# *Polarimetric Remote Sensing of Soil Moisture within TERENO*

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# *E-SAR and F-SAR – Versatile Tools for Airborne Active Microwave Remote Sensing*



**E-SAR were and F-SAR is operated** onboard **DLR's DO228-212** D-CFFU by the **Microwaves and Radar Institute** in cooperation with **DLR's Flight Facilities** based in Oberpfaffenhofen.
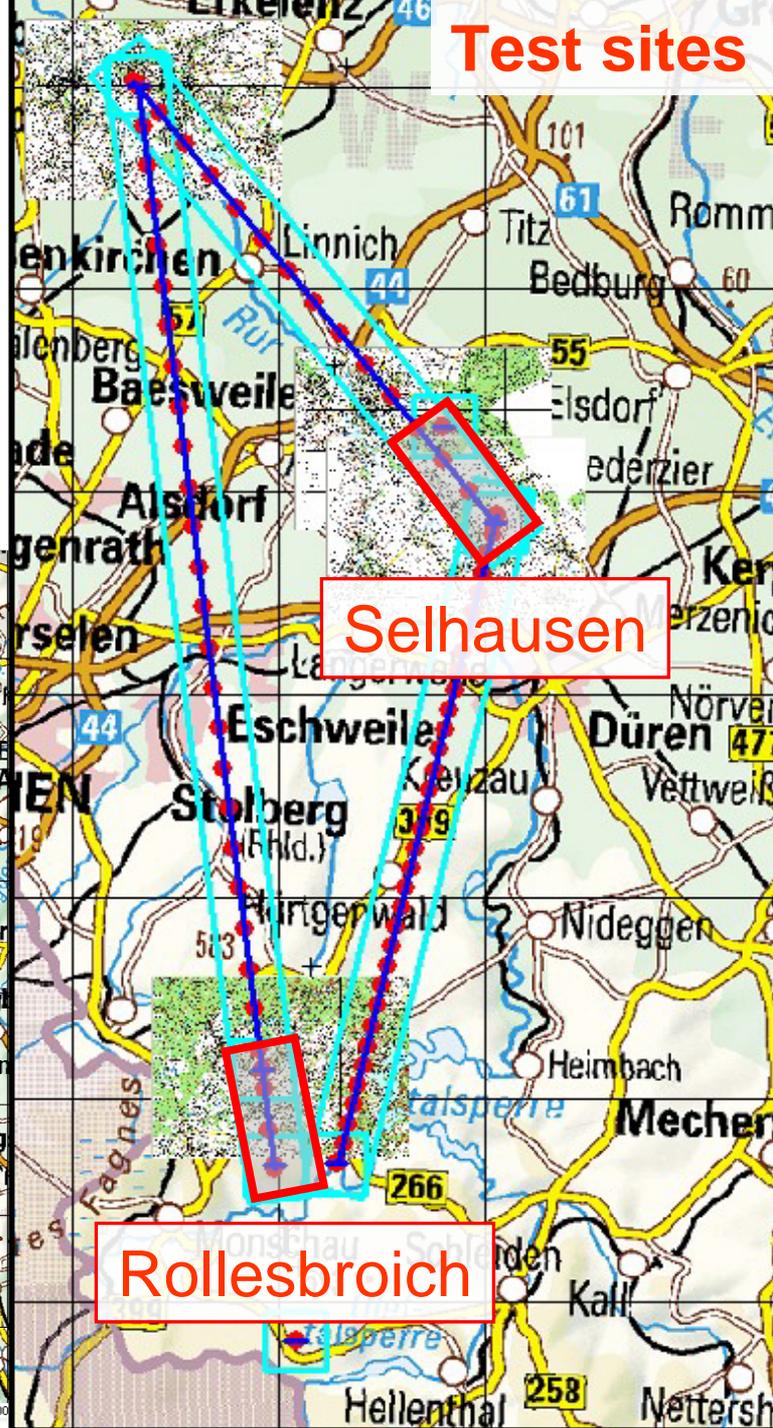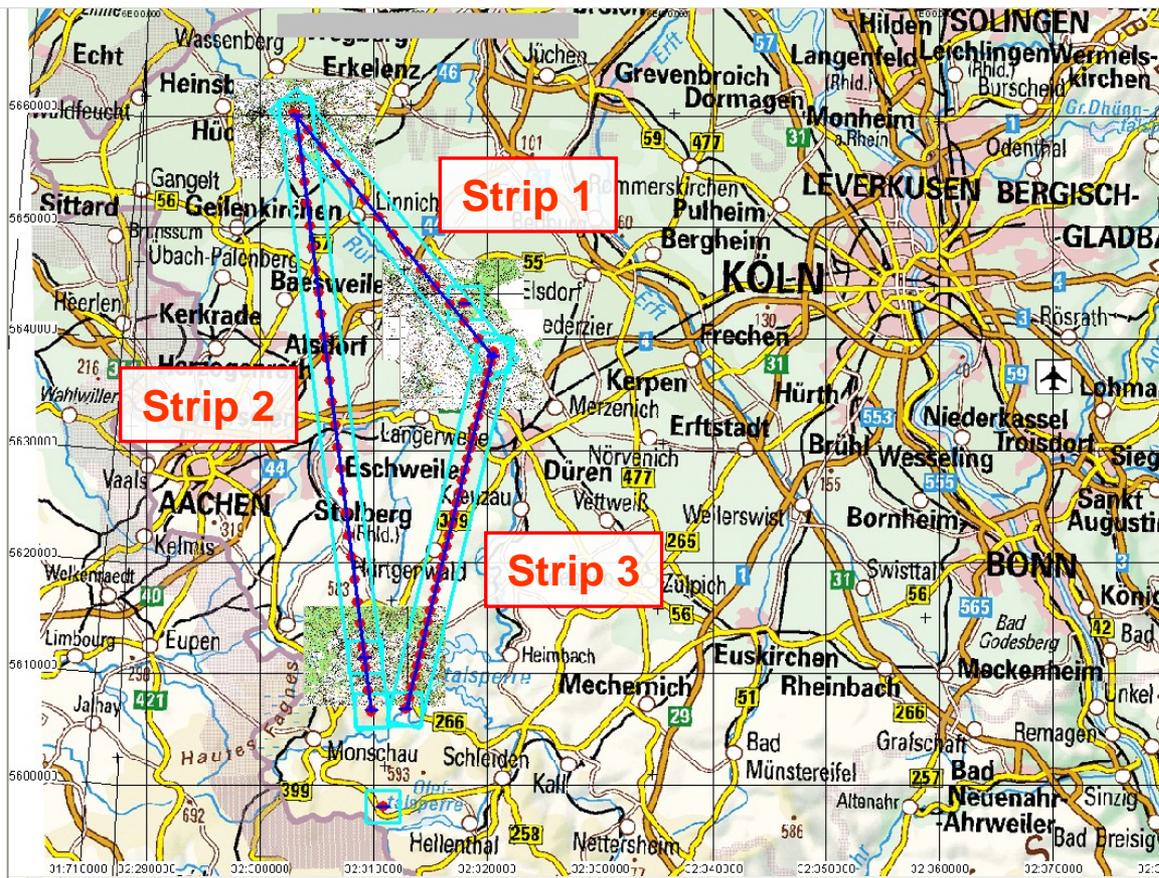
# E-SAR Flight Campaign May 2008

**Strip 1: Selhausen – Hückelhoven, Length ca. 28km**
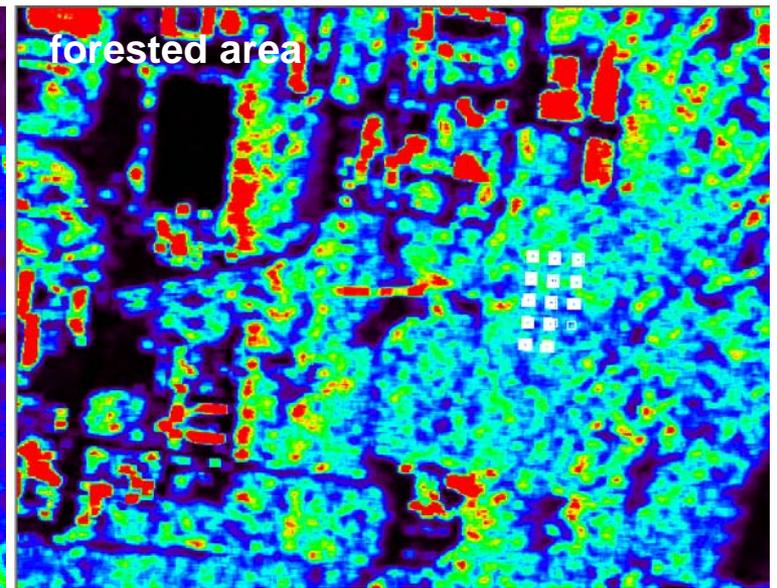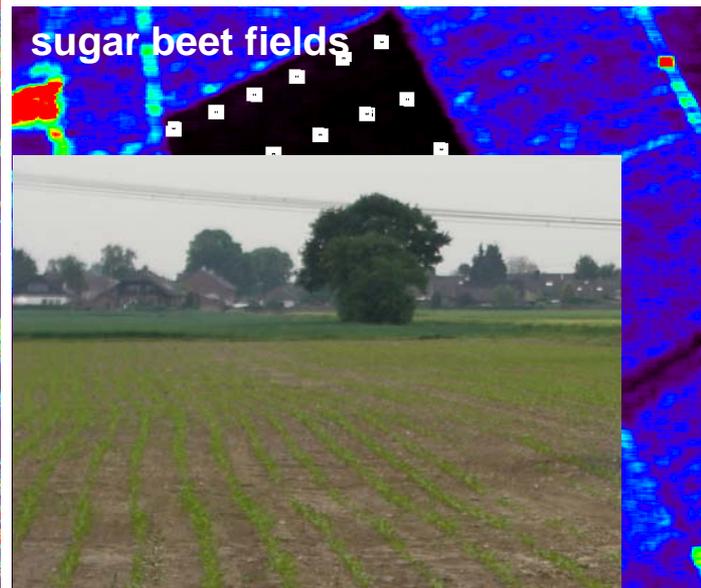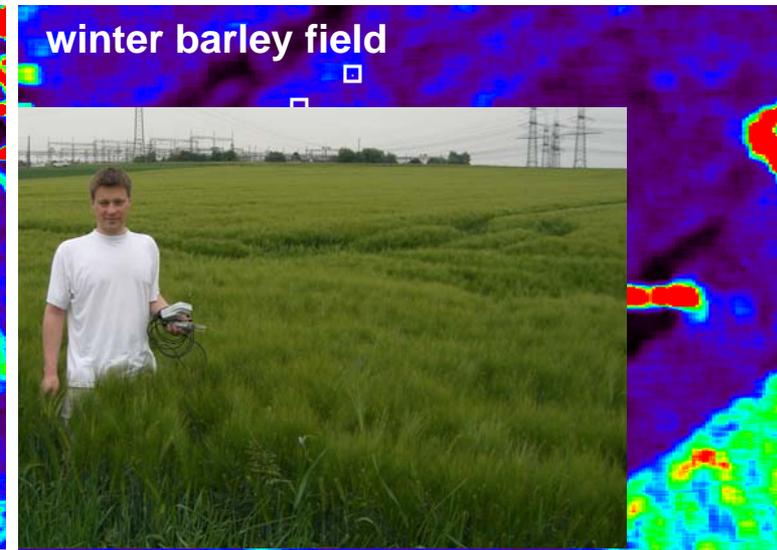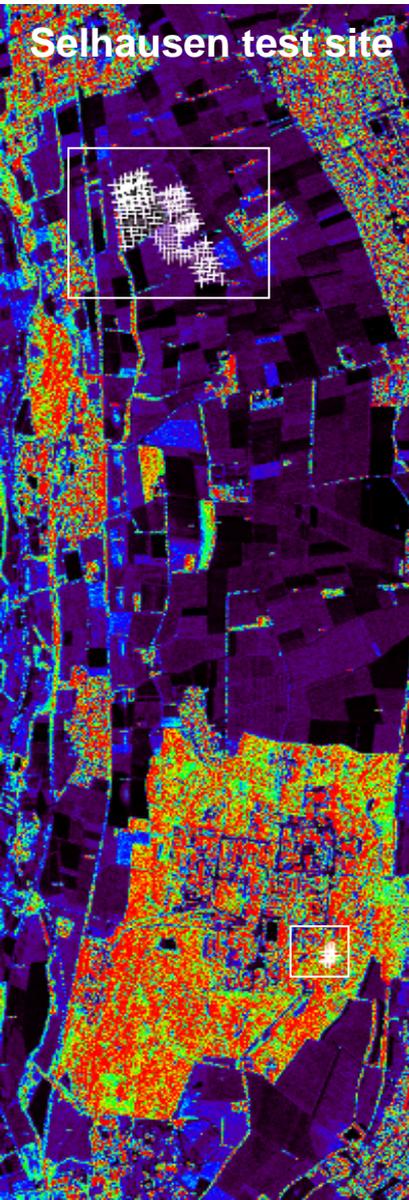**Strip 2: Hückelhoven – Wüstebach, Length ca. 61km**
**Strip 3: Wüstebach – Selhausen, Length ca. 40km**

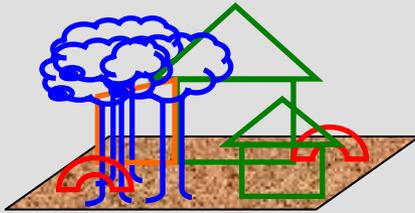**Frequency: L-band (fully polarimetric)**

Test sites

Selhausen

Rollesbroich

Strip 1

Strip 2

Strip 3

# Ground Measurements 2008: Soil Moisture [vol. %]



Selhausen test site

winter wheat fields
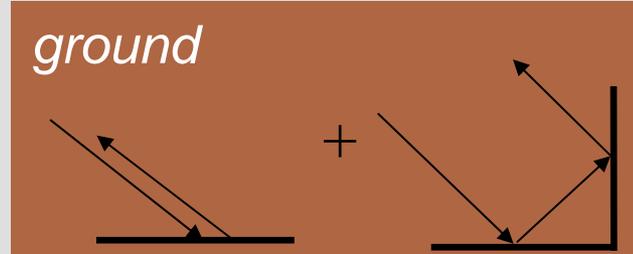
winter barley field

sugar beet fields

forested area

# Polarimetric Decompositions for Soil Moisture Inversion

**Recorded signal** = **Surface** (*ground*) + **Dihedral** (*ground*) + **Volume** (*vegetation*)
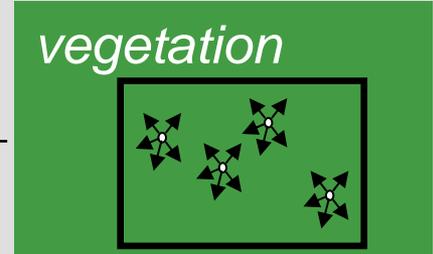
Removal of vegetation component and inversion for soil moisture

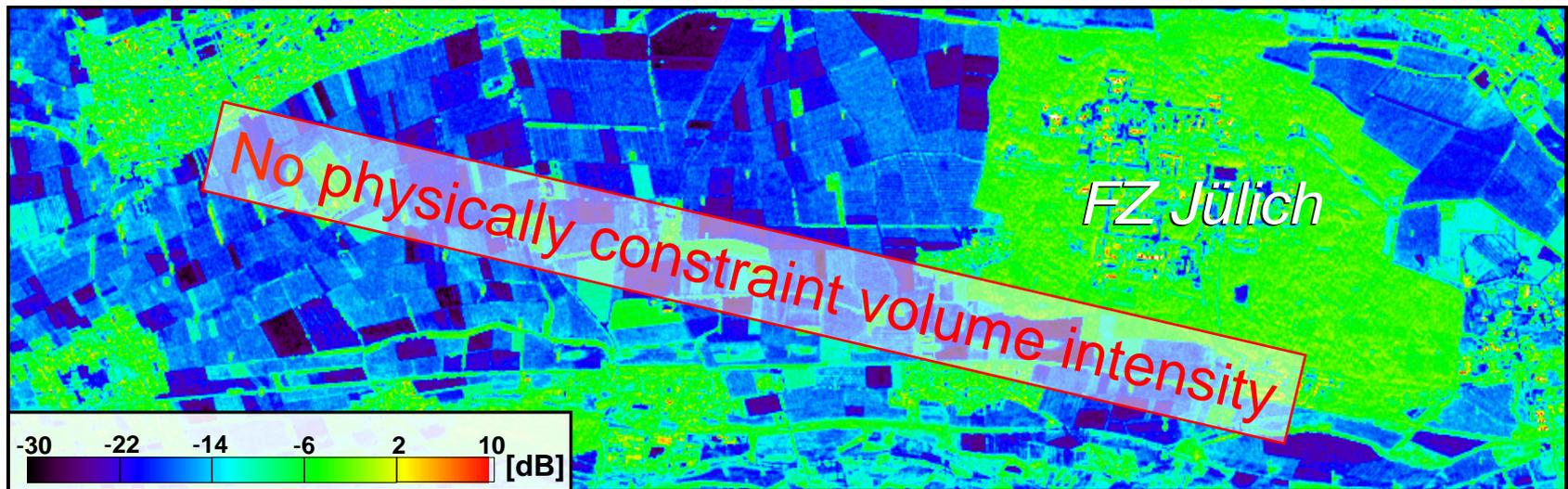*vegetation* − = *ground* (Surface) + *ground* (Dihedral)

Soil moisture [vol. %]

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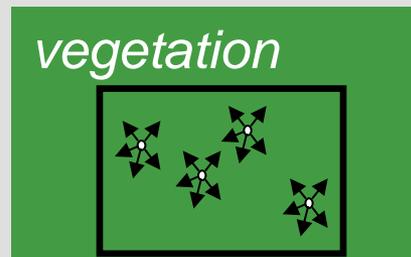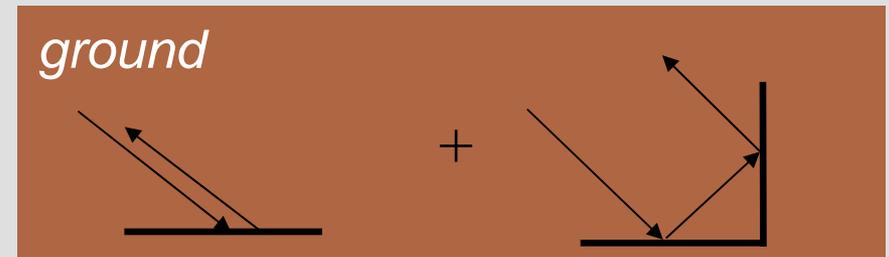
## *Soil Moisture Estimation under Vegetation with Polarimetric SAR?*

One solution: Estimation with polarimetric decompositions

### **Separation of vegetation from soil surface and dihedral**



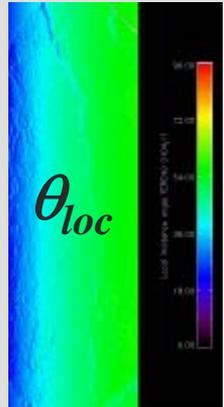No physically constraint volume intensity

*FZ Jülich*

-30   -22   -14   -6   2   10 [dB]

Volume intensity from Standard decomposition
Normalized Pauli RGB image from test site

Physically-constraint hybrid polarimetric decomposition

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# *Physically Constraint Hybrid Polarimetric Decomposition*



$\theta_{loc}$

+

$\varepsilon_S$-level: …
$\varepsilon_S$-level: 15
$\varepsilon_S$-level: 10
$\varepsilon_S$-level: 5

**Local incidence angle**
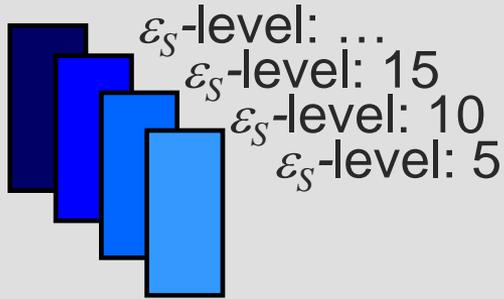
Forward modelling:
surface component ($\alpha_B$)

$\alpha_B$
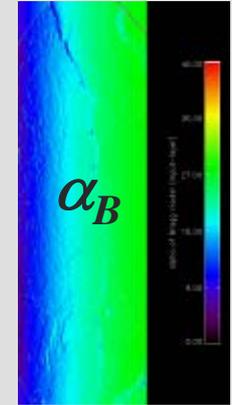
Calculus of data stack with
physically constraint $f_{vp}$ for
different $\varepsilon_S$-levels (using $\alpha_B$)

$f_{vp\varepsilon s...}$
$f_{vp\varepsilon s15}$
$f_{vp\varepsilon s10}$
$f_{vp\varepsilon s5}$
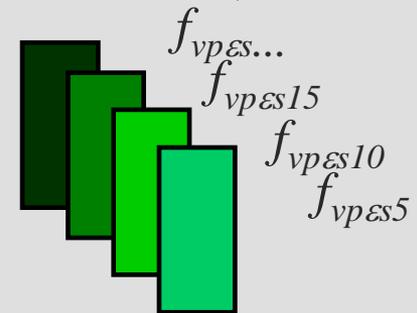
surface
$\alpha_s$

dihedral
$\alpha_d$

Hybrid
polarimetric
decomposition
&
Determination of
$\varepsilon_S$-level

# *Inversion for Soil Moisture from Surface Component*

**Polarimetric SAR data**

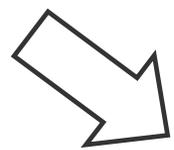**Surface scattering component from hybrid polarimetric decomposition**

$$\alpha_s$$

**Bragg scattering model**

**Surface scattering with $\theta_{loc}$ and a variety of $\varepsilon_S$**

$$\alpha_{sm} = \arctan\left(\frac{R_{VV} - R_{HH}}{R_{VV} + R_{HH}}\right)$$

$$R_{HH}, R_{VV} = f(\varepsilon_S, \theta_{loc})$$

**Minimization**
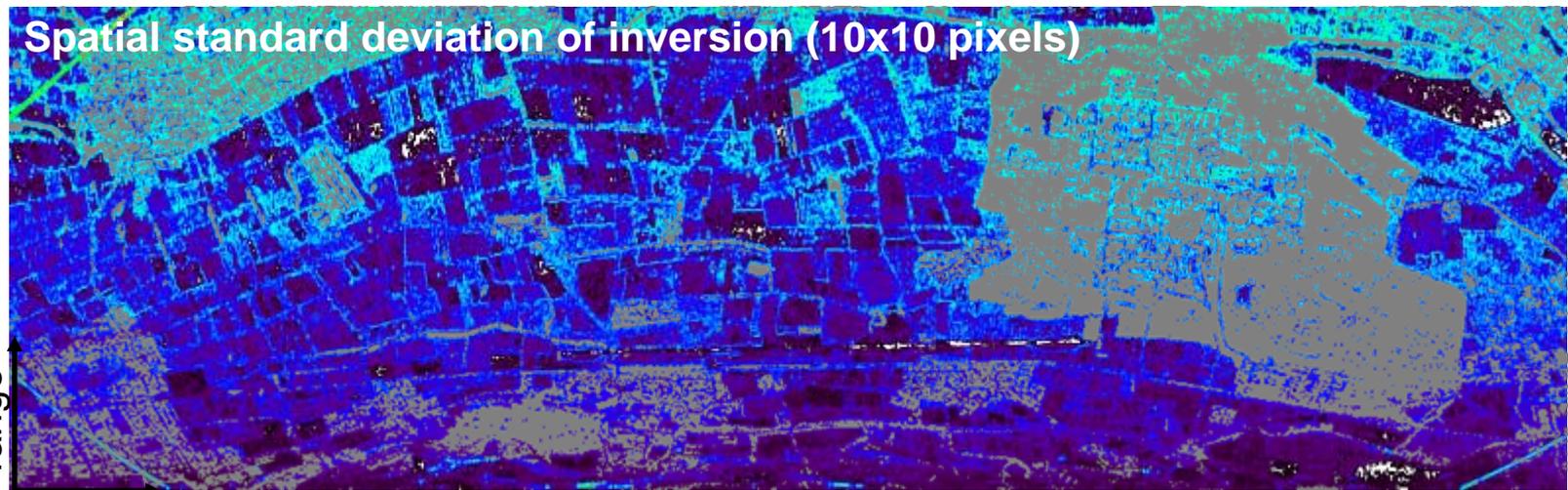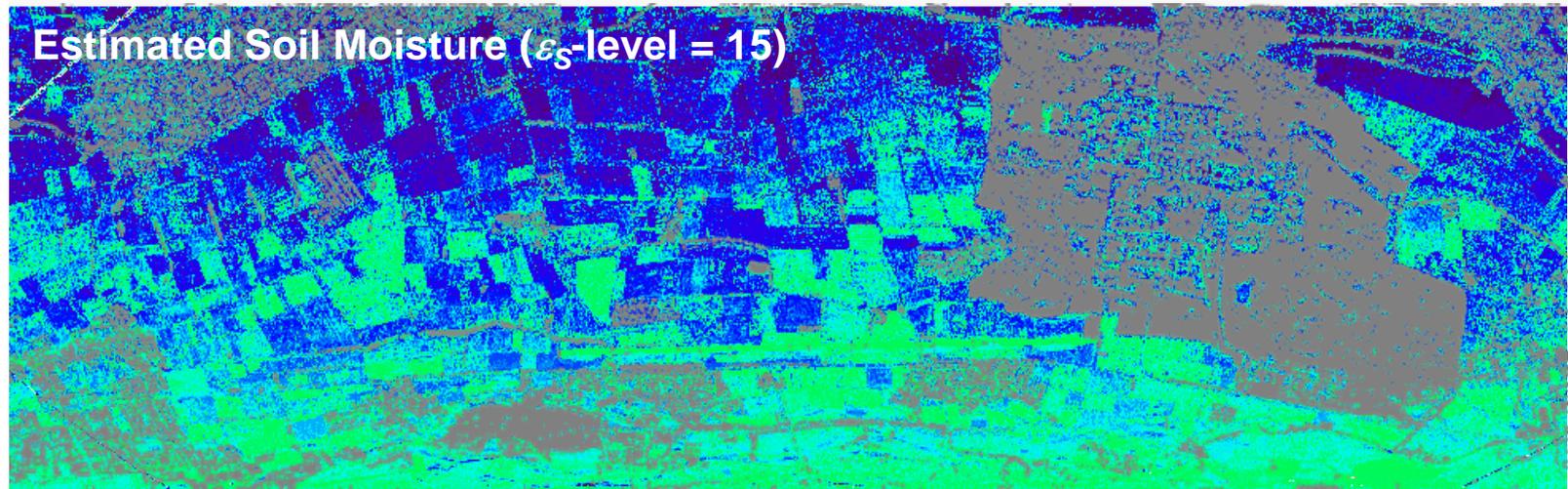
$$\min\{|\alpha_s - \alpha_{sm}|\}$$

**transfer function**

$$\varepsilon_S$$

Soil moisture [vol. %]

**of *Topp et al.***

# *Results for Soil Moisture Inversion (Selhausen)*



Estimated Soil Moisture ($\varepsilon_S$-level = 15)
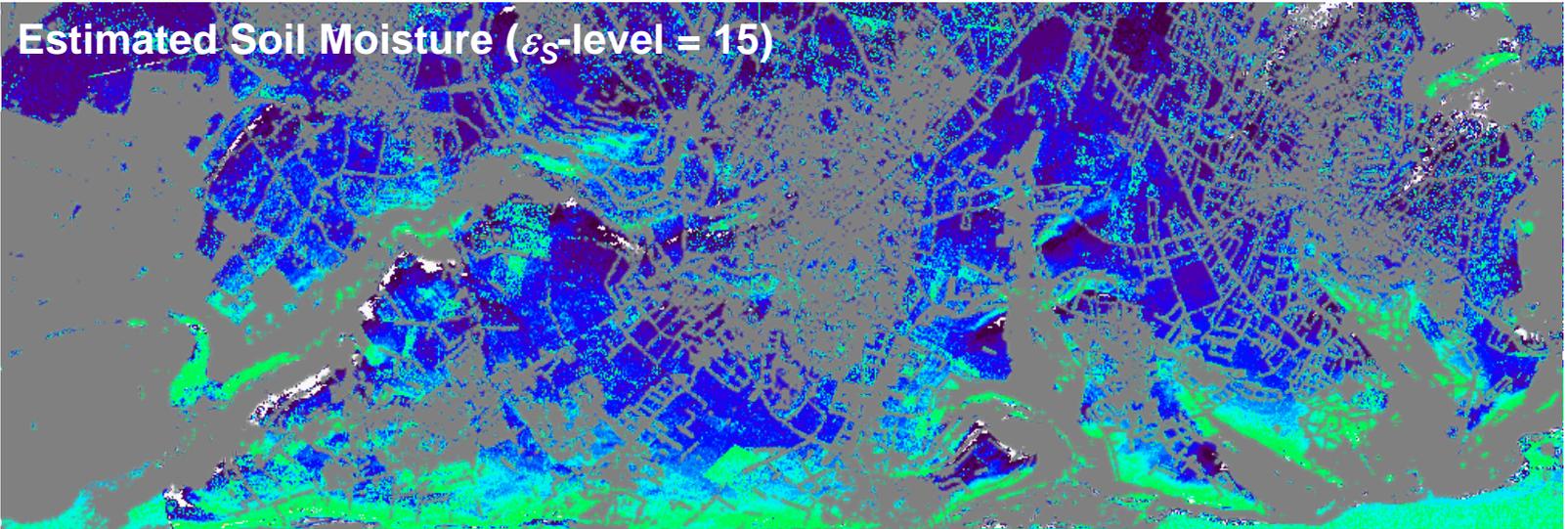
Spatial standard deviation of inversion (10x10 pixels)
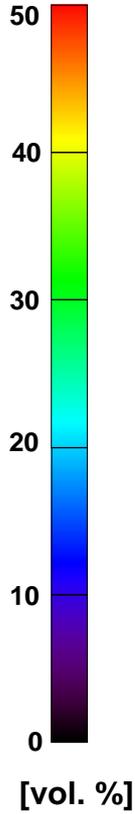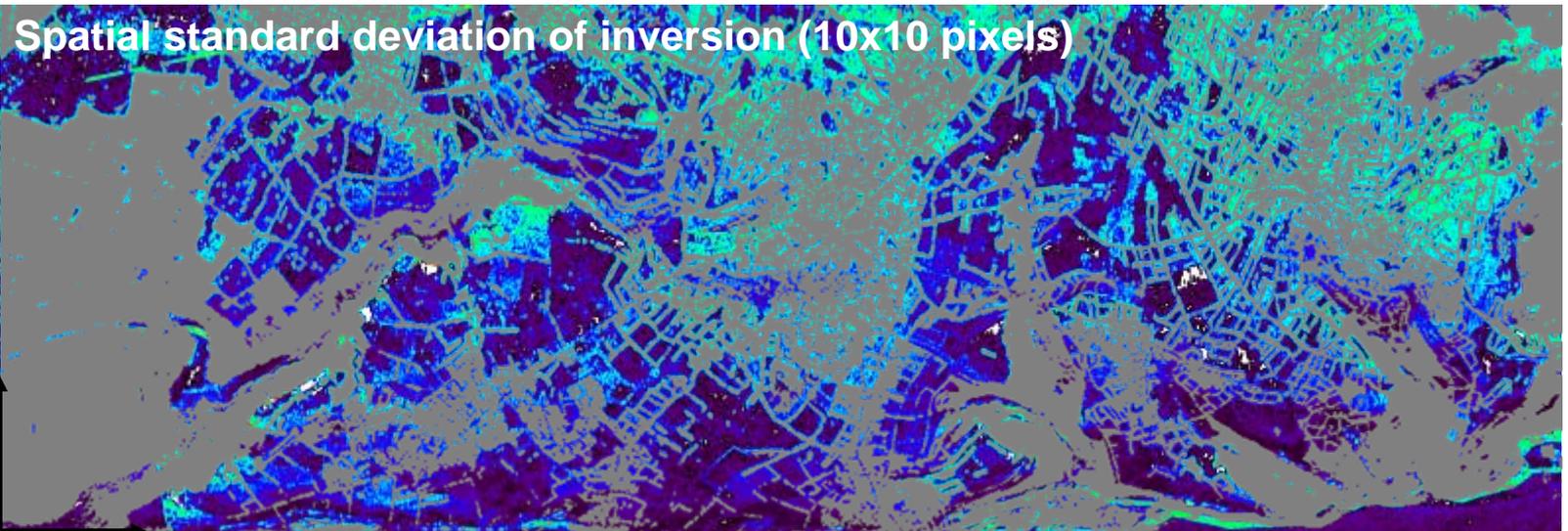
[vol. %]

range

azimuth

# Results for Soil Moisture Inversion (Rollesbroich)



Estimated Soil Moisture ($\varepsilon_S$-level = 15)

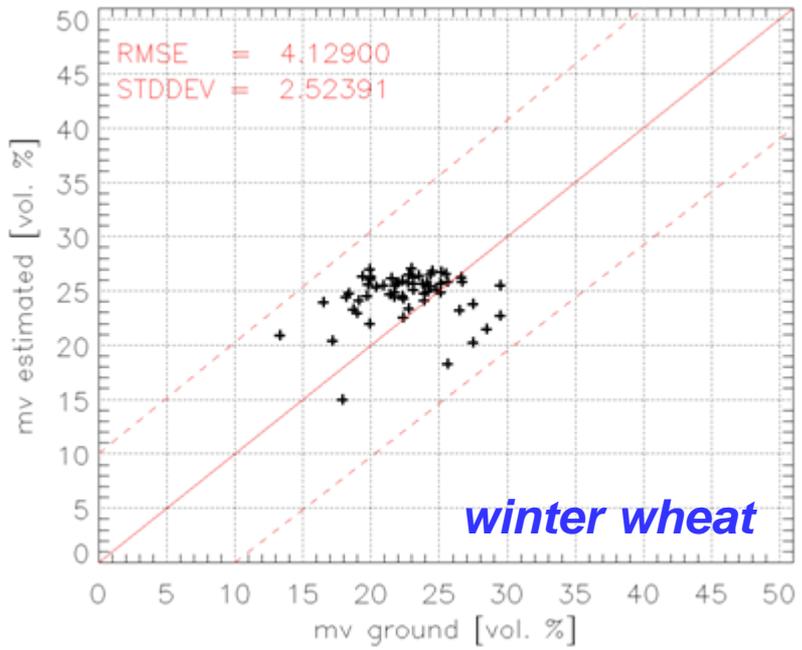Spatial standard deviation of inversion (10x10 pixels)

[vol. %]

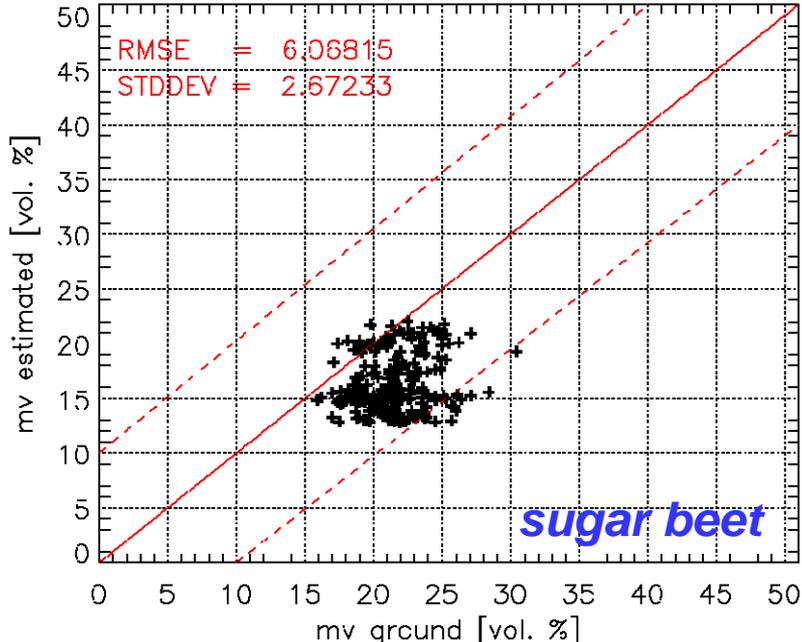50 — 40 — 30 — 20 — 10 — 0

range

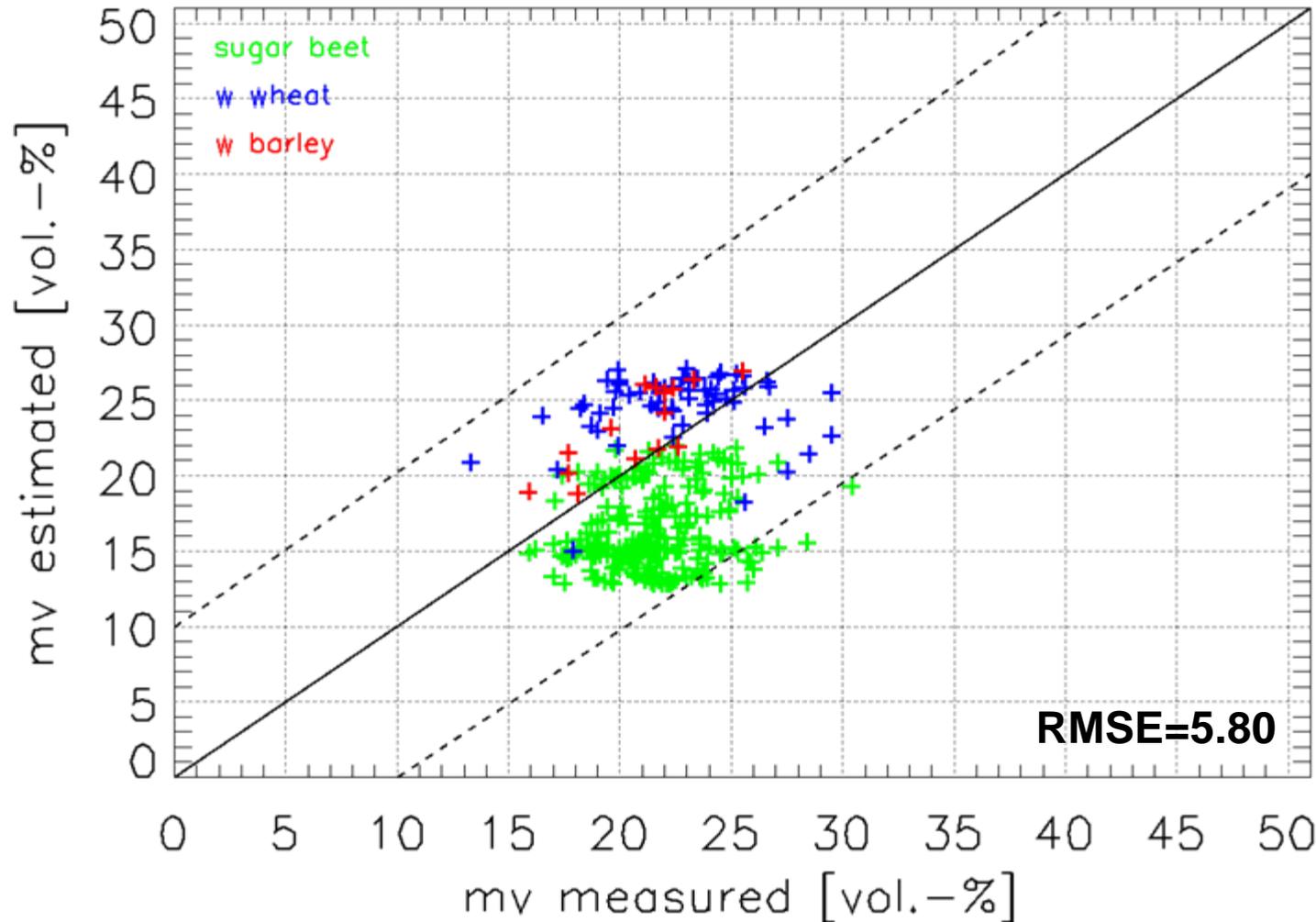azimuth

# *Validation for 3 Corp Types*
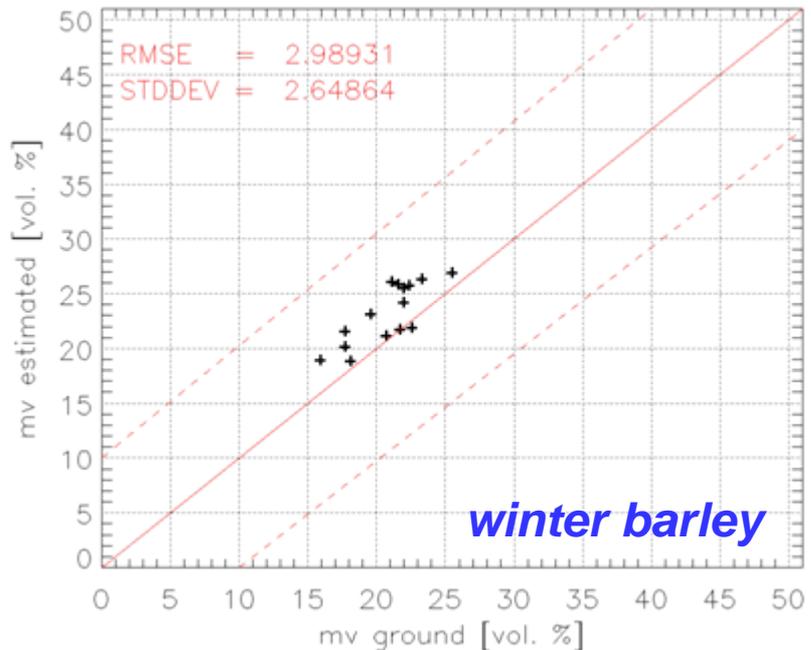


**Validation box:
13 x 13 Pixels**

## Validation for all fields of Selhausen



**Validation box: 13 x 13 Pixels**

# Summary and Outlook

**Soil moisture estimation under vegetation cover has been performed:**

> ➤ *The hybrid polarimetric decomposition including physical constraints has been successfully applied on the Rur Observatory (subsets Selhausen & Rollesbroich)*

> ➤ *The developed approach results in a inversion rate of >90% for both test sites over agriculture (forest still critical)*

> ➤ *Soil moisture inversion results are obtained for a variety of crop types with a RMSE < 6vol. % and a STDDEV < 3vol. %.*

**Further investigations:**

> ➤ *Hybrid model improvement (focus on the volume part)*

> ➤ *Investigation on steep incidence regions*

> ➤ *Investigation of dihedral scattering component ($\alpha_d$) for soil moisture inversion*
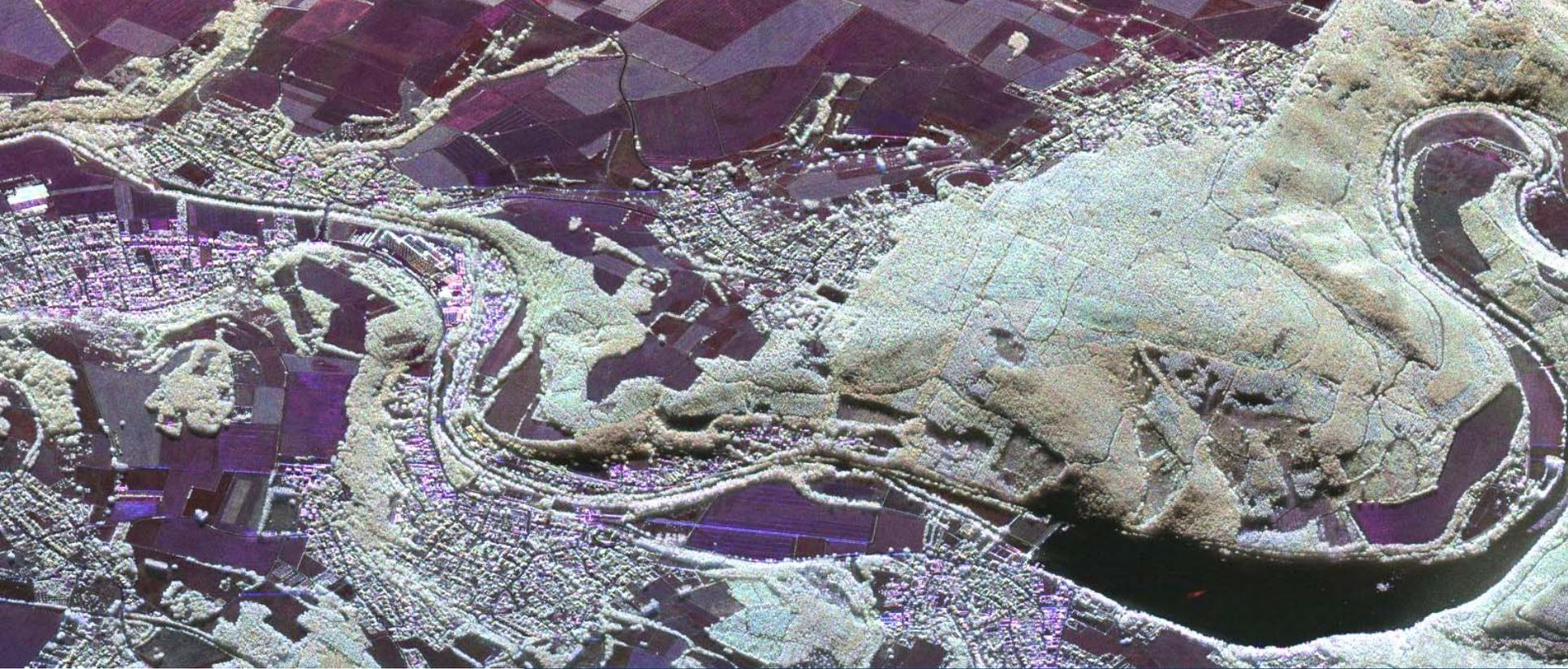
# TERENO F-SAR Airborne Campaign 2011 @ Rur, Bode and Ammer catchments
operated by DLR, FZJ, UFZ and KIT

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# F-SAR L-Band Subsystem (2011)



up/down converter with chirp

antenna front end
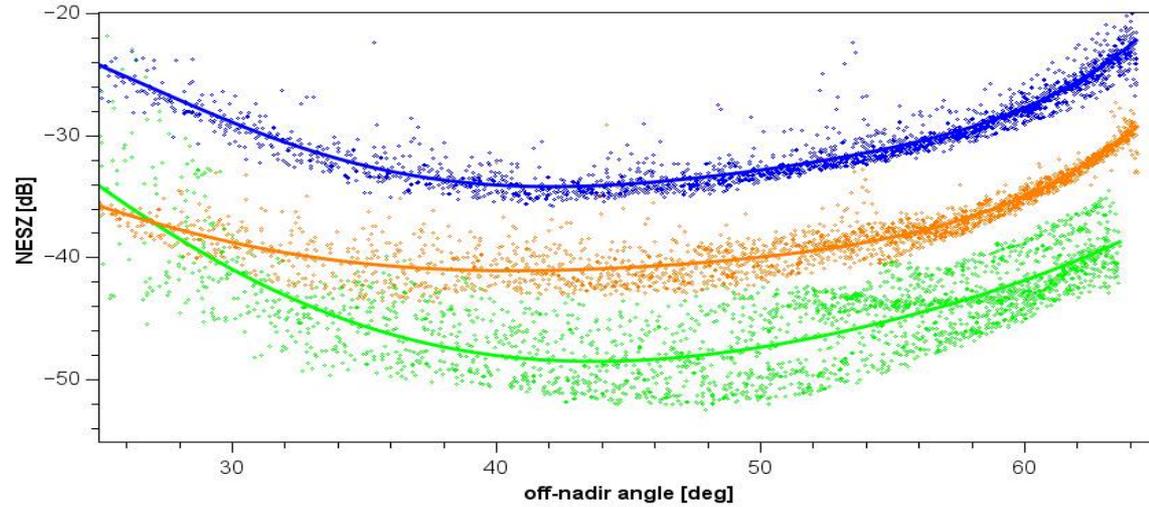
system control
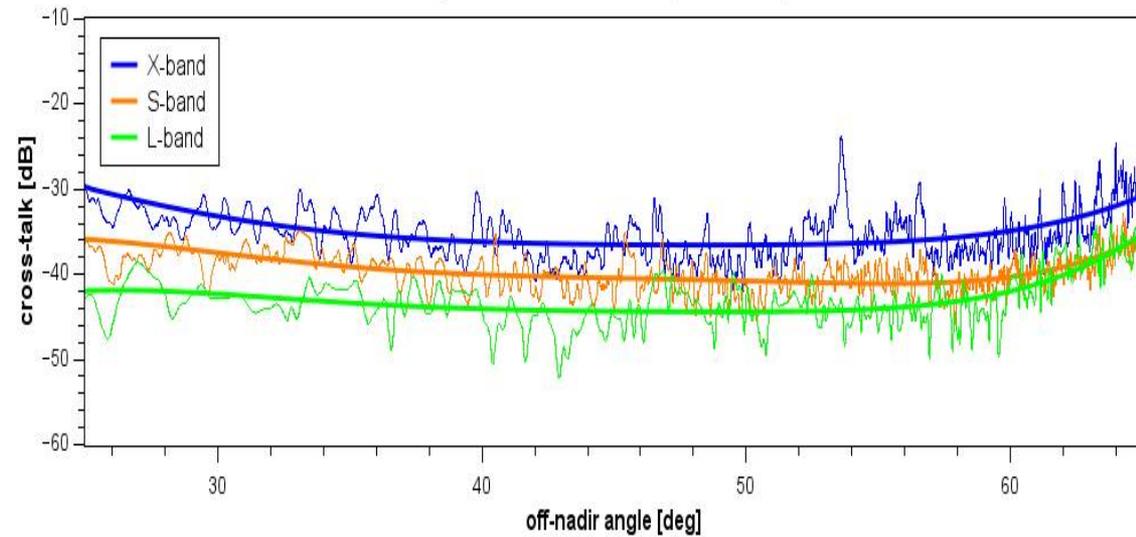
power supply

high power amplifier (HPA)





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# F-SAR High-Gain L-Band Antenna

**L-band without cowling**



**Noise Equivalent σ₀**



**polarimetric cross-talk (calibrated)**

# *Overview of TERENO Campaign 2011*

**DLR's SAR Sensor: F-SAR**

Frequency L-band
Fully polarimetric
Spatial Resolution (r/a): 2mx0.6m
Date: KW 21-22
(23.05.-03.06.2011)

**TERENO Observatories**

Ammer - KIT
Bode – UFZ/WESS
Rur – FZJ

**Ground Measurements**

were conducted by
the research institutes
of the observatories.
DLR supported for the
Ammer and the Bode
catchment.

| Catchment | Date | Data acquisition @ local time | No. of scenes |
|---|---|---|---|
| **Rur** | 30/05/2011 | 09:35-12:26 | 13 |
| **Bode** | 31/05/2011 | 09:12-10:41 | 8 |
| **Ammer** | 07/06/2011 | 10:26-11:33 | 6 |

| Catchment | Date | Ground measurements |
|---|---|---|
| **Rur** | 30/05/2011 | Soil moisture (cluster, mobile probes), soil roughness (Laser-profiler), vegetation height, biomass, LAI |
| **Bode** | 31/05/2011 | Soil moisture (mobile probes, EMI), soil roughness (Laser-scanning) vegetation height, phenology, biomass, VWC, LAI |
| **Ammer** | 07/06/2011 | Soil moisture (mobile probes) |

## Test site – Bode Watershed

*Flight strip of F-SAR: 10 x 3 km*
*Field measurements by UFZ/WESS/DLR:*
**Soil moisture** (FDR [6cm], EMI [experimental] )
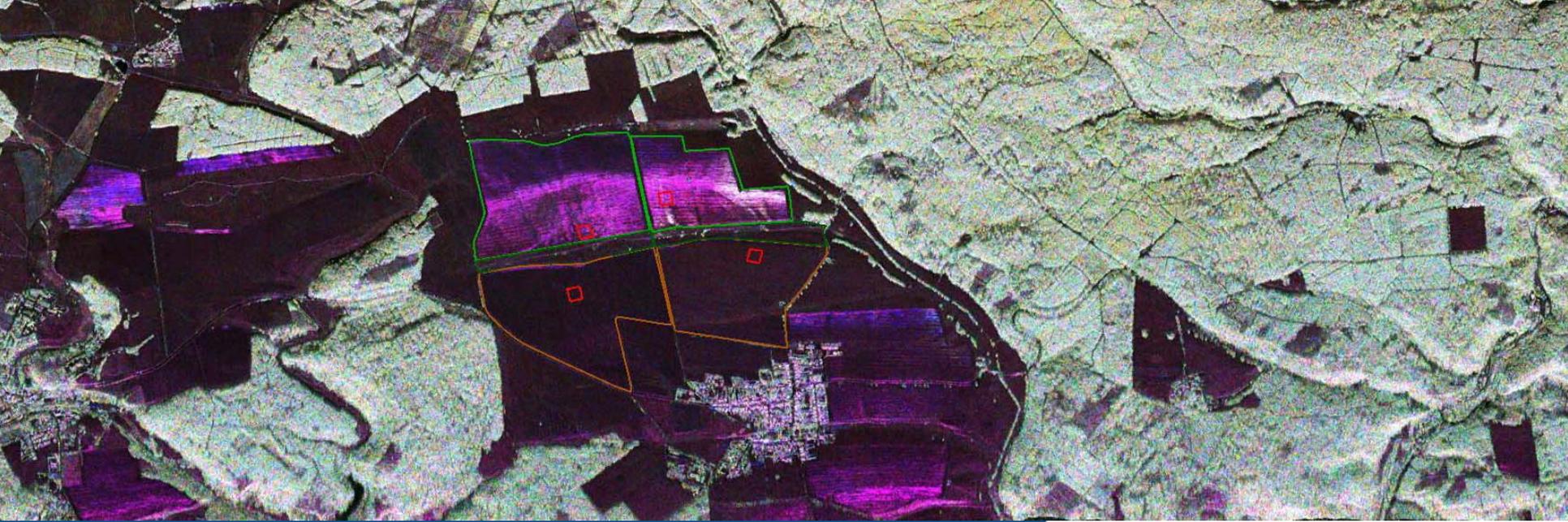**Soil roughness** (Laser scanning [experimental])
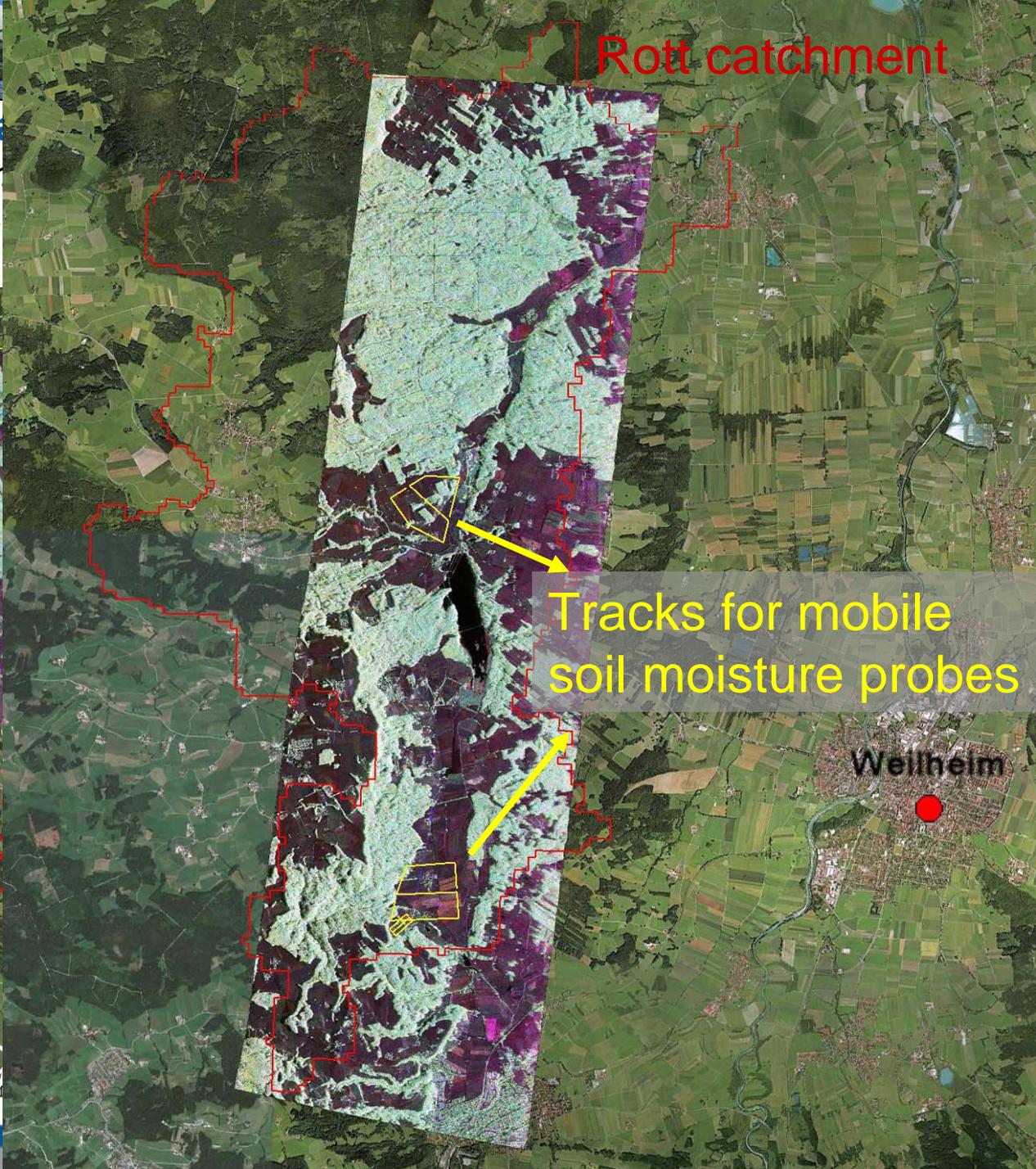**Vegetation** (height, phenology, biomass, VWC, LAI)

*TanDEM-X Strip*

corner reflectors

# Test site – Ammer/Rott Wa...

***Flight strip of F-SAR: 11 x 3 km***
***Field measurements by KIT/DL...***
(mobile FDR/TDR probes)

*F-SAR flig...*

**Rott catchment**

**Tracks for mobile
soil moisture probes**

Wellheim

# Test site – Rur Watershed

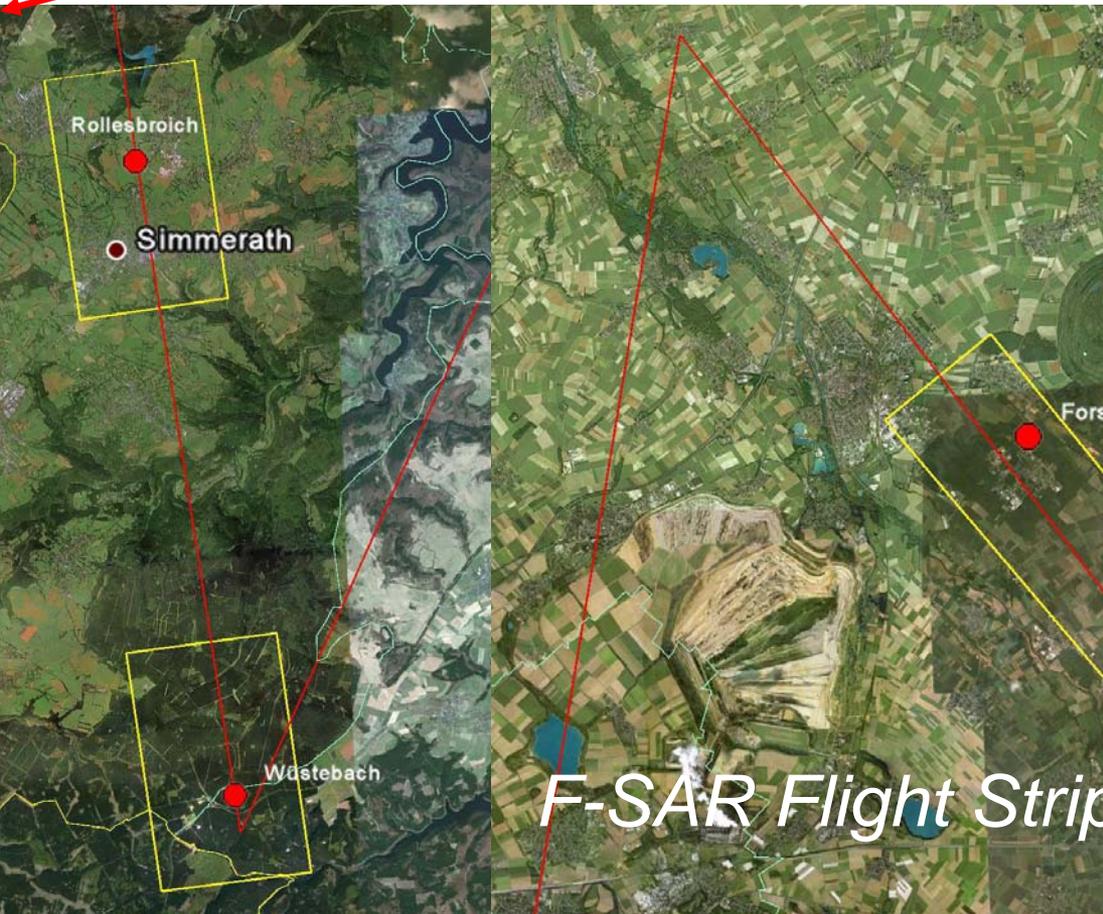*Triangular Flight configuration:*
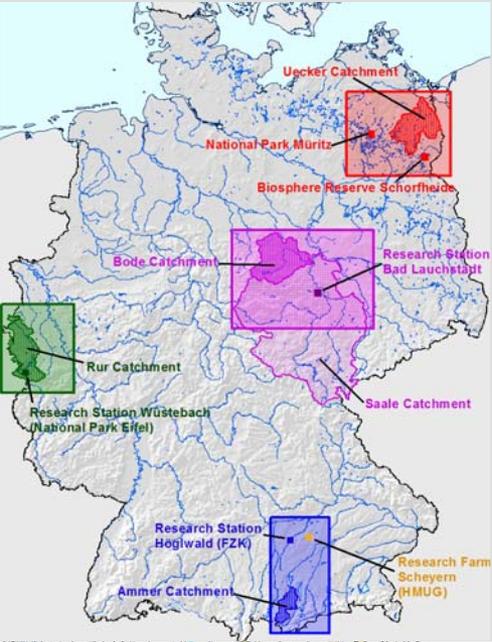*Yellow AOI ares: 5 x 3 km (2) and 10 x3 km*
*Field measurements by FZJ:* **Soil moisture, Vegetation**
  SoilNet (grassland (Rollesbroich), forest (Wüstebach))
  Active/passive arc experiment,
  Mobile TDR/FDR probes (Merzenhausen)

**Triangular flight configuration**

*F-SAR Flight Strip*

**Acknowledgement to the**

**Campaign Team**