Systematic InSAR tropospheric phase delay corrections from global meteorological reanalysis data

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2: Laboratoire de Géologie, Ecole Normale Supérieure de Paris, CNRS, France
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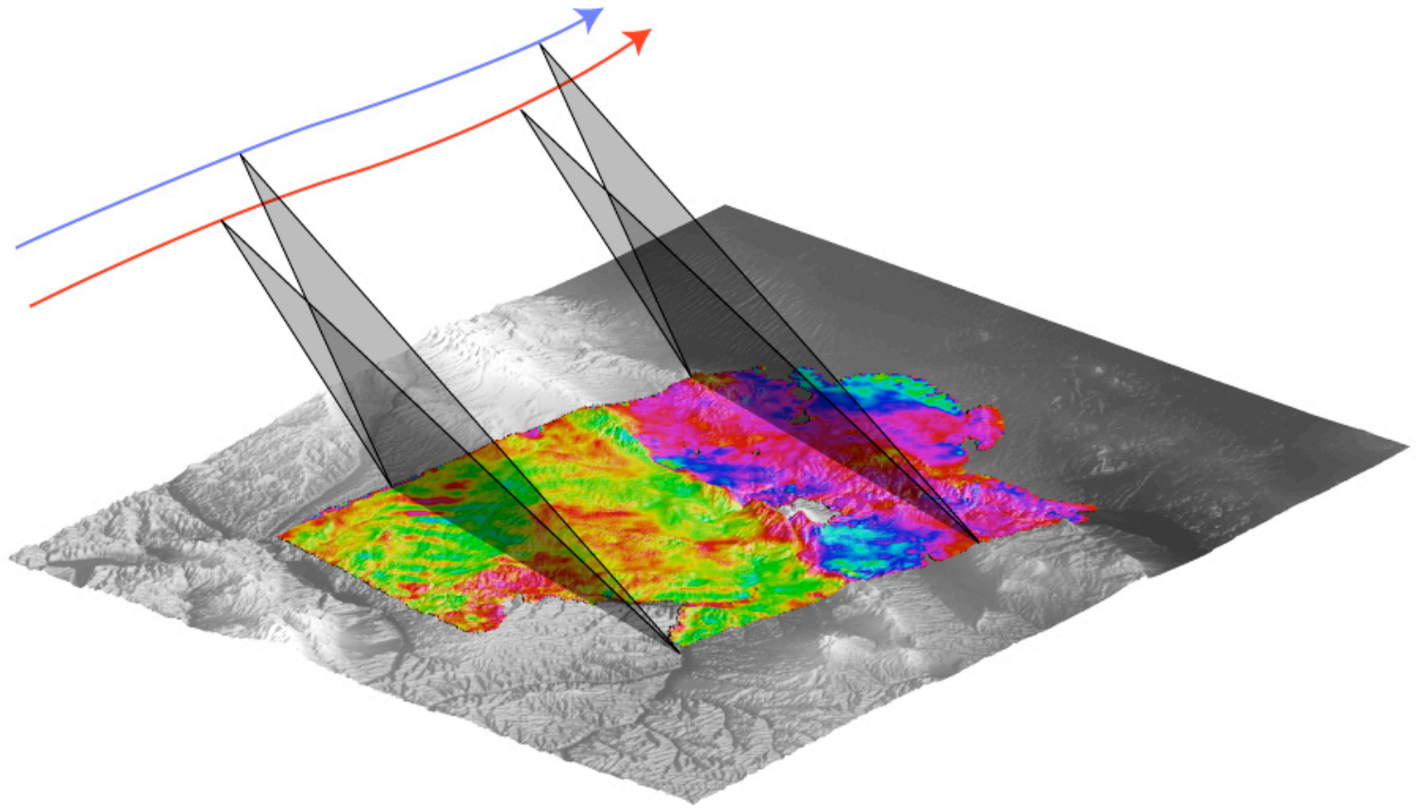
4: Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA

ISTerre
Institut des Sciences de la Terre



Jolivet, R., R. Grandin, C. Lasserre, M.-P. Doin, and G. Peltzer (2011), Systematic InSAR tropospheric phase delay corrections from global meteorological reanalysis data, Geophys. Res. Lett., 38, L17311, doi:10.1029/2011GL048757.

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Atmospheric Phase Screen

$$\Delta\Phi_{(i,j)} = \Delta\phi_{def} + \Delta\phi_{orb} + \Delta\phi_{atmo} + \phi_{noise}$$

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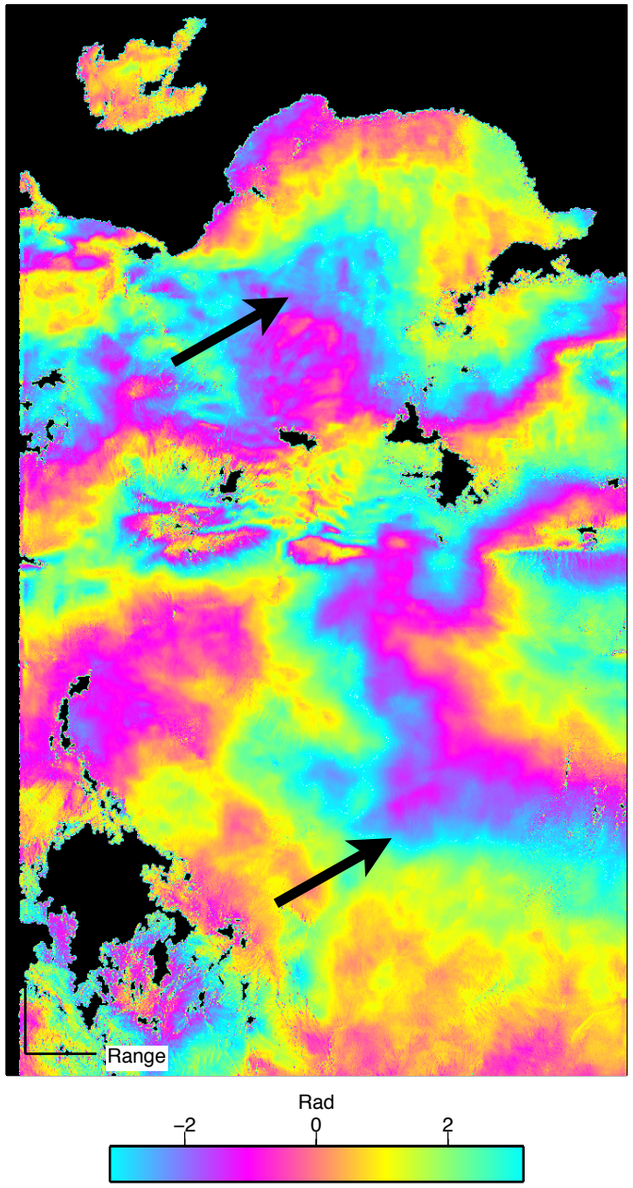
Stratified Tropospheric Delay

+

Turbulent Delay

==> Stacking or Time Series



- Random in Space and Time

- Numerous Acquisitions to average or smooth the signal

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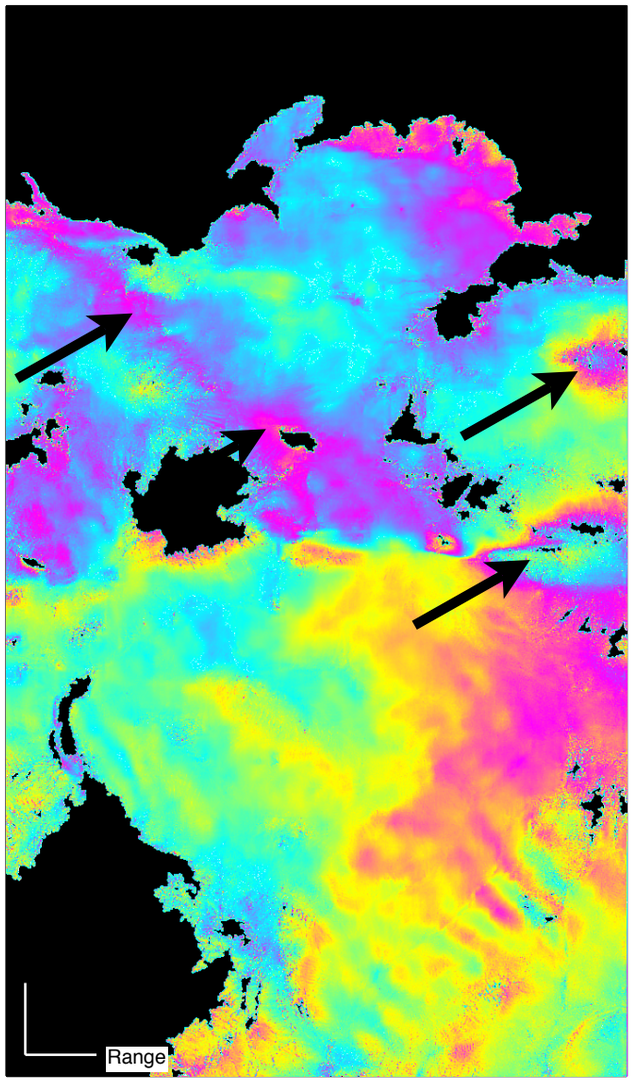

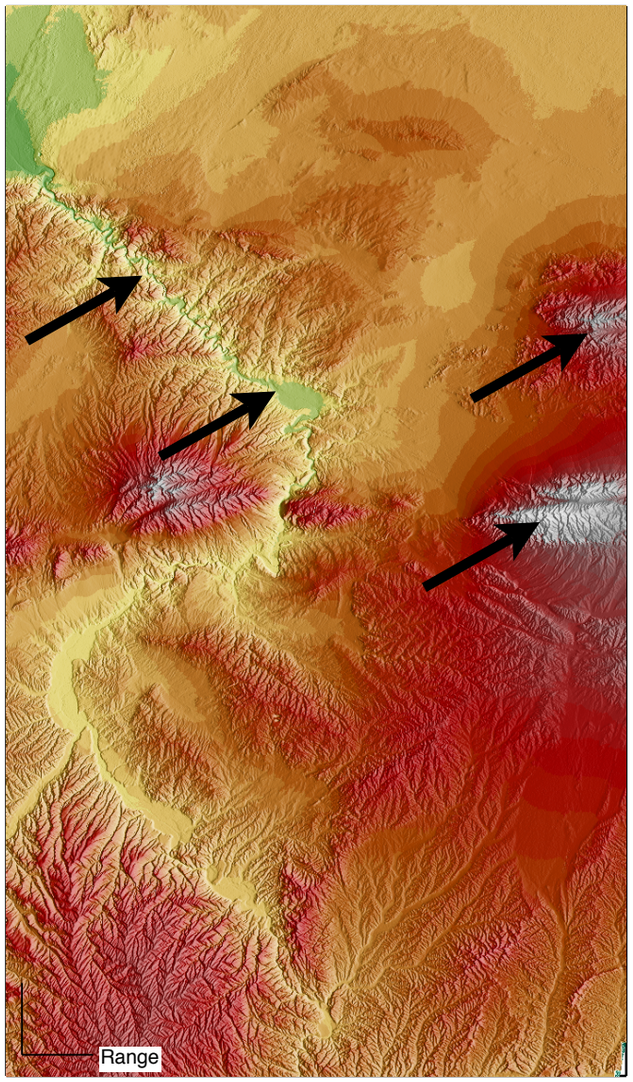

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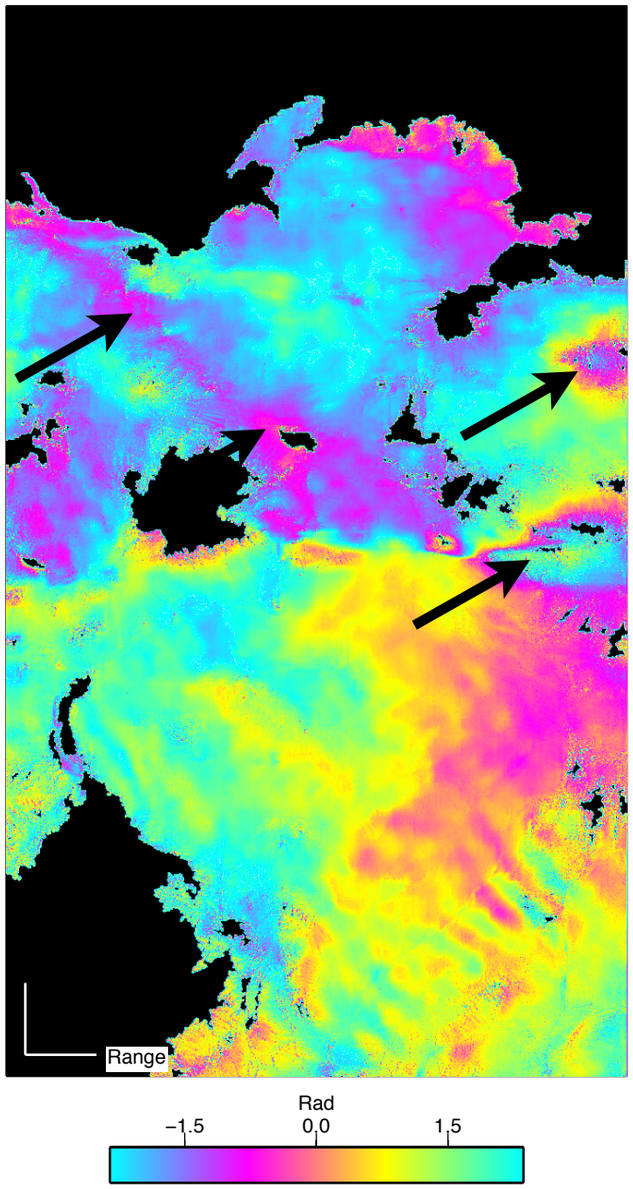

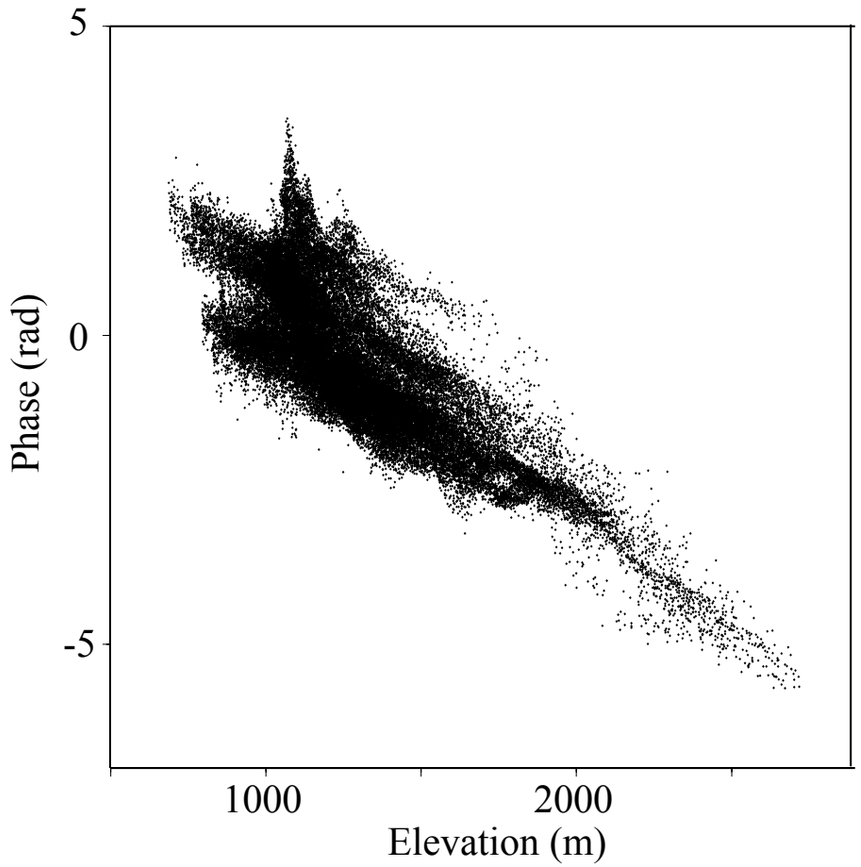

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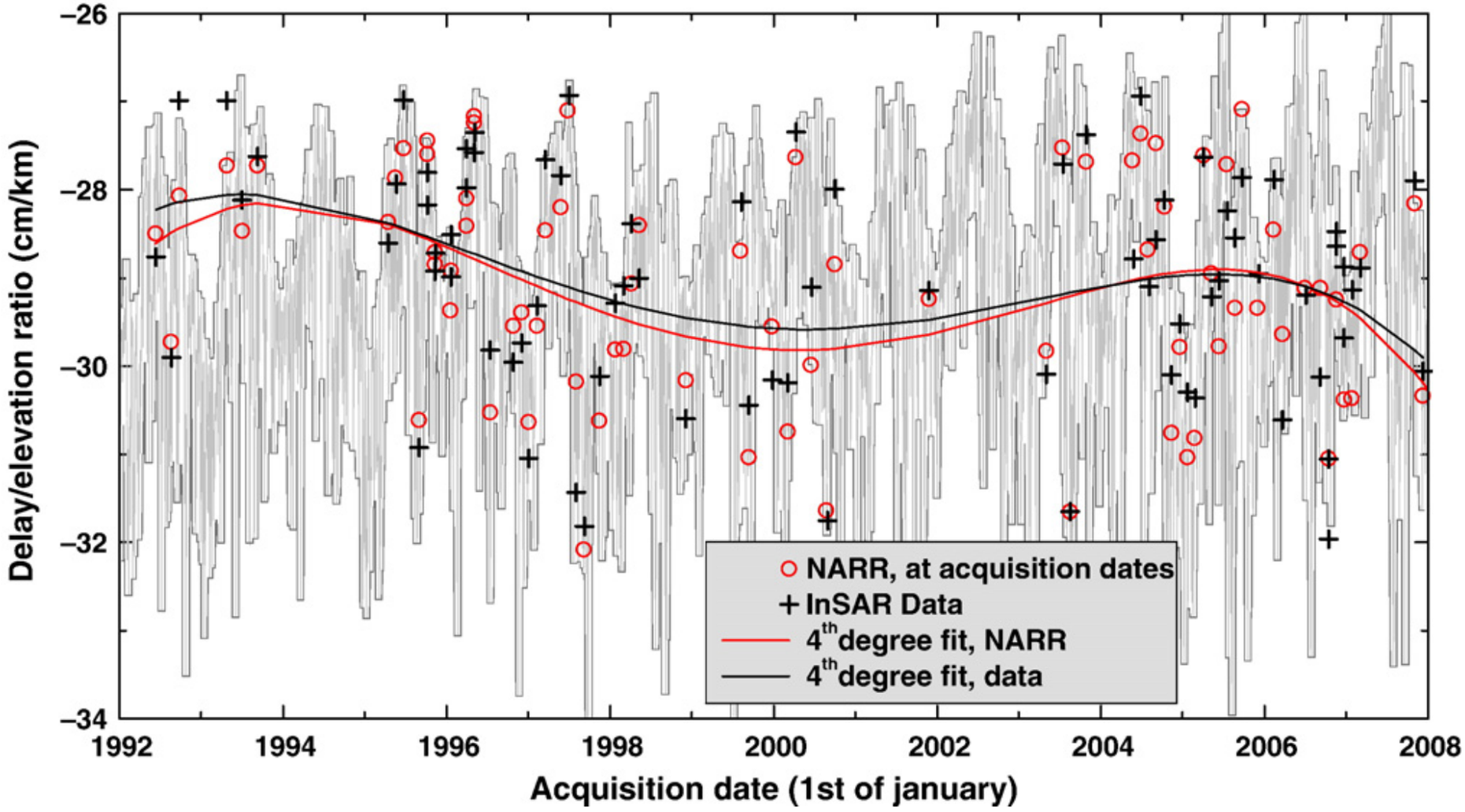

Doin et al., 2009

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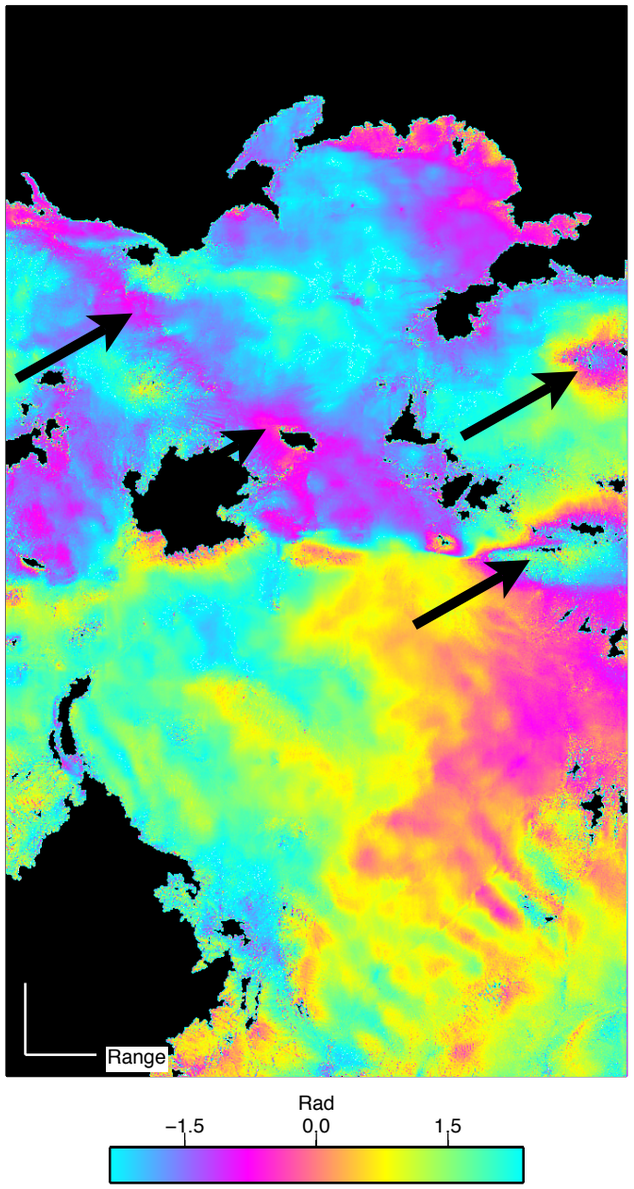

Correction methods:

- Local atmospheric data collection e.g. Delacourt et al, 1998

- GPS zenithal delay estimations e.g. Webley et al, 2002; Onn et al, 2006

- Satellite multispectral imagery (ex: MERIS) e.g. Li et al 2006

- Data assimilation in mesoscale meteorological models
  e.g. Puyssegur et al, 2007

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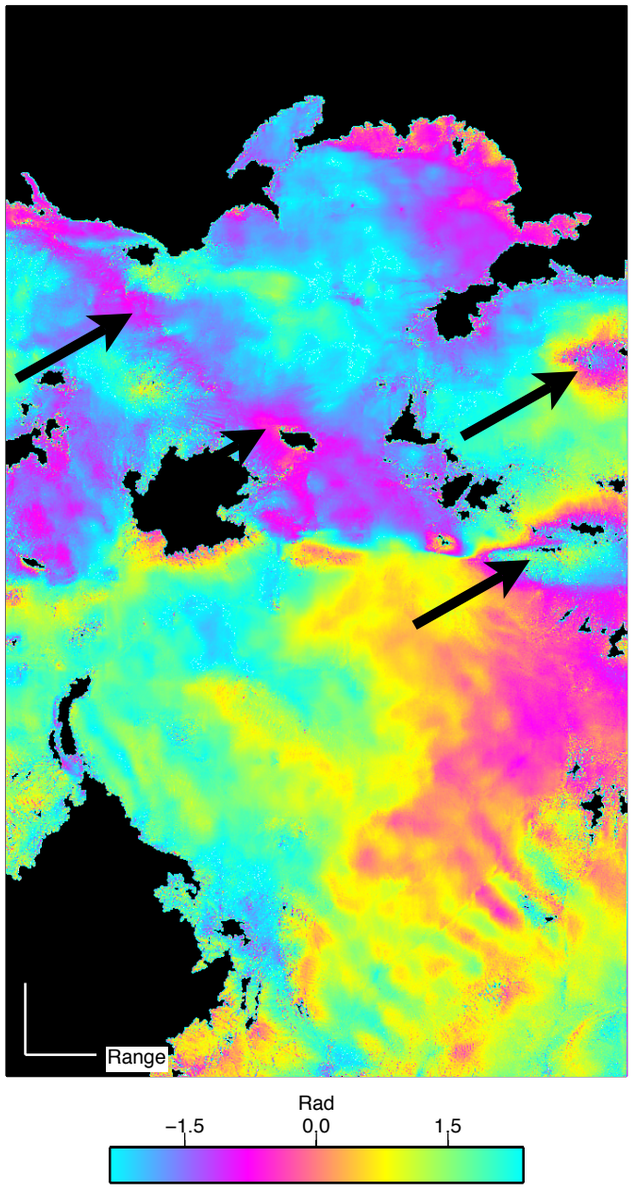

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What if no local data are available?

Empirical estimation

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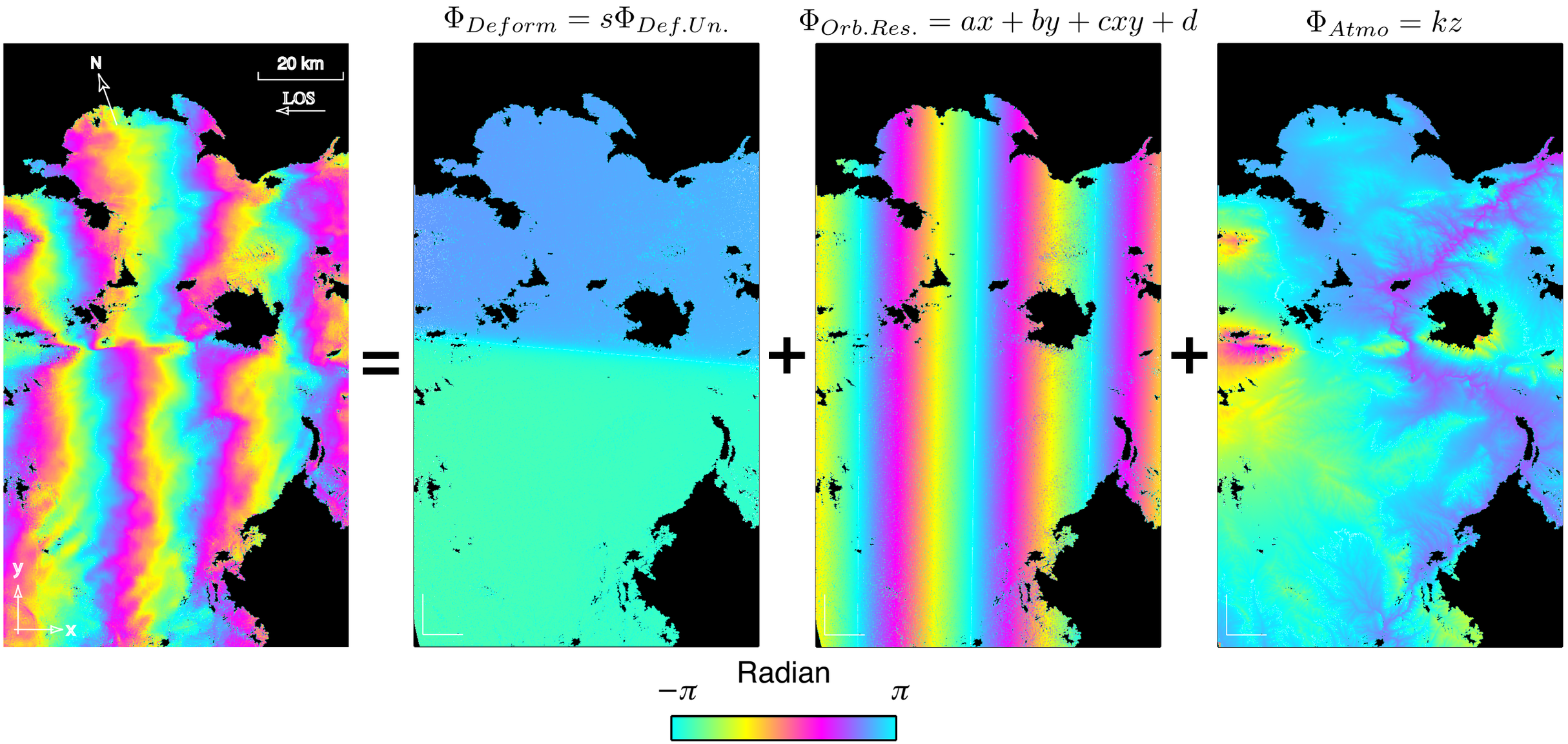

Beauducel et al., 1999; Remy et al., 2003

Cavalie et al, 2008; Lin et al, 2010; Jolivet et al., Submitted to JGR

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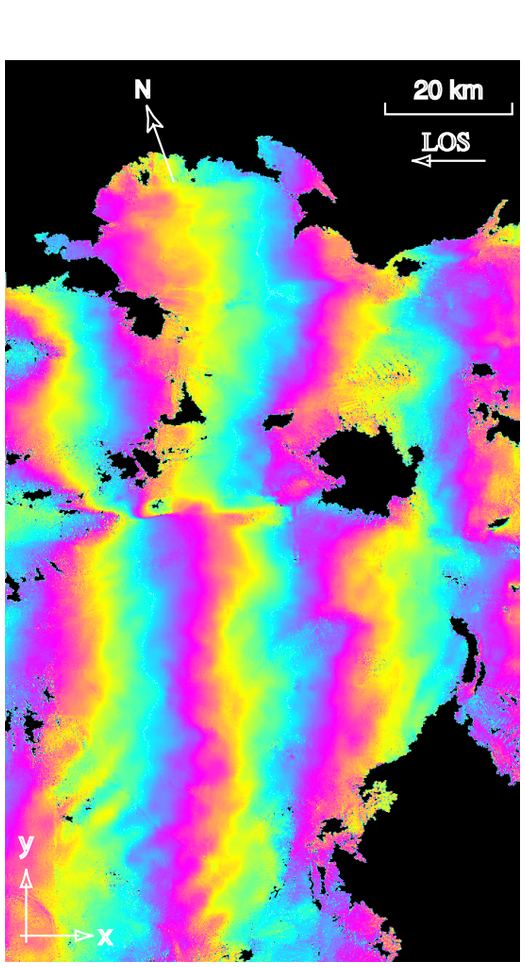
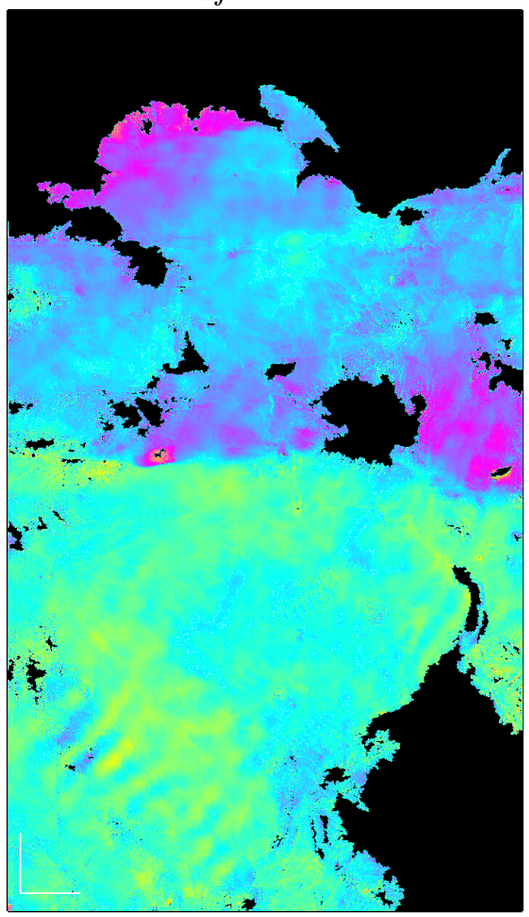
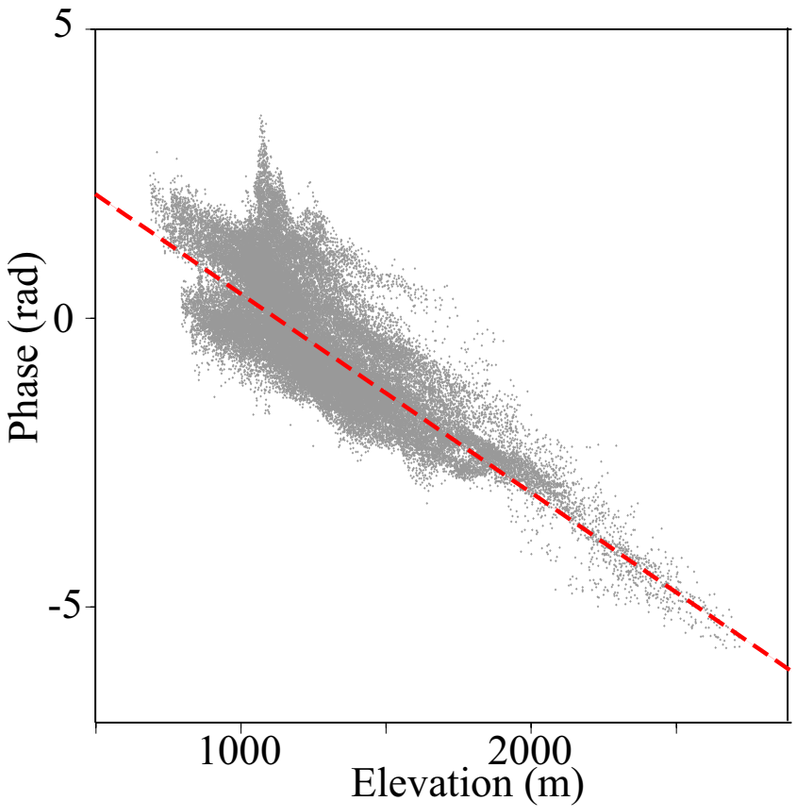


$\Phi = \Phi_{Deform} + \Phi_{Noise}$



Radian

$-\pi$ π



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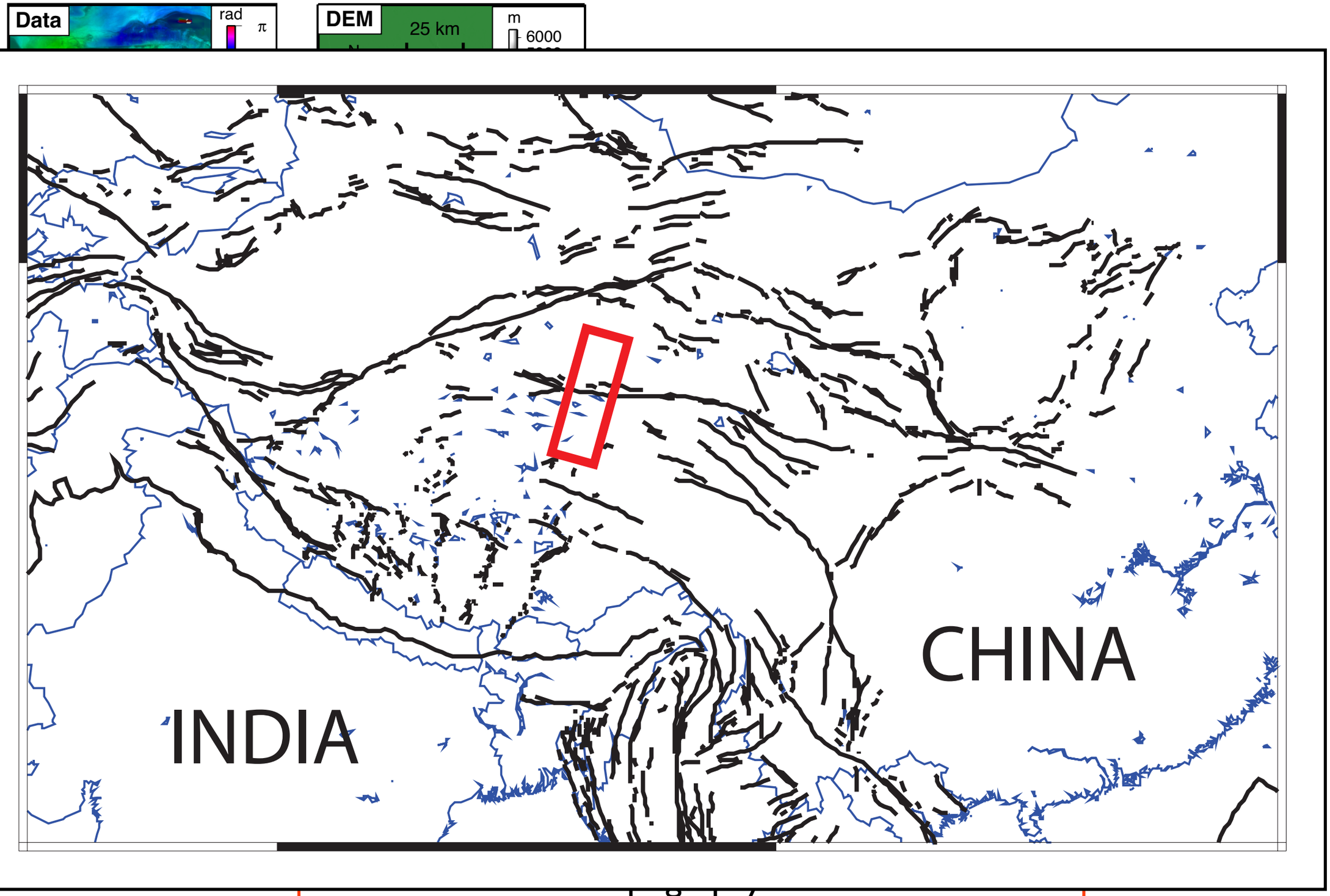
Empirical estimation but....



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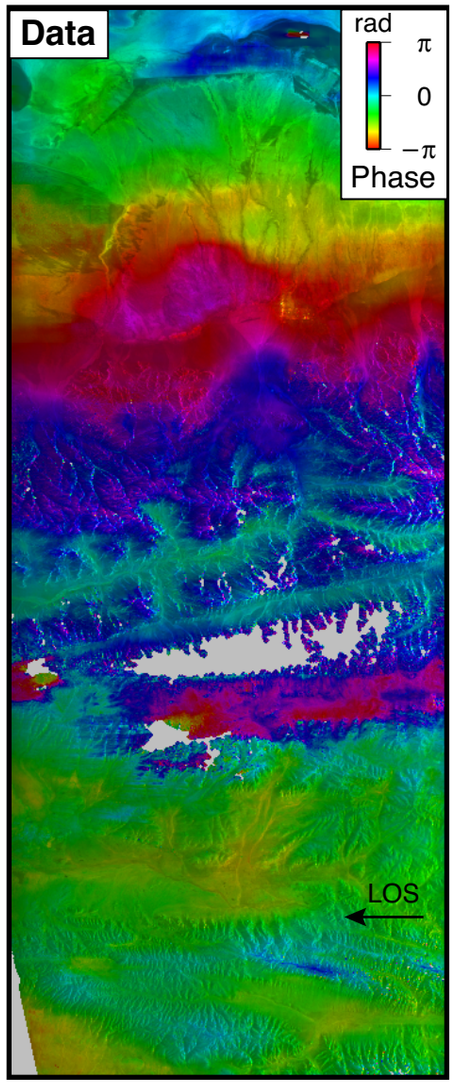
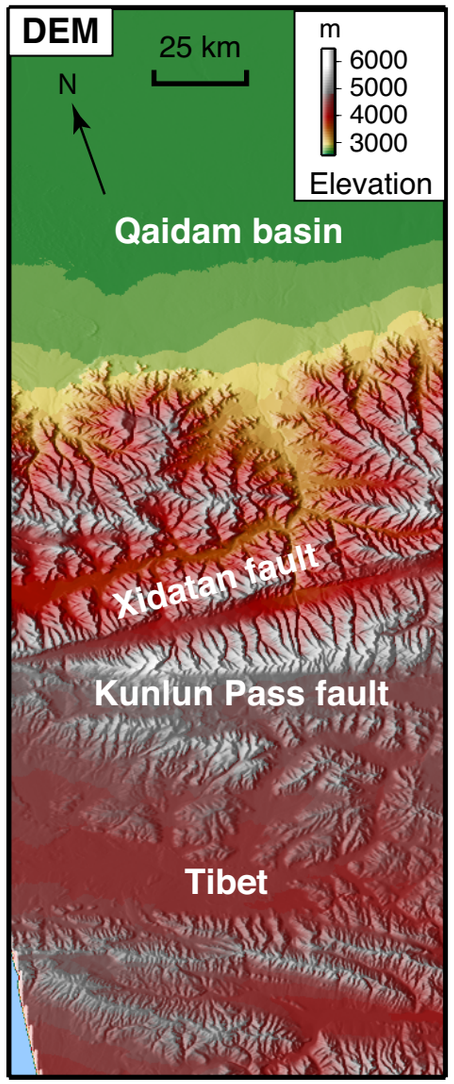
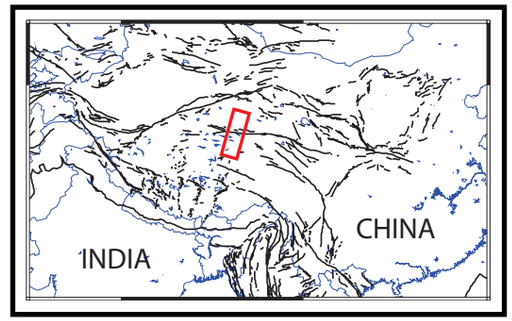
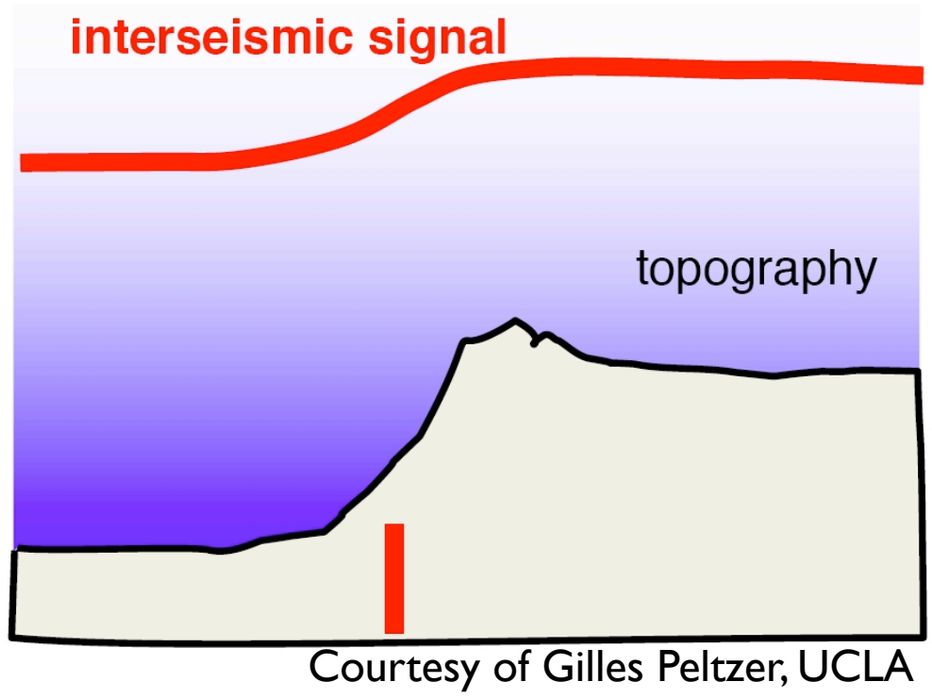






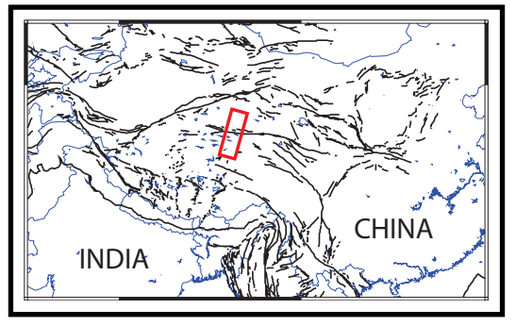


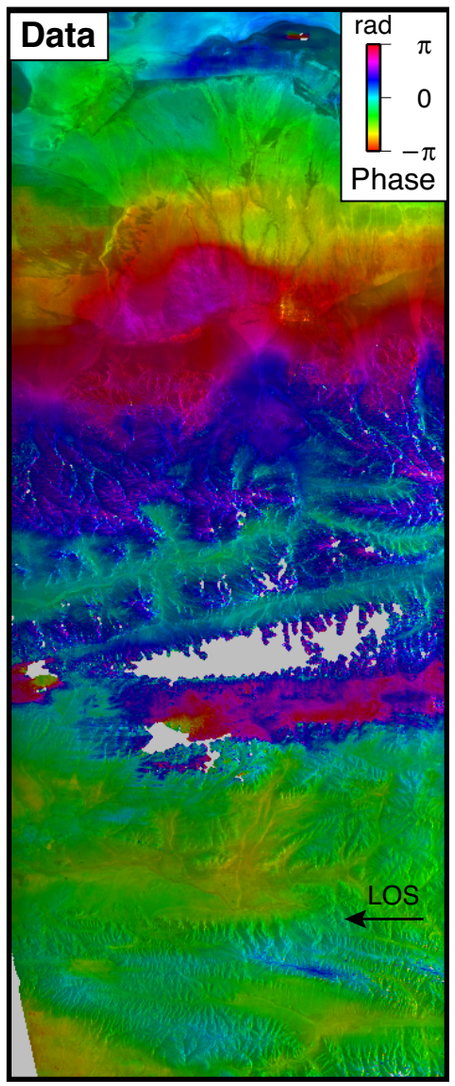
Courtesy of Gilles Peltzer, UCLA

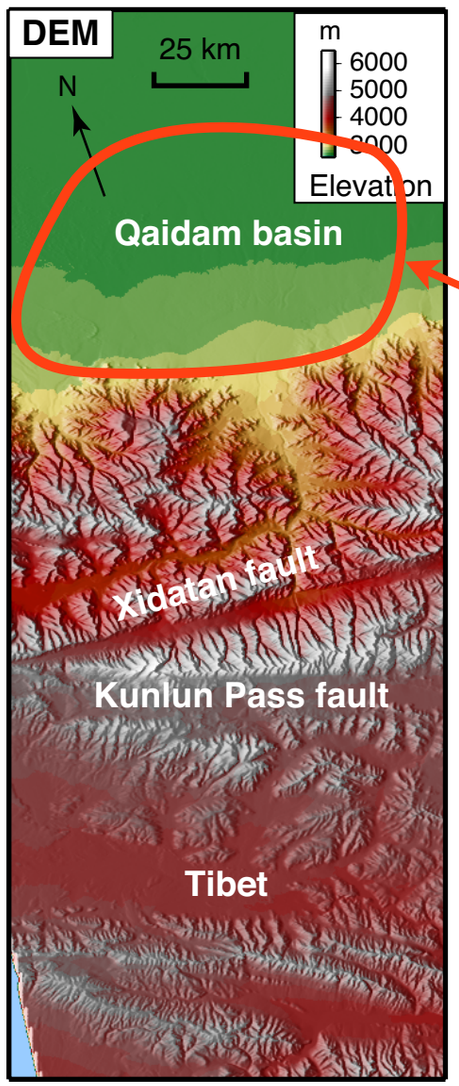
Difficult if:

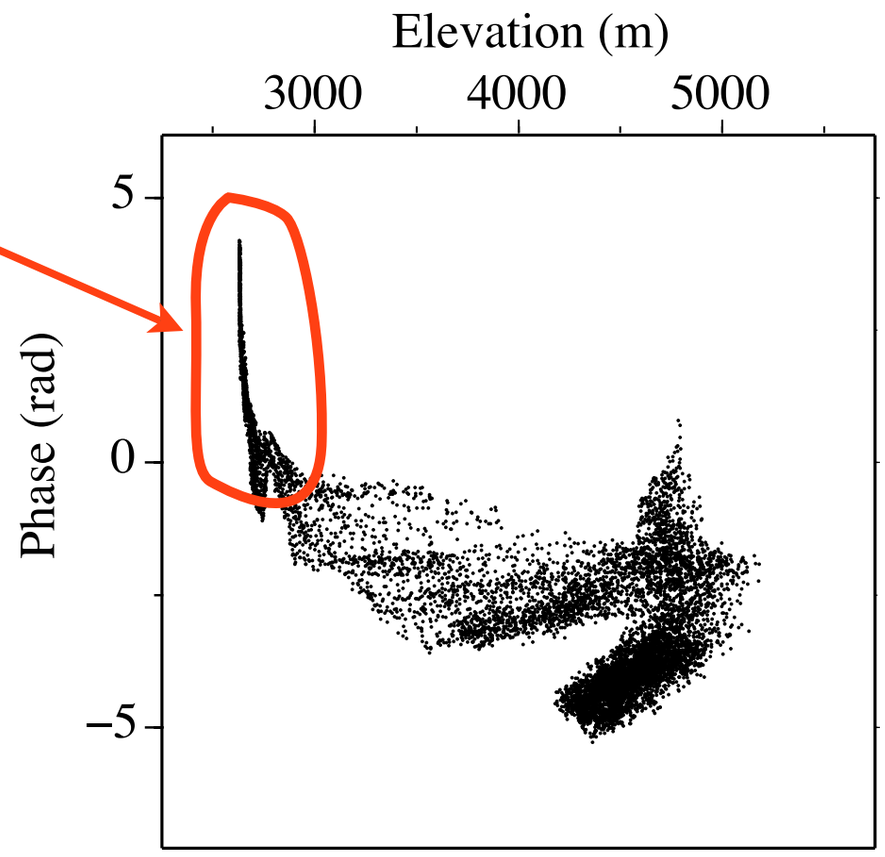
- Deformation and Topography are related

Empirical estimation but....





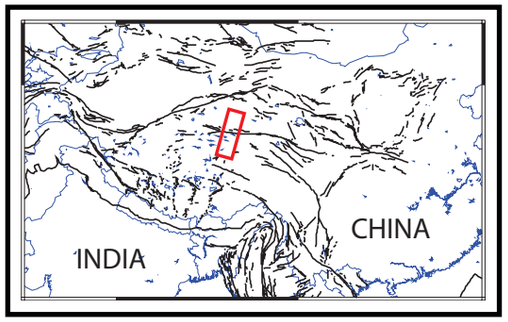


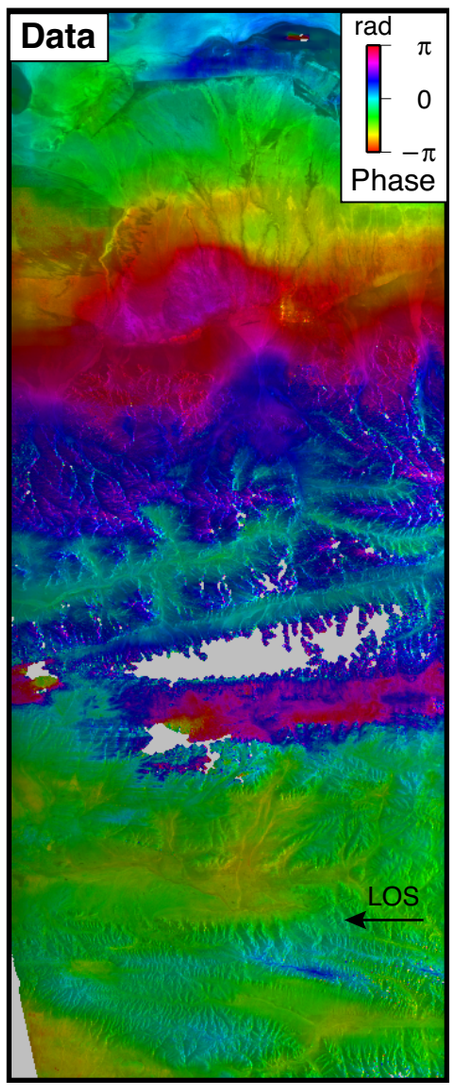


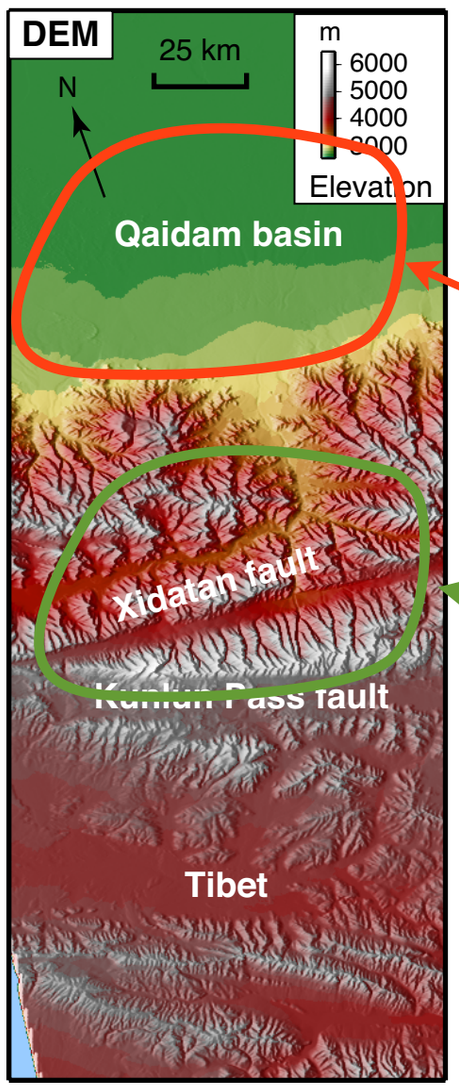
Difficult if:

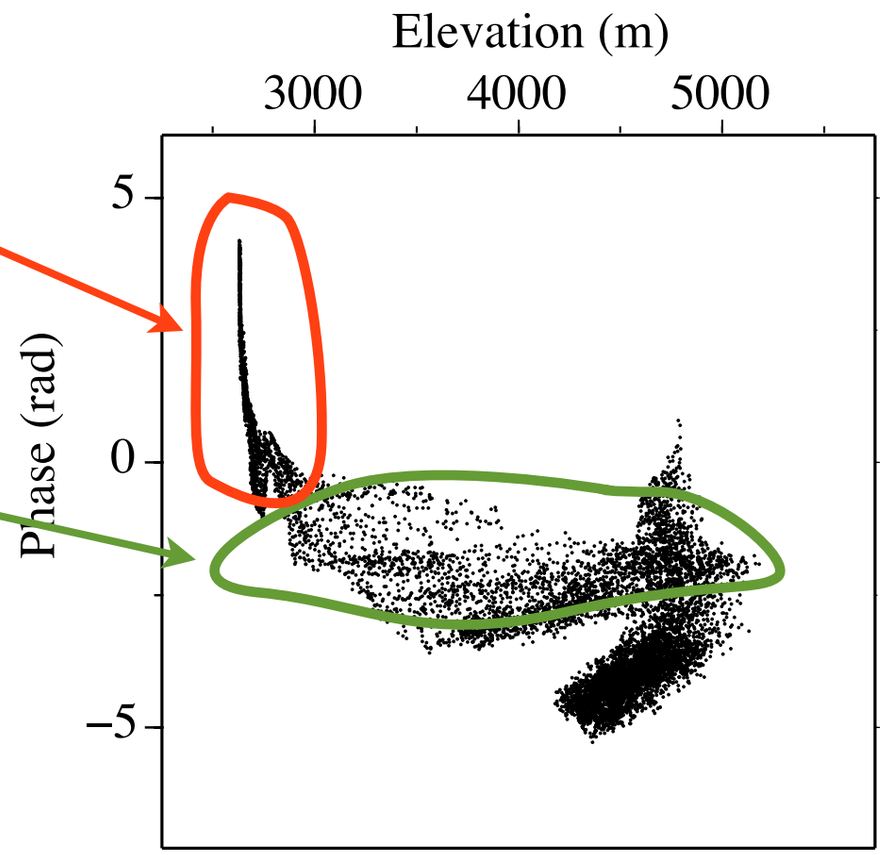
- Deformation and Topography are related
- Lateral variations of the atmospheric stratification

Empirical estimation but....









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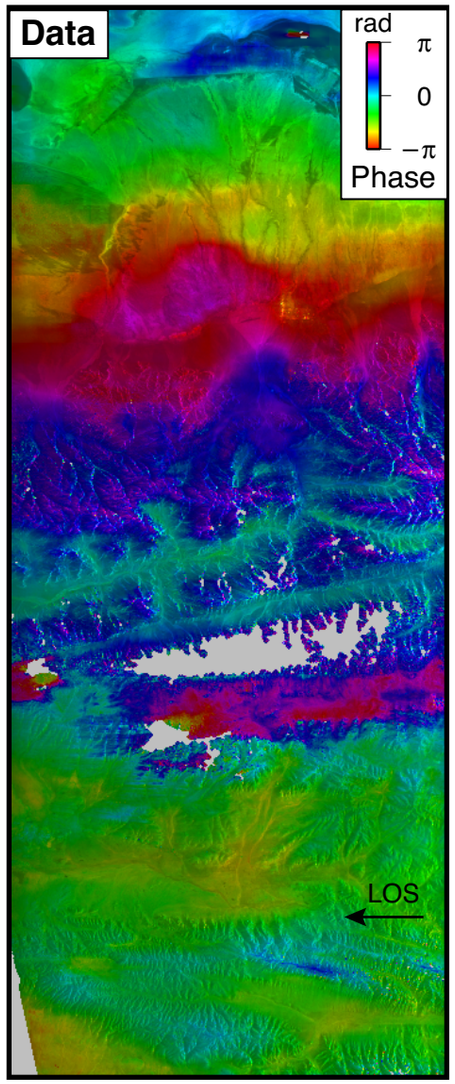

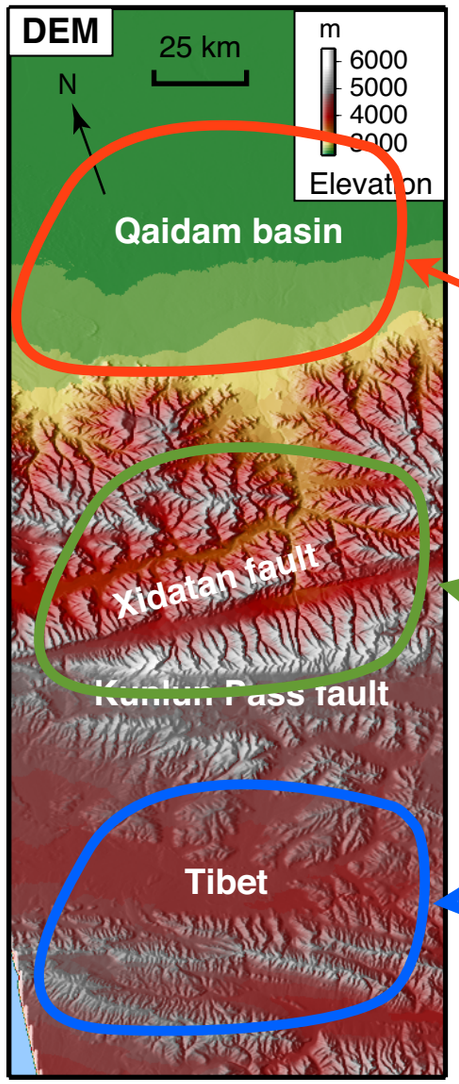

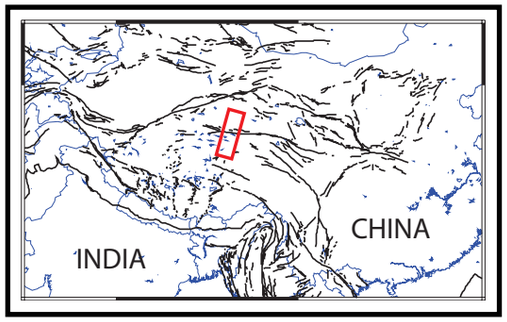

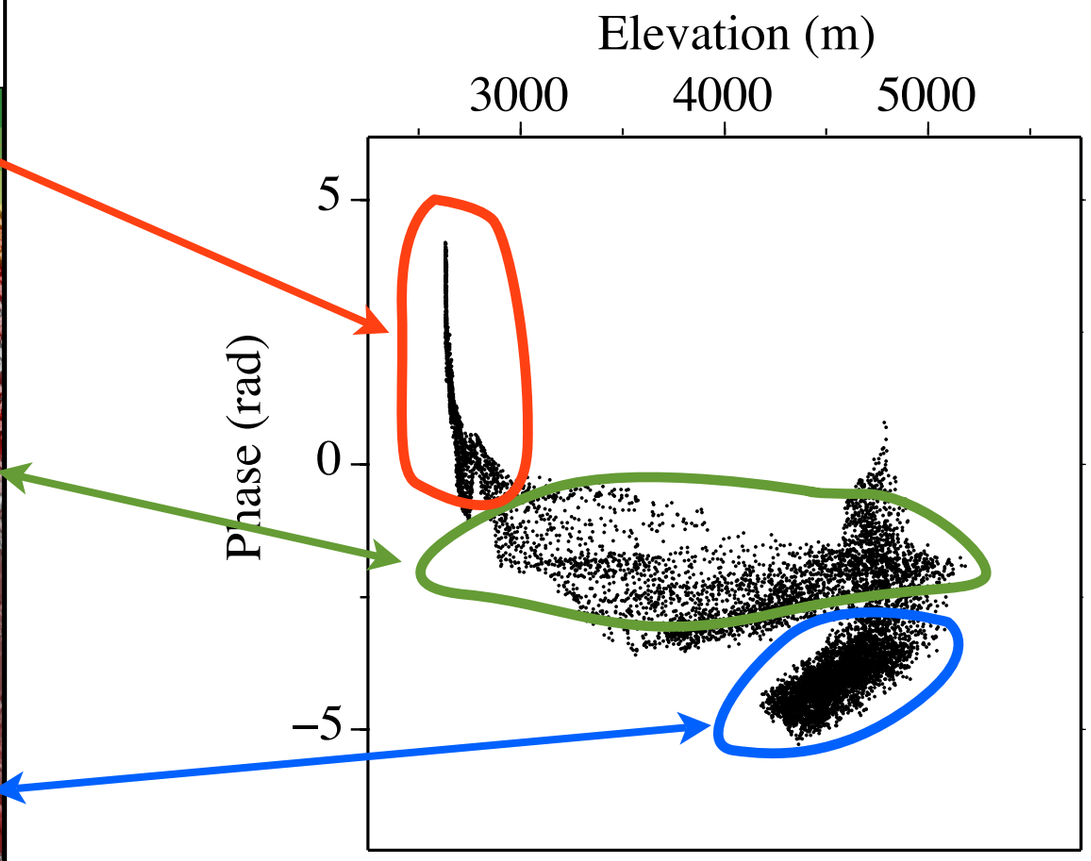

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Global Atmospheric Models

ERA-Interim Dee et al, 2011

- ECMWF atmospheric model
- Global ~75 km grid
- 1989-...
- 4 solutions a day at 0 am, 6 am, 12 pm and 6 pm
- Altitude, temperature and water vapor partial pressure at 37 pressure levels (surface to 50 km alt.)

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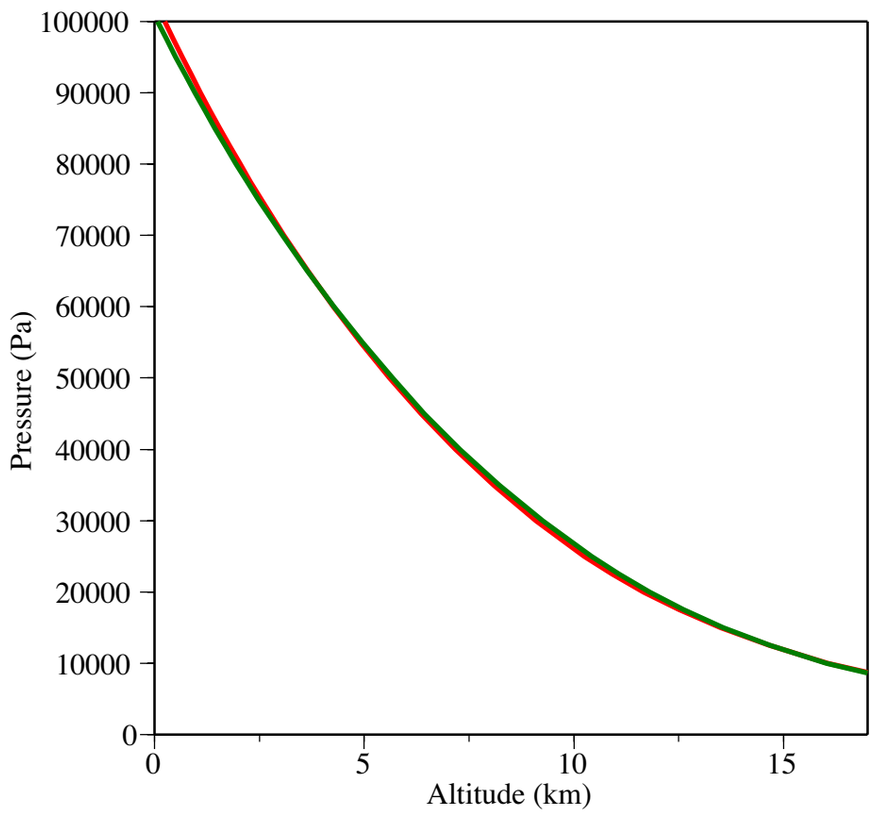

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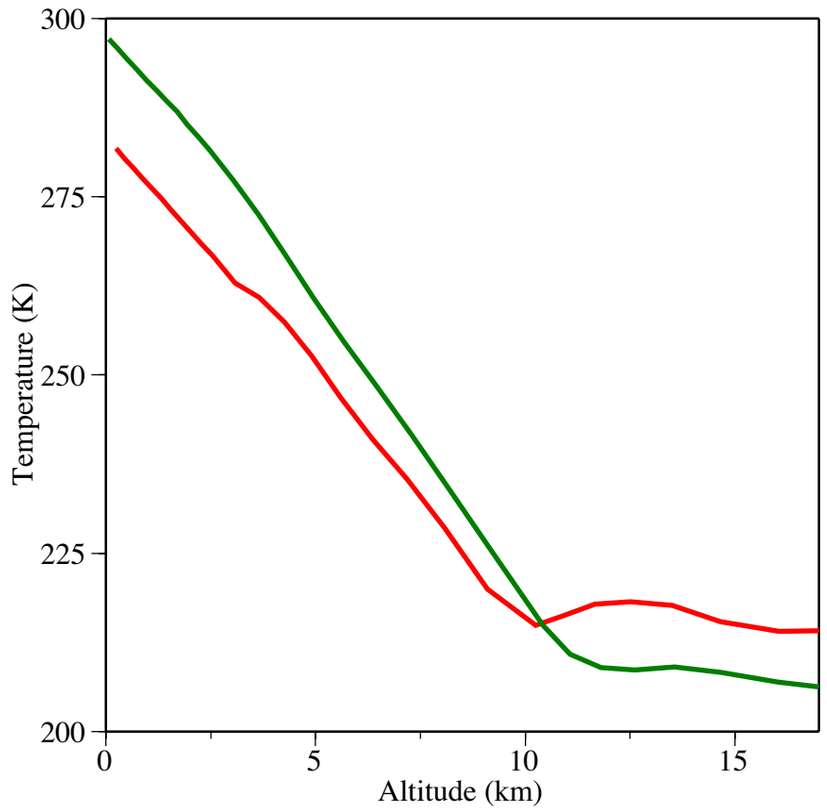

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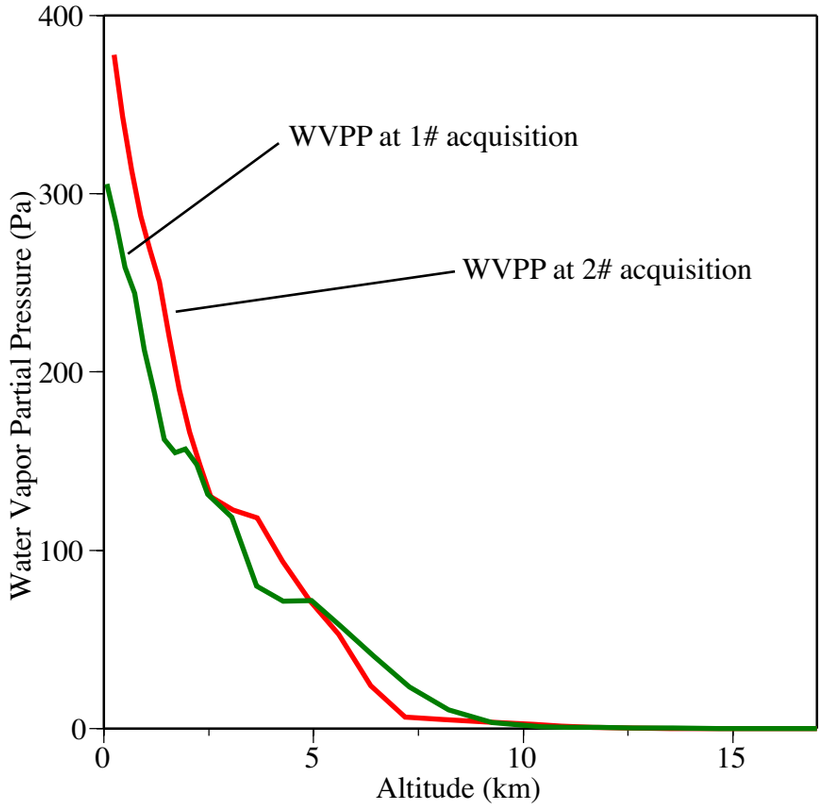

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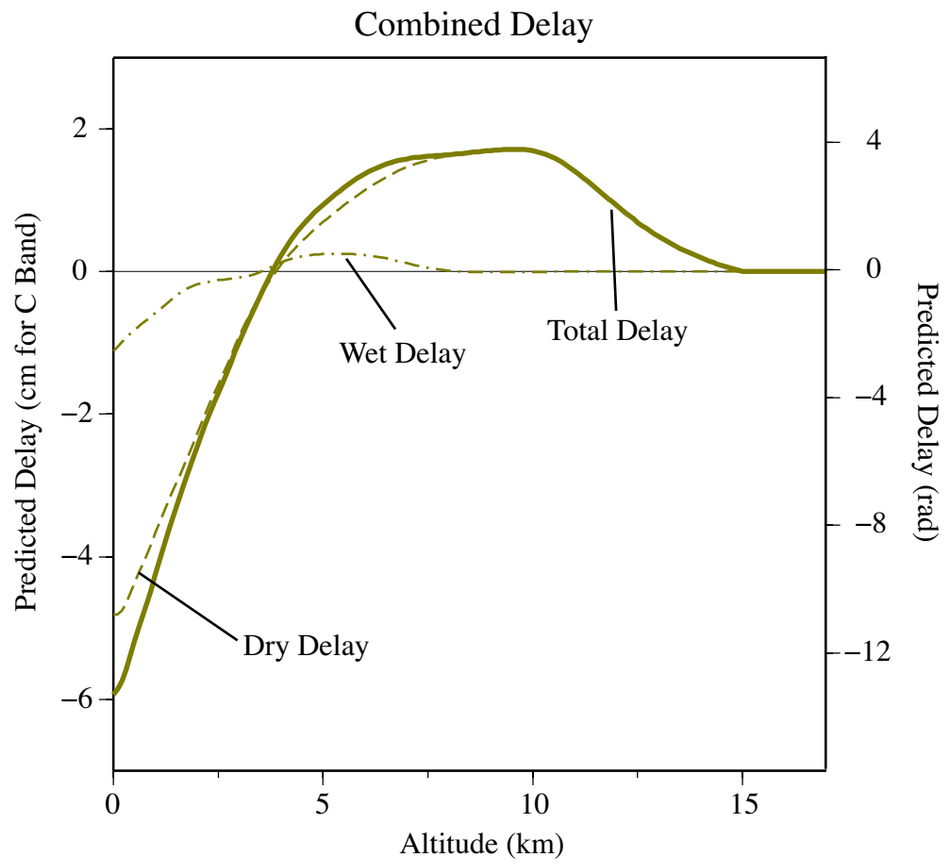
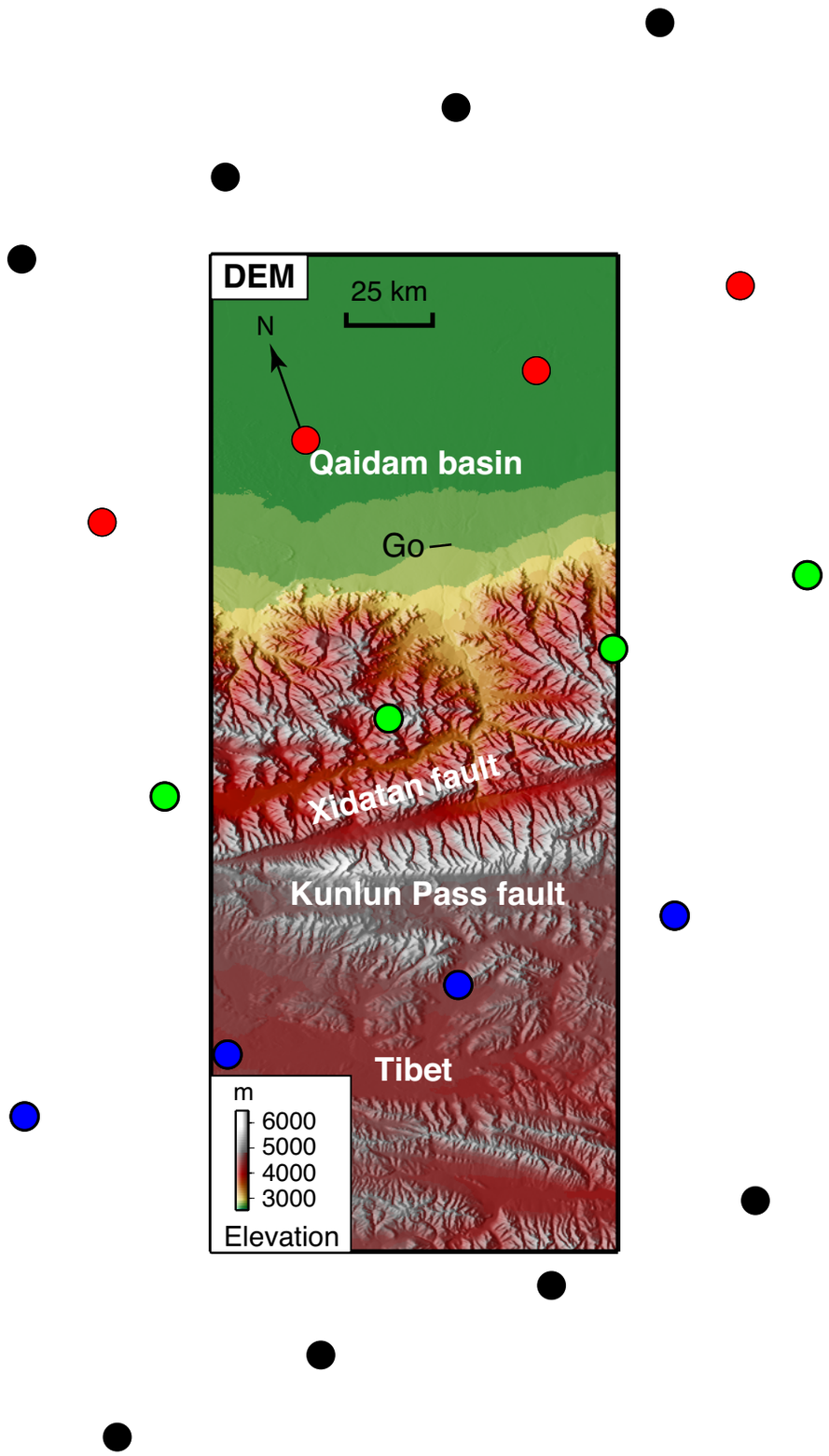
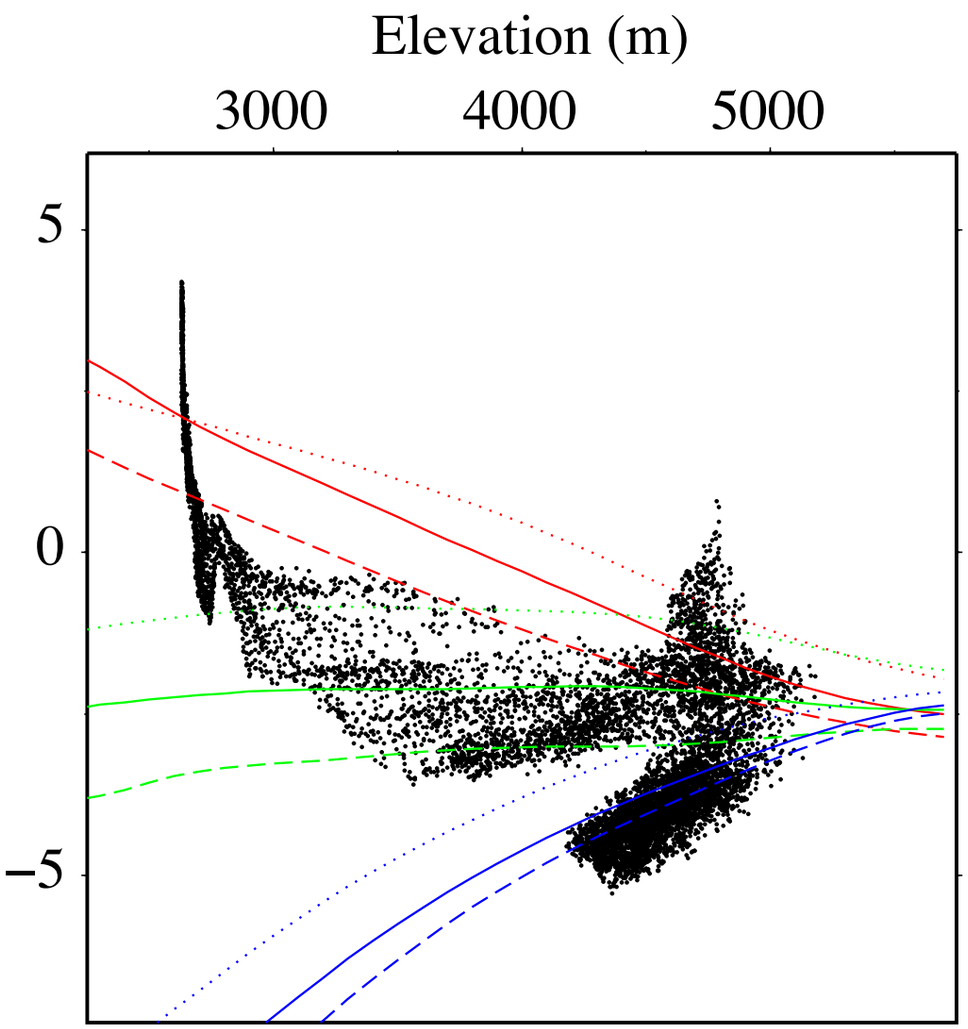
$$\Delta \mathrm{L}^{s}_{LOS}(z) = \delta \mathrm{L}^{s2}_{LOS}(z) - \delta \mathrm{L}^{s1}_{LOS}(z)$$



Computing Delay Maps from GAM

1 - Computing delay functions





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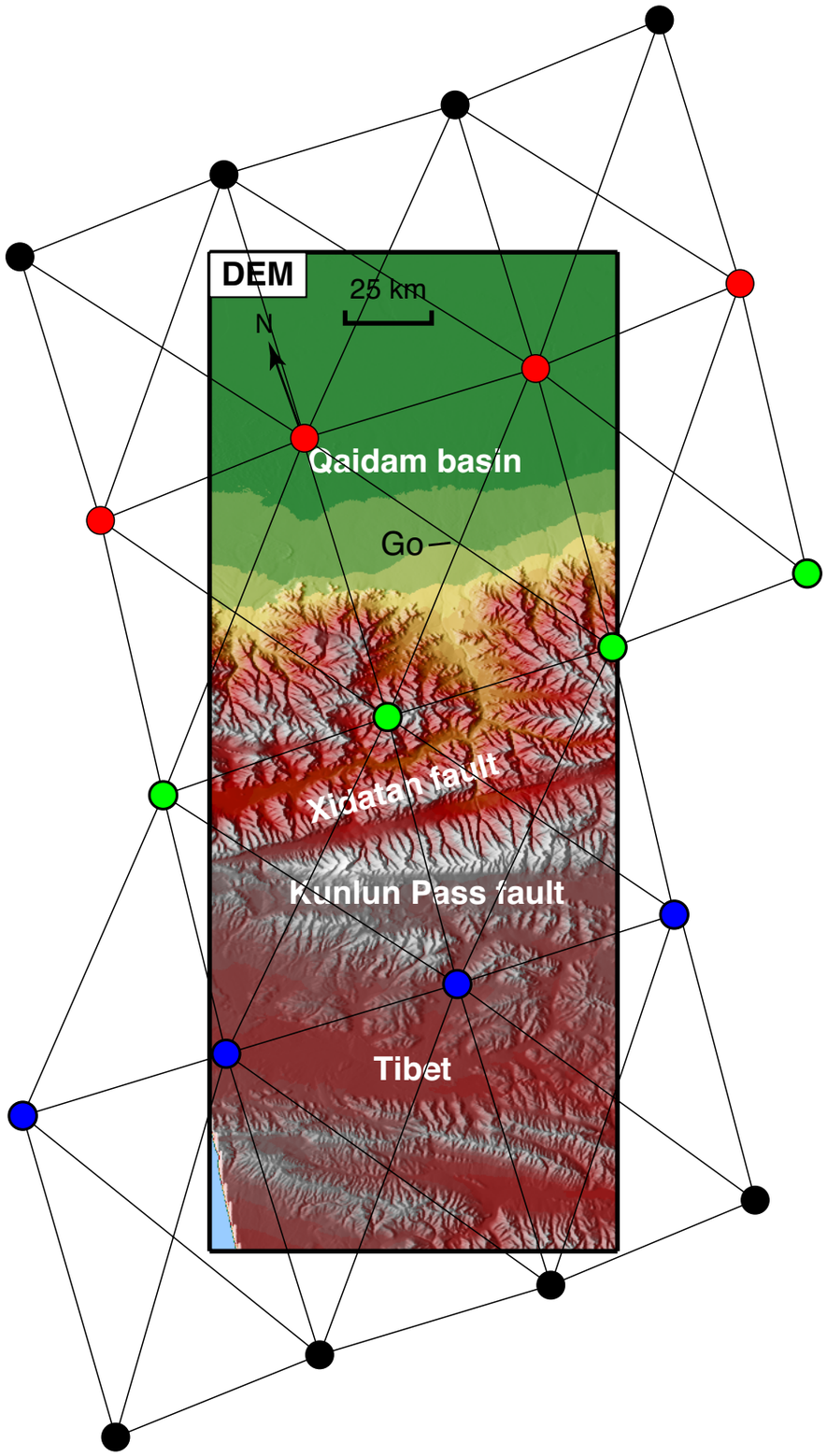
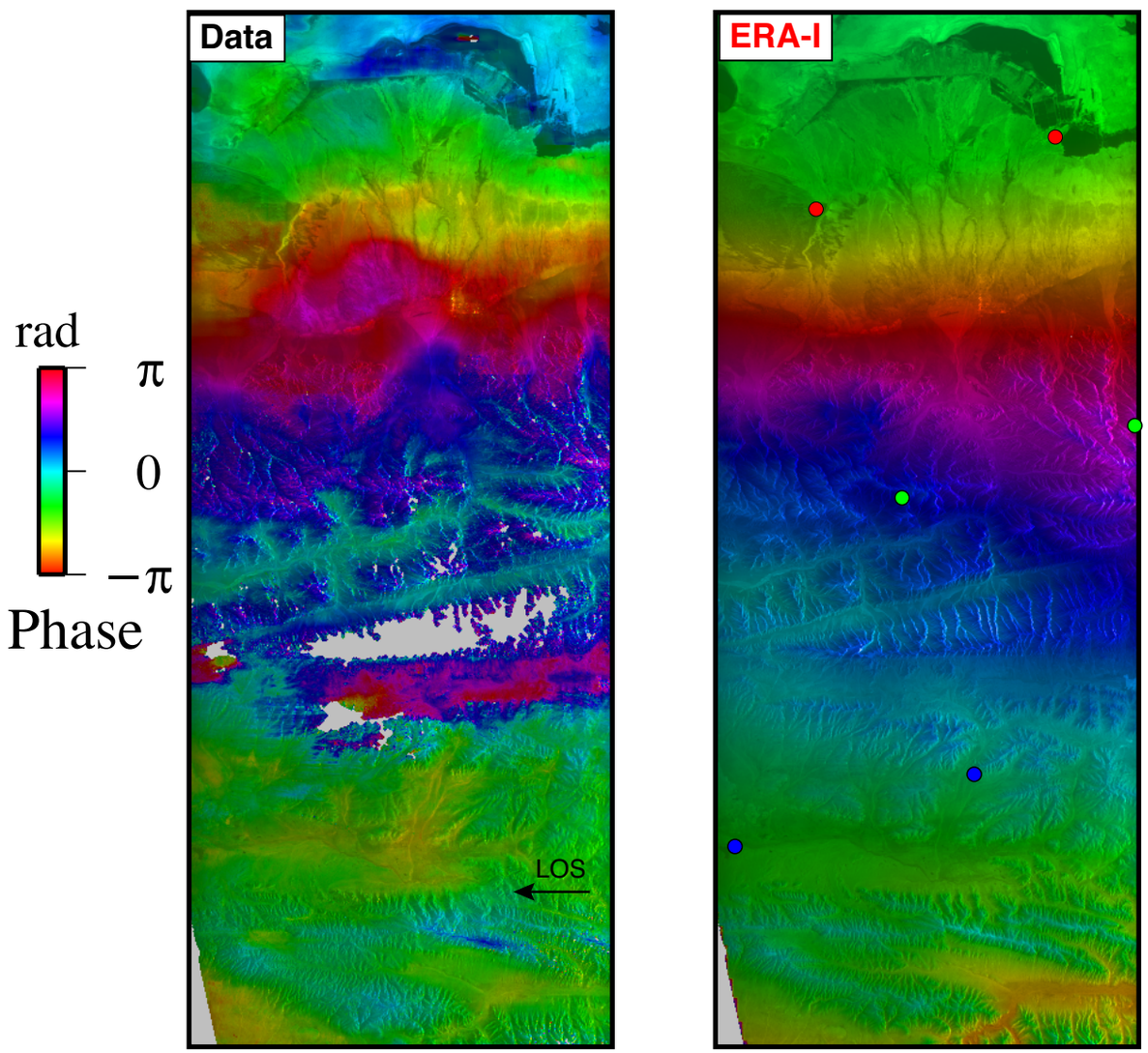


1 - Computing delay functions

2 - Spatial bilinear interpolation and spline interpolation for altitude

Validation on unwrapped interferograms

One month temporal baseline == no deformation expected



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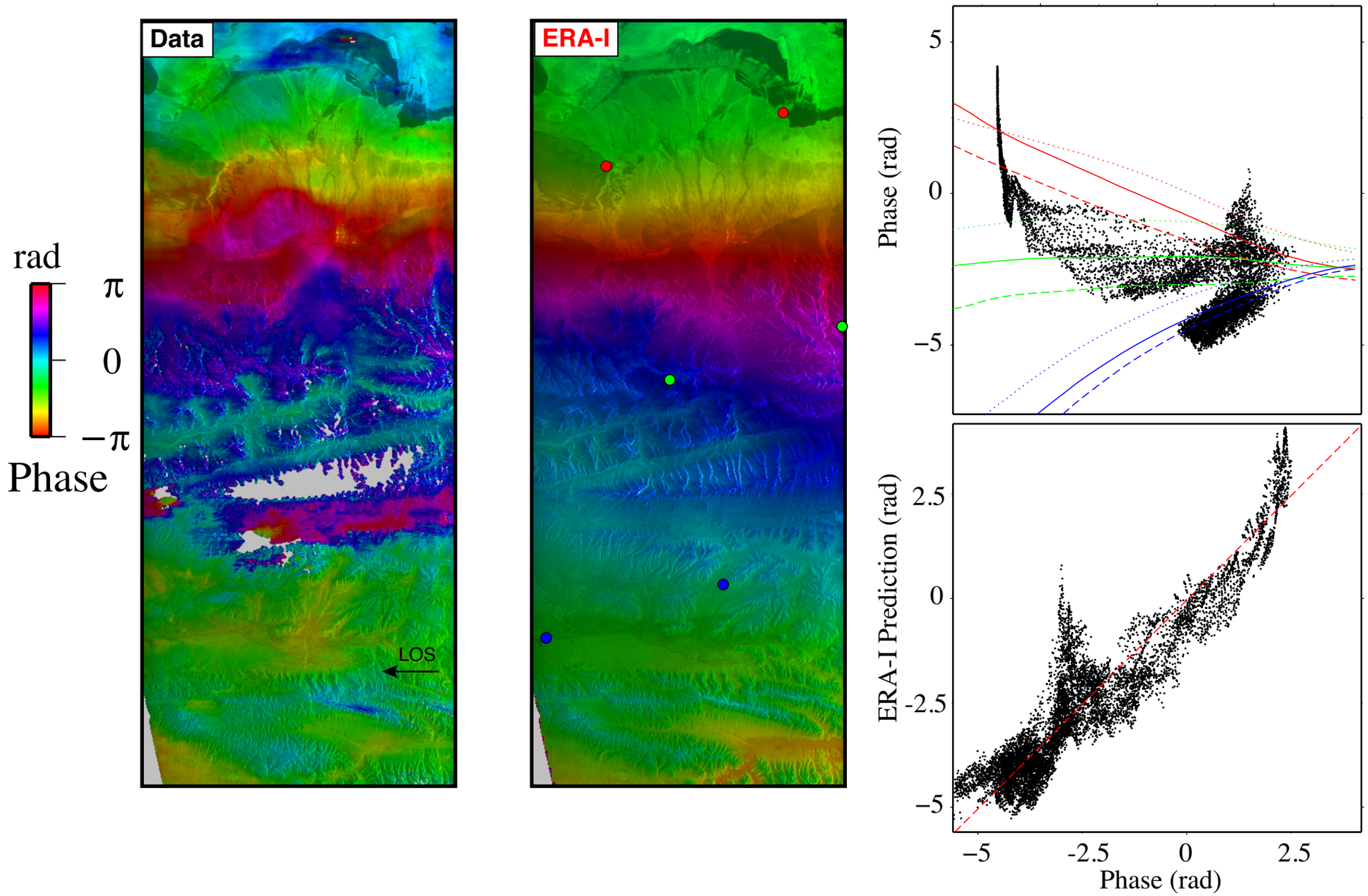
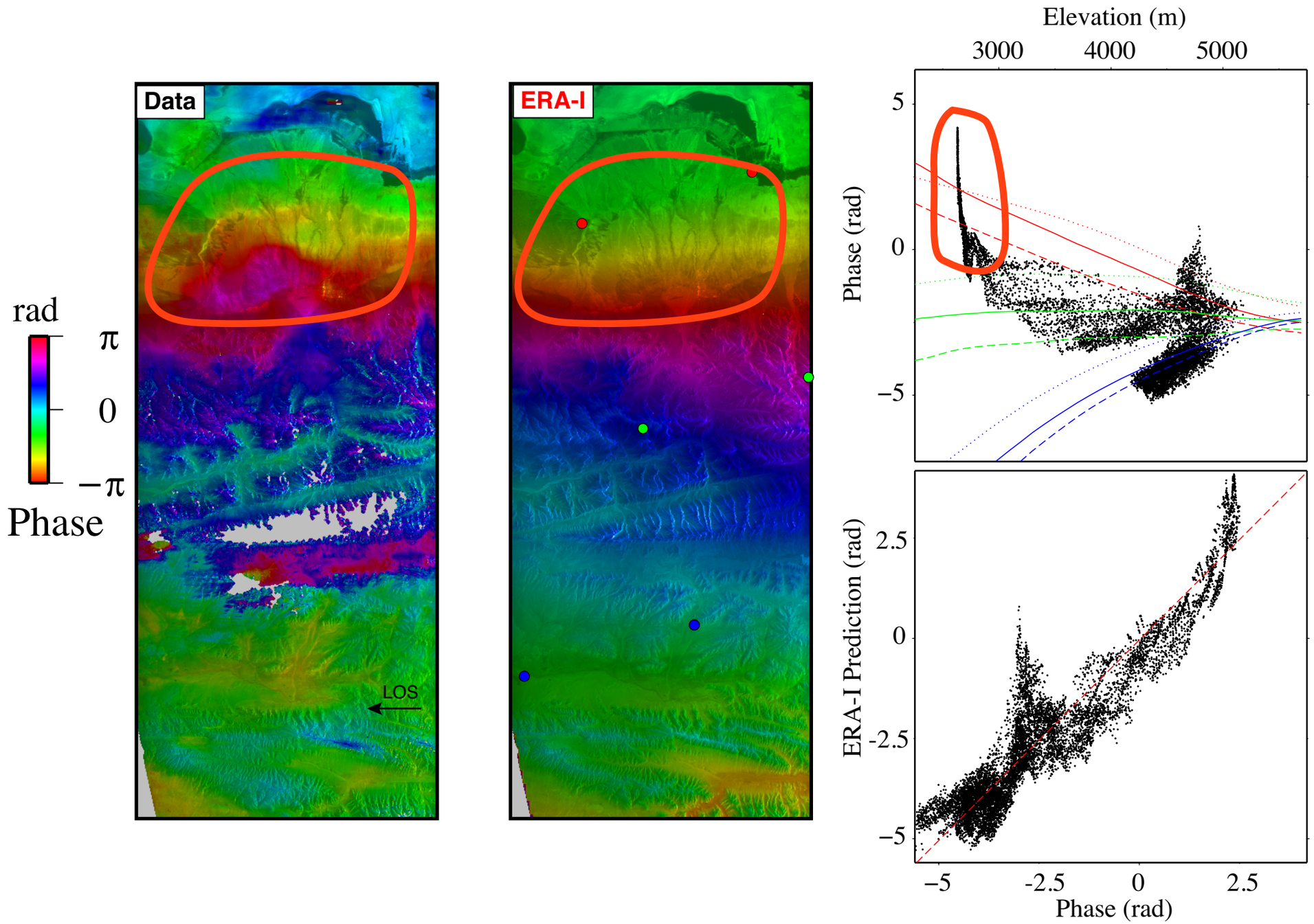


Data and prediction shows a good agreement

Lateral variations are predicted

Validation on unwrapped interferograms



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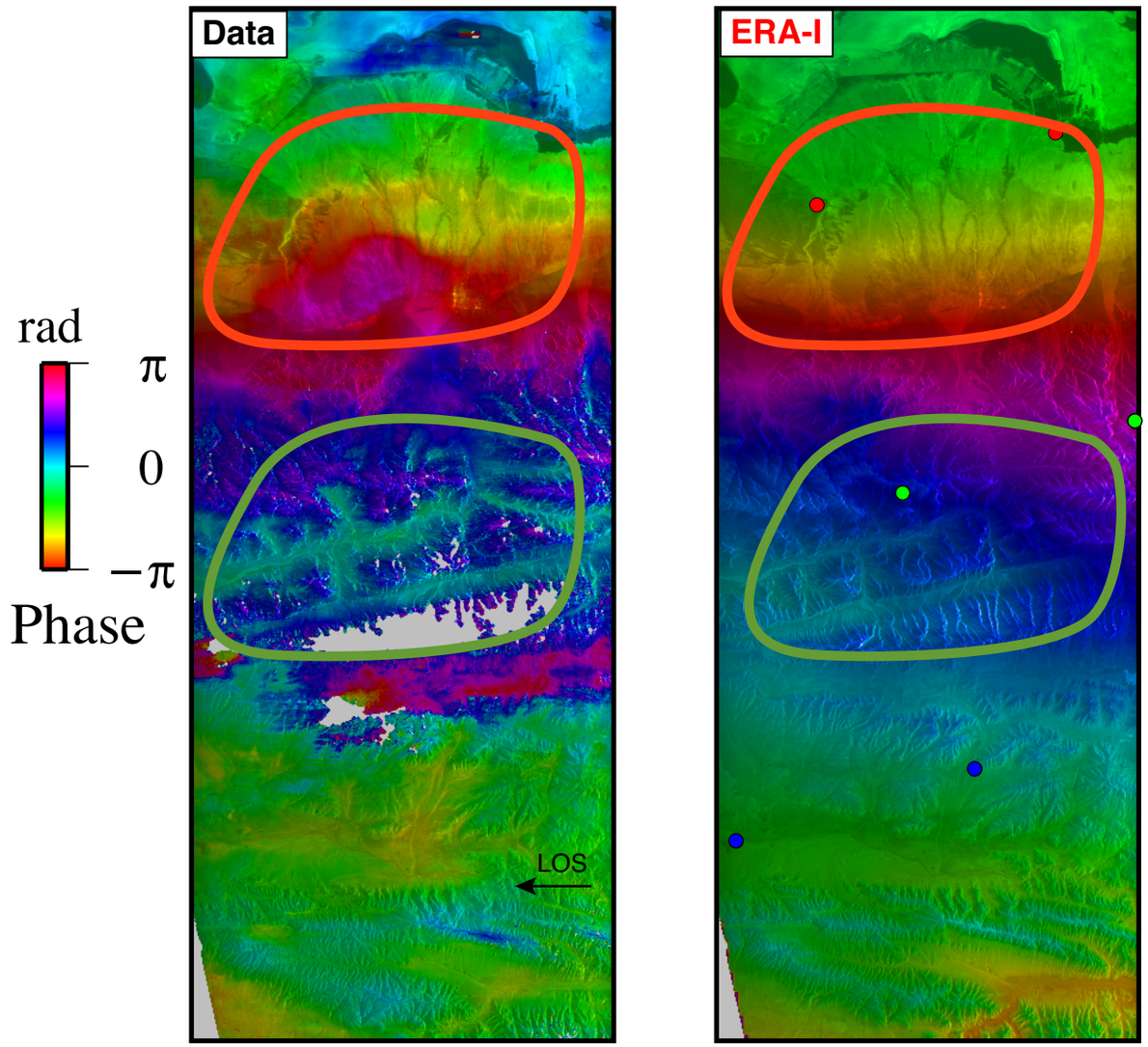

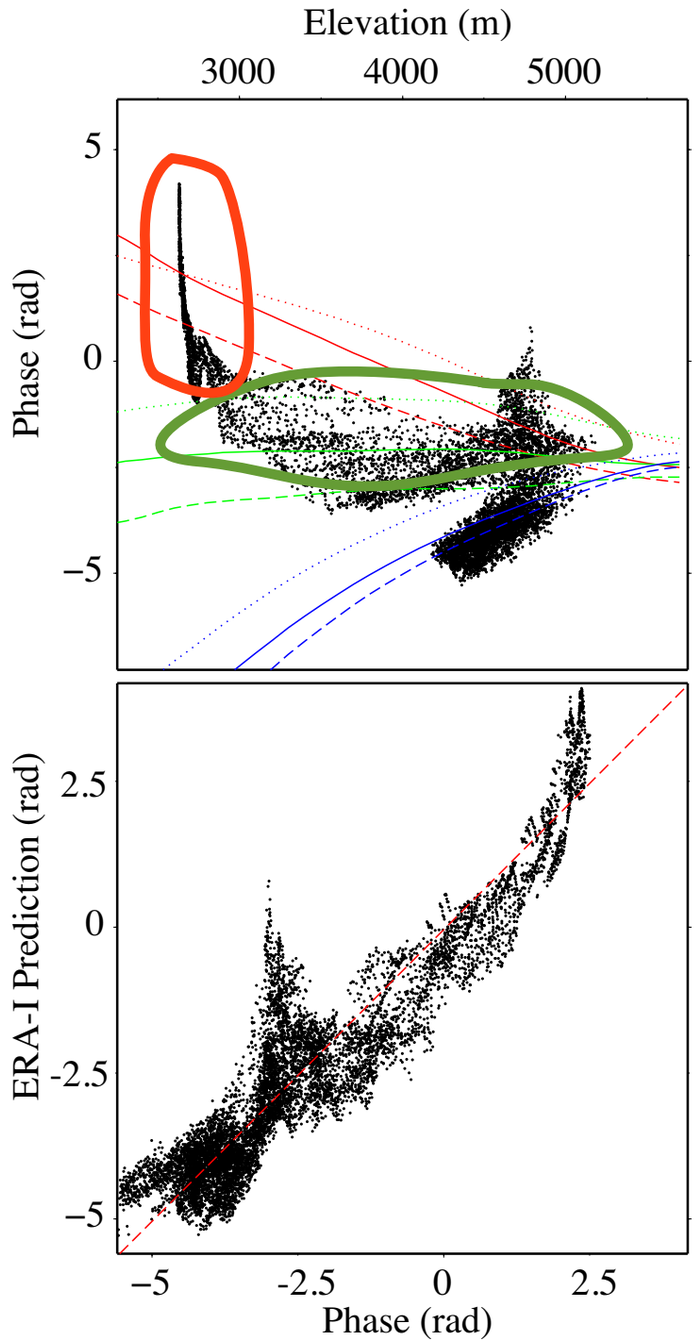

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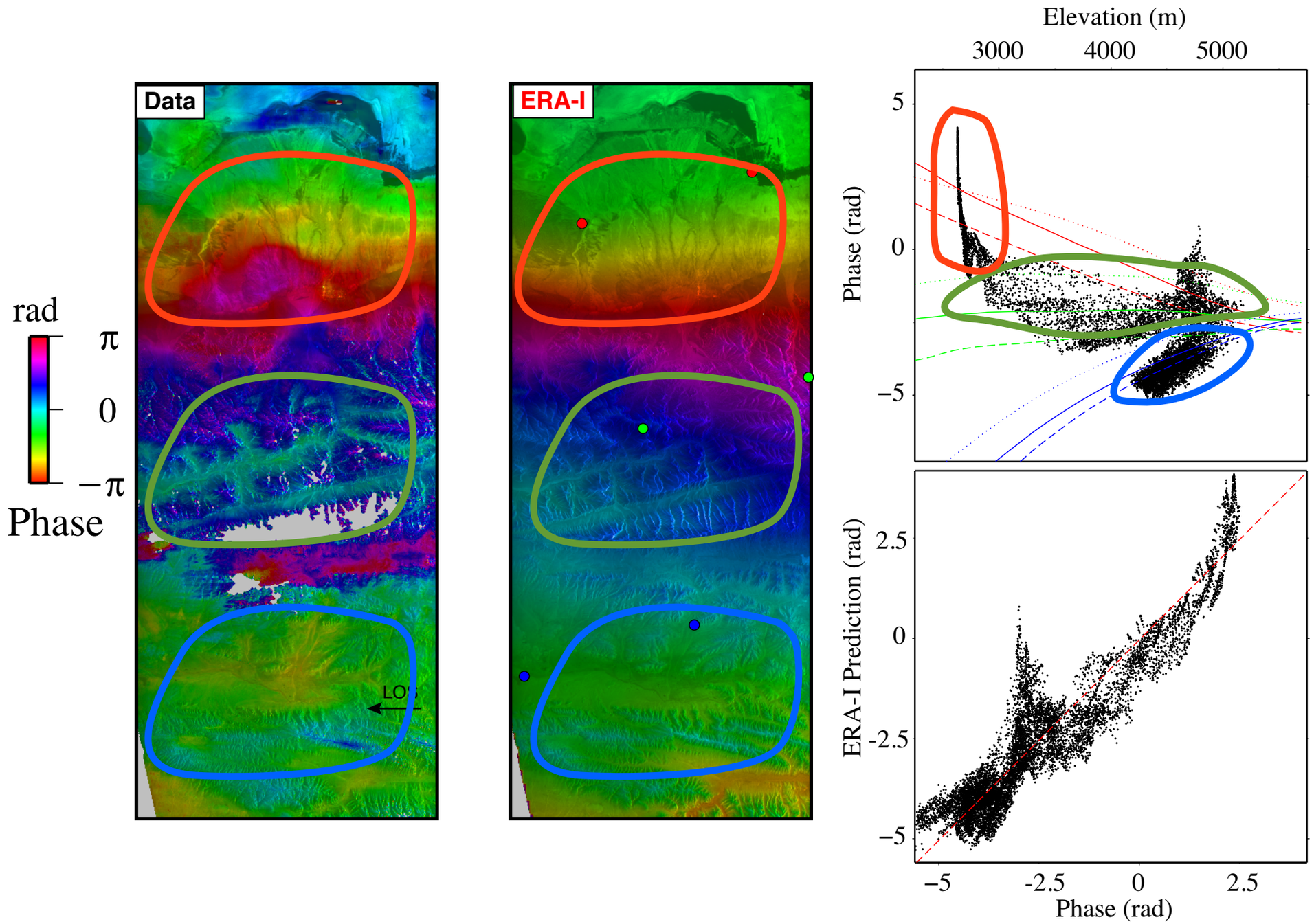
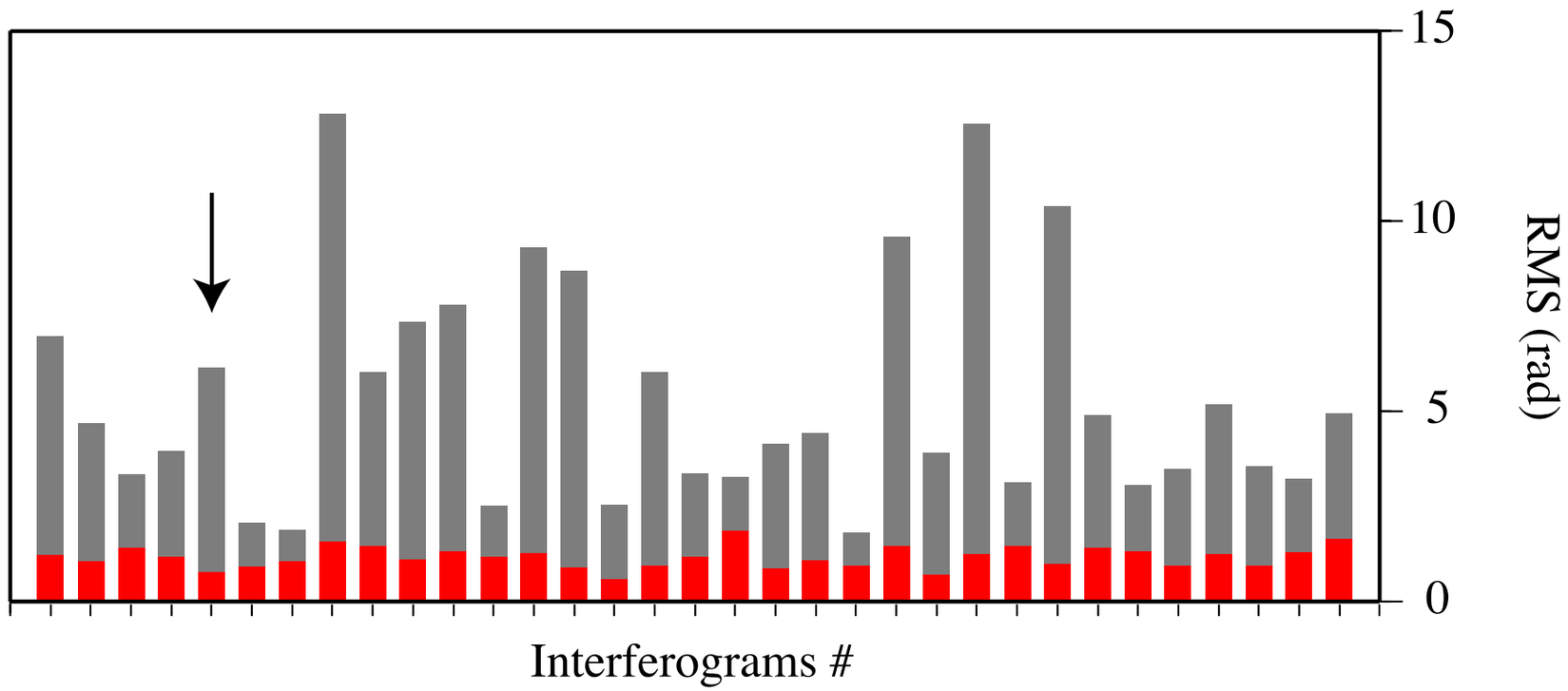


Data and prediction shows a good agreement

Lateral variations are predicted

Validation on unwrapped interferograms

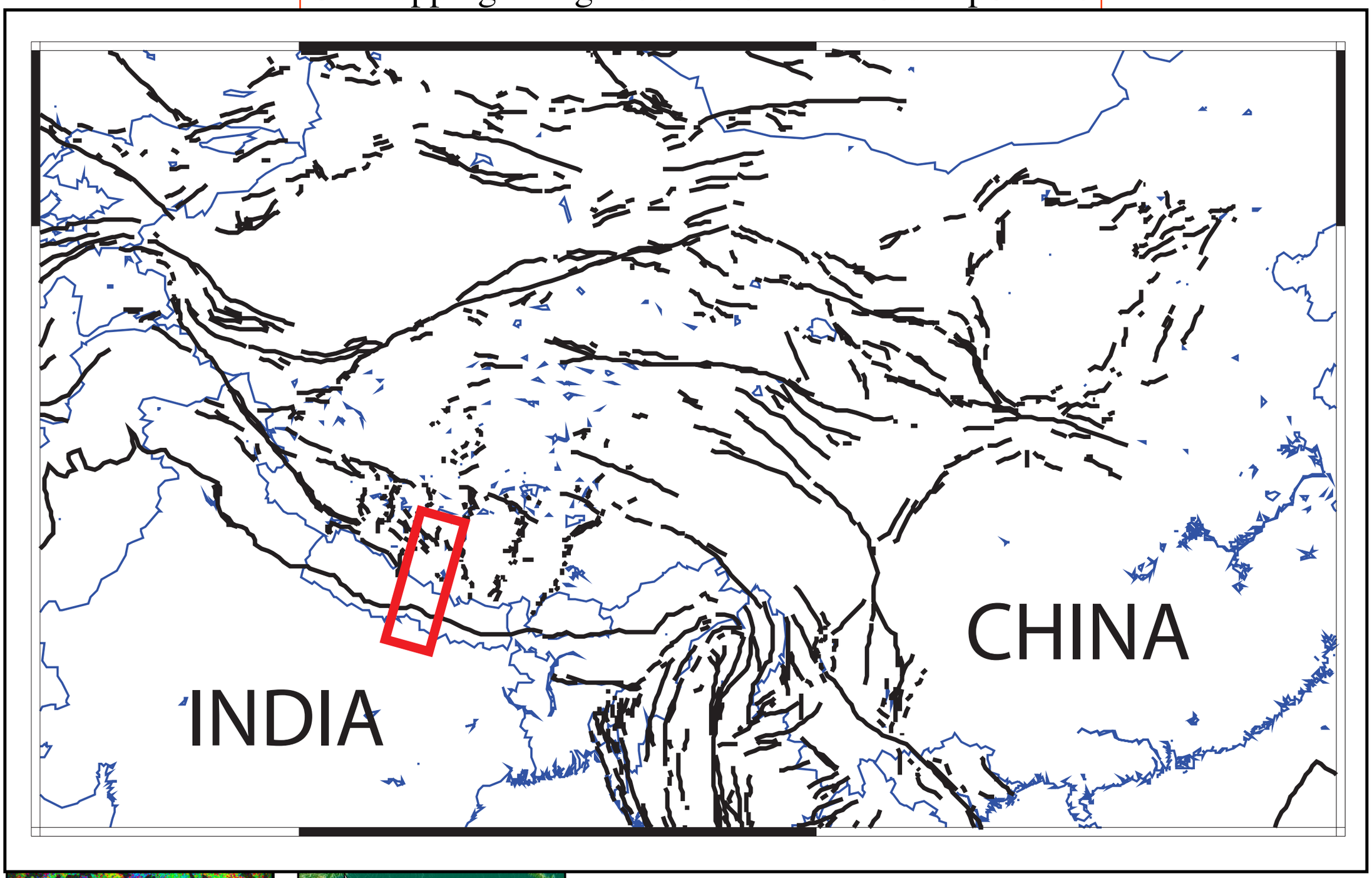


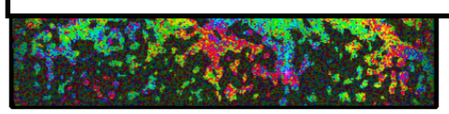
- 2D Full grid ERA-I correction: ~73% RMS reduction
- 1D ERA-I correction: ~71% RMS reduction
- Empirical correction (Cavalie et al 2008) : ~71% RMS reduction

-- At least as efficient as the empirical method
-- Unbiased method, no parameter estimation

Enhancing the Unwrapping

Unwrapping in high relief area is almost impossible





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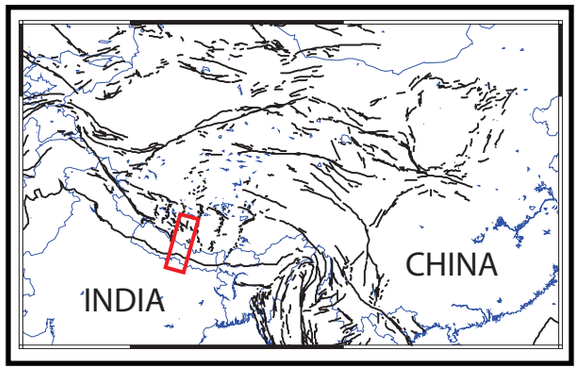
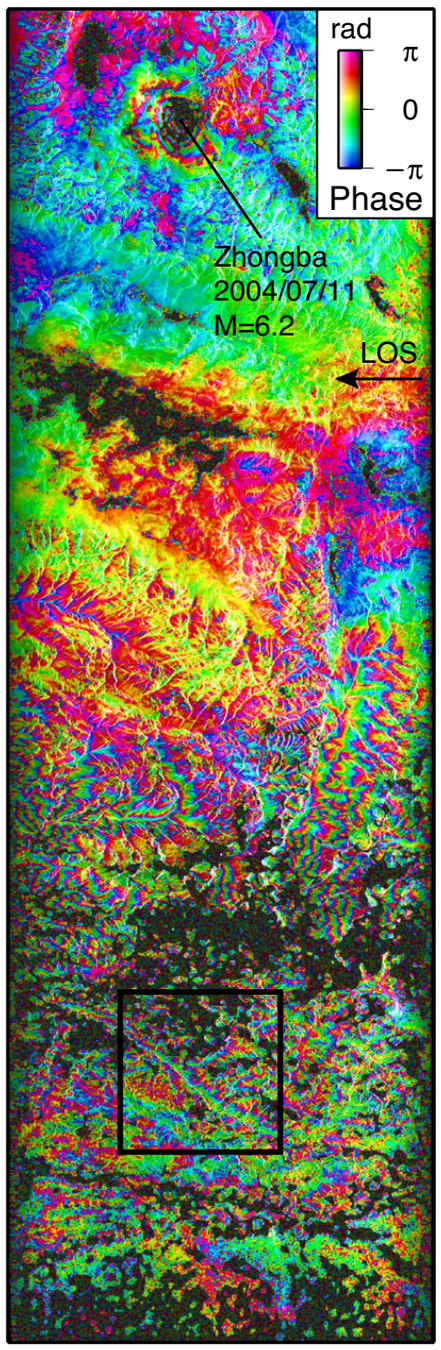
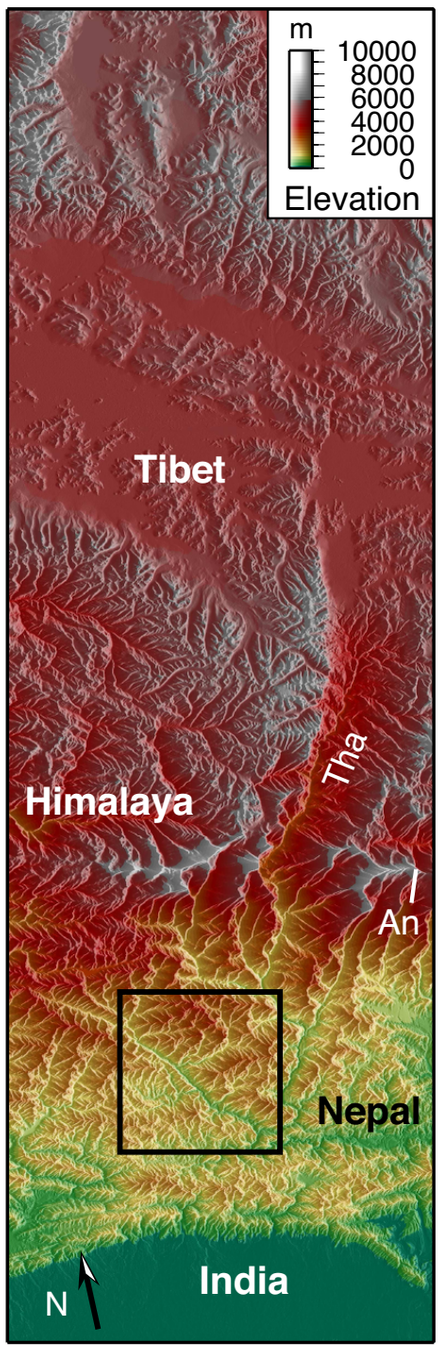




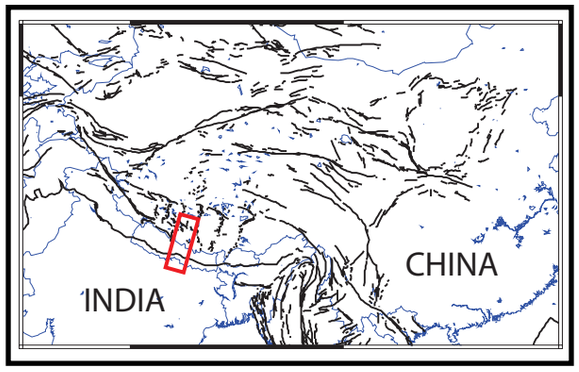


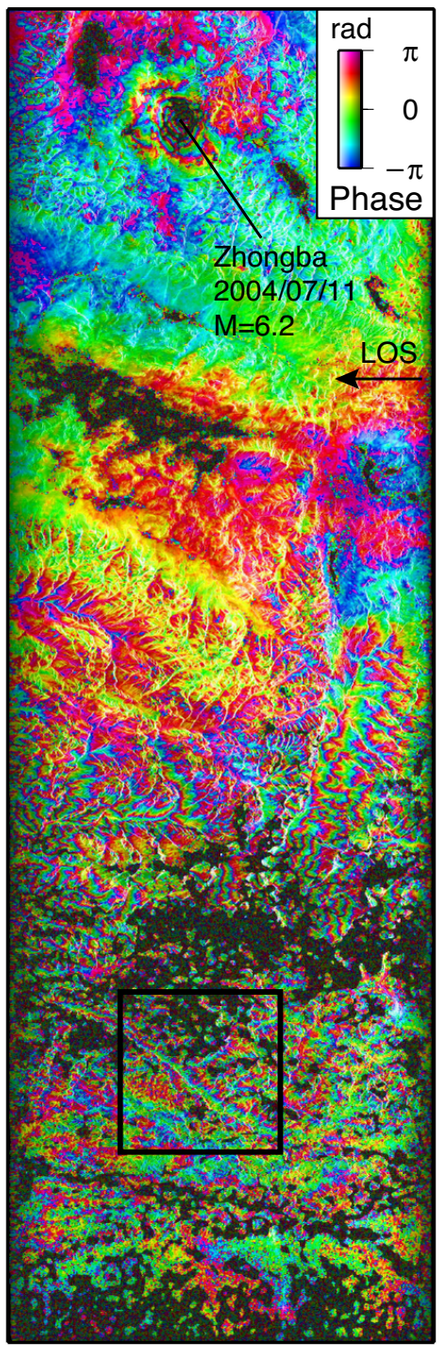
- In high relief areas, the coherence is poor.

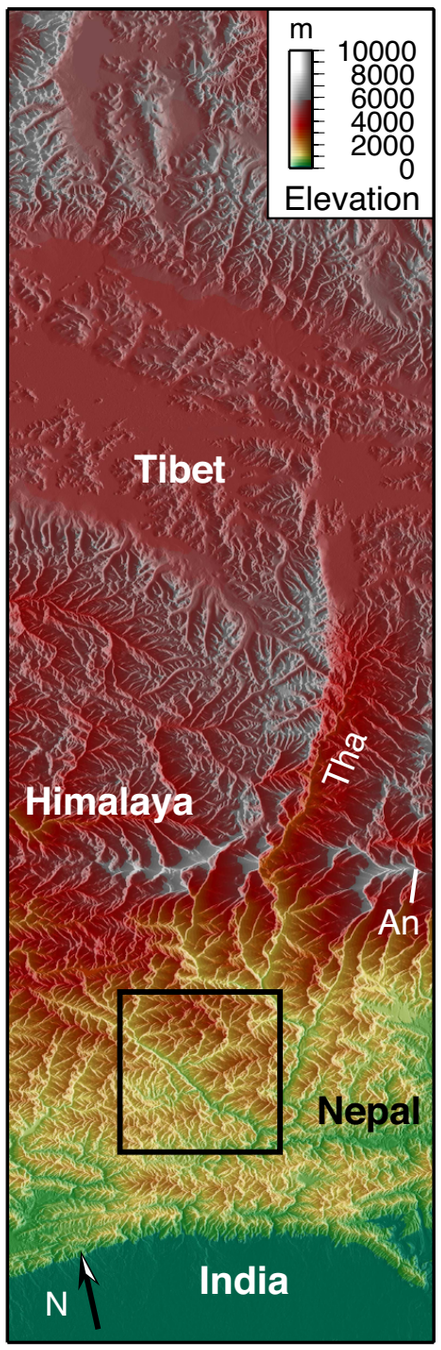
- Downlooking increases the coherence

Enhancing the Unwrapping

Unwrapping in high relief area is almost impossible







- In high relief areas, the coherence is poor.

- Downlooking increases the coherence

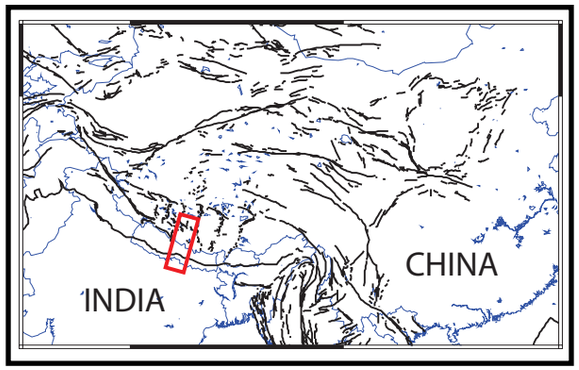
But...

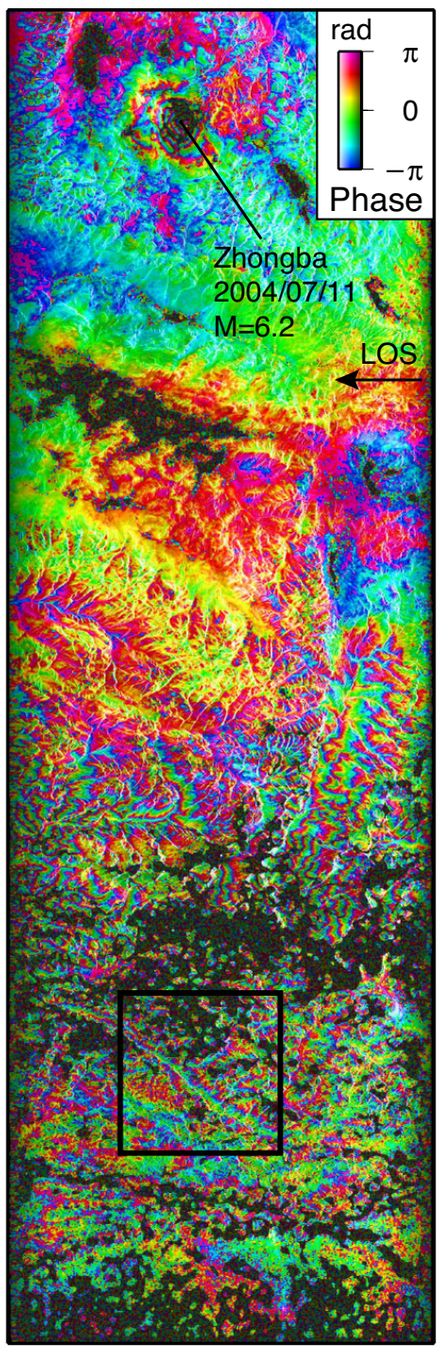
- Downlooking aliases fringes

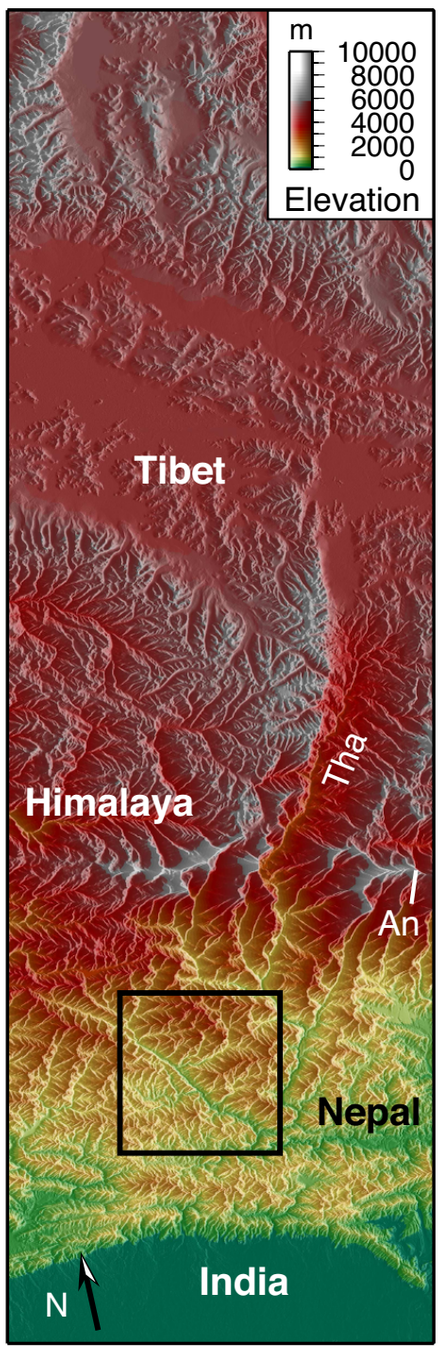
→ Unwrapping Errors

Enhancing the Unwrapping

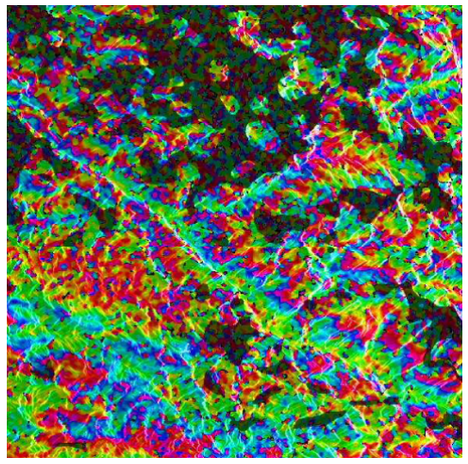
Unwrapping in high relief area is almost impossible
Atmospheric correction reduces the fringe rate



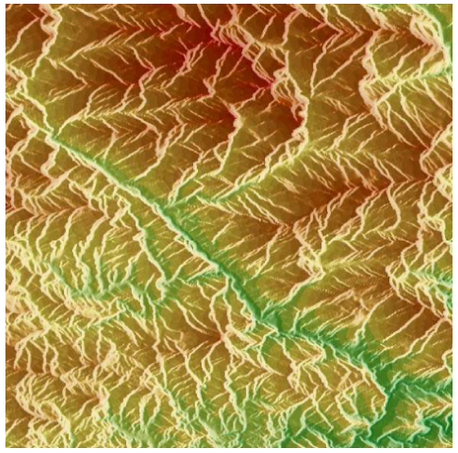




Data

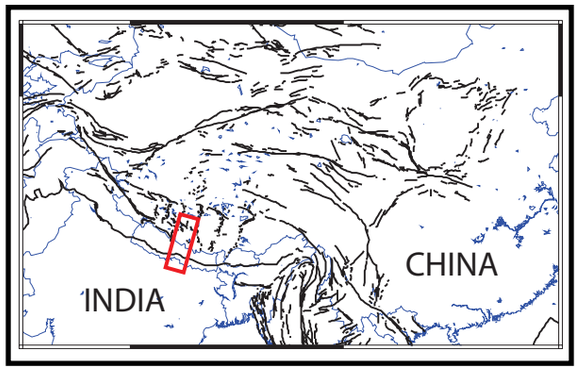


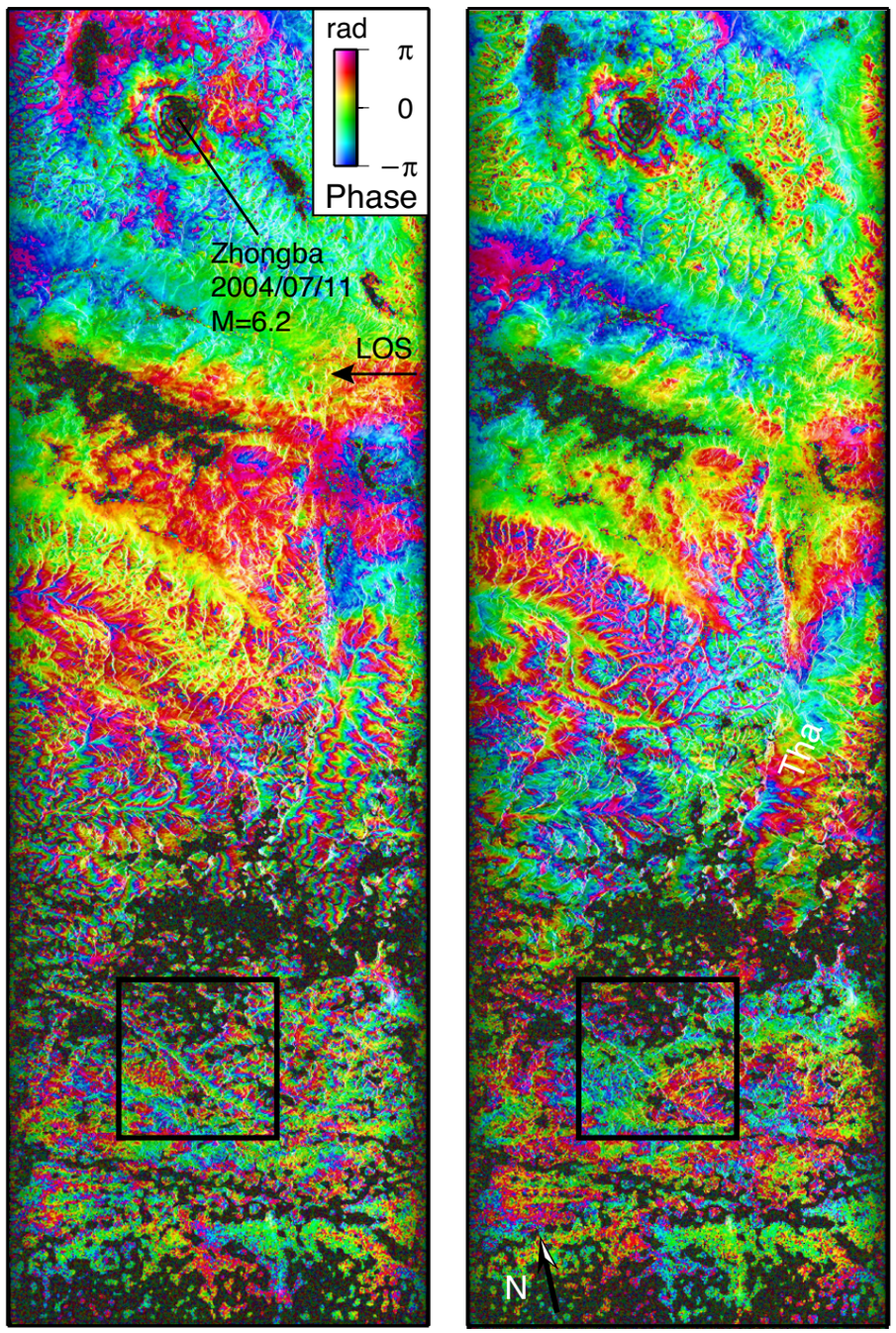
DEM



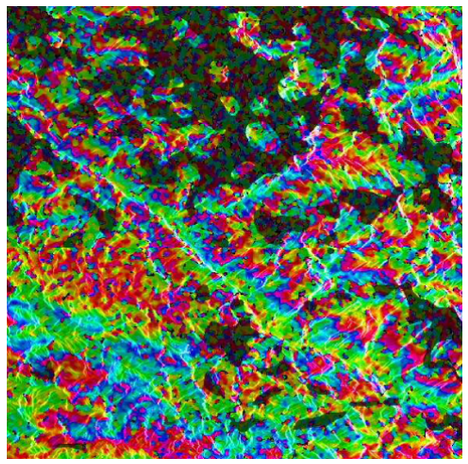
Enhancing the Unwrapping

Unwrapping in high relief area is almost impossible
Atmospheric correction reduces the fringe rate

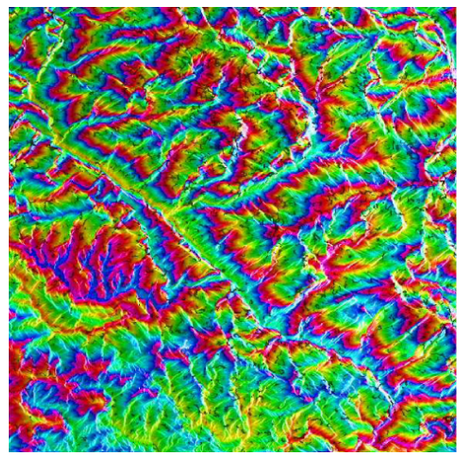




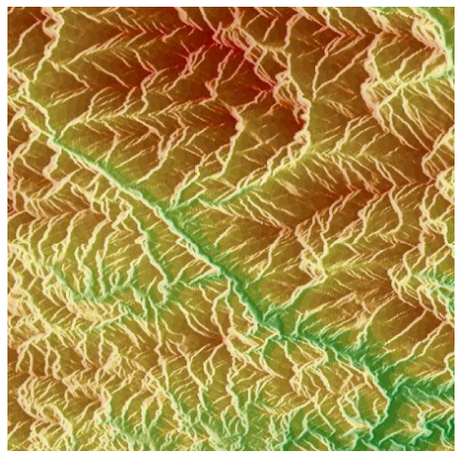
Data
Wrapped



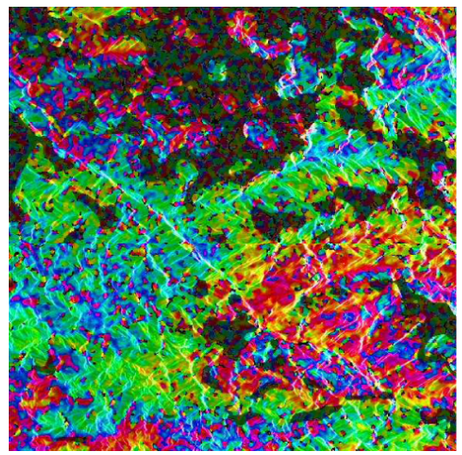
ERA-I Prediction
Wrapped



DEM



Residuals
Wrapped



Enhancing the Unwrapping

Unwrapping in high relief area is almost impossible
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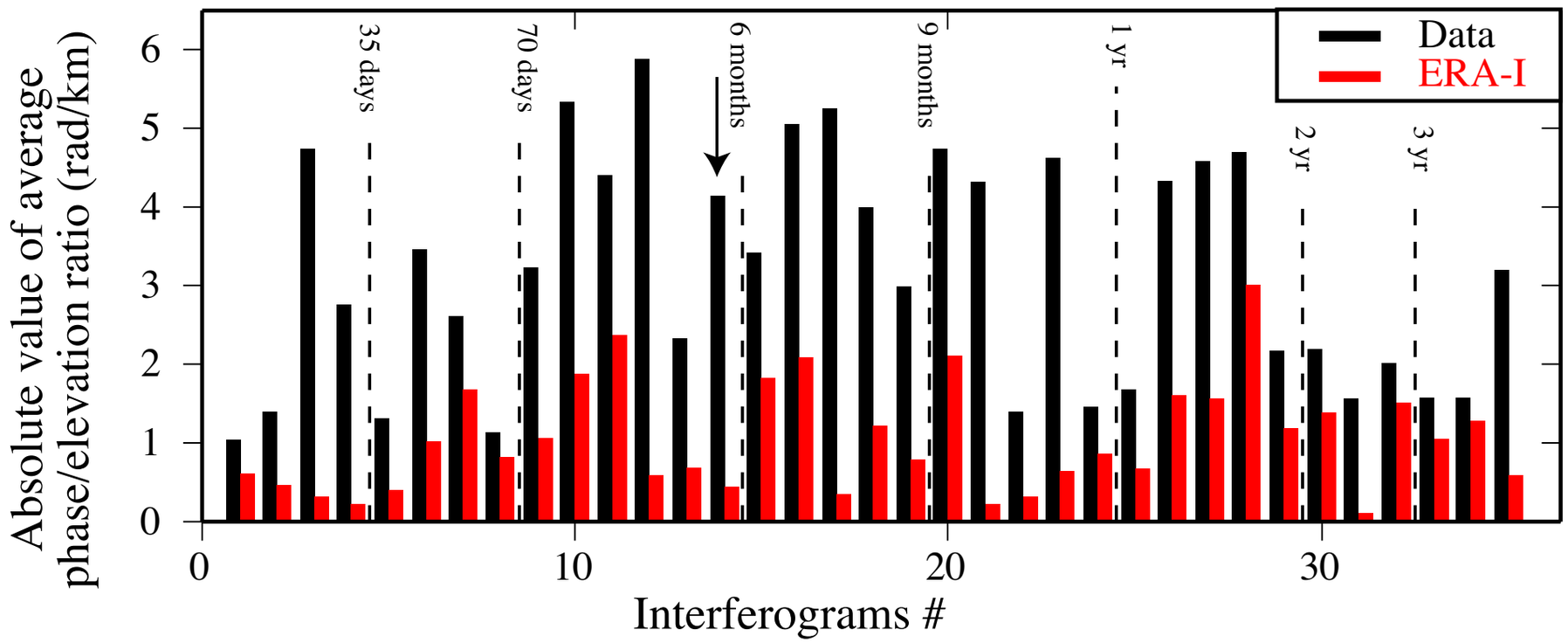


- Fringe rate reduction avoids fringe aliasing during downlooking
- Phase ambuigity is under control, so are unwrapping errors

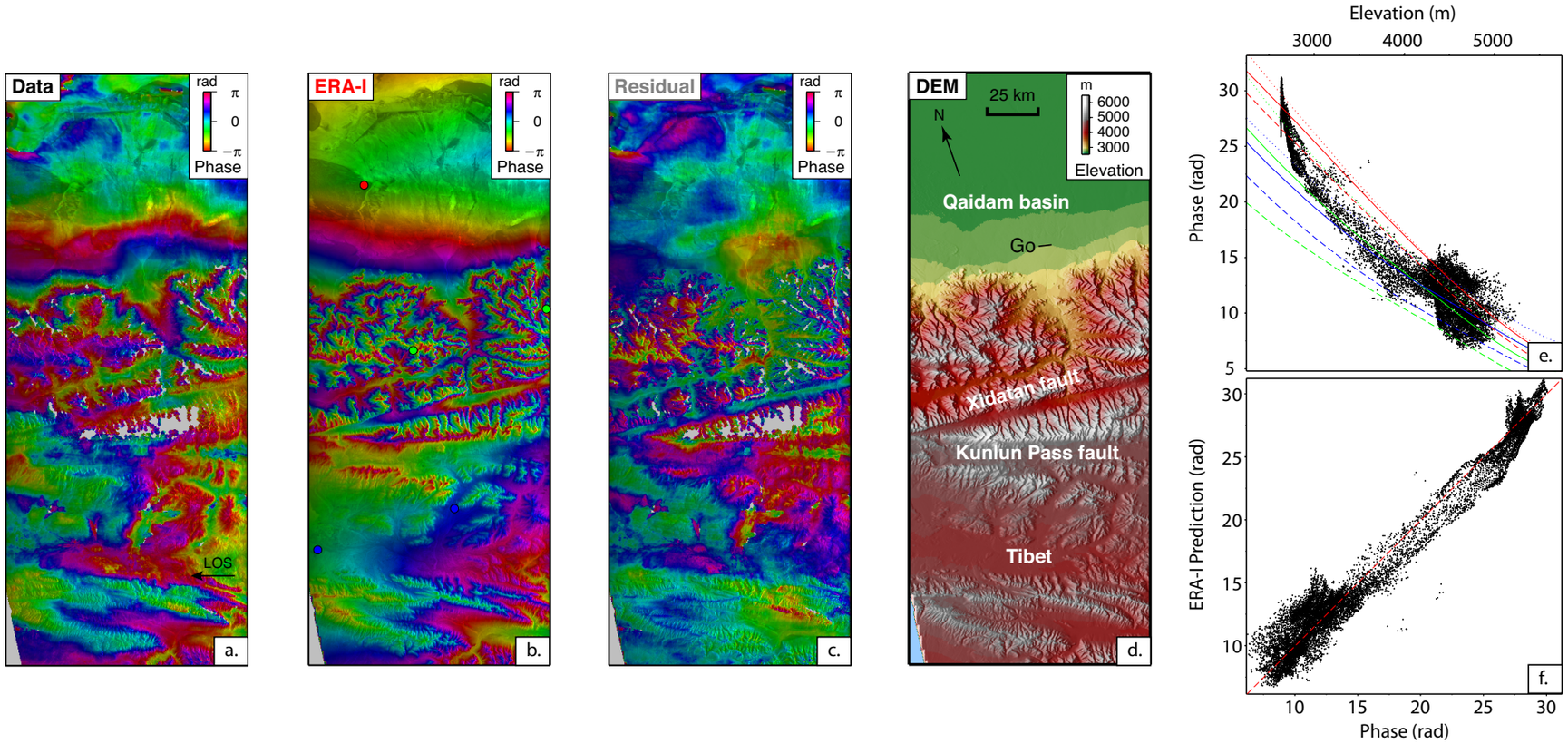
Conclusions

- We validate the use of GAM to produce stratified delay maps and correct interferograms

→ Unbiased corrections for unbiased time series analysis
Help the unwrapping process

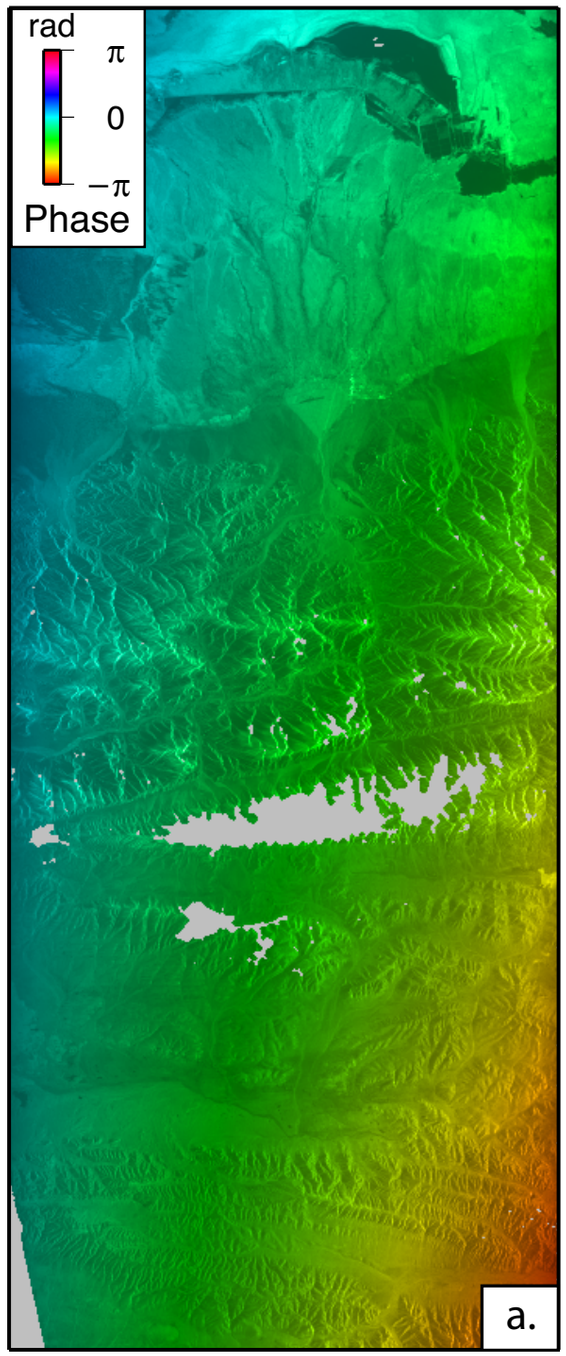
- This method is simple, its computational cost is low, it is global
We rely on GAM improvements for more precise corrections

→ It should be included in the future interferometric chains

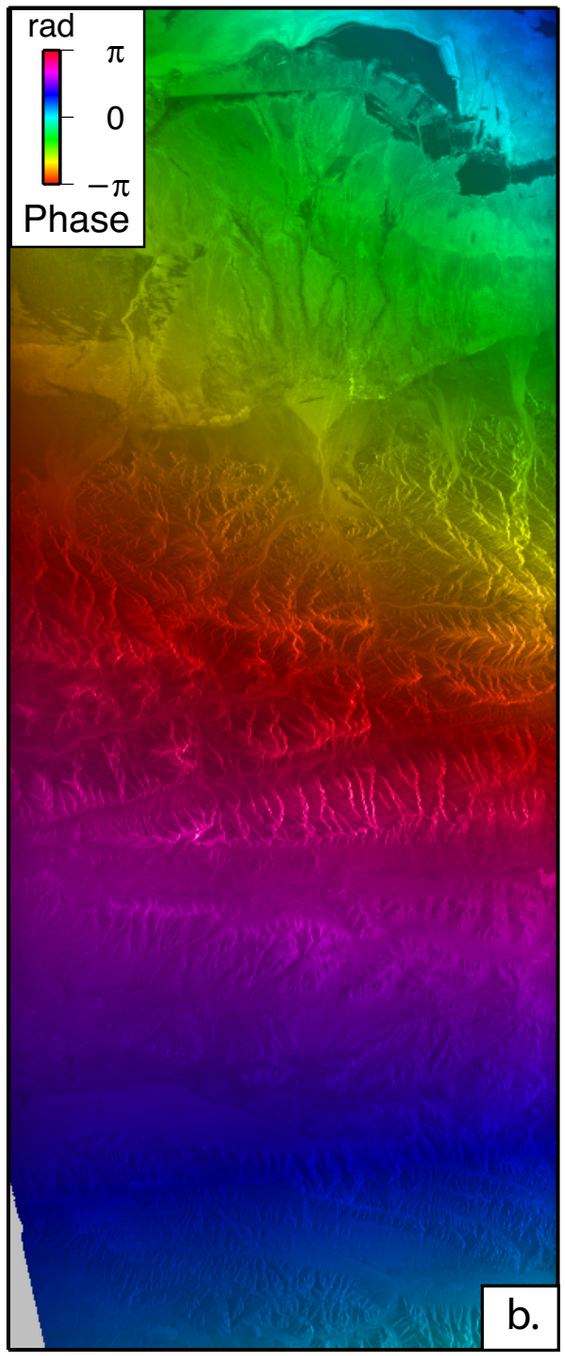


Orbit estimation

Empirical Estimation

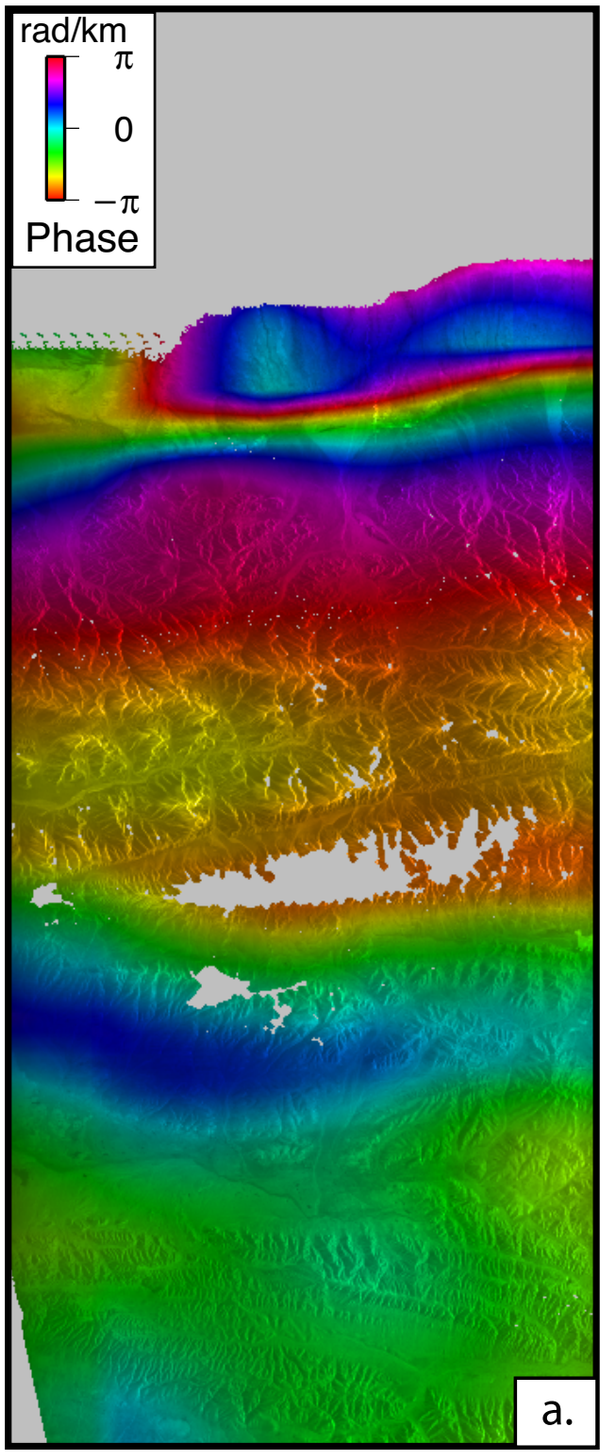


2D full grid ERA-I

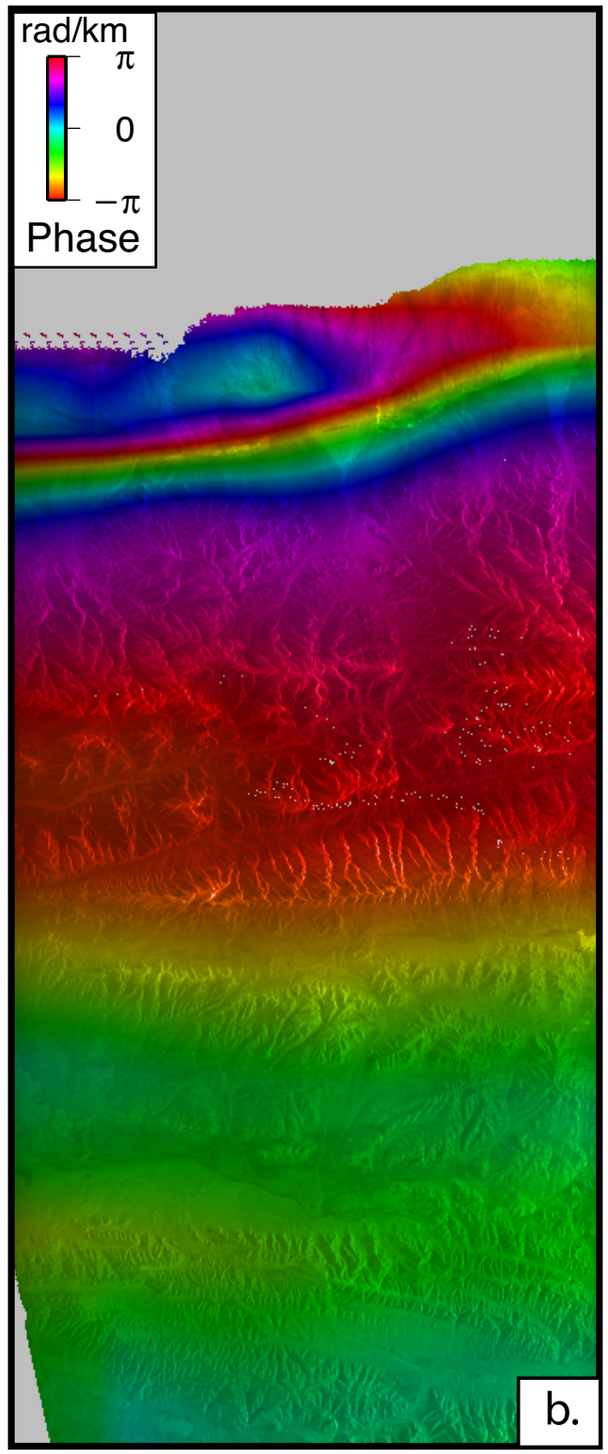


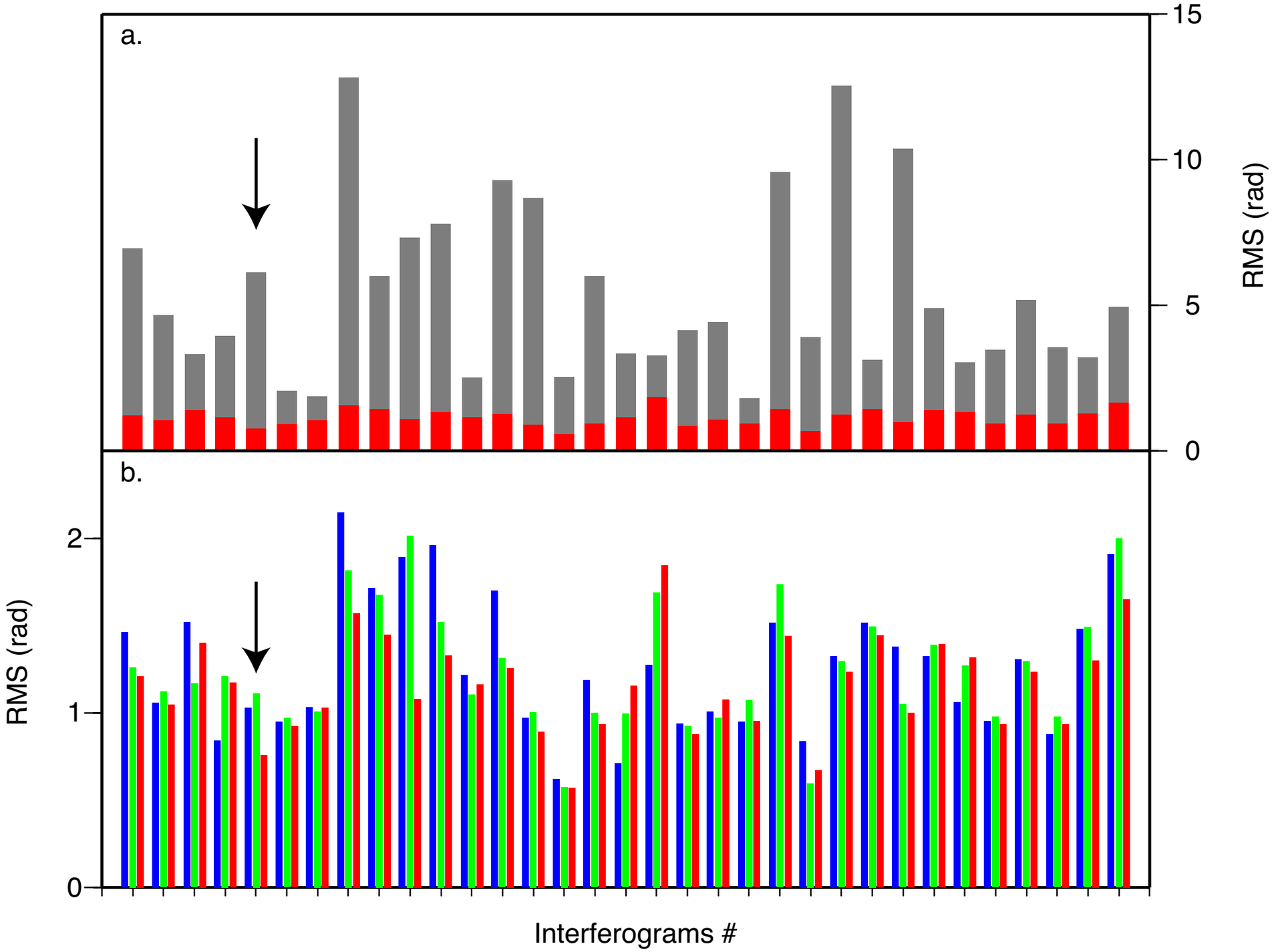
Local Phase/Topography Relationship

Unwrapped Data



2D full grid ERA-I




a.
15
10
5
0
RMS (rad)
b.
2
1
0
RMS (rad)
Interferograms #