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ATMOSPHERIC RADIATION, OPTICAL WEATHER, AND CLIMATE

Interannual Variability of Surface and Integrated Water Vapor and Atmospheric Circulation in Europe

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Abstract—The variability of time series of the integrated water vapor of the atmosphere and the surface partial pressure of water vapor for the territory of Europe over a long period have been studied. The main contribution to the variance of both integrated and surface water vapor is made by seasonal variations of 60–70%; mesoscale processes, 7–17%; and synoptic processes, 17–27%. The linear trend contributes less than 1% to the overall variance of the variability of the atmospheric water vapor in Europe. It has been shown that the interannual variability of the atmospheric water vapor manifests itself both in quasi-periodic variations in the annual average values and in variations in the intensity of synoptic processes. The irregular coherence of variations in the circulation indices and surface partial water vapor pressure in Europe with periods of 2–3, 5–6, 8–11, and 10–13 years has been established.

Keywords: atmospheric integrated water vapor, water vapor partial pressure, interannual processes, remote sensing by satellite navigation systems

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INTRODUCTION

Water vapor is one of main greenhouse gases; its spatiotemporal structure is closely related to the radiation balance of the atmosphere and Earth's surface and atmospheric circulation. The formation of spatiotemporal characteristics of humidity fields is influenced by atmospheric processes of different scales interacting with each other.

In recent times, GPS meteorology using global navigation satellite systems (GNSSs) for estimating the integrated water vapor (IWV) with a high spatiotemporal resolution have been developed [1]. Most atmospheric monitoring programs developed by the international scientific community use GPS signals, which demonstrates the relevance of this technology. Many studies were devoted to comparison between the IWV from aerologic and GNSS-measurements for different geographic regions: Australia and Antarctica [2], Sweden [3], Italy [4], the Unites States [5], China [6, 7], and India [8]; standard deviations are from 1 to 4 mm of precipitated water. Similar estimates of accuracy are obtained when GPS estimates are compared with radiometric data [9, 10], which indicates the reliability of GNSS monitoring data.

The GNSS data series accumulated during the last one and half decades allow one to investigate trends in the IWV. In [11], long-term IWV trends (1996–2010) over the western coast of Sweden were considered using data from four technologies: microwave radiometers, very-long-baseline radio interferometry, GNSS, and radiosondes. In all the series, IWV trends from 0.3 to 0.5 mm of precipitated water per decade were revealed. There are shifts between synchronized IWV data obtained by independent methods: radiointerferometer—GNSS, 0.39 mm; radiometer—GNSS, 0.4 mm; and radiosonde—GNSS, 0.01 mm of precipitated water.

In [12], the IWV was studied using a microwave radiometer (near Bern, Switzerland, 1994–2007). The GPS and radiosonde data were used for homogenization of the IWV series. It was shown that the diurnal cycle was weak, had amplitude of 0.32 mm with a maximum at 2100 and minimum at 1100 UTC. The linear IWV trend according to radiometer data is positive and is 0.39 mm/yr. The trend according to data of the nearest radiosonde station was 0.45 mm/yr; according to reanalysis data, 0.25 mm/yr, which exceeds values obtained in [11]. At the same time, it was mentioned that seasonal trends were ten times stronger. Positive trends in summer are partially compensated by negative trends in winter. It was stated that predicting climatic changes needs longer series of measurements. In [5], according to data of GNSS networks in the United States, IWV trends for 2002–2009 were found. It was established that revealing a trend of about 0.05 mm/yr needs 25–30 years of observations.

Unfortunately, in most works on studying moisture content, attempts were made to represent its variability by average or stationary processes: interannual processes, in the form of a linear trend; diurnal ones, in