Adv. Geosci., 23, 113–117, 2010
www.adv-geosci.net/23/113/2010/
doi:10.5194/adgeo-23-113-2010

Advances in Geosciences

Tropopause and jetlet characteristics in relation to thunderstorm development over Cyprus

A. Orphanou[1], **K. Nicolaides**[1], **D. Charalambous**[1,2], **P. Lingis**[1], **and S. C. Michaelides**[1]

[1]Meteorological Service, 1418 Nicosia, Cyprus
[2]Department of Physics, University of Lancaster, Lancaster, LA1 4YB, UK

Received: 17 April 2009 – Revised: 5 October 2010 – Accepted: 27 October 2010 – Published: 22 November 2010

Abstract. In the present study, the monthly statistical characteristics of jetlet and tropopause in relation to the development of thunderstorms over Cyprus are examined. For the needs of the study the 12:00 UTC radiosonde data obtained from the Athalassa station (33.4° E, 35.1° N) for an 11-year period, from 1997 till 2007, were employed. On the basis of this dataset, the height and the temperature of the tropopause, as well as the height, wind direction and speed of the jetlet were estimated. Additionally, the days in the above period with observed thunderstorms were selected and the aforementioned characteristics of the jetlet and tropopause were noted. The two data sets were subsequently contrasted in an attempt to identify possible relations between thunderstorm development, on the one hand, and tropopause and jetlet characteristics, on the other hand.

1 Introduction

The area of the Eastern Mediterranean, where Cyprus is located, is mainly affected by baroclinic depressions during the cold months of the year often accompanied by thundery activity (Kallos and Metaxas, 1980; Alpert et al., 1990; Flocas et al., 2001). During the transition months, thunderstorms are also observed (Savvidou et al., 2008), while due to the general synoptic pattern of the hot months of the summer, isolated thunderstorms caused by local instability occur. Individual thunderstorms have a limited spatial extent and are difficult to forecast with most Limited Area Models (Gallino and Turato, 2006). Thunderstorm development is of great interest from both thermodynamic and synoptic perspectives. In this work, the effort is focused on the statistical study of the characteristics of the tropopause level and of jetlet – wind speed > 70 knots – (Glickman, 2000) over the island of Cyprus in such a manner, that knowledge is gained about any change of their behavior on the days with and without thunderstorm development.

Correspondence to: A. Orphanou
(orphanoua@yahoo.gr)

2 Data and methodology

For the implementation of this work, the radiosonde data obtained from the Athalassa station (33.4° E, 35.1° N) at 12:00 UTC for an eleven year period (1997–2007) were used. A database was created comprising the tropopause height, temperature, wind direction and speed, as well as of the height at which the jetlet is found and wind direction and speed for each day. The database was filtered further to include only the days for which all the aforementioned parameters were available.

Since the jet stream is usually defined as an entity with a certain range of dimensions and speed, the term should only be used to describe an area satisfying these criteria. In the present work, where the wind is studied at a single point, the term "jetlet" is adopted; it denotes relatively small regions of maximum wind, falling within an arbitrary range of jet stream speed (Glickman, 2000). Since the wind speed threshold for a jet stream is 50 knots (Glickman, 2000) the threshold set in the present study (> 70 knots) may include cases where the maximum wind is part of a jet stream; however, due to the lack of information concerning the spatial extent of areas with maximum wind, the term "jetlet" was chosen.

It is worth mentioning that when tropopause features were found at two or more levels, either due to tropopause folding or breaking of the tropopause into polar and tropical (Michaelides et al., 2005), the one closer to the jetlet was studied.

Both the tropopause and jetlet heights were determined directly from the actual radiosonde data, using the commercial

Published by Copernicus Publications on behalf of the European Geosciences Union.

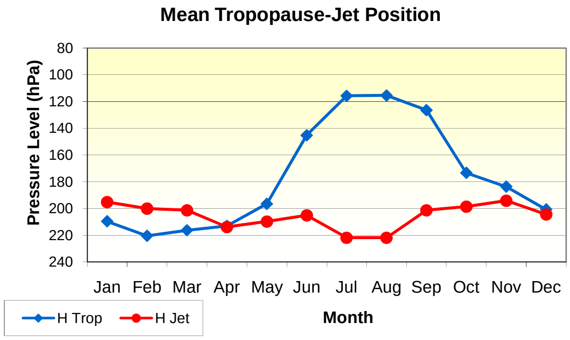

Fig. 1. Mean monthly position of the tropopause and jetlet over Cyprus.

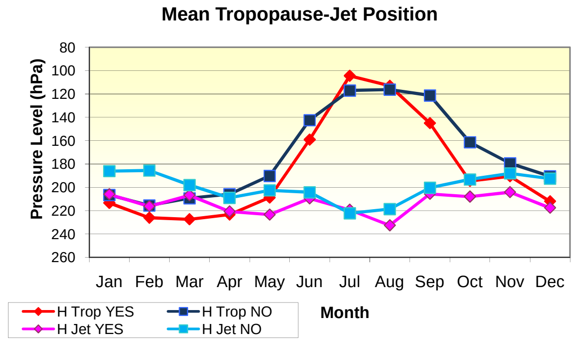

Fig. 3. Mean monthly position of the tropopause and jetlet for the days with and without observed thunderstorms.

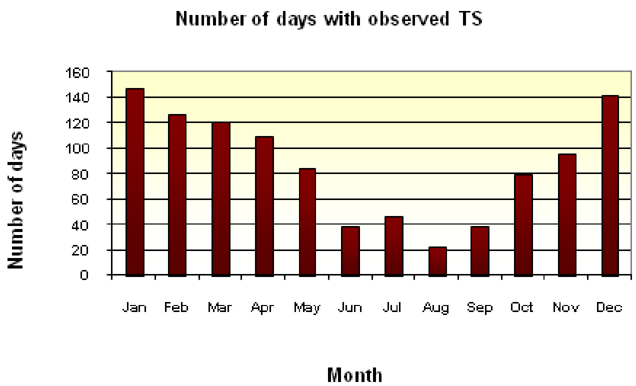

Fig. 2. Monthly distribution of the number of days with observed thunderstorms during the period 1997–2007.

software *Metgraph* developed by Vaisala. The frequent data collection allows for a relatively accurate determination of the relevant heights, to within 0.5 to 1.0 hPa.

The dates with observed thunderstorms were obtained from the database of the Meteorological Service of Cyprus.

The monthly distribution of heights where the tropopause and jetlet were detected was initially calculated for the whole dataset. The wind direction and speed at these levels was studied on an annual basis, since, from a preliminary examination, a very small seasonal and monthly variation was noted. The mean monthly temperature at the tropopause level was also examined.

Subsequently, all the aforementioned elements were separately studied for the days with observed thunderstorms and a comparison with the days without observed thunderstorms was carried out.

As a final remark, it should be noted that throughout the work presented here it is assumed that the radiosonde data are representative of the thermodynamic state of the atmosphere over the whole of Cyprus. This is not always the case, as the radiosonde follows the atmospheric flow and hence its horizontal displacement from the point of departure may be significantly large (of the order of 50 km).

3 Results

3.1 Tropopause and jetlet position – thunderstorm frequency

In Figs. 1 and 2 the mean monthly height of the tropopause (indicated as: *H* Trop) and the jetlet (indicated as: *H* Jet), as well as the monthly distribution of the days with observed thunderstorms are shown, respectively.

The height of the tropopause for the latitudes where Cyprus is located is relatively high, ranging between 220 hPa (winter) and 120 hPa (summer), allowing deep convective cloud to be formed and gain their maximum vertical extent. In other words, the mean position of the tropopause allows cumulonimbus cloud to be formed and thunderstorms to occur even in winter time. In summertime, although the height of the tropopause is very favorable for deep convection, the lack of moisture and high pressures over the mid troposphere makes thunderstorm development more difficult. Nevertheless, when the favorable conditions are satisfied, deep convection occurs.

The mean level at which the jetlet is found is located more or less at the same height throughout the year, namely, at around 200 hPa. During summer, it is found at a slightly lower level.

The tropopause is generally higher than the level of the jetlet during the summer and autum, from May till November. In January, February and March the jetlet overlies the tropopause.

In Fig. 3, the red and blue lines refer to the mean monthly height of the tropopause for the days with (indicated as: *H* Trop YES) and without (indicated as: *H* Trop NO) observed thunderstorms. For the majority of the months, the tropopause lowers by around (20 ± 1) hPa when thunderstorms occur.

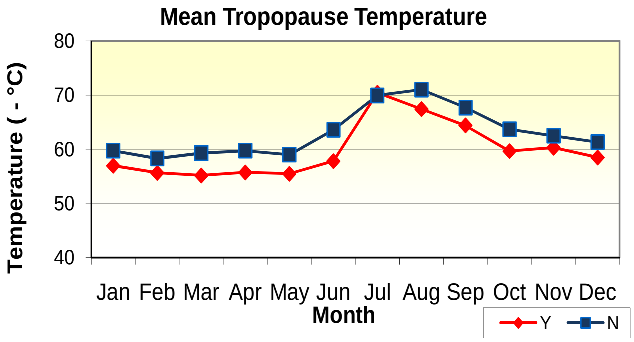

Fig. 4. Mean monthly temperature at the tropopause level on the days with (*Y* – red) and without (*N* – blue) observed thunderstorms.

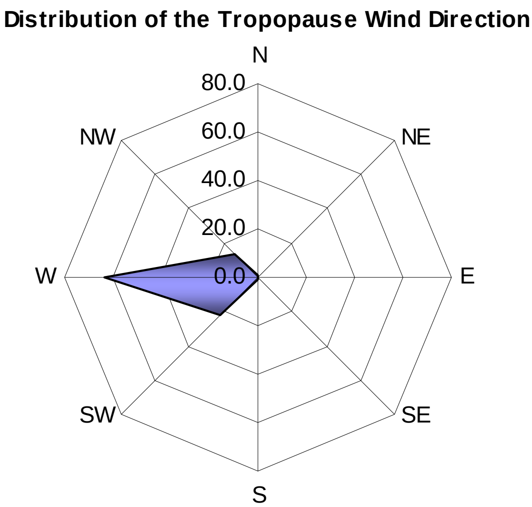

Fig. 5. Distribution of the wind direction at the Tropopause.

The only exception is in July and August, when thunderstorm development is related to a small tropopause rise.

The pink and aqua lines refer to the mean monthly height of the jetlet for the days with (indicated as: *H* Jet YES) and without (indicated as: *H* Jet NO) thunderstorms, respectively. Similarly to the tropopause, the jetlet is found at lower levels in the troposphere when thunderstorms occur. Especially during the winter months, December, January and February, this lowering is by around (30 ± 1) hPa. Only in July there is no significant shifting of the wind level between the two studied groups.

3.2 Tropopause temperature

By looking at the monthly distribution of the temperature at the tropopause level (Fig. 4), it is evident that temperature increases by 3 °C to 4 °C when thunderstorms develop.

For the days with observed thunderstorms, the mean monthly temperature ranges between −60 °C and −55 °C for the majority of the months, while in July, August and

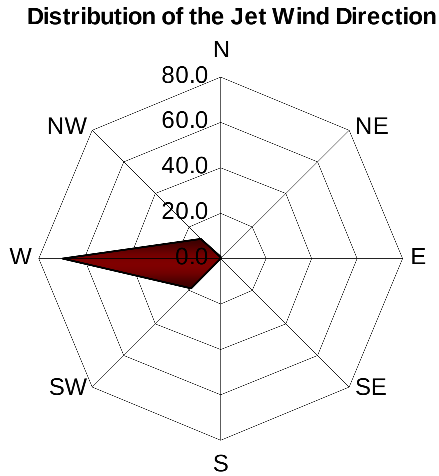

Fig. 6. Distribution of the wind direction at the jetlet.

September the temperature is even lower, between −70 °C and −64 °C.

3.3 Wind direction

For the study of the wind direction, all directions have been clustered into eight main compass directions, as indicated in Table 1. Figures 5 and 6 show the distribution of the wind direction at the tropopause and the jetlet, respectively, for both the days with and without thunderstorms.

At the tropopause level, in 64% of the cases the wind direction is from the west, 22% from the southwest and 14% from the northwest. At the jetlet level, in 70% of the cases the wind is from a predominantly westerly direction.

Similar results, but only for the days with observed thunderstorms are shown in Figs. 7 and 8 for the tropopause and the jetlet, respectively.

From these figures, it is evident that less than 10% of the days with observed thunderstorms are related with northwesterly winds at the levels of the tropopause and the jetlet.

By comparing the results for the whole dataset with the ones for the days with thunderstorms a northwesterly wind direction at the two studied levels, should be interpreted as an unfavorable factor for thunderstorm development.

The angle difference between the tropopause and the jetlet wind vectors was also studied and the results are shown separately for the days with and without observed thunderstorms in Figs. 9 and 10, respectively.

For the period from June till November, the wind backs from the jetlet level to the tropopause for both groups. For the days without observed thunderstorms a slight veering of the wind is noted from December till April. For the days with observed thunderstorms, the wind veers in May from the jetlet level to the tropopause.

Table 1. The main compass directions of the wind, used for clustering the wind direction.

Compass direction	Range in degrees (°)
N	[335,020]
NE	[020,065]
E	[065,110]
SE	[110,155]
S	[155,200]
SW	[200,245]
W	[245,290]
NW	[290,335]

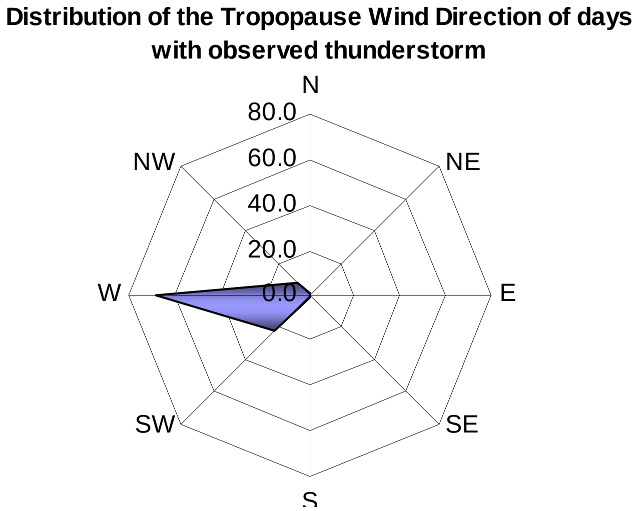

Fig. 7. Distribution of the wind direction at the Tropopause on the days with observed thunderstorms.

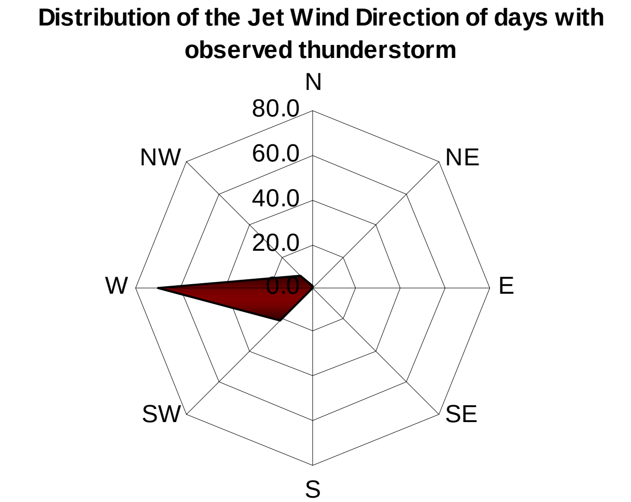

Fig. 8. Distribution of the wind direction at the jetlet on the days with observed thunderstorms.

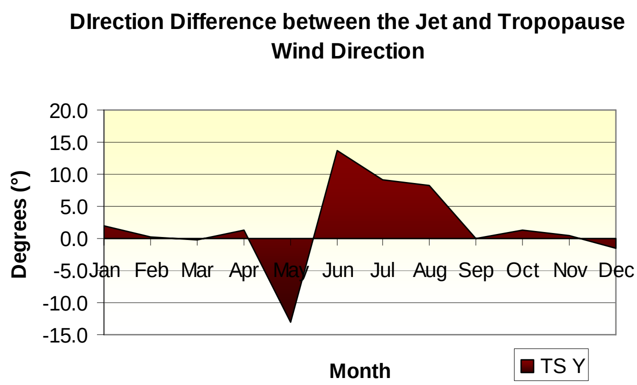

Fig. 9. Angle difference between the jetlet and tropopause wind direction for the days with observed thunderstorms (Y).

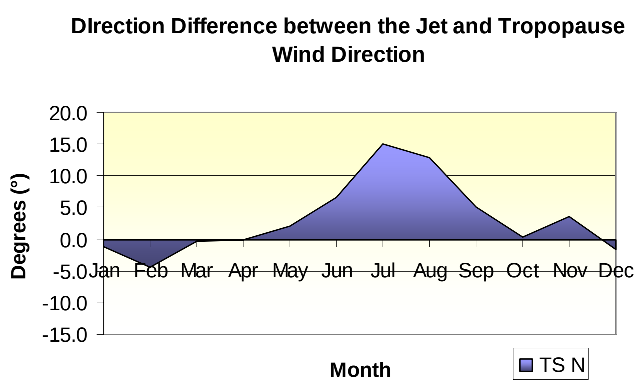

Fig. 10. Angle difference between the jetlet and tropopause wind direction for the days without observed thunderstorms (N).

A last examination was carried out concerning the wind direction and it referred to its change at the two studied levels from the day before an observed thunderstorm to the day it was actually observed (Figs. 11 and 12).

From Fig. 11 it is evident that at the tropopause level the wind backs when a thunderstorm is to develop for the majority of the months. Only in August and September a slight veering of the wind by less than 5° is noted.

Regarding the jetlet level (Fig. 12), it was found that the wind also backs. A very slight backing is noted in May, while a very slight veering is noted in September.

3.4 Wind speed

The results for the mean monthly wind speeds at the tropopause and jetlet levels for the days with and without observed thunderstorms are given in Fig. 13. By definition, the speeds at the level of the jetlet are higher than the respective ones at the tropopause, exhibiting higher values during the cold period of the year at both levels.

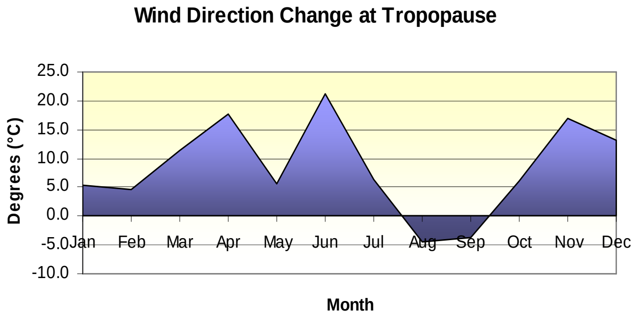

Fig. 11. Change in wind direction at the tropopause level from the day before to the day a thunderstorm has occurred.

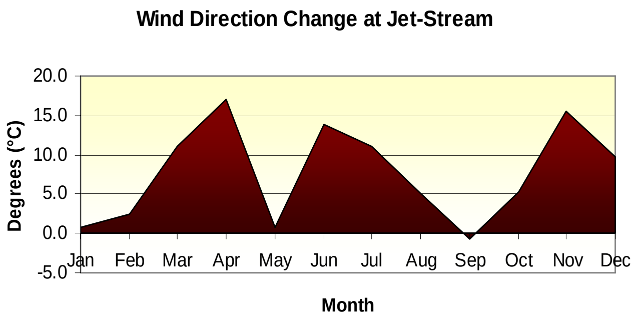

Fig. 12. Change in wind direction at the jetlet level from the day before to the day a thunderstorm has occurred.

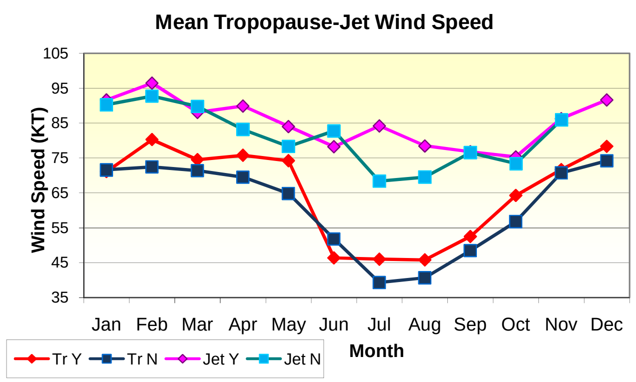

Fig. 13. Mean monthly wind speed at the Tropopause (Tr) and the Jetlet levels (Jet) on the days with (Y) and without (N) observed thunderstorms.

The mean monthly maximum wind speed ranges between 70 and 95 knots, with higher speeds on the days with observed thunderstorms.

An evident annual cycle is noted at the tropopause, with lower wind speeds prevailing during summer (40–60 knots) and higher speeds (70–80 knots) in winter, spring and autum. Again, the wind speed is found to be higher for the days with thunderstorms observed, compared with the ones without.

4 Concluding remarks

The study of the behavior of the tropopause and the jetlet level over Cyprus was the primary goal of this work. In addition, the change of their characteristics when thunderstorms develop was examined.

Since the tropopause, due to the latitudinal geographical position of the island, is relatively high, deep convection can develop when favorable conditions are met. It lowers by around (20 ± 1) hPa on the days with observed thunderstorms and warms by 3 °C to 4 °C.

The wind direction at the tropopause and the jetlet level is mainly from the west and backs on the day thunderstorms develop. A well-marked annual cycle of the wind speed is noted, with lower values during the summer period. The speed increases on the days with observed thunderstorms.

For the jetlet, it is evident that it lies near or at the jet stream's level (Nicolaides et al., 2004), at the level of around 200 hPa throughout the year and lowers when thunderstorms are observed.

Acknowledgements. The authors would like to acknowledge the two anonymous referees for their constructive comments.

Edited by: F. Tymvios
Reviewed by: two referees

References

Alpert, P., Neuman, B. U., and Shay-El, Y.: Climatological analysis of Mediterranean cyclones using ECMWF data, Tellus A, 42, 67–77, 1990.

Flocas, H. A., Maheras, P., Karacostas, S. T., Patrikas, I., and Anagnostopoulou, C.: A 40-year Climatological study of relative vorticity distribution over the Mediterranean, Int. J. Climatol., 21, 1759–1778, 2001.

Gallino, S. and Turato, B.: An operational approach to the nowcasting of an intense thunderstorm over Liguria, Adv. Geosci., 7, 395–400, 2006, http://www.adv-geosci.net/7/395/2006/.

Glickman, T. S.: Glossary of Meteorology, 2nd edition, American Meteorological Society, Boston, 2000.

Kallos, G. and Metaxas, D. A.: Synoptic processes for the formation of Cyprus lows, Rivista Meteorologia Aeronautica, XL (2–3), 121–138, 1980.

Michaelides, S., Nicolaides, K., and Karacostas, T.: Tropopause characteristics of baroclinic depressions in the area of Cyprus, Proceedings of the 7th Panhellenic (International) Conference of Meteorology, Climatology and Atmospheric Physics, 28–30 September 2004, Nicosia, Cyprus, 268–275, 2005.

Nicolaides, K., Michaelides, S., and Karacostas, T.: Spatial distribution of some dynamic parameters during the evolution of selected depressions over the area of Cyprus, Int. J. Climatol., 24, 1829–1844, 2004.

Savvidou, K., Michaelides, S., Nicolaides, K., Orphanou, A., and Charalambous, D.: Synoptic, dynamic and energetic characteristics of the depression that affected Cyprus from 9 to 12 May 2007, Proceedings of COMECAP 2008, Athens, Greece, 2008.