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Final report of NAG-3922
"Global Retrieval of cloud particle size and optical thickness using ISCCP data"

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The primary thrust of this investigation is to develop an algorithm to retrieve cloud particle sizes using ISCCP data. The research under this grant has been successful in obtaining initial results of global distribution of ice-particle sizes. Further research about possible problems caused by nonsphericity of ice particle sizes is currently underway.

1. Research Results

Following the global survey of cloud droplet sizes of water clouds (Han et al., 1994), the research under NAGW-3922 has been successful in retrieving ice-cloud particle sizes in a near-global scale and achieved the following results:

1.1 Developing an Algorithm for Retrieving Ice Particle Sizes

An algorithm of retrieving ice-cloud particle sizes using ISCCP CX data has been developed. This scheme is based on phase functions of hexagonal columns supplied by Dr. Takano at the University of Utah using the ray tracing technique. The threshold of $Tc < 240$ K is used for ice-cloud detection. The radiative transfer model adopted to calculate synthetic radiances is the same model used to retrieve water cloud microphysics (Han et al. 1994).

1.2 The First Near-Global Survey of Ice-Particle Size

The first survey of ice-particle size in a near-global scale has been completed. Using the developed retrieval scheme and ISCCP CX data, ice-cloud particles over ocean areas, which has a simple surface reflectance pattern, are retrieved as the first step (Han et al. 1995). Then, land surface reflectances are included in the retrieval (Han et al. 1996a). Comparison with in situ measurements of ice crystal sizes during FIRE I shows good agreement. The initial results show that the global mean size of ice crystals (De) is about 60 micron. This result is consistent with the range of in situ measurements all over the world if definitions of effective particle size are unified (see next section). The survey also shows that there is no distinct difference of ice-particle sizes between continental and maritime ice-clouds. This can be explained by the uniform background aerosol concentrations in the upper troposphere all over the world.

1.3 Comparisons Between Different Definitions of Effective Ice Particle Size

There are many different definitions of effective particle size used in ice-cloud research. Simple comparisons between values of in situ measurement and satellite remote sensing are misleading and may lead to incorrect conclusions. We reviewed different definitions of effective particle sizes used in the literature and compared their relative magnitudes. The results show that effective diameter

De is about twice that of re which is used for model calculations but about the same as re used for in situ measurements. This research is a necessary step in the study of ice-cloud microphysics and parameterizations.

1.4 Investigation on Dependency of Ice Crystal Size on Temperature

Relationships between cloud temperatures/optical thickness and cirrus ice crystal sizes are of critical importance because the microphysics of cirrus clouds modifies the relationship between cloud optical depth and cloud ice/liquid water path. Climate models not accounting for this relationship cannot correctly predict the temperature dependence of infrared emittance of cirrus clouds (e.g., Platt 1989) and thus arrive at wrong conclusions about climate change. Using different techniques, regional measurements have arrive at different conclusions (Heymsfield and Platt, 1984; Platt et al., 1987; Atlas et al., 1995; Brown et al., 1995). While these data supply valuable information about this relationship, they are all regional measurements of short duration for mostly thick cirrus clouds. We investigated this relationship based on the cirrus particle size data retrieved from ISCCP CX data. We found that for thick clouds (tau > 10), similar to those found by aircraft measurements, most of the regions over the globe show positive relationships between cloud temperature and cirrus ice crystal sizes. However, if relatively thin clouds are included (tau > 3), this correlation becomes negative for tropical areas but remains mostly positive for midlatitudes. The possible explanation includes different cirrus systems over tropics and midlatitudes. The strong convective motion in the tropics brings large ice crystal particles up to very high and cold regions and spread out to form vast and relatively thin anvils. Further information about the underlying mechanism and possible explanations are under investigation.

1.5 Phase Function Selection in Remote Sensing of Ice Crystal Sizes

Most of the remote sensing techniques for retrieving ice crystal sizes assume phase functions of hexagonal columns (e.g., Ou et al. 1993, Minnis et al. 1994). However, as reported by Mishchenko et al. (1996), this approach may cause errors when aggregated ice crystals or highly irregular shapes are present in ice-clouds. Our investigation shows that phase functions of hexagonal columns are valid for simple aggregated ice crystals such as bullet rosettes; that Tc less than -25 degree C is an appropriate threshold to avoid highly irregular shapes.

2. Papers published in journals

Han, Q., W. Rossow, R. Welch, A. White, and J. Chou, 1995: Validation of Satellite Retrievals of Cloud Microphysics and Liquid Water Path Using Observations from FIRE. *J. Atmos. Sci.*, **52**, 3936-3948.

Han, Q. Y., W. B. Rossow, J. Chou, and R. M. Welch, 1998a: Global survey of the relationship of cloud albedo and liquid water path with droplet size using ISCCP. *J. Climate*, **11**, 1516-1528.

Han, Q. Y., W. B. Rossow, J. Chou, and R. M. Welch, 1998b: Global Variation of Droplet Column Concentration of Low-level Clouds. *J. Geophys. Letts.* **25**, 1419-1422.

Mishchenko, M. I., L. D. Travis, W. B. Rossow, B. Cairns, B. E. Carlson, and Q. Han, 1997: Retrieving CCN column density from single-channel measurements of reflected sunlight over the ocean: A sensitivity study. *Geophys. Res. Lett.*, **24**, 2655-2658.

3. Papers presented in conferences

Han, Q., Y., W. B. Rossow, J. Chou, and R. M. Welch, 1998e: The effect of nonspherical shape on the retrieval of ice particle sizes from satellite observations. Preprints Conf. On light scattering by nonspherical particles: Theory, measurements, and applications. P55-59.

Han, Q., W. B. Rossow, J. Chou and R. M. Welch, 1997a: Comparison of ice cloud particle sizes retrieved from satellite data derived from in situ measurements. In *Preprint 9th Conf. Atmospheric Radiation,* 2-7 Feb. 1997, Long Beach, CA, AMS, 368-372.

Han, Q., W. J. Chou, and R. M. Welch, 1998b, On the definition of ice particle size used in satellite remote sensing. Preprints in the CERES Team Meeting, 16-18, Apr. 1998, Langley, VA.

Han, Q., J. Chou, and R. M. Welch, 1997f: Relationship between Cirrus Particle Size and Cloud Top Temperature. *1997 International Geoscience and Remote Sensing Symposium (IGARRSS'97) Digest,* Singapore, Aug, 1997.

Han, Q., W. B. Rossow, J. Chou and R. M. Welch, 1996a: A Near-Global Survey of Cirrus Particle Size. In *Proceedings 8th Conf. on Satellite Meteorology and Oceanography,* Jan 28 - Feb 2, 1996, Atlanta, GA, Amer. Meteor. Soc., 369-372.

Han, Q., R. M. Welch, and J. Chou, 1995b: Retrieval of cirrus microphysics over oceans on a near-global scale using ISCCP data. *Preprints, AMS Conf. Cloud Physics*, Jan 15-20