Anticipated new insights into warm clouds from the EarthCare mission

Graham Feingold[1]

Tak Yamaguchi[1,2], Franziska Glassmeier[3], Fabian Hoffmann[4], Tom Goren[5], Jan Kazil[1,2]

[1]NOAA Chemical Sciences Laboratory Boulder Colorado

[2]CIRES, U. of Colorado, Boulder

[3]TU Delft, Netherlands

[4]LMU, Munich, Germany

[5]U. of Leipzig, Germany

Leveraging EarthCare with other assets

EarthCare

Active and
Passive
Remote Sensing

PoR + Met

Geostationary (Geo)

Meteorological
Reanalysis

Analysis Tools

Multi-Dimensional
Geophysical Variable
'Maps'

Compositing

Simulators

Models

LES

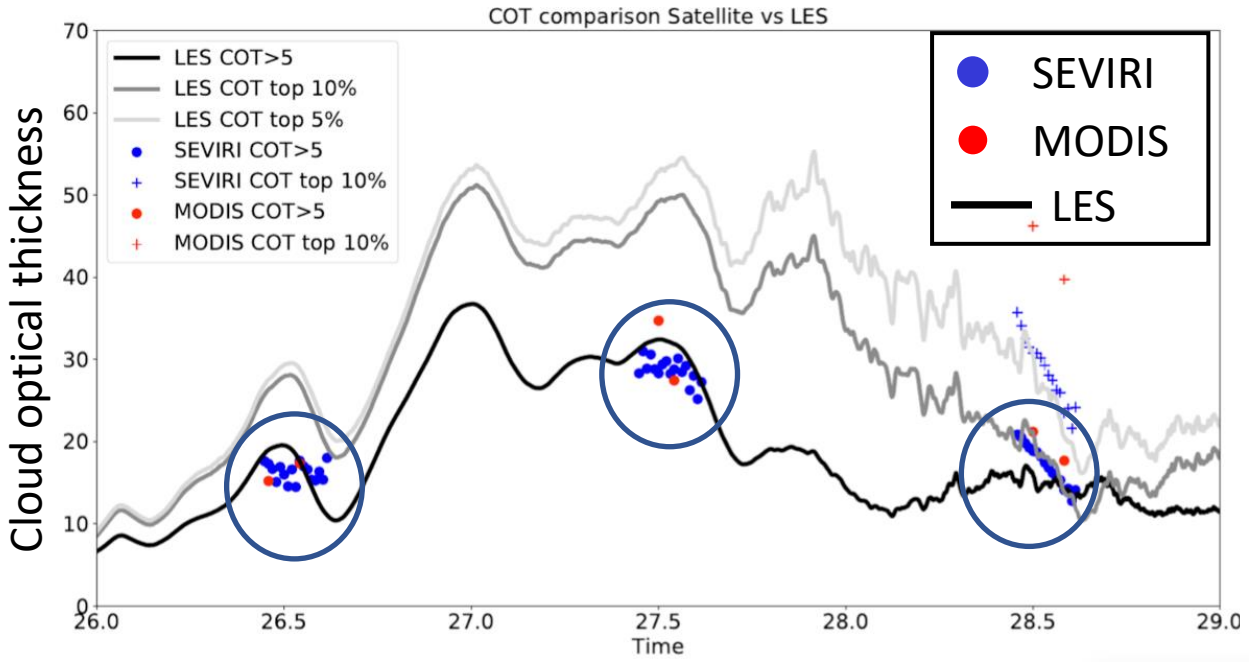
Global CRMs

GCMs

EarthCare + Geostationary:

Extending EarthCare's time resolution

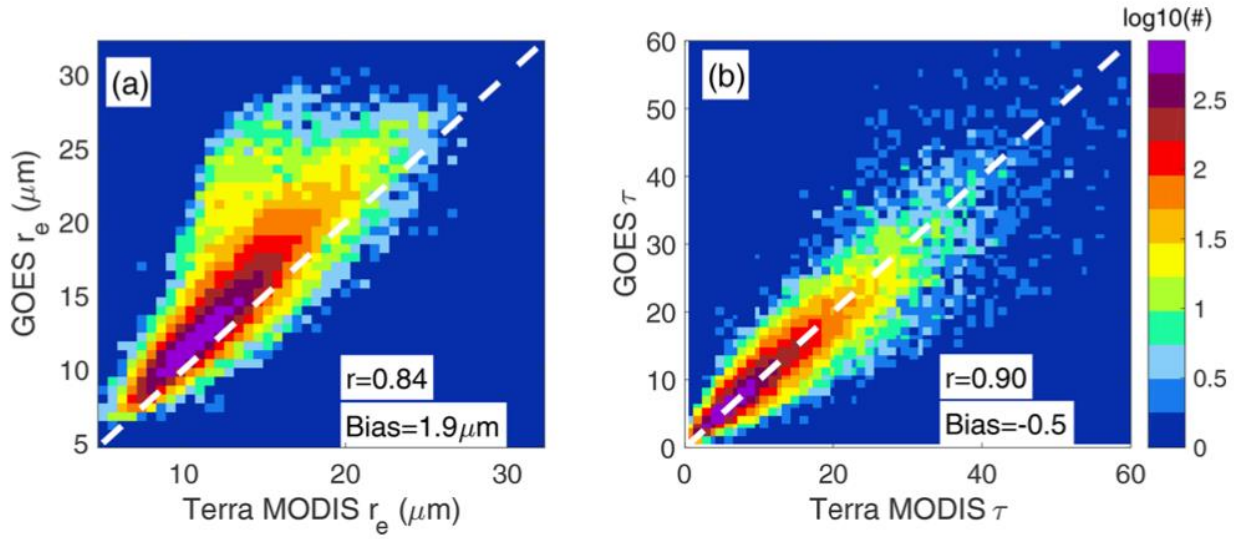
timeseries of cloud microphysical properties (daytime)



Goren et al. (2019)

GOES vs. MODIS

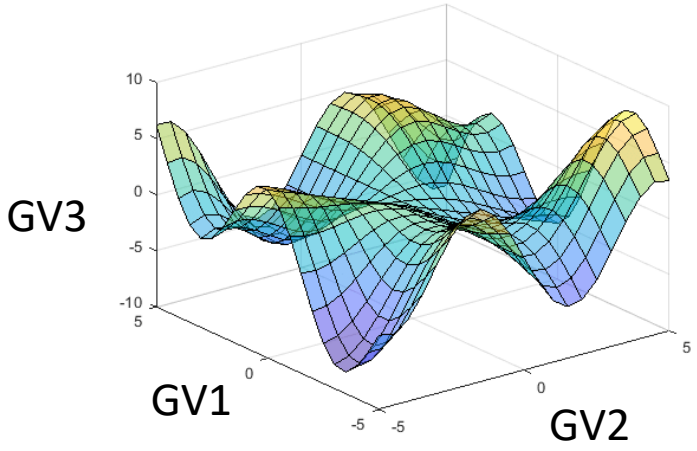
Issues: viewing angles, instrument differences, SZA, ...

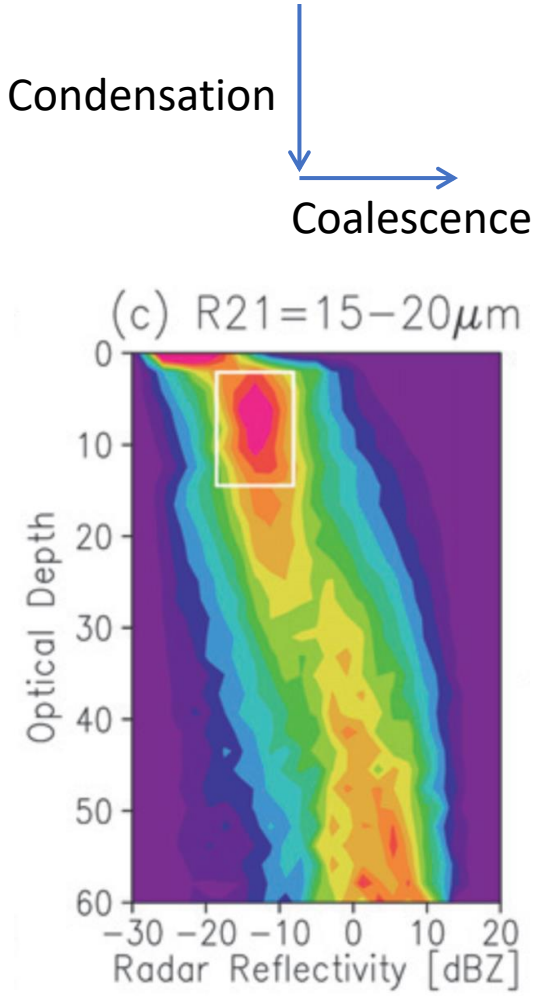


Painemal et al. (2021)

Evaluating Models:
Multi-Dimensional Geophysical Variable (GV) Retrievals

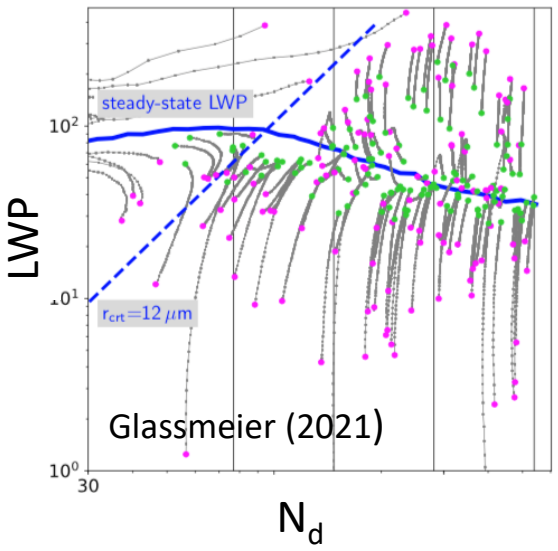
- Tells you *what* is there and *why*
  - *Process*
  - *Model Constraints*
- ECare variables
  - Albedo, τ_c, Z, N_d, CF, LWP, CRE, w, τ_a, extinction(z)
- *Thoughtful combinations of GVs, to constrain various aspects of models*
  - *Simulators*
  - *Attention to aggregation scale*
- Meteorology (ERA5 or similar)



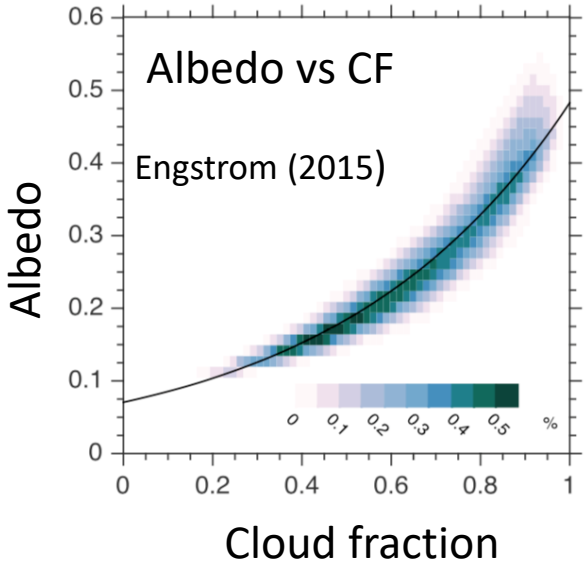


Suzuki et al. 2010

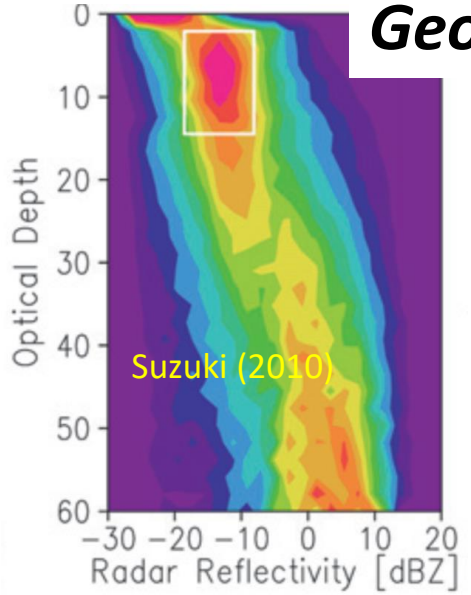
Microphysics

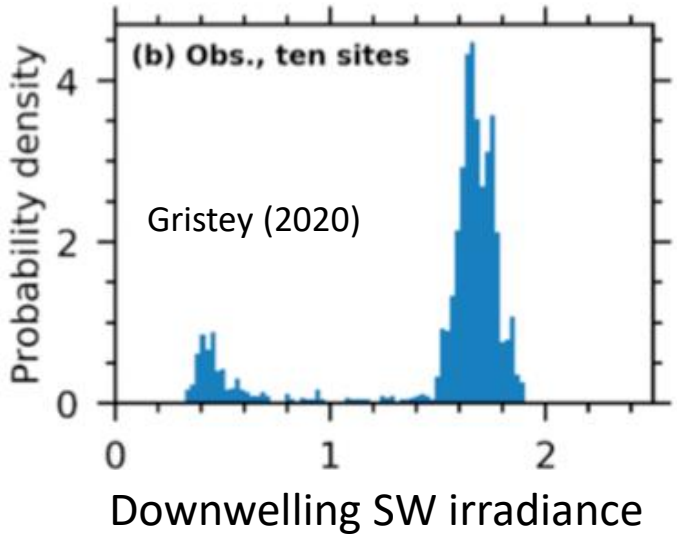


Radiation



Geophysical Variable Maps

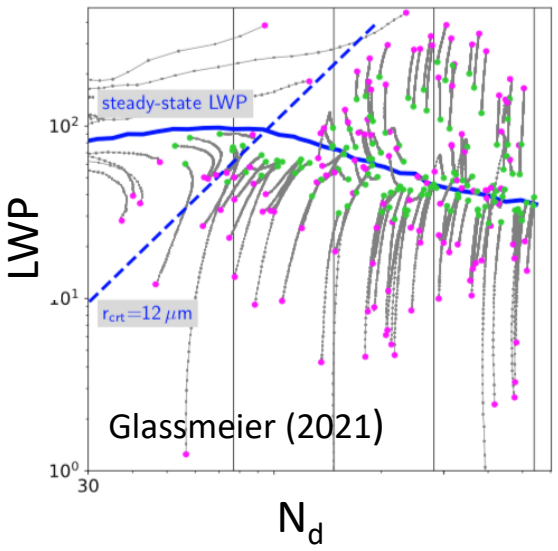




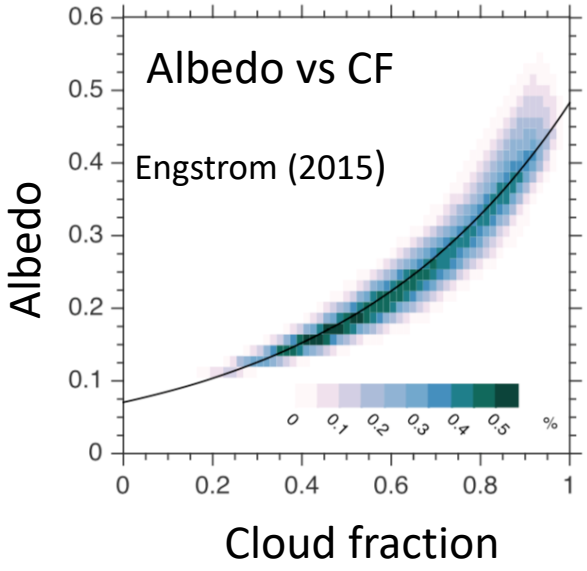
GV maps encode physical processes!

See also Matsui et al. (2014)

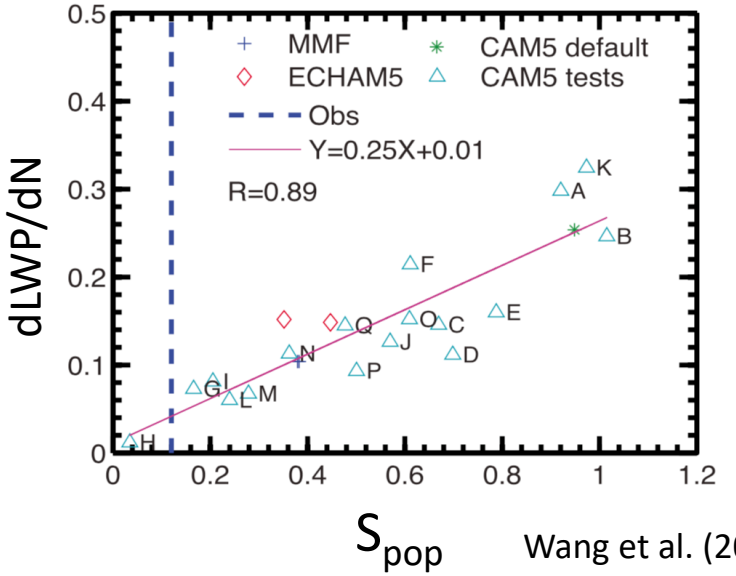
Microphysics



Radiation

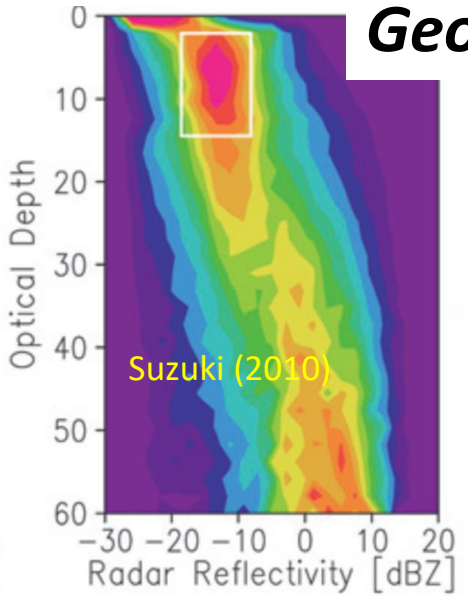


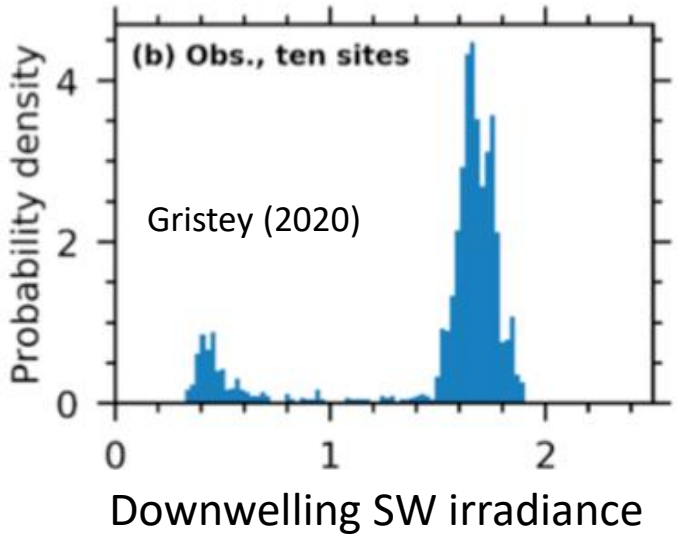
Emergent Constraints

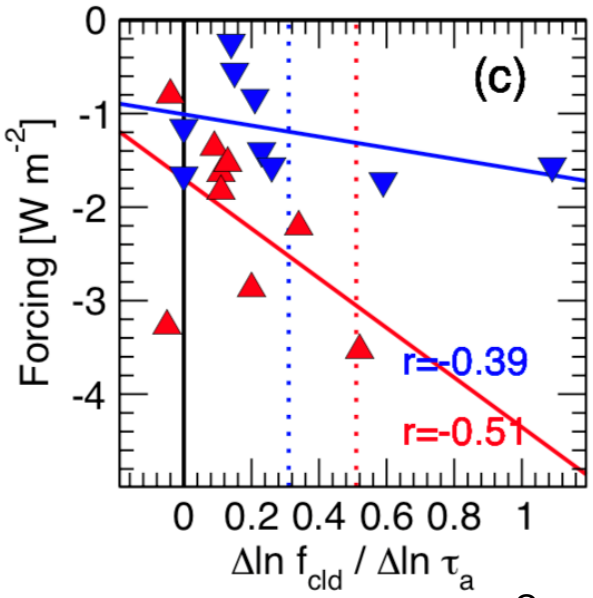


Wang et al. (2012)

Geophysical Variable Maps







Quaas (2009)

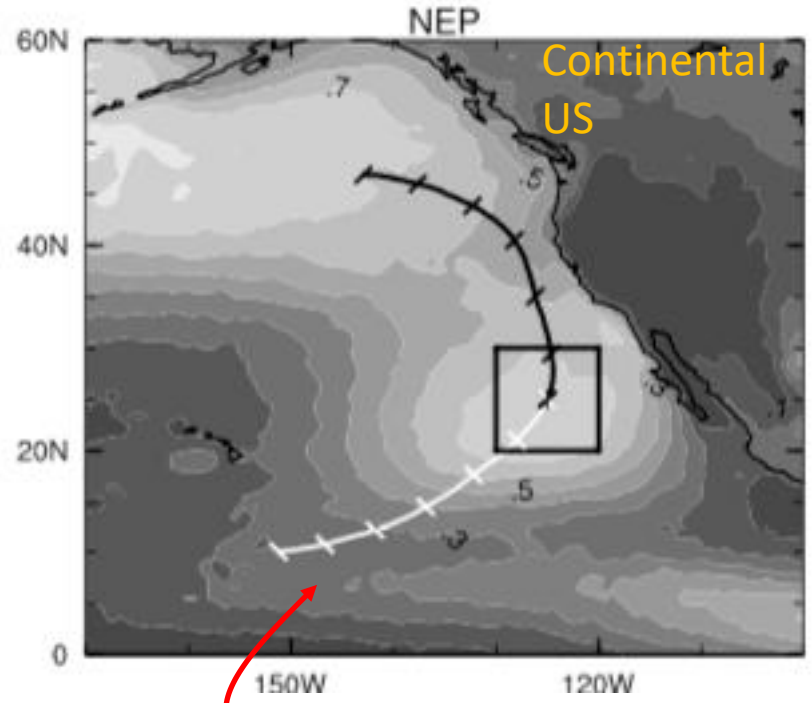
Science

1. ACI and Mesoscale Organization
   - Stratocumulus to Cumulus Transition (SCT)
     - Role of smoke
     - Role of drizzle
   - Pockets of open cells (POCS)
2. Timescales of ‘LWP adjustments’ (dLWP/dN)
3. Albedo vs. cloud fraction

Themes

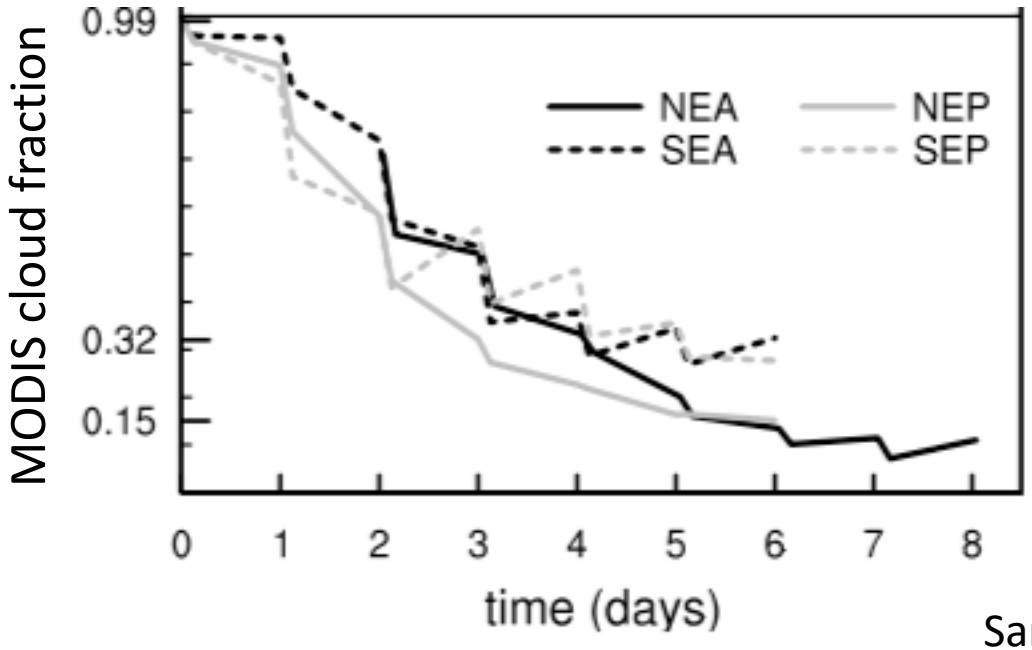
- *How to evaluate/improve models by ECARE data?*
- *What are the major issues/biases of models in representations of cloud, convection, precipitation, and aerosols?*
- *Process understanding: cloud, precipitation, convection, radiation, and their coupling*
- *New research areas/subjects arising from ECARE*

1. ACI and Mesoscale Organization: SCT



Contours: cloud fraction

Forward trajectory



Sandu et al. (2010)

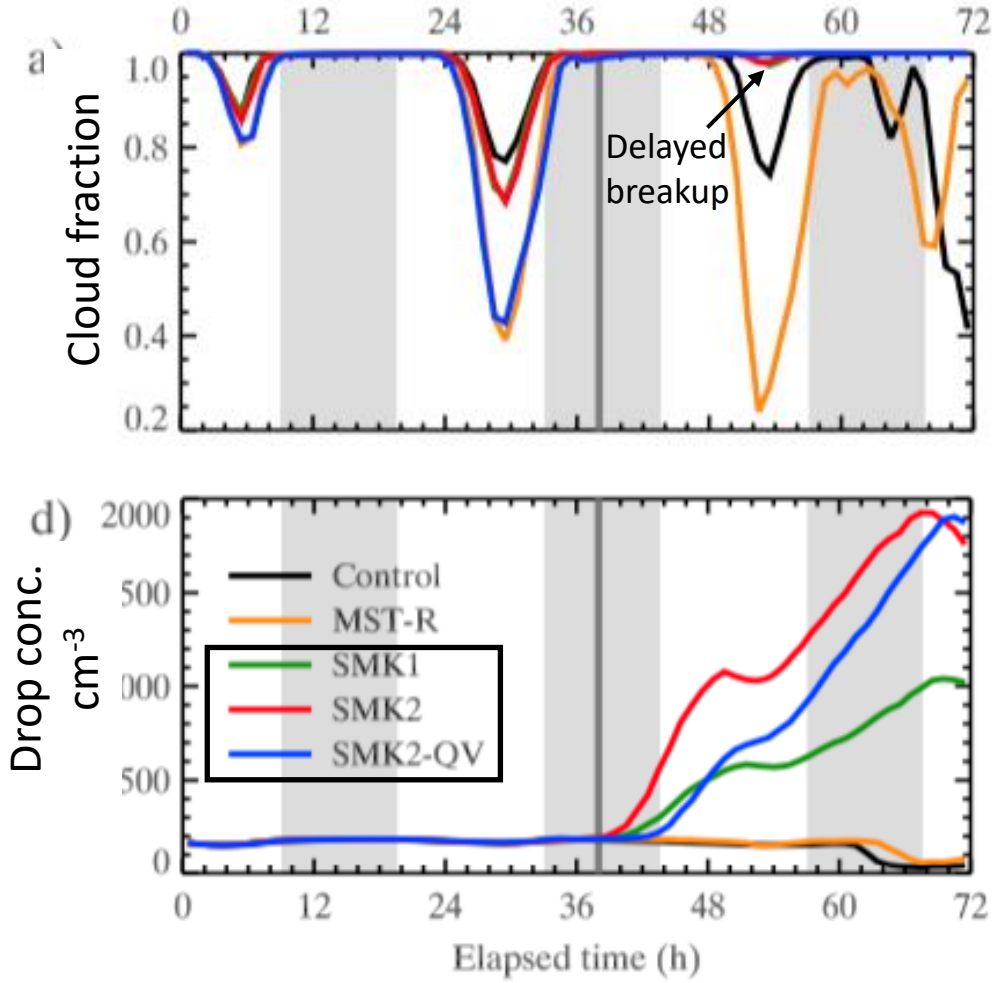
Transition from solid stratocumulus to broken cumulus as SST increases/subsidence decreases

Sc → Cu Transition

1. ACI and Mesoscale Organization: SCT

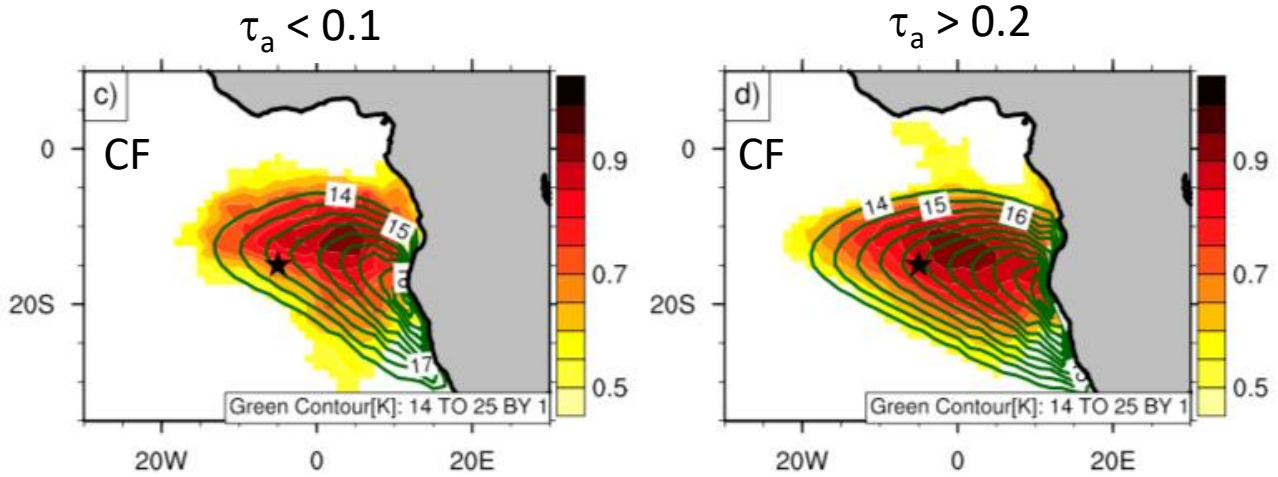
Role of Smoke

LES: Smoke delays transition



Yamaguchi et al. (2015) Lagrangian LES

MODIS: smoke delays transition



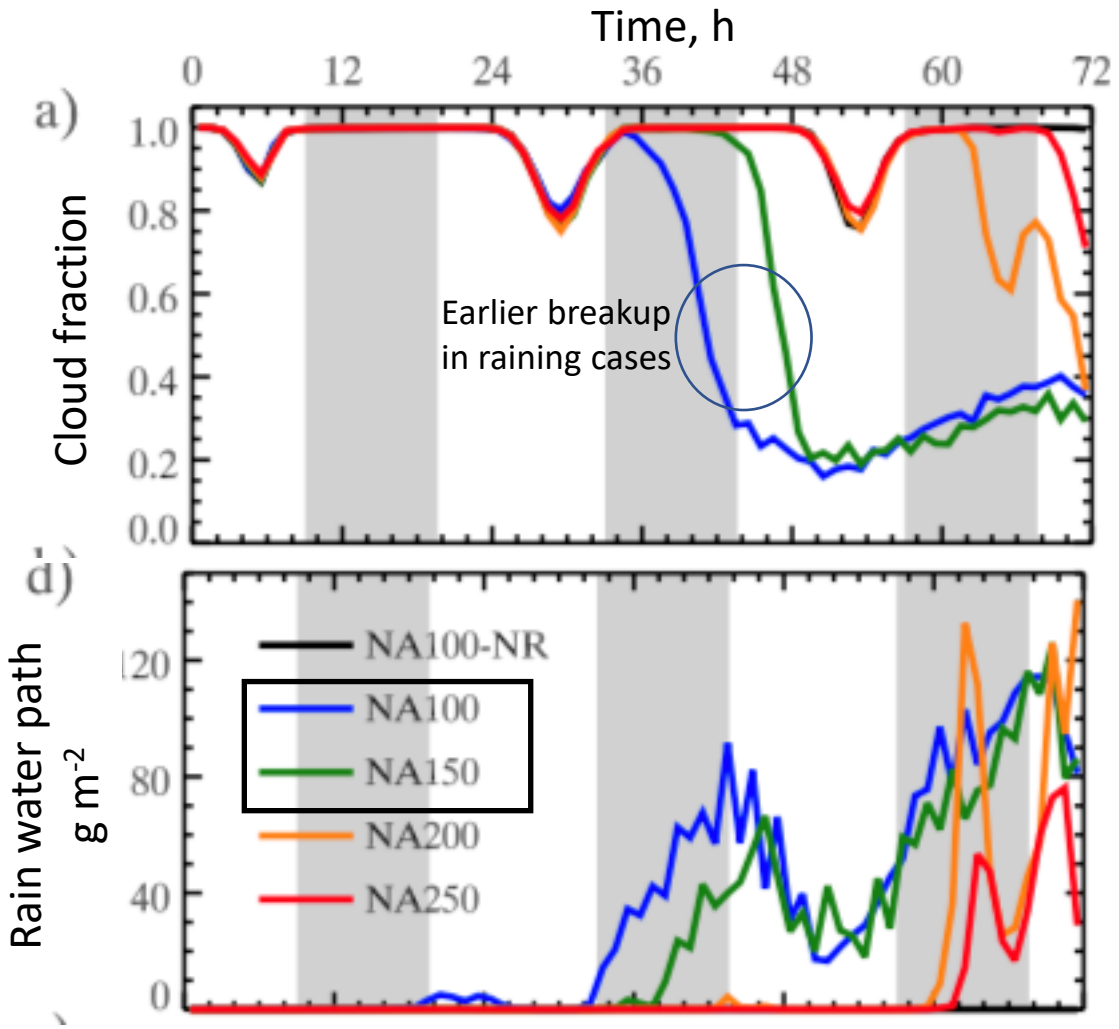
Adebeyi et al. (2015)

Approach:

- *Geo to identify transitions*
- *ECare: drizzle + CF, τ, r_e, aerosol profiles, smoke contact with cloud*
- *Compositing based on ERA-5/diurnal cycle*
- *Lagrangian LES*

1. ACI and Mesoscale Organization: SCT

Role of Drizzle



Yamaguchi et al. (2017) Lagrangian LES

LES suggests a potentially important role for drizzle induced transition due to local scavenging of aerosol.
Is their observational evidence?

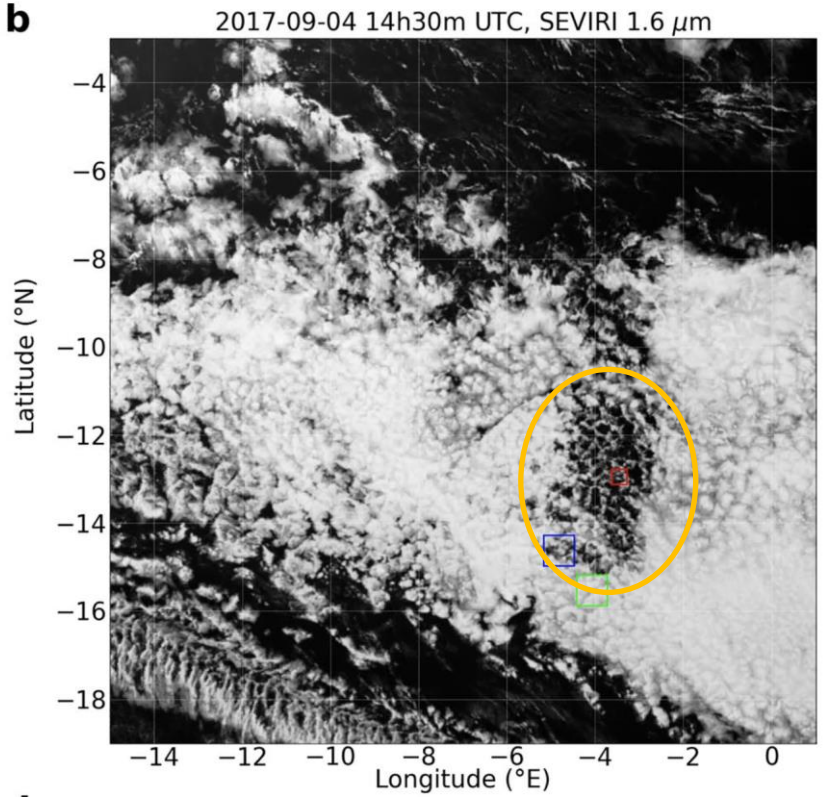
<u>Approach:</u>

- *Geo to identify transitions*
- *ECare: drizzle + CF, τ, r_e, w, aerosol profiles*
- *Compositing based on ERA-5*
- *Lagrangian LES*

1. ACI and Mesoscale Organization: Pockets of Open Cells

Closed-Open

Pocket of open cells



SE Atlantic
SEVIRI 2017-09-04 (Kazil et al. 2021)

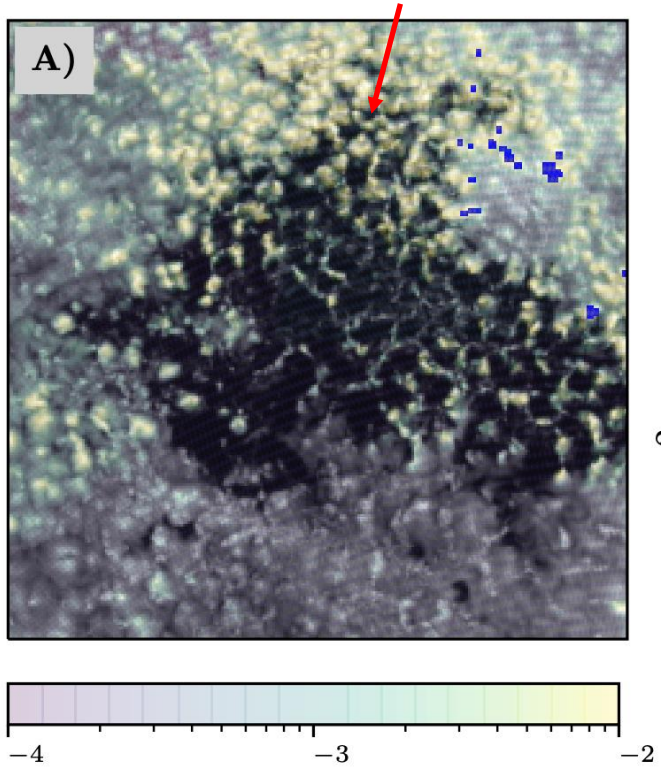
Strong role for drizzle-induced transition due to local scavenging of aerosol

<u>Approach:</u>

- Geo to identify transitions
- ECare: drizzle + CF, τ, r_e, w *in cell walls*, *aerosol* profiles in POC
- Compositing based on ERA-5
- LES

1. ACI and Mesoscale Organization: Closed-Open Cells

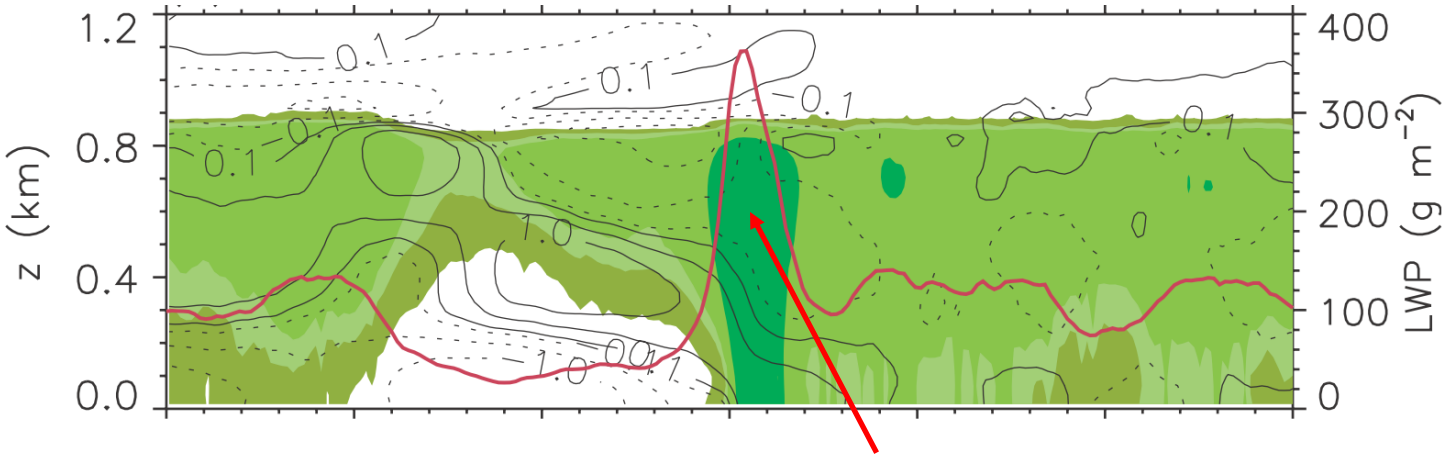
Highest rain rate at edge of POC



GOES + AMSR-2 rain rates (color)

Smalley et al. (2021)

LES: Highest LWP, rain rate, and TKE at edge of POC



Color contour: rain
Red line: LWP
Line contours: u-wind

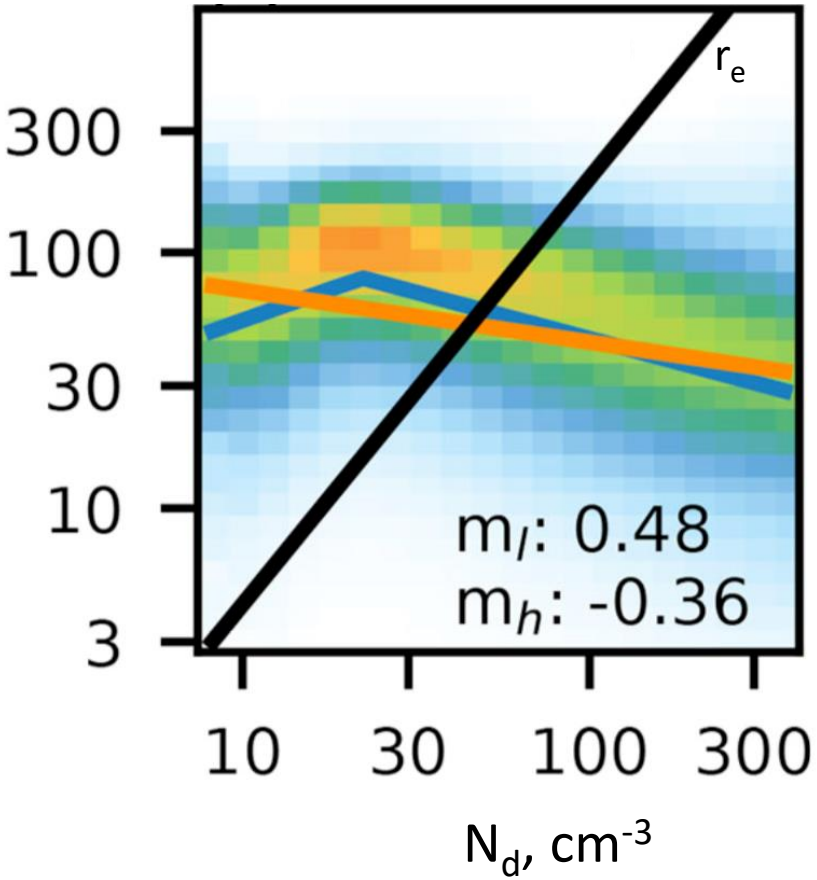
High TKE re-circulation zone
Use of ECare w measurements

Wang and Feingold (2009)

Closed-Open

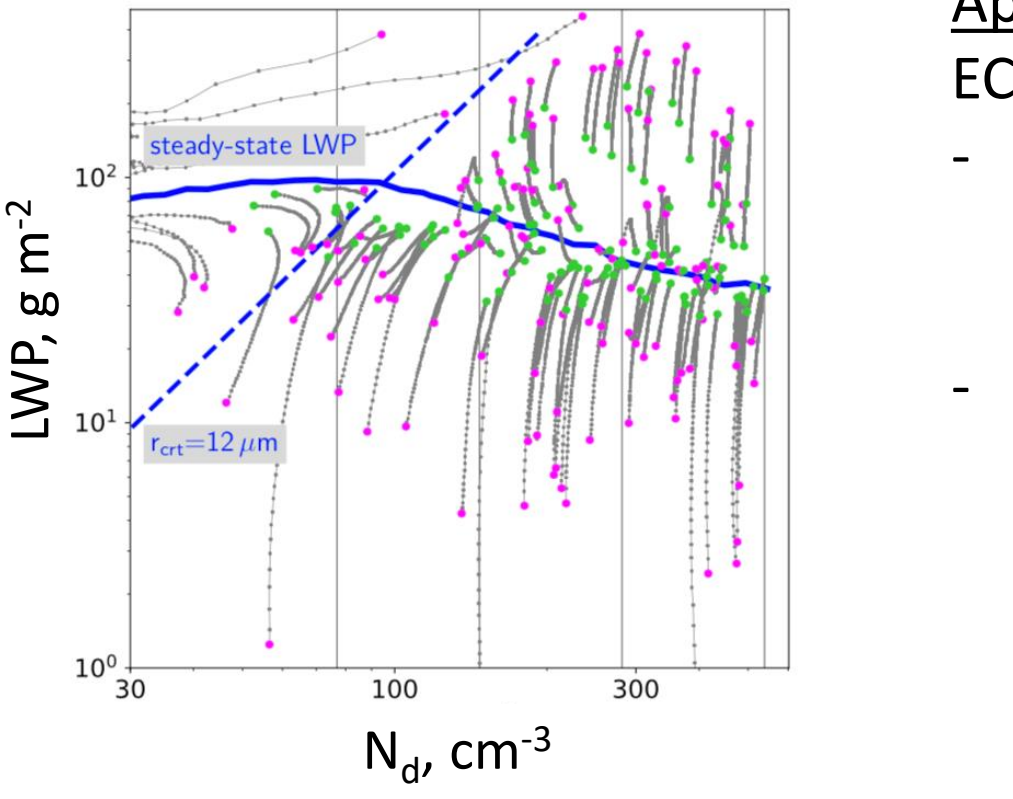
2. LWP Adjustments dLWP/dN: non-monotonicity

A-Train (snapshots)



Gryspeerdt et al. (2019)

Large ensemble of LES:
evolution of individual runs



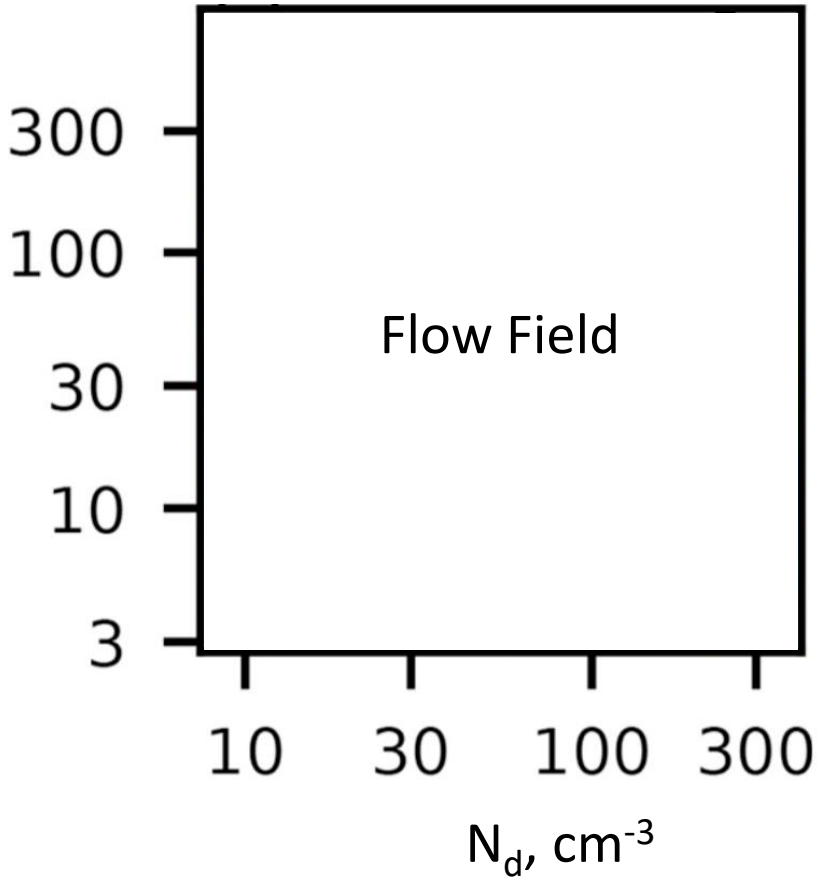
Glassmeier et al. (2021)

Approach:
ECare + Geo

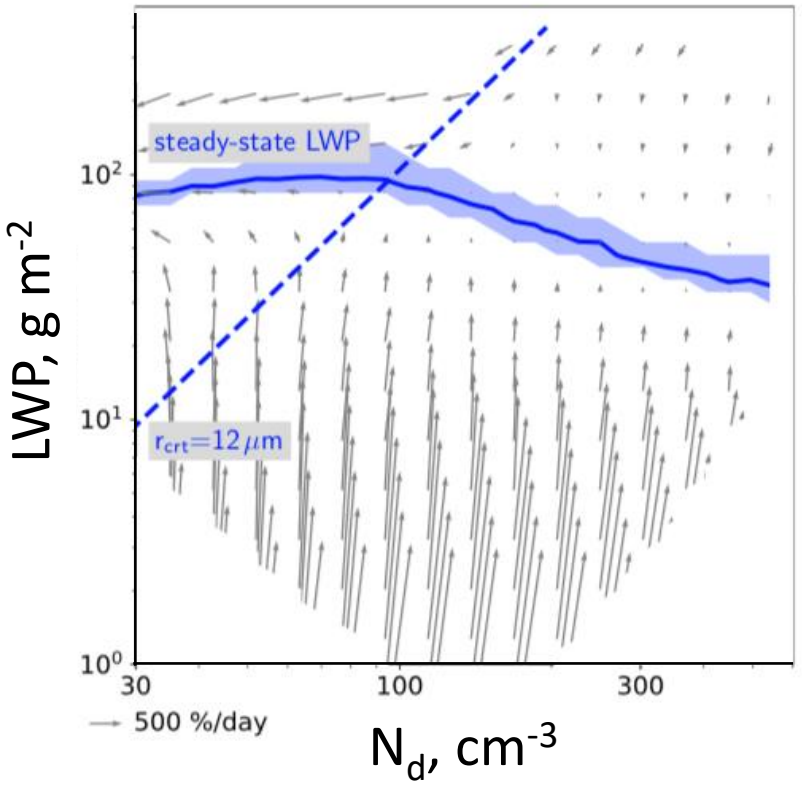
- Compositing based on ERA-5/diurnal cycle
- LES connects to processes

2. LWP Adjustments: Satellite and LES flow fields

Satellite-based (*flow field*)



LES emulator: dLWP/dN *flow field*



Glassmeier et al. (2021)

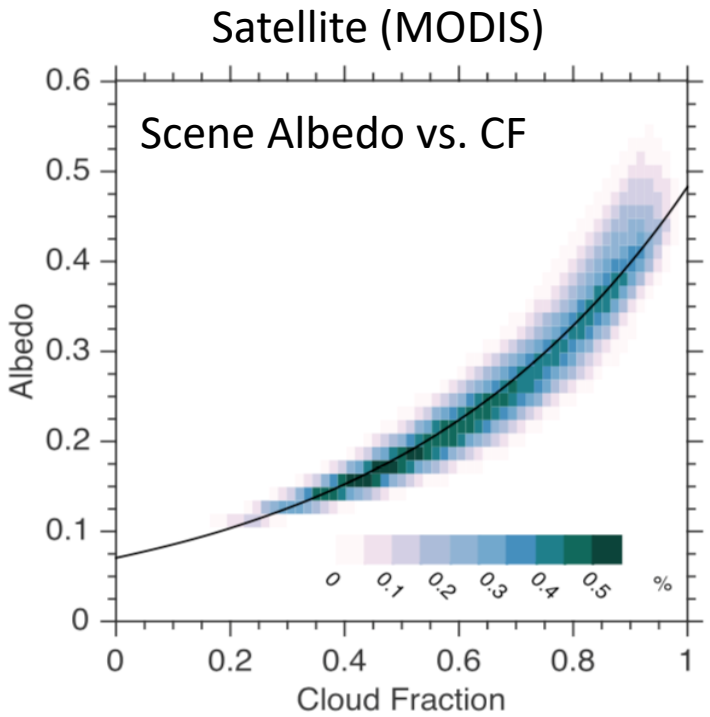
<u>Approach:</u>

ECare + Geo

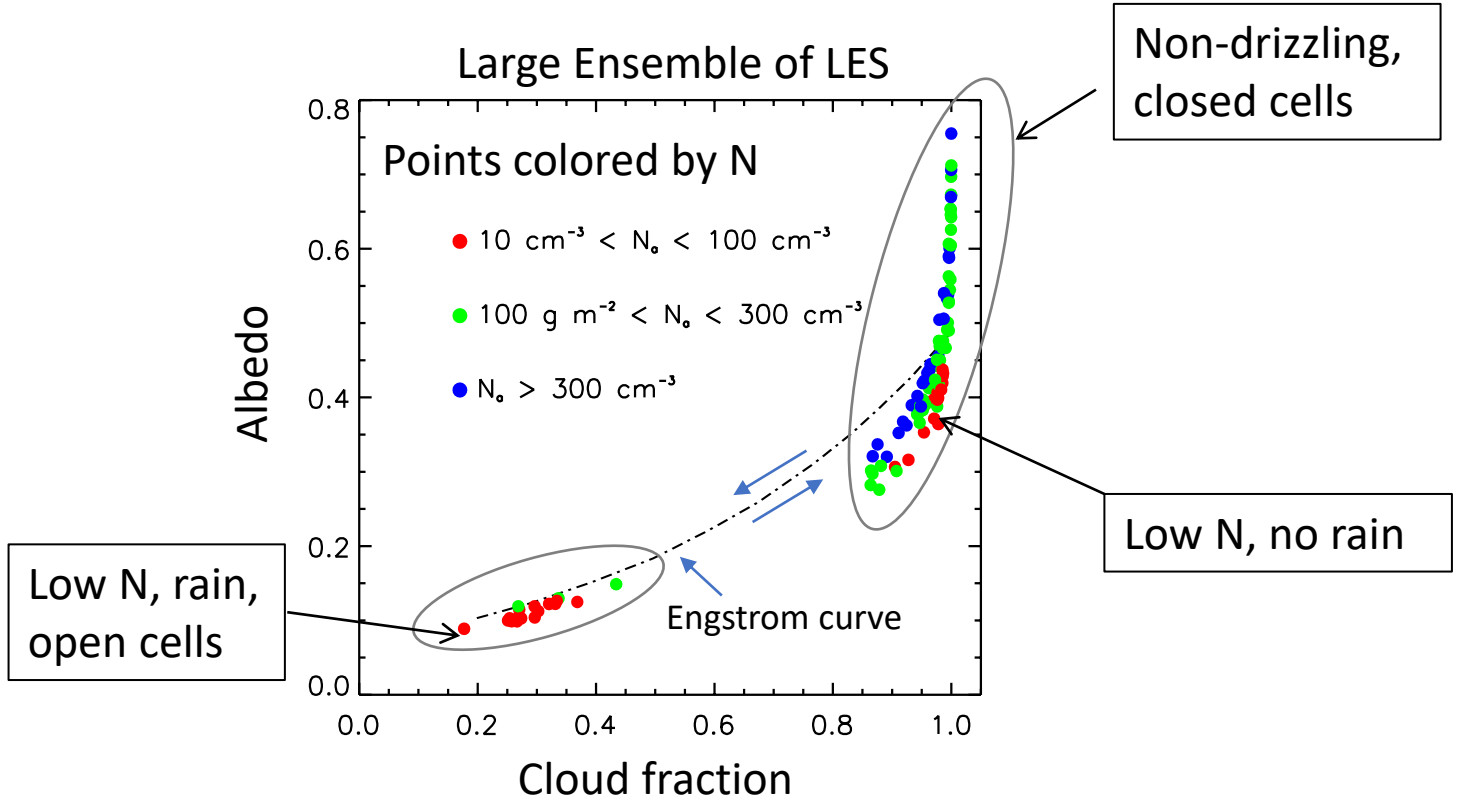
- Compositing based on ERA-5/diurnal cycle
- Explore timescales of dLWP/dN

3. Albedo - Cloud Fraction

Shape of these traces encodes micro/macrophysics
Rate of opening/closing of POCs using ECare + Geo + Met



Engstrom et al. (2015)



Adapted from Feingold et al. (2016)

Summary Points

EarthCare opportunities

<u>EarthCare</u>

1. New instruments
2. New Geophysical Variables (GVs)
3. Better aerosol, drizzle
4. Conditional sampling by *w*
5. *System wide constraints using multiple GVs*

<u>Geostationary, reanalysis, other..</u>

1. Geo for high Δt temporal resolution
2. ERA-5 meteorology
3. Compositing
4. *LES, Global Cloud Resolving, Climate Model evaluation in GV spaces of interest*

- Improved Process Understanding
- Improved Earth System Predictability at a range of scales