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FORCING OF INTERANNUAL VARIABILITY OF THE TROPICAL TROPOPAUSE AND LOWER STRATOSPHERE

George N. Kiladis[1] and Katherine H. Straub[1,2]
[1]NOAA Aeronomy Laboratory, Boulder, CO
[2] Cooperative Institute for Research in Environmental Sciences (CIRES), Boulder, CO

1. INTRODUCTION

Increasing interest in stratosphere/troposphere exchange processes has prompted renewed investigation into the relationship be the tropical tropopause (TT) and deep convection. Many past studies have also identified the El Niño/Southern Oscillation (ENSO) phenomenon as being a significant factor in interannual variability of the TT and lower stratosphere (see references in Kiladis et al., 2001). Here we investigate the impact of ENSO on the thermal structure of the tropical troposphere and stratosphere in order to identify the dynamical causes of the observed signals. To demonstrate the impact of ENSO, we utilize the "Niño 3.4" sea surface temperature (SST) index, obtained by monthly averaging the SST between 5ºN-5ºS, 170ºW-120ºW, and subtracting these values from a 1961-1990 climatology. During warm events when SST is anomalously high in the central tropical Pacific, there is enhanced convection over that sector, along with a region of suppressed convection over the warm pool.

2. RESULTS

By using the long records of Koror (w. Pacific) and Lihue (Hawaii) radiosonde ascents the evolution of thermal structure of the atmosphere at these sites with respect to Niño 3.4 SST can be calculated (Fig. 1). At both stations, most of the troposphere is warm above approximately 800 hPa, with SST leading the temperature at tropopause level by around 2 months and by a few more months at lower levels (see studies by Sobel et al., this volume). Cooling is seen at both stations in the lower stratosphere, with the largest amplitude at or slightly below 70 hPa. However, this cooling extends below the level of the tropopause at Lihue, down to around 150 hPa, but is present only to around 80 hPa at Koror, well above the tropopause.

Another interesting feature in Fig. 1a is the apparent downward phase propagation of the stratospheric temperature perturbations at Koror, where the signals at 70 hPa appear to originate above 10 hPa more than a year earlier. The length of time between the two negative temperature perturbations at around 20 hPa in Fig. 4a is 26 months, suggesting a relationship with the QBO. Since the QBO is known to affect the tropopause, Fig. 1a indicates that such links are not entirely independent of ENSO.

A global view of the response of the tropopause to tropical Pacific sea surface temperature variations, derived from NCEP/NCAR reanalysis, is shown in Fig. 2. These maps show the simultaneous regression of tropopause height (Ztrop) and temperature (Ttrop) scaled to a +2.0ºC perturbation in Niño 3.4 SST. Throughout most of the tropics between about 20ºN and 20ºS, a higher (lower) than normal tropopause accompanies warm (cold) events in Niño 3.4 SST. While there is a strong zonally-symmetric tropical Ztrop signal related to ENSO, Ttrop has a much more zonally varying structure at low latitudes. A comparison of Figs. 2a and 2b shows that almost everywhere in the extratropics where the ENSO signal is manifested, there is a strong negative correlation between Ztrop and Ttrop, such that when the tropopause is high (low) it is also cold (warm). This is also true throughout the subtropical and equatorial central and eastern Pacific. However, despite the higher than normal tropopause over the western Pacific, Ttrop there is actually anomalously warm. The geographical extent of the region where the tropopause is high and also warm corresponds closely to the region of suppressed convection centered on Indonesia. This suggests that the origin of this tropopause warming might be increased upwelled longwave radiation from the surface, since this area is less cloudy than normal during ENSO warm phases.

In the central Pacific anomalous convection is associated with the most pronounced enhancement of the local Hadley circulation, leading to a spin-up of the Pacific subtropical anticyclones and negaive potential vorticity (PV) anomalies maximized close to tropopause level. Anticyclonic PV perturbations in the upper troposphere lead to an upward displacement in the tropopause, and require cold temperature anomalies above and warm temperature anomalies below them to maintain hydrostatic balance, as seen in Fig. 1b. It seems evident that, on interannual time scales at least, the tropopause perturbations at most locations can be explained primarily through dynamical arguments, although we can not discount the possibility that diabatic or "downward control" principles may be of some importance to the details of the distribution.

3. REFERENCE

Kiladis, G.N., K.H. Straub, G.C. Reid, and K.S. Gage, 2001: Aspects of interannual and intraseasonal variability of the tropopause and lower stratosphere. Quart. J. Roy. Met. Soc., **127**, 1961-1984.

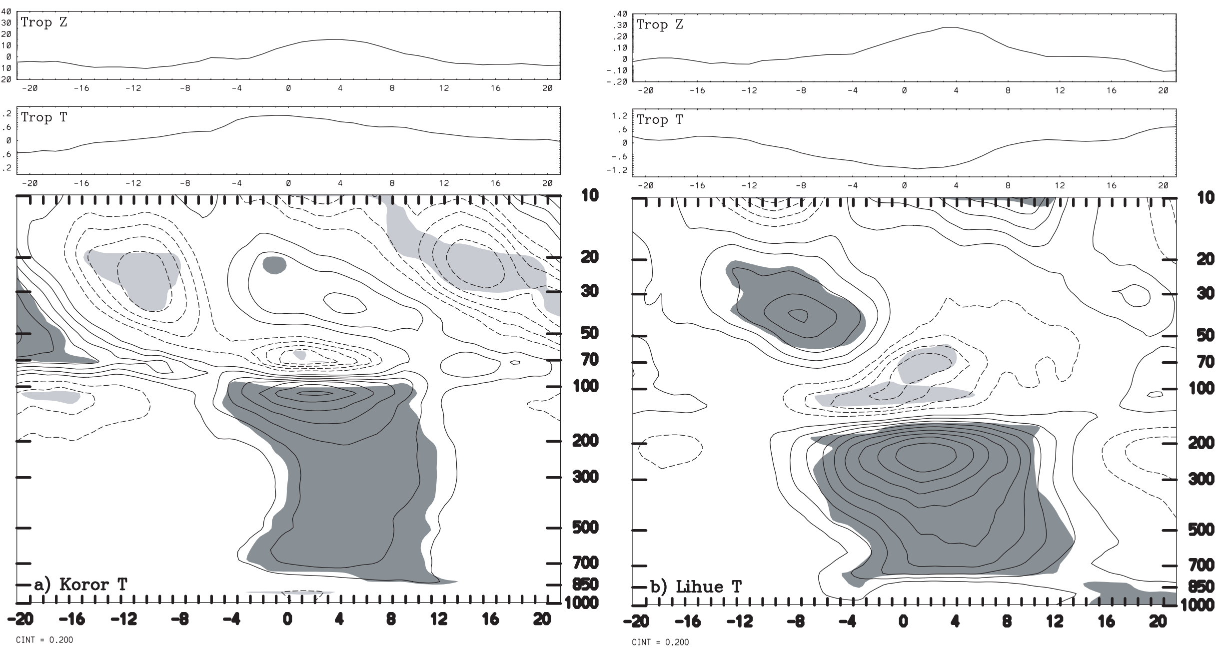
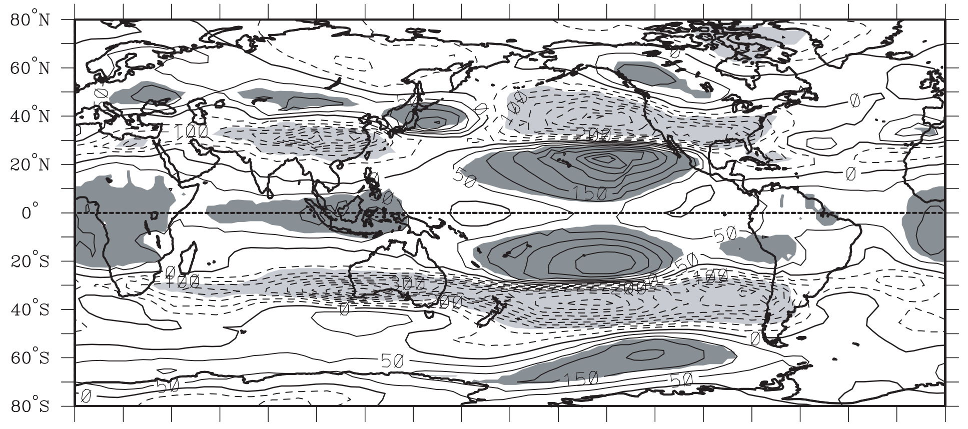


Fig. 1. Vertical cross section of lagged temperature perturbations from radiosonde data at (a) Koror and (b) Lihue regressed onto Nino 3.4 SST, using all monthly data from 1957-1999. Also shown on top are lagged tropopause heights and temperatures. Values are plotted for a +2.0 ºC perturbation in SST at lag 0. Contour interval is 0.2 ºC. Dark (light) shading denotes statistically significant positive (negative) perturbations.

a) Tropopause Height



b) Tropopause Temperature

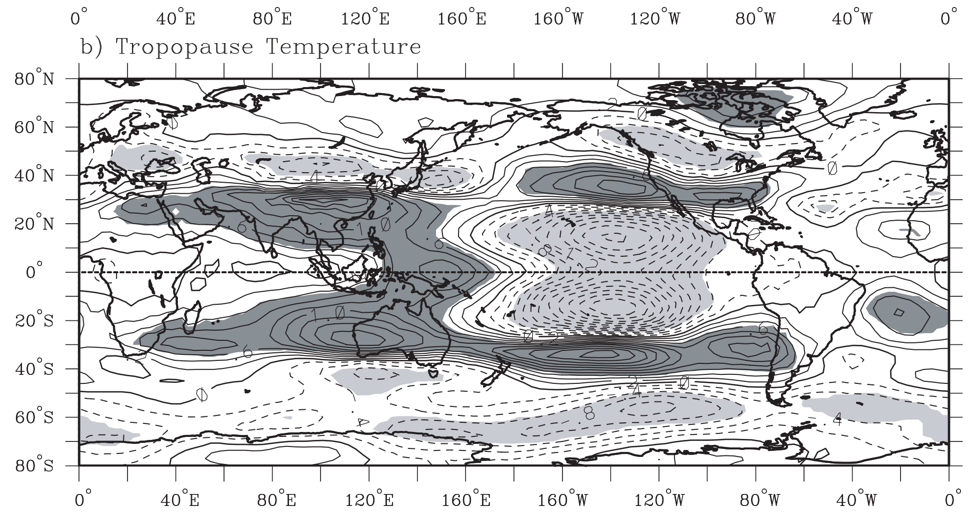


Fig. 2. As in Fig. 1, except for maps of (a) tropopause height and (b) tropopause temperature at lag zero. Contour interval is 50 m in (a) and 0.2 ºC in (b). Heavy (light) shading denotes significant positive (negative) values.

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* Corresponding author address: George N. Kiladis, NOAA Aeronomy Laboratory, 325 Broadway, R/AL3, Boulder, CO 80305-3328. Email: gkiladis@al.noaa.gov