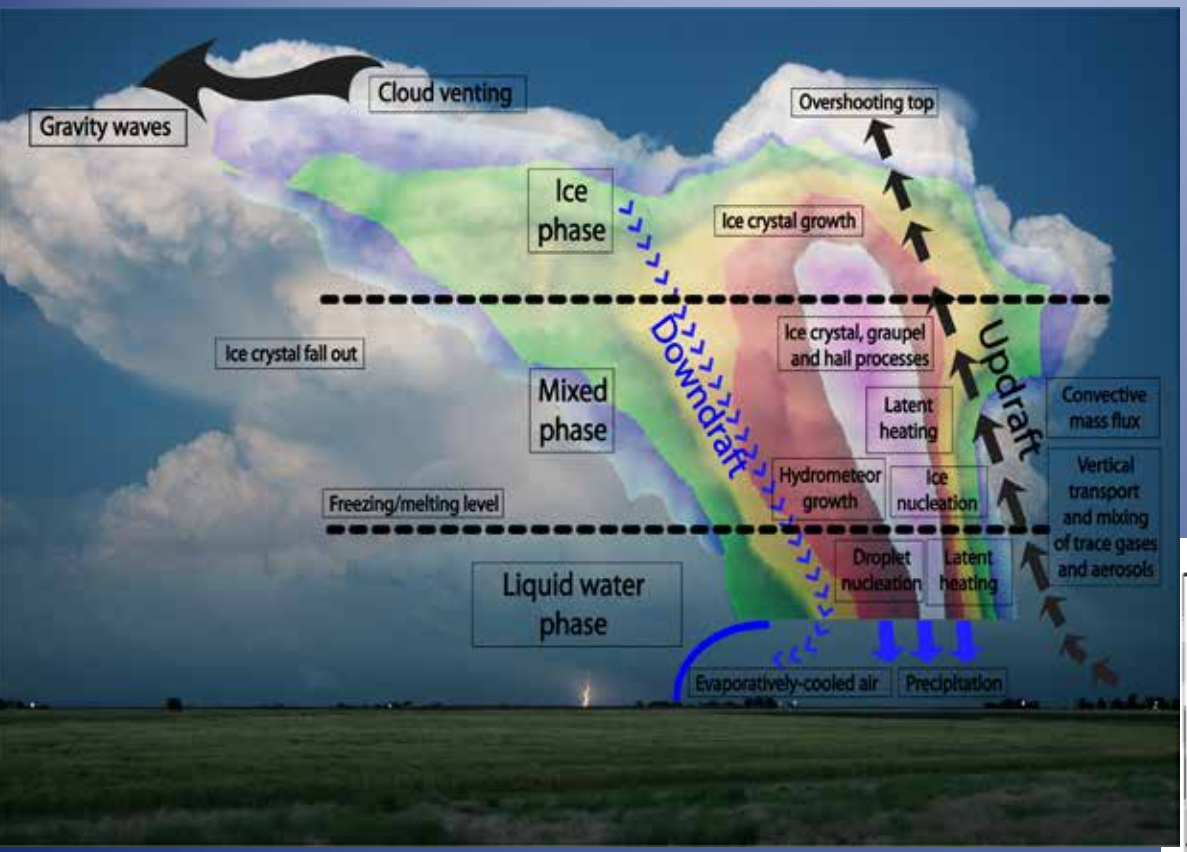
As we go down in scale, the *processes* (e.g., microphysics) increasingly become the weak link- i.e., unresolved and 'approximated' by parameterization –> better observations will be increasingly important

An Integrated Approach to Atmospheric Energy, Water Cycle Processes and Climate Change

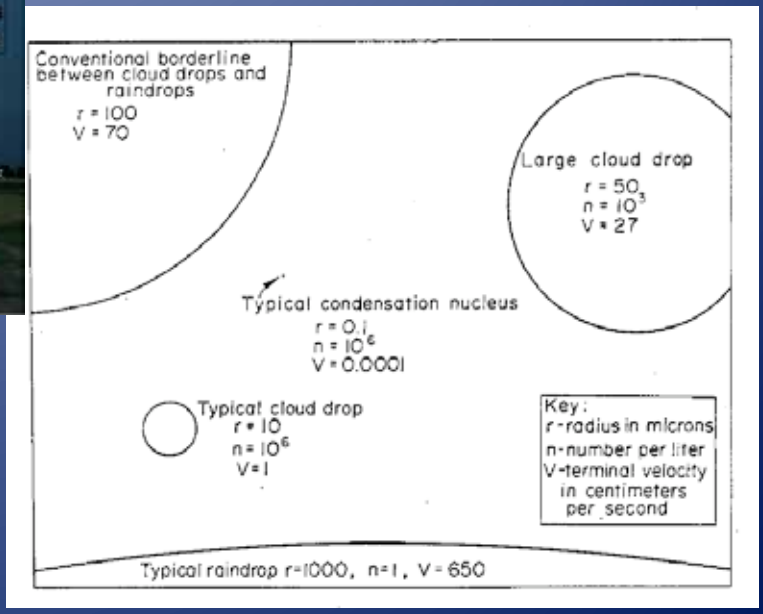


Cloud and Precipitation Processes

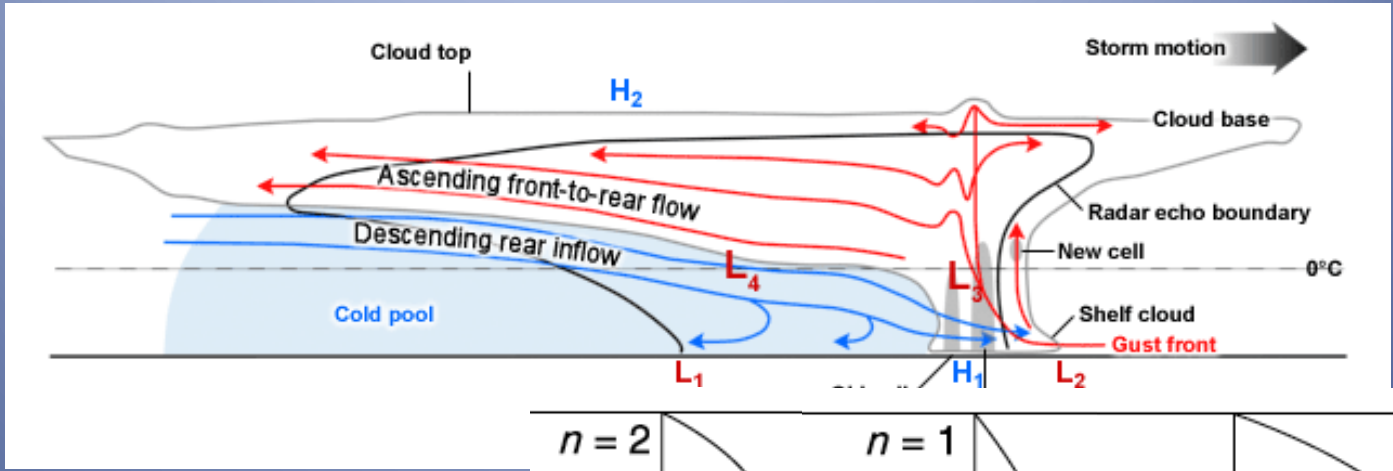
Convection

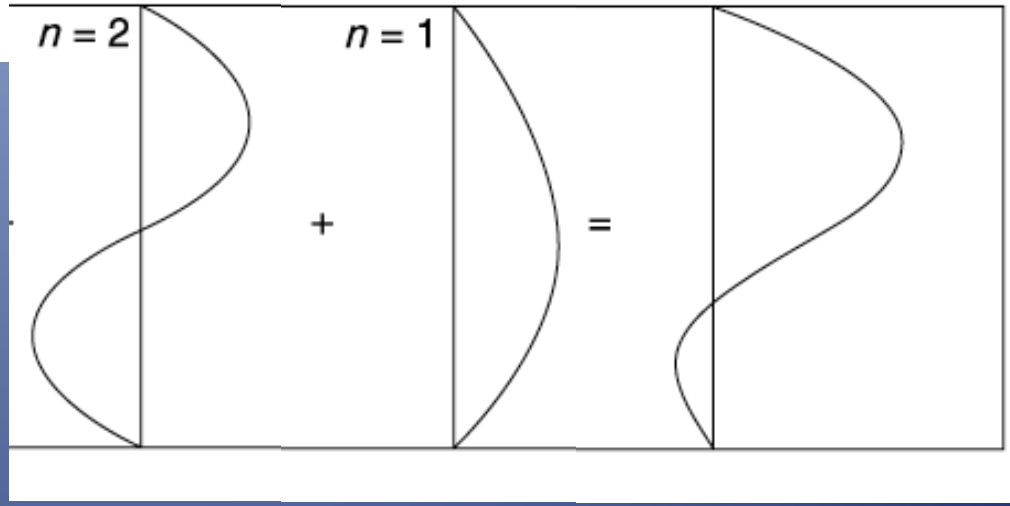


Microphysics



Vertical Velocity => Latent Heating



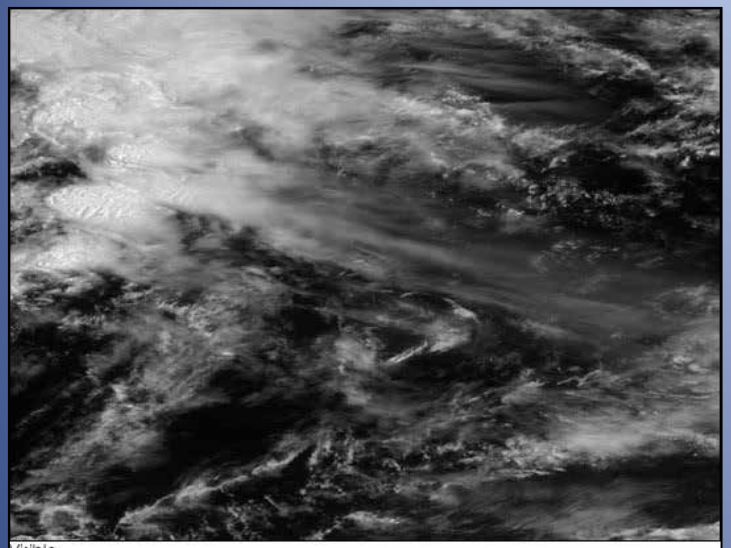


- Substantial contributions to vertical heating profiles
- Feedbacks to storm organization and intensity
- Current latent heating satellite products rely on CRM-based estimates of vertical velocity

Stratiform (~0.5m/sec) Convective (>2 m/sec) Mature MCS

The flow regimes in a typical squall line system (Houze et al 1989) and the latent heating profiles associated with the convective and stratiform regions (after Nicholls et al 1991).

Vertical Velocity => Venting



- Cloud venting / convective mass flux - the process of transporting heat, moisture, momentum, trace gases and aerosols from the lower troposphere into the middle and upper troposphere
- Varies as a function of storm type and updraft strength
- Model results suggest venting of entire boundary layer (BL) about 90 times per year due to convective storms
- No global estimates of venting

Top: In the GOES image thin cirrus clouds are streaming (from left to right) off the convective cores of a line of thunderstorms demonstrating the vertical and horizontal transport and redistribution of water by organized storms. Bottom: Dust being lofted and transported by the outflow boundary of a mesoscale convective system.

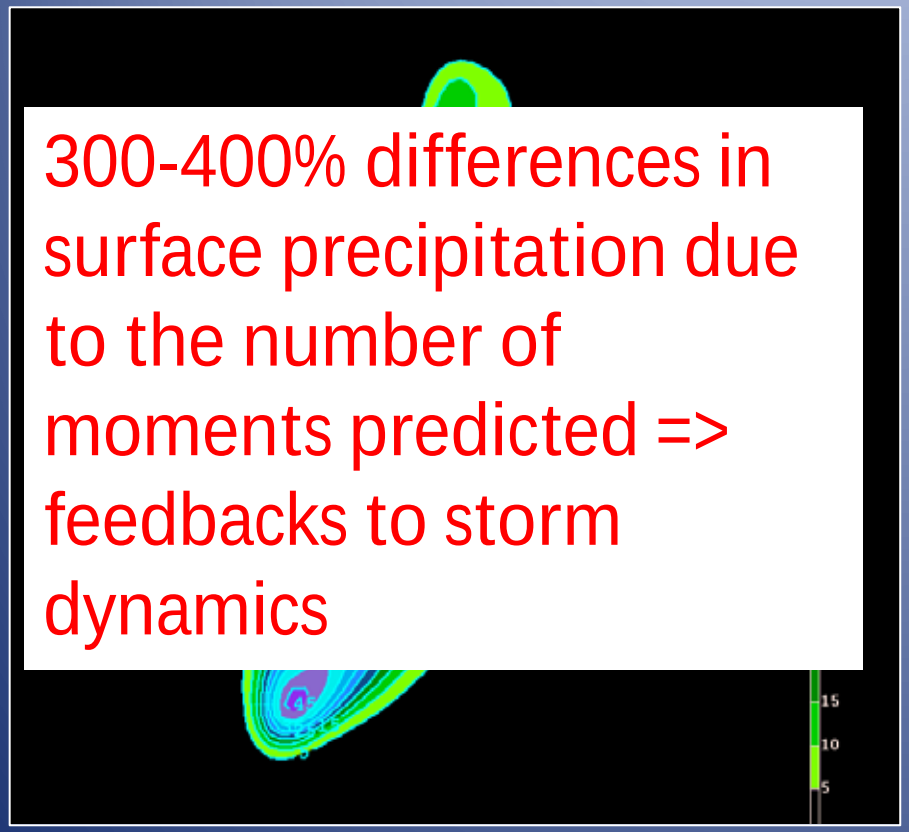
Ice Processes

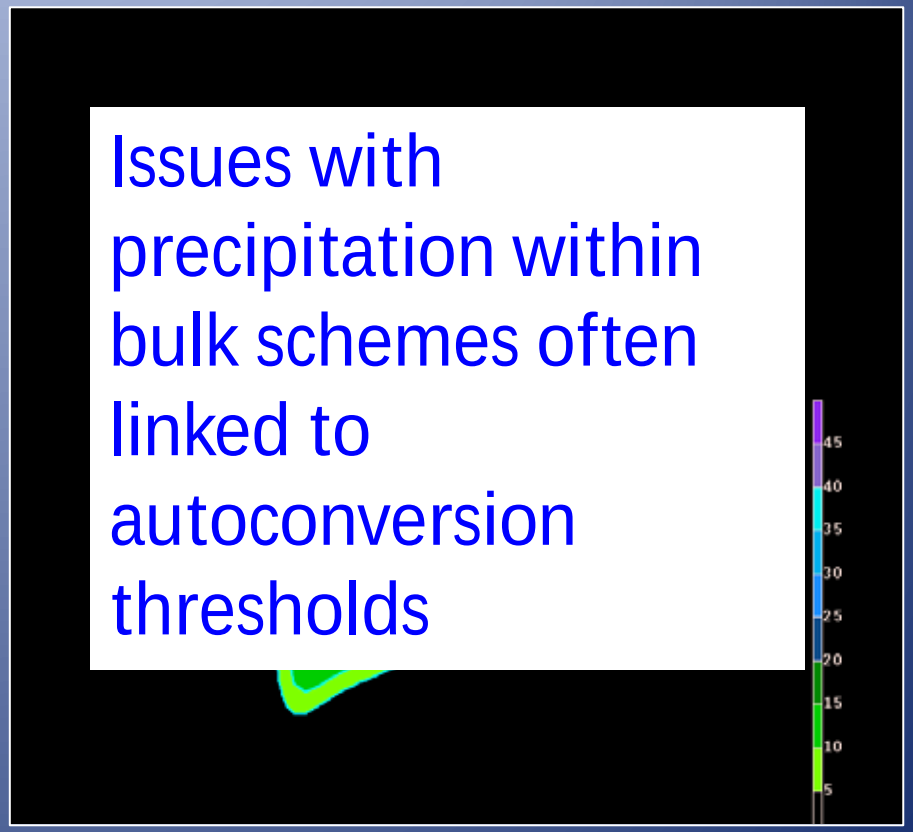
- Arguably the most challenging problem in developing microphysical parameterizations right now => hence one of the most challening CRM problems
- Reasons:
  - Many different pathways to ice formation
  - Crystal habits
  - Secondary ice production
  - Difficult to observe from ground and space-borne platforms
- Can't accurately parameterize what we don't understand from a basic point of view

Precipitation Processes

1-moment Simulation

2-moment Simulation





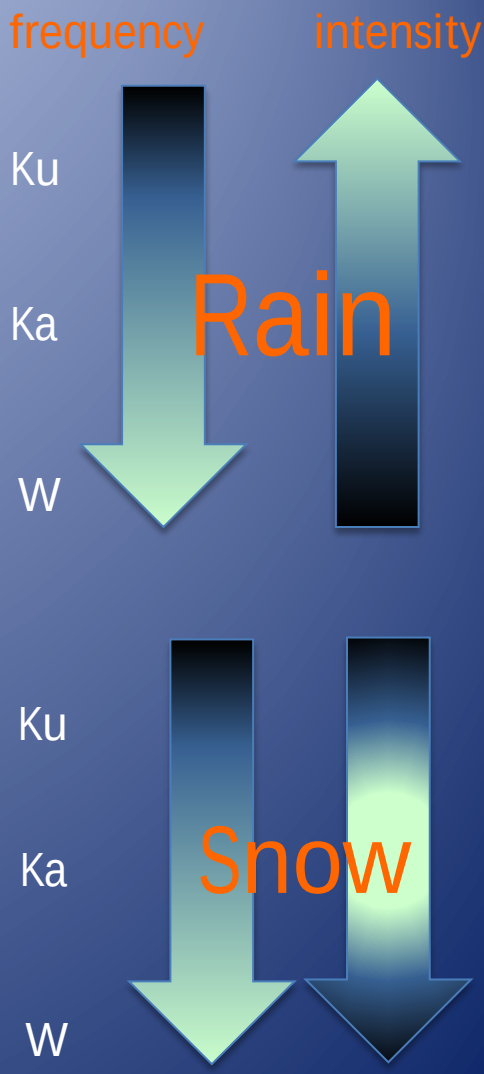
Accumulated surface precipitation produced by a supercell for (left) single-moment and (right) two-moment simulations (image provided by Steve Saleeby).

Precipitation Characteristics: Frequency AND Intensity

accumulation over Δt = Σ freq of occurrence X intensity when raining

Wish list: 3 frequency system

- Ku - heavy rain
- Ka – heavy-to light rain/snow/cloud
- W – light/rain/drizzle/snow cloud



Measurement Recommendations (Dream Scenario/Unlikely to have all these capabilities)

This mission should build upon enhanced radar capabilities (to gain better physical insights) together with complementary passive instrumentation (for spatial coverage):

- A baseline radar system would comprise a triple-frequency system centered upon scanning Ku, Ka and W-band (13, 35 and 94 GHz) radars, with Doppler capability at all frequencies. To retrieve light, shallow precipitation the radar system would need a high-sensitivity, fine range resolution capability
- For extended spatial coverage, a multi-channel, wide frequency range microwave radiometer will provide information from surface characteristics to thin cirrus clouds. Frequencies of interest include: 10-89, 50-60, 118, 183-640 GHz, with V and H polarizations as appropriate.
- A multi-channel visible/infrared radiometer would provide additional complementary information on atmospheric and cloud-top properties.

Conclusions/Summary

- CaPPM team continues to refine concept
- Ongoing meetings & teleconferences & discussions with potential partners
- Modeling studies to constrain measurement needs being conducted by Tao, van den Heever, and L'Ecuyer to help develop a science traceability matrix
- Short white paper in development
- We soon expect to receive refinement on the required decadal survey inputs (mission concepts?, science questions? measurement needs? Other?)
- Avoiding instrument selection(s), spacecraft(s), orbit etc. until we know more detail from the NASA Decadal Survey or NASA Earth Venture Opportunities.

- QUESTIONS?