

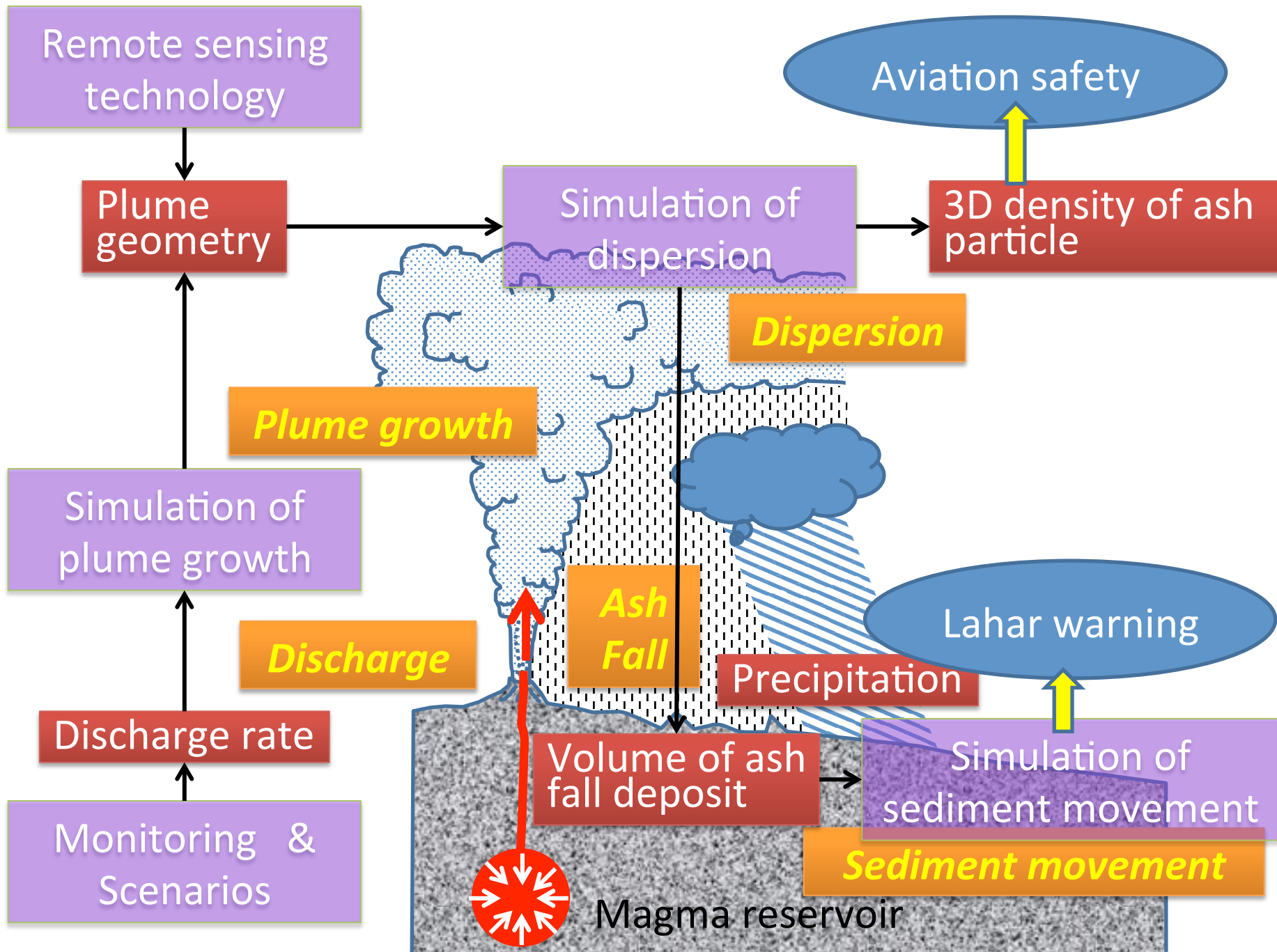


SATREPS Workshop 2015 in Yogyakarta

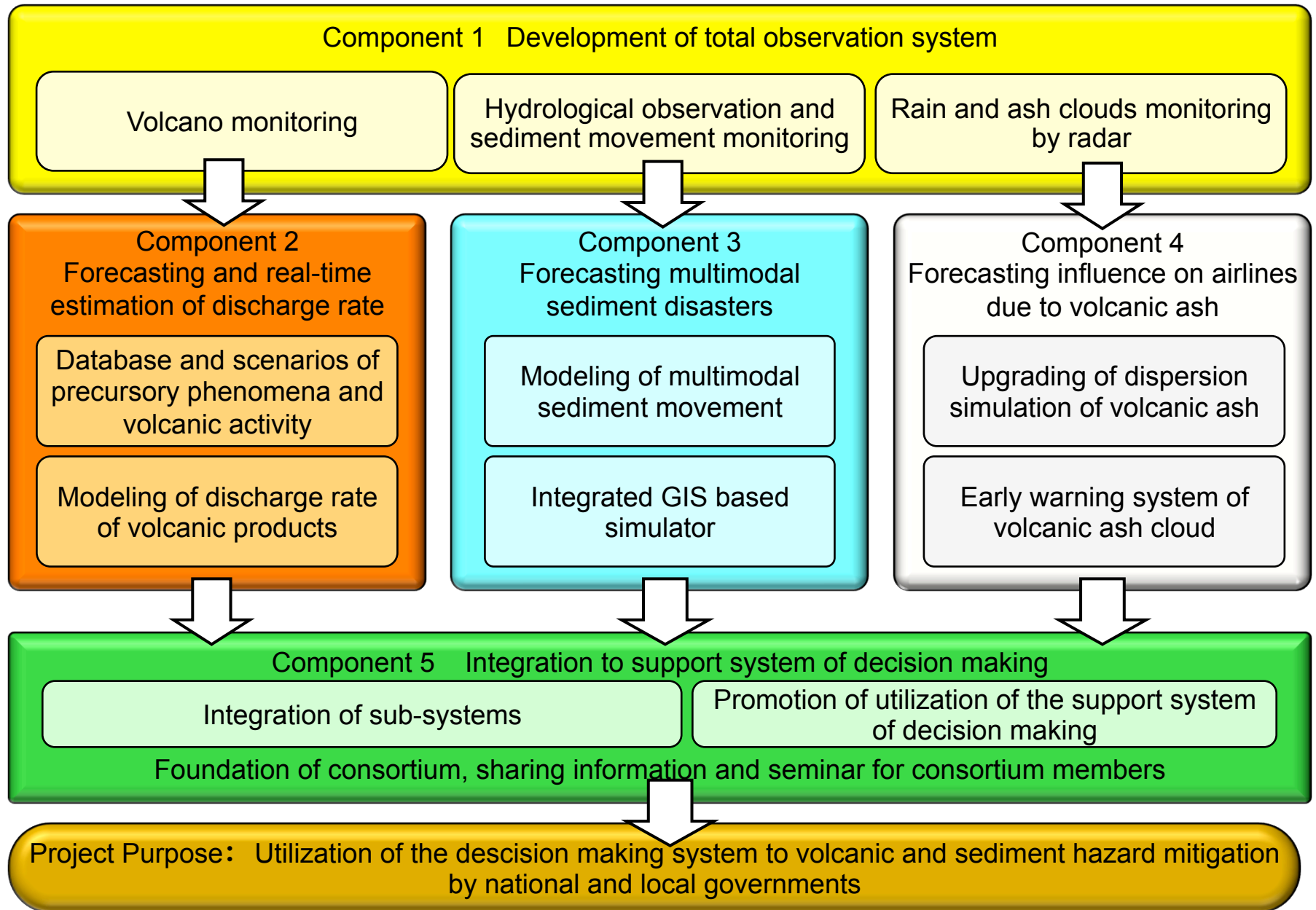
**Recent volcanic activity of  
Sakurajima and Kuchinoerabujima  
volcanoes and application of  
SATREPS technology**

Masato Iguchi

Disaster Prevention Research Institute,  
Kyoto University, Japan



# Integrated study on mitigation of multimodal disasters caused by ejection of volcanic products : Master Plan Image

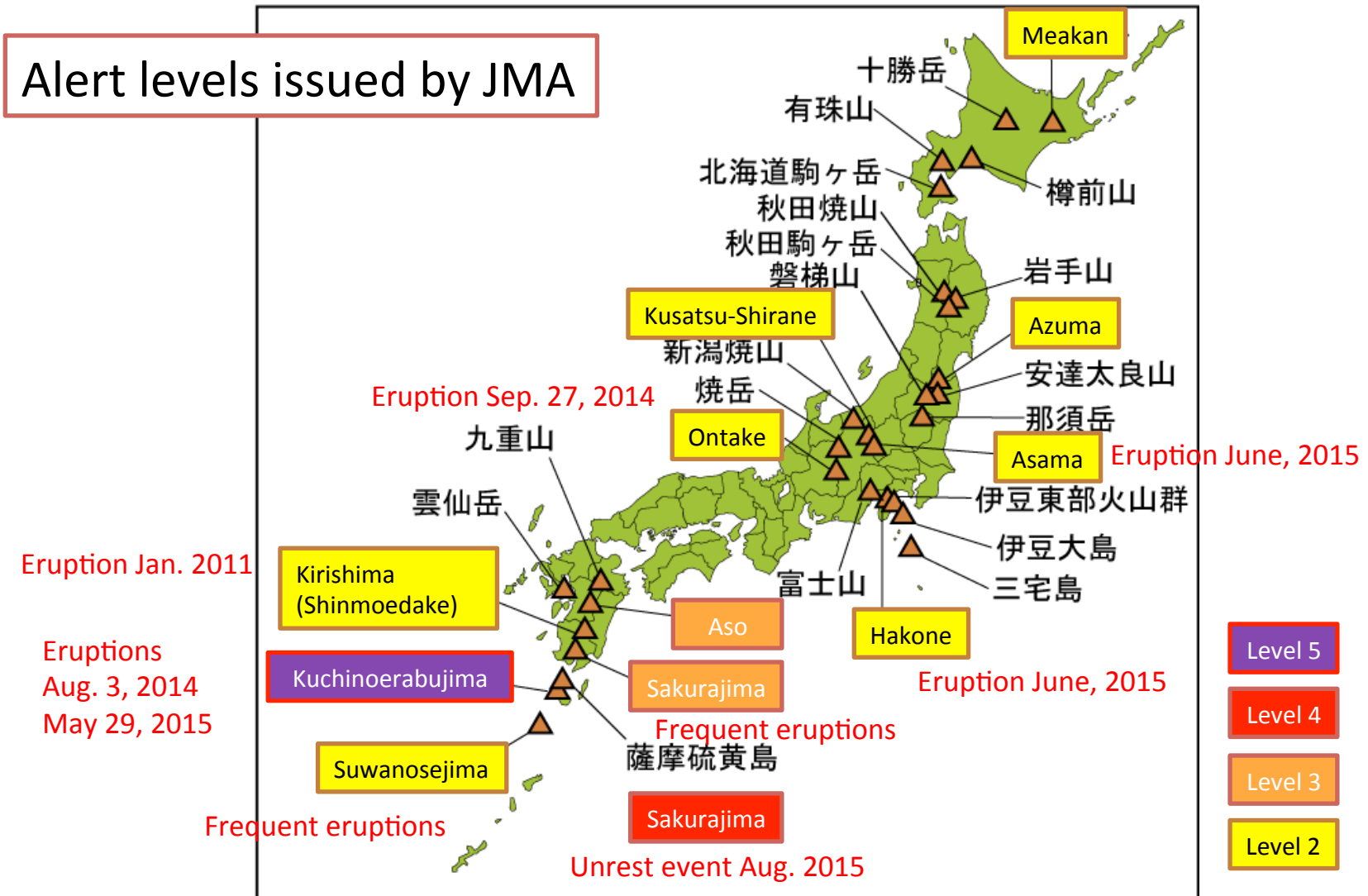


# Alert levels in Japan

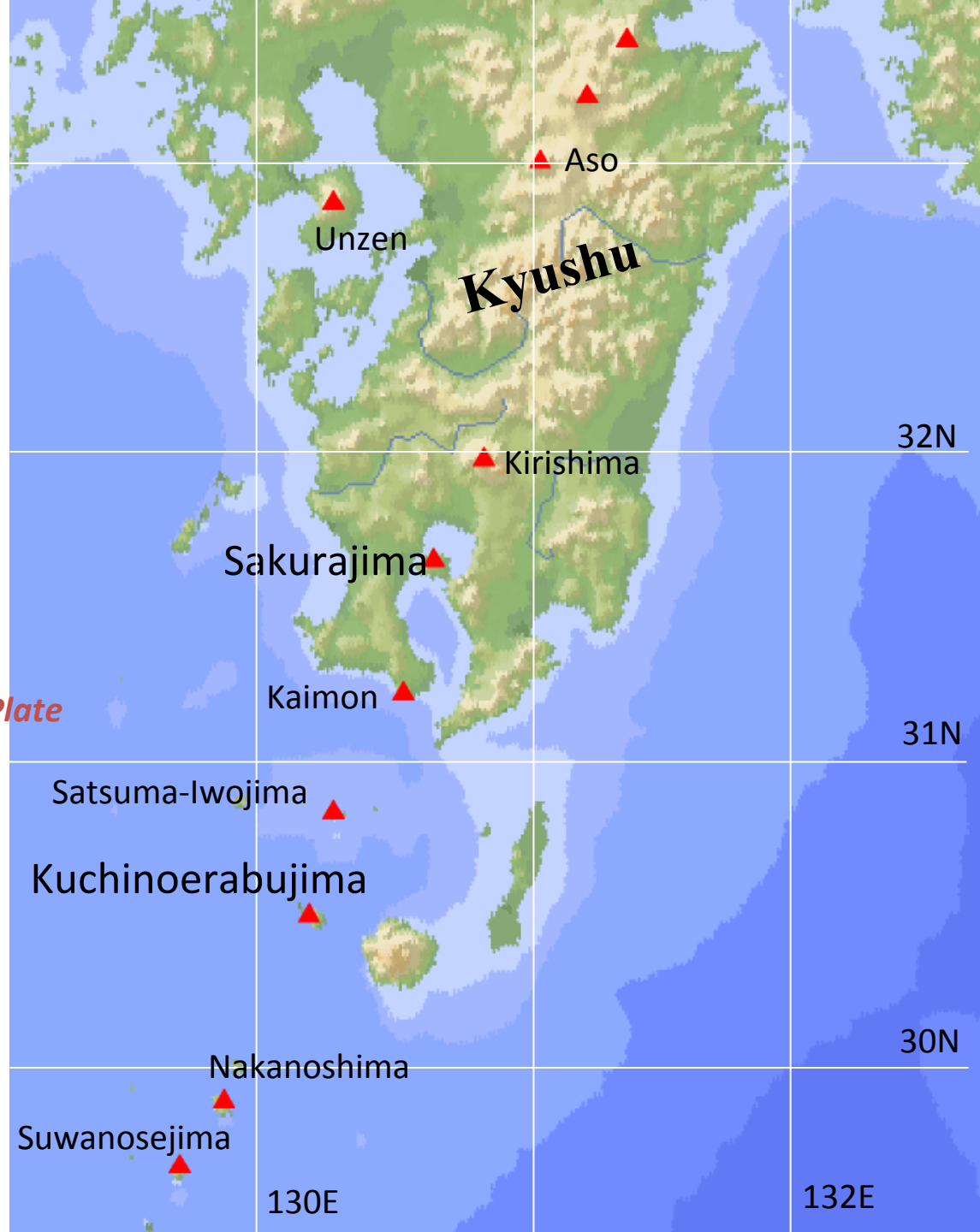
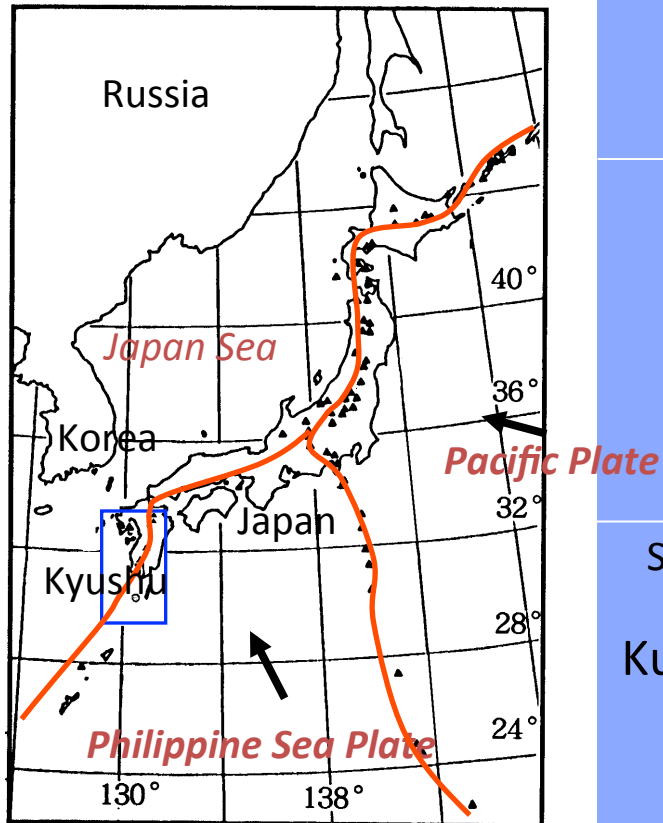
Warning	Level	Status	Residents	Hikers
Eruption Warning	Level 5 Evacuate	Eruption or imminent eruption causing significant damage to residential areas	Evacuate from the danger zone	
	Level 4 Prepare to evacuate	Possibility of eruption causing significant damage to residential areas (increased probability).	Those within the alert area should prepare for evacuation. Those requiring protection in the event of a disaster must be evacuated.	
Crater Area Warning	Level 3	Eruption or prediction of eruption causing significant damage to areas near residential areas (entering area is life threatening).	Normal life	Do not approach the volcano
	Level 2	Eruption or prediction of eruption affecting area around crater (entering area is life threatening).		Do not approach the crater
Eruption Forecast	Level 1 Normal	Little or no volcanic activity		No

# Present alert level in Japan

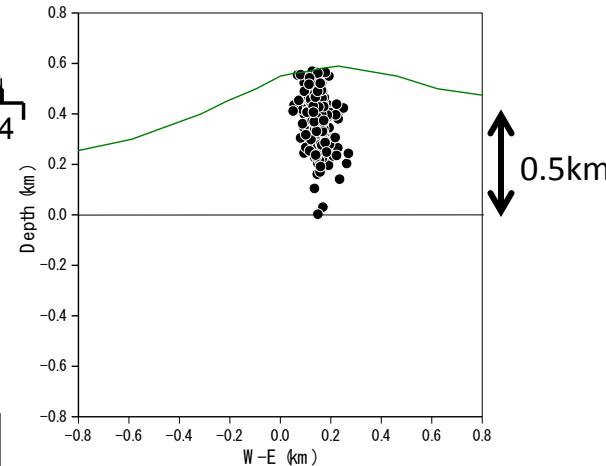
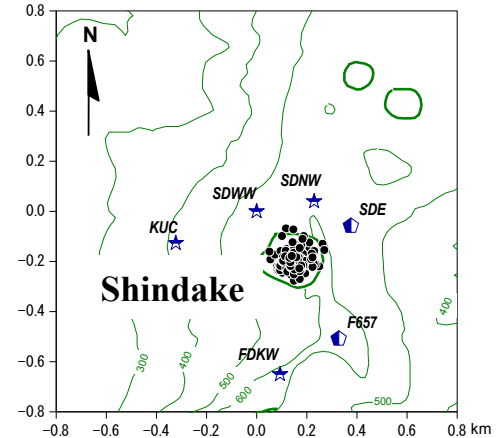
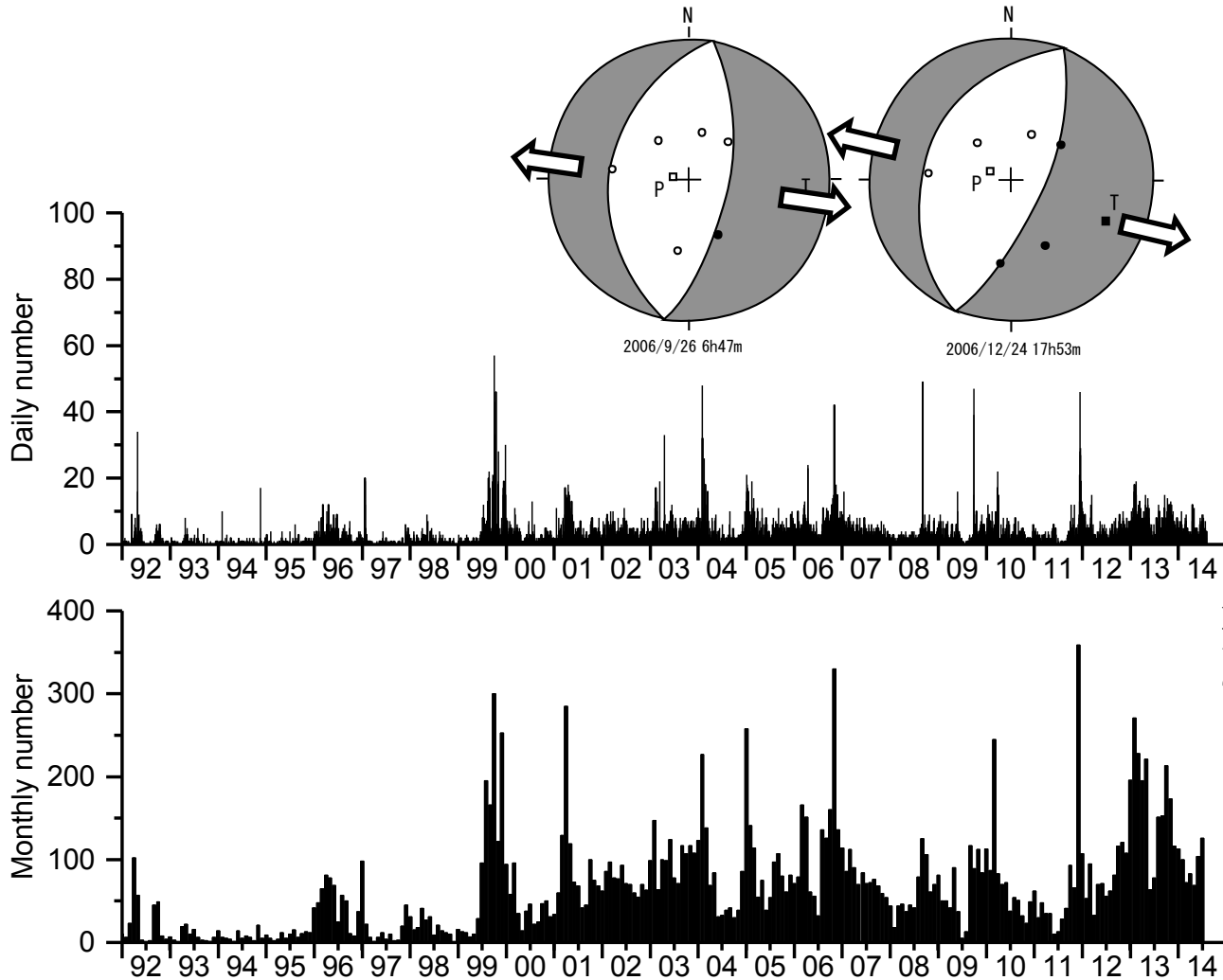
November 2015



# Active volcanoes in Kyushu



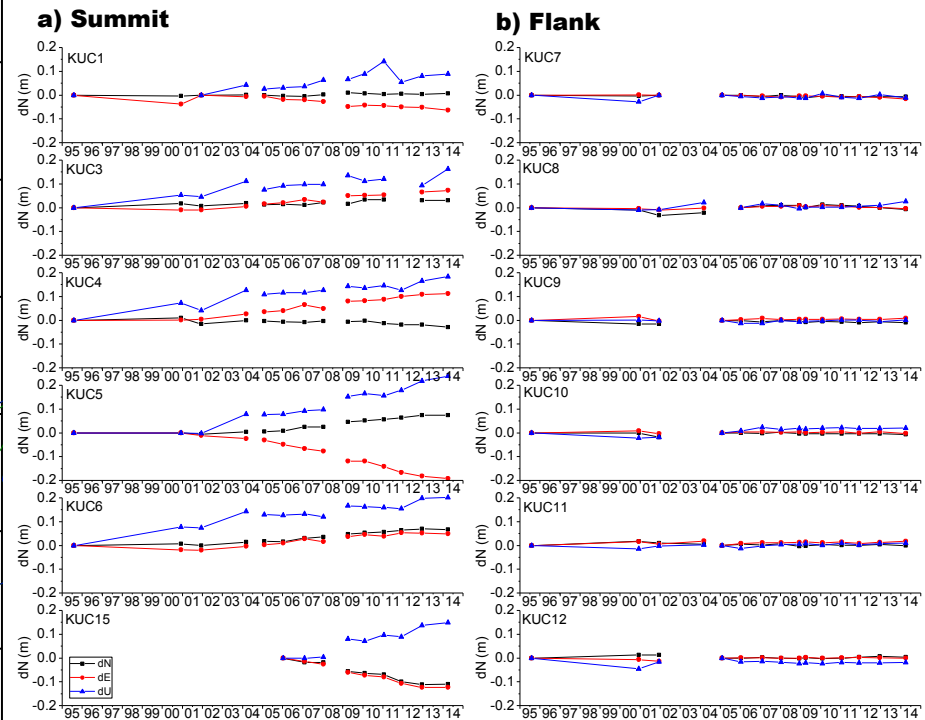
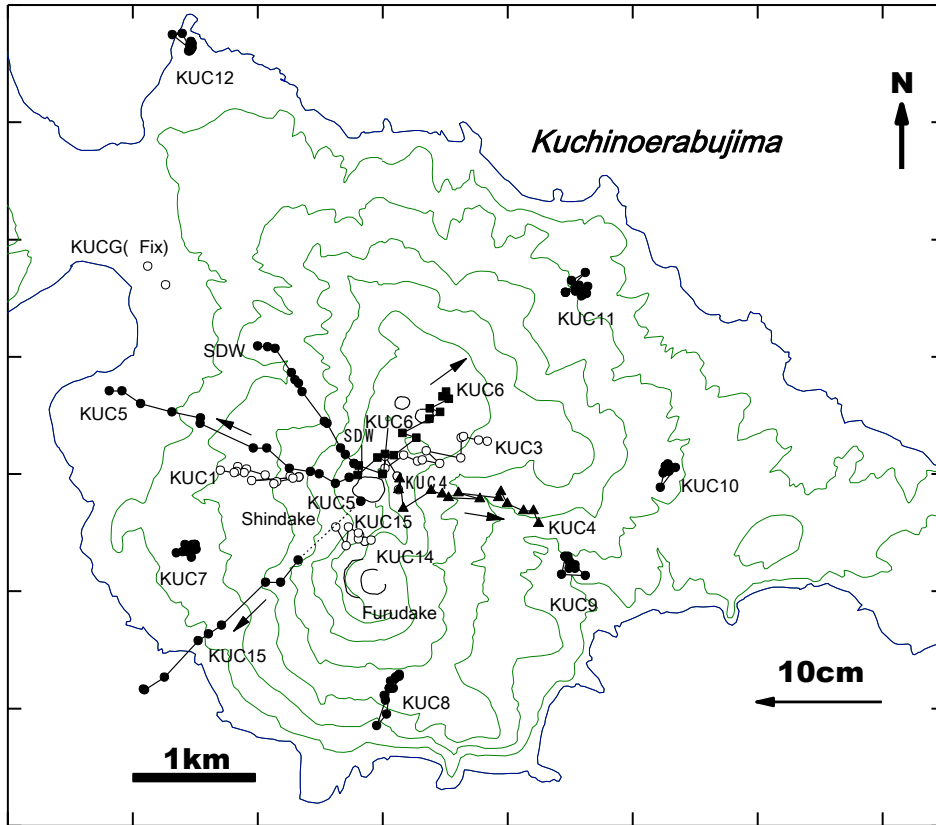
# Increase in seismicity of volcanic earthquake



Triastuty et al. (2009)

Extremely shallow VT type events are dominated.

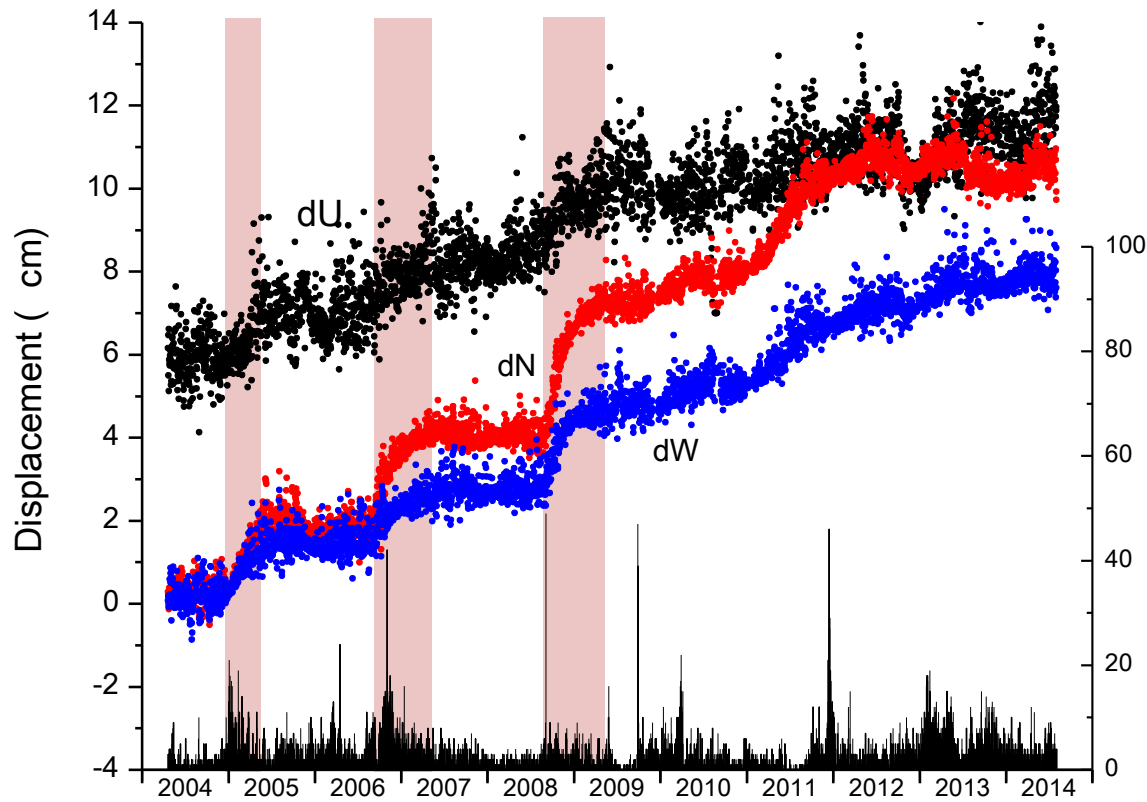
# Inflation of ground around the crater



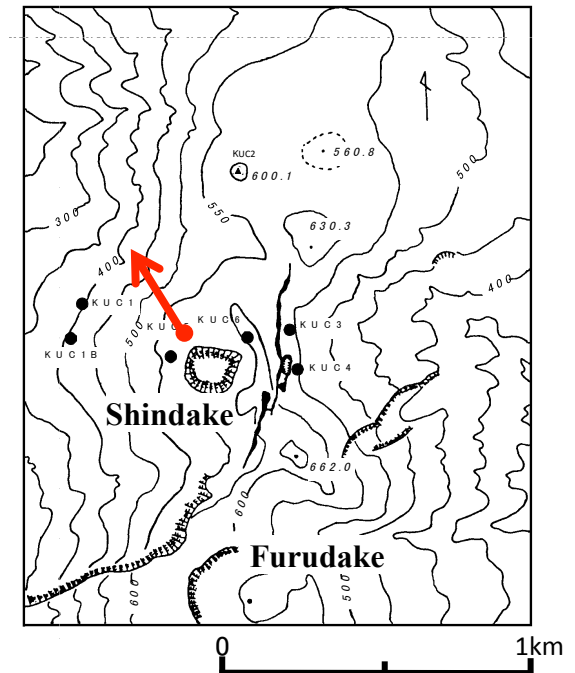
Displacement obtained by GPS campaigns



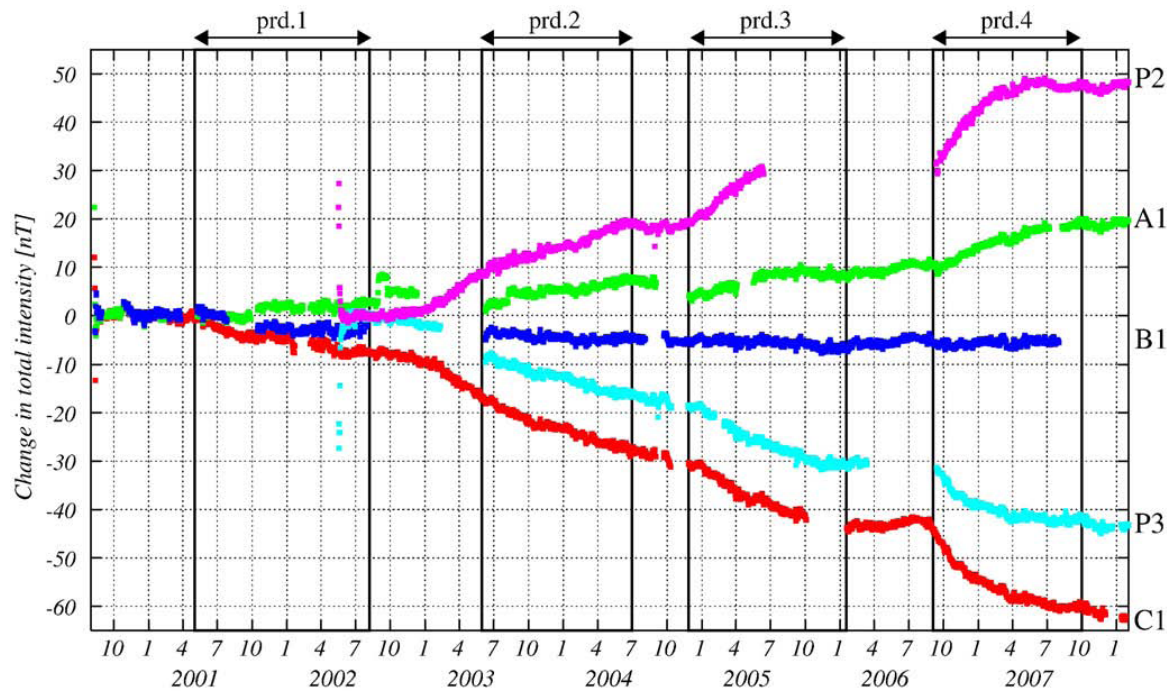
# Corresponding inflation to increase in seismicity



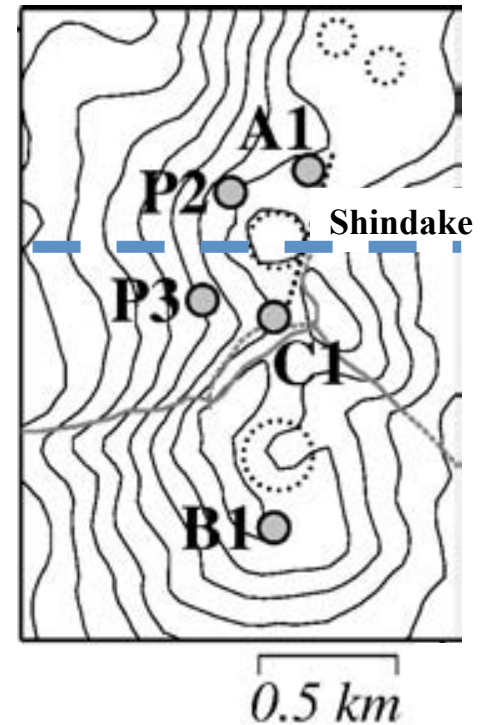
Location of GPS (SDW)



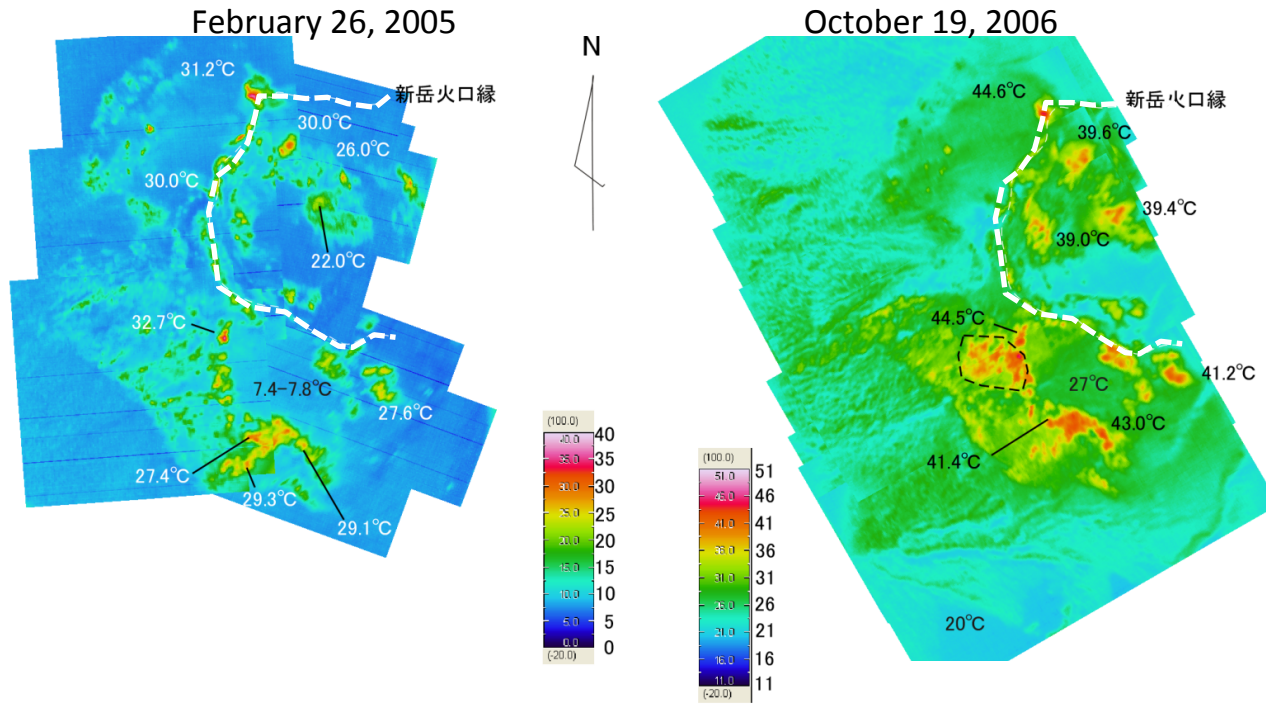
# Heat accumulation revealed by geomagnetic total force



Kanda et al. (2010)



# Increase in geothermal activity



Airborne survey by infrared scanner

Appearance of new fumarole

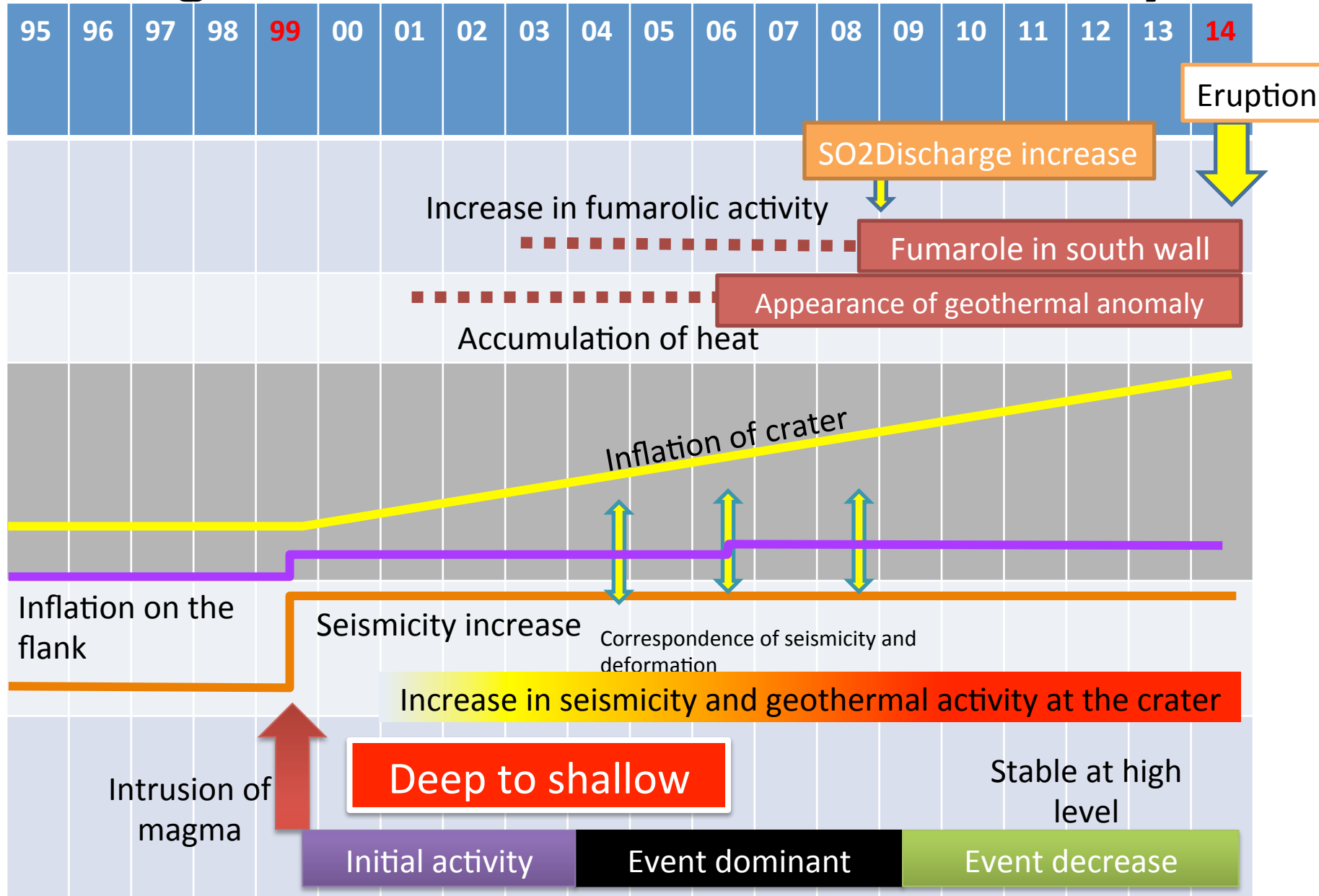


October 4, 2008

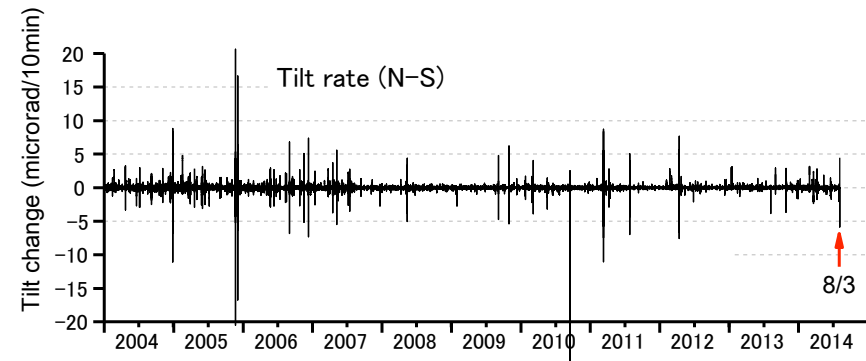
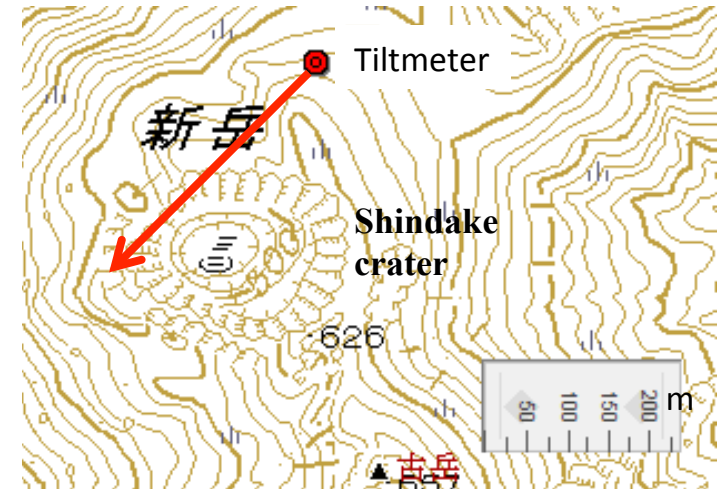
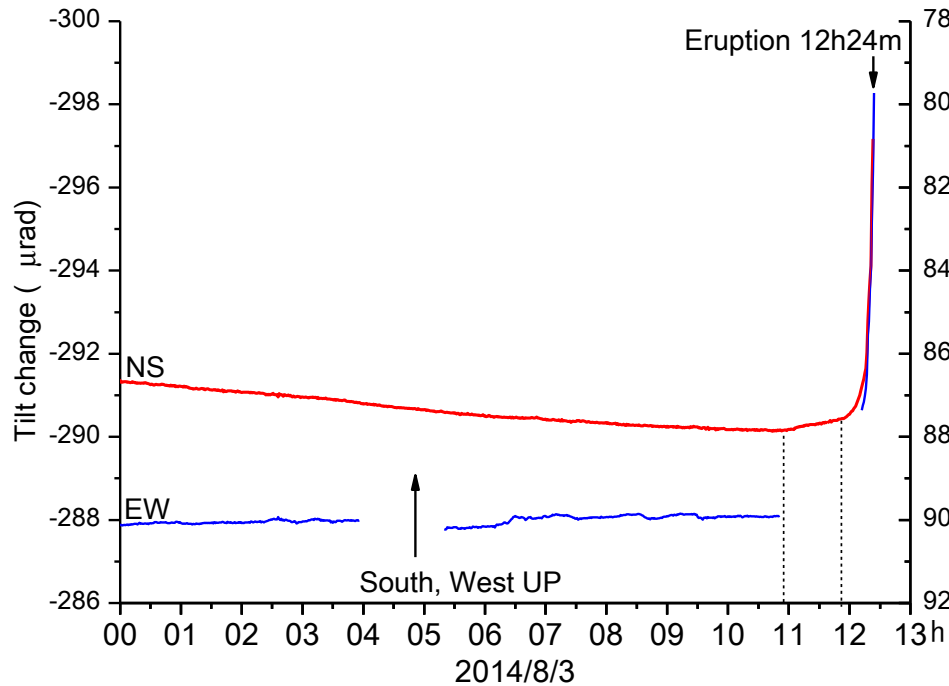


April 7, 2014 (4 months before eruption)

# Long-term increase in volcanic activity



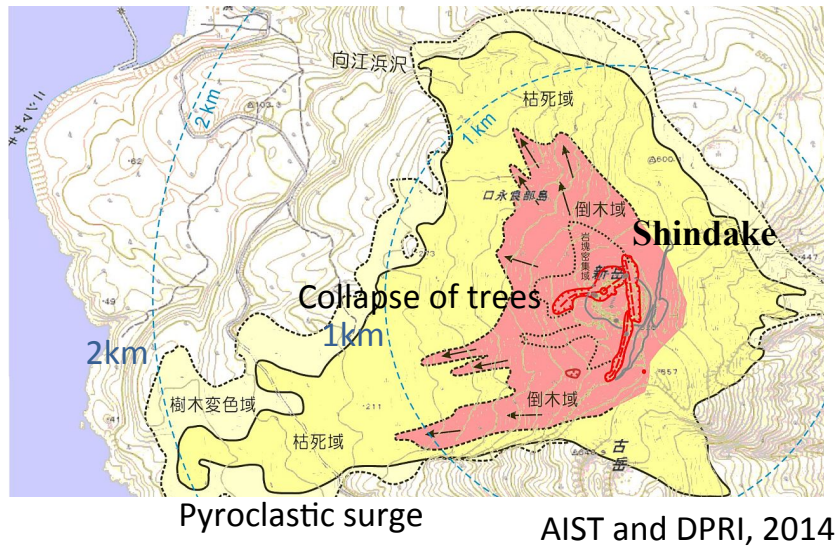
# Upward tilt immediately before the eruption



All the spikes induced by distant earthquakes

# Kuchinoerabujima eruption on August 3, 2014

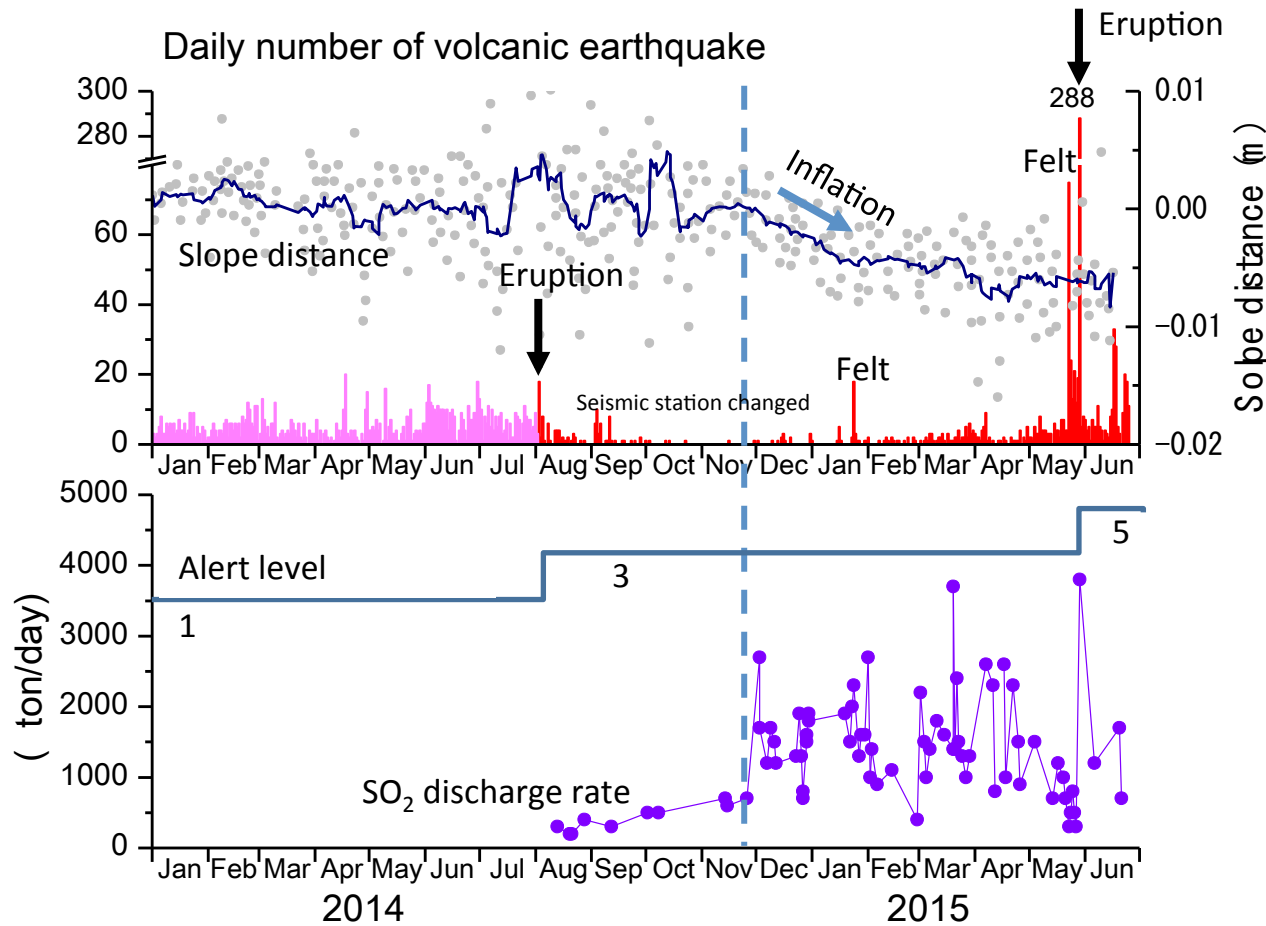
Mostly phreatic (slight effect of magma)



Monitoring camera by JMA, Time lapse rate x8

Alert level stayed at the lowest level 1 before the 2014 eruption and was upgraded to 3 after the eruption occurred.

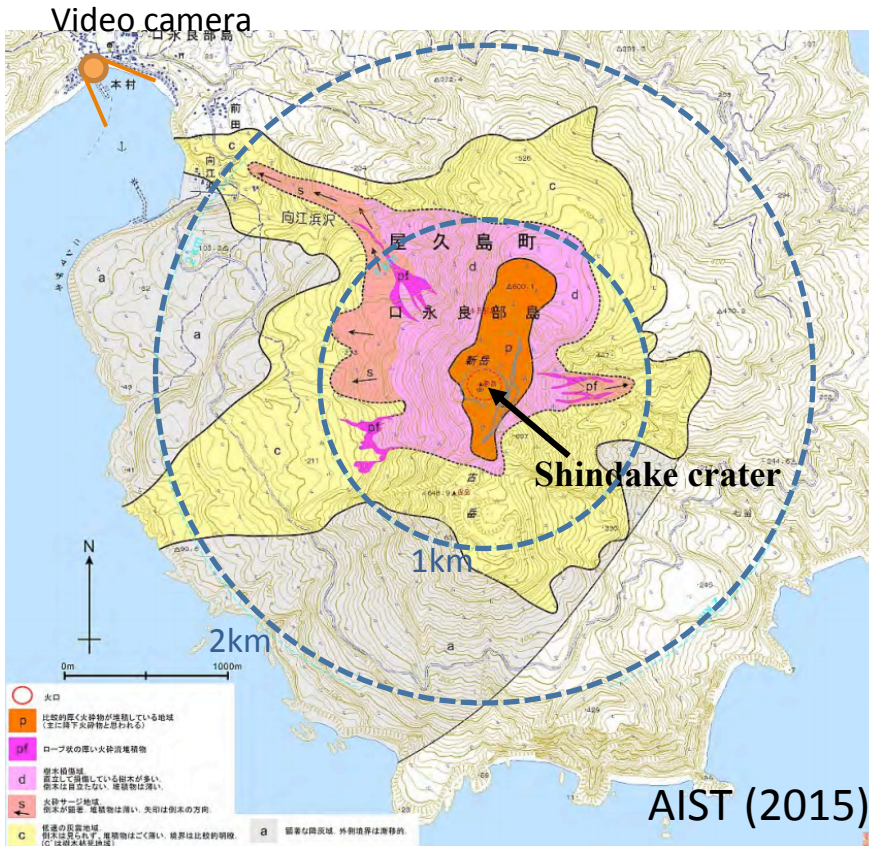
# More intense precursors to the 2015 eruption



Volcanic glow from March 24, 2015

# Eruption on May 29, 2015

Volcanic cloud reached 10 km high. VEI 1-2. After the eruption, JMA upgraded the alert level to 5 (max) from 3. All the residents evacuated from the island.



Monitoring camera by JMA, Time lapse rate x8



# Comparison of precursors before 2014 and 2015 eruptions ▪ ▪ ▪ **Much intense activity before the 2015 eruption**

	2014 eruption	2015 eruption
Duration	15 years	10 months
Seismicity	Increase in volcanic earthquake at quite shallow depth beneath the crater No felt earthquake	Felt earthquakes on Jan 24 and May23 (M2.6) at depths 2-4 km at western flank
Ground deformation	Concentrated the crater	Detected on the flanks
Discharge rate of SO <sub>2</sub>	300 ton/day (2008~2009)	Maximum 4000 ton/day
Surface phenomena	Only increase in fumarolic activity No volcanic glow	Volcanic glow after March 24 (higher geothermal activity)

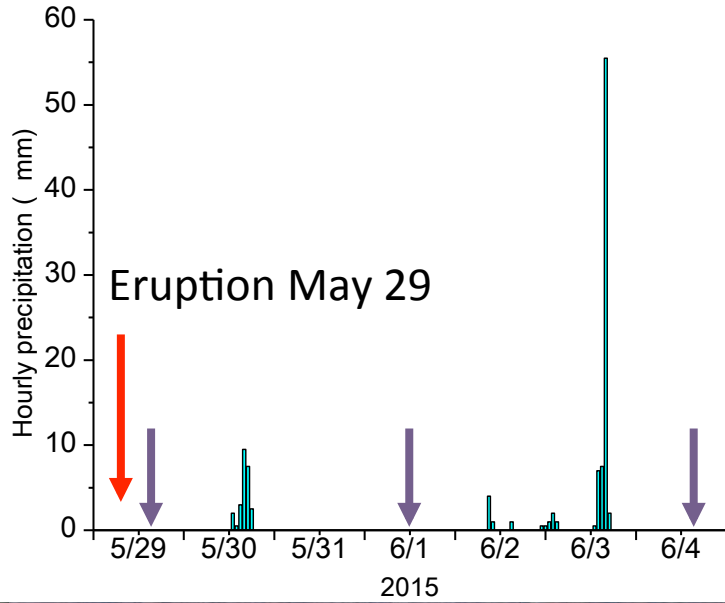
# Pyroclastic flow



# Lahar due to heavy rain fall

Kyushu Regional Development Bureau, MLIT

Taken from Helicopter Harukaze

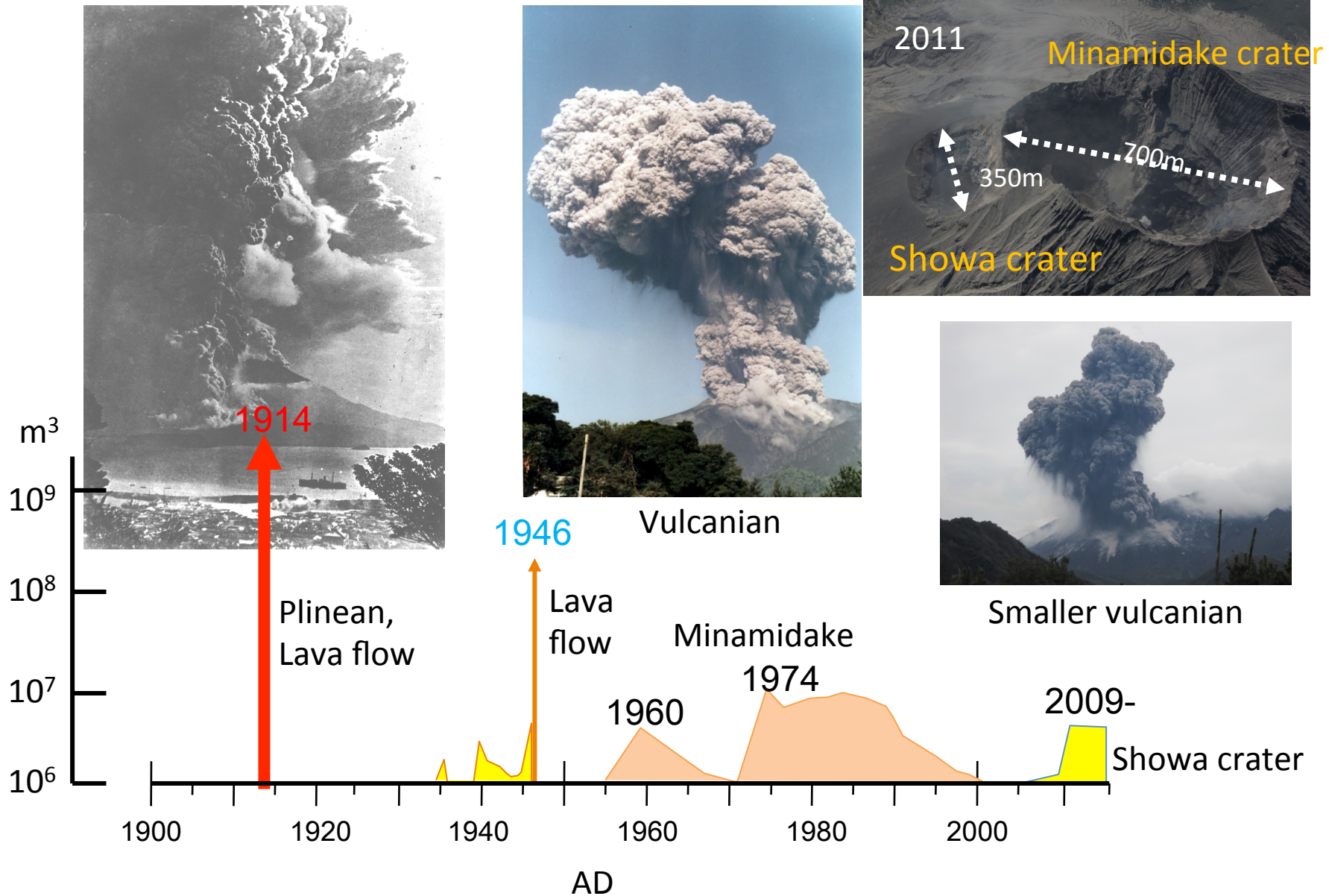


Hazard zone of >50cm volcanic ash by eruption by VEI 4

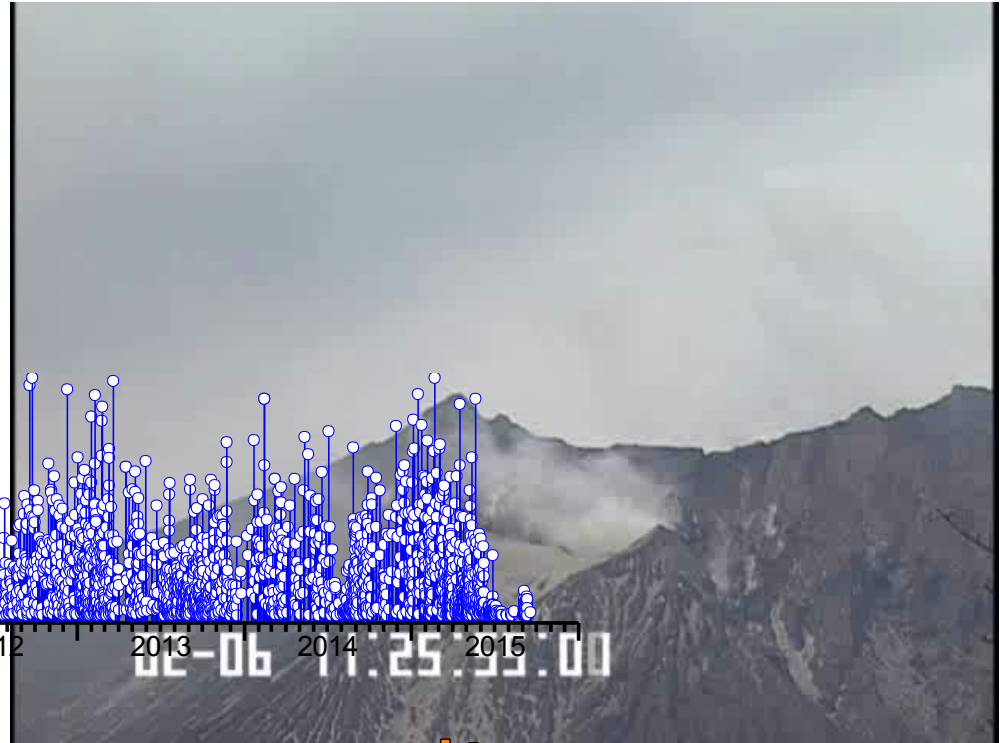
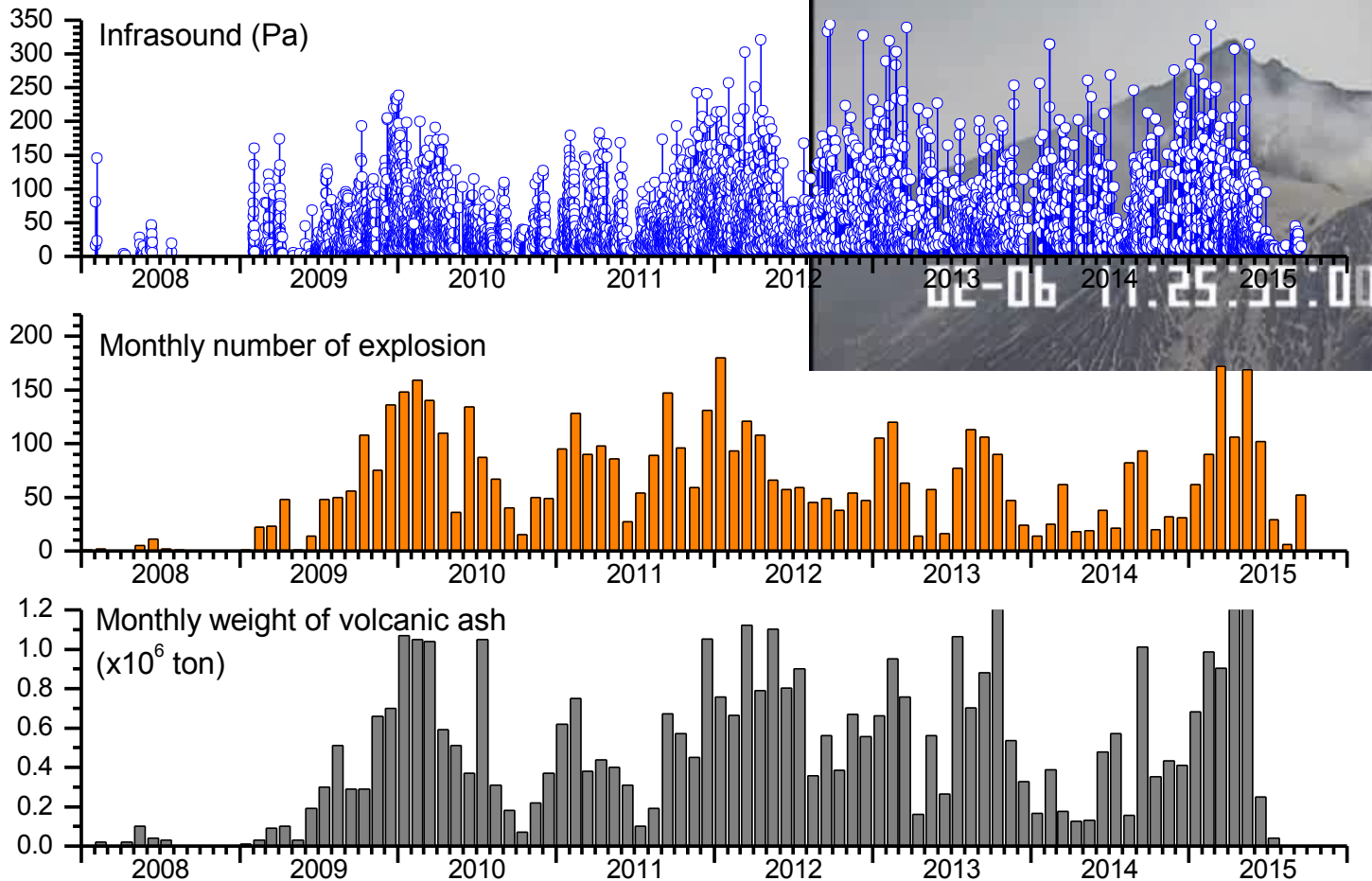
Population <20km zone  
800,000



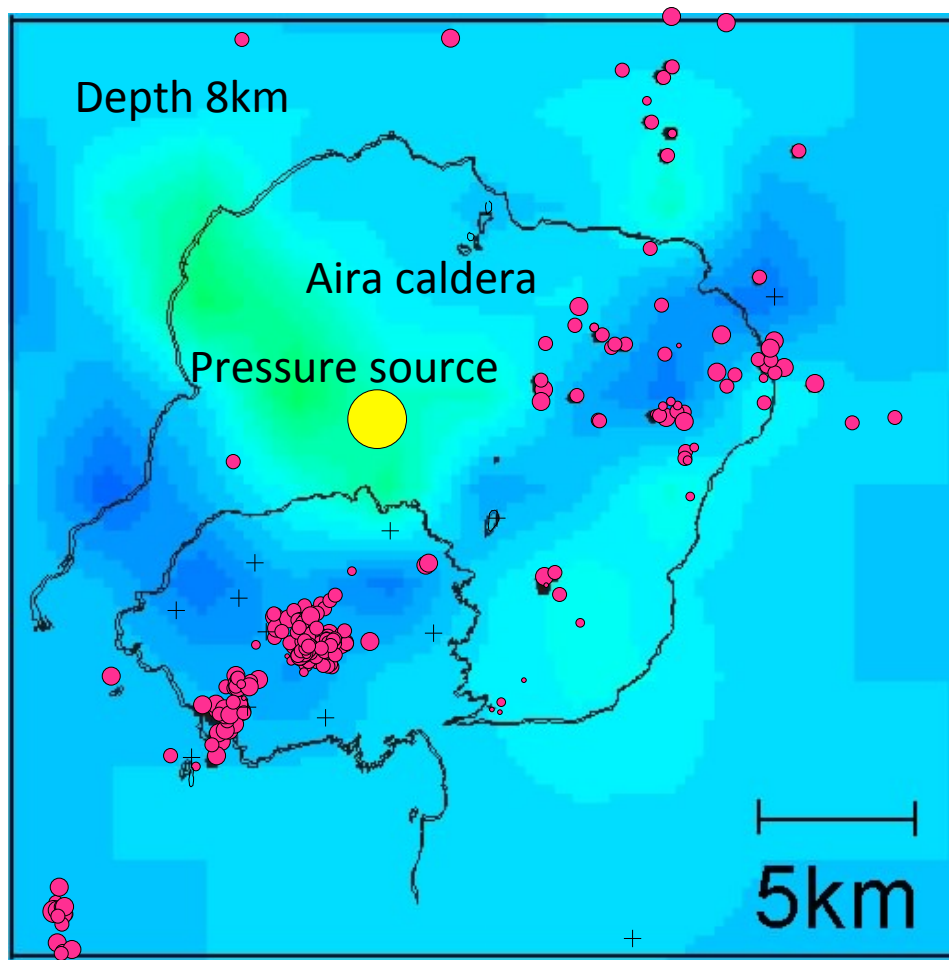
# Eruptive activity after the 20<sup>th</sup> century



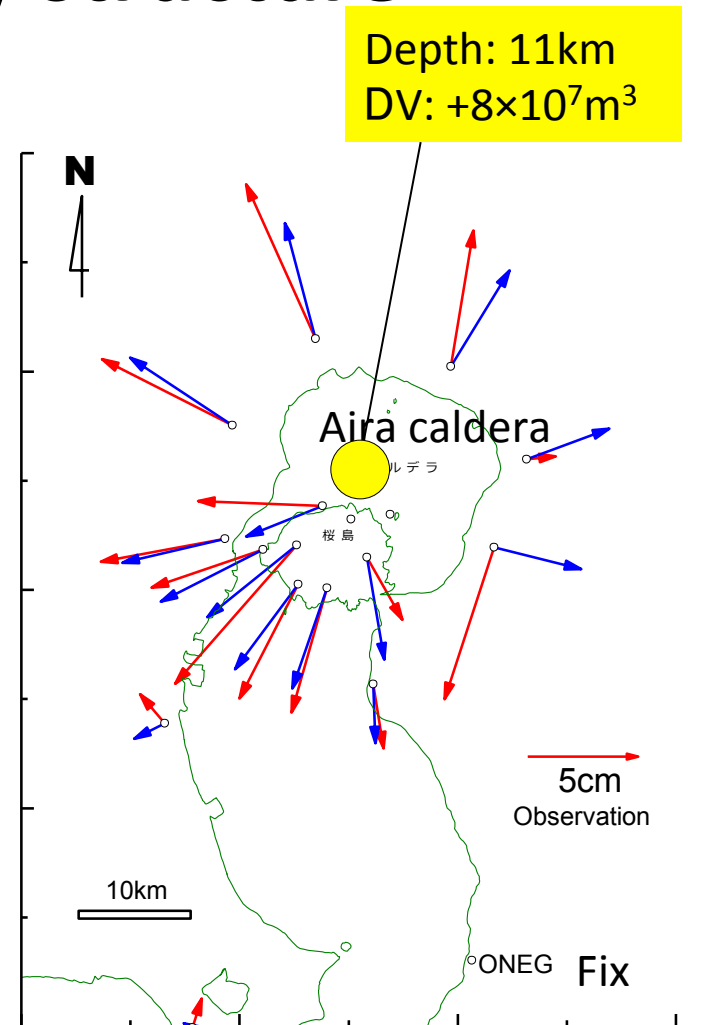
# Increase in explosivity at the Showa crater of Sakurajima volcano



# Hypocenter of VT earthquakes and P-wave velocity structure



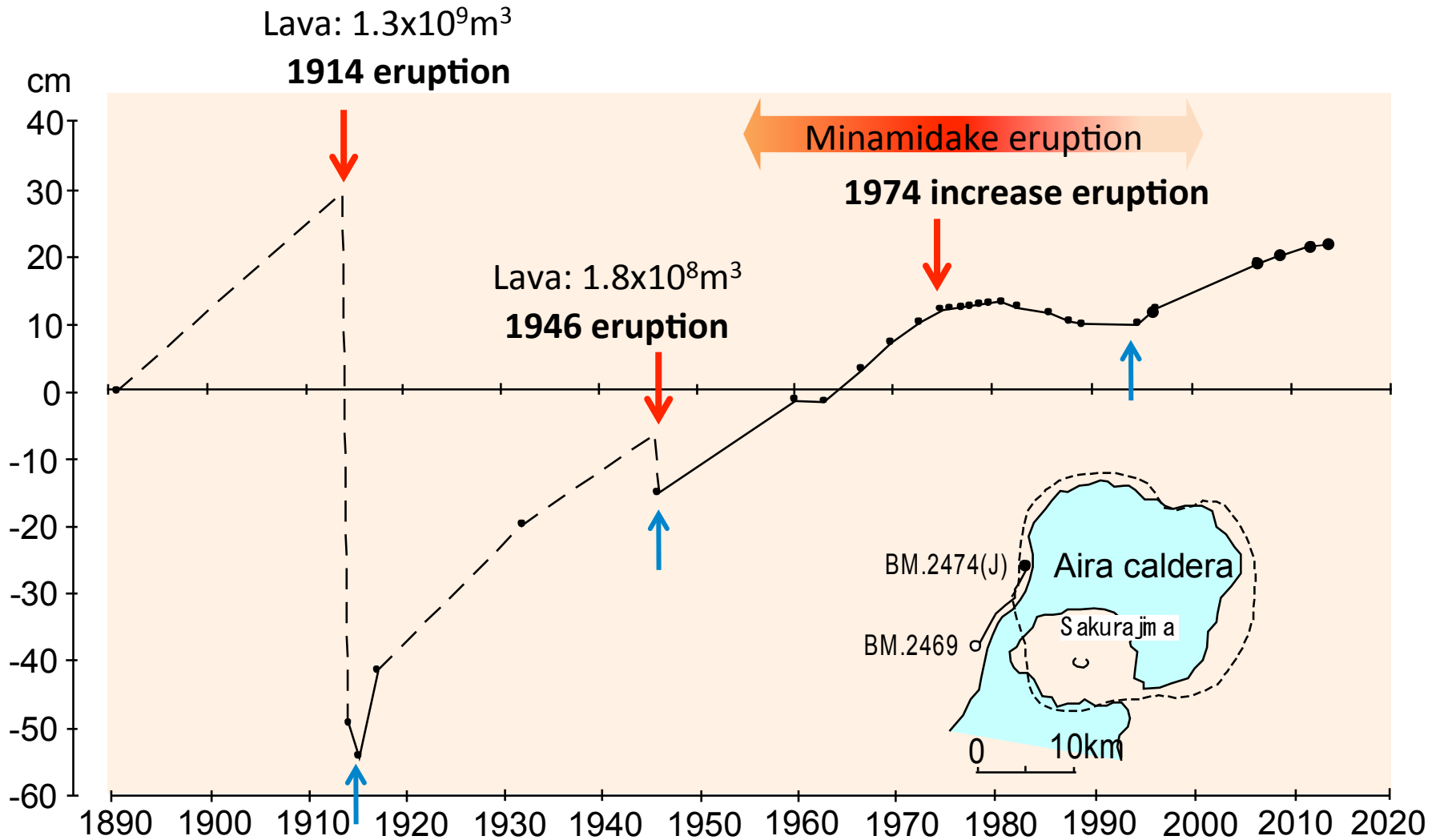
No VT earthquakes occurred in low velocity zone including the pressure source.



Dec 2007 - Dec 1996

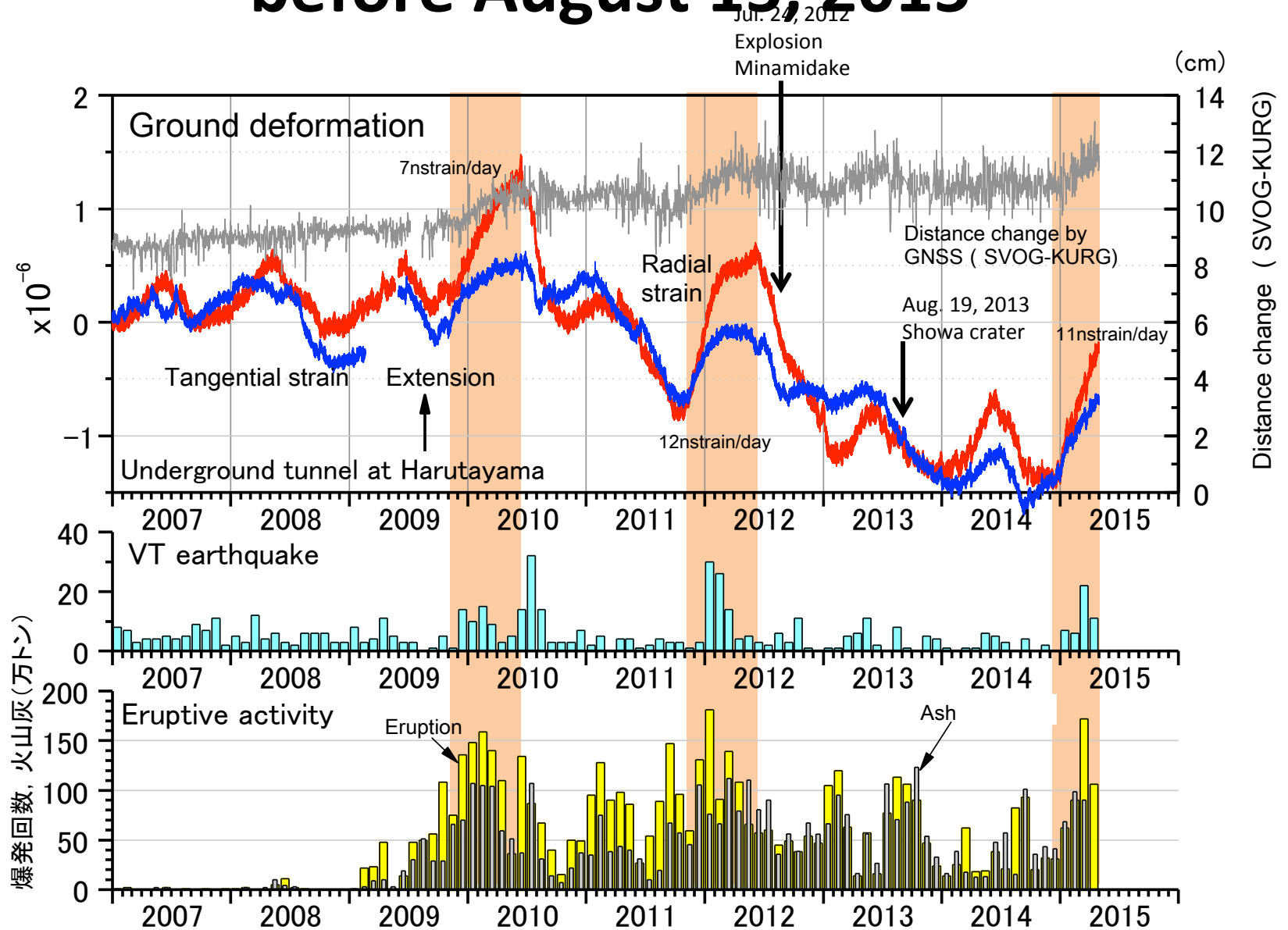
Horizontal displacements by GNSS

# Vertical displacement of the Aira caldera -Precise leveling-





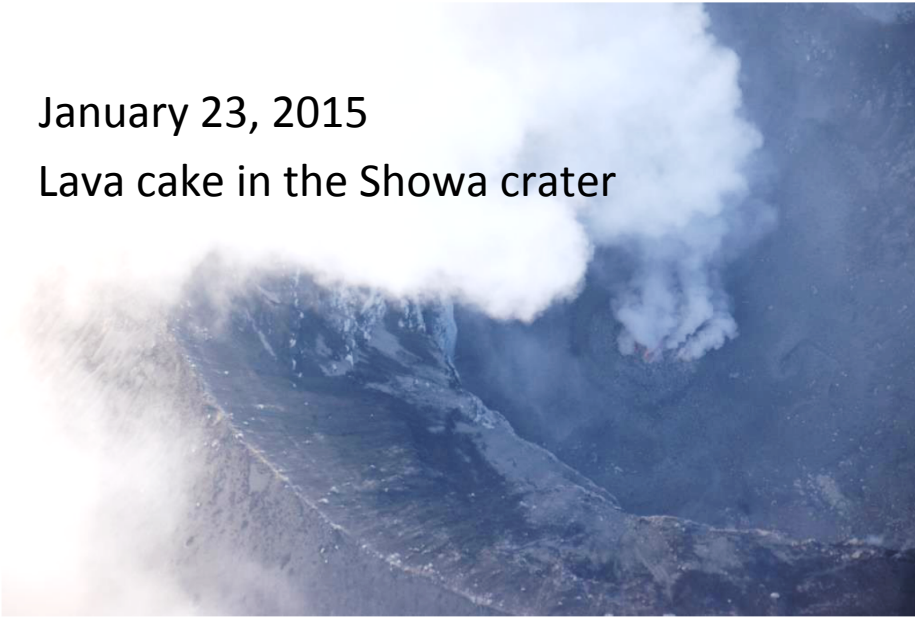
# Increase in volcanic activity before August 15, 2015



# Formation of lava dome in craters

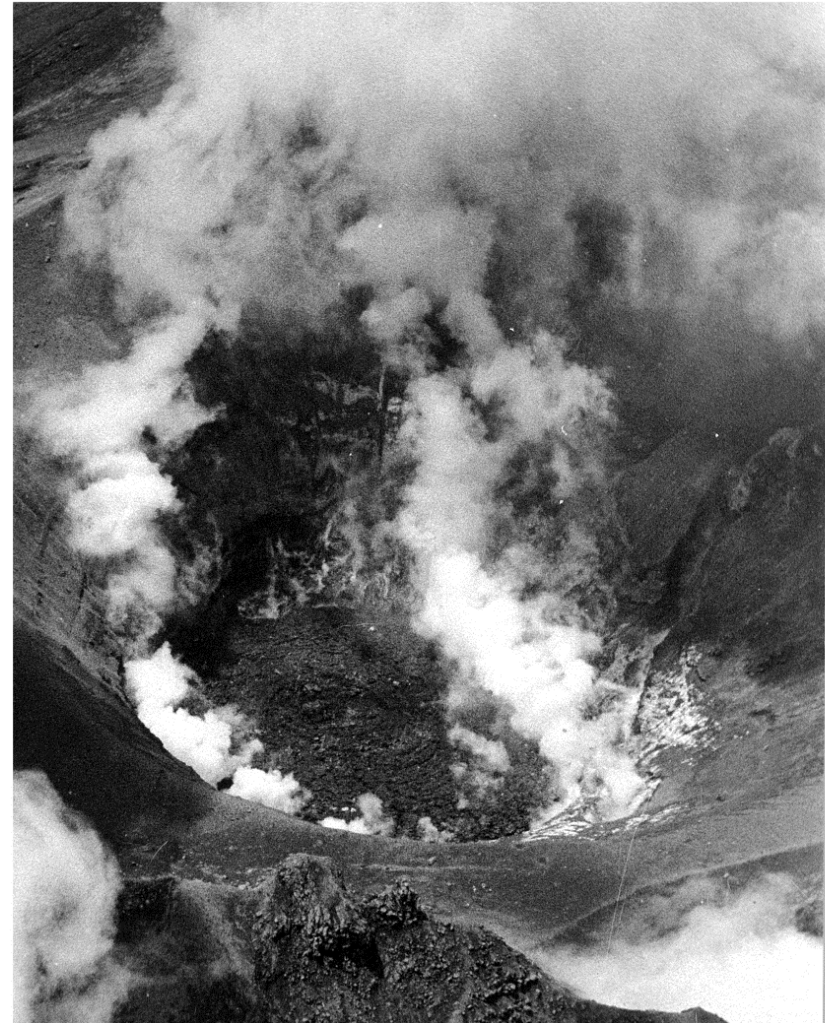
January 23, 2015

Lava cake in the Showa crater



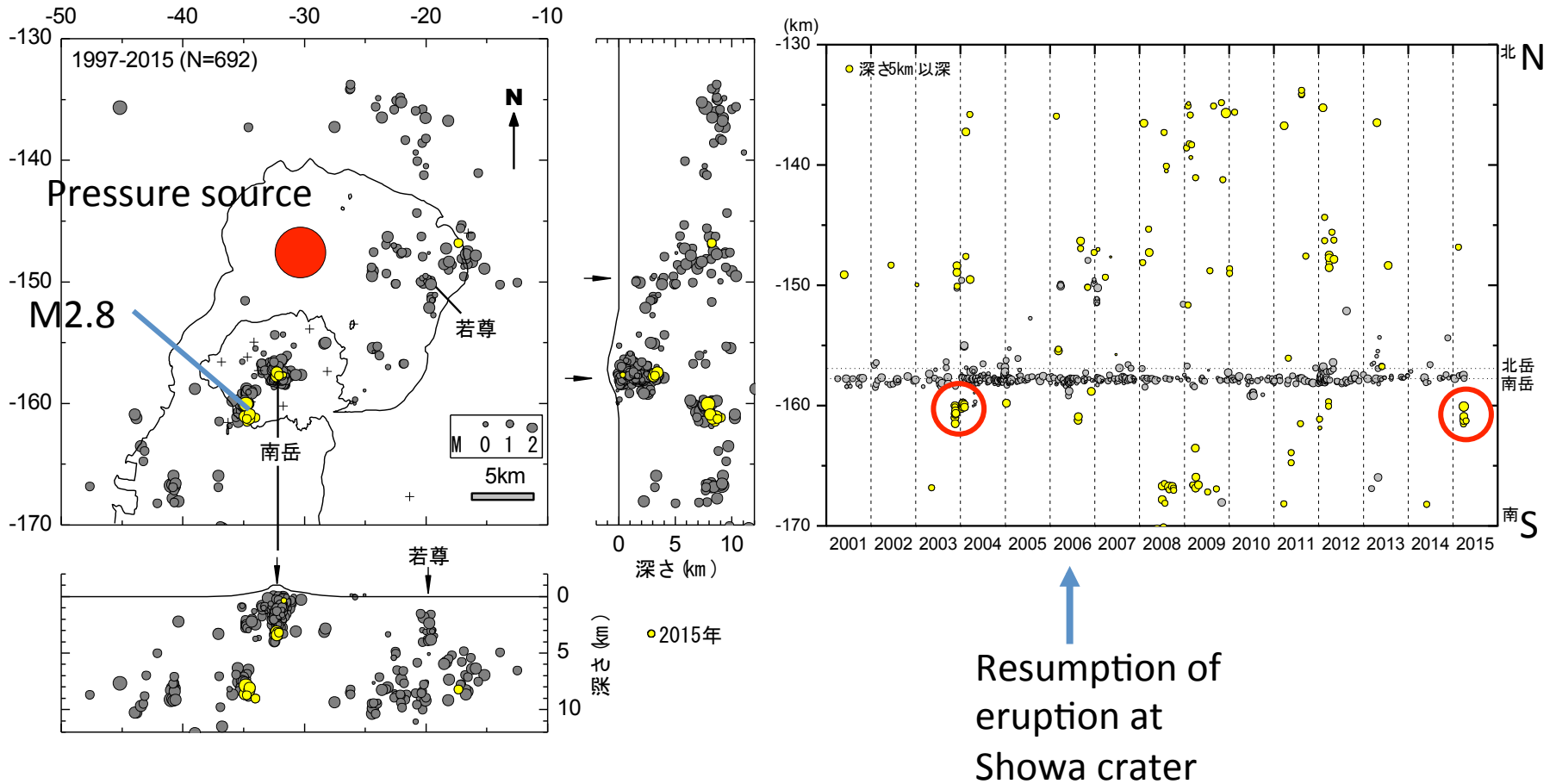
February 10, 2015

Lava cake in the Showa crater



Lava cake in the Minamidake crater  
on May 29, 1967

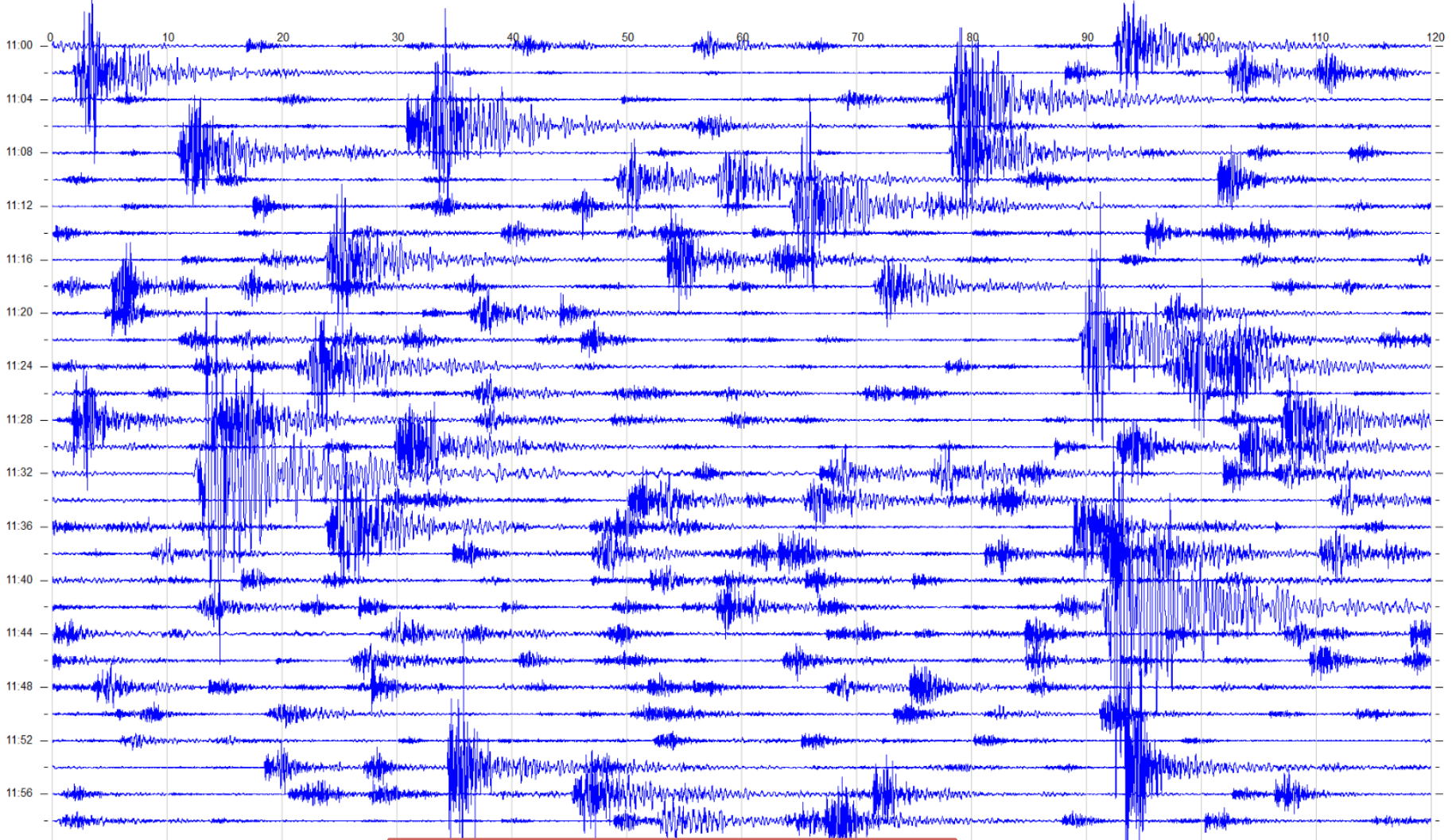
# Felt VT earthquake on March 31, 2015



# VT earthquake swarm on August 15

## Alert level upgraded to 4, evacuation order

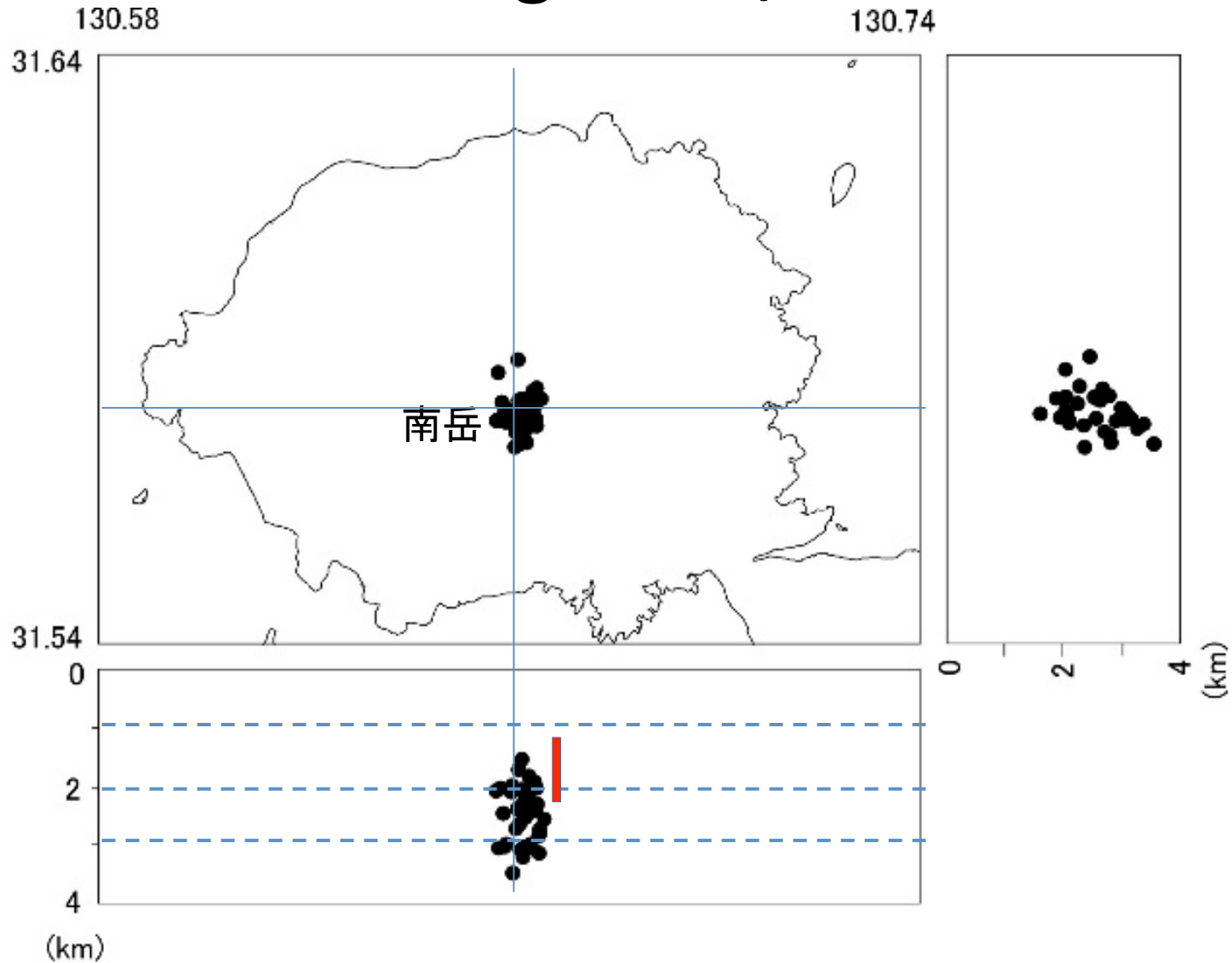
From:2015/08/15 11:00:00 To:2015/08/15 12:00:00 AR1-V Interval 2 min Scale:100 % of 500 Mode:Fine Resolution:16bit



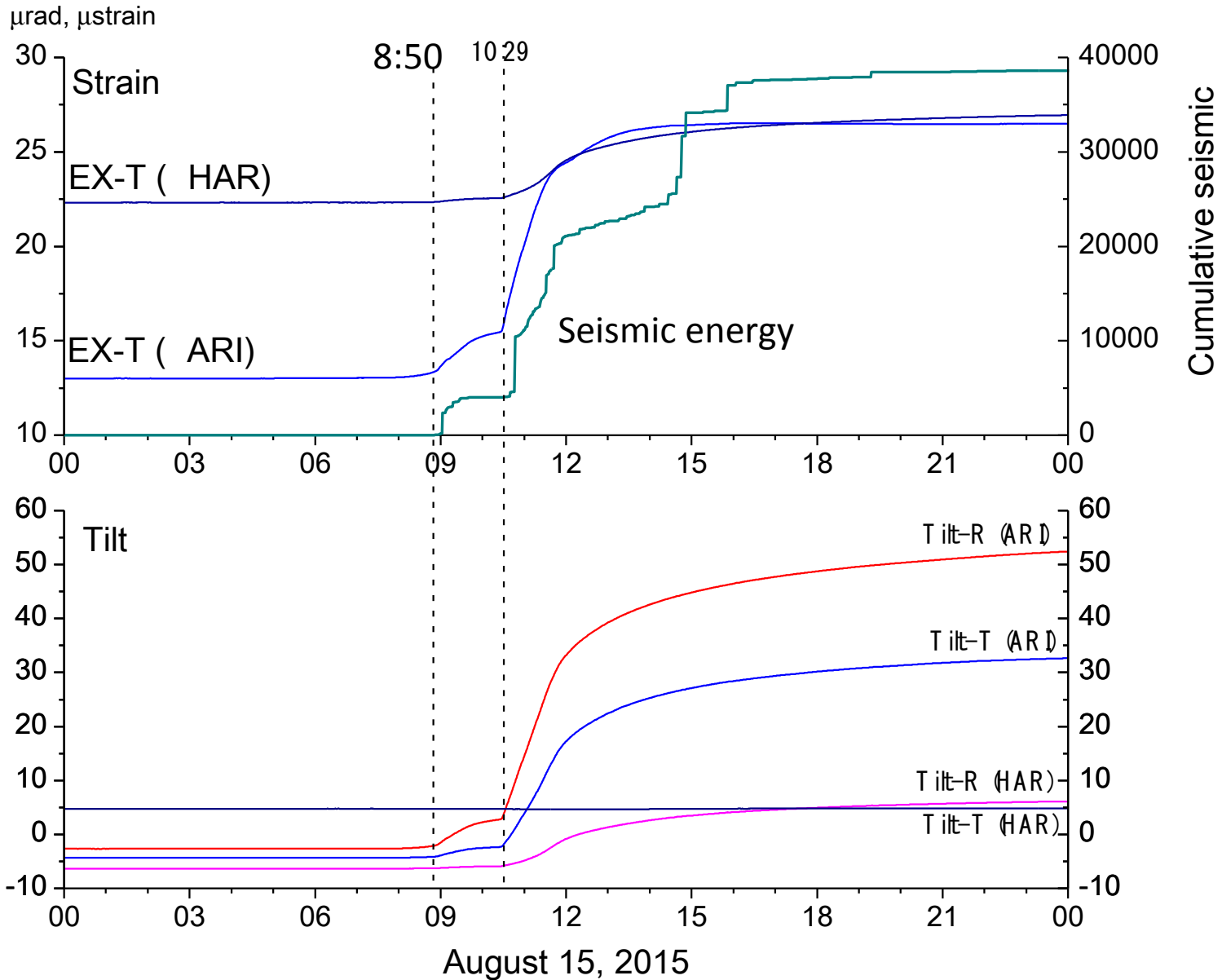
11h-12h

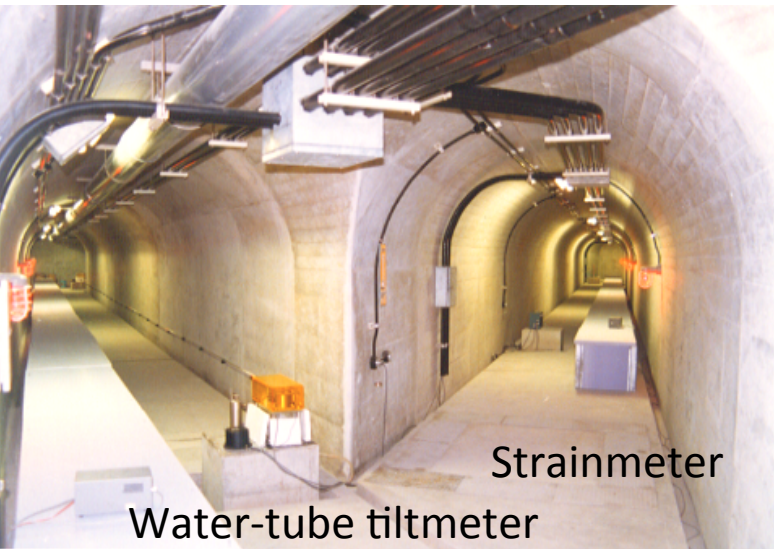
VT earthquake swarm began at 7h

# Hypocenters of VT earthquake on August 15, 2015

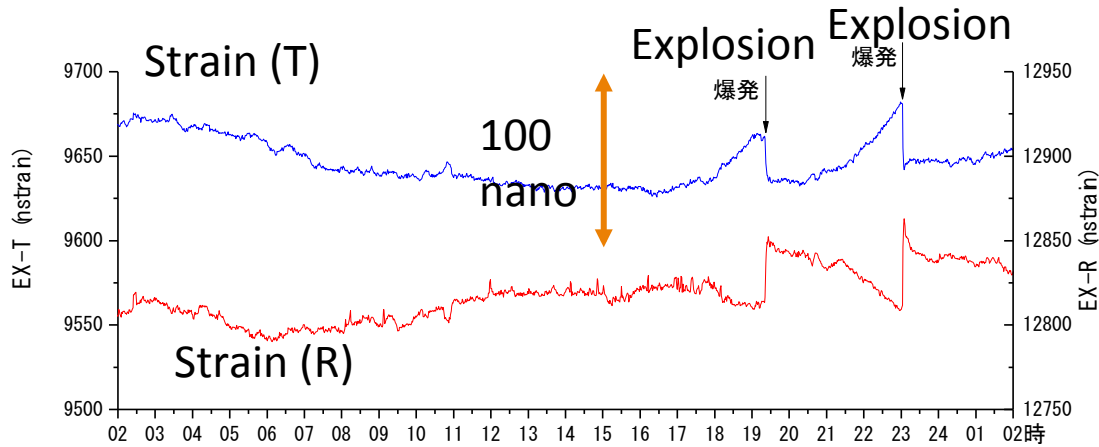
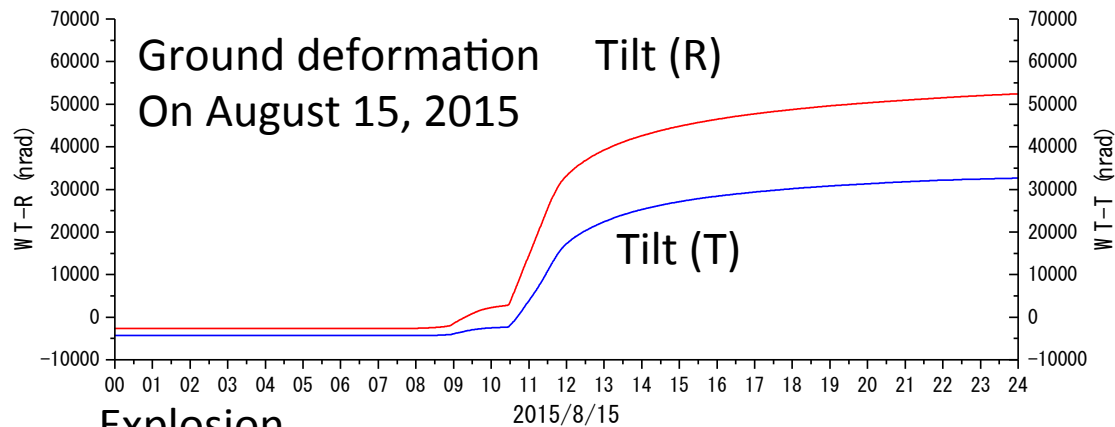
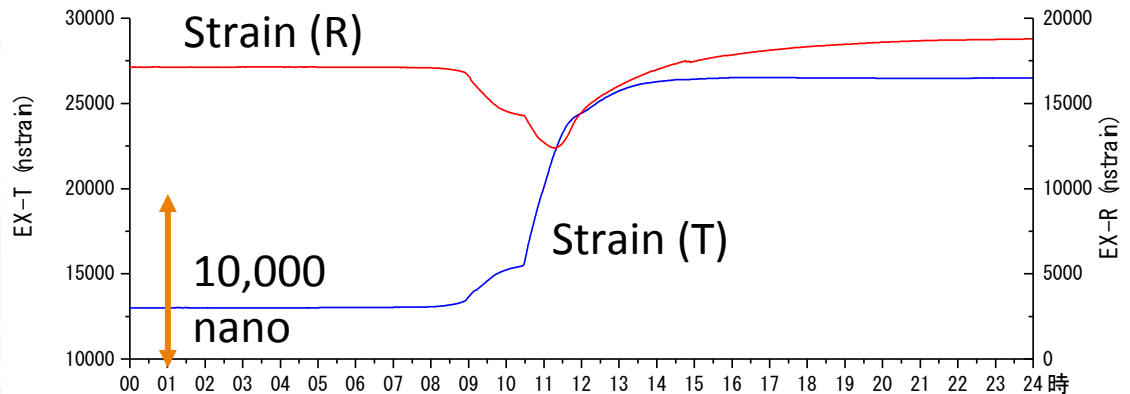


# Seismicity and ground deformation



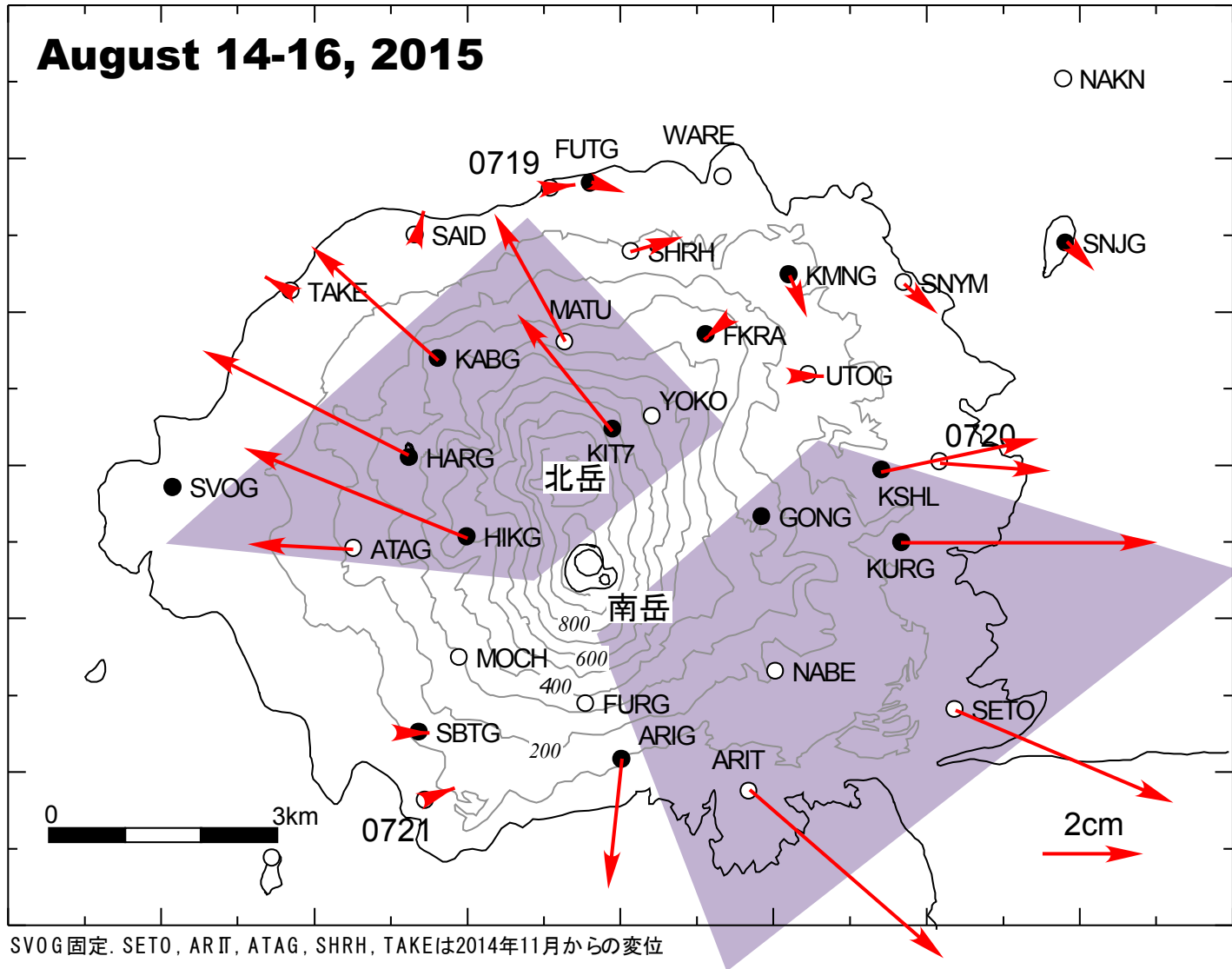


Harutayama underground tunnel



Ground deformation associated with usual eruptions

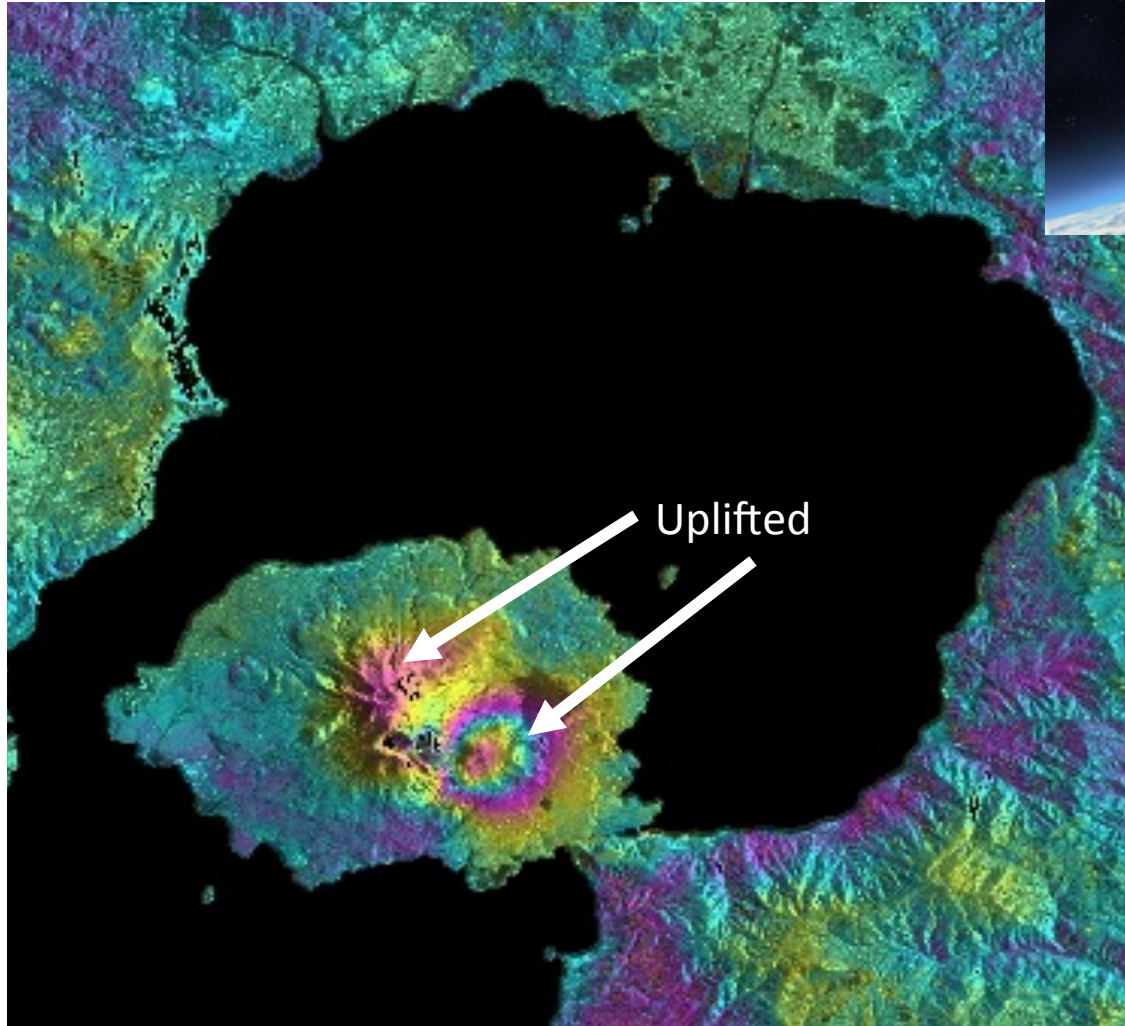
# Horizontal displacement detected by GNSS



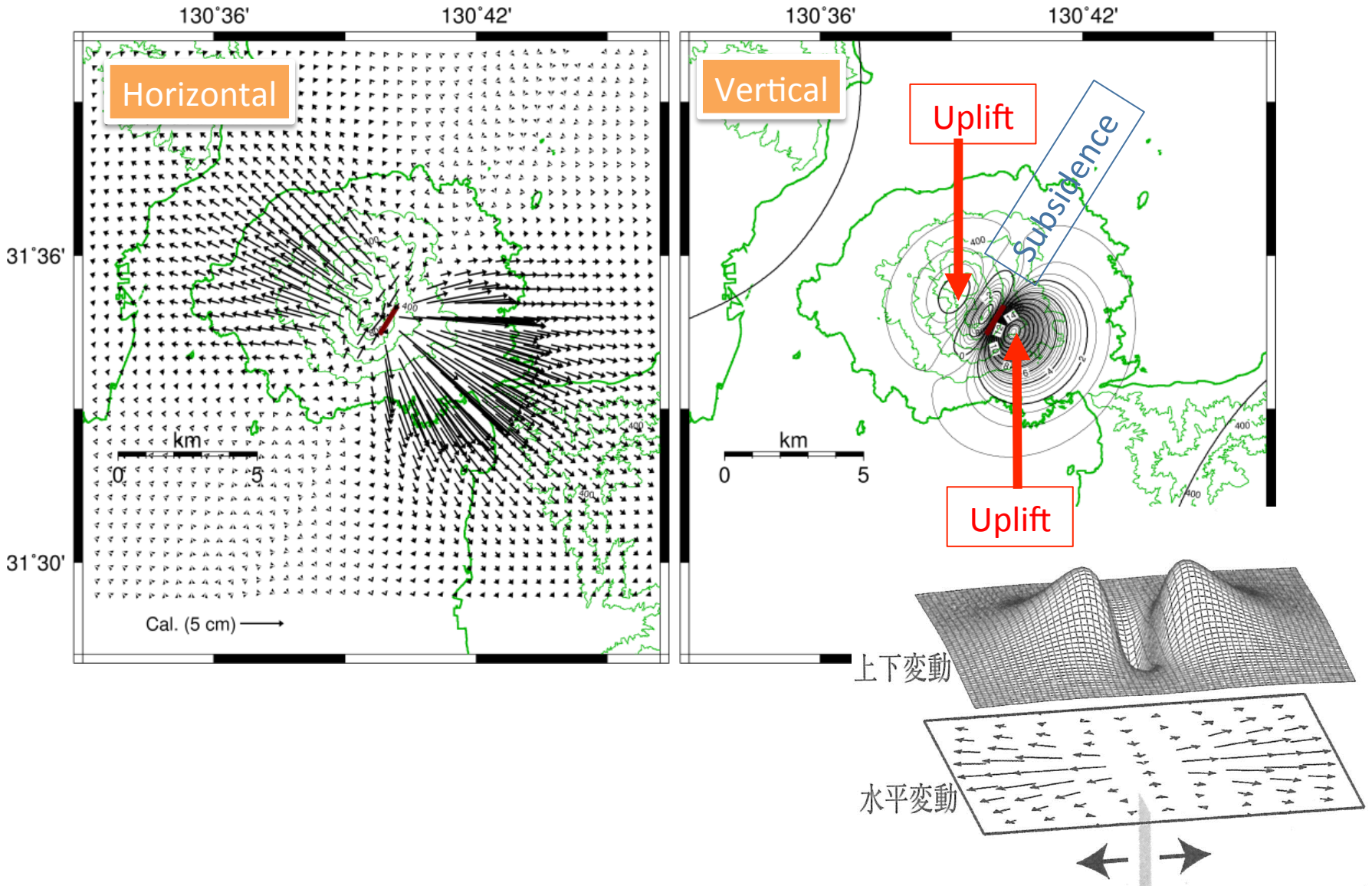


ALOS2

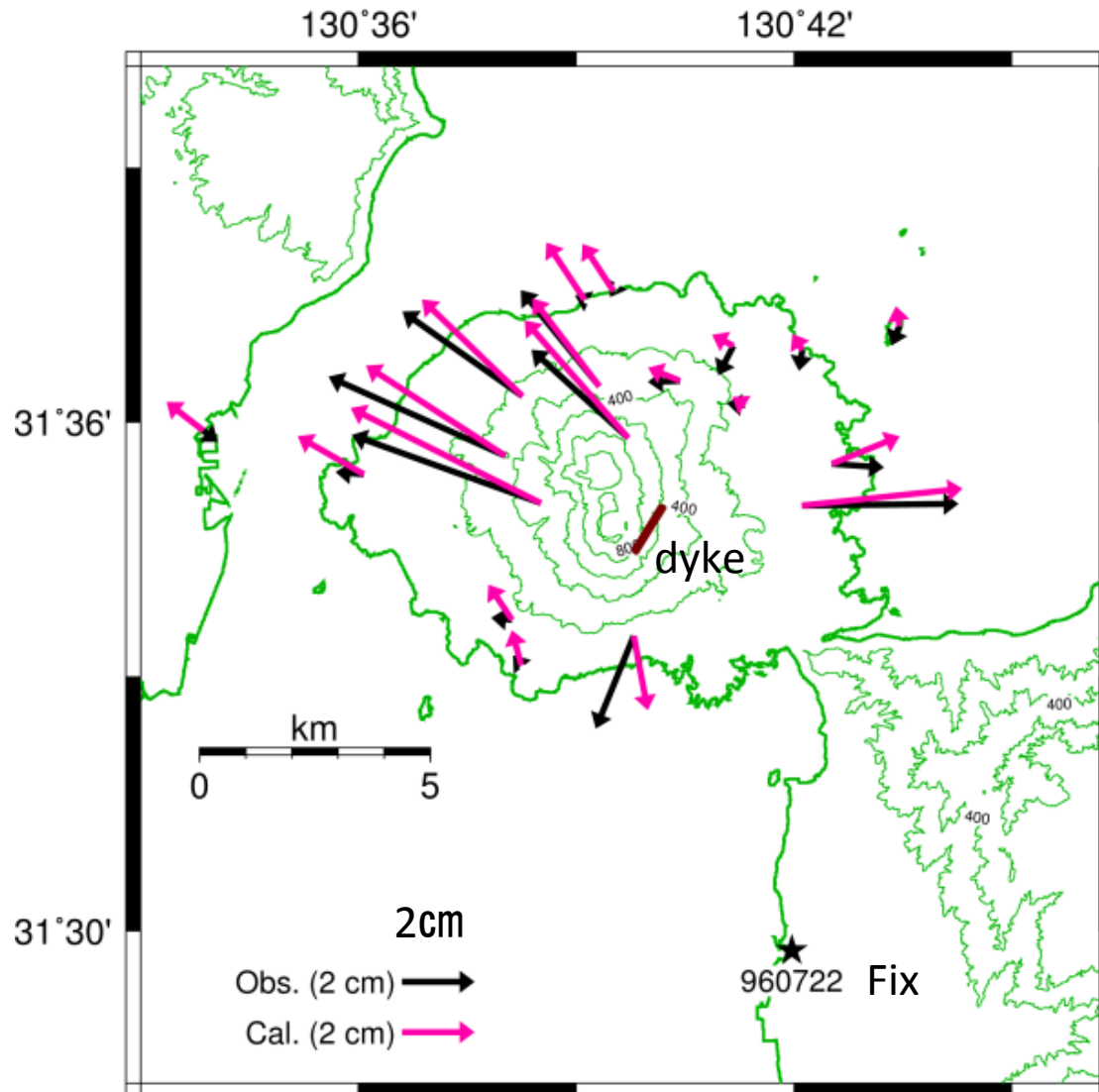
# In-SAR (ALOS2)



# Ground deformation caused by tensile crack



# Modeling by tensile crack

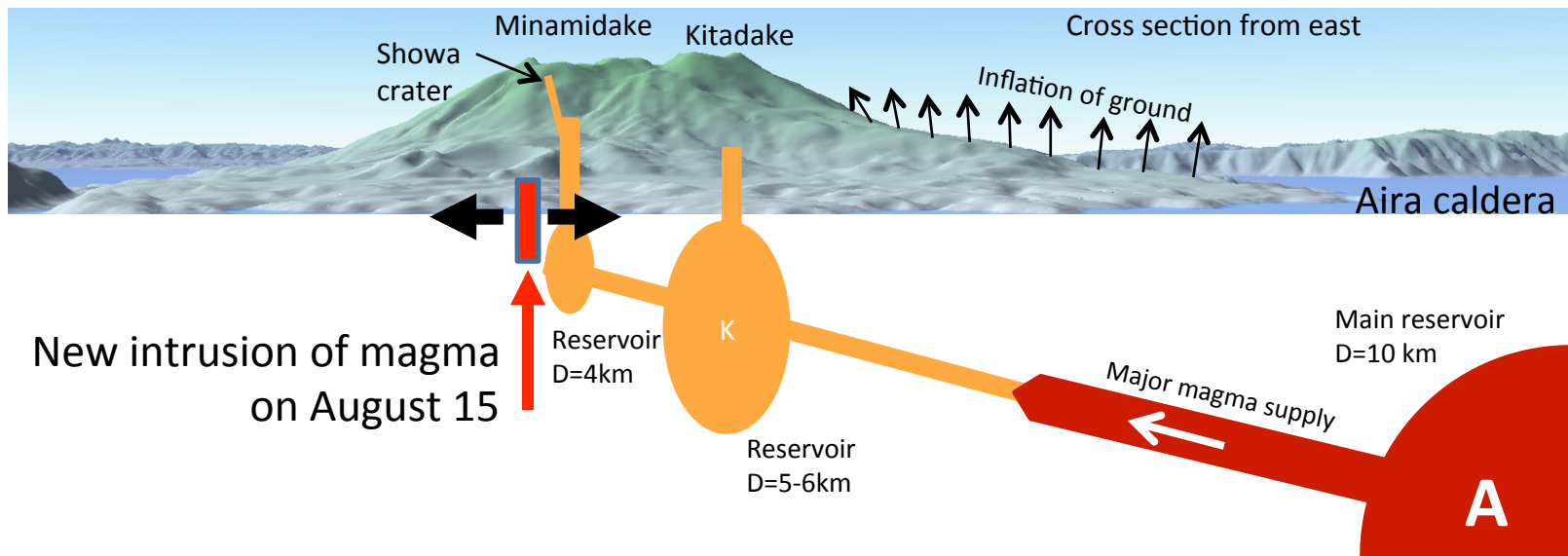
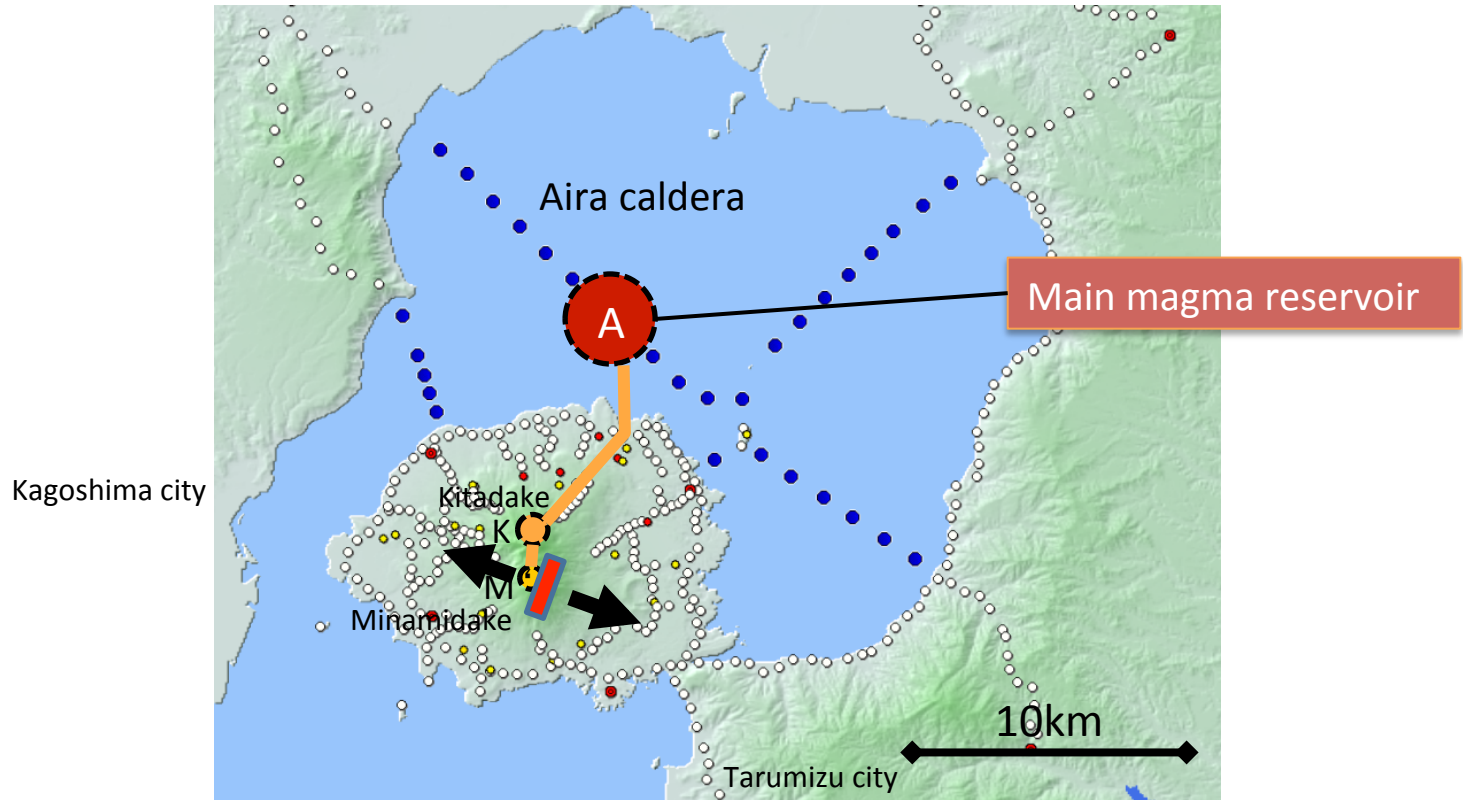


Crack location  
X(EW)=0.6 km  
Y(NS)=-0.1 km  
Z(depth)=1.1 km

Dip=71°  
Strike=N32° E  
Length=1.2 km  
Width=0.3 km

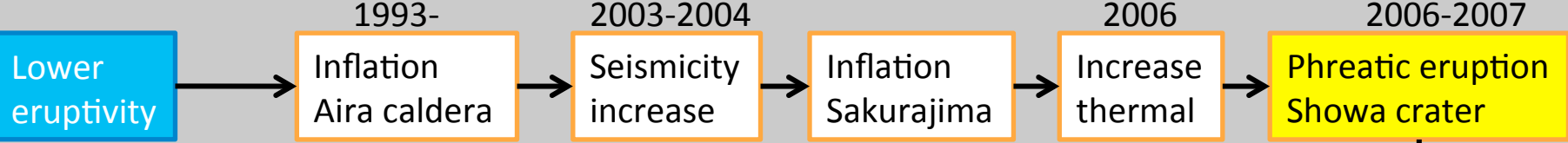
Open:6.97 m

Volume increase:  
 $2.5 \times 10^6 \text{ m}^3$

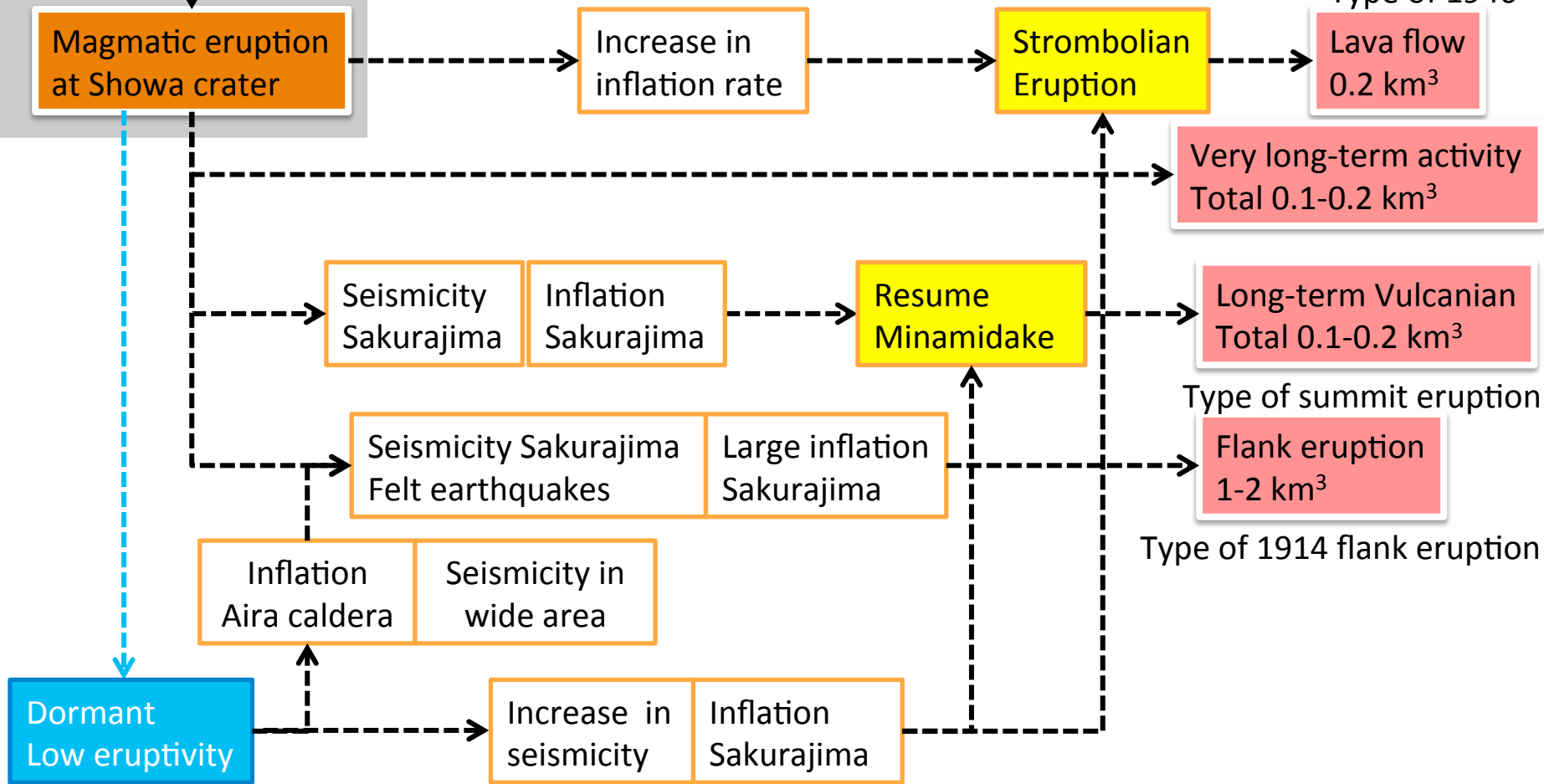


# Past volcanic activity and future scenarios

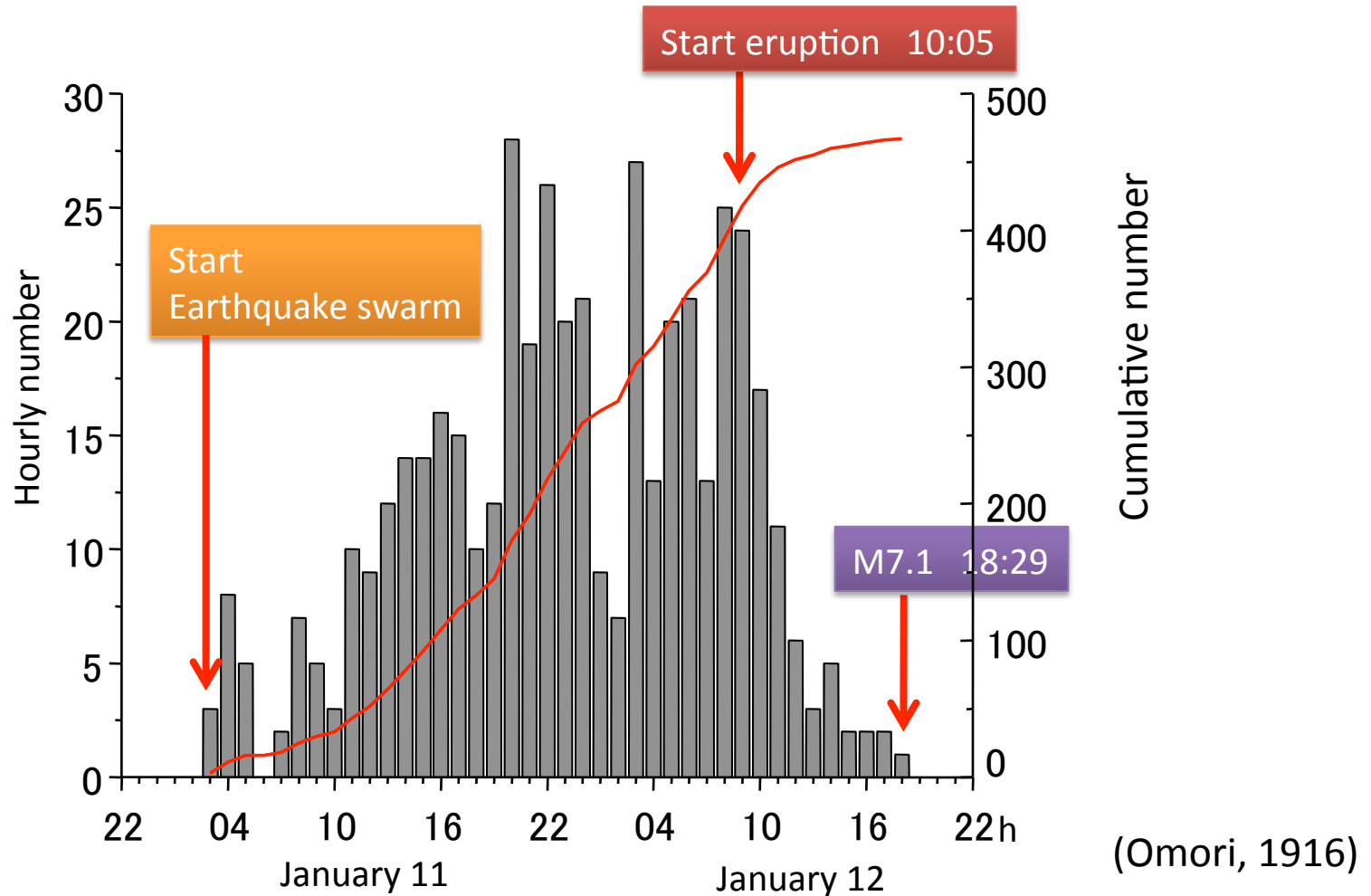
## Activity from 1990's to 2006



## 2009-present



# Increase in precursory VT earthquakes prior to the 1914 eruption

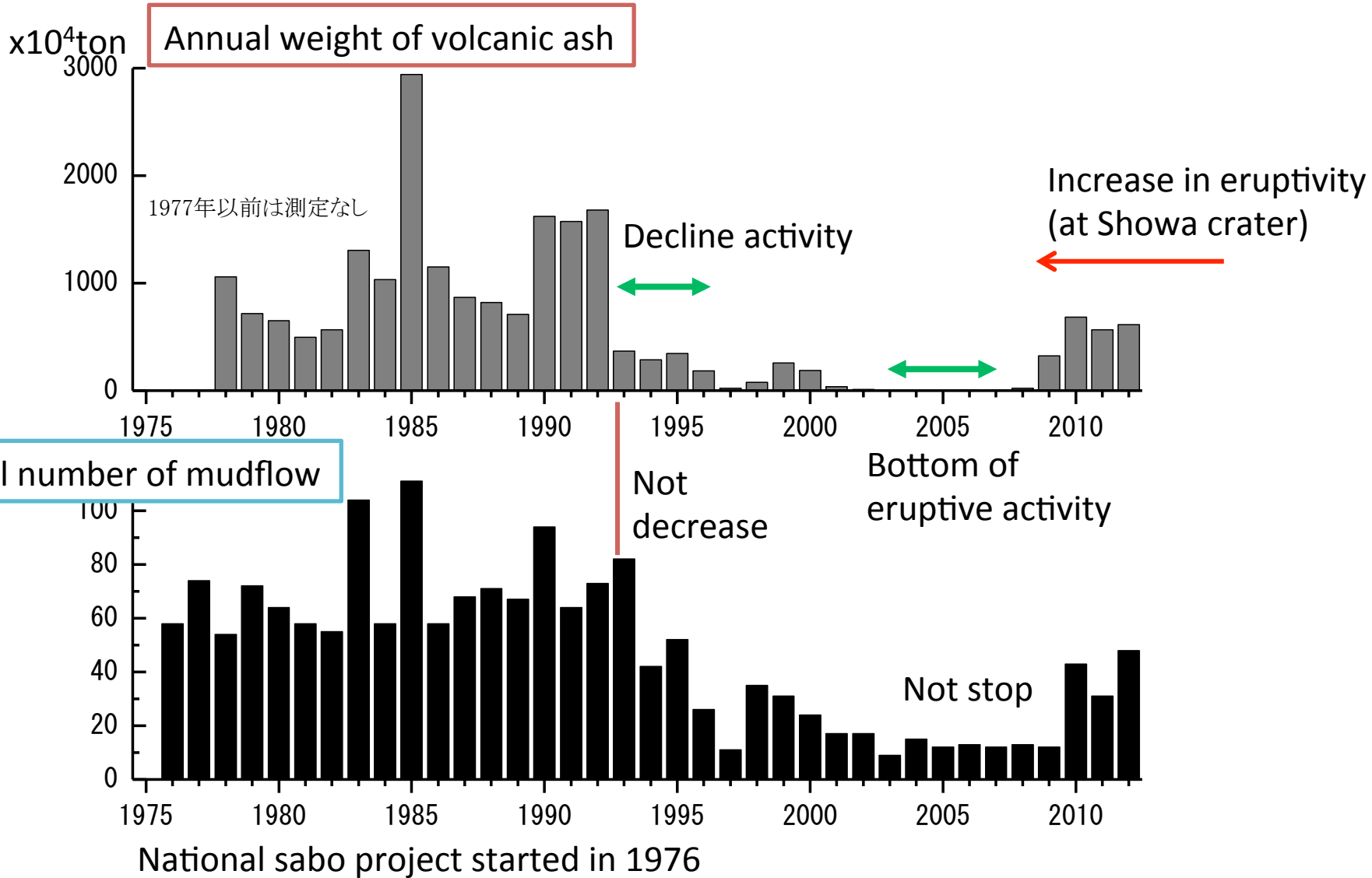


Felt earthquakes increased 1day before the 1779 eruption, too

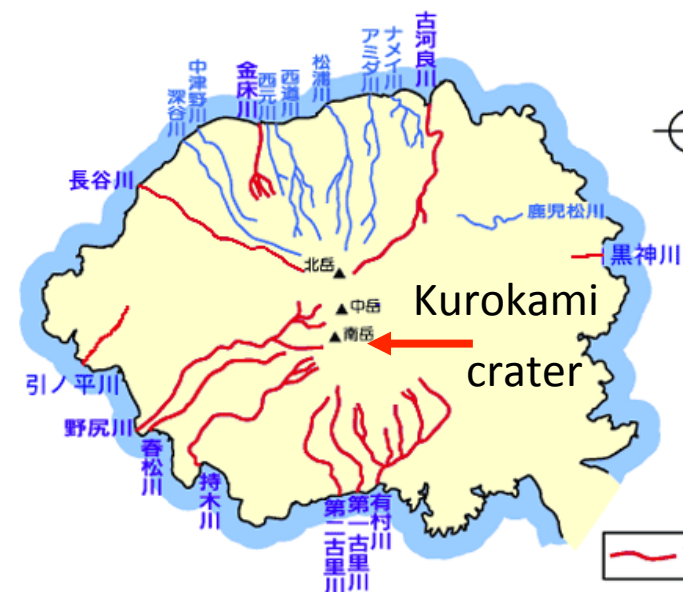
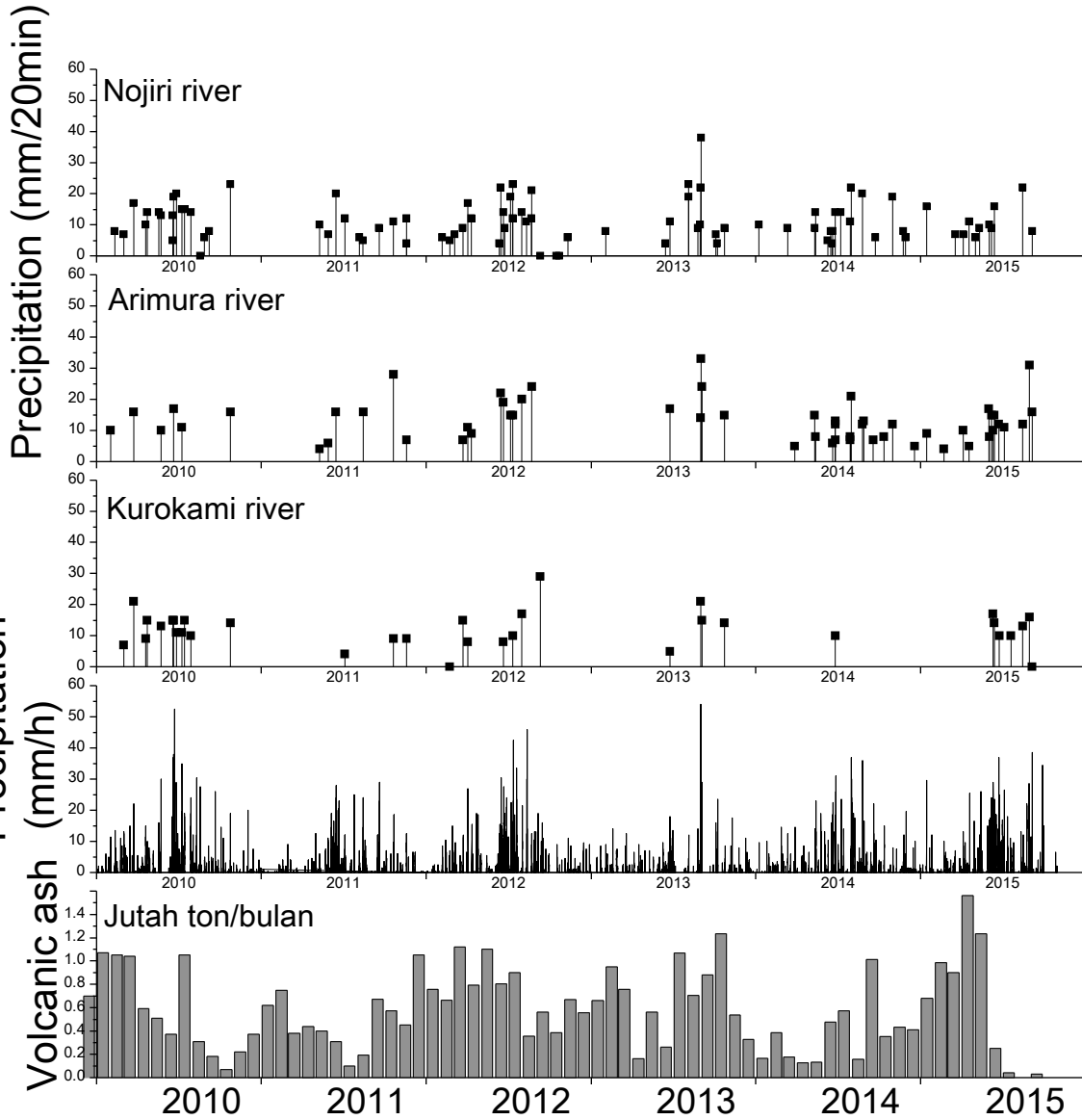
# Lahar of Sakurajima volcano

○ Frequency of mudflow depends of ejection rate of volcanic ash

○ Sediment disaster continued for longer time than volcanic eruption



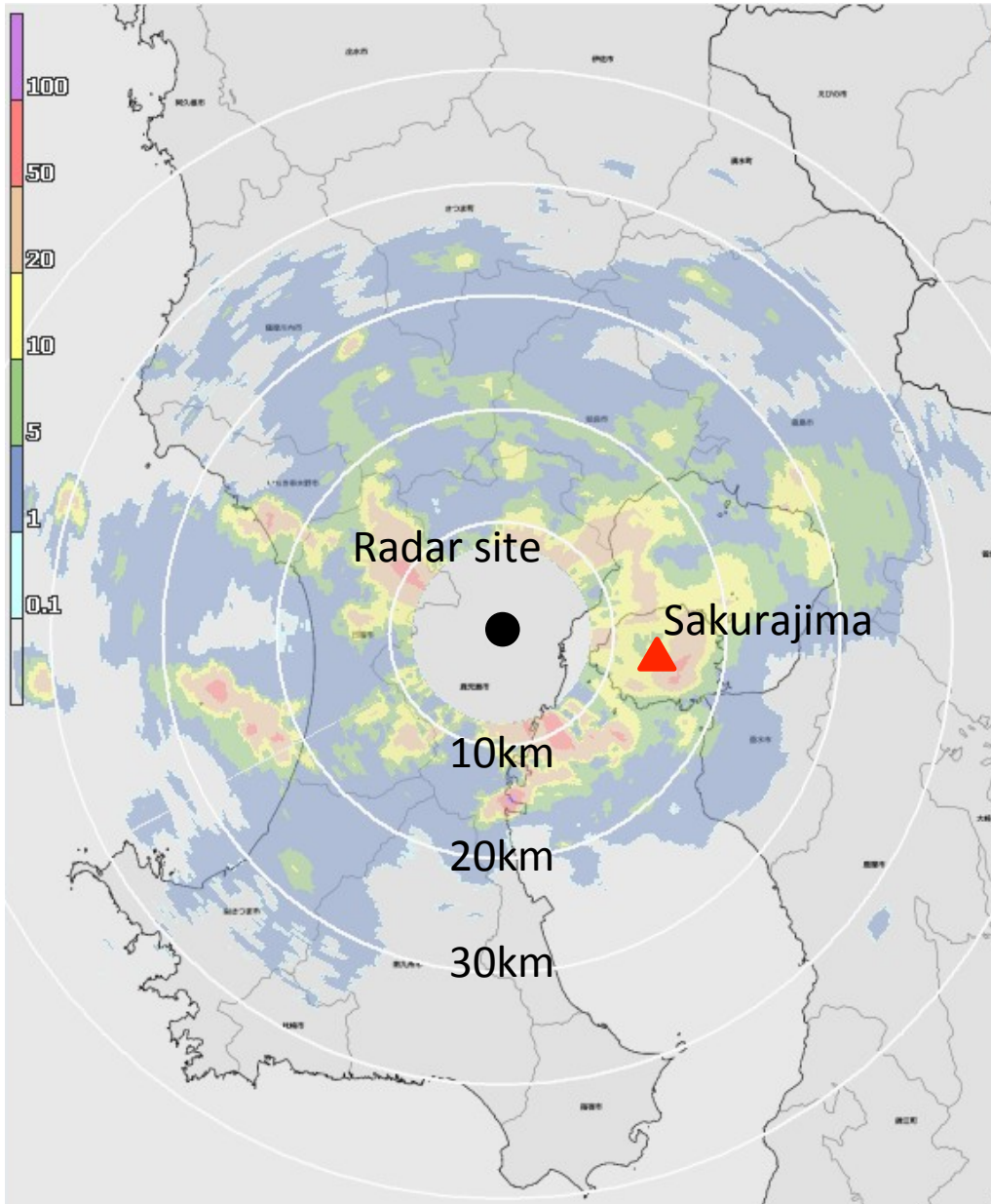
# Lahar of Sakurajima volcano after increase in volcanic ash ejection



Arimura  
Nojiri



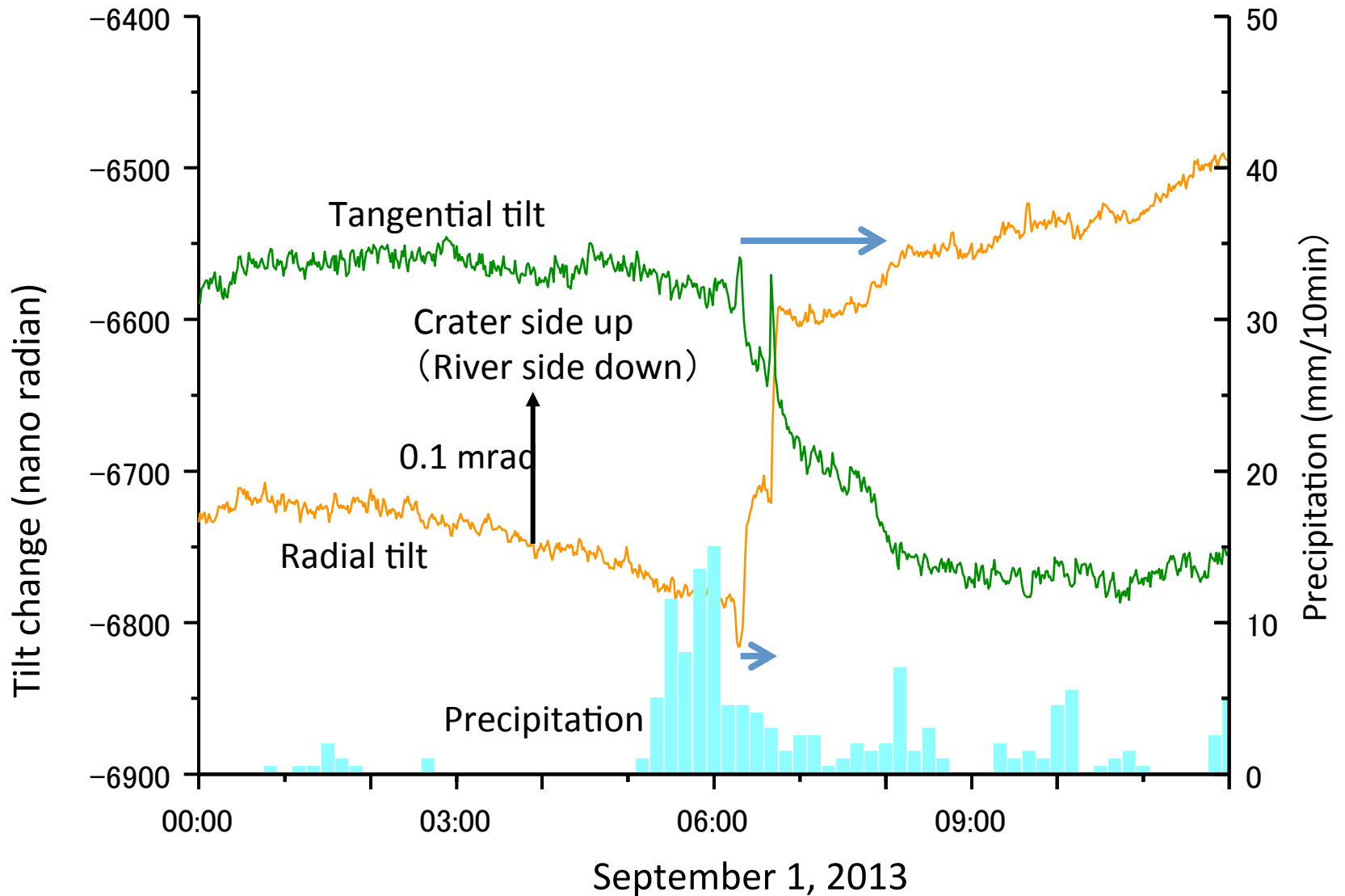
# X-band MP radar for Sakurajima



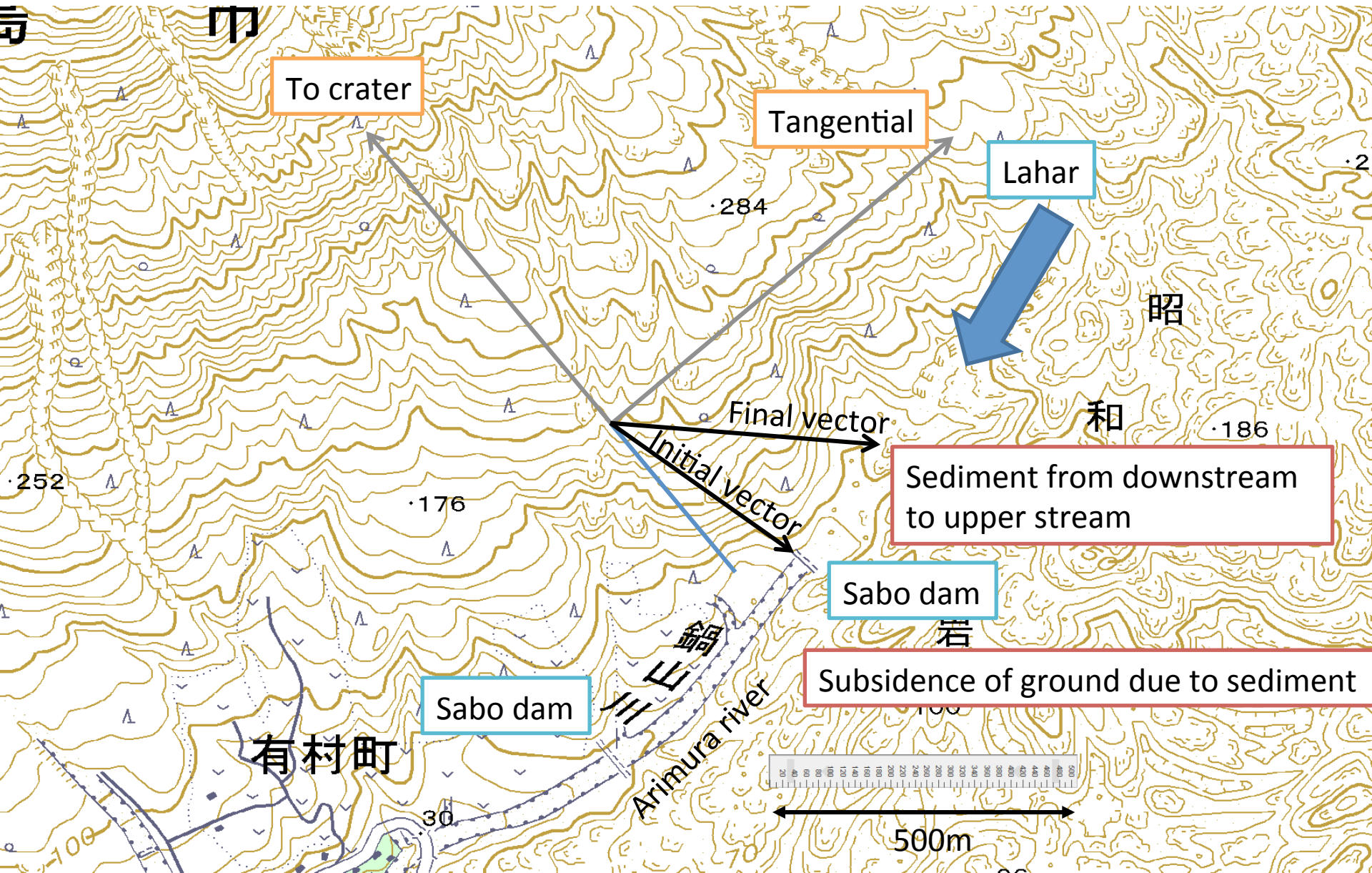
Radar site at Takeoka High School in Kagoshima city

# Tilt change due to lahar

Tilt change due to lahar is much bigger than that associated

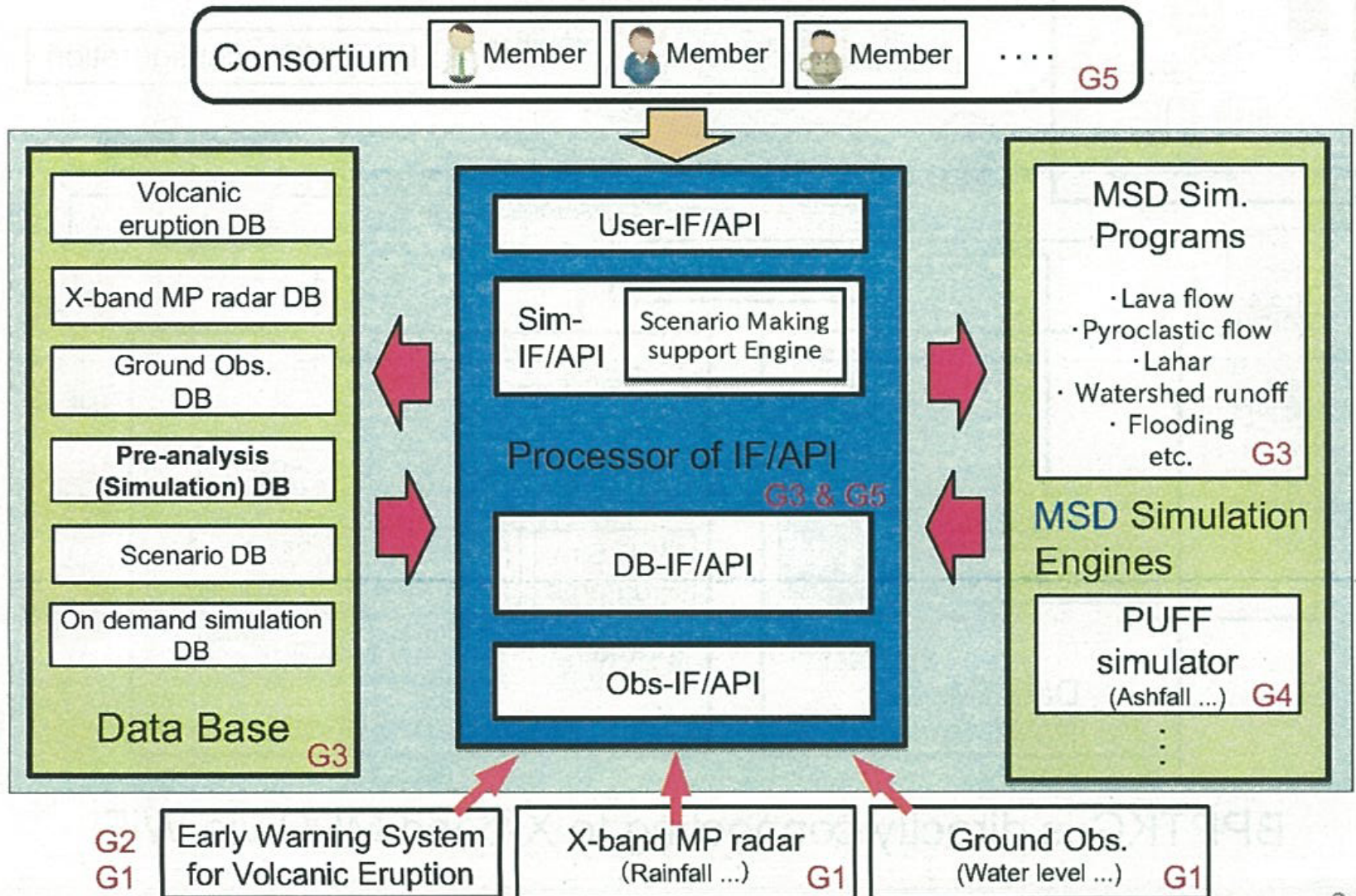


# Direction of downward tilt due to lahar



# Support system of decision making

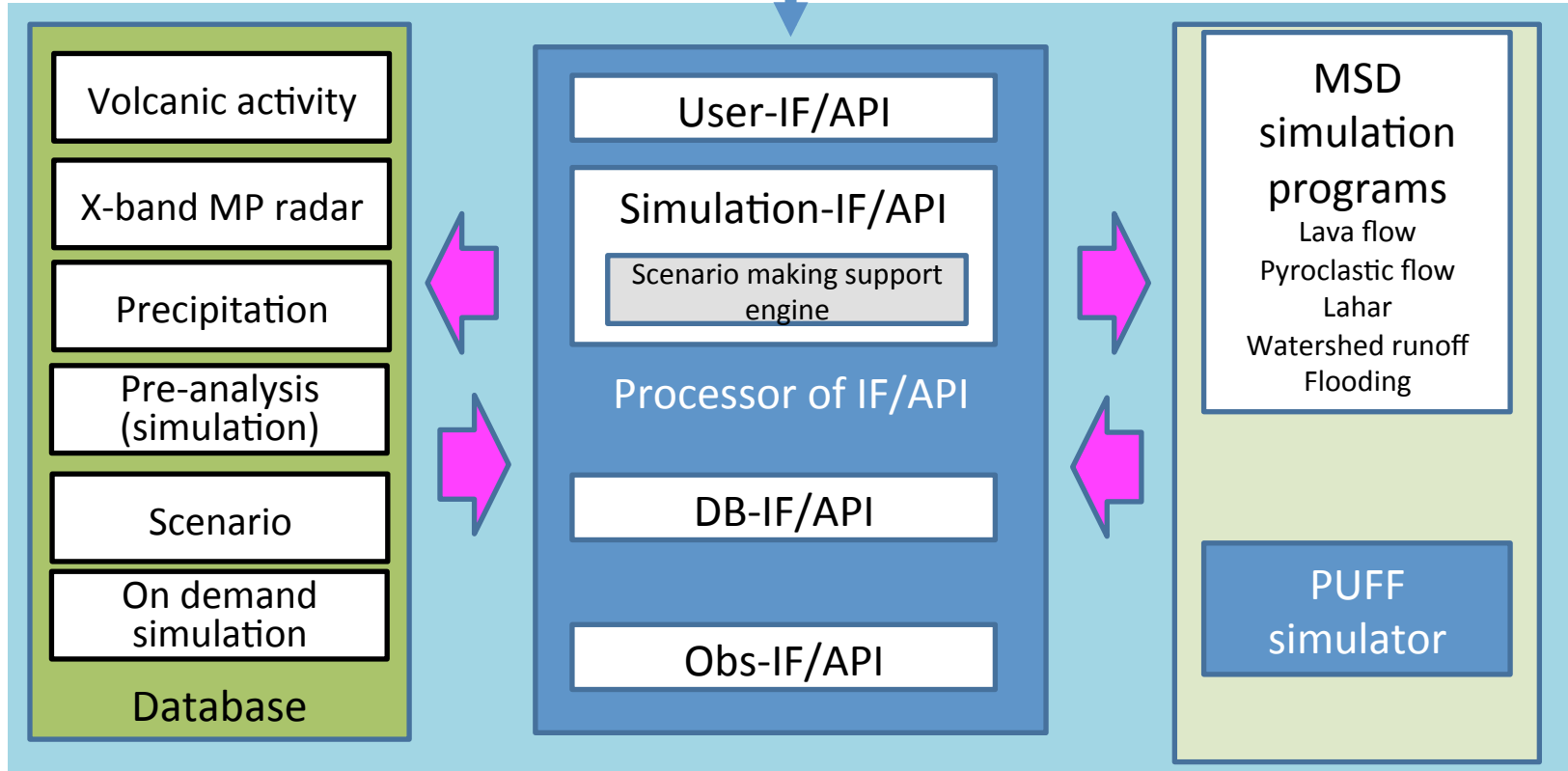
## Architecture of GIS-MSD Simulator



# Support system of decision making for Sakurajima volcano

University of Tsukuba

Install at Sakurajima Volcano Research Center



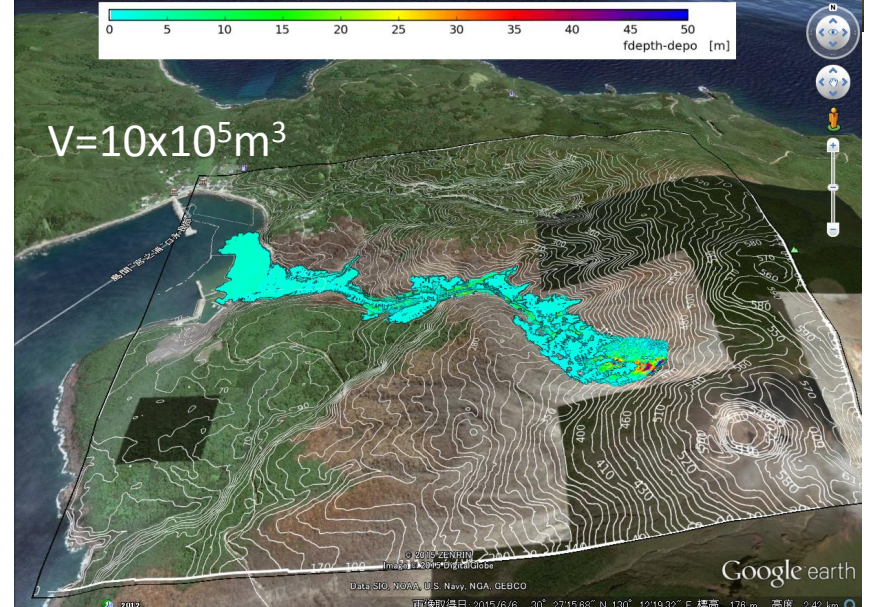
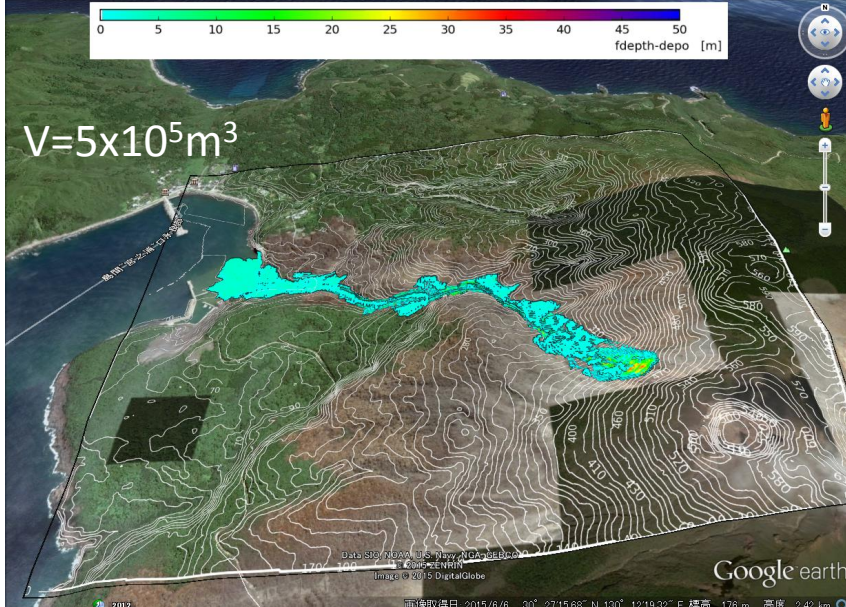
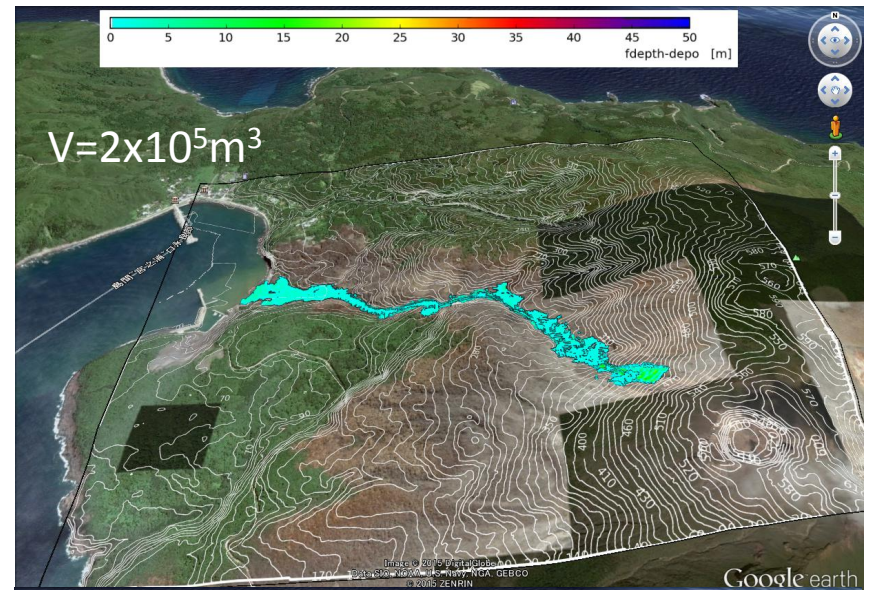
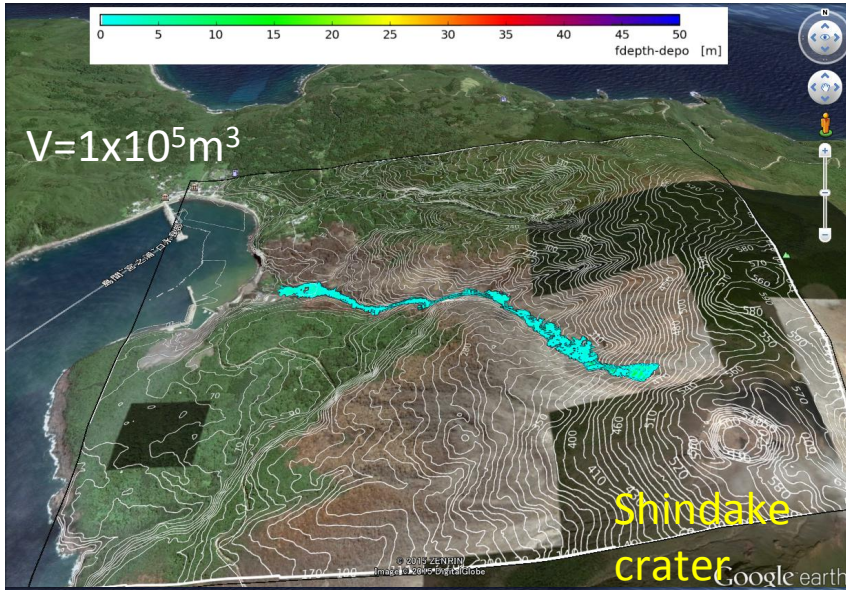
Seismic data  
Ground deformation

X-band MP radar

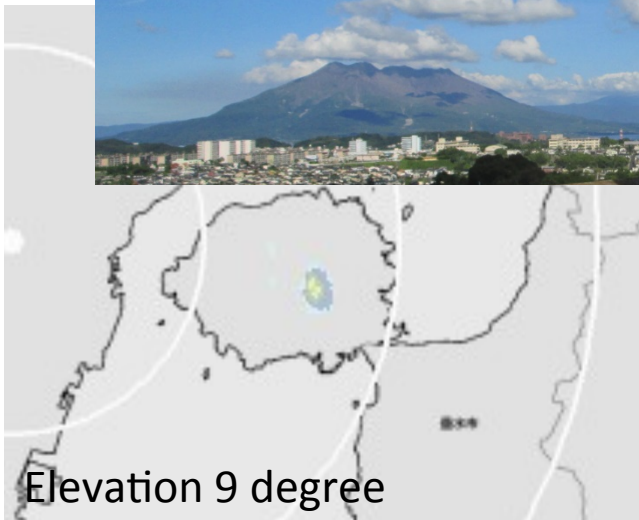
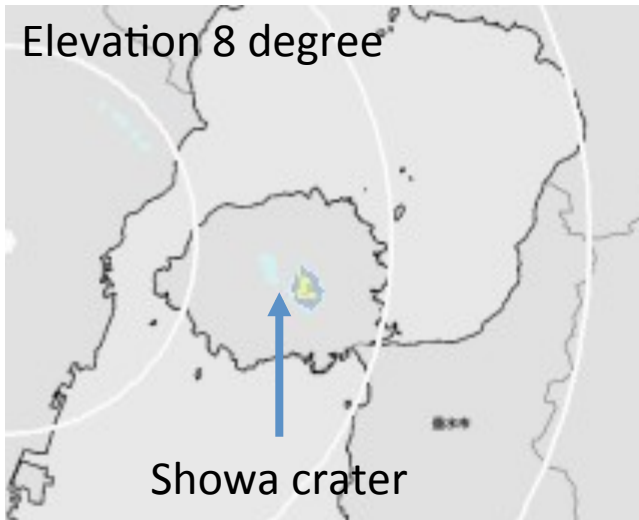
Precipitation  
Sediment (MLIT)

# Simulation of pyroclastic flow by SSDM

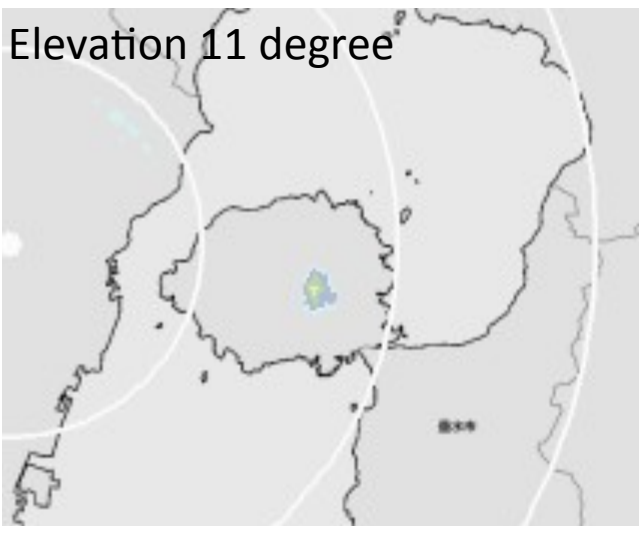
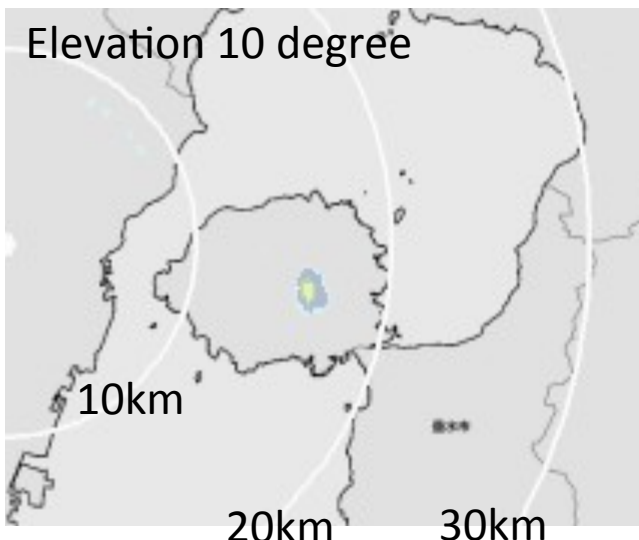
## Application to Kuchinoerabujima volcano



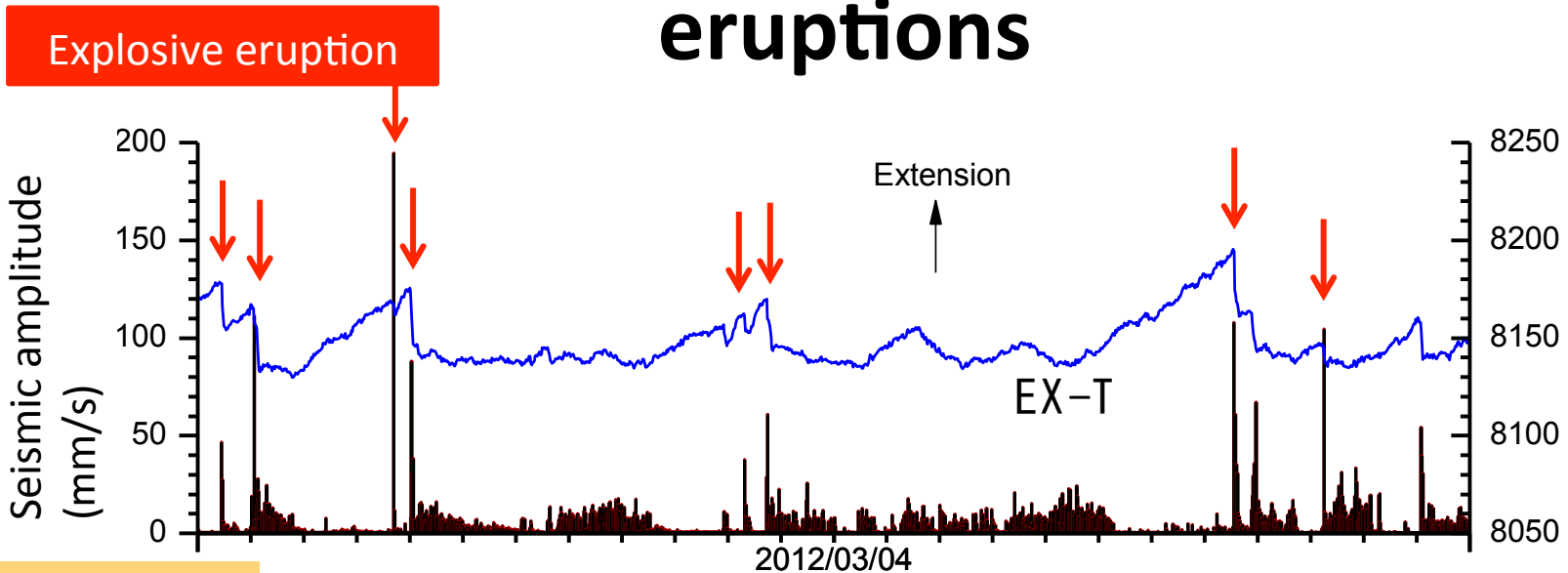
# Detection of volcanic ash cloud



08:18 April 18, 2015  
Height of volcanic cloud  
3300 m



# Explosive eruption and non-explosive eruptions



Non-explosive eruption

Volcanic tremor

Ground deformation

$$W = \alpha \sum_i^N A_i + \gamma + \beta \sum_i^N V_i$$

(g: correction)

$W$  : weight of volcanic ash (ton)

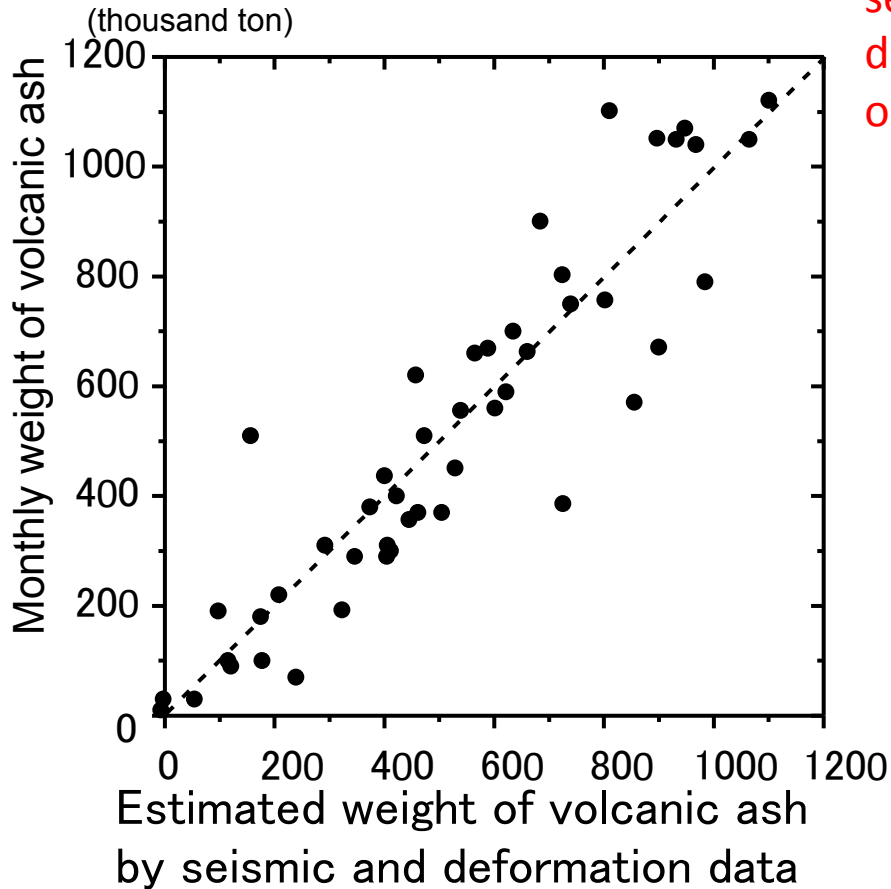
$A$  : power spectra of seismic tremor (2 – 3Hz)

$V$  : volume change of pressure source ( $\text{m}^3$ )

$$\alpha = 4.9 \times 10^{-4}, \beta = 2.6, \gamma = -11.3 \times 10^4$$

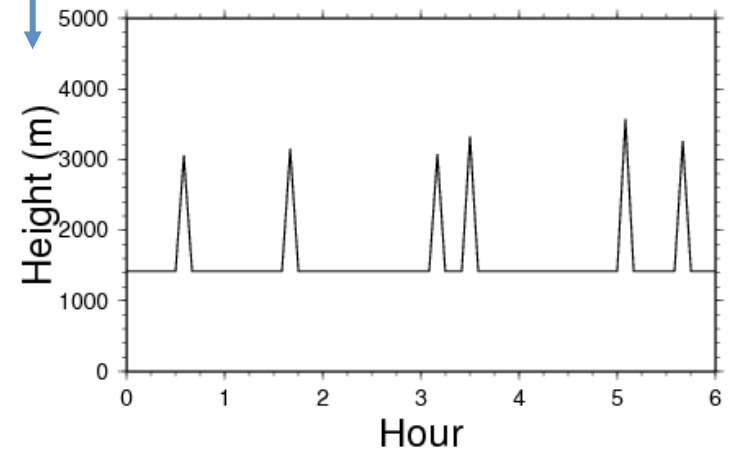
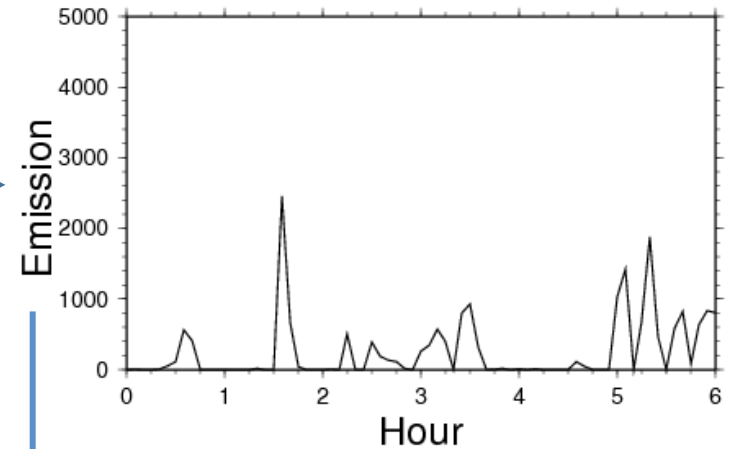


# Estimation of emission rate and volcanic plume height



seismic and ground  
deformation  
observations

Sakura-jima Emission (ton/5min)  
Start time: 2015/03/25 14:00 JST



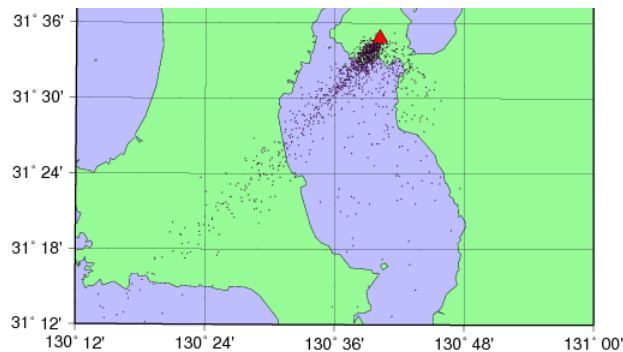
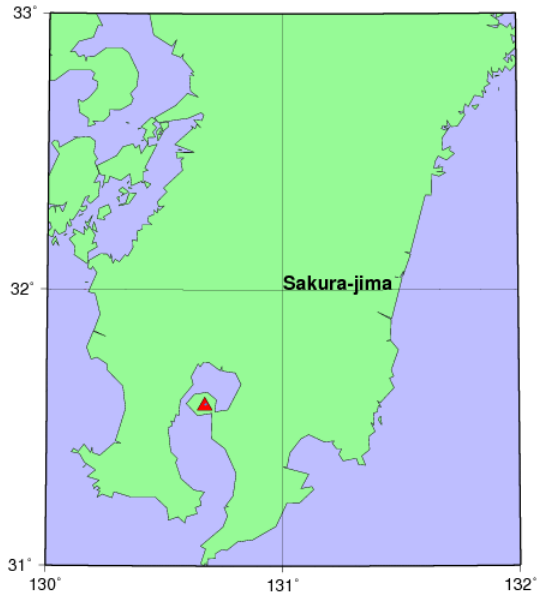
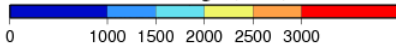
# Simulation of dispersion of volcanic ash by PUFF model

Sakura-jima

Start\_time: 2015/03/25 14:00 JST

Prediction: 14:00 JST

Plume Height (meter)

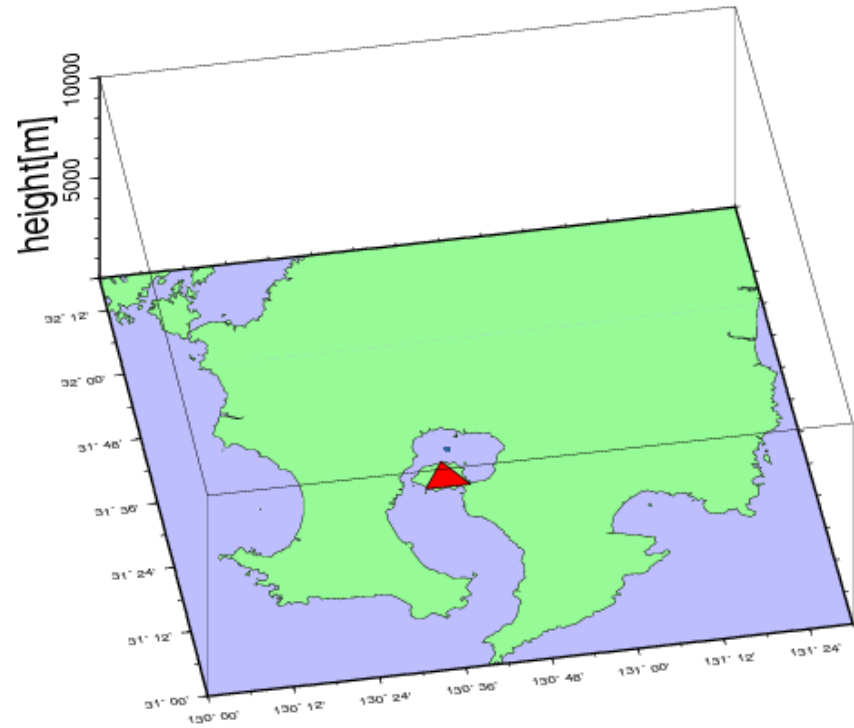


3-D image for Sakura-jima

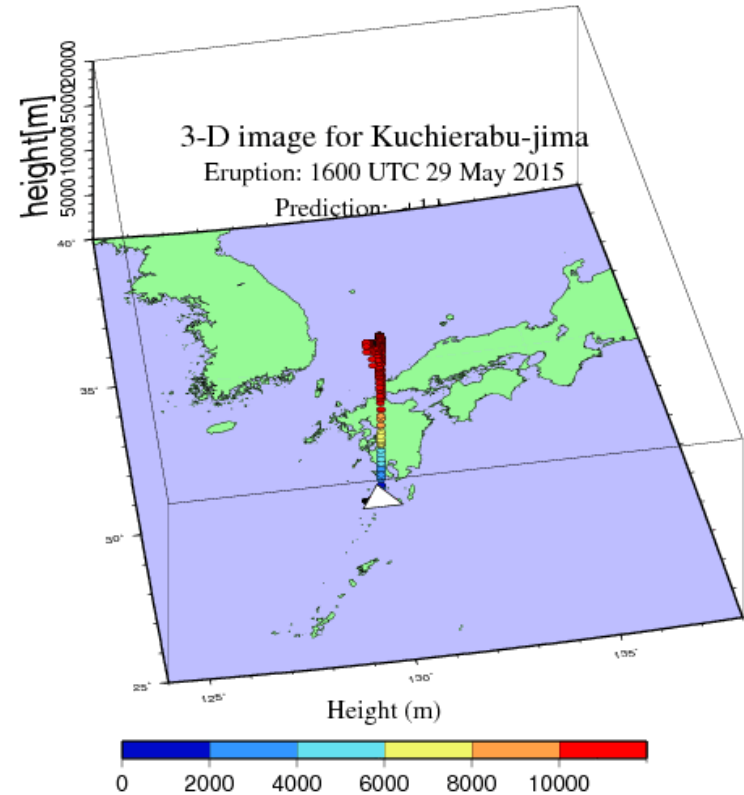
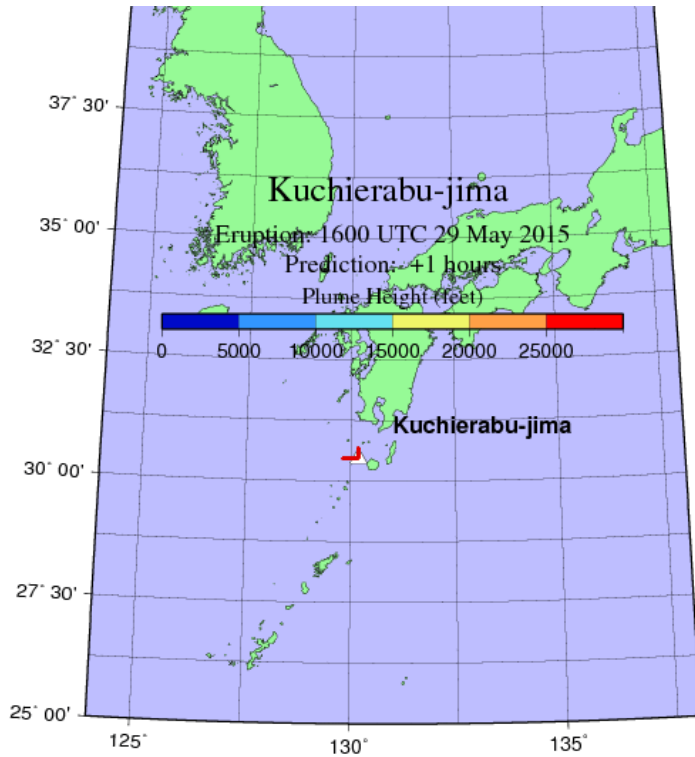
Start Time: 15/03/25 14:00 JST

Prediction: 14:00

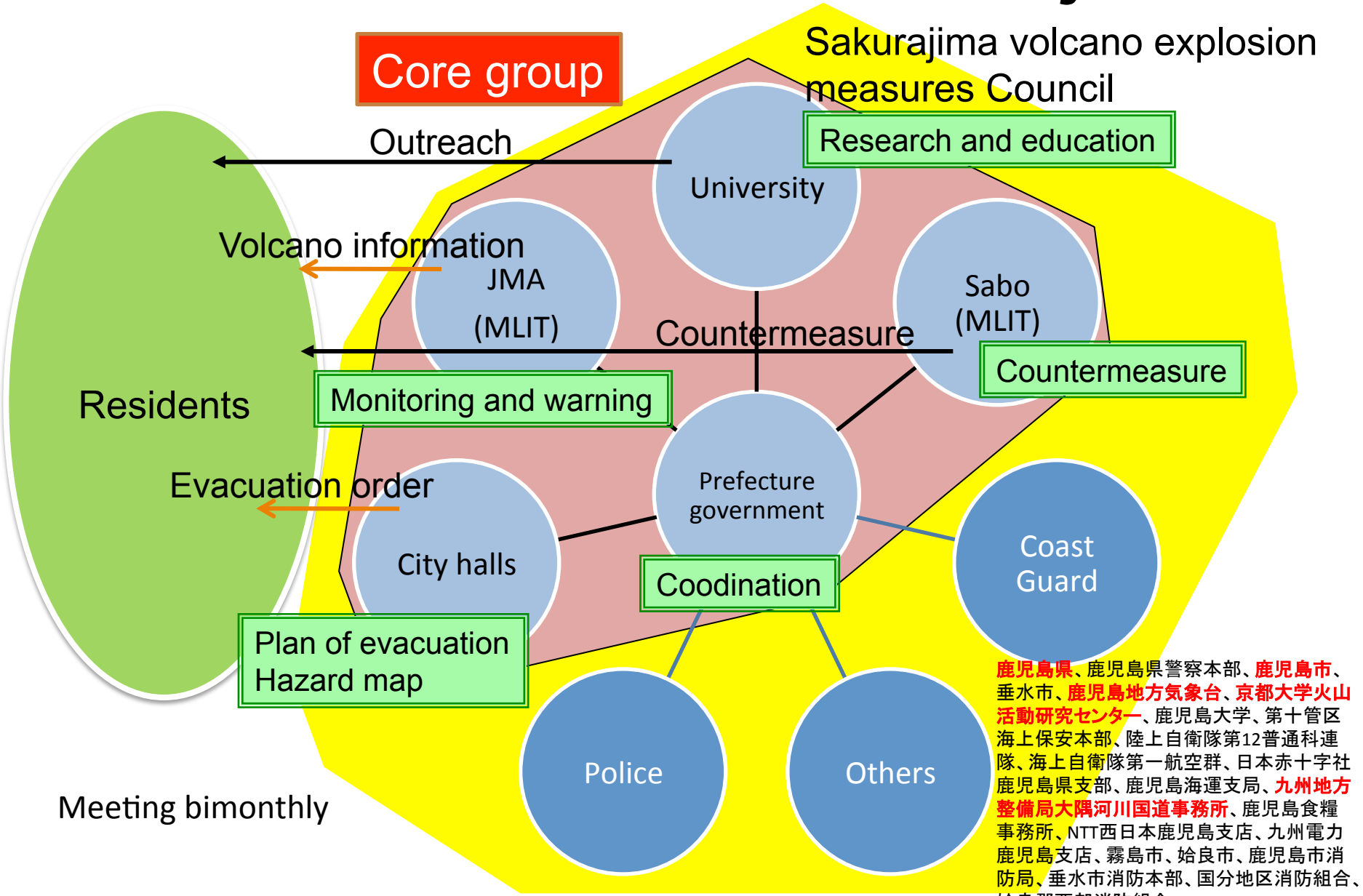
Height



# Simulation of dispersion of volcanic ash by PUFF model



# Volcano council for Sakurajima



鹿児島県、鹿児島県警察本部、鹿児島市、垂水市、鹿児島地方気象台、京都大学火山活動研究センター、鹿児島大学、第十管区海上保安本部、陸上自衛隊第12普通科連隊、海上自衛隊第一航空群、日本赤十字社鹿児島県支部、鹿児島海運支局、九州地方整備局大隅河川国道事務所、鹿児島食糧事務所、NTT西日本鹿児島支店、九州電力鹿児島支店、霧島市、始良市、鹿児島市消防局、垂水市消防本部、国分地区消防組合、始良郡西部消防組合



# Simulation of dispersion of volcanic ash by PUFF model

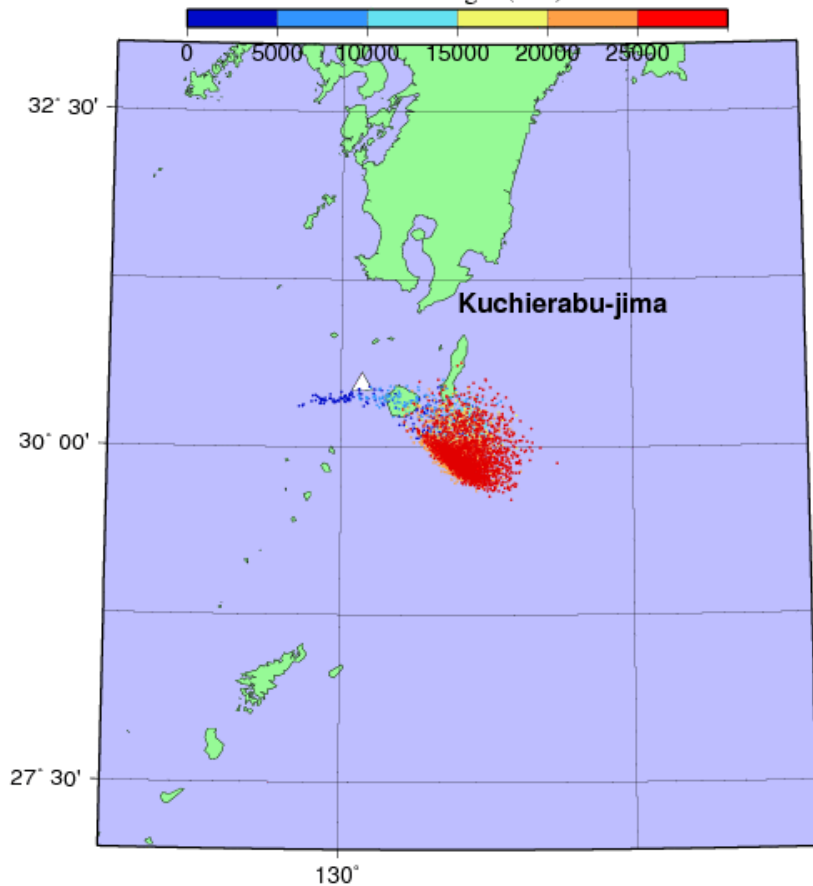
4 hours later

Kuchierabu-jima

Eruption: 1:00 UTC 29 May 2015

Prediction: +4 hours

Plume Height (feet)



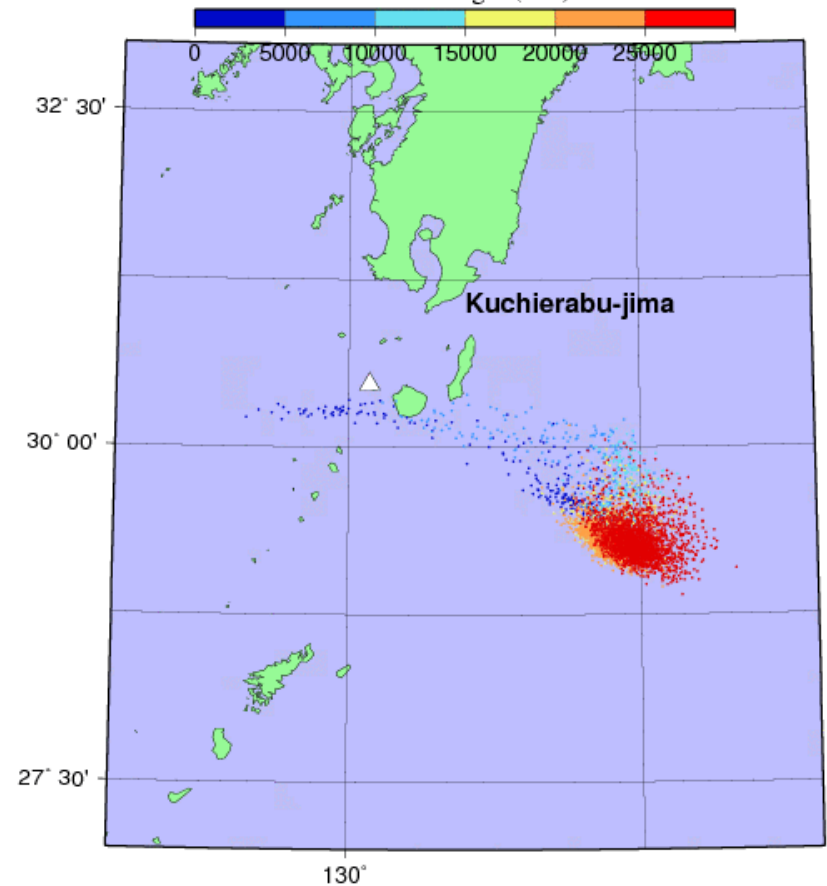
8 hours later

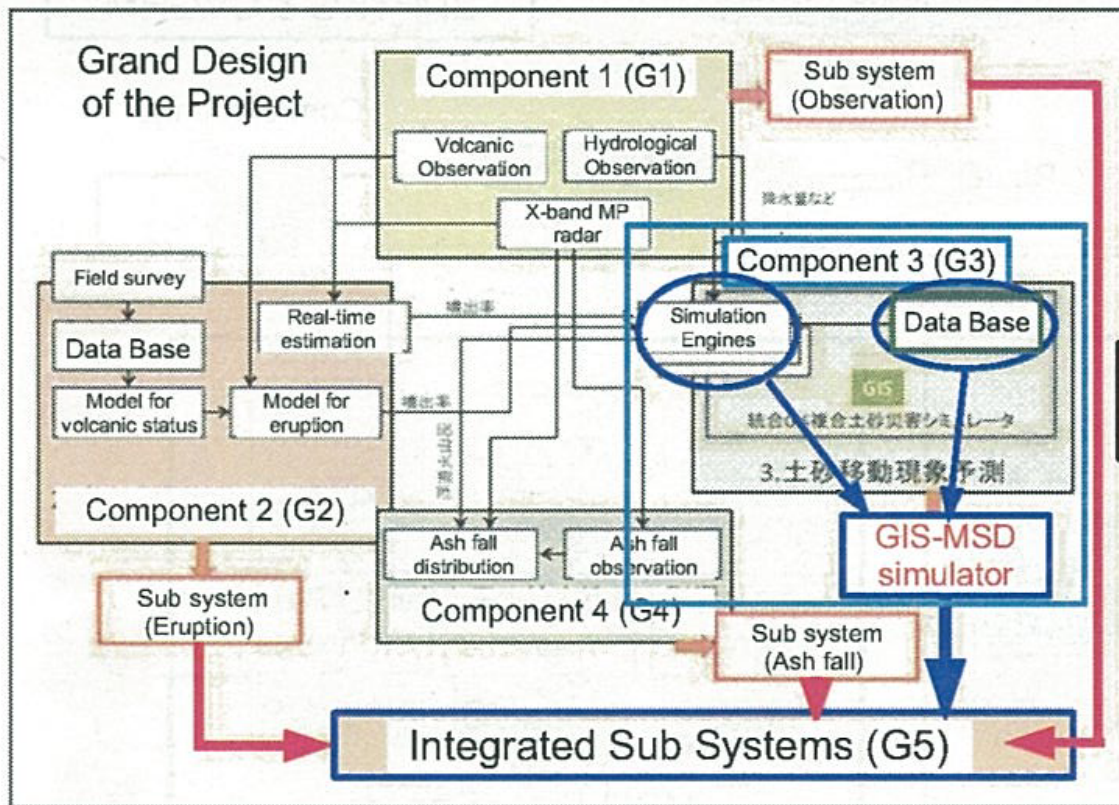
Kuchierabu-jima

Eruption: 1:00 UTC 29 May 2015

Prediction: +8 hours

Plume Height (feet)

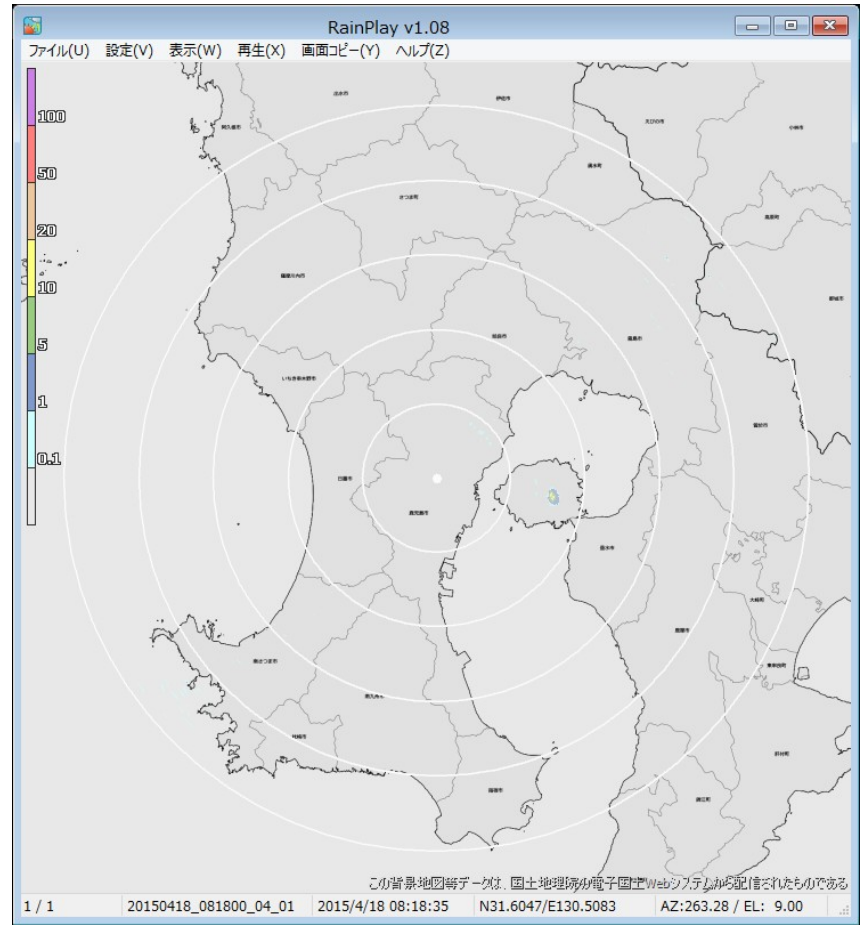
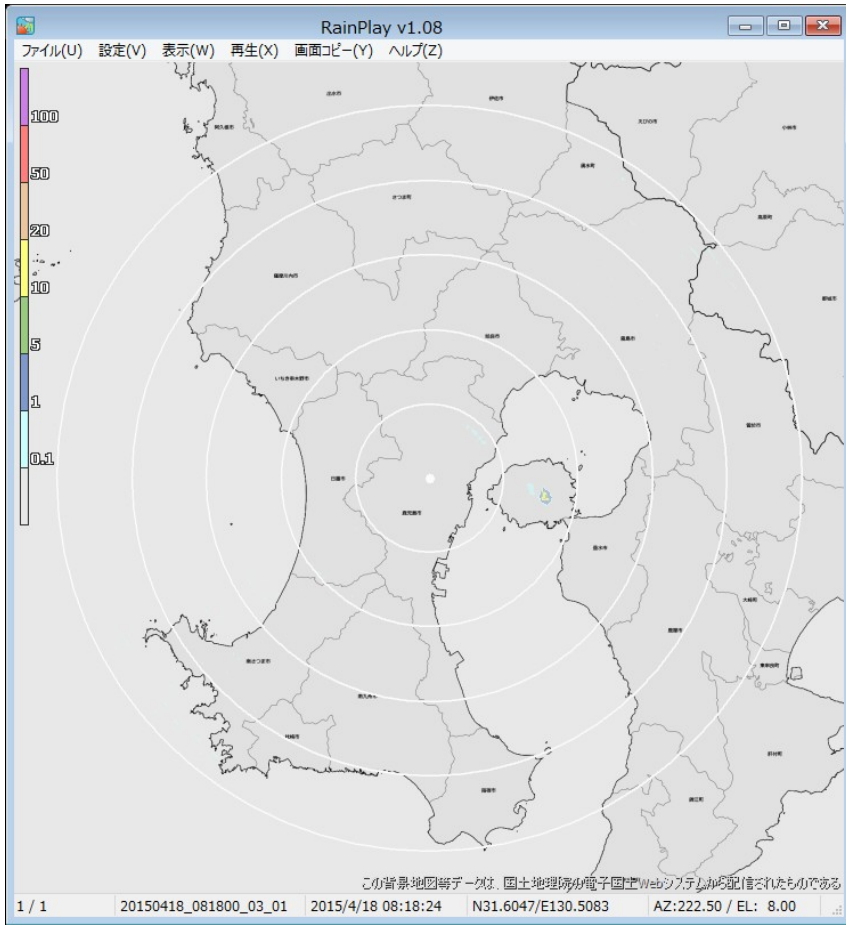




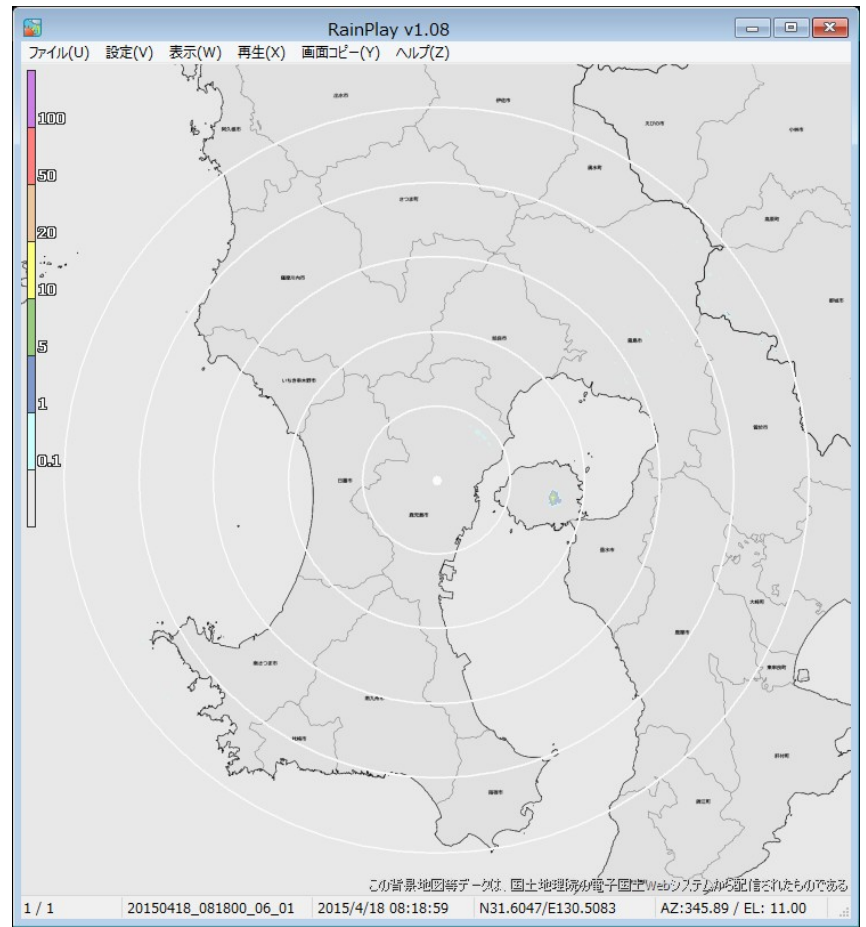
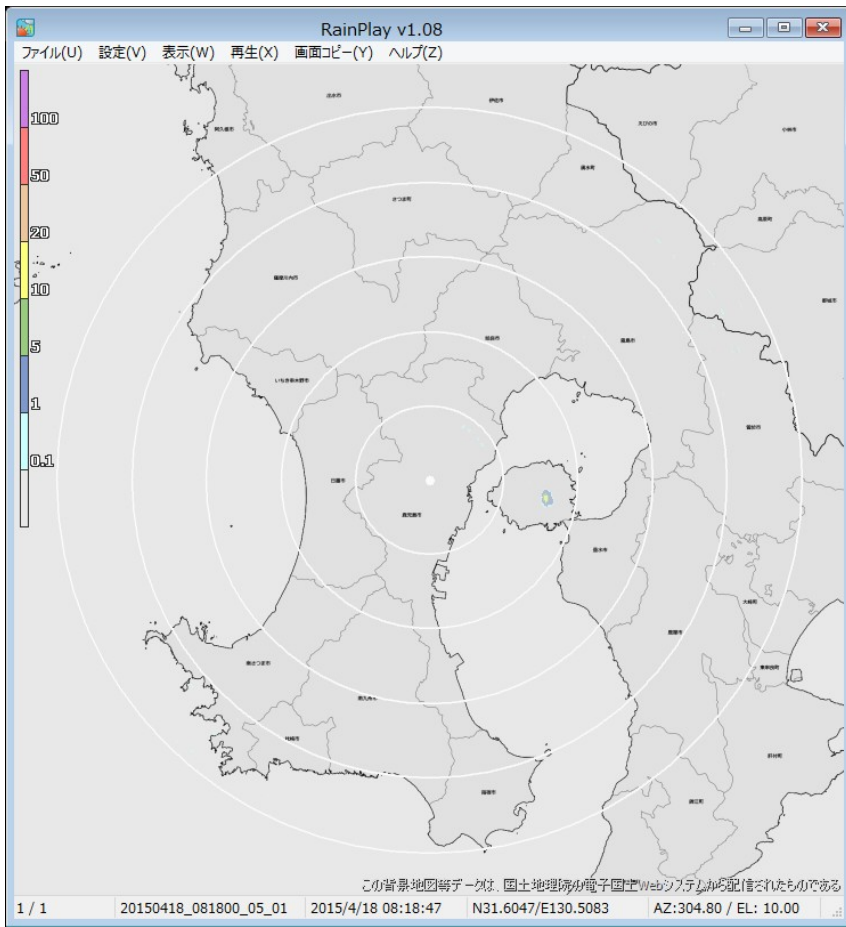
**Task of development Integrated system**

Develop. DataBase  
Develop. InterFace

(Modified [http://www.svo.dpri.kyoto-u.ac.jp/indonesia-vs/project\\_s/project-flow/](http://www.svo.dpri.kyoto-u.ac.jp/indonesia-vs/project_s/project-flow/))







# Support system of decision making (SSDM)

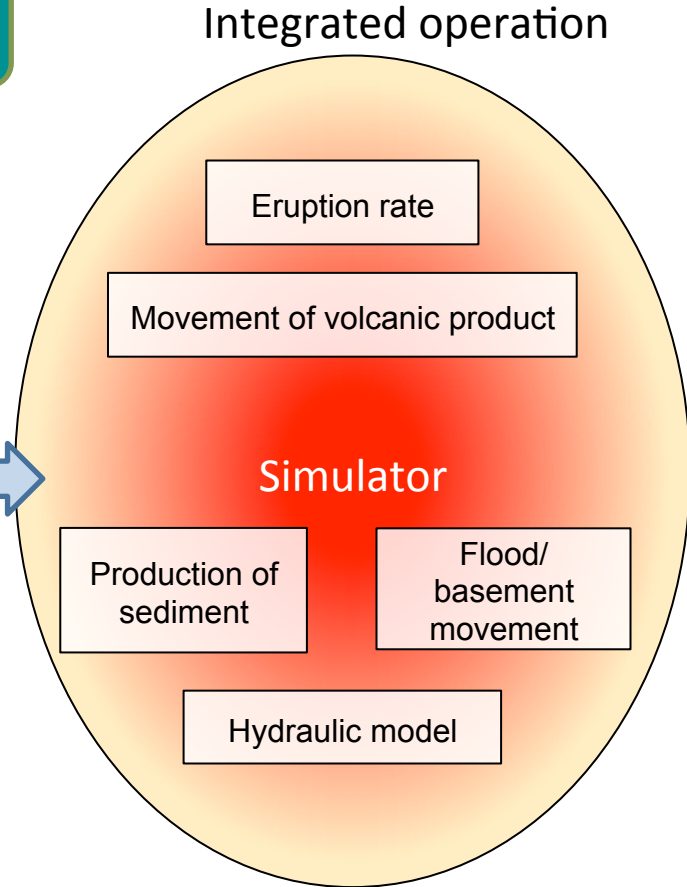
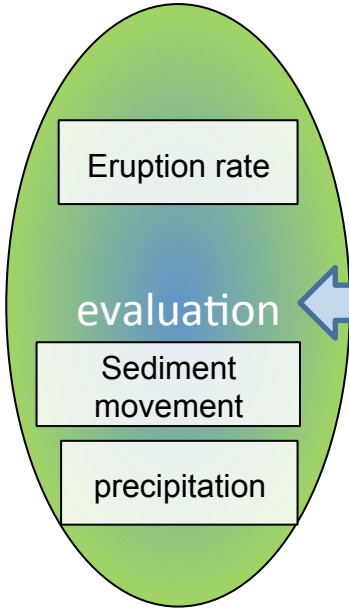
National and local governments,  
community

↕ bilateral

Google Earth, text  
Communication engine

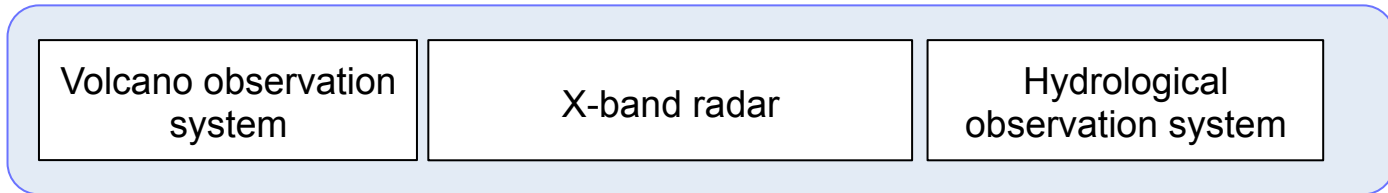
GIS database  
(GRASS & Q-GIS)

scenarios | Social data



Real-time data analysis

↕



Simulation for forecasting