CMMAP
August 2007

Cirrus cloud climatology using CALIPSO data

Hovakim Nazaryan[1], M. Patrick McCormick[1], and Kuan-Man Xu[2]

[1] CAS, Hampton University, Hampton, VA, 23668; [2] NASA LaRC, Hampton, VA, 23681

Corresponding Author: hovakim.nazaryan@hamptonu.edu

Abstract

We study the global and seasonal distribution of cirrus clouds that have been identified as one of the most uncertain components in weather and climate studies. Few instruments can deduce the presence of cirrus clouds, especially subvisual clouds and those of low optical thickness. However, those clouds are critical to understanding feedback processes that regulate or modulate the climate response to forcing. Cirrus clouds play a significant role in the energy budget of the earth-atmosphere system by means of their effects on the transfer of radiant energy through the atmosphere. Further, the scattering of solar radiation and absorption of IR radiation by cirrus clouds often contaminate aerosol products retrieved from satellite-based measurements using channels located in the visible and near-IR spectral region. The presence or absence of cloudiness must be accurately determined in order to retrieve properly many atmospheric and surface parameters. Satellite lidar has the ability to profile multi-layer cloud structures and it is particularly useful for the detection of invisible cirrus. The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite mission provides comprehensive observations of cloud vertical structure on a near global scale. We investigate the occurrence frequency and thickness of cirrus clouds measured by CALIPSO as a function of time, latitude, and altitude. In particular, we examine the latitude-longitude and vertical distributions of cirrus clouds. Our investigation of the top-layer cirrus clouds shows maximum occurrence frequency of up to 70% near the tropics at the 100° - 180° longitude band. The average thickness of cirrus clouds is generally between 1.5 and 1.8 km in the majority of latitude-longitude bins from June 2006 to June 2007. We also analyze the seasonal behavior of the cirrus cloud frequency and geometric thickness. Our results show large latitudinal movement of cirrus cloud cover with the changing seasons.

1. Description of the Instrument

- The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) is developed within the framework of collaboration between NASA, France's Centre National d'Etudes Spatiales (CNES), and Hampton University.
- CALIPSO was launched on April 28, 2006 and is in a sun-synchronous 705-km circular polar orbit with an ascending node equatorial crossing time of 13:30 local time.
- CALIPSO flies in formation with the EOS Aqua satellite as part of the Aqua constellation, which consists of the Aqua (with MODIS onboard), Aura, CALIPSO, CloudSat, and PARASOL satellites.
- The CALIPSO payload consists of three nadir-viewing instruments: the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP), the French-built Imaging Infrared Radiometer (IIR) and the Wide Field Camera (WFC).
- CALIOP is a three-channel lidar system (1064 nm and 532 nm parallel and perpendicular) with a 1 m receiving telescope.
- The IIR is a non-scanning imager and provides calibrated radiances measurements at 8.65 µm, 10.6 µm, and 12.05 µm, having a 64 km by 64 km swath. Both the infrared emissivity and particle size of thin cirrus cloud particles can be estimated employing the three IIR channels.
- The WFC provides meteorological context for the lidar measurements and is used during daytime only.
- The CALIPSO data reports vertical resolution of 30 m from 0 to 8 km and 60 m from 8 to 20 km.

2. Cirrus Clouds

- We study clouds with Cloud Layer Base altitude higher than 8 km in the tropics (15° S - 15° N) and higher than 5 km in the extratropics.
- The thickness of the clouds under consideration is less than 8 km.
- Integrated Volume Depolarization Ratio is greater than 0.2 (greater than 20%).
- During our calculations we employ the 5 km layer CALIPSO Cloud product.
- We define the cloud occurrence frequency as the ratio of the number of retrieved cirrus cloud layers to total number of observations by CALIPSO.

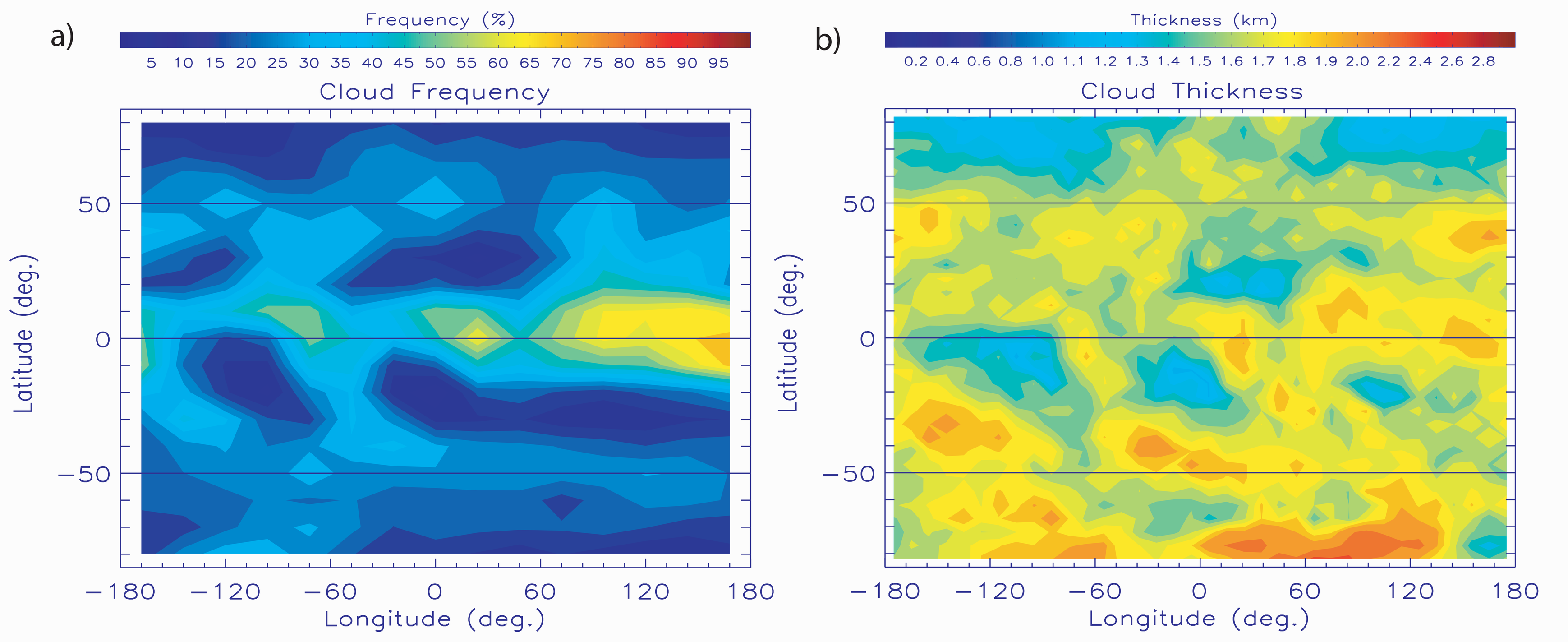

Figure 1. Latitude-Longitude distribution of the CALIPSO cirrus cloud (a) occurrence frequency and (b) geometrical thickness from June 2006 to June 2007.

3. Latitude-Longitude Distribution of Cirrus Clouds

- To investigate the zonal variability to cloud occurrence frequency, the CALIPSO measurements are grouped into 10° latitude by 24° longitude bins.
- We take into account only the top-layer clouds and obtain the cirrus cloud occurrence frequency distribution for single-layer clouds using the following formula:

$$\textit{Single Layer Frequency} = \frac{N_S}{N_T}$$

where N_S is the number of the retrieved top-layer cirrus clouds, and N_T is the number of total observations.

- We calculate the latitude-longitude distribution of the cirrus cloud thickness by averaging the thickness of the observed clouds for every 5° latitude and 10° longitude bin.
- To examine the seasonal behavior of the cirrus cloud frequency and thickness distributions, the CALIPSO data are further grouped according to season.

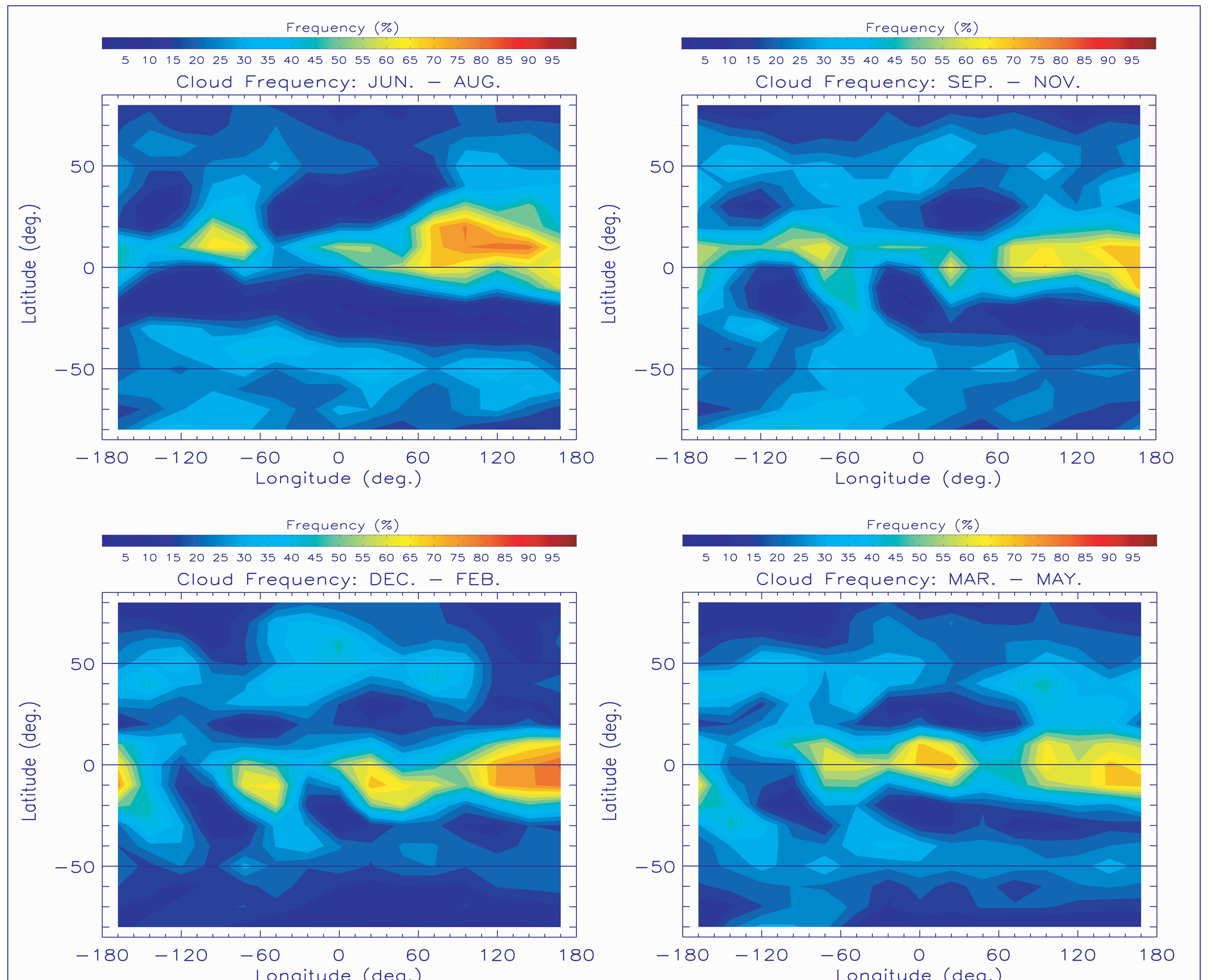

Figure 2. Seasonal variations of the Latitude-Longitude distributions of the CALIPSO cirrus cloud occurrence frequency of the top-layer clouds from June 2006 to May 2007.

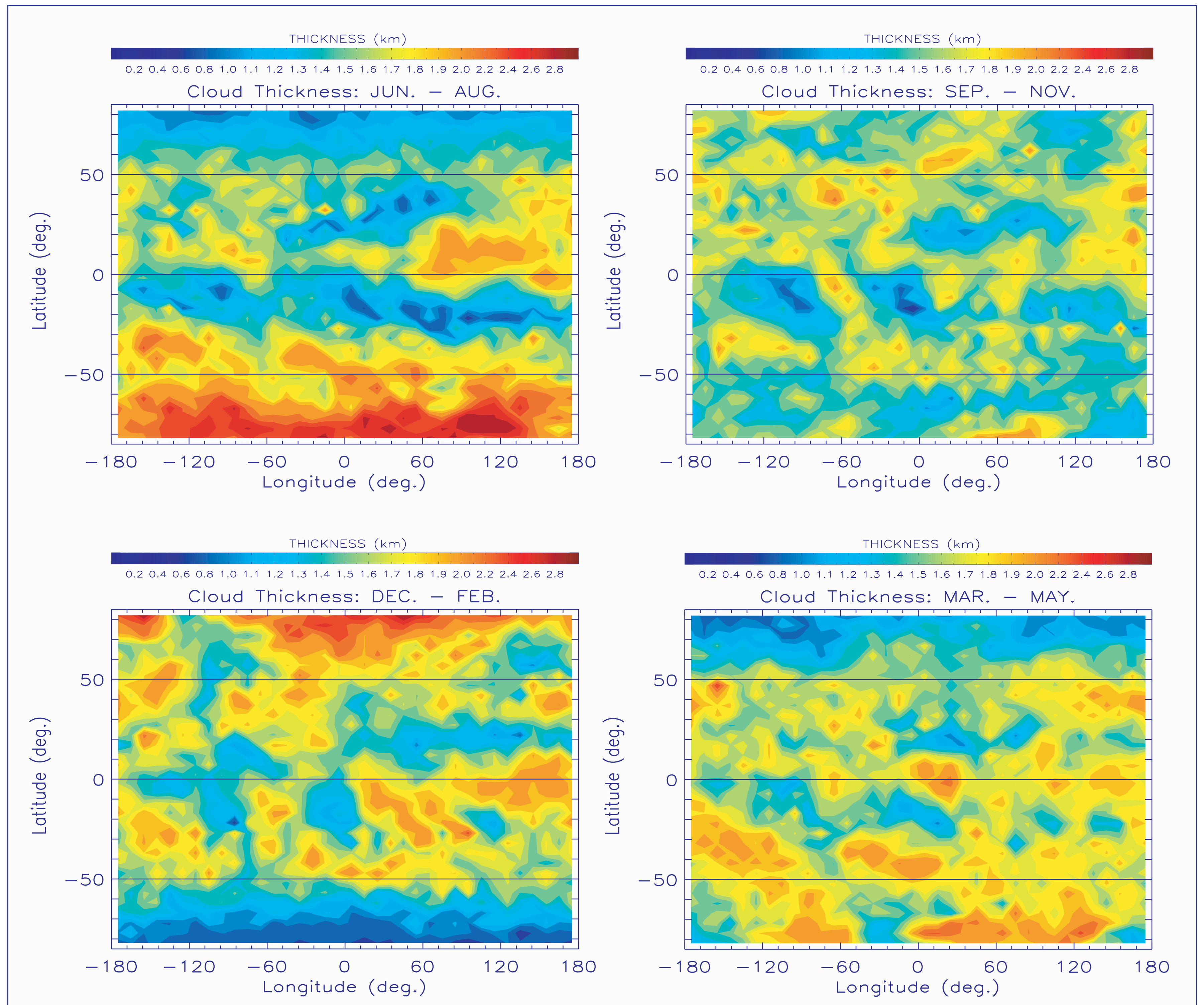

Figure 3. Seasonal variations of the Latitude-Longitude distributions of the CALIPSO cirrus cloud thickness of the top-layer clouds from June 2006 to May 2007.

4. Vertical Distribution of Cirrus Clouds

- One of the largest sources of uncertainty in estimating long-wave radiative fluxes at the Earth's surface and within the atmosphere is connected with difficulties in determining the vertical distribution and overlap of multi-layer clouds.
- We investigate the vertical distributions of frequency of the cirrus cloud top and base altitudes measured by CALIPSO and the frequency of cloud thickness.
- The ratio of the number of cirrus cloud measurements to the total number of observations by the CALIPSO experiment from June 2006 to June 2007 is calculated for each 1 km altitude step.
- The frequency of the cirrus cloud thickness is calculated for each 0.5 km.

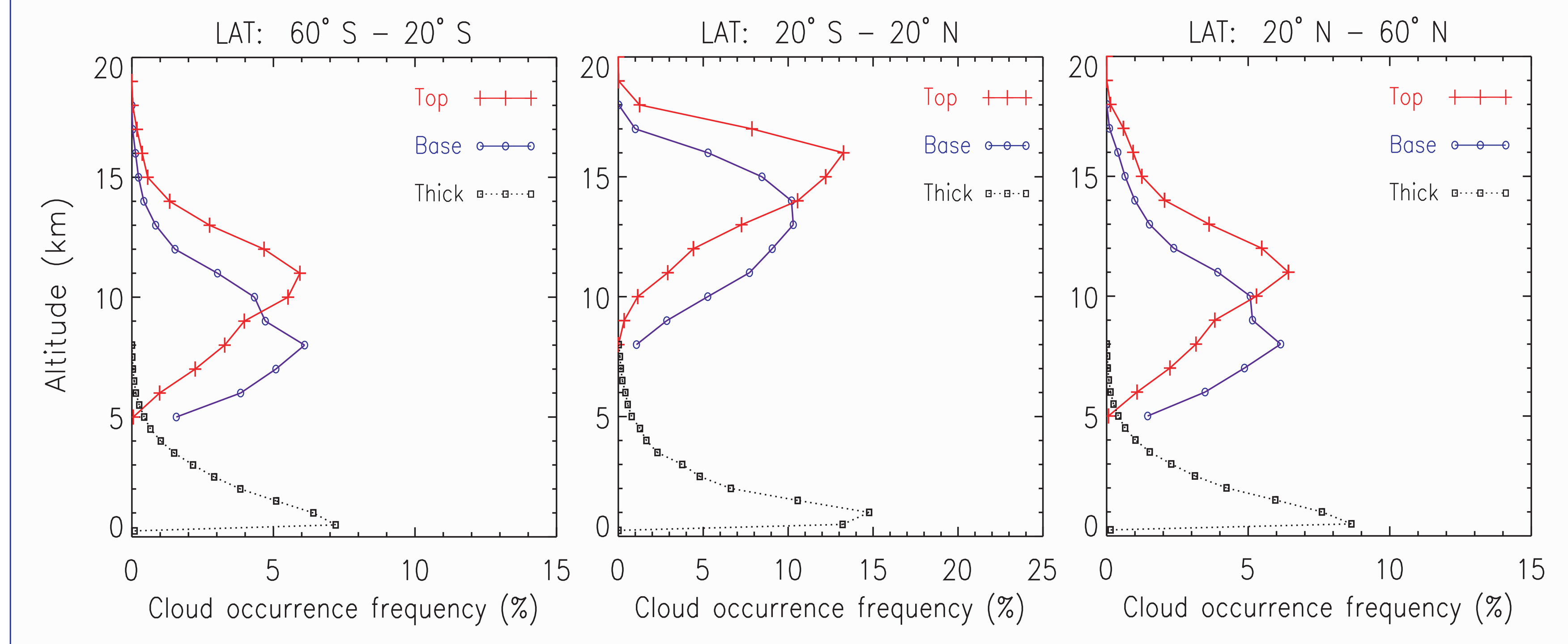

Figure 4. Vertical distribution of the frequency of the Cloud Layer Top Altitudes (red solid line) and Layer Base Altitudes (blue solid line) from the CALIPSO data set from June 2006 to June 2007. The dashed line indicates the thickness of the clouds.