數值方法中
植物對大氣循環之影響

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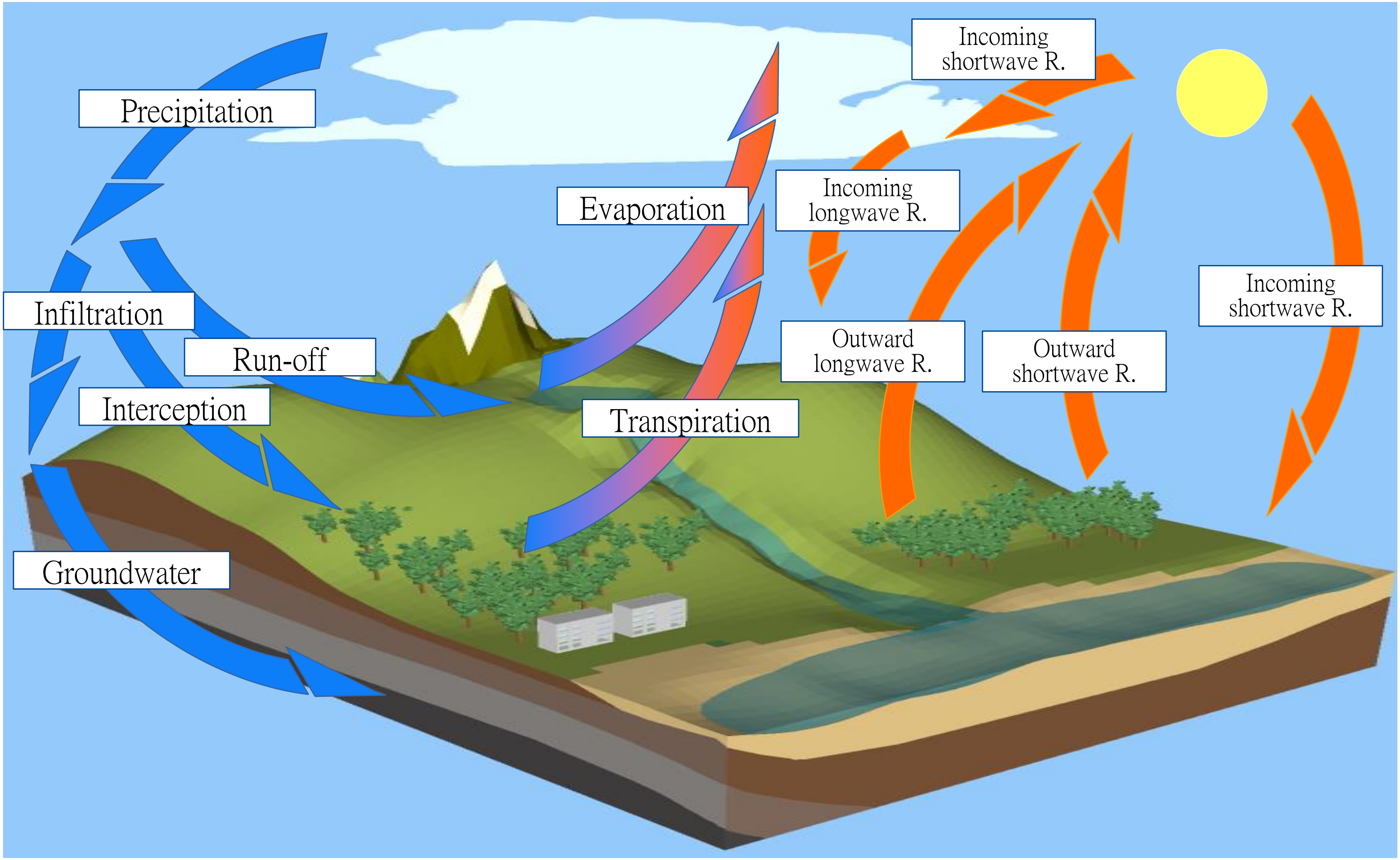
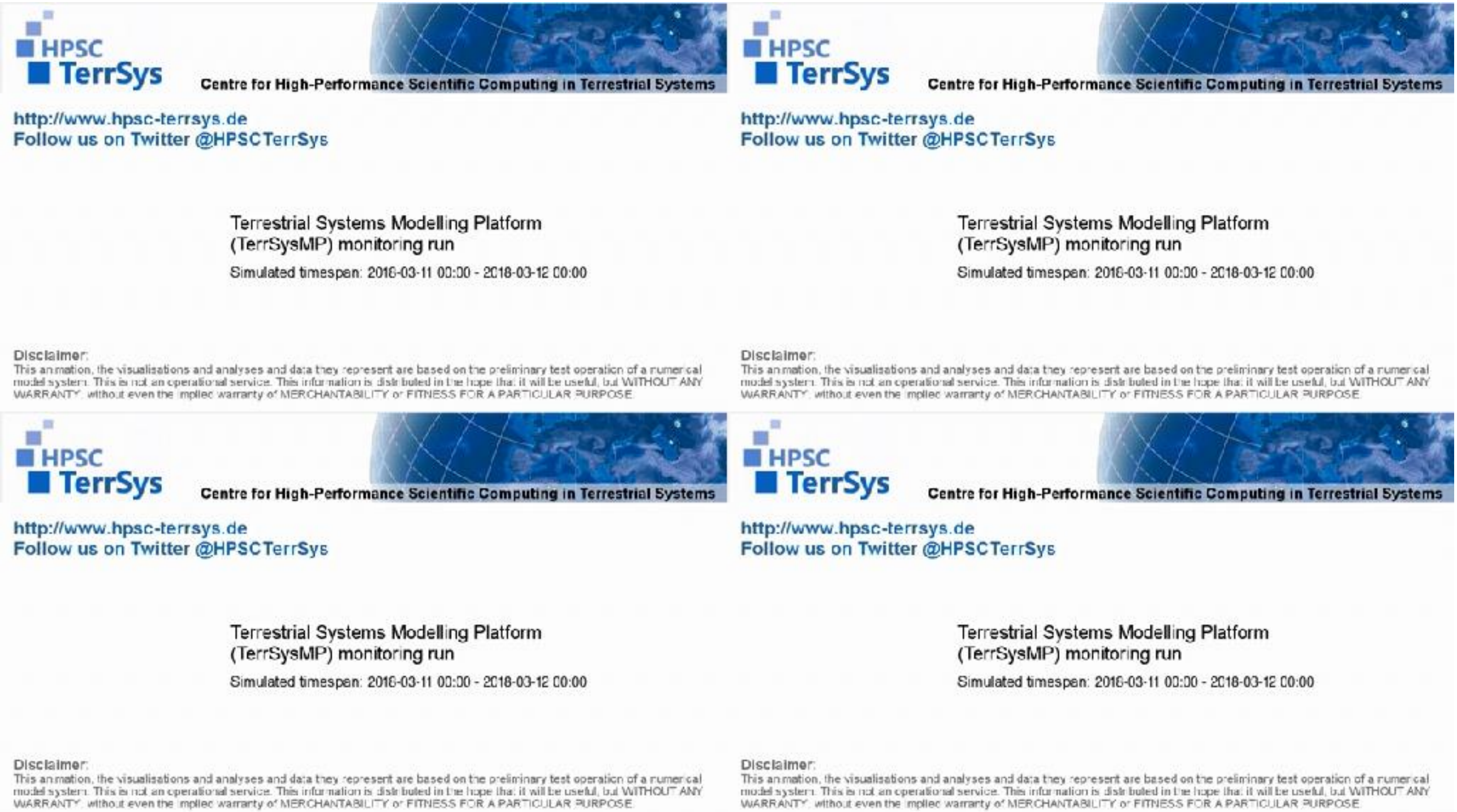
2018.05.22 @ 水保局技研小組Seminar

Overview


Precipitation
Evaporation
Incoming shortwave R.
Incoming longwave R.
Infiltration
Run-off
Interception
Transpiration
Outward longwave R.
Outward shortwave R.
Incoming shortwave R.
Groundwater

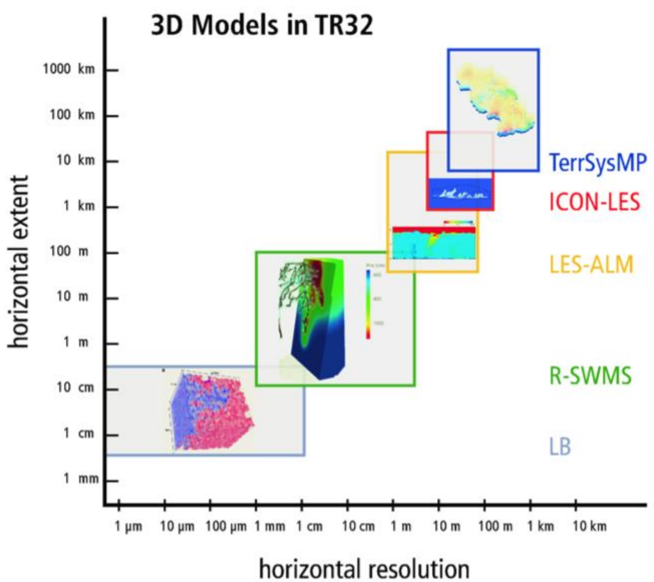
The central goal of studies on terrestrial system

The pattern-based **prediction** of states and fluxes of water, CO_2, and energy in terrestrial systems across scales

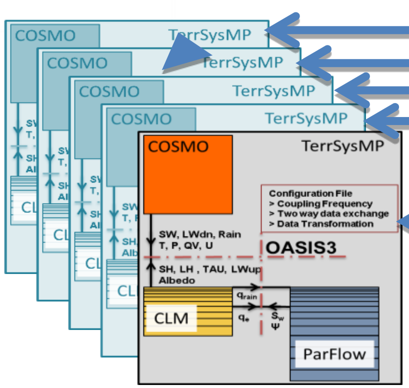


Goal of SFB/TR32 Project

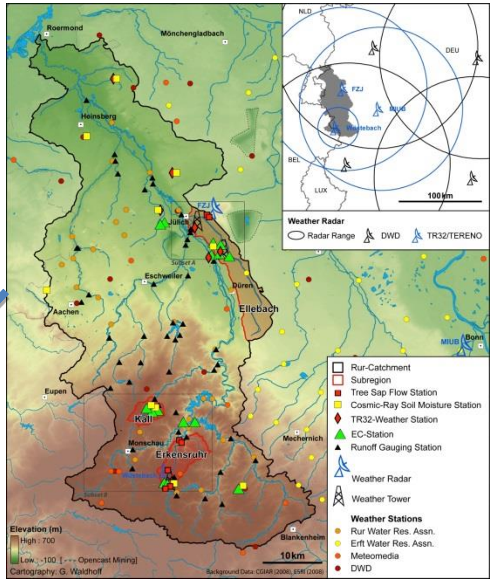
Determine the predictability of states and fluxes of water, carbon, and energy of terrestrial systems



B: across-scale, multi-compartment **modeling**



A: multi-scale **monitoring**

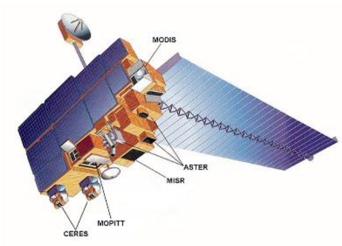


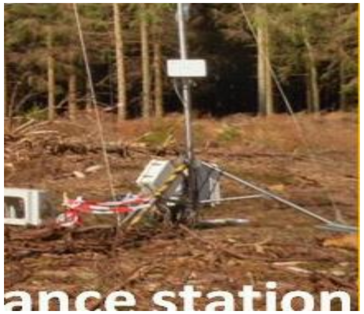
DART

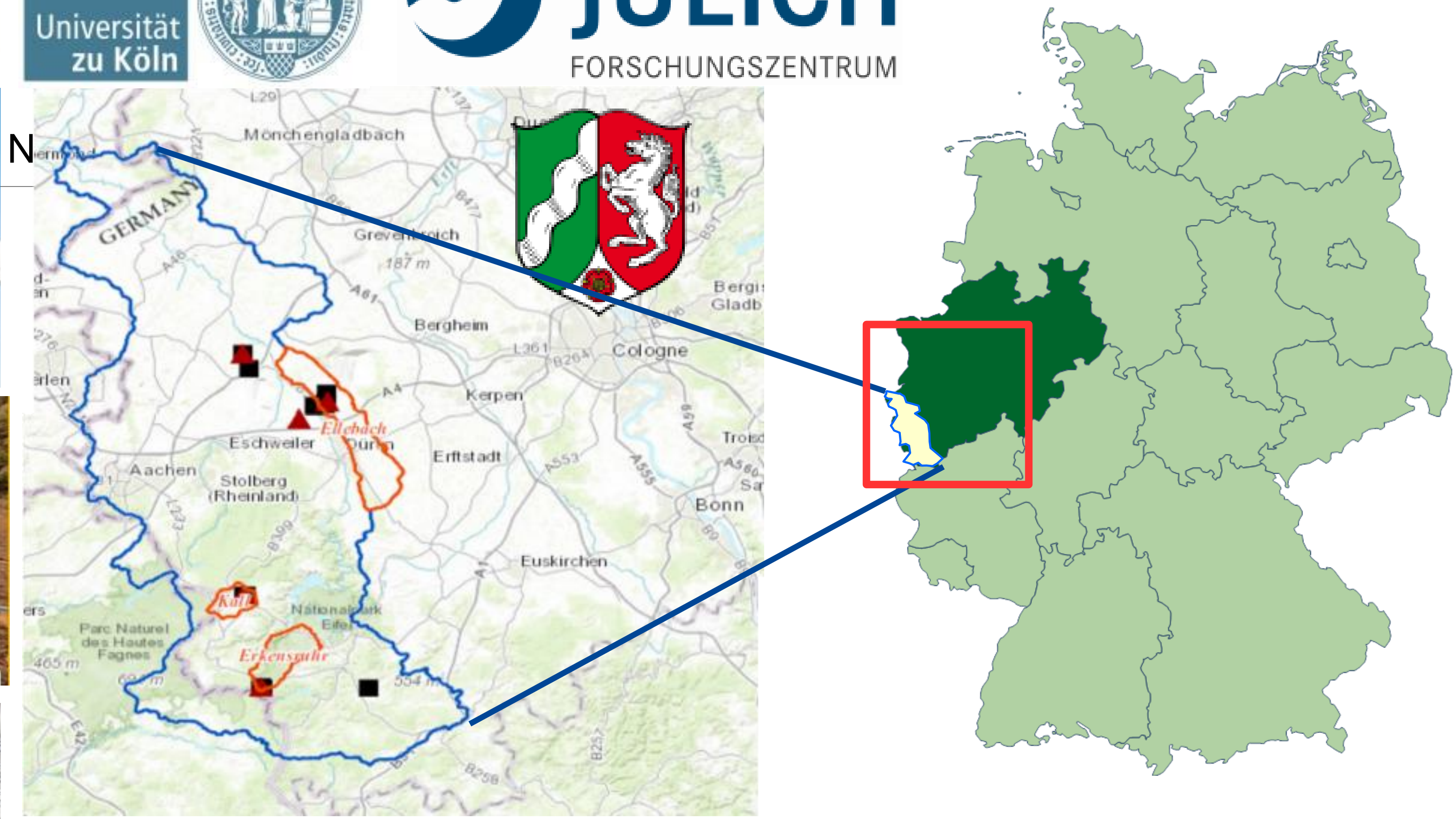
C: **assimilation** of state variables and system parameters

…honoring pattern for up- and downscaling

Study Region: Rur Catchment / NRW

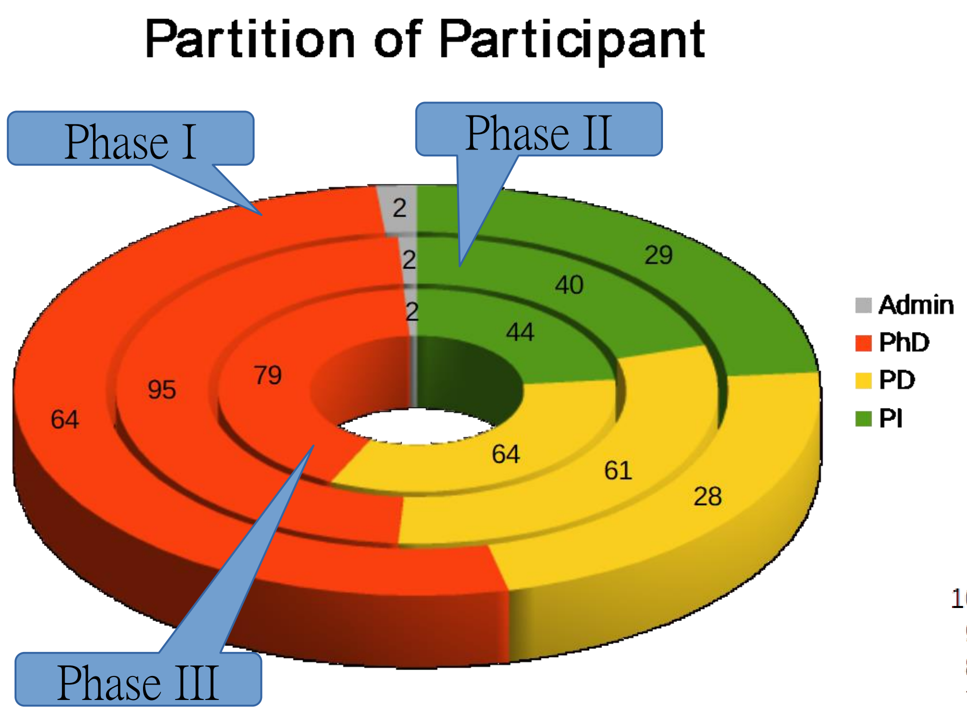


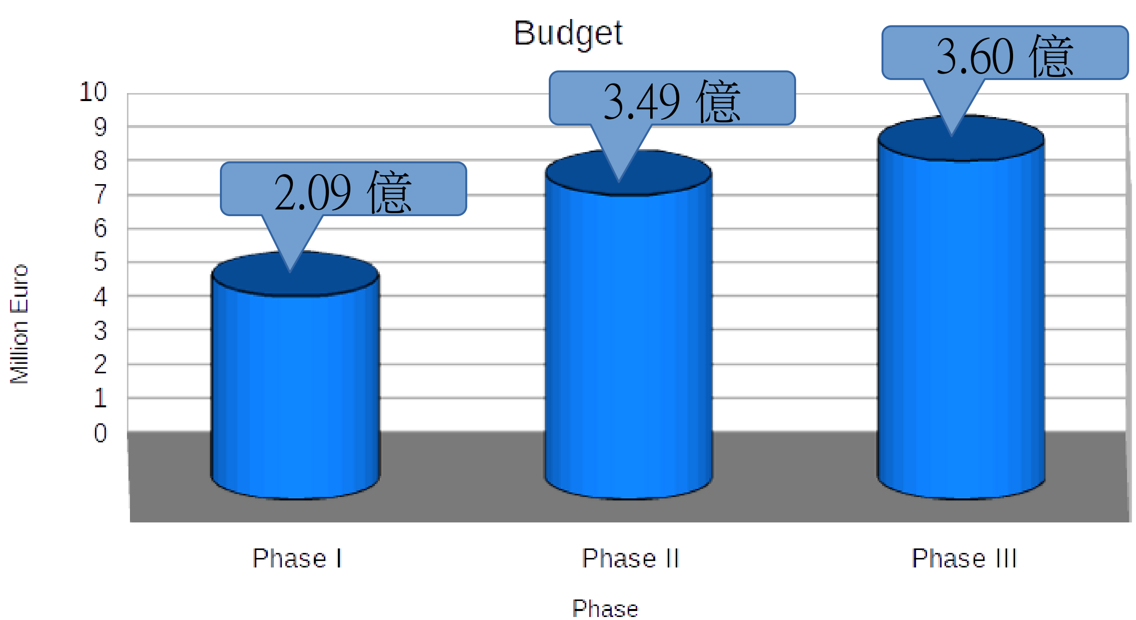




https://en.wikipedia.org/wiki/North_Rhine-Westphalia; https://www.nasa.gov/mission_pages/terra/spacecraft/index.html; https://www2.meteo.uni-bonn.de/staff/stroemel/doku.php; http://www.tereno-conference2014.de/SharedDocs/Bilder/TERENO-CONFERENCE/EN/ec_measurements.jpg http://www.fz-juelich.de/ias/jsc/EN/Expertise/Supercomputers/JUQUEEN/JUQUEEN_node.html; http://www.tr32db.uni-koeln.de/data.php?dataID=763

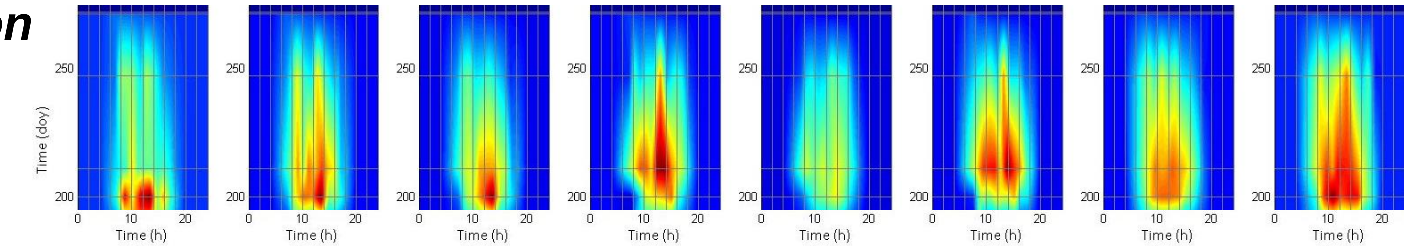
SFB/TR32 Manpower & Budget



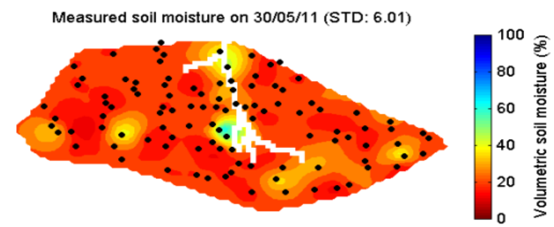


Major Achievements of TR32 - Monitoring

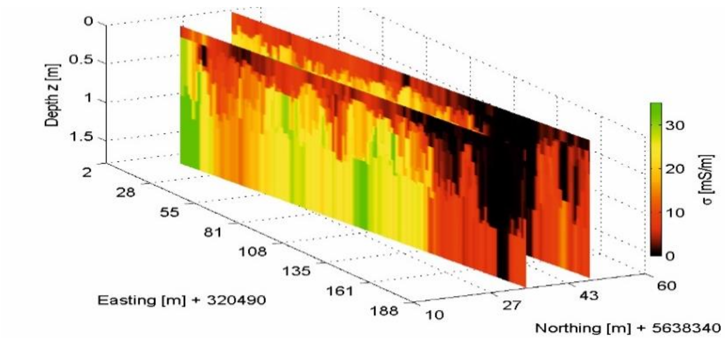
In-situ soil/vegetation observations: Sap-flow on crops and trees, sun-induced fluorescence, MIRS



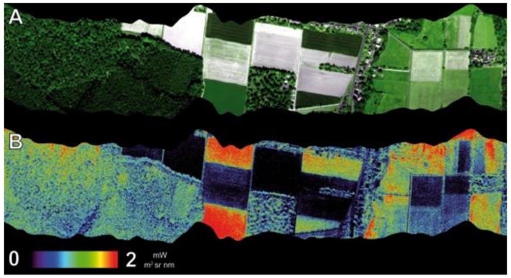
Soil moisture and flux network: EC-stations, in-situ SM sensors, neutron probes



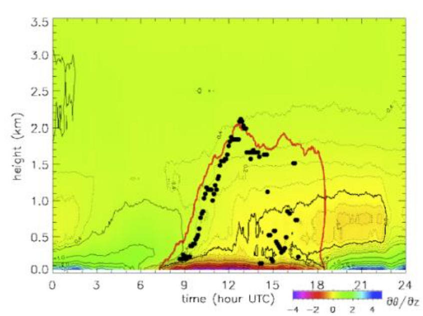
Geo-electric observations: slim-line NMR-tool, combined inversion of SIP, EMI, GPR

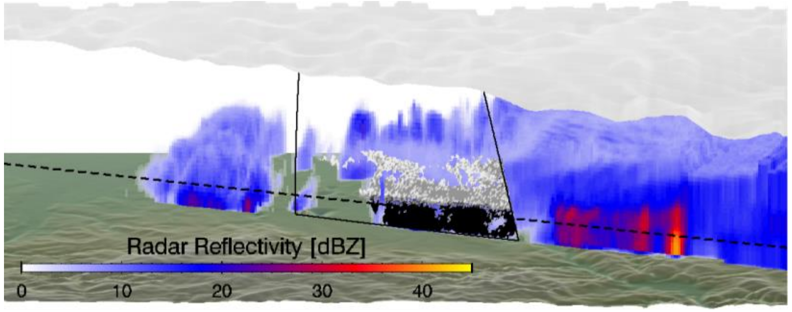


Satellite/airplane remote sensing: soil moisture in cropped fields, sun-induced fluorescence

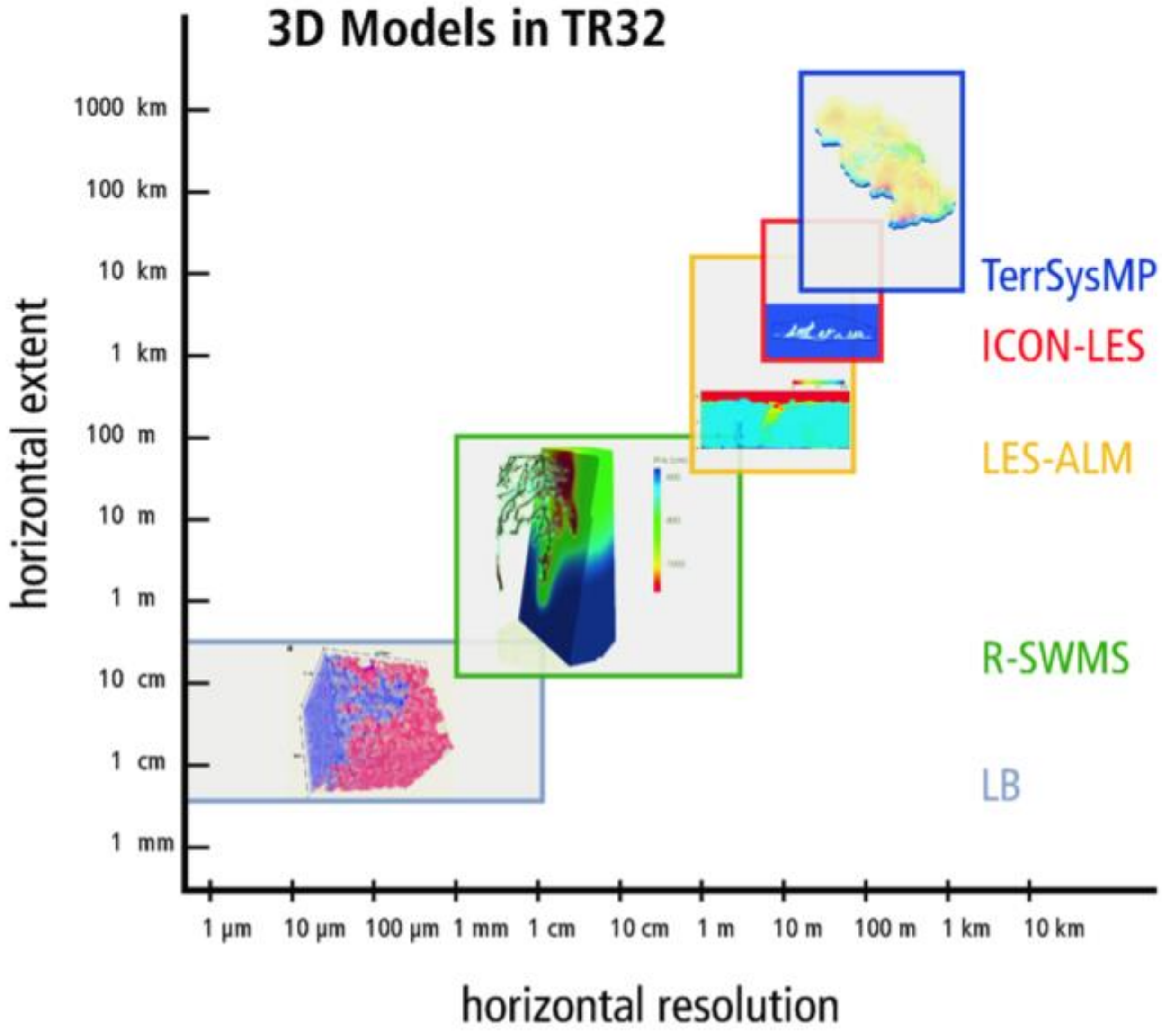


Ground-based remote sensing: JOYCE, Twin-X-band radar



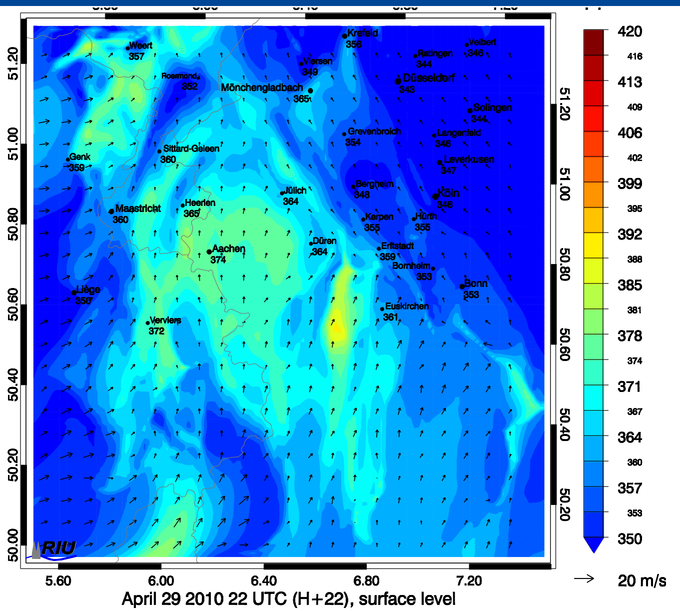


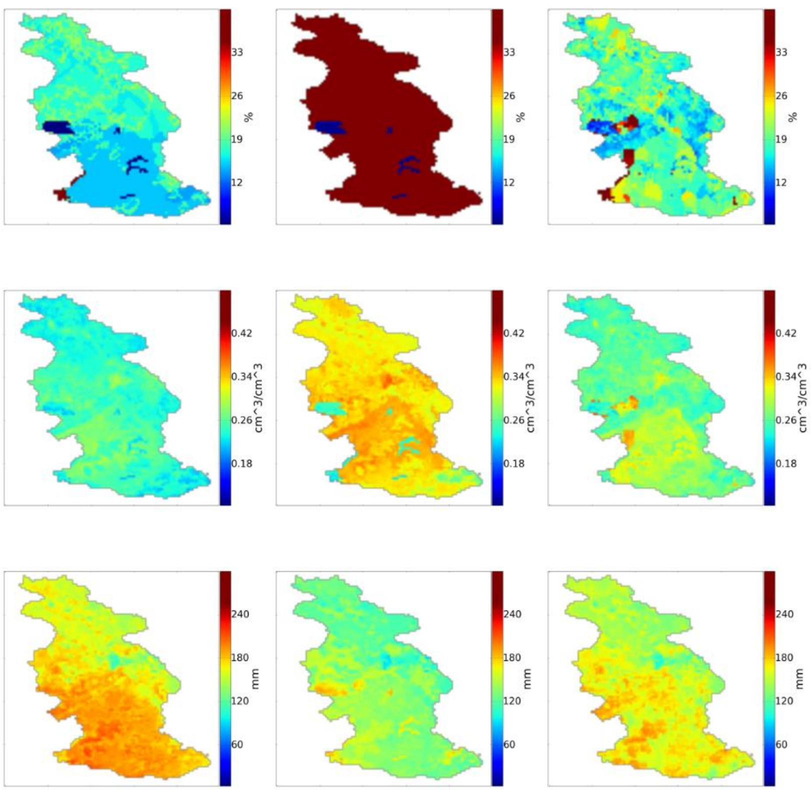
Major Achievements of TR32 - Modeling



Major Achievements – Data Assimilation

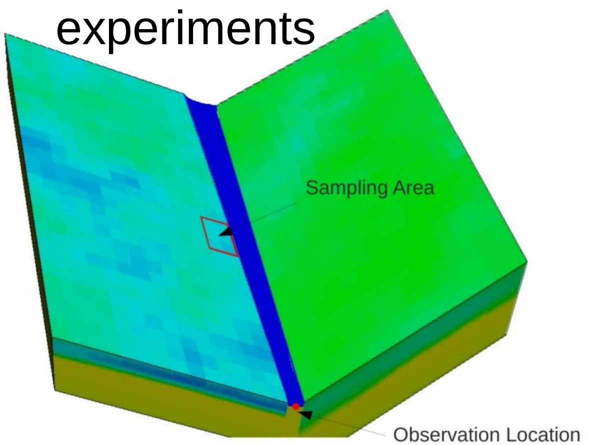
EURAD: joint optimisation of initial values and emission factors





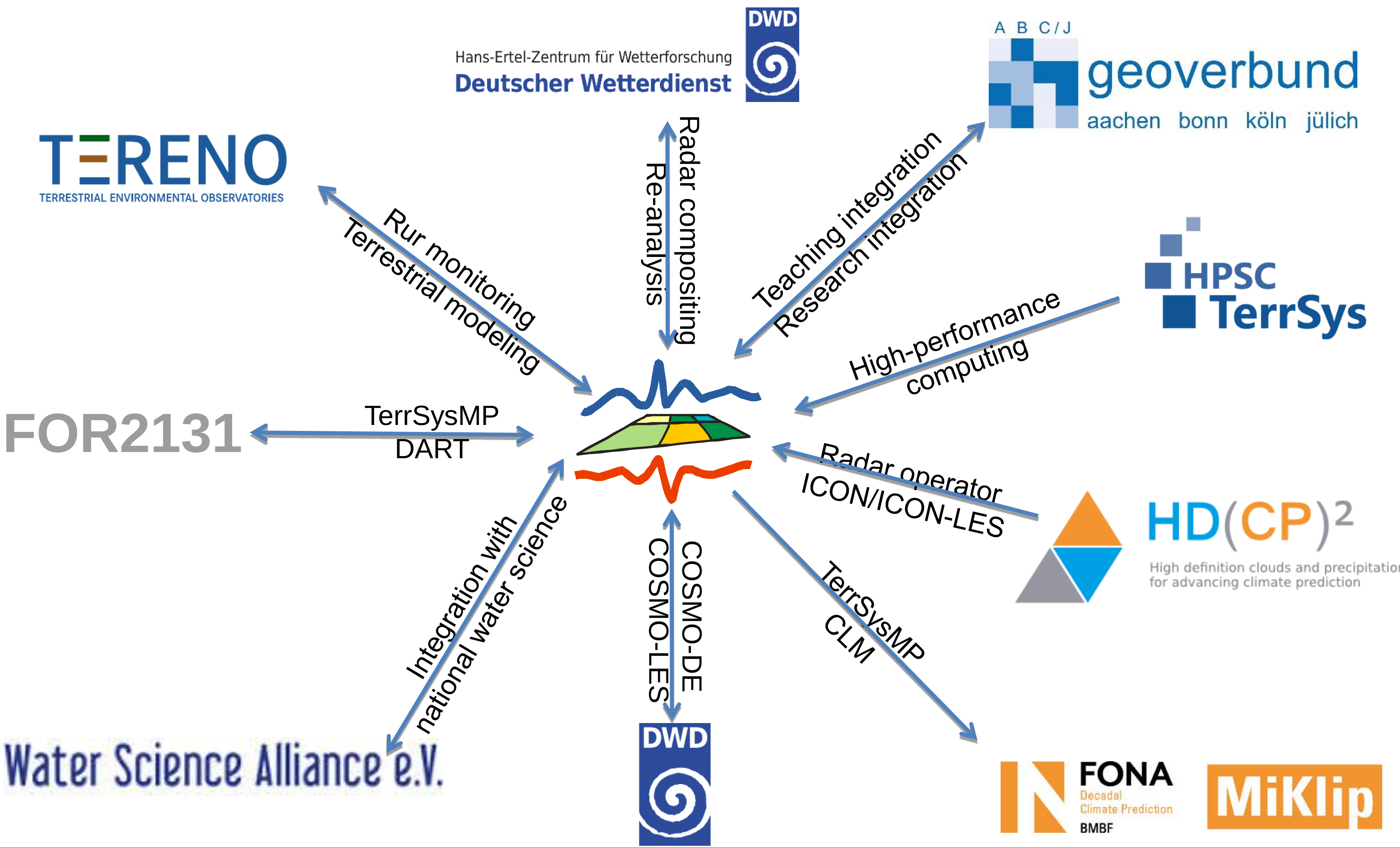
CLM-ParFlow-PDAF: combined state variable and parameter estimation on the catch-mentscale

TerrSysMP-DART: idealized data assimilation experiments



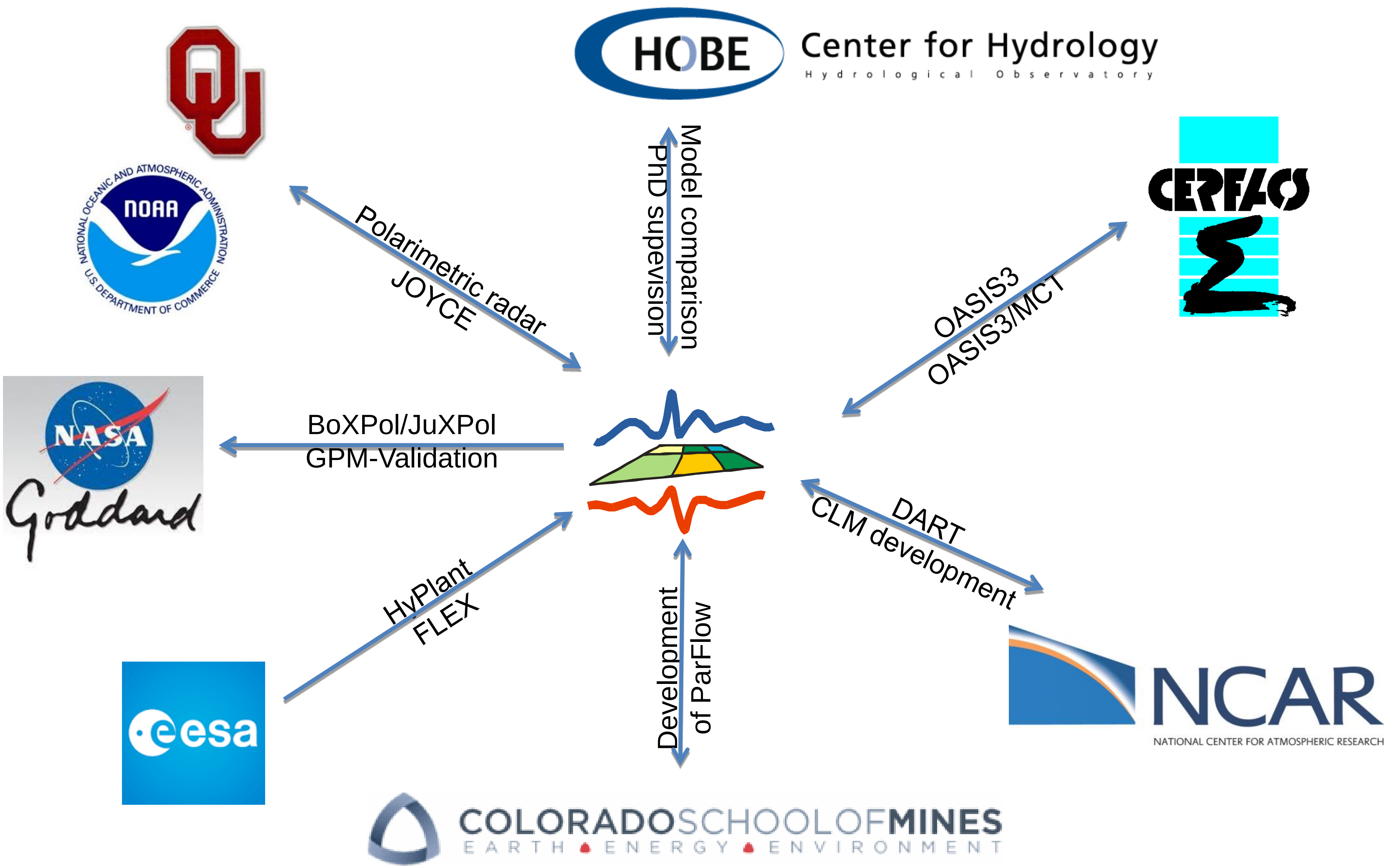
The SFB/TR32 Project

- Regional Cooperation

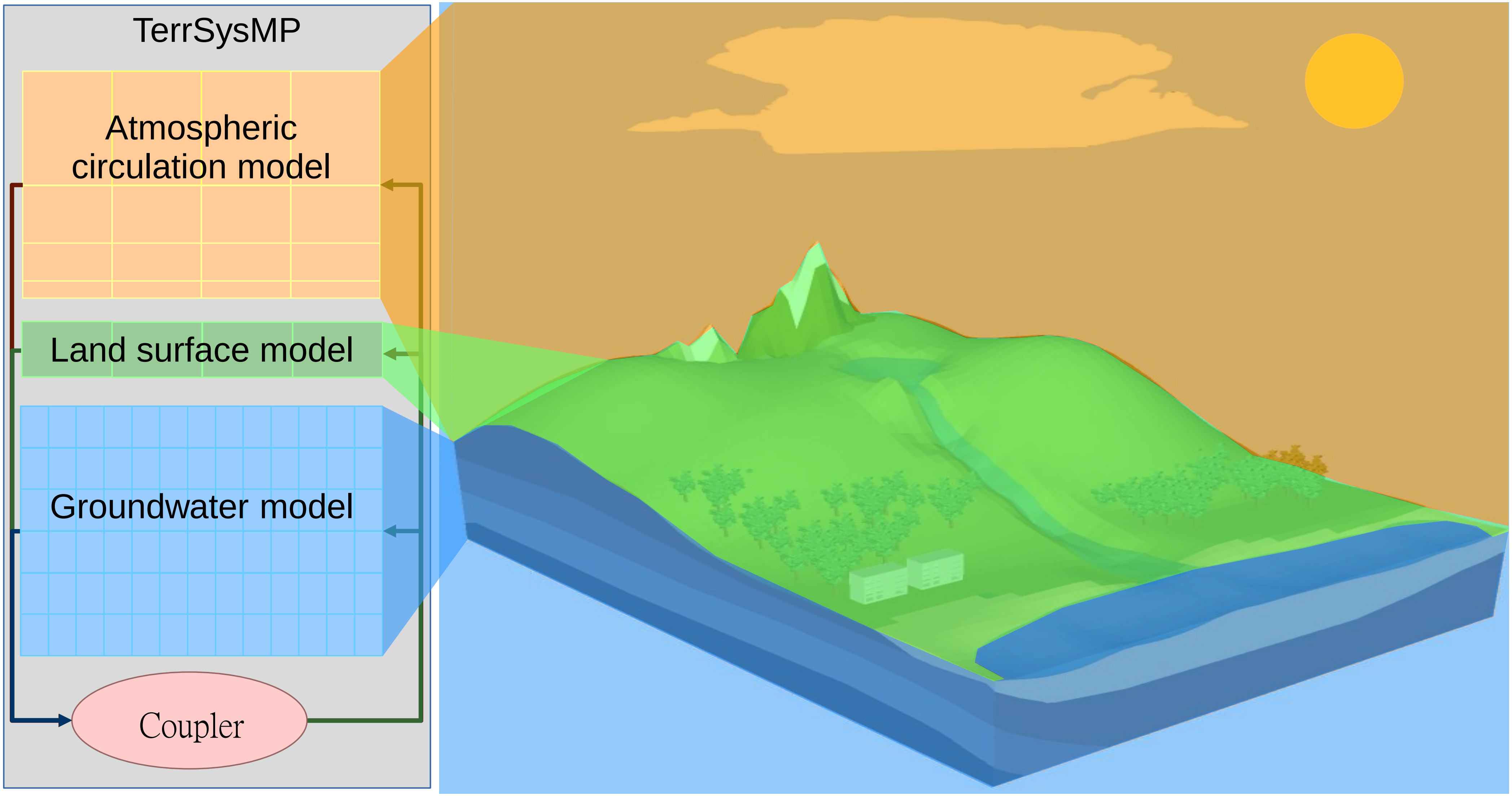


The SFB/TR32 Project

- International Cooperation

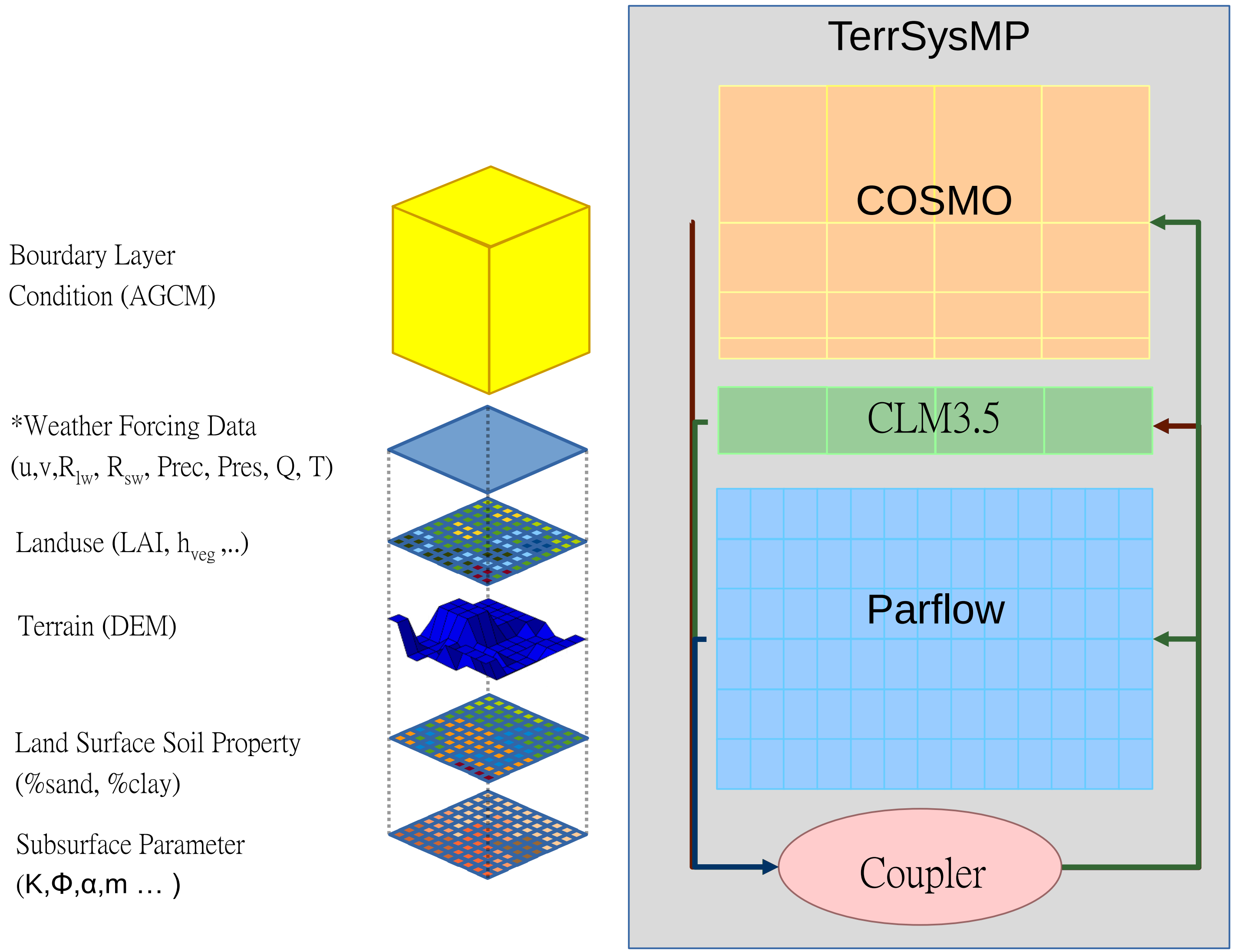


How to build a terrestrial system model?



Terrestrial System Modeling Platform

- Input data, model structure, and output



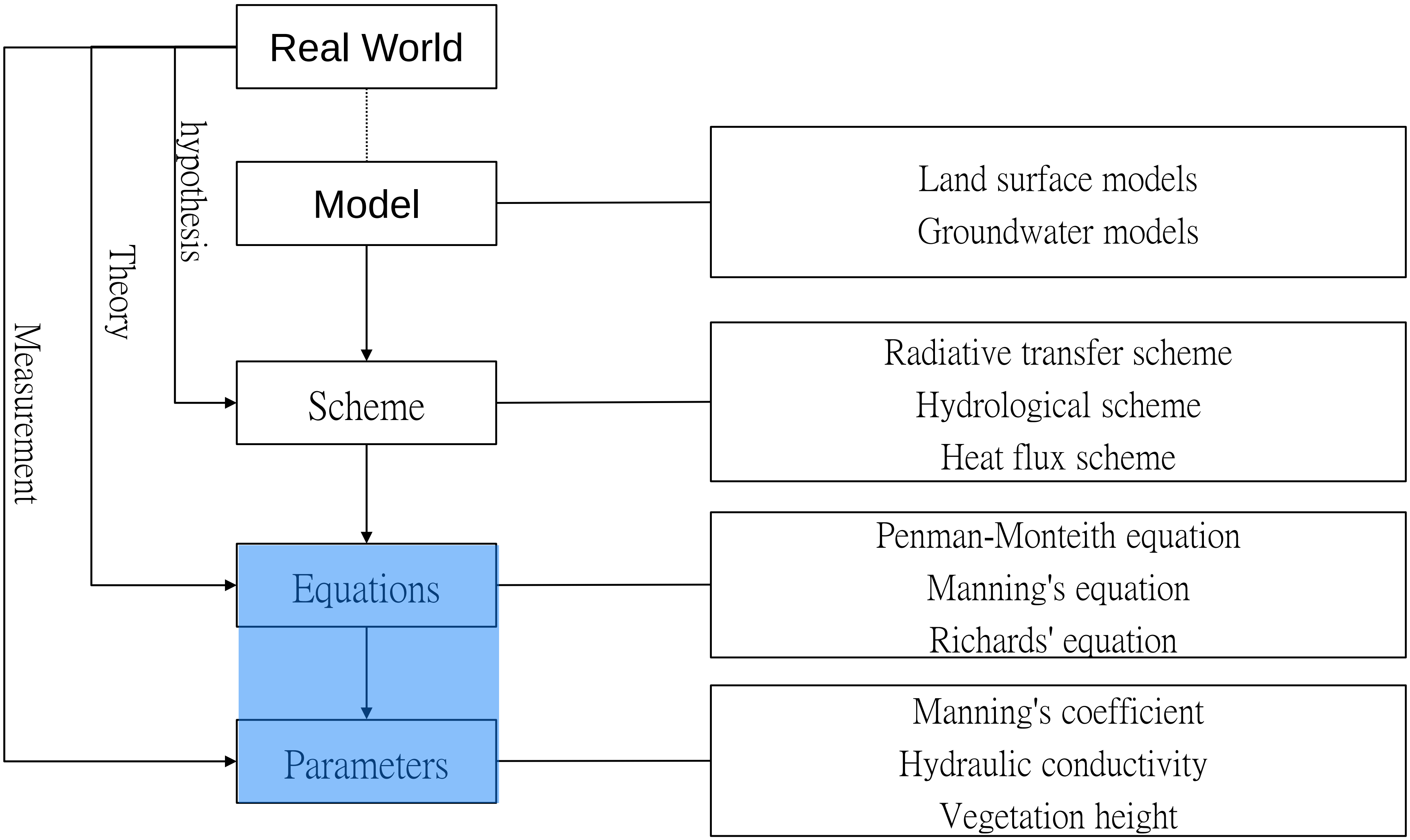
Theories

Land surface model schemes

&

Coupled model system

Numerical model structure

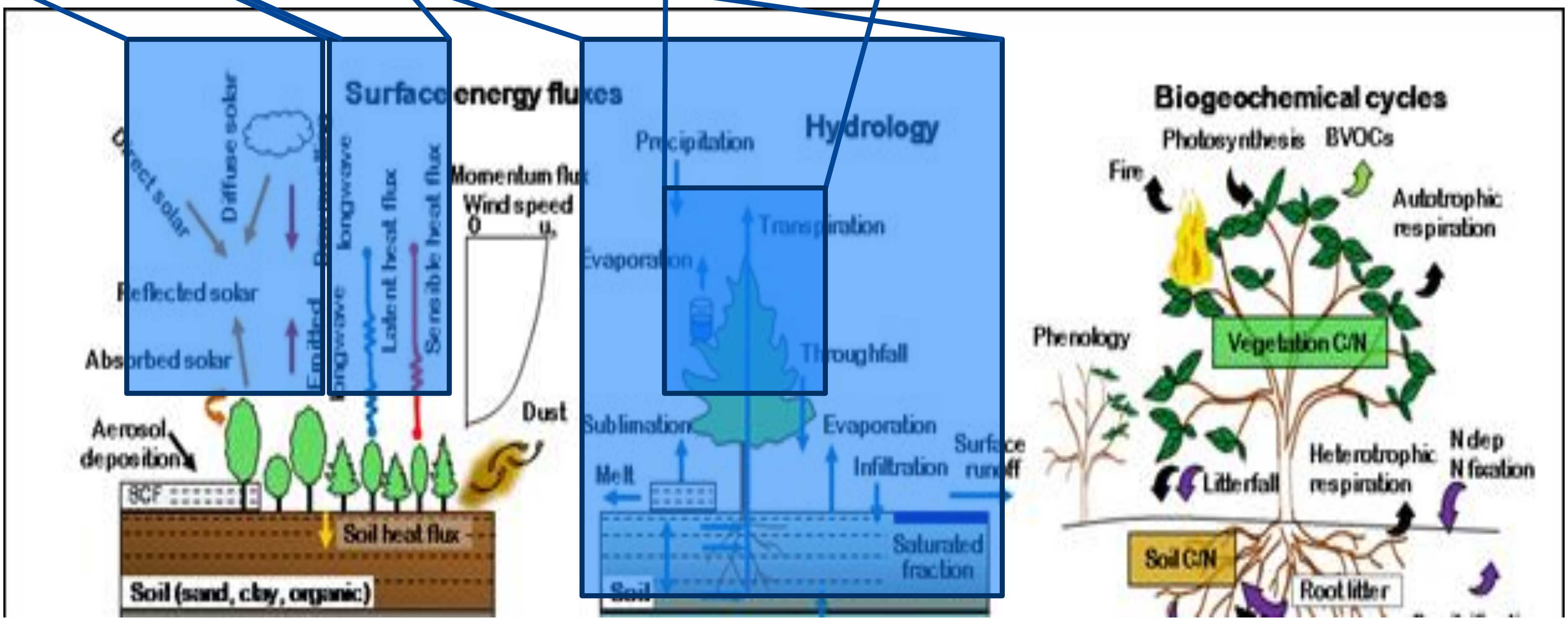


Core of land surface model

- Energy and mass conservation

$$ENGERY_{in} = ENERGY_{out} + \Delta ENERGY$$
$$MASS_{in} = MASS_{out} + \Delta MASS$$

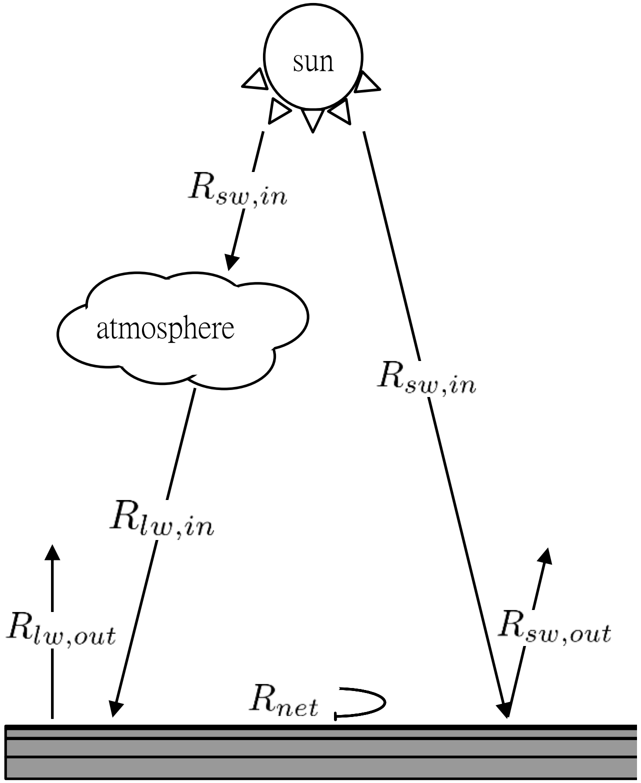
Major schemes				Minor schemes		
Radiative Transfer	Heat flux	Hydrology	Vegetation	Carbon cycle	Nitrogen cycle	Urban



CLM: Land surface process (1)

Radiative transfer scheme

$$R_{net} = R_{sw,in} + R_{lw,in} - R_{sw,out} - R_{lw,out}$$

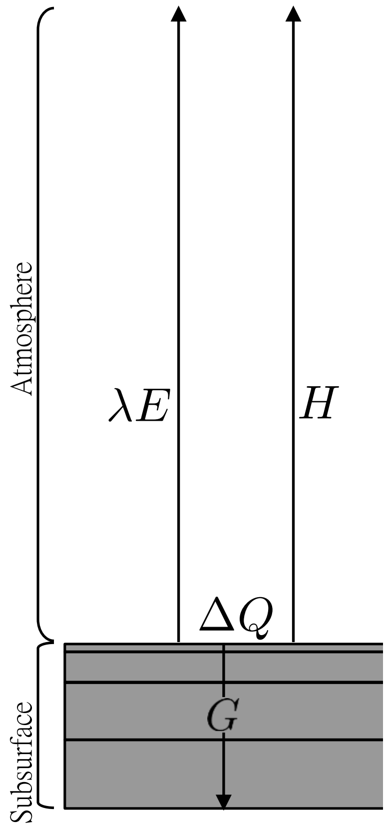


(a) Radiative transfer scheme

CLM: Land surface process (2)

Heat fluxes scheme

$$R_{net} = \lambda(E_T + E_C + E_G) + H_V + H_G + G$$

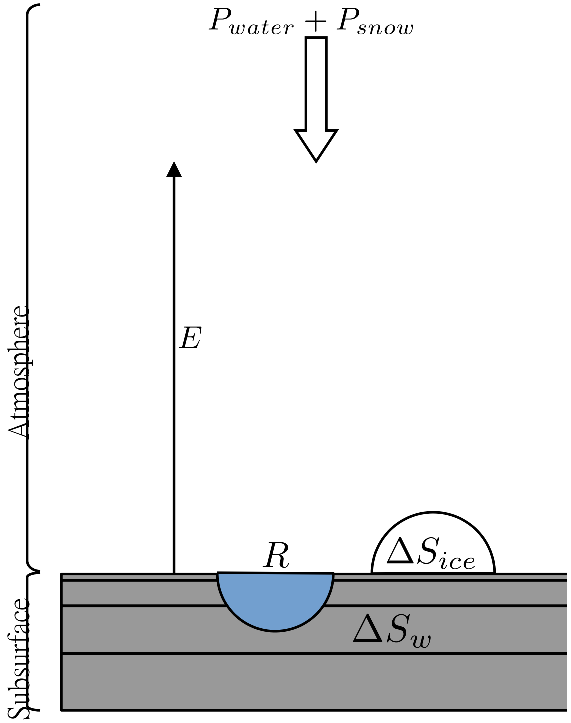


(a) Heat flux scheme

CLM: Land surface process (3)

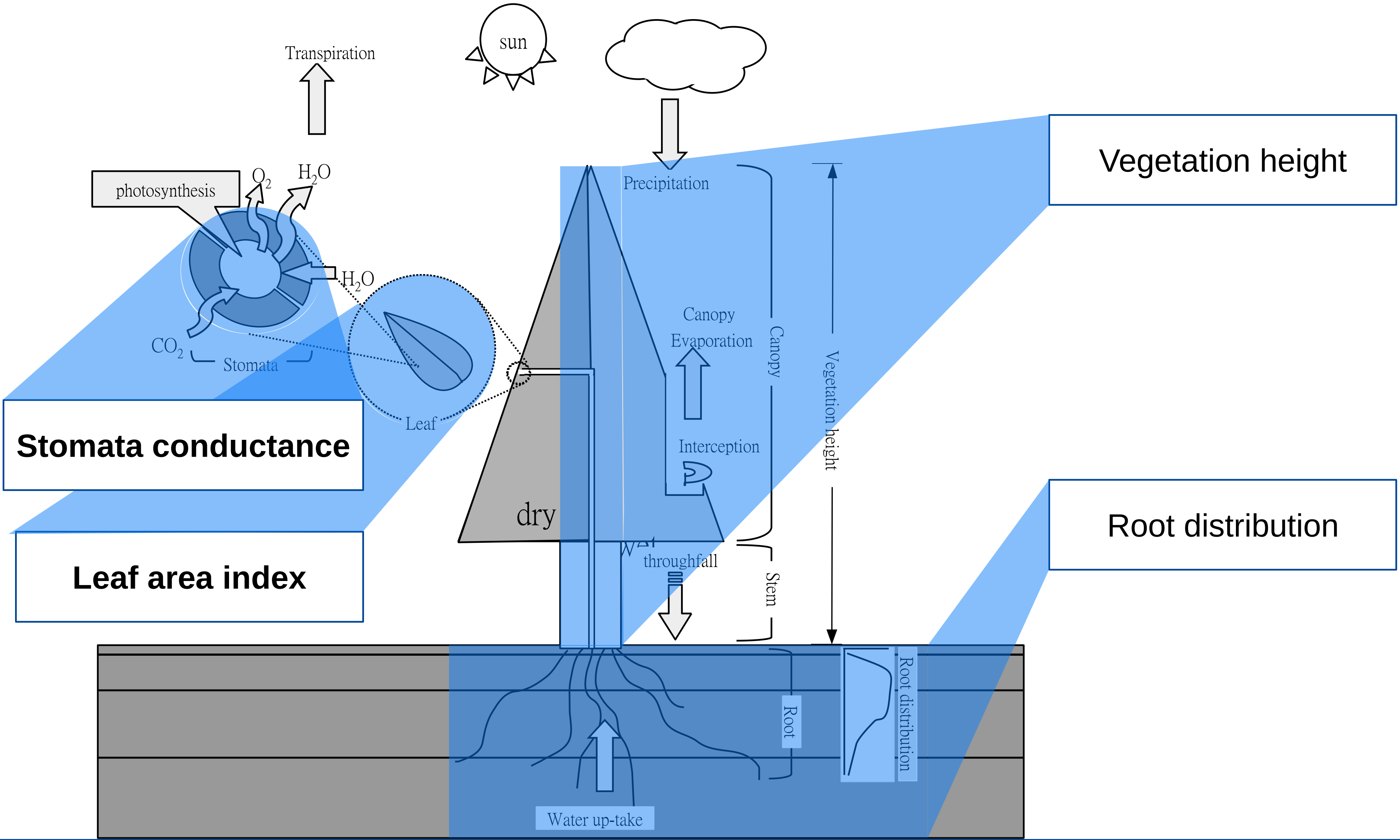
Hydrological scheme

$$P = (P_{liq.} + P_{sol.}) = E + R + \frac{\partial S_w}{\partial t} + \frac{\partial S_{ice}}{\partial t} \frac{\partial S_{canopy}}{\partial t}$$

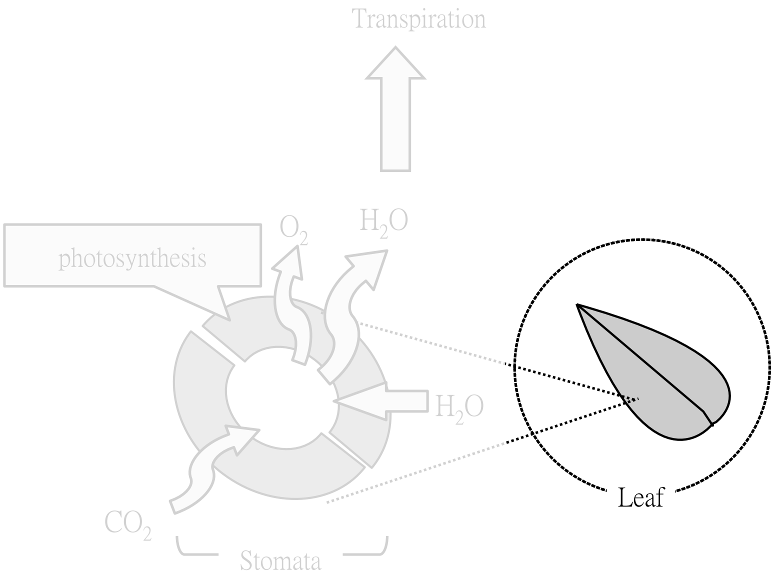


(a) Hydrological scheme

Vegetation scheme



Vegetation scheme: Leaf Area Index



LAI input types

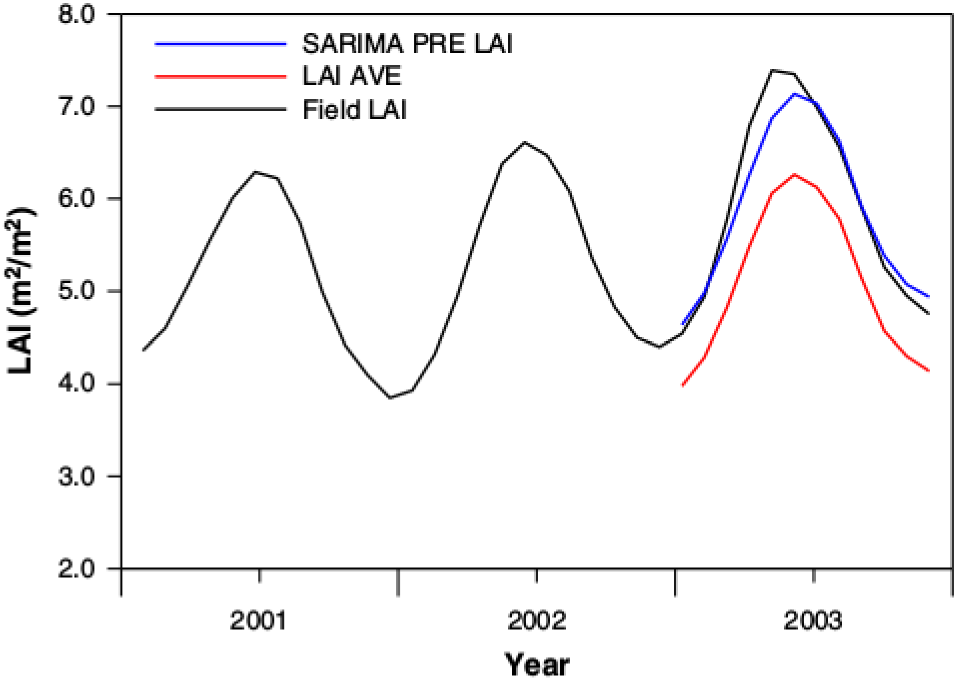
Measurement

LAI input types

Satellite

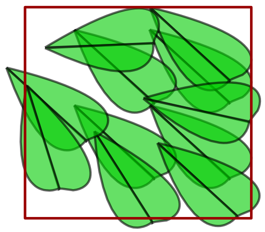
LAI input types

Modeling / Parameterization



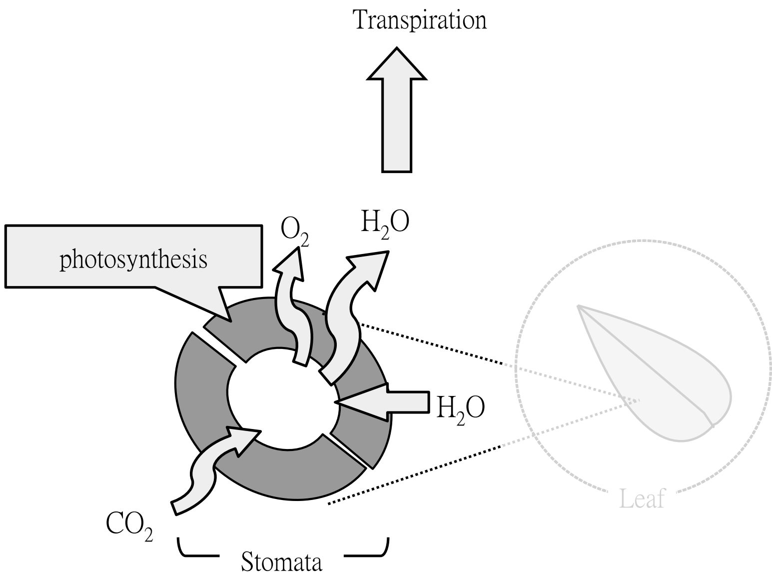
Purpose

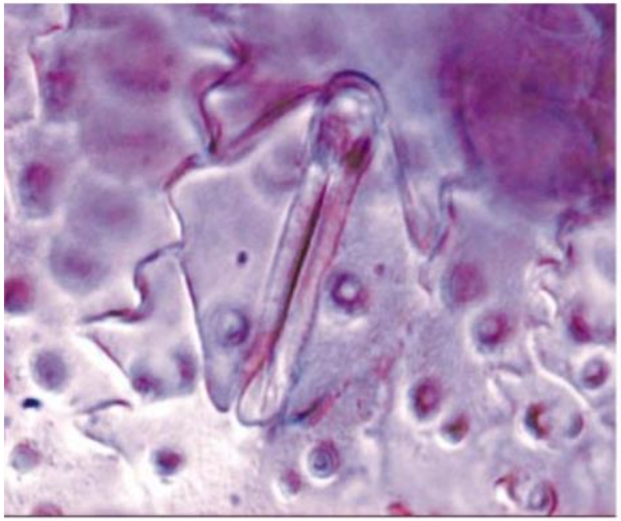
Scaling up from leaf to canopy

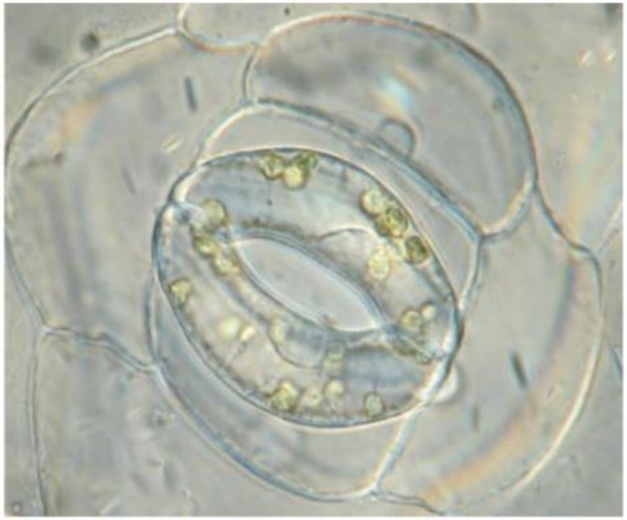


0.0 ~ 14.0 (m^2 m^{-2})

Vegetation scheme: stomatal conductance





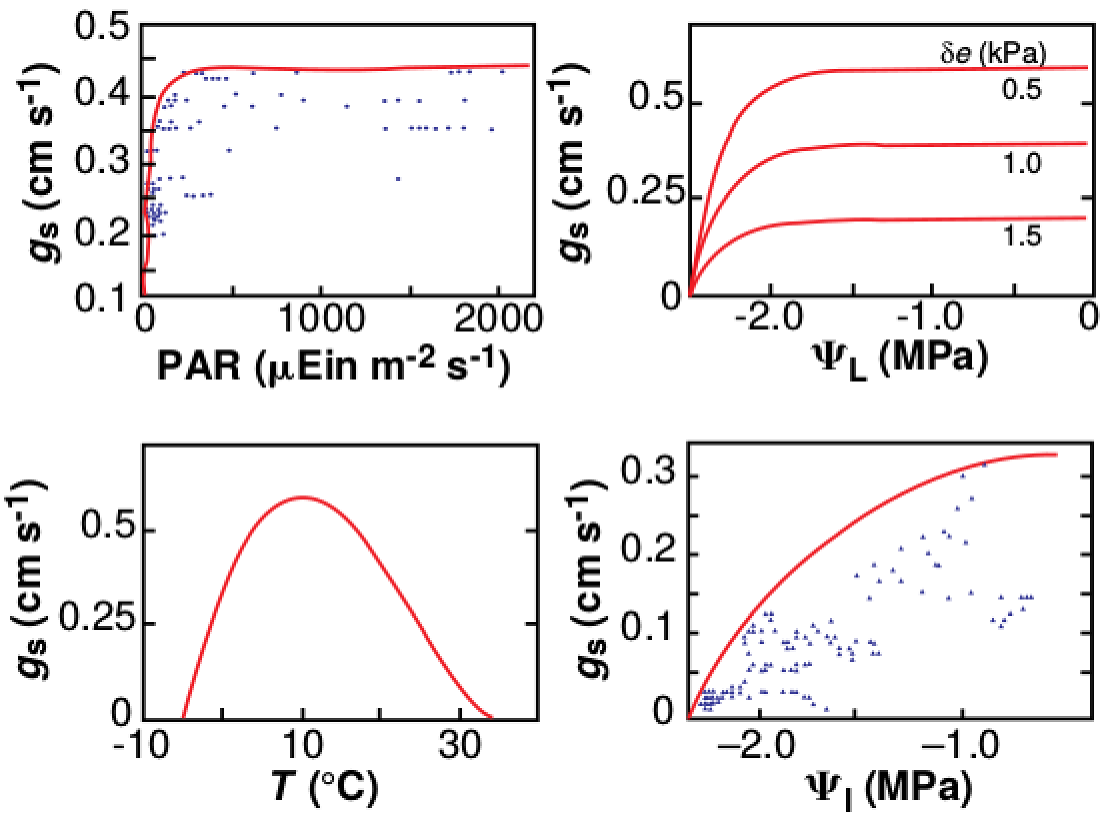


28.	Oren *et al.* 1999	$g_s = \frac{K_{tot}}{A_L}\cdot\frac{\Psi_s-\Psi_l}{VPD}$
29.	Tyree & Sperry 1988 Sperry *et al.* 1998	$F = K_{AB}\,(\Psi_A - \Psi_B)$ architecture description
30.	Tuzet *et al.* 2003	$g_s = 1.6\left[g_0 + f(\Psi_l)\cdot a\frac{A_{net}}{C_i-\Gamma}\right]$ $f(\Psi_l) = \frac{1+\exp(s\cdot\Psi_f)}{1+\exp[s(\Psi_f-\Psi_l)]}$ $\quad E = \frac{\Psi_s-\Psi_l}{\chi_v}$
31.	Jones & Sutherland 1991	$\Psi_l - \Psi_s = -\frac{c\cdot VPD\cdot g_s}{K_{tot}(\Psi)}$ $K_{tot}(\Psi) = \begin{cases} K_{max} & \text{if } \Psi_{cav} < \Psi_l \\ K_{max}\frac{\Psi_l-\Psi_{100}}{\Psi_{cav}-\Psi_{100}} & \text{if } \Psi_{cav} > \Psi_l > \Psi_{100} \\ 0 & \text{if } \Psi_{100} > \Psi_l \end{cases}$
32.	Cochard *et al.* 1996a Lu *et al.* 1996	$E_{crit} = K_{tot}\,(\Psi_s - \Psi_{cav})$
33.	Dewar 2002	$g_s = \chi(P_g - P_e)$ $\quad g_s = \chi(\Delta\pi - \Delta\Psi)$ $\Delta\Psi = \frac{E}{k}$ $\quad \Delta\pi = \frac{(A_{net}+R_d)/C_i}{d_{min}\exp\{[ABA]\cdot\beta\cdot\exp(\delta\Psi_e)\}}$
34.	Gao *et al.* 2002	$g_s = \frac{1}{\beta}P_g$ $\quad g_s = \frac{1}{\beta}(\Psi_g - \pi_g)$ $g_s\cdot VPD = K_{tot}\,(\Psi_s - \Psi_g)$ $\quad \pi_g = \pi_0 - \alpha\cdot Q$
35.	Buckley *et al.* 2003	$g_s = \chi(P_g - mP_e)$ $\quad g_s = \chi[(\Psi_g - \pi_g) - mP_e]$ $g_s\cdot VPD = K_{tot}(\Psi_s - \Psi_g)$ $\quad \pi_g = f(T, P_e)$

(Hetherington & Woodward, 2002, *Nature*)
(Damour et al. , 2010)

Vegetation scheme: stomatal conductance

Stomata equations	
Jarvis-Stewart (1988)	$g_s = f(PAR)f(T_{leaf})f(\delta e)f(\theta_w)$



(Jarvis, 1976; Stewart, 1988)
(Sellers et al., 1997, *Science*, based on Jarvis (1976))

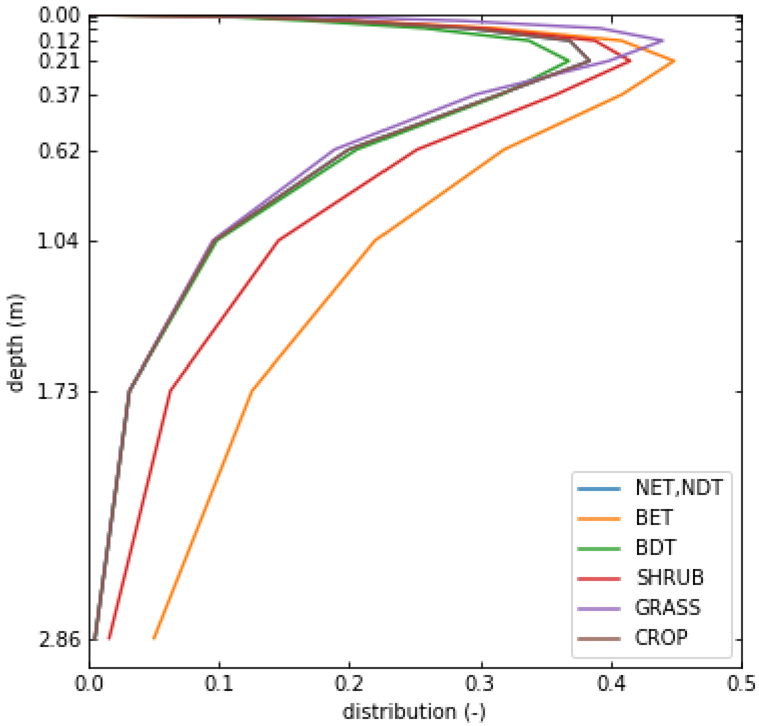
Vegetation scheme: stomatal conductance

Stomata equations	
Ball-Berry-Collatz (1991)	$g_s = g_{s,min} + m\frac{A_{net} H_R}{C_s}$
Ball-Berry-Leuning (1994)	$g_s = g_{s,min} + m\frac{A_{net} f(\delta e)}{C_s - \Gamma}$

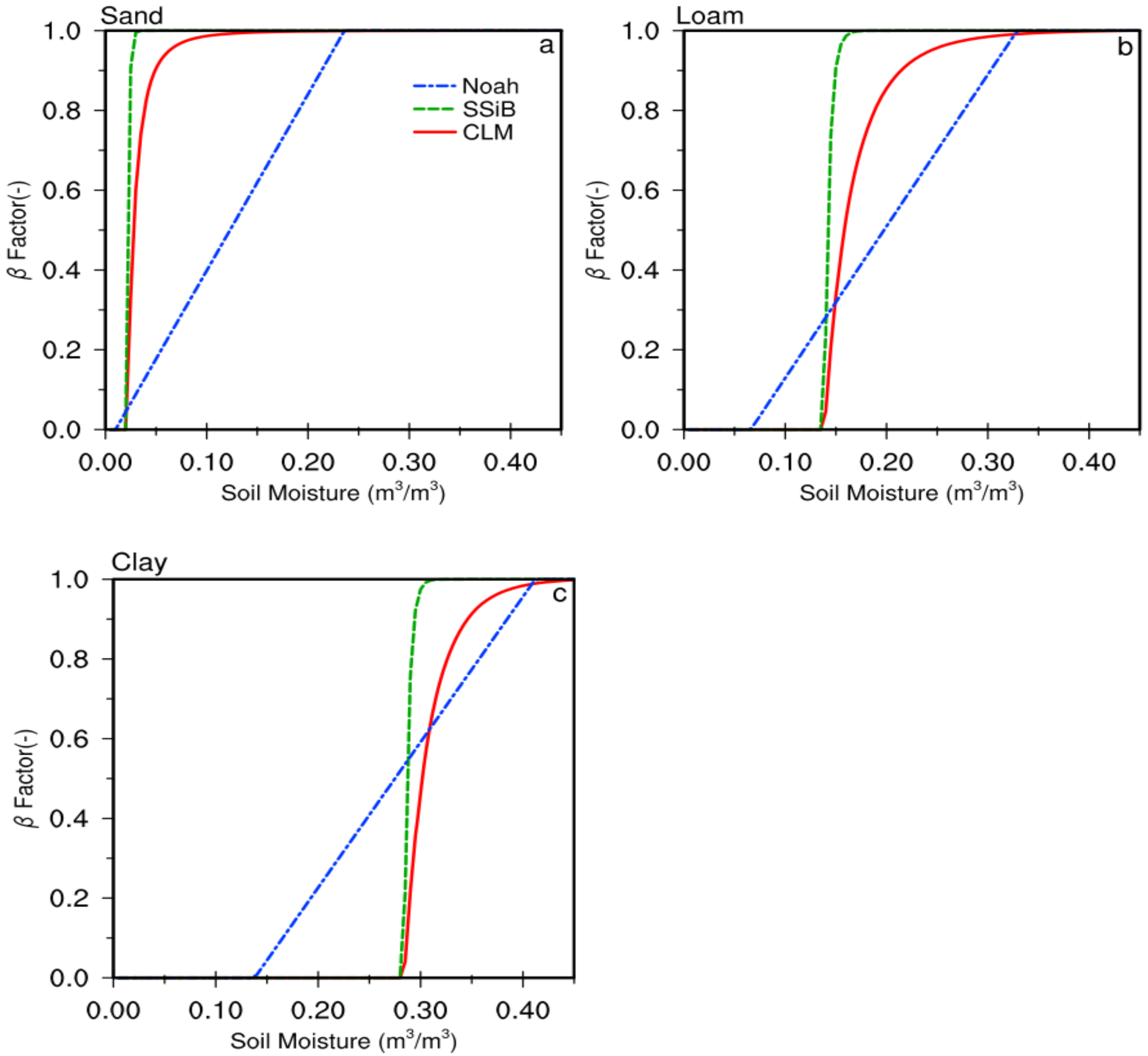
CO_2 Assimilation rate (Photosynthesis)	
Farquar et al. (1980)	$A \approx \min\begin{cases} J_E \\ J_C \end{cases}$ $J_C = \frac{V_m(p_i - \Gamma_*)}{p_i + K_c(1 + [O_2]/K_o)}$

Vegetation scheme: Root distribution

Root distribution

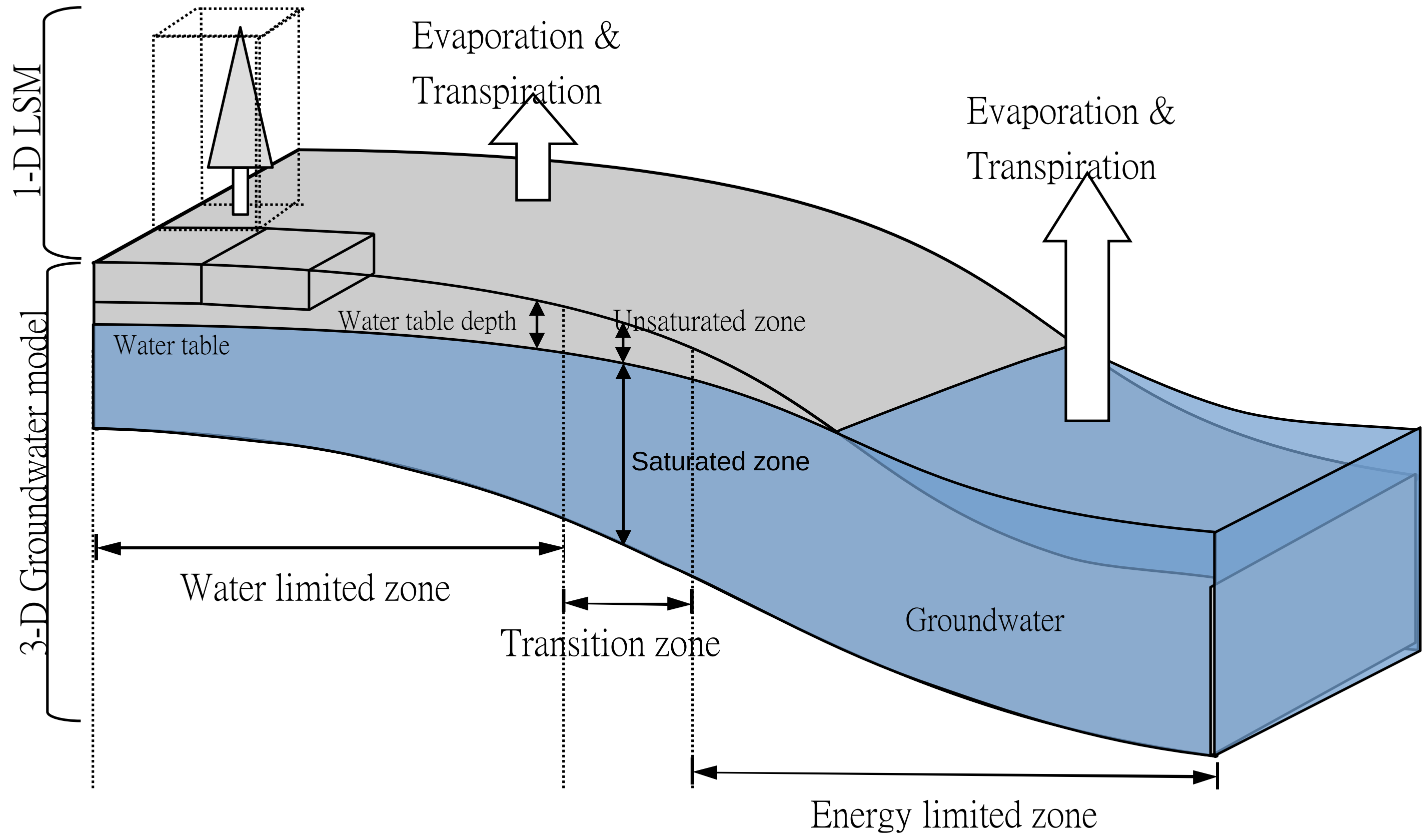


Soil water limitation factor(s)



(Nie et al. 2011)

Hypothesis


1-D LSM
3-D Groundwater model
Evaporation &
Transpiration
Evaporation &
Transpiration
Water table depth
Unsaturated zone
Water table
Saturated zone
Groundwater
Water limited zone
Transition zone
Energy limited zone

Parflow: groundwater model

- Surface flow:

$$\underbrace{\frac{\partial \psi_s}{\partial t}}_{\text{Change of water height on surface}} = \overbrace{\nabla \vec{v} \psi_s}^{\text{Water outflow}} + \underbrace{q_r}_{\text{Precipitation}} + \overbrace{q_e}^{\text{Infiltration}}$$

- Flow velocity (Manning's Equation)

$$\vec{v} = \frac{\sqrt{S_f}}{n} \psi_s^{2/3}$$

- Subsurface flow

$$\underbrace{S_s \theta_s(\psi_h) \frac{\partial \psi_h}{\partial t}}_{\text{Compressed water releasing}} + \underbrace{\frac{\partial(\theta_s(\psi_h) \cdot \phi)}{\partial t}}_{\text{Change of water storage}} = \overbrace{\nabla \cdot q}^{\text{Water flow}} + \underbrace{q_s}_{\text{Sink/ Source}}$$

- Flow velocity

$$q = -k_s k_r(\psi_h) \nabla(\psi_h - z)$$

Results & Discussion

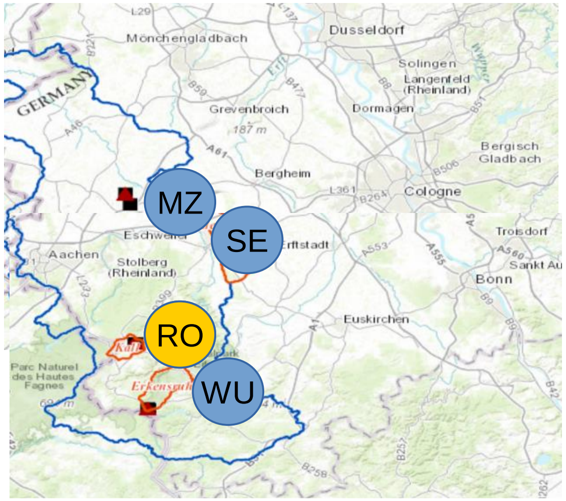
Stomatal conductance

LAI

Turbulent heat fluxes

Groundwater

Model setup



data period: 2012-2013

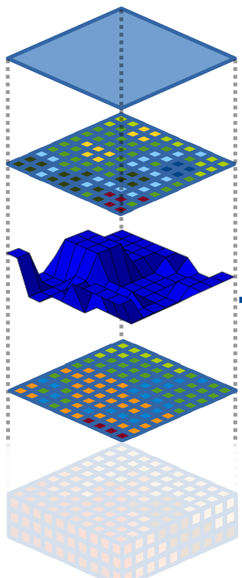
*Weather Forcing Data
(u,v,R_{lw}, R_{sw}, Prec, Pres, Q, T)

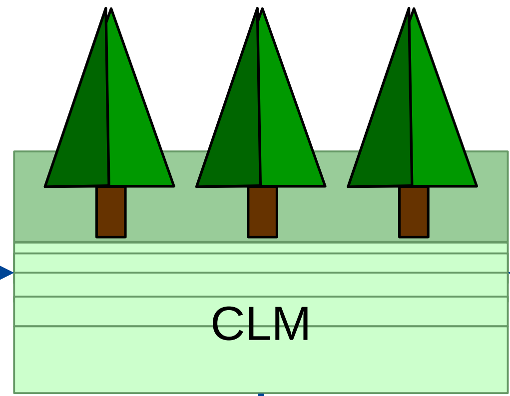
Landuse (LAI, h_{veg} ,..)

Terrain (DEM)

Land Surface Soil Property
(%sand, %clay)

Subsurface Parameter
(K,Φ,α,m …)





Model output

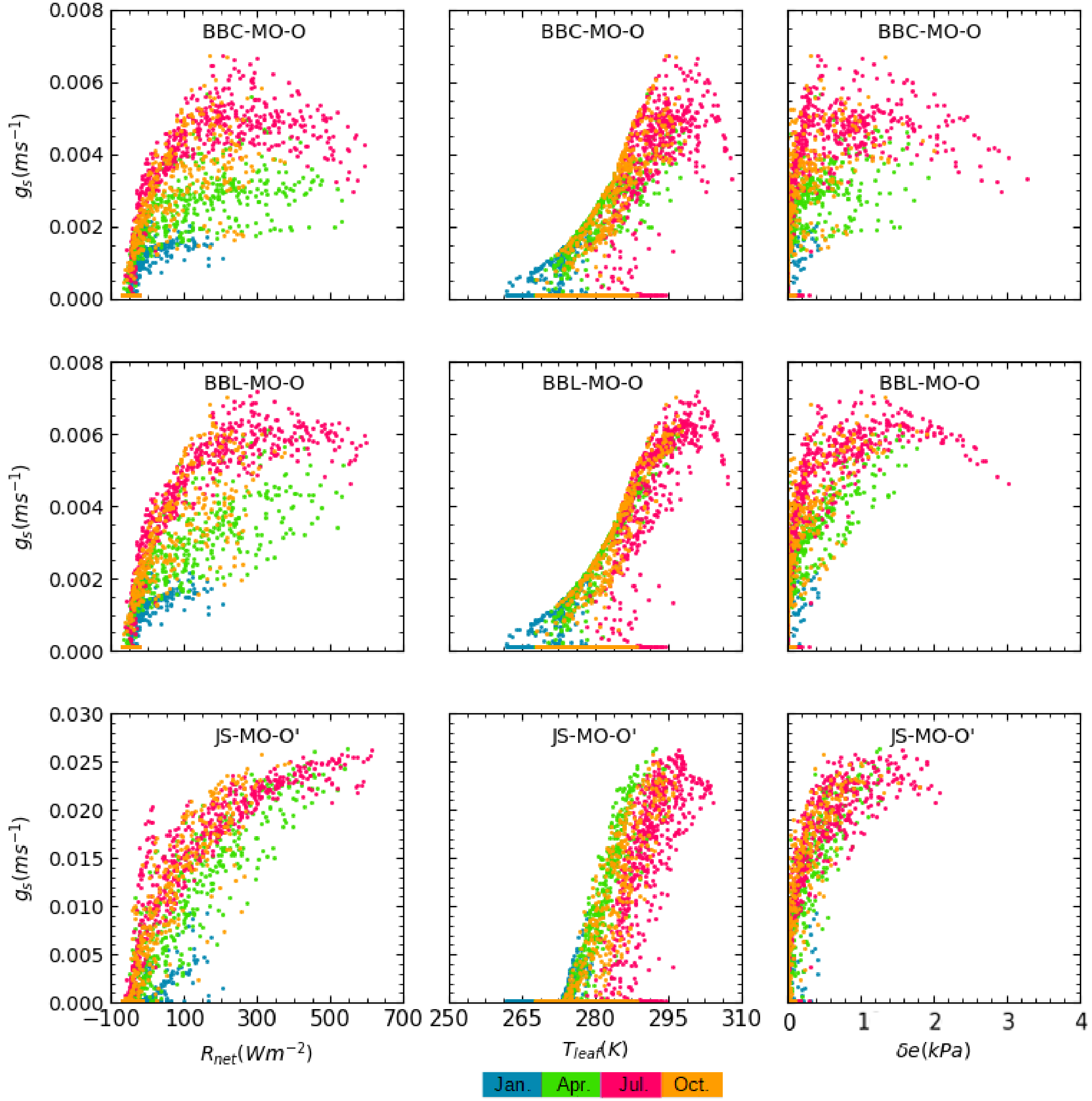
Analysis
(Validation)

Stomata equations
JS-type
BBC-type
BBL-type

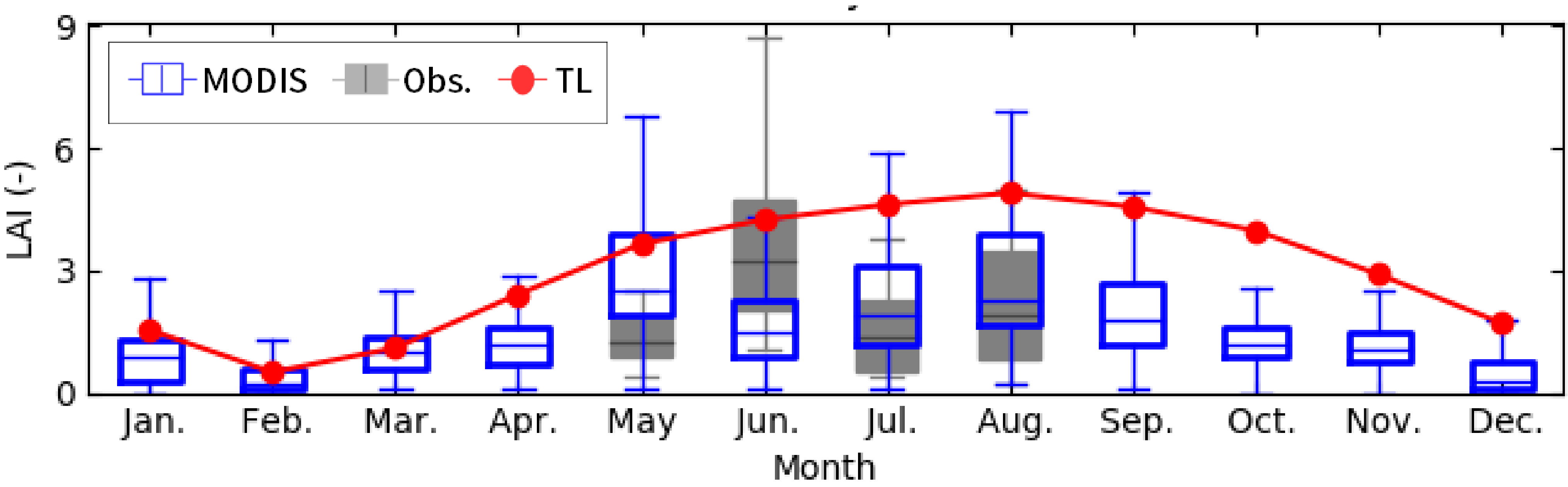
LAI Input
MODIS data (MCD15A2)
Simple Dynamic LAI

Using general vegetation parameters
(No calibration)

Stomata conductance



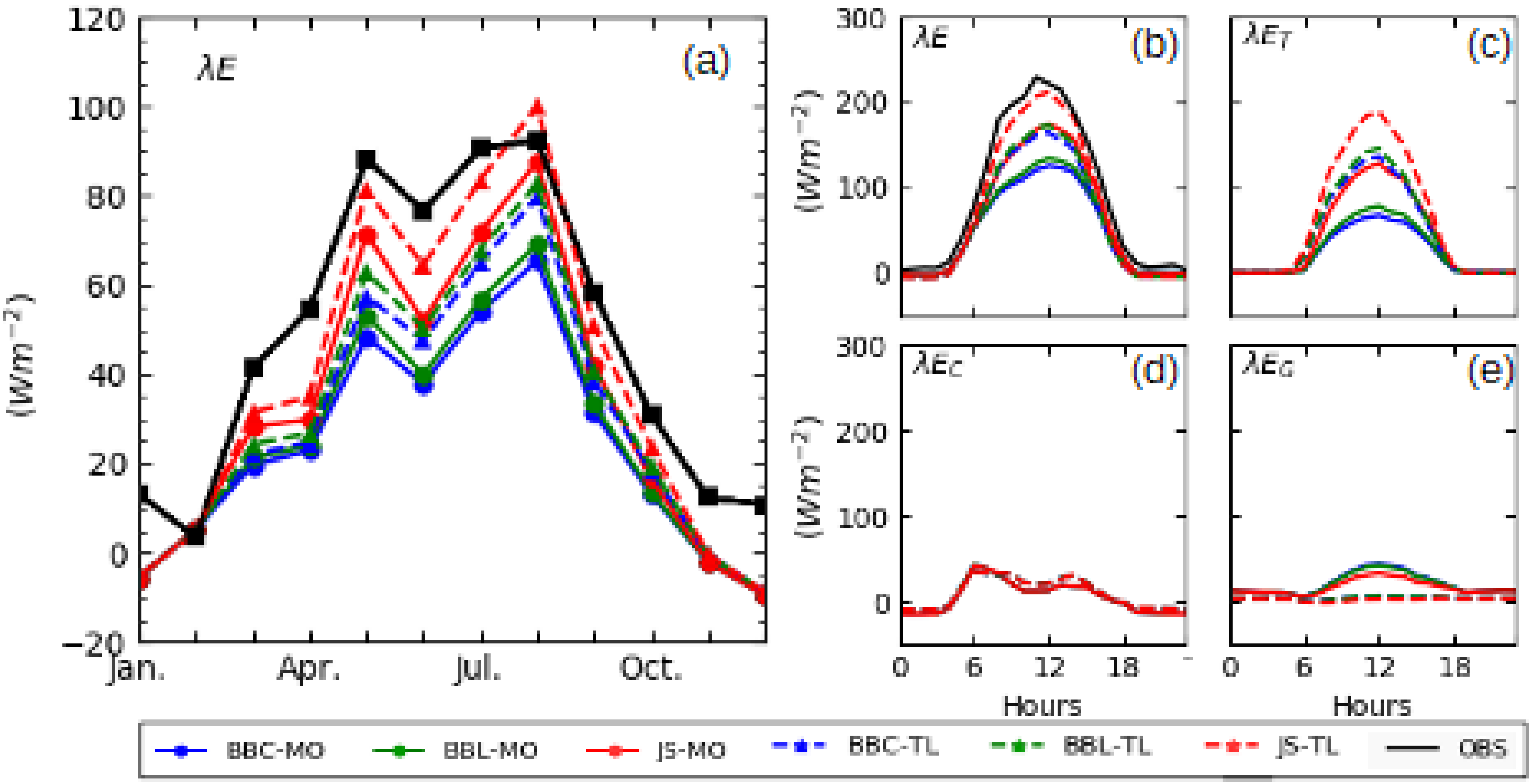
Leaf Area Index



Results : Latent heat flux

Monthly mean latent heat flux

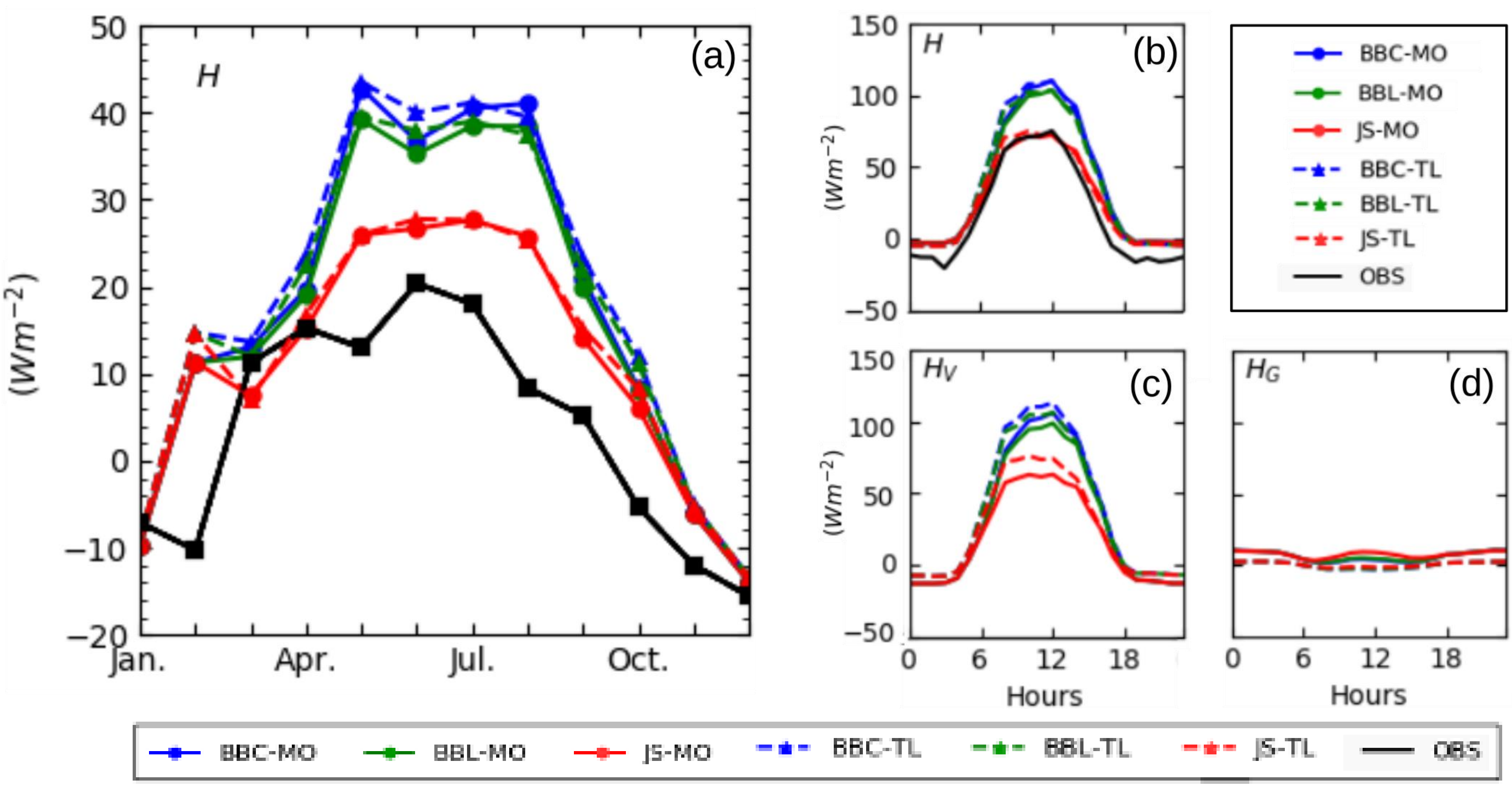
Monthly averaged diurnal cycle of components of latent heat flux, July



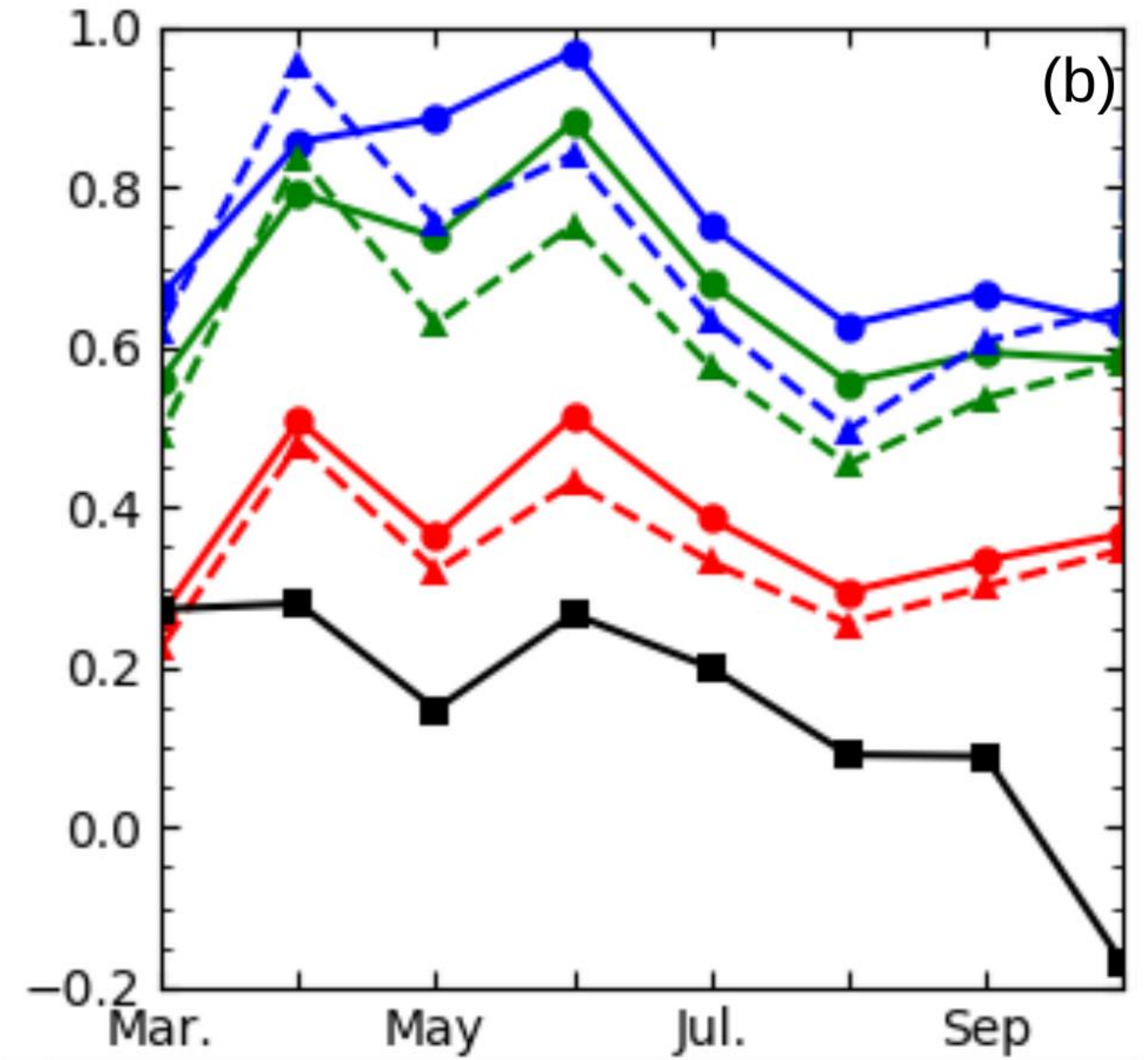
Results : Sensible heat flux

Monthly mean sensible heat flux

Monthly averaged diurnal cycle of components of sensible heat flux, July

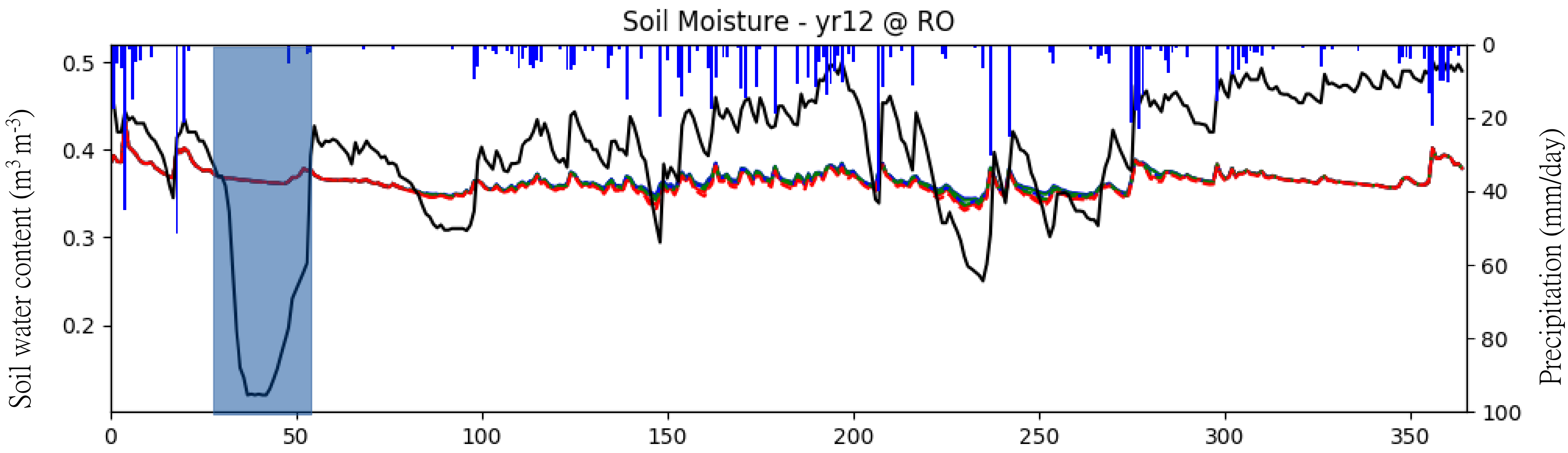


Result: Bowen Ratio



Results: soil moisture

- Daily mean soil water content



Device malfunction
during freezing time

Results: model performance for grass

- index of agreement

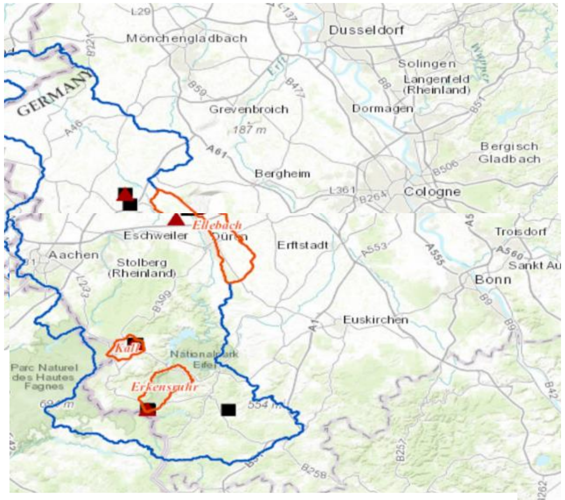
$$IoA = \frac{\sum_{t=1}^{N}(O_t - \bar{O})^2 - \sum_{t=1}^{N}(P_t - O_t)^2}{\sum_{t=1}^{N}(O_t - \bar{O})^2}$$

	R_{net}	λE	H	T_g
BBC-MO	0.87	0.28	0.58	0.80
BBL-MO	0.87	0.46	0.60	0.80
JS-MO	0.87	0.81	0.57	0.80
BBC-TL	0.86	0.72	0.61	0.83
BBL-TL	0.86	0.77	0.62	0.83
JS-TL	0.86	0.86	0.62	0.83

Not affected at all

Not affected at all

Simulation setup



data period: 2012-2013

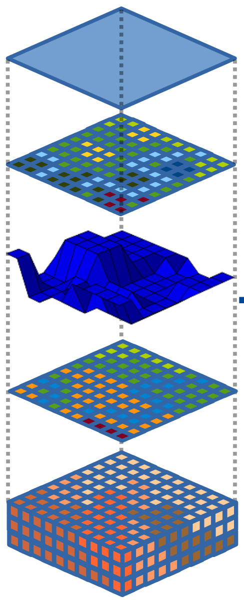
*Weather Forcing Data (u, v, R_{lw}, R_{sw}, Prec, Pres, Q, T)

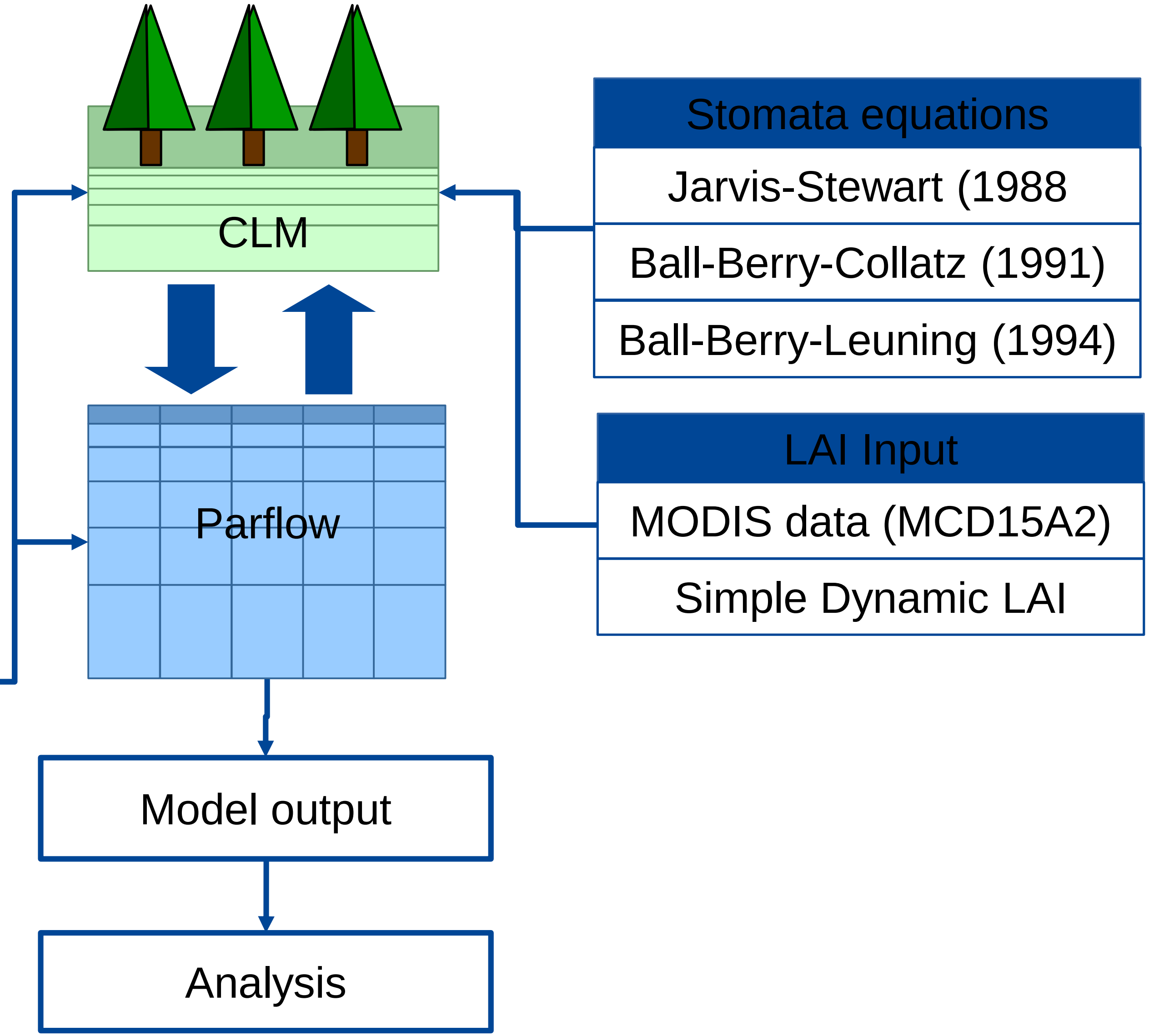
Landuse (LAI, h_{veg} ,..)

Terrain (DEM)

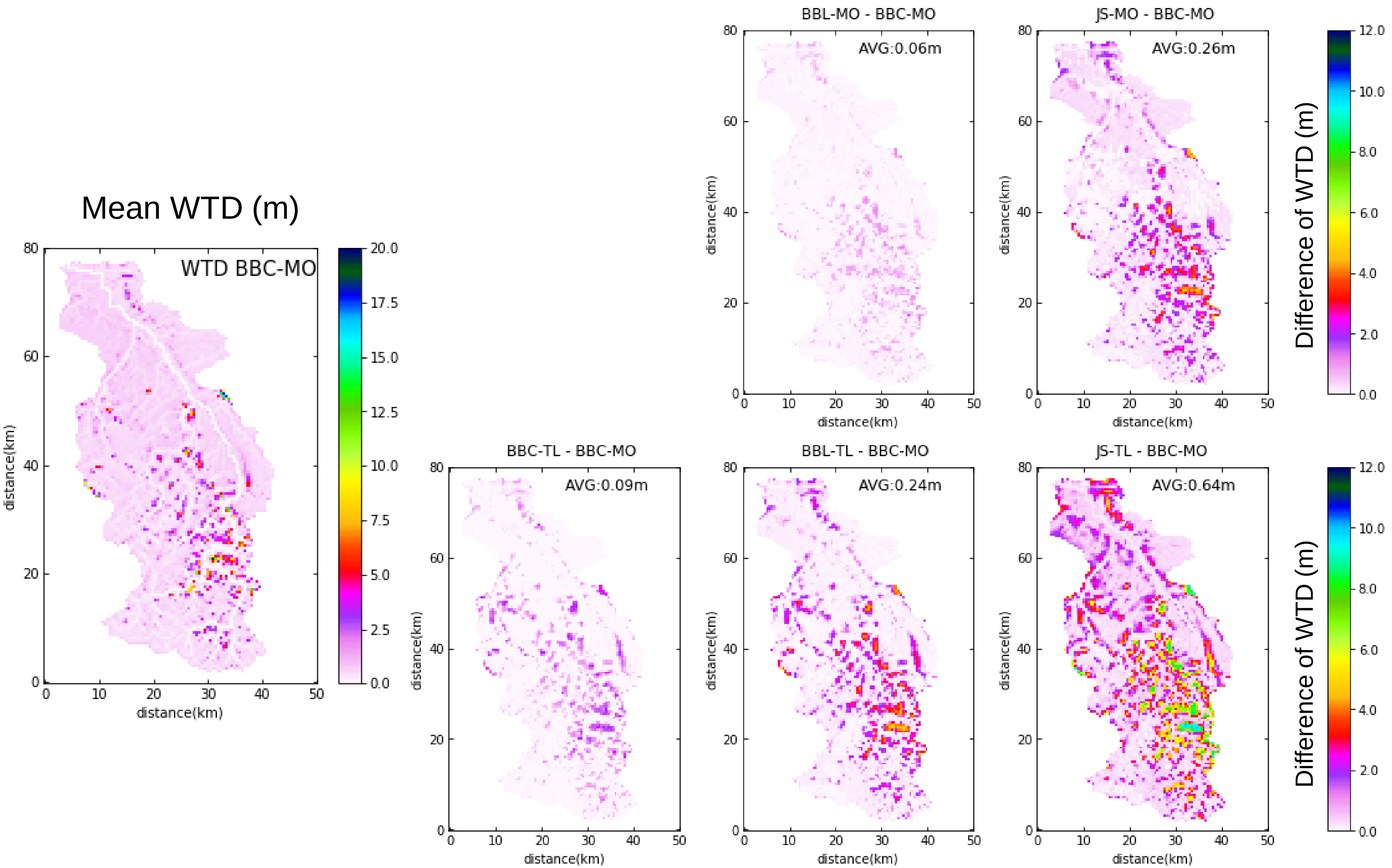
Land Surface Soil Property (%sand, %clay)

Subsurface Parameter (K,Φ,α,m …)



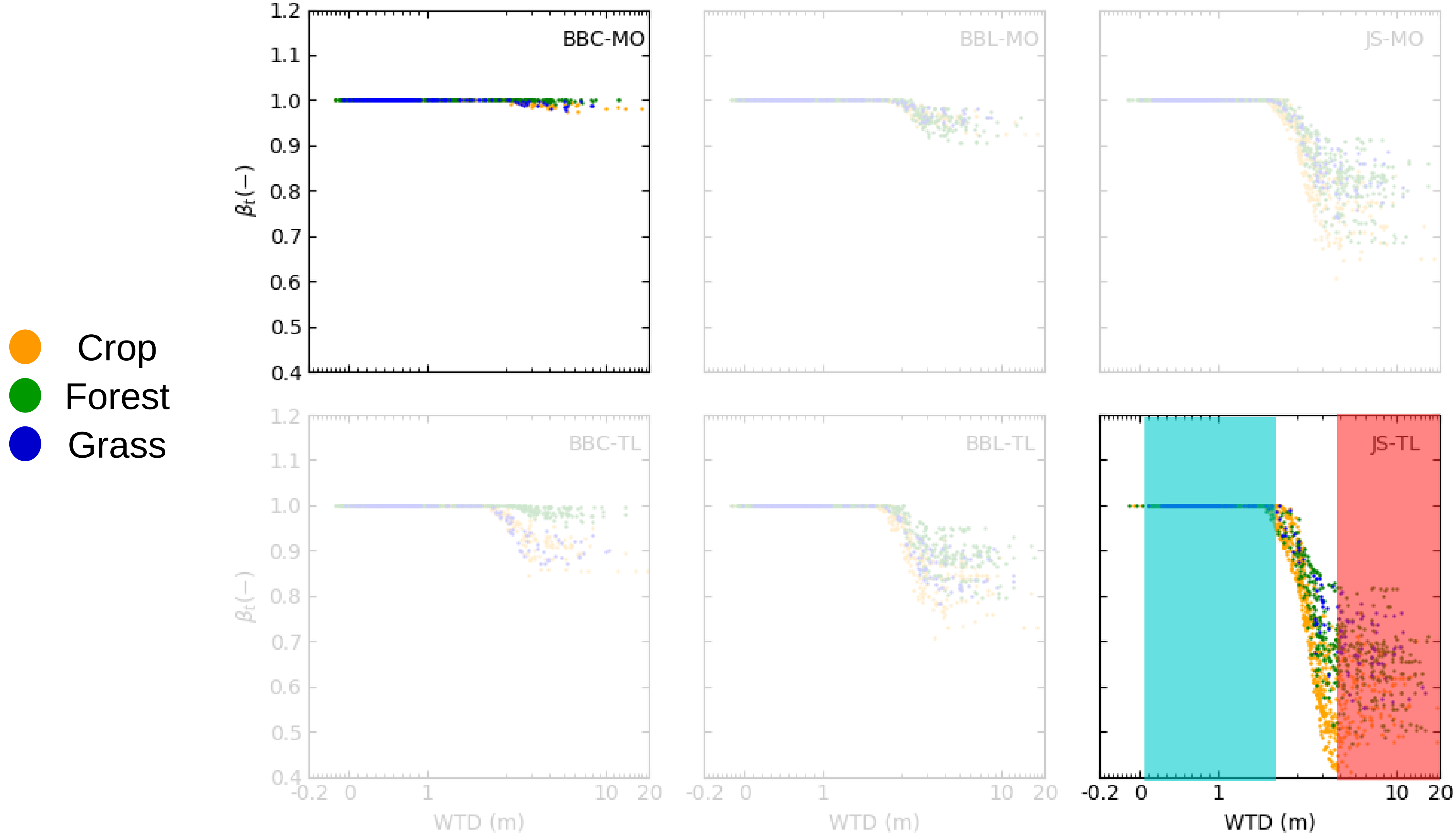


Results: water table depth (WTD)

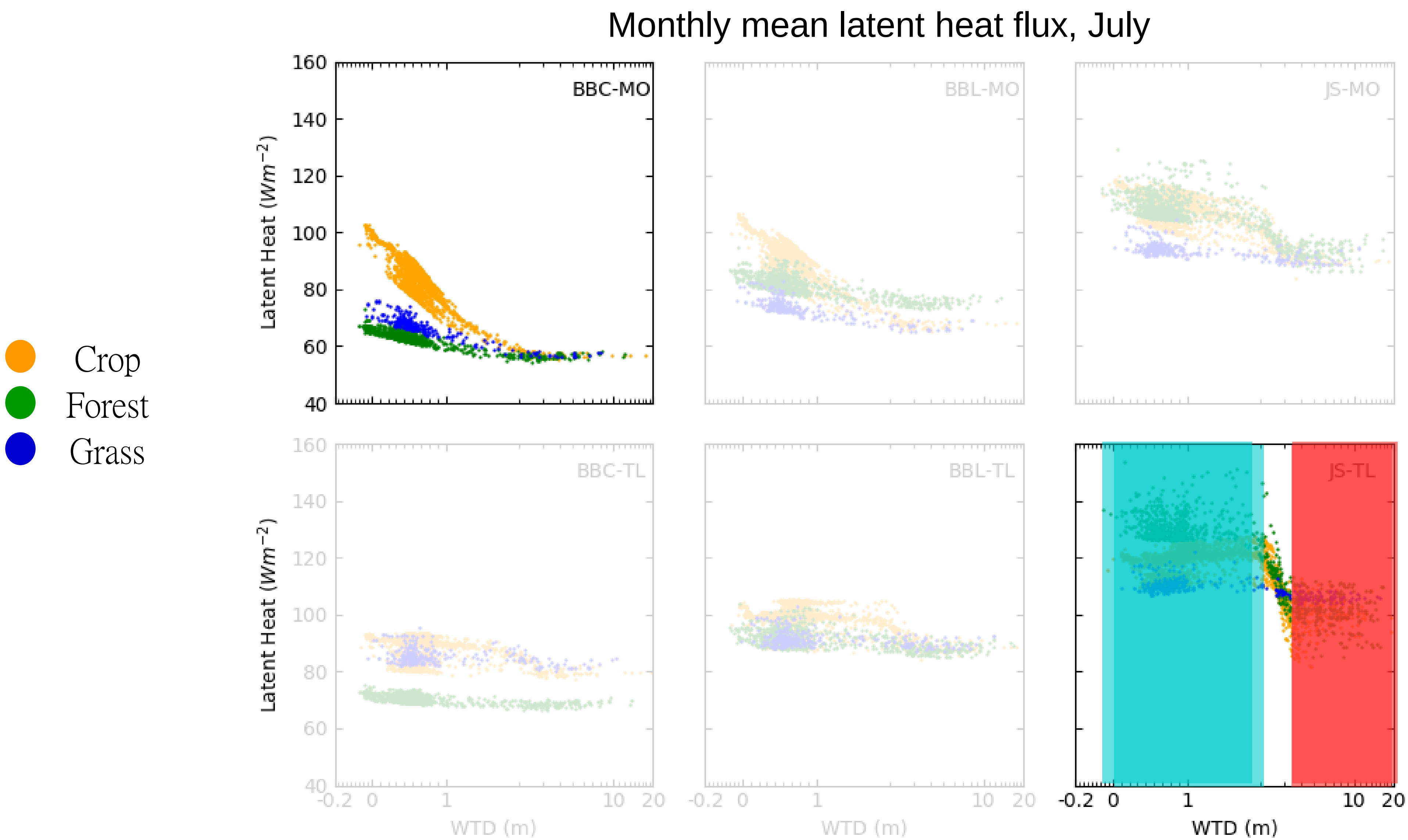


Results: vegetation scheme - WTD

Monthly mean soil moisture limitation factor (β_t), July

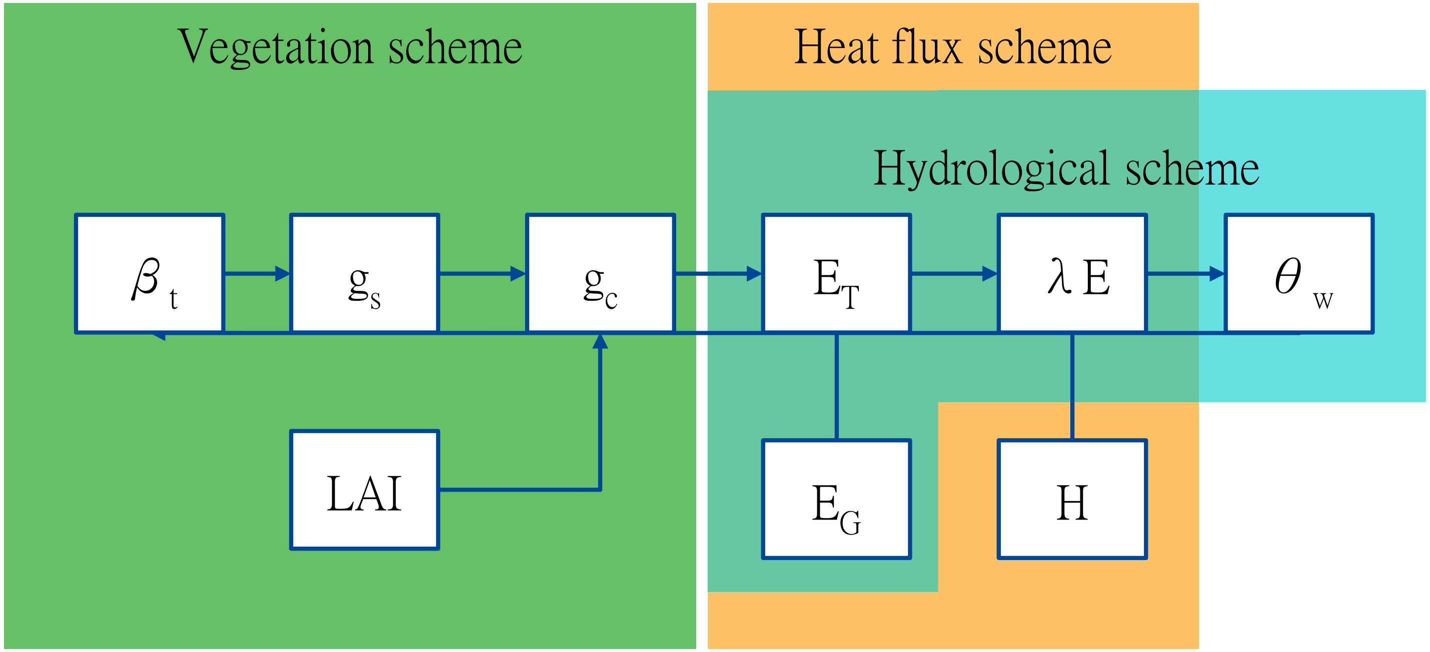


Results: heat fluxes - WTD



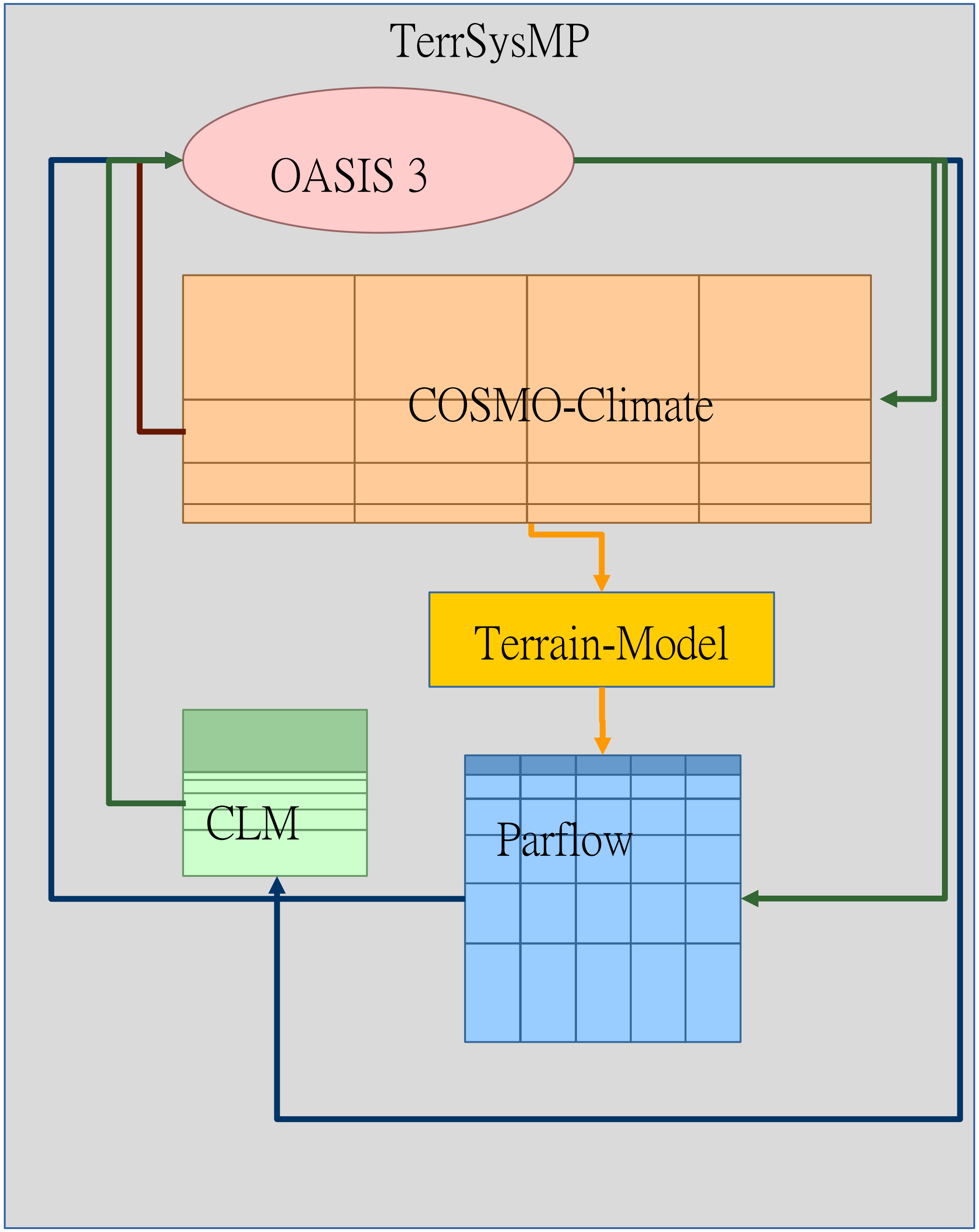
Discussion

- Propagation path:



Outlook

- **Future Work**
  - Improving vegetation scheme
  - Validation with observation data
  - Incorporating with slope stability analysis
  - Effect of climate change on terrain modification (e.g. erosion …)



Thank you for your attention