A Literature Survey on Parameterization of Cirrus Ice

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Introduction

-Cirrus clouds are the highest of clouds in the troposhere

-Cirrus clouds form above 6 km in altitude and are composed of ice crystals

-The temperature of cirrus are generally below -20°C

-Cirrus clouds cover about 20% of the globe

-Cirrus clouds are trapping the outgoing terrestrial radiation, and reflecting the incoming solar radiation

-Depending on their properties, cirrus clouds can cause either warming or cooling at Earth's surface

-Tropical cirrus have been shown, in general circulation models and satellite studies, to have a major effect on the Earth's radiation balance

Properties to Parameterize

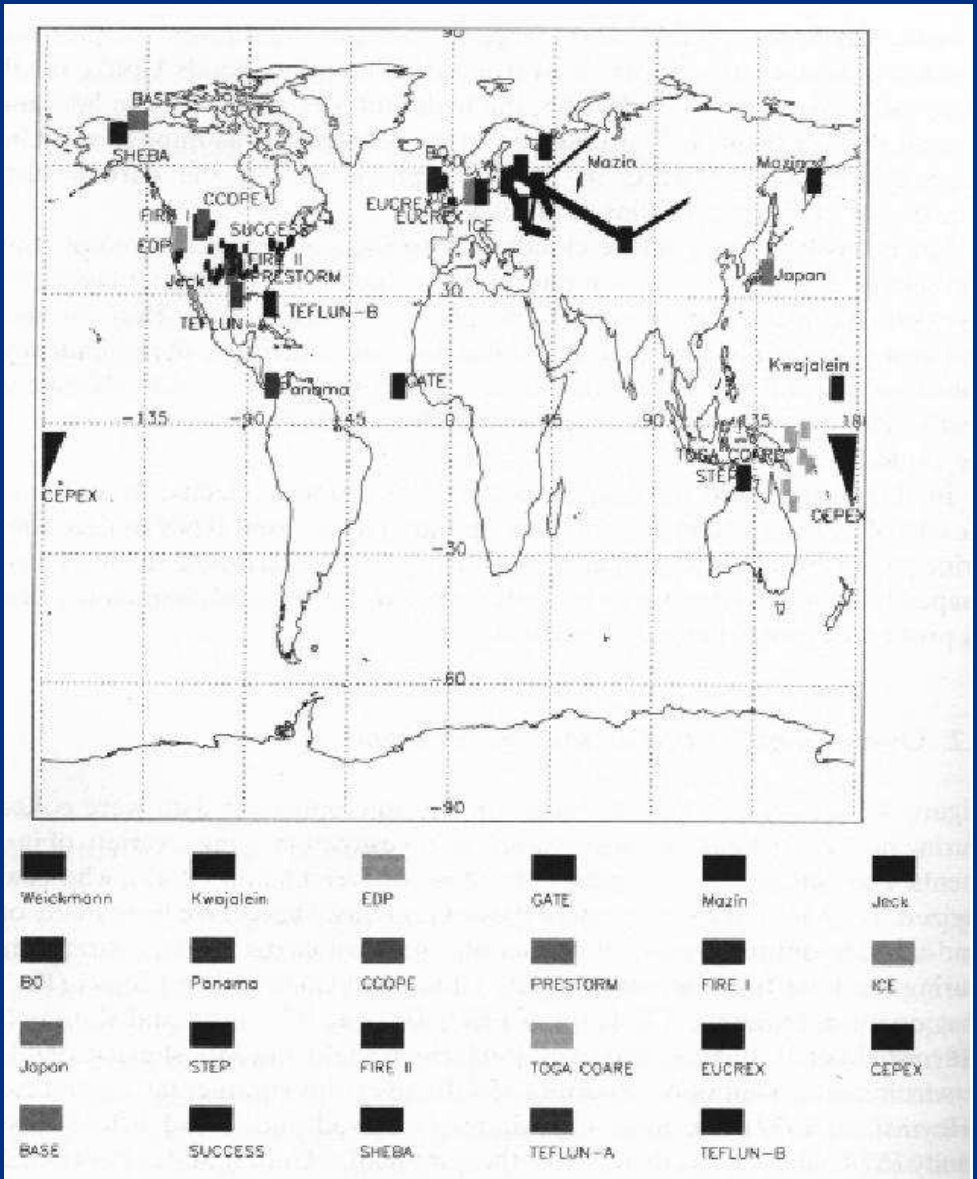
-Because of uncertainties about the properties of cirrus clouds they are not well treated in climate and forecasting models

-Measurements are needed to better parameterize cirrus clouds properties

-Properties that are important to parameterize are ice crystal size and shape distribution, and how the ice crystal size distribution depends on ice water content (IWC) and temperature, and how the shape distribution depends on temperature, cloud types, and where in the clouds the crystals are etc.

-It is also important to look for differences between mid latitude cirrus and tropical cirrus

Overview of Previous in situ Measurements



-There have been a number of in situ measurements campaign of mid latitude and tropical cirrus

← Locations were in situ measurements of cirrus have been done. (from Heymsfield and McFarquhar)

Comparison of some Previous Measurements

-Heymsfield and Platt (1984) (EDP) used a data set from in situ measurements with a forward scattering spectrometer, a 1-D optical array probe, and a 1-D probe to measure ice crystal size distribution in mid latitude cirrus

-McFarquhar and Heymsfield (1997) (CEPEX) studied two in situ measurements from a video ice particle sampler (VIPS) and a 2-D cloud probe to find the particle size distribution of tropical cirrus

-Ivanova et al. (2001) (ARM and FIRE II) studied two in situ measurements with a forward scattering spectrometer probe (FSSP) and a laser imaging 2DC probe to find the particle size distribution of mid latitude cirrus.

-Donovan (2003) estimated the ice cloud effective particle size using combined lidar, radar reflectivity, and average radar Doppler velocity for mid latitude cirrus

Parameterization

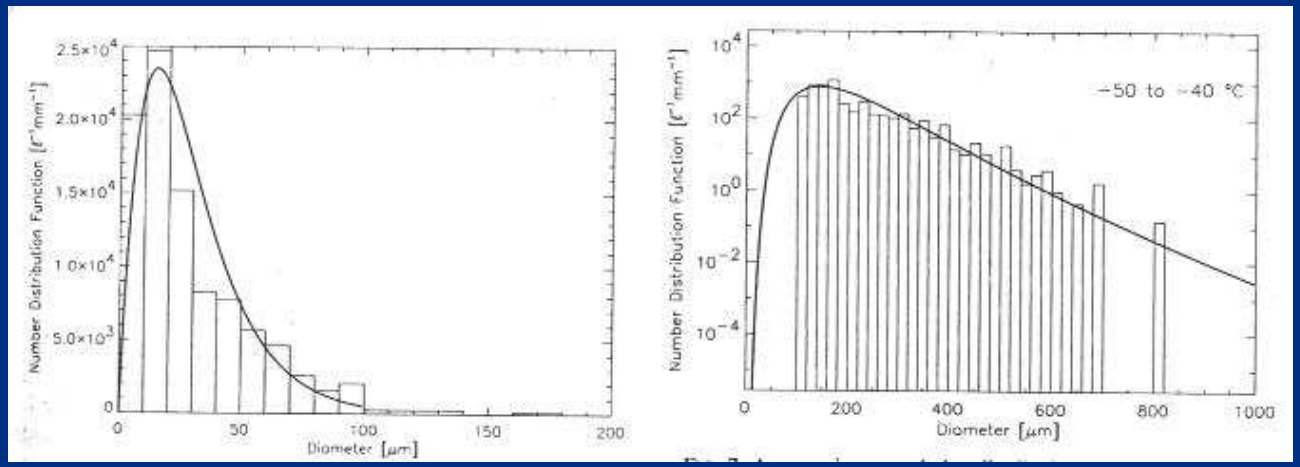
-Heymsfield and Platt (mid latitude cirrus) found that the particle size distribution in each temperature intervall could be represented by at most two curves of the form $N=AD^B$

-Given T and IWC and using their parameters the spectra can be calculated

-McFarquhar and Heymsfield (tropical cirrus) parameterized a first order gamma distribution for small crystals and a lognormal distribution for large crystals

-Given T, IWC, and some constants the size distribution can be determined

-They did not have enough data to look for trends with T for small crystals



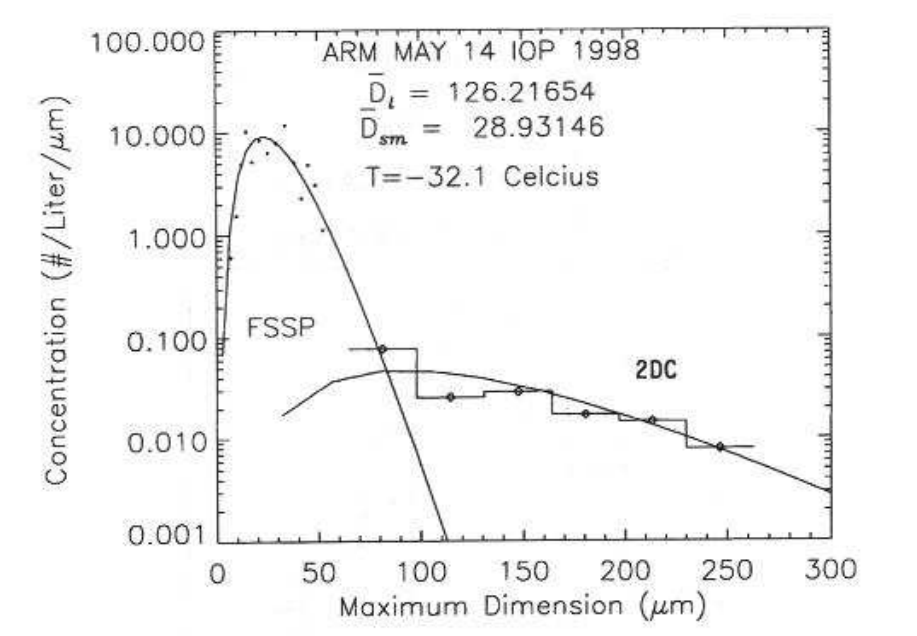
← Ice crystal spectrum and data fit. (from McFarquhar and Heymsfield)

Parameterization

-Ivanova et al. (mid latitude) parameterized a gamma bimodal size spectra for planar polycrystals with 3 gamma parameters for each mode. 3 of the parameters are constant while the other 3 depends on IWC and/or T.

$$N(D) = N_0 D^v \exp(-\lambda D) \tag{1}$$

-The input of the parameterization is T, IWC, 3 constants from measurement, and constants for planar polycrystals

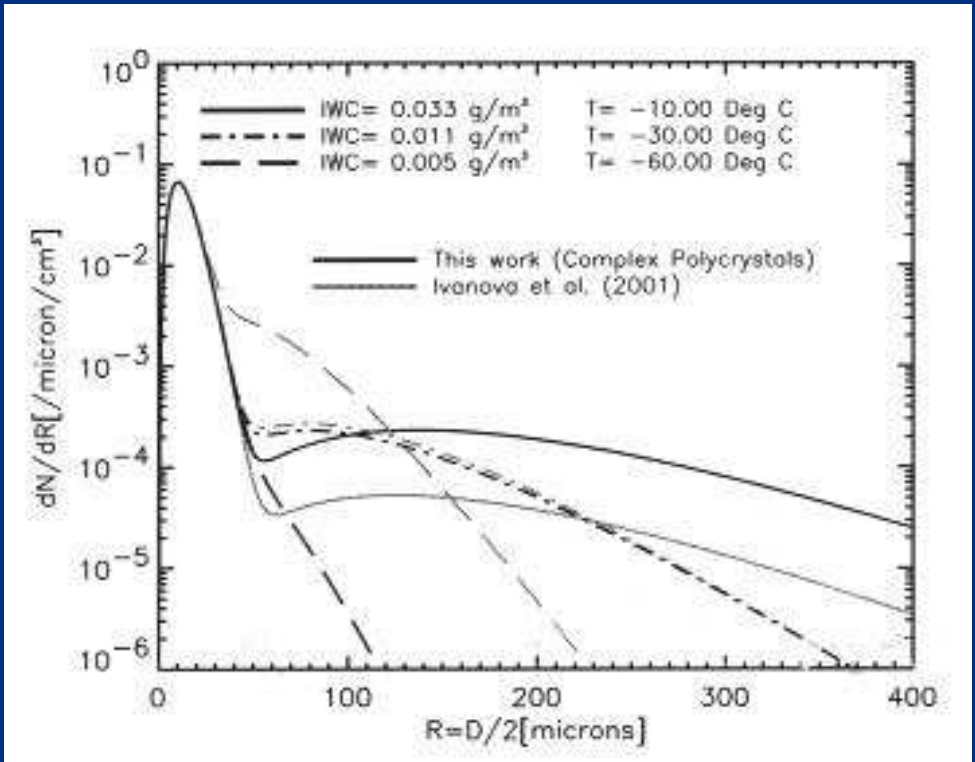


← Example of Ivanovas parameterized gamma fits. (from Ivanova)

Parameterization

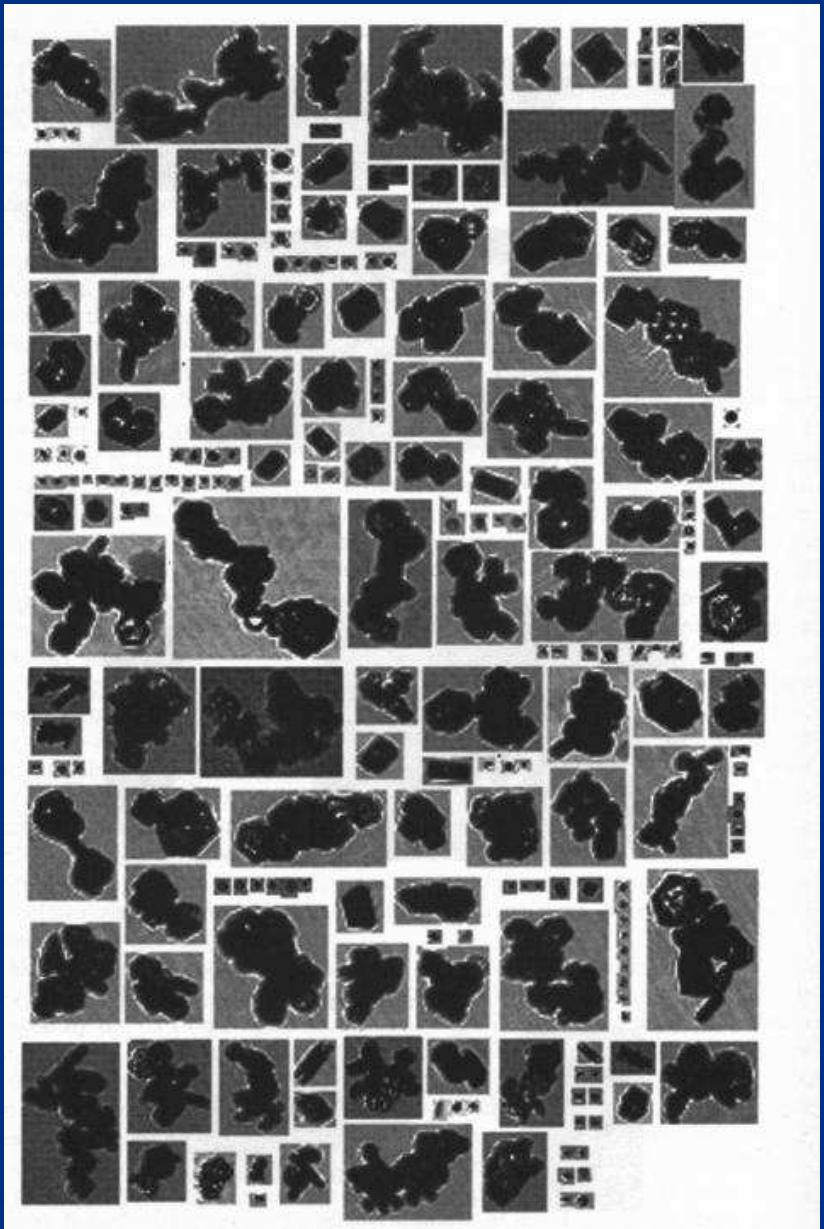
-Donovan (mid latitude) used a two mode generalized gamma distribution (similiar to Ivanova) to represent the crystal size distribution to fit his data

-The mode radius of the large particles tended to increase with both temperature and IWC whereas in Ivanovas parameterization it is a function of T alone



← Comparison of predicted size distribution of Donovans and Ivanovas parameterization. (from Donovan)

Shape Distribution



-There are many different crystal shapes that have been observed in cirrus

-Heymsfield and Platt described the crystal shapes in mid latitude cirrus for different temperature ranges, for different types of cirrus, and if the crystals are within the cloud or near cloud top

-The shape of crystals in tropical clouds are poorly known

← Crystal images recorded by CPI (1998) during TEFLUN-B. (from Heymsfield and McFarquhar)

Results from the Measurements and Parameterization

-I have compared 3 mid latitude, and one tropical cirrus parameterizations

-They all found that the particle size spectra depends on both temperature and IWC

-They also all use a bimodal ice particle size distribution

-Heymsfield and Platt's mid latitude parameterization is only for crystal dimensions greater than 20μm

-Ivanova's and Donovan's mid latitude parameterizations are for the whole particle size spectra and are more sophisticated than Heymsfield and Platt's

-Ivanova's and Donovan's parameterizations are similiar for high temperatures, but differ at predictions for low temperature and small crystals

-There are more articles of interest that I have not had time to go trough, one example is Evans et al. "Submillimeter-wave cloud ice radiometer: simulations of retrieval algorithm performance".

References

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[3] McFarquhar, G.M., Heymsfield, A.J., *Parameterization of tropical cirrus ice crystal size distibutions and implications for radiative transfer: results from CEPEX*, J. Atmos. Sci.,54, 2187-2200, 1997

[4] Donovan, D.P., *Ice-cloud effective particle size parameterization based on combined lidar, radar reflectivity, and mean Doppler velocity measurements*, J. Geophys. Res., 108, 18, 2003

[5] Ivanova, D., Mitchell, D.L., Arnott, P.A., Poellot, M., *A GCM parameterization for bimodal size spectra and ice mass removal rates in mid-latitude cirrus clouds*, Atmos. Res., 59-60, 89-113, 2001