Condensate variability in ice clouds – a lifetime effect?

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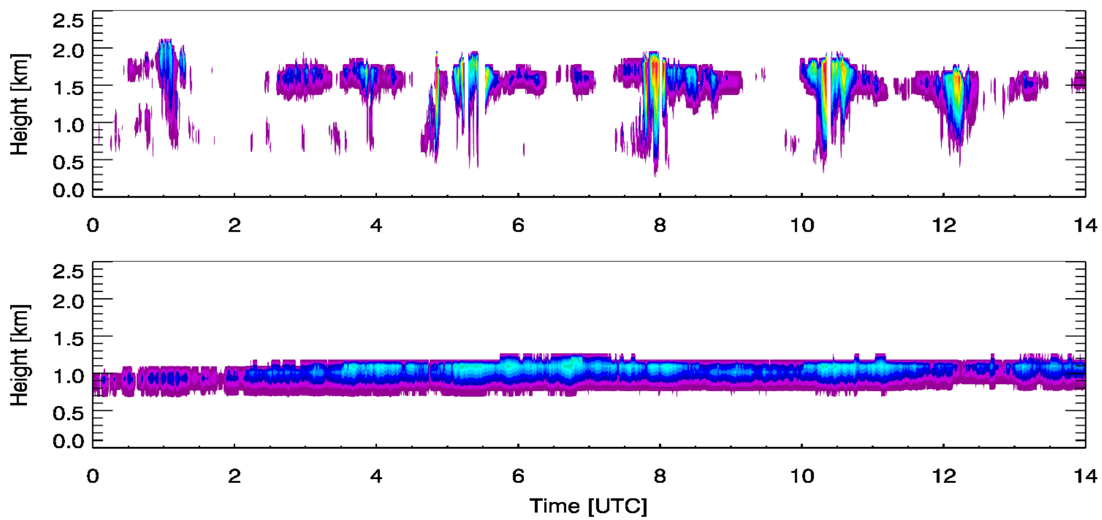
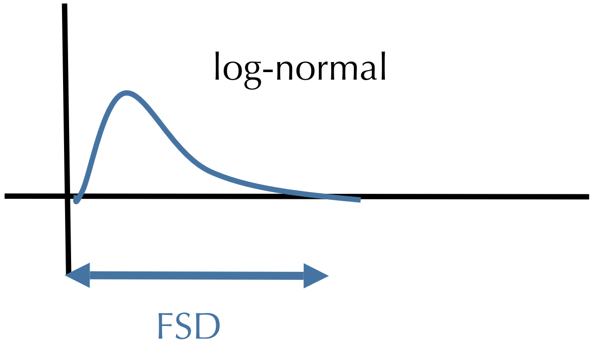
Why do we care about condensate variability?

Illustrating the contrast in condensate variability between BL cumulus and stratocumulus at ENA



- Model predicts cloud fraction, grid box mean condensate amount - “homogeneous cloud”
- Process rates in radiation/microphysics depend on local value, not grid box mean
- Parameterize - how does condensate variability vary with cloud type or regime?



e.g. log normal pretty good assumption

Huang and Liu 2012

Characterize condensate variability as a “fractional standard deviation”:

$$FSD = \frac{\sigma}{mean}$$

current assumption in IFS: FSD=1 everywhere

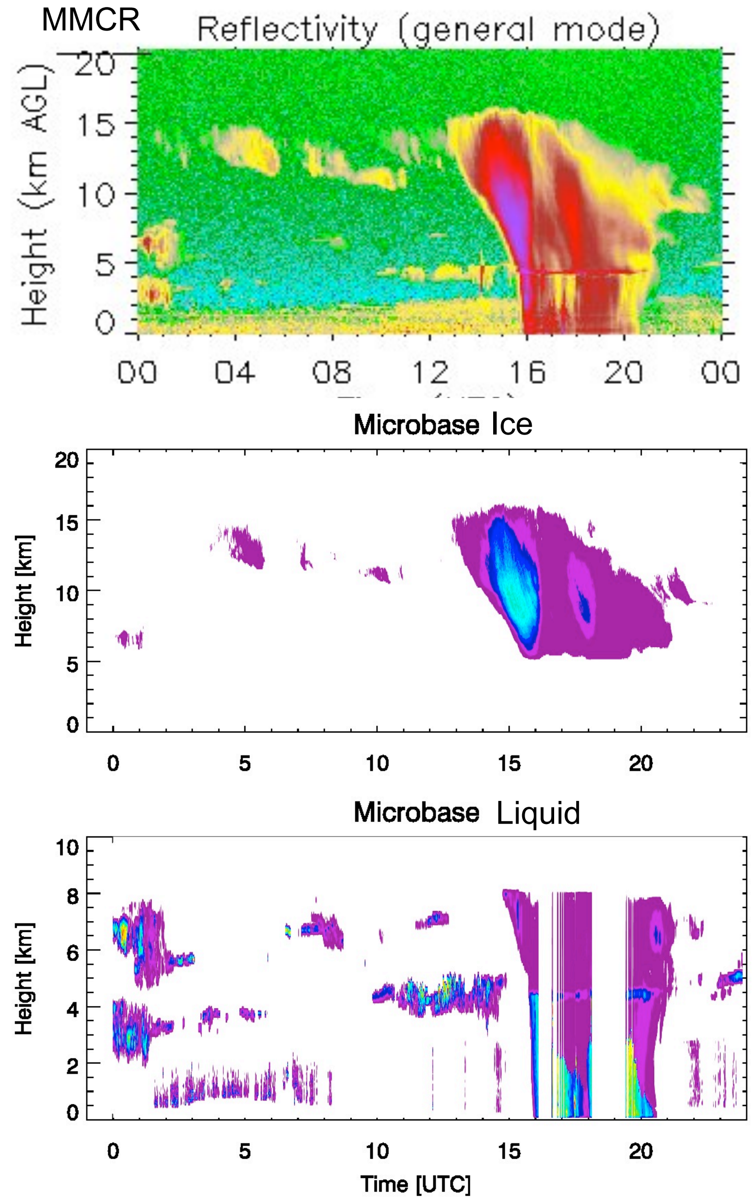
Impact of changing this value from 1 to 0.75: TOA SW changes order 10W/m^2

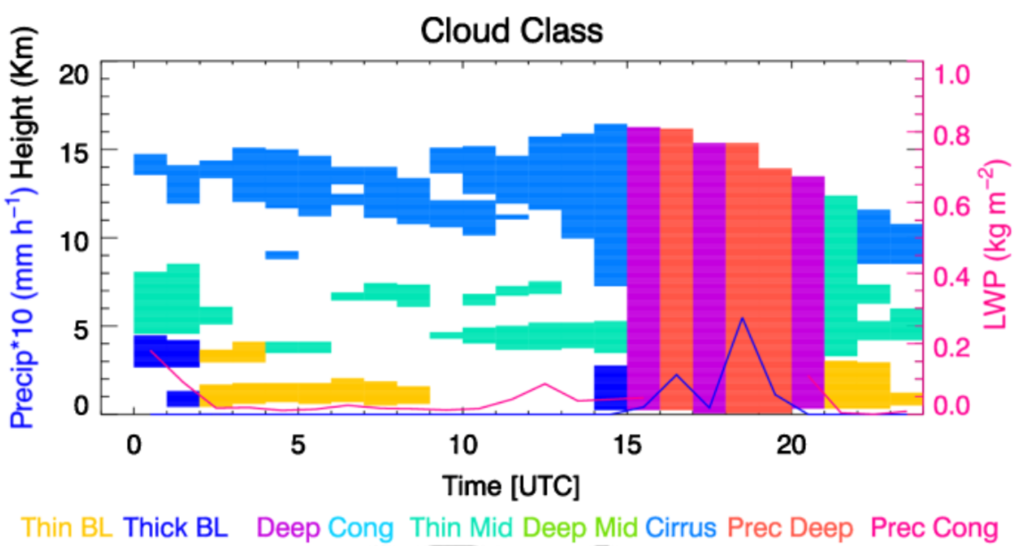
Analyzing five ARM sites across the globe: NSA, SGP, ENA, TWP1 and 3

Challenges:

- Multiple retrieval algorithms, not always the same for all sites
- Retrieval quality affected by conditions (e.g. heavy precip -> unreliable MWR LWP)

Question: To what degree are differences between sites “real”, or merely reflect retrieval differences, or sampling differences between sites?

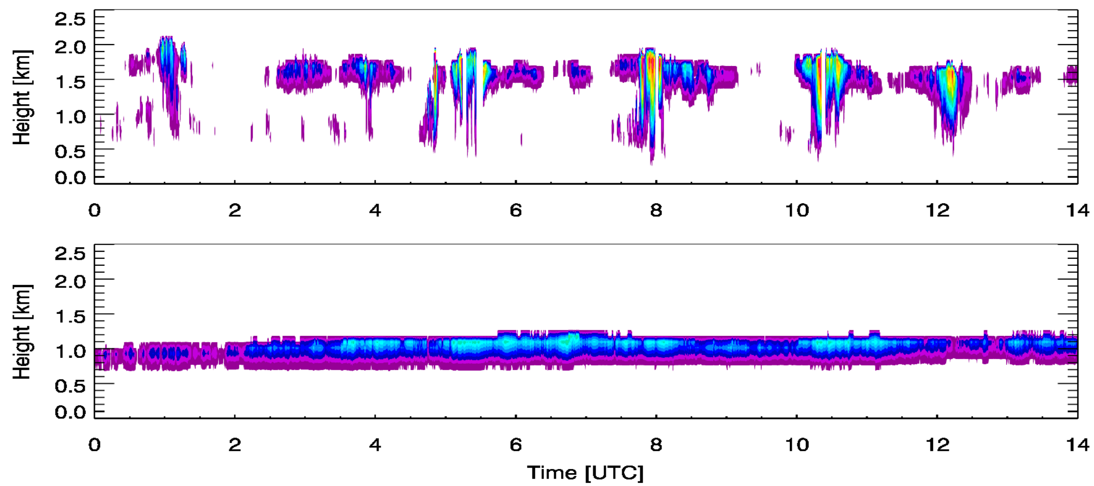


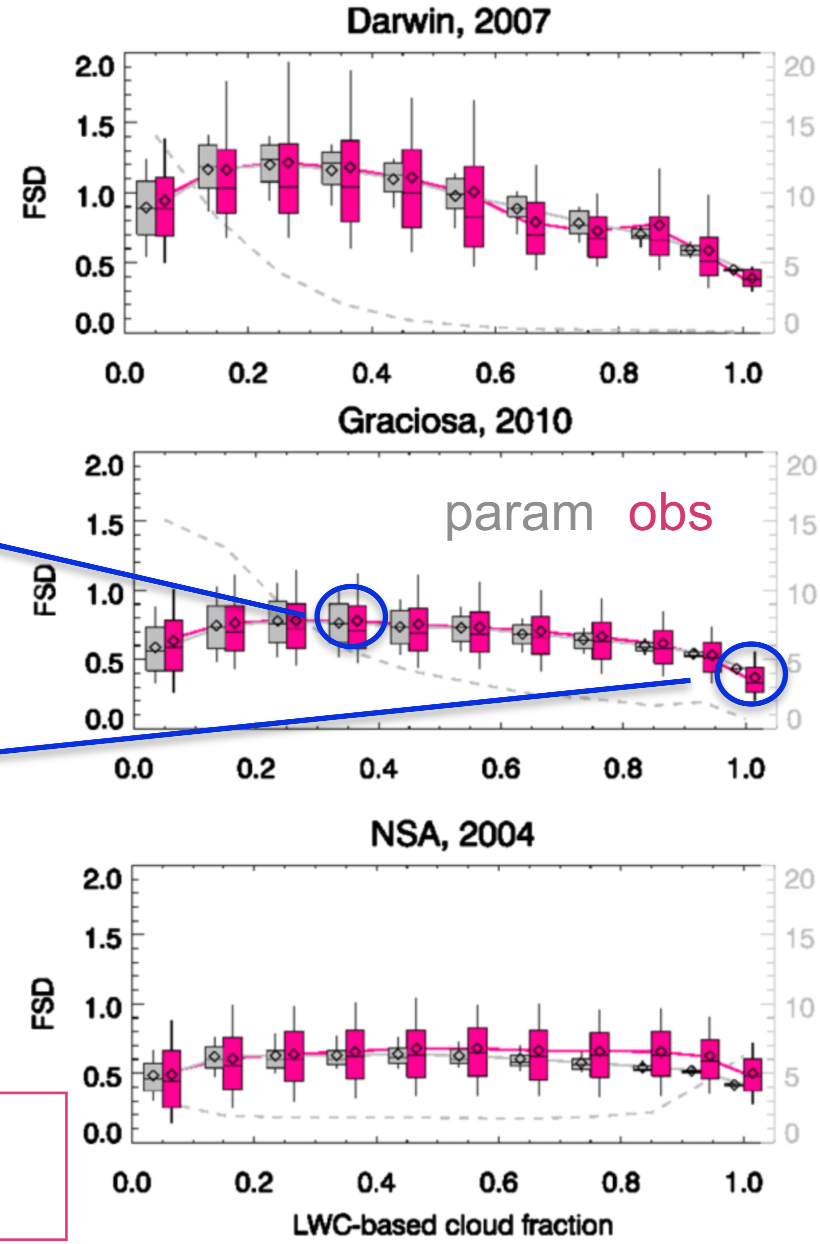


Liquid condensate variability

Warm boundary layer clouds are robust category
Radiatively important

Contrast in variability between overcast and broken warm BL clouds is much greater in the Tropics than in mid-latitudes or Arctic





New parameterization captures these site-to-site differences...

Ahlgrimm, M., R.M. Forbes, 2016: Regime dependence of cloud condensate variability observed at the Atmospheric Radiation Measurement sites. Accepted to QJRMS. DOI: 10.1002/qj.2783

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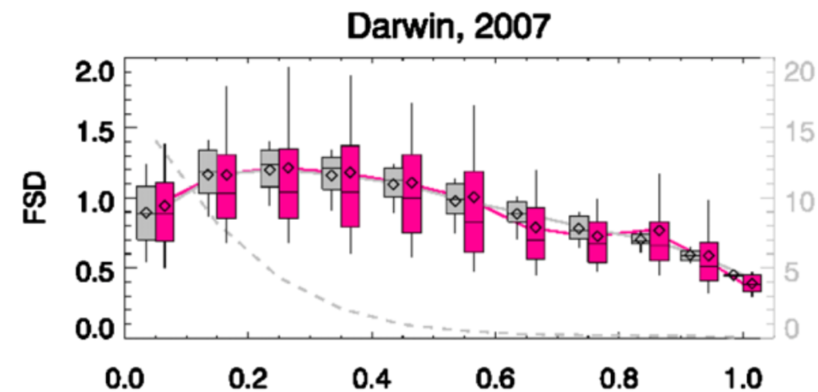
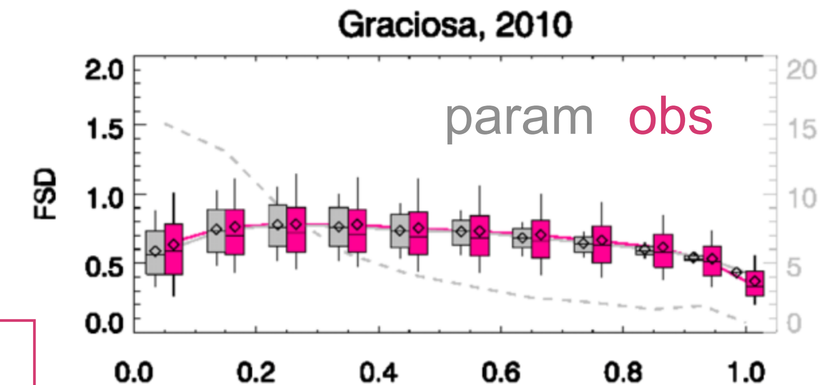
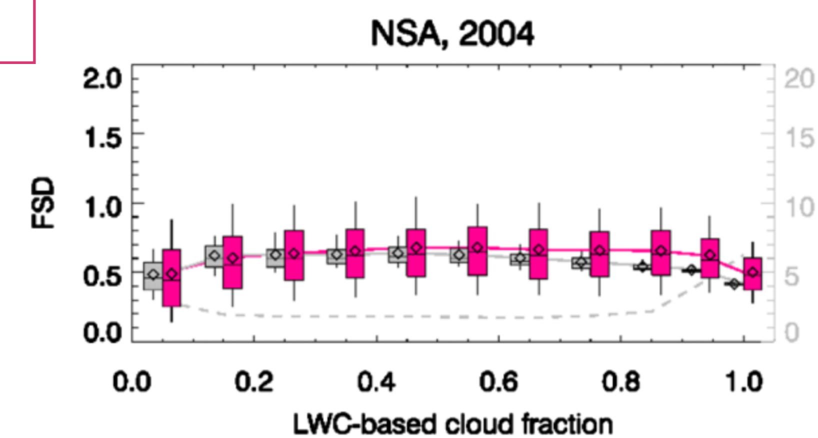
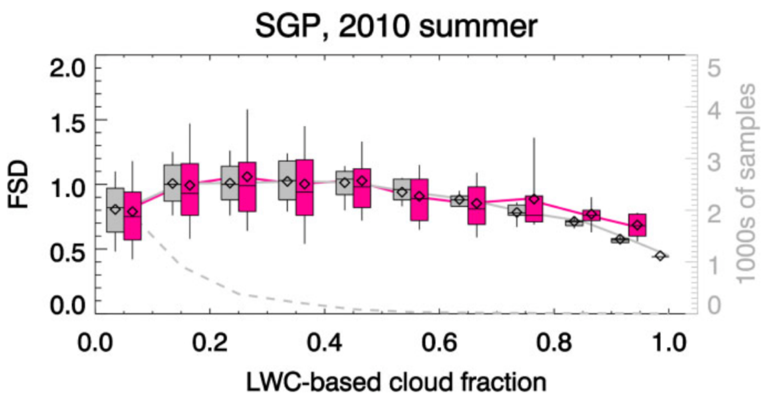
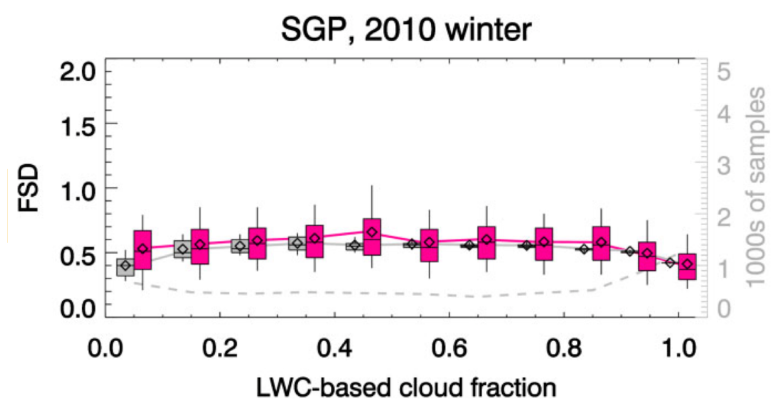










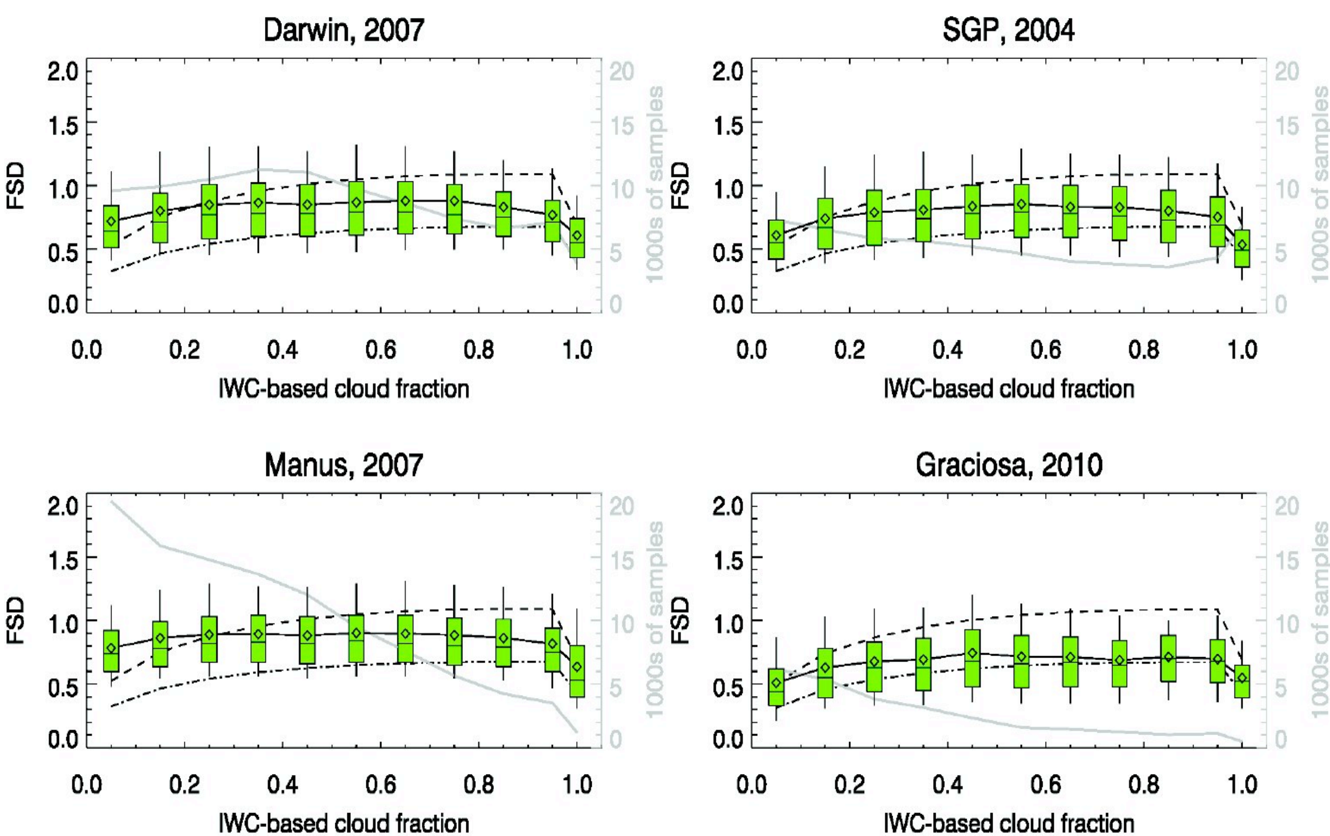
...and seasonal variations

Ahlgrimm, M., R.M. Forbes, 2016: Regime dependence of cloud condensate variability observed at the Atmospheric Radiation Measurement sites. Accepted to QJRMS. DOI: 10.1002/qj.2783

Ice clouds pose their own challenges

- Frozen hydrometeor category – radar not distinguishing between suspended and falling ice
- Ground-based: precipitation-affected retrievals, shielding a problem (lidar attenuated, tenuous cirrus)

Isolated cirrus



Fewer site-to-site differences,
weaker cloud fraction dependence
BUT
By definition, ignoring much of the cloud associated with deep convection

Complementary:

Top-down perspective from satellite provides an all-in view

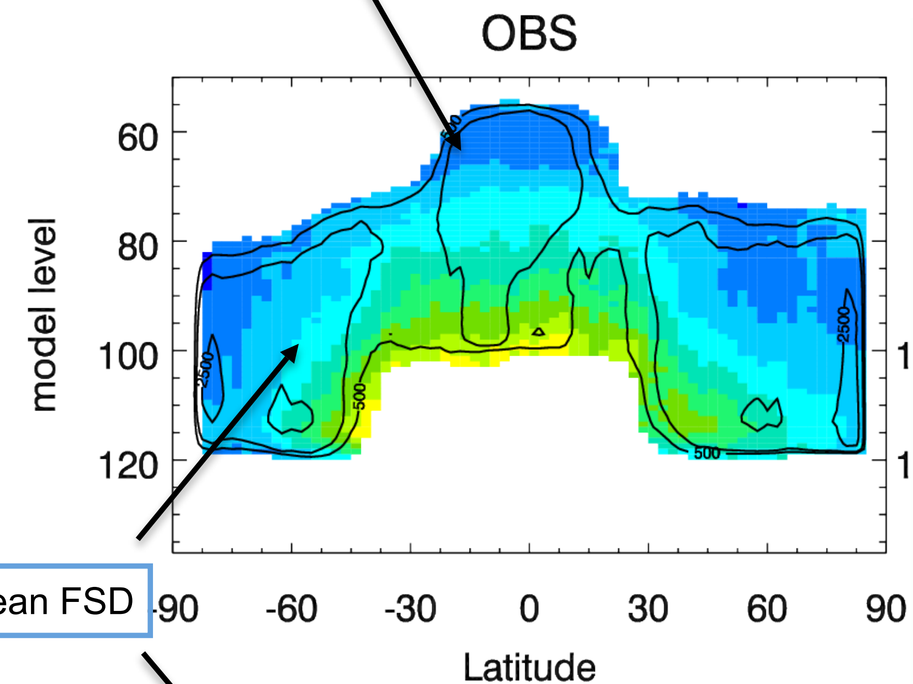
Global perspective: Greater FSD in convective regions, apparent height

- Higher FSD in convective regions - consistent with previous work (e.g. Hill et al. 2015)
- In zonal mean view, appears as though FSD is height dependent
- This is relevant – for solar radiation, what happens at the top of the cloud matters most

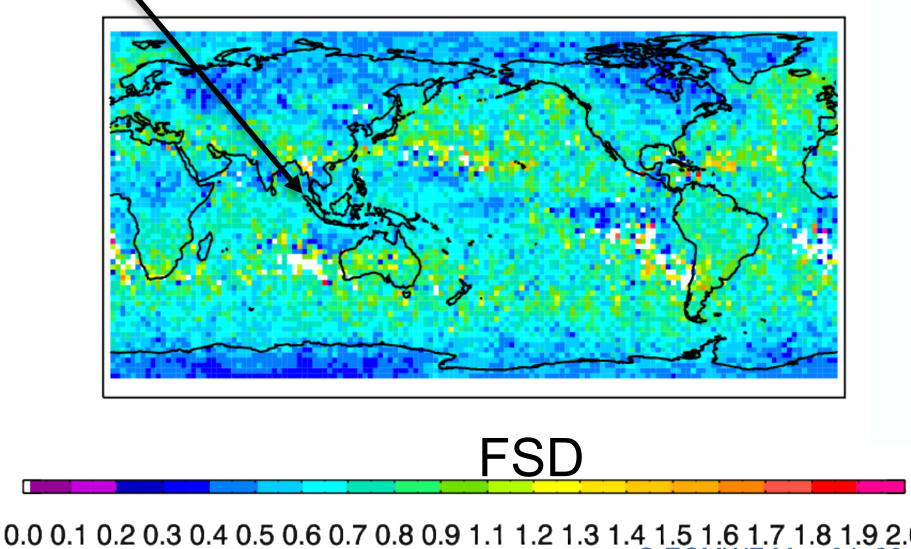
What contributes to the height dependence?

Contour: sample numbers

Jan 2008



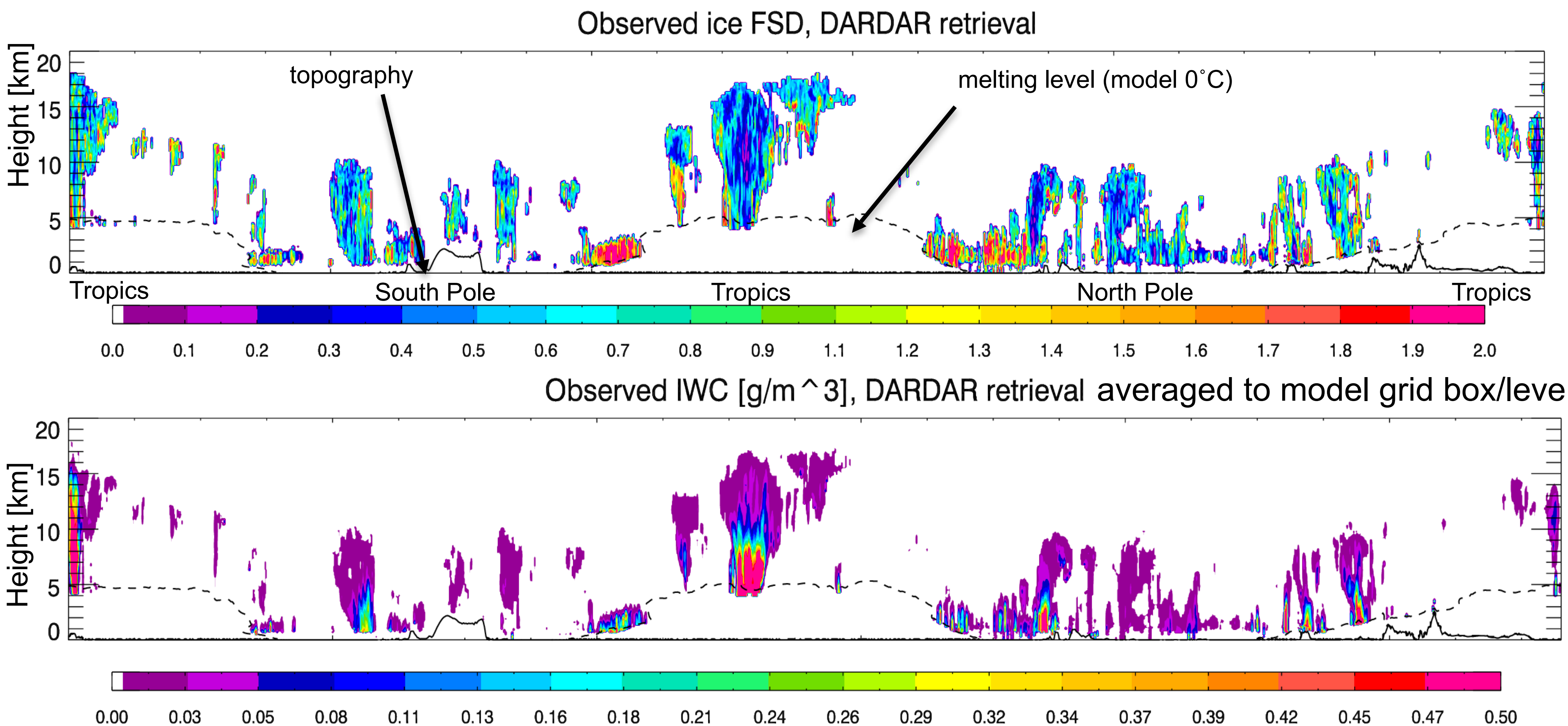
Shading: mean FSD



DARDAR IWC retrieval, based on CloudSat/ CALIPSO/MODIS (Delanoe and Hogan, 2010)

Individual sample track - one orbit

- Deep clouds reaching the tropopause – can have lower FSD
- Clouds just peaking above the melting level - have high FSD
- Could this be a lifetime effect?



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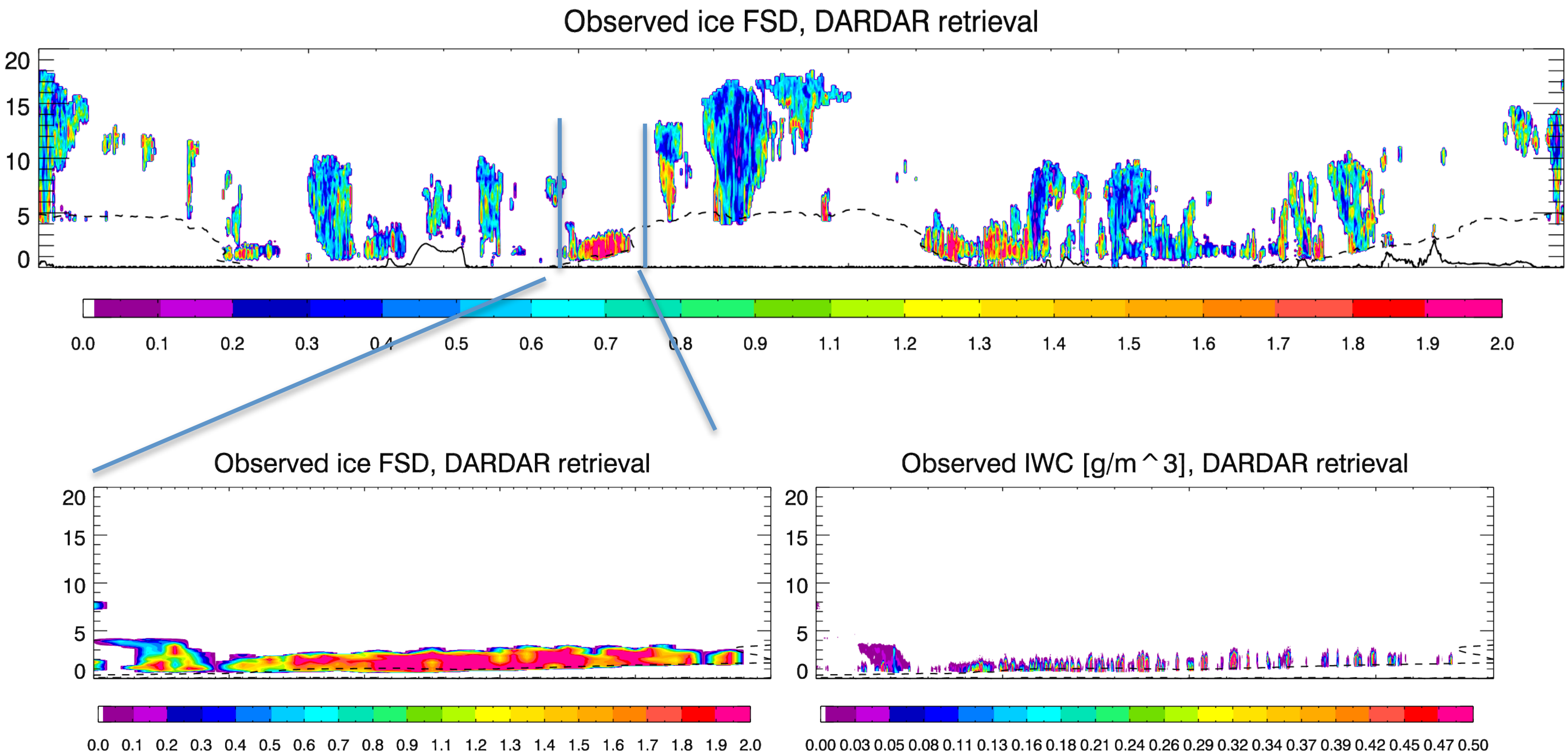
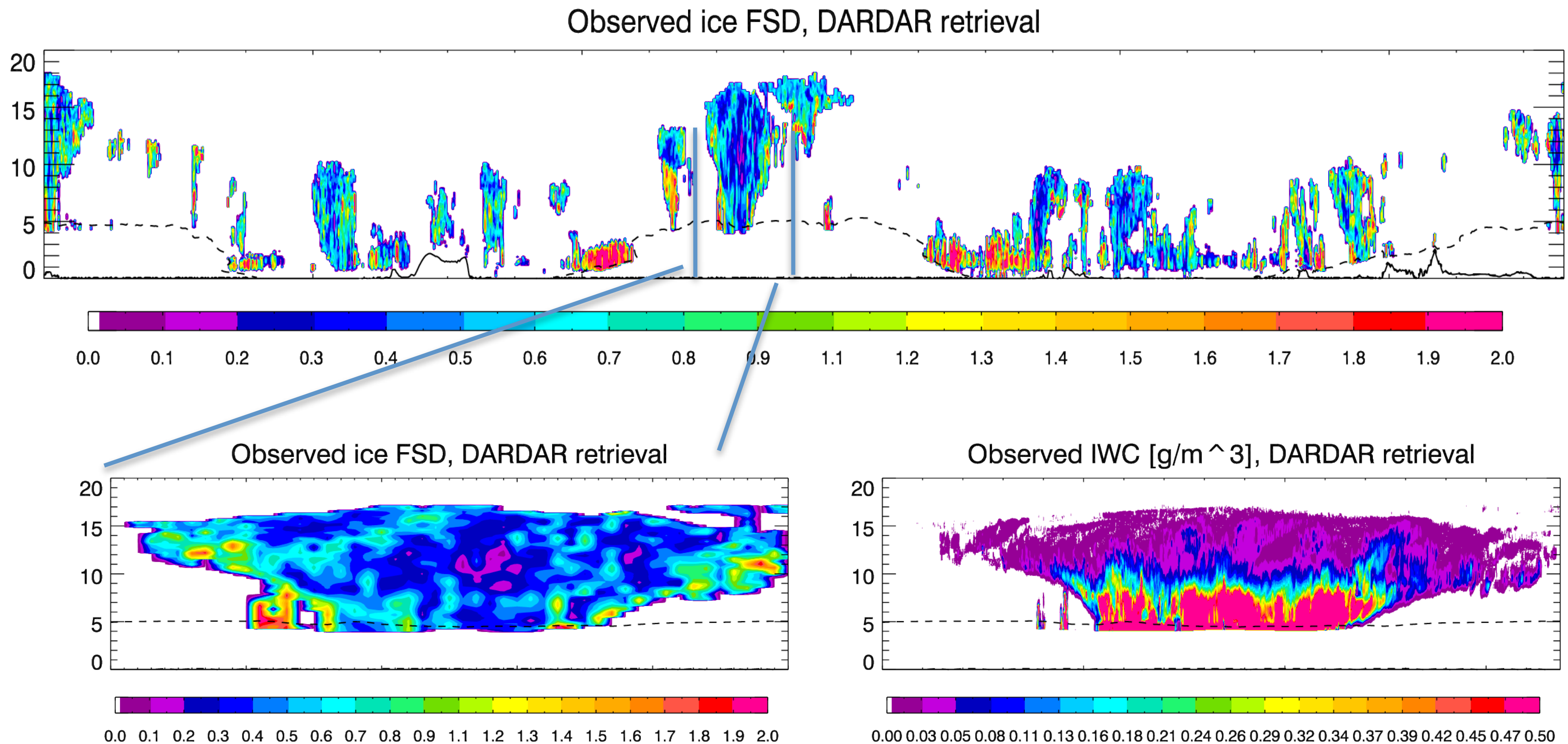


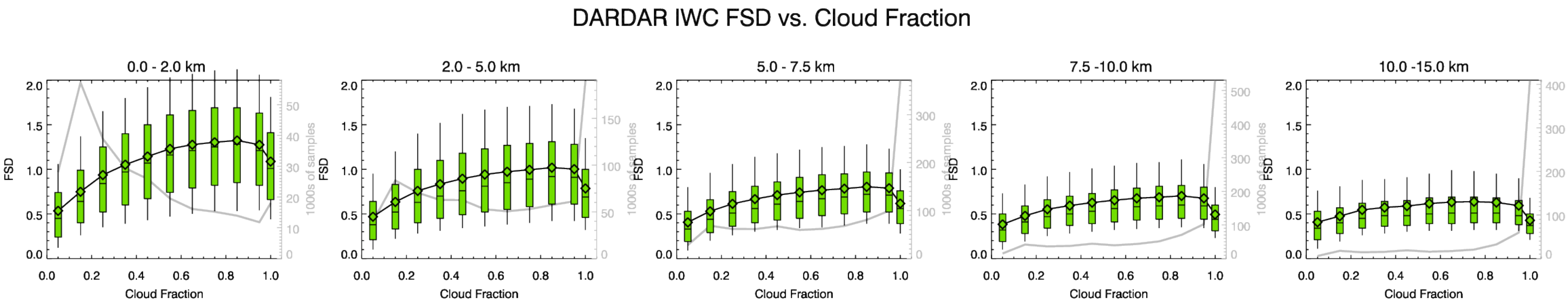
Greater FSD for “immature” clouds, just pushing above melting level, little stratiform outflow

Individual sample track - one orbit



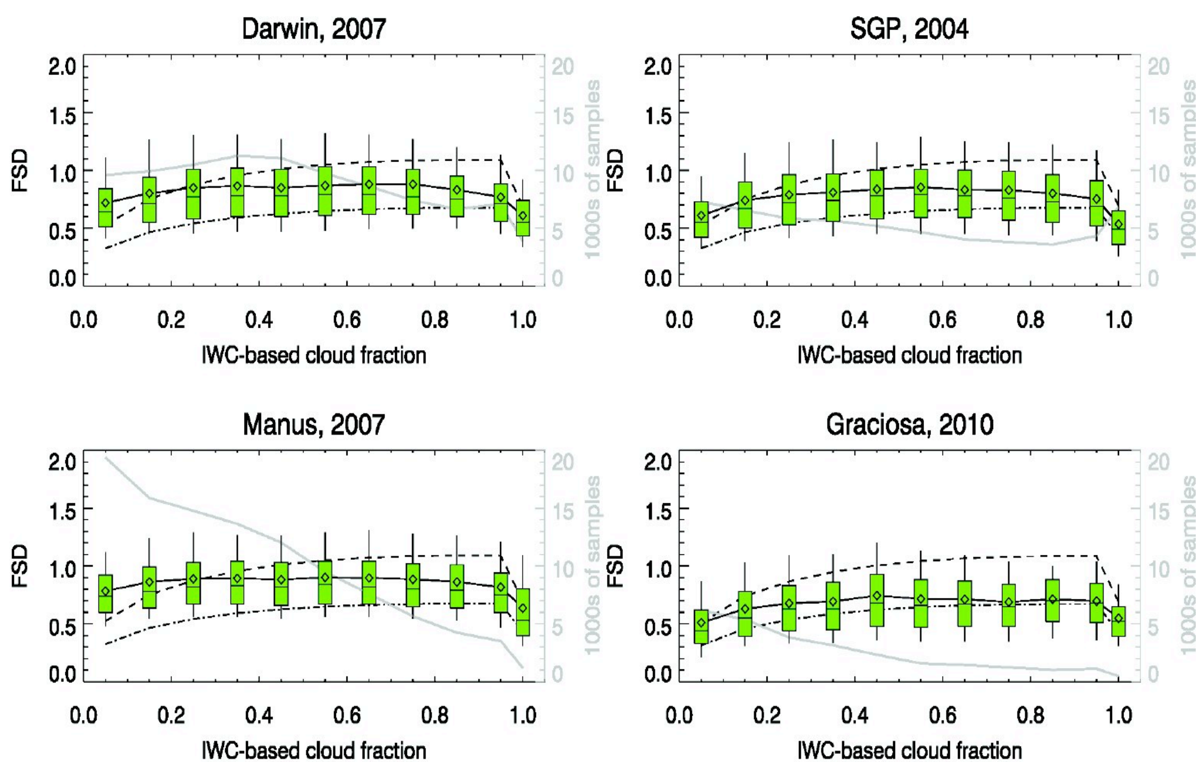
"Mature" convective clouds/systems reaching to the tropopause have lower FSD

Observed ice FSD - stratified by cloud fraction and "cloud top distance from melting level"



Cloud tops near melting level

Clouds reaching the tropopause



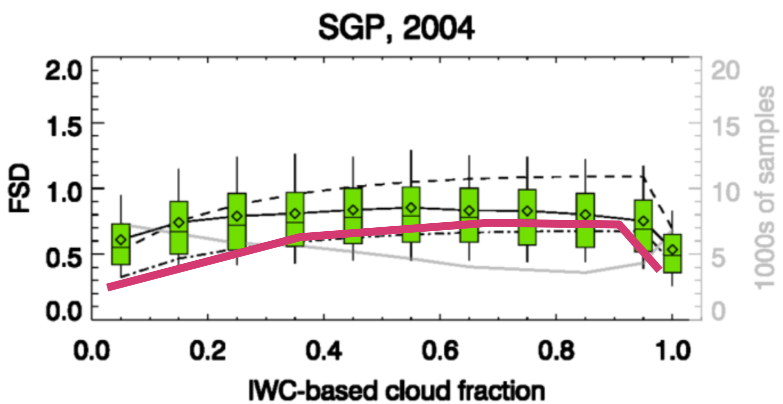
ECMWF

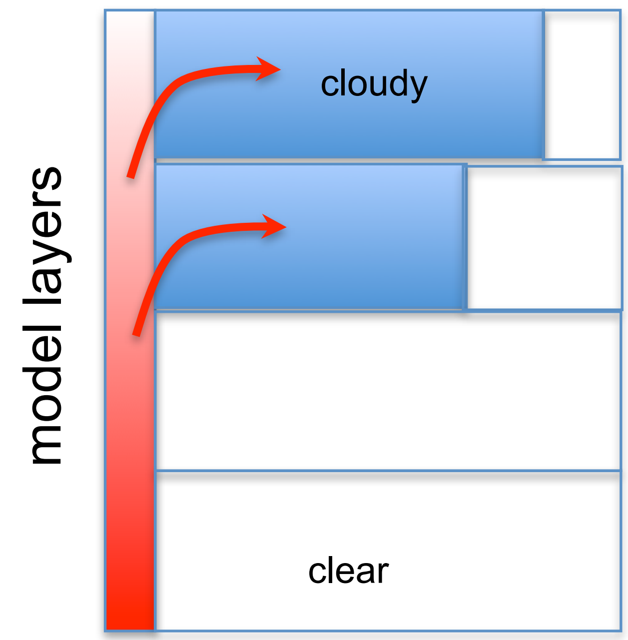
How to parameterize in the model?

Prognostic cloud scheme – has some memory

1) Background FSD dependent on cloud fraction

(loosely based on Hill et al. 2015)



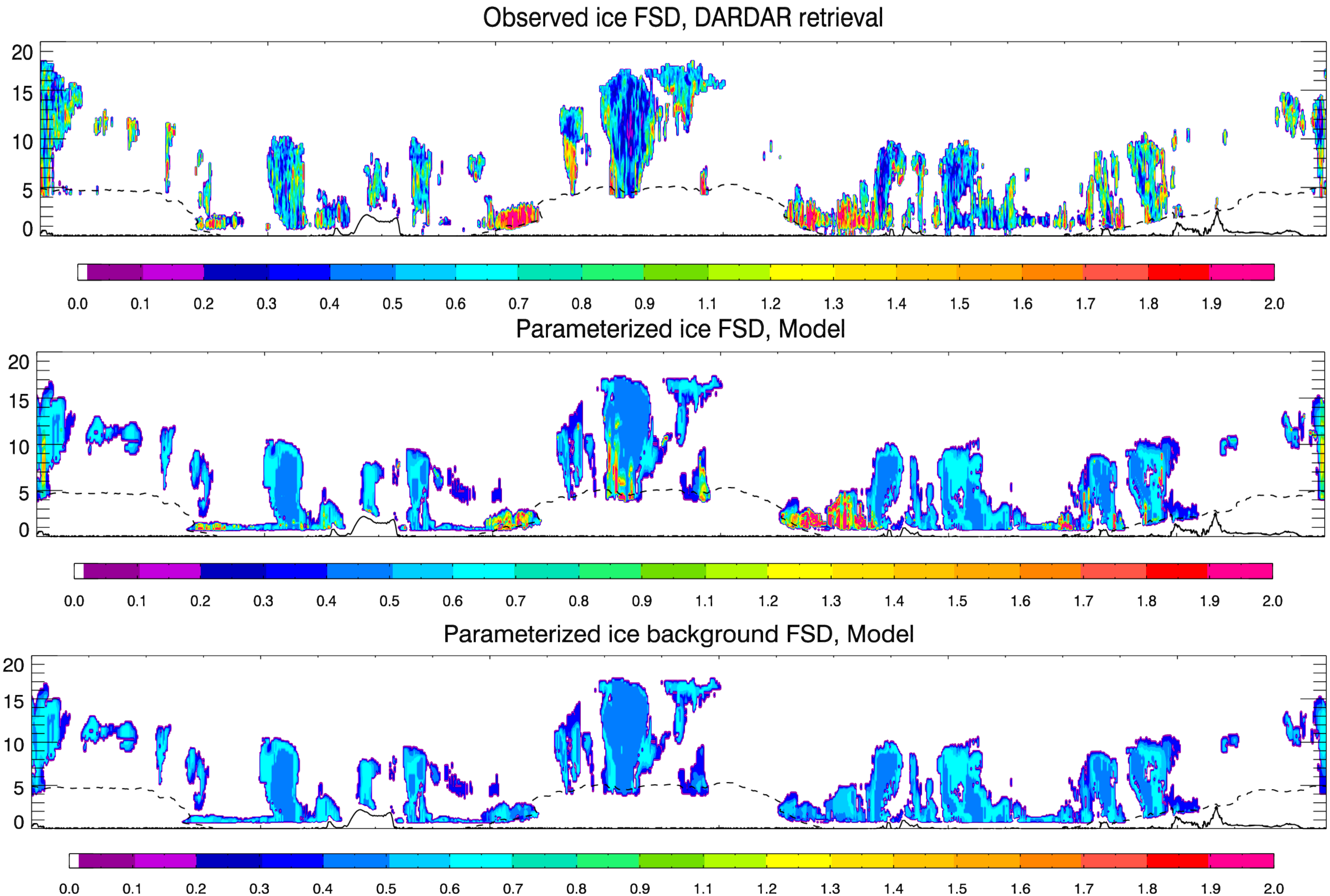


<u>Tiedtke scheme:</u>
mass detrained from convection is source term for mass in stratiform cloud scheme

2) Ratio of detrained mass to existing cloud condensate as proxy for life stage of cloud

Is the convection actively creating new cloud (large ratio)?

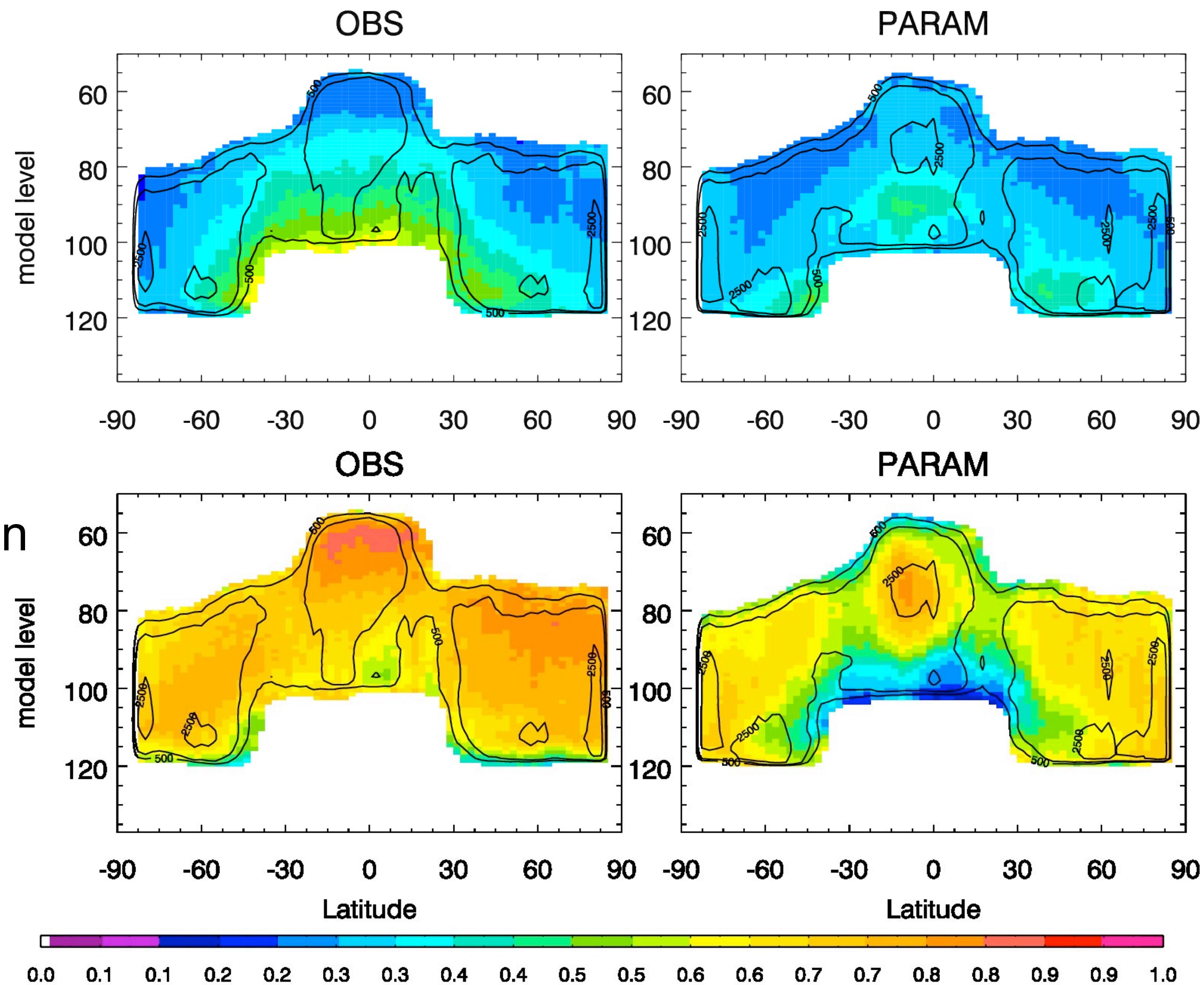
Parameterized ice FSD for a single track



Captures some of the key features, but still needs some fine tuning...

FSD (contour: sample count)

Cloud Fraction



Convolution of model errors in cloud (&precip):

- occurrence
- amount when present
- with imperfect parameterized relationships