# Application and verification of ECMWF products 2012

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## 1. Summary of major highlights

In the section 2.1 the implementation of pre-filling forecast tables is presented. Currently HR and EPS raw data are used in the frame of our "Best Model". These tables are derived for a few synoptic stations and only a few surface parameters from D2 to D14 included. The weight of the HR is not negligible from D2 to D4 and the forecasts can be too deterministic and jumpy for these ranges.

A new approach using an EVMOS post-processing is now developed to experiment a more objective pre-filling based on the EPS raw data where hindcasts are used. In a near future, this post-processing should be tested operationally for a selection of surface parameters, a larger number of synoptic stations and the first two weeks of the forecasts. The pre-filling should be extended later to other parameters like the surface wind, the risk of precipitations for different classes and types… and may be experimented for the weather types.

In the section 3.1 the verification results of direct and post-processed (Kalman filtered) model outputs are presented.

In the section 3.2 a subjective verification is based on synoptic studies from the autumn 2011 up to the summer 2012. It's mainly the quality of the EPS forecasts for the first two weeks (D2 to D14 included) which is pinpointed and illustrated for a choice of critical events (cold and heat waves, …) and transitions between synoptic regimes retrieved in the ECMWF clustering.

From the expertise of forecasters interpreting HR and mostly EPS raw data for medium range forecasts we can retain the following comments and suggestions:

- a large spread and a significant jumpiness detected both in the plumes, EPS-grams, clustering, … indicate the difficulty to forecast a dominant weather regime and/or a transition between regimes sometimes already for the first week of the forecast (D2 to D7) and more often for the second week (D8 to D14)
- blocking regimes have been regularly well detected for the first week of the forecast and sometimes also for the second week (D8 to D14). Over Western Europe the predictability of blockings seems to be better for their onset than for their decay or transition to other regimes.

Furthermore main products exploited by forecasters to forecast blockings are up to now: successive days with light and variable or mostly northerly to southeasterly winds, a small probability of precipitation (less than 20%), a small spread in the plumes and a small number of clusters or rather similar ones over our areas.

For our areas it could be interesting to discriminate a blocking regime over Western Europe, near Atlantic ocean and Great Britain from a blocking regime over Scandinavia and eastern or central Europe.

To achieve it we could suggest to experiment a more limited domain at synoptic scale centred over our areas with an additional clustering more based on EPS data at lower levels (using T850, Z1000 and 850, …).

- the persistence of zonal regimes (NAO+, NAO-) like in December 2011 and in July 2012 is more reliable and useful
- the use of EPS raw data to forecast the so-called "extreme" events values must still be tested: it seems that the spread of EPS data is not large enough to assess these "extreme" values. In these situations the observed minima and maxima surface temperature tend to overshoot the most probable EPS values (let's say between the percentiles 10 and 90).

- the major cold spell at the end of January and for the first decade of February has been well predicted at least 10 to 15 days in advance. The 2m temperatures and mostly the minima have been generally underestimated.
- the heat wave of August has been predicted at quite shorter time range only 5 to 7 days in advance over Western Europe. The 2 m temperatures and mostly maxima have also been underestimated.

EPS indices like EFI and SOT for these "extreme" events should be tested and used more operationally. The way to attribute "extreme" values for one or several surface parameters and to get more reliable probabilities for chosen high/low threshold values has to be developed.

## 2. Use and application of products

It includes medium-range deterministic and ensemble forecasts

### 2.1 Post-processing of model output

#### *2.1.1 Statistical adaptation*

#### *2.1.2 Physical adaptation*

#### *2.1.3 Derived fields for medium range forecasts*

More recent High Resolution model (HR) and EPS are exploited to implement pre-filled tables for a few synoptic stations and a small number of surface parameters. For HR model we use the 0.25 latitude x longitude ECMWF dissemination.

A "best model" recipe has been elaborated at the RMI. This recipe depends on the different ranges of the forecasts:

- from D2 to D4 (ANA+48h to ANA+96h) a weighted linear combination of HR and EPS raw data is computed
- from D4 to D10, EPS-10 days model is used
- from D10 to D15, the fully atmosphere-ocean EPS version is used

The following surface parameters are treated to get pre-filling tables:

- TN: 2m minimum temperature for the previous night (a period between the previous day at 18h00 and the day itself at 06h00 u.t.c.)
- TX: 2m maximum temperature for the day itself (a period between 06h00 and 18h00 u.t.c.)
- RR: for the whole day period (00h00 to 24h00 u.t.c.)

These pre-filled tables contain the values of TN, TX and RR for given percentiles of the raw forecast distributions, P15 – P50 (median) and P85, for each time ranges (Fig. 2) and a few synoptic stations in Belgium (Fig. 1):

- eleven stations for D2
- five stations from D3 to D7 included
- one station (Brussels) from D8 to D14 included

These values are retrieved from the extrapolation at the station of the nearest land model grid point data and the chosen stations are supposed to be representative for a selection of Belgian sub-regions (let's say "provinces").

These pre-filled parameter values for TN, TX and RR are corrected and/or adapted by forecasters in adequacy with their more likely weather scenario built on conceptual models (weather systems). Forecasters take the uncertainties of their weather scenarios into account (examining jumpiness, timing, locations, intensities, scales, … of weather systems) to adapt the pre-filled percentiles values..

The other surface parameters like the Weather type(s) including cloudiness, Wind speed and direction, RR, risk of occurrence of precipitation, confidence index are fully completed by forecasters in adequacy with their more probable scenarios.

The medium range forecast products are issued by forecasters to feed our web site (http://www.meteo.be) updated several times per day and to inform medias and external users. The end products gather:

- adapted and completed forecast tables for different surface parameters.

These corrected pre-filled tables for TN, TX and RR are treated by forecasters for a few stations. The plumes for these parameters are displayed for one synoptic station (Uccle (Brussels)) from D2 to D14 and displayed on our web site (Fig. 2).

- more likely weather scenario forecasts are reported separately into three texts:

A text for D2, a text for D3 to D7 included ("first week of the forecast") and the last one for the second week from D8 to D14 (Fig. 3).

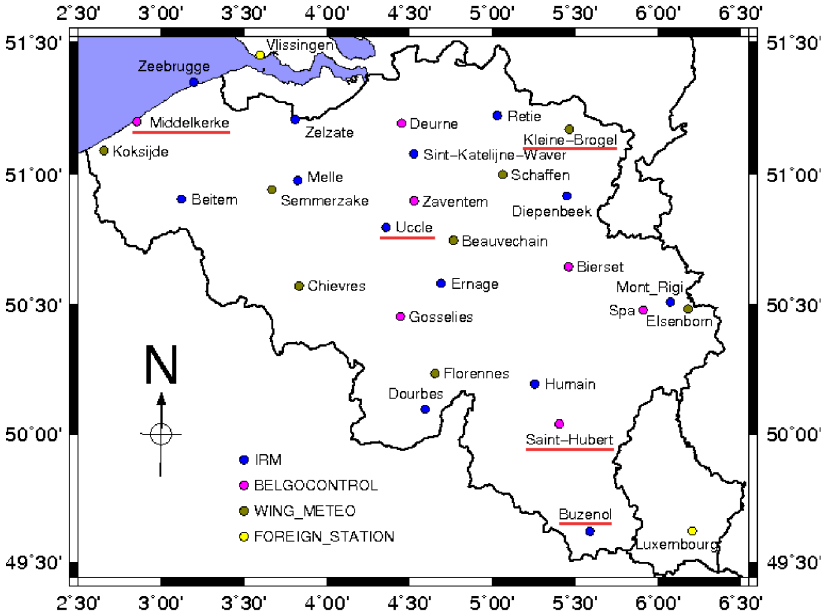
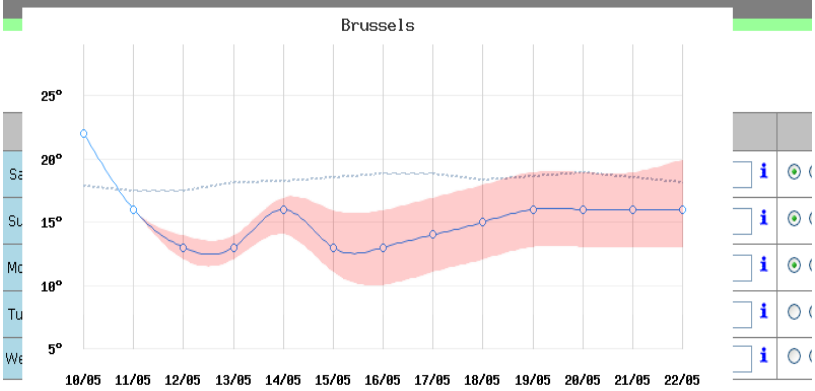



**Figure 1** Five synoptic stations in Belgium used for D3 to D7 forecasts. These stations are underlined in red.

## Forecast 7d: Wednesday 09/05/2012 at 17h

| MAXIMA | OST | BRU | KLB | STH | VIR |
|---|---|---|---|---|---|
| Sat 12/05/2012 | 12[12,13] | 13[12,14] | 14[13,15] | 10[9,11] | 12[11,13] |
| Sun 13/05/2012 | 13[12,14] | 13[12,14] | 14[13,14] | 9[8,10] | 11[10,12] |
| Mon 14/05/2012 | 15[14,17] | 16[14,17] | 17[15,19] | 11[9,12] | 13[12,15] |
| Tue 15/05/2012 | 13[11,15] | 13[11,16] | 13[11,16] | 12[9,14] | 13[10,15] |
| Wed 16/05/2012 | 13[11,16] | 13[10,16] | 14[11,17] | 9[6,12] | 11[8,14] |




**MT forecast table issued from the forecaster (D3 to D7 included)**

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5 Synoptic stations (see columns)

Parameter : TX (synoptic maxima)

D3 (date) **TX [TX1, TX2] :**

D4 (date) **TX**: most probable maxima

D5 (date) **[TX1, TX2]** : most probable interval around TX but not centred on TX

D6 (date)

D7 (date)

**MT forecast plume for Brussels (Uccle): it corresponds to the upper table (D3 to D7) + a similar table (D8 to D13) both implemented by the forecaster**

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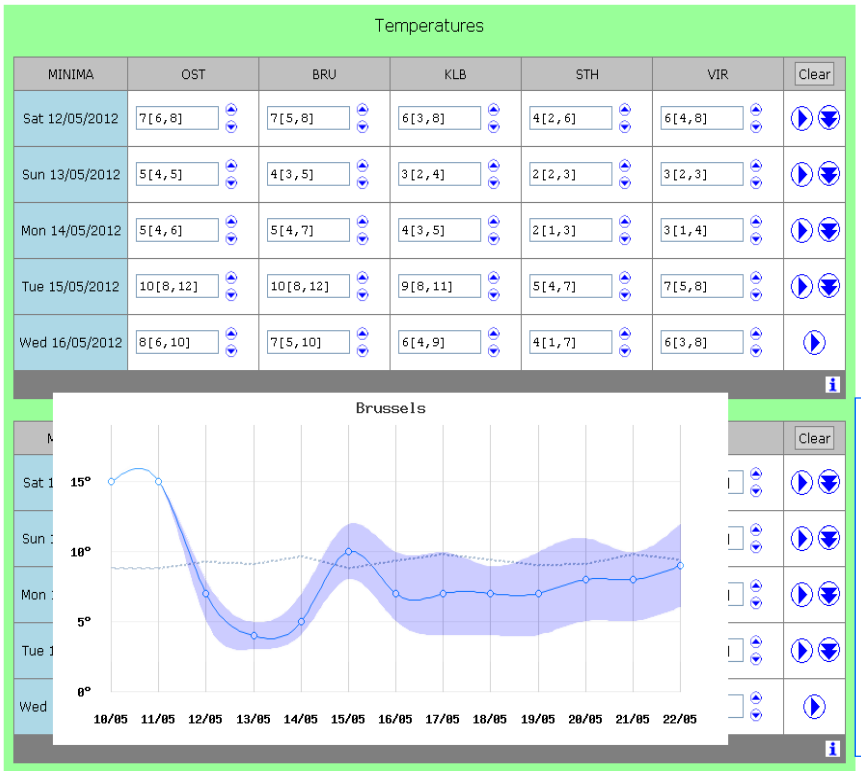
one synoptic station : Uccle (Brussels)

Blue continuous line: most probable TX (in °C)
+
red enveloppe : most probable interval around the most probable value TX (in °C)
+
Stippled line: climatology for TX at Uccle (mean daily values on the last 30 years period (1981 – 2010))

## Forecast 7d: Wednesday 09/05/2012 17h




MT forecast table issued from the forecaster (D3 to D7 included)

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5 Synoptic stations (see columns)

Parameter : TN (synoptic minima)

D3 (date) **TN [TN1, TN2] :**

D4 (date) **TN**: most probable minima

D5 (date) **[TN1, TN2]** : most probable interval around TN but not centred on TN

D6 (date)

D7 (date)

MT forecast plume for Brussels (Uccle) : it corresponds to the upper table (D3 to D7) + a similar table (D8 to D13) both implemented by forecaster

---

one synoptic station : Uccle (Brussels)

blue continuous line: most probable TN (in °C)
+
blue enveloppe : most probable interval around the most probable value TN (in °C)
+
stippled line: climatology for TN at Uccle (mean daily values on the last 30 years period (1981 – 2010))

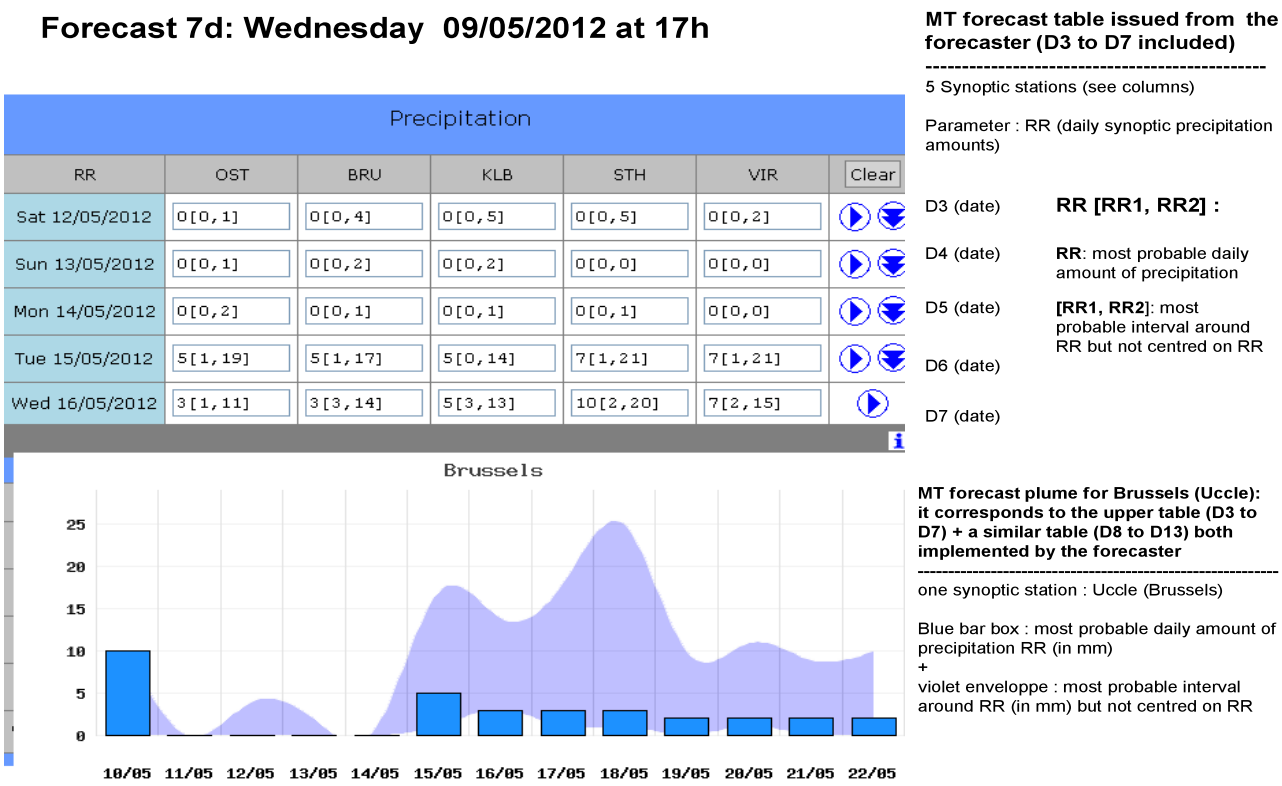


**Figure 2** Corrected/adapted pre-filled forecast tables for five synoptic stations respectively for TN, TX and RR and from D3 to D7. The same adaptation is made from pre-filled tables for the same parameters but only one station (Brussels) from D8 to D14. A plume is designed for one station (Brussels) from D2 to D14. This plume is an end product which includes the corrections made by forecasters on the pre-filled tables.

**MT texts**: they reflect **a most probable weather scenario** issued by forecasters which is consistent with the matrix forecast tables (For7d and For14d)

**Medium Range Forecasts from Saterday to Wednesday (D3 to D7 included)**

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From Saterday to Monday the weather will stay dry but with a variable cloudiness. In the morning we expect mist and even fogpatches.
The temperatures will stay rather fresh from 10 to 14 degrees during the weekend. Monday the temperatures will be
Higher and close to the temperature for the time of the year between 11 and 17 degrees. The wind will be moderate
from north and then will decrease and veering to est and southeast.

Tuesday it will be mainly very cloudy with rainy periods. The temperatures will be again fresher, between 10 and 14 degrees.

Wednesday it will be partly or very cloudy with showers and the weather will still be fresh with maxima between 9 and 14 degres.
The wind will be moderate verring to southwest.

**Medium Range forecasts from Thursday to Wednesday (D8 to D14)**

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The weather will stay (highly) variable with regularly precipitations and a few clearances or dry periodes.
The weather will still remain a little bit fresh for the time of the year with maxima around 15 degrees.

**Figure 3** Example of a more likely weather scenario reported in texts for the medium range forecasts

## 2.2 Use of products

The ECMWF raw data are operationally used for short range (Day and D1) and medium range forecasts (Day2 to Day14).

For short range forecasts the last two or three runs are compared with analysis or observations in real time. Main meteorological objects (fronts, troughs, L/H, thermal troughs, …) are identified and an evolution of a more probable tridimensional (3D) scenario is elaborated by forecasters linking upper-level and lower levels fields.

HR data are adapted by forecasters to elaborate forecast tables for eleven Belgian synoptic stations and surface parameters (TN, TX, Weather types, Wind speed and direction, gusts, RR, soil surface temperature during the night, confidence index) dividing the day into two twelve hour periods (Night time: 18h00-06h00 u.t.c; and Day time : 06h00-18h00 u.t.c.).

For medium range forecasts the last two or three runs of HR and EPS are examined. HR forecasts are mostly helpful to identify the main weather systems forecasted for our areas and EPS are more exploited to assess their uncertainties affecting different parameters and weather types. Both HR and EPS are exploited by forecasters to elaborate a more probable weather scenario for the first week (D2 to D7) and also the second week (D8 to D14).

A project to exploit additional raw ECMWF HR model data is in progress (planned for 2013). These data will be used to compute derived meteorological fields or parameters like instability indices, helicity fields, …. These fields will be used into an interactive checklist named “severe convection” to assess the risk of (severe) thunderstorms at short term over our areas (whole Belgium or a selection of sub-regions (“provinces”)).

# 3. Verification of products

## 3.1 Objective verification

### *3.1.1 Direct ECMWF model output (both deterministic and EPS)*

The operational forecasts produced at the RMI are still based on direct model output and when required the forecasters can tweak manually the values predicted by the models. These corrections are often necessary due to significant systematic model biases. Figures 4 and 5 show the mean and root mean square errors of 2-metre temperature forecasts in Brussels-Uccle (6447) from the high-resolution model (HR - ECMWF) and the ensemble mean (EPSMean) for the period January to July 2012 (7 months). The time increment is 3 hours in Fig. 4 (HR model, short range only) and 6 to 12 hours in Fig. 5. These plots, which are fairly typical for most Belgian locations, reveal diurnal cycles in the biases with, in many instances, negative errors developing overnight. These errors can be particularly large during radiative nights, more especially in winter. As expected, the forecasts based on the ensemble mean become systematically more accurate at time horizons beyond 48 hours as a result of the averaging process. Another typical feature is the slightly better accuracy of the 12-UTC runs.

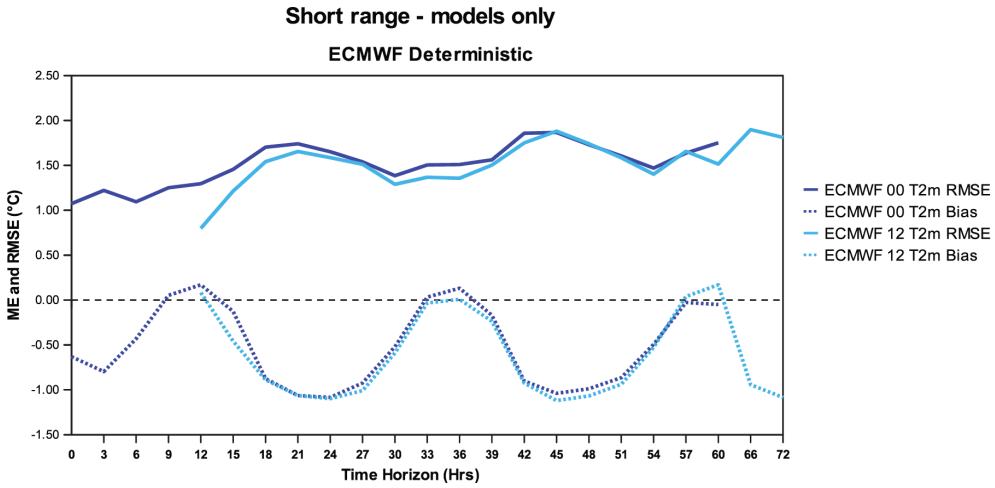


**Figure 4** Mean errors (ME, dotted lines) and root mean square errors (RMSE, solid lines) of 3-hourly predicted 2-metre temperatures in Uccle (06447) for the 00-UTC (dark blue) and 12-UTC (light blue) runs of the high-resolution ECMWF model. Verification period from 1 January to 31 July 2012. Time range up to 72 hours.

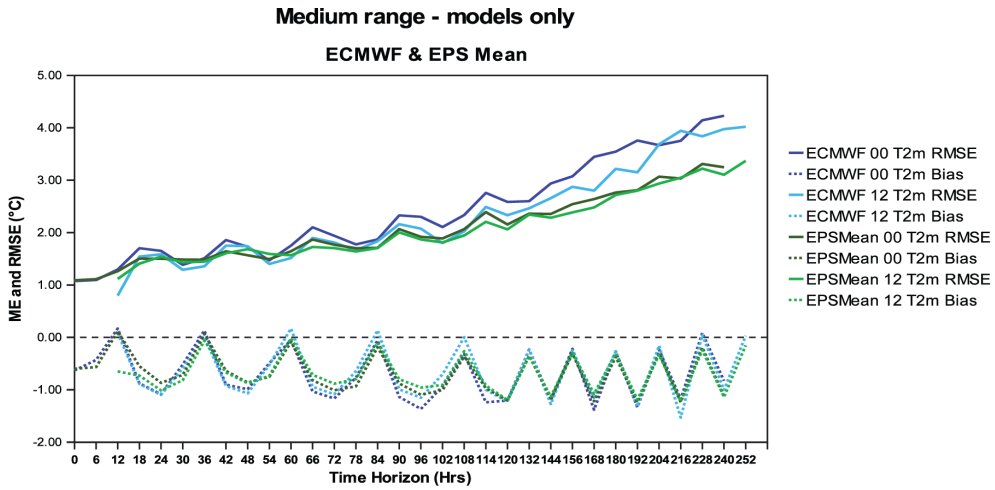


**Figure 5** Mean errors (ME, dotted lines) and root mean square errors (RMSE, solid lines) of predicted 2-metre temperatures in Uccle (06447) for the 00-UTC (dark) and 12-UTC (light) runs of the high-resolution deterministic ECMWF model (ECMWF, blue) and the ensemble mean (EPSMean, green). Verification period from 1 January to 31 July 2012. Time range up to 240 hours. 6-hourly timesteps up to 120 hours, 12-hourly timesteps afterwards.

### *3.1.2 ECMWF model output compared to other NWP models*

In Fig. 6, the performance of the ECMWF high-resolution model in the short range is compared over the same period with RMI's own regional model Alaro-7 (7-km horizontal resolution). Alaro is run 4 times per day with initial times at 00, 06, 12 and 18 UTC.

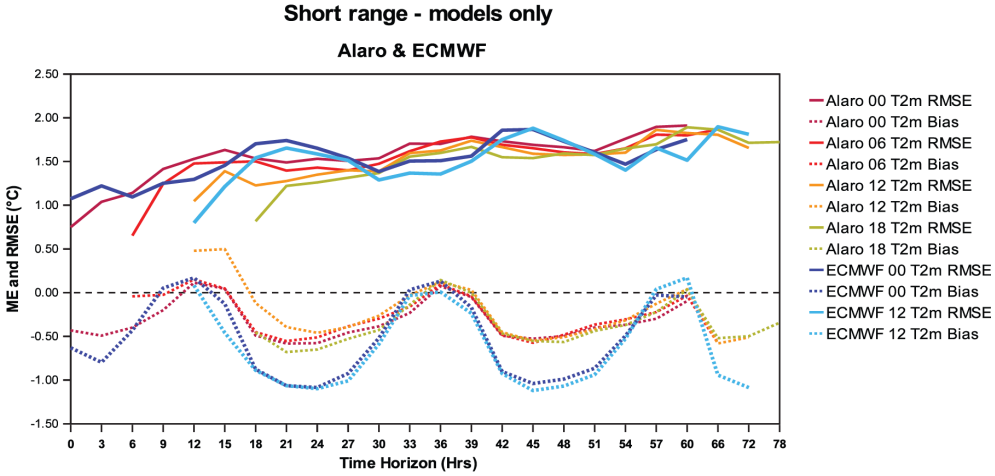


**Figure 6** Comparison of ECMWF performance results vs. Alaro-7. Results for successive Alaro-7 runs are shown in dark red (00UTC), light red (06 UTC), orange (12 UTC) and yellow (18 UTC). See caption of Fig. 16 for more explanations on the plot features.

Alaro shows a similar behaviour with negative errors that tend to predominate overnight. Alaro's biases are clearly less pronounced than ECMWF's, the former having roughly half the amplitude (~-0.5°C) of the latter (~-1°C). From the figure, it is also evident that the accuracy of ECMWF forecasts is degraded as a result of the larger biases. Where biases are close to zero, ECMWF tends to be more accurate than Alaro whereas it becomes less accurate than Alaro where the biases have maximum amplitude.

### *3.1.3 Post-processed products*

At the RMI, some research efforts have been spent lately to try and deploy automated operational procedures for post-processing ECMWF forecasts so as to keep the number of manual corrections to a minimum. For example, Van Schaeybroek (2012) presented results from a newly-developed post-processing scheme of ensemble forecasts based on hindcasts at the last Users' Meeting. Another statistical approach based on a one-dimensional formulation of the Kalman filter (KF) has also been devised and is currently being implemented operationally. Performance results of the KF vs. direct model output are shown in Fig. 7 below. The benefit of bias removal through KF can be seen clearly: post-processed ECMWF forecasts achieve equal or higher accuracy than their Alaro counterparts.

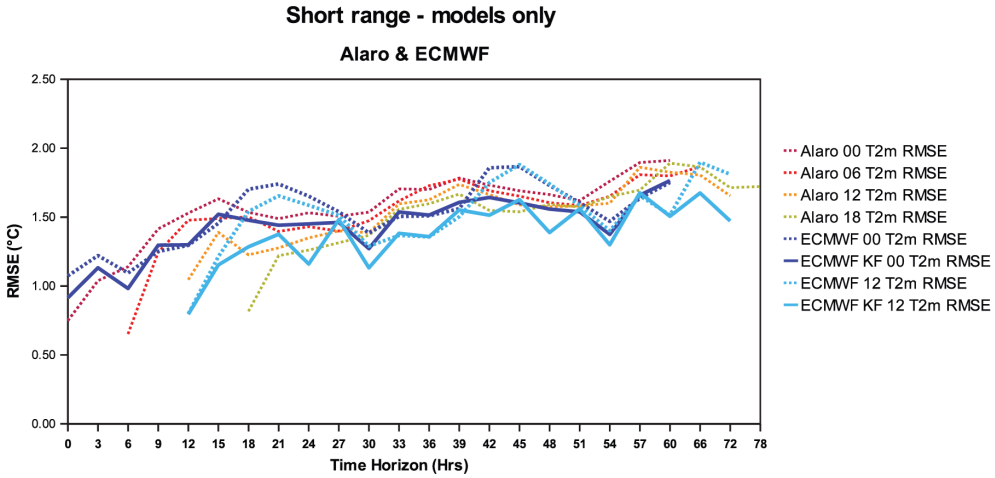


**Figure 7** RMSE of ECMWF and Alaro-7 2-metre temperature forecasts as shown in Fig. 6, this time indicated by dotted lines. The solid lines correspond to the Kalman filtered ECMWF forecasts.

The KF elimination of diurnal bias cycles can be extrapolated advantageously from the short range to well into the medium range. Figure 8 shows a performance comparison between the high-resolution model and the ensemble mean. 00-UTC runs are not shown here to avoid cluttering the figure. Significant gains in accuracy are featured across the board.

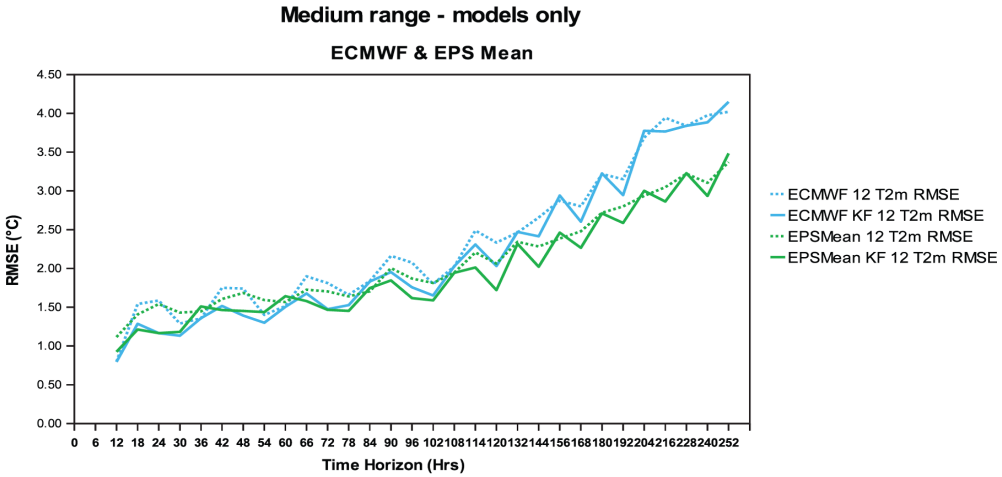


**Figure 8** RMSE of ECMWF high-resolution (ECMWF, blue) and ensemble mean (EPSMean, green) 2-metre temperature forecasts, runs starting from 12 UTC. The dotted lines indicate the accuracy of the uncorrected forecasts, the solid lines the accuracy of the Kalman filtered forecasts.

The KF has also been applied to the predicted surface minimum and maximum temperatures. Figures 9 and 10 show again significant improvements in accuracy, thus confirming the results obtained for 2-metre temperatures. The filtered ensemble mean forecasts are as accurate as the filtered high-resolution forecasts in the short range, and more accurate in the medium range.

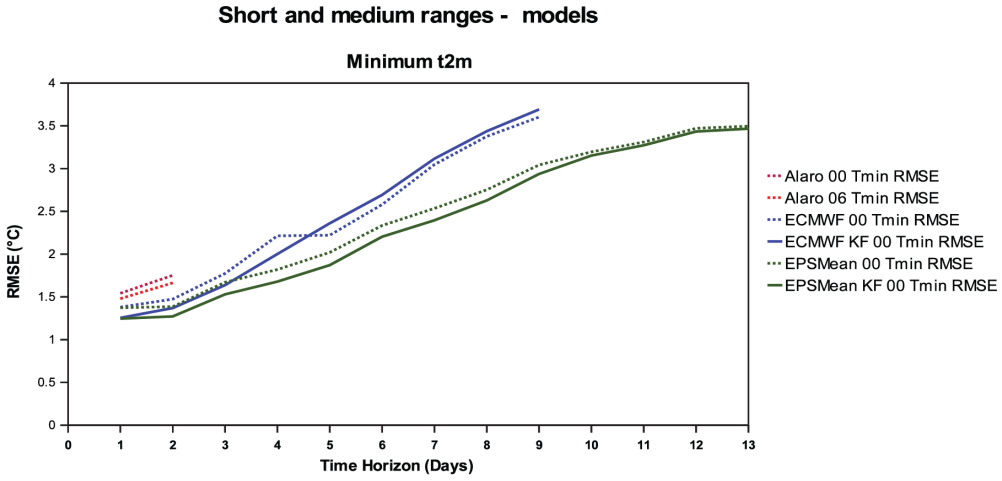


**Figure 9** RMSE of ECMWF high-resolution (ECMWF, blue), ensemble mean (EPSMean, green) and Alaro-7 (Alaro, dark and light red) minimum temperature forecasts for Uccle (06447), runs starting from 00 UTC (ECMWF, EPS Mean, Alaro-7) and 06 UTC (Alaro-7). Verification period from 1 January to 31 July 2012. Time range up to 13 days. The dotted lines indicate the accuracy of the uncorrected forecasts, the solid lines the accuracy of the Kalman filtered forecasts.

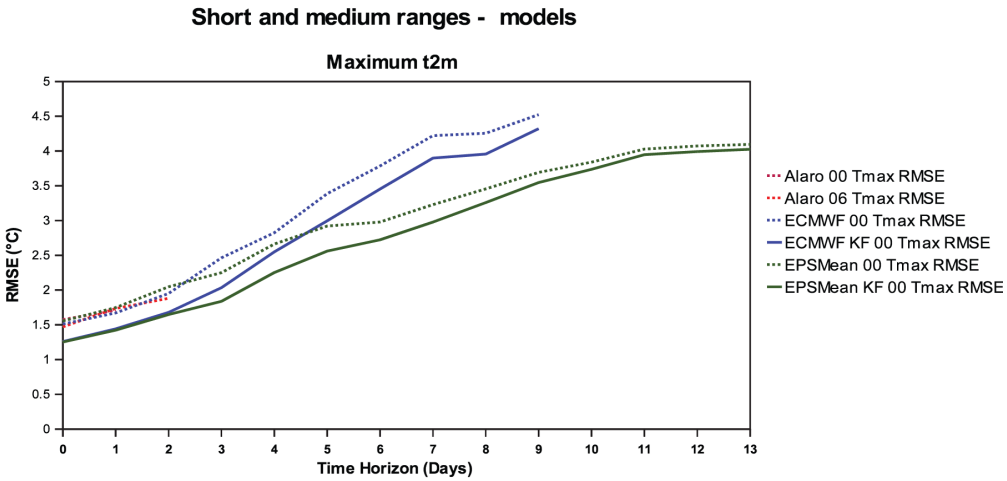


**Figure 10** Same as in Fig. 21 with maximum temperature forecasts.

The KF technique has also been applied to Alaro's forecasts, albeit with less success. This model appears to be more volatile than ECMWF, which can sometimes lead to an unstable behaviour of the filter.

*3.1.4 End products delivered to users*

## 3.2 Subjective verification

*3.2.1 Subjective scores (including evaluation of confidence indices when available)*

*3.2.2 Synoptic studies*

For the previous year, from the autumn 2011 to the summer 2012, a general survey of the model forecasts has been made focusing mainly on the medium range forecasts and exploiting the HR and mostly the EPS system. Main characteristics of the weather regimes forecasts for a choice of more remarkable periods have been described and a verification of their quality or usefulness has been reported.

**September 2011:**
*Forecast:* a temporal transition between a perturbed zonal flow (NAO+) and a more blocked regime over Western Europe, between the 13th and the 17th of September, forecasted about seven days in advance.
*Verification:* the spread and the variability of the successive EPS runs are too large to forecast this transition with a high confidence. The analysis indicates that this transition is not clear cut and not widespread over Western Europe.

**October 2011:**
*Forecast*: persistence of blocking regime over Northern and Central Europe with a High developing and migrating from Great Britain to Scandinavia and Central Europe, between the 20th and the 25th of October.
*Verification*: the persistence of this weather regime is well forecasted for this period.

**November 2011:**
*Forecast:* persistence of stable conditions associated to a blocking regime over Western or Central Europe.
*Verification:* this weather regime has been well forecasted with a decay of the blocking to a NAO regime (mostly NAO+) at the end of the month

**December 2011:**
*Forecast:* persistence of a rapid zonal flow over Western and Northern Europe (NAO+ and NAO- regimes) with a succession of frontal waves producing regularly strong winds, significant precipitations and mild weather (no frost).
*Verification:* this weather regime(s) have been generally well forecasted up the one or two weeks in advance.

**January & February 2012:**
*Forecast:* a blocking regime developing from near Atlantic ocean to Northern Europe and Russia, from the 28th of January to the 12th of February

*Verification:* useful forecasts for the cold spell at least forecasted from the 20th of January and also for its duration. However the surface temperatures have been overestimated to a certain extent by the model with too high values as well for minima and maxima 2m temperatures.

**March 2012:**
*Forecast:* consistent forecasts for different blocking regimes like:
- a blocking centred over Great Britain, from the 10th to the 16th of March
- a blocking centred over Great Britain moving to the south of Scandinavia, from the 20th to about the 28th of March

*Verification:* the onset of blockings is well forecasted at least 5 to 7 days in advance. The decay of blocking or its transition to another regime is a little bit less clear.

**May 2012:**
*Forecast:* consistent forecasts for a blocking onset over northern Europe (Scandinavian High pattern) more or less seven days in advance from the run of the 17th of May for the period of the 24th to about the end of May.
*Verification:* the onset of the blocking regime appears more clearly than its decay during the last days of May.

**July 2012:**
*Forecast:* consistent forecasts for the first three weeks characterized by a variable and rather fresh weather over Western Europe (dominant NAO+ and NAO- regimes) and for the last week (roughly from the 21th to the 28th of July) where a blocking regime was forecasted from the 14th of July.
For the first three weeks medium range forecasts are mainly based on the following EPS products; the absence of blocking clusters over Europe whatever the number of clusters, the predominant south westerly flow and no indication of high temperatures and for the last week; a dominant blocking regime over Europe, a drier period, a weaker flow with mainly variable directions or north easterly ones, higher temperatures but no heat wave hints
*Verification:* the dominant regime and their periods have been forecasted with a high degree of reliability

**August 2012:**
*Forecast:* an heat wave forecasted for the verifying period of the 17th to the 19th of August is illustrated in the Figures 11 to 22.

From the EPS run of the 11th of August:
- no clear indication of a blocking regime but for a majority of clusters a zonal regime (mostly NAO-) over Europe. Both a predominant Low in the vicinity of Great Britain or near Ocean and also a High ridge developing from Spain to southern France and Alpine areas are indicated. Furthermore no indication of a dry and very warm period over Western Europe

From the EPS run of the13th of August:
- a first indication of a blocking regime developing over Western Europe is given for the end the week (so switching from NAO- to blocking in the clustering and probably linked to (slightly) more developed ridge over France). For the same run a consistent indication of a heat wave is given by the EFI for the next week-end (18th and 19th of August)

From the EPS runs of the 14th to the 16th of August:

- a consistent indication of a blocking regime is given with (very) mild TN and warm TX

*Verification:* this heat wave has been reasonably well predicted 5 or 6 days in advance. Its intensity has been slightly underestimated over Western Europe up to a few days before the event; TN were reasonably good but TX have been underestimated over a large part of Western Europe looking at a too low median value and a too small spread.

Fig. 11 to 15: EPS-grams for Uccle (Brussels) respectively for the runs of the 14th, 15th, 16th, 17th and 18th of August 2012 at 12h00 u.t.c.

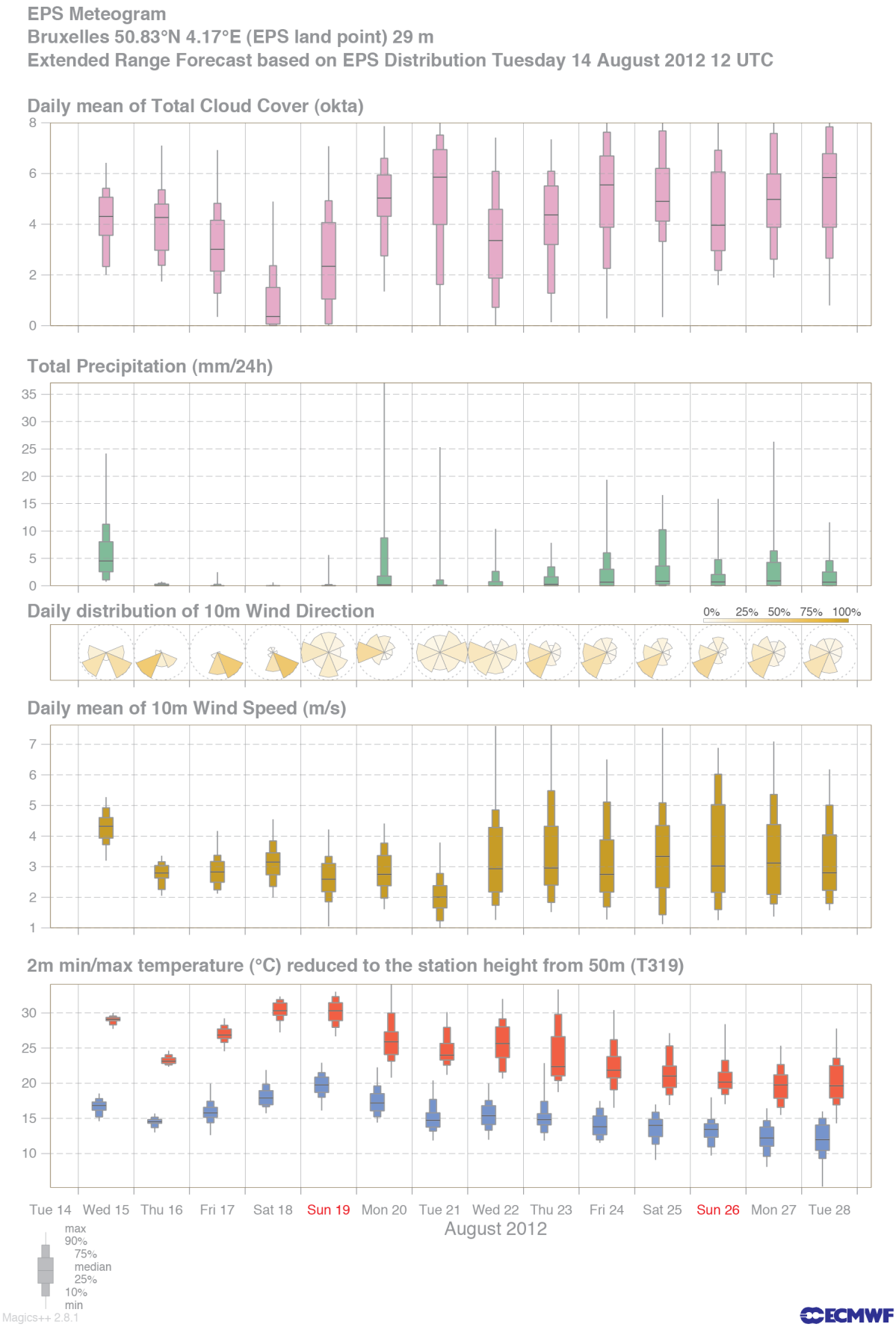


**Figure 11** run date - 14/8/2012 at 12h00 u.t.c.

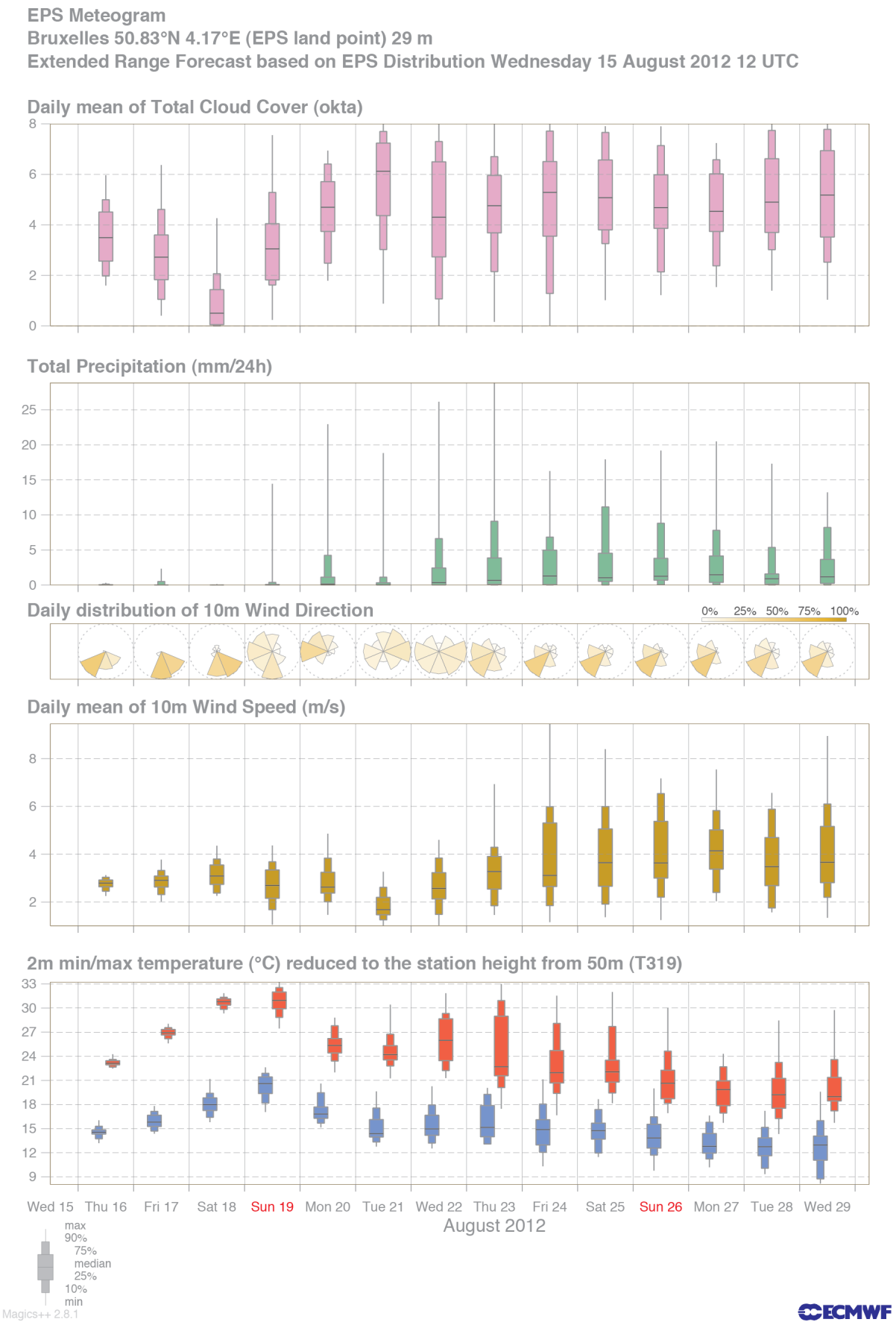


**Figure 12** run date - 15/8/2012 at 12h00 u.t.c.

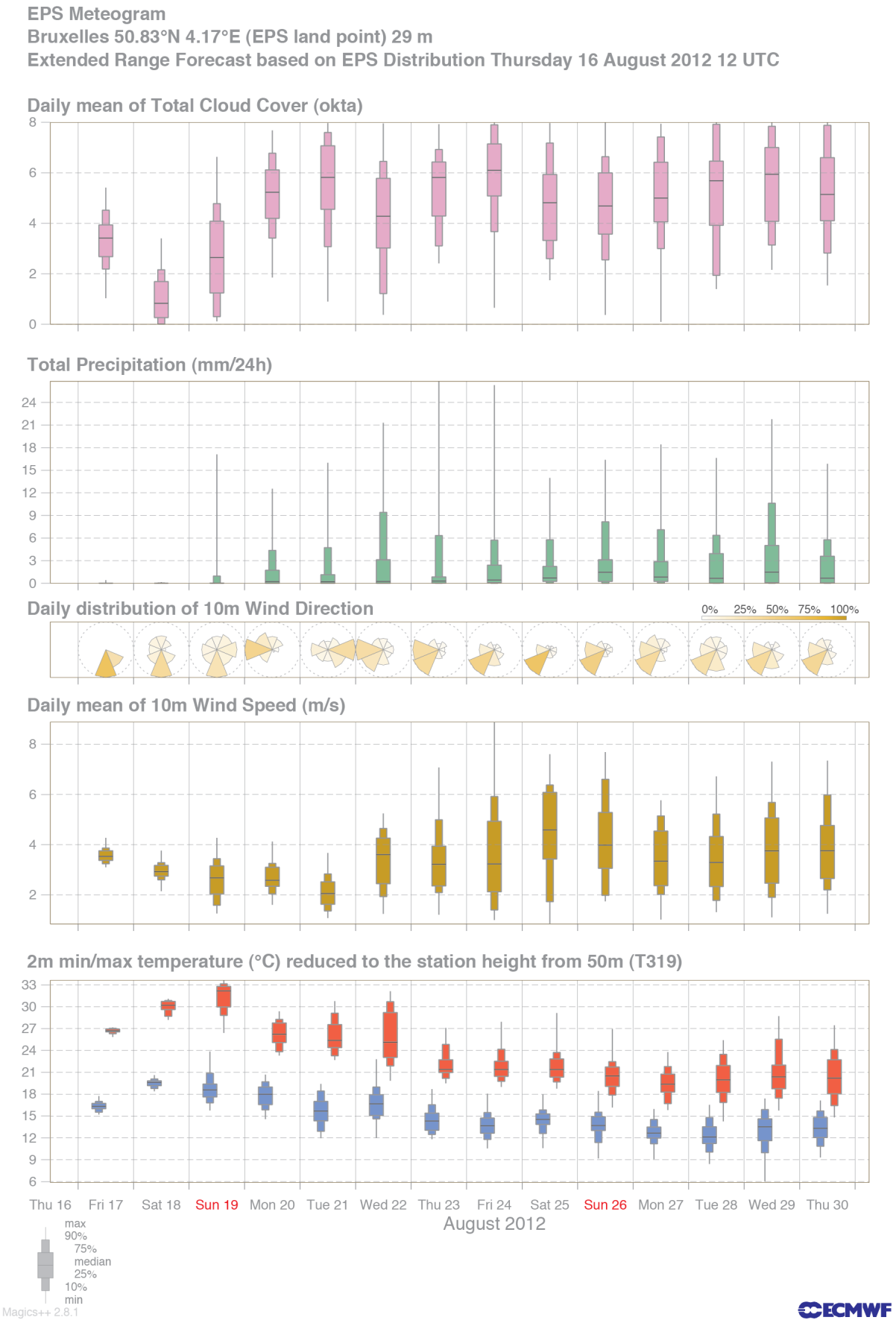


**Figure 13** run date - 16/8/2012 at 12h00 u.t.c.

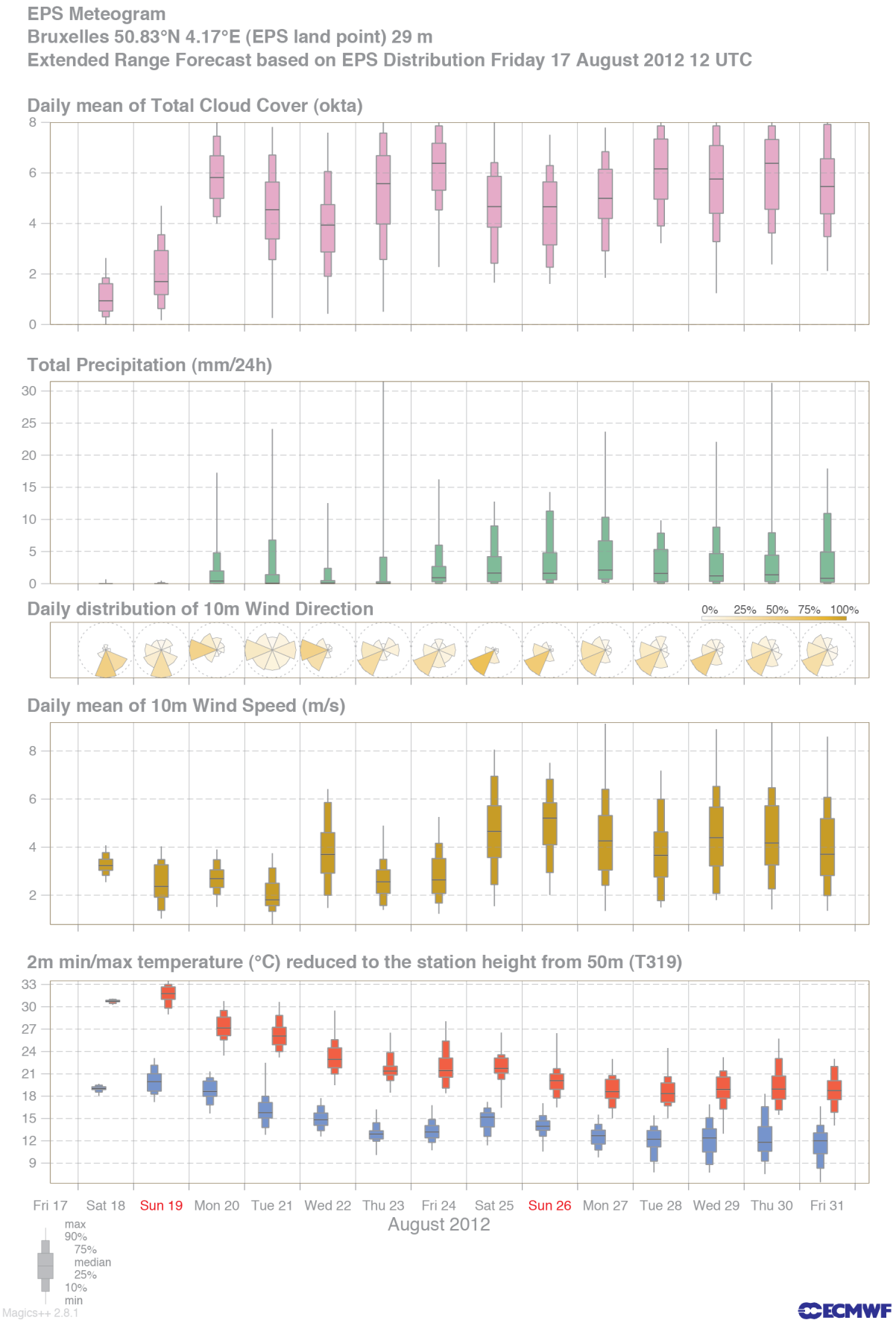


**Figure 14** run date – 17/8/2012 at 12h00 u.t.c.

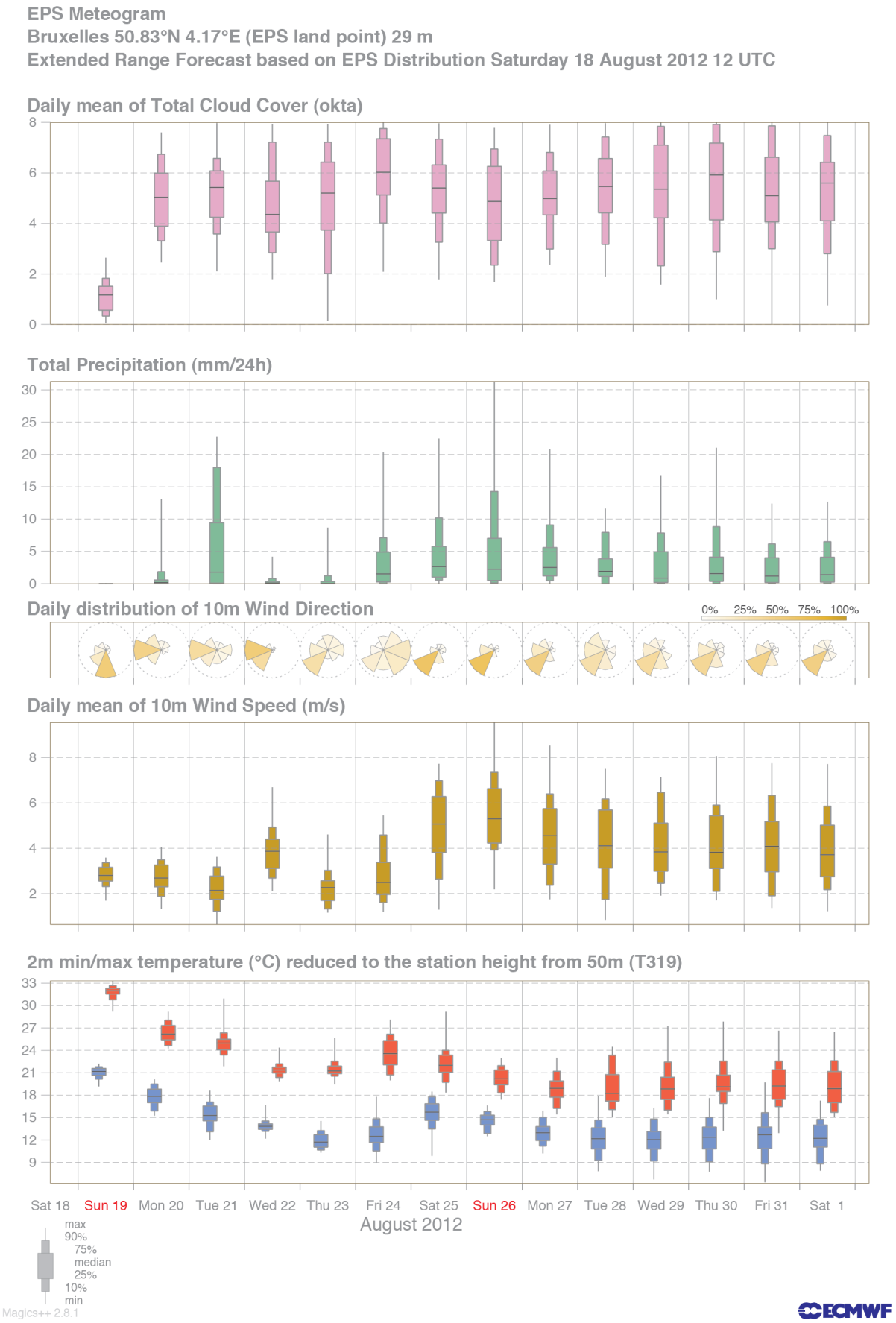


**Figure 15** run date 18/8/2012 at 12h00 u.t.c.

Fig. 16 Extreme Forecast Index (EFI) computed for 2m Temperature over Europe, respectively from the EPS runs of the 13th and the 14th of August at 12h00 u.t.c. and verifying respectively the 18th and the 19th of August 2012

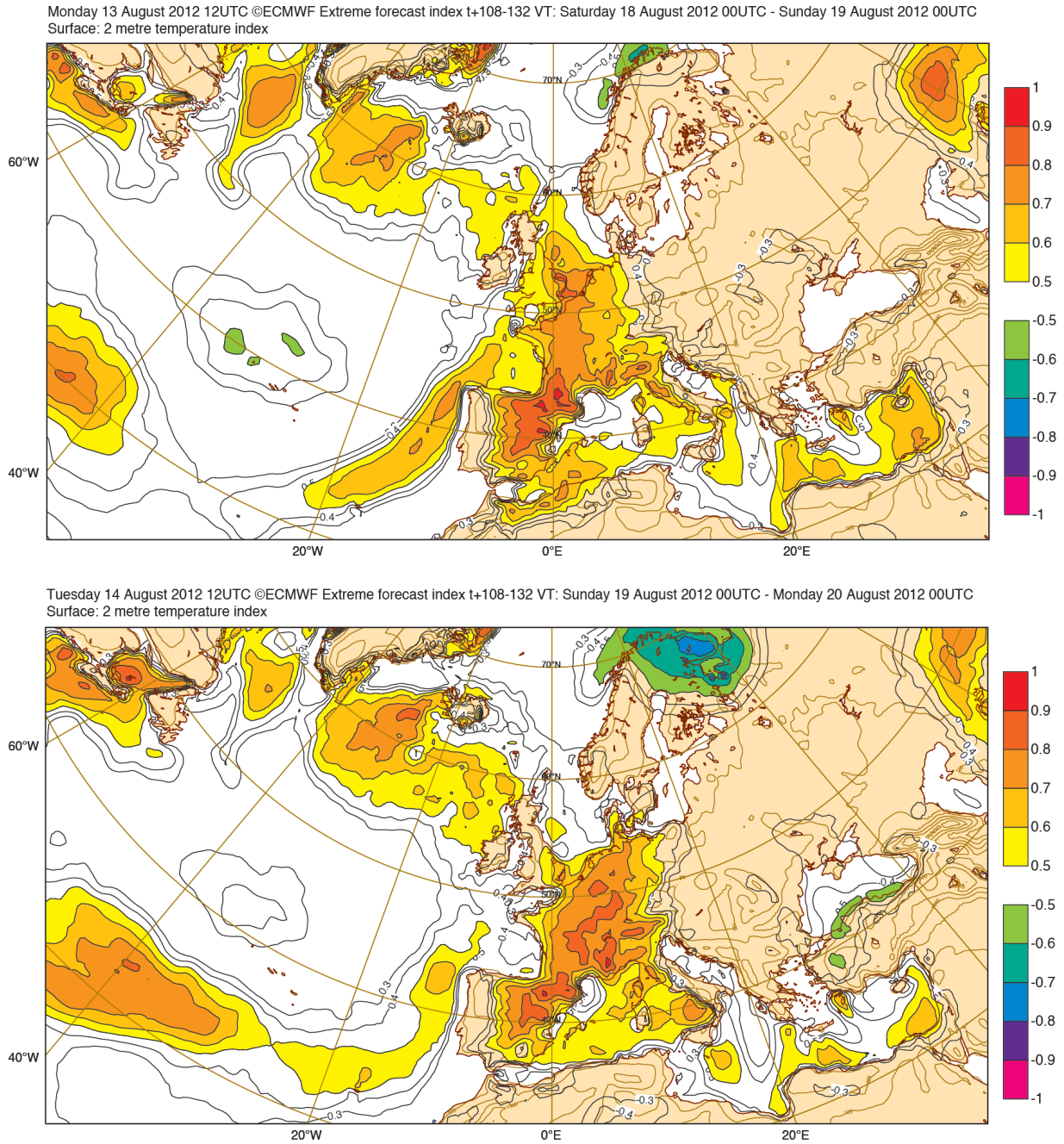


**Figure 16** EFI index forecasts for 2m temperature over near Ocean and Europe, respectively for the 18th and the 19th of August

Fig. 17 EFI and Shift Of Tail (SOT) computed for 2m maxima temperature (TX ) over Europe, from the EPS runs of the 16th of August and verifying respectively the 18th and the 19th of August 2012

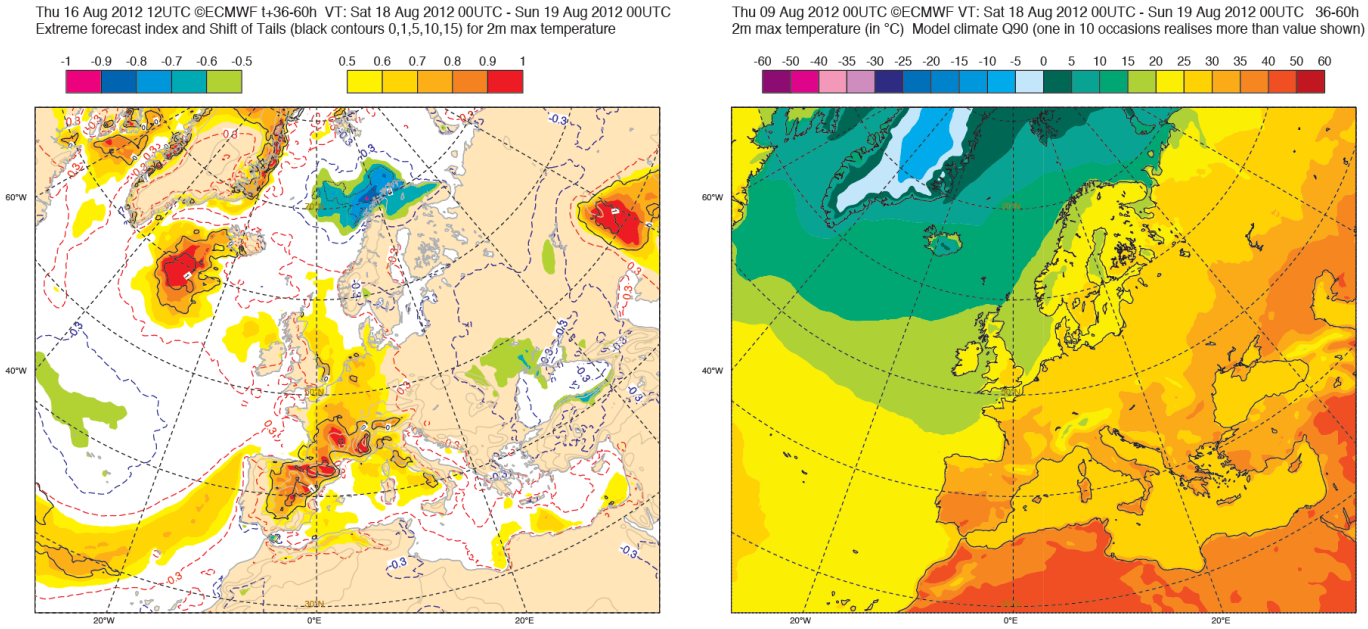


**Figure 17** EFI + SOT index forecasts for the 2m maxima temperature over near ocean and Europe, respectively for the 18th and the 19th of August

Fig. 18 to 22: EPS clusters for successive EPS runs at 12h00 u.t.c. – respectively from the 11th to the 15th of August and verifying during the heat wave period between the 17th and the 19th of August 2012

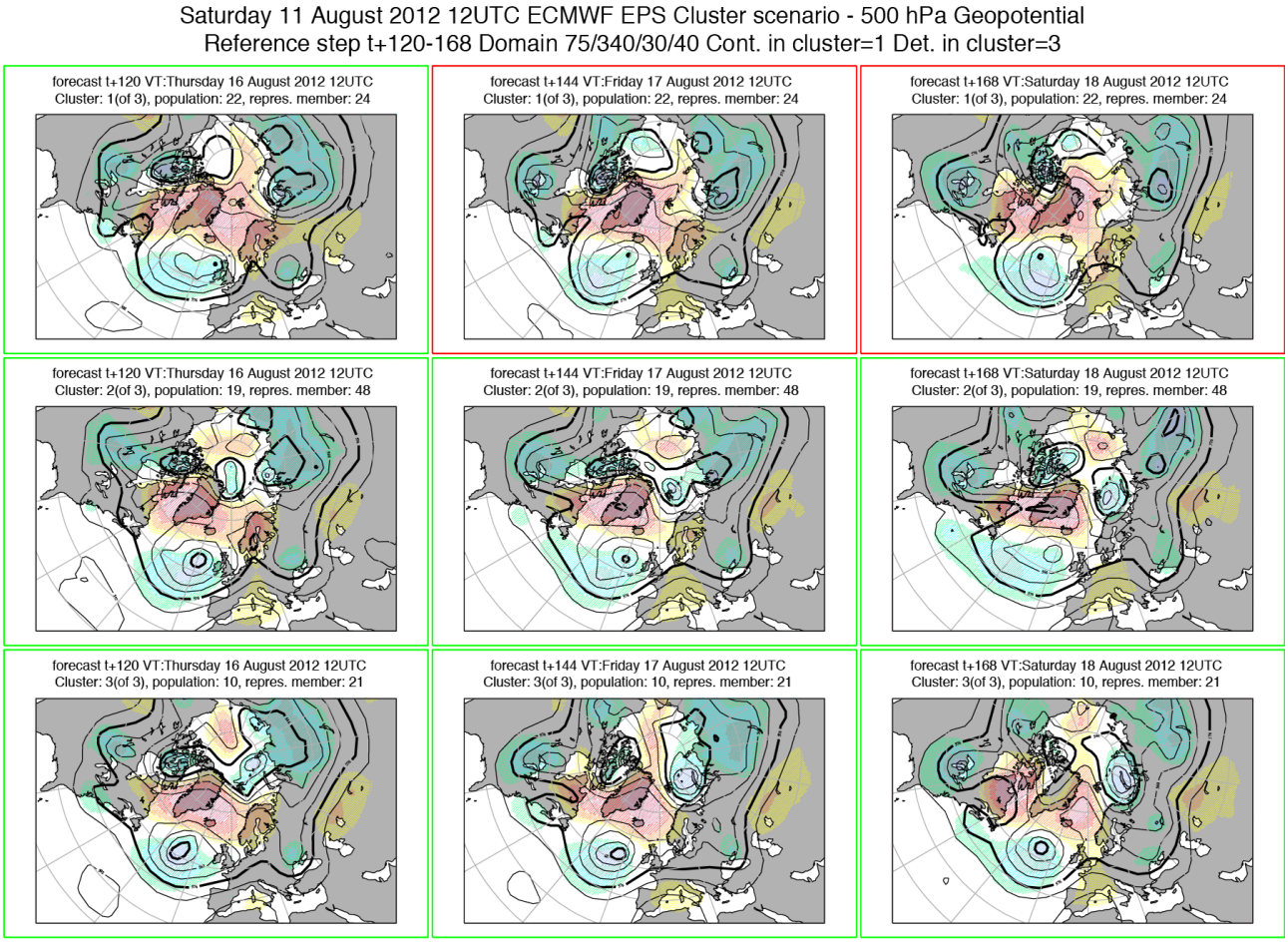


**Figure 18** EPS clustering - run of the 11th of August - verifying for 16th to 18th

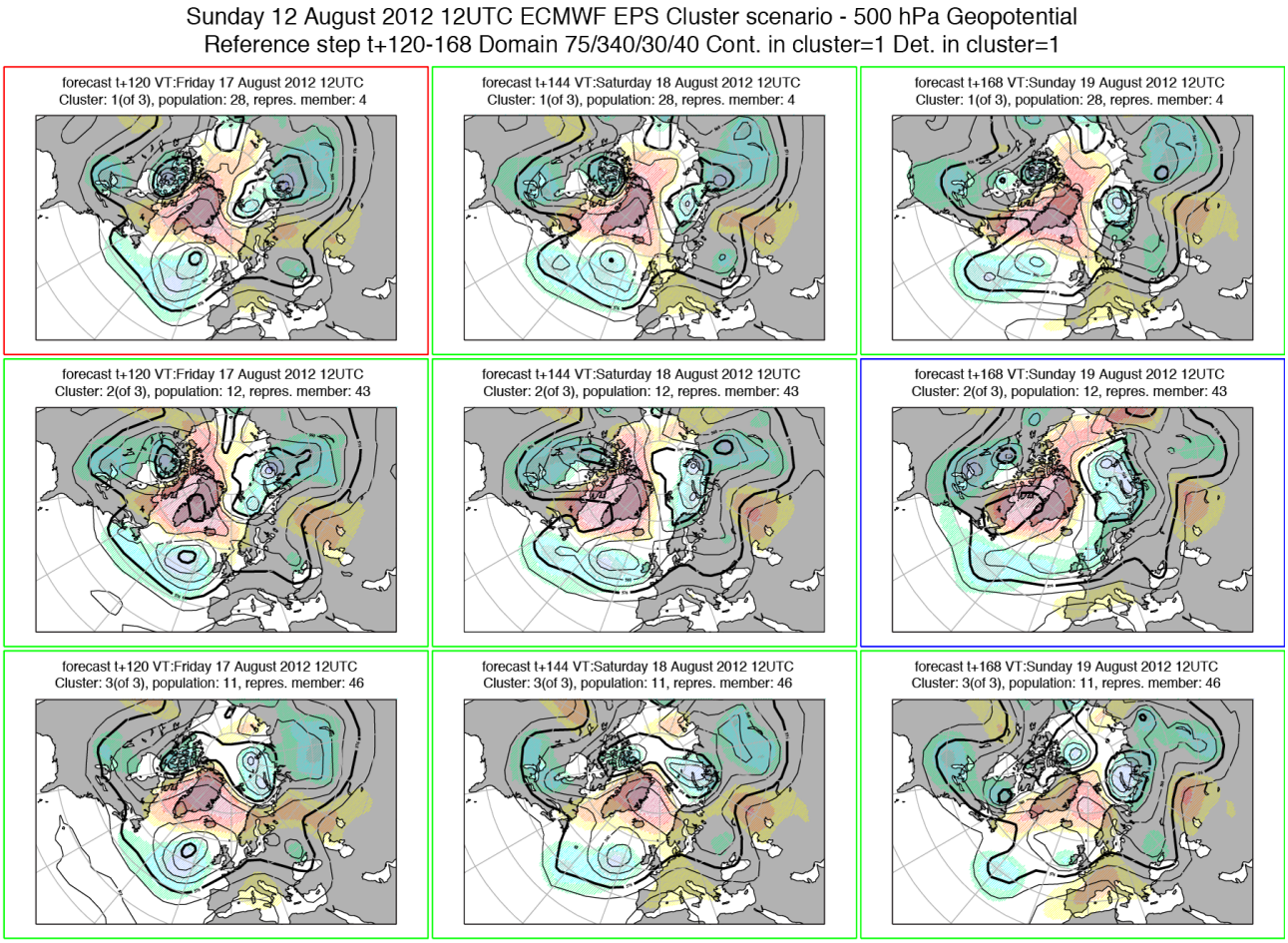


**Figure 19** EPS clustering - run of the 12th of August - verifying for 17th to 19th

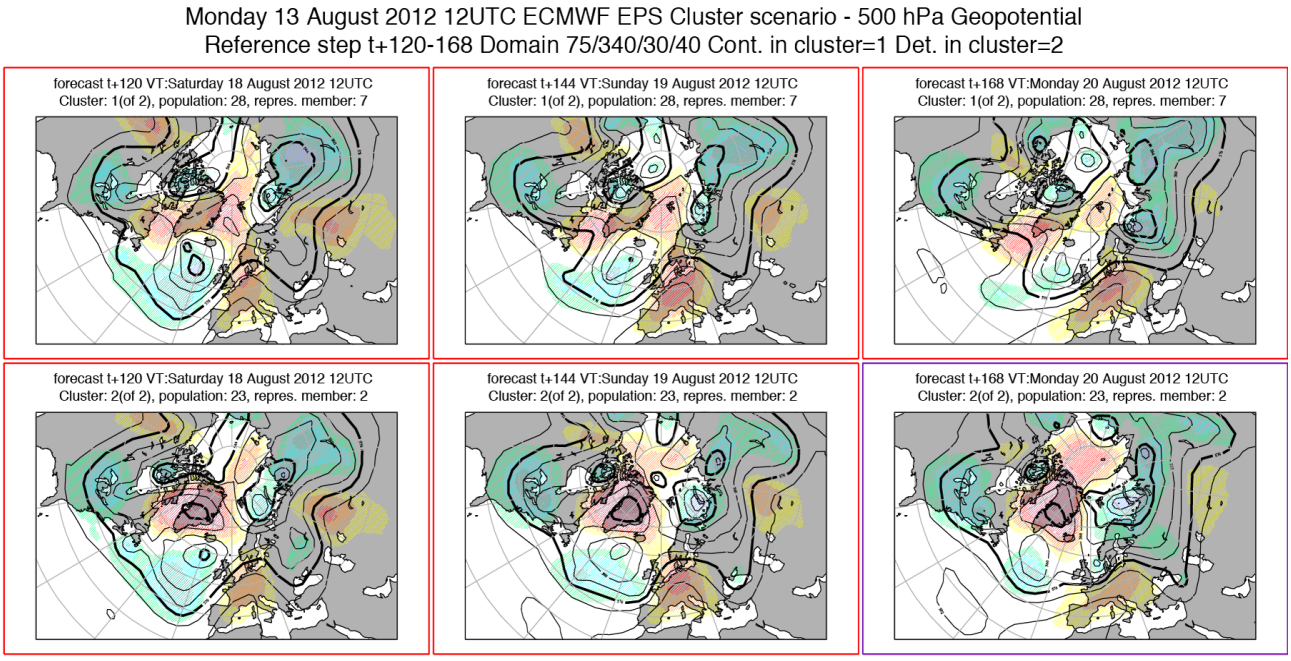


**Figure 20** EPS clustering - run of the 13th of August - verifying for 18th to 20th

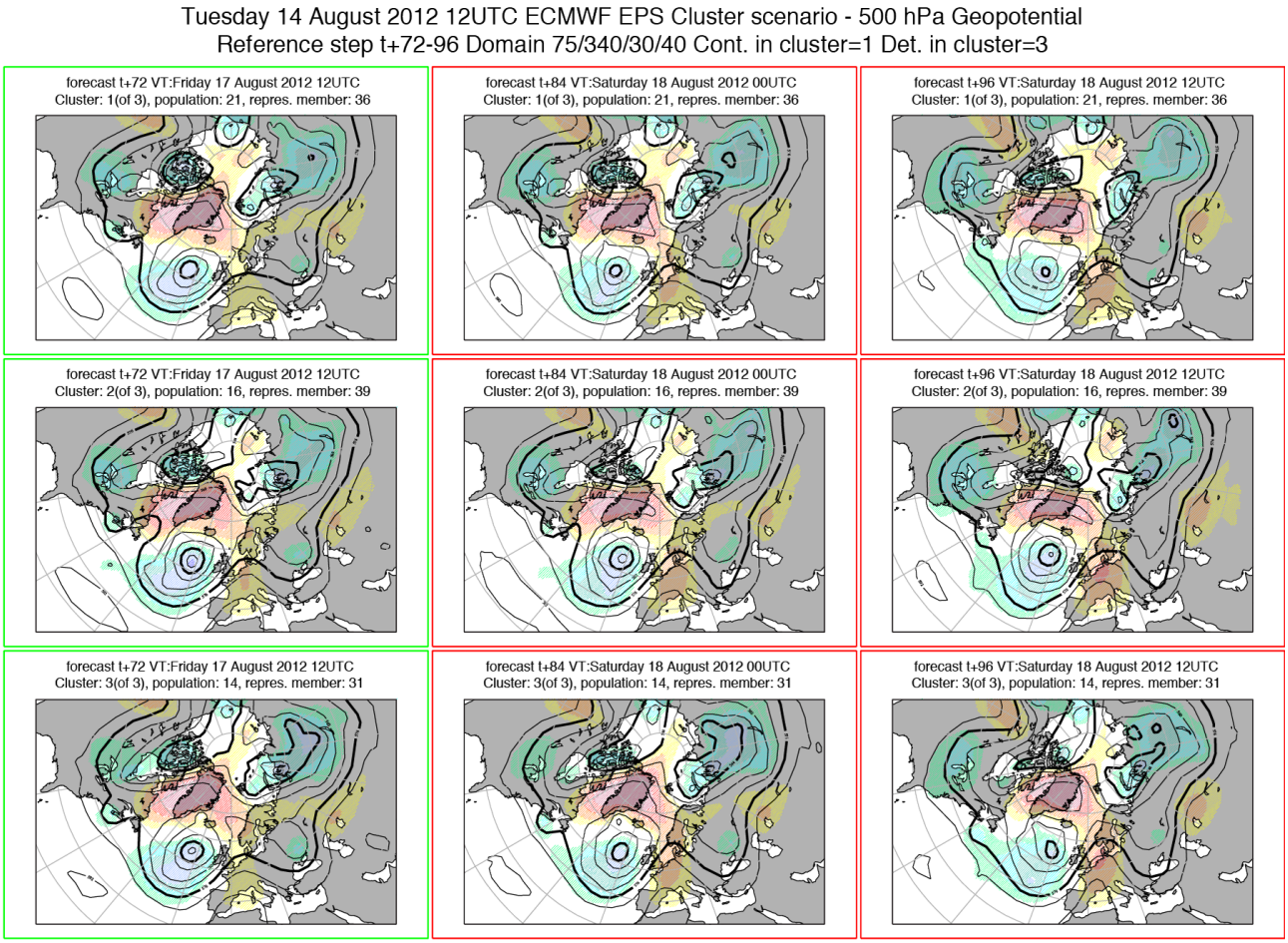


**Figure 21** EPS clustering - run of the 14th of August - verifying for 17th to 18th

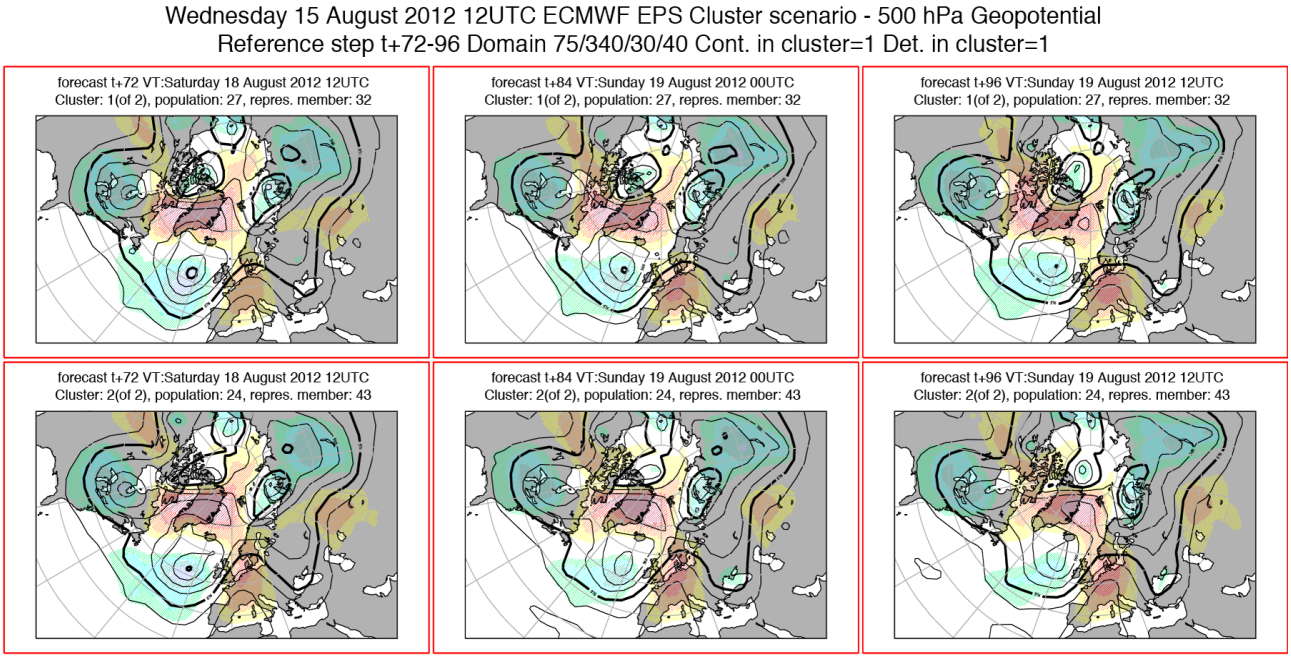


**Figure 22** EPS clustering - run of the 15th of August - verifying for 18th to 19th

## 4. References to relevant publications

**Van Schaeybroeck, B.,** 2012: Towards post-processing ensemble forecasts based on hindcasts. *ECMWF Forecast Products Users' Meeting*, Reading (UK), 20-22 June 2012.