Near Real Time Flood Alerting for the Global Disaster Alert and Coordination System

Tom De Groeve
Joint Research Centre of the European Commission
tom.de-groeve@jrc.it

Zsofia Kugler
Joint Research Centre of the European Commission
zsofia.kugler@jrc.it

G. Robert Brakenridge
Dartmouth Flood Observatory
G.Robert.Brakenridge@dartmouth.edu

ABSTRACT

A new flood monitoring module is in development for the Global Disaster Alert and Coordination System (GDACS). GDACS is an information system designed to assist humanitarian responders with their decisions in the early onset after a disaster. It provides near-real time flood alerts with an initial estimate of the consequences based on computer models. Subsequently, the system gathers information in an automated way from relevant information sources such as international media, mapping and scientific organizations. The novel flood detection methodology is based on daily AMSR-E passive microwave measurement of 2500 flood prone sites on 1435 rivers in 132 countries. Alert thresholds are determined from the time series of the remote observations and these are validated using available flood archives (from 2002 to present). Preliminary results indicate a match of 47% between detected floods and flood archives. Individual tuning of thresholds per site should improve this result.

Keywords

Flood alerts, disaster alerts, humanitarian aid, microwave remote sensing.

INTRODUCTION

Of all natural disasters, floods are most frequent (46%) and cause most human suffering and loss (78% of population affected by natural disasters). They occur twice as much and affect about three times as many people as tropical cyclones. While earthquakes kill more people, floods affect more people (20000 affected per death compared to 150 affected per death for earthquakes) (OFDA/CRED, 2006). A study of the United Nations University (2004) shows that floods impact over half a billion people every year worldwide and might impact two billion by 2050, of which a disproportionate number live in Asia (44% of all flood disasters worldwide and 93% of flood-related deaths in the decade 1988-1997). According to a 2003 report of the World Water Council, flood and drought losses increased globally ten-fold (inflation corrected) over the second half of the 20th century, to a total of around US$ 300 billion in the 1990s. Since 2002, losses are estimated at US$ 96 billion (OFDA/CRED, 2006). In general on third of humanitarian aid goes to flood related disasters and the European Commission alone has spent €36 million on floods since 2002 (excluding funds for the tsunami of 2004)[1].

Notwithstanding the seriousness of the socio-economic consequences of floods, there is at present no global system for their prediction nor even for consistent identification of flood events. Currently floods are not monitored systematically in all countries let alone globally. The only sources of information are human reports channelled through the international media or international organisations. Two global flood catalogues, the DFO database (Brakenridge and Anderson, 2007) and the EM-DAT database (Guha Sapir and Below, 2006)), both rely exclusively on these sources. There is no system based on physical measures, such as a seismological network for earthquakes or a meteorological network for tropical cyclones. Inevitably, media and organisations are biased towards regions of

---

[1] These numbers obtained from analysis of the European Commission Humanitarian Office funding database by the authors.

interest and reports on new floods are not systematically covering the world. Consequently, most of the international humanitarian aid and disaster response community has only a partial and delayed awareness of floods which can sometimes lead to delayed or inappropriate response (Darcy and Hofmann, 2003; De Groeve and Ehrlich, 2002).

Humanitarian aid for floods typically is delivered after several days. Typical aid is in the form of food, shelter and medical aid. Most urgent in case of flooding is the provision of uncontaminated drinking water, which should happen the first 24 hours after the flooding (OCHA, 2006). In spite of these urgent needs, international humanitarian aid is more often than not only requested after several days or even weeks (Kugler, 2003). Countries are often hesitant to request international assistance for internal political factors or in fear of being perceived as unable to handle their internal affairs (Boyd, 2003, Stoddard 2004). The relevant timeframe for flood information for the humanitarian community is therefore in the order of days. This opens the way for systems that do not predict floods in advance, but rather detect floods when they occur.

This paper describes research that is ongoing at the Joint Research Centre of the European Commission and the Dartmouth Flood Observatory to set up an operational global flood detection system in support of the humanitarian community.

FLOOD DETECTION METHODOLOGY

Most developed countries have reasonably sophisticated flood-prediction systems which are based on a models using real-time reporting of extreme precipitation and other surface meteorological variables from in situ, radar and, in some cases, satellite observations (Bates and De Roo, 2000; Beven and Kirkby, 1979; De Roo, Wesseling and Van Deurzen, 2000; Galland, Goutal and Hervouet, 1991; Horritt and Bates, 2001). Such sophistication does not extend, however, to the developing world. For instance, in the Mozambique floods of 2000, only a handful of precipitation stations in the country were reporting over the WMO Global Telecommunication System—a number that would have made predictive modelling used in most flood-prediction systems in the developed world unfeasible to implement (Lettenmaier, De Roo and Lawford, 2006).

If floods can not be forecasted, they may be detected in near-real time. Recent availability of daily satellite observations can provide the mean to do so. Barrett (1998) and others have shown that hydrographic data can be obtained from satellite sensors. However, most studies are restricted by the use of satellite resources not enabling daily monitoring.

The use of sensors in the visible or infrared portion of the spectrum is limited due to cloud cover. The microwave portion of the spectrum is not restricted by cloud cover. Early work on active (Smith, 1997) and passive (Sippel, Hamilton, Melack and Choudhury, 1994) microwave sensors for flood monitoring could not rely on satellites with daily revisit times. Since 1997 a set of new generation microwave instruments has been launched with improved performance and daily revisit capability. One of these, the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) instrument on board of the NASA EOS Aqua satellite (launched in 2002), also has an extremely efficient data distribution mechanism making the data available for public download only hours after their acquisition. The US National Snow and Ice Data Center (NSIDC) provides preliminary swath data within 16 to 72 hours after acquisition on board. Since its launch in 2002, researchers looked at using this data for soil moisture monitoring (Njoku, Jackson, Lakshmi, Chan and Nghiem, 2003) and rainfall monitoring (Hossain and Anagnostou, 2004) and flood forecasting (Bindlish, Crow and Jackson, 2004; Lacava, Cuomo, Di Leo, Pergola, Romano and Tramutoli, 2005), but not flood detection.

In 2005, Brakenridge, Nghiem, Anderson and Chien (2005) developed a daily monitoring of river systems around the globe based on AMSR-E data. The researchers demonstrate that, using a strategy first developed for wide-area optical sensors (Al Khudhairy, Leemhuis *et al.*, 2002; Brakenridge, Nghiem, Anderson and Mic, 2007) AMSR-E can measure river discharge changes and river ice status. The methodology uses the 36GHz H-polarization band of the descending (nightly) orbit of AMSR-E with a footprint size of approximately 8x12km, available in the level 2A product. The aim of the method is to detect water surface area change or, in other words, observe riverine inundation increase (land cover change) of a flood event from passive microwave sensor. Due to the different thermal inertia and emission properties of land and water the observed microwave radiation in general accounts for a lower brightness temperature for water and higher for land. This makes it possible to detect inundation change of a river site in a sub-pixel dimension since most of the observed river channels are not as wide as the observation footprint. However, in spite of the great radiation dissimilarity of water and land cover, the raw brightness temperature observations cannot be used to reliably detect changes in surface water area. This is because brightness temperature measures are influenced by other factors such as physical temperature, permittivity, surface roughness and atmospheric moisture. While the relative contribution of these factors cannot be measured, they are assumed to be constant over a larger area. Therefore, by comparing a "wet signal" received over a river channel of a potential inundation location with a "dry signal" without water cover the mentioned noise factors can be minimized. Thus normalisation of the wet signal by the dry observation was implemented where the brightness temperature values of the measurement/wet signal were divided by the calibration/dry observations (referred to as M/C ratio). Results of this kind of calibration eliminates daily and seasonal temperature changes, soil moisture, vegetation influences by assuming that the wet and the dry location has the same properties except for the water surface extent.

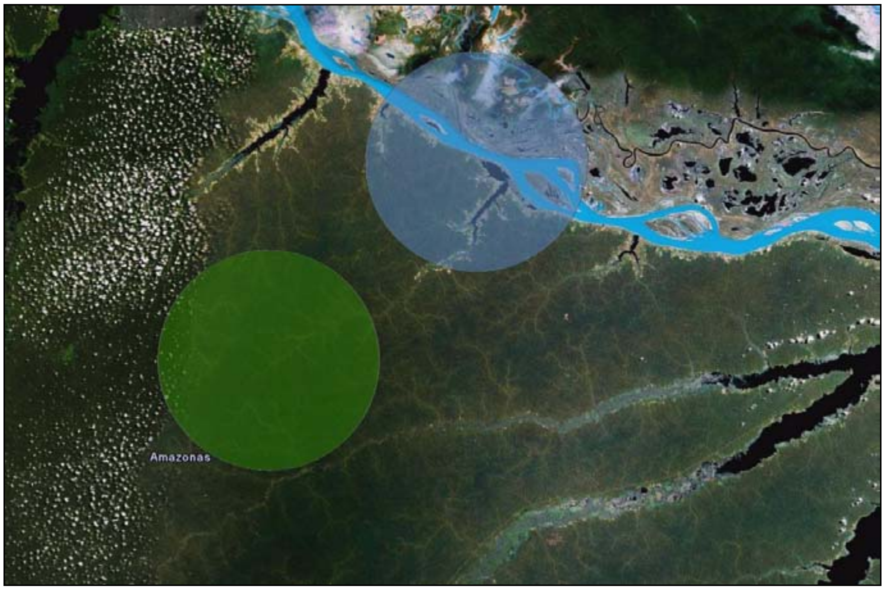


Figure 1. Observation sites over the River Amazon in Brazil. Blue dot refers to the footprint of the "wet" observation pixel observation, green dot to the "dry" calibration pixel. (Background: Google Earth)

In collaboration with DFO the Joint Research Center (JRC) of the European Commission implemented and automated the methodology on a near-real time basis to monitor the major river sites globally from AMSR-E satellite data. A fully automatic operational system was set up to obtain, process satellite imagery to monitor flooding around the globe. Observation sites over river channels were set up around the globe. The list of sites initially monitored at DFO – about 100 locations – was extended to over 2500 sites at JRC. Sites were selected if they were sensitive to surface water area change with increasing discharge. Selection was made manually at DFO based on historical flood events detected in MODIS low resolution images mounted on the same satellite platform Aqua. Calibration pixels were selected to be close to the measurement pixel – to enable the assumption of constant vegetation, soil moisture and meteorological conditions – but far enough not to be affected by flood inundation (see also Brakenridge *et al*., 2007).

To detect flood or major flooding events, thresholds need to be set for each site individually. Therefore, the complete archive of AMSR-E data was downloaded at JRC and processed according to the described method. This created time series of 4 years for all 2500 sites. Because sites have been chosen based on the presence of a major flood in the past 4 years, this time series is sufficiently long to represent normal flow and flood hydrological status. On the other hand, this time series is not long enough to correctly identify the recurrence interval of floods for these sites, neither to determine the hydrological status in other areas where no major floods occurred in the past 4 years. Thresholds were then calculated for each site based on the statistics of the time series: a major flooding event is defined as a signal in the 95% percentile (more than 2 standard deviations from the mean) and a flood as a signal in the 80% percentile (more than 1.5 standard deviations from the mean) of the cumulative histogram. These thresholds have been set arbitrarily based on previous calibration with river gauging data for certain sites. When flood events (per month) are compared with floods in the same country and the same month recorded in at least one of 4 flood databases (DFO, EM-DAT, GLIDENumber and OCHA's Financial Tracking System) there is an average match of 47%; 400 sites have 100% match. Note that the 4 flood databases are not necessarily independent. However, for the sake of the analysis this is not important, since we combine the four into a single database which should be more complete than each of the four individual databases.

However, further calibration is necessary for each site based on comparison with flood disaster databases and/or gauging data. This is ongoing work and only partial results are available at this time. When this work is completed, 1435 rivers in 126 countries will be systematically monitored for flood events.

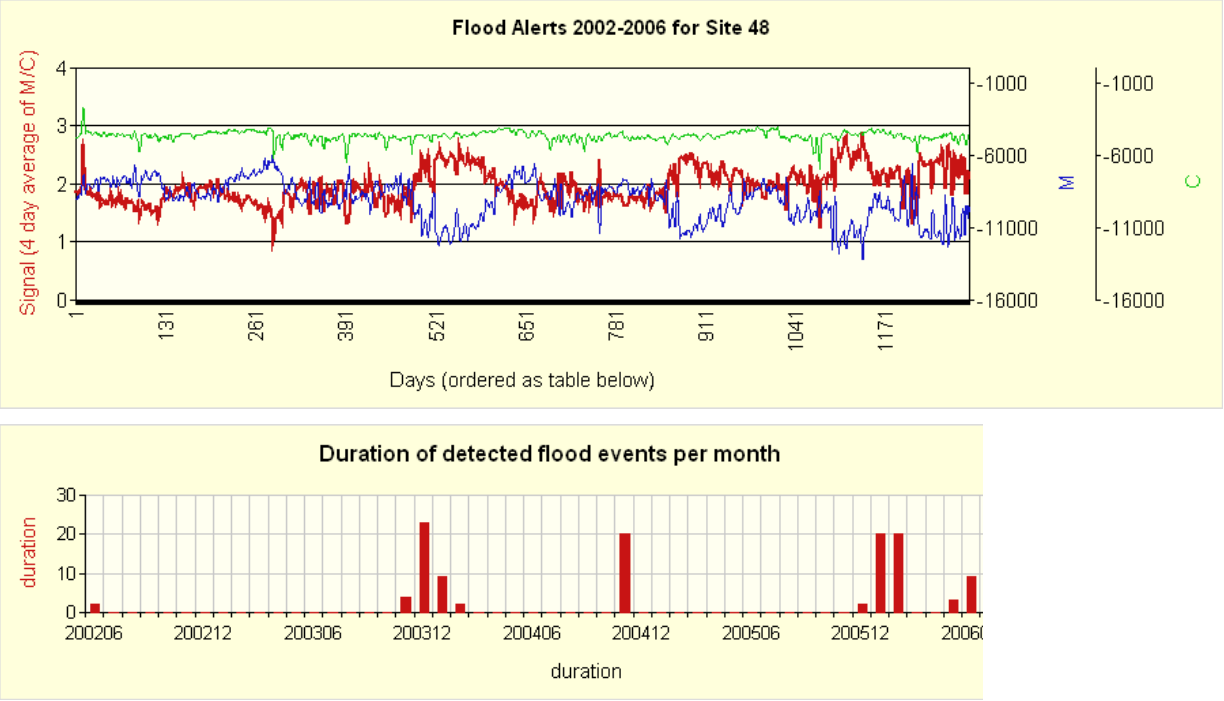


Figure 2. Example of time series for site 48 on the Cauca River in Colombia: M=measurement brightness temperature (blue), C=calibration brightness temperature (green); the Signal (red) is the ratio of M/C. Using a threshold of 95%, several events are detected. These can be compared with a historical flood disaster databases.

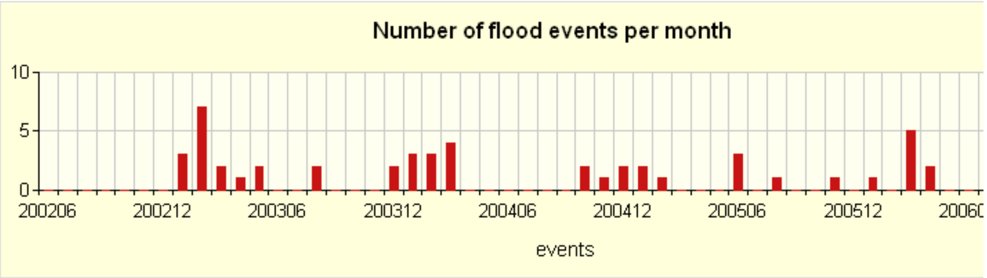


Figure 3. Historical floods recorded for Colombia in DFO, EM-DAT, Financial Tracking System of OCHA and the GLIDENumber database. The floods of site 48 should be recorded in this database.

HUMANITARIAN ALERT AND INFORMATION

As with earthquakes and tropical cyclones, floods are only noteworthy for the humanitarian community if they disrupted or threaten to disrupt society significantly. Therefore, the detection of a new flood is not enough to launch a flood alert. The risk of disruption must be calculated, which is a combination of population affected, their vulnerability and the size of the flood. This is the purpose for the Global Disaster Alert and Coordination System (De Groeve, Vernaccini and Annunziato, 2006).

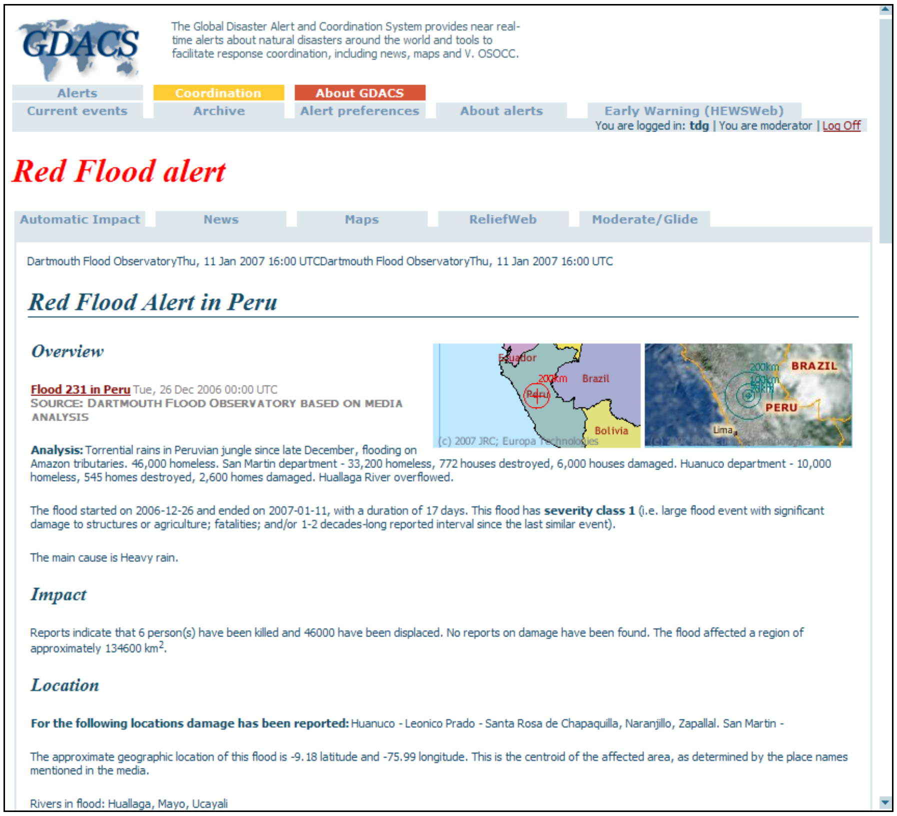
At this point in time, the GDACS system provides flood alerts based on the manual evaluation of the impact by the Dartmouth Flood Observatory. DFO maintains a list of floods based on media analysis and records the number of people affected. The GDACS alert score reflects DFO's flood magnitude scale, which takes into account the flood duration, severity and affected region.

$$Magnitude = \ln(duration) \times severity\_class \times \sqrt{affected\_region} / 100$$

The affected region is in square kilometres and is estimated from the polygon containing all place names reported in the media. If the duration is a single day, it is set to 1.1 for the purpose of this calculation. Severity classes are defined as follows:

- Class 1: large flood events: significant damage to structures or agriculture; fatalities; and/or 1-2 decades-long reported interval since the last similar event.
- Class 2: very large events: greater than 20 year but less than 100 year recurrence interval, and/or a local recurrence interval of at 10-20 year.
- Class 3: Extreme events: with an estimated recurrence interval greater than 100 years.

The GDACS alert score (or DFO magnitude) is translated into an alert level or colour as follows: less than 1 is Green, 1 and less than 2 is Orange and 2 or more is Red. From the definitions it is clear that only floods with casualties or floods with large recurrence intervals are shown. If compared with other databases, most events recorded by DFO are associated with disastrous events. Of the 1274 floods recorded by DFO since 2002, 1133 (or 89%) match EM-DAT records (for which the criteria are 10 or more people killed, 100 people affected, declaration of a state of emergency or call for international assistance).



The Global Disaster Alert and Coordination System provides near real-time alerts about natural disasters around the world and tools to facilitate response coordination, including news, maps and V. OSOCC.

You are logged in: **tdg** | You are moderator | Log Off

Red Flood alert

Dartmouth Flood ObservatoryThu, 11 Jan 2007 16:00 UTCDartmouth Flood ObservatoryThu, 11 Jan 2007 16:00 UTC

Red Flood Alert in Peru

Overview

Flood 231 in Peru Tue, 26 Dec 2006 00:00 UTC
SOURCE: DARTMOUTH FLOOD OBSERVATORY BASED ON MEDIA ANALYSIS

Analysis: Torrential rains in Peruvian jungle since late December, flooding on Amazon tributaries. 46,000 homeless. San Martin department - 33,200 homeless, 772 houses destroyed, 6,000 houses damaged. Huanuco department - 10,000 homeless, 545 homes destroyed, 2,600 homes damaged. Huallaga River overflowed.

The flood started on 2006-12-26 and ended on 2007-01-11, with a duration of 17 days. This flood has **severity class 1** (i.e. large flood event with significant damage to structures or agriculture; fatalities; and/or 1-2 decades-long reported interval since the last similar event).

The main cause is Heavy rain.

Impact

Reports indicate that 6 person(s) have been killed and 46000 have been displaced. No reports on damage have been found. The flood affected a region of approximately 134600 km^2.

Location

For the following locations damage has been reported: Huanuco - Leonico Prado - Santa Rosa de Chapaquilla, Naranjillo, Zapallal. San Martin -

The approximate geographic location of this flood is -9.18 latitude and -75.99 longitude. This is the centroid of the affected area, as determined by the place names mentioned in the media.

Rivers in flood: Huallaga, Mayo, Ucayali

Figure 4. Example of GDACS report for a flood in Peru. Besides this report, GDACS provides focused news monitoring, automatic collection of damage assessment maps and syndication of ReliefWeb content.

As with other disaster types, GDACS further collects in an automatic way relevant news articles (from the European Media Monitor; Best, Van Der Goot and De Paola, 2005) and damage maps (from humanitarian mapping organisations including UNOSAT, JRC/ISFEREA and ReliefWeb). Because floods are not detected in advance or in real-time, immediate alerting of GDACS users has not been implemented. Instead, flood alerts are combined with other alerts in a multi-hazard newsletter sent once per day.

Even if the currently implemented method allows having a systematic overview of ongoing flood events of interest for the humanitarian community, it is based on international media monitoring which is not necessarily consistent for all countries in the world. Physical monitoring based on remote sensing provides a consistent way to monitor flood disasters. However, the impact of large flood events on the population is not provided by the satellite. The impact must be calculated by risk models, as it is done in GDACS for earthquakes and volcanoes. The only information available is the location and magnitude of the water surface increase at a gauging site.

A GIS analysis of the region around the gauging site can provide relevant elements to estimate the impact of the flood. Population density, degree of slope, percentage of land used for agriculture and the density of infrastructure (roads and railways) can characterise the site as well as secondary risks such as landslides. A risk formula then must take into account the magnitude of the flood and the characteristics of the site to provide a risk score. The amount of agriculture land covered by the floods, combined with the time of year can indicate potential economic losses and possible need for food aid. Location of populated places and critical infrastructure, such as airports and main roads, can add value to the GDACS flood report.

DISCUSSION

The first results of the passive microwave flood detection methodology are very positive. Already in 2005, Brakenridge *et al.* (2005) demonstrated that the AMSR-E signal can be used to detect changes in discharge and therefore the hydrological status of the river. Expansion of this methodology from about 40 sites to over 2500 sites is ongoing. The key challenges with this expansion are the validation of sites (e.g. is the calibration site well chosen to be independent of flooding and only dependent on atmospheric and other effects) and the determination of appropriate signal thresholds for each site related to flood and major flooding. Early results show that the default thresholds (based on the thresholds of the 40 sites studied by DFO) are too low, resulting to significant commission of events. Further statistical analysis combined with detailed case studies will be conducted in order to obtain better thresholds.

If the methodology can be proven to work, it can be expanded. There are other microwave sensors, such as the QuickScat sensor, that can provide alternative measurements. In case cloud cover is absent, even optical sensors such as MODIS can be used in a similar fashion. It can also be interesting to study meteorological satellites: they have coarse ground resolution, but very high temporal resolution. Again, in absence of cloud cover, floods could be monitored on an hourly basis.

Finally, GDACS is not the only system that can benefit from a global flood detection system. Such a system could trigger action in rapid mapping organizations such as UNOSAT (who routinely create satellite based damage maps for humanitarian purposes). It could also be used as an independent source of information to validate predictive flood models.

REFERENCES

1. Al-Khudhairy, D.H.A., Leemhuis, C., Hoffmann, V., Shepherd, I.M., Calaon, R., Thompson, J.R., Gavin, H., Papadimos, D. (2002) Monitoring wetland ditch water levels using Landsat TM and ground-based measurements, Photogrammetric Engineering and Remote Sensing 68 (8), pp. 809-818.
2. Barrett, E. (1998) Satellite remote sensing in hydrometry. In: Ed, H. (Ed.), Hydrometry: Principles and Practices. Wiley, Chichester, UK, pp. 199–224.
3. Bates, P.D. and De Roo, A.P.J. (2000) A simple raster-based model for flood inundation simulation, Journal of Hydrology, 236: 54-77.
4. Beven, K. J. and Kirkby, M. J. (1979) A physically based variable contributing area model of basin hydrology, Hydrol. Sci. Bull., 24(1), 43-69.
5. Best, C., Van Der Goot, E., De Paola, M. (2005) Thematic indicators derived from world news reports. Lecture Notes in Computer Science 3495, pp. 436-447
6. Bindlish, R., Crow, W.T., Jackson, T.J. (2004) Potential role of passive microwave remote sensing in improving flood forecasts, International Geoscience and Remote Sensing Symposium (IGARSS) 3, pp. 1866-1869.
7. Boyd, E., 2003. The political determinants of natural disaster response: a cross-country comparison. Thesis (M.A.), University of New Orleans, 2003, 118p.
8. Brakenridge, G. R., Nghiem, S. V., Anderson, E., Chien, S. (2005) Space-based measurement of river runoff. Eos 86 (19), pp. 185-188.

9. Brakenridge, G.R. and Anderson, E. (2007) Flood tables 1985-2007, Dartmouth Flood Observatory, Hanover, USA, digital media, http://www.dartmouth.edu/~floods (last accessed 23/01/2007).
10. Brakenridge, G. R., Nghiem, S.V., Anderson, E., Mic, R. (2007) Orbital microwave measurement of river discharge and ice status, Water Resources Research, in press.
11. Darcy J. and Hofmann, C-A. (2003) "According to need? Needs assessment and decision-making in the humanitarian sector", Humanitarian Policy Group Report 15, London: Overseas Development Institute.
12. De Groeve, T. and Ehrlich, D. (2002) DMA Earthquake Alert Tool, A decision support tool for humanitarian aid, Technical Note No. I.02.75, Institute for the Protection and the Security of the Citizen, Cybersecurity and New Technologies for Combating Frauds, European Commission Joint Research Centre.
13. De Groeve, T., Vernaccini, L. and Annunziato, A. (2006) Global Disaster Alert and Coordination System, In Proceedings of the 3rd International ISCRAM Conference, Eds. B. Van de Walle and M. Turoff, Newark, pp.1-10.
14. De Roo, A.P.J., Wesseling, C.G., Van Deurzen, W.P.A. (2000) Physically based river basin modelling within a GIS: the LISFLOOD model. Hydrological Processes 14, 1981–1992.
15. Galland, J.C., Goutal, N., Hervouet, J.-M. (1991) TELEMAC—a new numerical-model for solving shallow-water equations. Advances in Water Resources 14 (3), 138–148
16. Guha Sapir D. and Below R. (2006) *Collecting data on disasters: easier said than done*, in: Asian Disaster Management News, April-June 2006, 12 (2): 9-10
17. Horritt, M.S. and Bates, P.D. (2001) Predicting floodplain inundation: raster-based modelling versus the finite-element approach, Hydrological Processes, 15(5): 825-842.
18. Hossain, F., Anagnostou, E.N (2004) Assessment of current passive-microwave- and infrared-based satellite rainfall remote sensing for flood prediction, Journal of Geophysical Research D: Atmospheres 109 (7), pp. D07102 1-14.
19. Kugler, Z. (2003) Flood Disaster Management with Geographic Information Systems and Remote Sensing in Mozambique, Diploma thesis, May, 2003, University of Salzburg (Austria), 81pp.
20. Lacava, T., Cuomo, V., Di Leo, E.V., Pergola, N., Romano, F., Tramutoli, V. (2005) Improving soil wetness variations monitoring from passive microwave satellite data: The case of April 2000 Hungary flood, Remote Sensing of Environment 96 (2), pp. 135-148.
21. Lettenmaier, D.P., De Roo, A. and R. Lawford (2006) Towards a capability for global flood forecasting, WMO Bulletin 55(3), July 2006, p.185-190.
22. Njoku, E.G., Jackson, T.J., Lakshmi, V., Chan, T.K., Nghiem, S.V. (2003) Soil moisture retrieval from AMSR-E, IEEE Transactions on Geoscience and Remote Sensing, 41 (2), pp. 215-229.
23. OCHA (2006) UNDAC Handbook, edition 2006. United Nations, 418pp.
24. OFDA/CRED (2006) 2005 disasters in numbers, OFDA/CRED, http://www.em-dat.net (last accessed 23/01/2007).
25. Sippel, S. J., Hamilton, S. K., Melack, J. M. and Choudhury, B. J. (1994) Determination of inundation area in the Amazon River floodplain using SMMR 37 GHz polarization difference, Remote Sensing Environment 48, 70–76.
26. Smith, L. C. (1997) Satellite remote sensing of river inundation area, stage, and discharge: A review, Hydrol. Processes 11, 1427-1439.
27. Stoddard, A., 2004. You Say You Want a Devolution. Prospects for remodelling humanitarian assistance. Journal of Humanitarian Assistance. http://www.jha.ac/articles/a154.pdf (last accessed 15/03/2007).
28. United Nations University (2004) Two Billion People Vulnerable to Floods by 2050; Number Expected to Double or More in Two Generations Due to Climate Change, Deforestation, Rising Seas, Population Growth (News Release), http://www.unu.edu/news/ehs/floods.doc (last accessed 23/01/2007).