Microwave remote sensing application for monitoring of floods

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सार – अनेक बार भारी और लगातार वर्षा के होने से नदियों के जल स्तर बढ़ जाते हैं और बाढ़ आ जाती है। वर्ष 2011 में मॉनसून ऋतु के दौरान बिहार (भारत) में गंगा एवं कोसी नदियों में तथा पश्चिम बंगाल (भारत) की दामोदर एवं हुगली नदियों में विनाशकारी बाढ़ें आईं। इस शोध पत्र में वर्ष 2011 में मॉनसून ऋतु के दौरान भारत के दरभंगा (बिहार) और मिदनापुर (पश्चिम बंगाल) में आई बाढ़ों का पता लगाने एवं मानीटरन करने के लिए निष्क्रिय सूक्ष्मतरंग दूरसंवेदी डेटा का उपयोग किया गया है। बाढ़ की घटनाओं की पहचान एवं मानीटरन करने के लिए 19 गिगा हर्ट्ज और 91 गिगा हर्ट्ज पर स्पेशल सेन्सर माइक्रोवेव इमेज साउन्डर (SSMIS) द्युति तापमान (Tb) का उदग्र एवं क्षैतिज दोनों ही स्थितियों में ध्रुवण किया गया तथा मृदा नमी एवं महासागरीय लवणता (SMOS) द्युति तापमान (Tb) का 1.4 गिगा हर्ट्ज पर उपयोग किया गया हैं। क्षैतिज एवं उदग्र दोनों ध्रुवणों के साथ 19 गिगा हर्ट्ज द्युति तापमान, 19 एवं 91 गिगा हर्ट्ज द्युति तापमान के अंतर तथा 1.4 गिगा हर्ट्ज द्युति तापमान का उपयोग करते हुए इस शोध पत्र में बाढ़ की घटनाओं की पहचान एवं मानीटरन करने का प्रयास किया गया है। क्षैतिज ध्रुवण में (19 गिगा हर्ट्ज - 91 गिगा हर्ट्ज) द्युति तापमानों के लिए बाढ़ आने की अधिकतम सुग्राहिता प्रेक्षित की गई है। बाढ़ प्रभावित क्षेत्रों को (19 गिगा हर्ट्ज - 91 गिगा हर्ट्ज) द्युति तापमानों (क्षैतिज ध्रुवीकरण सहित द्युति तापमान) के मानों के उपयोग से मानचित्रित किया गया है और इसकी तुलना रेडार उपग्रह-1 चित्रों से की गई है जिससे निष्क्रिय तथा सक्रिय सूक्ष्मतरंग दूरसंवेदी डेटा के बीच एक आम सहमति हो सके। तुलनात्मक अध्ययन यह भी बताते हैं कि निष्क्रिय सूक्ष्मतरंगीय डेटा से बाढ़ प्लावित क्षेत्रों का आकलन अधिक है।

ABSTRACT. Many times heavy and continuous rains give rise to flooding in the rivers. Devastating floods occurred in rivers Ganga and Kosi in Bihar (India) and in Damodar and Hooghly rivers in West Bengal (India) during 2011. In the present paper, passive microwave remote sensing data is utilized for detection and monitoring of floods that occurred in Darbhanga (Bihar) and Midnapore (West Bengal) India, in the year 2011during monsoon season. Special Sensor Microwave Imager Sounder (SSMIS) brightness temperature (Tb) data at 19 GHz & 91 GHz in both vertical and horizontal polarisations and Soil Moisture and Ocean Salinity (SMOS) Tb data at 1.4 GHz are used to detect and monitor the flood occurrences. An attempt has been made to detect and monitor the flood events using 19 GHz Tb, difference of 19 and 91 GHz Tbs, and 1.4 GHz Tb, with both horizontal and vertical polarizations. Highest sensitivity to flood occurrence is observed for (19 GHz - 91 GHz) Tbs in horizontal polarization. Flood affected areas are mapped using (19 GHz - 91 GHz) Tbhs (Brightness temperatures with horizontal polarisation) values and compared with the Radarsat-1 images to show a general agreement between passive and active microwave remote sensing data. The comparison also shows an over-estimation of flooded area from passive microwave data.

Key words – Flood detection, Microwave remote sensing, SSMIS, SMOS, RADARSAT-1.

1. Introduction

Remote sensing techniques are being used since last several years to collect data for disaster detection and management. Depending upon the wavelength used for monitoring the phenomena, there are two types of remote sensing techniques, *viz*., optical/IR based and Microwave based. At the time of rains and floods, generally there is no cloud free environment. Hence, optical remote sensing is not successful in rain for flood detection. But microwave based remote sensing is very useful in such cases because of its all weather and day-night capabilities

Fig. 1. Methodology flow chart

and penetration through clouds (Ulaby *et al.*, 1981). In addition, active remote sensing techniques are also used for flood monitoring using microwave, to compliment the data obtained from the other methods.

Lot of work related to flood monitoring has been done with optical and microwave sensors in past years. Since image acquisition by optical sensors are limited byweather influence, clouds and precipitation conditions (Tran, 2009), therefore now a days both active and passive microwave remote sensing techniques are being utilized. Tran (2009) has reported results of their studies using active microwave remote sensing data obtained from Envisat Advanced Synthetic Aperture Radar (ASAR) data. However, it has the limitation of revisit time (3 days) in wide swath mode (Baldassarre *et al.*, 2011). Based on the passive microwave techniques for flood detection, Kuglera *et al.*, (2007) utilized Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) brightness temperature (Tb) data at 36 GHz with horizontal polarization, to detect river inundations resulting into floods. They defined a M/C ratio, according to equation 1.

Measured/Calibration (M/C) ratio = Tbm / Tbc   (1)

Where Tbm is the brightness temperature at 36 GHz with horizontal polarization over the river which is to be monitored (river pixel) and Tbc is the corresponding brightness temperature at same 36 GHz with horizontal polarization, over nearby area which is not flooded (calibration pixel). As soon as the river floods over-bank, the proportion of water in the river pixel greatly increases and there is a strong response in the M/C ratio. Due to the lower emission of water the signal of the river pixel (Tbm) lowers consequently, the M/C Ratio increases indicating flood inundation. But Kuglera *et al.* (2007) have not used Special Sensor Microwave Imager/Sounder (SSMI/S) Tb data for flood monitoring.

Calla (2009) has reported that values of dielectric constant (real part) of soil decrease with increasing microwave frequencies at given soil moisture condition and thus have a negative slope. Calla (2009) also showed that the magnitude of the slope increases with increase in soil moisture content. Tb at any microwave frequency has inverse relation with dielectric constant of the soil [Ulaby *et al.*, (1981)]. Thus, as the moisture content increases in the soil, more negative difference will be observed between Tb at lower frequency and Tb at higher frequency (*i.e.*, Tb_{lower} - Tb_{higher}). This motivates one to use values of (Tb_{lower} - Tb_{higher}) as a parameter to detect and monitor
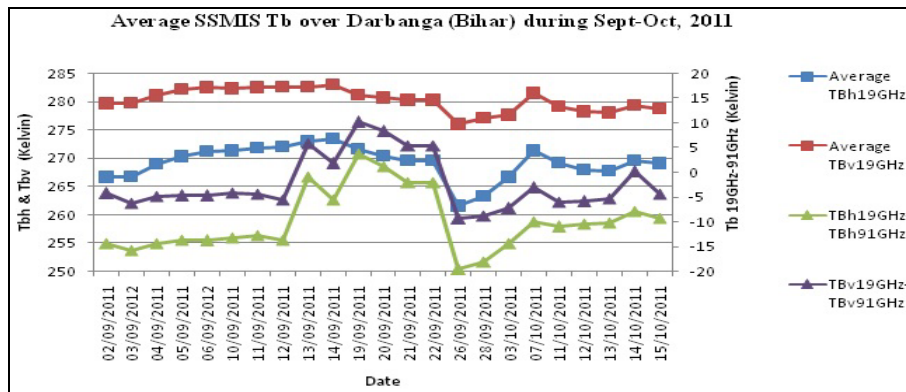
Fig. 2. Analysis of SSMIS brightness temperature over Darbhanga (Bihar) during September & October, 2011
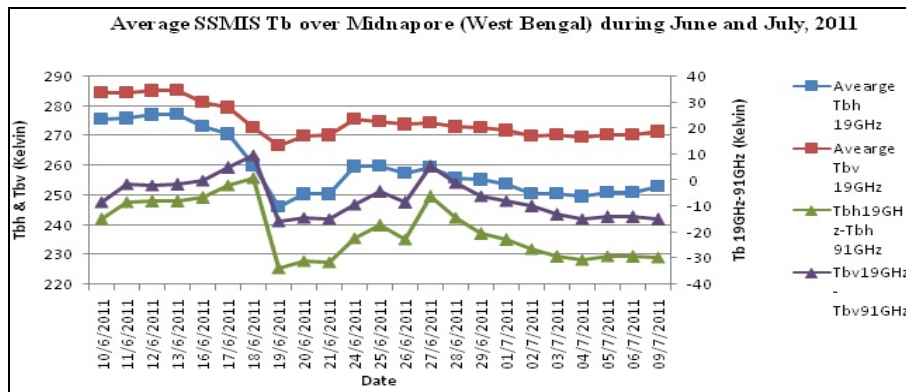

Fig. 3. Analysis of SSMIS brightness temperature over Midnapore (West Bengal) during June and July 2011
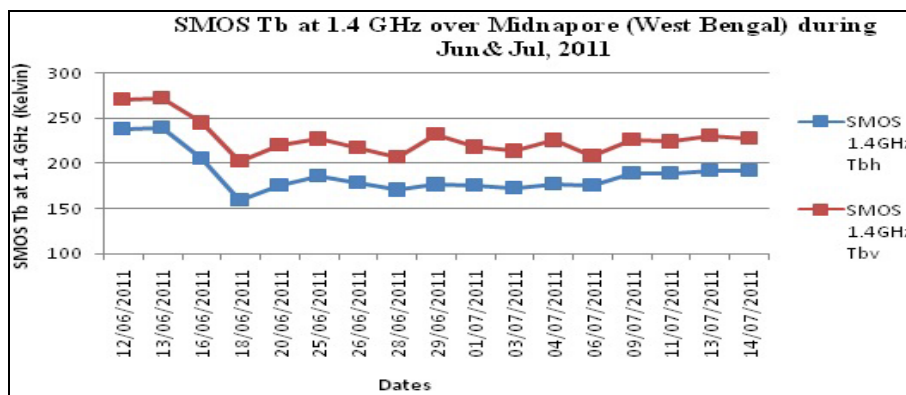

Fig. 4. Analysis of SMOS brightness temperature over Midnapore (West Bengal) during June and July, 2011

floods. In the present paper, this new technique is proposed, in which, SSMIS Tbs at 19 GHz and 91 GHz with both polarizations are used to detect flood inundations. In addition to this, individual brightness temperatures at 19 GHz and 1.4 GHz with both polarizations are also analysed. Tbs at 1.4 GHz are retrieved from Soil Moisture and Ocean Salinity (SMOS)

satellite launched by European Space Agency (ESA) in November, 2009 [Kerr *et al.* (2010)]. 1.4 GHz is considered to be the most effective frequency to monitor surface soil moisture over land [Kerr *et al*. (2010) & Kerr *et al.* (2012)]. Due to high contrast in dielectric constant values of pure dry soil (~2 to 3) and pure water (~80) at 1.4 GHz, Tb at this frequency is highly sensitive to
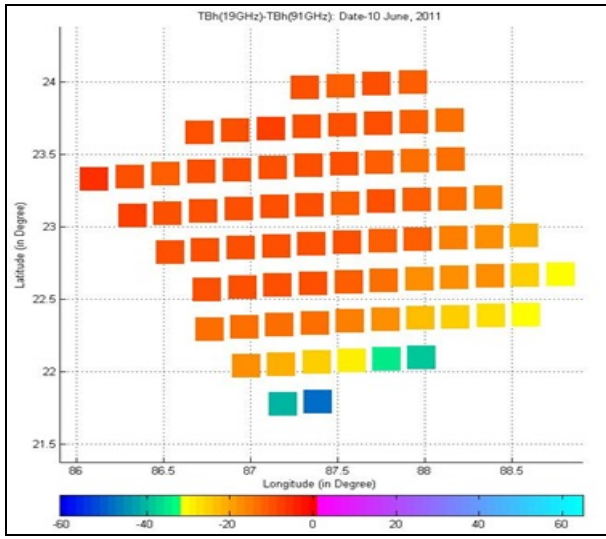
Fig. 5. Geo-spatial mapping of SSMIS Tb difference (19GHz - 91 GHz) data set with horizontal polarization for 10th June, 2011 over Midnapore (West Bengal)
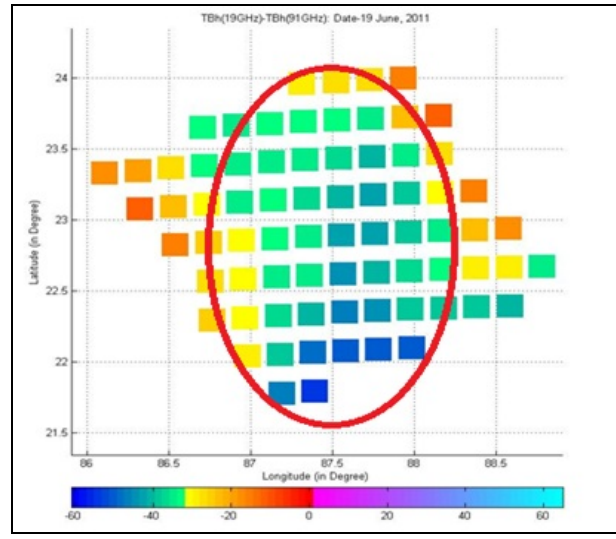

Fig. 6. Geo- spatial mapping of SSMIS Tb difference (19 GHz - 91 GHz) data set with horizontal polarization for 22 June, 2011 over Midnapore (W.B.). In red ellipse shows the flooded area

surface soil moisture. Thus, for this reason SMOS Tb at 1.4 GHz has also been analyzed during the flood occurrence. A good correlation is observed between SSMIS and SMOS Tb data sets.

2. Data description

For flood detection in Bihar and West Bengal, during the period under present study the following types of microwave sensors data have been used.

SSMIS Data - Special Sensor Microwave/Imager (SSM/I) and Special Sensor Microwave Imager Sounder (SSMIS) data products are produced as part of NASA's Pathfinder Program (http://www.oso.noaa.gov/dmsp/ & http://www.ssmi.com/ssmi/ssmi_description.html). Defence Meteorological Satellite Program (DMSP) F16 and F17 satellites carry the SSMIS instrument which provide in both polarization brightness temperature (Tb) data at 19, 37, 91 GHz and in only vertical polarization at 22 GHz. In the present paper, data of F17 SSMIS 19 GHz and 91 GHz Tbs with both vertical and horizontal polarizations are used for detection of floods.

SMOS Data - SMOS was launched in November, 2009 as part of second earth explorer mission program of ESA. This has the onboard passive microwave sensor called Microwave Imaging Radiometer with Aperture Synthesis (MIRAS) (McMullan *et al*., 2008), which works at L-band (1.4135 GHz). SMOS data during the flood events are used in the present study over West Bengal region.

3. Methodology

Fig. 1 shows the flow chart of general methodology adopted in the present study. Firstly, the selection of study area (*i.e*., Darbhanga (Bihar) and Midnapore (West Bengal) regions) has been done using Google Earth software. For these regions, both SSMIS and SMOS Tbs have been analysed for the dates depicted in the flow chart. Figs. (2-4) show the variation of average values of Tb retrieved from SSMI/S with both polarizations over Darbhanga (Bihar) & Midnapore (West Bengal) and variation of average values of Tb retrieved from SMOS with both polarizations over Midnapore (West Bengal), respectively. Figs. (2 & 3) also show the variation of difference in Tb values at 19 GHz and Tb values at 91 GHz (*i.e*., Tb19 GHz – Tb91 GHz) with both polarizations, for the selected dates, over Darbhanga (Bihar) & Midnapore (West Bengal) respectively. In Figs. 2 & 3 Tbh represents brightness temperature with horizontal polarization and Tbv represents brightness temperature with vertical polarization.

Threshold values of each data sets (Tbh 19 GHz, Tbv19 GHz, Tbh1.4 GHz, Tbv1.4 GHz, Tbh (19 GHz - 91 GHz) & Tbv (19 GHz - 91 GHz) can be decided by observing the data of non flooded dates, so as to distinguish and estimate total flood affected area. In the present paper, threshold value of the difference of Tbhs (19 GHz and 91 GHz) is decided at -31° Kelvin, by observing data sets (Tbh 19 GHz - 91 GHz) of non-flooded date (10th June, 2011) over Midnapore, West Bengal (Figs. 3 & 5). Thus, values of Tbh (19 GHz- 91 GHz) lower than -31° Kelvin over the region indicate
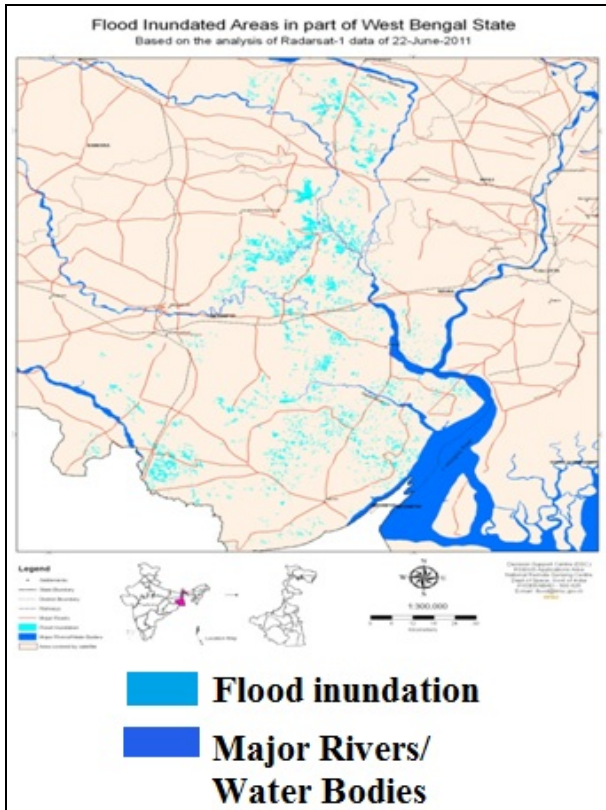
Fig. 7. RADARSAT-1 image of Midnapore (West Bengal) during 22 June, 2011. In this, sky blue shade depicts the flooded area. (Courtesy: NRSC, India)

the flood affected area, which is shown with red ellipse in Fig. 6. Canadian RADARSAT-1, carrying a Synthetic Aperture Radar (SAR) operating at 5.3 GHz, has also detected these flood affected areas with high spatial resolution (Fig. 7). Fig. 6. is compared with the corresponding RADARSAT-1 image (Fig. 7), to show general agreement between passive and active microwave sensor data sets.

Similarly, threshold values can also be decided for other data sets (Tbh 19 GHz, Tbv19 GHz, Tbh1.4 GHz, Tbv1.4 GHz & Tbv (19 GHz - 91 GHz) and flood affected areas can be estimated.

4. Results and discussion

From the analysis of SSMI/S Tb data sets (Tbh 19 GHz, Tbv19 GHz, Tbh (19 GHz - 91 GHz) & Tbv (19 GHz - 91 GHz) shown in Figs. 2 & 3 for Darbanga (Bihar) and Midnapore (West Bengal) respectively, highest sensitivity to floods, is observed for Tbh (19 GHz-91 GHz) data sets. Therefore, Tbh (19 GHz - 91 GHz) data set can be used to detect and monitor flood disasters.

By analysing the various data sets for the dates before the flood occurrence, threshold values can be decided for a given region, as -31° Kelvin is decided in the present paper for Tbh (19 GHz - 91 GHz) data set to estimate flood affected area over Midnapore, West Bengal. It must be noted that the complete area (equal to spatial resolution of microwave passive sensor data) over which single value of brightness temperature data is below the decided threshold value will be indicated as flooded area, even though there is no flood inundation over some part of the given area. Thus, the passive microwave sensors have tendency to overestimate the extent of flood affected areas due to their inherent low spatial resolution (~ 25 km). The same is observed by comparing the flood affected area, estimated using passive microwave sensor data (area within the red ellipse shown in Fig. 6), with the high resolution RADARSAT-1 image shown in Fig. 7. However, passive microwave sensor data has an advantage of high temporal resolution. In the present case, SSMI/S Tb data are daily available for a given region. Thus, using passive microwave data one can regularly monitor flood prone areas with the inherent limitation of its low spatial resolution.

In the present paper, SMOS Tb at 1.4 GHz has also been analysed to detect flood, as shown in Fig. 4. The main reason to analyse data at this frequency is its high sensitivity to surface soil moisture. Results show that Tb at 1.4 GHz is also very sensitive to flood occurrence (Fig. 4). But, in spite of its good sensitivity to flood detection, it is not combined with SSMI/S data sets because of two reasons. First, SSMI/S data has better temporal resolution (once daily) as compared to SMOS maximum 3 days temporal resolution. Secondly, Radio Frequency Interference (RFI) at 1.4 GHz is a major concern because of which SMOS data can be affected (http://www.cesbio.ups-tlse.fr/SMOS_blog/?tag=rfi). However, in the non-RFI regions, SMOS data can also be used to detect and monitor floods.

It can also be seen from Figs. (2-4) that Tbs with horizontal polarization at 19 GHz & 1.4 GHz are more sensitive than the corresponding Tbs with vertical polarization.

From Figs. (2-4), it is also observed that all the data set values of both SSMI/S and SMOS, over Midnapore (West Bengal), are considerably lower as compared to the data set values over Darbhanga (Bihar) for the long duration after the flood occurrence. The main reason is the occurence of low rainfall over Darbhanga and the continuous rainfall occurence over Midnapore after the flood events. This has been verified with the India Meteorological Department rainfall data, which are freely available on IMD website at- http://www.imd.gov.in.

5.   Conclusion

From the analysis of SSMI/S data for the two flood events of 2011 over the areas of study, it can be concluded that Tbh (19 GHz - 91 GHz) data set, among other SSMI/S data sets, have highest sensitivity to detect floods and can be used to monitor flood prone areas regularly. The passive microwave remote sensing data set has over-estimated the flood affected area (Fig. 6) as compared to active microwave remote sensing data (RADARSAT-1 image shown in Fig. 7). In addition, the passive microwave remote sensing data, due to its high temopral resolution, can be used as complimentary data to monitor floods regularly, when active microwave remote sensing data is non-available over a given area due to its low temporal resolution and comparatively lower swath width.

SMOS Tb data has also shown a good sensitivity to detect floods (Fig. 4). These can also be used to detect floods. In spite of its high sensitivity to surface soil moisture, its use is limited by RFI contamination in certain parts of the world. Therefore, in Non-RFI regions it can be utilized to detect and monitor floods.

In general Tbs with horizontal polarization are found to have more sensitivity to floods as compared to Tbs with vertical polarization for all data sets of both SSMI/S and SMOS.

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