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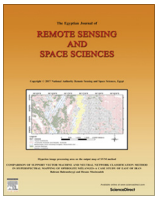

Research Paper

Long term temporal trends and spatial distribution of total ozone over Pakistan

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ABSTRACT

Considering the potential importance of the concentration of ozone in the atmosphere and threat to its depletion in Pakistan's environment, AQUA-AIRS Level-3 Daily Global satellite data is used to monitor the Total Column Ozone (TCO) over the entire region of the country. During 2003–2011 with spatial resolution of 1ox 1o lat/long grid, inter-annual analysis of TCO over the area (62°-76°E and 23°-37°N) showed that overall average distribution of TCO alterations are dependent on latitude and varied from 275 to 278 DU in the regions of Sindh and Baluchistan province with 297–300 DU in the northern and KPK province regions. Seasonal variations have shown that in the region 23°-29°N, highest concentration of ozone is recorded in summer season (JJA) and lowest in winter season (DJF) with mixed trend in both spring (MAM) and autumn (SON) seasons whereas in the region between 30°-37°N, maximum is recorded in winter (DJF) and spring (MAM) seasons with minimum in summer (JJA) and autumn (SON) seasons respectively. Statistical analysis revealed that linear relationship exists between year to year TCO and solar activity.

1. Introduction

Ozone represents only 0.0012% of the total atmospheric composition (Iqbal, 1983) but this amount plays a very important role in controlling the climate and the chemical composition of the atmosphere. It is acting as a major greenhouse gas (Kiehl et al., 1999; Rex et al., 2004) like a natural shield against the harmful ultra violet radiation (UVR) which reaches the Earth's surface and exerts unfavorable influence on ecosystems i.e.; the human health and other biological life. The variations in the T-O_3 amount based on short-term, seasonal, inter-annual and long-term time scales are due to continuous motion in the atmosphere. In the lower atmosphere (troposphere and lower stratosphere), ozone variability is chiefly due to the dynamical (transport) process (Chipperfield, 2003; WMO, 2003) where ozone acts as a tracer of atmospheric motion while in the upper stratosphere, the variability is mainly due to the photochemical processes, which involves the creation and destruction of ozone. Ozone in the lower atmosphere has a longer lifetime than ozone higher up because of the screening out of the ultraviolet radiation that drives ozone photochemistry by the ozone higher up in the stratosphere (Felix, 2009). Considering the potential importance of monitoring total ozone and with the increasing awareness to safeguard our environment, many studies have been initiated all over the world (Chipperfield and Randel, 2003; Frith et al., 2004; Levelt et al., 2006) to monitor the concentrations of T-O_3 and other harmful atmospheric constituents using satellite based data.

The seasonal and latitudinal mean variations in T-O_3 using ground based observations are accurately described by (Angell and Korshover, 1978; Dutsch, 1980). However, the ground-observing network is not adequate for monitoring of Ozone trends or for synoptic representation of Ozone for circulation studies. London and Reber (1979) have constructed hemispheric maps of monthly mean T-O_3, using Dobson observations from 1957 to 1967. However, (Hilsenrath and Schlesinger, 1981) have revealed with the help of satellite data that important characteristics were missed in the southern hemisphere because of scarcity of the observing stations.

Numerous scientific studies around the world have been conducted utilizing satellite based data (Ghauri et al., 1994; Tanimoto et al., 2005; Badarinath et al., 2007; Hegazy and Effat, 2010; Mohammed, 2011; Rajab et al., 2013) but such studies over

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the Pakistan's study area are scant, therefore it is first time that AQUA-AIRS satellite based data is used to observe the concentration of Total Column Ozone (TCO) over Pakistan.

2. Materials and methods

2.1. Study area

Pakistan is located between latitude 24° and 37° North and longitude 62° and 76° east (Fig. 1). Pakistan borders are shared with four neighboring countries; Iran is located on the west side, India in the east, Afghanistan in the north-west where as China in the north and Arabian Sea on the south. The total area of Pakistan is app: 8, 03,950 sq. km. The country has five provinces Sindh, Punjab, Baluchistan, Khyber Pakhtunkhwa and Gilgit-Baltistan (Basir et al., 2013). There are four seasons in Pakistan; winter (December – February), spring (March – April), summer (May – September) and autumn (October – November) (Ali et al., 2014). The central and southern regions of the country have increased temperature both in summers and winters and it may go as high as 45 °C in summers. However the northern mountains weather is very cold during winter and mild-warm in summer. In these areas the temperature can fall below freezing point (Sethi, 2007).

2.2. Data used & data description

2.2.1. AQUA AIRS: total ozone Contents (DU-Dobson unit)

The Atmospheric Infrared Sounder (AIRS) is a hyperspectral infrared instrument on board the AQUA satellite that is designed to measure the Earth's atmospheric water vapour, temperature profiles, total and vertical amount of trace gases like Carbon Monoxide, Methane and Ozone on a global scale. AIRS has 2378 infrared channels in the spectral range between 3.7 and 15.4 μm (Chahine et al., 2005), with a coarse spatial resolution of 13.5 km. We used AIRS Level-3 Daily Global 1 × 1 degree data of Ozone, which was acquired from GES-DISC Interactive Online Analysis Infrastructure (Giovanni) as part of the NASA Goddard Earth Sciences Information Services Center (DISC).

2.2.2. Sunspots

The Bureau of Meteorology is an agency of Australia's national weather, climate and water. It provides the oceanographic, hydrological, meteorological and observational services to all the states and territories of Australia. The government of Australia uses its services for the warning, forecasting, monitoring and advice pass over purposes to the regions of Australia and Antarctic territory. The Australian Government Bureau of Meteorology monthly Sunspot number data set acquired from http://www.sws.bom.gov.au/Solar/1/6 based on IPS (Ionospheric Prediction Service) Radio and Space Weather Services of Australia by observing the solar indices (Sunspots) for cycle 24 (AGBM, 2015).

2.3. Methodology

This paper is based upon the analysis of seasonal and inter-annual variations of AIRS data based TCO over Pakistan region during 2003–2011. First the AIRS TCO daily data acquired from latitude 23–36 and longitude 62–76 with spatial resolution of 1° × 1° at lat/long grid, and then monthly, annual (yearly) and seasonal means are calculated based on the daily TCO values assuming that they are representatives of daily means. The monthly average is then used to determine the monthly variability. Annual averages are calculated by averaging the monthly means spatial variations (latitude) and seasonal/annual trends are examined using monthly means of TCO respectively. Seasonal variability in TCO is calculated by using the monthly average for December, January and February (DJF), March, April and May (MAM), June, July and August (JJA), and September, October and November (SON).

Sunspots cycle 23 and 24 are used to compare the effect of TCO over Pakistan.

3. Results and discussion

3.1. TCO over Pakistan

The AIRS data during 2003–2011, compiled over 1° × 1° lat/long grid (Fig. 2), show that overall average distribution of TCO has

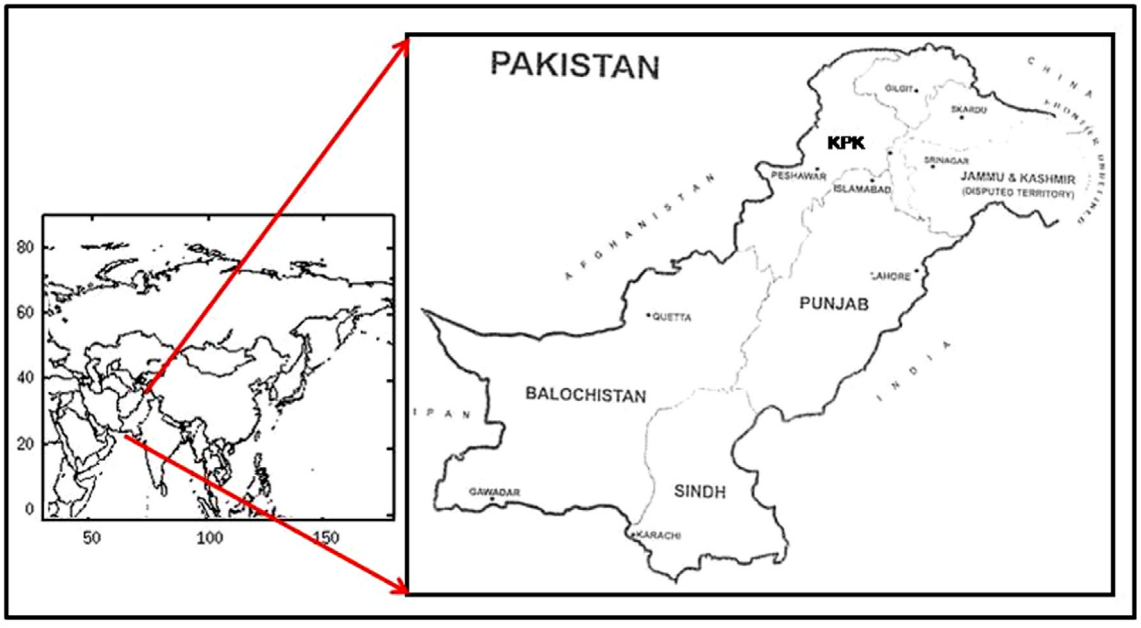

Fig. 1. Location of study area.