Downscaling of seasonal soil moisture forecasts using satellite data

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4th COSMOS workshop
05.-08.05.2014, Leipzig, Deutschland

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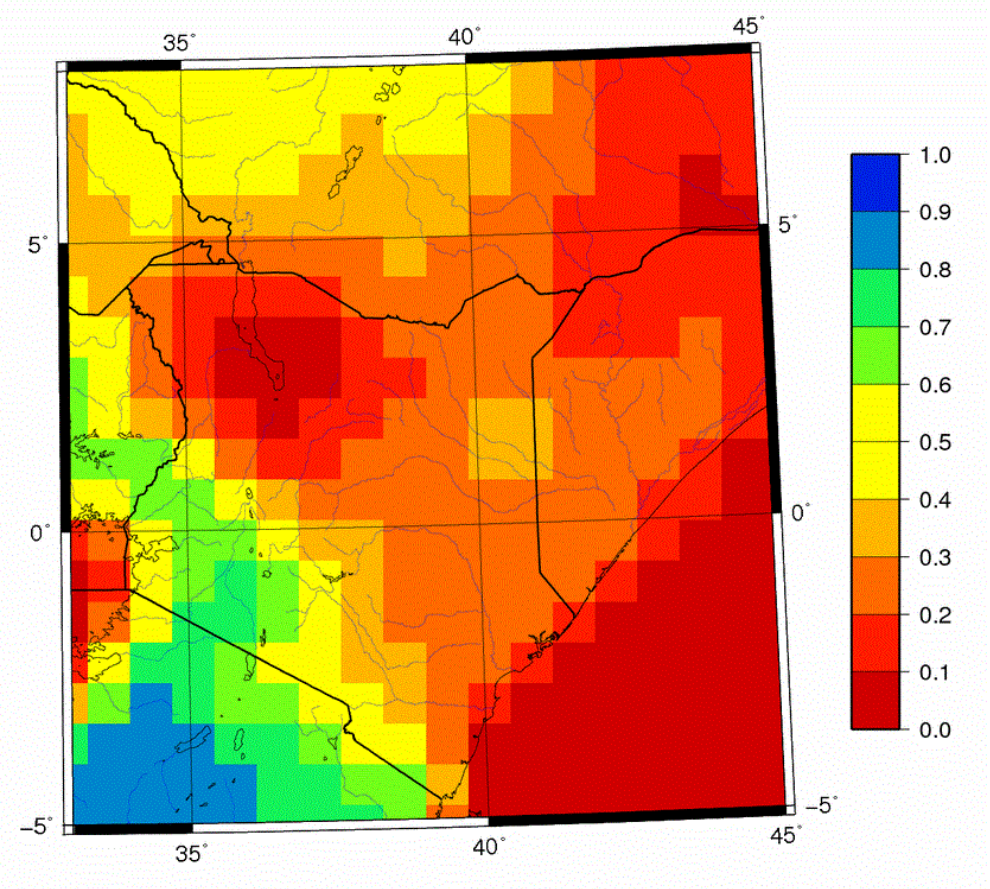
Motivation

Global seasonal forecasting fields have a spatial resolution of ~500km^2

Users would be interested in more regional details.

To downscale forecasts, soil data / ground measurements would be necessary - usually, they are not available in high resolution

→ try to use 1km^2 information which is available by satellite



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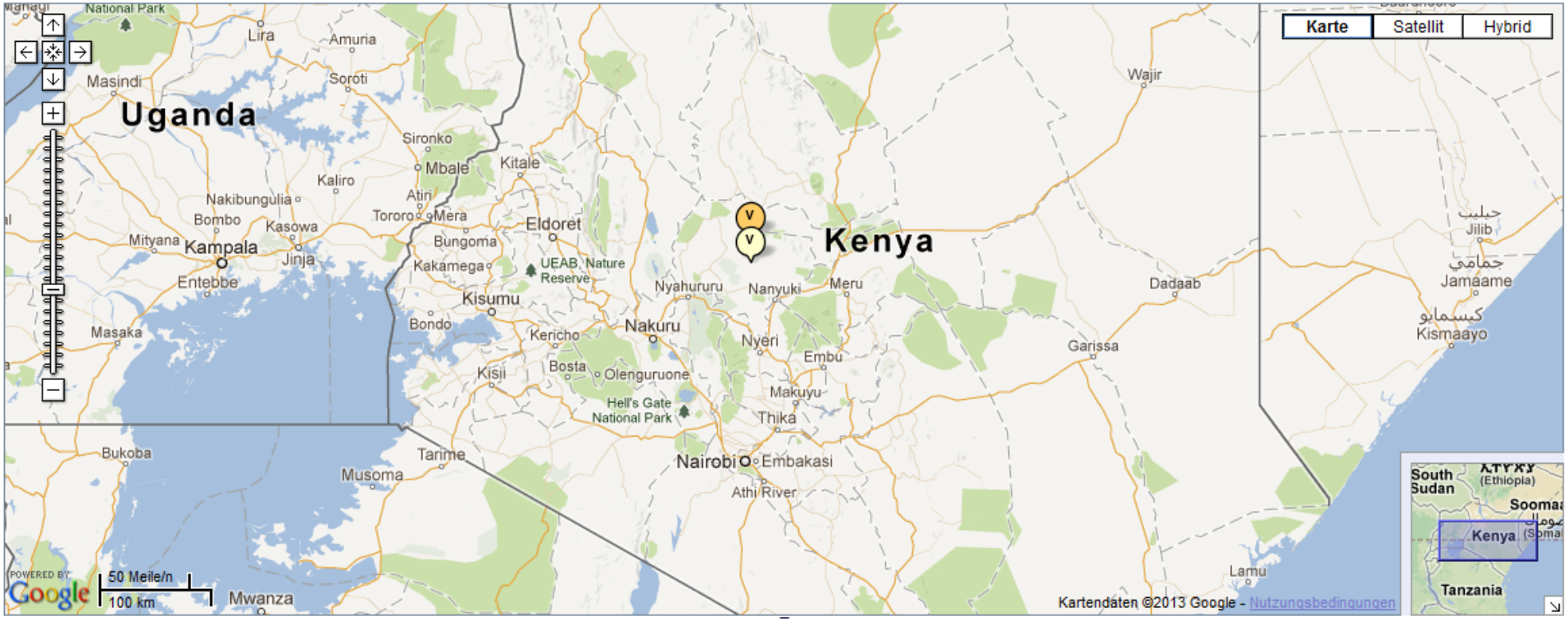
Motivation



http://cosmos.hwr.arizona.edu/Probes/probemap.php

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Goals

- Downscale IFS EPS soil moisture forecasts from 500km^2 to 1km^2 + add value to the forecasts
- beat climatology (=soil moisture analyses from 2000-2011)
- use METOP ASCAT – ENVISAT ASAR relationship

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Input data

ECMWF seasonal forecast („EPS“)

Model:	IFS EPS System4
	51 ensemble members
Soil model:	HTESSEL: 4 levels (7, 28, 100, 289cm)
	7 soil types
Spatial resolution:	0.7°
Temporal resolution:	1 day
Forecasting range:	7 months
Forecasts:	7 (October 2011 – April 2012)

<u>Reference forecasts from ECMWF („IFS“)</u>

Ensemble made of historical high resolution analyses
0.125° grid (upscaled)
2001-2012

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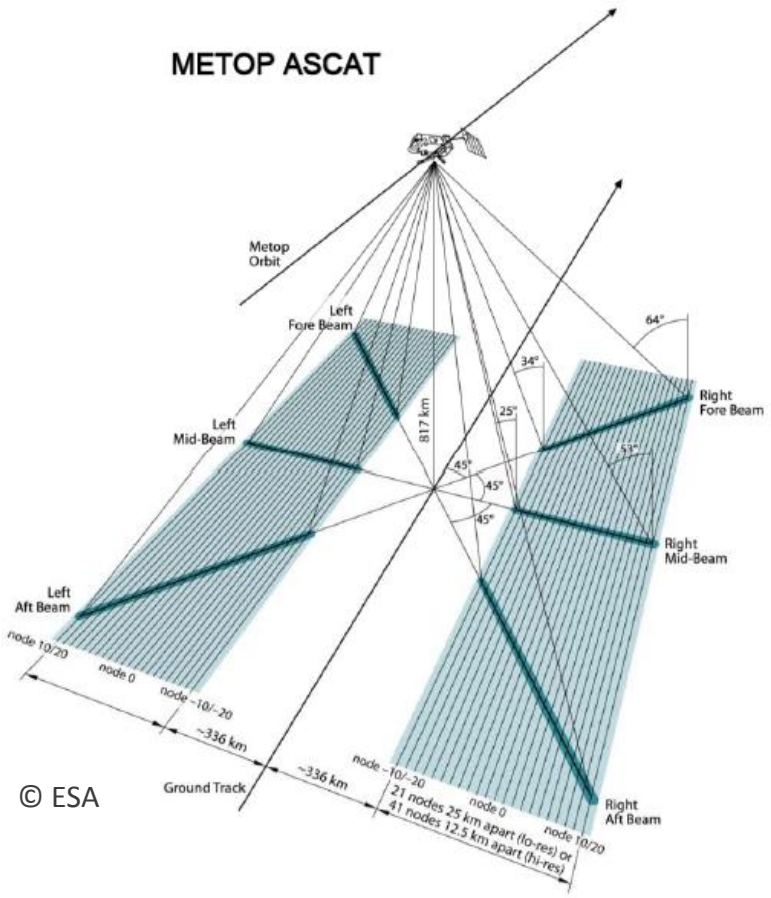
Input data

METOP-A ASCAT (Advances Scatterometer)



polar orbiting satellite
active Scatterometer
microwave spectrum (λ=5.7cm)

spatial resolution: 25km
temporal resolution: ~1.5 days
Data availability: ~2 hours after the measurement

soil moisture value valid for 0-2cm depth

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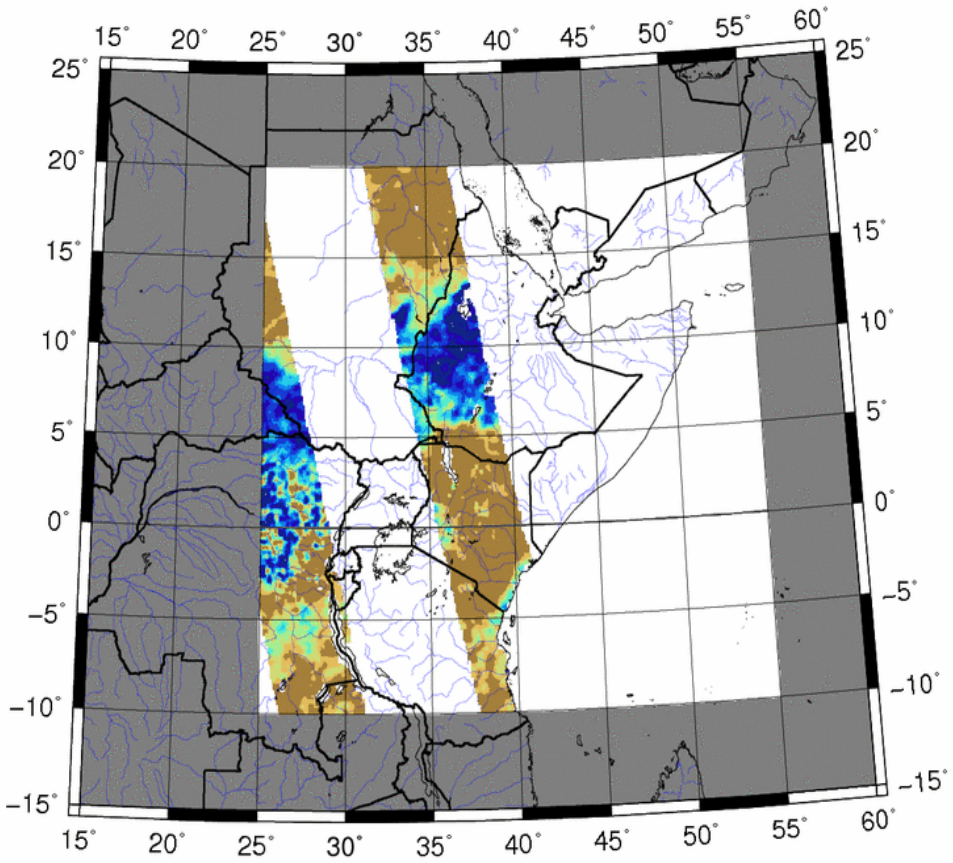
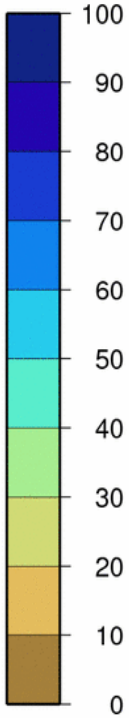
Input data

METOP-A ASCAT (Advances Scatterometer)





02.07.2009, 19UTC

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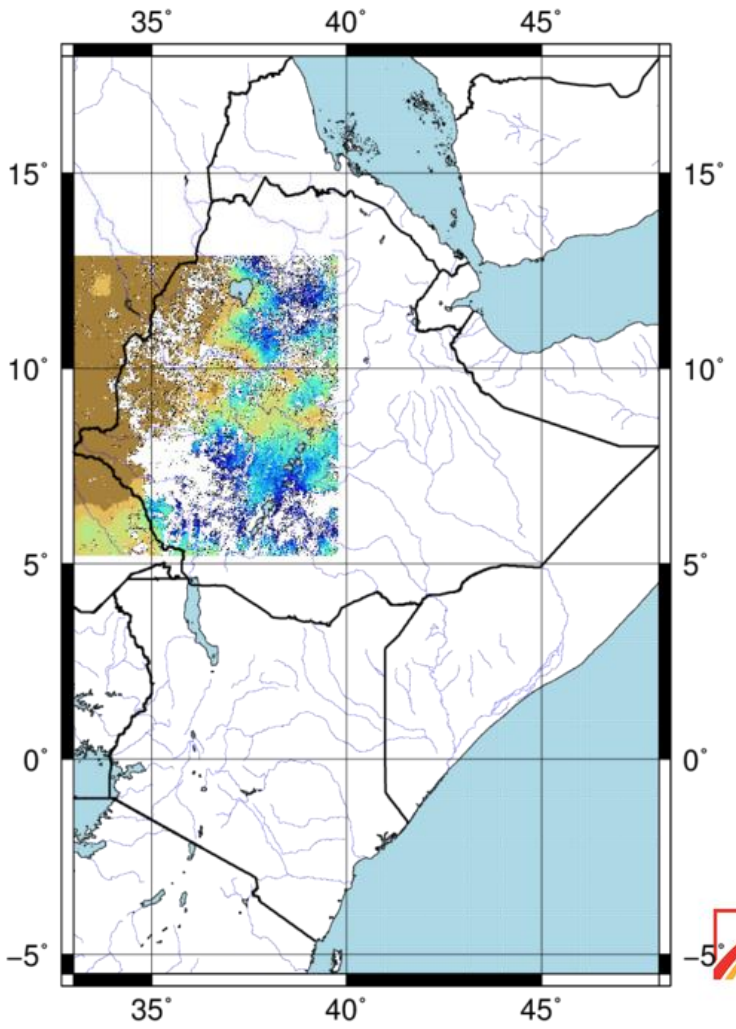
Input data

ENVISAT ASAR (Advanced Synthetic Aperture Radar)

Spatial Resolution: approx1000m x 1000m
(Global Monitoring mode)
Swath Width: 400km
(Global Monitoring mode)
Microwave: C-band,
with choice of 5 polarisation modes
(VV, HH,VV/HH, HV/HH, or VH/VV)
Earth Topics: Landscape Topography, Snow and Ice , Ocean Currents and Topography)

using ASCAT-ASAR relationship
for downscaling (Wagner et al., 2008)

$$m_s^{1km}(t,x,y) = c_{ASAR}(x,y) + d_{ASAR}(x,y) m_s^{25km}(t)$$



12.04.2012

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Input data

COSMOS network in-situ measurements

2 stations in Kenya (KLEE, 1824m; Mpala North, 1619m)
hourly measurements of volumetric soil moisture [m^3/m^3]
soil moisture value valid for 15-30cm soil depth
Horizontal footprint: > 660m Ø

http://cosmos.hwr.arizona.edu/Probes/probemap.php

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Input data

COSMOS network in-situ measurements

Preprocessing:

- Correction for atmospheric water vapour
  (method of Rosolem et al., 2013; guidance by Trenton Franz and Rafael Rosolem)
- Weekly average
- Conversion to soil moisture index (0-100%) by taking min/max of the whole time series as 0/100

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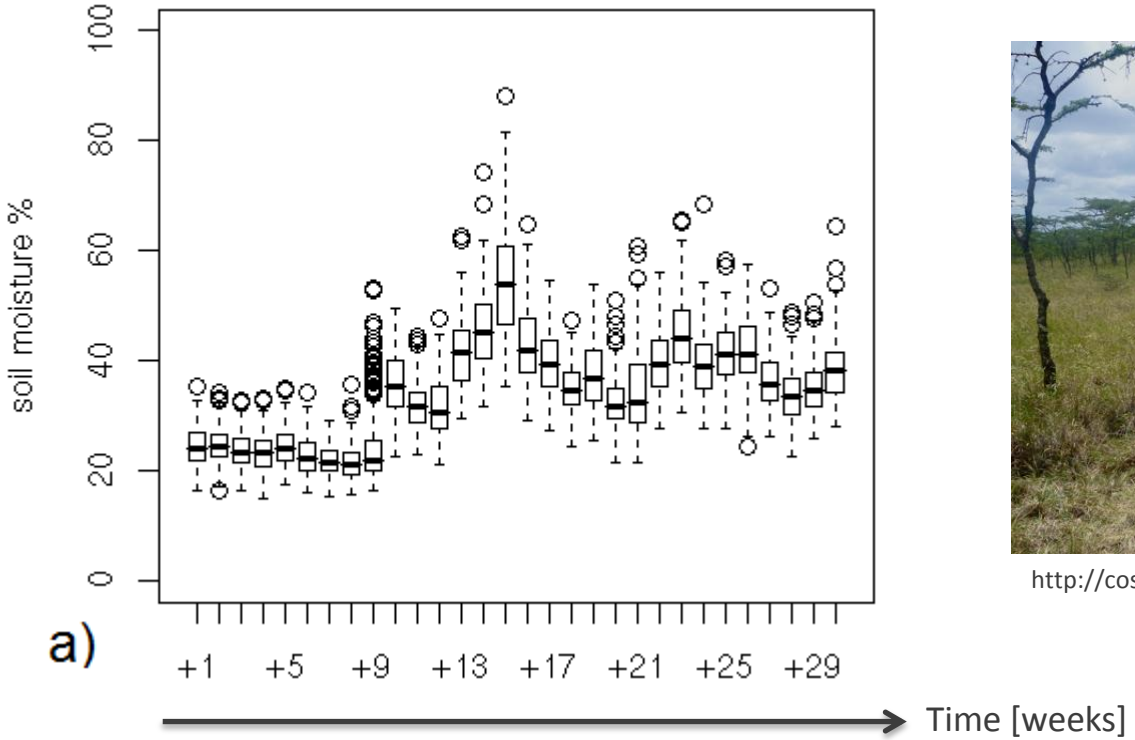
Input data

COSMOS network in-situ measurements

COSMOS measurements (KLEE) from February to August 2012



http://cosmos.hwr.arizona.edu/SitePhotos/cosmosklee.jpg

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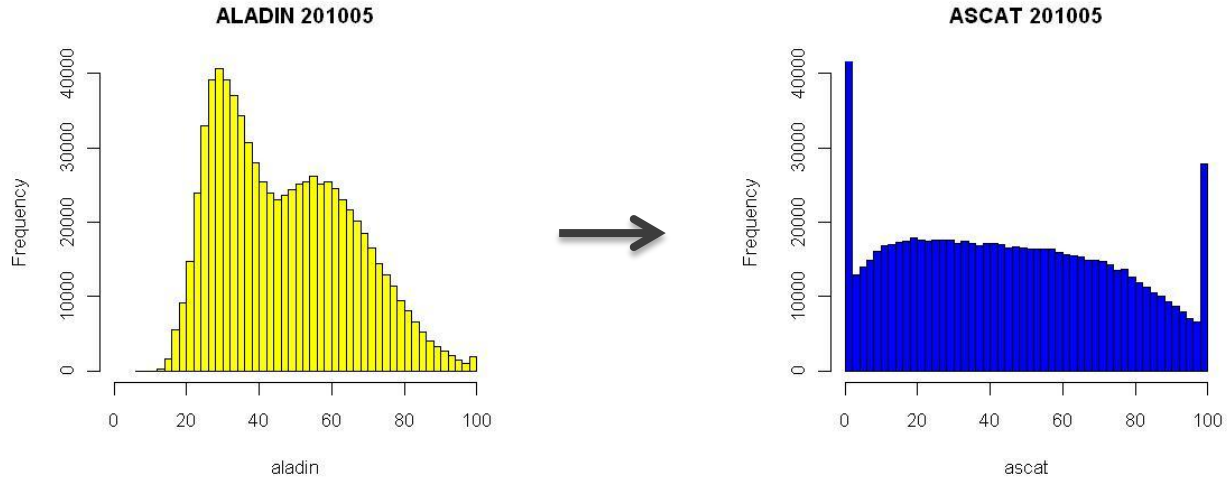
Downscaling method

2 steps:

1. Calibration of IFS climatology to ASCAT climatology



2. Downscaling with ASCAT-ASAR relation

$$m_s^{1km}(t,x,y) = c_{ASAR}(x,y) + d_{ASAR}(x,y) m_s^{25km}(t)$$

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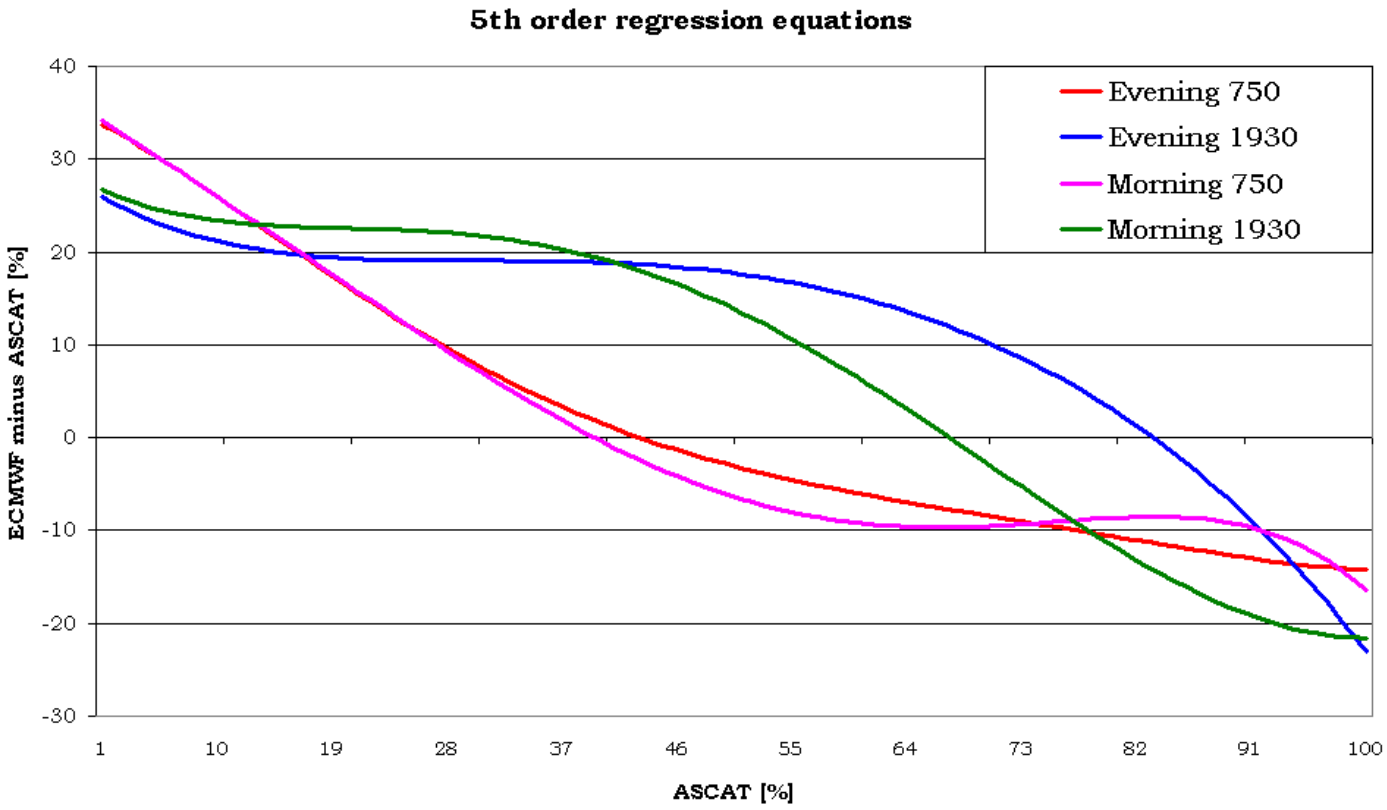
Downscaling method

Calibration with CDF matching

Cumulative distribution function (CDF) matching (Reichle and Koster, 2004)



CDF matching for 2 ECMWF grid points in Sudan (750) and Kenya (1930)

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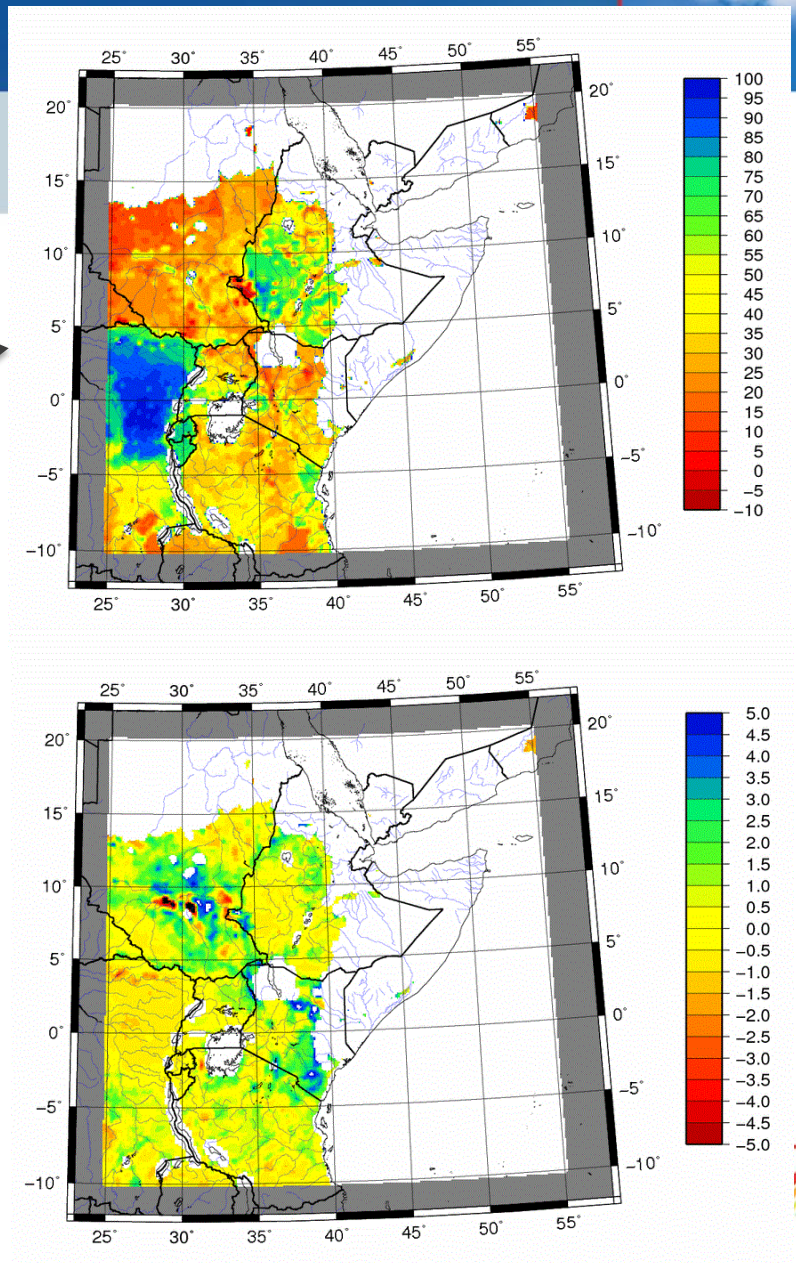
Downscaling method

Calibration with CDF matching

4th order polynomial fit:

- Expectation
- Variance
- Skewness
- Kurtosis



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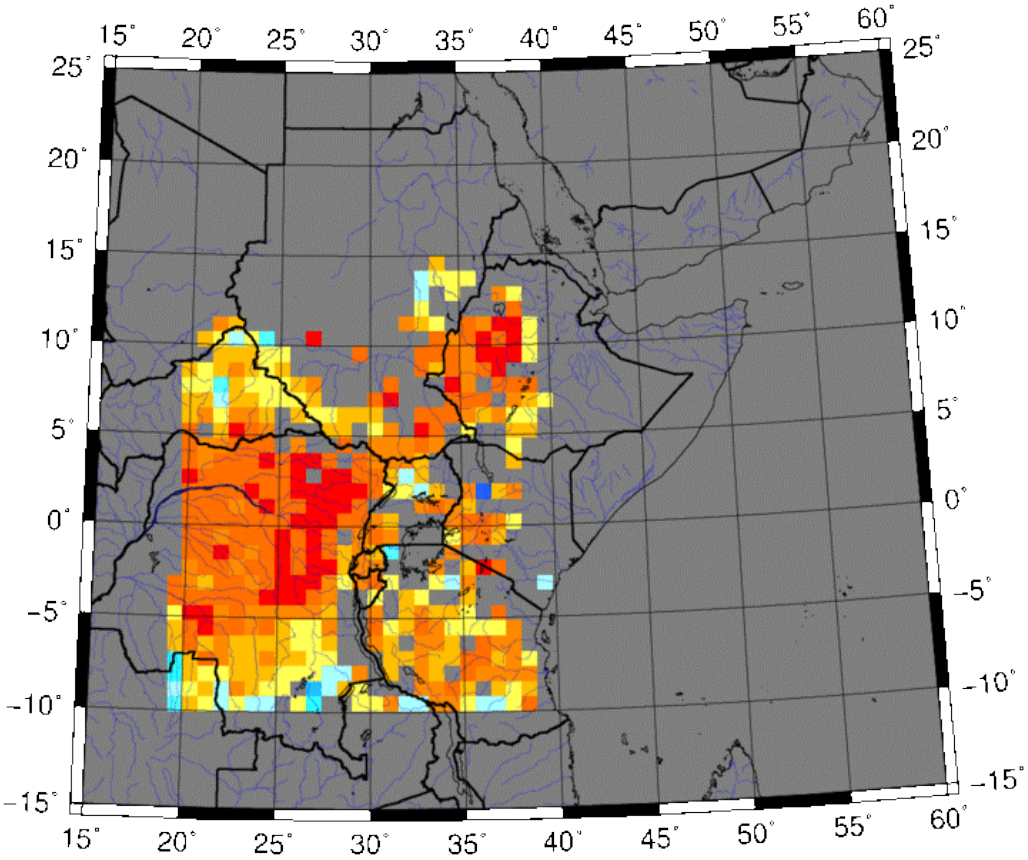
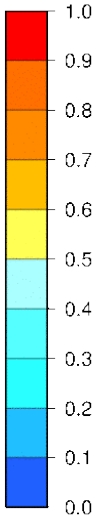
Downscaling method

Calibration with CDF matching



The predefined value of 0.5 at each EPS grid point (0.7°) has a value of



after CDF matching.

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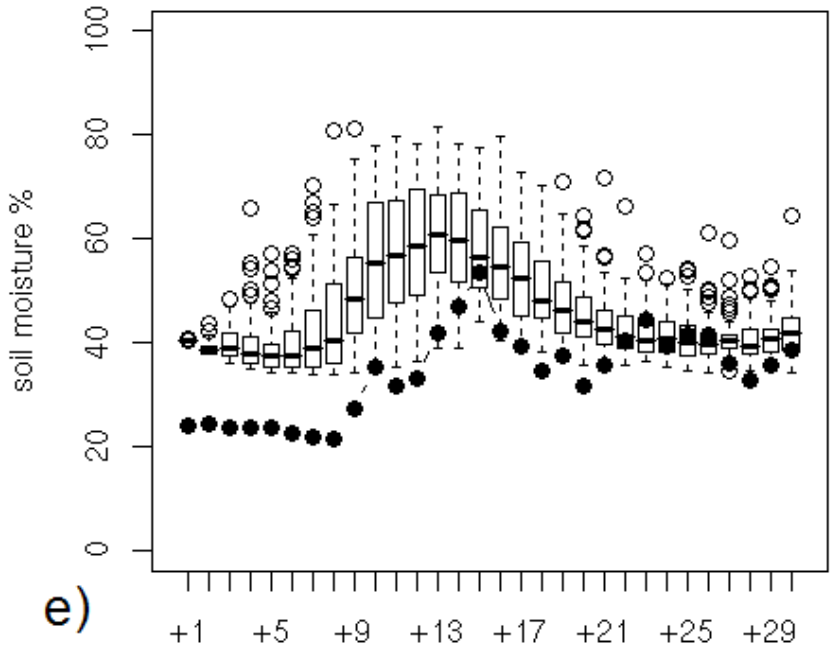
Downscaling method

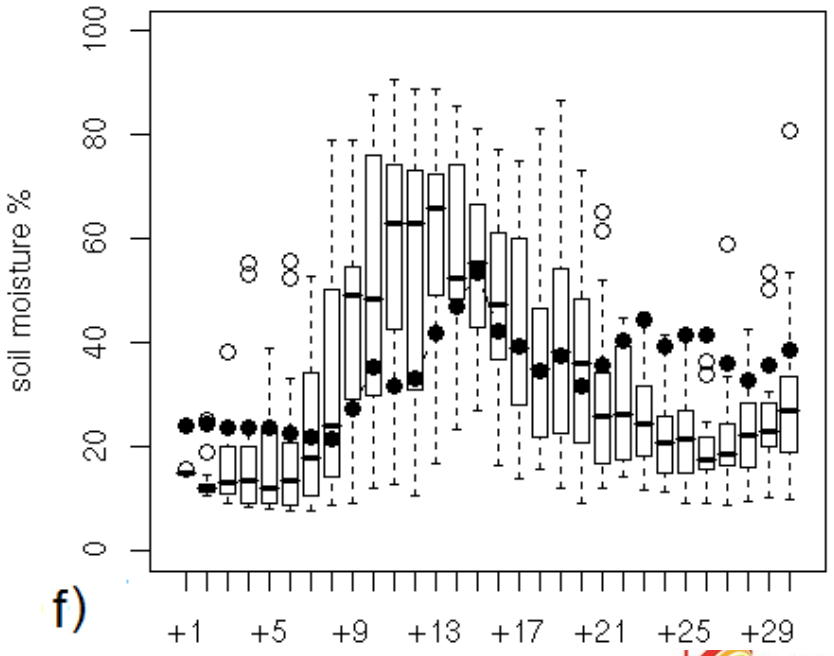
Calibration with CDF matching

for each model grid point separately
-> EPS histogram matching to ASCAT histogram

EPS



EPS calibrated



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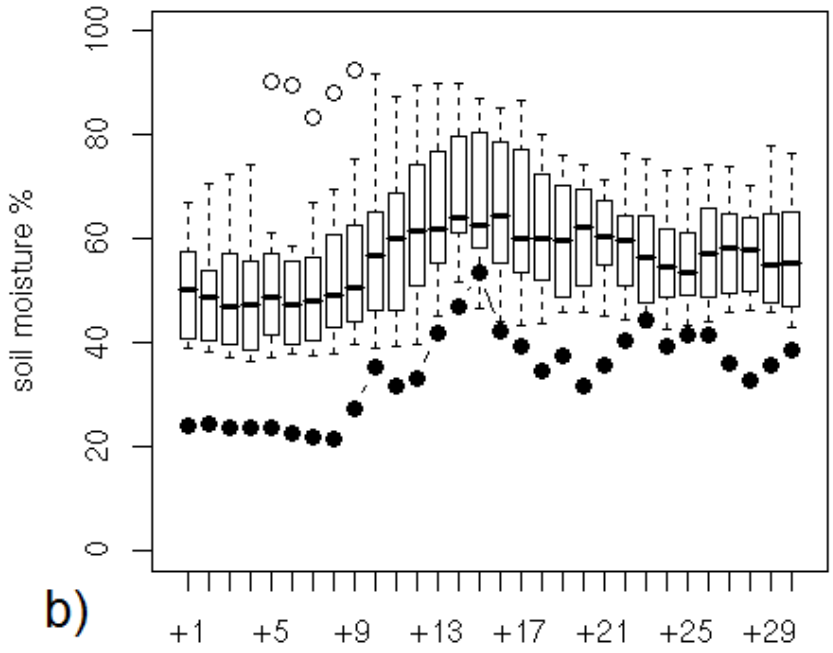
Downscaling method

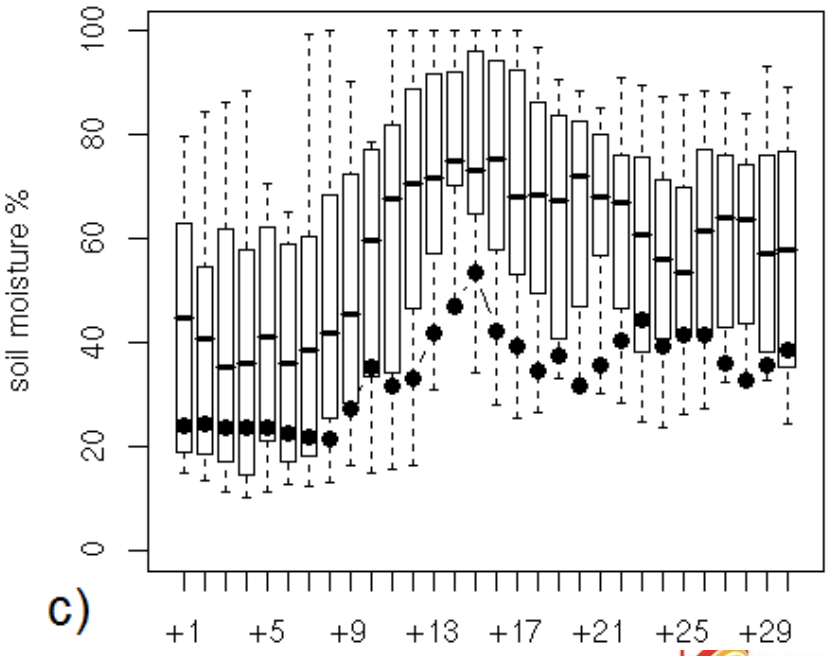
Calibration with CDF matching

for each model grid point separately
-> Climatology (IFS) histogram matching to ASCAT histogram

IFS



IFS calibrated



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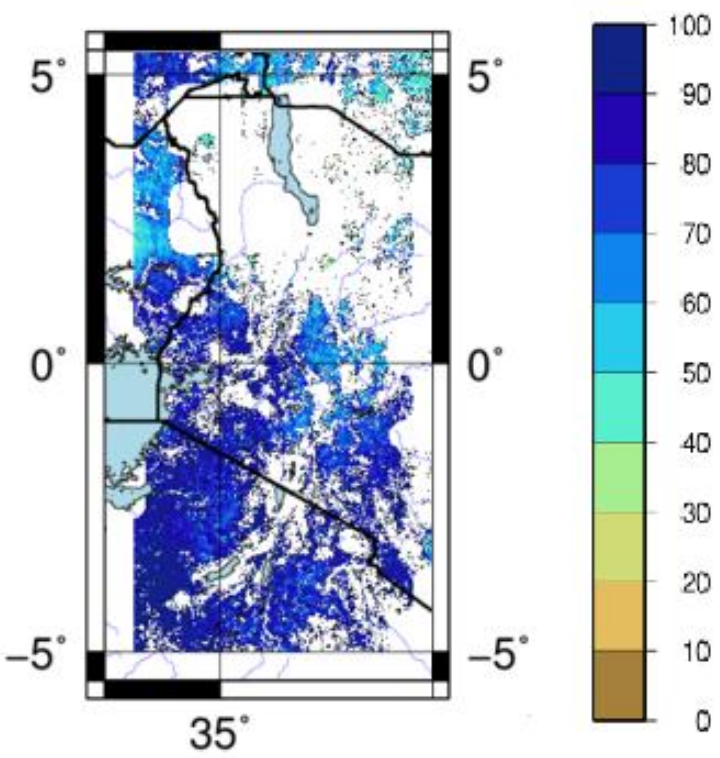
Downscaling method

Applying ASCAT-ASAR relation



$$m_s^{1km}(t,x,y) = c_{ASAR}(x,y) + d_{ASAR}(x,y) m_s^{25km}(t)$$

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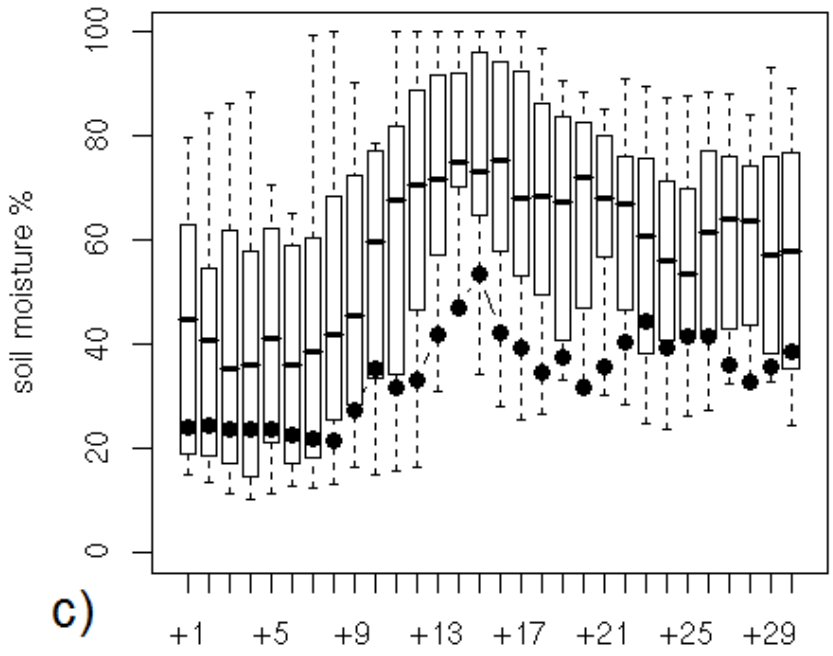
Statistical Downscaling

Applying ASCAT-ASAR relation

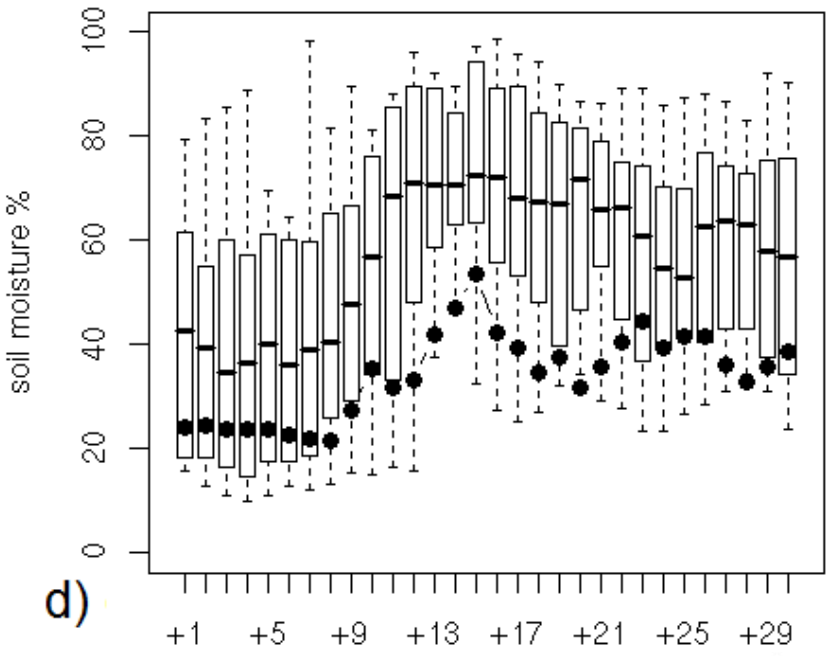
METOP-A ASCAT – ENVISAT ASAR relationship

applying linear relationship to calibrated IFS data
-> Climatology on 1km grid

IFS calibrated



IFS calibrated+downscaled



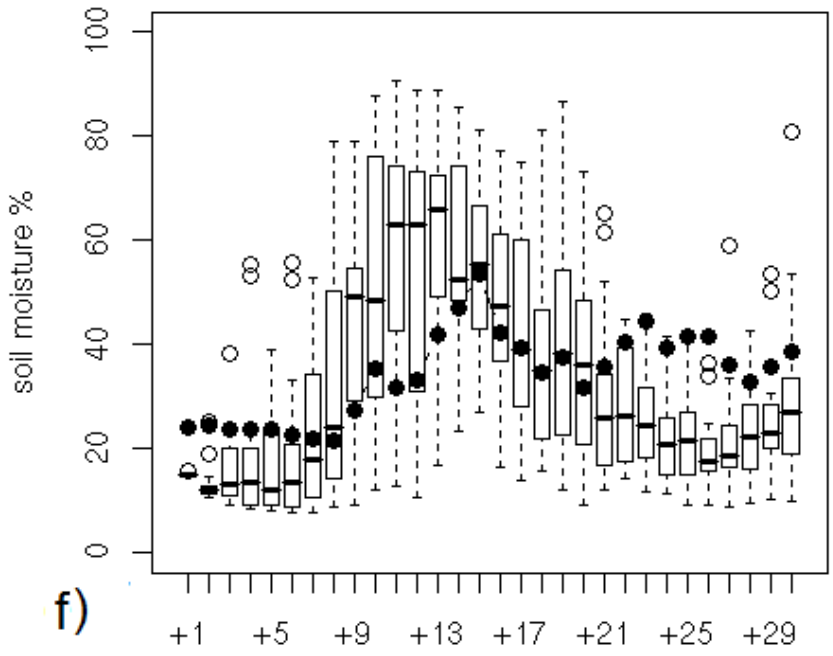
Statistical Downscaling

Applying ASCAT-ASAR relation

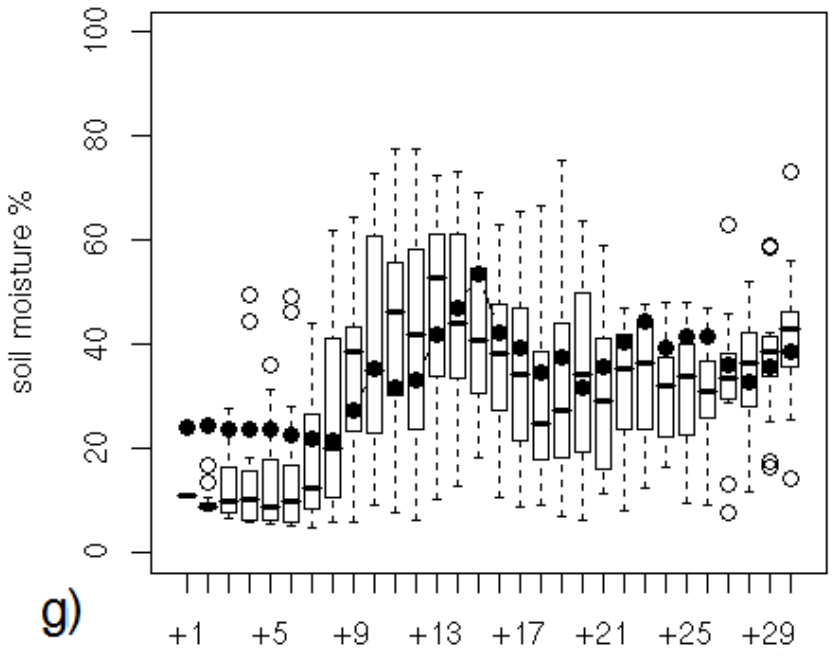
METOP-A ASCAT – ENVISAT ASAR relationship

applying linear relationship to calibrated EPS data
-> EPS on 1km grid

EPS calibrated



EPS calibrated+downscaled



Verification

Method

Compare
- COSMOS (weekly average) with
- Forecasts (weekly + ensemble average)

for each seasonal forecast

Compute
- Root mean squared error (RMSE) and
- Pearson coefficient of linear correlation (PCC)

Average of the 7 seasonal forecasts is tested for significance (Wilcoxon-Mann-Whitney test in R)

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Verification

Seasonal forecasts vs. Climatology

	KLEE					MPALA				
	IFS CDF	IFS CDF 1	EPS	EPS CDF	EPS CDF 1	IFS CDF	IFS CDF 1	EPS	EPS CDF	EPS CDF 1
RMSE										
IFS	▲	▲	▲	▲	▲	▲	▲	⮟	▲	↑
IFS CDF		↑	▲	⮝	▲		↑	▼	↓	▼
IFS CDF 1			▲	⮝	▲			▼	↓	▼
EPS				↓	▲				▲	▲
EPS CDF					▲					▼
PCC										
IFS	↓	↑	▼	▼	⮟	↓	↑	↓	↑	↑
IFS CDF		↑	▼	▼	⮟		↑	↑	⮝	↑
IFS CDF 1			▼	▼	▼			↓	↑	↑
EPS				↑	↑				↑	⮝
EPS CDF					↑					↑

↑ not significant
⮝ significant (75-89.9)
▲ highly significant (90-100)

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Verification

Downscaling

	KLEE					MPALA				
	IFS CDF	IFS CDF 1	EPS	EPS CDF	EPS CDF 1	IFS CDF	IFS CDF 1	EPS	EPS CDF	EPS CDF 1
RMSE										
IFS	▲	▲	▲	▲	▲	▲	▲	⮟	▲	↑
IFS CDF		↑	▲	⮝	▲		↑	▼	↓	▼
IFS CDF 1			▲	⮝	▲			▼	↓	▼
EPS				↓	▲				▲	▲
EPS CDF					▲					▼
PCC										
IFS	↓	↑	▼	▼	⮟	↓	↑	↓	↑	↑
IFS CDF		↑	▼	▼	⮟		↑	↑	⮝	↑
IFS CDF 1			▼	▼	▼			↓	↑	↑
EPS				↑	↑				↑	⮝
EPS CDF					↑					↑

↑ not significant
⮝ significant (75-89.9)
▲ highly significant (90-100)

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Verification

More details …

… can be found in:

“Downscaling of seasonal soil moisture forecasts using satellite data”

Hydrol. Earth Syst. Sci. Discuss., 10, 14783-14799, 2013
www.hydrol-earth-syst-sci-discuss.net/10/14783/2013/
doi:10.5194/hessd-10-14783-2013

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Outlook

- Test the approach for other climate regions, more stations & more seasonal forecast runs
- Investigated in detail the spatial variability on the 1km grid
- Use the downscaled products in combination with crop models (draught indices).

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Thank you for your attention!

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&

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Project FarmSupport

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