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“Cirrus Clouds in Relationship with Multiple Tropopause Events”

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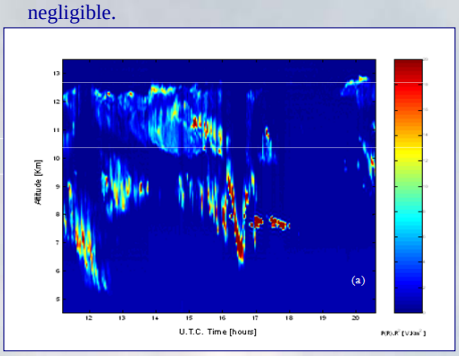
ABSTRACT: Cirrus clouds have been identified by the Intergovernmental Panel on Climate Change (IPCC) (2001) as one of the priority areas for research due to their radiative and dynamic influence on the Earth’s climate. Since cirrus clouds are located at high altitudes, their formation mechanism and evolution are sensitive to atmospheric conditions in the upper troposphere and lower stratosphere (UTLS). Therefore, studying UTLS conditions could give important hints on what drives cirrus cloud formation and how to better predict their properties. The tropopause temperature inversion has a constraining effect on cloud altitude, and several studies have focused on the properties of cirrus clouds near the tropopause, but especially at tropical latitudes. Hence variability in the thermodynamic structure of the tropopause could affect the properties of cirrus clouds near the UTLS transition. Multiple tropopauses are symptoms of actual physical phenomena that can help detect and analyze specific atmospheric conditions of cloud formation. This study focuses on the relationship between the tropopause(s) and cirrus clouds, thus only clouds whose top altitudes are located higher than 7 km will be considered. The aim of the work is to study the possible relationship between MT at midlatitudes and ice clouds considering collocated in situ and remote-sensing observations made between 2002 and 2003. Tropopause levels were retrieved from temperature profiles obtained through a data set of radiosoundings (launched at 00 and/or 12 UT) from the Argentine Servicio Meteorológico Nacional (SMN). Lidar observations are provided by the elastic backscatter lidar located in Villa Martelli near Buenos Aires and is based on Nd: YAG laser transmitter which delivers around 300 mJ by pulse at 532 nm with a 10 Hz pulse rate, 5 ns pulse duration, with a tilt angle less than 0.6 mrad. The lapse-rate tropopause definition is based on the variability in lapse rate in an atmospheric temperature profile. This technical definition, which is used in the rest of the present study actually reflects dynamical disturbances to the temperature profile resulting in multiple temperature inversions in the UTLS that can lead to tropopause foldings and mixing of stratospheric and tropospheric air. Analysis of temperature profiles from the Buenos Aires radiosoundings (34.6ºS, 58.5ºW) shows that multiple tropopauses occur in almost 50% of cases, with a third tropopause near 6 % of cases (additional tropopauses were considered to be negligible). Cloud with tops above the first tropopause occur in more than 30% of the observations, out of which a strong 50% happen in a multitropopause situation. These related clouds occupy a limited region between the first and second tropopauses, with their top in the lower of the intertropopause zone. Almost no cirrus cloud was detected with a top altitude above the second tropopause. Therefore it appears that clouds that cross the lowest tropopause live in an unstable temperature profile, which leads a large fraction of them to rise or expand vertically until they reach the next tropopause.

Results

❑As an example of the dataset analyzed, a cloud observed on 27 May 2003 is shown in Figure 1a. The first and second tropopauses are marked with solid lines, at 10.9 and 12.8 km, respectively, and seem to be relevant in the temperature profile from the 12 UT radiosounding. Analysis of 2000 temperature profiles from the Buenos Aires rawinsondes on the 2002–2003 period shows that multiple tropopauses occur in near 30% of cases, with a third tropopause in 10% of cases (not shown) . Additional tropopauses were considered to be negligible.

❑a



❑b

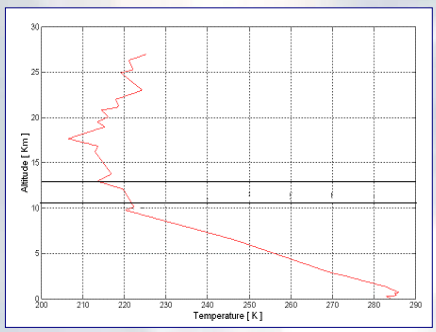
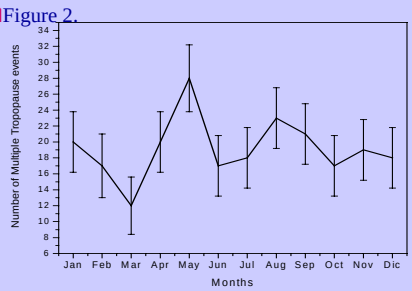
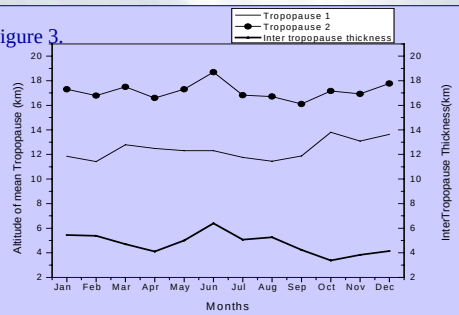


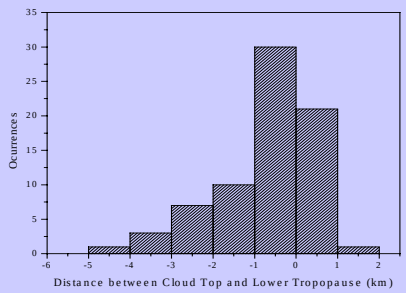
Figure 1. Backscattering coefficients observed by the lidar on 27 May 2003 as a function of time and altitude, (b) Temperature profile from radiosoundings on 27 May 2003. On both figures, the first two tropopauses are indicated using solid lines.

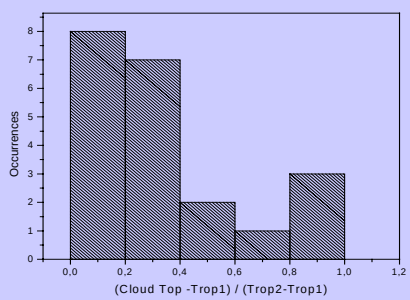
❑Figure 2.



❑Figure 3.







❑Figure 2 shows the annual cycle of MT occurrences, averaged over the 2002–2003 period. The annual MT occurrence cycle begins with high occurrences close to 20% in January, followed by the first minimum in March (13%). The first maximum is reached during May with percentages near 29%, followed by a second maximum reached during August (23%). High MT occurrences in April-June and August-September coincide with the higher occurrences of fronts or jets and also with the transitions between summer and winter circulation patterns over central Argentina. Figure 3 shows the annual cycle of tropopause altitudes and the mean intertropopause thickness (IT) considering only the first and second tropopauses of the data. The IT annual cycle displays a minimum in October (2.2 km) and two maximum between April-August. These maximums may be correlated with the increase in MT frequency over the same period (Figure 1), but with its first maximum centered in July instead June. The averaged IT thickness spreads from 2.8 km to 6.4 km. Clouds with tops above the first tropopause occur in 25% of the observations, out of which almost 90% occur in MT events; therefore for these cases, a possible relationship between tops and second tropopause deserves to be analyzed (Figure 4). In order to evaluate this correlation and how much of this region is filled with clouds, we use the ratio of the distance between cloud top and first tropopause to the distance between the first and second tropopauses, following the criteria applied by Noël and Haefelin (2007) ((Figure 5).

CONCLUSIONS

The study of cloud-top and base altitude respect to tropopause altitude reveals that most cirrus clouds are contained below the lower tropopause, but representative part of them crosses the tropopauses. There were not detected cirrus clouds totally contained between the first and second tropopause. The frequency of occurrence of the cirrus clouds increases with decreasing distance between cloud top and the first tropopause as Figure 3a shows. With the same trend, clouds are more frequent as cloud bases get closer to the tropopause; nevertheless, the maximum occurrence was found 3 -2 km below the tropopause.

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