Increase of Upper Troposphere/Lower Stratosphere wave baroclinicity during the second half of the 20th Century

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Contribution

A strengthening of the equatorward temperature gradient in the upper troposphere/lower stratosphere (UTLS), at subtropics and mid-latitudes, is consistently reproduced in several modelling studies of the atmospheric response to the increase of greenhouse gas radiative forcing. Some of them suggest an increase of the baroclinicity in the UTLS region because of the enhanced meridional temperature gradients [e.g. García and Randel, 2008].

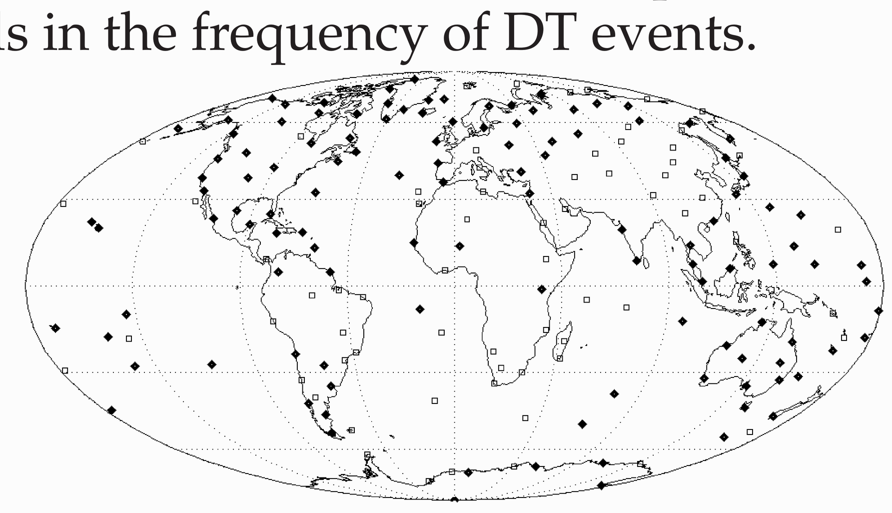
Here we present observational evidence of an increase of UTLS wave baroclinicity, during the second half of the 20th century. The evidence is given by significant positive trends in the energy of baroclinic normal modes of the NCEP/NCAR reanalysis, in the eddy available potential energy of the ERA-40 reanalysis and in the frequency of double tropopause (DT) events in radiosonde data.

Data and Methodology

Part of the study is based on NCEP/NCAR reanalysis and covers the 1958-2006 period. We analyze the Northern Hemisphere cool season (November to April) daily means of the horizontal wind components (u, v) and of the geopotential height, available on 17 standard pressure levels from 1000 to 10 hPa, on a 2.5°x 2.5°horizontal grid. The global horizontal wind (u, v) and geopotential (φ) fields were expanded in terms of the normal modes of the NCEP/NCAR reference atmosphere [Liberato et al., 2007].

Radiosonde observations from a 187-station global network, described by Añel et al. [2008], were analyzed for the 1970-2006 period. The soundings retained in the analysis satisfy the following homogenization criteria: i) the 50 hPa (70 hPa) level must be reached in the tropics (extratropics); ii) there must be at least one reported level in the vicinity of each of the following mandatory pressure levels: 500, 400, 300, 200, 150, 100, 70, and 50 hPa; iii) the sounding station must report soundings satisfying condition i) and ii) at least in five different years for each of the following periods: 1970-79, 1980-89, 1990-99, and 2000-06.

Figure 1 shows the radiosonde stations considered in the study. The solid symbols represents the stations retained for the computations of the trends in the frequency of DT events.



Results

Observing the energy values in the top panel of Fig. 2, it may be concluded that it is the mode m = 4 which shows the largest trend of energy. Incidently, this vertical mode is the most sensitive to variability in the UTLS region. Thus, results suggest that most of the increase in baroclinic energy comes from the UTLS region.

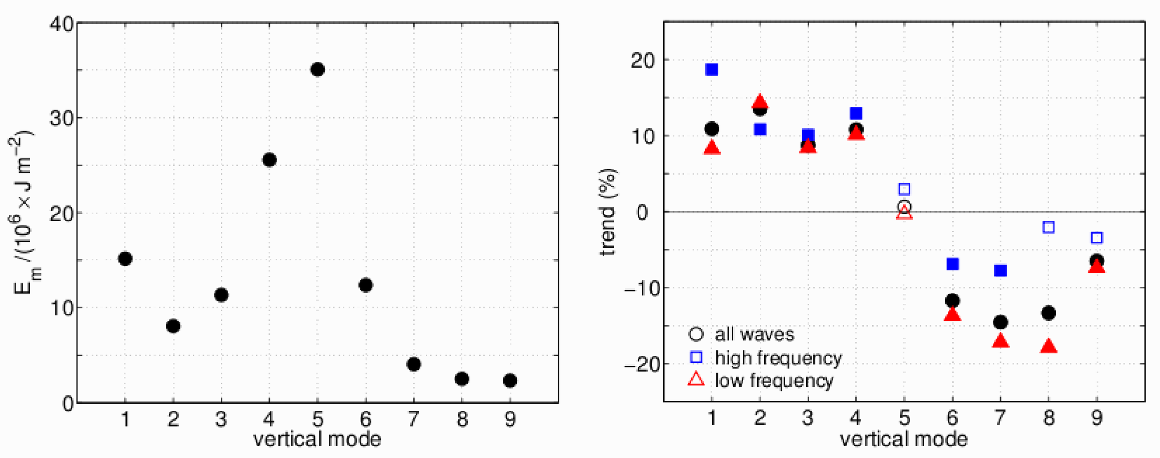
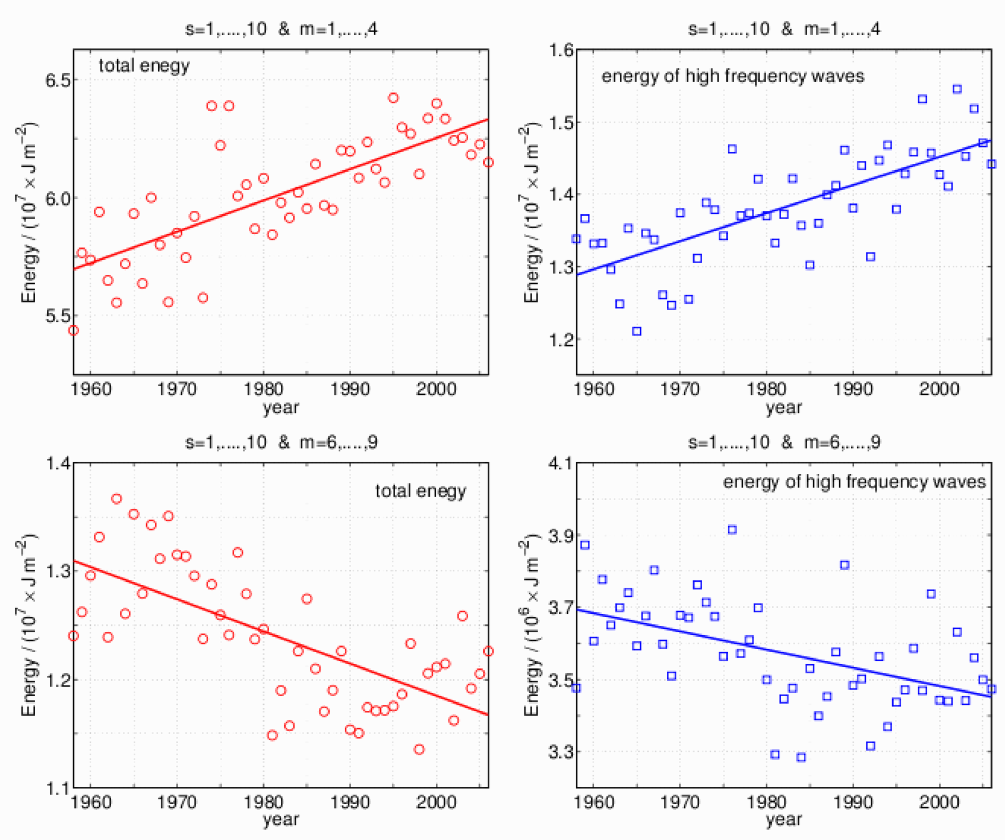


Figure 2: (top) Vertical spectrum of the mean energy (E_m) associated with the baroclinic Rossby waves of wave numbers s = 1,..., 10. (bottom) Linear trends of the November-April mean energy associated with the Rossby waves of wave numbers s = 1,..., 10, for the first 9 baroclinic modes. The trends are given as percentages of the respective mean energies in the period of 1958-2006.

Figure 3 shows the time series of the November-April mean energy of Rossby waves with wave numbers s = 1,..., 10. The upper row represents the energy sum for the deeper baroclinic modes (m < 5) and shows positive energy trends. The left panel shows the time series of the energy of all frequencies and the right panel shows the energy of high frequency waves. The lower row in the figure shows similar time series but for the sum of the energy of the shallower baroclinic modes (m > 5) with linear decreases.



Randel et al. [2007] suggested that the occurrence of double tropopauses is due to the excursions of the low latitude (tropical) tropopause to higher latitudes, overlying the lower extratropical tropopause. Consequently, the occurrence of double tropopauses is typical of baroclinic circulation in the UTLS region. Thus, an event of double tropopause must be associated either with the generation of high frequency baroclinic waves or with the amplification of stationary baroclinic waves, with vertical structures which may explain the circulation variability in the UTLS region. Therefore if the wave baroclinicity of the UTLS has increased during the last five decades, it may also be expected that an increase in the frequency of double tropopause events has occurred.

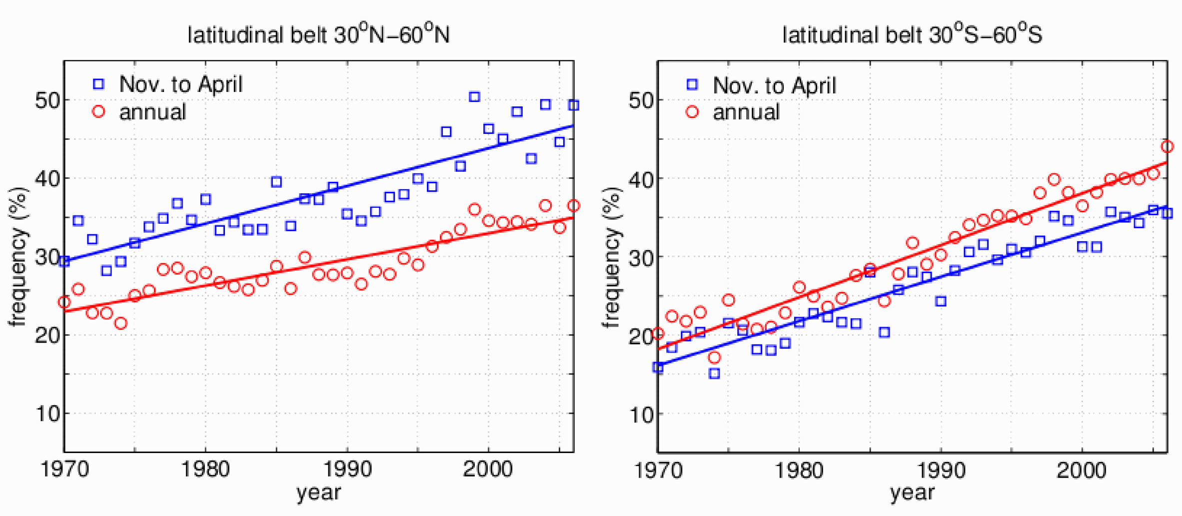


Figure 4: relative frequency of DT events in the 30°N-60°N (left panel) and 30°S-60°S (right panel) latitude belts.

References

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