Satellite observations for extreme events interpretation

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ABSTRACT

The use of satellite observations could help in order to extend our present capabilities in the interpretation of extreme events related to rainfall. In this work the Advanced Microwave Sounding Unit (AMSU) products have been used in order to obtain a complete description of a catastrophic flooding in Romania and Hungary in March 1999. Two people dead and eight thousand houses severely damaged were consequent to the events observed on 12-14 March 1999. Soil features combined with antecedent precipitation events have been considered as possible preparing conditions. Surface parameter retrievals, obtained by AMSU data, have been used in order to characterize soil humidity and land cover. Data coming from Advanced Very High Resolution Radiometer (AVHRR) and High Resolution Infrared Radiation Sounder (HIRS) have been used in order to locate flooded areas and to evaluate total precipitable water field before, during and after the event as well as to recognize meteorological features at the synoptic scale.

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1 INTRODUCTION

Flooding events are produced, generally, by different causes related not only to meteorological conditions but also to surface characteristics and status. An accurate analysis and monitoring of such events should be devoted to a complete description of all variables playing a role in the event generation and its space-time dynamics. Satellites could represent a powerful tool in this matter because of their global coverage, continuous measurements and wide spectral ranges.

Several studies (Engman and Chauhan 1995, Ferraro 1997, Grody 1991, Teng *et al.* 1993) have been computed in recent years in order to investigate extreme events by means of different satellite platforms and sensors (i.e. METEOSAT, DMSP, NOAA, etc.). In particular polar orbiting NOAA satellites, providing different spectral bands and spatial resolutions, global coverage and high repetition rate (two passes per day), can be suitable for extreme events analysis and monitoring.

In this work data coming from Advanced Very High Resolution Radiometer (AVHRR), High Resolution Infrared Radiation Sounder (HIRS), Microwave Sounder Unit (MSU) and Advanced Microwave Sounder Unit (AMSU), all flying aboard NOAA platforms, have been used in order to describe a flooding disaster happened last March in Danube and Tisza rivers valleys, in western Hungary and Eastern Romania.

By means of an integrated use of multi-sensor data both surface characteristics and meteorological conditions have been analysed before, during and after the flooding event in order to describe its space-time evolution.

2 EVENT DESCRIPTION

Starting from the end of February until the first half of March 1999 the valleys of eastern Hungary and western Romania (see fig. 1) experienced severe flooding. Heavy rains, together with a continuous snow melting, caused a severe flooding event: 15 rivers overflowed throughout the region, many roads were blocked and there were 1300 houses and 16000 hectares of farmland affected by the floods. Flooding spread into north-eastern Hungary at the beginning of March. By March 4, in the Tisza valley villages, 70 houses collapsed, 300 people evacuated and 200000 hectares of farmland were damaged. On 9 March the number of settlements to be protected from inland waters was more than sevenfold of the number recorded on 23 February. By March 10 over 5% of the arable land in Hungary, about 360000 hectares was under water and the Tisza river reached record water levels. The highest water was observed between 12 and 14 March 1999. More than 10000 people mobilised by the local governments and supported by the civil protection were involved in protection activities for many days (Anderson 1999).

Figure 1: The investigated area: western Hungary and eastern Romania.

3 MULTI-SENSOR APPROACH

Previous studies have demonstrated satellite capabilities in flooding events investigation both in microwave and infrared bands (Nativi *et al* 1995, Gabriele *et al.* 1997). The possibility to exploit a wide range of satellite remote sensed data in order to derive a quite complete set of useful information has been here investigated. Data coming from AVHRR, HIRS, MSU and AMSU (with very different spatial/temporal/spectral resolutions), all flying aboard NOAA platforms, have been analysed in order to asses the multi-sensor approach capabilities in extreme events interpretation and comprehension.

3.1 AVHRR data

The AVHRR is a scanning radiometer with five spectral channels, from the visible to the thermal infrared parts of the electromagnetic spectrum. Its quite high spatial resolution (1.1 km at nadir), together with the daily repetition rate and spectral properties, make this sensor suitable for flooded areas detection as well as for their temporal evolution monitoring.

A set of AVHRR images, acquired at the IMAAA HRPT satellite station, from 15/02/99 until 25/03/99, has been processed at full resolution and analysed in order to localise flooded areas and follow their space-time evolution. It is well know, in fact, that AVHRR has great potential for flood disaster monitoring. Obviously, the success mainly depends on the availability of cloud-free passes during the event. Cloud-free scenes permit also the possibility to compute the Apparent Thermal Inertia (ATI) parameter (from a night/day couple of images), which is directly related to the soil wetness.

3.2 TOVS data

TOVS package is composed of 20 HIRS channels (19 in infrared regions and 1 in a visible band) and 4 MSU channels all in microwave region. The spatial resolution changes depending on the sensor (from 20 up to 170 km). Here TOVS data have been used because of their higher temporal resolution (4 passes per day coming from two different satellites NOAA-12 and NOAA-14) which allow to better follow atmospheric parameters dynamics. The International Tovs Processing Package (ITPP) has been used in order to process these data. ITPP includes a non linear physical retrieval algorithm using AVHRR, HIRS/2 and MSU radiances in order to retrieve atmospheric temperature and moisture profiles and other parameters in clear and partially cloudy atmospheres.

3.3 ATOVS data

During the past ten years there has been a dramatic increase in the use of microwave derived products by the world-wide community of meteorological and oceanographic organizations (Grody 1999, Grody *et al*. 1999, Weng *et al.* 1999).

ATOVS package is a TOVS new generation release including HIRS/3 and AMSU sensors. Whereas the HIRS instrument has been improved only concerning its spatial resolution, AMSU has been totally changed primarily to improve the accuracy of temperature sounding beyond that of the four MSU channels. Moreover with AMSU data, the atmospheric and surface parameters can be derived in all weather conditions, which is an advantage over the TOVS measurements. It consists now of three modules AMSU-A1, AMSU-A2 and AMSU-B. AMSU-A1 module includes channels in the 50-60 GHz portion of the oxygen band to provide temperature soundings from the surface to about 1mb. The AMSU-A1 and A2 include window channels too at 32.4 GHz and 89 GHz to monitor surface features and precipitation, and they contain a 23.8 GHz channel suitable for computing the total precipitable water over oceans. The AMSU-B module consists of four channels around the 183.31 GHz water vapor line designed for moisture profile estimation.

AMSU data have been processed by means of the AVHRR and ATOVS Processing Package (AAPP), a software tool, provided by the European Organization for The Exploitation of Meteorological Satellites (EUMETSAT), devoted to the calibration, navigation and re-mapping of AMSU/AVHRR data into the HIRS Field Of View (FOV). A simple soil wetness index can be obtained by using the difference between AMSU channels at 89 and 23.8 Ghz. Positive values greater than 5 K are associated with wet surfaces.

4 RESULTS

In fig. 2 a time series of night-time AVHRR images is shown. Three orbits, acquired at the IMAAA satellite station before, during and after the event, have been processed (calibrated and navigated); for each channel a subset image (over the investigated area) has been extracted at full resolution, and analyzed in order to monitor the space-time evolution of flooding areas. In figure 2 each pass is depicted as a RGB color composition of AVHRR infrared channels 3 (3.55 μm), 4 (10.5 μm) and 5 (11.5 μm). It seems quite clear that flooded areas are well identified as brightest pixels due to higher values of brightness temperatures for water in night time. Therefore AVHRR, because of its spatial (1.1 km) and temporal (6 h) resolution, could be considered as suitable for flooding monitoring, even if problems still remain related to clouds presence over the scene. In this case, for instance, a complete analysis, together with an Apparent Thermal Inertia estimation, it was not possible just because of clouds.

Figure 2: RGB composite colors of AVHRR channels 3,4 and 5. Three passes, acquired during the flooding period are considered

Atmospheric conditions, investigated by means of TOVS data, are shown in figures 3 and 4 concerning, respectively, skin temperature and water vapor columnar content maps. Only two cases, computed from passes of 08/03/99 and 11/03/99, few days before of the highest water, are reported. Both parameters increased moving from 08/03/99 to 11/03/99. This increase, together with heavy rains happened on 07/03/99, contributed to the rapid snow melting process which caused the subsequent rivers overflowing.

Figure 3: TOVS skin temperatures retrievals for 08/03/99 (left side) and 11/03/99 (right side)

Figure 4: TOVS water vapor total columnar content retrievals for 08/03/99 (left side) and 11/03/99 (right side)

AMSU data have been processed in order to derive soil wetness index for each day starting from 20/02/99 until 20/03/99. All early morning NOAA-15 orbits were full processed by using the AAPP software package. Figure 5 shows a simple soil wetness index computed before (on 01/03/99) and during (11/03/99) the event over a subset scene covering the flooded zone (between 47°and 50° latitude North and 20° and 22° longitude East). Note the strong increase in soil moisture confirming the good sensitivity of AMSU instrument in surface parameters investigation. Value on Z-axis have been normalized to 5 K therefore a value greater than 1 indicates soil wetness conditions.

A set of rainfall ground-based measurements, carried out in 6 different stations and obtained by courtesy of Meteorological Service of Hungary, has been plotted in figure 6 (left side) versus days of March. The plot shows an unmistakable peak measured on 07/03/99 when more than 10mm rains are fallen over all considered stations. In the right side of the same figure a mean spatial value of soil wetness index, normalized to 5 K, and computed as a spatial average over the investigated area, is reported. A quite good correlation could be observed between two figures (the maximum increase in soil wetness index is just around 7 March 1999, the most rainy day) confirming a good sensitivity of the AMSU sensor in surface properties estimation.

Figure 5: Normalized soil wetness index computed over the flooded areas before (01/03/99) and during (11/03/99) the event.

Figure 6: Left: rainfall ground-based measurements performed on several days of March 1999; Right: spatial mean soil wetness index values over the investigated area.

5 CONCLUSIONS

In order to evaluate surface characteristics as well as atmospheric conditions before, during and after a severe flooding event which hit western Hungary and eastern Romania valleys in March 1999, data coming from different NOAA sensors have been employed. The flood areas have been clearly detected by AVHRR thermal channels and regions of most serious flooding were determined. Multi-temporal analysis of soil wetness index, determined by AMSU window channels, indicate a continuous increase of soil moisture due to both heavy rainfall and snow melting. TOVS water vapour retrievals, moreover, seem to confirm an increased atmospheric humidity which could have speeded up the snow melting process.

All satellite data, together with ground-based, rainfall measurements obtained by courtesy of the Meteorological Service of Hungary, contribute to provide a complete description of such an event. In particular the AMSU instrument, with improved capabilities in surface and atmospheric parameters estimation, also in cloudy conditions, seems to be a powerful tool in flood events monitoring and interpretation. Moreover, its high repetition rate (twice a day), makes it a useful instrument also in possible prediction activities devoted, for example, to an early warning of extreme events.

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