

## NOTES AND CORRESPONDENCE

## Ozone Valley in the Subtropics

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## ABSTRACT

Detailed analysis of about 30 years total ozone data and associated meteorological processes have been carried out in the region where global maps of total ozone show a minimum value during the Northern Hemisphere summer. It is seen that the appearance of minima in total ozone over the subtropical belt of the Indian subcontinent may be the result of some unique features of thermal and dynamic processes appearing in that region.

## 1. Introduction

It is well known that the global ozone distribution has its minimum in the equatorial belt and increases poleward. This distribution is strongly influenced by meteorological transport processes (Dobson et al. 1946; Angell et al. 1985; Bojkov 1987; Tung and Yang 1988), hence it is not uniform with longitude also. The detailed analysis of total ozone maps shows a minimum in January in the western Pacific and over India in July (Ghazi 1980). In this regard, it should be noted here that some anomalous meteorological processes like the remarkable northward shifting of Hadley cell, extraordinary deep intrusion of the ITCZ and the appearance of thunderstorm cloud tops at 21–22 km altitude (overshooting in the stratosphere) occur over India and adjacent regions during the summer season. In light of these and some other important meteorological phenomena, about 30 years data of total ozone in this region have been examined. The possible connection between the occurrence of ozone minima and anomalous meteorological processes is obtained and presented as follows.

## 2. Results and discussion

The geographical location of stations measuring total ozone regularly as per WMO standards, along with the axis of the subtropical westerly jet stream (STJ), tropical easterly jet stream (TEJ) and the region of persistent monsoon trough is shown in Fig. 1. It can be seen that some stations fall in the region of the subtropics where the monsoon trough exist and STJ appears aloft

at 200 mb level, and some stations in the tropics where TEJ appears aloft at 150 mb level. It is necessary to keep in mind that over India, the STJ appears during all seasons except in the monsoon season (June through September), whereas the TEJ appears only in the monsoon season. During this season both jet streams appear about 15 degrees of latitude away from the axis

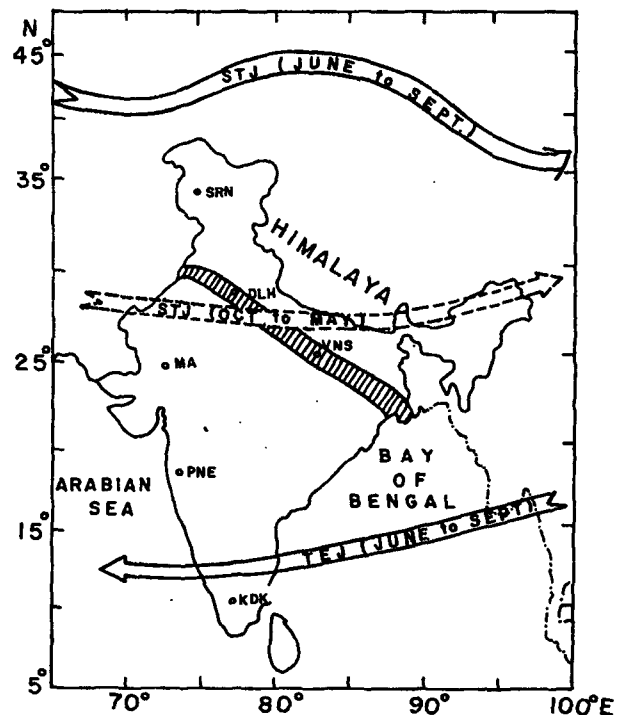


FIG. 1. Geographical location of stations (SRN: Srinagar, DLH: Delhi, VNS: Varanasi, MA: Mount Abu, PNE: Poona and KDK: Kodaikanal) measuring total ozone over India, and normal position of monsoon trough (shaded belt), subtropical westerly jet stream (STJ) and tropical easterly jet stream (TEJ).

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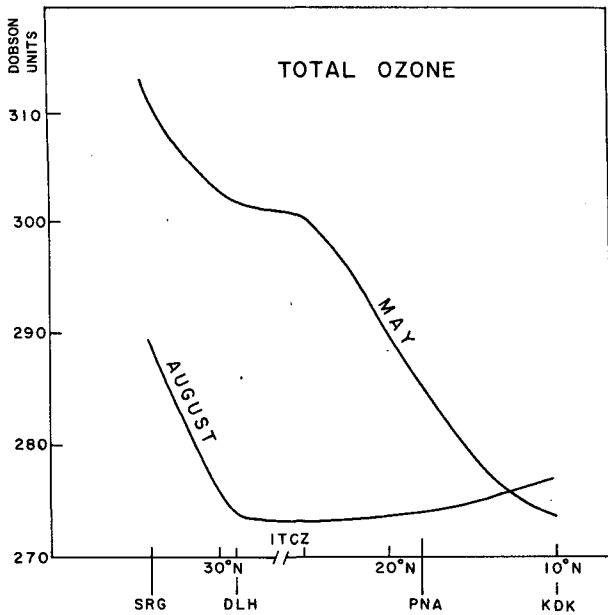


FIG. 2. Mean values of total ozone for the month of May (Pre-monsoon) and August (monsoon) from Srinagar to Kodiakanal.

of the monsoon trough i.e., the STJ and TEJ appear 15° north and south of the ITCZ, respectively (see Fig. 1). With this background, a simple analysis of the monthly mean total ozone distribution at these stations and for the months of May and August is shown in Fig. 2. The monthly mean value is obtained from a record of 29 years starting from 1959, which is provided by the India Meteorological Department. The important point to bring out from this figure is that, during the middle part of the monsoon season, the values of total ozone at subtropical stations like Delhi and Varanasi are lower than those at tropical stations like Kodaikanal and stations lying outside the monsoon trough

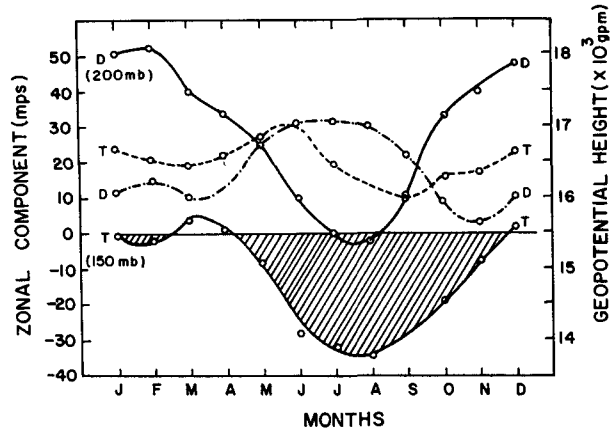


FIG. 4. Mean monthly march of tropopause height (dotted curves) and mean zonal wind component (continuous curves) for Delhi (D) and Trivandrum (T: 8.6°N, 76.8°E), respectively.

area. We define this anomaly as “Ozone-Valley” in the subtropics. The meteorological processes that could be responsible for the occurrence of ozone valley are discussed as follows.

### 3. Deep intrusion of continental ITCZ, topography and elevation of the tropopause

Mean position of the equatorial low pressure trough, i.e., the intertropical convergence zone (ITCZ) in January and July is shown in Fig. 3. The extraordinary deep intrusion of the ITCZ during July can be seen only over Asia where it is also known as the monsoon trough. This unique feature of the ITCZ is undoubtedly due to differences in topography and land-sea contrast in this region. The average height of the Asian landmass is remarkably more than the rest of the landmass in the tropics and subtropics. The east-west extension of the great Himalayan mountain wall (2500 km long

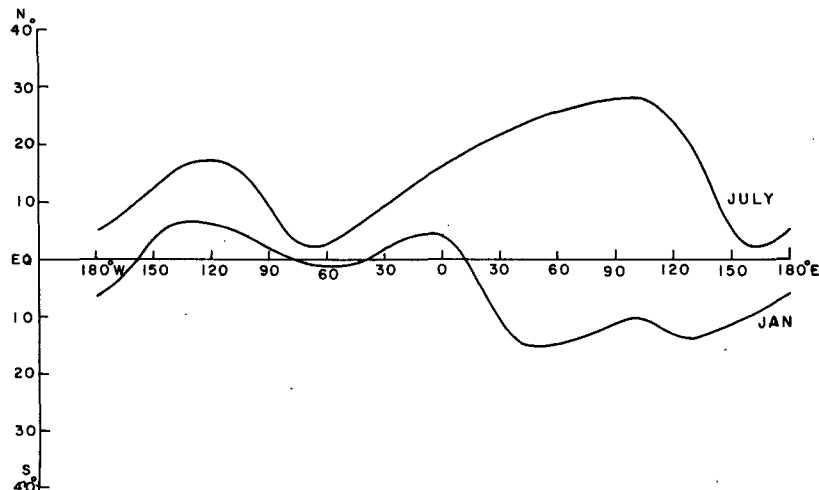


FIG. 3. Mean position of global ITCZ (also, see Riehl 1979).

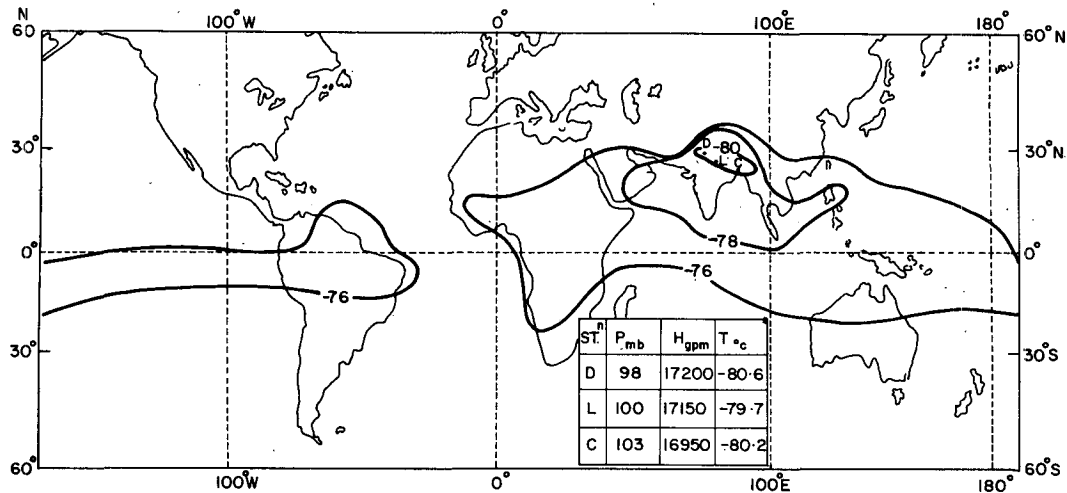


FIG. 5. Ten years (1975 to 1984) average temperature of 100 mb level for the month of July. Tropopause height and its temperature over some of the stations like Delhi (D), Lucknow (L), and Calcutta (C) lying along monsoon trough are shown inside the square. It may be noted here that, tropopause temperature during July of several years is less than even  $-83^{\circ}\text{C}$  over these stations.

and peak height about 9 km) causes the orographic lifting of moist monsoon air. The elevated heat source of the high and broad Tibetan plateau (average height 4.5 km) induces a reversal of the thermal gradient in the upper troposphere. The combined effect of both these should lead to a thermal and dynamical lifting of moist monsoon air and raises the average tropopause height in this region. The monthly marches of tropopause height over Delhi (subtropical station) and that over Trivandrum (tropical station) are shown in Fig. 4. It clearly shows that the tropopause height at the subtropical station during July and August, when the ozone valley occurs, is significantly higher than that over the tropical station. This feature is anomalous to the global normal feature of the tropopause. This observed higher tropopause can lead to a lower total ozone over this region. Further, it is also seen that globe's coldest tropopause during July and August appears above the monsoon trough (see Fig. 5), which may be due to the adiabatic expansion of moist air rising from below in deep convection. Therefore as stated by Newell and Gould-Stewart (1981), a stratospheric fountain or the area where air enters the stratosphere from the troposphere occurs over this region during the mon-

soon. This fountain can carry ozone-poor air from the troposphere to the ozone-rich lower stratosphere.

Above results and discussion lead to the conclusion that the occurrence of ozone valley in the subtropics may be the combined effect of thermal and dynamical lifting of tropospheric air into the stratosphere.

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