Deformation during the 1975–1984 Krafla rifting crisis, NE Iceland, measured from historical optical imagery

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Principle of image correlation

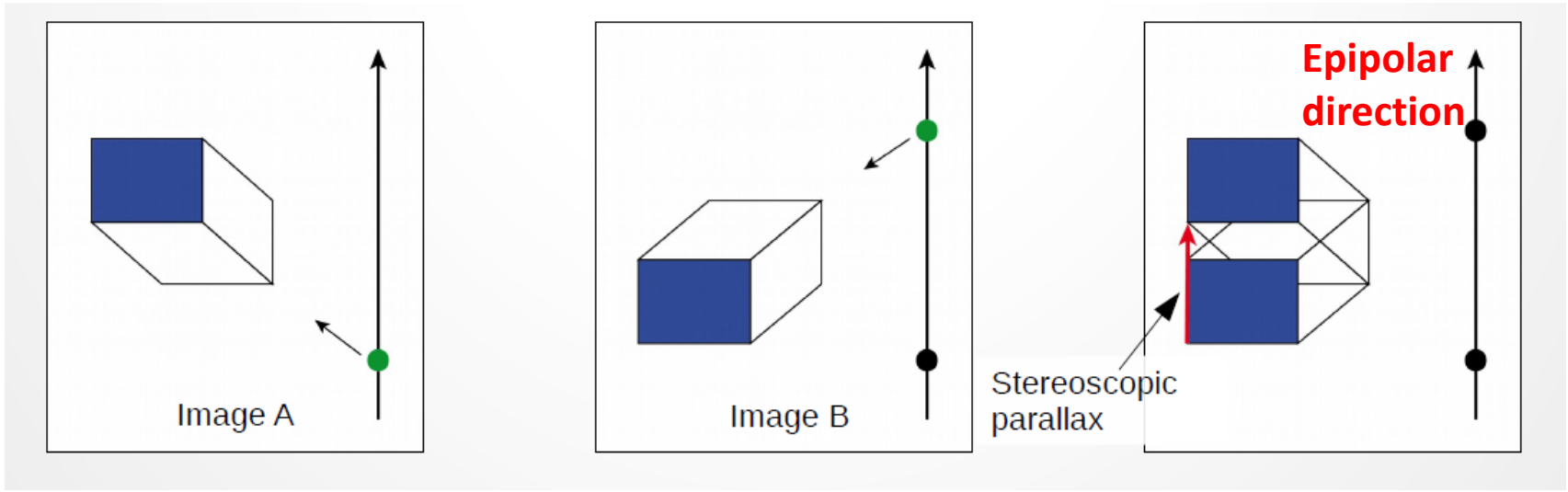
How to measure the surface deformation that results from tectonics?

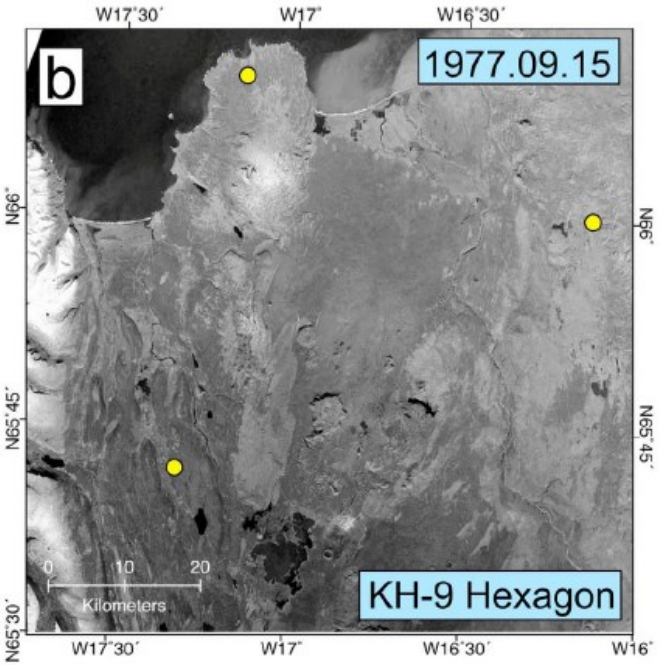
GPS, leveling, InSAR … **Satellite/Aerial Image correlation!**

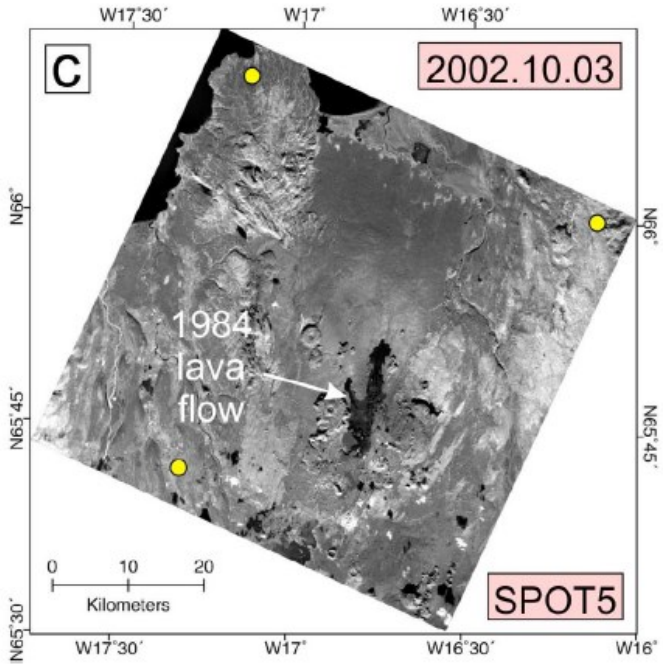
To detect the displacement of pixels in the images shoot before and after tectonic activity.

However, the displacement of original image will include not only tectonic signals but also topographic effect.

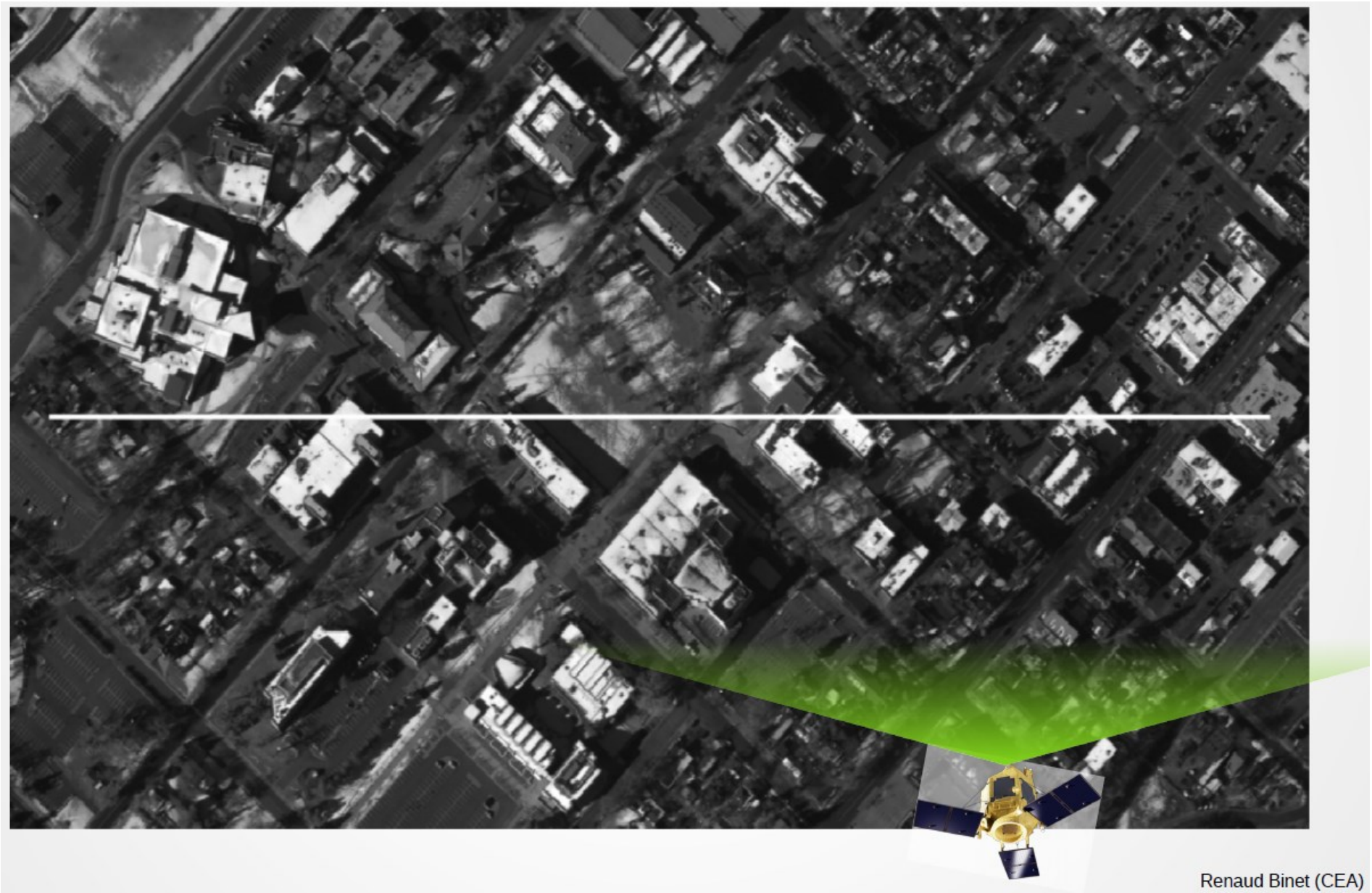
Therefore, **perform the orthorectification with DSM is necessary**

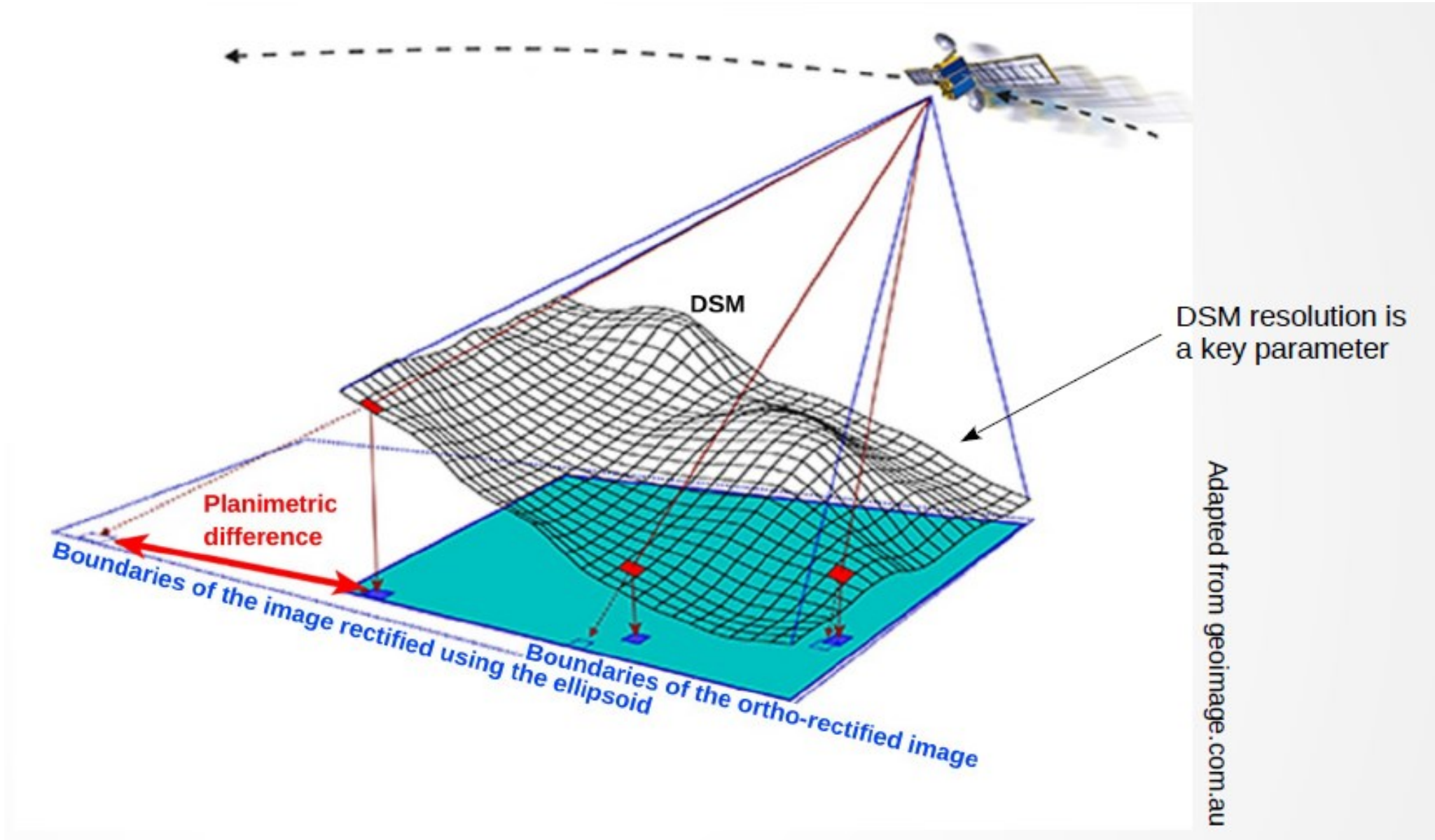


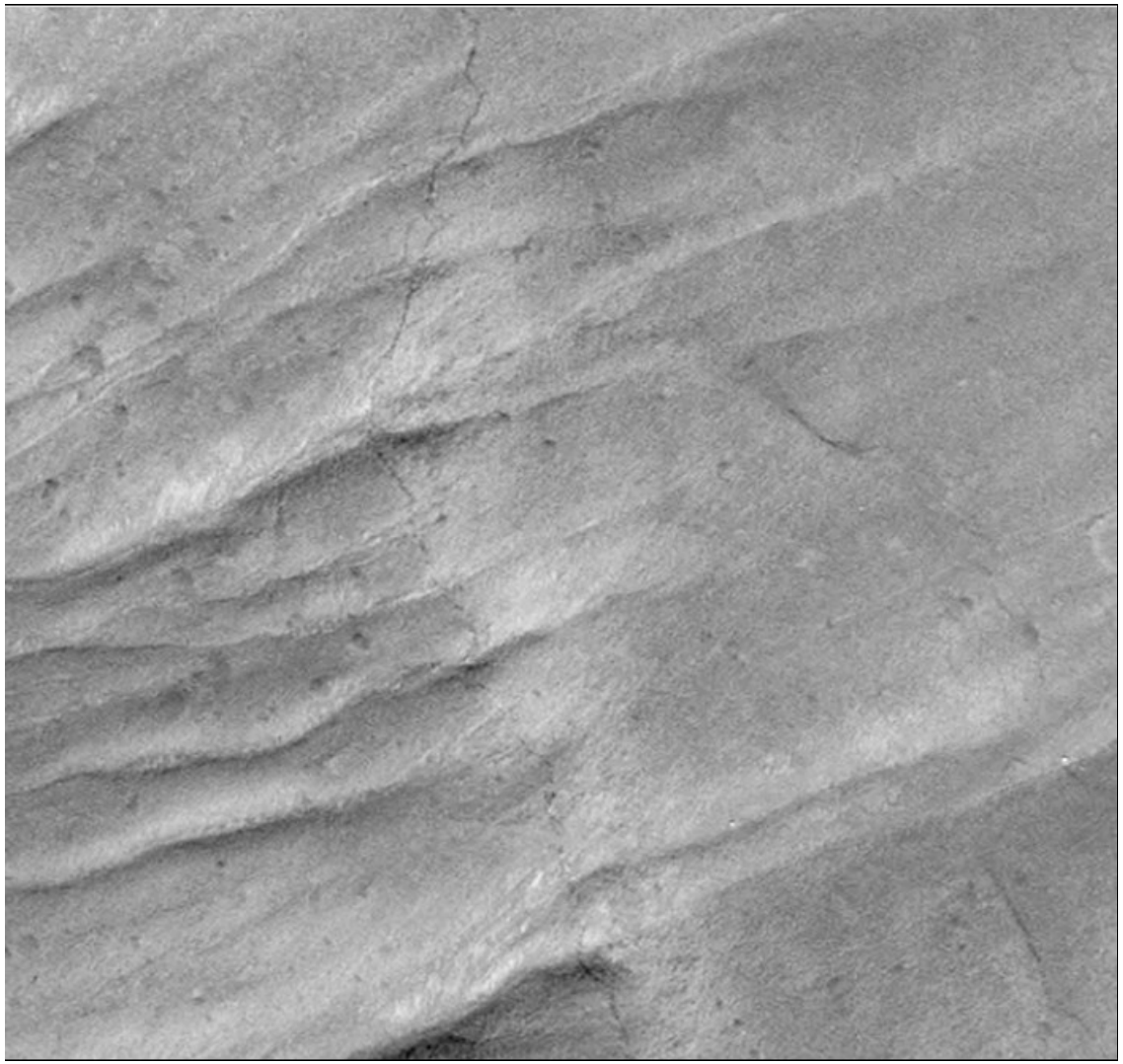




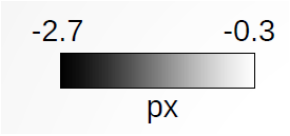
Topography effect and epipolar direction



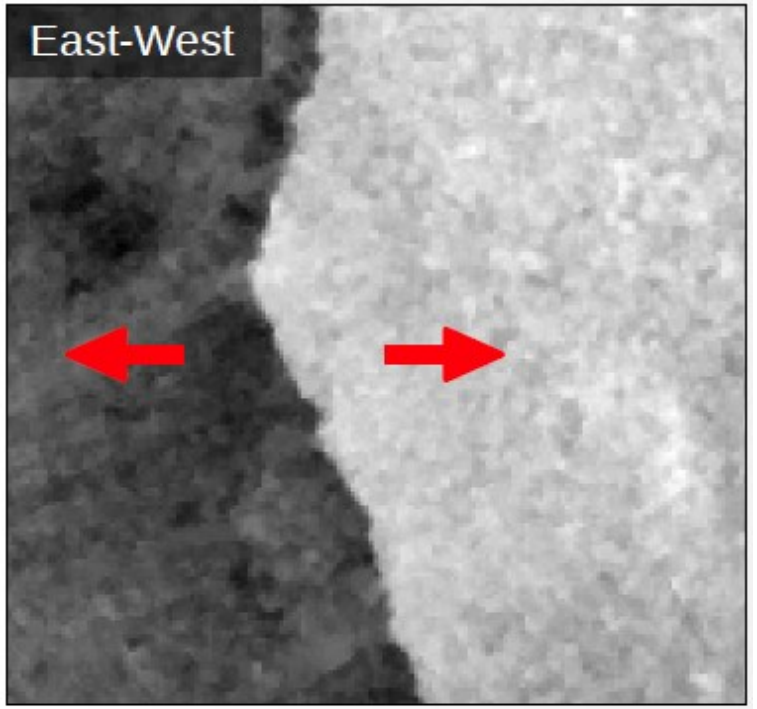

DSM
DSM resolution is
a key parameter
Planimetric
difference
Boundaries of the image rectified using the ellipsoid
Boundaries of the ortho-rectified image
Adapted from geoimage.com.au

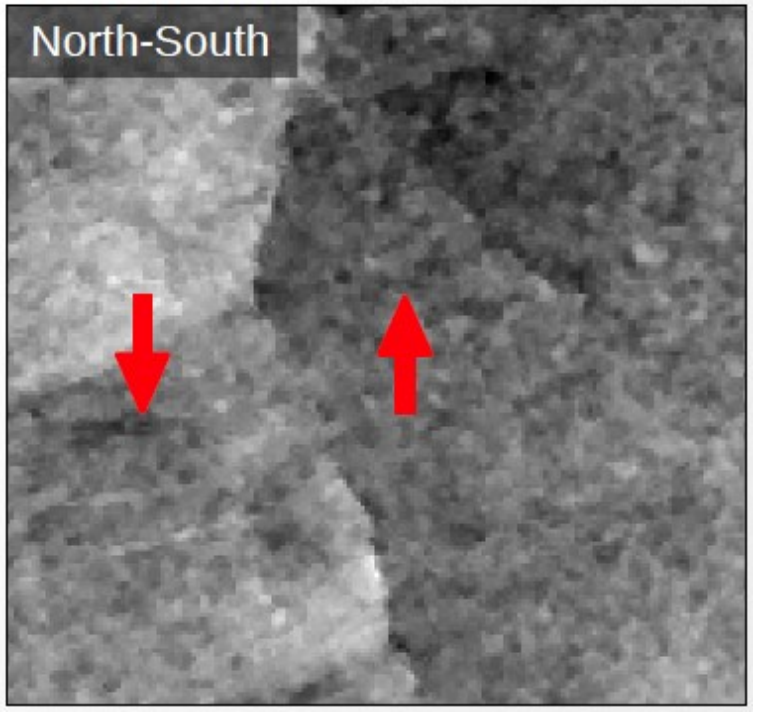


Images are provided by Arthur Delorme
(Norcia earthquake, Italy, 2016)



~2 px (1 m) of relative horizontal displacement between the two blocks





Case study: 1975-1984 Krafla rifting crisis, Northern Iceland

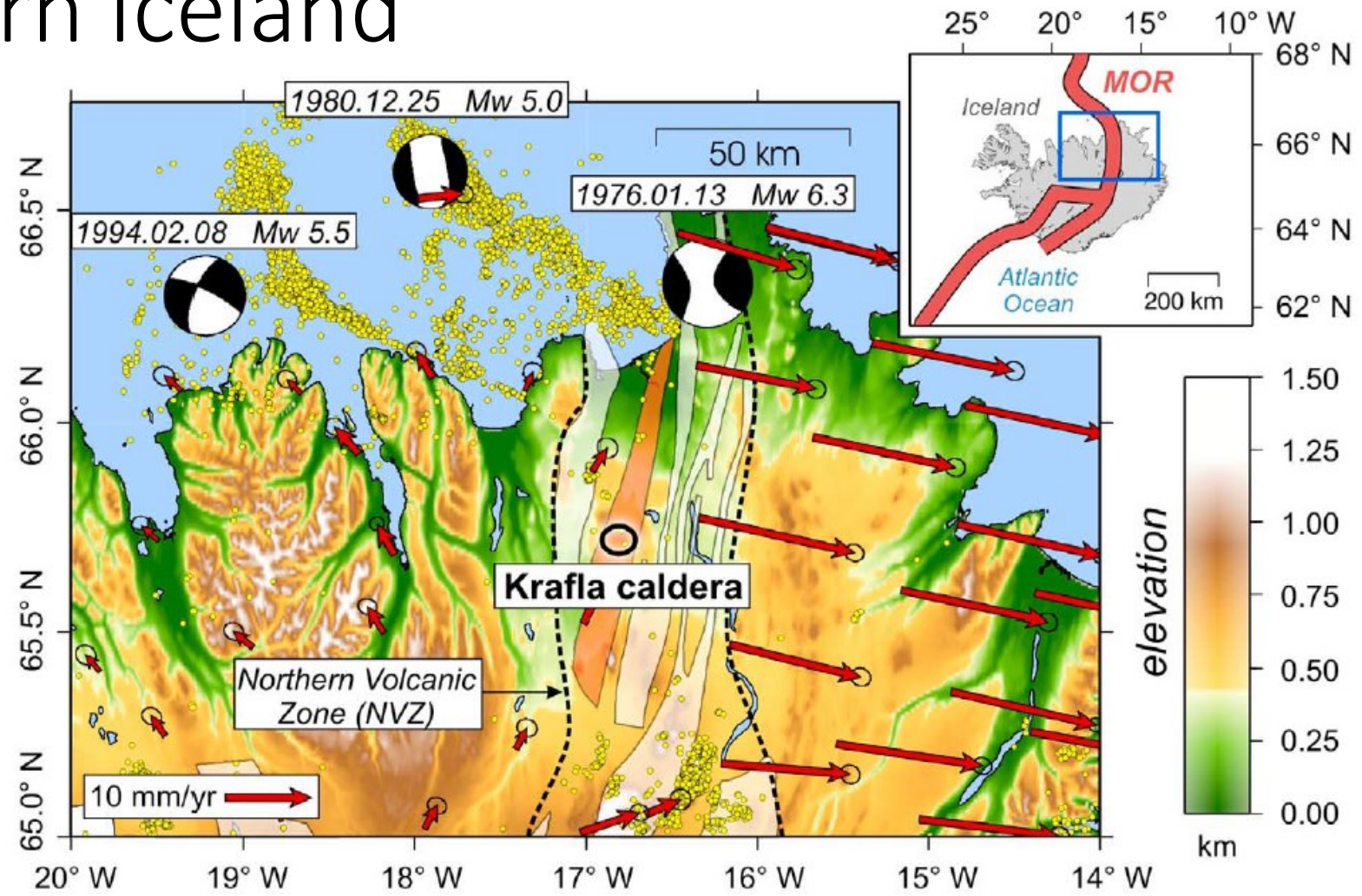


Figure 1. Topographic map of the northern central region of Iceland

Case study: 1975-1984 Krafla rifting crisis, Northern Iceland

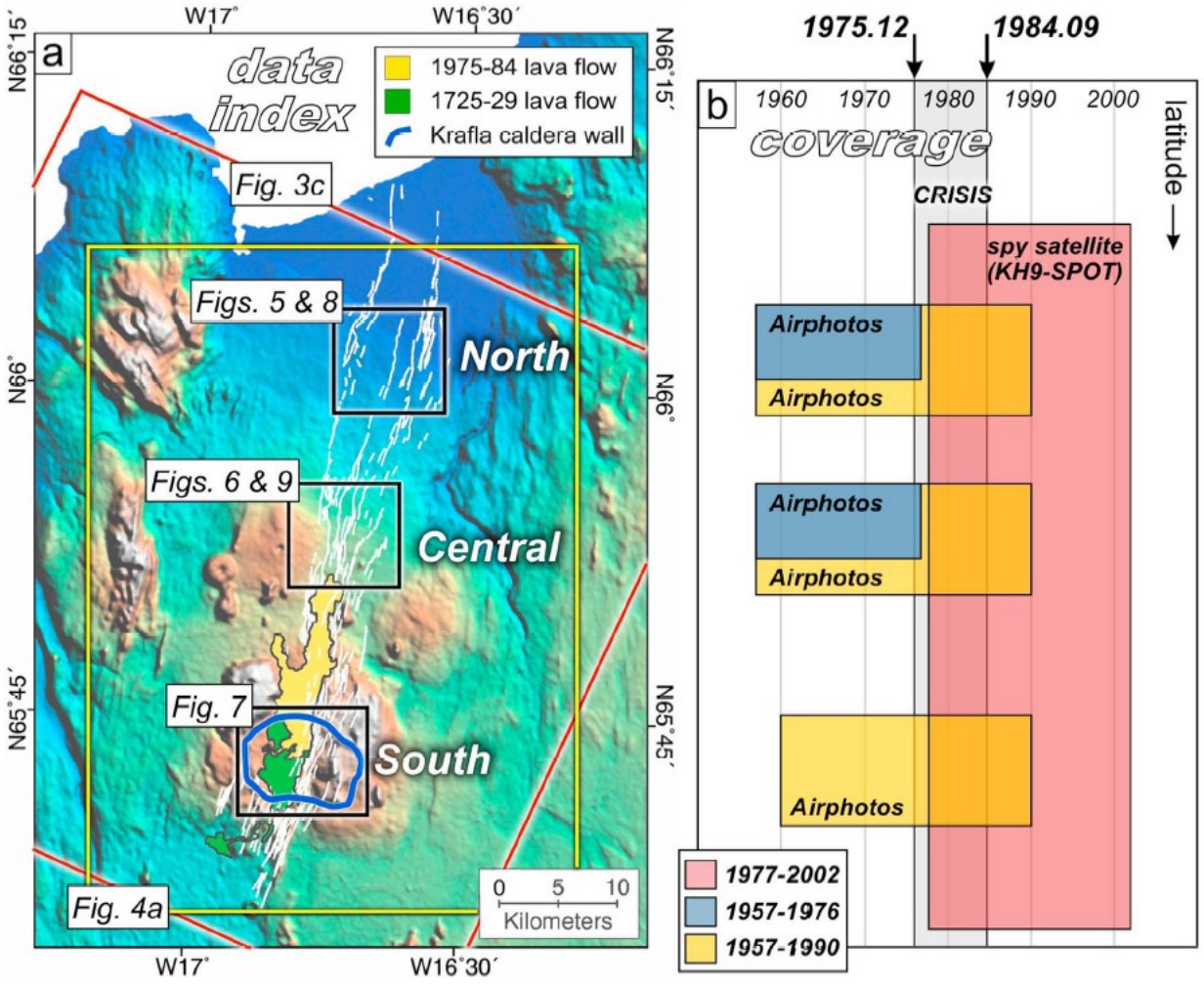


Figure 2. (a) Topographic map of the Krafla region of NE Iceland.

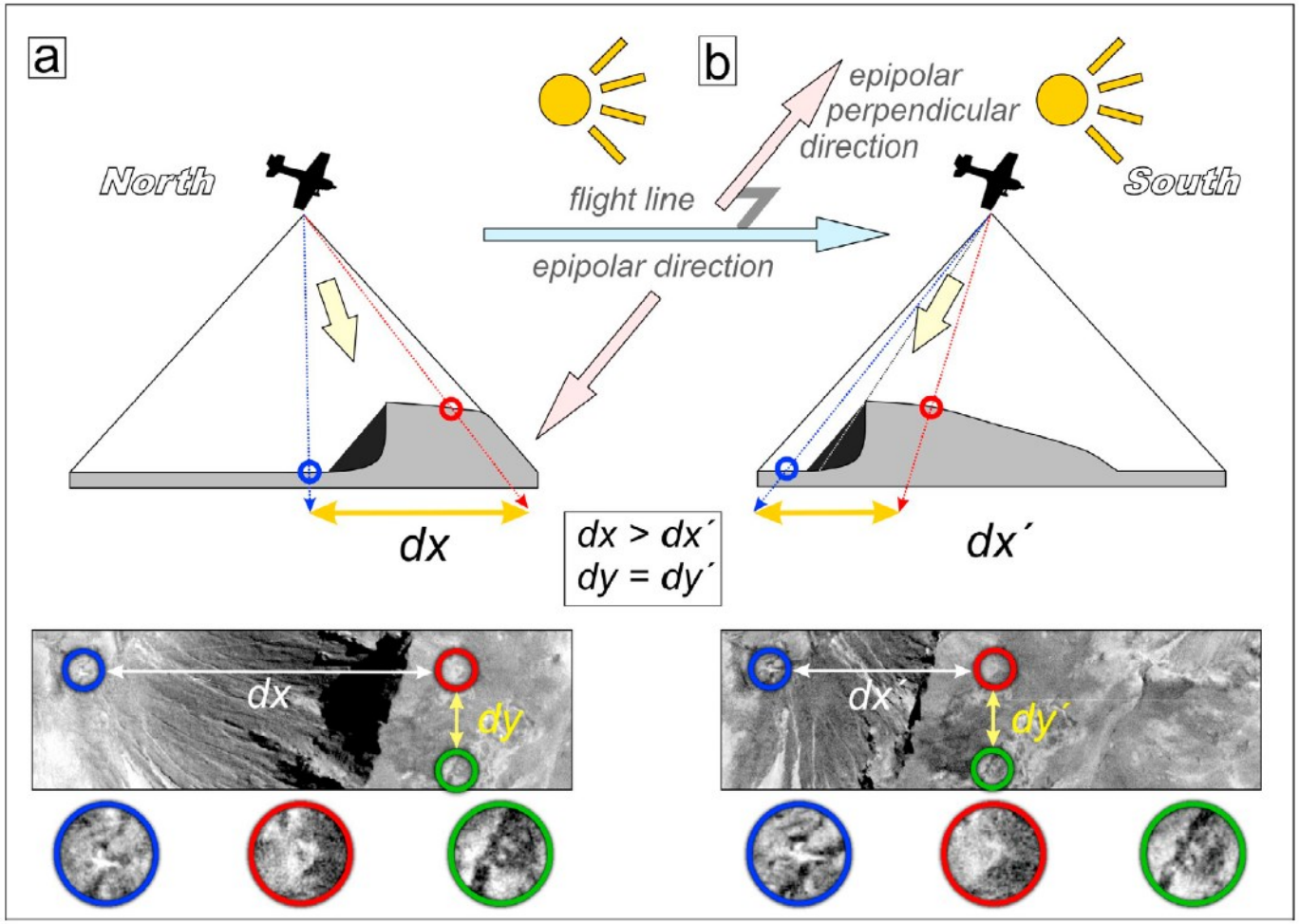
Image acquisition:
-- SOPT5 satellite image: 2002 resolution = 2.5m
-- KH-9 satellite image: 1977 resolution = 6-9m
-- aerial image: 1957-1990 resolution < 1m

DEM for orthorectification: 30m ASTER Global DEM

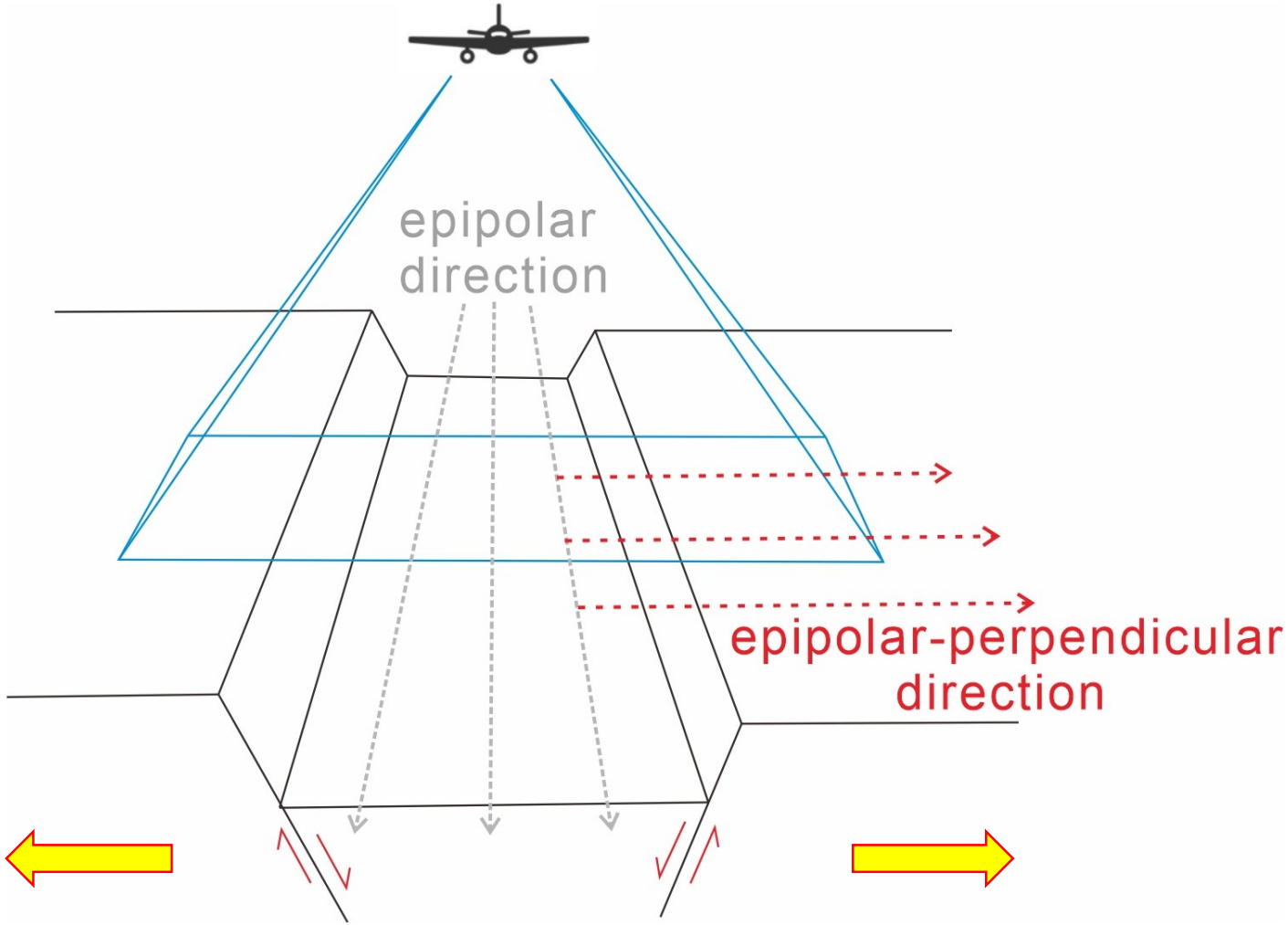
Notice! The DEM **resolution is lower** then all the satellite/aerial image, **the result will still have topographical residuals.**

The solution is to **project the displacement** maps into **epipolar-perpendicular direction**

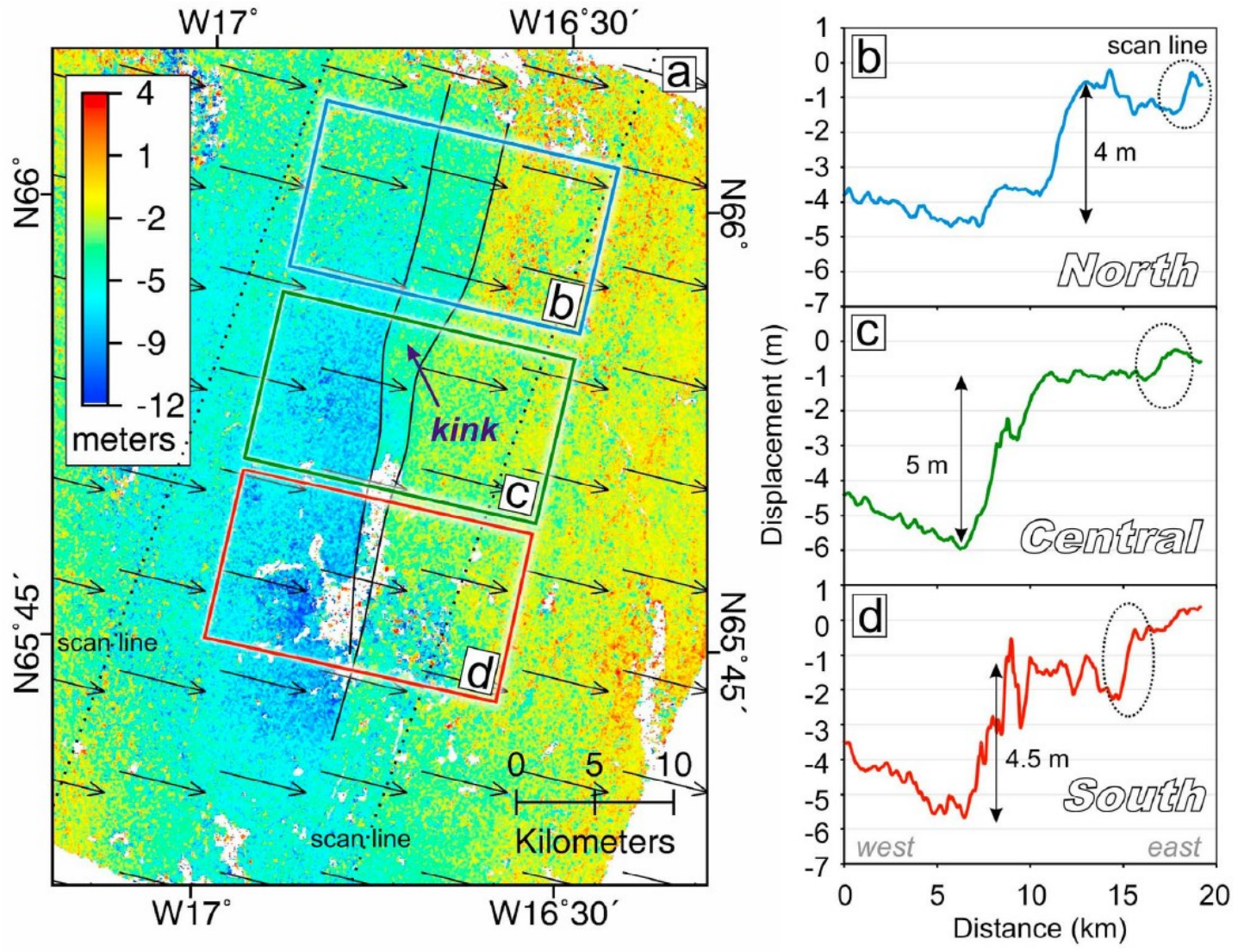
Case study: 1975-1984 Krafla rifting crisis, Northern Iceland

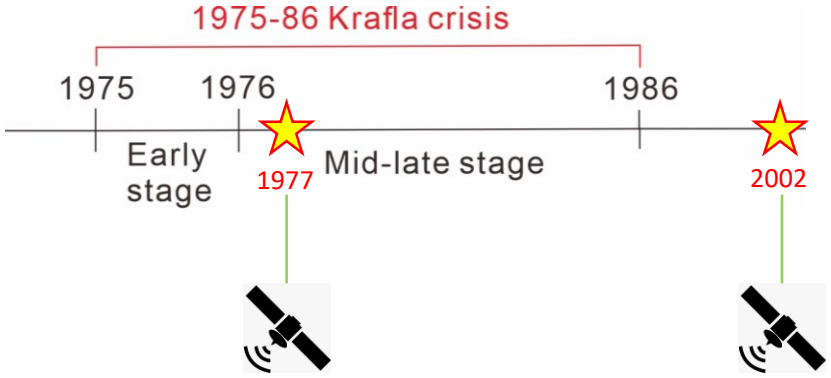


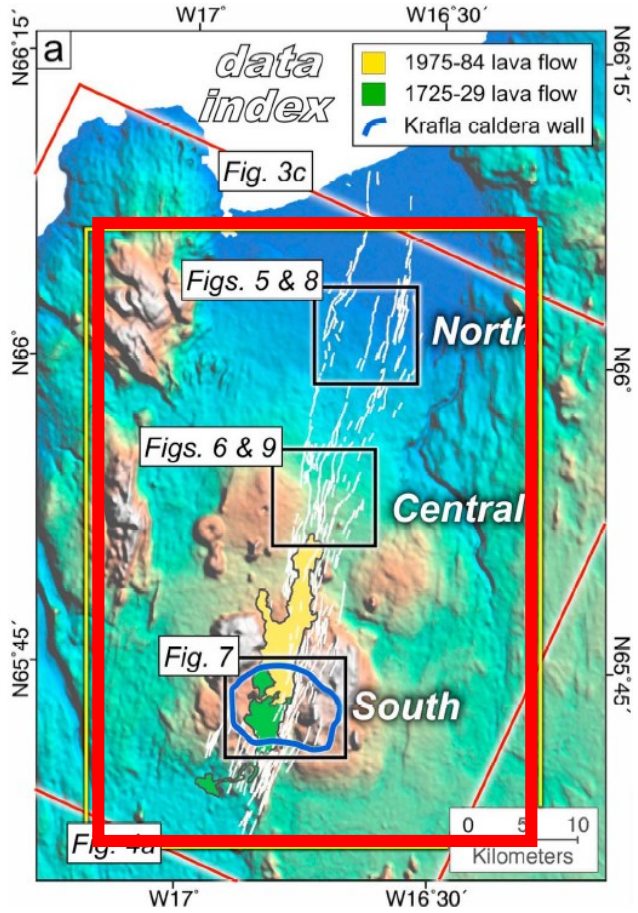
Case study: 1975-1984 Krafla rifting crisis, Northern Iceland



Satellite image correlation result of **full area 1977-2002**

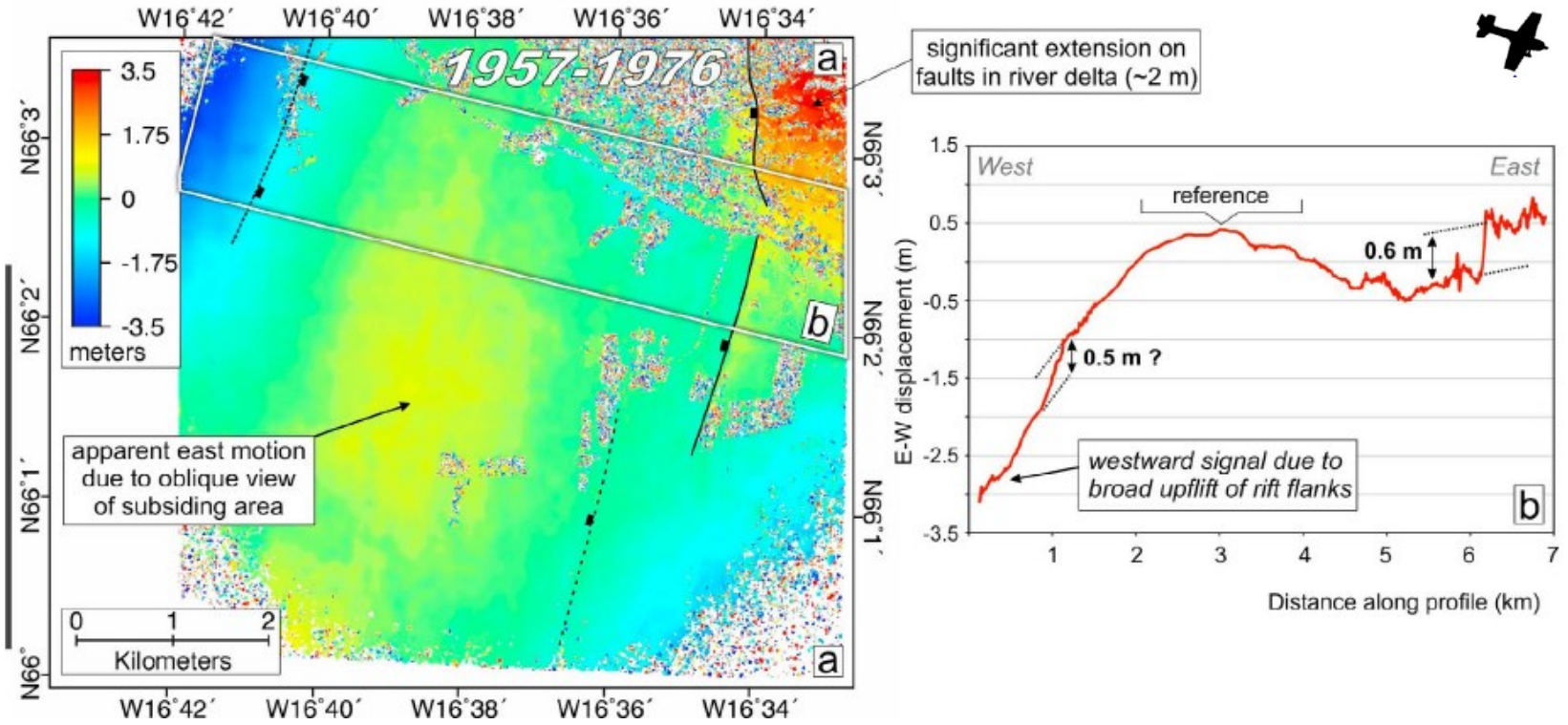


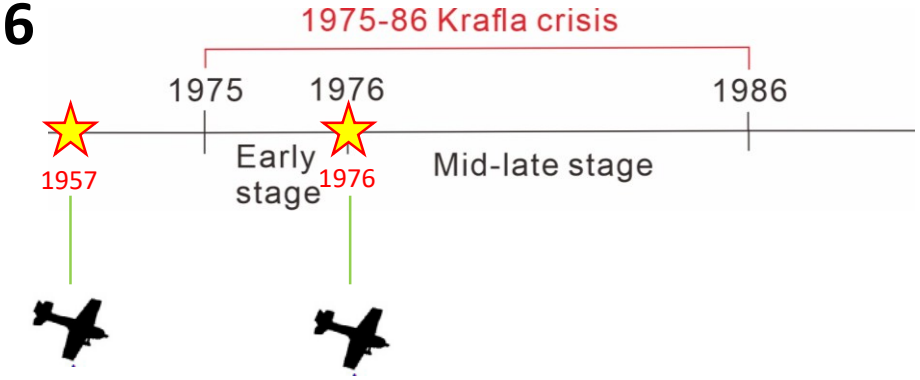


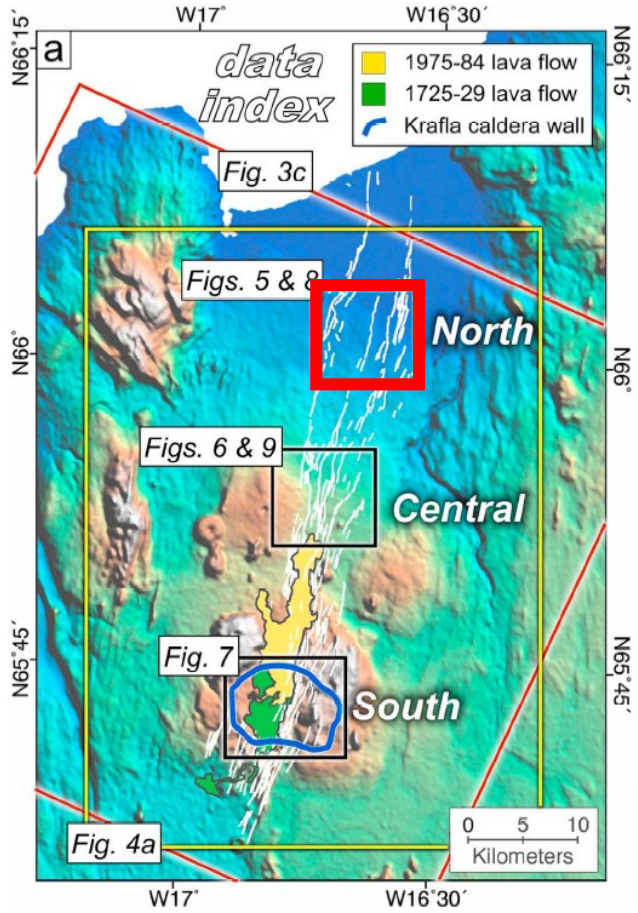


The **width of rifting zone increased northward**, from 1 km to 5 km

Areial image correlation result of **north** region **1957-1976**

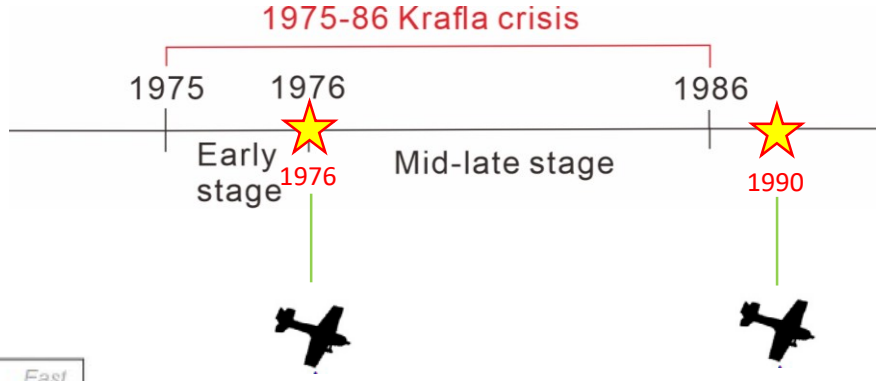


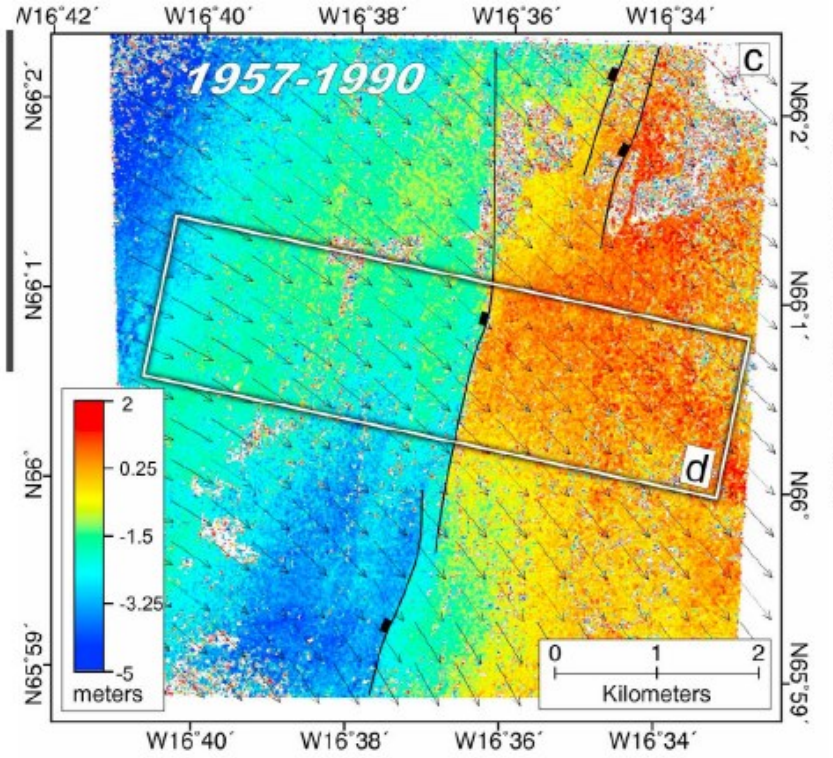


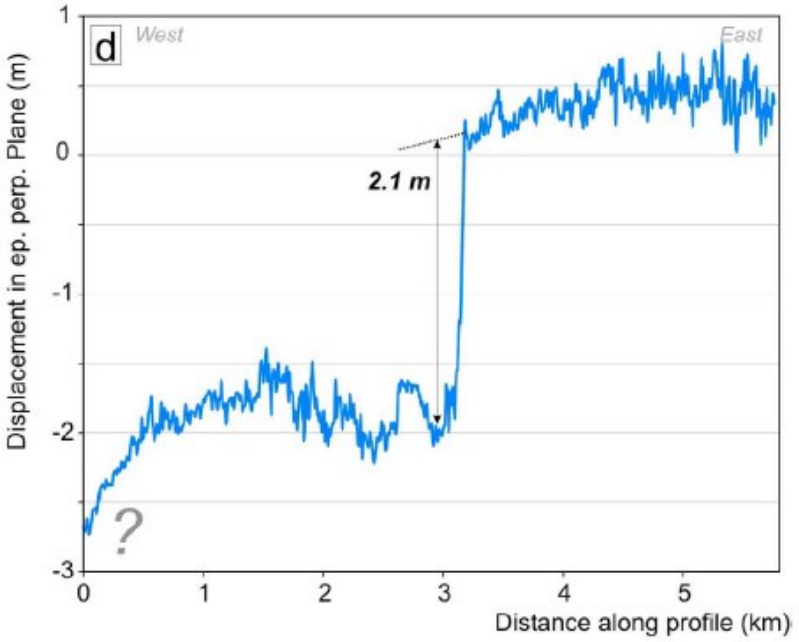


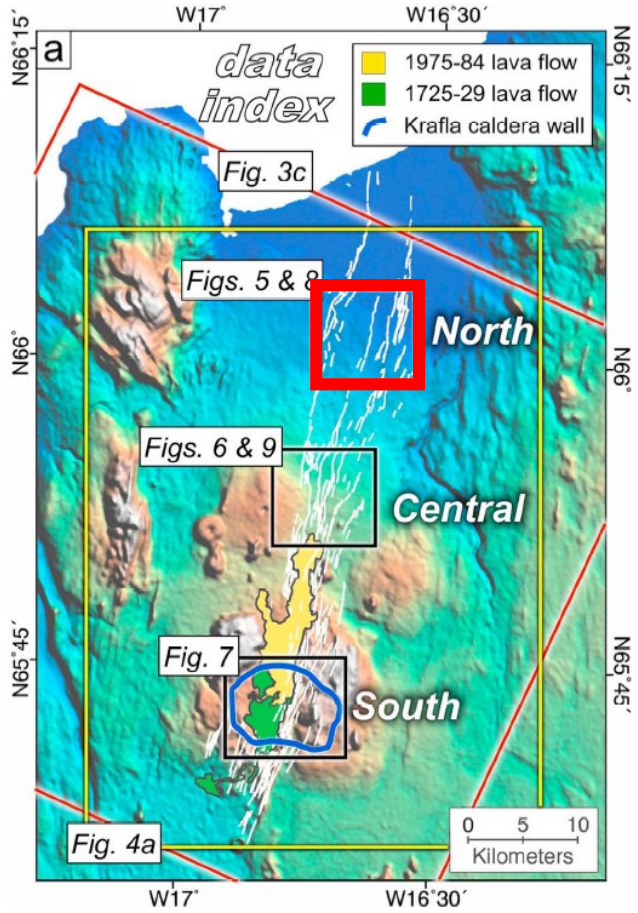
Significant **extension (~2m)** occurred **at early stage** of Krafla crisis.

Areial image correlation result of **north** region **1976-1990**



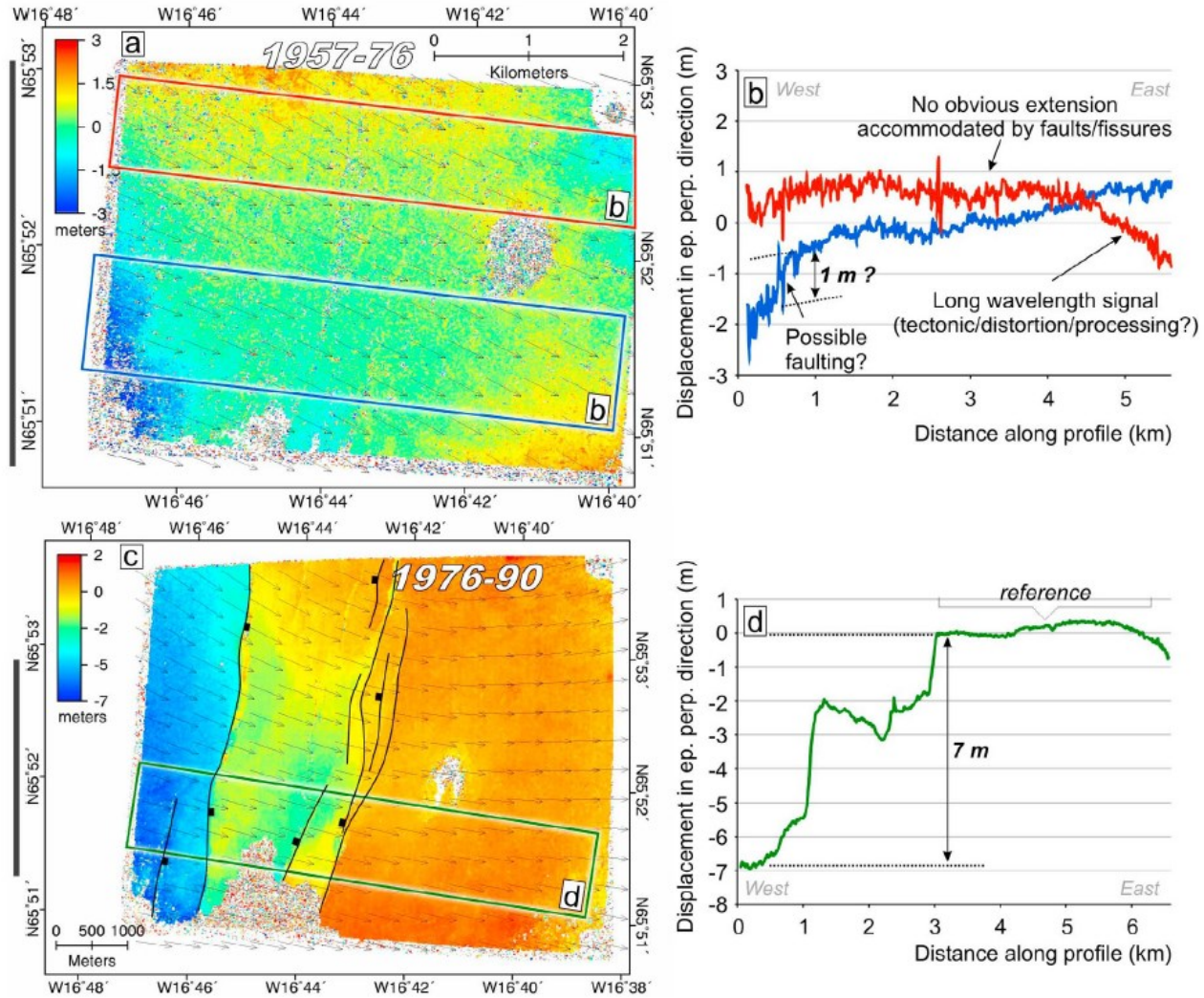


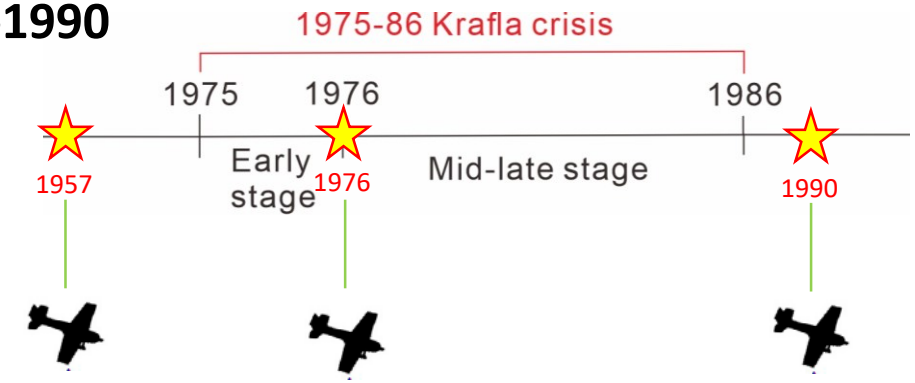


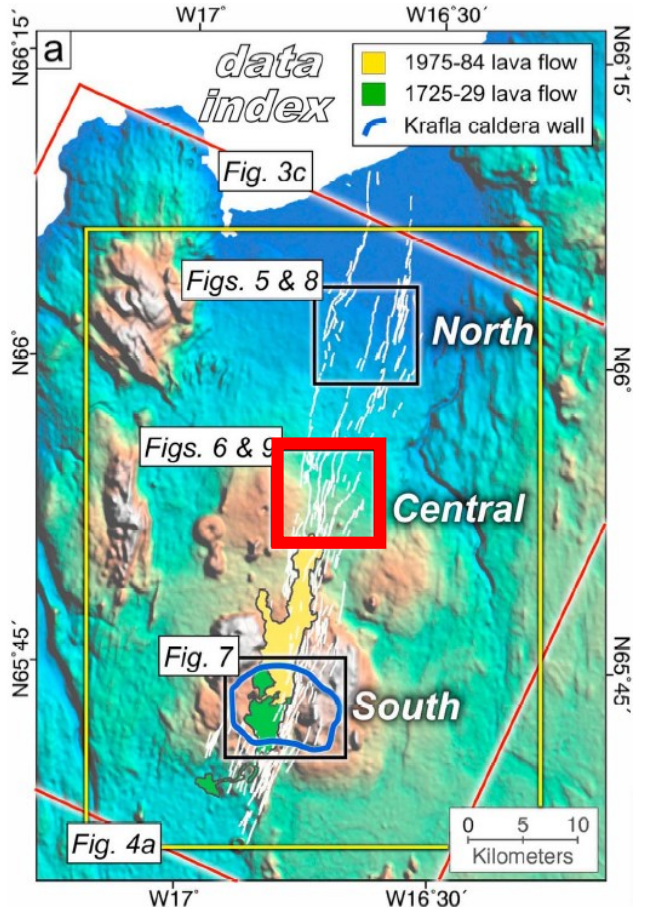


Significant **extension (~2m)** occurred **at early stage** of Krafla crisis.
However, the total deformation remain the same across the whole crisis.
➔ During mid-late stage, almost no extension at the north

Areial image correlation result of **central** region **1957-1976 & 1976-1990**

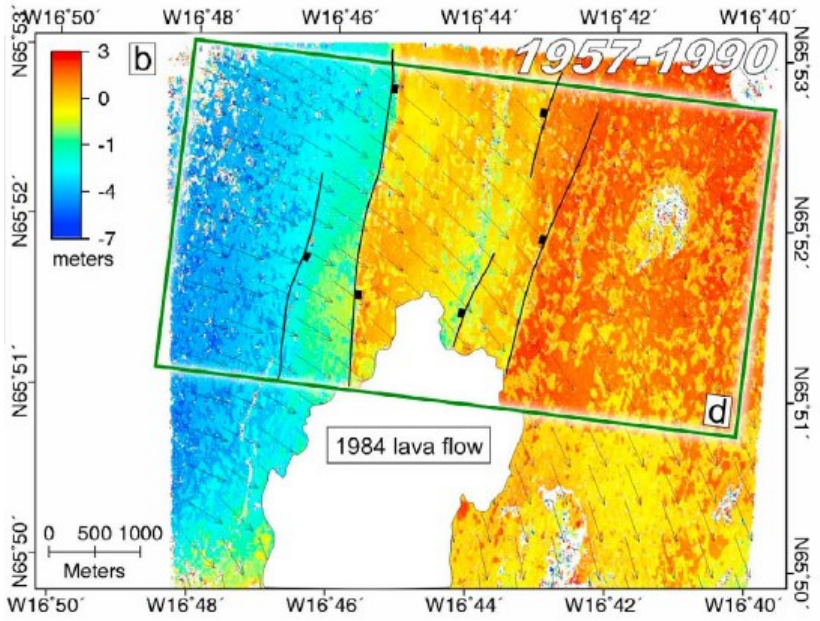


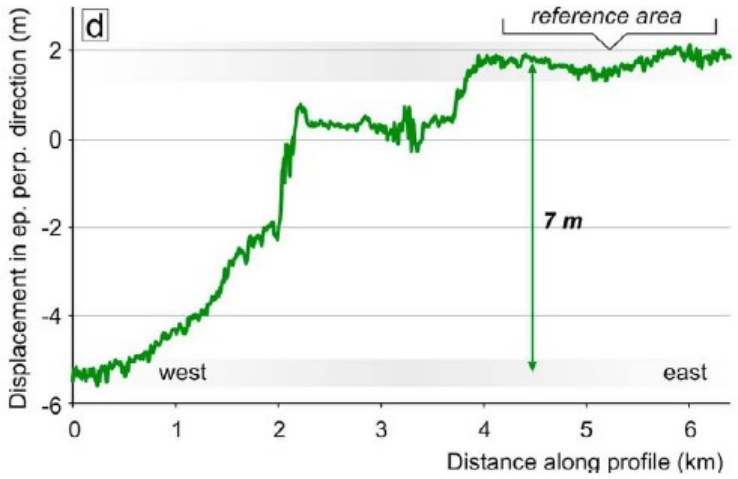


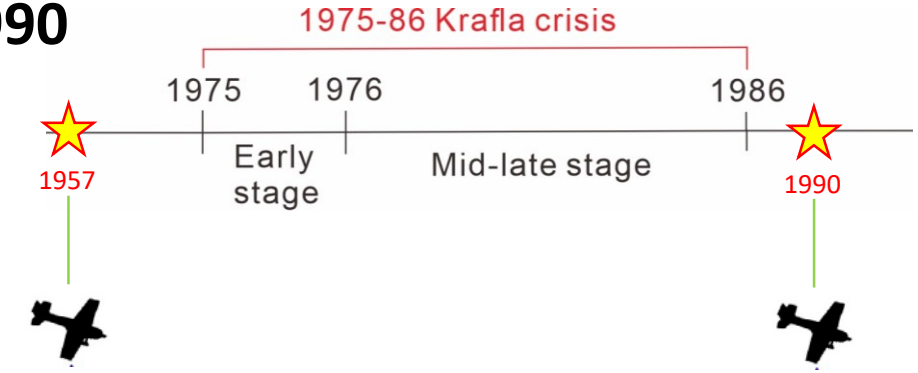


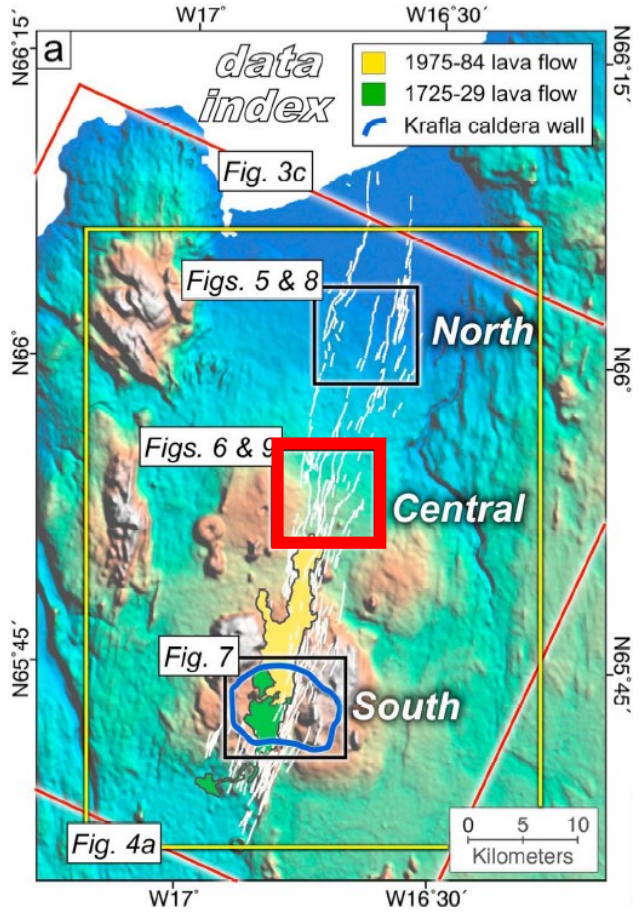
In contrast, we can't observe extension at **central area** during early stage, but **more significant extension (~7m)** can be seen **during mid-late stage**.

Areial image correlation result of **central** region **1957-1990**



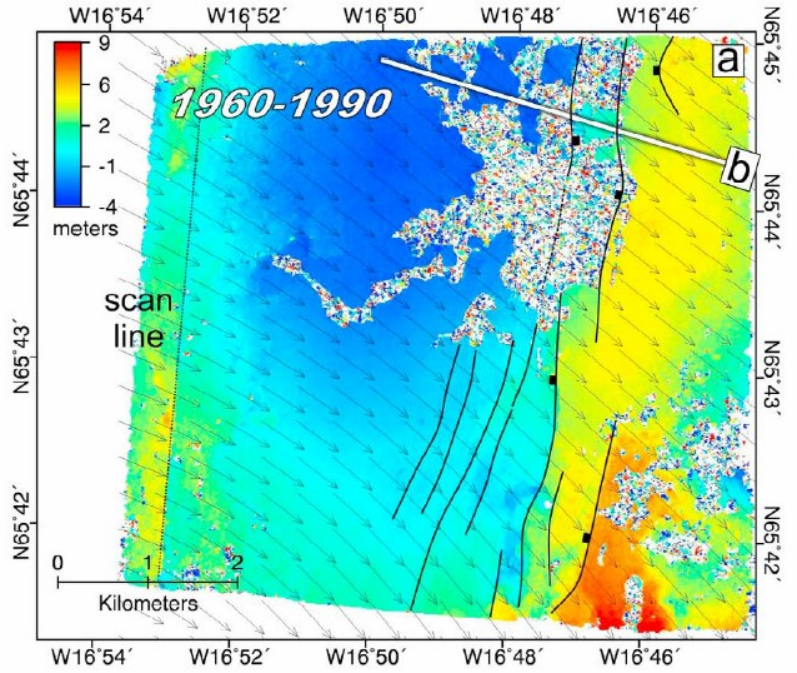


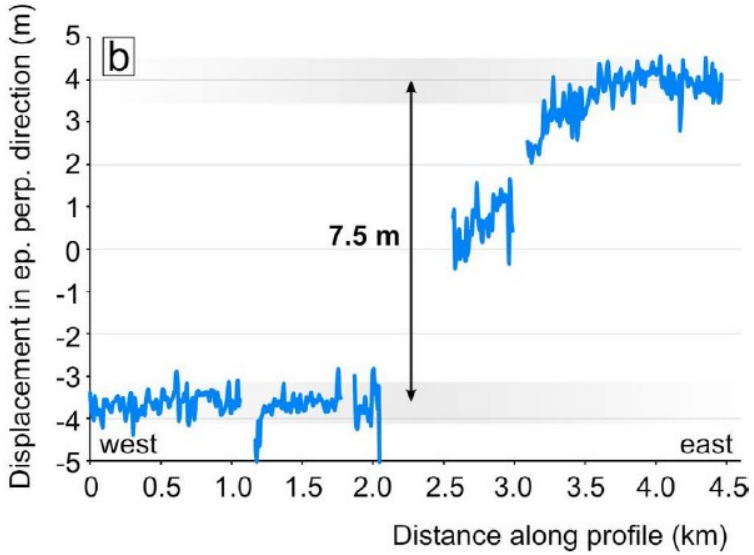




The displacement measurement from 1957-1990 can help us check the consistency

Areial image correlation result of **south** region **1960-1990**





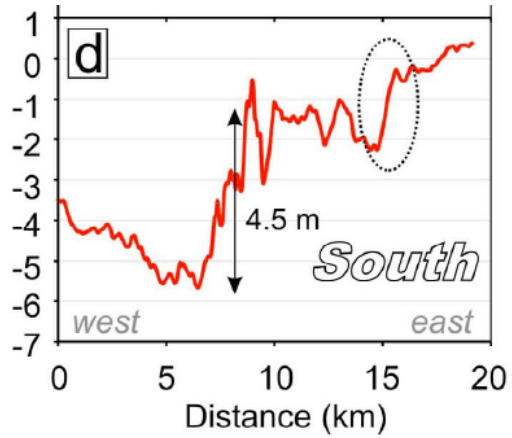
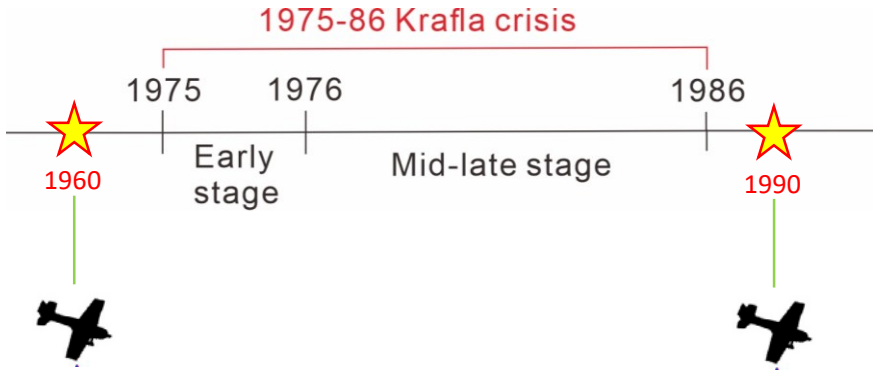
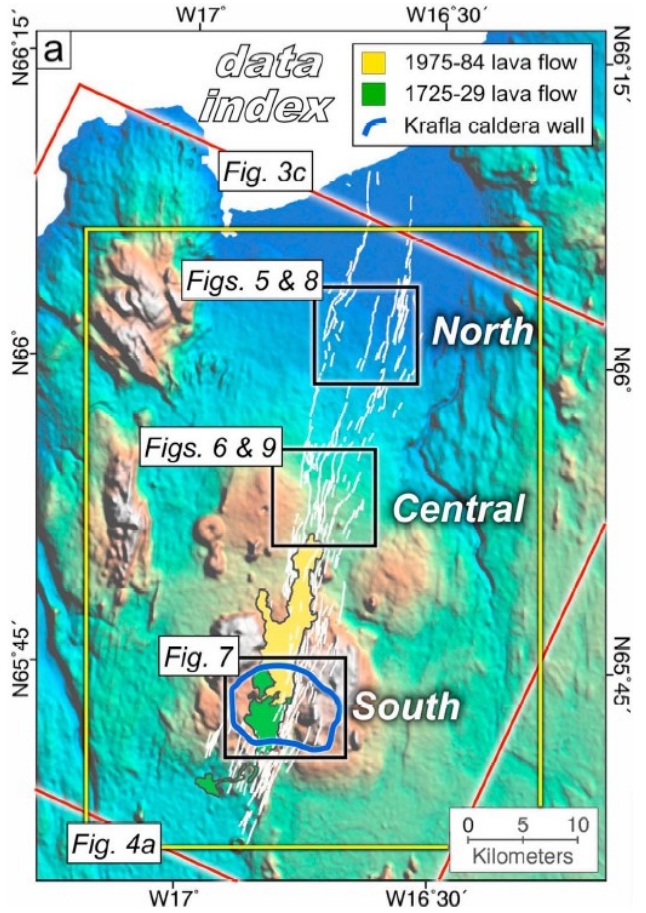


Figure 7. (a) Epipolar perpendicular displacement field for the southern section of the Krafla fissure swarm (see Figure 2 for location) from correlation 1960 and 1990 aerial photos. Decorrelated areas in





The total extension is 7.5m at the south.
If we compare the result of satellite image correlation, the **extension at early stage is ~3m**

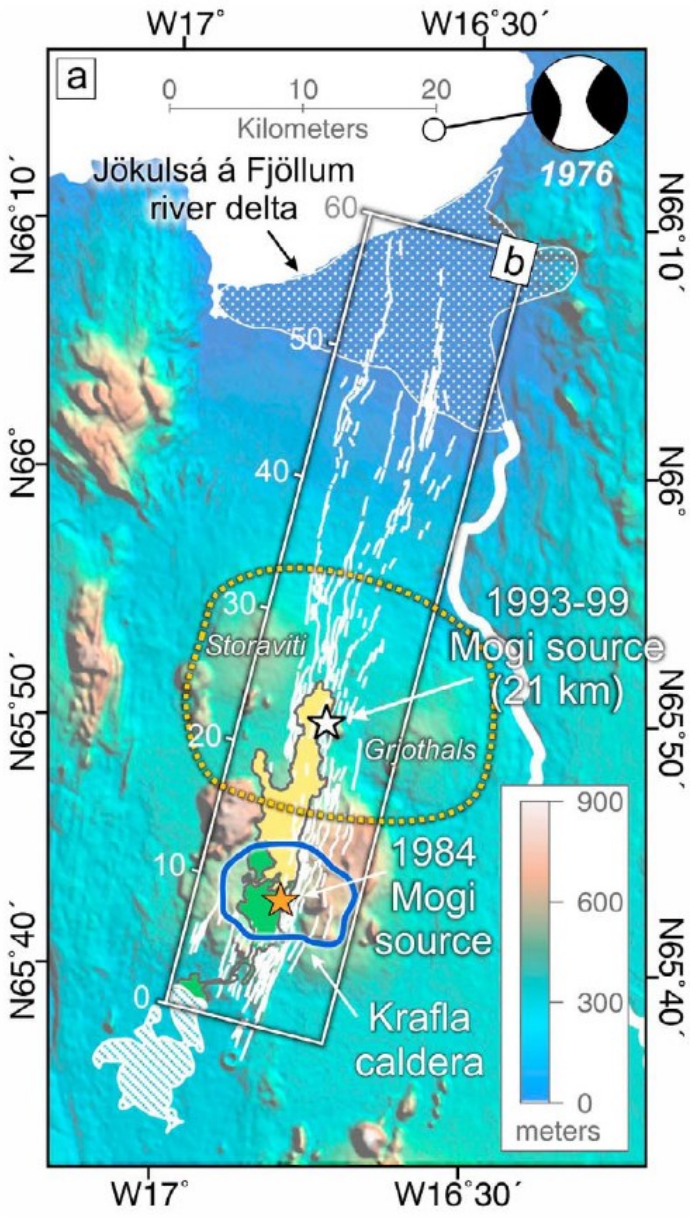


Figure 12. Bathymetry and topography of the northern Krafla fissure swarm. Faults are shown by white lines. The

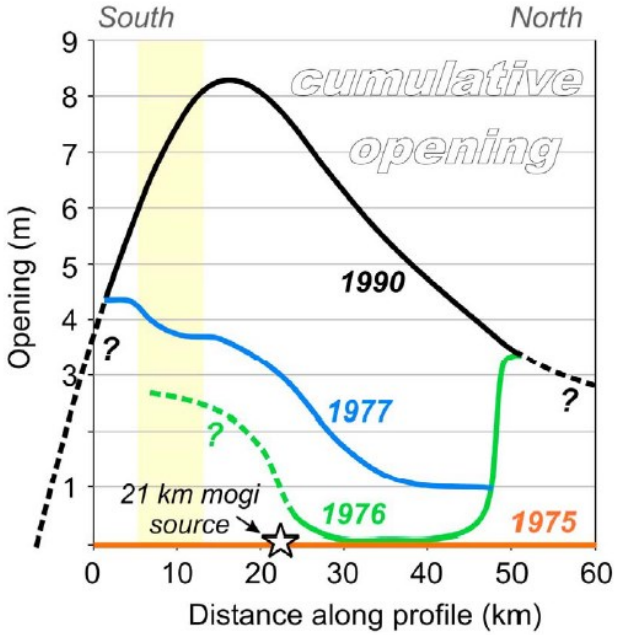
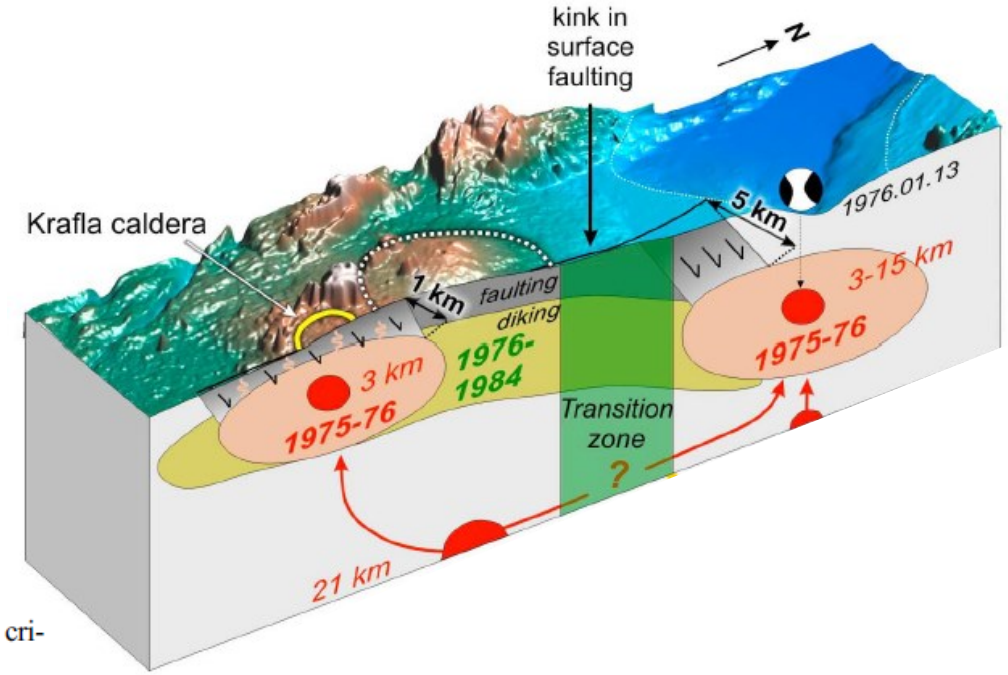


Figure 11. Cumulative opening along the length of the crisis (axes are the same as for Figures 10b and 10c).



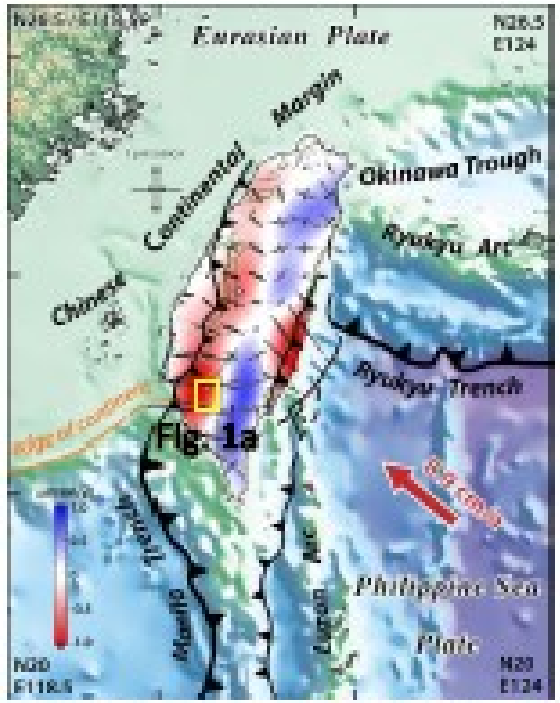
-- During the **early stage**, **the extension at south(caldera) and north(coast line) was very active**. However, there was almost **no activity at central part**.

-- Central part started to **active at mid-late stage**, and activity at the south continued, but the **extension at north stopped**.

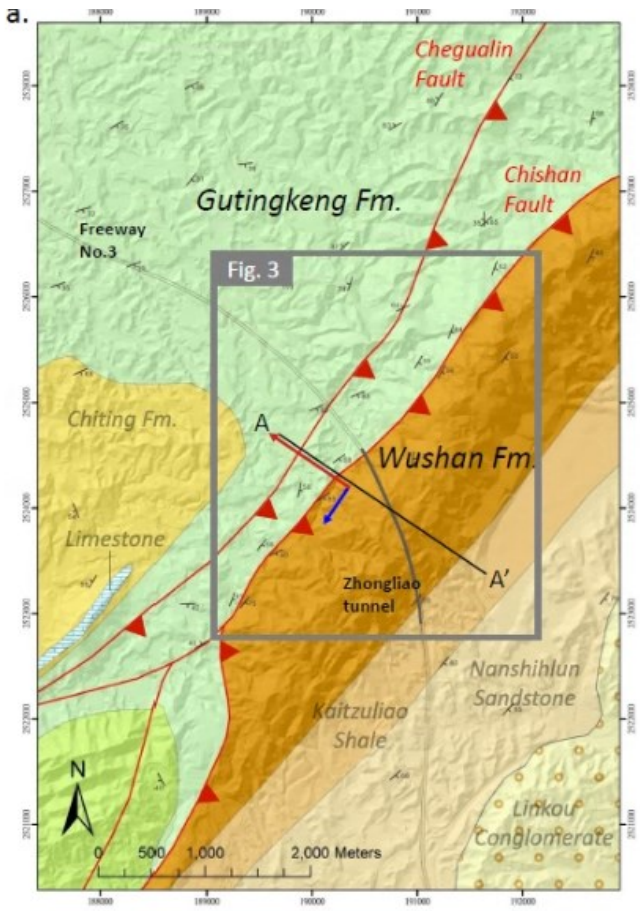
-- A **bi-modal pattern of opening** along the rift could be **produced by two different magma sources**, located at the **northern and southern ends of the rift zone**.

-- Alternatively, the bi-modal pattern of opening **may also result from a weakening of the host rock** along the northern end of the rift, **as magmatic volatiles transition** to ambient pore fluids feeding the dike tip cavity.

Future work



Tectonic setting of Taiwan (Strain rate map from Hsu et al., 2009)



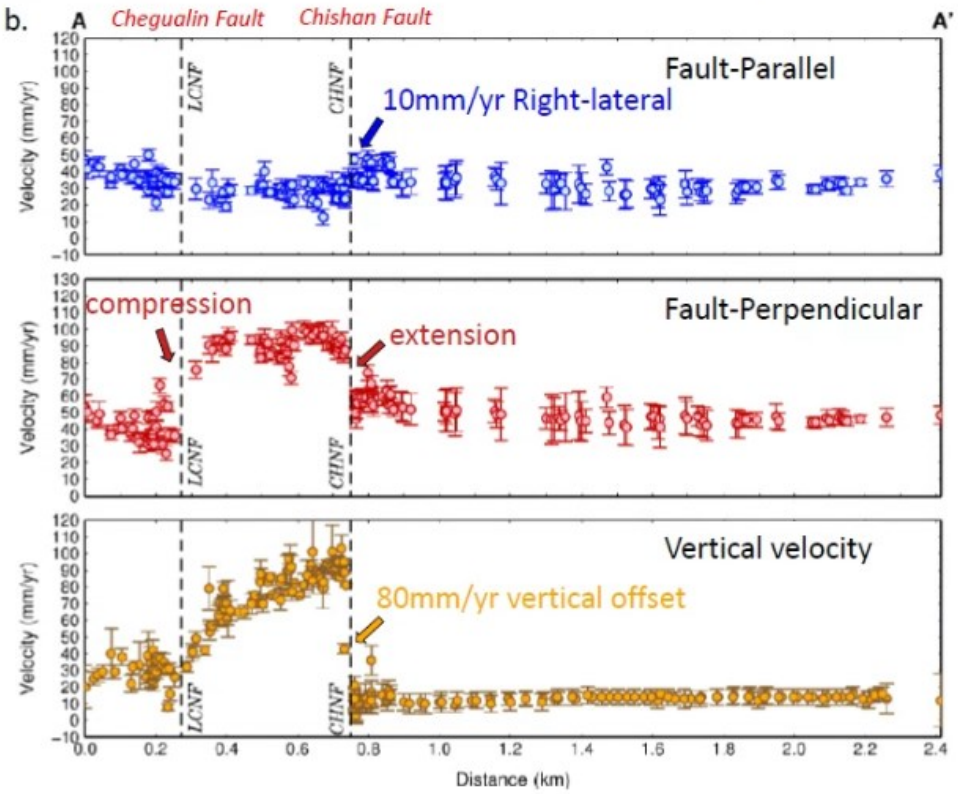
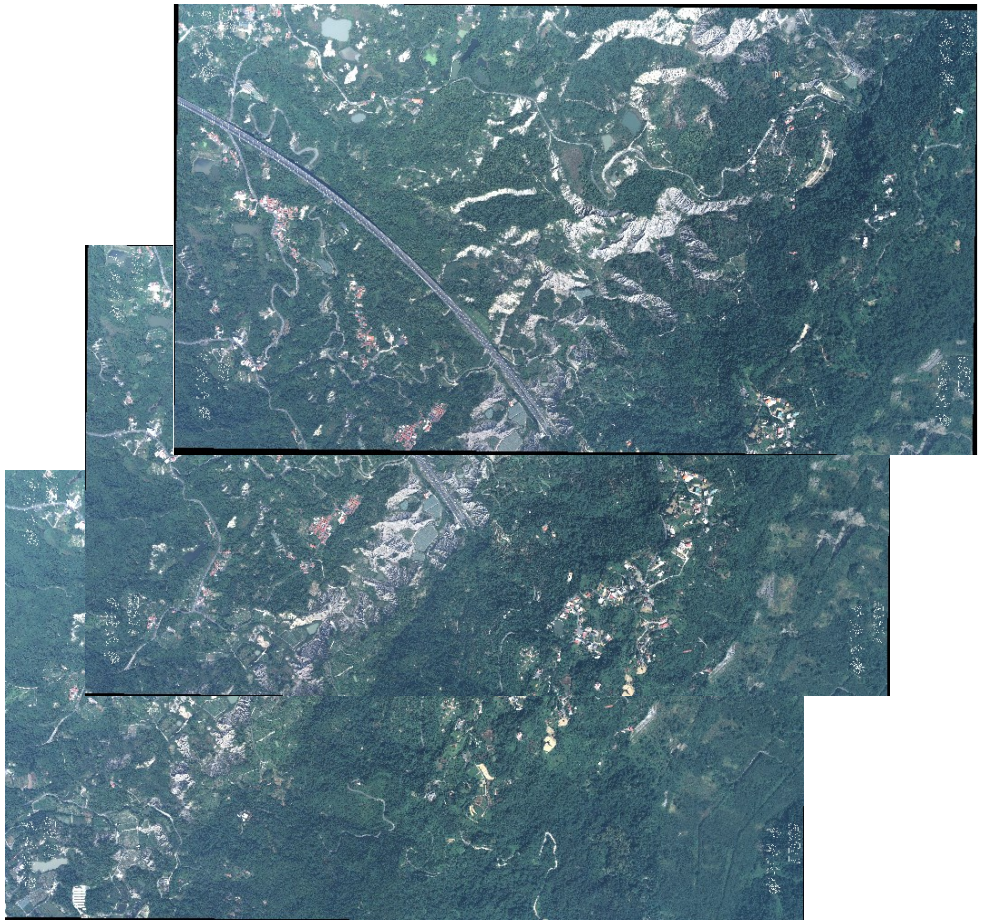
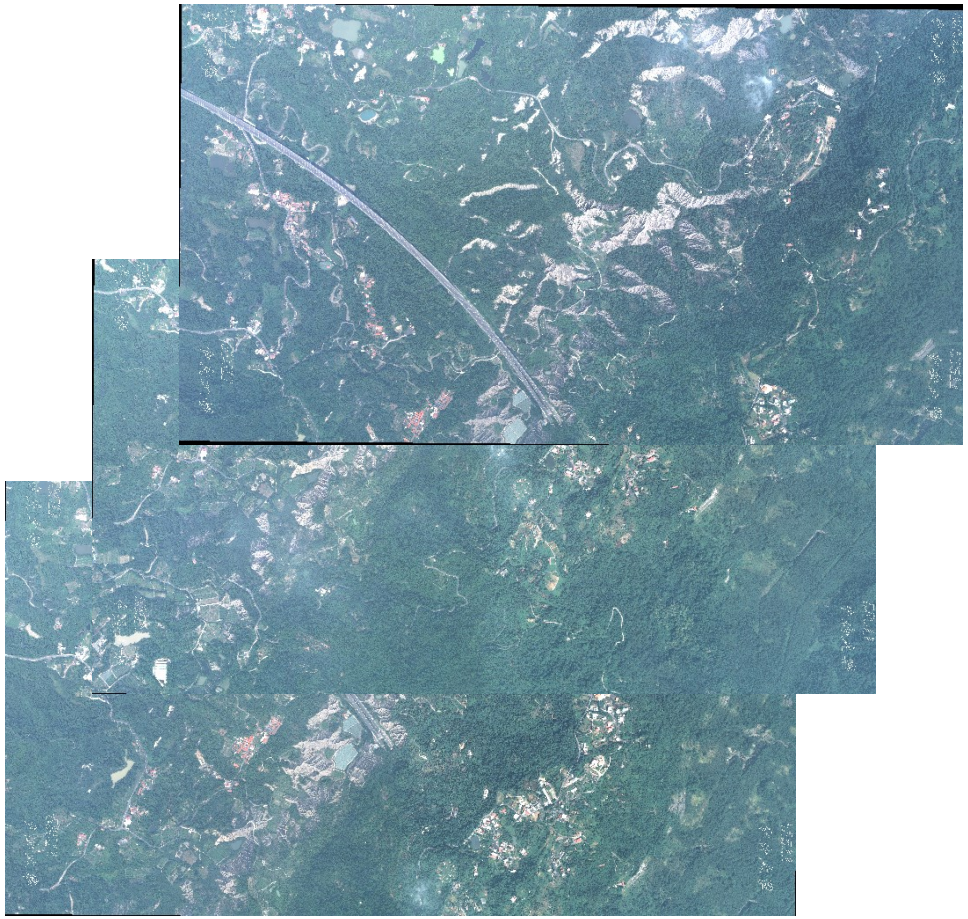


Fig. 1 (a) Geological map of Zhongliao tunnel area (Lin CW, 2013, complemented with our observations along the Chishan fault). (b) Velocity relative to Penghu based on geodetic measurements, projected on AA' line (Chang-Lee, 2014).

2012 Aerial Images



2015 Aerial Images



Using aerial images acquired from Forest Bureau, Aerial Survey Office

Thank You for your attention!!