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# 7.7 A Near-Global Survey of Cirrus Particle Size Using ISCCP

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## 1. INTRODUCTION

Cirrus is the most frequently occurring and widely distributed cloud type. The average annual frequency of occurrence for cirrus is 34% and its global coverage is about 20-30% (Warren et al. 1985). It strongly influence weather and climate processes through its effects on the radiation budget of the earth and the atmosphere (Liou 1986). Microphysics of cirrus is a critical component in understanding cloud-climate radiative interactions. For example, ice water content feedback is positive from a 1-D model study. But the feedback is substantially reduced upon the inclusion of small ice crystals (Sinha and Shine 1994). Due to the complexity caused by the non-spherical shape of ice crystals in cirrus, retrievals of cirrus properties are difficult. In recent years, advances have been made both in models and in case studies (e.g., Takano and Liou 1989, Young et al. 1994), but no global scale survey has been conducted.

Similar to our previous near-global survey of droplet sizes of liquid water clouds (Han et al. 1994), a survey of cirrus ice crystal sizes is conducted over both continental and oceanic areas. We describe a method for retrieving cirrus particle size information on a near-global scale (50°S to 50°N) using currently available satellite data from ISCCP. To retrieve cirrus particle size, we use a radiative transfer model that includes all major absorbing gases and cloud scattering / absorption to compute synthetic radiances as a function of satellite viewing geometry. Ice crystal shapes are assumed to be hexagonal columns and plates. The model results have been validated against clear sky observations and are consistent with the observed radiance range under cloudy conditions.

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The initial results of this near-global survey show that the peak frequency of cirrus crystal effective diameter $D_e$ for hexagons is about 70 μm, the mean value corresponding to a 26.5 μm radius for an equivalent sphere. The survey also reveals that about 14% of the small crystal sizes are less than 23 μm in diameter. The geographical distribution of small crystal sizes is consistent with the results of Prabahakara et al. (1988). There are no significant differences between particle sizes of continental and maritime cirrus.

## 2. MODEL AND DATA

The radiative transfer algorithm is based on the model developed by Lacis and Hansen (1974). The atmosphere is divided into twelve plane-parallel layers that are horizontally homogeneous. The temperature and humidity profiles can be arbitrarily prescribed from other datasets. Solar irradiance data come from Neckel and Labs (1984). The absorbing constituents of the atmosphere include $H_2O$, $CO_2$, $O_3$, $O_2$, $N_2O$, $CH_4$ for line absorption and $H_2O$, $O_3$, $N_2$ for continuum absorption. Surface reflectance can be prescribed either as Lambertian or bi-directional reflectance with a specific model used for water surfaces (Rossow et al., 1989). Clouds are inserted into the atmospheric model as horizontally homogeneous layers. Mie scattering and the doubling and adding method are utilized to compute multiple scattering in clouds. Twelve Gaussian points are used to account for different solar zenith angles. The standard gamma-distribution is used for the cloud drop size distribution. This distribution agrees with experimental data for stratus, altostratus and fair weather cumulus (Hansen, 1971). The correlated k-distribution method (Lacis and Oinas, 1991) is used to model gaseous line absorption in a vertically inhomogeneous atmosphere. The model results have been validated against clear sky observations and are consistent with the observed radiance range under cloudy conditions. A method has been developed for estimating instrument noise and accounting for its effects on the analysis. Error sources and the range of their contributions are included for each retrieved cloud particle size (Han et al. 1994).

Shapes of ice crystals are assumed to be hexagonal columns and plates. The effective size of crystals is defined, following Fu and Liou (1993), as

$$D_e = \frac{\int_{L_{min}}^{L_{max}} D^2 \cdot n(L) L dL}{\int_{L_{min}}^{L_{max}} D \cdot n(L) L dL}$$

Five different size distributions from observations are used, i.e., cold cirrus ($D_e$=23.9 μm), warm cirrus ($D_e$=47.6 μm), -40°C cirrus ($D_e$=64.1 μm), Nov. 1 cirrus ($D_e$=75.1 μm) and Cirrus uncinus ($D_e$=123.6 μm). Phase functions of these five size distributions for channels 1 and 3 (Ou and Takano 1994, personal communication) are applied in the model for calculations of multiple scattering. Thermal emission of channel 3 is calculated according to channel 4 radiances based on same emissivity assumption. Ocean reflectance of channel 3 is taken as 0.025, according to theretical model (Takashima and Takayama, 1981) and satellite observations (Han 1992).

The dataset used to retrieve cirrus effective sizes is the ISCCP (International Satellite Cloud Climatology Project) analysis (Rossow and Schiffer, 1991) at the individual pixel level. These CX data are a combination of ISCCP B3 data (Schiffer and Rossow, 1983) and the cloud detection and radiative model analysis results that describe cloud and surface properties at original B3 image resolution. Specifically we use the results from AVHRR observations, which contain the radiances of all 5 AVHRR spectral channels. The atmospheric temperature and humidity profiles needed in our retrieval are taken from NOAA TOVS data. Details are described in Han et al. (1994).

## 3. RESULTS

The following table lists the mean value of ice particles in equivalent radius (in μm) for 1987.

| | Jan | Apr | Jul | Oct | Annual |
|---|---|---|---|---|---|
| Ocean | 26.0 | 26.7 | 26.7 | 26.0 | 26.3 |
| Land | 25.6 | 27.6 | 29.1 | 27.2 | 27.6 |
| Ocean+ Land | 26.2 | 27.0 | 27.5 | 26.3 | 26.7 |

Figure 1 shows the histogram of effective sizes of cirrus over global ocean and continent regions for July 1987. Cirrus is determined by cloud top temperature below 240 K from ISCCP CX data. It reveals that the peak frequency of cirrus crystal effecive sizes is about 70 μm. It also displays that there are about 14% of small crystal sizes less than 23 μm.

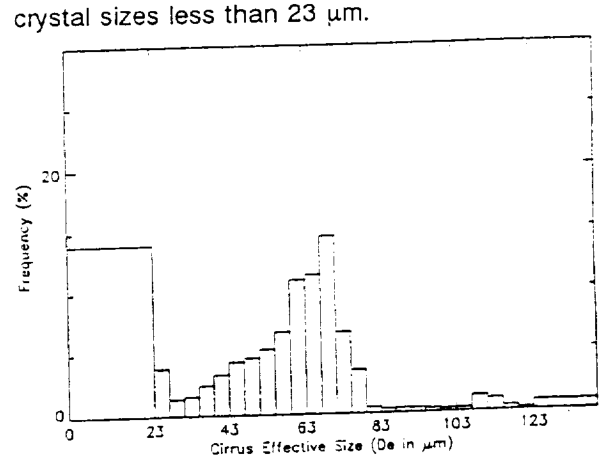


**Fig. 1. Histogram of cirrus effective sizes for July 1987.**

Figure 2 is a near-global survey of ice crystal effective sizes for July 1987. The geographical distribution of small crystal sizes is consistent with the result by Prabahakara et al. (1988).

## 4. DISCUSSION

Unlike the contrast of droplet radius of liquid water clouds between continent and maritime clouds, crystal sizes of cirrus clouds dc not show much differences between continent and maritime clouds. It appears that the microphysics of low-level liquid water clouds are affected by CCNs near the ground whereas the microphysics of cirrus clouds are influenced by upper air aerosols. Observations of CCN vertical profiles from five different geographical locations (Hoppel et al. 1973) found that at higher altitudes (around 3.5 km), there are no systematic differences between oceanic and continental environments.

The phase functions used in this study are from five different cirrus size distributions. The different size distributions may play a role in determining the scattering properties and thus affect the retrieved effective sizes. We are investigating the effect of size distributions on crystal size retrievals, which requires more observational data about crystal size distributions and model calculations based on realistic assumptions.

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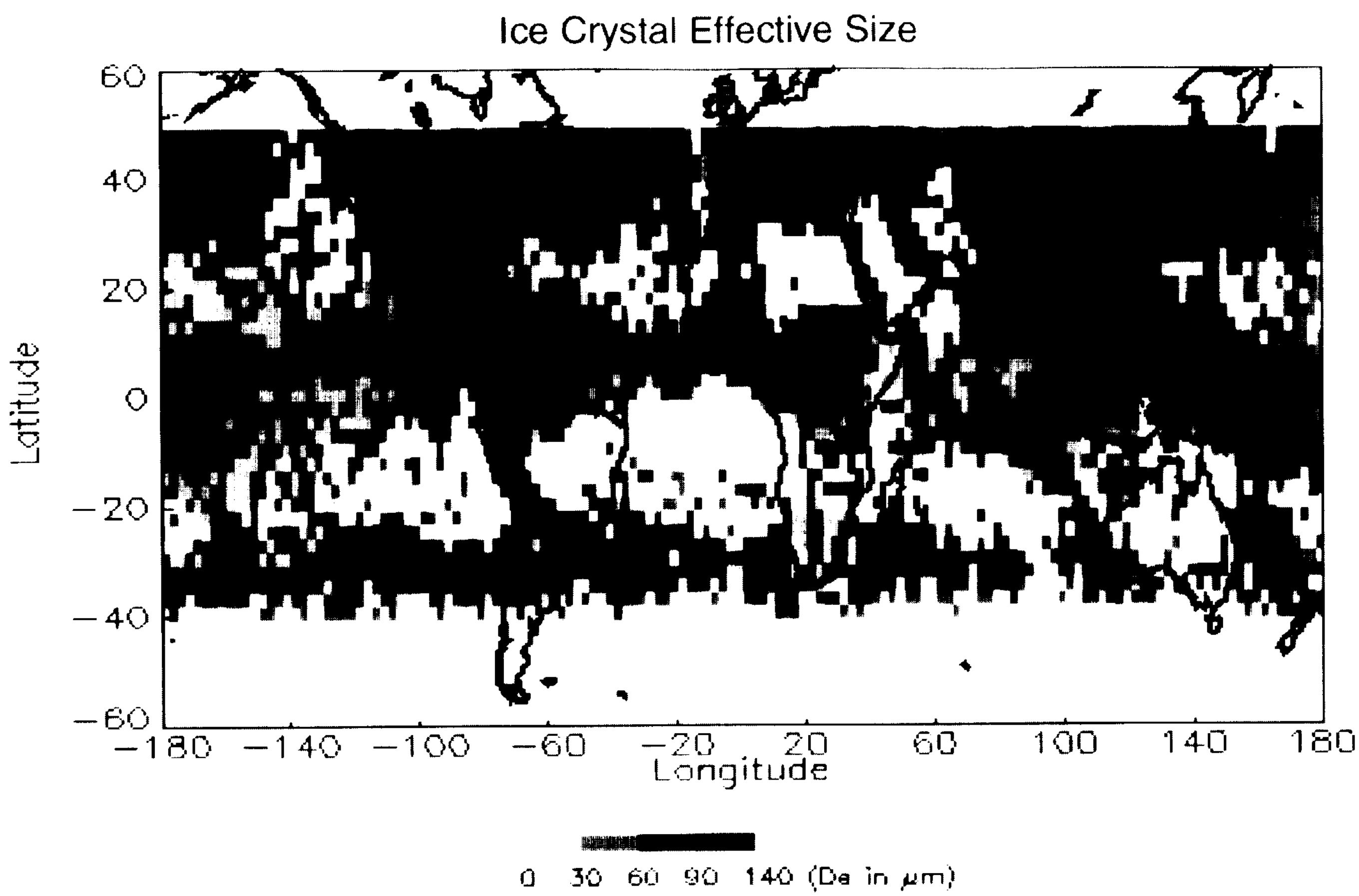


Fig. 2. Near global survey of ice crystal effective sizes for July 1987.