An Analysis of the Global Climatology of Ice Cloud Effective Radius using PATMOS-X

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Introduction and Background

Satellite observations of clouds and thunderstorms have been documented since the advent of the Geostationary Operational Environmental Satellites (GOES) in the 1970's. Since the 1980's, polar orbiting satellites have been providing high resolution imagery, twice each day data over the entire globe, allowing for a more detailed analysis of cloud top features. The NOAA POES system began with NOAA-6 and 7 in 1981. NOAA-18 is the most recent, launched in 2005. The AVHRR Pathfinder Atmospheres - Extended (PATMOS-x) dataset provides cloud products from the Advanced Very High Resolution Radiometer (AVHRR) for each NOAA POES satellite. Beginning in 2000, the NASA EOS satellites (Terra and Aqua) provide similar cloud products as well as other properties, including aerosol optical depth (AOD) over land, using the Moderate Resolution Imaging Spectroradiometer (MODIS). The collection 5 monthly Level-3 (global 1x1 degree) MODIS Atmosphere Monthly Global Product, MOD08, from 2002-2006 were used to collect AOD data over land.

Aerosols, especially in the mid and lower layers of the atmosphere, have been shown to be an important mechanism in changing the microphysical properties of a cloud. Ice nucleating behavior has been observed in the atmosphere in the presence of modestly supercooled water with Asian dust (Sassen, 2002), and an increase in ice nuclei concentrations has been observed during dust storms (Levi and Rosenfeld, 1996). A climatological study of cloud top properties was performed using GOES data over the continental U.S. during the northern hemisphere summer (Lindsey et al., 2006), showing that thunderstorms over the mountains and High Plains tend to generate smaller cloud-top ice crystals than those which were further east. This is possibly due to the low-level thermodynamic environment lofting tiny drops can be to the homogeneous freezing level where they nucleate as very small ice crystals. Cloud condensation nuclei (CCN) may play a role in the cloud-top ice crystal size, and is supported by recent work by Rosenfeld et al. (2006). Thus, when storms form in areas with abundant CCN, their cloud droplets are small and numerous and are easily lofted to the upper portions of the storm.

The goal of this study is to extend the GOES analysis presented in Lindsey et al. (2006) to a global analysis for the years encompassing the 25 years in the PATMOS-x AVHRR dataset.

This study will seek to investigate the spatial patterns in ice cloud effective radius between the tropics, subtropics, and midlatitudes, as well as between ocean and land. While both climatologies are used to compare the consistency between in cloud optical properties, the PATMOS-x dataset will allow for long term patterns to become evident. Thus, if there are significant geographical features, they should emerge in this analysis.

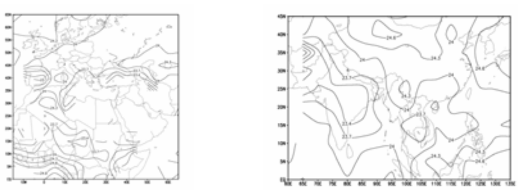
Spatial analysis of ice effective radius

Northern hemisphere summertime (June, July and August) averages from Lindsey et al. (2006) GOES analysis, the PATMOS-x and MOD08 datasets are shown over continental US to determine robustness of feature. Same minimum of ice effective radius in southeast CO appears in all three datasets, meaning both the PATMOS-x and MOD08 datasets can be used to find other features. Differences in the magnitude of the minimum of ice effective radius, are likely due to differences in the lookup tables and the method used to calculate the ice effective radius.

Summertime cloud top ice effective radius from PATMOS-x (left), MOD08 (center) and Lindsey et. al, 2006 (right).

Patterns in the Northern Hemisphere

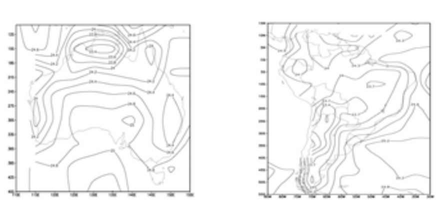
- Local minimums are evident over Chad in central Africa, over Spain and Portugal, one over western India and over Laos during the Northern Hemisphere summer (JJA).
    - The suggested minimums in Europe are possibly due to similar reasons as the one in SE Colorado
    - Other of the minimums have no easy meteorological explanation. Thus aerosols might be responsible for these minimums.
    - A suggested minimum in the northern portion of the Middle East is possibly due to the transition from maritime to continental airmass, as proposed in Rosenfeld and Lensky (1998).



Summertime cloud top ice effective radius from PATMOS-x over Europe and Africa (left) and Southeast Asia (right)

Patterns in the Southern Hemisphere

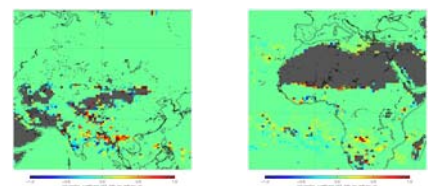
- Three local minimums are evident in Southern Hemisphere during the Southern Hemisphere summer (DJF).
    - A local minimum in the southwest part of South America is located in a meteorologically similar region to eastern Colorado. This area is known for Zonda wind, similar to Chinook winds in the Rockies. A second minimum is located over the Brazilian rainforest with no obvious mechanism to influence the size of the ice particles for this area.
    - A dryline appears in the model reanalysis data in the vicinity of the effective radius minimum in northern Australia. No other potential mechanism appears for the minimum in this area.



SH Summertime cloud top ice effective radius from PATMOS-x over Australia (left) and South America (right)

Effective radius and aerosol comparison

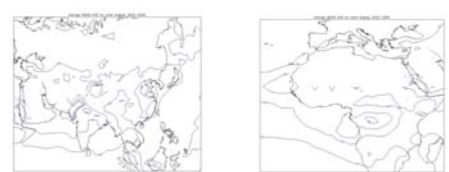
- Correlation analysis showed three regions of significant correlation (areas of greater than 0.5) between aerosol optical depth (AOD) and ice effective radius.



Correlation of AOD with ice effective radius from MOD08, for July, Southeast Asia (left) and Africa (right).

- Area over Laos and Thailand, while not a significantly high AOD, have a high spatial and temporal correlation with ice effective radius.
    - This is a possible indication of aerosol transport from higher AOD regions.
    - The effective radius minimum in this area occurs in Northern Hemisphere summer and winter.
    - The maximum summer temporal correlation occurs in July and August.

- An area of high correlation between AOD and ice effective radius is western India over the Thar Desert.
    - A temporal analysis is lacking due to masking out of the Thar desert by the MOD08 dataset



Aerosol optical depth from MOD08, averaged over 2.5 degrees, JJA, 2002-2006 for Southeast Asia (left) and Africa (right).

Two areas of moderate to weak correlation in Africa,
- -Area near Chad has a high AOD, but possibly influenced by meteorological effects.
    - -Spatially correlated, but temporally, the highest correlation is near second minimum in central Congo basin. Possible indication of transport, but more study is needed to find mechanism.
- -The area located to the west of the Sahara, is similar to that over Southeast Asia, in terms of AOD and correlation with ice effective radius, but with a weaker correlation.
    - -Dust from the Sahara potentially injected into the atmosphere, effecting particle size of convective storms in the ITCZ, but over a broader area.
    - -Maximum temporal correlation occurs in June

Conclusions and Future Work

1. Higher spatial resolution imager data and a longer datasets test have been used to test the robustness of features found and constancy of climatological datasets.
2. The GOES analysis first presented in Lindsey et al. (2006) has been compared to other datasets with similar features present in both the MOD08 and PATMOS-x datasets. Differences in the value of the minimums are likely due to differences in the lookup tables used for each dataset.
3. The Lindsey et al (2006) GOES analysis was extended globally through the use of the 25-year PATMOS-x AVHRR dataset. Although similar meteorological conditions can be used to explain some of the features present in the current study (E. Colorado, E. Andes, N. Iberian Penisula) other regions can not be explained meteorologically. These areas (Central Africa, SE Asia, E. Atlantic near Africa) appear to possibly be due to aerosols in these areas. Yet others seem to have no obvious reason for the ice effective radius to be a minimum (N. Australia).
4. A further investigation of some of these areas that are not easily explained is planned.

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