Estimation of Tropospheric Delays in Multi-Temporal InSAR

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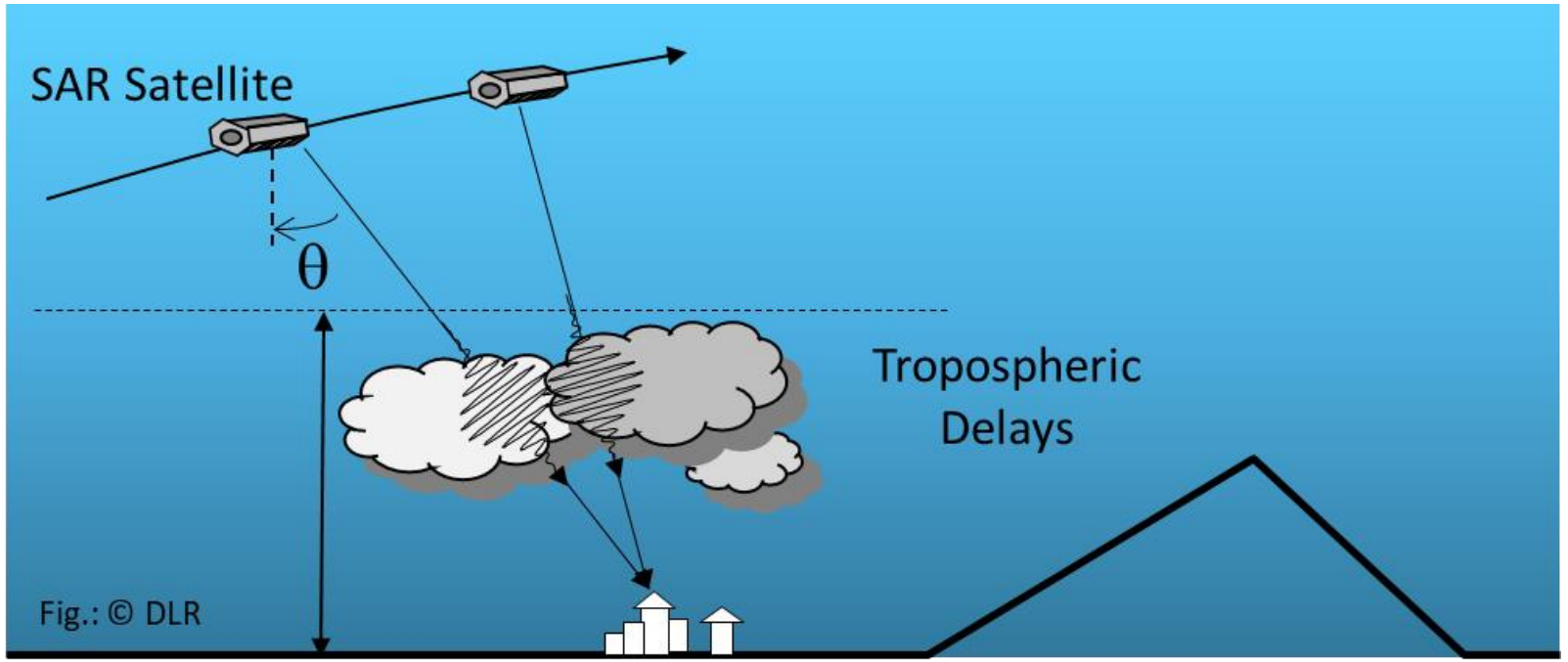
Introduction: InSAR Tropospheric Delays (TD)



Characteristics:

- Related to temperature, pressure, humidity, etc.
- Varying in space and time

Introduction: Current Solutions for TD

Based on auxiliary data:

- GNSS
- Radiometric measurements
- Weather model

Limitations:

- Low spatial/temporal resolutions
- Limited overall accuracy

Based on InSAR data

- Stacking, spatiotemporal filter

Limitations:

- Accuracy often limited

- Correction based on elevation

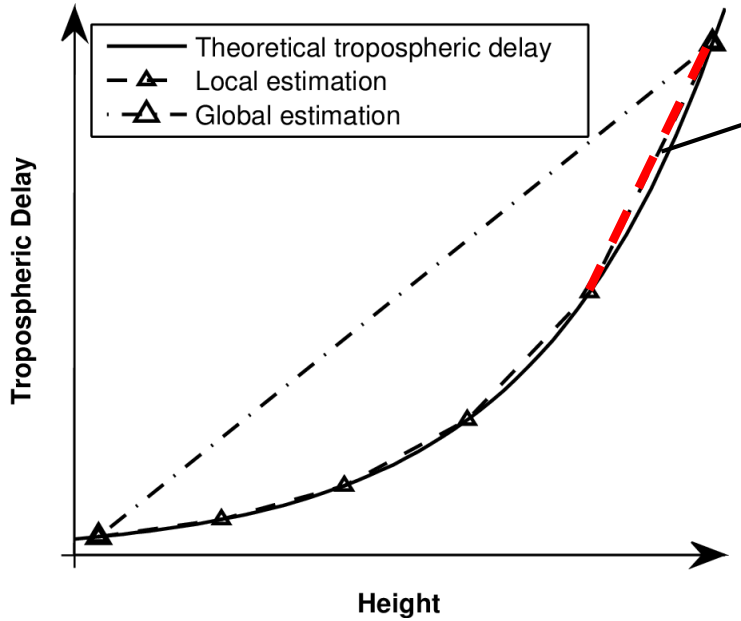
$$\emptyset_{trop} = K \cdot \Delta h + \emptyset_0$$

Limitations:

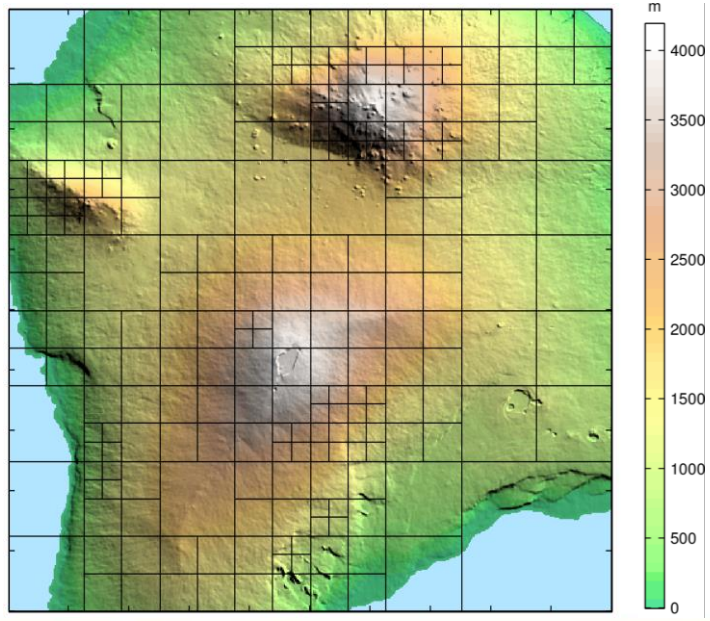
- Spatial variability
- Effects of other signals (e.g. deformation, topographic error)

Methodology: Basic Concept

- Divide an area of study into overlapping windows
- Window size varies with slope gradient as aided by a quadtree model
- Assume linear phase-elevation model within each window
- Estimate tropospheric delays jointly with other parameters



Linear phase-elevation model in local area



$$\emptyset_{trop} = K \cdot \Delta h + \emptyset_0$$

Methodology: Joint Model

Jointly estimate TD, deformation and topographic errors

- Tropospheric delay difference:

$$\Delta\emptyset^{i}_{tropo,slc,p,q} = (h_p - h_q) \cdot K^{i}_{slc}$$

h_p ,h_q: elevations for point p and q
K^{i}_{slc} : tropospheric delay coefficient for single SAR image

- Deformation rate & topographic error:

$$\emptyset^{i}_{defo+topo,p} = \left[-\frac{4\pi}{\lambda} \cdot T_j \quad -\frac{4\pi}{\lambda} \cdot \frac{B_{\perp,j}}{r \cdot sin\theta}\right] \cdot \begin{bmatrix} v_p \\ \Delta h_p \end{bmatrix}$$

v_p,Δh_p: deformation rate and topographic error for point p
T_j , $B_{\perp,j}$: temporal and spatial baseline

- Joint model construction

$$\underset{(G \times M) \times 1}{\Delta\Phi^{i}} = B^{i} \cdot P^{i} + \underset{(G \times M) \times 1}{R^{i}}$$

Phase difference observations

Design matrix

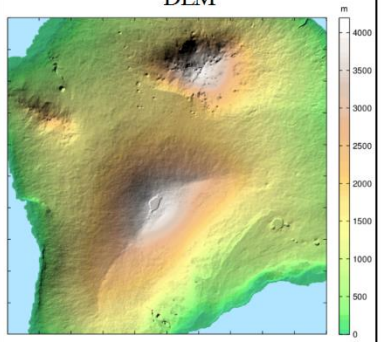
Parameters for TD, deformation rate and topographic error

Residuals

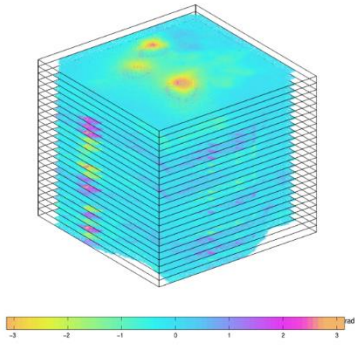
Methodology: Workflow

Step 1: Input data

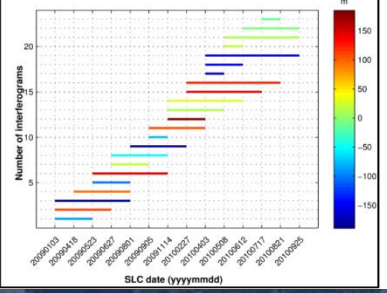
DEM



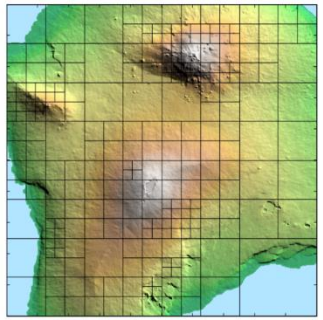
Interferogram stack and correcting for orbital errors



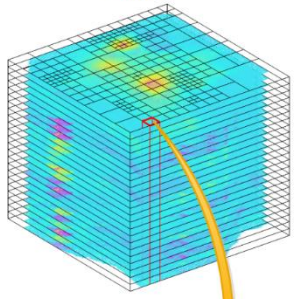
Temporal and spatial baselines



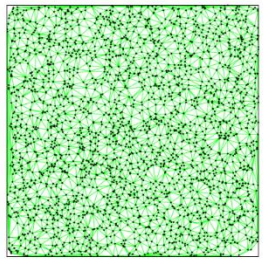
Step 2: Segment quadtree windows



Step 3: Locally estimate tropospheric delays by joint model

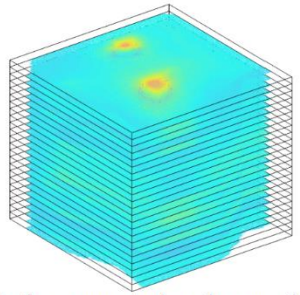


Construct network

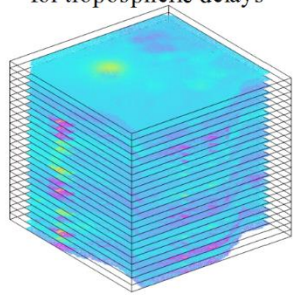


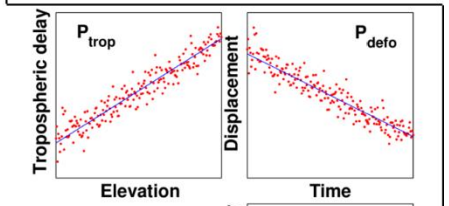
Step 4: Correct tropospheric delays in whole scene

Estimated tropospheric delay stack



Interferogram stack and correcting for tropospheric delays





Joint model

$$\Delta\Phi = B \cdot P + R$$

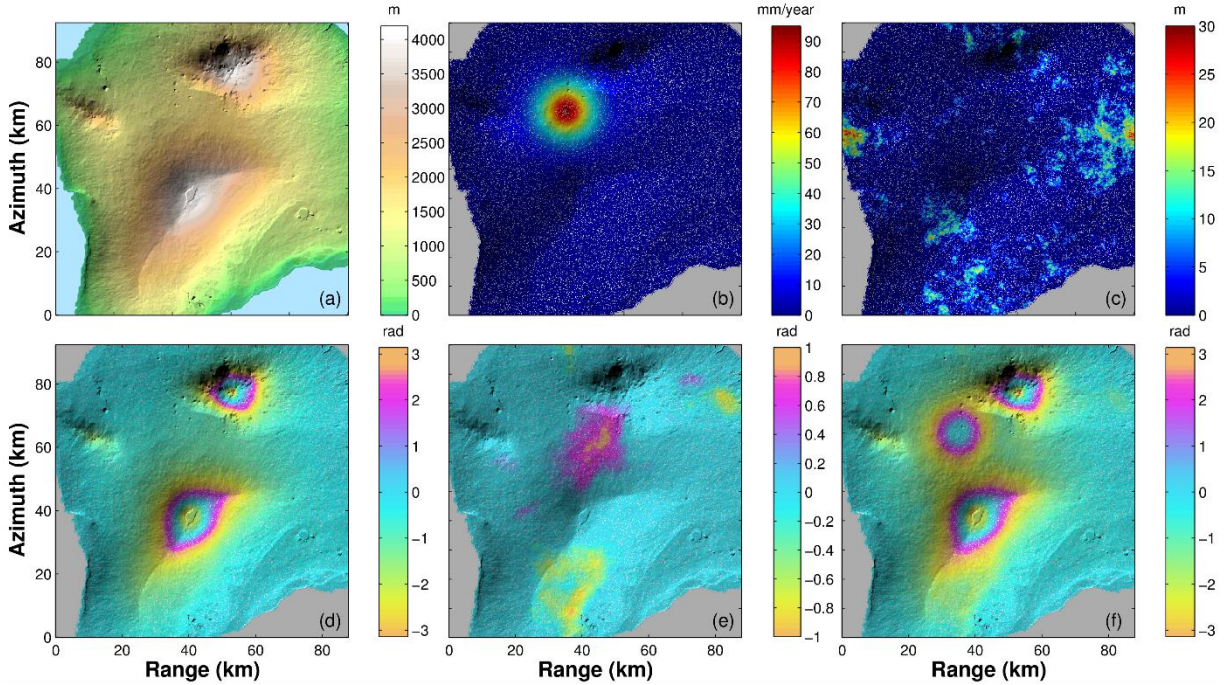
Experiments: Simulated Data

Signal components:

DEM

Deformation rate

Topographic error



Tropospheric delays

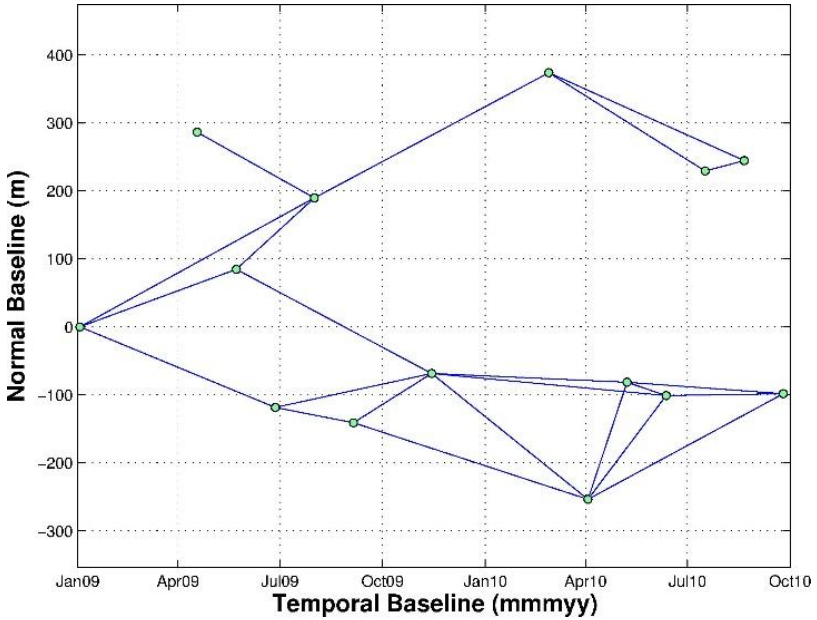
Turbulence

Interferogram contains deformation, topographic error, tropospheric delays

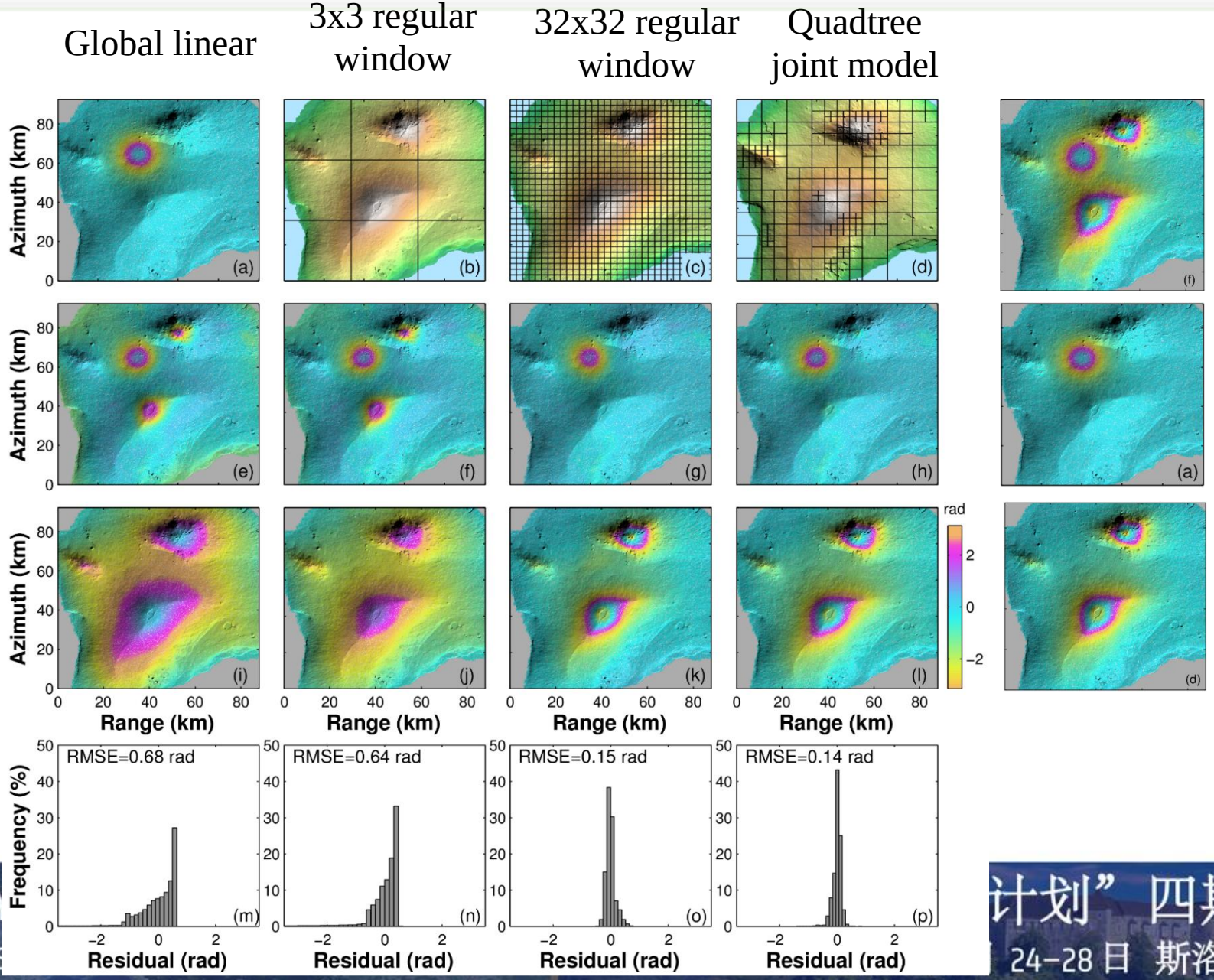
Baselines:

14 SAR images

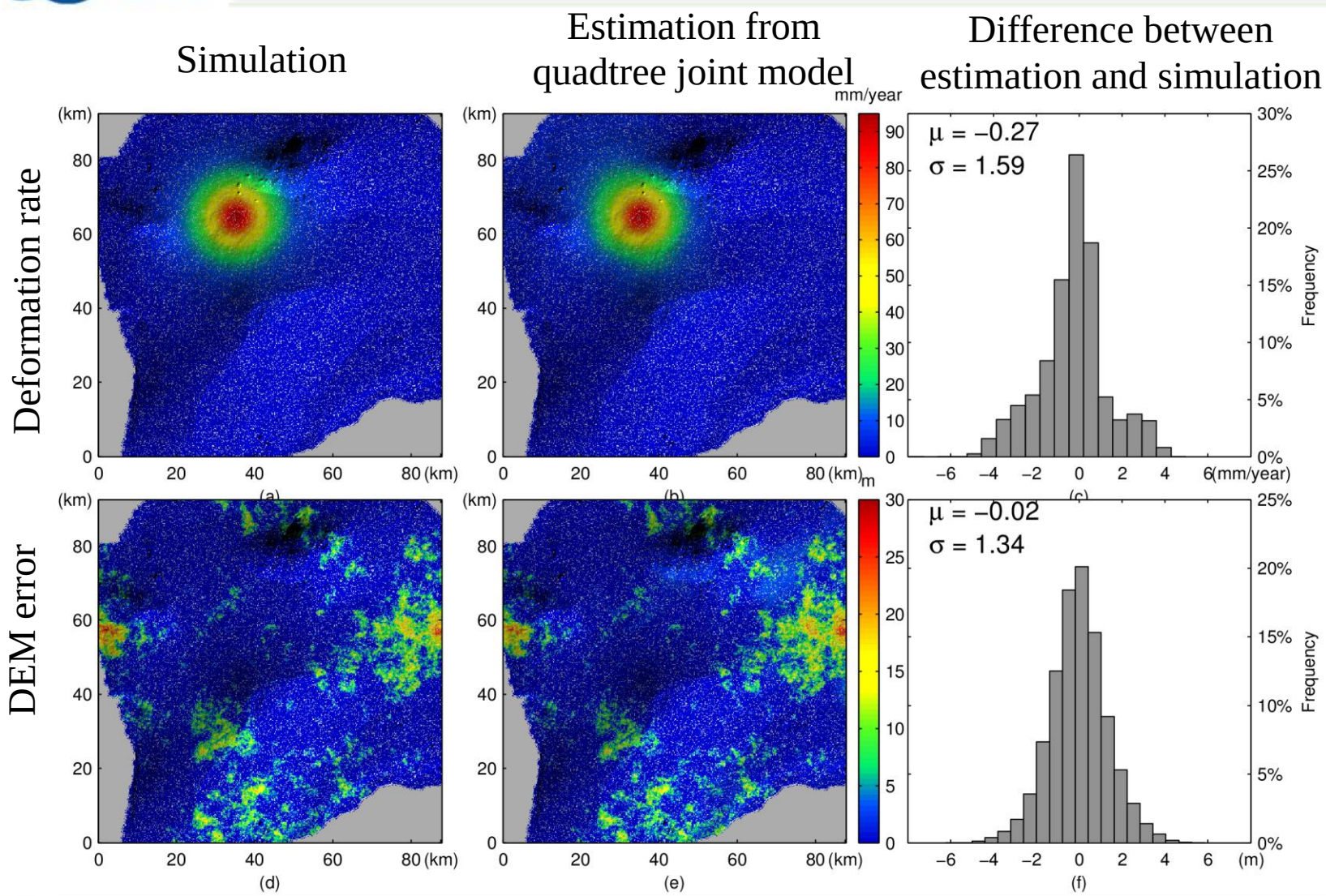
23 interferograms



Experiments: Simulated Data

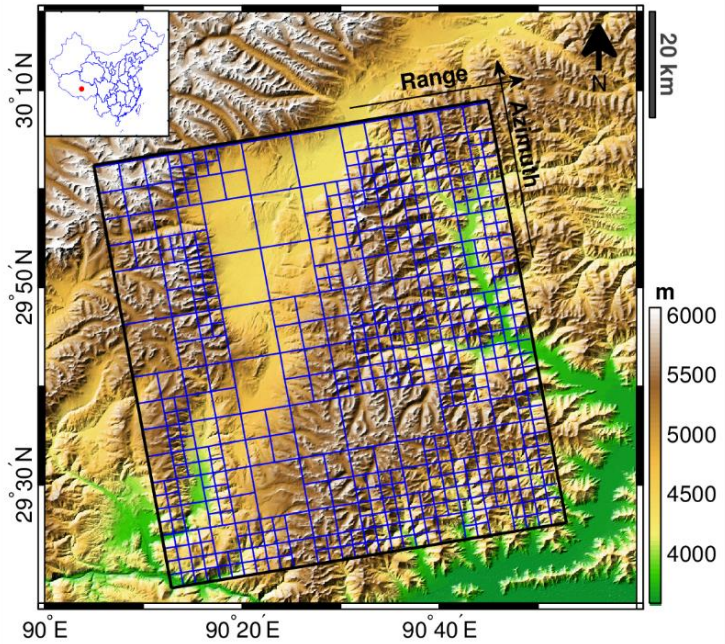


Experiments: Simulated Data



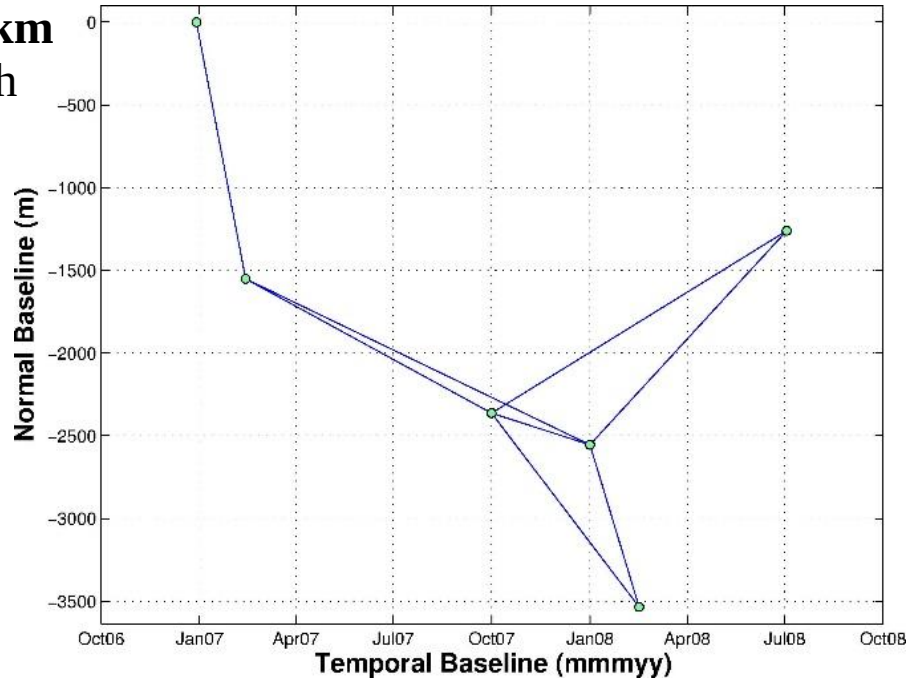
	Standard deviation of estimation error	
	Deformation rate (mm/year)	DEM error (m)
Global linear method	1.74	1.42
3x3 regular window	1.71	1.41
32x32 regular window	2.13	1.33
Quadtree joint model	1.59	1.34

Experiments: Real Dataset 1 (Dangxiong, Tibet)



Location: Dangxiong, Tibet, China
Data: ALOS/PALSAR-1
Period: Dec 2006 – Jul 2008
Pre-seismic deformation

Number of windows: **526**
Size of smallest window: **2km x 2km**
Maximum height difference in each window: **1km**



Interferometric pair	Perpendicular baseline (m)	Temporal baseline (day)
20061229-20070213	1552	46
20070213-20071007	813	230
20071001-20080101	192	92
20071001-20080216	1174	138
20071001-20080703	-1105	276
20080101-20080216	981	46
20080101-20080703	-1297	184

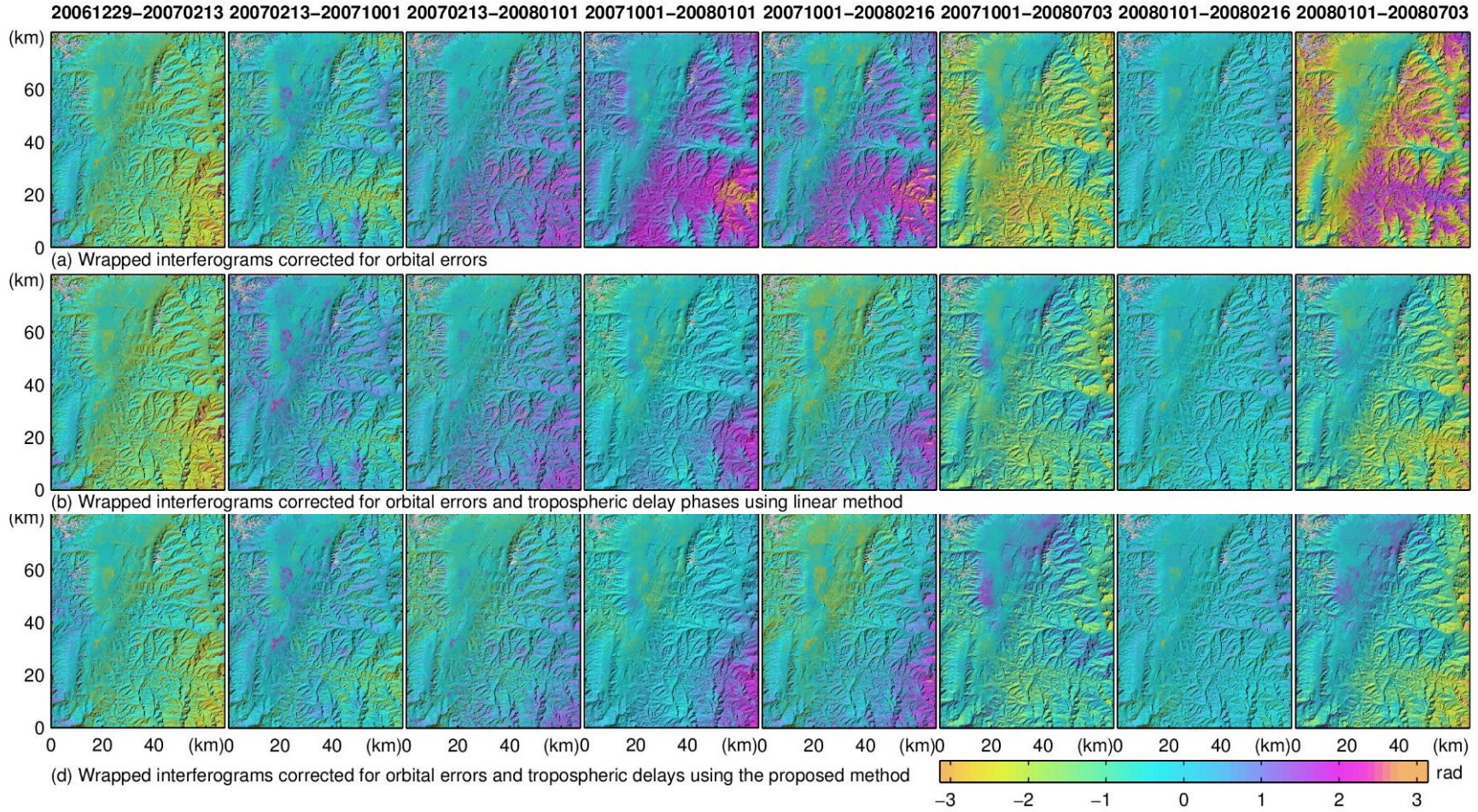
Experiments: Real Dataset 1 (Dangxiong, Tibet)

Effects of corrections on interferograms

Before correction

After linear method

After Joint model



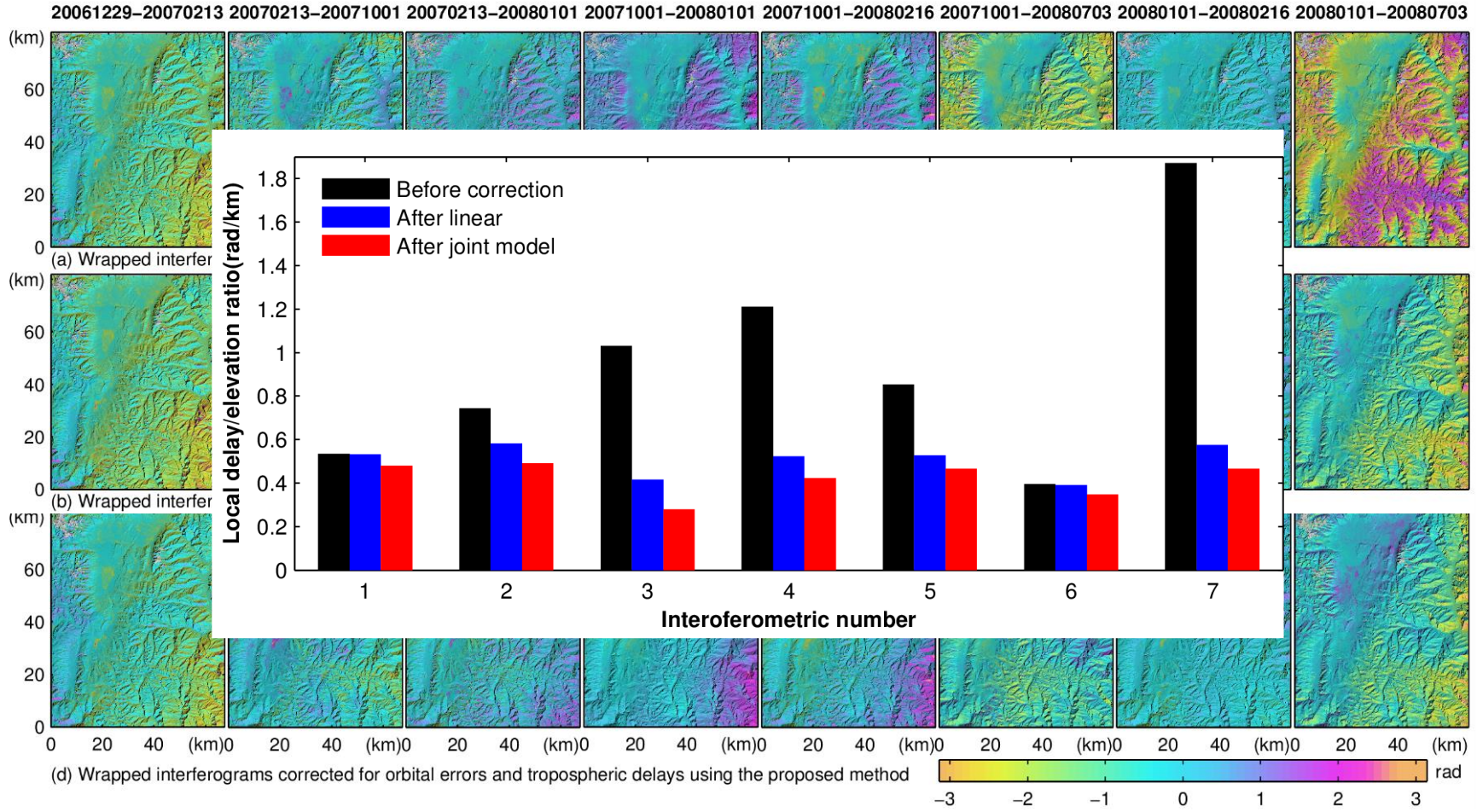
Experiments: Real Dataset 1 (Dangxiong, Tibet)

Statistical analysis: Relationships between unwrapped phase and elevation

Before correction

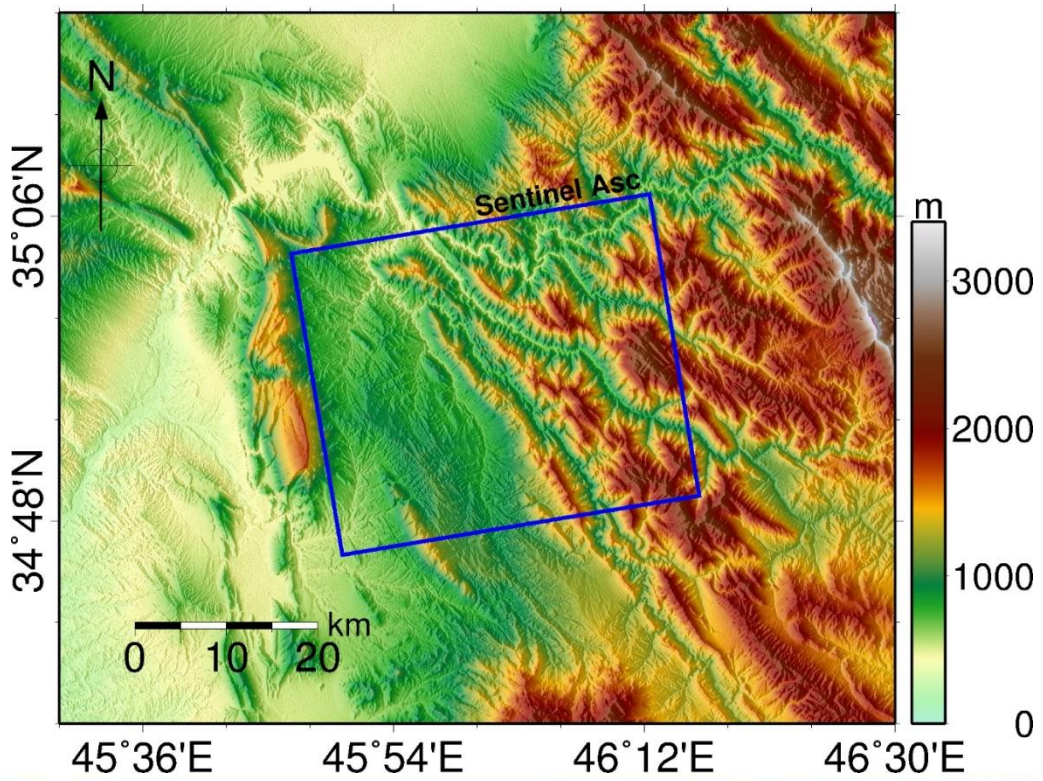
After linear method

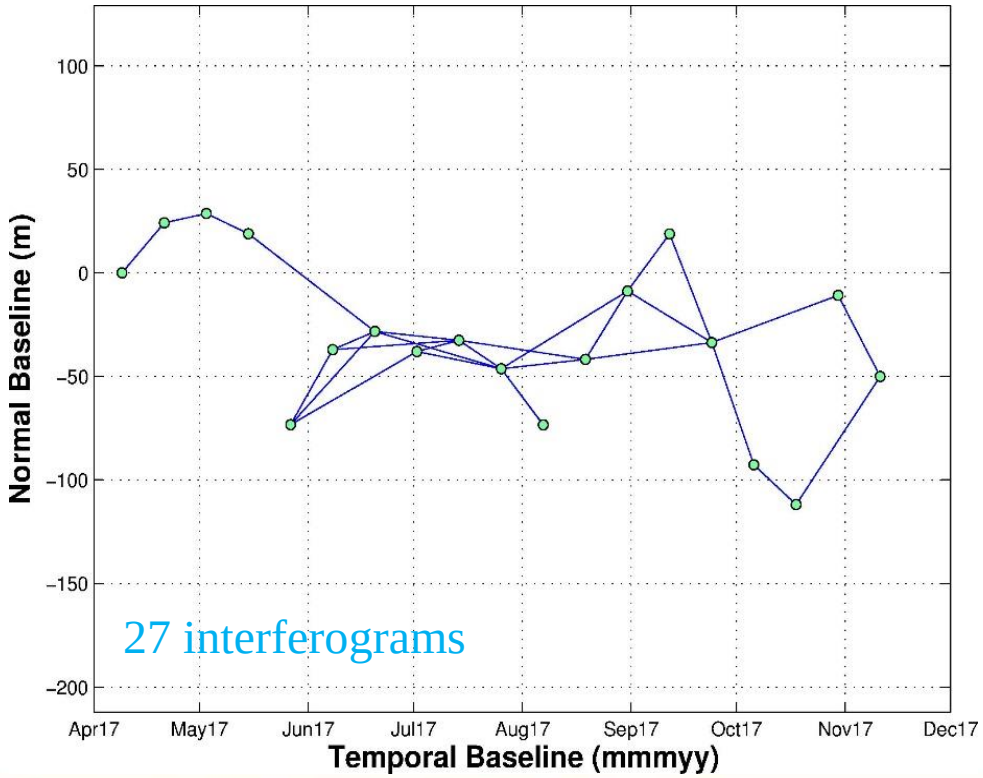
After Joint model



Experiments: Real Dataset 2 (Iran-Iraq Border)

Location: Iran-Iran border
Dataset: 19 ascending Sentinel-1A
Period: April 2017 – November 2017
Deformation: Pre-seismic





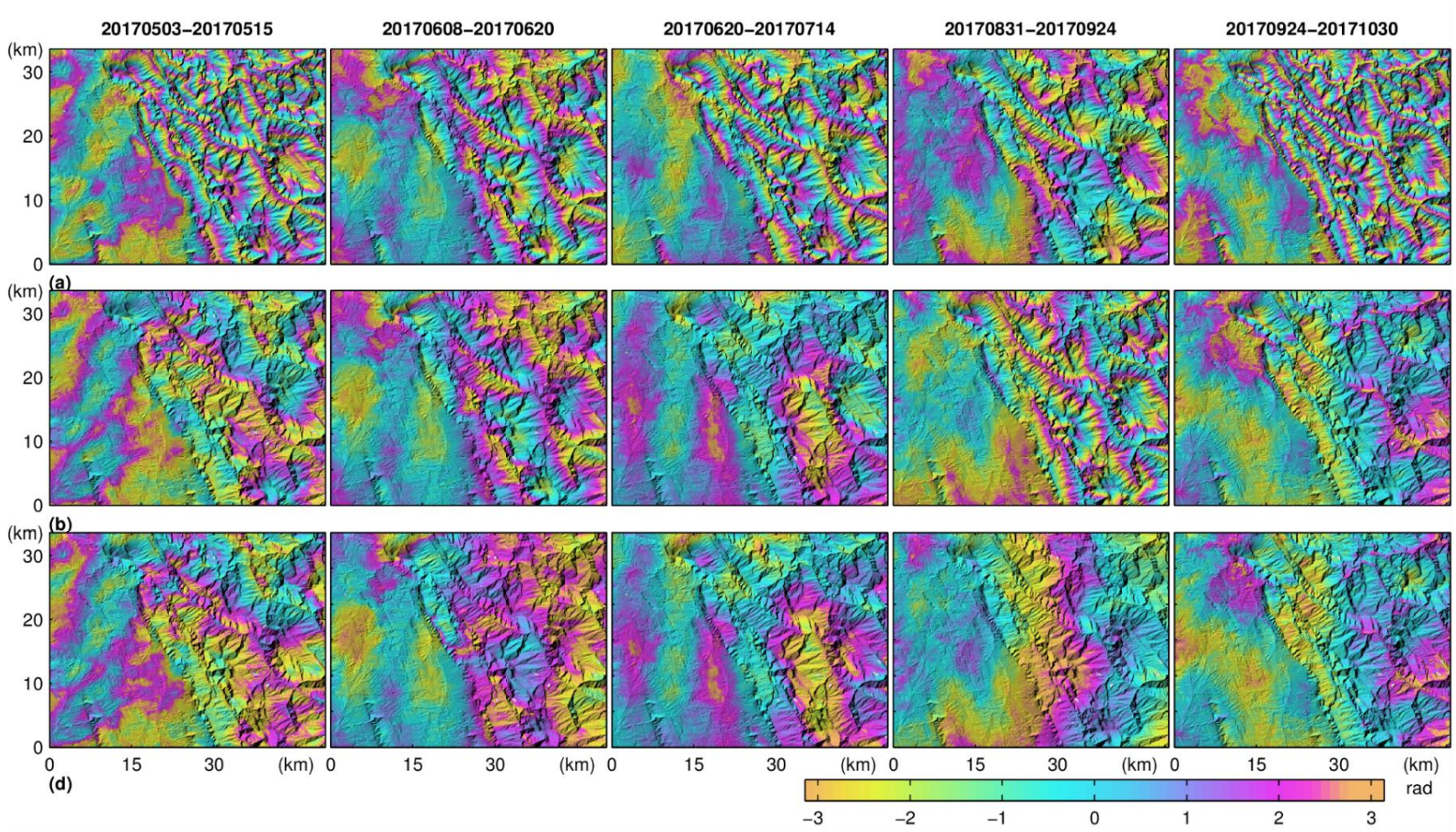
Experiments: Real Dataset 2 (Iran-Iraq Border)

Correction of Tropospheric Delays

Before correction

After linear method

After jointmodel



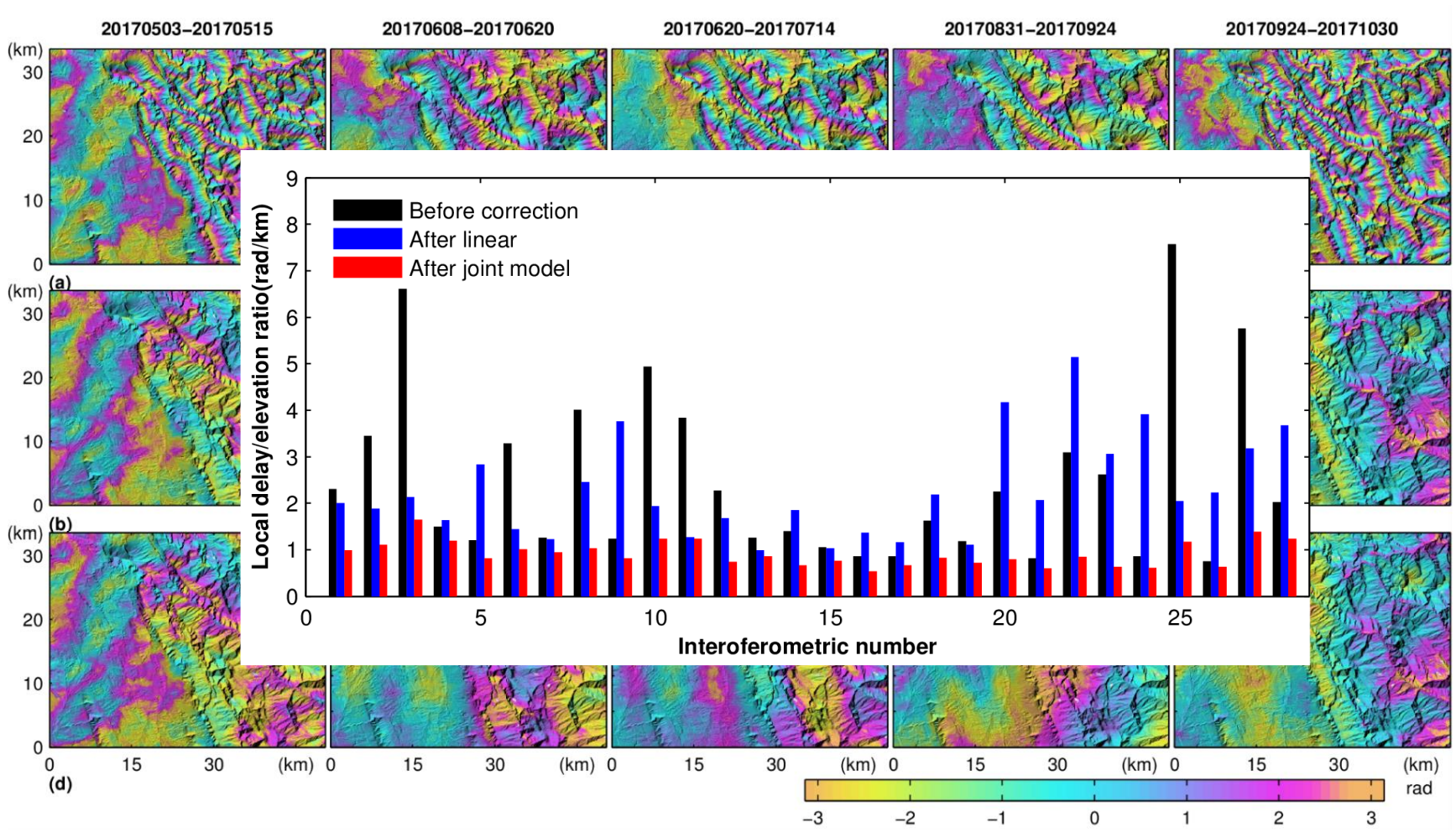
Experiments: Real Dataset 2 (Iran-Iraq Border)

Statistical analysis: Relationships between unwrapped phase and elevation

Before correction

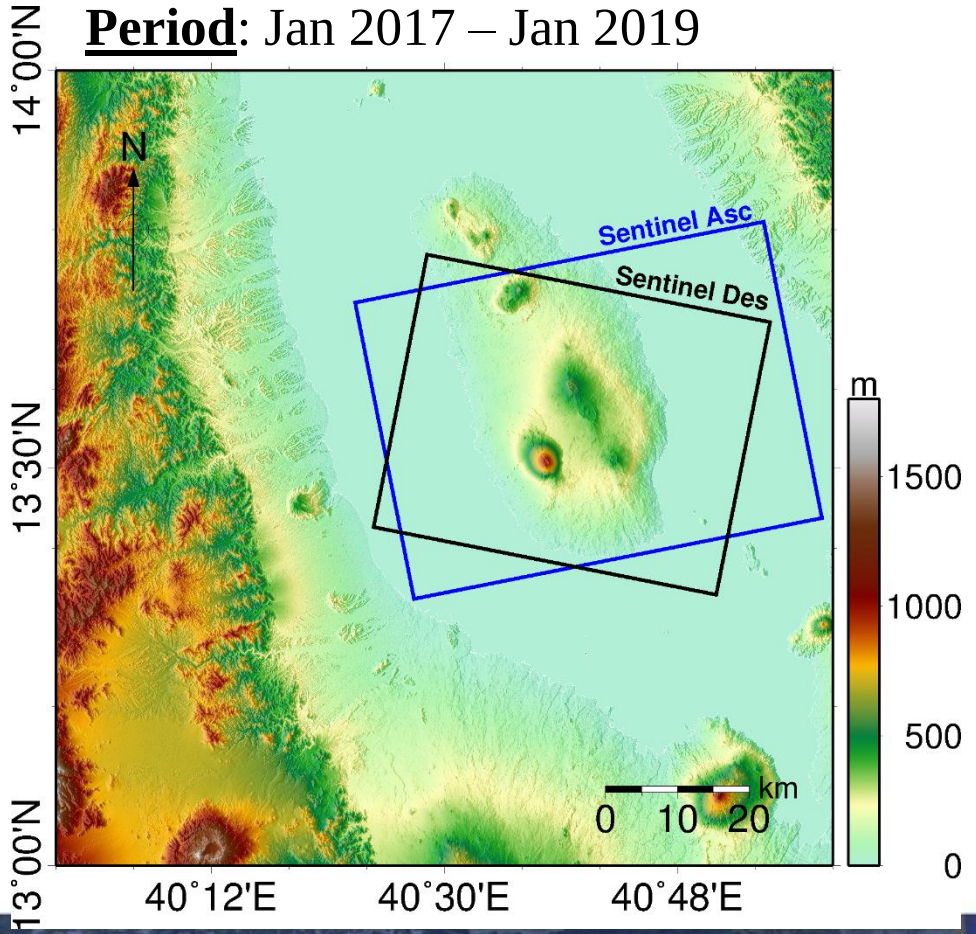
After linear method

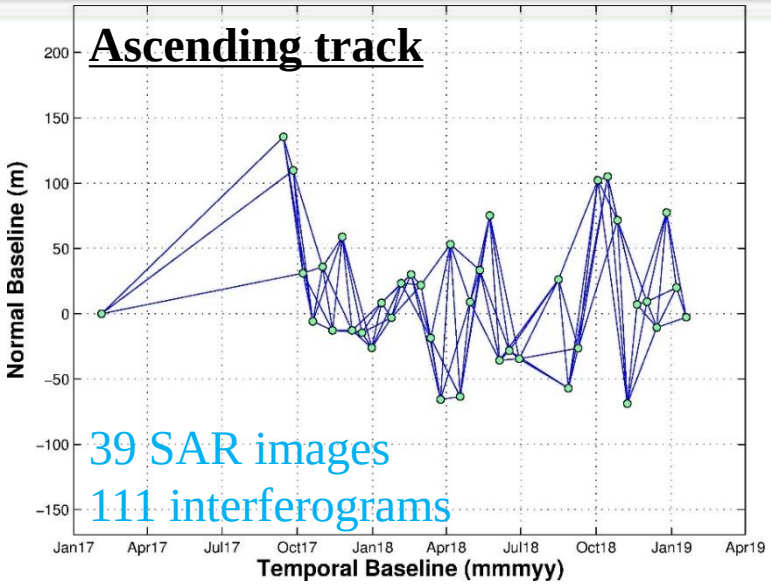
After jointmodel

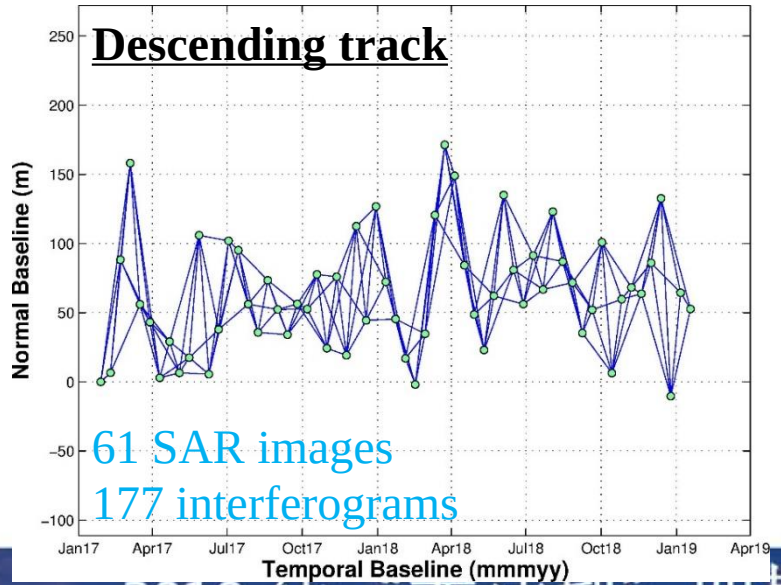


Experiments: Real Dataset 3 (Ale Bagu Volcano)

Location: Ale Bagu Volcano, Ethiopia
Dataset: 39 ascending and 61 descending Sentinel-1A
Period: Jan 2017 – Jan 2019

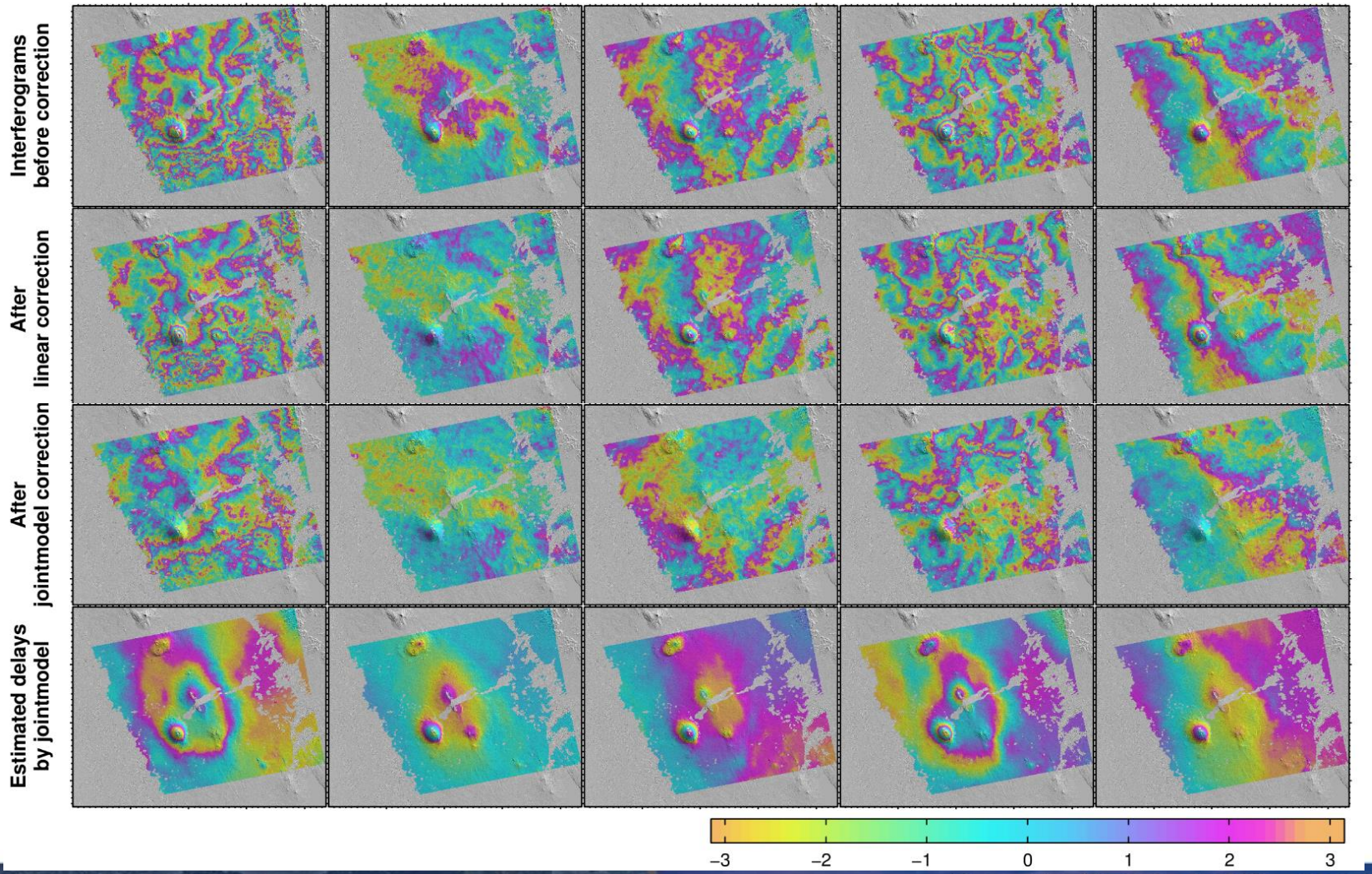






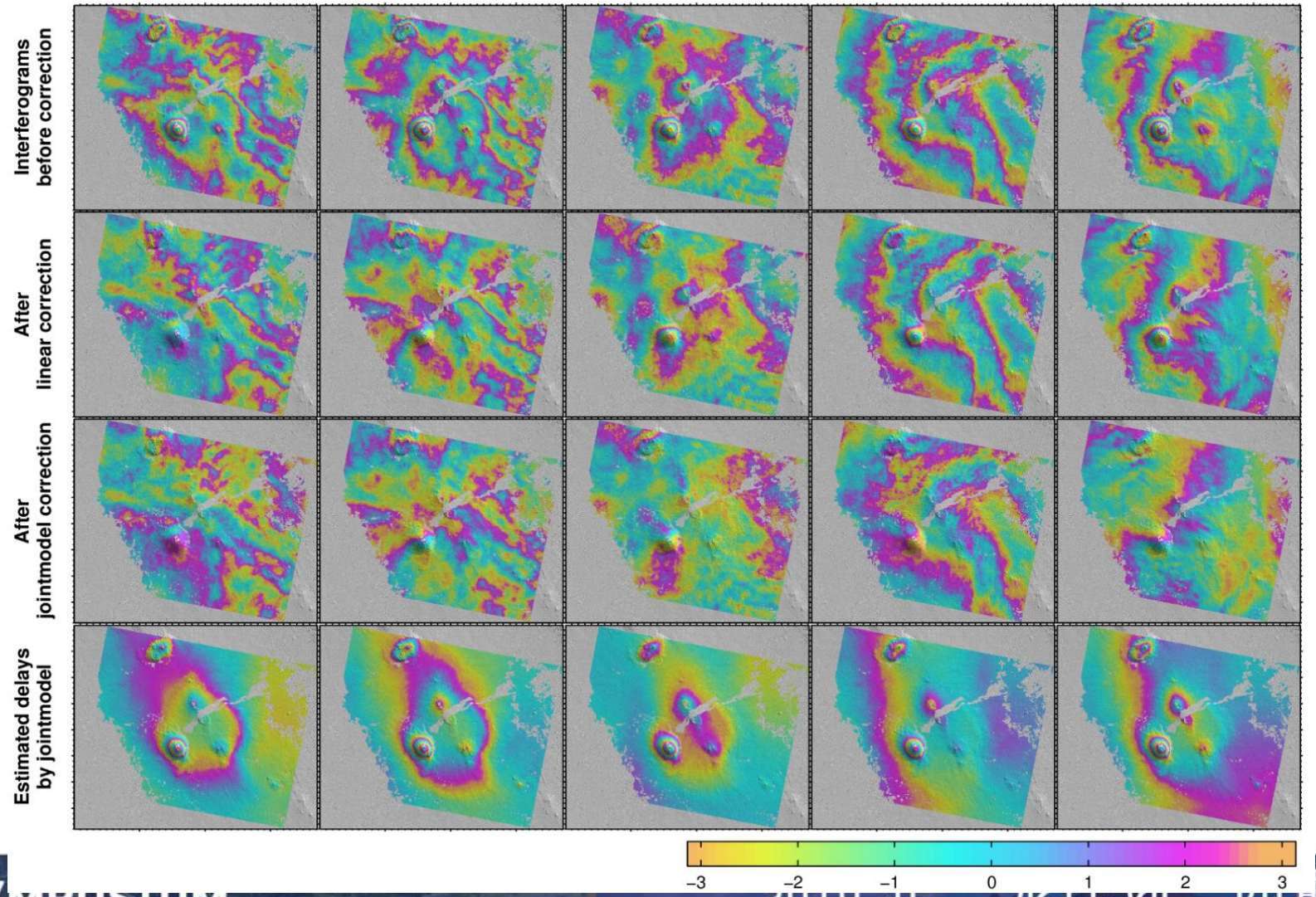
Experiments: Real Dataset 3 (Ale Bagu Volcano)

Ascending Track – Tropospheric delay correction results



Experiments: Real Dataset 3 (Ale Bagu Volcano)

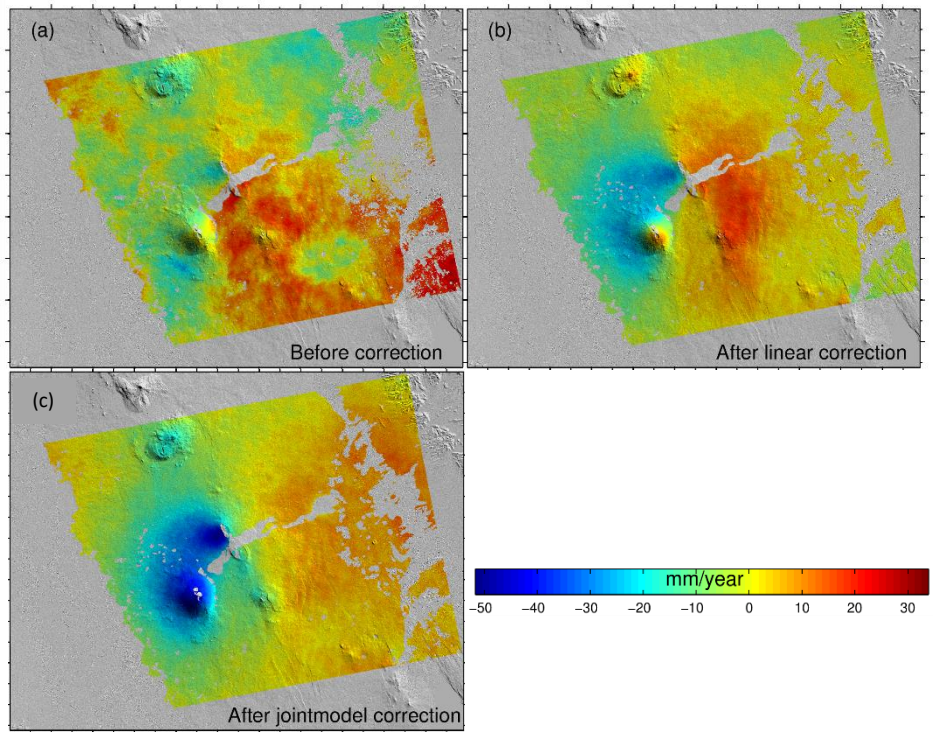
Descending Track – Tropospheric delay correction results



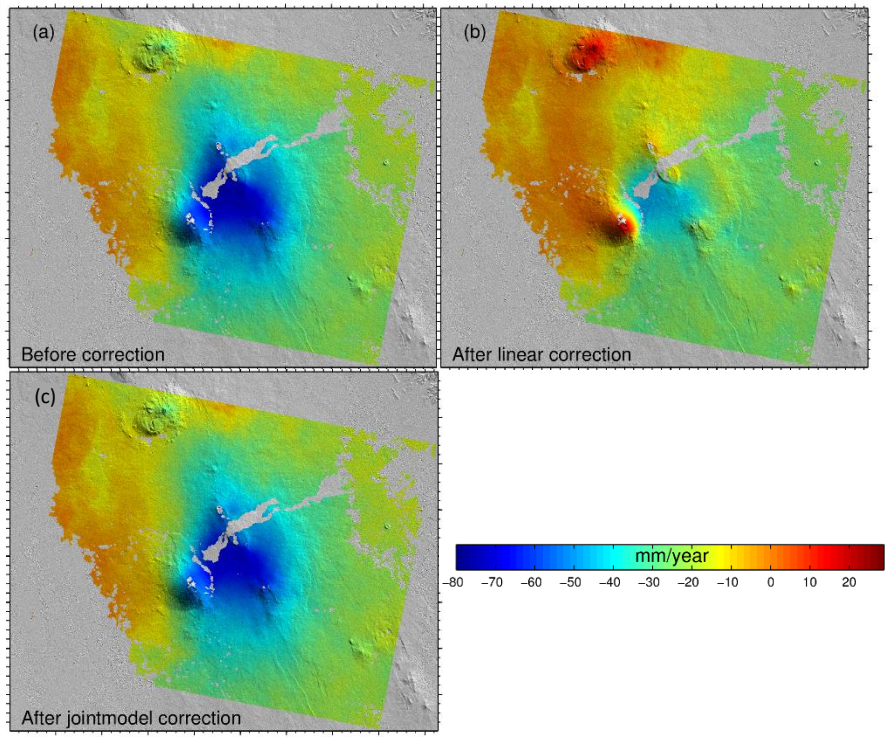
Experiments: Real Dataset 3 (Ale Bagu Volcano)

Deformation rate maps

Ascending Track



Descending Track



Conclusions

- A new approach for joint estimation of tropospheric delays and other parameters in multi-temporal InSAR has just been proposed.
- Experimental results have demonstrated the approach is effective.

Liang, H., Zhang, L., Ding, X., Lu, Z., & Li, X. (2018). Toward Mitigating Stratified Tropospheric Delays in Multitemporal InSAR: A Quadtree Aided Joint Model. *IEEE Transactions on Geoscience and Remote Sensing*, (99), 1-13.