Examination of Static Stress Change due to Tectonic Earthquake - Triggering of 2013 Eruptions of Sinabung volcano

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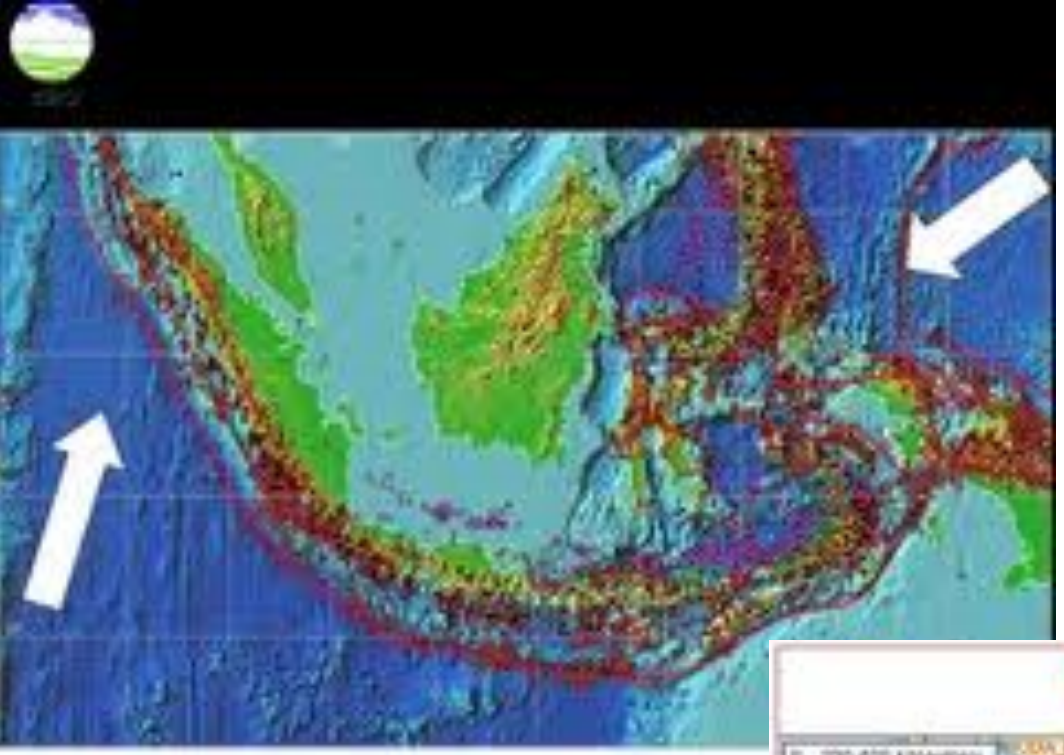
***Geodesy and Geomatics, ITB

Outline

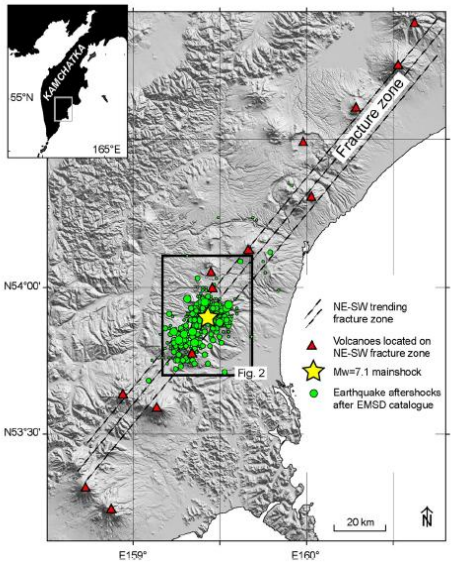
1. **Introduction**
2. **Volcanic eruption and stress triggering**
3. **Sinabung volcanic activities**
4. **Examination of static strains change of volcano due to tectonic earthquake - triggering of Sinabung volcanic activities**
5. **Mechanism of triggering and possible thresholds of the earthquake parameters on static triggering to volcanoes**
6. **Conclusions**

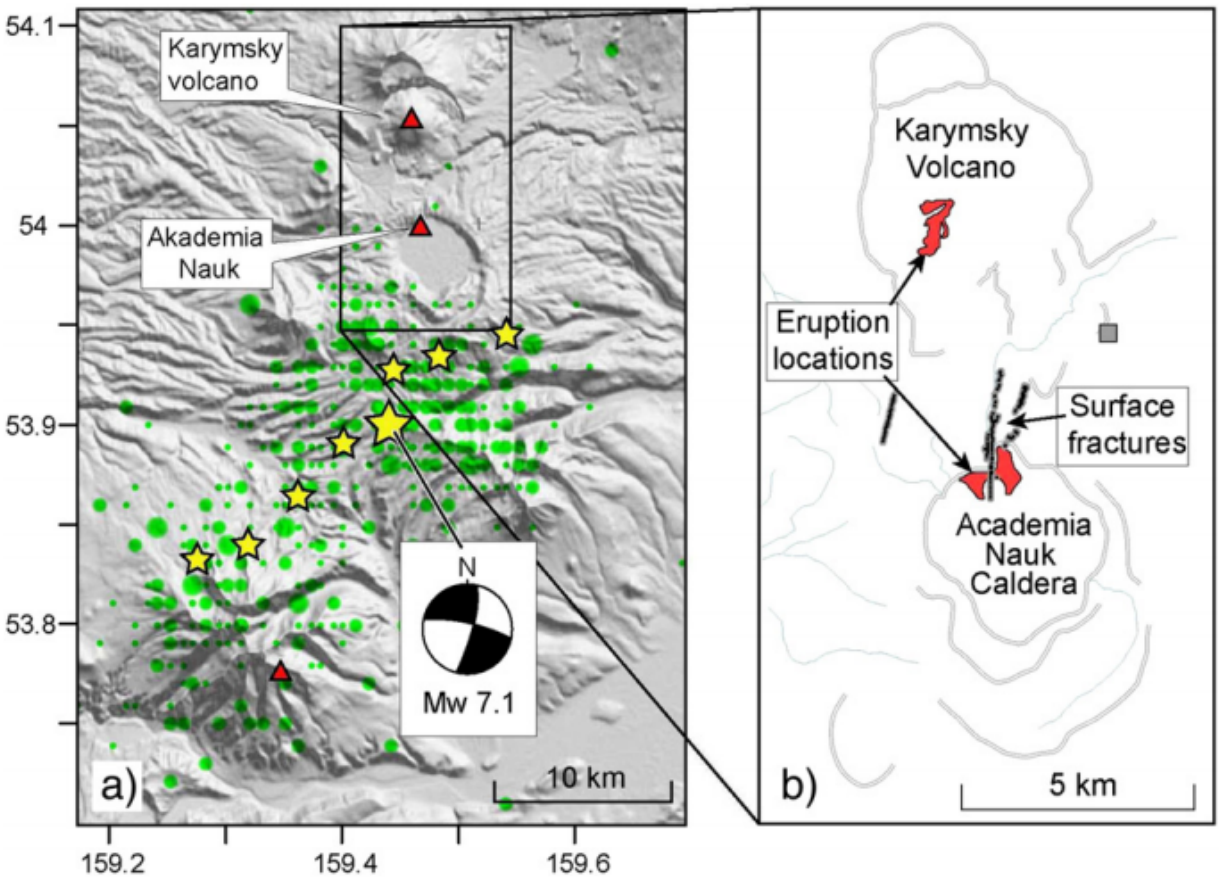
Background

- The stress and strain variations induced by great earthquakes could play an important role in reactivating a volcanic activity.
- Sustainable scientific approach to understand the tectonic and magmatic processes = sufficient information to volcanic disaster mitigation.
- Knowing well the triggers mechanism ⇨ the understanding of magmatic and tectonic-magmatic relations.



http://
indonesiancommunity.multiply.com
/journal/item/1410

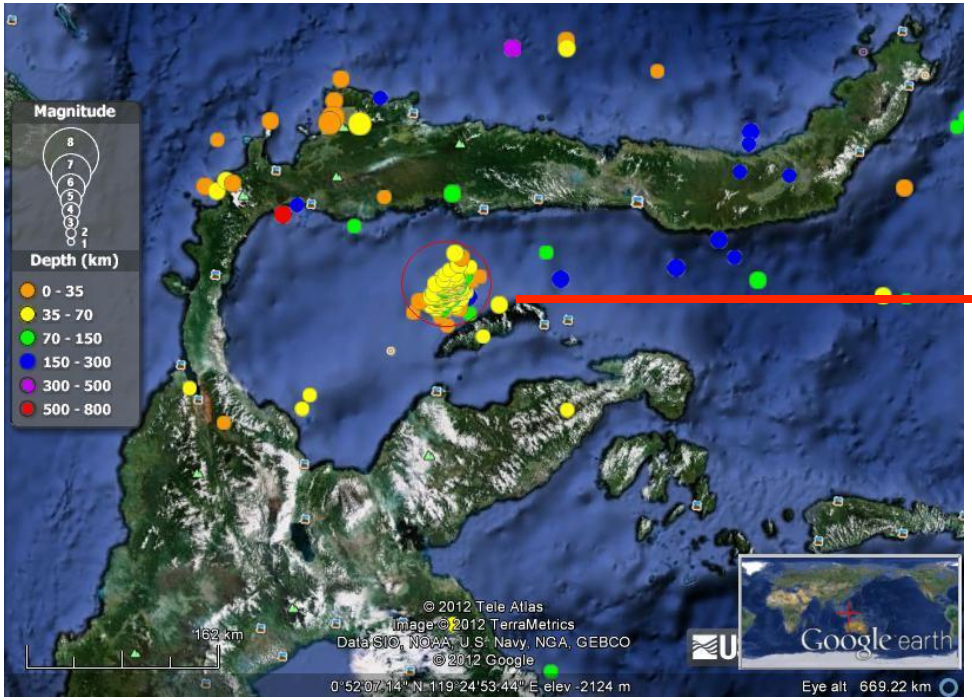




1 January 1996

(Walter, 2007)

TECTONIC EQ TELUK TOMINI 8 JULY 1983

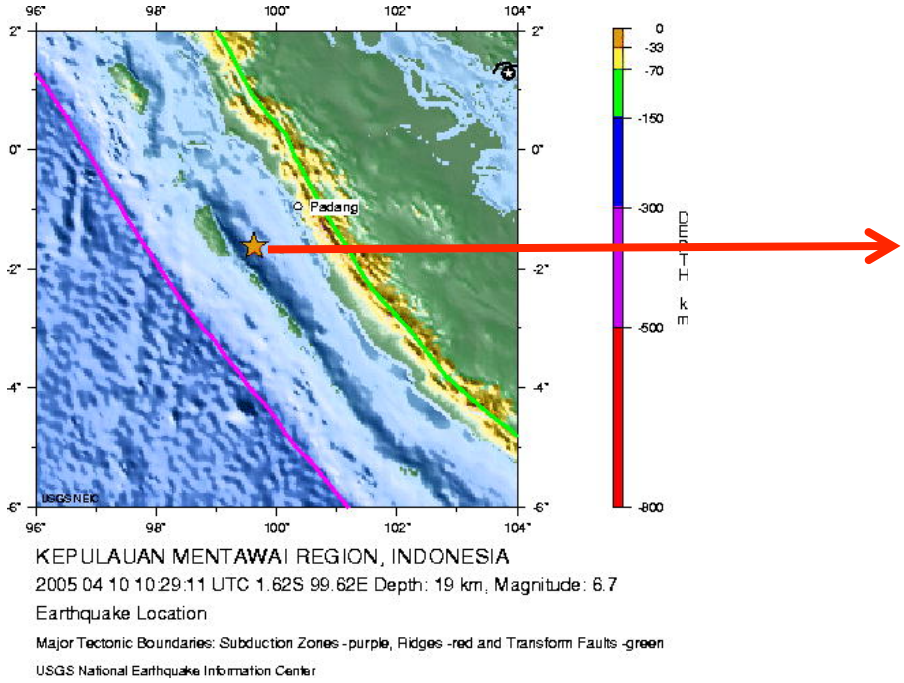


http://neic.usgs.gov/neis/eq_depot/

COLO VOLCANO 18 JULY 1983

Courtesy of Maurice Krafft (http://www.volcano.si.edu/world/volcano.cfm?vnum=0606-01=&volpage=var).

Mentawai EQ
10 april 2005

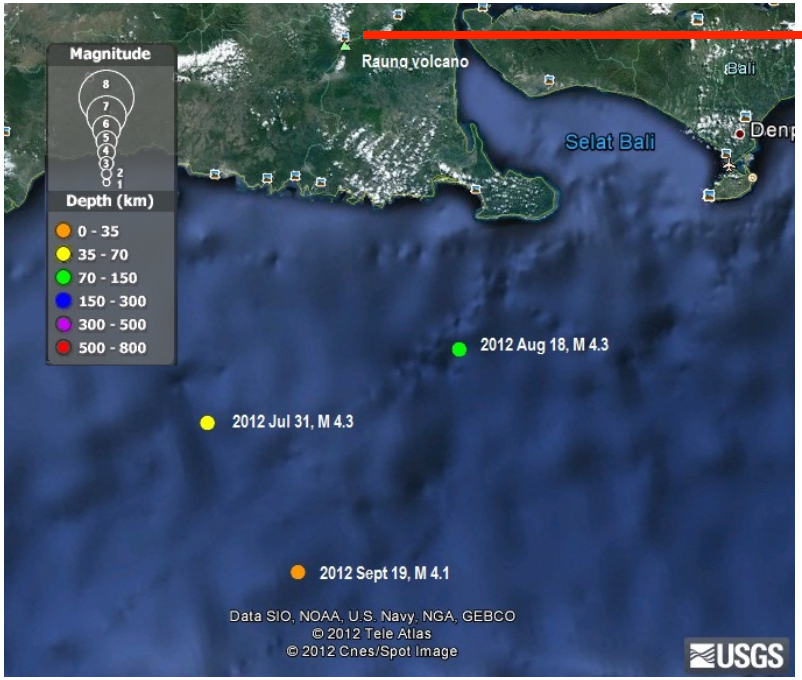


http://neic.usgs.gov/neis/eq_depot/2005/eq_050410/neic_wsap_l.html

TALANG VOLCANO
12 APRIL 2005

http://onyxdua.blogspot.com/2010/11/talang-volcano.html

Earthquakes in Southern Java
JULY - SEPTEMBER 2012

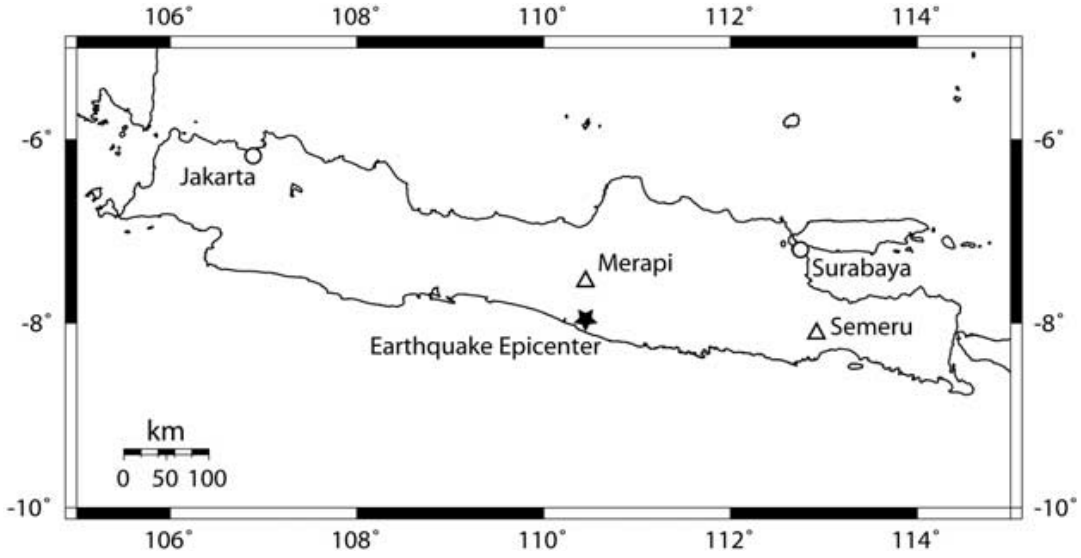


http://neic.usgs.gov/neis/eq_depot/

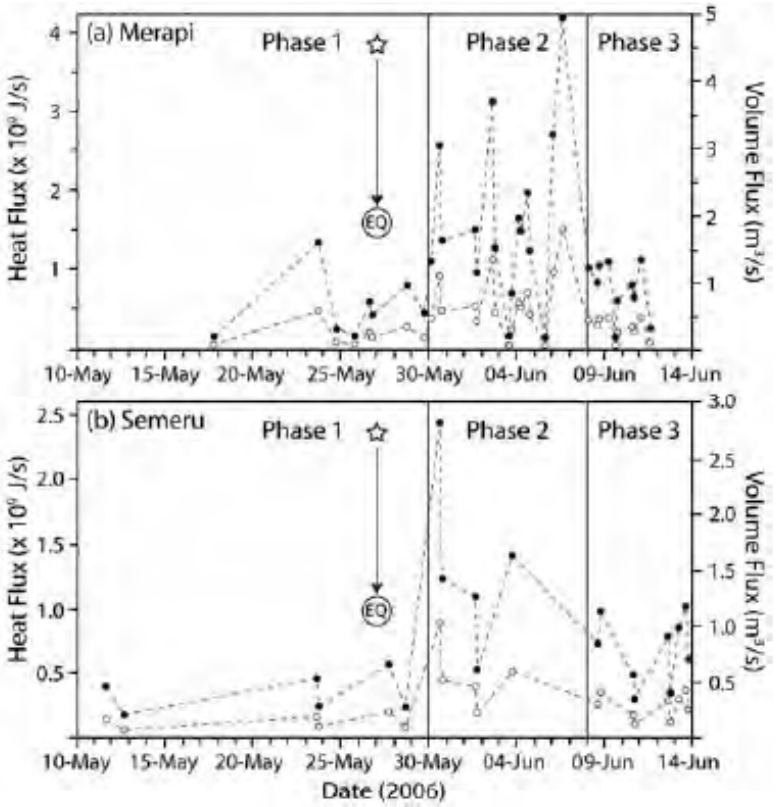
RAUNG VOLCANO
OKTOBER – NOVEMBER 2012

http://www.volcanodiscovery.com/raung/news/21309/Raung-volcano-East-Java-strombolian-activity-observed-from-crater.html

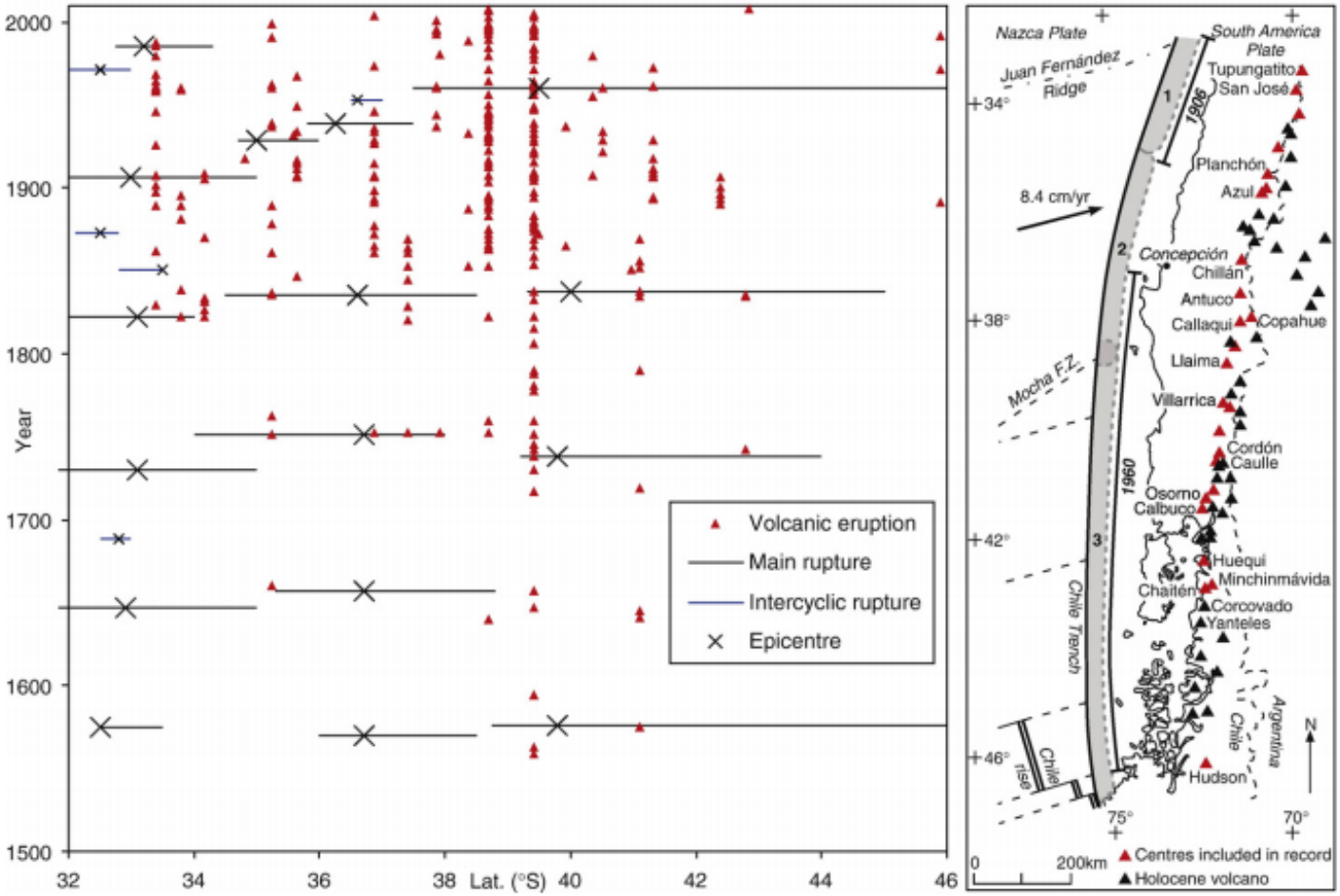
Merapi eruption May 2006



Jogja EQ, 26 May 2006
(Harris, 2007)



Pengaruh gempa tektonik (magnitudo di atas 7.5) terhadap jumlah erupsi di sepanjang zona subduksi Chili



(Watt, 2009)

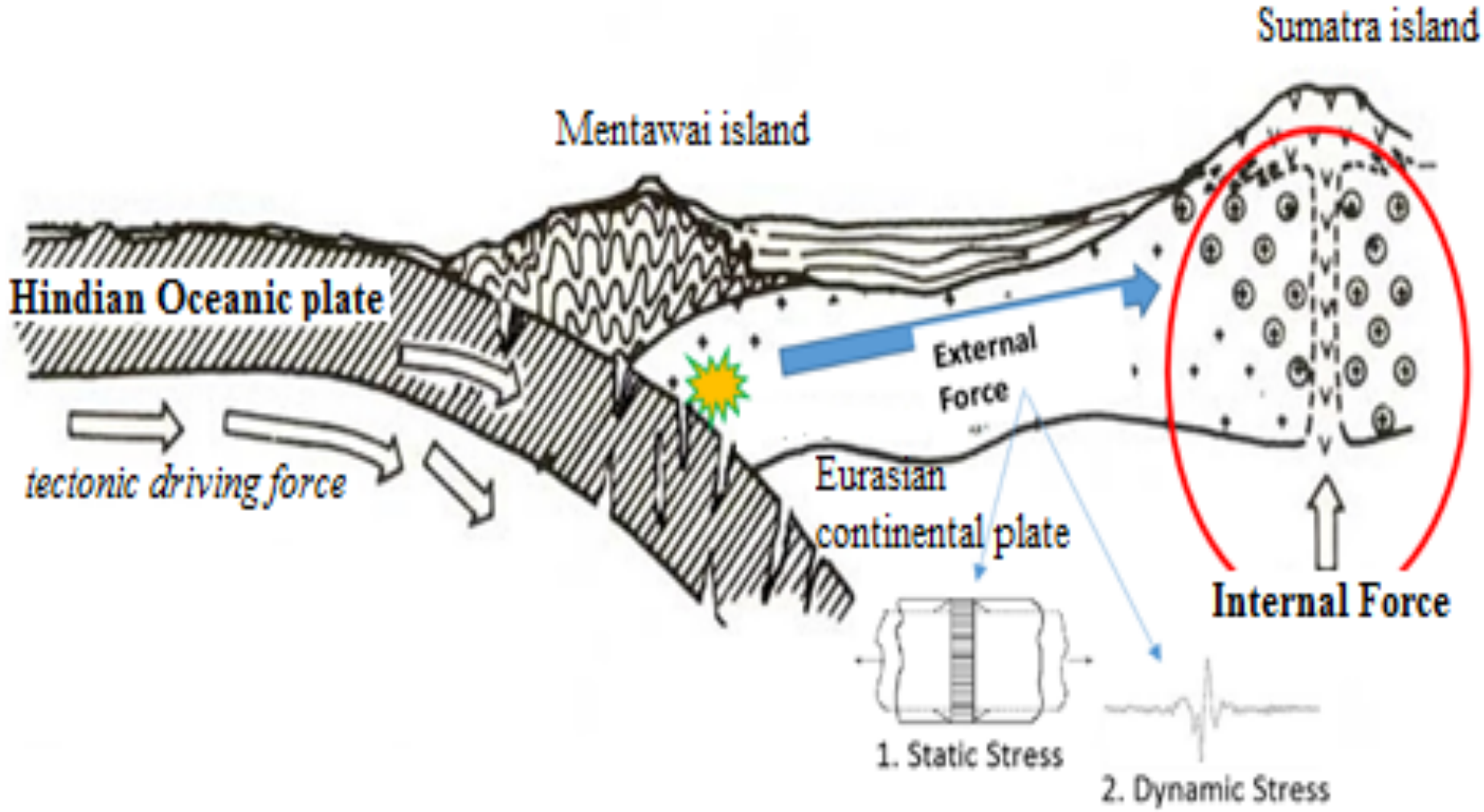
- Which one? - What are the major parameters which can be a candidate as factors controlling earthquake triggering to volcanic activity.

- How? - Mechanism of the triggering

Data

- The research use earthquake data from USGS (Earthquakes Hazard Program dari USGS, http://earthquake.usgs.gov/) and Global CMT solutions (http://globalcmt.org) of 2010-2013 to analyze strain caused by tectonic earthquakes
- Sinabung volcano eruption history (CVGHM)
- Seismic data of Sinabung volcanoes (2010 – 2013)
- Continuous GPS data of Sinabung volcano in the period of 2011-2013.
- Geological data of Sinabung volcanoes

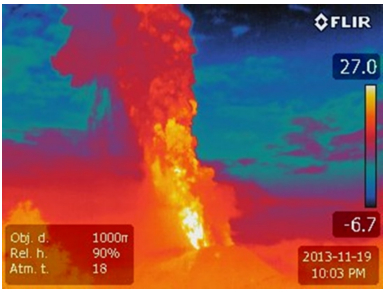
Simple model for increase in volcanic activities triggerring



SINABUNG VOLCANIC ACTIVITY

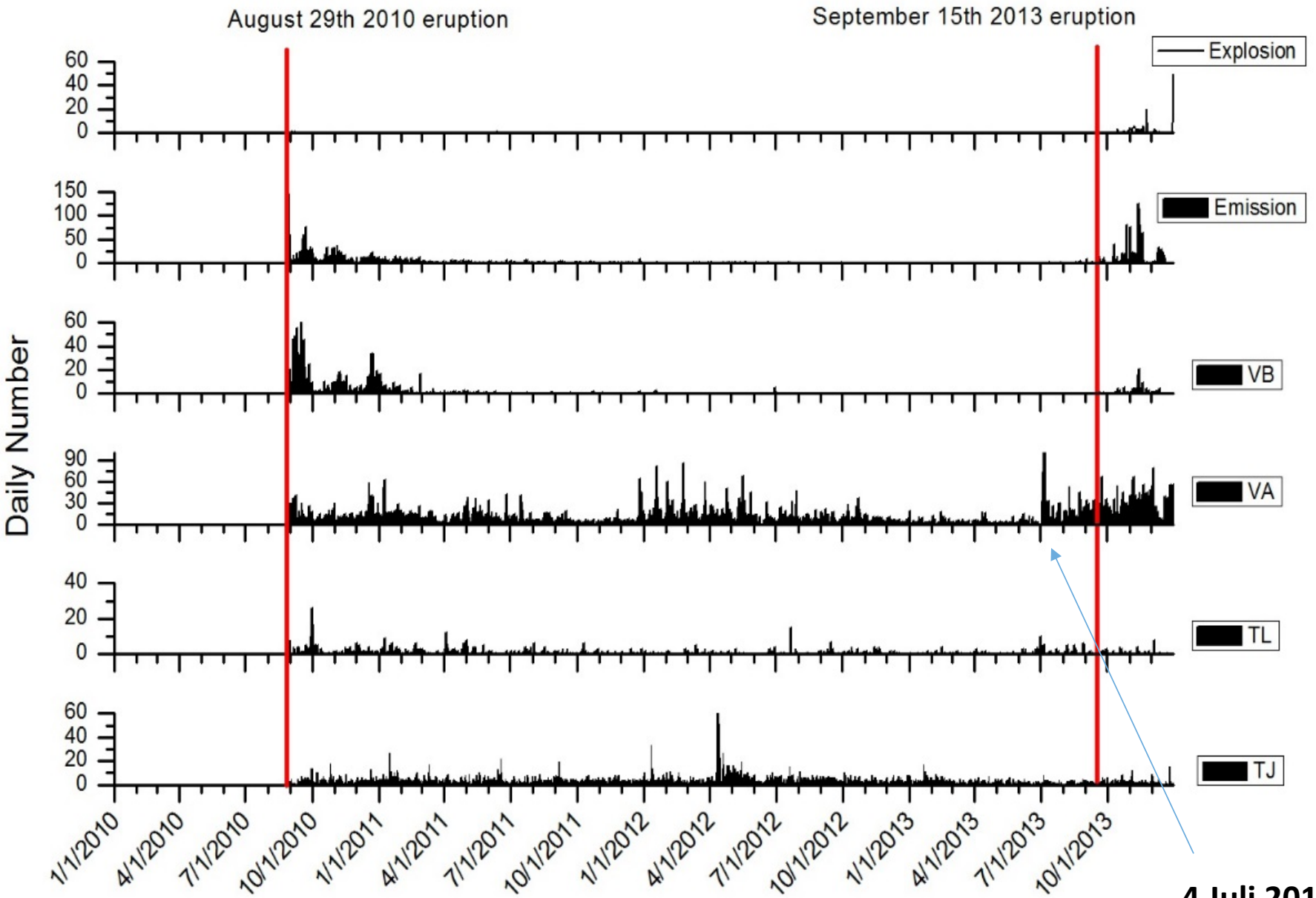
Sinabung Eruptions

- A series of Sinabung volcano eruption occurred on August 27, 2010 for the first time after dormain probably several hundred years, continued until September 7, 2010. Ash plumes from the new eruption at Sinabung volcano reached at least 8 km above sea level.



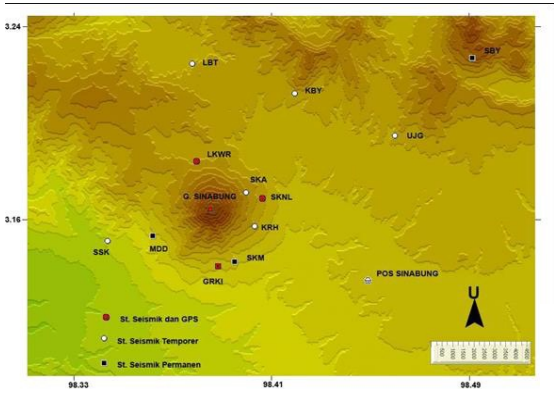
- In September 15th, 2013, a new phase of Sinabung volcano eruption forces peoples surrounding the volcano to evacuate homes. The eruption is still continuing, ash plume are reaching 10 kilometer above summit. The eruptions also generate pyroclastic flows and lahars.

Sinabung Seismicity

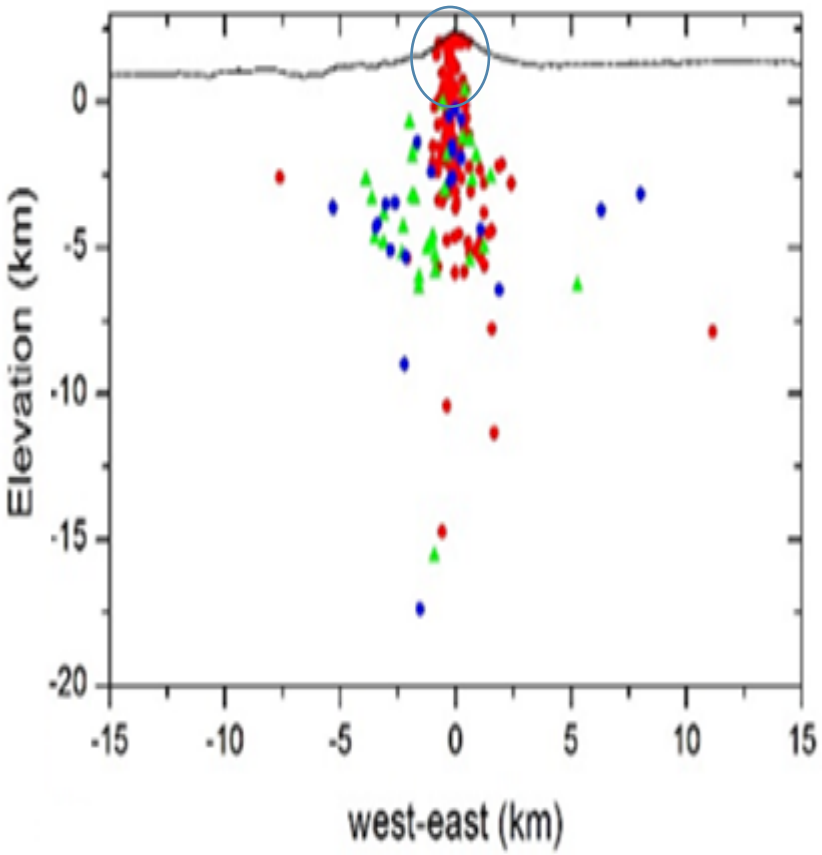


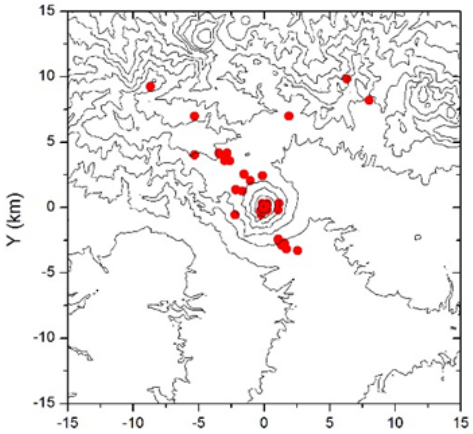
4 Juli 2013

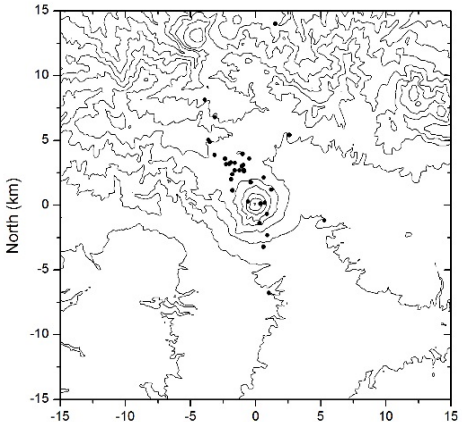
Sinabung Seismicity

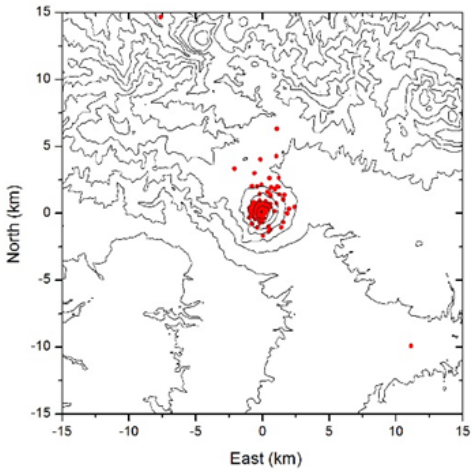


May – Juy 2013



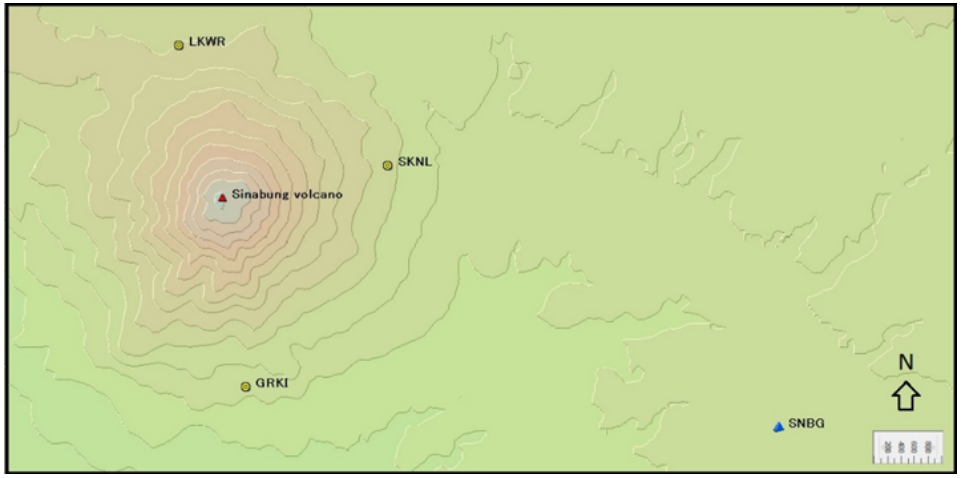




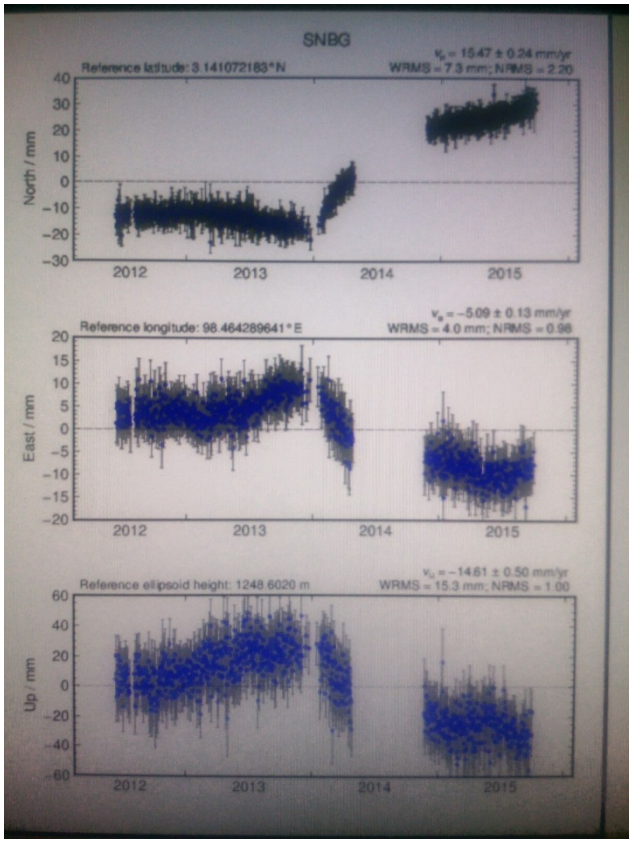


Sinabung Continous GPS 2011 - 2015

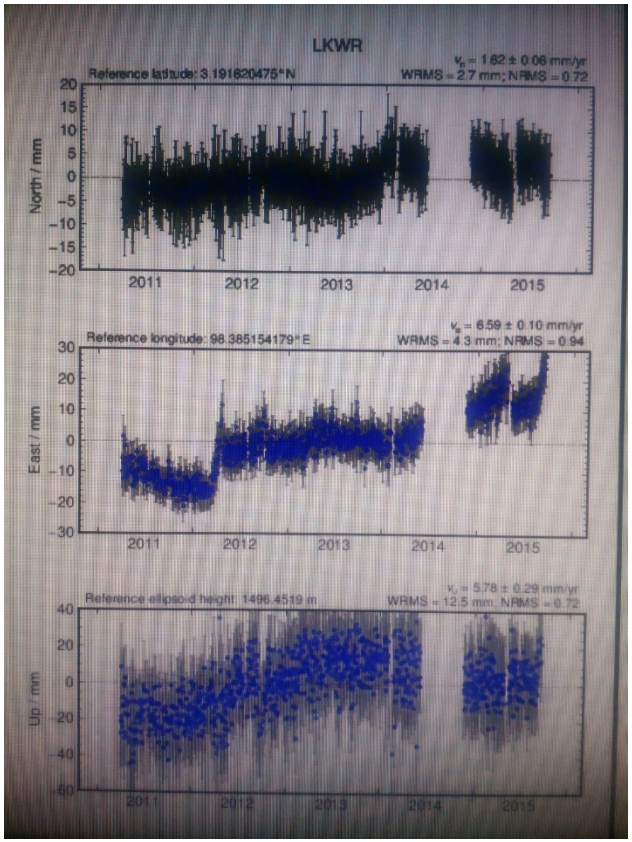
Reference = SAMP



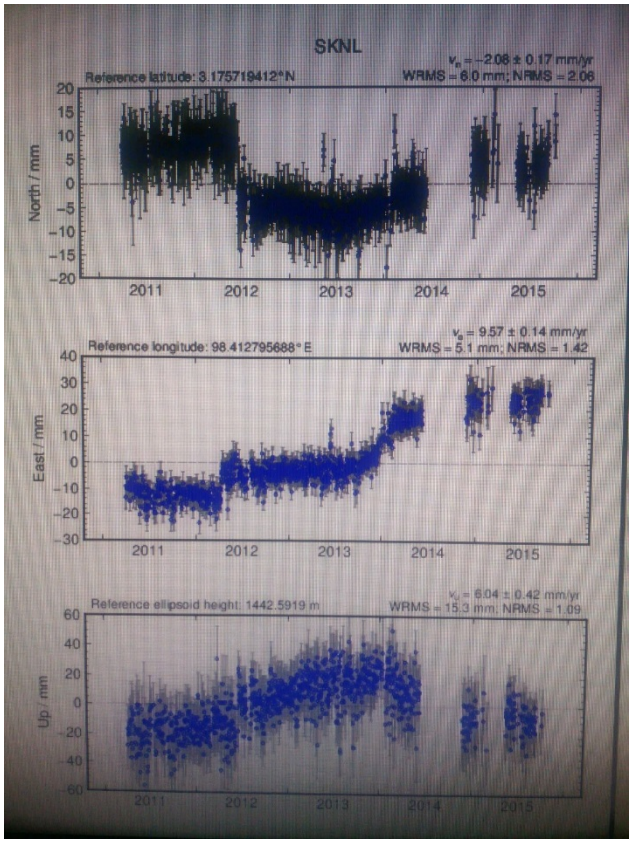
SNBG



LKWR



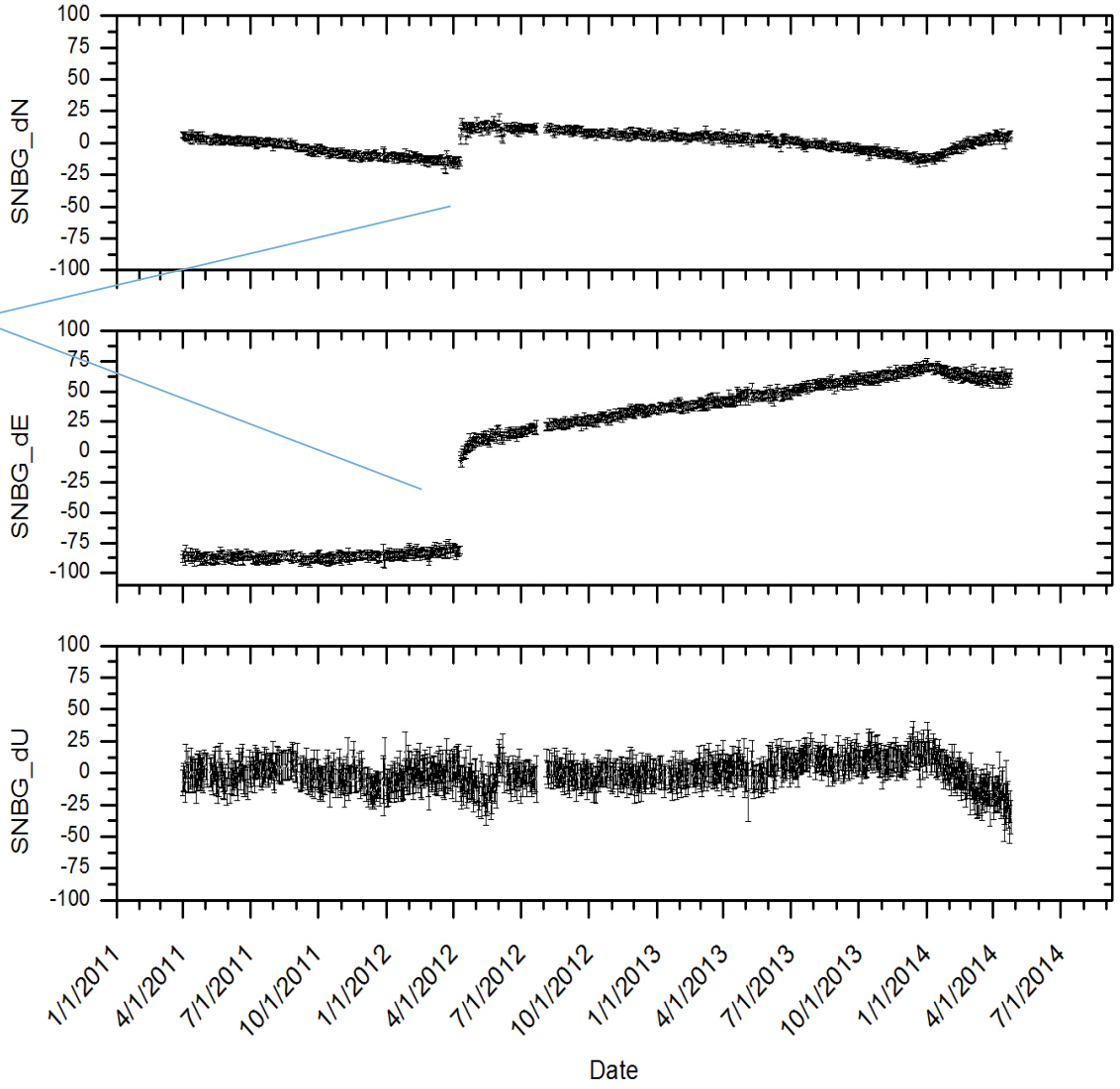
SKNL



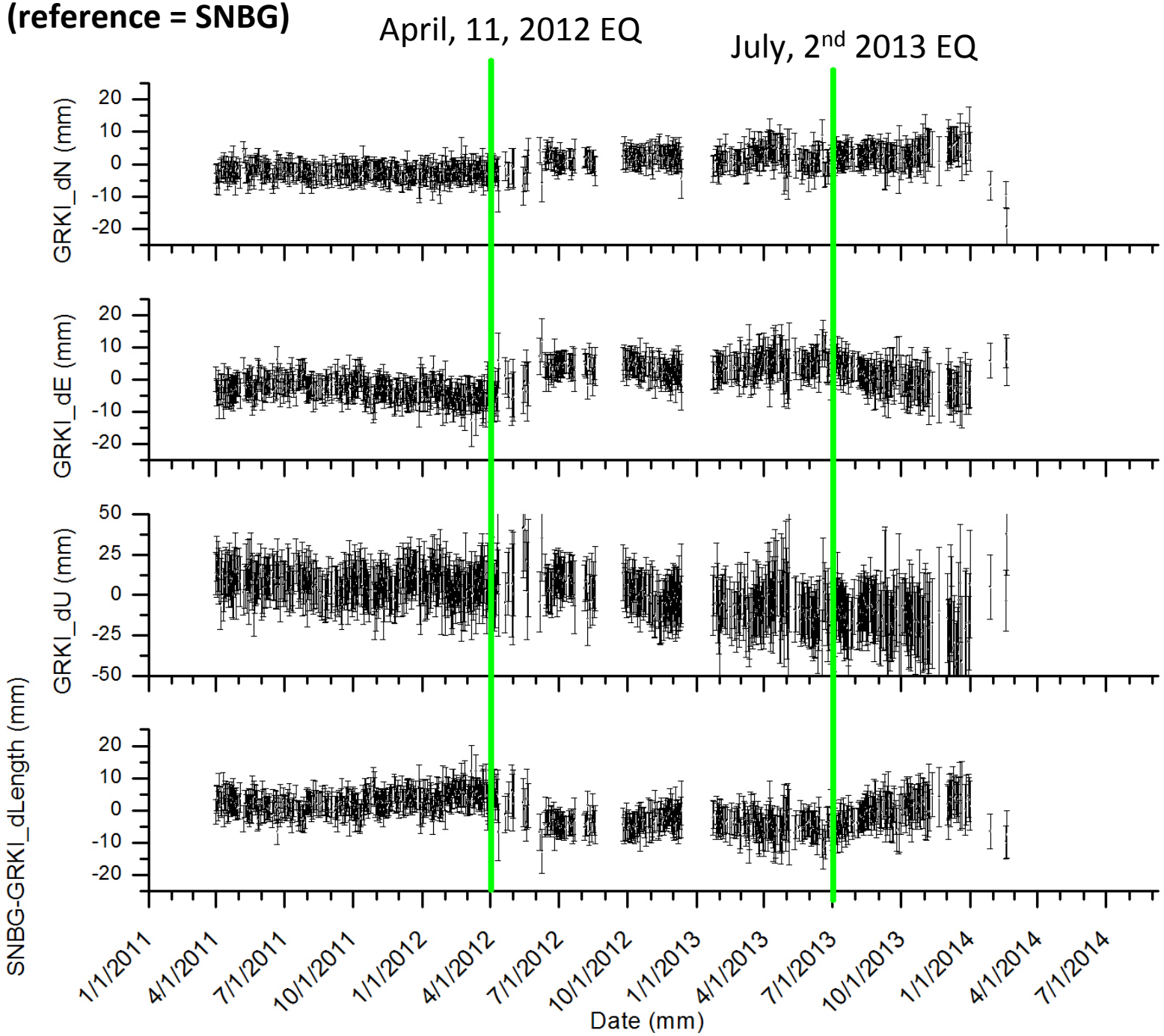
Sinabung Continous GPS

SNBG (reference frame = ITRF2008)

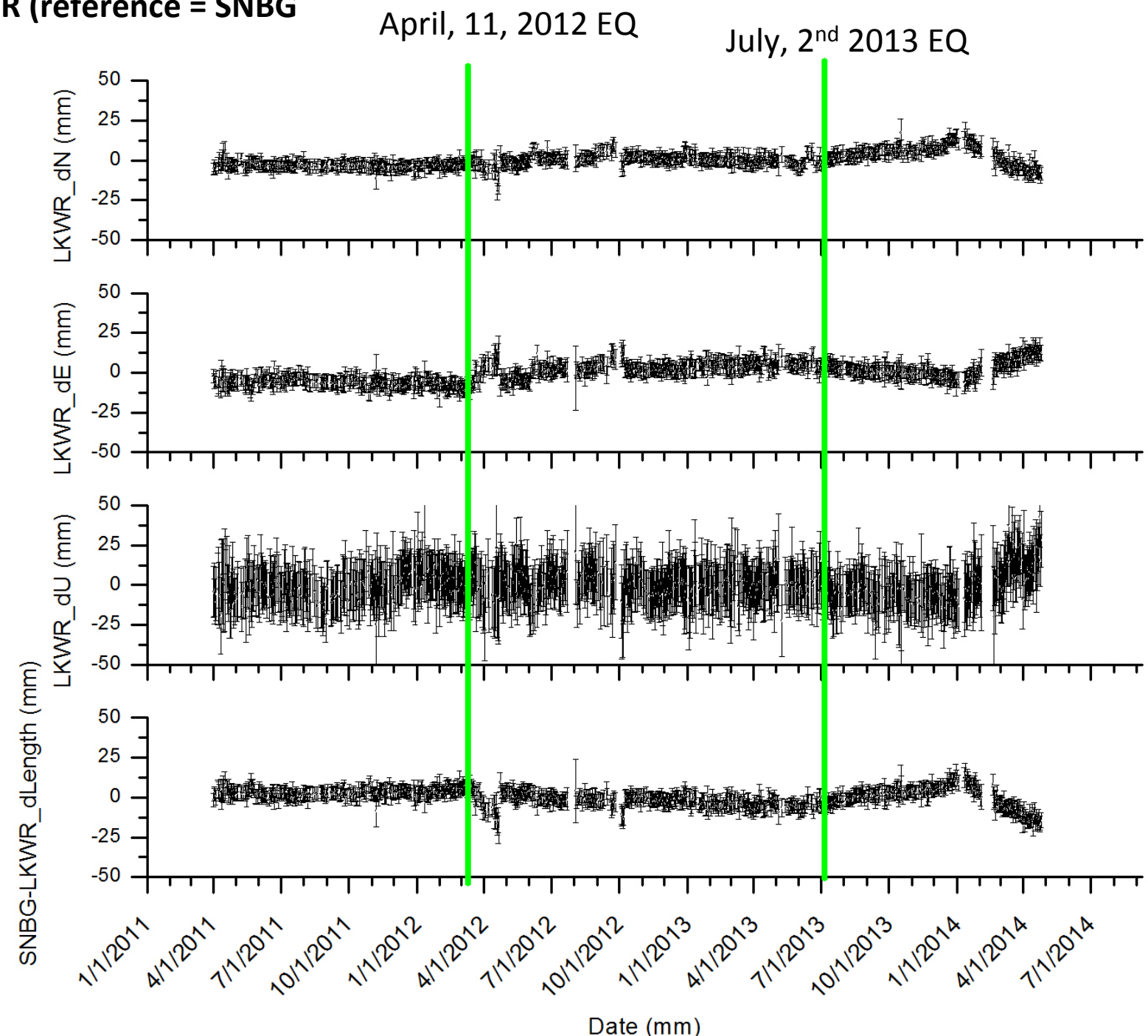
April 11 2012
(M8.6)



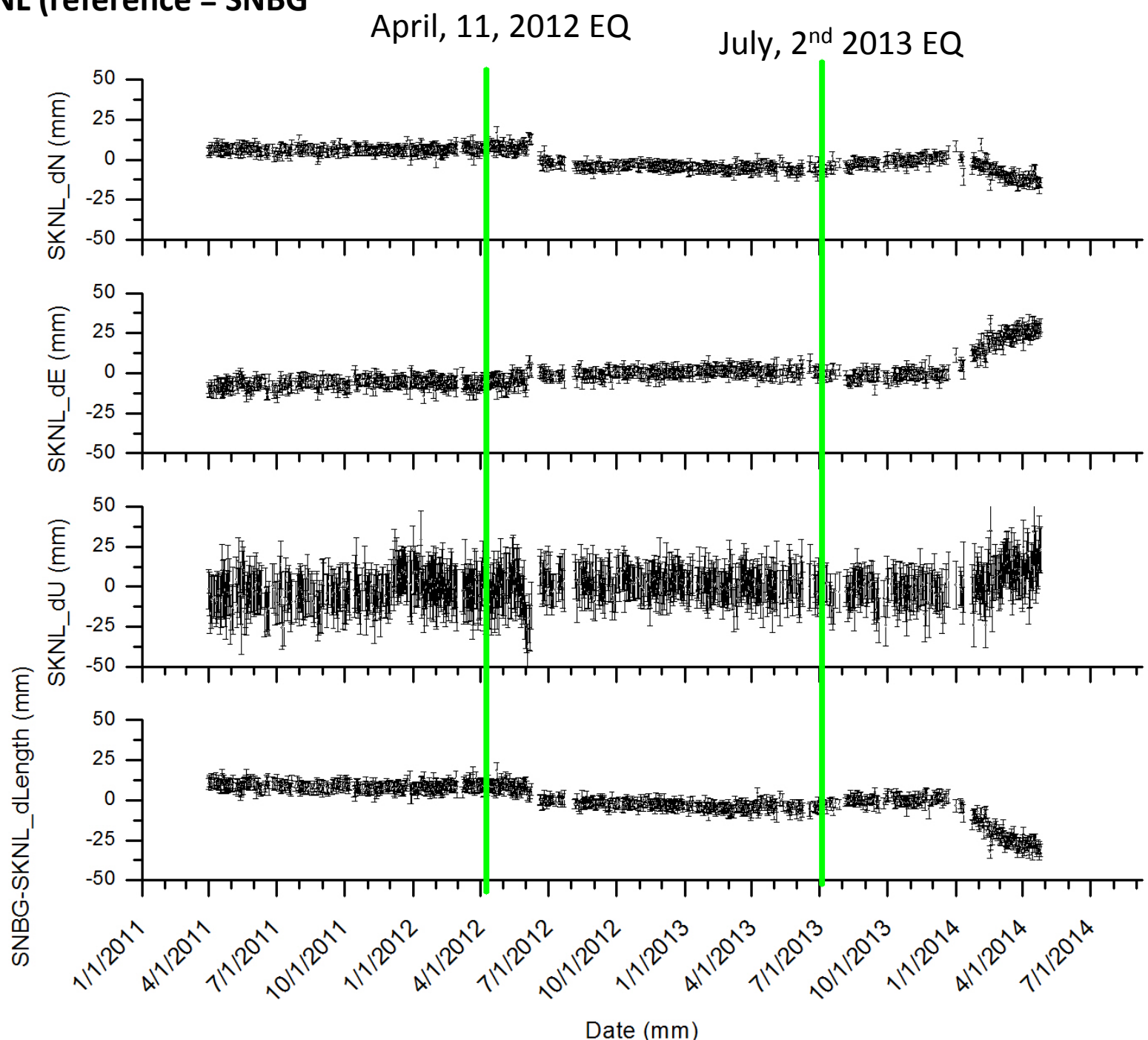
GRKI (reference = SNBG)



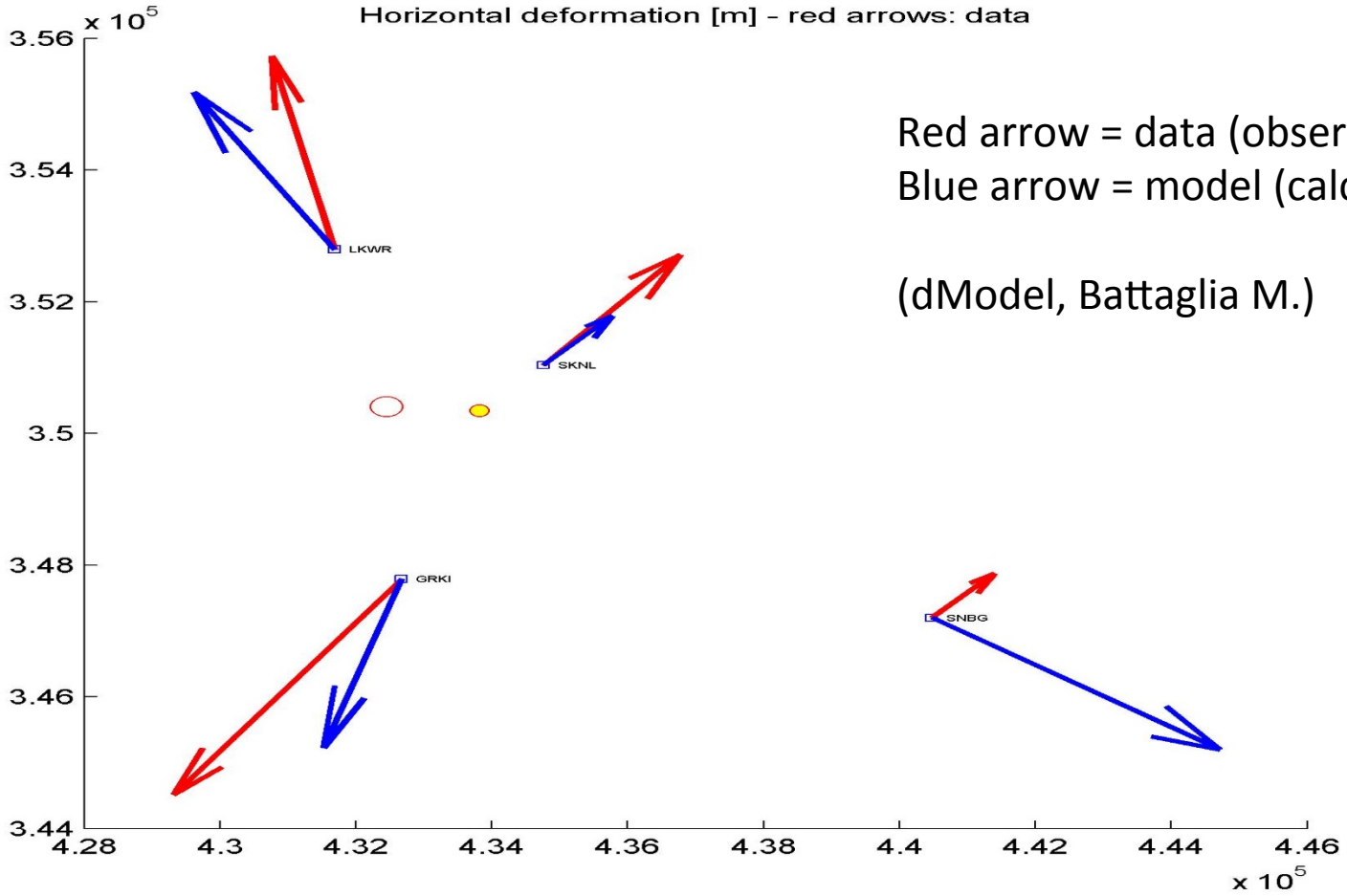
LKWR (reference = SNBG



SKNL (reference = SNBG



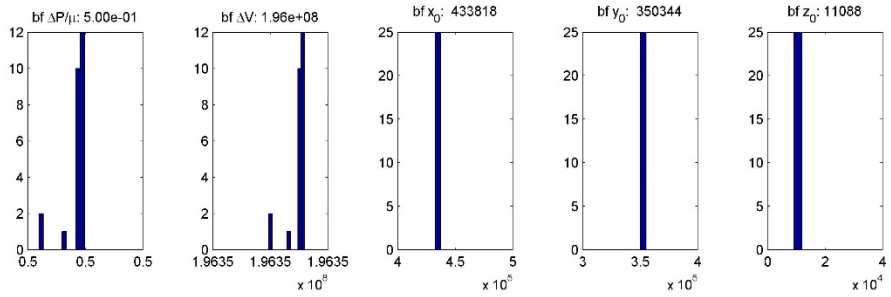
Sinabung GPS (reference = SAMP)



Red arrow = data (observed)
Blue arrow = model (calculated)

(dModel, Battaglia M.)

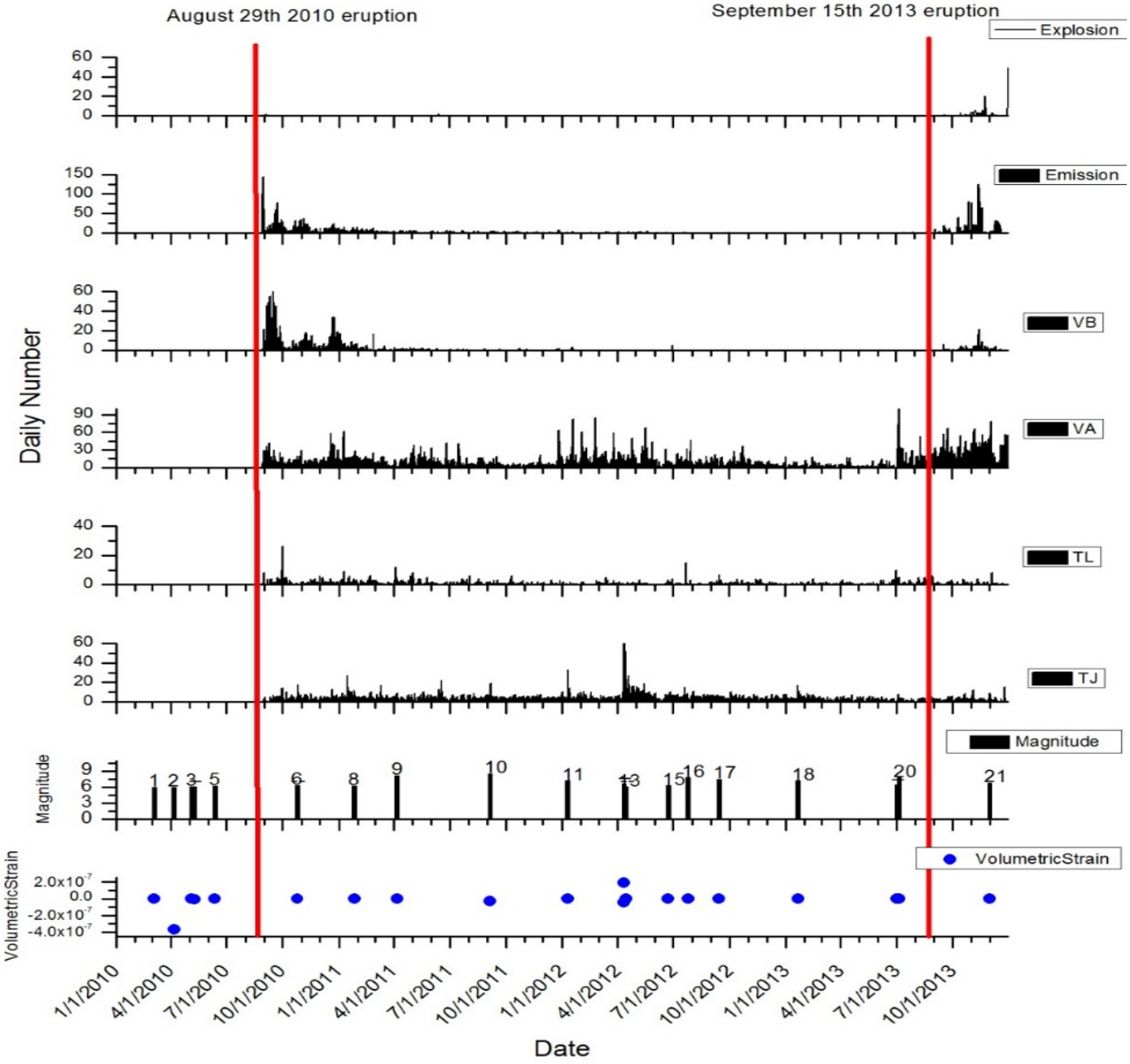
July, 2 – September 14, 2013
Depth = 11 km
Volume change = 1.96 x 10^8



STATIC STRAIN CHANGE

of Sinabung Volcanoes Associated with Tectonic Earthquakes

No.	Location	Date	Mw	Distance (km)	Vol_strain (strain)
1	Kepulauan Mentawai region, Indonesia	3/5/2010	6.8	824.0	4.98E-12
2	Northern Sumatra, Indonesia	4/6/2010	7.8	173.3	-3.68E-07
3	Southern Sumatra, Indonesia	5/5/2010	6.5	858.6	3.21E-12
4	Northern Sumatra, Indonesia	5/9/2010	7.2	272.0	-5.02E-09
5	Nicobar Islands, India region	6/12/2010	7.5	889.8	1.51E-10
6	Kepulauan Mentawai region, Indonesia	10/25/2010	6.3	716.8	3.57E-12
7	Kepulauan Mentawai region, Indonesia	10/25/2010	7.8	764.5	-1.35E-09
8	Simeulue, Indonesia	1/26/2011	6.1	204.5	-3.59E-10
9	Nias region, Indonesia	4/6/2011	6.0	226.3	-2.48E-10
10	Northern Sumatra, Indonesia	9/5/2011	6.7	60.0	-3.12E-08
11	off the west coast of northern Sumatra	1/10/2012	7.2	582.7	-1.67E-09
12	off the west coast of northern Sumatra	4/11/2012	8.2	710.7	-4.43E-08
13	off the west coast of northern Sumatra	4/11/2012	8.6	600.6	1.93E-07
14	off the west coast of northern Sumatra	4/15/2012	6.2	906.7	2.19E-11
15	Northern Sumatra, Indonesia	6/23/2012	6.1	58.0	-1.58E-09
16	Simeulue, Indonesia	7/25/2012	6.4	266.3	-3.16E-10
17	Kepulauan Mentawai region, Indonesia	9/14/2012	6.2	762.7	1.16E-12
18	47km SSW of Sigli, Indonesia	1/21/2013	6.1	338.9	4.01E-12
19	**55km S of Bireun, Indonesia**	**7/2/2013**	**6.1**	**252.9**	**-2.84E-10**
20	157km SW of Sungai Penuh, Indonesia	7/6/2013	6.0	756.4	2.59E-12
21	69km SE of Sinabung, Indonesia	12/1/2013	6.0	214.7	-3.47E-10

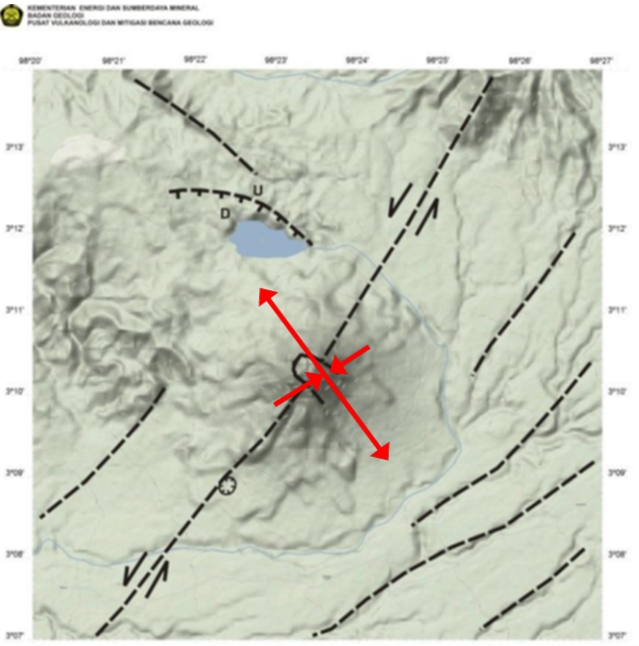

August 29th 2010 eruption
September 15th 2013 eruption
Explosion
Emission
VB
VA
TL
TJ
Magnitude
VolumetricStrain
Daily Number
Magnitude
VolumetricStrain
Date
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013

Direction of Extensional Strain

Direction of Principal Strain in Sinabung volcano

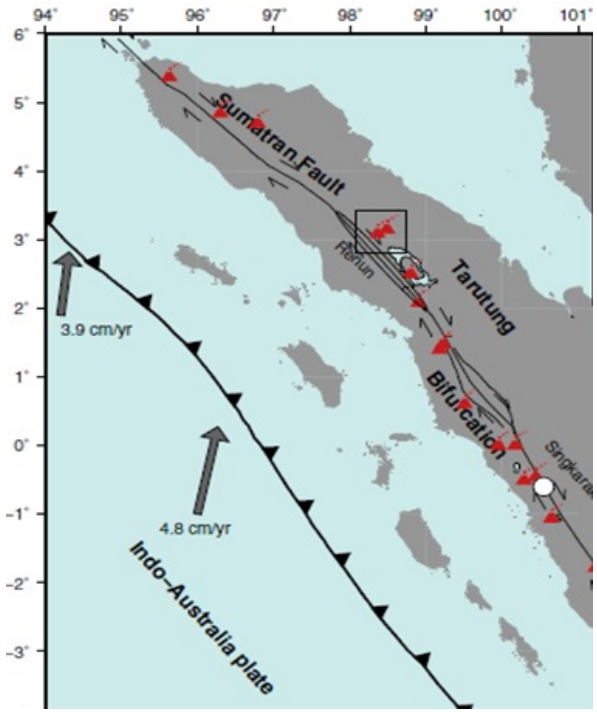
trigger August 2010 eruption

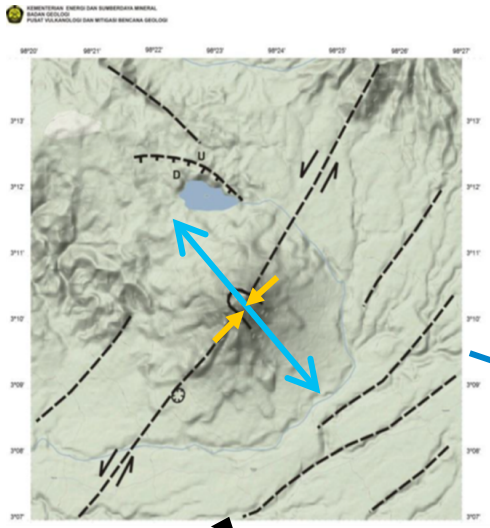
No.	Date	Max_shear	Max_strain	Min_strain	Max_Direct strain	Min_Direct strain
1	3/5/2010	1.47E-11	-1.09E-11	1.84E-11	-5.7	84.3
2	4/6/2010	5.26E-07	-8.02E-07	2.50E-07	26.3	116.3
3	5/5/2010	4.13E-12	-1.72E-12	6.54E-12	-5.7	84.3
4	5/9/2010	2.17E-08	-2.54E-08	1.79E-08	-31.0	59.0
5	6/12/2010	2.54E-09	-2.42E-09	2.65E-09	36.2	126.2
6	10/25/2010	8.52E-12	-5.85E-12	1.12E-11	-10.1	79.9
7	10/25/2010	2.45E-09	-3.47E-09	1.44E-09	0.4	90.4
8	1/26/2011	4.56E-10	-7.25E-10	1.87E-10	25.3	115.3
9	4/6/2011	4.80E-10	-6.66E-10	2.94E-10	-39.2	50.8
10	9/5/2011	2.11E-08	-4.45E-08	-2.30E-09	2.5	92.5
11	1/10/2012	3.42E-09	-4.67E-09	2.17E-09	-28.1	61.9
12	4/11/2012	4.55E-08	-7.87E-08	1.23E-08	12.9	102.9
13	4/11/2012	3.34E-07	-1.89E-07	4.78E-07	-24.1	65.9
14	4/15/2012	4.59E-11	-2.95E-11	6.23E-11	-29.2	60.8
15	6/23/2012	3.35E-09	-4.54E-09	2.16E-09	21.2	111.2
16	7/25/2012	9.42E-10	-1.18E-09	7.05E-10	-15.2	74.8
17	9/14/2012	4.02E-12	-3.16E-12	4.89E-12	-6.6	83.4
18	1/21/2013	4.83E-10	-4.80E-10	4.86E-10	34.3	124.3
19	7/2/2013	6.34E-10	-8.47E-10	4.20E-10	25.1	115.1
20	7/6/2013	2.40E-12	-4.61E-13	4.34E-12	-8.4	81.6
21	12/1/2013	4.32E-10	-6.92E-10	1.72E-10	22.6	112.6



Sinabung volcano
Tectonic strain due to
July 2nd , 2013 EQ

Increase in eruption intensity and avalanches

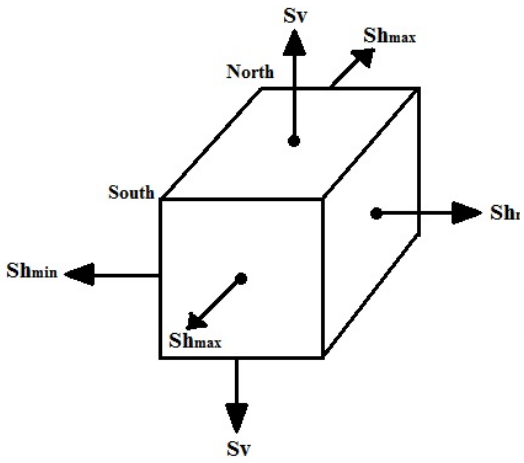




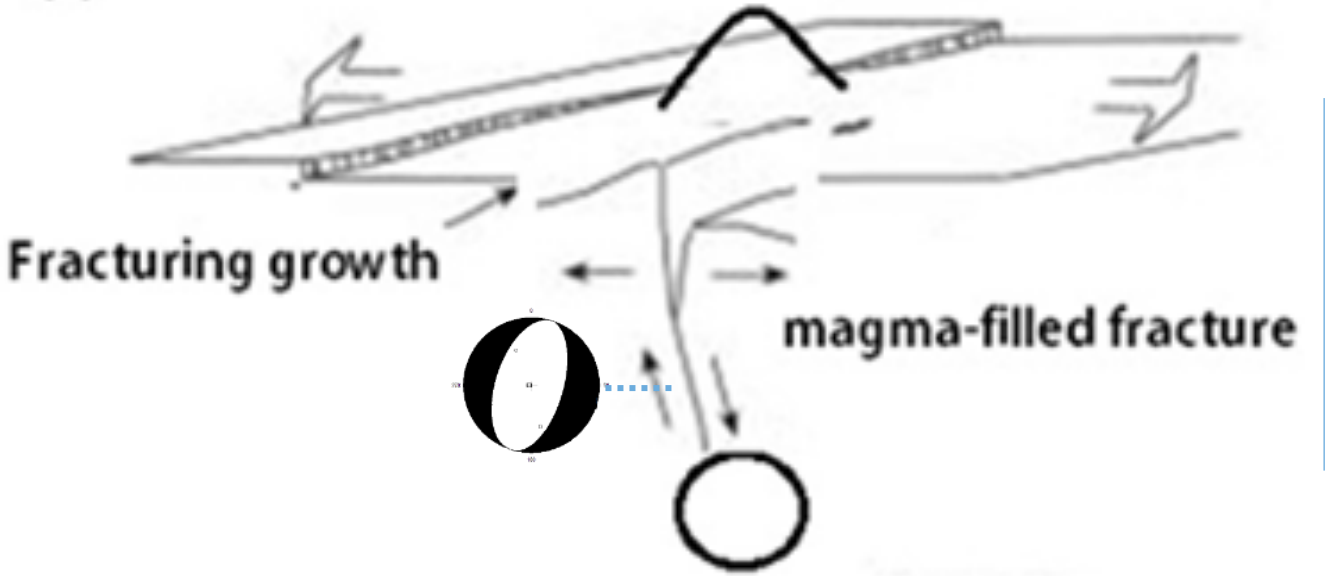
Sh_{min}

Sh_{max}

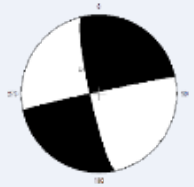
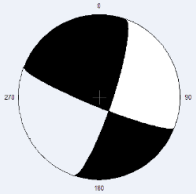
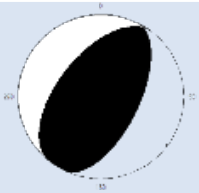
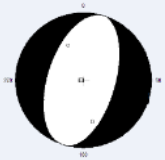
1. Extensional Strain in Sh_{min} direction
2. Normal stress in vertical direction decrease
3. Normal faulting
4. Fracturing growth and magma fill the fracture
5. Magma ascent to the surface through fracturing

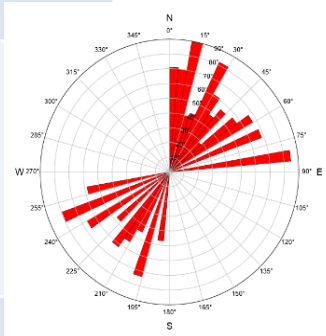


(2)



Focal mechanism

Type	Example	Number of events	
		May – June 2013	July 2013
Strike slip	 5/11/2013  5/24/2013	17	35
Reverse	 7/10/2013  7/4/2013	24	71
Normal 1	 7/27/2013	17	44
Normal 2	 6/3/2013	10	30



Conclusions

- The threshold of volumetric strain value in volcanic area due to tectonic earthquake will depends on the volcanic activity. The threshold of strain value which allows an earthquake can affect Sinabung volcanic activities is $3x10^{-10}$.
- Consider that the static stress caused by the earthquake is very small compared to dynamic stress or other processes, it is requiring a magnitude more than 6 to trigger an eruption.
- The distance should be relatively close to volcano (less than 700km distance from the volcano).
- The extensional strain acts on the fault perpendicularly to the plane, failure will be initiated and will be associated with fracturing growth, will open the conduit, facilitated dike propagation and allow magma to move along the opened conduit.

Arigatou ……