

Volcanic unrest at the Erta Ale ridge and the 3D surface velocity in Afar

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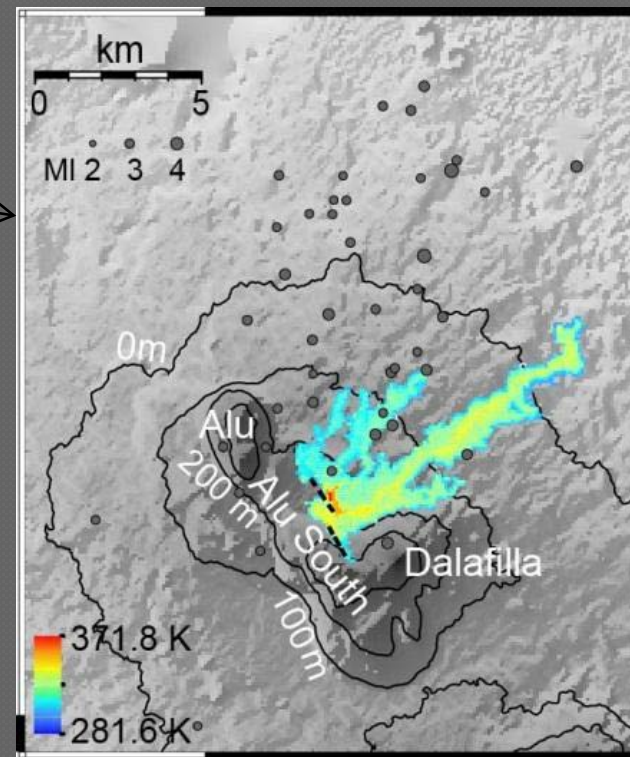
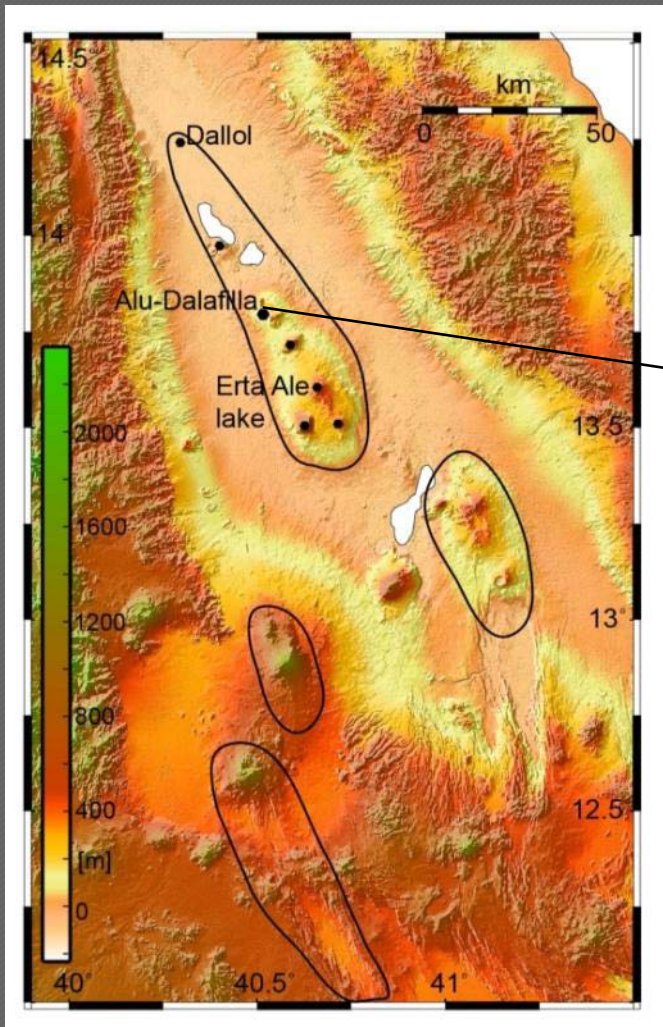
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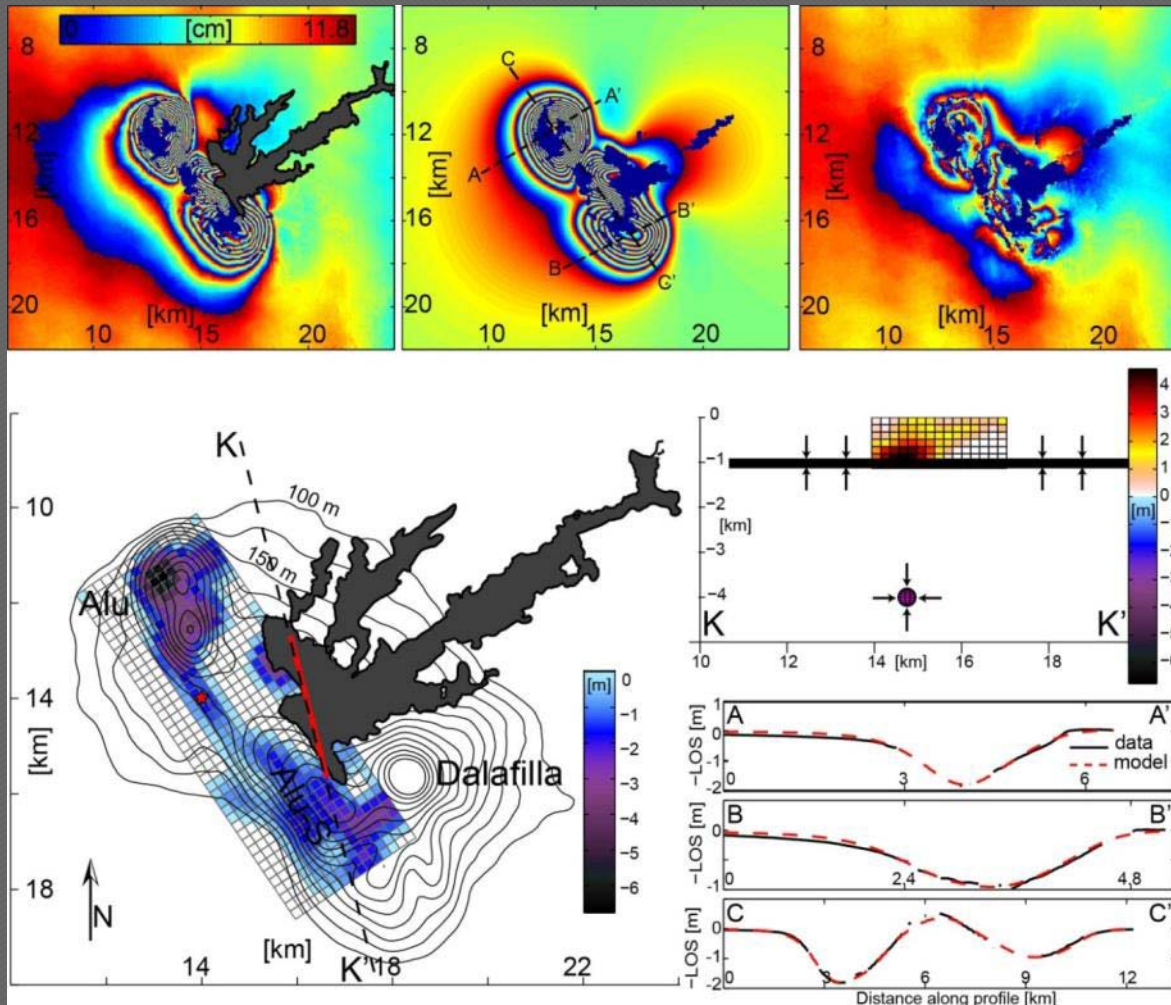
Alu-Dalafilla

Eruption 3-6 Nov. 2008

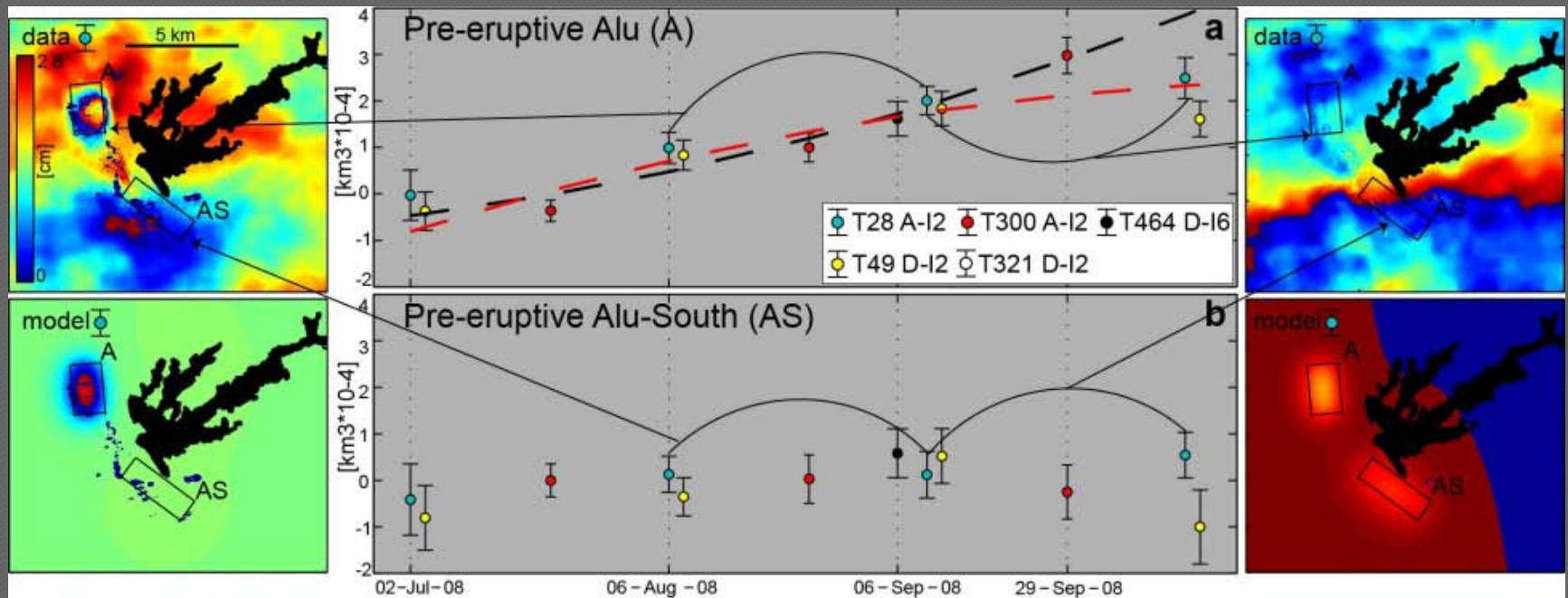


Pagli et al., *Nature Geoscience*, in press

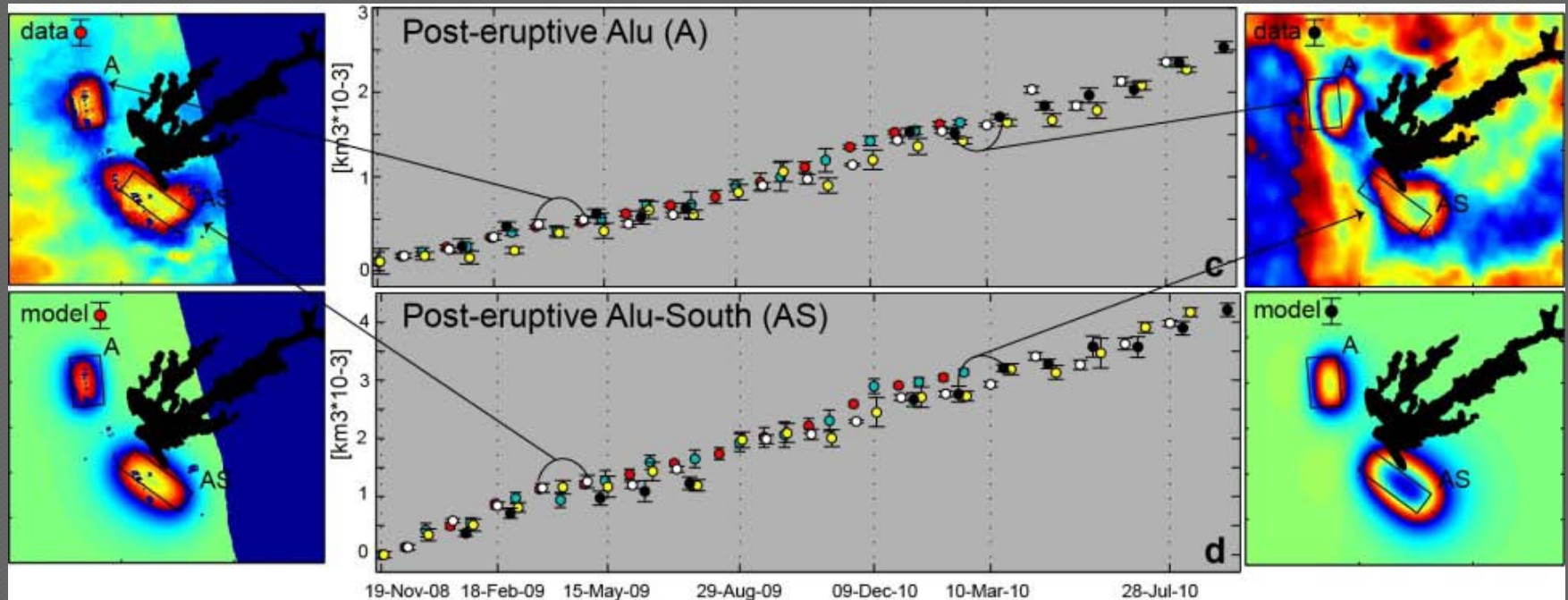
The eruptive deformation



The pre-eruptive phase



The replenishment phase



What is the 2008 Alu-Dalafilla eruption telling us?

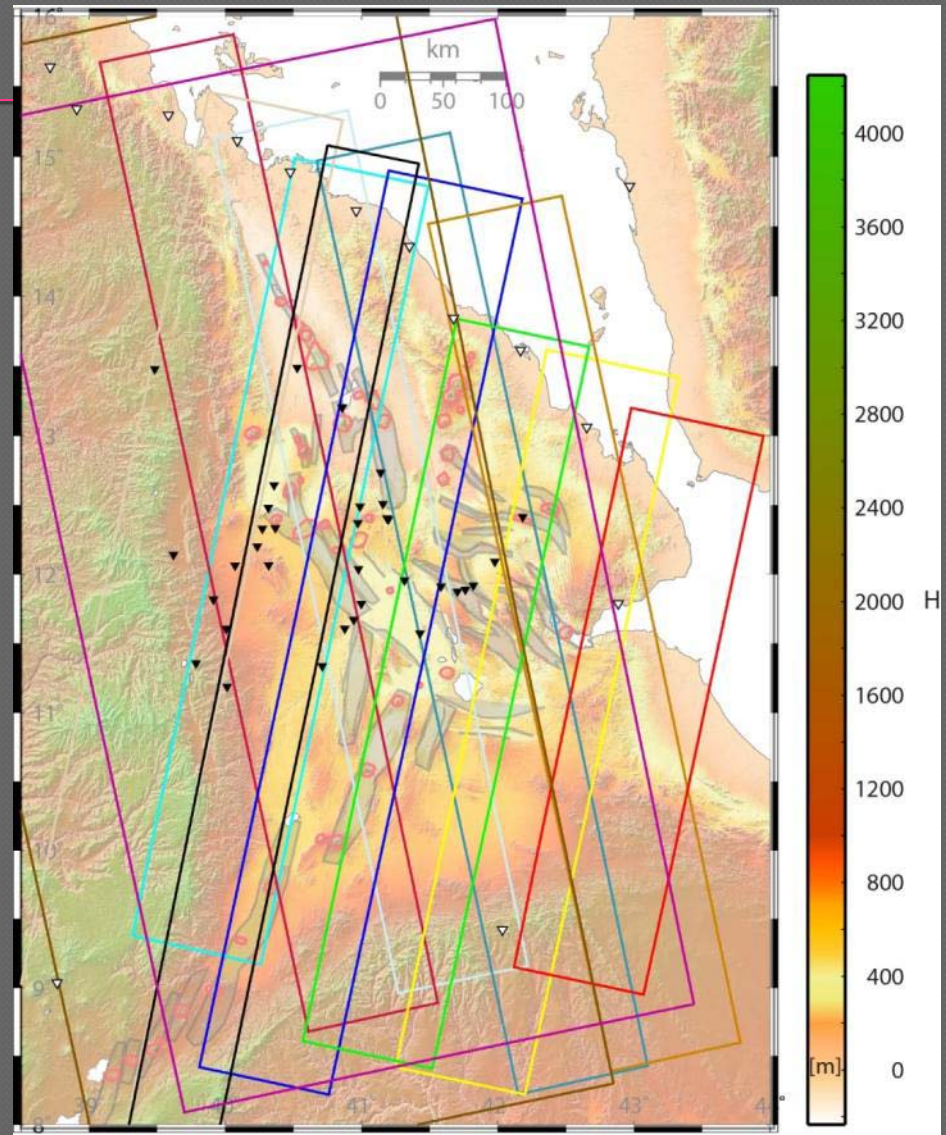
- ◉ Shallow axial magma chamber exists at slow spreading ridges. Previously observed only at fast spreading ridges
- ◉ Alu-Dalafilla chamber is inconsistent with thermal models, that balance heat by intrusion and hydrothermal circulation.
- ◉ Persistence of shallow chamber in Alu-Dalafilla could be due to high magma production, high frequency of magma replenishments, proximity of the Afar plume and the lack of any hydrothermal circulation

In Afar 2005-2010

- 450 SAR images from over 10 tracks
- 30 GPS sites

Purpose

Combine InSAR and GPS to obtain 3D velocity field of Afar



Combine InSAR and GPS to obtain 3D velocity field

Two-step approach

1. Obtain (LOS) average deformation rates and rms misfit for each InSAR track
2. Combine the LOS deformation rates with GPS and invert for 3D velocity field with a mesh and interpolation method

π -rate

<http://homepages.see.leeds.ac.uk/~earhw/pirate>

Load Data

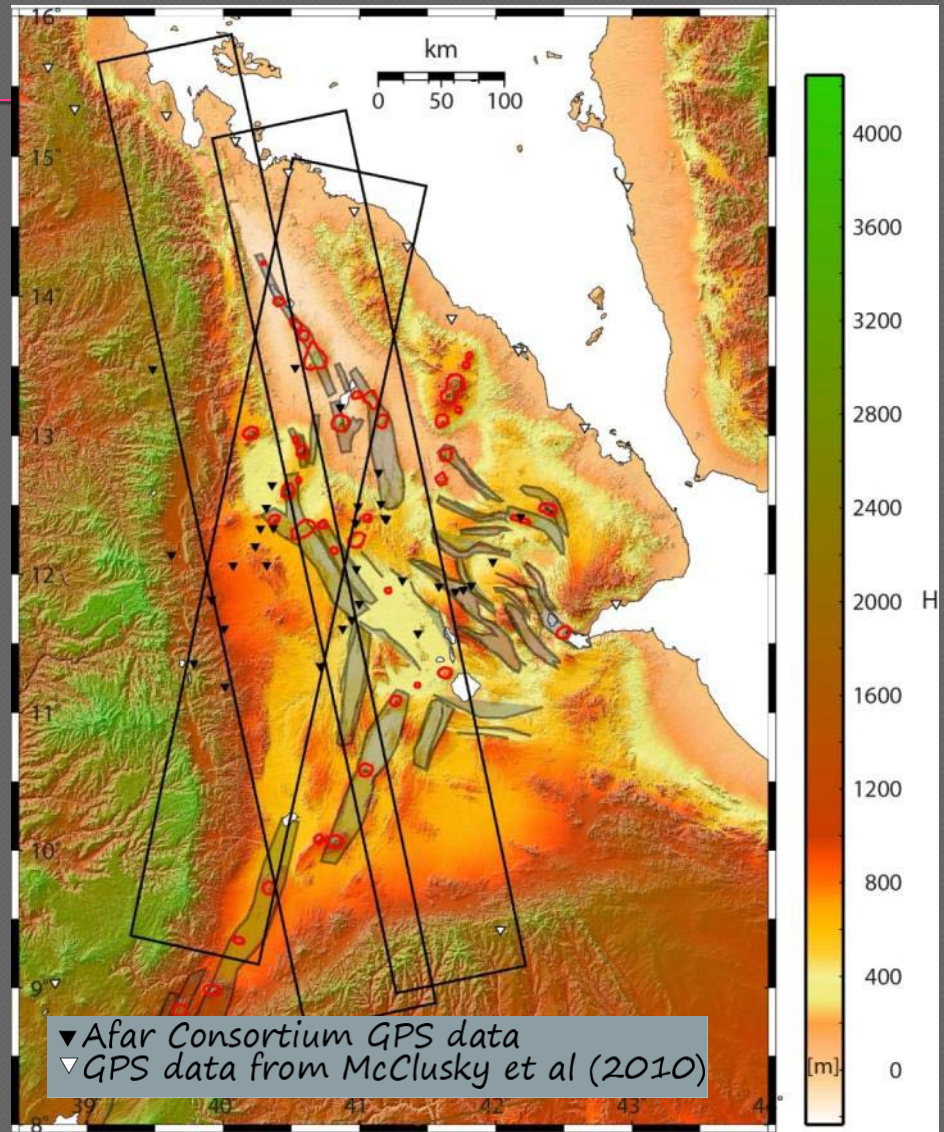
Orbital Error
Correction

Topo-atmos Error
Correction

VCM Estimattion

APS

Average rate map
and rms misfit maps



π -rate references

Biggs et al., 2007, GJI; Elliott et al., 2008, GRL; Wang et al., 2009, GRL.

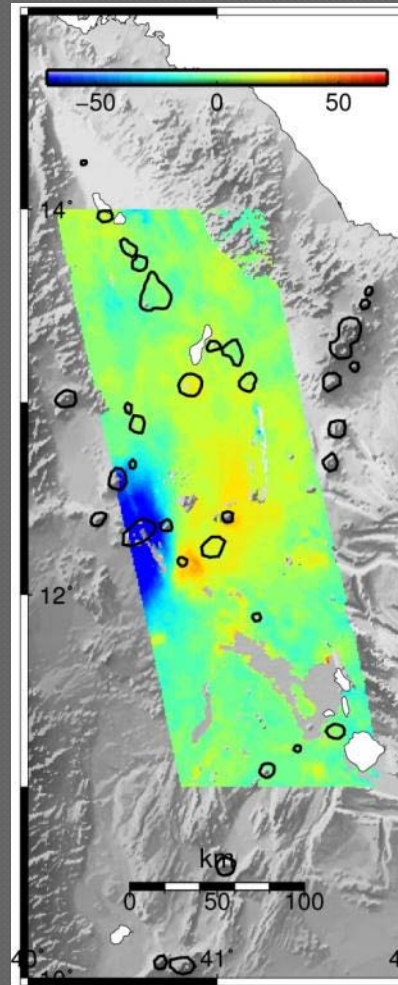
Track 28 asc.

Focus on linear
deformations
2004-2010

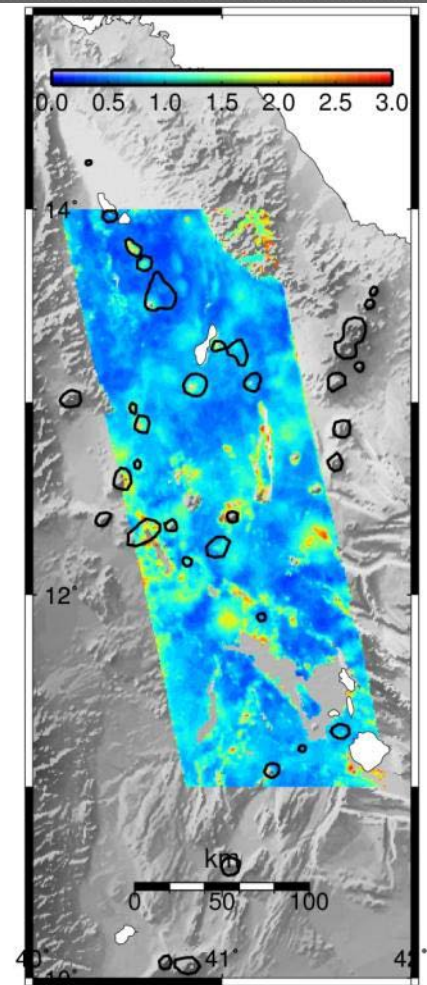
Sudden deformations
are removed by cross-
correlation

Set a priori RMS
misfit threshold
3 mm/yr

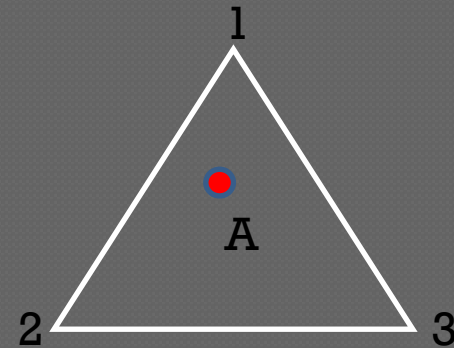
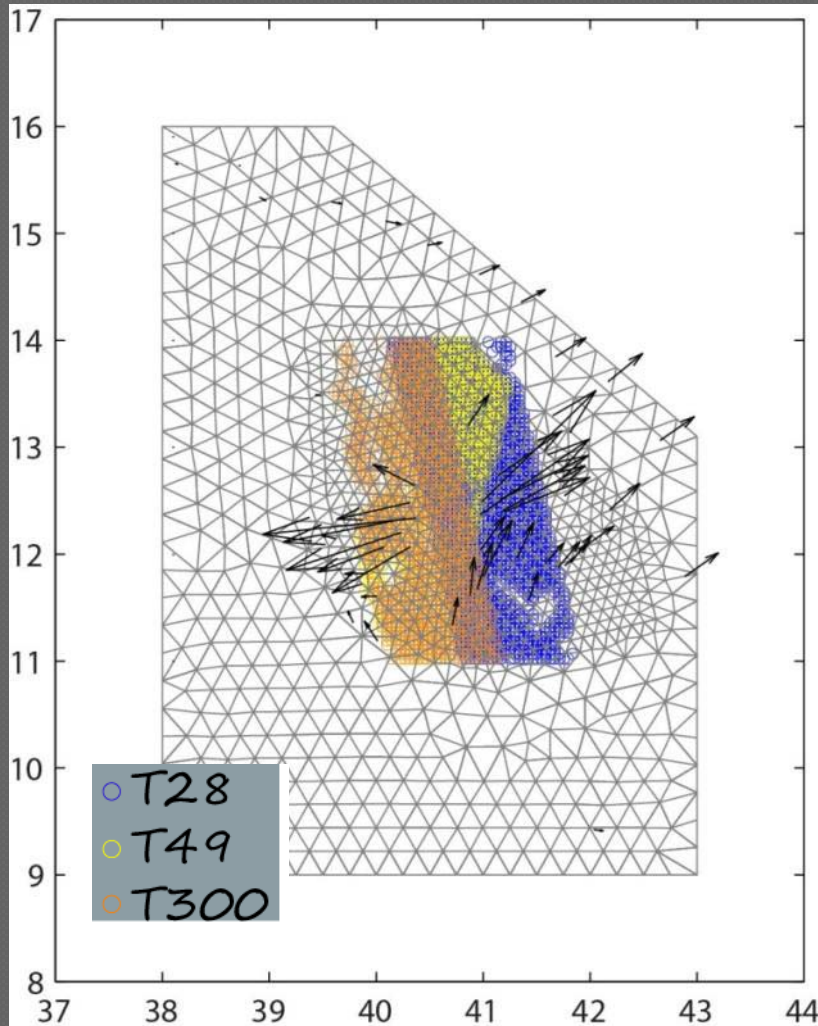
LOS Rate
mm/yr



RMS misfit
mm/yr



Combine all InSAR and GPS



$$\begin{bmatrix} \mathbf{G}_{sar} & \mathbf{G}_{orb} & \mathbf{G}_{atm} \\ \mathbf{G}_{gps} & \mathbf{0} & \mathbf{0} \\ \mathbf{K}^2 \nabla^2 & \mathbf{0} & \mathbf{0} \end{bmatrix} \begin{bmatrix} \mathbf{M}_{vel} \\ \mathbf{M}_{orb} \\ \mathbf{M}_{atm} \end{bmatrix} = \begin{bmatrix} \mathbf{d}_{sar} \\ \mathbf{d}_{gps} \\ \mathbf{0} \end{bmatrix}$$

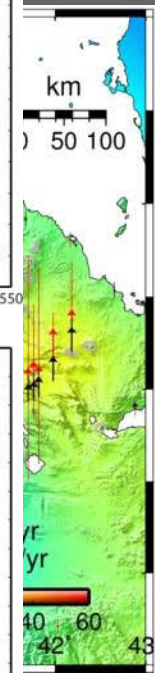
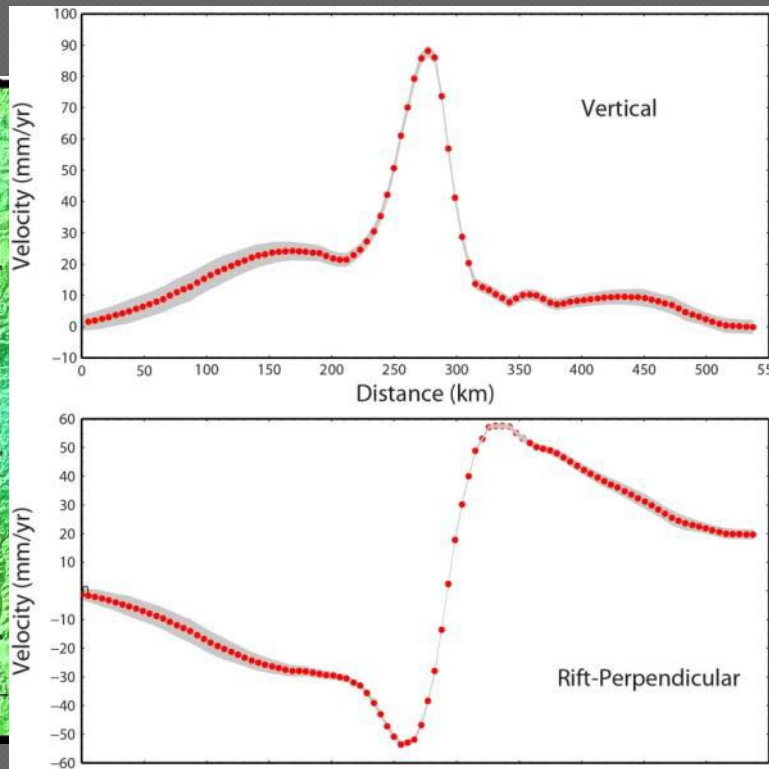
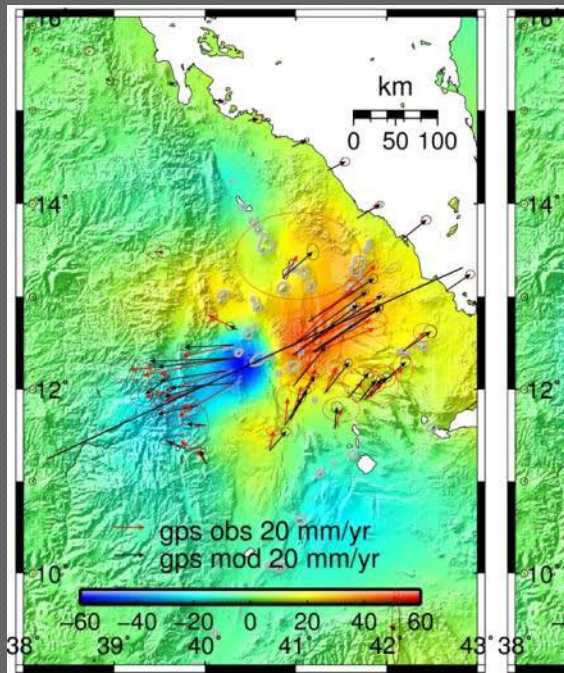
$$\hat{\mathbf{M}} = (\mathbf{G}^T \mathbf{W} \mathbf{G})^{-1} \mathbf{G}^T \mathbf{W} \mathbf{d}$$

RMS InSAR 8 mm/yr

RMS GPS 10 mm/yr

3D Velocity

East



Conclusions

- Extensive InSAR archive of varying acquisitions geometry can be combined with GPS into 3D velocity maps.
- Post-rifting in Afar is marked by accelerated spreading and sharp uplift centred at the rift axis and broad uplift perhaps asymmetric