Karlsruhe Institute of Technology

The impact of groundwater dynamics and soil-type for modeling coupled water exchange processes between land and atmosphere

B. Fersch, S. Wagner, T. Rummler, D. Gochis, H. Kunstmann

IAHS Assembly Gothenburg, July 24th 2013

Institute of Meteorology and Climate Research (IMK-IFU), Garmisch-Partenkirchen, Germany

Closing the Regional Water Balance

- Regional atmospheric (dynamical) modeling studies focus typically on the prediction skill for precipitation and temperature

- Coupling to hydrological models is usually realized in one way direction or in an offline coupled bi-directional way often with bias correction for the exchange variables

- Such approaches often violate the closure of the water (and energy) balance and also the equilibrium for subsurface-surface-atmosphere hydrometeorologic applications

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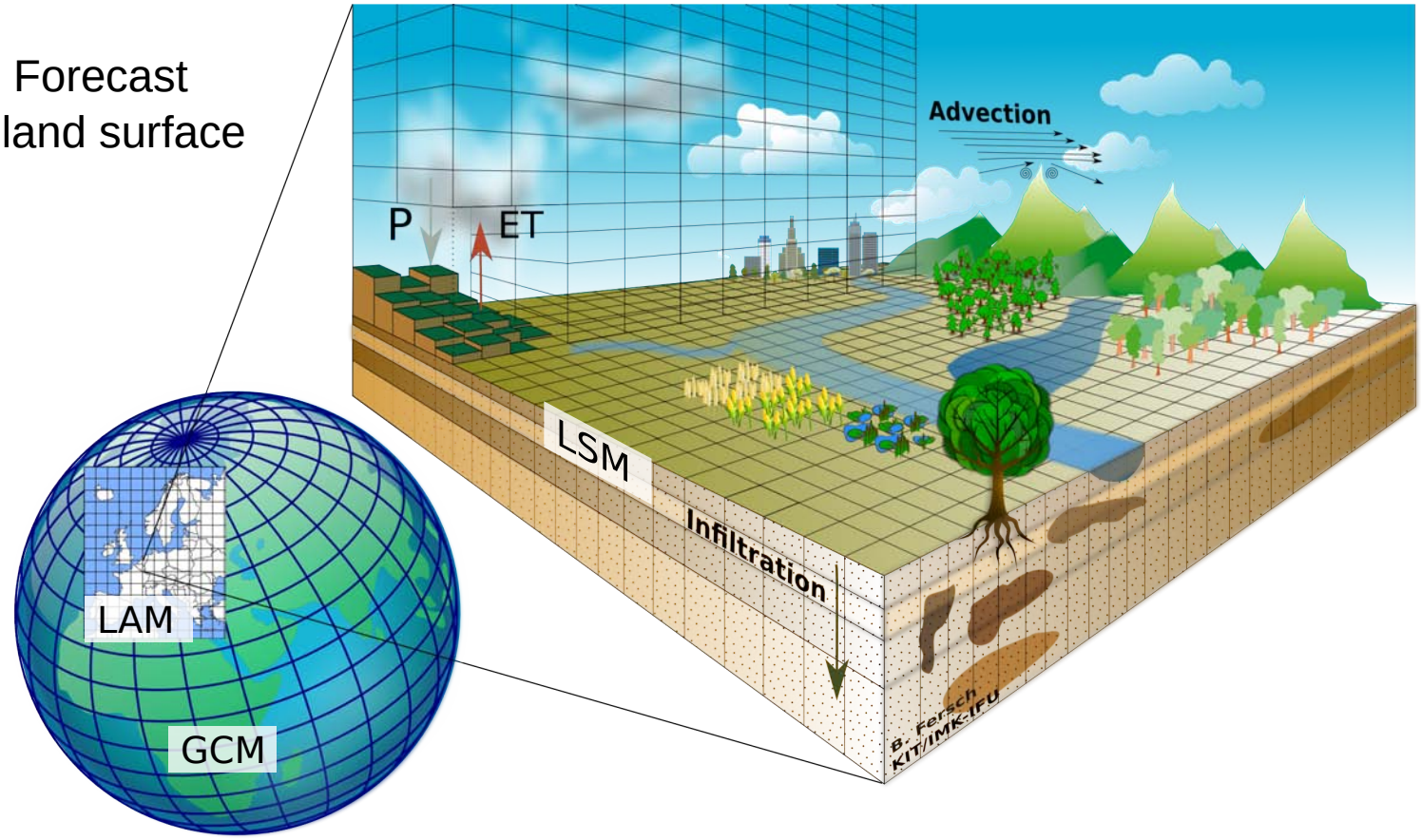
WRF Noah-LSM

- Weather Research and Forecast Model WRF with Noah land surface model



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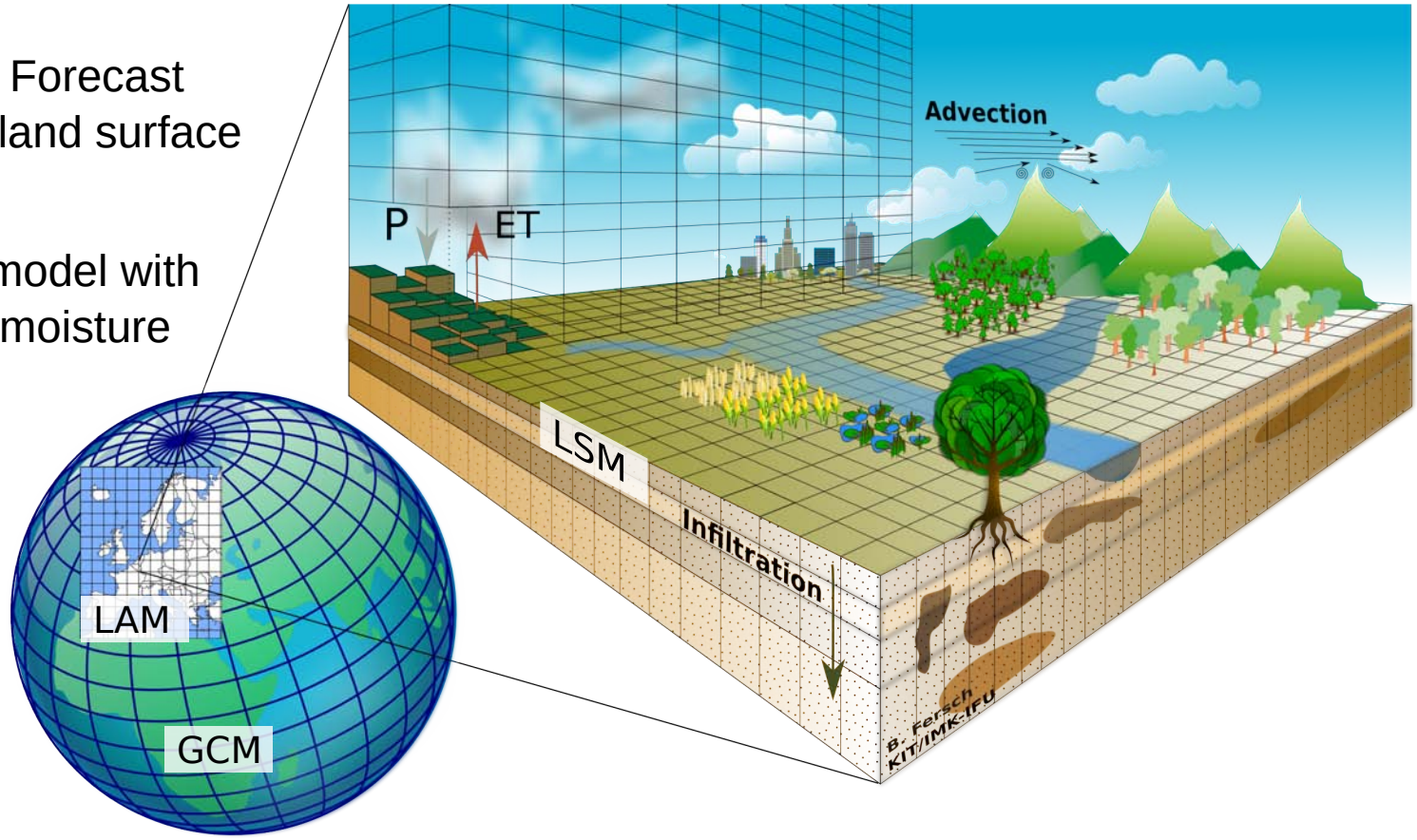

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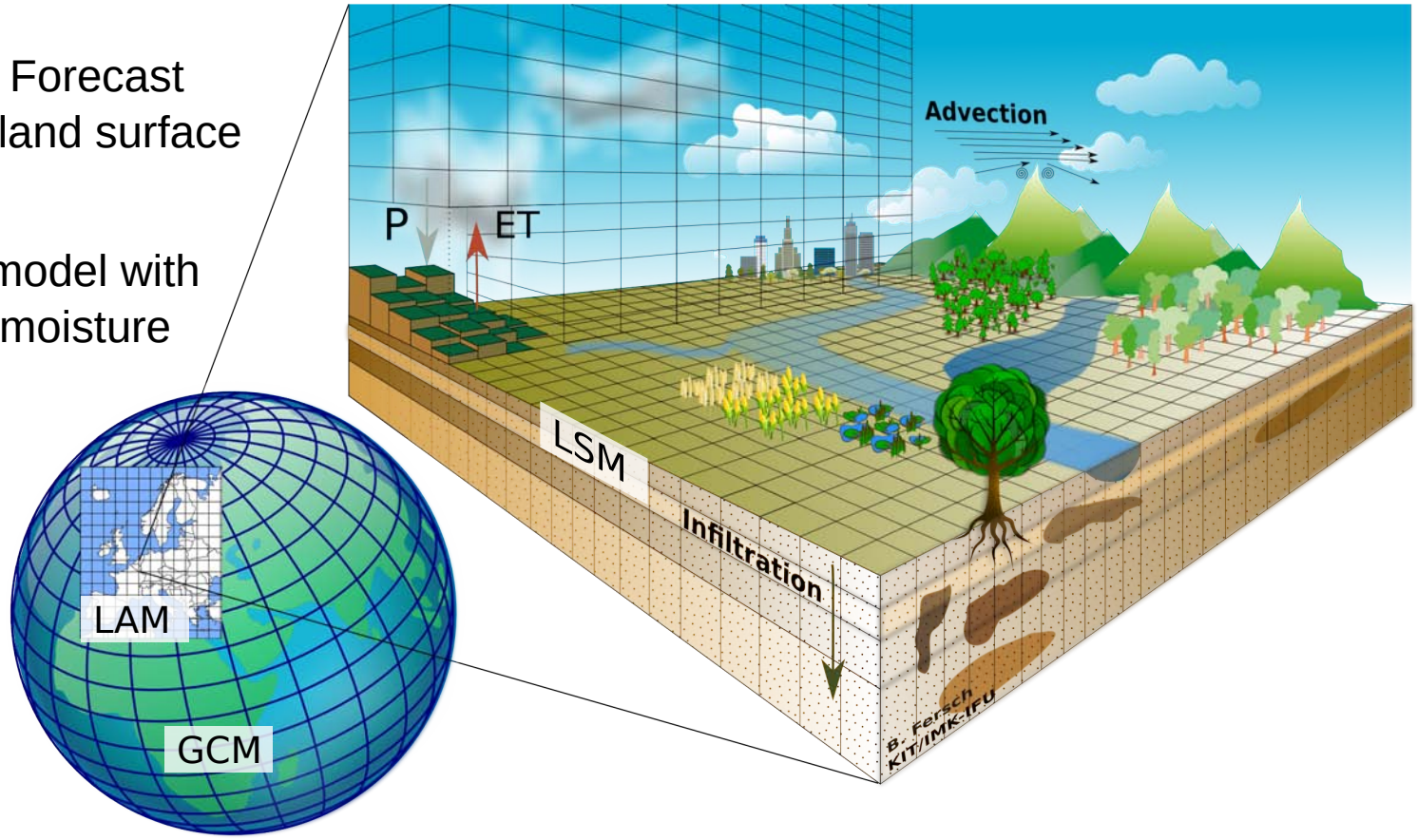

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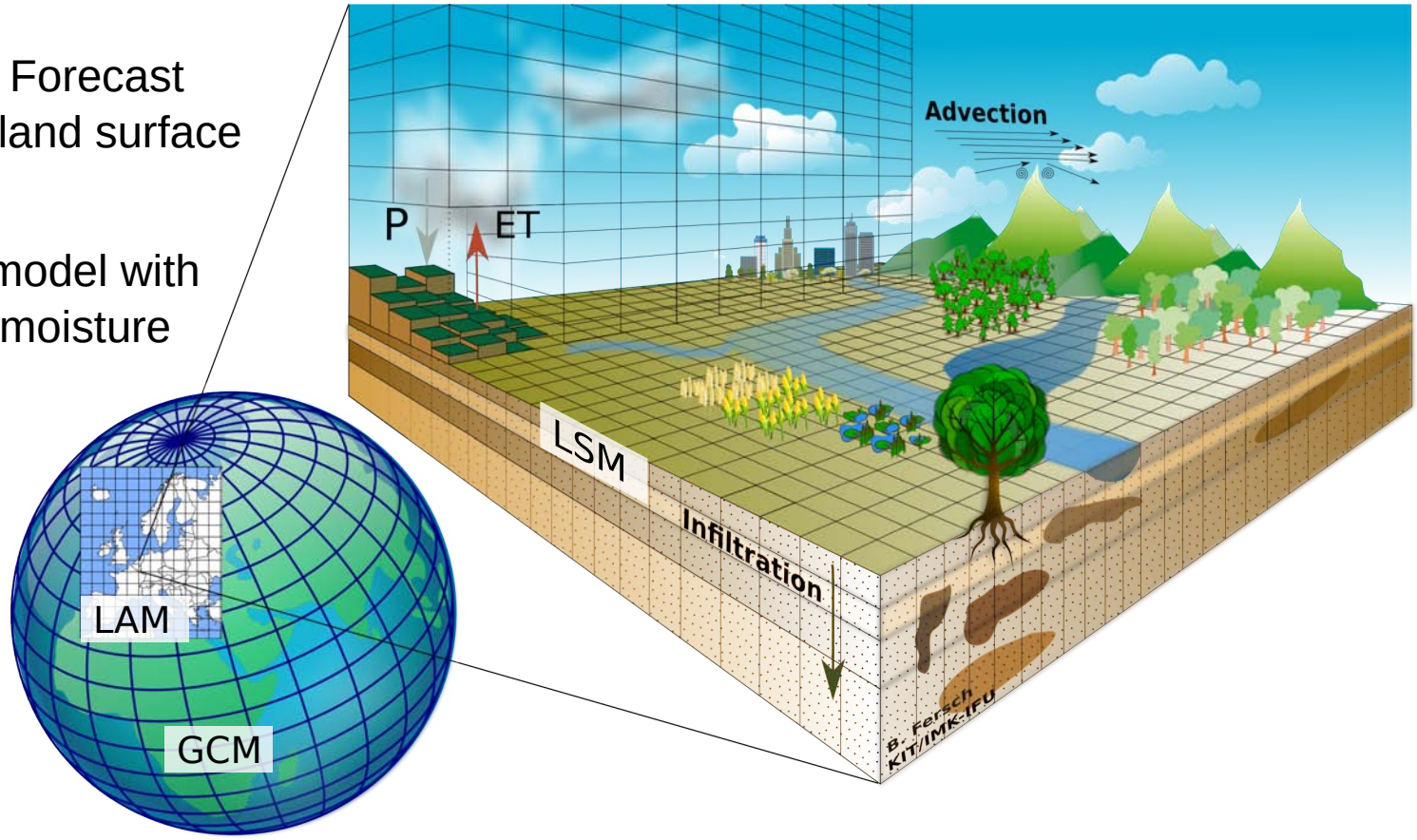

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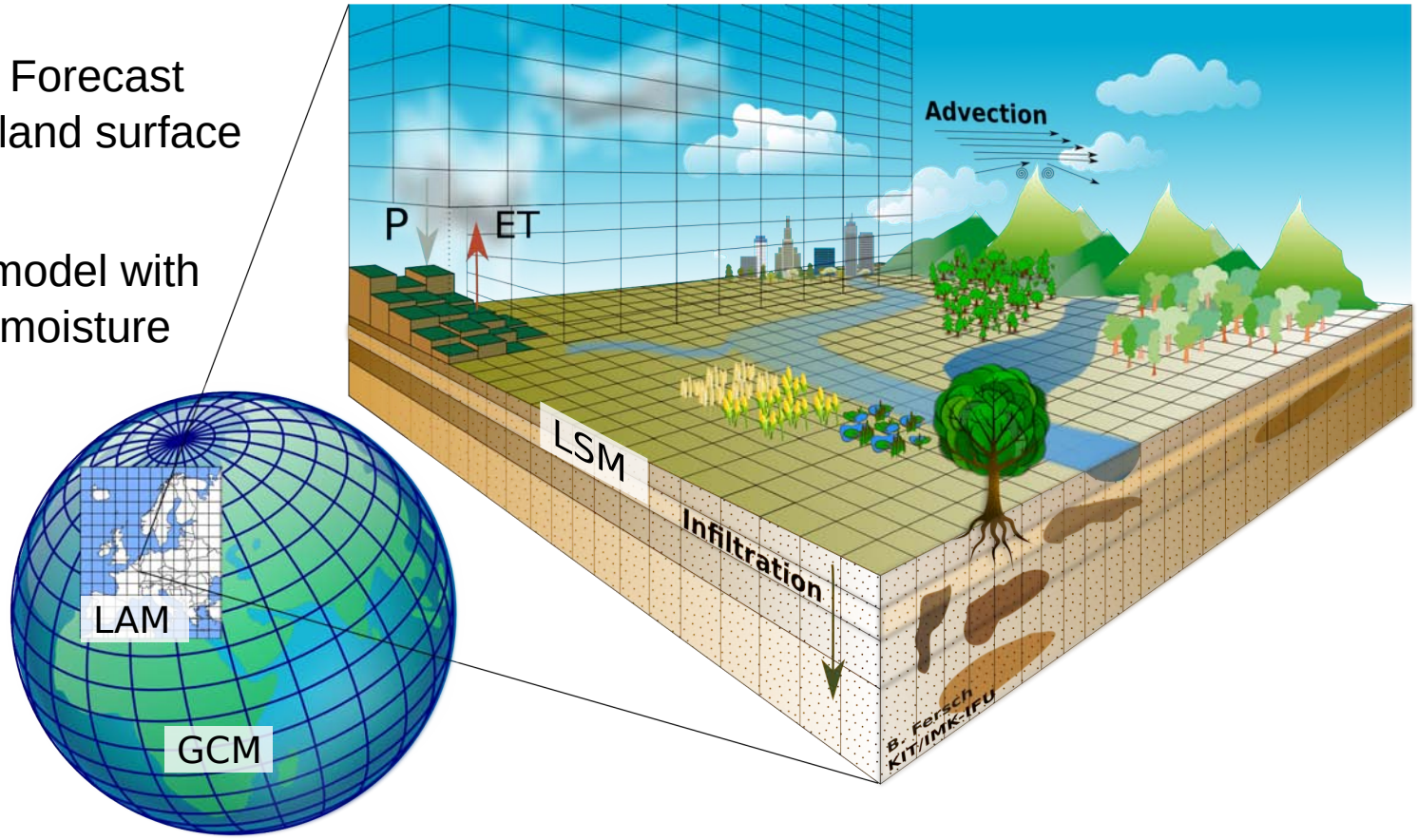

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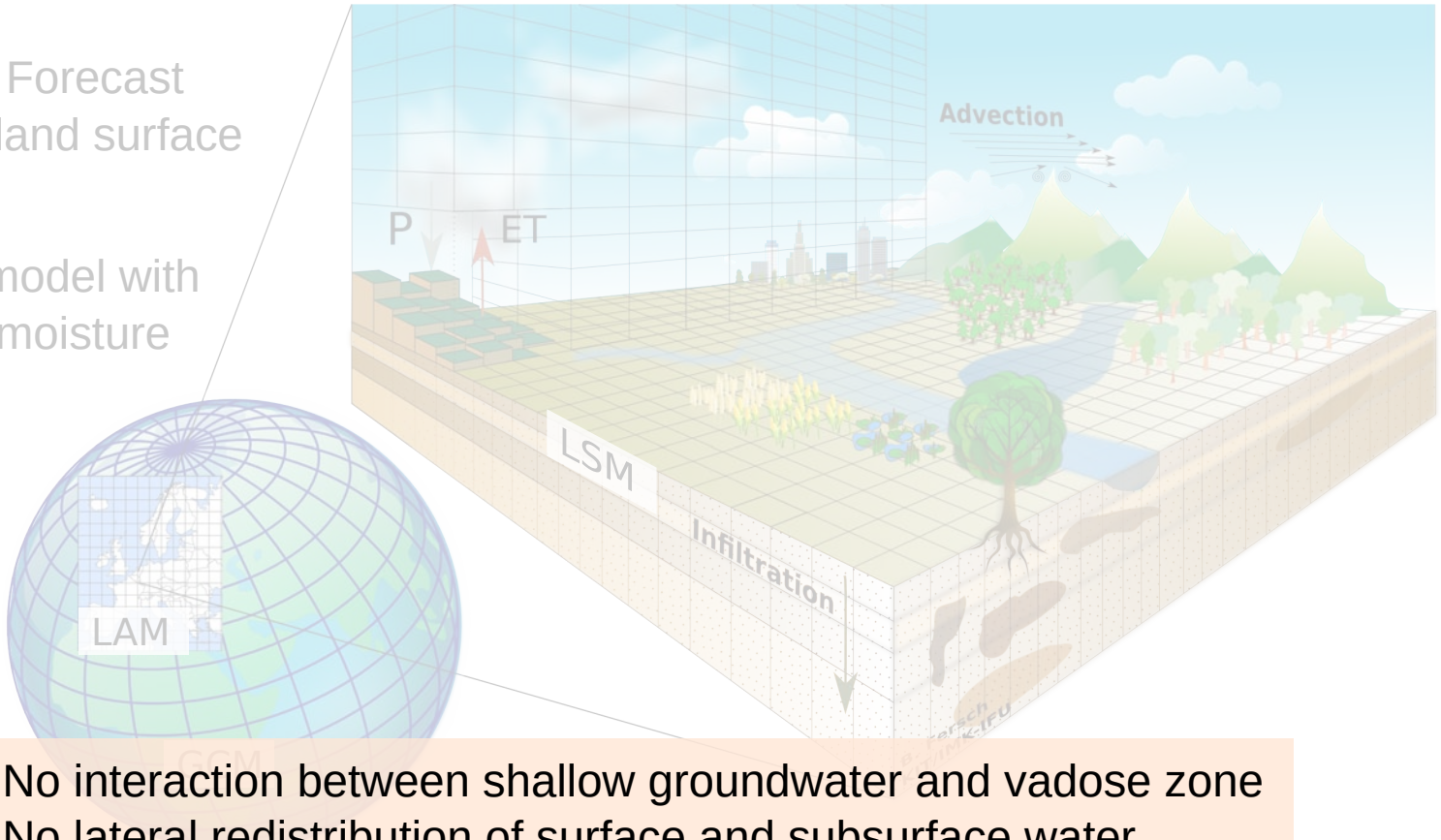

No interaction between shallow groundwater and vadose zone
No lateral redistribution of surface and subsurface water

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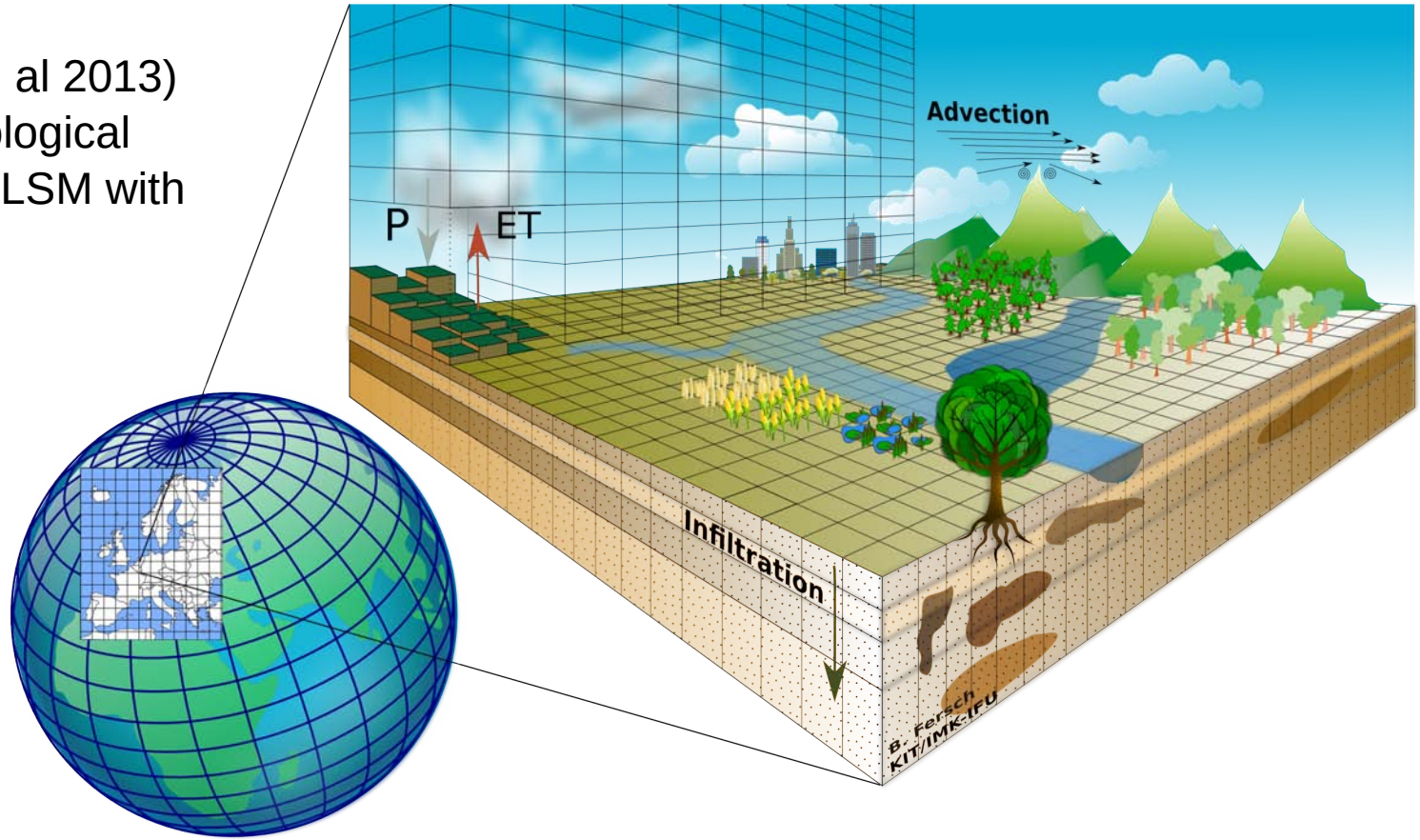
Noah-LSM Extended

- WRF-Hydro (Gochis et. al 2013) introduces lateral hydrological processes to the Noah-LSM with sub-grid (0.1 to 1km)



http://www.ral.ucar.edu/projects/wrf_hydro/

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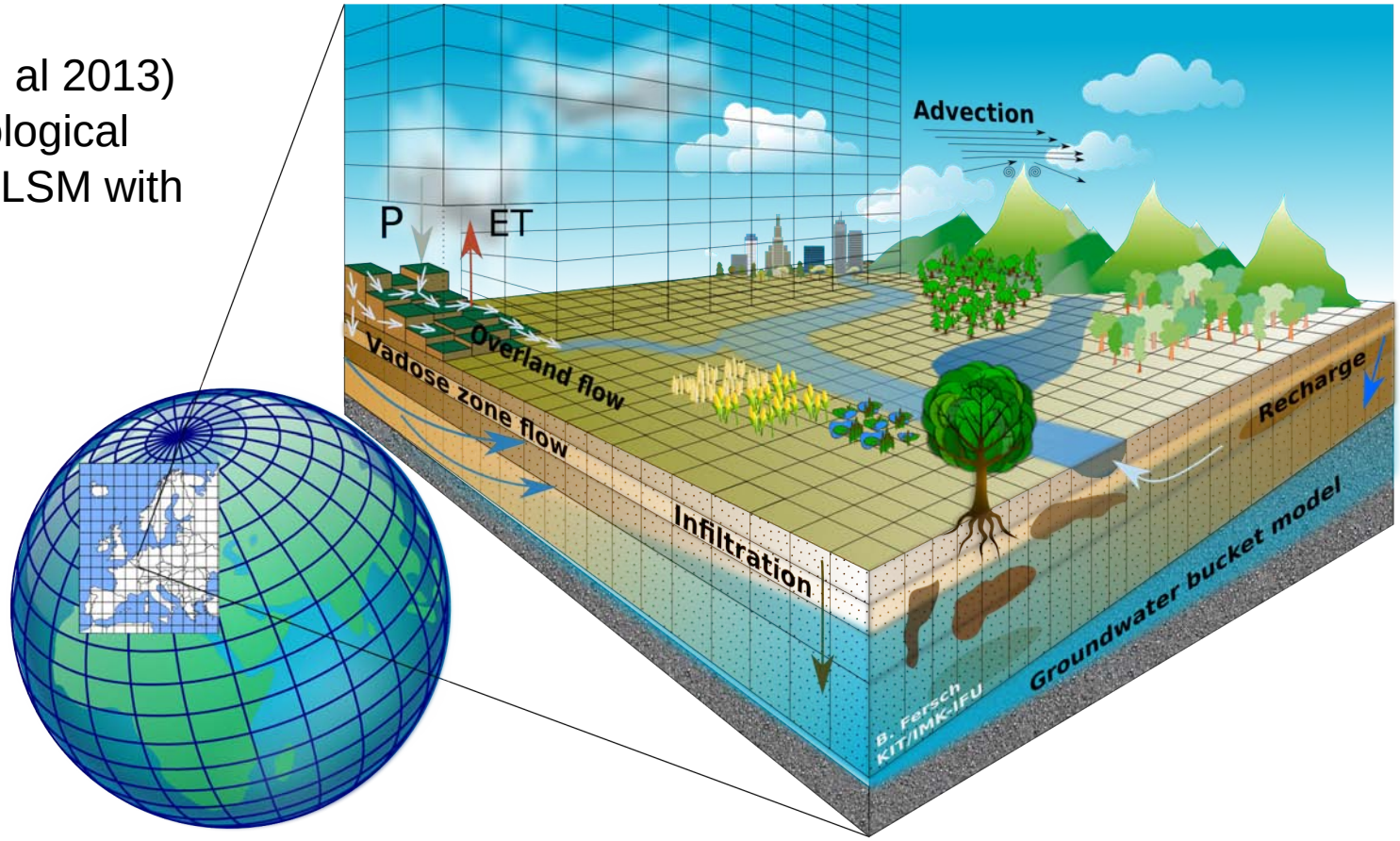
- River channel flow
- Reservoirs and lakes
- Bucket groundwater model



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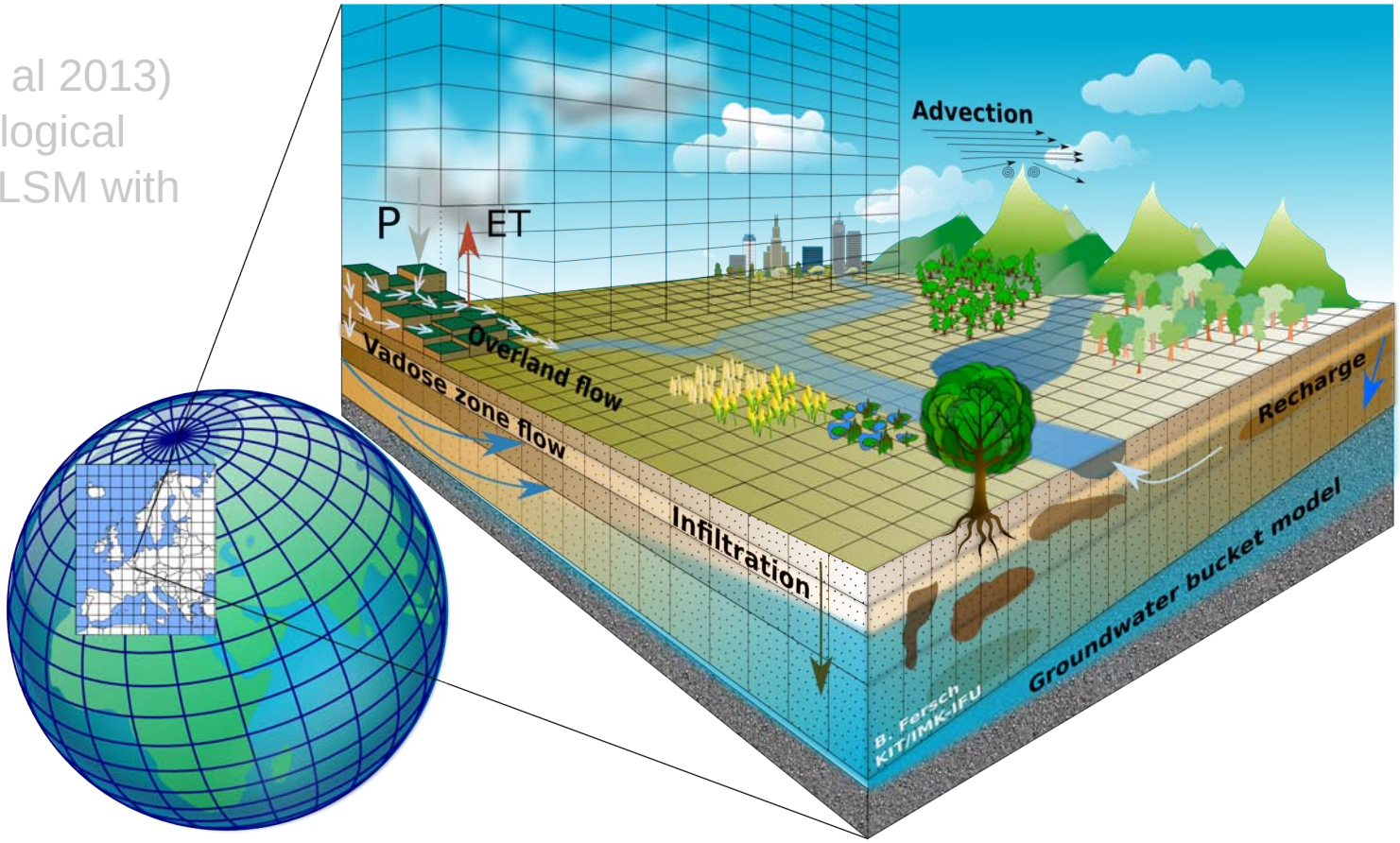

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No interaction between shallow groundwater and vadose zone

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groundwater <-> land surface model coupling

Coupling Methods

capillary rise

computational efficiency

groundwater recharge

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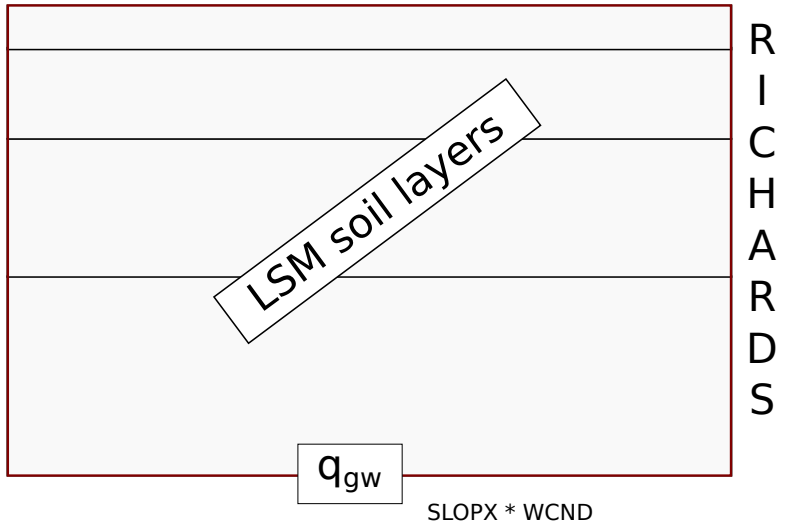
Groundwater-Soil Coupling

Noah-LSM
Free drainage boundary

(after Marth et al. 1984)



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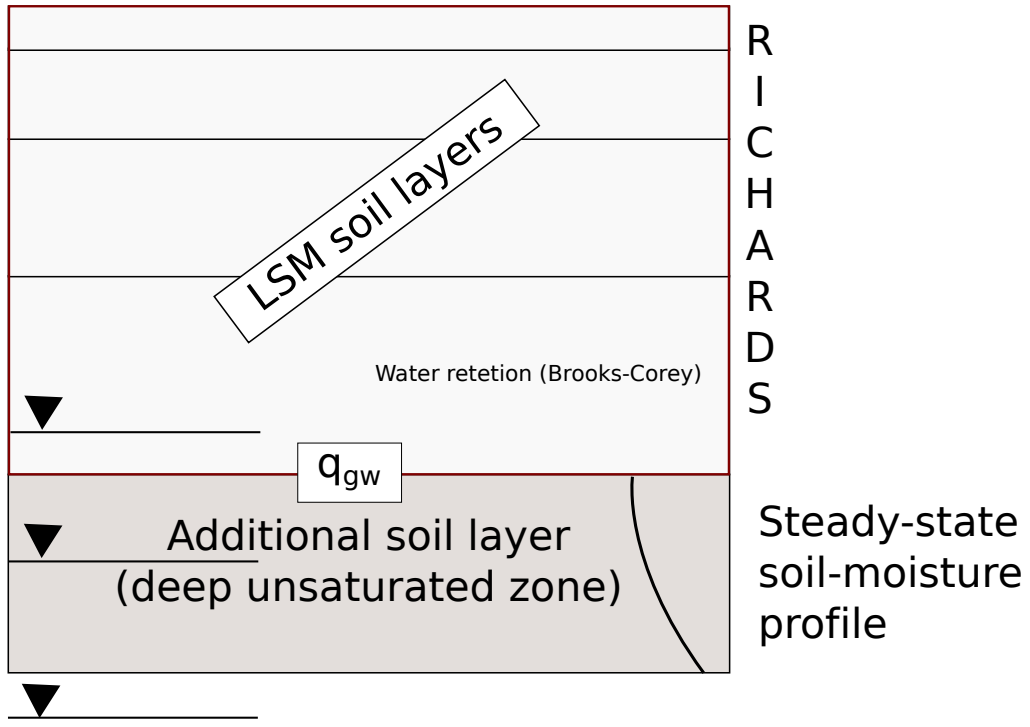
Groundwater-Soil Coupling

Fixed-head
boundary condition

Zeng & Decker (2009)
De Rooij (2010)



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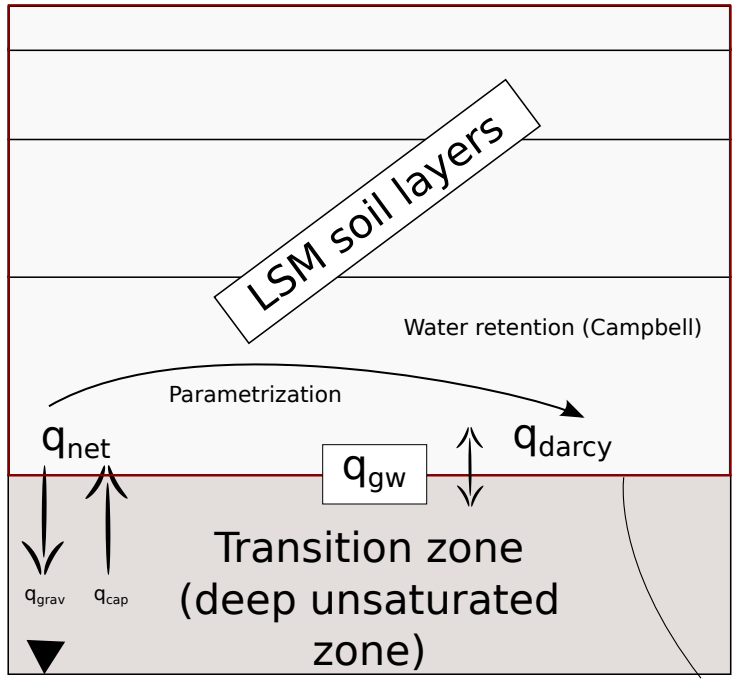
Groundwater-Soil Coupling

Darcy-flux
source/sink term

Bogaart et al. (2008)



Gardner (1948)
Eagleson (1978)
Approach

Steady-state
soil-moisture
profile

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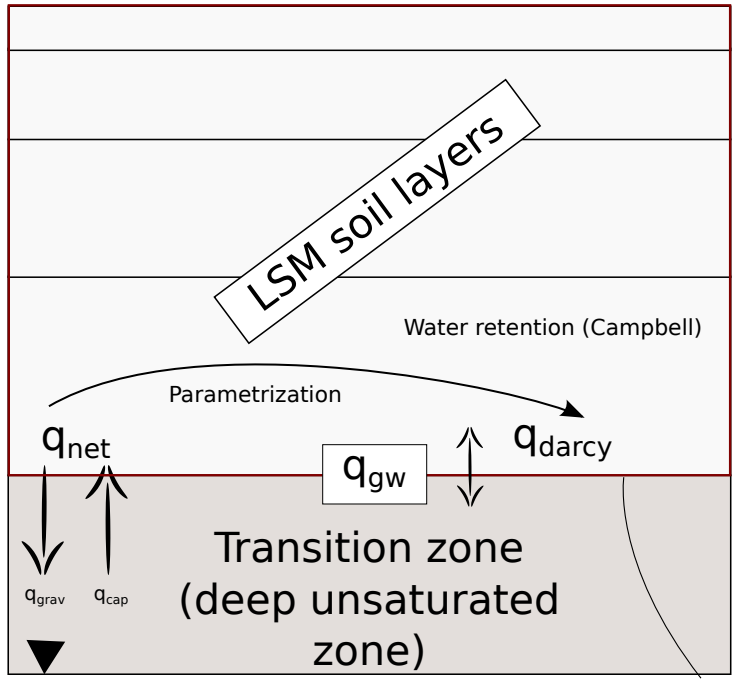
Groundwater-Soil Coupling

Parameterization of q_{darcy}

- Relative saturation of lowest LSM soil layer
- Thickness of the transition zone (distance to GW)
- Soil type

Darcy-flux source/sink term

Bogaart et al. (2008)



RICHARDS

Steady-state soil-moisture profile

Gardner (1948)
Eagleson (1978)
Approach

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groundwater <-> land-surface-model coupling

Sensitivity Study

applicability

coupling methods

soil type

observation driven

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GW Sensitivity Study

Darcy-flux
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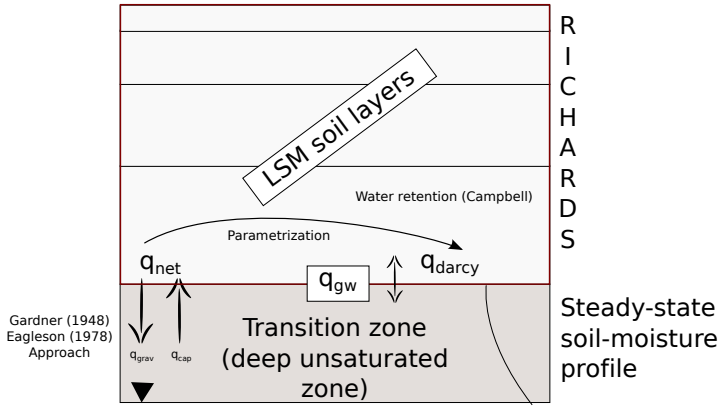
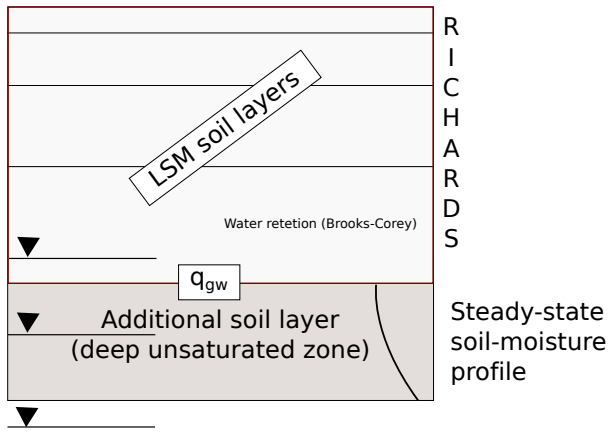


2 coupling methods

Fixed-head
boundary condition

Zeng & Decker (2009)
De Rooij (2010)



12 soil-types
(Clapp & Hornberger 1972)

Sand (S)
Loamy Sand (LS)
Sand Loam (SL)
Silt Loam (SiL)

Silt (Si)
Loam (L)
Sandy Clay Loam (SCL)
Silty Clay Loam (SiCL)

Clay Loam (CL)
Sandy Clay (SC)
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Clay (C)

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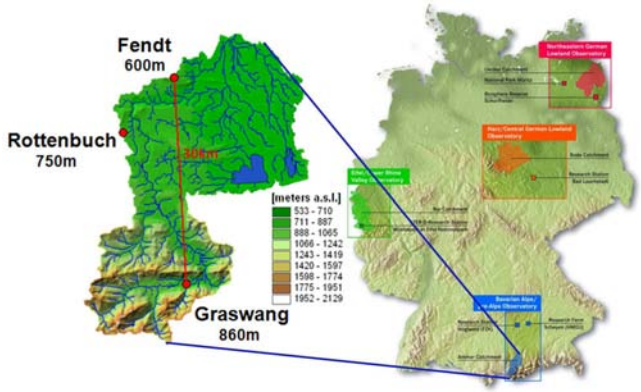
Model Driving: TERENO



TERENO
Terrestrial Environmental Observatories

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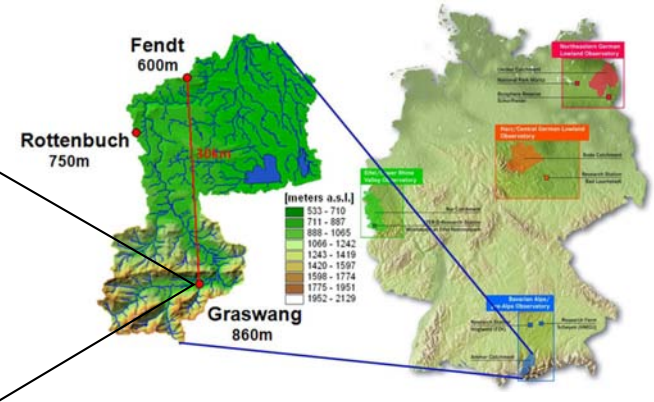

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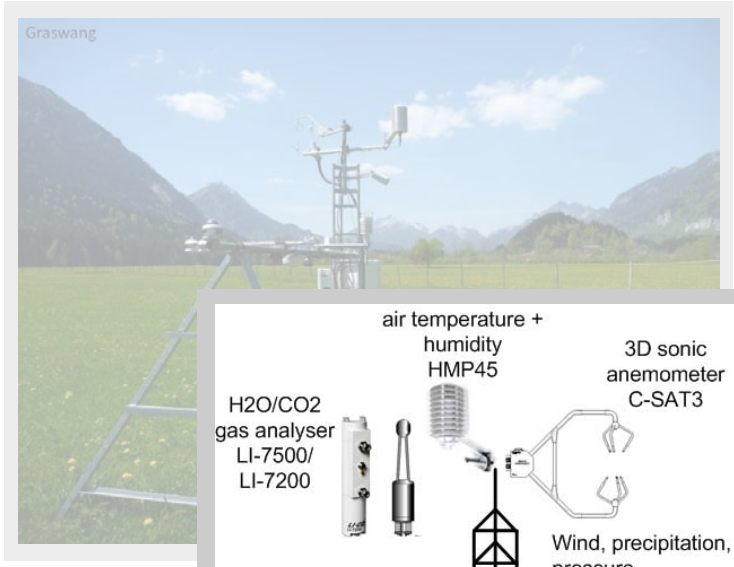

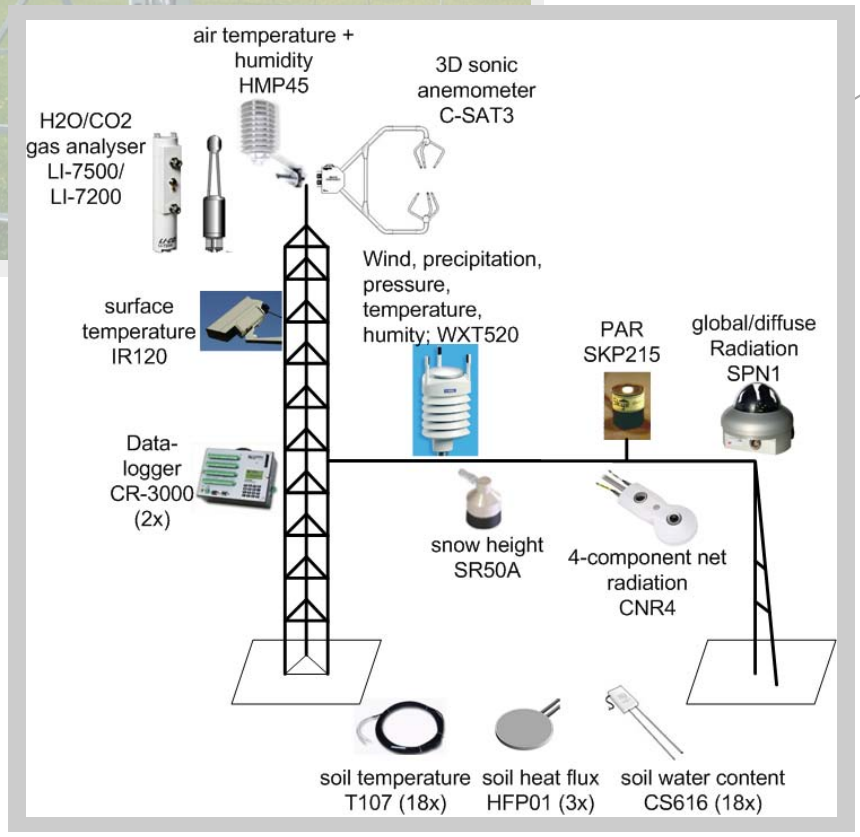

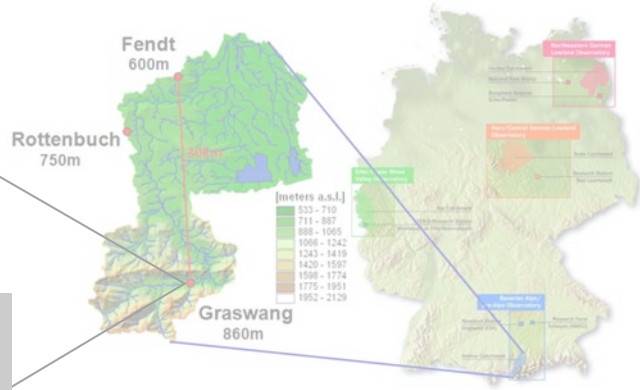

TERENO
Terrestrial Environmental Observatories

- Noah-LSM driving
- Available 2010-now
- 10 minutes resolution

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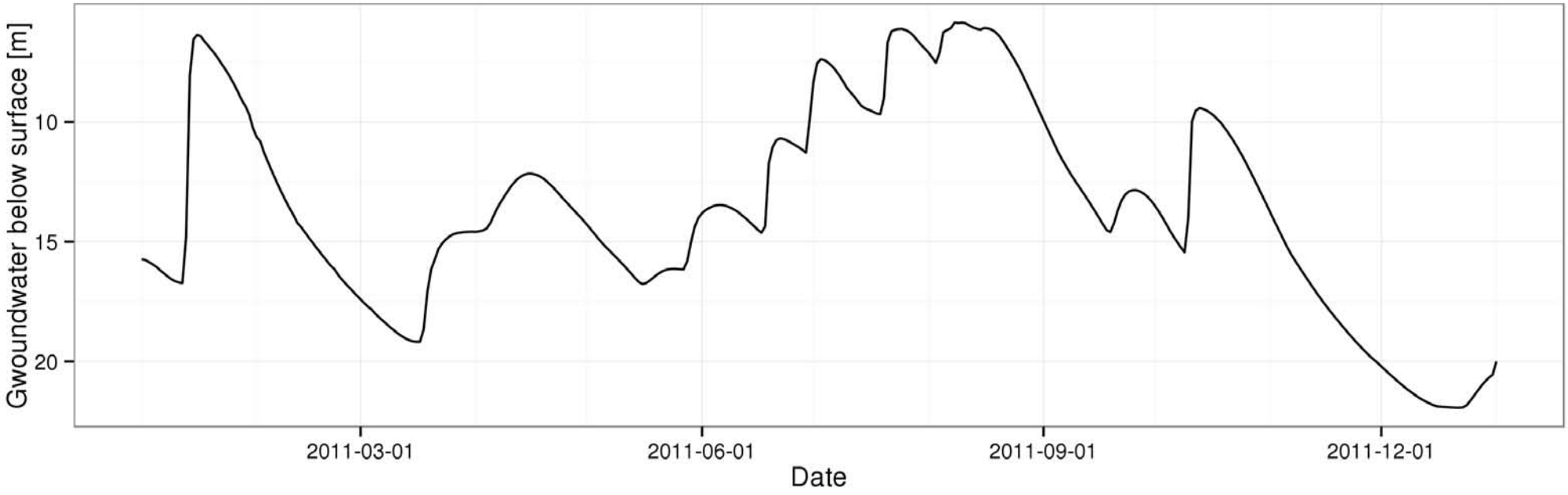
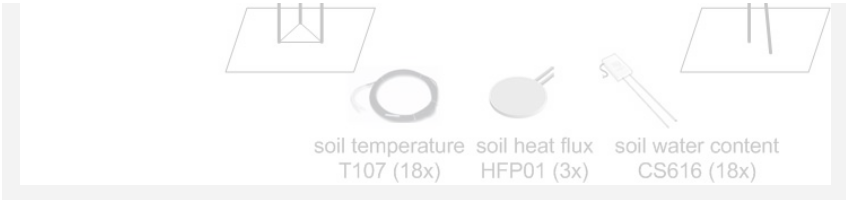
Model Driving: TERENO

Groundwater Dynamic





- 10 minutes resolution

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sensititvity study

RESULTS

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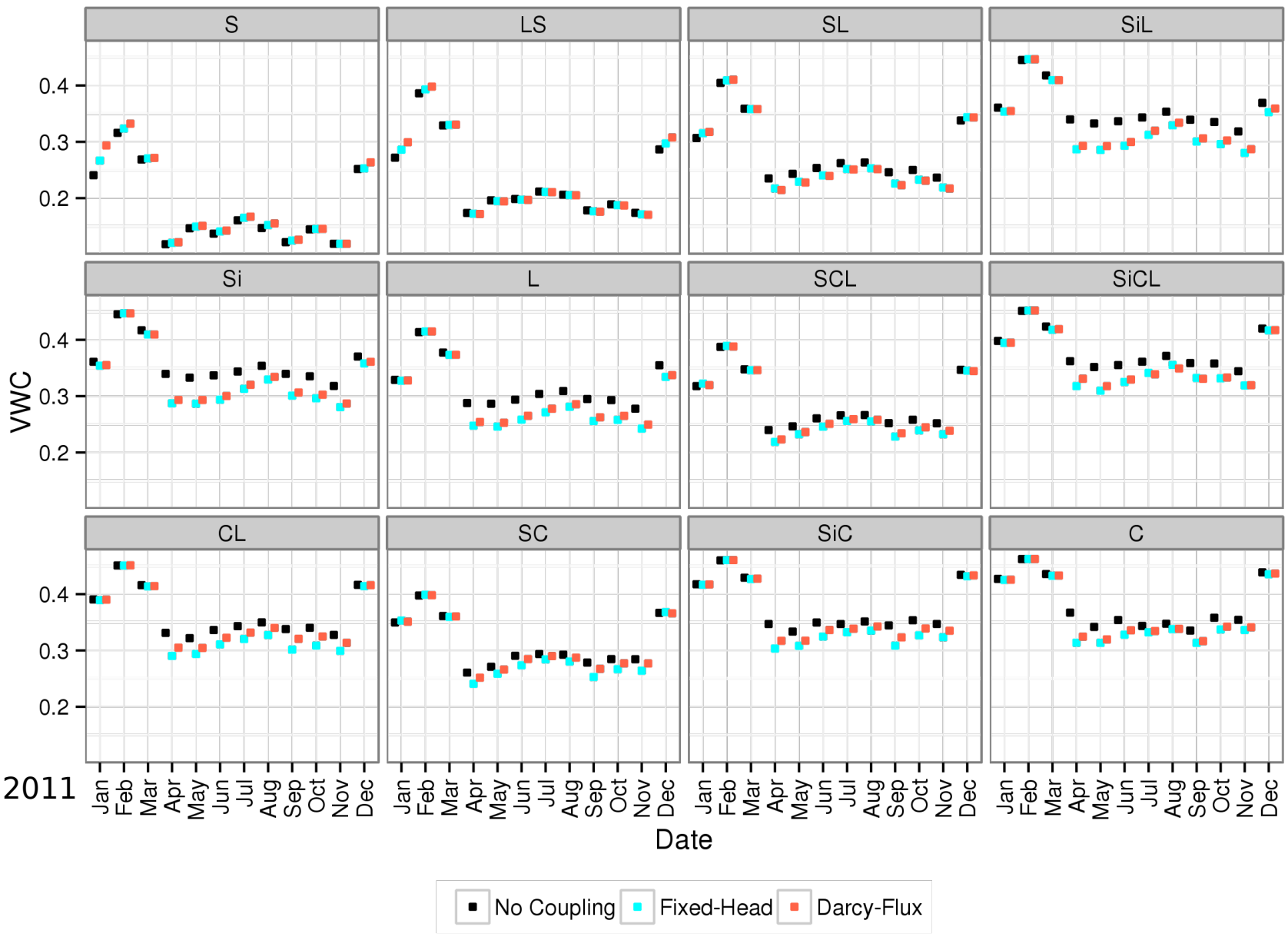
Soil Moisture



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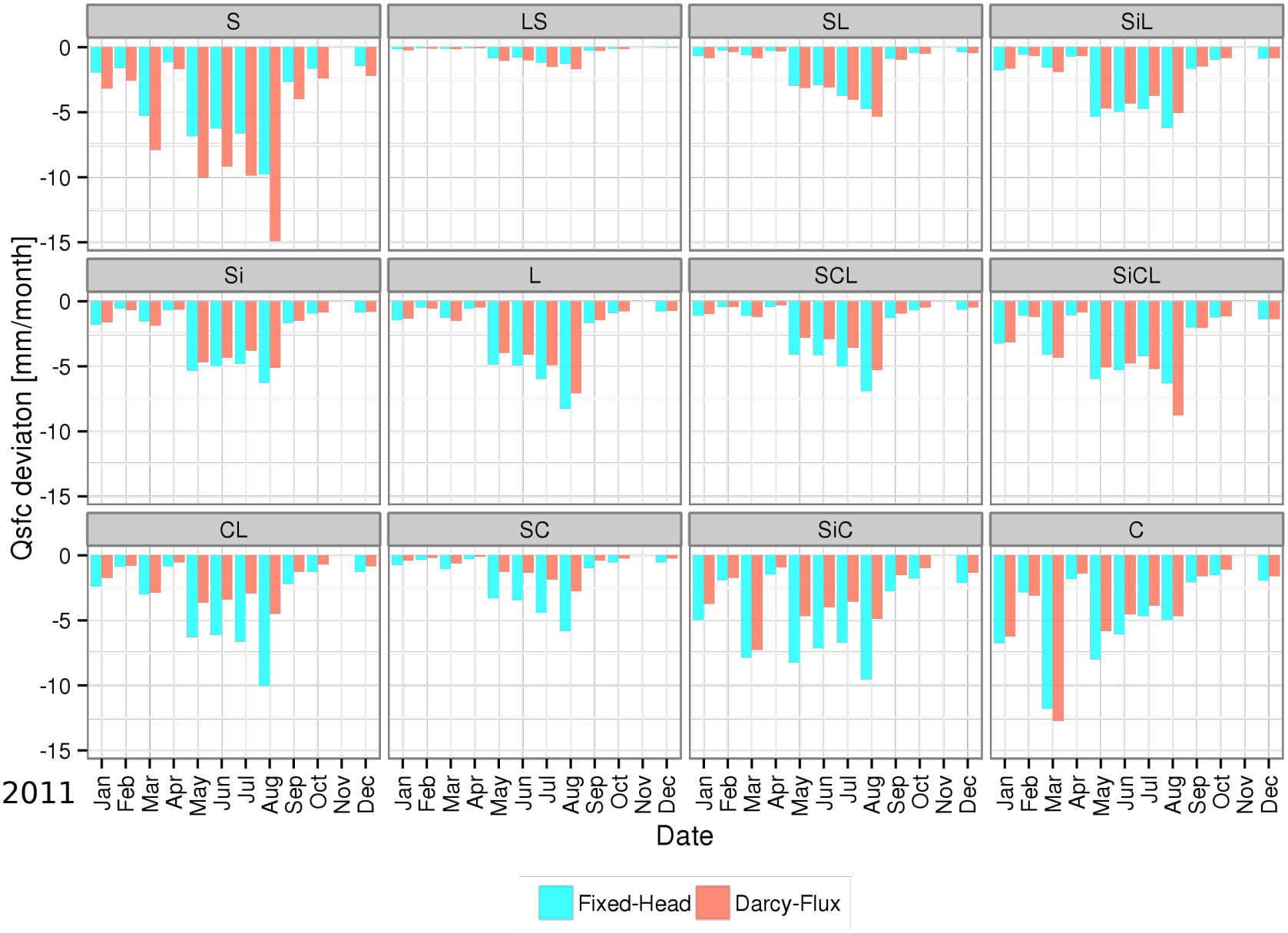
Surface Runoff



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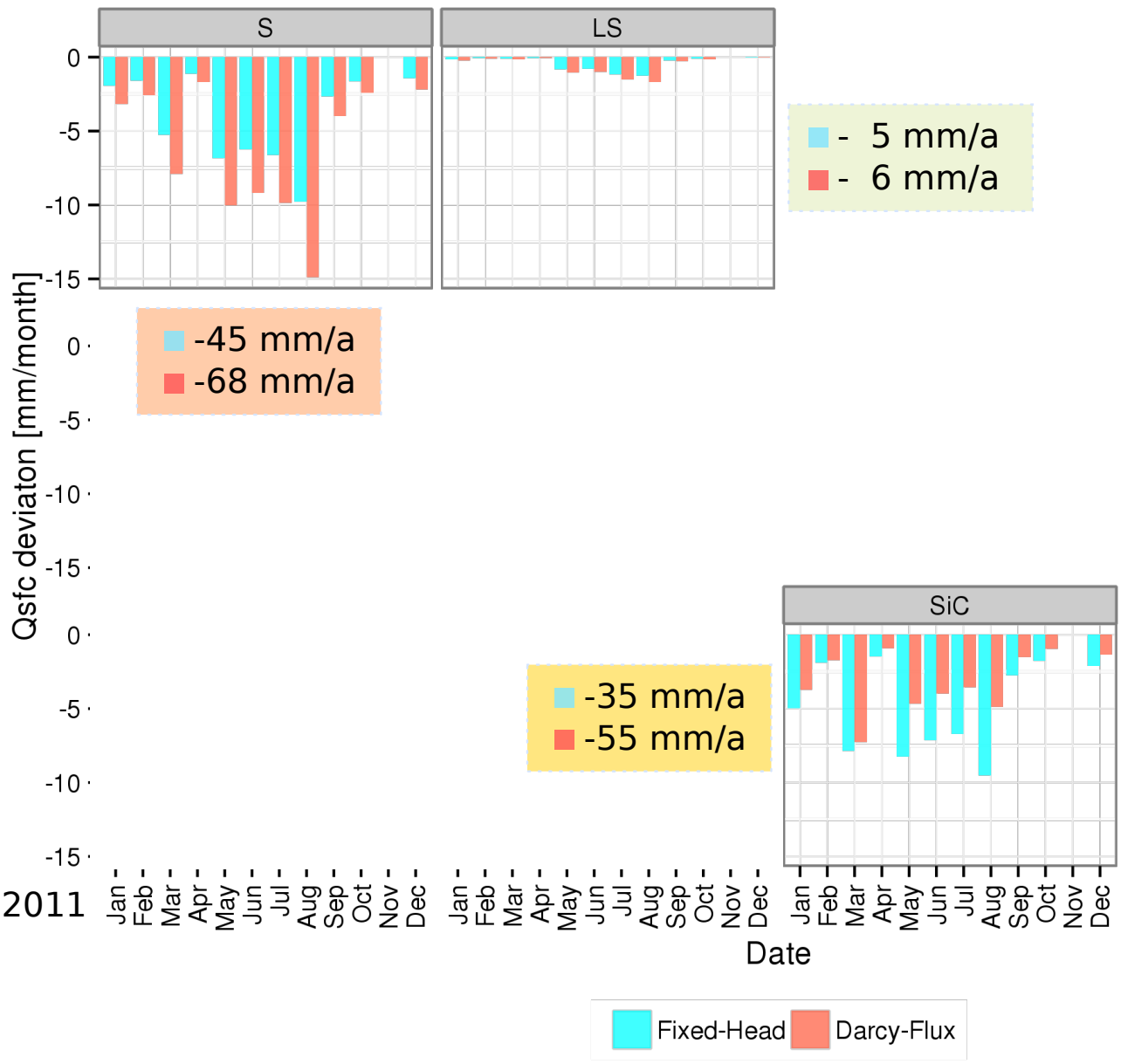

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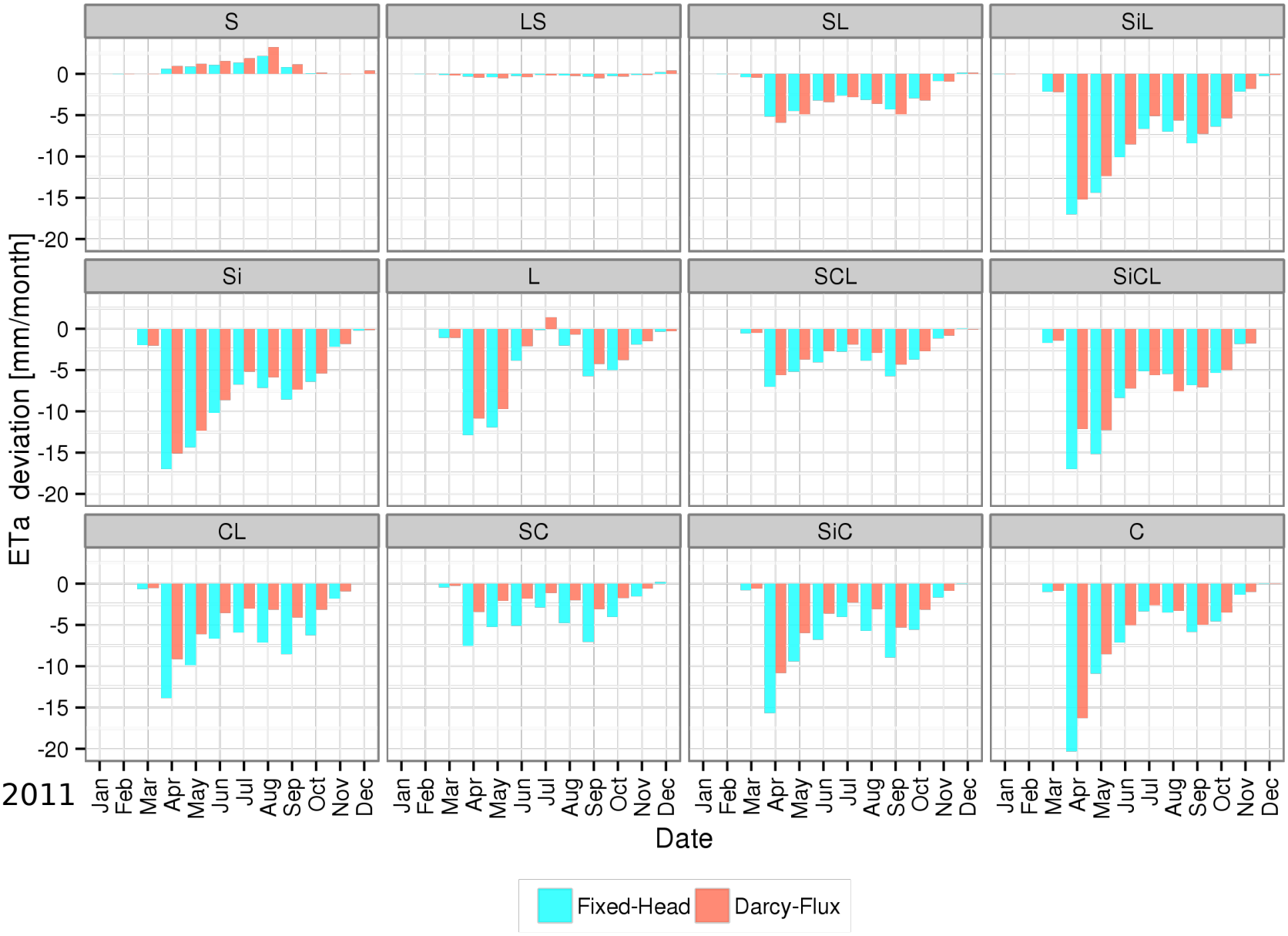
Evapotranspiration



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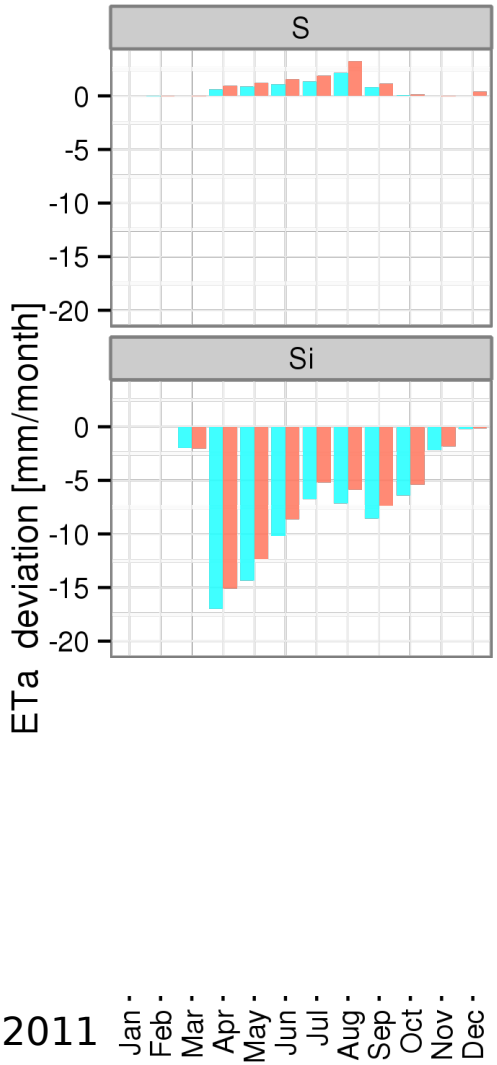

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Skin Temperature

Sand (S)
Loam Sand (LS)
Sand Loam (SL)
Silt Loam (SiL)

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Soil Moisture Evaluation

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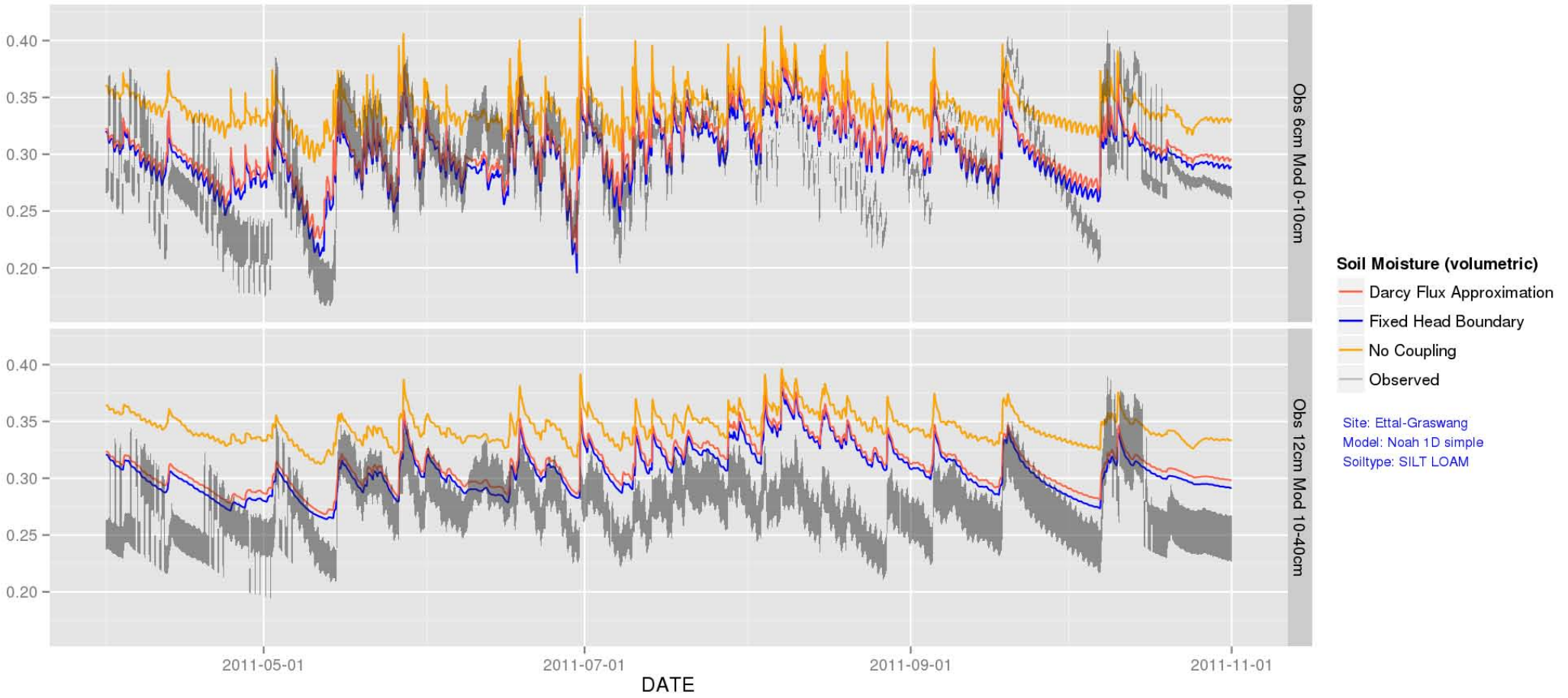

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Conclusions

- The groundwater coupled lower soil moisture boundary condition in the extended Noah-LSM considerably affects the water budgets at the land surface for most of the tested soil types
- The deviation intensity varies with the soil type
- Strongest deviations occur during the vegetation period
- Both applied coupling methods show the same tendencies with deviations between 10 and 30%

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- The deviation intensity varies with the soil type
- Strongest deviations occur during the vegetation period
- Both applied coupling methods show the same tendencies with deviations between 10 and 30%
- For the Graswang site groundwater coupling leads mainly to increased aquifer recharge and to considerably decreased surface runoff and evapotranspiration
- Groundwater coupling could improve the simulation of the soil moisture dynamics for an observation-driven 1-D Noah-LSM simulation at a location with a shallow and dynamic groundwater level

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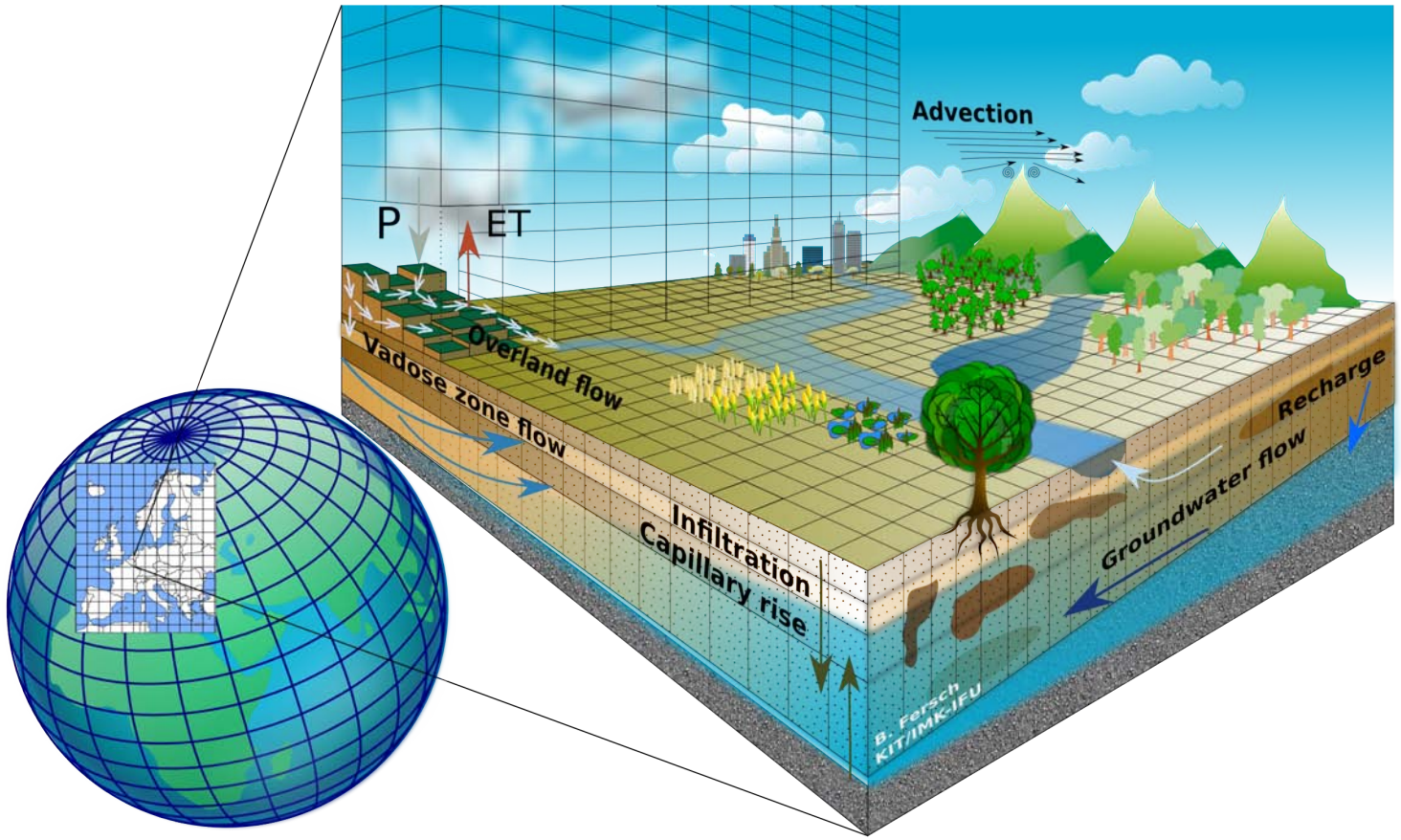
Outlook



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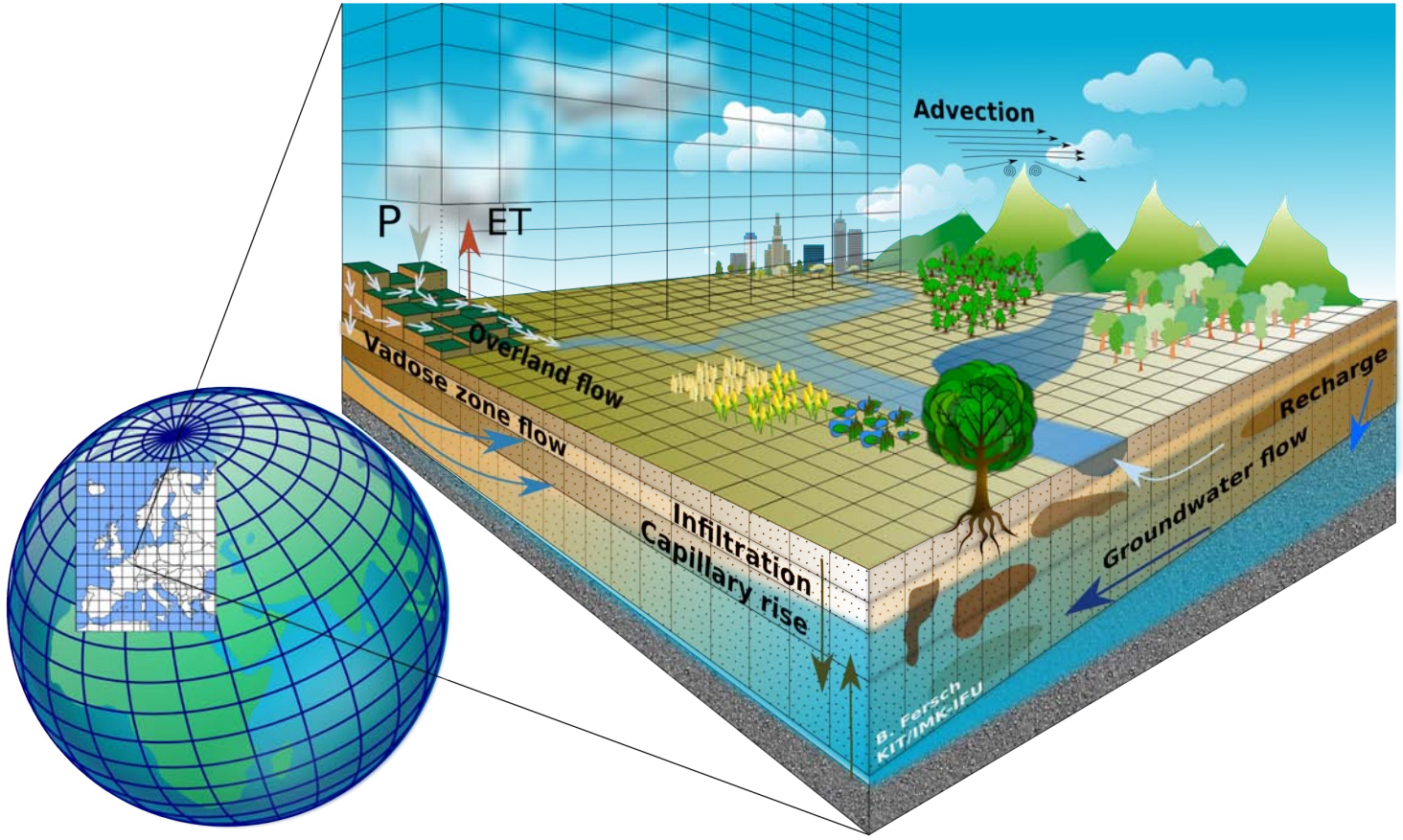

- Include horizontal groundwater transport (2-d, single layer model, unconfined aquifer)

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Outlook

Fully coupled, cross-compartment, distributed dynamical hydro-meteorological model system

Tool for investigating terrestrial-atmospheric moisture and energy exchange and feedback under changing land-use and climatic conditions

- Include horizontal groundwater transport (2-d, single layer model, unconfined aquifer)

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Thank you!

Thank you!
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IMK-IFU: Atmospheric Environmental Research

www.imk-ifu.kit.edu

REKLIM
Helmholtz-Verbund
Regionale Klimaänderungen

www.reklim.de

NCAR

www.ral.ucar.edu

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