FINAL REPORT ON RESEARCH ACTIVITIES CONDUCTED UNDER ALOS SCIENCE PROGRAM

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1. ABSTRACT

Flooding is the inundation of land with unwanted water causing damages to lives and livelihood. Flooding can be triggered by heavy rain fall accumulation, due to cyclones that may generate intense rains, due to tides at coastal areas, due to melting of glaciers or stream blockage in nearby areas. Floods can hit the region's economy badly. In 2006 Pakistan's city Mardan was badly hit by heavy rains that caused heavy damage to infrastructure including the main bridge onto River Kalpani. In 2007 floods in Pakistan affected 2700 sq km of land displacing about 2 million people. In February 2010 landslide triggered floods in River Hunza northern Pakistan, affecting 15.5 km length of Karakoram Highway along with 150 houses in near by villages. The report presents the results and observations acquired from study of above mentioned flooding events. For the mapping of these cases Advance Land Observing Satellite (ALOS) data were efficiently used and further successfully verified. Report presents the summary of work done under project four years approved project titled: 'Mapping of River Indus Flood Plains Using ALOS Data' with JAXA, Japan.

2. INTRODUCTION

In Pakistan, the Northern mountain barrier influences the rainfall pattern by intercepting monsoon winds from the South. Melting snow from the mountains and heavy precipitation in the catchment areas feed the rivers including the Mighty Indus. The flow in the rivers, which is the lifeline for the economy of Pakistan, due to intense rainfall turns into destructive flood and results in heavy damages. Since 1947, floods in the Indus River Basin in Pakistan have claimed more than 7000 lives and caused massive infrastructure and crop losses. Area in active flood zone is 7.7 million acres [1]. Very recently, i.e. in 2010 during monsoon, about thirty major cities in Pakistan were marked to have received remarkably more rain fall than normal, that had left large area of country drown into water [2].

For monitoring of floods, today earth observing satellites prove the good resource along with other ancillary and ground data. Earth observing satellites can provide comprehensive and multi-temporal coverage of large areas. To map the flooded areas along Indus basin, a proposal was submitted by SUPARCO in 2nd Research Announcement (RA) of JAXA in 2007. It is appreciated that proposal was accepted by JAXA. The proposal was an attempt to monitor and map the flooded areas in Pakistan along River Indus; taking into account the efficiency of JAXA's newly launched earth observing satellite, i.e. ALOS. The purpose was to explore the potential of its sensors in context of its applications for mapping of flooding areas. For the assessment of flood disasters along River Indus plain, ALOS data, soil characteristic data, topographic maps and meteorological data including rain fall, temperature were planned to be incorporated. Physical verification along with study of satellite images was said to be conducted by field observations of selected sample areas to determine the extent, degree and intensity of flood and its triggering parameters. Keeping in view the research need in the field of flood mapping a research proposal was submitted to JAXA.

The research plan for the three years was:
Year 2007:

- Literature Studies
- To classify land use/ land cover using appropriate ALOS Data
- To generate DEM using PALSAR and PRISM data
- To map flooding area through ALOS data processing / analysis
- To identify and prepare inventory of dominant parameters (including atmospheric data, slope, land use/land cover etc) which trigger the susceptibility of flooding hazards
- To determine physiographic terrain related to flooding by means of satellite data analysis (including DEM generation)

Year 2008:

- To generate map of flood prone area through terrain analysis using ALOS data
- Track size and movement of glaciers
- Generation of DEM to determine the volume of snow pack

Year 2009 & 2010:

- Field observation and validation: to assess the accuracy of mapping, to validate the result of analysis
- To define standardized method of flood damage assessment integrating satellite data and GIS techniques
- Preparation of final report

The objectives of research study were to evaluate flooded areas for better planning and to promote awareness through on –job training and seminars. It is felt that the objectives were fulfilled. The flooding events occurring during period of 2006-2010 were studied and mapped to access the damages as well as the vulnerable areas along Indus River. Multi temporal analysis is also carried during flooding situations to analyze the extensive area of floods, on the basis of availability of images. The work carried out has proved to be useful not only for single flood event but the for all major flooding events that occurred during 2006 to 2010.

ALOS data were successfully used for mapping the flood situations and flooded areas for flood incidents of 2006, 2007 and 2010 and validated for region of Pakistan.
The target was to acquire accuracy in mapping of flooded areas using ALOS-AVNIR data. For this purpose numerous test have been applied on the data. First the case study of floods in Sindh during July 2007 was studied using ALOS PALSAR data along with UNOSAT provided info and field data [1]. Then another case study was carried out for mapping the flooding situation in city Mardan of Pakistan, August 2006, in which ALOS AVNIR and PRISM data were tested and verified with field data [2]. Another flooding event of February 2010 was monitored using same ALOS AVNIR images [3]. The respective work was presented and published in the 1st, 3rd and 4th PI Symposia of JAXA in 2007, 2009 and 2010 respectively.

3. METHODOLOGY

In general the methodology followed for the study was as follows,

1. First to locate the main cause of floods, like cyclone, heavy rains or land slide triggered floods over the passing by streams.
2. Then accordingly monitor the situation of hazard that caused floods like cloud coverage using Meteosat and MODIS data or rain fall intensity / accumulation via TRMM satellite 3b42 V6 data along with meteorological rain gauge data or so on and to plot rain-intensity duration graphs
3. To locate flooded areas using AVNIR or PALSAR images
4. To Map the situation of flood in flooded rivers by using PALSAR or AVNIR images
5. To determine DEM from PRISM or SRTM,
6. To find out the low laying areas
7. To determine land cover from pan-sharpened PRISM & AVNIR images
8. Finding out the land cover under inundation by overlaying the extracted layer of low laying areas onto panchromatic image of PRISM and hence to mark the area under flooding after field verification.
9. To combine the determined info to find the inundated land cover and asses the damages
10. To locate the inundated areas from local information and UNOSAT provided information
11. In case of PALSAR, since it could capture the land even when cloud covered, was used when studied floods due to cyclone, its HH HV HV combination was used to locate on land water in blue color in image
12. Verification of all information extracted from field and UNOSAT provided map information

The July 2007 flood affected 2400 sq Km of land 2 million people and displaced about 250,000 (local survey) from their homes [3]. The methodology applied for the study was as follows,

- Rain intensity-duration graphs had been plotted for some specific locations of rain affected areas considering the point data of TRMM 3B42 V6. Ground verification had also been done from the reports published in news papers.
- Image of PALSAR of 26 June 2007 had been downloaded form AUIG link of ALOS and geo-rectified to update geo-information of flood risk map
- The flash floods had caused inundation in villages of Sindh along with Balochistan Province of Pakistan; the inundated areas were located using ALOS-PALSAR-Radarsat composite images (UNOSAT).

- Simple maps (incorporated from Encarta) were used to assess topographic conditions of land of Balochistan and Sindh Province of Pakistan.
- The pre and post flood image of PALSAR had been downloaded and region of interest (ROI) were drawn using ENVI software along the path of Indus River to distinguish flooding in the river.
- The PALSAR images used were geo-rectified using ENVI-software
- The PALSAR-post flood image of 26 June 2007 opened in HV (R) HV (G) HH (B) combination using ENVI-software had been used to distinguished open water on land in blue color in Dadu district of Sindh province.

Another case study was carried out for mapping inundated areas in Mardan city in NWFP Province of Pakistan that was hit by intense heavy rains during month of August, 2006 [4]. For the study it was thought to use PRISM DEM for analysis of low laying areas and pan sharpened PRISM + AVNIR images for land cover study. The methodology followed was, as given below:

- SRTM DEM was used to get information about elevation differences (Figure 8). SRTM DEM of flooded area showed that the lowest point was 296 meter a.s.l and highest point up to which flood water reached was Bank road in Mardan which is 310 meters a.s.l. This range of elevation values was extracted from the SRTM DEM used. The extracted layer was called on the panchromatic image of PRISM sensor onboard ALOS satellite and has marked as the area under flooding.
- Ground information collected from various persons who witnessed the flooded situation was almost matching the extracted flooded area from SRTM DEM (Figure 9).
- PRISM data was also used for preparing the land use / cover map of the city and for identification of various bridges on the Kalpani River including Hoti Bridge damaged during flooding (Figure 10).
- Graphs plotted between monthly rain fall totals overlying 1998 to 2006 for specific month of August for Mardan (Figure 11).
- It showed the extent of rain was high for year 2006 in august as compared to previous six years, it also showed the increasing rate of rains at Mardan. Graph-1b for Mardan city was plotted between daily rain fall totals for month of August 2006. These all graphs used the TRMM 3B42RT V6 data rain fall total data as mentioned above.

Similar work was done for another flood study that hit the north region of country, during February 2010. The floods or inundation in villages near by affected area had occurred due to land slide that blocked the flow of glaciated fed river Hunza, causing upstream villages under water [5].

Methodology followed was as is given below:

- AVNIR images of Hunza Valley; before the landslide (26 October 2009) and after the landslide (13 March 2010, 13 June 2010) (Figure -13) have been utilized.
- The images were geometrically corrected. 13 June 2010 ALOS image was classified for the extraction of vegetation (forest, fruit trees, and cropland) class in the study area.
- Houses and crop fields were annotated with the help of google-earth (the only source of high resolution imagery).
- All these layers were overlaid on relief map extracted from ASTER DEM, hence getting a landuse / land cover / relief map.
- The map was used to analyze the damages to various land use / cover due to the formation of the lake.
- To compare the changes in the flood area before and after the flood, the area covered by water in all the images was digitized as polygons.
- The vector layer of 13 June 2010 was overlaid to find out the damages to roads (Karakoram Highway), houses, and cropland, forest and fruit trees.
- The methodology is shown below as a flow chart (Flowchart - 1).

4. RESULTS & DISCUSSION

The results were submitted and presented to JAXA in form of three research publications during last four ALOS Symposia. The results are discussed as follows.

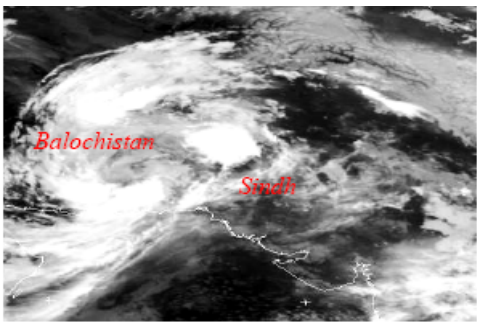


Figure 1: Meteosat Image of 25 June 2007 showing tropical cyclone over Baluchistan Province of Pakistan

For monitoring floods, cloud covered areas were estimated using Meteosat or MODIS images which gave information about timely cloud cover. In situation like floods of 2007 in Sindh province of Pakistan, Meteosat / MODIS results were incorporated for study. Figure 1 shows the thick clouds over provinces of Sindh and Balochistan, during June 2007. In July 2007 the area was affected due to heavy rains triggered by cyclone. Accumulated rain fall and intensity of rains were monitored using Pakistan Meteorology department's rain gauge data and JAXA's TRMM precipitation data. Results from TRMM 3B42 6V product, were used to estimate intensity of rain in the flash flood affected areas.

For floods of 2007, it was observed that the cyclone had caused heavy rains in Balochistan and Sindh. The rain intensity data were plotted for the four major cities of both provinces that were hit by floods adversely. Rain intensity curves showed that in Makran and Turbat (Balochistan) intensity of rains was much higher than in Jaferabad and Johi (Sindh) during June to July in 2007, refer figure 2. The accumulation of water took place due to varying topography in Balochistan (hilly areas) and Sindh (plain areas). The data was verified with ground data. The same satellite's data were incorporated for studies of floods of August 2006.

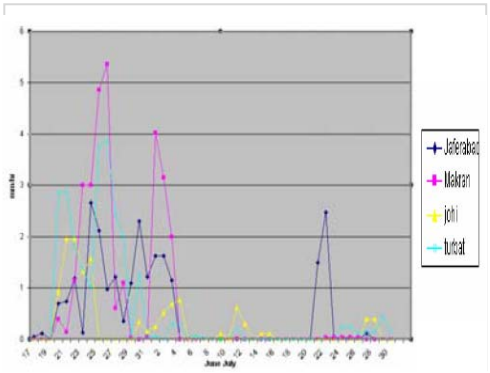


Figure 2: Rain intensity curves for the month of June and July 2007 for Turbat (Baluchistan), Makran (Baluchistan), Johi (Sindh) and Jaferabad (Sindh)

To study the variation in the pattern of Indus basin ALOS-PALSAR images were used. For floods of 2007, PALSAR images were used to map pre and post flood situation in Dadu district in Sindh province along Indus River; as figure 3 & 4 are showing the pre and post flood situation in River Indus along Sehwan city in Sindh and Kirthur hills in Balochistan. The areas were covered by clouds so it was not possible to use optical imagery in that case, so PALSAR images were used to determine the inundated areas. Figure 4 is showing the open water (accumulated rain water on land) in blue color on 26 June 2007.

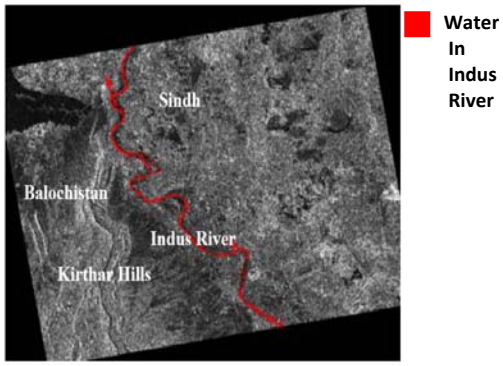


Figure 3: PALSAR image of 08 February 2008 indicating pattern of Indus River before flood

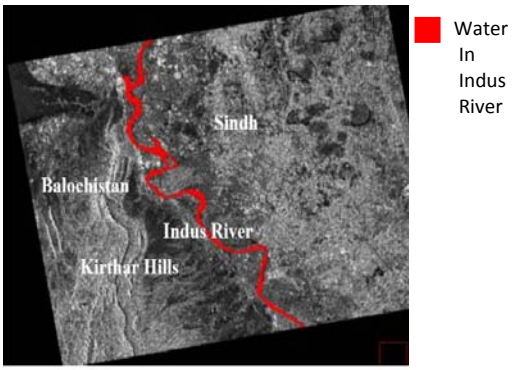


Figure 4: PALSAR image (JAXA-ALOS) of 26 June 2007 indicating pattern of Indus River during flood

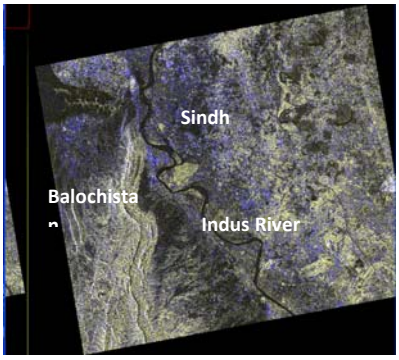


Figure 5: Image shows HV (R) HV (G) HH (B) combination of PALSAR- post flood Image of date 26 June 2007. Blue color in the images depicts open water on land due to heavy rains there

Figure 6 shows composite images of PALSAR and Radarsat that indicate inundated area of villages in Balochistan and Sindh in blue color, where red colored dots show the villages within 1Km of flood water and green colored dots show those villages which are 1Km away of flood water.

The down stream areas of Turbat and Mirani Dam including Gawadar, Jaferabad, Nasirabad, Dasht, Kalakut, Kosh, Kalat and Tazag and several other villages were badly affected by these 'flashfloods'.Flood water flowing from Balochistan via Qambar, Shahdadkot district and other villages near border due to abrupt elevation difference entered Mehar, Taluka of Dadu district on 06 July 2007 and inundated more 30 villages in Fareedabad, Madu area. These flash floods had resulted into inundation of more than 150 villages in three union councils near Shahdadkot district, Sindh.

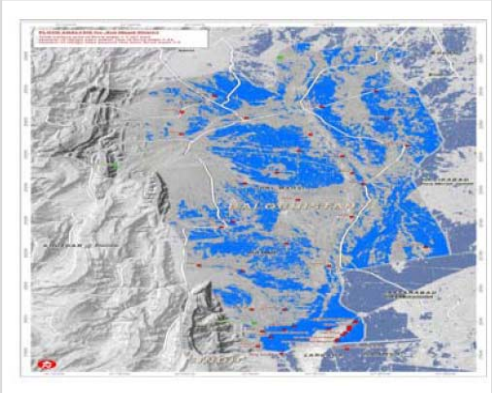


Figure 6: PALSAR-Radarsat images of 26 June and 05 July 2007 of Baluchistan a UNOSAT

The outcomes of study were complied to form the research paper titled, "" which was presented in first PI Symposium of ALOS Kyoto in Japan, 2007.

For floods of 2006, in Pakistan, rain accumulation curves were drawn. Graphs had been plotted between monthly rain fall totals overlying 1998 to 2006 for specific month of August for Mardan (figure 7).

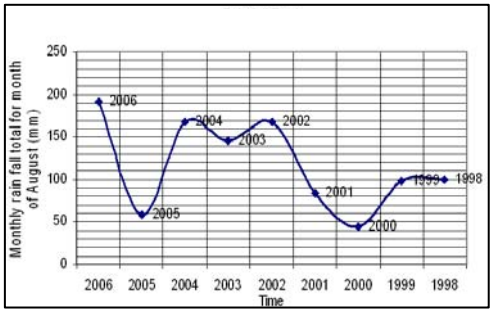


Figure 7

It showed that the extent of rain had been high for year 2006 in august as compared to previous six years, it also indicated the increasing rate of rains at Mardan. Graph of figure 8 for Mardan city was plotted between daily rain fall totals for month of August 2006. These all graphs used the TRMM 3B42RT V6 data rain fall total data as mentioned above.

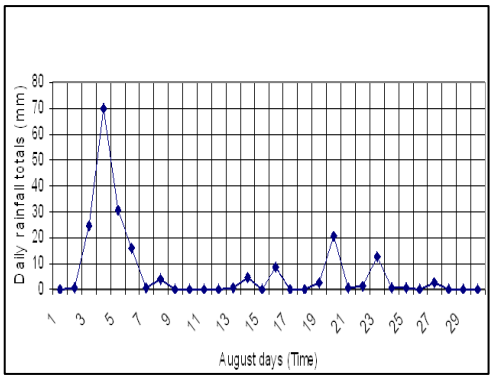


Figure 8

Both graphs showed that the rains became intense during 1 to 7, another peak was observed on 9 August 2006. The analysis shows that the intense rain situation was observed on 4th that caused the flooding on 5th August causing inundation in the city and damage to infrastructure. Rain had continued from the end of the month of July till first week of August in 2006 inundating 136 villages in Mardan district affecting 7,343 people.

SRTM DEM of flooded areas showed that the lowest point was 296 meter a.s.l and highest point up to which flood water reached was Bank road in Mardan which is 310 meters a.s.l. This range of elevation values was extracted from the SRTM DEM used. The extracted layer was called on the panchromatic image of PRISM sensor onboard ALOS satellite and has marked as the area under flooding. Ground information collected from various persons who witnessed the flooded situation was almost matching the extracted flooded area from SRTM DEM (Figure 9).

PRISM data was also used for preparing the land use / cover map of the city and for identification of various bridges on the Kalpani River including Hoti Bridge damaged during flooding (Figure 10).

The analysis showed that the intense rain situation had been observed on 4th that caused the flooding on 5th August causing inundation in the city and damage to infrastructure. One of the bridges over Kalpani River at

Hoti 30-foot-high (figure 9 and figure 10) got damages on 05 August 2006 breaking the link between two junctions of city.

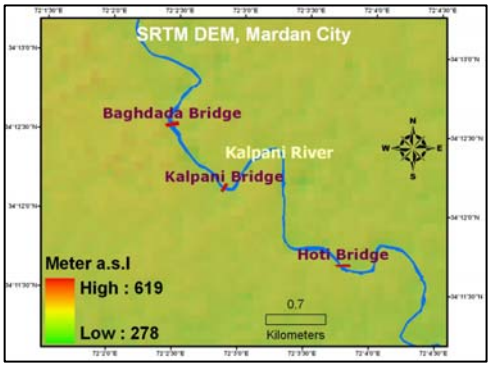


Figure 9: SRTM DEM, overlaid with shape file of Kabul River. Image is showing bridges that were

Analysis of SRTM DEM and AVNIR/PRISM land use land cover maps showed that 7-9 feet water was being passing through the roads like bank road in Mardan (figure 10), the same were verified from ground survey and reports from local news papers.

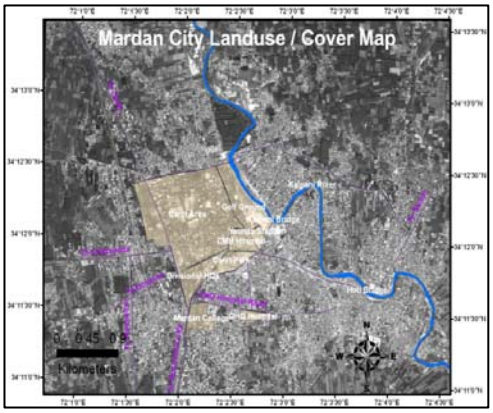


Figure 10: Pan sharpened image from PRISM and AVNIR

The down stream areas of Sikandari Korona, Sehri, Muhalla Dehli, Mal Mandi and Sabzi Mandi in the city were inundated and affected by these flashfloods.

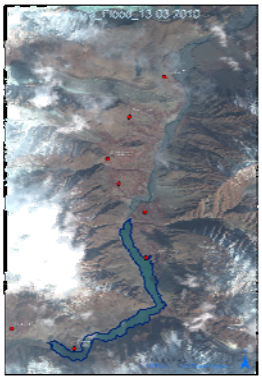
That increased the havoc in district and caused a number of casualties.

Another case study was done for floods of 2010, the results are discussed below.

For floods of February 2010, the cause was not rains but debris of landslide that blocked the down flow of stream along river Hunza in Northern region of Pakistan, causing water jam.

Satellite image results were later used for mapping. After finding the cause, situation was further monitored using satellite imagery. Information acquired was verified from ground information and local reports.

Based on ALOS AVNIR images, it was observed on 26, October 2009 that most of the area was not inundated and showed normal flow of the lake spread over 0.912 Sq Km.



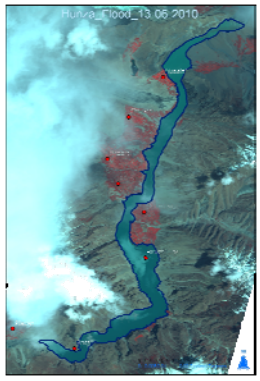


Figure 11

In contrast, same sensor images of 13 March 2010 showed inundation, as the images belonged to period after landslide. Extent of flood water spread over 3.972 Sq Km (figure 11). Flood monitoring from ALOS satellite data provided the opportunity to quickly and precisely overview flooded areas. In this study, using SRS and GIS techniques, the timely and detailed information about the extent of flood water required for locating and identifying the affected flooded areas and to implement corresponding damage monitoring and mitigating the losses.

5. CONCLUSION

ALOS data proved to be very useful to monitor the flooding situation occurred. If further data is to be studied it is thought that many other ways will be discovered.

6. ACKNOWLEDGMENT

The Authors would like to acknowledge JAXA, Japan for providing ALOS data in time, which proved to be very helpful in the study.

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