Evidence for Slip Partitioning and Active Faulting along the Longmu Gozha Co Fault (LGCF) System from Continental-scale, Sentinel-1 InSAR Time-series analysis

<u>Marguerite MATHEY</u>, Raphaël GRANDIN, Cécile LASSERRE, Martine SIMOES,
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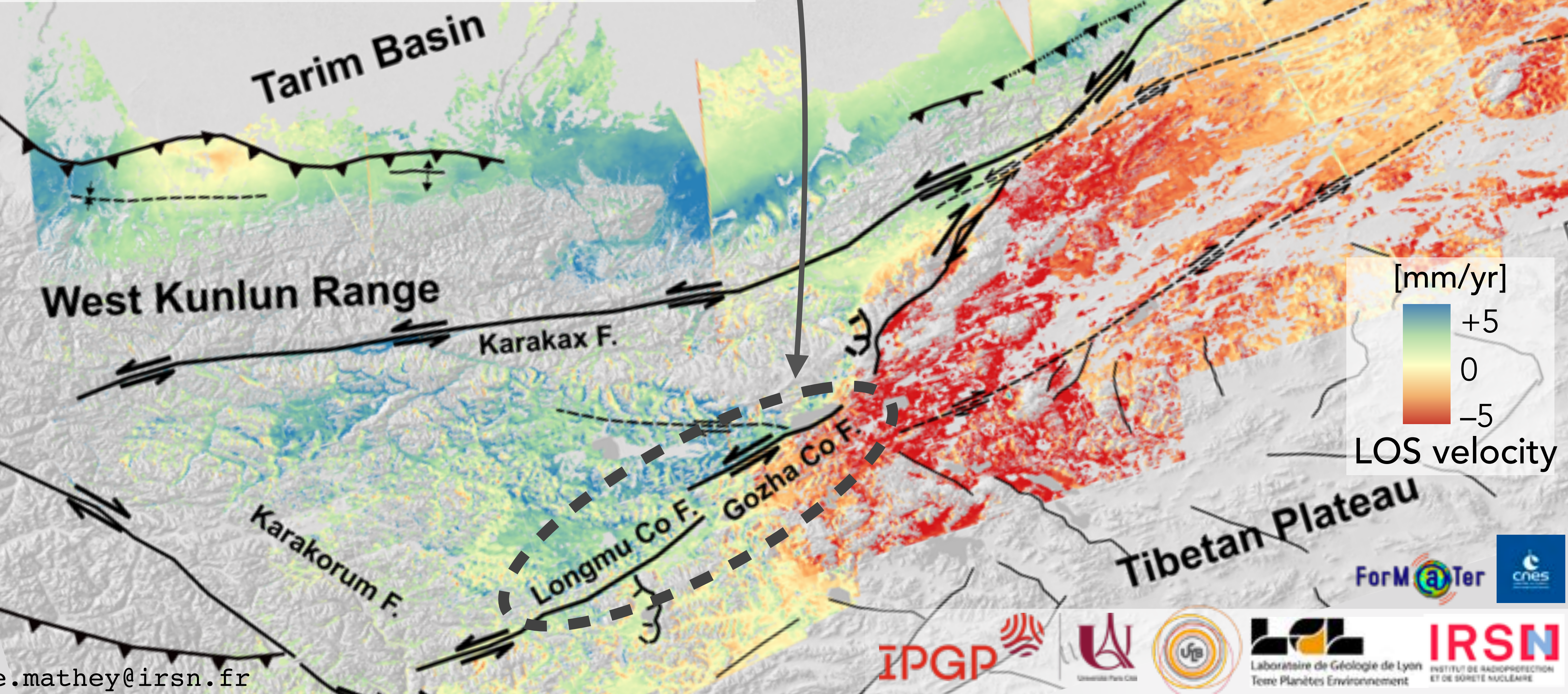

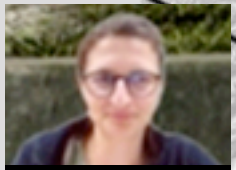

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Case study:
Western Kunlun-Northern Tibetan Plateau

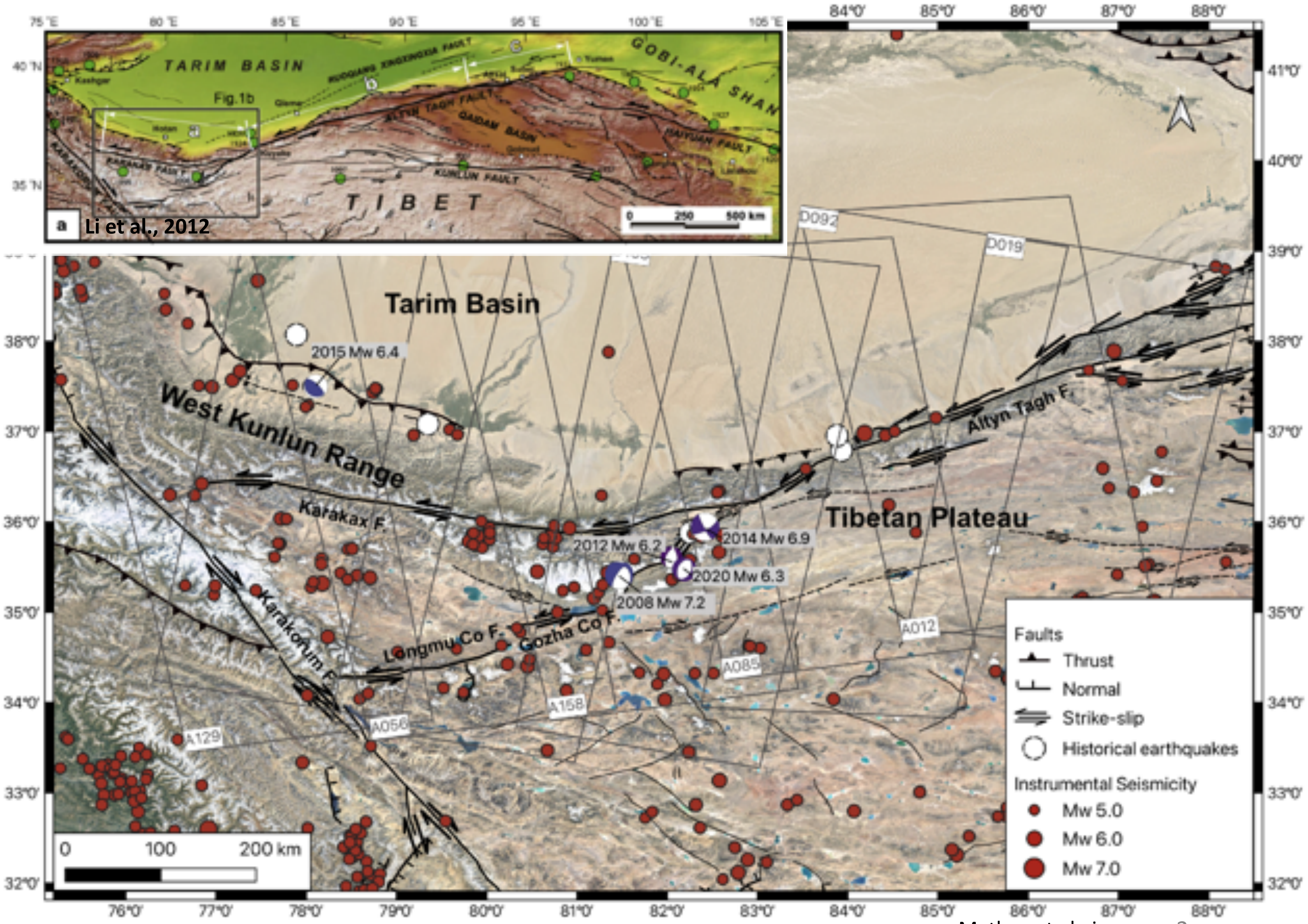
- Western Altyn Tagh Fault (ATF) not as well documented as Central ATF

- Complex kinematics with triple junction

- Few field studies (high elevations, remoteness)

- No success in previous geodetic attempts

Can we assess interseismic loading and present-day kinematics thanks to Sentinel-1 data and InSAR time-series processing ?



Mathey et al., in prep

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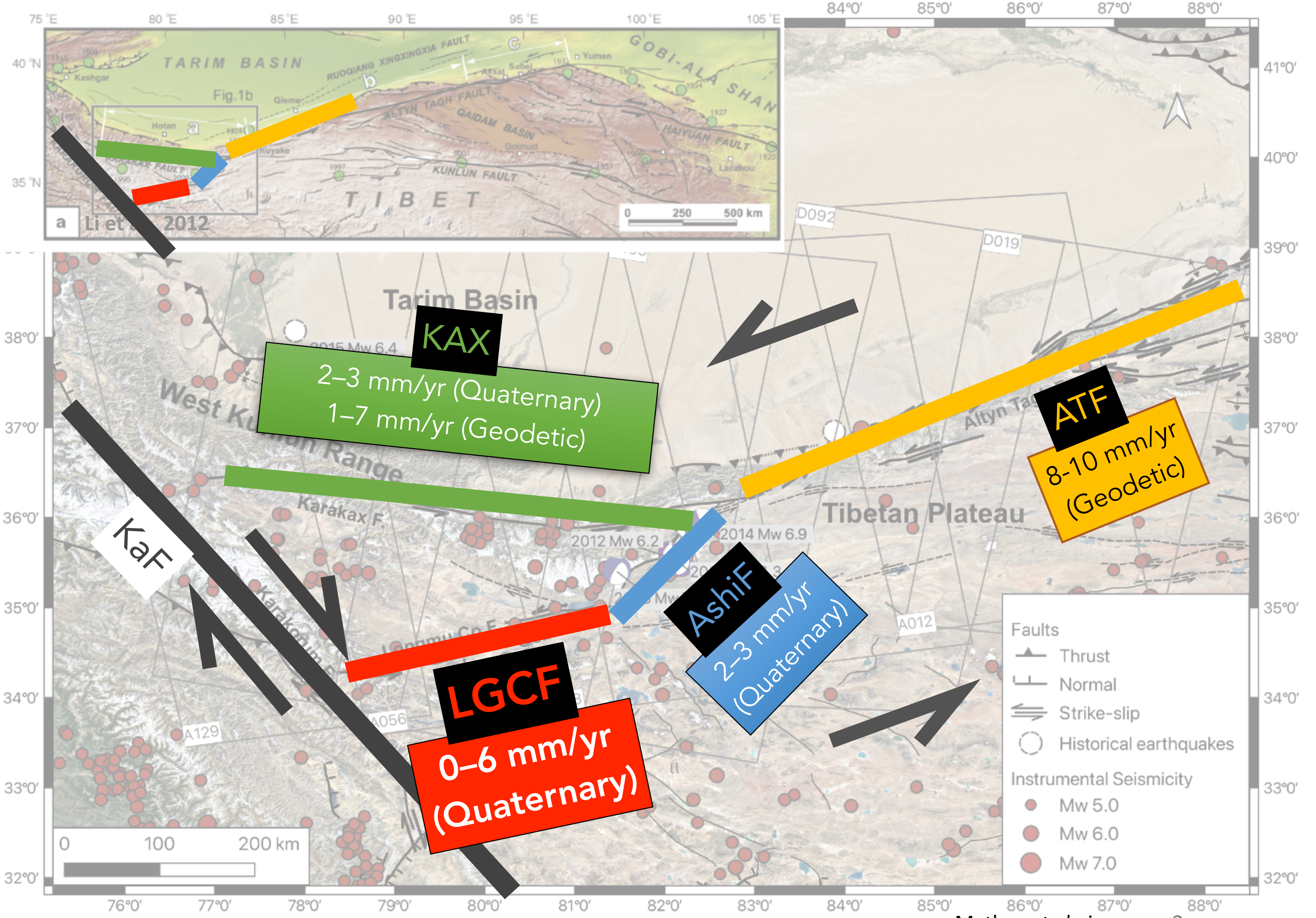


Mathey et al., in prep

Challenges

Wide area : 10 tracks of 250 km width each

Topographic gradients = low SNR

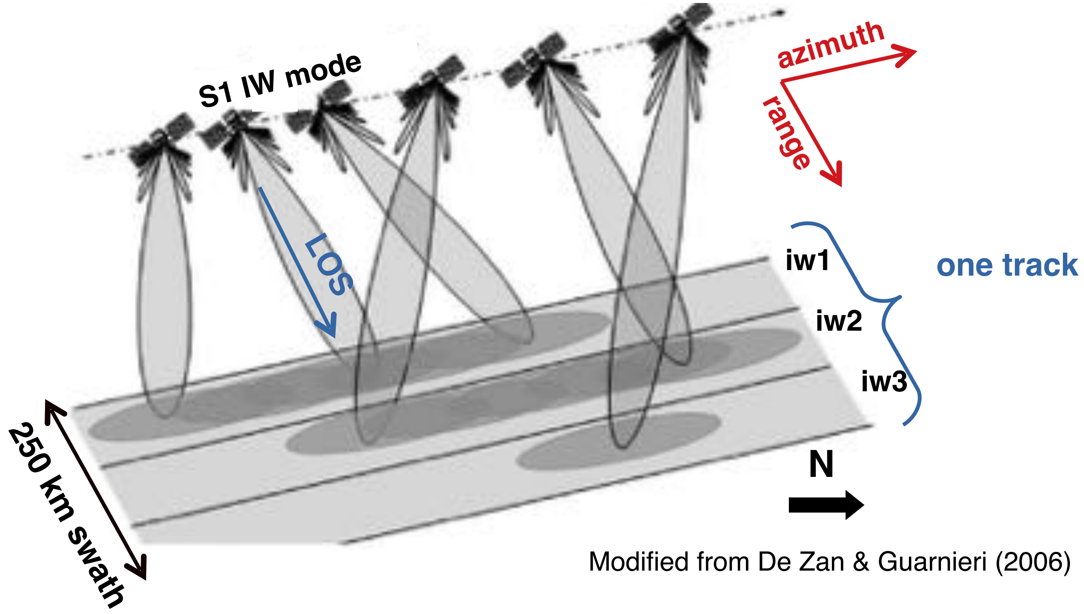
Snow, glaciers, vegetation, sand dunes = loss of coherence

Sentinel-1 Satellite

Launched in 2014

Unmatched acquisition frequency: 6–12 days

High sensitivity to vertical motion



Modified from De Zan & Guarnieri (2006)

FLATSIM service

ForM@Ter (2020): FLATSIM Data Products. CNES. (Dataset).
doi: [10.24400/253171/FLATSIM2020](https://doi.org/10.24400/253171/FLATSIM2020)
Thollard et al., 2021, MDPI
doi: [10.3390/rs13183734](https://doi.org/10.3390/rs13183734)

Automatic processing from L1-SLC to time-series, @CNES HPC facility

Small baseline subset approach (NSBAS, Doin et al., 2011; Grandin, 2015) for low deformation using time redundancy of acquisitions (interferograms)

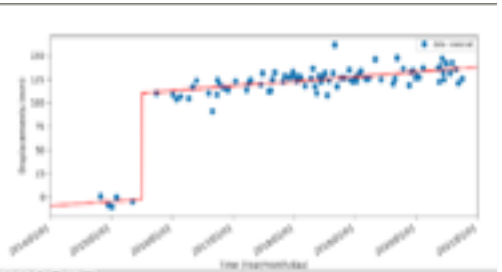
ERA-5 ECMWF atmospheric corrections (Jolivet et al., 2011)

Delivers displacement time-series in the Line of Sight of the satellite (LOS) and quality indicators

https://www.poleterresolide.fr/projets/en-cours/flatsim/

Post-processing workflow of FLATSIM products

FLATSIM **time-series** of cumulative displacement for each pixel



Masking each pixel of each track according to quality criteria

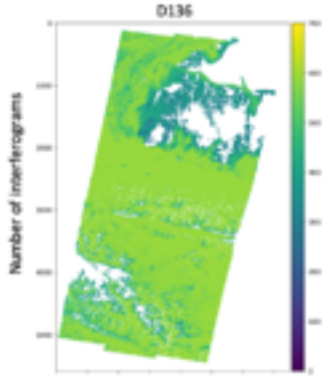
Reference all tracks to a common reference frame

Signal separation of LOS velocities between linear and seasonal components

Eastward-Upward inversion using ascending+descending geometries

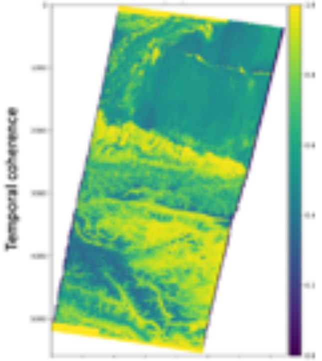
Map of **Tectonically-representative velocities**

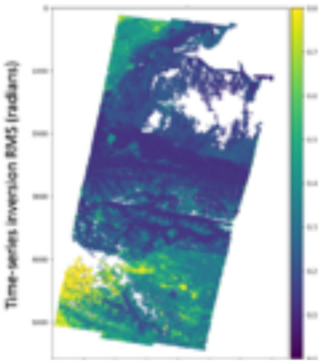
Stacked **profiles** of **fault-parrallel velocities**



Number of interferograms

Temporal coherence



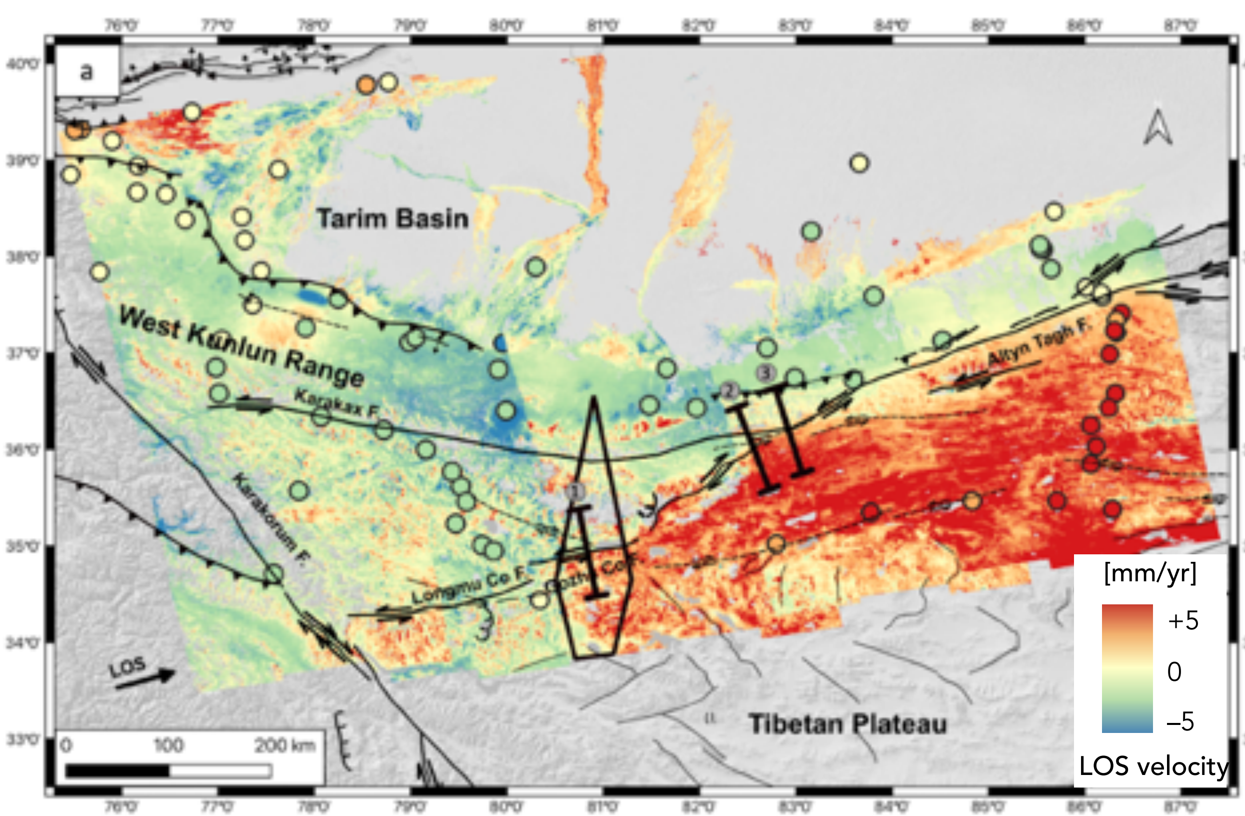


Time-series inversion RMS

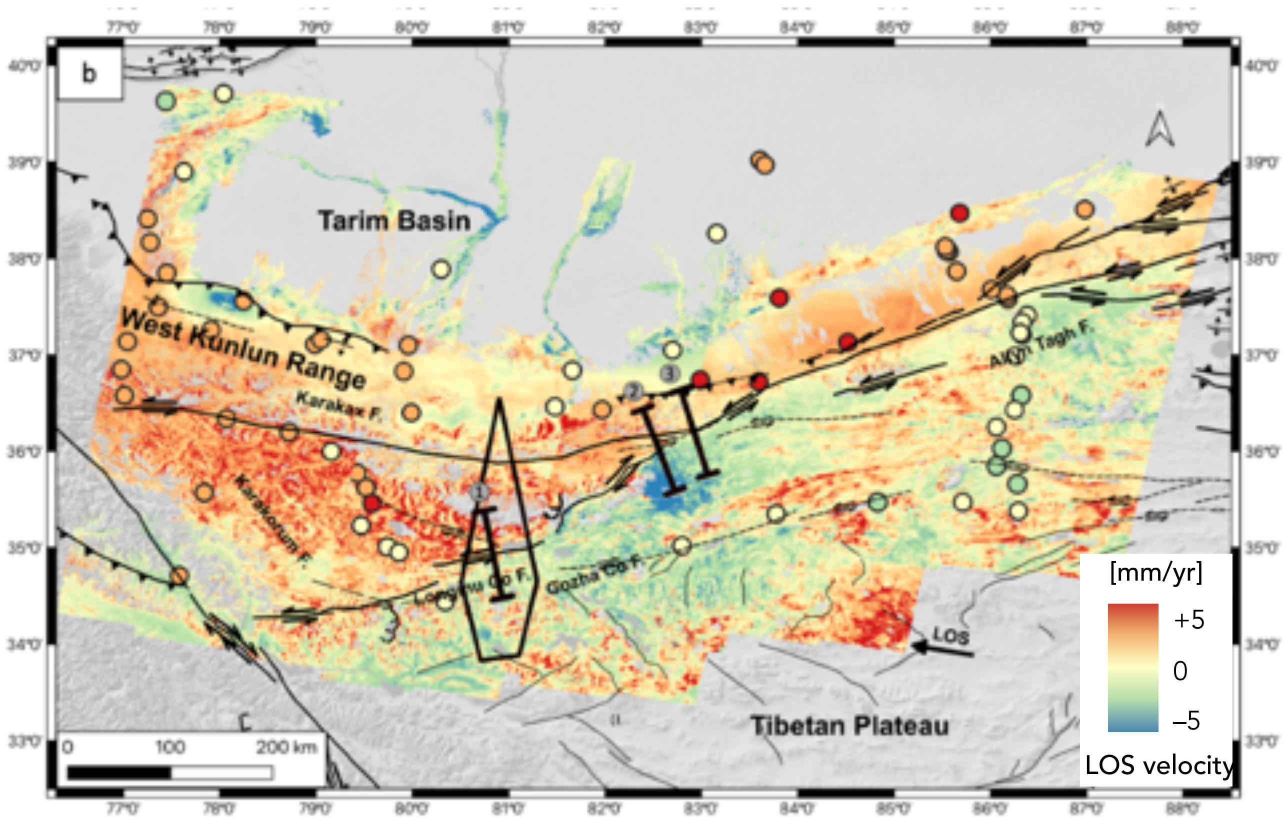
Referencing of LOS velocities

- → Common referencing to GPS wrt Eurasia (Wang et al. 2020)
- → Bilinear ramps in range and azimuth
- → 1st order signal along the Altyn Tagh Fault (ATF)
- → A lot of short-wavelength signals (permafrost? gravity-driven motion? hydrological processes?)

Ascending (mosaic of 5 tracks)



Descending (mosaic of 5 tracks)

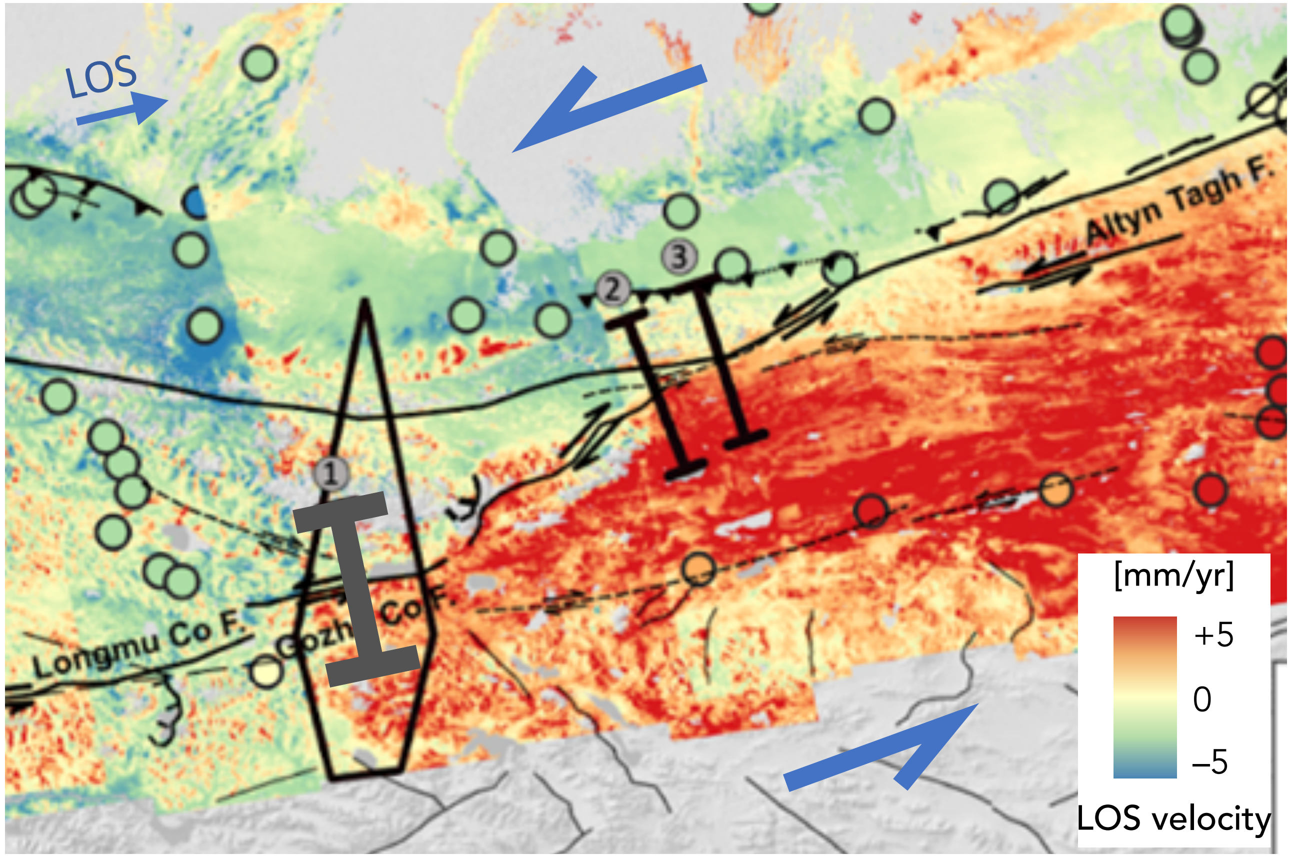


Creep on the Gozha Co Fault (GCF)

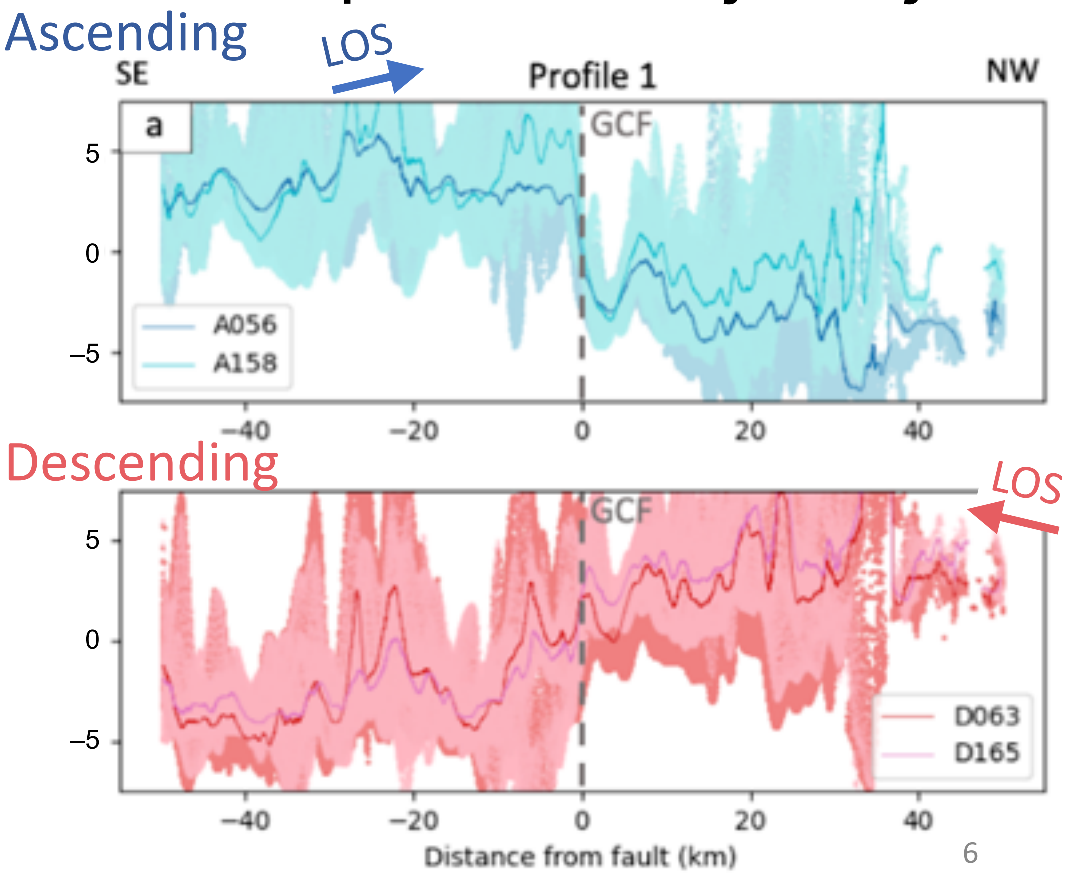
→ Left-lateral strike-slip fault

→ Creep clearly visible in Ascending geometry, less so in Descending geometry

→ Fit a simple step function and remove it to analyse non-tectonic motions

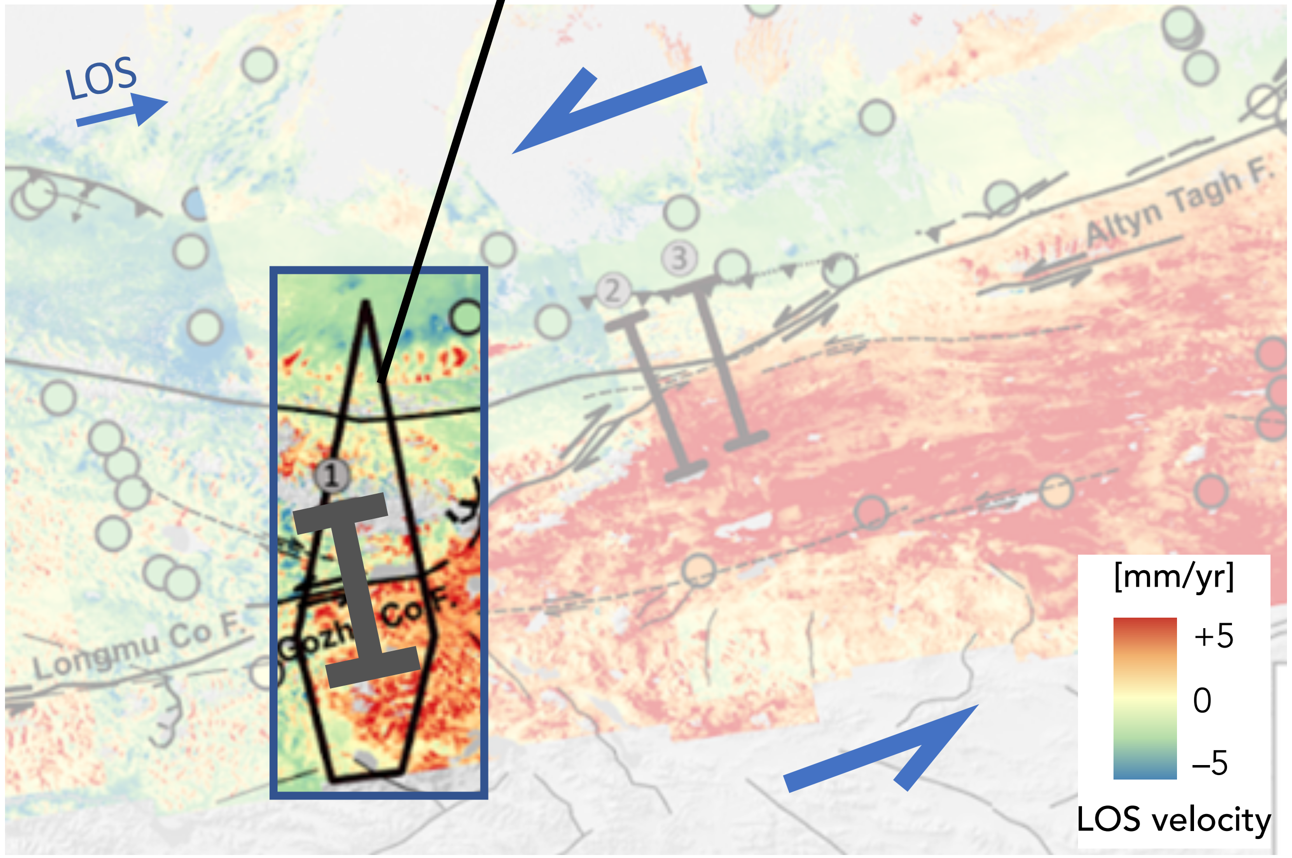


Fault-parallel velocity [mm/yr]



Creep on the Gozha Co Fault (GCF)

4 tracks overlap



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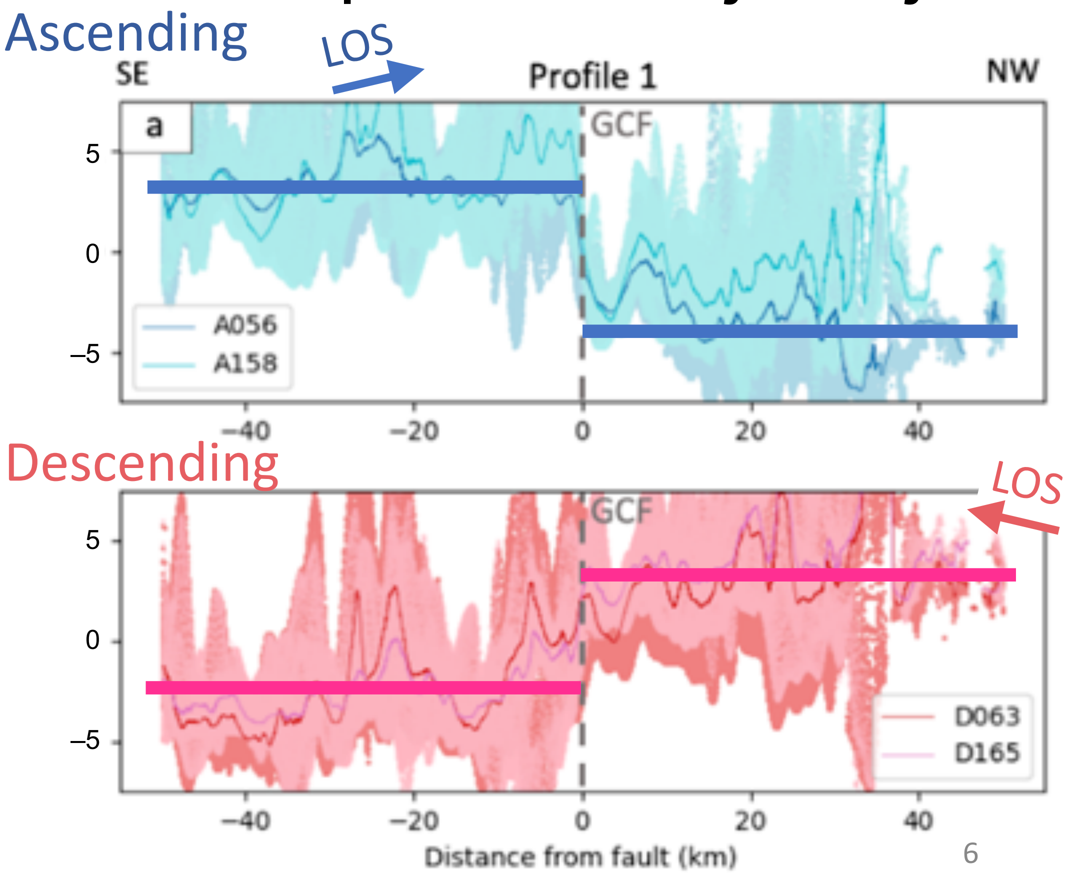
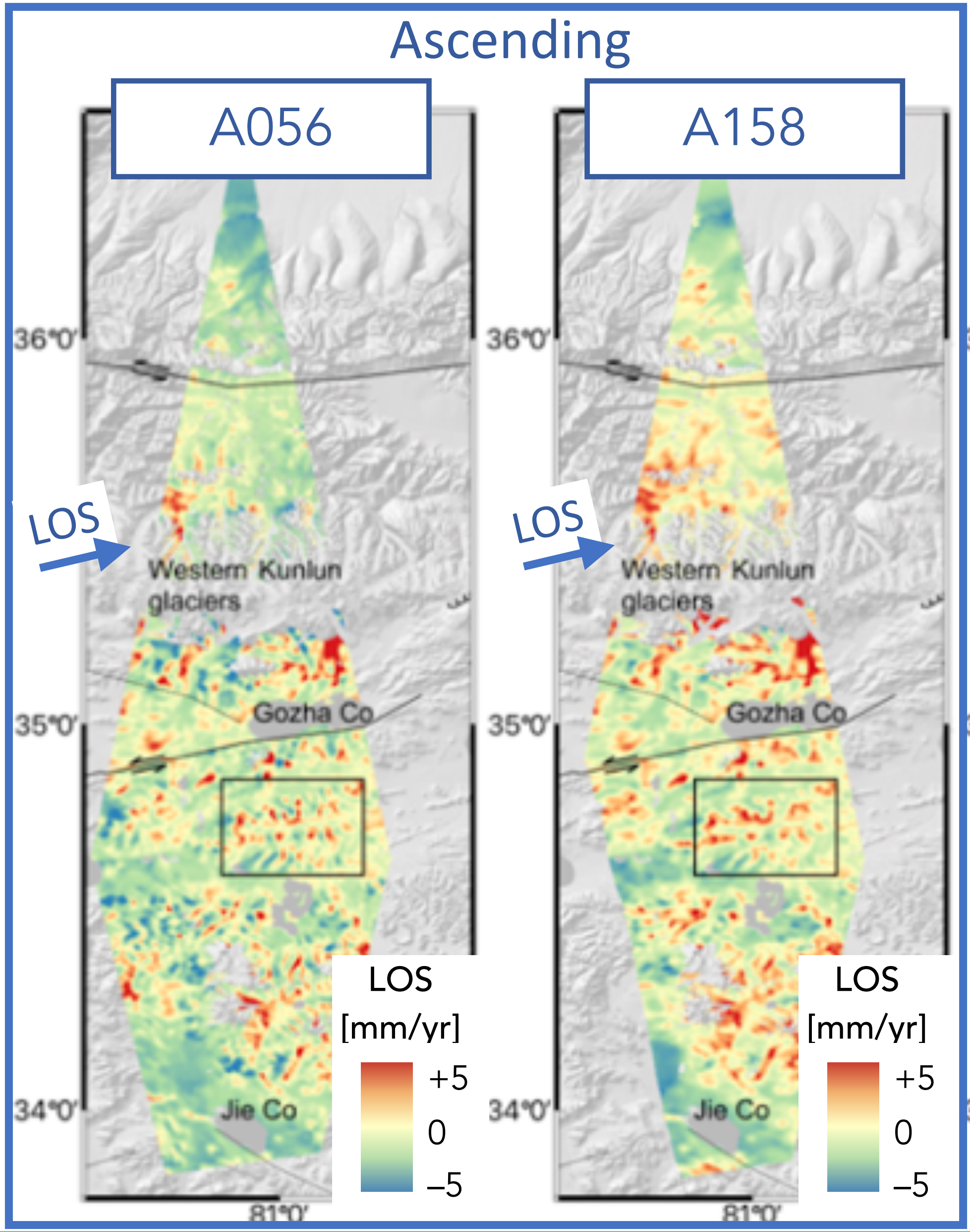
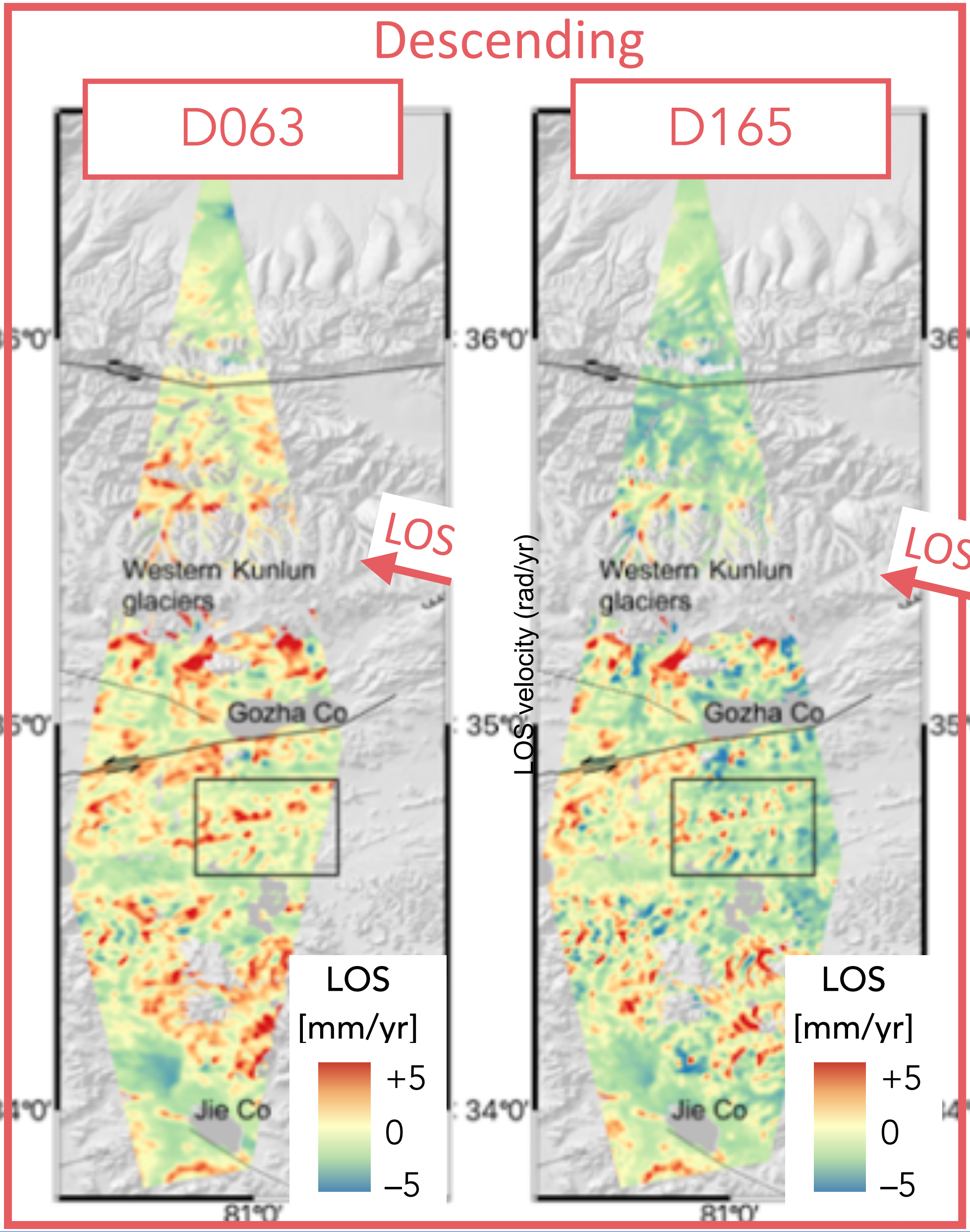


Linear/Seasonal signal separation and Eastward/Upward inversion

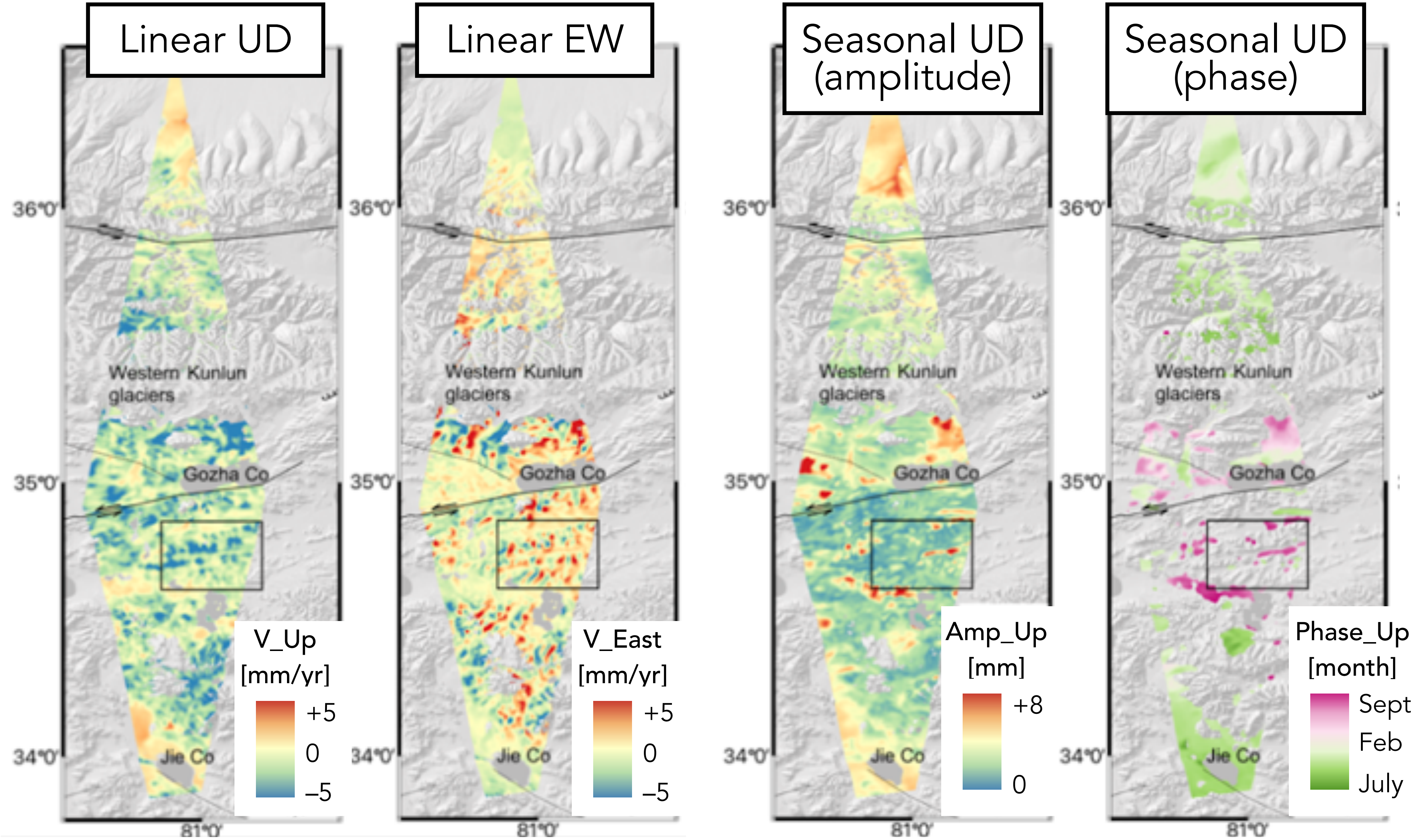
Tectonic signal (step function) removed

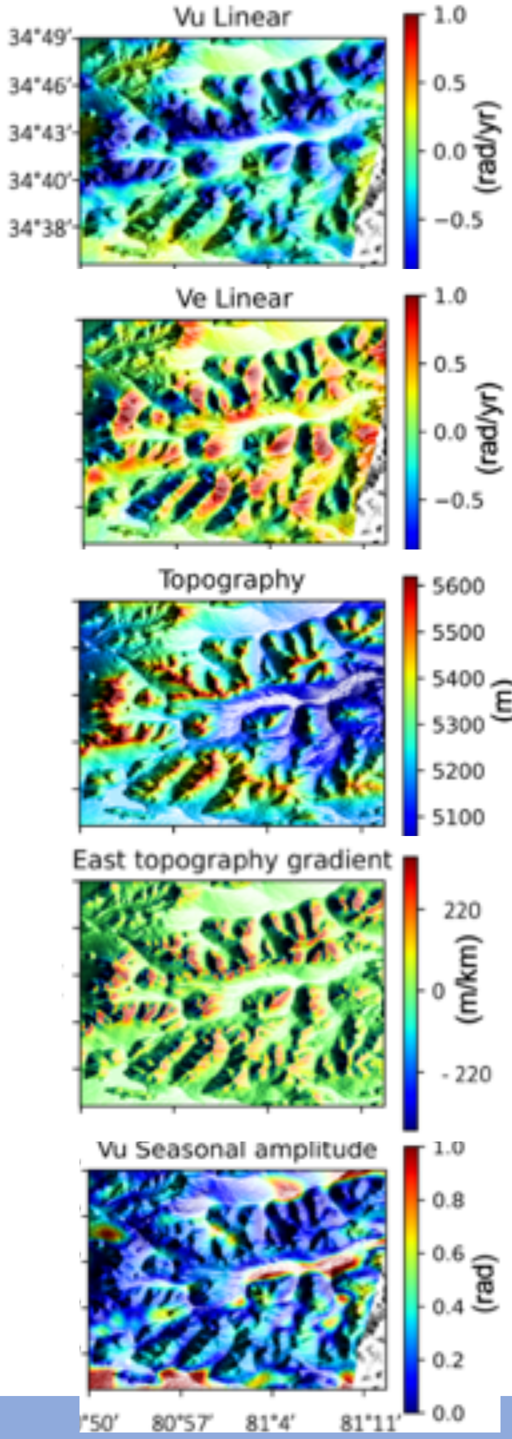
4 tracks overlap





Linear/Seasonal signal separation and Eastward/Upward inversion





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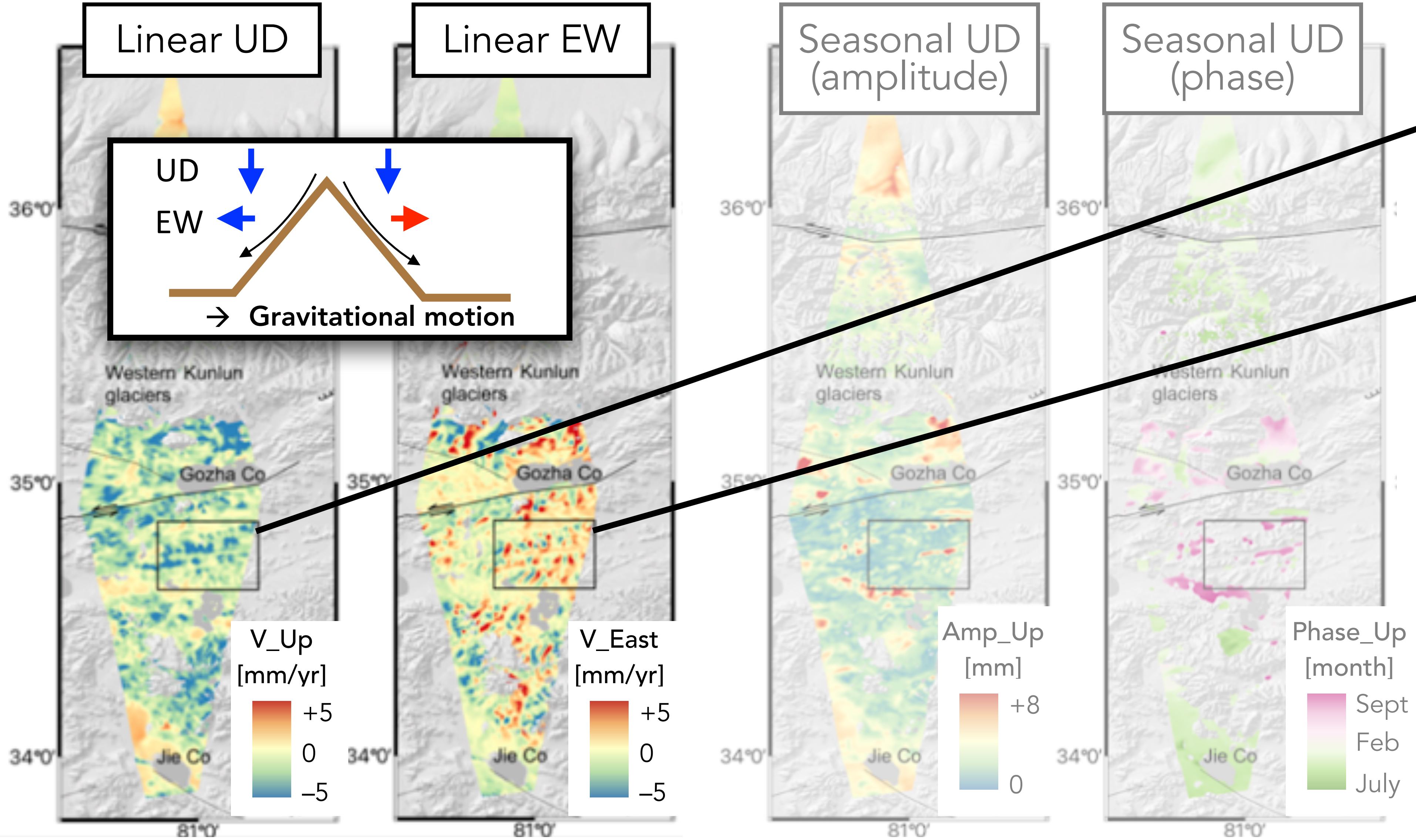
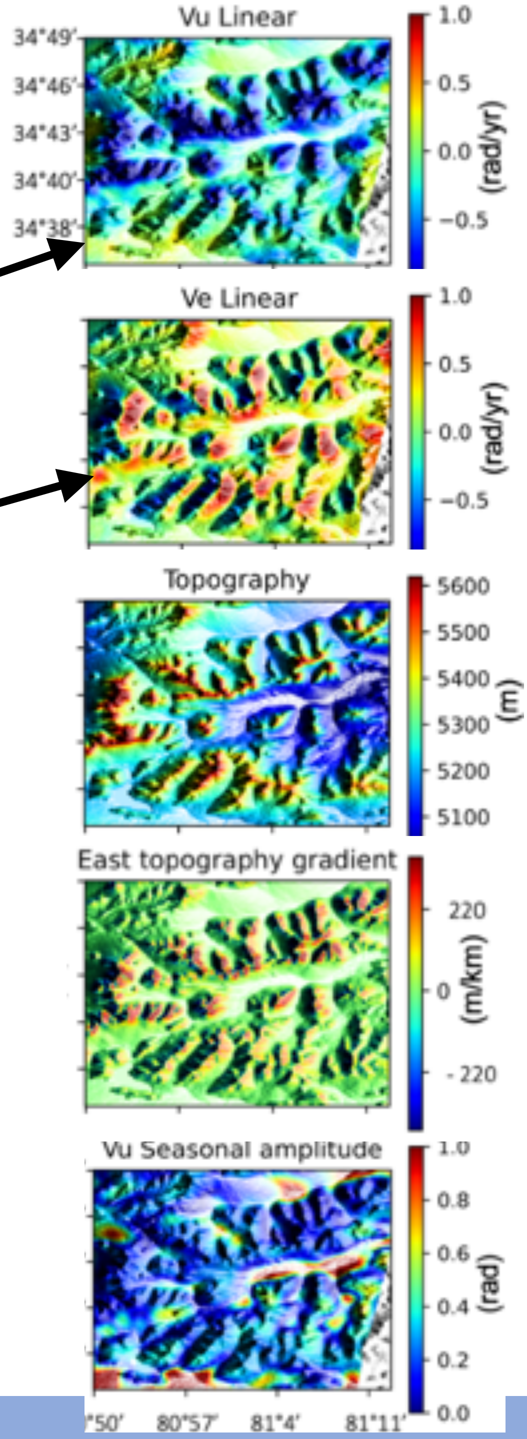
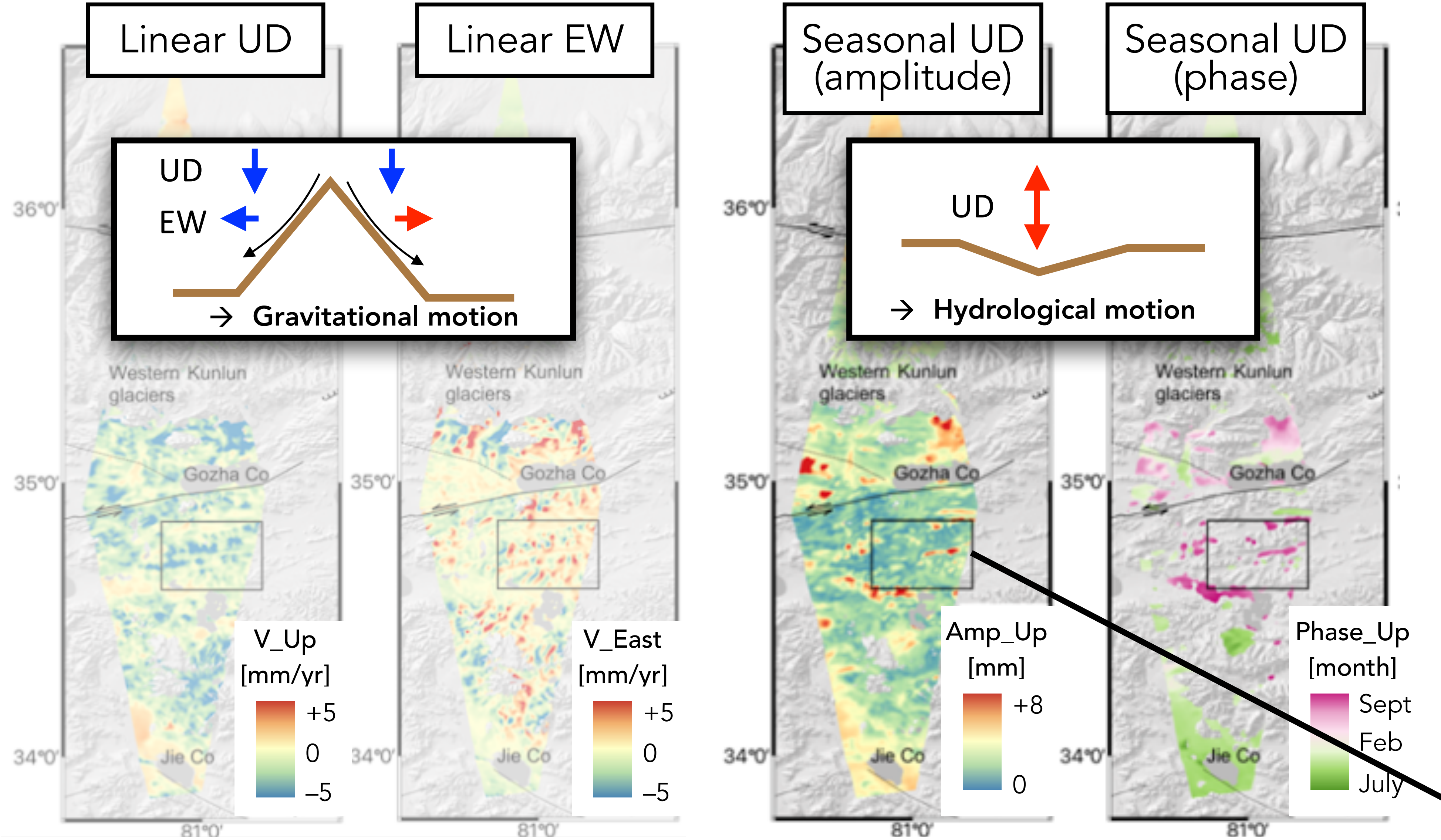


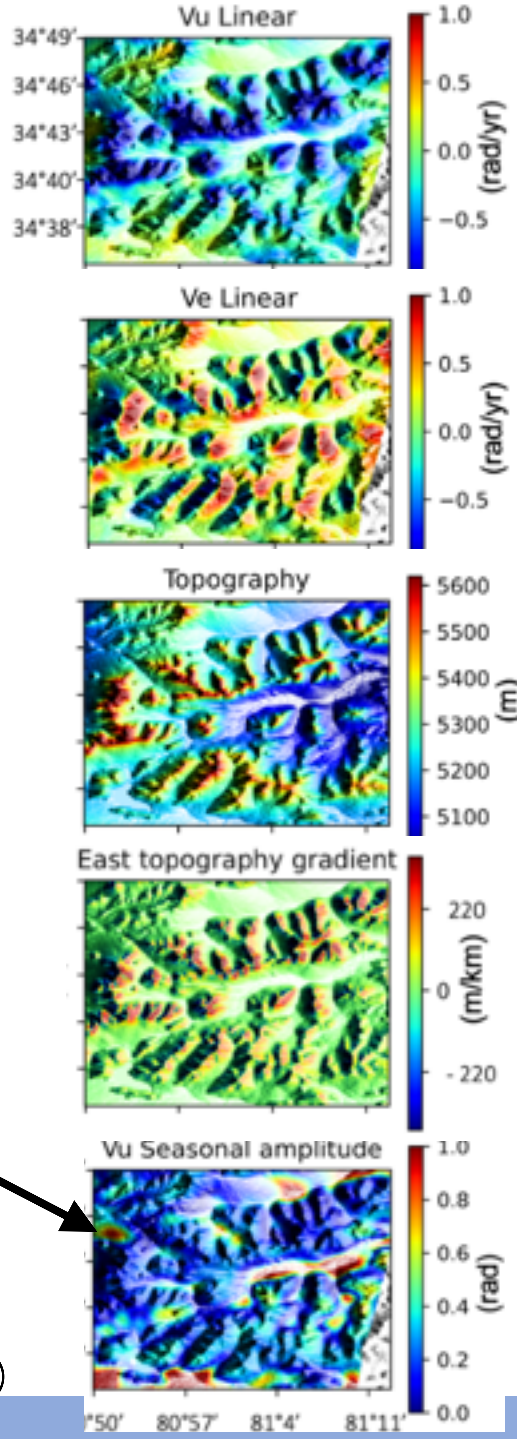


- Correlation between Vu and summits
- Correlation between Ve and slopes

→ **Gravitational motion**

Linear/Seasonal signal separation and Eastward/Upward inversion





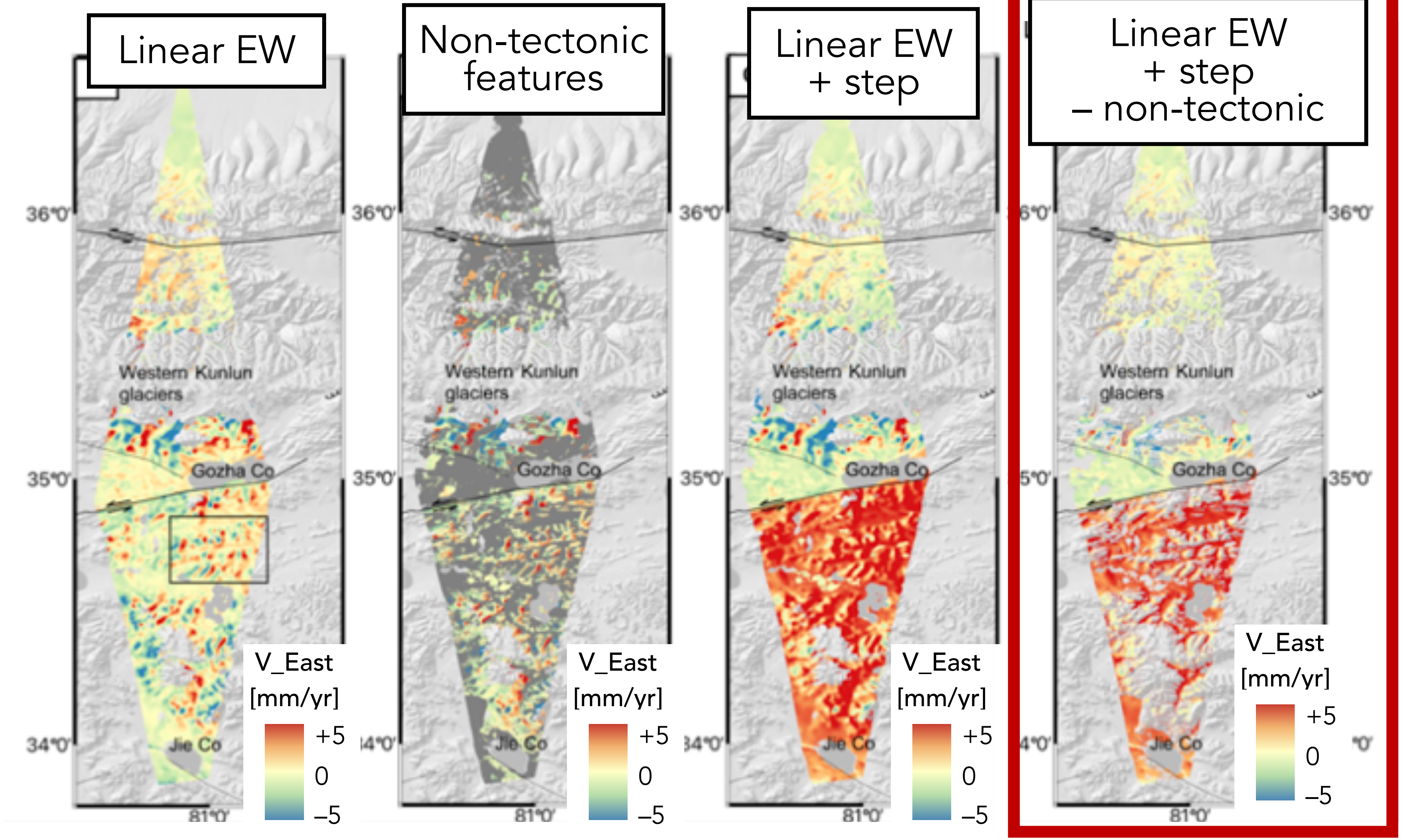
- Correlation between Vu and summits
- Correlation between Ve and slopes

→ **Gravitational motion**

- Correlation between amplitude of seasonal motion and geology
- Timing consistent with freeze-thaw cycles

→ **Hydrological motion** (permafrost or seasonally-frozen ground)

Signal separation : tectonic VS non-tectonic features

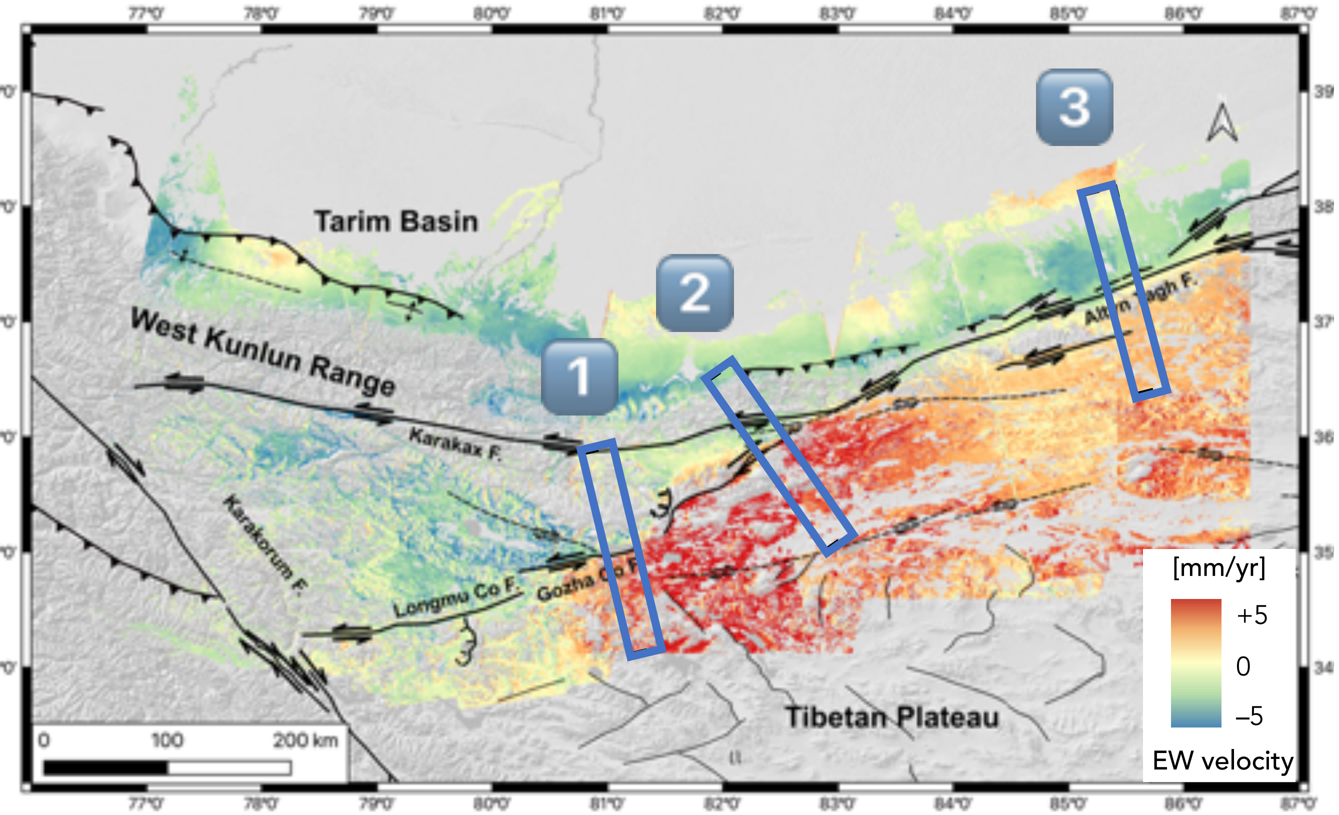


Slope > 30° and
Slope azimuth ∈ [N30W;N30E]

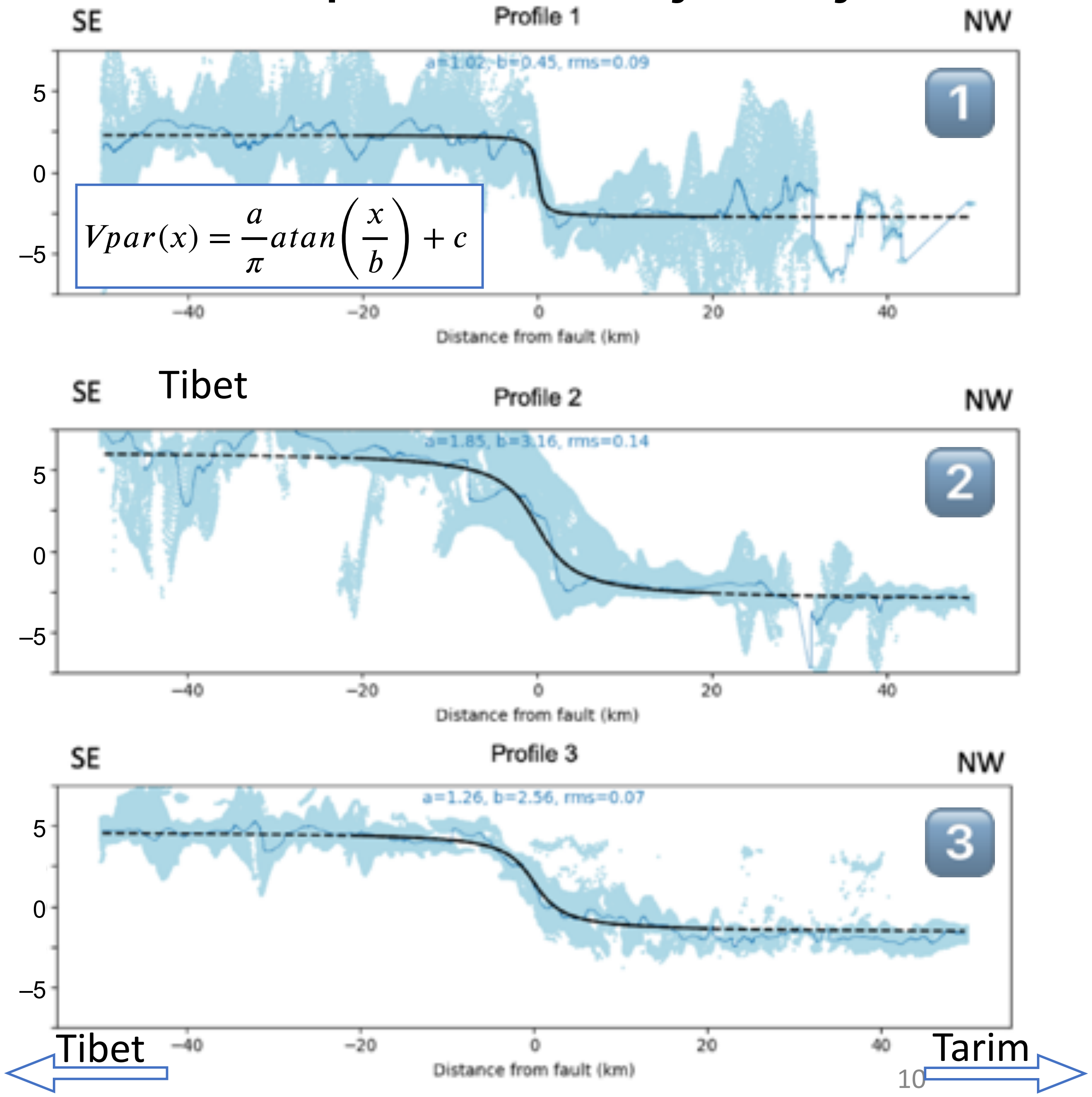
Slope < 30° or
Slope azimuth ∉ [N30W;N30E]

= **Tectonically representative velocity map**

Tectonically representative velocities



Fault-parallel velocity [mm/yr]



$$Vpar(x) = \frac{a}{\pi} atan\left(\frac{x}{b}\right) + c$$

- **First imaging of LGCF using InSAR :**
  - slip-rate ~5 mm/yr, consistent with morphotectonic observations
  - shallow locking depth
  - Gozha segment mostly creeping
- Transition from localized deformation near the ATF-LGCF junction, and more diffuse deformation near LGCF-Karakorum
- LGCF may be the most active western branch of the ATF (ongoing short-cutting ?)

Key conclusions

- We are able to **separate tectonic and non-tectonic signals** of the order of **a few mm/yr over 5** years with **Sentinel-1** satellite

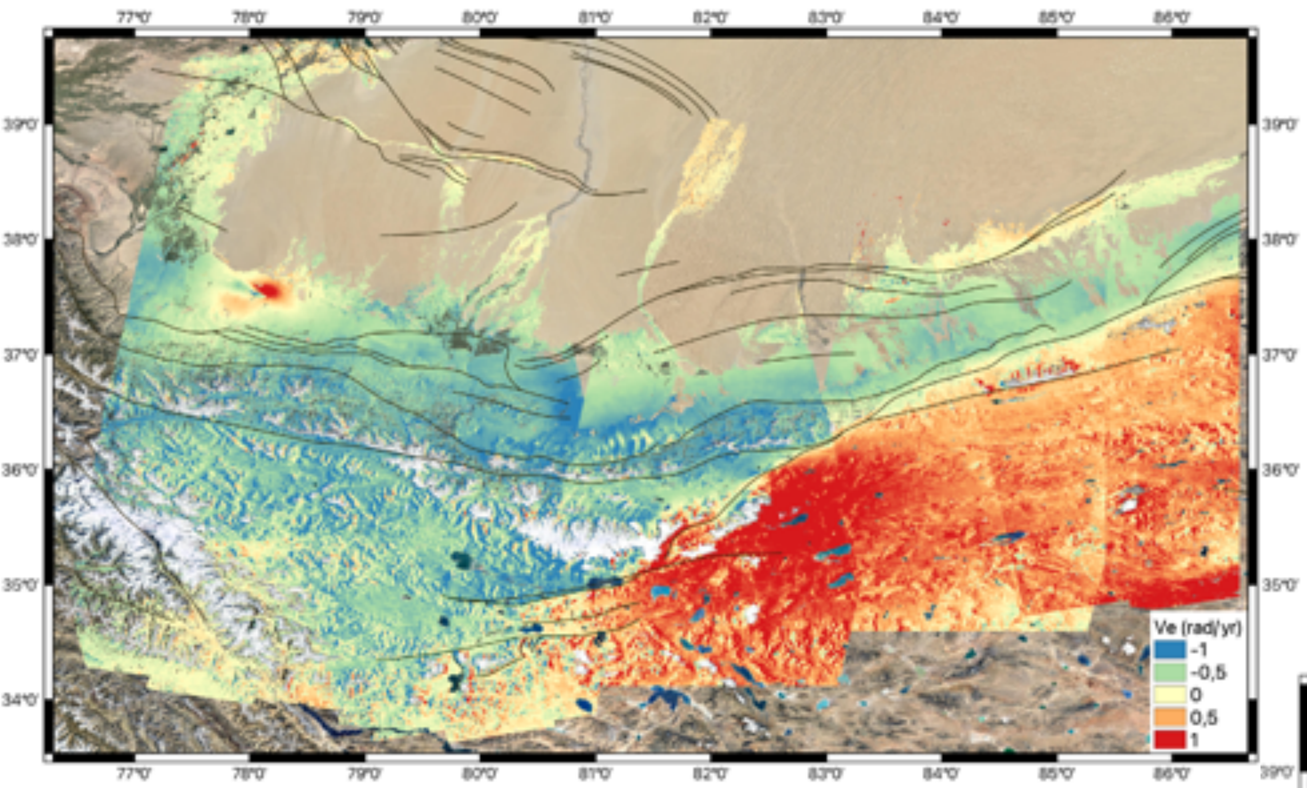
- Enhancement of automatic processing services, such as **FLATSIM**, will allow for improving the **detection threshold of numerous active faults** in the upcoming years :
  - less processing required by the (end-) user
  - broader areas

- Quality-check and **post-processing** still required

Upward/Eastward components

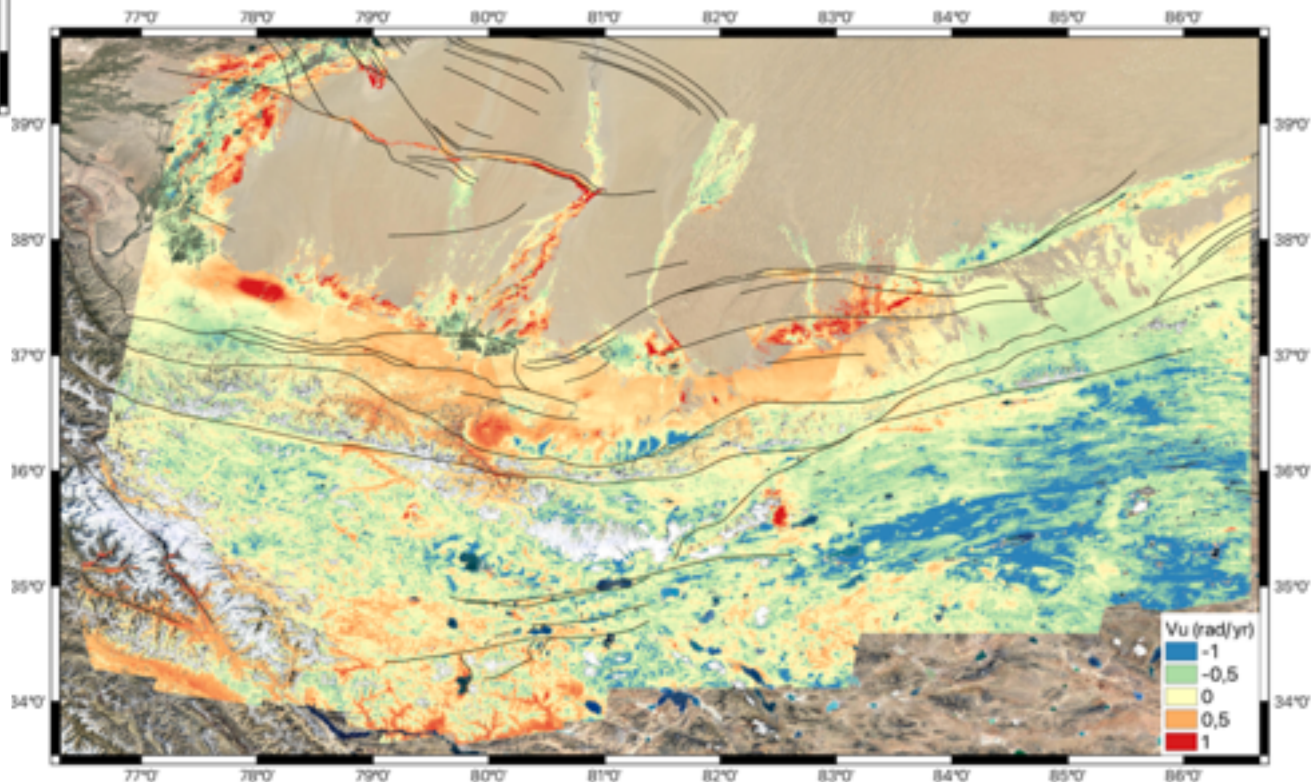
$$V_{los} = \left[sin\theta cos\alpha - sin\theta sin\alpha - cos\theta \right] \begin{bmatrix} V_e \\ V_n \\ V_u \end{bmatrix}$$

Assume null northward motions

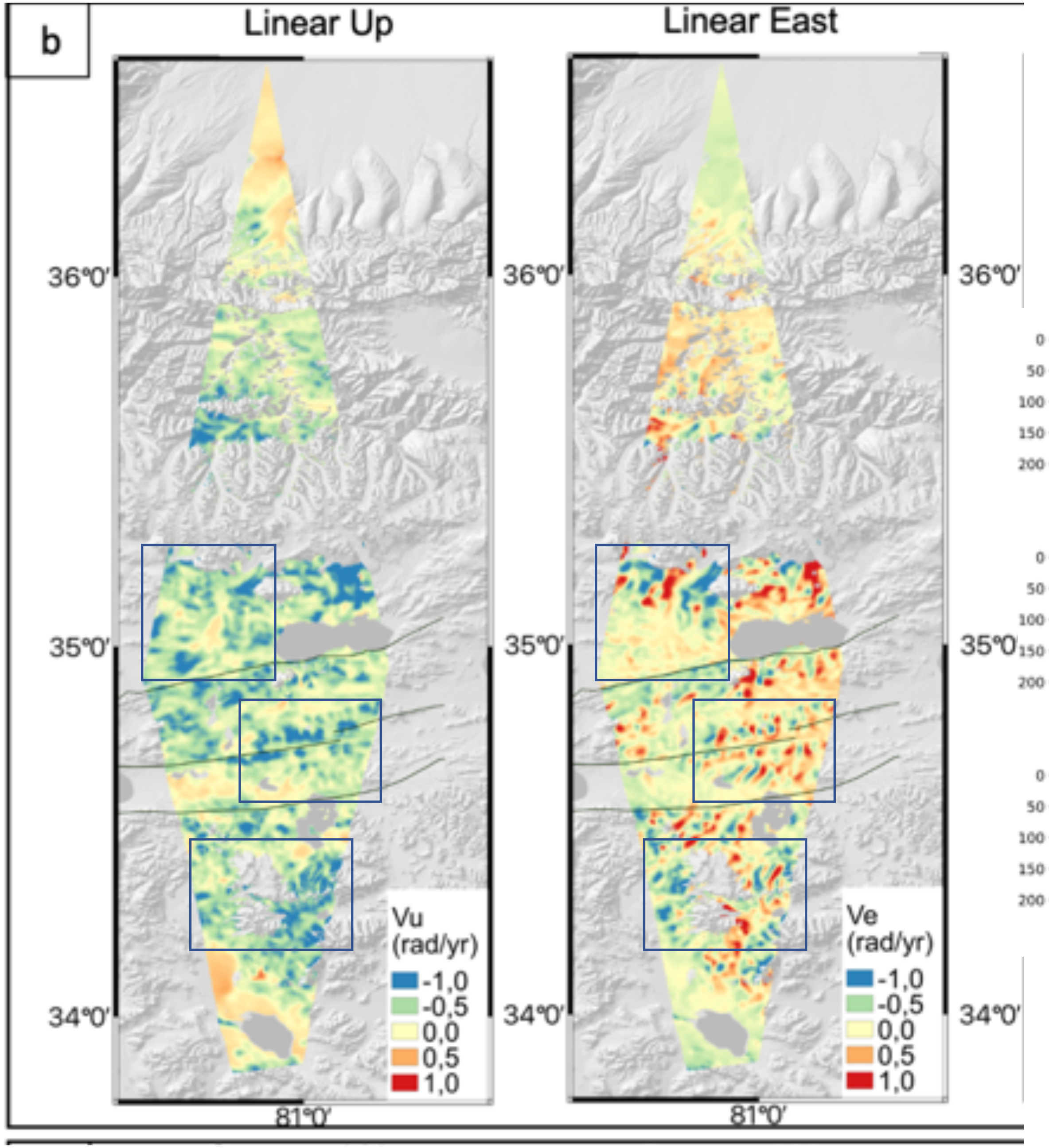


East-West velocities (positive = eastward)

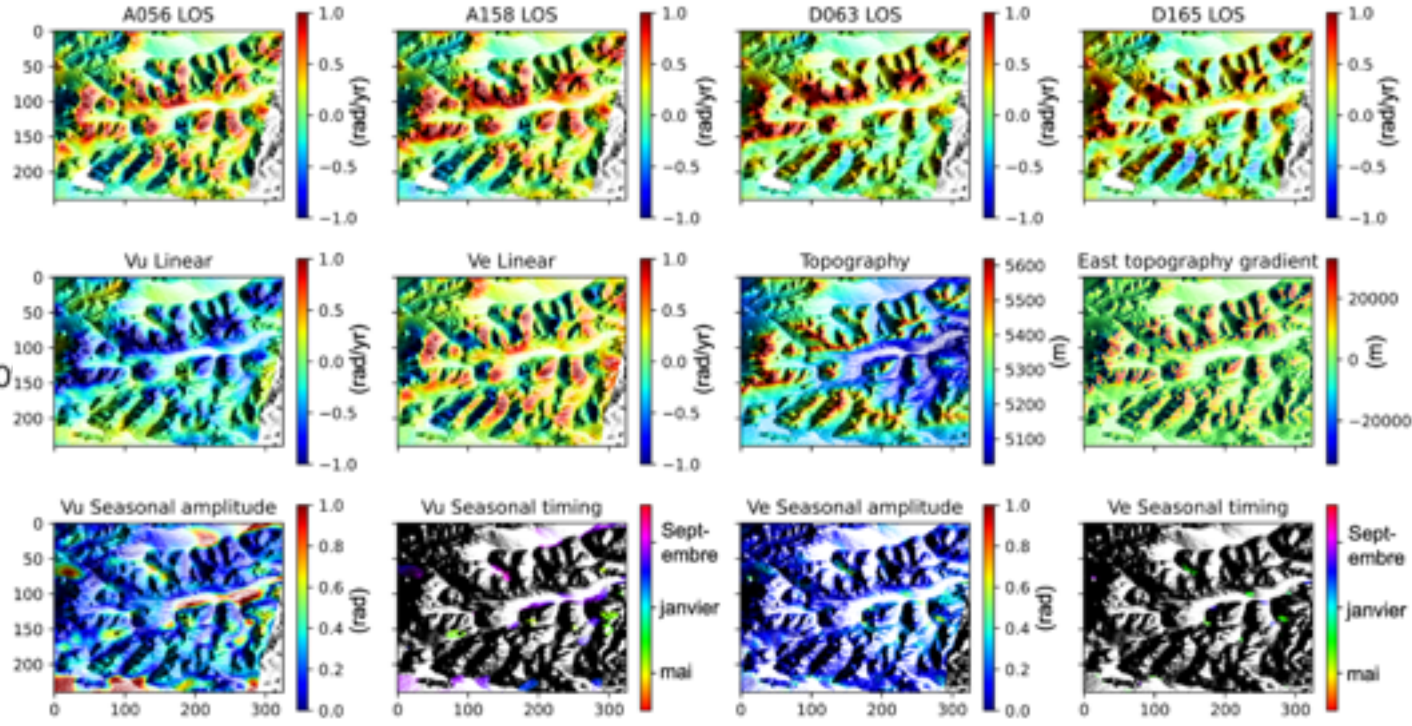
Upward velocities (positive = uplift)



Use track redundancy : Signal separation along the Ghoza Co fault



- → Horizontal/vertical velocity inversion
- → Correlation between Ve and slopes ?
- → Correlation between Vu and summits ? Local referencing to basins…



Decreasing the detection threshold of active faults with InSAR

What is the lowest interseismic slip-rates that can be detected with InSAR ?

→ depends on satellite, SNR_area, observation time span

How reliable are InSAR-derived slip-rates ?

→ formal uncertainties on slip-rates do not reflect all error sources

→ unwrapping errors ? referencing ? residual atmospheric delays ? non-tectonic signal separation ..?