Volcano monitoring as a strategy to reduce risk due to volcanic eruption

Objectives

- Understand how geologists monitor volcanoes.
- Understand what data indicate a volcano is awakening from dormancy, and what data indicate that an actual eruption is imminent.
- Understand what factors determine whether volcano monitoring can be effective in mitigating risk to people and property.

Prework

Monitoring volcanoes

- Ground Deformation

  http://www.youtube.com/watch?v=sNYQkxxd_0Q

  – Tilt (tiltmeters)
  – High precision GPS
    - Movement of stations
    - Baseline length changes

- Seismicity

  http://www.youtube.com/watch?v=nlo-2JoNHrw

- Gas Emission

  http://www.youtube.com/watch?v=owk4fWbw4qM

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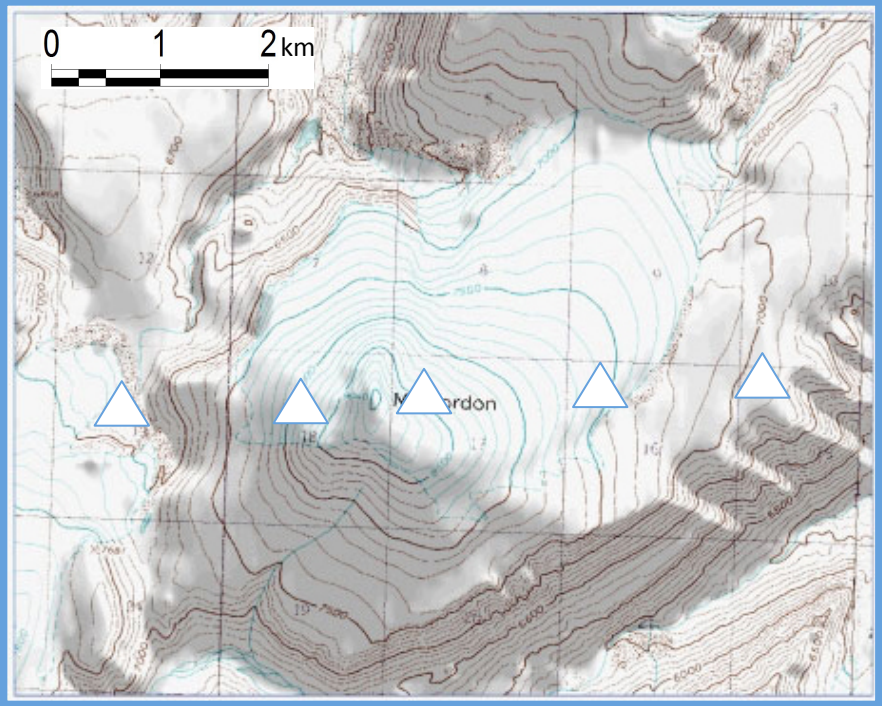
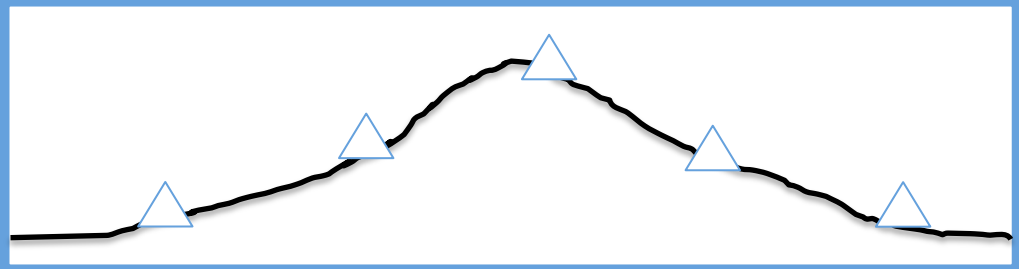
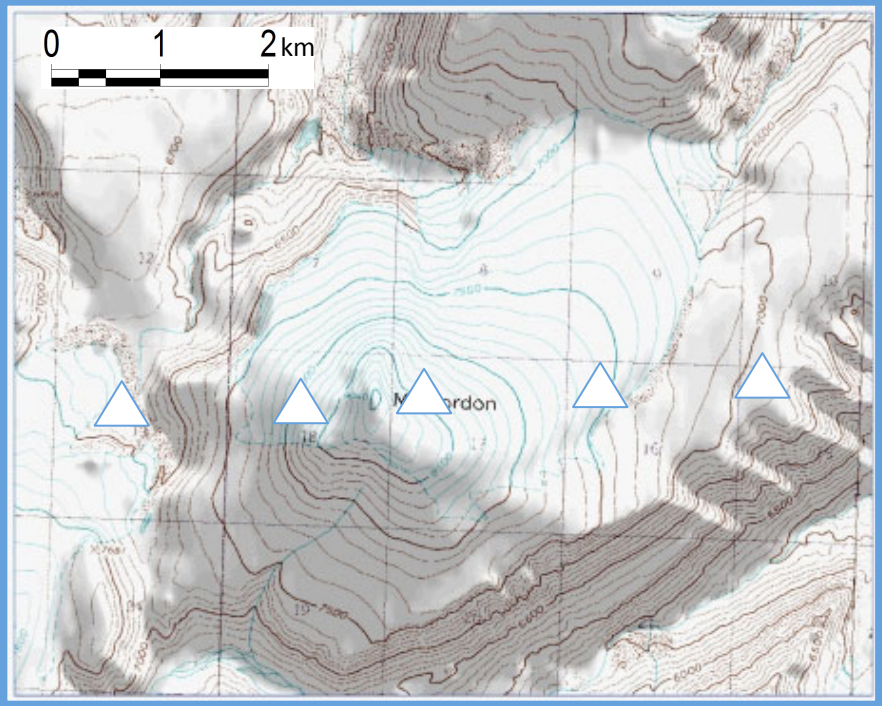
Thought experiment

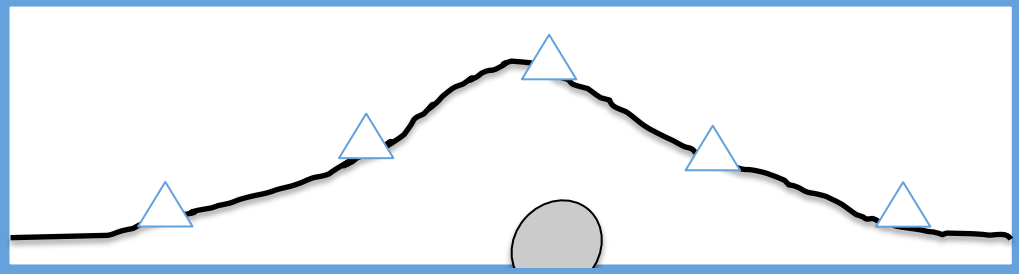
A volcano, with five GPS stations on the surface of the volcano (blue triangles) that continually record their locations.



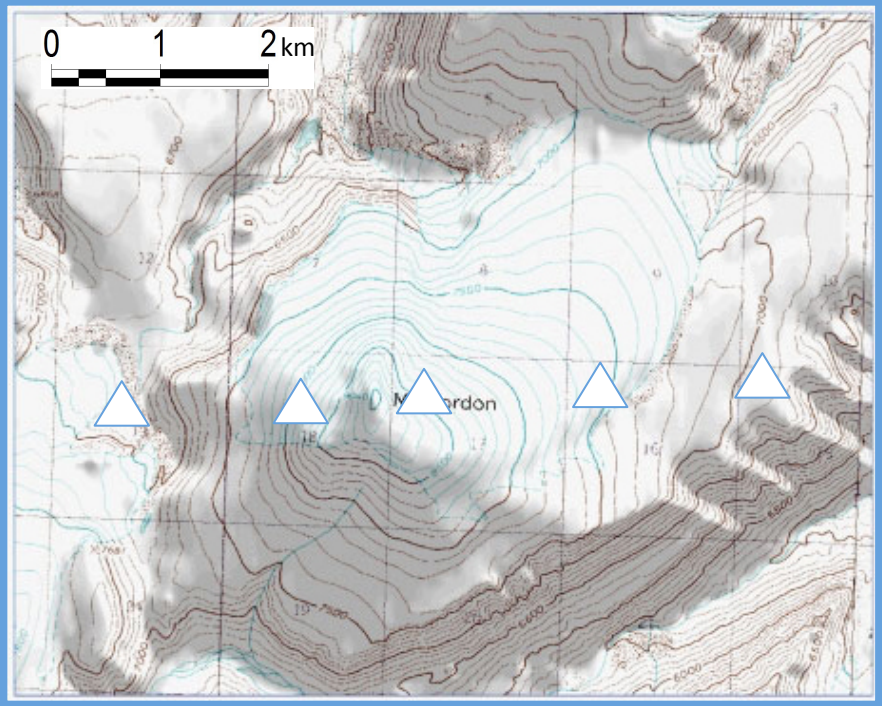


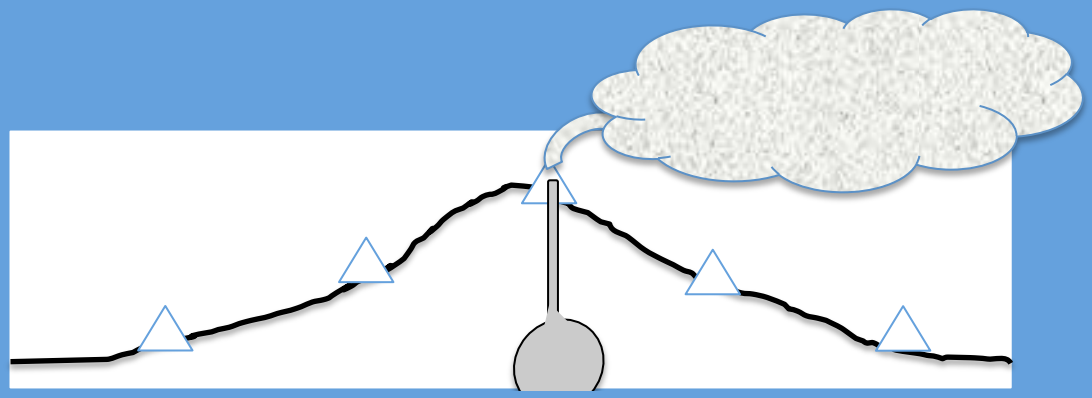
1. Imagine that a body of magma intrudes below the summit of the volcano, *without* erupting. Predict how the GPS stations will move.



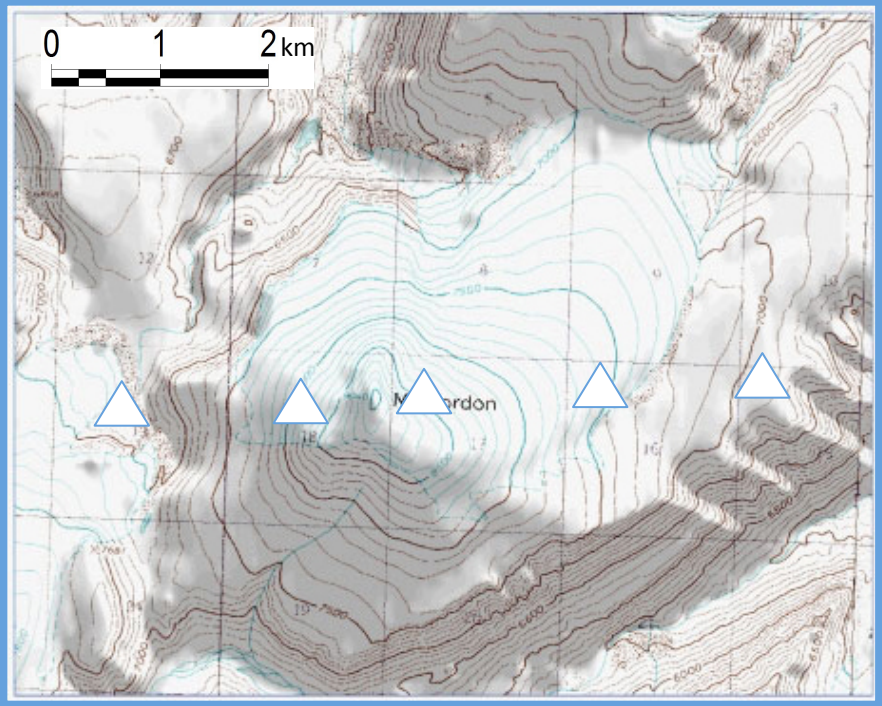


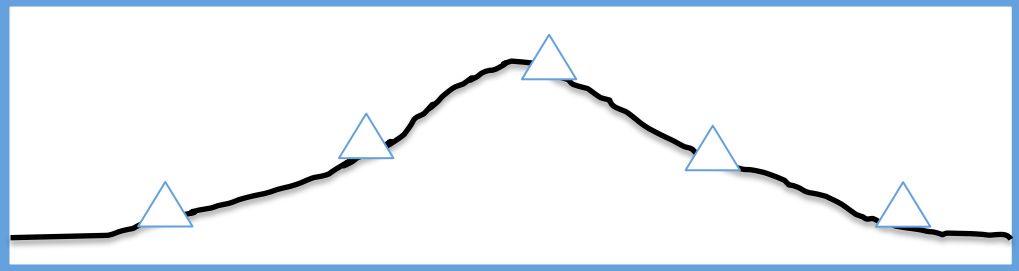
Eruption!





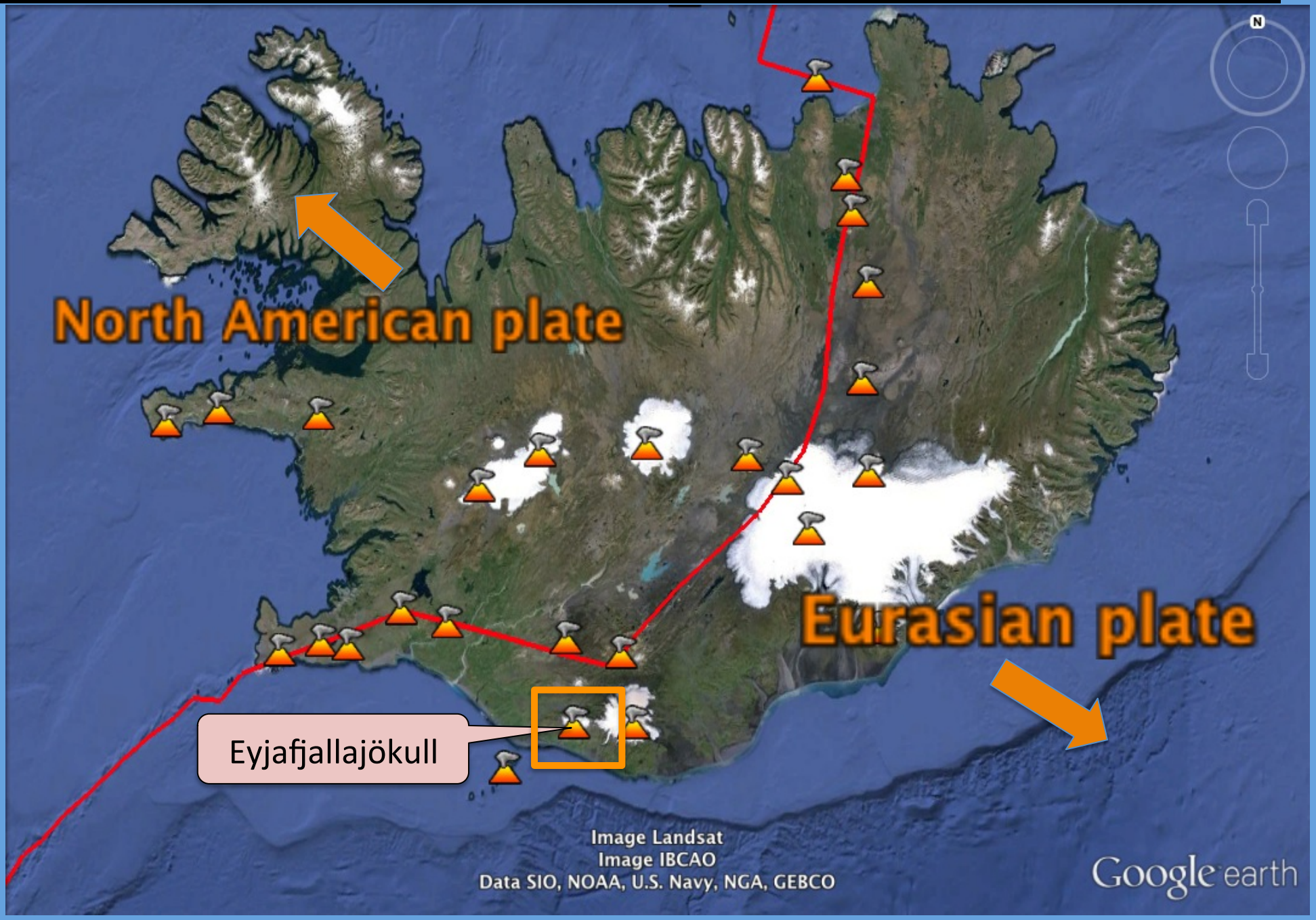
2. The eruption is over. Predict how the GPS stations will move.





Part 2: Mitigating the Risk

Anatomy of an eruption – 2010 events at Eyjafjallajokull



Eyjafjallajökull

2010 eruption of “Island Mountain Glacier”

(term actually refers to the ice cap atop the volcano)

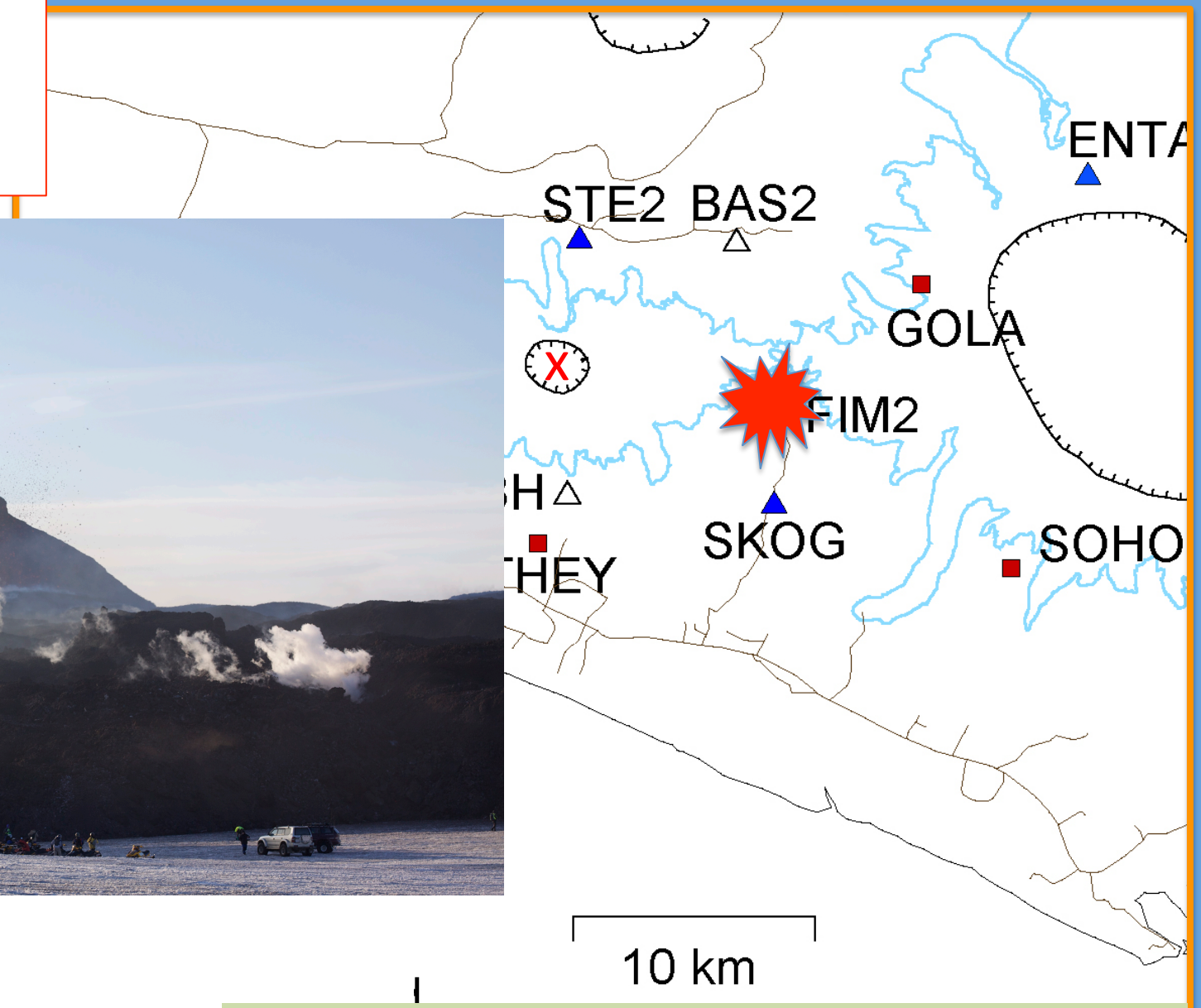
Date of photo:
March 25, 2006

Last active:
1821-1823

Before 2009, the area had been seismically quiet for 13 years, and ground motion was stable. In 2009, small earthquakes began to be detected underneath the volcano.

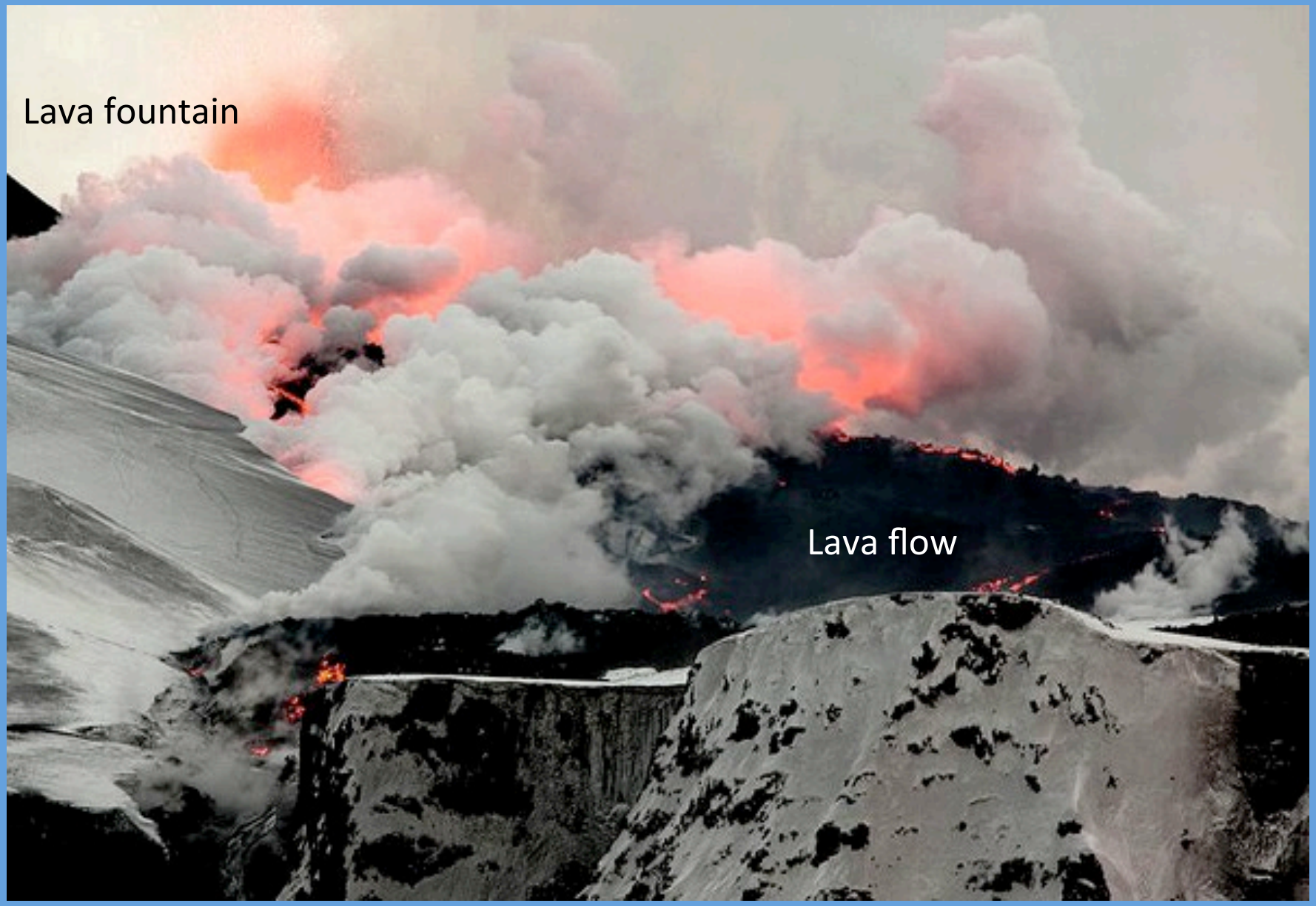
DURING THE ERUPTION

March 20: Eruption!



Non-explosive eruption begins:

Fissures open on flank 10 km east of summit, with lava fountaining and lava flows.


Lava fountain
Lava flow

DURING THE ERUPTION

April 14:
More eruption!

Eruption migrates to summit, with much greater explosivity and volume!

April 17

Air travel over Europe shut down for six days; 95,000 flights cancelled.

Explosive phase April 14-May 24

- **April 14-20** 250 meters of the ice cap melted in 4 hours, and interaction with meltwater caused explosive activity and produced lots of ash. Glacial meltwater destroyed roads, including the major coastal highway, and caused evacuations.
- **April 20-May 3** Lava flow in northern part of the glacier melted ice sufficient to form a 150m-deep ice depression at the surface.
- **May 4-May 18** Most vigorous explosive phase, producing >30 kilotons of SO_2, 150 kilotons of CO_2 and a huge ash plume up to 10km high that stratospheric winds carried across Europe.
- **May 19-May 24** Eruption waned and plume gradually declined. Volcanic gas emissions slowed until the eruption stopped.

https://www.geolsoc.org.uk/Geoscientist/Archive/April-2011/Online-Special-Rock--ice-Eyjafjallajkull-and-Climate-Change

Eruption Consequences

- European airspace disrupted; shut down completely for 6 days; ~95,000 flights cancelled. $2 billion lost by airlines.
- Travel, commerce, tourism disrupted worldwide.
- 800 people, and dozens of farms evacuated (and in some cases abandoned due to fluorine-containing ash, poisonous to grazing animals).
- Damage to roads by glacial floods.
- Silting up and and subsequent dredging of rivers.
- No deaths, injuries or ash-related illnesses

Preparedness/Response

The Icelandic Meteorological Office (IMO) http://en.vedur.is/ monitors weather, earthquakes, volcanoes, stream flow, and avalanche conditions.

During Eyjafjallajokull events, the IMO worked closely with the

- Civil Protection Department (CPD) of the National Commissioner of the Icelandic Police
- Institute of Earth Sciences at the University of Iceland
- London Volcanic Ash Advisory Centre of the British Meteorological Office

These agencies cooperate to:

- Monitor, collect and analyze data
- Issue timely warnings
- Put emergency/crisis procedures and action plans into action

Monitoring volcanoes

- Ground Deformation
  - Tilt (tiltmeters)
  - High precision GPS
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- Seismicity
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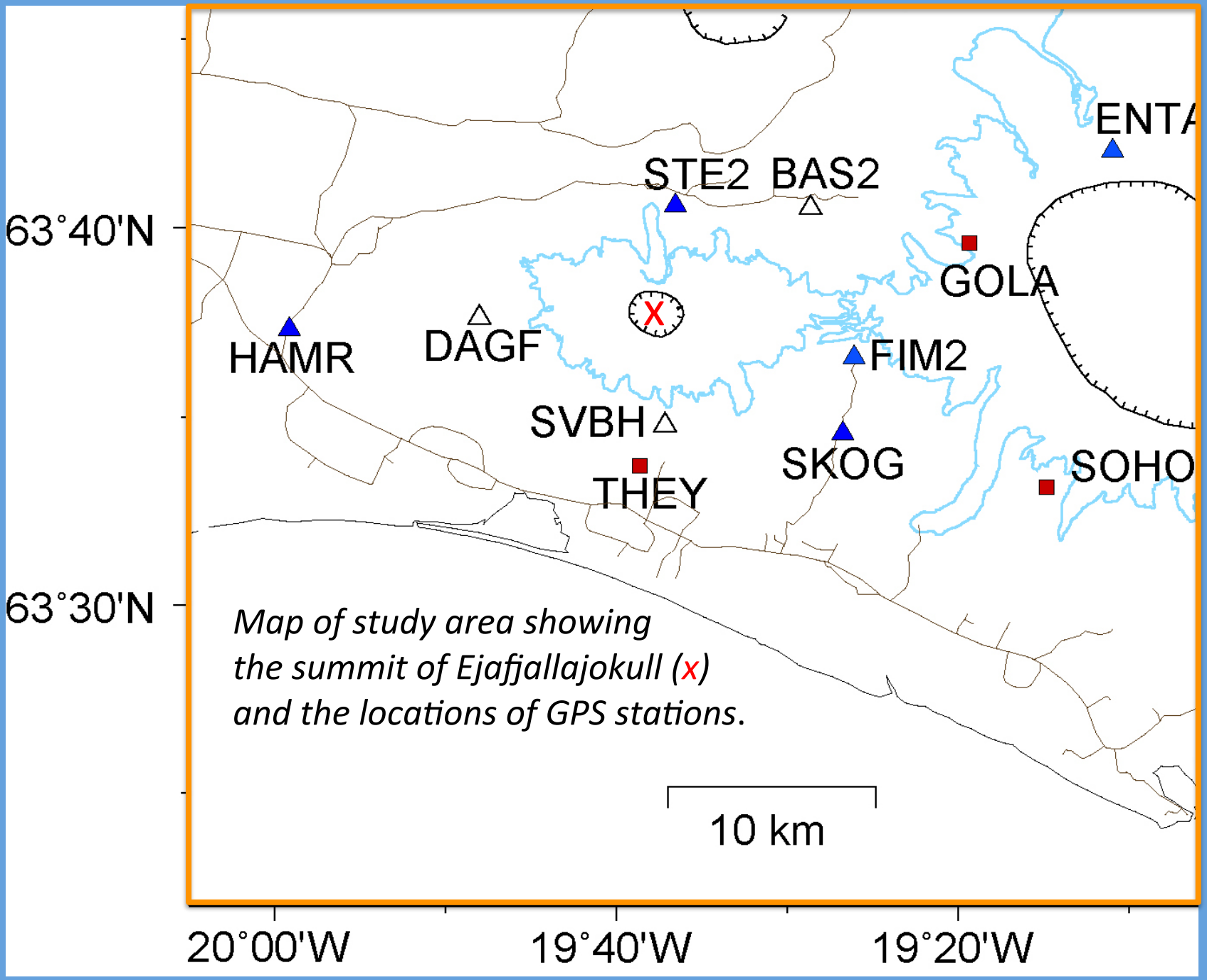
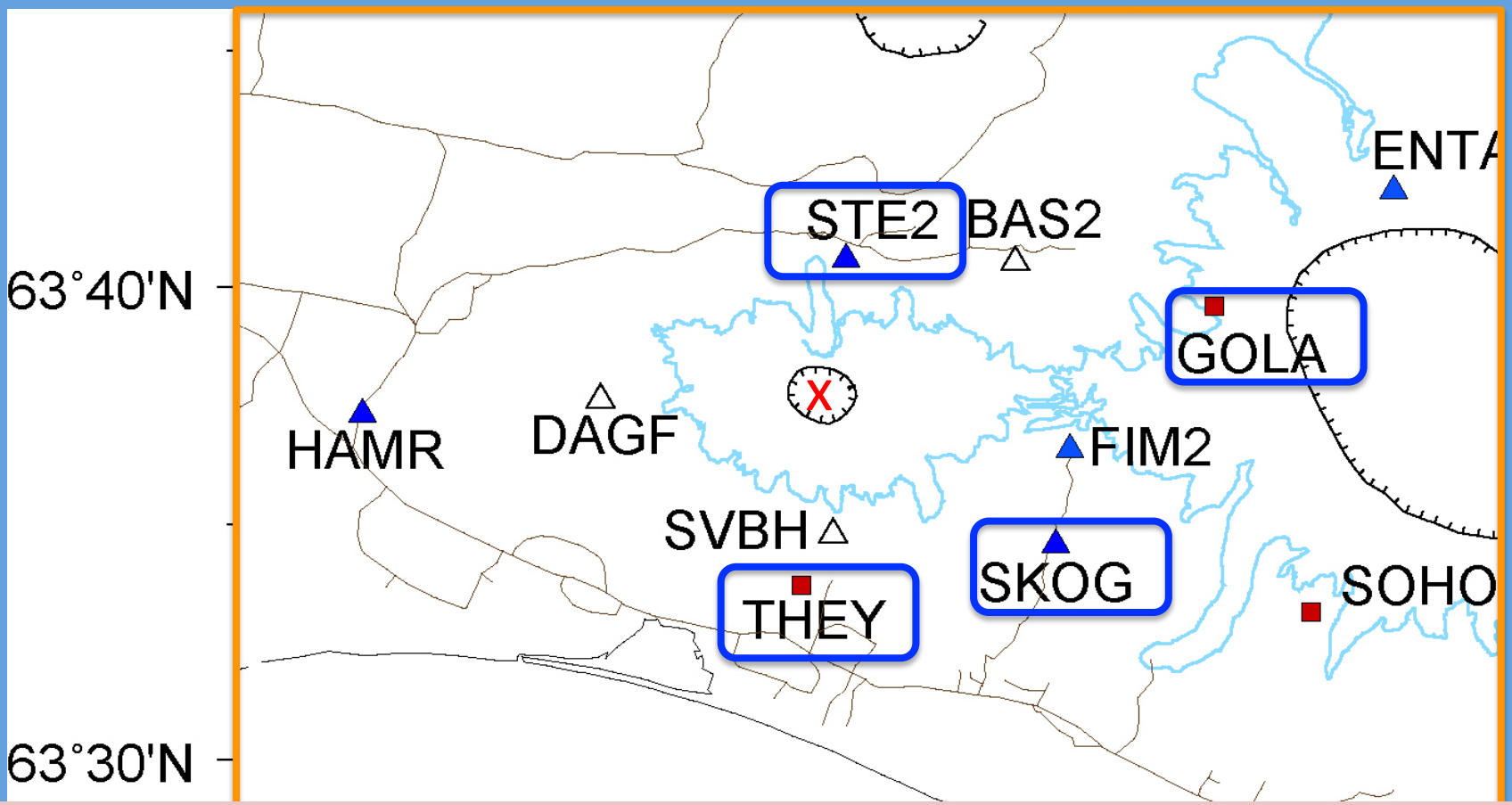
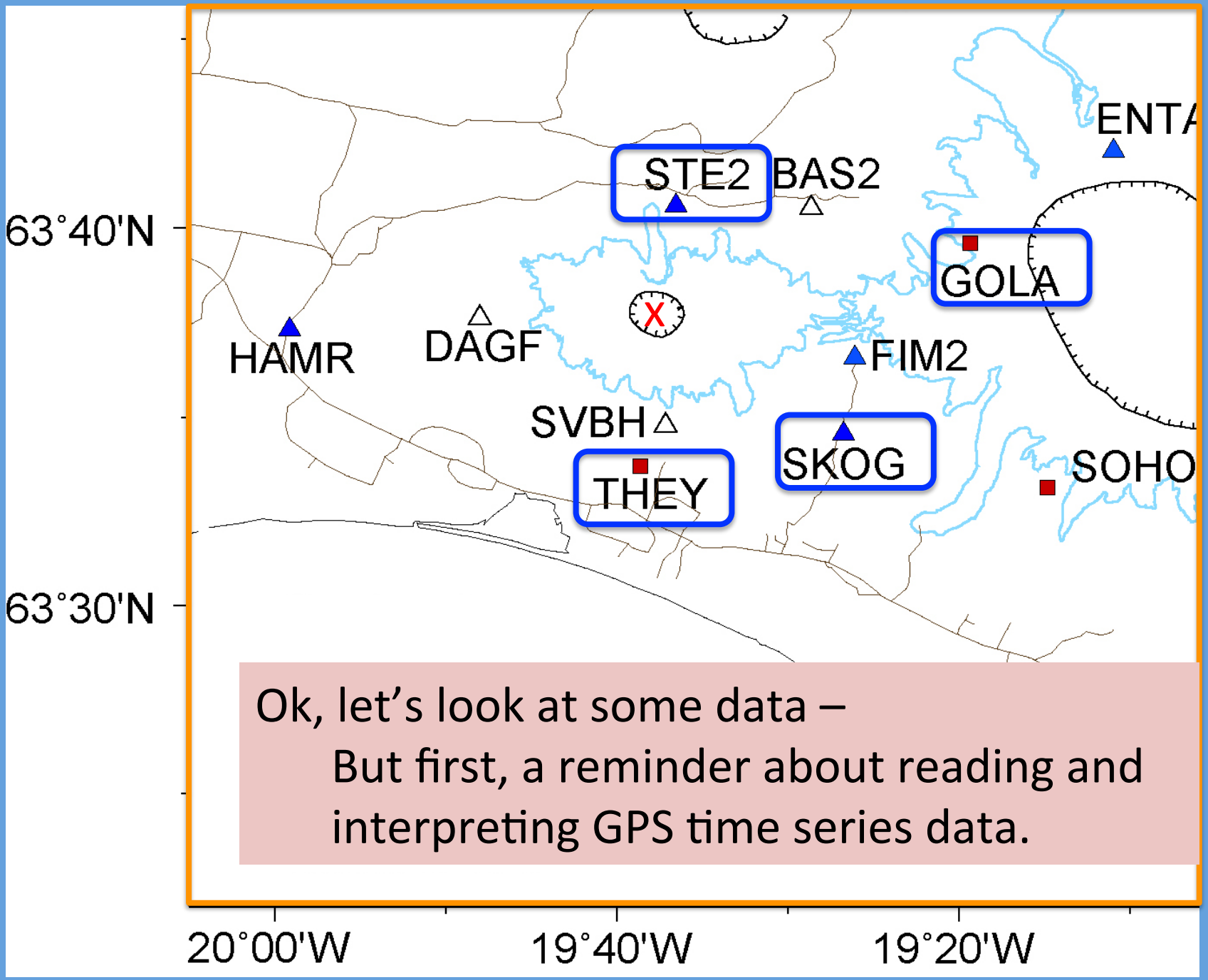


Map of study area showing the summit of Ejafjallajokull (x) and the locations of GPS stations.



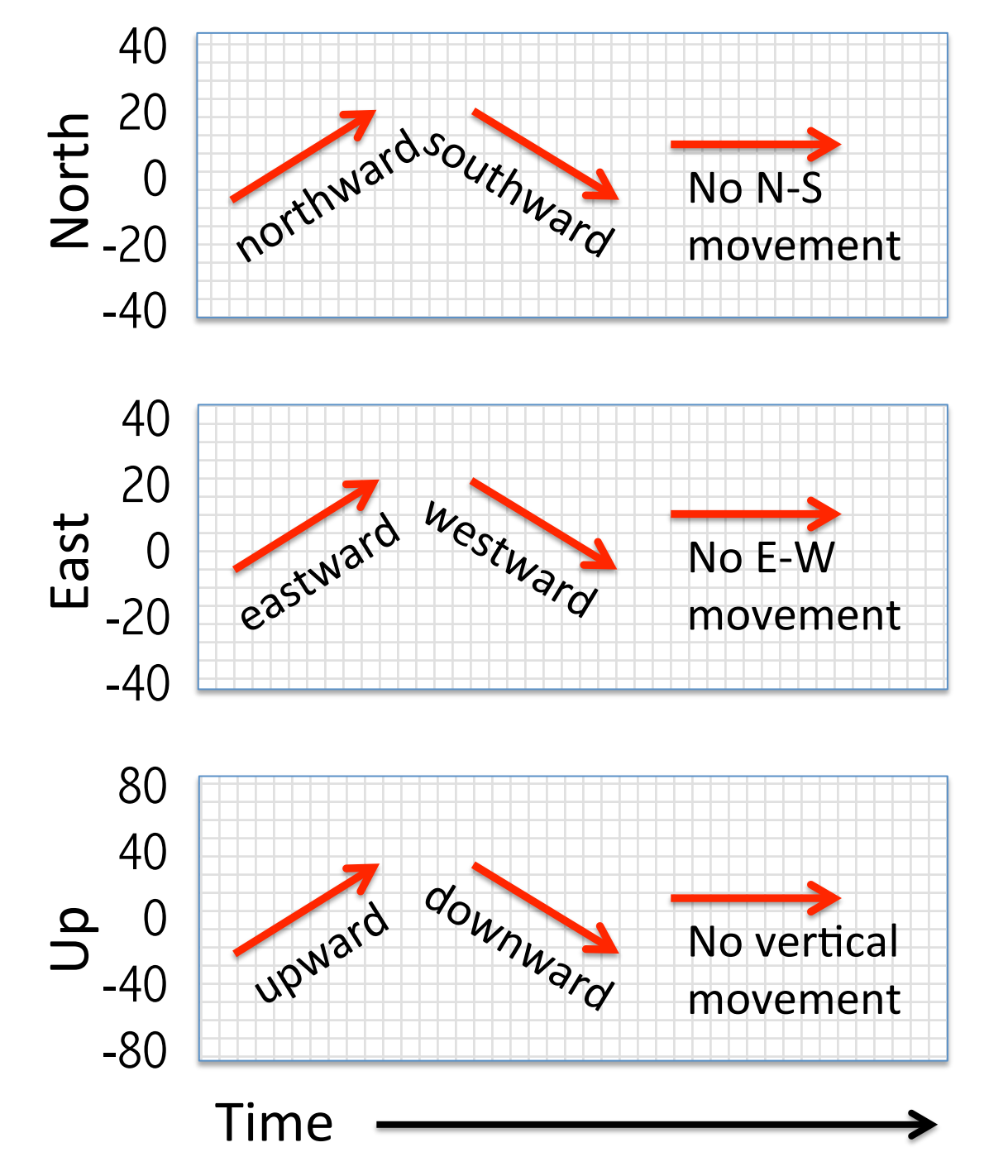
3. PREDICTED MOTION: Describe how you think your station will move before, during and after an eruption at Eyjafjallajokull. Draw arrows on the map indicating the motion(s) you predict *and* describe your predictions. Be sure to indicate compass direction AND the vertical component (UP or DOWN) for each stage of motion.

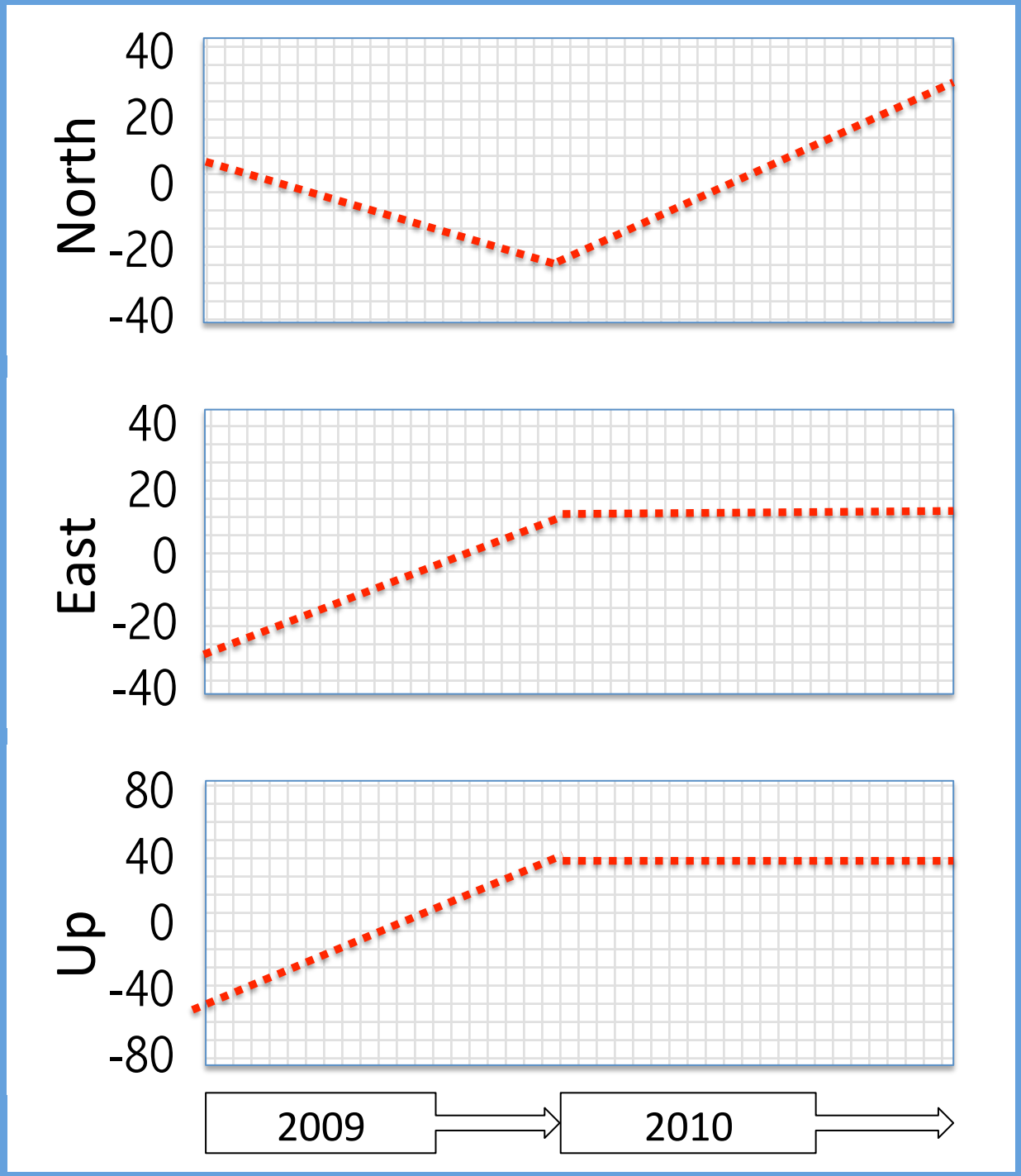


Ok, let's look at some data –

But first, a reminder about reading and interpreting GPS time series data.

Reading GPS time series: motion is resolved into three components





Test yourself:

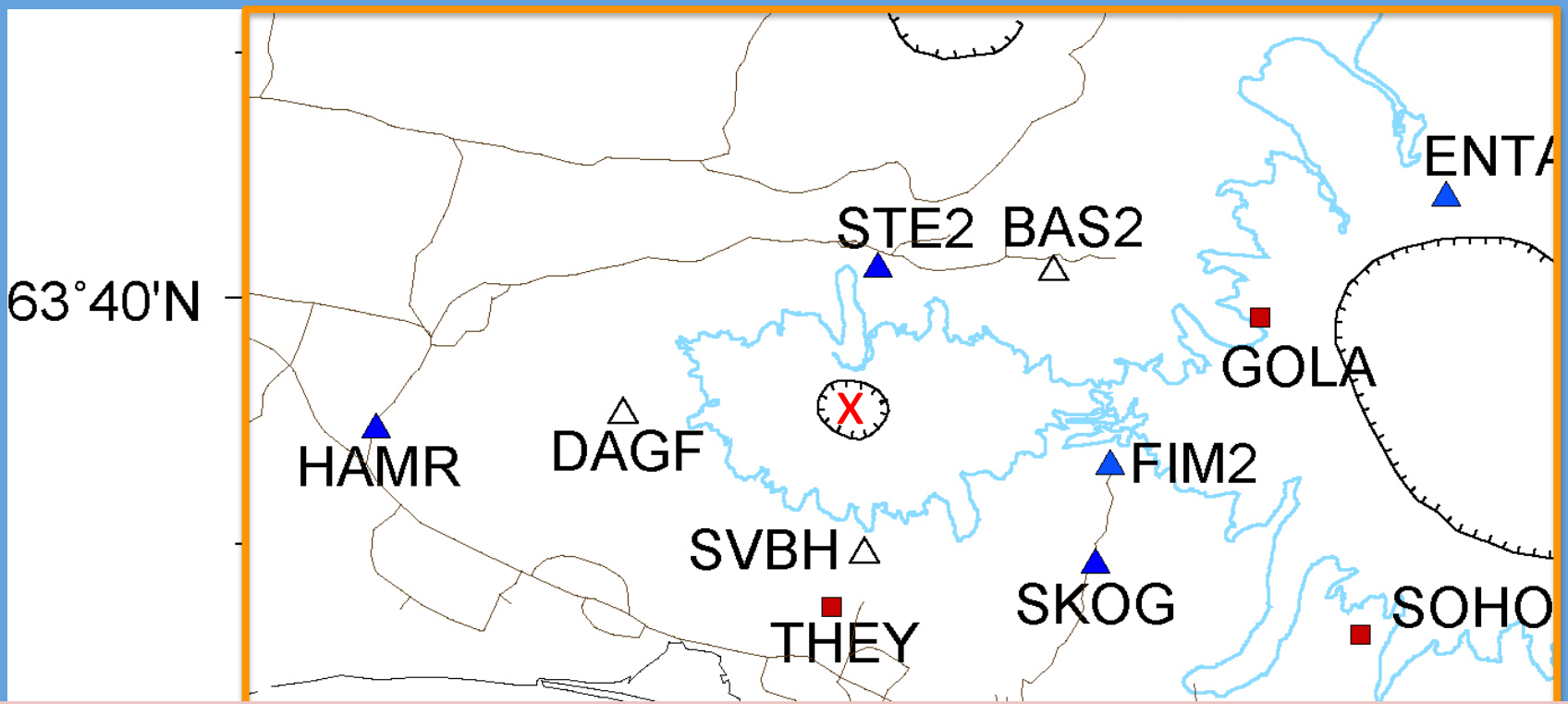
Which way was this station moving in 2009?

- *Up to the SE*

Which way was this station moving in 2010?

- *Due north, with no change in the vertical component.*

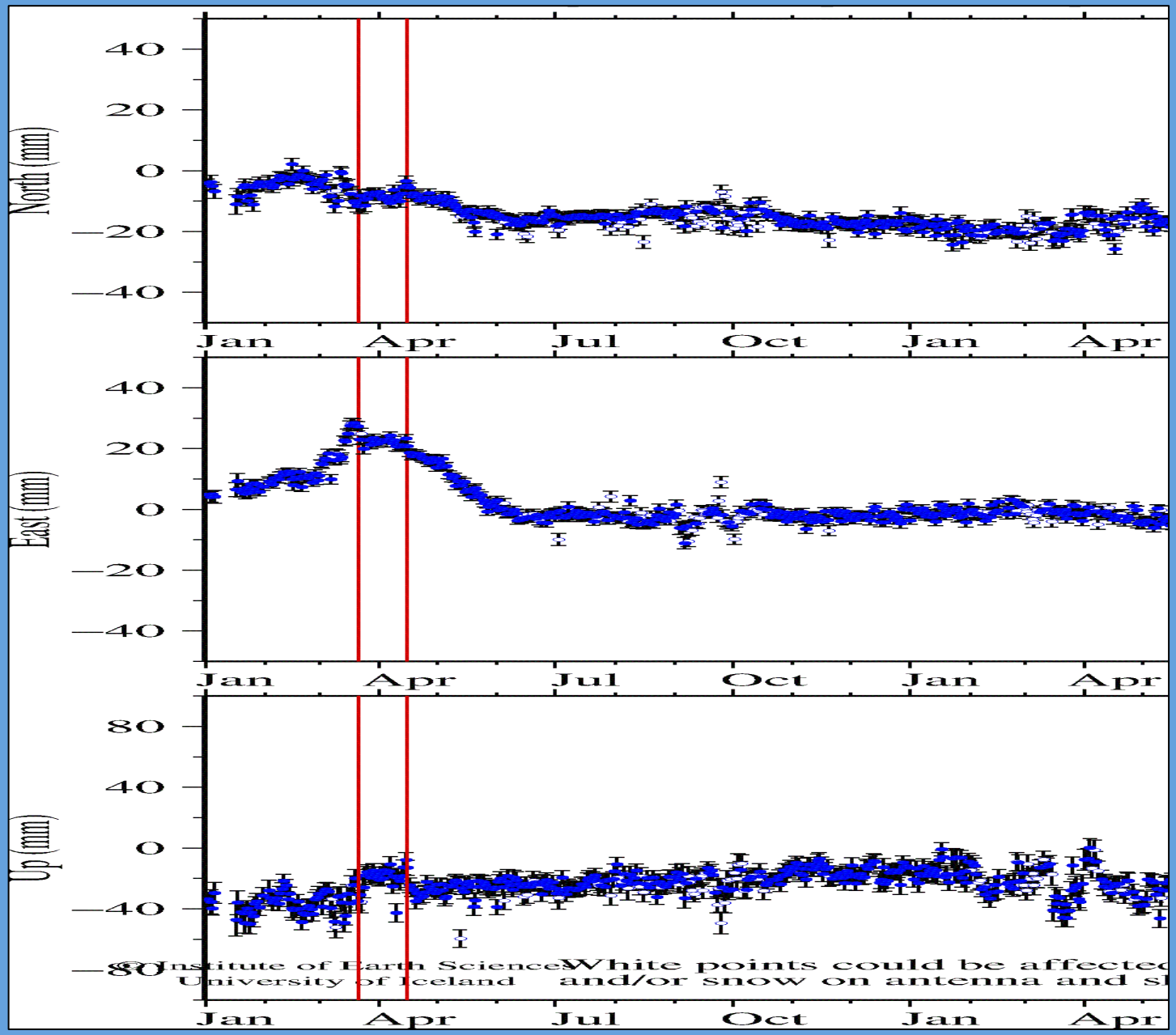
N.B. Today we are just interested in the general trend, not fully resolving the direction and rate.



4. ACTUAL MOTION Analyze the GPS time series and describe the actual motion of your station before, during and after the eruption. Draw arrows on the map indicating the motion(s) and describe your predictions. Be sure to indicate compass direction AND the vertical component (UP or DOWN) for each stage of motion.

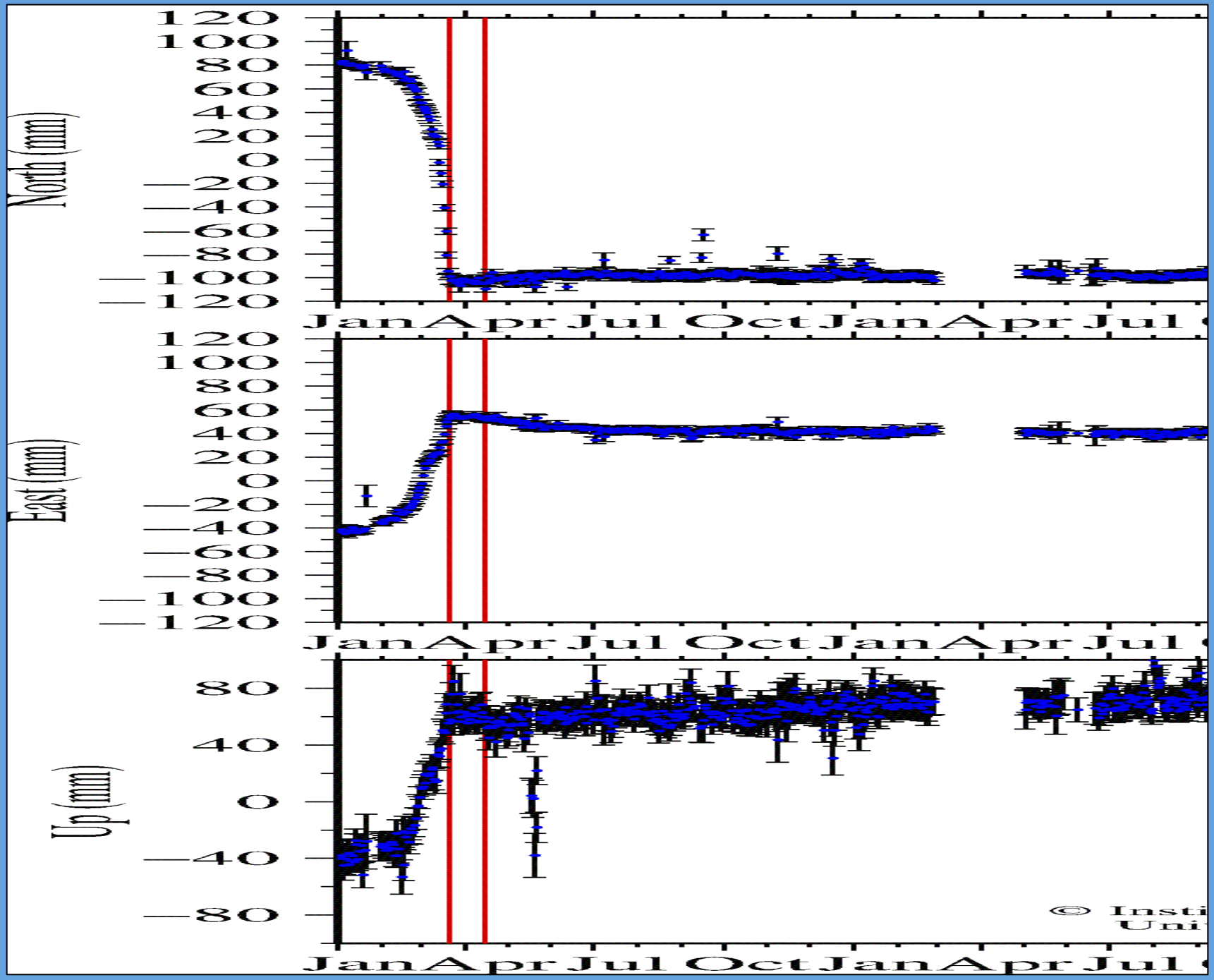
5. How does the actual motion compare with your predictions?

Station GOLA:



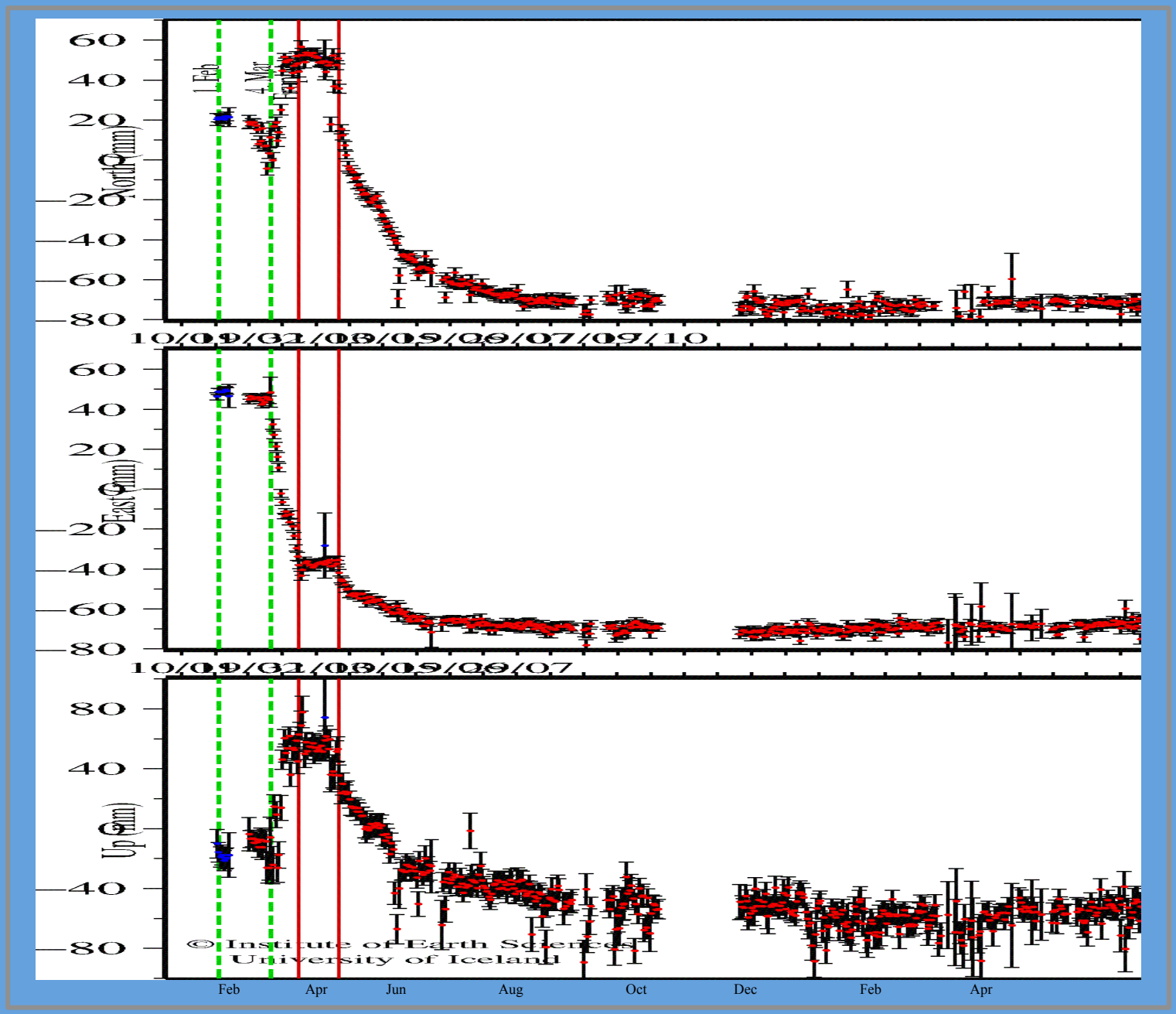
https://notendur.hi.is/~runa/eyja_gps.html

Station SKOG:



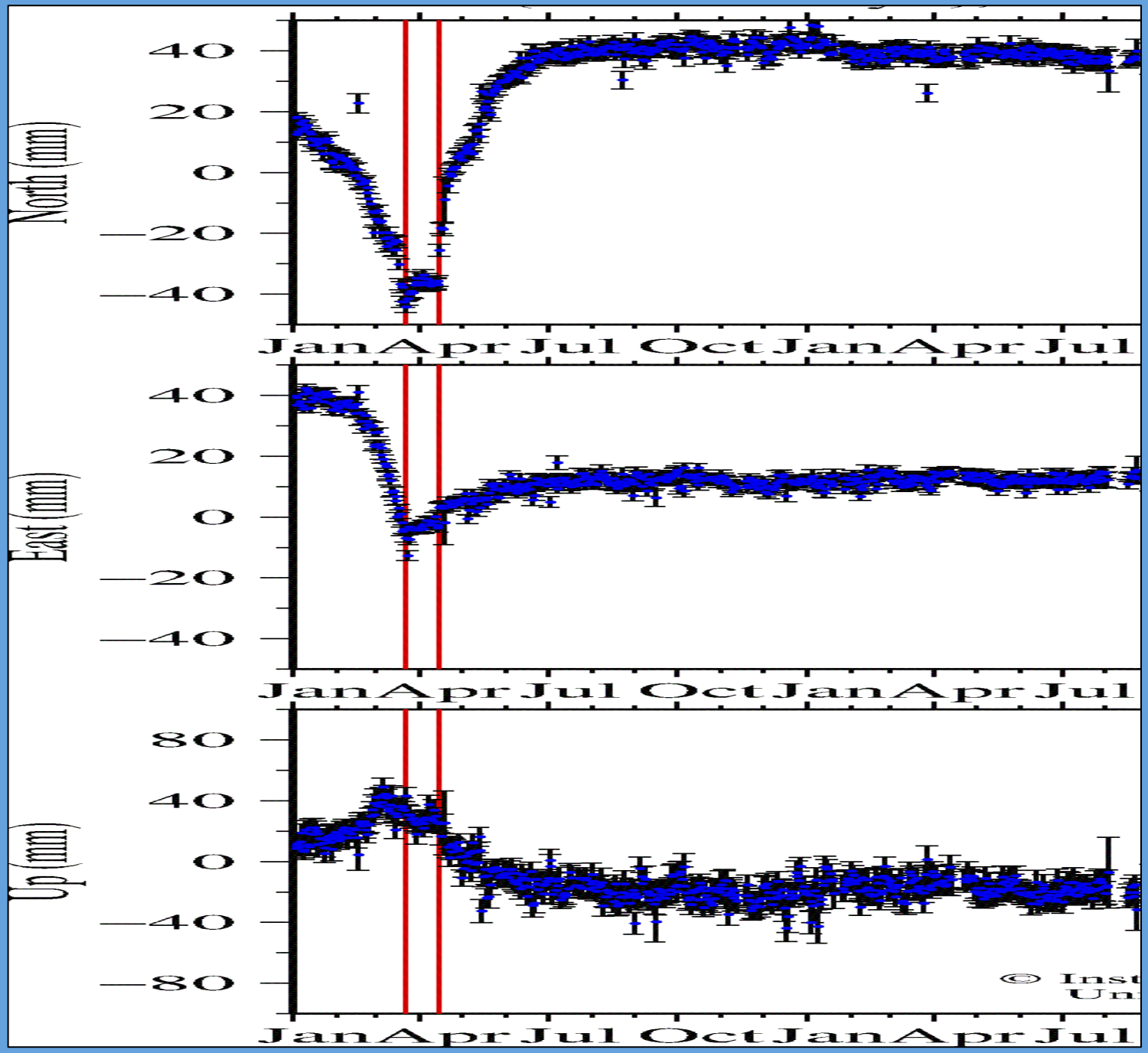
https://notendur.hi.is/~runa/eyja_gps.html

Station STE2:



https://notendur.hi.is/~runa/eyja_gps.html

Station THEY:



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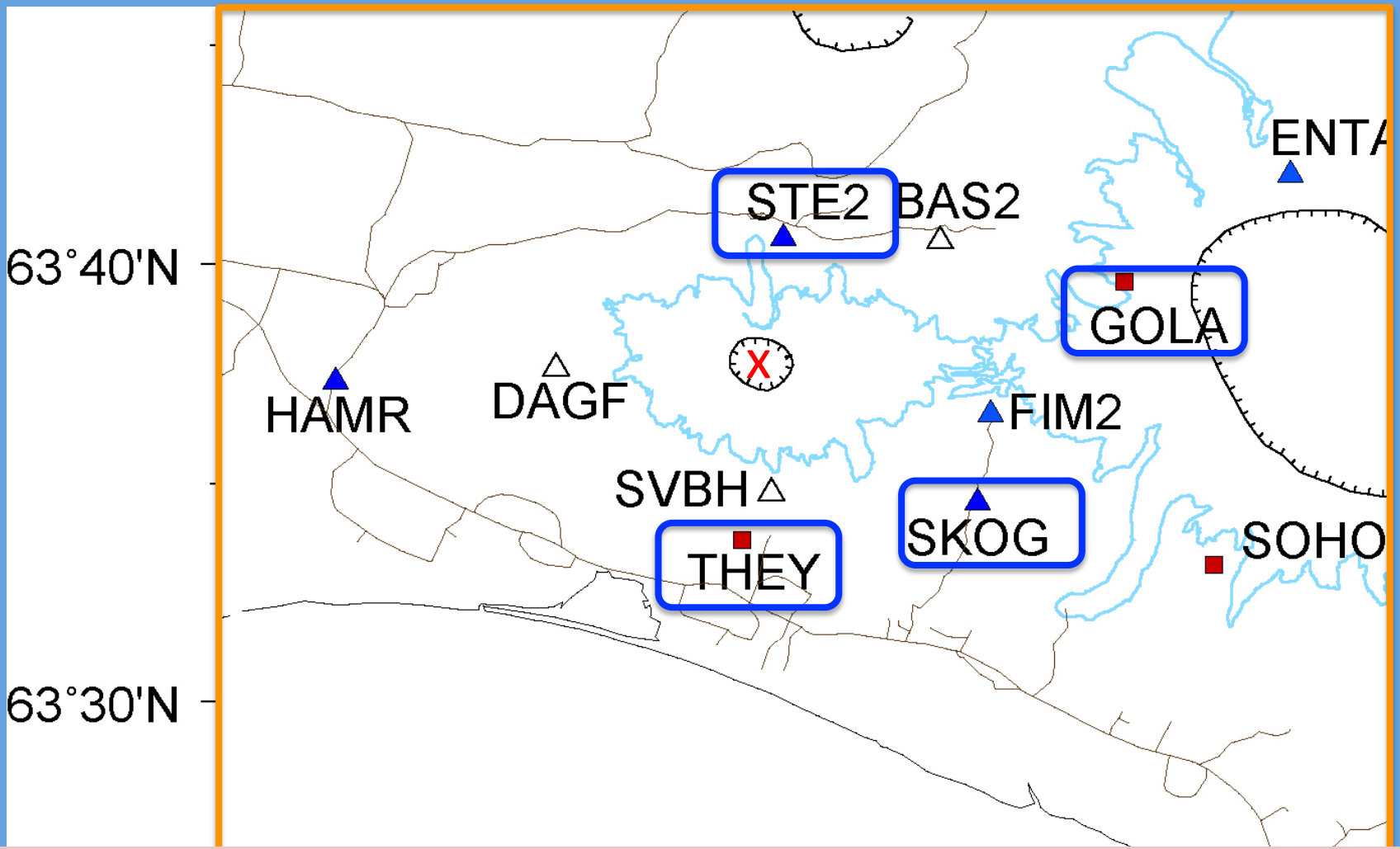
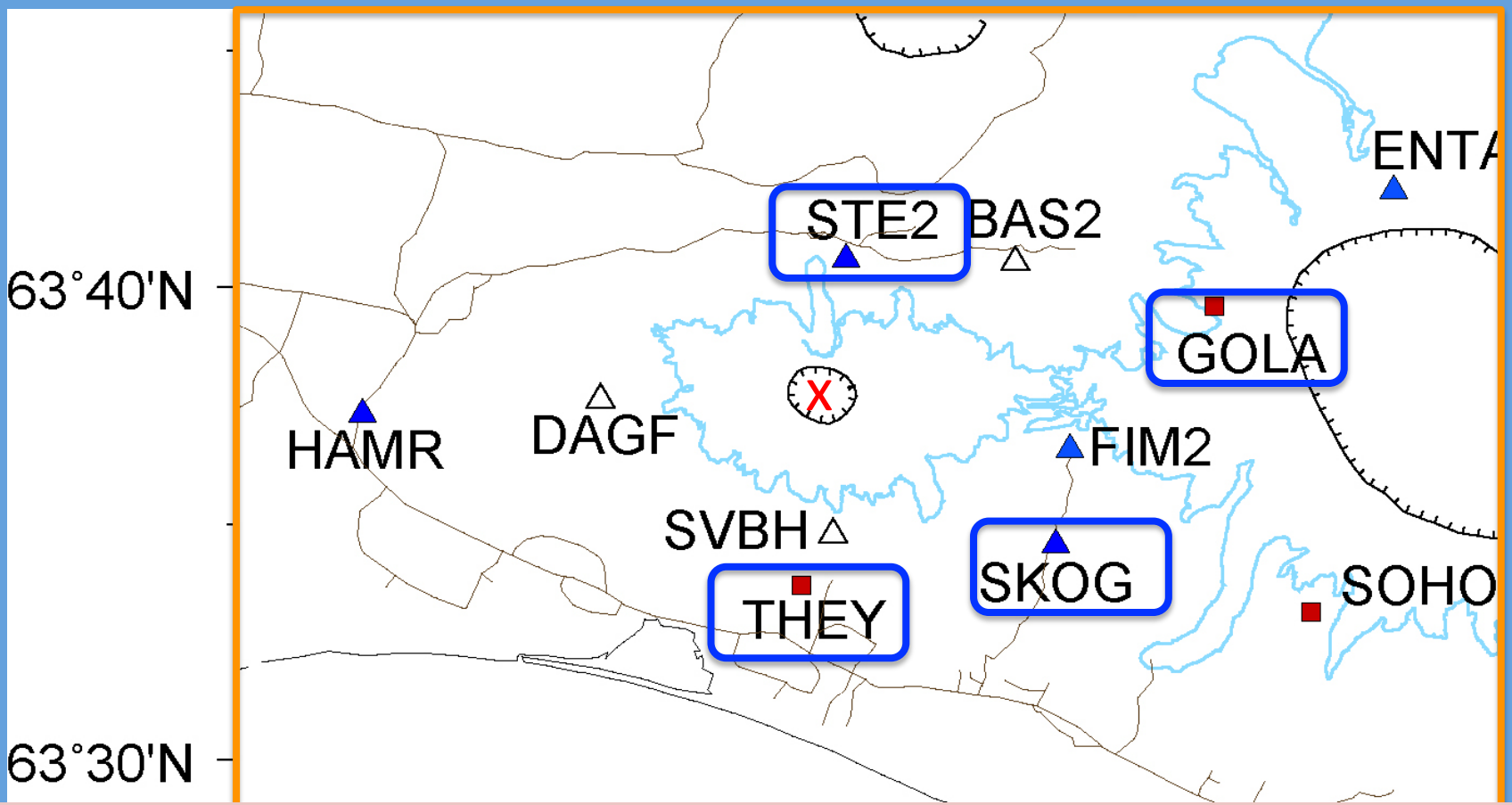


6. After reports from other groups, add arrows indicating the motions of the other stations. Is the behavior of the volcano consistent with the scenario you imagined in the thought experiment? Why or why not?



7. Describe the extent to which the stations recover their original, pre-eruption locations (it might be different for different stations). If one or more stations did not recover their original location, why not? What does this imply about the shape of the volcano as a result of the eruption?

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Animation of earthquake activity underneath Eyjafjallajokull January-May, 2010

http://vimeo.com/10708403

8. Watch this ~1 minute video several times. Describe the earthquake activity, taking note of numbers, depths and locations of epicenters. Note:

- Date format in upper left is in dd/mm/yyy format
- The darker the symbol, the deeper the epicenter

9. Relate the earthquake activity to the GPS data. What do you think is happening at the volcano to cause the observed earthquake activity?

Discussion questions

10 a. What were the indications that the volcano was “waking up” and entering a phase of volcanic activity?

Discussion questions

10 b. What were the indications that the volcano was not only “waking up” but actually about to erupt?

Discussion questions

10 c. How much warning time was there between the first indications that the volcano was “waking up” and the time the volcano actually erupted?

Discussion questions

11. At least for the inhabitants of Iceland (if not the airline companies), this was a low-risk eruption. No lives were lost and property damage was limited. What factors helped account for this?