# Process-oriented Analyses

Combined used of obs.
and theoretical formulation

Lagrangian Approach

Budget analysis of MSE and CWV

□Definition of regimes in lifecycle

**Hiro Masunaga**

Eulerian Approach

$T_{cloud,top}$ and CAPE □ Entrainment Rate

**Graeme Stephens (Hanii Takahashi)**

Combined used of obs.
and LES/Idealized Models

Lagrangian Approach

Tendency from geostationary satellite

□Pathways in geophysical parameter space

**Tak Yamaguchi**

Tracking thermals

**Toshi Matsui, Tak Iguchi**

Eulerian Approach

CFAD of $Z_H$, $V_D$ □aggregation/riming signals

**Woosub Roh**

**Test bed, constraint**

**Subgrid inhomogeneity (liq/ice phase)**

**Test bed, constraint**

Science Target (expectation) of EarthCARE:

**Weak rain, Snow falling, and Phase partitioning in clouds**

with doppler velocity/radar/lidar, higher sensitivity, smaller FOV, and less ground clutter

**Tristan L'Ecuyer, Trude Storelvmo, Takashi Nagao(P13), Kenta Suzuki (P17)**

**Ann Fridlind (+Day1 talks)**

Supports from field campaigns
@ various regions/seasons/regimes
by WCRP/NASA/ESA/DLR/JAXA

**Research(advanced) products**
**□ How and where can we share such non-standard products?**

# Memory Refresher Slides

# The Energetics in the Lagrangian Evolution of Tropical Convective Systems

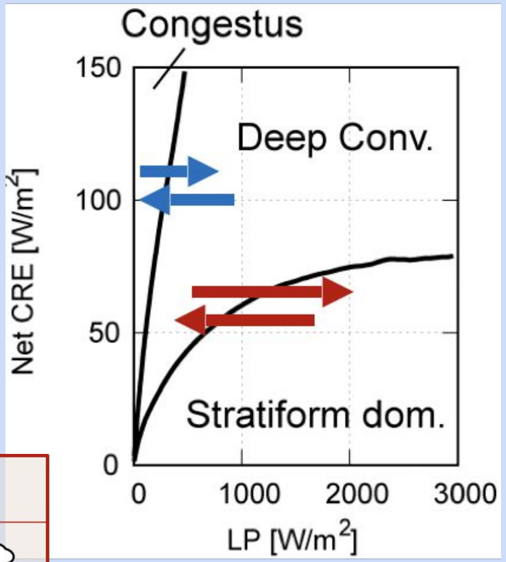
*Hiro Masunaga (Nagoya University)*

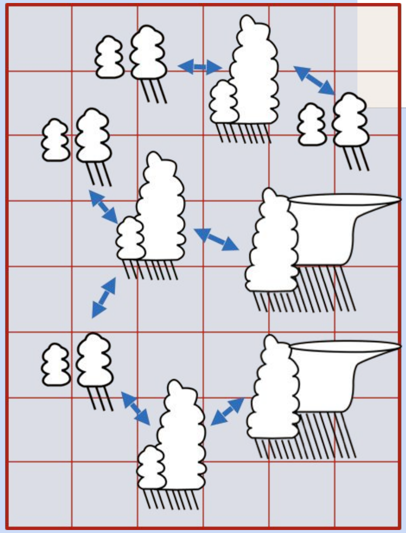
Lagrangian analysis of cloud lifecycles using ERA5 reanalysis, IMERG and CERES data

Analysis of the Moist Static Energy (MSE) combined with the Column Water Vapor (CWV) defines where different cloud types exist in CRE - LP parameter space.

Trajectory of rainfall systems through same CRE - LP parameter space determined (also exclusively for systems of extreme precipitation).

From Lagrangian viewpoint, rainfall systems do not follow monotonic path through parameter space, rather exist in dynamic equilibrium between different cloud types



# Process Level Understanding Gained with Geophysical Variable Maps

*Tak Yamaguchi (NOAA)*

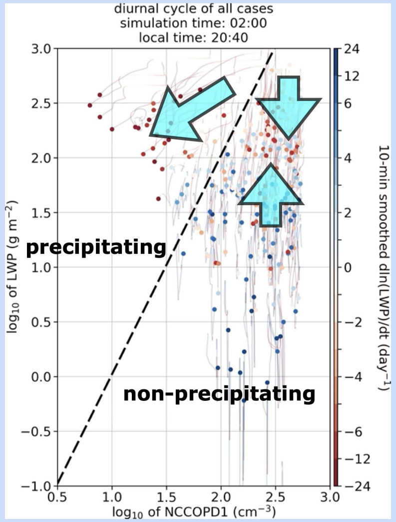
Lagrangian tracking by geostationary satellite can provide an explanation of the distinct modes in geophysical parameter spaces.

Our task is decoding the parameter space in combination with ensemble of LES simulations or idealized models.

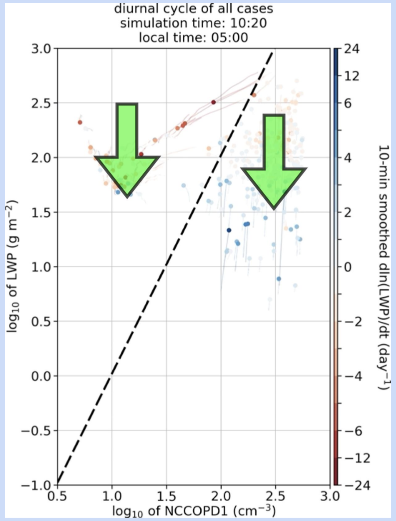
Atmospheric systems may have preferred states in parameter space. Finding these through models and/or observations can enhance process understanding:

- Example 1) Progression of atmospheric states in LWP-Nd parameter space

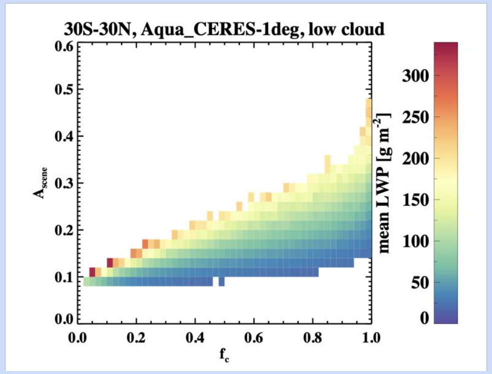
- Example 2) Progression of atmospheric states in albedo - cloud fraction (A-Fc) space.

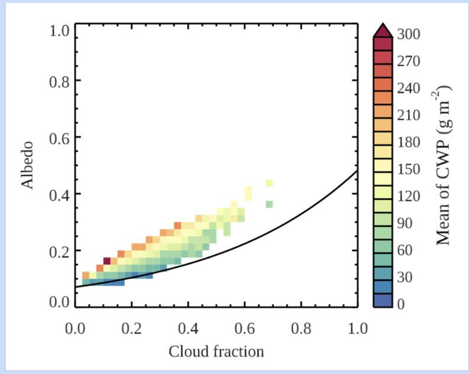


Nightime



After Sunrise

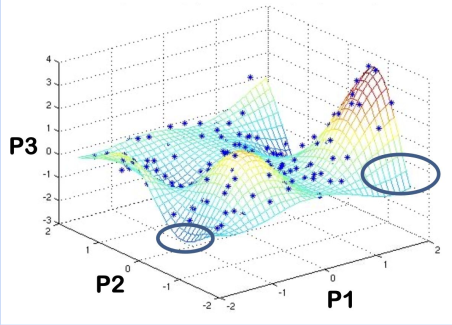


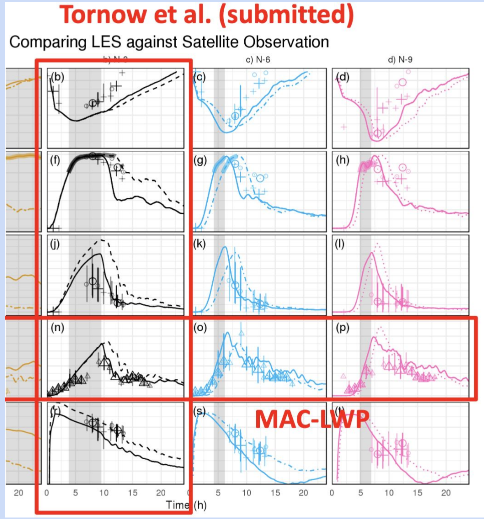



# A Proposal for Regime-Based LES-GCRM-ESM-observation-forward Simulation Closure Studies

*Ann Fridlind (NASA GISS)*

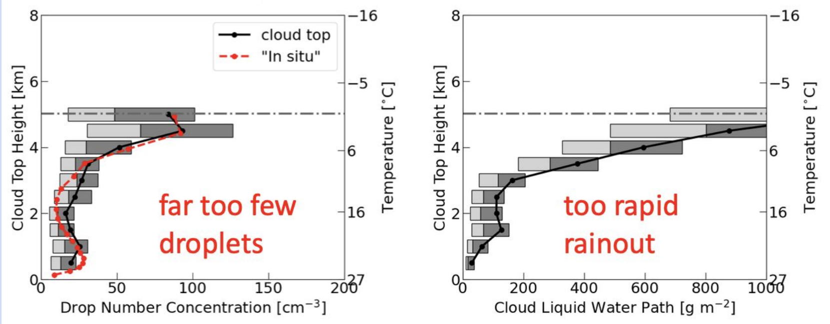
A) Multitude of field studies, each focussing on different atmospheric conditions.
B) Multitude of LES/SCM with different parameter values lying within (satellite data) uncertainty ranges. LES/SCM + Neural network therefore fill (highly dimensional) model parameter space




Comparison of (A) and (B) through closure calculations gives regime-based evaluation of models and observations as well as test bed for model development. (e.g. ACTIVATE LES case study)

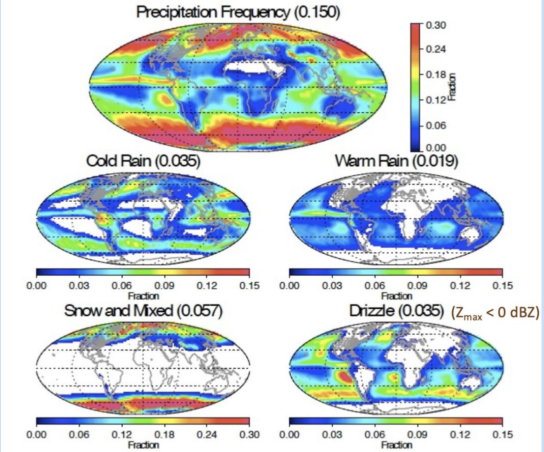
+ If ensemble of LES/SCM are representative of model uncertainty, then the degree to which individual observational data products are outlying could be quantified (e.g. CAMP2Ex tropical convection)
+ community results to explain needs for funding :)




How about compilation of research product?

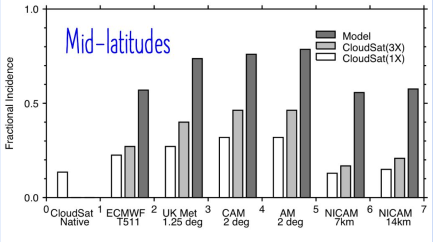
# EarthCARE's Potential for Constraining Models: Learning from the A-Train

*Tristan L'Ecuyer (Univ. Wisconsin)*

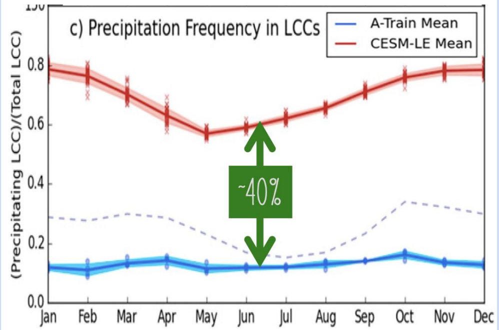



Like CloudSat (but better*) we can use EarthCARE to constrain model biases. Example: Precipitation Frequency Impacts Intensity Distribution

Surface return from W Band radar combined with reflectivity measurements can be used to determine global distribution of rain and snowfall. Gives new insights into e.g. "dreary mid-latitudes".




Comparison of hydrometeor distributions between EarthCARE and models used to eliminate / constrain model parameter possibilities




and can have wide reaching implications …
Example: too little Arctic snowfall from mixed phase clouds in models suggests need for adjustment to snow formation in cloud microphysics parameterization

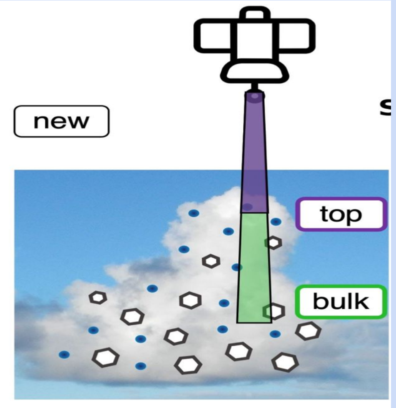
Will start to have climatological record too!

*better because EarthCARE is expected to more accurately detect precipitation with more sensitivity/smaller FOV/less ground clutter. (Could even detect drizzle and light rain from shallow clouds!)

# Constraining climate models with active remote sensing from Space

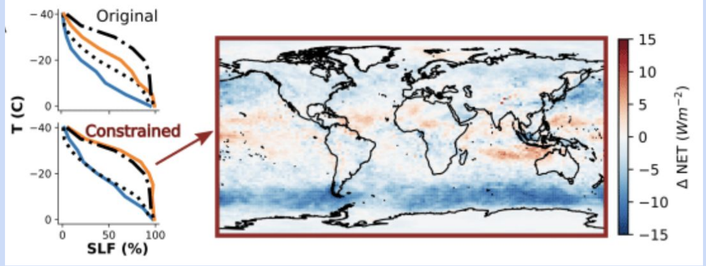
*Trude Storelvmo (Univ. Oslo)*

Focus on change in radiative effect due to changes in cloud phase / optical thickness in ubiquitous mixed phase clouds (0~-40degC).




Active remote sensing to measure sub-grid scale heterogeneity (due to pocket-like separation and due to vertical differentiation of ice and water phases):

- Measurements of pocket sizes confounded by lidar averaging (use data from Svalbard research flight instead)
- Temperature of cloud top water could be distinguished from cloud bulk/interior below.
  -> Also shows effect of areosol release due to biosphere awakening in northern hemisphere summer




Accounting for vertical heterogeneity by reducing ice to water conversion in model reduced TOA bias by increasing reflectivity, especially in southern ocean.

“Step Change” is new research project to investigate the potential tipping point when mixed phase clouds no longer have ice phase to convert to water (loss of strong negative feedback)

STEP CHANGE

(□ Research Products. ⬄ Nagao’s product)

# An Evaluation of Microphysics Schemes using a 94 GHz Doppler Radar

*Roh Woosub (AORI, The University of Tokyo)*

Doppler radar has 3 key benefits:

- not attenuated by rainfall
- measures radar reflected weighted fall velocity of hydrometeors
- measures vertical air motion

Demonstrated with heavy and weak precipitation case studies with observations and LES over over Tokyo area.

1 and 2 moment schemes show similar vertical velocity features

1 moment scheme underestimates graupel and hail, whereas 2 moment overestimates them but has more realistic snow growth. Differences attributed to different hydrometeor classification caused by different terminal velocity parameterisations.

Increased resolution shows moderate improvement in accuracy

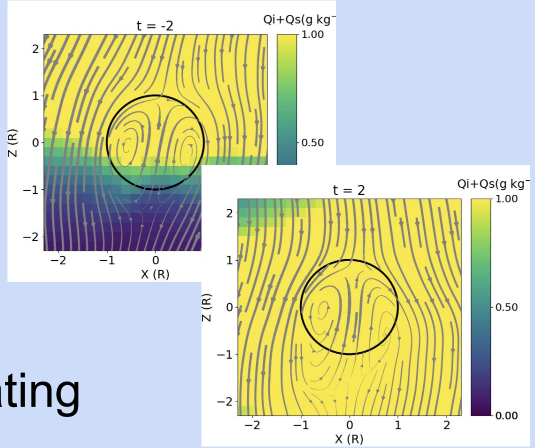
Doppler measurements show small fluctuations of vertical air motion which are attributed to roll convection in boundary layer

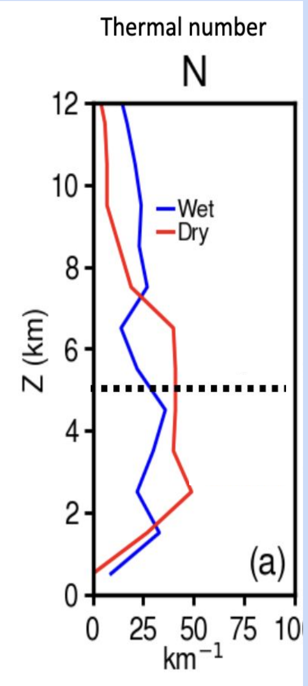
# Thermal-Tracking Analyses to Explain Graupel Generation by the GoAmazon LESs

*Toshihisa Matsui (NASA/Goddard)*

Thermals in wet and dry conditions have similar vertical velocity profile.
However compared to wet conditions, dry shows:

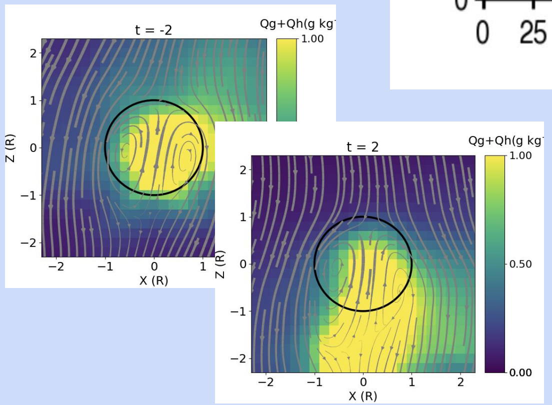
- higher supersaturation
- more condensed water
- ~x2 more thermals below 0degC isotherm at 7km
- shallower vertical advection
- ~x2  surface sensible heat flux




Thermals do not generate ice crystals, but rather entrains them by penetrating ice layers

During strong “droplet” thermal, mixed phase, thermals generate graupel and hail through riming between ice crystals and cloud droplets




Conclusion: Relative to the wet season, in the dry season low-level upward moisture advection initiates a larger number of thermals from lower levels, thereby loading more cloud droplets than wet season. This results in greater graupel and hail generation through interaction with ice layers

# Modeling Study of Life Cycles of Isolated Deep Convection during the TRACER Field Campaign

*Taka Iguchi (NASA/Goddard)*

Thermal identification and tracking used in TRACER golden case LES with 3 different levels of aerosol pollution (CCN concentration = [2300, 10000, 32000] $cm^{-3}$)

With higher CCN concentration…

- more cloud droplets are activated resulting in lower supersaturation but only a small effect on thermal buoyancy
- thermals are larger, with greater updraught strengths and longer lifetimes
- coalescence is suppressed resulting in fewer and smaller raindrops

LES with 10000$cm^{-3}$ CCN shows non-inductive charges in middle to bottom of thermal (related to mass-mixing-ratio of raindrops?)

Location of ice crystals is not strongly correlated with thermal centres suggesting thermals do not generate ice, but rather entrains ice from the surroundings