Separating transient tectonic signal from atmospheric signal in InSAR time-series, the case of the 2017-2018 Slow Slip Event in Guerrero (Mexico)

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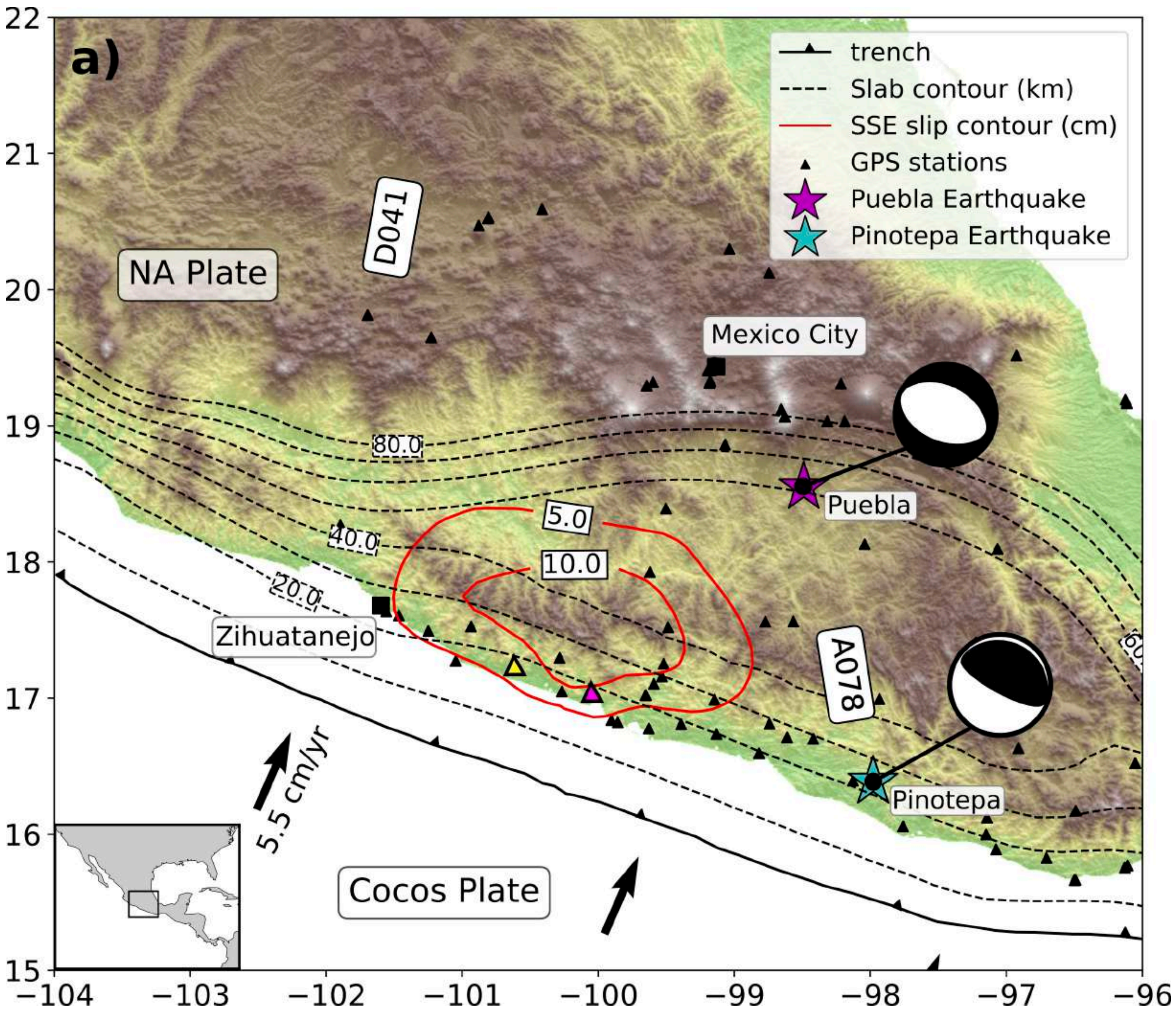
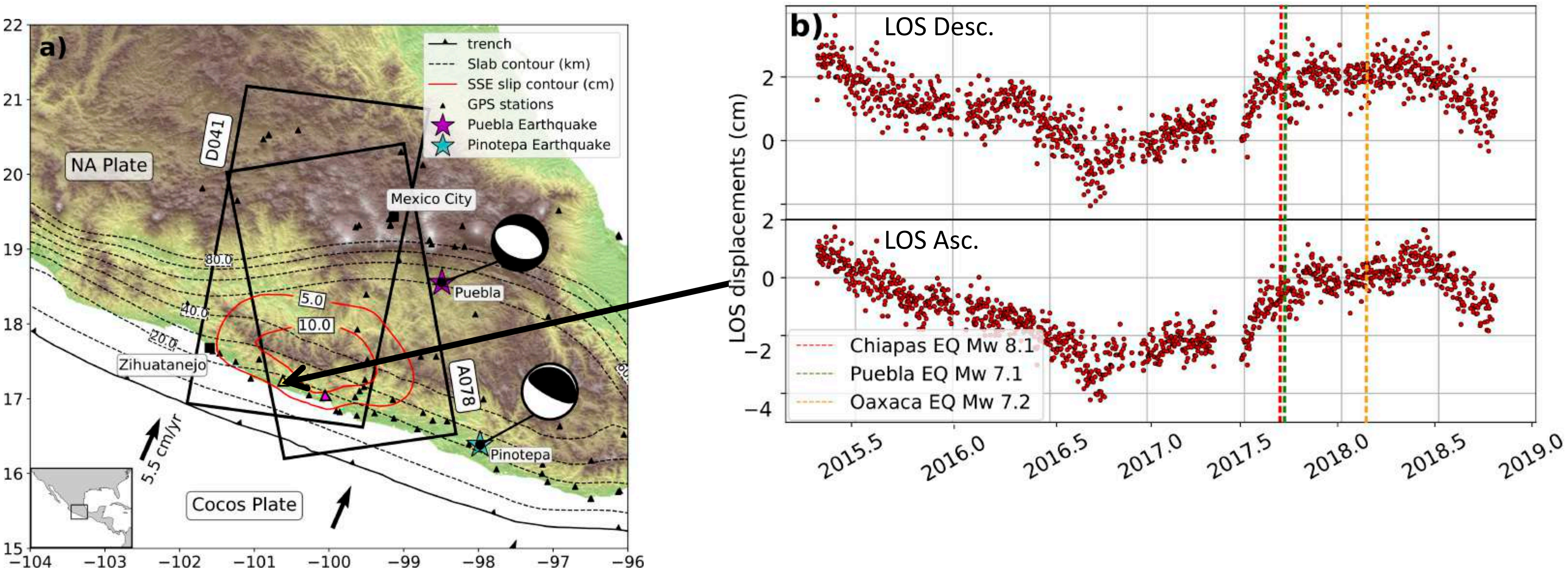
Context of Study

- Mexican subduction:
  - 1500 km long
  - Complex geometry: Flat Slab
- **Guerrero area**
  - Slow Slip events every 4 yr
  - Mw = 7.5
- Slow Slip Event (SSE) between <u>May 2017</u> and <u>June 2018</u>
- **3** major <u>earthquakes</u> since September 2017



Context of Study

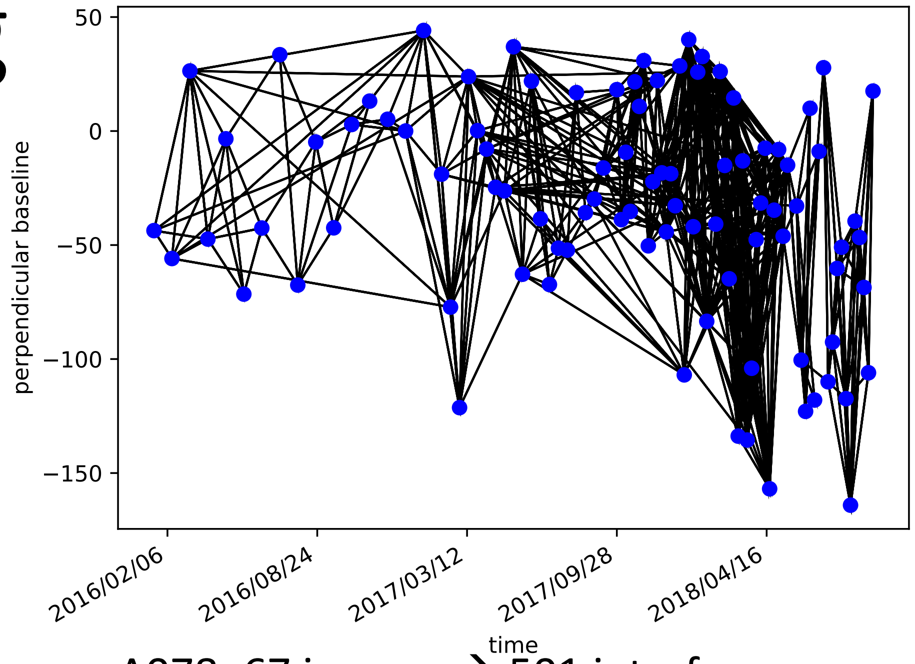


- **3 to 4 cm** of displacement during the last <u>SSE</u>
  - **<u>2 phases</u>**
- **<u>Objective</u>**: Enhance the spatial coverage of this SSE with InSAR time series
- **<u>Challenge</u>**: Signal separation of the different sources recorded in InSAR data
- <u>Atmospheric</u> signal on Mexico: **~20 cm**

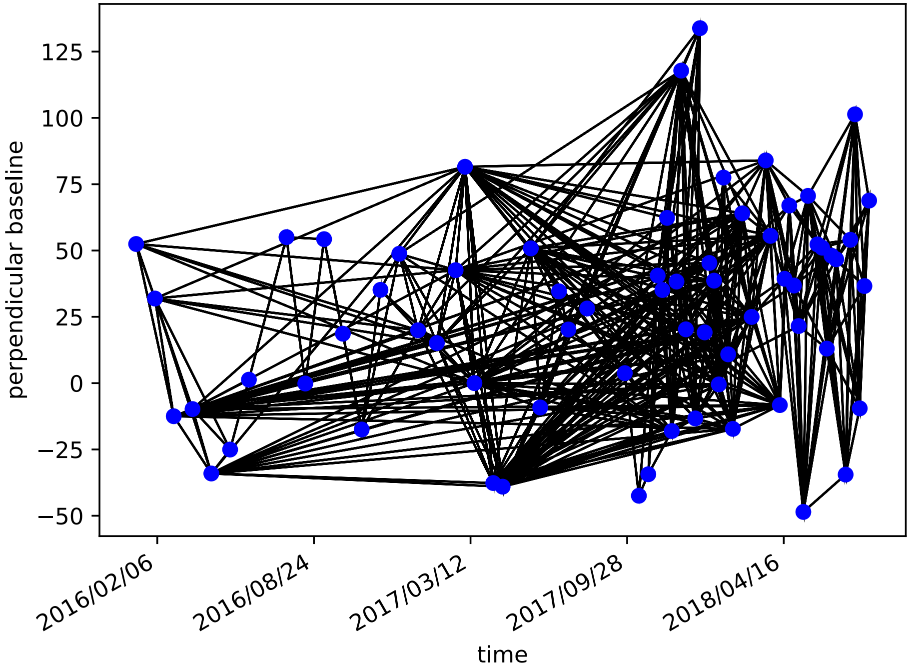
InSAR Processing

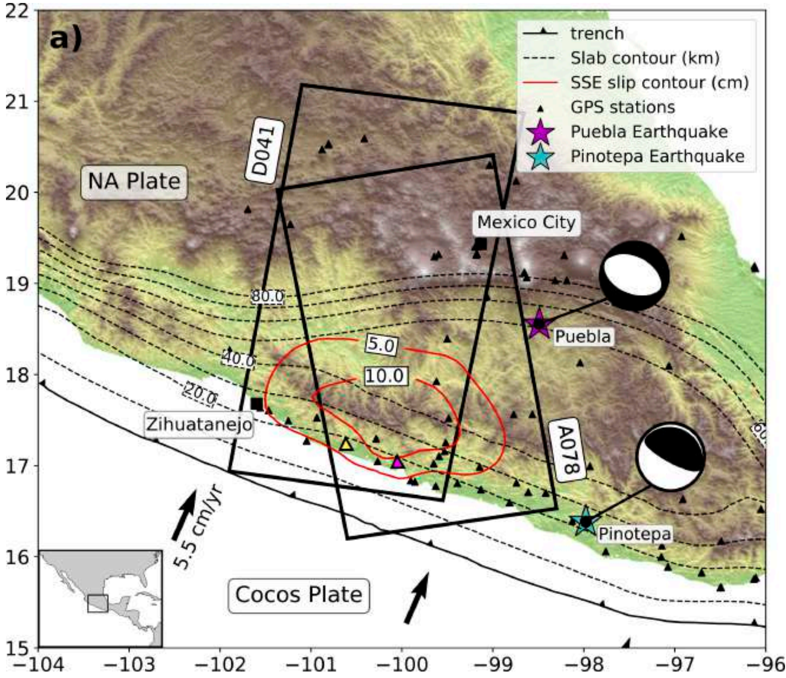
- **Sentinel-1:**
  - 1 image every 12 days
  - Swaths:
    - Descending Track 041: (2016 → 2018/09)
    - Ascending Track 078: (2016 → 2018/08)
- Processing chain NSBAS: Small Baseline Approach (Doin, M-P. et al. 2011)
- Unwrapped interferograms: no corrections applied

D041: 90 images → 624 interferograms



A078: 67 images → 501 interferograms





Time Series analysis

1st step: Phase Time Series generation

- SBAS approach (Doin, et al *2015*, Lopez- Quiroz, *2009*) : Singular Value Decomposition (SVD) of interferograms network → obtaining the phase by date:

$$\boldsymbol{\phi_i} = \boldsymbol{\phi_{def}} + \boldsymbol{APS} + \boldsymbol{\phi_{error}}$$

with : $\phi_{def} = \phi_{SSE} + \phi_{interseismic} + {}_{subsidence}$ (in LOS)

and APS = $Atmospheric\ phase\ screen\ (tropospheric\ part)$

2nd step: Signal sources separation

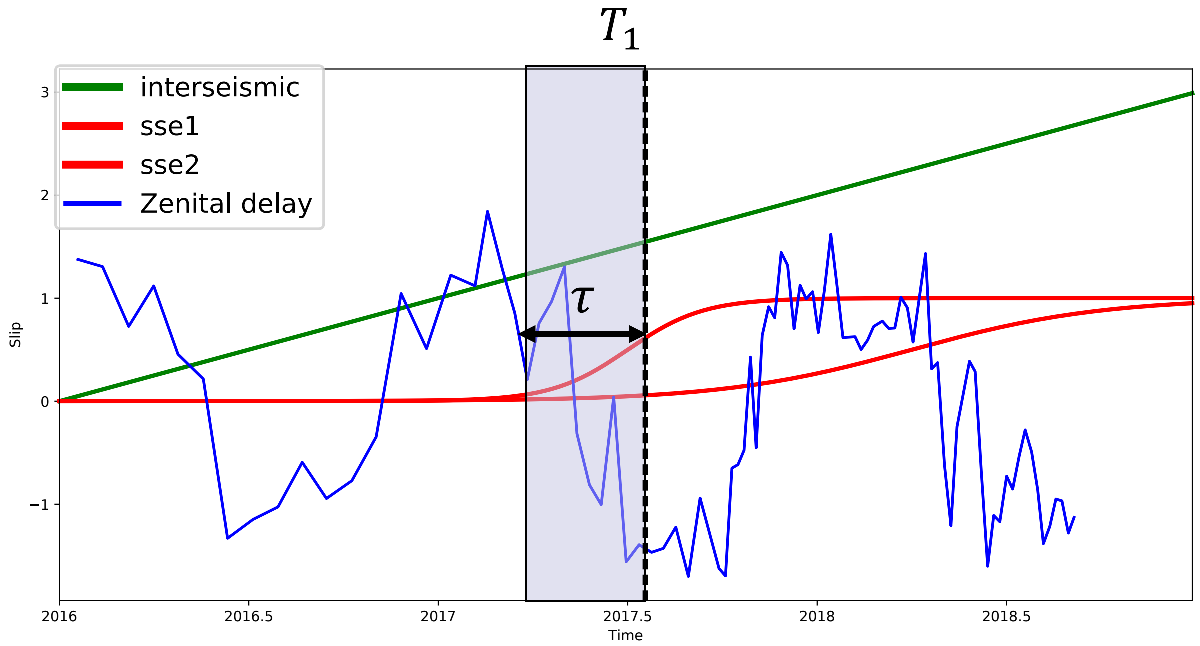
Two different approaches are tested

- Parametrized decomposition: Form of each component is imposed
- Independent Component Analysis (ICA)

Signal sources separation: Parametric decomposition

- For each pixel: 5 parameters are inverted, the temporal evolution follows:

  - $\phi(t) = \mathbf{a} * t + \mathbf{b} * APS(t) + \frac{\mathbf{C1}}{2}\tanh\left(\frac{t - T_1}{\tau_1}\right) + \frac{\mathbf{C2}}{2}\tanh\left(\frac{t - T_2}{\tau_2}\right) + \mathbf{d}$



- SSE characteristics are imposed based on GPS observations

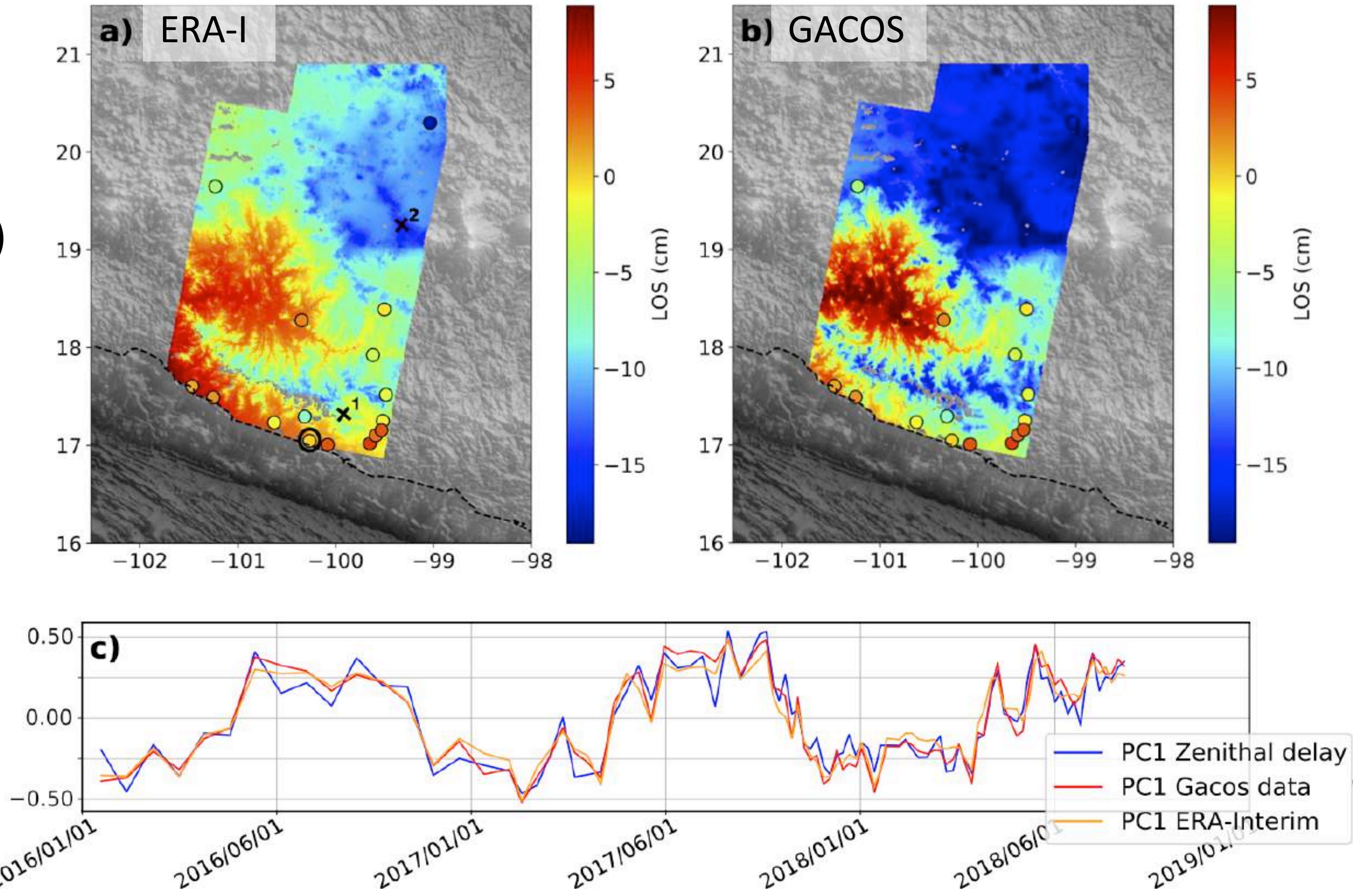
- $T_1 = 2017.5$ (07/2017); $T_2 = 2018.1$ (02/2018);
- $\tau_1 = 0.25$; $\tau_2 = 0.3$

Characterization of APS(t)

- 3 data sets:
  - Model: ERA-Interim
  - Model: GACOS (HRES-ECMWF, Yu et al 2018)
  - Data: ZTD from GPS

- PCA on these data to find the common component of the seasonal signal

- ZTD amplitude ≠ weather models
- Similar temporal evolution



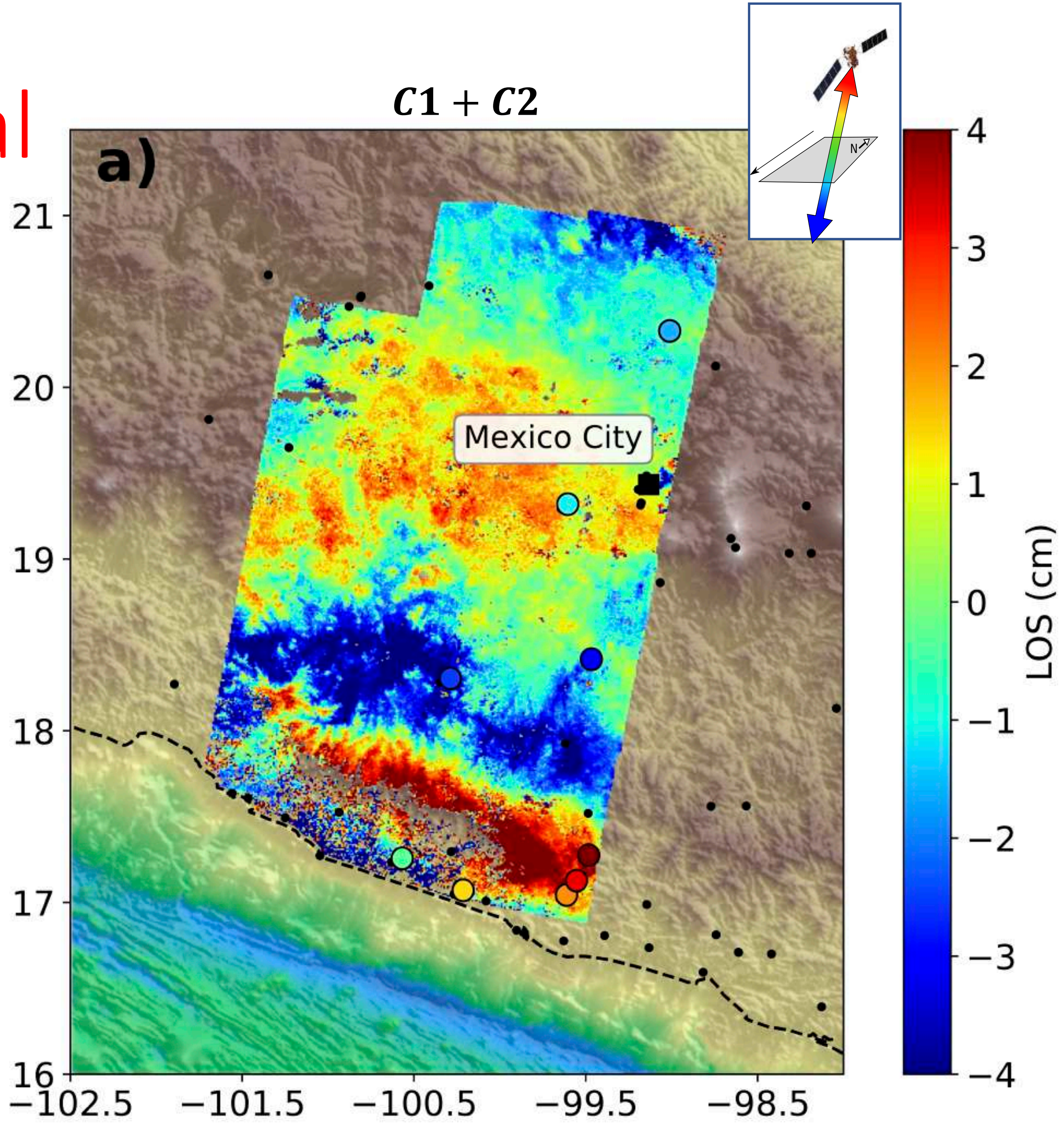
Amplitude of the SSE signal

Parametrized decomposition

- $\phi(t) = a * t + b * \mathrm{APS}(t) + \frac{C1}{2}\tanh\left(\frac{t - T_1}{\tau_1}\right) + \frac{C2}{2}\tanh\left(\frac{t - T_2}{\tau_2}\right) + d$

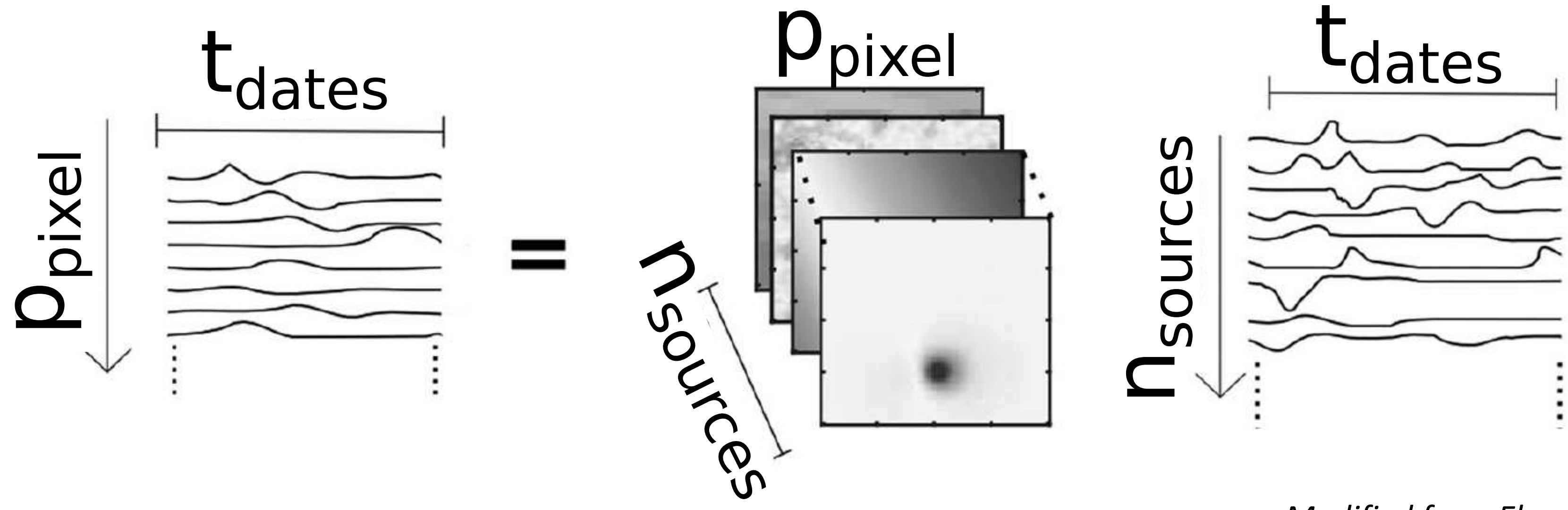
- Allow to extract an amplitude map in agreement with the GPS displacement
- Limitations: a priori requested on the SSE

➢ Second method: ICA



Signal sources separation: ICA decomposition

- <u>Algorithm FastICA</u> (Hyvärinen and Oja, 1997; Hyvärinen and Oja, 2000)
- $\boldsymbol{X}_{(\boldsymbol{t}*\boldsymbol{p})} = \boldsymbol{A}_{(\boldsymbol{t}*\boldsymbol{n})}.\boldsymbol{S}_{(\boldsymbol{n}*\boldsymbol{p})}$

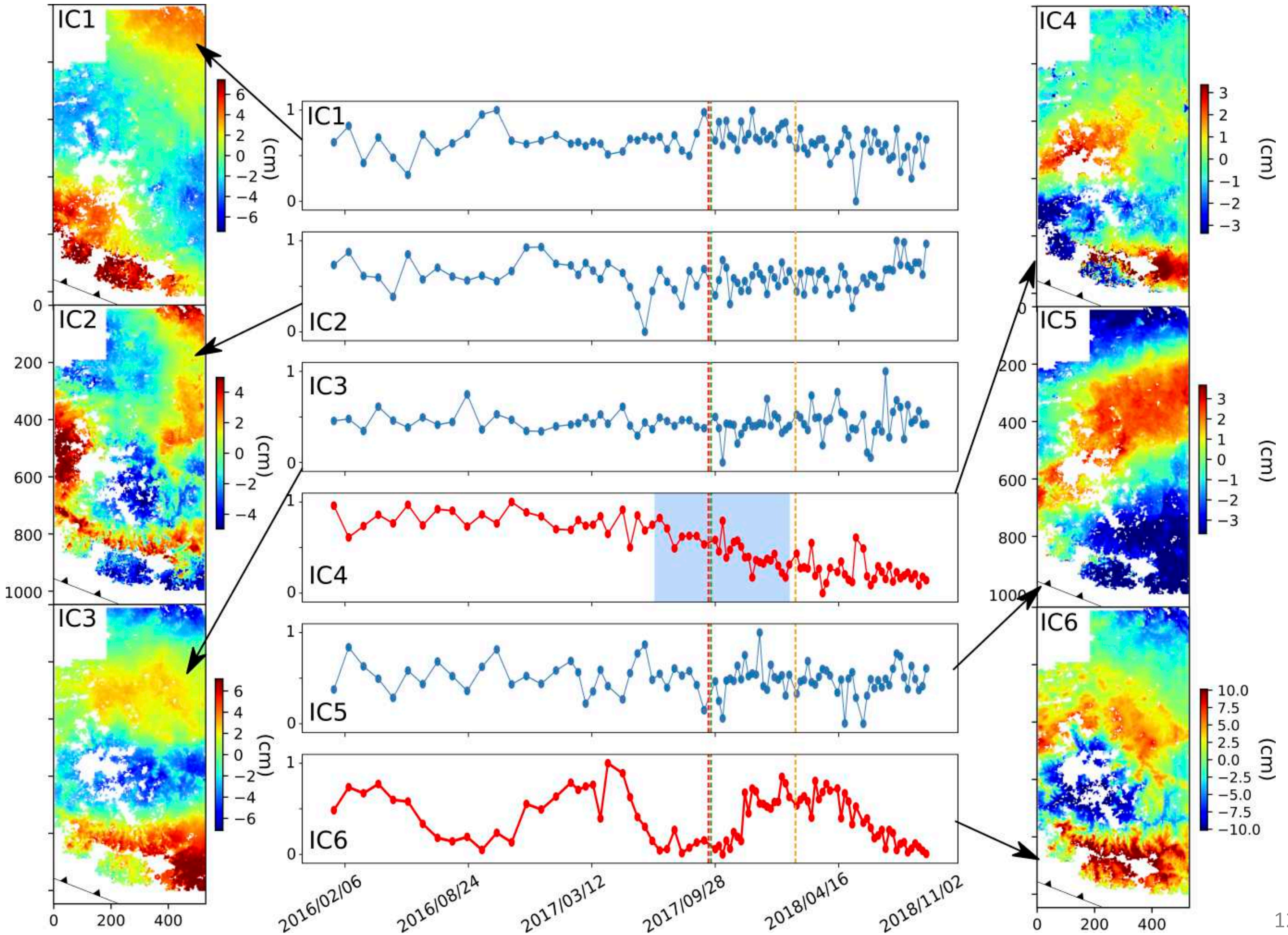


Modified from Ebmeier, S. 2016

ICA decomposition: Results

- IC4: temporal evolution and spatial pattern similar to the 2017-2018 SSE

- IC6: temporal evolution similar to the ZTD-PCA and spatial pattern similar to the topography

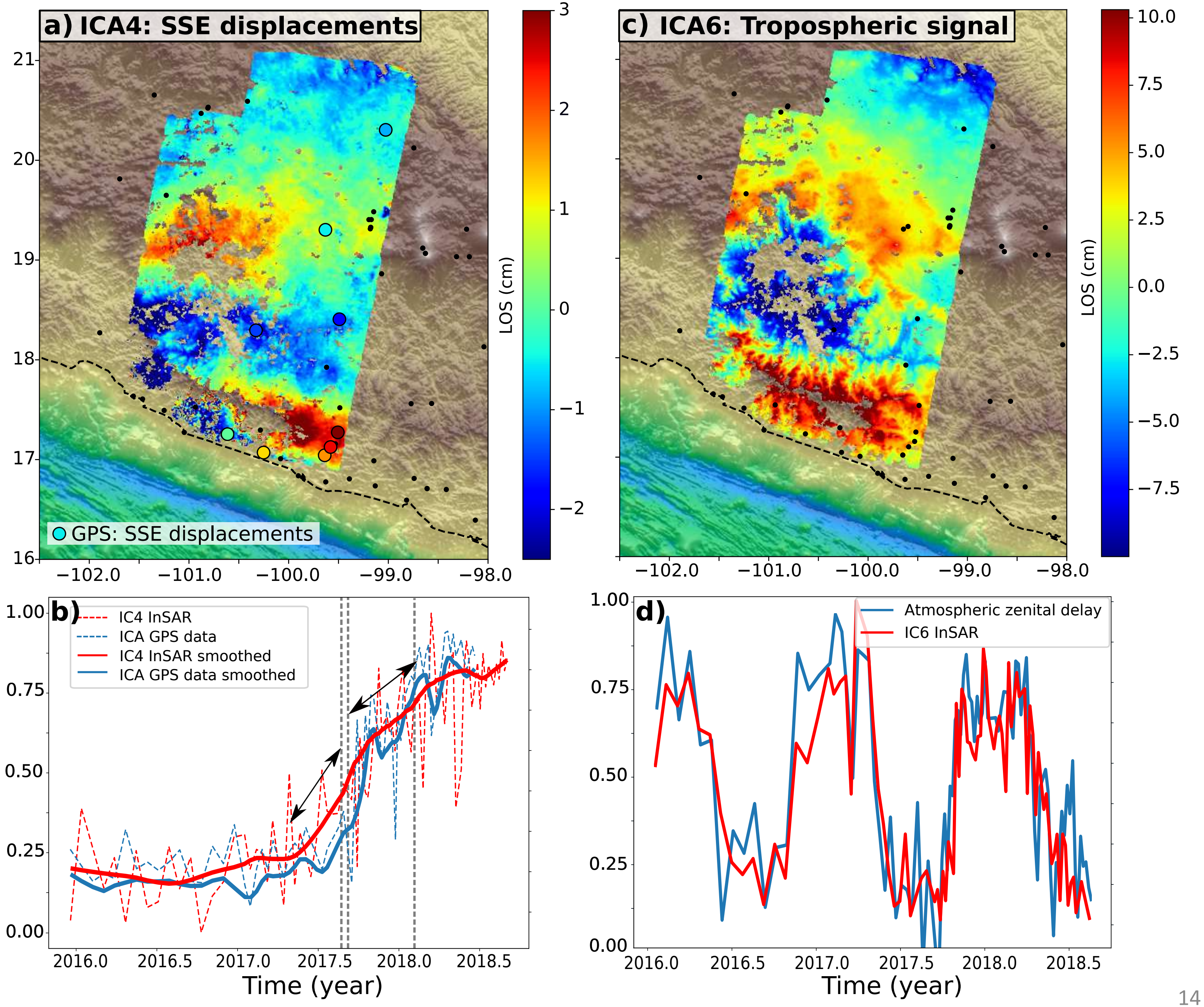


Validation of ICA components

ICA:

- One component in agreement with the zenithal delay
- One component in agreement with the GPS displacement during the SSE

- **SSE complex**
  - 2 slopes controlled by Sept. EQ

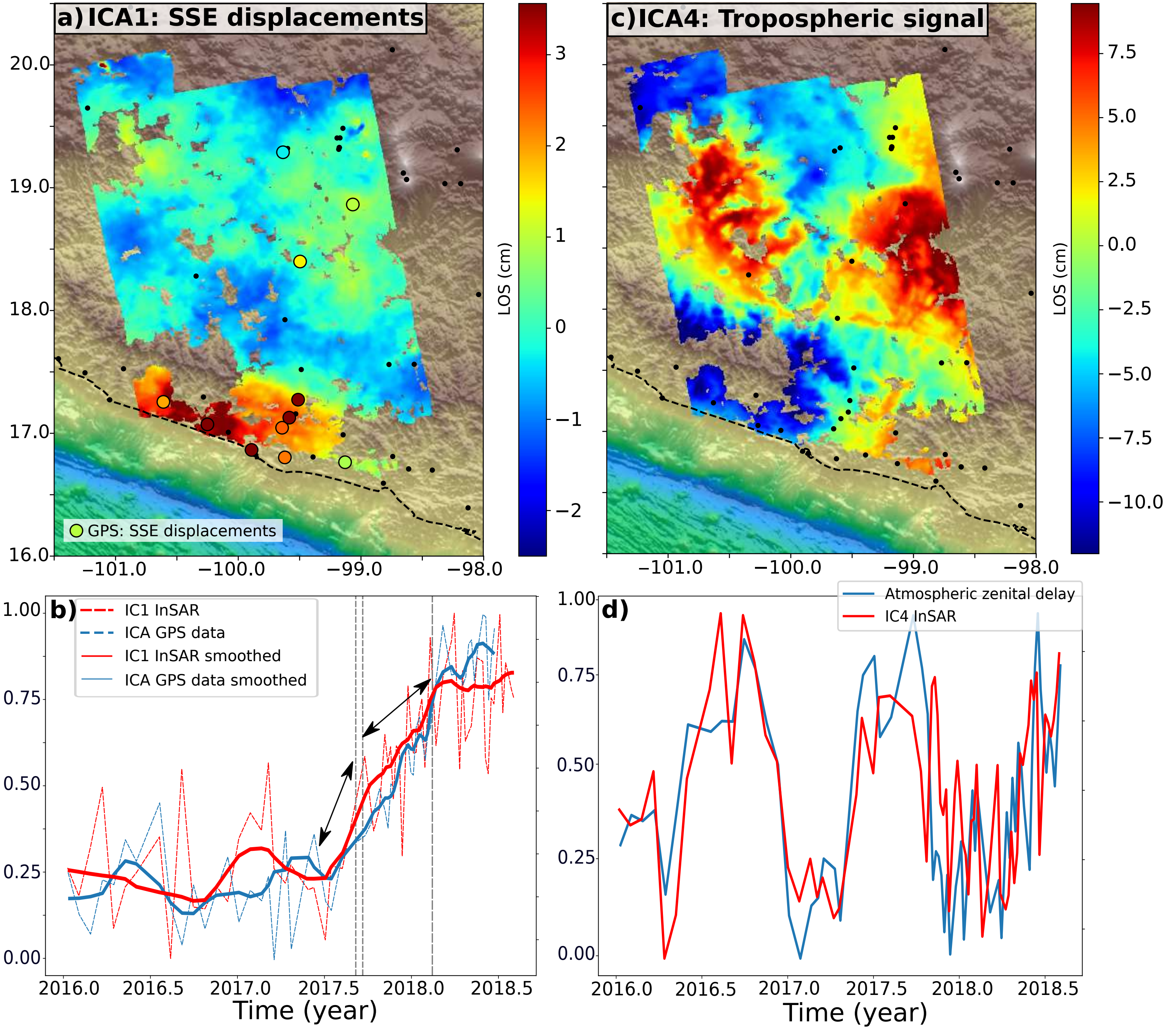


Validation of ICA components

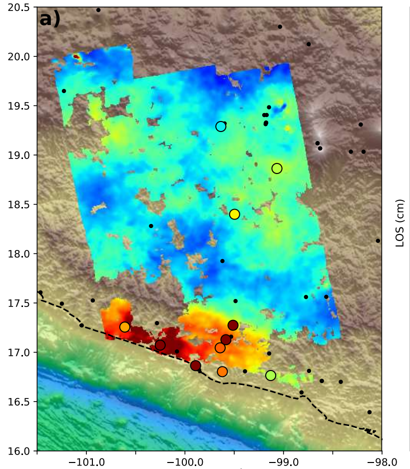
<u>ICA:</u>

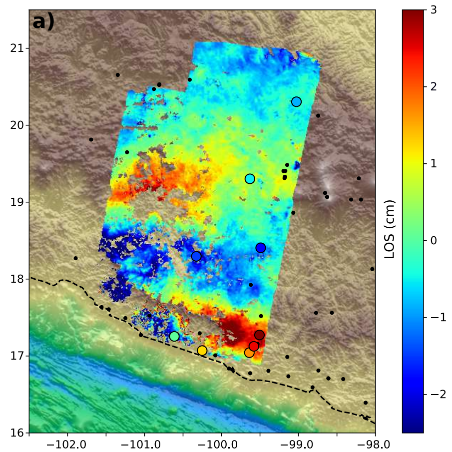
- One component in agreement with the zenithal delay
- One component in agreement with the GPS displacement during the SSE and with the parametrized decomposition

- **<u>SSE complex</u>**
  - 2 slopes controlled by Sept. EQ



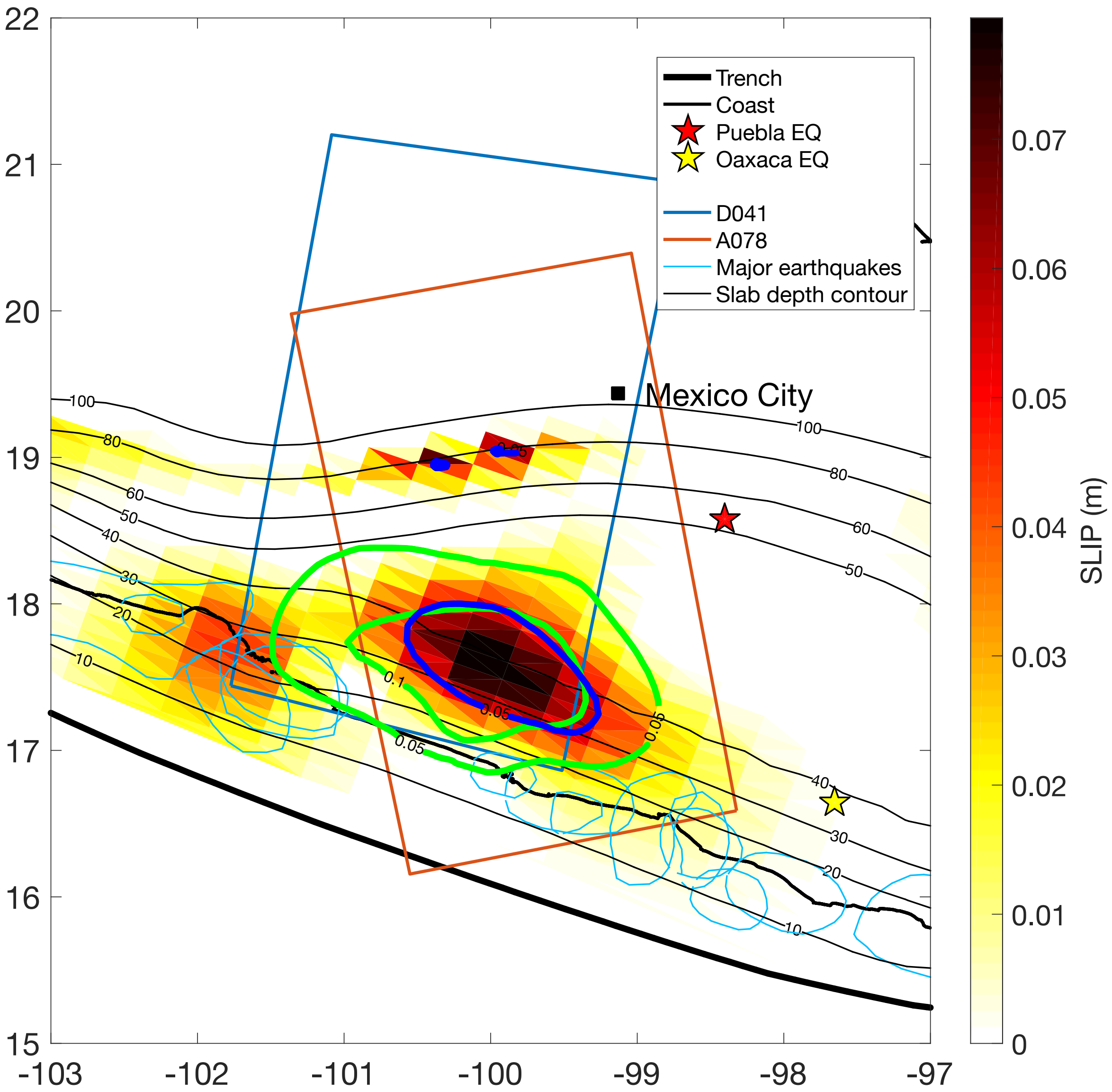
Modelling





Static inversion (PCAIM)

- Equivalent **Mw: 7.2**
  - Smaller than previous event
  - Location similar
- Maximum Slip at the depth: 8 cm
- $\chi^2 = 0.23$



Conclusion

- Both methods allow to extract a coherent tectonic signal
- **ICA** does not require a priori on the searched signal
- **ZTD-GPS** is efficient to charcterize the atmospheric signal

- <u>**SSE of 2017-2018**</u>
  - <u>Complex</u> SSE with at least <u>2 phases</u>
  - <u>Interaction</u> with the seismic sequence of Sept. 2017