

REPORT

Smoothing of Soil Wetness Index (SWI) in ALADIN/LACE domain

Stjepan Ivatek-Šahdan

Meteorological and Hydrological Service of Croatia

ivateks@cirus.dhz.hr

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1. Introduction

During the period 15th – 20th June 2002 Slovakian colleague Jan Masek noticed that during the day hot spots appear in 2m Temperature field (http://www.shmu.sk/aladin_lace/). They occur in flat areas, e.g. N Austria, SW Slovakia, Hungary. Hot spots do not move and they can be observed on the same place for several days. There is no corresponding pattern in 925hPa level. At these areas 2m Temperature was affected by too warm soil. The cause of hot spots problem in ALADIN/LACE is very probably the same as the cause of similar problems observed already in ARPEGE and ALADIN-France. The explanation is in the too strong horizontal variability of soil moisture in the model. The origins of this variability are multiple: long time scale evolution of total soil moisture, necessity of using switching conditions in the soil moisture analysis since the correlation's between 2m errors and soil moisture errors are mostly situation dependent.

On Figure 1, 2m Temperature field and Soil Wetness Index for June 18th 2002 15 UTC are shown, 15 hours forecast. There is good correlation between areas with high 2m Temperature and dry areas.

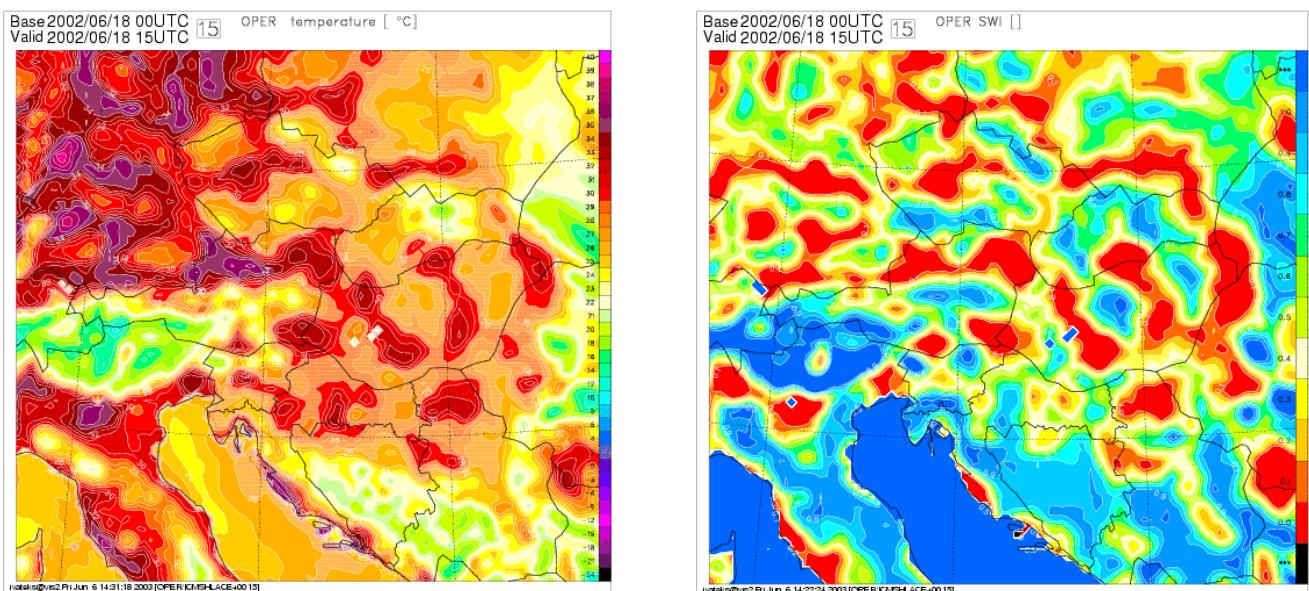


Figure 1 2m Temperature and Soil Wetness Index for June 18th 2002 15 UTC, 15 hours fcst

The aim of this work is to reduce the current unrealistic spatial heterogeneity of soil moisture by smoothing spatially the Soil Wetness Index (SWI). That heterogeneity caused hot spots in forecasted 2m Temperature during period 15th–20th June 2002 in ALADIN/LACE forecast. This period was tested first, with different combinations of smoothed SWI. Afterwards, the chosen combinations were tested on six cases in year 2003; January-3 days, April-2 days and May-1 day.

2. How Optimum Interpolation surface analysis works?

The Optimum Interpolation (OI) surface analysis is operational analysis in global model ARPEGE. As input for OI surface observation of 2m Temperature and Humidity are used. As it is known, in ALADIN or ARPEGE model we do not have level which corresponds to that height, and a vertical interpolation is required to compare the model fields with 2m observations. It interpolates the surface and the lowest model layer values supposing that the fluxes are calculated according to Monin Obukhov theory.

Analysis is sequential, with frequency of 6 hours, at that time observations are assimilated to correct background field.

After the OI, surface analysis of 2m SYNOP observations are interpolated at the model grid-point (by a 2m analysis). Because we don't have model level on 2m correction of surface parameters using 2m

increments ($\Delta T_{2m} = T_{2m}^a - T_{2m}^f$ & $\Delta RH_{2m} = RH_{2m}^a - RH_{2m}^f$) between analysed and forecasted values is needed. Surface parameters which are changed according the increments of 2m Temperature and Humidity are T_s – Surface temperature, T_p – Mean soil temperature, W_s – Superficial (liquid) soil water content and W_p – Total liquid soil water content.

On figure on a right hand side evolution of Total soil water according the increments of 2m Temperature and Humidity.

Increments for surface prognostic variables are defined by the following expresions:

- for Temperatures:

$$T_s^a - T_s^f = \Delta T_{2m}$$

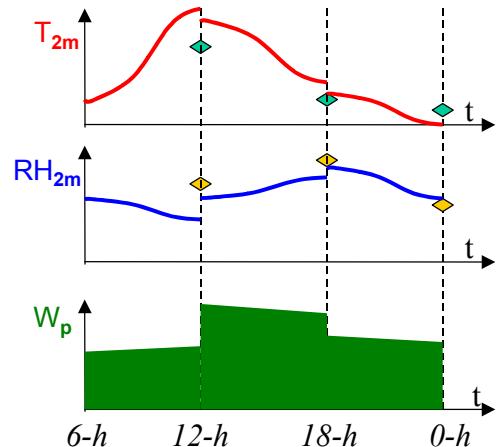
$$T_p^a - T_p^f = \Delta T_{2m}/2\pi$$

- for Soil water contents:

$$W_s^a - W_s^f = \alpha_{W_sT} \Delta T_{2m} + \alpha_{W_sRH} \Delta RH_{2m}$$

$$W_p^a - W_p^f = \alpha_{W_pT} \Delta T_{2m} + \alpha_{W_pRH} \Delta RH_{2m}$$

OI coefitiens $\alpha_{W_p/T/RH}$ are function of local time, percentage of vegetation, LAI/Rsmin, texture, atmospheric conditions.



After the Analisis is finished, only suface data are stored as model variables, and 2m variables are recalculated from lowest model level and surface variables. The measurments are not distributed homogeniusly, the surface analysis and forecast of connective precipitation have high degree of uncertainties which produce small scales features in the soil moisture. Surface analysis is done in ARPEGE (resolution from 20-200 km).

3. Soil Wetness Index (SWI)

The initialisation of soil moisture is very important in meteorological models since the repartition between sensible and latent heat fluxes at the surface depends on the quantity of water in the ground available for evapotranspiration.

The soil moisture in the LSS ISBA is represented by the superficial soil moisture W_s (quantity of water in 1 cm) and the total soil moisture W_p (quantity of water in the total reservoir depth dz). The total soil moisture is much more important to be initialised than W_s since the superficial reservoir has small capacity and W_s is relaxed towards W_p with a time scale of 2 days. The volumetric soil water content (W_p/dz) is not the best field to compare the available soil moisture for transpiration between grid-point. We often prefer the Soil Wetness Index (SWI), which represents the hydric stress of the vegetation. If $SWI \leq 0$ that means the transpiration of the plants is zero (dry soils) and if $SWI \geq 1$, the vegetation evaporate at the potential (maximal) rate (wet soils). Definition of SWI is shown bellow:

$$SWI = \frac{W_p + W_{pi} - W_{wilt}}{W_{fc} - W_{wilt}},$$

where is:

W_p - Total soil water content liquid (water),

W_{pi} - Total soil water content frozen (ice),

W_{wilt} - Soil water content at wilting point,

W_{fc} - Soil water content at field capacity.

Because SWI field has big gradients, it is possible to find completely dry and saturated soil on a distance of a few grid-points (~100 km), what is not realistic. The SWI field evolves on very long time scales, like W_p , because of the large capacity of the total soil reservoir in ISBA.

Smoothing is performed with subroutine elislap, which smooths a field by adding its laplacian times a constant factor (a length scale). Smoothing is performed just for land points, without snow cover and without ice in the ground, in the ALADIN model. The laplacian is calculated with the 5 nearest grid-points.

After that, because there is not **SWI** in ALADIN files, it was needed to convert SWI_{smooth} and put back $(W_p)_{smooth}$ and in ALADIN file. $(W_p)_{smooth}$ is calculated with these formulae:

$$(W_p)_{smooth} = SWI_{smooth} \cdot W_{fc} + (1 - SWI_{smooth}) \cdot W_{wilt},$$

and two more checks:

$$\text{if } (W_p)_{smooth} \leq veg \cdot W_{wilt} \text{ then } (W_p)_{smooth} = \max(W_p, (W_p)_{smooth})$$

$$\text{if } (W_p)_{smooth} \geq W_{fc} \text{ then } (W_p)_{smooth} = \min(W_p, (W_p)_{smooth})$$

$$(W_p)_{smooth} = \max(\max(W_s, dz), (W_p)_{smooth})$$

where is:

- veg** - Percentage of vegetation,
- W_s** - Surface soil water content liquid (water),
- dz** - Soil depth or reservoir depth.

To be able to make calculation of SWI next fields are needed in ALADIN or ARPEGE FA-file: Land/sea mask (SURFIND.TERREMER), Snow depth (SURFRESERV.NEIGE), Frozen deep soil wetness (PROFRESERV.GLACE), Percentage of vegetation (SURFPROP.VEGETAT), Soil depth (SURFEPAIS.SOL), Percentage of clay within soil (SURFPROP.ARGINE), Liquid (water) surface soil wetness (SURFRESERV.EAU), Liquid (water) deep soil wetness (PROFRESERV.EAU)

Smoothing is performed just for land points (Land/sea mask SUFRIND.TERREMER=1), points without snow cover (SURFRESERV.NEIGE=0), and without ice in a ground (Frozen deep soil wetness PROFRESERV.GLACE=0).

On Figure 2, analyzed and 6, 12 and 15 hour forecasts SWI are shown. There is no important change between analysis and forecasts. Dry areas remain dry and wet areas remain wet after 15 hours of forecast. SWI field has big gradients, on a distance of less than 100 km, it is possible to find completely dry and saturated soil, what is not realistic. With smoothing of SWI we would like to reduce the current unrealistic spatial heterogeneity of soil moisture.

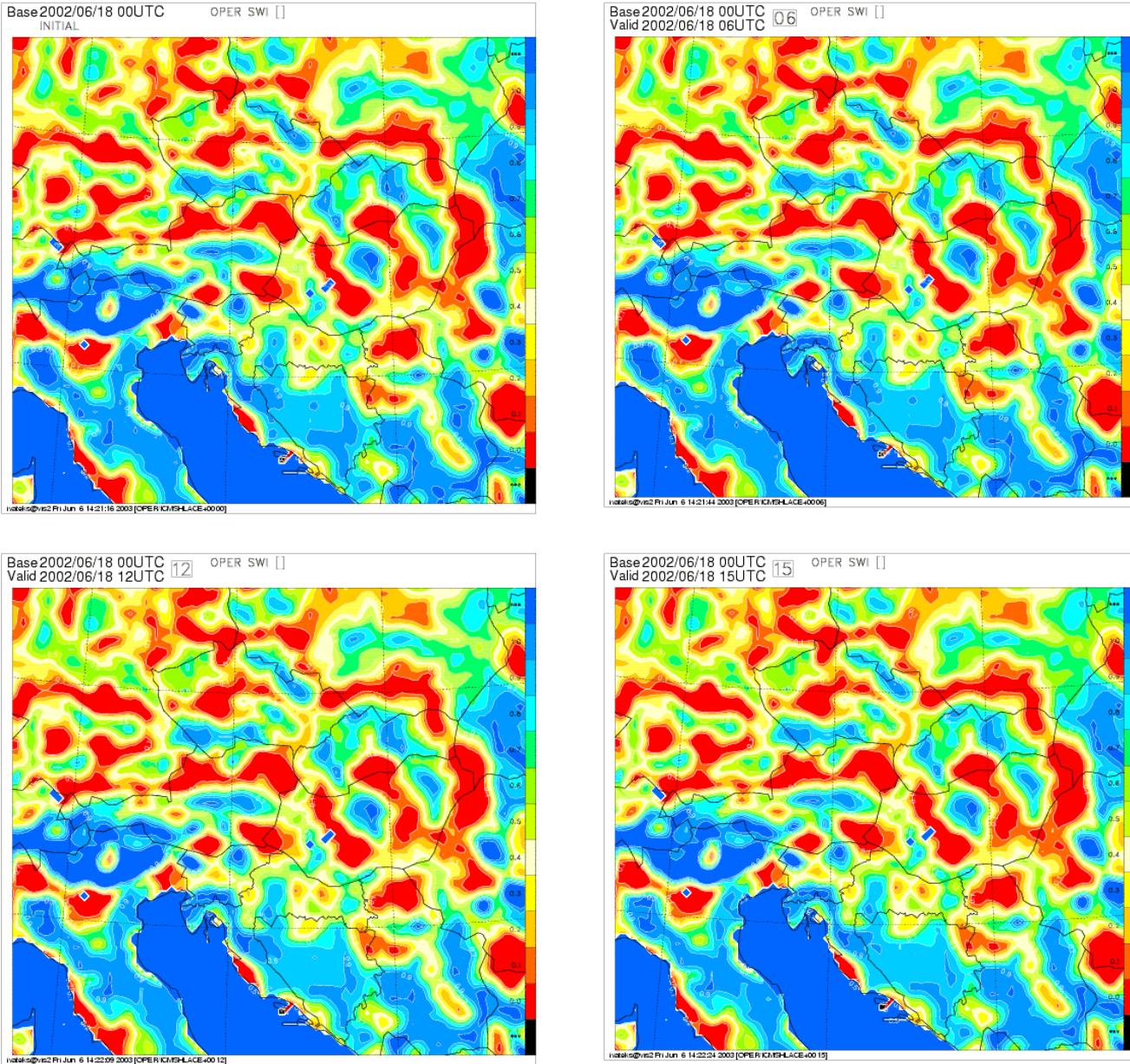


Figure 2 Smoothed Soil wetness index for operational run, start 18.06.2002. 00 UTC, analysis and forecasts for 6, 12 and 15 hours

4. Smoothing of SWI

With increasing of the radius of smoothing we increase area that is smoothed and amplitude of smoothing. After some value with increasing of the radius of smoothing results are the same like it is with lower radius. For LACE domain 12.2 km resolution results are the same for 8.1 and 6.1 km. In ALADIN smoothing is performed with data from just 5 nearest grid points and in ARPEGE it is with 7 grid points. Idea is just to smooth the SWI field over the land if there is no ice in a ground or snow cover. That means to high impact during the summer and low or no impact during the winter.

On Figures 3 and 4 results for smoothing of SWI for winter and summer are shown. For a summer period 00 UTC smoothing is performed for all domain, as it is shown on Figure 4. Radius of smoothing is 4.1 km (1/3 of grid size) or 6.1 km (1/2 of grid size), and numbers of smoothing are 10, 21 and 30. In legend XXSMRR, means that smoothing is performed XX times with radius of smoothing RR*0.1 km. 10SM61 means that 10 smoothings are performed with radius of 6.1 km. Smoothing is working quite well.

SWI-20030113_00

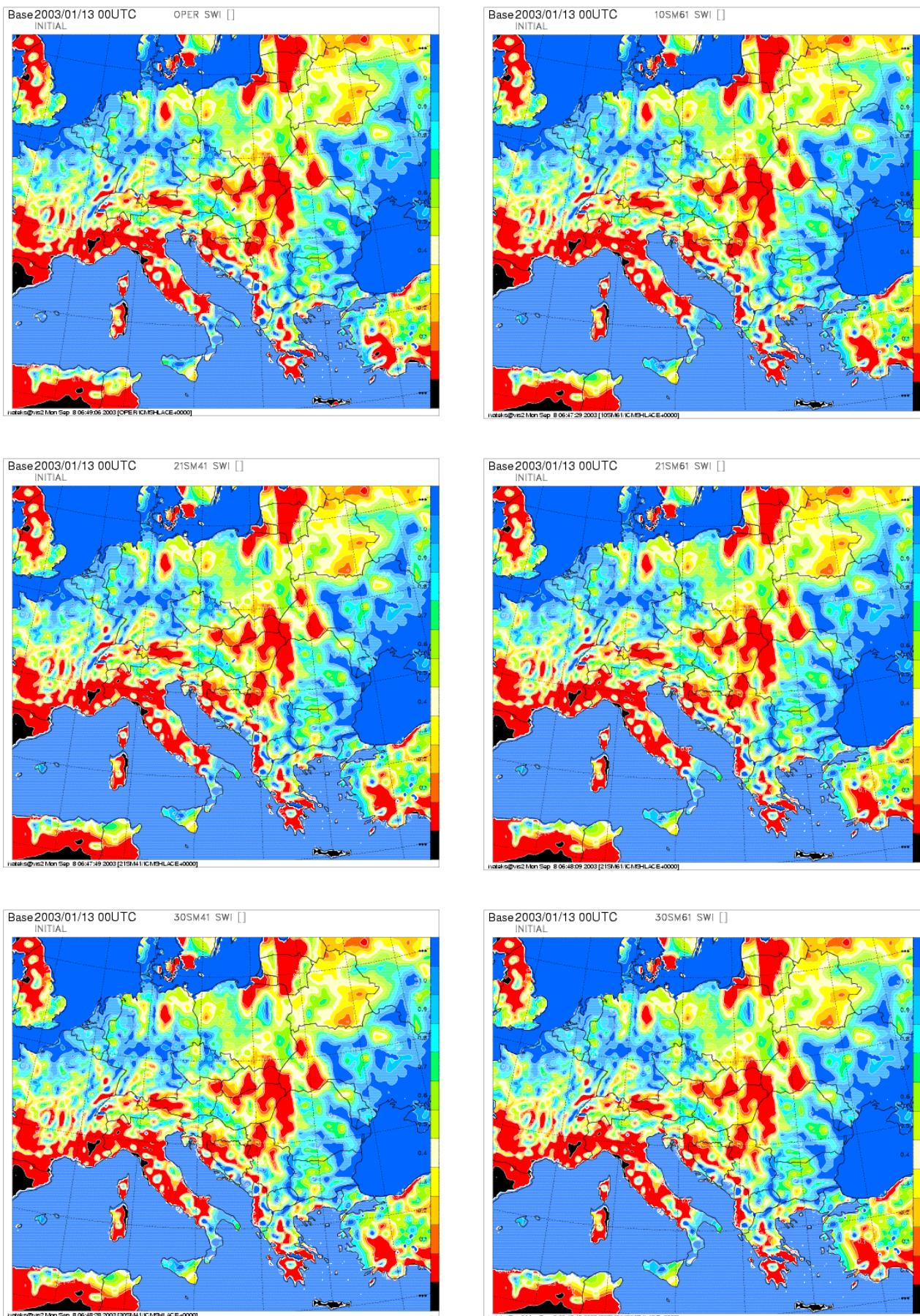


Figure 3 Smoothed Soil wetness index for operational run and for different numbers (10, 21, 30) and radius of smoothing (4.1, 6.1 km), for 13.01.2003. 00 UTC, winter example

SWI-20020619_00

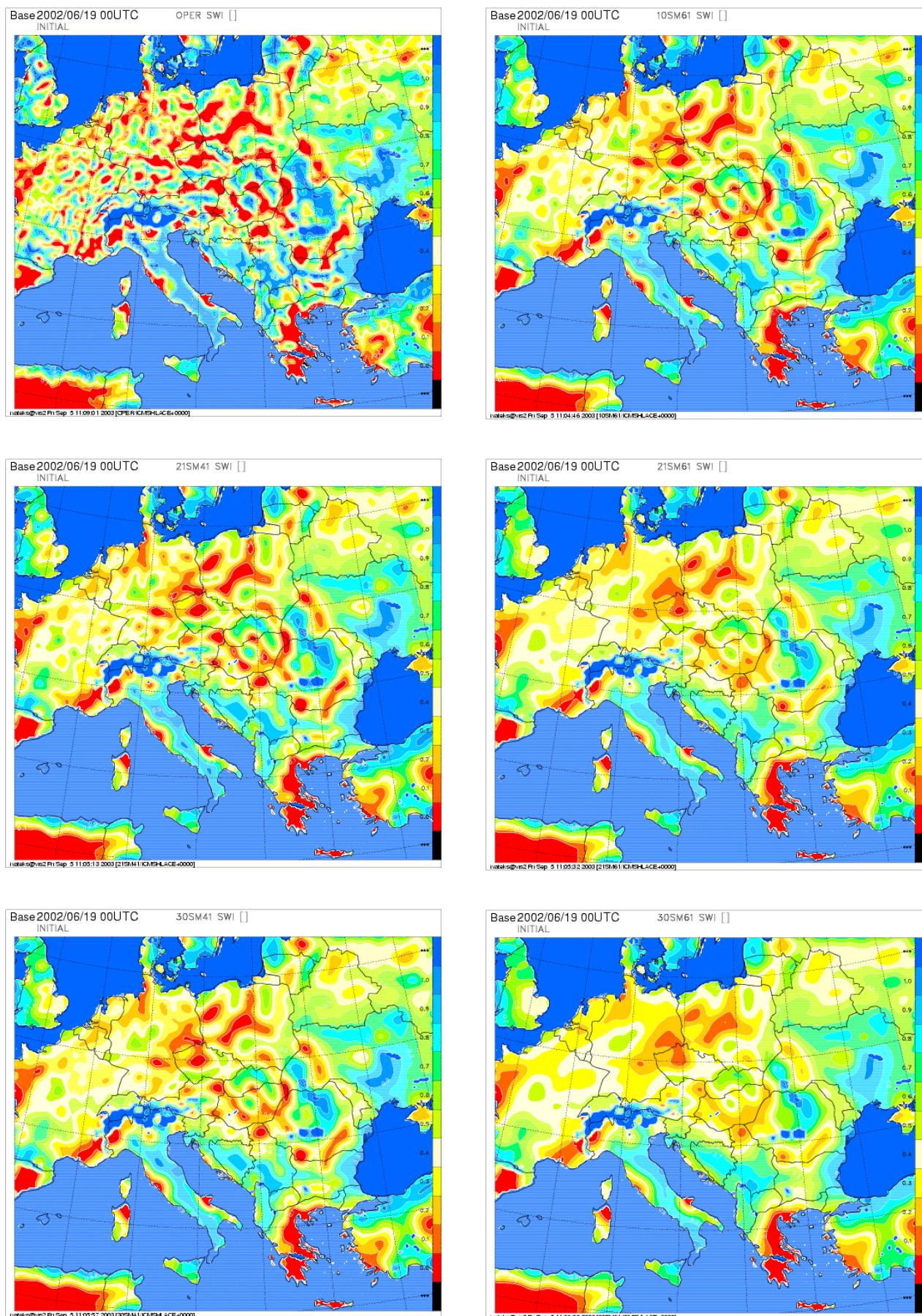


Figure 4 Smoothed Soil wetness index for operational run and for different numbers (10, 21, 30) and radius of smoothing (4.1, 6.1 km), for 19.06.2002. 00 UTC, summer example

As it is shown on Figure 3, there are some visible changes on Istria peninsula, Apennine peninsula Sicily and Africa, for other areas changes are to small, or there are not changes at all.

For SWI field during the summer smoothing for same number of smoothing with 6.1 km smooth SWI field more than with 4.1 km, like it was expected. Smoothed field for 21SM41 looks similar with 10SM61. For smoothing 21SM61 there is still some details in SWI field, what is not case for 30SM61. For smoothing 30SM61 SWI field is really smooth, maybe to smooth?

5. Results

Forecasts with operational version of ALADIN AL25T1_op2 in Croatia were done. 12 days are chosen for testing, 6 days in June 2002 and 6 days in year 2003, 3 days in January, 2 days in April and 1 day in May.

5.1. Results for winter examples, January 2003

3 days in January 2003 were tested (07th, 13th and 16th).

7th was day with lot of snow in Croatia and with precipitation in South Europe. Highest daily temperatures for 7th and 8th were around 0°C for continental part of Europe.

13th and 14th were days with highest daily temperature around 0 with some sunny periods.

16th and 17th were days with lot of sunshine, and without rain for continental Europe. Highest daily temperatures were higher than 0°C for continental part of Europe.

For Analysis, there are no changes bigger than ± 0.5 °C for 2m Temperature or ± 2 % for Relative Humidity.

In winter examples there are less than 5, from more than 600 points, with difference between OPER and smoothed SWI in initial field in forecasted 2 m Temperature (T2m) for more than 0.5 °C for each forecast.

For 2 m Relative Humidity (H2m) there is some bigger impact, less than 50 points from more than 600 points with difference between OPER and smoothed SWI in initial field in forecasted H2m for more than 2 % for each forecast. Difference higher than 10 % was just for 13th January 2003 for 36 and 48 forecasts.

From that results we could conclude that impact on T2m for winter examples is really small, and same is for H2m.

5.2. Results for spring examples, April 2003

Two days in April 2003 were chosen 2nd and 5th.

During the 2nd and 3rd there were moving cyclone with frontal system over the Europe. First day was sunny in Central and East Europe. Amplitude of T2m in continental Croatia were around 20 °C, next day amplitude in west part of Croatia was less than 5 °C.

During the 5th and 6th West Europe was without precipitation. T2m amplitude was more than 10 °C in south part of Europe.

No important changes for analyses.

For T2m there is less than 5% of points with changes bigger than ± 0.5 °C. There is just one different between forecast for more than 2 °C.

For H2m maximum 20 % of points were changed for more than $\pm 2 \%$. Just few times H2m were changed for forecasts for more than 10 %.

That means that there are some changes, bigger than for winter, but not big one.

5.3. Results for 2nd spring example, 6th May 2003

6th and 7th May, front moving over West Europe it stop on Alps, other part of Europe with T2m amplitude around 20 °C with lot of sunshine. Hot spots over a Central Europe, smaller for 7th.

No changes for analyses.

For H2m maximum 45 % of points are changed for more than H2m $\pm 2 \%$, and 9 % for more than $\pm 10 \%$. For T2m maximum 22 % of points are changed for more than T2m $\pm 0.5 \text{ }^{\circ}\text{C}$, and 2 % for more than $\pm 2 \text{ }^{\circ}\text{C}$.

For this period impact of smoothing of SWI is relatively big.

5.4. Results for problematic period in June 2002.

Period from 15th to 21st of June 2002 were very hot period with temperatures in Central Europe more than 30 °C, even with extreme values from the beginning of measuring. Very hot period was same and for West Europe but not during the whole period.

No changes for analyses. For Analysis, there are no changes bigger than $\pm 0.5 \text{ }^{\circ}\text{C}$ for 2m Temperature or $\pm 2 \%$ for Relative Humidity.

For forecasts, generally with increasing of the number of smoothing or radius of smoothing more and more points have changes bigger than $\pm 0.5 \text{ }^{\circ}\text{C}$ for 2m Temperature or $\pm 2 \%$ for 2m Relative Humidity.

For H2m maximum 65 % of points are changed for more than $\pm 2 \%$, and 17 % for more than $\pm 10 \%$. For T2m during this period maximum numbers of changed point is 53 % for more than $\pm 0.5 \text{ }^{\circ}\text{C}$, and 9 % for more than $\pm 2 \text{ }^{\circ}\text{C}$.

In problematic period it was noticed maximum changes of H2m and T2m for all tested examples.

For a summer examples in areas where a very big gradients of surface temperature were noticed improvement in forecast of T2m is really big, in same points for more than 2 °C for radius of smoothing 6.1 km and for 21 and 30 times of smoothing for 12 and 36 hrs forecast.

On following Figures 5-14, 15 and 36 hours forecast for T2m and H2m are shown, star June 19th 2002 00 UTC.

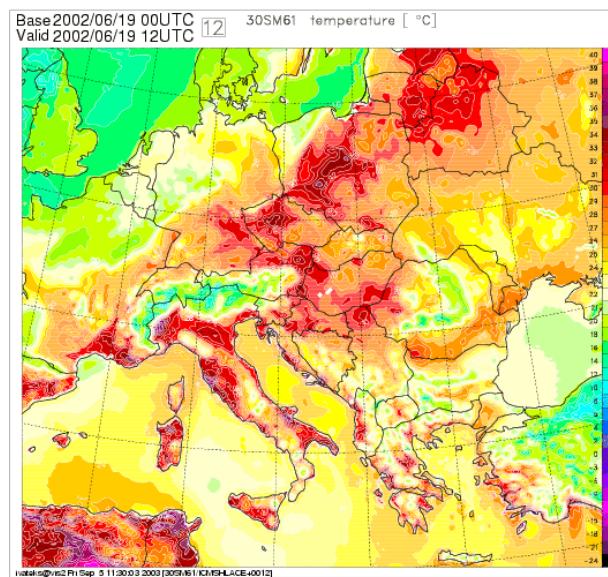
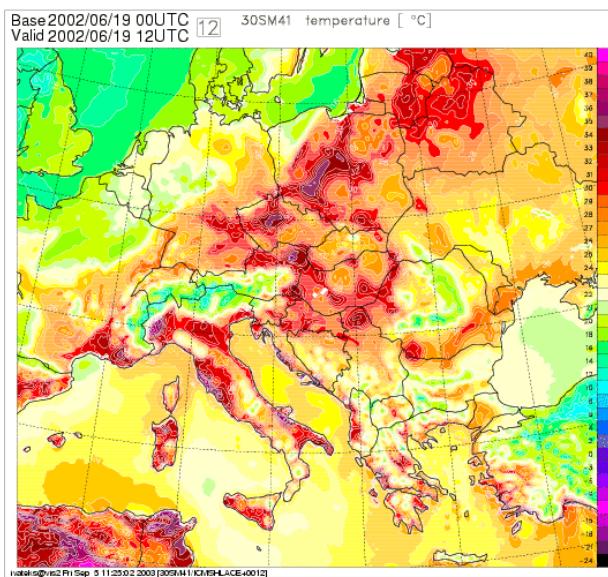
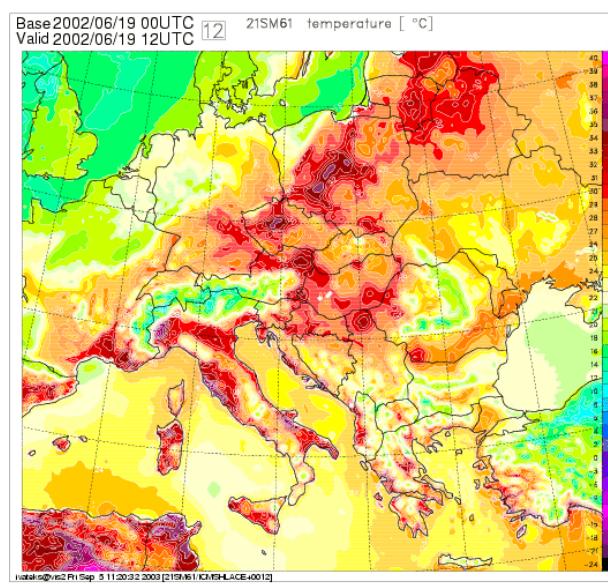
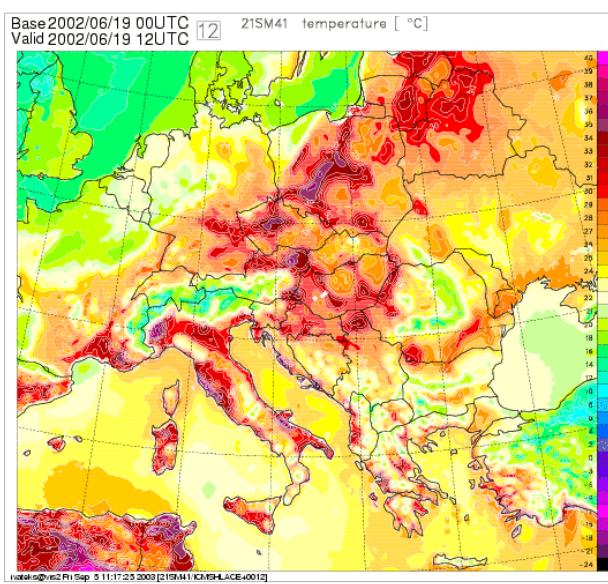
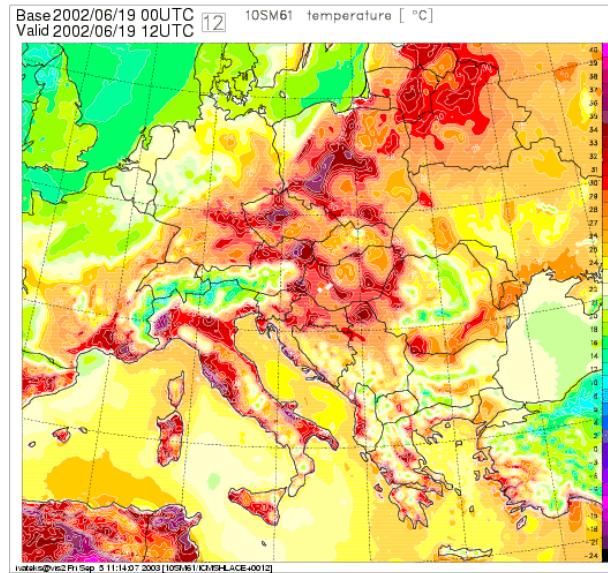
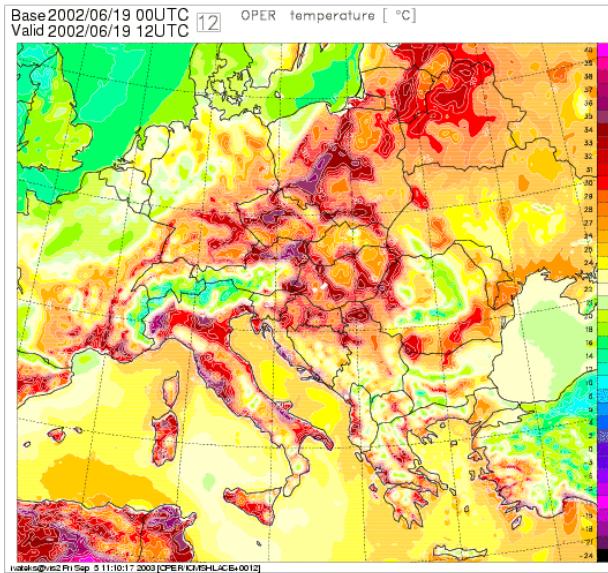


Figure 5 2 m Temperature 12 hrs forecast for operational run and for different numbers (10, 21, 30) and radius of smoothing (4.1, 6.1 km), start of the integration 19.06.2002. 00 UTC

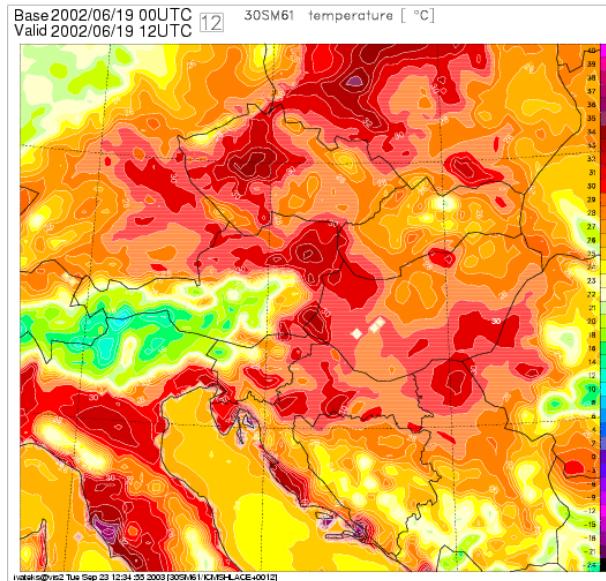
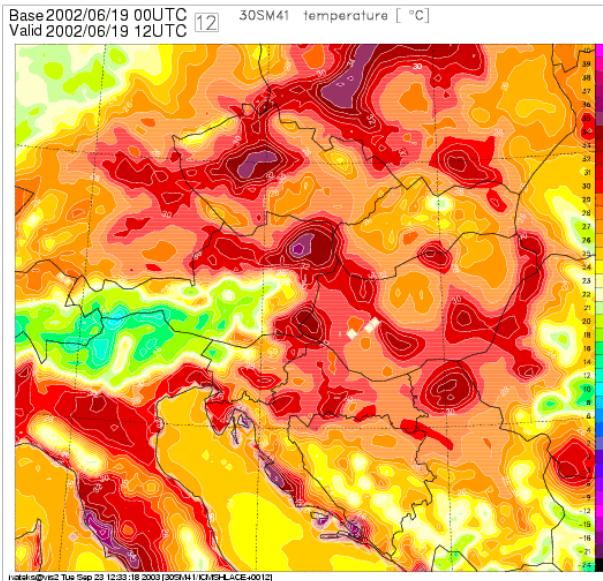
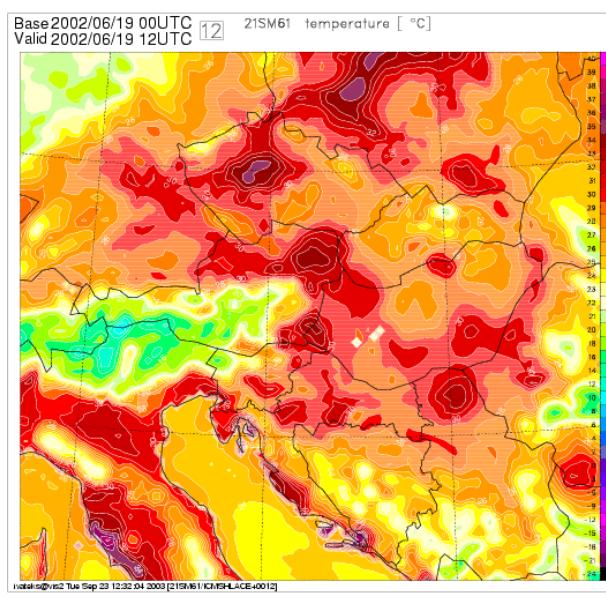
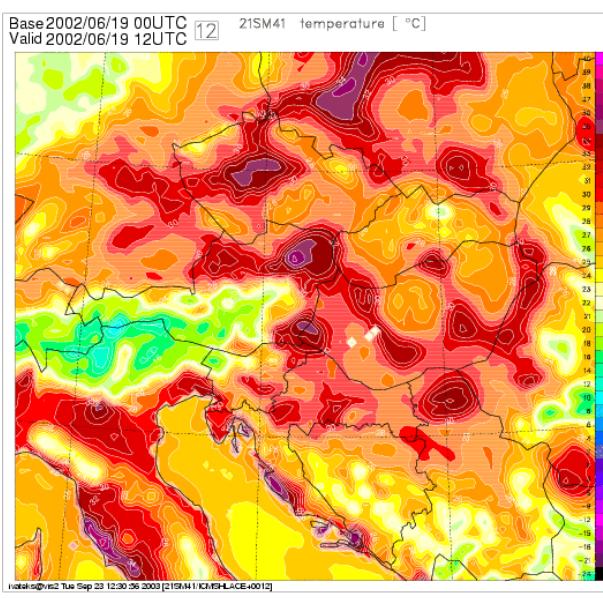
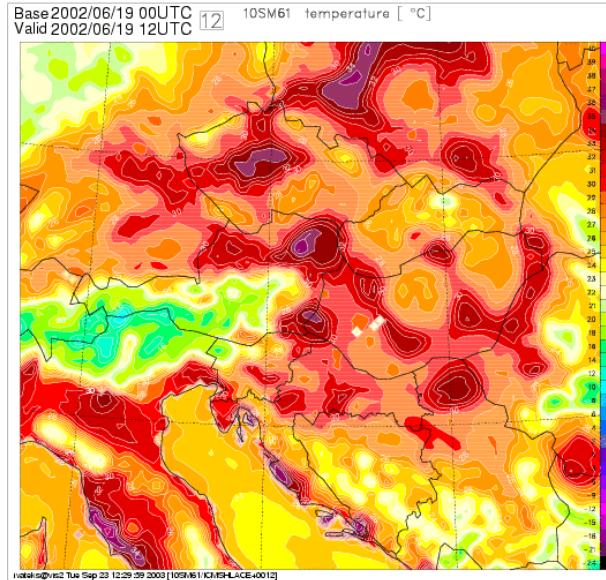
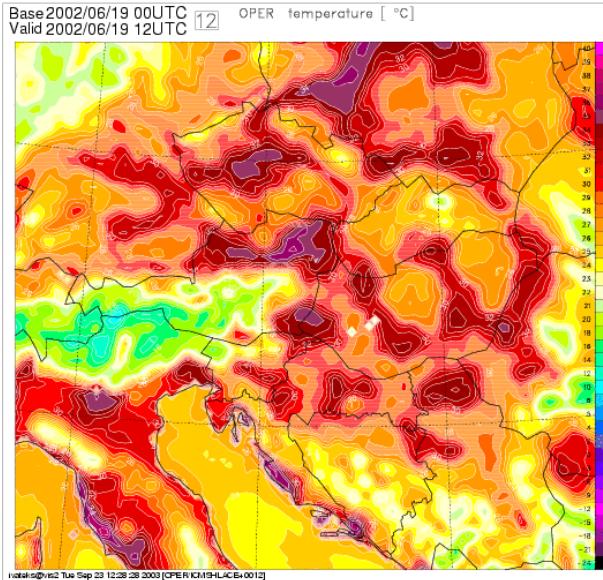


Figure 6 Zoom of T2 m 12 hrs forecast for operational run and for different numbers (10, 21, 30) and radius of smoothing (4.1, 6.1 km), start of the integration 19.06.2002. 00 UTC

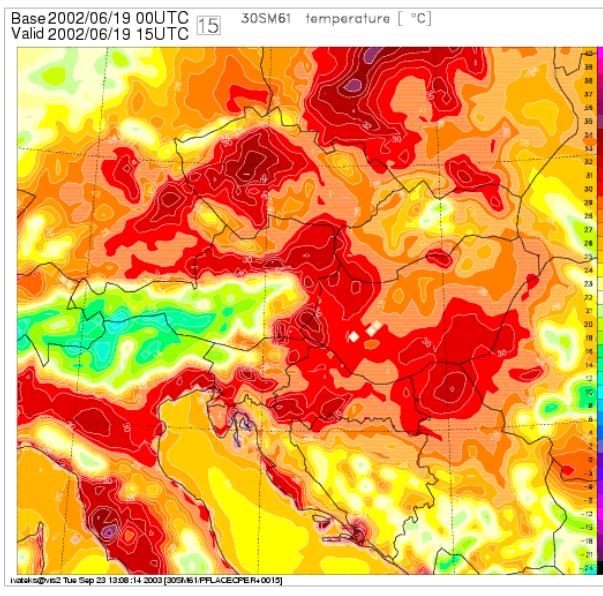
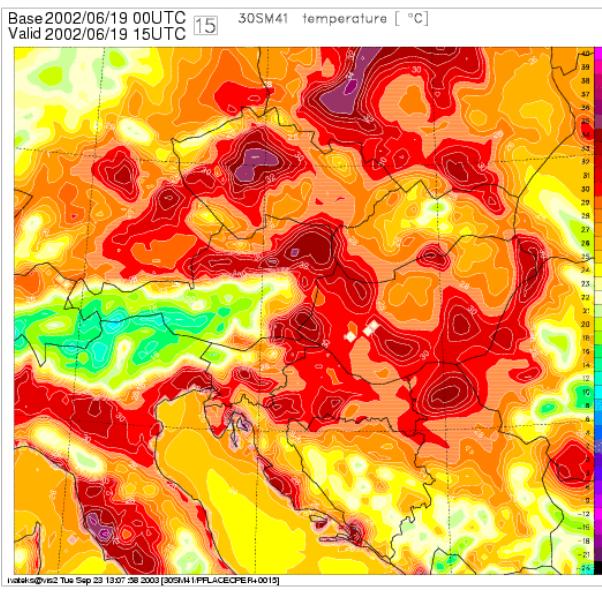
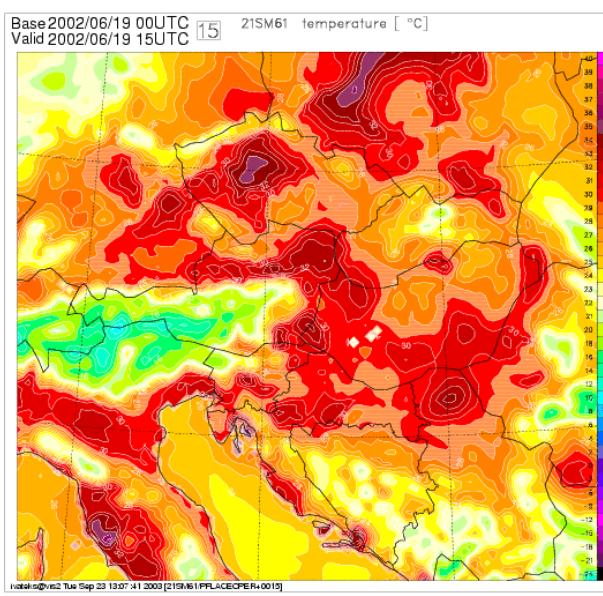
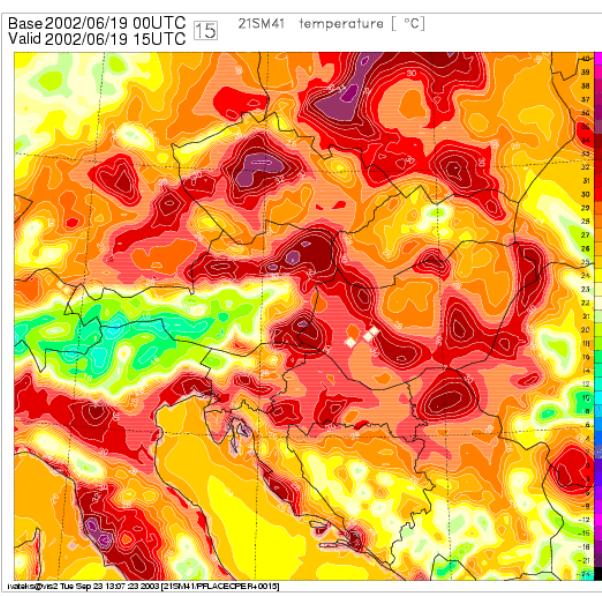
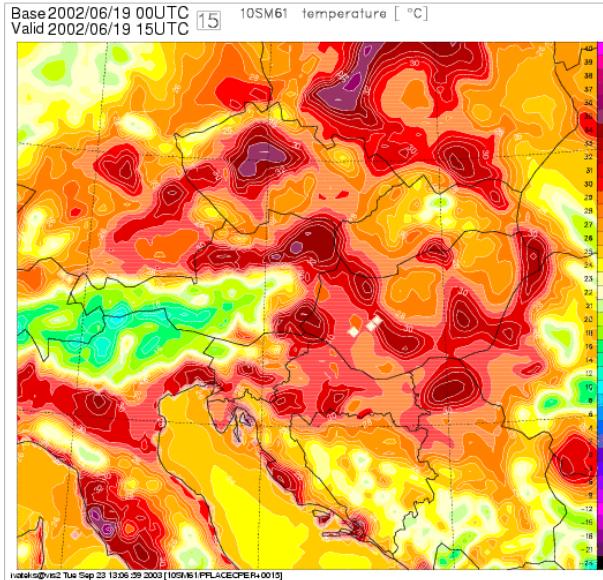
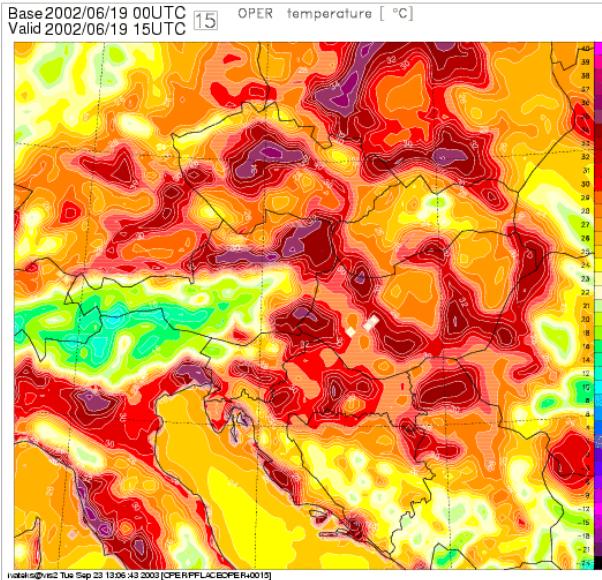


Figure 7 Zoom of T2 m 15 hrs forecast for operational run and for different numbers (10, 21, 30) and radius of smoothing (4.1, 6.1 km), start of the integration 19.06.2002. 00 UTC

There are no anymore-such big gradients in T2m field like it was in Operational run. For some points T2m is smaller for more than 2 °C if we compare operational run and smoothing with 21 and 30 smoothings with radius of smoothing 6.1 km.

On Figure 8 and 11 comparison of absolute error are shown. If the value on Figure(s) is less than zero (blue or green color of point) that means that operational forecast is better, absolute error is smaller for operational run. If the value on Figure is higher than zero (yellow, orange and red points) one of the tested smoothed forecast is better, absolute error is greater for operational run. Model results are compared with SYNOP data.

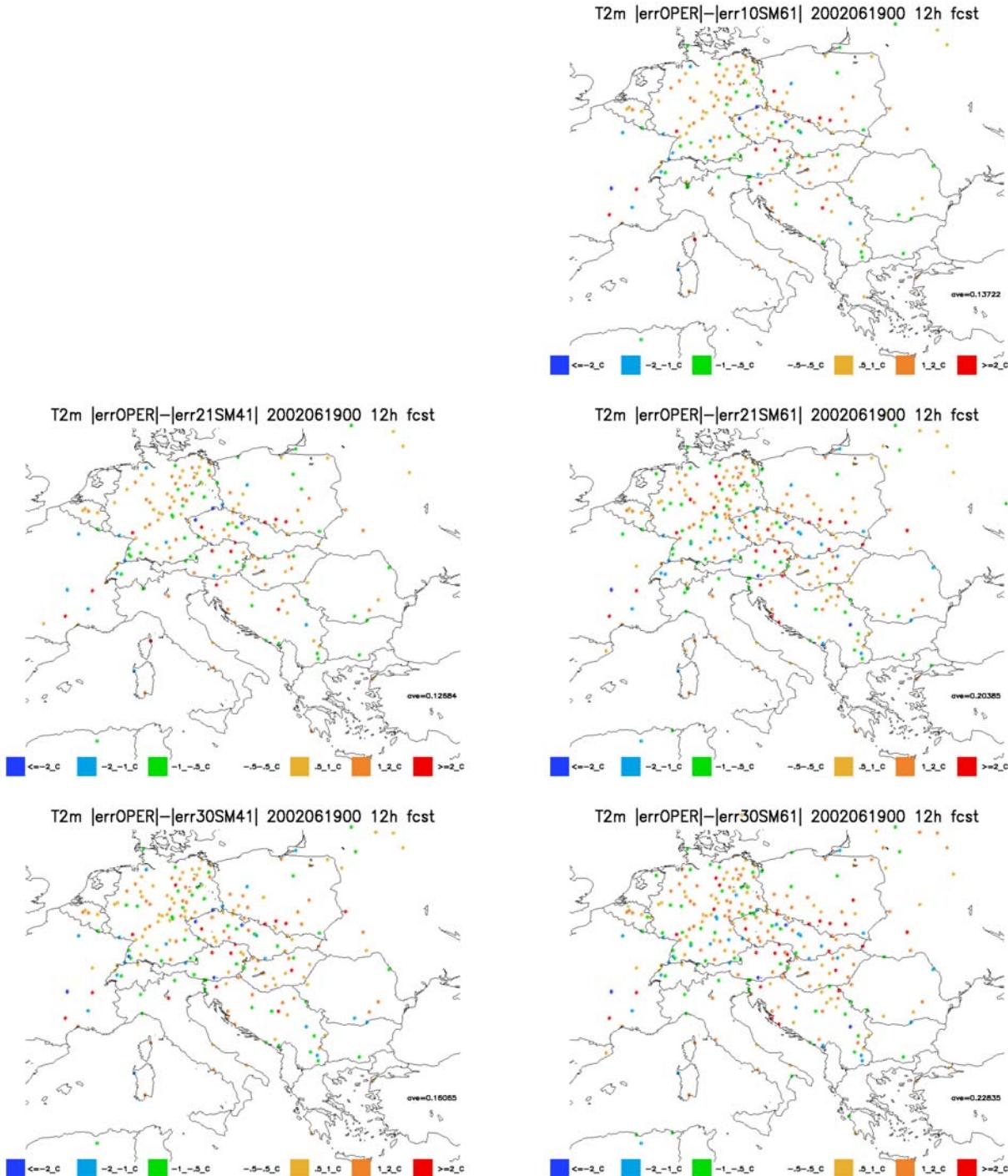


Figure 8 Comparison of absolute error for 12 hrs forecast of T2m for different numbers (10, 21, 30) and radius of smoothing (4.1, 6.1 km) with operational run forecast, start of the integration 19.06.2002. 00 UTC

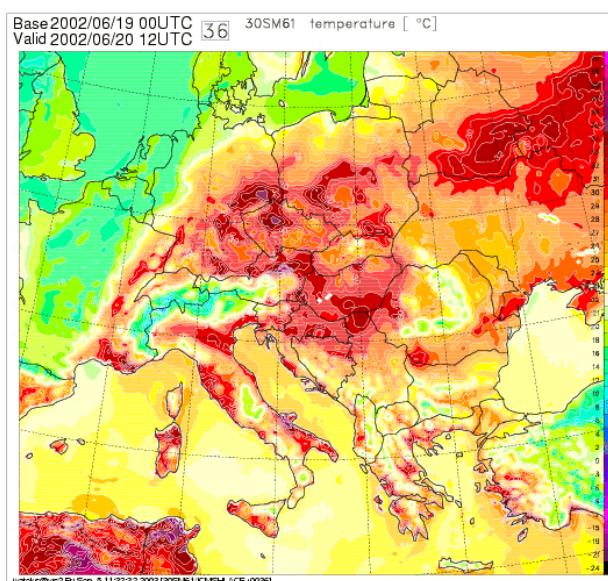
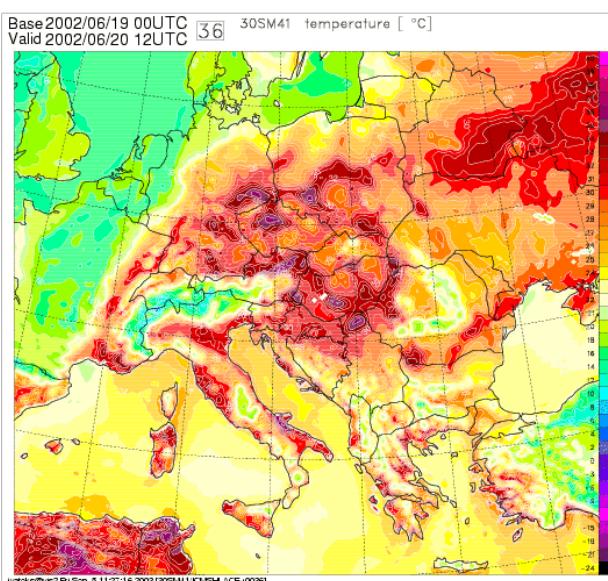
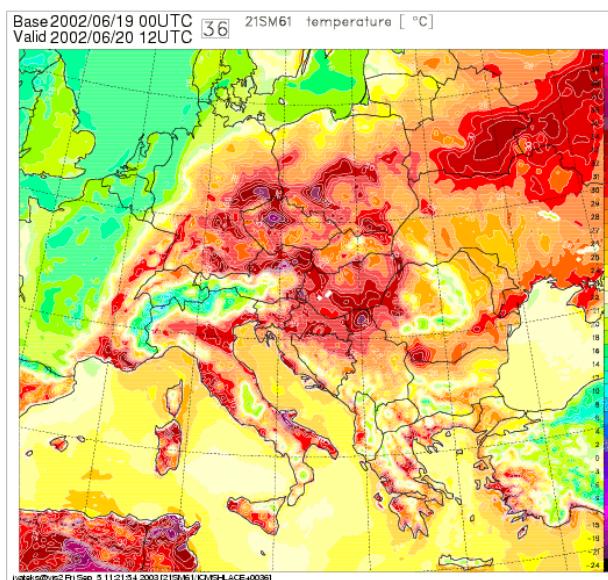
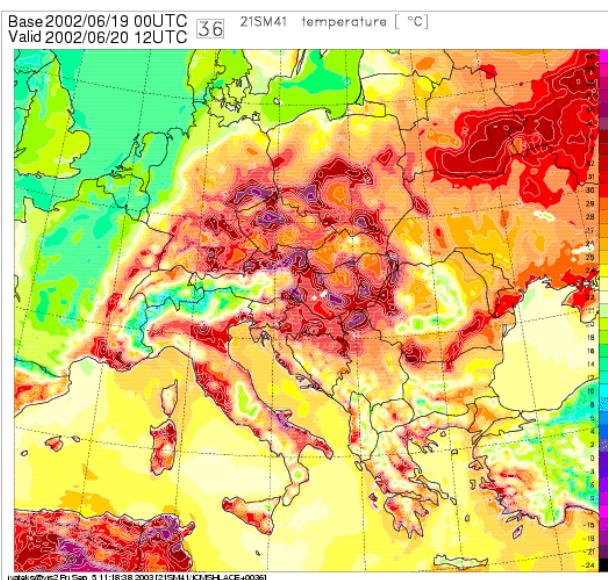
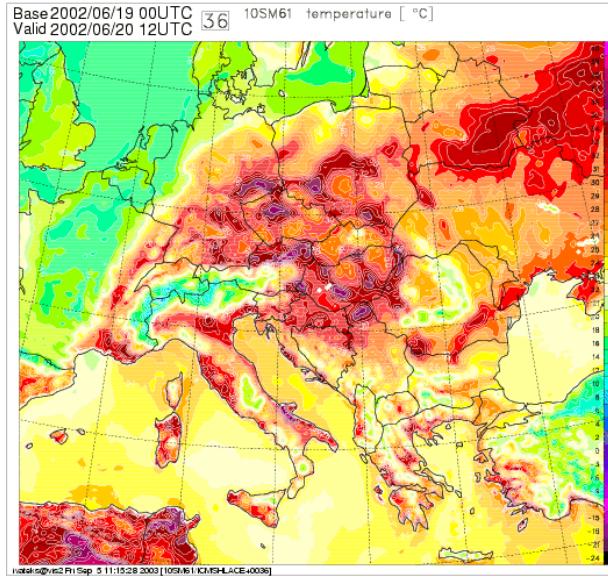
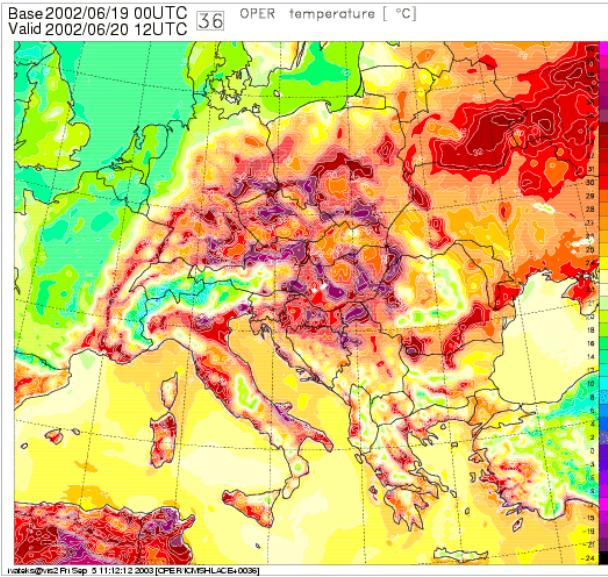


Figure 9 2 m Temperature 36 hrs forecast for operational run and for different numbers (10, 21, 30) and radius of smoothing (4.1, 6.1 km), start of the integration 19.06.2002. 00 UTC

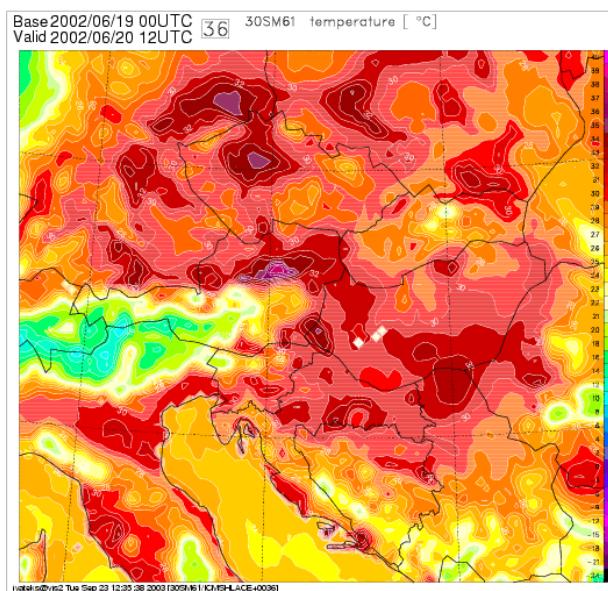
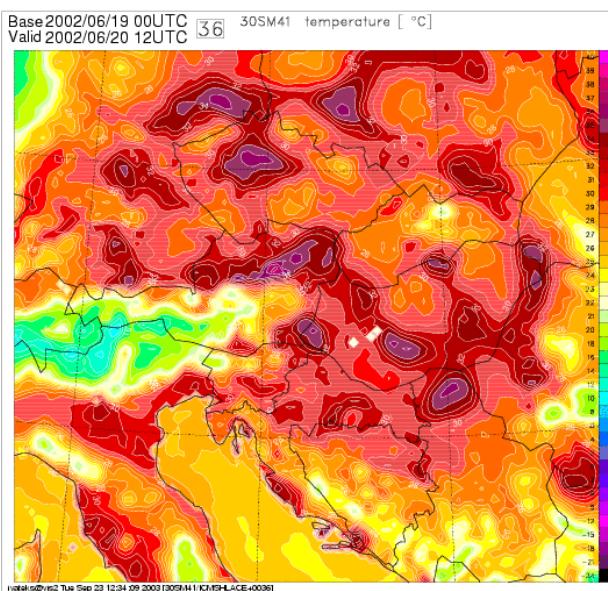
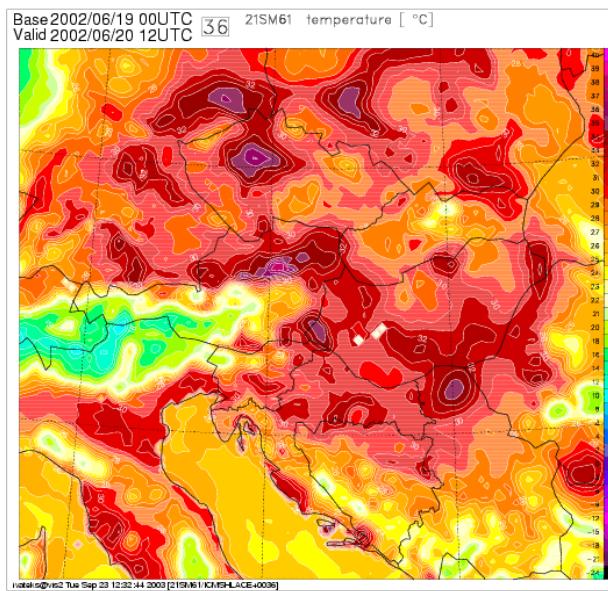
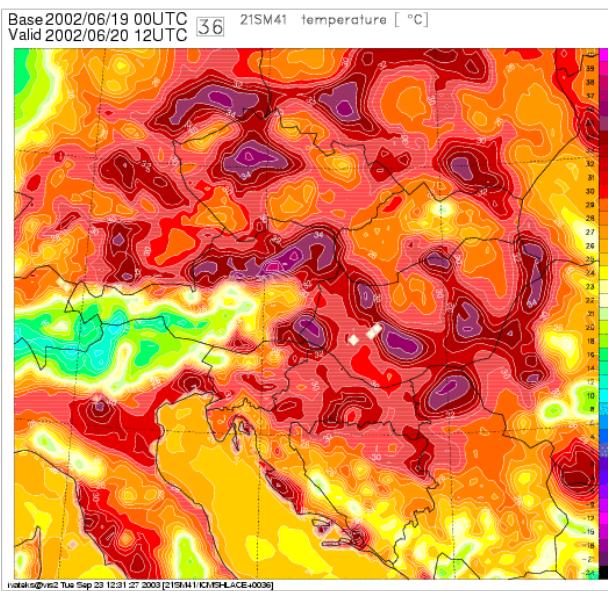
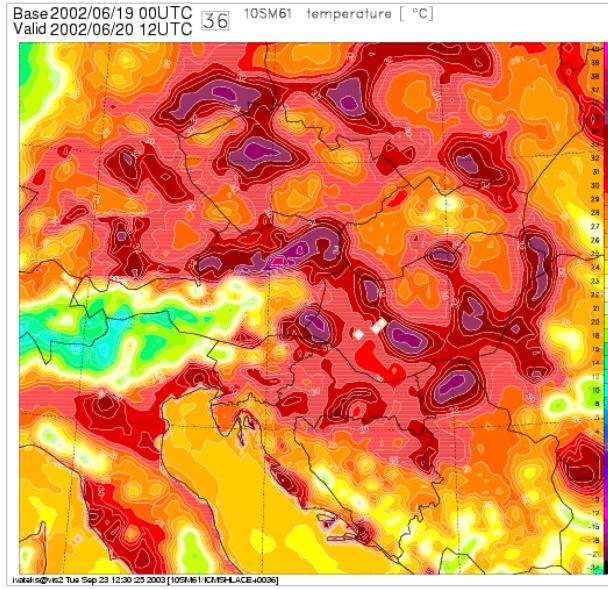
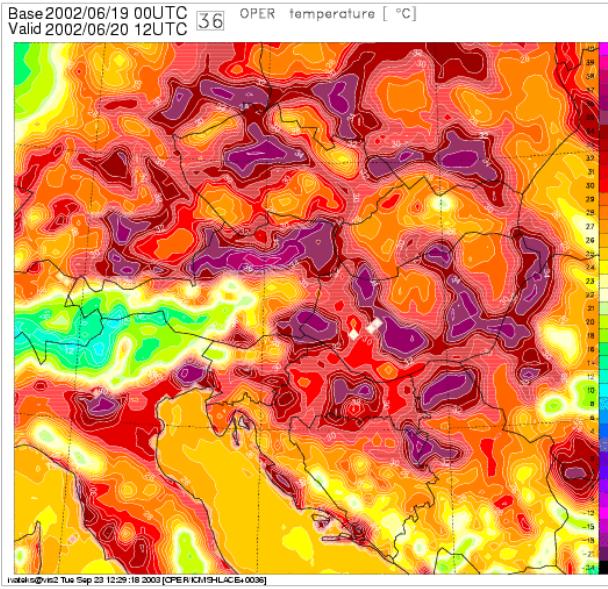


Figure 10 Zoom of T2 m 36 hrs forecast for operational run and for different numbers (10, 21, 30) and radius of smoothing (4.1, 6.1 km), start of the integration 19.06.2002. 00 UTC

It is not shown but it is obvious that in places where the maximum daily temperature is not to hot there is no changes with smoothed SWI. For both days West France was with low maximum T2m and than there are no changes bigger than ± 0.5 °C for 2m Temperature.

At the end of the report Tables with numbers of points in classes, RMS and BIAS are placed.

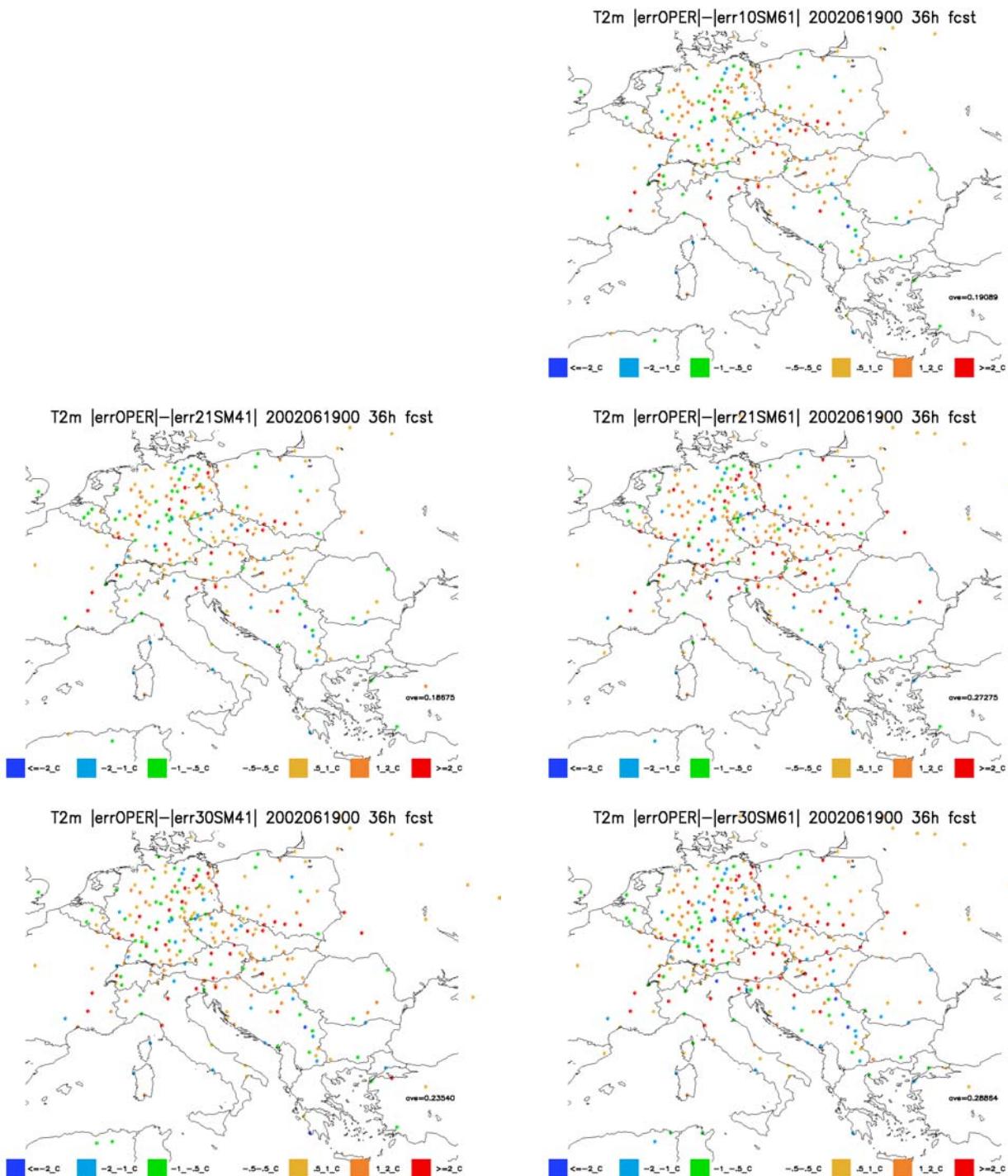


Figure 11 Comparison of absolute error for 36 hrs forecast of T2m for different numbers (10, 21, 30) and radius of smoothing (4.1, 6.1 km) with operational run forecast, start of the integration 19.06.2002. 00 UTC

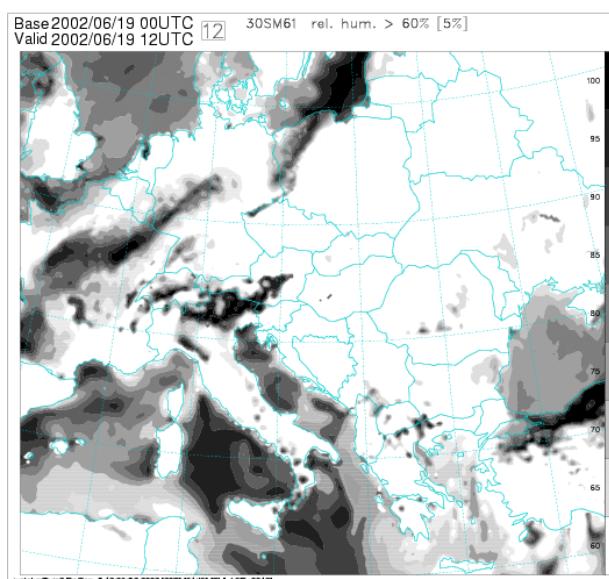
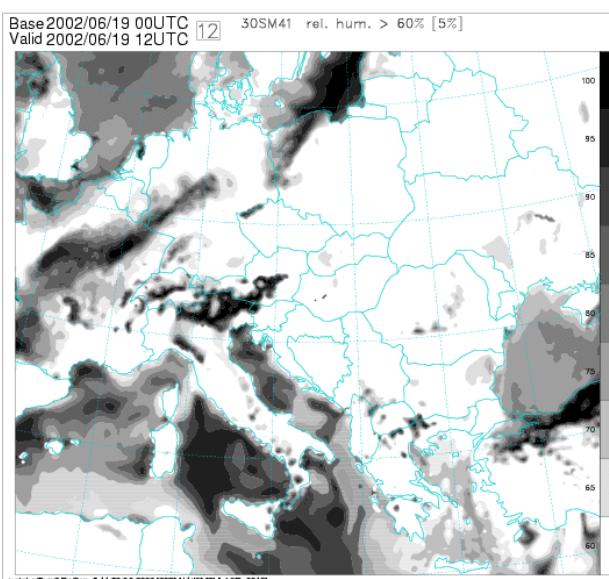
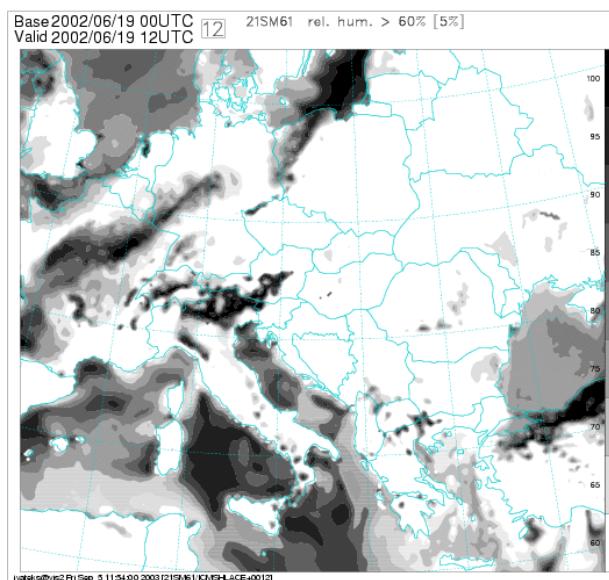
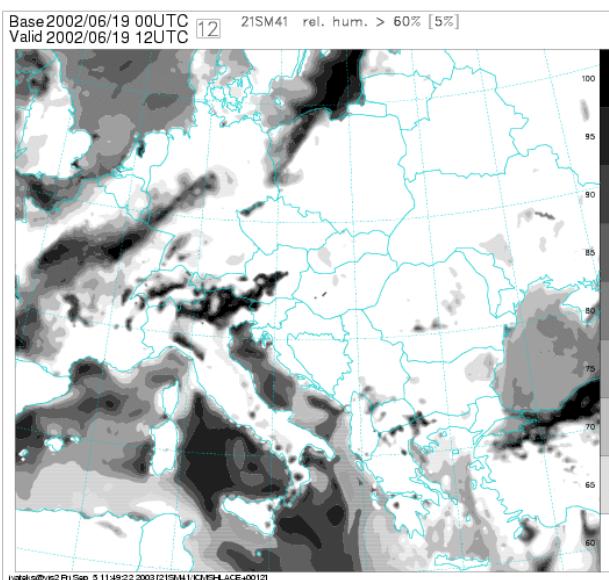
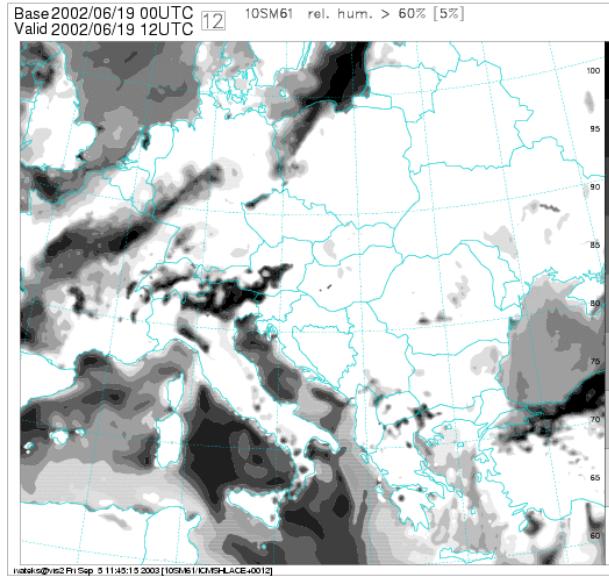
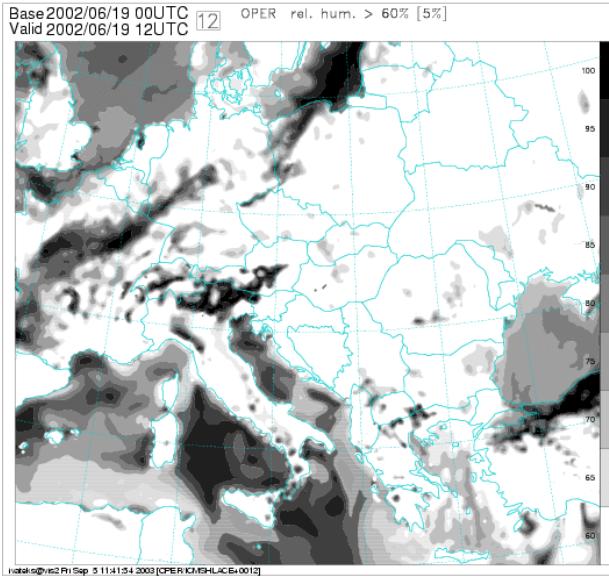


Figure 12 2 m Relative Humidity 12 hrs forecast for operational run and for different numbers (10, 21, 30) and radius of smoothing (4.1, 6.1 km), start of the integration 19.06.2002. 00 UTC

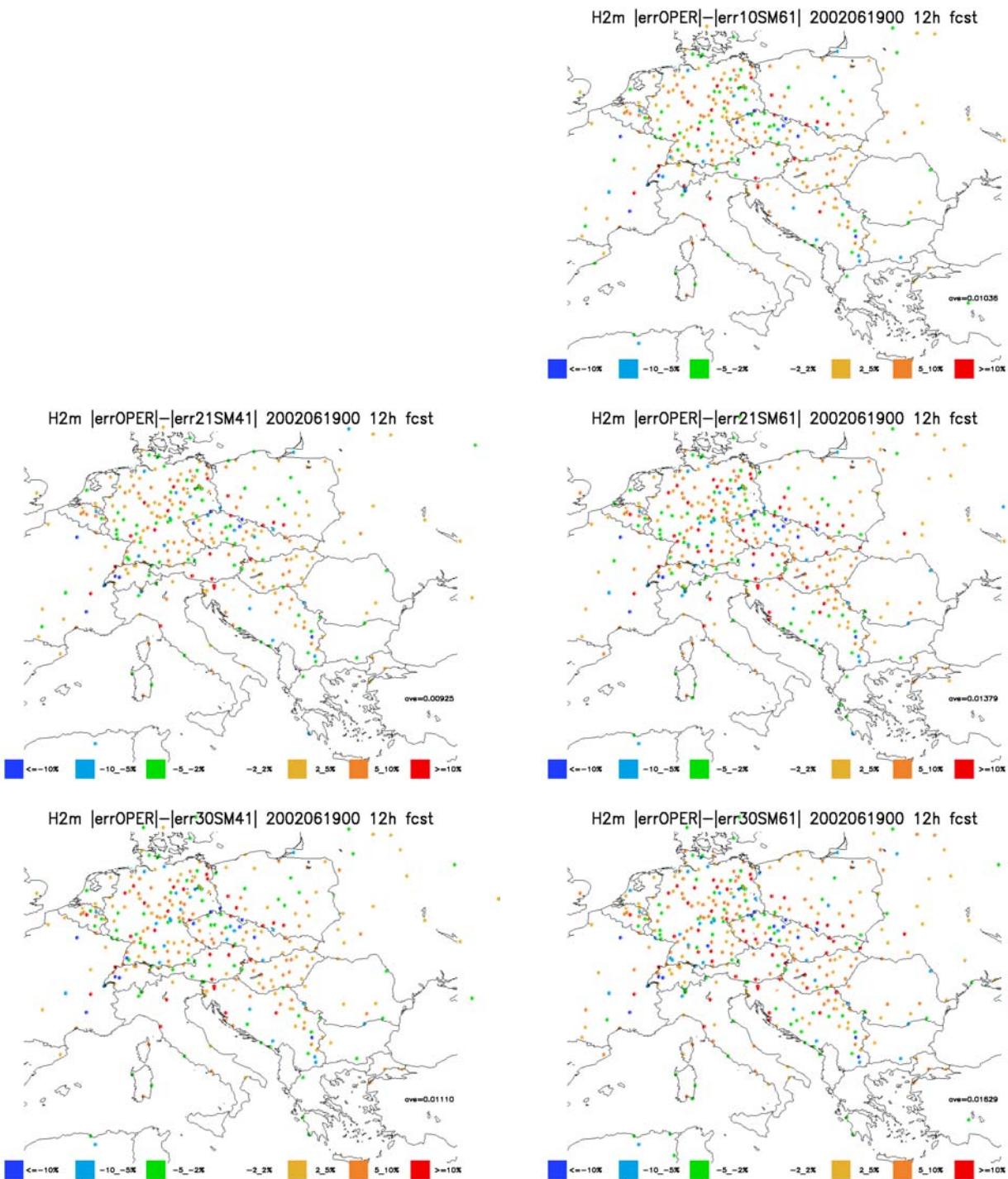


Figure 13 Comparison of absolute error for 12 hrs forecast of H2m for different numbers (10, 21, 30) and radius of smoothing (4.1, 6.1 km) with operational run forecast, start of the integration 19.06.2002. 00 UTC

As it was expected with increasing of smoothing 2m Relative Humidity be significantly changed more and more points be changed, same like it was for T2m.

There is a lot of points where are improvement of both parameters T2m and H2m.

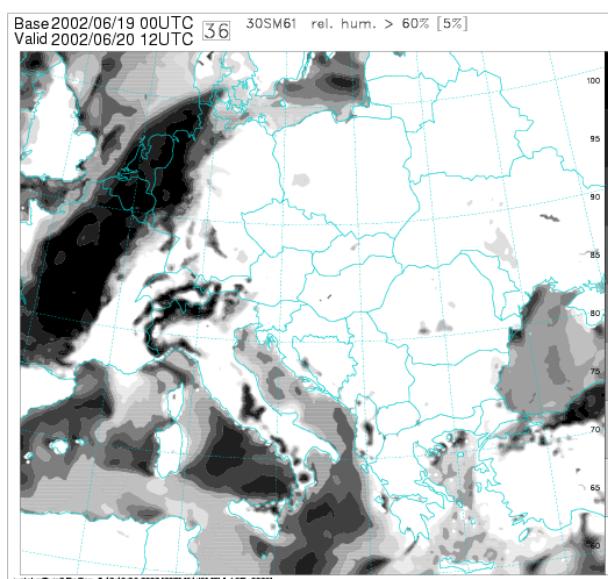
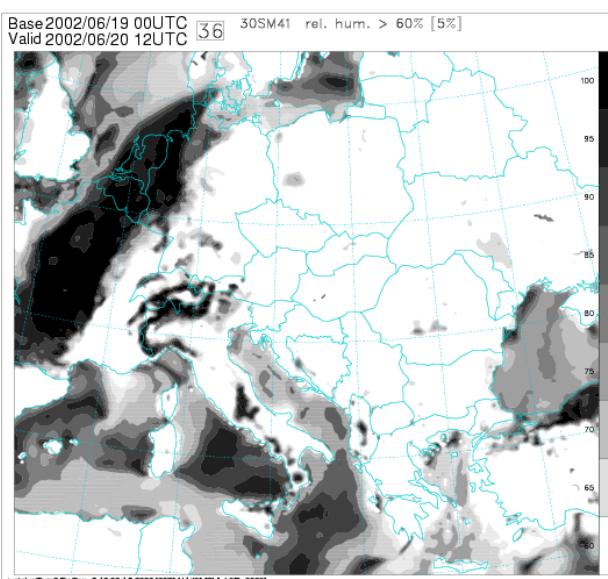
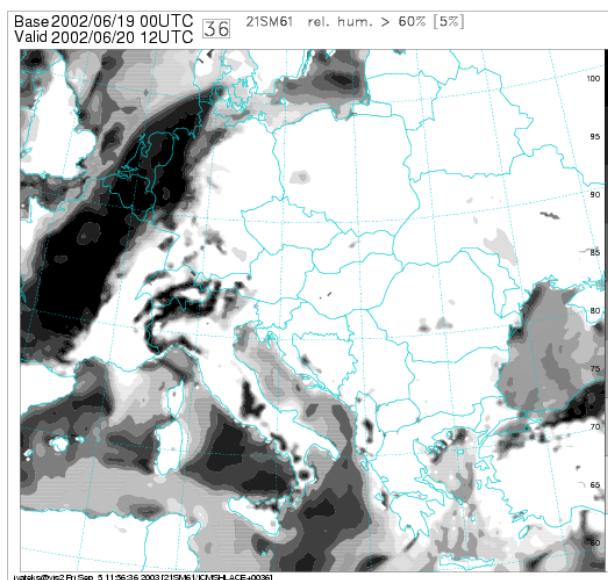
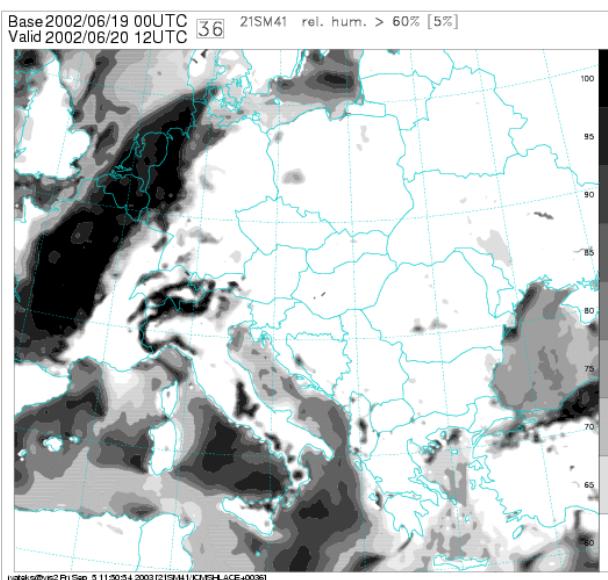
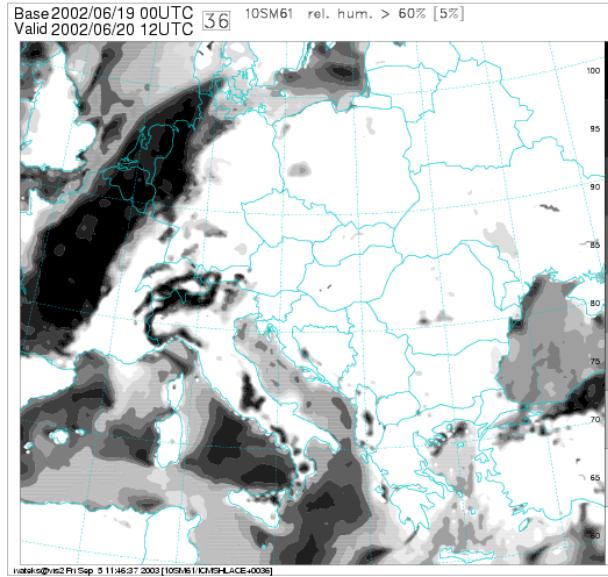
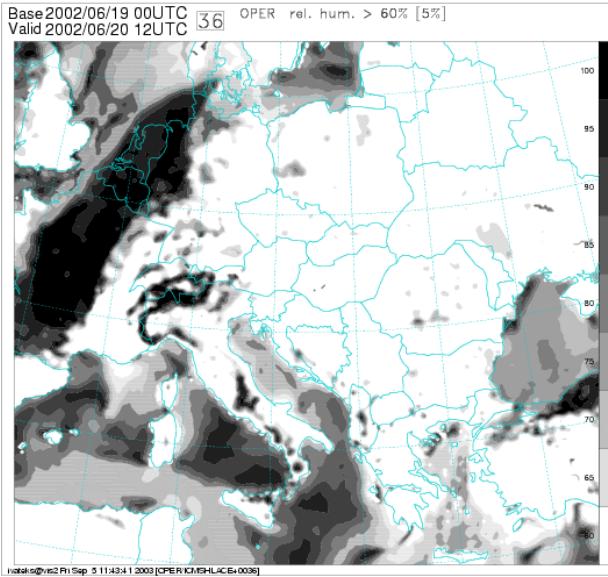


Figure 14 2 m Relative Humidity 36 hrs forecast for operational run and for different numbers (10, 21, 30) and radius of smoothing (4.1, 6.1 km), start of the integration 19.06.2002. 00 UTC

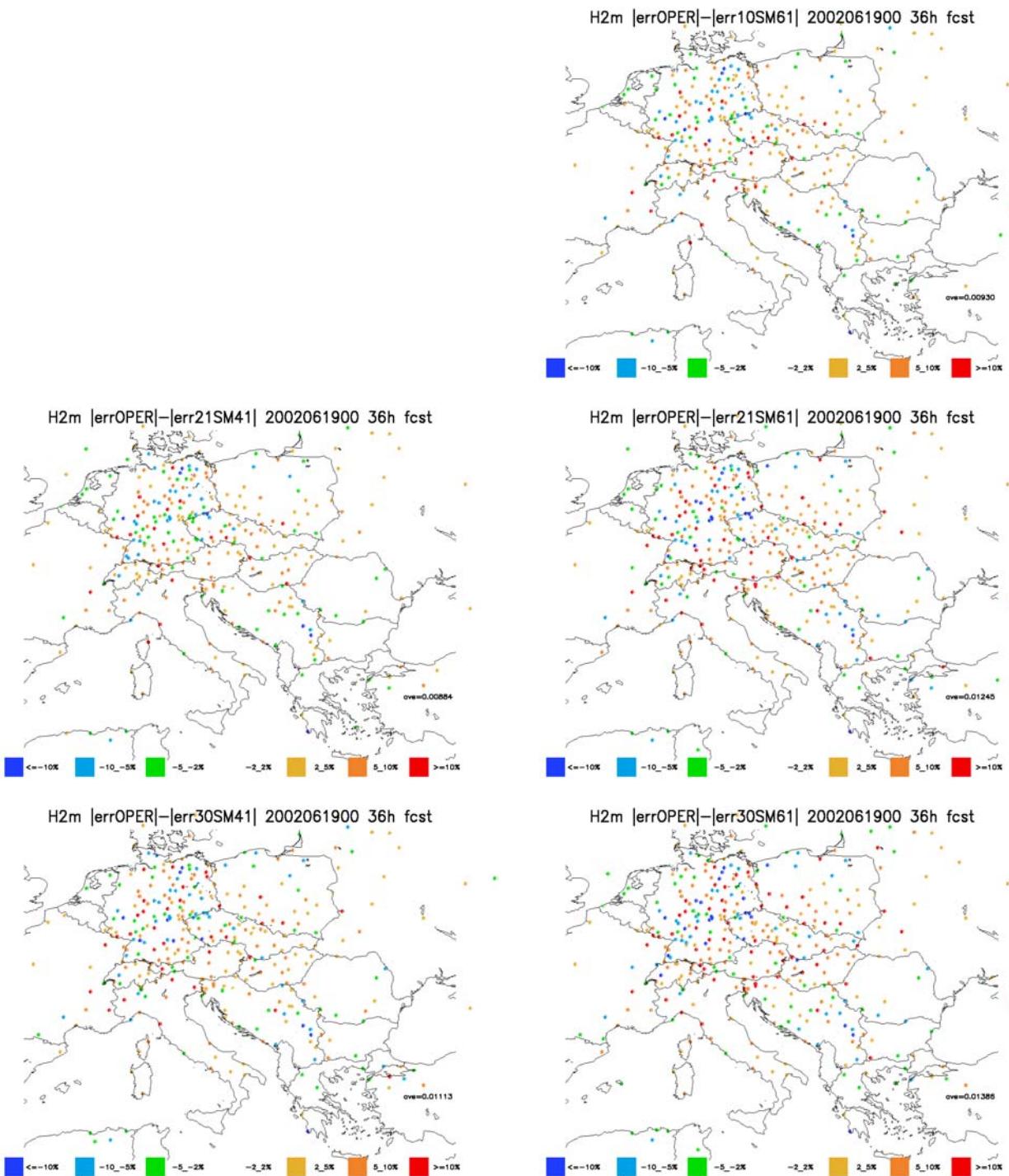


Figure 15 Comparison of absolute error for 36 hrs forecast of H2m for different numbers (10, 21, 30) and radius of smoothing (4.1, 6.1 km) with operational run forecast, start of the integration 19.06.2002. 00 UTC

6. Comparison of RMS and BIAS for H2m and T2m

Comparison of RMS and BIAS for H2m and T2m between operational run and runs with smoothed SWI. For winter days there is no important changes in RMS and BIAS. For examples in April 2003 there is some impact, but changes in RMS and BIAS are really small, smaller than 0.002 for H2m and smaller than 0.02 °C for T2m. For May example RMS is better sometimes for operational and sometime for smoothed SWI forecasts. Maximum differences for H2m are RMS=0.005 and for BIAS=0.013. For T2m maximum differences are RMS=0.05 BIAS=0.11.

For June 2002 with very high temperatures RMS is better for runs with smoothed SWI, maximum improvement of RMS for H2m is 0.022. For H2m and BIAS more times operational forecast is better than run with smoothed SWI, maximum difference for BIAS=0.024. For T2m RMS is usually better for smoothed SWI highest differences are for 12, 36 and 18 hrs forecast, maximum for RMS=0.33 °C. For all experiments BIAS is usually less than zero. Operational run is better for BIAS and difference is higher for 12, 18, 36 and 42 hrs forecasts. Maximal difference for BIAS=0.37 °C.

On next figures RMS and BIAS for all examples are shown.

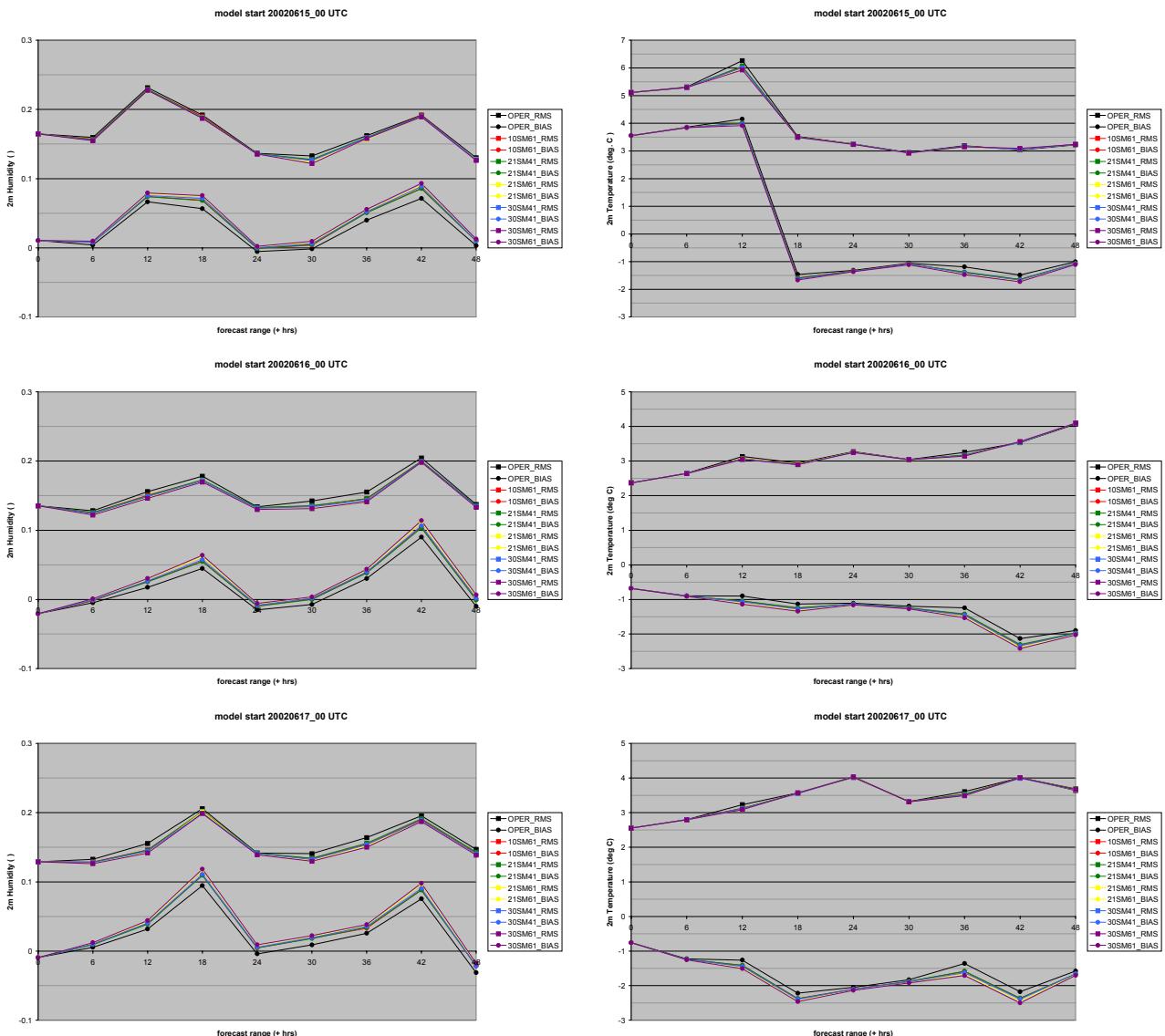


Figure 16 BIAS and RMS for T2m and H2m for period 15th-17th June 2002 00 UTC runs

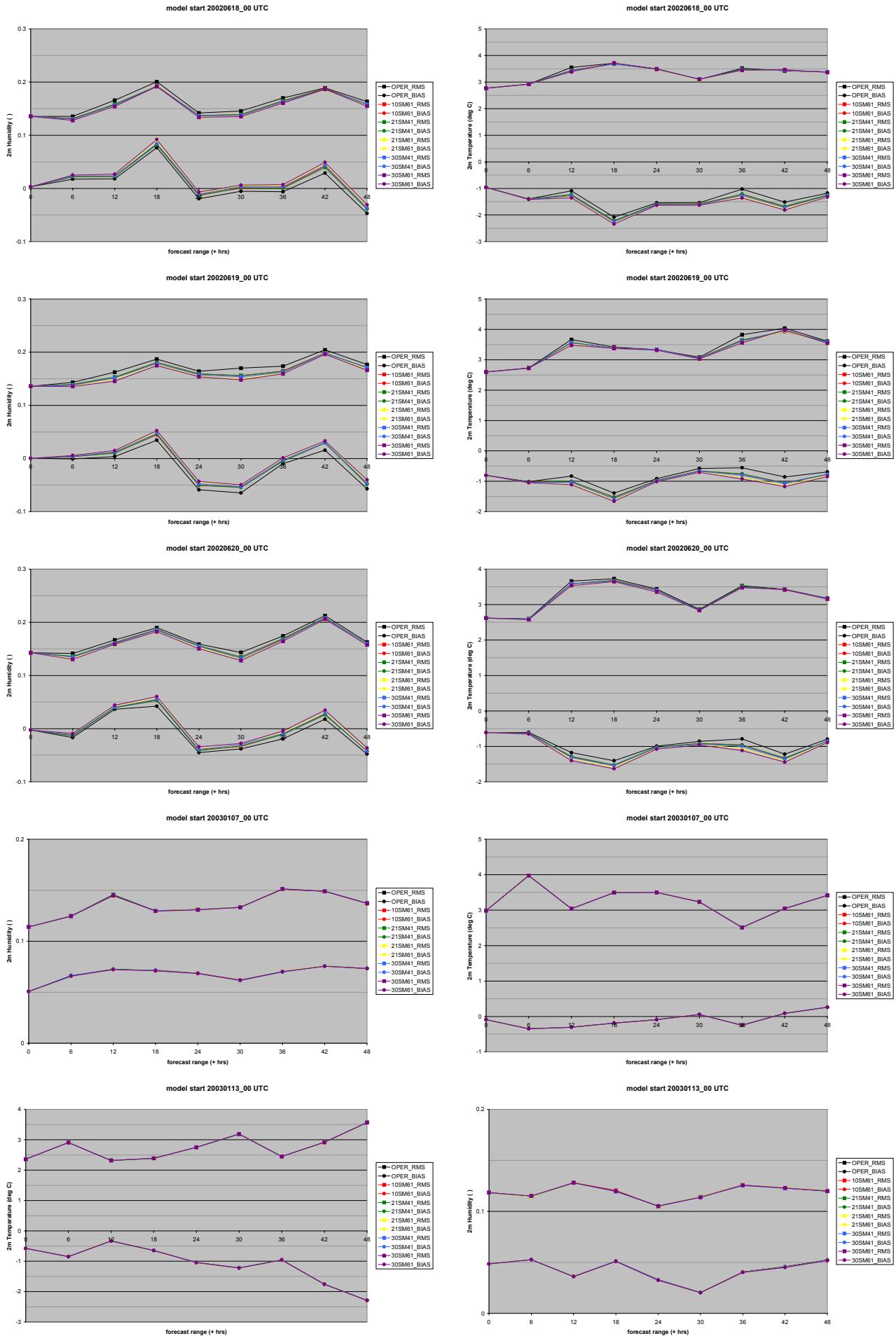


Figure 17 Same like on Figure 13 for period 18th-20th June 2002 and for 7th and 13th January 2003

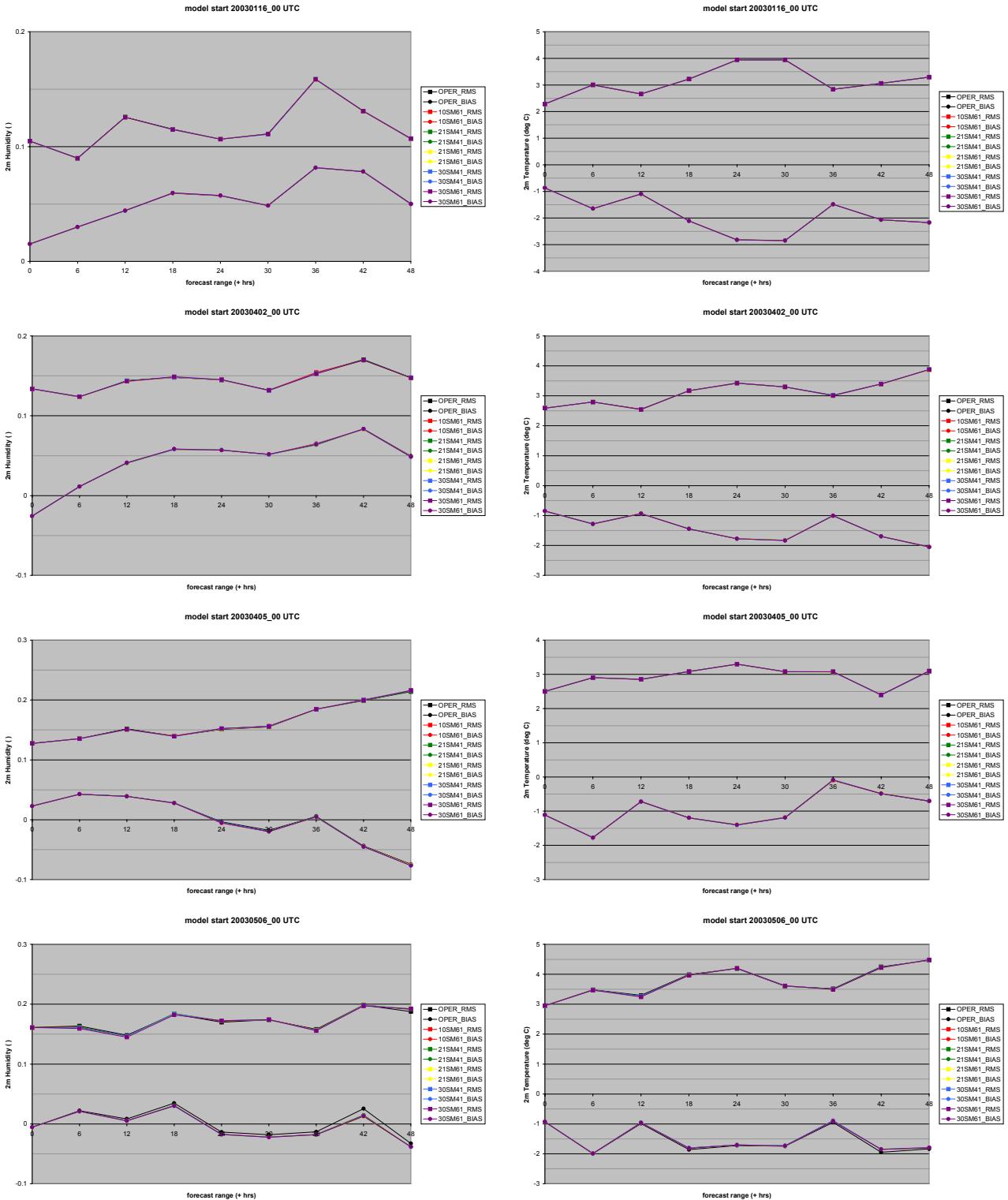


Figure 18 BIAS and RMS for H2m and T2m for 16th January, 2nd and 5th April and 6th May, 2003 00 UTC runs

During the January and beginning of April there is no some important changes in RMS and BIAS. During the worm period RMS is usually better for smoothed runs and BIAS for oper run.

If there is some impact on BIAS for T2m than there is opposite impact on H2m (in term of sign of), same is for H2m and T2m. This is case for all warm situations.

7. Comparison for period in June 2002

First comparison against to the operational run is shown, than comparison against 21SM61 smoothing.

7.1. Comparison of oper run and smoothings for period in June 2002

In Table 1 statistics for 3 kinds of weight are calculated.

Class “+++” means that there is big improvement of forecast (greater than 2 °C or 5 %) , “++” is for improvement (1-2 °C or 2-5 %) and class “+” means small improvement in forecast (0.5-1 °C or 0.5-2 %).

Same is for “-” classes, but for worse forecasts.

In Table 1 for 1st weight (explained below) and in Table 2 if the sign in table is great than zero than more points have better forecast.

1st weight “1*+++1*++1*+1*-1*--1*---” that means same weight for all classes, it is possible to see how many points have better or worst for all run. For period 15th – 20th Jun 2002 just once forecast with smoothed initial SWI for T2m have negative sign, 21SM61 for 17th Jun. For all other, forecasts with smoothed SWI were better.

2nd weight is “2*+++1.5*++1*+1*-2*--3*---” weight for worst forecast is little bit bigger than for better forecast.

Last (3rd) “2*+++1.5*++1*+1*-3*--4*---” have even bigger weight for worst forecast. That means if we don't want to risk too much but to have some small improvement these classes show us which one to choose.

Table 1 Comparison of number of better and worse points in comparison of oper run with smoothings runs, with different weights, for all days (15-20) and forecasts hours (00, 06,..., 48)

T2m 200206_15-20_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*--4*---	-448	-437	-830	-595	-1213
2*+++1.5*++1*+1*-2*--3*---	344	308	416	398	275
1*+++1*++1*+1*-1*--1*---	605	538	853	725	885
H2m 200206_15-20_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*--4*---	1051	1044	1072	1189	903
2*+++1.5*++1*+1*-2*--3*---	2544	2457	3153	2894	3246
1*+++1*++1*+1*-1*--1*---	2723	2608	3238	2943	3329

From Table 1 it look likes that there is no lot of data, which could help to find the best solutions of smoothing parameters. 21SM61 has the best results for 2nd weight in T2m and 2nd place in H2m. For 1st class the best are: 30SM61 for T2m and for H2m, 21SM61 are 2nd for both.

In 3rd class the best one are 21SM41 and 30SM41 for H2m.

Table 2 Comparison of number of better and worse points in comparison of oper run with smoothings runs, with different weights, for all forecast hours (00, 06,..., 48)

T2m 20020615_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*--4*---	-48	-48	-71	-77	-136
2*+++1.5*++1*+1*-2*--3*---	38	36	74	37	38
1*+++1*++1*+1*-1*--1*---	54	53	109	63	98
H2m 20020615_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*--4*---	-26	-9	-84	-65	-121
2*+++1.5*++1*+1*-2*--3*---	192	206	212	197	229
1*+++1*++1*+1*-1*--1*---	246	264	290	261	325

Table 2 Continuation of Table: Comparison of number of better and worse points in comparison of oper run with smoothings runs, with different weights, for all forecast hours (00, 06,..., 48)

T2m 20020616_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*-4*---	-110	-100	-215	-152	-258
2*+++1.5*++1*+1*-2*-3*---	11	14	-30	-2	-46
1*+++1*++1*+1*-1*-1*---	56	53	47	53	56
H2m 20020616_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*-4*---	192	173	234	285	219
2*+++1.5*++1*+1*-2*-3*---	415	378	528	524	551
1*+++1*++1*+1*-1*-1*---	407	371	502	488	525
T2m 20020617_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*-4*---	-201	-232	-339	-247	-408
2*+++1.5*++1*+1*-2*-3*---	-44	-79	-92	-61	-129
1*+++1*++1*+1*-1*-1*---	27	-6	47	23	39
H2m 20020617_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*-4*---	257	232	243	292	221
2*+++1.5*++1*+1*-2*-3*---	510	470	599	582	610
1*+++1*++1*+1*-1*-1*---	513	473	604	563	594
T2m 20020618_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*-4*---	-84	-68	-191	-133	-306
2*+++1.5*++1*+1*-2*-3*---	78	83	52	76	3
1*+++1*++1*+1*-1*-1*---	145	147	150	169	153
H2m 20020618_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*-4*---	158	168	64	146	5
2*+++1.5*++1*+1*-2*-3*---	455	448	495	485	480
1*+++1*++1*+1*-1*-1*---	523	506	551	523	558
T2m 20020619_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*-4*---	53	66	91	112	32
2*+++1.5*++1*+1*-2*-3*---	196	202	307	281	294
1*+++1*++1*+1*-1*-1*---	216	210	324	287	327
H2m 20020619_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*-4*---	362	404	446	415	461
2*+++1.5*++1*+1*-2*-3*---	613	634	808	715	855
1*+++1*++1*+1*-1*-1*---	614	615	750	679	766
T2m 20020620_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*-4*---	-58	-56	-106	-98	-138
2*+++1.5*++1*+1*-2*-3*---	66	53	104	67	116
1*+++1*++1*+1*-1*-1*---	107	81	176	130	212
H2m 20020620_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*-4*---	109	78	170	116	119
2*+++1.5*++1*+1*-2*-3*---	360	323	512	392	523
1*+++1*++1*+1*-1*-1*---	420	379	541	429	561
T2m 20030506_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*-4*---	-11	2	-30	-24	-29
2*+++1.5*++1*+1*-2*-3*---	37	45	64	48	76
1*+++1*++1*+1*-1*-1*---	46	51	82	69	93
H2m 20030506_00	OP - 10SM61	OP - 21SM41	OP - 21SM61	OP - 30SM41	OP - 30SM61
2*+++1.5*++1*+1*-3*-4*---	-335	-337	-413	-382	-447
2*+++1.5*++1*+1*-2*-3*---	-159	-150	-143	-153	-134
1*+++1*++1*+1*-1*-1*---	-50	-47	3	-30	39

Table 3 Comparison of numbers of worse points in comparison of oper run with smoothings runs, for all days (15-20) and forecasts hours (00, 06,..., 48) for T2m

T2m 200206_15-20_00	OPI - 10SM61	OPI - 21SM41	OPI - 21SM61	OPI - 30SM41	OPI - 30SM61
Just worse forecasts	-160	-180	-193	-180	-237

We are searching for smoothing with highest values in Tables 1, 2 and 3.

In Table 3 sum of just T2m forecasts worse than operational one during the period 15th – 20th June 2002. Such table for H2m is not available because for all forecast hours smoothed forecasts have more betters than worse forecasts.

From Table 3 it is possible to conclude that just last one 21SM61 have more worse points than other one, if we take in account just worse points it is possible to eliminate 21SM61.

For problematic period smoothing 21SM61 have or the best one or second results for T2m and for 1st weight, same is for May example.

For H2m results for 21SM41 are usually in a middle or in a better part, same is for May example.

7.2. Comparison of 21SM61 smoothing with others for period in June 2002

In following tables comparison of 21SM61 smoothing with OPER run and other smoothings for period in June 2002 are shown. In the Table 4 if D < 0 (first 3 rows) means that absolute error for smoothing 21SM61 is lower than for other. 2161 is 21SM61, 3041 is 31SM41, etc. If the background is yellow means that more points have smaller than greater absolute error. If the background is yellow in first tree rows (D < 0), in Tables 4 and 5, 21SM61 smoothing have more points with better forecast. If the background is yellow in last tree rows (D > 0), in Tables 4 and 5, 21SM61 smoothing have more points with worst forecast.

Table 4 Number of better and worse points for T2m in comparison of 20SM61 with other runs (OPER and other smoothings: 10SM61, 21SM41, 30SM41 and 30SM61), sum for all forecasts hours: 00, 06, 12... 48 UTC, and for whole period, 15th-20th of June 2002

T2m 00,06,...,48	2161 - OPER	2161 - 1061	2161 - 2141	2161 - 3041	2161 - 3061
T2m_all_D <= -2 C	433	39	45	13	9
-2 C < D <= -1 C	1228	259	290	119	50
-1 C < D <= -.5 C	2287	857	916	532	400
-.5 C < D < .5 C	27179	32090	31920	33013	33318
.5 C <= D < 1 C	1849	743	798	440	374
1 C <= D < 2 C	1008	220	235	100	66
2 C <= D	238	14	18	5	5

Table 5 Number of better and worse points for H2m in comparison of 20SM61 with other runs (OPER and other smoothings: 10SM61, 21SM41, 30SM41 and 30SM61), sum for all forecasts hours: 00, 06, 12... 48 UTC, and for whole period, 15th-20th of June 2002

H2m 00,06,...,48	2161 - OPER	2161 - 1061	2161 - 2141	2161 - 3041	2161 - 3061
H2m_all_D <= -10 %	1269	159	179	78	57
-10 % < D <= -5 %	2755	792	884	407	303
-5 % < D <= -2 %	4522	3230	3288	2419	1624
-2 % < D < 2 %	20219	27102	26744	28992	29753
2 % <= D < 5 %	3227	2167	2328	1763	1974
5 % <= D < 10 %	1430	488	517	330	305
10 % <= D	651	135	133	84	57

If we compare all forecasts hour and whole period smoothing 21SM61 is better than others. Just smoothings 30SM41 and 30SM61 are better for some classes.

In tables 6 and 7 comparison are made separately for every forecast for whole period, 15th-20th of June 2002.

Table 6 Number of better and worse points for T2m in comparison of 20SM61 with other runs (OPER, 10SM61, 21SM41, 30SM41 and 30SM61), for 06, 12... 48 UTC, 15th-20th of June 2002

T2m 15-20.06.2002	2161 - OPER	2161 - 1061	2161 - 2141	2161 - 3041	2161 - 3061
06 D <= -2 C	0	0	0	0	0
-2 C < D <= -1 C	4	1	1	0	0
-1 C < D <= -.5 C	58	14	17	10	4
-.5 C < D < .5 C	3849	3927	3926	3937	3938
.5 C <= D < 1 C	35	7	5	2	7
1 C <= D < 2 C	3	0	0	0	0
2 C <= D	0	0	0	0	0
12 D <= -2 C	136	10	11	2	1
-2 C < D <= -1 C	311	75	80	30	8
-1 C < D <= -.5 C	377	173	192	135	57
-.5 C < D < .5 C	2681	3554	3523	3690	3762
.5 C <= D < 1 C	279	93	99	60	84
1 C <= D < 2 C	131	24	24	13	18
2 C <= D	15	1	1	0	0
18 D <= -2 C	59	6	7	2	1
-2 C < D <= -1 C	192	33	39	17	11
-1 C < D <= -.5 C	326	126	137	64	78
-.5 C < D < .5 C	2751	3463	3432	3617	3669
.5 C <= D < 1 C	247	141	148	99	56
1 C <= D < 2 C	185	56	60	29	13
2 C <= D	71	6	8	3	3
24 D <= -2 C	7	1	0	0	1
-2 C < D <= -1 C	75	12	16	5	3
-1 C < D <= -.5 C	218	71	71	45	25
-.5 C < D < .5 C	3033	3461	3448	3516	3546
.5 C <= D < 1 C	185	48	53	30	20
1 C <= D < 2 C	78	6	11	3	4
2 C <= D	3	0	0	0	0
30 D <= -2 C	3	0	0	0	0
-2 C < D <= -1 C	74	10	8	5	3
-1 C < D <= -.5 C	246	63	71	35	22
-.5 C < D < .5 C	3376	3809	3803	3879	3890
.5 C <= D < 1 C	196	55	53	22	23
1 C <= D < 2 C	44	4	6	0	3
2 C <= D	2	0	0	0	0
36 D <= -2 C	145	14	16	5	2
-2 C < D <= -1 C	274	73	86	37	6
-1 C < D <= -.5 C	440	190	192	112	82
-.5 C < D < .5 C	2508	3457	3420	3674	3727
.5 C <= D < 1 C	299	151	166	75	91
1 C <= D < 2 C	210	39	43	21	16
2 C <= D	49	1	2	1	1
42 D <= -2 C	66	6	9	4	4
-2 C < D <= -1 C	190	38	40	15	15
-1 C < D <= -.5 C	334	122	129	75	107
-.5 C < D < .5 C	2559	3419	3397	3603	3643
.5 C <= D < 1 C	362	174	181	111	59
1 C <= D < 2 C	245	72	75	28	8
2 C <= D	81	6	6	1	1
48 D <= -2 C	17	2	2	0	0
-2 C < D <= -1 C	108	17	20	10	4
-1 C < D <= -.5 C	288	98	107	56	25
-.5 C < D < .5 C	2813	3391	3362	3488	3534
.5 C <= D < 1 C	246	74	93	41	34
1 C <= D < 2 C	112	19	16	6	4
2 C <= D	17	0	1	0	0

Table 7 Number of better and worse points for H2m in comparison of 20SM61 with other runs (OPER, 10SM61, 21SM41, 30SM41 and 30SM61), for 06, 12... 48 UTC, 15th-20th of June 2002

H2m 15-20.06.2002	2161 - OPER	2161 - 1061	2161 - 2141	2161 - 3041	2161 - 3061
06					
D <= -10 %	47	4	5	1	1
-10 % < D <= -5 %	187	41	44	19	8
-5 % < D <= -2 %	450	253	244	174	82
-2 % < D < 2 %	2918	3525	3512	3642	3708
2 % <= D < 5 %	281	113	129	96	134
5 % <= D < 10 %	47	5	6	9	8
10 % <= D	11	0	1	0	0
12					
D <= -10 %	205	11	13	5	5
-10 % < D <= -5 %	435	100	120	47	35
-5 % < D <= -2 %	688	489	496	318	172
-2 % < D < 2 %	1911	2995	2932	3335	3450
2 % <= D < 5 %	414	255	290	171	227
5 % <= D < 10 %	193	58	61	32	25
10 % <= D	71	9	5	9	3
18					
D <= -10 %	241	39	44	25	15
-10 % < D <= -5 %	404	148	165	62	72
-5 % < D <= -2 %	556	478	485	381	295
-2 % < D < 2 %	1766	2625	2567	2908	2977
2 % <= D < 5 %	418	358	374	309	354
5 % <= D < 10 %	254	106	120	88	73
10 % <= D	163	48	47	29	16
24					
D <= -10 %	55	8	10	5	4
-10 % < D <= -5 %	223	58	68	30	21
-5 % < D <= -2 %	477	308	294	214	134
-2 % < D < 2 %	2303	2987	2956	3150	3218
2 % <= D < 5 %	387	171	211	148	164
5 % <= D < 10 %	108	42	32	27	32
10 % <= D	25	4	7	4	5
30					
D <= -10 %	170	21	23	9	6
-10 % < D <= -5 %	309	99	107	55	25
-5 % < D <= -2 %	587	381	394	337	208
-2 % < D < 2 %	2290	3115	3084	3263	3377
2 % <= D < 5 %	389	263	277	237	277
5 % <= D < 10 %	160	51	49	31	37
10 % <= D	29	4	0	2	4
36					
D <= -10 %	225	16	20	7	3
-10 % < D <= -5 %	507	124	141	50	27
-5 % < D <= -2 %	676	487	516	331	238
-2 % < D < 2 %	1697	2869	2827	3249	3379
2 % <= D < 5 %	452	353	327	239	228
5 % <= D < 10 %	253	54	74	32	36
10 % <= D	105	12	10	7	4
42					
D <= -10 %	243	52	56	20	19
-10 % < D <= -5 %	418	162	159	101	86
-5 % < D <= -2 %	611	473	502	415	335
-2 % < D < 2 %	1578	2566	2469	2795	2937
2 % <= D < 5 %	485	389	444	364	353
5 % <= D < 10 %	260	122	129	88	65
10 % <= D	218	49	54	30	18
48					
D <= -10 %	83	8	8	6	4
-10 % < D <= -5 %	272	60	80	43	29
-5 % < D <= -2 %	477	361	357	249	160
-2 % < D < 2 %	2166	2830	2807	3060	3117
2 % <= D < 5 %	401	265	276	199	237
5 % <= D < 10 %	155	50	46	23	29
10 % <= D	29	9	9	3	7

For all forecasts: 06, 12, 18, 24, 30, 36 and 48 21SM61 smoothing are usually better than other smoothing except for 31SM61 smoothing.

7.3. Comparison of 21SM61 and 30SM61 smoothings for period in June 2002

In following tables comparison of 21SM61 and 30SM61 smoothings are shown. If the number in tables is less than 0 21SM61 smoothing have better forecast.

Table 8 Comparison of number of better and worse points for T2m in comparison of 20SM61 with 30SM61 smoothings runs, with different weights, $|\text{err}(21\text{SM61})| - |\text{err}(30\text{SM61})|$, 15th-20th of June 2002

T2m 20020615-20_00	T2m +06	T2m +12	T2m +18	T2m +24	T2m +30	T2m +36	T2m +42	T2m +48
2*+++1.5*++1*+1*-3*-4*---	3	26	-33.5	-12	-3.5	9	-95	3
2*+++1.5*++1*+1*-2*-3*---	3	35	-21.5	-8	-0.5	17	-76	7
1*+++1*++1*+1*-1*-1*---	3	36	-18	-5	1	18	-58	9

Table 9 Comparison of number of better and worse points for H2m in comparison of 20SM61 with 30SM61 smoothings runs, with different weights, $|\text{err}(21\text{SM61})| - |\text{err}(30\text{SM61})|$ 15th-20th of June 2002

H2m 20020615-20_00	H2m +06	H2m +12	H2m +18	H2m +24	H2m +30	H2m +36	H2m +42	H2m +48
2*+++1.5*++1*+1*-3*-4*---	36	-26.5	-75.5	9	33.5	-41	-182.5	31.5
2*+++1.5*++1*+1*-2*-3*---	45	13.5	11.5	34	64.5	-11	-77.5	64.5
1*+++1*++1*+1*-1*-1*---	51	43	61	42	79	0	-4	80

With comparison of just two smoothing for T2m and H2m it is not clear which smoothing is better. If more weight is given to bigger improvement than results are better for 21SM61, especially it is case for H2m.

8. Conclusion

During the hot summer days, hot spots appear in 2m Temperature field, caused by small scales features in the soil moisture. They are the consequences of switching condition in the surface analysis and of connective precipitation which both have high degree of uncertainties. More over this smoothing is coherent with the soil moisture analysis which is not able to connect spatial scales lower than 100 km because of the Surface Observations network. Surface analysis is made in ARPEGE.

When the smoothing of SWI is applied, during the winter there is some visible changes of SWI on Istria peninsula, Apennine peninsula Sicily and Africa, for other areas changes are to small, or there are not changes at all. During the summer smoothing for the same number of smoothing with 6.1 km smooth SWI field more than with 4.1 km, like it was expected. Smoothed field for 21SM41 looks similar with 10SM61. For smoothing 21SM61 there is still some details in SWI field, what is not case for 30SM61, maybe 30SM61 is to smooth.

With smoothed SWI there are no anymore-such big gradients in T2m field like it was in Operational run. For some points T2m is smaller for more than 2 °C if we compare operational run and smoothing with 21 or 30 smoothings with radius of smoothing 6.1 km.

For winter days there is no important changes in RMS and BIAS. For examples in April 2003 there is some small impact. For May example RMS is better sometimes for operational and sometime for smoothed SWI forecasts. For June 2002 with very high temperatures RMS is better for runs with smoothed SWI, maximum improvement of RMS for H2m is 0.022. For H2m and BIAS more times

operational forecast is better than run with smoothed SWI, maximum difference for BIAS=0.024. For T2m RMS is usually better for smoothed SWI highest differences are for 12, 36 and 18 hrs forecast. Maximum for RMS=0.334 °C. For all experiments BIAS is usually less than zero. Operational run is better for BIAS and difference is higher for 12, 18, 36 and 42 hrs forecasts. Maximal difference for BIAS=0.369 °C.

If there is wish to smooth SWI proposal is to use 21SM61 smoothing, results for the period 15th – 20th June 2002 are the best. It is very important to make forecast worst in minimal number of points. If somebody like to use it 21 means 21 smoothings are apply and 61 is for radius of smoothing is 6.1 km (half of the horizontal grid).

Some longer parallel test during the late spring and summer is needed to conclude if the impact of smoothing SWI will improve or not the 2 m scores. The best solution is to improve assimilation in ARPEGE or to applay smoothing of SWI in ARPEGE than it is not needed in ALADIN.

