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Intercomparison of high spatial resolution surface soil moisture products derived from microwave data

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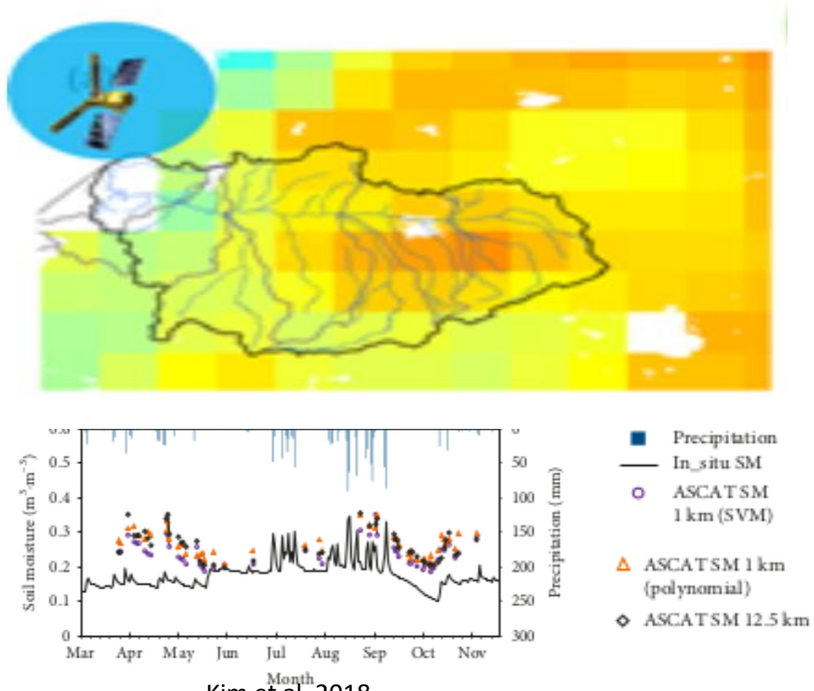
Surface soil moisture products

Literature / numerous intercomparison studies of SSM products at coarse resolution

- ASCAT (12.5 km - 1km)
- SMAP (36 km - 1km)
- SMOS (25 km -1km)
- ESA CCI (25 km, -1km)
- …

Qu et al. 2021; Al-Yaarial. 2019; Kim et al. 2018; Brocca et al. 2011; Gruhier et al. 2010; Rüdiger et al. 2009 …

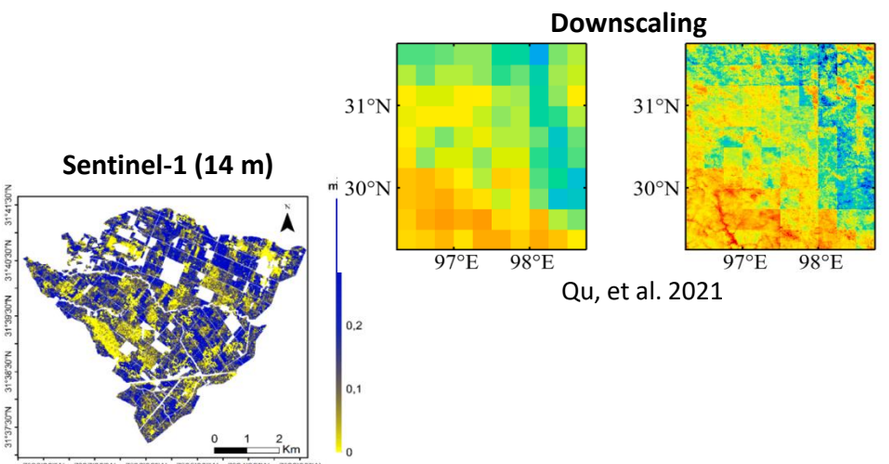


Kim et al. 2018

Lack of such studies at high spatial resolution / more relevant for plot-scale applications

High spatial resolution SSM products increasingly available

1. Downscaling of passive microwave data SMAP and SMOS
2. High resolution radar data / free products from Sentinel-1



Qu, et al. 2021

Ouaadi et al. 2020

→ Intercomparison of high spatial resolution SSM products within the frame of LIAISE project

Study area

Urgell region (Catalonia-Spain)

SSM database collected during 2021

1. Site I : Prat De Boldu
2. Site II : Ivars

- Semi-arid influenced by a continental climate
- Annual precipitation ~ 376 mm/year
- Variable air temperature (mild winter and hot summer)

SSM measurement data base

Prat De Boldu / LONIM soil moisture network

- Low-cost network designed at CESBIO (Toulouse)
- Hourly measurements
- A network of 11 soil moisture stations installed over 11 fields (gateway receiving and storing data and transmit to a server)
  - → Winter fields : March – April
  - → Summer fields : May – September
- fields cropped with : barley, wheat, maize, peas, alfalfa and apple trees
- Irrigation : Flood, sprinkler and drip

Ivars / Manually soil moisture dataset

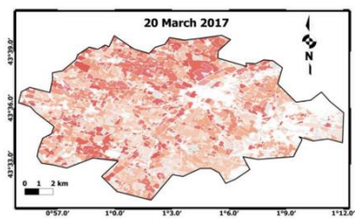
- Field campaigns during two weeks of July : 15→28 July 2021
- Collected using thetaprobs
- 22 fields
- cropped with : wheat, maize, alfalfa pear and apple trees
- Irrigation : Flood and drip irrigation

SSM satellite data base

4 products are initially investigated

1 Theia product

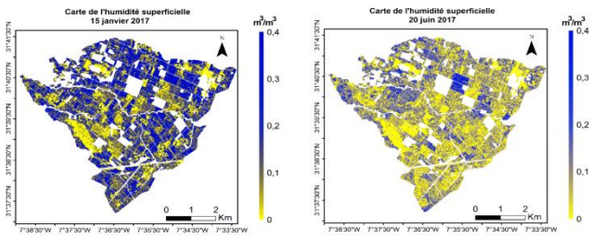
Plot scale product derived from a synergy of Sentinel-1 and Sentinel-2 using a machine learning algorithm (available via the Theia website)



El Hajj et al. 2017

2 Coherence (ρ) product

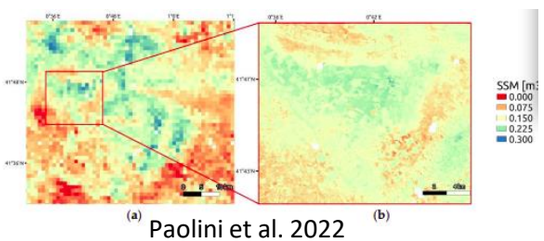
Product at 14 m resolution derived from Sentinel-1 backscattering coefficient and interferometric coherence using a brute-force algorithm



Ouaadi et al. 2020

3 SMAP20m product

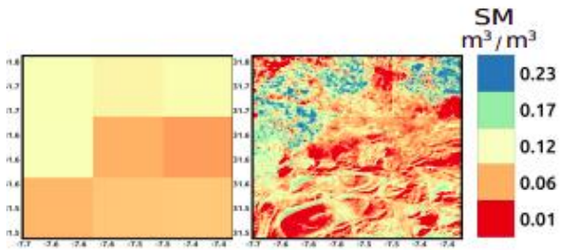
Product at 20 m resolution disaggregated from SMAP using Sentinel-3 and Sentinel-2 data



Paolini et al. 2022

4 SMAP100m product

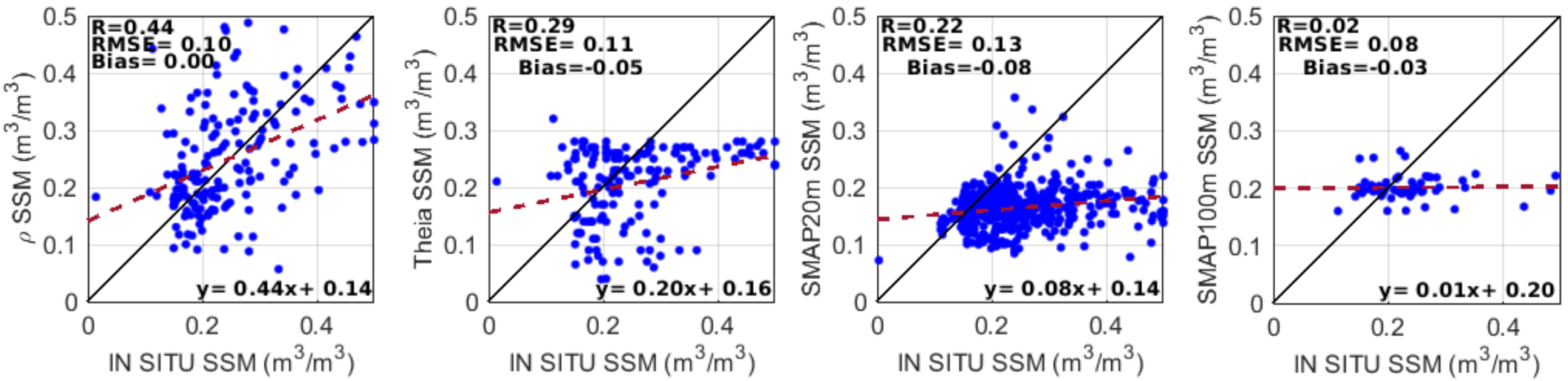
Product at 100 m resolution derived from SMAP disaggregated using Landsat 7 and 8



Ojha et al. 2021

Results / SSM scatterplots

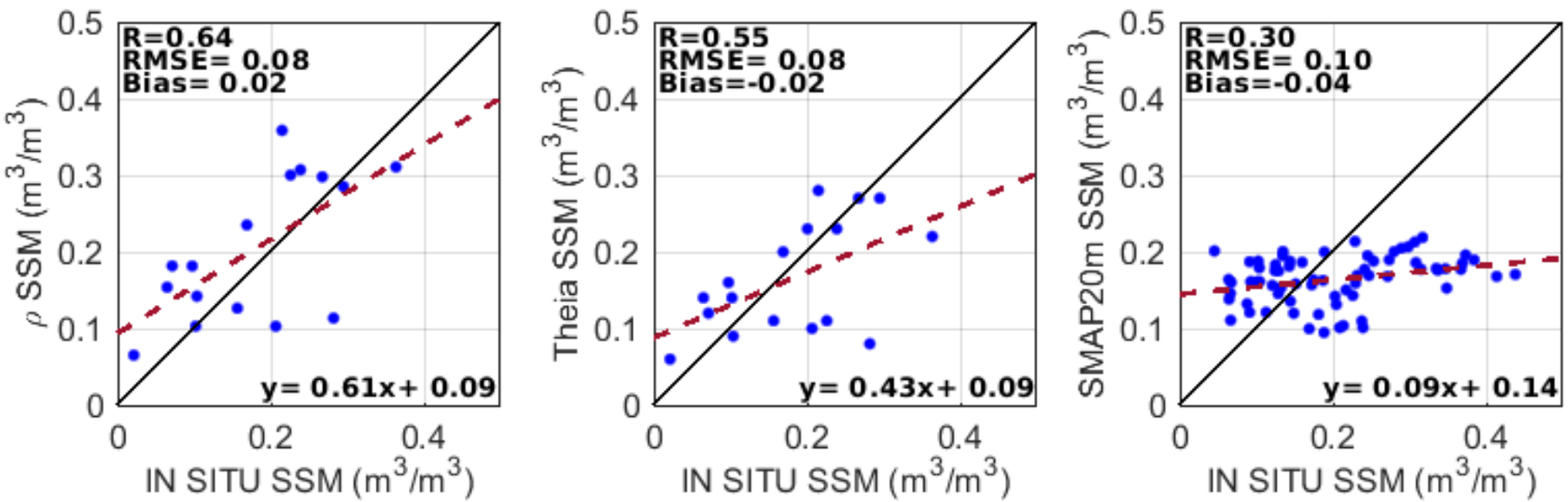
Prat De Boldu



- Good results obtained using Sentinel-1 products in particular ρ product
- The main problem limiting the performance of Theia is the quick saturation at ~0.3 m^3/m^3
- SMAP20m can reach higher values but there is a significant insensitivity for SSM>0.25 m^3/m^3
- SMAP100m, similar performance as SMAP20m with a lower data number because of the low temporal resolution of LandSat combined with the cloud cover presence

Results / SSM scatterplots

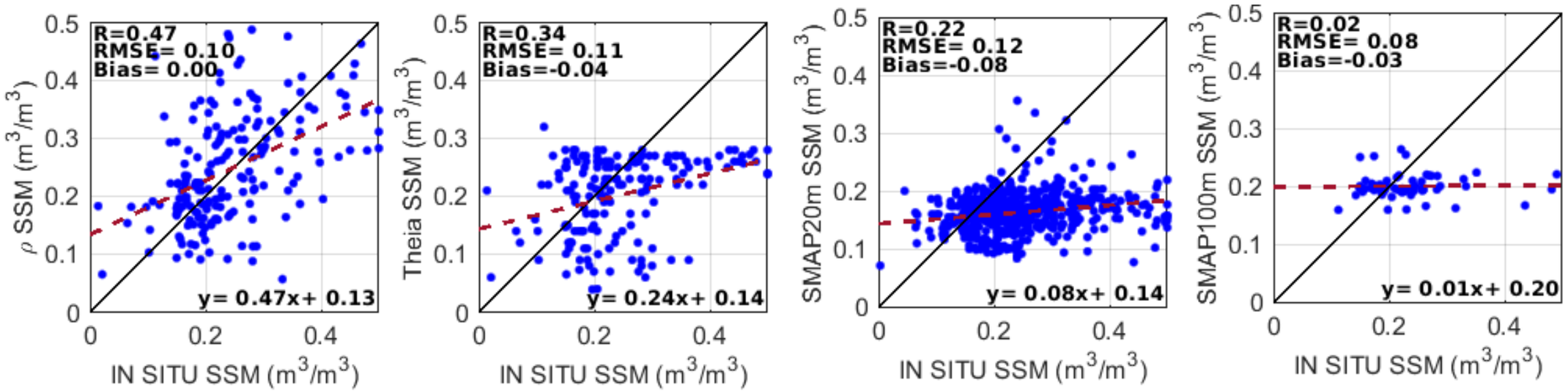
Ivars



- Good results obtained using Sentine-1 products in particular ρ product
- Measurement ~limited to 0.3 m^3/m^3 → Theia provide also good estimates
- SMAP20m is insensitive for SSM>0.25 m^3/m^3
- SMAP100m is not provided because of the limited number of available data

Results / SSM scatterplots

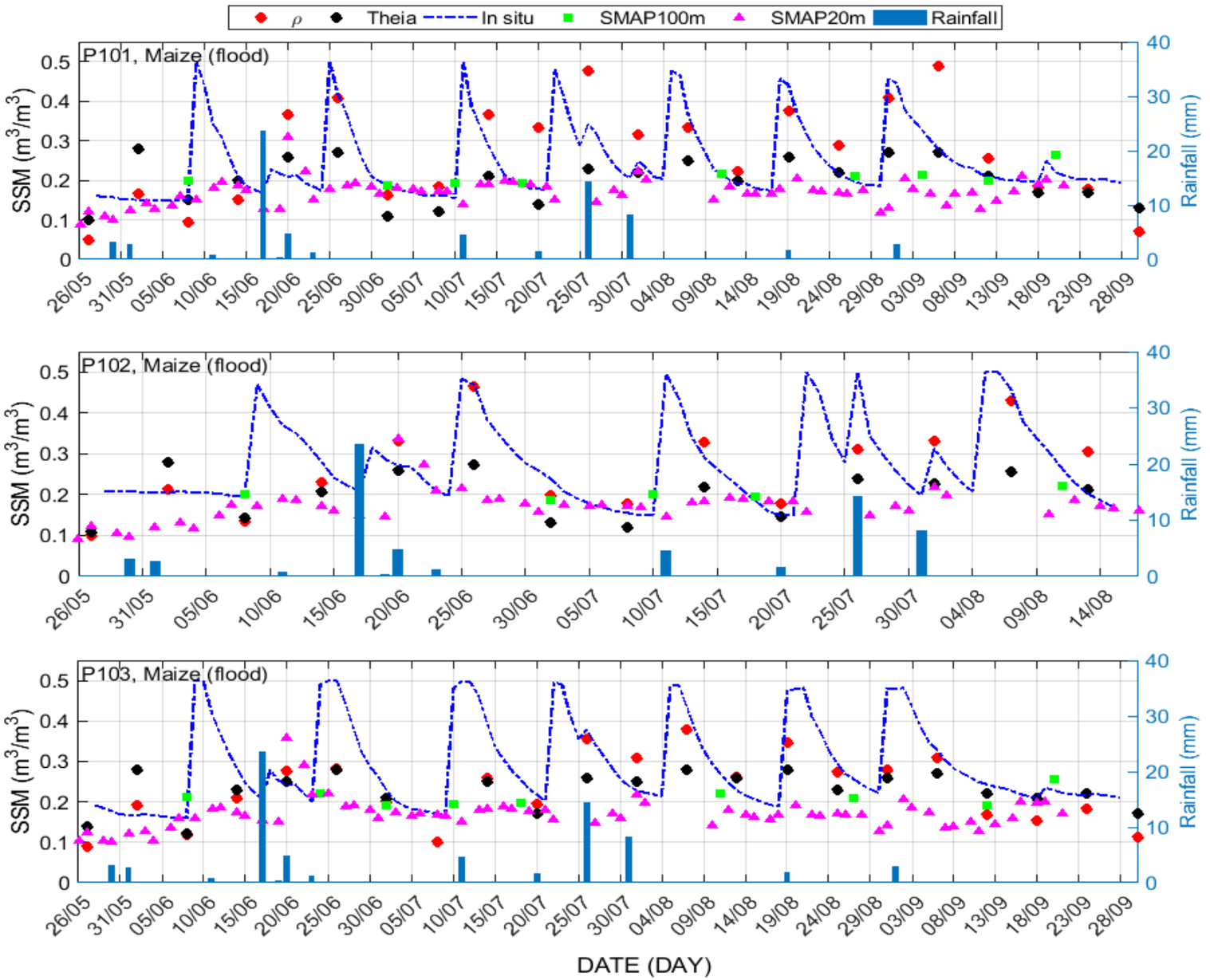
All data (Prat De Boldu + Ivars)



- Good results obtained using Sentine-1 products in particular coherence
- The main problem limiting the performance of Theia is the quick saturation at ~0.3 m3/m3
- SMAP20m can reach higher values but there is a significant insensitivity for SSM>0,25 m3/m3
- SMAP100m, similar performance as SMAP20m with a lower data because of the low temporal resolution of LandSat combined with the cloud cover presence

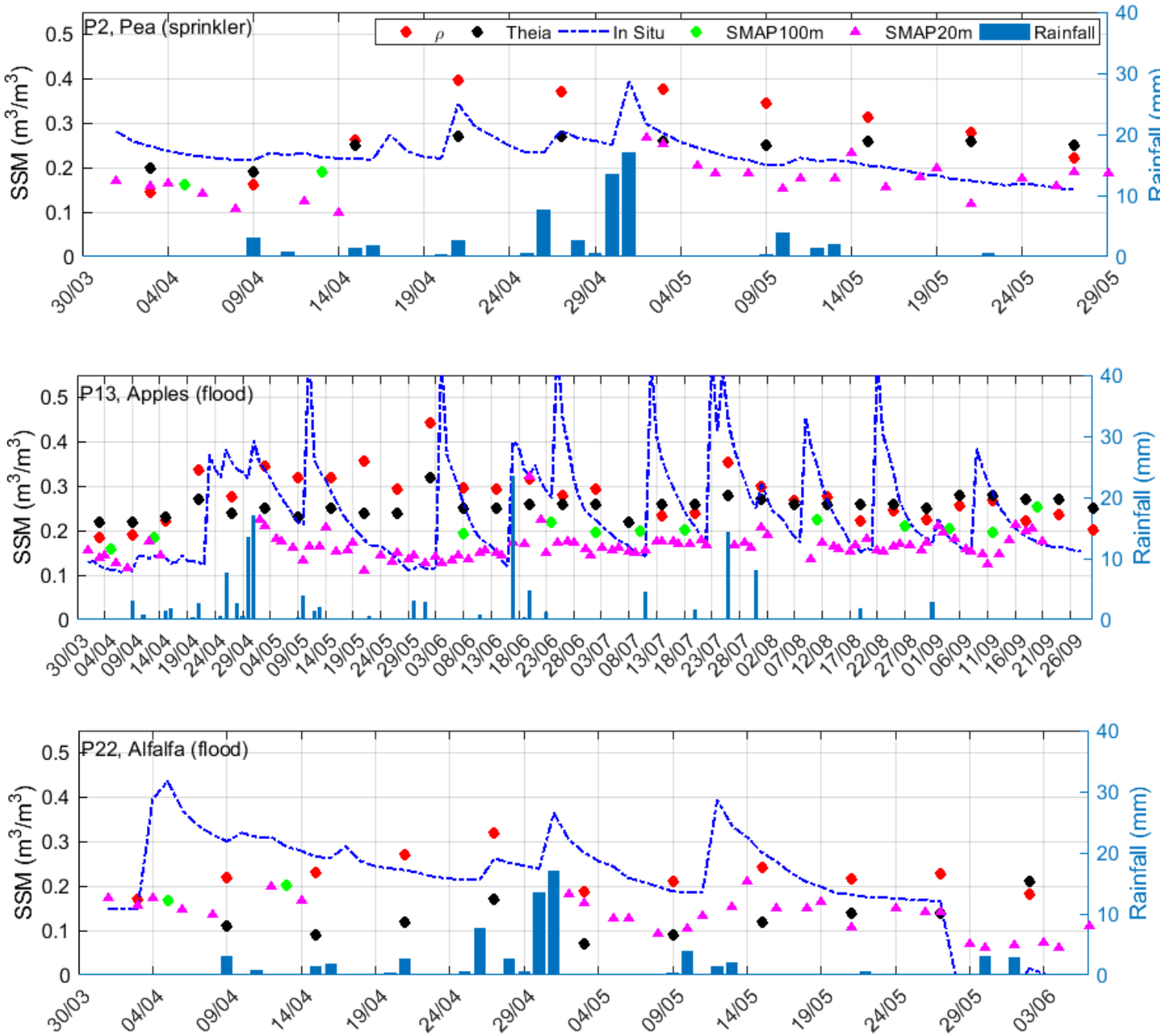
Results / SSM time series over Prat De Boldu

- SSM variation better captured by Sentinel-1 products
- Accurate maximum values retrieved using ρ product
- SMAP20m and SMAP100m are limited in [0.1, 0.2]
- SMAP20m is frequent but can't capture the irrigation signal → Sentinel-2 does not contain the information on SSM
- High values retrieved using SMAP20m around 20/6 because of a rainfall event (observed in all fields)
- SMAP100m : low number of data



Results / SSM time series over Prat De Boldu

- Limited performance of Sentinel-1 products over some fields
- Over trees : need for parameter calibration of the backscatter model over trees
- Limited performance of SMAP20m and SMAP100m
- Long periods without SMAP20m and SMAP100m because of the presence of clouds

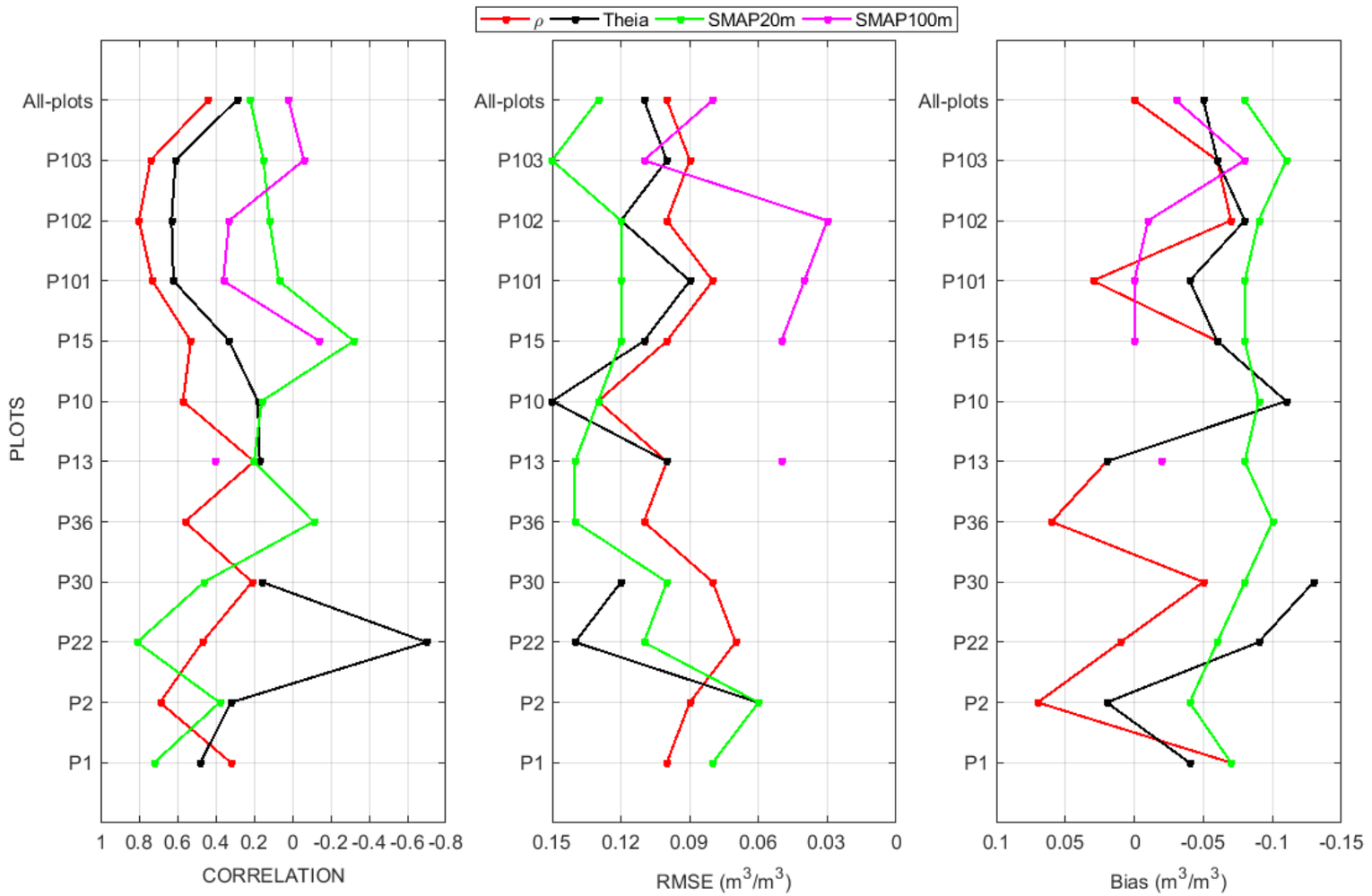


Results / statistical metrics comparaison

Prat De Boldu

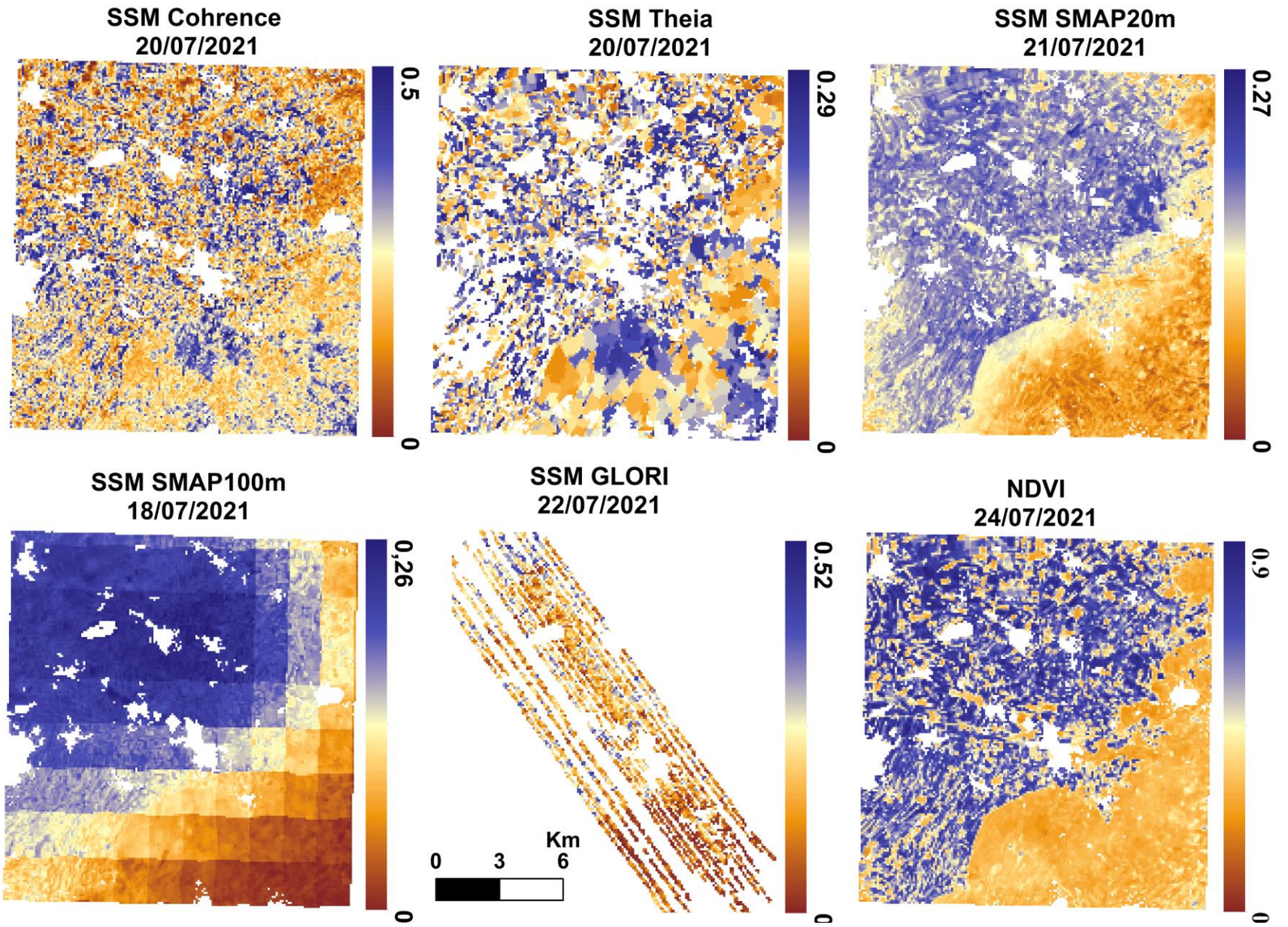
- ρ outperform the 3 approaches for 8 of 11 fields
- SMAP20m outperform the approaches over 3 plot in winter : no data for the irrigated period + daily data at the end of the season

-but higher RMSE and significant underestimation of SSM



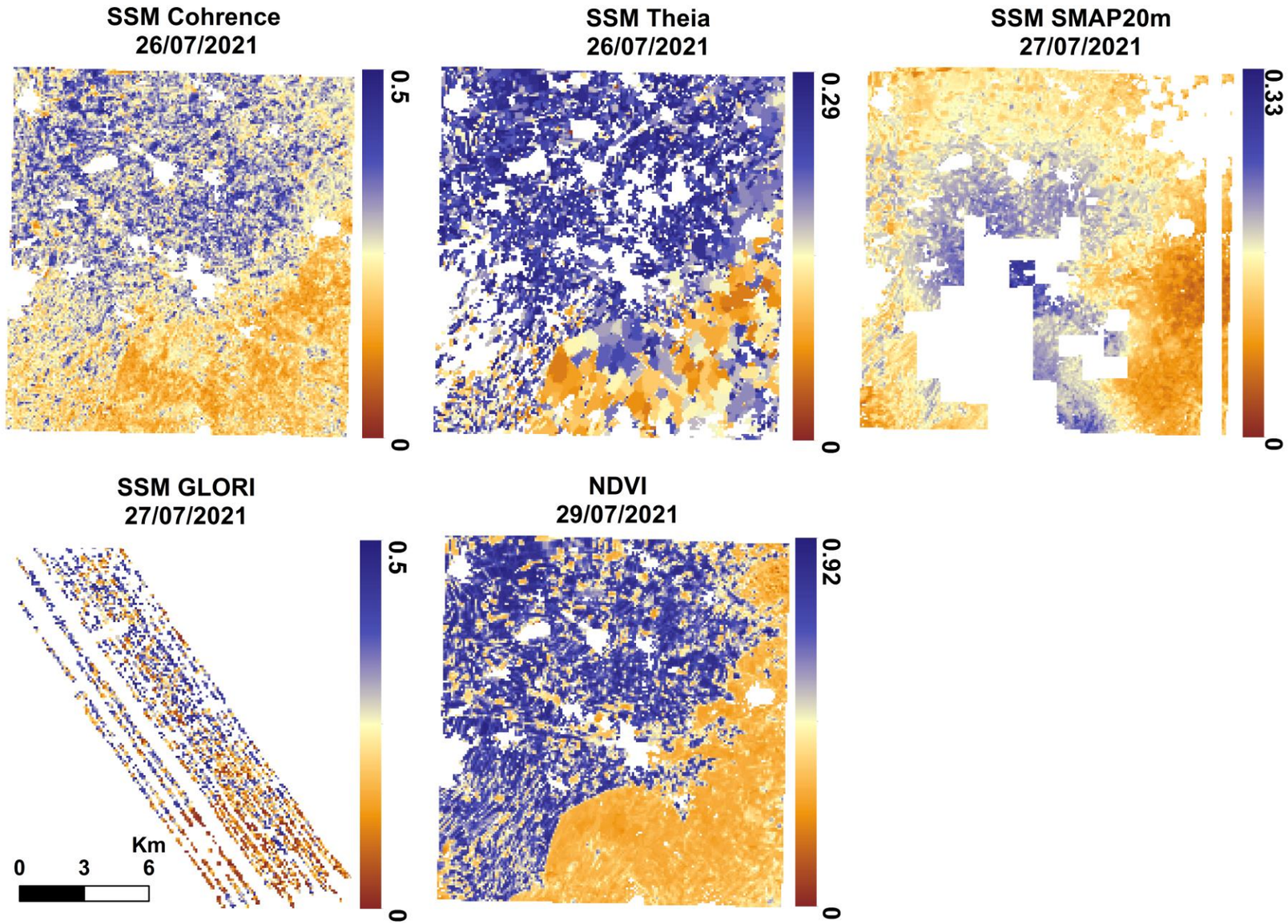
SSM mapping

- Maps at 100m resolution (GLORI resolution)
- All the approaches can differentiate between the irrigated and non irrigated parts
- Similar spatial pattern between ρ and Theia products with differences in the max values
- An irrigated part is detected by Sentinel-1 approaches only (right-bottom)
- Missing data in Theia probably because of the approach limitation (masked crops?)
- SMAP20m is similar to NDVI map



SSM mapping

- Problem of cloud : SMAP20m with several pixels contaminated and SMAP100m not available
- Difference in the right-bottom side between two Sentinel-1 approaches →difference in the scale (SSM around 0.25 in both)
- More homogeneous due to a large irrigation event
- More spatial pattern in ρ approach because of SSM higher range (Theia saturate at 0.3)



Summary and conclusions

- The high resolution surface soil moisture products are increasingly available and need to be evaluated over different area to be used (more relevant at the plot scale application)
- Sentinel-1 derived approaches outperform the desegregated products → Coherence can reach high values of SSM comparing
- Saturation of Theia products at 0.3 → lower accuracy if SSM>0.3
- Radar approaches can be improved by specifying backscatter coefficients for each vegetation type
- SMAP20m can't catch the irrigation signal → insensitivity to SSM variation /use of Sentinel-2 optical data for disaggregation which do not contain SSM related information.
- SMAP20m and SMAP100m can be improved by using thermal data in the perspective of new missions such as TRISHNA and LSTM with both high temporal and spatial resolution data.