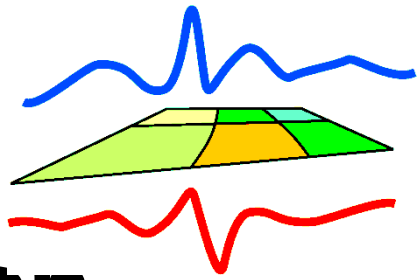


Patterns in Soil-Vegetation-Atmosphere Systems

Monitoring, Modelling & Data Assimilation

M. Masbou [1], C. Simmer [1], S. Kollet [1], S. Crewell [2], B. Diekrüger [3], N. Klitzch [4], A. Schomburg[5], V. Venema[1] , H. Vereecken [6] & TR32 Team.

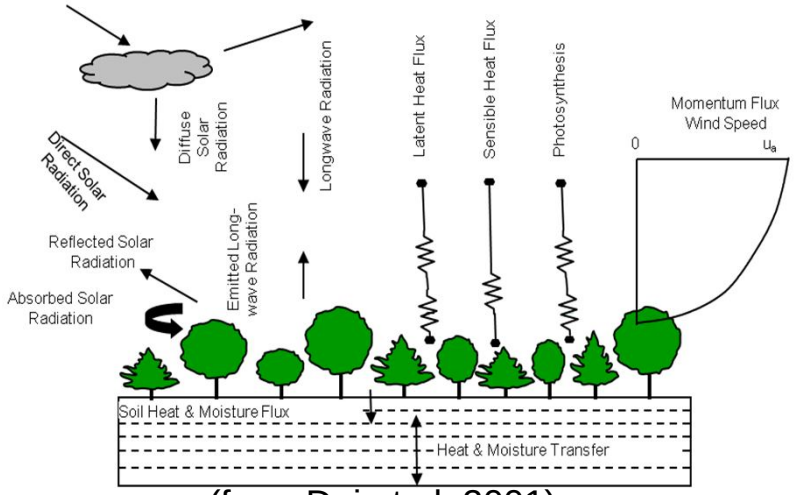
[1] Meteorological Institute, University of Bonn, Germany
[2] Institute for Geophysics and Meteorology, University of Cologne, Germany
[3] Geographical Insitute, University of Bonn, Germany
[4] E.ON Research Center, RWTH Aachen, Germany
[5] German Meteorological Service, Offenbach, Germany
[6] Institute for Bio- and Geosciences, Agrosphere, Research Center Jülich, Germany

universitätbonn

RWTH AACHEN

Significance

- The **land surface** is a key component of the **climate system**
  - Radiation exchange and transformation
  - Carbon exchange and storage
  - Moisture exchange and storage
  - Heat exchange and storage
  - Momentum exchange

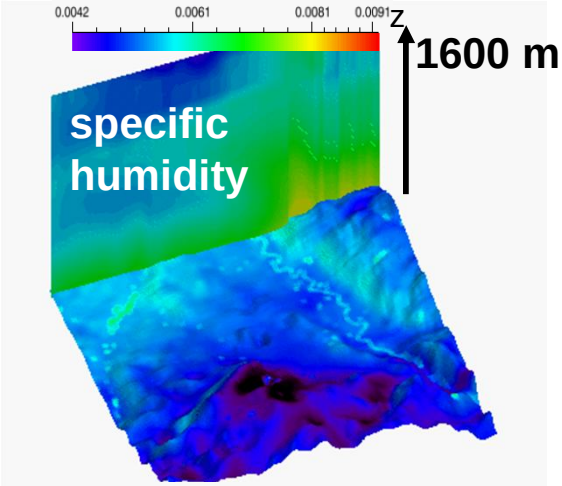


(from Dai et al. 2001)

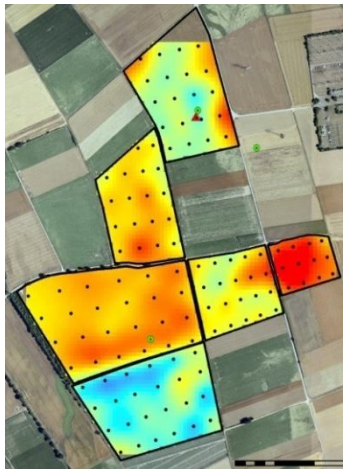
- **All processes are coupled** via common state variables and via the balance equations for energy, mass and momentum.

- Thermodynamics requires that the land surface **dissipates the incoming energy** as efficiently as possible - and **at all scales...**

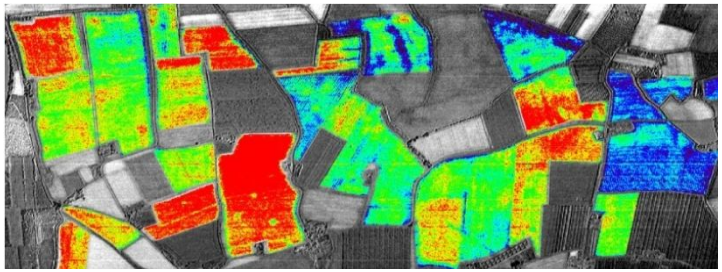
...resulting in patterns and structures



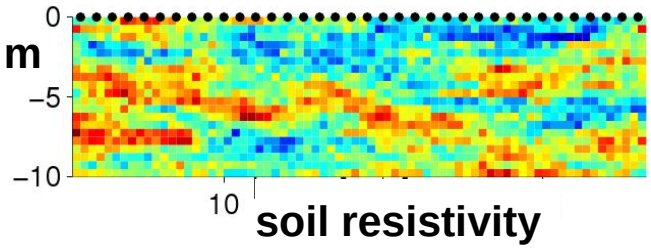
surface temperature



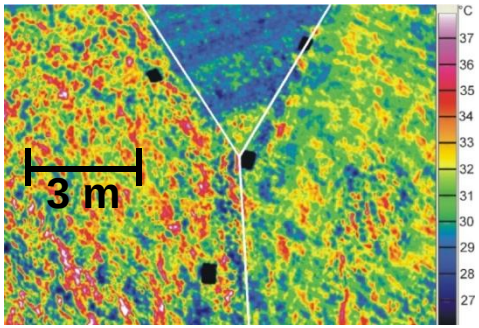
Soil moisture



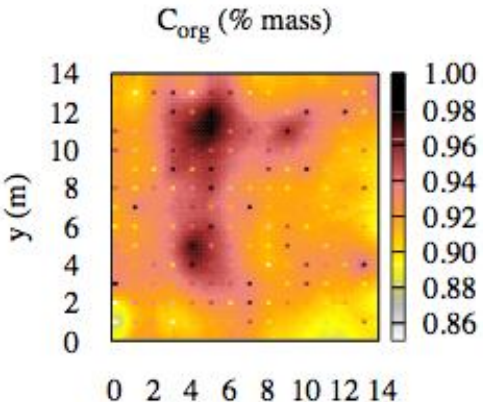
sun induced fluorescence



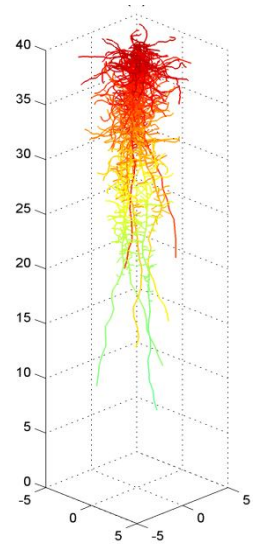
soil resistivity

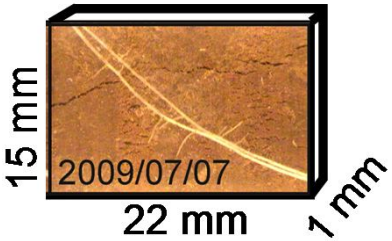


land surface temperature



% soil organic carbon





What is TR32 ?

- 2nd funding phase : **2011- 2014**
- **25 subprojects**, research groups in:
  soil and plant science, Remote sensing, Hydrology, Meteorology, Mathematics
- **5 Institutions:**
  Universities of Aachen, Bonn, Braunschweig, Cologne, Research Centre Julich

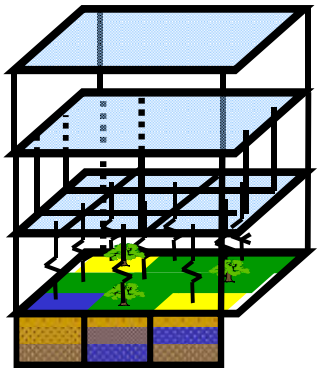
Goal:

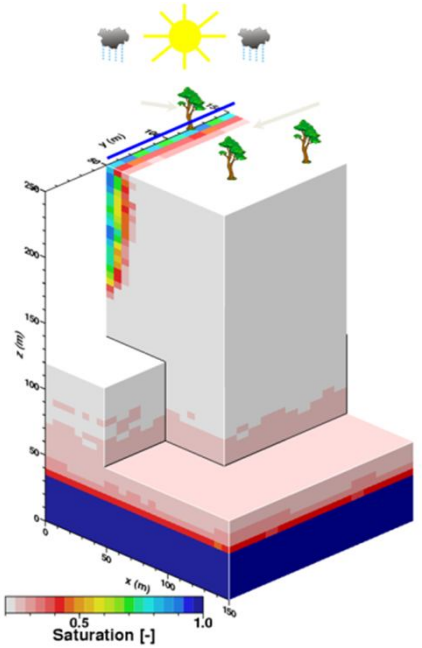
Understand the mechanims leading to **spatial and temporal patterns** in energy and matter fluxes of the **Soil-Vegetation-Atmosphere System.**

Specific Goals

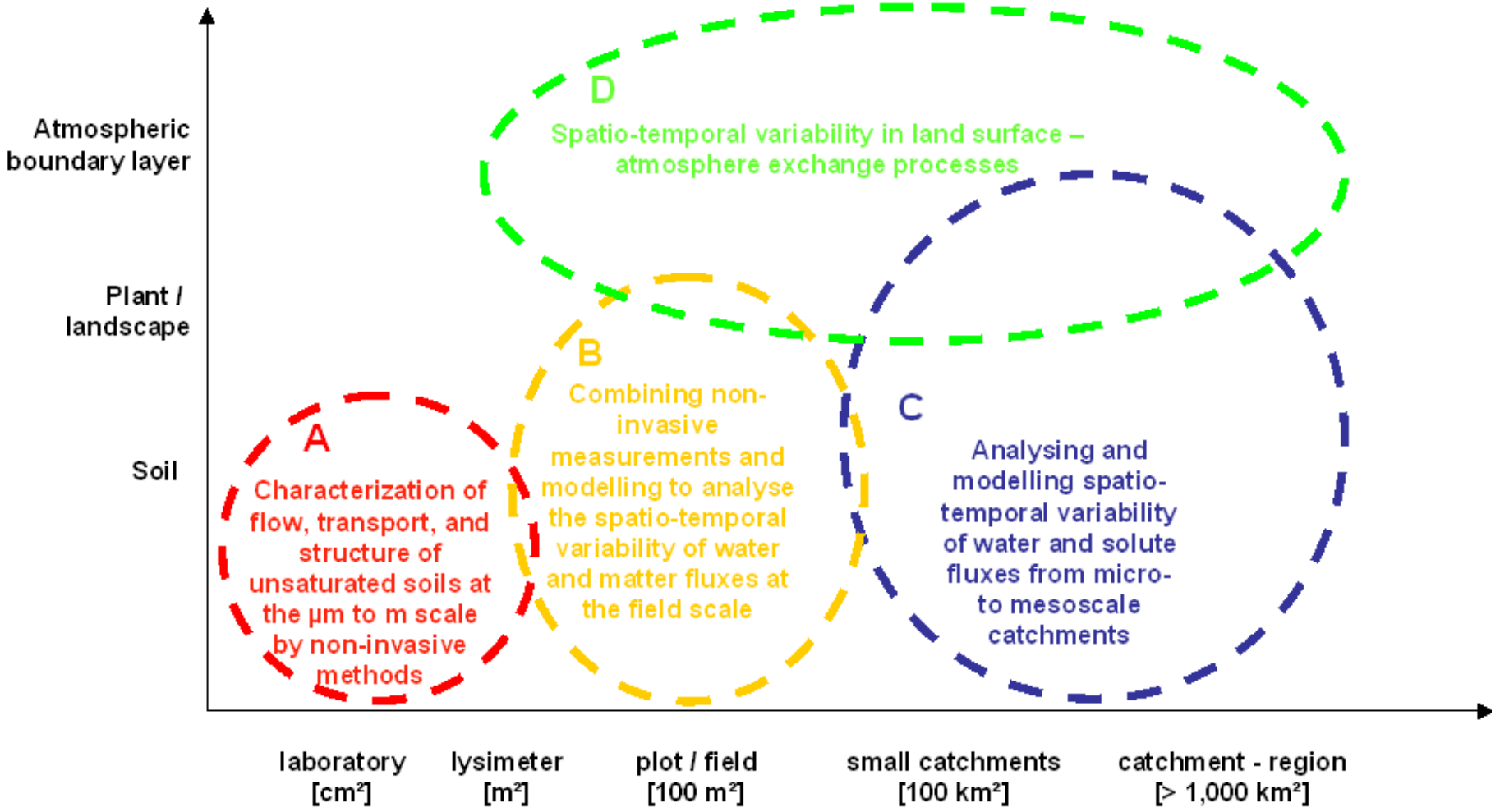
- Suitable **sensors/strategies for** SVA system

- **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**



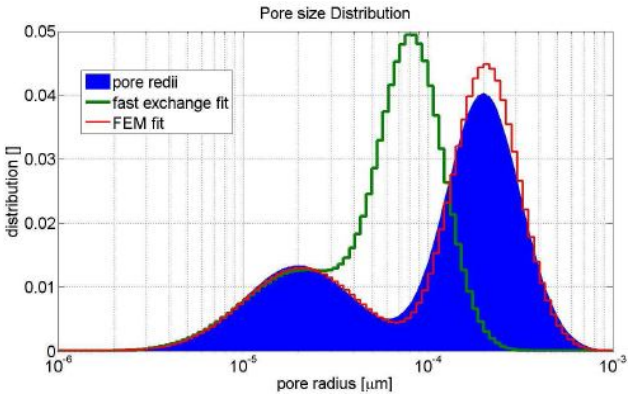


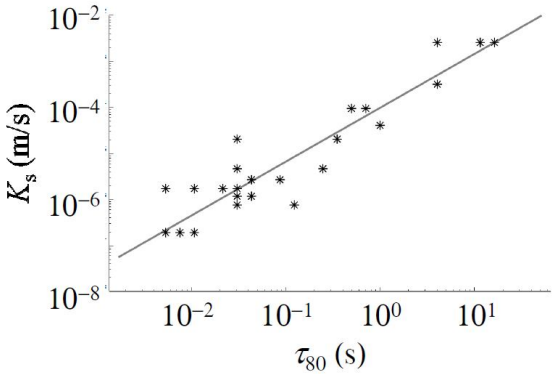
TR32 Organisational Structure



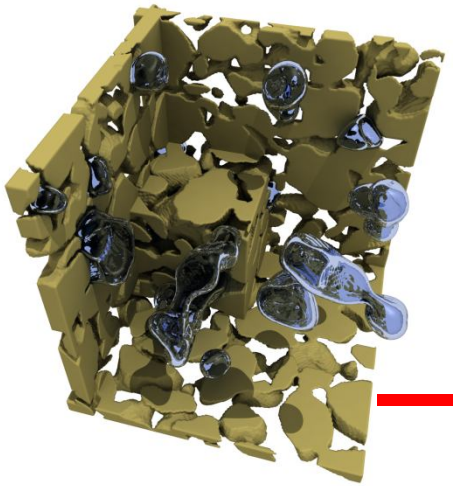
Cluster A

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





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



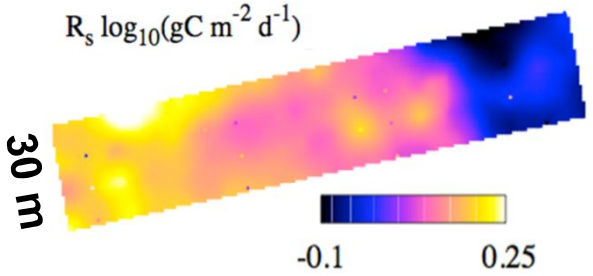
Pore's plant scale: Lattice Boltzmann simulation

evaporation of wetting fluid from a porous medium

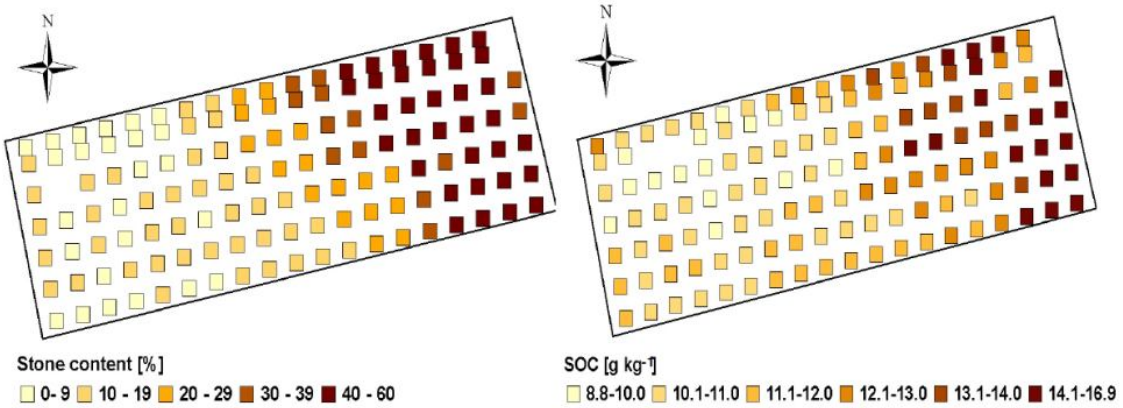
Cluster B

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

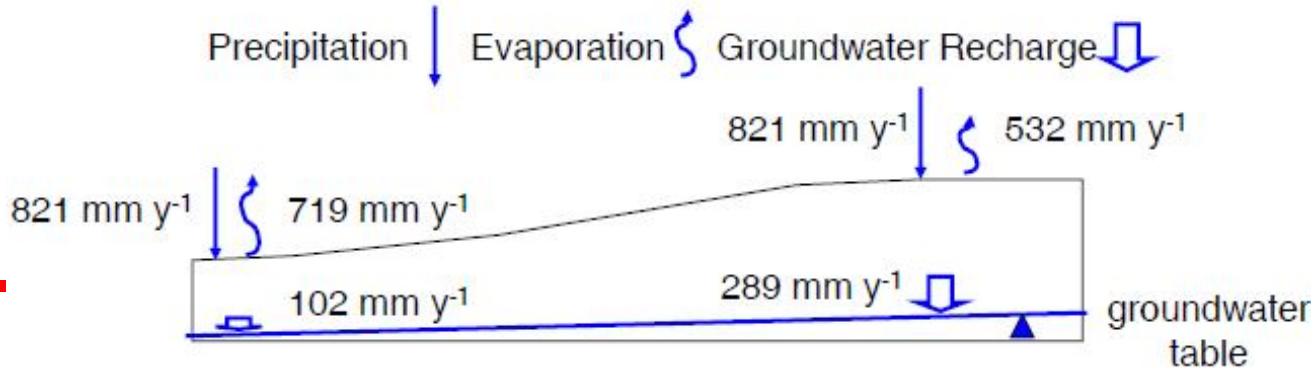
- soil respiration a function of soil moisture temperature



- carbon pools differentiated by MIRS and explained by soil structure

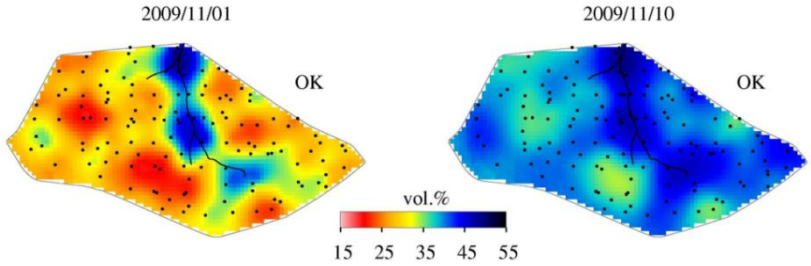


- Groundwater table influences bare soil evaporation.

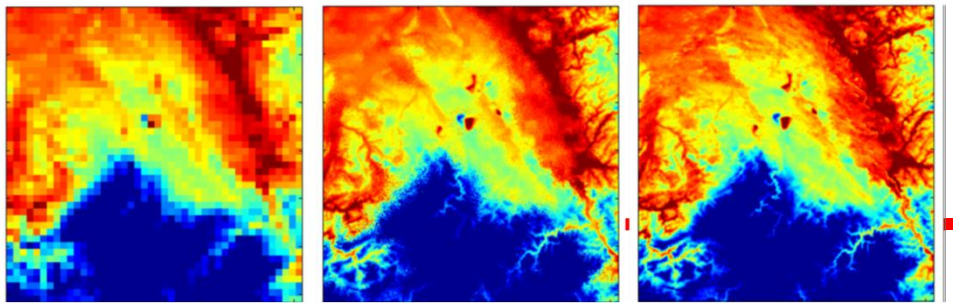


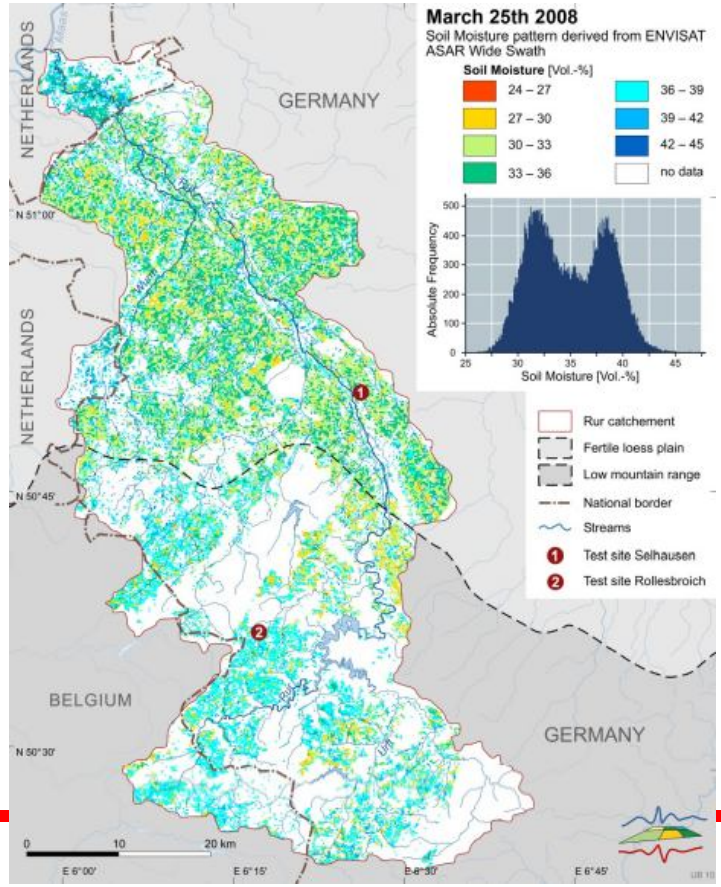
Cluster C

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.

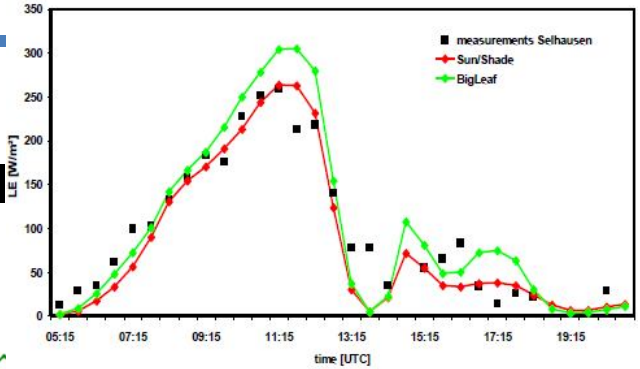




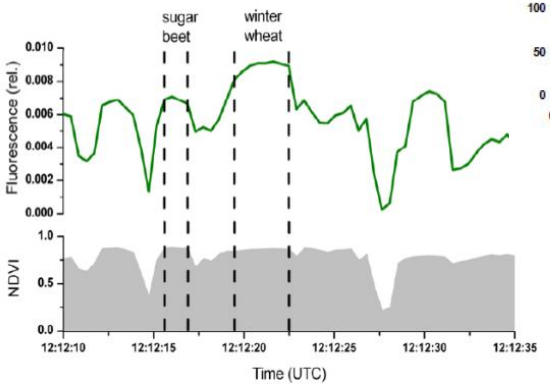
Cluster D

Atmospheric boundary-layer

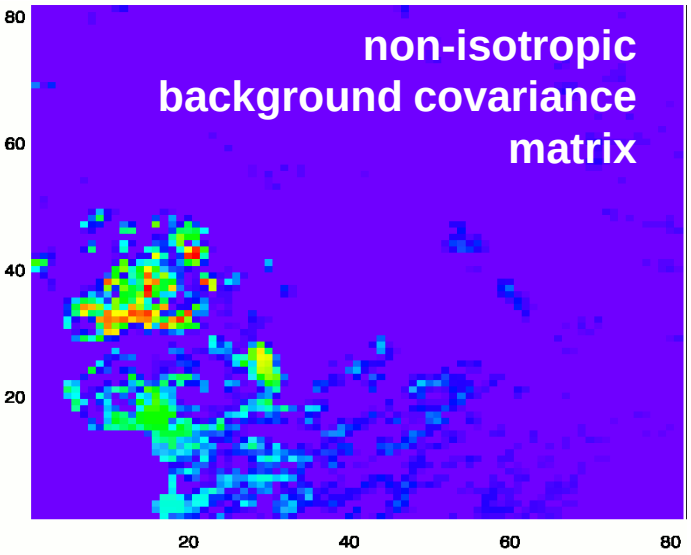
- Modelling and measuring of boundary CO_2-H_2O covariances



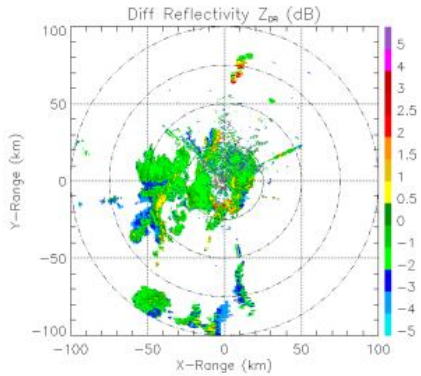
- Plant state from sun-induced fluorescence

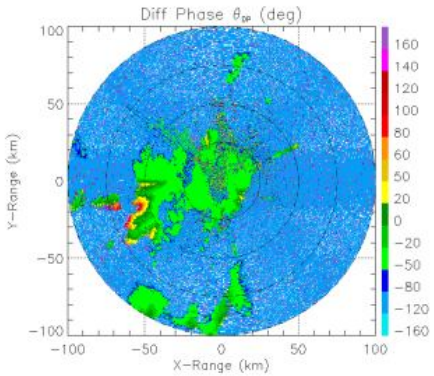


- 4DVar data assimilation now possible in CLM



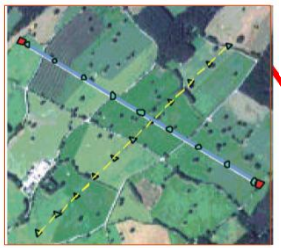
- New radar retrieves rain in melting layer





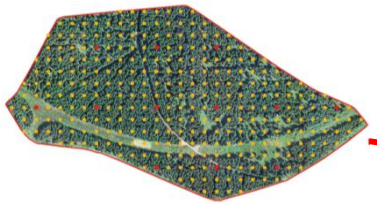
The Rur catchment and its measurement infrastructure

Testgebiet “Rollesbroich”

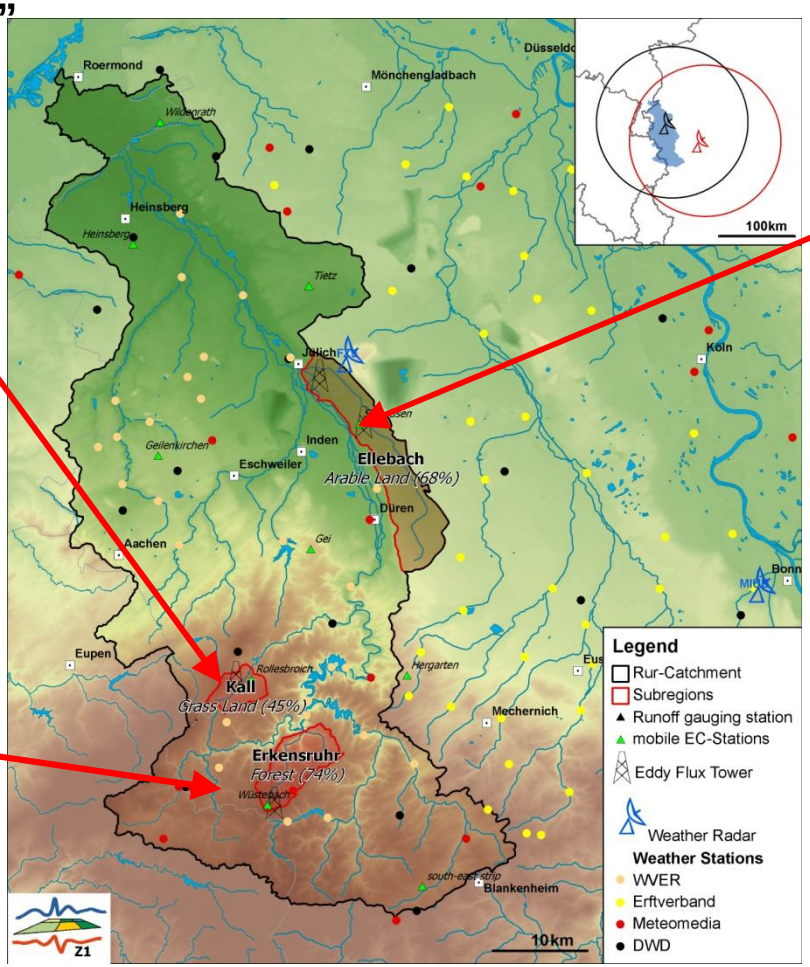


- Eddy Correlation Station
- Soil moisture measurements
- Soil CO_2 flux measurements

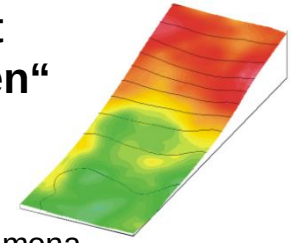
Testgebiet “Wüstebach”



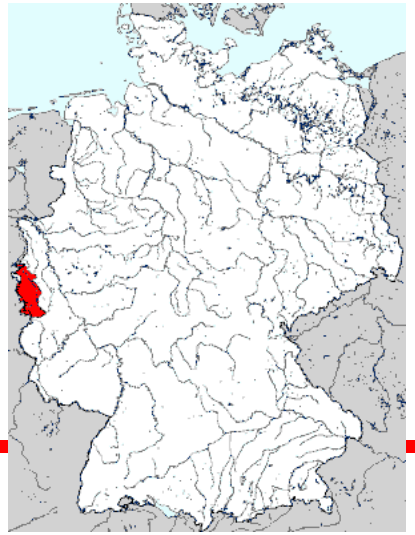
- Eddy Correlation Station
- soil moisture sensor network
- groundwater monitoring
- Discharge and solute concentration
- Soil-CO_2 flux measurements



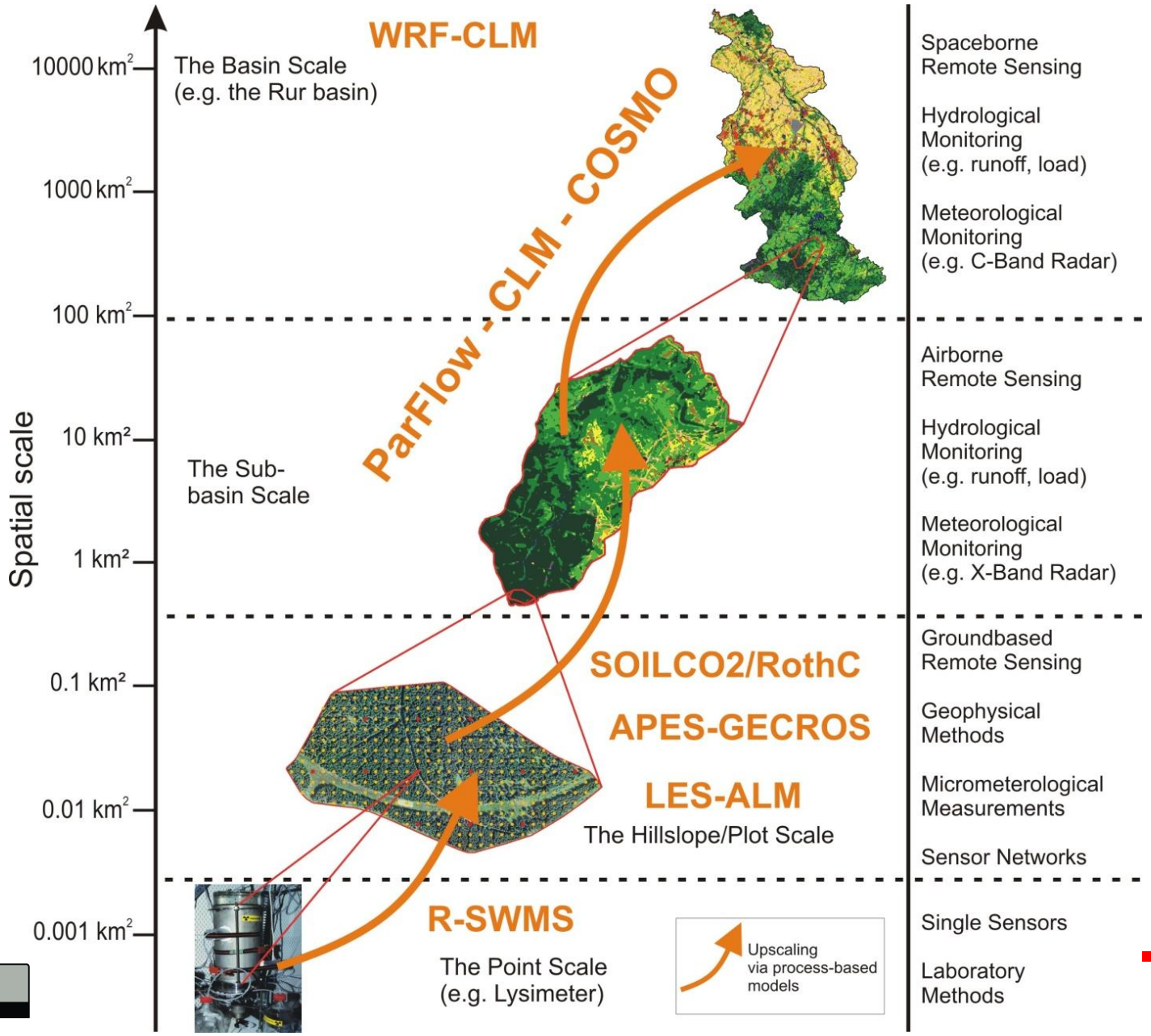
Testgebiet „Selhausen“



- 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

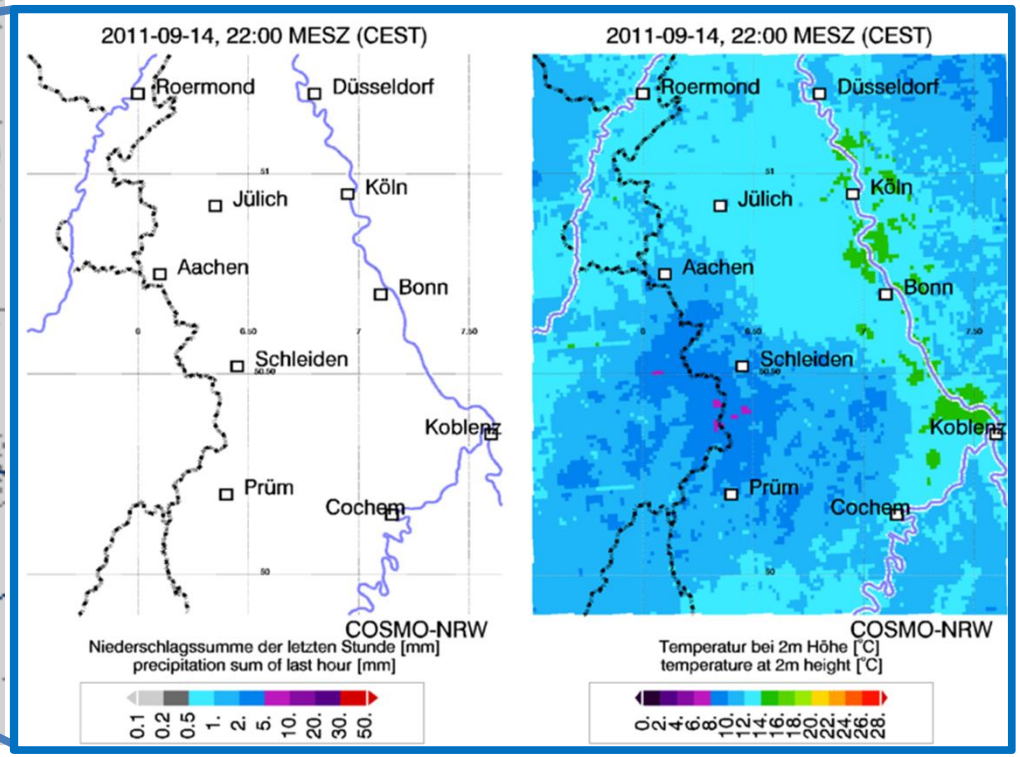


Coordinated Modeling strategy



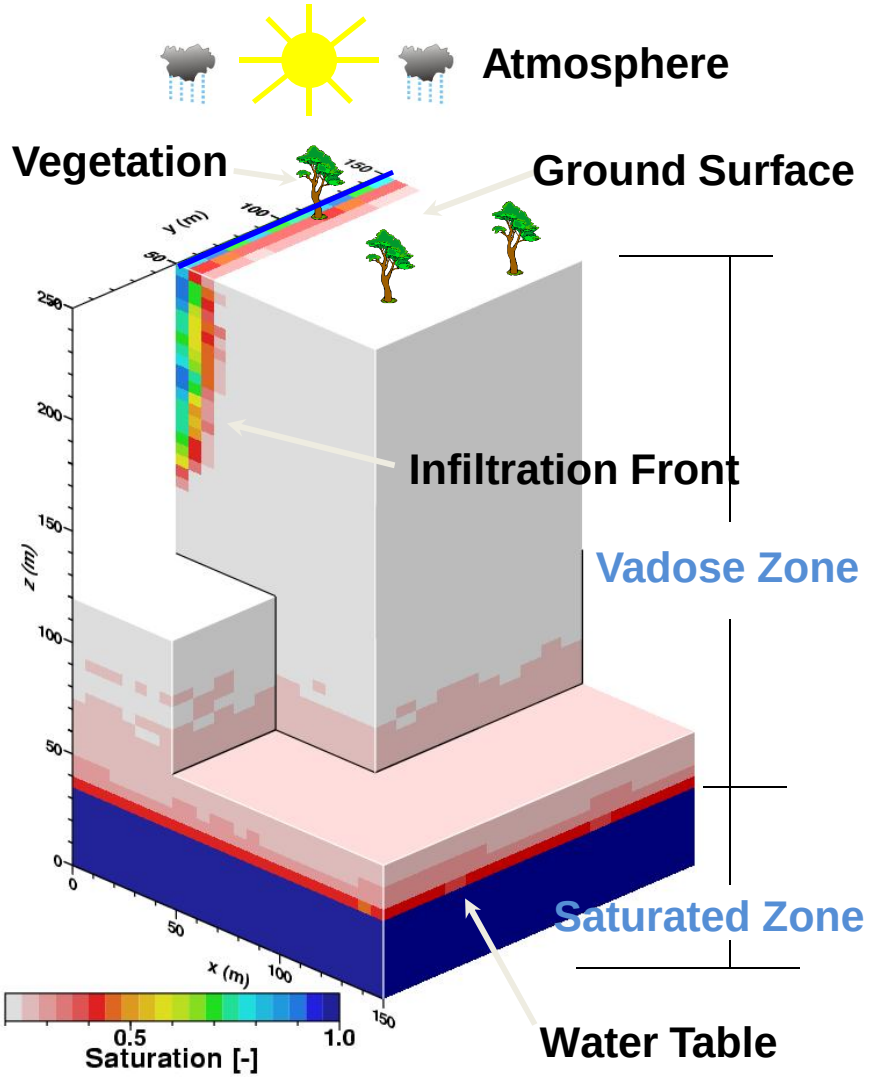
COSMO-NRW

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

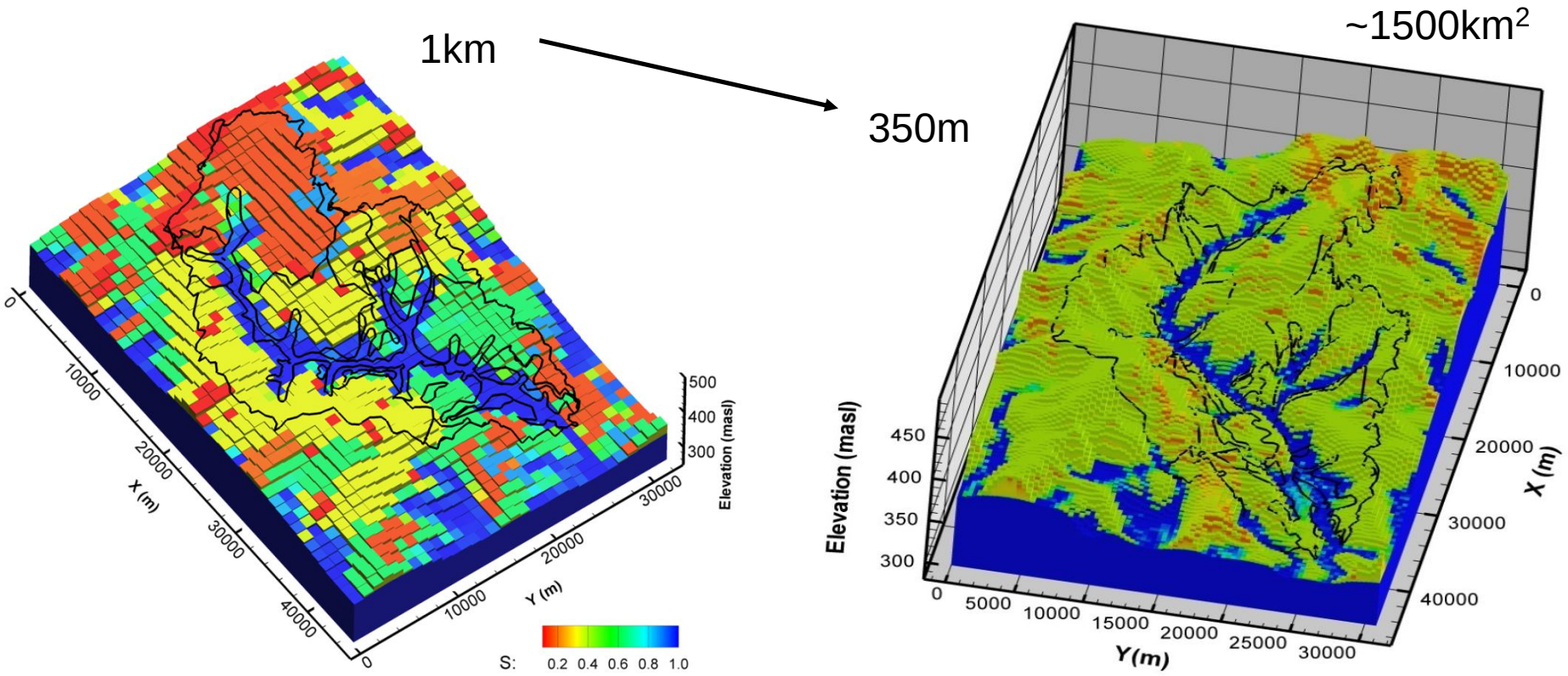


Integrated, parallel simulation platform ParFlow-CLM

- **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

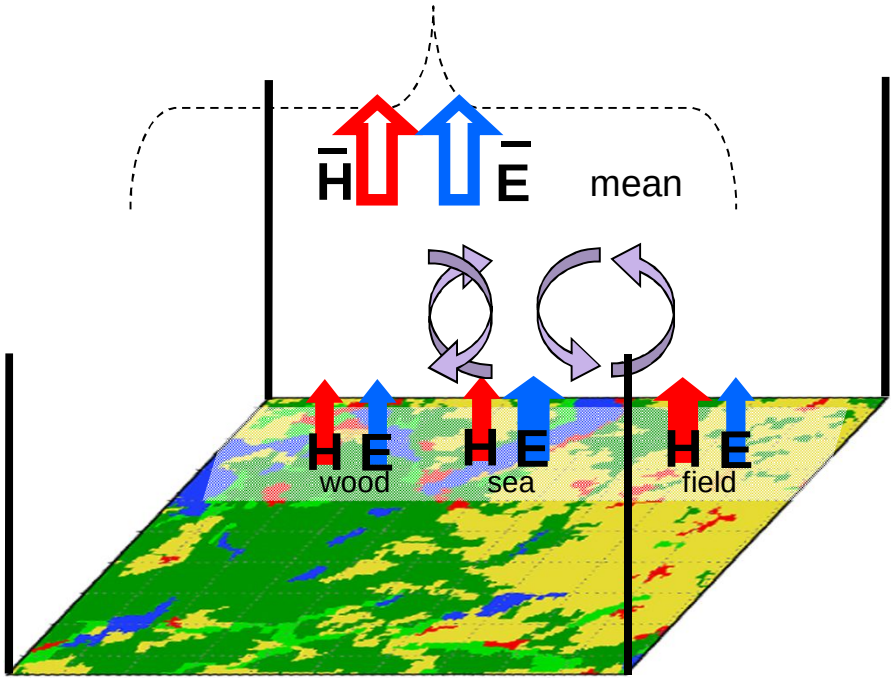


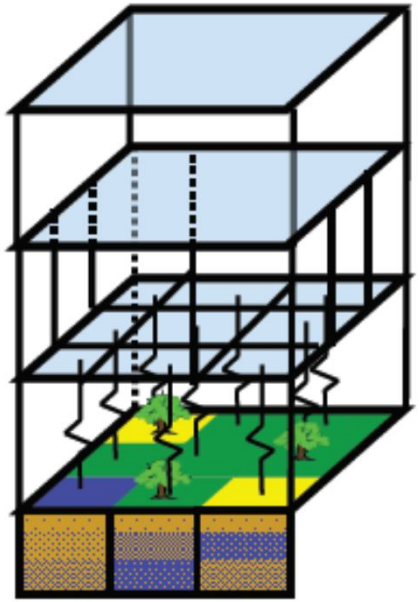
Increasing resolution results in more realistic soil moisture fields: Little Washita, OK, USA



Kollet & Maxwell, WRR (2008)

Scale consistent two-way coupling of land surface and atmosphere





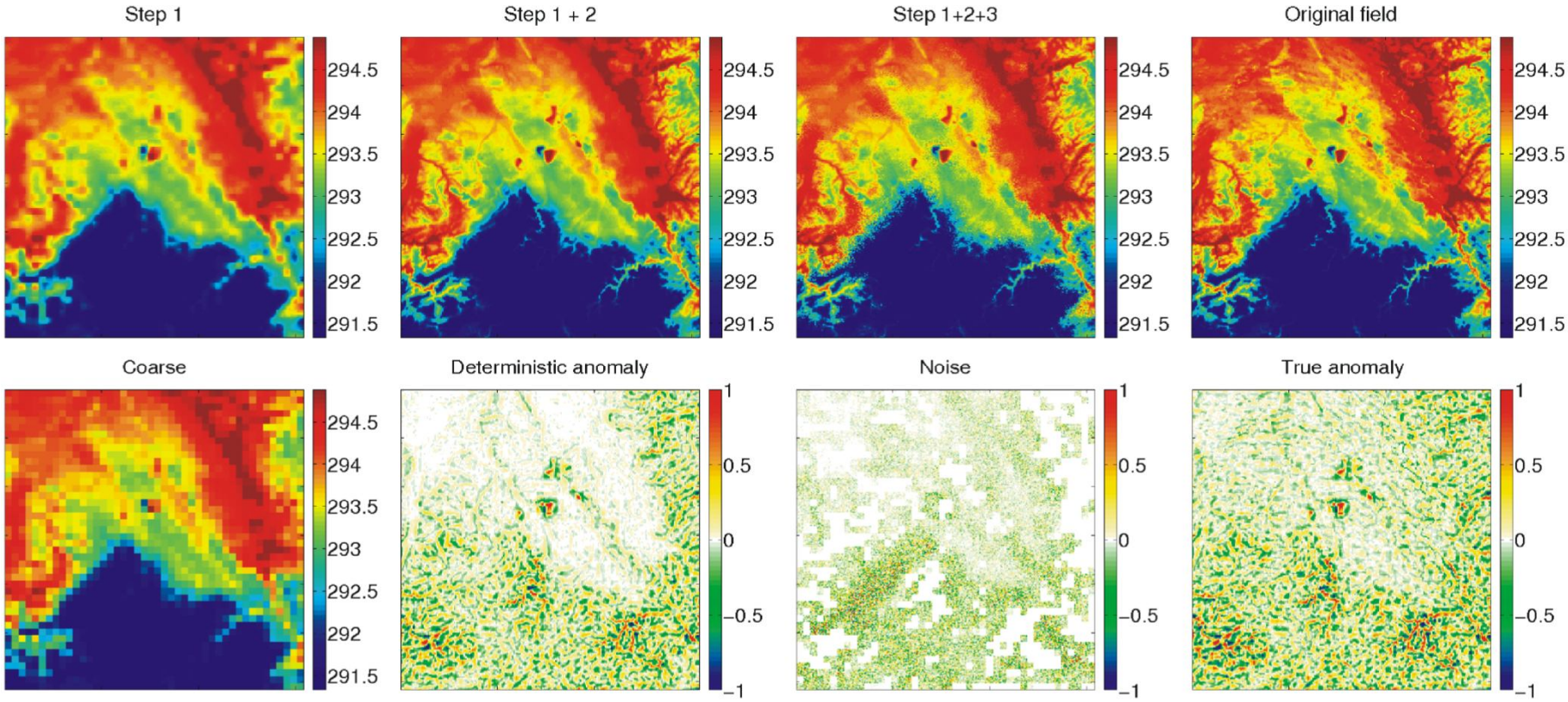
- Aggregation effects because of simplified averaging laws
- Dynamic effects because of induced atmospheric circulation

(Schomburg et al. 2010)

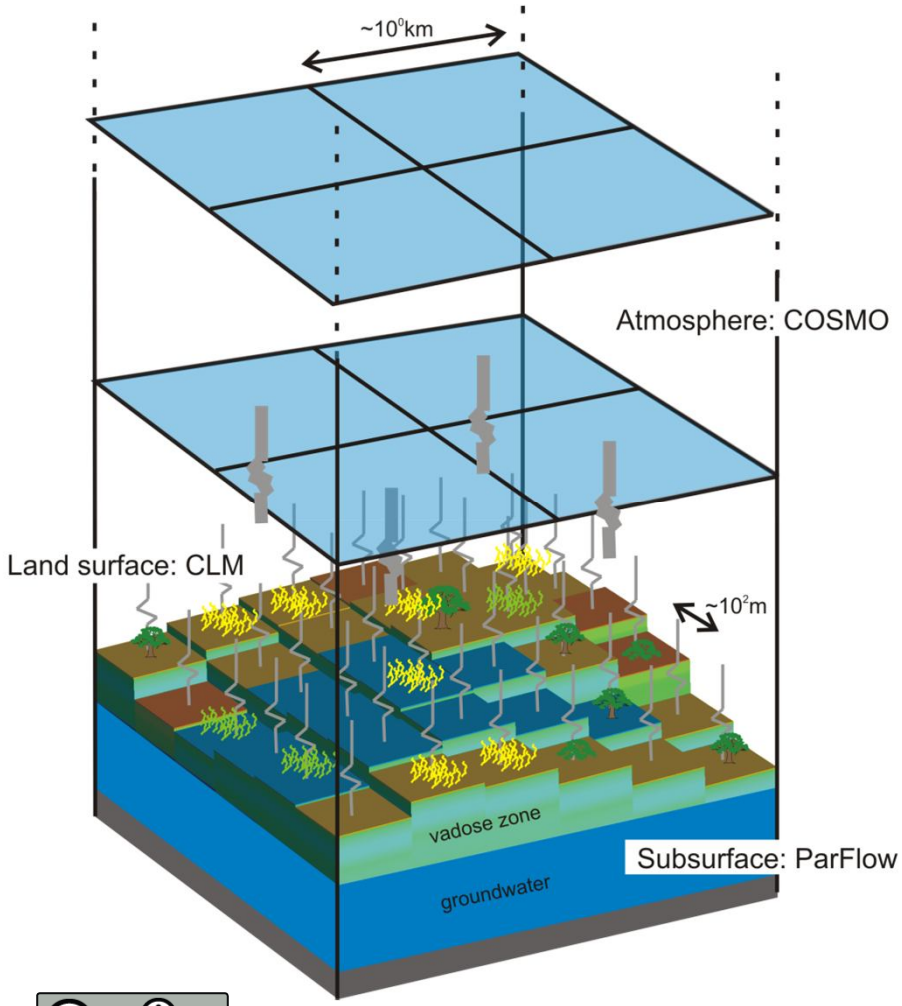
Downscaling of atmospheric variables

- 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



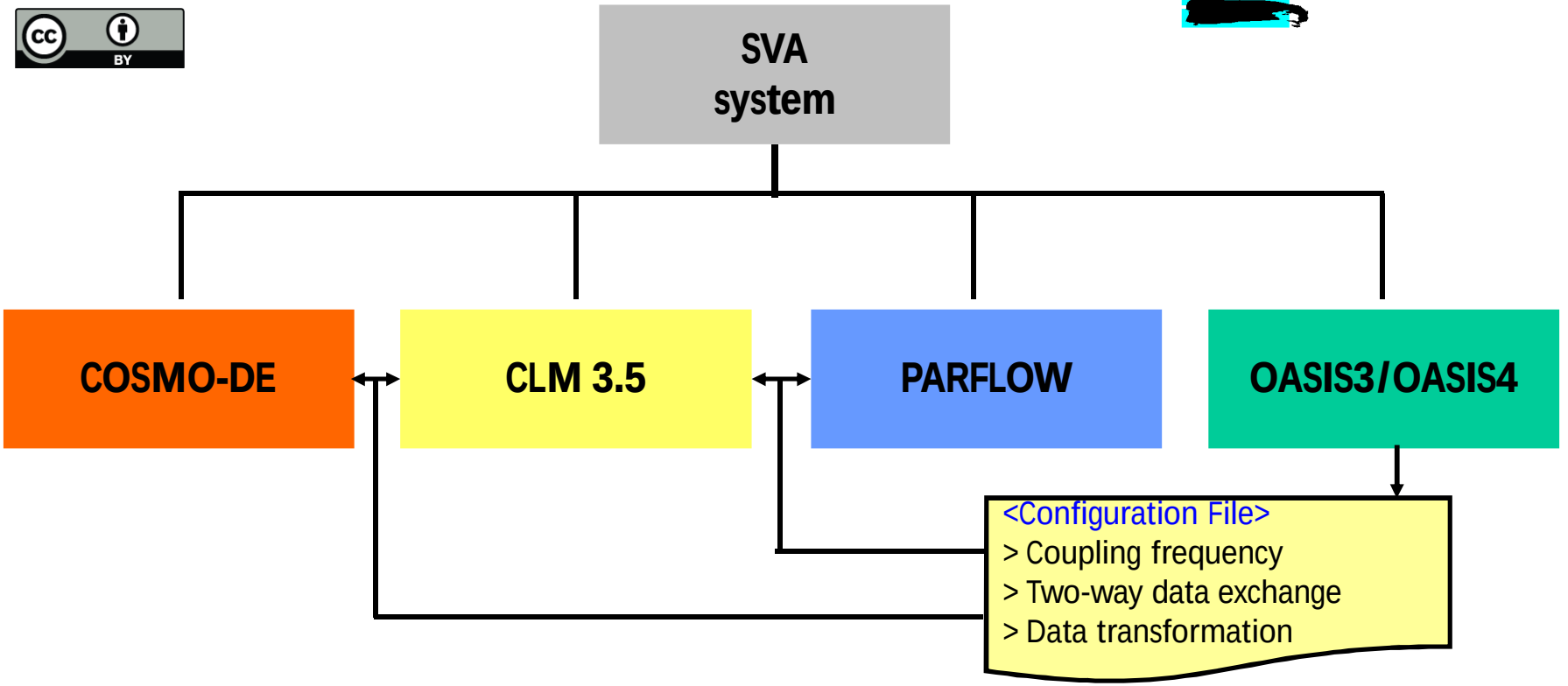
COSMO-CLM interactions, regulated

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**

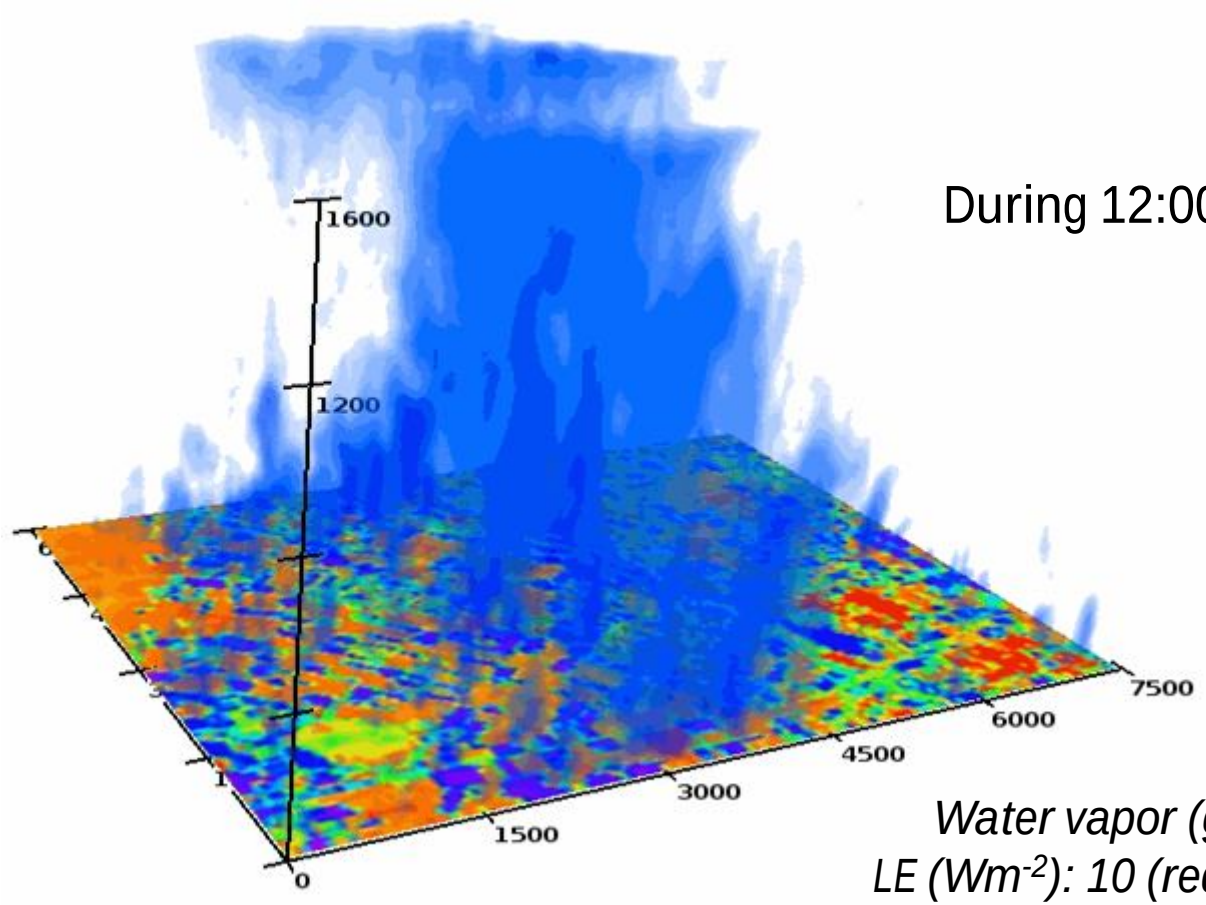
With OASIS Coupler – cooperation with



- **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.

High resolution atmospheric modelling

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

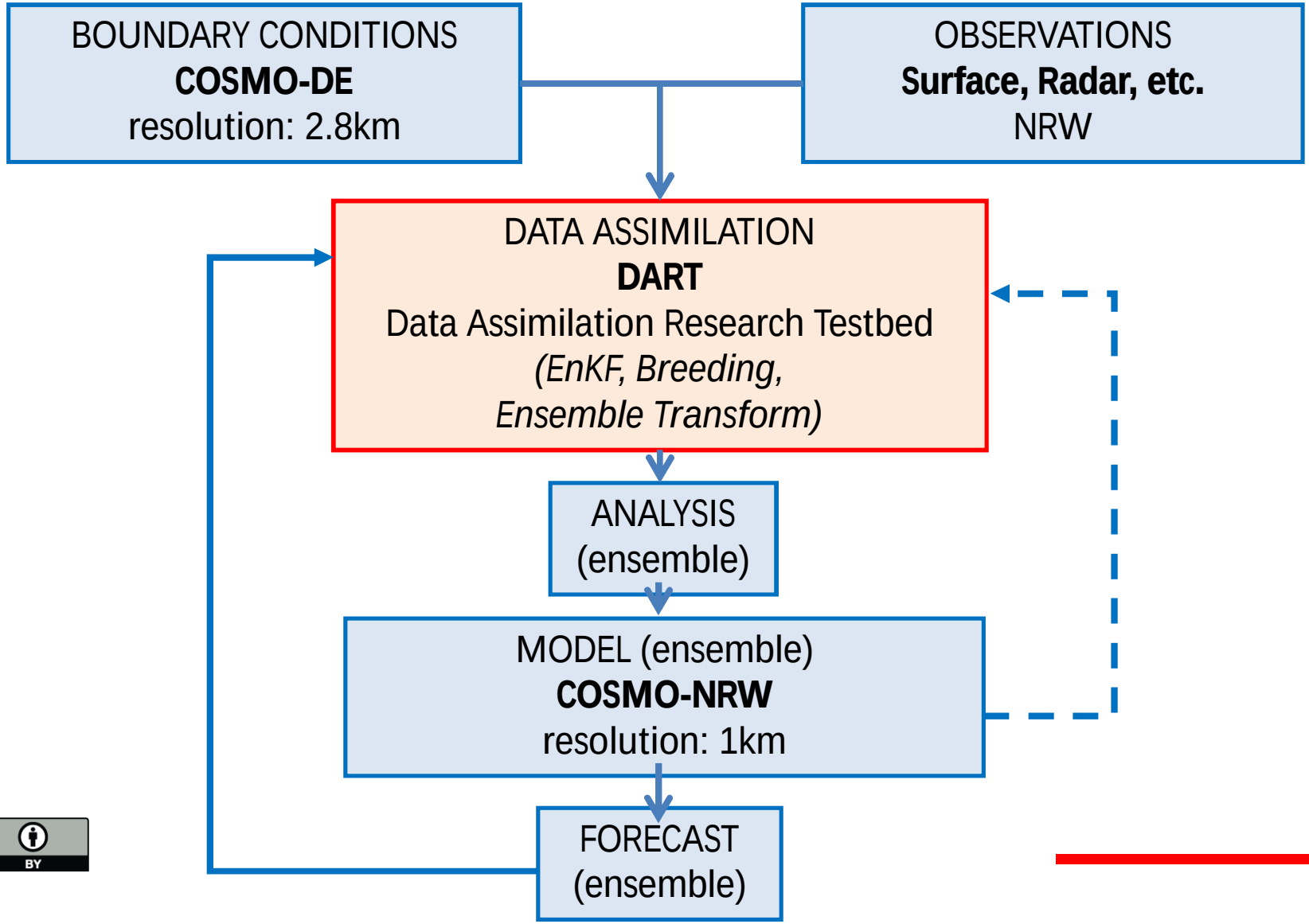


During 12:00 ~ 12:02

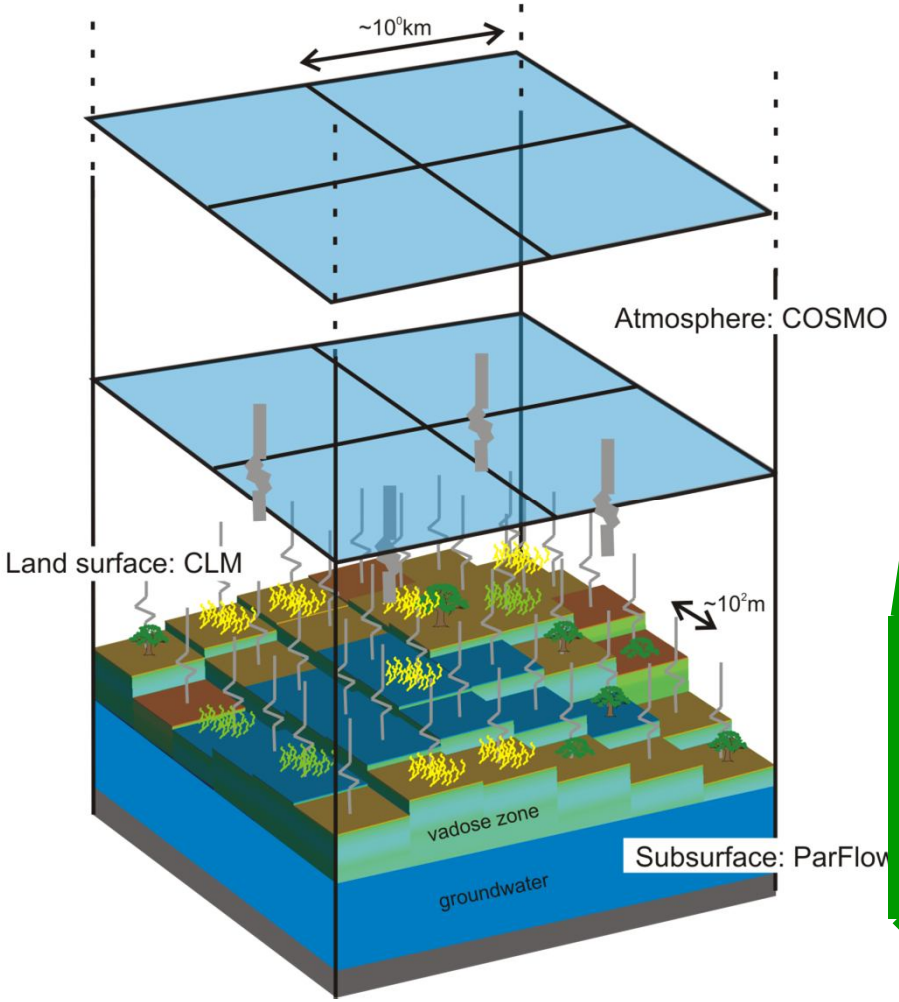
Water vapor (g/kg): 6 ~ 7
LE (Wm^{-2}): 10 (red) ~ 300 (blue)

Data Assimilation with COSMO-DART

cooperation with NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH



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.

...sustainable issue for the scientific community

- Further information:

www.tr32.de