

# Using independent component analysis (ICA) with time series of InSAR data to monitor volcanoes

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SUSI EBMEIER<sup>1</sup>

LIN SHEN<sup>1</sup>

RICHARD RIGBY<sup>2</sup>



**COMET**

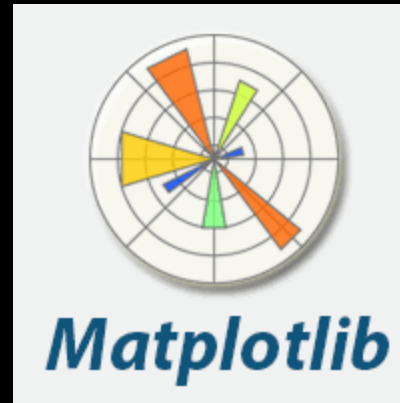
CENTRE FOR OBSERVATION & MODELLING  
OF EARTHQUAKES, VOLCANOES & TECTONICS



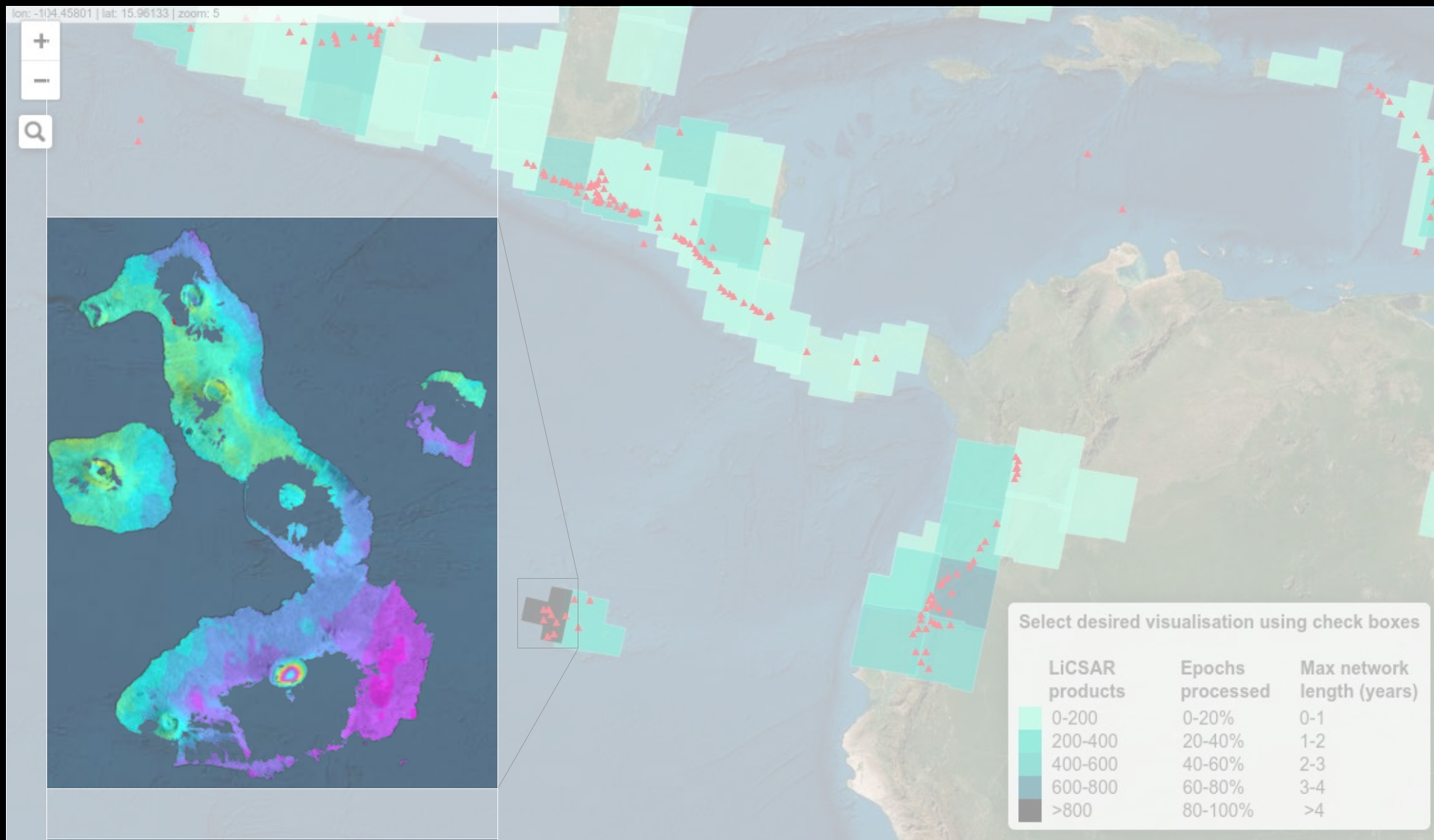
<sup>1</sup>COMET, School of Earth and Environment, University of Leeds, U.K.

<sup>2</sup>CEMAC, School of Earth and Environment, University of Leeds, U.K.

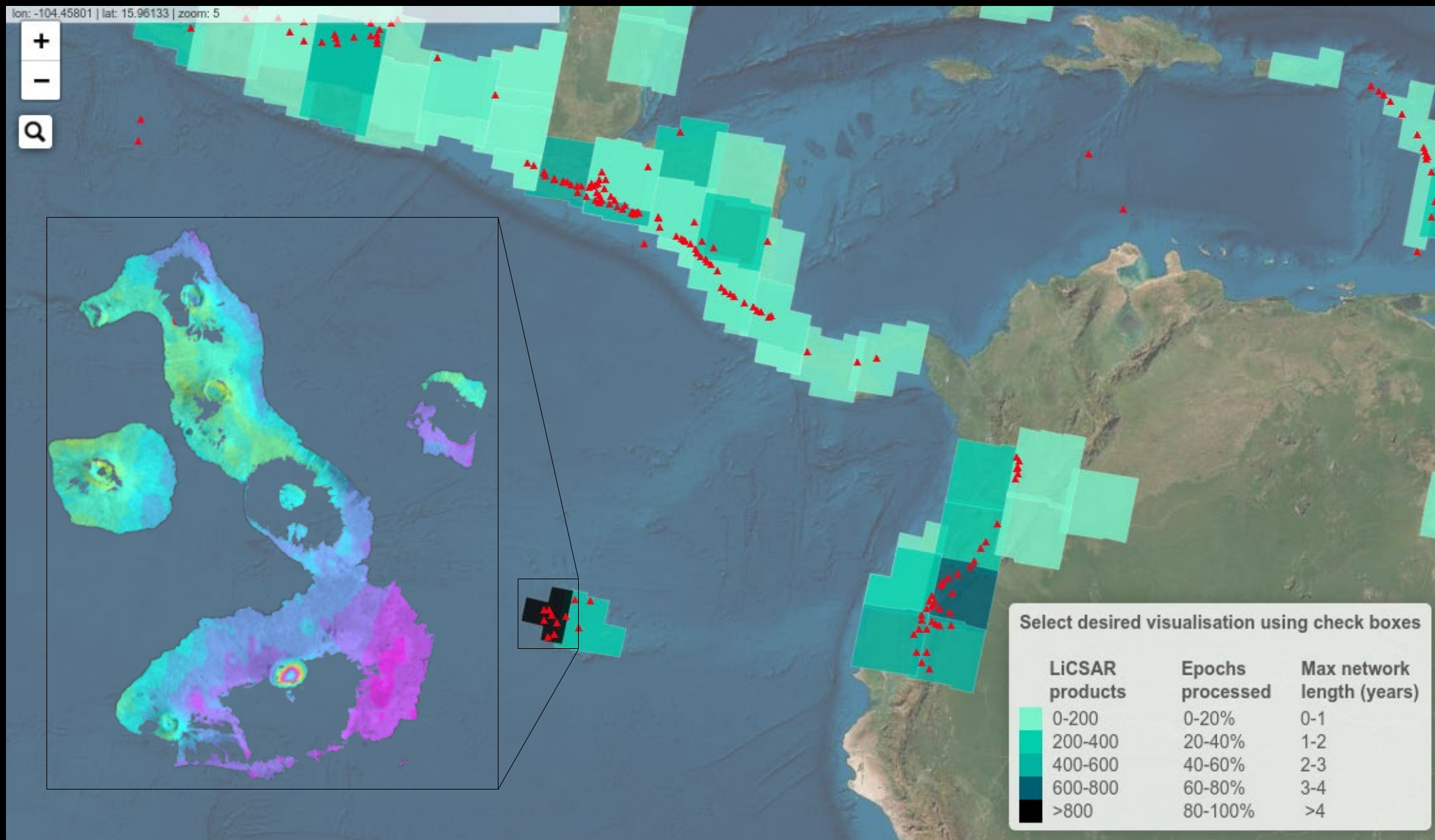
Image: European Space Agency.



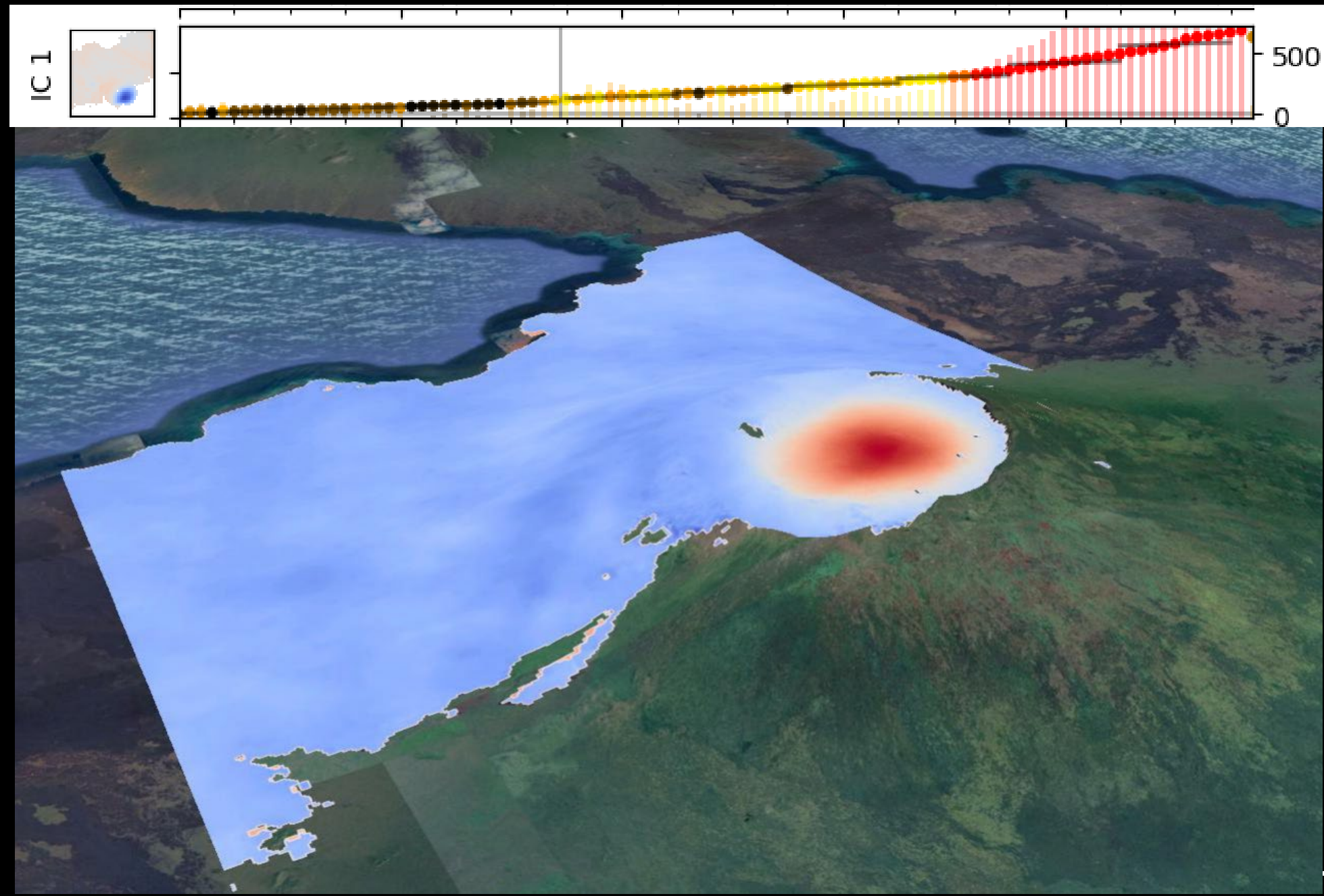
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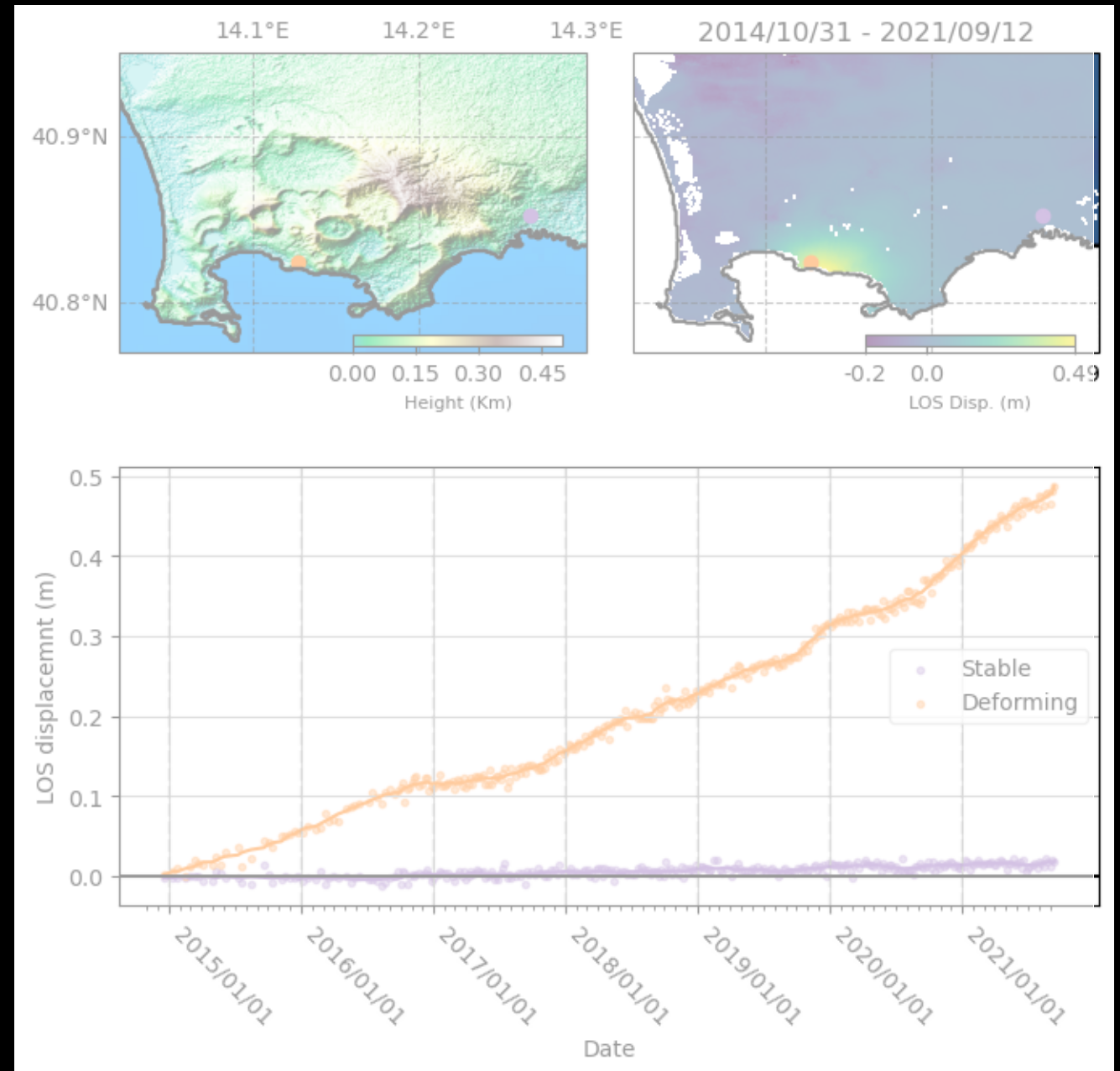


# Previous results: isolating large deformation and detecting changes in rate



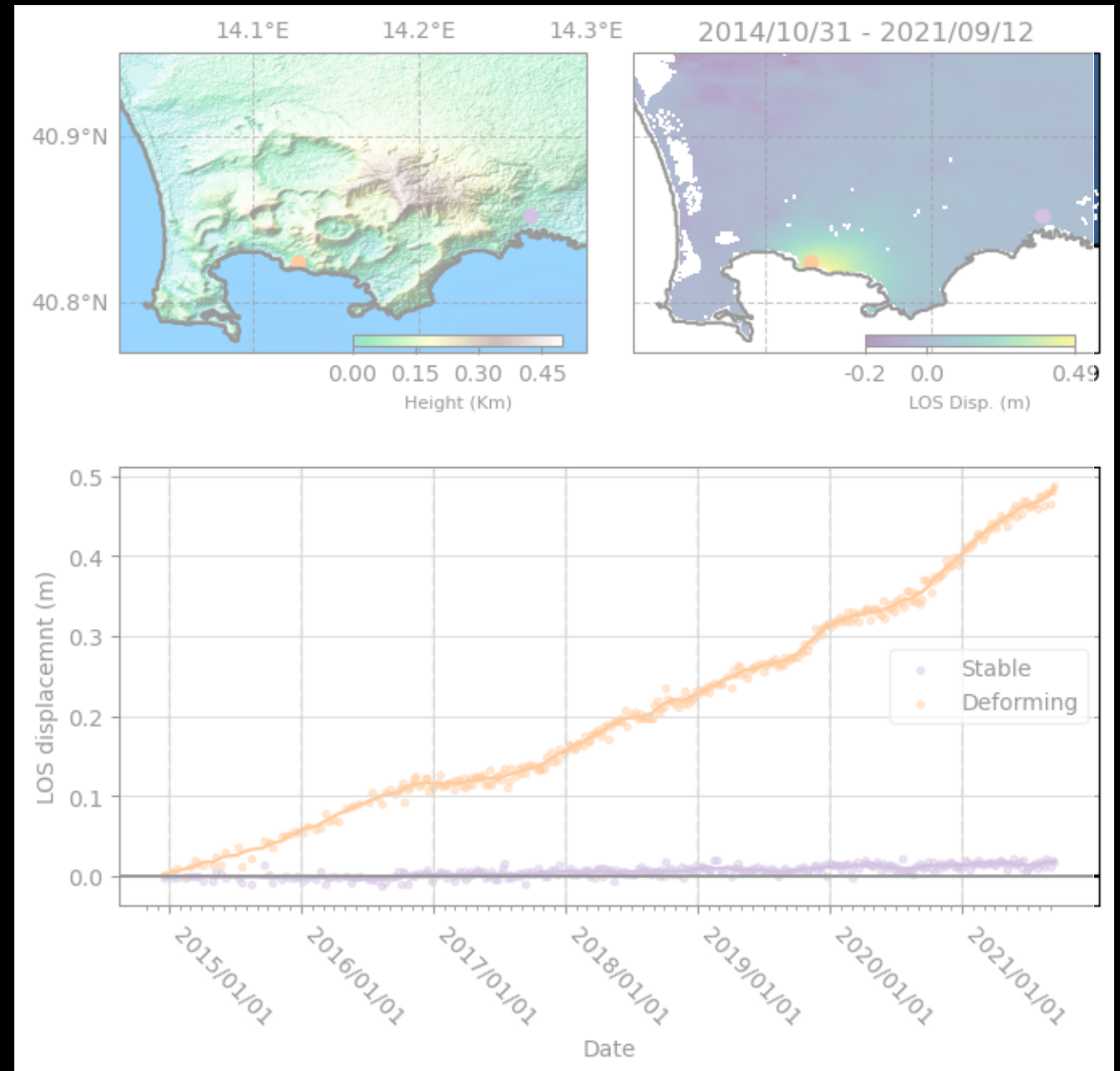
# Our new monitoring algorithm: LiCSAlert

- Increase the variance of deformation signals to recover them.
- Apply ICA temporally at stratovolcanoes.
- Visualise status for large number of volcanoes (using deep learning).
- Apply globally by implementing on JASMIN computing system



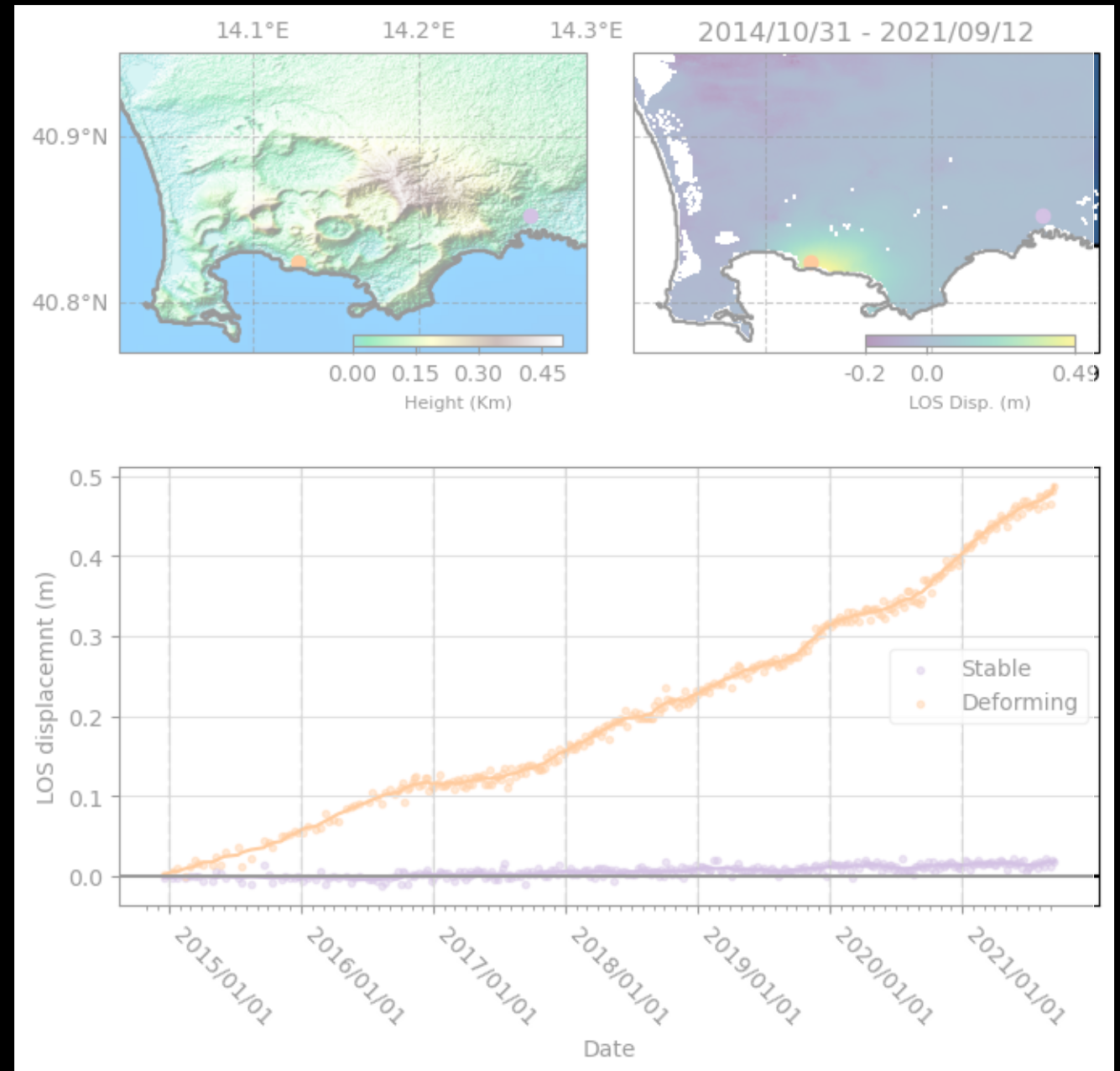
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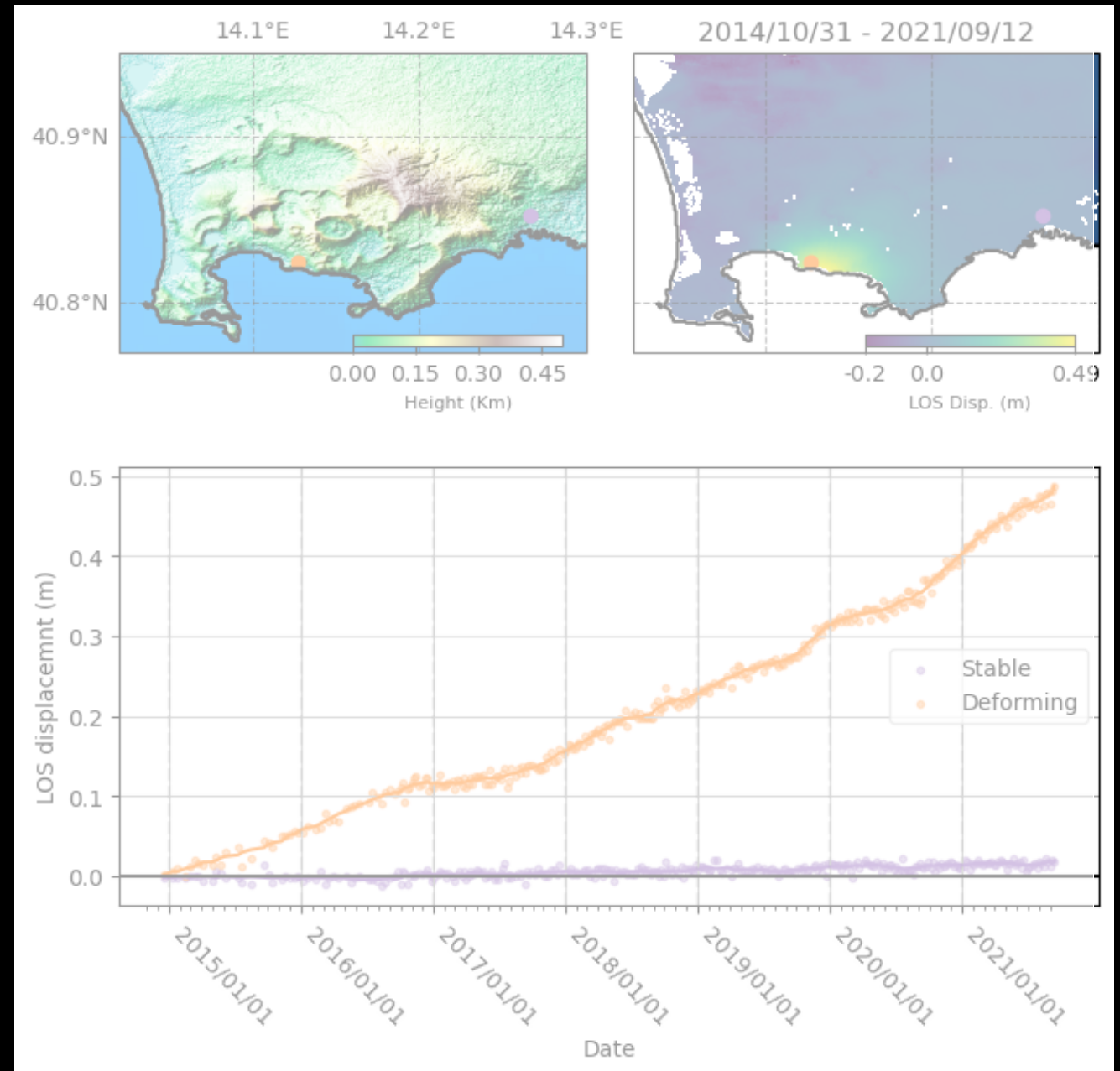
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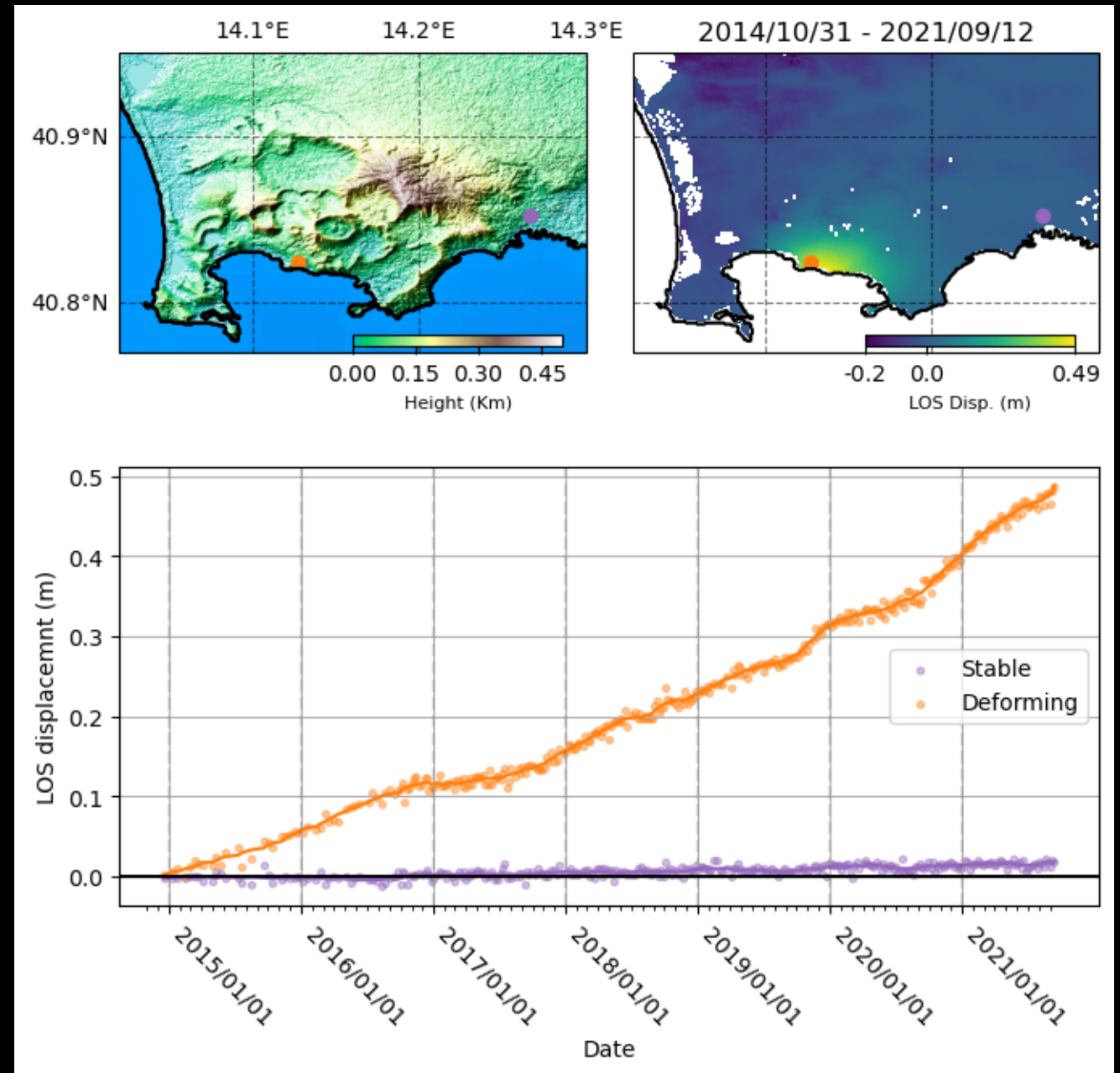
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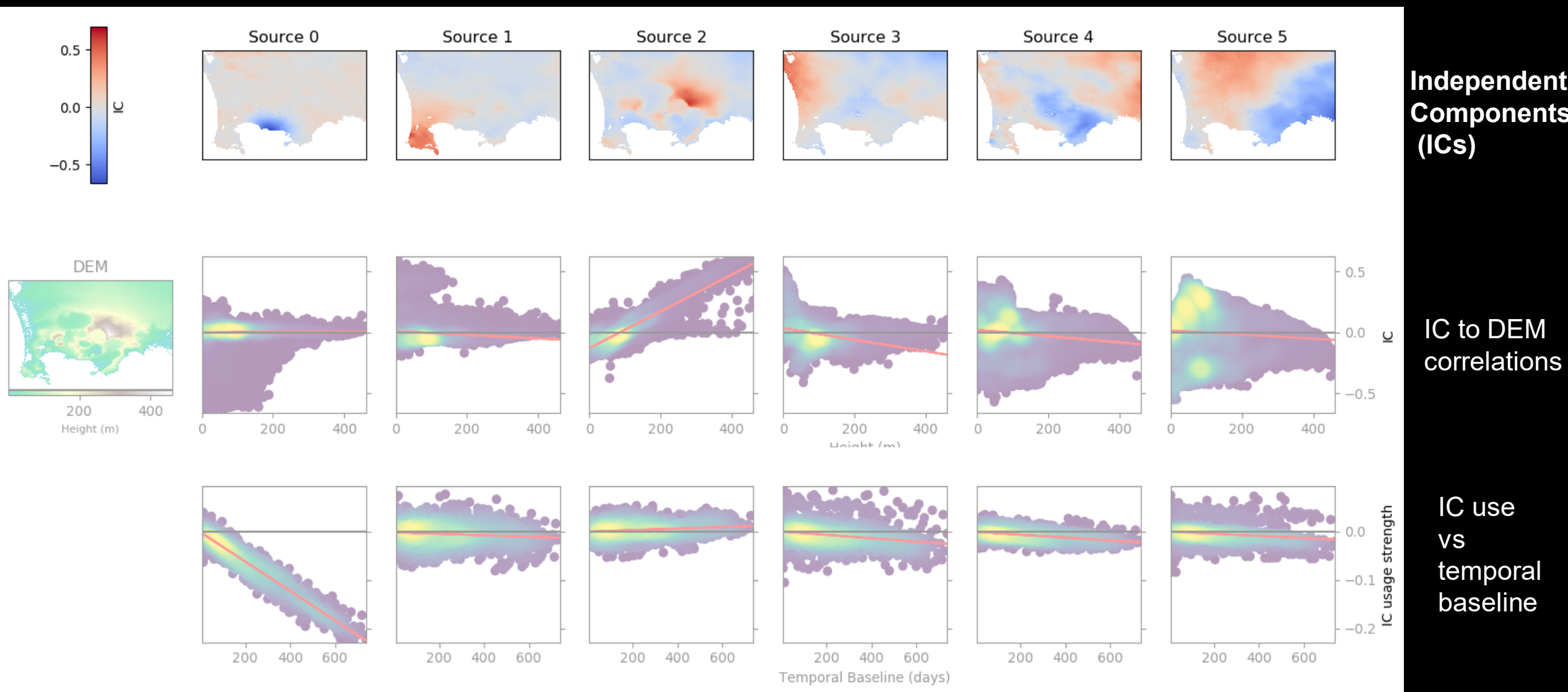
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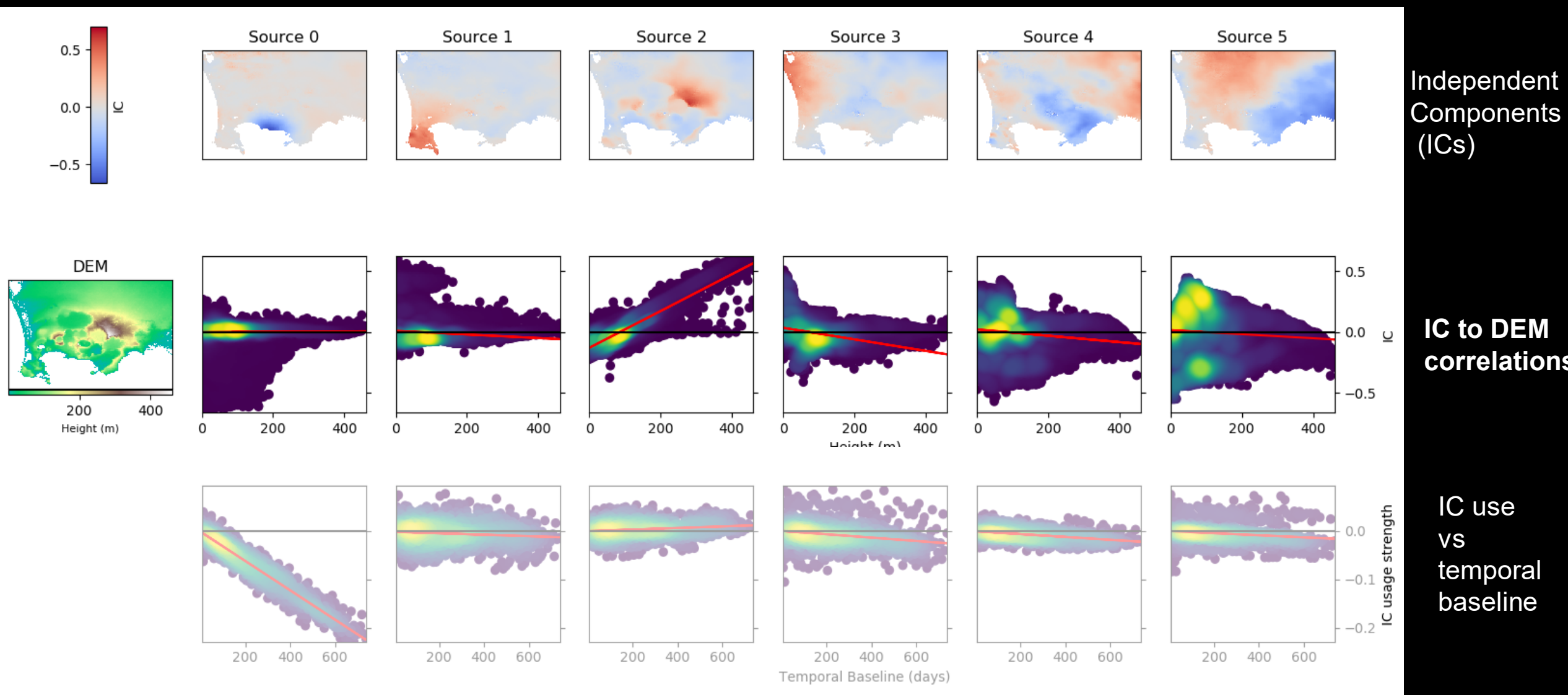
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- Create a network of interferograms that maximises deformation variance.



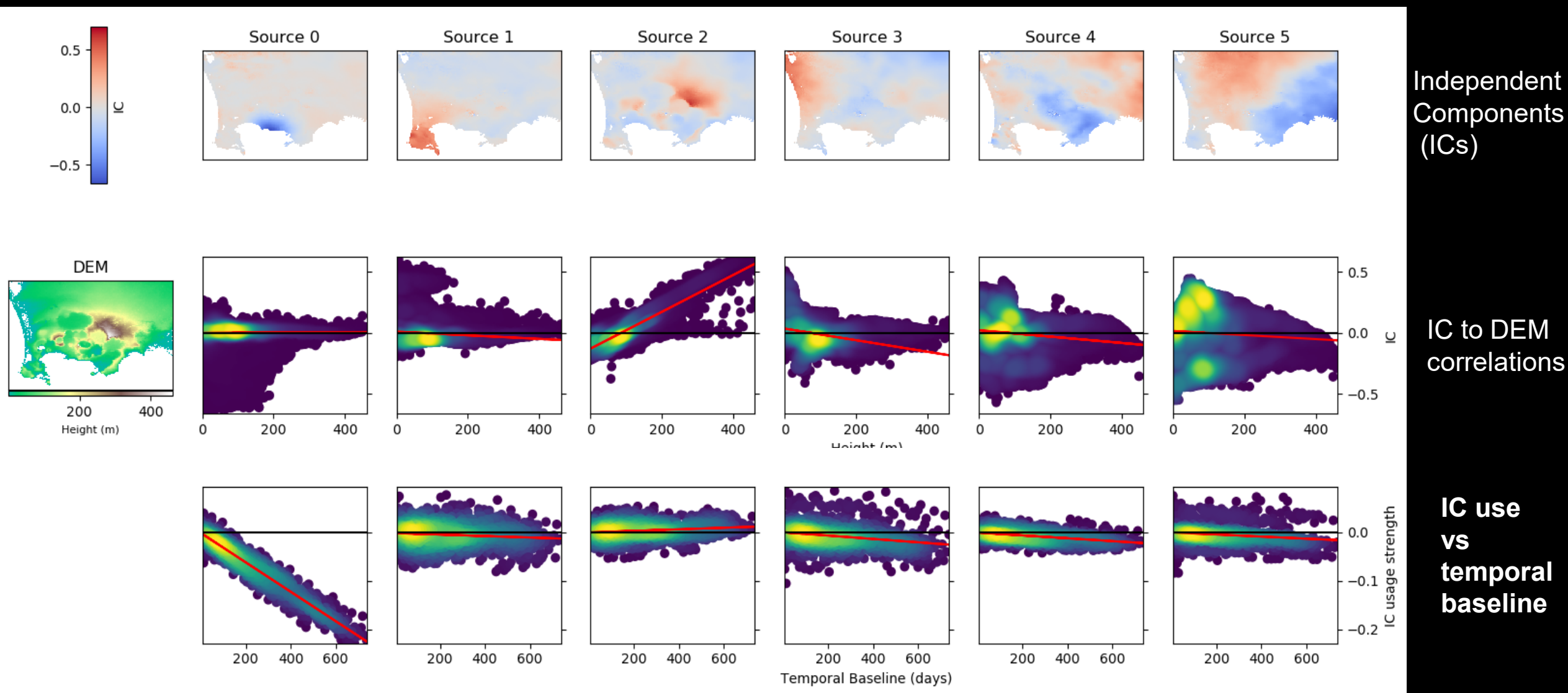
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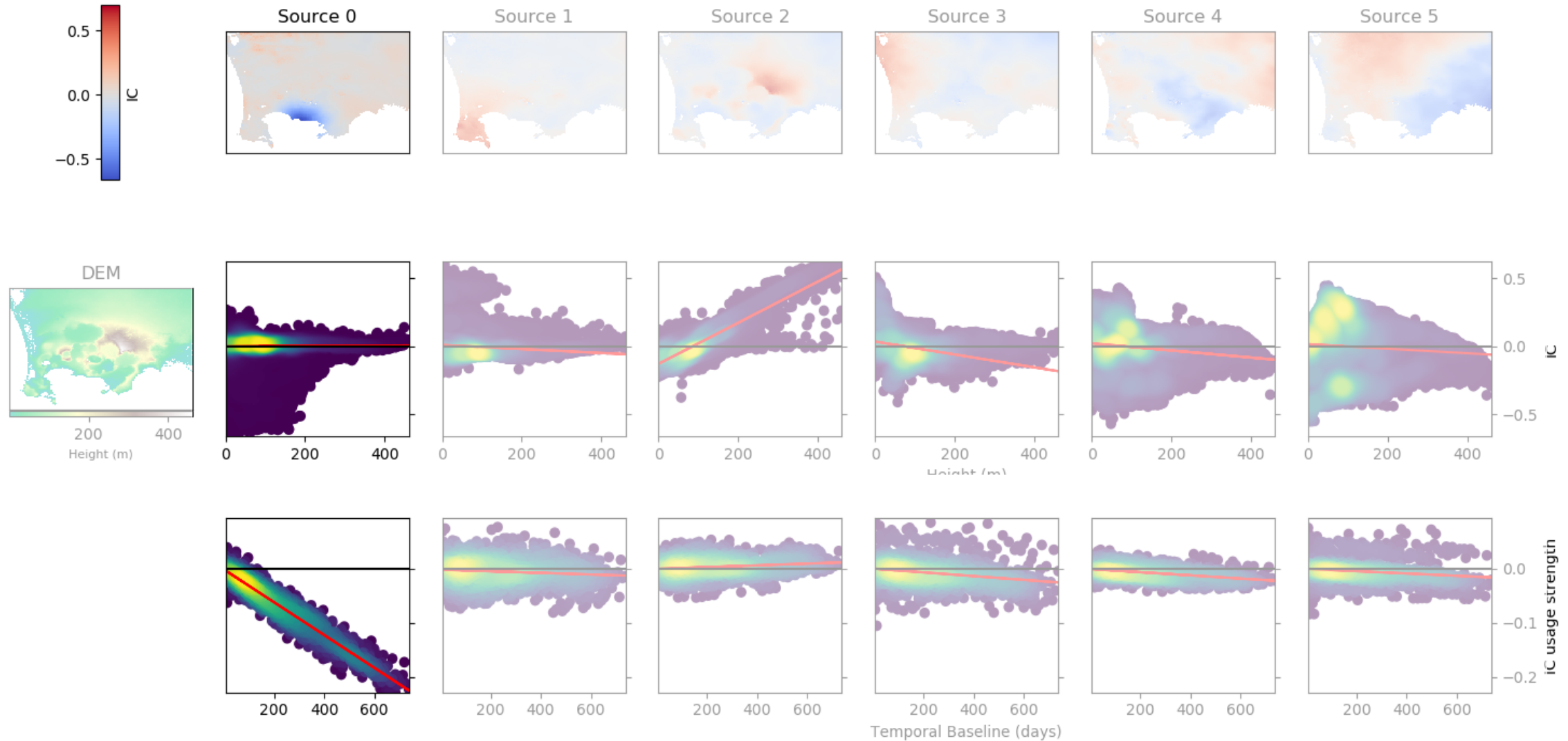
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## Deformation



Independent Components (ICs)

IC to DEM correlations

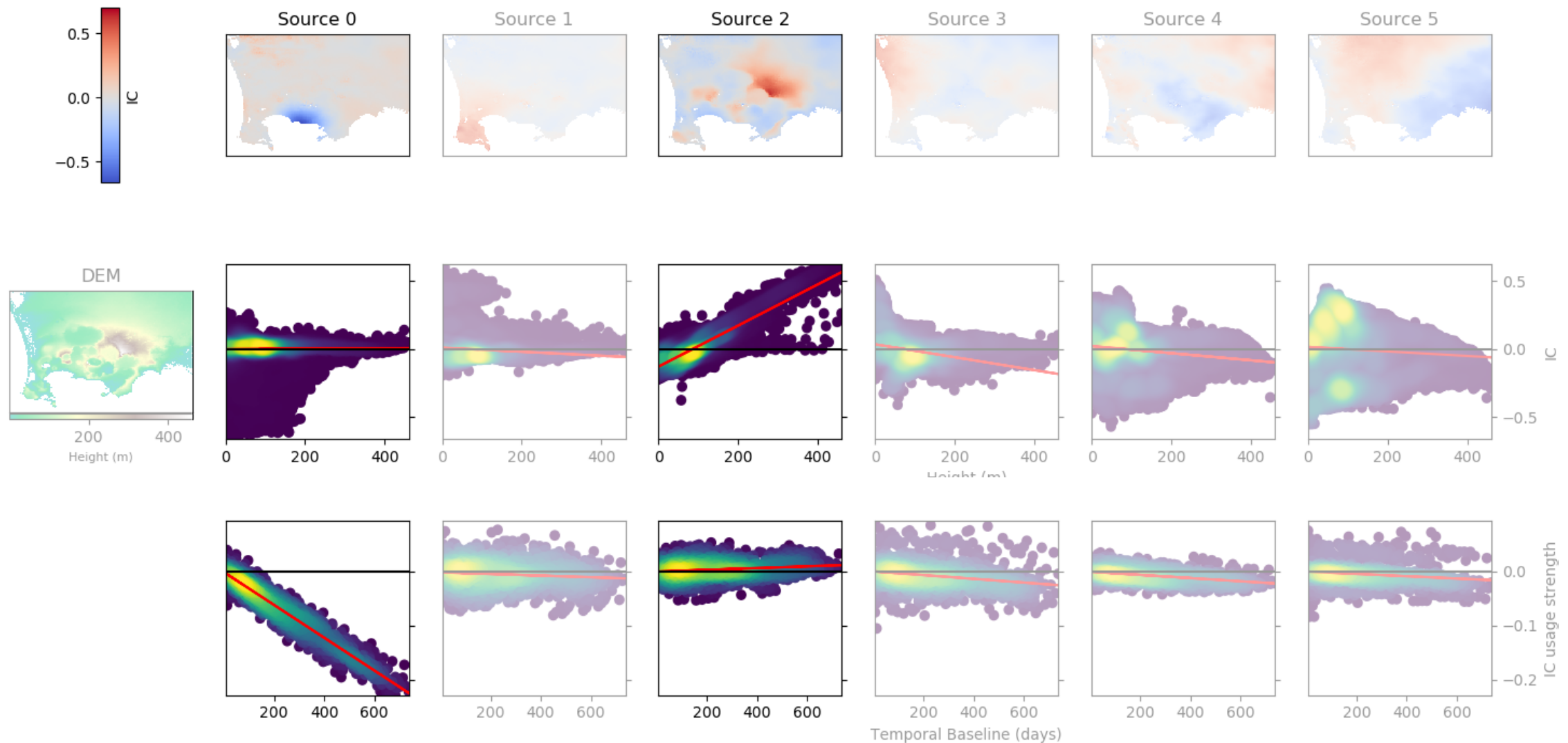
IC use vs temporal baseline

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Deformation

Topographically correlated  
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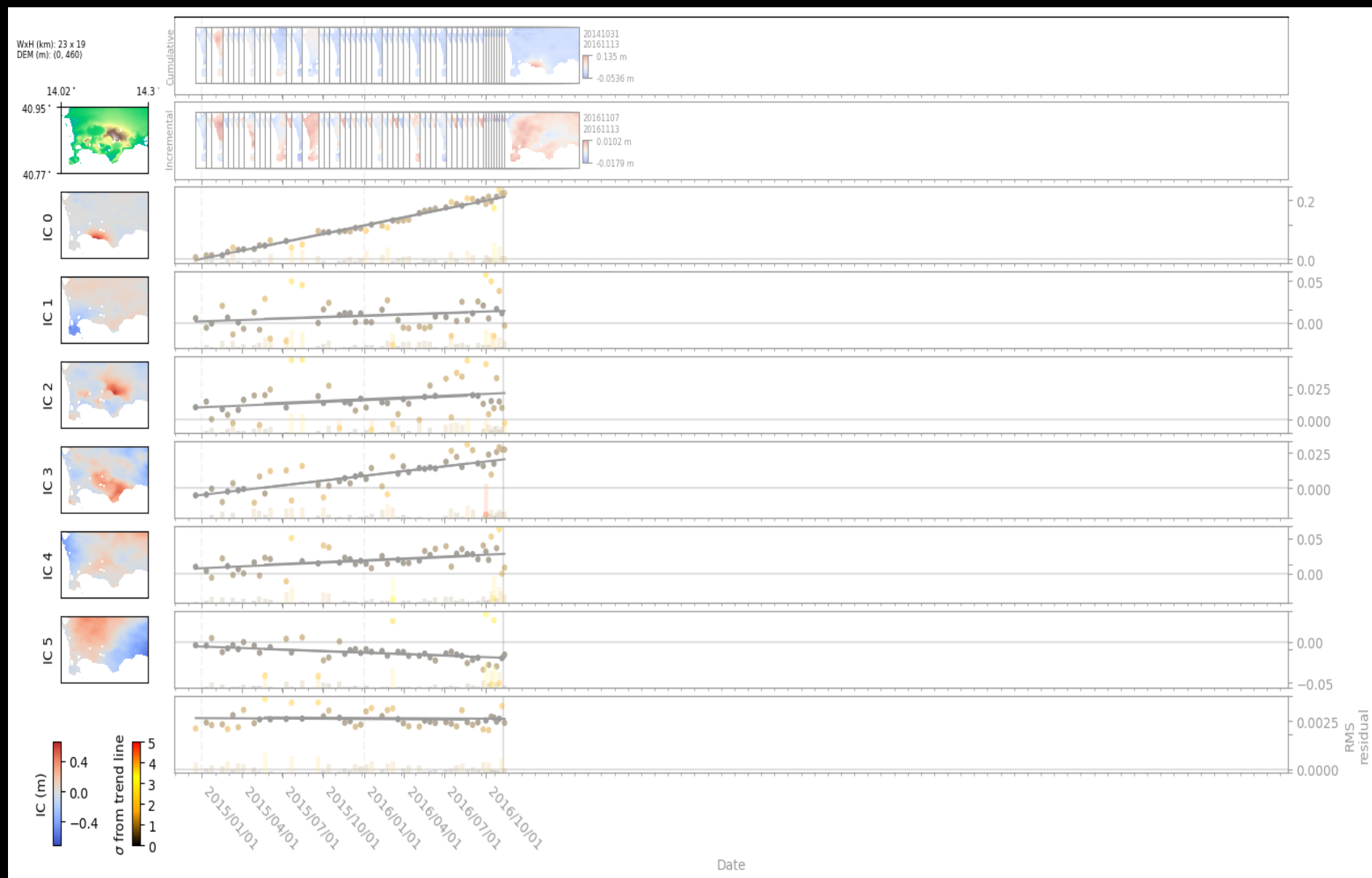
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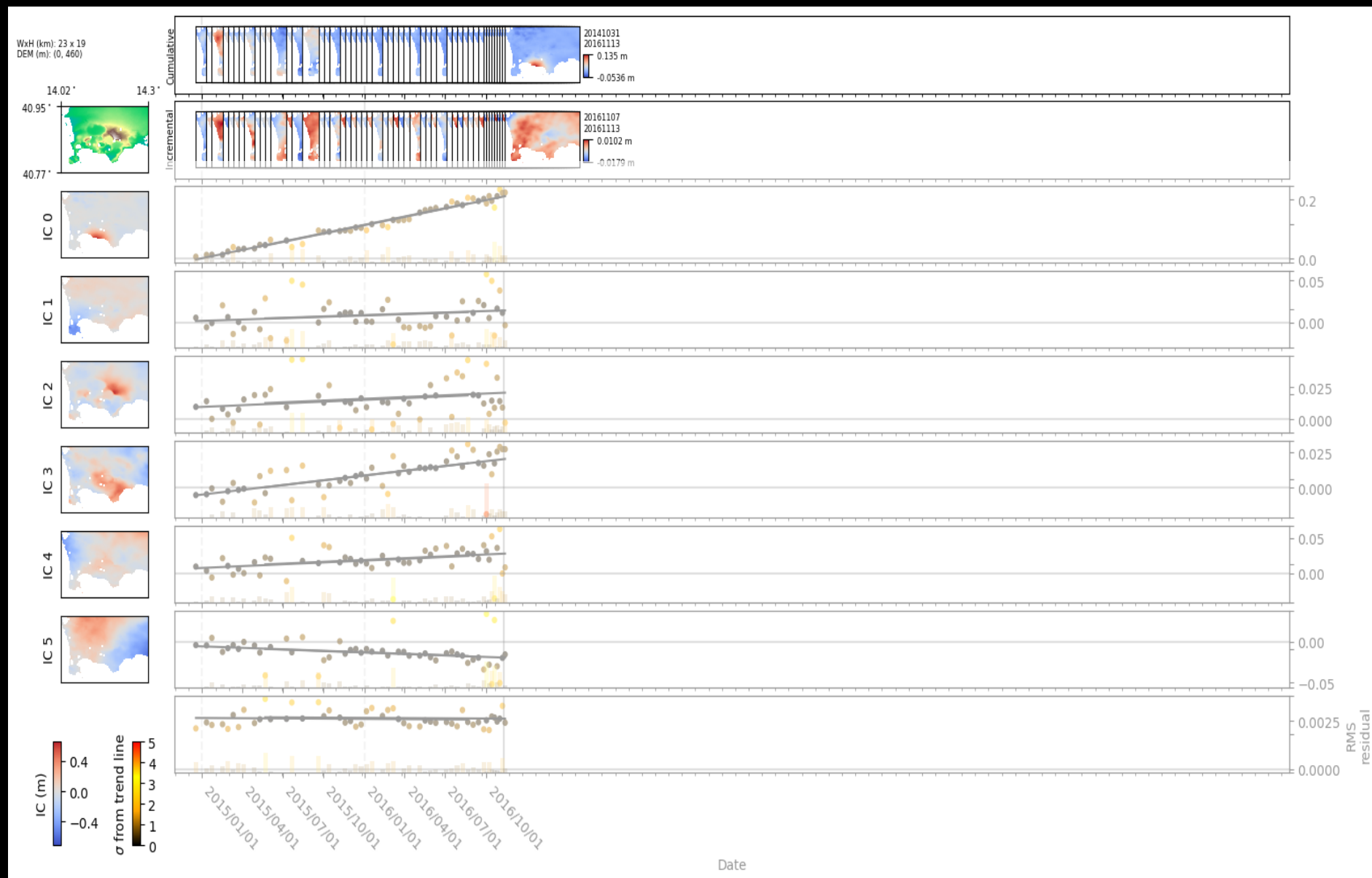
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- Invert to fit each interferogram using ICs
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- Fit linear trend through IC time courses and residual.
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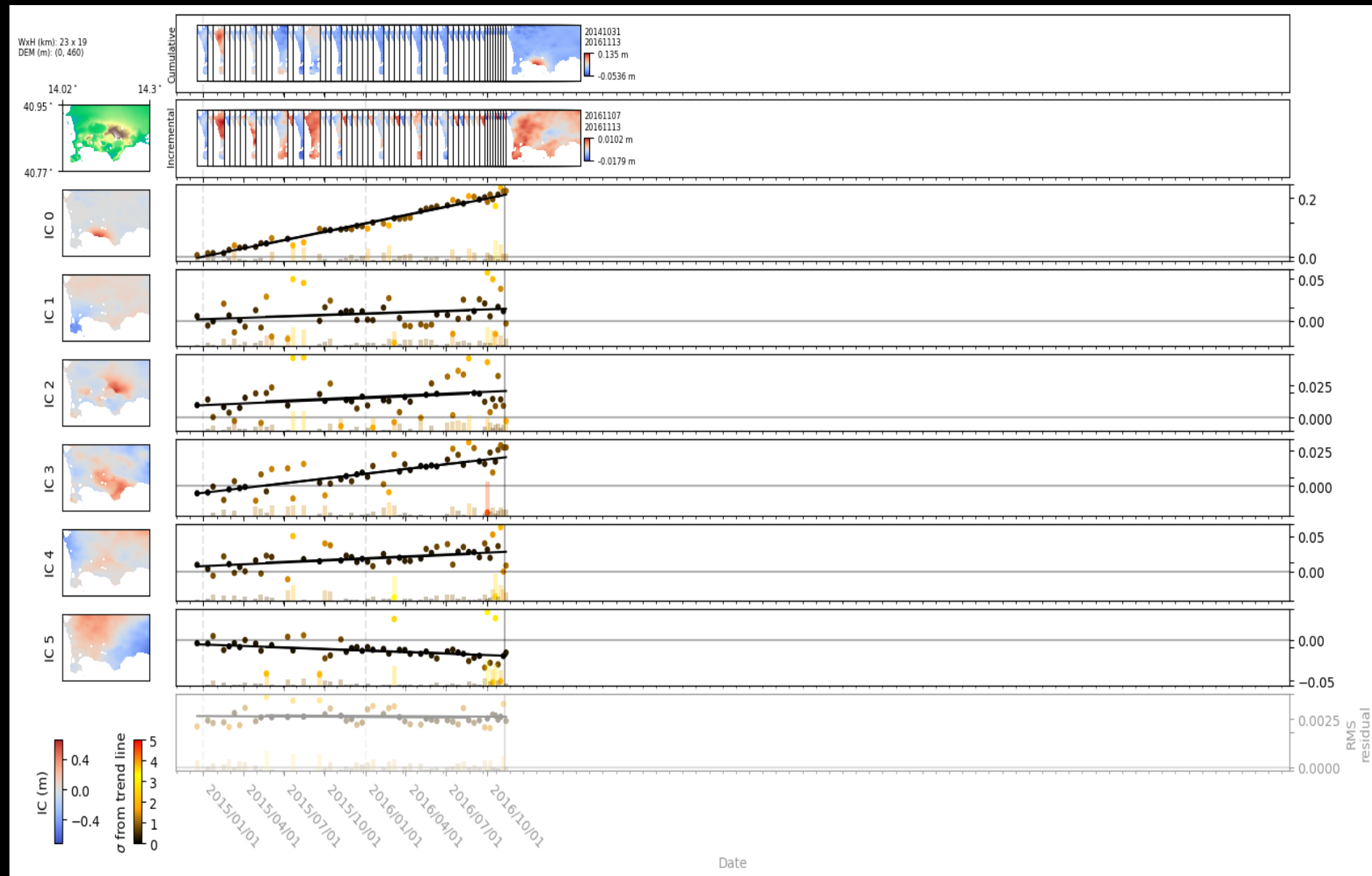
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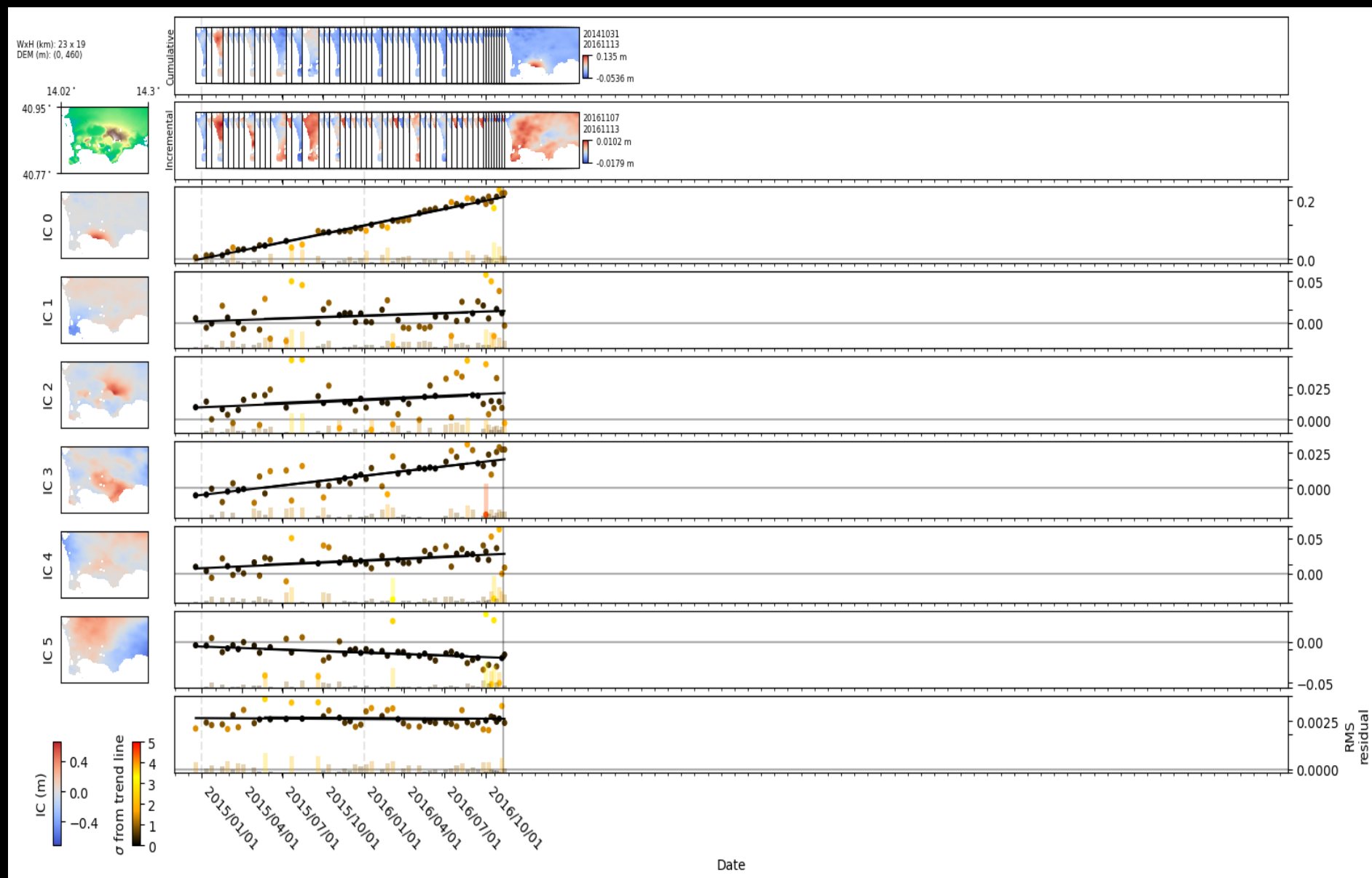
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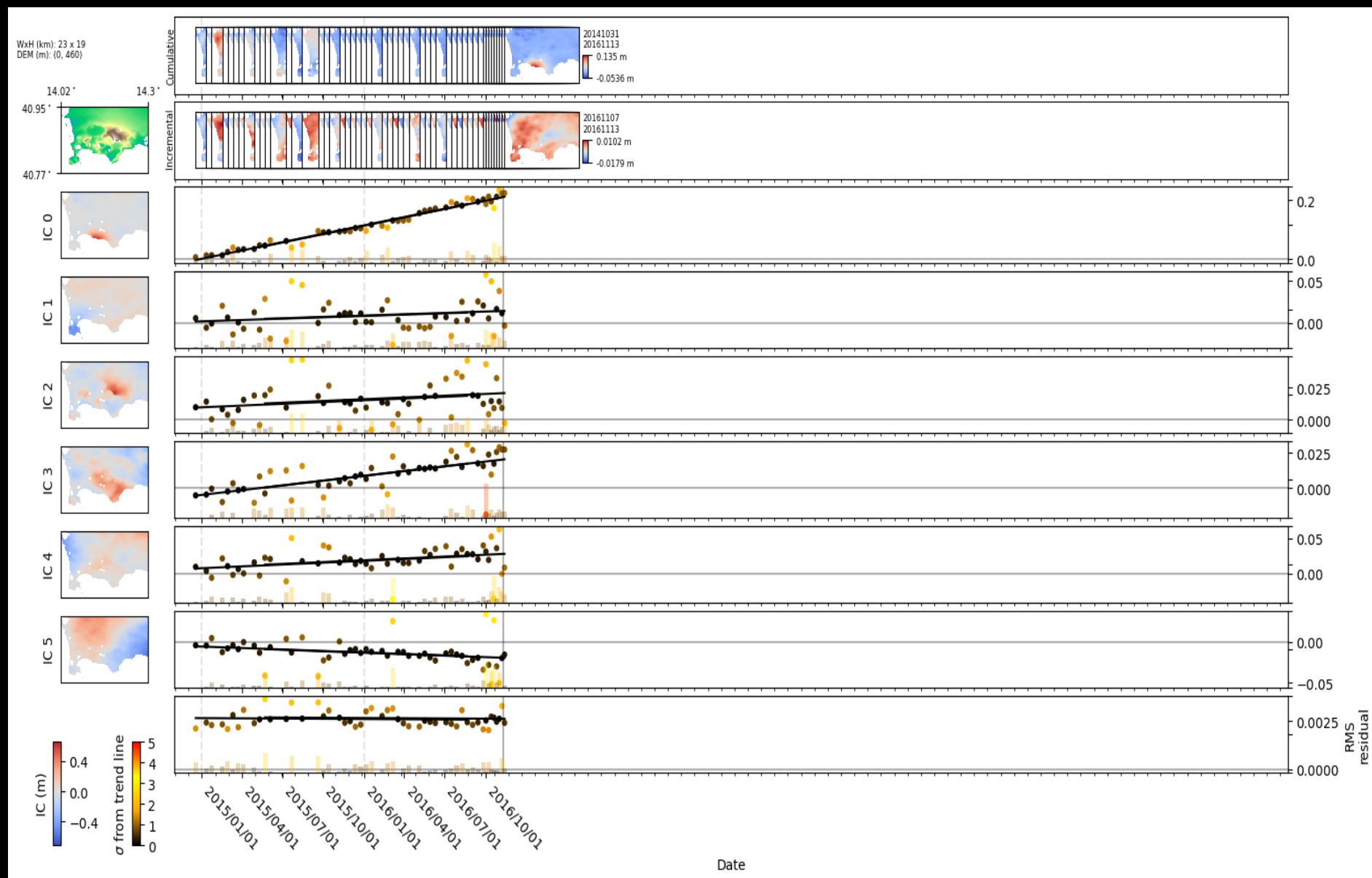
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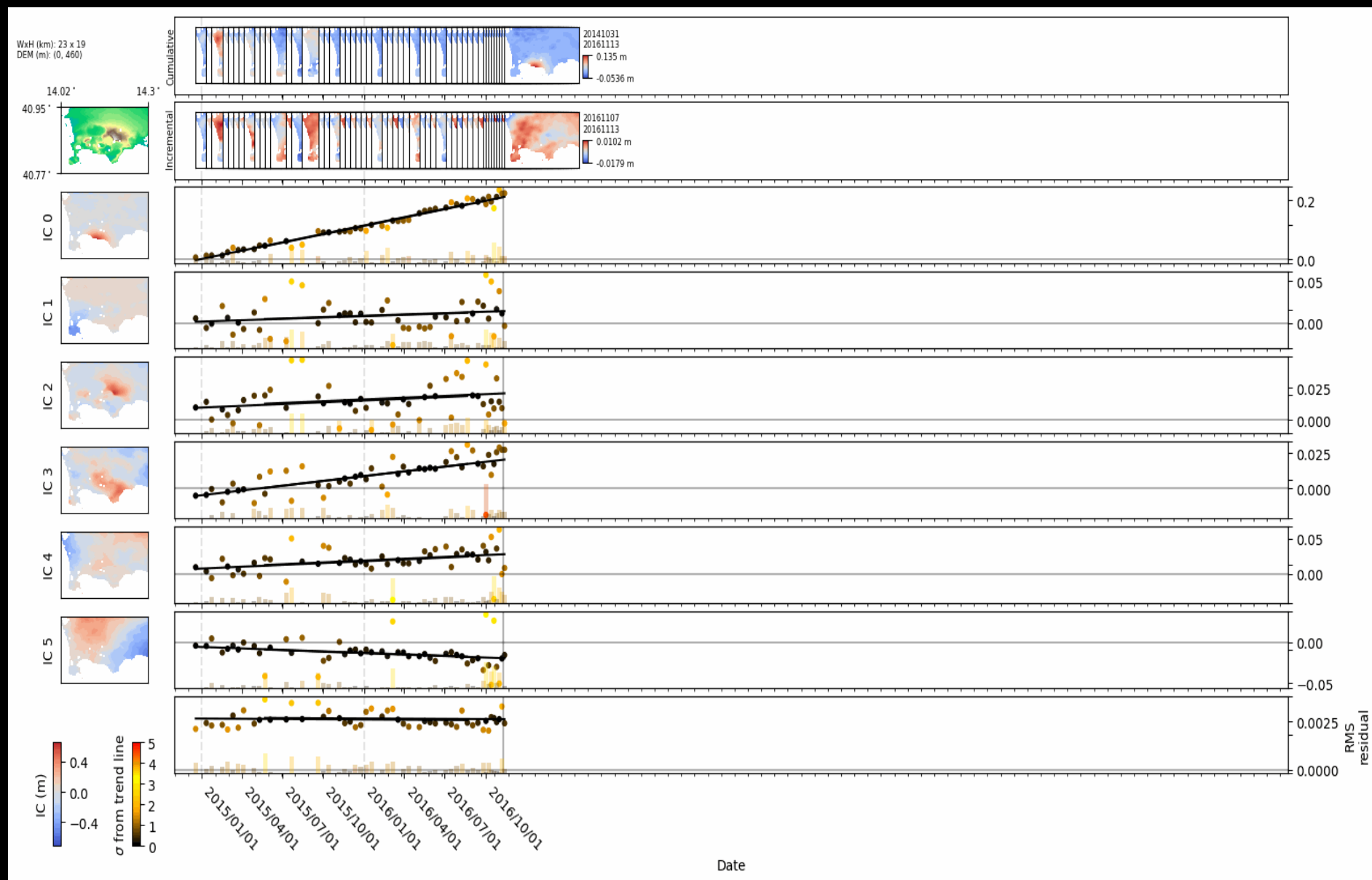
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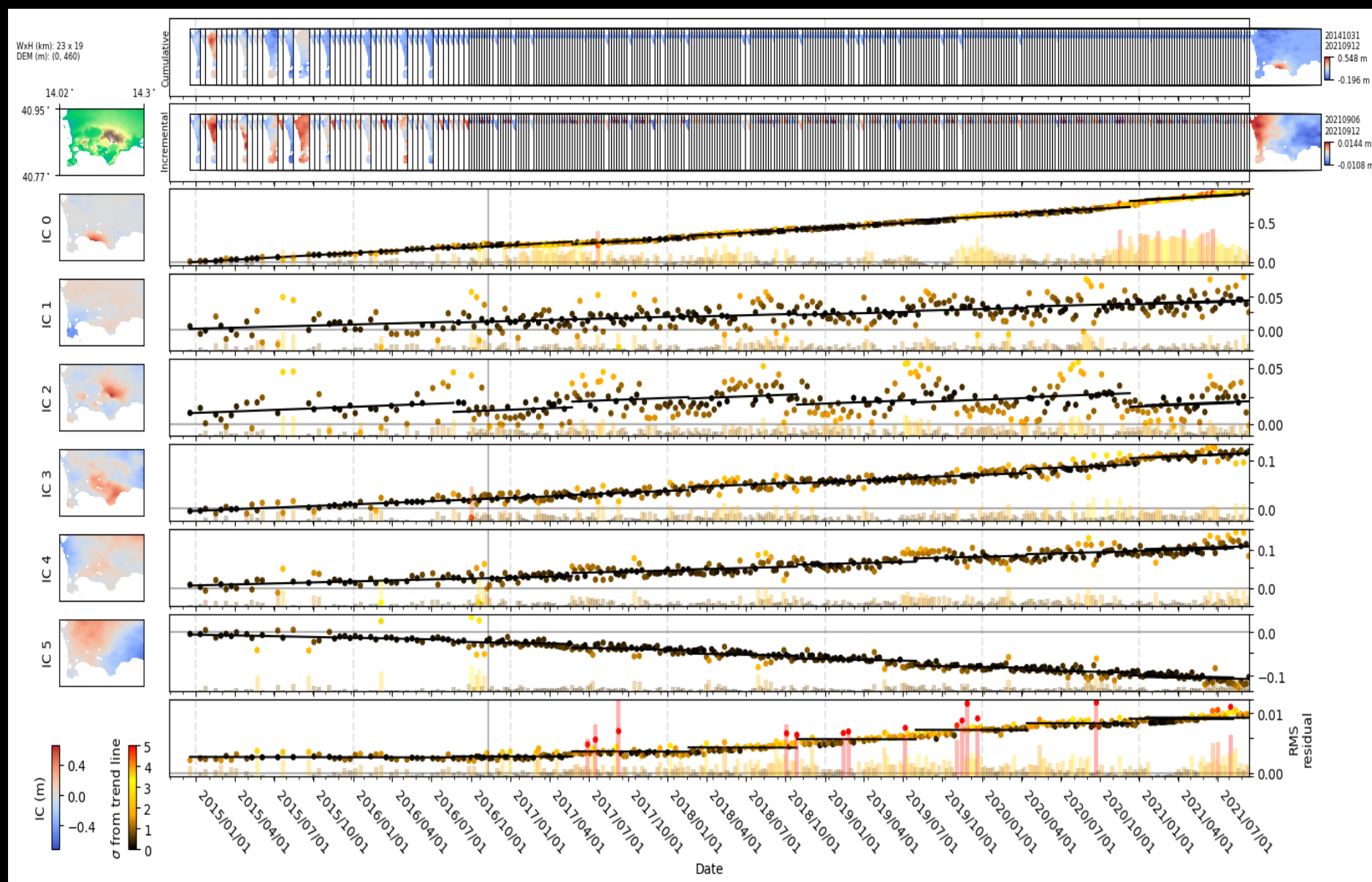
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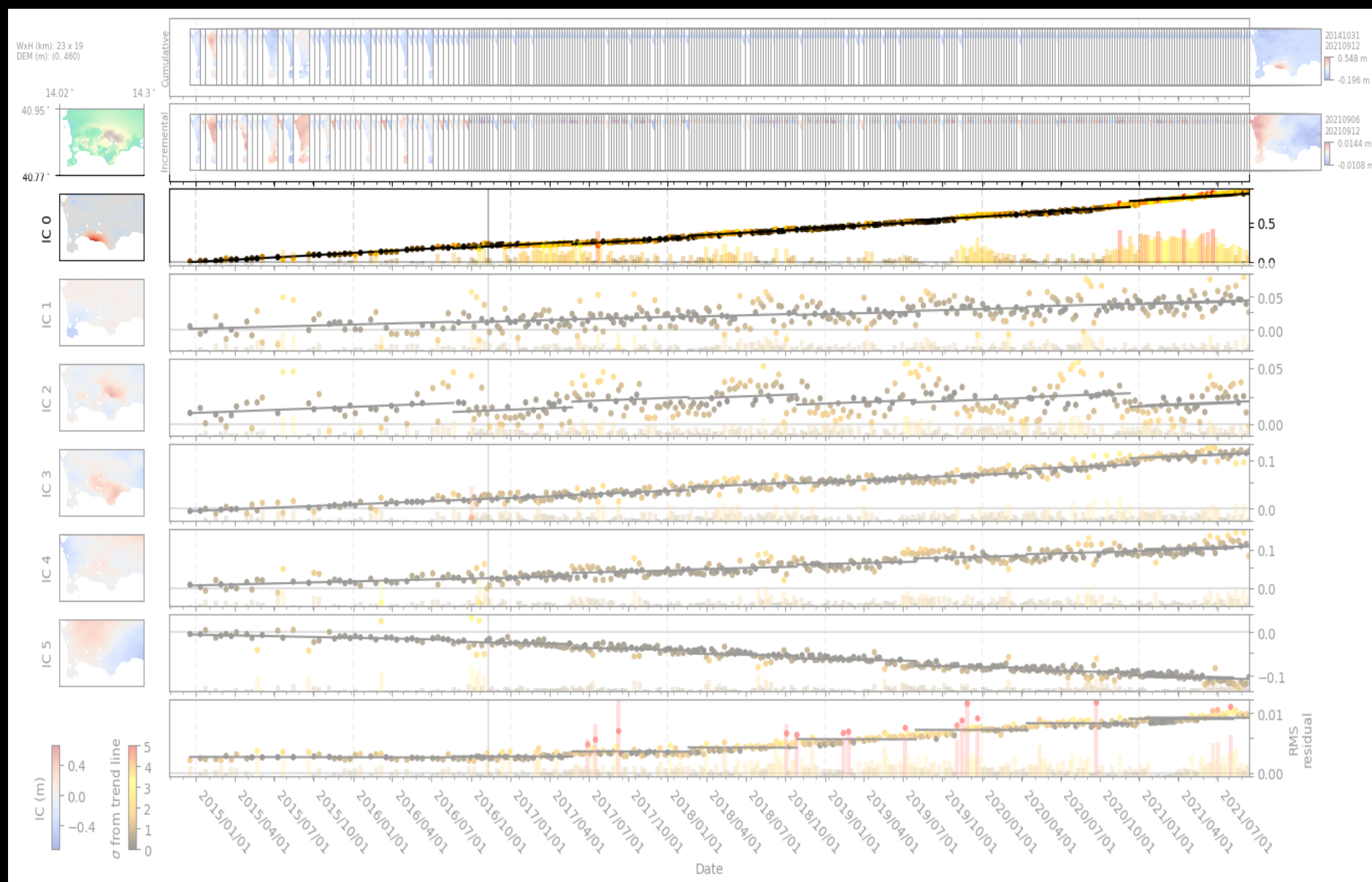


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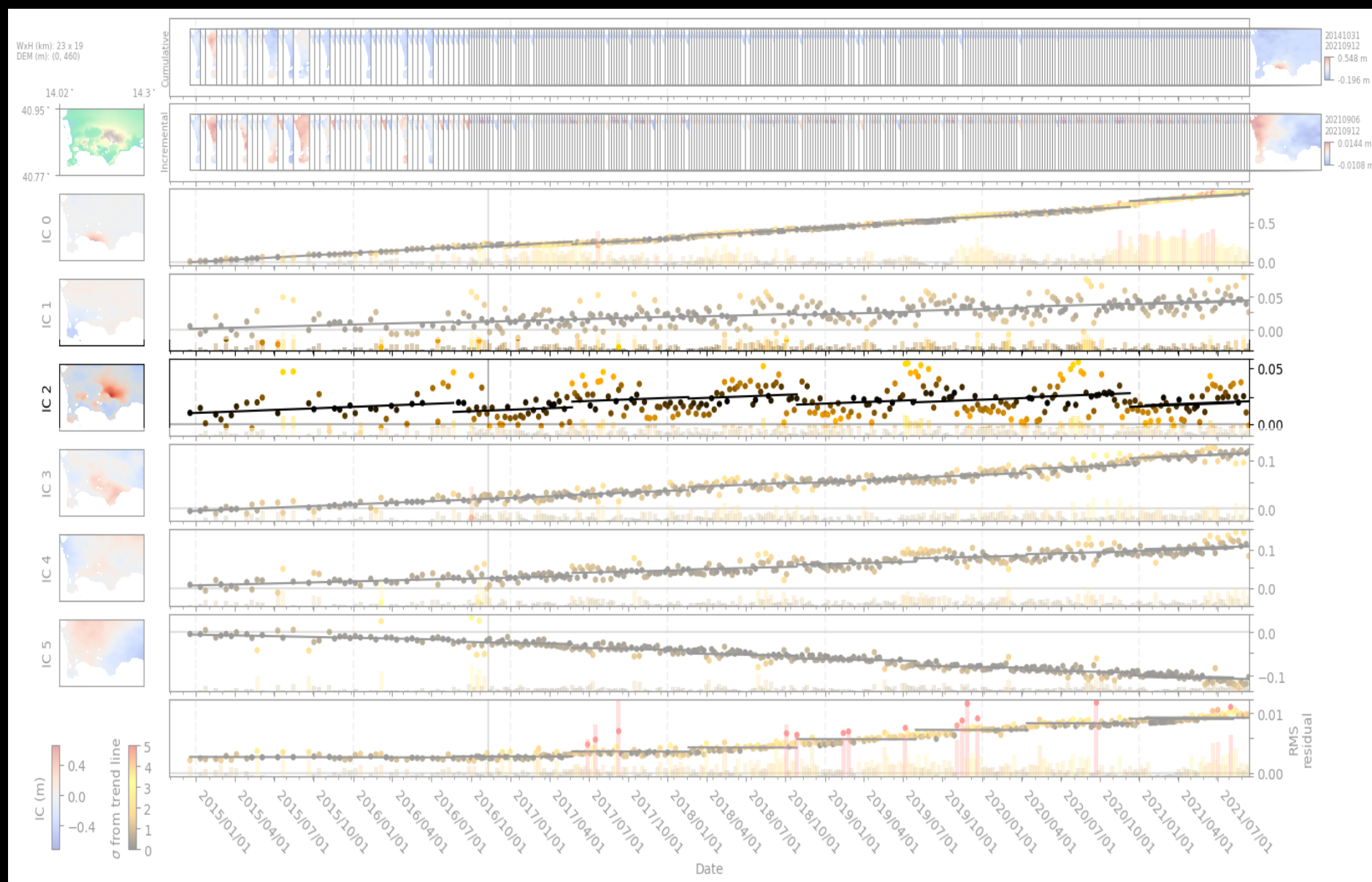


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- IC2 = Topographically correlated APS – note annual nature.
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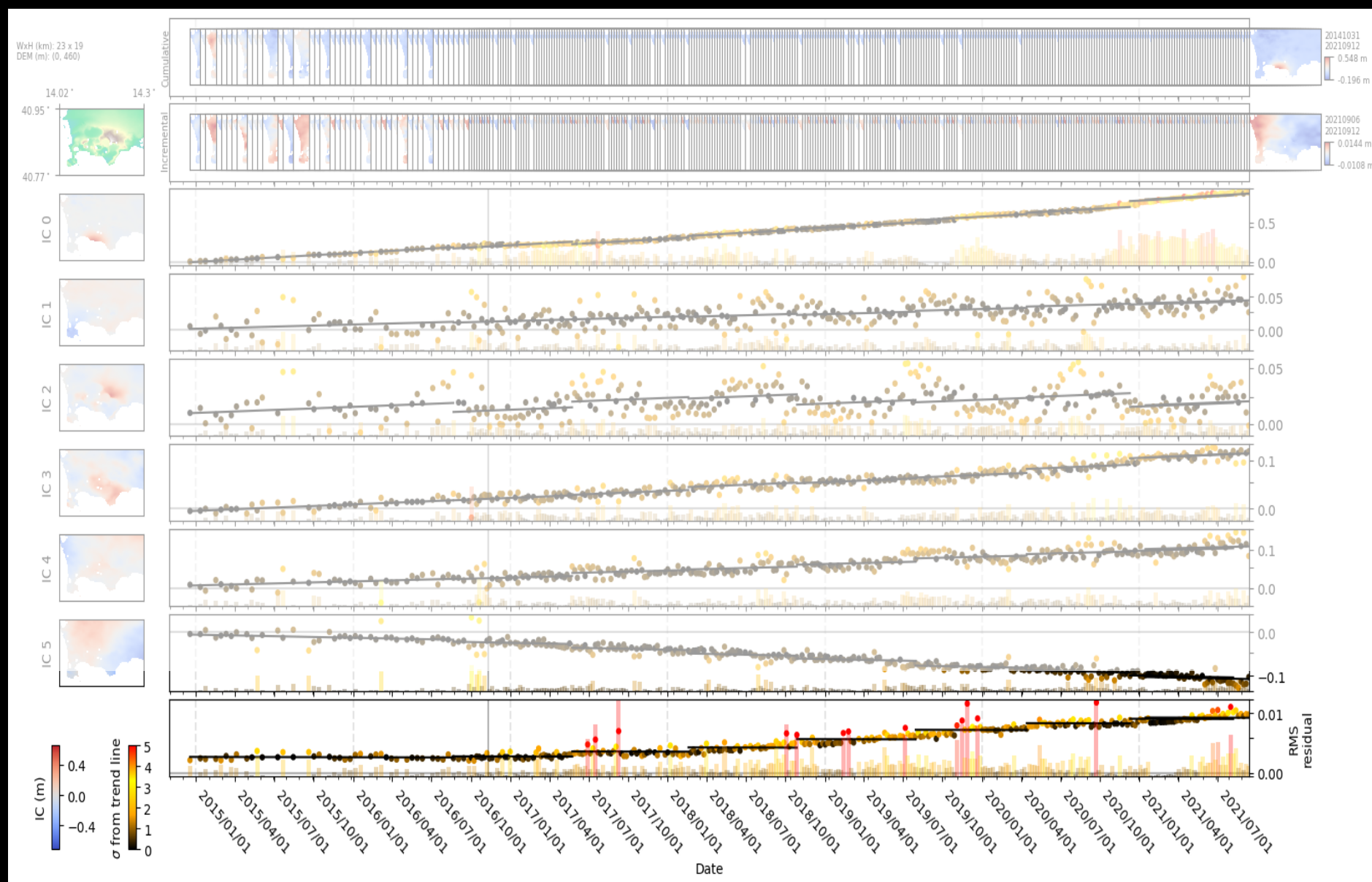
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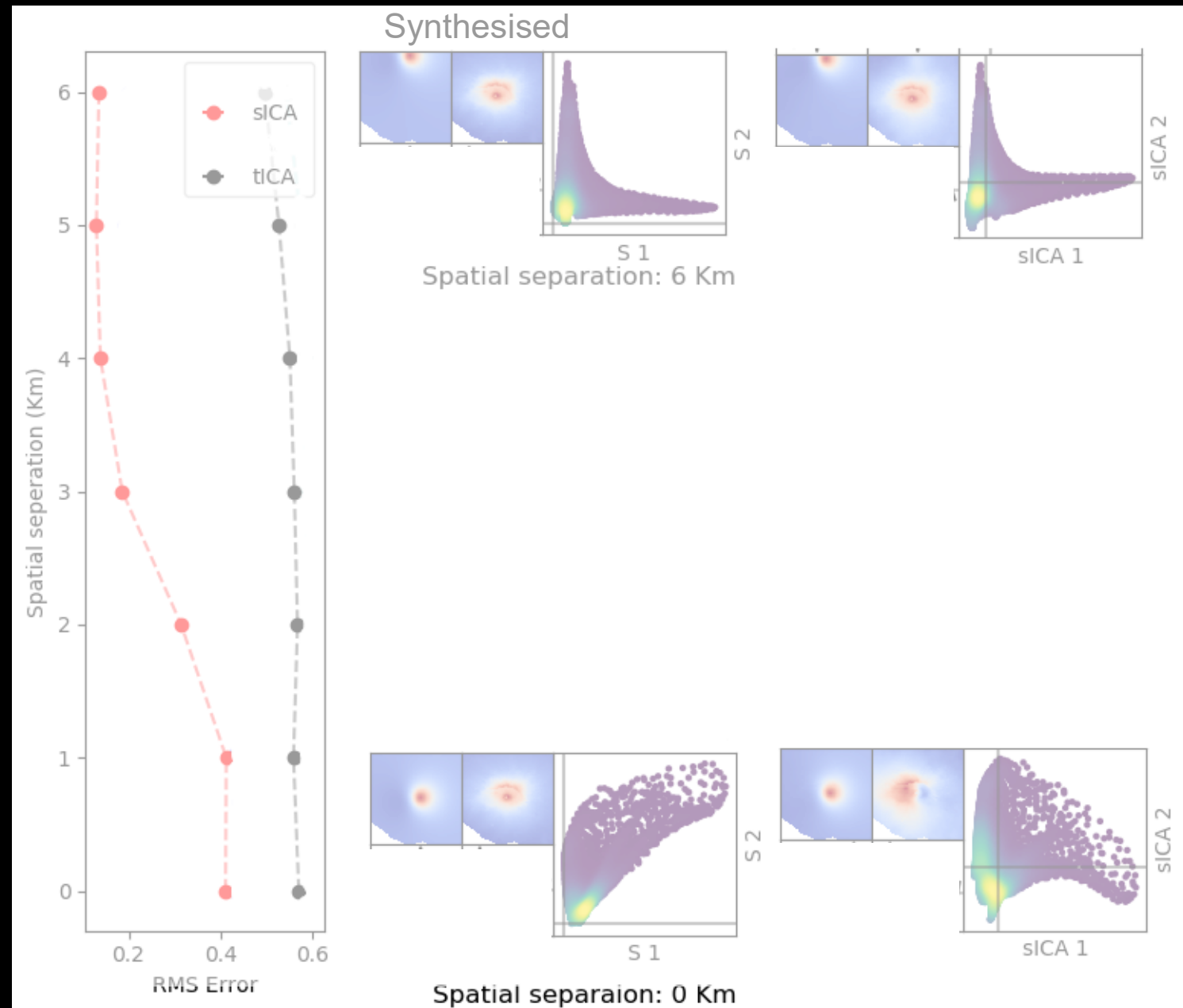


# At stratovolcanoes, sICA often works poorly

- How non-Gaussian are signals in time/space?
- How independent are signals in time/space?
- How many samples do we have in space (pixels) vs in time (acquisitions)?
- Synthetic example where we vary the spatial independence.

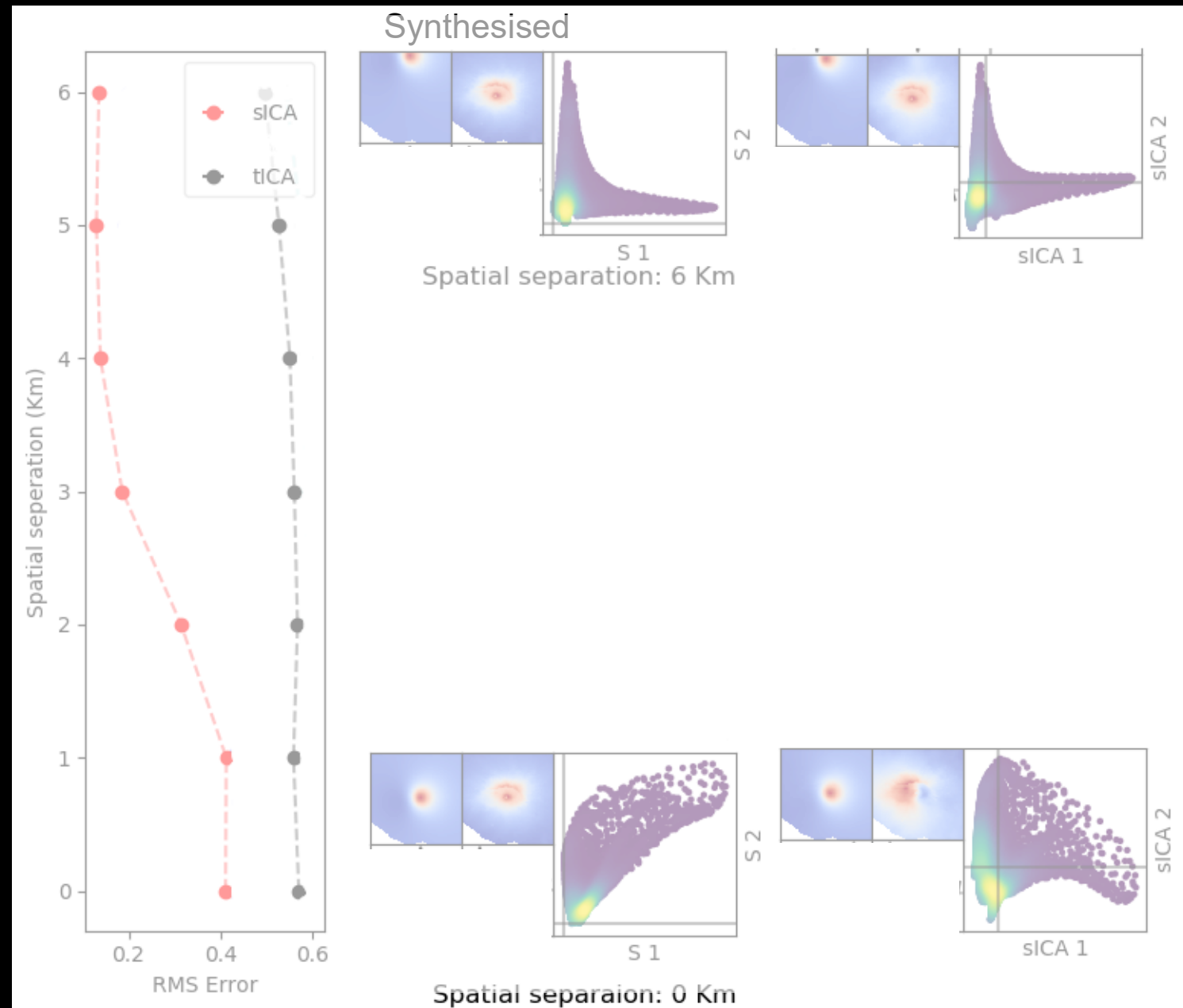
→ Non-overlapping (independent) signals work well with sICA.

→ When signals overlap, sICA is not accurate.



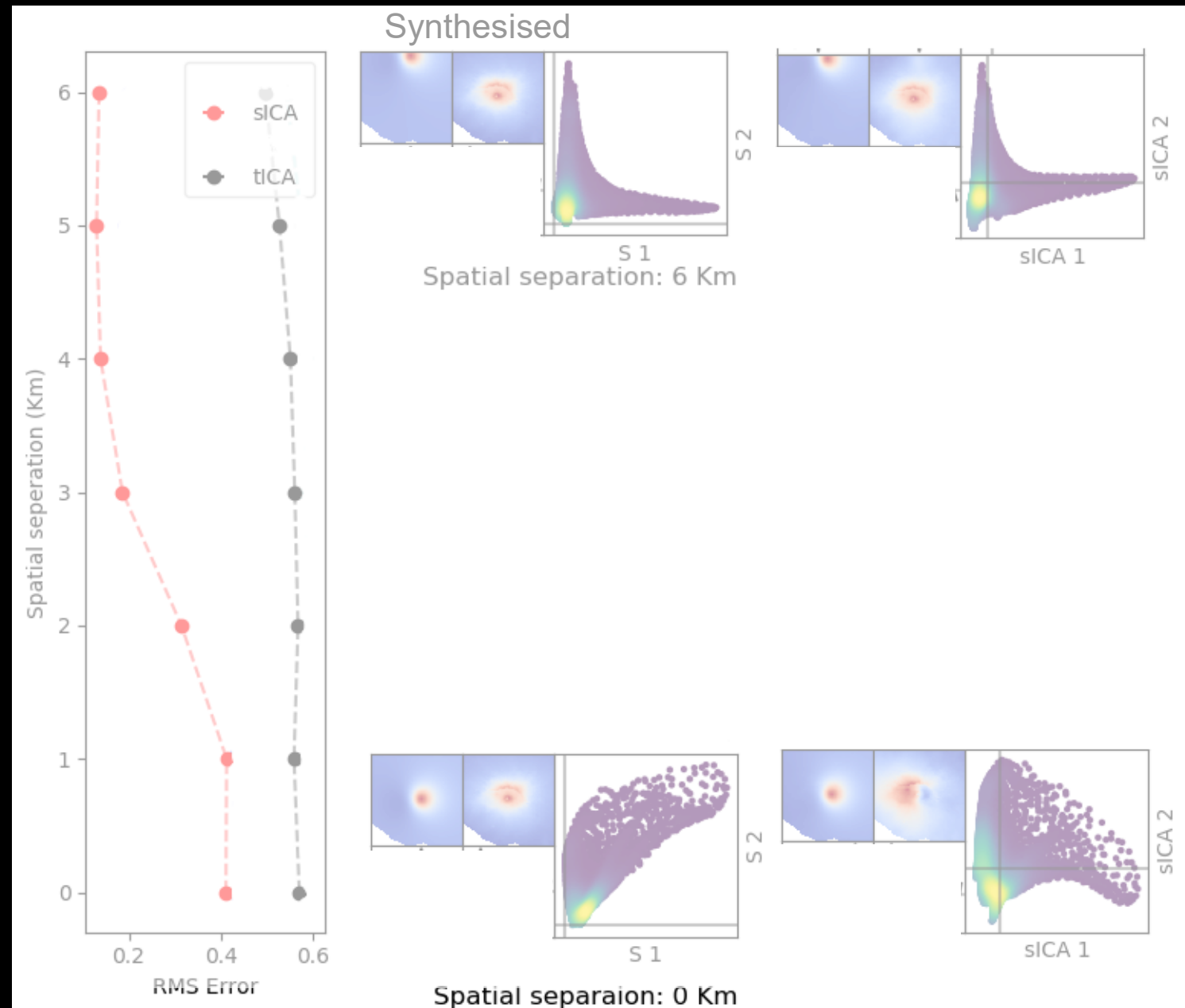
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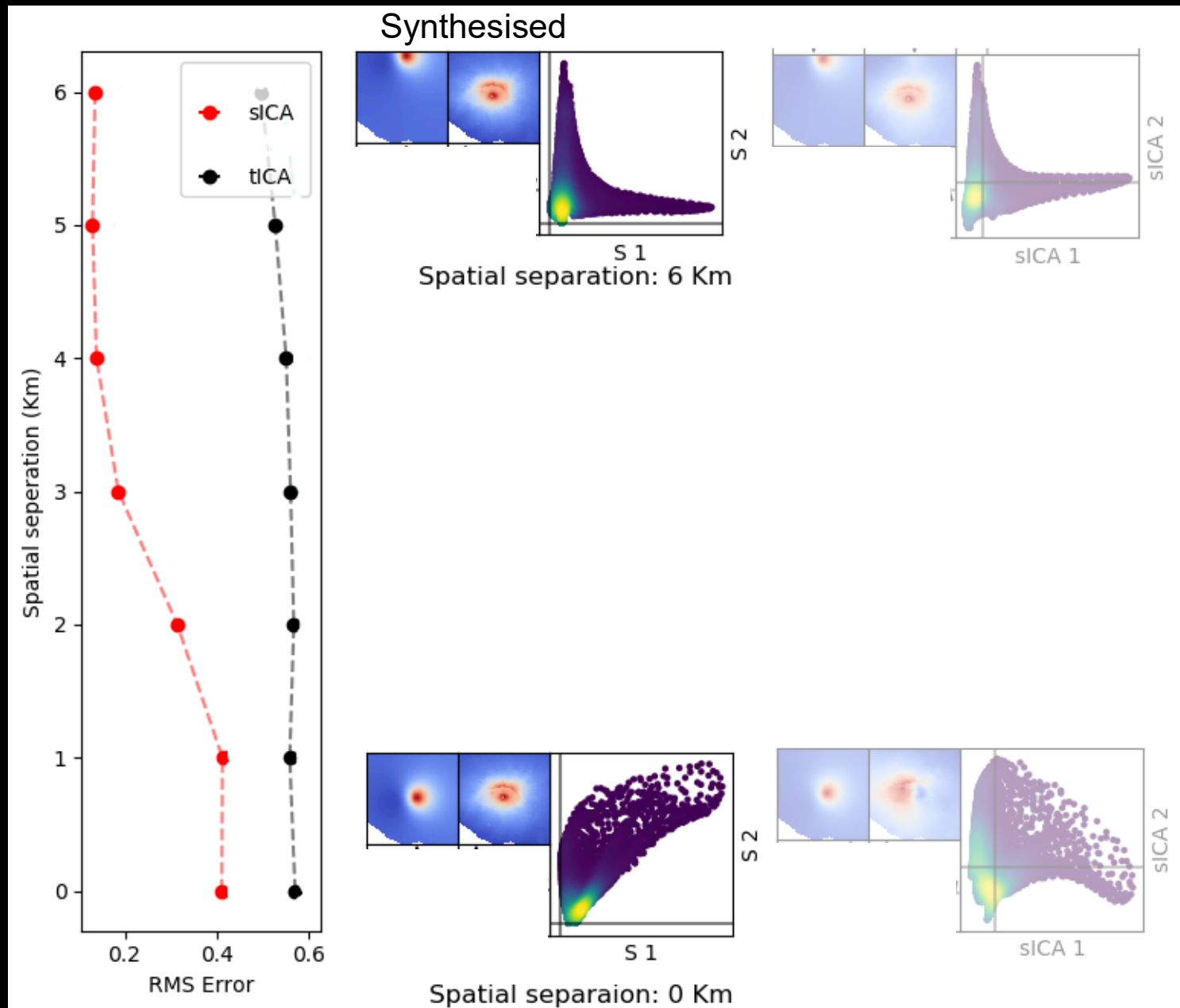


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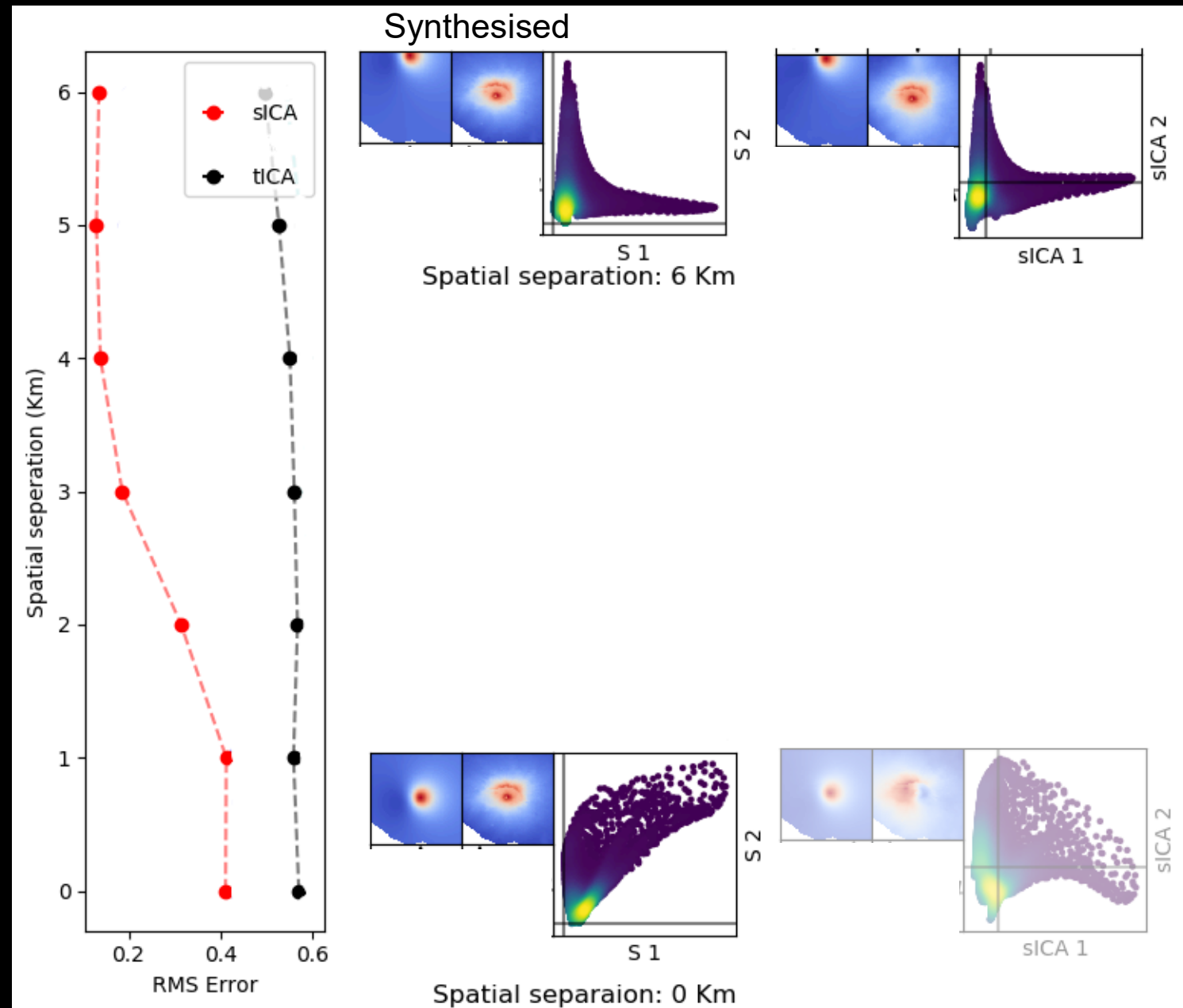


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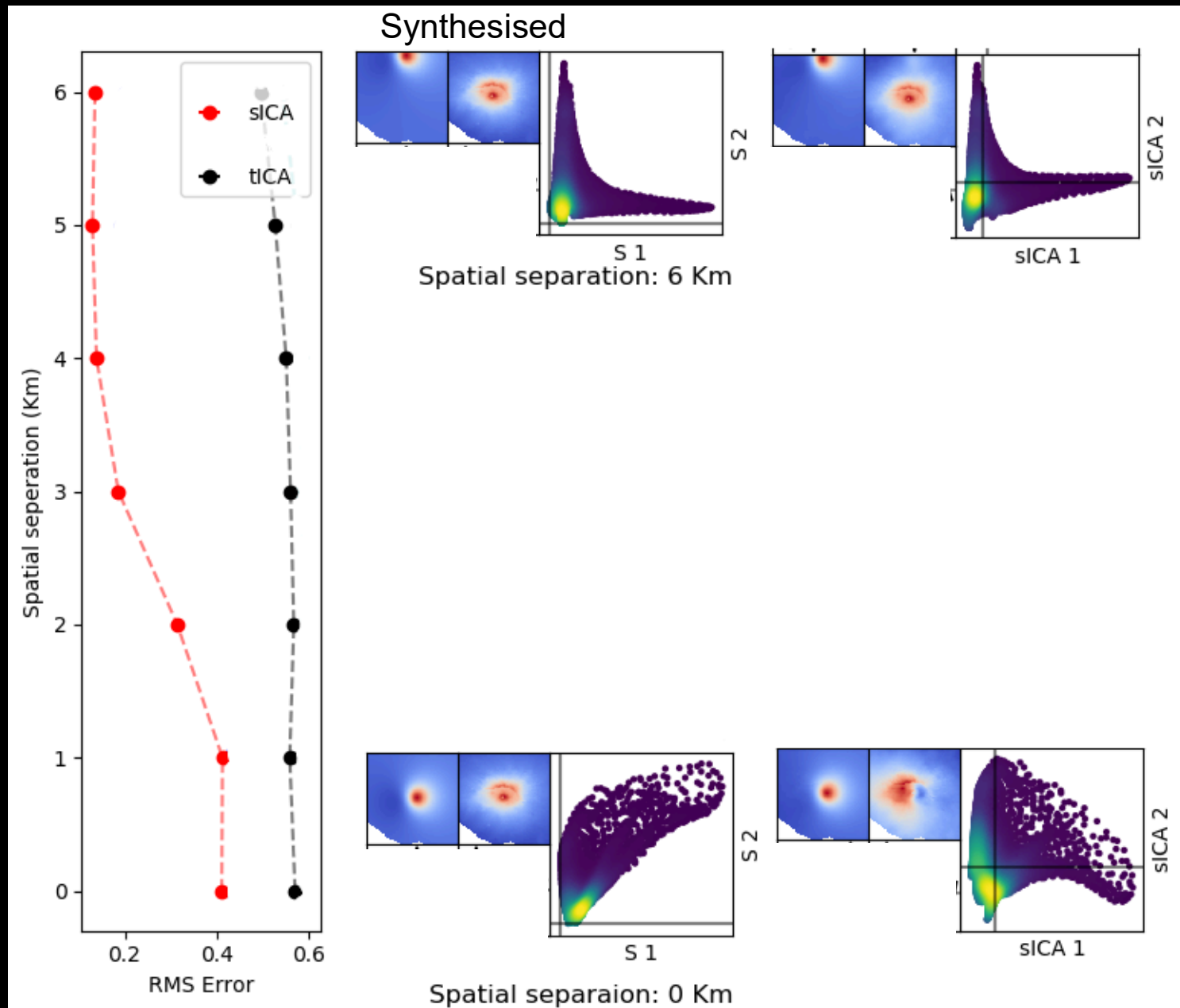


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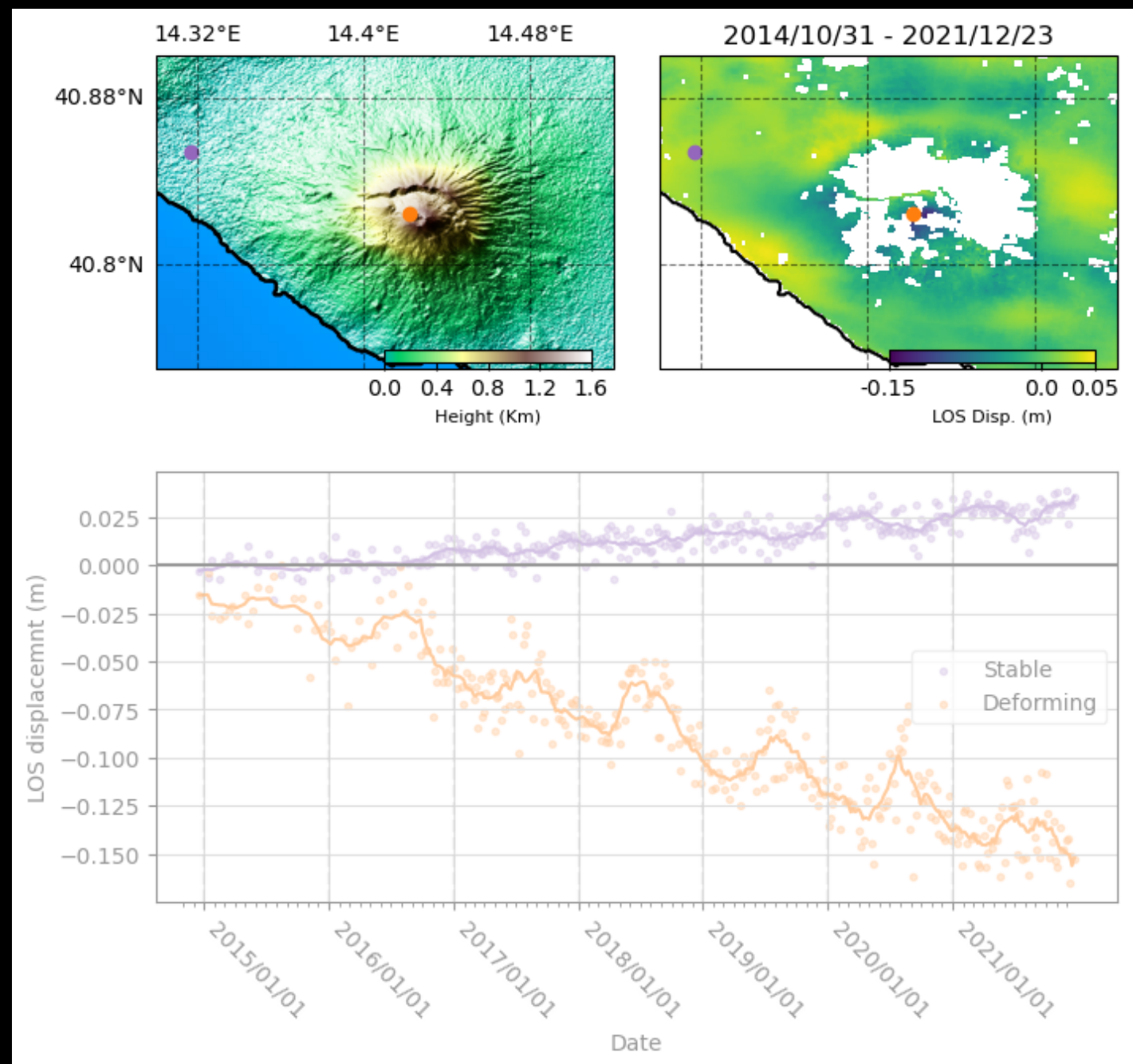
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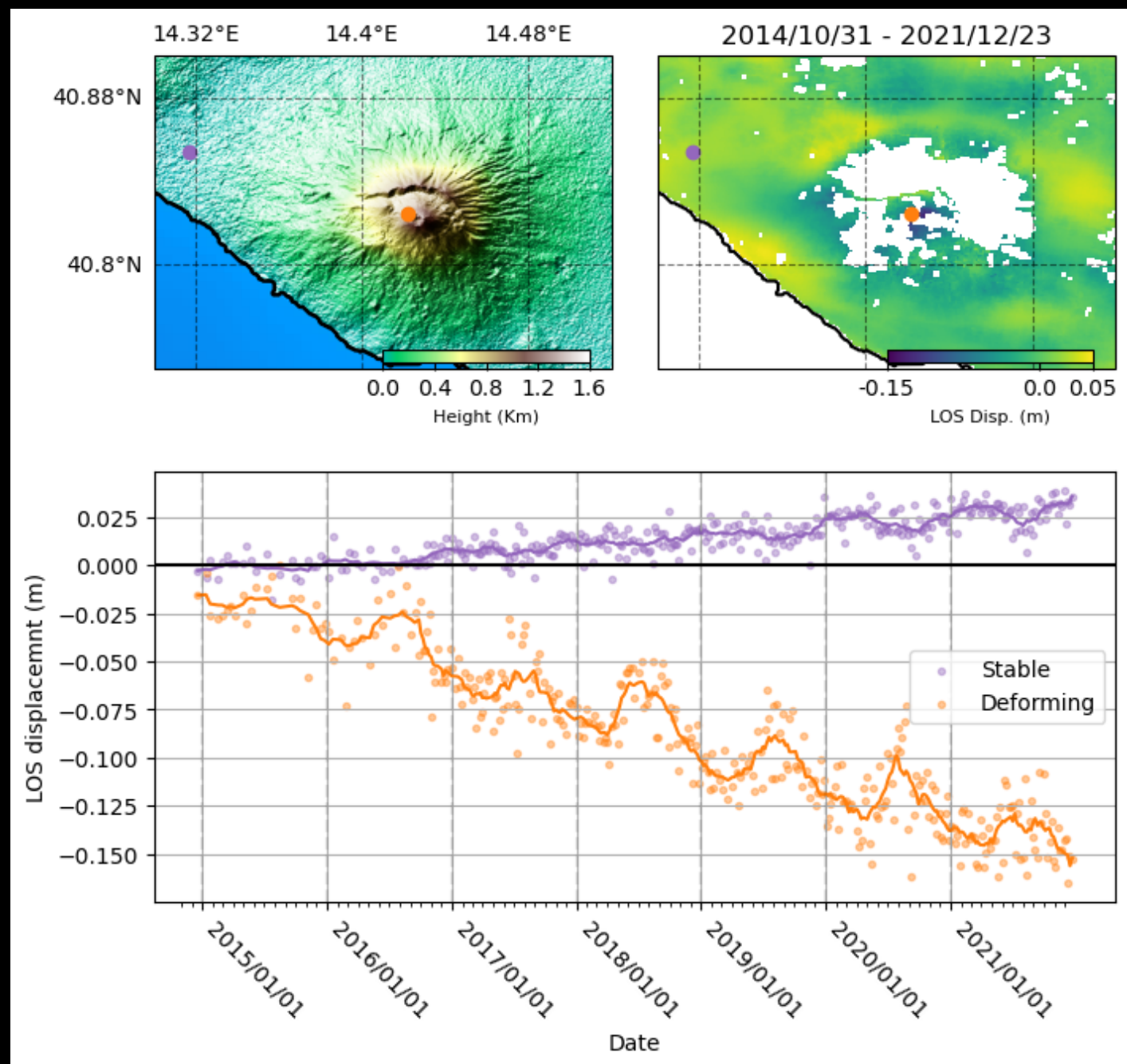
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- LiCSBAS time series shows highly variable deformation (direction reversal).
- Challenging to monitor without separating deformation from atmosphere.





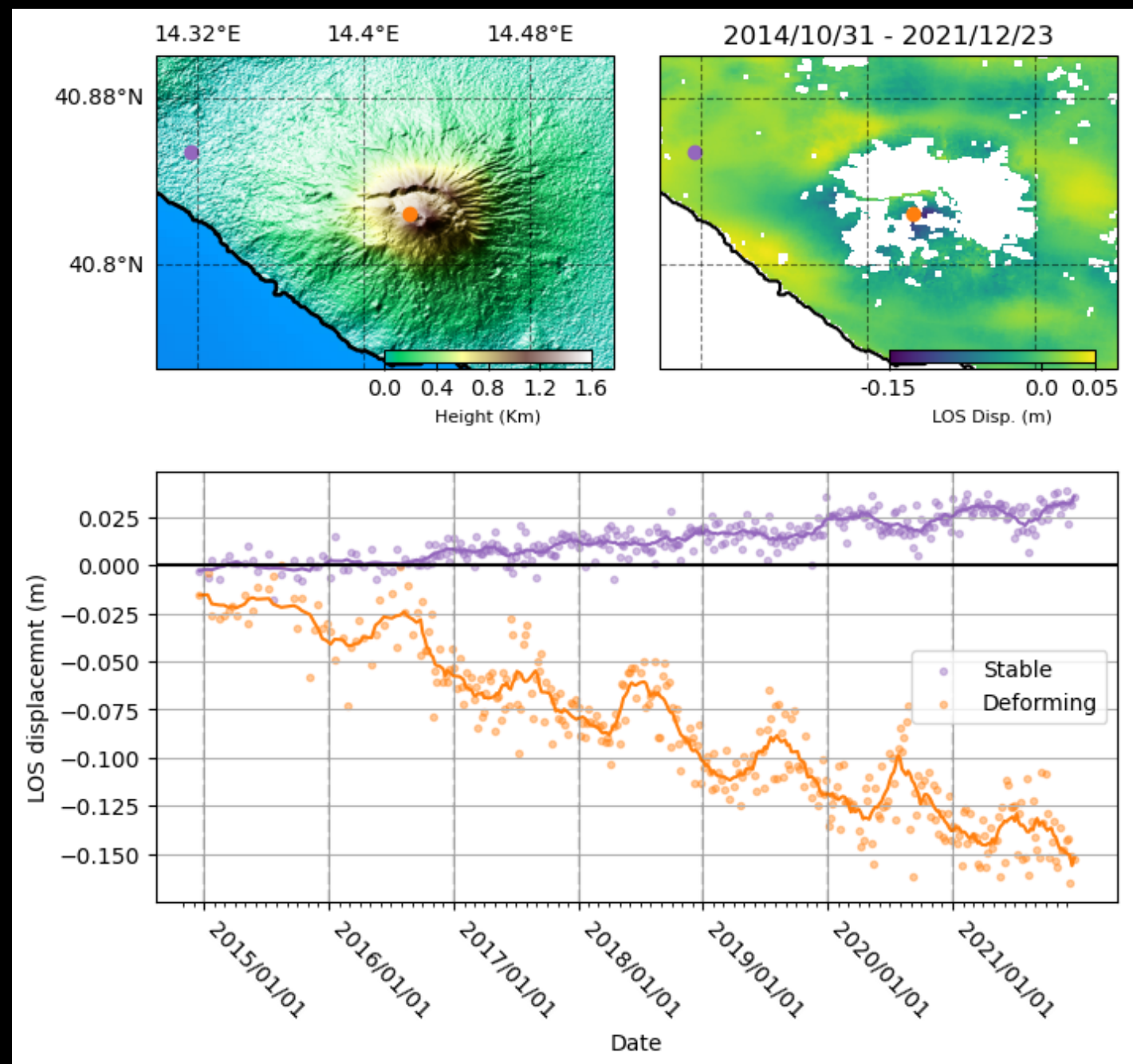
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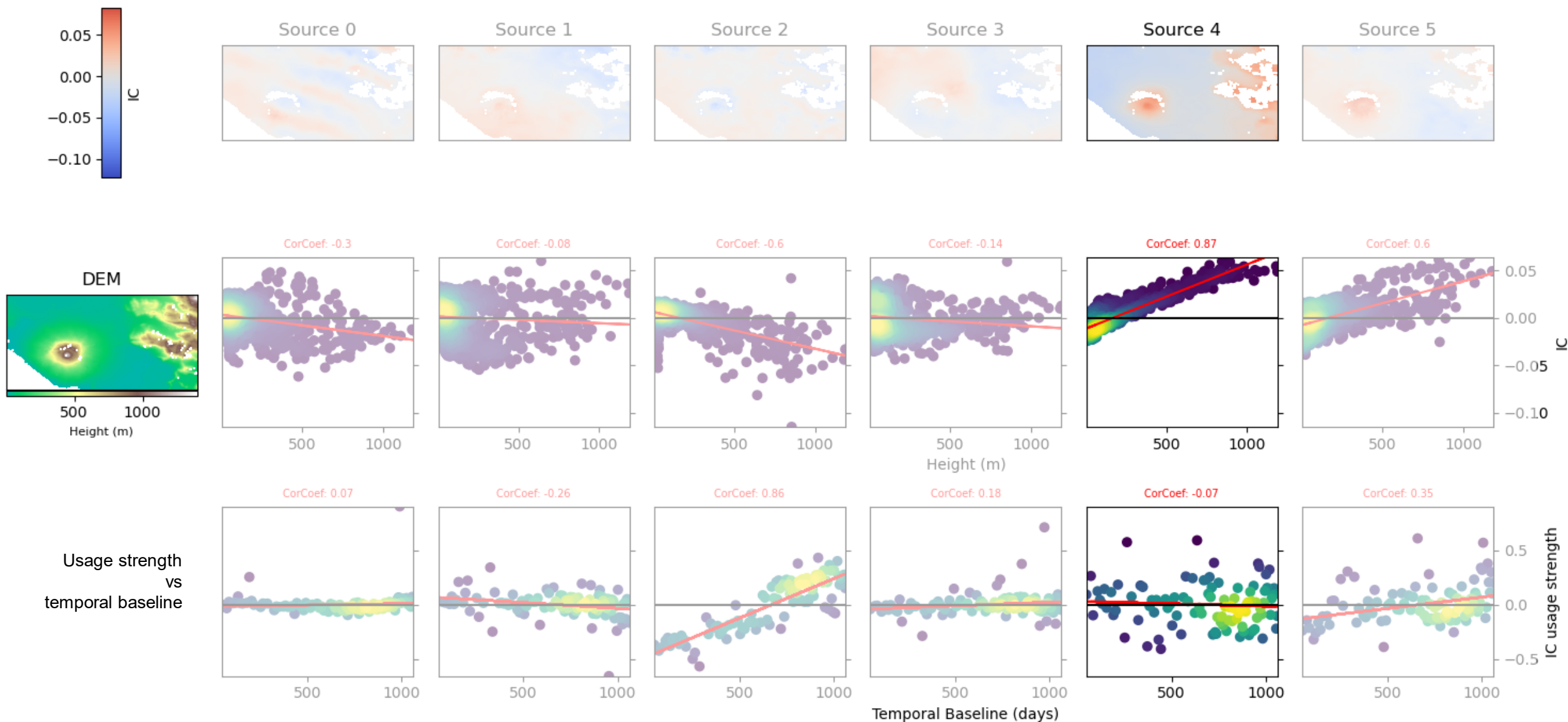
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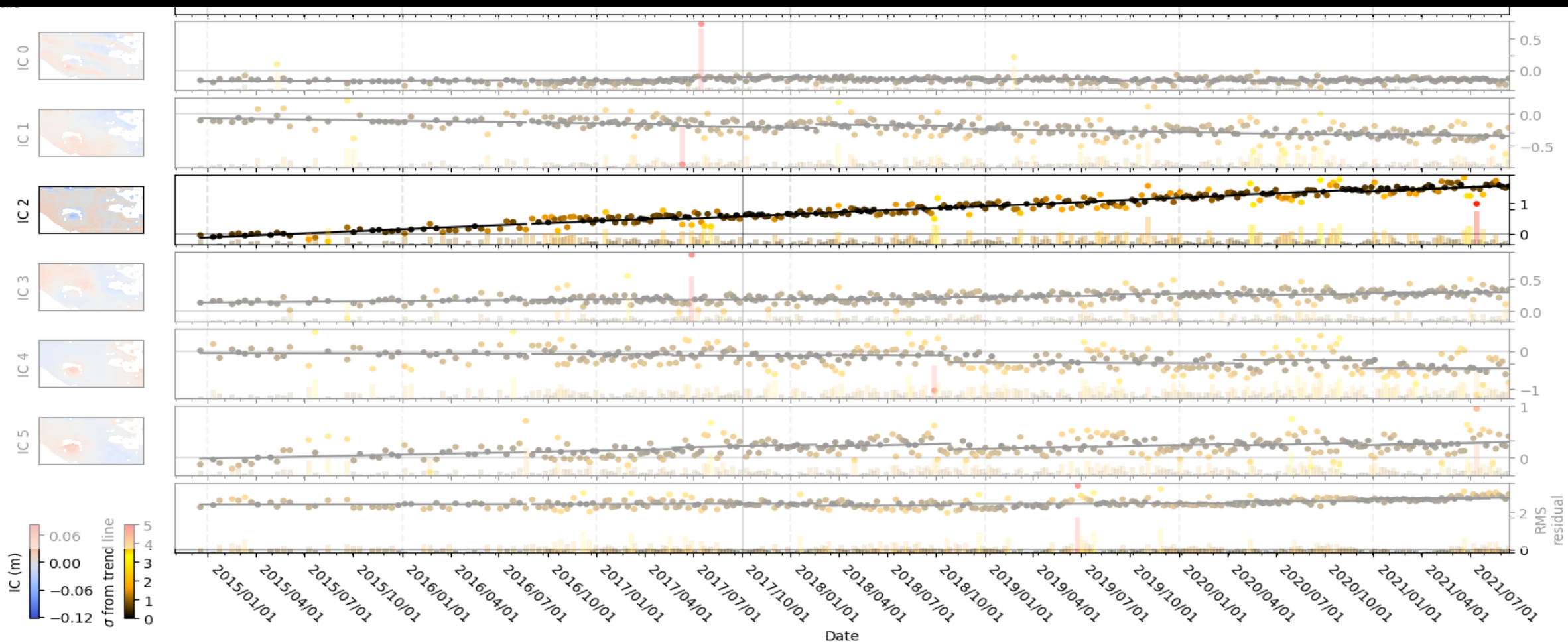
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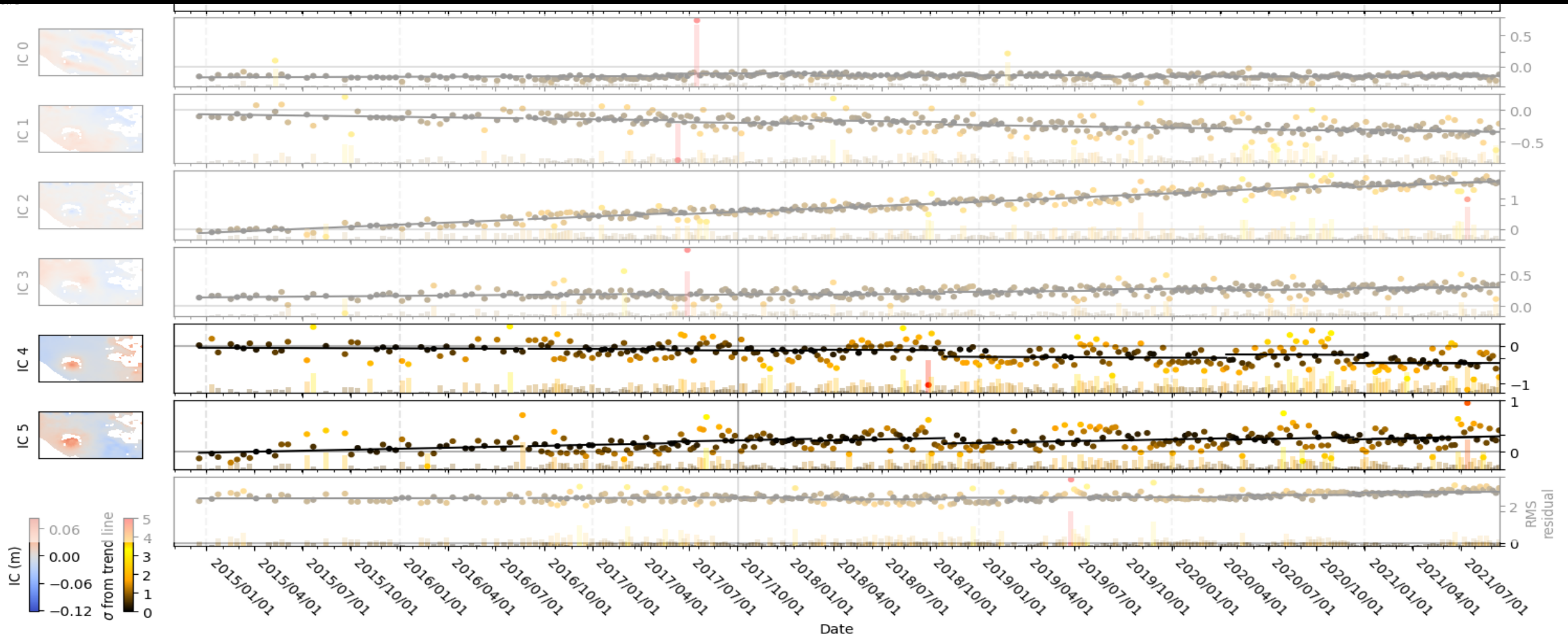
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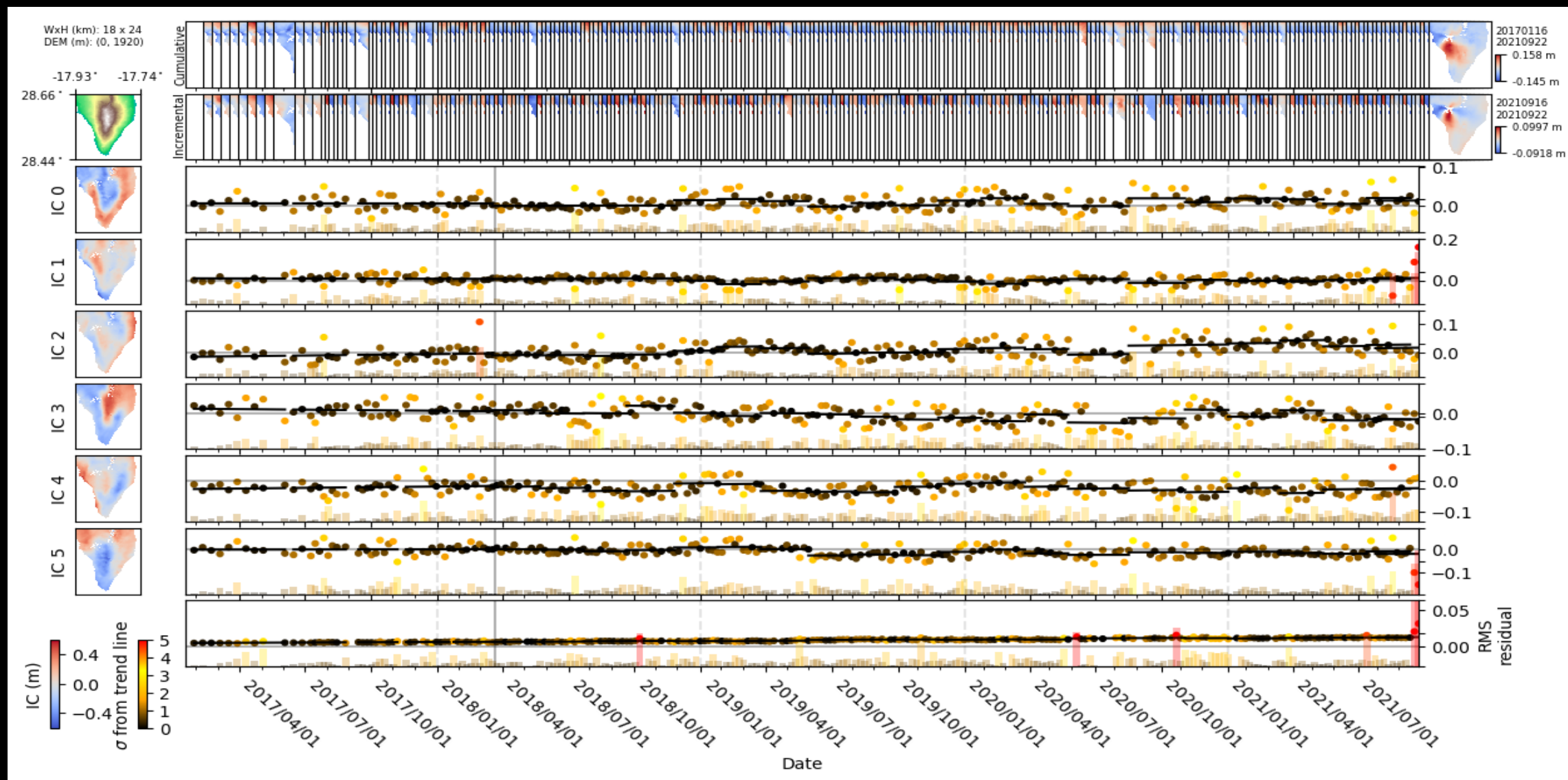
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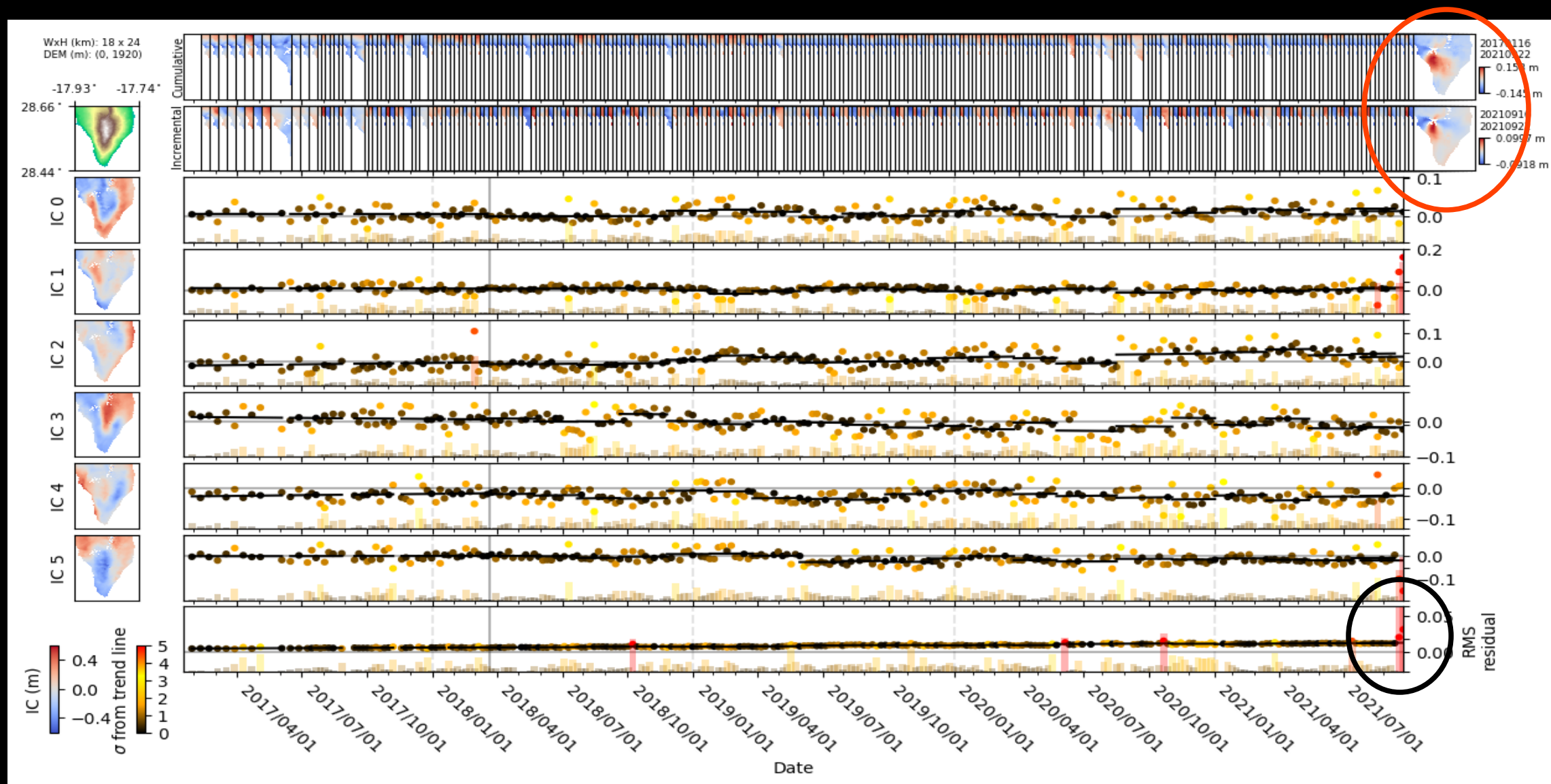
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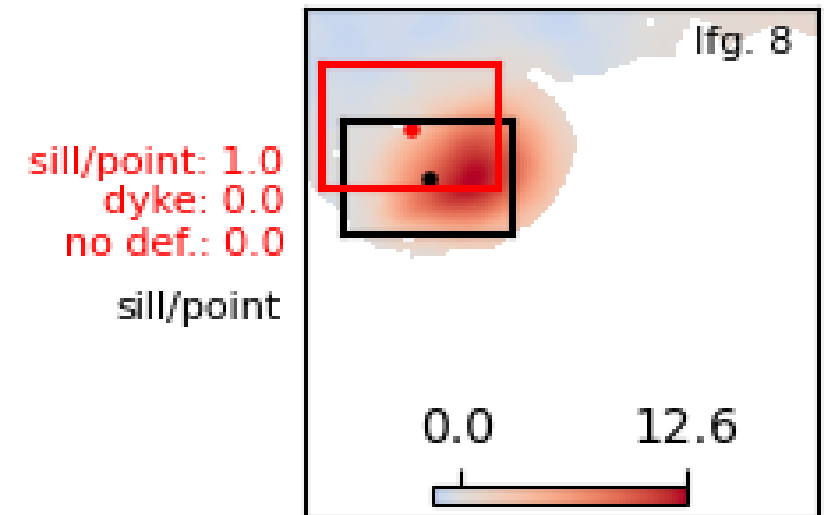
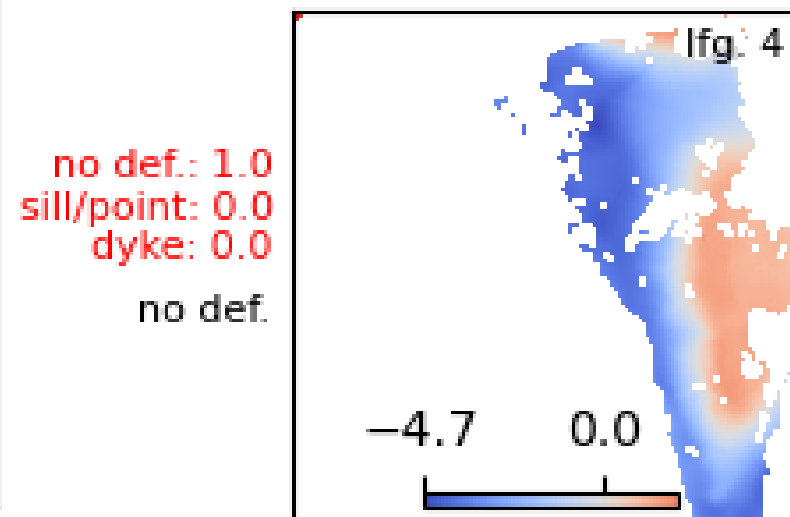
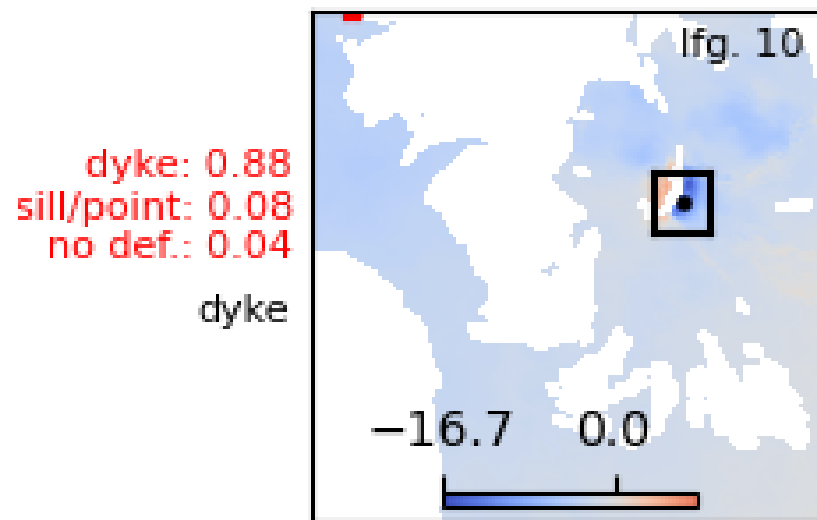
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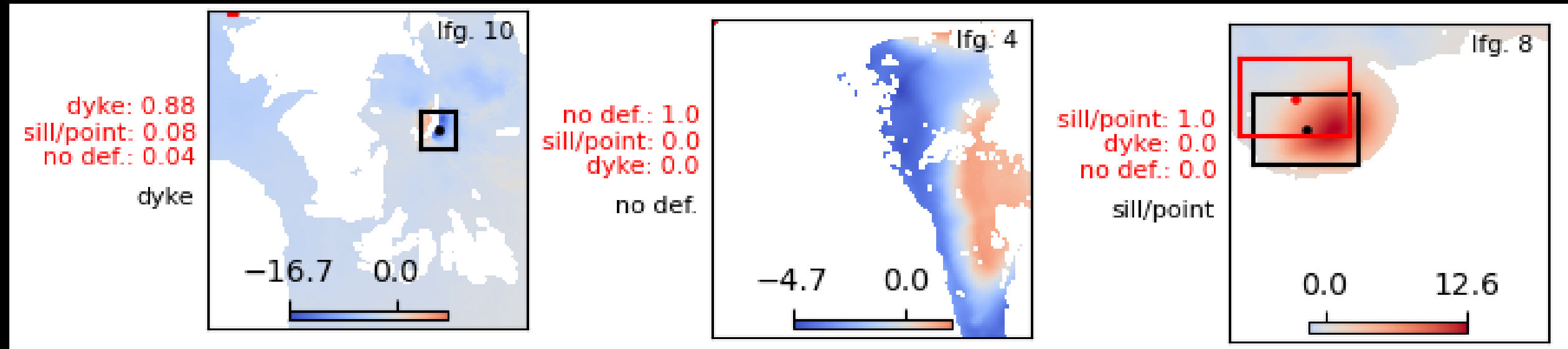
# How to visualise thousands of results?

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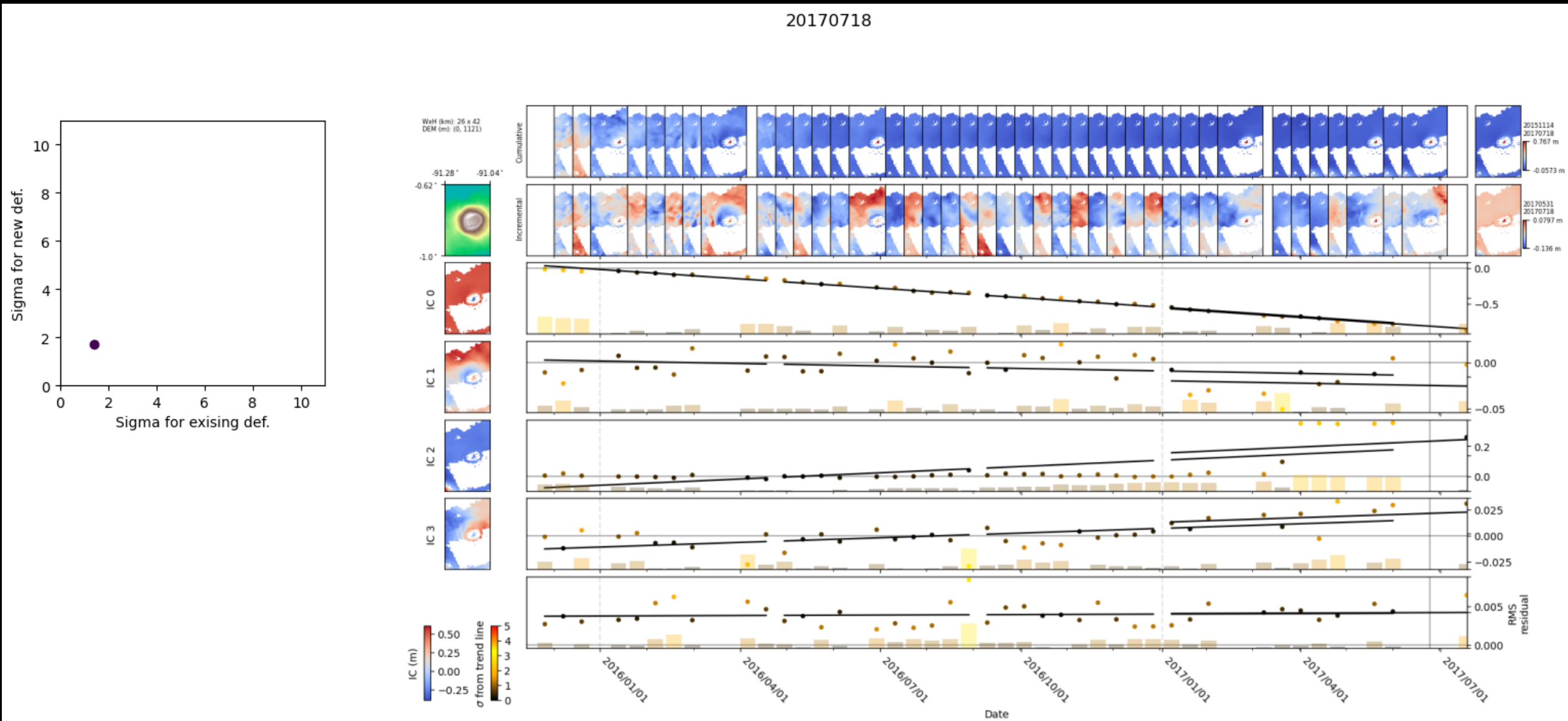
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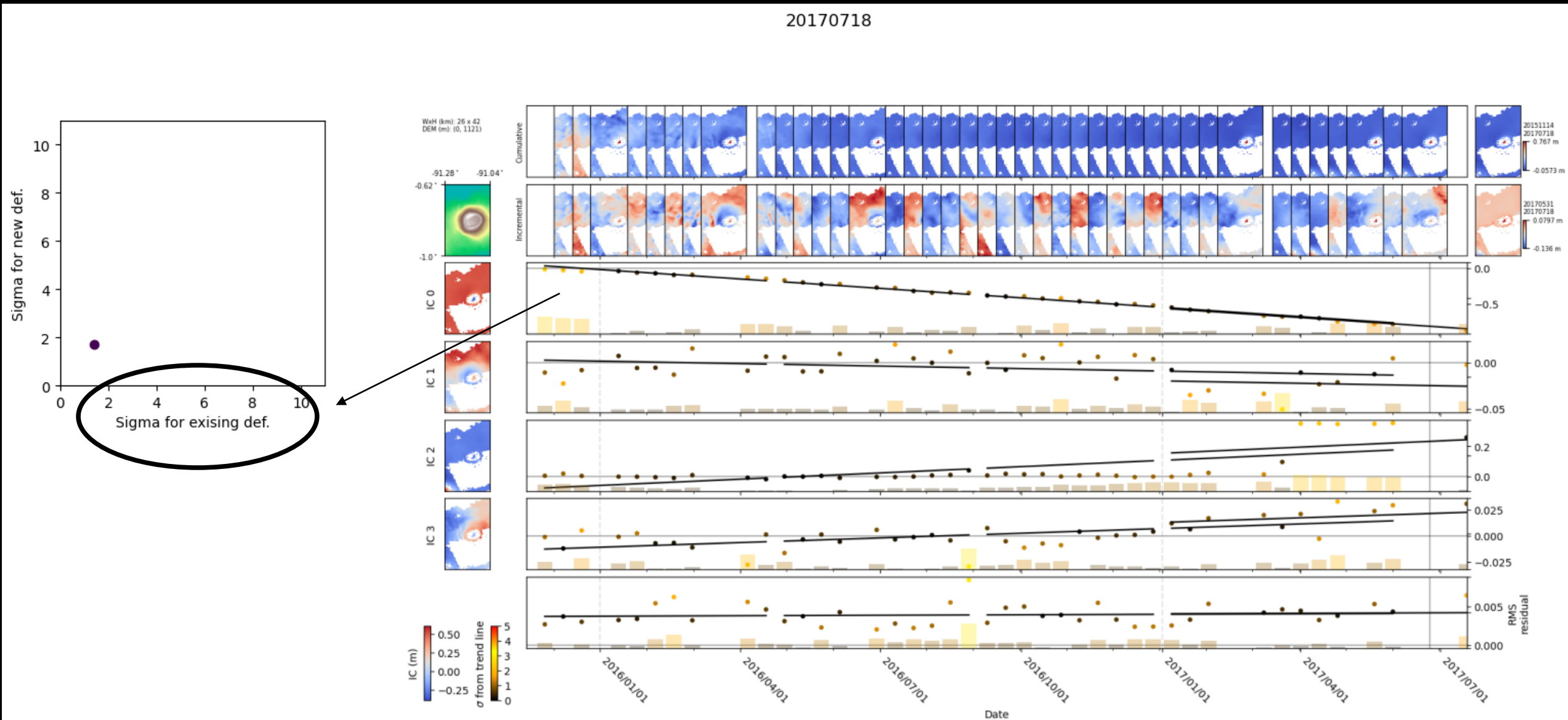
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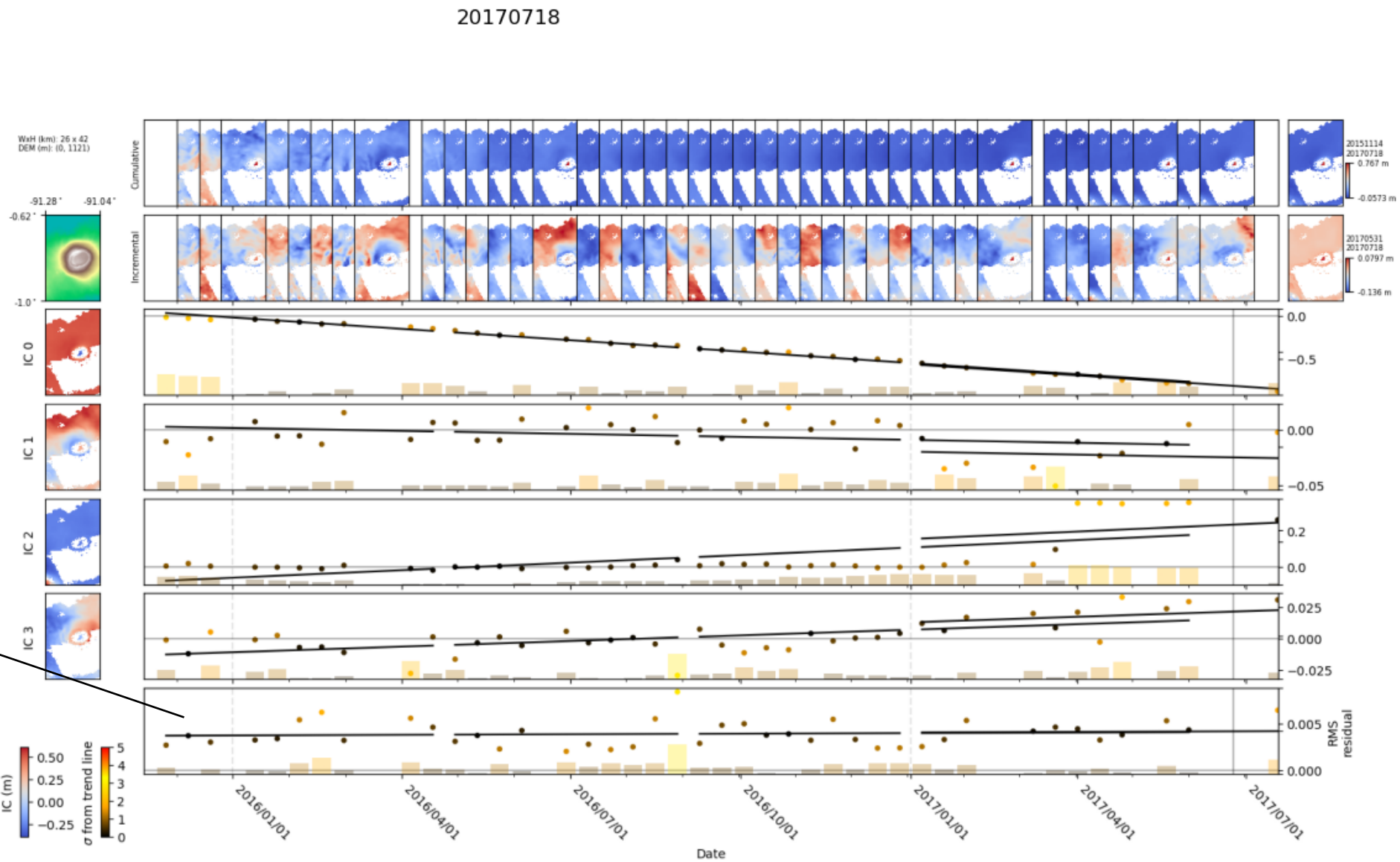
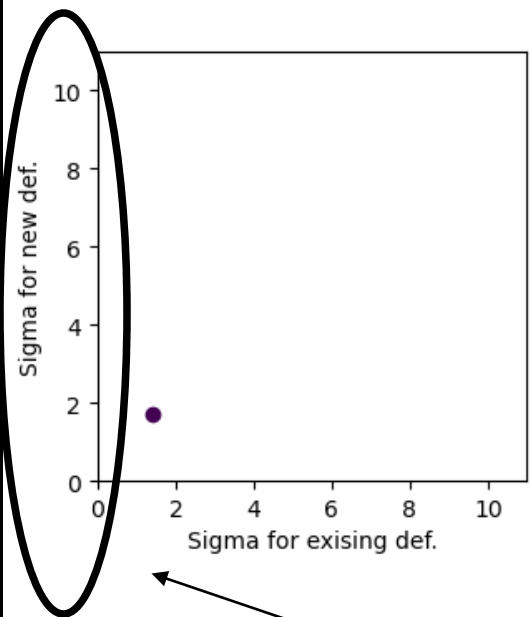
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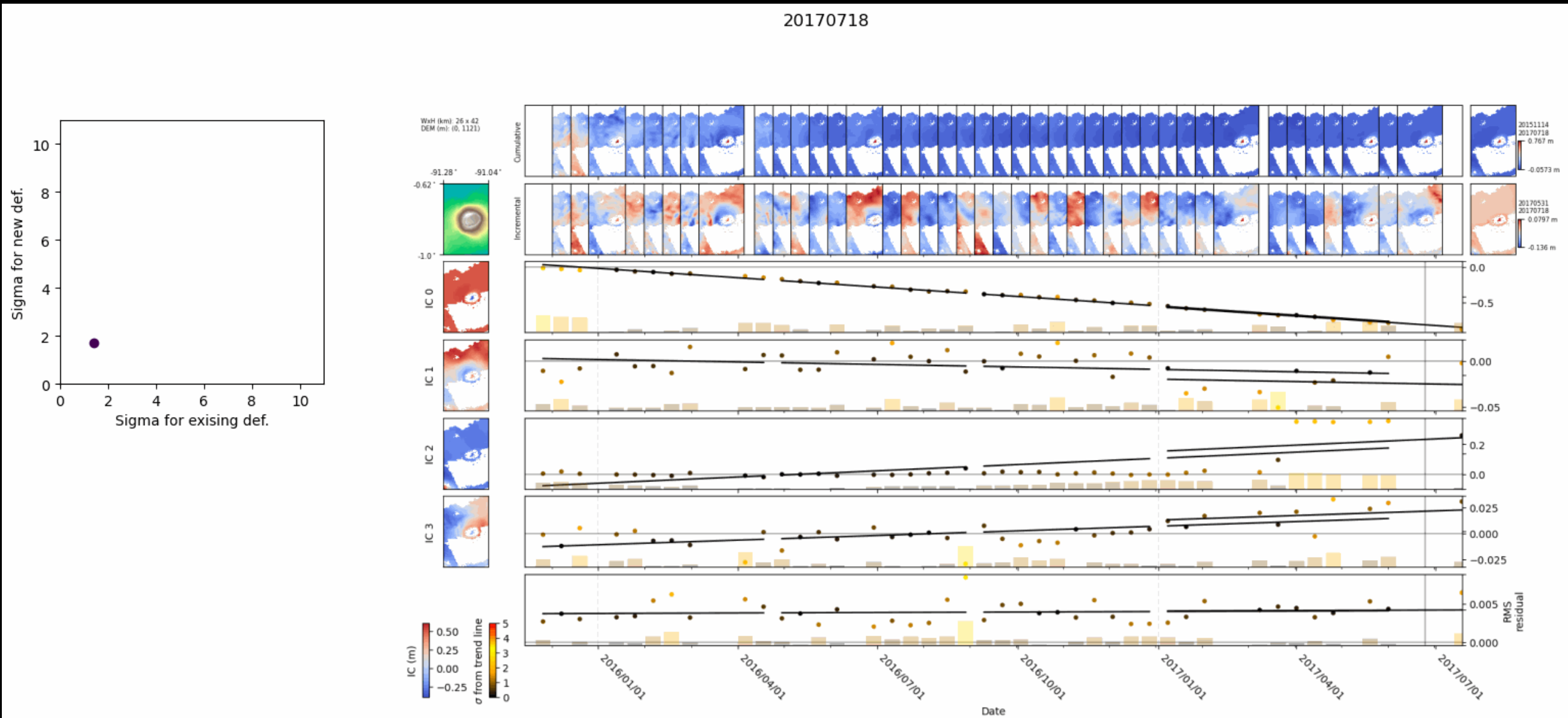
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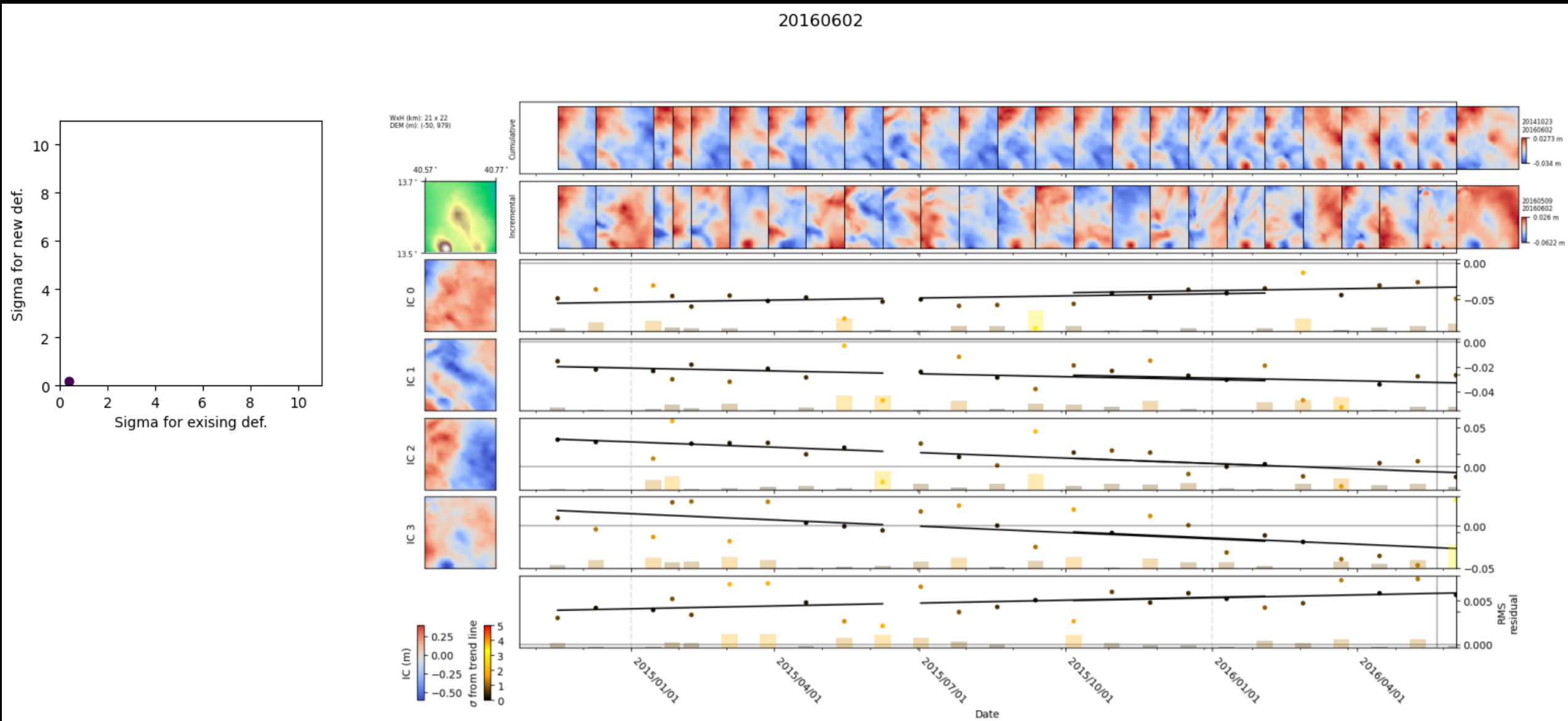
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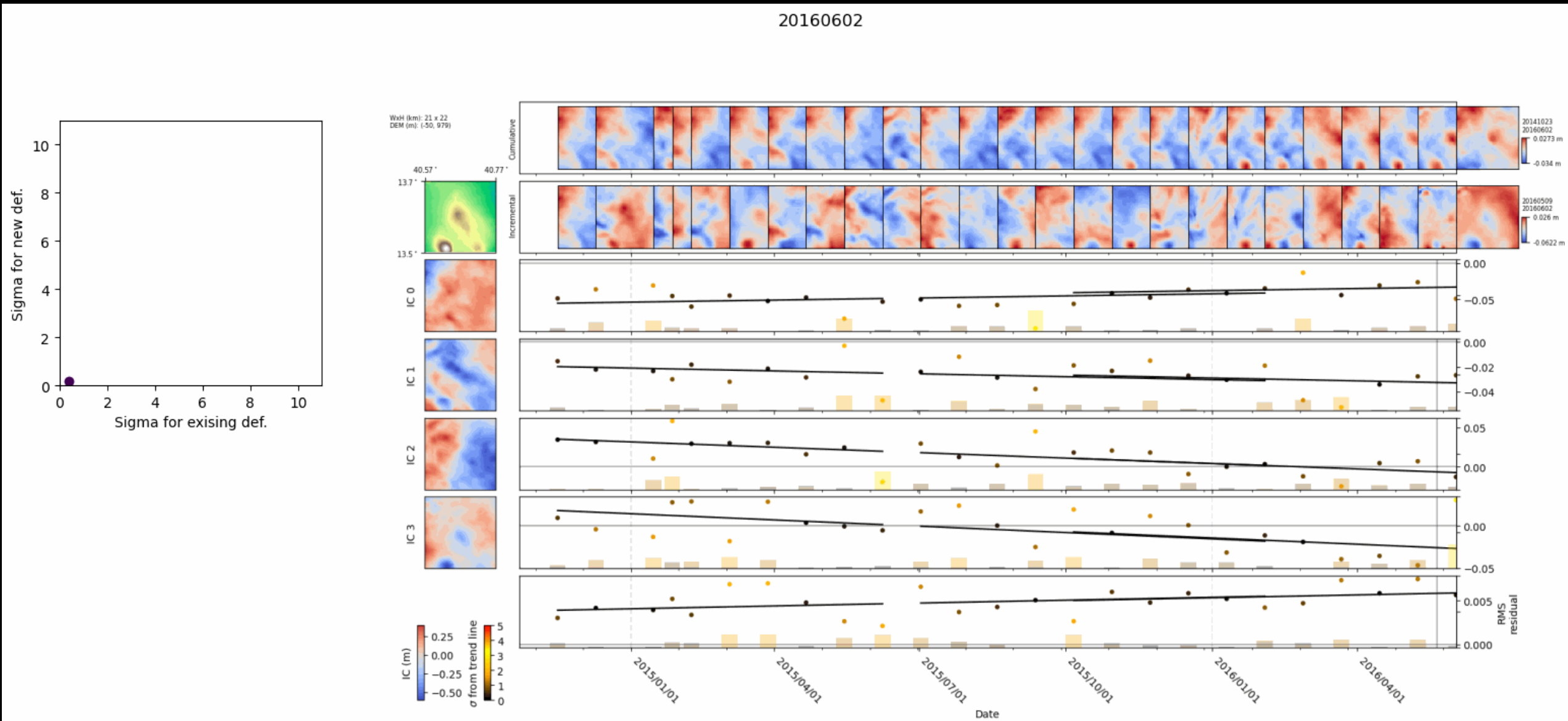
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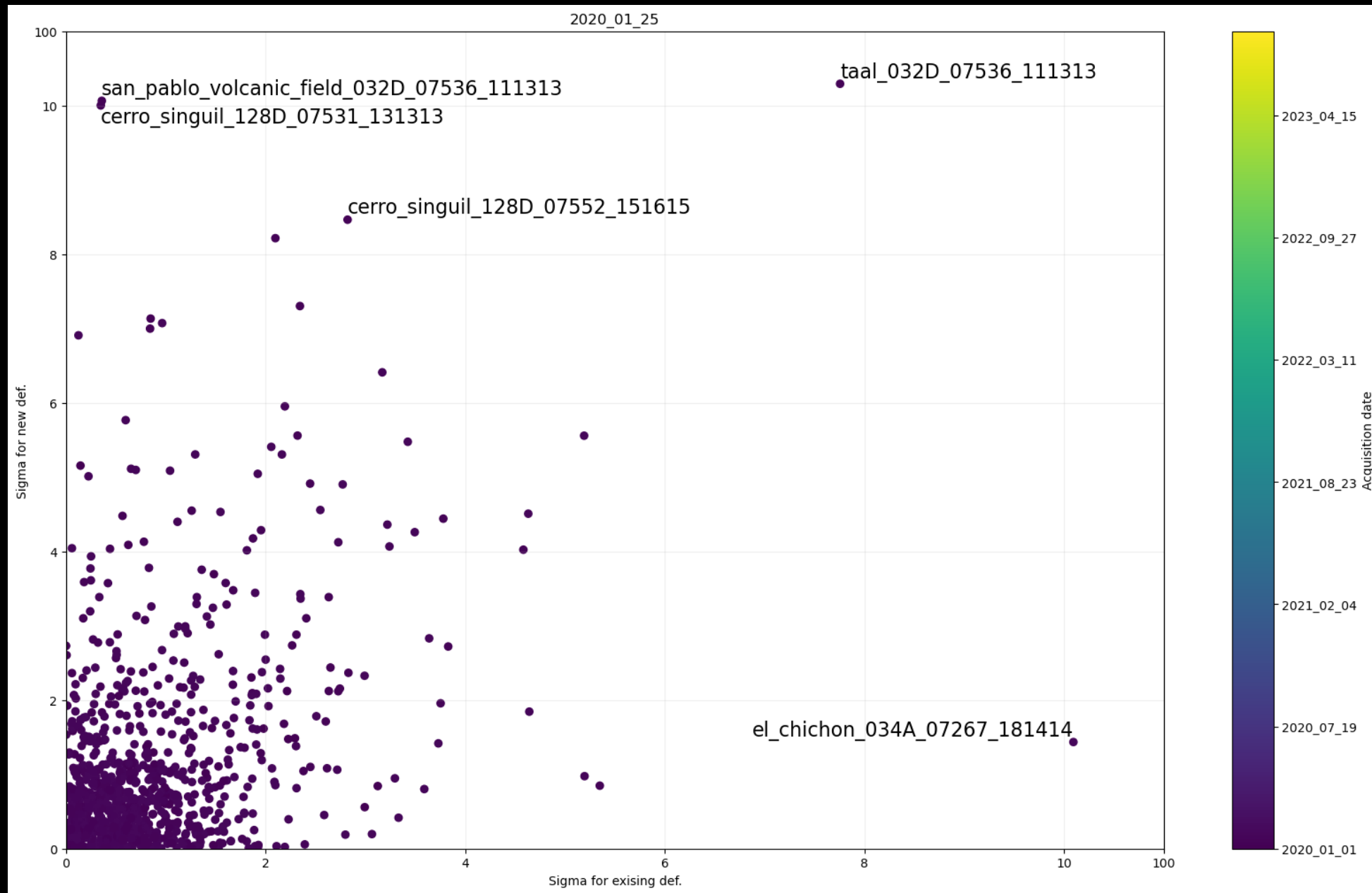
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# Visualising the status: ~500 volcanoes, 1 time

- Applied to ~1500 LiCSAR frames



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- Web-based interactive LiCSAlert figure (possibly on COMET Volcano Portal).
- Community use/feedback from case studies – the code is on GitHub!

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- **Community use/feedback from case studies – the code is on GitHub!**

The image shows a screenshot of a GitHub profile's 'Pinned' repositories section. The page has a dark theme. At the top left, it says 'Pinned' and at the top right, 'Customize your pins'. There are six repository cards arranged in a 3x2 grid. The second card in the first column, 'LiCSAlert', is circled in red. Each card displays the repository name, a 'Public' badge, a brief description, the programming language (Python), and star/fork counts.

Repository Name	Public	Description	Language	Stars	Forks
VolcNet	Public	A database of labelled Sentinel-1 data featuring examples of volcanic unrest.	Python	4	3
VUDLNet_21	Public	Volcanic Unrest Detection and Localisation Net 2021: A CNN that is able to detect and localise deformation in Sentinel-1 unwrapped interferograms.	Python	4	3
<b>LiCSAlert</b>	Public	Volcano monitoring using Sentinel-1 InSAR data	Python	15	2
SyInterferoPy	Public	Generate synthetic interferograms that are similar to those produced by the Sentinel-1 satellites.	Python	18	6
ICASAR	Public	An algorithm for robustly applying sICA to InSAR data	Python	32	5
SRTM-DEM-tools	Public	Tools for making and manipulating SRTM1 and SRTM3 Dems.	Python	2	3

- **Conclusions**

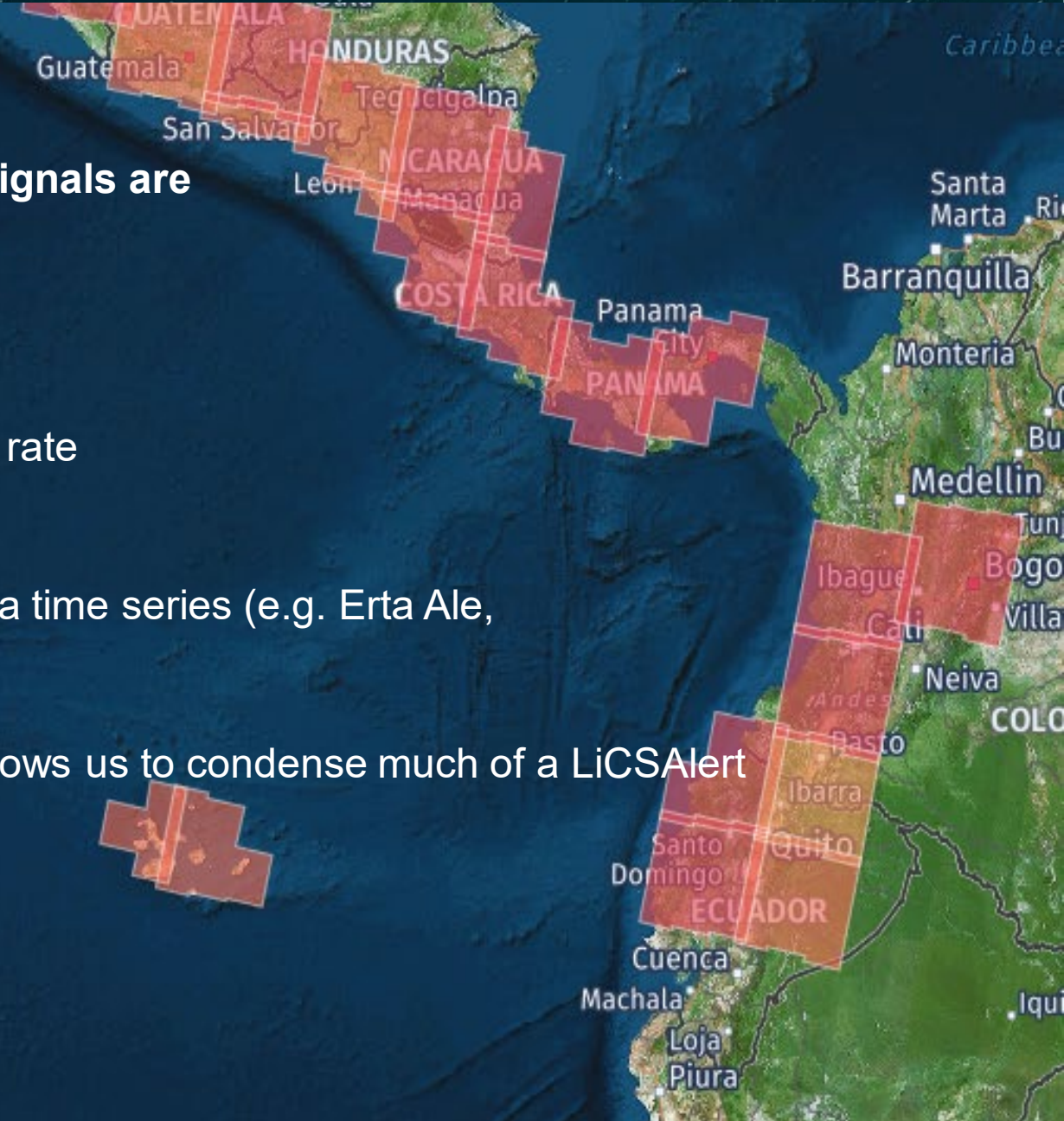
- **Networks that increase the variance of deformation signals are needed when using sICA at most volcanoes.**

- At stratovolcanoes, tICA outperforms sICA.

- LiCSAlert is able to detect subtle changes in deformation rate (e.g. Campi Flegrei).

- LiCSAlert is able to detect when new deformation enters a time series (e.g. Ertá Ale, La Palma).

- Using deep learning to identify the deformation source allows us to condense much of a LiCSAlert figure into a simple 2D plot.



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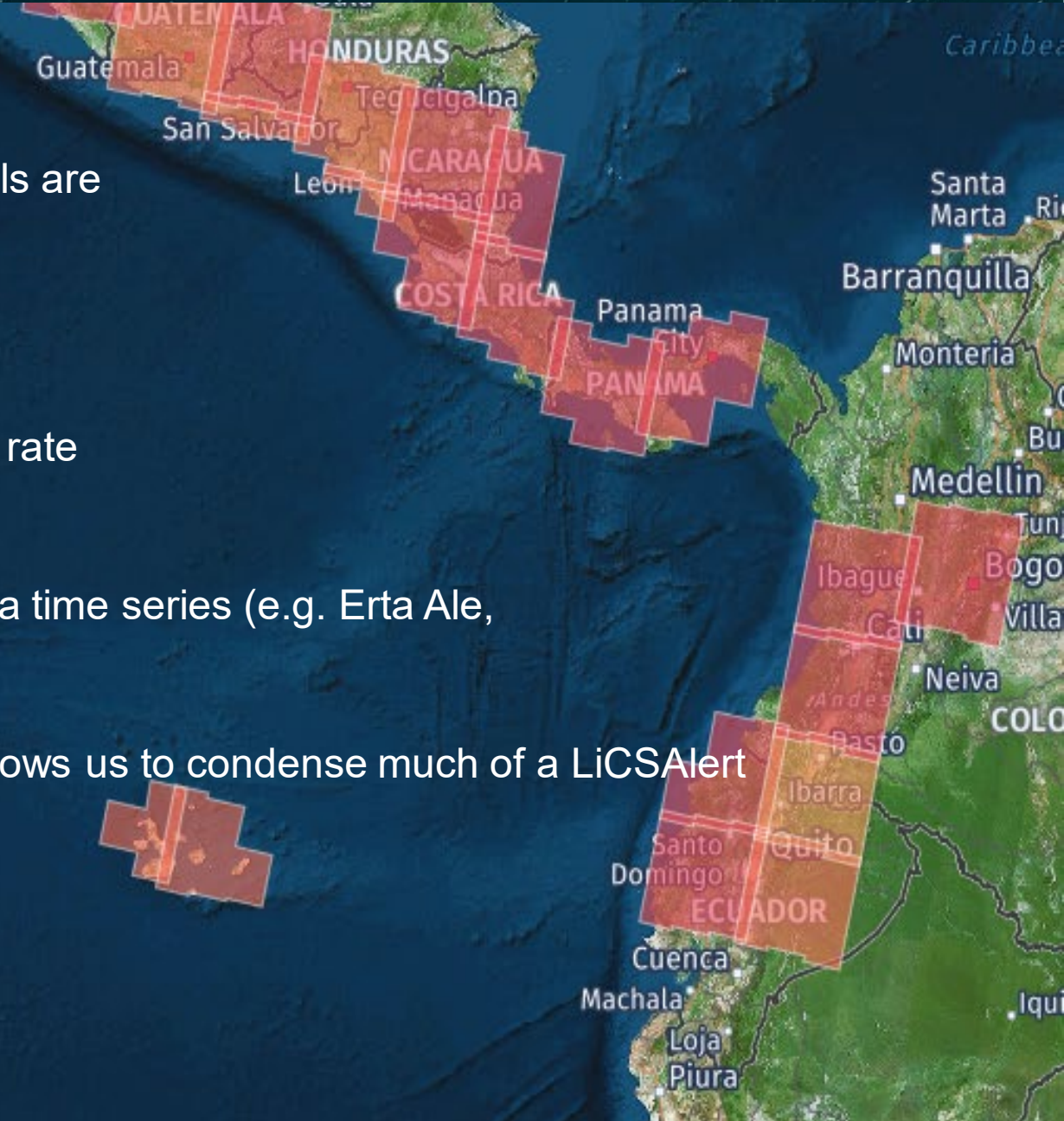
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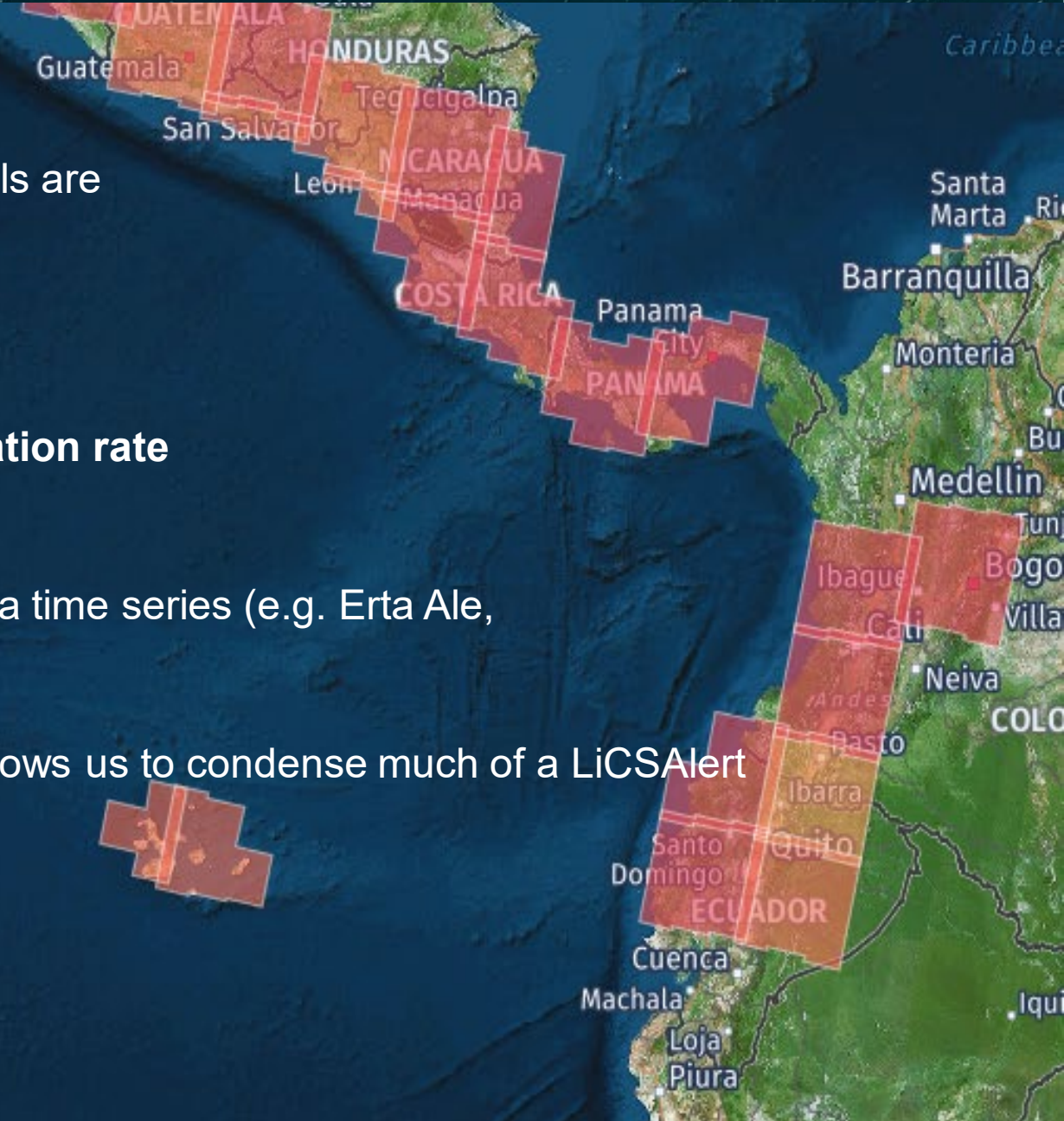
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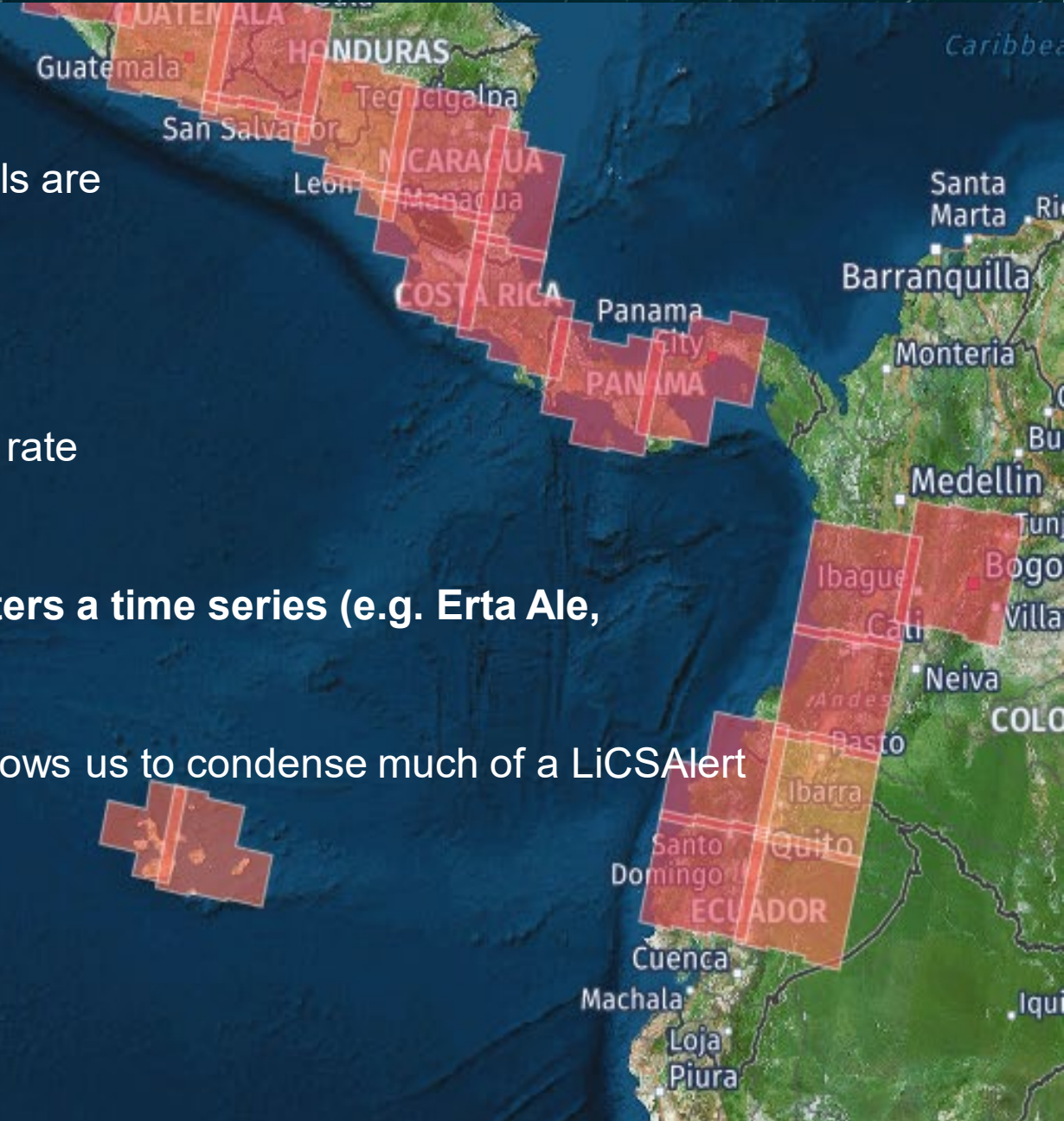
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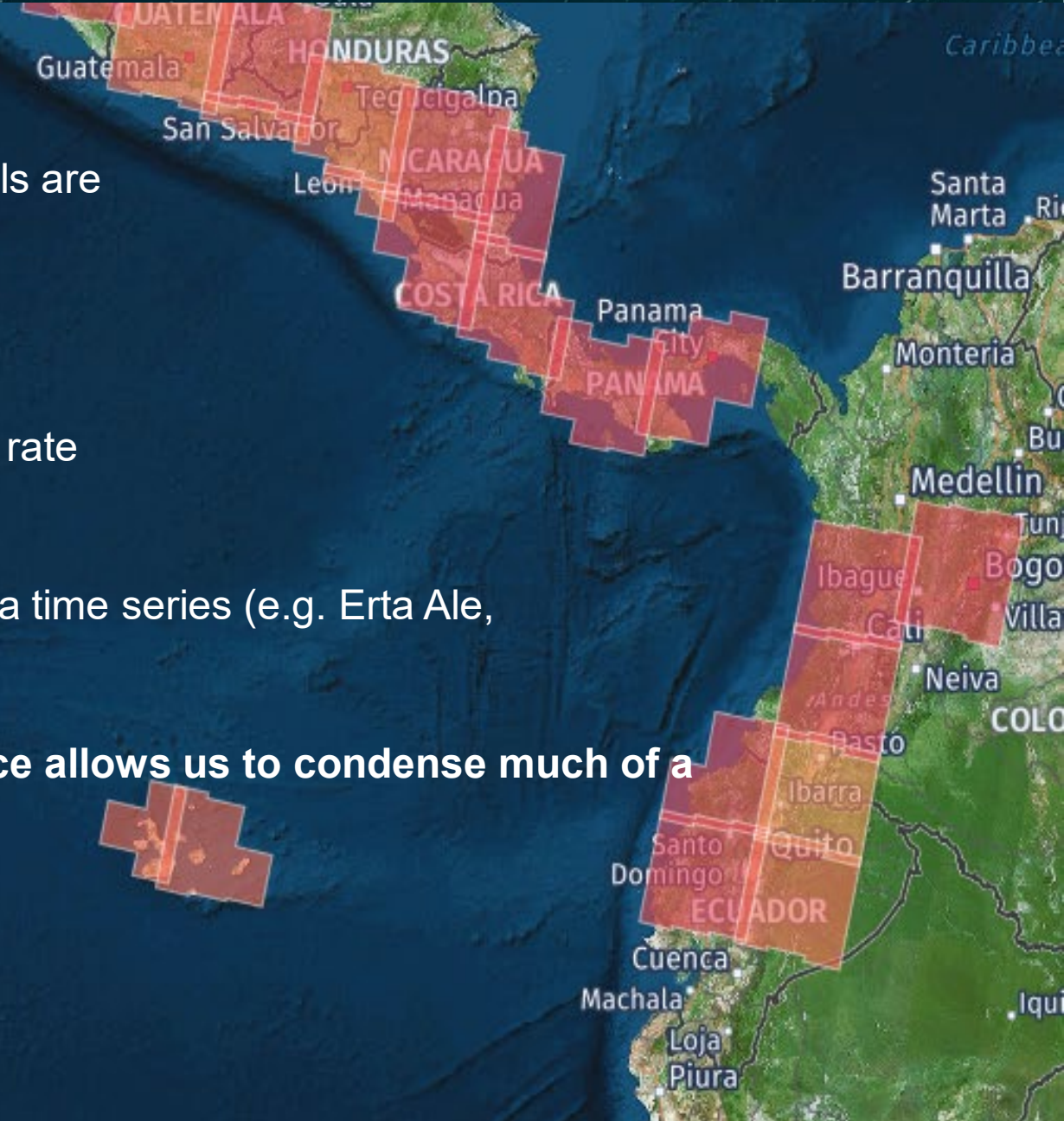
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# Title

- bullet