WG3a-Activities and PT ConSAT:

- ✓ **Experiences with the stochastic boundary layer perturbation**
- ✓ **Results from monitoring the operational LPI in COSMO-DE**
- ✓ **Implementation of Tiedke-Bechthold Cumulus Convection Scheme**
- ✓ **Implementation and validation of the EDP-forecast derived from TURBDIFF within the ICON model**
- ✓ **Recent verification results of the common blocked TURBDIFF with COSMO-DE**
- ✓ **Towards a new diagnostic of equilibrium surface temperature in combination with SAT and the soil model**
- ✓ **Applicability of a tile approach in cases with stable stratification**

Matthias Raschendorfer

Boundary layer perturbations for convection triggering in COSMO-DE

Ulrich Blahak[2] (DWD), Kirstin Kober[1] (LMU)

[1] Original inventor
[2] Implementation and testing at DWD

Random perturbations

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Generation of perturbation fields:

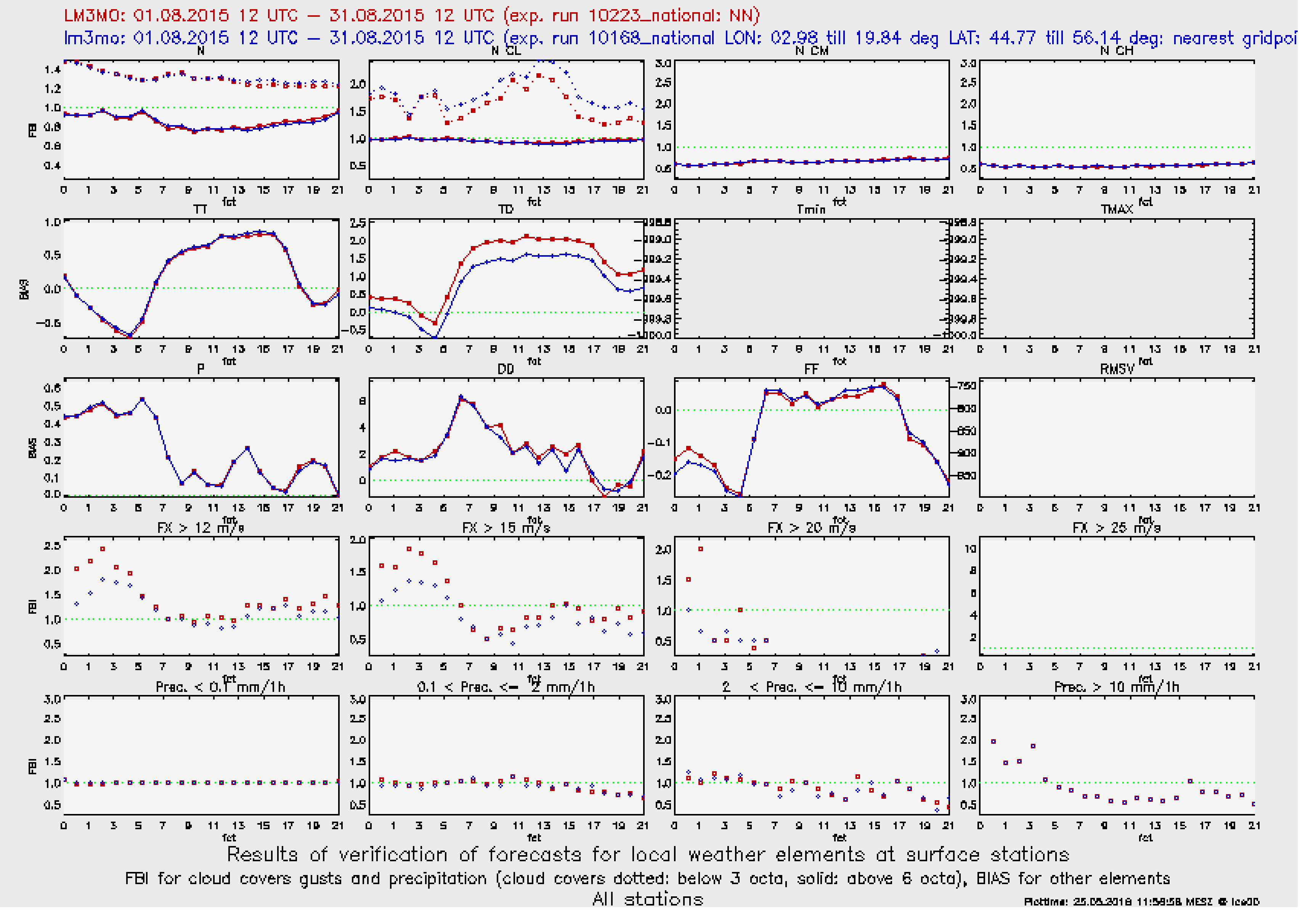
- stochastic pert. of T, qv and w in the PBL only, coupled to the variances of these quantities as derived in the turbulence scheme (Kober et al, 2015)
- original: $$\left(\frac{\partial\Phi(z,t)}{\partial t}\right)^{pert} = \left(\frac{\partial\Phi(z,t)}{\partial t}\right)^{phys} + \alpha_{sh}\eta_{sh}\langle\Phi'^2(z,t)\rangle^{1/2} \qquad \alpha_{sh} = \alpha_{sh,\Phi}\cdot\frac{\ell_\infty}{5\cdot dx}\cdot\frac{1}{dt}$$
  (Kober et al., 2015)
- modified: $$\left(\frac{\partial\Phi(z,t)}{\partial t}\right)^{pert} = \left(\frac{\partial\Phi(z,t)}{\partial t}\right)^{phys} + \alpha_{sh}\eta_{sh}\begin{cases}\max\limits_{[0,z]}\left[\langle\Phi'^2(z,t)\rangle^{1/2}\right] & , z_{k_e-1}\le z\le z_{pbl}\\ 0 & , z<z_{k_e}\wedge z>z_{pbl}\end{cases}$$
  (devel options by U. Blahak)
  $$z_{pbl} = \min\left[\max\left[\left\{z\,\middle|\,\frac{\partial\theta_v(z,t)}{\partial z}<0.001\,\mathrm{K}\right\}\right],\ 1500\,\mathrm{m\ AGL}\right]$$
- Φ = {T, qv, w}
- Stddev(Φ) diagnosed from turbulence scheme (only itype_turb=3)
- Choose space- and time-coherence scales for random number field below effective model resolution of these two quantities
- α_{sh} = namelist parameter (<= 5, otherwise danger of crashes!)
- η_{sh} = 2D random number field, smoothed by Gaussian kernel to generate coherent structures. Held constant for typical eddy turnover times (~10‘)

New namelist parameters (/RUNCTL/)

PARAMETER	DEFAULT	TYPE	MEANING
luseblpert	.FALSE.	L	Master switch
itype_blpert	1 *	INT	1 = original implementation 2…8 = modified options from devel
ladvect_blpert	.FALSE. *	L	If .TRUE. the random numbers η_{sh} are advected with the windspeed at level ke-10
blpert_sigma	2.5 *	REAL	STDDEV of Gaussian smoother for random numbers in units of grid points
blpert_const	2.0 *	REAL	$\alpha_{sh,\Phi}$
blpert_fixedtime	600.0 *	REAL	Time increment [s] of random number update (~eddy turnover time)
seed_val	-999	INT	If -999, use either model start time or system time for the initial random number seed
lseed_use_starttime	.TRUE.	L	If seed_val = -999: if .TRUE. ‚ydate_ini‘ determines seed, otherwise system time ‚DATE_AND_TIME()‘

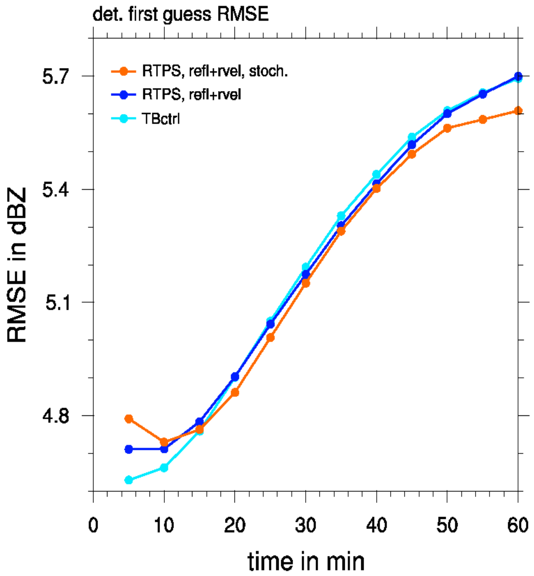
* If luseblpert=.TRUE., these defaults reproduce the orignial Kober (2010) settings, aside from the random seeding

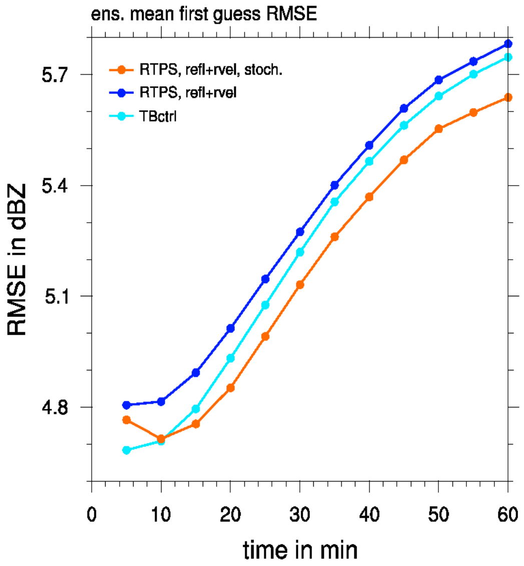
Experiment 10223 COSMO-DE driven by ICONEU with EDA for August 2015, comparison to 10168

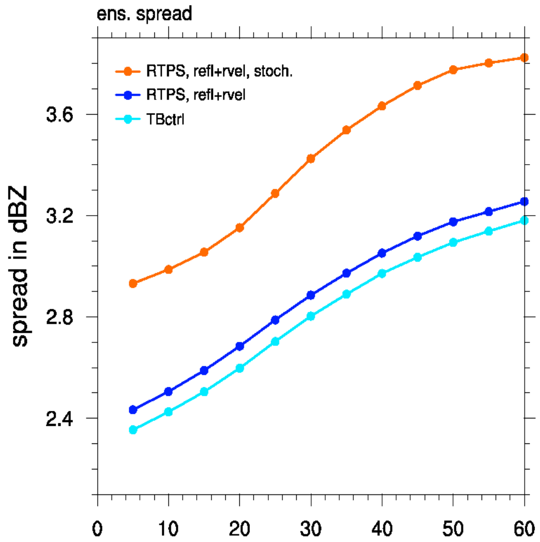


First COSMO-DE-KENDA experiment by Axel using (almost) the setup of Th. Bick

- Spread and RMSE in the 1 h assimilation cycle**: improved spread vs. RMSE**





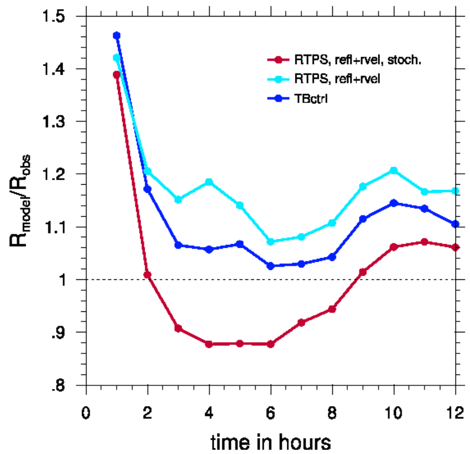


TBctrl = setup of Bick et al (2016) as reference
(no radial winds, RTPS)

Very strong spin-down, worse scores than without perturbations! This does not look good in the deterministic forecast.

Maybe perturbations are too strong and need another tuning. But maybe other effects at work!

domain averaged precipiation rate vs. obs.



Lightning Potential Index from COSMO-DE

Ulrich Blahak (DWD)

Concept of the LPI

- Yair et al. (JGR, 2010), Lynn and Yair (Adv. Geosci., 2010)
- Charge separation in thunderstorms is correllated with the **simultaneous presence** of **updrafts**, **supercoolded liquid water**, **graupel** and other frozen hydrometeor types („**cloud ice**“, „**snow**“)
- This concept was modeled by the authors within the LPI-Index:

$$\mathrm{LPI} = f_1 \, f_2 \, \frac{1}{H_{-20^\circ \mathrm{C}} - H_{0^\circ \mathrm{C}}} \int_{H_{0^\circ \mathrm{C}}}^{H_{-20^\circ \mathrm{C}}} \epsilon \, w^2 \, g_{(w)} \, dz$$

$$\epsilon = \frac{2\sqrt{q_L \, q_F}}{q_L + q_F}$$

$$q_L = q_c + q_r$$

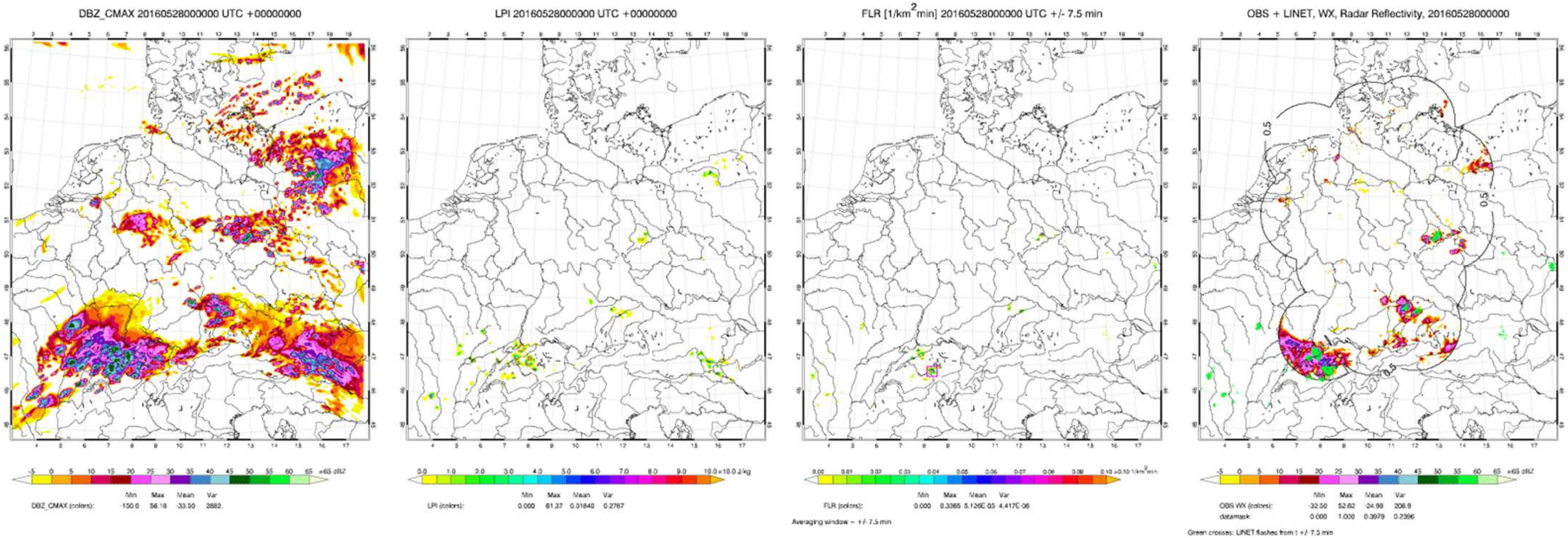
$$q_F = \frac{q_g}{2} \left[\frac{2\sqrt{q_i \, q_g}}{q_i + q_g} + \frac{2\sqrt{q_s \, q_g}}{q_s + q_g} \right]$$

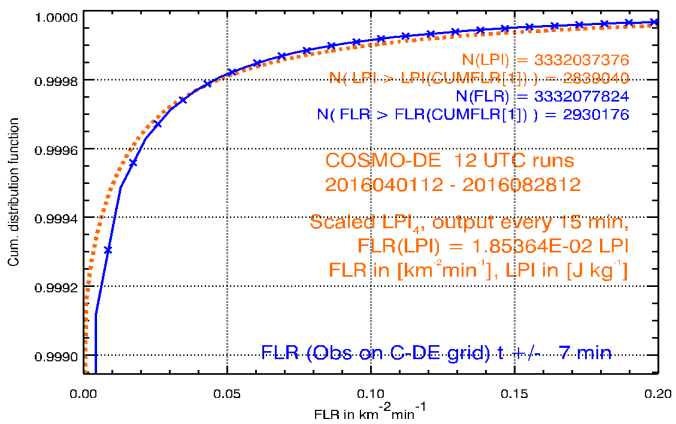
f_1, f_2 and g(w) see next-next slide!

COSMO-DE oper. forecast 28.5.-31.5.2016, combined 00 UTC runs until vv=23 h

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

sim. dBZ_max | **sim. LPI** | **obs. FLR t +- 7.5 min** | **obs. dBZ + LINET**





Probability-matched relation on COSMO-DE grid:

FLR in km^{-2} min^{-1} ≈ 0.017 * LPI in J/kg

➔1 flash per grid cell per 15 min (due to obs „+- 7.5 min“) equals LPI ≈ 2.0 J/kg

Summary

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

The comparison with lightning data (flash rates) „by eye“ shows:

➔Overall statistics of the space-time distribution of the LPI values > 0 corresponds well with that of the observed flash rates and suggests a simple linear probability-matched relation.

➔**LPI intimately tied to (and limited by) the explicit simulation of convective cells** in the model and its ice microphysics (updraft strength, supercooled liquid, graupel, cloud ice, snow). **Ensemble prediction like COSMO-DE-EPS**

➔LPI leads to different flash signals compared to, e.g., TQG or TOT_PREC alone. Not every convective cell, which has a high TQG, leads to an LPI signal.

➔Note: absolute LPI values have to be re-calibrated whenever the model‘s resolution or microphysics is changed.

➔Possibility to assimilate Lightning data based on presented statistical LPI-FLR-relation!

Implementation of ECMWF-IFS (Tiedtke-Bechtold) Cumulus Convection Scheme into COSMO

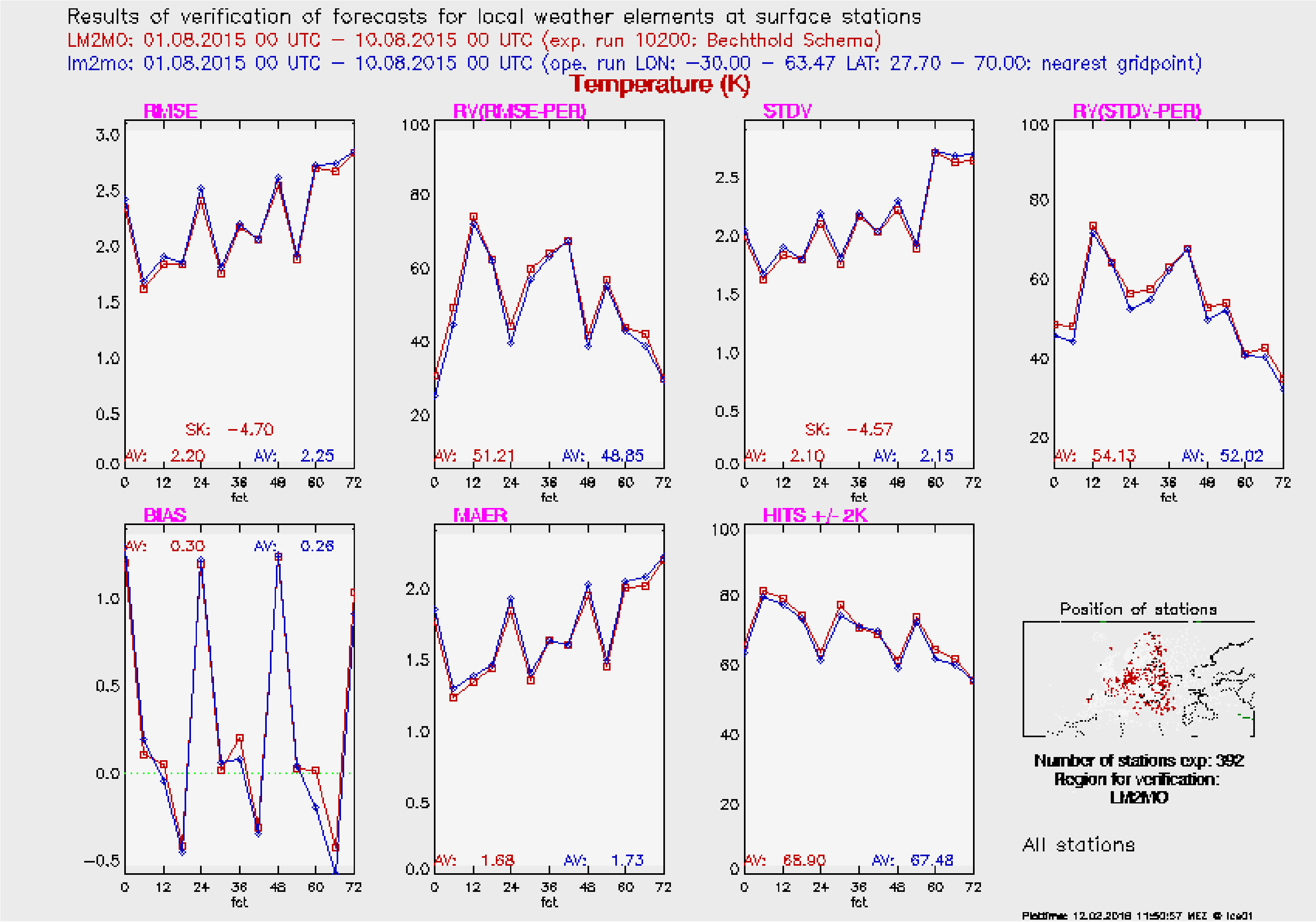
Jochen Förstner and Dmitrii Mironov

German Weather Service, Research and Development, FE14, Offenbach am Main, Germany

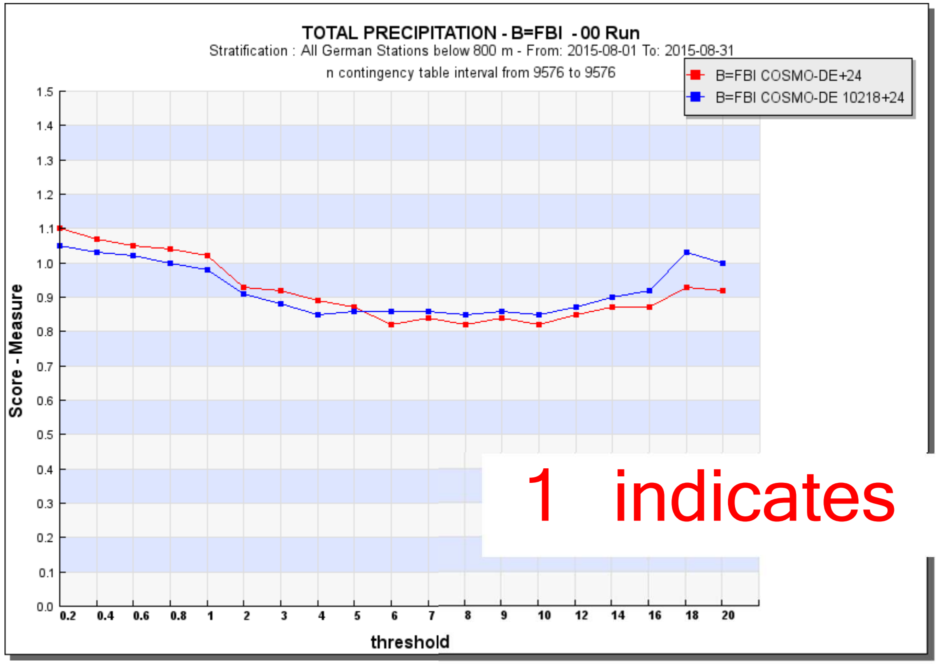
(jochen.foerstner@dwd.de, dmitrii.mironov@dwd.de)

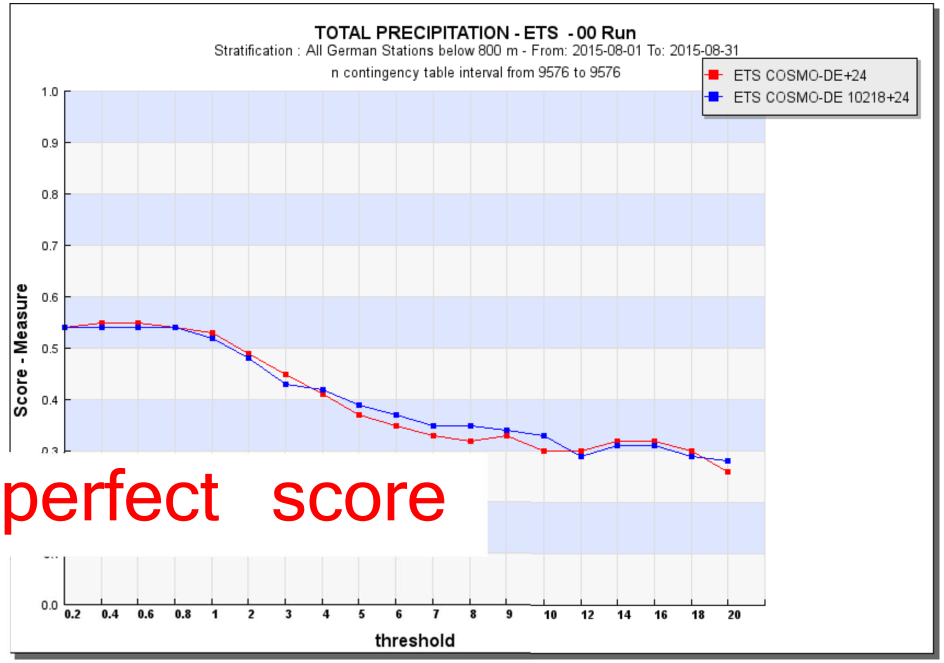
COSMO General Meeting, 5–9 September 2016, Offenbach am Main, Germany

COSMO-EU: Surface Verification (01-10.08.2015, COSMO-EU Domain, 00 UTC forecasts)

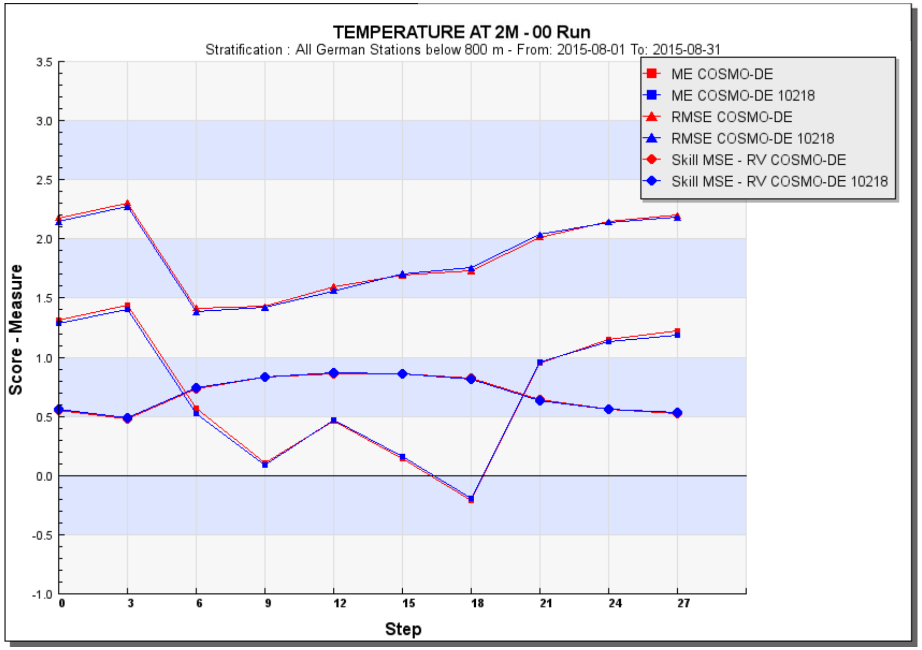


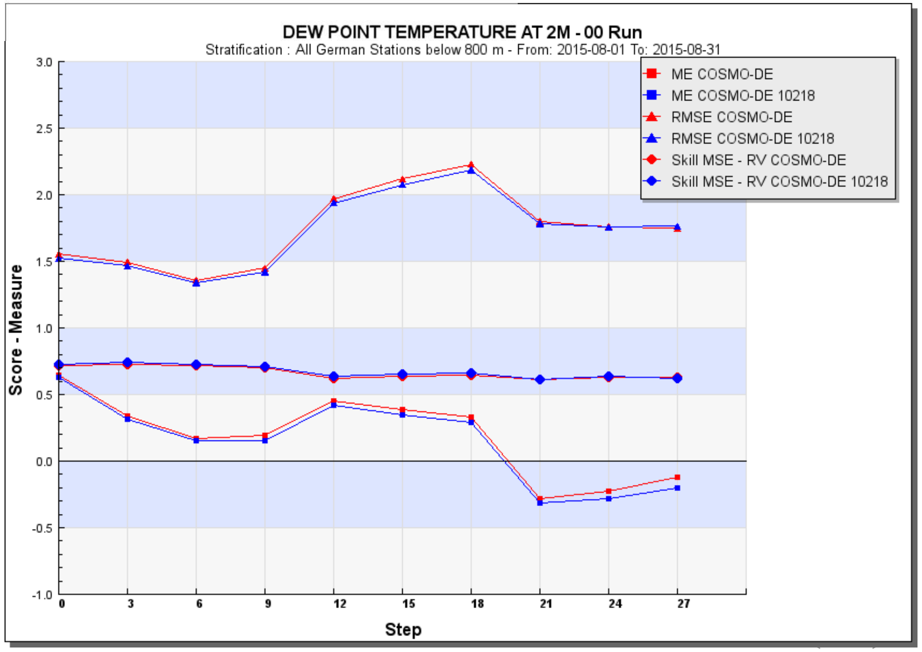
COSMO-DE: Surface Verification (01-31.08.2015, 00 UTC frsts)





1 indicates perfect score





- ECMWF-IFS (Tiedtke-Bechtold) cumulus convection is implemented into COSMO
- IFS scheme is included into the official COSMO code (version 5.05/5.04b)
- Results from test runs look reasonable; verification scores are neutral to slightly positive

In the future:

- Address drizzle problem (cf. ICON)
- IFS scheme may/should become a default option within COSMO (towards unified COSMO-ICON physics)

Global EDP forecasting with ICON – implementation and validation

Tobias Göcke & Ekaterina Machulskaya

FE14

COSMO Seminar WG 3a, 05.09.2016, Offenbach

EDR-Prognosis:

Enabled by the concept of :

separate parameterization of interacting scale regimes

above BL

POST { dTKEcon — **GRIB**; + dTKEshs — (GRIB) } + dTKEsso — (GRIB) = CShr

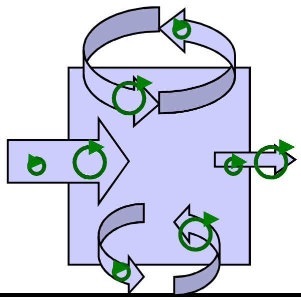
GRIB — $\partial_t(\rho \cdot TKE)$; (GRIB) — EDR

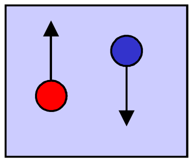
$$\partial_t(\rho \cdot \mathrm{TKE}) = \mathrm{Adv} + \mathrm{Dif} + \mathrm{Boy} + \mathrm{Shr} + \mathrm{CShr} - \mathrm{EDR}$$

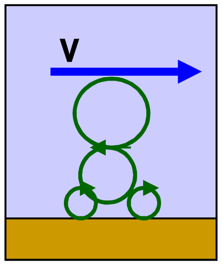
$$\mathrm{dTKEcon} + \mathrm{dTKEshs} + \mathrm{dTKEsso} = \mathrm{CShr}$$

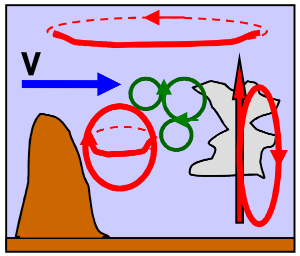
$$\partial_t\left(\bar{\rho}\cdot\frac{1}{2}\overline{q}|_L^{\,2}\right) = \frac{1}{2}\bar{\nabla}\cdot\left(\bar{\rho}\,\overline{q^2}|_L\,\hat{\tilde{\mathbf{v}}} + \sum_{i=1}^{3}\overline{\left(\rho v_i''^2\tilde{\mathbf{v}}''\right)}|_L\right) + \underbrace{\frac{g}{\hat{\theta}_v}\overline{\rho\theta_v''w''}|_L}_{=:\,-\bar{\rho}\,\overline{q}|_L\,\ell S^H F^H} + \underbrace{\left[-\sum_{i=1}^{3}\overline{\rho v_i''\tilde{\mathbf{v}}''}|_L\cdot\bar{\nabla}\hat{v}_i\right]}_{=:\,\bar{\rho}\,\Gamma\,\overline{q}|_L\,\ell S^M F^M} + \underbrace{\left[-\sum_{i=1}^{3}\overline{\overline{\rho v_i''\tilde{\mathbf{v}}''}|_L{}'\cdot\left(\bar{\nabla}\hat{v}_i\right)|_L{}'}\right]}_{=:\,\bar{\rho}\,\Gamma\,\overline{q}|_L\,\ell S^M F^M_C} + \left[-\bar{\rho}\frac{\overline{q}|_L^{\,3}}{\alpha^{MM}\ell}\right]$$

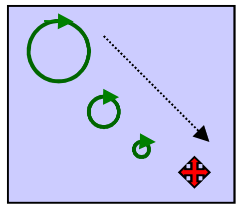
time tendency	transport (advection + diffusion)	buoyancy production	shear production by the mean flow	shear production by sub grid scale circulations	eddy-dissipation rate (**EDR**)
		labil: >0 neutral: $=0$ stabil: <0	≥ 0	≥ 0	<0









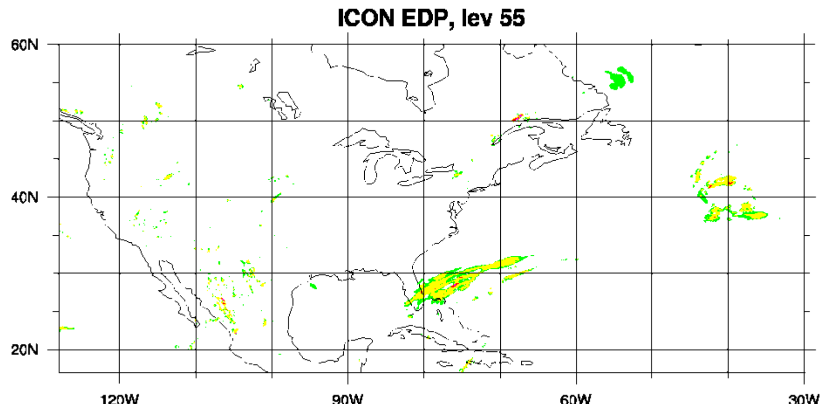


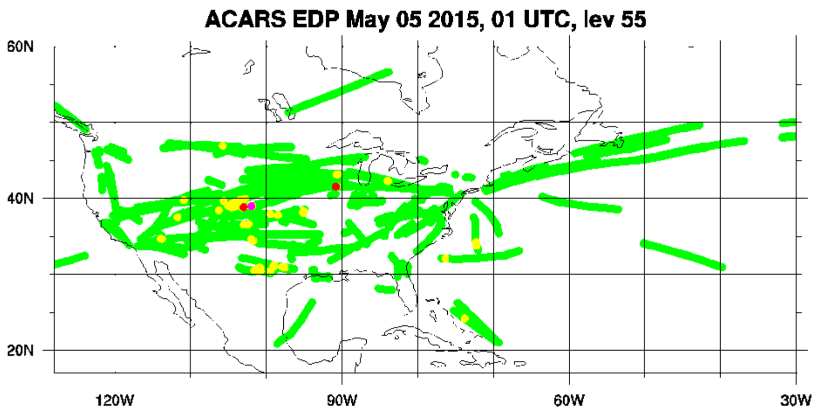
Convection as TKE source

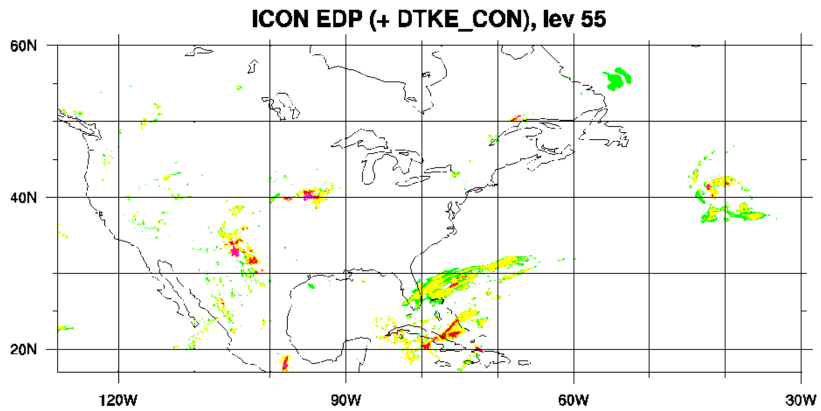
Turbulence observed in the neighbourhood of convective events

TKE production due to convection only diagnostically added in post processing so far

$$\mathrm{EDP} := \sqrt[3]{EDR + dTKEcon}$$







Verification: ROC

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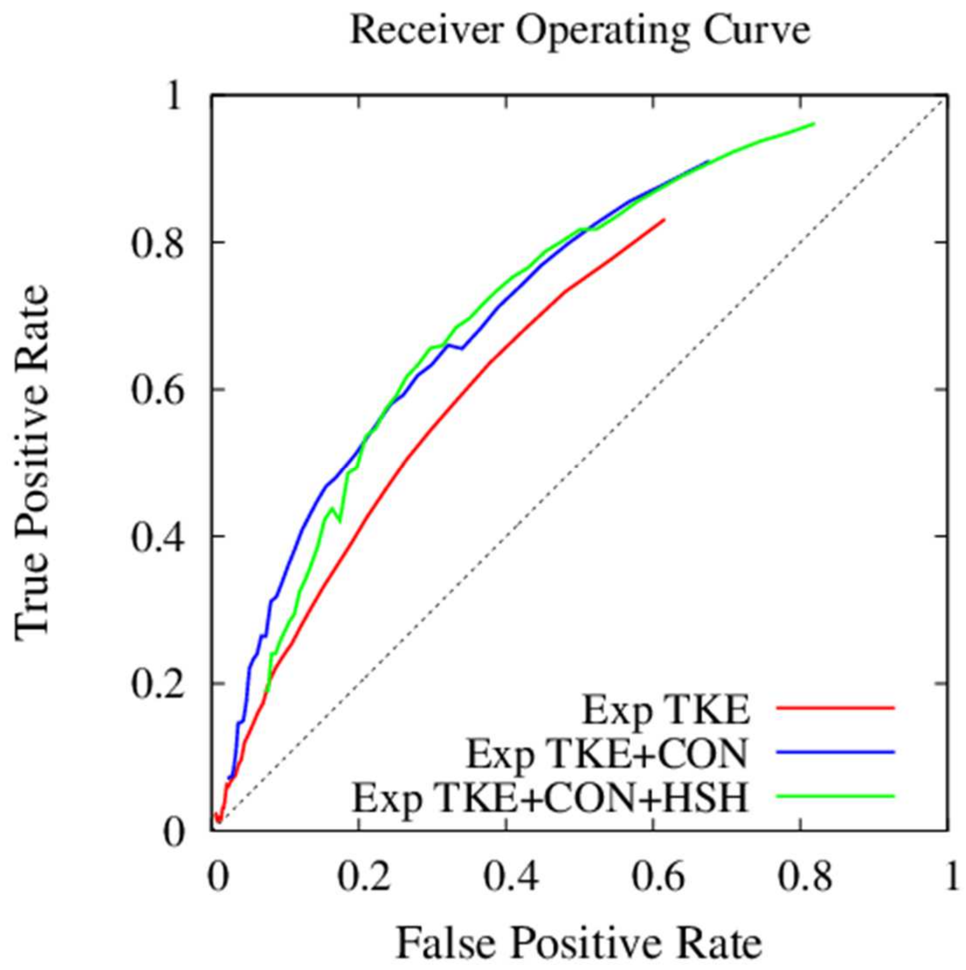
Wetter und Klima aus einer Hand



August – September 2015, USA

TKE already contais dTKEsso + dTKEshs

CON: dTKEcon added in postpocessing

HSH: additional dTKEshs-contribution in post-processing

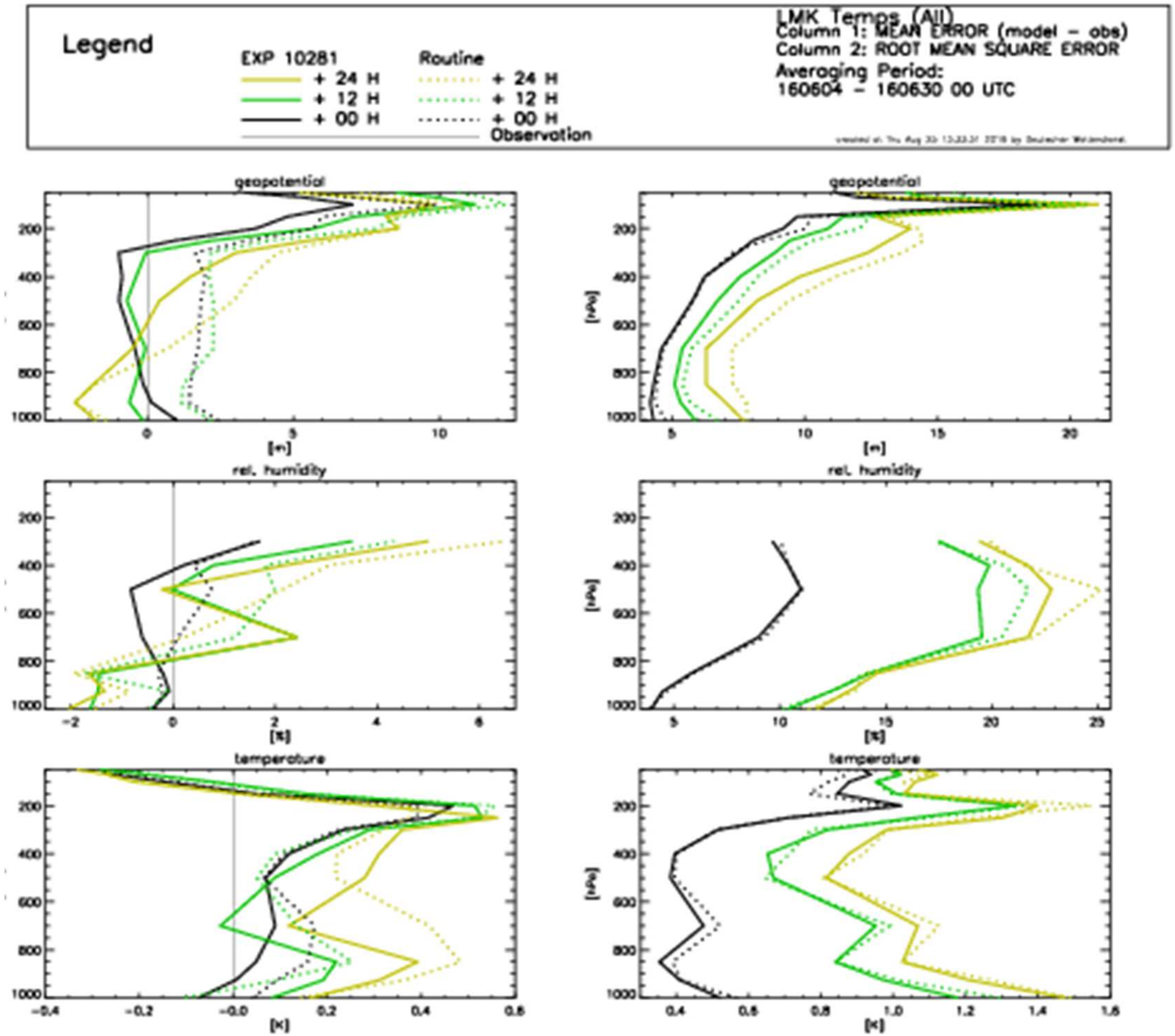
Work related to

PT ConSAT:

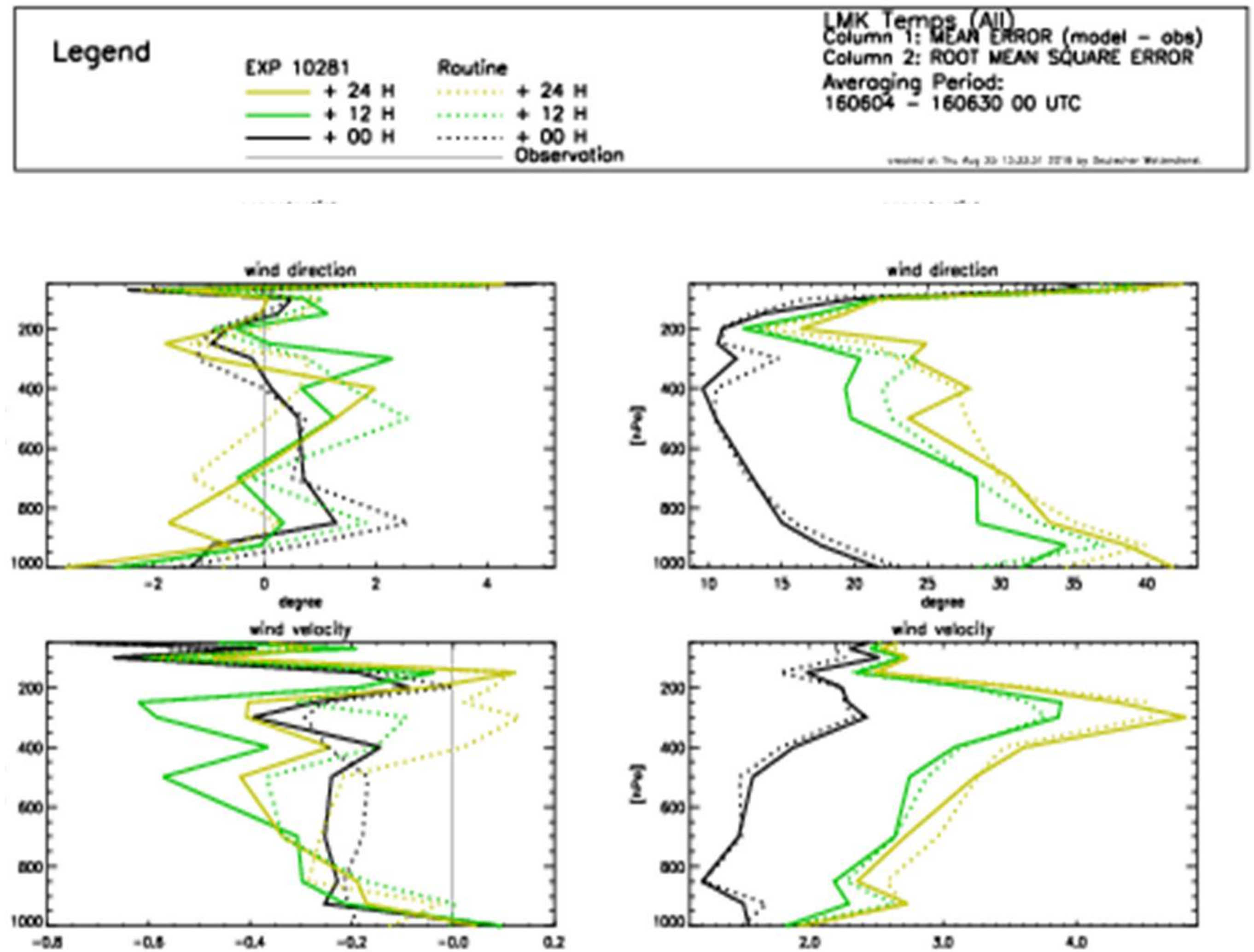
Recent verification results of the common blocked TURBDIFF with COSMO-DE:

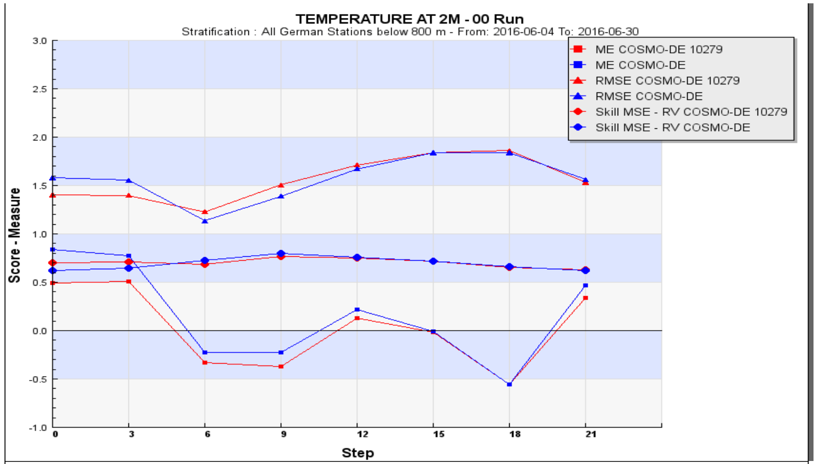
- ✓ **Exp 10279: Turbulence model and VDiff as in ICON**
- ✓ **Exp 10281: Turbulence model as in ICON; VDiff with current unblocked version**

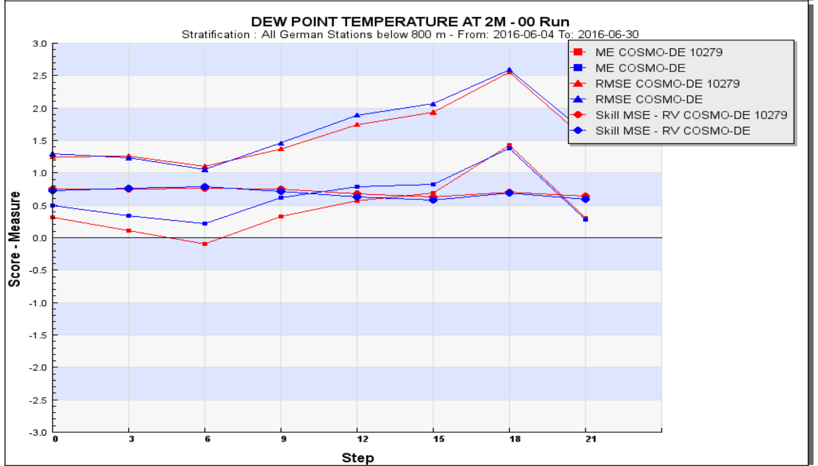
Matthias Raschendorfer

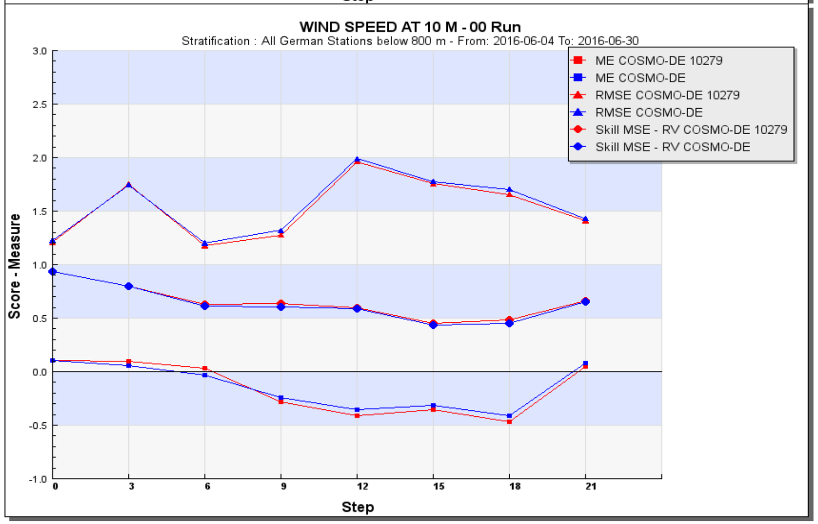


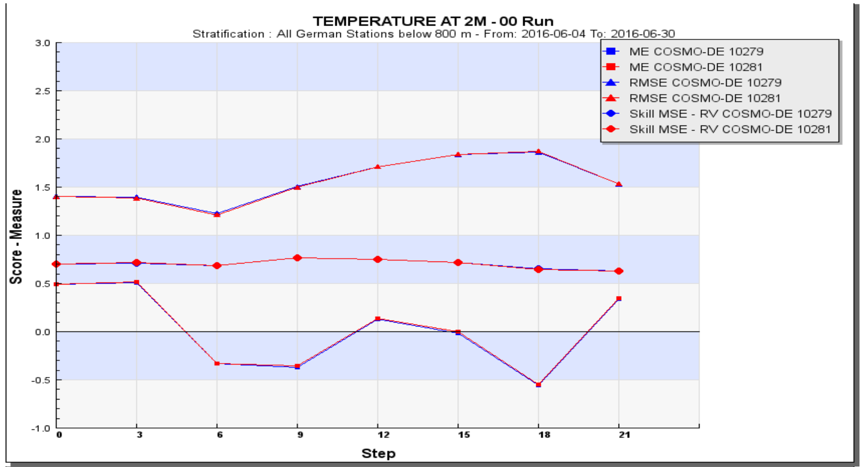
Legend
EXP 10281
+ 24 H
+ 12 H
+ 00 H
Routine
+ 24 H
+ 12 H
+ 00 H
Observation
LMK Temps (All)
Column 1: MEAN ERROR (model - obs)
Column 2: ROOT MEAN SQUARE ERROR
Averaging Period:
160604 - 160630 00 UTC
geopotential
[m]
rel. humidity
[%]
temperature
[K]
[hPa]

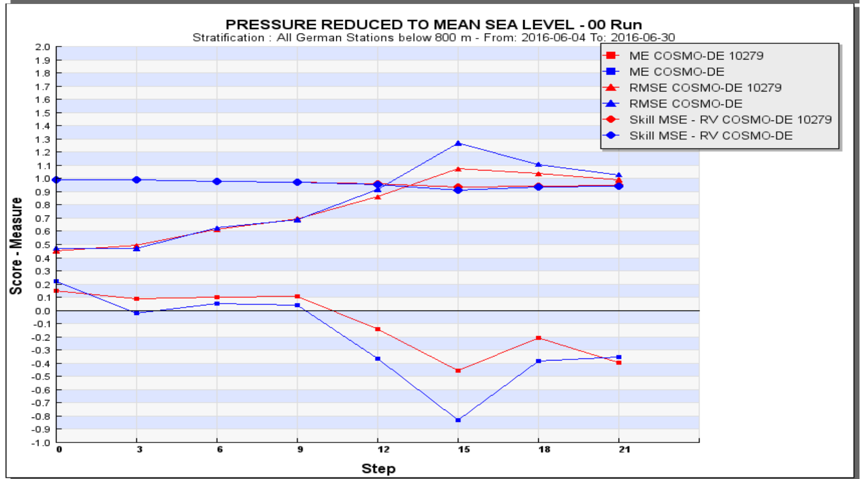

Legend
EXP 10281
+ 24 H
+ 12 H
+ 00 H
Routine
+ 24 H
+ 12 H
+ 00 H
Observation
LMK Temps (All)
Column 1: MEAN ERROR (model - obs)
Column 2: ROOT MEAN SQUARE ERROR
Averaging Period:
160604 - 160630 00 UTC
wind direction
degree
wind velocity
[hPa]

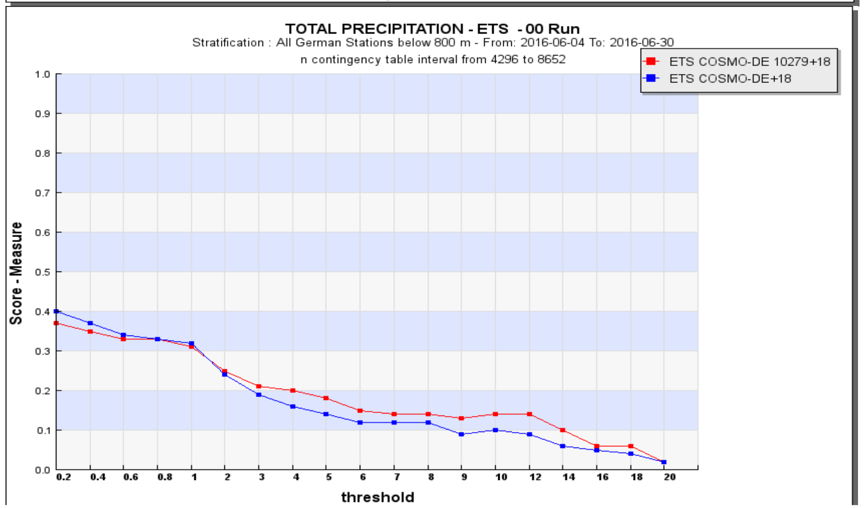

TEMPERATURE AT 2M - 00 Run
Stratification : All German Stations below 800 m - From: 2016-06-04 To: 2016-06-30
ME COSMO-DE 10279
ME COSMO-DE
RMSE COSMO-DE 10279
RMSE COSMO-DE
Skill MSE - RV COSMO-DE 10279
Skill MSE - RV COSMO-DE
Score - Measure
Step


DEW POINT TEMPERATURE AT 2M - 00 Run
Stratification : All German Stations below 800 m - From: 2016-06-04 To: 2016-06-30
ME COSMO-DE 10279
ME COSMO-DE
RMSE COSMO-DE 10279
RMSE COSMO-DE
Skill MSE - RV COSMO-DE 10279
Skill MSE - RV COSMO-DE
Score - Measure
Step

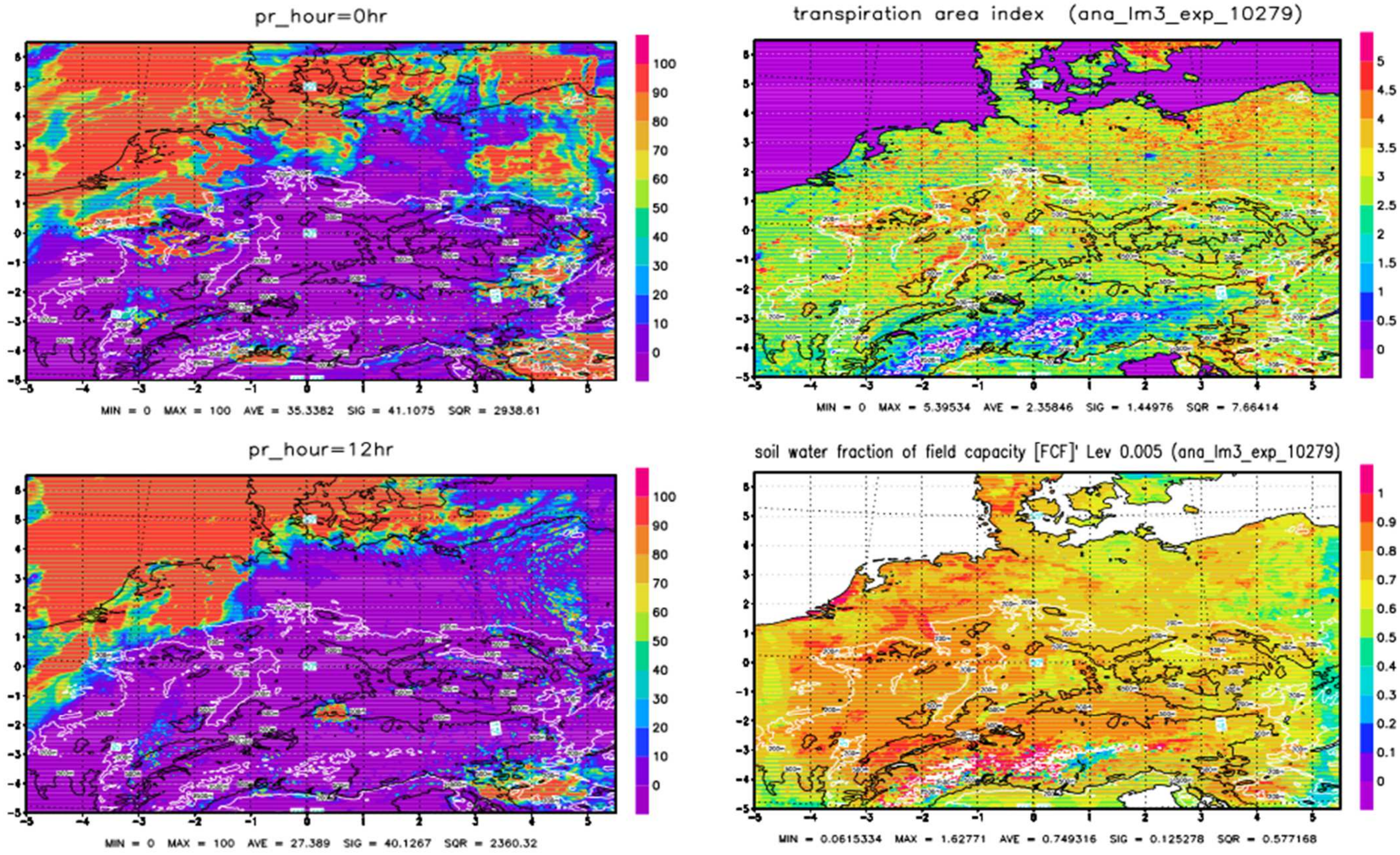

WIND SPEED AT 10 M - 00 Run
Stratification : All German Stations below 800 m - From: 2016-06-04 To: 2016-06-30
ME COSMO-DE 10279
ME COSMO-DE
RMSE COSMO-DE 10279
RMSE COSMO-DE
Skill MSE - RV COSMO-DE 10279
Skill MSE - RV COSMO-DE
Score - Measure
Step


TEMPERATURE AT 2M - 00 Run
Stratification : All German Stations below 800 m - From: 2016-06-04 To: 2016-06-30
ME COSMO-DE 10279
ME COSMO-DE 10281
RMSE COSMO-DE 10279
RMSE COSMO-DE 10281
Skill MSE - RV COSMO-DE 10279
Skill MSE - RV COSMO-DE 10281
Score - Measure
Step

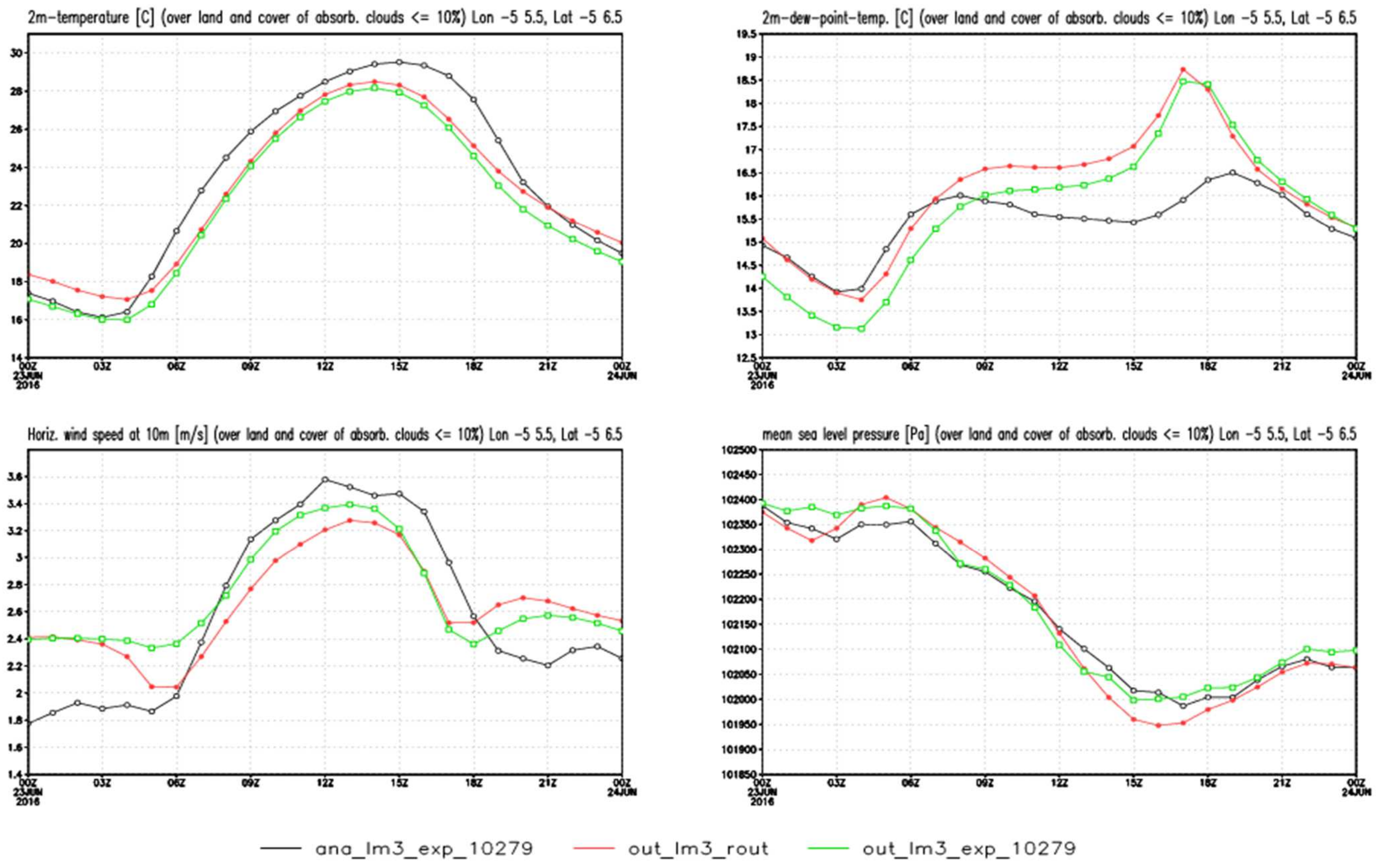

PRESSURE REDUCED TO MEAN SEA LEVEL - 00 Run
Stratification : All German Stations below 800 m - From: 2016-06-04 To: 2016-06-30
ME COSMO-DE 10279
ME COSMO-DE
RMSE COSMO-DE 10279
RMSE COSMO-DE
Skill MSE - RV COSMO-DE 10279
Skill MSE - RV COSMO-DE
Score - Measure
Step

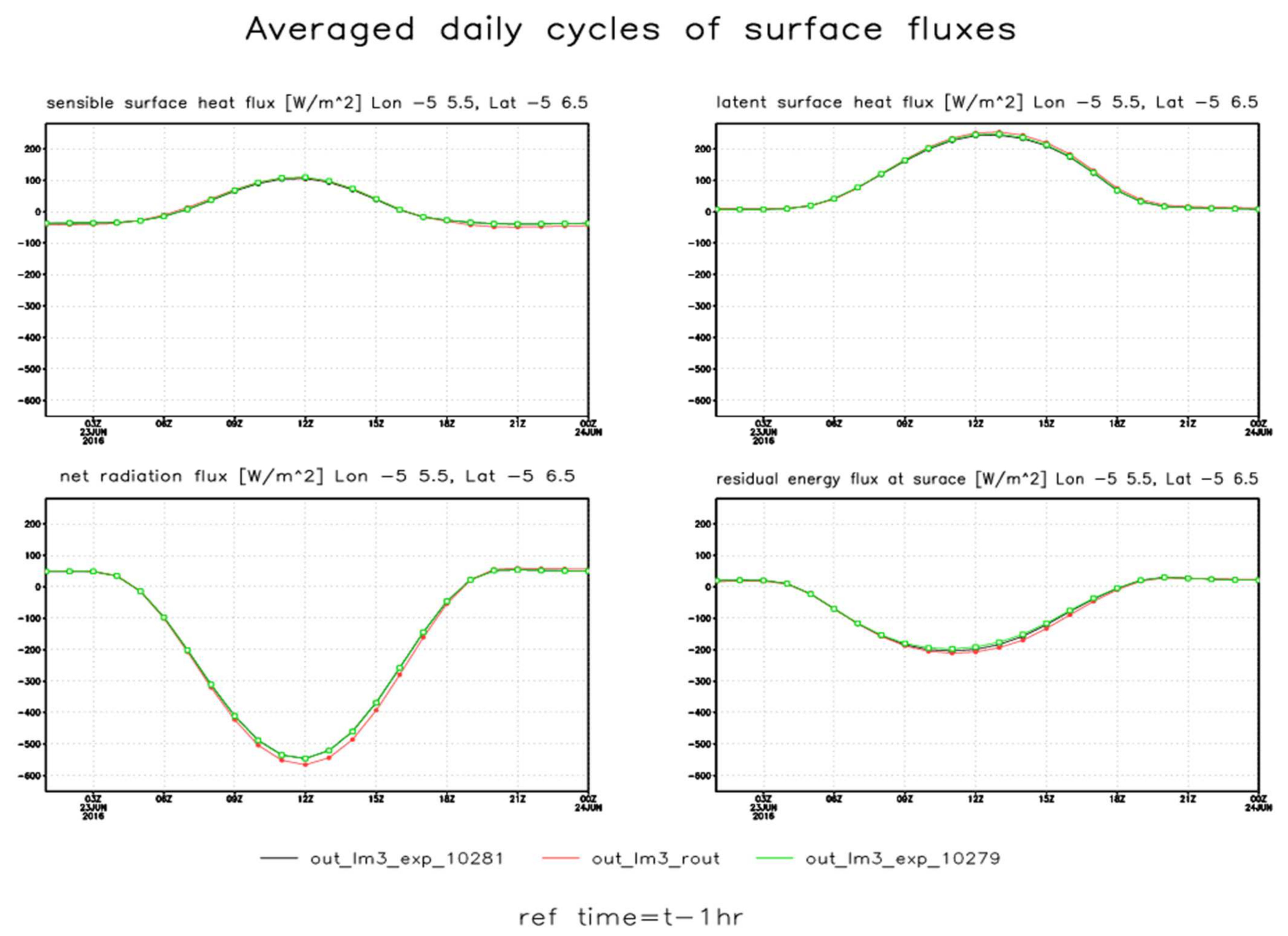

TOTAL PRECIPITATION - ETS - 00 Run
Stratification : All German Stations below 800 m - From: 2016-06-04 To: 2016-06-30
n contingency table interval from 4296 to 8652
ETS COSMO-DE 10279+18
ETS COSMO-DE+18
Score - Measure
threshold

low- and mid level cloud cover in %



st time=00Z23JUN2016 vers=ana lm3 exp 10279 domain averaged daily cycles of near-surface variables





Averaged daily cycles of surface fluxes
sensible surface heat flux [W/m^2] Lon -5 5.5, Lat -5 6.5
latent surface heat flux [W/m^2] Lon -5 5.5, Lat -5 6.5
net radiation flux [W/m^2] Lon -5 5.5, Lat -5 6.5
residual energy flux at surace [W/m^2] Lon -5 5.5, Lat -5 6.5
200
100
0
-100
-200
-300
-400
-500
-600
03Z 23JUN 2016
06Z
09Z
12Z
15Z
18Z
21Z
00Z 24JUN
out_lm3_exp_10281
out_lm3_rout
out_lm3_exp_10279
ref time=t-1hr

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

- ✓ **Completion of the roughness layer model**
- ✓ **Thermal decoupling of a Cover above the dense soil**
- ✓ **Representation of the thermal energy storage of the roughness layer**

Matthias Raschendorfer

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

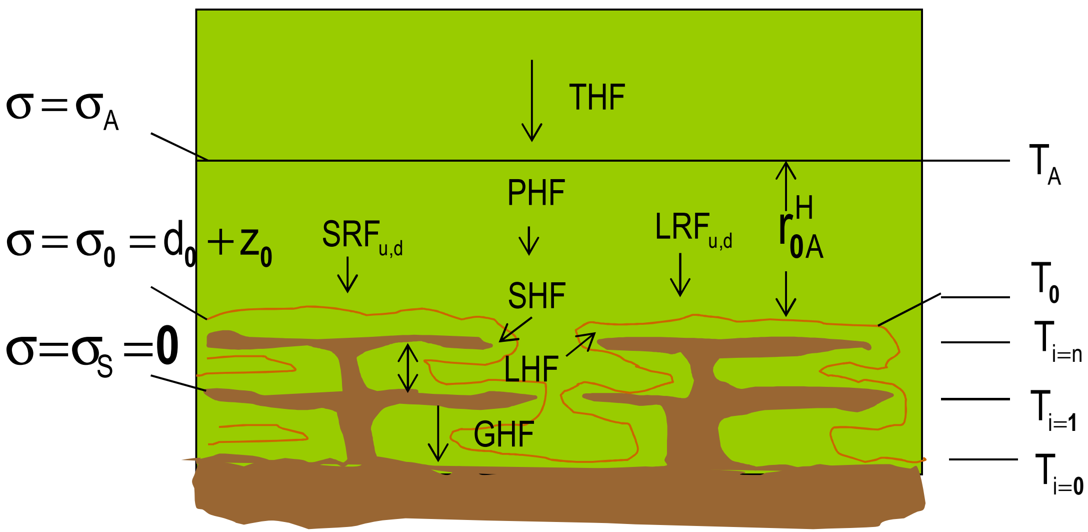
- Only **a part of the inner surfaces is connected to A** by the resistance chain, the **other part is for the inter- surface exchange** ⇨ Strongly effects the **LAI-impact of transpiration**!

$$r_{SA}^H = r_{S0}^H + r_{0A}^H$$

$$r_{S0}^H = \frac{1}{\kappa S_0 \cdot u_0^H} \cdot \left(\lambda^H + \ln \frac{\kappa z_0 u_0^H}{k^H} \right) = \frac{1}{\kappa u_0^H} \cdot \ln \left[\frac{z_0}{z_0^H} \right]$$

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

$$S_0 = \frac{(SAI-1)\cdot(SAI_\infty - 1)}{(SAI-1)+(SAI_\infty - 1)} + 1 \begin{cases} = 1 & , SAI = 1 \\ \xrightarrow[SAI\to\infty]{} SAI_\infty & \end{cases}$$



$$a_B + a_C = 1 = a_B^R + a_C^R$$

functions of SAI only

$$T_{i=n} = T_R = a_B^R T_B + a_B^R T_C$$

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

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

T_C

$$T_S = a_B T_B + a_C T_C$$

'turbtran': $T_{A}, q_{v_A}, p, (u_m, v_m)_A \rightarrow r_{SA}^{H,M}, tke_H, K_H^{H,M} \quad r_{0A}^{H,M}$

$\quad S \quad v_{S*} \quad S$

'terra': $T_{A}, q_{v_A}, r_{SA}^{H} \rightarrow$ $\quad S$

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

q_{vS} valid for **this** time level, related to **current evaporation**

$\vert\,\vert$

q_{vS}^{*} used for **next** time level

after tile loop: averaged grid cell values

- Diagnostic of surface temperature:

itype_surf=0 | itype_surf=1

$$T_C = T_B + (T_S - T_B)/a_C \qquad T_R = T_B + (T_C - T_B)\cdot a_C^R$$

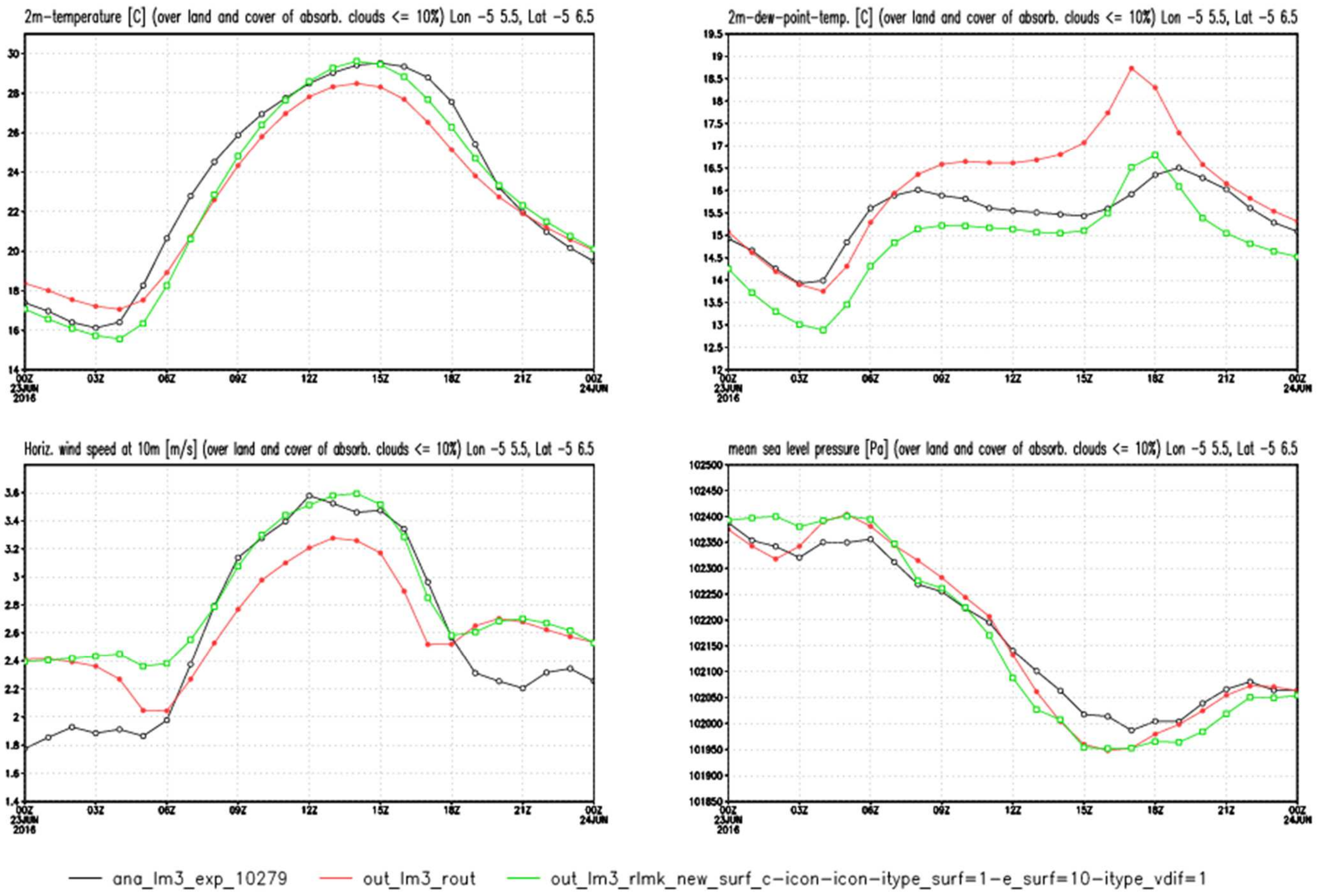
$$THF^0 = \left(SRF_{u,d}^0 + LRF_d^0 + PHF^0\right) + LRF_u^0 + \partial_T\left[LRF_u^0\right]\cdot\left(T_R^0 - T_S^0\right) + SHF^0 + LHF^0 \rightarrow T_B$$

$$T_S = T_B$$

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

$$T_S = a_B T_B + a_C T_C$$

domain averaged daily cycles of near–surface variables



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

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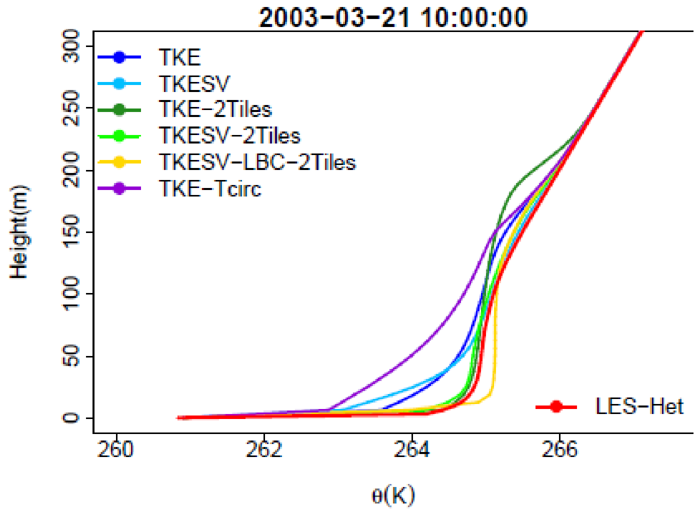
Which tools does COSMO need to simulate the effect of the subgrid thermal heterogeneity of the surface in stable situation?

Method: To compare COSMO-LES and COSMO in idealized case studies, testing the available tools (thermal circulation parameterization in turbulence code) and possibly coming tools (tile approach, turbulence scheme with prognostic scalar variance equations).

- **COSMO+Tile** already catches the general features (eg. less stable profile) but overestimates turbulent diffusion
- **COSMO+Tile+TKESV** improves the Tile performance (reduced overestimation of turbulent diffusion)
- **COSMO+Tcirc** does not catch the general features ↔ it is designed as a thermal SSO-term!



Next: consider different stratification intensities and heterogeneities