LONG TERM OBSERVATIONS OF STRATOSPHERIC AND MESOSPHERIC TEMPERATURE BY NIES OZONE DIAL OVER TSUKUBA, JAPAN

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ABSTRACT

The paper presents results from differential absorption lidar (DIAL) observations of time series of temperature at the National Institute for Environmental Studies (NIES) in Tsukuba (36 N, 140 E), Japan. The lidar system has been making routine observation more than 20 years. From beginning of the measurements in 1988 up to now, more than 600 vertical profiles of stratospheric and mesospheric temperature as well as stratospheric ozone were obtained. This lidar observation is a part of international Network for the Detection of Atmospheric Composition Change (NDACC). The temperature data are compared with satellite data (NCEP). Comparison of the temperature profiles measured by lidar and NECP showed agreement 7 K in the 35- to 50-km altitude range.

1. INTRODUCTION

Over the last decades, the increasing attention has been paid increasingly to stratospheric and mesospheric species and parameters related to the ozone depletion and the climate change. To understand the characteristics and their changes in the stratosphere, long-term measurements of ozone, aerosols and temperature have been conducted by using ground-based sensors. The Network for the Detection of Atmospheric Composition Change (NDACC) [1] was established in 1991 and has been playing a key role in international long-term monitoring efforts. Lidars have demonstrated to be reliable ozone-profiling instruments with relatively high altitude resolution [2]. Therefore, lidars, which measure ozone, aerosol and temperature, have become key NDACC instruments. In this paper, we present an overview of the lidar results in context of long-term observation of temperature for period from 1988 to 2008. The data are compared with those of NCEP (National Center for Environmental Prediction).

2. METHODS AND APPARATUS

The NIES ozone lidar system is a typical UV differential absorption lidar (DIAL) system for low stratospheric ozone measurements. The design of the lidar system allows high quality observations of the stratospheric and middle mesospheric temperature that is the subject of this paper. The lidar system is in operation from 1988, as several replacements and improvements have been made since it was first installed [3, 4]. Detailed description of system parameters and improvements are present in a paper by Park et al. [5].

Currently, the NIES ozone lidar system uses wavelength channels of 308/355 nm (for the Mie/Rayleigh scattering DIAL mode) and 332/386 nm (for the Raman scattering DIAL mode). The 355-nm signal is used for aerosol and temperature measurements. The 308 nm laser radiation is generated by an oscillation-amplified XeCl laser, and the 355 nm laser radiation is generated by a Q-switched Nd:YAG laser with a third-harmonic generator. The output energy of the XeCl and Nd:YAG lasers are 400 mJ and 300 mJ, respectively. The repetition rates of both lasers are set at 50 Hz. The 1 m primary mirror telescope collects backscattered light.

To cover the dynamic range of the system, two channels with high and low sensitivity are allocated to the 308- and 355-nm wavelengths by applying a beam intensity ratio of 95%/5% to the beam splitters. Interference filters with bandwidths 2 nm are used to reduce background light. Photomultiplier tubes with electrical gates and pre-amplifiers are used to detect light pulses at the six channels. Photocathode pulses from the PMTs are processed by discriminators, and recorded by photon counters.

In this study, we apply an improved data processing and retrieval algorithm (version 2 [5]) for ozone and temperature. This algorithm includes removing of systematic errors in the signals (background signals, signal-induced noise, and dead-time corrections) as well as removing of errors owing to the scattering and extinction of the atmosphere (air molecule extinction correction and aerosol corrections).

The vertical profiles of temperature were obtained using the algorithm of Chanin and Hauchecorne [6]. The upper boundary value for the algorithm is given by the modeled atmosphere (CIRA86) in the 70-120 km
altitude range, where the statistical error of the lidar signal is approximately 15%. The error due to the uncertainty of boundary value decreases quickly to a negligible level in the lower altitudes.

The NCEP vertical profiles of temperature were obtained from ftp://ftp.cpc.ncep.noaa.gov/wd53rl/ndscdata/ncep/temp. The NIES lidar vertical profiles of temperature were restricted to data obtained with statistical errors smaller than 15%.

3. RESULTS AND DISCUSSION
3.1 Time series of stratospheric and mesospheric temperature

Figure 1 plots point-to-point long-term temporal variations in temperature measured at altitudes of 35, 40, 45, 50, 55, and 60 km. The solid circles present results of measurements by NIES DIAL during period from 1988 to 2007. On the same figure by open red squares are also shown the temperature time series obtained by interpolation from the three-dimensional...
grid data (NCEP upper atmosphere data) on the same day and at the same time. The figure plots 574 temperature profiles retrieved from lidar signals and 6791 NCEP temperature profiles.

In general, seasonal variations and year-to-year variations in temperature exhibit good agreement between two data sets. The variations in temperatures measured with the NIES lidar and the NCEP temperatures agreed within 7 K in the 35- to 50-km altitude range, which corresponding to relative difference smaller than 2%

3.2 Climatological means and Annual cycles.

The vertical profiles of the climatological mean obtained from the lidar data, the NCEP data, and CIRA’86 atmospheric model are shown in Figure 2, along with the relative differences between the three sets of data. These profiles were obtained by averaging all the available monthly mean profiles from 1988 to 2008, separately for three instruments.

The climatological mean temperature profiles measured by lidar and by NCEP agreed within ±1.5% in altitude range from 30 km to 53 km and within 3% up to 55 km. Temperature profiles measured by lidar and profiles obtained with the CIRA86 model agreed ±2% in altitude range from 30 km to 60 km and within ±3% up to 65 km.

The average annual cycles of temperature recorded by the lidar and NCEP are shown in Figure 3 for altitudes 30, 35, 40, 45, 50, 55 and 60 km. These average annual cycles was obtained by averaging of all monthly mean profiles, separately for each month of the year. The annual cycles for lidar data are in very good agreement with that for NCEP for the altitudes 30, 35, and 50 km as relative difference is smaller than 1%. The values obtained by lidar are higher than NCEP data in altitudes 40 and 45 km for all the months of the year. However, the relative difference remains smaller than 2%.

Figure 2. Climatological mean vertical temperatures profiles (left panel) based on monthly means obtained with NIES lidar, from the NCEP and with CIRA86 model, along with relative differences (center and right panel).

The annual cycles of the temperature show highest levels occur in late spring and early summer – May to June at all presented altitude. All the features temperature’s annual cycles are typical for Northern Hemisphere.

4. SUMMARY

Long-term variations of stratospheric and mesospheric temperature over Tsukuba, Japan were observed by NIES ozone DIAL. Comparison of the climatological mean ozone profiles measured by lidar and NCEP showed agreement within ±1.5% in altitude range from 30 km to 53 km and within 3% up to 55 km. The annual cycles of the temperature show highest temperature values in late spring at all altitudes.
5. ACKNOWLEDGMENTS
This observation was funded by the Monitoring Program of the Center for Global Environmental Research (CGER) at NIES.

REFERENCES


