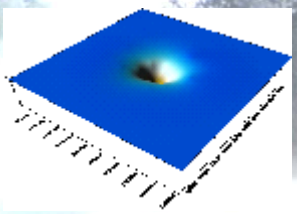
Ground Displacement around LUSI Mud Volcano Indonesia as Inferred from GPS Surveys



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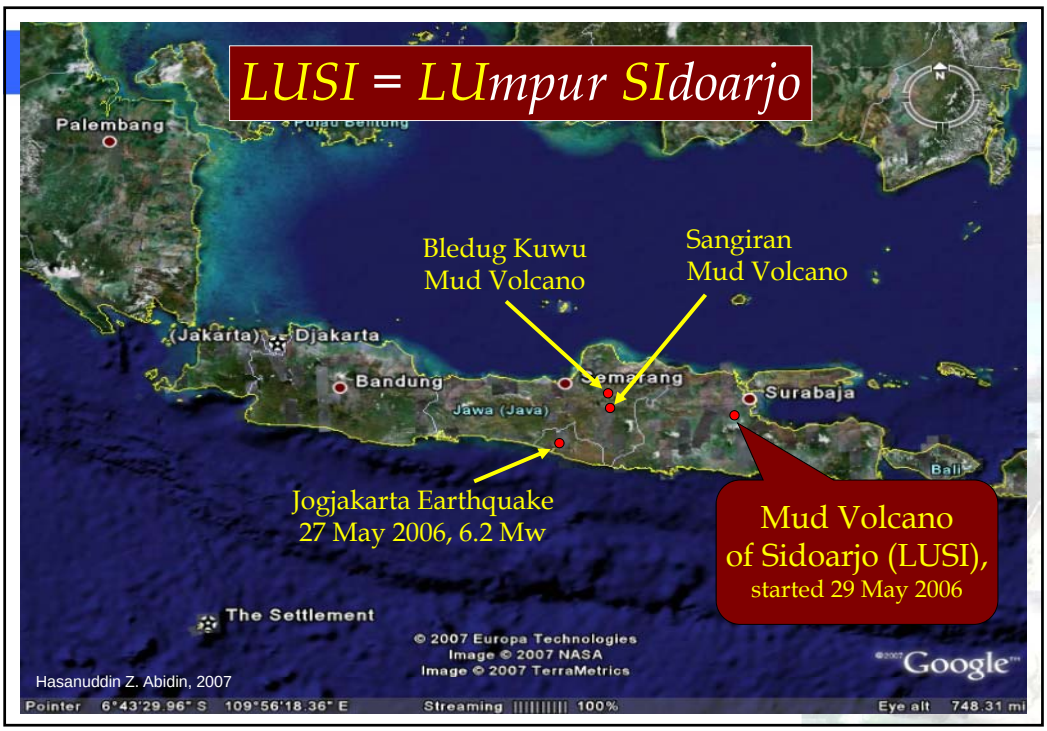
Indonesia

FIG Congress 2010, Facing the Challenge-Building the Capacity. Sydney, Australia, 11-16 April 2010

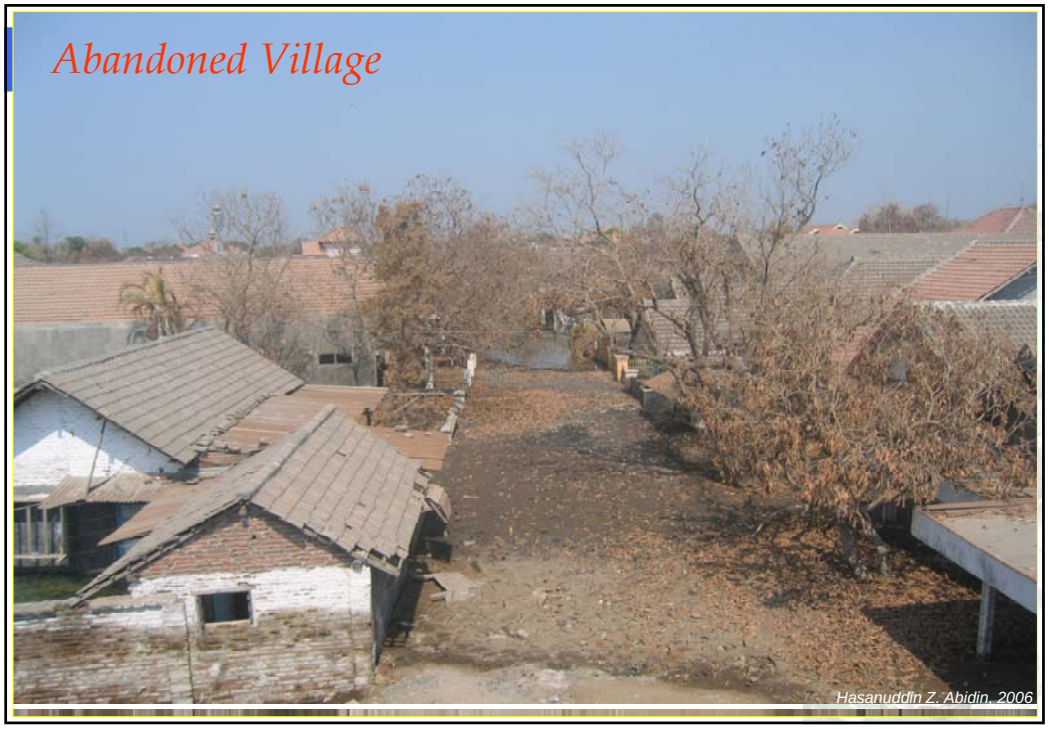


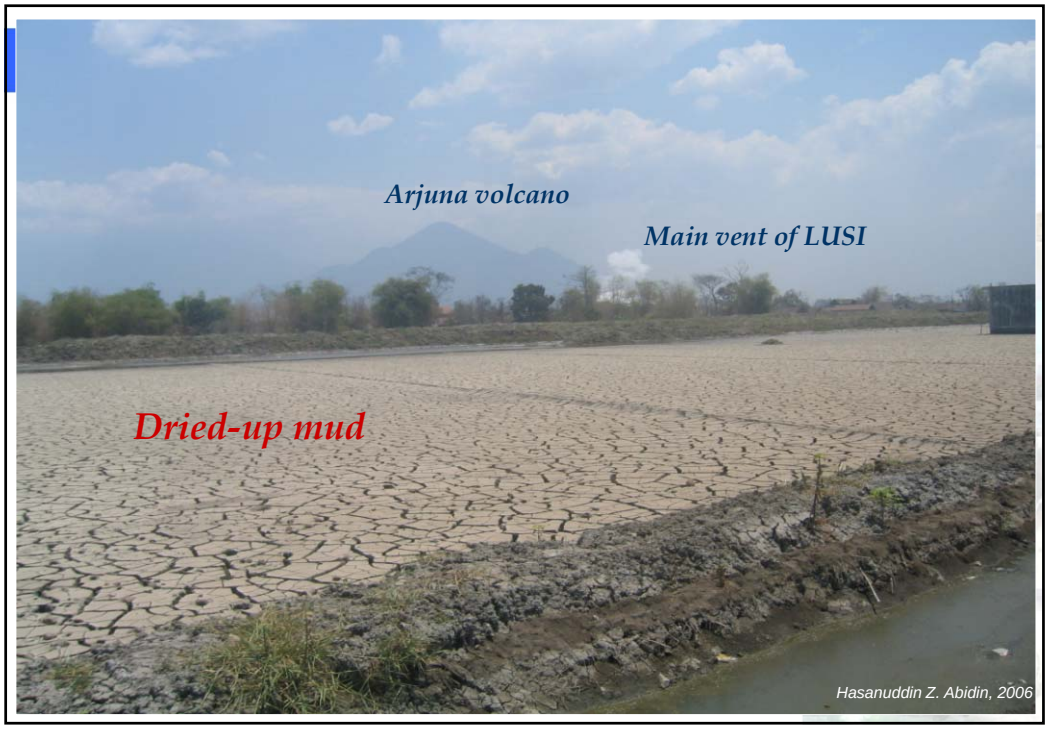

Main Vent of LUSI
http://www.nytimes.com

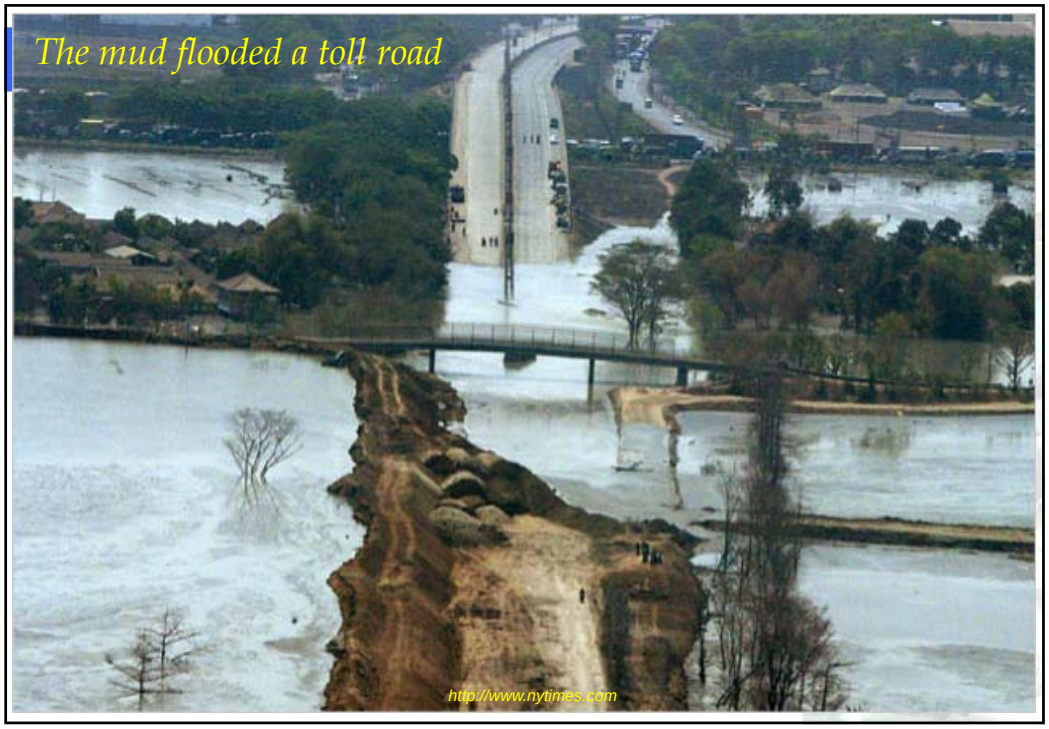

Steam spraying out from the main vent of LUSI
http://www.nytimes.com


Flooded Factories
Hasanuddin Z. Abidin, 2006


Flooded Houses

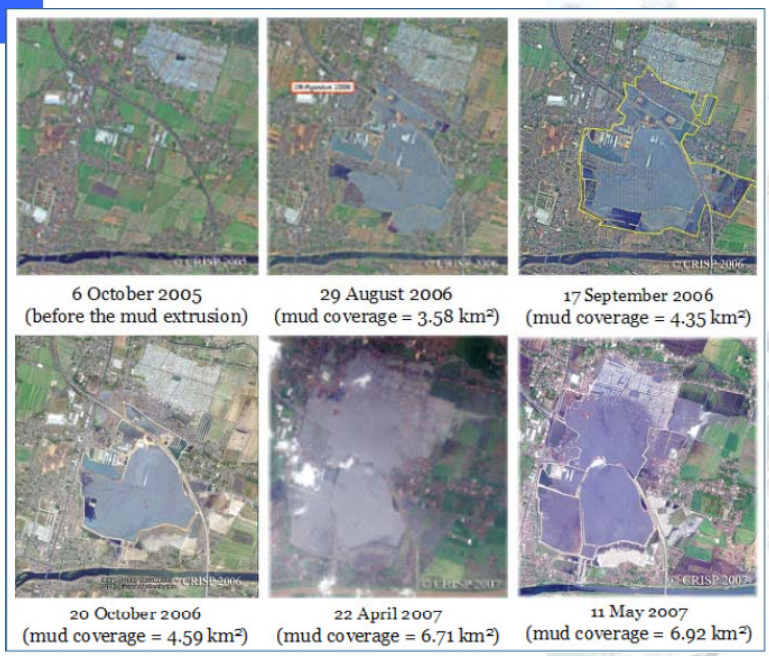

Abandoned Village
Hasanuddin Z. Abidin, 2006


Arjuna volcano
Main vent of LUSI
Dried-up mud
Hasanuddin Z. Abidin, 2006


The mud flooded a toll road
http://www.nytimes.com


Arjuna volcano
Mud Lake of LUSI
Hasanuddin Z. Abidin, 2006

INCREASED COVERAGE OF MUD



6 October 2005
(before the mud extrusion)

29 August 2006
(mud coverage = 3.58 km²)

17 September 2006
(mud coverage = 4.35 km²)

20 October 2006
(mud coverage = 4.59 km²)

22 April 2007
(mud coverage = 6.71 km²)

11 May 2007
(mud coverage = 6.92 km²)

LUSI LEAVING INFRASTRUCTURE DAMAGE

Crack on the ground around Relief Well 2.

LUSI LEAVING INFRASTRUCTURE DAMAGE

Documentation on cracks on the wall, streets, floor around Renokenongo village

LUSI LEAVING INFRASTRUCTURE DAMAGE

Documentation on cracks on the wall, house, floor around Sengon village

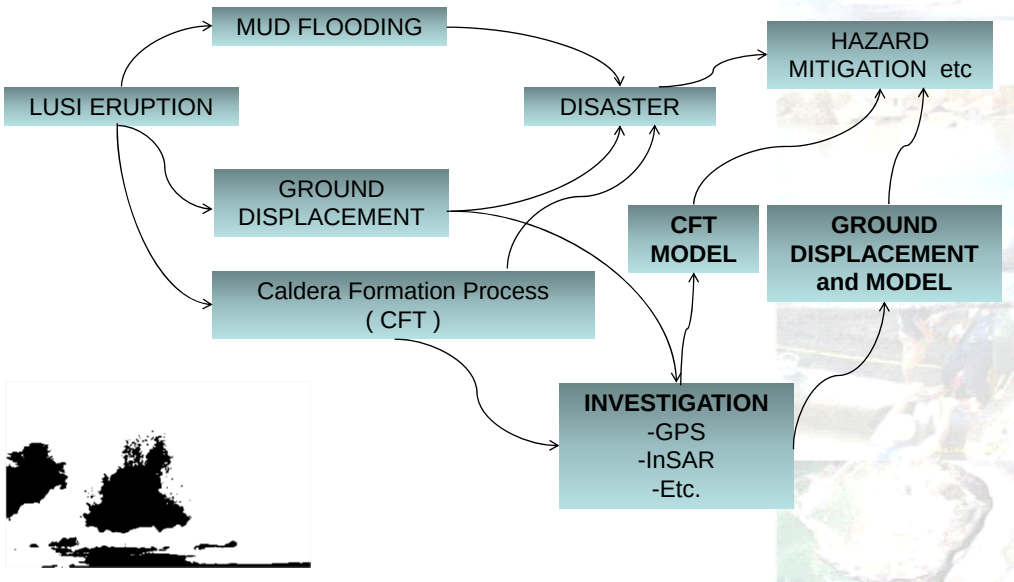
LUSI LEAVING INFRASTRUCTURE DAMAGE AND LIFE LOSSES

Explosion of gas pipeline killed 18 people

Crashes of Pipe water belong to district water management of Porong SIdoarjo

Bending on the railway (photo by BPLS)

LUSI SCENARIO



INVESTIGATION OF GROUND DISLPACEMENT ON LUSI MUD VOLCANO

13 GPS campaigns have been conducted between June 2006 and May 2009

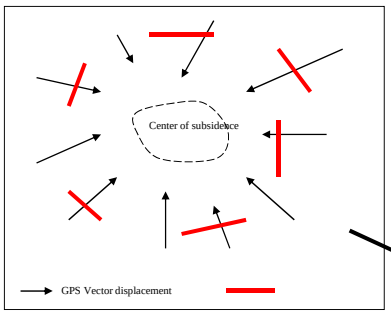
GPS surveys were performed on up to about 50 stations with set area over 10 kilometers rounding the center of eruption, using dual-frequency geodetic-type receivers, with observation session lengths of about 5-10 hours.

Due to the change in mud coverage area, the numbers of observed GPS stations were different from survey to survey, and the observed stations could not always be the same.

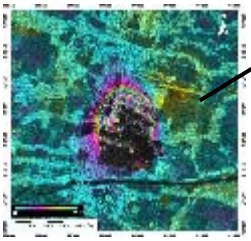
INVESTIGATION OF GROUND DISLPACEMENT ON LUSI MUD VOLCANO

Documentation of GPS Survey around LUSI Mud Volcano

INVESTIGATION OF CFT ON LUSI MUD VOLCANO

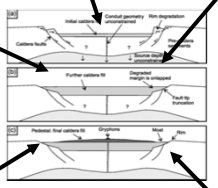


GPS derived horizontal component

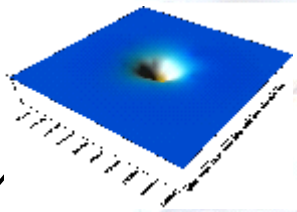


Result from InSAR

Cracks observation



CFP



GPS derived vertical component

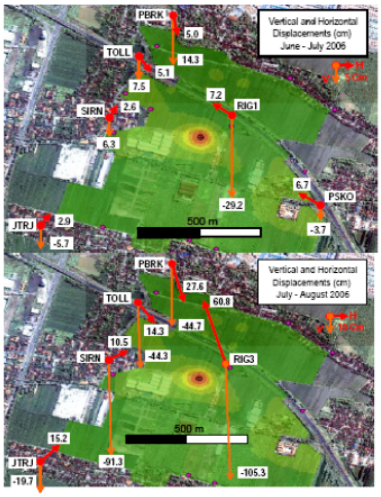
Image solution

GROUND DISPLACEMENT ON LUSI MUD VOLCANO

In the first three months of mud extrusion it can be seen that the rates of displacements are increasing with time. In this period, the rates of horizontal and vertical displacements were up to 2 - 4 cm/day, respectively; and vertical displacements are dominated by subsidence.

Based on GPS results, the affected area of displacements up to end of August 2006 is contained to about 1 km around the extrusion centre. Starting from the third campaign, more GPS stations were observed (Abidin, 2008).

GROUND DISPLACEMENT ON LUSI MUD VOLCANO



Period	Vertical Displacement	Horizontal Displacement
June-July 2006	Rate < 1.1 cm/day; Subsidence (all stations)	Rate < 0.3 cm/day; Directions: all to north-west of the main vent
July-Aug 2006	Rate < 3.6 cm/day; Subsidence (all stations)	Rate < 0.9 cm/day; Directions: all to north-west of the main vent
Aug-Sep 2006	Rate < 2.1 cm/day; Subsidence and Uplift	Rate < 0.7 cm/day; Directions: mostly to north-west of the main vent
Sep-Oct 2006	Rate < 2.4 cm/day; Mostly subsidence	Rate < 0.9 cm/day; Directions: mostly to north-west of the main vent
Oct 2006-Feb 2007	Rate < 0.3 cm/day; Subsidence (all stations)	Rate < 0.3 cm/day; Directions: all to north-west of the main vent
Feb-March 2007	Rate < 0.3 cm/day; Mostly subsidence	Rate < 0.3 cm/day; Directions: some to north-west of the main vent
March-May 2007	Rate < 0.2 cm/day; Subsidence and Uplift	Rate < 0.1 cm/day; Directions: some to north-west of the main vent
May-June 2007	Rate < 0.2 cm/day; Subsidence and Uplift	Rate < 0.1 cm/day; Directions: no specific pattern of direction

Figure 4 Figure and table showing vertical and horizontal displacement around LUSI mud volcano on periode June 2006 up to june 2007 (Abidin, 2008)

GROUND DISPLACEMENT ON LUSI MUD VOLCANO

What happen after two and three years turn out that the ground displacement has slowering at rates. Its not 2-4 cm/day anymore but only several centimeter up to desimeter in a years time. A linier trend were replaced by exponential decay instead.

GROUND DISPLACEMENT ON LUSI MUD VOLCANO

Table 1 The number of ground displacement at some monitored GPS station after 1 year eruption in meter rate

SNGN	GLAG	RMKN	JBPR	GMPL	BPN18	1210	PGN1	BT16	BMT2	BMT4	KCMT	KLDN	GPOL	ORFF	5BRR	5CCC
0.94 km	1.08 km	1.29 km	1.86 km	1.80 km	1.86 km	2.01 km	2.06 km	2.51 km	2.63 km	2.80 km	3.39 km	3.68 km	3.68 km	4.10 km	5.27 km	6.88 km
-0.7242	-0.6562	-0.5690	-0.3872	-0.4041	-0.3882	-0.3491	-0.3360	-0.2391	-0.2147	-0.1847	-0.0854	-0.0481	-0.0478	0.0052	0.0000	0.0000

Table 2 The number of ground displacement at some monitored GPS station after 3 year eruption in meter rate

		RMKN	JBPR	GMPL	BPN18	1210	PGN1	BT16	BMT2	BMT4	KCMT	KLDN	GPOL	ORFF	5BRR	5CCC
		1.29 km	1.86 km	1.80 km	1.86 km	2.01 km	2.06 km	2.51 km	2.63 km	2.80 km	3.39 km	3.68 km	3.68 km	4.10 km	5.27 km	6.88 km
		-1.1381	-1.1784	-0.7252	-0.7372	-0.4347	-0.4990	-0.3291	-0.5014	-0.3768	-0.1750	-0.1915	-0.1733	-0.0768	-0.0668	-0.0917

THE MODEL OF GROUND DISPLACEMENT ON LUSI MUD VOLCANO

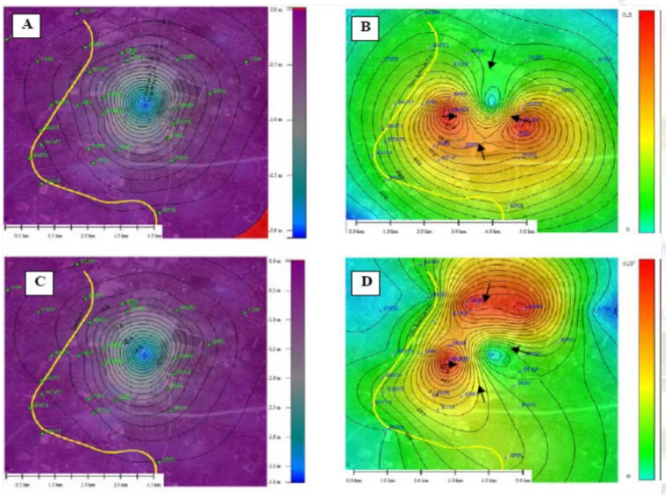


Figure . (a) Model derived vertical displacements after 1 year of LUSI mud volcano erruption, (b) Model derived horisontal displacements after 1 year LUSI mud volcano erruption, (c) Model derived vertical displacements after 3 year LUSI mud volcano erruption, (d) Model derived horisontal displacements after 3 year LUSI mud volcano erruption,

THE MODEL OF CFP ON LUSI MUD VOLCANO

The GPS derived information together with field surface representation of displacement (cracks), and also occurred bubble plotting, micro seismic, etc were showing the good fact on explaining caldera formation processes that happening in LUSI mud volcano.

We believe that caldera formation is being developed in LUSI mud volcano

THE MODEL OF CFP ON LUSI MUD VOLCANO

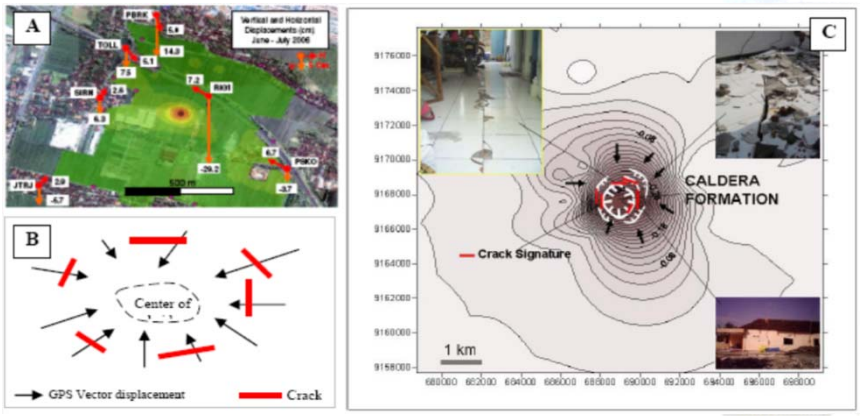


Figure. (a) GPS derived displacements, June to July2006; (b) Data overlay illustration of crack signatures and horizontal displacement from GPS result, (c) Illustration of caldera formation processes on recently birth LUSI Mud Volcano

CLOSING REMARK

Based on GPS results, the affected area of displacements up to early 2007 is contained to about 1-2 km around the mud lake outer boundary.

In this region, after 2-3 years the ground displacements has slowing down and the rates are about several cm to dm pper year. An early liniear trend were replaced by exponential decay instead.

How about the ground displacement inside the mud lake ??

CLOSING REMARK

The analysis showed that ground displacements consisted of two stages which are rapid ground displacement (associated with Caldera formation processes) and slow ground displacement caused by the effects of mud loading, ground relaxation due to mud outflow, etc.

This information of rapid and slow ground deformation will be a useful information for infrastructure development planning, hazard evaluation, etc.


THANK YOU