# Automatic error-term separation approach in InSAR time-series analysis and application to Arima-Takatsuki fault zone, western Japan

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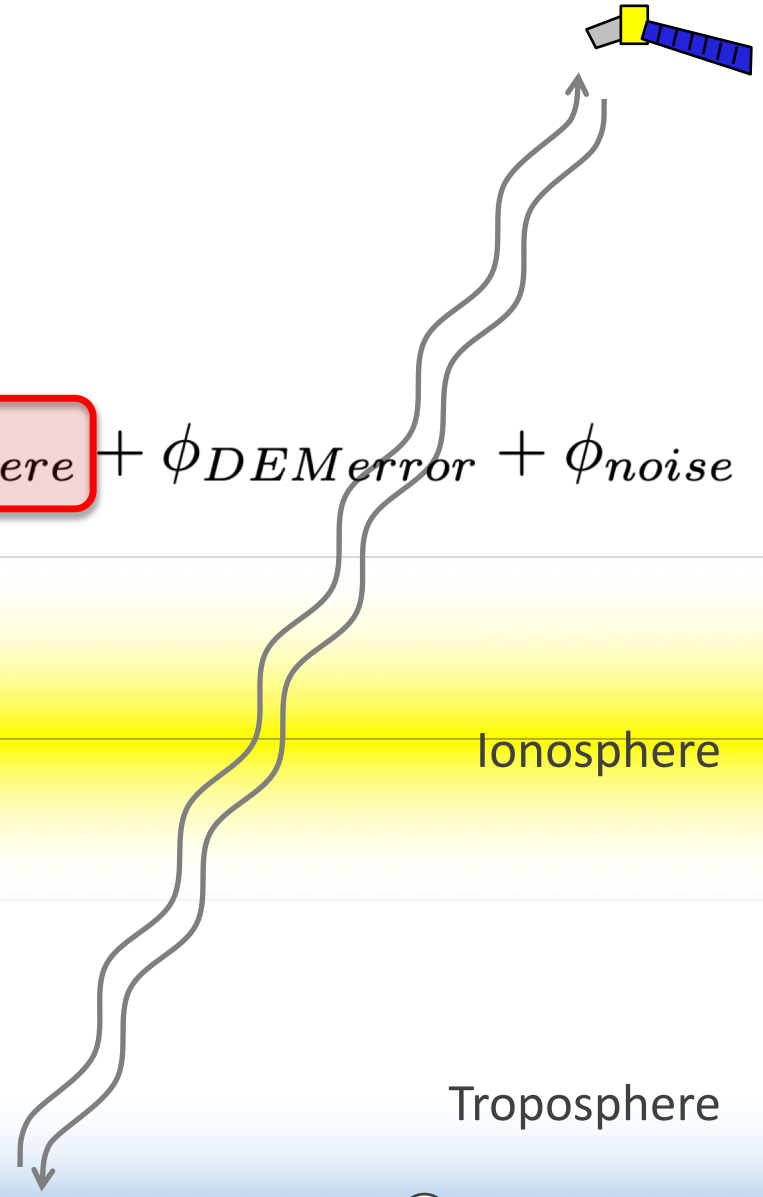
# “Noise” terms in InSAR

Observed phase of an interferogram:

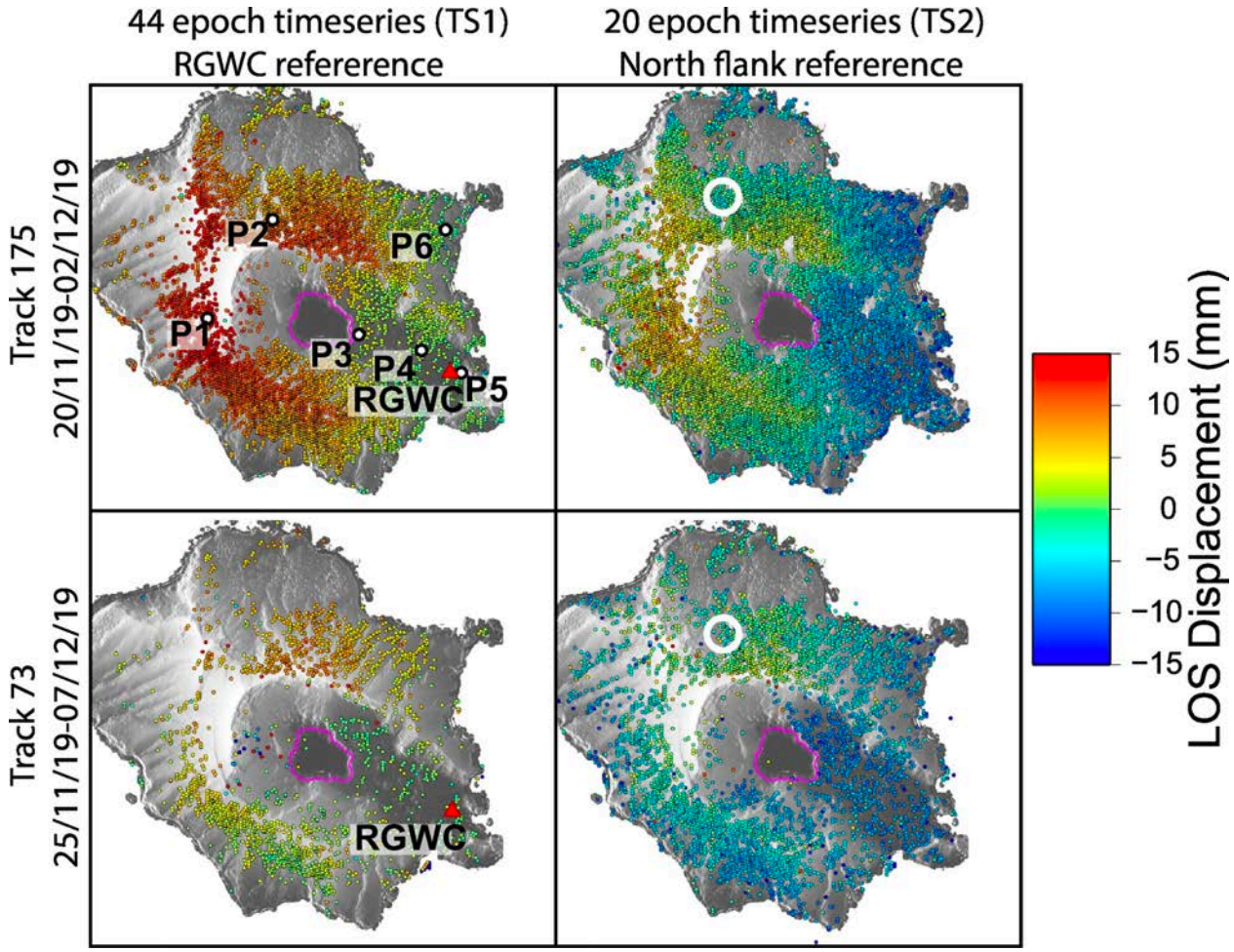
$$\phi_{observation} = \phi_{deformation} + \boxed{\phi_{offset} + \phi_{orbit} + \phi_{ionosphere} + \phi_{troposphere}} + \phi_{DEMerror} + \phi_{noise}$$

can often be problematic



# Problem of reference location selection in InSAR time-series analysis

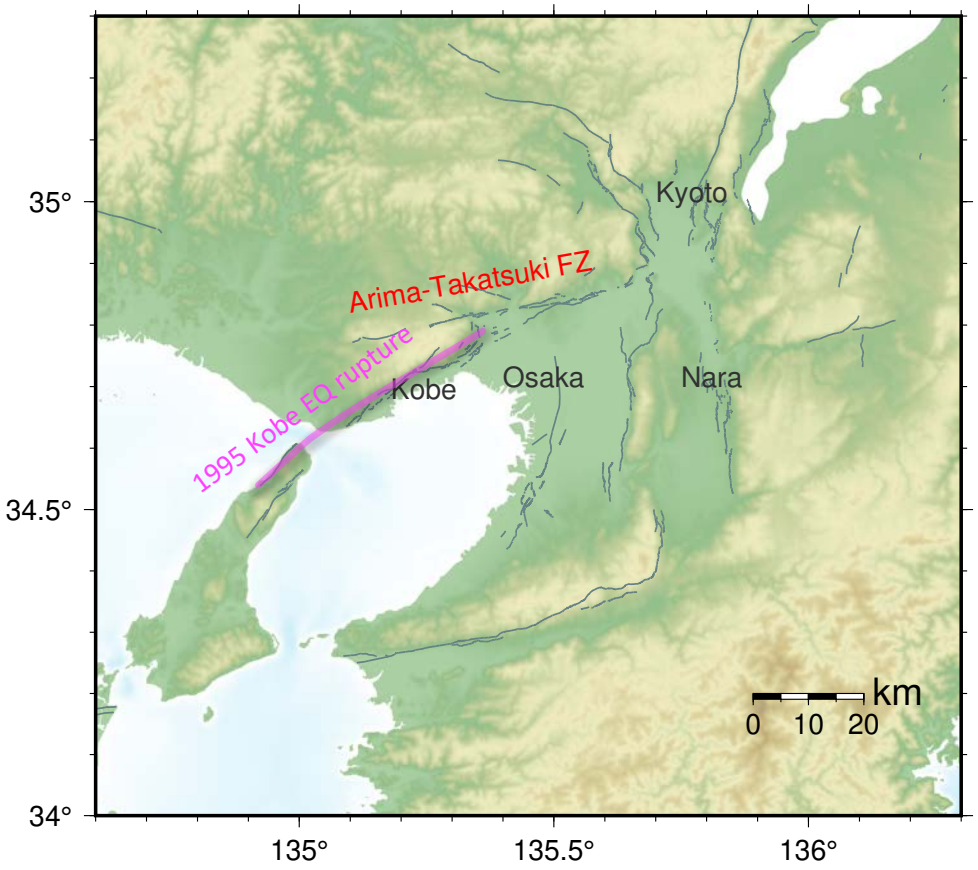
Problematic if the reference point was actually moving and/or the location was affected by atmospheric noise.




Hamling and Kilgour (2021)

# Purpose

- By adopting **De-Noising while solving for Time-Series (DeNTiS)** approach, this study derives InSAR displacement time-series while automatically minimizing other noise components
- Apply the DeNTiS algorithm on Osaka plain area, in which Arima-Takatsuki Fault Zone (ATFZ) is located.
- About ATFZ:
  - Located north of the 1995 Kobe earthquake (M7.2) rupture fault
  - Right-lateral
  - Ruptured in 1596 (M~7.5, slip ~ 3m)



# DeNTiS Algorithm

Essence: Small-baseline analysis, solve for velocity time-series and noise components (coefficients of linear functions) with regularization.
(Based on Fukushima et al., 2019, EPS, doi: 10.1186/s40623-019-1096-5)

For the *i*-th interferogram, *m*-th time step, and *k*-th pixel:

**Observation Equations**

$$d_{i,k} = d_{i,k}^{deform} + d_{i,k}^{error}$$

$$d_{i,k}^{deform} = \mathbf{g}_i \mathbf{v}_k$$

Topography↓

$$d_{i,k}^{error} = a_i + b_i x_k + c_i y_k + \ldots + f_i h_k$$

↑Can be any order of polynomials

+

**Regularization Equations**

$$\Sigma_m (v_{m,k} \Delta t_{m,k}) = \bar{v}_k \Sigma_m (\Delta t_{m,k})$$

↑Const. velocity (NSBAS, LiCSBAS)

$$\Sigma_m v_{m,k} = 0$$

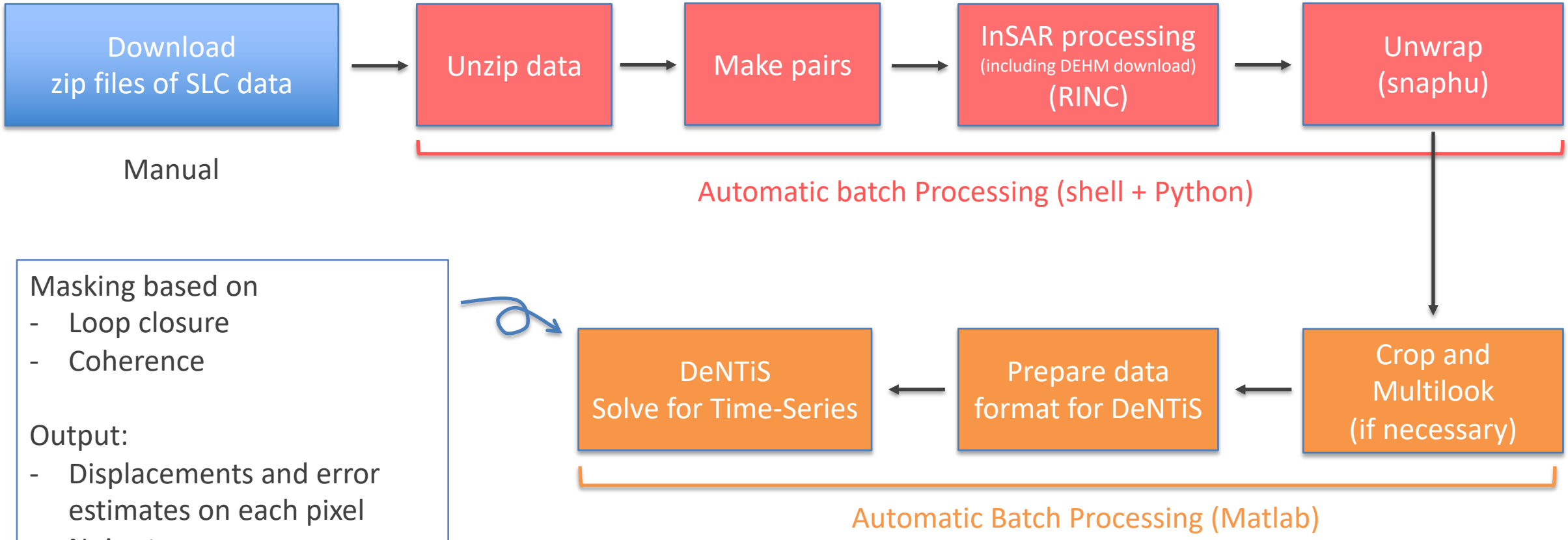
↑Min. cumulative velocity (only 1st step)

※ **Weights of these regularization are made small enough**

1st step: Estimate the noise terms from subsampled points

2nd step: px-by-px inversion on denoised ifgs.

# Analysis Flow



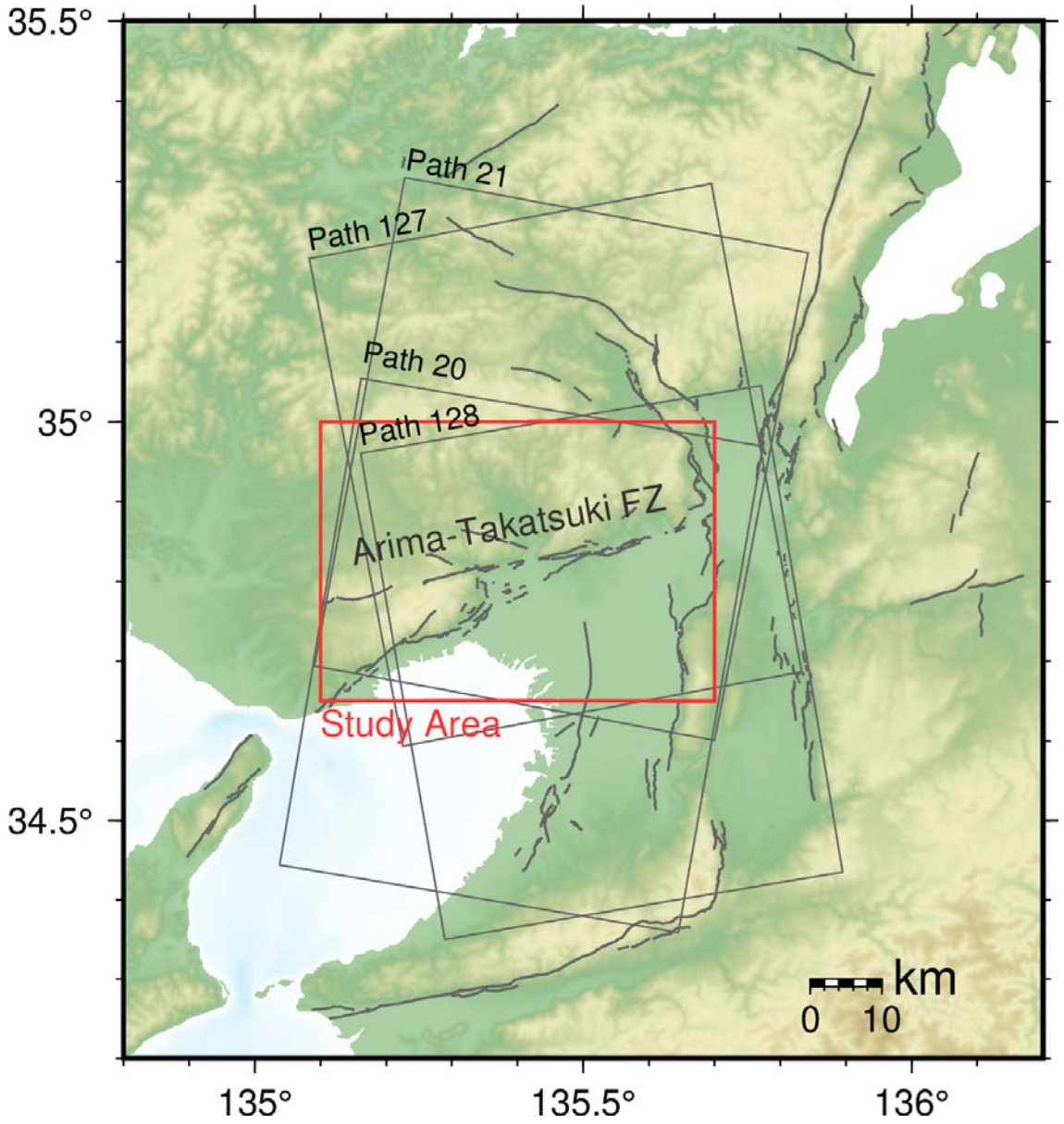
# Data

ALOS-2, Ultra-Fine-Beam Mode (SM1)

Acquired betw. Aug 2014 – Mar 2021

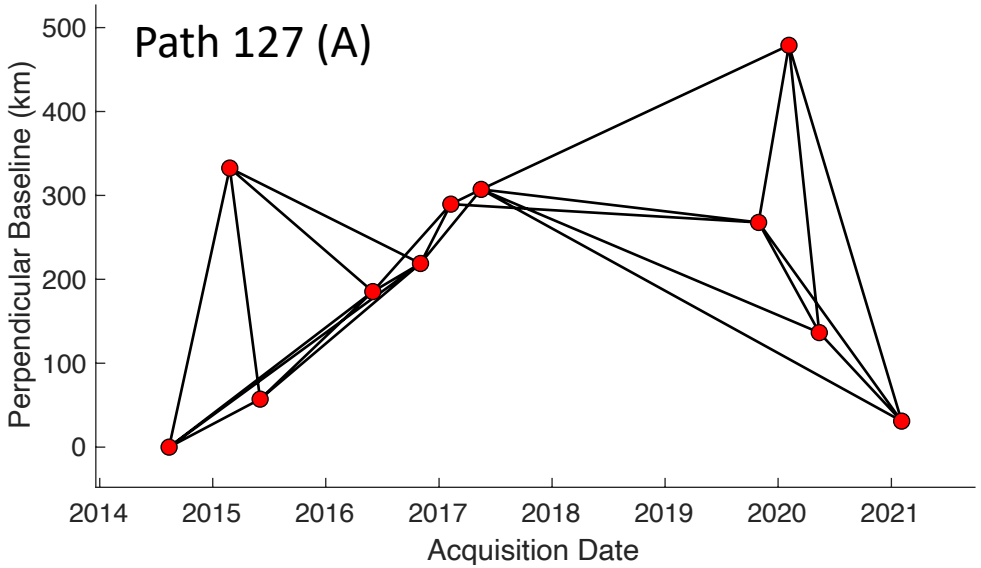
Data sets of four paths:

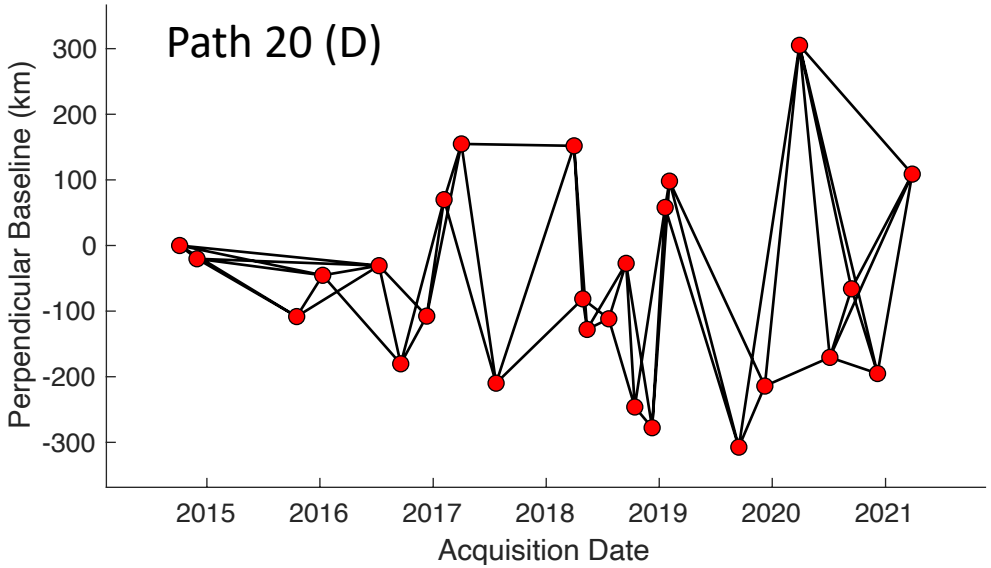
| Path | Orbit | Incidence Angle (deg) | Number of Images | Number of Interferograms |
|---|---|---|---|---|
| 20 | D | 42.9 | 26 | 55 |
| 21 | D | 32.4 | 24 | 51 |
| 127 | A | 32.4 | 11 | 25 |
| 128 | A | 42.9 | 16 | 35 |

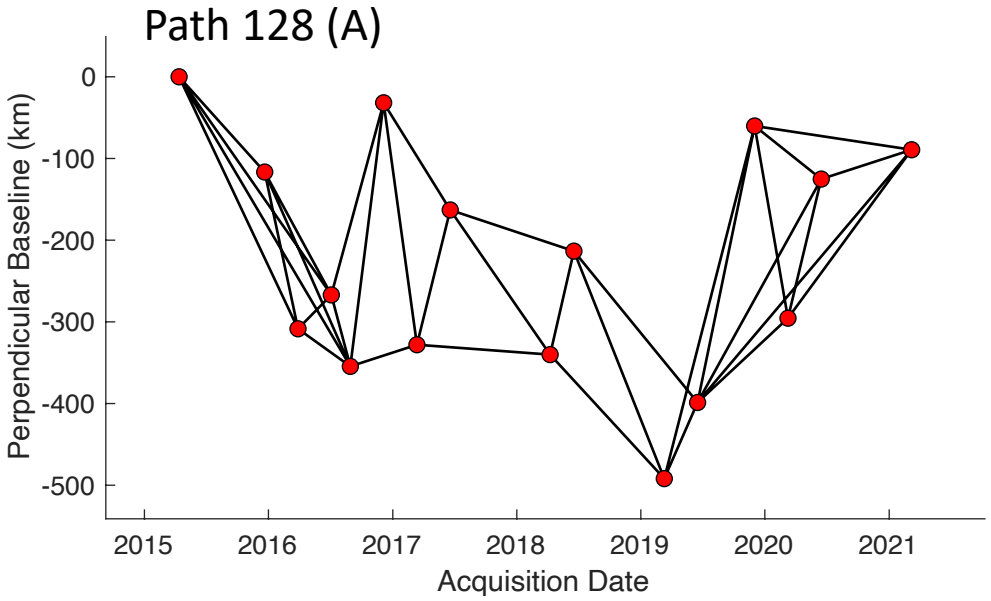


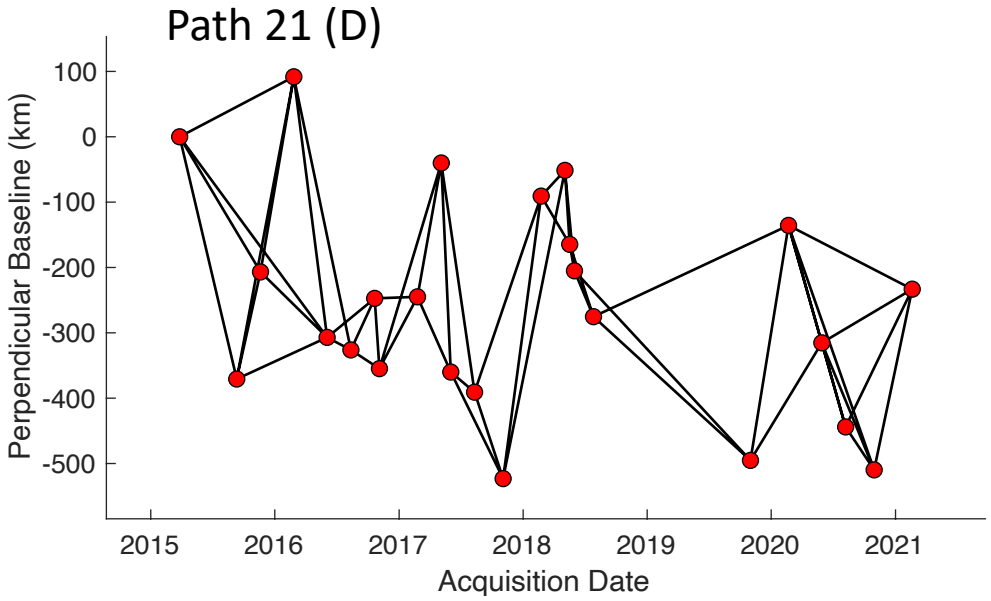
# Baselines

3 or 4 ifgs per acquisition



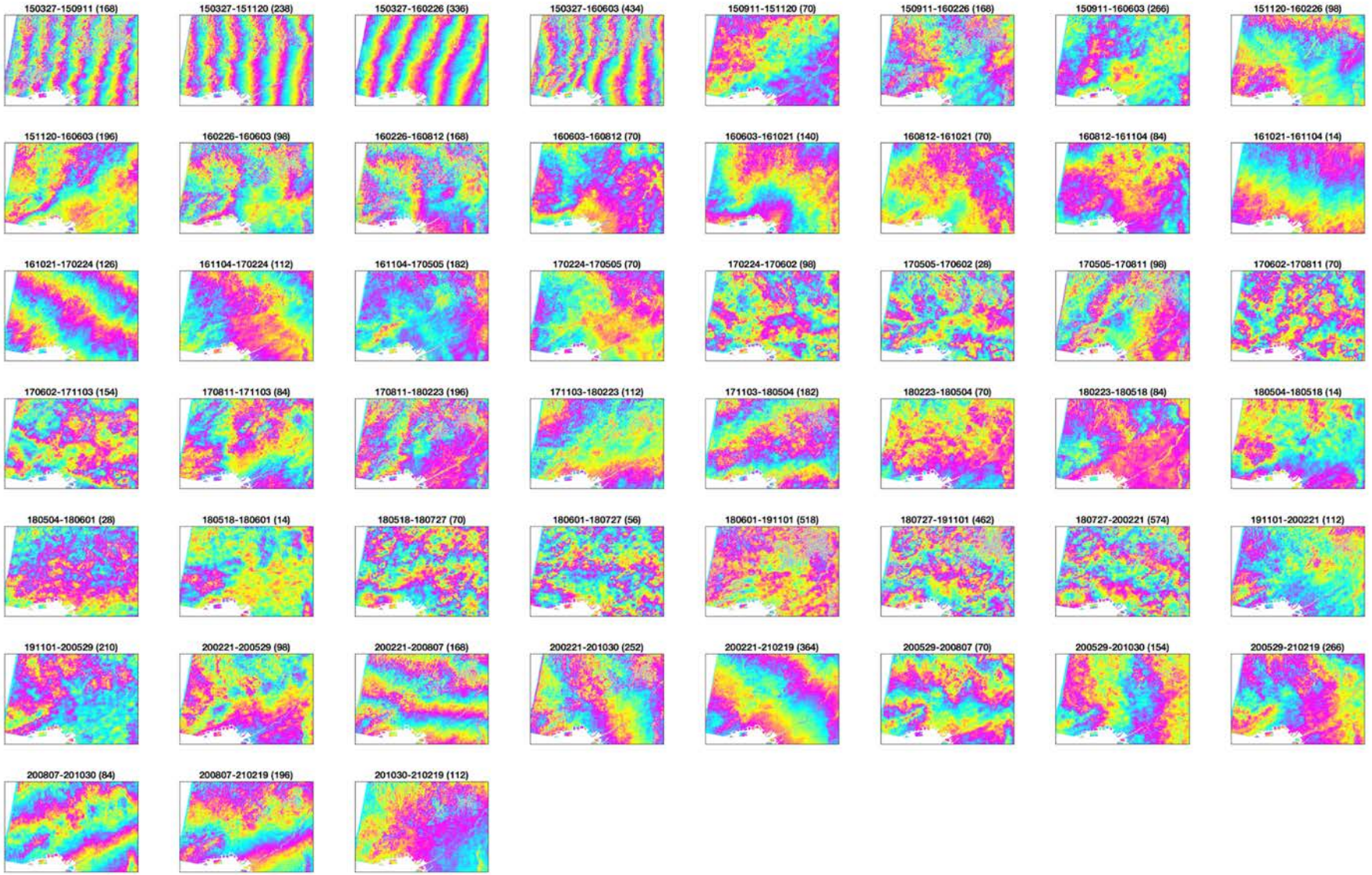



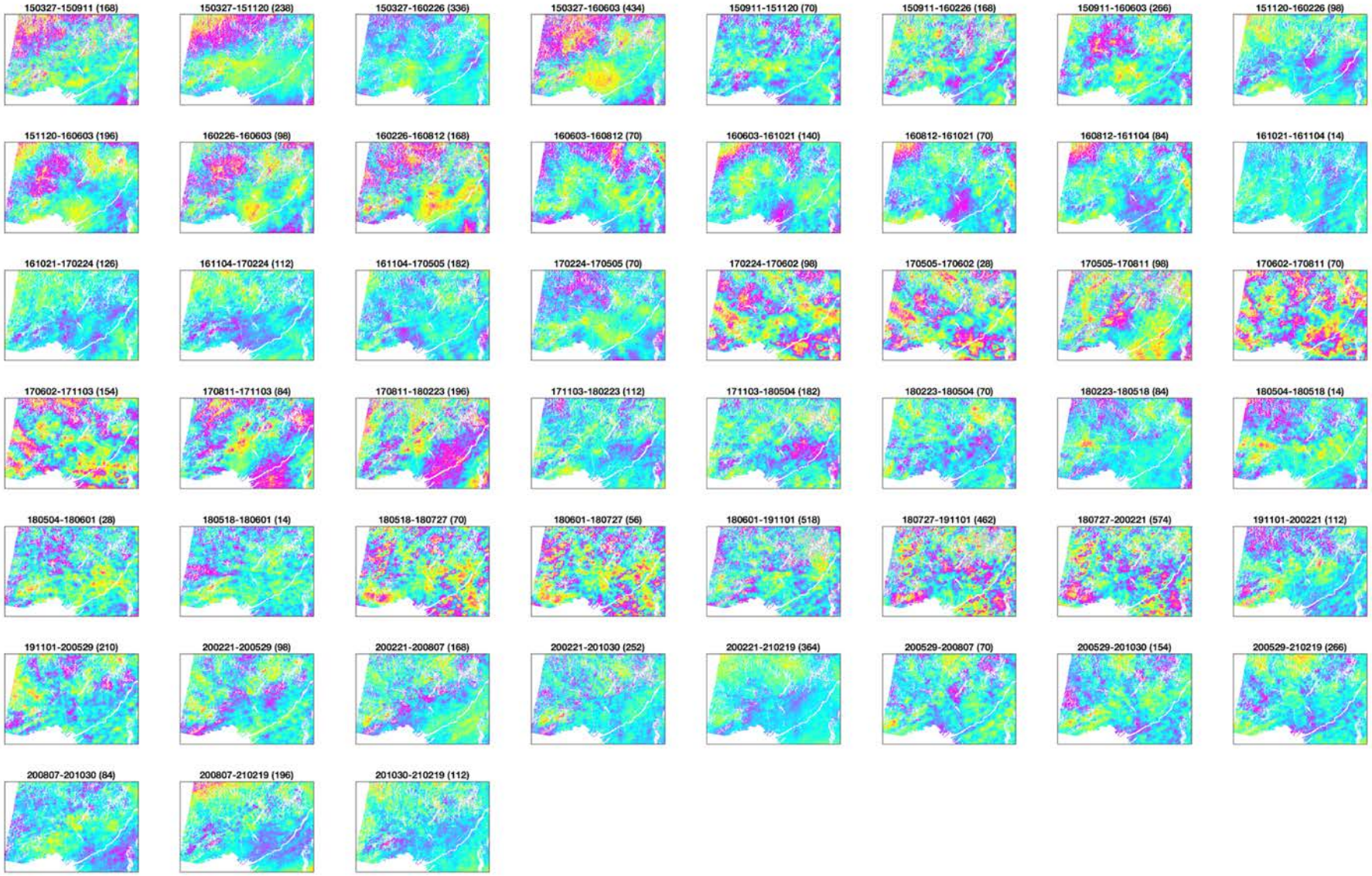
# Original interferograms

Path 21 (descending)
Rewrapped to [0, 5cm]



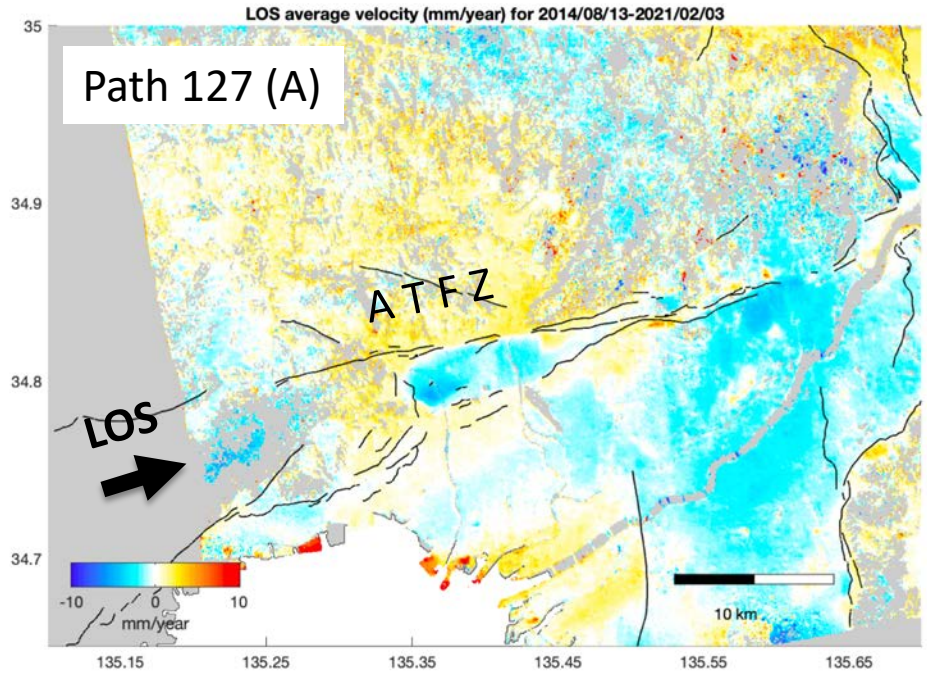
# Denoised interferograms

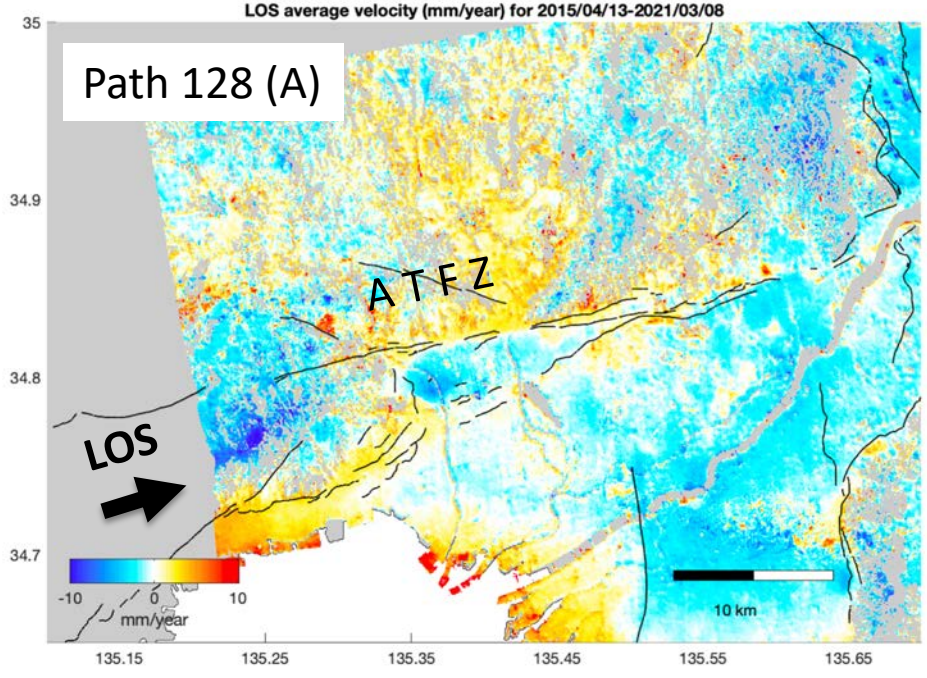
Path 21 (descending)
Rewrapped to [0, 5cm]

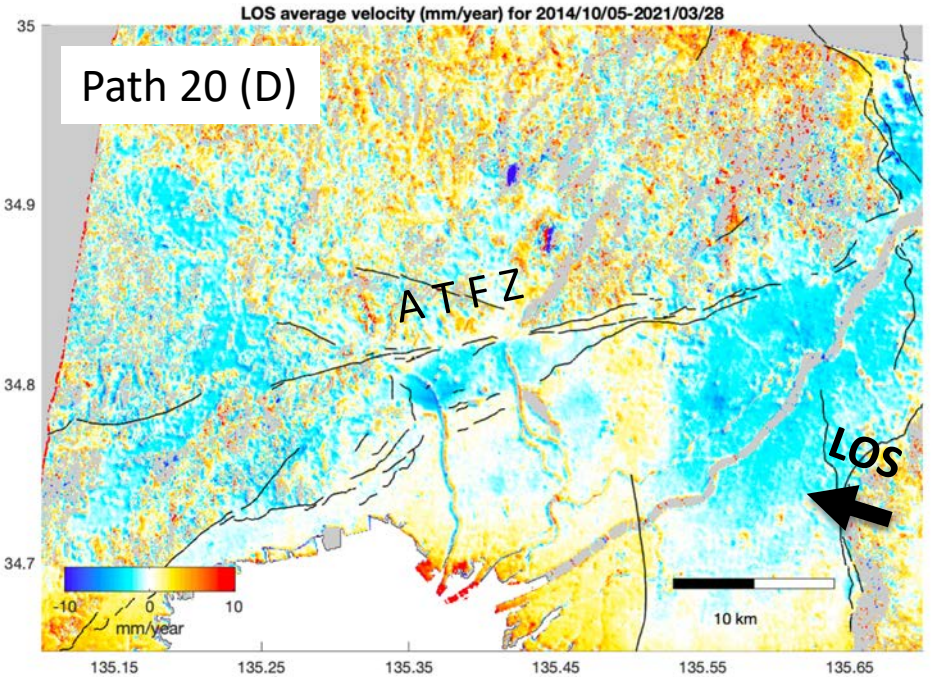


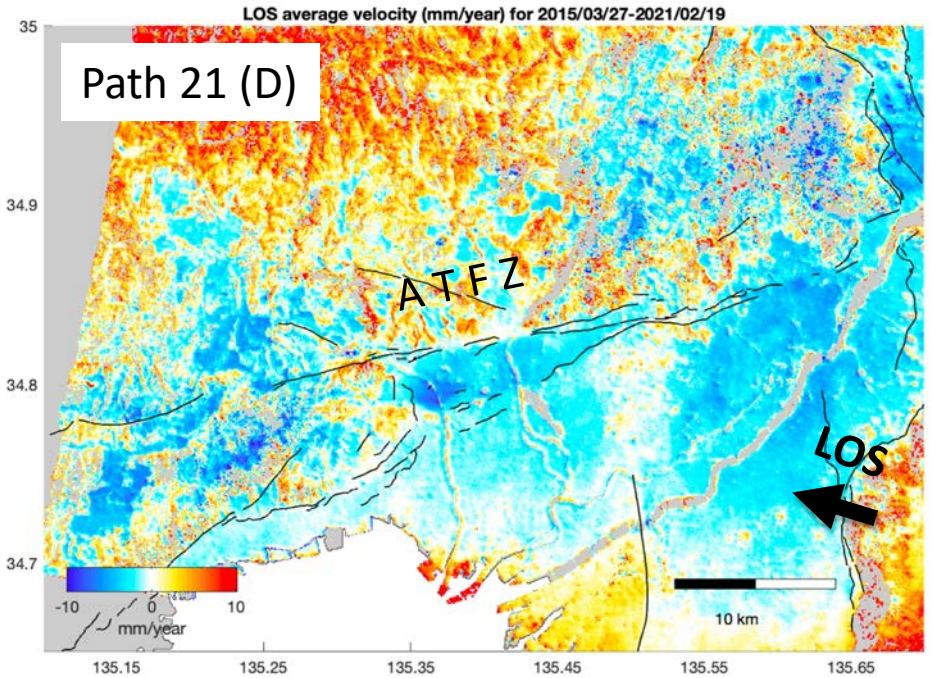
# Mean Velocity

Red: away from satellite
Blue: toward satellite

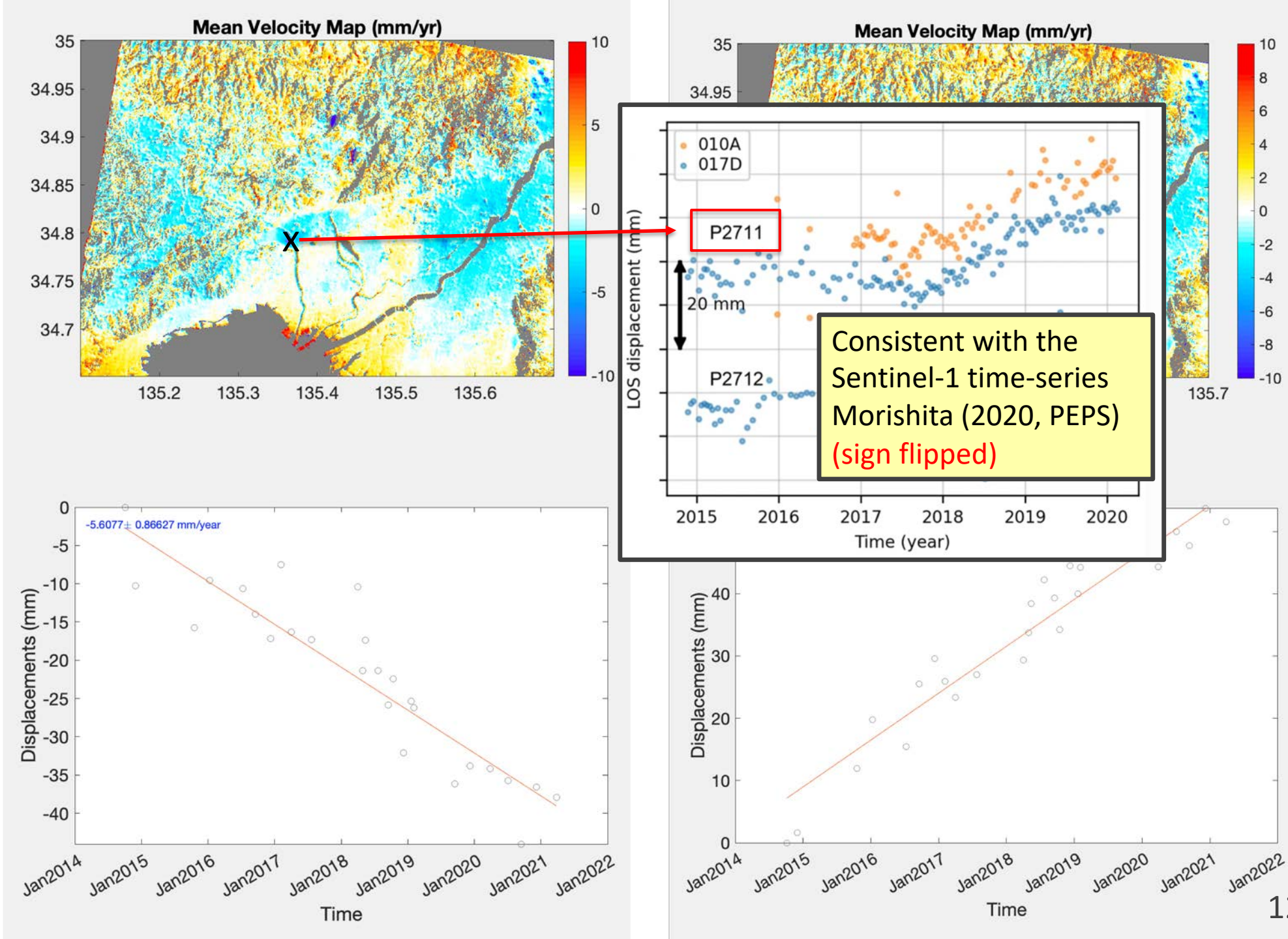


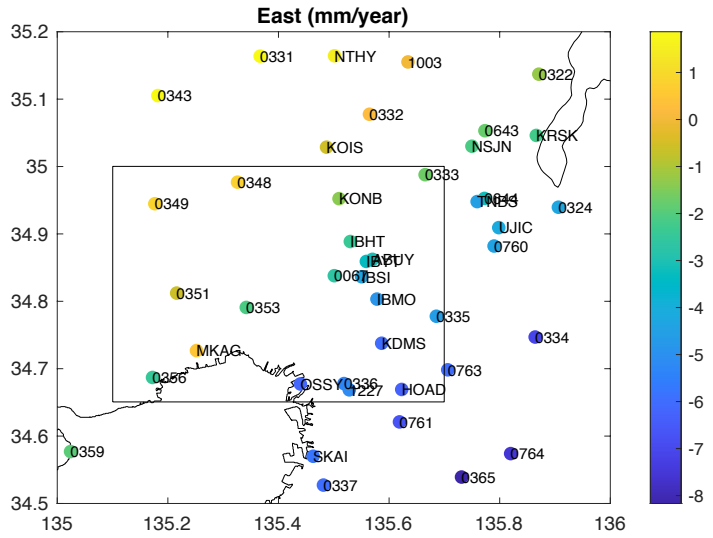



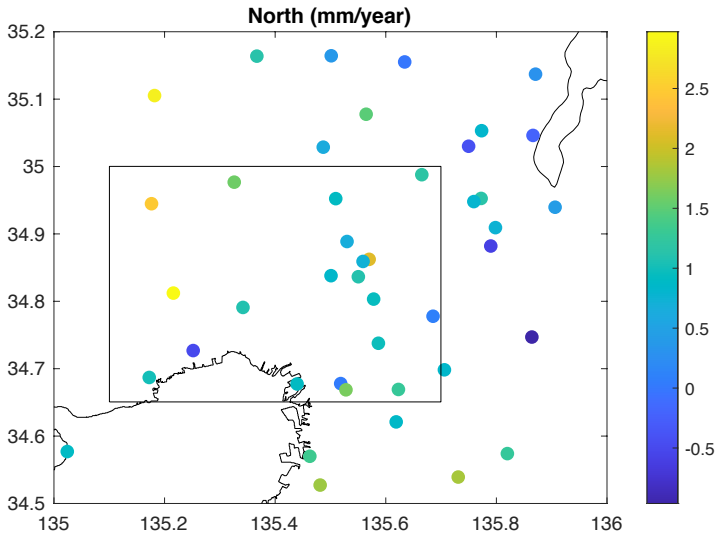



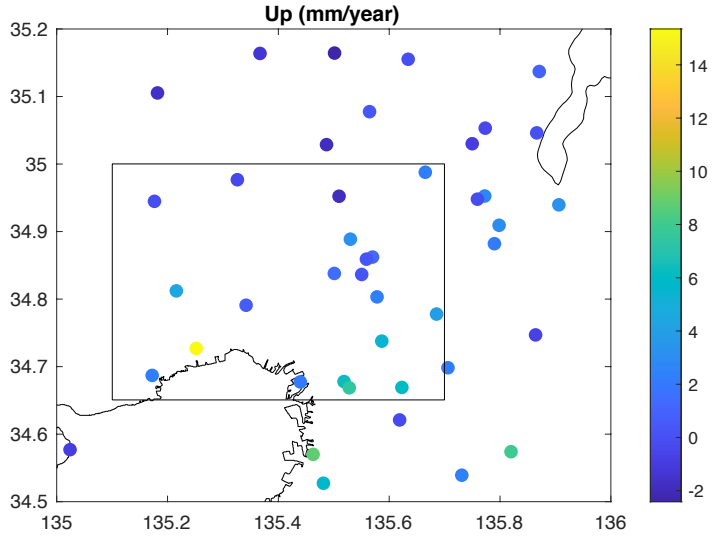
# Examples of time-series (Path 20)



# Comparison with GNSS time-series



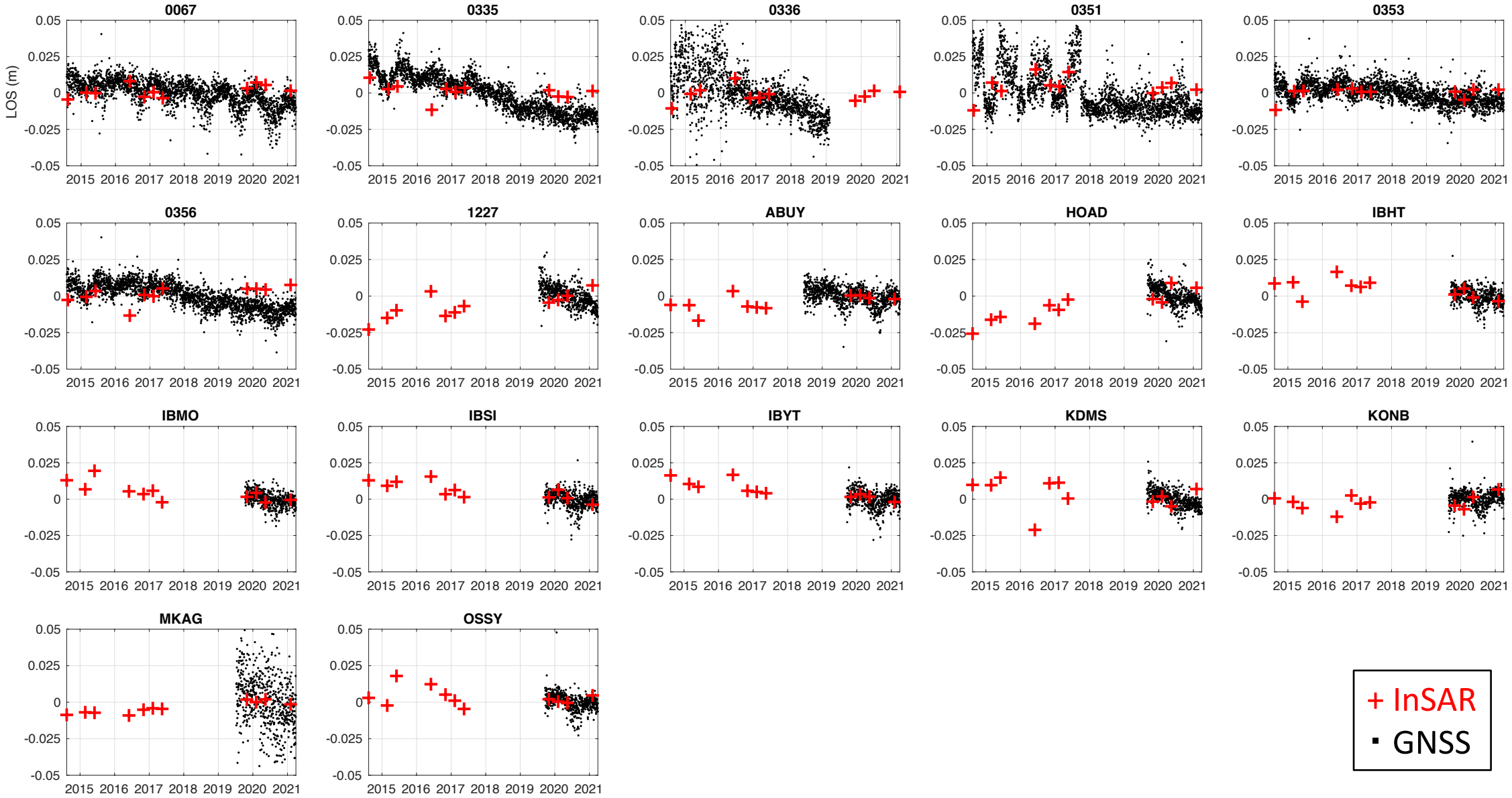




Data courtesy of GSI, T. Nishimura, and K. Miyahara

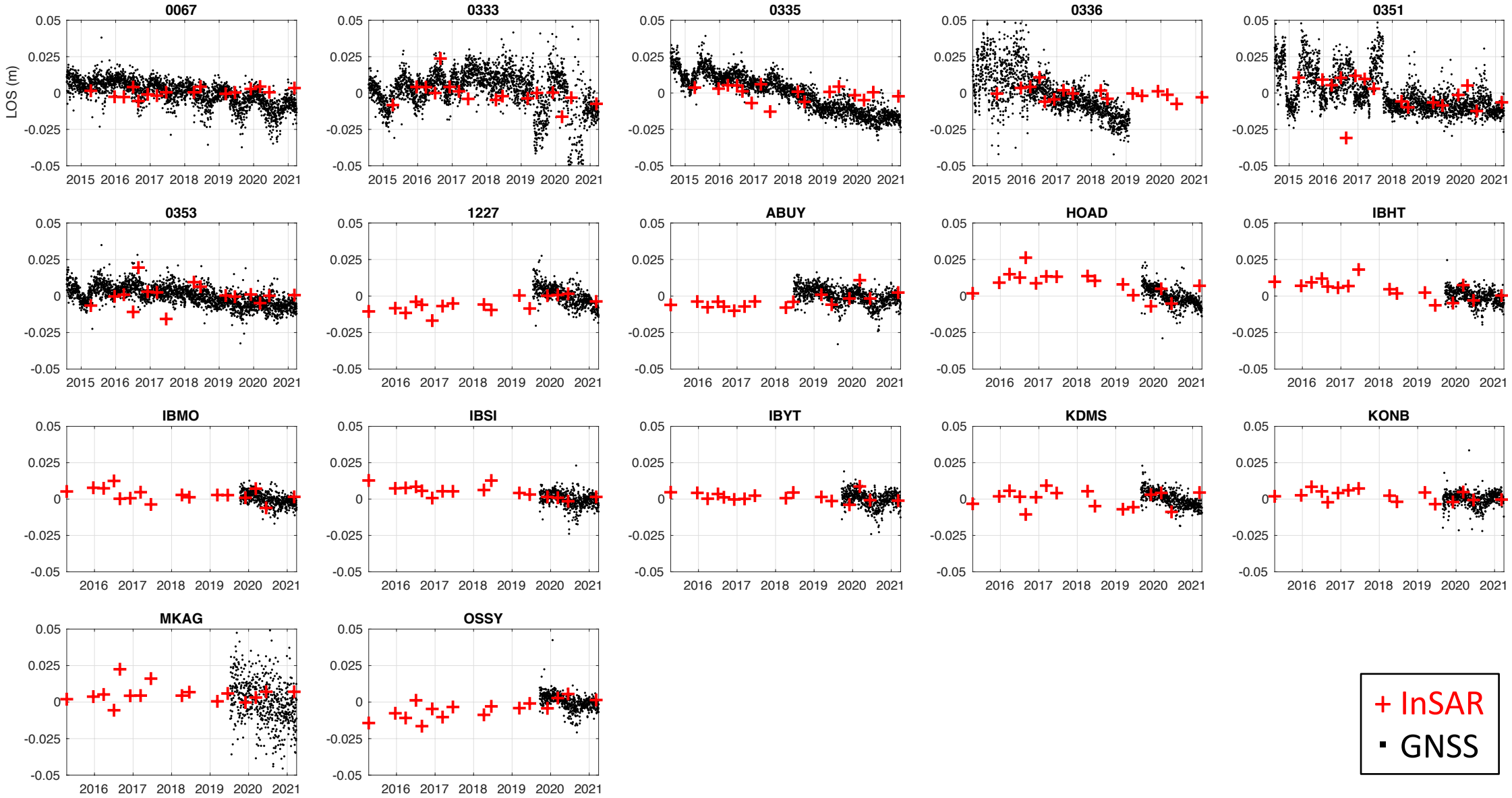
# Comparison with GNSS time-series (Path 127)

RMS = 10.8 mm



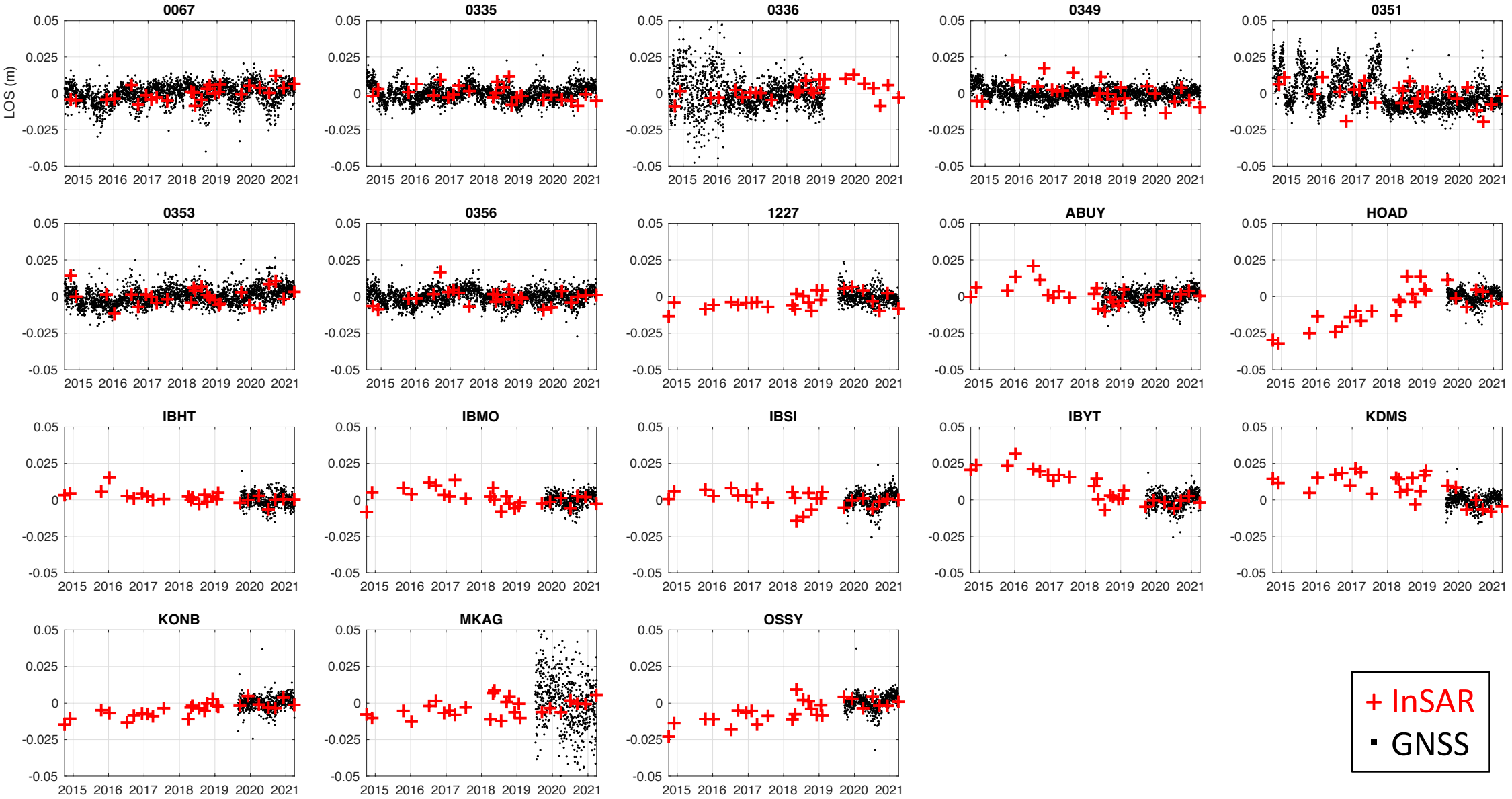
# Comparison with GNSS time-series (Path 128)

RMS = 10.3 mm



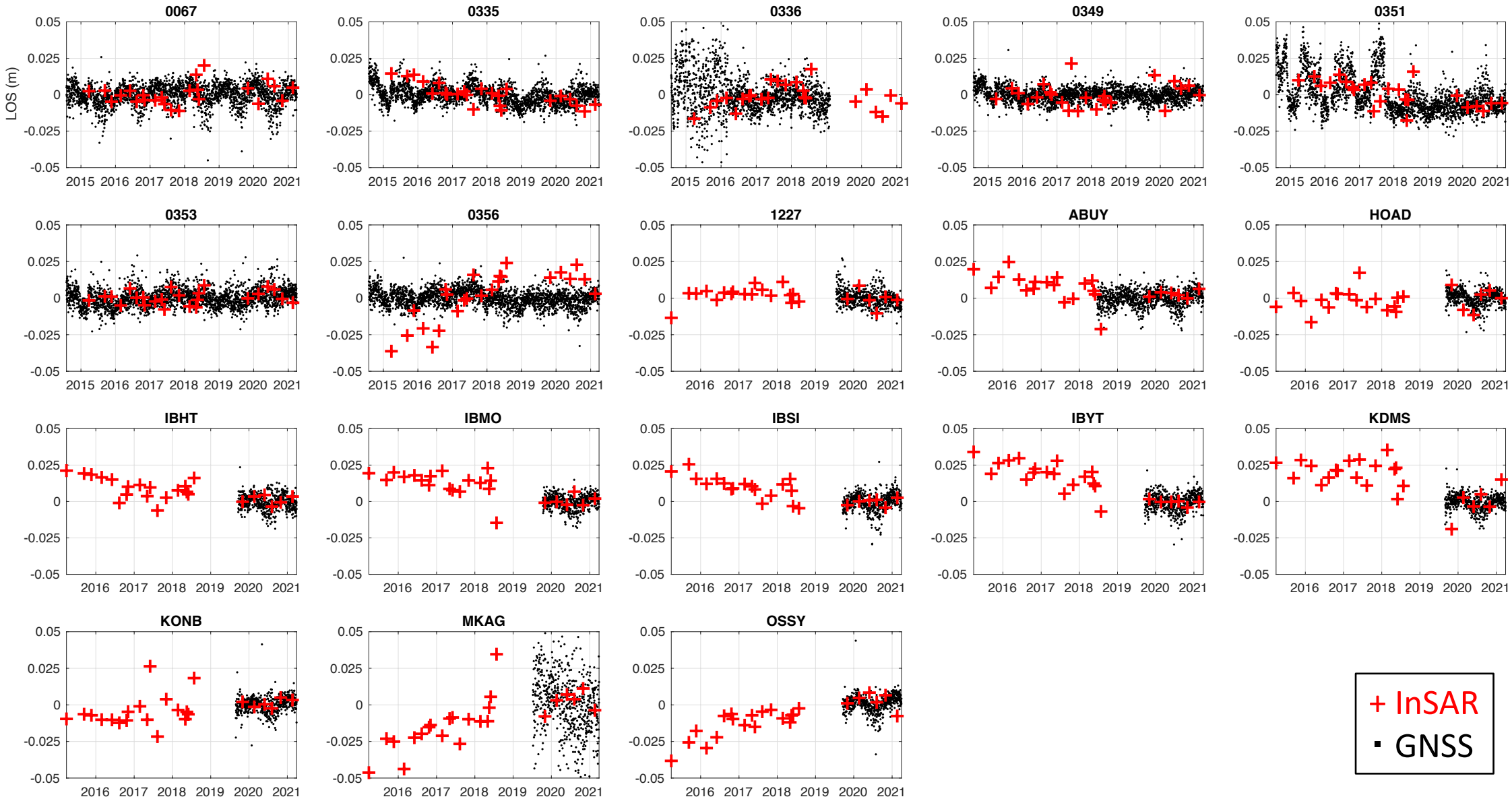
# Comparison with GNSS time-series (Path 20)

RMS = 7.5 mm



# Comparison with GNSS time-series (Path 21)

RMS = 10.0 mm



# Summary

- De-Noising while solving for Time-Series (DeNTiS) algorithm is developed (formulation written in Fukushima et al. (2019, Earth Planets and Space).
- By applying DeNTiS on ALOS-2 data, the displacement time-series and the mean velocity map around the Arima-Takatsuki Fault Zone were obtained.
- Results consistent with those using Sentinel-1 data (much denser temporal sampling) were obtained, showing the effectiveness of the approach.

Please contact fukushima@irides.tohoku.ac.jp if you want to try the codes.

# Acknowledgements

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