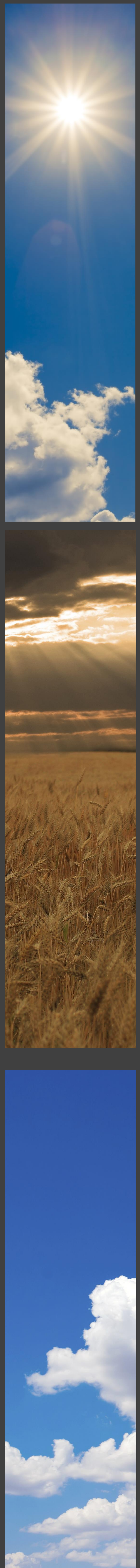

Condensate variability in ice clouds – a life time effect?

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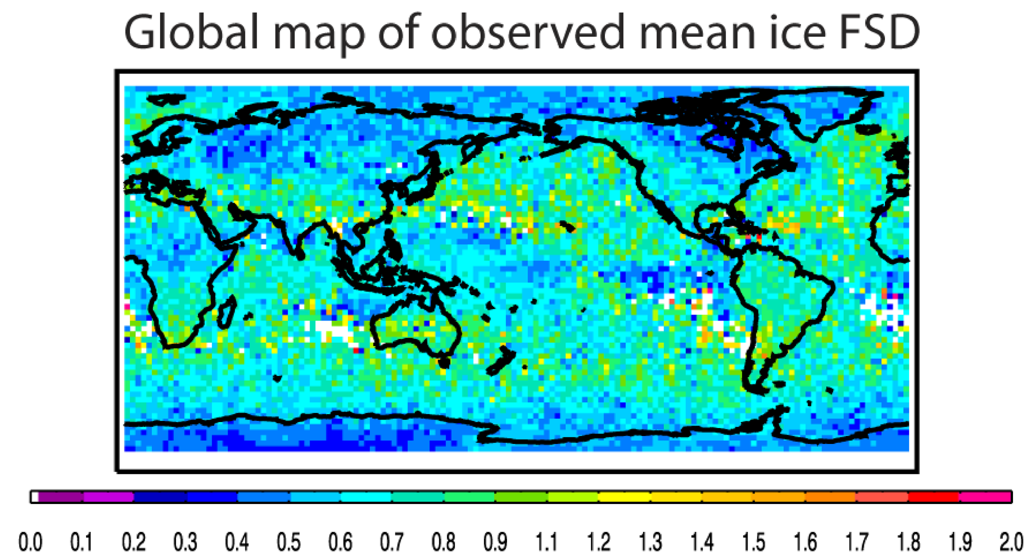
1. Introduction

Radiation and microphysics act on scales much finer than those typically represented in global models. For schemes predicting grid box mean cloud properties (such as the ECMWF model) the effect of subgrid-scale heterogeneity of clouds on these processes has to be parameterized. Here, we are trying to characterize how condensate variability in ice clouds varies across the globe.

Ground-based retrievals of ice cloud condensate can be hampered by signal attenuation during heavy precipitation events, making it more difficult to observe ice condensate variability across the full range of meteorological situations. Satellite-derived retrievals from CloudSat and CALIPSO provide a complementary perspective in this case. Results shown here are from the DARDAR ice condensate retrieval for the month of January 2008 (Delanoë and Hogan 2010).

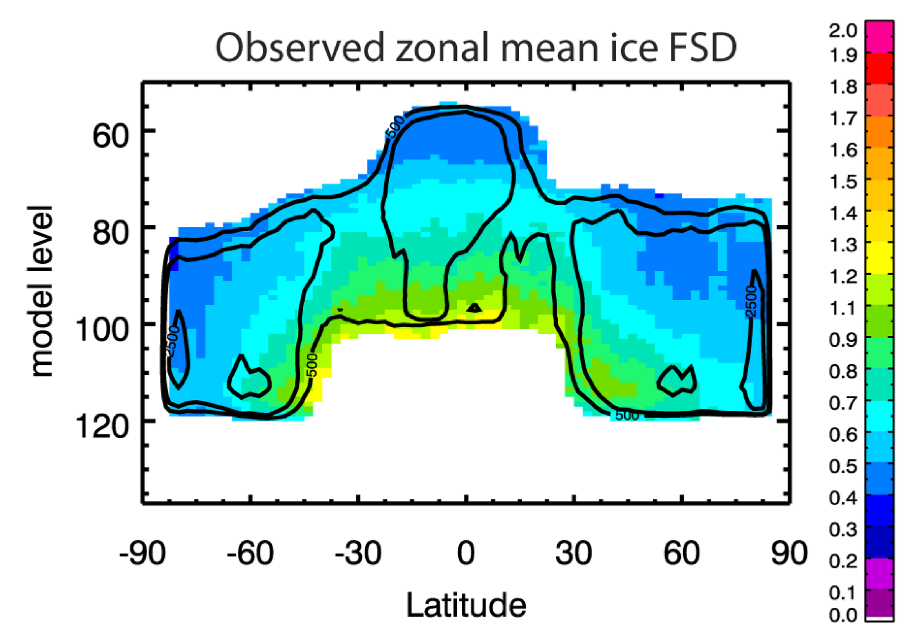
2. Condensate variability is greater in convective regions

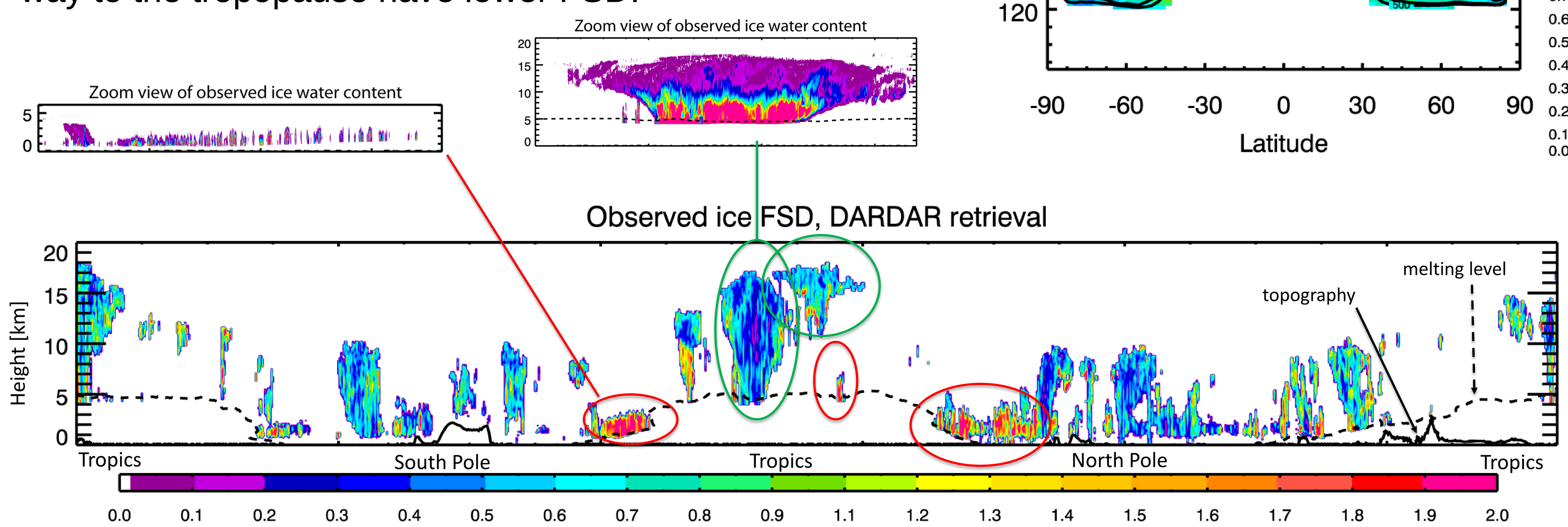
Maybe not surprisingly, areas associated with deep convection have greater condensate variability in the long-term mean. This map shows monthly mean ice condensate characterized in the form of a fractional standard deviation (FSD, standard deviation divided by the mean). The observations are mapped onto the model grid (~40km horizontal resolution) and an FSD value is calculated for each grid point and level. These samples are then averaged over a month for each 2.5˚ latitude/longitude bin.



3. Apparent height dependence – a lifetime effect?

When averaged in the zonal mean, condensate variability appears to decrease with height. However, this view does not tell the full story. Individual clouds do not necessarily show a pattern of decreasing condensate variability with height. Rather, clouds with tops nearer the melting level tend to have higher FSD, while clouds reaching all the way to the tropopause have lower FSD.



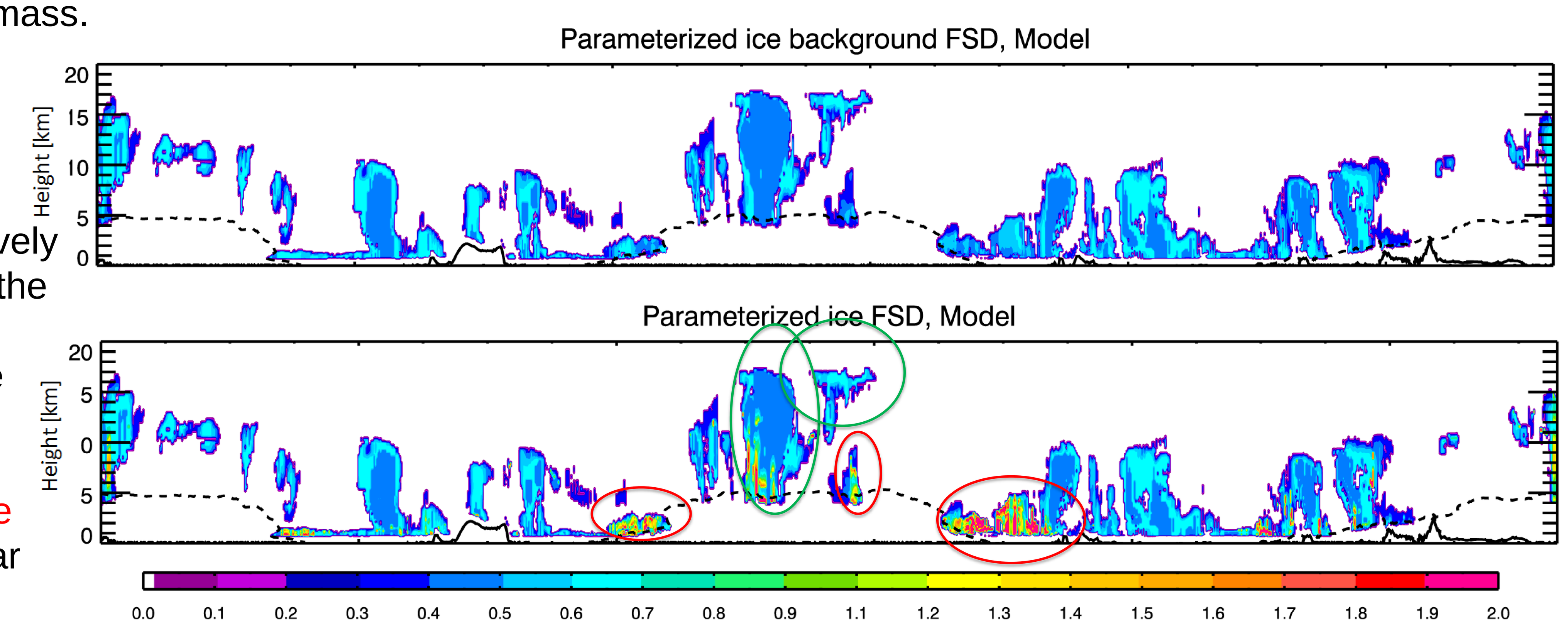


We hypothesise that this is an expression of a life-time effect: Immature, actively growing convective clouds with lower tops show greater FSD, while more mature deep convective systems with large anvil outflow tend to have lower FSD.

4. Parameterization in the model

In the prognostic cloud scheme of the IFS, detrained condensate from the convection scheme is a source of moisture for the stratiform cloud. This provides a limited amount of "memory" for the cloud's life stage. If the detrained cloud mass is much greater than any existing stratiform cloud mass, then convection is playing an active part in creating new cloud – the cloud is "young". If convective detrainment is relatively small compared to the existing cloud mass, then the cloud is likely more mature and in a less actively developing phase. The proposed parameterization combines a cloud-fraction dependent background FSD (loosely based on Hill et al. 2015) with a component dependent on the ratio of detrained to stratiform condensate mass.

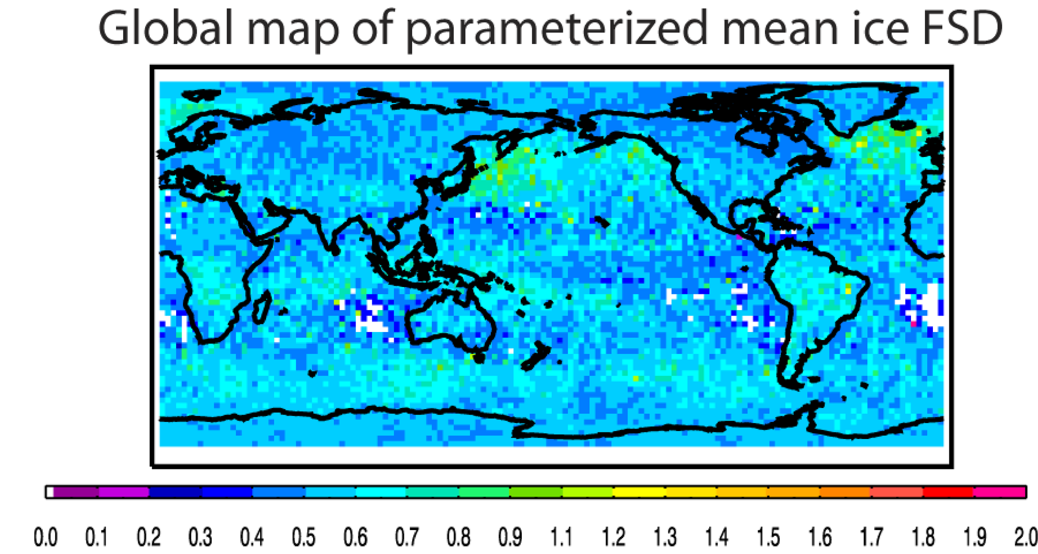
The cloud fraction dependent background FSD is relatively uniform, but the contribution based on the convective detrainment enhances the FSD in similar areas as observed.

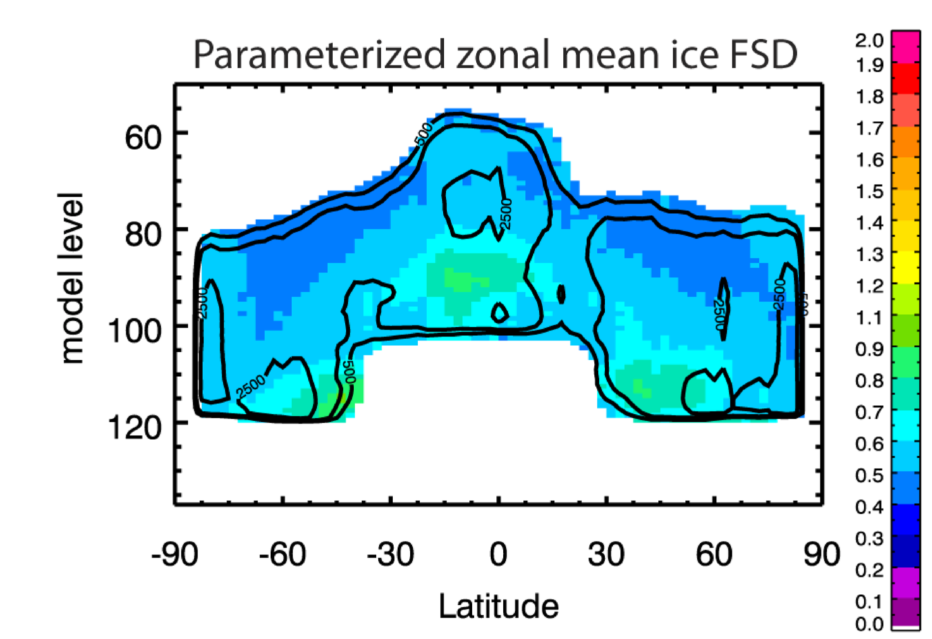


The model output from short-term forecasts is extracted along the satellite track for the cross sections above. These cross sections are then treated the same as the observations for the monthly averages shown below.

6. Summary

The new parameterization manages to capture the key features of the observed condensate variability for ice: FSD is enhanced in deep convective regions and just above the melting level. However, the overall monthly mean FSD remains low compared to observations. Several factors contribute: The model underestimates cloud fraction in the mid-troposphere, yet produces clouds more frequently at this height (black contours in the zonal mean figures show sample numbers), thus counting more low-FSD samples on average. This is a difficult area to assess, since ice and snow both contribute to the observed radar reflectivity, and a comparison with the model is not straight forward. But it also appears that the model convection scheme is not always active when high FSD is observed. The scheme needs a bit more development to perform well.





References:

Delanoë, J., and **R. J. Hogan** (2010), Combined CloudSat-CALIPSO-MODIS retrievals of the properties of ice clouds, *J. Geophys. Res.*, **115**, D00H29, doi:10.1029/2009JD012346.

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