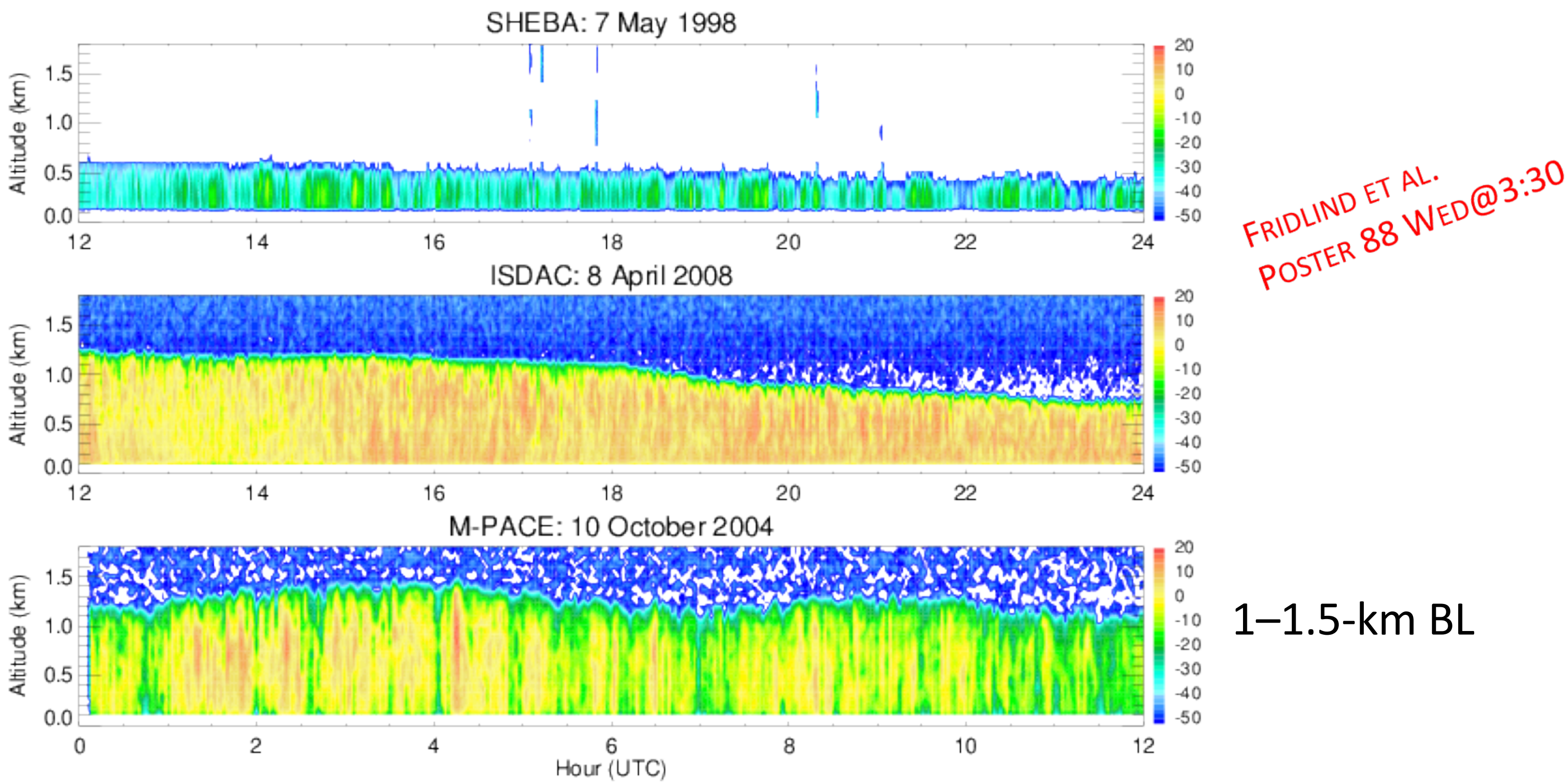
Modeling challenges simulating the microphysics of cold air outbreak conditions vs other mixed-phase shallow clouds



1–1.5-km BL

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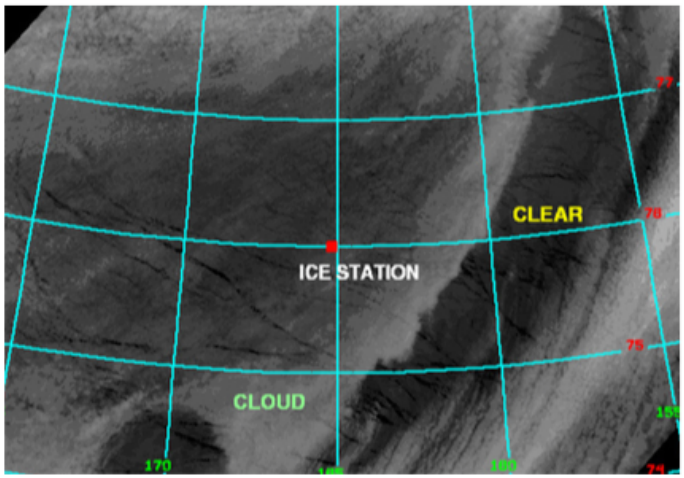
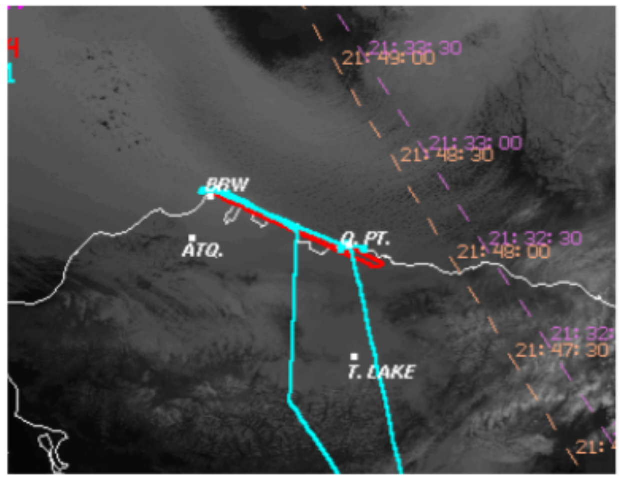
Mixed-phase stratiform cloud case studies

Field	Observation	Cloud Top	Cloud Temp. (C)		Path (g m^{-2})		Conc. (cm^{-3})	
Campaign	Period (UTC)	Height (m)	Top	Base	Liquid	Ice	Drops	Ice
SHEBA	7 May 1998	500	−20°	−18°	5–20	0.2–1	200	∼0.0005
M-PACE	9–10 Oct. 2004	1000	−16°	−9°	110–210	8–30	40	∼0.01
ISDAC	26 April 2008	800	−15°	−11°	10–40	2–6	200	∼0.001

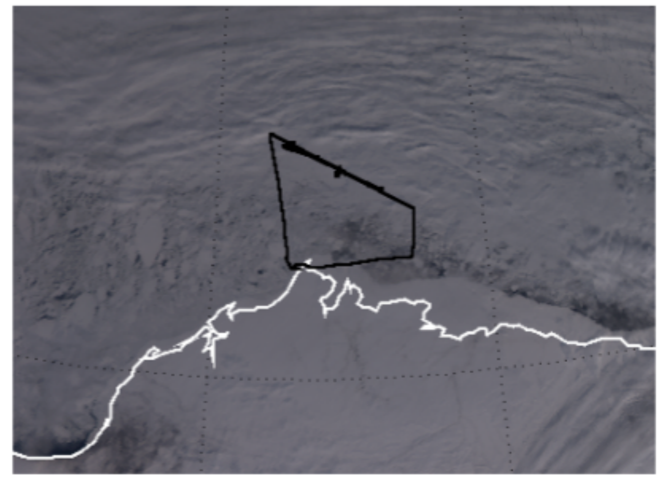
SHEBA



M-PACE



ISDAC



Mixed-phase stratiform cloud case studies

Field Campaign	Observation Period (UTC)	Cloud Top Height (m)	Cloud Temp. (C) Top	Cloud Temp. (C) Base	Path (g m^{-2}) Liquid	Path (g m^{-2}) Ice	Conc. (cm^{-3}) Drops	Conc. (cm^{-3}) Ice
SHEBA	7 May 1998	500	−20°	−18°	5–20	0.2–1	200	~0.0005
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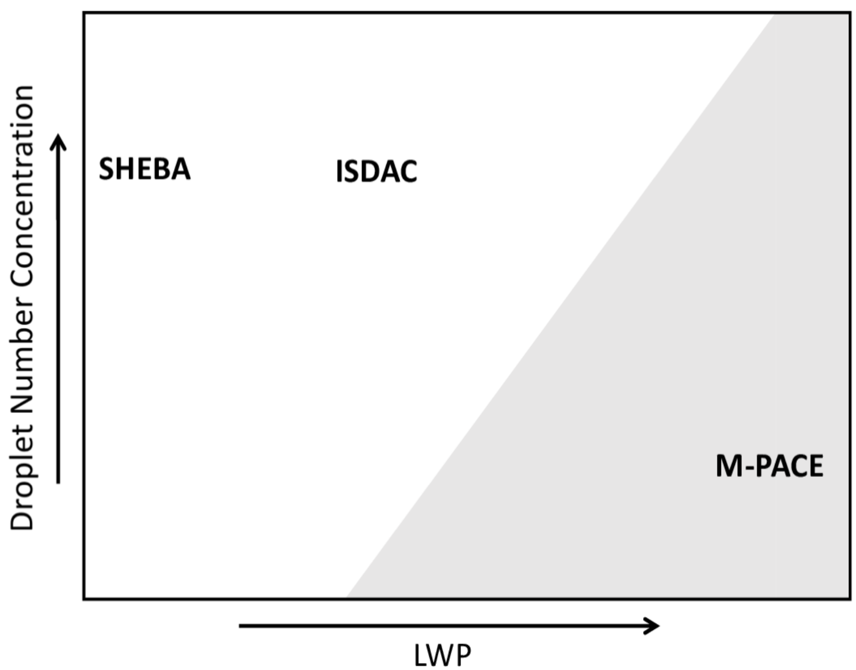
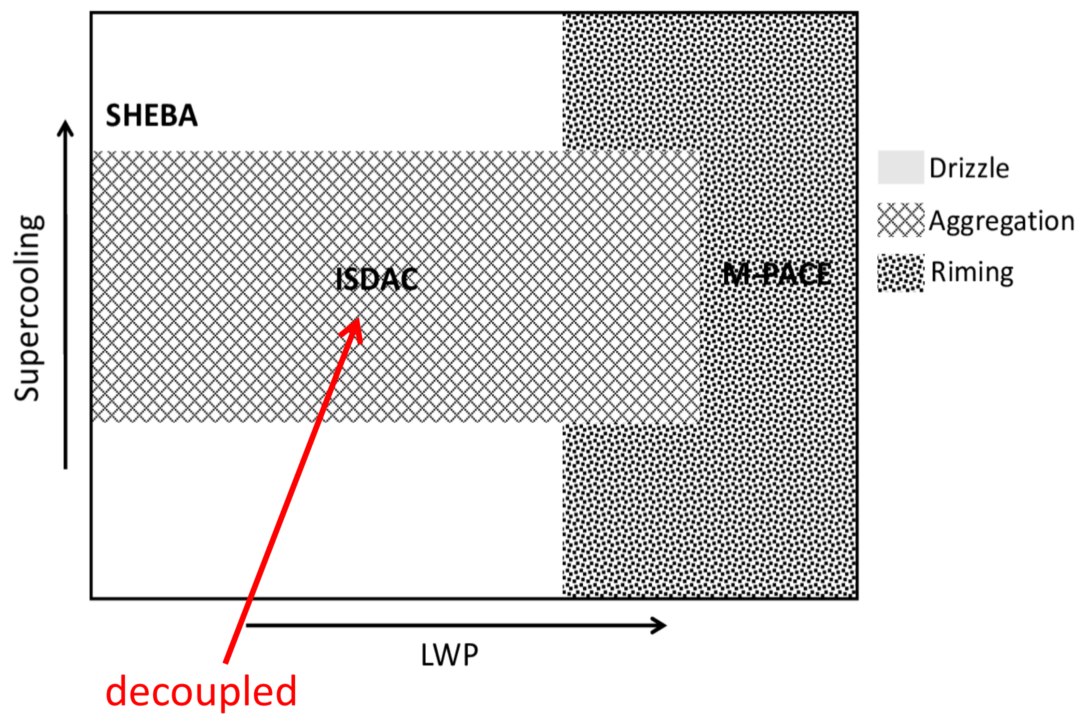




M-PACE: well-mixed, overcast, drizzling

- first stationary domain LES of similar roll convection reported by Gryschka et al. (2005)

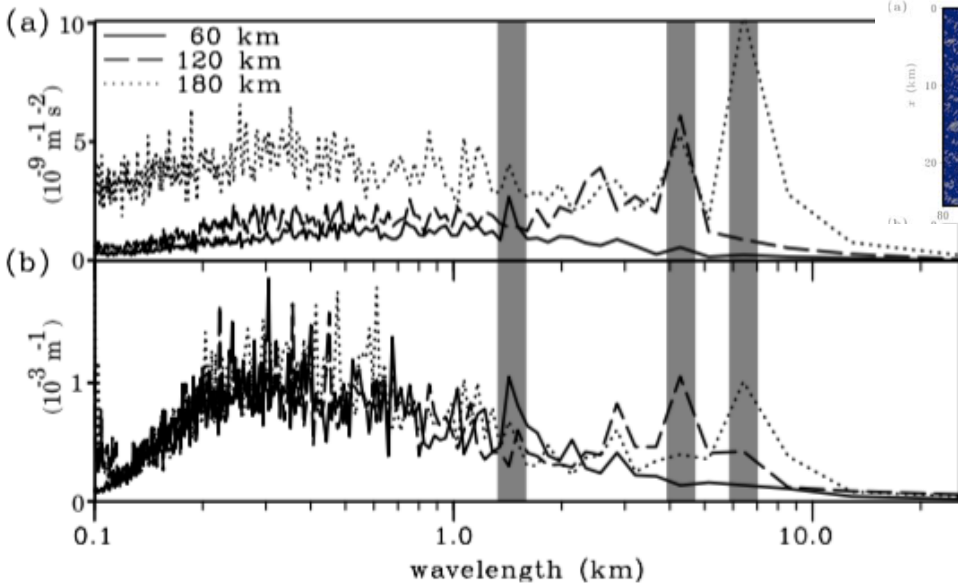
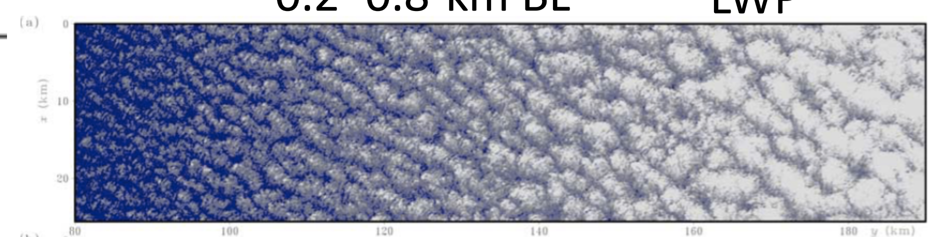
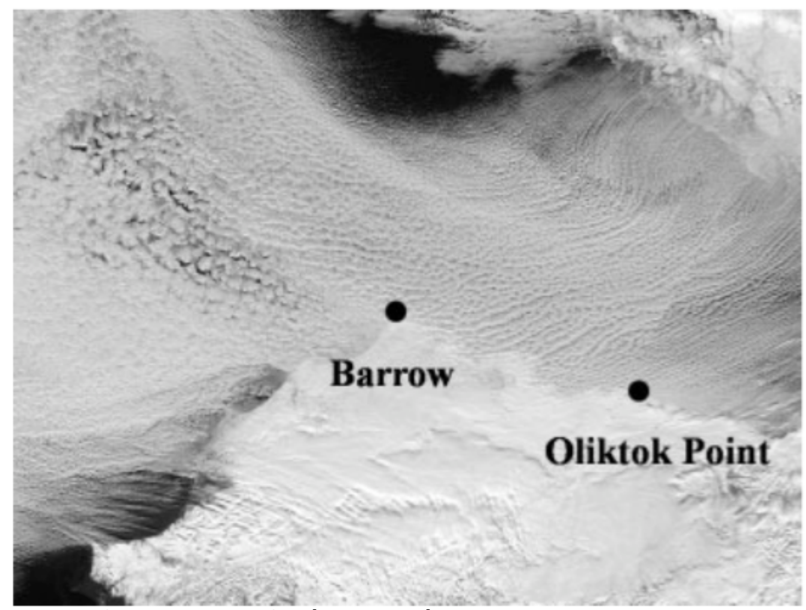


Figure 3. Spectra multiplied with the wave number at successive distances from the ice edge at 5 hours (a) of the liquid water content q_l at the top of the boundary layer and (b) of the friction velocity u_* in the surface layer. The shaded bars indicate the wavelengths at which clear maxima appears in (a) as well as in (b).

0.2–0.8-km BL LWP

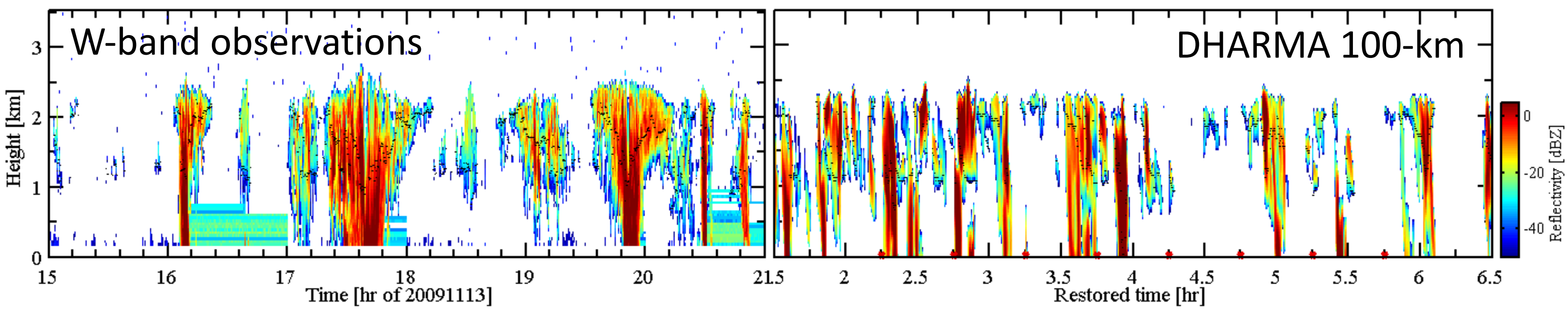


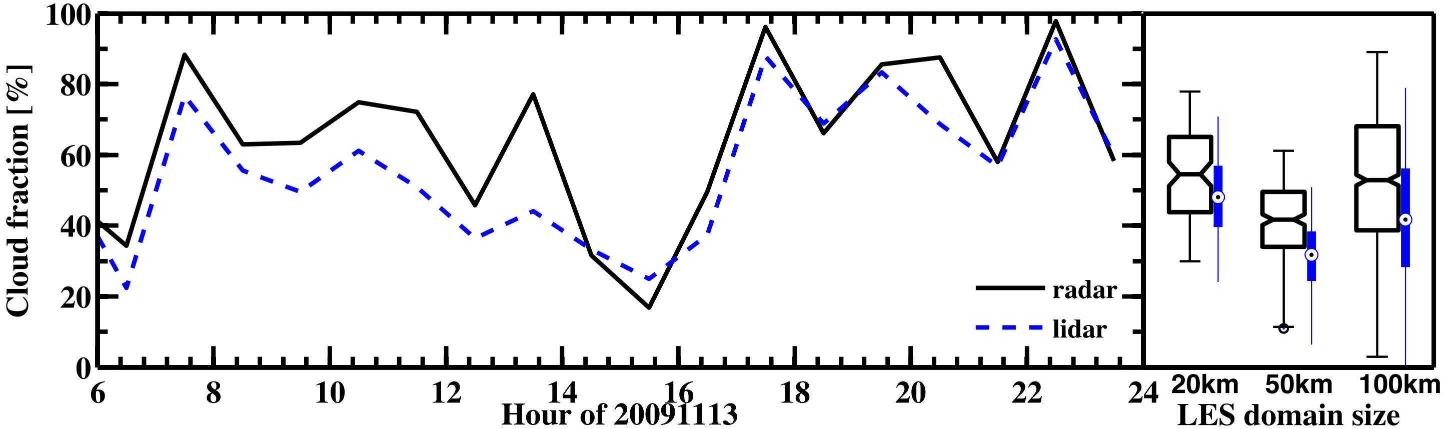


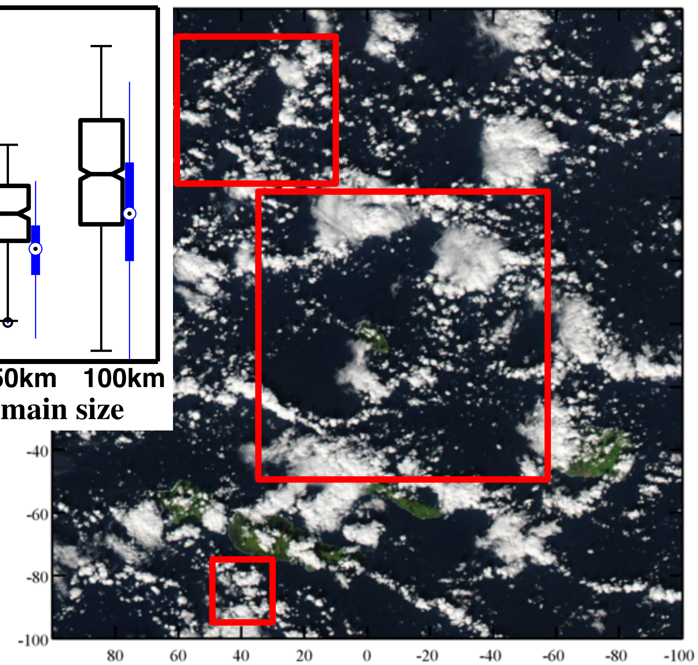
Klein et al. (2009)

CAP-MBL: stratified, raining convective cells

2–2.5-km BL



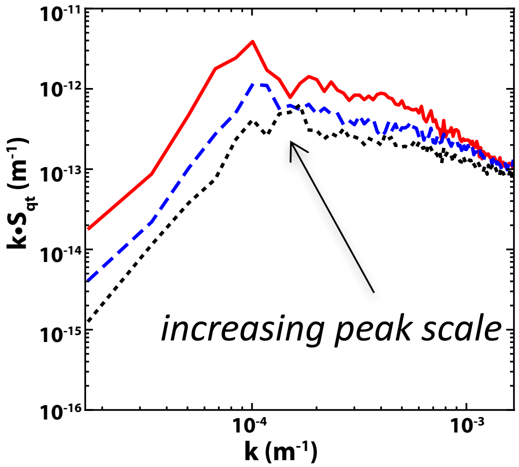




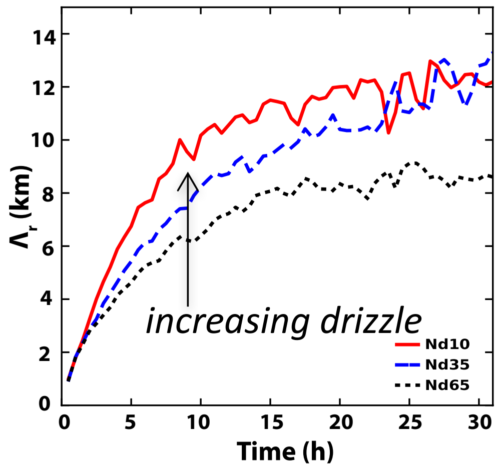
LES with periodic BCs may be able to spin up similar structures without upstream shear history (contrast to convective rolls)

Mesoscale structures may depend on microphysics

Variance spectra of q_t at 10 h



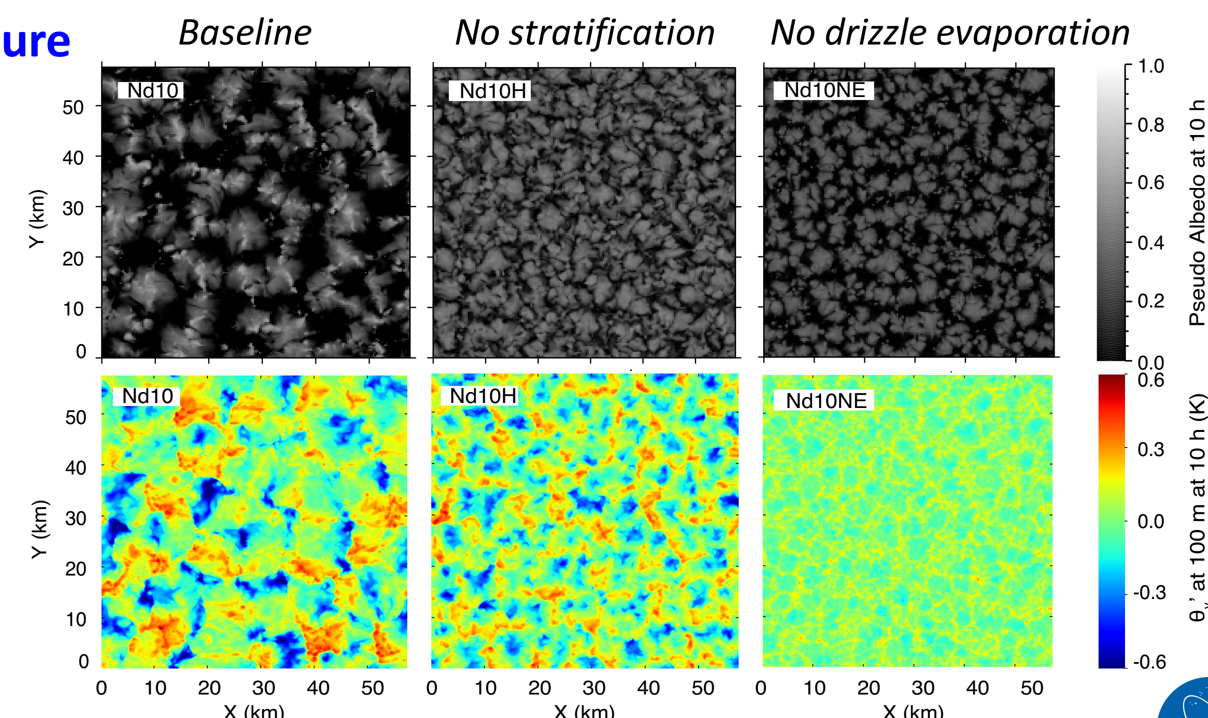
Evolution of spectral length scale of q_t at 700 m



Zhou et al. (submitted)
DHARMA with two-moment microphysics

How does drizzle amplify moisture variance scales?

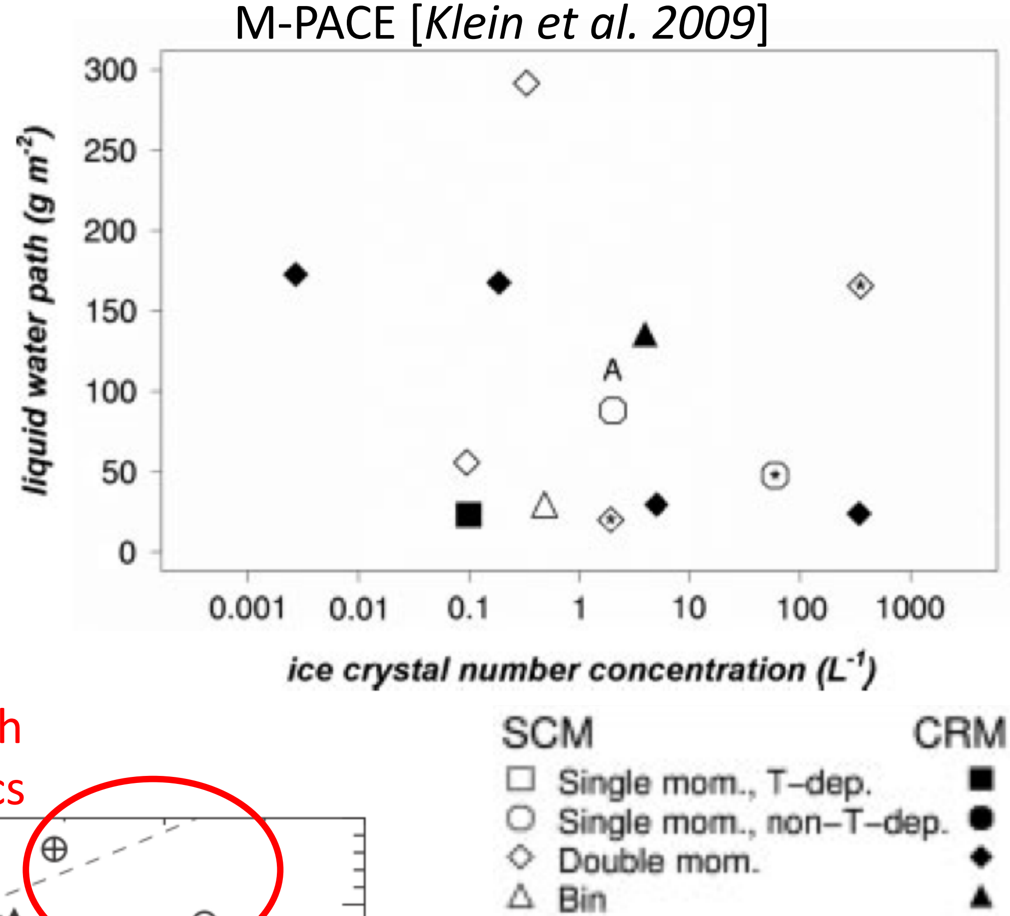
- **drizzle evaporation increases moisture stratification**
- **moist cold pools respond to rather than determine the horizontal scales**



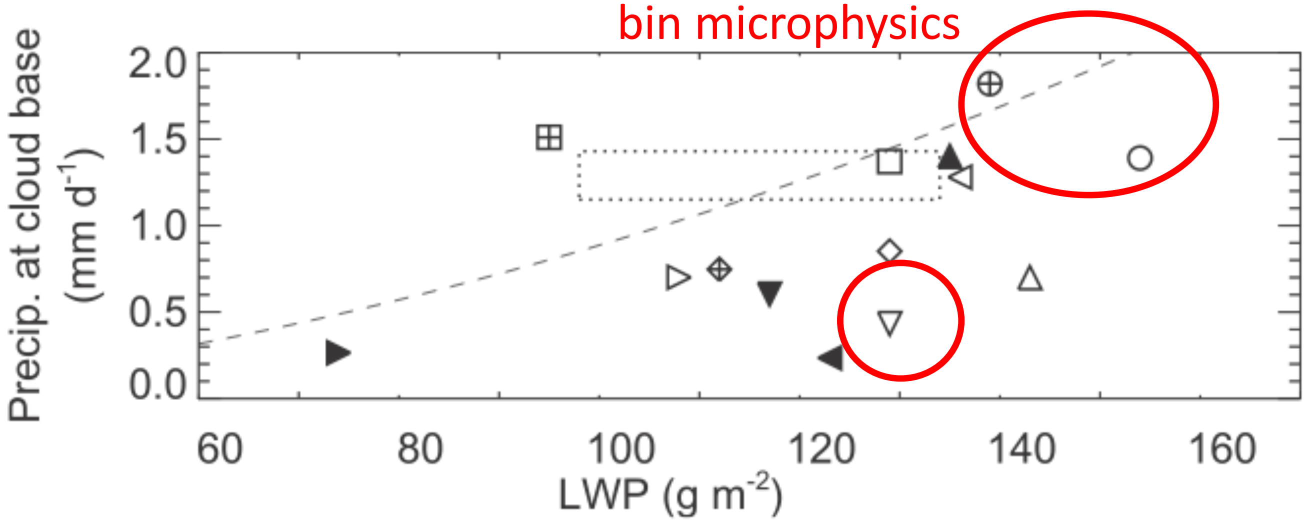
Different LES and microphysics schemes differ

- ever since M-PACE, similar intercomparisons have specified ice number concentration
- evidence of unknown ice formation process, perhaps associated with drizzle
- LWP and liquid-phase precip also still challenging for LES regardless of microphysics complexity

M-PACE [*Klein et al. 2009*]



simulations with bin microphysics



DYCOMS-II-RF02 [*Ackerman et al. 2009*]

Observational objectives?

- constraining simulated dynamics
  - rolls and clusters undersampled by vertically pointing instruments
  - if stratification is expected (or even if not), dropsondes?
  - downwelling longwave radiative flux above cloud top
  - measurement approach to establish horizontal length scales?
- constraining microphysics
  - stratiform and well mixed but mixed phase?
    - aerosol and droplet number size distribution, aerosol hygroscopicity
    - liquid water path mesoscale structure
    - ice crystal properties (e.g. CPI), plus analyses to give quantitative guidance
    - ice nucleation rates, aerosol surface area (commonly dominated by supermicron mode under relatively clean conditions)
    - expect drizzle in mixed-phase if clean
  - cumuliform?
    - establishing structure by radar more central
    - radar supported in situ measurements