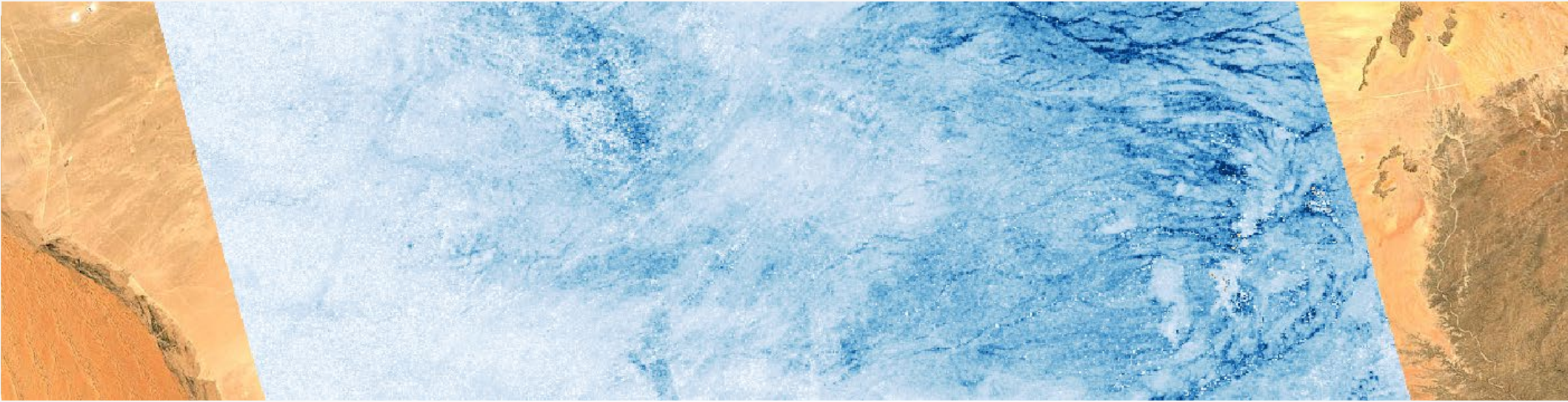

Soil Moisture Derived from InSAR:
Experiments at C-band and Contributions from L-band

2023-09-15

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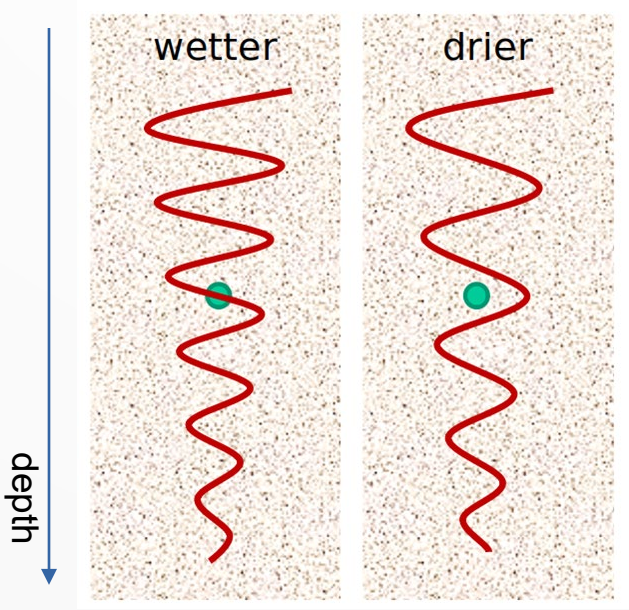
2 - Research Institute for Geo-Hydrological Protection, National Research Council, Italy
3 - Department of Civil and Environmental Engineering, University of Perugia, Italy

Soil moisture with InSAR

Physical principle

- In the soil we have **phase propagation** and amplitude attenuation
- Different moisture conditions yield **different propagation phases at all depths**
- The theoretical sensitivity of InSAR phase is very high : 1 mm at C-band = 0.11 mm of water (1% if depth is 1 cm)



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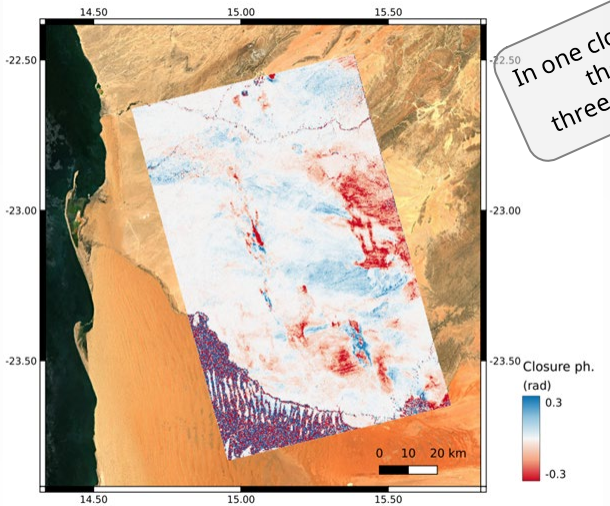
The inversion is based on closure phases from SAR interferometry

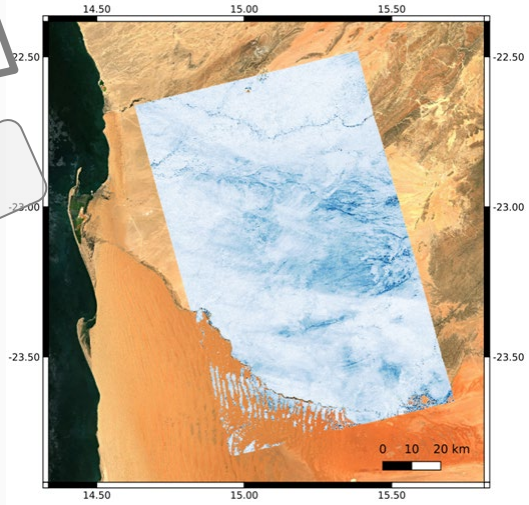
2021-01-21 / 2021-02-14 / 2021-03-22



In one closure phase there are three dates mixed

Soil moisture

2021-01-21



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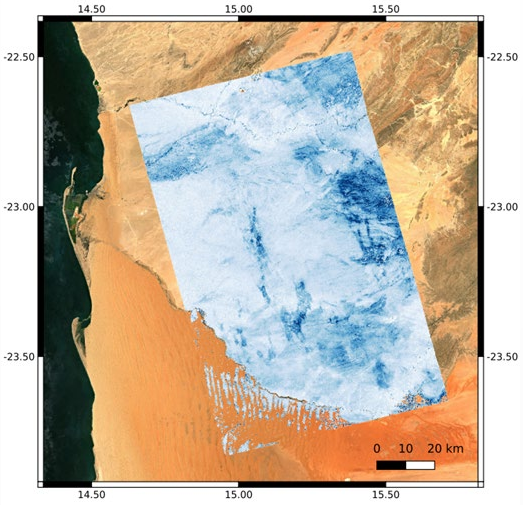
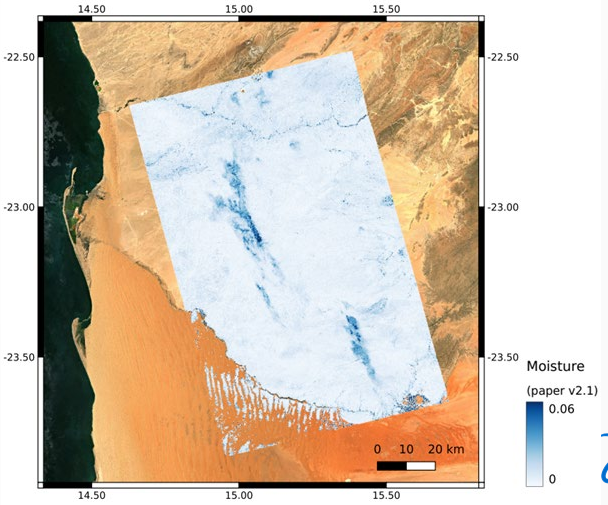
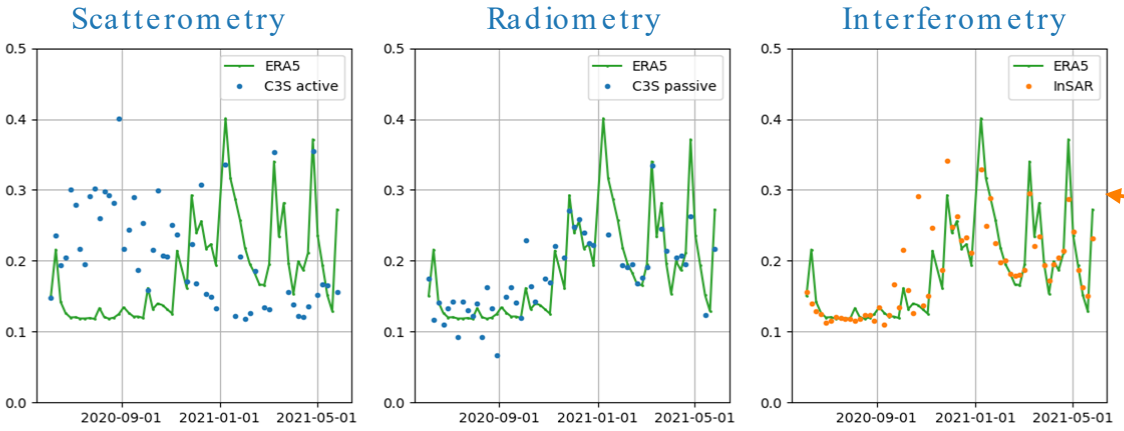


2021-03-22



Soil moisture product validation

- Spain (Murcia, Alicante)
- Time: 2020-06-06 → 2021-05-26 (58 dates, 1 year with Sentinel-1)



- Comparison with C3S products (0.25° x 0.25°) and ERA5
- The difference std between ERA5 and InSAR product is **less than 3%** (Mv)

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Preliminary cross-comparison

Spearman correlation	AMSR2_C	AMSR2_X	SMAP	GLEAM	RT1 t-f	RT1 s&t-f	InSAR	InSAR t-f	InSAR s-f	InSAR s&t-f
AMSR2_C	1	0.7897	0.7451	0.7067	0.1592	0.1769	0.5338	0.5404	0.6884	0.6939
AMSR2_X	0.7897	1	0.7875	0.739	0.1535	0.1681	0.5594	0.5687	0.7243	0.7335
SMAP	0.7451	0.7875	1	0.8875	0.1879	0.2063	0.664	0.6698	0.8569	0.8611
GLEAM	0.7067	0.739	0.8875	1	0.1156	0.1146	0.661	0.6706	0.8478	0.8559
RT1 temporal filter	0.1592	0.1535	0.1879	0.1156	1	0.8344	0.1123	0.1112	0.1798	0.1777
RT1 spatial & temporal filter	0.1769	0.1681	0.2063	0.1146	0.8344	1	0.1173	0.1156	0.1915	0.1886
InSAR	0.5338	0.5594	0.664	0.661	0.1123	0.1173	1	0.9927	0.7638	0.7616
InSAR temporal filter	0.5404	0.5687	0.6698	0.6706	0.1112	0.1156	0.9927	1	0.7667	0.7693
InSAR spatial filter	0.6884	0.7243	0.8569	0.8478	0.1798	0.1915	0.7638	0.7667	1	0.9944
InSAR spatial & temporal filter	0.6939	0.7335	0.8611	0.8559	0.1777	0.1886	0.7616	0.7693	0.9944	1

A more thorough validation activity is to come...

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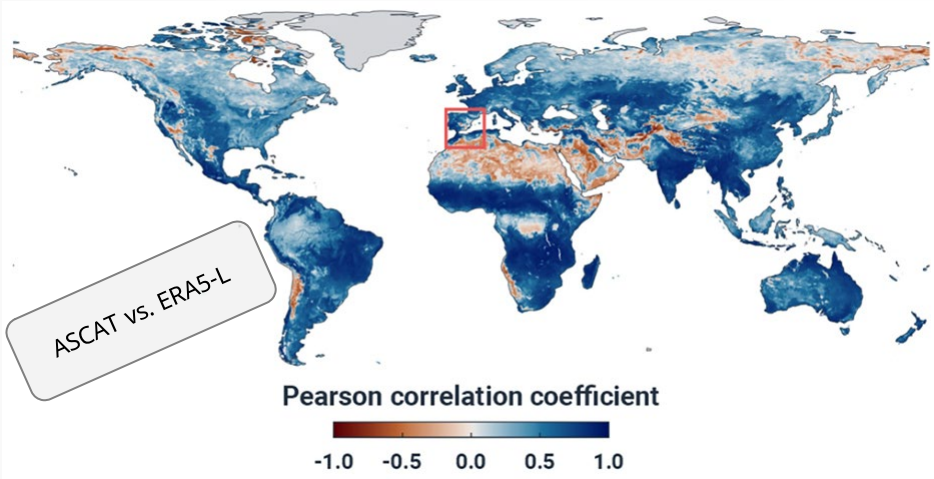
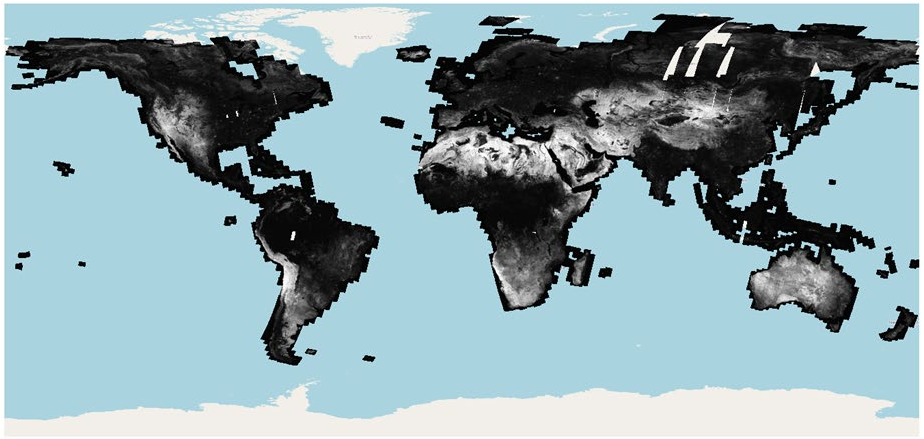
Backscatter and phase complementarity

C-band backscatter anomalies



W. Wagner et al., " *Widespread occurrence of anomalous C-band backscatter signals in arid environments caused by subsurface scattering*", Remote Sensing of Environment, Volume 276, 2022.

C-band summer coherence



Kellndorfer, J. et al., 2022. *"Global seasonal Sentinel-1 interferometric coherence and backscatter data"*. Scientific Data. From NASA Alaska Satellite Facility Synthetic Aperture Radar Distributed Active Archive Center

Low backscatter-moisture correlation (left) often corresponds to high C-band coherence (right)

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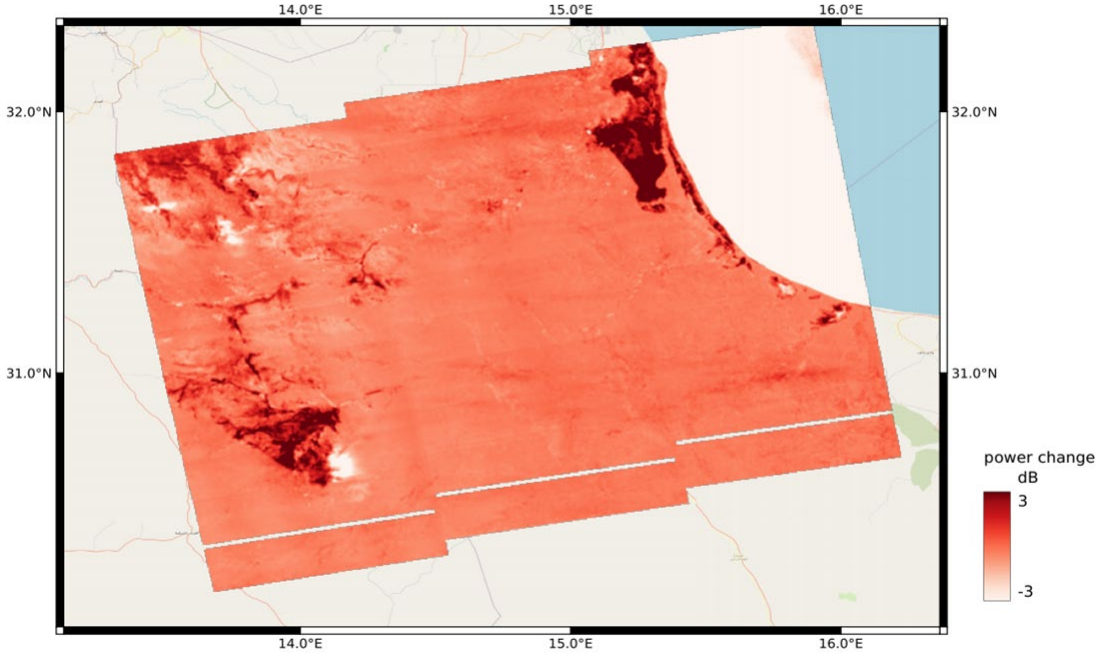
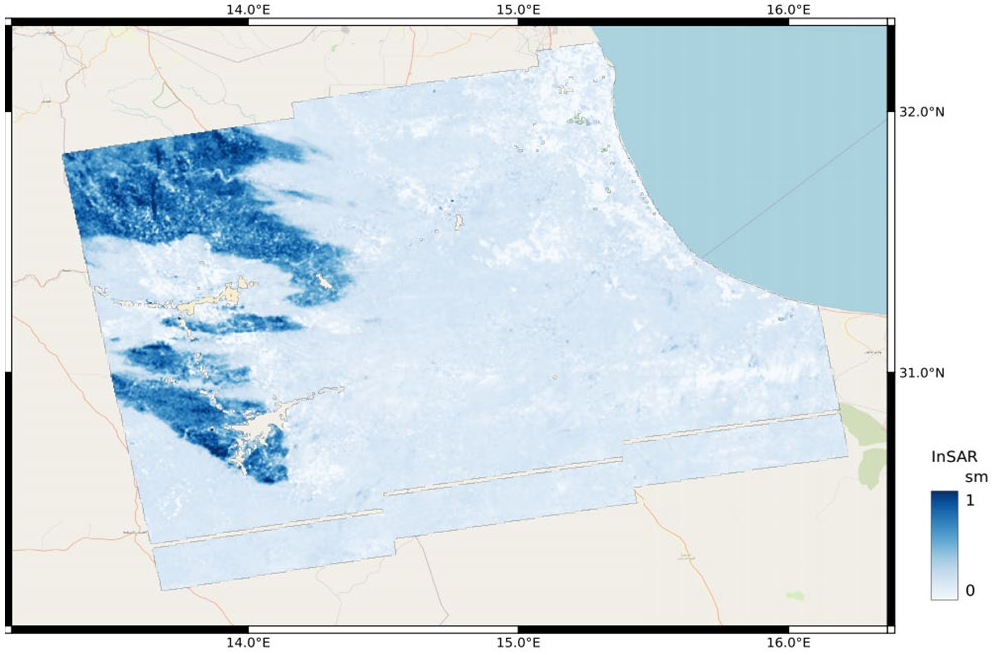
Libya 2020-09-11

Backscatter change



InSAR-based soil moisture index



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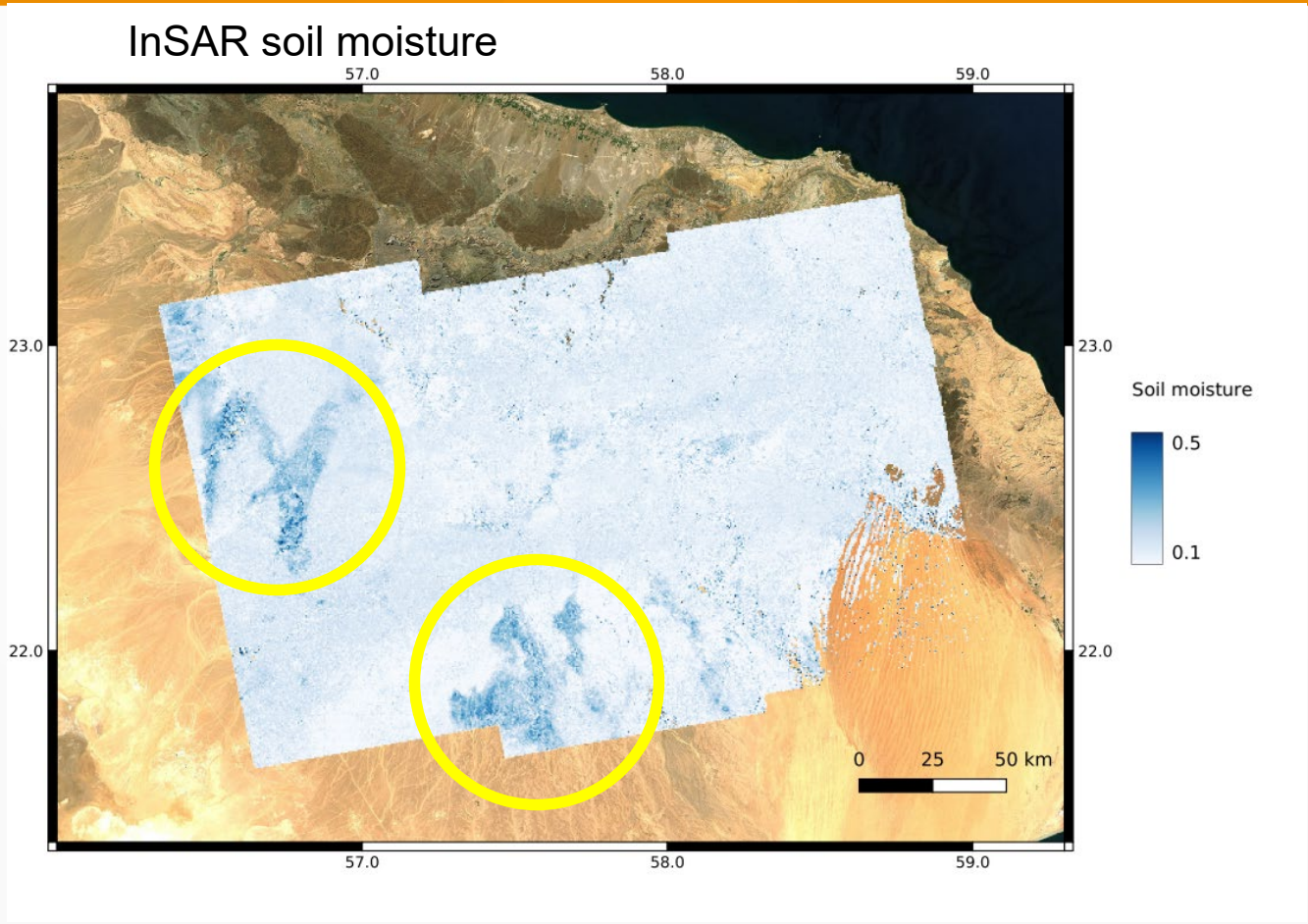
Oman: rain in June 2021



2021-06-19 IMERG

2021-06-20 10:30 Terra

2021-06-20 13:30 Aqua

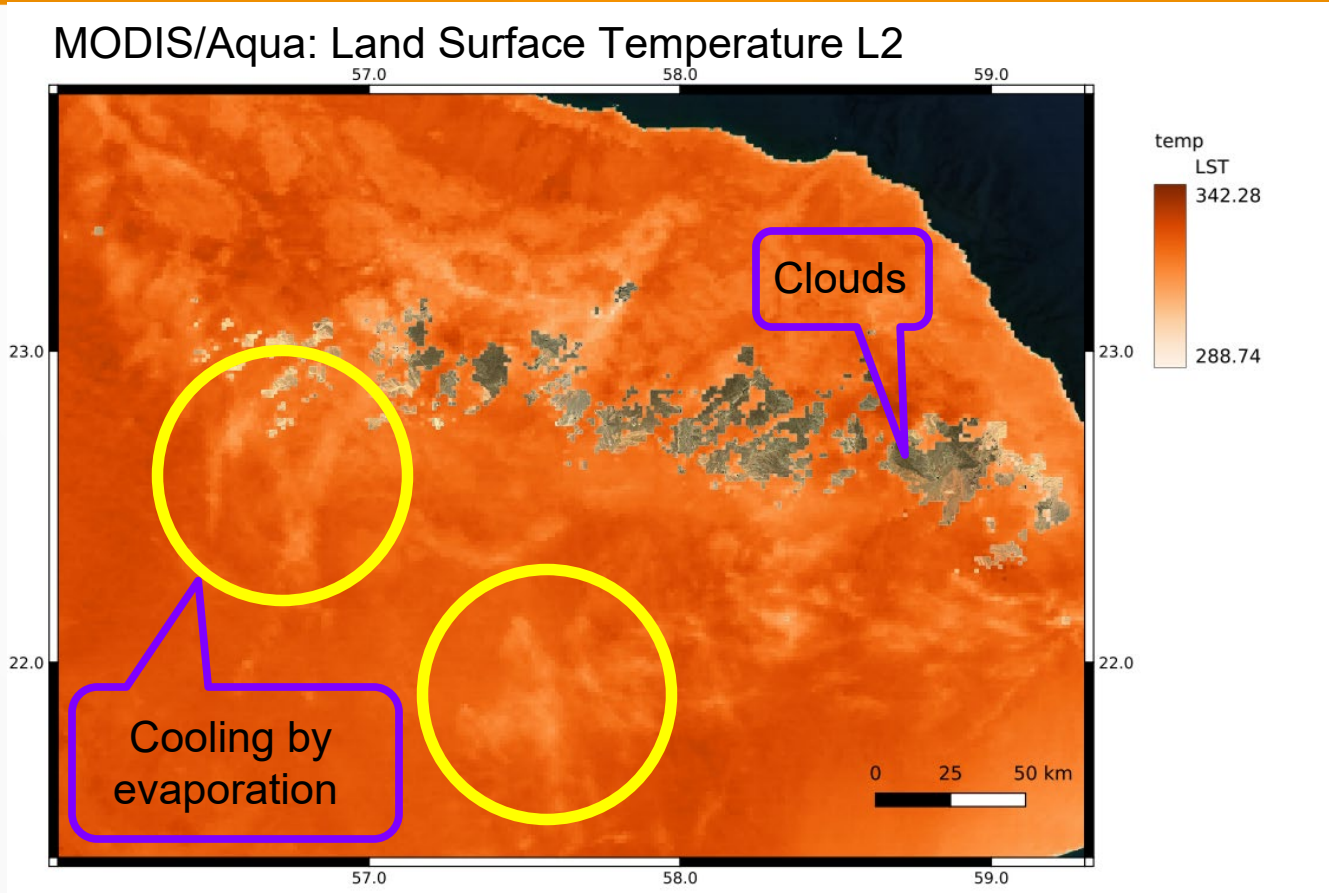
2021-06-22 CCI passive

2021-06-22 18:00 S-1

remote sensing

Oman: rain in June 2021

Land surface temperature confirms the spatial patterns in the moisture product



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2021-06-20 10:30 Terra

2021-06-20 13:30 Aqua

2021-06-22 CCI passive

2021-06-22 18:00 S-1

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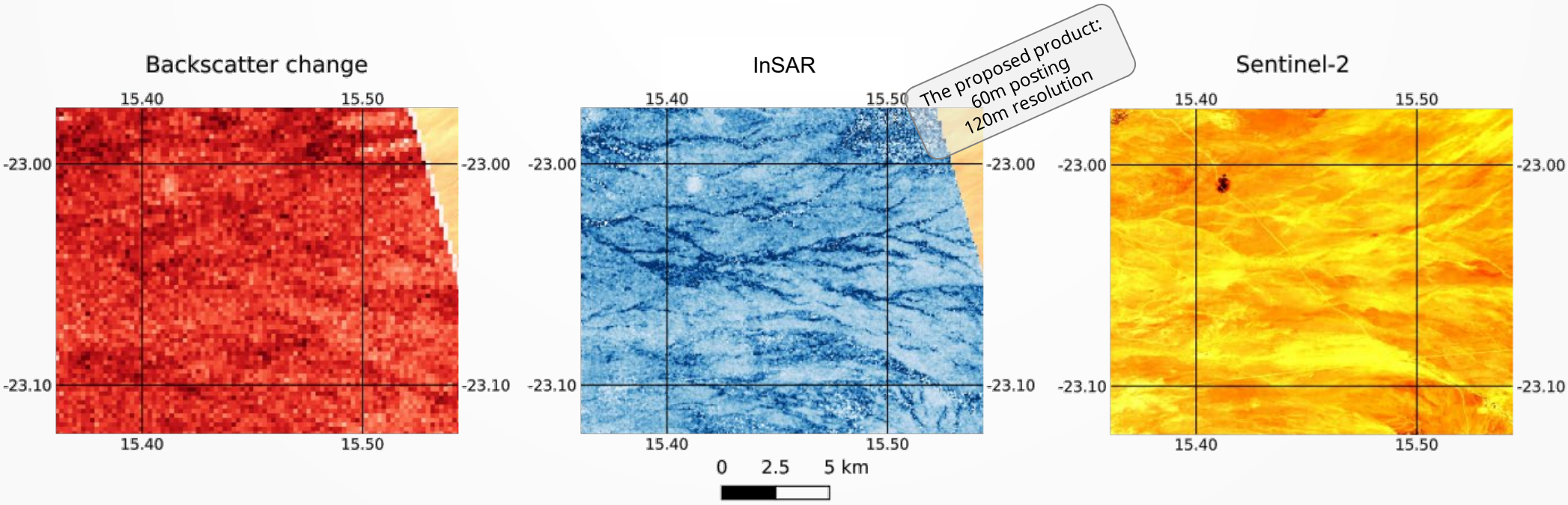
High resolution with InSAR



Example over Namib Desert gravel plain, rain and floods in Jan. 2021

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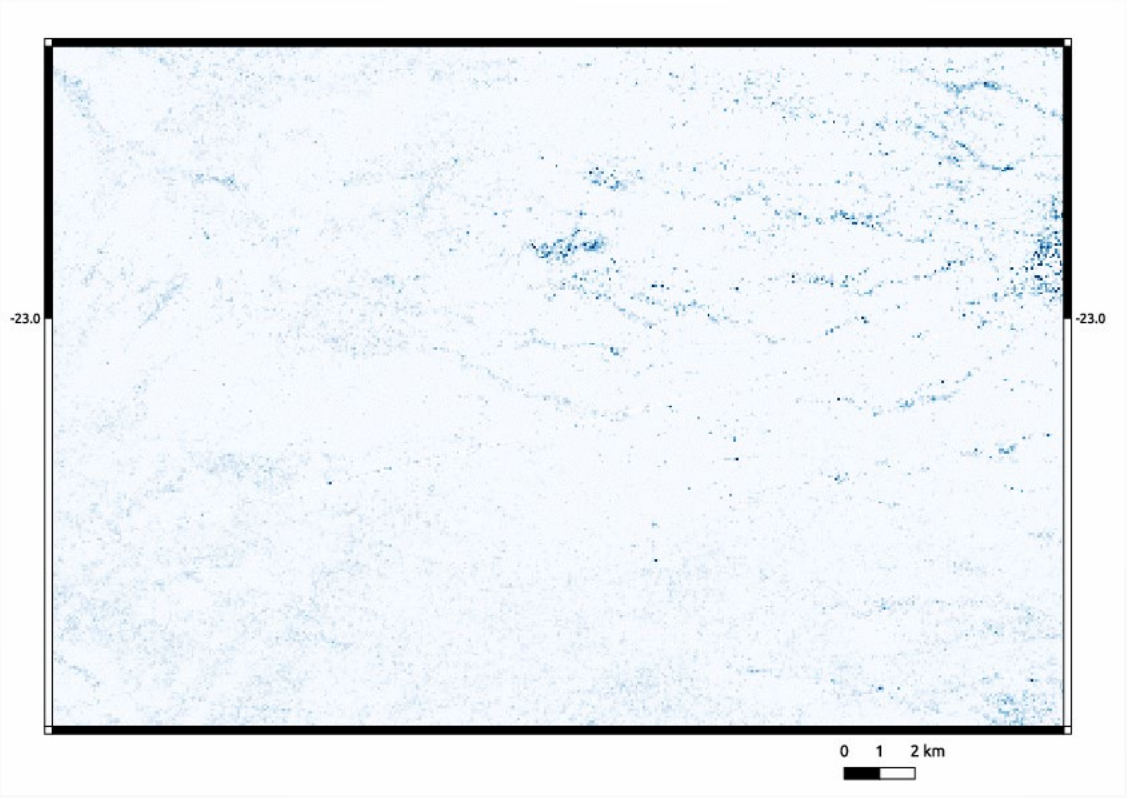
High resolution with InSAR



Time series
2020-12-28
2022-03-22
(every 12 days)

Posting: 60 m
Resolution: 120 m

Example over Namib Desert gravel plain, rain and floods in Jan. 2021

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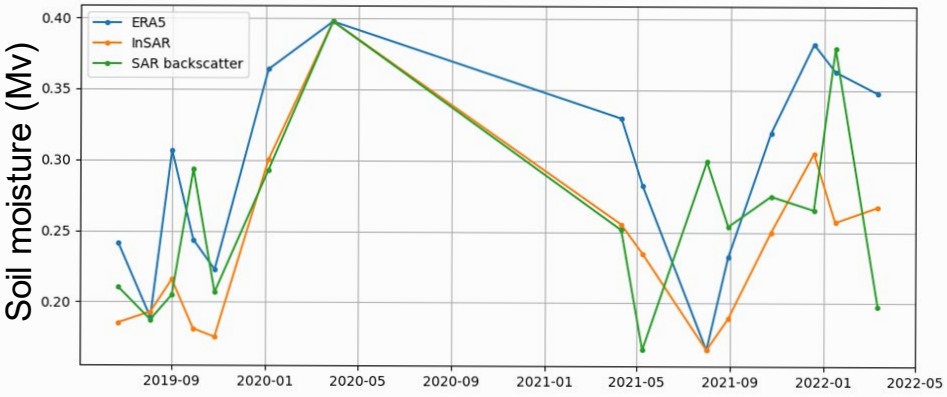
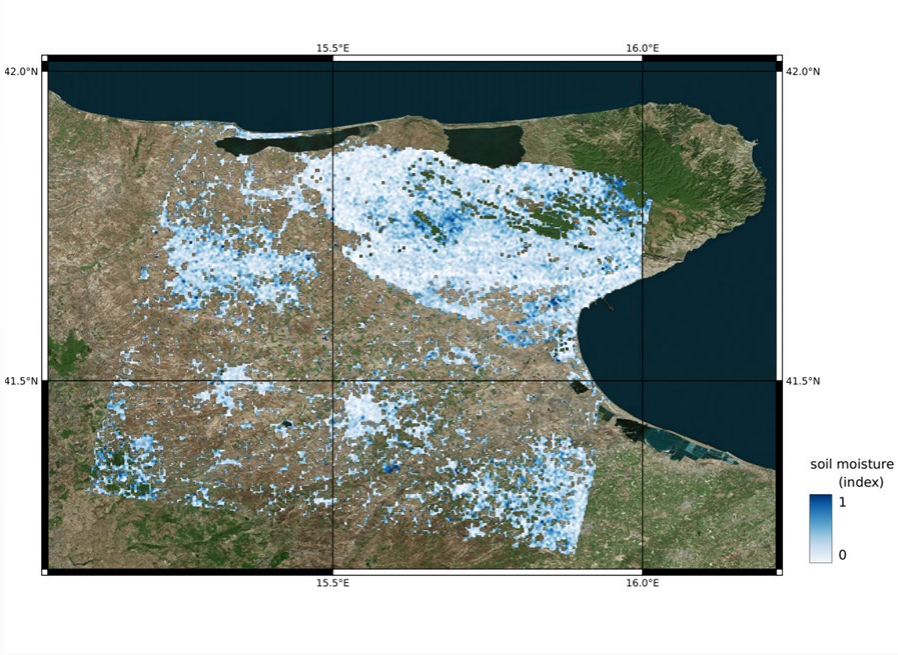
L-band experiment with ALOS-2

- A sparse time-series over northern Apulia, Italy
- Soil moisture product sampled at 200 m
- Total time-span: ~3 years
  - Coherence is not good over agricultural areas
  - Shorter and denser time series could be better!
- Apparently, good results over undisturbed terrain





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From C-band to L-band

- We expect:
  - More coherence, better coverage
  - Longer time spans
  - Similar or better sensitivity!
    - Less phase for the same amount of water (1/lambda)
    - But: more penetration (lambda) → sensing more water
- Thinking of ROSE-L we should check:
  - The coverage that we can get at L-band
  - The complementarity with backscatter at L-band
- NISAR data are going to be very valuable!

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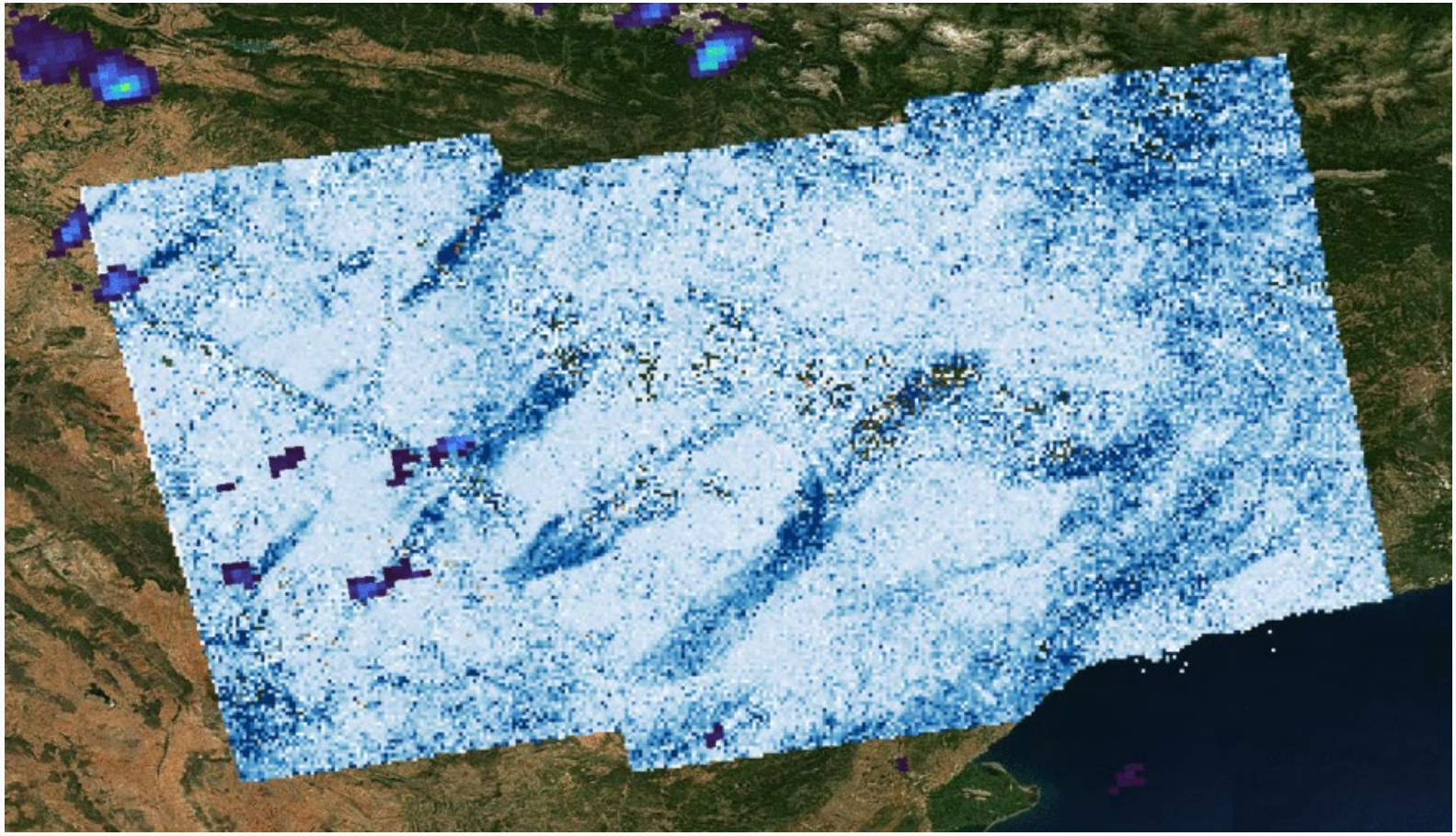
AEMET weather radar superimposed on InSAR-based soil moisture



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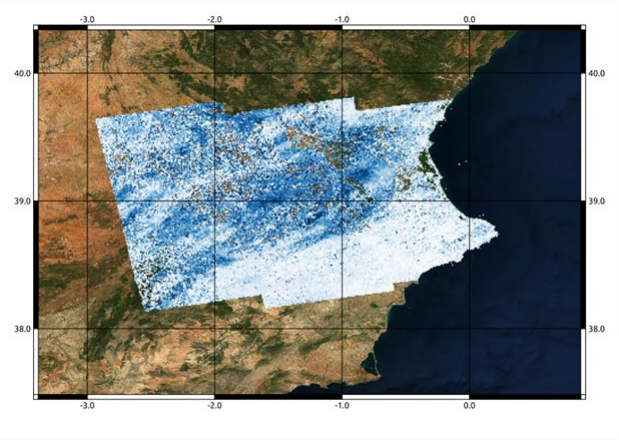
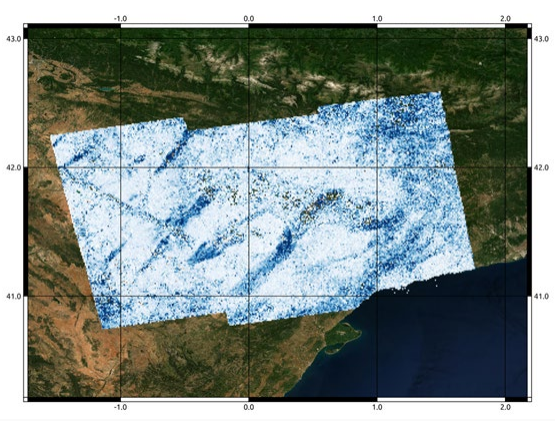
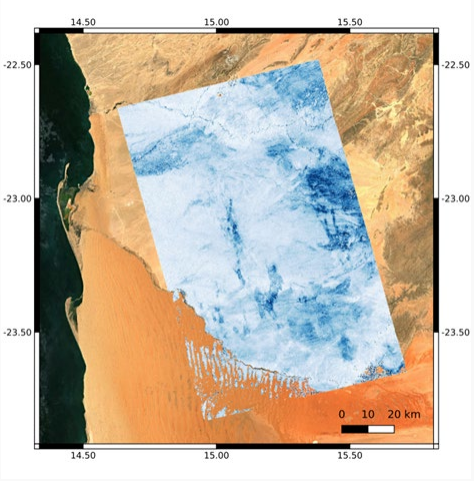
References and contact

- Relevant publications on InSAR soil moisture model and inversion algorithm
  - "A SAR Interferometric Model for Soil Moisture", De Zan et al., *IEEE Transactions on Geoscience and Remote Sensing* 2014
  - "Vegetation and soil moisture inversion from SAR closure phases: First experiments and results", De Zan and Gomba, *Remote Sensing of Environment*, 2018







Contact: francesco.dezan@delta-phi.eu

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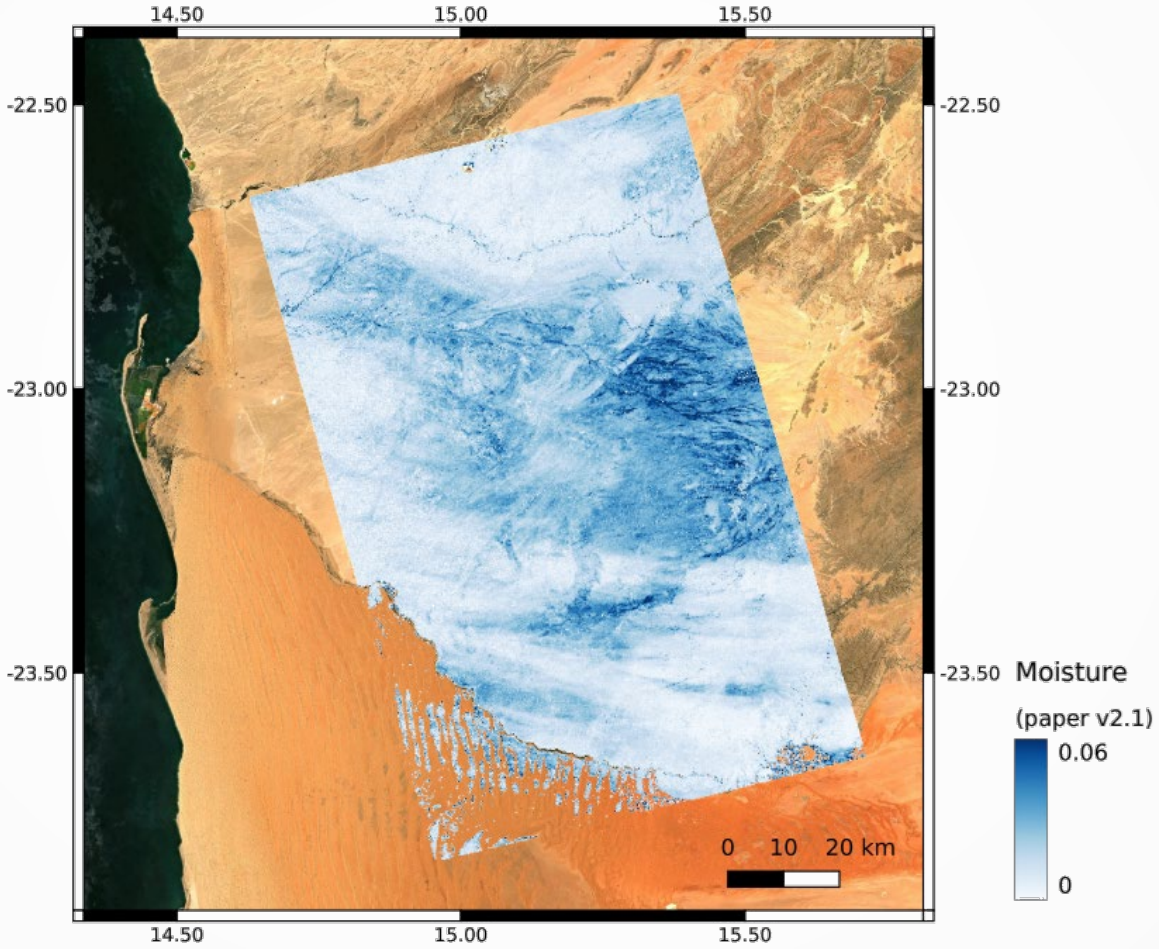
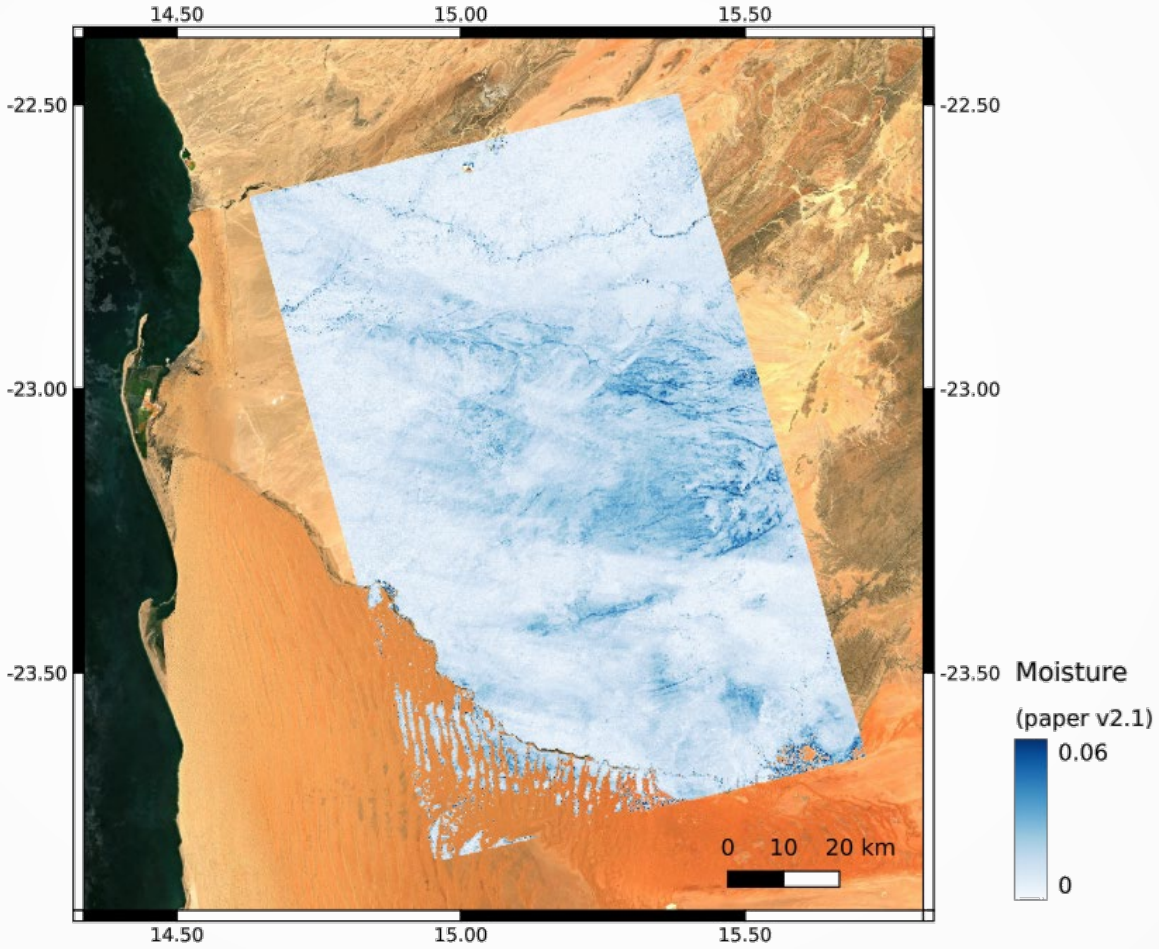
- Extra viewgraphs

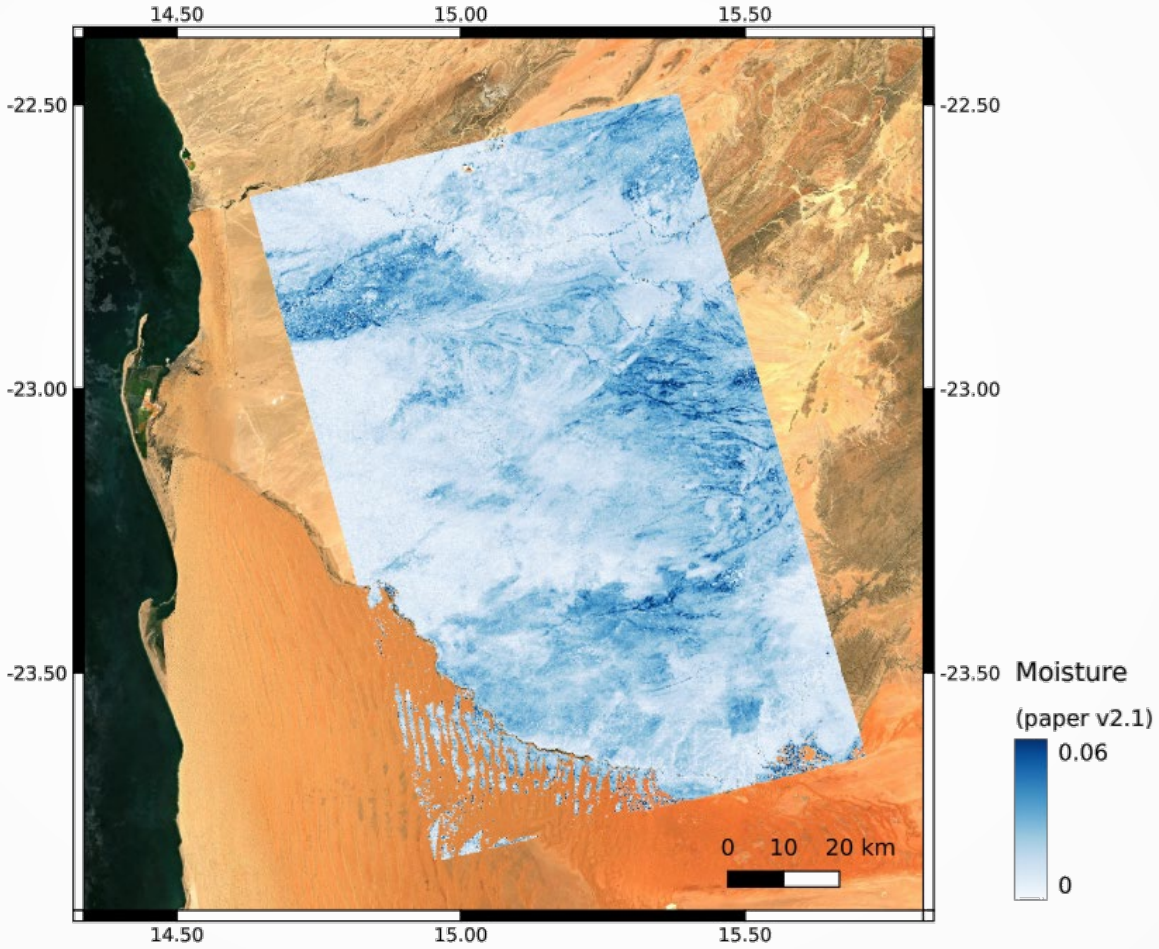
Namibia 2021 -01-09



Namibia 2021 -01-21



Namibia 2021 -02-02



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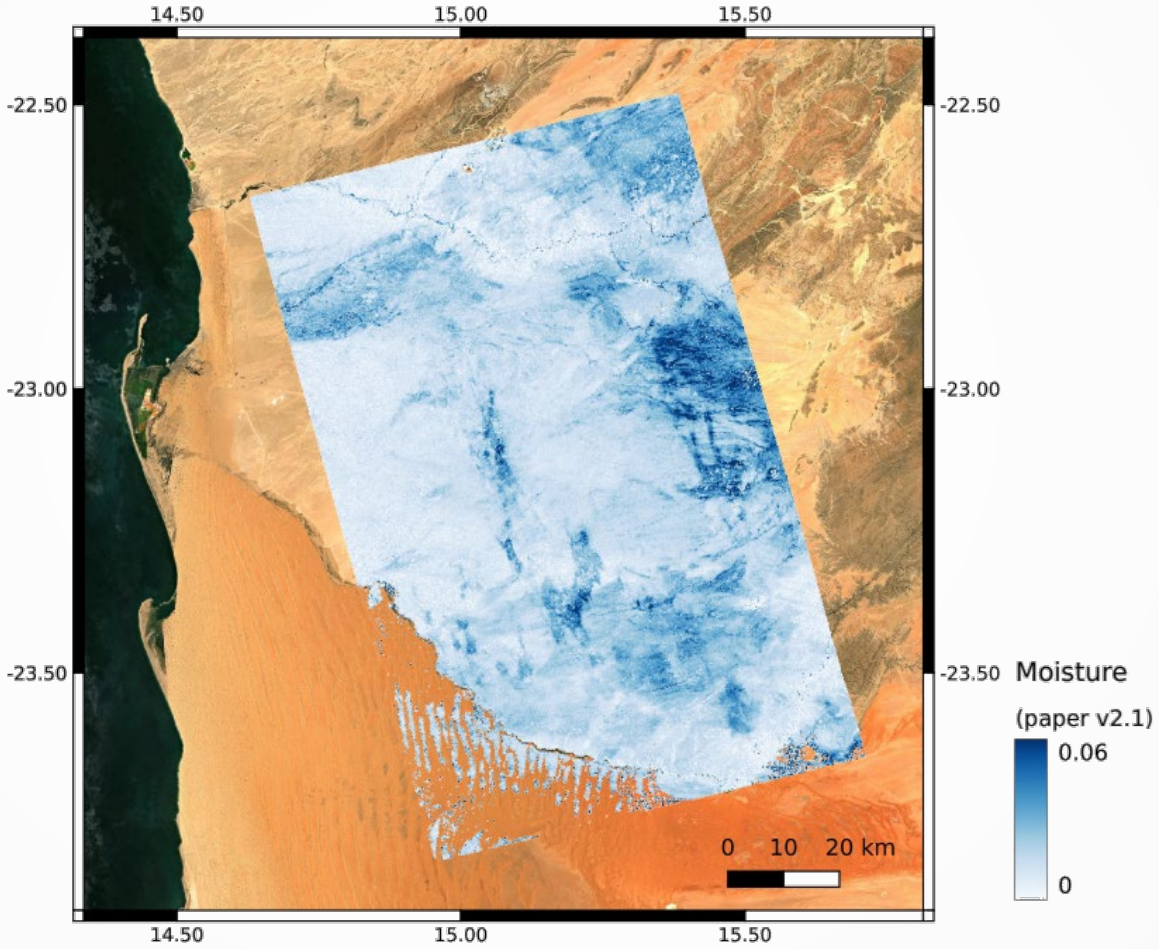

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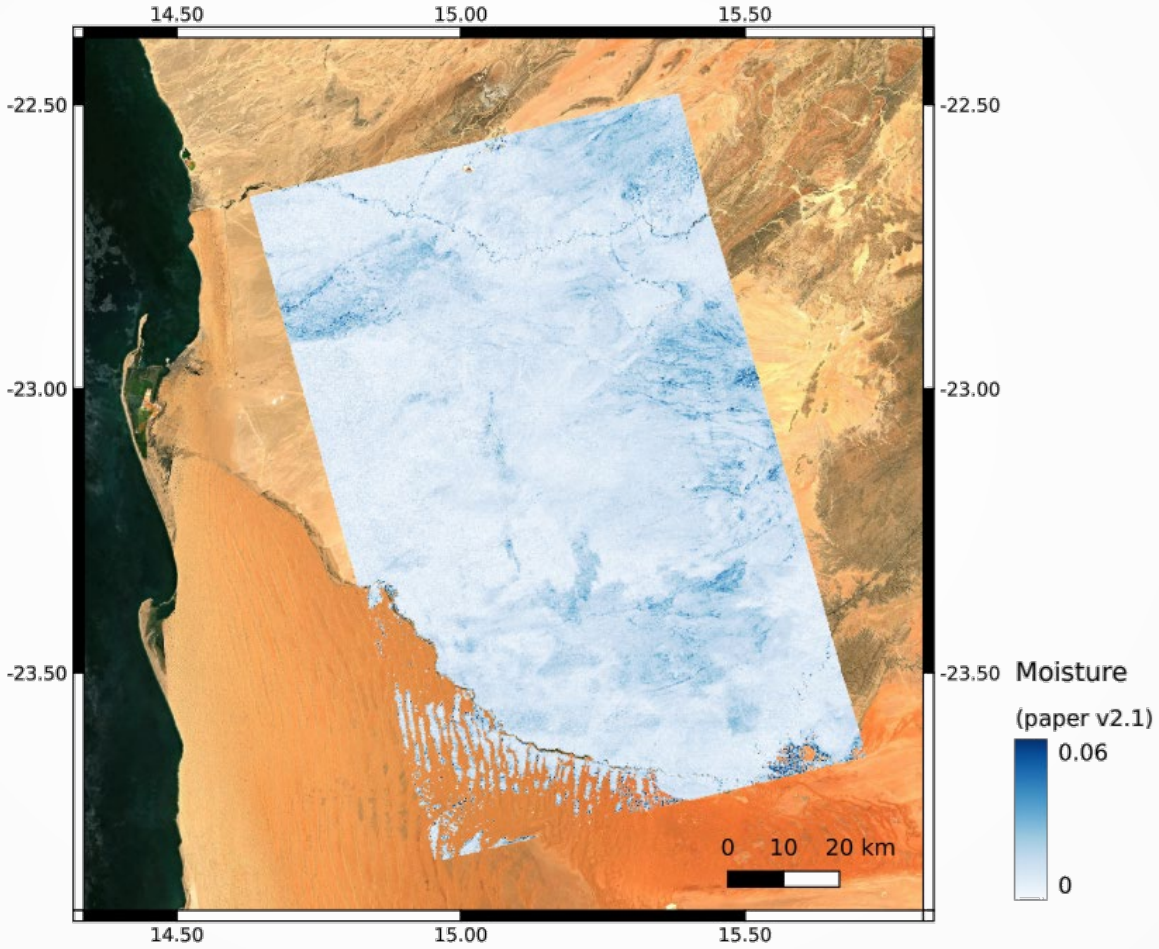

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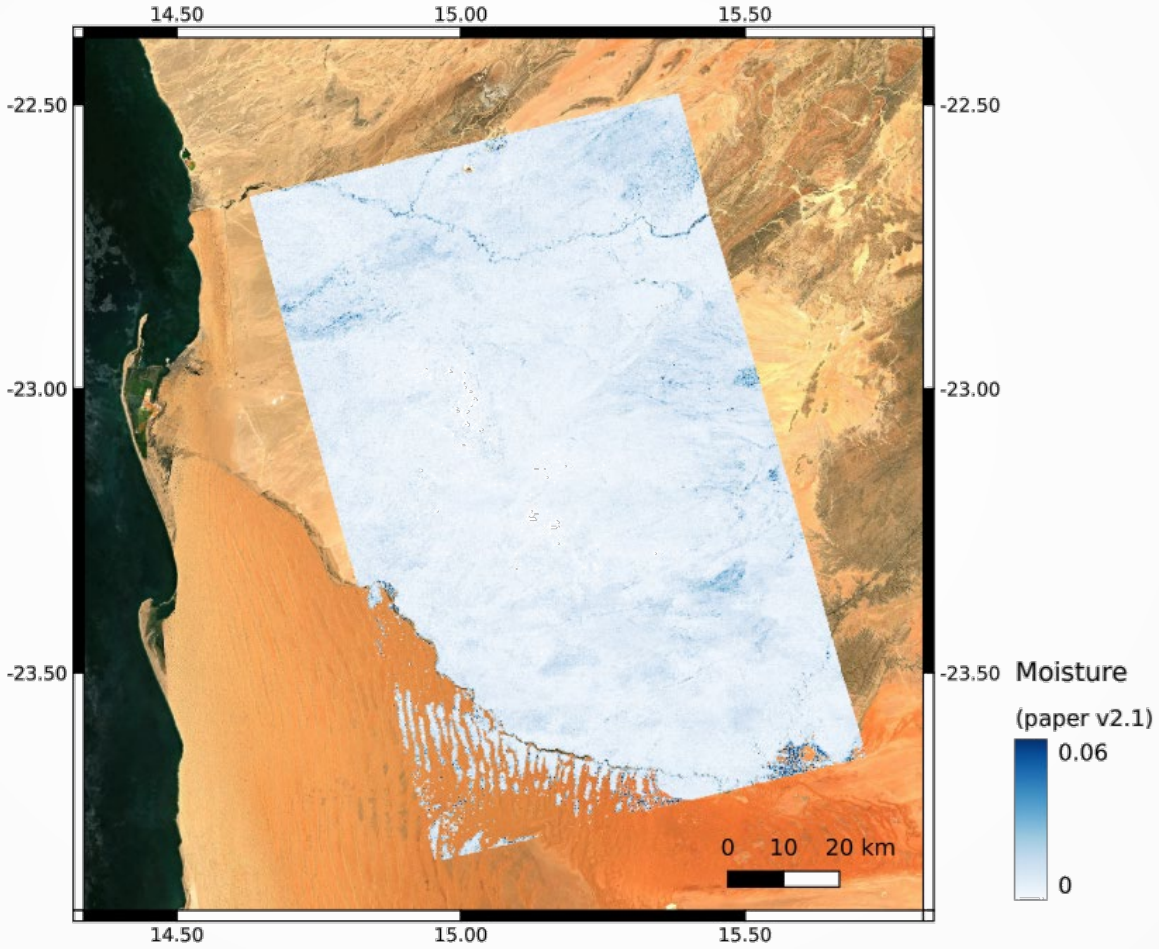
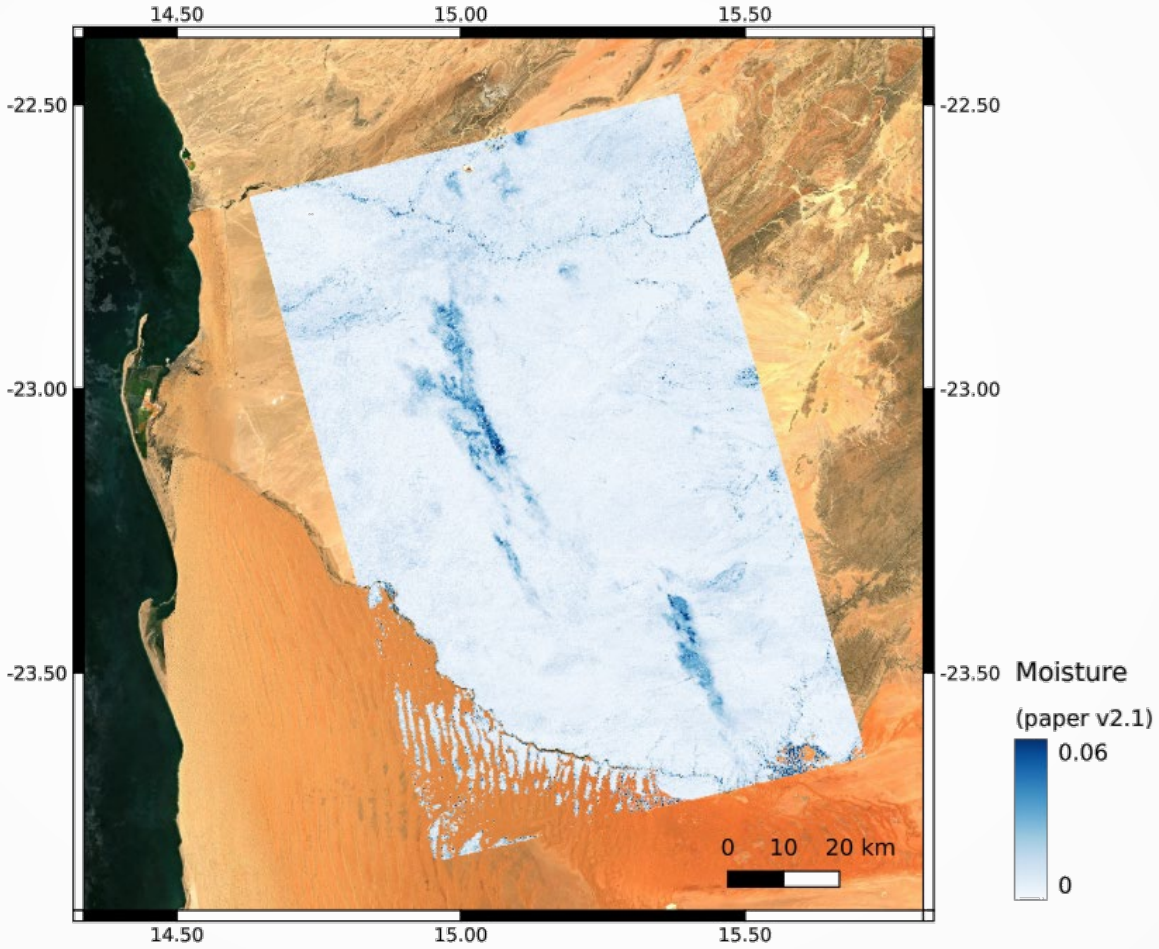
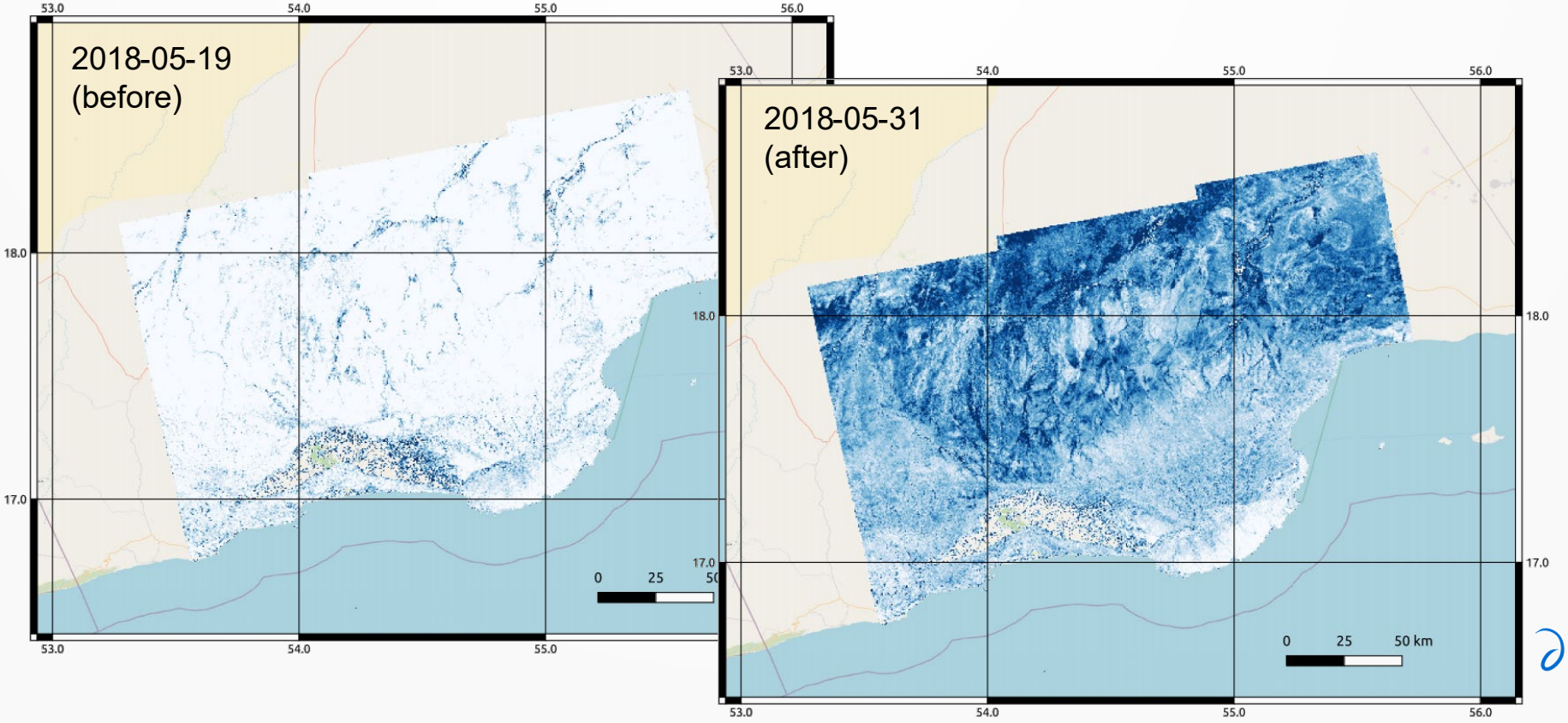


Namibia 2021 -03-22



Dhofar, cyclone Mekunu (2018 May 25 -27)

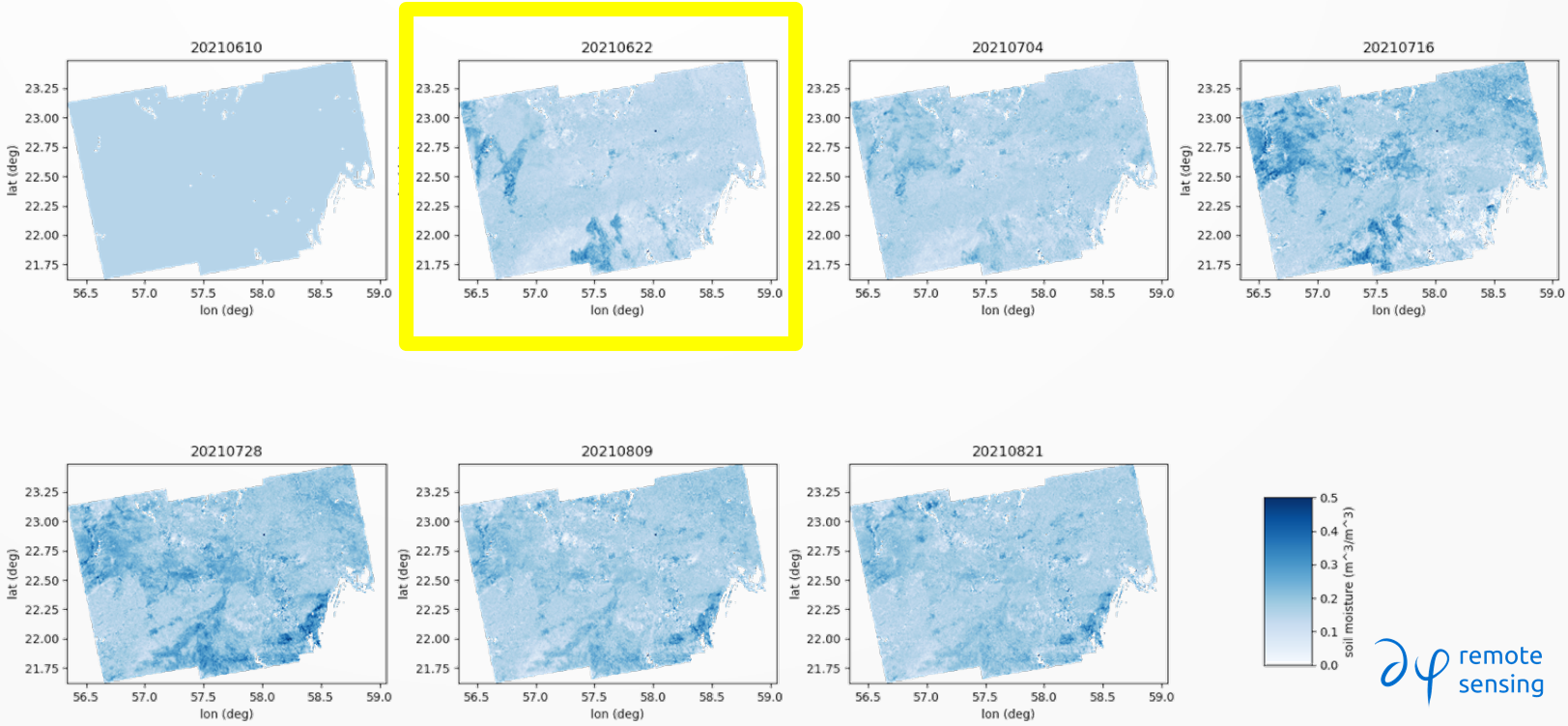
Soil moisture product: before and after the cyclone



Soil moisture with InSAR on Oman

InSAR soil moisture time series during June – July 2021 rain event

Oman



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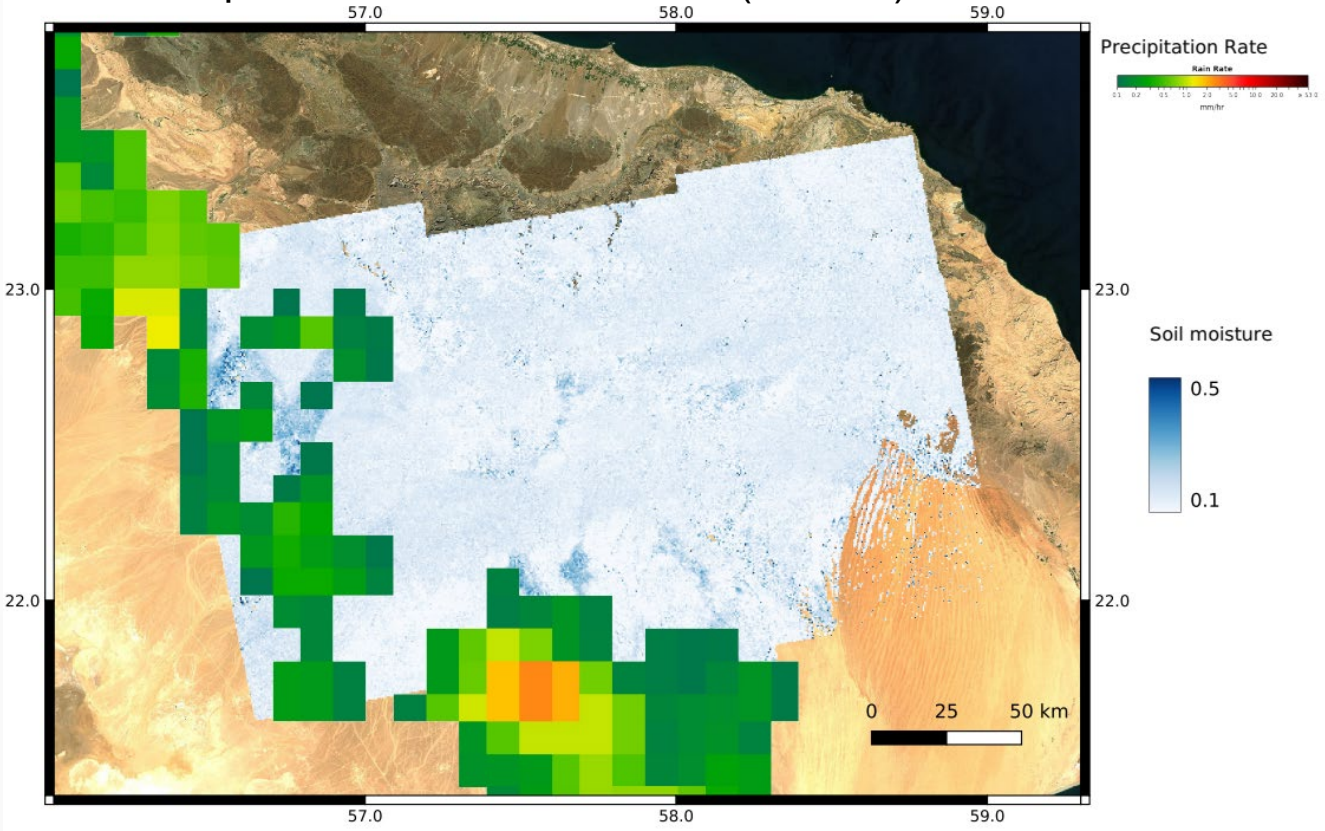
Oman: rain in June 2021

Low resolution, but it confirms the location of precipitation!

Precipitation rate from satellites (IMERG)



2021-06-19 IMERG

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