Priority Task: Terra Nova – Final Report

06/08/2019

Task Leader: Yiftach Ziv (IMS)

Goal:

Testing the new version of the soil module - TERRA

Task	Contributing Scientist(s)	FTE-Years	Start	Deliverables	Date of Delivery
0	Y. Ziv (IMS) A. Shtivelman (IMS)	0.08 0.07	9.2016	COSMO environment set up in ECMWF computational centre, enabling test runs of the task -	2.2017
1	Y. Ziv (IMS) I. Rozinikina (RHM) M.Nikitin (RHM) Y. Levi (IMS) J.M Bettems (MCH) J. Helmert (DWD) J. P. Schultz (DWD)	0.48 0.05 0.20 0.01 0.07 0.02 0.02	1.2017	(1) A set of simulations based on the reference COSMO/TERRA v5.00, and the associated observation listed in the previous table, available for further studies. (2) A set of simulations based on COSMO v5.05 with new and old TERRA module and turbulence scheme to assess the contribution of each factor to change in simulations results. (3) Documenting the differences between the various versions of TERRA and standard near surface measurements in terms of RMSE, MBE and other scores used, for instance, by MCH "Movero" (standard verification). (4) Documenting the differences in land surface temperature between the three versions of TERRA and CM-SAF data base, according to CM-SAF validation methods (Anke et al. 2016).	06.2019

Status report of Sub-Tasks:

Task0: Securing computational resources for execution of simulations

Deliverables:

(1) COSMO environment set up in ECMWF computational centre, enabling runs of the task

(2) Securing enough billing units for execution of the PT.

Status:

- Environment for running COSMO simulations on ECMWF computation centre was set up. Prolongation of the task resulted in introducing new versions of int2lm which required adaptation of the environment during the period of the task
- Extensions of the task raised the need for additional Billing Units, which were promptly secured by MeteoSwiss. A total of ~15 Million BUs were used for the task.

Task1: Compare various TERRA versions over various domains

Deliverables:

Subtask 1.1: Defining and executing the simulations.

Subtask 1.2: Verification of the simulations and documentation of the main differences.

a. A set of simulations based on the reference COSMO/TERRA v5.00.
b. A set of simulations based on COSMO v5.05 with new and old TERRA module and turbulence scheme to assess the contribution of each factor to change in simulations results.
c. Documenting the differences between the various versions of TERRA and standard near surface measurements in terms of RMSE, MBE and other scores.
d. Documenting the differences in land surface temperature between the three versions of TERRA and CM-SAF data base, according to CM-SAF validation methods (Anke et al. 2016).

Status:

- The task was greatly delayed because of a late delivery of v5.05 which is crucial for this task.
- Once v5.05 was officially released, the simulations to be tested within this task were determined.
  3 domains were selected: Mediterranean (MED), Central Europe (EU), North-East-Europe (NE);
  2 resolution for each domain: ~6.5km and ~2.5km;
  for each domain and resolution a "Reference" model version was simulated: v5.00 was utilized in MED & EU domains for compatibility with GPU. V5.03 was utilized in NE domain for compatibility with RHM system and tools.
  Over MED & EU domains and resolutions 3 additional configurations of v5.05 were simulated,

while over NE domain 2 additional configurations for the 2.2km resolution were simulated:
"Basic" – v5.05 set-up as close as possible to reference simulation i.e. old TERRA, old turbulence scheme and old aerosol scheme. This configuration was simulated only for MED & EU domains;
"Adv. Old Turbulence" – v5.05 with new TERRA features and set up, but old turbulence scheme and old aerosol scheme;
"Advanced" – v.5.05 with all new features of v5.05, excluding bare-soil evaporation scheme which crashed the simulation after 8 months.
For the full description of the various domains, resolutions and configurations please refer to appendix 1.

- Simulations were all executed in hindcast mode – 24h in a time. Boundary conditions were obtained every 3 hours from IFS analysis (00Z, 12Z) and forecast (all other). ICON data was used for NE domain in the same manner. Atmospheric initial conditions were also supplied from IFS (ICON for NE domain), but the soil temperature and water content were transferred from the previous day, thus enabling the state of the soil to develop solely by the examined model, while keeping the atmosphere "updated". It is worth mentioning that no Soil Moisture Analysis was used for none of the simulations.
- Soil and surface parameters were obtained from ICON for MED & NE domains (IFS soil parameters are practically unusable). For EU domain, soil data was obtained from MeteoSwiss archived data. Each simulation was started a few months prior to the desired period in order to allow some spin-up of the soil. Thus, EU & NE simulations started at autumn, while the examined period was spring and summer, while MED simulations started in January, for examination period starting in March, because there is no thawing in this domain. All in all, the equivalent of 292 months (24.25 years) were simulated, using 18 Million Billing Units on ECMWF HFPC (allocated by MeteoSwiss for the task) and additional computing resources from RossGydroMet for the NE domain.
- Due to the characteristics of the NE domain (i.e. vicinity to Freezing seas and many large water bodies), both the sea-ice scheme (lseaice=TRUE) and lake scheme (llake=TRUE) were activated. The initial conditions for the lake parameterization were set during the “cold start” procedure, which assumes that lakes have neutral stratification of water. Such stratification is observed during spring and autumn, that’s why such beginning days of experiments for NE domain were selected. Lake fields were saved on day-to-day basis and were used as initial conditions for calculations for the next day similar to the soil fields. In addition, both stomata resistance and emissivity maps were switched off for the NE domain (lstomata=FALSE, lemiss=FALSE).
- Coarser resolution of the EU domain was also used to compare COSMO-TERRA v5.00 results with COSMO-CLM Community Land Model (COSMO CLM^2) in weather mode results. This

comparison was made in ETH Zurich by Verena Bessenbacher – a student in Prof. Sonia Seneviratne's group. Some of the results are discussed hereafter.

- Verification for MED & EU domains was conducted for surface temperature and relative humidity and soil temperature and water content using Matlab code developed in IMS, while the VERSUS tool was used for the NE domain.

  For the MED & EU domains a comparison to in-soil measurements was also performed.

  For the EU domain in coarser resolution, a comparison with gridded data from various sources was performed by ETH Zurich group.

  A taste of some of the results is available in appendix 2.
- Discussing verification results:
  - There is no "clear-cut" differences between the various configurations over the domains and resolutions.
  - In EU & NE domains, some cooling at night is evident in v5.05 configurations – this is a desired outcome of the new version. This cooling is not evident in the MED domain.
  - In EU domain appears an excess cooling and moistening at 18Z for the "Advanced" version. This effect is observed also in ICON and it is probably due to an exaggeration in transfer coefficient values during sunset. In NE domain a moistening is evident, but only minor cooling, while in the MED domain no cooling nor moistening is evident in the evenings.
  - Soil parameters (temperature and water content) do not differ much between the various versions and are in accordance with soil measurements (MED & EU domain only). In any case, even in the "Advanced" configuration, no drying of the soil is evident, unlike the soil behavior in ICON.
  - Comparing COSMO-TERRA (6.5km resolution) results to COSMO-CLM results, performed in ETH Zurich by Verena Bessenbacher show "overshooting of sensible heat production at the expense of evapotranspiration. Additionally, COSMO-TERRA increases in error of latent heat estimation with LAI and summer heat, while COSMO-CLM is more robust. It is also shown that Enhanced surface energy balance representation in COSMO-CLM did, quite non-intuitively, not translate into a better temperature representation. COSMO-CLM is constantly colder than COSMO-TERRA, most pronounced in the Mediterranean. This cold bias is beneficial to model performance compared with EOBS, but degrades model performance compared to SLST. COSMO-CLM outperforms COSMO-TERRA at 2 meters except for maximum temperatures, and COSMO-TERRA outperforms COSMO-CLM for radiative temperatures, except for minimum temperatures." (Bessenbacher, 2018).

It is noticeable however, that COSMO-CLM boasts a much more elaborated surface-vegetation-atmosphere scheme, which makes the above results more sensible.

Conclusions:

- Various configurations of v5.05 do not differ much from one another, nor from the reference version, at least in the parameters examined within the task. While the down side is that it shows no improvement in results, it also shows no significant hampering, meaning these configurations, and mainly the "Advanced" configuration can be used operationally.
- It seems that EU & NE domains do share some behavior, i.e. cooling in nights, moistening in evening, while MED domain do not exhibit such characteristics. It may be speculated that this is related to the greater portion of bare soil in the MED domain. A failed attempt was made to run a simulation with the new bare soil parametrization (itype_evsl=4), so it remains unclear whether this is truly the reason.
- No significant drying of the soil is evident in the "Advanced" configuration as witnessed in DWD previous experiments. In fact, in NE domain some moistening of all levels of the soil by newer version is evident. This suggests, again, that this version is "safe" to use even without Soil Moisture Analysis (or any other form of soil data assimilation).
- No major differences are witnessed across domains, suggesting that these versions are robust enough
- Introducing skin conductivity scheme (v5.06) and bare-soil evaporation scheme (itype_evsl=4) will most probably improve on some of these results.
- A better representation of the surface-vegetation-atmosphere interface, either by introducing turbulence scheme developed by Matthias Raschendorfer, or by adopting some schemes from COSMO-CLM, will most probably improve on some of these results as well.
- A common verification tool for the entire COSMO community is well needed (VERSUS could not be installed in IMS & MCH).

Bibliography:

- Anke D. T., Jedrzej B., Frank G., Isabel T., 2016, *Validation Report- Meteosat Land Surface Temperature- Edition 1*, EUMETSAT Satellite Application Facility on Climate Monitoring (CM-SAF), DOI: 10.5676/EUM_SAF_CM/LST_METEOSAT/V001.
- Bessenbacher V., 2018, Comparison of COSMO-TERRA and COSMO-CLM2 in weather mode for summer heat extremes. Master Thesis, ETH Zurich
- COSMO Documentation.

APPENDIX 1 – Simulations Setup

List of Configurations*:

EU & MED Domains

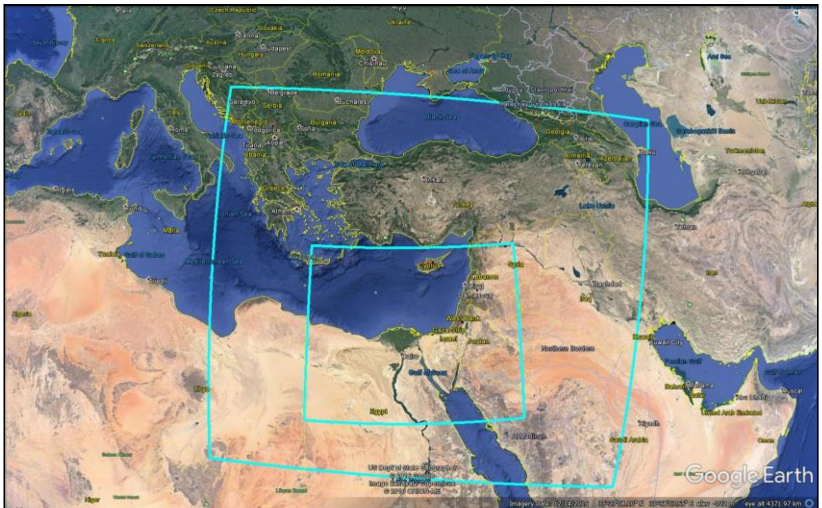
		V5.00	V5.05		
Namelist parameter	Module	Reference	Basic	Adv. Old Turb	Advanced
/TUNING/					
tkhmin	Turbulence	0.4	0.4	0.4	0.75
tkmmin		0.4	0.4	0.4	0.75
rat_sea		20.0	20.0	20.0	7.5
patlen		500.0	500.0	500.0	750
turlen		150.0	150.0	150.0	500
a_hshr		0.2	0.2	0.2	2.0
c_soil		1.0	1.0	1.0	1.75
/PHYCTL/					
loldtur	Turbulence	N/A	TRUE	TRUE	FALSE
itype_vdif		-1	-1	-1	-1
ltkeshs		FALSE	FALSE	FALSE	TRUE
itype_sher		1	1	1	0
imode_tran		1	1	1	0
imode_turb		1	1	1	1
icldm_tran		0	0	0	2
itype_aerosol	Aerosol	1	1	1	2
itype_root	TERRA	1	1	2	2
itype_heatcond		1	1	3	3
itype_evsl		2	2	2	2
idiag_snowfrac		N/A	1	1	1
cwimax_ml		N/A	1.0E-6	0.0005	0.0005
lemiss		FALSE	FALSE	TRUE	TRUE
lstomata		FALSE	FALSE	TRUE	TRUE

* Following Uli Schattler's document depicting DWD experiments with TERRA

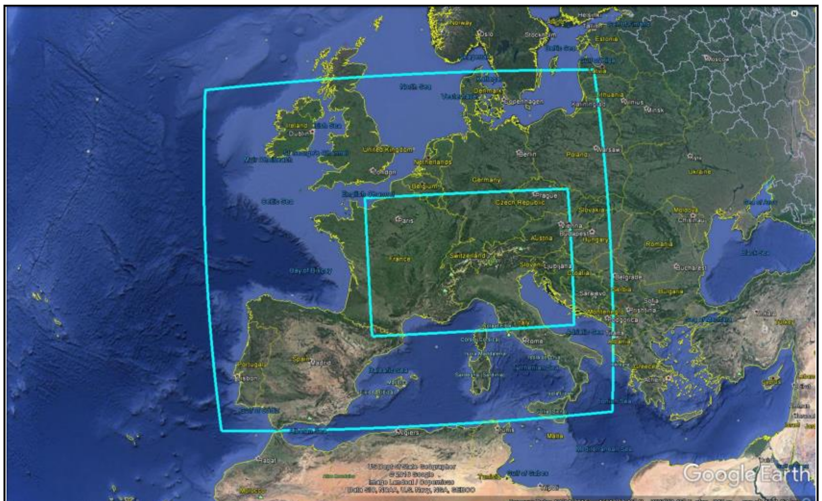
NE Domain

		V5.03	V5.05	
Namelist parameter	Module	Reference	Adv. Old Turb	Advanced
/TUNING/				
tkhmin	Turbulence	0.4	0.4	0.4
tkmmin		0.4	0.4	0.75
rat_sea		20.0	20.0	20.0
patlen		500.0	500.0	500
turlen		150.0	150.0	150.0
a_hshr		0.2	0.2	1.0
c_soil		1.0	1.0	1.0
/PHYCTL/				
loldtur	Turbulence	N/A	TRUE	FALSE
itype_vdif		-1	-1	1
ltkeshs		FALSE	FALSE	TRUE
itype_sher		1	1	0
itype_root	TERRA	1	2	2
itype_heatcond		1	3	3
itype_evsl		2	2	2
cwimax_ml		N/A	1.0E-6	1.0E-6
lemiss		FALSE	FALSE	FALSE
lstomata		FALSE	FALSE	FALSE

Domains:



MED 6.25km & 2.5km



EU 6km & 2km

NE 6.6km & 2.2 km

Simulations & Verification Properties:

EU

			Configurations				Verification				
resolution (km)	from	untill	v5.0	Basic	Advanced Old Turb	Advanced	T2m	RH2m	T Soil (18, 54 cm)	W Soil (18, 54 cm)	Gridded Databases*
6	01/11/14	31/12/15	√	√	√	√	√	√	√	√	√
6	01/11/02	31/12/03	√	√							√
6	01/11/05	31/12/06	√	√							√
2	01/11/14	31/12/15	√	√	√	√	√	√	√	√	√

MED

			Configurations				Verification				
resolution (km)	from	untill	v5.0	Basic	Advanced Old Turb	Advanced	T2m	RH2m	T Soil (18, 54 cm)	W Soil (18, 54 cm)	
6.25	01/01/16	31/08/15	√	√	√	√	√	√	√	√	
2.5	01/01/16	31/08/15	√	√	√	√	√	√	√	√	

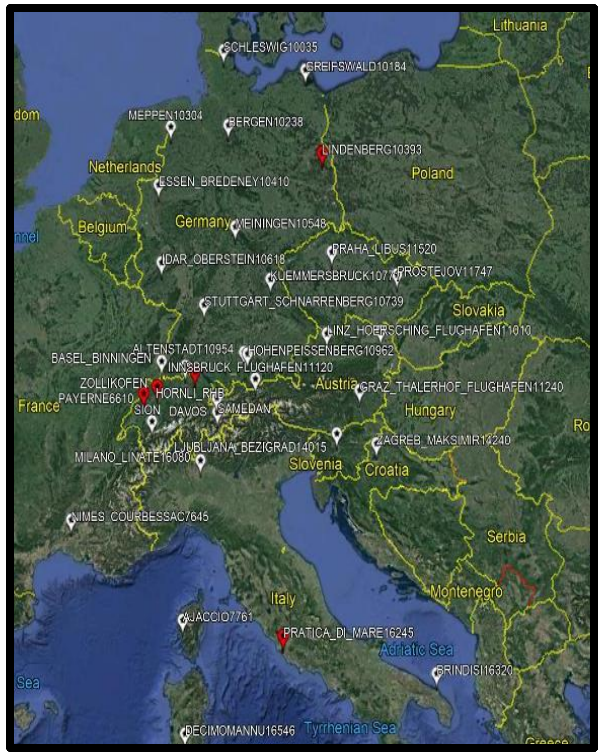
NE

			Configurations				Verification				
resolution (km)	from	untill	v5.3	Basic	Advanced Old Turb	Advanced	T2m	DP2m	T Soil intercomparison	W Soil intercomparison	
6.6	01/11/15	31/12/16	√		√	√	√	√	√	√	
2.2	15/04/16	31/10/16	√		√	√	√	√	√	√	

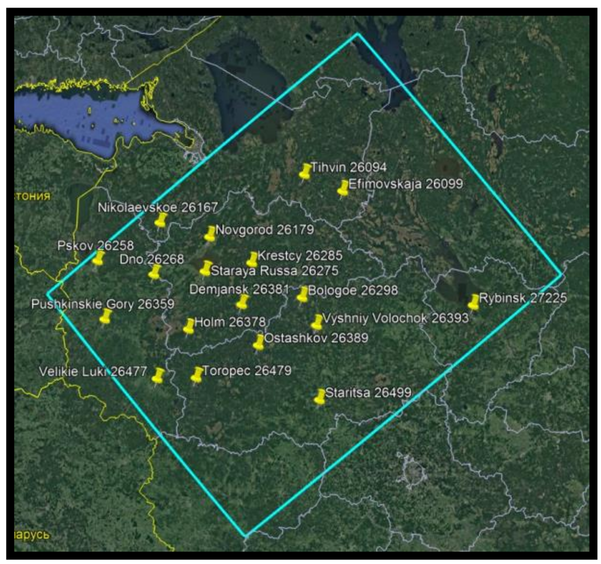
* Performed by Verena Bessenbacher as part of her M. Sc. Thesis (Bessenbacher V., 2018)

APPENDIX 2 – Verification & Results

Ground stations for verification:



Ground stations for verification of Temperature and Relative Humidity in MED (top- left panel), EU (top- right panel) and NE (bottom-right) domains.



2 meter T & RH verification – EU domain:

st_name	00	V500	Basic	AdvOld	Adv	06	V500	Basic	AdvOld	Adv	12	V500	Basic	AdvOld	Adv	18	V500	Basic	AdvOld	Adv
PAYERNE6610		2	-1	-1	-1		1	-0	-0	0		2	-0	0	0		1	0	0	1
KLOTEN		2	-0	-0	0		4	0	0	1		2	1	0	2		5	1	1	2
ZOLLIKOFEN		2	-0	-0	1		1		0	1		2	0	0	1		2	1	1	2
SAMEDAN		2	0	1	1		2	-0	0			4	-0	1	1		4	-0	1	1
SION		4	0	2	3		5	0	1	2		5	0	1	2		6		2	2
HORNLI_RHB		2	0	0	1		2	-0	-0	0		2	-0	-0	-0		2	-0	-0	0
DAVOS		2	-0	0	1		1	-0		0		3	-0	1	1		3	0	1	1
BASEL_BINNINGEN		1	-0	-0	1		1		0	1		2	0		1		2	1	1	2
LINDENBERG10393		2	0	-0	1		1	0	0	0		2	0	0	0		2	1	0	1
NIMES_COURBESSAC76		2	-0	-0	1		1	1	1	1		2		0	1		1	0	0	1
AJACCIO7761		1	-0	-0	1		1	0		0		2	0	0	0		1	0	0	1
SCHLESWIG10035		1	-0	-0			1		0	0		2		-0	0		1	0	0	0
GREIFSWALD10184		1	-0	-0	-0		1	0	0	-0		2	-0	-0	0		1	0	0	1
BERGEN10238		2	-0	-0	-0		1					2	0	0	1		2	1	0	1
MEPPEN10304		2	-0	-0	-0		1	0		0		2	0		0		1	0	0	1
ESSEN_BREDENEY1041		1	0	0	0		1		0	0		2	-0		0		1	0		1
MEININGEN10548		1	0	0	1		1	0	-0	0		2	-0		0		2	1	0	2
IDAR_OBERSTEIN10618		2	-1	-0			1	-0	-0			2	1	0	1		2	1	1	2
STUTTGART_SCHNARR		1	0	0	1		1	0		1		2	0	0	1		2	1	0	1
KUEMMERSBRUCK1077		1	-0	-0	0		1	-0	-0	0		2	1	0	1		2	1	1	2
ALTENSTADT10954		2	-0	-0	-0		1	-0	-0	-0		2	0	0	1		2	0	0	1
HOHENPEISSENBERG1(		2			1		2		-0	1		2	-0	-0	-0		2		0	1
LINZ_HOERSCHING_FLU		1	0		1		1			1		2	1	0	1		3	1	1	1
WIEN_HOHE_WARTE11		1	0	0	1		2	1	0	0		2	0		0		2	1	0	1
INNSBRUCK_FLUGHAFE		3	0	1	1		3	-0	0	1		5	0	1	2		5	0	1	2
GRAZ_THALERHOF_FLU		2	-0	-0	-0		1	-0	0			1	0	0	1		1	1	1	1
PRAHA_LIBUS11520		1	0		1		1	0	0	0		2	1	0	1		2	1	0	1
PROSTEJOV11747		2	-0	-0	-0		2	0	0			2	0		0		2	1	1	1
LJUBLJANA_BEZIGRAD1		2	-0	-0	1		1	-0	-0	0		2	0	-0	1		2	0	1	1
ZAGREB_MAKSIMIR1424		2	-1	-1	-1		1	0	0	0		1	0	0	1		2	1	1	1
MILANO_LINATE16080		2	-0	0	1		2	0	0	1		2	-1	-1	-0		2	-0	-0	0
PRATICA_DI_MARE1624		1	-0	-0	1		1		0	0		1	0	0			1	0	0	1
BRINDISI16320		1	0	0	1		1	0	0	0		1	0	0	0		2	0	0	1
TRAPANI_BIRGI16429		2	0	0	0		1	0		0		1	0				2	0	0	1
DECIMOMANNU16546		1	0	0	2		1		0	0		1	-0				2	0	0	1
MEAN		2	2	2	2		2	2	2	2		2	2	2	2		2	3	3	3
STD		1	1	1	1		1	1	1	1		1	1	1	1		1	1	1	1

st_name	00	V500	Basic	AdvOld	Adv	06	V500	Basic	AdvOld	Adv	12	V500	Basic	AdvOld	Adv	18	V500	Basic	AdvOld	Adv
PAYERNE6610		2	1	0	-1		1	-0	-0	-1		1	-0	-0	-1		0	-1	-1	-2
KLOTEN		1	0	-0	-2		3	2	2	1		-1	-2	-2	-3		2	1	1	-1
ZOLLIKOFEN		1	-0	-0	-2		0	-1	-1	-2		-0	-1	-1	-2		-1	-2	-2	-3
SAMEDAN		-2	-2	-3	-3		-1	-1	-1	-2		-4	-4	-5	-5		-3	-3	-4	-5
SION		-4	-5	-6	-7		-5	-5	-6	-7		-5	-5	-6	-7		-6	-6	-7	-8
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DAVOS		-1	-1	-2	-2		-1	-1	-1	-2		-3	-3	-4	-4		-2	-3	-3	-4
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LINDENBERG10393		1	-1	-1	-2		0	-1	-0	-1		0	-0	0	-0		-0	-1	-1	-1
NIMES_COURBESSAC76		1	0	-1	-2		-1	-2	-2	-3		1	0	1	-1		0	-1	-1	-2
AJACCIO7761		1	1	0	-2		0	0	0	-1		0	0	0	-1		-1	-1	-2	-3
SCHLESWIG10035		0	-0	-0	-0		-1	-1	-1	-1		-1	-1	-1	-2		-1	-1	-1	-1
GREIFSWALD10184		1	0	0	-1		-0	-1	-0	-0		0	0	0	-0		-1	-1	-1	-2
BERGEN10238		1	0	0	-0		-0	-1	-1	-1		-0	-1	-0	-1		-1	-2	-1	-2
MEPPEN10304		1	0	-0	-0		-0	-1	-1	-0		0	-0	-0	-1		-1	-1	-1	-2
ESSEN_BREDENEY1041		0	-1	-1	-1		-0	-1	-1	-1		1	-0	1	-1		-0	-1	-1	-1
MEININGEN10548		0	-1	-1	-2		1	-0	-0	-1		1	-0	0	-1		-0	-2	-1	-3
IDAR_OBERSTEIN10618		1	0	0	-1		1	0	0	-0		-0	-1	-1	-2		-2	-3	-2	-3
STUTTGART_SCHNARR		0	-1	-1	-2		0	-1	-1	-1		0	-1	-0	-1		-1	-3	-2	-3
KUEMMERSBRUCK1077		1	-0	-0	-1		1	-0	-0	-1		-0	-2	-1	-3		-2	-3	-3	-4
ALTENSTADT10954		1	1	0	-1		1	0	0	-0		-1	-1	-1	-3		-1	-2	-2	-3
HOHENPEISSENBERG1(		0	-1	-1	-2		0	-0	-0	-1		1	1	1	-1		1	-0	-0	-1
LINZ_HOERSCHING_FLU		0	-1	-1	-2		-1	-1	-1	-1		-1	-2	-1	-2		-2	-3	-3	-4
WIEN_HOHE_WARTE11		-0	-1	-1	-2		-1	-2	-2	-2		-1	-2	-1	-1		-1	-2	-2	-2
INNSBRUCK_FLUGHAFE		-3	-3	-4	-4		-2	-2	-3	-4		-3	-3	-4	-5		-5	-5	-6	-6
GRAZ_THALERHOF_FLU		1	1	0	-1		0	-0	0	-1		-0	-1	-1	-1		-1	-2	-2	-2
PRAHA_LIBUS11520		0	-1	-1	-2		-1	-1	-1	-1		-1	-2	-1	-2		-1	-3	-2	-3
PROSTEJOV11747		1	0	0	-1		-1	-1	-2	-1		-2	-2	-2	-2		-1	-2	-2	-3
LJUBLJANA_BEZIGRAD1		1	-0	-1	-2		1	0	0	-1		-0	-1	-1	-2		-1	-2	-2	-3
ZAGREB_MAKSIMIR1424		2	0	0	-1		-0	-1	-1	-1		0	-1	-1	-2		-0	-2	-2	-3
MILANO_LINATE16080		1	-1	-1	-2		-1	-2	-2	-2		2	0	0	-1		1	-1	-1	-2
PRATICA_DI_MARE1624		1	0	0	-2		-0	-1	-1	-1		0	0	0	-0		-1	-1	-1	-2
BRINDISI16320		-0	-1	-1	-1		1	1	1	1		1	1	1	1		-2	-2	-2	-3
TRAPANI_BIRGI16429		-0	-1	-1	-1		0	0	0	1		1	1	1	1		-2	-2	-2	-2
DECIMOMANNU16546		-0	-1	-1	-3		-0	-1	-1	-1		0	0	0	-1		-1	-2	-2	-2
MEAN		0	-0	-1	-2		-0	-1	-1	-1		-0	-1	-1	-2		-1	-2	-2	-3
STD		1	1	1	1		1	1	1	1		1	1	2	2		1	1	1	1

Upper Panel:

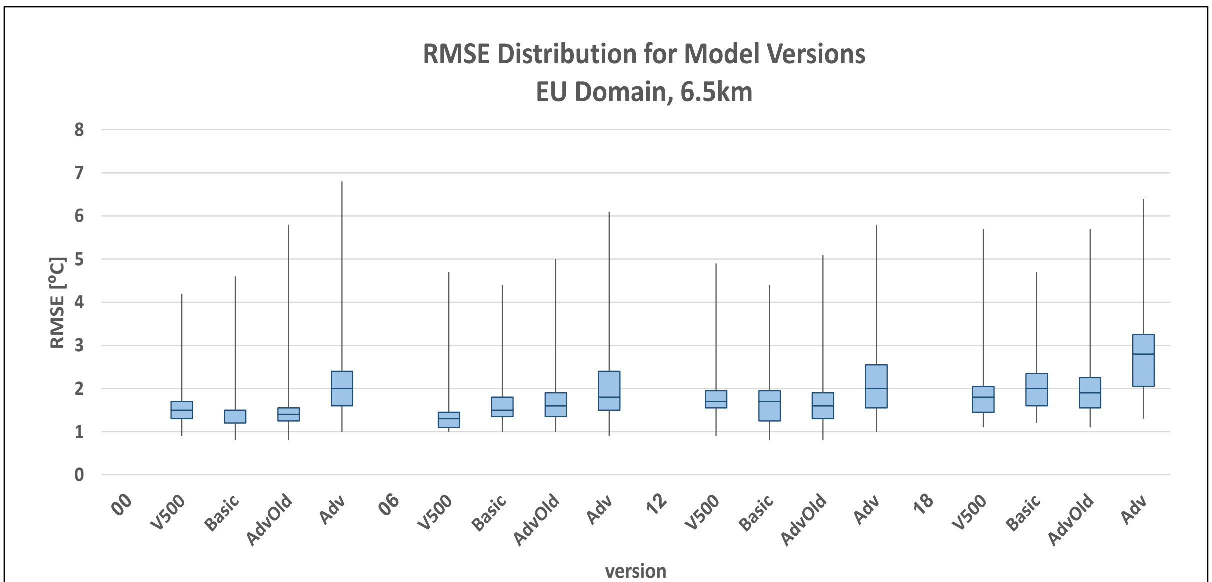
Verification for 2m temperature in EU domain, 6.5km resolution*. Left panel shows RMSE for 00z (24h fcst), 06z (6h fcst), 12z & 18z. For each time of day, reference configuration absolute RMSE appears on the left most coloumn, the darker the shading – the worse the RMSE. For v5.05 configurations (Basic, Ad.Old, Adv.) the difference from the reference configuration is shown - green for better RMSE, red for worse.*

Right panel shows MBE for same times of day and configurations. Warm bias colored red, cold bias colored blue.

In example: 18z fcst of Adv. configuration shows worse RMSE than reference configuration because of a cold bias, as discussed above.

Lower Panel:

Box plot of RMSE for same stations shown in upper panel. Box lines depicts 1^{st}, 2^{nd} and 3^{rd} quartiles, while whiskers depict minimum and maximum of RMSE per time of day.



2 meter T & RH verification (Continued) – EU domain:

st_name	00 V500	Basic	AdvOld	Adv	06 V500	Basic	AdvOld	Adv	12 V500	Basic	AdvOld	Adv	18 V500	Basic	AdvOld	Adv
PAYERNE6610	14	-6	-6	-6	11	-3	-3	-4	9	-1	0	0	9	2	2	3
KLOTEN	8	-1	-2	2	8	0	0	2	11	3	2	6	14	6	6	14
ZOLLIKOFEN	12	-4	-4	-2	10	-3	-2	-3	9	2	1	2	10	6	4	11
SAMEDAN	8	1	-0	-1	12	1	-3	-5	12	-3	3	0	15	-2	3	2
SION	11	-1	1	2	9	-0	1	3	13	-2	2	2	16	1	7	8
HORNLI_RHB	11	1	1	5	10	-0	1	3	12	-1	-1	-1	11	1	2	9
DAVOS	8	0	1	-1	8	-0	-1	-2	16	-3	5	4	14	0	6	7
BASEL_BINNINGEN	10	-3	-3	1	7	0	0	3	8	2	2	3	11	6	4	11
LINDENBERG10393	12	1	1	1	10	0	-1	-1	10	0	0	1	10	4	1	2
NIMES_COURBESSAC7(	11	-2	-3	-1	8	0	0	2	7	-0	0	1	8	1	-1	3
AJACCIO7761	10	1	1	-1	10	1	0	2	15	0	1	-4	11	0	-0	2
SCHLESWIG10035	7	-1	-2	-2	7	-0	-1	-1	9	1	-1	1	7	2	1	3
GREIFSWALD10184	10	-2	-2	-3	8	0	-1	-1	10	-1	-1	-0	8	1	1	2
BERGEN10238	11	-2	-2	-5	8	-1	-1	-2	9	2	2	2	10	3	0	5
MEPPEN10304	8	-1	-0	-1	8	-1	-1	-1	10	-0	1	0	11	2	2	4
ESSEN_BREDENEY1041	10	-1	-2	-1	9	0	-1	-1	11	-1	-1	0	11	2	-1	3
MEININGEN10548	9	1	0	4	10	-1	-2	-1	10	1	0	1	11	6	3	9
IDAR_OBERSTEIN10618	12	-3	-2	-2	11	-3	-1	-4	9	3	0	1	12	7	0	7
STUTTGART_SCHNARR	9	3	0	6	9	2	1	1	8	4	2	4	11	9	2	8
KUEMMERSBRUCK1077	10	1	1	2	7	0	-0	1	9	3	1	5	14	7	3	13
ALTENSTADT10954	8	-0	-0	0	9	-2	-2	-3	11	2	2	5	15	3	3	9
HOHENPEISSENBERG1(	15	2	0	5	13	2	1	6	12	1	1	3	17	2	2	7
LINZ_HOERSCHING_FLU	8	3	2	4	10	0	1	1	12	3	3	2	17	3	4	7
WIEN_HOHE_WARTE11(	11	1	1	2	11	1	0	-2	9	2	0	1	14	4	3	2
INNSBRUCK_FLUGHAFE	11	-1	-2	-1	9	0	-2	-3					14	3	5	9
GRAZ_THALERHOF_FLU	13	-3	-4	-6	9	-2	-1	-2	9	3	2	2	10	4	3	6
PRAHA_LIBUS11520	9	3	1	4	9	2	1	1	9	4	0	1	12	7	1	6
PROSTEJOV11747	10	1	-1	-1	11	1	1	-0	12	3	2	0	12	5	3	8
LJUBLJANA_BEZIGRAD1	12	-4	-4	-2	11	-2	-3	-3	11	-1	-1	2	13	2	2	8
ZAGREB_MAKSIMIR1424	15	-6	-6	-8	11	-1	-2	-2	8	0	0	2	13	1	0	4
MILANO_LINATE16080	14	-4	-3	-1	11	-2	-2	0	11	-1	-1	1	14	-1	0	5
PRATICA_DI_MARE1624!	10	1	2	-3	13	0	1	1	12	1	1	0	11	-0	-0	-2
BRINDISI16320	7	1	1	0	10	1	1	1	14	1	0	0	7	1	0	1
TRAPANI_BIRGI16429	7	0	-0	0	7	-0	0	1	19	0	0	1	13	-1	-1	-2
DECIMOMANNU16546	15	-2	-1	-7	13	2	2	1	16	0	1	0	16	-2	-1	-3
MEAN	10	10	9	10	10	9	9	9	11	12	12	12	12	15	14	17
STD	2	2	2	3	2	2	2	3	3	2	3	3	3	4	4	5

st_name	00 V500	Basic	AdvOld	Adv	06 V500	Basic	AdvOld	Adv	12 V500	Basic	AdvOld	Adv	18 V500	Basic	AdvOld	Adv
PAYERNE6610	-12	-4	-4	3	-7	-2	-2	1	-3	4	3	2	-2	7	8	9
KLOTEN	-4	1	2	9	0	3	4	9	8	11	12	16	11	18	18	27
ZOLLIKOFEN	-9	-2	-2	7	-6	0	-0	4	1	8	6	9	4	14	12	19
SAMEDAN	-4	-6	-1	1	-11	-13	-8	-6	6	3	12	10	6	4	14	14
SION	0	2	7	10	2	2	6	10	4	6	11	12	11	15	21	23
HORNLI_RHB	3	7	6	13	0	3	3	10	-4	-2	1	6	3	8	10	18
DAVOS	-2	-4	1	3	-5	-6	0	3	12	9	20	18	11	10	19	19
BASEL_BINNINGEN	-8	-0	-2	9	-2	4	4	9	1	7	5	9	5	15	14	21
LINDENBERG10393	-4	6	1	8	-5	2	-1	0	-1	4	1	1	-1	8	4	6
NIMES_COURBESSAC7(	-9	-4	-3	7	-4	1	-0	7	-5	-3	-4	2	-5	-2	-2	7
AJACCIO7761	-5	-5	-8	1	-2	-2	-4	-2	-13	-14	-14	-6	-6	-4	-5	7
SCHLESWIG10035	-4	-3	-2	-2	-2	-2	-0	-2	-2	2	0	3	0	5	4	6
GREIFSWALD10184	-7	-2	-3	1	-1	1	1	1	-4	-1	-2	-1	2	6	5	8
BERGEN10238	-8	-2	-3	-0	-3	1	-0	0	0	6	2	5	2	9	5	10
MEPPEN10304	-1	2	2	4	0	2	2	2	1	5	4	4	5	9	9	13
ESSEN_BREDENEY1041	-5	2	1	4	-4	1	-1	0	-4	1	-3	0	-0	7	3	9
MEININGEN10548	-3	7	4	11	-4	3	-0	4	-2	5	2	7	2	13	9	18
IDAR_OBERSTEIN10618	-9	-0	-3	5	-9	-2	-6	-2	-2	5	1	6	4	15	9	17
STUTTGART_SCHNARR	-1	9	5	13	-1	7	3	7	2	9	5	6	5	17	11	16
KUEMMERSBRUCK1077	-2	6	5	10	-2	4	3	5	2	9	6	13	10	19	16	27
ALTENSTADT10954	-3	-0	-0	6	-7	-3	-3	2	5	8	10	14	10	14	15	22
HOHENPEISSENBERG1(	6	9	9	16	5	8	8	14	2	5	6	10	10	14	15	21
LINZ_HOERSCHING_FLU	3	6	8	12	6	7	9	9	11	14	14	13	15	18	19	22
WIEN_HOHE_WARTE11(	4	9	9	11	7	9	9	6	4	8	6	5	9	14	13	12
INNSBRUCK_FLUGHAFE	-5	-2	0	5	-6	-7	-4	2					11	13	18	21
GRAZ_THALERHOF_FLU	-11	-8	-7	-1	-5	-2	-2	-1	3	9	7	7	5	11	10	14
PRAHA_LIBUS11520	0	8	5	10	0	5	4	4	2	9	5	5	6	16	10	15
PROSTEJOV11747	-4	0	1	4	6	8	9	7	8	12	11	10	10	16	14	19
LJUBLJANA_BEZIGRAD1	-8	-2	-2	7	-7	-4	-4	1	0	5	5	9	5	12	13	20
ZAGREB_MAKSIMIR1424	-13	-4	-5	0	-4	3	3	6	-4	5	3	7	-3	8	6	15
MILANO_LINATE16080	-7	3	2	9	-3	4	4	8	-6	1	1	5	-3	6	7	15
PRATICA_DI_MARE1624!	-7	-9	-10	1	-8	-8	-10	-6	-8	-8	-9	-5	-6	-5	-7	1
BRINDISI16320	-3	-4	-5	2	-9	-10	-10	-9	-13	-14	-14	-13	1	2	0	4
TRAPANI_BIRGI16429	2	3	3	5	-1	-1	-1	-3	-18	-18	-18	-19	-10	-8	-8	-7
DECIMOMANNU16546	-14	-12	-13	-6	-13	-14	-15	-13	-15	-15	-16	-14	-15	-13	-15	-11
MEAN	-4	0	-0	6	-3	0	0	2	-1	3	2	5	3	9	8	14
STD	5	5	5	5	5	6	5	6	7	8	8	8	7	8	8	8

Upper Panel:

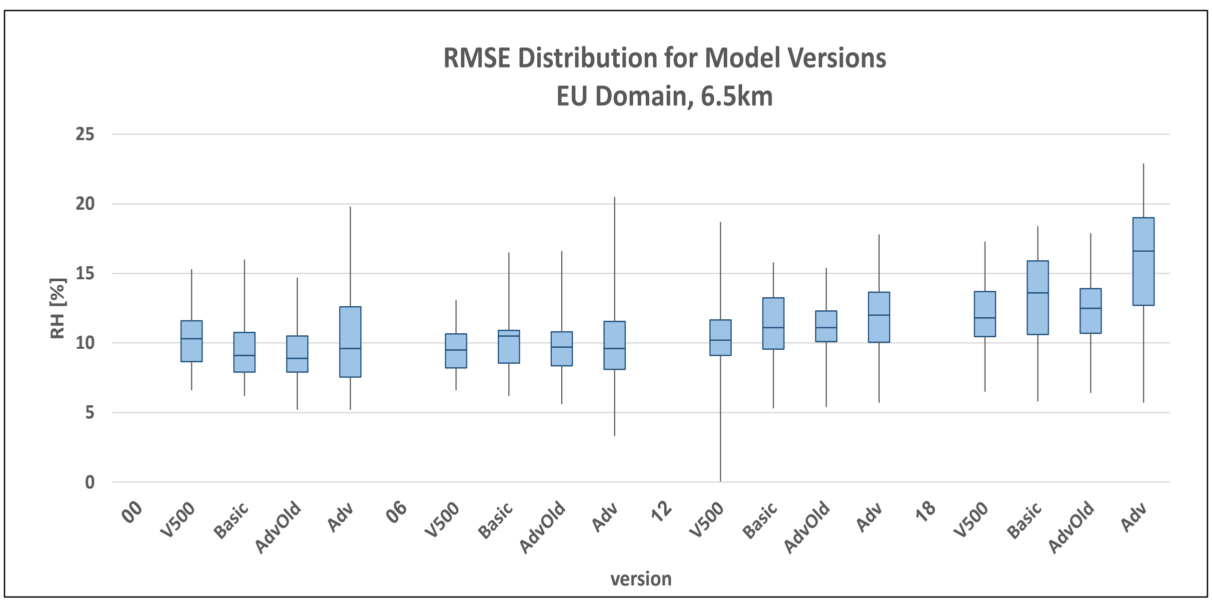
Verification for 2m relative humidity in EU domain, 6.5km resolution*. Left panel shows RMSE for 00z (24h fcst), 06z (6h fcst), 12z & 18z. For each time of day, reference configuration absolute RMSE appears on the left most coloumn, the darker the shading – the worse the RMSE. For v5.05 configurations (Basic, Ad.Old, Adv.) the difference from the reference configuration is shown - green for better RMSE, red for worse.*

Right panel shows MBE for same times of day and configurations. Dry bias colored yellow, humid bias colored blue.

<u>In example</u>: 18z fcst of Adv. configuration shows worse RMSE than reference configuration because of a humid bias, as discussed above.

Lower Panel:

Box plot of RMSE for same stations shown in upper panel. Box lines depicts 1st, 2nd and 3rd quartiles, while whiskers depict minimum and maximum of RMSE per time of day.



2 meter T & RH verification (Continued) – MED domain:

st_name	00	V500	Basic	AdvOld	Adv	06	V500	Basic	AdvOld	Adv	12	V500	Basic	AdvOld	Adv	18	V500	Basic	AdvOld	Adv
AFULA_NIR_HAEMEQ		1.7	-0	-0	-0		2	0.2	0.2	-1		1.1	-0	0	-0		0.9	0.1	0.4	0
BEER_SHEVA		1.3	0.2	0.6	0.5		1.2	0.2	0.3	-0		1.1	-0	-0	-0		0.9	0.3	0.7	0.7
BESOR_FARM		1.5	-0	-1	0		0.9	0.1	0.2	0		2.2	0	-0	-1		0.7	0.2	0.4	0.3
BET_DAGAN		1.1	0.3	0.4	0.2		1.4	0.1	0.1	-0		1.2	0	0.1	0.1		2.2	0.3	0.3	-0
BET_HAARAVA		0.8	0.4	1.4	1.2		1	0	0.1	-0		4.4	-0	0.5	0.9		0.9	0.1	0.4	0.2
DAFNA		1.9	0.5	0.8	1.4		1.9	0.1	0.1	-1		0.8	0	0.1	0.1		1.5	0.7	1.1	1.1
DOROT		1.5	-0	-0	0		1.4	0.1	0.4	-0		1.1	0	-0	-0		0.7	0.1	0.1	-0
EDEN_FARM		1.5	0.2	0.2	-0		1.2	0.1	0.3	-0		1.2	-0	0	0.2		1.5	0.4	0.5	0.3
ELAT		0.9	0.1	0.2	0.2		1.3	0	0	-0		1.9	0	0.1	0.9		1.6	0	0.1	-0
ELON		1.5	0.1	0.3	0.3		2.1	0.1	0.1	-1		1.8	-0	0	0.1		1.5	0.4	0.7	0.8
EN_HASHOFET		0.9	0.1	0.1	0.3		0.9	0	-0	0.2		1.6	0	-0	0		1	-0	-0	-0
EN_KARMEL		1.5	0.1	0.2	0		2	0.1	0.2	-1		1.2	0	0	-0		1.6	0.4	0.6	0.4
ESHHAR		1.1	0	0	0.2		0.8	0.1	0.1	0.2		1.9	0.1	0	0		1.3	-0	-0	-1
EZUZ		1.6	0	0	-1		1.2	0.1	0.2	0.1		1.8	0	0.1	-0		0.9	0	-0	-0
GAMLA		1.4	-0	-0	-0		1	0	0	0		1.5	0.1	0	0.6		1.5	-0	-0	0
HAIFA_TECHNION		1.3	0.2	0.3	0.4		0.7	0	0.1	0.3		2.2	-0	-0	-0		0.7	0.2	0.3	0.2
HAR_HARASHA		1.2	0	0.1	0.2		1.1	0.1	0.1	0.3		1.3	0	0	0		1.4	-0	-1	-1
HAZEVA		1.1	0	0	-0		1	0	0	-0		2.7	0	0.2	0.3		1	0	0.1	0.1
ITAMAR		2.5	-1	-1	-1		2.2	0	0	0.3		2.3	0.1	-0	-0		3	-1	-1	-1
JERUSALEM_CENTRE		1.2	0	0.1	0.6		1.2	0	0	0		1.3	0.1	0	0.1		1.1	0.1	0.2	0
MEROM_GOLAN_PICMAN		2.6	0	-0	-0		2	-0	0	-0		1	0	0	0		1.8	-0	-0	-0
MIZPE_RAMON		2.2	-0	-0	-1		1.6	0.1	0.2	0.2		2.7	0	0.1	0.3		2.4	-0	-0	-0
NAHSHON		2.7	-1	-1	-1		1.4	0.1	0.2	-1		0.9	0.1	0	-0		1.6	-1	-1	-1
NEGBA		1.2	0	-0	0.2		1	0.1	0.1	-0		1.3	0	-0	-0		0.9	-0	-0	-0
NEOT_SMADAR		3.3	-0	-0	-1		1.3	-0	0	0		3.3	0	0.2	0.4		1.5	-0	-0	-0
NETIV_HALAMED_HE		4.2	-0	-1	-1		1.7	0.2	0.3	-0		1	-0	0	0.2		1.7	-1	-1	-1
QARNE_SHOMERON		1.2	0.1	0.2	0.4		1.1	0.3	0.3	-0		1.4	0.1	-0	-0		0.9	0.6	0.9	0.8
SEDE_BOQER		1.9	0	0.1	-0		1.1	0.1	0.2	-0		1.3	0	0.1	0		0.9	0.1	0.2	0.2
SHANI		1.8	-0	-0	-0		1.6	0.1	0	-0		1.1	0.1	0.1	0		1.2	-0	-0	-0
TAVOR_KADOORIE		1.6	0.2	0.2	0.2		1.5	0.2	0.4	-0		1	0	0	0		1.3	0.6	0.6	0.6
YOTVATA		1.5	-0	-0	-0		1	0	-0	0		2.7	0	0.3	0.5		0.9	0	0	0
ZEFAT_HAR_KENAAN		2.4	-1	-1	-0		2.1	-0	-0	0.6		5.4	0	-0	-0		5	-1	-1	-1
ZEMAH		1.6	0.1	0.2	-0		1.9	0.3	0.6	-0		1.4	0	0	0		1.4	0.5	0.5	0.4
ZOMET_HANEGEV		1.7	0	0	-0		1.2	0.2	0.2	0.1		1.8	0	0.1	-0		0.7	0	0.1	0
MEAN		1.7	1.7	1.7	1.6		1.4	1.5	1.5	1.3		1.8	1.8	1.8	1.9		1.4	1.4	1.5	1.4
STD		0.7	0.6	0.6	0.5		0.4	0.4	0.4	0.4		1	1	1	1.1		0.8	0.7	0.7	0.7

st_name	00	V500	Basic	AdvOld	Adv	06	V500	Basic	AdvOld	Adv	12	V500	Basic	AdvOld	Adv	18	V500	Basic	AdvOld	Adv
AFULA_NIR_HAEMEQ		1.1	-0	-0	-0		-2	-2	-2	-1		-0	-0	-0	-0		0	-1	-1	-1
BEER_SHEVA		-1	-1	-1	-2		-1	-1	-1	0.2		0.3	0.4	0.3	-0		-1	-1	-2	-2
BESOR_FARM		1.4	0.9	0.4	1		-0	-0	-0	0.3		2.2	2.2	2	1.6		0	-1	-1	-1
BET_DAGAN		-1	-1	-1	-1		-1	-1	-1	-1		-1	-1	-1	-1		-2	-3	-2	-2
BET_HAARAVA		-0	-1	-2	-2		-0	-0	-0	0.1		4.4	4.2	4.9	5.3		0	-1	-1	-1
DAFNA		-1	-2	-2	-3		-2	-2	-2	-1		-0	-0	-1	-1		-1	-2	-3	-3
DOROT		1.3	0.7	0.5	1.1		-1	-1	-2	-1		0.7	0.8	0.5	0.1		0.2	-1	-0	-0
EDEN_FARM		-0	-1	-1	-1		-1	-1	-1	-1		-1	-1	-1	-1		-1	-2	-2	-2
ELAT		-1	-1	-1	-1		-1	-1	-1	-1		1.6	1.6	1.7	2.8		-1	-1	-1	-0
ELON		-1	-1	-1	-2		-2	-2	-2	-2		-2	-2	-2	-2		-1	-2	-2	-2
EN_HASHOFET		0.1	-0	-0	-1		0	0	-0	0.8		1.4	1.5	1.4	1.4		0.7	0.2	0.2	0.2
EN_KARMEL		0.1	-0	-1	-0		-2	-2	-2	-1		-1	-1	-1	-1		-1	-2	-2	-2
ESHHAR		0.1	-1	-1	-1		0.2	0.1	0	0.7		1.8	1.9	1.8	1.7		1.2	0.5	0.4	0.4
EZUZ		1.3	1.2	1	0.5		0	-0	-0	0.5		1.7	1.7	1.8	1.5		0.7	0.7	0.5	0.3
GAMLA		0.8	0.1	0.1	0.1		0.4	0.2	-0	0.6		1.3	1.5	1.2	2		1.2	0.8	0.8	1.2
HAIFA_TECHNION		-1	-1	-2	-2		0.1	0.1	0.1	0.8		2.1	2	2	2		-0	-1	-1	-1
HAR_HARASHA		0.4	0	-0	-1		0.2	0.3	0.3	0.7		1	1	0.9	1		1.2	0.5	0.2	0.2
HAZEVA		0.2	0	-0	-1		-0	-0	-0	-0		2.5	2.5	2.9	2.9		-0	-0	-1	-1
ITAMAR		2.2	1.6	1.4	0.5		2.1	2.1	2.1	2.4		2.3	2.4	2.2	2.3		3	2.1	1.9	1.7
JERUSALEM_CENTRE		0.1	-0	-0	-2		-0	-0	-0	0.2		0.9	1	0.9	1.1		0.2	-0	-1	-1
MEROM_GOLAN_PICMAN		1.9	2	1.8	1.2		-2	-1	-2	-1		0.3	0.2	-0	0.2		1.5	1.2	1	0.8
MIZPE_RAMON		2.1	1.9	1.8	1		1.1	1.3	1.4	1.5		2.7	2.6	2.8	3		2.3	2.2	2.1	2
NAHSHON		2.7	2.1	1.7	1.9		-1	-1	-1	-0		0.5	0.6	0.5	0.2		1.6	0.9	0.5	0.7
NEGBA		0.8	0.1	-0	0.5		-1	-1	-1	-0		1.1	1.1	0.8	0.7		0.7	0	-0	0.1
NEOT_SMADAR		3.2	3.1	2.9	2.7		1	0.9	0.9	1		3.2	3.2	3.5	3.7		1.3	1.2	1.1	1
NETIV_HALAMED_HE		4.1	3.5	3.3	3		-2	-2	-2	-1		-1	-0	-1	-1		1.6	0.9	0.6	0.6
QARNE_SHOMERON		-0	-1	-1	-1		-1	-1	-1	0		1.2	1.2	1.1	0.8		-1	-1	-2	-2
SEDE_BOQER		0.4	0.3	0.2	-0		-0	-0	-0	0.2		0.9	0.9	1	1		-1	-1	-1	-1
SHANI		1.4	1.2	1	0.3		-1	-1	-1	-0		0.5	0.6	0.5	0.5		0.7	0.1	0.1	0.2
TAVOR_KADOORIE		-0	-1	-1	-1		-1	-2	-2	-1		-0	-0	-1	-1		-1	-2	-2	-2
YOTVATA		1.4	1.3	1.1	1		0.4	0.3	0.3	0.5		2.6	2.6	2.9	3.2		0.2	0.1	0	0.3
ZEFAT_HAR_KENAAN		2	1	0.7	1.3		1.2	0.9	0.6	1.8		5.4	5.4	5.1	5.4		5	4.4	4.1	4
ZEMAH		0.2	-1	-1	-1		-2	-2	-2	-2		0.4	0.5	0.2	0.3		-1	-2	-2	-2
ZOMET_HANEGEV		1	0.7	0.5	0.2		0.1	0	0.1	0.7		1.7	1.8	1.9	1.4		0.1	-0	-1	-1
MEAN		0.7	0.3	0	-0		-0	-1	-1	-0		1.1	1.2	1.1	1.1		0.3	-0	-0	-0
STD		1.2	1.3	1.3	1.3		1	1	1.1	1		1.5	1.5	1.6	1.7		1.4	1.4	1.4	1.4

Upper Panel:

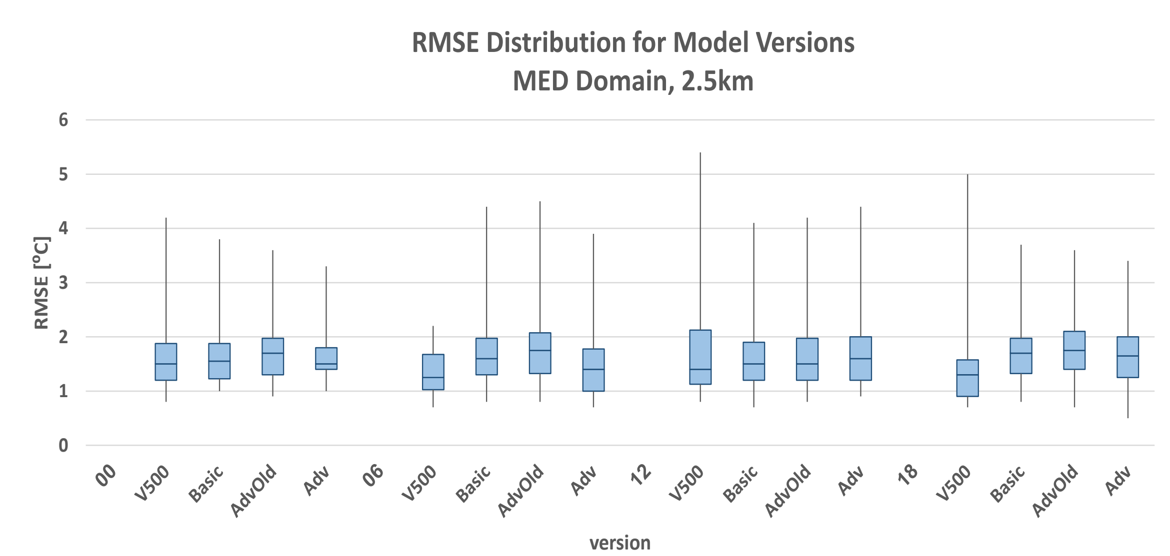
***Verification for 2m temperature in MED domain, 2.5km resolution**. Left panel shows RMSE for 00z (24h fcst), 06z (6h fcst), 12z & 18z. For each time of day, reference configuration absolute RMSE appears on the left most coloumn, the darker the shading – the worse the RMSE. For v5.05 configurations (Basic, Ad.Old, Adv.) the difference from the reference configuration is shown - green for better RMSE, red for worse.*

Right panel shows MBE for same times of day and configurations. Warm bias colored red, cold bias colored blue.

<u>In example</u>: 18z fcst of Adv. configuration shows worse RMSE than reference configuration because of a cold bias, as discussed above.

Lower Panel:

Box plot of RMSE for same stations shown in upper panel. Box lines depicts 1st, 2nd and 3rd quartiles, while whiskers depict minimum and maximum of RMSE per time of day.



2 meter T & RH verification (Continued) – MED domain:

st_name	00	V500	Basic	AdvOl	Adv	06	V500	Basic	AdvOl	Adv	12	V500	Basic	AdvOl	Adv	18	V500	Basic	AdvOl	Adv
AFULA_NIR_HAEMEQ		7.9	0.1	-0	-1		5.2	0.9	1.4	-1		5.5	-1	-0	-1		6.9	0.7	0.7	-2
BEER_SHEVA		10	0.9	0.9	0		8.8	1.3	1.4	-2		5.2	-0	-0	-1		8	[illegible]	1.8	1.5
BESOR_FARM		7.5	0.6	0.8	0.1		5.8	1.6	2	0.8		7.5	0.8	0.2	-1		6.7	1.2	2.3	0.8
BET_DAGAN		7.6	2.1	1.9	-0		6.4	0.5	0.3	-2		5.9	-0	-0	[illegible]		15	0.3	0.1	-2
BET_HAARAVA		6.3	1.6	3.4	1.5		5.7	0.4	0.4	-1		5.9	0.4	0.7	1.2		5	0.4	1.7	0.4
DAFNA		12	0.7	1.8	-1		8.9	1.7	1.9	2.8		4.3	0.3	0	0.1		7	1	1.7	1.1
DOROT		8.1	1.6	1.7	-1		7.7	1.5	2.2	-3		5.6	0.5	0	-1		6.8	1	1.1	-1
EDEN_FARM		9.8	1.3	1.3	-3		5.4	0.7	0.8	-1		[illegible]	0	0.3	0		7.6	1.3	1.5	0.3
ELAT		6.7	0	0.1	0		6.2	0.2	0.5	0.1		4.5	0	0.2	0.9		7.6	-1	-0	-2
ELON		12	0.7	0.4	-0		6.8	0.6	1	-2		5.9	0.1	0.2	-1		9.9	1.5	2	-0
EN_HASHOFET		7	1.1	1.3	-0		6.1	0	-0	1.9		6.8	0.4	-0	0.8		9	1.1	0.8	-2
EN_KARMEL		5.9	1.2	1	-1		6.3	0.3	1.4	-1		6	-1	-1	-0		7.6	2.1	2.7	1.5
ESHHAR		11	-0	-0	-2		5.5	0.7	0.7	1.3		7.4	1	0.5	0.8		13	-3	-2	-5
EZUZ		11	1.7	1.9	-2		11	0.8	0.9	-0		4.6	0.1	0	-0		8	0.3	0.2	-1
GAMLA		10	-0	-0	-1		9.2	0.3	-0	2.5		6.5	0.3	-0	2.2		11	-0	-1	0.4
HAIFA_TECHNION		9.5	0.6	0.3	0.8		4.4	0.6	0.5	1.9		9.6	0.7	0.4	0.6		7.3	0.6	0.8	1.4
HAR_HARASHA		14	0.3	0.1	-1		11	0.9	0.4	0.1		6.7	0.3	0.3	0.4		11	-1	-1	-3
HAZEVA		7.6	0.8	0.8	0.3		7.2	0.1	0.1	-1		3.6	-0	-0	0.3		5.3	-0	-0	0.1
ITAMAR		17	-2	-3	-5		12	0.2	-0	0		6.1	0.5	0	0.3		19	-4	-5	-8
JERUSALEM_CENTRE		14	0	0	0.8		9.6	0.3	-0	-1		5.7	0.3	0.2	0.2		13	-1	-1	-3
MEROM_GOLAN_PICMAN		24	1.4	1.5	-3		11	0.4	0.6	-0		6	0.5	0.4	0.5		21	-0	-1	-4
MIZPE_RAMON		17	0.5	0.6	-4		11	0.7	0.8	-1		4.6	0.1	0.1	0		13	0.7	0.3	-2
NAHSHON		8.1	0.5	1.1	2		7.4	1.5	2.2	-2		5.4	0.1	-0	-1		5.1	0.3	1.1	0.7
NEGBA		7.6	1.4	1.4	0.1		6.5	1.2	1.1	-1		5.8	0.4	0	0		5.4	1.1	1.8	-0
NEOT_SMADAR		13	-0	-0	-0		8.8	0	0	-0		4.7	0	0.1	0.6		5.7	-0	-0	0.3
NETIV_HALAMED_HE		14	0	0.3	-2		8.7	1.4	1.8	-3		5.2	0.1	-0	-0		6.4	0.3	0.6	-1
QARNE_SHOMERON		11	0.2	0.7	-3		7.5	1.6	1.7	-0		6.6	1.1	0.6	-0		6.7	2.7	3.4	2.3
SEDE_BOQER		14	1.2	1.1	-5		10	0.9	0.8	-1		4.8	-0	0	[illegible]		7.6	0.3	0.9	0.5
SHANI		15	0.1	0.2	-1		11	0.6	0.4	-1		5.7	-0	-0	[illegible]		13	-1	0.1	-2
TAVOR_KADOORIE		8.5	0.9	1.3	0.4		5.5	1.2	1.6	-1		4.8	0.4	0.1	-0		8.1	2.1	2.2	1.8
YOTVATA		7.6	0	-0	-0		7.3	0.3	0.2	0.1		3.5	0.1	0.3	0.5		4.9	-0	0	[illegible]
ZEFAT_HAR_KENAAN		18	2.3	2.3	0.4		12	-1	0	1.4		10	0.4	-0	1		16	0.3	-0	-2
ZEMAH		8.2	-1	-2	-3		5.9	0.7	1	-0		6.6	0.2	0	0.2		7.4	-1	-0	-1
ZOMET_HANEGEV		9.7	1.5	1.8	-2		11	1.6	1.4	-0		5.4	-0	-0	-1		6.6	0.1	0.5	-0
MEAN		11	11	12	9.9		8	8.8	8.9	7.7		5.8	6	5.8	5.8		9.1	9.4	9.6	8.3
STD		3.9	4	3.9	3.5		2.2	2.2	2.2	2.6		1.4	1.6	1.4	1.7		3.9	3.5	3.2	2.8

st_name	00	V500	Basic	AdvOl	Adv	06	V500	Basic	AdvOl	Adv	12	V500	Basic	AdvOl	Adv	18	V500	Basic	AdvOl	Adv
AFULA_NIR_HAEMEQ		-5	0.3	1.5	2.2		3.5	3.9	4.3	0.3		1.5	0.3	1.1	0.8		-4	0.2	2.6	1.2
BEER_SHEVA		4.3	3.2	4.7	7.3		1.1	0.4	0.1	-3		0.1	-1	-1	0.2		4.5	5.2	7	9.1
BESOR_FARM		-1	-0	1.3	-0		-2	-2	-2	-5		-7	-8	-7	-5		3.5	5.4	7.4	6.9
BET_DAGAN		5.4	6.1	6.2	4.7		3.6	2.7	2.7	1.7		5.5	5	5.1	4		15	15	15	13
BET_HAARAVA		-1	1.9	6	5.8		-2	-1	-1	-2		-5	-6	-6	-7		2.5	3.2	5.4	3.7
DAFNA		-7	-8	-7	-4		-6	-8	-8	-11		-1	-2	-2	-2		-0	2.4	4.1	5.6
DOROT		-2	-2	-0	-2		1.9	1.4	3.3	0.2		-2	-4	-2	-1		2	4.6	4.3	4.2
EDEN_FARM		-3	-2	-1	2.8		-2	-2	-1	-2		1.3	0.1	0.8	1.1		4.3	6.2	6.7	6.4
ELAT		-2	-2	-2	-3		-2	-3	-3	-3		-2	-3	-3	-5		4.6	3.4	3.7	0.4
ELON		0.6	1.1	2.1	6.2		2.6	2.7	3.1	0.2		2.2	0.5	1.3	1.2		0.8	2.6	3.9	7.1
EN_HASHOFET		-0	0.3	0.5	3.3		-2	-2	-1	-6		-5	-6	-5	-6		-4	-4	-4	-2
EN_KARMEL		2.6	3.3	3.5	3.1		3	2.4	3.7	-0		-3	-3	-2	-3		4.1	6.3	7.1	7.5
ESHHAR		-4	-2	-2	1		-1	-1	-1	-4		-6	-7	-6	-6		-11	-6	-7	-5
EZUZ		-5	-6	-5	0.9		-4	-4	-4	-5		-0	-1	-1	0.2		-4	-5	-5	-1
GAMLA		-5	-3	-3	-2		-8	-8	-6	-10		-4	-5	-4	-8		-8	-8	-7	-8
HAIFA_TECHNION		7.9	7.4	7.6	9		0.3	-1	-0	-4		-8	-9	-8	-8		4.7	4.1	5.1	5.7
HAR_HARASHA		-5	-5	-5	3.5		-7	-8	-7	-7		-3	-4	-4	-4		-7	-4	-3	2.1
HAZEVA		-1	-2	-1	3.3		-1	-1	-1	0.5		0	-1	-1	-2		-0	0.3	0.8	2.2
ITAMAR		-13	-10	-9	1.6		-9	-9	-9	-8		-4	-5	-4	-4		-17	-12	-11	-6
JERUSALEM_CENTRE		-3	-2	-2	10		-0	-1	-1	0.7		-1	-2	-2	-3		-9	-5	-4	1.4
MEROM_GOLAN_PICMAN		-21	-24	-23	-17		-4	-7	-6	-7		-2	-3	-2	-3		-19	-19	-17	-13
MIZPE_RAMON		-10	-11	-10	-3		-5	-7	-7	-5		-1	-1	-2	-2		-10	-11	-11	-8
NAHSHON		-2	-2	-1	-0		0.1	-0	-0	-2		-2	-3	-3	-2		-1	1.3	3.4	3.3
NEGBA		1.3	2.2	3.2	1.9		-1	-1	-1	-2		-4	-4	-3	-4		0.9	3.3	4.9	2.9
NEOT_SMADAR		-11	-11	-11	-10		-5	-6	-6	-5		-3	-3	-3	-4		-2	-2	-2	-2
NETIV_HALAMED_HE		-9	-7	-7	-1		0.1	0.7	1	0		0.5	-1	-1	0.7		-3	0.2	1.8	3
QARNE_SHOMERON		-6	-4	-3	4		-4	-4	-3	-5		-4	-6	-5	-4		0.7	6	7.9	7.6
SEDE_BOQER		-6	-8	-7	2.6		-3	-3	-4	-4		1.7	1.1	1.3	1.7		0.6	0.2	1.5	4.6
SHANI		-6	-6	-6	3.2		2.3	2	2	0.7		0.5	0.5	0.3	-0		-9	-7	-7	-6
TAVOR_KADOORIE		-2	-0	0.3	6.2		0.3	0.4	1.4	-2		-1	-2	-1	-1		-1	4.6	4.6	6.8
YOTVATA		-5	-5	-5	-5		-3	-4	-4	-3		-1	-1	-2	-2		1.8	1.5	1.8	1
ZEFAT_HAR_KENAAN		7.7	13	13	8.1		2.7	4.1	4.9	-1		-9	-10	-9	-11		-10	-9	-8	-5
ZEMAH		-7	-3	-2	0.2		-2	-2	-1	-2		-3	-4	-3	-4		-3	0.4	0.2	1.1
ZOMET_HANEGEV		-2	-3	-3	3		-4	-4	-5	-6		-1	-2	-2	-2		0.3	0.1	1.8	3.2
MEAN		-3	-3	-2	1.4		-2	-2	-2	-3		-2	-3	-2	-3		-2	-0	0.5	1.6
STD		5.7	6.2	6.4	5.2		3.3	3.5	3.6	3.1		3	3	2.9	3.1		6.7	6.5	6.6	5.6

Upper Panel:

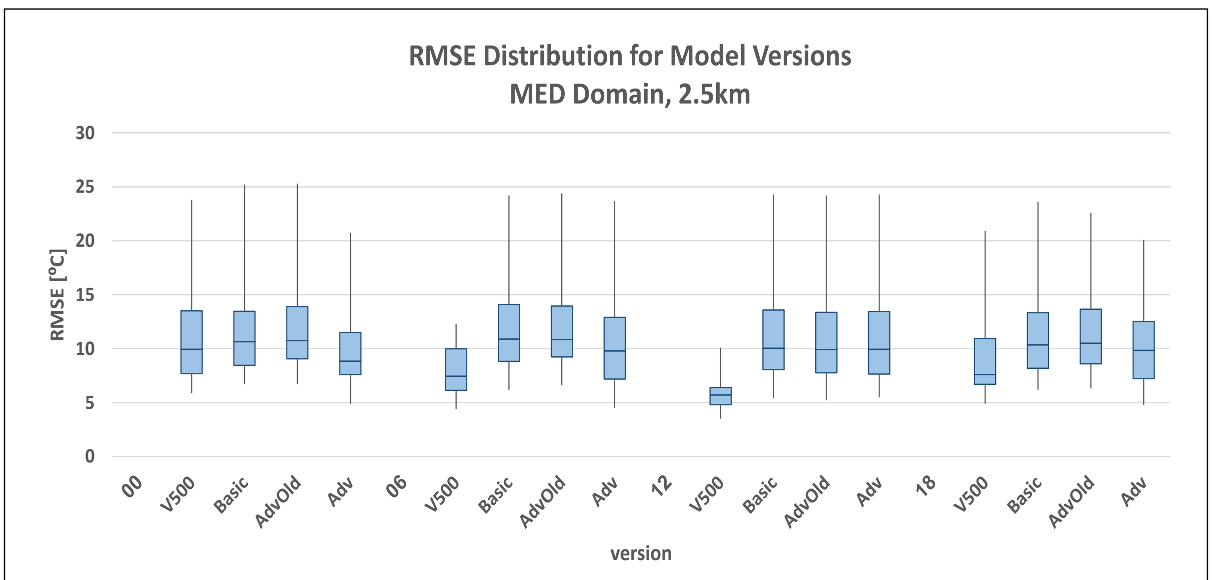
***Verification for 2m relative humidity in EU domain, 6.5km resolution**. Left panel shows RMSE for 00z (24h fcst), 06z (6h fcst), 12z & 18z. For each time of day, reference configuration absolute RMSE appears on the left most coloumn, the darker the shading – the worse the RMSE. For v5.05 configurations (Basic, Ad.Old, Adv.) the difference from the reference configuration is shown - green for better RMSE, red for worse.*

Right panel shows MBE for same times of day and configurations. Dry bias colored yellow, humid bias colored blue.

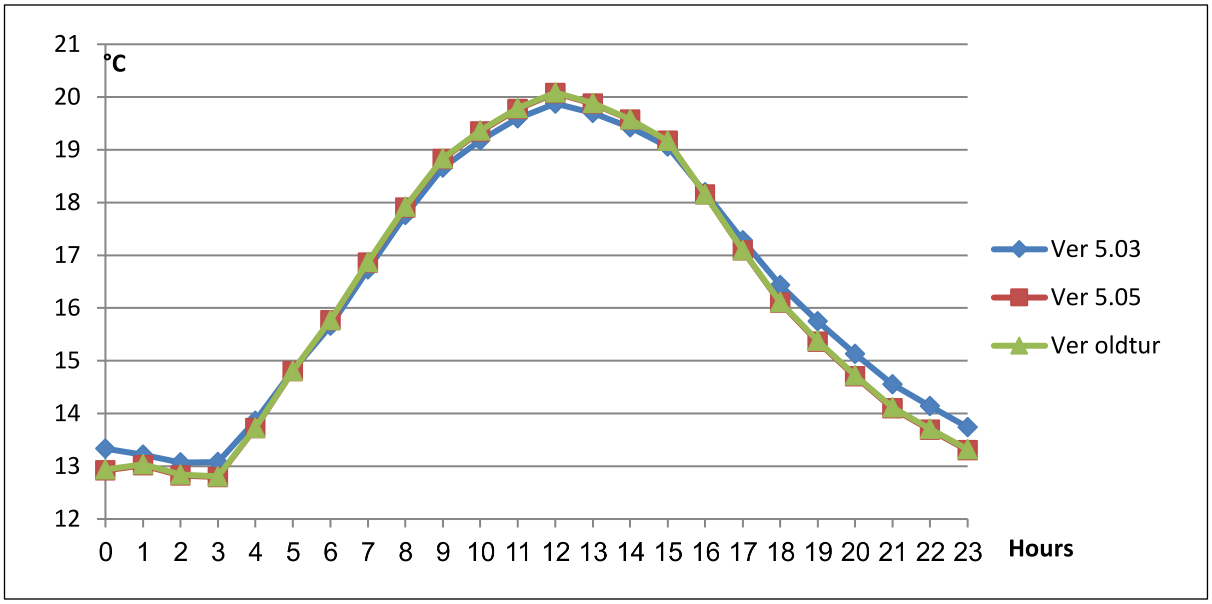
In example: 18z fcst of Adv. configuration shows worse RMSE than reference configuration because of a humid bias, as discussed above.

Lower Panel:

Box plot of RMSE for same stations shown in upper panel. Box lines depicts 1st, 2nd and 3rd quartiles, while whiskers depict minimum and maximum of RMSE per time of day.

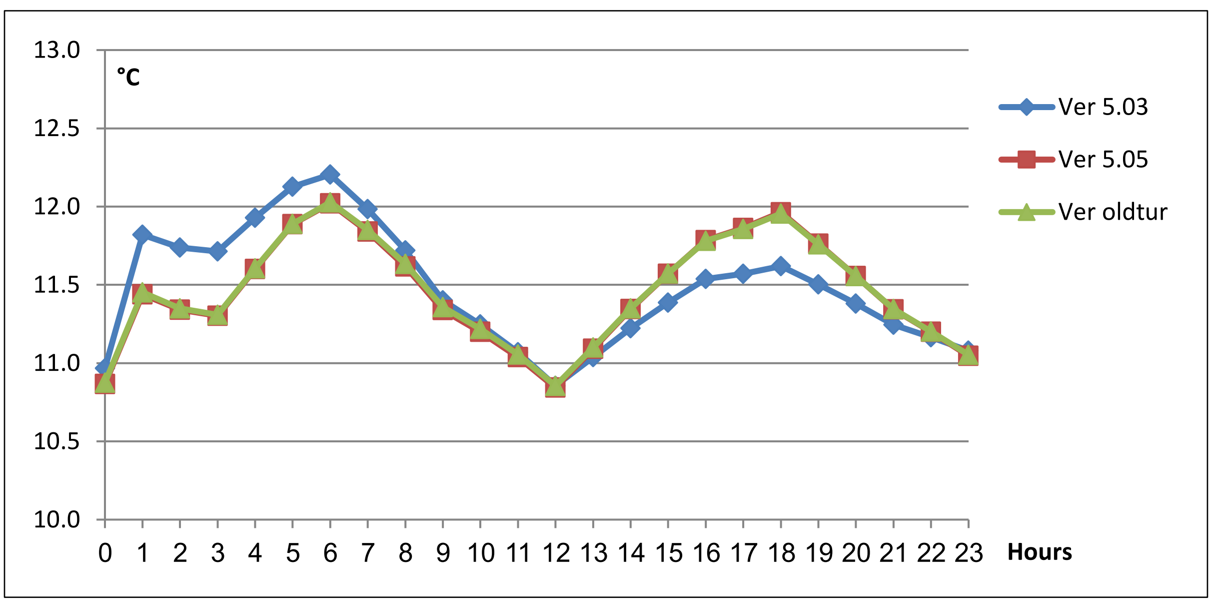


2 meter T & RH verification (Continued) – NE domain:

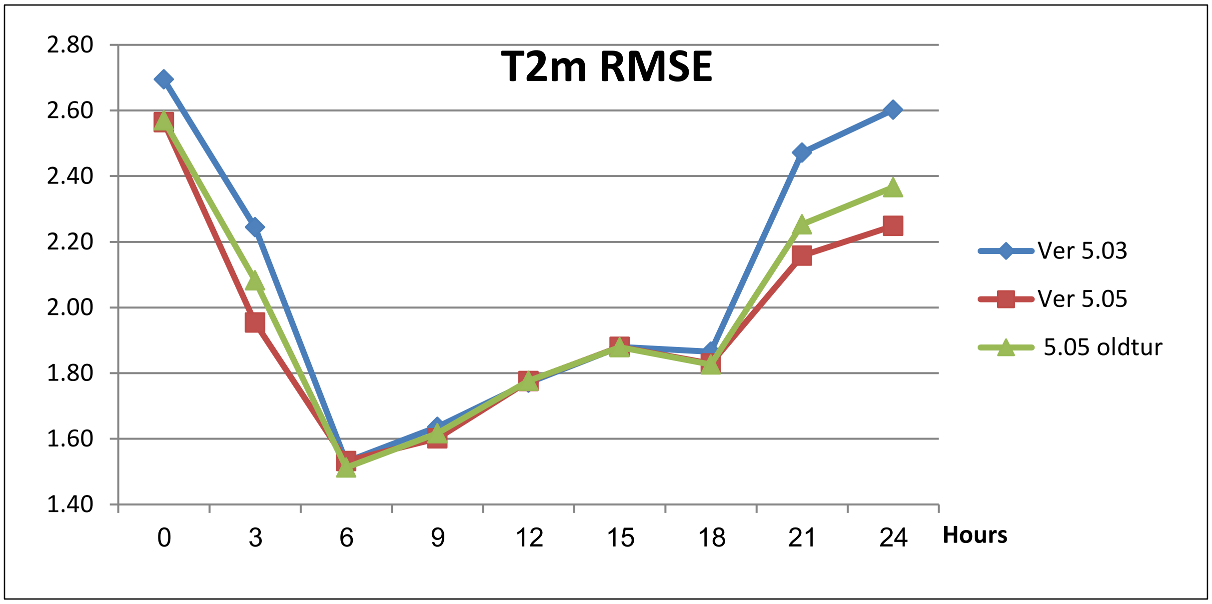


Upper Panel:
Domain averaged daily cycle of air temperature at 2m in NE domain, 2.2km resolution *from the 1 of May till the 30 of September 2016. Showing model versions 5.03, 5.05 (NE "Advanced") and 5.05 oldtur (NE "Adv. Old Tur.).*
Lower Panel:
Domain averaged daily cycle of dew-point temperature at 2m in NE domain, 2.2km resolution *from the 1 of May till the 30 of September 2016. Showing model versions 5.03, 5.05 (NE "Advanced") and 5.05 oldtur (NE "Adv. Old Tur).*

While both versions of 5.05 configuration are practically identical in the mean values for the entire domain, it is evident that 5.05 version shows some cooling at evening and night with moistening in the evening and drying at the early morning

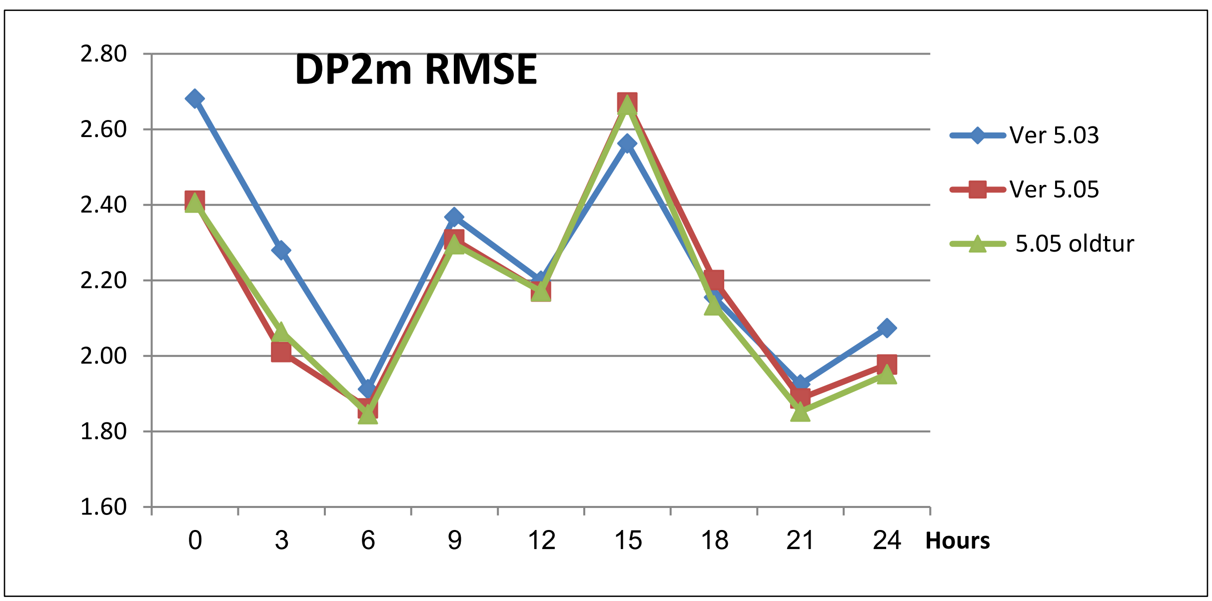


2 meter T & RH verification (Continued) – NE domain:

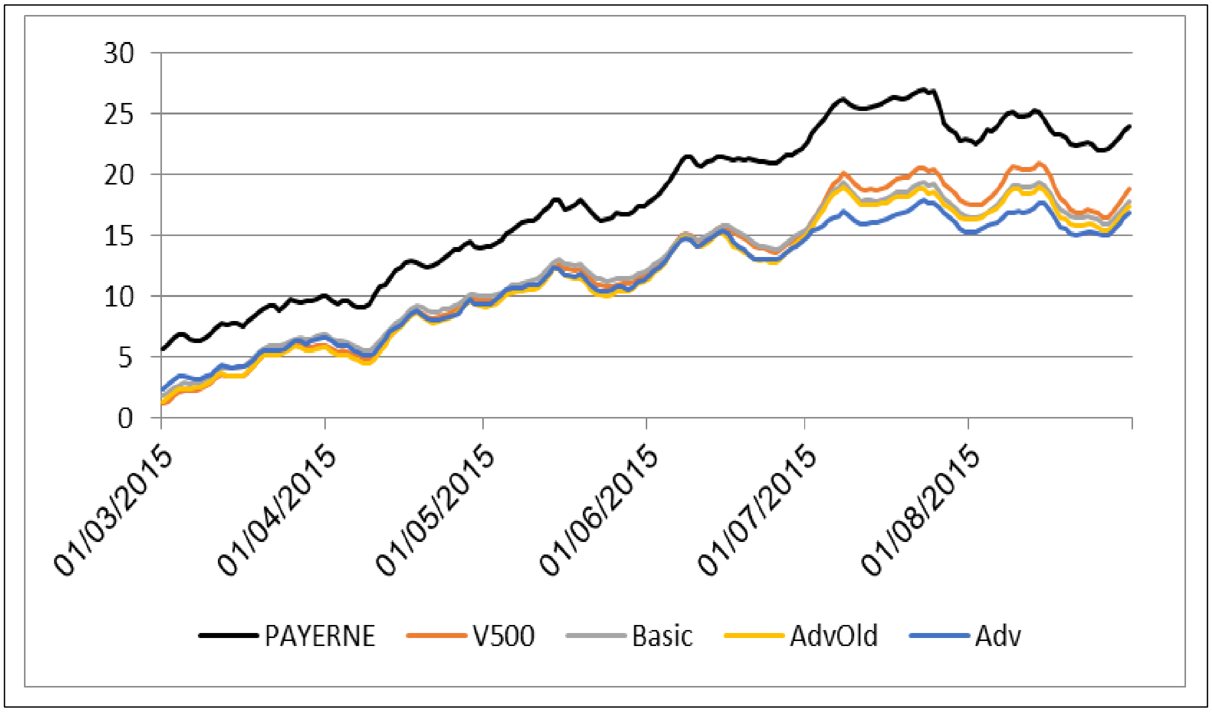


Upper Panel:
Verification over 18 station of air temperature at 2m in NE domain, 2.2km resolution*. Showing model versions 5.03, 5.05 (NE "Advanced") and 5.05 oldtur (NE "Adv. Old Tur.).*
Lower Panel:
Verification over 18 station of dew point temperature at 2m in NE domain, 2.2km resolution*. Showing model versions 5.03, 5.05 (NE "Advanced") and 5.05 oldtur (NE "Adv. Old Tur.).*

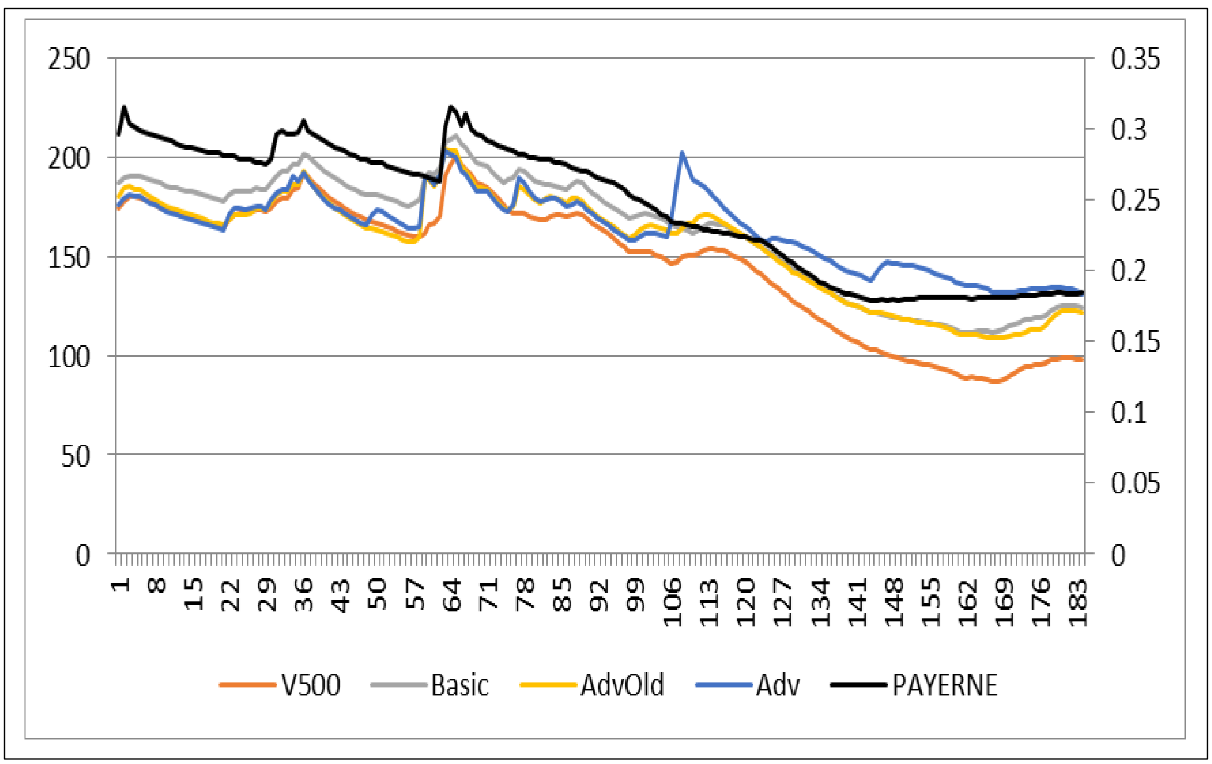
Version 5.05 shows improvement in both temperature and dew point RMSE over almost all hours of the day. Improvement is greater during night, suggesting that fluxes are depicted better by version 5.05 as desired.



Soil temperature & water content – EU domain:

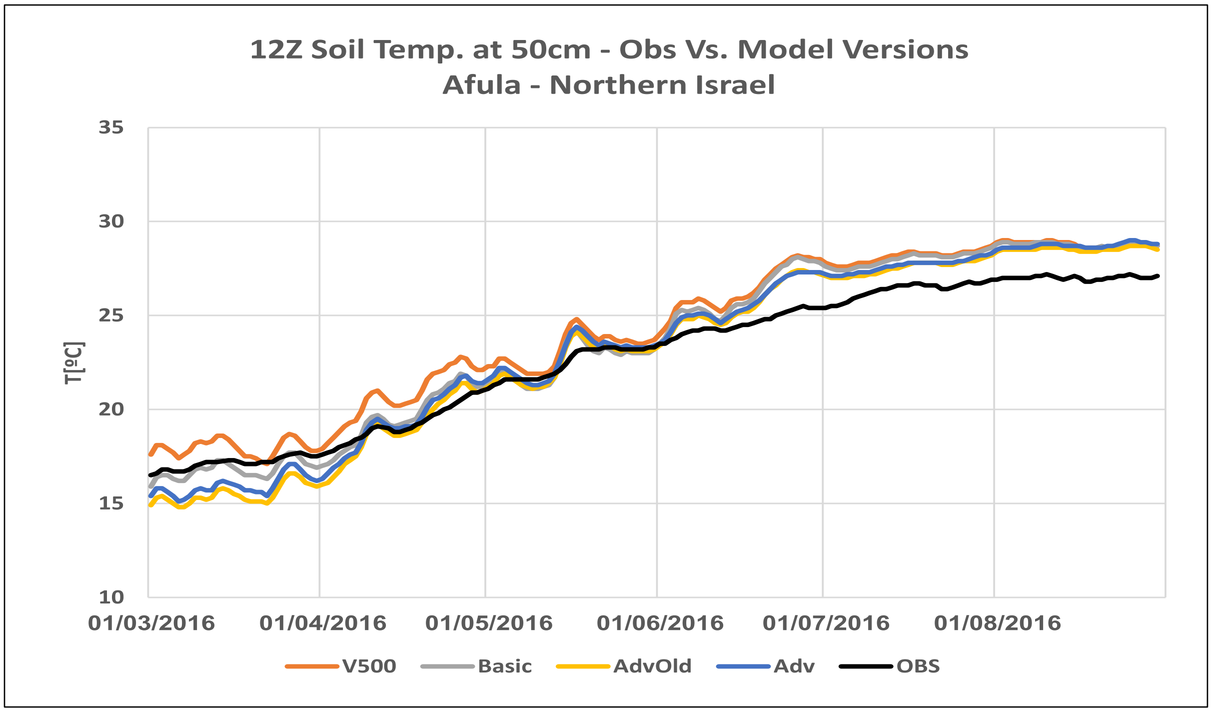


Verification for soil temperature, 54cm deep in Payerne, switzerland (EU domain, 2km resolution)*. All configurations show same behavior with Adv. configuration showing colder bias starting mid-June.*

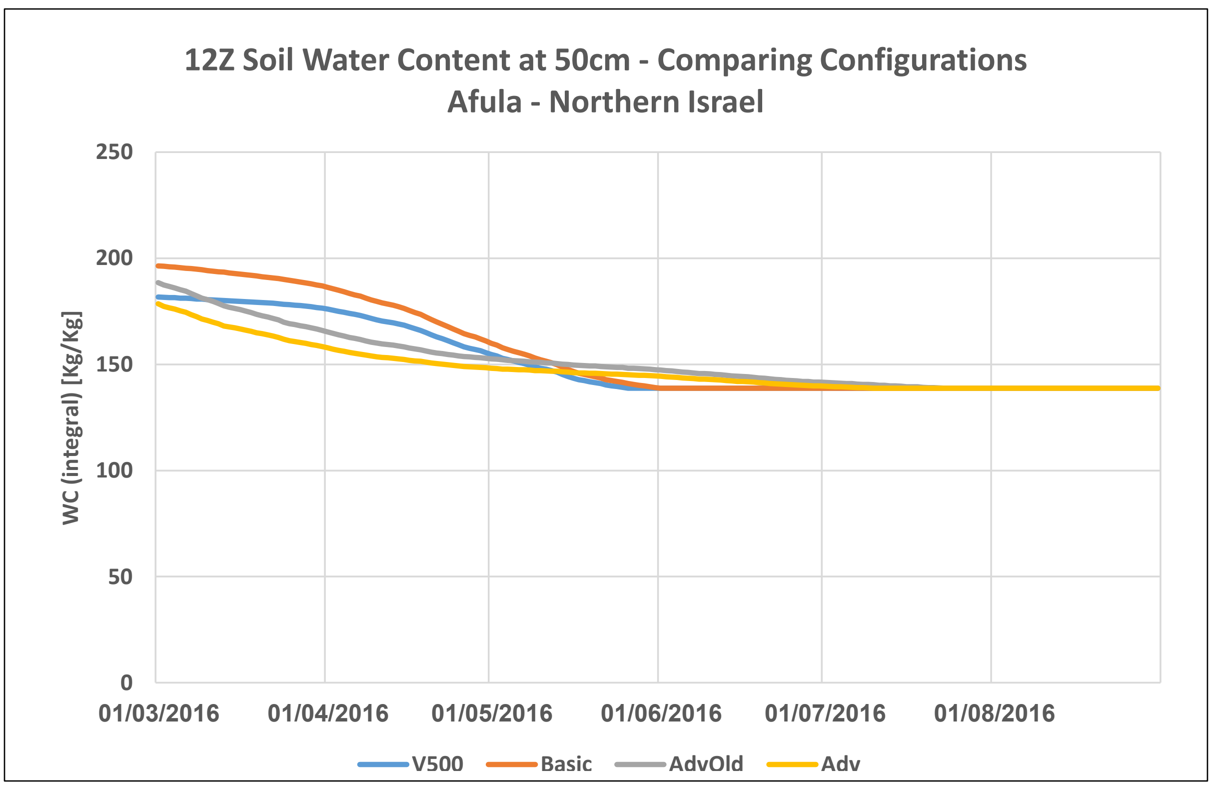


Verification for soil water content, 54cm deep in Payerne, switzerland (EU domain, 2km resolution)*. All configurations show same behavior with Adv. configuration showing wetting event around day 110 (20/6/15). No drying of soil is evident in Adv. configuration.*

Soil temperature & water content (Continued) – MED domain:

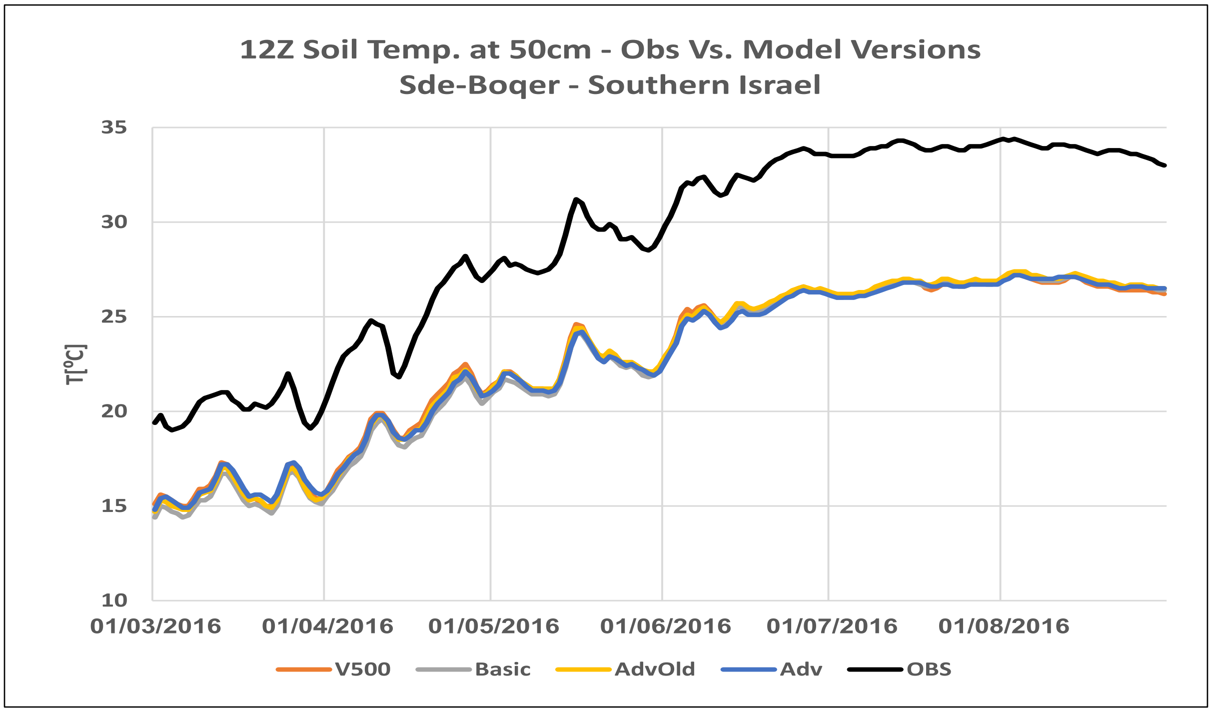


Comparison of soil temperature, 54cm deep in Afula, northern Israel (MED domain, 2km resolution)*. All configurations show same behavior which over estimates temperature during summer.*

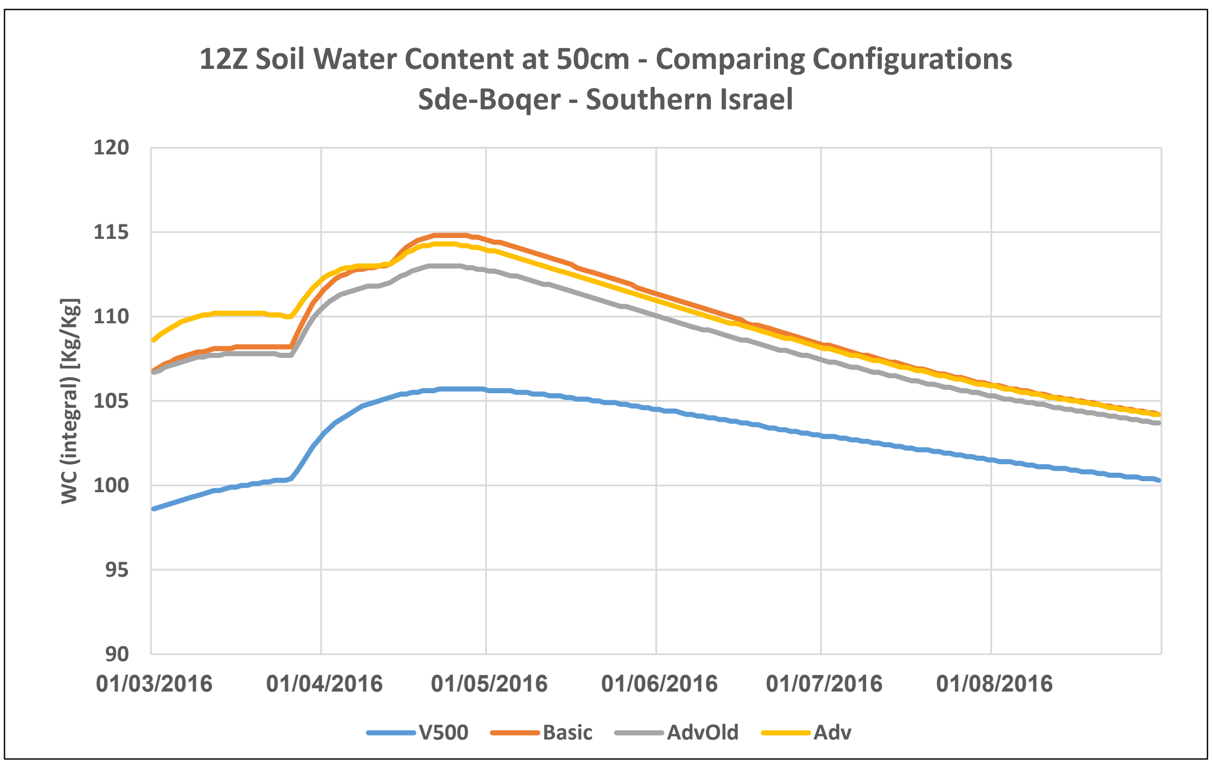


Comparison of soil water content, 54cm deep in Afula, northern Israel (MED domain, 2km resolution)*. All configurations reach same WC by Mid July, but both "Advanced" configurations show faster drying of the soil at that depth.*

Soil temperature & water content (Continued) – MED domain:

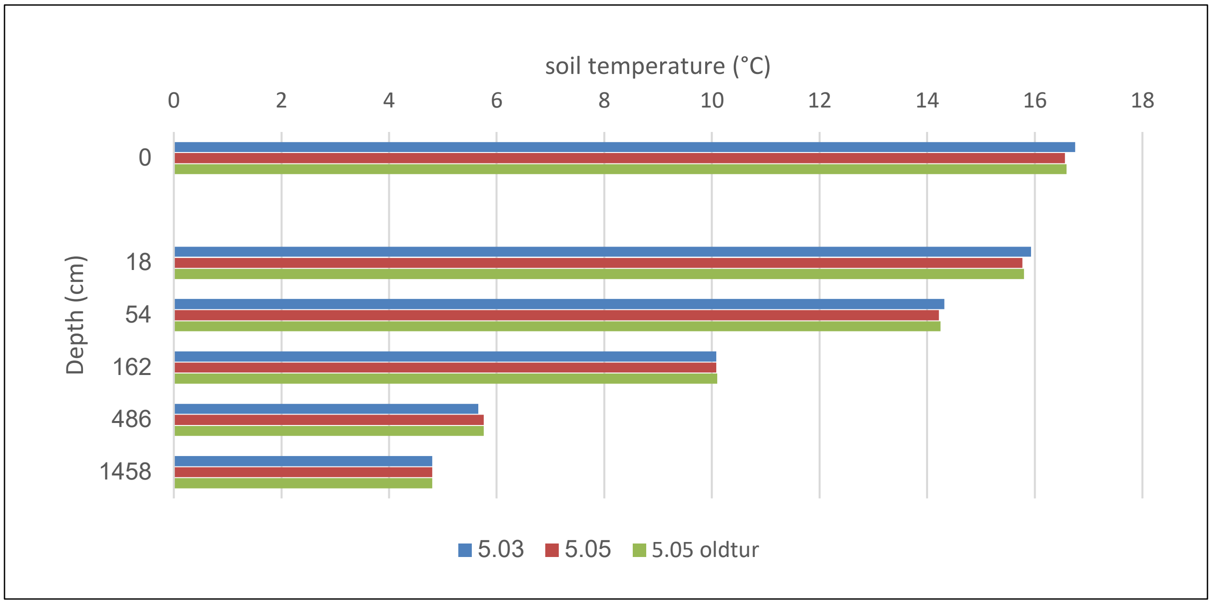


***Comparison of soil temperature, 54cm deep in Sde-Boqer, southern Israel (MED domain, 2km resolution)**. All configurations show same values and same 5°C bias. This bare soil location suggests a more realistic depiction of this environment is necessary.*



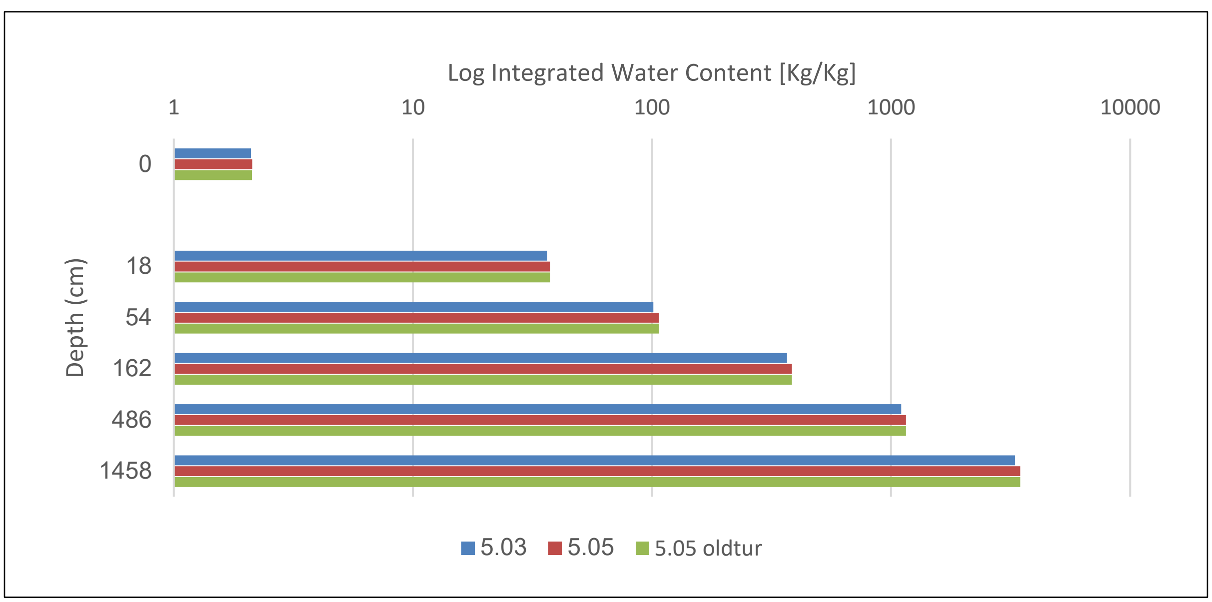
***Comparison of soil water content, 54cm deep in Sde-Boqer, southern Israel (MED domain, 2km resolution)**. All 5.05 configurations show higher WC for the period shown relatively to the reference configuration. Furthermore, while 5.00 configuration shows only one increase in WC attributed to rain, 5.05 configurations show two incidents of increase in WC. In fact it precipitated in Sde-Boqer on March 26th (8mm) and on April 10th to 13th (17mm). This suggests that 5.05 version might depict better even rain events.*

Soil temperature & water content (Continued) – NE domain:



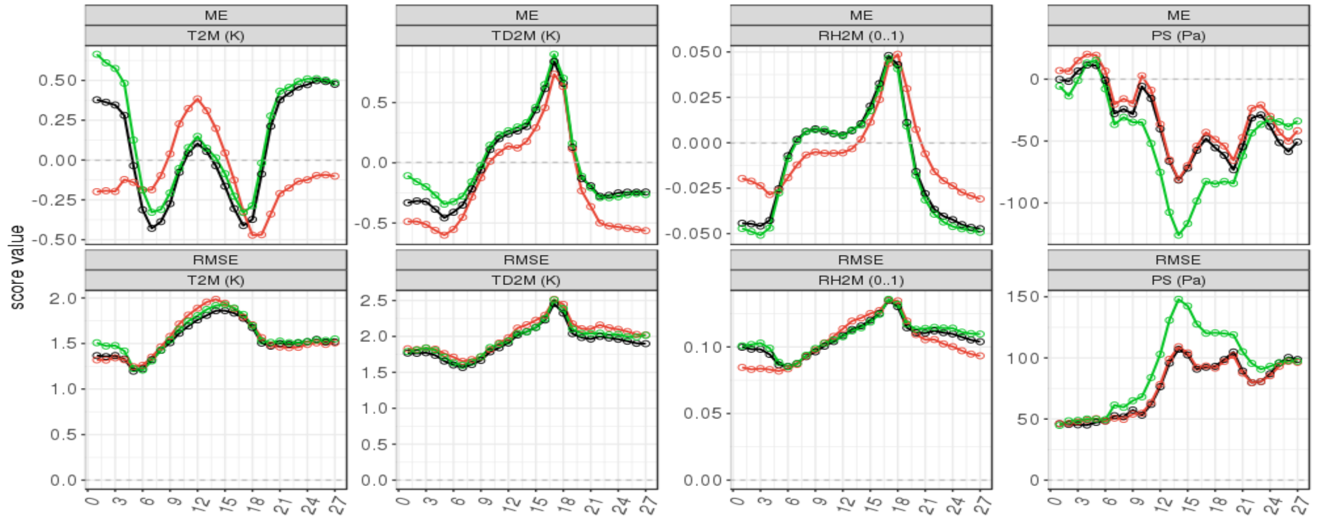
Upper Panel:
Domain averaged soil temperature in various depths in NE domain, 2.2km resolution *from the 1 of May till the 30 of September 2016. Showing model versions 5.03, 5.05 (NE "Advanced") and 5.05 oldtur (NE "Adv. Old Tur.).*
Lower Panel:
Domain averaged soil water content (integrated for the entire soil coloumn) in various depths in NE domain, 2.2km resolution *from the 1 of May till the 30 of September 2016. Showing model versions 5.03, 5.05 (NE "Advanced") and 5.05 oldtur (NE "Adv. Old Tur.).*

Both configurations of version 5.05 show similar results, while differences between versions 5.03 and 5.05 are more noticeable, but also quite small. On upper soil levels in version 5.03 soil is 0.1-0.15°C warmer than in version 5.05. On the other hand, on soil level 486 cm, soil is colder by 0.1°C. In addition, in version 5.05 soil water content is higher than in version 5.03.



Additional data - DWD experiments:

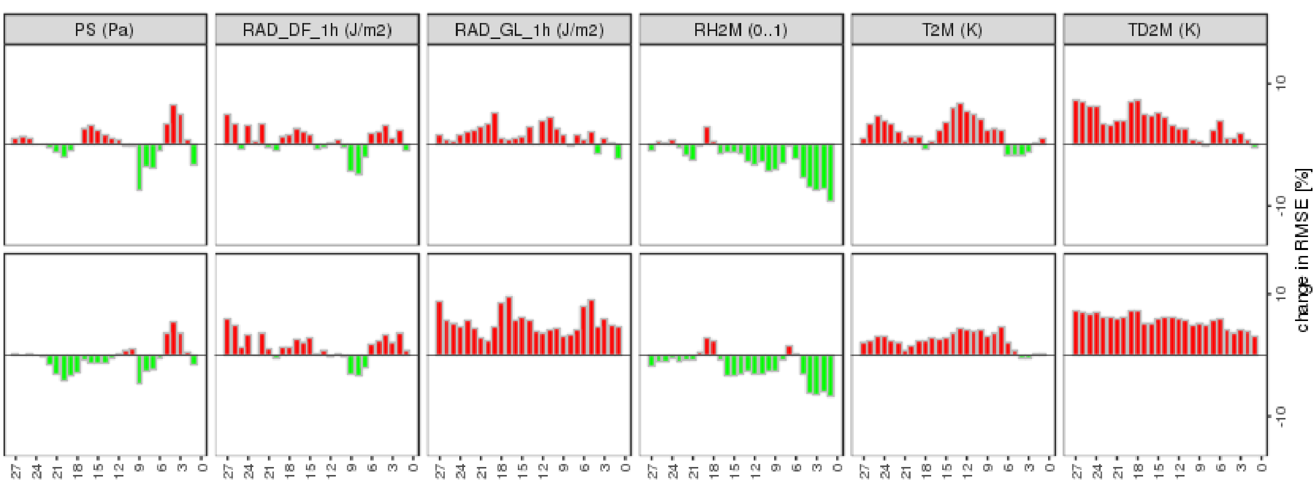
ME and RMSE for surface parameters – ref. version (Black), new TERRA (Red), COSMO (Green)



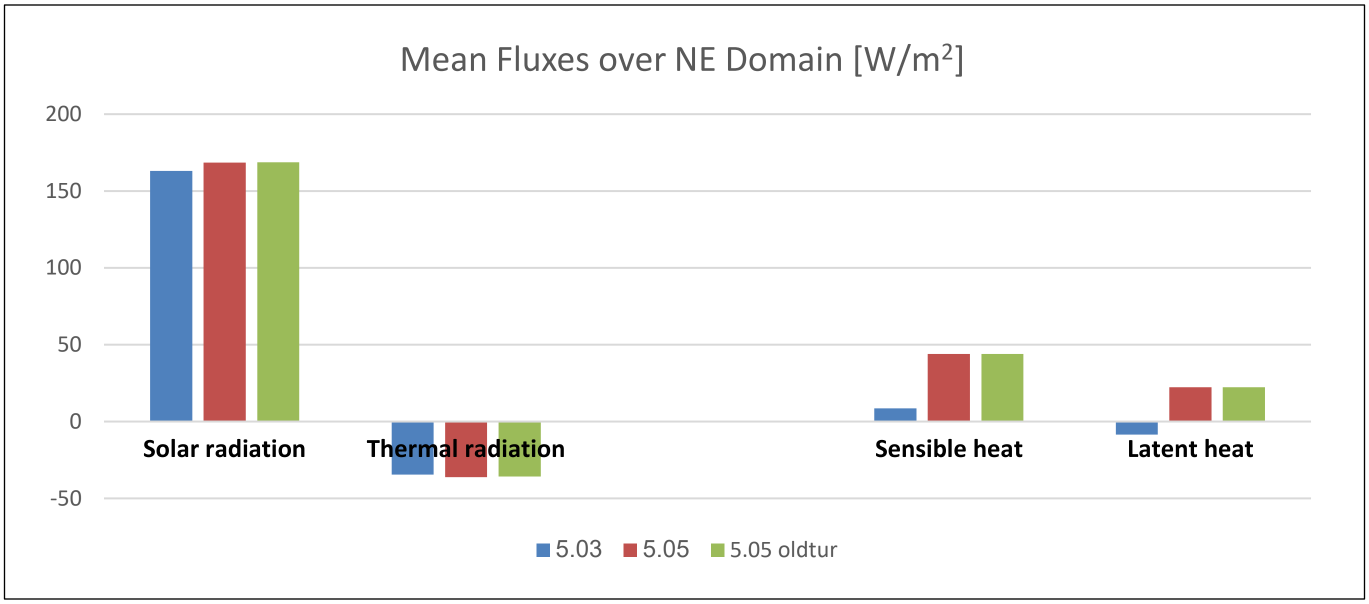
Upper Panel:
Domain averaged surface parameters, German domain, 2.2km resolution *from the 26 of May till the 13 of June 2016.*
Lower Panel:
Domain averaged surface parameters, German domain, 2.2km resolution *from the 26 of May till the 13 of June 2016. Chart showing improvement (green) or worsening (red) of RMSE for the new TERRA scheme in comparison to the reference version.*

While relative humidity shows some improvement, all other parameters seem to be worse with the new scheme (red line compared to black line). It is argued by DWD that in order to obtain better results with the new scheme, data assimilation and/or soil moisture analysis should still be used with the new scheme.

Difference in RMSE - new TERRA scheme compared to reference version.



Additional data (Continued) – mean fluxes data – NE domain:



Upper Panel:
Domain averaged flux data overn NE domain, 2.2km resolution *from the 1 of May till the 30 of September 2016. Showing model versions 5.03, 5.05 (NE "Advanced") and 5.05 oldtur (NE "Adv. Old Tur.).*
Lower Panel:
Domain averaged flux data overn NE domain, 2.2km resolution *from the 1 of May till the 30 of September 2016. Showing model versions 5.03, 5.05 (NE "Advanced") and 5.05 oldtur (NE "Adv. Old Tur.).*

While both versions of 5.05 configuration are practically identical in the mean values for the entire domain, it is evident that 5.05 version shows an excessive sensible ***and*** *latent heat values for the entire domain during that period.*