« Données, algorithmes et applications 3D »

Towards near-real time monitoring of volcanic deformation and lava flow using Capella SAR images

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in collaboration with

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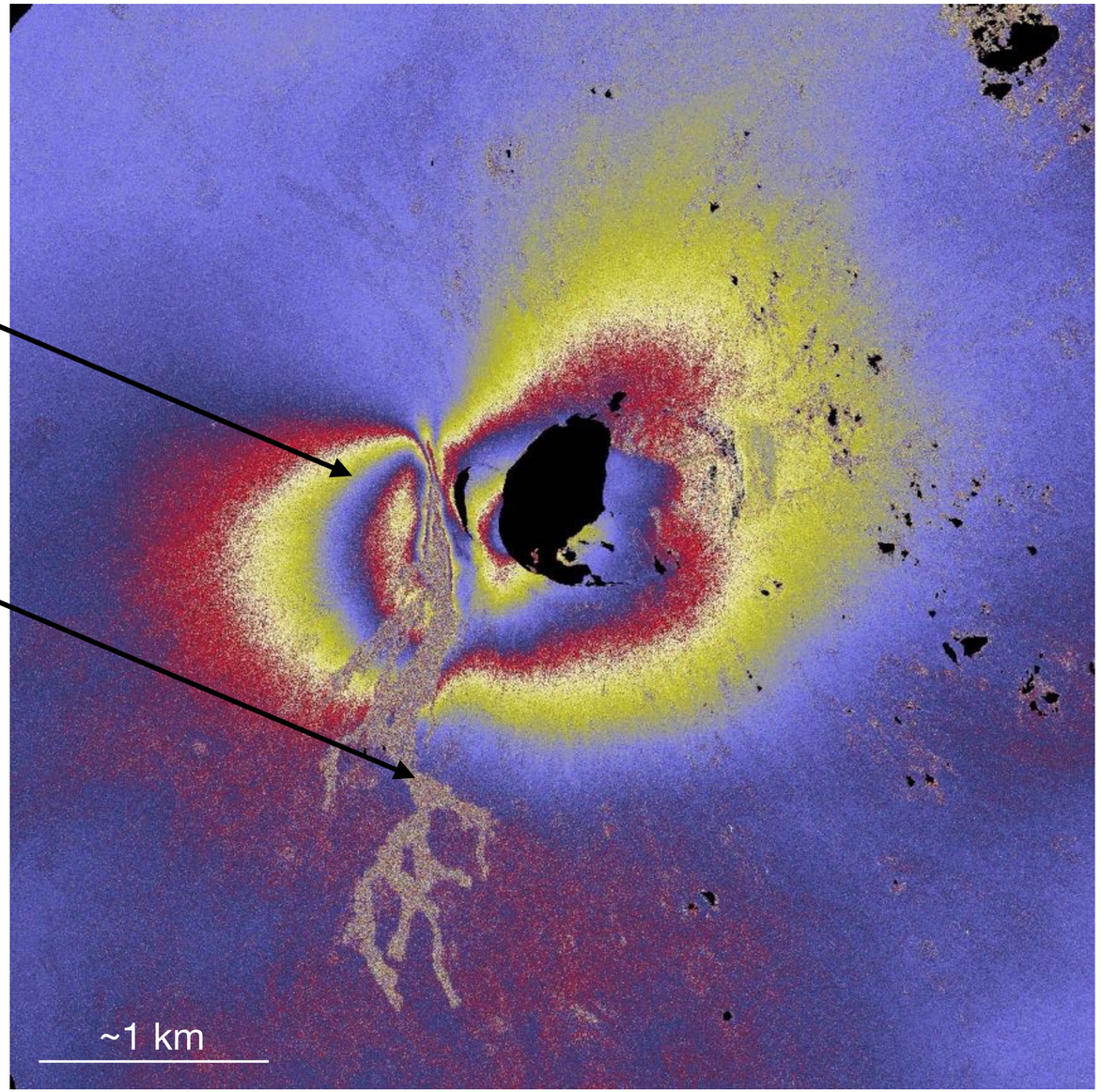
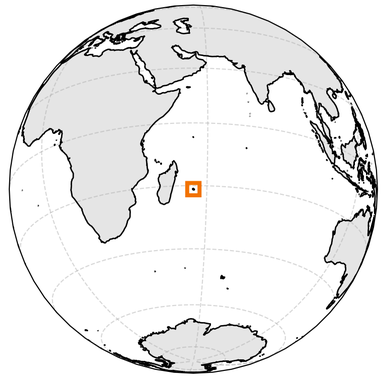
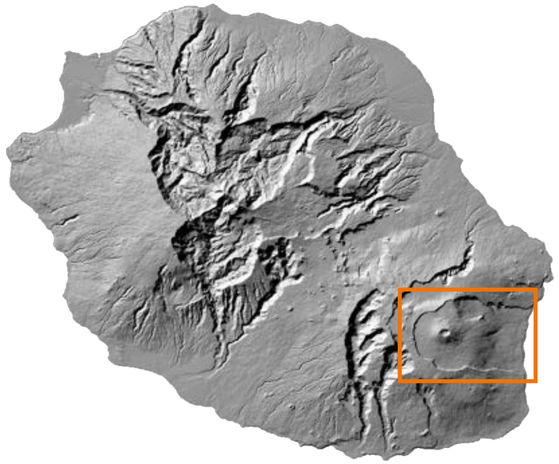
Why not use InSAR?

deformation

lava flow







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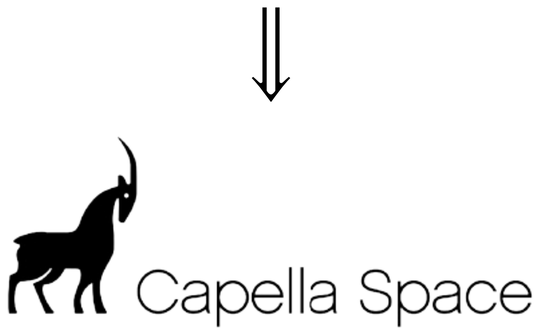
ALOS-2 Spotlight interferogram
Piton de la Fournaise, 2015

Problem

InSAR: revisit time of ~10 days

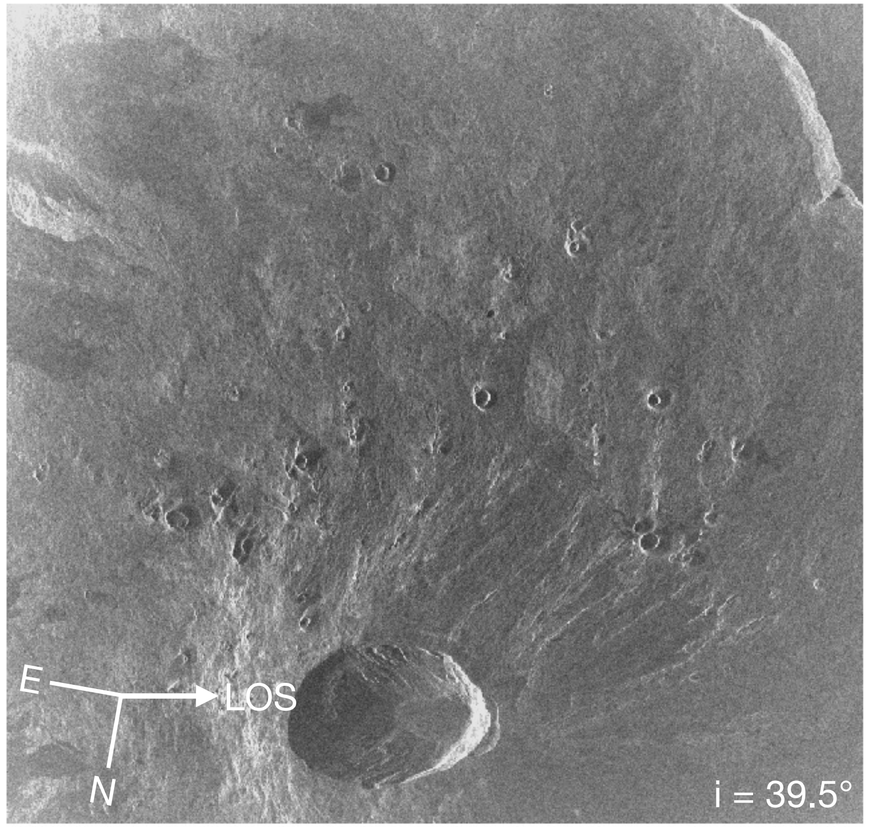
Near-real time ($\lesssim$ 1 day) observations required to detect changes in the course of an eruption

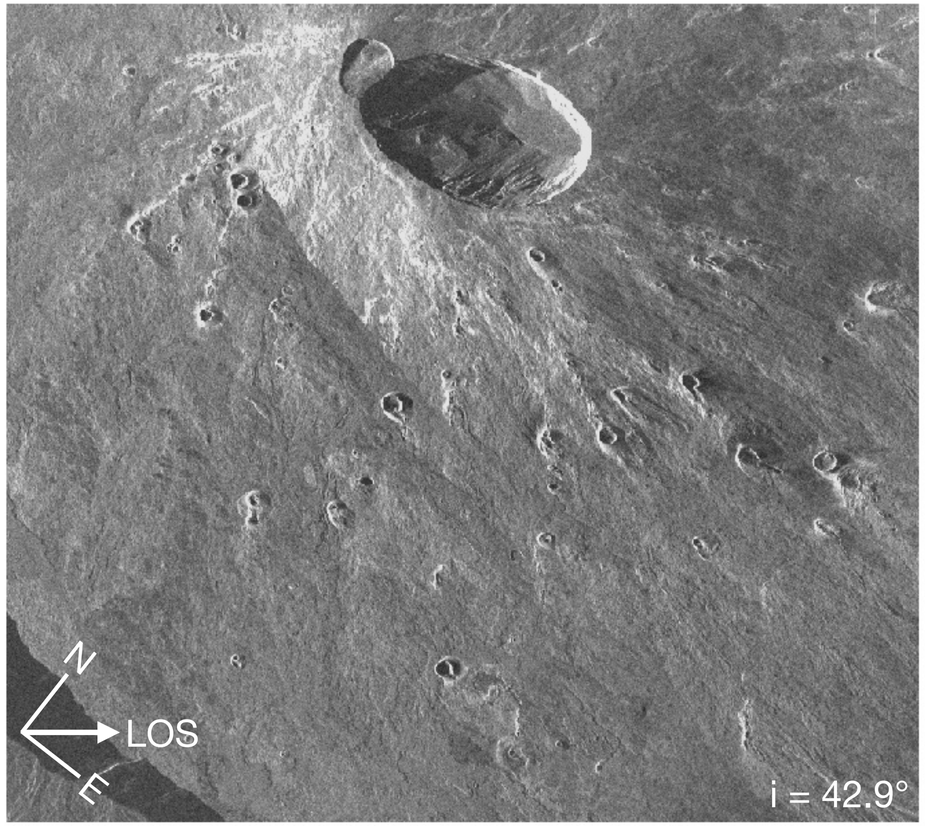


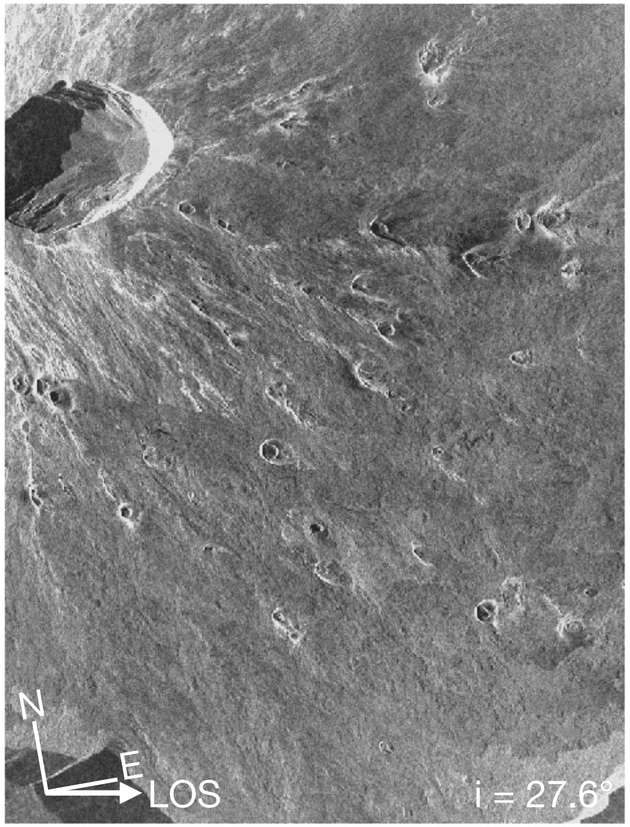
No stability of the acquisition geometry

Changing geometry

Capella Space







1 October

2 October

4 October 2022

$\Delta_{1\text{-DEM}}$

$\Delta_{2\text{-DEM}}$

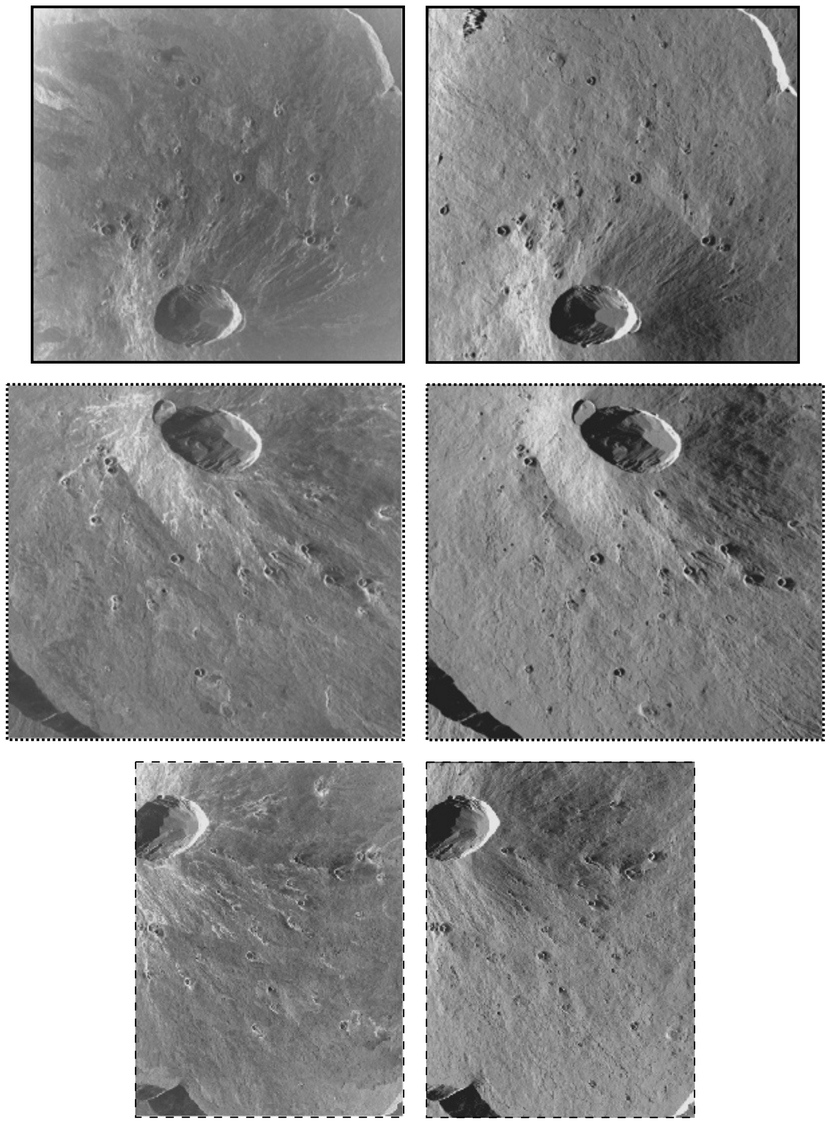
$\Delta_{4\text{-DEM}}$

DEM

Piton de la Fournaise
Sept.-Oct. 2022 eruption

Co-eruptive images

Pre-eruptive synthetics

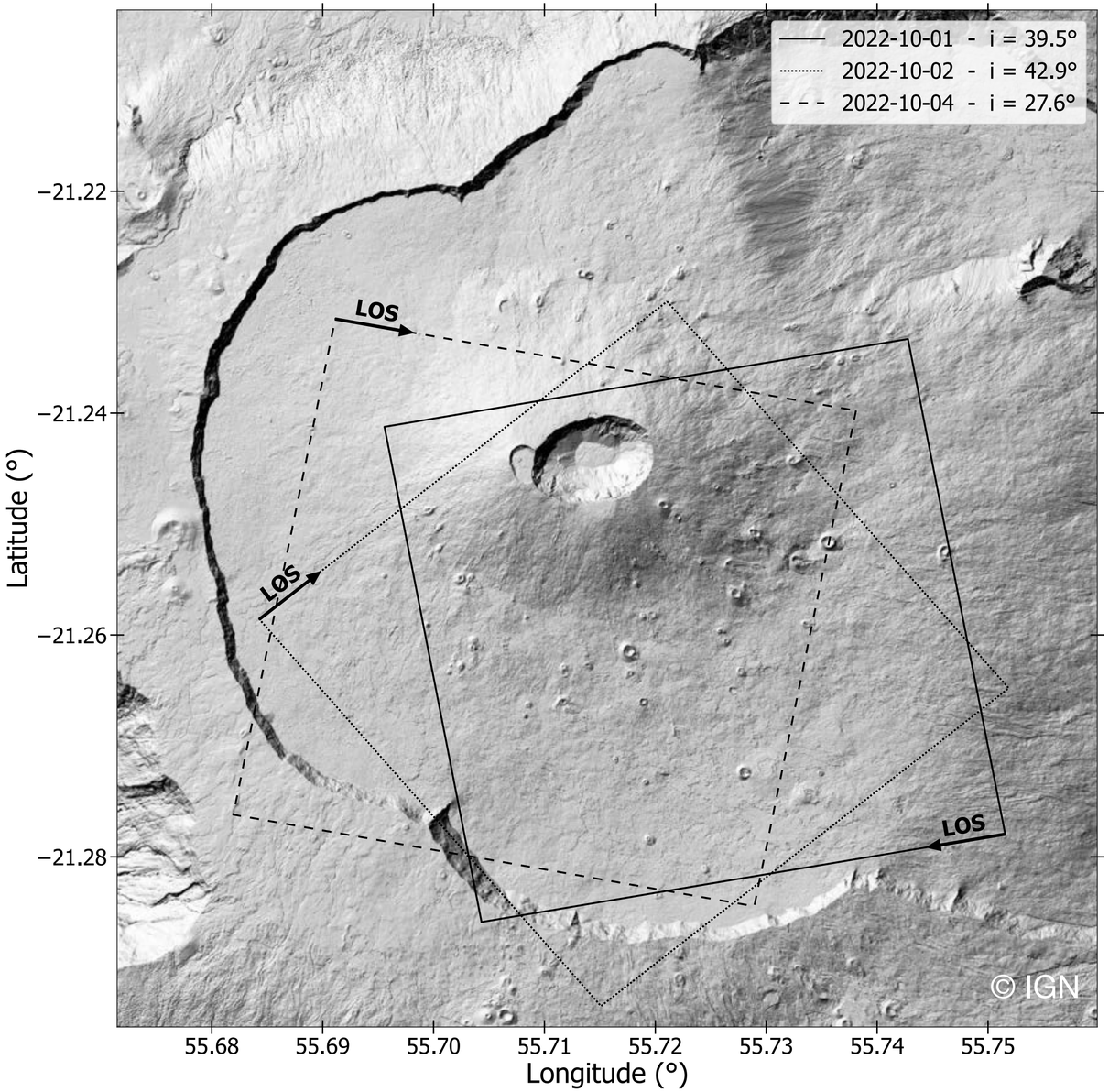


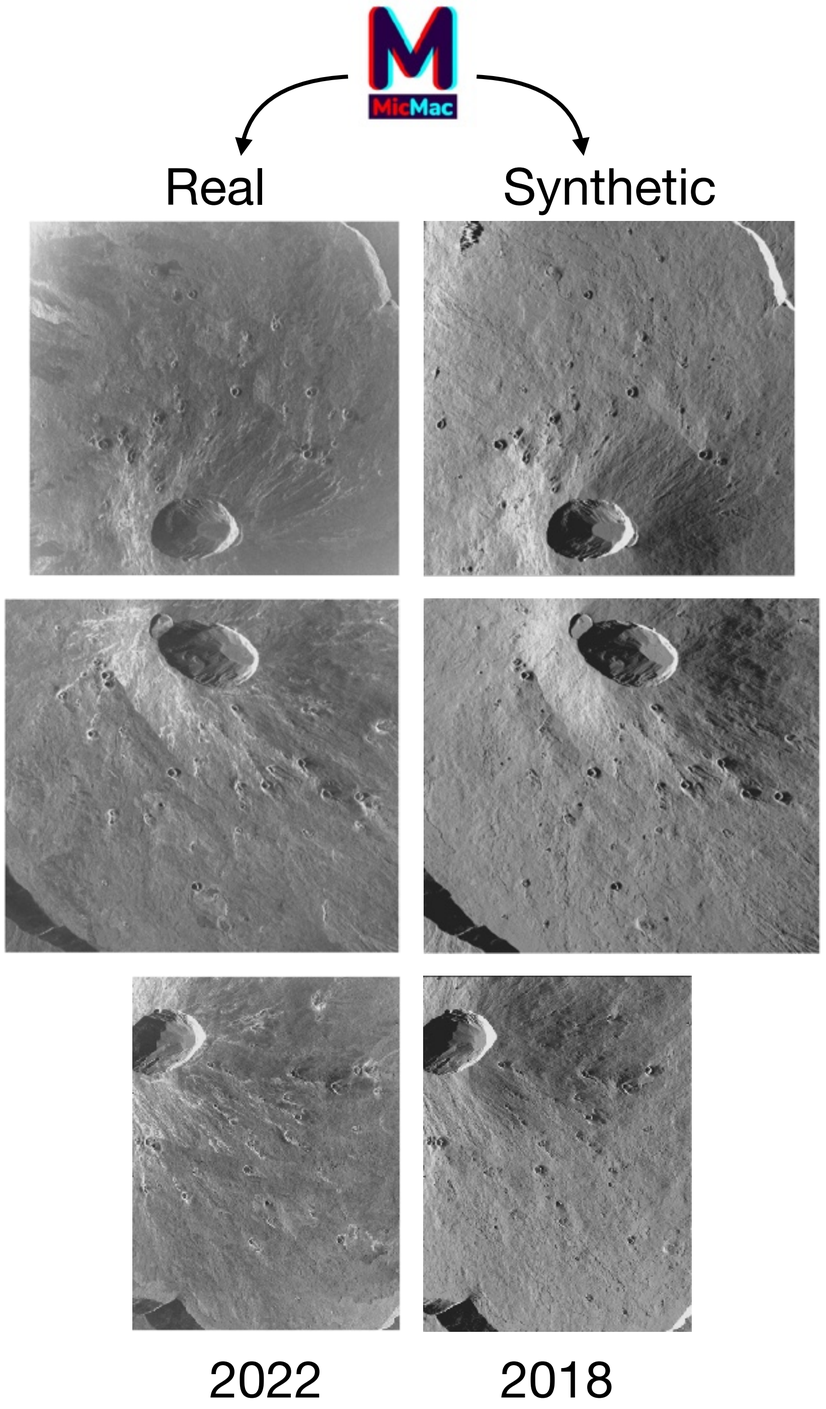
2022 2018

Small, 2011

EOS-SAR
Kayrros

Pre-eruptive DEM
2018

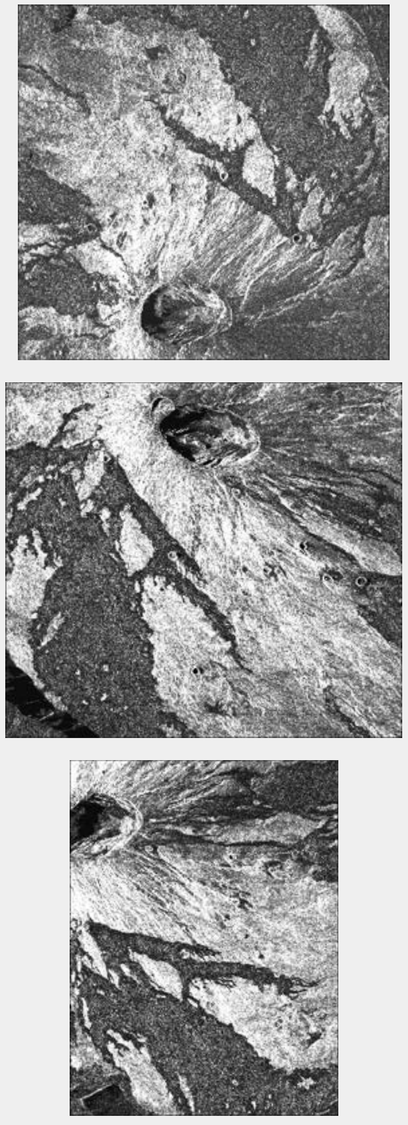




Output 1

Lava flows

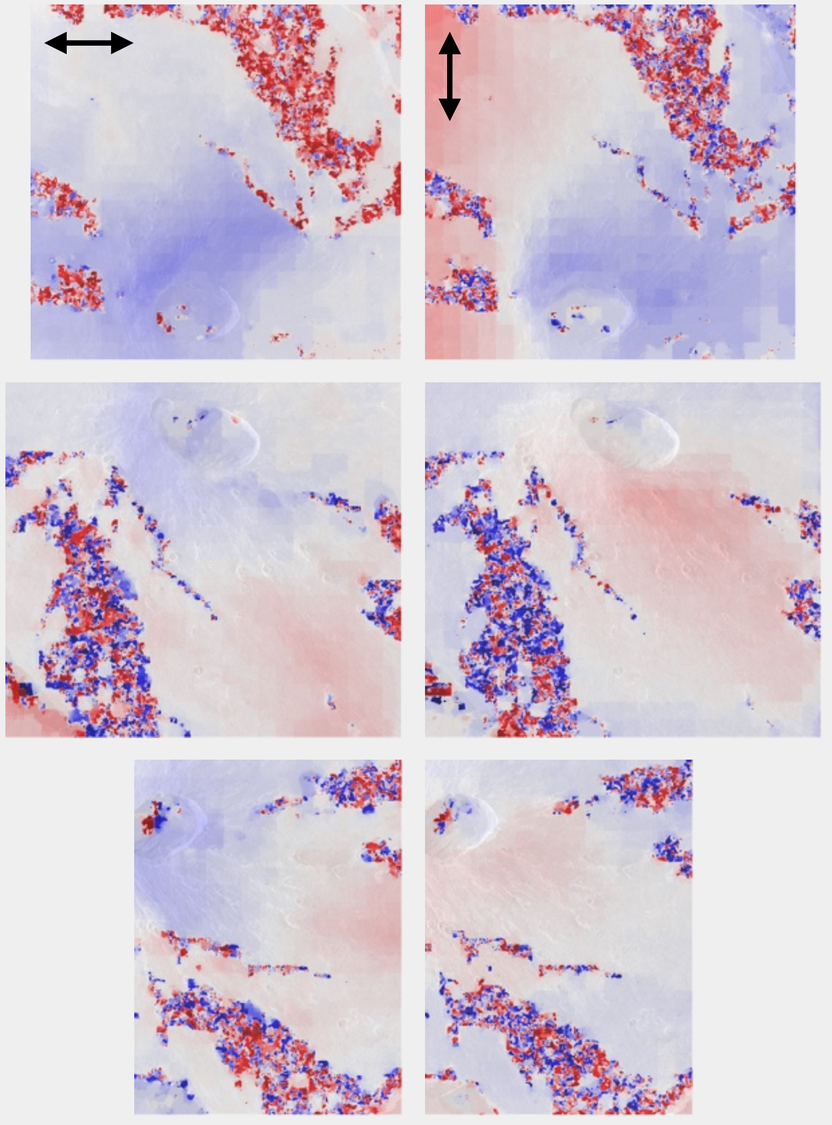
Correlation score



Output 2

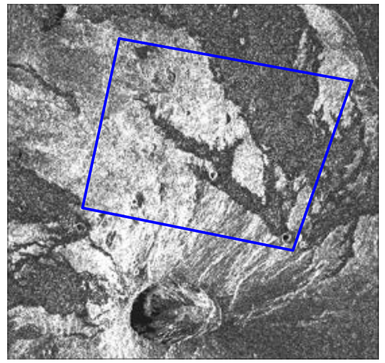
Deformation

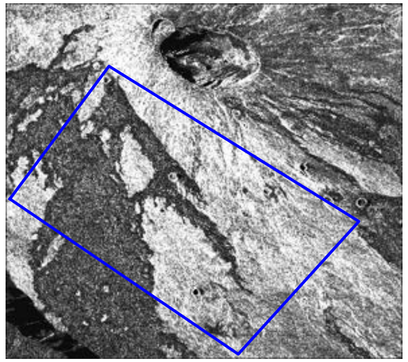
Shifts

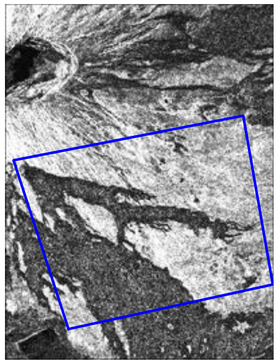


1. Lava flows

Apr. 2018 DEM

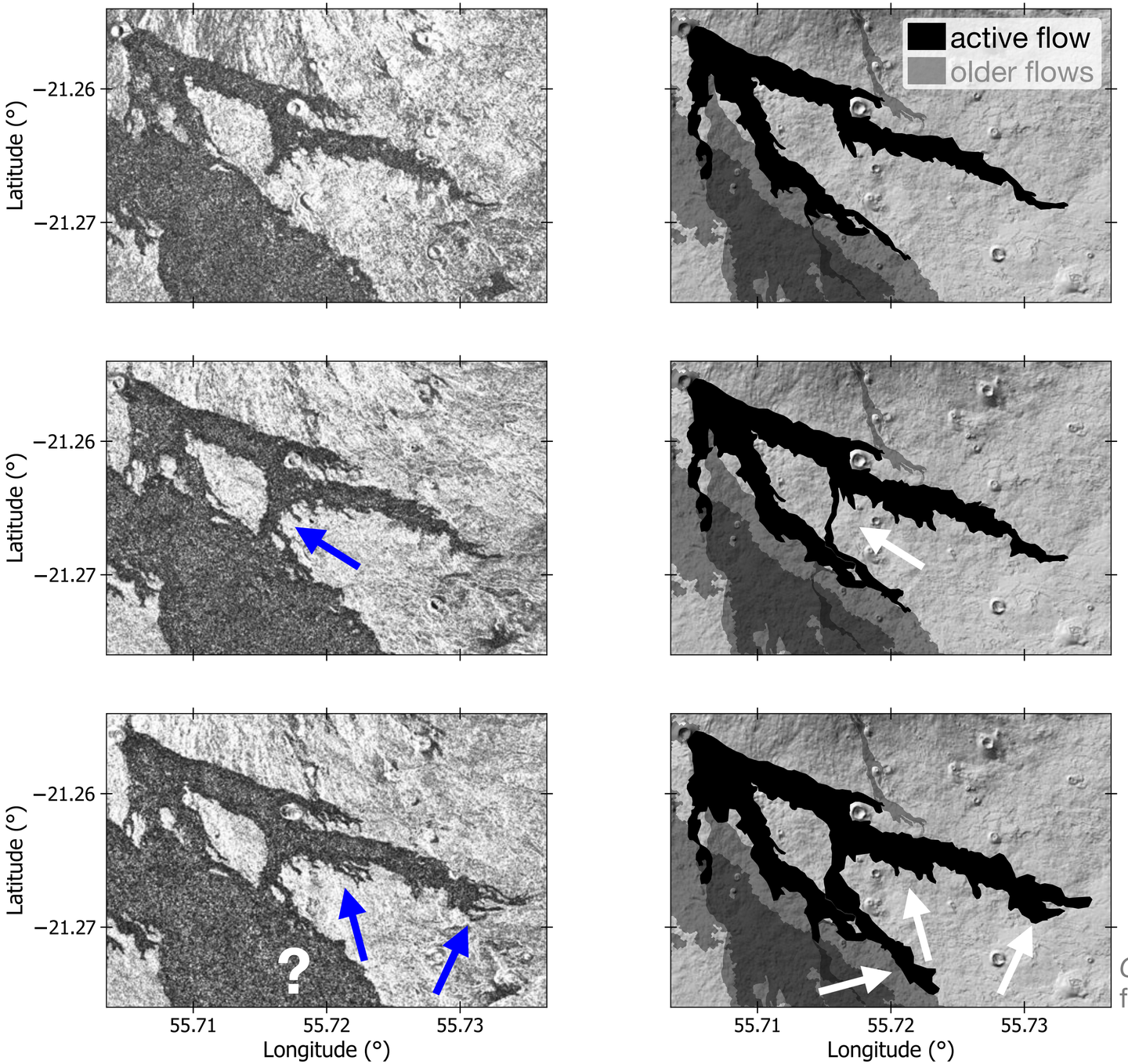






Correlation score

Ground truth



1 October

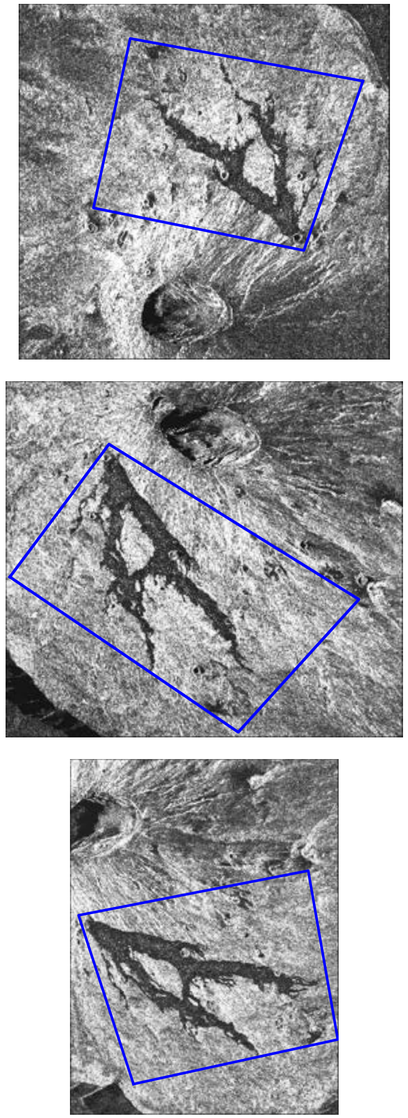
2 October

4 October 2022

Chevrel et al., 2023
from PlanetScope images

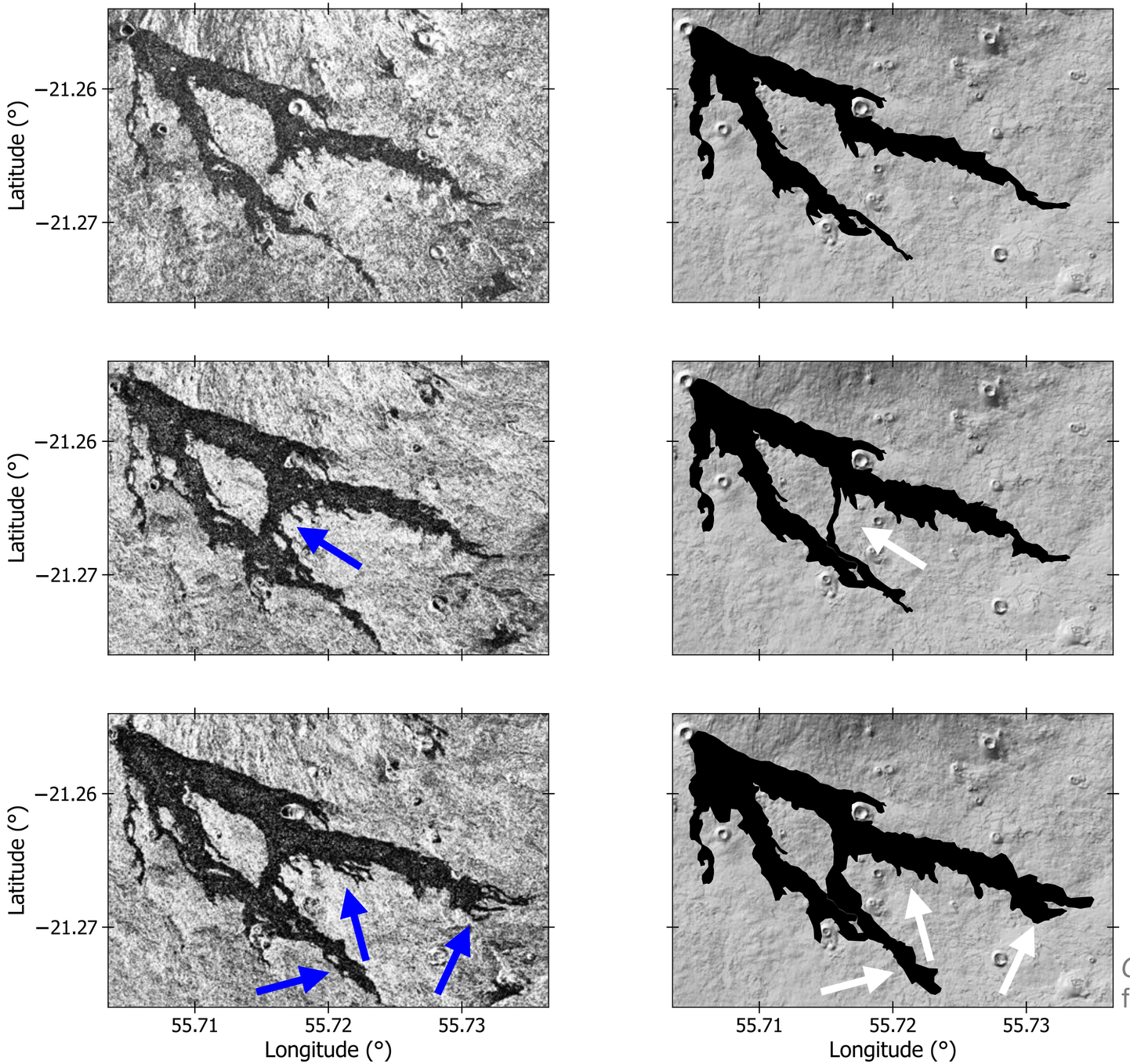
1. Lava flows

Feb. 2022 DEM



Correlation score

Ground truth



1 October

2 October

4 October 2022

Chevrel et al., 2023
from PlanetScope images

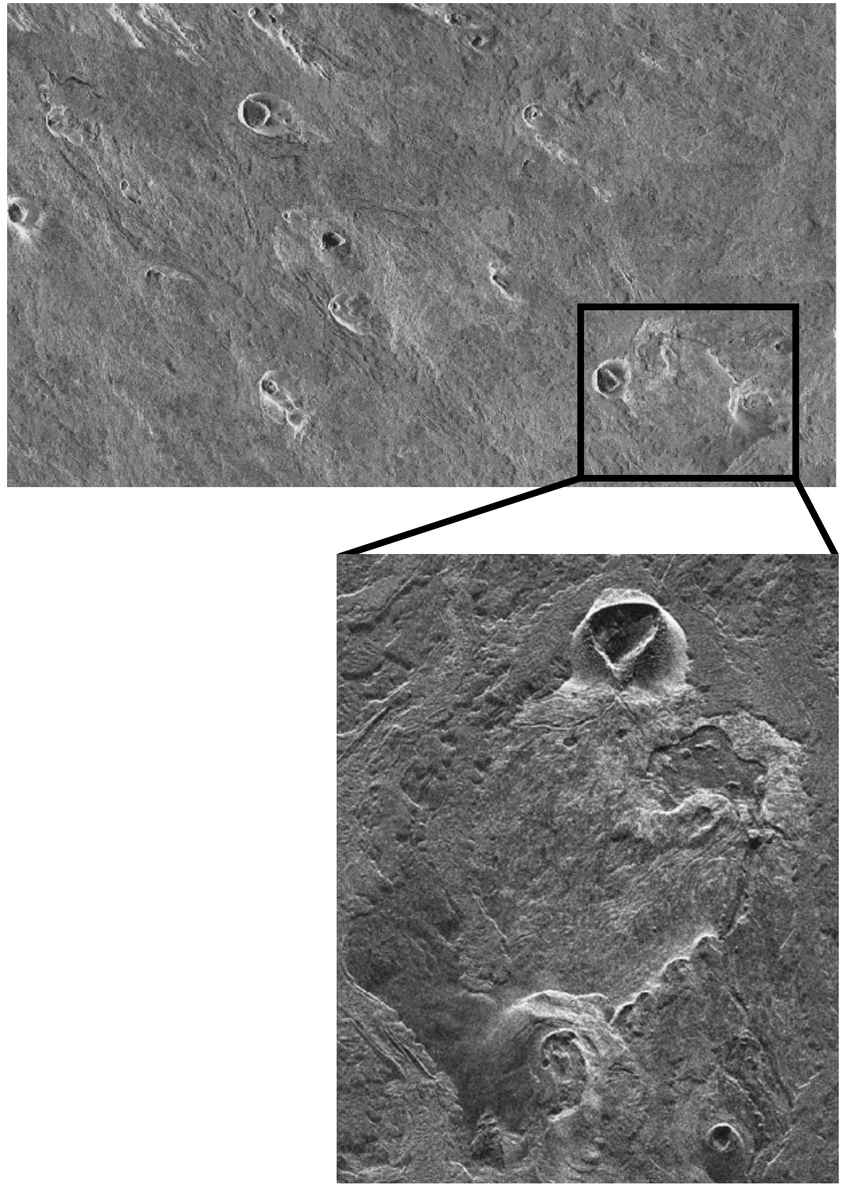
1. Lava flows

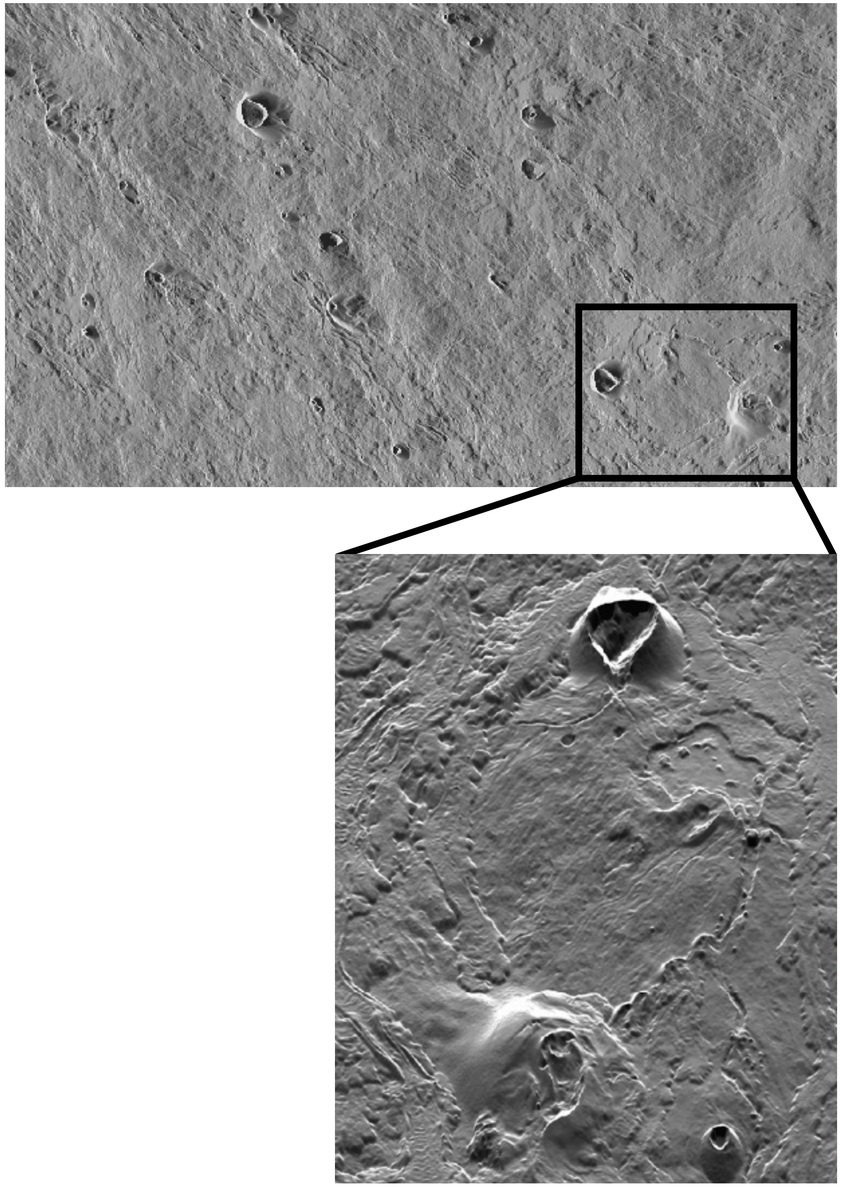
Synthetic images

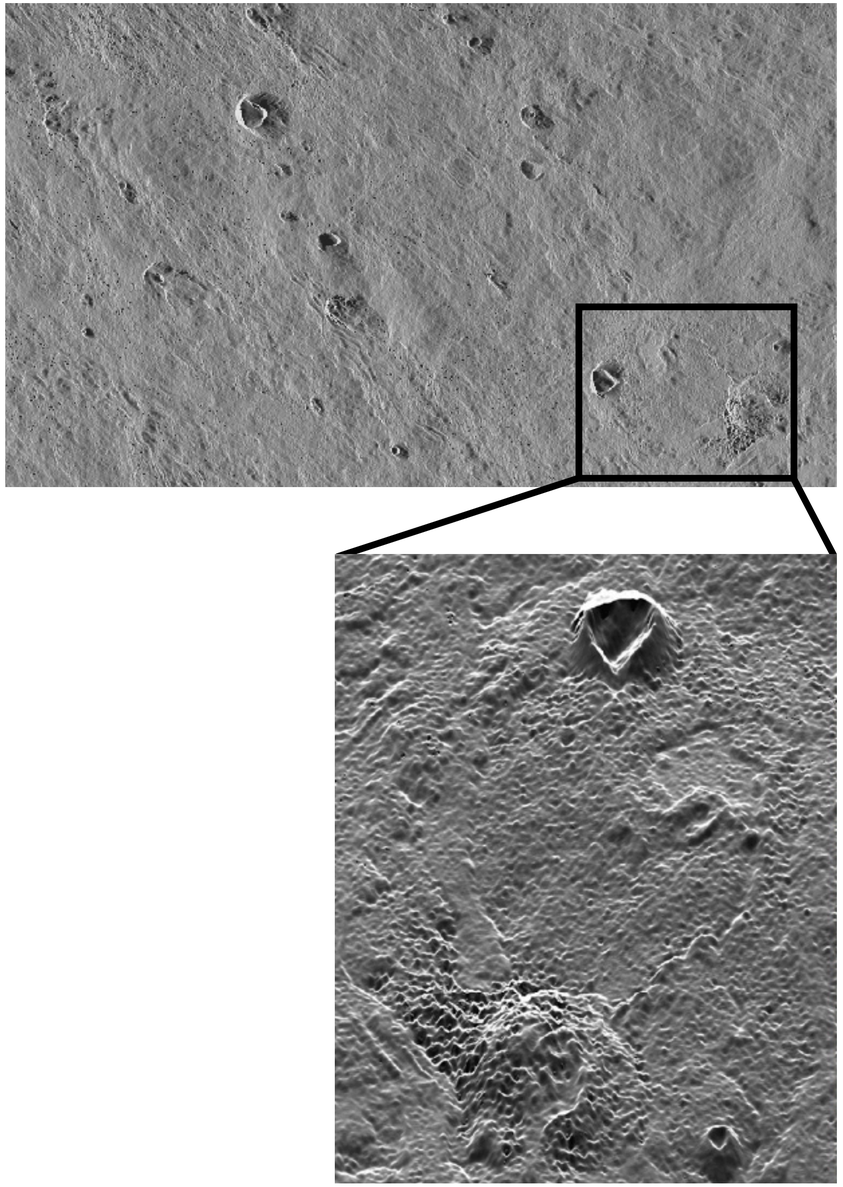
Capella Space image

LiDAR DEM

Pléiades DEM







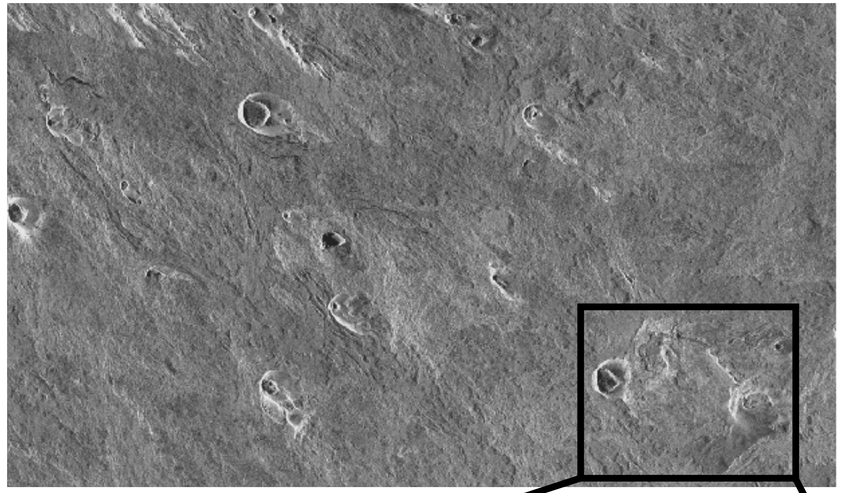
1. Lava flows

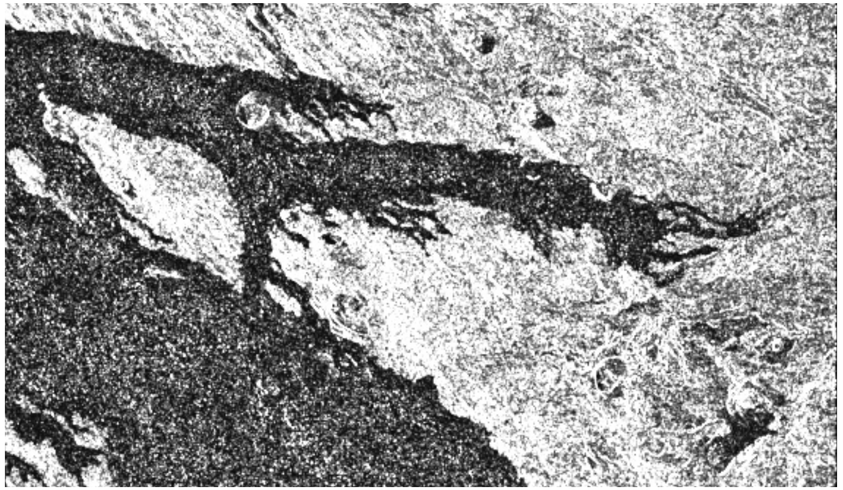
Correlation score

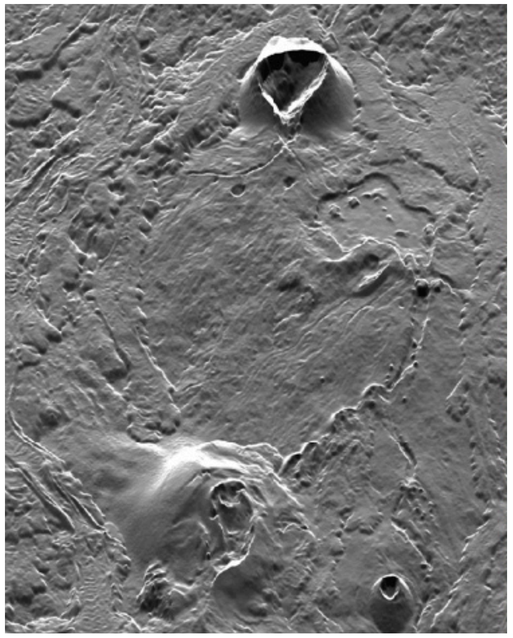
Capella Space image

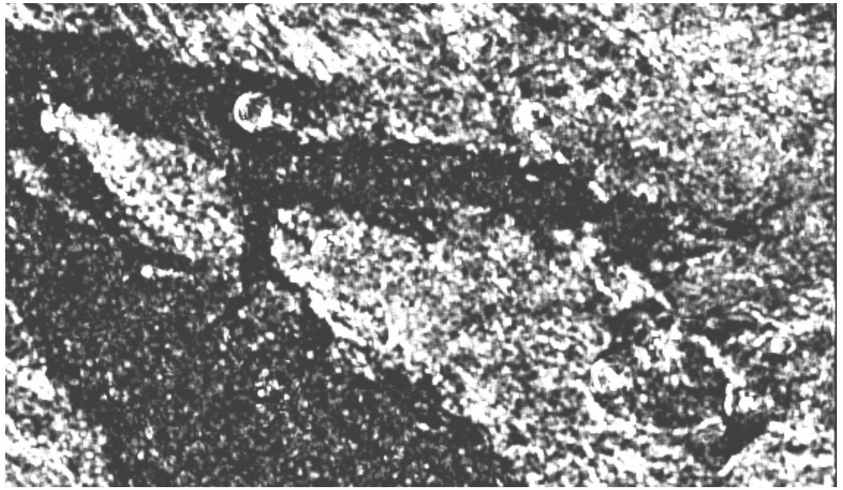
LiDAR DEM

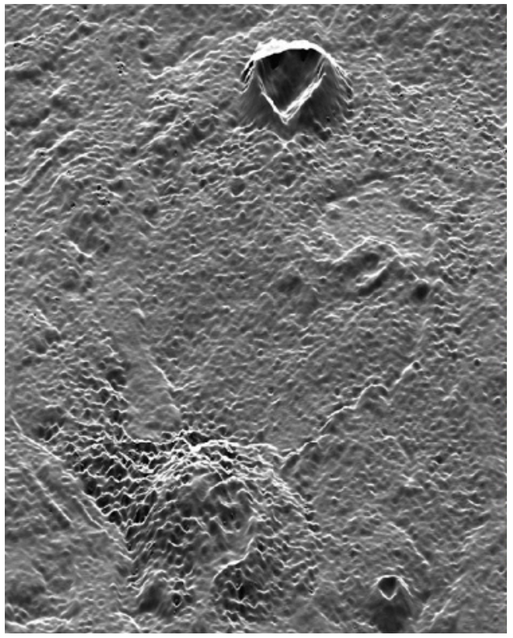
Pléiades DEM



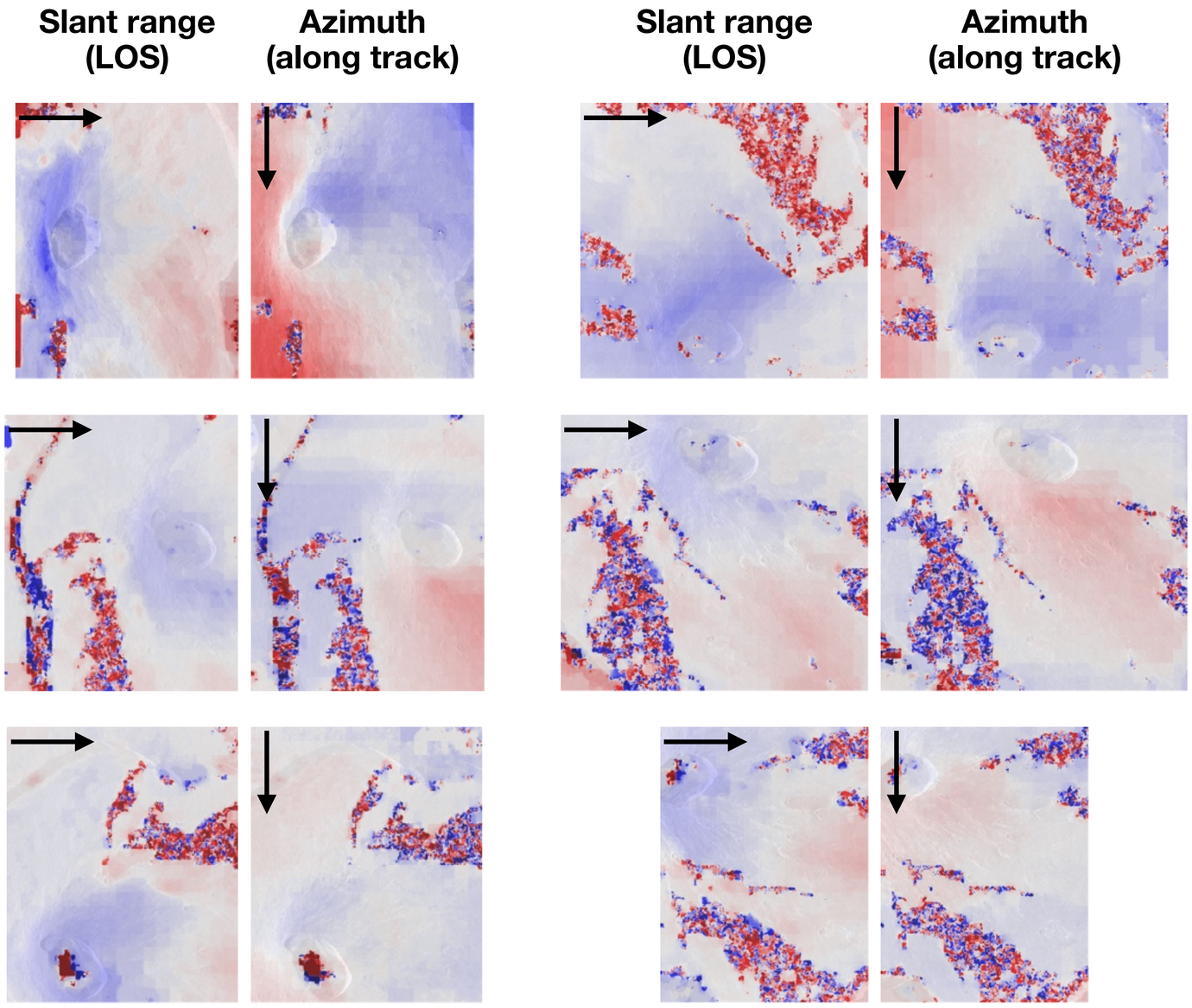


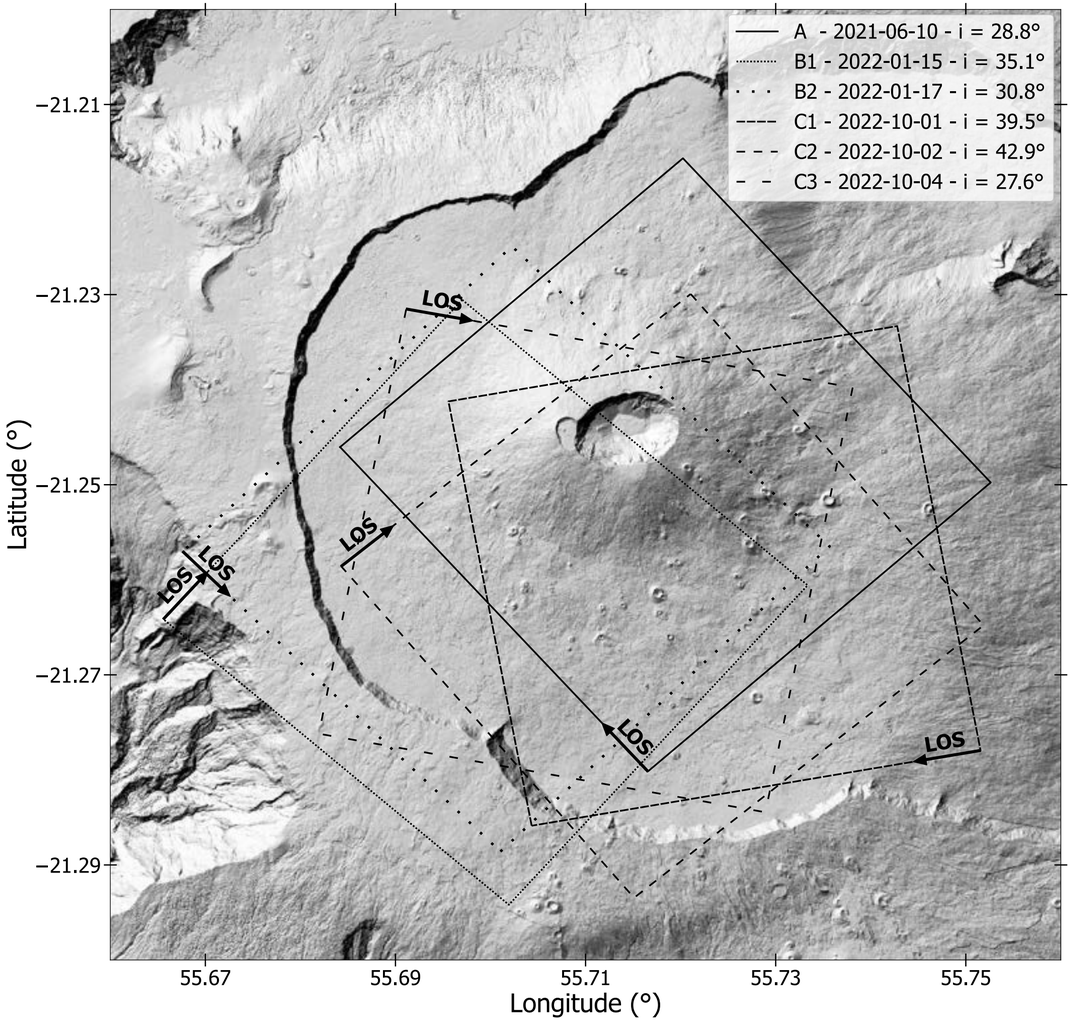






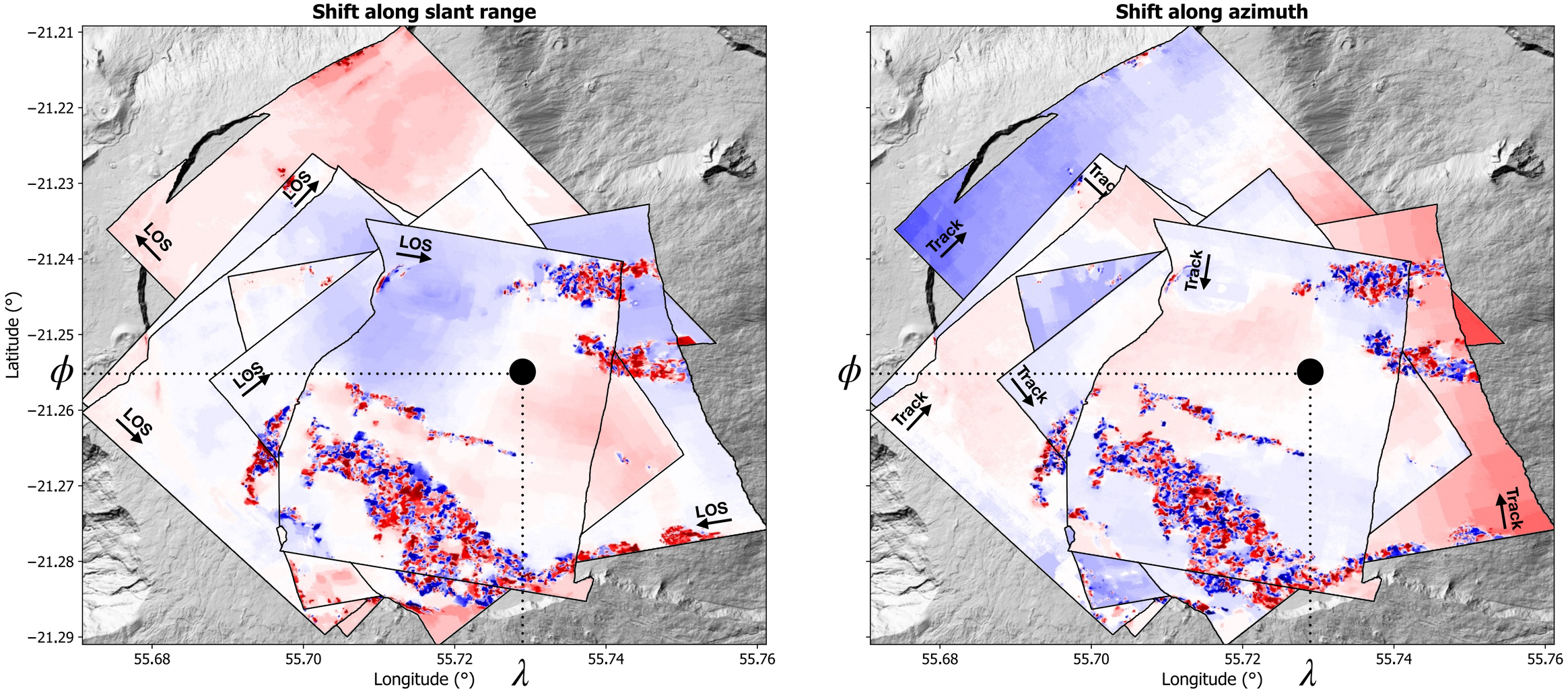
2. Volcanic deformation





2. Volcanic deformation

$$n_{obs}(\lambda, \phi) = 2 \times n_{images}(\lambda, \phi)$$



2. Volcanic deformation

$$n_{obs}(\lambda, \phi) = 2 \times n_{images}(\lambda, \phi)$$

$$\Downarrow$$

We can only get the 3D displacement of points where

$$n_{images}(\lambda, \phi) \geqslant 2$$

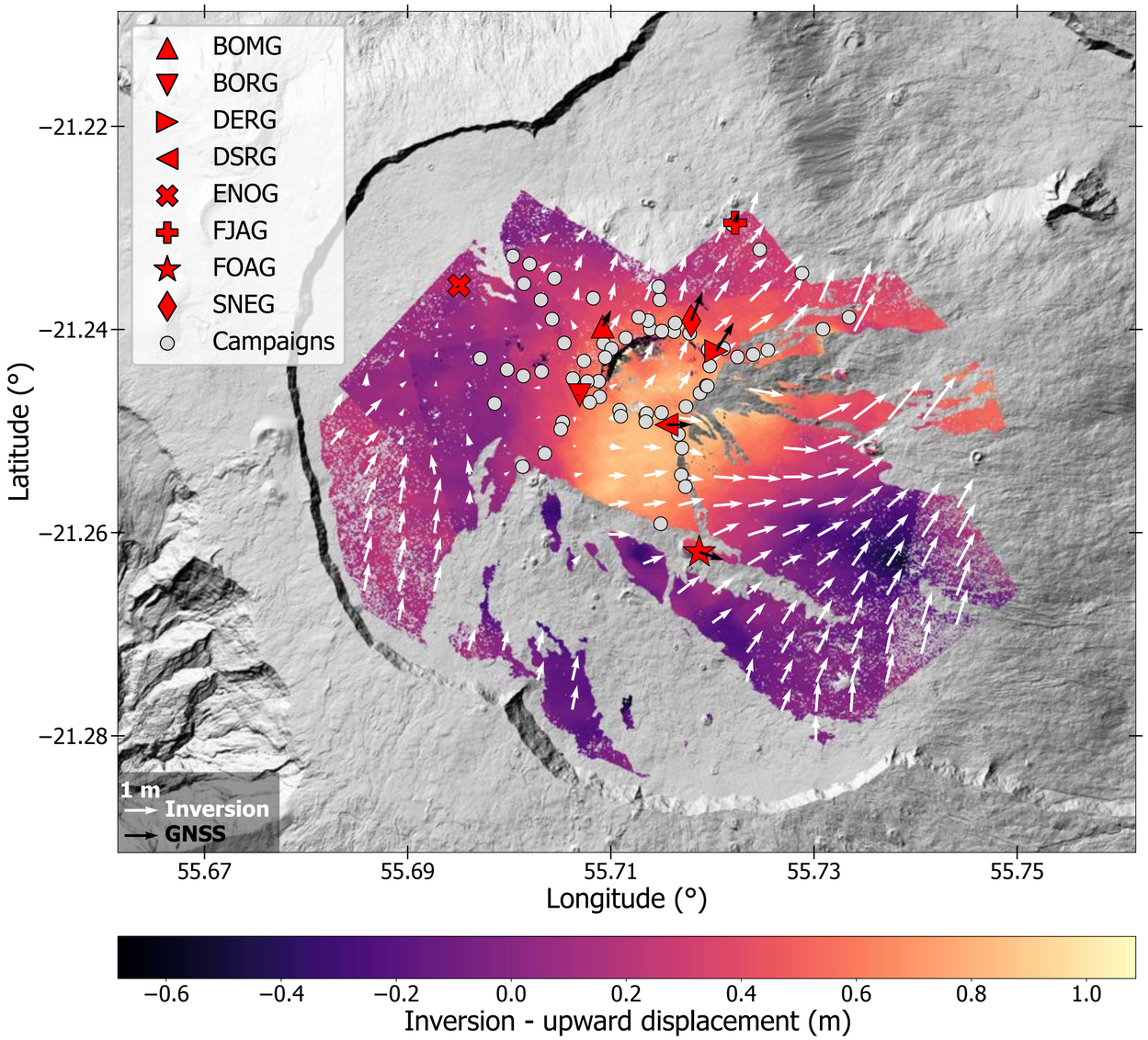
$$\begin{pmatrix} \left(\delta_{\mathbf{LOS}_\omega}\right)_{\omega \in \Omega} \\ \left(\delta_{\mathbf{Track}_\omega}\right)_{\omega \in \Omega} \end{pmatrix} = \begin{pmatrix} \left(\mathbf{LOS}_\omega\right)_{\omega \in \Omega} \\ \left(\mathbf{Track}_\omega\right)_{\omega \in \Omega} \end{pmatrix} \cdot \begin{pmatrix} \Delta x \\ \Delta y \\ \Delta z \end{pmatrix}, \quad \Omega = \left\{ images(\lambda, \phi) \right\}$$

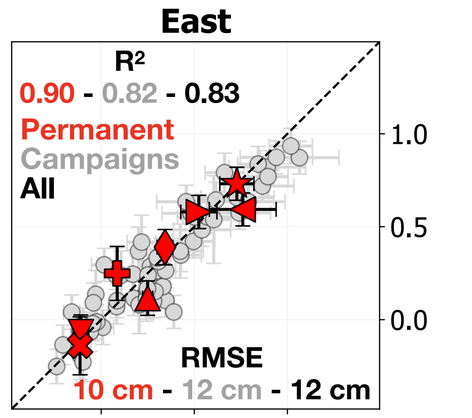
$2n_{images}(\lambda, \phi) \times 1$ $\quad$ $2n_{images}(\lambda, \phi) \times 3$ $\quad$ 3×1 $\quad$ $n_{images}(\lambda, \phi)$

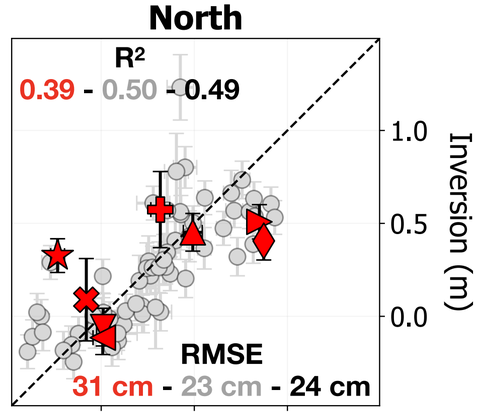
2. Volcanic deformation

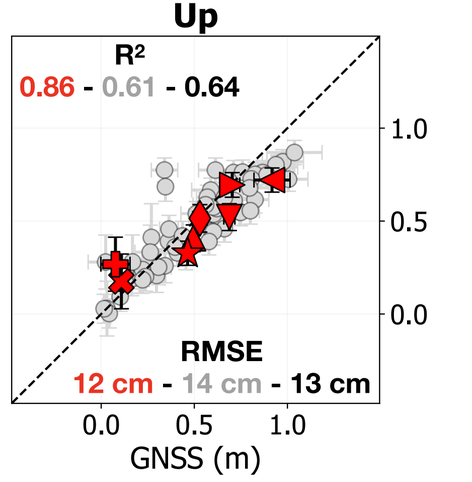
2018 - 2022

Absolute displacement



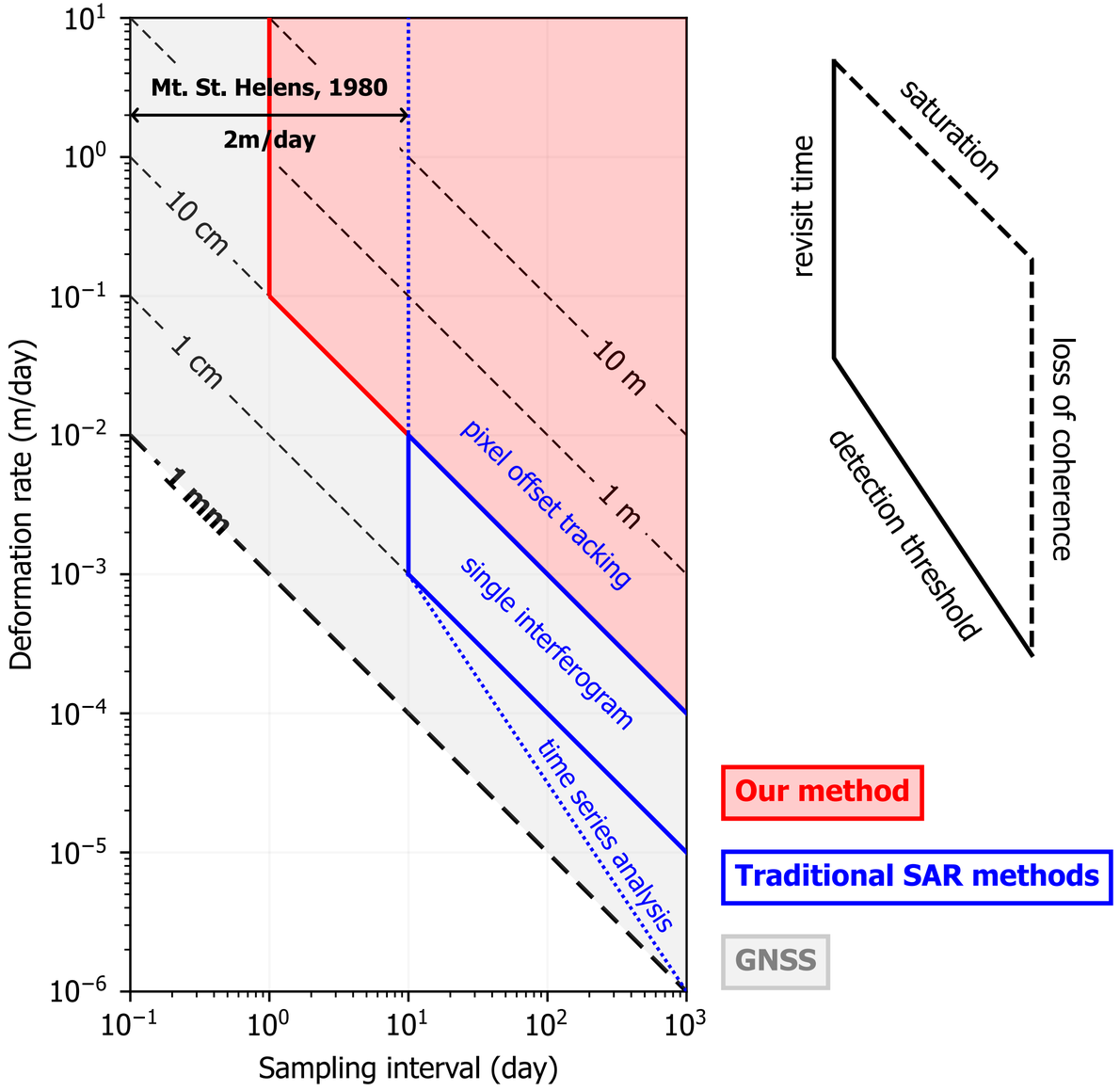






2. Volcanic deformation

	GNSS	InSAR	Our method
Sampling interval	~ 1 s	~ 10 days	~ 1 day
Detection threshold	~ 1 mm	~ 1 cm	~ 10 cm
Saturation	No	~ λ/2 / pixel	No
Spatial continuity	No	Yes	Yes
Damaged during eruptions	Potentially	No	No



Conclusion

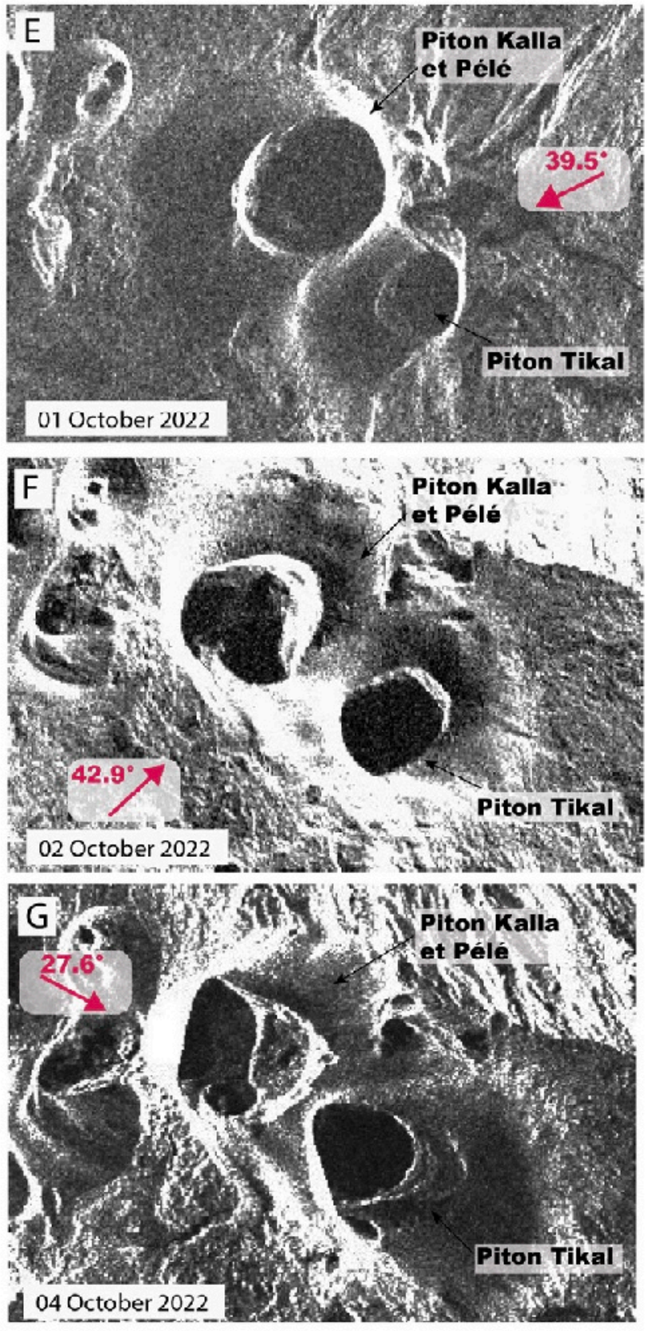
To assist volcanic eruptions monitoring from space we need:

- a very high spatial resolution $\lesssim$ **1 m**
- a very high temporal resolution $\lesssim$ **1 day**

To that end, we have to use every available image, **no matter its acquisition geometry**.

Using **Capella Space SAR images** and a **high resolution DEM** we are able to:

- map **lava flows** on a daily basis
- measure **volcanic deformation**



Capella Space

Chevrel et al., 2023

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