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CONSORTIUM FOR SMALL SCALE MODELING
COSMO

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

COSMO Soil & Surface: -Activity Review-

Jean-Marie Bettems / MeteoSwiss (WG coordinator)
Matthias Raschendorfer / DWD (reporting)

Roma, EWGLAM/SRNWP, October 2016

TERRA – EURO-CORDEX

- **EURO-CORDEX: Historical ERAint-driven RCM runs over Europe (0.44 degree)**
  Edouard Davin, Eric Maisonnave, Sonia Seneviratne / ETHZ

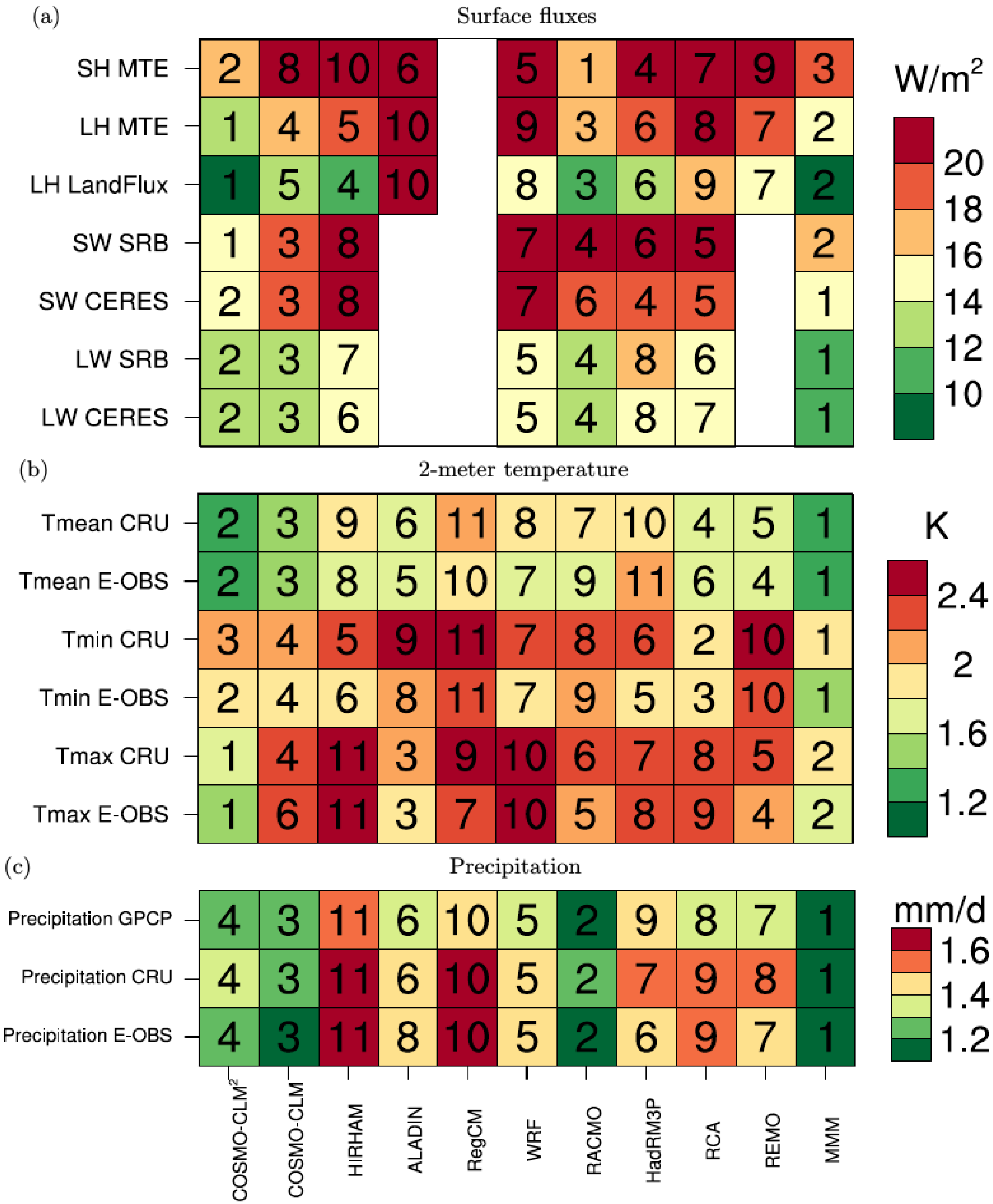
Model	Institution	LSM
ALADIN 5.2	HMS	ISBA (Noilhan and Planton, 1989; Douville et al., 2000)
HIRHAM 5	DMI	(Hagemann, 2002)
WRF 3.3.1	IPSL-INERIS	NOAH (Ek et al., 2003)
RACMO 2	KNMI	(Balsamo et al., 2009)
HadRM 3P	MOHC	MOSES (Cox et al., 1999)
RCA 4	SMHI	(Samuelsson et al., 2006)
REMO 2009	MPI-CSC	(Hagemann, 2002; Rechid et al., 2009)
RegCM 4.3	ICTP	BATS (Dickinson, 1984)
COSMO-CLM 4.8.17	CLM-Community	TERRA_ML (Doms et al., 2011)
COSMO-CLM^2	ETH Zurich	CLM4.0 (Oleson et al., 2010; Lawrence et al., 2011)

TERRA – EURO-CORDEX

- RMSE score integrating spatial and temporal performance (based on monthly means)
- Surface fluxes, temperature, precipitation
- Whenever possible several reference datasets are used

Dataset	Variables	Resolution	Time period	Reference
CRU TS3.22	2-m temperature precipitation cloud cover	0.5x0.5	1990-2008	(Harris et al., 2014)
E-OBS v11	2-m temperature precipitation	0.5x0.5	1990-2008	(Haylock et al., 2008)
GPCP2.2	precipitation	2.5x2.5	1990-2008	(Huffman et al., 2009)
FLUXNET MTE	latent heat sensible heat	0.5x0.5	1990-2008	(Jung et al., 2011)
LandFlux-EVAL	latent heat	1x1	1990-2005	(Mueller et al., 2013)
SRB3.0	shortwave radiation longwave radiation	1x1	1990-2007	(Zhang et al., 2015)
CERES	shortwave radiation longwave radiation	1x1	2001-2008	(Rutan et al., 2015)

TERRA – EURO-CORDEX



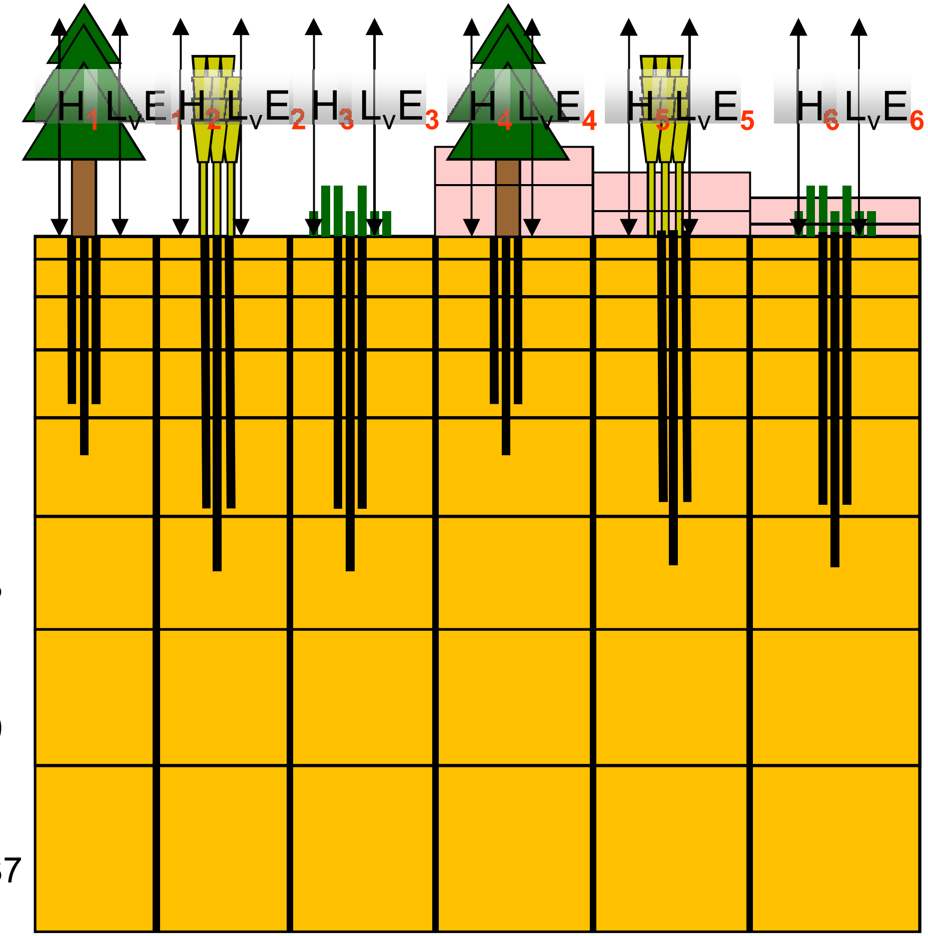
Multi-scores ranking:

RMSE over whole spatial and temporal range

Community-Land-Model in place of TERRA

- COSMO-CLM² outperforms COSMO-CLM and most other RCMs for surface fluxes and temperature

- No improvement by COSMO-CLM² for precipitation



- ➔ **surface tiles** (only in ICON so far)
- ➔ new treatment of a **thermally decoupled surface cover** (running development: M. Raschendorfer]
- ➔ more **advanced treatment of snow-fraction** (including effect of vegetation and SSO) and **revision of interception store;** ICON-version: G. Zängl)
- ➔ **new multi layers snow model** (not yet operational: E. Machulskaya)

- ➔ **resistance based bare soil evaporation** (ICON-version, test-phase: J.-P. Schulz)
- ➔ **exponential root density profile** and **impact of roots on thermal and hydraulic conductivity** (ICON-version: J. Helmert)
- ➔ **moisture dependent soil heat conduction** (operational: J.-P. Schulz)
- ➔ **tuned GlobCover 2009 look-up table** for land-use parameters (ICON-version: G. Zängl)
- ➔ some **special tuning** (desert, Geenland-ice,; ICON-version: G. Zängl)

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Parameters and Data

External parameters

- **External parameters recently added to EXTPAR**
  - MACv2 aerosol climatology (→ Radiation)
  - Impervious surface area (→ TERRA-URB)
  - Annual mean anthropogenic heat flux (→ TERRA-URB)

TERRA-URB *(Wouters, H., KU Leuven)*

- Goal: *add cheap but realistic bulk parameterization of urban effects mainly by adapted* **urban external parameters**
- Benefit: *variability of urban heat island well reproduced*
- Status: *peer reviewed paper in '*Geoscientific Model Developme

  code will be available in COSMO 5.05
  code responsibility by Uli Blahak / DWD
- Evaluation in progress at ARPA-Piemonte (Torino/Cira)

Objective Calibration of COSMO Model (CALMO)

Method : Omar Bellprat, ETH

- Describing the dependency of a (user oriented) **model performance metric** (that can be represented by **observations**) as a function of **unsecure and sensitive model parameters** by a **cheap** **meta-model** based on quadratic forms
- Searching for the **global maximum** (**optimal parameter tuple**) of the performance metric for the given **parameter space** (bounded by the valid range of each parameter) **by means of the meta-model**

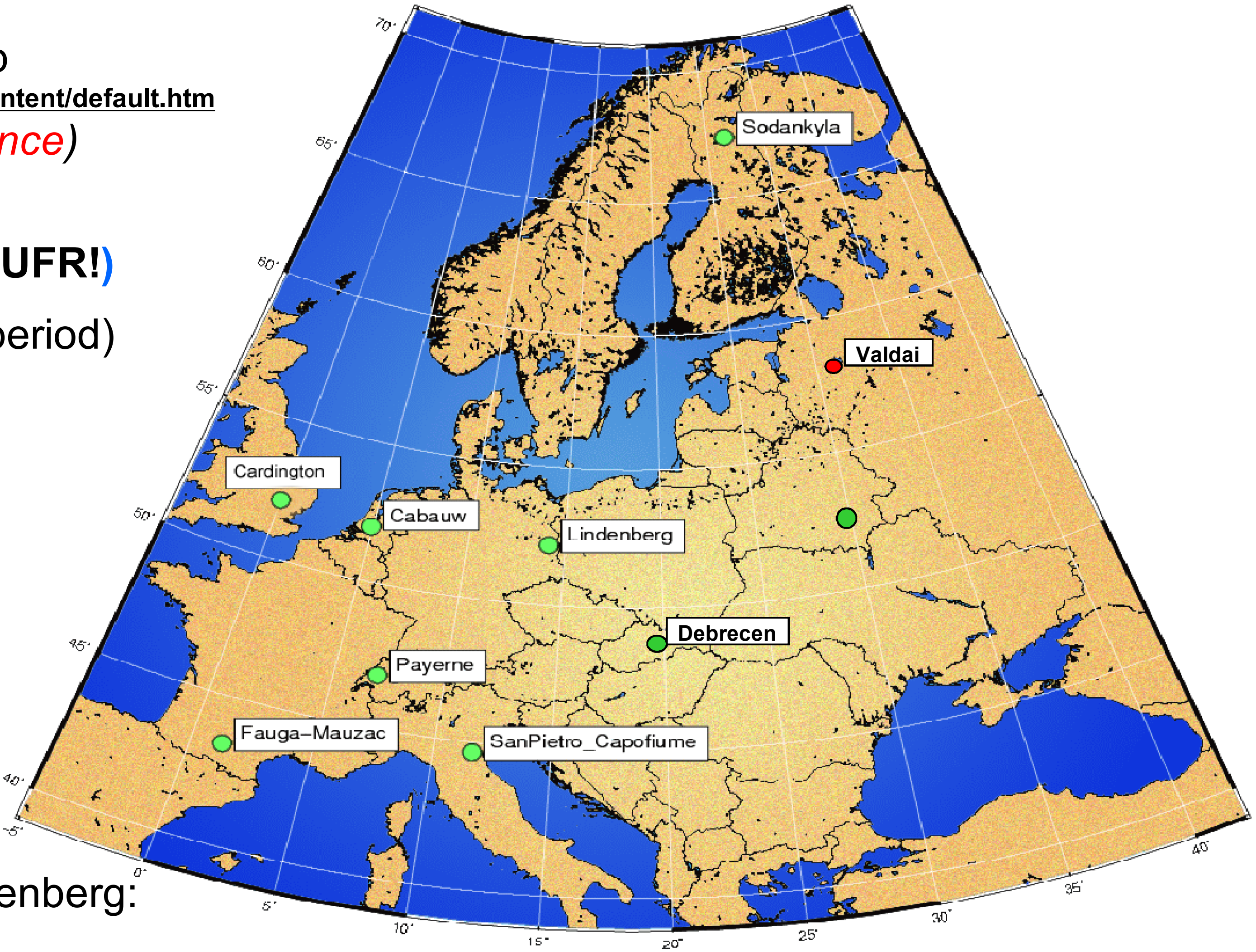
Calibration of COSMO-2, daily 36h forecast, full year 2013

- **Performance function** based on Client Oriented Scale of Improvement (COSI) score using
  - *T2m daily min/max, 24h precipitation*
  - *total column water*
  - *wind, temperature, humidity at 3 standard pressure levels*

➢ **Improvement of 4% of COSI score**

SRNWP data pool

- Access from COSMO web
  http://www.cosmo-model.org/srnwp/content/default.htm
  (*currently under maintenance*)
- Data from **2006-2015**,
  in **ASCII & NetCDF (no BUFR!)**
- **9 sites** (some for limited period)
- **Soil**, **surface** and
  BL observations
- Annual actualization
  (or earlier on request)
- Open for R&D-institutions
- Sometimes problems with
  quality and availability
  of a few stations
- Work done at DWD / Lindenberg:



Use the opportunity to get these very valuable data!!

Advertise these data in COSMO-, SRNWP- or ECMWF-Newsletters!!

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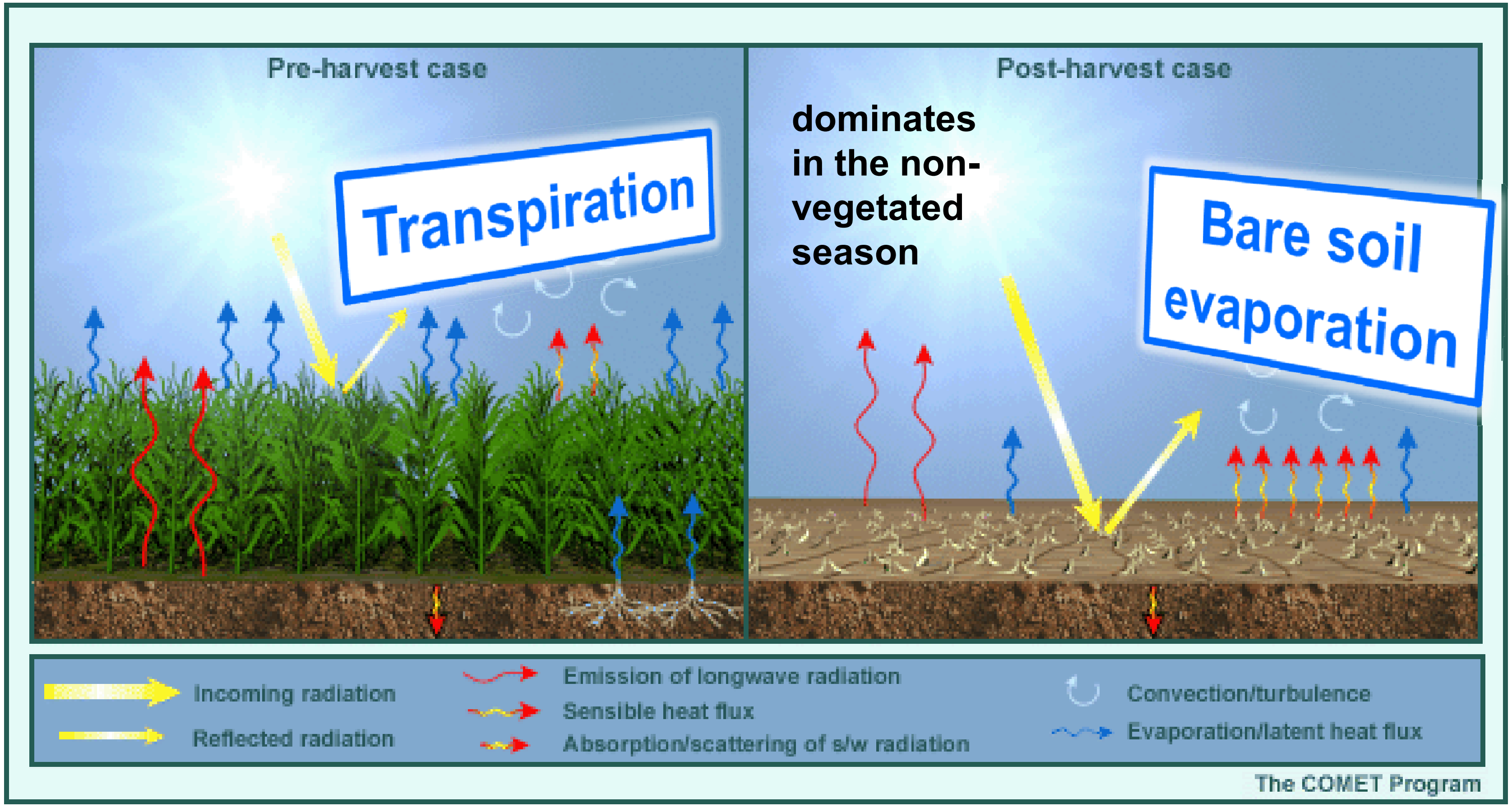
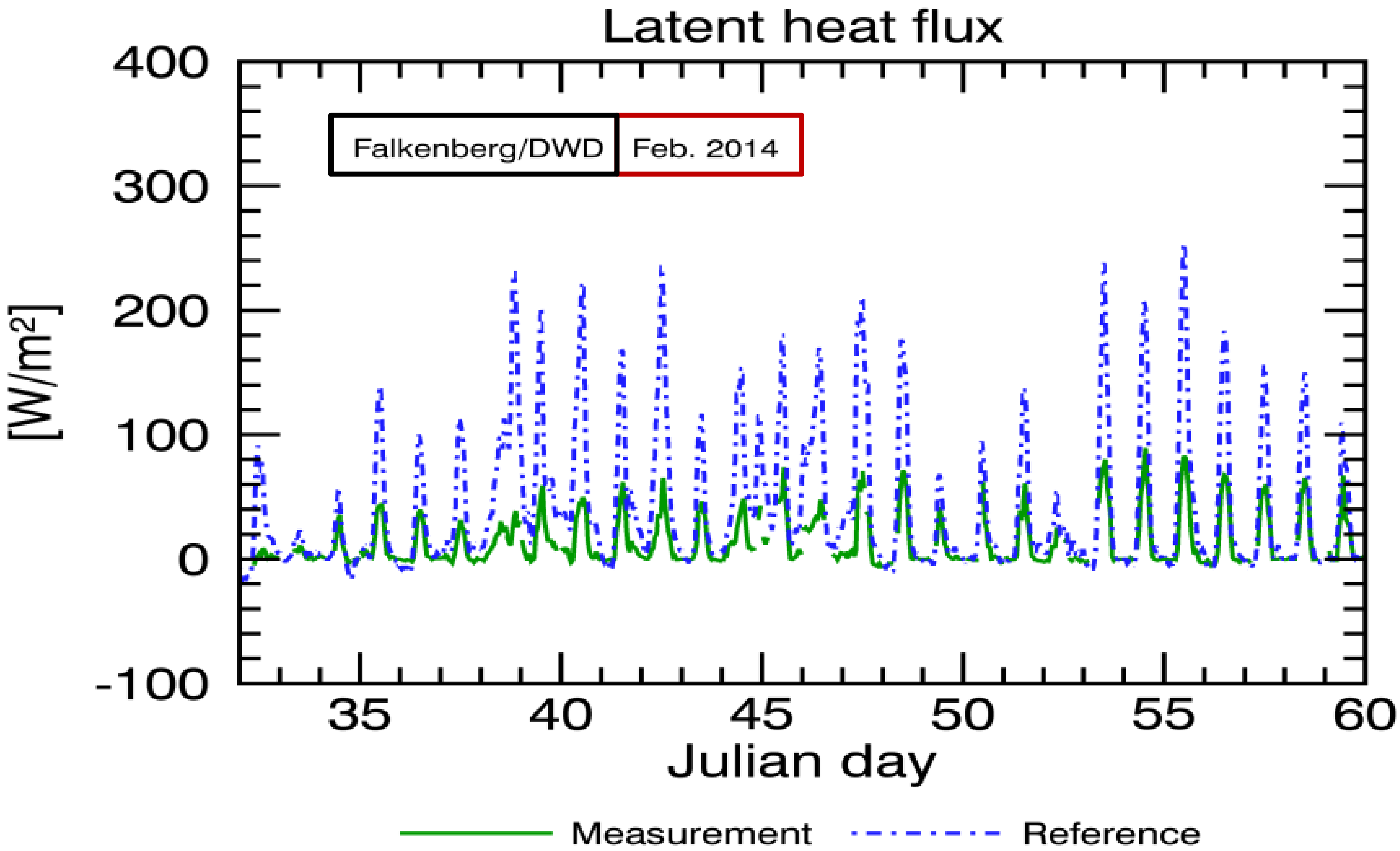
Soil: TERRA

Implementation of a new parameterization of bare soil evaporation into the soil model TERRA



Jan-Peter Schulz[1] and Gerd Vogel[2]

[1]Deutscher Wetterdienst, Offenbach, Germany
[2]Deutscher Wetterdienst, Lindenberg, Germany



- **General finding:**
  - underestimated under **medium-dry to dry** conditions.
  - overestimated under **medium-wet to wet** conditions.

➢ **Possibly a wrong implementation in TERRA**

Formulation of (downward) transfer layer water flux densities:

general **pore evaporation** **above a homogeneous soil surface**

$$WVF^B_{por} = f^B_{red} \cdot WVF^B_{wat}$$

reduction-factor

$$WVF^B_{wat} = \frac{q_{vA} - q_{vsat}(T_B)}{r^H_{SA}}$$

above an open water surface (potential evaporation)

transfer layer resistance for heat (and other scalars) between surface (**S**) and lowest atmospheric model level(**A**)

$$f^B_{red} = \begin{cases} 1 & WVF^B_{wat} \geq 0 \quad \text{downward flux} \\ f^B_{por} & WVF^B_{wat} < 0 \quad \text{upward flux} \end{cases}$$

Current formulation of pore reduction-factor according to Dickinson (1984)

maximum evaporation (dependent on soil type)

$$f^B_{por} = \min\left\{1, \frac{WVF^B_{max}}{WVF^B_{wat}}\right\}$$

as a function of

- soil depth values of surface-zone and root-zone
- together with corresponding soil water levels

had been chosen **much too big!!**

new formulation similar to transpiration treatment by Dickinson

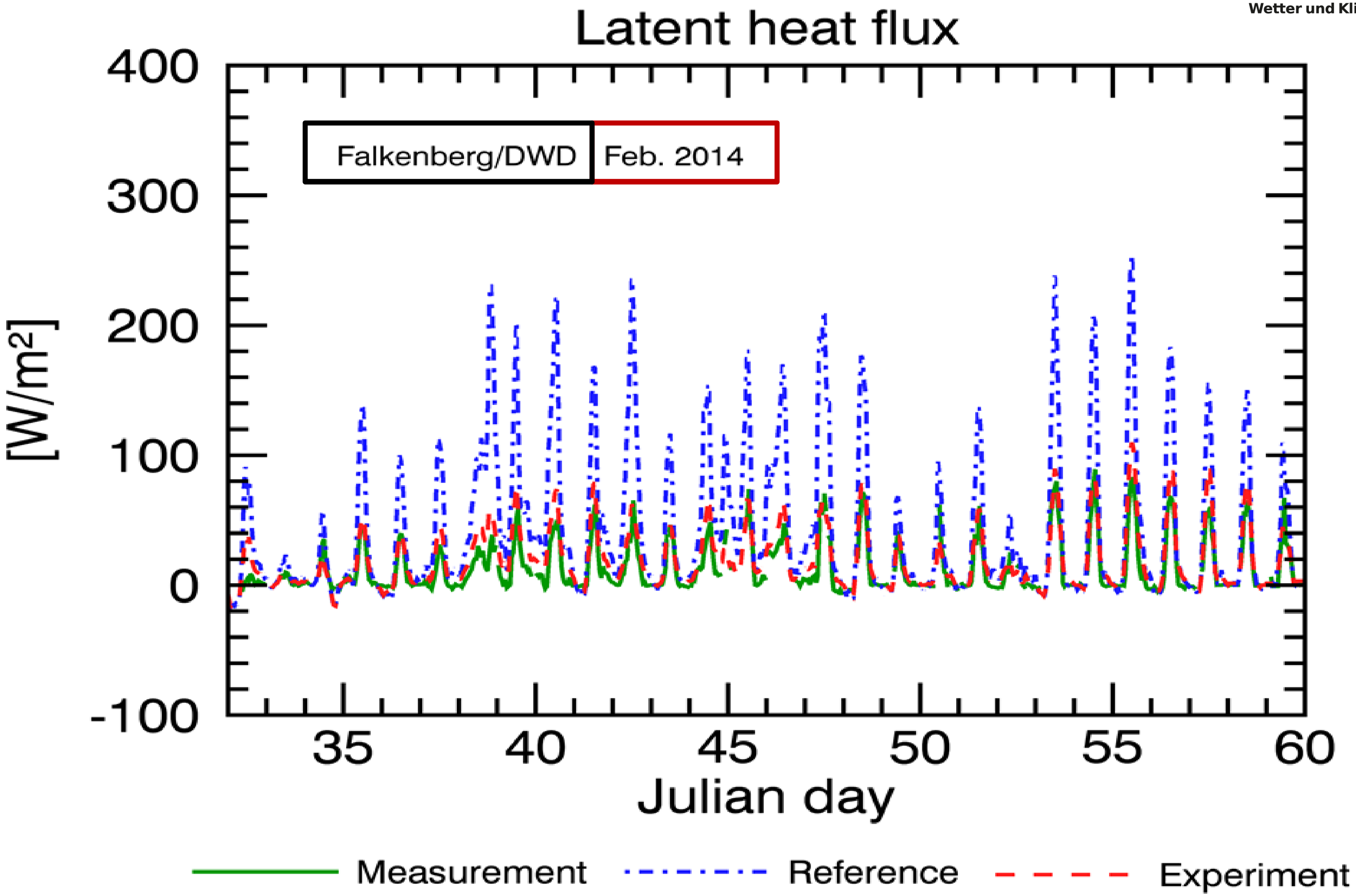
introduced by J.P. Schulz

$$f^B_{por} = \frac{r^H_{SA}}{r^H_{SA} + r^B_{IS}}$$

volumetric soil water content of top-layer

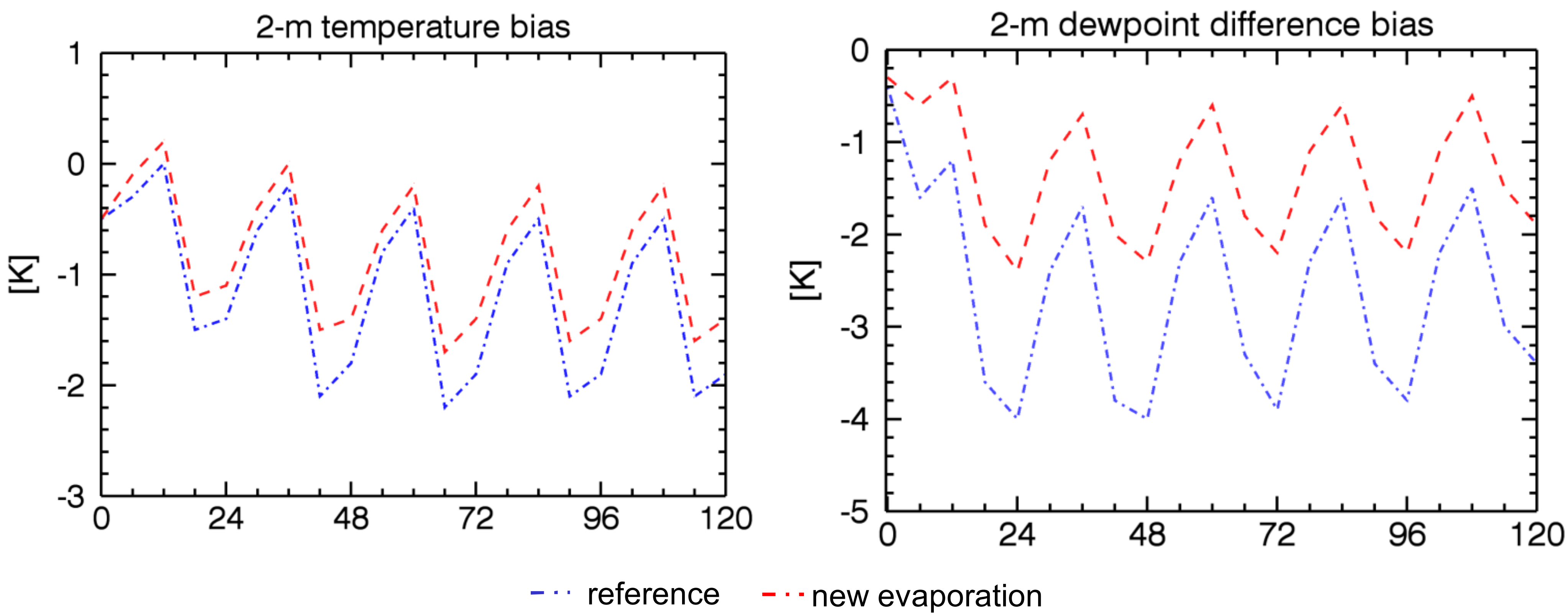
$$r^B_{IS} = r^B_{IS,\,min} \cdot \frac{q^{soil}_{max} - q^{soil}_{min}}{q^{soil}_{top} - q^{soil}_{min}}$$

pore resistance of soil similar to stomata-resistance of vegetation



- Overestimation of LHF substantially decreased!

ICON: NE America, January 2012, 00 UTC (snow-free)



- Cold bias significantly reduced!

If evaporation is dominant compared to plant transpiration:

- Moist bias substantially reduced!

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Roughness- and Transfer-Layer:
TERRA <-> TURBTRAN

Towards a new prognostic equilibrium surface temperature in combination with SAT and the soil model:

- ✓ Completion of the roughness layer model (TERRA-part)
- ✓ Thermal decoupling of a Cover built by roughness elements(canopy) above the dense soil (shading effect)
- ✓ Representation of the thermal energy storage of the roughness layer

Matthias Raschendorfer

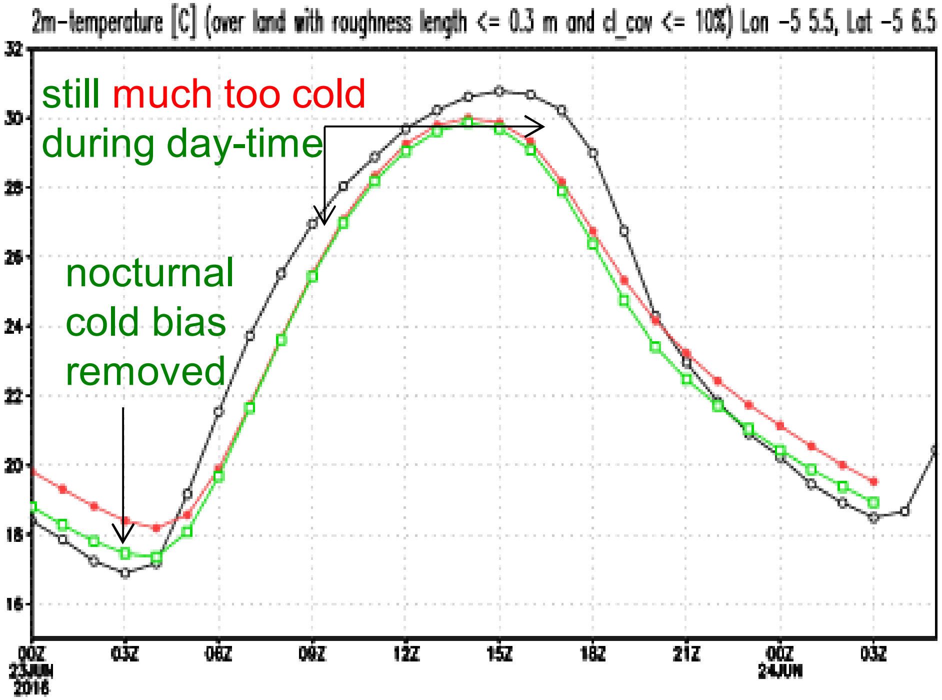
Case study: 23.06.2016

COSMO-DE with lateral boundaries from ICON-EU

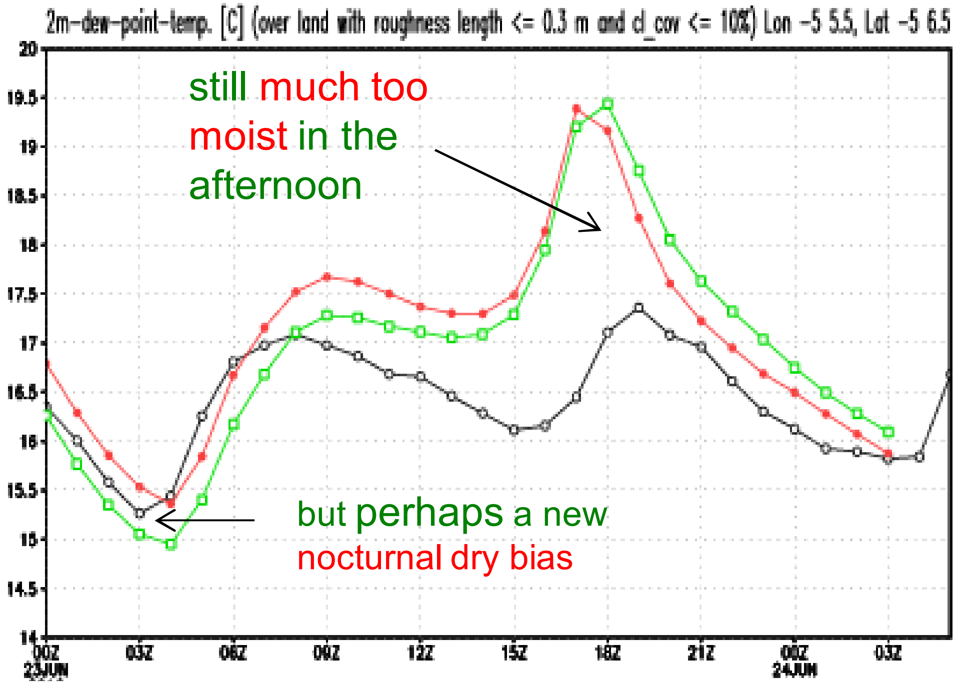
- ✓ **only for rather smooth surfaces; applied filter**
- ✓ **almost saturated soil due to long standing rain period before**
- ✓ **almost no clouds due to high pressure situation; + applied filter**

domain averaged daily cycles of near-surface variables

T_2m



TD_2m



ana_lm3_exp_10279	out_lm3_rout	out_lm3_exp_10279
direct analysis of T_2m and TD_2m	operational configuration	revised TURBDIFF imported from ICON

- **n** **cover layers** including the **surface of the dense soil** (n=0) are connected by long-wave radiation interaction and sensible heat exchange

  ➡ **thermally decoupled roughness elements (shading)**

- Only **a part of the inner surfaces is connected to A** by the resistance chain, the **other part is for the inter- surface exchange**

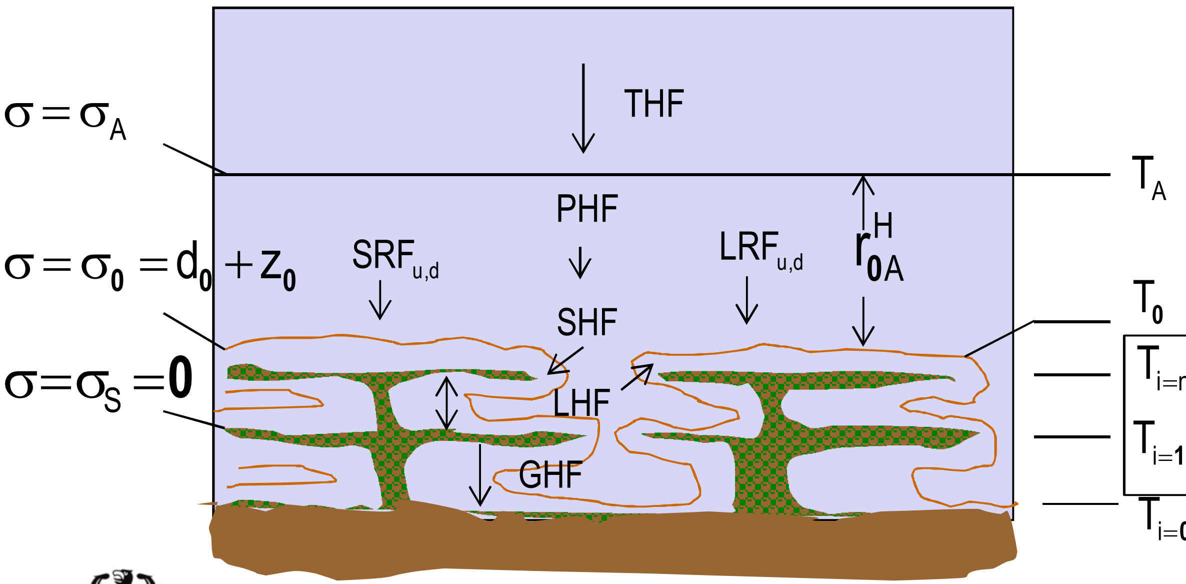
  ➡ strongly effects the **LAI-impact of transpiration**!

$$r^H_{SA} = r^H_{S0} + r^H_{0A}$$

$$r^H_{S0} = \frac{1}{\kappa S_0 \cdot u^H_0} \cdot \left(\lambda^H + ln \frac{\kappa z_0 u^H_0}{k^H} \right) = \frac{1}{\kappa u^H_0} \cdot ln \left[\frac{z_0}{z^H_0} \right]$$

$$SAI = 2n + 1 = 2 \cdot LAI + c\_Ind$$

$$S_0 = \frac{(SAI - 1) \cdot (SAI_\infty - 1)}{(SAI - 1) + (SAI_\infty - 1)} + 1 \quad \begin{cases} = 1 & , SAI = 1 \\ \rightarrow SAI_\infty & , SAI \rightarrow \infty \end{cases}$$



$$a_B + a_C = 1 = a^R_B + a^R_C$$

functions of SAI only

$$T_{i=n} = \blacksquare = a^R_B T_B + a^R_B T_C$$

$$T_{i=1} = T_B + \frac{i}{n} \cdot (T_R - T_B)$$

$$T_{i=0} = T_B$$

T_C, T_B

$$T_S = a_B T_B + a_C T_C$$

TURBTRAN: $T_A, q_{v_A}, p_A, (u_m, v_m)_A \rightarrow$ ■
$\quad S \quad v_{S^*} \quad S$

TERRA: $T_A, q_{v_A}, r^H_{S0}, r^H_{0A} \rightarrow$ ■
$\quad S$

valid for **next** time level may be **out of equilibrium**

valid for **this** time level,
associated to **current** **evapotranspiration**

used for **next** time level

- **Diagnostic of surface temperature:**

$$THF^0 = \left(SRF^0_{u,d} + LRF^0_d + PHF^0\right) + LRF^0_u + \partial_T\left[LRF^0_u\right] \cdot \left(T^0_R - T^0_S\right) + SHF^0 + LHF^0 \rightarrow ■$$

itype_surf=0

■ $= T_B$

itype_surf=1

$$T_C = T_B + \left(T_S - T_B\right)/a_C \qquad T_R = T_B + \left(T_C - T_B\right)\cdot a^R_C$$

$$\frac{(MC)_C}{\Delta t}\cdot\left(T_C - T^0_C\right) = THF^0 + \partial_{T_B}\left[LRF^0_u + SHF^0 + LHF^0\right]\cdot\left(T_B - T^0_B\right) + \partial_{T_C}\left[SHF^0 + LHF^0\right]\cdot\left(T_C - T^0_C\right) - \partial_T\left[GHF^0\right]\cdot\left(T_C - T_B\right)$$

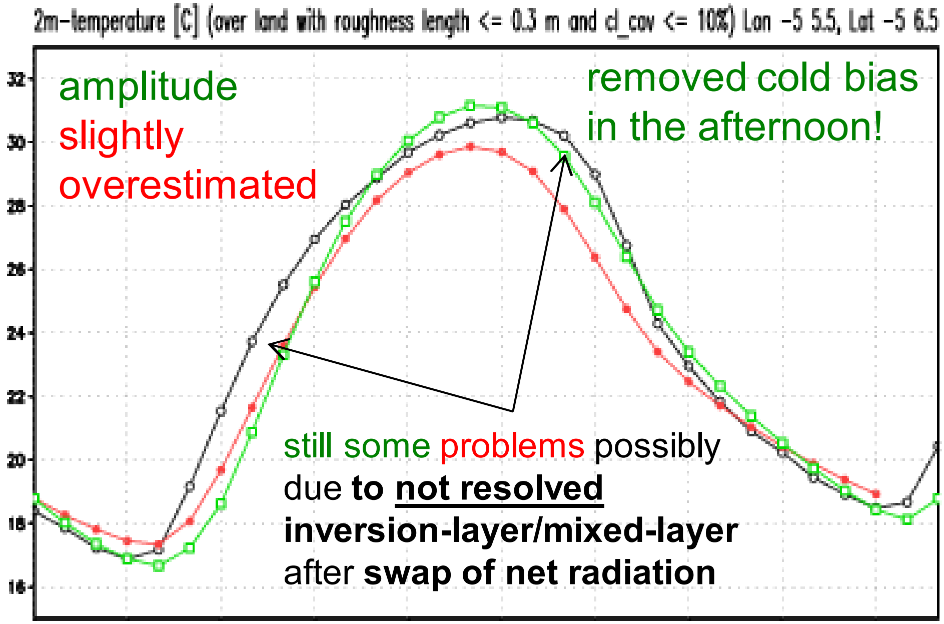
■ $= a_B T_B + a_C T_C$

COSMO-DE with lateral boundaries from ICON-EU

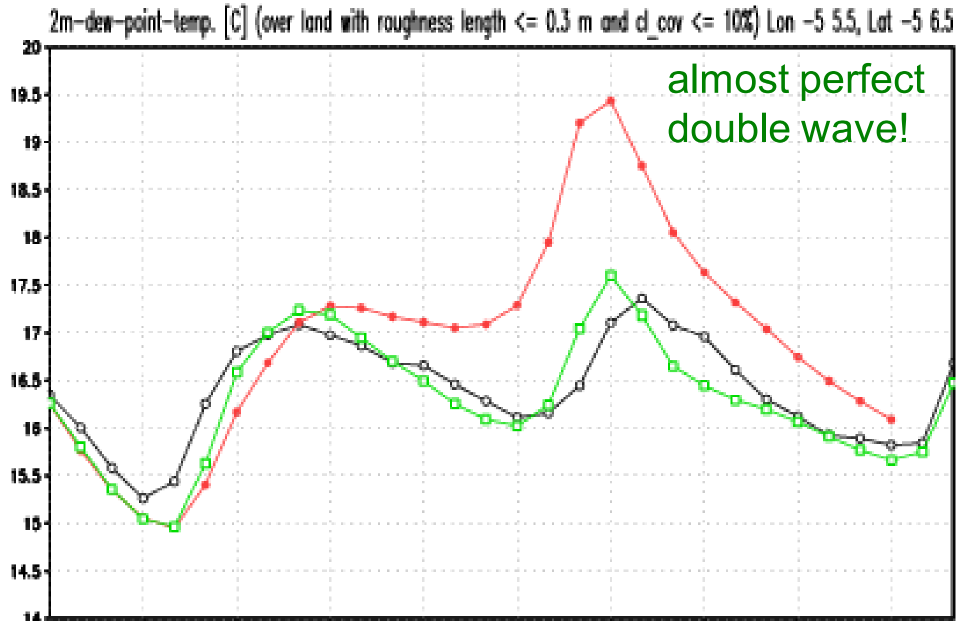
- ✓ only for rather smooth surfaces; applied filter
- ✓ almost saturated soil due to long standing rain period before
- ✓ almost no clouds due to high pressure situation; + applied filter

domain averaged daily cycles of near−surface variables

T_2m



TD_2m



— ana_lm3_exp_10279 — out_lm3_exp_10279 — out_lm3_rlmk_new_surf−icon−icon−itype_surf=1−lsfluse=T−e_surf=10−c_soil=2−itype_vdif=1

direct analysis of T_2m and TD_2m

revised TURBDIFF imported from ICON

revised TURBDIFF imported from ICON + new decoupled surface cover: $SAI_{\infty} = 10$

Subgrid scale thermal surface heterogeneity treatment in the turbulence scheme for stable PBL

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Ekaterina Machulskaya[3]

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[2] Arpae-Emilia Romagna SIMC, Italy
[3] Deutscher Wetterdienst, Germany

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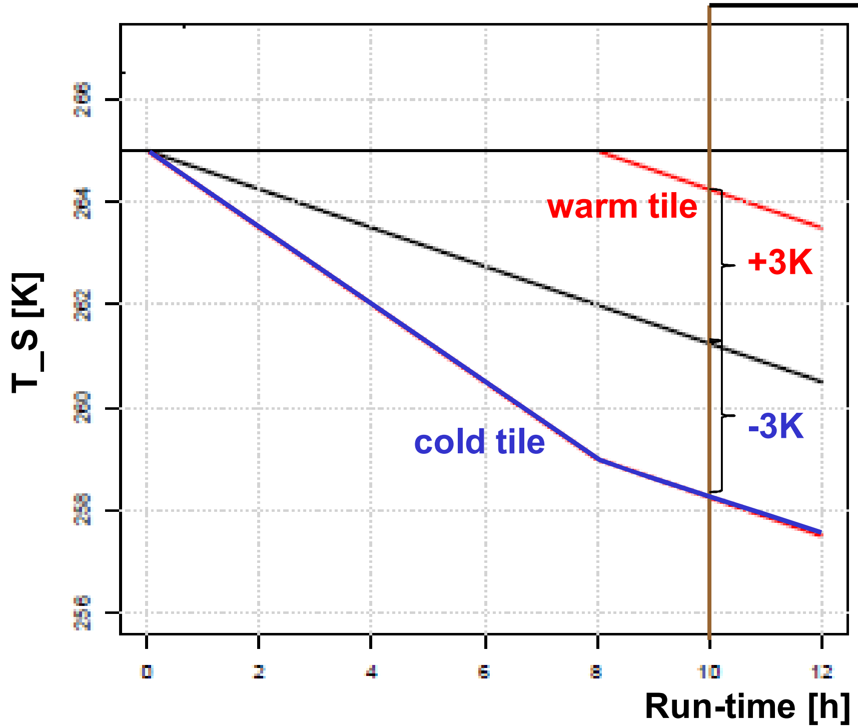
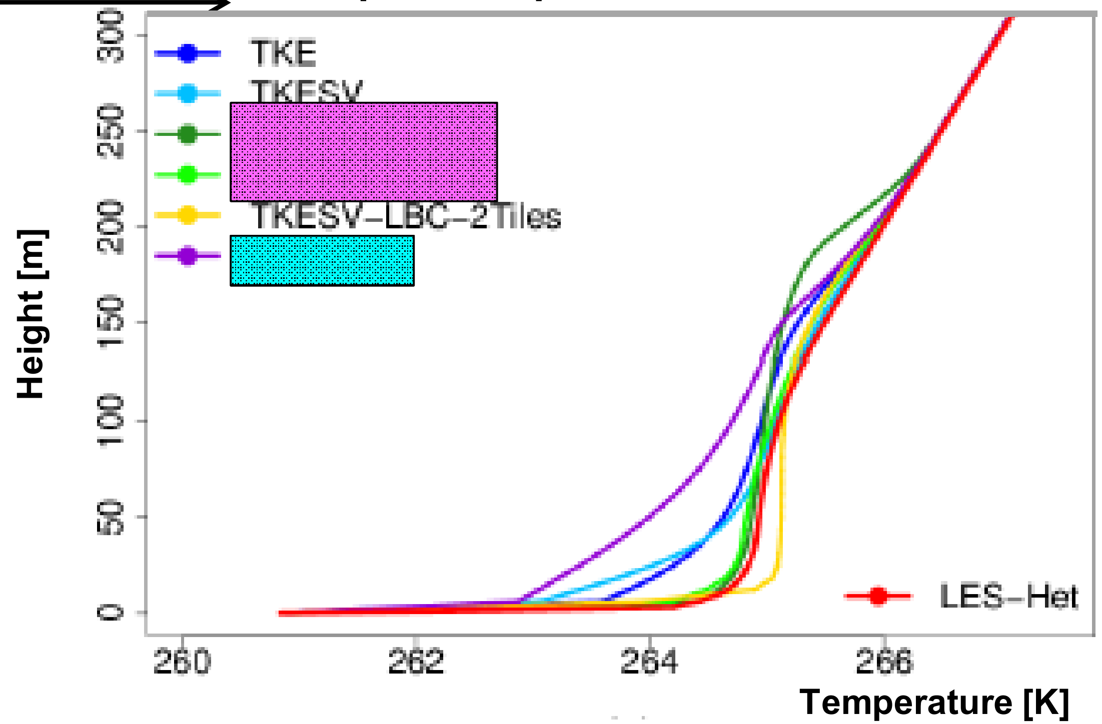
Idealized simulation of the stable BL above thermal surface patterns:

decreasing surface temperatures



temperature profiles after 10 hours



Experimental setup:

- simulation with COSMO-Single-Column
- representing column above a 400X400m² idealized flat surface
- with 100X100m² checker board elements (of ΔT_S=6K after 8h)
- using TURBDIFF (with):
  - surface tiling (2Tiles),
  - a STIC-term for thermal driven near surface circulations (Tcirc)
  - progn. scalar variances (SV), (with) Var(T_S) as lower BC (SBC)
- COSMO-LES: 3.125 m horizontal resolution

Results:

- patterns of T_S even sharpen decoupling of surface
- already represented by tiling

➢ non-linearity of "flux=K*grad(T)" dominates against extra mixing by thermal circulations

➢ Tcirc is a thermal SSO-term and (in contrast) produces MORE mixing. It should not be active at flat surfaces!

Physical Process in COSMO		Method		Name	Authors
Local Parameterizations of atmospheric source terms	**Radiation Transport**	δ two-stream; revised optical cloud properties			Ritter and Geleyn (1992) Blahak (->)
	Microphysics	1-moment; 3 prognostic ice phases; prognostic rain and snow			Doms (2004) Seiffert (2010)
		optionally 2-moment version			
Grid-scale Parameterizations of sub-grid scale atmospheric processes **(dependent on horizontal resolution)**	**any other not yet considered process (e.g. SSO driven thermal circulations or horizontally propagating GW)**				
	Convection — **deep** / **shallow**	2-class (updraft-downdraft) mass-flux equations with moisture convergence closure and simplified microphysics			Tiedke (1989), update by Bechthold et al. (2008) optionally
	Sub-grid Scale Orography (SSO) effects	orographic blocking and breaking of vertically propagating Gravity Waves (GW)			Lott and Miller (1997)
	Quasi-Isotropic Turbulence	2-nd order closure; progn. TKE with addit. scale-interaction terms (**STIC**); horizont. BL-approx. with opt. 3D-extensions; turb. sat.- adjustm.		TURBDIFF	Raschendorfer (2001,->)
	Surface-to-Atmosphere Transfer and Roughness Layer effects	transfer resistances based on constant **turbulent**/laminar diffusion fluxes normal to roughness-covering surfaces; separate heat budget of roughness elements (shading)	not yet tiled	TURBTRAN	
Modelling the Non-atmospheric part below the surface	**Vertical Heat and Water Transport of the Soil including Vegetation and a Snow-cover**	1- layer snow; m.- layer soil; freezing of soil water; resistances for vapor from stomata of leaves and soil pores; moisture and root mass dep. conduct.; coupled with roughness-layer concept		TERRA	Heise and Schrodin (2002), Schulz (2016, ->), Helmert (->), Raschendorfer (->)
		optional m.-layer snow			Maschulskaya (->)
	Heat Transport and Phase Change of Lakes	1-layer with an assumed shape function of temperature profiles; including freezing of lake water and a possible snow-cover		FLAKE	Mironov (2008)
	Heat Transport and Amount of Sea Ice				