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Vertical distribution of ozone over a tropical station: Seasonal variation and comparison with satellite (MLS, SABER) and ERA-Interim products

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HIGHLIGHTS

- Vertical distribution of ozone observed using ozonesonde measurements is presented.
- How well the satellite and re-analysis products represent the ozone profile is examined.
- Ozone tropopause variations in relation to other tropopause parameters are investigated.
- Back trajectory analysis is done to find the sources for the observed ozone.

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ABSTRACT

In the present study, vertical distribution of ozone observed using ozonesonde measurements obtained during 2010–2014 from a tropical station Gadanki (13.48°E, 79.18°E) is presented with special emphasis on the variability within the atmospheric boundary layer (ABL), in the free troposphere and in the lower stratosphere. In general, a clear semi-annual oscillation in ozone is seen within ABL and free-troposphere with peak during pre- and post-monsoon seasons. Whereas annual oscillation with peak during monsoon season dominates in the lower stratosphere. Interestingly, there is a delay of one month in the peak in the ozone mixing ratio (OMR) in the free troposphere when compared to the ABL during pre-monsoon and these features are quite different compared to other stations in the Indian region. One of the main objectives of the present study is to examine how well the present satellite (MLS and SABER) and re-analysis (ERA-Interim) ozone data sets represent the variability of ozone over the tropical station. In general, MLS and ERA-Interim overestimate the OMR by 97% and 80%, respectively, near the tropical tropopause, in comparison with ozonesonde data. Thus, caution is to be exercised in using these data sets for investigating the stratosphere–troposphere exchange (STE) process. However, all the three data sets show very good agreement with ozonesonde measurements above 22.5 km. ERA-Interim data set is found to agree well in the free troposphere but not in the ABL. Interestingly, the ozone tropopause is found to be more associated with the convective outflow level than cold point tropopause height. Back trajectory analysis reveals that the observed ozone in the troposphere over Gadanki region is mostly transported from the western region and from the higher altitudes. These features are discussed in the light of current understanding of the generation and transport of the ozone in the troposphere.

1. Introduction

Ozone plays an important role in Stratosphere–Troposphere Exchange (STE) processes and hence on the climate change issues (Intergovernmental Panel on Climate Change (IPCC), 1995). It's continuous monitoring at all the levels of the atmosphere is very important. Several instruments have been designed to measure the ozone at various levels. For obtaining the profile of ozone, ozonesondes have a proven record of measurements with good accuracies and vertical resolutions (Smit et al., 2007; Thompson et al.,

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2003). Ozone is also being monitored at a few places using Brewer/Dobson spectrophotometers (Petropavlovskikh et al., 2011) and DIfferential Absorption Lidars (DIAL) systems (Jacques Pelon and Gerard Megie, 1982). However, network of these instruments is too sparse so as to provide a global picture. A few satellites have carried payloads to measure ozone globally. Using the above mentioned data bases together with relevant physics, a few reanalysis centers (for example ERA-Interim) are providing ozone data products. In the absence of ozonesonde data, it is quite natural to depend on these data sets for investigating several issues related to ozone. However, how far these data sets compare with ozonesonde remained a question.

Continuous monitoring of the atmosphere is done on a routine basis from National Atmospheric Research Laboratory (NARL) located at Gadanki, (13.48°N, 79.18°E), a tropical station in India. NARL is well equipped with remote sensing (both radio and optical) and in-situ measurements. Using these instruments, it was shown that the cold point tropopause altitude (CPH) over Gadanki is higher than Truk (Western Pacific) and cold point temperature (CPT) is colder (<192 K) in summer than Truk (~194 K), but during winter Gadanki CPT (~190 K) is slightly higher than that of Truk (~189 K) (Mehta et al., 2010). MST radar observations at Gadanki showed the existence of updrafts throughout the year in the upper troposphere and lower stratosphere (UTLS) region (Narayana Rao et al., 2008; Venkat Ratnam et al., 2014). The multi instrument observations from Gadanki can be best utilised to explore the unexplored areas of STE process and the chemistry and dynamics of the UTLS.

As shown in Fig. 1, there are only three (Trivandrum (8.3°N, 76.6°E, 61 m), Pune (18.3°N, 73.5°E, 559 m) and New Delhi (28.4°N, 77.1°E, 216 m)) ozonesonde launching stations in India presently excluding Gadanki. Those three stations data is also not available from the year 2011. Continuous monitoring of the ozone from tropical regions is very important, since the changes in ozone concentration in tropics have more impact on surface temperature than in mid-latitudes because of the higher surface temperature and smaller ozone amount in tropics compared to the subtropics. Note that these two regions give opposite feedback to the greenhouse effect (Wang et al., 1980). Back trajectory analysis at different pressure levels carried out as part of the Indian Ocean experiment (INDOEX) showed that India and East Asia are the major source regions of ozone on the northern side of equator and African continent on the southern side of the equator in the Indian Ocean region (Peshin et al., 2001). The Sothern Hemispheric Additional Ozonesonde Network (SHADOZ, http://croc.gsfc.nasa.gov/shadoz) shown in Fig. 1 initially started operation with a motivation of validation of satellite measurements of ozone vertical profiles from tropics and subtropics and further extended the number of stations to Paramaribo (5.8°N, 55.2°W) in 1999, Kuala Lumpur (2.7°N, 101.7°E) in 2002, Heredia Costa Rica (10°N, 84°W) in 2005, Cotonou (6.3°N, 2.4°E) during 2004–2007 (Thompson et al., 2012). Note that there is no SHADOZ station from southwest of Asia and northern Africa for carrying out regular ozone observations. The distance between Nairobi (Kenya) and Kuala Lumpur (Malaysia) stations is about 7000 km and Gadanki station comes in the middle, though located little north to the two stations. Further, Indian monsoon region is unique where anti-cyclonic flow (though peak is located over Tibetan high) and tropical deep convection co-exits thus, leading to better understanding the STE processes. With this background, we started collecting observations of ozone from Gadanki which can become a good complement data set to the existing SHADOZ stations.

As mentioned earlier, it is quite common to depend on the satellite observations and the re-analysis products in the absence of ozonesonde data. How far these observations compare with high resolution ozonesonde remains unexplored. In this paper, we compared the profiles of ozone from the satellite borne Microwave Limb Sounder (MLS) on-board Earth Observing System (EOS) and the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) on-board Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellites and ERA-Interim products with the ozonesonde profiles collected over Gadanki. The continuous ozonesonde launchings started from October 2011 onwards. The three main objectives of this study are i) to examine how well the satellite and re-analysis products represent the ozone profile over this tropical station as these data products are

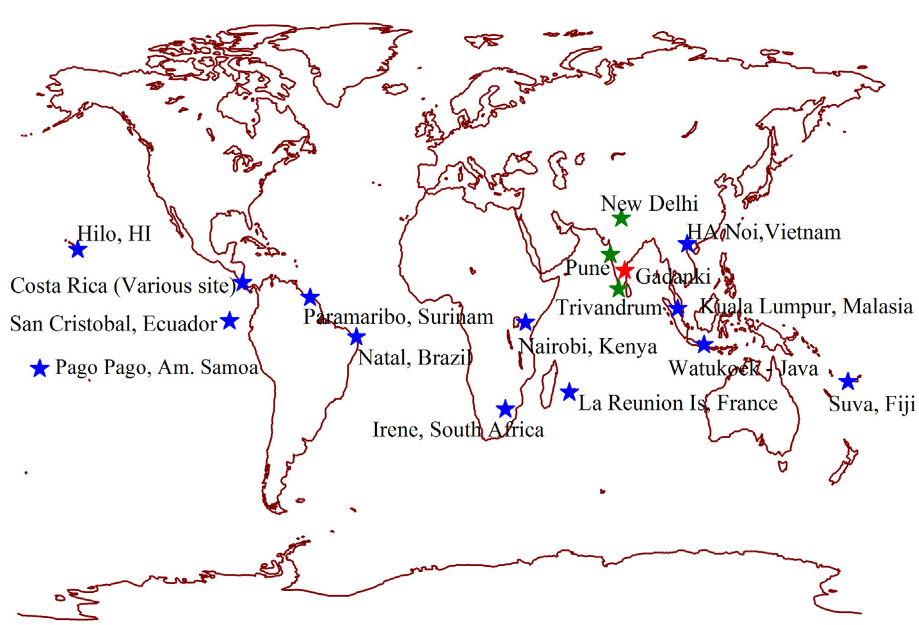

Fig. 1. Map showing the currently operational SHADOZ sites (blue stars), location of Gadanki in India (red star) and other active ozonesonde launching station in India (green stars). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)