Lidar Study of Stratospheric Thermal Structure and Long Term Trends over a Sub-tropical Station Mount Abu (24.5° N, 72.7° E)

Som Sharma1*, S. La1, Y. B. Acharya1 A. Jayaraman2 and H. Chandra1

1Physical Research Laboratory, Navrangpura, Ahmedabad-380 009, INDIA
2National Atmospheric Research Laboratory, Gadanki-517 112, INDIA

* somkumar@prl.res.in

Abstract: Stratosphere plays a vital role in deciphering various global atmospheric phenomena taking place in the Earth’s atmosphere. It is also a well known reservoir of ozone which protects us from the hazard of the UV radiation emanating from the Sun. For more than two decades, Rayleigh Lidar has become a dynamic atmospheric probe for providing high profile of temperature in the middle atmospheric region. A Nd:YAG laser based Rayleigh Lidar was set up at a high altitude observatory near Mt. Abu (24.5°N, 72.7°E, msl ~1.7 km) in the Indian sub-tropical region to study the Earth’s neutral thermal temperature structure. The system transmits pulses of 7 ns duration at a frequency of 10 Hz with an average power of about 350 mJ at 532 nm. For the study of temperature climatology in the stratosphere, we have used the Rayleigh Lidar data collected for 5 years from 1997 to 2001. The temperature profiles are derived from photon count profiles following the method of Hahn-oorrece and Chansin (1980). The systematic and statistical errors in deriving temperature are found to be less than ~1 K below 50 km. The monthly mean temperature profiles obtained are compared with three different model atmospheres (CIRA-86, MSISE-90 and Indian low latitude model). To study the inter-annual variability, mean monthly temperature profiles have been estimated for different years. The mean stratosphere height and its temperature are found to be 48 km and 270 K, respectively. For the study of long term changes in the thermal structure of the stratosphere, consistently good data series for 11 years from 1997 to 2007 has been investigated. Monthly mean temperature profiles for each month have been removed to show seasonality. Linear regression analysis is performed to calculate temperature trends in different altitude regions. Considering the imprints of seasonal and solar cycle variability, a linearly decreasing temperature trend in stratospheric temperature has been found using the data from 1997-2007. Temperatures observed by HALO/ onboard UARS also shows similar trends, over Indian sub-tropical region.

Introduction
Lidar is a powerful technique for active remote sensing of the middle atmosphere. Lidar probing of the atmosphere utilizes both scattering and absorption by the medium. Rayleigh scattering by air molecules has been used extensively to determine the density of the atmosphere in the region from 30 to 100 km. Temperature profiles are derived from relative density data assuming that the atmosphere obeys the barometric equation. From the perturbations in the density or temperature profiles one can also determine gravity wave features. Lidar probing of the atmosphere was initiated at the Physical Research Laboratory (PRL) in the early nineties. A powerful Nd-YAG laser based lidar (operating at 355 nm) is situated at Mt. Abu and regular measurements of density and temperature are being made since November 1997. During the monsoon period from mid-June to mid-September over the site, regular measurements are not possible due to poor weather condition. A total of 600 nights of observations were made in the Rayleigh mode of operation during the period from November 1997 to November 2007, out of which 450 nights have provided data of sufficient quality to yield temperature profiles. Monthly mean temperature profiles have been obtained in the altitude range from 30 to 75 km from September to June.

What are the Causes for possible trends in Earth’s atmosphere?
- Global warming in the lower atmosphere accompanied by cooling in the middle atmosphere
- Chemical contamination due to man-made and natural causes
- Long-term changes in the solar activity
- Changes in tidal forces in the middle atmosphere
- Long term changes in gravity and planetary wave activity
- Effects of volcanic activity (mostly confined to the stratosphere) etc.

Certain Facts about Anthropogenic & Natural forcing of the Atmosphere
- Atmospheric abundances of greenhouse gases are increasing because of human activities
- Greenhouse gases absorb and radiate infrared radiation efficiently. This property acts directly to heat/cool the planet
- All long-term natural variations are not exhibiting the feature observed
- Climate itself has considerable inertia, mainly because of the high heat capacity of the world ocean
- Human-induced CO2 increases and ozone decreases in the stratosphere have already produced more than 1°C global average cooling there.
- This stratospheric cooling is generally consistent with model predictions
- Natural variability of climate adds confusion to diagnose human-induced climate changes
- Apparent long-term trends can be artificially amplified or damped by the contaminating effects of unforced natural variations

Summary
- Statistical Cooling trend is found at Mt. Abu (a sub-tropical station) during 1997-2007.
- Temperature models (CIRAS8, MSISE90, Indian low latitude model) are not exhibiting the feature observed.
- There is a need for further refinement of the models with more observational input.
- HALO onboard UARS also shows similar temperature trends over Mt. Abu.
- Observed Cooling trends are possibly associated with the reducing stratospheric ozone over Mt. Abu.

Concluding remark: It is demanding to have more observational inputs from different regions and platforms to quantify the role of natural and anthropogenic forcing in the observed trends and their association with other processes.

Acknowledgments
My sincere thanks to colleagues at PRL for their help and support in smooth running of Lidar Observation at Mt. Abu, India. Thanks to my colleagues Gomis and Banar for very useful discussions and help in preparing this manuscript. Supported by a grant from University of Roorkee and Dr. Philippe Kocklet (CNR, France) for their kind support. Thanks to Dr. CIOLOSKY (WCRP) and Prof. Francesco Driese (WCRP) for financial support for attending the WCRP General Assembly at Bologna, Italy.