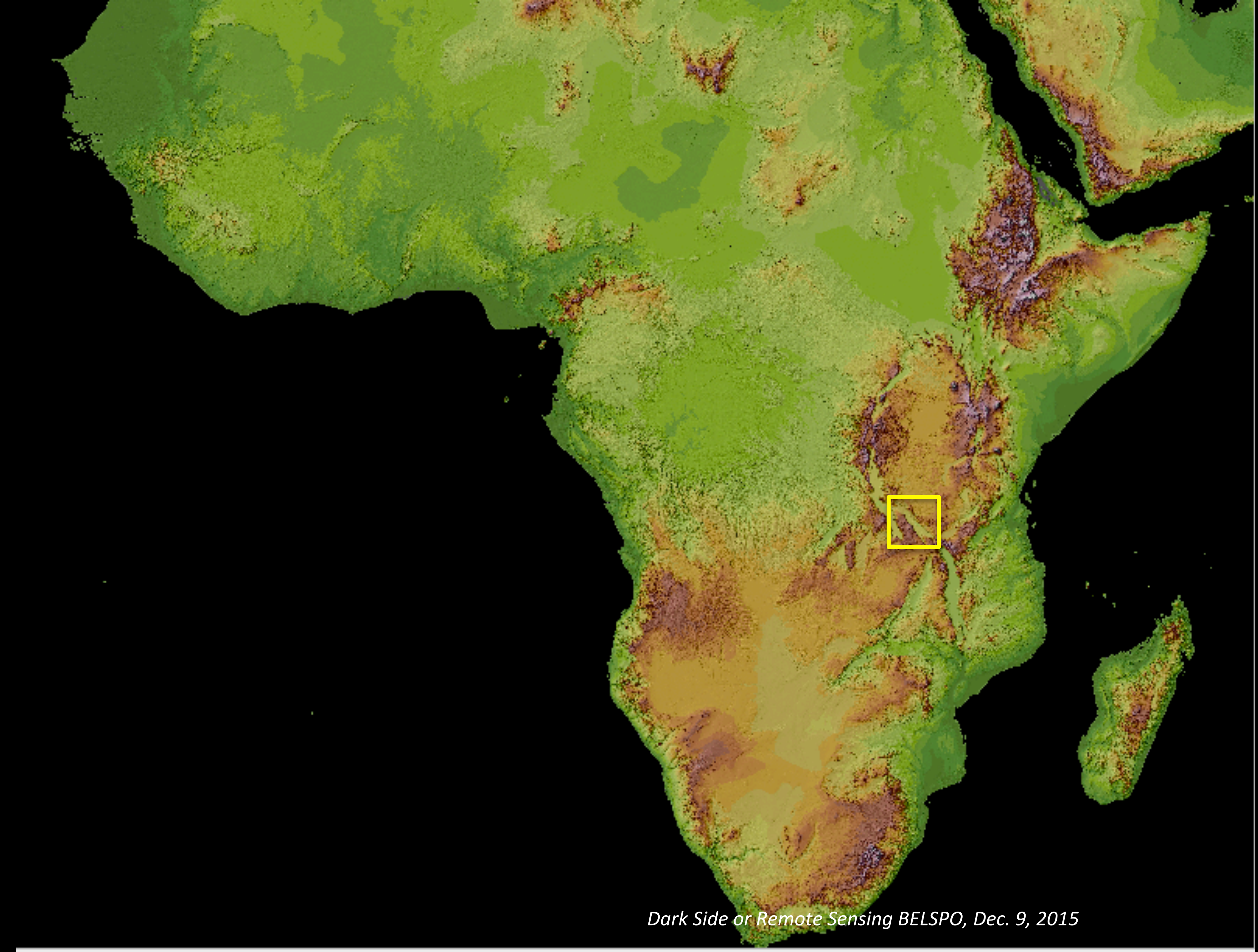
Classical InSAR: example of application in various volcanic and tectonic context

François Kervyn
Royal Museum for Central Africa
Earth Science Dept / Natural Hazards
And many others…

Dark Side or Remote Sensing BELSPO, Dec. 9, 2015

Sumary

- Topography and geomorphology
  - Tectonic context
  - Volcanic context
- Mapping co-eruptive deformations
- Mapping co-seismic deformations



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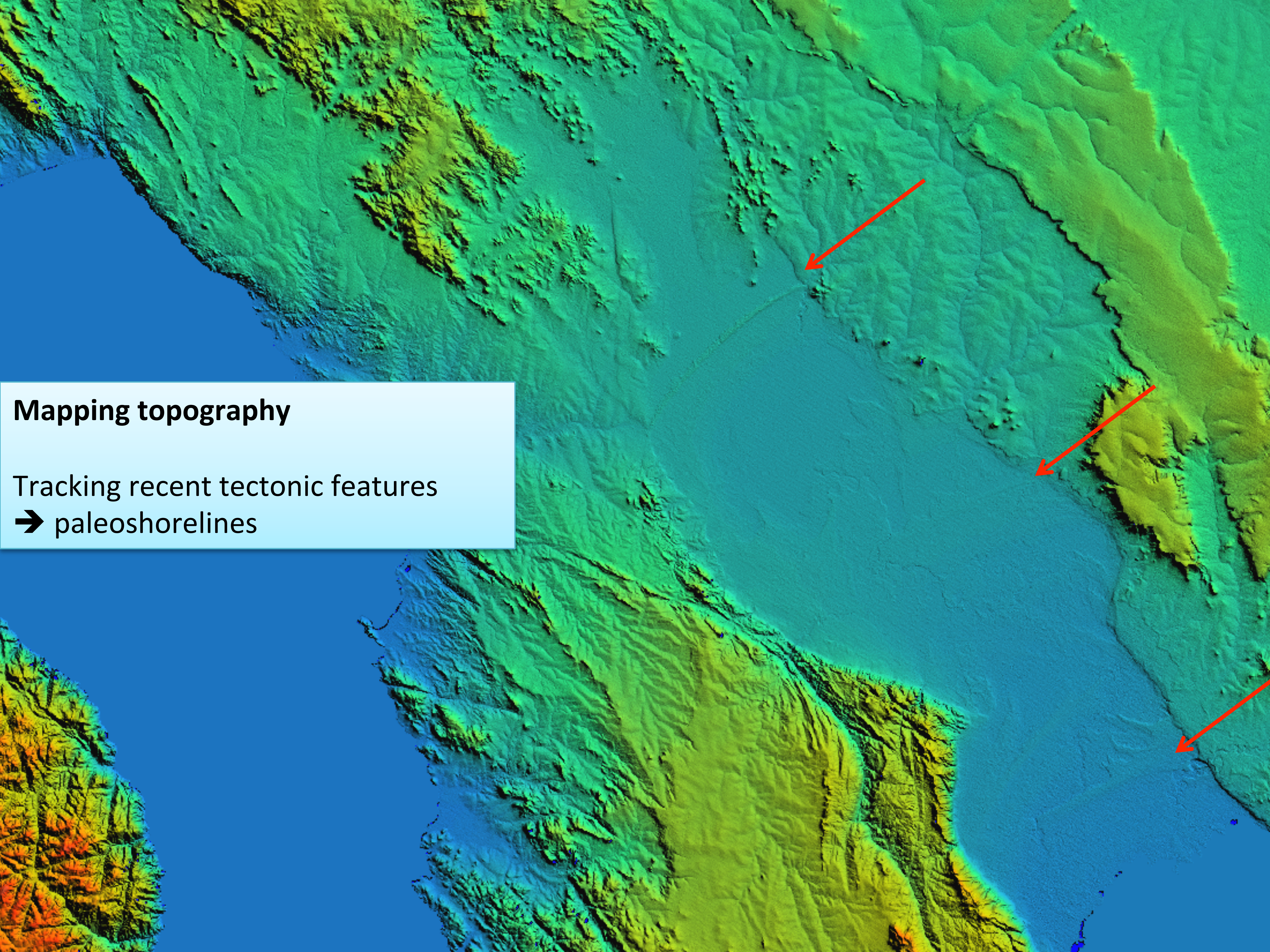
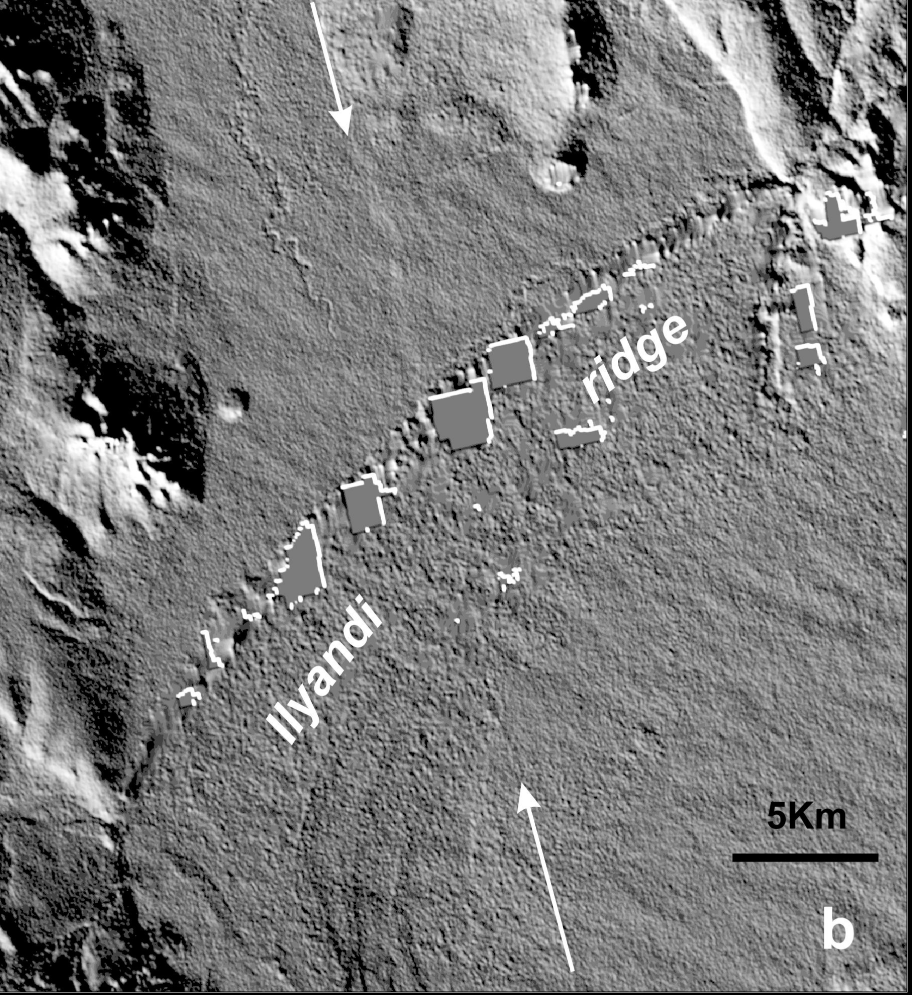
Mapping topography

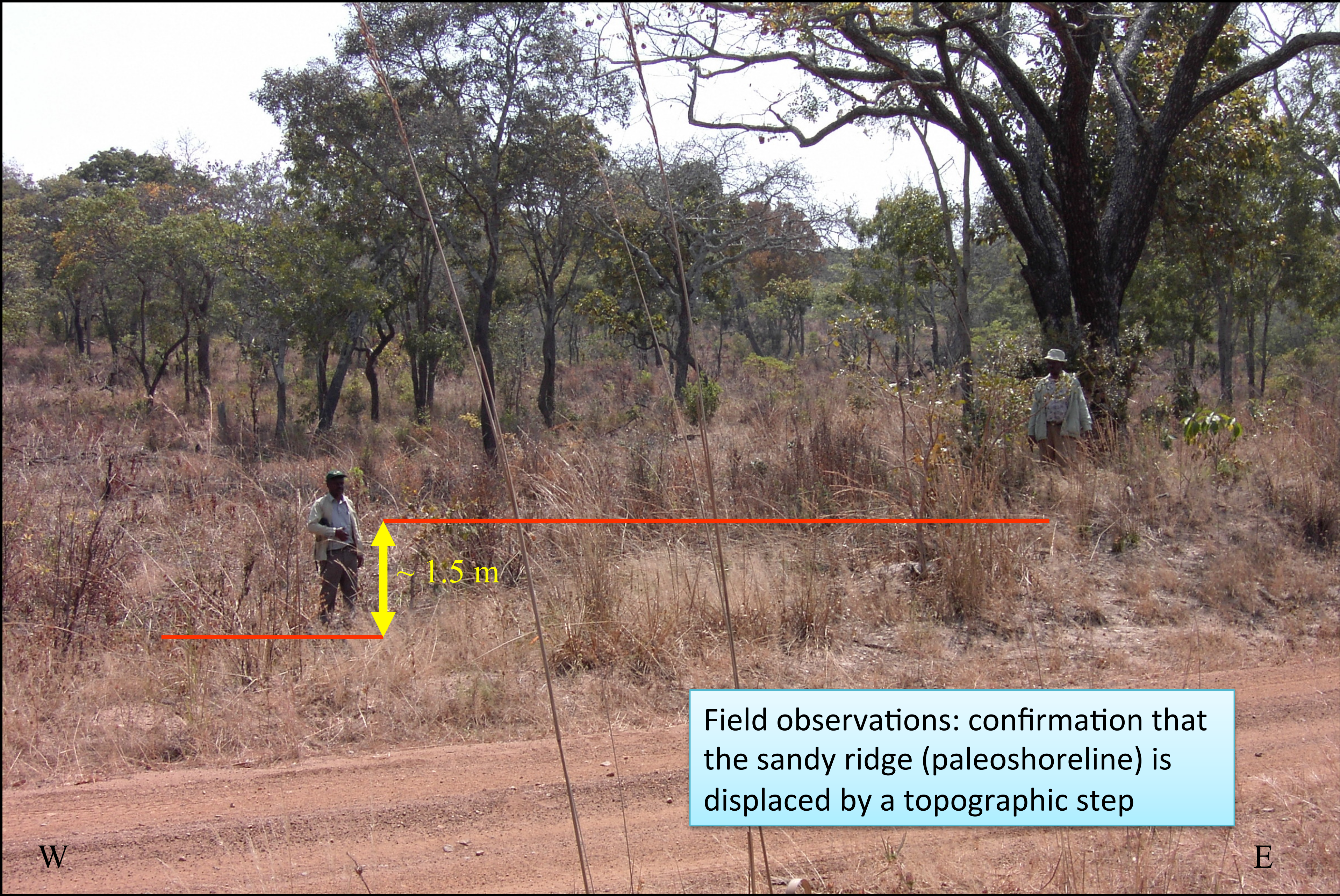
Tracking recent tectonic features
➔ paleoshorelines



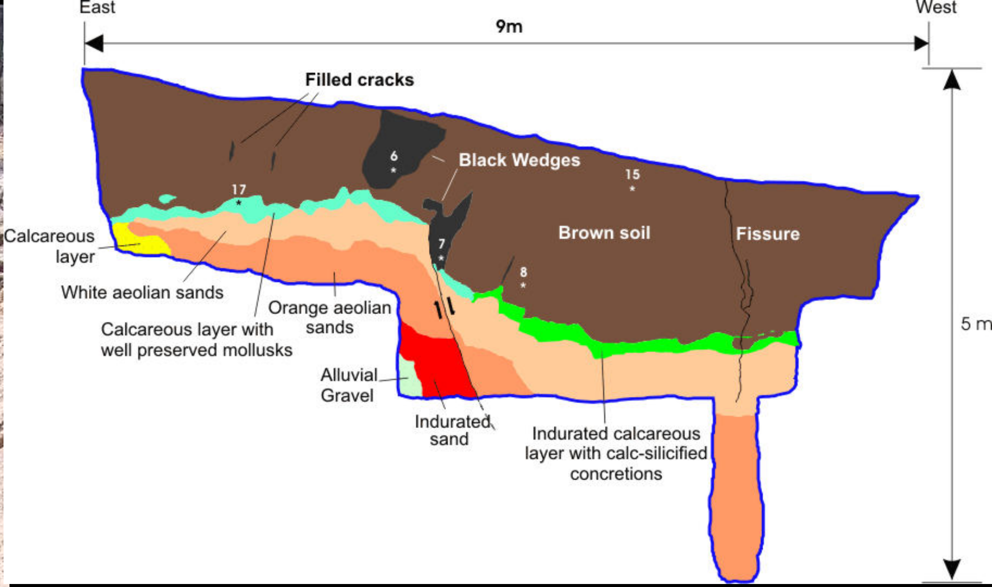


Subtle topographic step undetected on 1/50,000 topographic maps

Cross correlation with optical remote sensing (LSAT NDVI):
➔ contrast in vegetation related to soil moisture

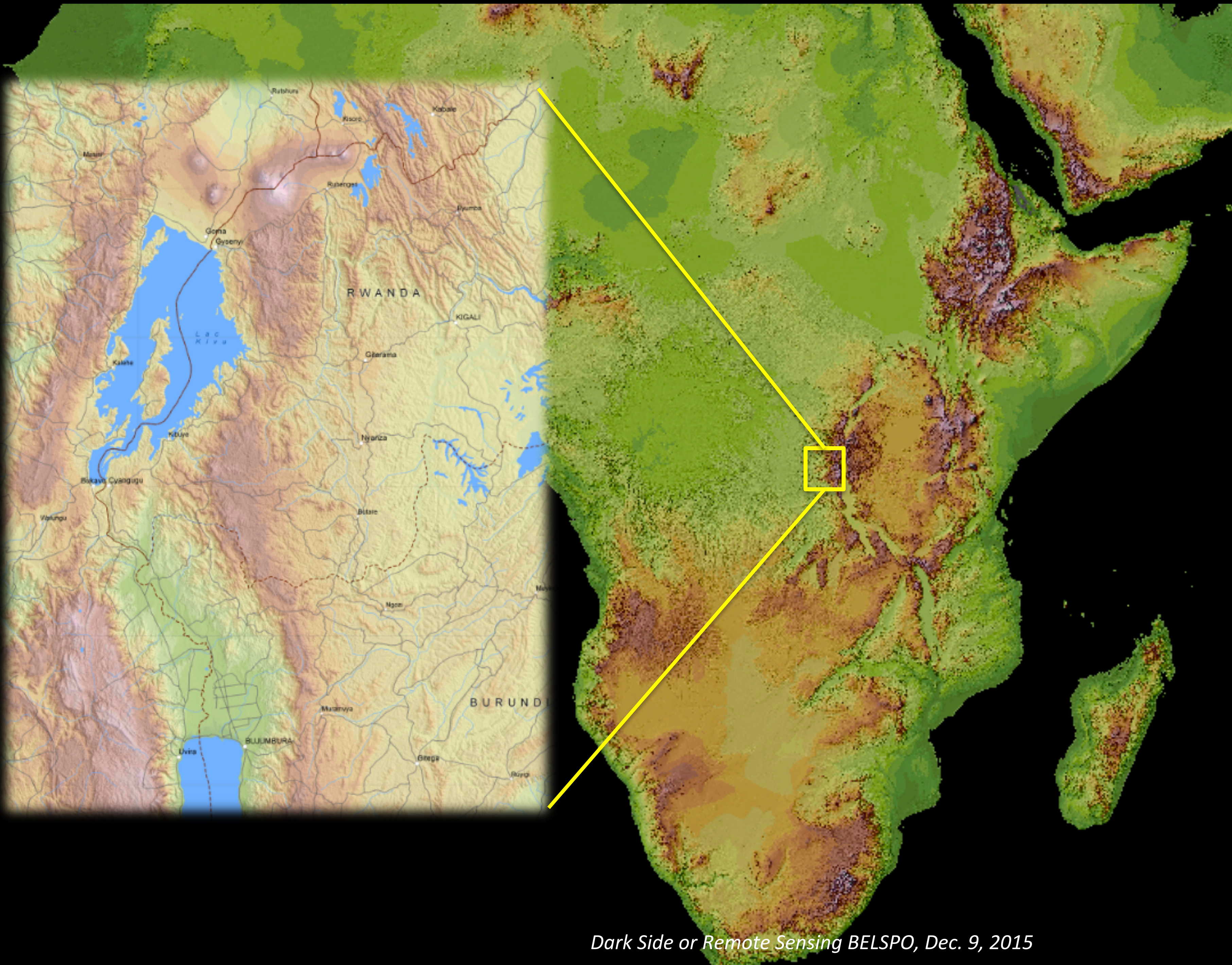

~ 1.5 m
Field observations: confirmation that the sandy ridge (paleoshoreline) is displaced by a topographic step
W
E

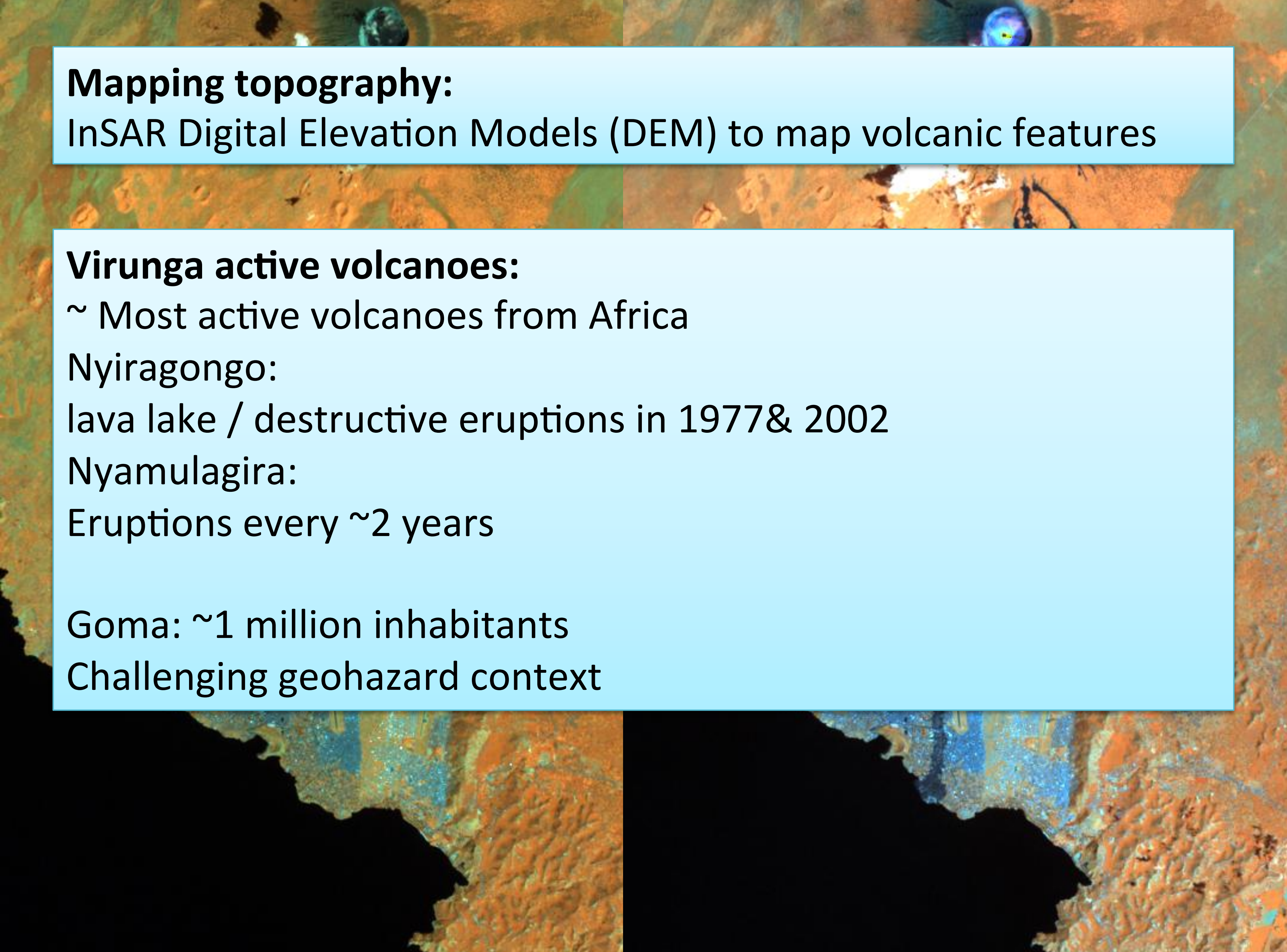
Looking East



Trench excavation accorss the scarp
- ➔ Evidence a tectonic fault
- ➔ date of last movement +/- 600Bp

CONCLUSION:
InSAR topography more sensitive than existing standard datasets
Demonstrates that InSAR is a suitable tool for neotectonic studies


Kabale
Ruhengeri
Goma
Gisenyi
RWANDA
KIGALI
Gitarama
Nyanza
Bukavu
Cyangugu
Butare
BURUNDI
BUJUMBURA
Uvira
Gitega



Mapping topography:

InSAR Digital Elevation Models (DEM) to map volcanic features

Virunga active volcanoes:

~ Most active volcanoes from Africa

Nyiragongo:

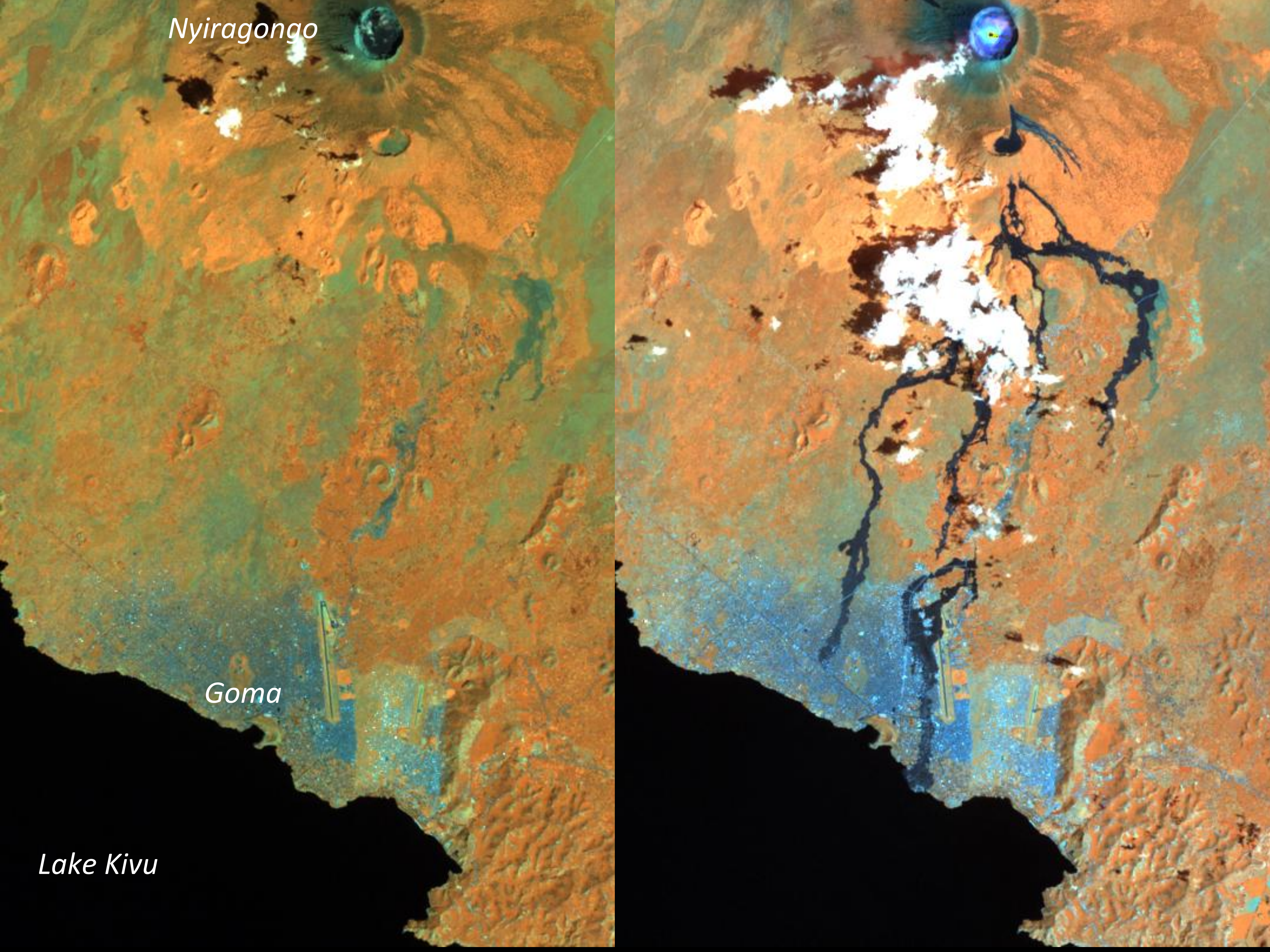
lava lake / destructive eruptions in 1977& 2002

Nyamulagira:

Eruptions every ~2 years

Goma: ~1 million inhabitants

Challenging geohazard context

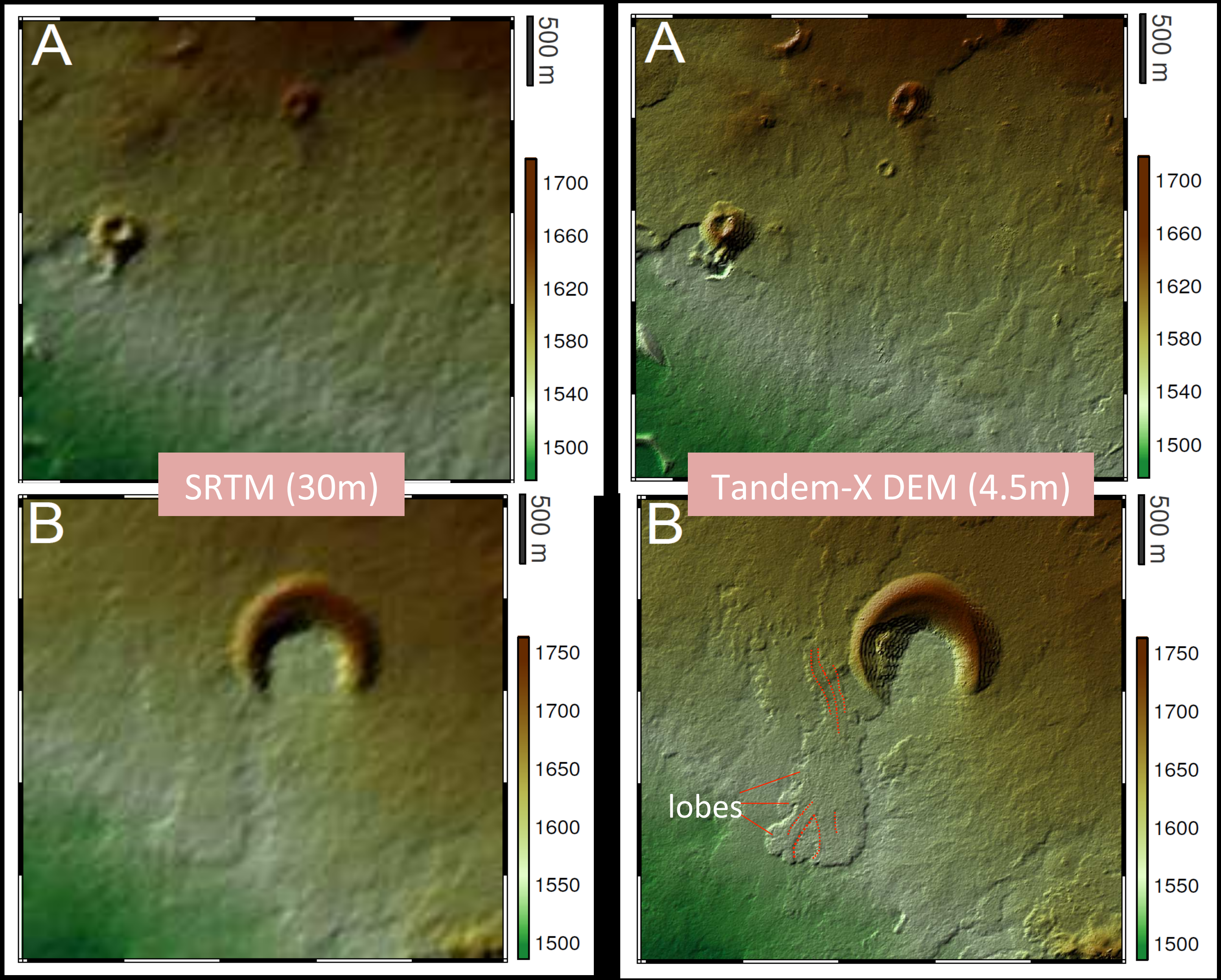

Nyiragongo
Goma
Lake Kivu

Topography for volcanic features

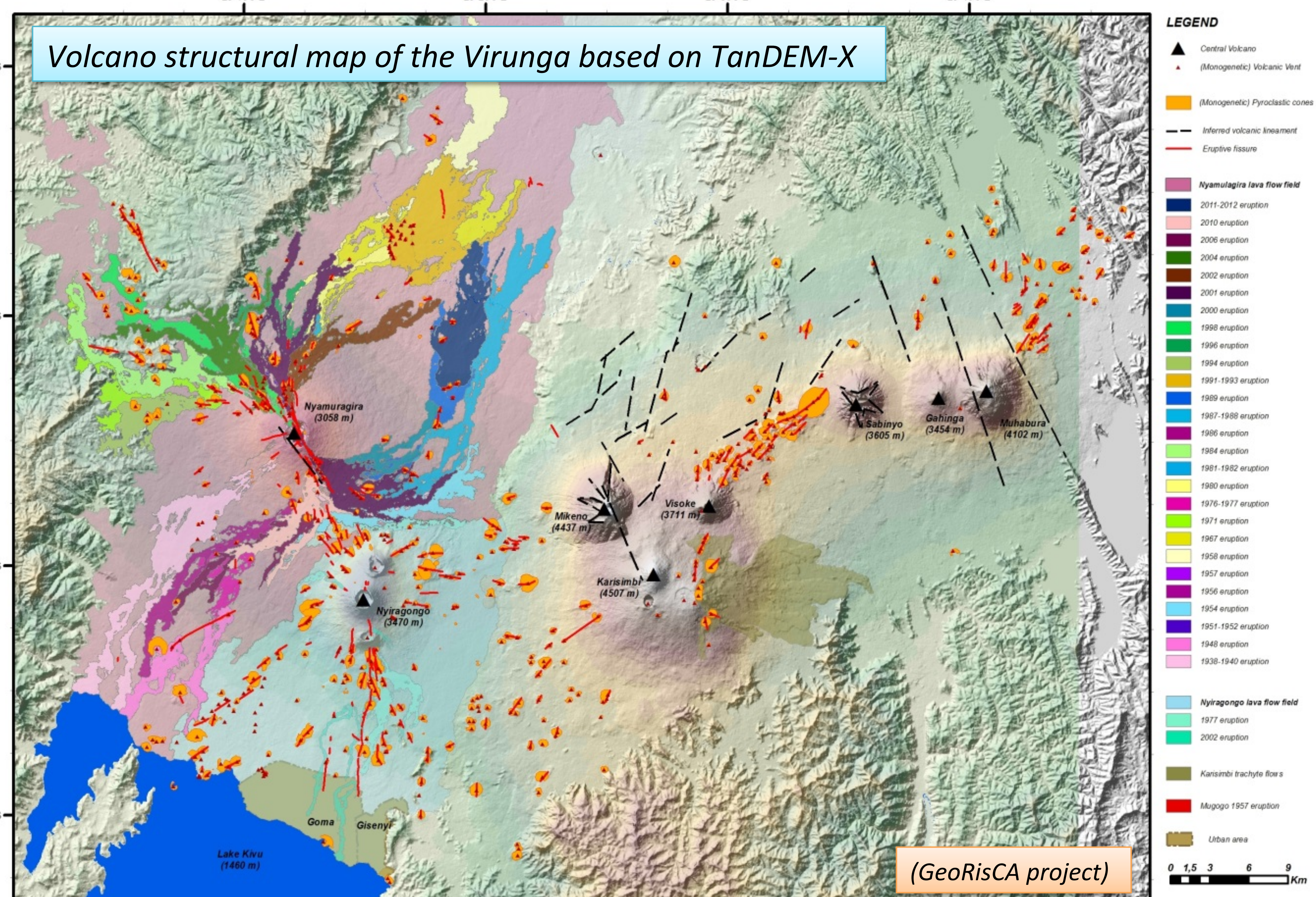
- Study of the volcanic geomorphology:
  - To understand past events (types, behaviour, relative chronology…)
  - To link with regional geodynamic mechanisms
  - To quantify extruded lava volumes or volcanic cones
  - To model lava flow paths
  - To contribute to other related studies (hazard mapping, risk analysis…)

Example: mapping volcanic features

Spatial/spectral resolution matters



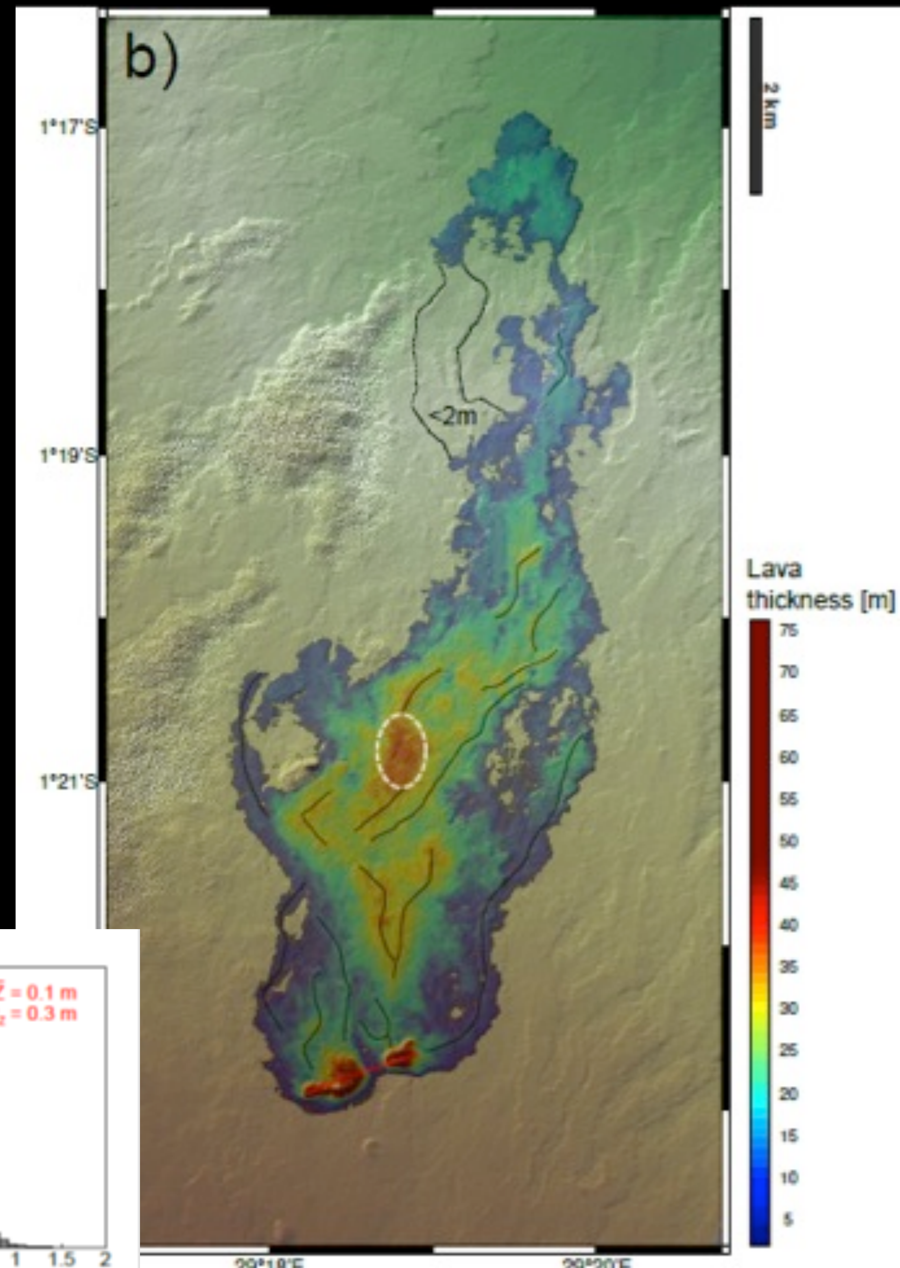
Volcano structural map of the Virunga based on TanDEM-X

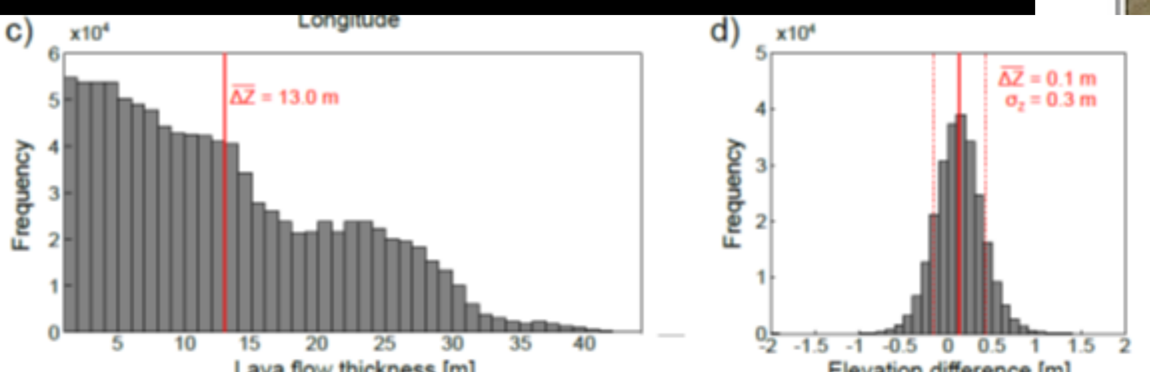


(GeoRisCA project)

Example: mapping surface changes (InSAR DEM)

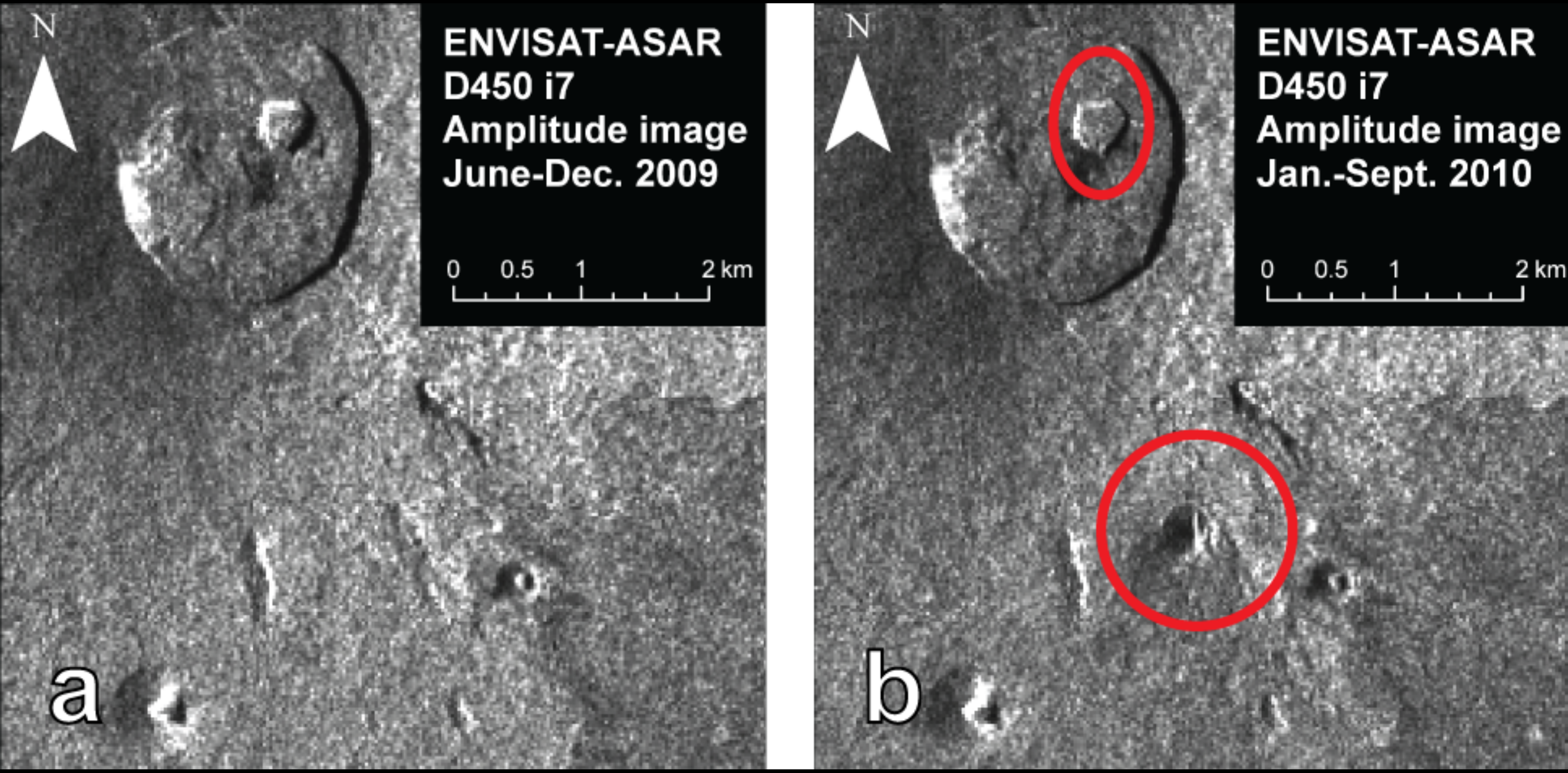
Substracting pre-event topography from new topography:
➔ lava flow volume





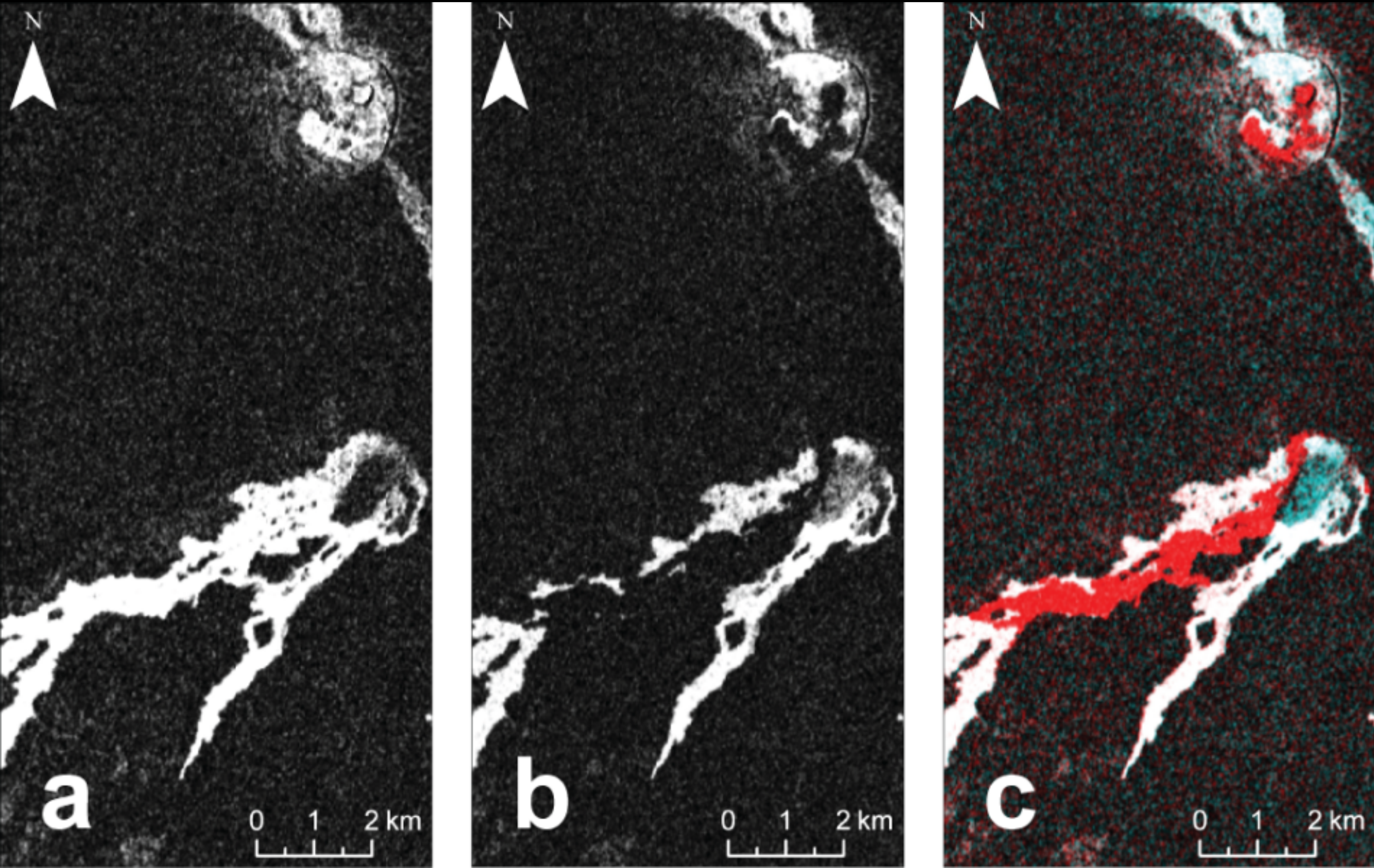
Example: mapping surface changes (SAR amplitude)

- ➔ Depth of pit floor
- ➔ New vent

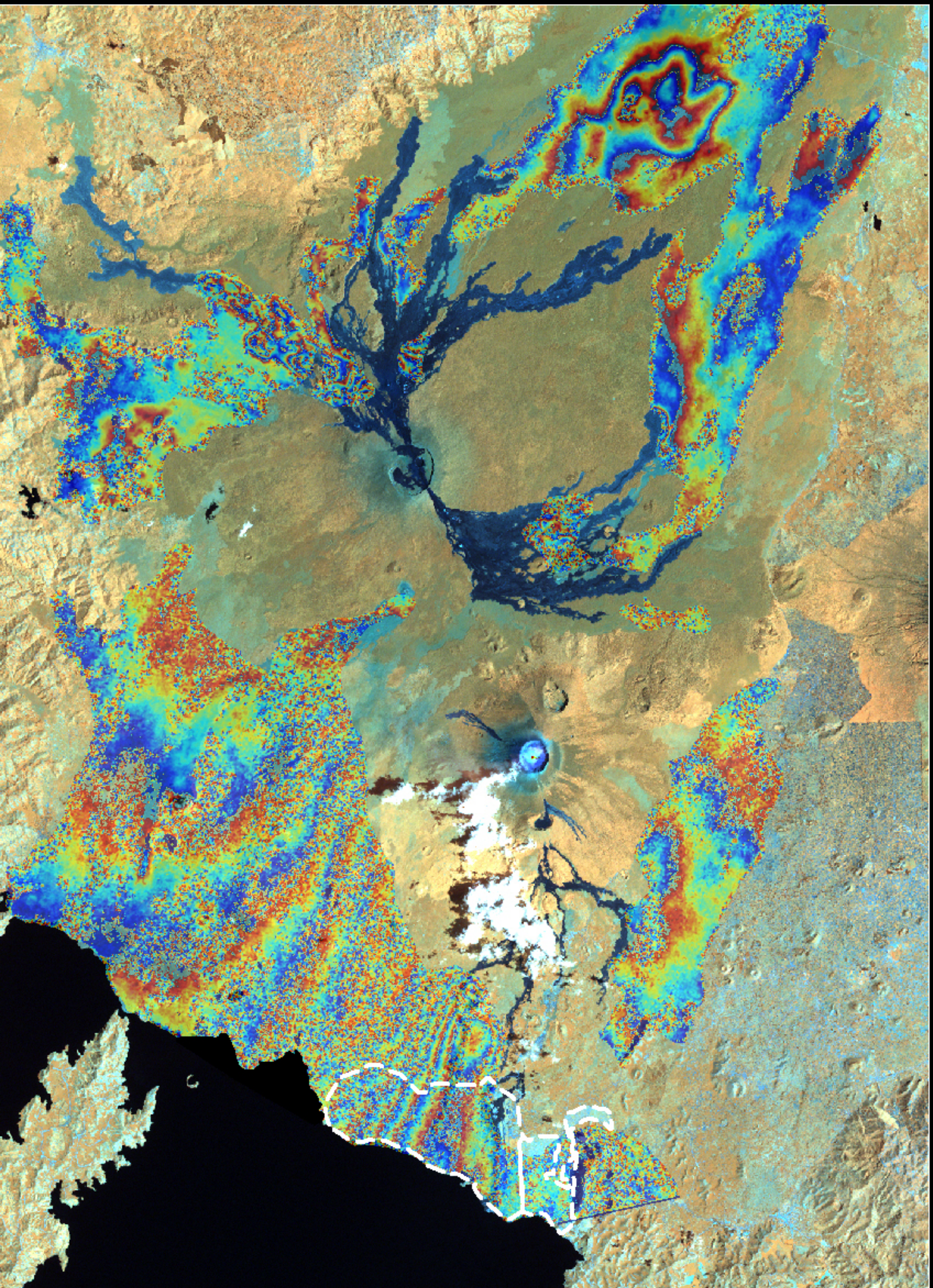


Example: mapping surface changes (Phase coherence)

➔ New lava flows = loss of coherence



ERS 6 Sept. 2000 – 3 July 2002

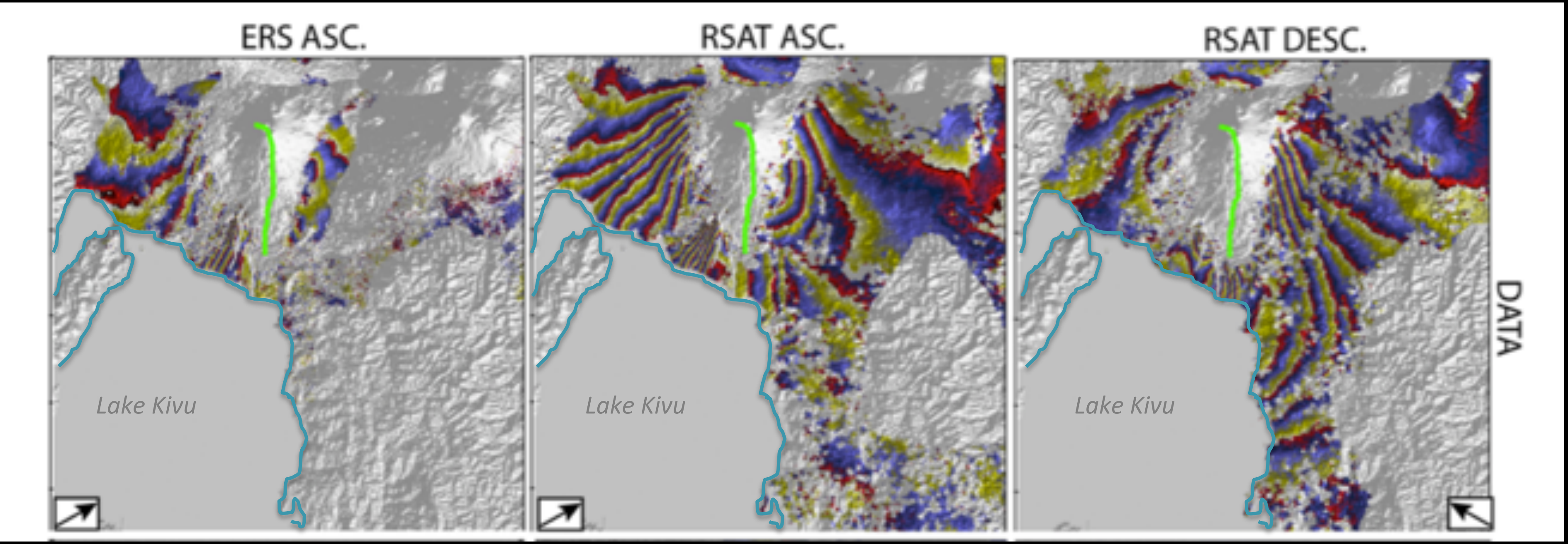


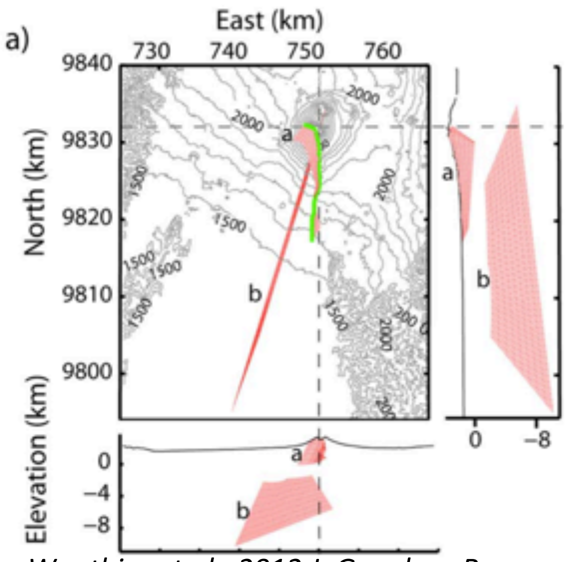
Co-eruptive ground deformations

- ➔ Detect ground displacements
- ➔ Model source of deformation and infer mechanisms

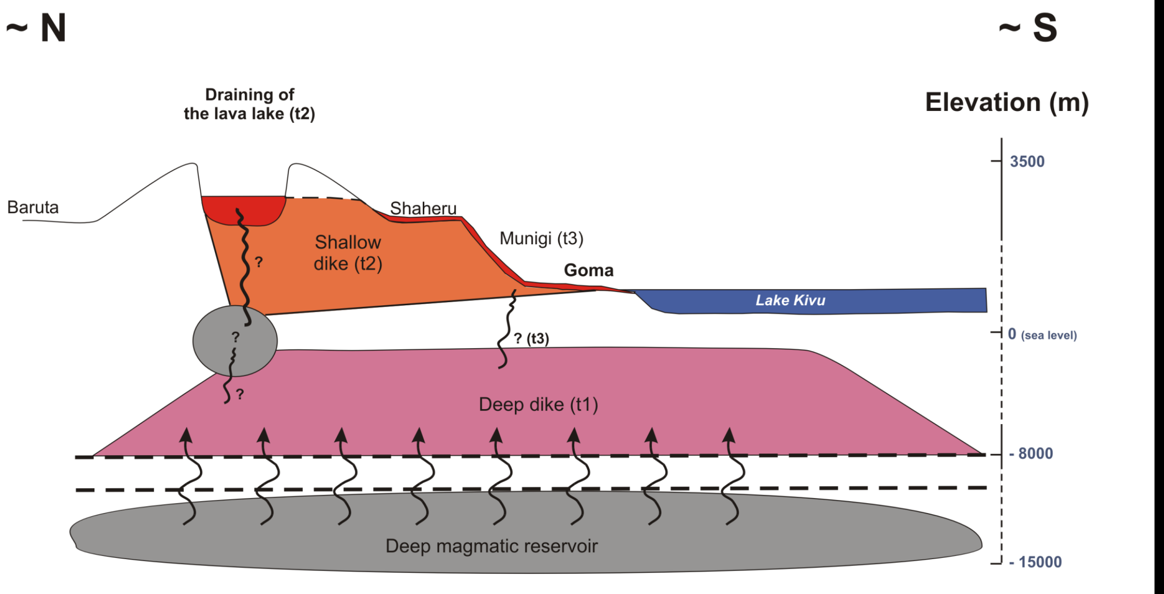
Example of the Nyiragongo 2002 eruption:

Major regional deformation





Wauthier et al., 2012 J. Geophys. Res.



Coseismic ground deformations

Example: Bukavu Feb. 2008: What happened ?

- Main shock: Mw 5.9 near Bukavu (DRC) and Cyangugu (Rw)
- Dozen of felt aftershocks recorded by international seismic networks (USGS NEIC catalog)
- > 700 aftershocks recorded by local seismic network over the next 3 weeks
- > 43 people killed, 1090 people injured, more than 5000 houses destroyed, landslides.

Context

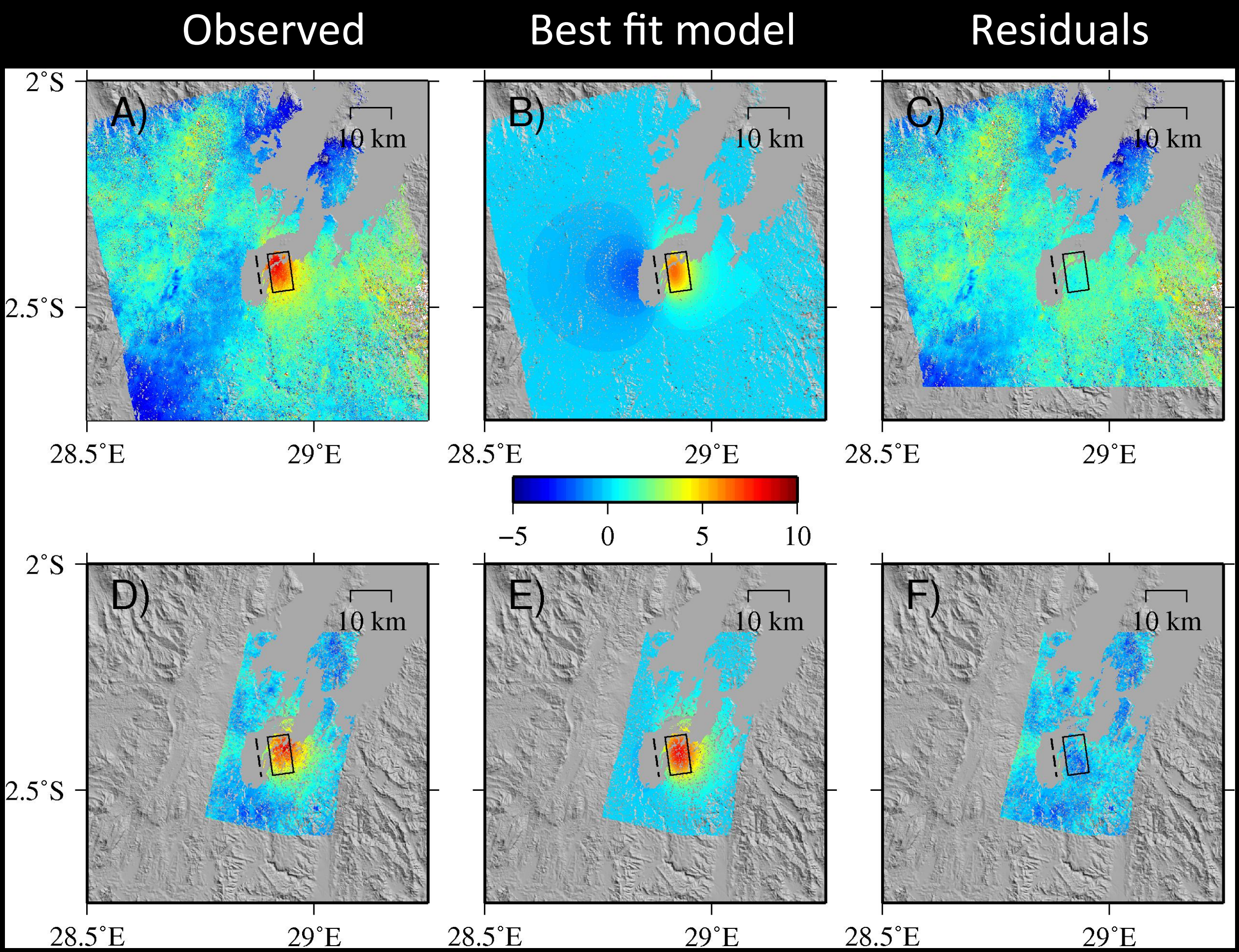
Seismicity

- Historical seismicity: Mw > 5 are not common
- 2nd largest event since 1973 after the 2002 6.2 event
- Shallow depth with no traces at the surface
- Associated to an intense seismic (and also volcanic) activity in that portion of the rift

Monitoring

- No local seismic records at the time of main shock
- Local data 5 days after EQ
- Global Seismographic Network. + Afar Consortium seismic arrays in Ethiopia
- SAR (ENVISAT systematic monitoring + ALOS) in the frame of GORISK project
- Field investigations 2 days after event

InSAR: Ground deformation [in cm in LOS]

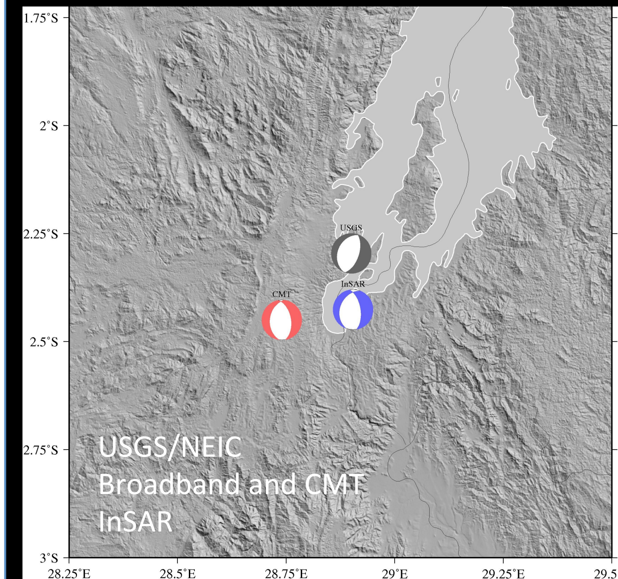


Ascending ALOS PALSAR
L-band (23,6 cm)
2007/12/29 – 2008/03/30
Bp 111m, Look angle 34 deg.

Descending ENVISAT ASAR
C-band (5,6 cm)
2008/01/10 – 2008/02/14
Bp 125m, Look angle 22 deg.

Envisat, ALOS and Joint inversion compared to Broadband and CMT

Inversion data set	Depths (km)	Dip (Deg)	Strike (Deg)	Rake (Deg)	Latitude (Deg)	Longitude (Deg)	Moment (10^{17} Nm)
ENVISAT	9.3 ± 0.6	46.6 ± 2.5	351.5 ± 10.0	-91.5 ± 14.3	28.9425 ± 0.0009	-2.4060 ± 0.0036	9.61 ± 0.10
ALOS	9.8 ± 0.3	63.0 ± 0.5	352.3 ± 0.5	-92.5 ± 15.7	28.9196 ± 0.0006	-2.4216 ± 0.0004	11.64 ± 0.02
Joint ENVISAT+ALOS non-weighted	8.9 ± 0.3	58.6 ± 0.8	352.4 ± 1.6	-105.2 ± 16.6	28.9260 ± 0.0006	-2.4219 ± 0.0020	9.79 ± 0.004
Joint ENVISAT+ALOS weighted	8.9 ± 0.4	55.1 ± 1.4	354.5 ± 1.4	-97.9 ± 15.9	28.9299 ± 0.0850	-2.4145 ± 0.369	8.99 ± 0.010
Broadband+CMT	7.8 ± 2.0	51.5	350.1	-100.6	28.74 ± 0.01	-2.45 ± 0.01	9.43 ± 0.06



CONCLUSIONS:

- Independent SAR data set : similar results
- Inversions of seismic and geodetic data: similar results
- Consistent with tectonic context
- Accurate location

- Shallow depth and no magma involved

General conclusions

- Classical InSAR offers a wide variety of applications from DEM generation to ground displacement detection and mapping
- InSAR DEM are valuable complement in areas where no or limited pre-existing topographic data
- Very important in cloudy areas
- InSAR always used in combination with other techniques

- Requires baseline of existing archive
- May require regular and frequent acquisitions