Geo-information as Disaster Management Tools in Aceh and Nias, Indonesia: a Post-disaster Area

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Abstract

Tsunami catastrophe had destroyed every sector of living of Acehnese. Efforts to help Acehnese carry on of their life have been conducted by Indonesian government and its partner from all around the world. There are many things that have been done, but still there are many things that should be done. This paper will bear the utilisation of geo-information within the rehabilitation and reconstruction processes in Aceh and Nias, Indonesia, by focusing on employment of geo-information within disaster management phases.

1. Introduction

On December 26, 2004, the world has evidenced one of the most horrible tragedies in history of human-kind. Up to 30 metres high tsunami waves wipe coastlines of Aceh and northern part of Sumatra, Indonesia, and several other countries in South East Asia. The catastrophe was even becoming worst as nobody was aware of what was happening. It was reported that tsunami waves travelled at an initial speed of 700-800 km/h and reached the shores of Aceh and northern part of Sumatra within 10-15 minutes[4] [Hakim, 2005]. See Figure 1 for the affected areas by tsunami.

According to Hakim (2005), tsunami catastrophe cost 229.000 lives, including more than ten of thousand of them that are still missing. Over 21.000 houses were destroyed and approximately 800.000 of Acehnese were displaced. The estimation of total impact of the catastrophe is IDR 41.4 trillion, including the IDR 27.2 trillion of damaged assets and IDR 14.2 trillion of losses in the future flow of economy. See Table 1 for details.

The tsunami has clearly shown that many improvements are need in disaster management. This paper will concentrate on only one of them, which is utilisation of geo-information. In order to systematically examine the role of geo-information as disaster management tools in Aceh, Section 2 will describe the Indonesian government's master plan of rehabilitation and reconstruction of Aceh and Nias will be brought, as well as what has been achieved at this moment. Section 3 will examine the roles of geo-information within disaster management phases regarding tsunami catastrophe in Aceh. The discussion on the role of geo-information as disaster management tools will be brought within Section 4, followed by concluding remarks in Section 5.

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[4] See: http://jarlspantry.com/GIS/DM_GIS.htm

2. Rehabilitation and Reconstruction of Aceh

Tsunami catastrophe in Aceh became a national tragedy for Indonesian. Every Indonesian was mourning for the lost of their father, mother, brother and sister in nationality. Many international institutions also got provided help Acehnese to move forward with their life. Aids and supports were flowing to show sympathy for Acehnese. However, the Indonesian government was the authority that had to deal with the aftermath and live re-organisation of the people from devastated areas.

Fig. 1: Affected Areas (shown in red) in Aceh and northern Sumatra, Indonesia [Hakim, 2005]

	Total Impact (in IDR Billion)		
	Damage	Losses	Total
Social Sector	15577	612	16189
Infrastructure	5915	2239	8154
Production Sector	3273	7721	10994
Cross Sectoral	2346	3718	6064
	27161	14240	41401

Tab.1: Summary of estimation of impact of tsunami catastrophe [BAPPENAS, 2005a; Hakim, 2005]

2.1 The Indonesian Government's Master Plan

The Indonesian government was quickly responding to the catastrophe. The Indonesian government appointed National Development Planning Agency (Badan Perencanaan Pembangunan Nasional/BAPPENAS) to create master plan for rehabilitation and reconstruction of Aceh. By April 15, 2005, the five-year master plan for rehabilitation and reconstruction of Aceh was published. The master plan is intended to become a guideline for actions as follows [BAPPENAS, 2005b]:

1. Create understanding and commitment of the central government, provincial, municipality, the business community, the communities concerned, universities and academicians, NGOs, donor agencies and the international community for the future reconstruction of Aceh and Nias;
2. Prepare a post-earthquake-and-tsunami action plan for the Rehabilitation and Reconstruction of Aceh and Nias Islands that can be immediately implemented by related parties;
3. Coordinate, synchronize and integrate plans of various sectors, the business community and the community (stakeholders) for formulating the Action Plan for the Rehabilitation and Reconstruction of Aceh and Nias Islands based on timeframes, locations, funding sources and the parties in charge;
4. Disseminate and distribute data as well as information to local, national and international communities with respect to the disaster, disaster aftermath, damage and loss assessment, need assessment, as well as early warning system in anticipation of any exposure to disaster;
5. Promote solidarity, participation, and involvement of civil society in the plans and efforts for the rehabilitation and reconstruction of Aceh and Nias Islands through dialogue and public consultations;
6. Design a system and mechanism for the mobilization of funds originating from the State Budget (APBN), Regional Budgets (APBD), the communities concerned and the international community in an efficient, effective, transparent, participatory and accountable manner based on good governance principles.

The master plan of rehabilitation and reconstruction of Aceh and Nias consists of a main and 11 detailed plan. The detailed plan is divided into 11 activity sectors as follows [BAPPENAS, 2005b]:

1. The spatial layout and land affairs sector plan: a guideline to rebuild the region, cities, areas and settlement environments which were damaged by the quake and tsunami disaster in order to allow the community to without delay resume activities in a better and secure condition from any disaster;
2. The natural resources and environment sector plan: to provide direction concerning considerations of the environment for the compilation of a regional spatial layout plan and to provide direction concerning the work plan of the related sectors through management of natural resources as well as of the environment in the rehabilitation and reconstruction phase of Aceh and Nias post tsunami disaster;
3. The infrastructure and housing sector plan: a guideline of rehabilitation and reconstruction of infrastructure and settlement;
4. The economic and manpower sector plan: to assist the victims of the disaster in the effort to restore their economic life by creating opportunity to work and develop productive assests;
5. The regional institution system plan: to strengthen regional government's roles in the implementation of effective accountable and transparent pubic services; developing and putting dynamic public spaces into an effect by involving all stakeholders in the progress of planning, policy formulation, decision making, monitoring and evaluation; and developing and recovering infrastructures to support public service process;
6. The education and health sector plan: to redevelop the life and welfare of people of Aceh and Nias after tsunami, especially by providing educational and health services that is supported by science and technology;

7. The religious, social cultural and human resources plan: to redevelop the life and welfare of people of Aceh and Nias by providing foods, clothing and housing; religious, social, cultural, youth, sports, child protection services etc;
8. The legal sector plan: a guideline for law enforcement;
9. The public order, security, and resilience sector plan: to provide security assurance on rehabilitation and reconstruction processes;
10. Implementation of good governance and supervision: to ensure the target achievement of the master plan and to prevent corruption and other deviations;
11. Funding: to map the needs and the sources of funds and monitor the implementation of master plan.

2.2 Progress on Rehabilitation and Reconstruction of Aceh and Nias

The five-year master plan of rehabilitation and reconstruction of Aceh and Nias is divided into three stages as follows [BAPPENAS, 2005b]:

1. Emergency response stage (January 2005-March 2005): to rescue the surviving community members and to immediately fulfil their minimum basic needs;
2. Rehabilitation stage (April 2005-December 2006): to enhance public services to an acceptable level as well as to solve the various issues related to the legal aspect through settlement of rights of land and to the psychological aspects through the handling of disaster victims' trauma;
3. Reconstruction stage (July 2006-December 2009): to reconstruct areas and communities affected by disaster, either directly and indirectly.

By the end of March 2005, emergency response stage has ended. A lot of works have been done within this stage, such as evacuation of those who have passed away, providing health treatment for those who were survived, relocation of the survivors to temporary accommodation, providing basic needs of the survivors, cleaning up the ruins etc.

Since many institutions have been involved within the emergency response and rehabilitation stages, it is hard to acquire the exact information regarding what have been achieved up to now. There are 11 multilateral institutions, 20 countries, more than 40 NGOs and several UN agencies that have been working together and/or separately. In order to manage projects being carried out by government agencies, donor institutions, non-governmental institutions (NGOs) and/or private sector; the Rehabilitation and Reconstruction Agency (Badan Rehabilitasi dan Rekonstruksi/BRR) for Aceh and Nias was established on April 16, 2005[5]. BRR will be acting as a coordinating agency that role is to ensure transparency, accountability and speed in the rehabilitation and reconstruction of Aceh and Nias.

Having coordinated by BRR, there have been progresses on some activity sectors such as[5]:

1. Manual of land registration in the affected areas by tsunami in Aceh and Nias under spatial planning and land policy sector;
2. Customs procedures at Belawan Port, Medan and ILO guide on responses to support the recovery and reconstruction efforts in crisis-affected areas in Indonesia under economy and labour sector;
3. Project on Strengthening Camats' Role in The Recovery through Harnessing Village-Level Information under institutional development sector;
4. IOM Tsunami and Earthquake Emergency Relief and Rehabilitation Programme under health and education sector;

[5] See: http://e-aceh.bappenas.go.id/Pledge/

5. Aceh Emergency Response and Transitional Recovery Programme under legal and judicial institutions sector;
6. Procedures and Forms for the Registration of Vehicles in Banda Aceh under security, public order and resilience sector.

As the rehabilitation stage has begun on April 2005, the constructions of several infrastructures have been started as well [BRR, 2005].

3. The Roles of Geo-information in Disaster Management Phases

As it can be realised many activities in the Master plan are related to (depended on) availability of geo-information. Worldwide the interest in geo-information increases. Almost every month in 2005 was a conference or an activity (Gi4DM, Delft; Bentley Research Seminar, Baltimore; GISplanet, Lisbon; Disaster Across continents, Toronto, etc.) appealing for a strengthen role of geo-information

Geo-information (from maps to advanced simulations) has been always used in all the phases of disaster management. In such systems, most of the important data and information necessary are spatially related and therefore a GIS component in such a support system becomes of special relevance. Systems to support decision makers in the phases mitigation, preparedness and recovery are in widely use. For example, GIS based flood simulations. Results of such simulations can be computed and further used to predict the risk and the potentially quantum of damages (mitigation). GIS-based simulation systems are also necessary to develop useful and realistic scenarios to be used in trainings (preparedness). In recovery phase, there is often a high public and political interest to see a situation before and after an emergency and to set priorities for the rebuilding.

There are two general factors that are challenging the use of geo-information in disaster management: the nature of the application and the status of geo-information. Disaster management and especially the crisis response are applications that pose high requirements due to very specific characteristics:

1. Decision have to be taken fast, which requires rapid geo-information technology;
2. Many actors are involved (rescue forces, decision makers at different levels, citizens) that must coordinate their activities;
3. Decisions are taken under severe time and psychological pressure;
4. Usually there is a lot of uncertainty (due to lack of tamely information) that creates the need for ad hoc decision making often based on experience and intuition rather than information;
5. External pressure (such as that of media) is extremely high, which affects work on all the teams;
6. There are not criteria (at the moment) for estimation of the correctness of the taken steps and decision, assessment of the decision making process is done afterwards.

Geo-information is scattered in different organizations, systems, formats and applications, devoted to completely different tasks. It is often discussed that the real barriers for the use of geo-information in disaster management sector are difficulties in making data available, finding the most appropriate data and making systems cooperate (Zlatanova, 2005). The lack of interoperability, due to proprietary standards and developments, delays systems to be connected and updated without massive investments, which are too expensive for many organisations. This results into islands of automation on dedicated tasks, unable to deliver intelligence to multi-user groups.

To which extend is geo-information used is tricky to measure and differs with respect to the counties. Table 2 gives an estimation of the use of geo-information within disaster management phases in the Netherlands. Table 2 also reveals that in some phases there has been a needs on geo-information while geo-information still could not support the implementation within those phases. For example, the number of systems for technical support in response phase is quite limited.

Use of geo-information \ Phases	Pro-activeness	Mitigation	Preparedness	Response	Recovery
Publicity	X	X		X	X
Inform	X	X		X	X
Organisations involved	X	X	X	X	X
Simulation	X	X	X	N	
Risk analysis	X	X		X	X
Querying	X	X	X	X	X
Prediction	X	X		N	
Data collection	X	X		N	X
Visualisation	X	X	X	X	X
Equipment			X	X	
System performance				N	X
Rescue team performance				N	N
Making plans to attack a disaster			X	X	
Financial responsibility check	X	X			N

Tab. 2: Roles of geo-information within disaster management phases. Notes: X = Implemented, N = Needed

Concerning tsunami catastrophe in Aceh and Nias, geo-information has been playing the important roles on every disaster management phase. Sub-sections below will illustrate what has been done by using geo-information regarding tsunami catastrophe in Aceh and Nias on every disaster management phase.

3.1 Pro-activeness

The December 26 tsunami was actually generated by 9.0 Richter scale earthquakes. The cause of the earthquake was the fault line's slip along the subduction zone, where the India Plate dives under the Burma Plate[6]. As we all already knew, the South East Asia region is a tectonically complex region where several plates are colliding with relative speeds of up to 10 cm per year, compared with plate motions in Europe that catch up speeds of 1 to 1.5 cm per year [Ambrosius, 2005].

Approximately one year before the catastrophe happened, a project called South-East Asia Mastering Environmental Research with Geodetic Science technique (SEAMERGES) began. One of the tasks of SEAMERGES is the sharing of Global Positioning System (GPS) measurement data among the partner institutions. SEAMERGES GPS network comprises 49 continuously operating stations in Indonesia, Malaysia and Thailand [Vigny, 2005].

Based on GPS measurement data on December 26, there has been a large co-seismic displacement that covered up to 1000 km distance from the epicentre of the earthquake [Ambrosius, 2005]. According to

[6] See: http://en.wikipedia.org/wiki/2004_Indian_Ocean_earthquake

Vigny (2005), the co-seismic displacement measured by the nearest sites, more than 400 km away from the epicentre, are 27 cm in Phuket, Thailand; 17 cm in Langkawi Island, Malaysia; and 15 cm in Sampali, Indonesia. While the network was extended to comprise 9 regional and 21 global stations of the International GPS Service (IGS), small but significant co-seismic jumps (5 to 10 mm) were detected at stations more than 3000 km away from the earthquake epicentre. Overall deformation field points inward towards the earthquake epicentre. East-west-trending displacements at mid-latitudes (between 00 and 150), north-south-trending displacements at higher latitudes (below 00 or above 150), and absece of significant displacements north and south of the rupture were due to a thrust focal mechanism, aligned with the Sumatran trench west of the west coast of Sumatra. Large displacements in northern Thailand (8 cm in Bangkok and almost 3 cm in Chiang Mai) implied a rupture extending far north into the Andaman Sea, in agreement with the distribution of aftershocks. In contrary, the very strong increase of displacement detected along the Malaysian peninsula (2 cm in Singapore and 17 cm in Langkawi Island) suggested a limited amount of slip on the southern section of the fault. See Figure 2 for details.

Besides above GPS data compilation, the crustal deformations in Indonesia have already been monitored since 1992 by Department of Geodetic Engineering of Bandung Institute of Technology (Institut Teknologi Bandung/ITB) [ITB, 2004]. There has been cooperation between Bandung Institute of Technology and ERI Tokyo University, DPRI Kyoto University, etc on West Java geodynamics monitoring within period 1992-1997. The volcano displacements have also been monitored by Bandung Institute of Technology and its partner since 1996 [ITB, 2004].

3.2 Mitigation

As it is mentioned in Section 2, the Indonesian government appointed BAPPENAS for creating the master plan on rehabilitation and reconstruction of Aceh and Nias. BAPPENAS has included this phase of disaster management in the spatial structuring process on the master plan. The purpose of this post-earthquake and post-tsunami spatial structuring of Aceh and Nias Islands is to reconstruct areas, cities, regions and settlements devastated by the disaster, enabling community members to conduct their activities under improved conditions, safe from disaster [BAPPENAS, 2005b]. According to BAPPENAS (2005b), the post-disaster development of Aceh and Nias Islands will continue to adhere to the sustainable development principle, prioritizing balance between economic, social and environmental aspects and considerations and inter- and intra-generation development. Other aspects such as the use of modern, effective and environmentally friendly technology and possible future disaster will also be taken into account in the sustainable natural resources and environmental development.

The most important part of guidelines on spatial structuring is policy on spatial use and pattern of Aceh. Even though it has been criticized as missing many details, large scale spatial planning has been established within documentation of master plan on rehabilitation and reconstruction of Aceh and Nias. The spatial use directive has been divided into nine areas. See Figure 3 for directive on zoning of Meulaboh, Aceh.

In the master plan of rehabilitation and reconstruction of Aceh and Nias, BAPPENAS (2005b) has defined the components of spatial land use of safe zone as follows:

1. Housing for the community in general;
2. Government facilities, secondary to tertiary education facilities, hospitals, local and central government office buildings, culture and science museums;
3. Local and regional trade and services, industrial and warehousing facilities etc;
4. Intercity and provincial land transport terminal;
5. Environment supporting utilities, such as electricity generators, water supply, fuel distribution, telecommunications centres.

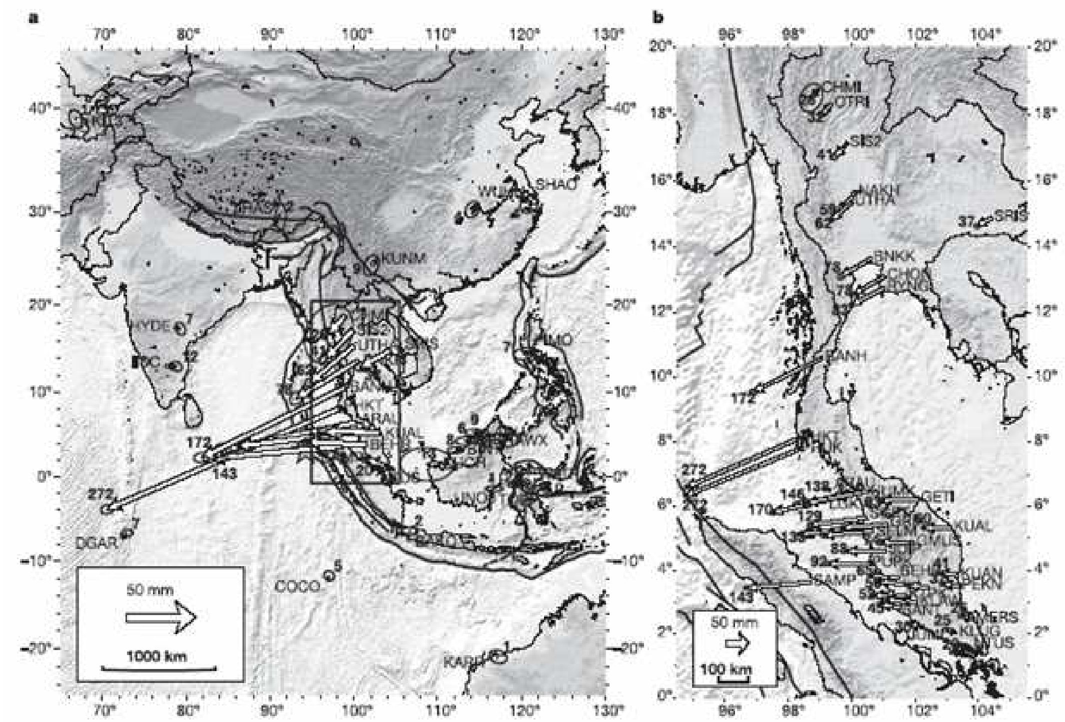

Fig.2: Co-seismic displacement field derived from GPS observations at more than 60 sites. Panel a shows a large scale overview from a low-density subset. Panel b provides more detail, zooming in on a smaller area (rectangular box in a). Note the high-density sub-network on the Malaysian peninsular. Bold numbers next to arrow heads give the displacement in mm [Vigny, 2005]

According to BAPPENAS (2005b), components of zoning detail, which is considering the safe zone as well, of Kota Barat, Sabang, Aceh, are as follows:

1. Beach/ maritime tourism site;
2. Settlement areas;
3. Highland (hills)/ evacuation area;
4. Evacuation route;
5. Port area;
6. Plantation estates/ protection forests;
7. Fish farming/ floating cage culture;
8. Coastline;
9. Beach morphology: geographically, Kota Bawah Besar lies at the east peninsula of Sabang Island. It features important port activities in a rather closed area of sea. The most outer section of the peninsula features highland/ hills surrounded by beaches abundant in coral reef ecosystems. To the south of the town are hilly areas where smallholder estate cropping takes place and which feature a tropical forest with a steep topography to the west and sloping downwards to the east. The island's beach substrate

comprises white sand mixed with crushed marine biota (coral, shells, etc). Settlements are present inland up to the shoreline. Long-shore currents move eastwards;

10. Disaster mitigation through spatial planning: Tsunamis form a serious threat to coastal towns, which has created the need for coastal spatial planning that is disaster free. The illustration to the right depicts an ideal arrangement of spatial allocation (spatial planning) to mitigate tsunami impacts:
    - Settlements are sited in an area surrounded by greenbelts.
    - The port area is sited in a bay.
    - Coastal areas are designated for beach/maritime tourism.
    - Highland areas are designated as evacuation sites in case of disaster.
    - South part of the bay is designated as a fish farming zone

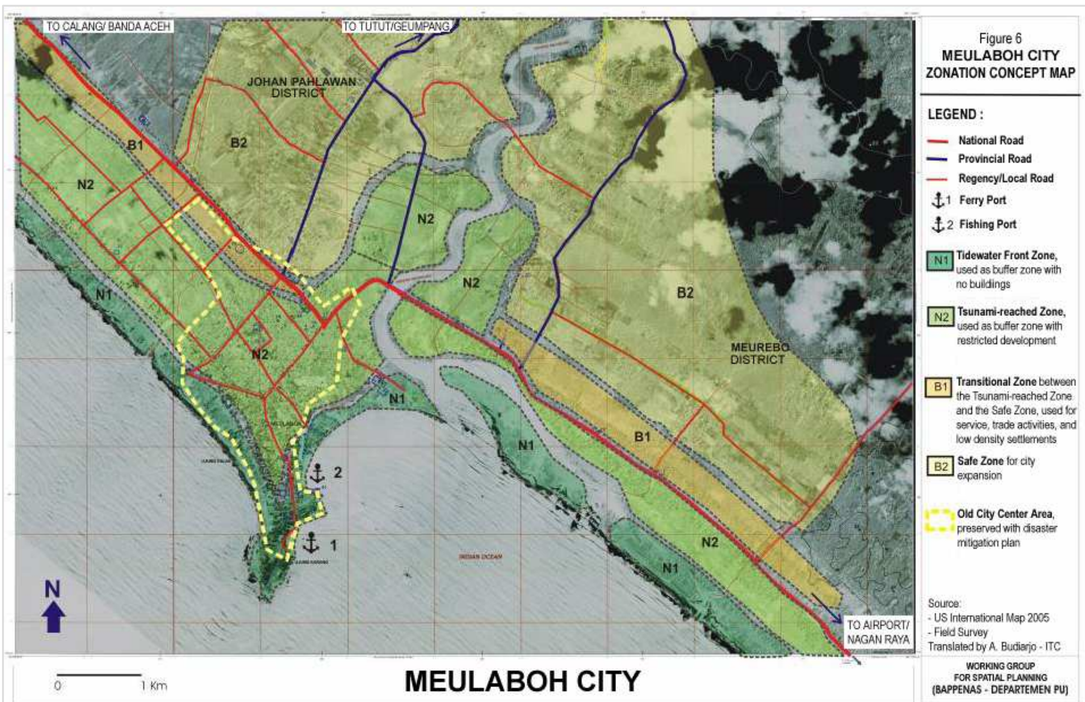

Fig. 3: Conceptual zoning plan for Meulaboh, Aceh [BAPPENAS, 2005b]

3.3 Preparedness

Although it is estimated that the next slip of fault line in Indonesian subduction zone will happen within next hundred years, it is necessary to prepare for the next horrible tsunami and earthquake catastrophe. The preparedness of the next tsunami catastrophe is included in spatial planning and land policy guideline, especially on spatial use directive.

In addition to the plans for building better infrastructure able to better resist future disasters, the government is busy with plans for better response to disasters by training the rescue unities, preparing Emergency and Escape Plans, and preparing appropriate instructions to citizens. Such check lists for citizens is available by the Red Cross and FEMA[7]. Geo-information will be considered widely in preparation of plans with evacuation routes, risk maps and safe areas.

3.4 Response

Up to now, geo-information utilisation regarding tsunami in Aceh and Nias under response phase of disaster management is almost equal to nothing. The only significant effort within this phase is the monitoring of sea level by Radar Altimeter Database System (RADS), which is maintained by Delft University of Technology and NOAA [Ambrosius, 2005]. The imageries generated by TOPEX/Poseidon and Jason-1 altimeter systems could become important inputs for the beginning of the response phase. See Figure 3 and Figure 4 for sea level monitoring generated by TOPEX/Poseidon and Jason-1 altimeter systems.

Since most of altimeter satellites have long repeated cycle (e.g: TOPEX/Poseidon length of a repeat cycle is about 10 days), the more accurate and real-time system is needed to support the performance of response phase of disaster management.

3.5 Recovery

In this phase of disaster management, geo-information is actually becoming a basic instrument to be able to recover the tsunami affected areas, especially for setting up spatial planning and land use policy. The role of geo-information is also needed while implementing land administration policy. According to BRR (2005), the parcel mapping has been started on August 26, 2005. BRR urges local community to conduct their own village mapping. BRR has developed Participative Land Mapping Guidelines to conduct the whole processes of parcel mapping. The citizens of Aceh and Nias will perform the mapping of their own parcel boundary. The parcel mapping activity is also supported by photogrametric and large-scale satellite imagery of areas affected by tsunami before the catastrophe.

4. Discussion

The experience of the Indonesia government in usage of geo-information has shown major problems:

1. Much of the existing geo-information in the Indonesian offices was outdated. The information that was mostly relevant was obtained from international organisations.
2. Many of offices able to provide local geo-information were destroyed. Backups of this information did not exist elsewhere.
3. Similarly to many other countries, the data available are stored, and managed by authorities that have distinct authorizations, which work independently of each other. The systems they use are not designed to work in a multidisciplinary environment, and their systems are hardly interoperable. Furthermore geo-data is managed by different systems (mostly GIS) in specific details, resolutions, object definition, schemas and formats. Exchange of data is based on creating a copy of data sets in a specific format that is readable by the systems of the other party.
4. Technology ground field update was completely missing. The country relied on satellite images, which scale is often too small for certain details (conditions of houses, people and environments).

[7] See: http://www.fema.gov/pdf/library/epc.pdf

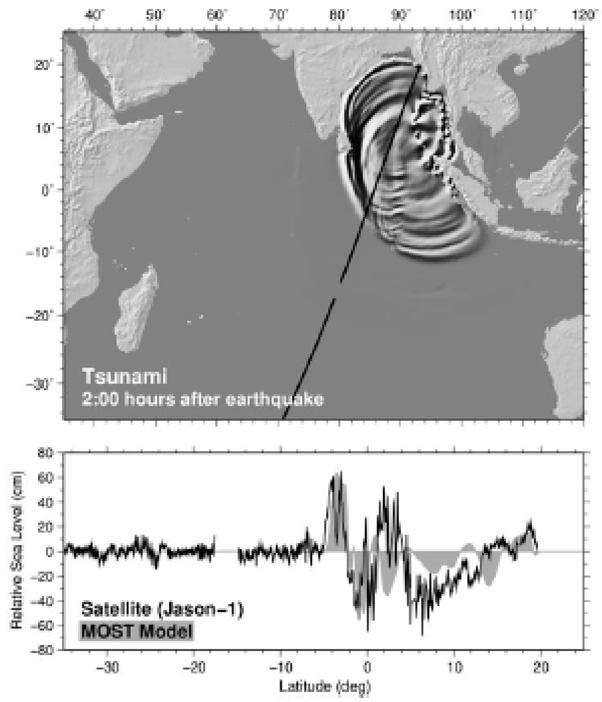

Fig. 3: The 26 December 2004 tsunami seen by the JASON-1 altimeter jointly operated by NASA and CNES. The ground track intersects the equator 2 hours after the earthquake on December 26, 2004. The upper map shows the modelled tsunami and the satellite track along which altimeter data was used to obtain sea level anomalies. The bottom graph shows the observed relative sea level in black, the shaded line shows the sea level predicted by NOAA's tsunami model[8] [Ambrosius, 2005]

The Indonesian respective authorities responsible for maintenance of geo-information are currently discussing (with the help of international organizations) the future organization of geo-information to be able to serve better disaster management.

The progress on utilisation of geo-information in Aceh and Nias concerning disaster management phases should be considered as tremendous achievement, regarding its short working period. Unfortunately, there is still a lack of utilisation of geo-information concerning the response phase of disaster management. Even though the efforts on mitigation and preparedness phases have been initiated, there is no single existing scheme and/or application that could initiate the quick response on disaster. One of the examples of scheme and/or application that will make sure the quick response on disaster is early warning system.

[8] See: http://www.pmel.noaa.gov/tsunami/indo_1204.html

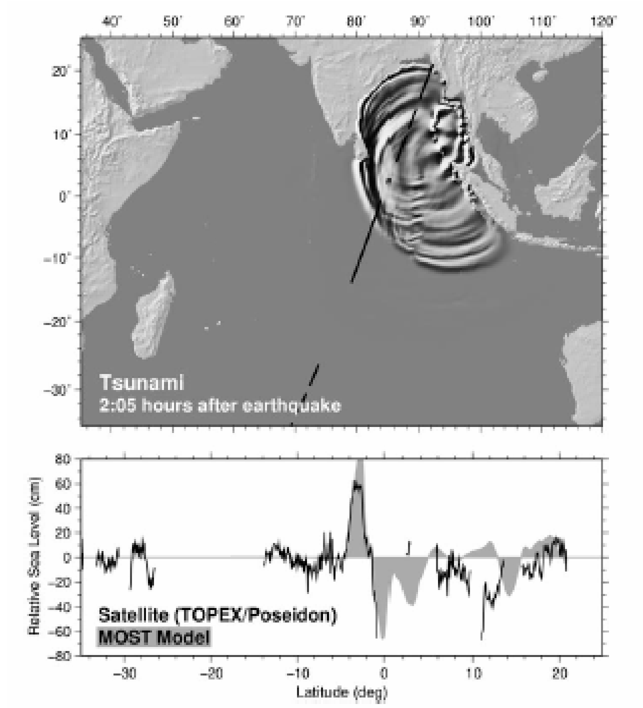

Fig.4: The tsunami seen by the TOPEX/Poseidon altimeter operated by NASA at 2 hours and 5 minutes after the Earthquake on December 26, 2004. This shows the largest recorded gravity wave seen by any of the four altimeters; the maximum observed crest to through height is about 1.2 meter [Ambrosius, 2005]

5. Conclusion

In this paper we have analyzed the role of geo-information in Indonesia. It is evident that the government needs and uses various maps and imagery in the response, recovery and mitigation phases. The role of all geo-specialists in Indonesia is to provide the appropriate geo-information to the authorities when requested. Still many aspects of geo-information acquisition, management, analysis and presentations have to be addressed. As any other country, Indonesia needs to develop Spatial Data Infrastructure, which will especially help in exchange of data. Dedicated research and corresponding developments has to focus on systems for fast response, early warnings, communication and collaboration between emergency teams.

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