Trends and case studies for the H SAF ASCAT root-zone soil moisture data records

7th SALGEE meeting

November 24th 2021

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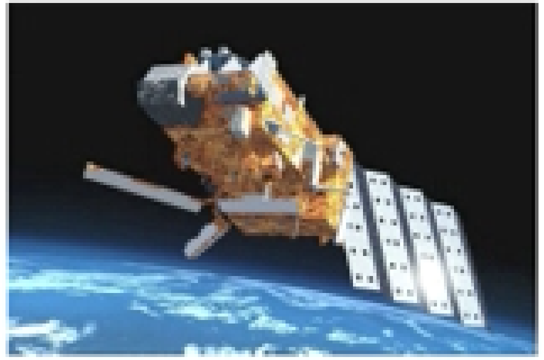
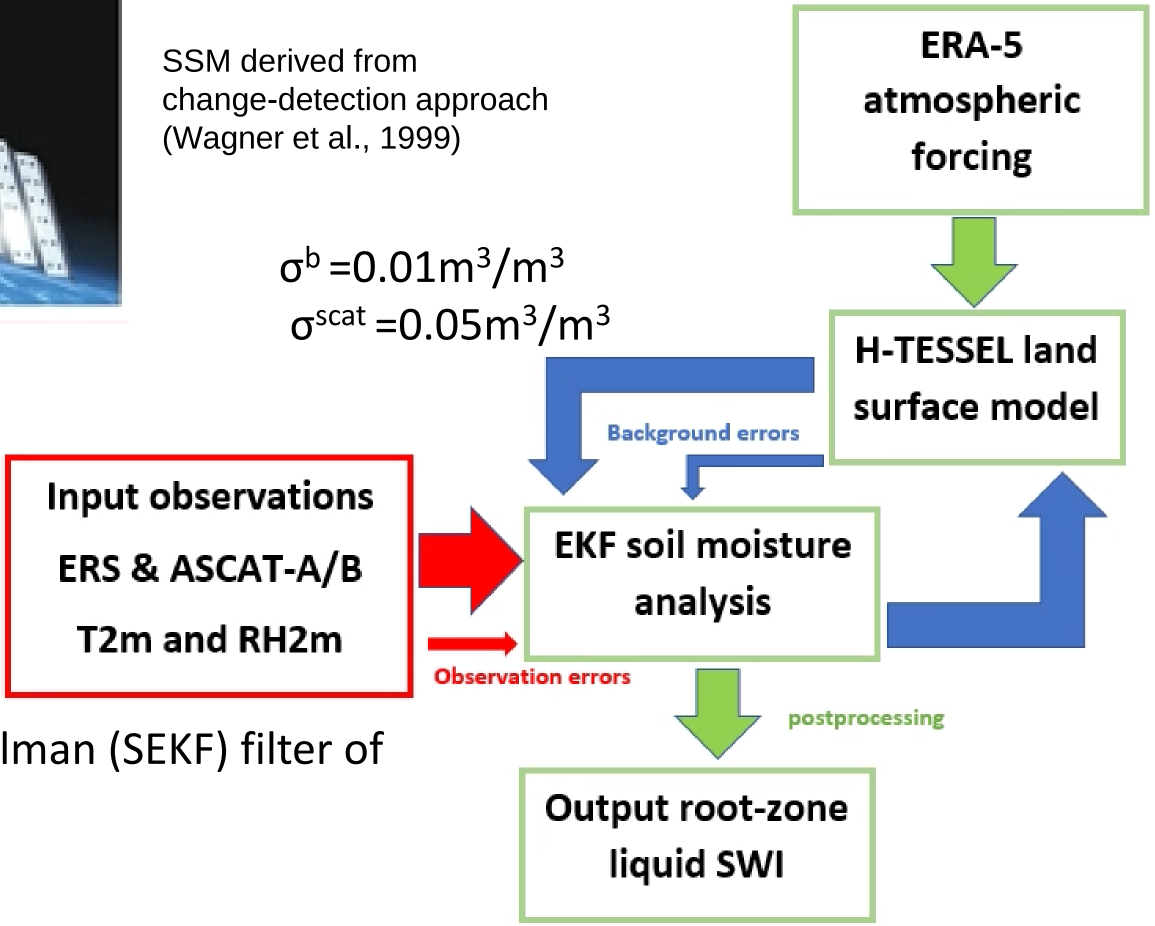
Contents

1. Overview of RZSM-DR2019-10km

EUMETSAT H SAF
SUPPORT TO OPERATIONAL HYDROLOGY AND WATER MANAGEMENT



SSM derived from change-detection approach (Wagner et al., 1999)



Simplified Extended Kalman (SEKF) filter of de Rosnay et al., 2013

Simplified EKF analysis

$$\mathbf{x}^a(t_i) = \mathbf{x}^b(t_i) + \mathbf{K}_i\left[\mathbf{y}^o(t_i) - \mathcal{H}_i(\mathbf{x}^b)\right],$$

$$\mathbf{K}_i = \left[\mathbf{B}^{-1} + \mathbf{H}_i^T\mathbf{R}^{-1}\mathbf{H}_i\right]^{-1}\mathbf{H}_i^T\mathbf{R}^{-1},$$

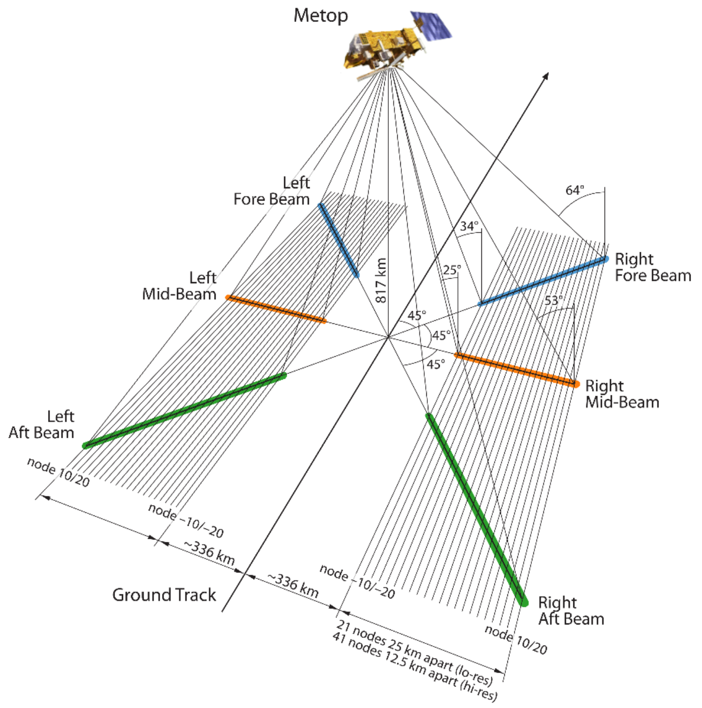
$$\mathbf{H}_{mn,i} = \frac{\mathcal{H}_{m,i}(\mathbf{x}^b + \delta\mathbf{x}_n^b) - \mathcal{H}_{m,i}(\mathbf{x}^b)}{\delta x_n}.$$

SM analysed over first 3 layers in H-TESSEL:
Layer 1: 0-7 cm
Layer 2: 7-28 cm
Layer 3: 28-100 cm
Layer 4 (not analysed): 100-289 cm

- Global root-zone liquid soil wetness index at 10 km sampling
- Assimilates reprocessed scatterometer-derived surface SM and screen-level T2m/RH2m
- Offline surface model forced by ERA5
- Available daily at 00 UTC and extended annually (RZSM-DR-EXT-10km, 2019-2020)

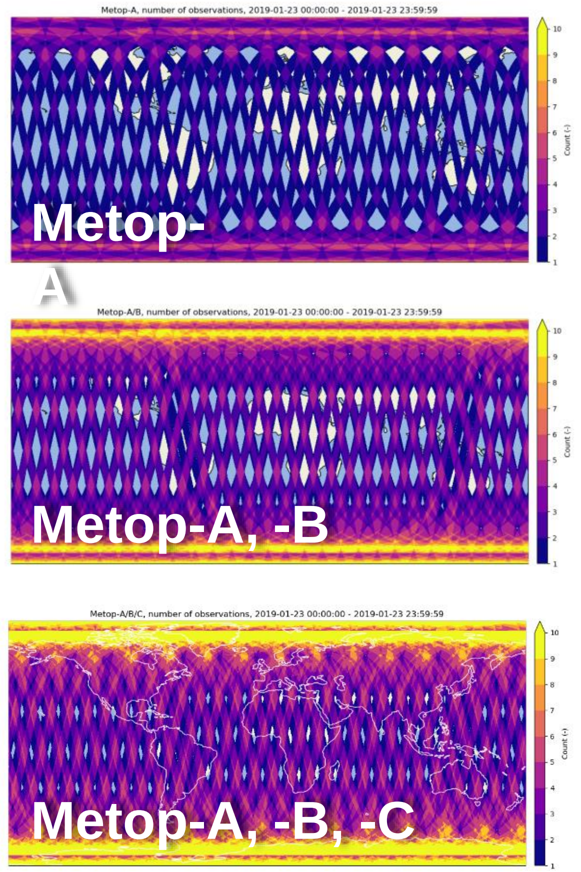
2. Advanced Scatterometer (ASCAT) on-board Metop

- Sensor characteristics
  - Active microwave scatterometer
  - Frequency: C-band, 5.255 GHz
  - Polarisation: VV
  - Spatial resolution: 25/50 km
  - Antennas: 2 x 3
  - Swath: 2 x 500 km
  - Multi-incidence: 25-65°
  - Daily global coverage: 82%



Figa-Saldana, et al., The advanced scatterometer (ASCAT) on the meteorological operational (MetOp) platform: A follow on for European wind scatterometers, Canadian Journal of Remote Sensing, 28(3), 404–412 (2002). http://dx.doi.org/10.5589/m02-035

Spatial coverage in 24 h



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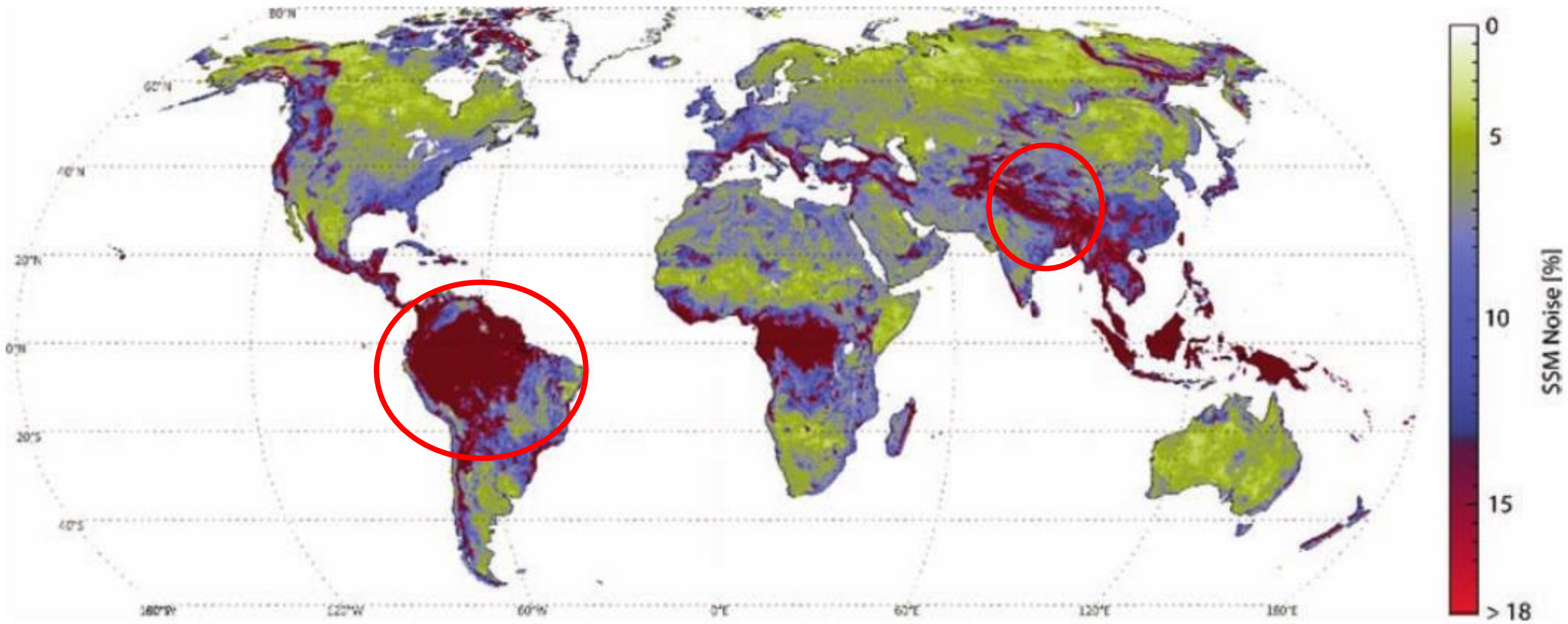
ASCAT observation accuracy



Estimate of noise (%) in ASCAT-derived observations. From Figure 6 of Wagner et al (2013). Based upon the methods presented in Naiemi et al. (2009).

- Most areas have a high signal-to-noise ratio. But observations in highly vegetated regions and mountainous regions are noisy.

3. H-TESSEL land surface model

- Land surface models (LSMs) provide continuous and spatially complete estimates of root-zone soil moisture.
- Dependent on accuracy of model and atmospheric forcing, notably precipitation and radiative forcing;
- LSMs require parameterizations (e.g. soil texture, vegetation type), which are not always accurate;

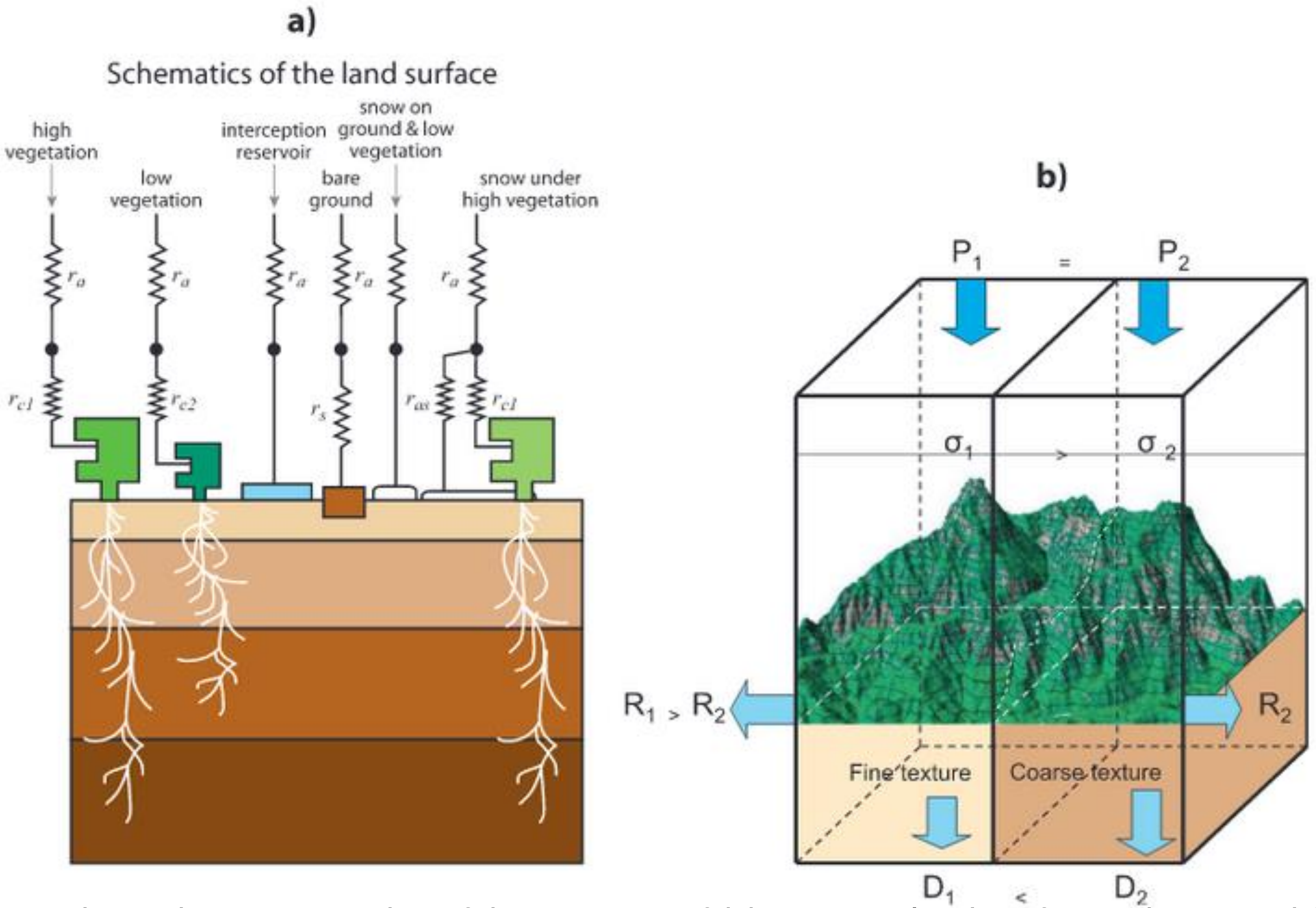


Figure 1: Schematic representation of the structure of (a) TESSEL land-surface scheme and (b) spatial structure added for H-TESSEL. From Balsamo *et al* (2009).

4. SEKF data assimilation

Simplified EKF analysis

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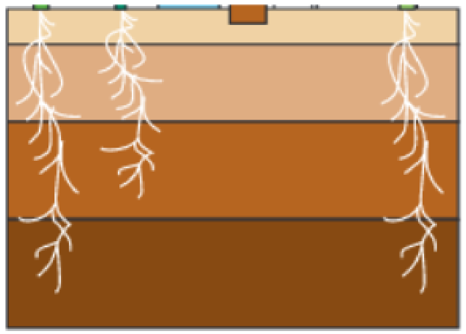

- SEKF based on de Rosnay et al, (2013);
- **B** is diagonal, with background-error standard deviation 0.01 m^3m^{-3} for each layer;
- **R** is diagonal, with observation-error standard deviation 0.05 m^3m^{-3} for ASCAT-derived SSM, 1 K for 2 m temperature and 4% for relative humidity.

SEKF data assimilation

Simplified EKF analysis

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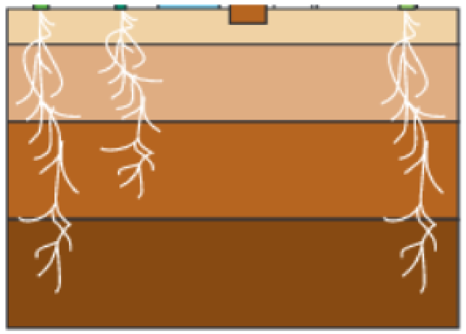
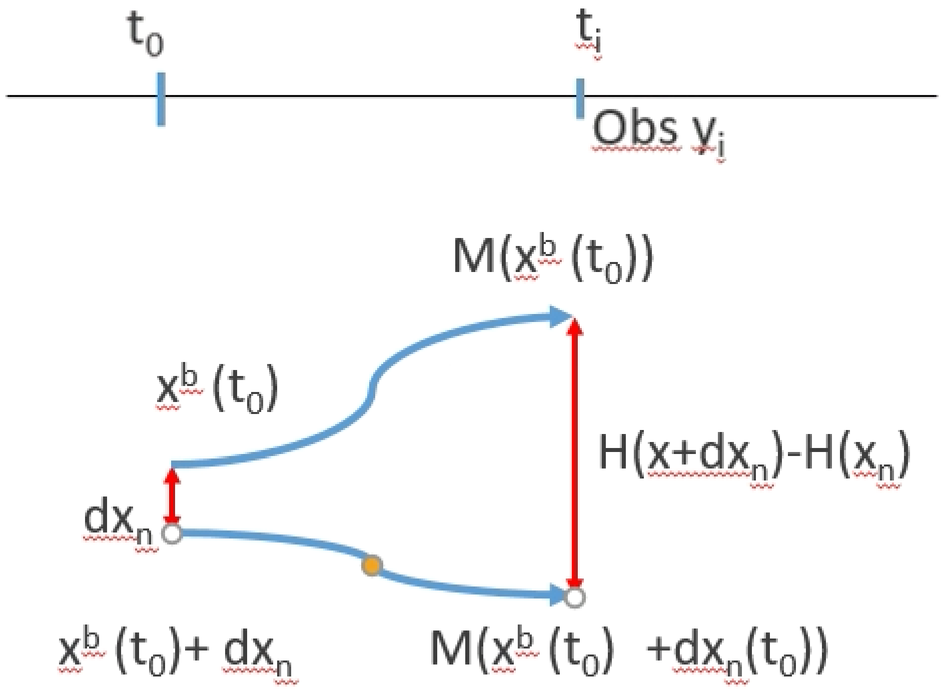
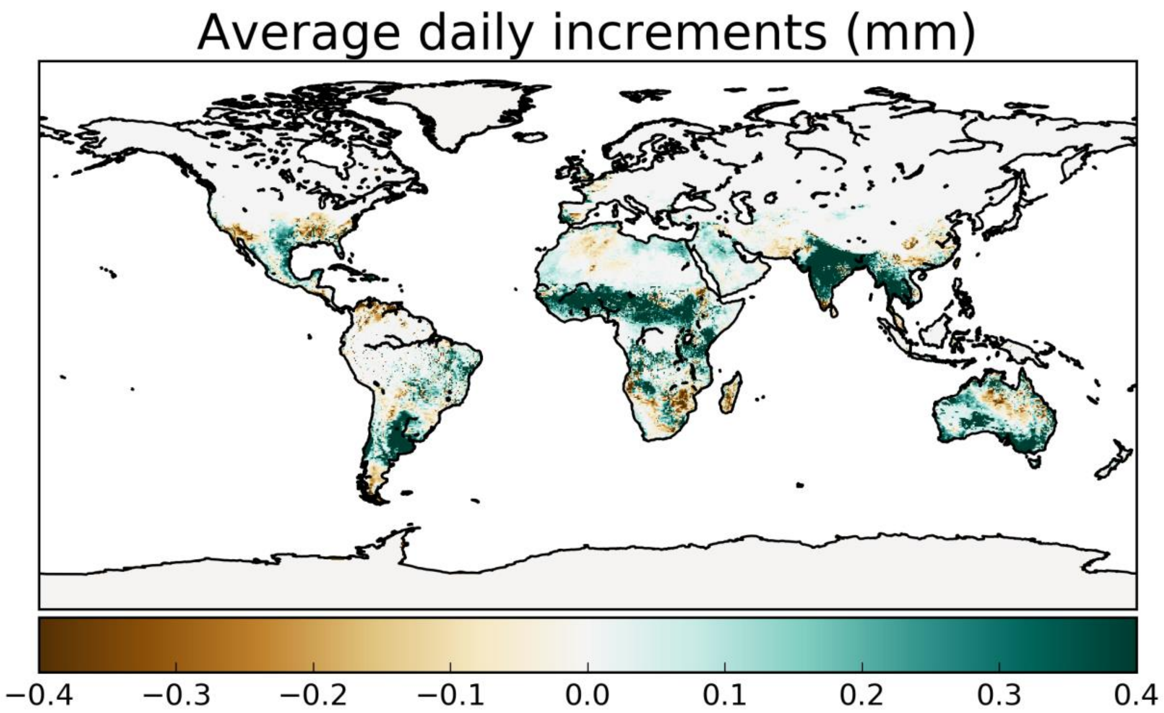


- Jacobian elements H_{nm} for analysis variable n and observation m calculated using finite differences:

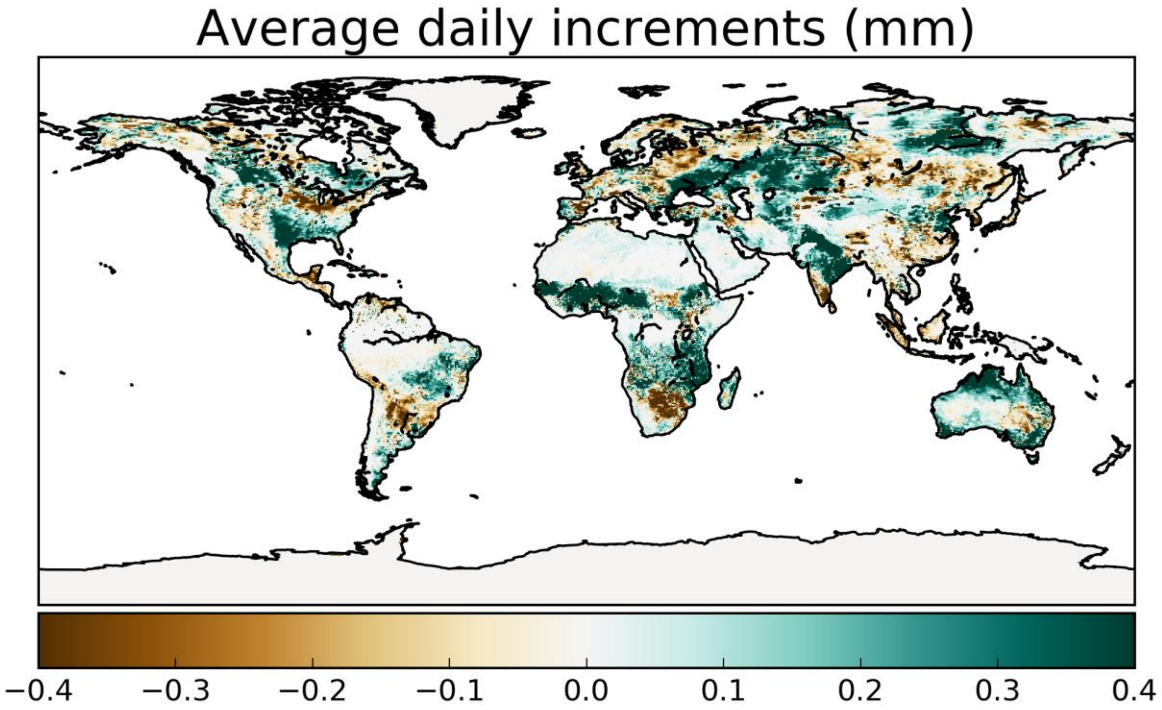


Average daily RZSM increments

January 2009:



June 2009:



5. Data record validation

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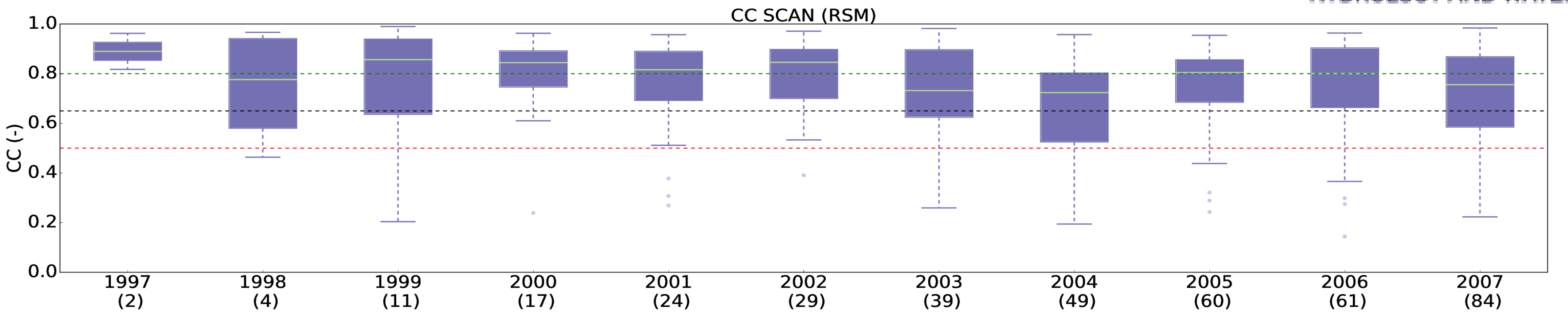
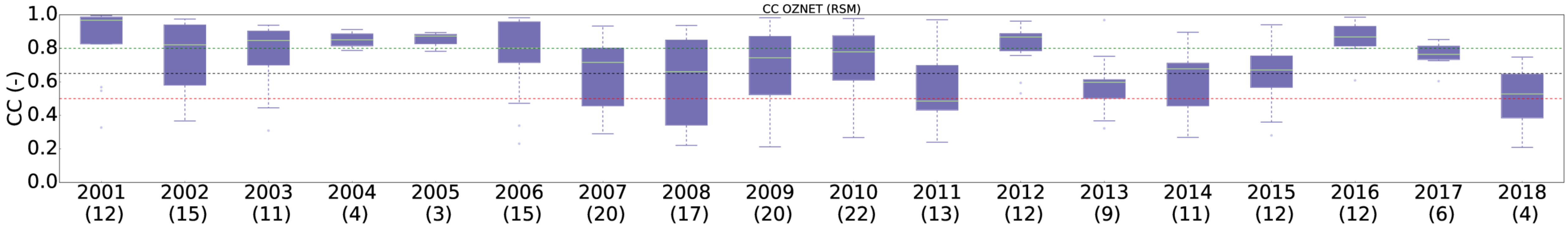
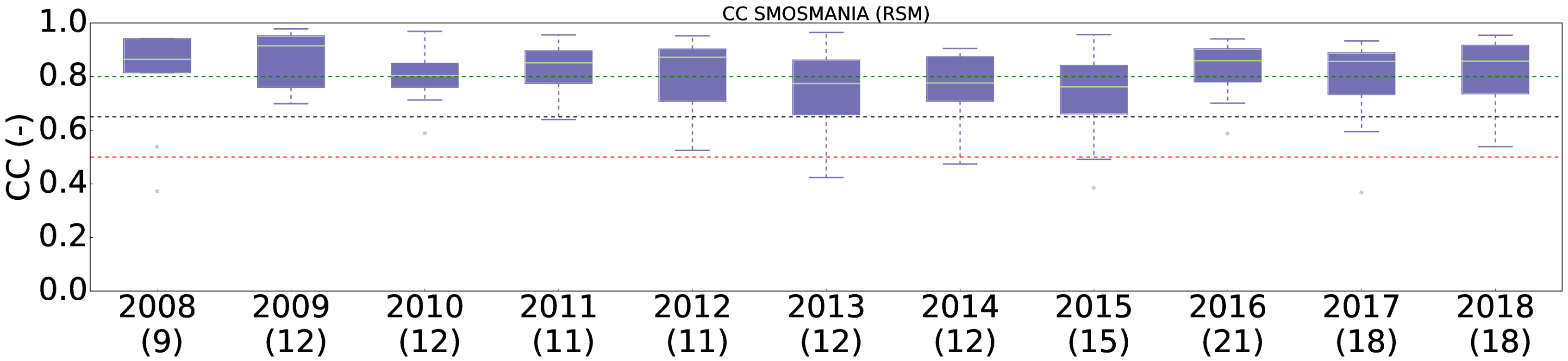
- RZSM validated annually with in situ data from networks in four countries:
(1) SMOSMANIA (France)
(2) USCRN/SCAN/SNOTEL (US)
(3) REMEDHUS (Spain)

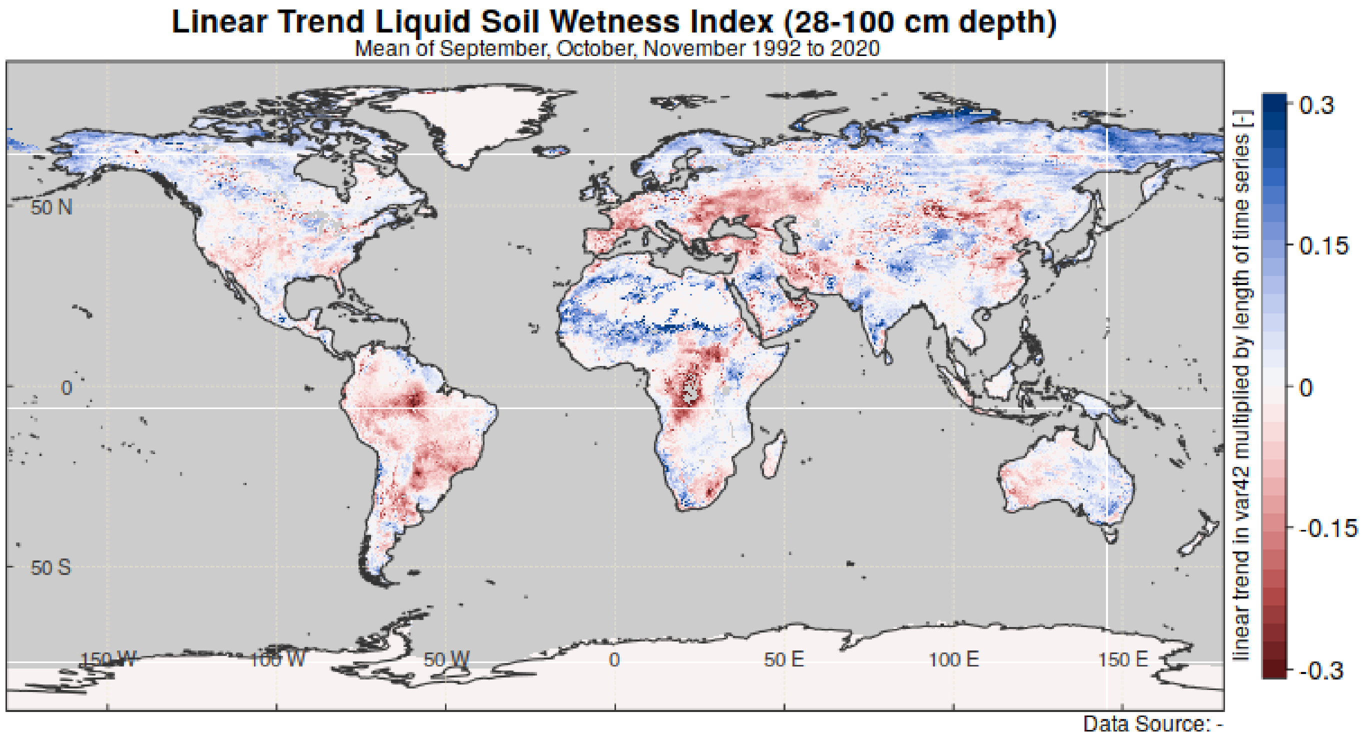


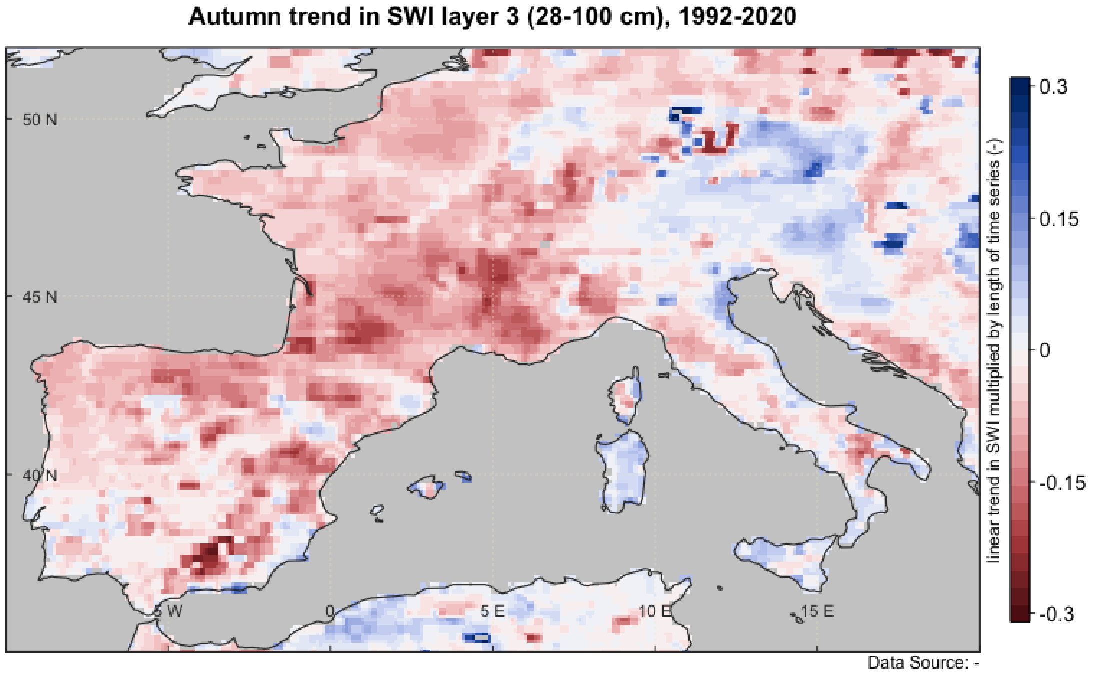


- Good overall performance, with CC>0.65 over most stations



6. Soil moisture trends (1992-2020)





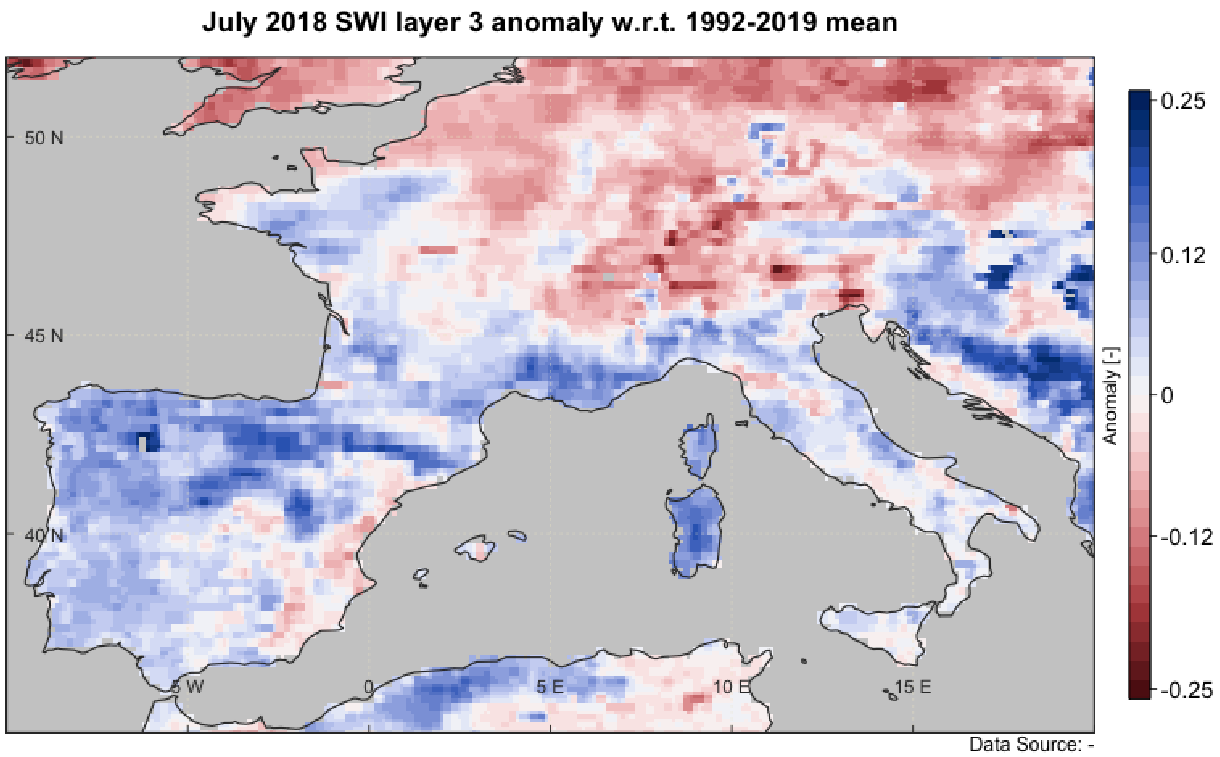
Trends calculated using CMSAF toolbox software (Kothe et al., 2019)

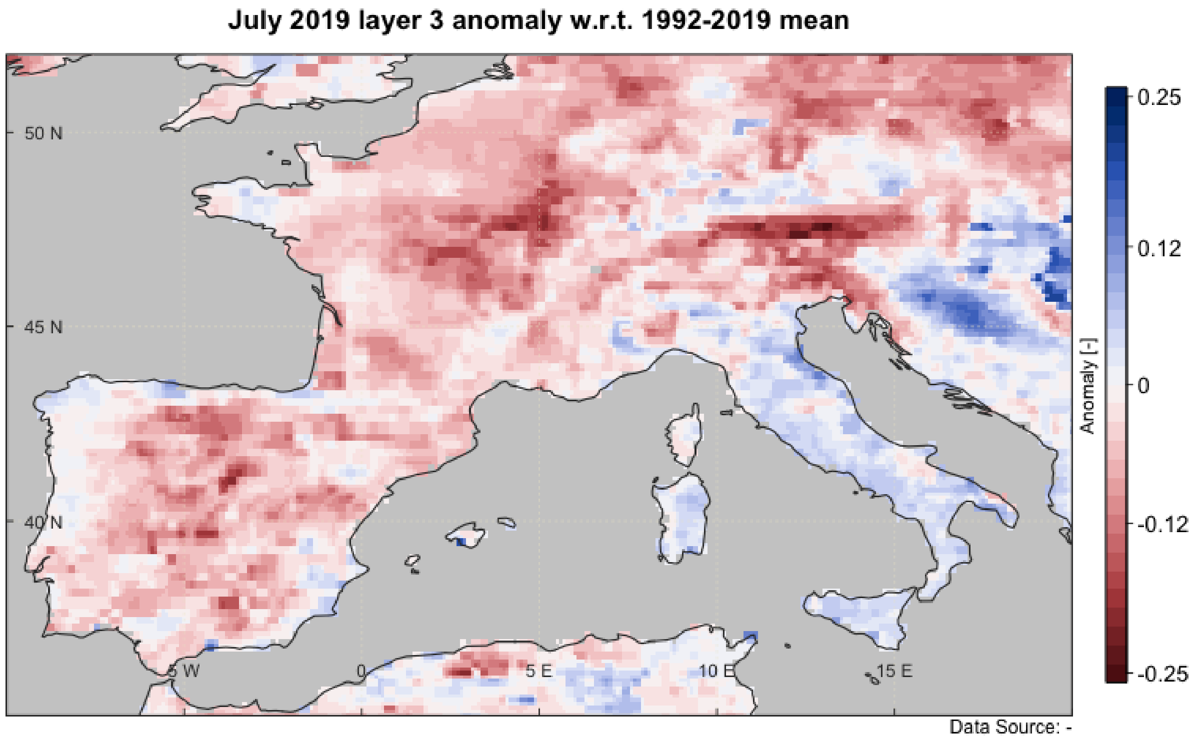
- Soil moisture has decreased by up to 30% in midlatitude autumn months, especially Europe
- Winter/spring trends are less significant
- Possible climate change mechanisms:

(1) Hotter summers drying soil

(2) Relative humidity reducing due to land warming faster than sea (Simmons *et al.*, 2010)

Recent Soil moisture anomalies





Anomalies calculated using CMSAF toolbox software (Kothe et al., 2019)

- Contrasting soil moisture conditions in July 2018 associated with dry (wet) weather over northern (southern) Europe
- Widespread dry conditions over July 2019 over Europe, when several temperature records were broken

7. German floods in July 2021

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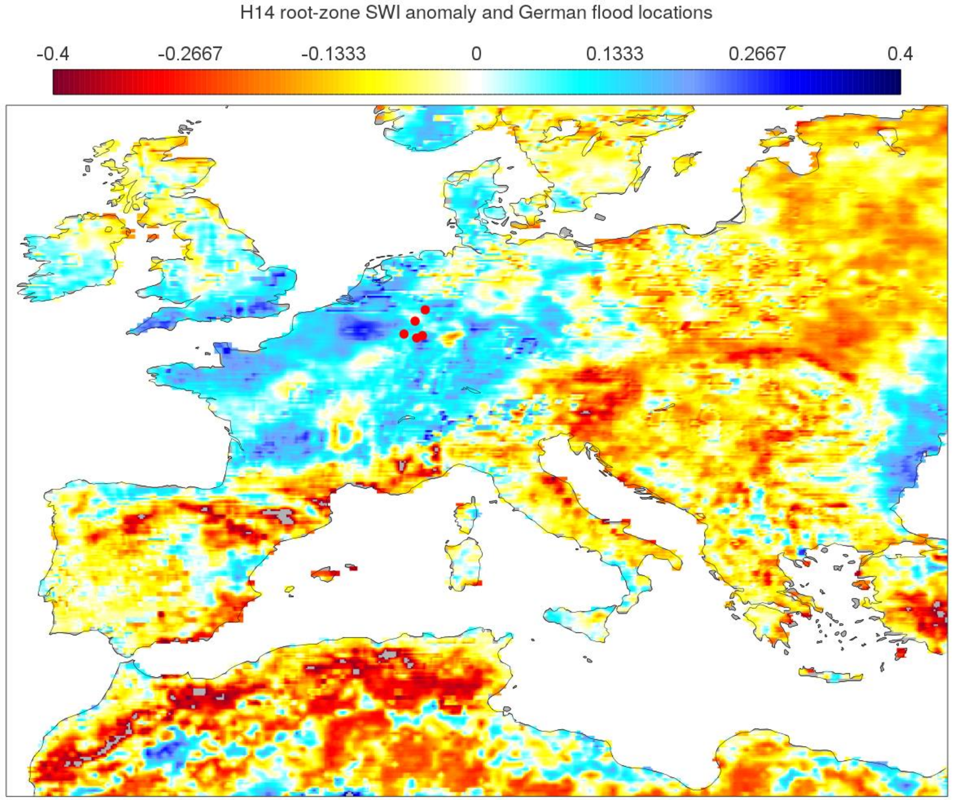
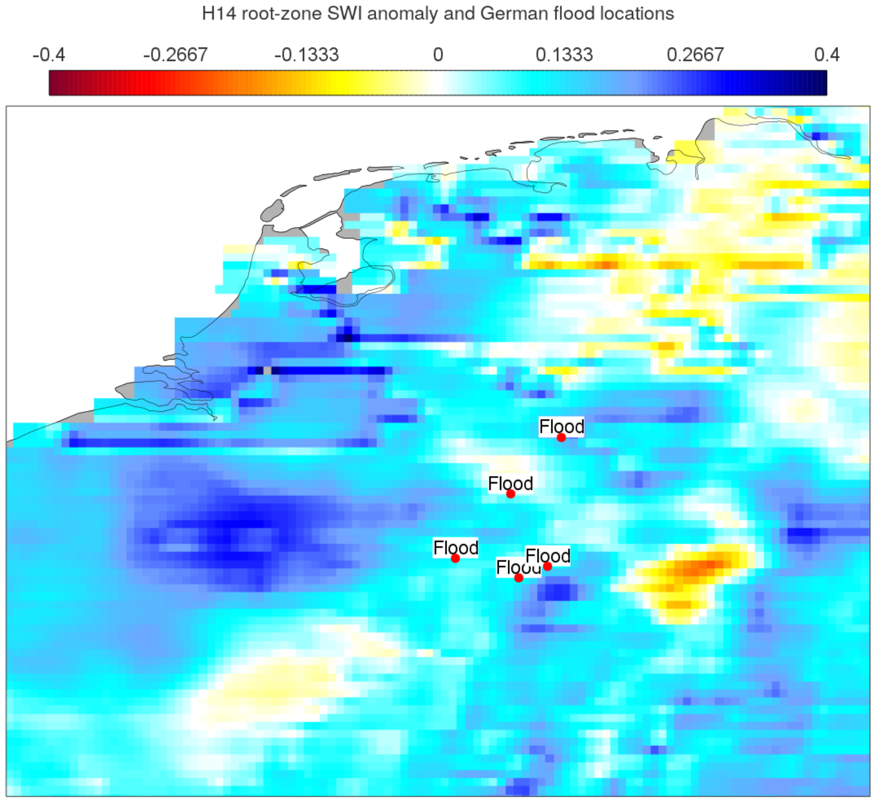
- Near-real-time daily root-zone SM product (SM-DAS-2) can be used to calculate anomalies relative to RZSM-DR2019-10km climatology with a latency of 12-36 hours
- A positive SWI anomaly was detected on 14/7/2021 at 00 UTC , approximately 24 hours before the main rainfall event that caused the flooding in northwest Germany





8. Summary

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- Global H SAF root-zone soil wetness index data record (RZSM-DR2019-10km, 1992-2018) and Offline extension (RZSM-DR-EXT-10km, 2019-2020) at 10 km sampling
- Scatterometer-derived SSM and SLV data assimilation in offline LDAS forced by ERA5
- SEKF data assimilation provides dynamic link between assimilated obs and soil moisture layers
- Data record well correlated with in situ data (US, France and Spain) with average CC>0.65
- Drying of root-zone SM over Europe (1992-2020) in summer/autumn probably linked to hotter summers and a reduction in relative humidity
- Near-real-time root-zone SWI detected positive SWI anomalies relative to data record climatology prior to flooding in Germany during July 2021

9. Future work

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- In 2023, new RZSM data record to be released (1992-2022) with
  - recalibrated scatterometer bias correction
  - 12-hour assimilation windows (consistent with new near-real-time product).
  - Dynamic SEKF Jacobians from ensemble of data assimilations (EDA)

- EUMETSAT 2nd generation (EPS-SG) scatterometer derived surface soil moisture data to be assimilated in future data records – higher spatial resolution (12.5 km) than current ASCAT (25 km)

User information

- **To access H SAF data**, first register with H SAF: http://hsaf.meteoam.it/user-registration.php to obtain username and password

- **User documentation/training:**
  - PUM, ATBD and validation reports for RZSM-DR2019-10km: https://confluence.ecmwf.int/display/LDAS/H+SAF
  - Online user training course: http://hsaf.meteoam.it/training-courses.php
  - EUMETRAIN event week 4^{th} – 8^{th} November 2019: http://eumetrain.org

References

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