WG3b activities at Deutscher Wetterdienst

TERRA development goals

- ➔ Multi-level snow model
- ➔ Subgrid heterogeneity – TILE approach
- ➔ Implementation of new EXTPAR data sets – MODIS, HWSD
- ➔ Revision of rainfall interception and surface water storage

More TERRA development goals

- Rough consideration of soil heat conductivity - Revision of soil heat condictivity approach
- Model difficulties to capture snow processes in forests - Improved snow-vegetation interaction
- Difficult to use the COSMO model below 1km resolution - Need of high-resolution orography data for COSMO-resolutions below 1 km.
- Initialisation of soil moisture -> Assimilation of soil moisture from remote sensing products
- Rough approximation of vegetation state
- Model extensions - Soil model forcing with atmospheric data - for model development purposes
- Sea-ice/Lake-ice with snow, urban model

Improvements in the multi-layer snow model

E. Machulskaya

Improvements in the multi-layer snow model

Problem: too low temperatures in the "multi-layer" model at nights

Solution: **switch to single-layer model** where ground heat flux is "almost implicit" (anyway, it makes no sense to resolve the vertical temperature profile in snowpack of 1 mm)
<u>In the official code since 4.27.</u>

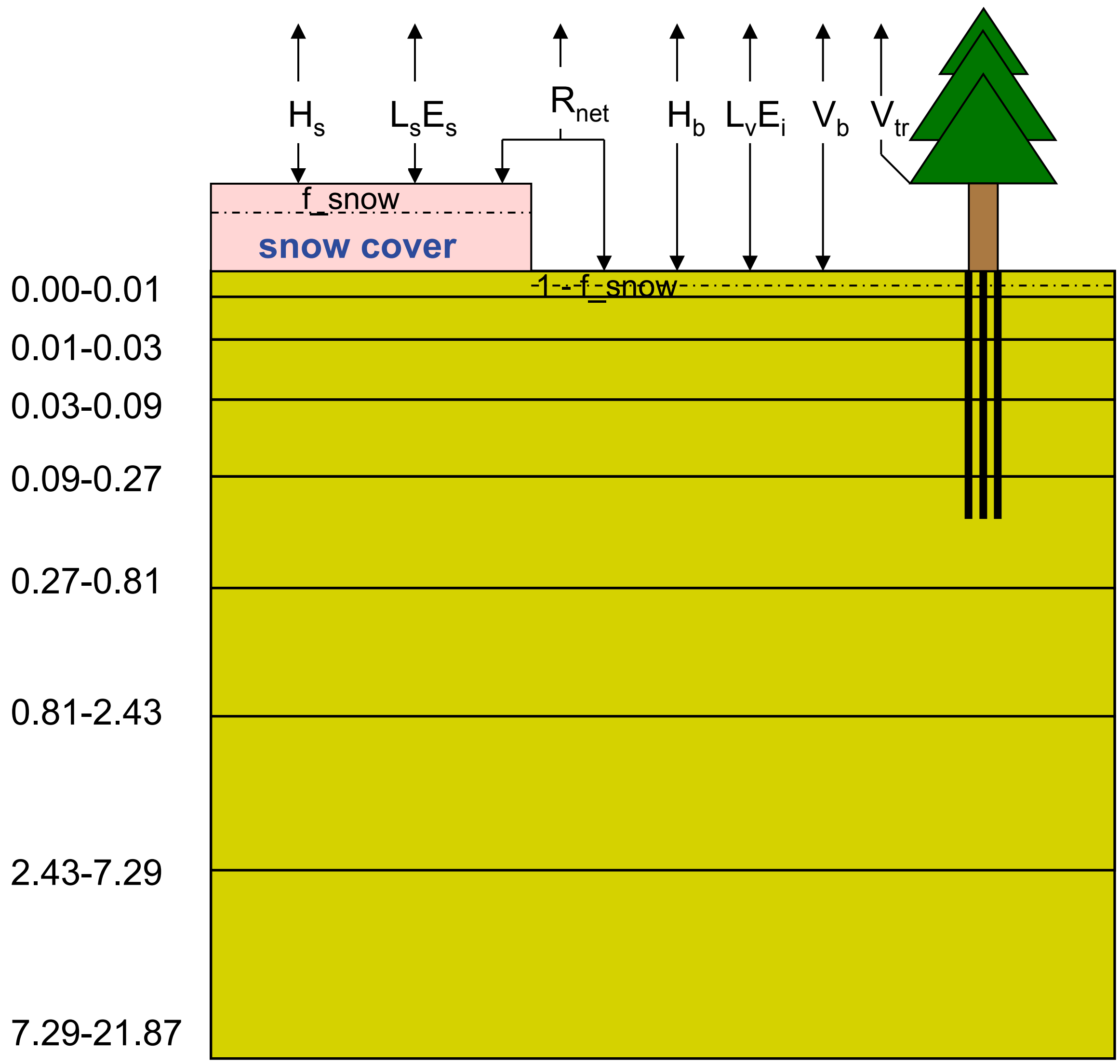
Bug fix: ground heat flux was lost if single-layer model is switched on (very thin snowpack) – minor bug

Bug fix: in the case of partial snow cover, latent heat flux due to rain freezing was added not only to the snow surface heat balance, but to the heat balance of soil surface (free of snow) too. However, if soil temperature is above freezing point, this flux is zero over snow-free soil (rain is not freezing) – in some situations can be important
<u>Not yet in the official code, will be soon.</u>

Coarse approximation of subgrid inhomogeneities
–
TILE approach

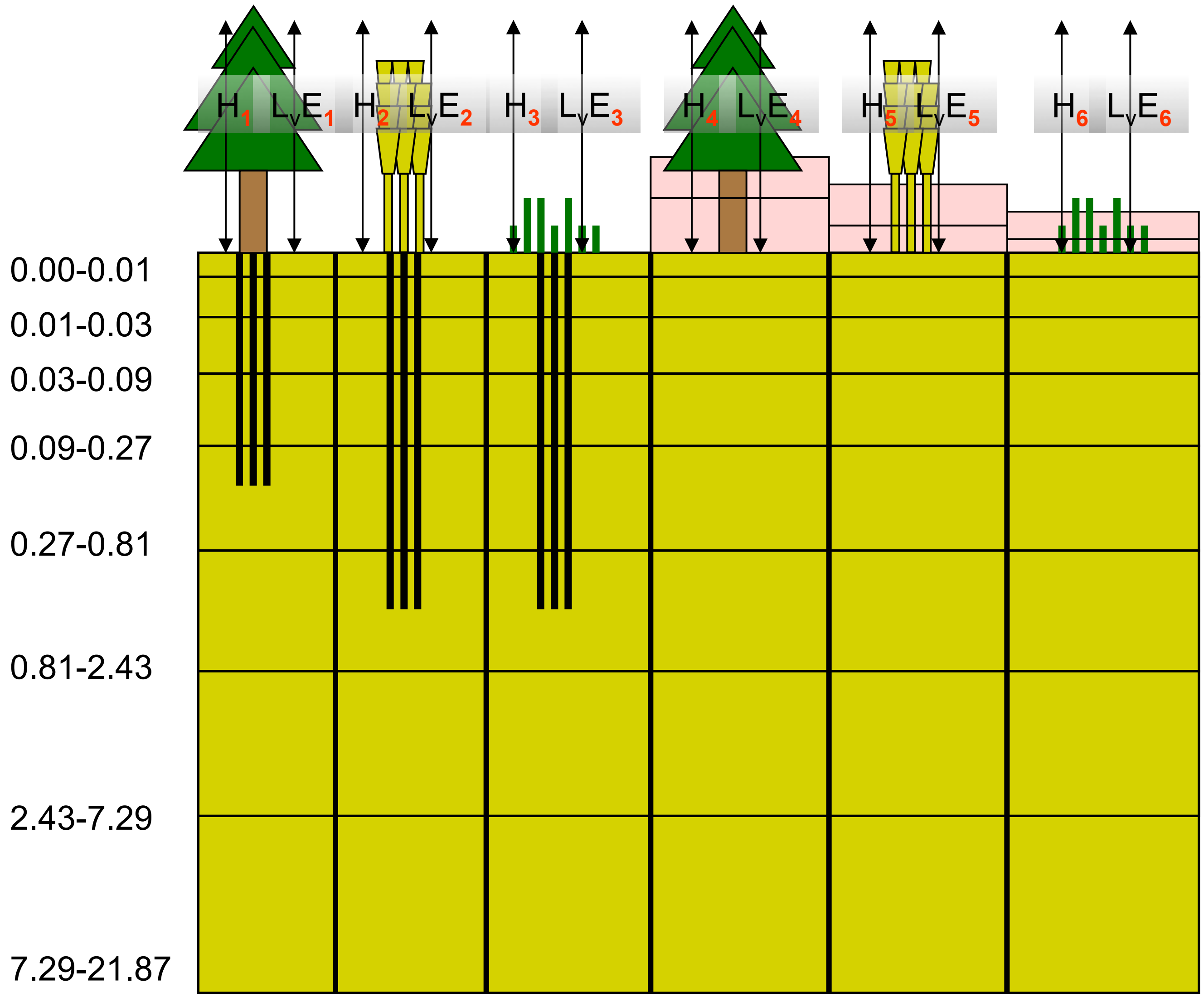
E. Machulskaya, J. Helmert, M. Köhler, D. Reinert, G. Zängl

TERRA no-Tiles



TERRA Tiles

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

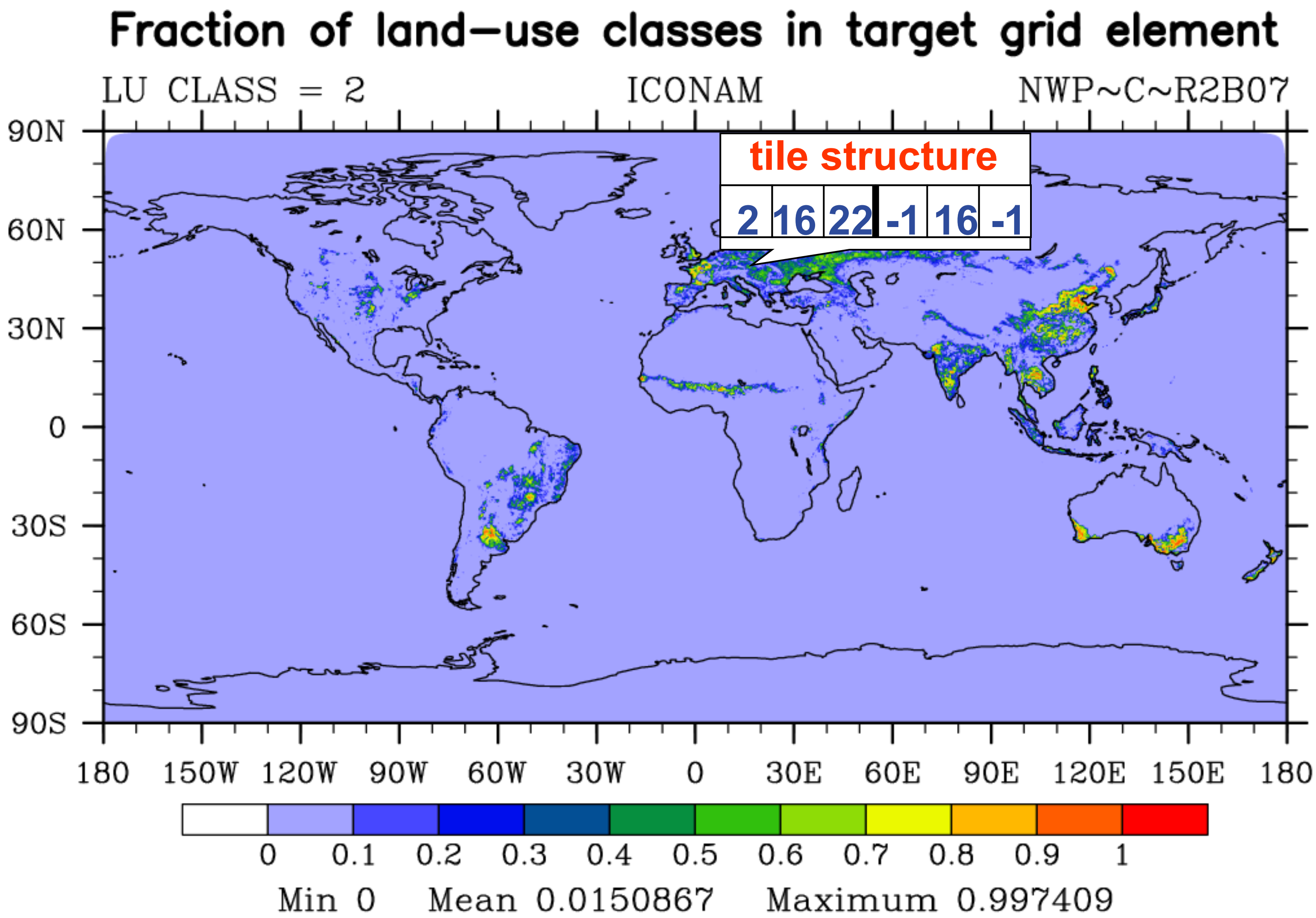


Land-use data for tile fractions

GlobCover 2009

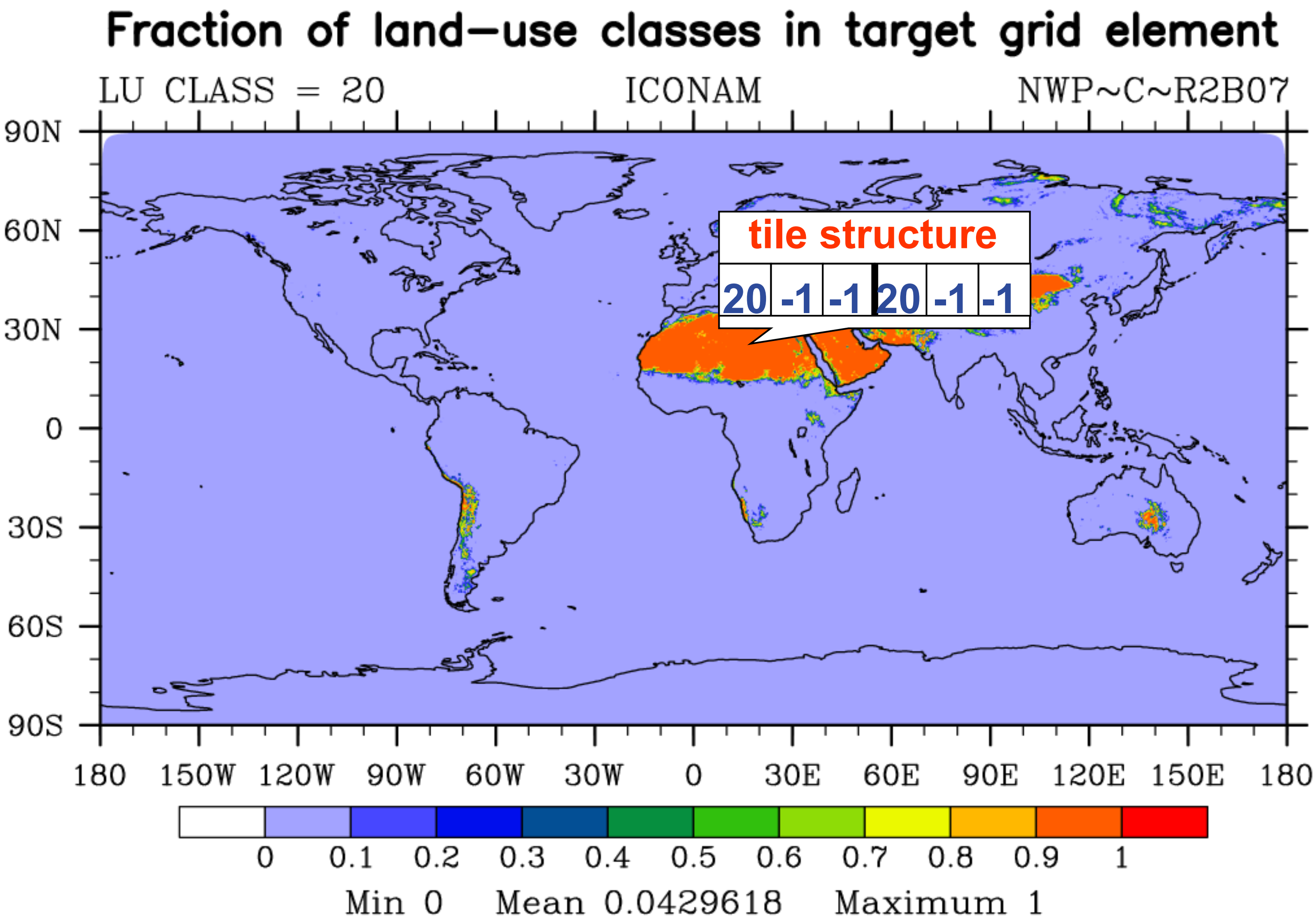
```
#          z0       pcmx   laimx   rd     rsmin     snowalb snowtile

1   /   0.07,   0.9,   3.3, 1.0, 120.0,   -1.0, 1., & ! irrigated croplands
2   &   0.07,   0.9,   3.3, 1.0, 120.0,   -1.0, 1., & ! rainfed croplands
3   &   0.25,   0.8,   3.0, 1.0, 120.0,   -1.0, 1., & ! mosaic cropland (50-70%) - vegetation (20-50%)
4   &   0.07,   0.9,   3.5, 1.0, 100.0,   -1.0, 1., & ! mosaic vegetation (50-70%) - cropland (20-50%)
5   &   1.00,   0.8,   5.0, 1.0, 250.0,   0.38,-1., & ! closed broadleaved evergreen forest
6   &   1.00,   0.9,   6.0, 1.0, 150.0,   0.31,-1., & ! closed broadleaved deciduous forest
7   &   0.15,   0.8,   4.0, 2.0, 150.0,   0.31,-1., & ! open broadleaved deciduous forest
8   &   1.00,   0.8,   5.0, 0.6, 150.0,   0.27,-1., & ! closed needleleaved evergreen forest
9   &   1.00,   0.9,   5.0, 0.6, 150.0,   0.33,-1., & ! open needleleaved deciduous forest
10  &   1.00,   0.9,   5.0, 0.8, 150.0,   0.29,-1., & ! mixed broadleaved and needleleaved forest
11  &   0.20,   0.8,   2.5, 1.0, 150.0,   -1.0, 1., & ! mosaic shrubland (50-70%) - grassland (20-50%)
12  &   0.20,   0.8,   2.5, 1.0, 150.0,   -1.0, 1., & ! mosaic grassland (50-70%) - shrubland (20-50%)
13  &   0.15,   0.8,   2.5, 1.5, 120.0,   -1.0, 1., & ! closed to open shrubland
14  &   0.03,   0.9,   3.1, 0.6,  40.0,   -1.0, 1., & ! closed to open herbaceous vegetation
15  &   0.05,   0.5,   0.6, 0.3,  40.0,   -1.0, 1., & ! sparse vegetation
16  &   1.00,   0.8,   5.0, 1.0, 150.0,   -1.0,-1., & ! closed to open forest regulary flooded
17  &   1.00,   0.8,   5.0, 1.0, 150.0,   -1.0,-1., & ! closed forest or shrubland permanently flooded
18  &   0.05,   0.8,   2.0, 1.0,  40.0,   -1.0,-1., & ! closed to open grassland regularly flooded
19  &   1.00,   0.2,   1.6, 0.6, 120.0,   -1.0,-1., & ! artificial surfaces
20  &   0.05,   0.05,  0.6, 0.3, 120.0,   -1.0, 1., & ! bare areas
21  &   0.0002, 0.0,   0.0, 0.0, 120.0,   -1.0,-1., & ! water bodies
22  &   0.01,   0.0,   0.0, 0.0, 120.0,   -1.0,-1., & ! permanent snow and ice
23  &   0.00,   0.0,   0.0, 0.0, 250.0,   -1.0,-1.  / !undefined
```

rainfed croplands



bare areas

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



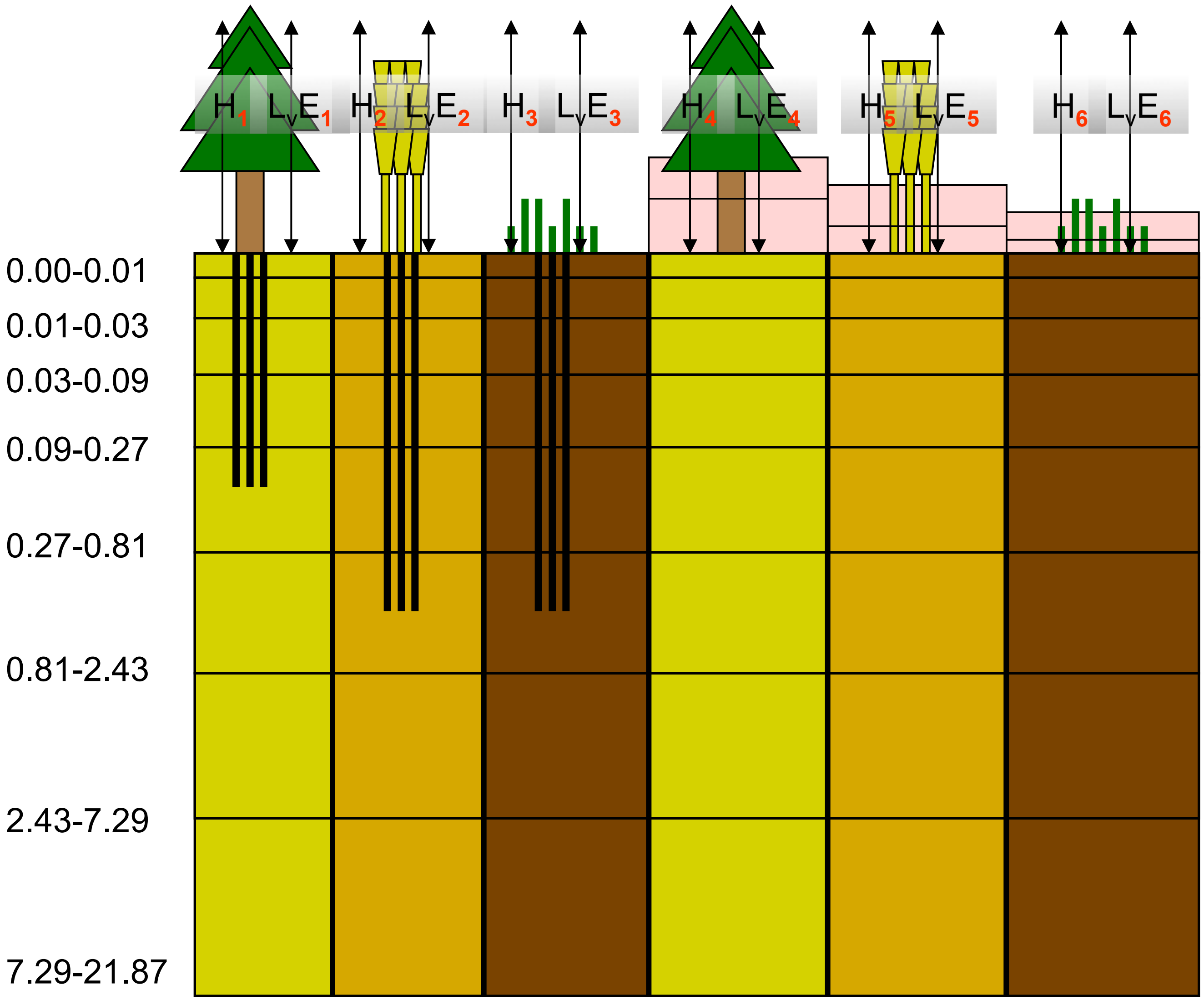
Statistics – Example R2B6N7

```
Index list generation - number of tiles:     3
Number of land points in domain  1:      95219
Number of sea points in domain  1:     231996
Number of lake points in domain  1:        465
Number of points in tile 1:     95219
Number of points in tile 2:     65854
Number of points in tile 3:     51090

Number of land points in domain  2:      46060
Number of sea points in domain  2:      32929
Number of lake points in domain  2:        183
Number of points in tile 1:     46060
Number of points in tile 2:     31125
Number of points in tile 3:     26519
```

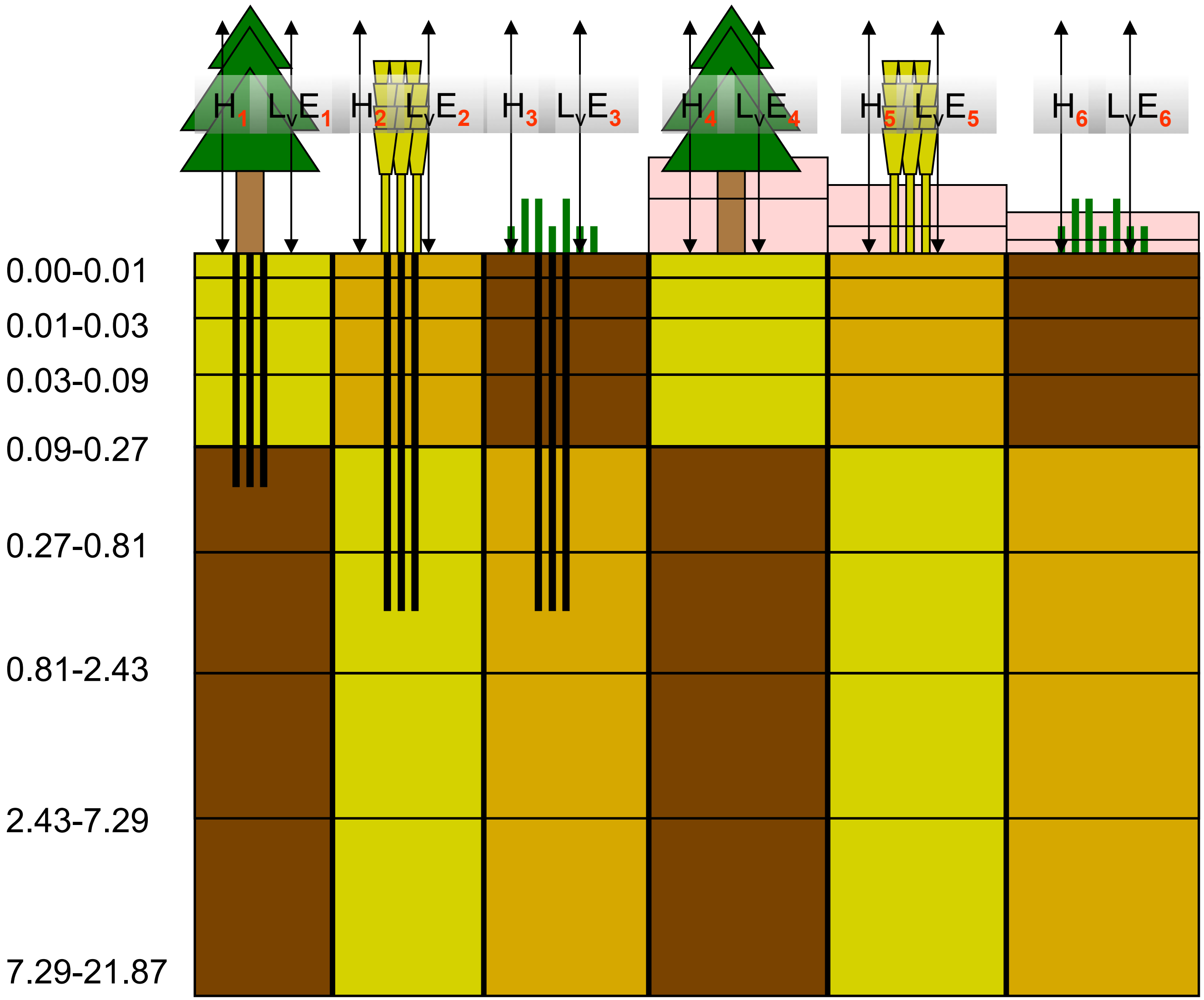
Advanced ICON version of TERRA-TILES

- Efficient usage of dominant land-use fractions
- Extensive usage of index lists
- Avoid computation of non-existent land-use classes
- Allows treatment of snow in own tiles
- Treatment of different soil profiles feasible

TERRA Tiles


H1 LvE1
H2 LvE2
H3 LvE3
H4 LvE4
H5 LvE5
H6 LvE6
0.00-0.01
0.01-0.03
0.03-0.09
0.09-0.27
0.27-0.81
0.81-2.43
2.43-7.29
7.29-21.87

TERRA Tiles

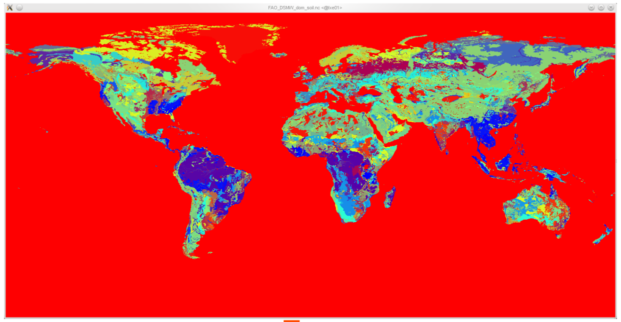

H_1 L_vE_1
H_2 L_vE_2
H_3 L_vE_3
H_4 L_vE_4
H_5 L_vE_5
H_6 L_vE_6
0.00-0.01
0.01-0.03
0.03-0.09
0.09-0.27
0.27-0.81
0.81-2.43
2.43-7.29
7.29-21.87

Advanced soil data sets
–
HWSD data

J. Helmert, E.-M. Gerstner, G. Smiatek

Retrieval of TERRA soil properties Option I

Soil data set



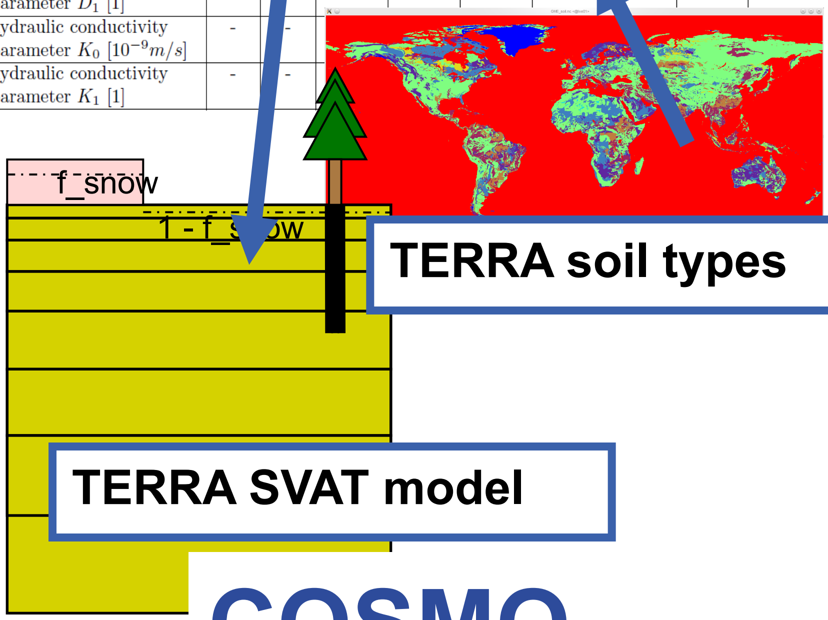
Soil textures

TERRA soil types

EXTPAR

soil type	1 ice	2 rock	3 sand	4 sandy loam	5 loam	6 loamy clay	7 clay	8 peat
volume of voids w_{PV} [1]	-	-	0.364	0.445	0.455	0.475	0.507	0 .863
field capacity w_{FC} [1]								
permanent wilting point w_{PWP} [1]								
air dryness point w_{ADP} [1]								
hydraulic diffusivity parameter D_0 $[10^{-9} m^2/s]$	-	-	18400	3460	3570	1180	442	106
hydraulic diffusivity parameter D_1 [1]	-	-	-8.45	-9.47	-7.44	-7.76	-6.74	-5.97
hydraulic conductivity parameter K_0 $[10^{-9} m/s]$	-	-						
hydraulic conductivity parameter K_1 [1]	-	-						

TERRA look-up table physical properties



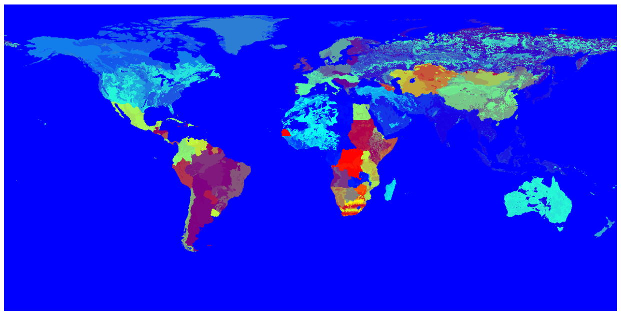
TERRA soil types

TERRA SVAT model

COSMO

Retrieval of TERRA soil properties Option II

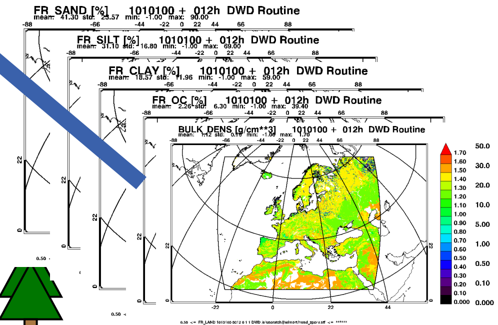
Soil data set

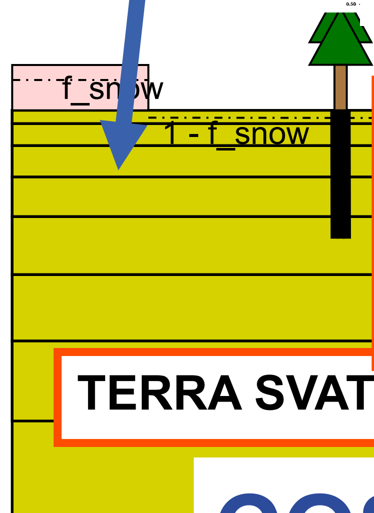


Fractions of sand, silt, clay, organic matter; soil bulk density

EXTPAR

Pedotransfer functions physical properties





Fractions of sand, silt, clay, organic matter; soil bulk density

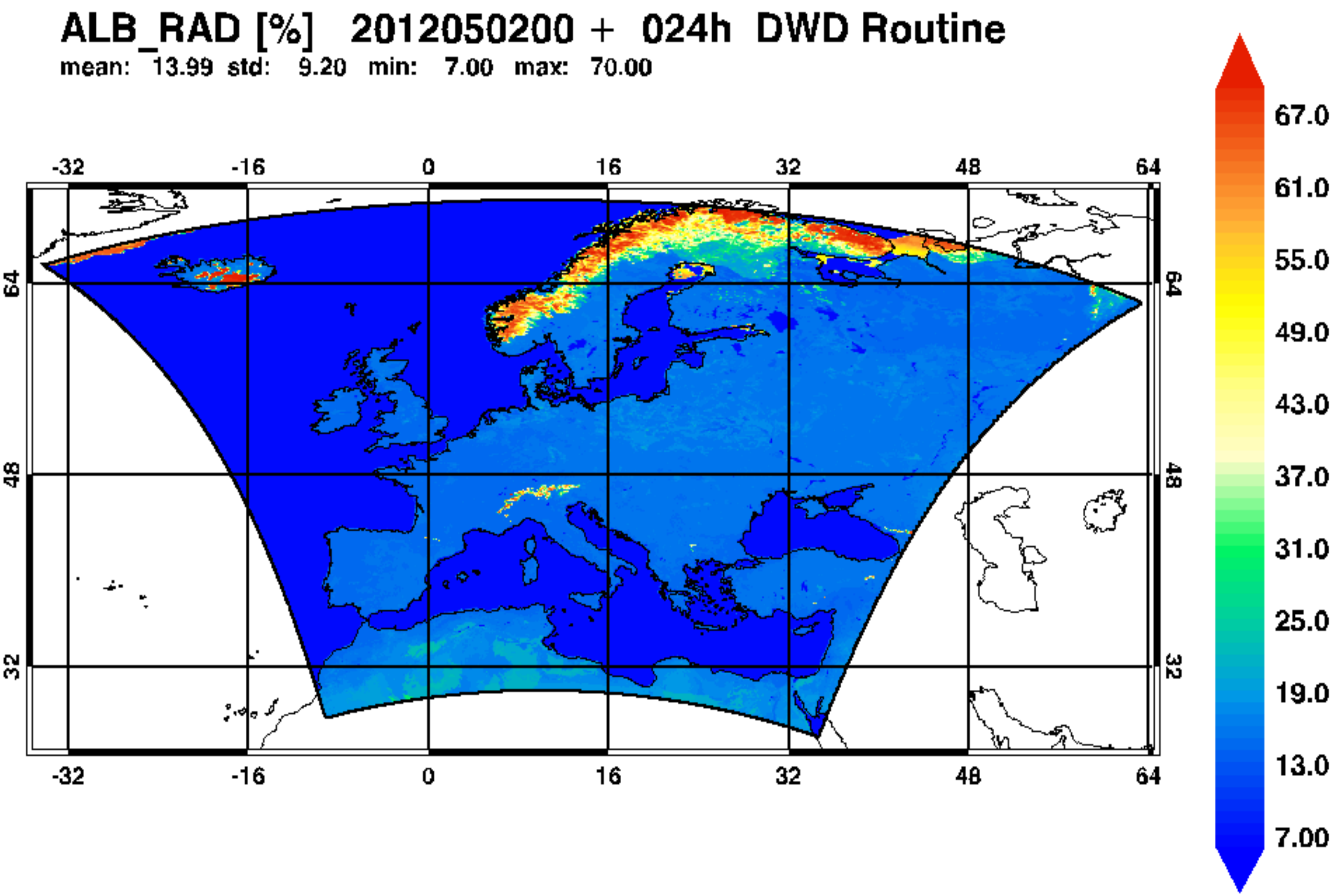
TERRA SVAT model

COSMO

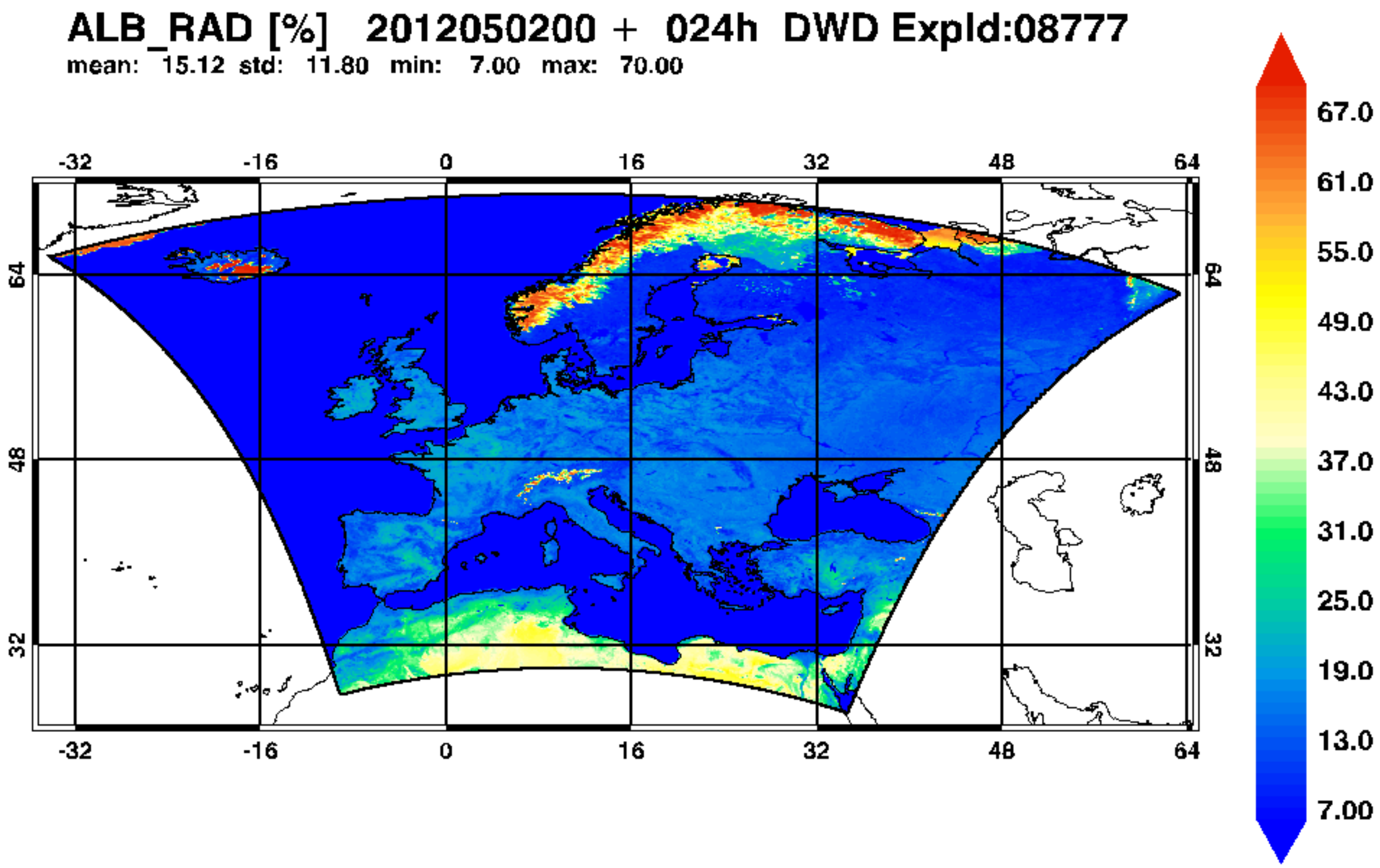
Advanced albedo data sets
–
MODIS data

F. Brenner

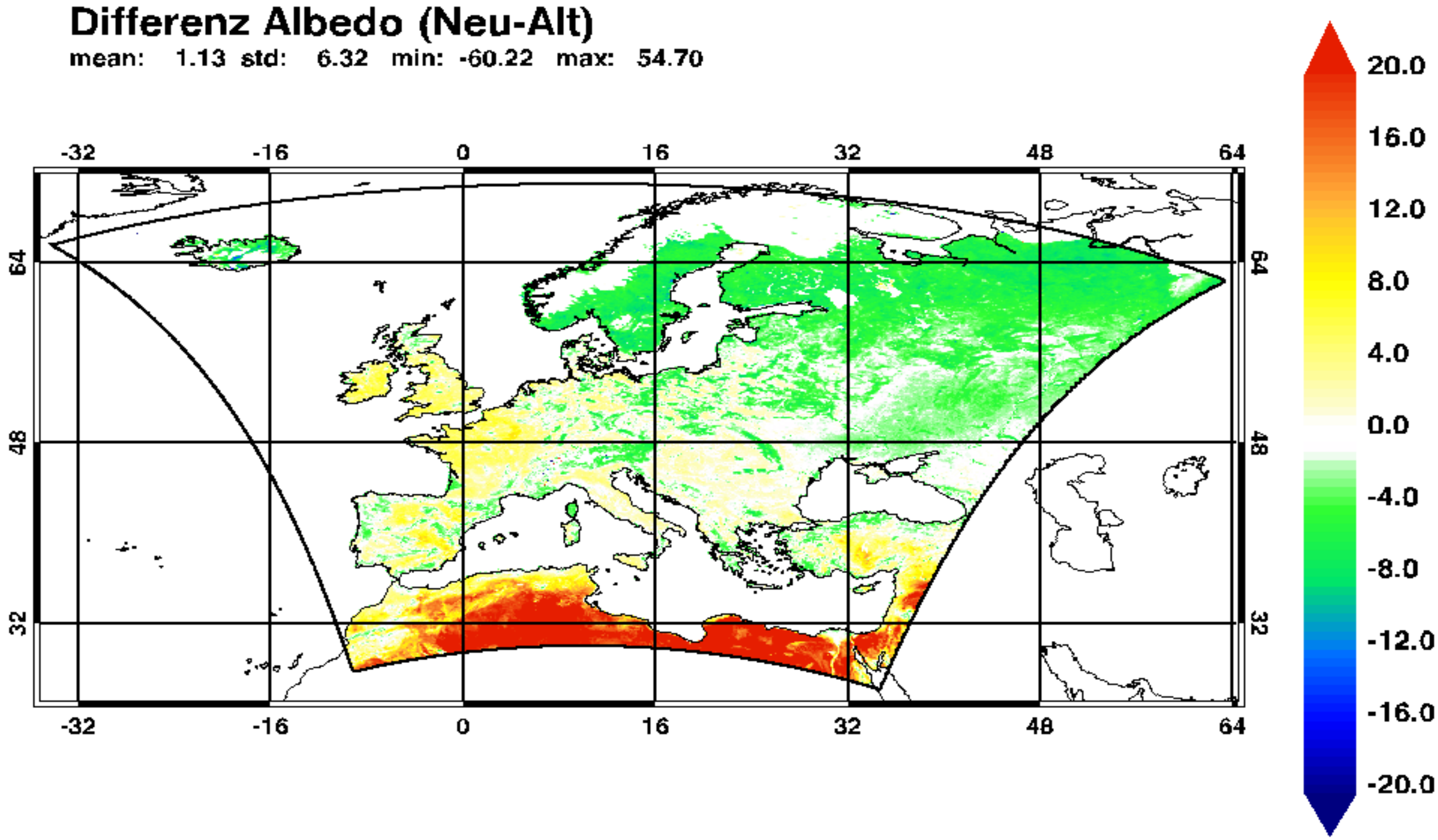
Soiltype based albedo



MODIS albedo



COSMO-EU experiment



COSMO-EU experiment – model skill

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experiment month in 2012			8777_04	8777_05	8777_06	8777_07	8777_08
RMSE (all elements)	00 UTC	Deutschland	-0,84	-0,73	-0,81	-0,32	-0,36
Global Skill	00 UTC	Westeuropa	0,14	-0,13	0,24	-2,11	-0,89
	00 UTC	LM2MO	0,18	-0,11	-0,01	0,35	0,39
	12 UTC	Deutschland	-0,81	-0,48	-0,4	-1,45	-1,19
	12 UTC	Westeuropa	-0,34	-0,16	0,34		-0,92
	12 UTC	LM2MO	-0,09	0,15	0,15	-0,25	-0,23
RMSE (all elements)	00 UTC	Deutschland	-1,58	0,19	-1,43	-2,22	-0,67
temperature (2m)	00 UTC	Westeuropa	-0,59	0,56	0,5	0,88	-2,38
	00 UTC	LM2MO	-0,66	-0,33	-0,55	-0,85	-1,14
	12 UTC	Deutschland	-0,96	0,43	-1,15	-1,85	-2,09
	12 UTC	Westeuropa	-0,04	-0,11	0,43	0,77	-0,43
	12 UTC	LM2MO	-0,63	-0,3	-0,88	-1,12	-1,74

Rainfall interception and surface water storage

J. Helmert and Gerd Vogel

Motivation

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

- Precipitation interception and surface water storage are significant components of the surface water balance

- Processes at the beginning of the sequence of land surface hydrological processes

- Interception loss due to evaporation of intercepted water accounts for 10-48% of the gross precipitation (Hörmann et al., 1996)

- Substantially impact the partitioning of precipitation between infiltration, evapotranspiration, and runoff

Present situation in TERRA

- Neglection of the water interception in GME (and COSMO)

$W_{i,mx} =$ 1.E-6m

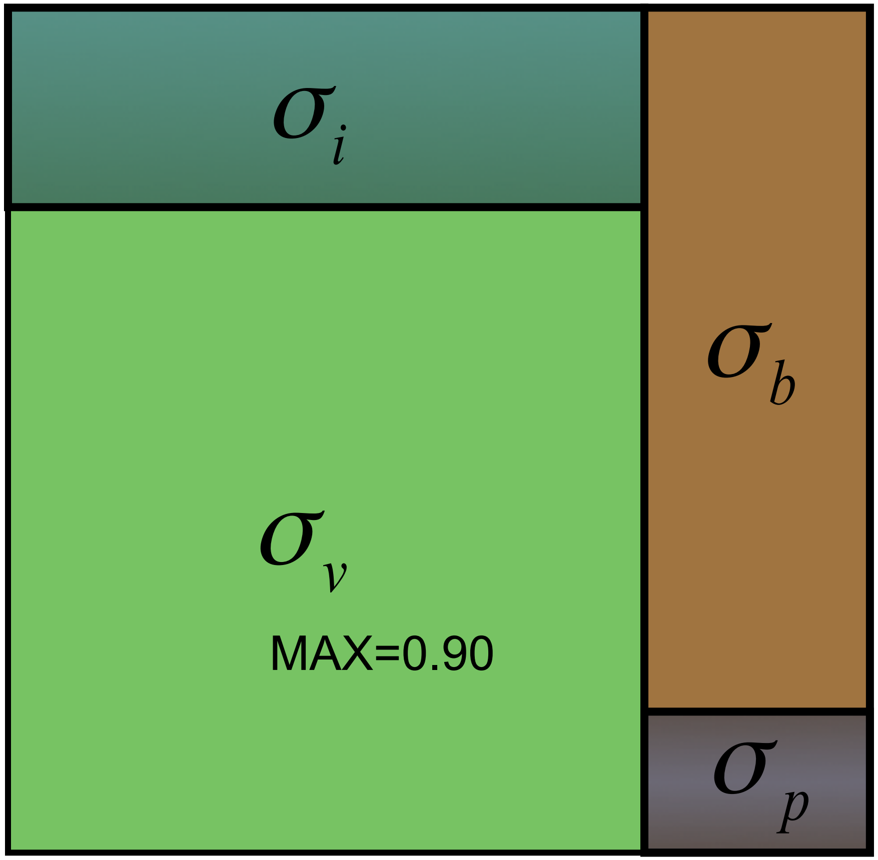
- Interception treated as a fixed sequence of evaporation, percolation, runoff rather than a balance equation

- Separation of precipitation questionable

- Alternative solution: Balance equation - Deardorff, 1978 (e.g.,SURFEX)

$$\frac{\partial W_r}{\partial t} = vegP - (E_v - E_{tr}) - R_r; \quad 0 \le W_r \le W_{r,\max}$$

Conception



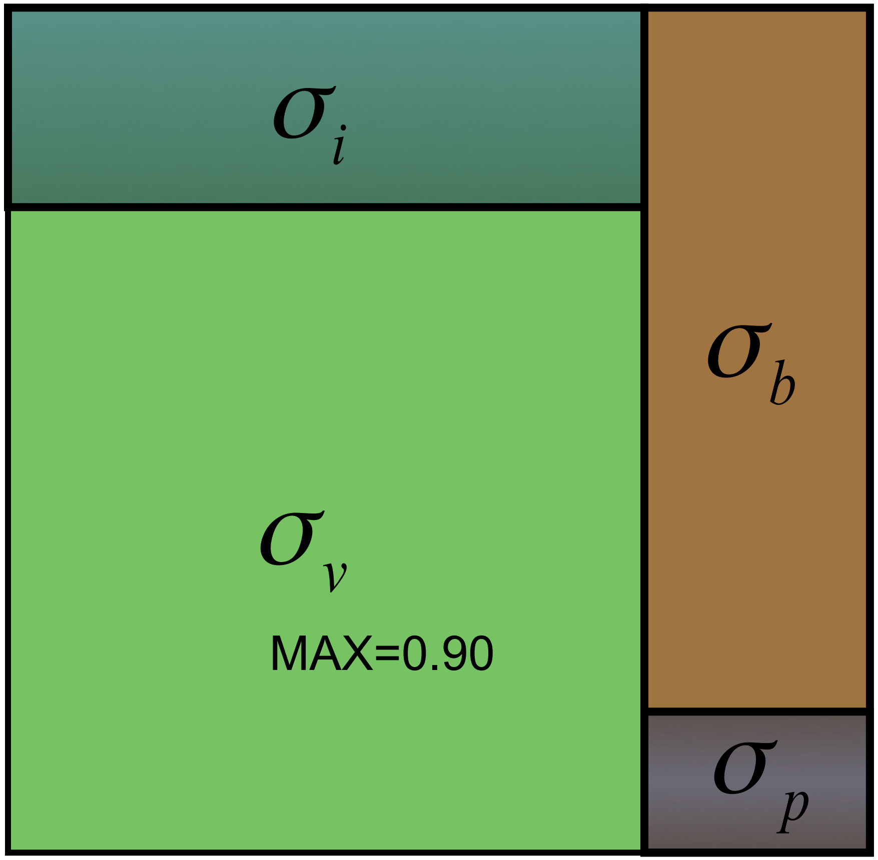
- Bucket approach for interception and surface water store

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

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

Conception

Interception store



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

$I = \sigma_v (P_r + P_{snow})$, T_sfc > T_melt

$$E_i = \sigma_v E_{pot} \left(\frac{W_i}{W_{i,mx}} \right)^{2/3}$$

$$\sigma_i = \left(\frac{W_i}{W_{i,mx}} \right)^{2/3}$$

Ratio of wet canopy
Deardorff, 1978

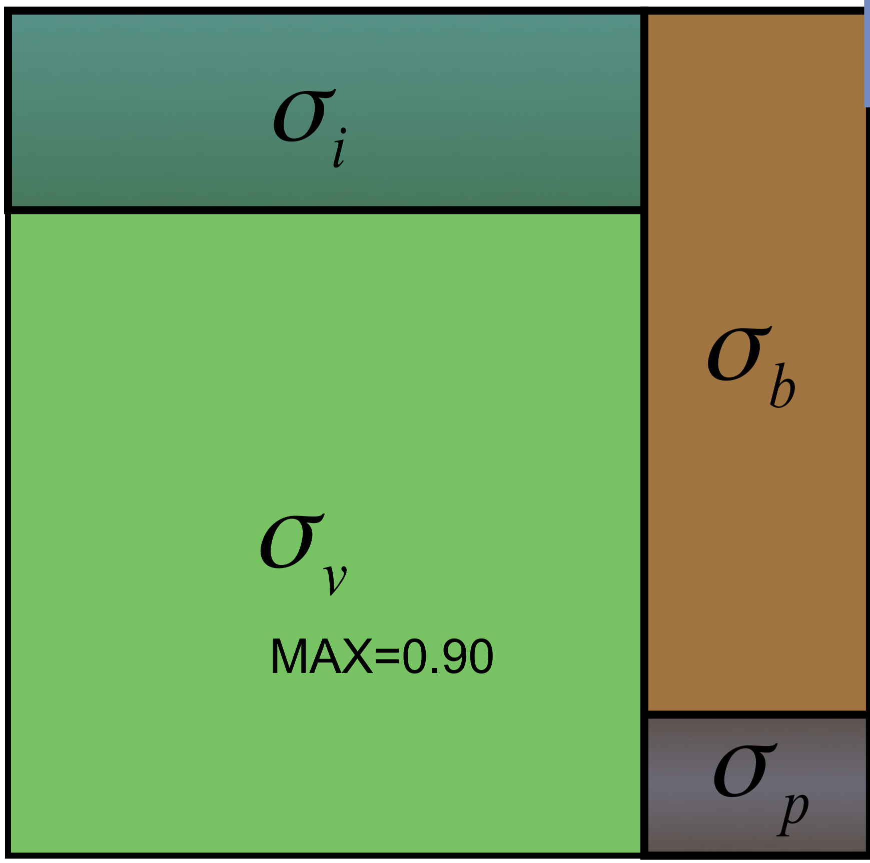
$$D = \frac{W_i - W_{i,mx}}{\Delta t}, \quad W_i > W_{i,mx}$$

$$W_{i,mx} = 0.0002 LAI \quad [\mathrm{m} \quad H_2\mathrm{O}]$$

Dickinson, 1984 (e.g. SURFEX)

Conception

Surface water store



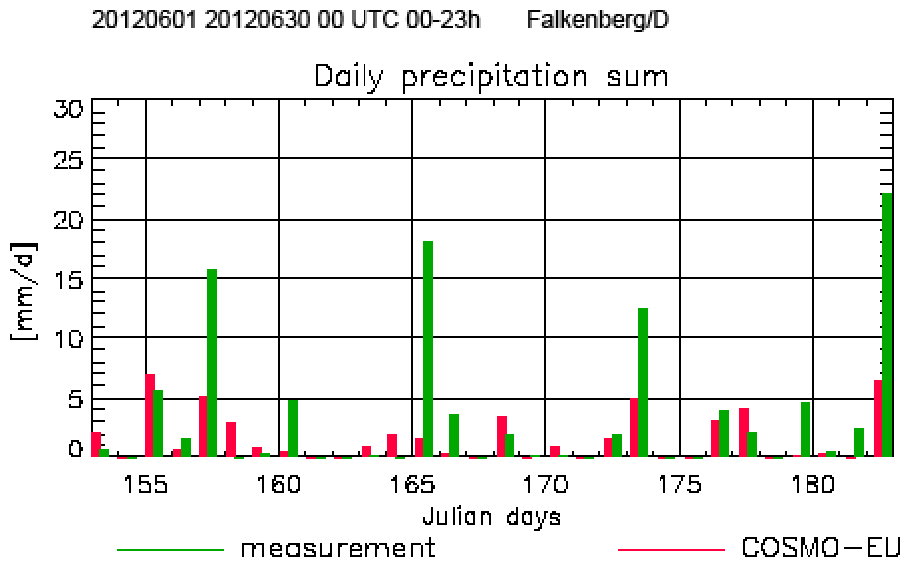
$$\frac{\Delta W_p}{\Delta t} = D + (1 - \sigma_v) P_r - I_g + E_p$$

$$I_g = \begin{cases} D + (1 - \sigma_v) P_r, & \text{for } I_g < I_{g,mx} \\ I_{g,mx}, & \text{for } I_g \geq I_{g,mx} \end{cases}$$

$$E_p = (1 - \sigma_v) E_{pot} \left(\frac{W_p}{W_{p,mx}} \right)^{2/3}$$

$$\sigma_p = \left(\frac{W_p}{W_{p,mx}} \right)^{2/3}$$

June Falkenberg

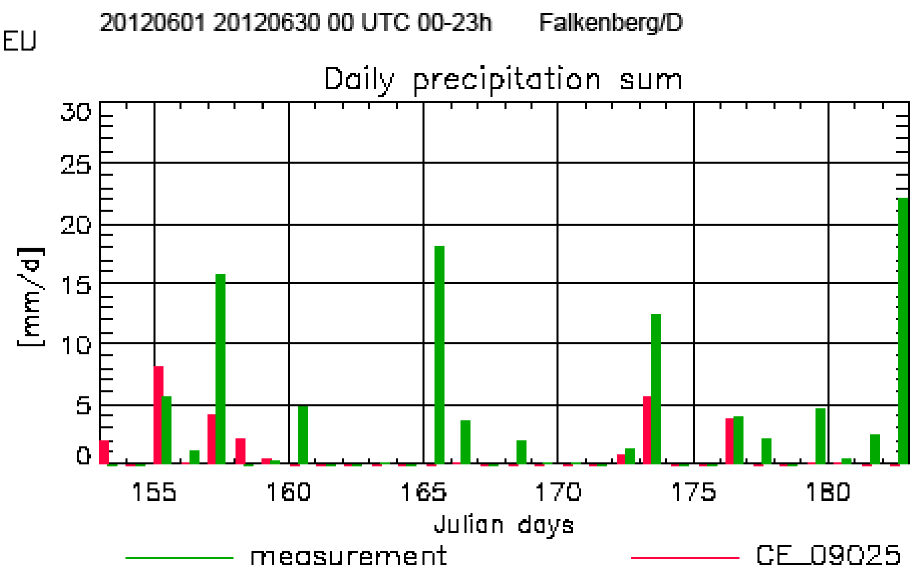


Selected case studies for:

2 – 4 June 2012 (154 – 156)

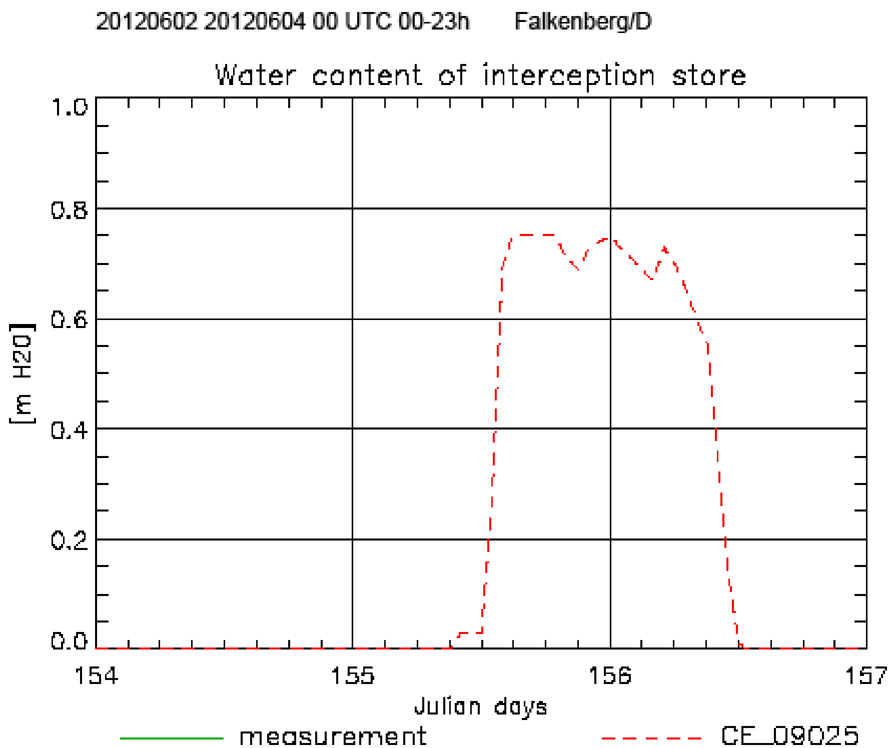
4 – 6 June 2012 (156 – 158)

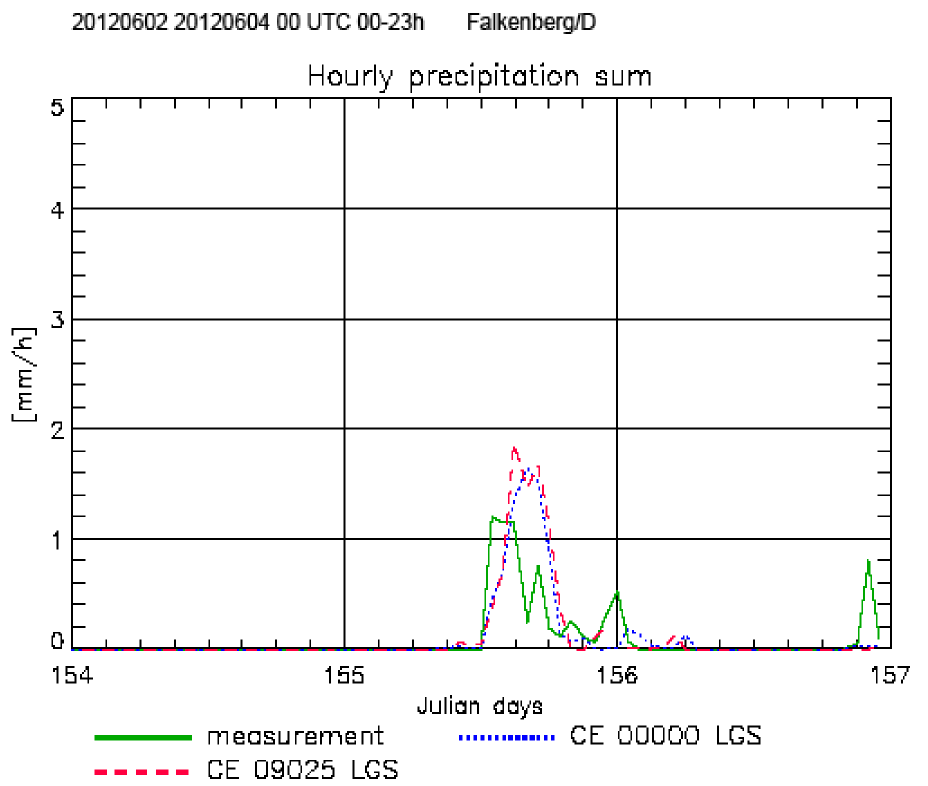
20 – 22 June 2012 (172 – 174)



2 – 4 June 2012

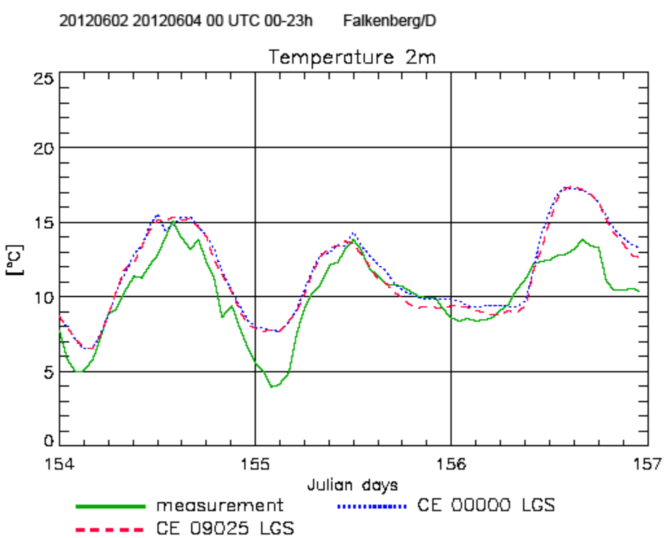
Falkenberg $W_{i,mx} = 0.0002 LAI \quad [\mathrm{m} \quad H_2\mathrm{O}]$

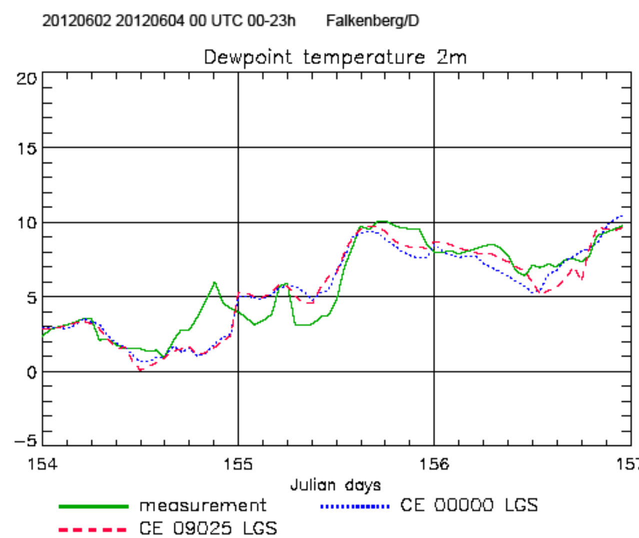


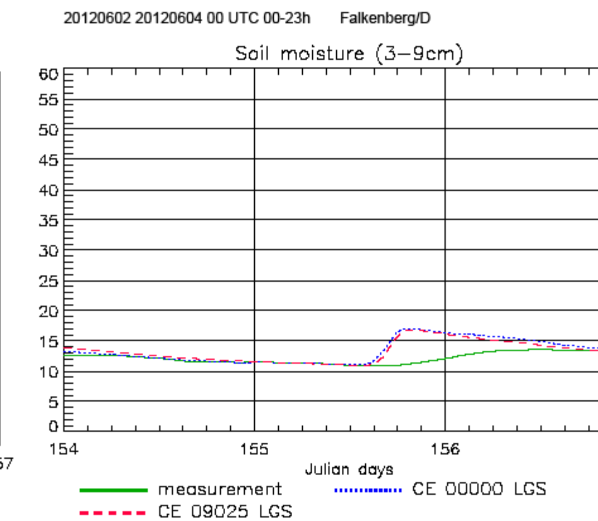


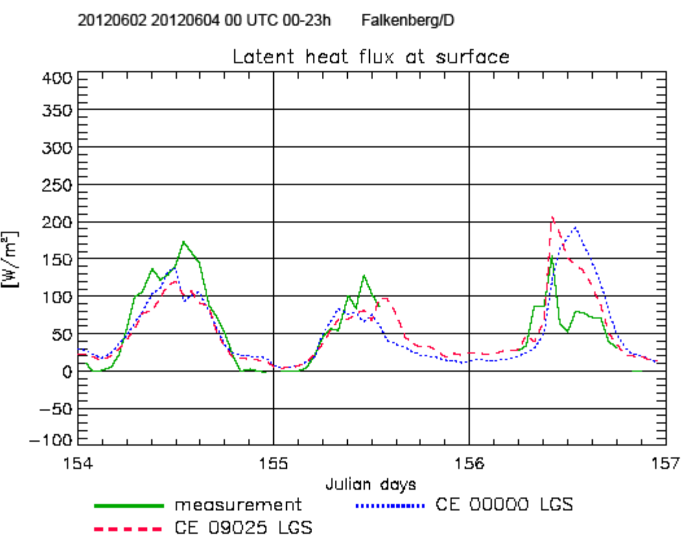
2 – 4 June 2012

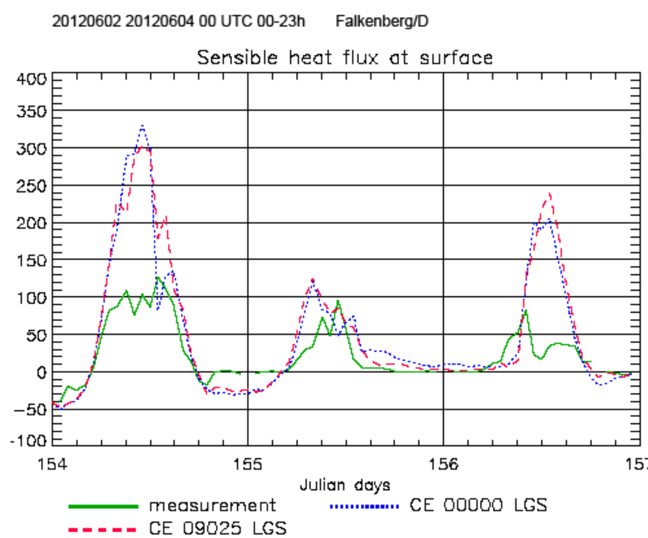
Falkenberg $W_{i,mx} = 0.0002LAI \quad [\mathrm{m} \quad H_2\mathrm{O}]$

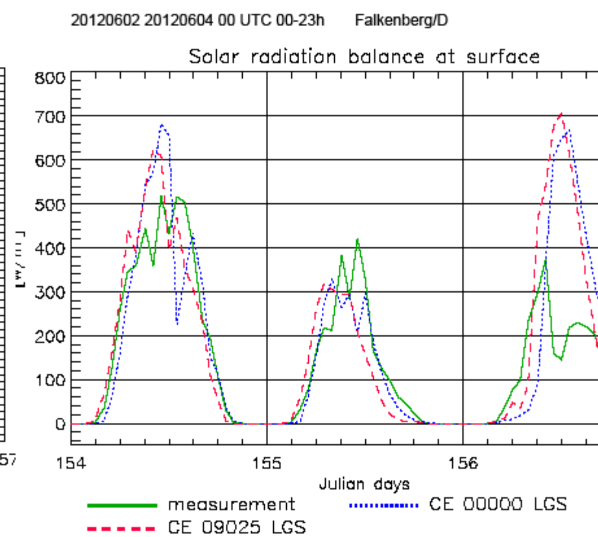






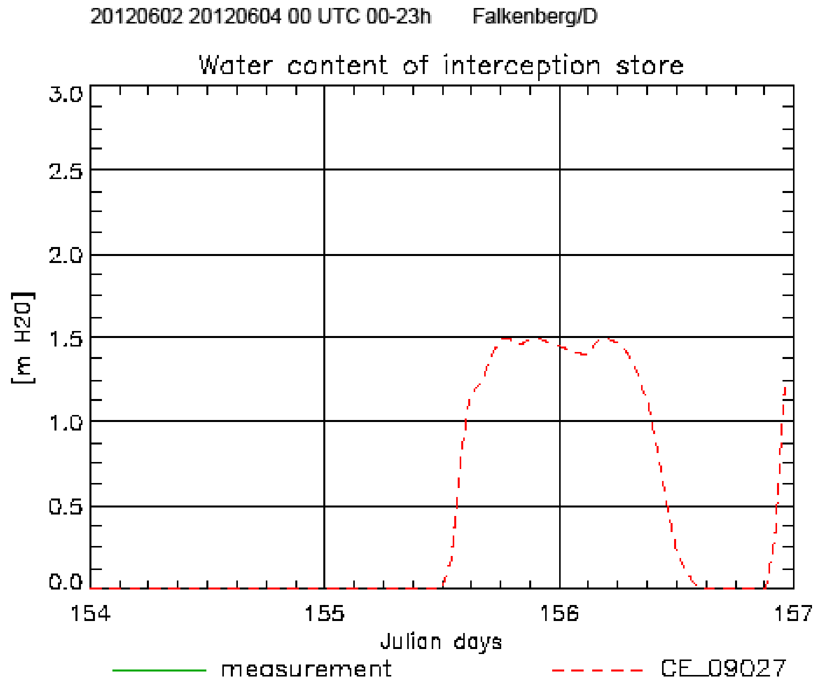


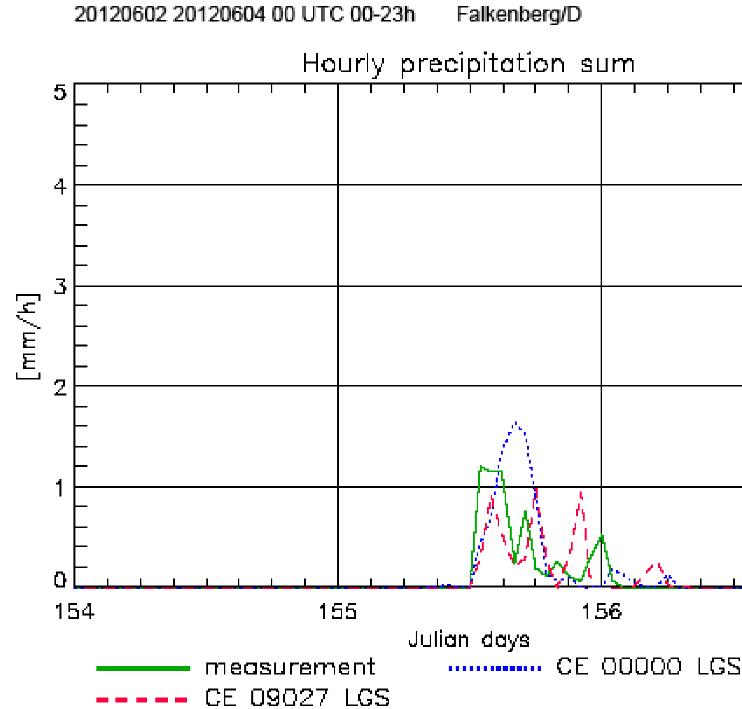




2 – 4 June 2012

Falkenberg $W_{i,mx} = 0.0004 LAI \quad [\mathrm{m} \quad H_2\mathrm{O}]$





2 – 4 June 2012

Falkenberg $W_{i,mx} = 0.0004 LAI \quad [\mathrm{m} \quad H_2\mathrm{O}]$

CONSORTIUM FOR SMALL SCALE MODELING COSMO

Deutscher Wetterdienst DWD
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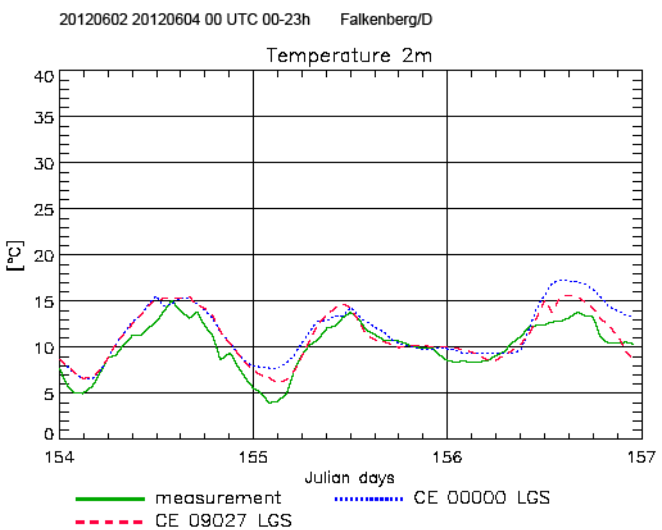
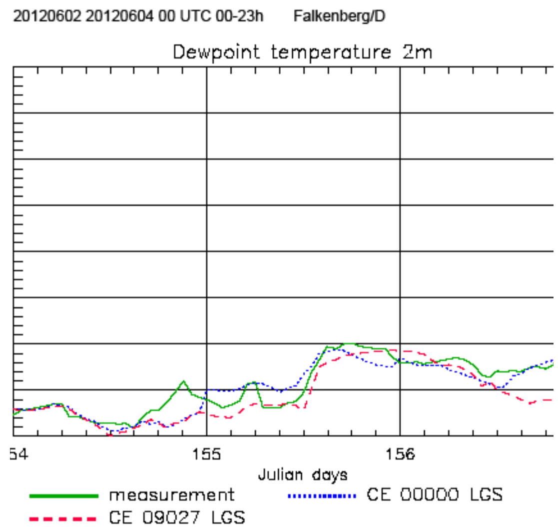
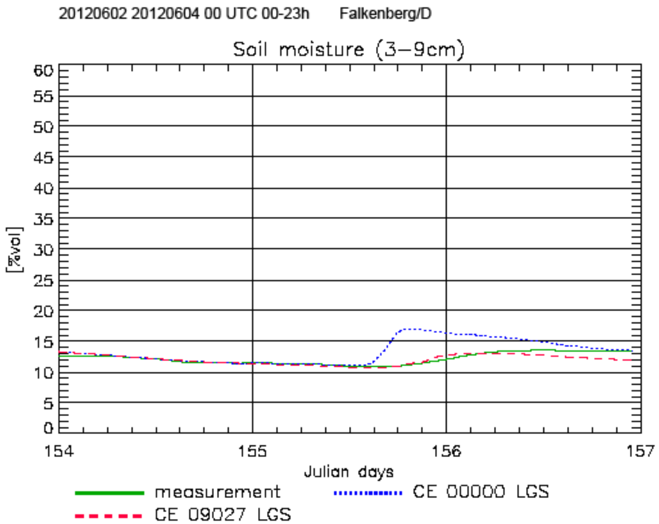
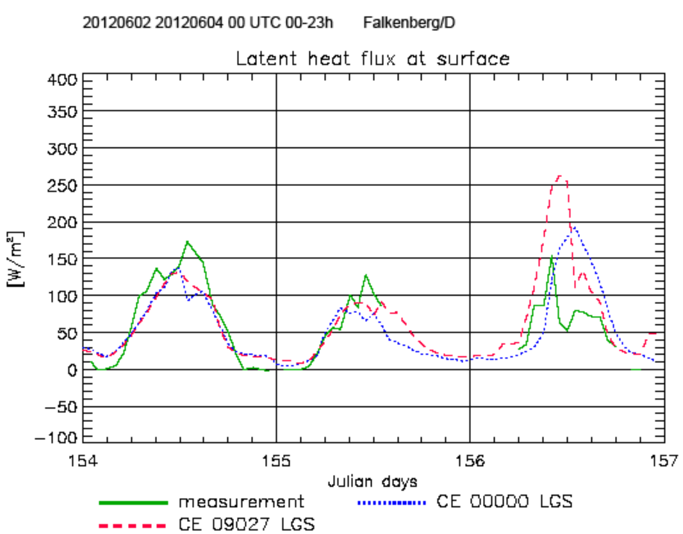
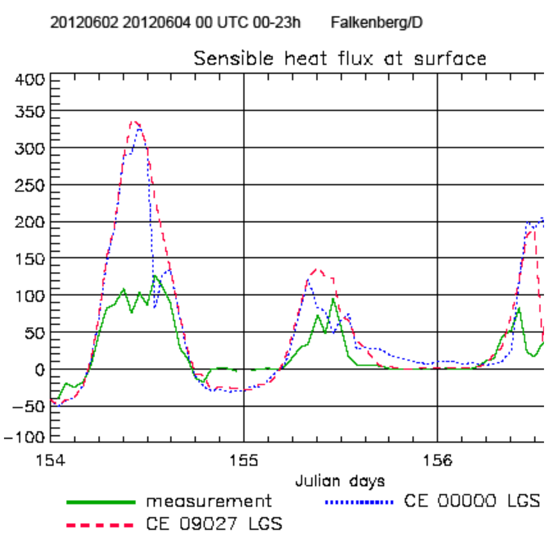
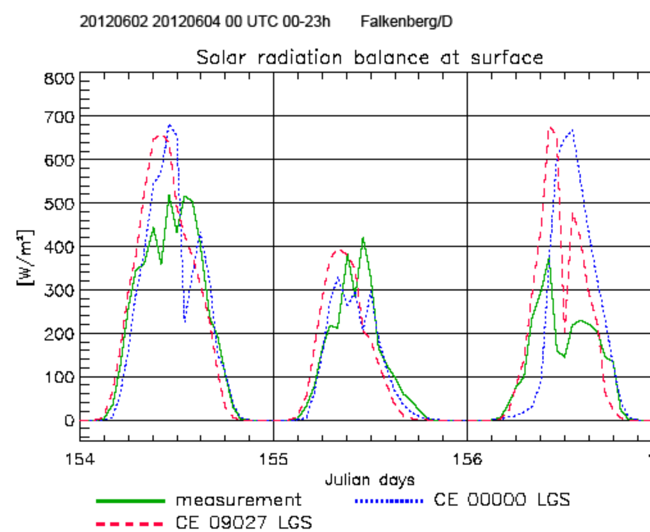








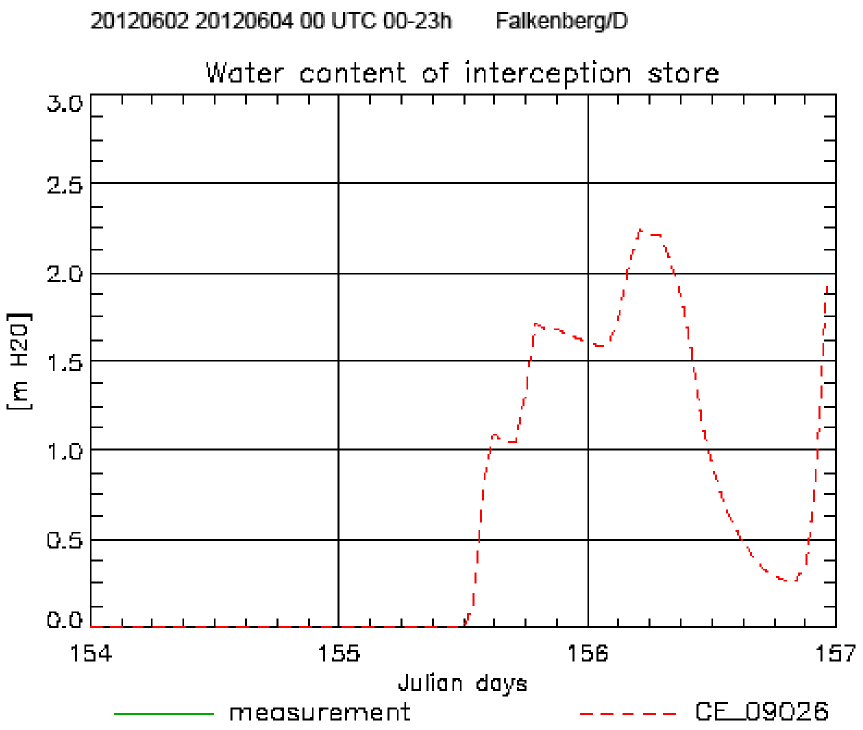


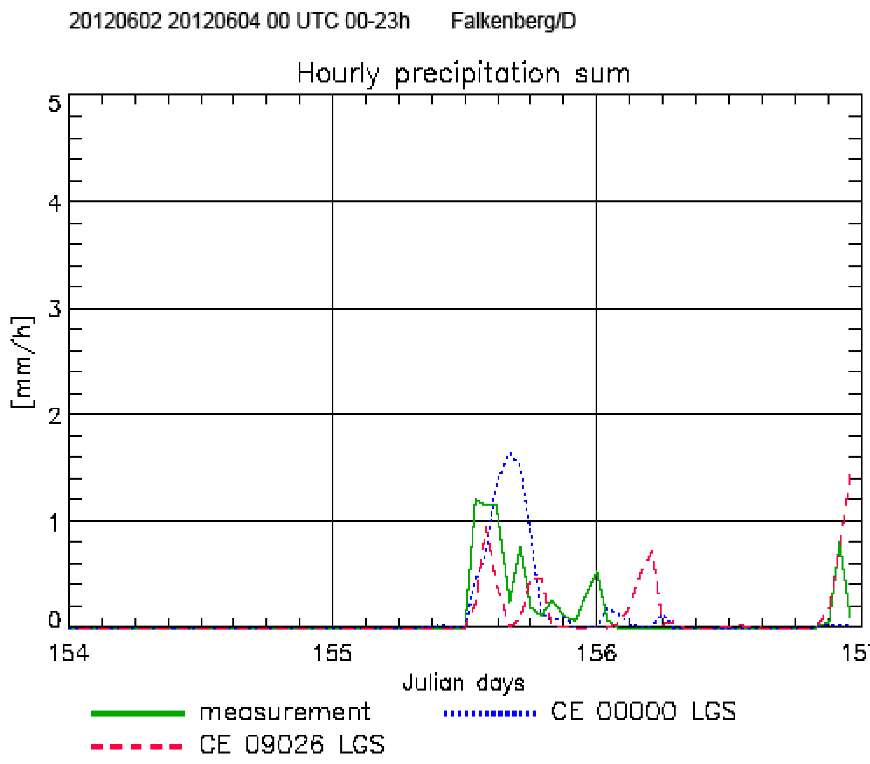


2 – 4 June 2012

Falkenberg $W_{i,mx} = 0.0006 LAI \quad [\mathrm{m} \ H_2\mathrm{O}]$

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



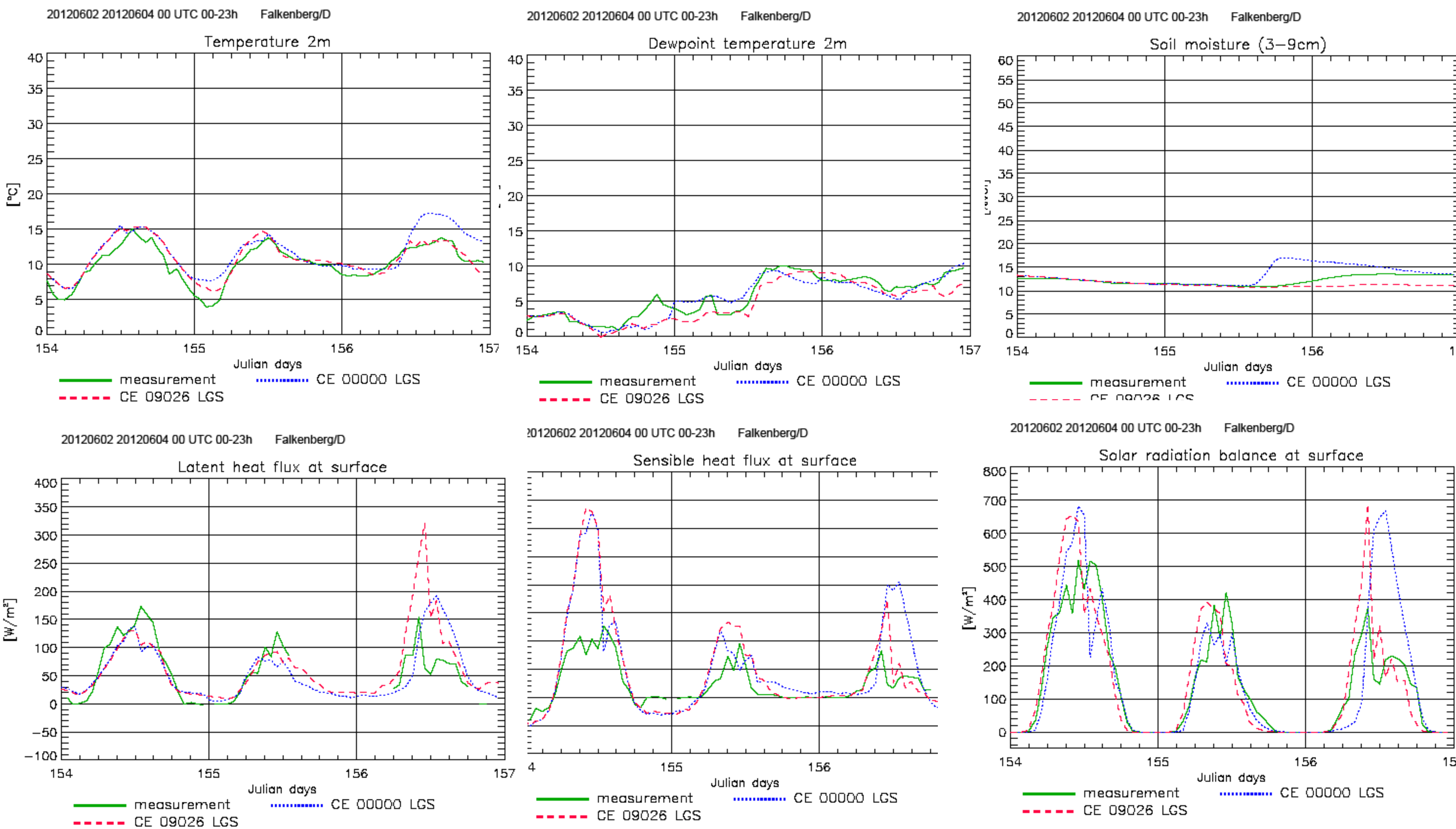


2 – 4 June 2012

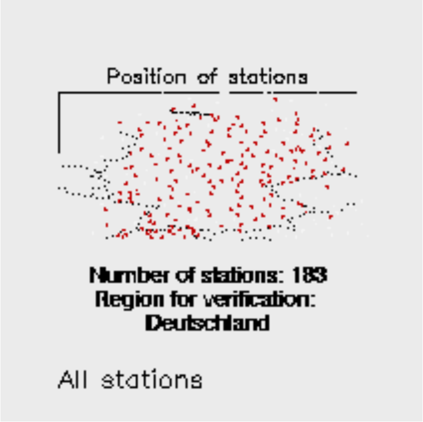
Falkenberg $W_{i,mx} = 0.0006 LAI \quad [\mathrm{m} \ H_2O]$

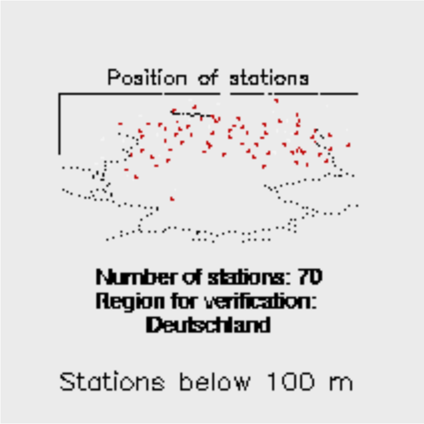
CONSORTIUM FOR SMALL SCALE MODELING COSMO

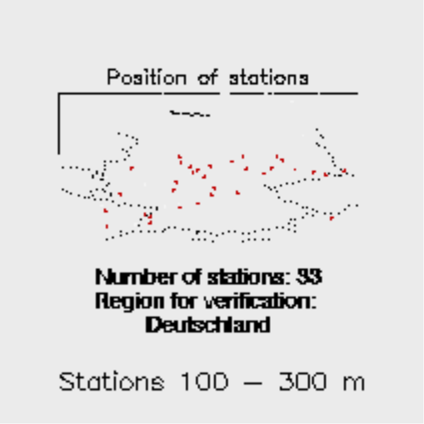
Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD

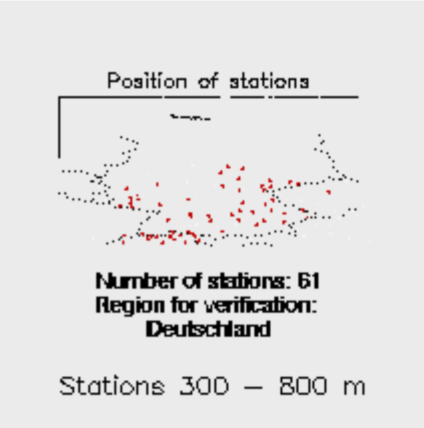


SYNOP stations for verification







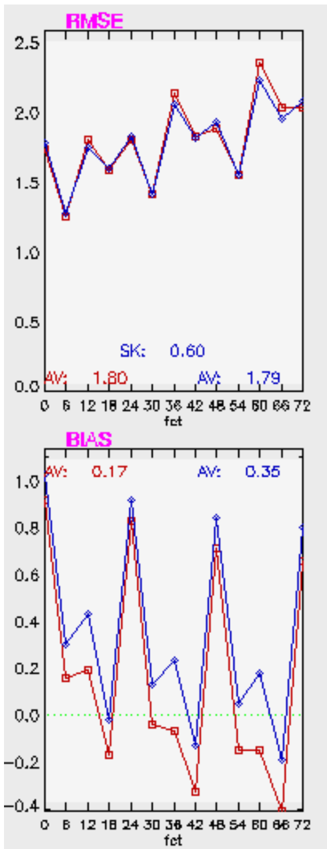


CEU-EXP verification #9025
01.06.-31.08.2012

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Results of verification of forecasts for local weather elements at surface stations
LM2MO: 01.06.2012 00 UTC – 31.08.2012 00 UTC (exp. run 9025: TERRA Interception)
lm2mo: 01.06.2012 00 UTC – 31.08.2012 00 UTC (ope. run LON: 5.5 – 15.5 LAT: 47. – 56.: nearest gridpoint)
Temperature (K)

all stations



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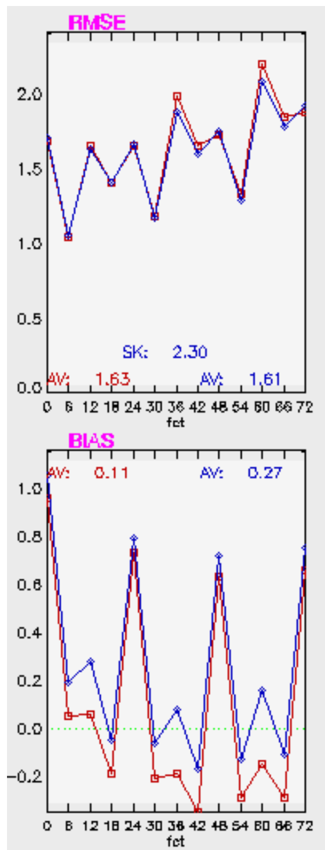
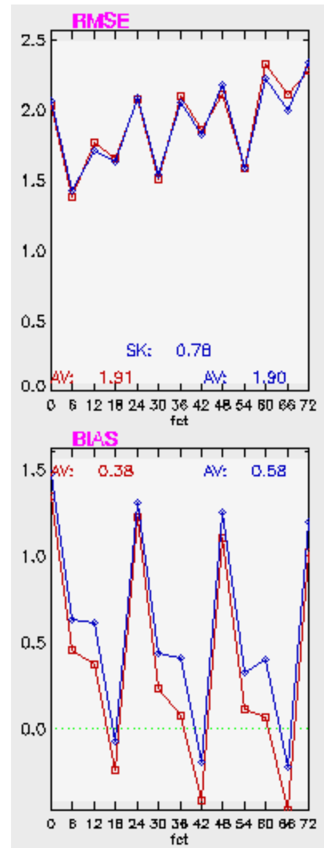
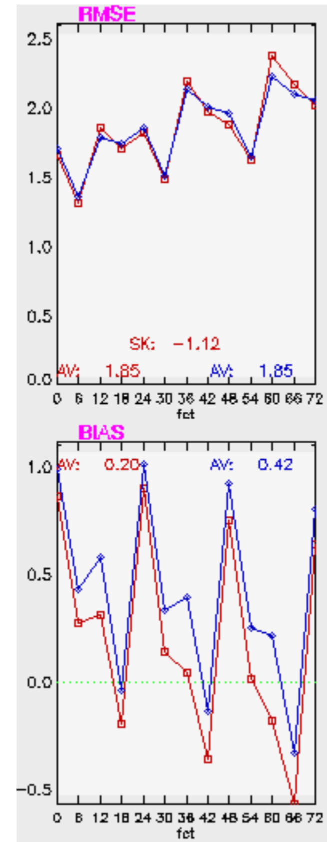


100m – 300m



300m – 800m

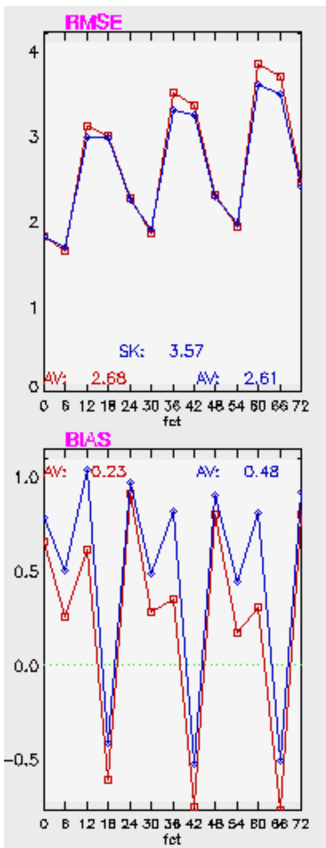


CEU-EXP verification #9025
01.06.-31.08.2012

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Results of verification of forecasts for local weather elements at surface stations
LM2MO: 01.06.2012 00 UTC – 31.08.2012 00 UTC (exp. run 9025: TERRA Interception)
lm2mo: 01.06.2012 00 UTC – 31.08.2012 00 UTC (ope. run LON: 5.5 – 15.5 LAT: 47. – 56.: nearest gridpoint)
Dew point depression (K)

all stations



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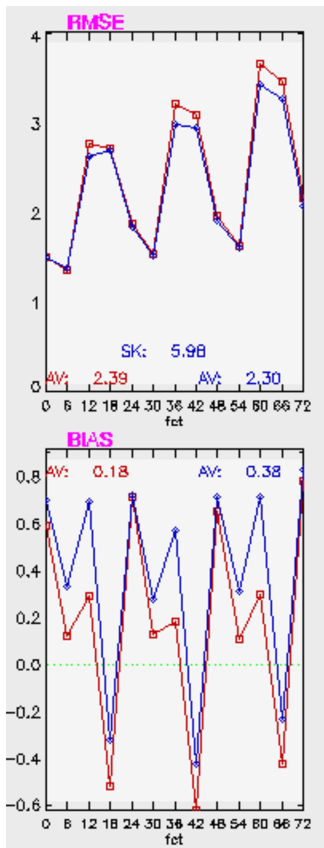
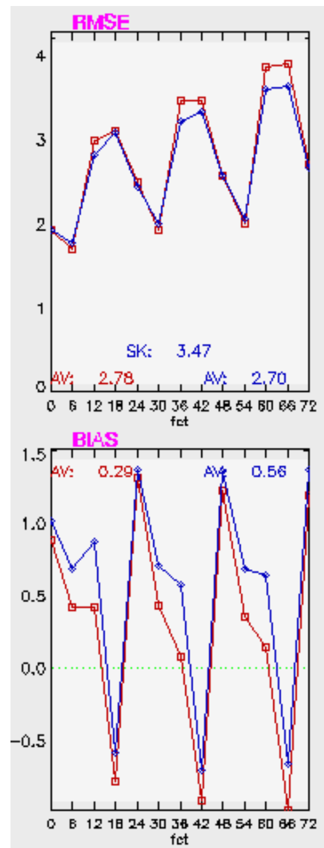
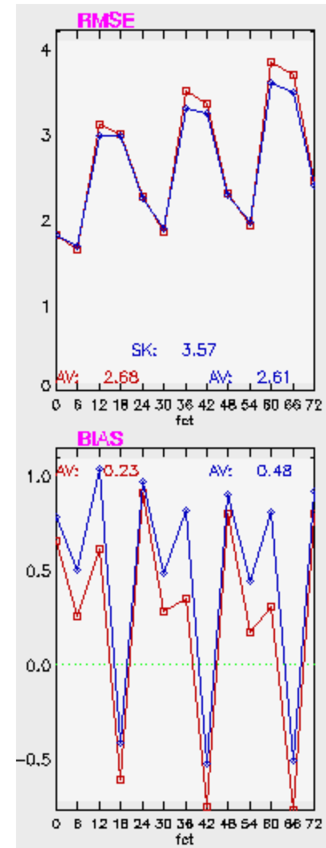


100m – 300m

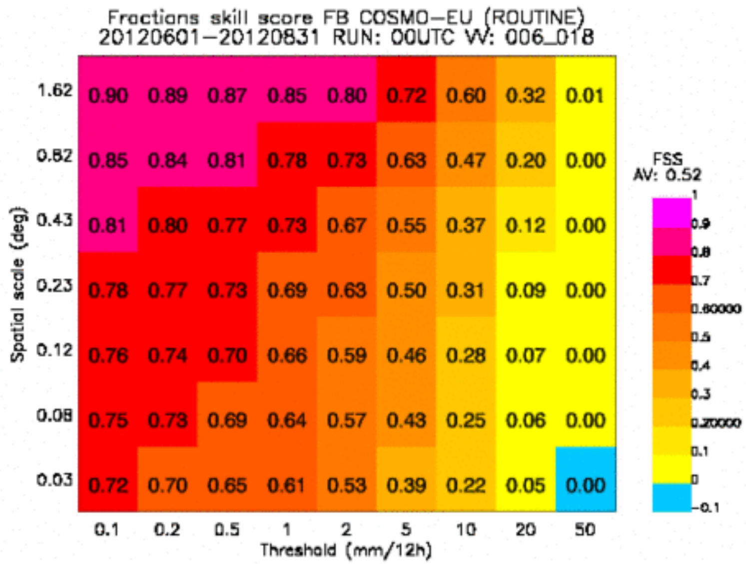


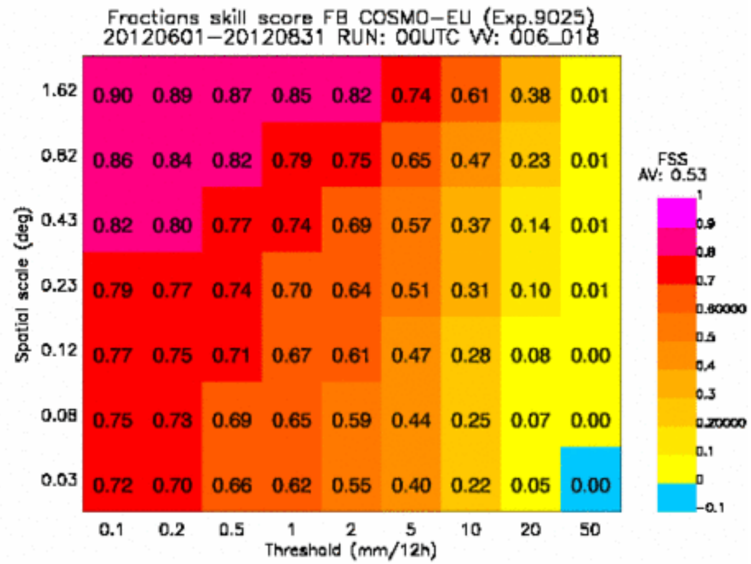
300m – 800m

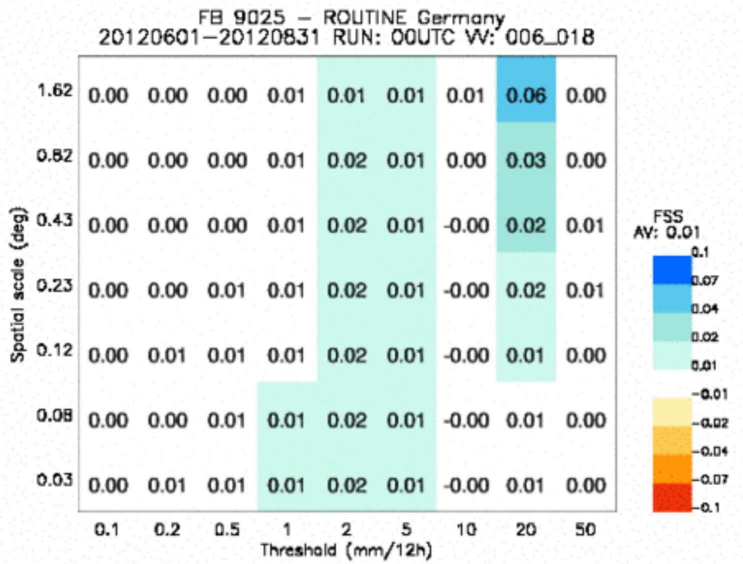


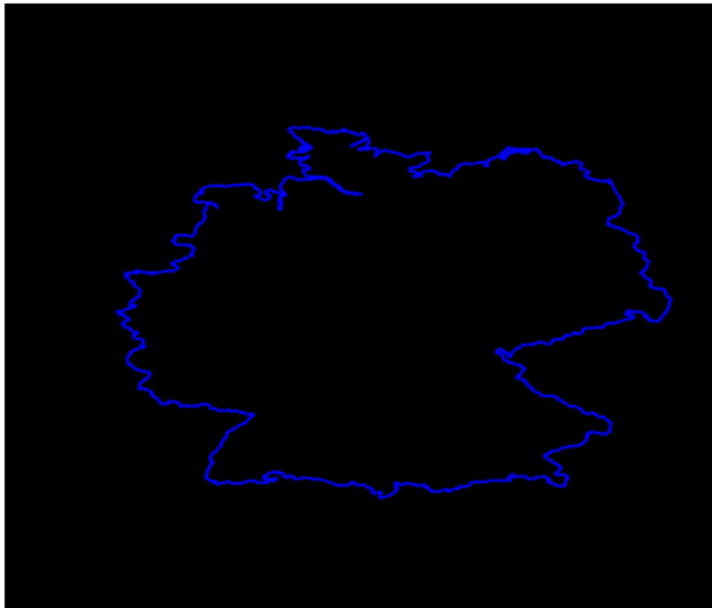
CEU-EXP verification #9025
01.06.-31.08.2012

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









Conclusions

Usage of the interception store in TERRA

- leads to more realistic hydrological cycle
- reduction of dewpoint depression bias – more water vapour in the boundary layer
- reduction of warm T2m-bias
- impact on cloudiness and precipitation – feedback effects