Patterns in Soil-Vegetation-Atmosphere Systems

Monitoring, Modelling & Data Assimilation

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RWTHAACHEN

What is TR32 ?

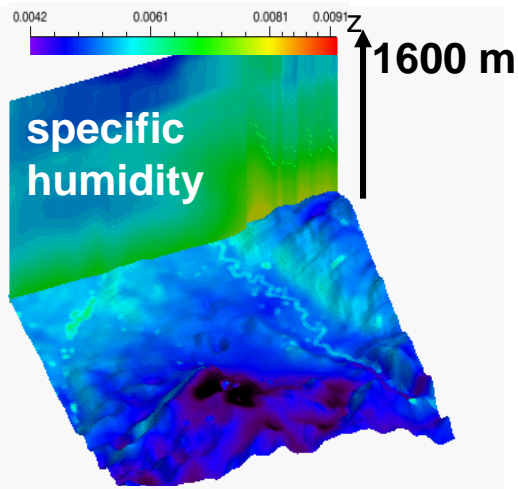- 2nd funding phase : **2011- 2014**

- **24 subprojects**, research groups in:
  soil and plant sciences, Remote sensing, Hydrology, Meteorology, Mathematics

- **5 Institutions:**
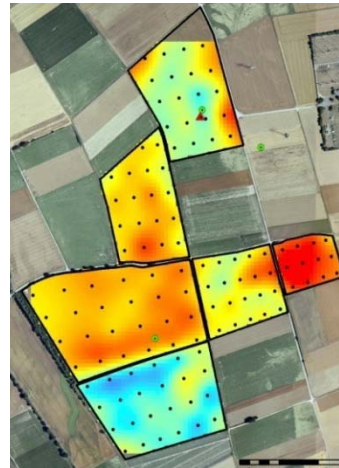 Universities of Aachen, Bonn, Braunschweig, Cologne, Research Centre Julich

Goal:
Understand the mechanims leading to **spatial and temporal patterns** in energy and matter fluxes of the **Soil-Vegetation-Atmosphere System.**
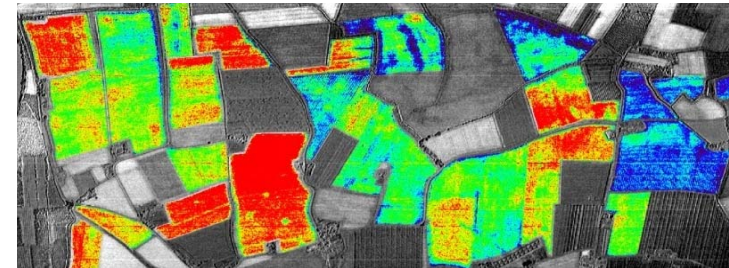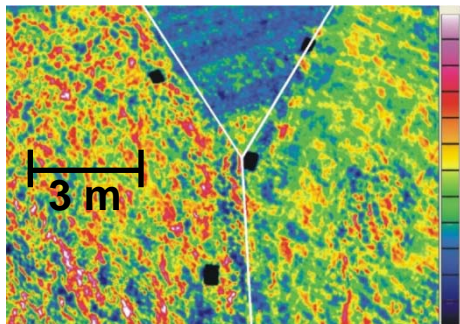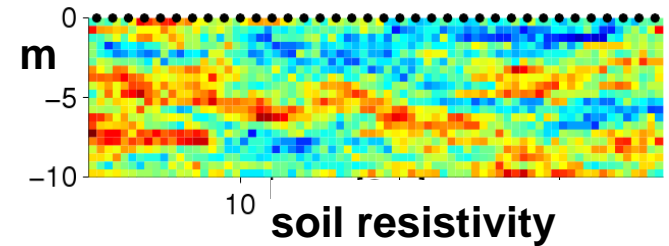
…resulting patterns and structures

specific humidity

1600 m

surface temperature

Soil moisture

sun induced fluorescence

soil resistivity

land surface temperature

3 m

C_{org} (% mass)

% soil organic carbon

2009/07/07

15 mm

22 mm

1 mm
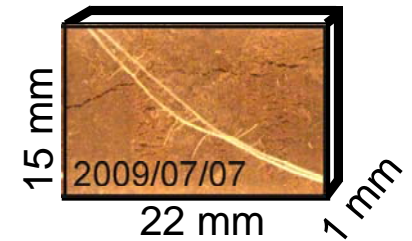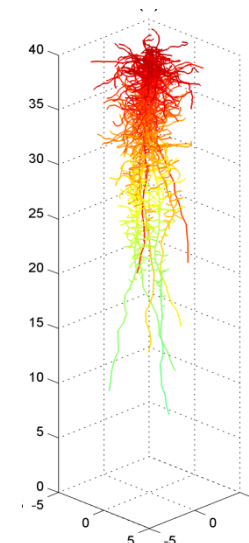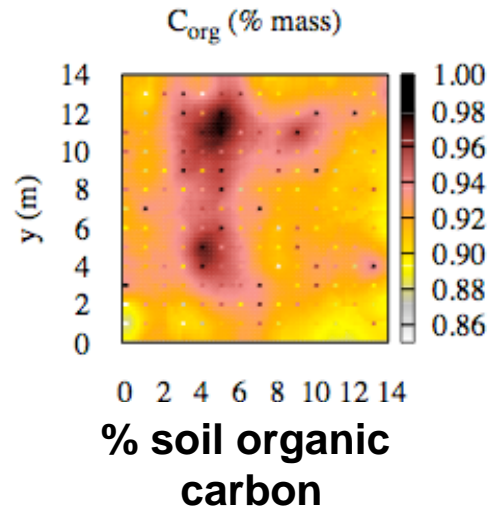
Specific Goals

- Suitable **sensors/strategies for** SVA system
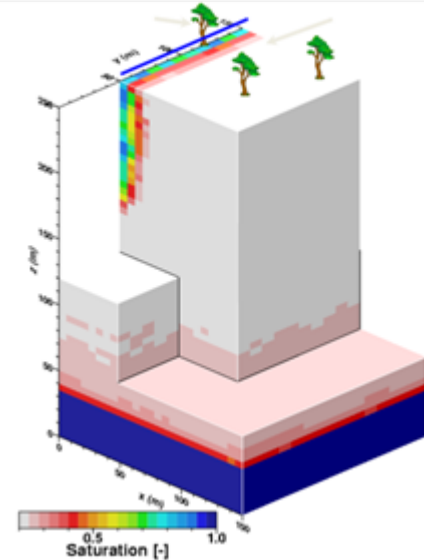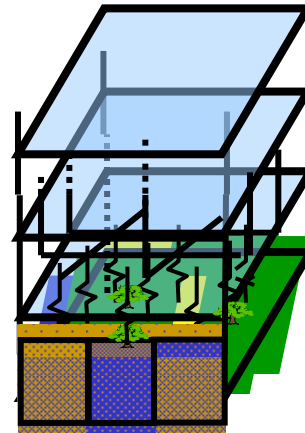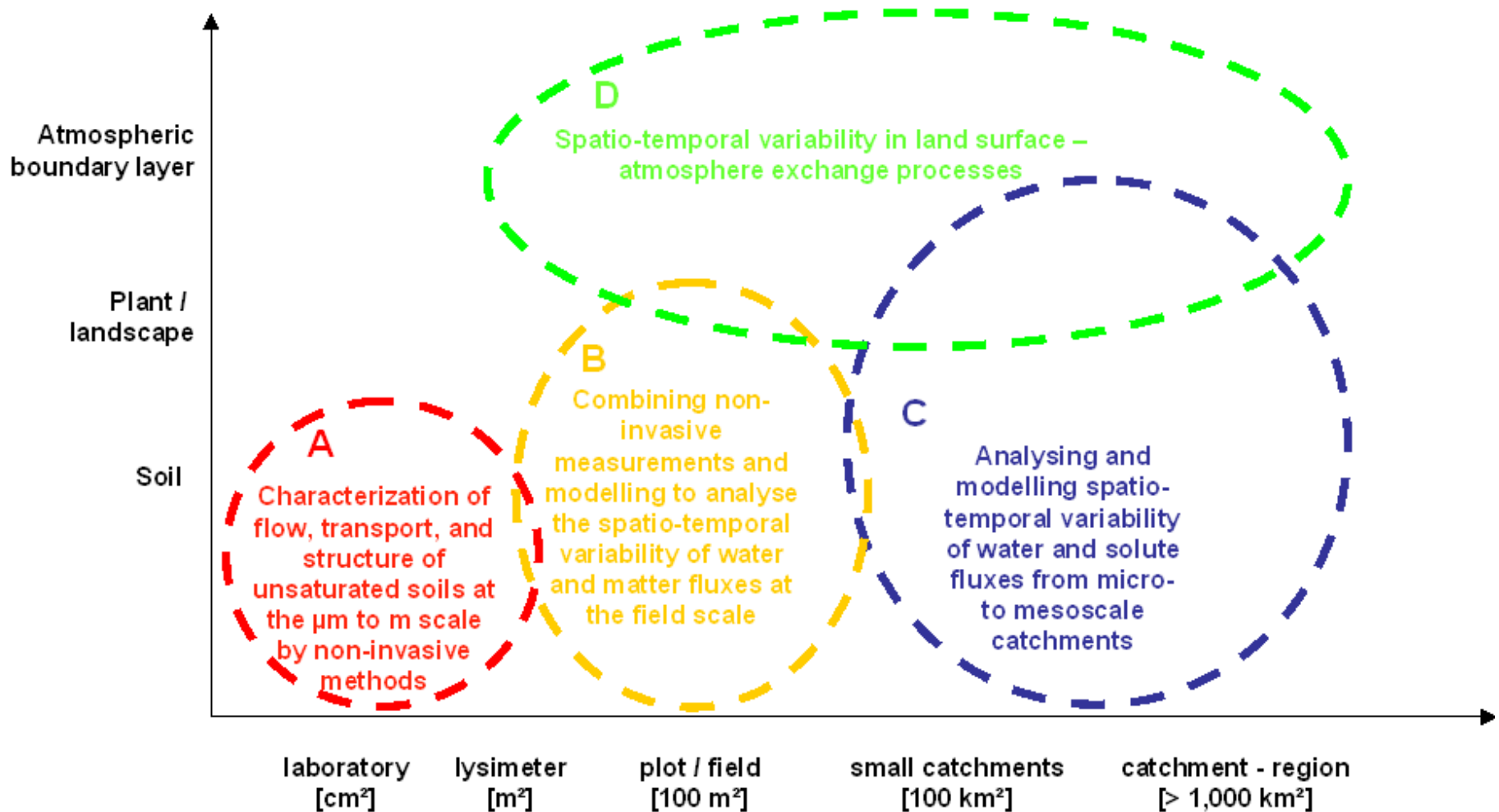
- **Integrated models** from the groundwater to the atmosphere for both the m- and km-scale

- **bridge the scale gaps via explicit consideration of patterns**

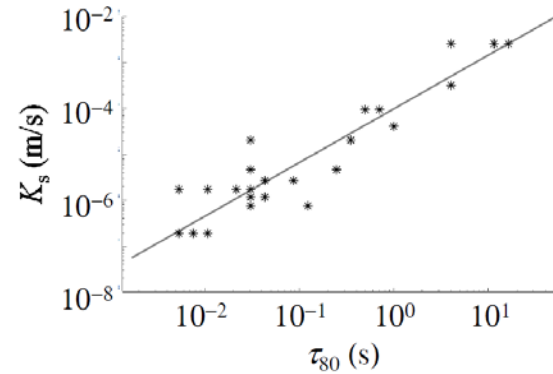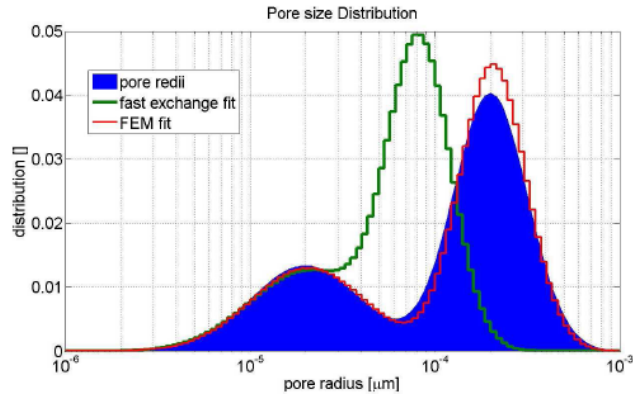- Fusion of integrated models and observations via **data assimilation and inverse theory**

TR32 Organisational Structure
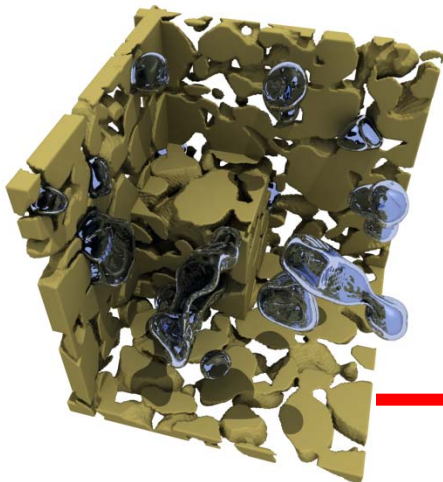
Cluster A

NMR and SIP sense the very small soil scales in the laboratory by model-data integration

Pore size Distribution

- pore size distribution and connectivity
- hydraulic conductivities of the soil

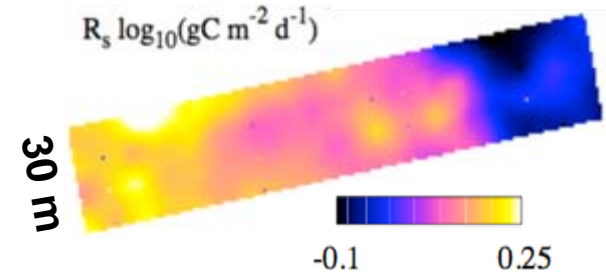Pore's plant scale: Lattice Boltzmann simulation evaporation of wetting fluid from a porous medium
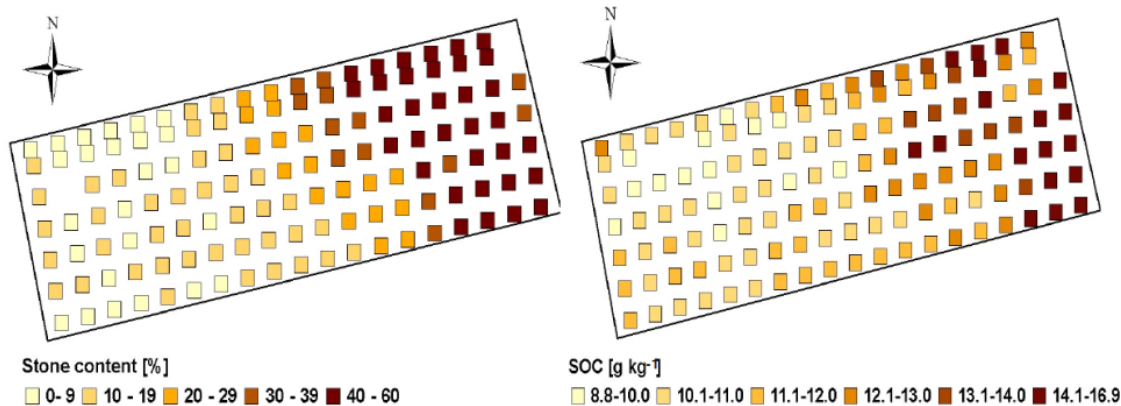
Cluster B

Patterns of soil-carbon, evapotrans-piration and respiration in the field

- soil respiration a function of soil moisture temperature

$R_s \log_{10}(gC\ m^{-2}\ d^{-1})$

30 m

-0.1   0.25

- carbon pools differentiated by MIRS and explained by soil structure

Stone content [%]
☐ 0 - 9 ☐ 10 - 19 ■ 20 - 29 ■ 30 - 39 ■ 40 - 60

SOC [g kg⁻¹]
☐ 8.8-10.0 ☐ 10.1-11.0 ■ 11.1-12.0 ■ 12.1-13.0 ■ 13.1-14.0 ■ 14.1-16.9

- Groundwater table influences bare soil evaporation.

Precipitation   Evaporation   Groundwater Recharge

821 mm y⁻¹   532 mm y⁻¹

821 mm y⁻¹   719 mm y⁻¹

102 mm y⁻¹   289 mm y⁻¹   groundwater table

Cluster C

Catchment-scale measuring and integrated modeling of exchange processes

•Monitored 3D soil moisture distribution successfully modeled and related to soil structure

•Soil moisture is retrieved from satellites and used to initialize SVAT-models

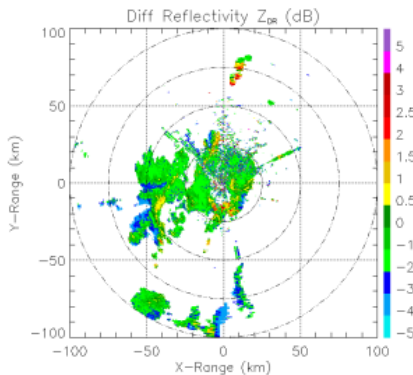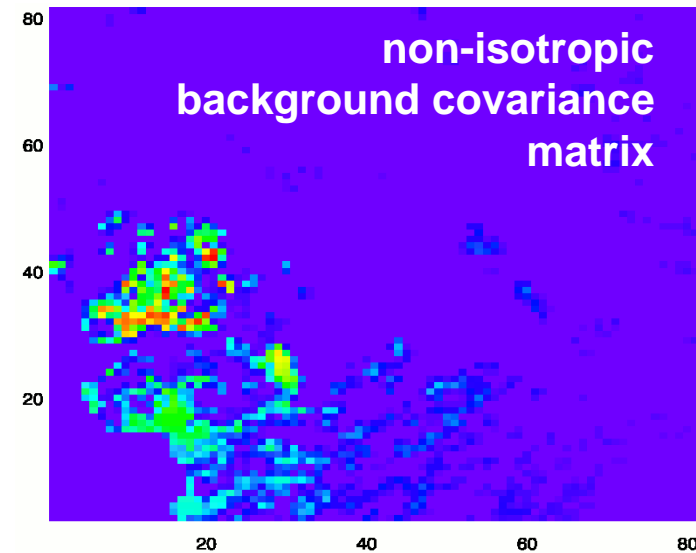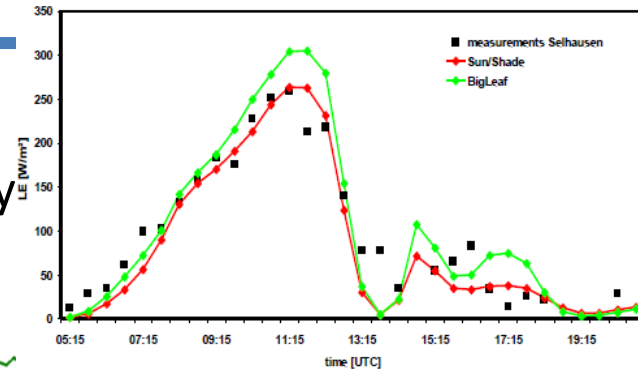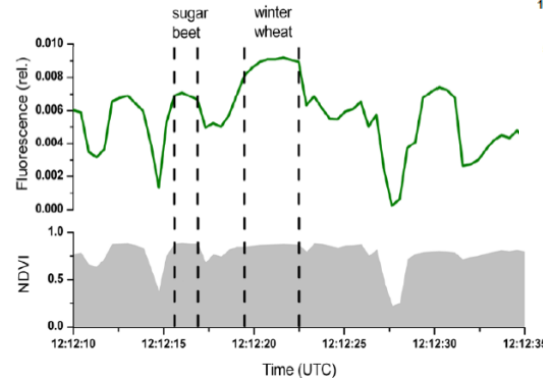•sub-scale atmospheric patterns in integrated model.

Cluster D

Atmospheric boundary-layer

- Modelling and measuring of boundary-lay
  H_2O covariances

- Plant state from
  sun-induced fluorescence

- 4DVar data assimilation now possible in CLM

- New radar retrieves rain in melting layer

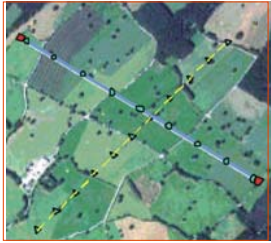non-isotropic
background covariance
matrix
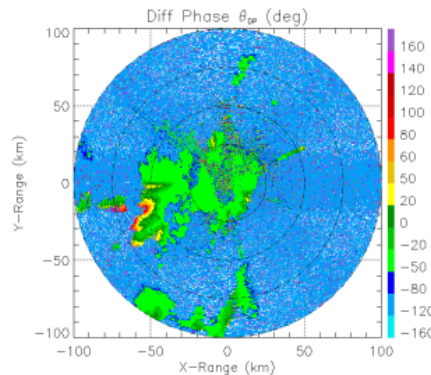
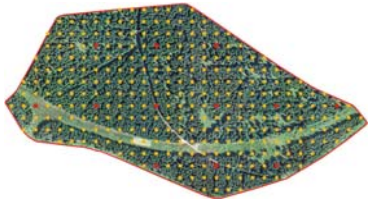# The Rur catchment and its measurement infrastructure

Cooperation with

TERENO
TERRESTRIAL ENVIRONMENTAL OBSERVATORIES
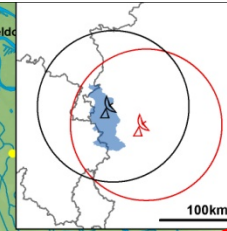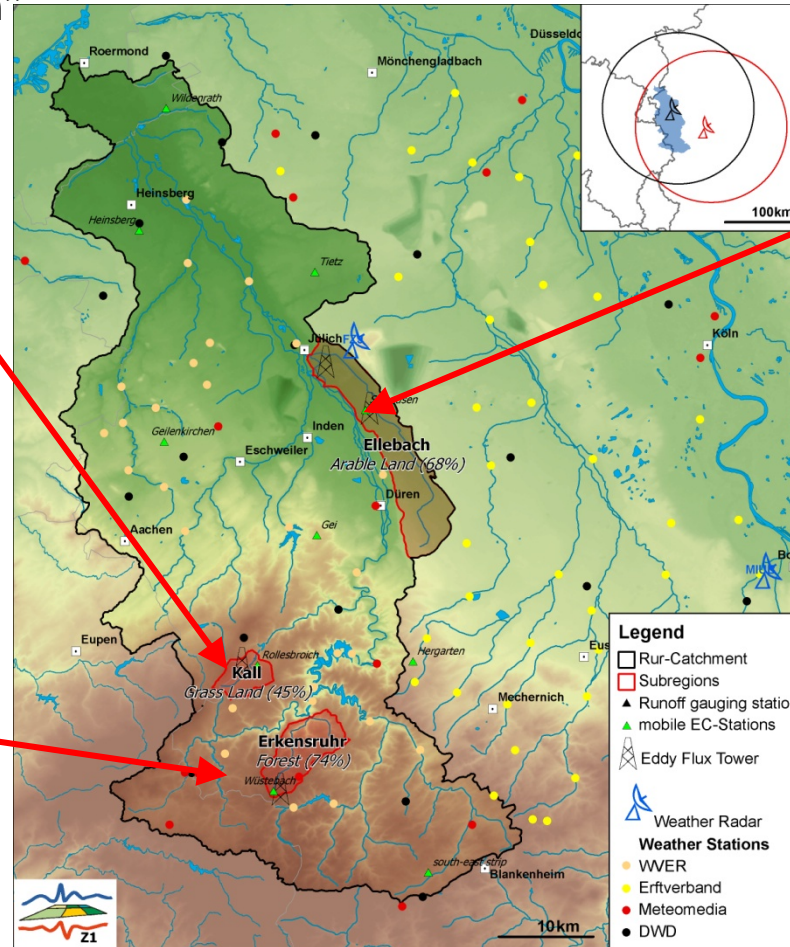
Testgebiet "Rollesbroich"

- Eddy Correlation Station
- Soil moisture measurements
- Soil CO_2 flux measurements

Testgebiet "Wüstebach"

- Eddy Correlation Station
- soil moisture sensor network
- groundwater monitoring
- Discharge and solute concentration
- Soil-CO_2 flux measurements
- Cosmic Ray network

Testgebiet "Selhausen"

- Airborne
  - MetAir Dimona
  - small remote planes
- Captive ballons
- Ground remote sensing
  - active/passive micro waves
  - Lidar, Szintillometer etc.
- Eddy Correl. & profile stations
- Soil CO_2 flux measurements
- Soil moisture measurements

Legend
- ▢ Rur-Catchment
- ▢ Subregions
- ▲ Runoff gauging station
- ▲ mobile EC-Stations
- ▨ Eddy Flux Tower
- ▷ Weather Radar

Weather Stations
- ● WVER
- ● Erftverband
- ● Meteomedia
- ● DWD

# Identification of **atmospheric patterns** on long term

Synergy of different sensors for the validation of TR32 models and indirectly conclude on flux processes.

- **Atmospheric Emitted Radiance Interferometer AERI** (cloud droplet size, cloud optical thickness, T & H profile)
- **Ceilometer** (altitude of cloud, aerosol layer)
- **Wolkenradar MIRA** (cloud thickness & structure)
- **Infrarot Pyrometer** (cloud detection, cloud base temperature)
- **Mikrowellenradiometer HATPRO** (T, H profile, liquid water content of cloud)
- **Mikro Regen Radar MRR** (droplet spectrum, rain rate)
- **Sodar** (wind vector up to 400 m)
- **Total Sky Imager TSI** (cloud cover, cloud thickness)
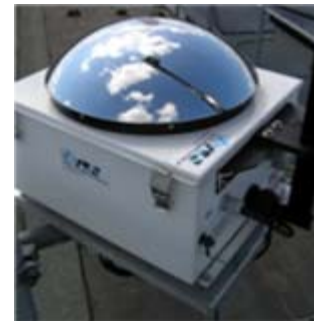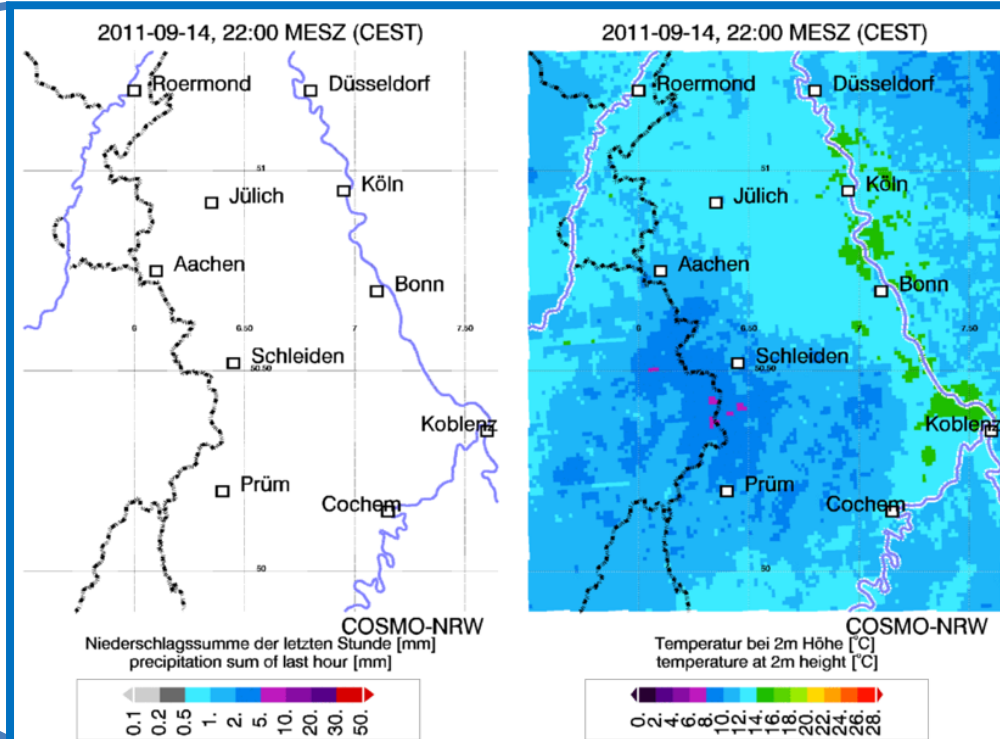
Coordinated Modeling strategy
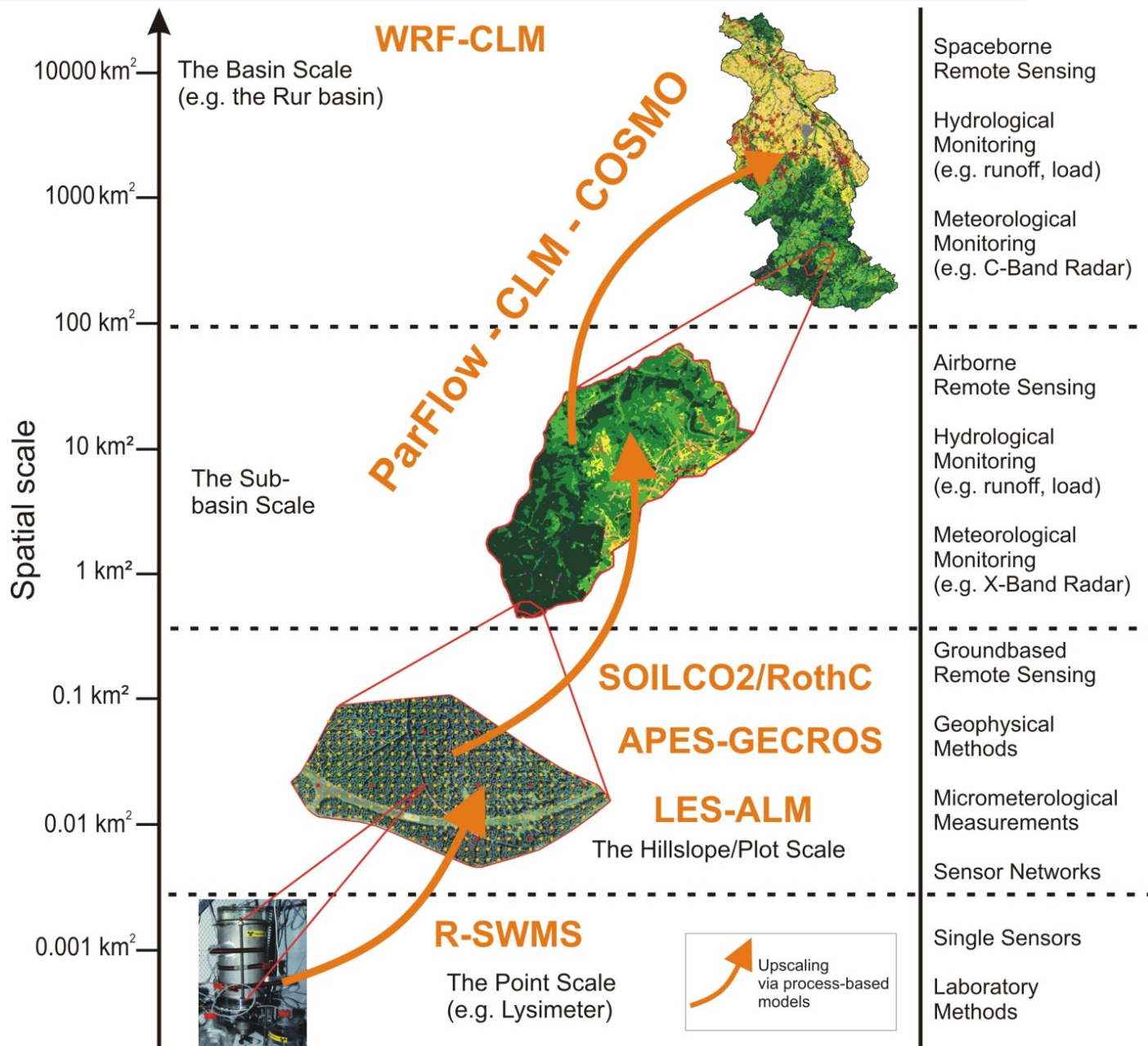
COSMO-NRW

„Operational" **COSMO model run,**
over NRW region, Germany
**Grid: dx = 1 km**
21 hour forecast

Integrated, parallel simulation platform ParFlow-CLM

- **3D** variably saturated subsurface **flow** and E transport (Jones & Woodward, 2001; Kollet et al., 2009)

- Integrated **land surface** and also atmospheric model (e.g., Kollet & Maxwell, 2008)

- Integrated **overland flow** (Kollet & Maxwell, 2006; Maxwell & Kollet, 2008; Frei et al., 2009)

- Efficient multigrid **linear and nonlinear solvers**

- **Parallel**; **designed for HPC** which enables large-scale, high-resolution simulations
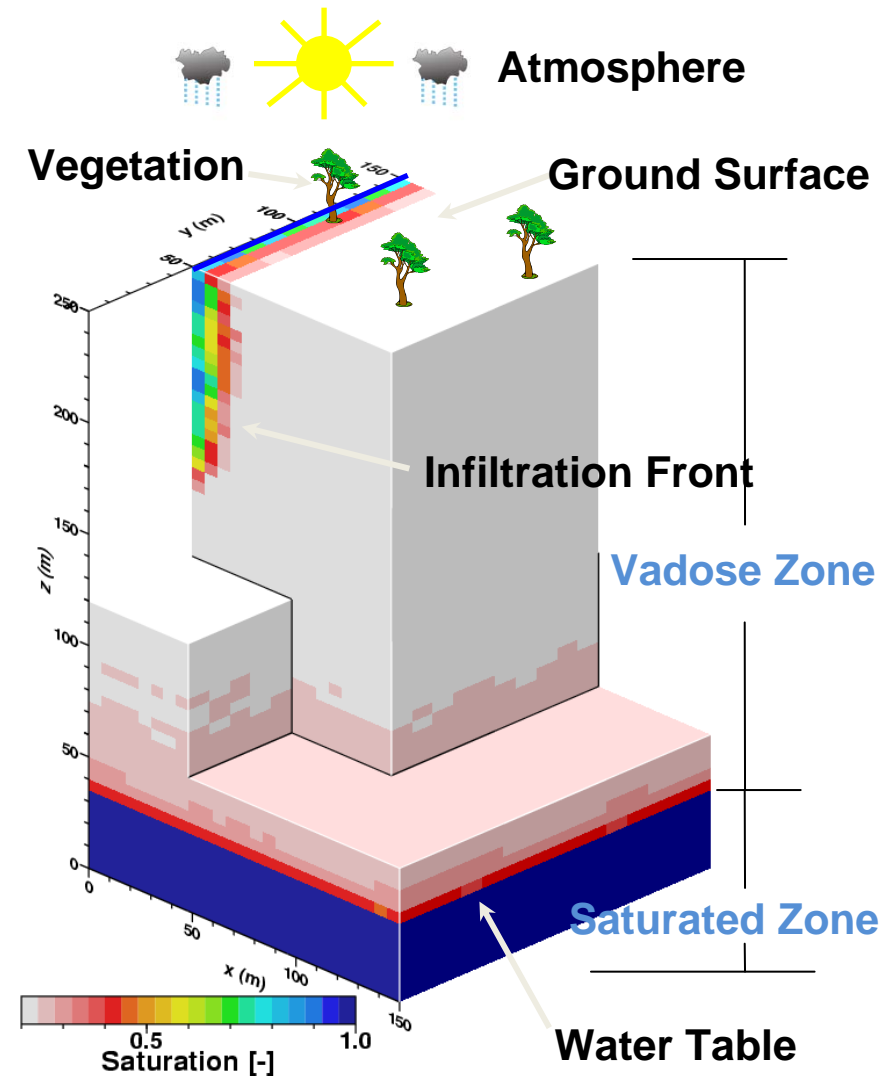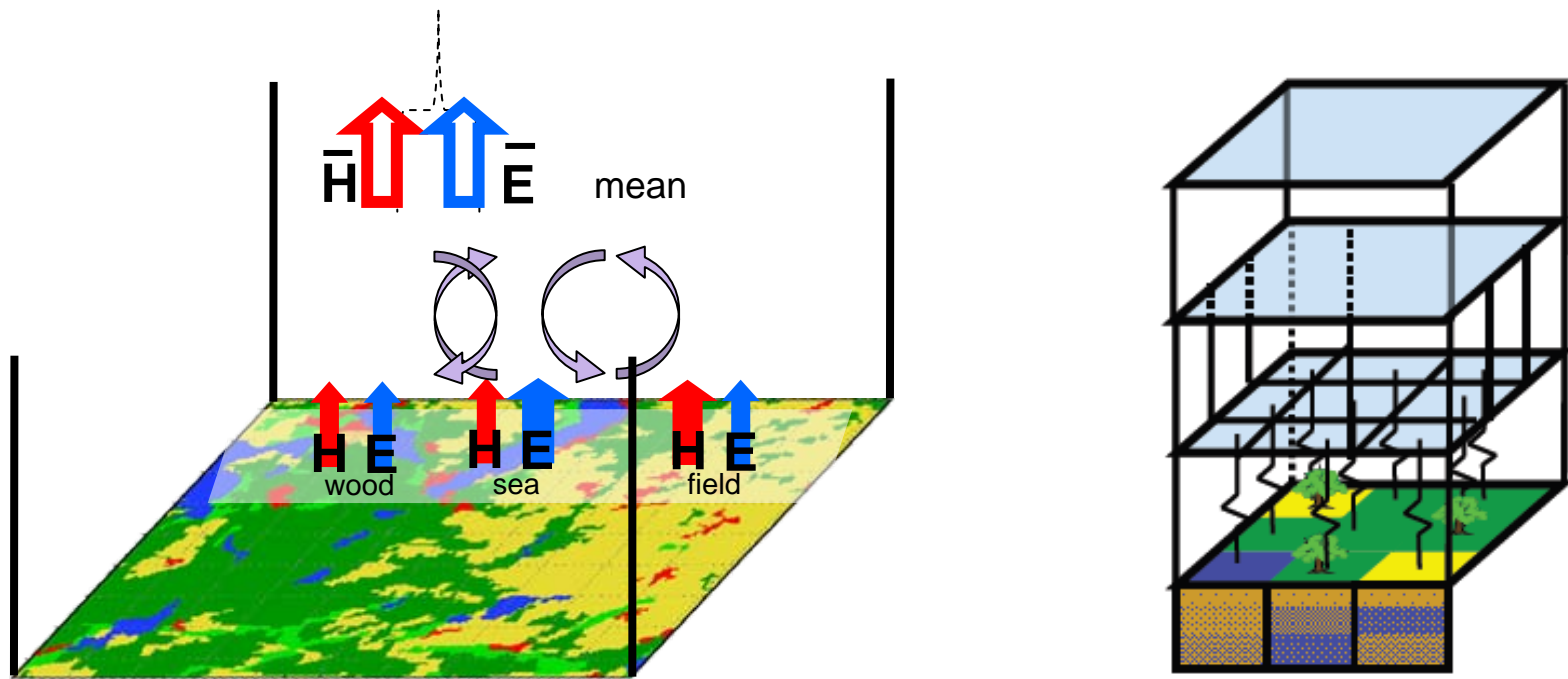
Increasing resolution results in more realistic soil moisture fields: Little Washita, OK, USA

1km

350m

~1500km²
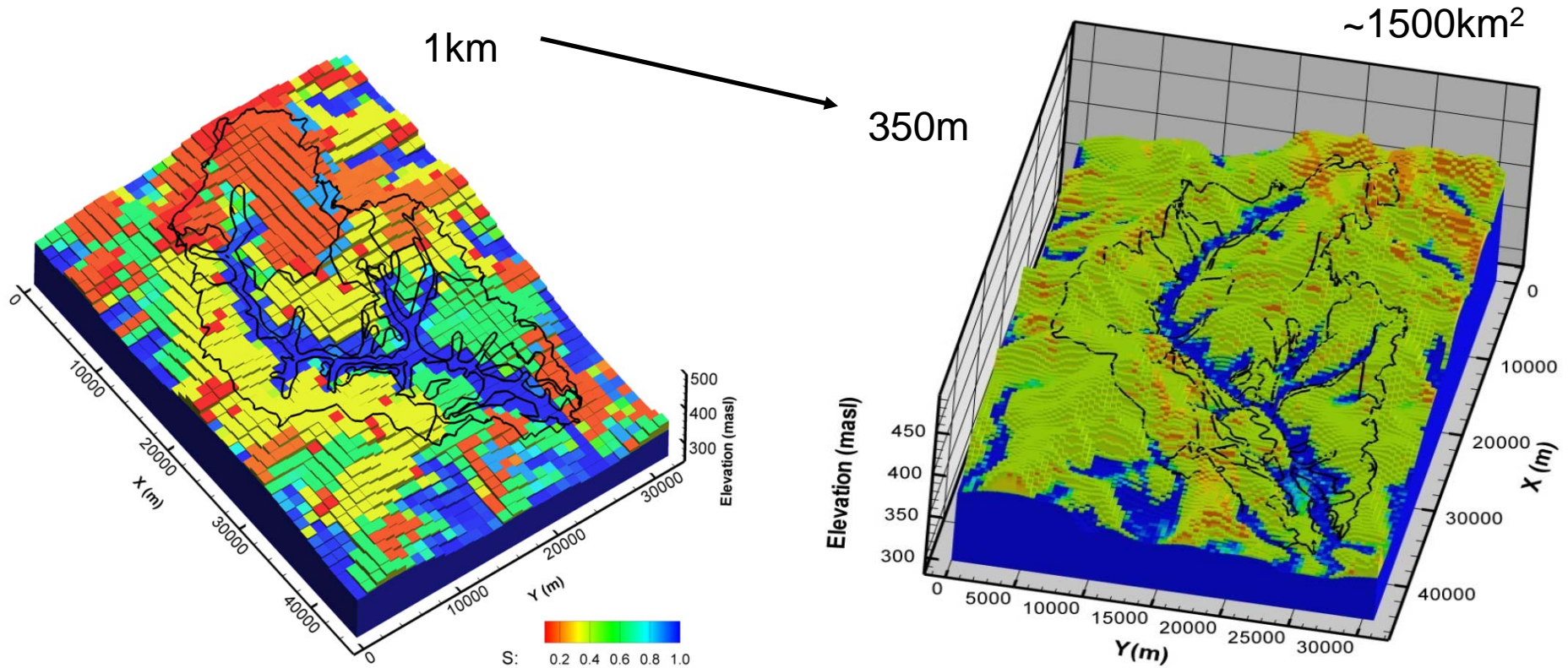
Kollet & Maxwell, WRR (2008)

Scale consistent two-way coupling of land surface and atmosphere

- Aggregation effects because of simplified averaging laws
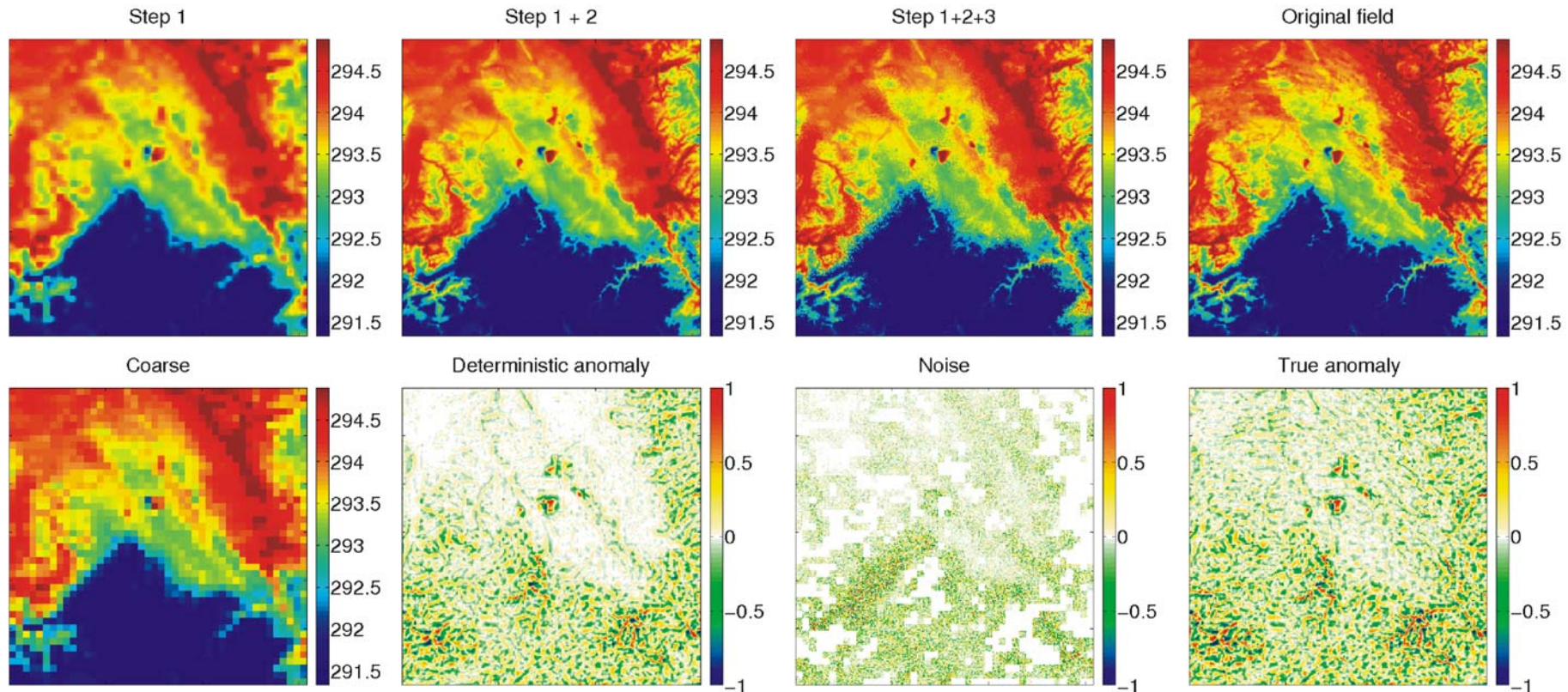- Dynamic effects because of induced atmospheric circulation

(Schomburg et al. 2010)

Downscaling of atmospheric variables

- Spline smoothing of the field
- Deterministic downscaling based on various rules (topography, land use)
- Addition of spatially correlated (structured) noise
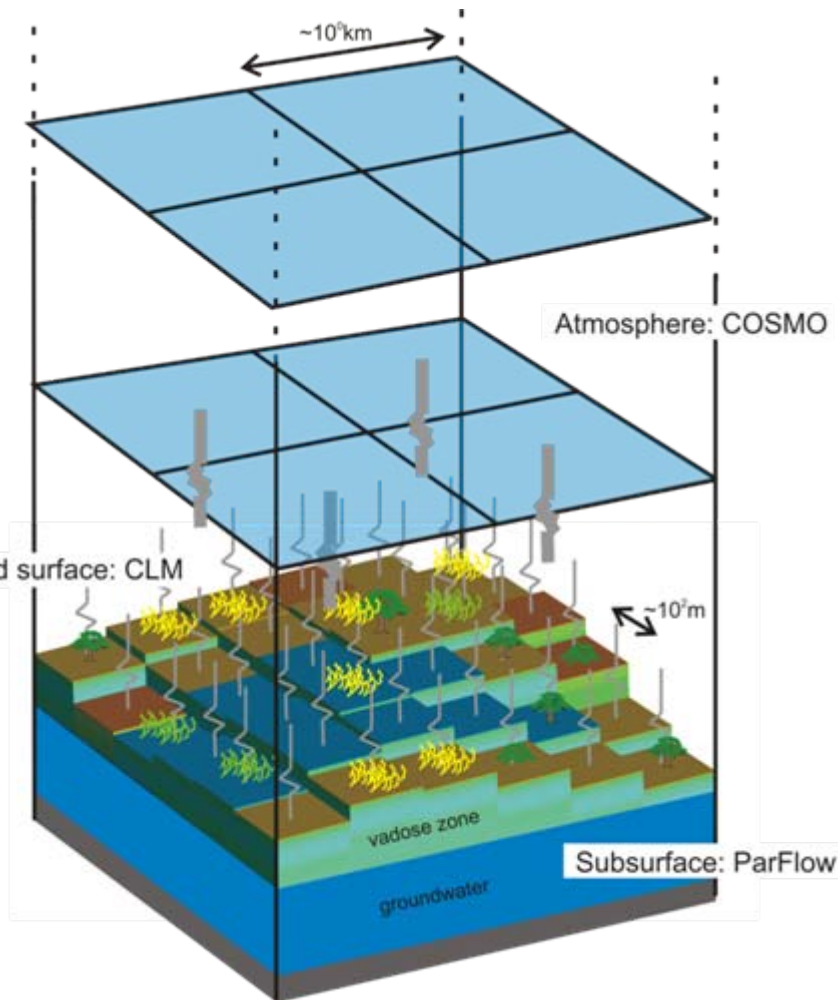
(Schomburg et al. 2010, 2011)

COSMO-CLM-ParFlow Coupling

~10^0km

Atmosphere: COSMO

Land surface: CLM

~10^2m

vadose zone

Subsurface: ParFlow

groundwater

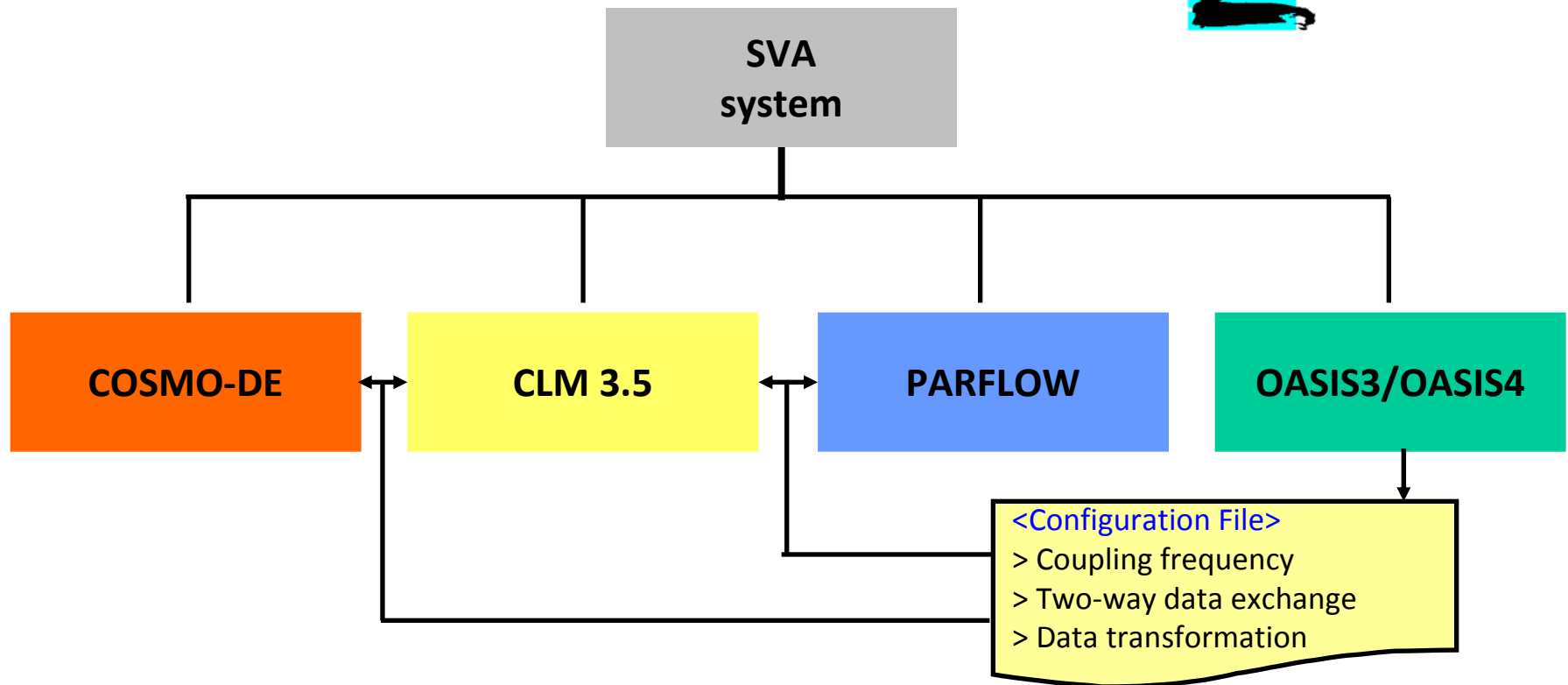**COSMO-CLM interactions**, regulated

by a **coupler** including:

• Mosaic approach

• Deterministic downscaling (topography, pressure)

• CO_2 Fluxes (soil respiration, soil storage)

• etc…

In order to **include Structures and patterns influences**

With OASIS Coupler – cooperation with CERFACS IACETH

```
                        ┌──────────────┐
                        │     SVA      │
                        │    system    │
                        └──────────────┘
                               │
        ┌──────────────┬───────┴───────┬──────────────┐
┌────────────┐  ┌────────────┐  ┌────────────┐  ┌────────────────┐
│  COSMO-DE  │◄►│   CLM 3.5  │◄►│  PARFLOW   │  │  OASIS3/OASIS4 │
└────────────┘  └────────────┘  └────────────┘  └────────────────┘
```

<Configuration File>
> Coupling frequency
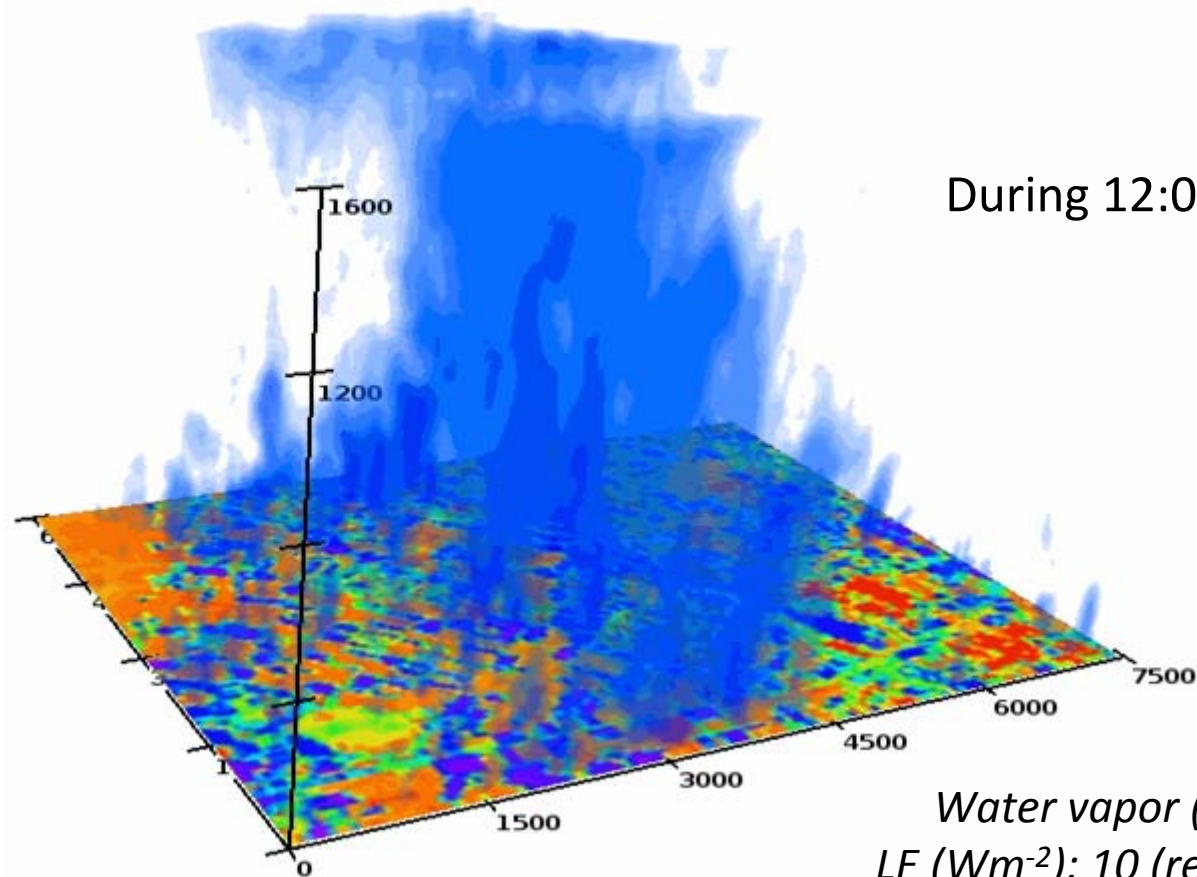> Two-way data exchange
> Data transformation

- **Modular modeling platform** of the complete SVA system.

- **separate executable**: OASIS3/OASIS4 coupler.

- OASIS3/OASIS4 coupler **less intrusive** (calls implemented for init and data transfer).

- **Easier to maintain updated version** of SVA system.
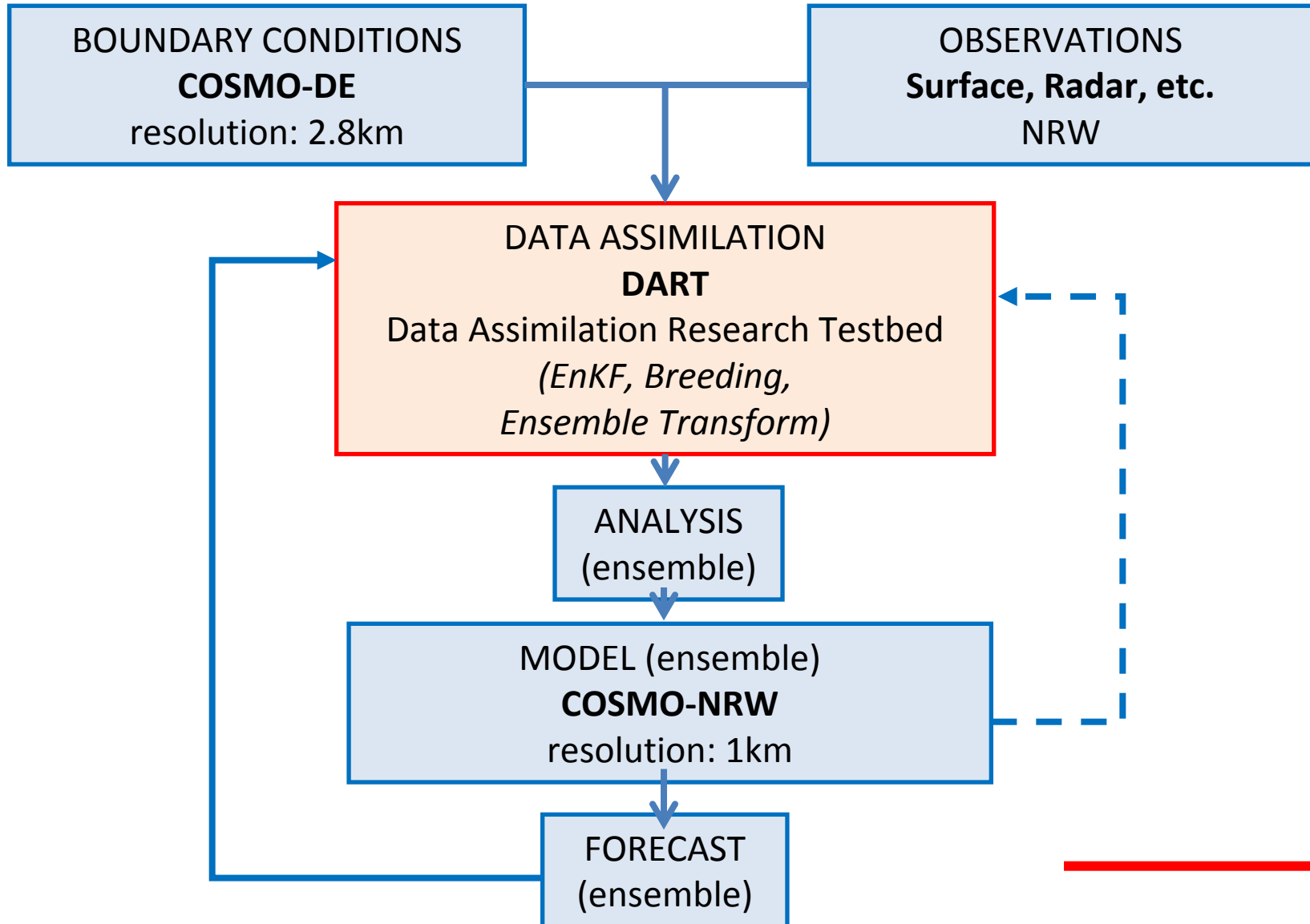
Bridge the scale gaps with...

fully coupled land surface-LES model LES-ALM
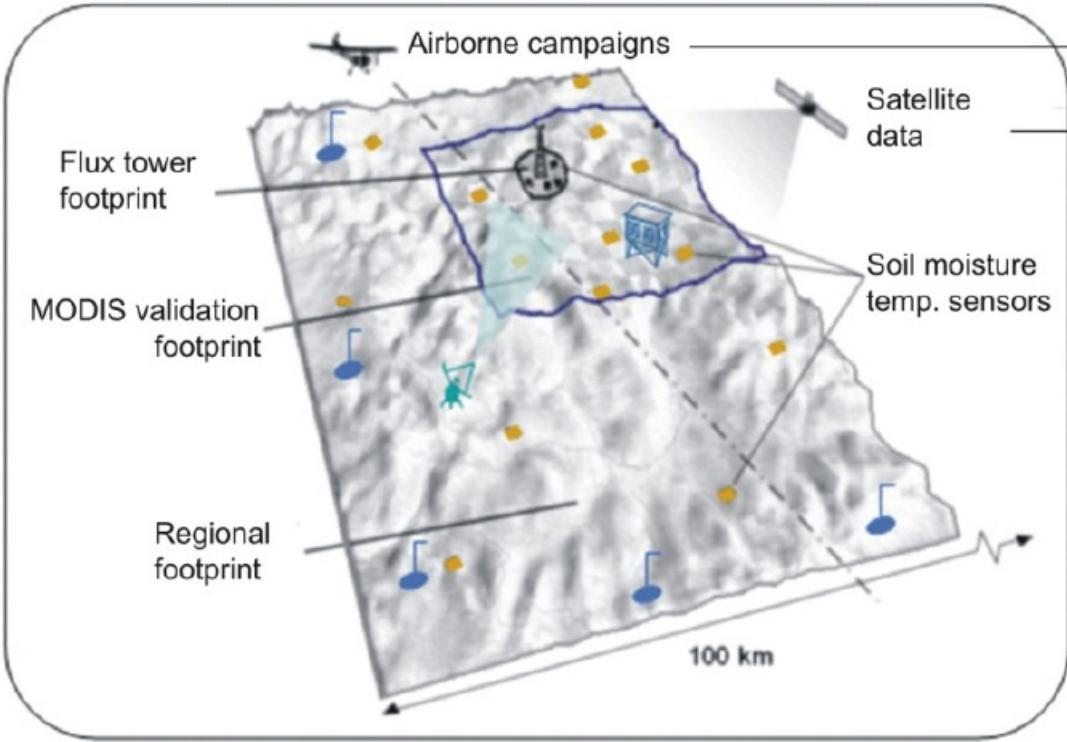with SW/LW radiation schemes & canopy model.

During 12:00 ~ 12:02

Water vapor (g/kg): 6 ~ 7
LE (Wm⁻²): 10 (red) ~ 300 (blue)

Data Assimilation with COSMO-DART

Data Assimilation & Inverse modelling with CLM-PF

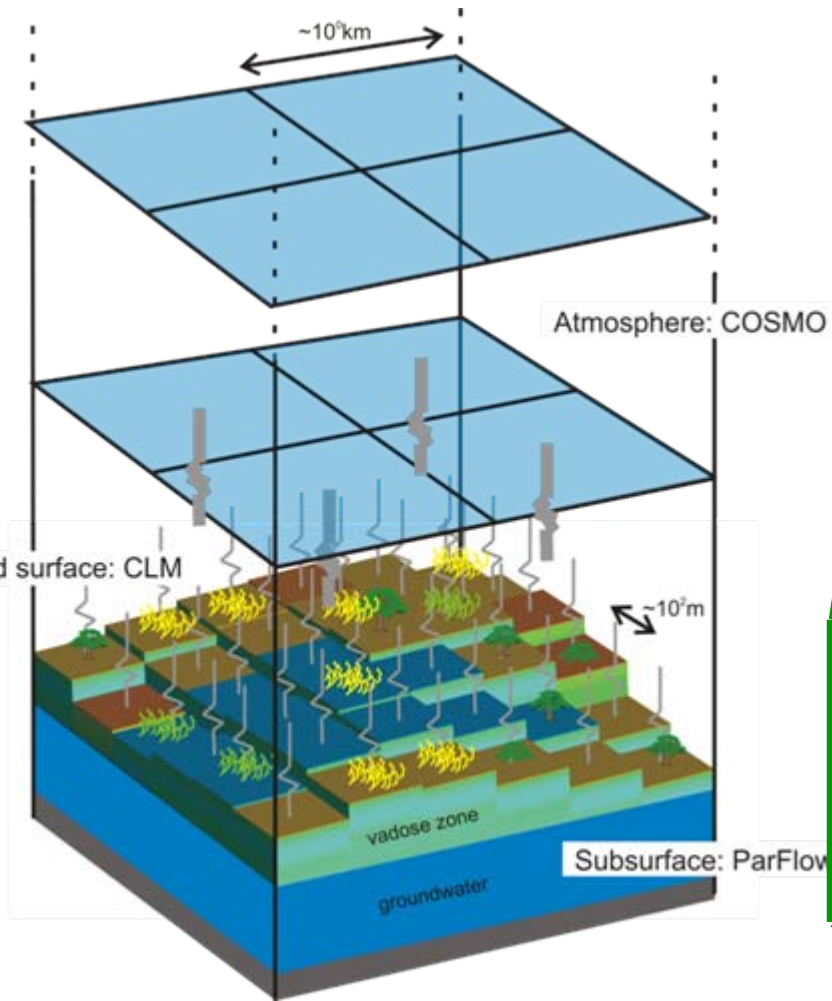# Improvements of CLM parameterizations

- Implement **Additional PFT** (forest,…)

- Time dependent **plant physiological parameters** (crop modelling)

- **Root** parameterisation

- New parameterisation of **soil evaporation**

- Parameterisation of **soil hydraulic** & **vegetation** properties

Summary and Outlook

- TR32 focuses on **exchange soil-atmosphere** for momentum, moisture, energy and CO_2…

    … at all scales

- TR32 **cumulates expertise** in hydrology, crop system processes, soil physics, meteorology and land surface interactions

- TR32 develops a **model suite - COSMO-CLM-ParFlow** – in order to centralize the improvements of soil-atmosphere exchange within the project.

- TR32 has a **coordinated** technical **support for instruments** and data **quality control** and processing

    …sustainable issue for the scientific community

- Further information:

    www.tr32.de