Thaw-season InSAR surface displacements at Zackenberg, NE Greenland

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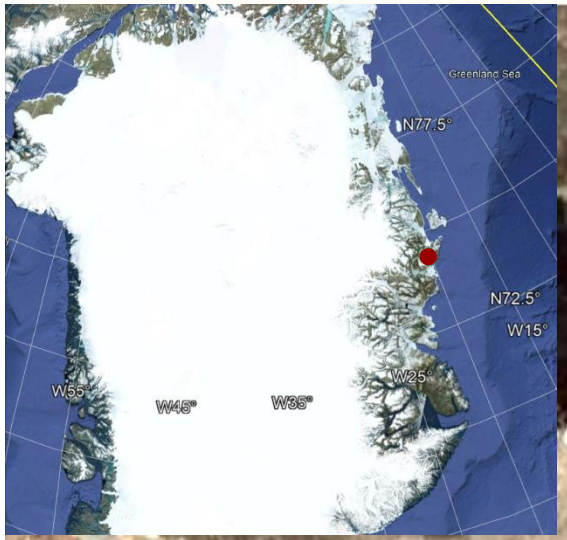
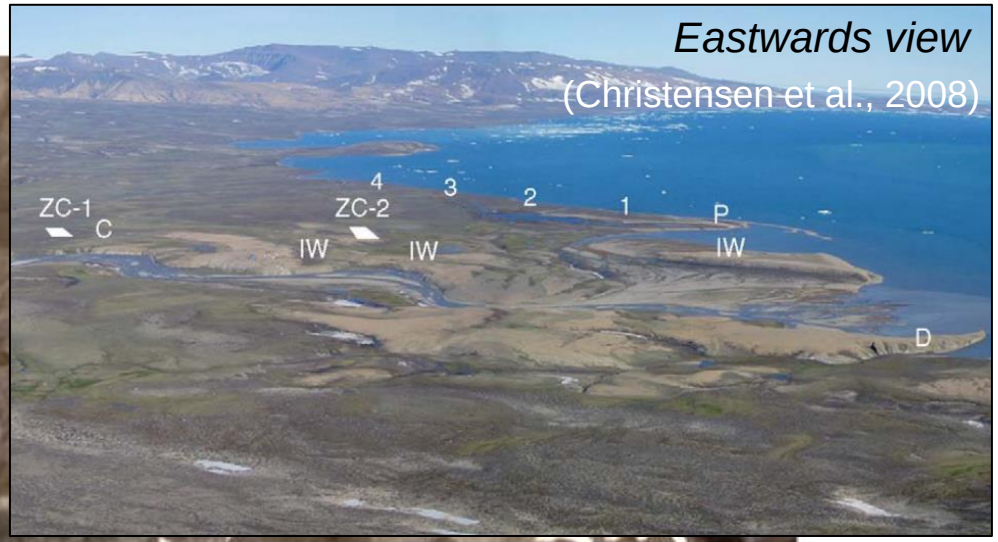
Acknowledgements: Paul Senty, DHI, and Thomas Ingeman-Nielsen, DTU

Zackenberg

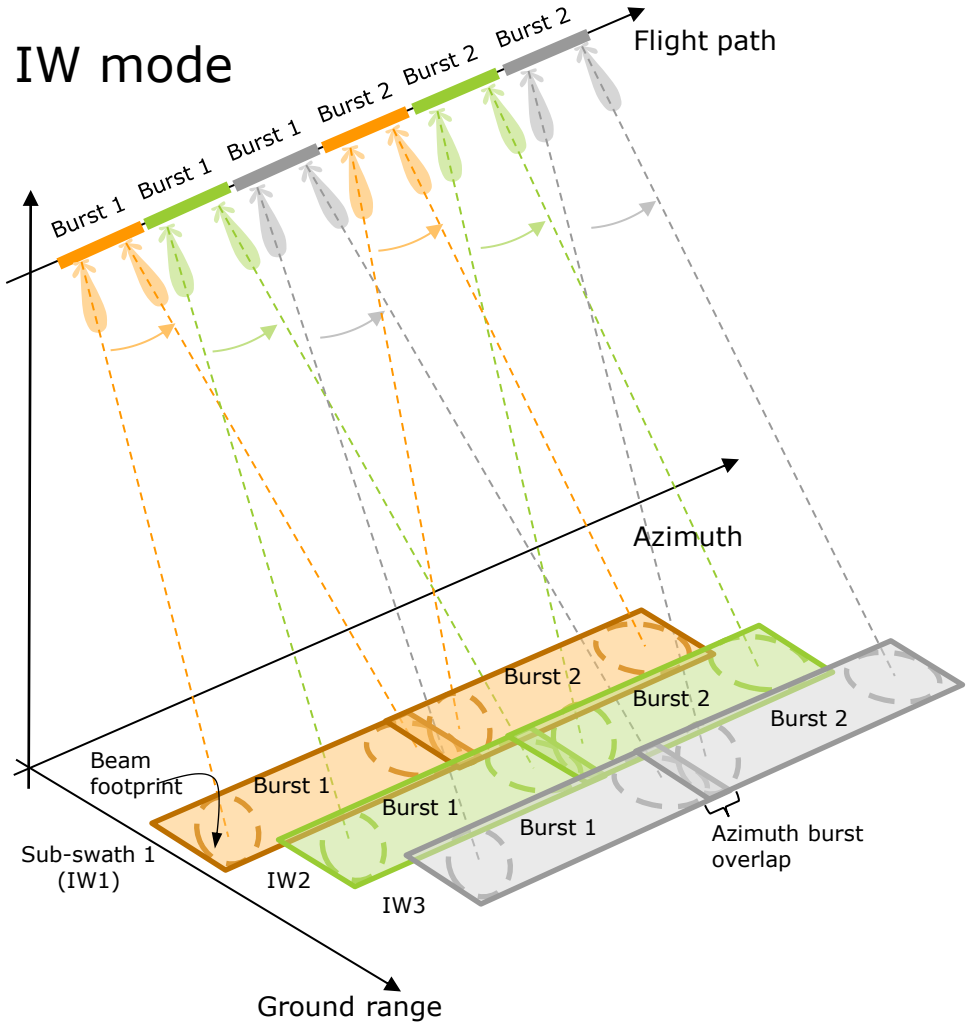

Greenland Sea
N77.5°
N72.5°
W15°
W25°
W35°
W45°
W55°


Eastwards view
(Christensen et al., 2008)
ZC-1
C
ZC-2
IW
4
IW
3
2
1
P
IW
D

Zackenberg mountain
Research station
10 km

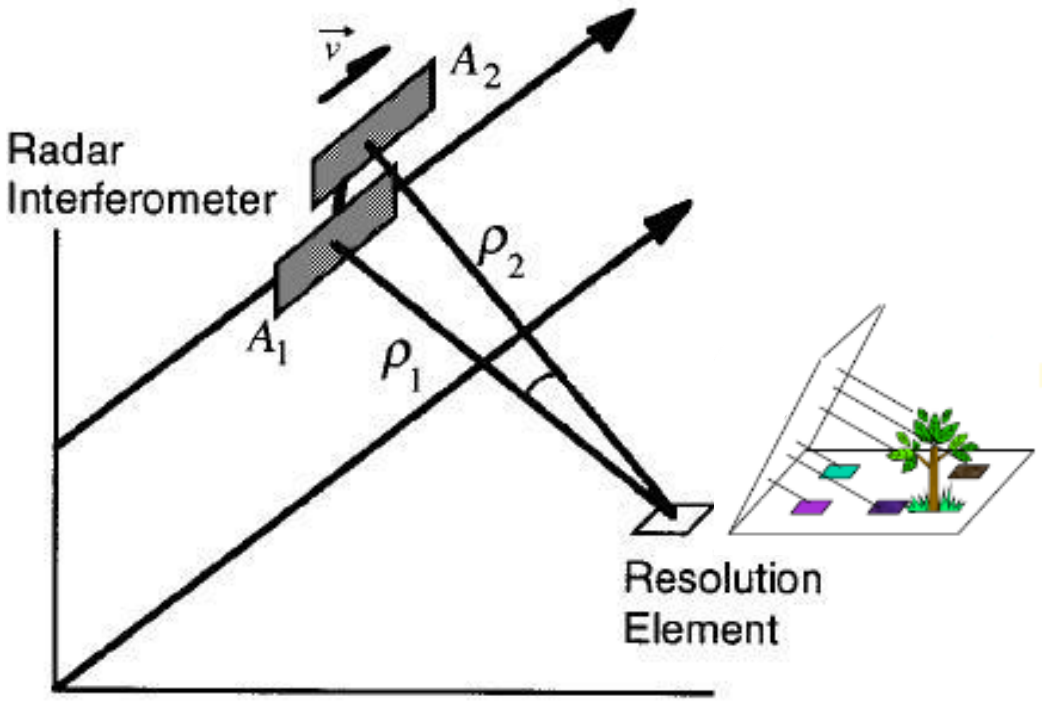

Research station

Sentinel-1 data



- Data used for this study:
  - IW ascending track 74, from May-Oct. 2017 through 2021;
- Both Sentinel-1a and 1b available: 6-day temporal sampling, 5x20 m imagery spatial resolution

InSAR working principle



- The phase of a single SAR image appears random due to “speckle” (interference between the radar returns of elementary scatterers);
- The phase difference between two images (interferogram) is not random, provided the radar returns are statistically similar (coherent).

Image 1 (phase)

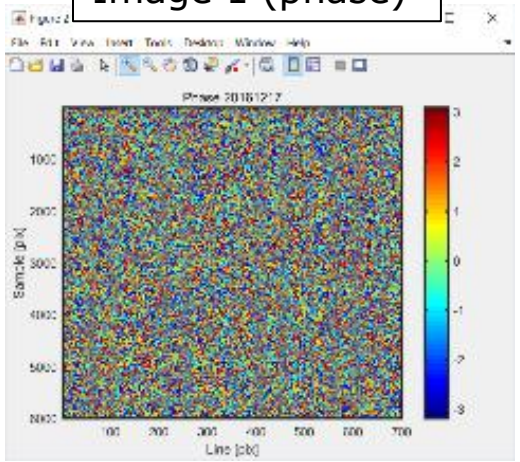
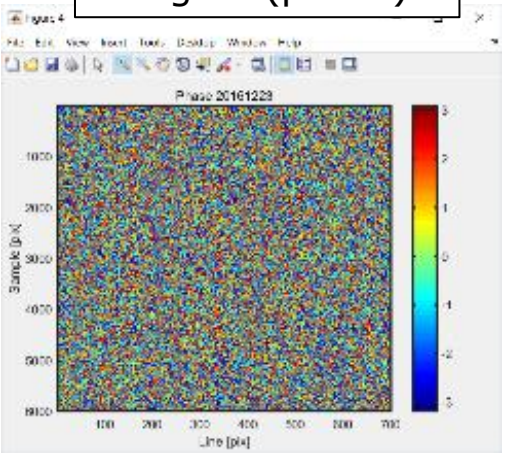
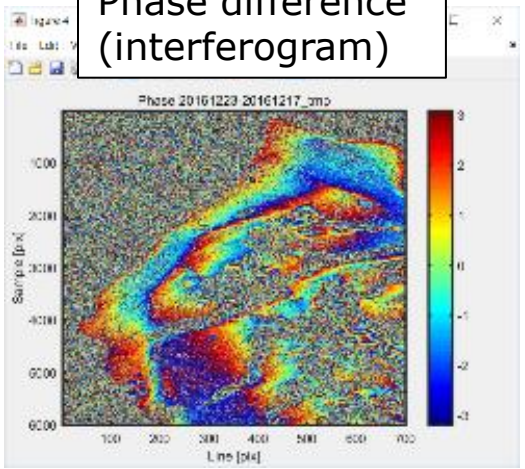


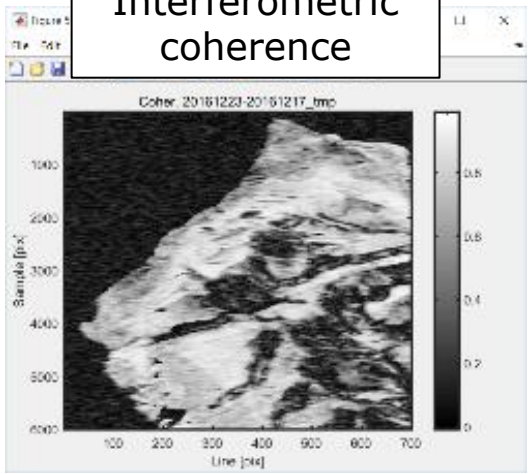
Image 2 (phase)



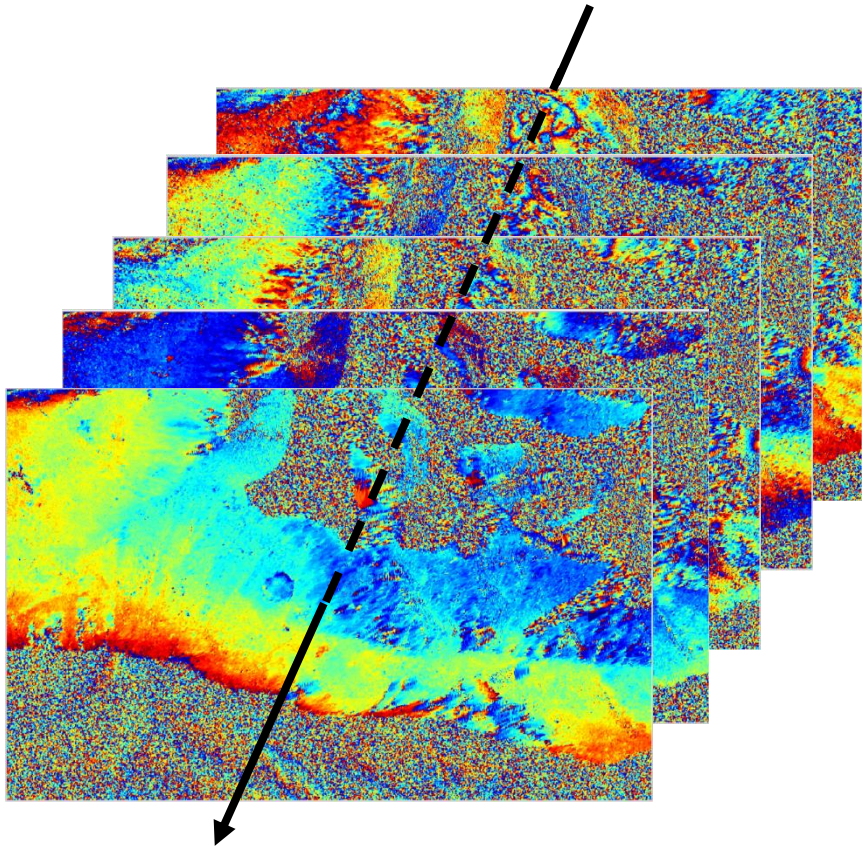
Phase difference (interferogram)

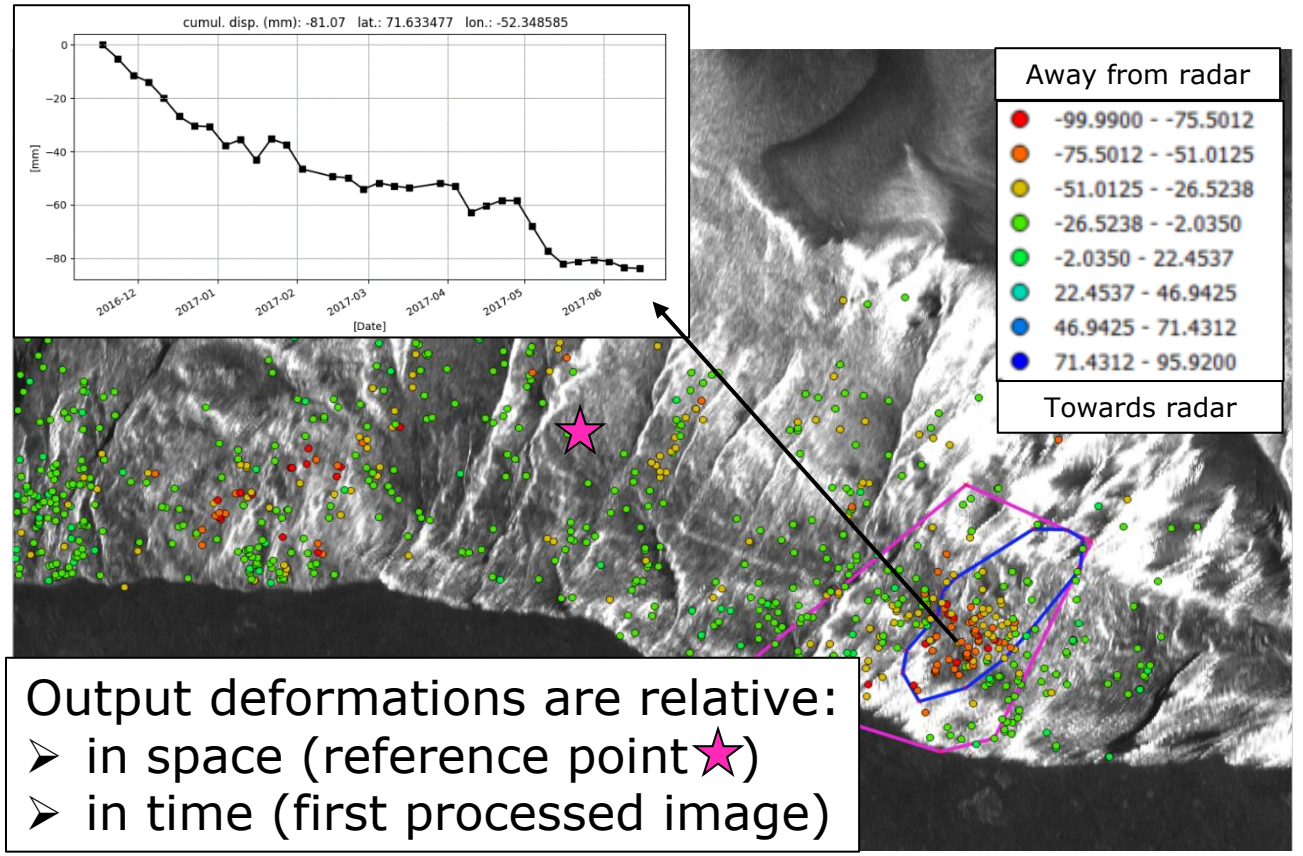


Interferometric coherence



Multi-temporal InSAR processing



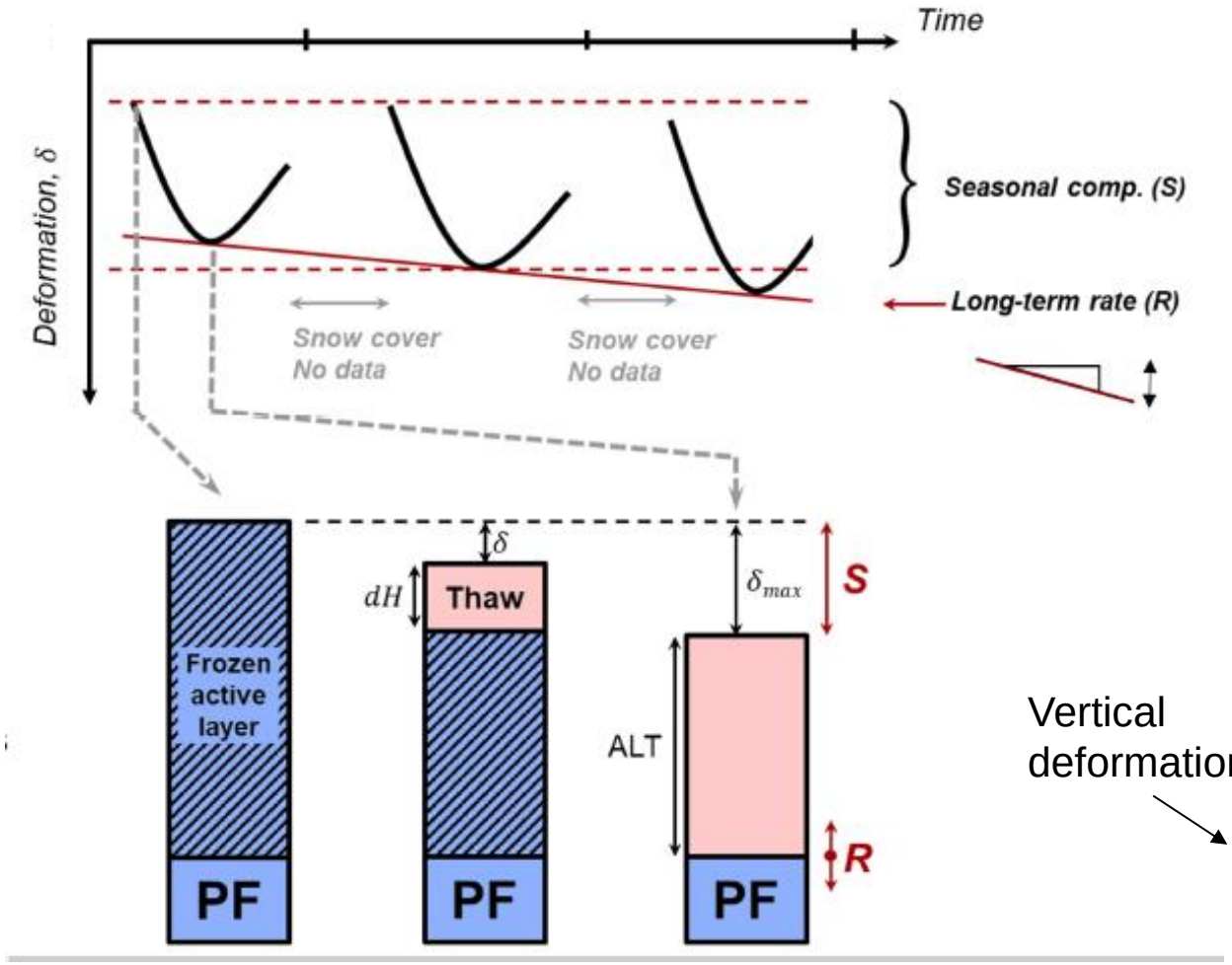


Output deformations are relative:
- in space (reference point ★)
- in time (first processed image)

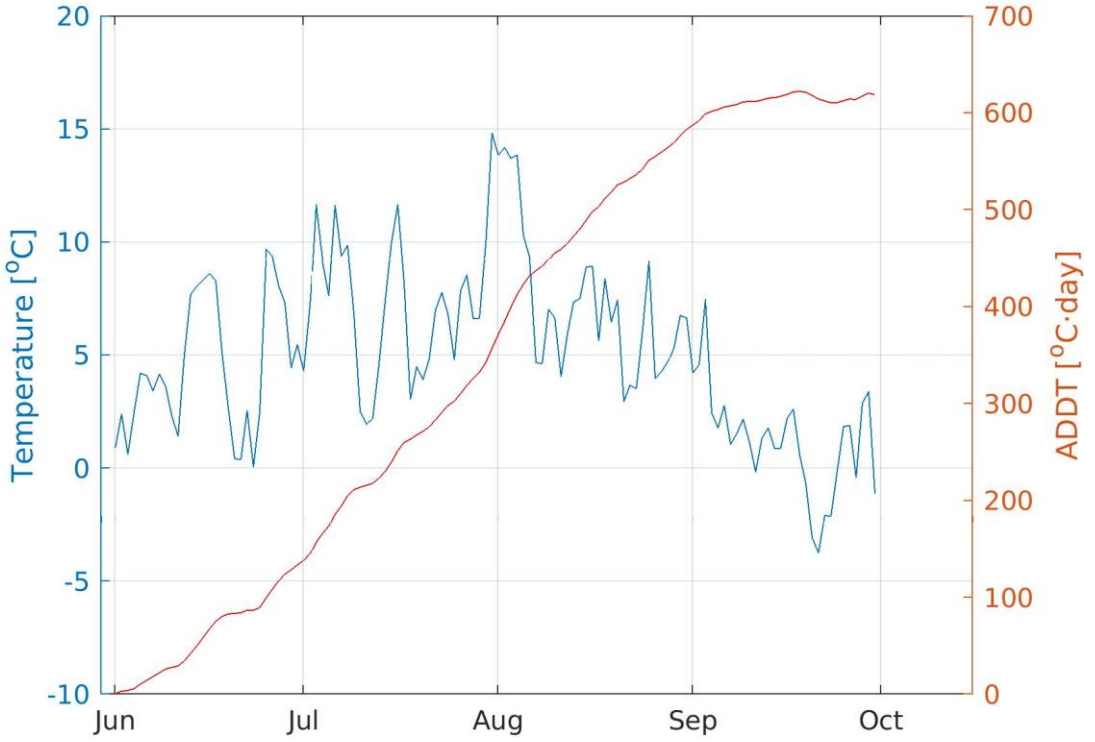
- DTU IPP InSAR software used
- InSAR pairs with temporal separations <= 48 days;
- 40 m x 40 m spatial resolution after averaging.

Interferogram stack generation → Least-squares inversion → 1D deformation time-series (towards/away from the radar)

Expected surface deformation



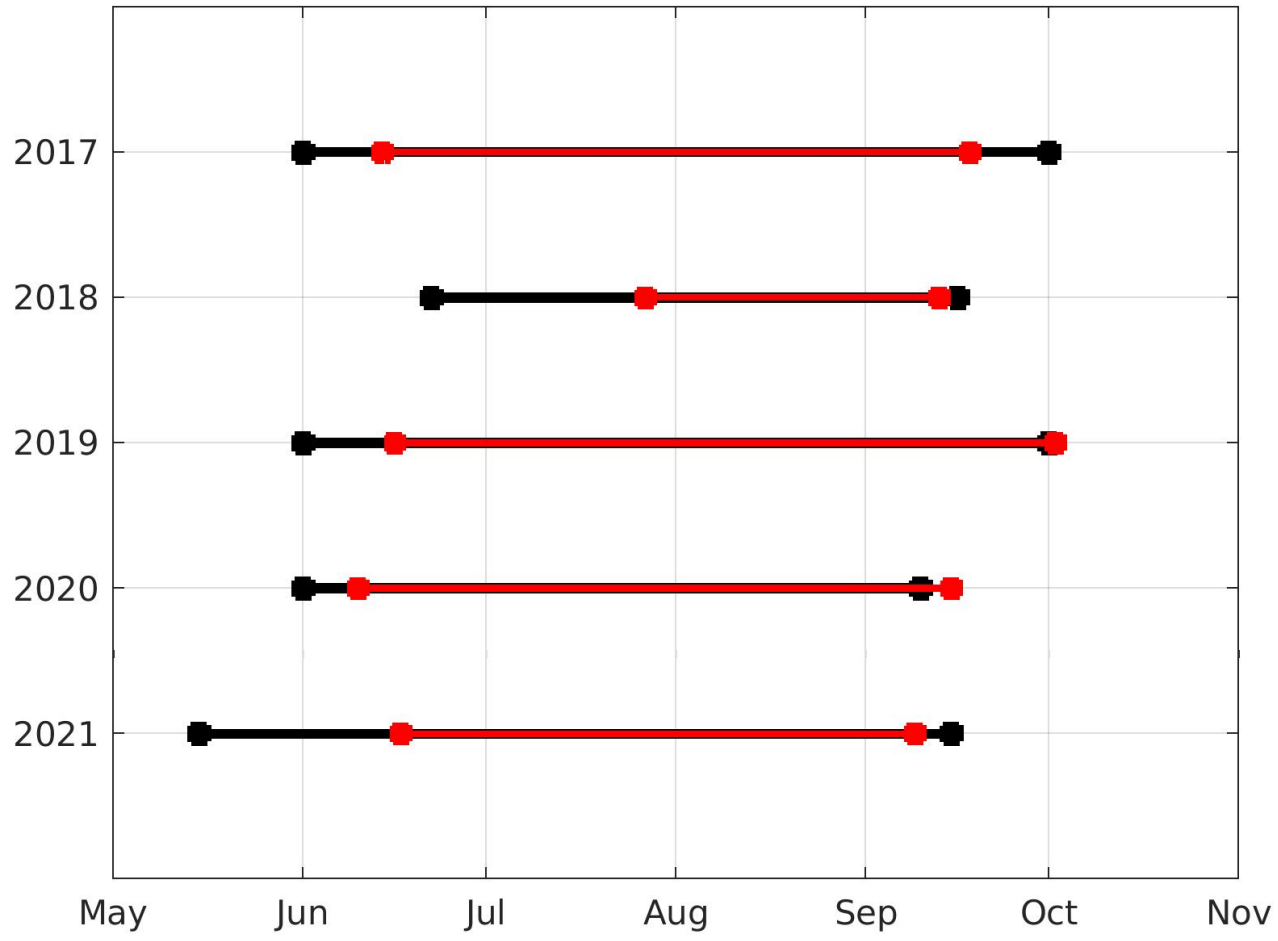
From Scheer et al., 2023, based on Liu et al., 2010 and 2012



Vertical deformation

$$\delta = \underbrace{R \cdot (t_2 - t_1)}_{\text{Long-term}} + \underbrace{\alpha \cdot \left(\sqrt{ADDT(t_2)} - \sqrt{ADDT(t_1)}\right)}_{\text{Seasonal}}$$

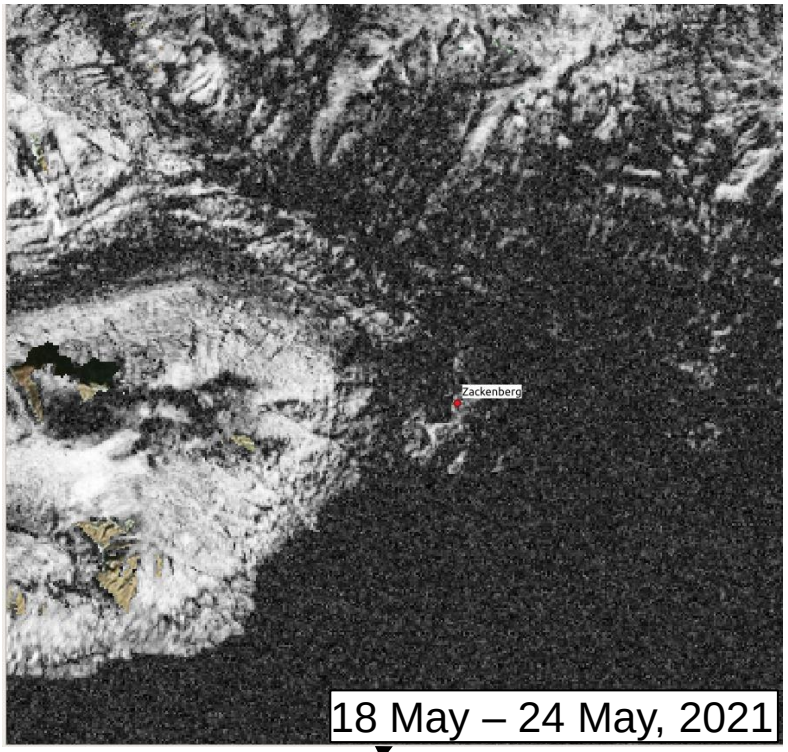
Thawing season vs. InSAR coherence



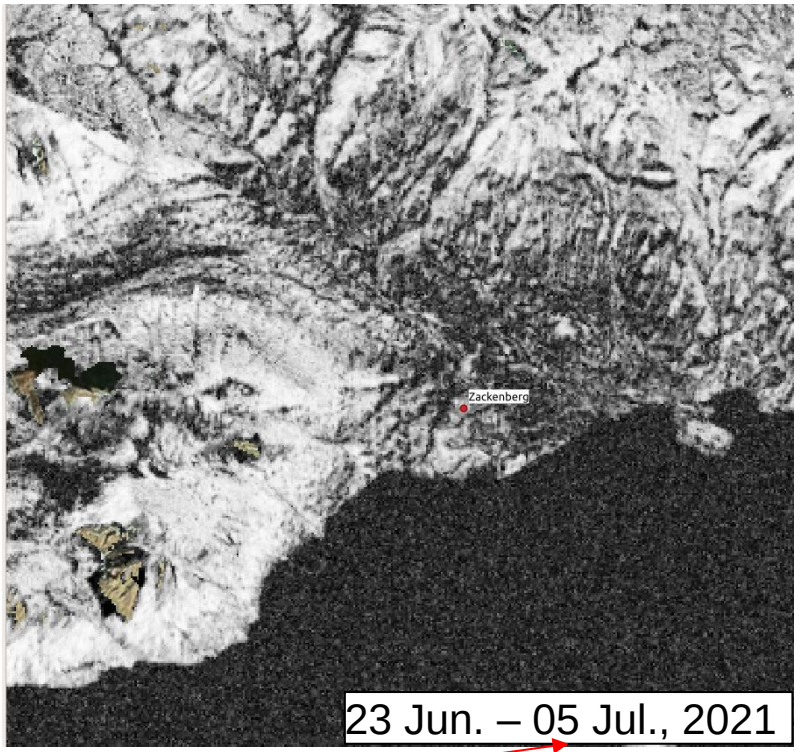
Thawing season

Sufficient InSAR coherence

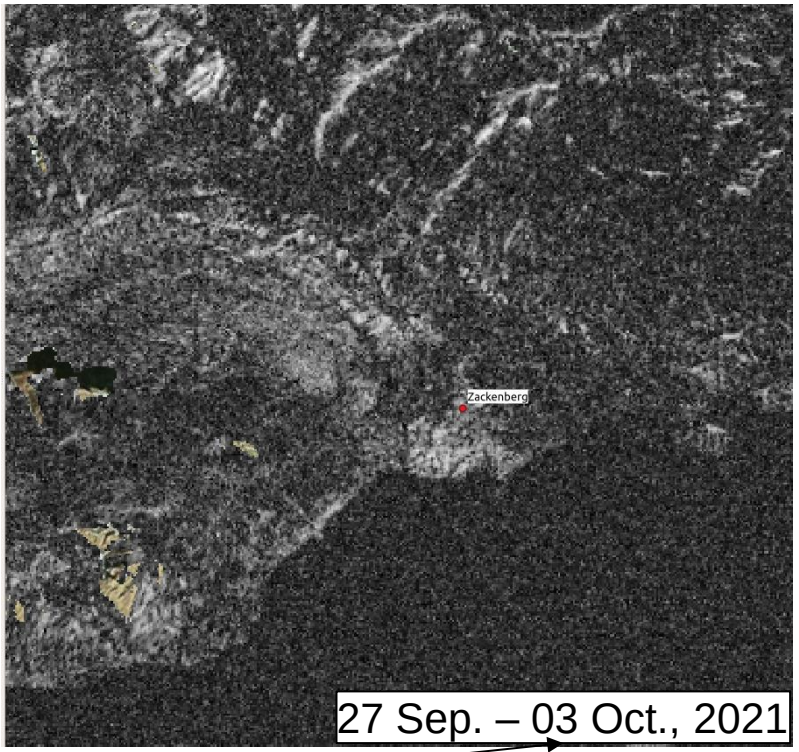
Thawing season vs. InSAR coherence continued



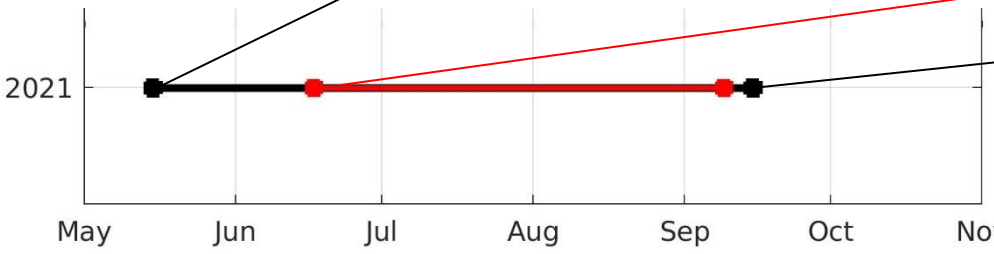
18 May – 24 May, 2021



23 Jun. – 05 Jul., 2021

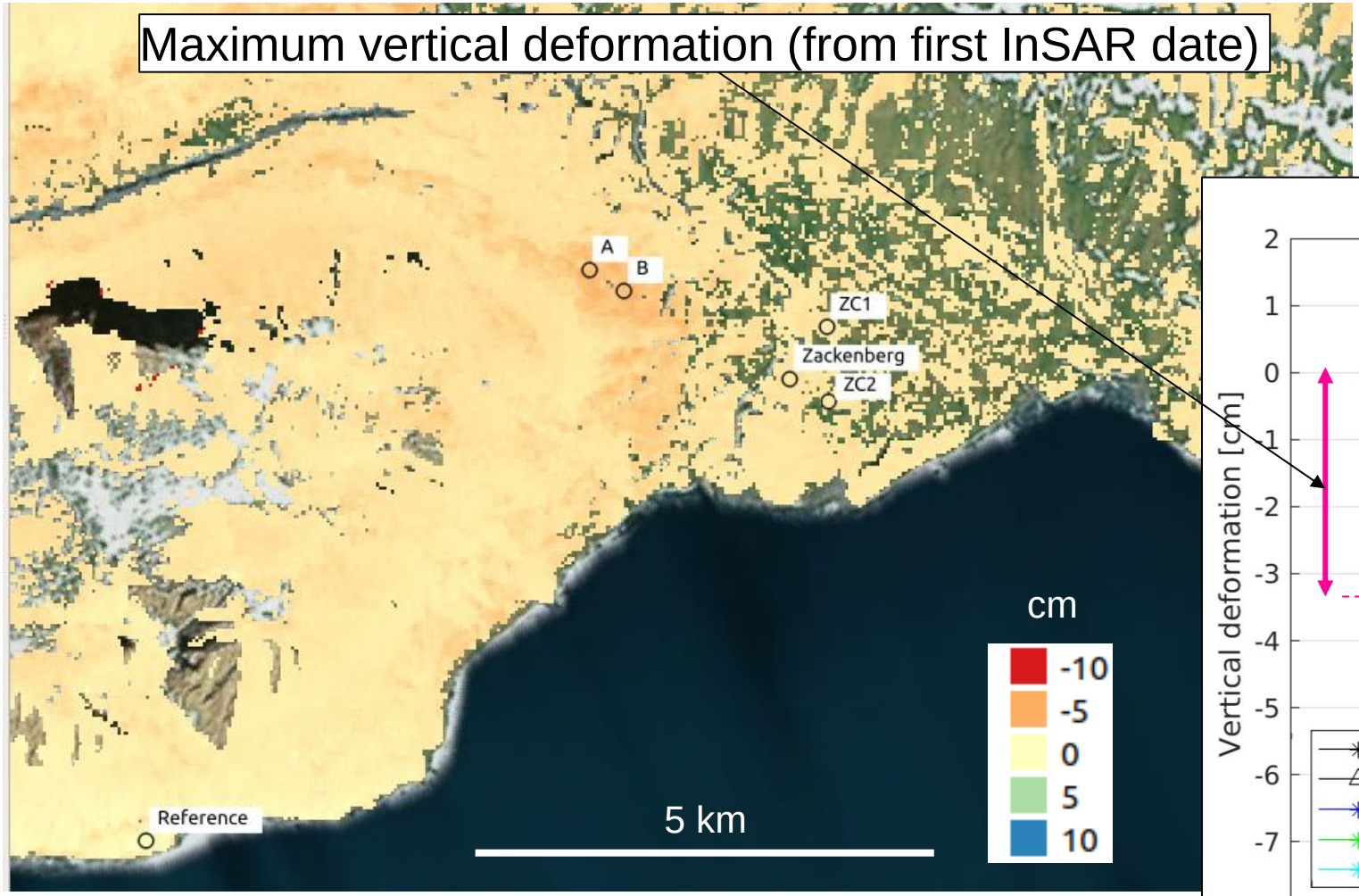


27 Sep. – 03 Oct., 2021



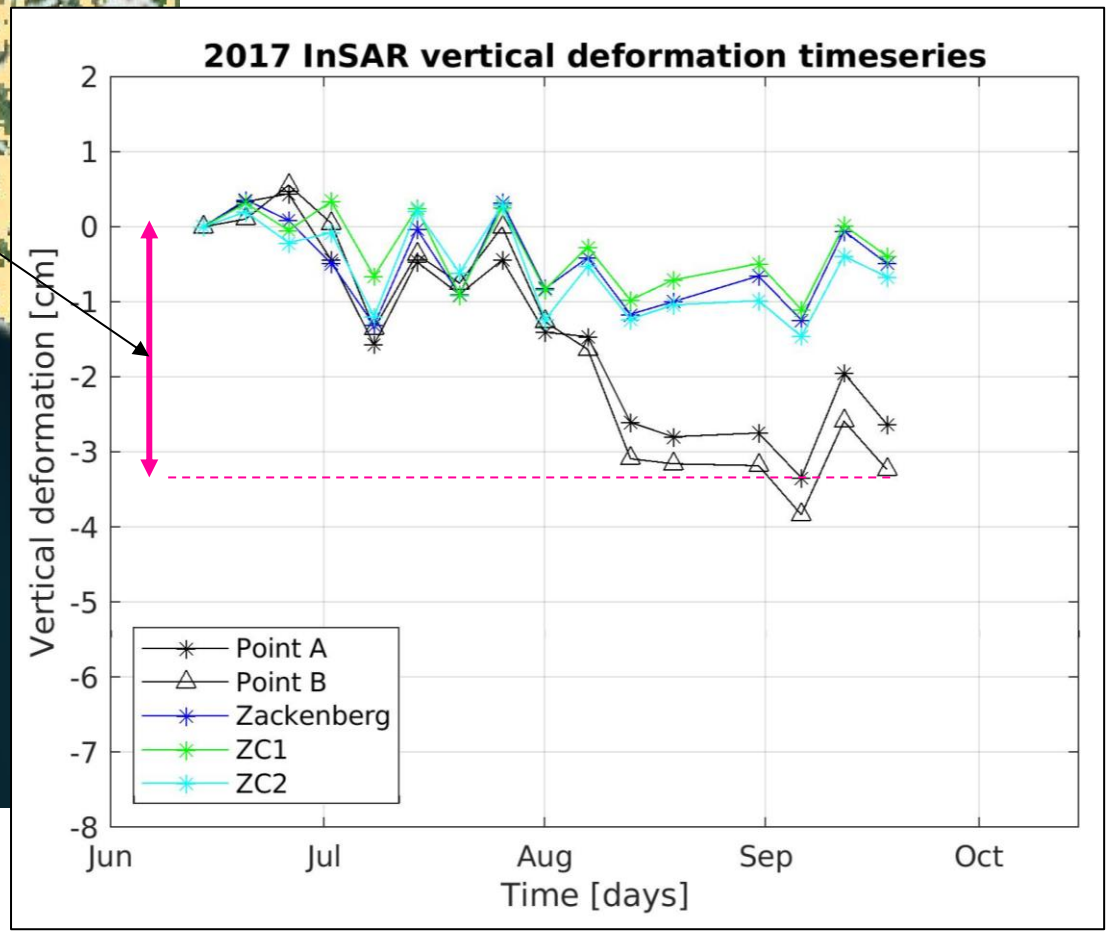
InSAR coherence magnitude

InSAR deformation measurements

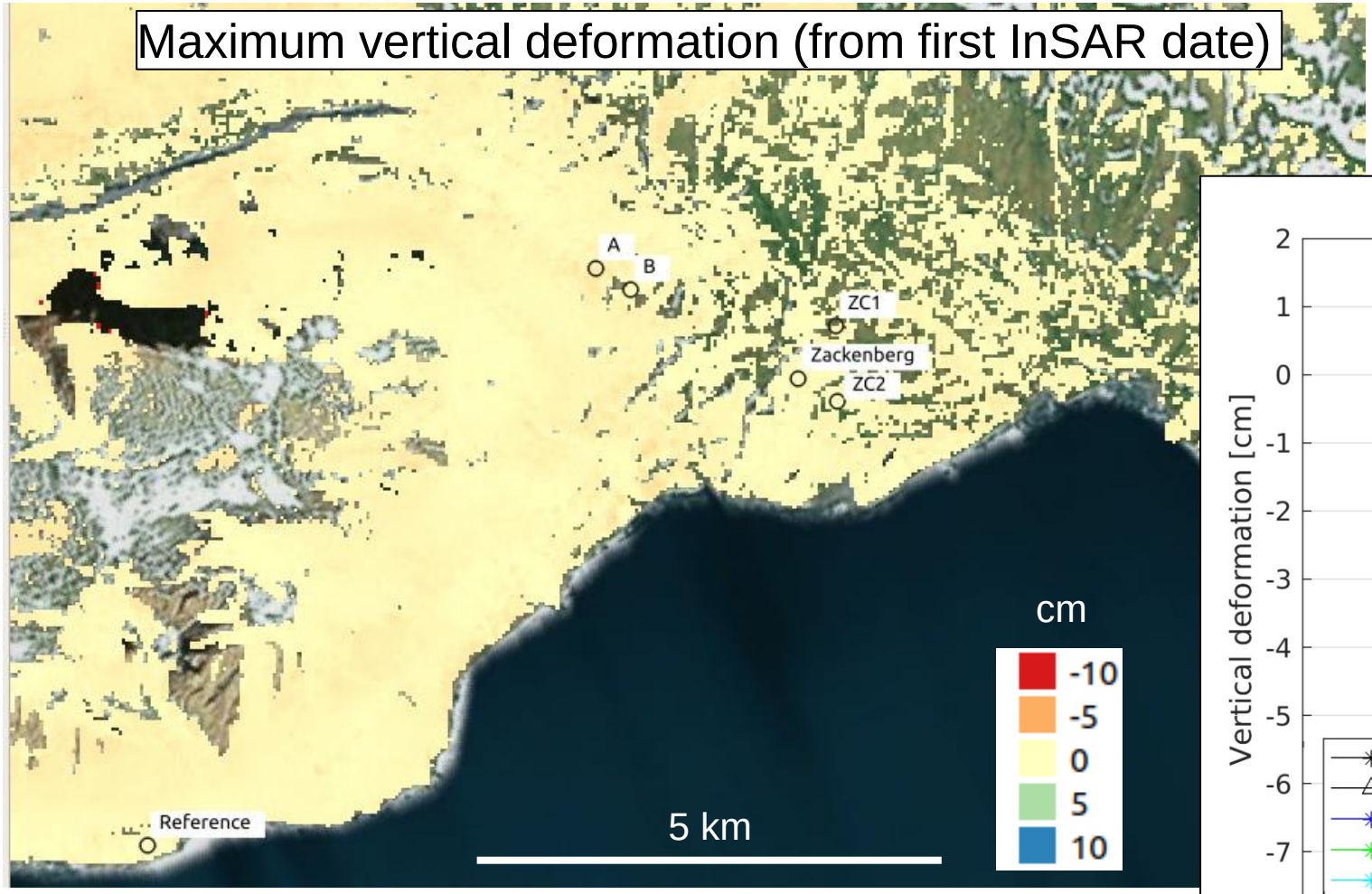


14 Jun – 18 Sep., 2017

(16 images, 84 interferograms)

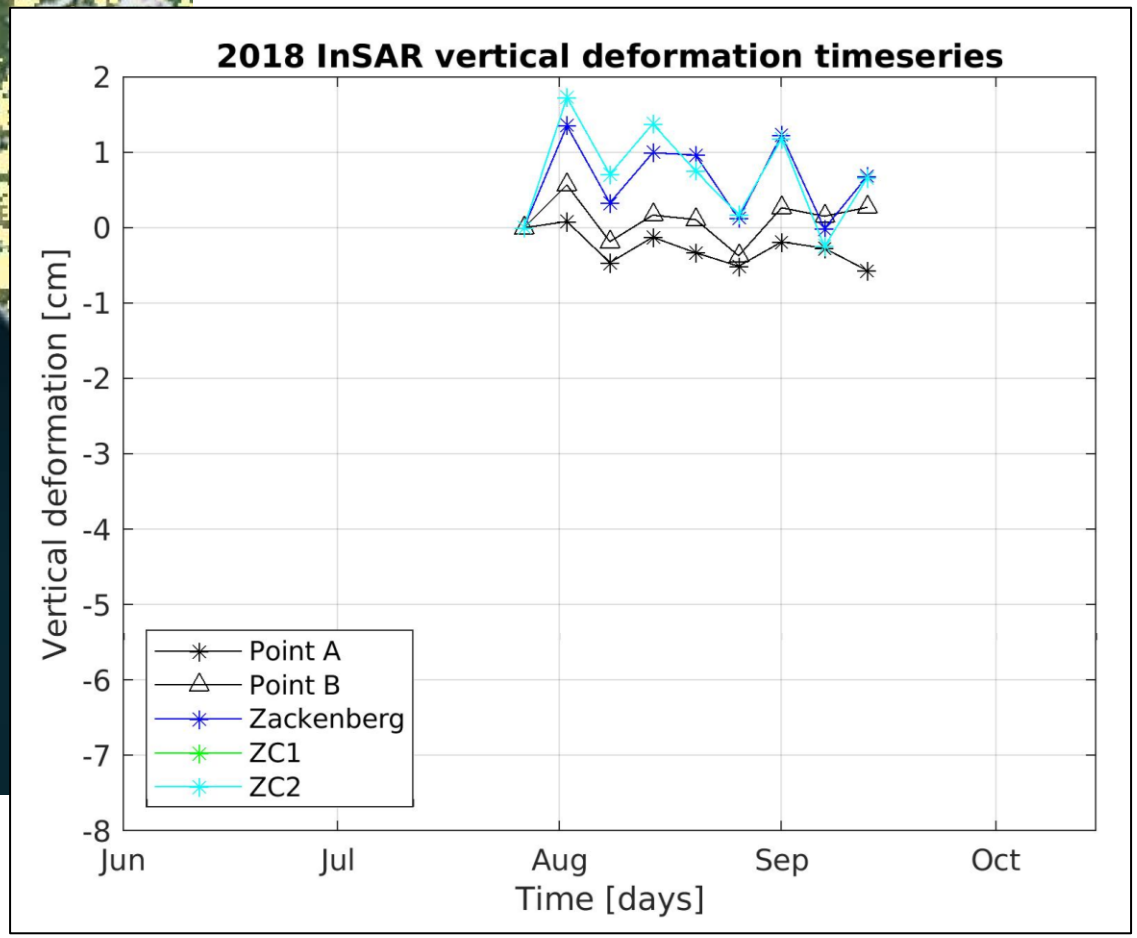


InSAR deformation measurements continued

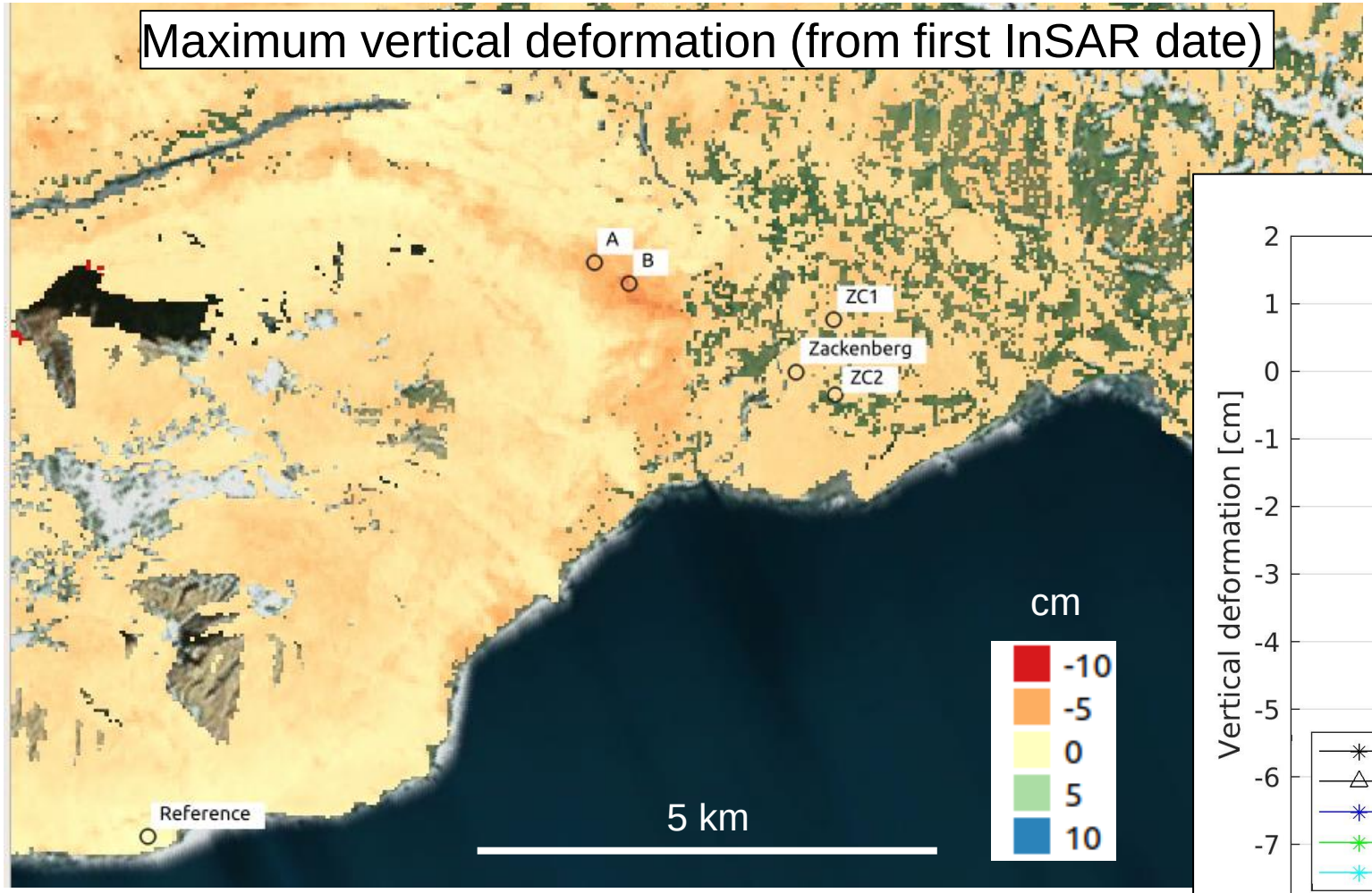


27 Jul – 13 Sep., 2018

(9 images, 32 interferograms)

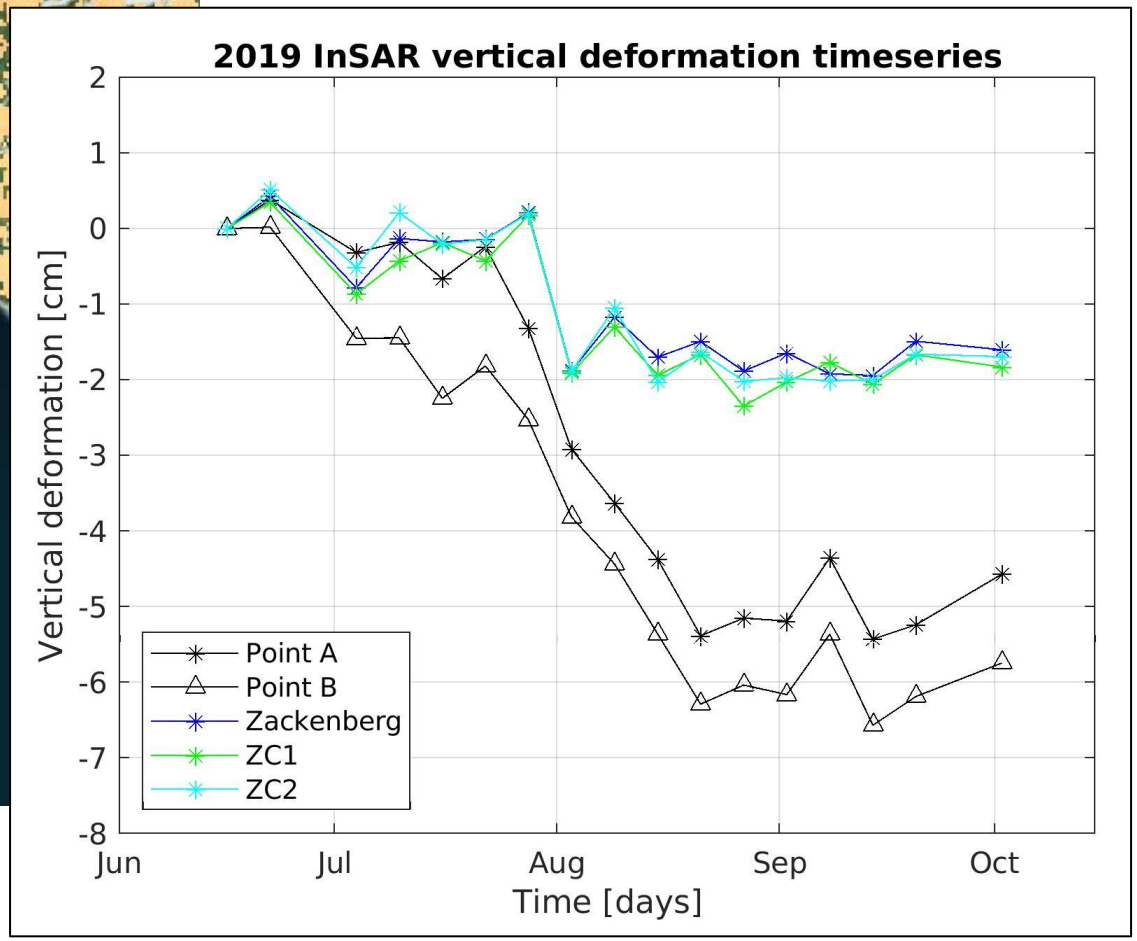


InSAR deformation measurements continued

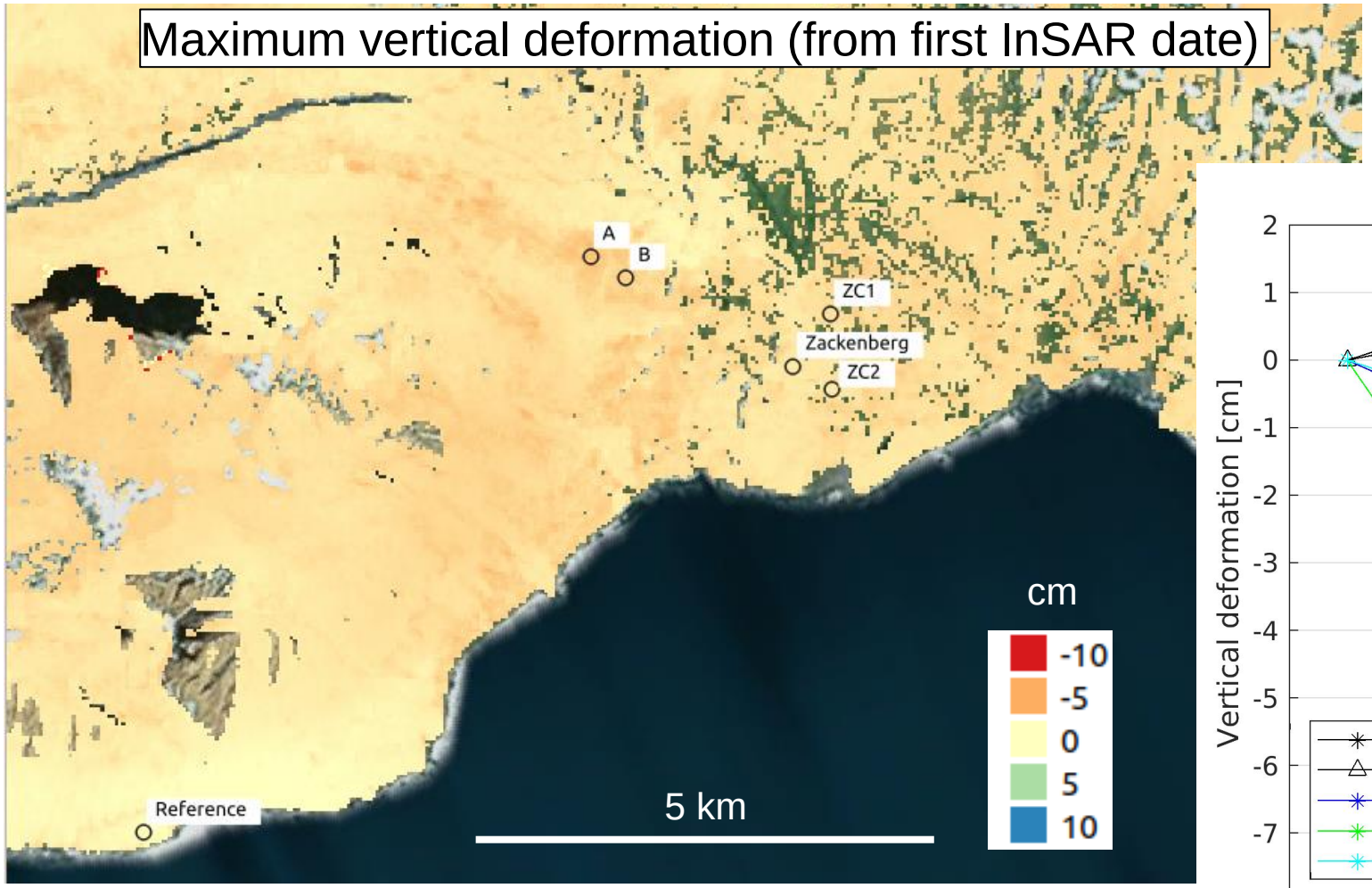


16 Jun – 02 Oct., 2019

(17 images, 88 interferograms)

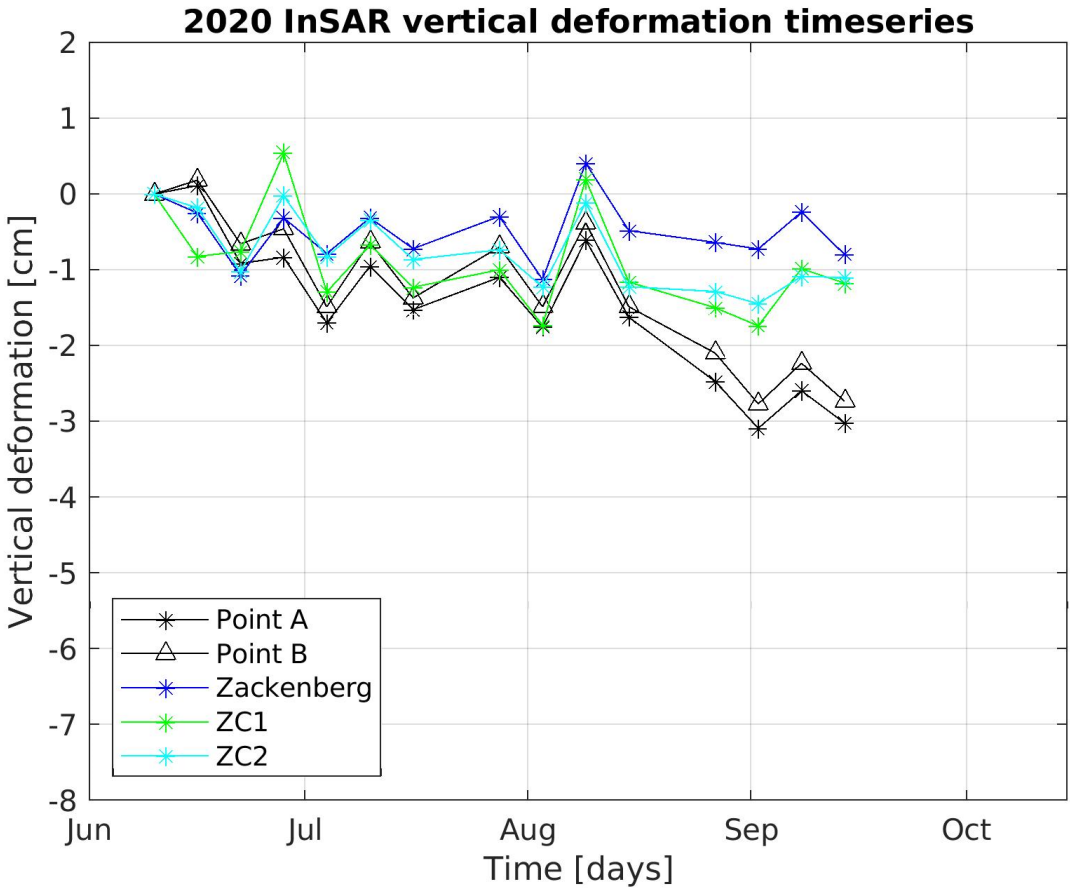


InSAR deformation measurements continued

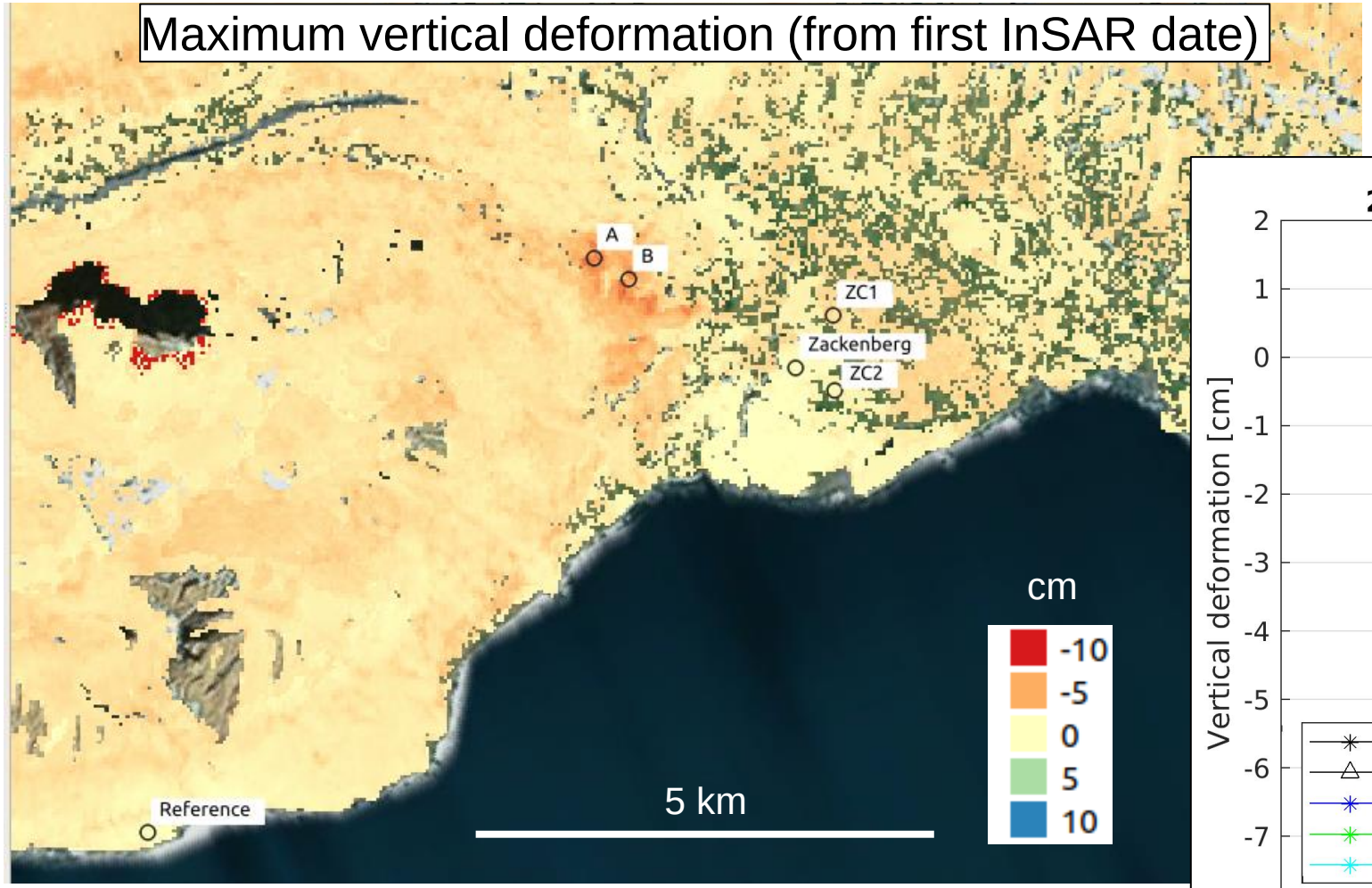


10 Jun – 15 Sep., 2020

(15 images, 70 interferograms)

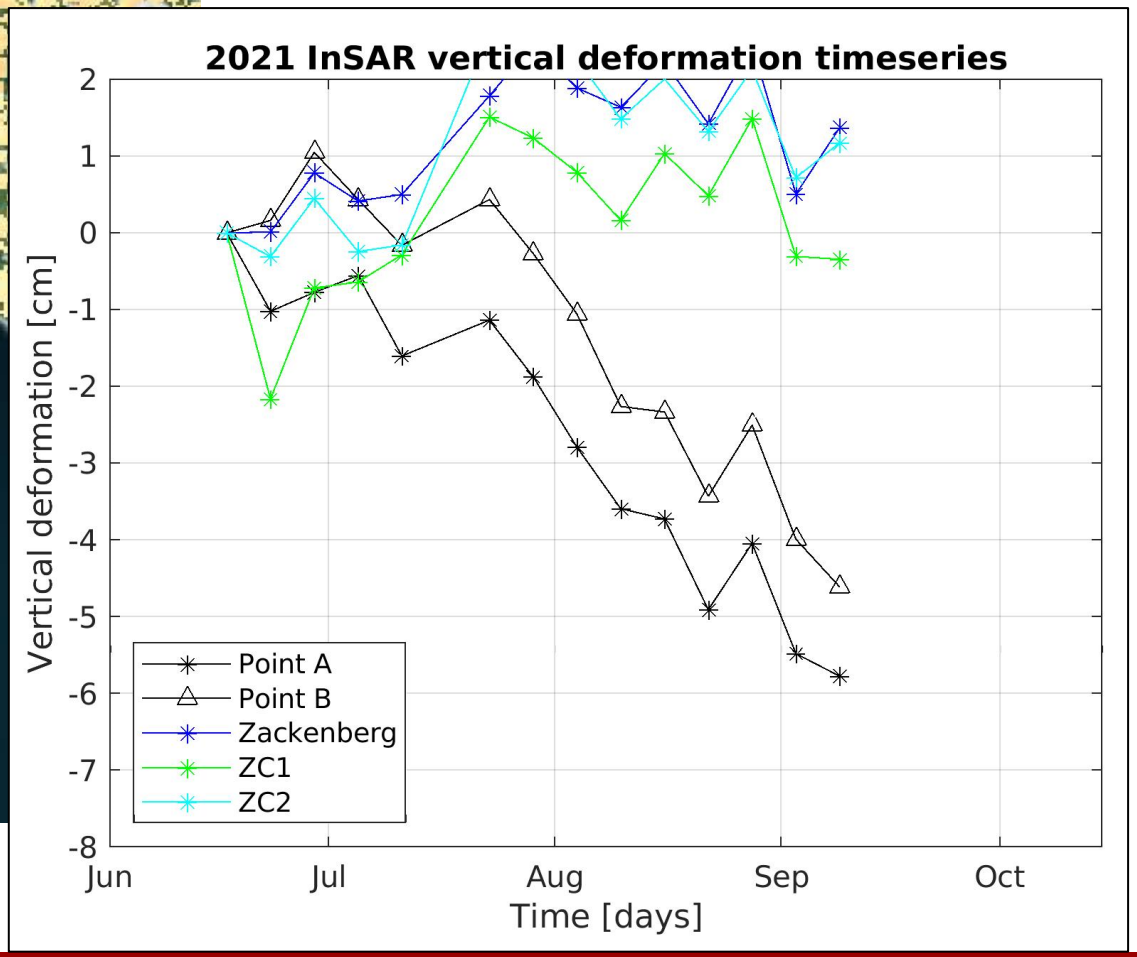


InSAR deformation measurements continued

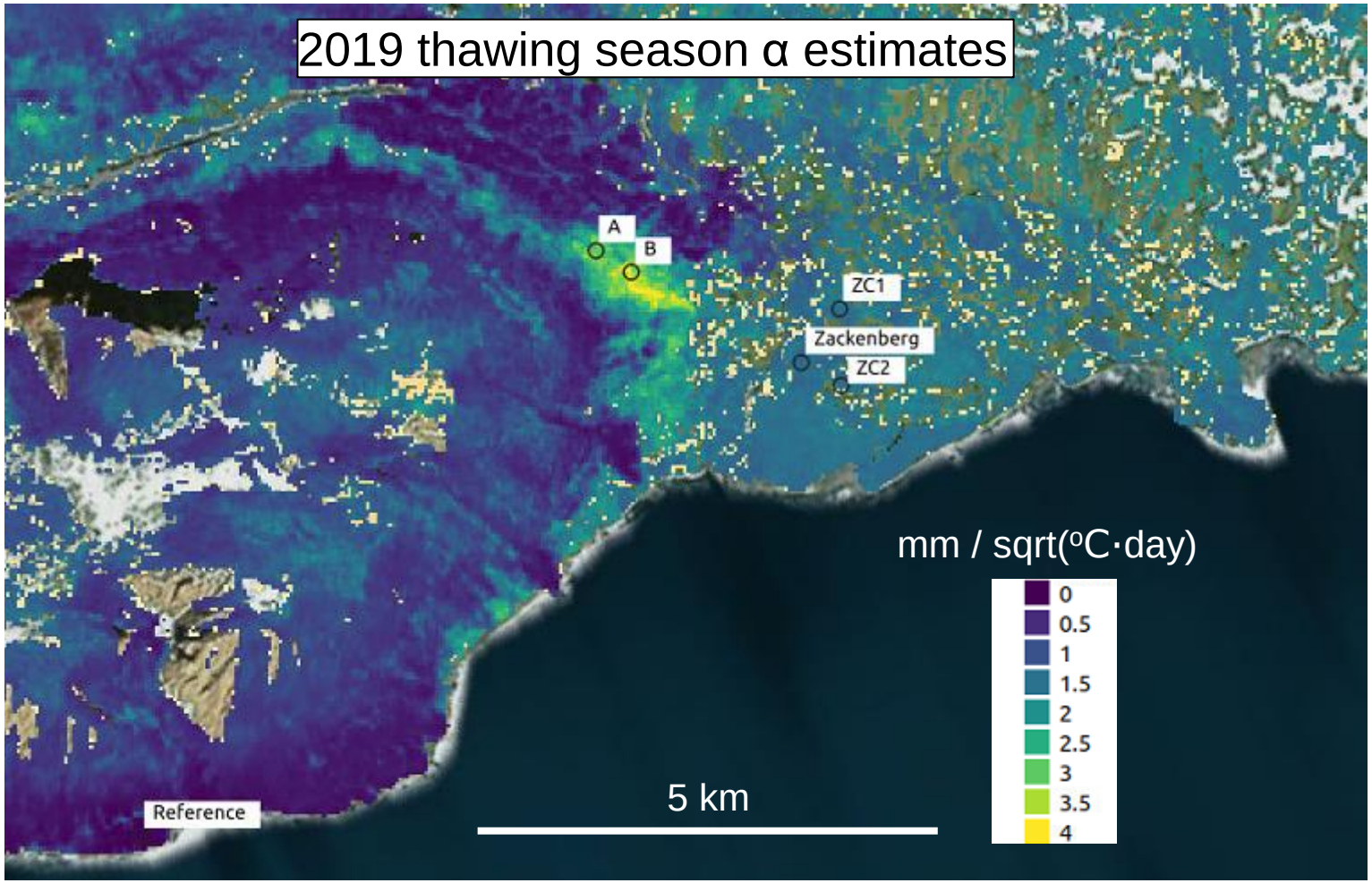


17 Jun – 09 Sep., 2021

(14 images, 44 interferograms)



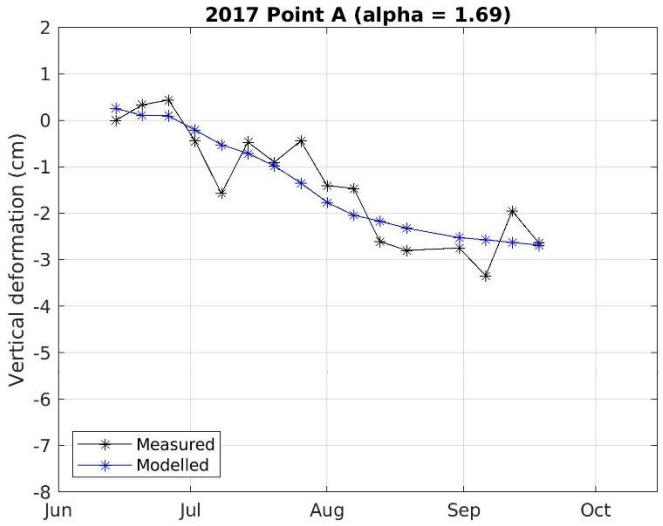
Comparison with model predictions

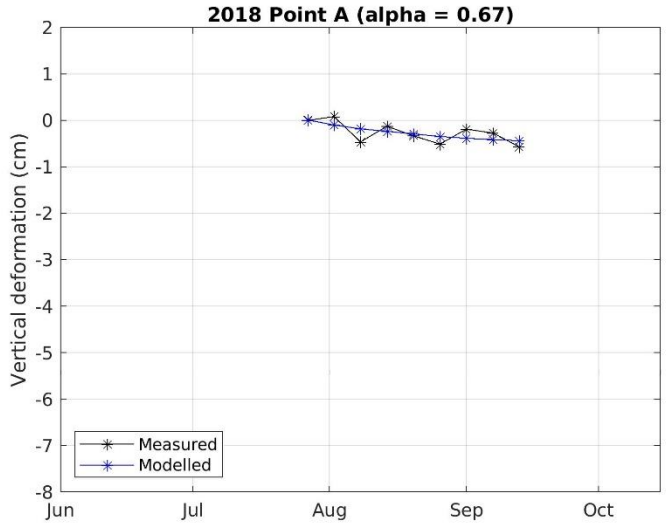


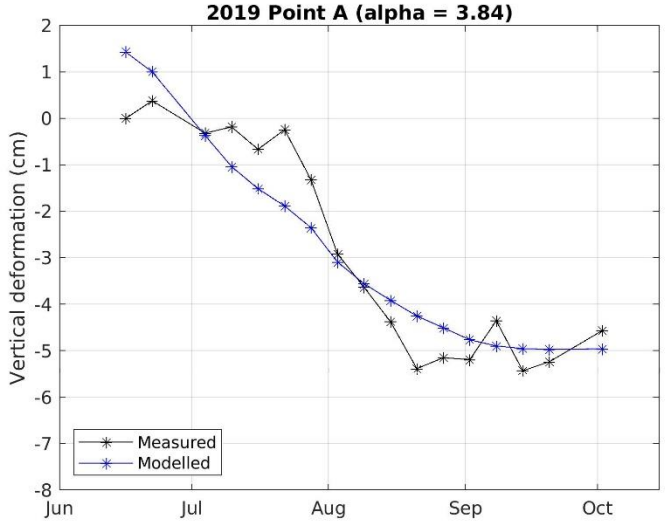
- Air temperatures for Zackenberg research station available from the Greenland Ecosystem Monitoring programme (https://data.g-e-m.dk/)
- Alpha parameter estimated via a per-pixel least-squares inversion of vertically-projected InSAR time-series

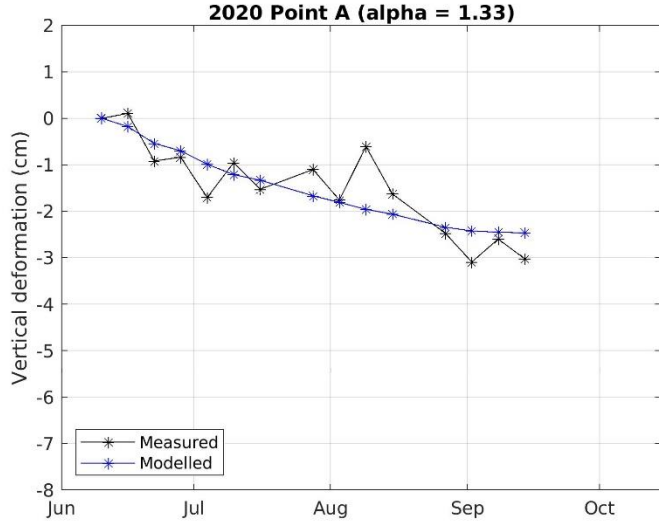
$$\delta_{InSAR}(t) \cong const + \alpha \cdot \left(\sqrt{ADDT(t)}\right)$$

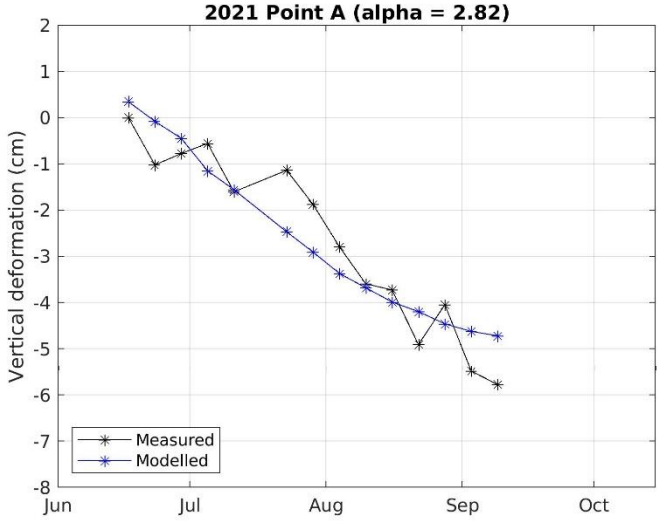
Comparison with model predictions continued











Thawing season alpha estimates (mm/sqrt(°C*day))

Year	Point A	Point B	Research station	ZC-1	ZC-2
2017	1.69	2.08	0.38	0.41	0.55
2018	0.67	-	-	-	0.48
2019	3.84	4.08	1.32	1.39	1.51
2020	1.33	1.23	0.09	0.55	0.55
2021	2.82	2.50	-	-	-

Conclusions

- Thawing season deformations in Zackenberg are observable with Sentinel-1 … most of the time:
  - InSAR coherence often becomes sufficiently high 2 weeks – 1 month into the thawing season;
  - In 2018, the thawing season was too short to provide reliable observations.
- Consistency of InSAR deformation patterns
  - The areas of highest deformation show a high spatial correlation and are generally consistent in the 2017-2021 timespan.
  - The Zackenberg research station is *not* in one of the highly deforming areas.
- Modelling and interpretation
  - The vertically-projected InSAR timeseries in the valley, are well modelled by the Stefan equation, although model parameters vary significantly from year to year;
  - It is yet to be established, whether these InSAR observations can provide reliable estimates of relevant parameters, e.g. Active Layer Thickness