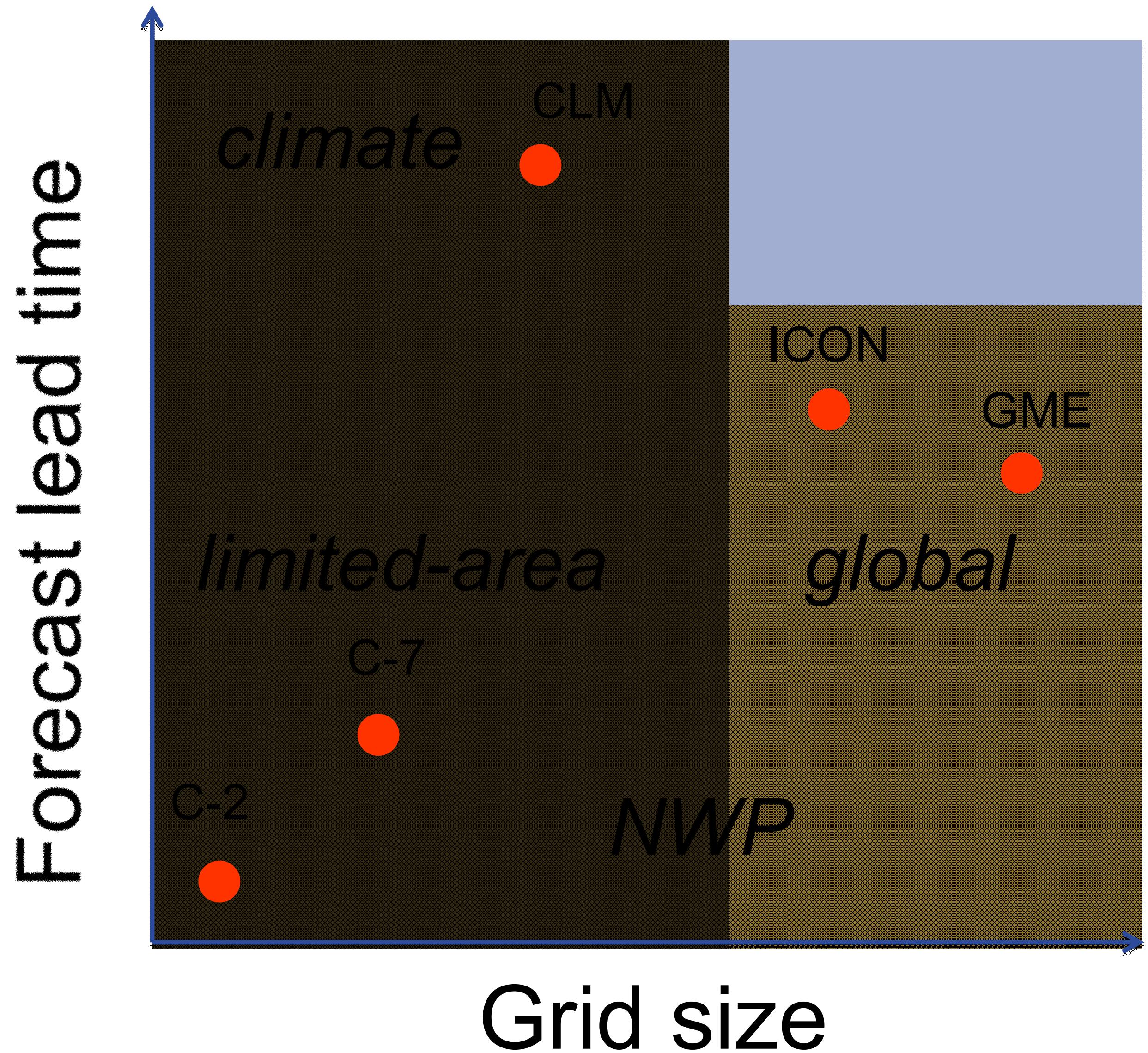
TERRA

Soil Vegetation Atmosphere Transfer
across
Models and Scales

DWD contribution

COSMO-GM 2013

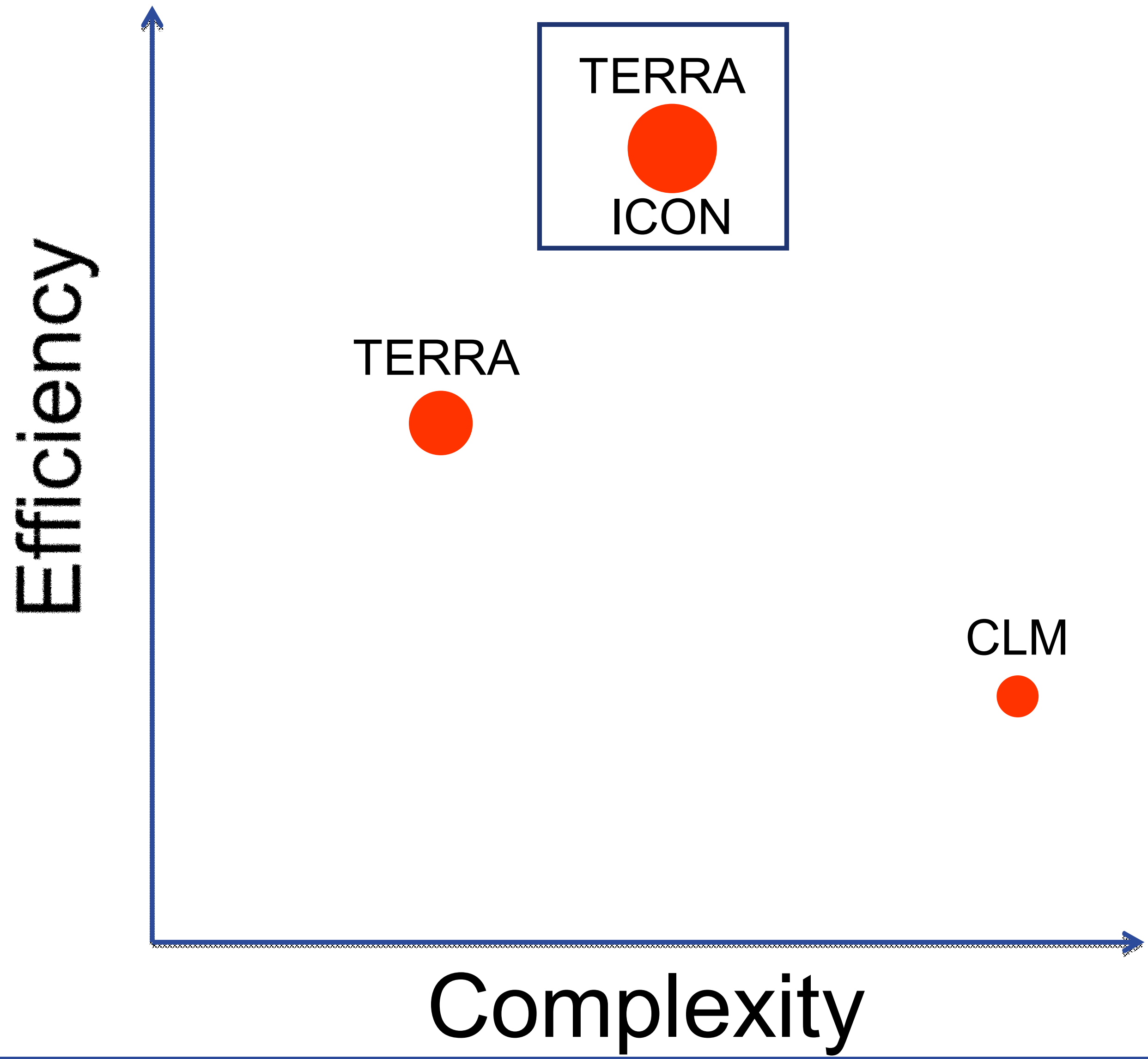
TERRA – Applications: Scales



TERRA - Features

- Efficient and reliable SVAT scheme, includes relevant SVAT processes
- Integrated in the NWP process (DA, MOS, ensemble)
- Long-time experience and development in operational environment exist
- Operational requirements slow down development process
- Basis for external developments - special applications (stream flow, urban model, 3D-soil, dynamic vegetation, soil chemistry)

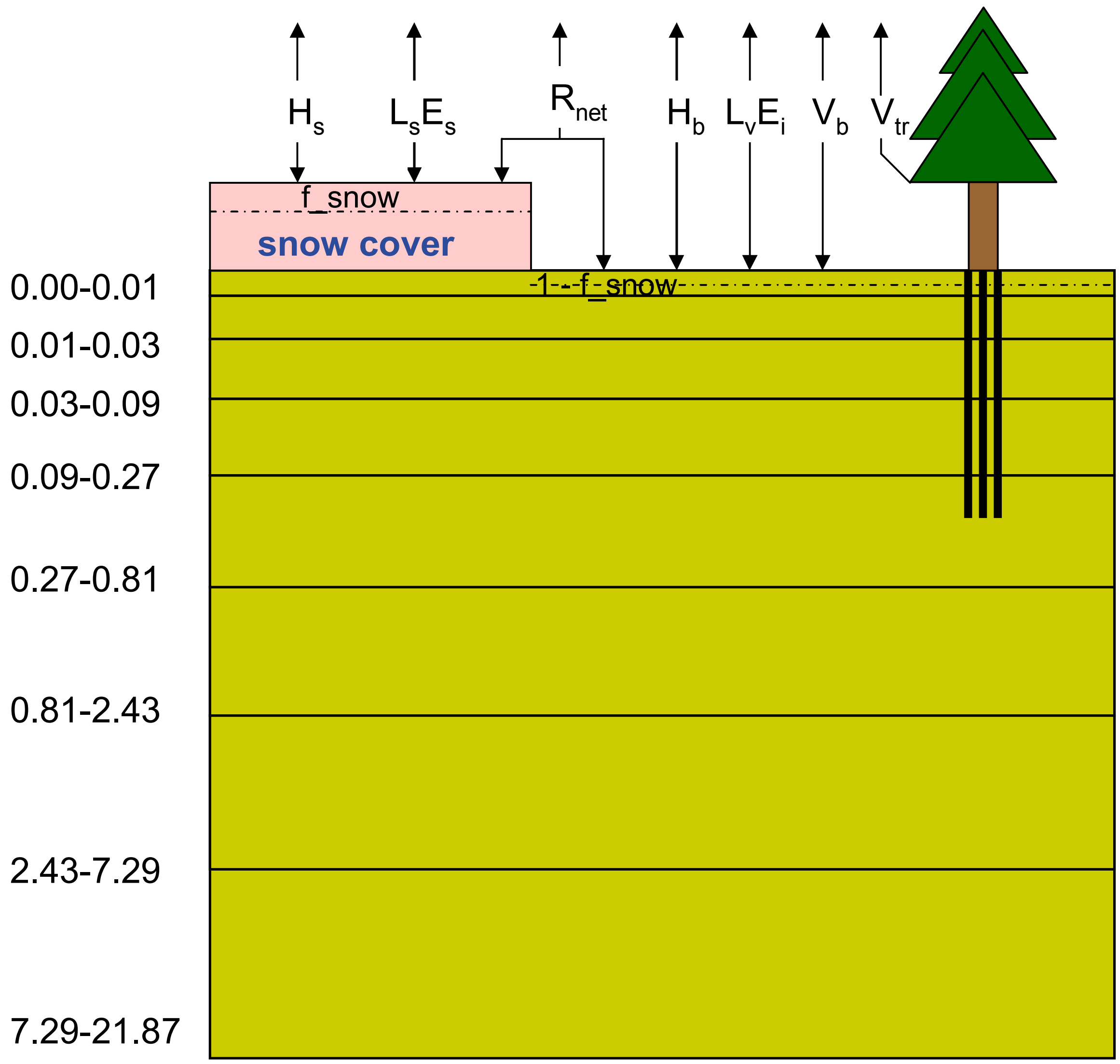
TERRA – Efficiency



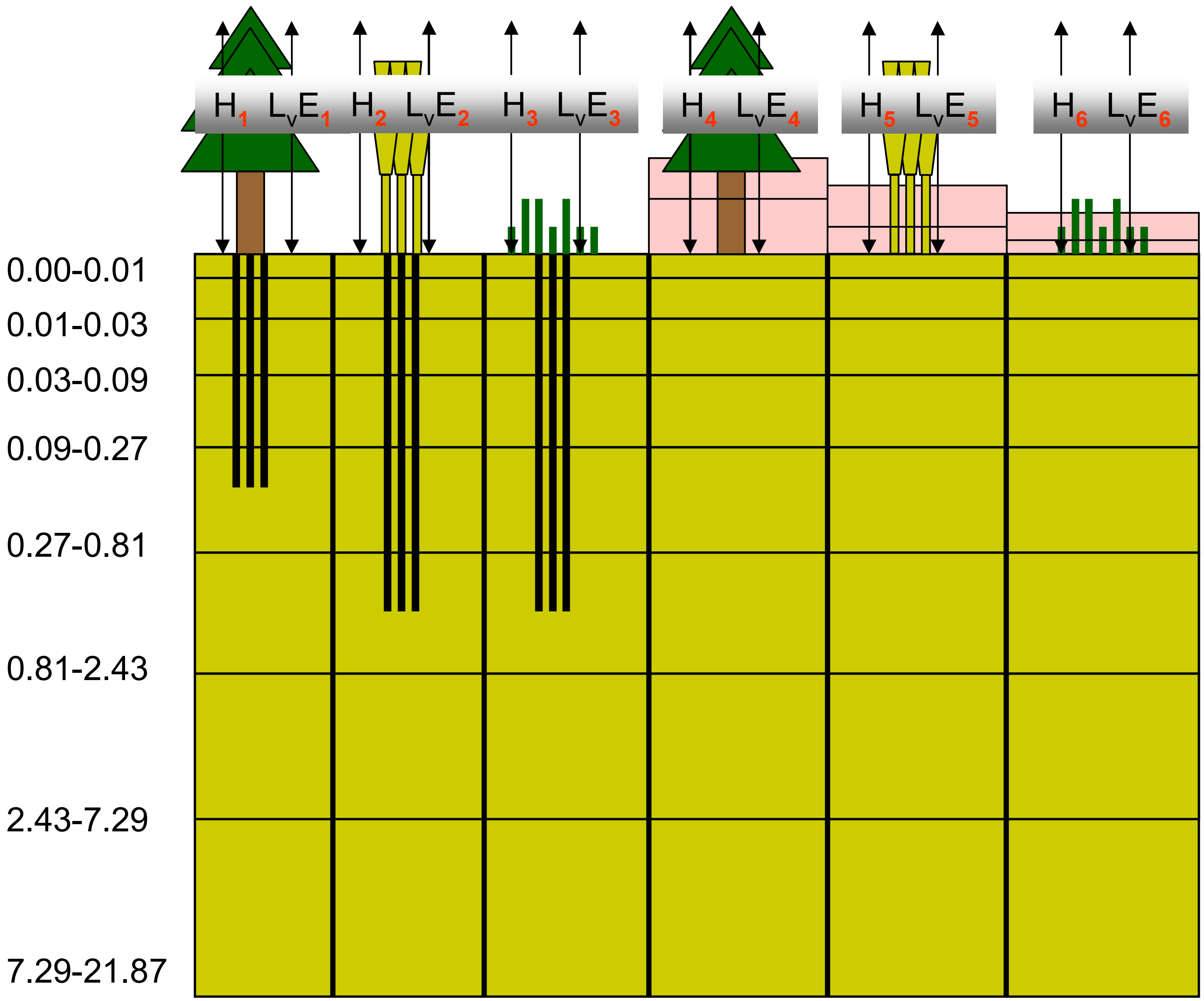
TERRA – New features

- Surface heterogeneity (TILE approach) and ML-SNOW
- Vegetation (roots, interception, NDVI climatology)
- Application of high-resolution input data sets (GlobCover-land use, HWSD heterogeneous soil)
- One source code – many scales: SCM, 2D, 3D (100m – 100km grid-size)
- Using uncertainties in input data sets for stochastic physics approach and for model calibration
- Model evaluation – IFS analysis, intercomparison, SRNWP

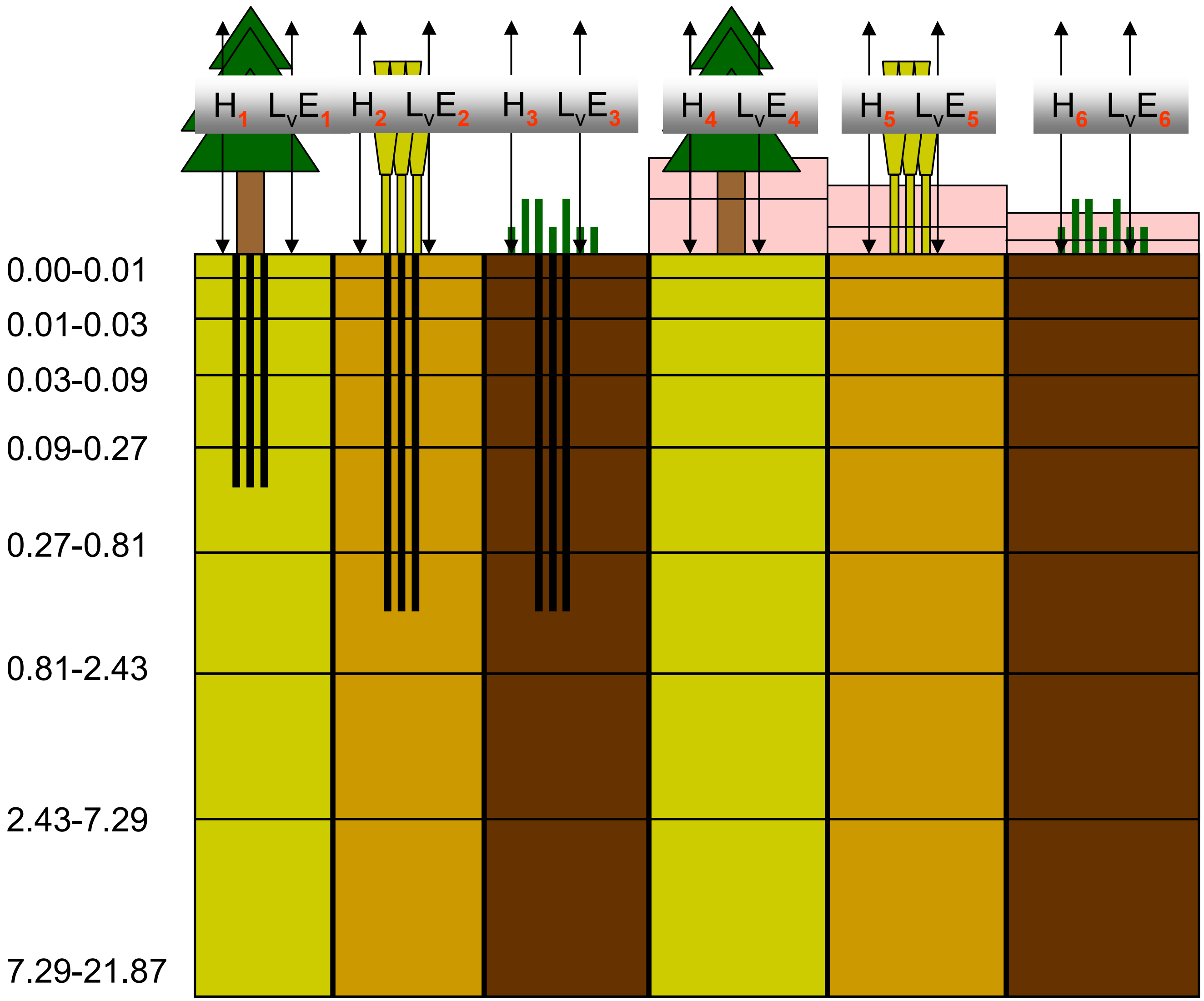
TERRA no-Tiles: HOM-SOIL



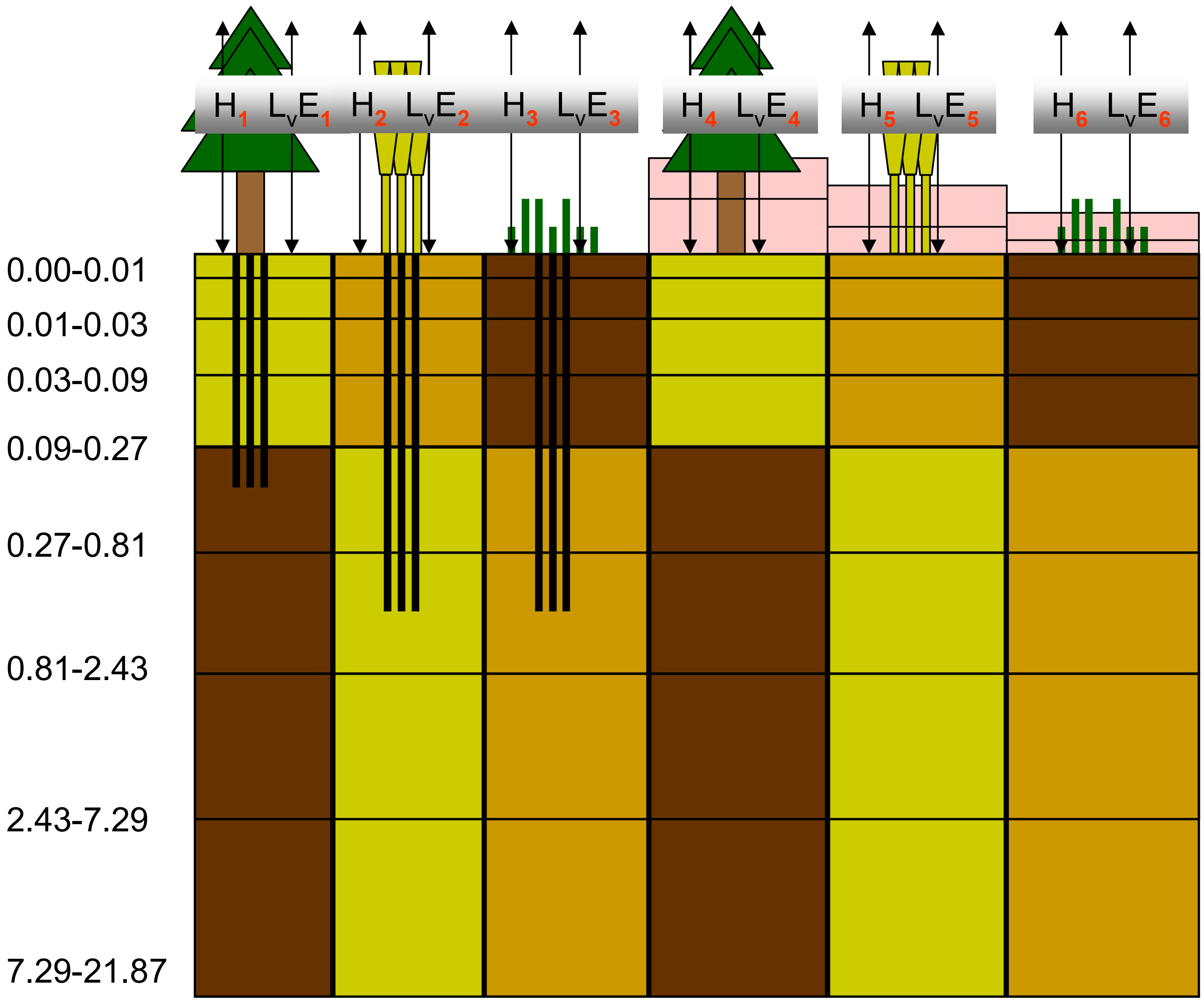
TERRA Tiles: HOM-SOIL



TERRA Tiles: HET-SOIL

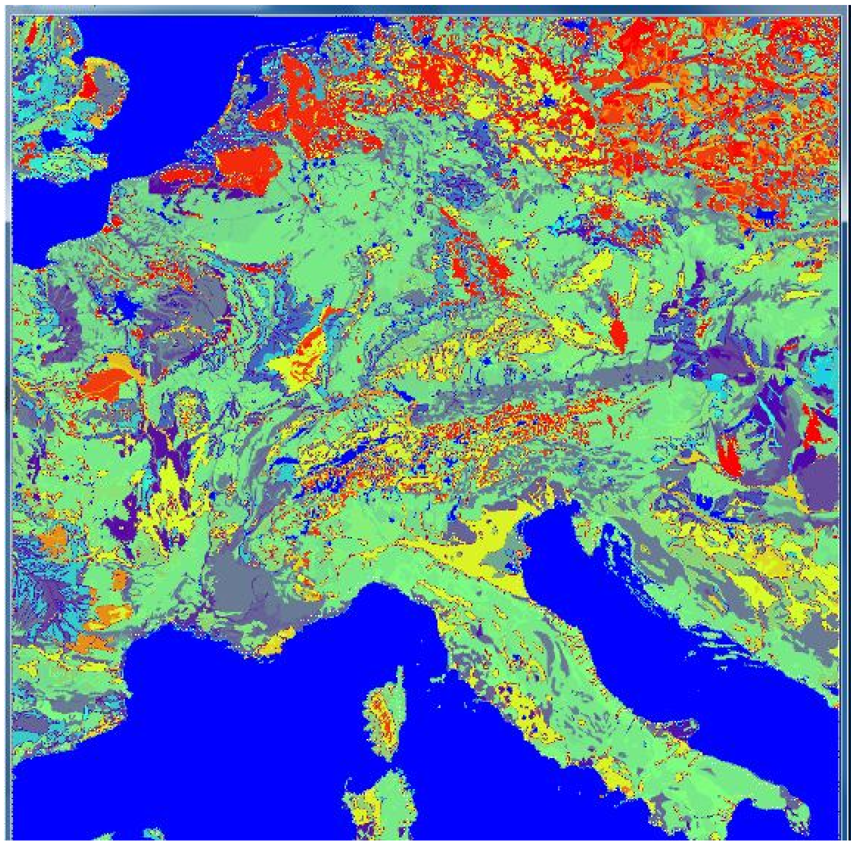


TERRA Tiles: HET+SUB-SOIL

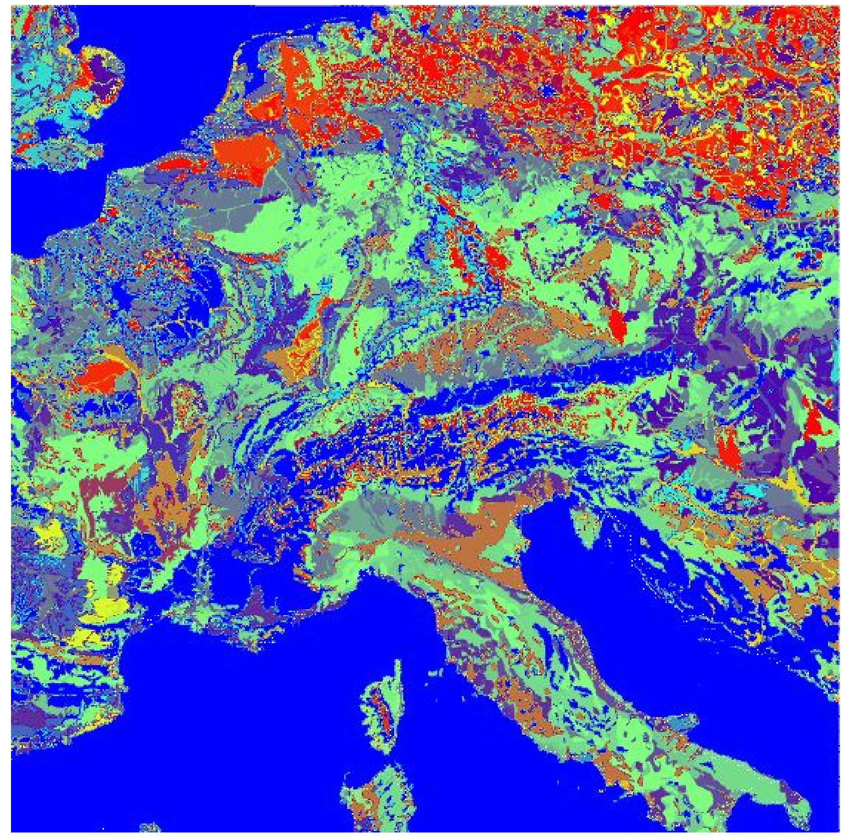


HWSD – Sand fraction

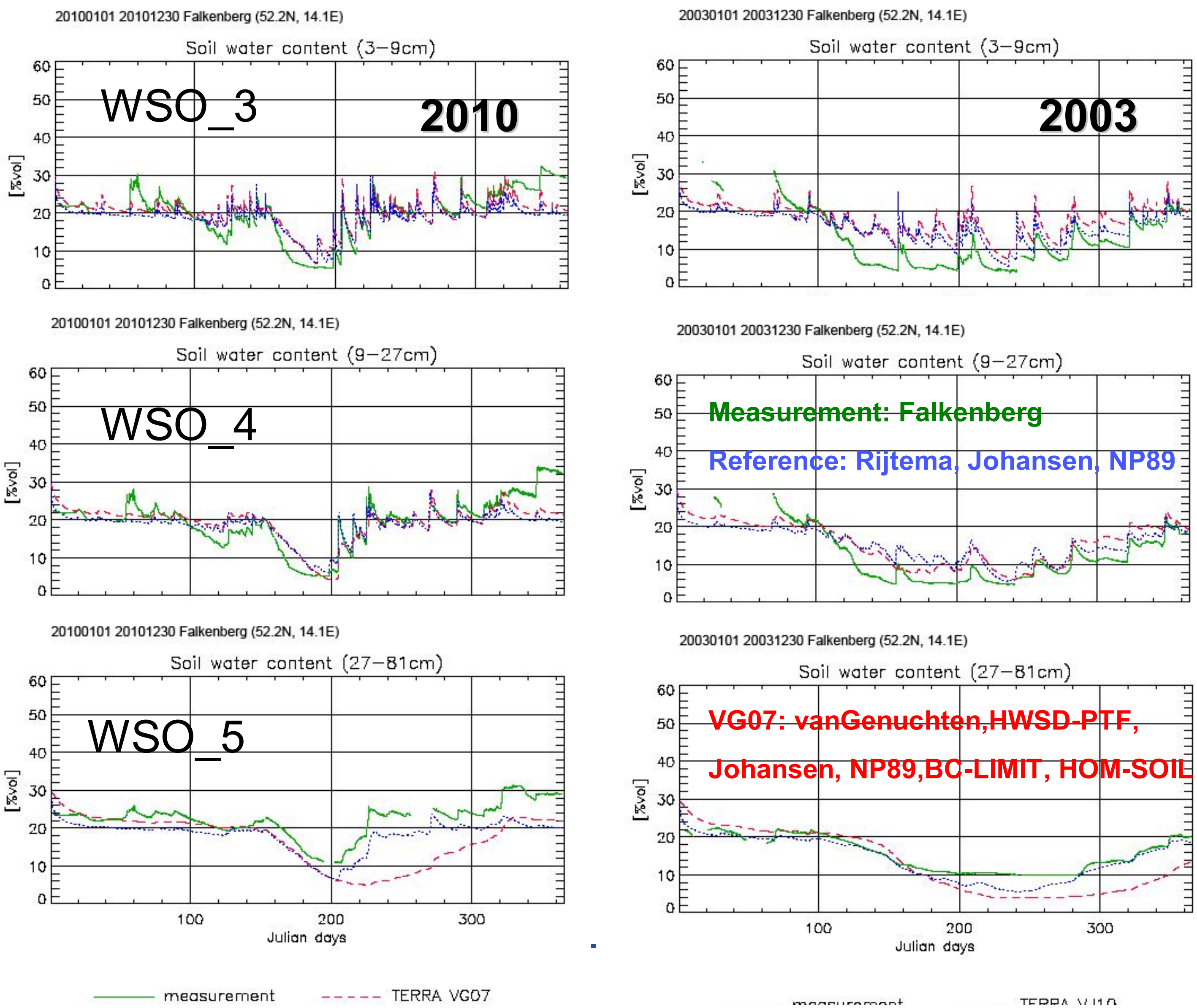
Sand fraction (0-30cm)



Sand fraction deep soil

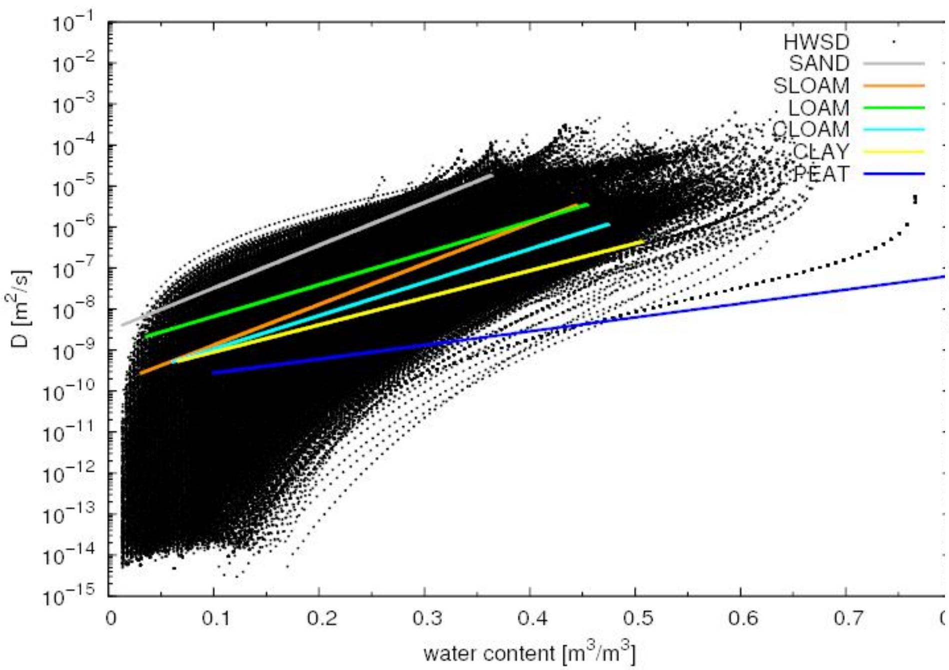


TERRA – VG hydraulics

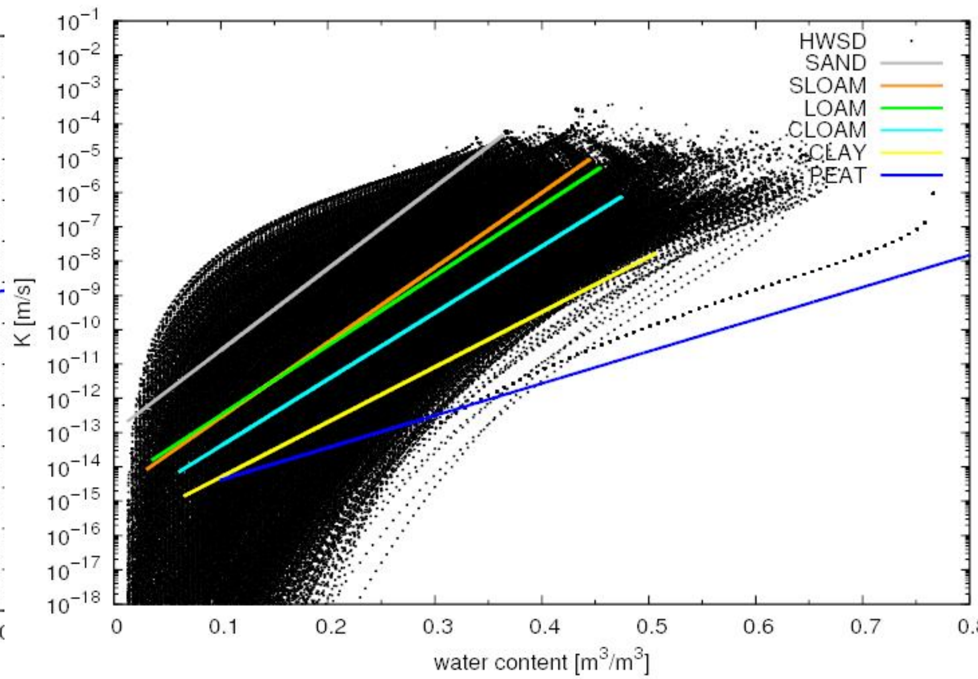


TERRA – VG hydraulics

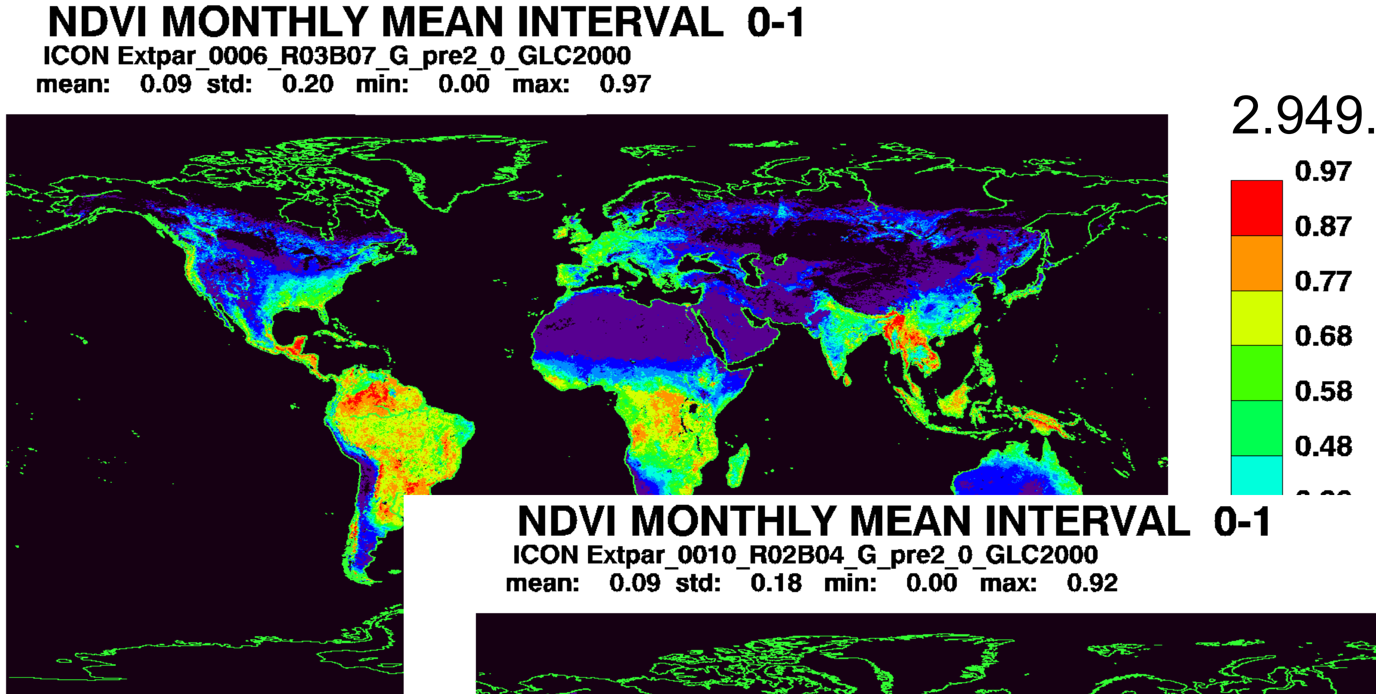
Diffusivity m²/s



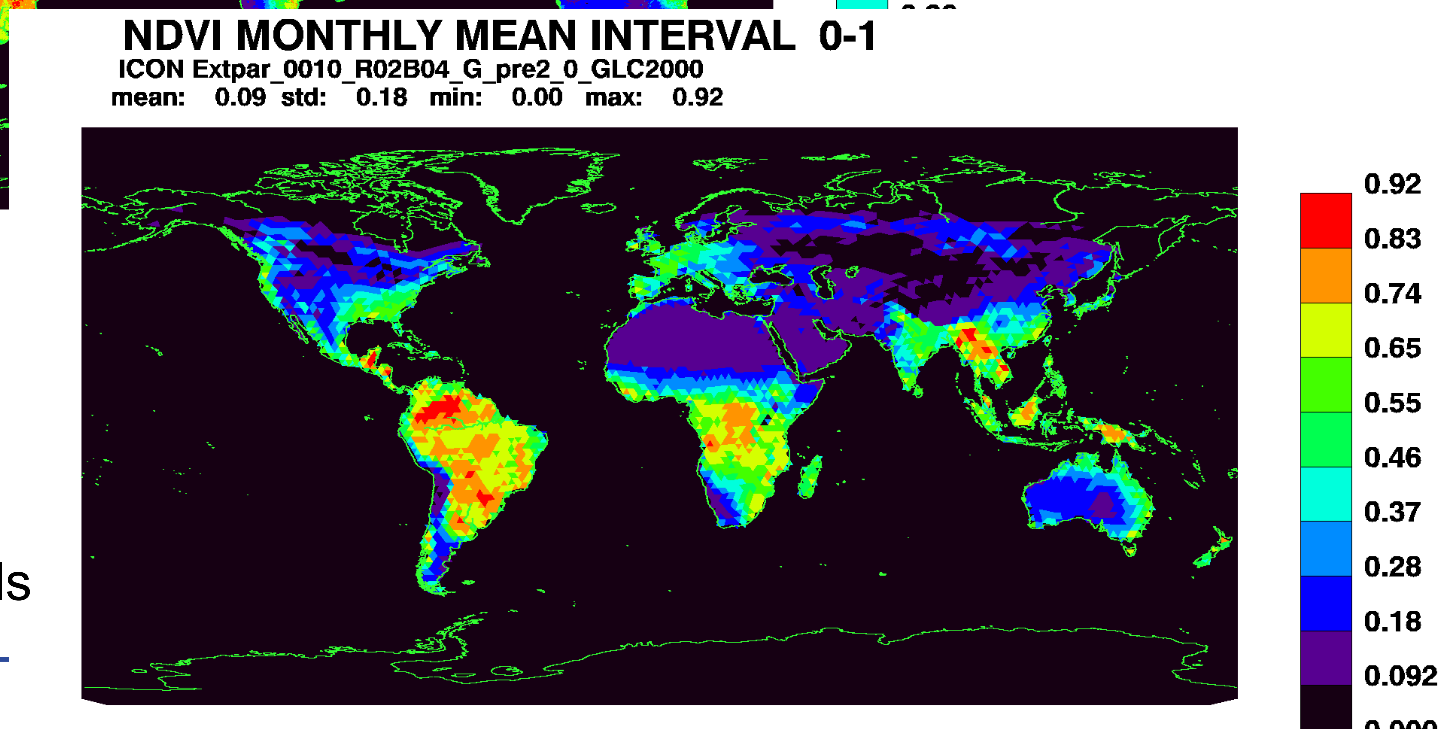
Conductivity m/s



TERRA – DYN-VEG

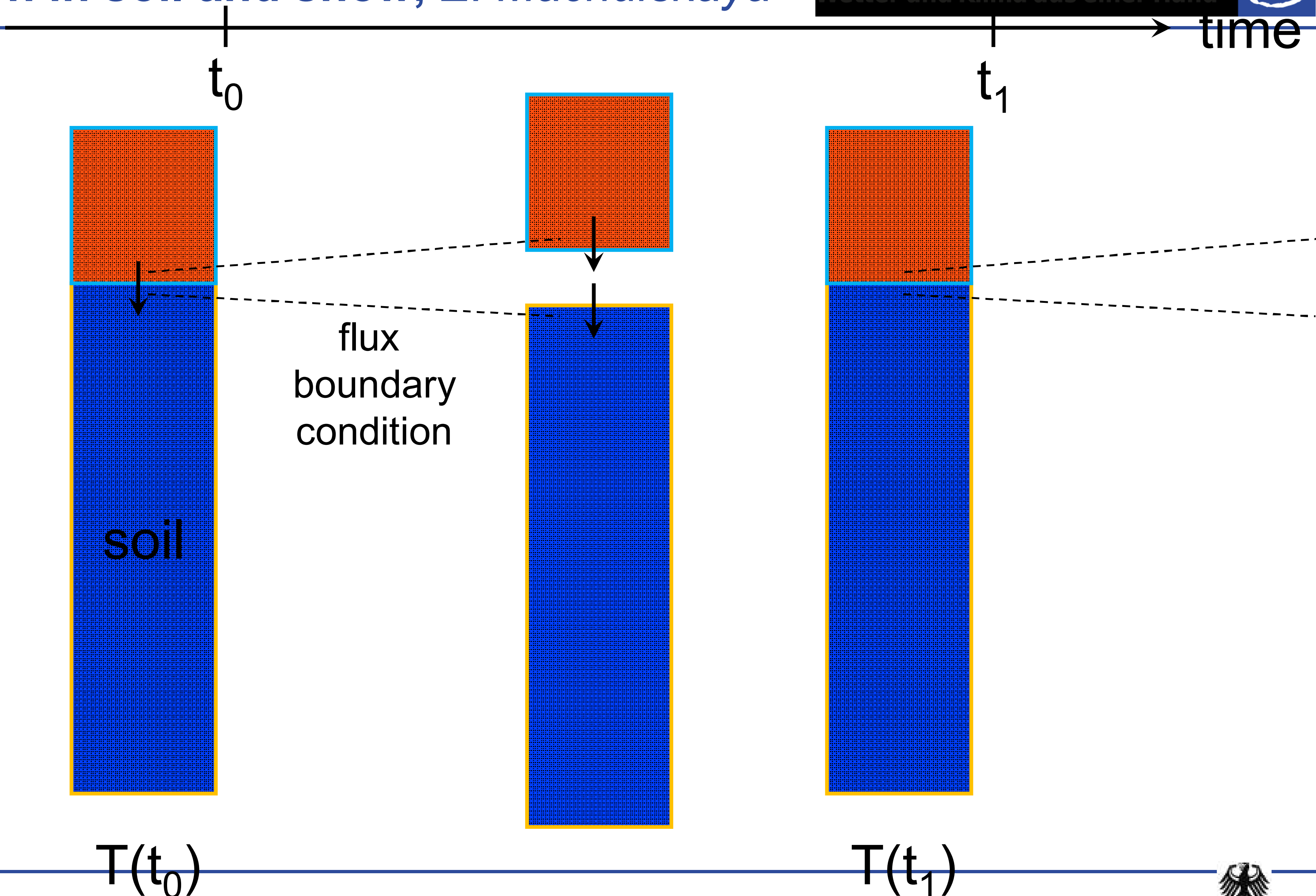


2.949.120 cells

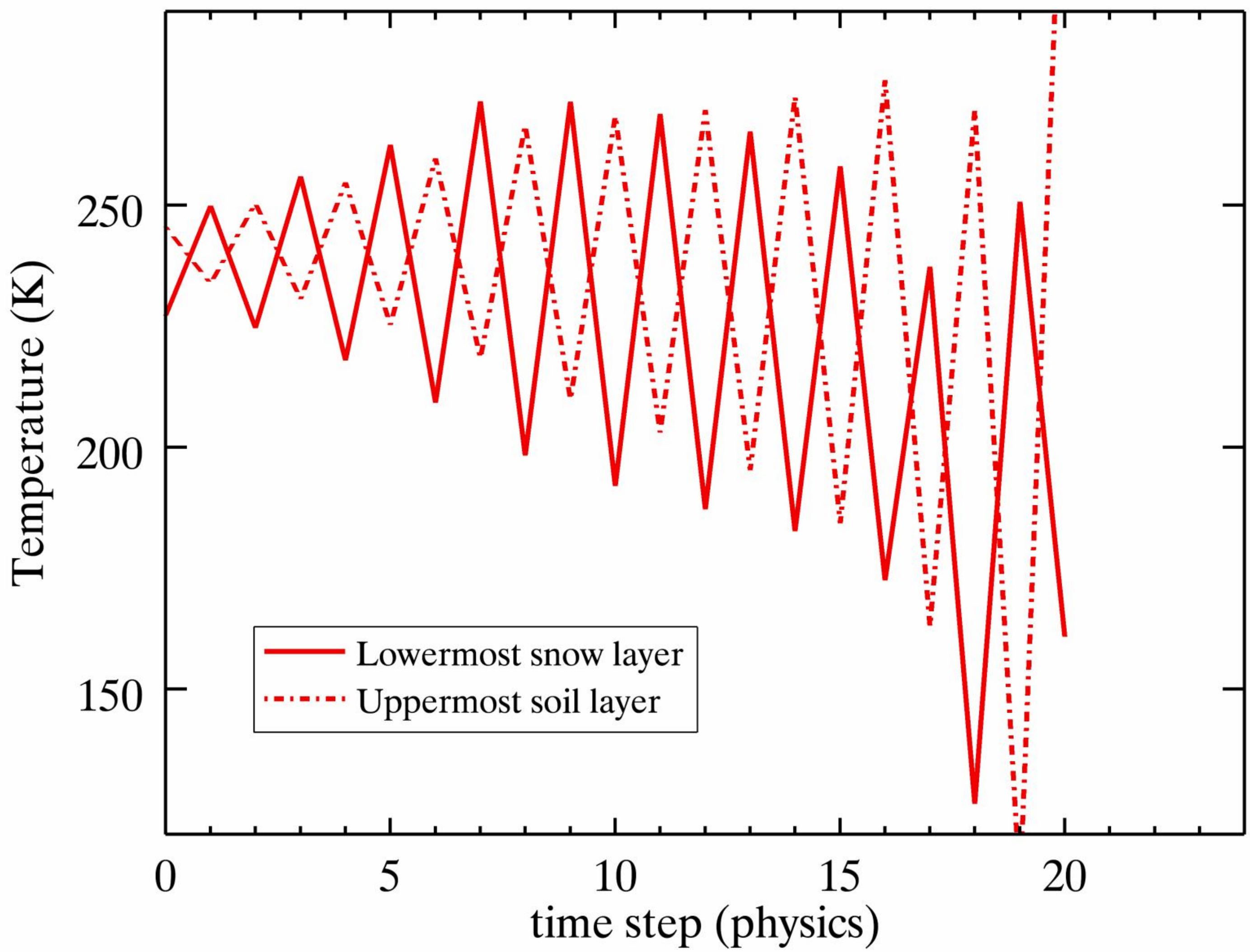


20.480 cells

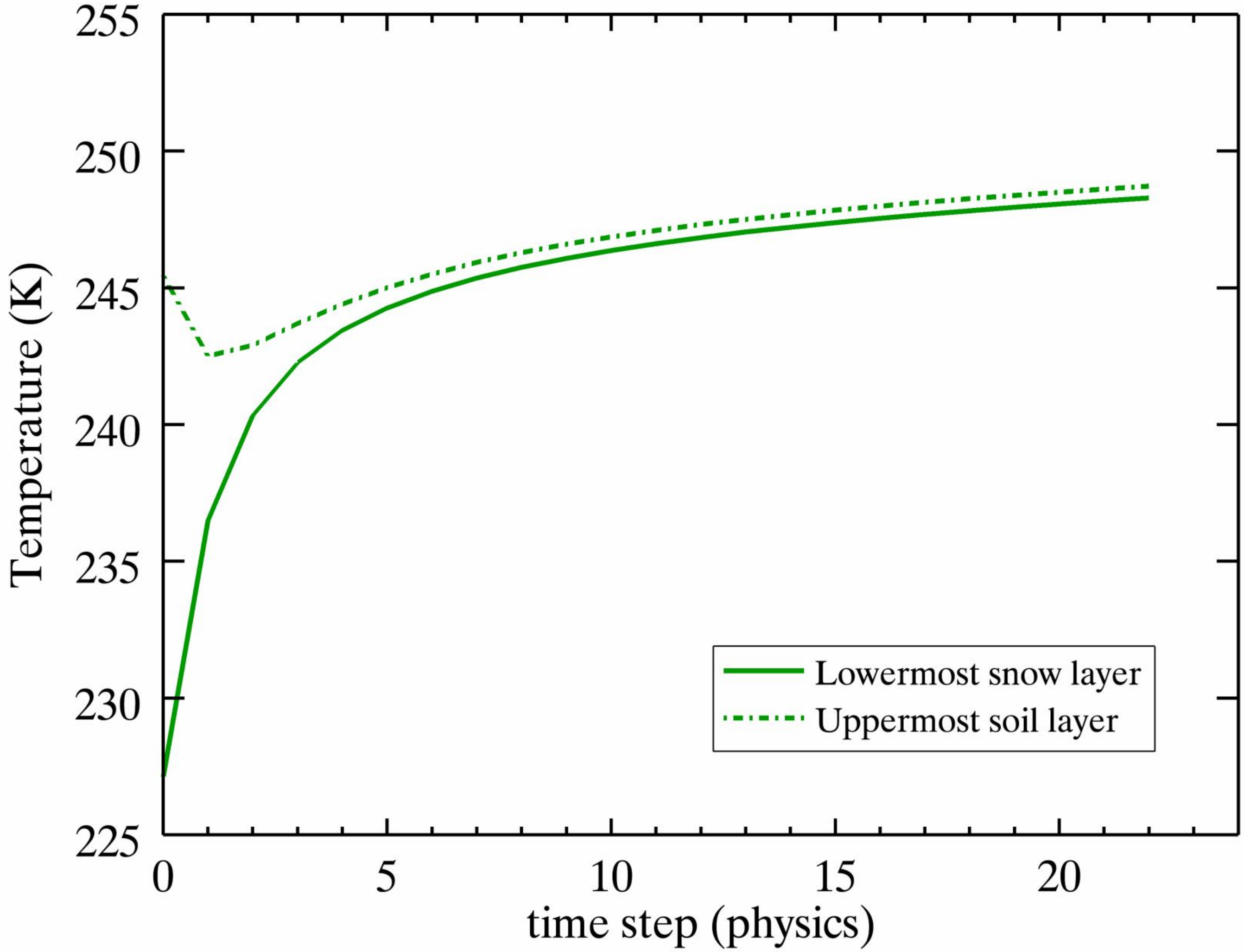
Solution of the heat conduction equation in soil and snow, *E. Machulskaya*



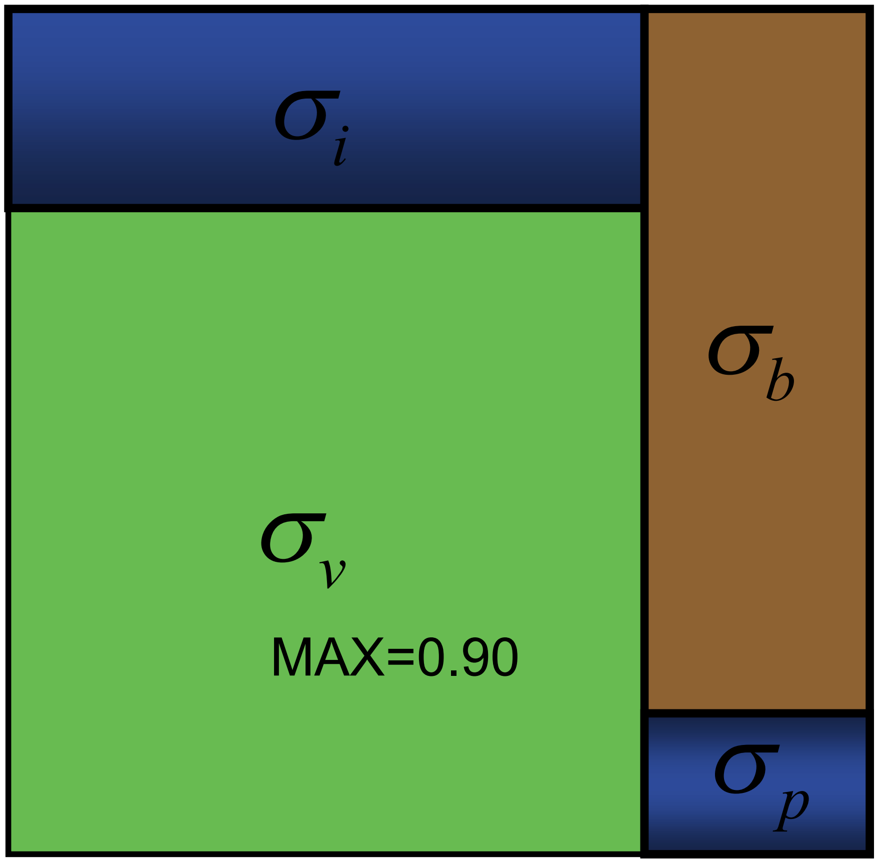
Solution of the heat conduction equation in soil and snow, *E. Machulskaya*



Solution of the heat conduction equation in soil and snow, *E. Machulskaya*



TERRA - Interception and surface water

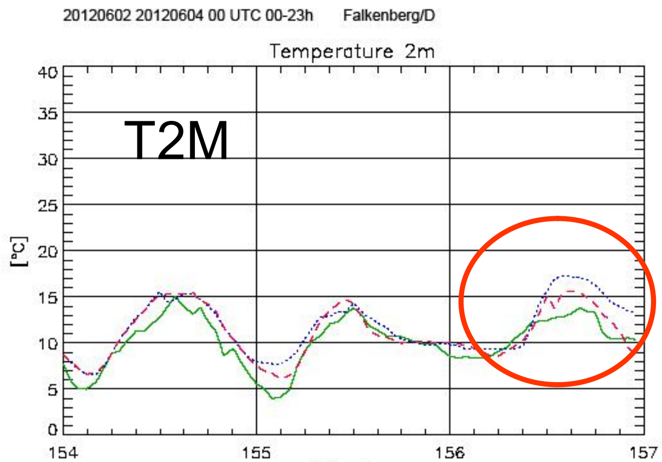


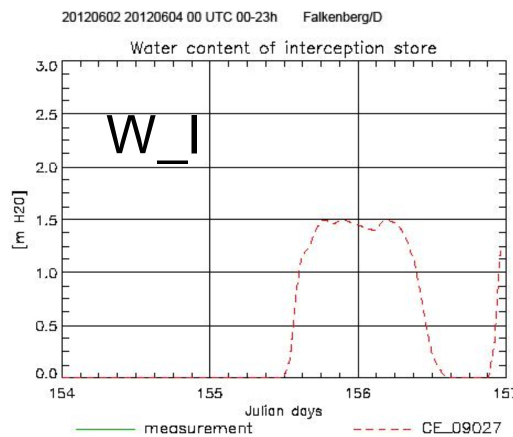
- Bucket approach for interception and surface water store

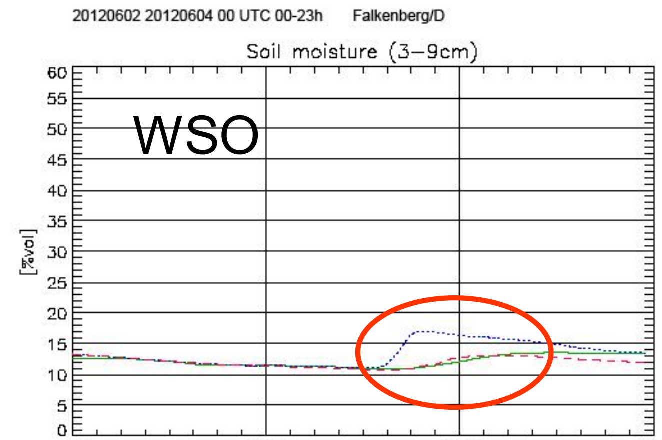
$$\frac{\Delta W_i}{\Delta t} = I + E_i - D$$

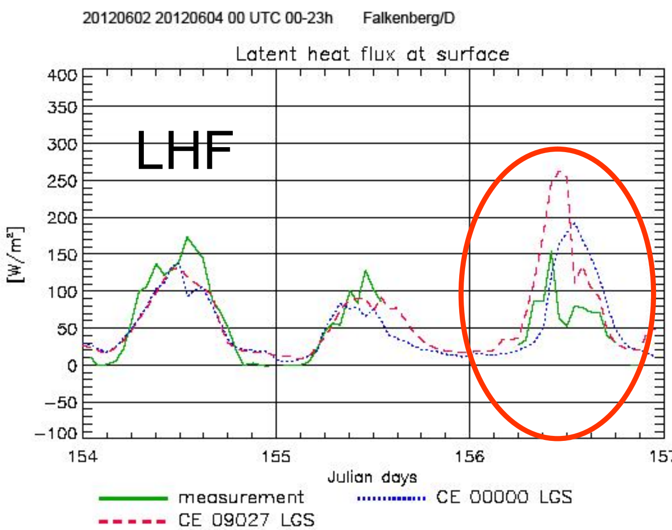
$$\frac{\Delta W_p}{\Delta t} = D + (1-\sigma_v)P_r - I_g + E_p$$

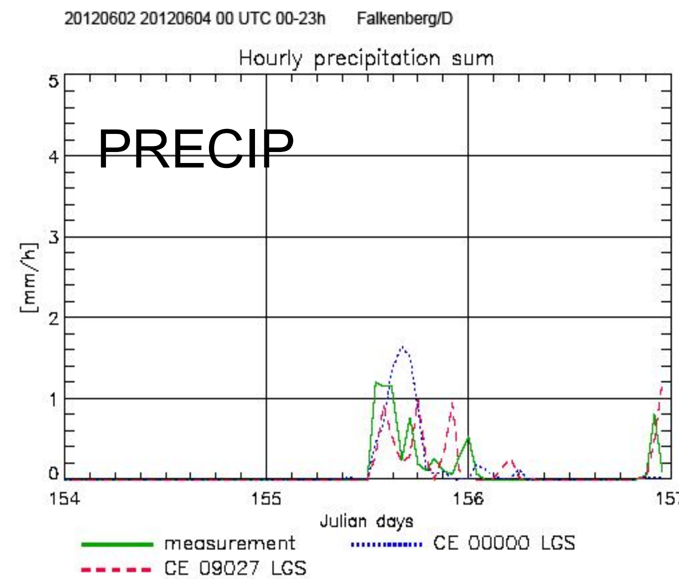
2 – 4 June 2012 COSMO
Falkenberg $W_{i,mx} = 0.0004 LAI \quad [\mathrm{m} \;\; H_2\mathrm{O}]$



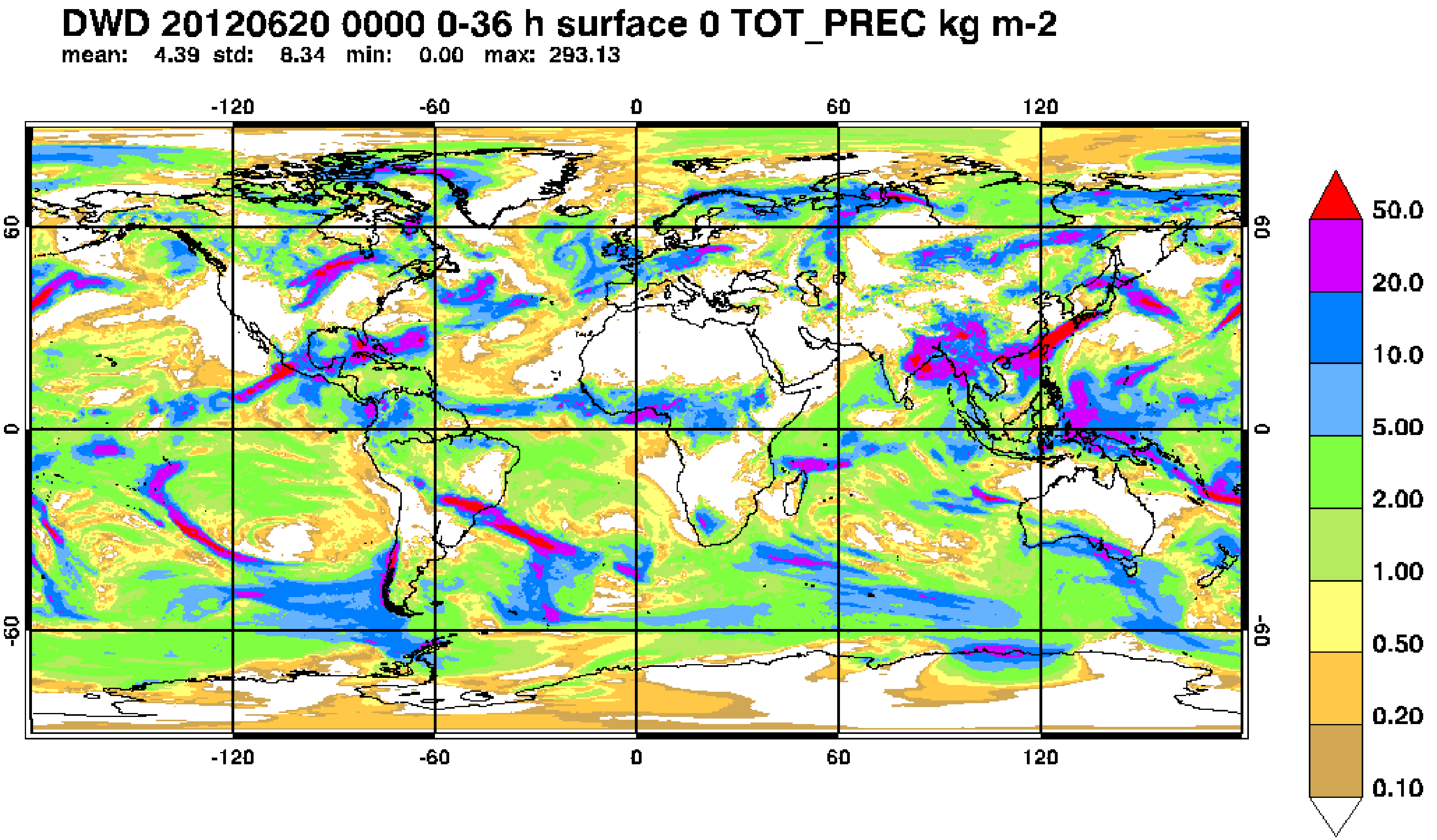




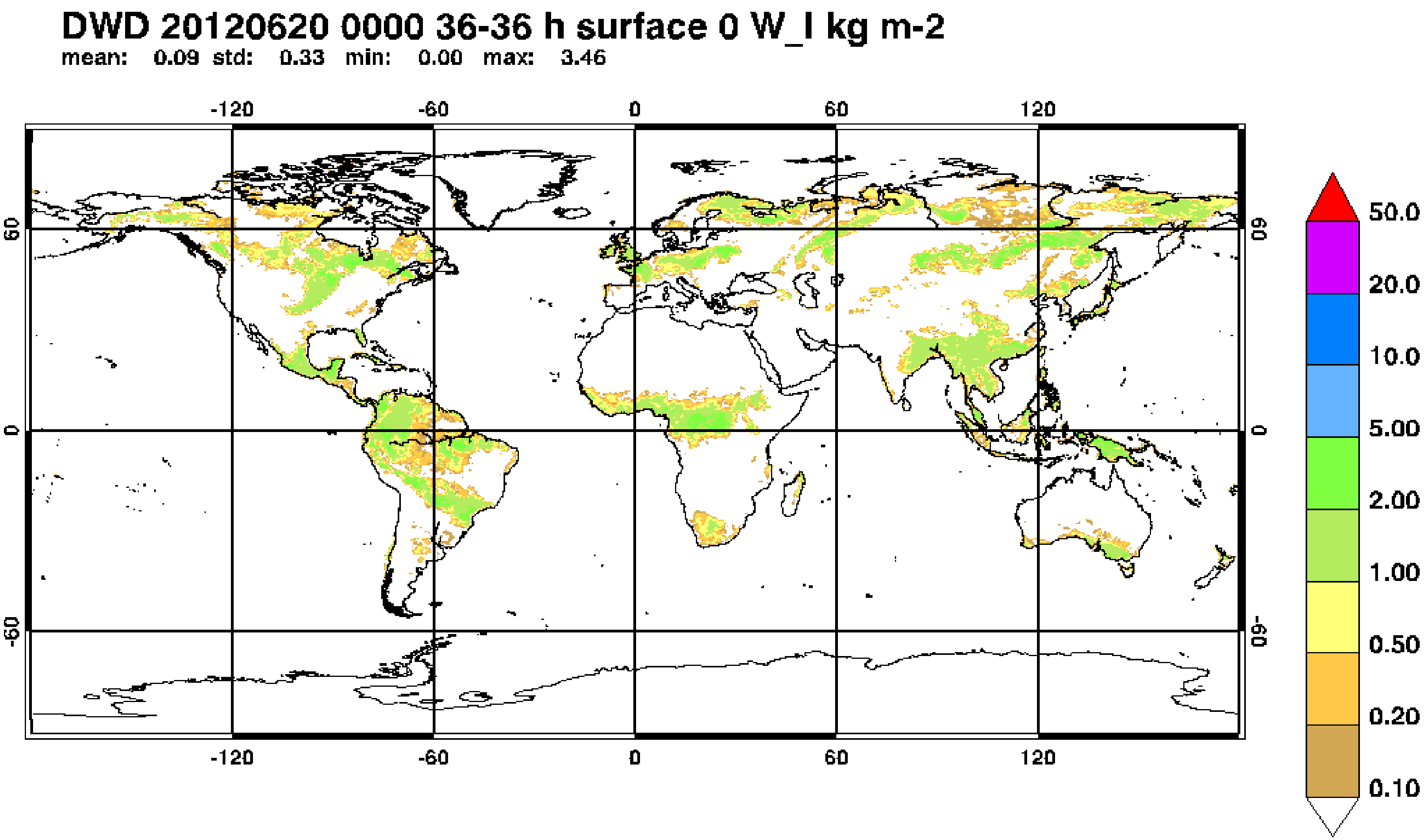




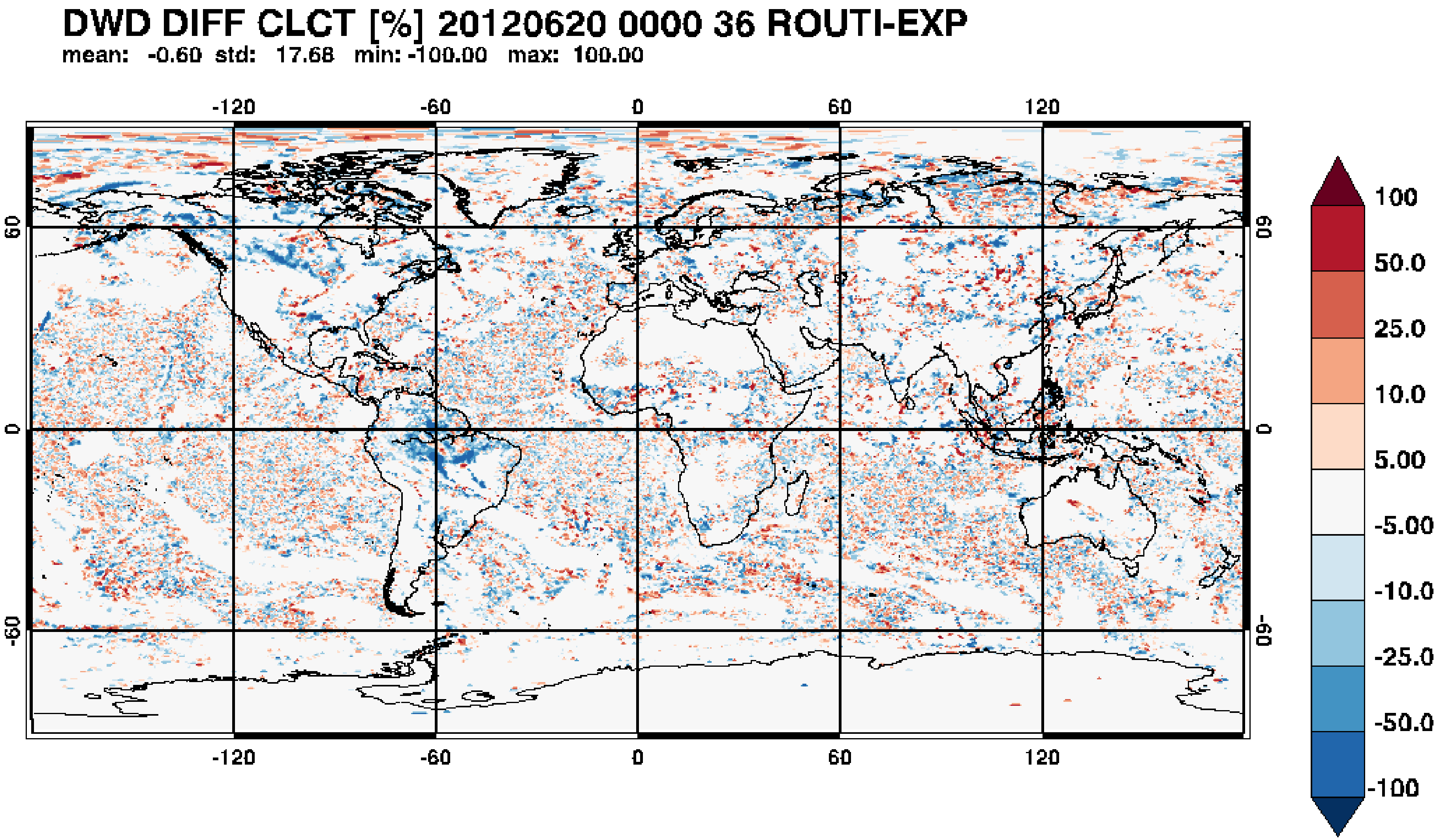
ICON EXP TOT_PRECIP



ICON EXP W_I


DWD 20120620 0000 36-36 h surface 0 W_I kg m-2
mean: 0.09 std: 0.33 min: 0.00 max: 3.46
-120
-60
0
60
120
50.0
20.0
10.0
5.00
2.00
1.00
0.50
0.20
0.10

ICON DIFF CLCT



TERRA - Conclusions

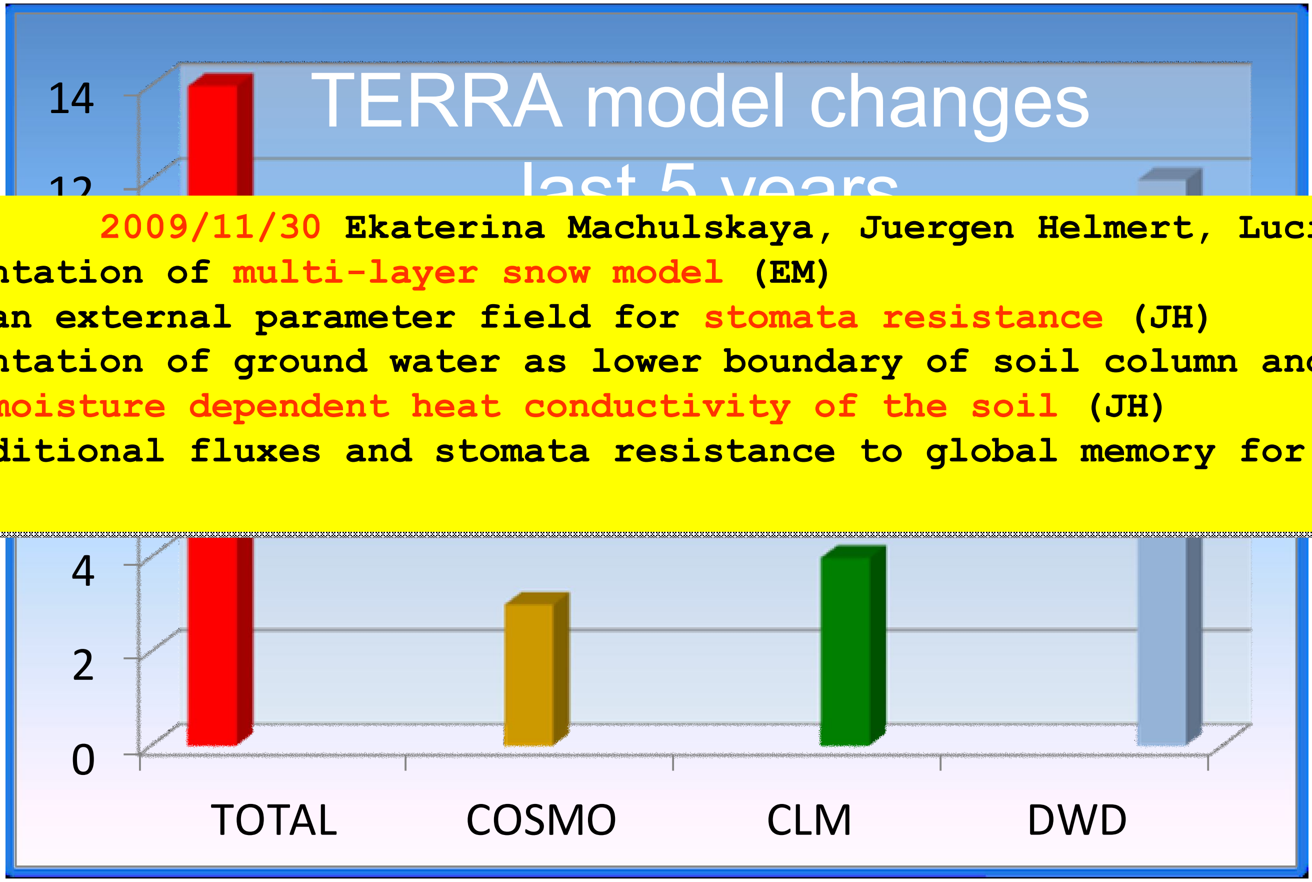
- Efficient and reliable SVAT model
- Continous improvement of ICON version within COSMO using shared physics library 2014
- Integrated in the NWP process
- „State of the art“ SVAT processes for NWP included (TILE, HWSD-SOIL, VEG-DYN, ML-SNOW)
- Active development of new features at NWP centers and research institutes with free of charge support from DWD
- Integration in COSMO and CLM community

TERRA - Outlook

- SVAT model intercomparison
- Collaboration with WG3a – Surface Atmosphere Transfer (resolved vegetation)
- Implementation of advanced soil properties data sets (e.g., Harmonized World Soil Database)
- Stochastic physics in TERRA
- Horizontal transports, implementation of soil water interflow, base flow, and ground table.

TERRA - Summary

State of the art, reliable, and efficient SVAT model, with a growing and vital user and development community




```
! V4_11        2009/11/30 Ekaterina Machulskaya, Juergen Helmert, Lucio Torrisi
!  Implementation of multi-layer snow model (EM)
!  Use of an external parameter field for stomata resistance (JH)
!  Implementation of ground water as lower boundary of soil column and
!    soil moisture dependent heat conductivity of the soil (JH)
!  Save additional fluxes and stomata resistance to global memory for output
(LT)
```

TERRA - Versions

! V4_4 2008/07/16 Ulrich Schaettler
! Splitting of a loop in Section I.4.3b (m_styp is not defined for sea points
! and must not occur together with llandmask in the same IF-clause)
! V4_7 2008/12/12 Ulrich Schaettler
! There were still some loops left with llandmask and m_styp in one line
! V4_9 2009/07/16 Ulrich Schaettler, Christian Bollmann
! Inserted Call to collapse loops
! V4_10 2009/09/11 Christian Bollmann
! Added compiler directive to use option _on_adb for NEC
! V4_11 2009/11/30 Ekaterina Machulskaya, Juergen Helmert, Lucio Torrisi
! Implementation of multi-layer snow model (EM)
! Use of an external parameter field for stomata resistance (JH)
! Implementation of ground water as lower boundary of soil column and
! soil moisture dependent heat conductivity of the soil (JH)
! Save additional fluxes and stomata resistance to global memory for output (LT)
! V4_12 2010/05/11 Ulrich Schaettler, Ekaterina Machulskaya
! Renamed t0 to t0_melt because of conflicting names
! Renamed prs_min to rsmin2d because of conflicting names
! Update of the new snow model (EM)
! V4_13 2010/05/11 Michael Gertz
! Adaptions to SVN
! V4_15 2010/11/19 Ulrich Schaettler (from H-J Panitz)
! Introduced snow_melt and ibot_w_so

! V4_18 2011/05/26 Ulrich Schaettler
! Run the initial steps also for ndfi=1, when nstart > 0!
! Changed the code owner
! V4_20 2011/08/31 Juergen Helmert
! Eliminated use of t_2m and use lowest atmospheric layer now (as is in GME)
! to remove dependency on diagnostic quantity t_2m
! V4_23 2012/05/10 Oliver Fuhrer, Burkhardt Rockel
! Removed obsolete Fortran features (OF)
! Correction for multi layer snow model in case of restart (BR)
! V4_25 2012/09/28 Anne Roches, Oliver Fuhrer, Ulrich Blahak
! Ekaterina Machulskaya
! Replaced qx-variables by using them from the tracer module
! Added hail rate (in case of two-moment microphysics) to the
! precipitation quantities at the ground where it seems necessary.
! Further developments in the multi-layer snow model (EM)
! V4_26 2012/12/06 Burkhardt Rockel, Ulrich Schaettler
! Initialize h_snow in case of restart
! Correct indices for gravity pre-setting (BR)
! Adapted variable names of multi-layer snow model to corresponding
! short names for I/O (US)
! V4_27 2013/03/19 Astrid Kerkweg, Ulrich Schaettler
! MESSy interface introduced

Impact of the SVAT model: IFS

ECMWF Newsletter No. 127 – Spring 2011

METEOROLOGY

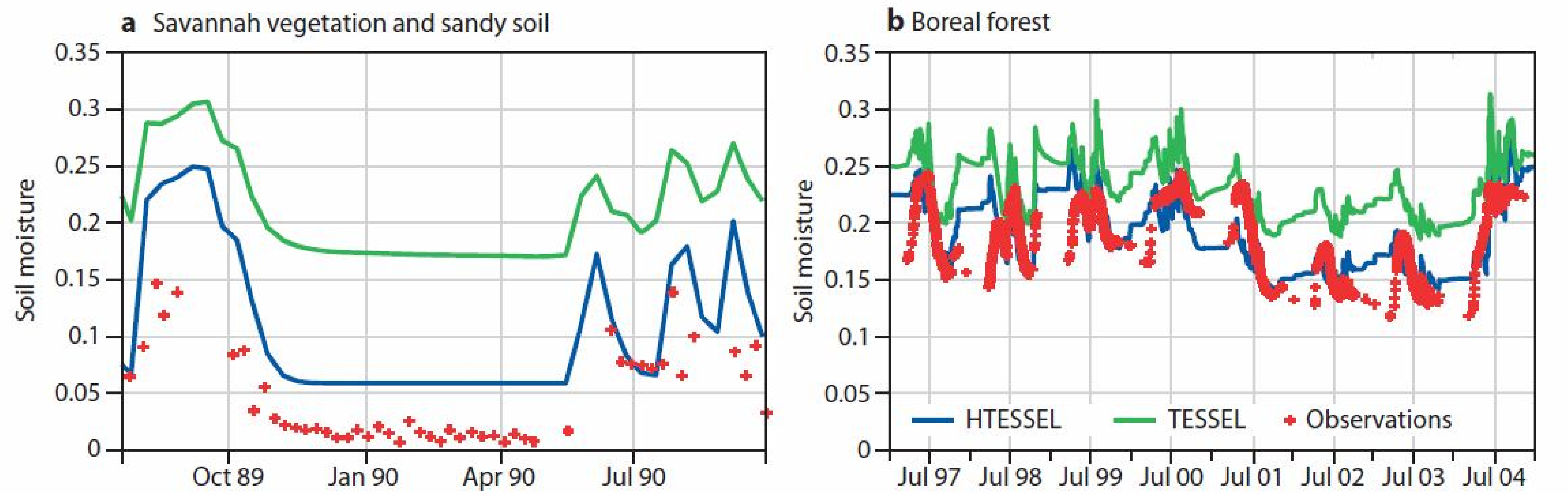


Figure 2 Evolution of soil moisture in TESSEL and HTESSEL in terms of volumetric content (m^3/m^3) compared to observations for two contrasting sites used for field experiments: (a) savannah vegetation and sandy soil (SEBEX, Sahel) and (b) boreal forest (BERMS, Canada).

GIANPAOLO BALSAMO, SOUHAIL BOUSSETTA,
EMANUEL DUTRA, ANTON BELJAARS,
PEDRO VITERBO, BART VAN DEN HURK

Impact of the SVAT model: IFS

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METEOROLOGY

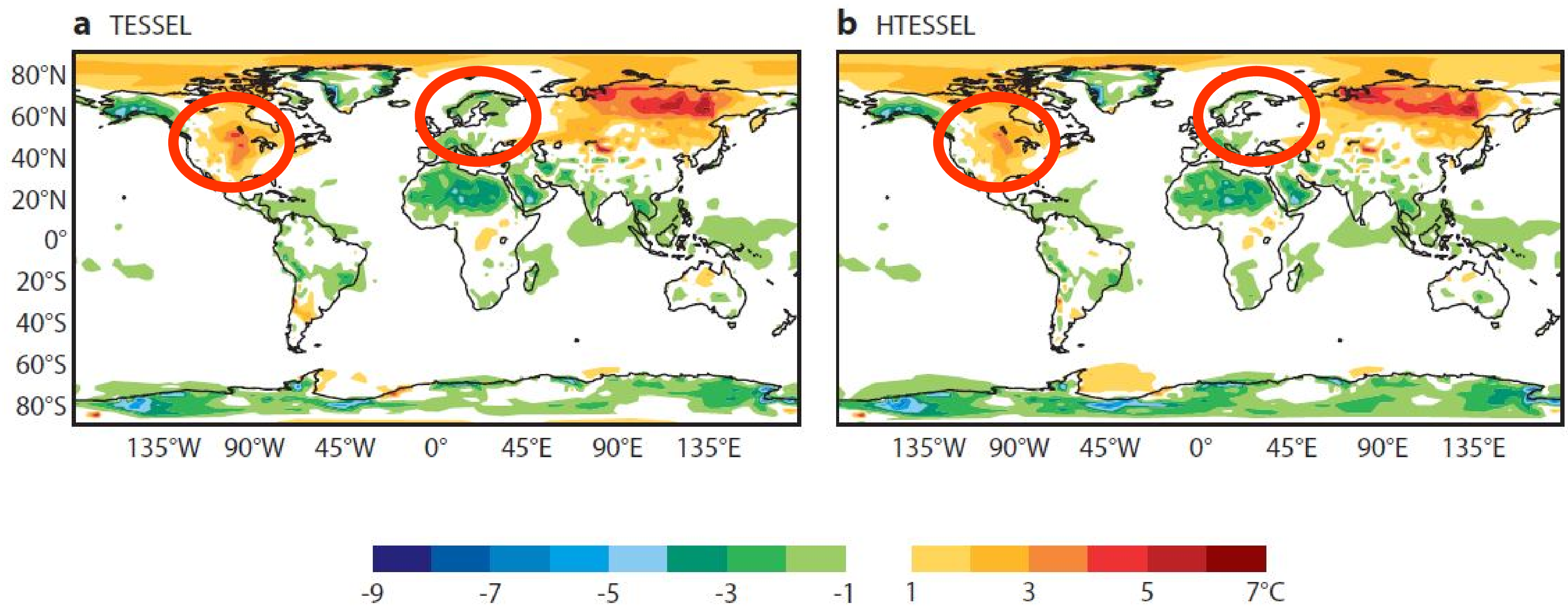

Figure 7 Mean annual 2-metre temperature errors in a long integration compared to ERA-Interim for (a) TESSEL (b) HTESSEL

1 yr, T159 ~125 km, daily specified SST

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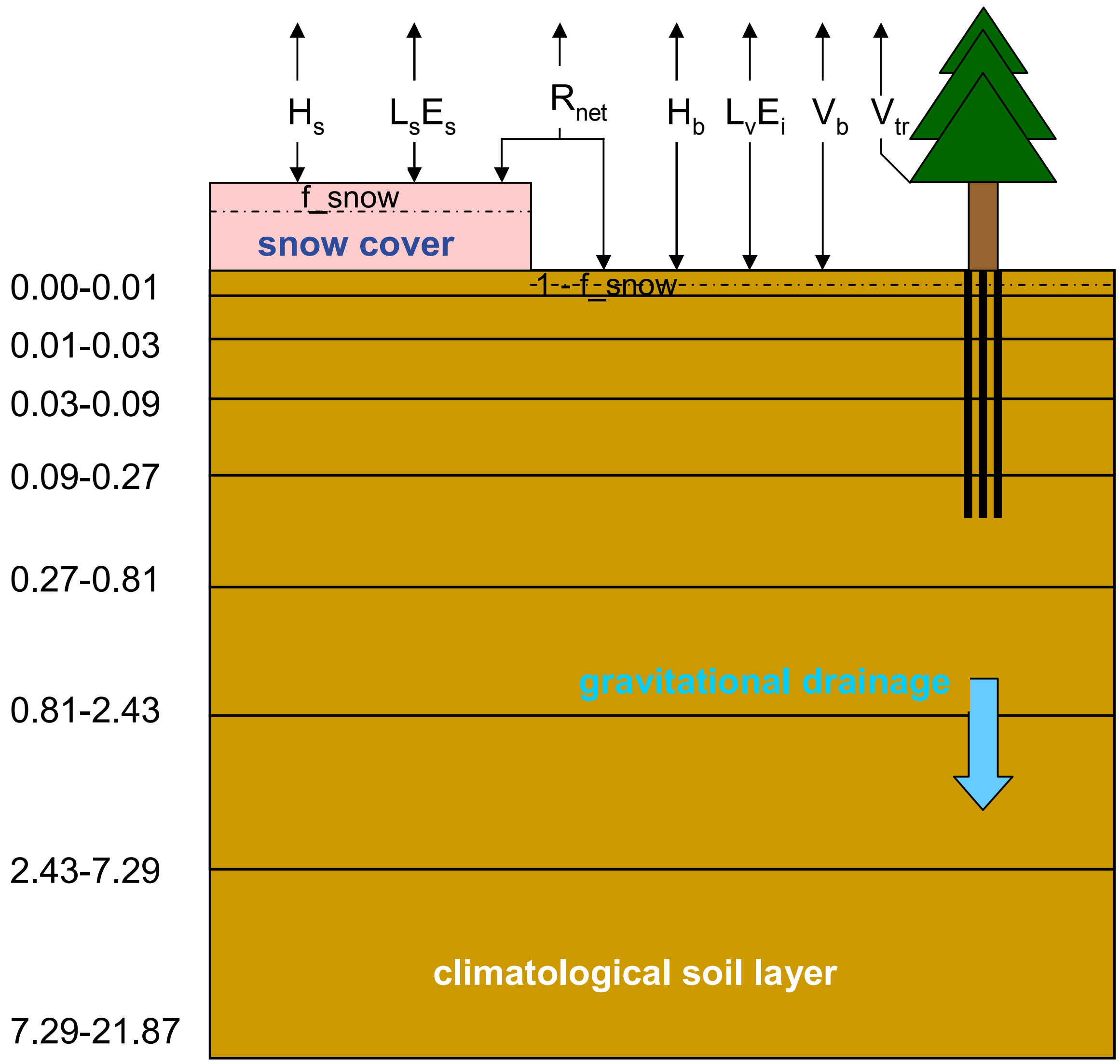
EMANUEL DUTRA, ANTON BELJAARS,
PEDRO VITERBO, BART VAN DEN HURK

Soil vegetation processes in TERRA



Soil water transport
Rijtema model in TERRA

$$\frac{\partial w_l}{\partial t} = \frac{1}{\rho_w}\frac{\partial F}{\partial z}$$

soil water change

$$F = -\rho_w \Big[- D_w(w_l)\frac{\partial w_l}{\partial z} + K_w(w_l) \Big]$$

soil water flux, Richards equation

$$D_w(w_l) = D_0 \;\; exp \;\; \Big[D_1(w_{PV} - \bar{w}_l)/(w_{PV} - w_{ADP}) \Big]$$

soil water diffusivity, Rijtema (1969)

$$K_w(w_l) = K_0 \;\; exp \;\; \Big[K_1(w_{PV} - \bar{w}_l)/(w_{PV} - w_{ADP}) \Big]$$

soil water conductivity, Rijtema (1969)

Soil water transport
van Genuchten **model**

$$\frac{\partial w_l}{\partial t} = \frac{1}{\rho_w}\frac{\partial F}{\partial z}$$

soil water change

$$F = -\rho_w\left[-D_w(w_l)\frac{\partial w_l}{\partial z} + K_w(w_l)\right]$$

soil water flux, Richards equation

$$D = \frac{(1-m)\cdot K_S}{\alpha\cdot m\cdot(\theta_S - \theta_r)}\cdot\theta^{\left(\frac{1}{2}-\frac{1}{m}\right)}\cdot\left[\left(1-\theta^{\frac{1}{m}}\right)^{-m} + \left(1-\theta^{\frac{1}{m}}\right)^{m} - 2\right]$$

$$\theta = \frac{\theta - \theta_r}{\theta_s - \theta_r}$$

$$\theta = \theta_r + \frac{\theta_s - \theta_r}{[1+(\alpha\cdot h)^n]^m}$$

$$K_r = \frac{\{1-(\alpha\cdot h)^{n-1}\cdot[1+(\alpha\cdot h)^n]^{-m}\}^2}{[1+(\alpha\cdot h)^n]^{\frac{m}{2}}}$$

$$\left(m = 1 - \frac{1}{n}\right)$$

$$K_r = \frac{K}{K_s}$$

Soil water transport
van Genuchten **model**

$$\frac{\partial w_l}{\partial t} = \frac{1}{\rho_w}\frac{\partial F}{\partial z}$$

soil water change

$$F = -\rho_w\left[-D_w(w_l)\frac{\partial w_l}{\partial z} + K_w(w_l)\right]$$

soil water flux, Richards equation

Determination of required soil parameters

$$\theta_r \quad \theta_s \quad \alpha \quad n \quad K_s$$

Soil properties – Option 1

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

J.H.M. Wösten et al. / Geoderma 90 (1999) 169–185

Table 4
Mualem-van Genuchten parameters for the fits on the geometric mean curves

	θ_r	θ_s	α	n	m	l	K_s
Topsoils							
Coarse	0.025	0.403	0.0383	1.3774	0.2740	1.2500	60.000
Medium	0.010	0.439	0.0314	1.1804	0.1528	−2.3421	12.061
Mediumfine	0.010	0.430	0.0083	1.2539	0.2025	−0.5884	2.272
Fine	0.010	0.520	0.0367	1.1012	0.0919	−1.9772	24.800
Very Fine	0.010	0.614	0.0265	1.1033	0.0936	2.5000	15.000
Subsoils							
Coarse	0.025	0.366	0.0430	1.5206	0.3424	1.2500	70.000
Medium	0.010	0.392	0.0249	1.1689	0.1445	−0.7437	10.755
Mediumfine	0.010	0.412	0.0082	1.2179	0.1789	0.5000	4.000
Fine	0.010	0.481	0.0198	1.0861	0.0793	−3.7124	8.500
Very Fine	0.010	0.538	0.0168	1.0730	0.0680	0.0001	8.235
Organic[a]	0.010	0.766	0.0130	1.2039	0.1694	0.4000	8.000

[a] Within the organic soils no distinction is made in topsoils and subsoils.

Hydraulic properties

Diffusivity m^2/s Conductivity m/s

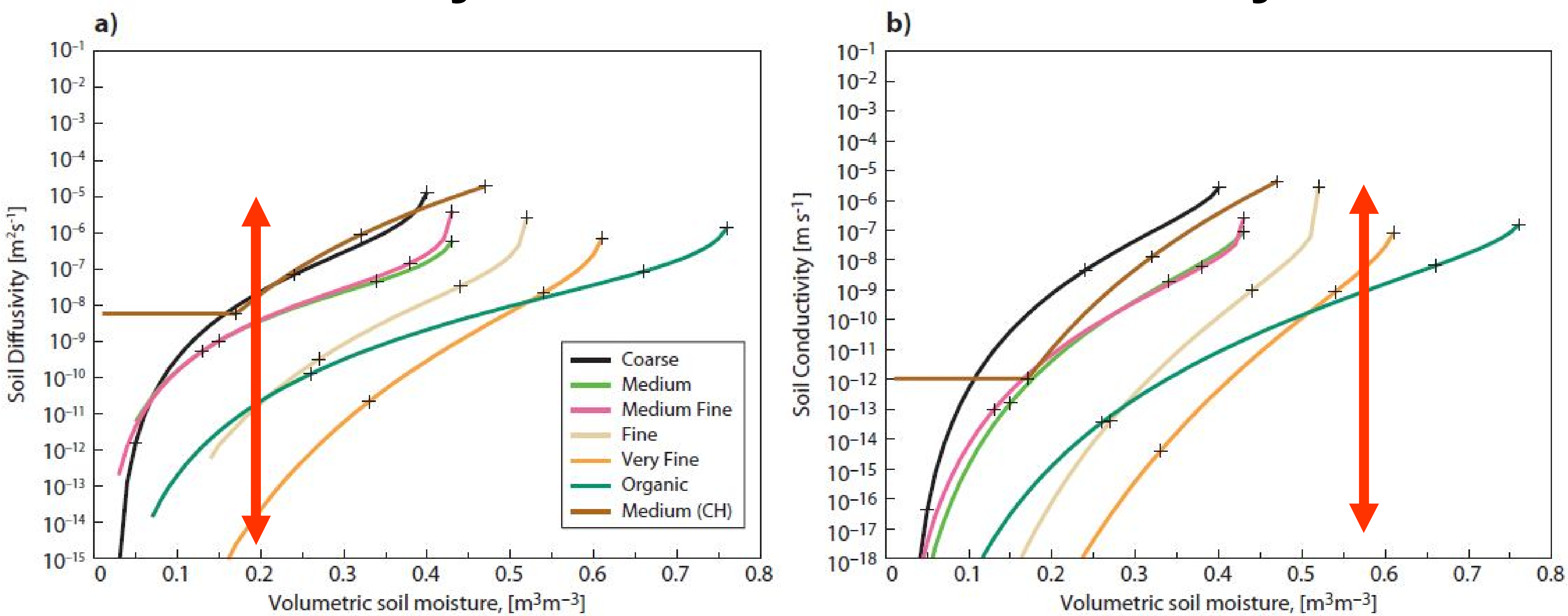


Figure 7.3 *Hydraulic properties of TESSEL and HTESSEL: (a) Diffusivity and (b) conductivity. The (+) symbols on the curves highlight (from high to low values) saturation, field capacity permanent wilting point.*

IFS documentation