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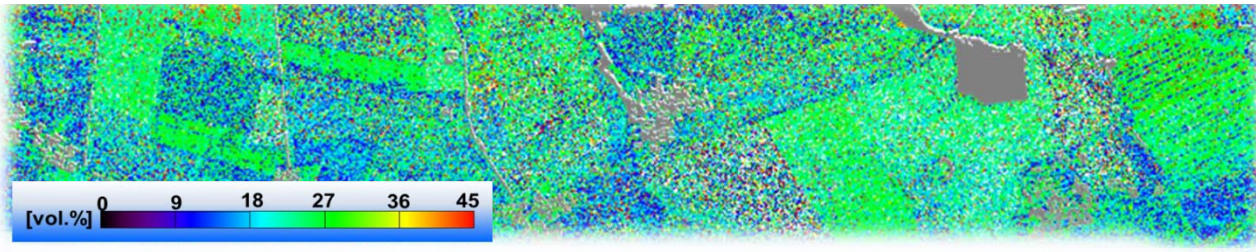

TERENO Observatories – Validation Sites for a SAR-Based Soil Moisture Retrieval under Vegetation Cover

T. Jagdhuber, I. Hajnsek, K.P. Papathanassiou

HELMHOLTZ ASSOCIATION

In situ data from C. Montzka, H. Bogena, Ch. Chwala, H. Kunstmann, S. Itzerott, D. Spengler, U. Wollschläger, M. Pause

International TERENO Conference, September, 28 – October, 2, 2014, Bonn, Germany

Thomas.Jagdhuber@dlr.de

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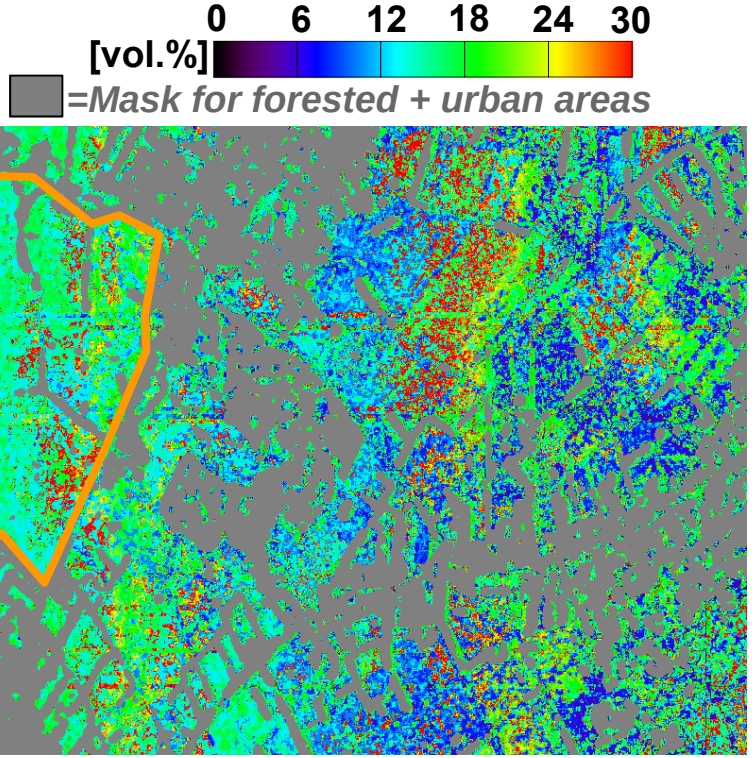
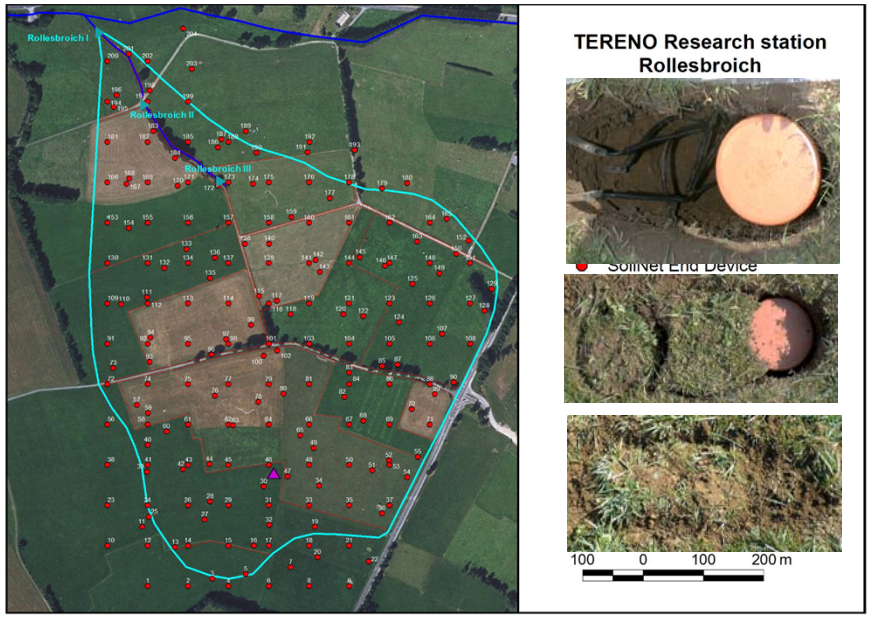
TERENO Observatories – Ideal Validation Sites for a Remote-Sensing-Based Geo-Physical Parameter Retrieval



SAR-Retrieved Soil Moisture under Vegetation @ Rollesbroich.



Soil Moisture Measurement Locations @ Rollesbroich.

In situ ground measurements enable a precise comparison and validation of the SAR-based soil moisture estimates.

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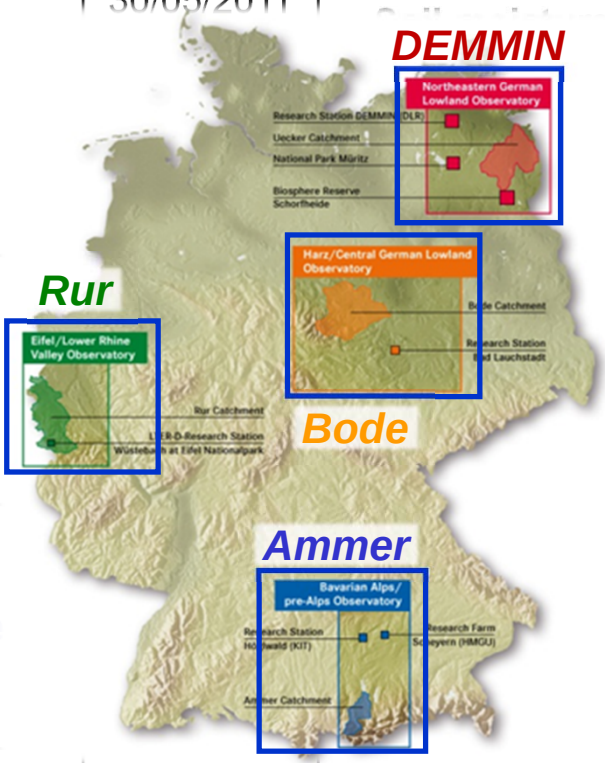
Experimental FSAR Campaigns – TERENO 2011 - 2012 - 2013

- **DLR's Novel SAR Sensor: F-SAR**
  - Frequency: L-band
  - Fully polarimetric (HH/HV/VH/VV)
  - Spatial Resolution (r/a): 2m/4mx0.6m
  - Date: KW 21-22, KW 19-21, KW16-18 (23.5.-7.6.2011, 10-23.5.2012,15.4.-2.5.2013)

- **TERENO Observatories**
  - Bavarian Alps: Ammer - KIT
  - Harz: Bode – UFZ/WESS
  - Eifel: Rur – FZ Jülich
  - NE Lowland: DEMMIN – DLR/GFZ

- **Ground Measurements**
  - Conducted by the research institutes of the observatories.
  - DLR supported for the Ammer and the Bode catchment in 2011.

Catchment	Date	Conducted *in situ* measurements
Rur	30/05/2011	(SoilNet probes), ness eight, s
Bode		(mobile SoilNet on height, ss, VWC,
Amme		ure es), eight
DEMMIN	23/05/2012	**Soil moisture** (SoilNet cluster, mobile probes), **vegetation** height, biomass, VWC



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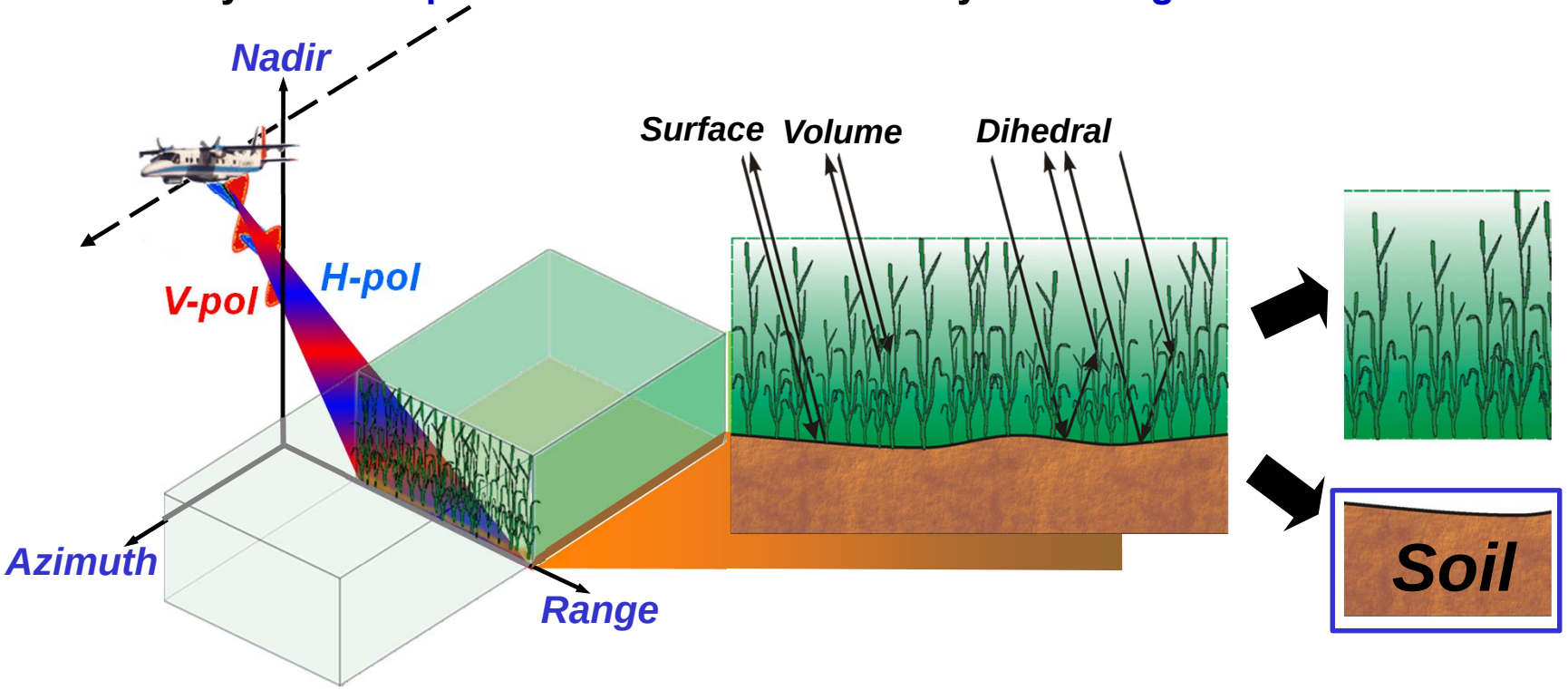
Retrieval of Geo-Physical Parameters with Polarimetric SAR

- Polarimetric SAR (PolSAR) is sensitive to the geometry (size, shape, orientation, density) and the intrinsic properties (permittivity, salinity) of scatterers
- Possibility to decompose into different elementary scattering mechanisms



Requirements for the retrieval algorithm

- High transferability to different areas of interest
- Limited a priori knowledge / No in situ input data
- Physically-Based inversion approach
- Fully polarimetric L-band data

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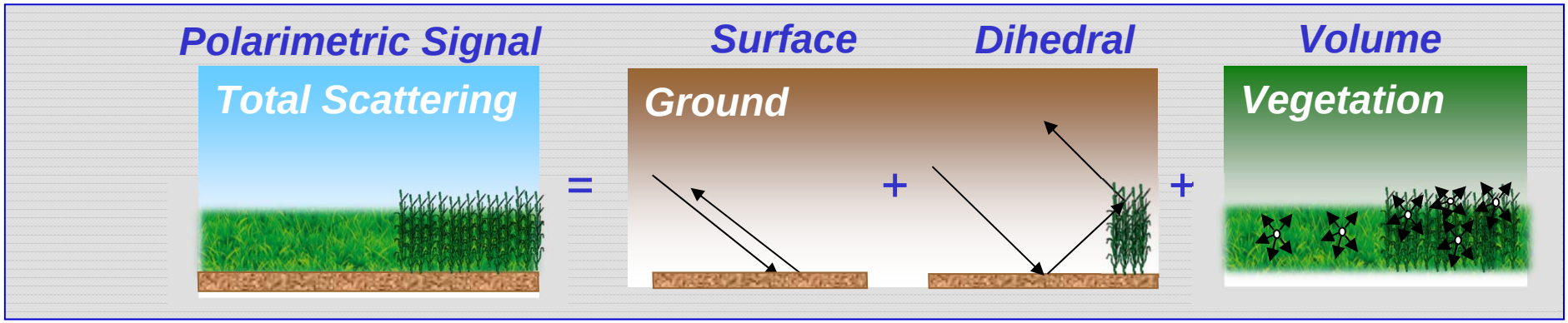
Polarimetric Decompositions for Vegetation Removal and Soil Parameter Estimation



Removal of Vegetation Component and Inversion for Soil Parameters

Problem of Conventional Polarimetric Decompositions

- Volume intensity over-estimation
- Static, inflexible vegetation volume type

⇩

Soil Moisture

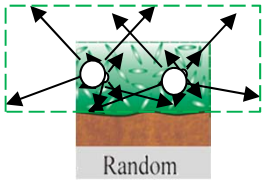
Scheme of Iterative, Generalized, Polarimetric Hybrid Decomposition and Inversion for Soil Moisture

Start of 2. Iteration

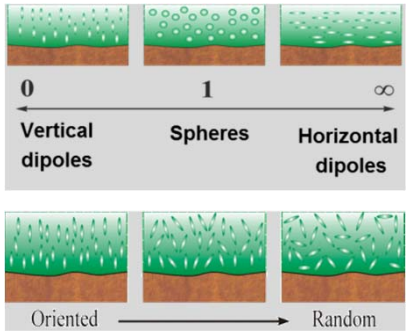
Physical Constraining of Vegetation Volume Component Using a Generalized Volume

Start of 1. Iteration

Physical Constraining of Volume Intensity Component Using a Random Volume

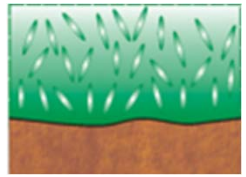


Generalized Polarimetric Hybrid Decomposition for a Variety of Different Vegetation Volume Types (Shapes, Orientations)



***Using Vegetation Types from 1. Iteration as Input in a Generalized Volume* for 2. Iteration**

Determination of Corresponding Vegetation Volume



Soil Moisture Estimation

End of 2. Iteration

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Harz Observatory @ Schäfertal Catchment

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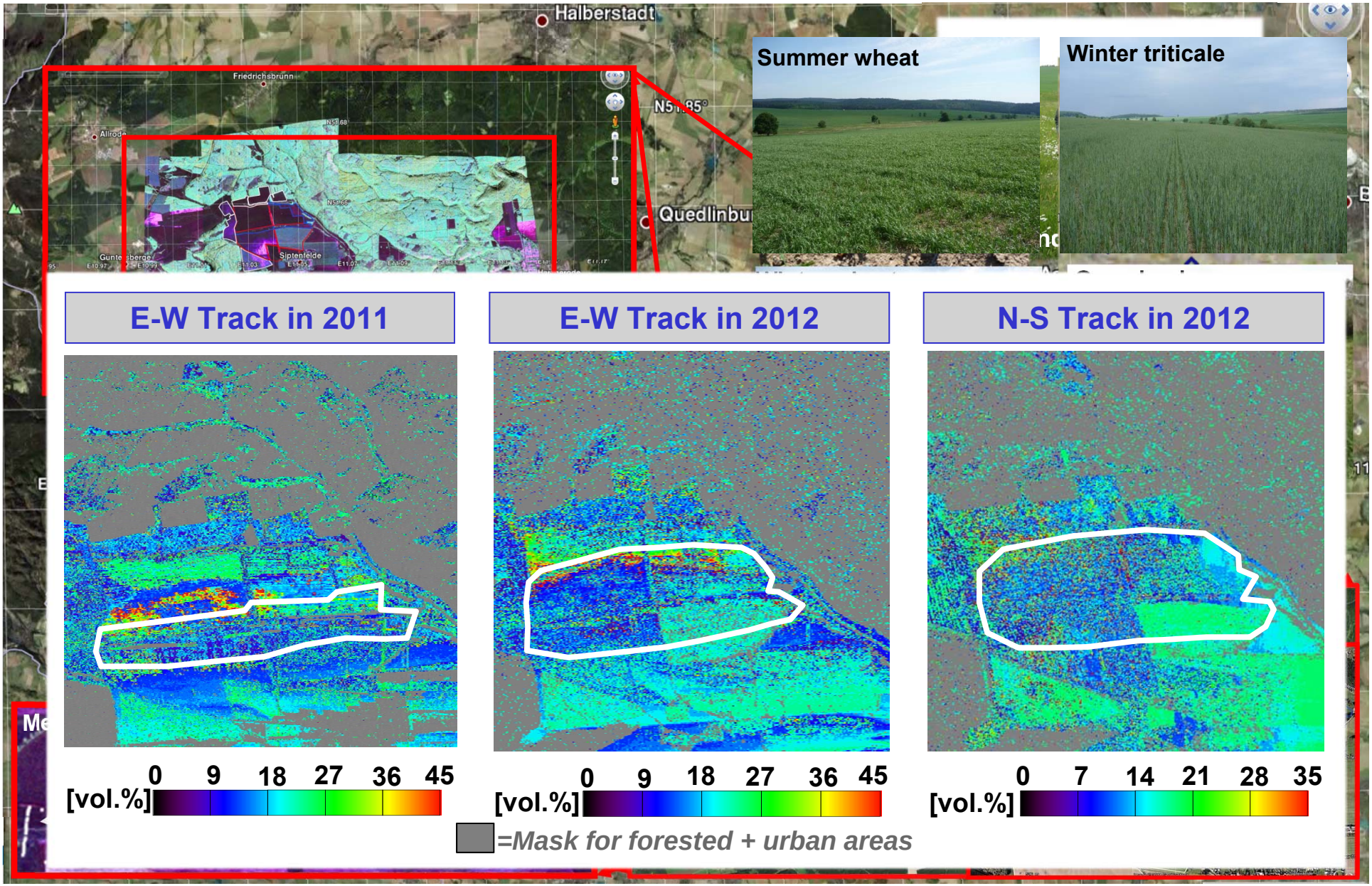
Flight strips of F-SAR: 11 x 4 km (E-W), 6 x 4km (N-S)

***Field measurements** by UFZ/WESS:* **Soil moisture**, **Vegetation** (height, phenology, biomass)



Eifel Observatory @ Rur Catchment

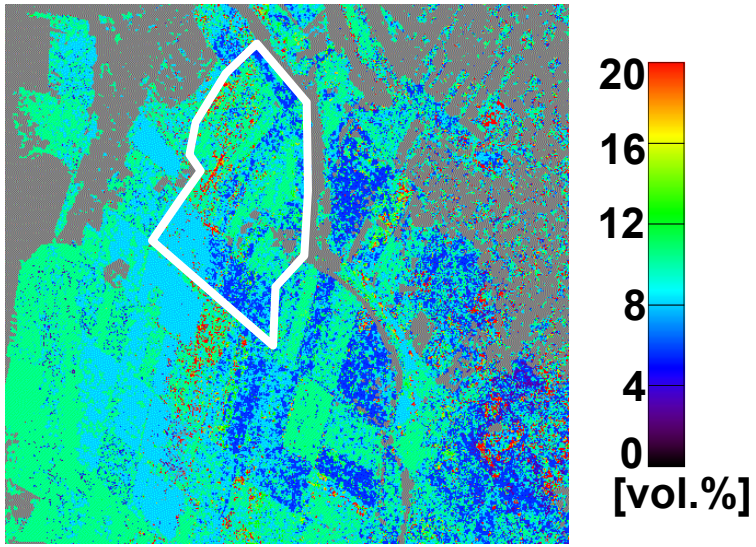
Triangular Flight Configuration

Measurement areas: 5 x 3 km (3) and 10 x3 km

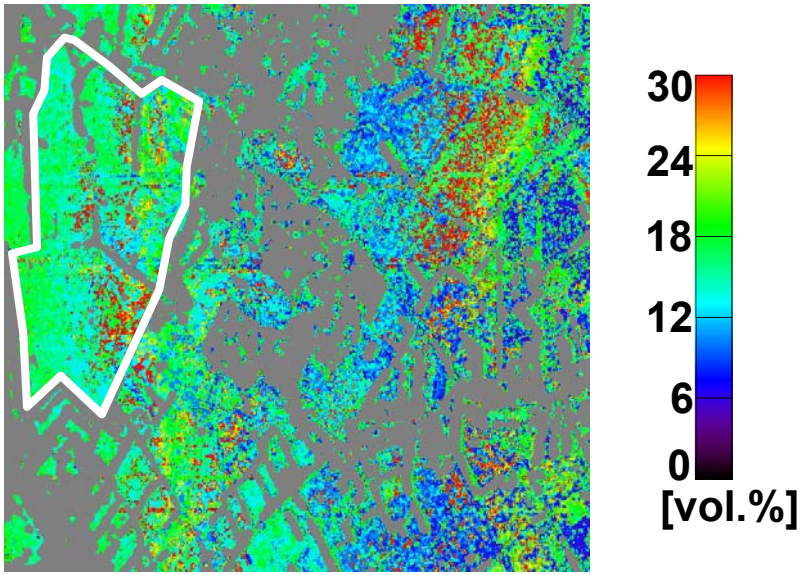
Field Measurements by FZJ: Soil Moisture, Vegetation

Soil Moisture Network (grassland (Rollesbroich))
Mobile FDR probes (agriculture (Merzenhausen, Selhausen))

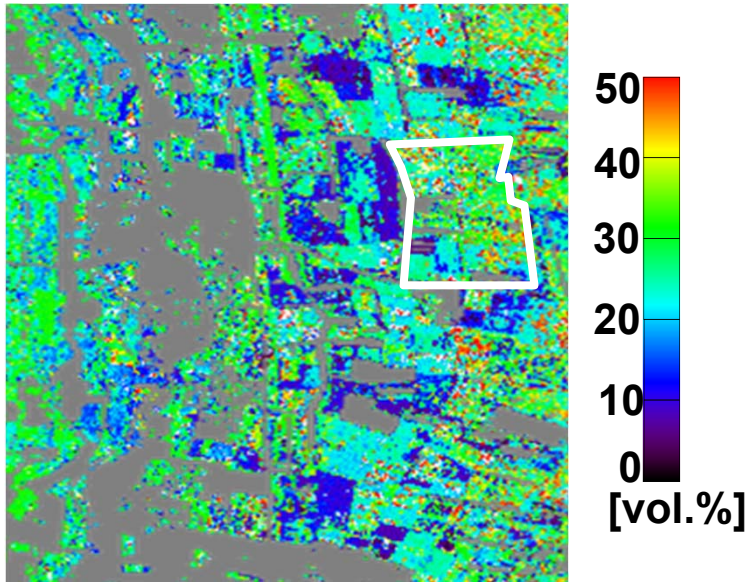
Merzenhausen in 2011



Rollesbroich in 2011



Selhausen in 2013



=Mask for forested + urban areas

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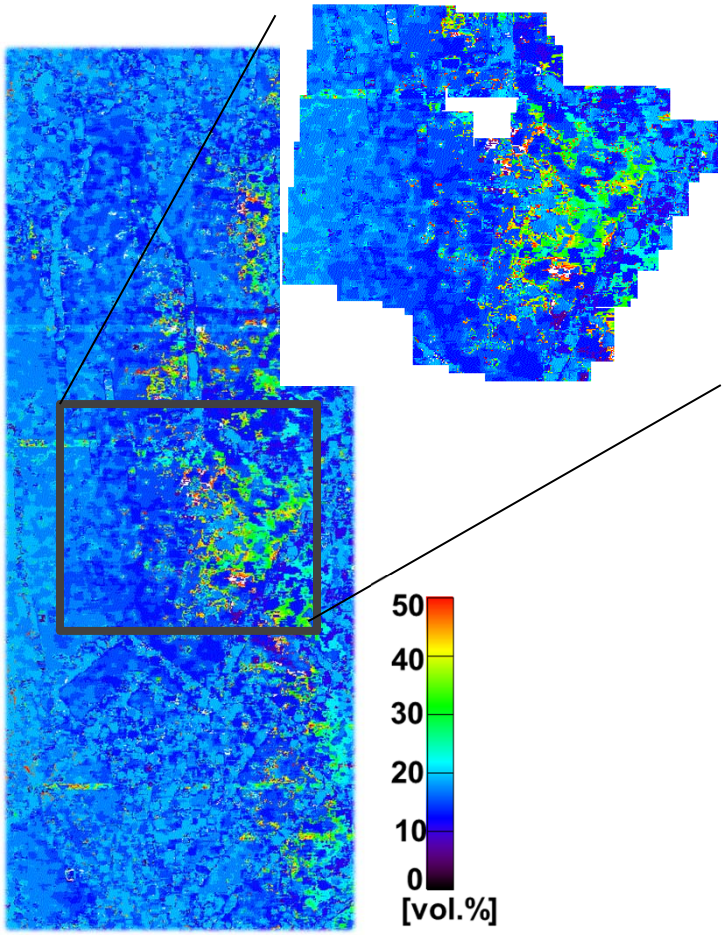
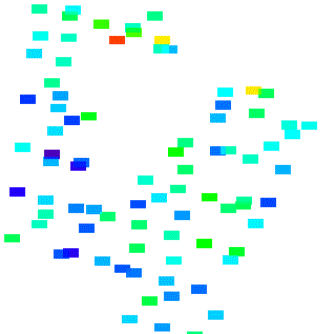
First Pattern Comparisons between Pol-SAR-Derived and SoilNet-Measured and Interpolated Moisture @ Rollesbroich

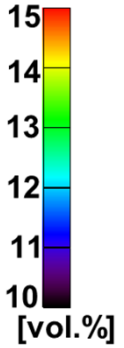
PolSAR-Derived Soil Moisture mv_{SAR}

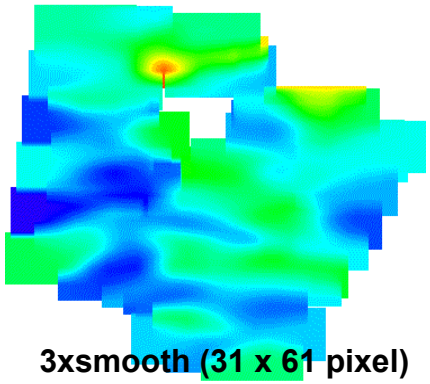


Measured and Interpolated Soil Moisture mv_{situ}



1xsmooth (15 x 31 pixel)

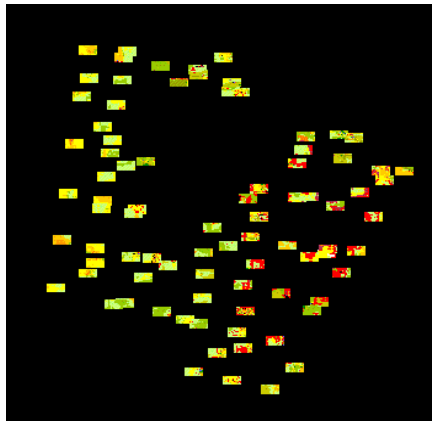


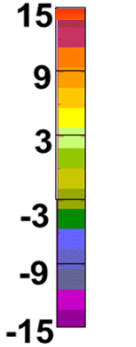


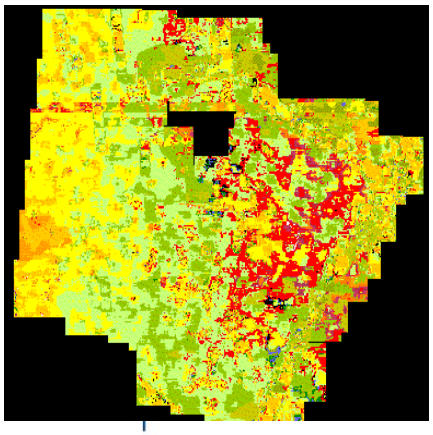
3xsmooth (31 x 61 pixel)

Interpolation of mv_{situ} is done with a multiply applied local smooth window (M x N pixel)

Moisture Difference = mv_{SAR} - mv_{situ}







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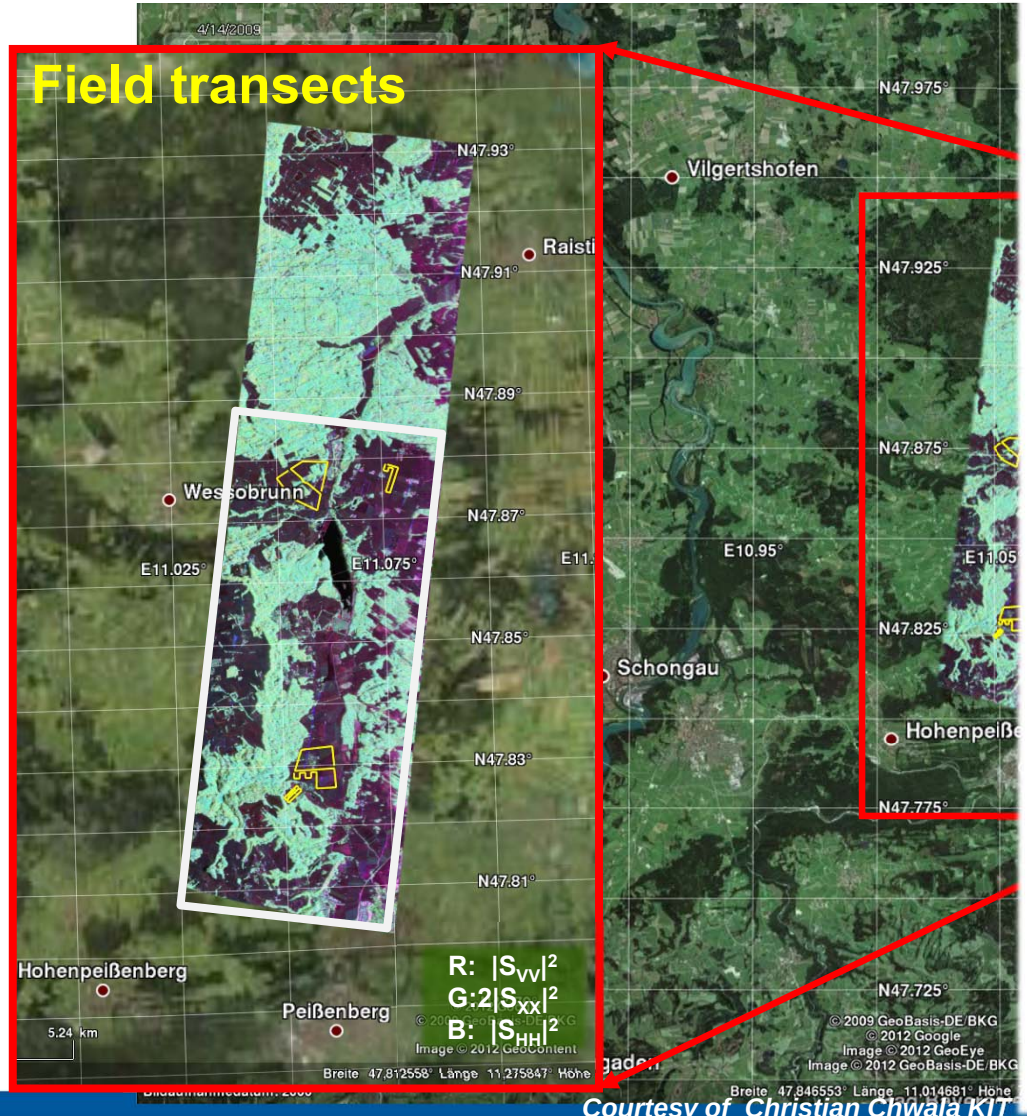
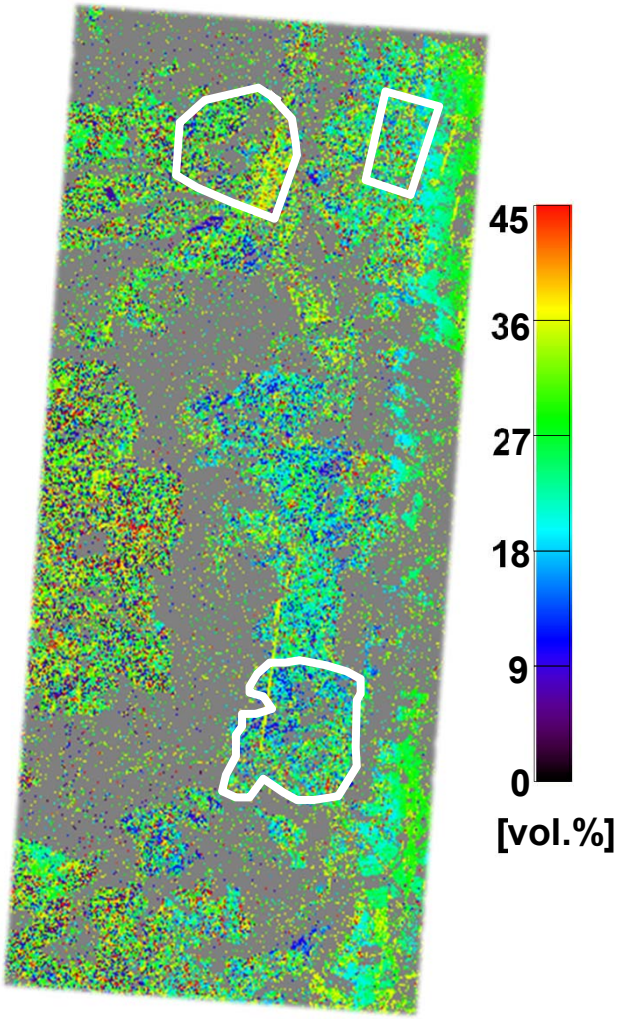
Bavarian Alps Observatory @ Fendt / Ammer Catchment

Flight strips of F-SAR: 14 x 4 km

Field measurements by KIT: **Soil moisture**,**vegetation** (height



Estimated Soil Moisture



Courtesy of Christian Chwala KIT

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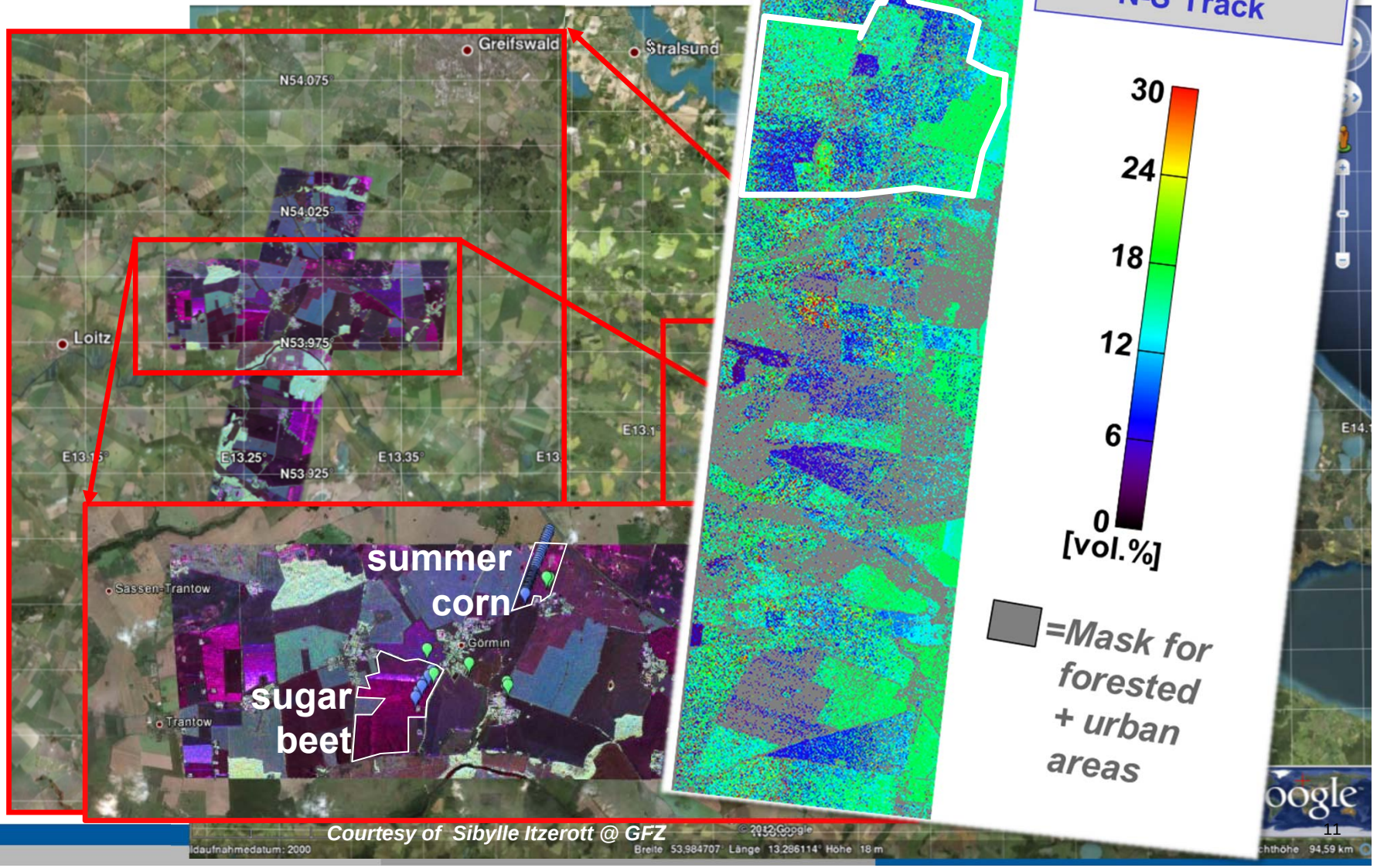
Test Site – NE Lowland Observatory /

Flight strips of F-SAR: 11 x 4 km (E-W), 27 x 4 km (N-S)

Field measurements by DLR/GFZ: **Soil moisture ,veget**



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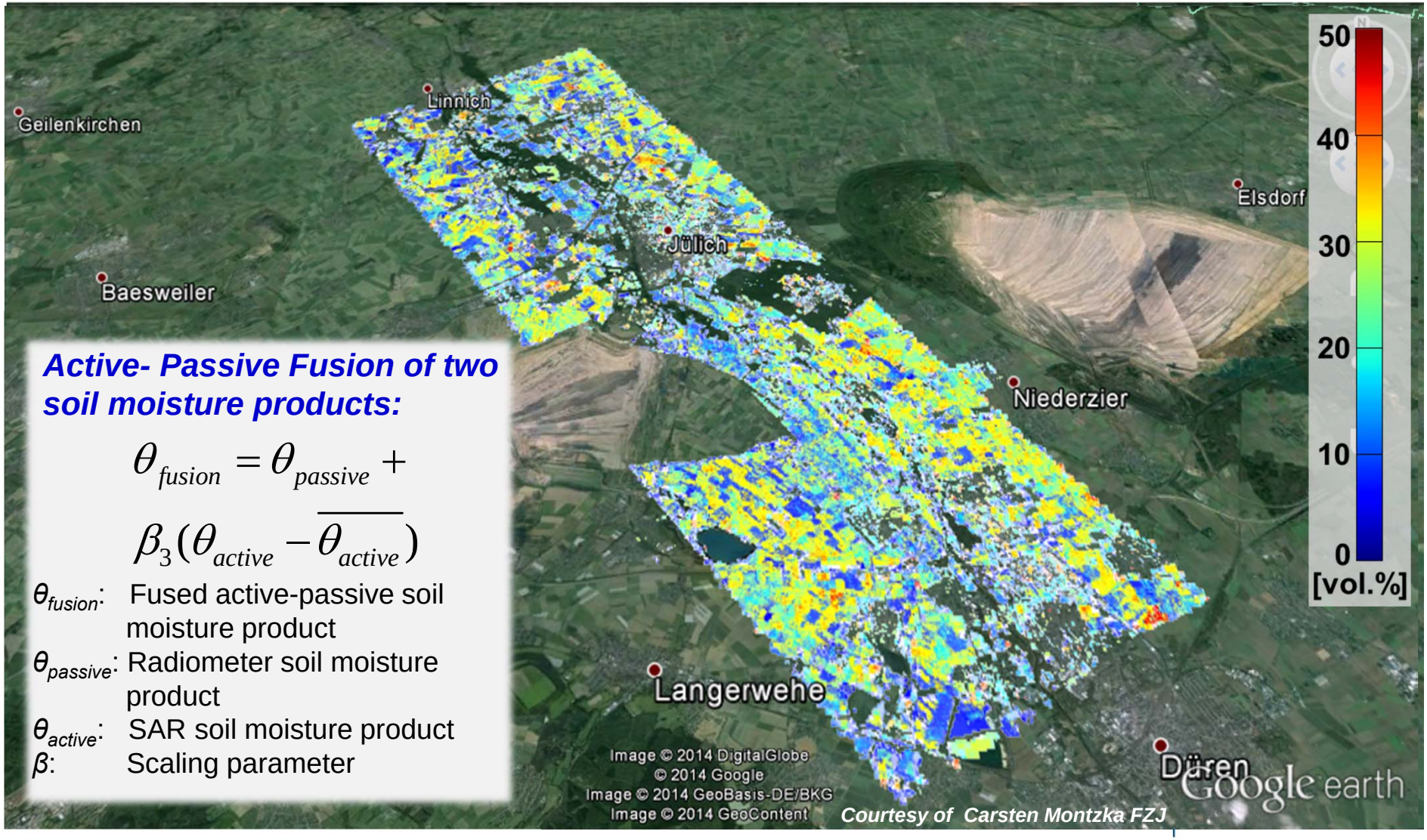
Geocoded and Mosaicked Soil Moisture for TERENO 2013 Campaign on 25/04/13 @ Eifel Observatory



Active- Passive Fusion of two soil moisture products:

$$\theta_{fusion} = \theta_{passive} + \beta_3(\theta_{active} - \overline{\theta_{active}})$$

θ_{fusion}: Fused active-passive soil moisture product

$\theta_{passive}$: Radiometer soil moisture product

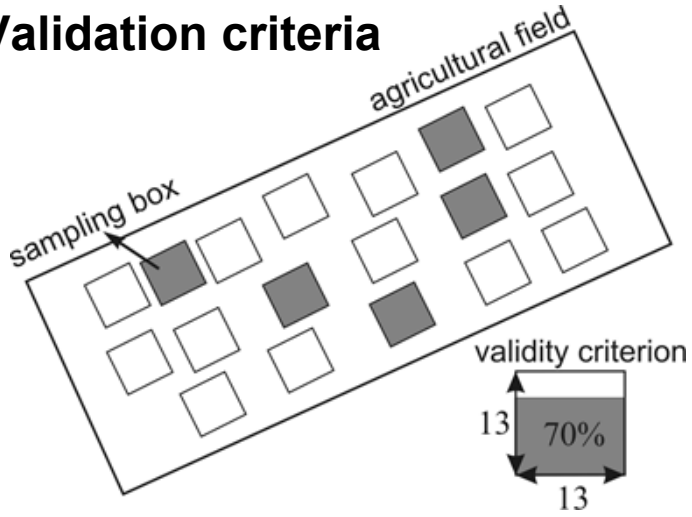
θ_{active}: SAR soil moisture product

β: Scaling parameter

Courtesy of Carsten Montzka FZJ

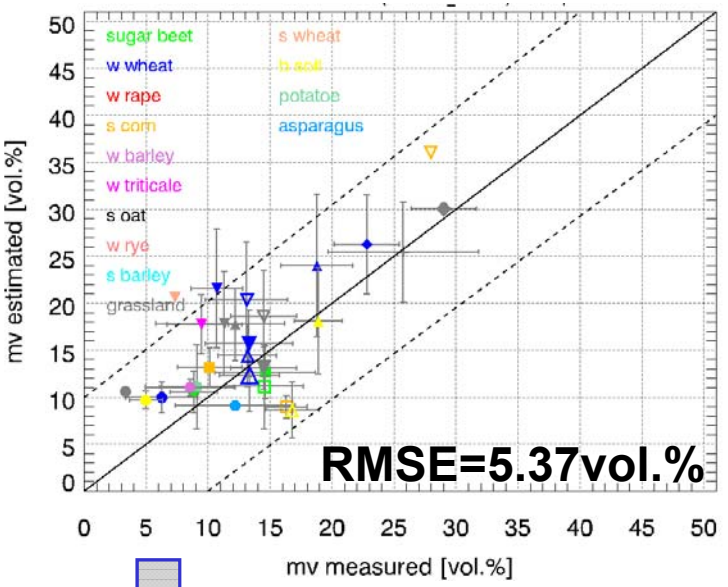
Validation of Soil Moisture Inversion under Vegetation Cover @ L-Band

Validation criteria

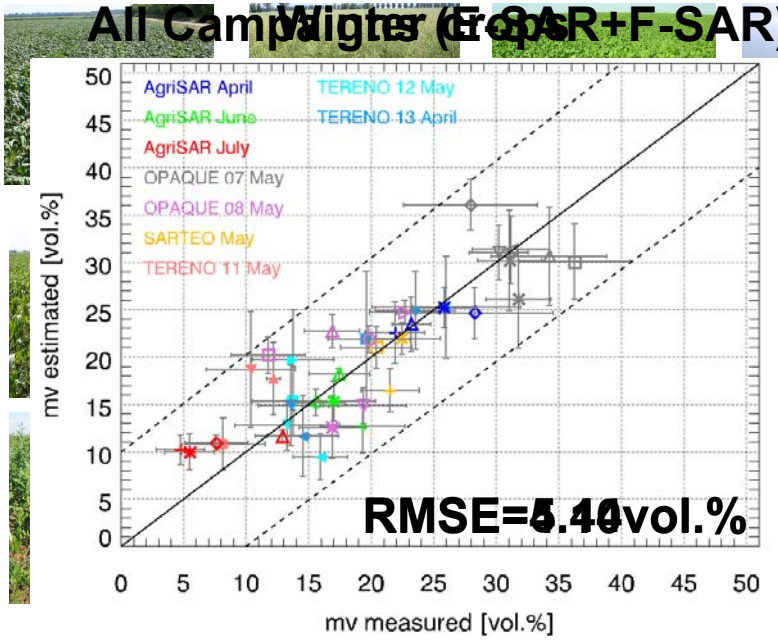


- ○ Merzenhausen
- △ Rollesbroich
- ◇ Selhausen
- ▽ Bode
- \+ Ammer
- □ Demmin

F-SAR 2011-2013 Campaigns

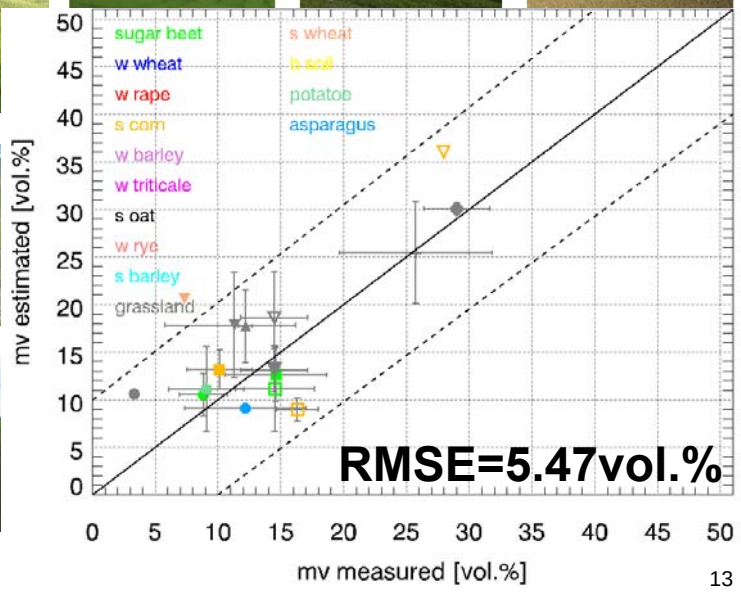


All Campaigns (TerraSAR+F-SAR)



Winter crops

Summer crops

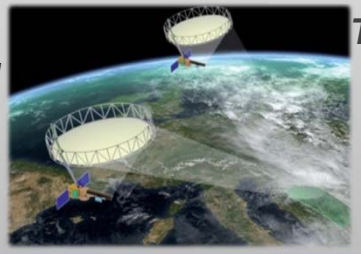


Summary and Outlook

- Inversion of soil moisture for variously vegetated TERENO observatories is feasible with very high inversion rates (>96%) using decomposition and inversion techniques on fully polarimetric SAR data @ L-band.
  - High-resolution (compared to passive sensors) and wide area (compared to field-based techniques) mapping is possible.
  - Monitoring period covers the entire growing season.
- Validation with ground-based sensors (thermogravic probes, FDR, TDR, Wireless SoilNets) revealed a well agreement with the SAR-based moisture estimates resulting in an RMSE of lower than 5.5 vol.% including a variety of crop types in different phenological stages.

- Further investigations on the retrieval algorithm towards operationality.
  - Refinement of volume type selection
  - Detailed spatial pattern analysis
- Fusion of active with passive microwave data for a combined soil moisture result in preparation of the SMAP mission.
- Algorithm implementation for upcoming, space-borne, long-wavelength SAR missions (ALOS-2, Tandem-L) heading towards a global monitoring strategy.

SMAP



Tandem-L