Winter Mesospheric Thermal Structure over Tibetan Plateau

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ABSTRACT

A mobile Rayleigh temperature lidar was deployed in Golmud (36.25°N 94.54°E), Qinghai in China for making measurements of mesosphere temperature from 55 up to 90 km. The mesospheric thermal structure was obtained during the winter seasons of Year 2013 and Year 2014. At the altitude of 57~79 km, lidar temperatures were much colder than the MSIS-00 model predictions. However, in the lower mesosphere region, lidar measurements were in reasonable agreement compared with the TIMED-SABER satellite data.

1. INTRODUCTION

Temperature is a key parameter for understanding the chemical, dynamic, and radiative processes in the atmosphere. Middle atmosphere is sensitive to solar activity as well as human being activities. In the stratosphere and mesosphere, rising CO_2 concentration increases the effects of radiative cooling. Modeling studies have predicted that mesosphere will cool in response to the increase of CO_2 [1]. On the other hand, atmospheric temperature is affected by waves (gravity waves, tides, and planetary waves) as well as atmospheric circulation [2]. While extensive temperature observations of middle atmosphere have been conducted at several critical sites, including the South Pole and the North Pole [3,4], few data were available in the Tibetan Plateau area, which is called the Third Pole with its great importance for monitoring global climate change.

Lidar has been used for decades and proved to be a powerful instrument for detecting the atmosphere. Rayleigh lidar, with its high spatial and temporal resolution, is an effective means for measuring vertical temperature profiles in the middle atmosphere [5].

The MARMOT (Middle Atmosphere Remote Mobile Observatory in Tibet) lidar was recently developed by the Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences (CAS). From August 2013 until December 2014, MARMOT lidar has been deployed in Lhasa, Tibet and in Golmud, Qinghai. In this paper, we report winter thermal structure derived from ~400 h of lidar measurements at Golmud during the winter seasons in 2013 and 2014.

2. INSTRUMENTATION

The MARMOT lidar consisted of three parts: laser transmitter, optical receiver, and signal acquisition & control unit (as shown in Fig.1). Lidar transmitter was mainly a Nd:YAG laser working at the wavelength of 532 nm. Optical receiver was a prime focus telescope of Φ1000 mm diameter. Rayleigh backscattered signals of 532 nm were collected by the telescope and then detected by a PMT. A mechanical chopper in the receiver chain blocked any signals below 50 km in order to prevent PMT saturation caused by strong lidar return signals from lower altitudes. A raw photon-count profile is obtained for every 1800 laser shots accumulated. The temporal and spatial resolutions are 1 min and 30 m,

Table 1. Lidar observational time during the winters of 2013 and 2014

Date(DEC/2013)	*1*	*2*	*3*	*4*	*5*	*6*	*7*					
Time(Hours)	**9**	**12**	**12**	**12**	**12**	**12**	**12**					
Date(NOV/2014)	*12*	*13*	*14*	*16*	*17*	*18*	*19*	*21*	*24*	*25*	*27*	*30*	
Time(Hours)	**7**	**11**	**10**	**11**	**11**	**11**	**10**	**2**	**5**	**4**	**10**	**4**	
Date(DEC/2014)	*1*	*2*	*3*	*4*	*6*	*7*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
Time(Hours)	**12**	**12**	**12**	**12**	**13**	**5**	**7**	**9**	**13**	**7**	**10**	**8**	**13**
Date(DEC/2014)	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	
Time(Hours)	**13**	**13**	**13**	**4**	**8**	**3**	**2**	**8**	**11**	**10**	**2**	**13**	

respectively.

Fig.1. The MARMOT lidar system, including the laser transmitter (upper figure), the optical receiver (middle figure), and the signal acquisition part (lower figure).

The main principle of Rayleigh temperature derivation is as follows. Considering that the aerosol content is extremely low above 30 km, the lidar backscattered signals mainly come from the Rayleigh scattering by gaseous molecules. By calculating the atmospheric backscattered signals, we can obtain the relative density profiles in the atmosphere. If we assume that the atmospheric temperature at an initial altitude can be taken from the MSIS-00 model [6], then by combining the ideal gas law and the hydrostatic equation, atmospheric temperature profiles can be derived downward using the relative density profiles [7].

3. OBSERVATIONAL RESULTS

Lidar data from November 12 to December 27, 2014 were used to calculate the mesospheric mean temperature profile in winter. The lengths of observation period during these days were listed in Table.1. In Fig.2, the red solid line represents the mean temperature profile in winter 2014, and the blue dashed line represents the mean temperature profile predicted by the MSIS-00 model in the same time period. The lidar temperatures in lower mesosphere between 57 km and 79 km were considerably lower than the MSIS-00 predictions. In Fig.3, the red line shows the difference between lidar temperatures and MSIS-00 temperatures. The greatest difference is ~16 K at the height of ~66 km. For comparison purpose, we chose another period of lidar data from December 1 to December 7, 2013, which were the only available lidar measurements during that winter season. The cyan solid line in Fig.2 represents the mean temperature profile in

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winter 2013. Although a little warmer than the winter of 2014 at the altitude between 57 km and 79 km, it is still considerably colder than the MSIS-00 results.

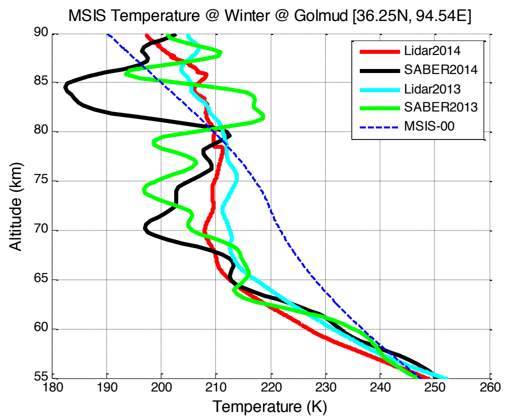

Fig.2. Comparison among the lidar measured temperatures (cyan solid line for Year 2013 and red solid line for Year 2014), the MSIS-00 model temperatures (blue dashed line for Year 2014), and the TIMED-SABER measured temperatures (green solid line for Year 2013 and black solid line for Year 2014) in the winter seasons over Golmud.

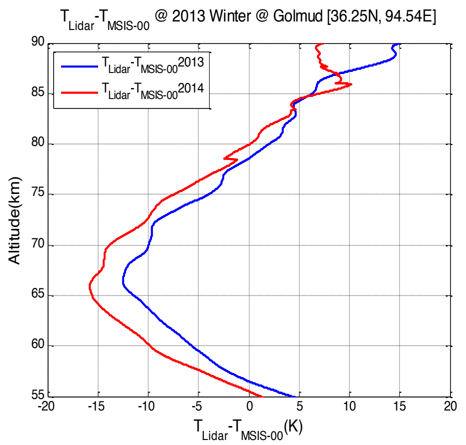

Fig.3. The difference between the lidar measured temperatures and the MSIS-00 temperatures in Year 2013 (blue line) and in Year 2014 (red line).

In addition, as plotted in Fig.2 are temperature data obtained from the Sounding of the Atmosphere using the Broadband Emission Radiometry (SABER) instrument [8] onboard the Thermosphere-Ionosphere-Mesosphere-Energetics and Dynamics (TIMED) satellite, which was launched on December 7, 2001. The black solid line in Fig.2 shows the temperature profile obtained by SABER at 36.20°N, 94.61°E on December 5, 2014. The green solid line in Fig.2 represents the temperature profile obtained by SABER at 37.01°N, 111.16°E on December 4, 2013. Both SABER measured temperatures show significant inversion layers in the upper mesosphere. In the lower mesosphere region, the satellite data were in reasonable agreement with the lidar temperatures, both considerably colder than the MSIS temperatures.

4. DISCUSSIONS

The MARMOT lidar measurements obtained over Tibet Plateau has been used for studying the mesospheric thermal structure during two winter seasons. The discrepancy between lidar and MSIS-00 results have suggested some limitations of the MSIS model over the Tibetan Plateau, since the model was developed under the circumstances that not much middle atmosphere observational data were available in that area. Therefore, lidar measurements could provide an effective tool for improving current atmospheric modeling, and for better understanding the middle atmosphere thermal structure, the waves, and the processes of momentum and energy exchange within layers.

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