Remote Sensing of Environment 206 (2018) 107–122

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

The first validation of the precipitable water vapor of multisensor satellites over the typical regions in China

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ARTICLE INFO

Keywords:
Precipitable water vapor (PWV)
Moderate resolution imaging spectroradiometer (MODIS)
Visible and infrared radiometer (VIRR)
Medium resolution Spectrum imager (MERSI)

ABSTRACT

Ground-based observations (2014–2015) indicated that the precipitable water vapor (PWV) values in China exhibited large spatial and temporal variations. The annual mean PWV values ranged from 4.0 ± 2.9 mm to 42.3 ± 10.6 mm from the Qinghai-Tibet Plateau to the South China Sea, and the seasonal variation ranged from 1.9 ± 1.2 mm to 50.5 ± 5.4 mm. The PWV values were retrieved from MODIS, VIRR and MERSI data, and the accuracies varied widely with relative errors from 10% to 899%. VIRR performed the best in the humid southern coastal regions of China (R = 93%) where the annual PWV was as high as 35 mm. MERSI was more suitable in the dry western region of China (R = 84%) where the average PWV value was lower than 15 mm. MODIS PWV products could be used to accurately observe the PWV in the city and urbanized areas of the eastern China Plain (R = 89%) where the annual mean PWV was 20–30 mm. All of the products yielded larger errors in the summer than in the winter. The MOD05 and MOD07 data performed better than the other satellite data in most regions.

1. Introduction

Precipitable water vapor (PWV) is the total atmospheric water vapor contained in a vertical column of cross-section unit (King et al., 1992; Ichoku et al., 2002a). Water vapor is a key element in the climate system of Earth (Pérez Ramírez et al., 2014; Czajkowski et al., 2002), as it is a key factor in meteorological processes (Rocken et al., 1991; Seemann et al., 2003), climate change (Raval and Ramanathan, 1989), and atmospheric chemistry and dynamics (Raja et al., 2008). Water vapor is also one of the most important input parameters for inversion atmospheric correction of remotes sensing data (Peng et al., 2006; Wang et al., 2005). Three types of algorithms, each using different retrieval channels, are used to derive columnar water vapor: the microwave retrieval method (Alishouse et al., 1990; Schulz et al., 1993), the near-infrared band retrieval method (Frouin et al., 1990; Gao and Kaufman, 1992; Bennartz and Fischer, 2001; Remer, 2005), and the thermal infrared band retrieval method (Chesters et al., 1983; Iwasaki, 1999; Jedlovec, 1990; Kleespies and Mcmillin, 1990; Susskind et al., 1984; Sobrino et al., 1994). The most common method to observe water vapor is through remote sensing. Some of the currently available satellite sensors can be used to retrieve atmospheric precipitable water data, and there are many ground-based observation networks that can be used to obtain water vapor data.

Sun photometers have used strong water vapor absorption channels to estimate water vapor column abundance (Liu et al., 2013). The Aerosol Robotic Network (AERONET) program is a federation of ground-based remote sensing aerosol networks established by NASA and PHOTONS, consisting of over 300 sun photometers worldwide. The main purpose of AERONET is to monitor aerosol optics and global microphysical properties and provide high-frequency, standardized

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https://doi.org/10.1016/j.rse.2017.12.022
Received 14 September 2017; Received in revised form 29 November 2017; Accepted 18 December 2017
0034-4257/

Table 1
Summary of the characteristics of the satellite data.

Data source	Product	Time span	Temporal sampling	Spatial resolution	Derivation method
MODIS	MOD05_L2 Water_vapor_Near_Infrared	2014/6–2015/5	Every day	1 km	Near-infrared retrieval algorithm
	MOD07_L2 Water_vapor	2014/6–2015/5	Every day and night	5 km	Infrared retrieval algorithm
VIRR	VIRR_DAY_TPWSDS	2014/6–2015/5	Every day and night	1 km	Infrared split window method
MERSI	MERSI_PWV	2014/6–2015/5	Every day and night	1 km	Near-infrared retrieval algorithm

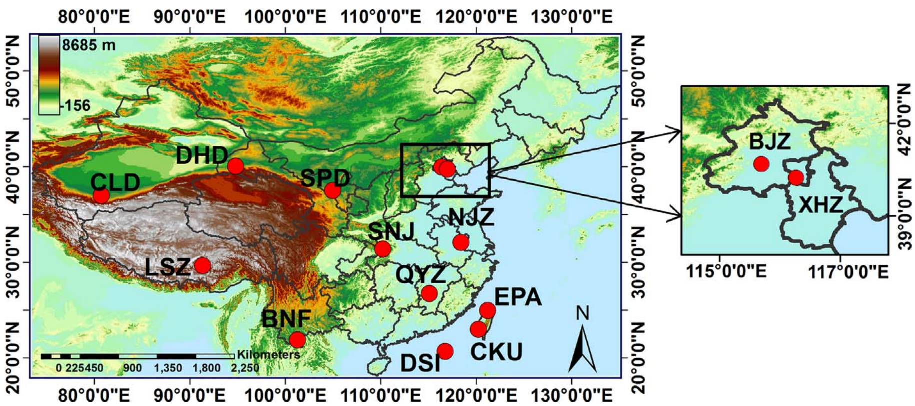

Fig. 1. Geographic distribution of the typical ecosystem sites in China.

Table 2
Geographic information for the thirteen sites in China.

No.	Station/code	Lon (°N)	Lat (°E)	Altitude (m)	Ecosystem	Data sources
1	Cele/CLD	80.72	37.00	1306	Taklamakan Desert	CARE-China
2	Dunhuang/DHD	94.79	40.04	1300	Kumtag Desert	CARE-China
3	Shapotou/SPD	104.95	37.5	1350	Tengger Desert	CARE-China
4	Lhasa/LSZ	91.33	29.67	3688	Qinghai-Tibet Plateau	CARE-China
5	Shennongjia/SNJ	110.2	31.4	1290	Subtropical forest	CARE-China
6	Xishuangbanna/BNF	101.27	21.9	570	Tropical rain forest	CARE-China
7	Nanjing/NJZ	118.4	32.1	62	Southeastern city	CARE-China
8	Qianyanzhou/QYZ	115.07	26.75	105	Southeastern suburbs	CARE-China
9	Beijing/BJZ	116.38	39.98	92	North city	AERONET
10	Xianghe/XHZ	116.96	39.75	36	North suburbs	AERONET
11	EPA-NCU/EPA	121.19	24.97	144	Taoyuan County, Taiwan	AERONET
12	Chen-Kung-Univ./CKU	120.22	23	50	Tainan City, Taiwan	AERONET
13	Dongsha Island/DSI	116.73	20.7	5	Islands of South China Sea	AERONET

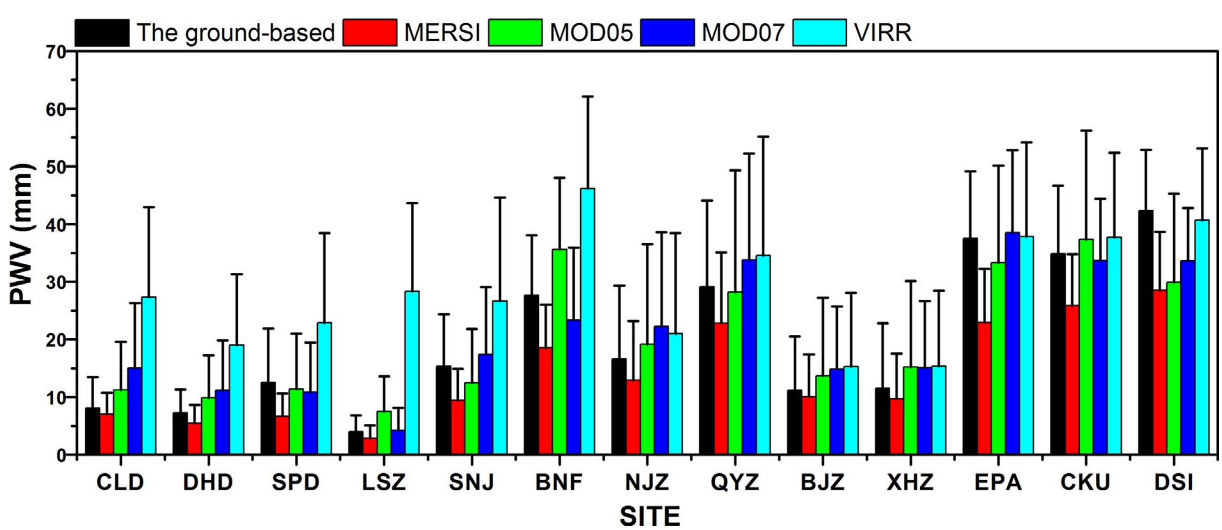

Fig. 2. The annual mean PWV determined from ground-based and satellite observations in the typical regions.