Near-real-time information extraction and dissemination in support of disaster management: case study of flooding in southeast Australia

Medhavy Thankappan, Bill Levett and Shanti Reddy

Australian Centre for Remote Sensing (ACRES)
Geoscience Australia, GPO Box 378, Canberra ACT 2601, AUSTRALIA
Email: Medhavy.Thankappan@ga.gov.au

Abstract

The Sentinel bushfire monitoring system at Geoscience Australia provides timely hotspots information over the Internet and is widely used by emergency managers during the bushfire season. The Sentinel system serves as an effective model for dissemination of information in near-real-time (NRT) to support disaster management applications. Geoscience Australia intends to expand this service to cover additional hazards such as flooding. The project would also develop links to regional disaster management initiatives like Sentinel Asia led by the Japan Aerospace Exploration Agency (JAXA). Two flood events in June 2007 that caused extensive damage to property and infrastructure in southeast Australia are used as case studies to highlight the key elements required for near-real-time extraction and dissemination of remotely sensed information. The first case study used Advanced Land Observing Satellite (ALOS) Advanced Visible Near-infrared Radiometer Type-2 (AVNIR-2) and Phased Array Linear Synthetic Aperture Radar (PALSAR) data to map flooding in the Hunter River. Cloud-free aerial photographs of the inundated areas were used to validate surface water extents derived from partly cloudy AVNIR-2 image. In the second case study, Landsat Thematic Mapper (TM) images were used to map the Mitchell River flood. In both case studies, a segmentation process was applied to the satellite images to generate image objects with maximum homogeneity. A custom built rule-set enabled semi-automatic classification of the segmented images and rapid extraction of the surface water extents, for use in a Geographical Information System (GIS), within one hour. Cloud cover, timing of peak flood and frequency of satellite revisit are key issues that affect satellite based flood mapping. Recent studies have demonstrated the benefits of using microwave radiometer data to address these issues. Results from our study demonstrate the merits of having access to multiple data sources and highlight the challenges for NRT delivery of remotely sensed flood information.

Keywords: Near-real-time hazard information, Disaster management, Flood mapping, Sentinel hotspots

1. INTRODUCTION

Emergency managers need information about disasters in the planning, preparedness, response and recovery phases of an event. Conventional ground based methods of gathering information may not be efficient or even possible when there is a catastrophic event. Satellite based remotely sensed data could provide information to support disaster management under such circumstances. However, recent natural disasters in Australia have highlighted some challenges associated with acquisition and rapid delivery of information derived from satellite data.

The Sentinel hotspots system has been in 24/7 operation at Geoscience Australia since 2004 (http://sentinel1.ga.gov.au/acres/sentinel/). Hotspots are locations with a higher than normal ground temperature. Sentinel provides hotspot products derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on the Terra and Aqua satellites and the Advanced Very High Resolution Radiometer (AVHRR) on NOAA 17 & 18 satellites on a continent-wide basis in Near-Real-Time (NRT). Users are able to access Sentinel via the Internet, query hotspot locations, select layers of contextual information and dynamically create maps. Sentinel users include disaster managers at all levels and the general public. A dramatic increase in the number of online visitors to the Sentinel website during the fire season is testimony of its success. The success of the Sentinel system in delivering NRT information on hotspots to the bushfire community for the last several years provides a model for rapid delivery of information about other hazards. The work reported in this paper, forms part of the effort to expand the Sentinel capabilities to deliver NRT information derived from satellite imagery across a number of hazards. Enhancement to the Sentinel system at Geoscience Australia would also support links to regional initiatives like Sentinel Asia led by the Japan Aerospace Exploration Agency (JAXA). Two major flooding events in southeast

Australia during June 2007 are used to identify the key elements for rapid delivery of hazard information derived from remote sensing.

2. METHOD

2.1 Study Area

Heavy rainfall during June 2007 caused flooding in the Hunter and Mitchell Rivers (Fig. 1) leading to widespread damage of property and infrastructure in southeast Australia. Satellite images acquired over the affected areas close to the time of peak floods and before the flooding were used to determine the extent of flooding.

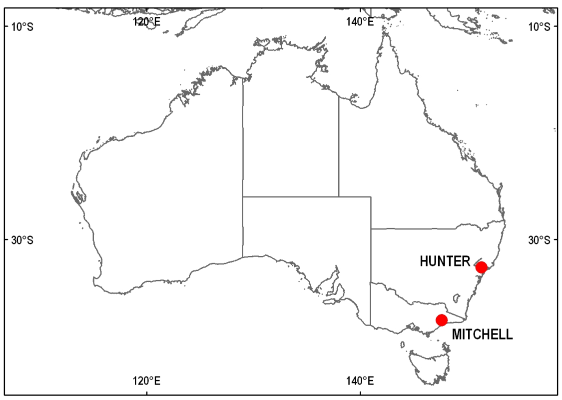

Figure 1. Location of the Hunter and Mitchell Rivers

2.2 Satellite and Ancillary Data

For the Hunter River case study, images before and during the flood acquired by the Advanced Visible Near-infrared Radiometer Type-2 (AVNIR-2) sensor onboard the Advanced Land Observing Satellite (ALOS) were used. An ALOS AVNIR-2 image of the flood affected area was acquired on 10 June 2007. The pre-flood AVNIR-2 image acquired on 19 November 2006 did not cover the affected area completely; therefore an ALOS Phased Array Linear Synthetic Aperture Radar (PALSAR) image acquired on 6 February 2007 was also used to delineate pre-existing water bodies. Surface water extents digitised from aerial photographs of the inundated area were used for validation of the surface water extent derived from satellite imagery.

For the Mitchell River case study, a Landsat-5 Thematic Mapper (TM) image acquired on 29 June 2007 (close to peak floods) and a MODIS image acquired on 30 June 2007 were used. A Landsat-5 TM image acquired on 13 June 2007, two weeks before the heavy rains, was used to delineate pre-existing water bodies. The geographic locations of flood assistance requests received by the State Emergency Services (SES) in Victoria were used to validate the satellite based surface water extent.

2.3 Data Analysis and Information Extraction

A multi-resolution segmentation process was applied to the satellite images used for both case studies. The segmentation process enabled the generation of objects or groups of image pixels with minimum spectral or textural heterogeneity. The parameters used for image segmentation were determined by the sensor type (multi-spectral or SAR), and spatial and/or spectral resolution of the data. Results from the initial segmentation were improved by applying an additional spectral difference segmentation that merged similar objects (e.g. water). Additional analyst inputs were required to obtain a satisfactory segmentation result in the presence of cloud.

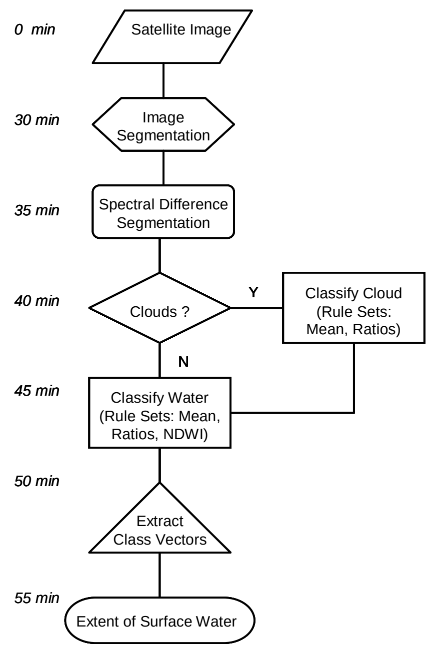

Figure 2. Process for extracting flood information

A semi-automatic process with built-in decision rules was developed to classify the objects of interest (e.g. water objects) in the segmented image. The decision rules were based on spectral and spatial image object parameters (e.g. band means, ratios, shape and texture). Following satisfactory classification of the segmented image, the boundaries for the classes of interest were extracted as polygons. The work flow for extraction of information from the raw satellite image for both case studies is shown in Fig. 2. The cumulative analysis time at each stage in the processing is shown on the left hand side of the flow chart. The analysis times are based on averages for single pre and post flood multi-spectral images (4-band) covering roughly 5000 sq km and only provide an indicative measure. With multiple images, the time for mosaicing and multi-resolution segmentation needs to be factored in. The processing time excludes time spent on validation of surface water extents derived from the raw satellite images against other sources.

3. OBSERVATIONS

The flood case studies helped us identify challenges associated with rapid delivery of information derived from remote sensing data. Our observations as they apply to each case study are used to outline the requirements for effective NRT delivery of flood information derived from remotely sensed data.

3.1 Hunter River Flood

Early requests to satellite operators for image acquisition following media reports of heavy rains in the region and warnings of possible flooding in the Hunter River reduced planning lead times. Synthetic Aperture Radar (SAR) data were also requested in anticipation of extended cloudy periods. Despite extensive cloud cover over the Hunter region, a large part of flooded Hunter River remained cloud-free at the time of ALOS overpass (Fig. 3). Timely coverage of the area by other optical or SAR satellites was not available for this study.

The pre-flood AVNIR-2 image covered only the eastern part of the study area; therefore a PALSAR image from the ACRES archive was also used to complement information derived from the pre-flood AVNIR-2 image. The decision rules applied for classification of surface water in the segmented AVNIR-2 image were based on band ratios and threshold values of the segmented image objects. The total analysis time for extraction of surface water extents was 58 minutes. Extensive cloud in the AVNIR-2 image required significant analyst interaction to modify the decision rules.

Poor discrimination between features in the PALSAR pre-flood image resulted in ambiguities between water bodies and other features, this required significant analyst interaction. The flood and pre-flood images were made available on the Geoscience Australia website within a few hours of being processed. The derived surface water extents shown in Fig. 4 were experimental and not released.

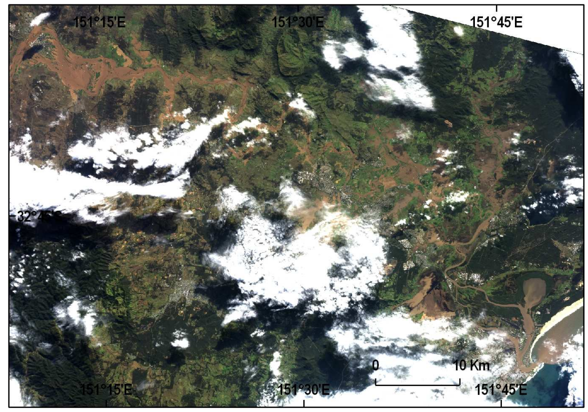

Figure 3. AVNIR-2 image acquired on 10 June 2007

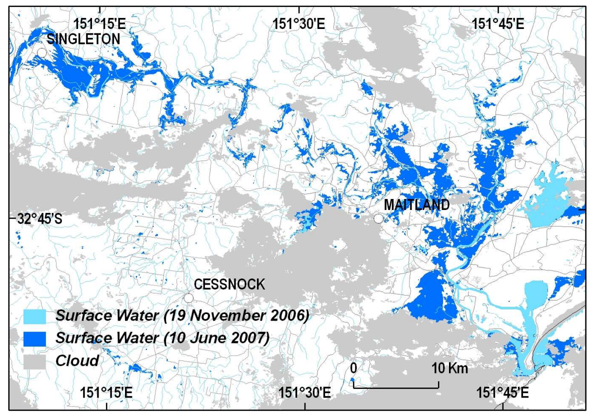

Figure 4. Surface water map derived from AVNIR-2

3.2 Mitchell River Flood

Landsat-5 TM and Terra MODIS imagery acquired on 29 and 30 June 2007, respectively, were used to determine the extent of flooding in the Mitchell River. Clouds were present in both images, but extensive cloud and associated shadow in the MODIS image compromised the image segmentation process. The Landsat-5 TM image of the Mitchell river flood shown in Fig. 5 was not obscured by cloud over the major flood affected areas. Timely SAR coverage of the Mitchell River flood was not available. The surface water map derived from the satellite images is shown in Fig. 6. A Landsat-5 TM image acquired on 13 June 2007 from the ACRES archive was used to delineate the pre-flood surface water extents. Decision rules based on band ratios and threshold values for image objects were applied on the TM images and produced excellent classification results. The total time for the extraction of surface water extents was 51 minutes. Classification results for MODIS were sub-optimal due to cloud and associated shadow, and compounded by the coarser spatial resolution. The multi-spectral satellite images and surface water extents were provided to the State Emergency Services (SES) in Victoria through standard File Transfer Protocol [1].

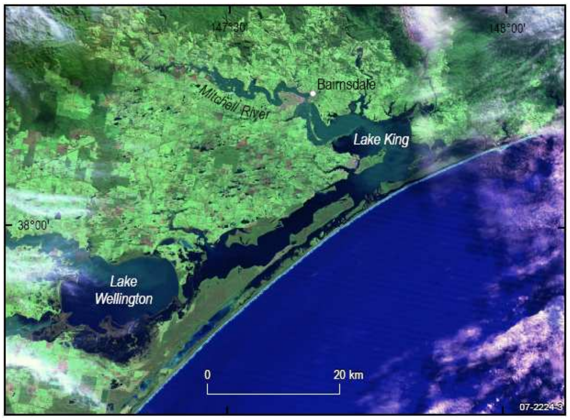

Figure 5. TM image acquired on 29June 2007

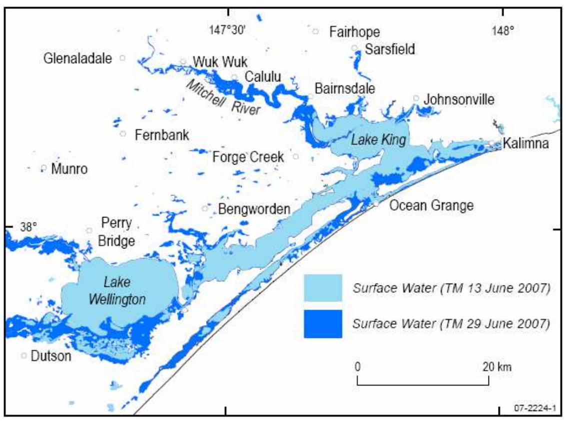

Figure 6. Surface water map derived from TM

3.3 Validation of Surface Water Extents

The satellite based surface water extent for the Hunter River case study was validated using the digitised surface water extent from aerial photographs acquired during the flood. There was good agreement between surface water extents derived from both sources for most of the affected area. The aerial photographs were acquired a day after the satellite images, therefore minor discrepancies in surface water extents resulting from rains and flooding that occurred between acquisitions were observed. The satellite based surface water extent for the Mitchell River case study was compared with geographic locations of flood assistance requests logged by SES Victoria. Feedback from SES Victoria confirmed that satellite based information complemented locally available information.

4. CONCLUSIONS & RECOMMENDATIONS

Key factors that influenced near-real-time delivery of hazard information are satellite coverage / revisit frequency, ability to rapidly task image acquisition from multiple sources, effective techniques for rapid information extraction, cloud in optical images and procedures affecting access and delivery of hazard information. Satellite data acquisition coincident with timing of peak flood is critical. However, the availability of relatively cloud-free multi-spectral data close to peak flood for both case studies was a matter of chance; routine access to multiple sources of satellite data is crucial for NRT delivery of flood information. Timely availability of SAR images during the floods could have helped. The decision rules developed for both case studies enabled semi-automatic extraction of surface water extents from 4-band multi-spectral images covering approximately 5000 sq km within an hour. Decision rules developed for one multi-spectral sensor could be quickly adapted for application to other multi-spectral sensors.

Digital Elevation Models could help further refinement of the decision rules. New sensors and innovative processing methods could alleviate the challenges posed by cloud cover for flood mapping; the Dartmouth Flood Observatory uses daily data from the Advanced Scanning Microradiometer (AMSR-E) to measure surface water area changes, river discharge and watershed runoff [2]. Well defined protocols for acquiring / processing data from multiple sources could reduce lead times significantly. Graphic tools for simultaneous visualisation of multiple satellite footprints could speed up the acquisition planning process and provide a full range of alternative options. Augmenting the capabilities of the Sentinel system could enable rapid dissemination of hazard information. Links to other initiatives like Sentinel Asia that support disaster management could reduce duplication in effort and increase the turnaround for data acquisition.

5. REFERENCES

[1] M. Thankappan, "Gippsland Flooding Revealed" AUSGEO News, Issue 87 September 2007 http://www.ga.gov.au/image_cache/GA10538.pdf

[2] G.R. Brakenridge, E. Anderson, S. Caquard, "Flood Inundation Map" DFO 2003-282, Dartmouth Flood Observatory, Hanover, USA, digital media, http://www.dartmouth.edu/~floods/2003282.html.