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EUCOS observing system experiments with the DMI HIRLAM Optimum Interpolation analysis and forecasting system

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Abstract

This note describes the preliminary results from an observing system experiment (OSE) related to the last part of the EUCOS (EUMETNET Composite Observing System) special observation period with an increased number of AMDAR (Aircraft Meteorological Data Reporting) aircraft observations as well as an increased number of radiosonde observations. The impact by reducing the number of radiosonde observations is negative in terms of observation verification scores and is also negative in terms of field verification scores over large parts of Europe. The impact of a few extra radiosonde observations and the extra AMDAR platform observations is in general negative in terms of the above mentioned measures. This is counter intuitive.

1. Introduction

This note summaries results from parallel experiments done at DMI addressing the EUCOS (EUMETNET Composite Observing System) special observational campaign that took place from 20 September to 14 November 1999. There is a relatively high density coverage of radiosonde observations over Europe. The associated costs are rather high and often the question of ways to reduce this network arises. The EUCOS campaign was set up in order to see if an increased number of AMDAR (Aircraft Meteorological Data Reporting) aircraft observing wind and temperature below the tropopause can replace radiosonde measurements. Besides an additional 116 AMDAR reporting units, 27 radiosonde stations uniformly distributed ($\approx 500\,\text{km}$ spacing) over Europe have been activated four times per day. This note illustrates the impact on short range forecast on a limited area model with the DMI-HIRLAM.

Section 2 gives an overview of the HIRLAM OI analysis system and the use of observations at DMI. Section 3 describes the observation system experiments (OSE), section 4 gives some results, and finally a summary of the conclusions drawn from the experiments are given in section 5. Appendix A lists the AMDAR platforms and radiosonde stations that were blacklisted in the experiments.

2. HIRLAM OI data assimilation system

The operational DMI HIRLAM data assimilation system up to the end of September 2000 was an intermittent data assimilation system including an Optimum Interpolation (OI) analysis scheme (version 4.6) and a forecast model (version 4.5). The system at DMI is documented in Sass *et al.* (1999) and further details concerning the HIRLAM OI analysis scheme can be found in Källén (1996) and Undén (2000).

The HIRLAM OI is a limited area version of the ECMWF OI scheme (Lönnberg and Shaw, 1987). The first-guess field is the 6 h forecast from the previous data assimilation cycle. Three-dimensional multi-variate statistical interpolation is used for the wind, geopotential, and surface pressure. Three-dimensional univariate statistical interpolation is used for relative humidity. The observation window covers a 6 h span around the analysis time (0000, 0600, 1200 and 1800 UTC). A standard observation set is used, including synoptic observations, ship observations, (drifting and moored) buoys, pilot balloons, radiosonde data and aircraft data. Here we would like to point out that no satellite observations have been included.

In a routine ACARS/AMDAR report are time, latitude, longitude, pressure altitude and the meteorological data elements wind direction and speed, air temperature, turbulence (if available) and humidity (if available). In the HIRLAM OI analysis only the wind parameters are used. Normally, humidity data are not reported but they could be essential if ACARS/AMDAR are to replace some radiosonde stations close to airports in the future.

In the former OI analysis system used operationally at DMI, no redundancy check was done on aircraft observations such as AMDAR (Aircraft Meteorological Data Reporting) and ACARS (Aircraft Communication Addressing and Reporting System). Accordingly, the time window for allowing these data types was reduced from the standard ± 3 h for other data types to $\pm\frac{1}{2}$ h to reduce along track analysis increments leading to spurious effects in the following forecast. Furthermore, area saturation by too many data has to be avoided around airports. This reduced time window was determined from observation verification of a series of test runs using different time windows. Since then the number of available AMDAR reports at DMI has increased substantially, however, a redundancy check and thinning procedure has also been introduced into the HIRLAM OI data assimilation system (Undén, 2000). Recently, an investigation of the use of AMDAR and ACARS (Aircraft Communication Addressing and Reporting System) was done at DMI (Amstrup and Mogensen, 2000). The difference on scores from experiments with a $\pm\frac{1}{2}$ h and a ± 1 h AMDAR/ACARS observation time window was very small and the operational time window of $\pm\frac{1}{2}$ h has been retained in the experiments here.

3. The OSE setup

A 27 day period, from 0000 UTC 20 Oct. to 1800 UTC 15 Nov. 1999, in the last part of the EUCOS special observation period with an extended set of AMDAR observations is chosen for the OI analysis data assimilation experiments.

The basic model applied in the present parallel experiment is DMI-HIRLAM-G (see Sass *et al.*, (1999) for details), built on reference version HIRLAM 4.5/4.6. Thus, the OI analysis includes the modified observation errors and also the moving platform checks as specified in Undén, (1999). The horizontal resolution is $0.45°$, the number of vertical levels 31, the number of grid points is 190×202, the time step is 240 s and the lateral boundary values are updated every 6 hours.

Some modifications are made compared to the operational runs: 1) ECMWF analysis or 6 h forecasts are used for boundary update; 2) 6 h data assimilation frequency and no restart from ECMWF analyses; 3) long 48 h forecasts are done at all assimilation hours (as is the case for the operational DMI-HIRLAM-E "Europe" model).

In order to compare the performance of different data assimilation experiments the forecasts are verified against observations from European radiosonde and synoptic stations to give an objective evaluation of the experiments. Since the stations involved in this obs-verification cover a limited part of the model domain, the forecasts are also compared with (initialized) analyses from their own data assimilation suite (field-verification). The DMI observation- and field-verification packages are used.

Three experiments have been made with the OI data assimilation system, two of those using blacklists as given by Carla Cardinali from ECMWF and the last experiment using all available data. The experiment named EU1 is a "control" experiment using almost the same radiosonde and aircraft data as before the EUCOS campaign. Thus, the extra AMDAR platforms are blacklisted in this experiments as well as some extra radiosonde data. The experiment named EU2 has the same AMDAR platform blacklist as do EU1 and in addition 36 radiosonde stations. The third experiment named EU3 has no blacklist of AMDAR platforms and radiosonde stations.

The number of aircraft observations presented to the analysis is shown in Figure 1 and the number of radiosondes is shown in Figure 2. The number of aircraft observations were identical in experiments EU1 and EU2. There is a large difference in the number of aircraft observations presented to the analysis between experiments EU1/EU2 and EU3. However, after redundancy check and data thinning the differences were substantially reduced (not shown). Figure 2 also show the large reduction of radiosonde observations in experiment EU2 compared with experiments EU1 and EU3. The difference in the number used in experiments EU1 and EU3 are much smaller.

4. Results

4.1. Observation verification

Observation (obs-) verification has been done using an EWGLAM (European Working Group on Limited Area Modeling) station list for the full period and for daily verification of 36 h forecasts. Note that bias (mean error) and standard deviation (std. dev.) are used for the daily verification and bias and root mean square (rms) are used for the full period. We use std. dev. for the daily verification in order to avoid that large fluctuations in daily biases show up. (It also takes away differences in systematic biases from different models. The latter is not the case here, however).

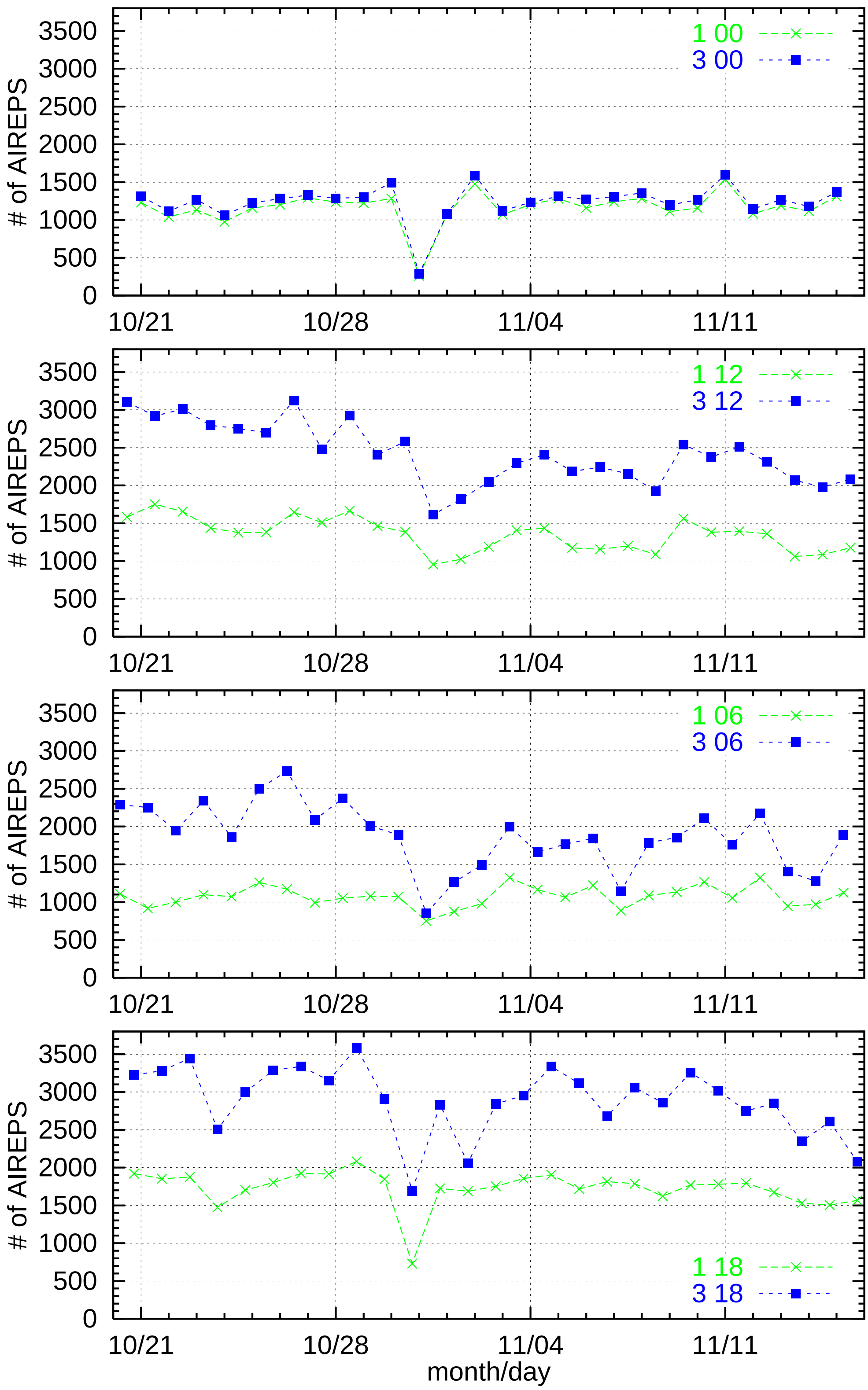

Figure 1: Number of aircraft observations presented to the analysis. From top to bottom is shown the numbers for analyses at 00 UTC, at 12 UTC, at 06 UTC, and at 18 UTC as specified by the labels. 1 stands for experiment EU1 and 3 stands for EU3.

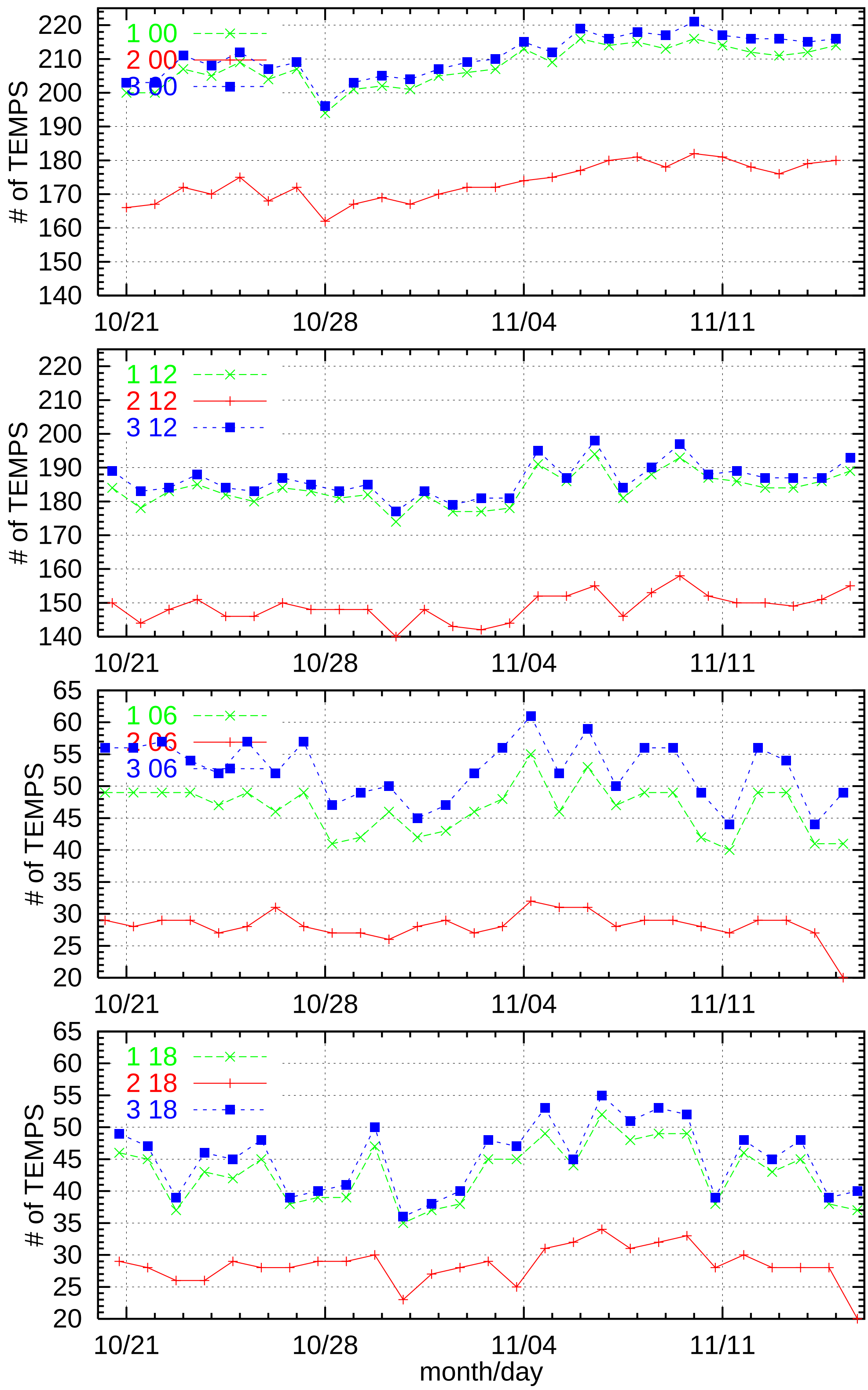

Figure 2: Number of radiosonde observations used in the analysis. From top to bottom is shown the numbers for analyses at 00 UTC, at 12 UTC, at 06 UTC, and at 18 UTC as specified by the labels. 1 stands for experiment EU1, 2 stands for EU2, and 3 stands for EU3.

Obs-verification scores using the EWGLAM station list for the full period for surface and upper level parameters are shown in Figures 3 and 4. The differences in scores are small for all parameters. It seems, however, that experiment EU1 in general has the best scores in rms and experiment EU2 the worst. Obs-verification for Danish stations only (not shown) shows a larger difference between rms scores for EU1 and EU2/EU3 for mslp.

Figure 5 shows daily verification scores for 36 hour mslp forecasts. There are large daily fluctuations in the bias for all runs. Which one is best also varies. However, only in a very few cases has EU1 the worst score. The same trend can be seen in Figure 6 showing daily obs-verification scores for 500 hPa geopotential height, and also for other parameters (not shown).

4.2. Field verification

Note that all figures and results from field verification in the OI data assimilation setup are done with a resolution of 0.9°, i.e., half the model resolution. Figure 7 shows the differences in standard deviations of 500 hPa geopotential height and mslp from field verifications of 48 h forecasts of EU1 and EU2. For both fields the scores for EU1 are better in large parts of northeastern Atlantic and western and central Europe. However, for 500 hPa geopotential height EU2 has better scores over parts of France. In the Arctic area the scores are mixed between EU1 and EU2 having the best/worst. A similar study (not shown) of differences between EU1 and EU3 standard deviations from field verification shows only small differences in Europe and the Atlantic for mslp.

4.3. Precipitation

Contingency tables of precipitation accumulated over 12 hours (from 6 to 18 hour forecasts and from 18 to 30 hours) are shown in Table 1. The numbers in these tables are obtained by counting the number of observed and predicted precipitation amounts in each of five classes for 25 Danish stations (as in the quarterly DMI verification reports). The five precipitation classes are (precipitation amounts in mm): $P1 < 0.2$, $0.2 \leq P2 < 1.0$, $1.0 \leq P3 < 5$, $5 \leq P4 < 10$ and $P5 \geq 10$. P is either F (forecast) or O (observation) in Table 1. The "sum" row and column are the sum of numbers in the given observation class or forecast class, respectively. The table clearly shows that the forecast model has a tendency to predict weak to moderate precipitation too frequently. For very short range (6–18 h) forecasts, EU3 seems to be a little better than EU1 being a little better than EU2. The basic differences are in the small or zero observed precipitation class (O1) for which EU3 has the largest number in the diagonal column/row, O1 versus F1. For the longer (18-30 h) forecast range, the list is reversed with EU2 being best and EU3 being worst. Again, the major difference is in the class with small or zero observed (O1) precipitation amounts with EU2 having the largest number in the diagonal column/row and smallest number in the "corner" column/row, F5 versus O1.

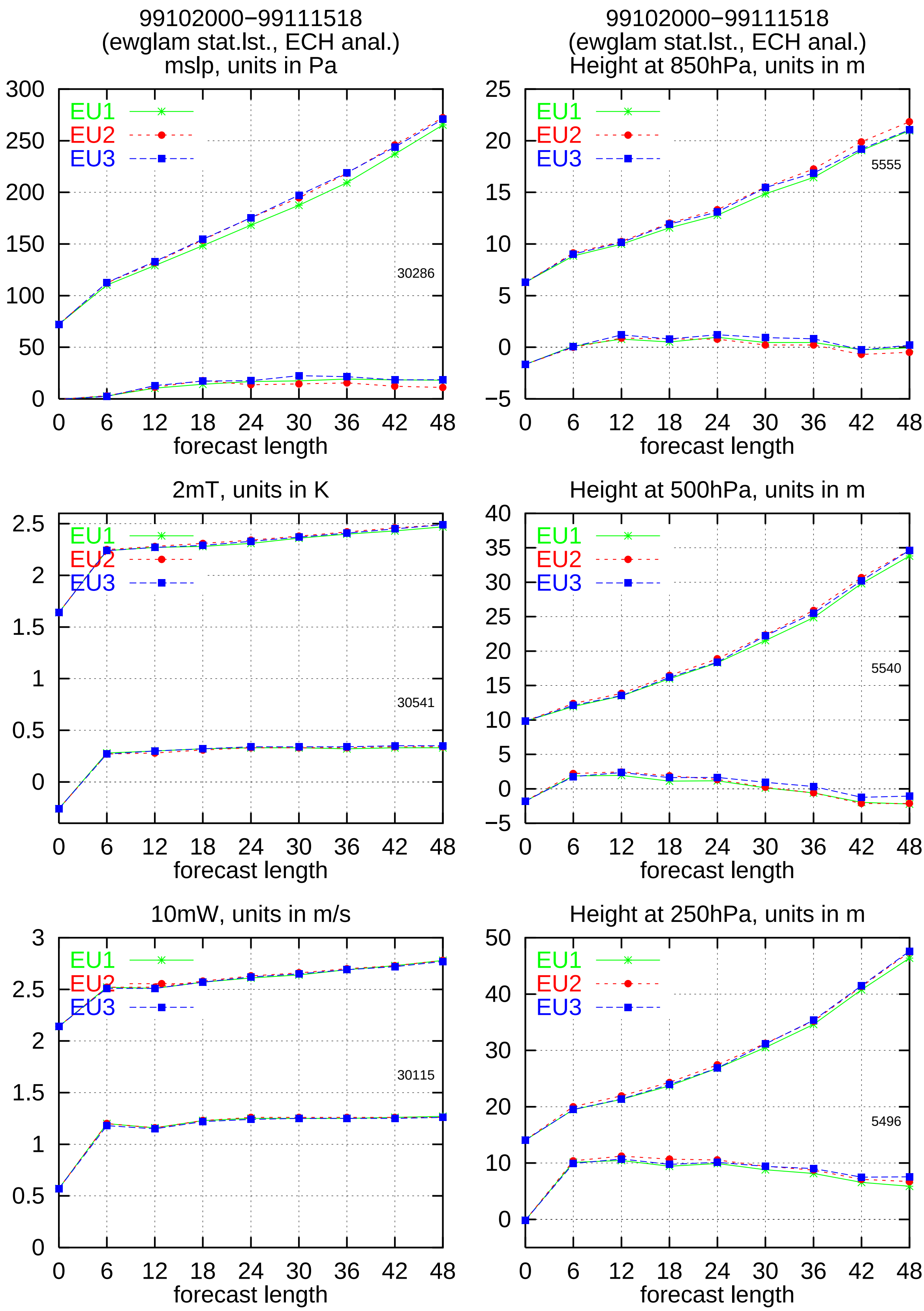

Figure 3: Obs-verification (bias and rms, EWGLAM station list) results for the Oct./Nov. 1999 period of surface parameters and geopotential height for pressure levels specified in the plot. ECMWF analyses have been used to reject observations and the analysis verification scores are for ECMWF. The small numbers in each plot indicate the number of observations used in the verification for the given variable.

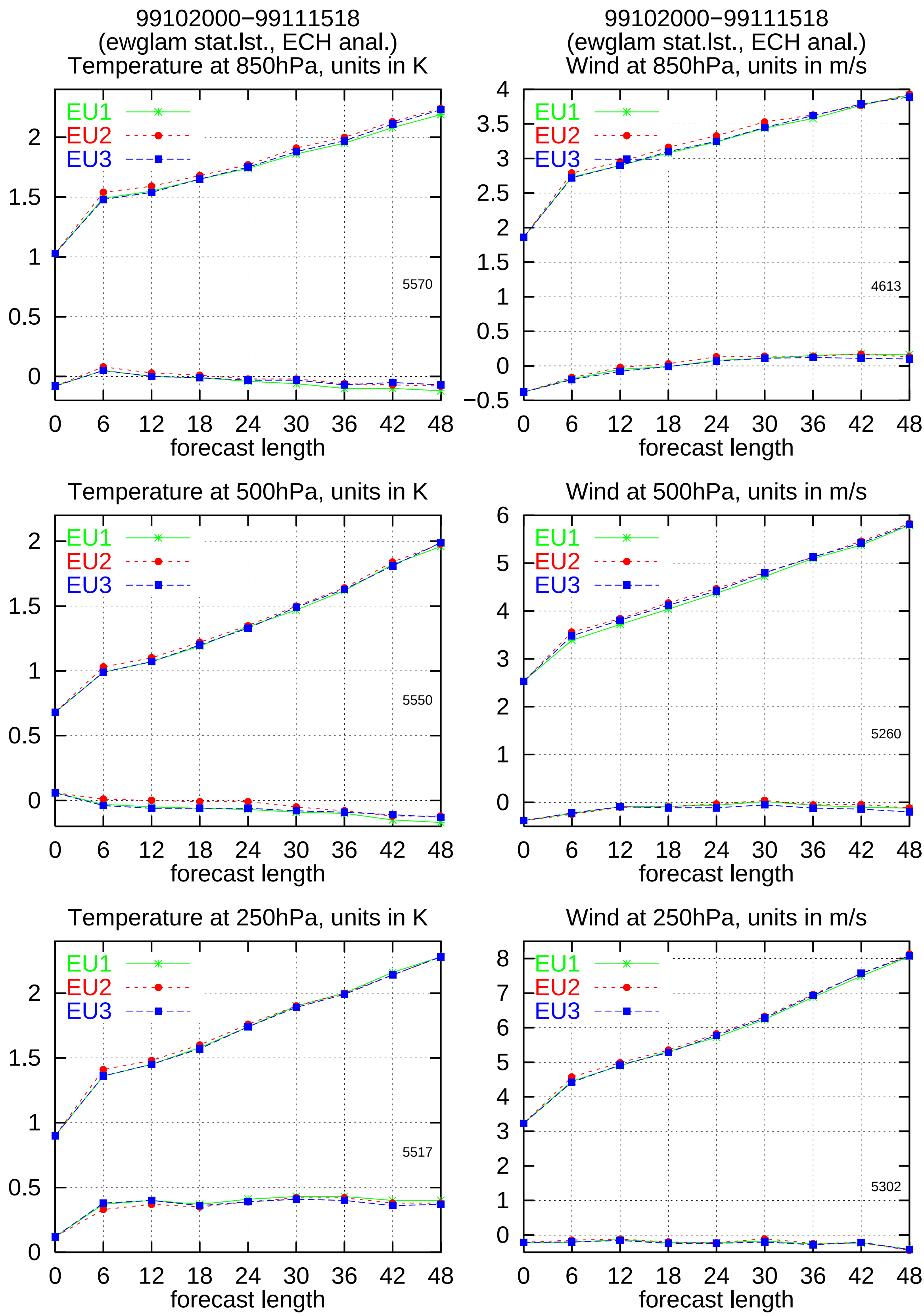

Figure 4: Obs-verification (bias and rms, extended EWGLAM station list) results for the Nov./Dec. 1999 period of temperature and wind for pressure levels specified in the plot. ECMWF analyses have been used to reject observations and the analysis verification scores are for ECMWF. The small numbers in each plot indicate the number of observations used in the verification for the given variable.

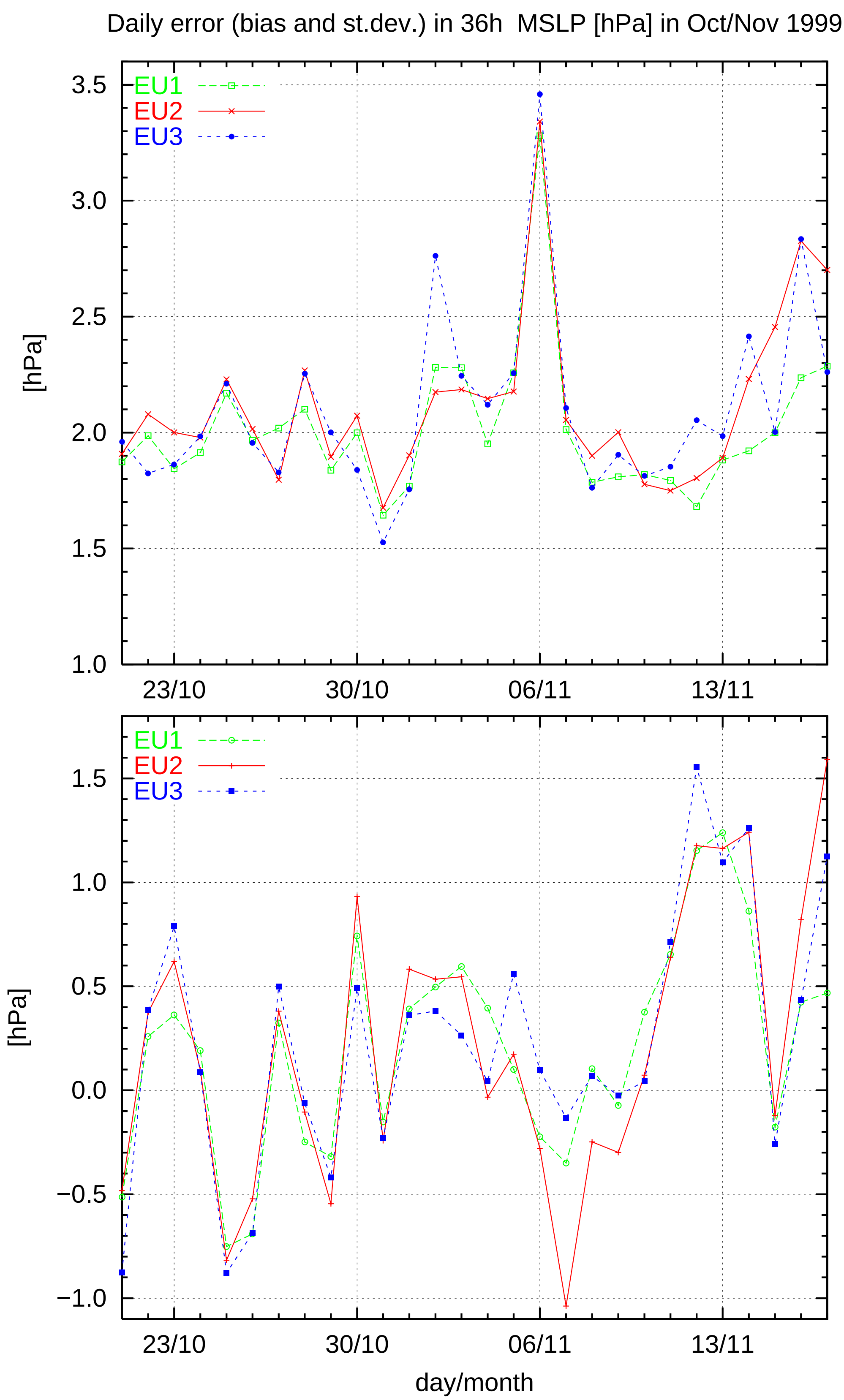

Figure 5: Daily obs-verification scores for 36 hour mslp forecasts. Upper plot is std. dev. and lower plot is bias. The EWGLAM station list is used and ECMWF analyses for observation screening. The date is valid date of the forecasts.

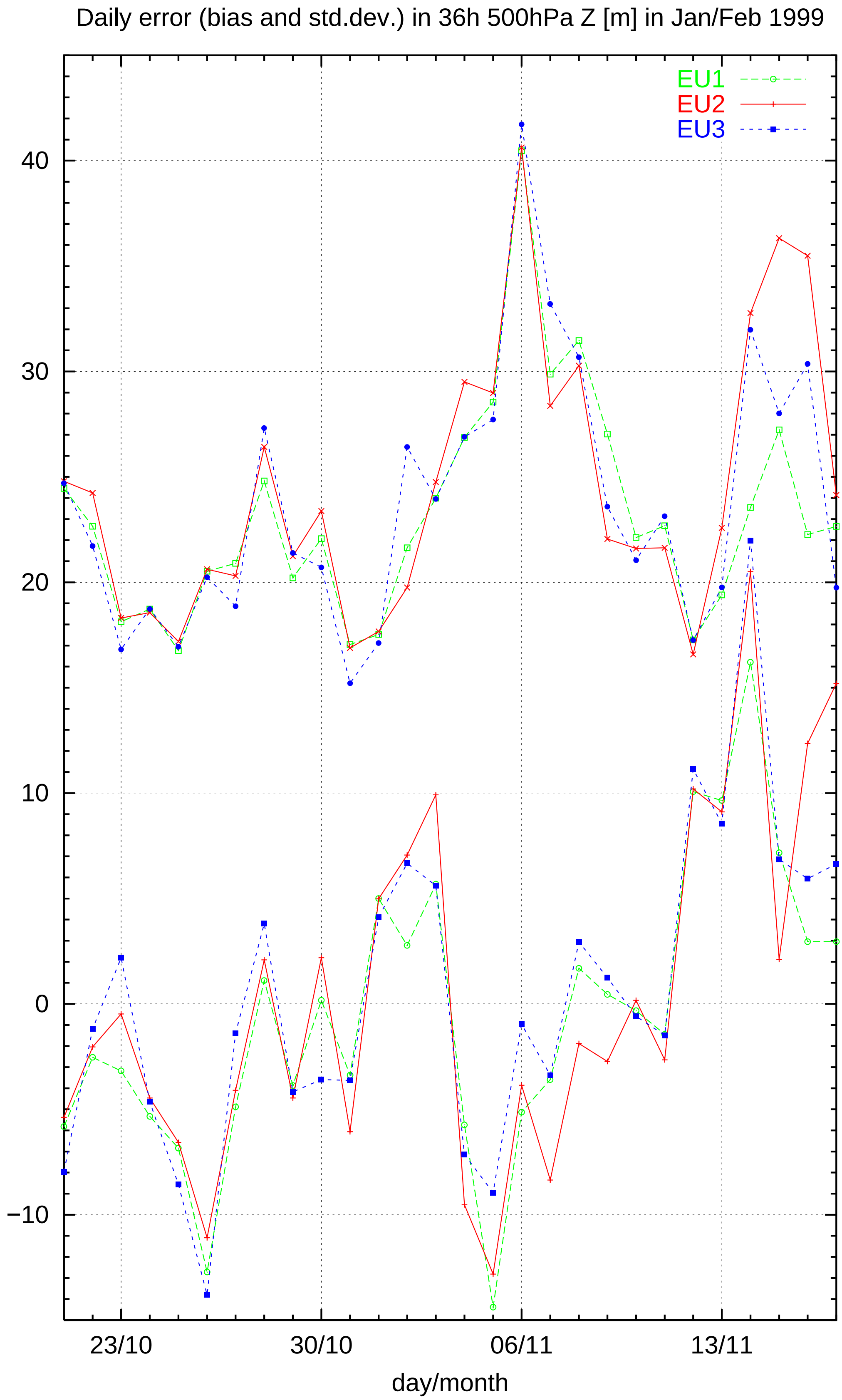

Figure 6: Daily obs-verification scores for 36 hour 500 hPa geopotential height forecasts. Upper part is std. dev. and lower part is bias. The EWGLAM station list is used and ECMWF analyses for observation screening. The date is the valid date of the forecasts.

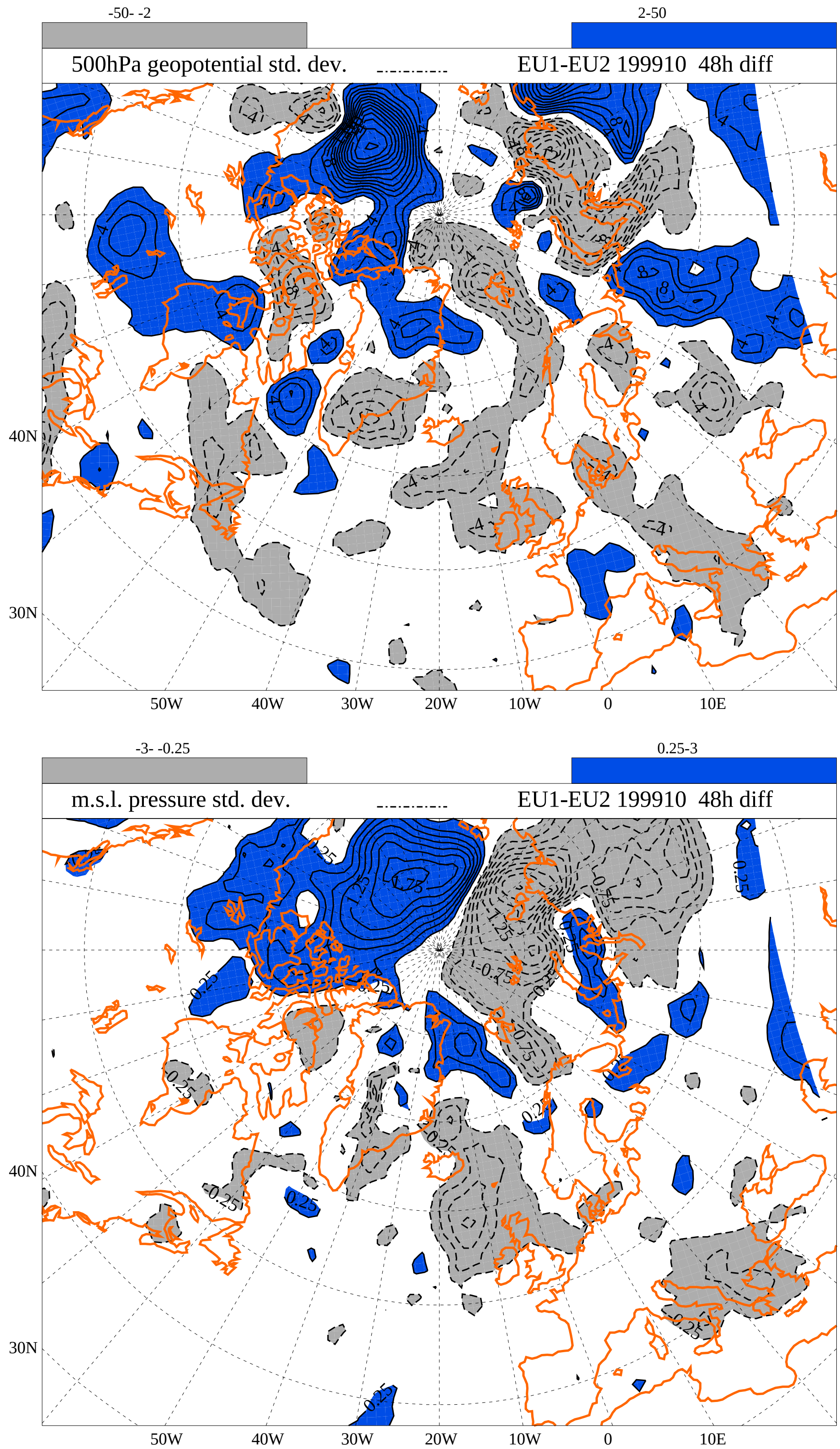

Figure 7: Difference of standard deviation between the EU1 and the EU2 for 48 h forecasts of 500 hPa geopotential height (upper) and mslp (lower) for the October/November 27 day period. Full lines/blue shaded for areas where EU2 is better and dashed lines/grey shaded for areas where EU1 has better standard deviation scores. Contour lines are for every 2 m and 0.25 hPa, respectively.

5. Conclusion

It should also be kept in mind that the period for the OSE is fairly short and cover only a part of one of the seasons of the year. Accordingly, the conclusions are by no means decisive.

The impact from reducing the number of radiosondes (experiment EU1 versus experiment EU2) is negative on basis of obs-verification. Also field verification show some negative impact in large parts of western and central Europe.

The comparison between EU1 and EU3 is more subtle. EU1 has in general better scores than EU3. The number of radiosonde observations in the EU3 analyses are consequently a little larger that the number of radiosonde observations in the EU1 analyses. The number of AMDAR aircraft observations are much larger in the EU3 analyses than in the EU1 analyses. Thus, we would expect the EU3 verification scores to be better than the EU1 scores. A possible explanation is that some bad AMDAR aircraft observations are used in the EU3 analyses in stead of being rejected.

With respect to verification of precipitation over Denmark based on contingency tables, the conclusion is reversed from very short (6-18 h) range forecasts to the next 12 hour period (18-30 h) forecast range. For very short range forecasts EU1 has the best scores and EU2 the worst scores.

Acknowledgment

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Table 1: Contingency tables for 9910/9911 period.

EU1 6–18 h forecasts						
	O1	O2	O3	O4	O5	sum
F1	**391**	16	3	0	0	410
F2	442	**75**	22	2	1	542
F3	53	49	**65**	20	4	191
F4	1	1	12	**1**	1	16
F5	0	0	0	0	**0**	0
sum	887	141	102	23	6	1159
%FO	44	53	64	4	0	46

EU1 18–30 h forecasts						
	O1	O2	O3	O4	O5	sum
F1	**394**	21	2	0	0	417
F2	372	**49**	28	3	0	452
F3	92	57	**59**	13	3	224
F4	5	10	11	**5**	3	34
F5	**4**	0	2	2	**0**	8
sum	867	137	102	23	6	1135
%FO	45	36	58	22	0	45

EU2 6–18 h forecasts						
	O1	O2	O3	O4	O5	sum
F1	**380**	21	4	0	0	405
F2	422	**59**	21	1	0	503
F3	82	58	**71**	19	2	232
F4	3	3	6	**2**	4	18
F5	0	0	0	1	**0**	1
sum	887	141	102	23	6	1159
%FO	43	42	70	9	0	44

EU2 18–30 h forecasts						
	O1	O2	O3	O4	O5	sum
F1	**415**	18	4	0	0	437
F2	361	**51**	27	4	0	443
F3	78	63	**49**	12	2	204
F4	12	5	16	**6**	4	43
F5	**1**	0	6	1	**0**	8
sum	867	137	102	23	6	1135
%FO	48	37	48	26	0	46

EU3 6–18 h forecasts						
	O1	O2	O3	O4	O5	sum
F1	**418**	18	1	0	0	437
F2	408	**64**	21	0	0	493
F3	57	55	**66**	18	1	197
F4	4	4	13	**5**	5	31
F5	0	0	1	0	**0**	1
sum	887	141	102	23	6	1159
%FO	47	45	65	22	0	48

EU3 18–30 h forecasts						
	O1	O2	O3	O4	O5	sum
F1	**384**	21	5	0	0	410
F2	389	**44**	21	3	0	457
F3	83	63	**56**	13	3	218
F4	6	9	20	**6**	2	43
F5	**5**	0	0	1	**1**	7
sum	867	137	102	23	6	1135
%FO	44	32	55	26	17	43

Appendix A. Blacklists

For EU1, the blacklist is:

```
RADIOSONDES and PILOTS:
"   11010" "   11120" "   07690" "   11240" "   06400" "   06496" "   06060"
"   07137" "   07255" "   07503" "   10304" "   10437" "   10828" "   10962"
"   06242" "   03023" "   03130" "   03213" "   03377" "   03414" "   03590"
"   03693" "   03696" "   03743" "   11036" "   11105" "   11123" "   07112"
"   07453" "   07613" "   07614" "   07615" "   07616" "   07664" "   10393"
"   11394" "   10722" "   06348" "   01010" "   06792" "   03501" "   03608"
"   03807" "   03840" "   16087" "   16113" "   16121" "   06831" "   06832"
"   06833" "   06842" "   06843" "   06844" "   11036" "   11105" "   11123"
"   07112" "   07453" "   07613" "   07614" "   07615" "   07616" "   07664"
"   10393" "   11394" "   10722" "   06348" "   01010" "   06792" "   03501"
"   03608" "   03807" "   03840"
AMDARS:
"  EU0088" "  EU0123" "  EU0143" "  EU0175" "  EU0201" "  EU0204" "  EU0221"
"  EU0245" "  EU0249" "  EU0254" "  EU0263" "  EU0274" "  EU0285" "  EU0291"
"  EU0300" "  EU0312" "  EU0332" "  EU0341" "  EU0347" "  EU0354" "  EU0357"
"  EU0363" "  EU0372" "  EU0385" "  EU0393" "  EU0405" "  EU0482" "  EU0574"
"  EU0720" "  EU0807" "  EU0934" "  EU0947" "  EU0961" "  EU0985" "  EU1002"
"  EU1222" "  EU1495" "  EU1593" "  EU1673" "  EU1688" "  EU1692" "  EU2378"
"  EU2399" "  EU2547" "  EU2578" "  EU2590" "  EU2618" "  EU2630" "  EU2634"
"  EU2689" "  EU2845" "  EU2890" "  EU2896" "  EU2912" "  EU2978" "  EU2984"
"  EU3056" "  EU3268" "  EU3321" "  EU3654" "  EU3684" "  EU3689" "  EU3908"
"  EU4002" "  EU4003" "  EU4021" "  EU4278" "  EU4387" "  EU4409" "  EU4529"
"  EU4587" "  EU4656" "  EU4838" "  EU5098" "  EU5167" "  EU5182" "  EU5349"
"  EU5590" "  EU5673" "  EU6287" "  EU6386" "  EU6524" "  EU6723" "  EU6893"
"  EU6923" "  EU7082" "  EU7285" "  EU7521" "  EU7634" "  EU7865" "  EU7866"
"  EU8264" "  EU8431" "  EU8478" "  EU8598" "  EU8605" "  EU8632" "  EU8736"
"  EU8789" "  EU8891" "  EU8943" "  EU9023" "  EU9356" "  EU9378" "  EU9589"
"  EU9678" "  EU9692" "  EU9734" "  EU9967" "  EU0041" "  EU0043" "  EU0047"
"  EU0050" "  EU0052" "  EU0059" "  EU0061" "  EU0106" "  EU0154" "  EU0158"
"  EU0167" "  EU0185"
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For EU2, the blacklist is:

```
RADIOSONDES and PILOTS:
"   06447" "   06181" "   02836" "   07110" "   07145" "   07180" "   07481"
"   07761" "   10184" "   10200" "   10238" "   10410" "   10486" "   10548"
"   10618" "   10739" "   10771" "   10868" "   16716" "   16080" "   16144"
"   16245" "   16429" "   01384" "   01400" "   08023" "   08160" "   08221"
"   08430" "   02365" "   03005" "   03502" "   03882" "   03920" "   11010"
"   11120" "   07690" "   11240" "   06476" "   06400" "   06496" "   06060"
"   07137" "   07255" "   07503" "   10304" "   10437" "   10828" "   10962"
"   06242" "   03023" "   03130" "   03354" "   03213" "   03377" "   03414"
"   03590" "   03693" "   03696" "   03743" "   11036" "   11105" "   11123"
"   07112" "   07453" "   07613" "   07614" "   07615" "   07616" "   07664"
"   10393" "   11394" "   10722" "   06348" "   01010" "   02591" "   06792"
"   03501" "   03608" "   03807" "   03840" "   16087" "   16113" "   16121"
"   06831" "   06832" "   06833" "   06842" "   06843" "   06844" "   11036"
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"   11105" "   11123" "   07112" "   07453" "   07613" "   07614" "   07615"
"   07616" "   07664" "   10393" "   11394" "   10722" "   06348" "   01010"
"   06792" "   03501" "   03608" "   03807" "   03840"
AMDARS:
"  EU0088" "  EU0123" "  EU0143" "  EU0175" "  EU0201" "  EU0204" "  EU0221"
"  EU0245" "  EU0249" "  EU0254" "  EU0263" "  EU0274" "  EU0285" "  EU0291"
"  EU0300" "  EU0312" "  EU0332" "  EU0341" "  EU0347" "  EU0354" "  EU0357"
"  EU0363" "  EU0372" "  EU0385" "  EU0393" "  EU0405" "  EU0482" "  EU0574"
"  EU0720" "  EU0807" "  EU0934" "  EU0947" "  EU0961" "  EU0985" "  EU1002"
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Not published

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