TERRA and EXTPAR

Recent developments at DWD

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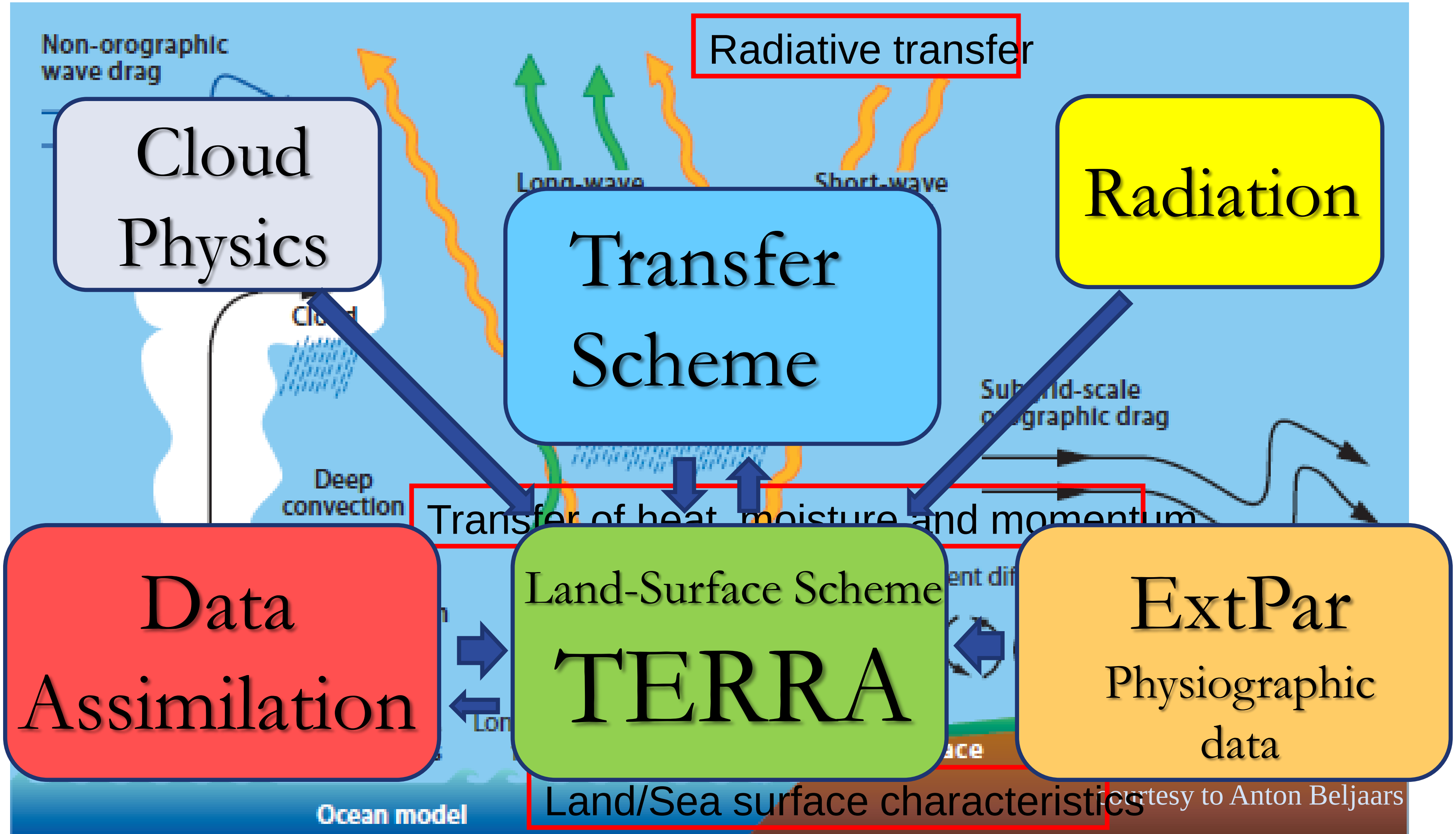
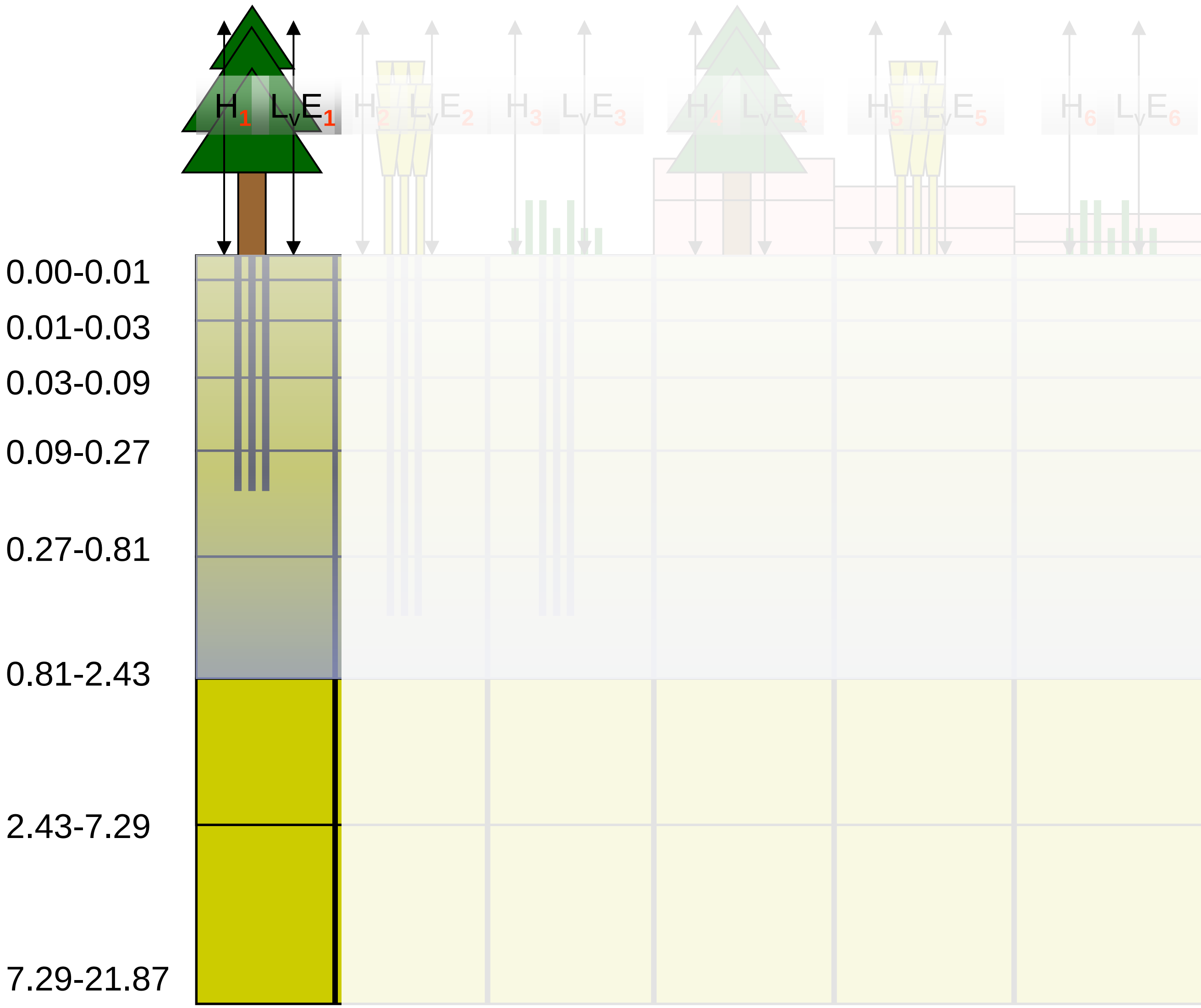
Key task for parametrization

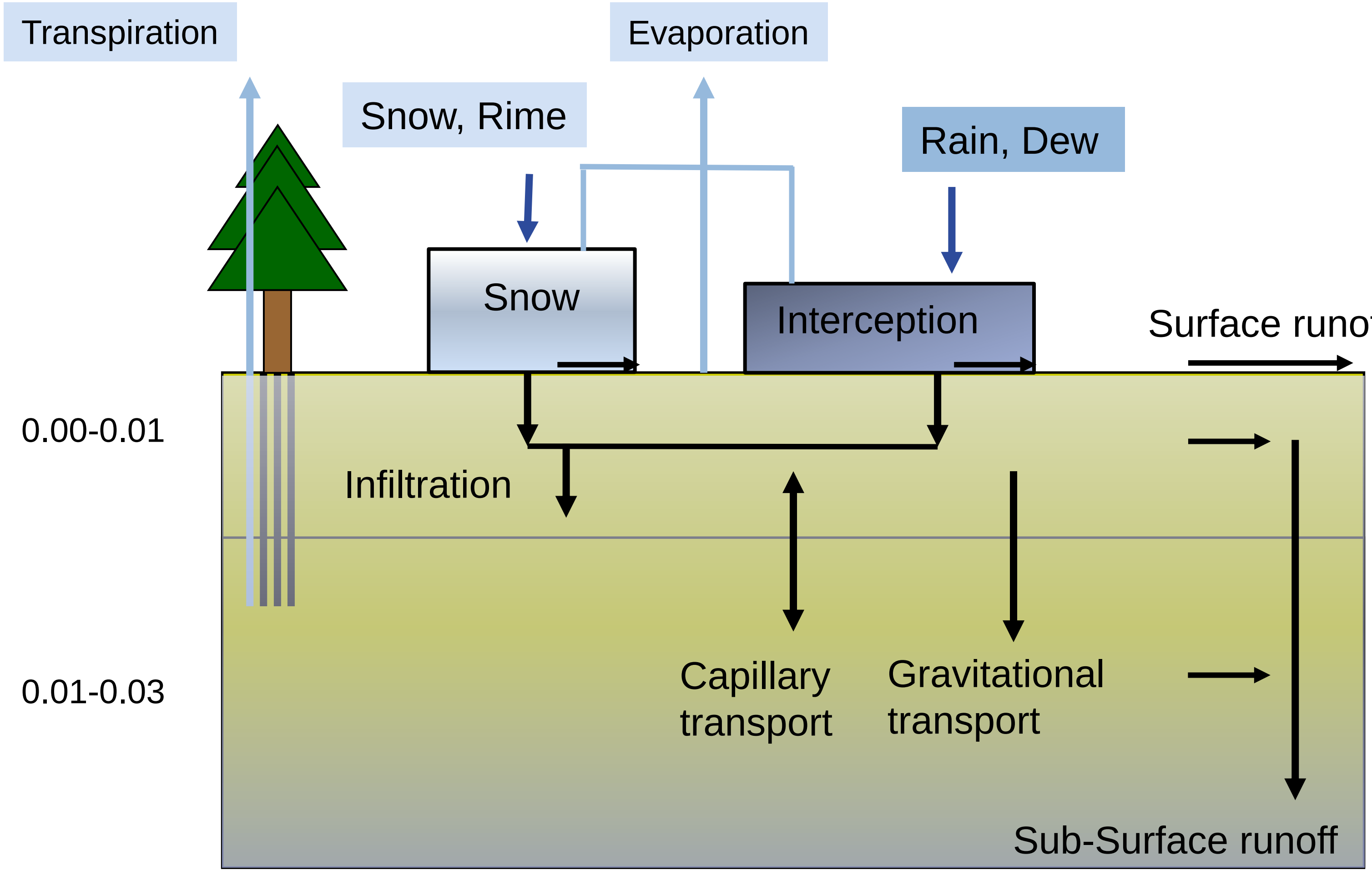
- Parametrization schemes express the effect of subgrid/subscale processes on resolved variables – solving the closure problem



TERRA - Structure



TERRA – Water budget



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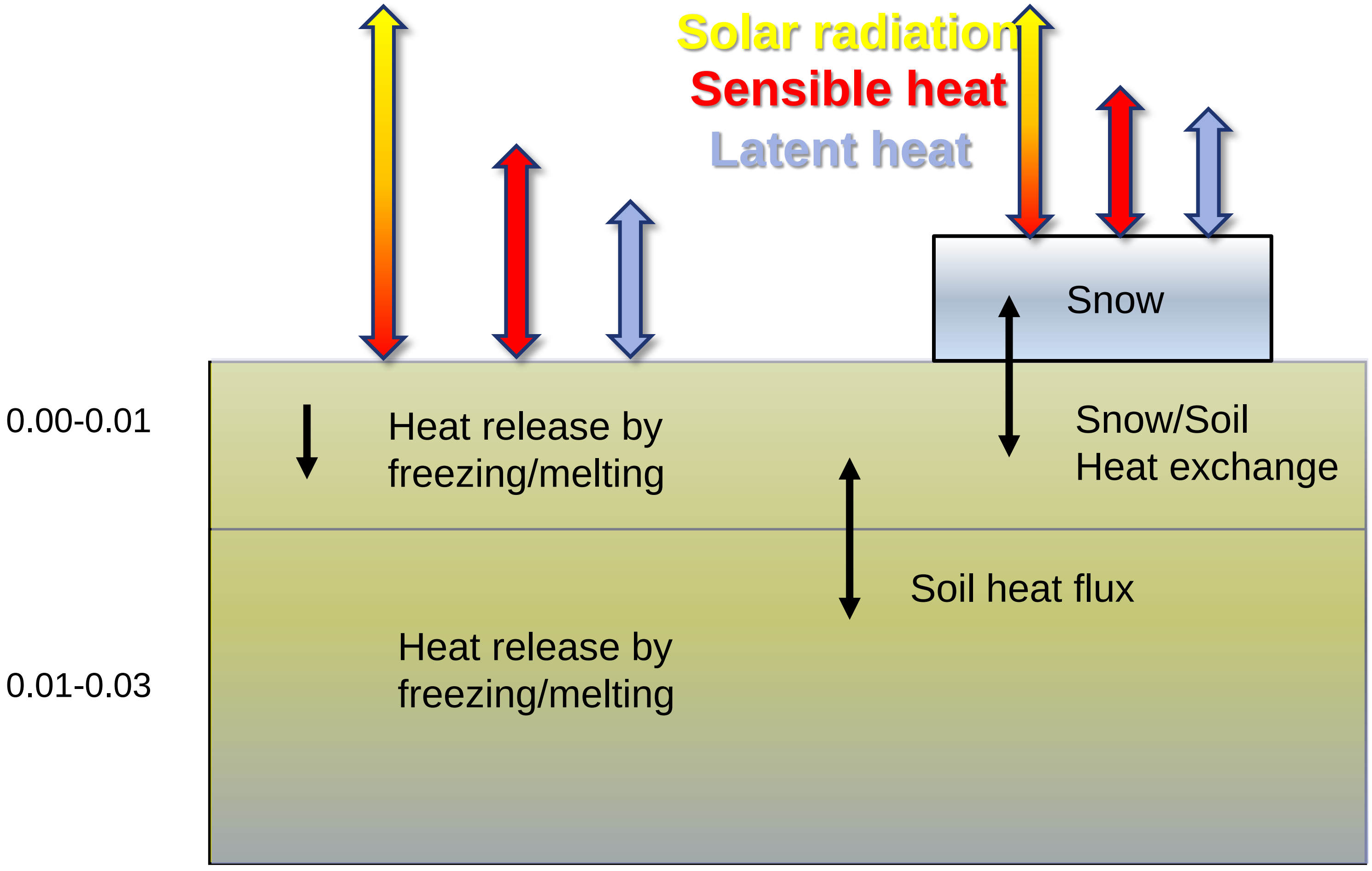
TERRA – Energy budget

CONSORTIUM FOR SMALL SCALE MODELING
COSMO
Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD



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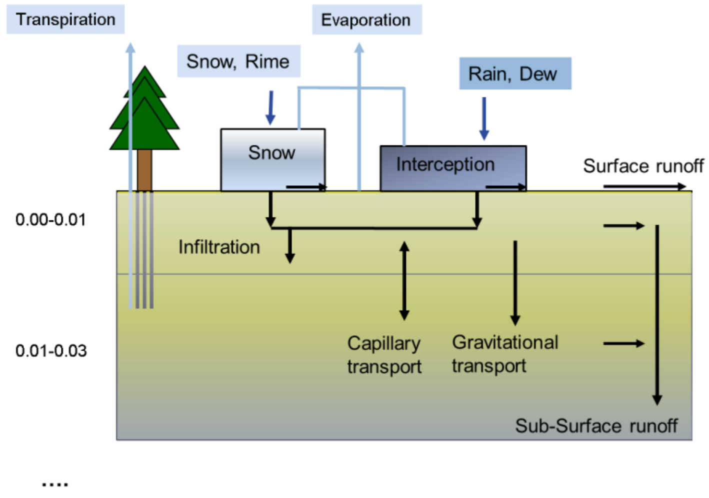
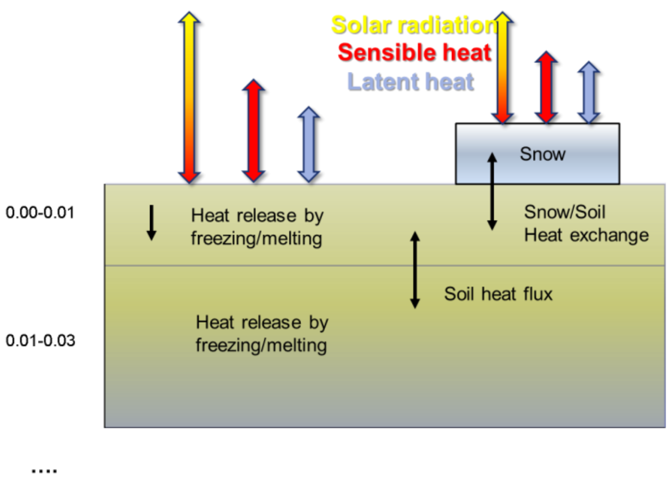
Recent improvements

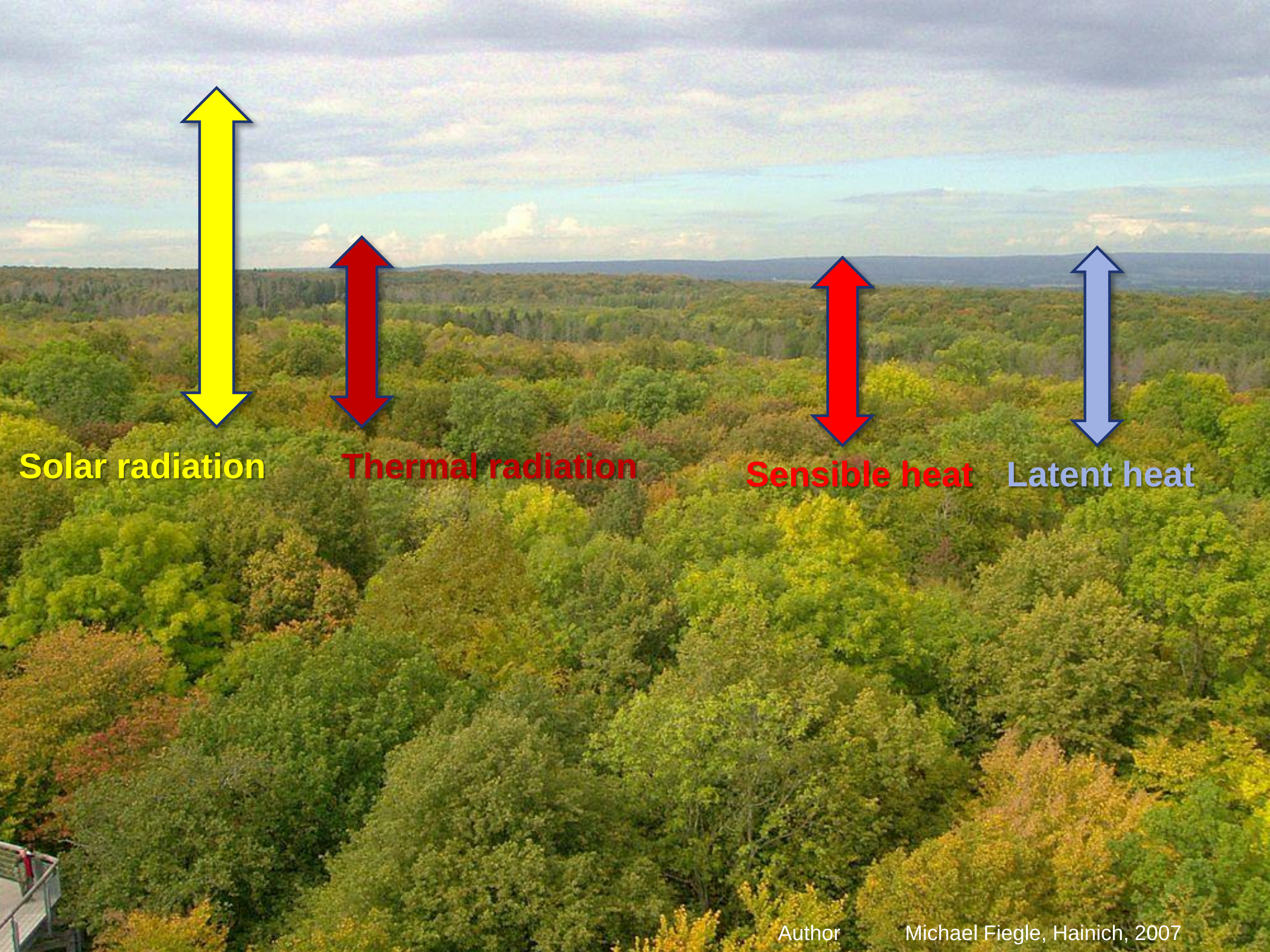
- Add option for predicting an additional snow density for the upper partof the snow pack in the case of the single-layer snow scheme
- Bug fix for ISBA bare soil evaporation scheme in TERRA
- Fix for evaporation limiter at wilting point in order to avoid oscillations
- Reduction of soil heat capacity in the presence of roots
- Fixes for numerical stability problems in TERRA: improved limitation of transfer coefficient, and limitation of qv_s to qsat(t_g)
- Fix for potential numerical instability in TERRA: reset snow temperature to soil top temperature at the time step when a grid point starts to become snow-covered
- Revision of snow cover fraction diagnosis for snow tiles
- Minor modification of snow aging parameterization

Current developments

- Canopy scheme in TERRA
- Heat conductivity for dry soil
- Bare soil evaporation
- Plant interception
- Fix sub-surface runoff






Solar radiation
Thermal radiation
Sensible heat
Latent heat
Author
Michael Fiegle, Hainich, 2007

Thermal processes

$$\frac{\partial T_{so}}{\partial t} = \frac{1}{(\rho c)} \frac{\partial}{\partial z} \left(\lambda \frac{\partial T_{so}}{\partial z} \right)$$

Evolution of the soil temperature

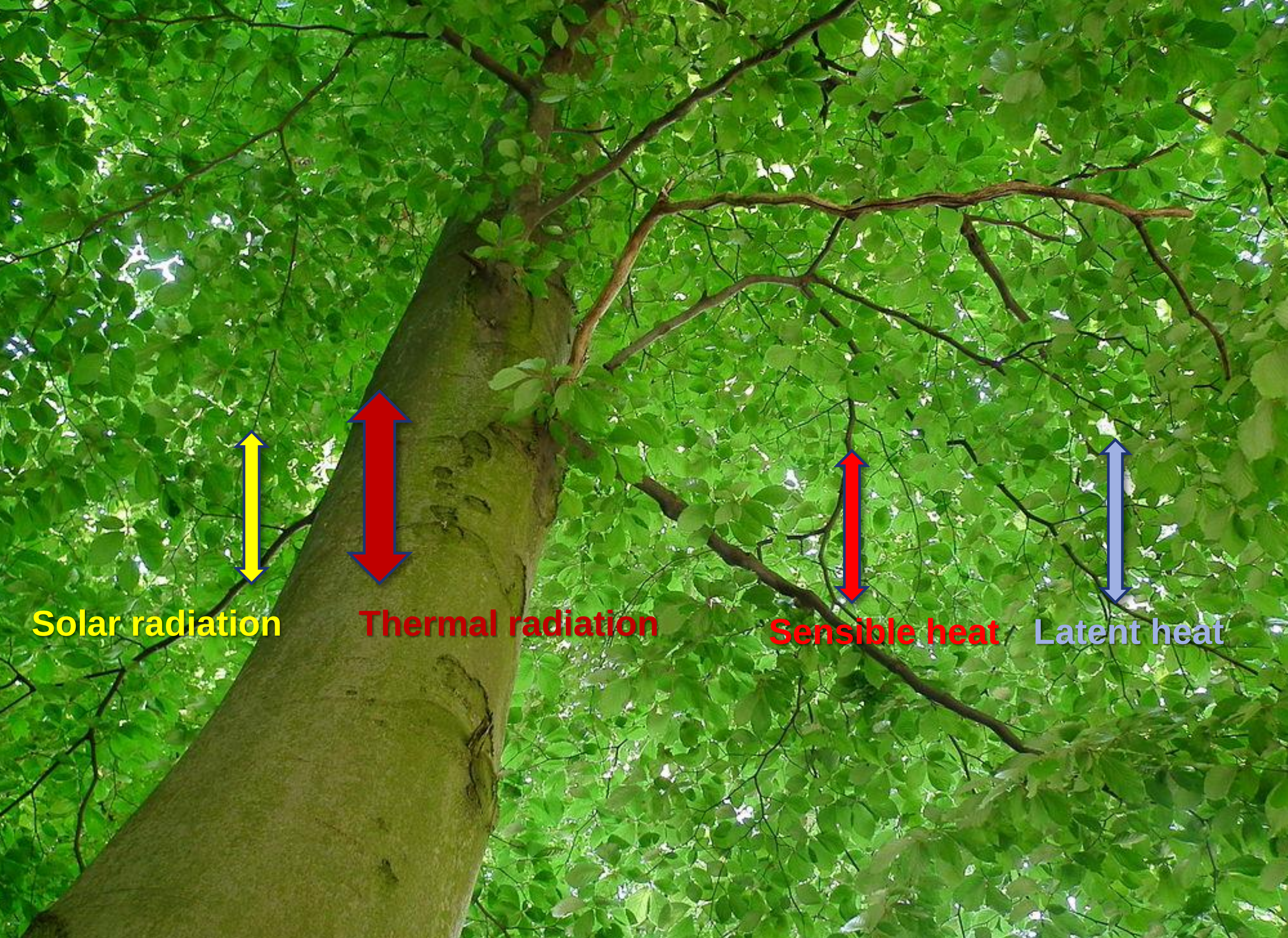
$$\left(\frac{\partial T_{so}}{\partial t} \right)_{k=1} = \frac{1}{\rho c \Delta z_1} \left[\lambda \frac{(T_{so})_{k=2} - (T_{so})_{k=1}}{z_{m,2} - z_{m,1}} + G_{sfc} \right]$$

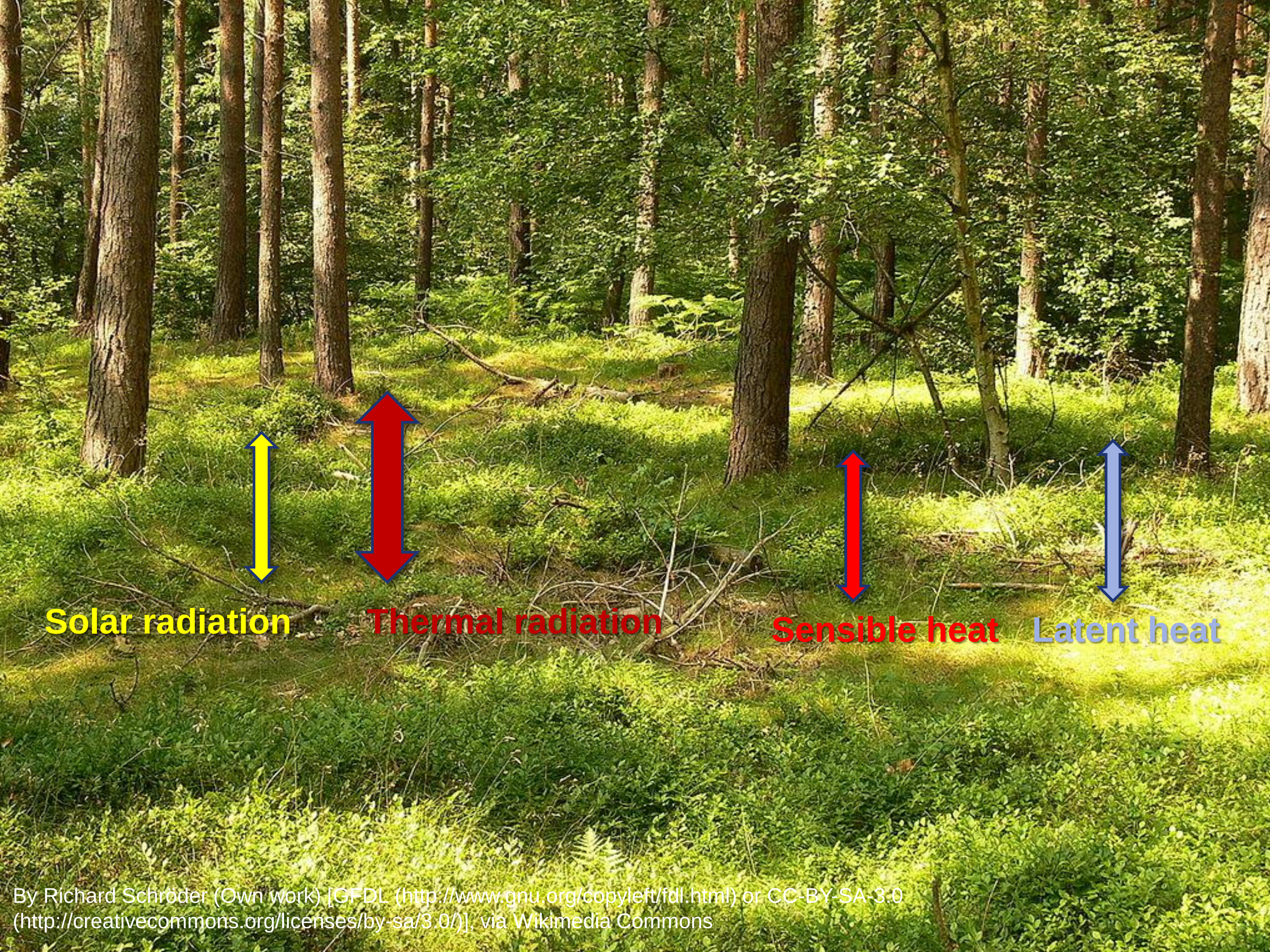
Evolution of the soil temperature layer 1

$$G_{sfc} = c_p \hat{H}^3_{sfc} + L(F^3_{q^v})_{sfc} + Q_{rad,net} + G_P + G_{snow,melt}$$

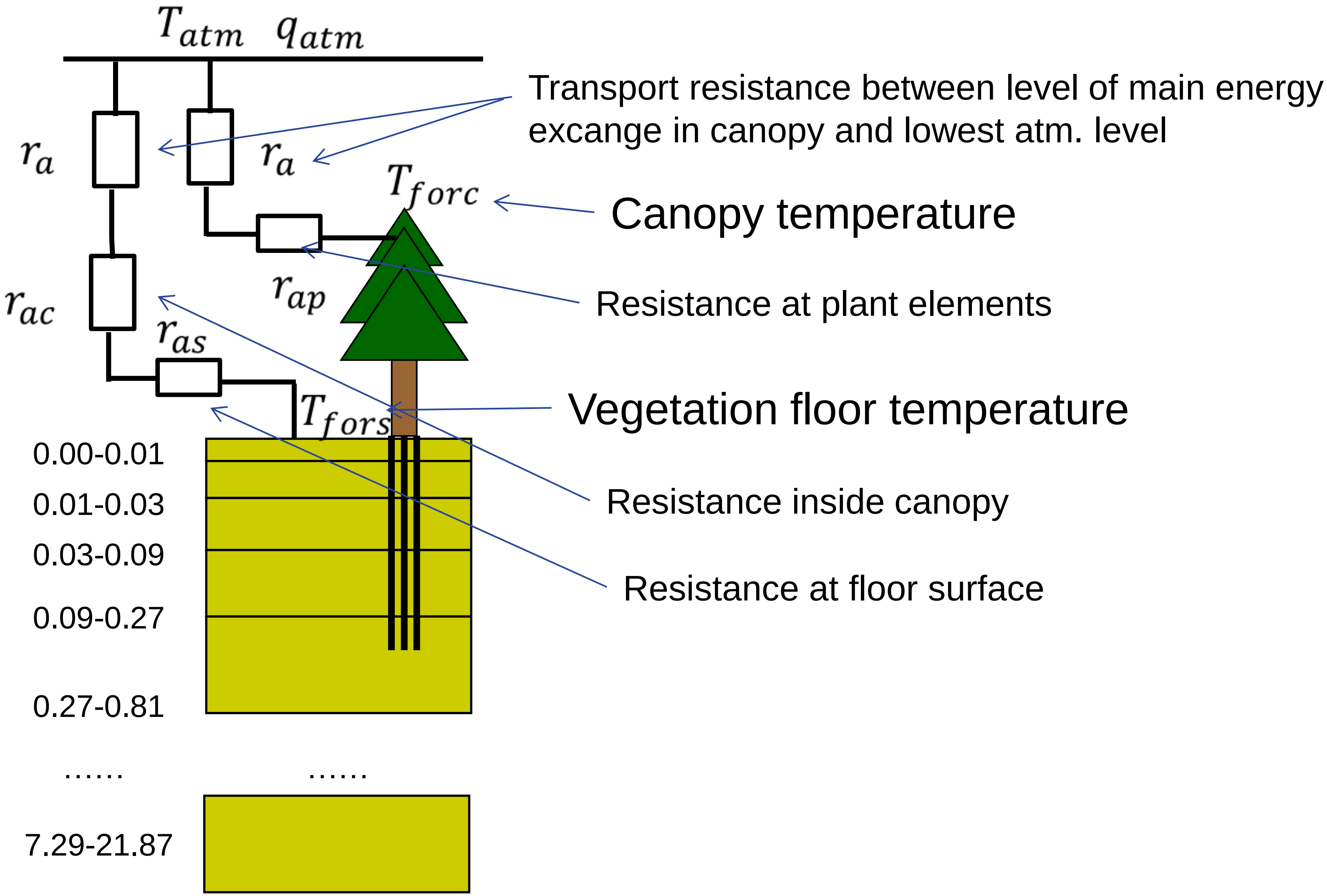
Surface forcing

Author Michael Fiegle, Hainich, 2007

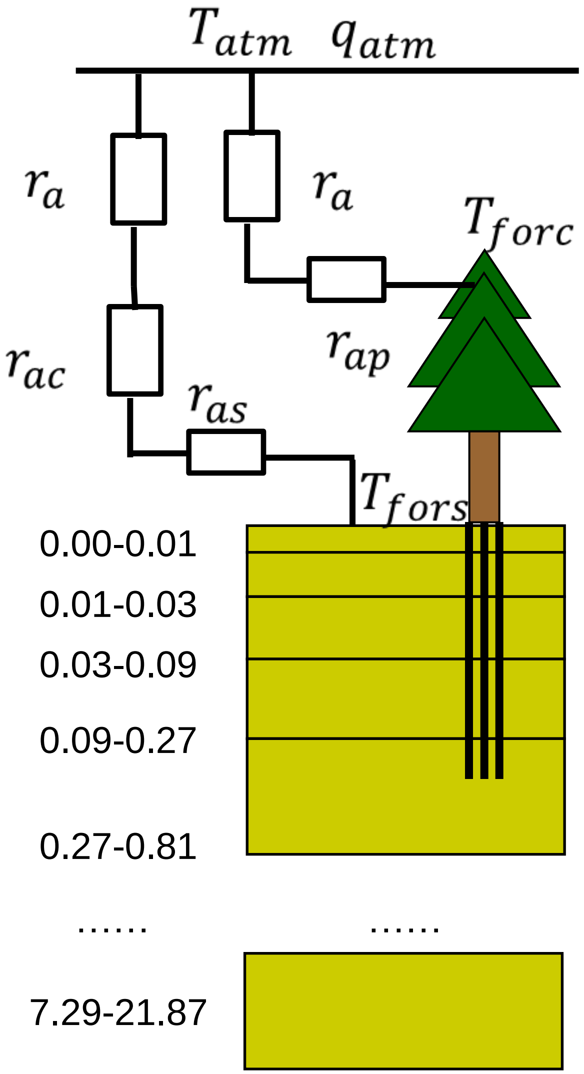

Solar radiation
Thermal radiation
Sensible heat
Latent heat


Solar radiation
Thermal radiation
Sensible heat
Latent heat

Canopy model



Canopy model



$$\phi_{forx} = Rn_{forx} + H_{forx} + E_{forx}$$

Forcing **Radiation** **Sensible heat** **Latent heat**

x is represented by forest canopy, forest soil, or forest snow

Samuelsson et al., 2006

$$\frac{\partial T_{forc}}{\partial t} = \frac{1}{C_{forc}} \Phi_{forc}$$ **Canopy**

$$\frac{\partial T_{fors}}{\partial t} = \frac{1}{(\rho C)_{fors} z_s} [\Phi_{fors} + \Lambda_s (T_{fors2} - T_{fors})]$$ **Floor**

$$\frac{\partial T_{forsn}}{\partial t} = \frac{1}{(\rho C)_{forsn} z_{forsn}} [\Phi_{forsn} + \Lambda_{forsn} (T_{forsns} - T_{forsn})]$$

Floor + Snow

$(\rho C)_{fors}$ and $(\rho C)_{forsn}$ are volumetric heat capacities

Λ_s and Λ_{forsn} are heat transfer coeff

$$C_{forc} = C_{veg} W_{veg} + C_w \rho_w w_{forc}$$

heat capacity of the forest canopy

C_{veg} is the vegetative heat capacity

W_{veg} is the standing mass

w_{forc} is the intercepted water

Canopy model

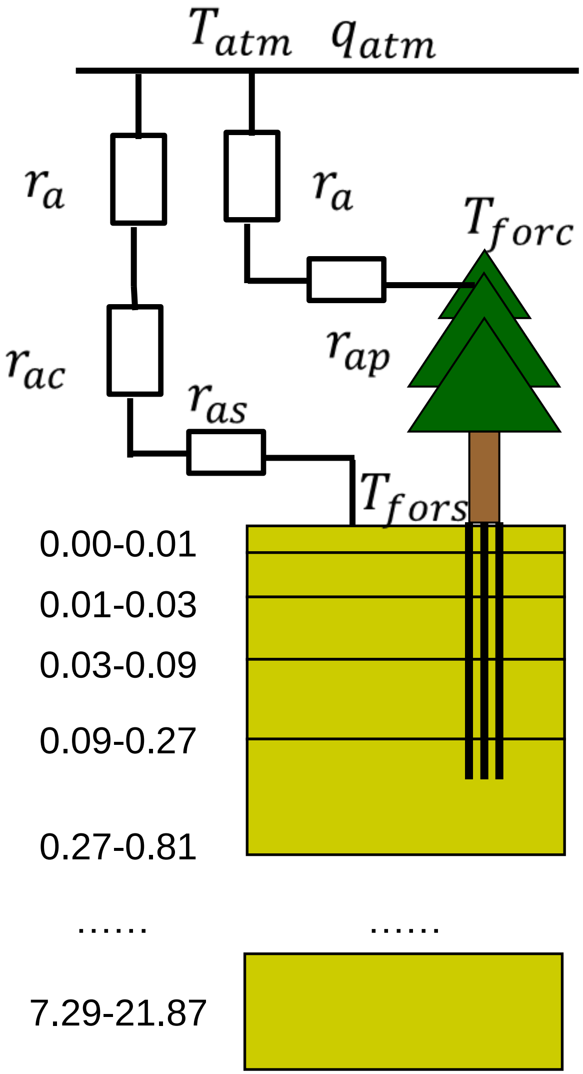


Table I. Parameters associated with land cover categories used in CLASS

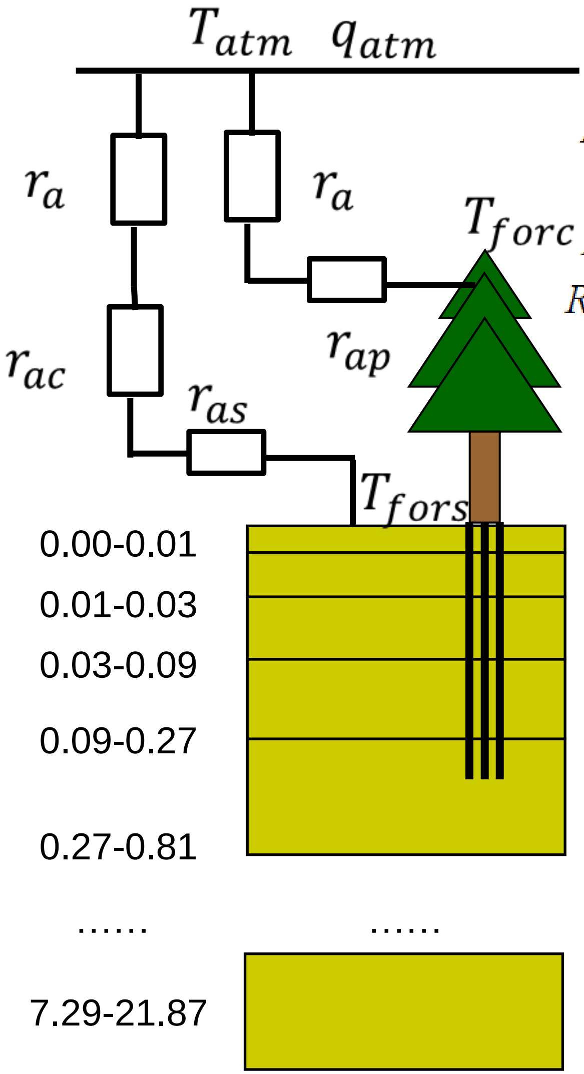
	Code[a]	$\bar{\alpha}_{c,\,VIS}$	$\bar{\alpha}_{c,\,NIR}$	$z_{o,\,max}$ (m)	Λ_{max}	Λ_{min}	$W_{c,\,max}$ (kg m^{-2})
Evergreen needleleaf tree	1	0·03	0·19	1·5	5·0	4·0	25·0
Evergreen broadleaf tree	2	0·03	0·23	3·5	10·0	10·0	50·0
Deciduous needleleaf tree	1	0·03	0·19	1·0	4·0	0·5	15·0
Deciduous broadleaf tree	2	0·05	0·29	2·0	6·0	0·5	20·0
Tropical broadleaf tree	2	0·03	0·23	3·0	10·0	10·0	40·0
Drought deciduous tree	2	0·05	0·29	0·8	4·0	4·0	15·0
Evergreen broadleaf shrub	2	0·04	0·28	0·15	4·0	4·0	8·0
Deciduous shrub	2	0·05	0·29	0·15	4·0	0·5	8·0
Thorn shrub	2	0·06	0·32	0·15	3·0	3·0	8·0
Short grass and forbs	4	0·06	0·34	0·02	3·0	3·0	1·5
Long grass	4	0·05	0·31	0·08	4·0	4·0	3·0
Arable	3	0·06	0·34	0·08	4·0	0·0	2·0
Rice	3	0·06	0·36	0·08	6·5	0·0	2·0
Sugar	3	0·05	0·31	0·35	5·0	0·0	5·0
Maize	3	0·05	0·31	0·25	4·0	0·0	5·0
Cotton	3	0·07	0·43	0·10	5·0	0·0	2·0
Irrigated crop	3	0·06	0·36	0·08	4·0	0·0	2·0
Urban	–	0·09	0·15	1·35	–	–	–
Tundra	4	0·05	0·29	0·01	1·5	1·5	0·2
Swamp	4	0·03	0·25	0·05	1·5	1·5	1·0
Bare soil	–	See text		0·0005	–	–	–
Glacier ice	–	See text		0·002	–	–	–

[a] Vegetation type to which each land cover is assigned: 1 = needleleaf tree, 2 = broadleaf tree, 3 = crops, 4 = grass.

C_{veg} is the vegetative heat capacity $2{\cdot}7 \times 10^3\,\mathrm{J\ kg^{-1}\ K^{-1}}$

according to Verseghy et al., 1993

Canopy model - Radiation



$$Rn_{forc} = (1-\chi)(1-\alpha_{forc})S\downarrow + (1-\chi)\varepsilon_{forc}\{L\downarrow + \sigma[(1-A_{forsn})T_{fors}^4 + A_{forsn}T_{forsn}^4 - 2T_{forc}^4]\}$$

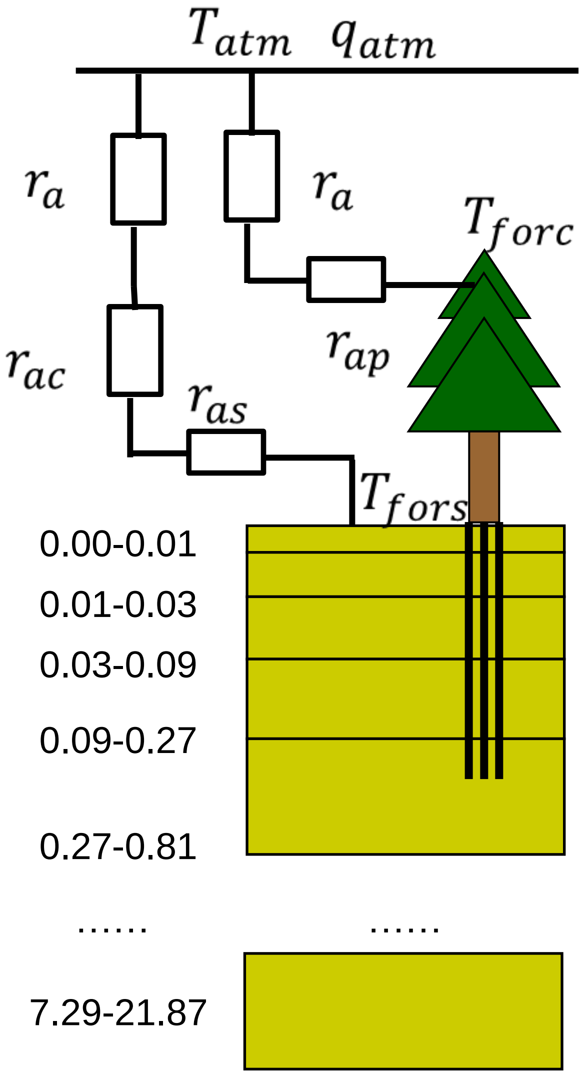
$$Rn_{fors} = \chi(1-\alpha_{fors})S\downarrow + \varepsilon_{fors}\{\chi L\downarrow + \sigma[(1-\chi)T_{forc}^4 - T_{fors}^4]\}$$

$$Rn_{forsn} = \chi(1-\alpha_{forsn})S\downarrow + \varepsilon_{forsn}\{\chi L\downarrow + \sigma[(1-\chi)T_{forc}^4 - T_{forsn}^4]\}$$

Sky-view fraction $\chi = e^{-0.5\,TAI}$

Strong attenuation for large TAI – needle leaf forest
No change in bare soil areas (deserts, glaciers)

Canopy model – turb. fluxes



Sensible Heat

$$H_{forc} = \rho c_p (T_{atm} - T_{forc}) \frac{1}{r_{ap} + r_a}$$

$$H_{fors} = \rho c_p (T_{atm} - T_{fors}) \frac{1}{r_{as} + r_{ac} + r_a}$$

Latent Heat

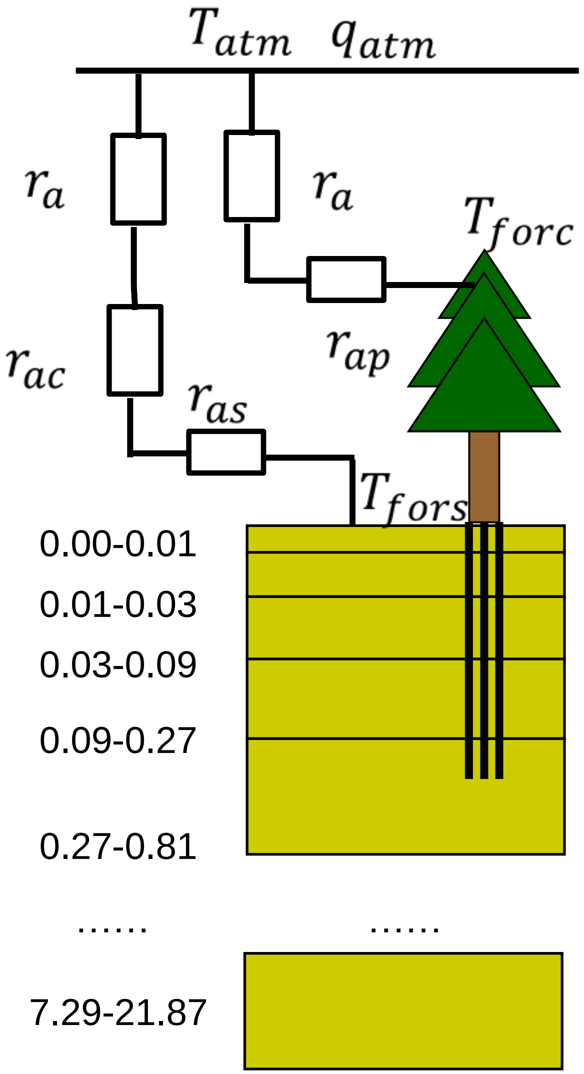
- Evapotranspiration at canopy level
- Using canopy temperature for potential evaporation
- Bare-soil evaporation at surface

Atmospheric resistances

r_a r_{ac} r_{ap} r_{as}

Braden, Harald, 1995: The model AMBETI - A detailed description of a soil-plant-atmosphere model

Canopy model – turb. fluxes



Atmospheric resistances

$$r_{ac} = 0.98 \frac{1}{u_* \kappa} ln \frac{z_{atm} - d}{z_{forc} - d}$$

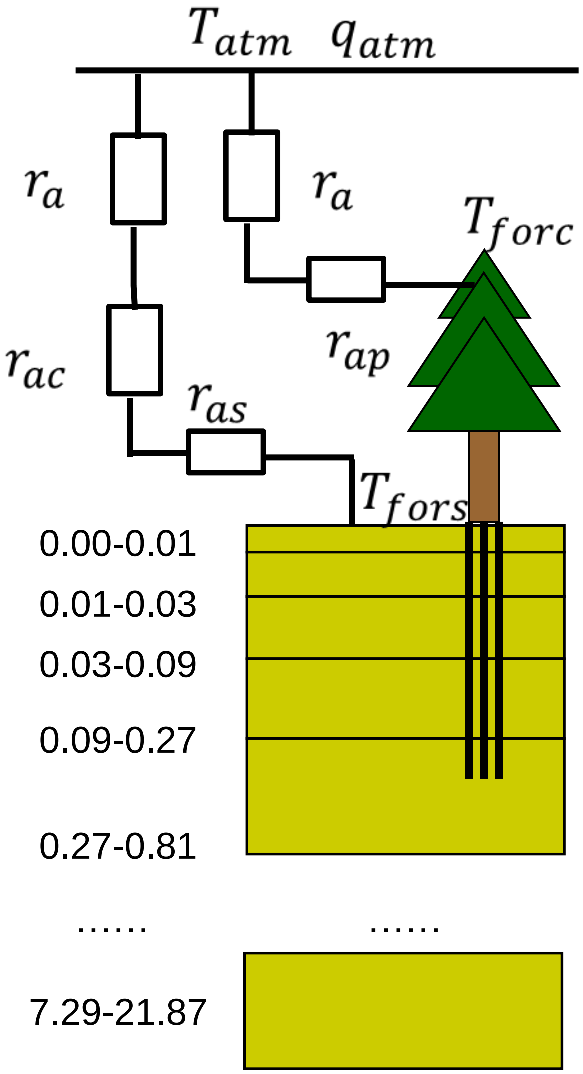
$$r_{ap} = 90 \sqrt{\frac{d_{leaf}}{u_{forc}}}$$

$$r_{as} = 307 \sqrt{\frac{d_{fors}}{u_{fors}}}$$

$$r_a = TURBTRAN$$

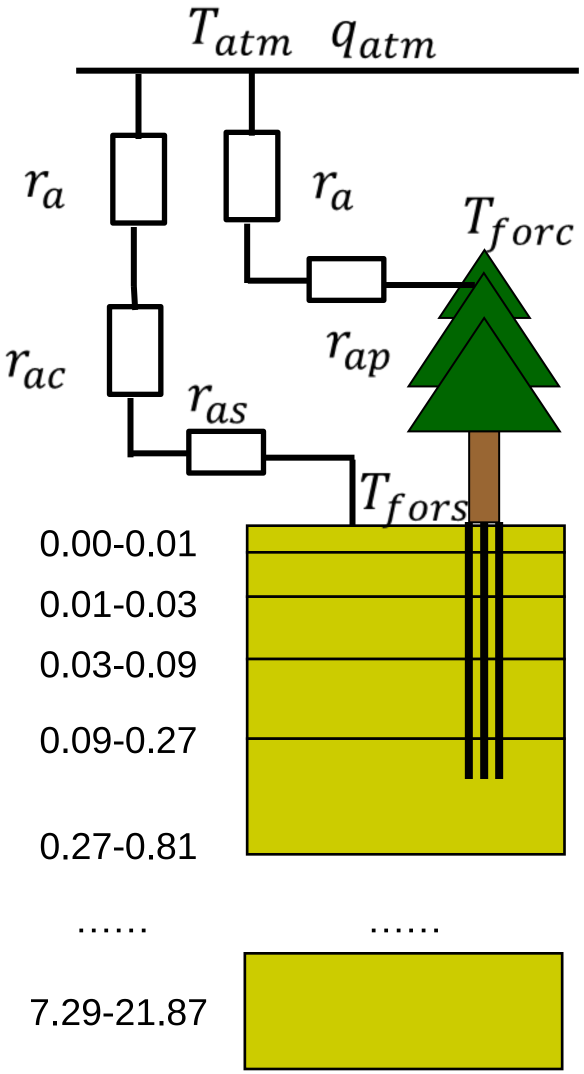
Braden, Harald, 1995: The model AMBETI - A detailed description of a soil-plant-atmosphere model

Canopy model – Experiment



COSMO V5.03 test with Canopy scheme for 2015-08-29 00:00 vv=0-72

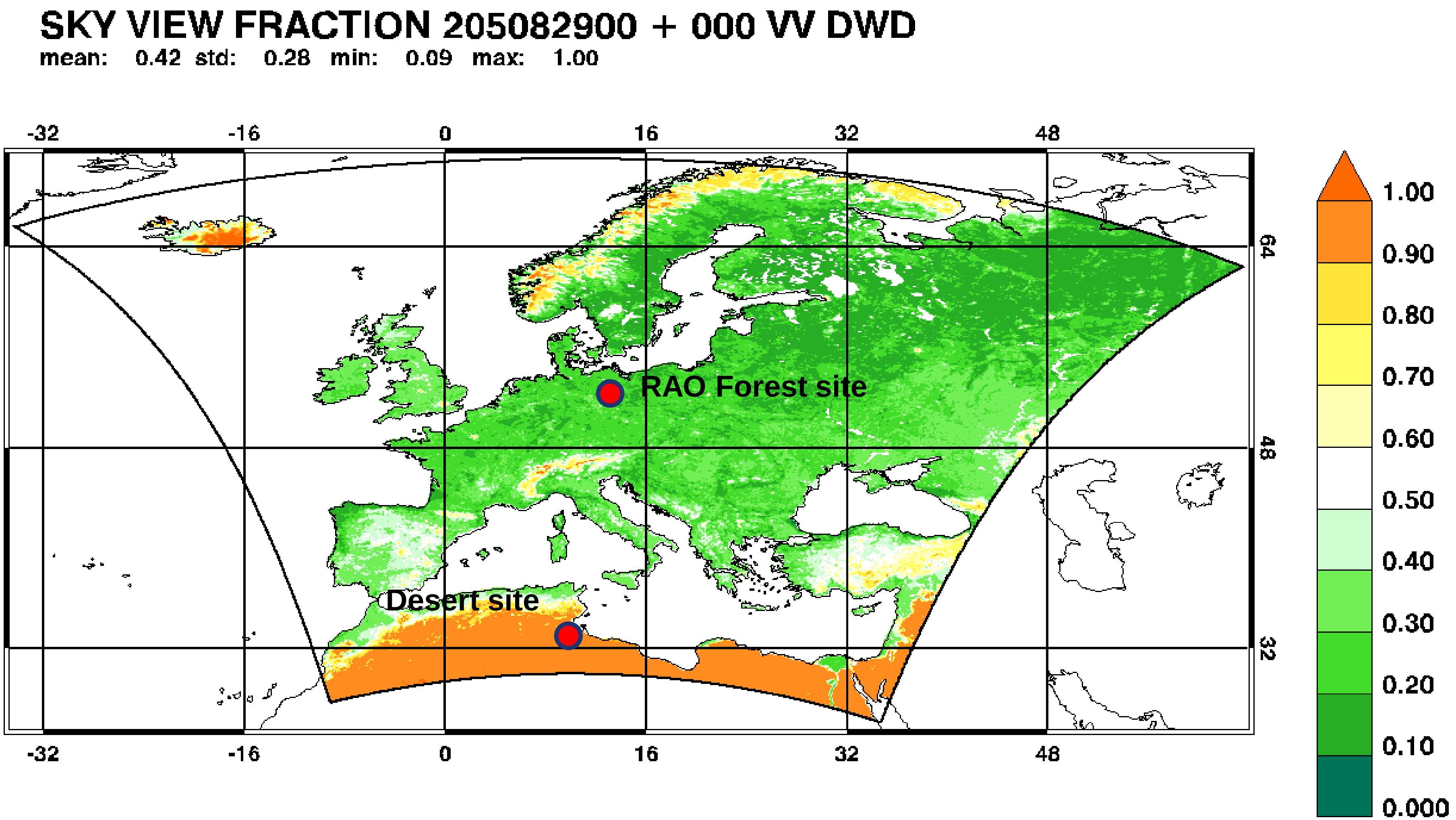
Canopy model – Experiment



Current restrictions:

- Canopy height $z_{forc} = g z_0$
- Fixed canopy heat capacity C_{forc} (needle leaf forest)
- Canopy temperature exists also on vegetation-free points
- Canopy temperature not yet used in transfer scheme

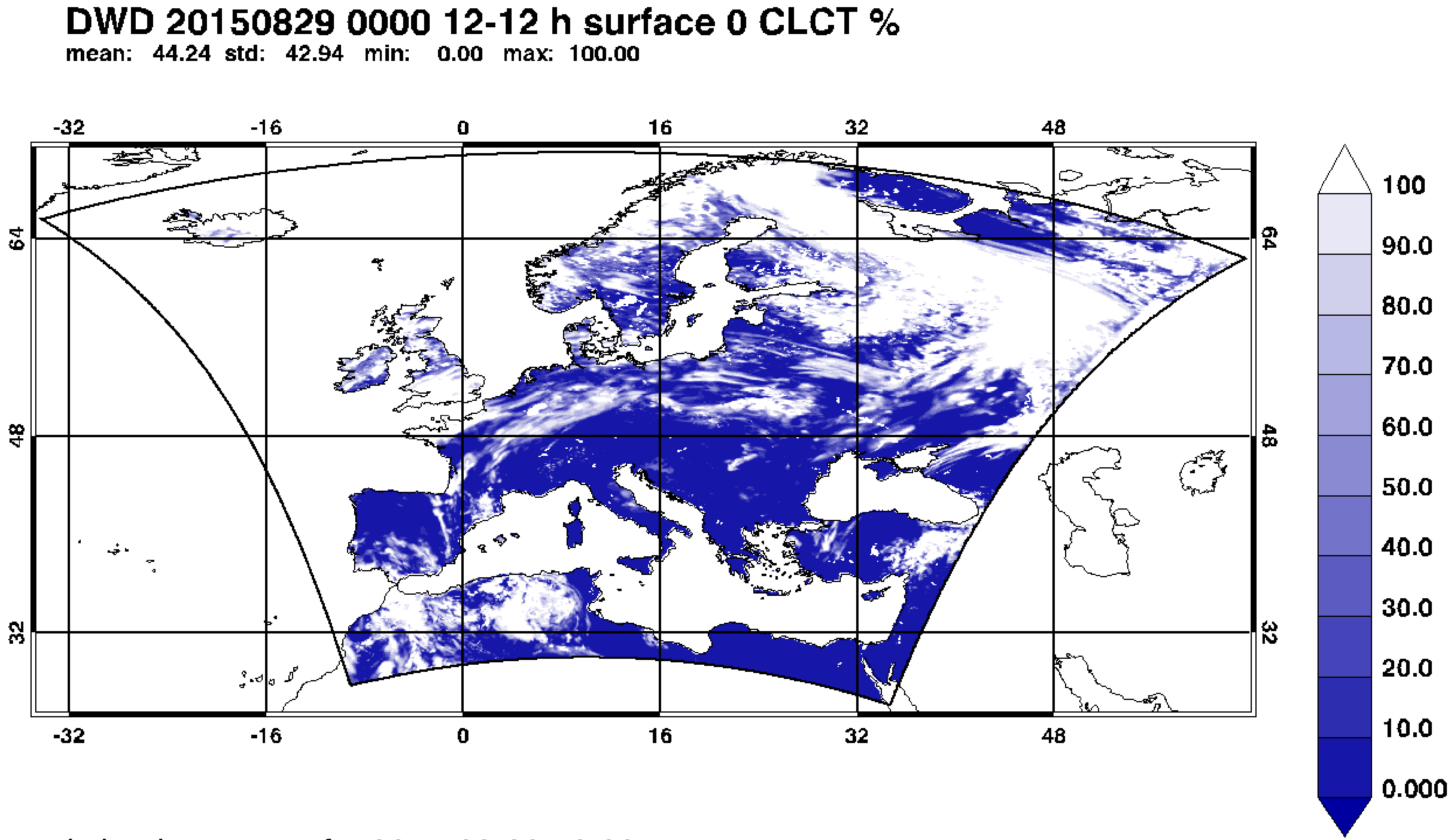
Canopy experiment



Sky view fraction for 2015-08-29 00:00

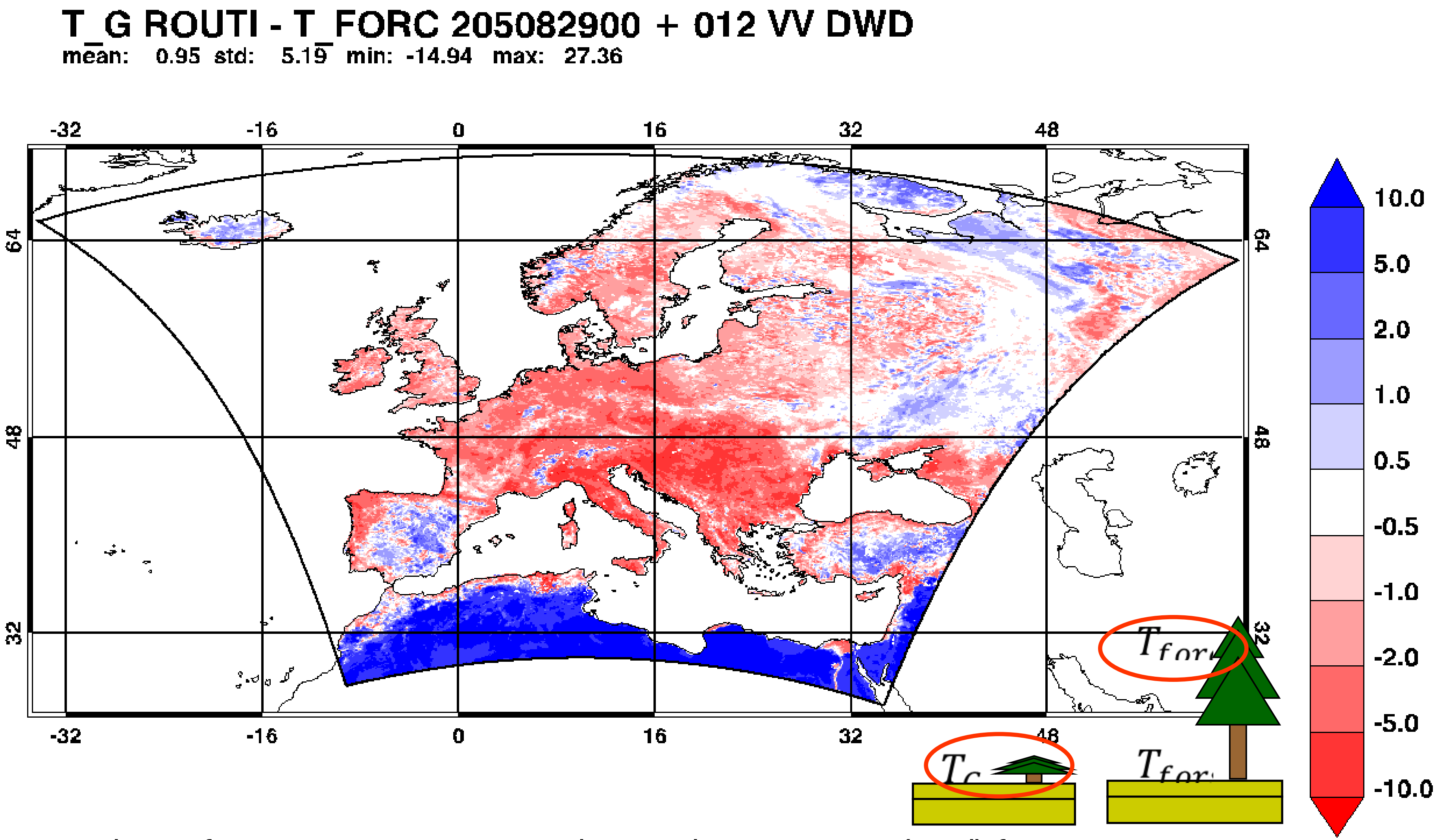
Canopy experiment

COSMO
CONSORTIUM FOR SMALL SCALE MODELING
Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD



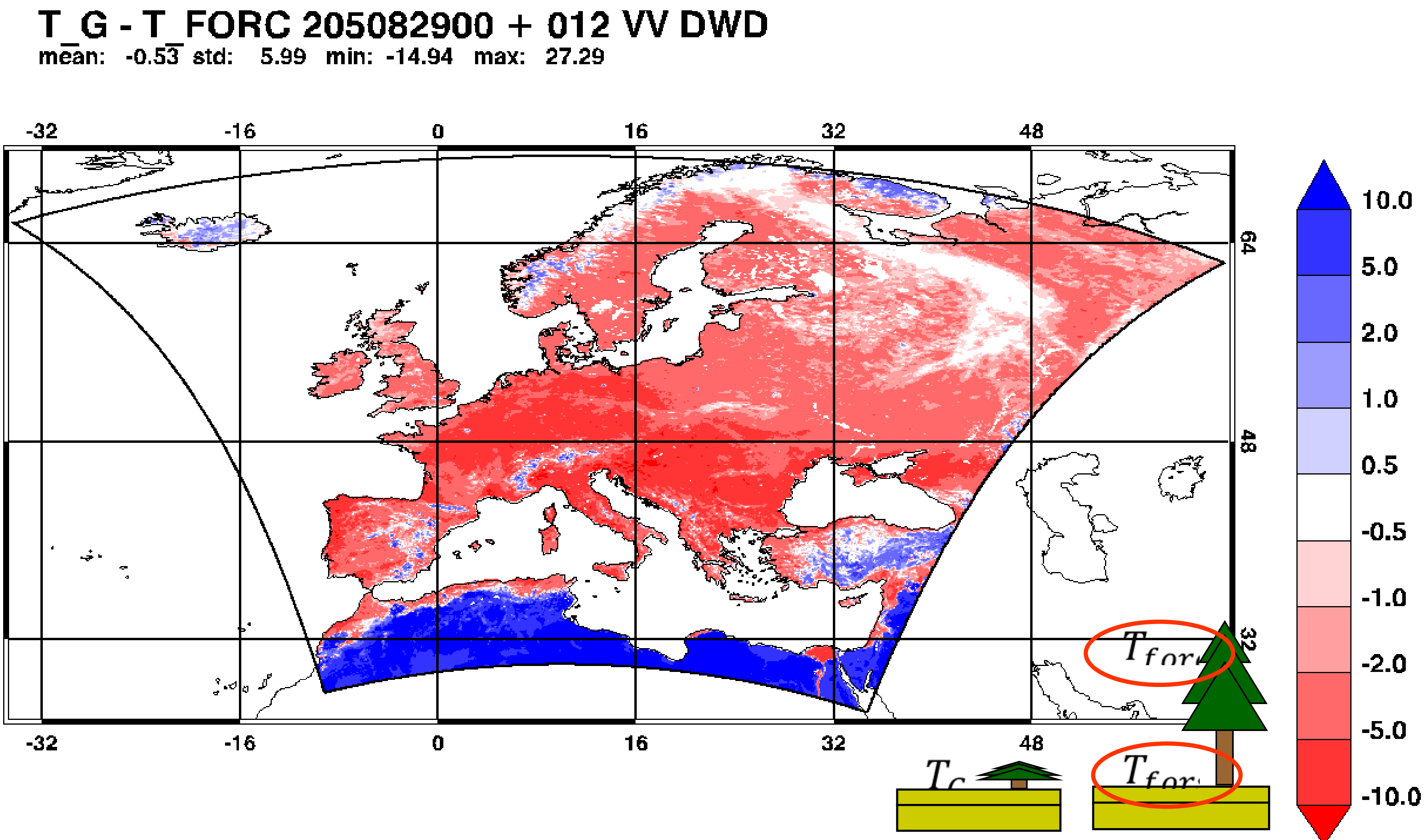
Total cloud coverage for 2015-08-29 12:00

Canopy experiment



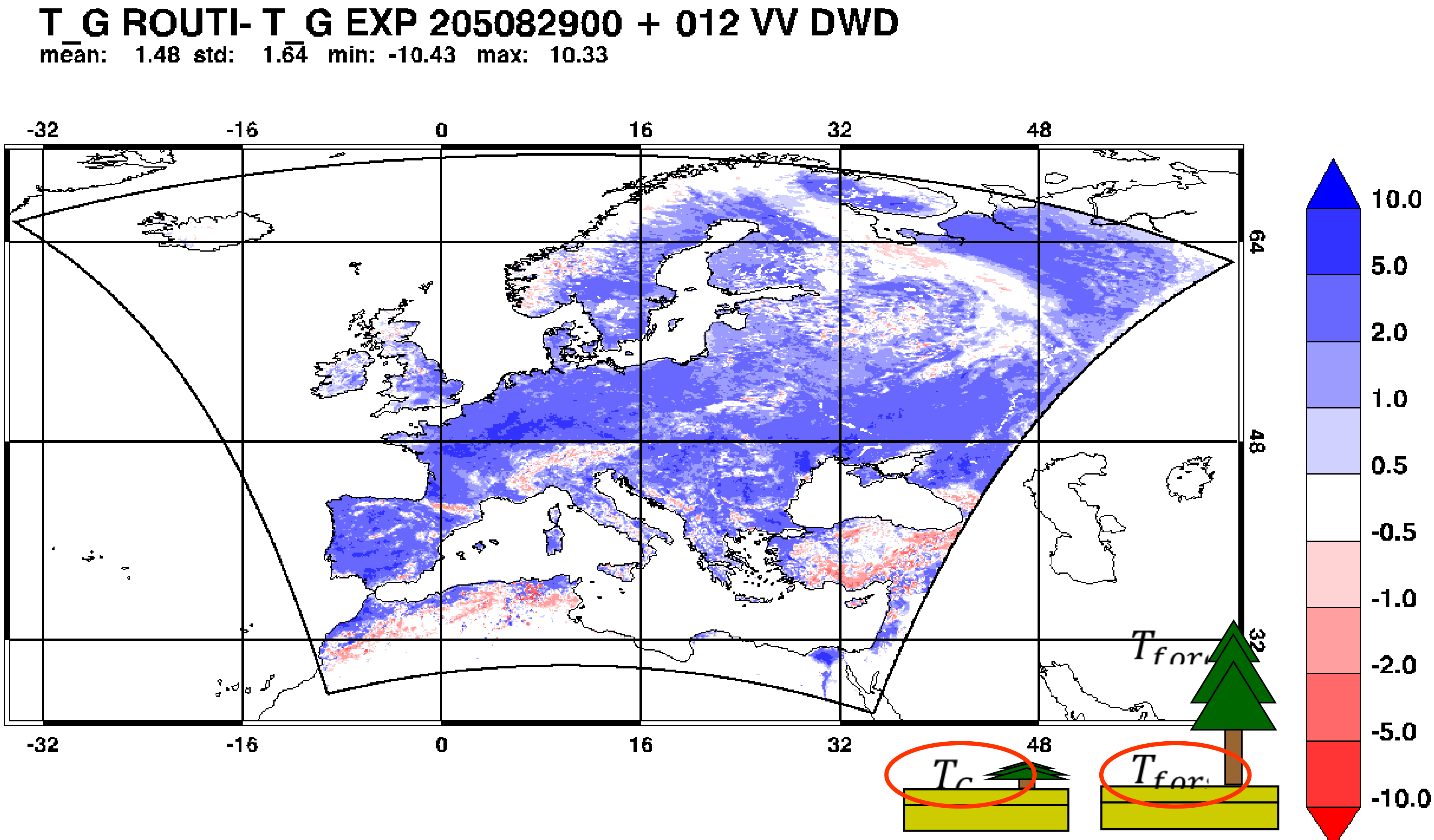
Comparison of canopy temperature and ground temperature (routi) for 2015-08-29 12:00

Canopy experiment



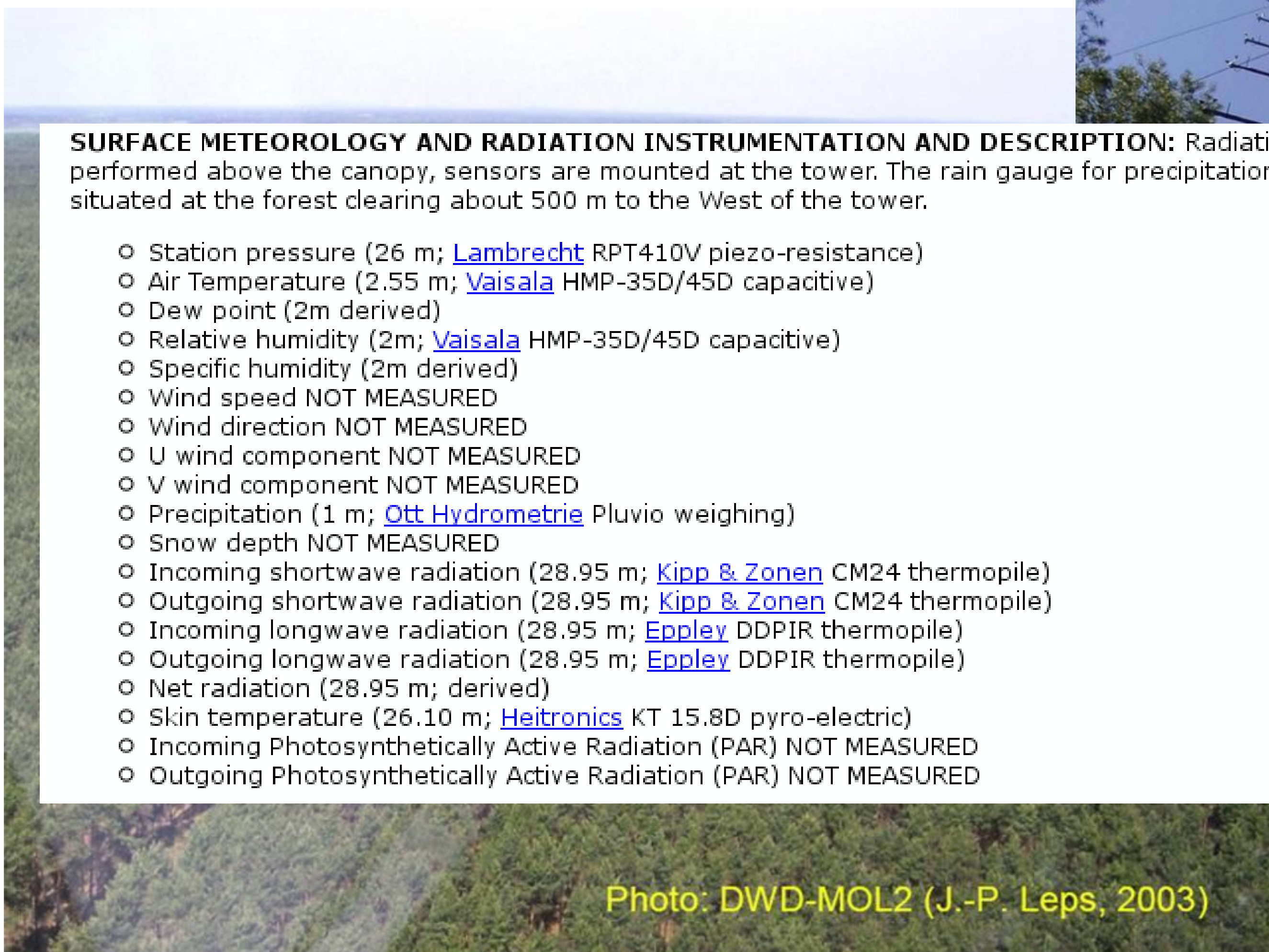
Comparison of canopy temperature and ground temperature (exp) for 2015-08-29 12:00

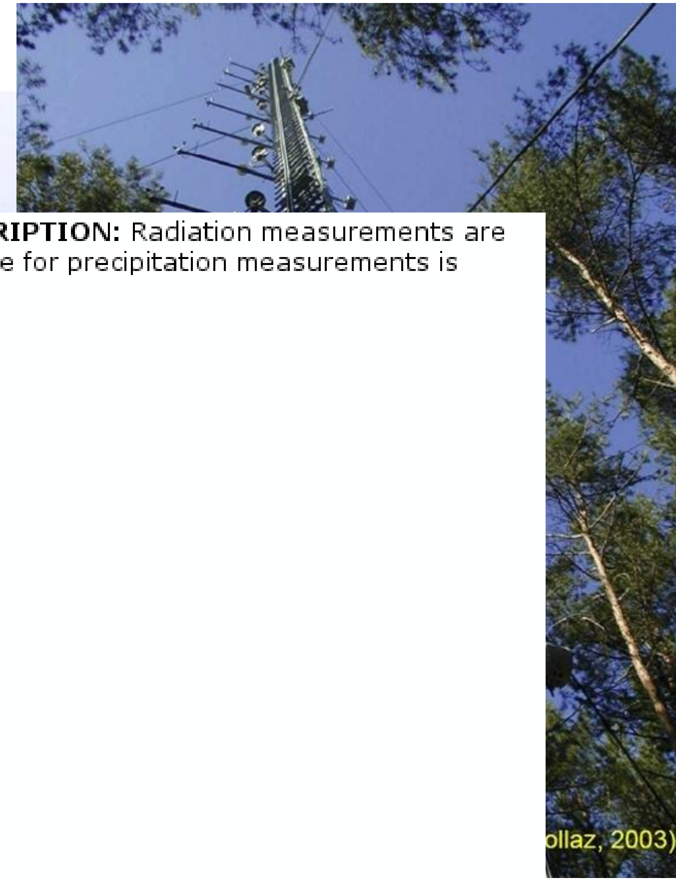
Canopy experiment



Comparison of canopy temperature and ground temperature (exp) for 2015-08-29 12:00

Validation: Forest site of the RAO



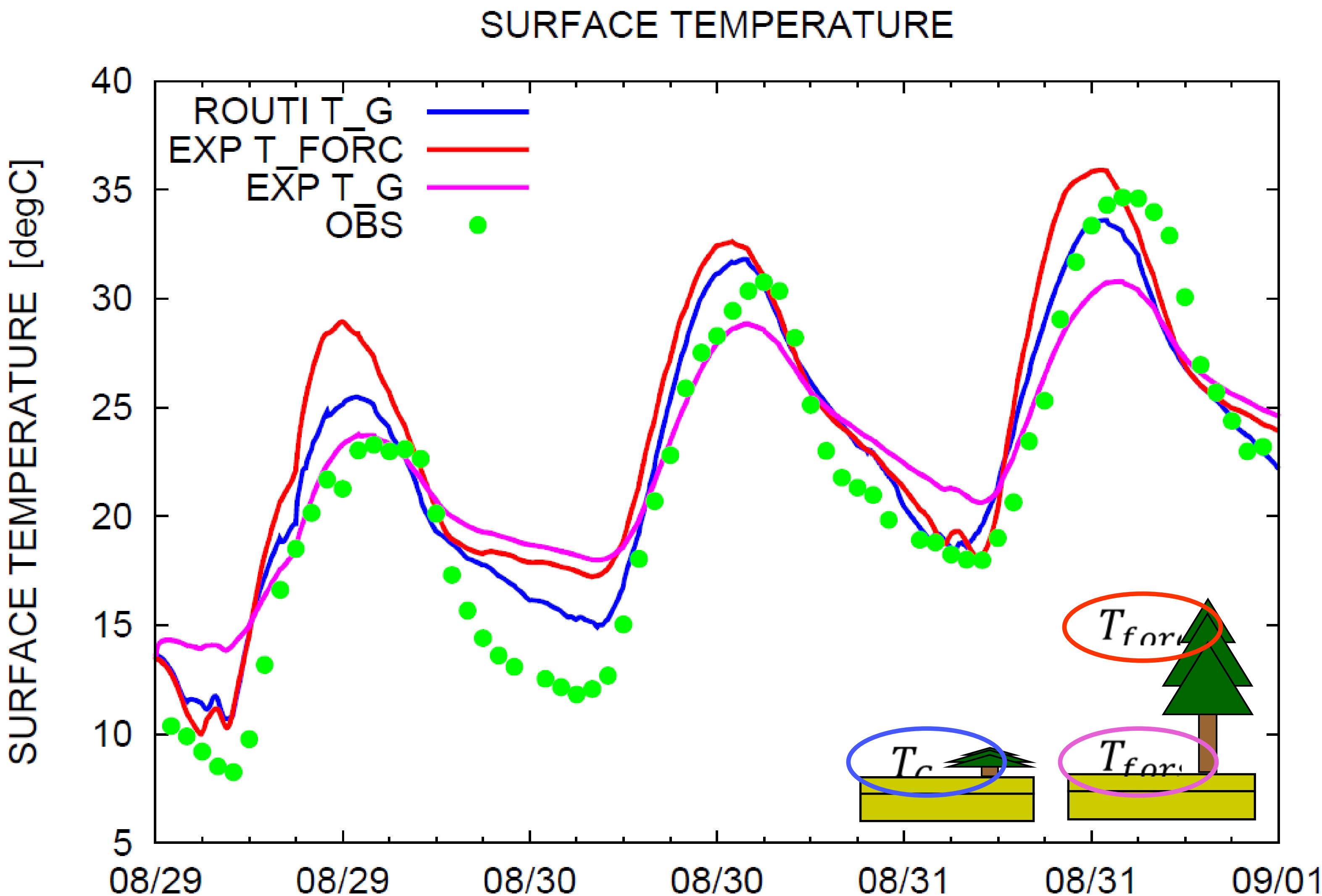


SURFACE METEOROLOGY AND RADIATION INSTRUMENTATION AND DESCRIPTION: Radiation measurements are performed above the canopy, sensors are mounted at the tower. The rain gauge for precipitation measurements is situated at the forest clearing about 500 m to the West of the tower.

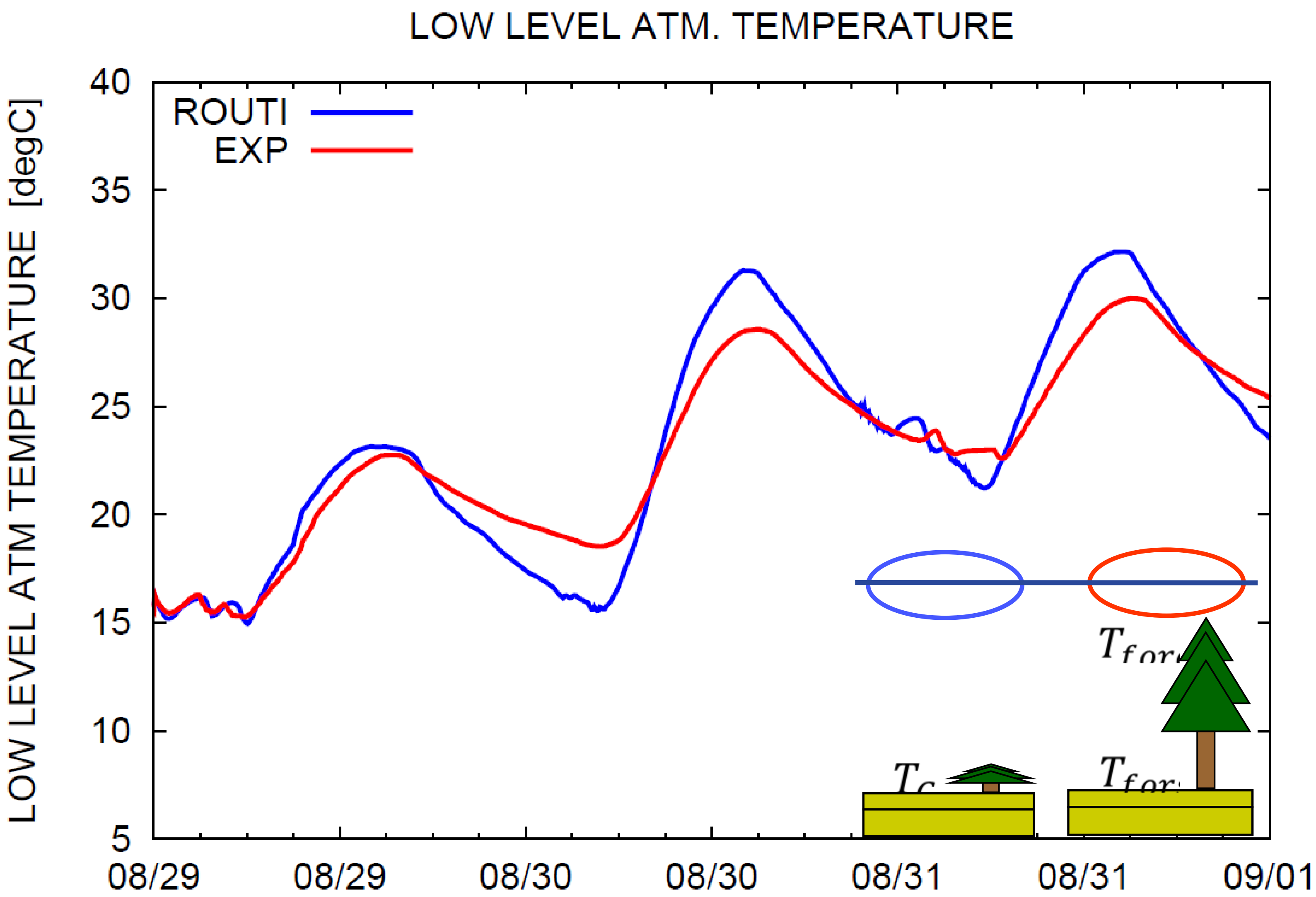
- Station pressure (26 m; Lambrecht RPT410V piezo-resistance)
- Air Temperature (2.55 m; Vaisala HMP-35D/45D capacitive)
- Dew point (2m derived)
- Relative humidity (2m; Vaisala HMP-35D/45D capacitive)
- Specific humidity (2m derived)
- Wind speed NOT MEASURED
- Wind direction NOT MEASURED
- U wind component NOT MEASURED
- V wind component NOT MEASURED
- Precipitation (1 m; Ott Hydrometrie Pluvio weighing)
- Snow depth NOT MEASURED
- Incoming shortwave radiation (28.95 m; Kipp & Zonen CM24 thermopile)
- Outgoing shortwave radiation (28.95 m; Kipp & Zonen CM24 thermopile)
- Incoming longwave radiation (28.95 m; Eppley DDPIR thermopile)
- Outgoing longwave radiation (28.95 m; Eppley DDPIR thermopile)
- Net radiation (28.95 m; derived)
- Skin temperature (26.10 m; Heitronics KT 15.8D pyro-electric)
- Incoming Photosynthetically Active Radiation (PAR) NOT MEASURED
- Outgoing Photosynthetically Active Radiation (PAR) NOT MEASURED

TAI = 3.12
SVF= 0.21

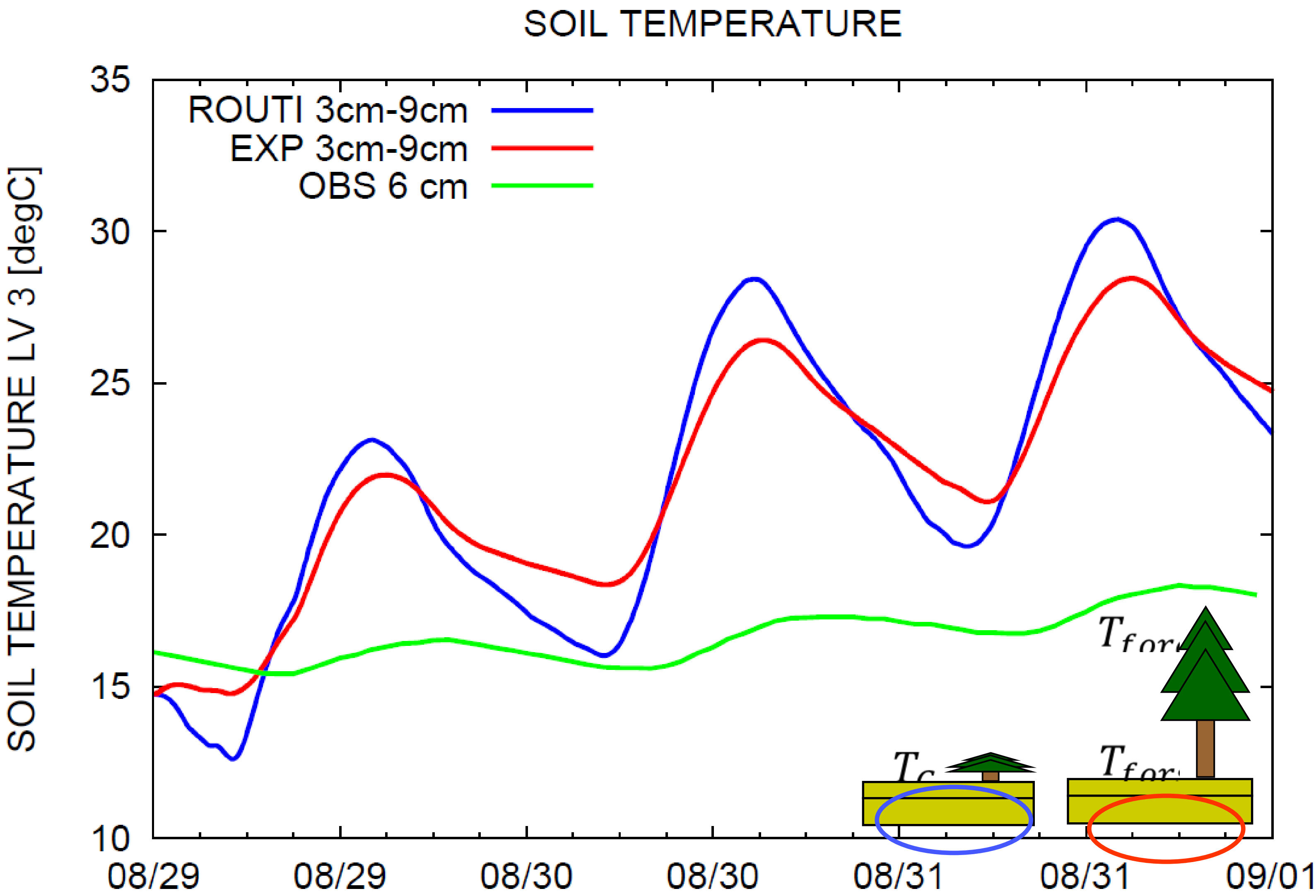
Validation: Forest site of the RAO



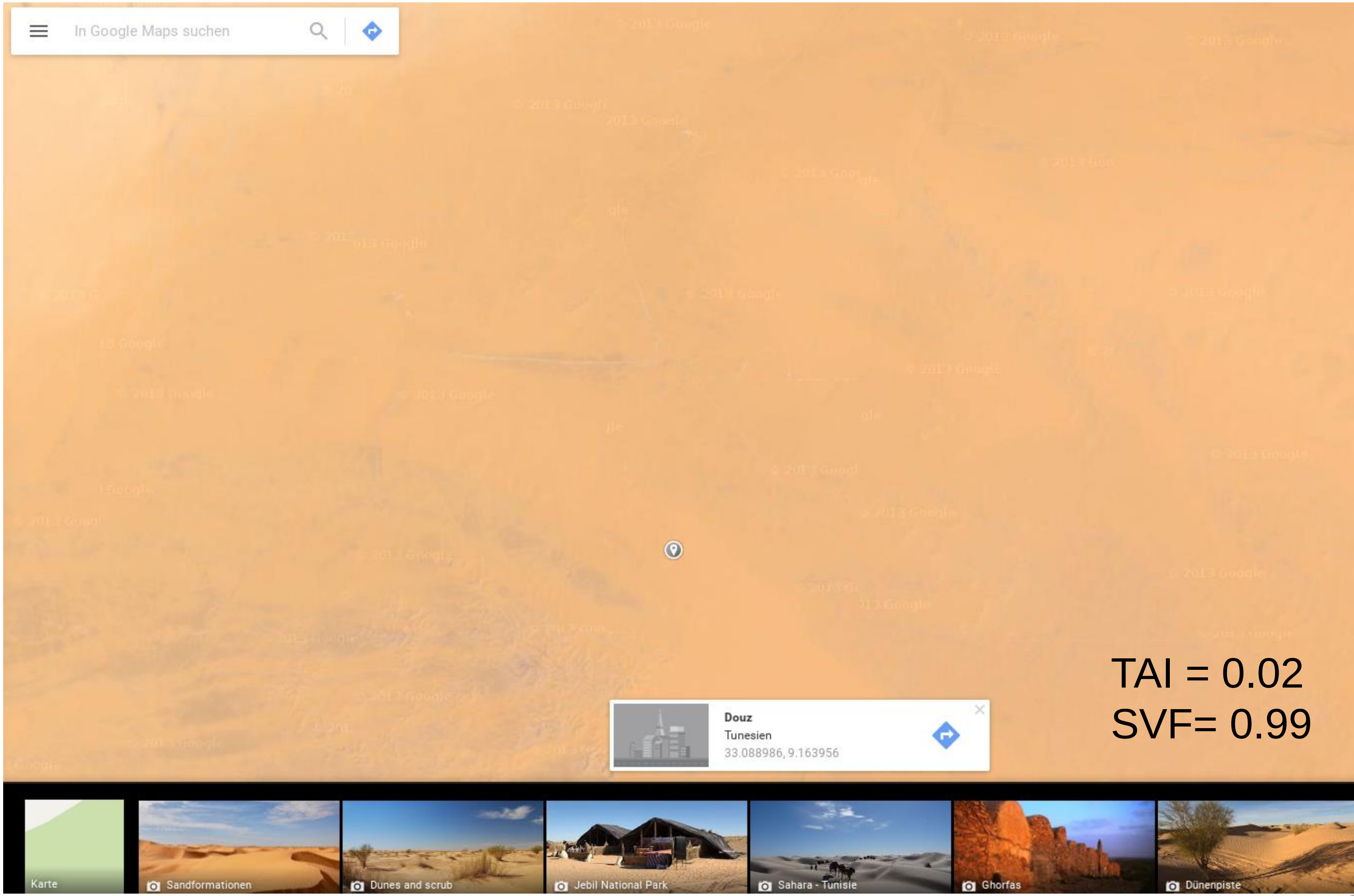
Validation: Forest site of the RAO



Validation: Forest site of the RAO

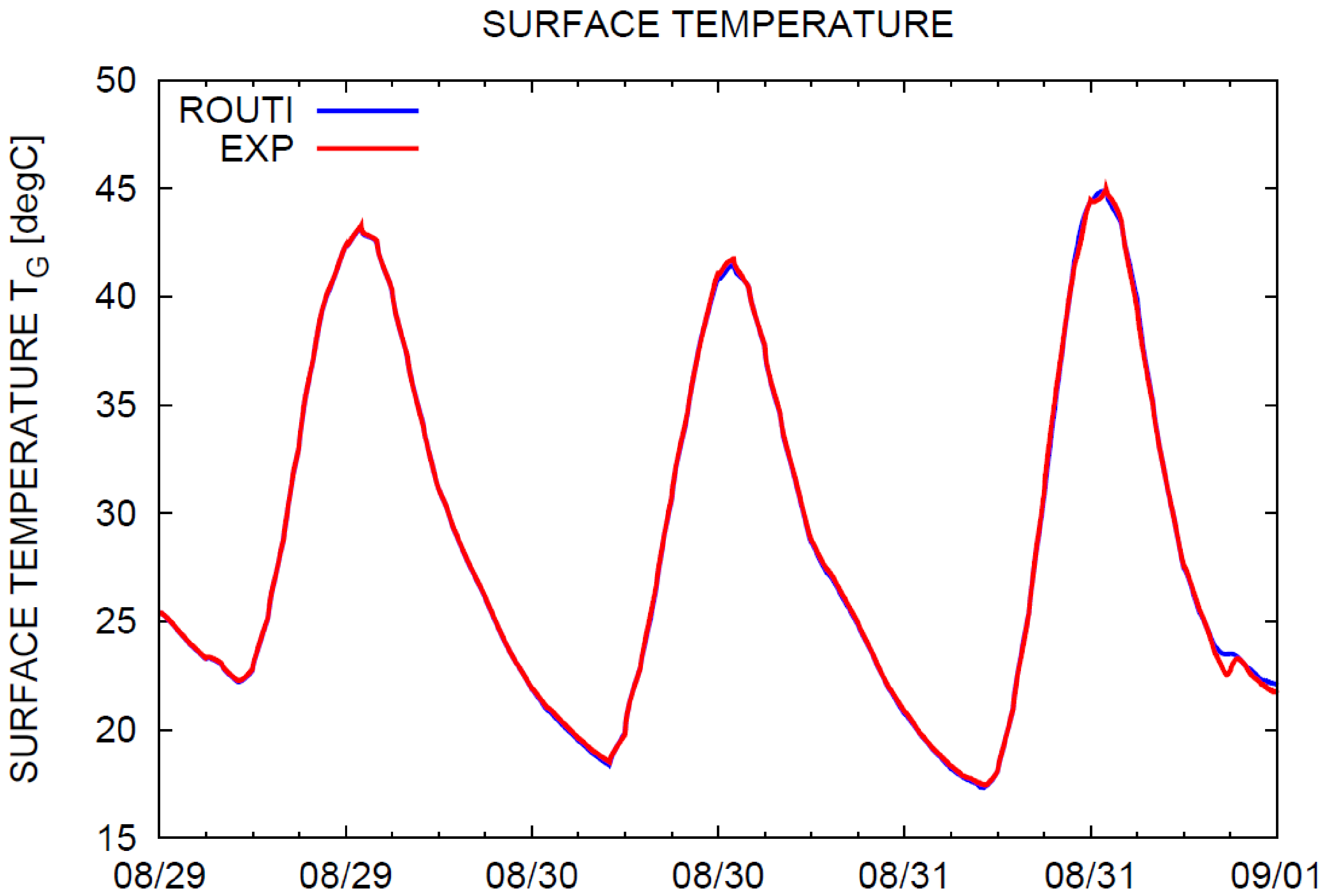


Desert site

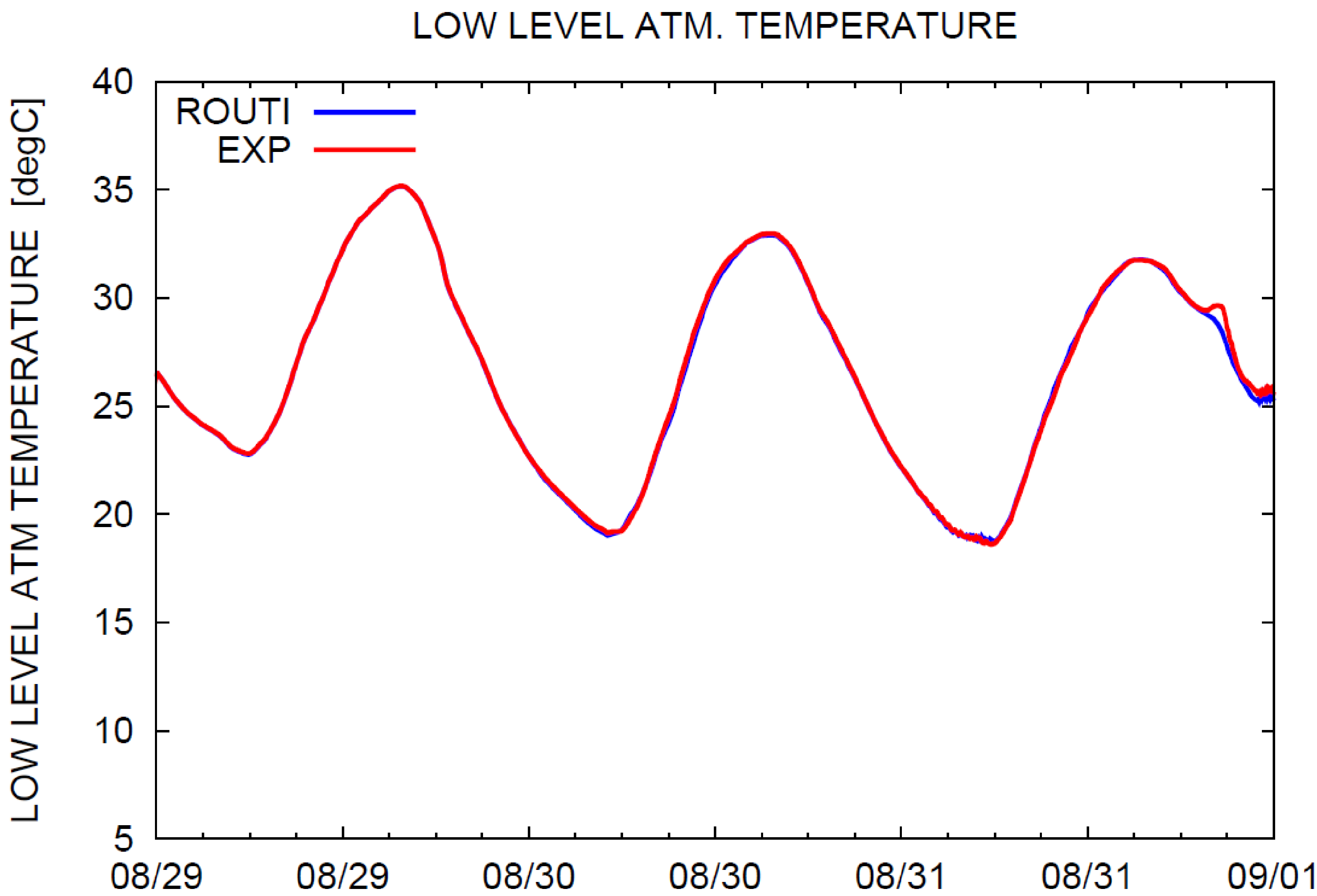


TAI = 0.02
SVF= 0.99

Desert site


SURFACE TEMPERATURE
ROUTI
EXP
SURFACE TEMPERATURE T_G [degC]
50
45
40
35
30
25
20
15
08/29
08/29
08/30
08/30
08/31
08/31
09/01

Desert site



LOW LEVEL ATM. TEMPERATURE
LOW LEVEL ATM TEMPERATURE [degC]
ROUTI
EXP
40
35
30
25
20
15
10
5
08/29
08/29
08/30
08/30
08/31
08/31
09/01

Summary

- First steps for implementation of a canopy scheme in COSMO
- Energy budget for canopy and vegetation floor
- Prognostic canopy temperature exists
- Atmospheric resistances parameterized
- First results as expected, but still some limitations
- Next steps: connection with the transfer scheme, experiments with snow

Outlook

- Implementation in the global NWP model ICON: Main focus on boreal forest areas in NH winter

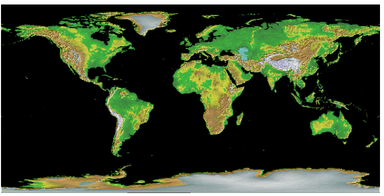
- Application in the project “Data assimilation including parameter estimation in the coupled land-atmosphere system” funded by Hans-Ertel-Zentrum für Wetterforschung

- Application in the power-grid safety project ORKA2

Physiographic data

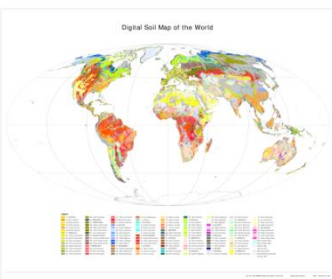
ExtPar
Physiographic data

NWP and Climate models: e.g. ICON R02B07 13 km, CDE 2.5 km



Orography
GLOBE: 1 km
ASTER: 0.03 km

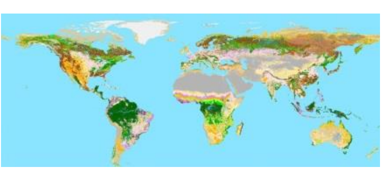
Aerosols: 500 km
NDVI: 5 km



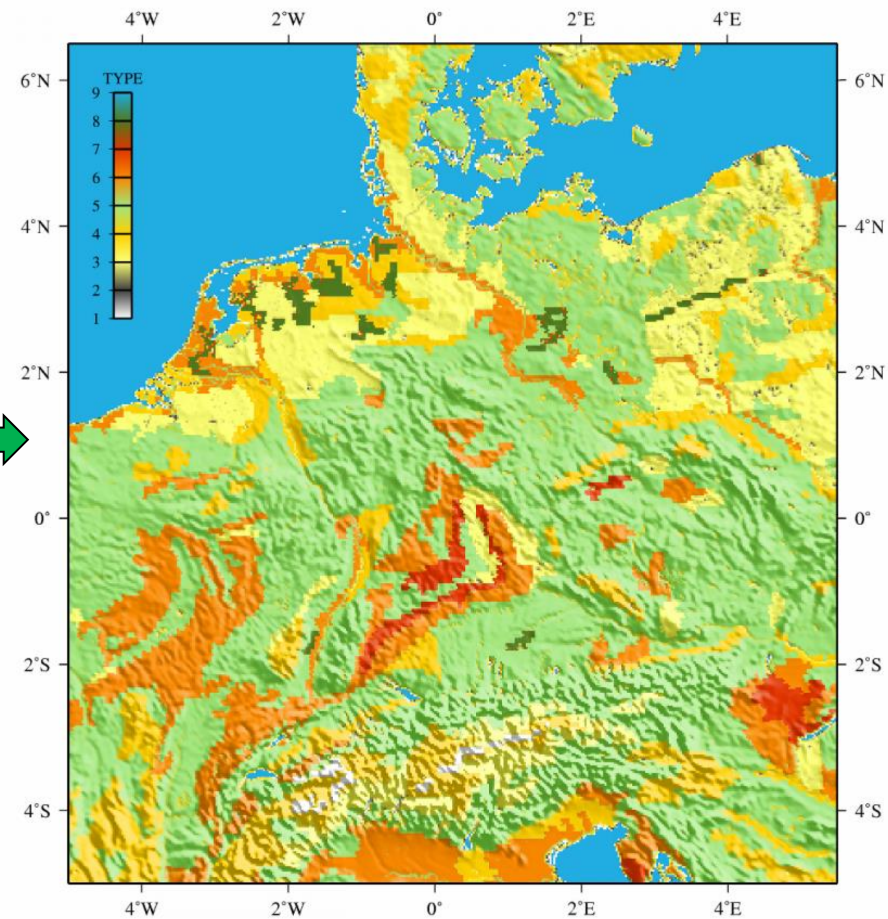
Soil data
DSMW: 10 km
HWSD: 1 km

Lake: 1 km
Surface albedo: 5 km
T2M climatology: 50/500 km

Land use
GLC2000 1 km
GLCC 1 km
GlobCover 0.3 km

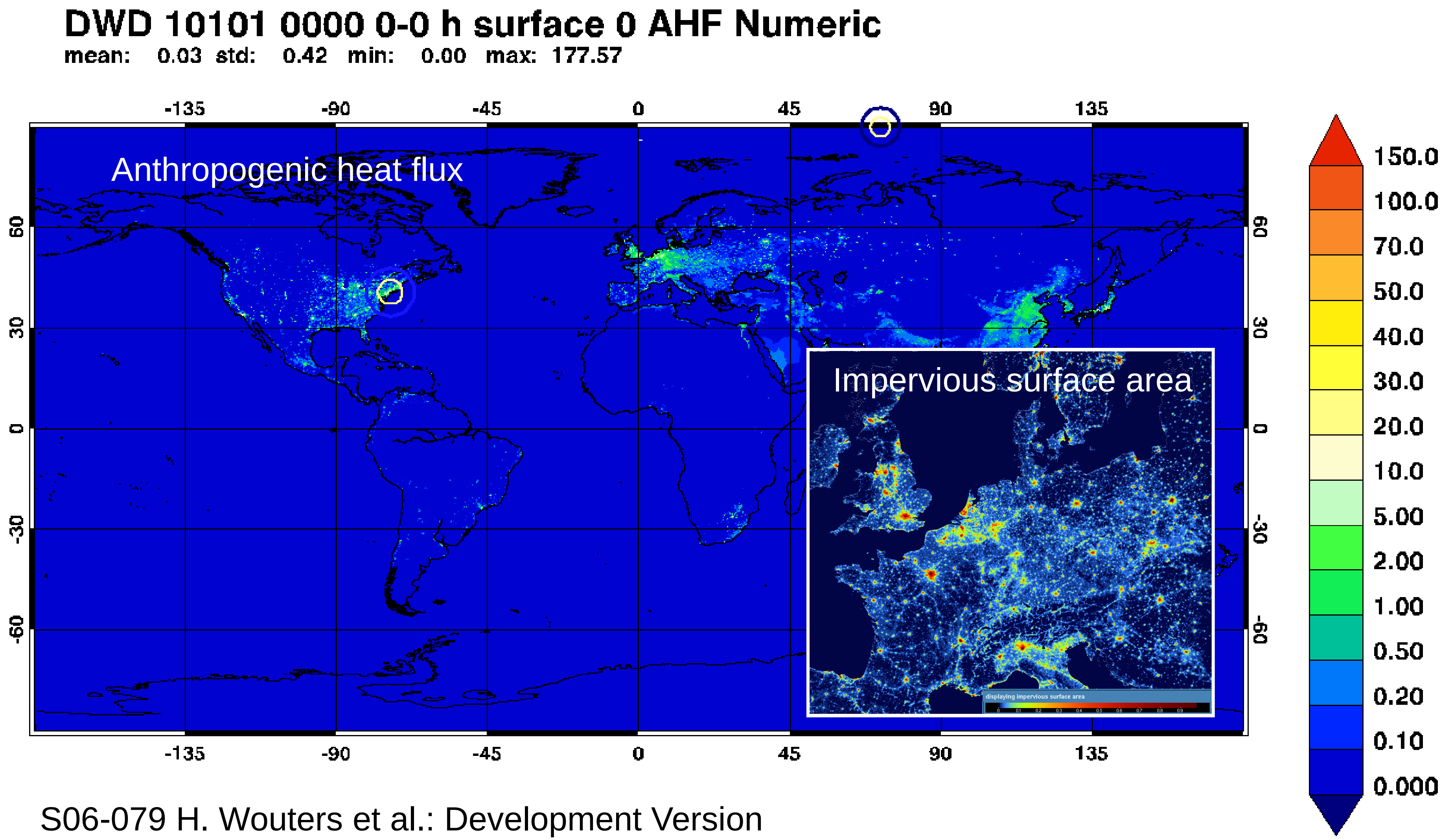


Aggregation, consistency proof



Physiographic data on model grid

EXTPAR V2.4



S06-079 H. Wouters et al.: Development Version (DV) release of TERRA_URB in COSMO(-CLM), overview and sensitivity to urban input parameters.

EXTPAR V2.5

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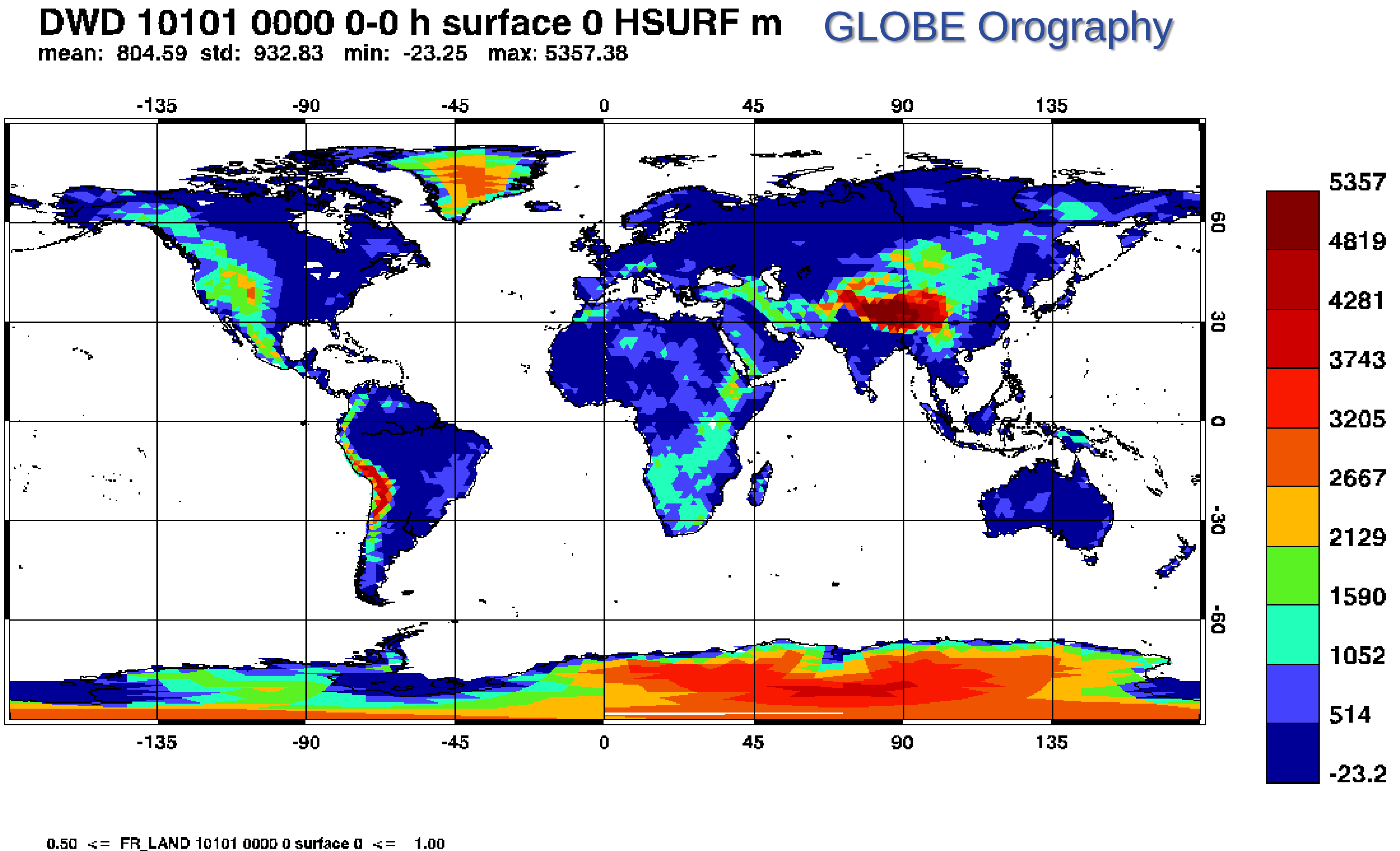
GLOBE Orography



MPI Parallelization by M. Pondkule

- High-resolution ICON domains are demanding for computational time and memory usage

- EXTPAR still uses OpenMP: limited on one node

- MPI improves memory usage in large clusters

- MPI is now implemented

- First preleminary results are promising (high resolution fields, e.g. R2B14, scaling, comparability)

- Now integration into EXTPAR preV2.6