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Anomalous changes in column water vapor after Gujarat earthquake

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Abstract

Remote sensing data have been used to analyze the changes in column water vapor in response to the Gujarat earthquake, occurred on January 26, 2001. Anomalous changes in water vapor have been found over the surrounding land and oceanic regions around epicentral region before and after the earthquake. The sudden increase in column water vapor in the atmosphere before the earthquake may be attributed to the increase in evaporation due to increase in surface latent heat flux (SLHF). SLHF is found to increase two days before the earthquake and decrease after the main event on January 26, 2001 before it acquires the background value. Water vapor over the epicentral region is found to increase just before the earthquake whereas over the ocean, water vapor is found to increase after the earthquake.

1. Introduction

The Gujarat earthquake (Gaur, 2001) of magnitude 7.8 occurred on January 26, 2001 at 8.46 a.m., rocking the whole of Gujarat state and the adjoining land and oceanic regions. The epicenter was located at 70.32°E and 23.33°N (black dot in Fig. 1). Efforts have been made to study the significant changes over land (Singh et al., 2001a,b; Singh et al., 2002) and ocean (Singh et al., 2001c) after the earthquake. Soon after the earthquake, the chlorophyll and suspended sediment concentrations along the Gujarat coast have been found to increase significantly (Singh et al., 2001c). Prominent surface manifestations of the palaeo-channels, water bodies, water-logging, liquefaction and emergence of lands along the coastline have been observed after the Gujarat earthquake (Singh et al., 2001a). Recent studies carried out by Hayakawa et al. (1994) have shown that the atmospheric phenomena may give information as precursor of earthquakes. In view of this, soon after the deadly Gujarat earthquake of January 26, 2001, detailed studies have been taken up to study the changes in land, ocean and atmospheric parameters. In the present paper, we have carried out detailed analysis of water vapor in the atmosphere over Gujarat state. The water vapor is retrieved from global data set and also computed using data obtained from various microwave remote sensing satellites. The water vapor in the atmosphere over epicentral region shows anomalous pattern before and after the earthquake. The cause of anomalous pattern of water vapor has been discussed in view of the changes in land and ocean parameters.

2. Data

Tropical rainfall Measuring Mission (TRMM) data (http://trmm.gsfc.nasa.gov/) have been used to retrieve the water vapor content in the atmosphere over the land regions, whereas Special Sensor Microwave Imager (SSM/I) data have been used over the oceans. TRMM satellite has five sensors onboard: (1) Precipitation radar, to provide three-dimensional mapping of storm structure. (2) TRMM Microwave Imager (TMI), to provide quantitative information about rainfall and total precipitable water (TPW). (3) Visible Infrared Radiometer (VIRS), to delineate rainfall and serve as a transfer standard to other measurements. (4) Cloud and Earth's Radiant Energy System (CERES), to study the energy exchanged between the sun, Earth's atmosphere, surface, clouds and space, and (5) Lightning Imaging Sensor (LIS), to detect and locate lightning over tropical region.

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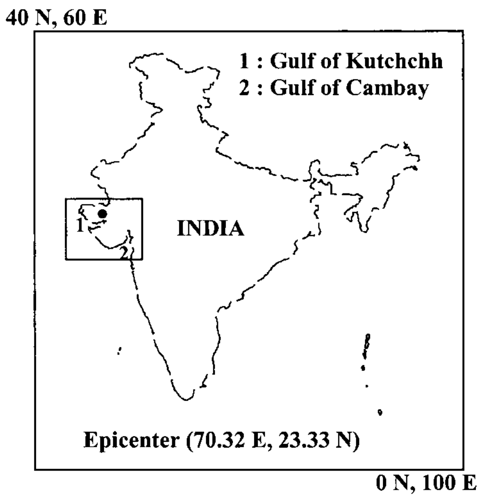

Fig. 1. Location of the study area.

In this paper, water vapor content in the atmosphere has been retrieved for the days before the earthquake, on the day of the earthquake and after the earthquake from TMI data, the details of the retrieval methods are given by Hou et al. (2001). TMI is a passive microwave sensor operational at 10.7, 19.4, 21.3, 37 and 85.5 GHz frequencies. These frequencies are similar to those of the SSM/I (Singh et al., 2001a), except that TMI has the additional 10.7 GHz channel designed to provide more linear response for the high rainfall rates common in tropical region (http://trmm.gsfc.nasa.gov/). The SLHF data have been taken from National Centers for Environmental Prediction (NCEP) data sets (http://iridl.ldeo.columbia.edu/).

The SSM/I is flown on the Defense Meteorological Satellite Program (DMSP) Block 5D-2 F8 spacecraft. It is a seven-channel four-frequency, linearly polarized, passive microwave radiometric system. It receives vertically and horizontally linearly polarized radiation at 19.3, 37.0 and 85.5 GHz and only vertically polarized radiation at 22.2 GHz (Singh et al., 2000). SSM/I covers the whole globe in two days, we have taken the average of two days data to study the changes over the adjoining oceans. TPW has been computed using SSM/I data over the oceans using following relation (Singh et al., 2000):

$$\begin{aligned}\mathrm{TPW} = {} & 232.89 - 0.1486(T_{\mathrm{B19V}}) \\ & - [1.8291 - 0.006193(T_{\mathrm{B22V}})](T_{\mathrm{B22V}}),\end{aligned}$$

where T_{B19V}, T_{B22V} and T_{B37V} are the brightness temperature at 19, 22 and 37 GHz vertical polarization, respectively.

3. Results and discussion

Anomalous water vapor content in the atmosphere over the epicentral and its surrounding regions has been computed during the period of January 22–30, 2001. The seasonal effect has been minimized to estimate the anomalous change in water vapor content before and after the earthquake. From Fig. 2, it is found that water vapor slowly builds up over the epicentral and surrounding region before the earthquake from January 23 and concentrates over the epicentral region until the preceding day (January 25) of the earthquake before it diminishes after the earthquake (Fig. 2). The extent of the anomalous water vapor concentration has been found to be highest on January 23, 2001 and the areal extent has been found to diminish afterwards. The concentration of water vapor on January 23 is found to be 0.9–1 g/m^2 over the epicentral region and 0.1–0.3 g/m^2 over the surrounding region. The SLHF is a function of surface temperature and depends on the terrain characteristics. It controls the fraction of the incident short-wave radiation and plays significant role in evaporation of water vapor into the atmosphere. The SLHF shows interesting behavior over the epicentral region (Fig. 3). The monthly averaged value for the month of January has been found to be 1.5 W/m^2. During the week of the earthquake from January 22–29, 2001, SLHF shows highest value (7 W/m^2) on January 24, 2001 and the lowest value (−2 W/m^2) on January 28, 2001 during the week (January 22–29, 2001). The anomalous water vapor content over the epicentral region has been found to be concentrated on January 25, 2001 (Fig. 2). This may be attributed to the increase in evaporation of the surface water due to the increased SLHF in the preceding day. The reason for the high SLHF before the earthquake may be attributed to the migration of positive holes to the Earth's surface (Tronin, 1999; Tronin et al., 2002) and the effect of the accumulation of stress in the region. The SLHF decreases to a minimum value (−2 W/m^2) soon after the earthquake on January 26, 2001 and afterwards acquire the average background value. TPW values deduced from SSM/I over the oceanic regions has been found to increase after the earthquake (Fig. 4). In the coastal areas of Gujarat (Gulf of Kutchchh and Gulf of Cambay), TPW varies within the range of 10–40 mm before the earthquake (Fig. 4). The epicenter of the Gujarat earthquake lies close to the oceans, the intense shaking leads to the ocean waves and coastal surfs (Singh et al., 2002) and higher ocean–atmosphere interaction. These changes on the land and ocean may increase TPW over the ocean after the earthquake. The effect is seen more prominent over the Gulf of Kutchchh (Fig. 1), where the TPW values increase by ~15 mm (Fig. 4) compared to the Gulf of Cambay (Fig. 1), which shows small increase (~5 mm) in TPW (Fig. 4). The concentration of the water vapor over the epicentral region before the earthquake may be attributed to the thermal anomaly developed in the region due to the earthquake. The anomaly pattern may

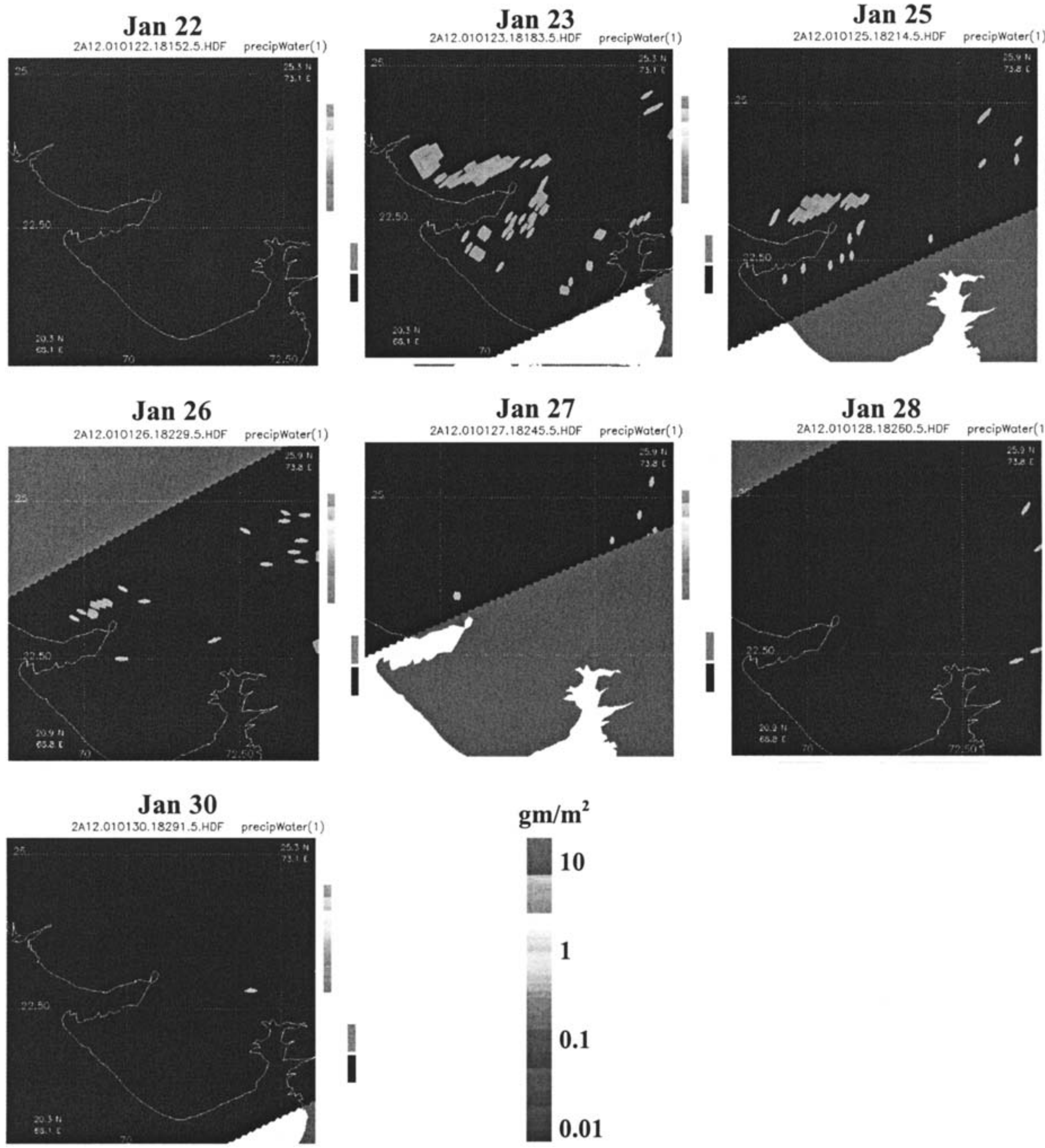

Fig. 2. TRMM derived water vapor content over the epicentral region.

be attributed to the higher surface latent heat flux, which has been observed before the earthquake. Over the oceans, the anomalously high water vapor content has been found after the earthquake. The intense surface manifestations in the form of liquefaction were seen in the epicentral region. Further, significant changes in brightness temperature were also observed. A close connection between land–ocean–atmosphere is plausible to explain water vapor anomaly associated with earthquake similar to Gujarat earthquake of January 26, 2001.

4. Conclusion

The reason for water vapor anomaly in the epicentral region is not very clear. The preliminary results of Gujarat earthquake show that the water vapor anomaly is seen before the earthquake over the land region. The distribution of high concentration of water vapor the epicentral region before the earthquake diminishes away after the main event. The anomaly pattern may be attributed to the higher SLHF, which has been observed before the earthquake. Over the oceans, the anomalous

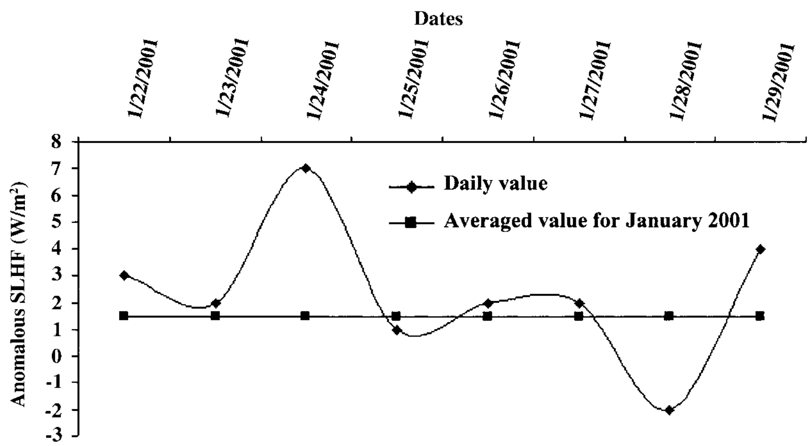

Fig. 3. Surface latent heat flux at the epicentral region.

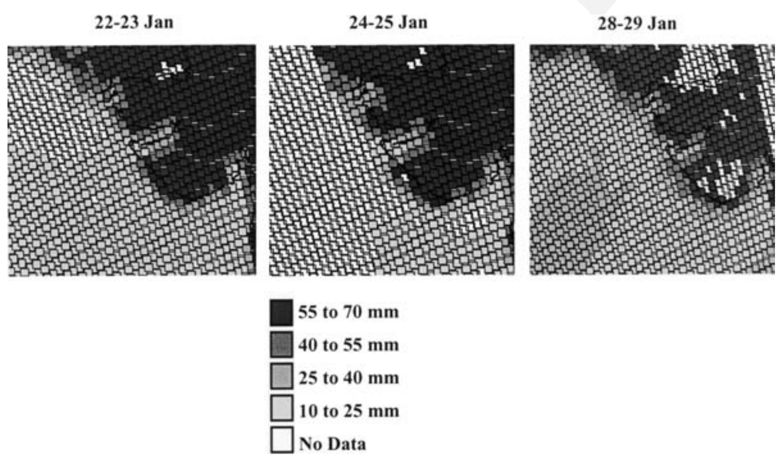

Fig. 4. TPW over the oceanic regions before and after the earthquake.

water vapor content may be attributed due to land–ocean–atmosphere coupling due to intense surface and subsurface deformations in the epicentral region. Detailed investigations of atmospheric water vapor content and its temporal variations prior and after earthquakes which occur especially near the ocean are required to examine its close connection with any earthquake.

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