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Verification of Operational Weather Prediction Models June to August 2024

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Kvernesfjorden. Photo: Lene Østvand

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More information...

Verification results are also available on internal web pages

- https://metcoop-comm.smhi.se/ and https://metcoop.smhi.se/ - MetCoOp Web Tools - including verification and observation monitoring
- https://harp.smhi.se/ - MetCoOp verification visualized with harp
- http://verif/vmap/ - timeseries and windroses - on Google map

About this report

This verification report indicates the quality of the main operational weather forecasting models used at the Norwegian Meteorological Institute for the period indicated. Another purpose of the verification report series is to provide a stable source of information suitable for monitoring longer trends in forecasting quality for interested readers. The report complements the verification and monitoring performed on individual models. Each model is monitored and developed according to the scientific method, where changes are only introduced when they can document a better likely prediction skill. Such documentation is available as research papers, consortium news, and presentations at team-, syndicate- and consortium-meetings. The skill of the forecasting service in severe weather situations is also documented with special emphasis on forecast failures, in order to learn from them and improve the system.

The report includes verification results for 3 Numerical Weather Prediction (NWP) models; MetCoOp ensemble prediction system (MEPS) covering Norway, Sweden, Finland, Denmark and the Baltic states, AROME-Arctic covering Svalbard, Novaja Semlja, Frans Josefs land and the Northern part of Scandinavia and the global ECMWF. The models are further described in the Models section. The variables verified are mean sea level pressure, temperature, wind speed and precipitation. The results are grouped by variable. A short summary of the results and cases studies by forecasters are also included.

Verification results are shown for different groups of stations: Norwegian, Svalbard and North Scandinavian. For temperature there are additional groups with Norwegian coastal and Norwegian inland stations, for wind speed Norwegian coastal and Norwegian mountainous stations, and for precipitation coastal stations, stations more than 500 m above sea level, and stations with daily mean precipitation > 4 mm. For MEPSctrl statistics at the observing sites are also visualized on maps with model climatology. The text size of the statistics increases with the value. Time series with observations and available models are included for selected stations. Post processed variables are compared with MEPSctrl.

Models

The following Numerical Weather Prediction (NWP) models are verified in this report. The verification measures are plotted for each model with the colors indicated in the table below.

ECMWF	Global model (IFS) at the European Centre for Medium-Range Weather Forecasts. From 26 January 2010 horizontal resolution approximately 16×16 km^2. From 8 March 2016 cycle 41r2 with horizontal resolution about 9 km. ECMWF is available about 5 hours later than models run at MET.
MetCoOp ensemble prediction system (MEPSctrl)	MEPS has 30 lagged ensemble members, constructed from 5 members updated hourly and run up to 66 hours. Only member 0, the control, is verified in this report. MEPS is based on HARMONIE with AROME physics and non-hydrostatic dynamics, horizontal resolution defined by a 2.5×2.5 km^2 grid. Experimental with cycle 37h1.1 from November 2012, on Yr since 1 October 2013, operational since March 2014, cycle 38h1.2 from December 2014, cycle 40h1.1 since November 2016 and cycle 43h2.1 from 23 March 2021. MEPS is run in cooperation with Swedish Meteorological and Hydrological Institute (SMHI), Finnish Meteorological Institute (FMI) and Estonian Environment Agency (ESTEA).
AROME-Arctic (AA25)	HARMONIE with AROME physics, horizontal resolution defined by a 2.5×2.5 km^2 grid. Experimental with cycle 38h1.2 from 15 October 2015, on Yr from 14 December 2016, cycle 40h1.1 since June 2017, cycle 43h2.1 since 5 May 2021.

Analysis and lead times of forecasts are denoted by e.g. 00+30 UTC which indicates forecast generated at 00 UTC and valid 30 hours later.

A change log for HARMONIE AROME is available on internal webpages
https://metcoop.smhi.se/dokuwiki/nwp/metcoop/changelog/start.

Post processed forecasts

Most of the raw NWP model data are post processed before being published on Yr.

The met nordic temperature forecasts, YrPP in the plots, are post-processed forecasts based on the latest MEPS control run. The MEPS temperature forecasts are first downscaled to 1 km resolution using the model lapse rate in a neighbourhood. The forecasts are then bias corrected using a fine scale 1 km temperature analysis as reference. The temperature analysis is based on multiple data sources using both conventional and citizen observations.

The MEPS 10 m wind speed forecast is post-processed by downscaling to 1 km resolution to better represent local topography, and called YrPP.

YrPP is plotted with the color below.

The HARMONIE system

HARMONIE is the acronym for HIRLAM's meso-scale forecast system (Hirlam Aladin Regional/Meso-scale Operational NWP In Europe). For documentation see
- *The HARMONIE-AROME Model Configuration in the ALADIN-HIRLAM NWP System* by Bengtsson et al. 2017, available at https://doi.org/10.1175/MWR-D-16-0417.1
- *AROME-MetCoOp: A Nordic Convective-Scale Operational Weather Prediction Model* by Müller et al. 2017, available at https://doi.org/10.1175/WAF-D-16-0099.1

More documentation is also available on hirlam.github.io/HarmonieSystemDocumentation/dev/, www.accord-nwp.org and www.cnrm.meteo.fr/gmapdoc/.

This section presents some of the main components and setups that are used at MET.

AROME physics

AROME (Applications of Research to Operations at MEsoscale) is targeted for horizontal resolution 2.5 km or finer. It uses physical parameterizations based on the French academia model Meso-NH and the external surface model SURFEX. AROME has been operational at Météo-France since 18 December 2008 with a horizontal resolution of 2.5 km and 65 vertical layers, and from April 2015 1.3 km and 90 vertical layers.

SURFEX as surface model

SURFEX (Surface externalisée) is developed at Météo-France and academia for offline experiments and introduced in NWP models to ensure consistent treatment of processes related to surface. Météo-France uses SURFEX in all their configurations. Surface modelling and assimilation benefit from the possibility of running offline experiments. SURFEX is also used for offline applications in e.g. hydrology, vegetation monitoring and snow avalanche forecasts.

SURFEX includes routines to simulate the exchange of energy and water between the atmosphere and 4 surface types (tiles); land, sea (ocean), lake (inland water) and town. The land or nature tile can be divided further into 12 vegetation types (patches). ISBA (Interaction between Soil Biosphere and Atmosphere) is used for modelling the land surface processes. There are 3 ISBA options; 2- and 3-layer force restore and a diffusive approach, where the first one is used in HIRLAM. Towns may be treated by a separate TEB (Town Energy Balance) module. Seas and lakes are also treated separately. The lake model, FLAKE (Freshwater LAKE), has recently been introduced in SURFEX. A global ECOCLIMAP database which combines land cover maps and satellite information gives information about surface properties. The orography is taken from gtopo30.

SURFEX Scientific Documentation and *User's Guide* are available on http://www.cnrm.meteo.fr/surfex/

Data assimilation

NWP models are updated regularly using observations received in real-time from the global observing system. MEPS is updated each third hour; at 00, 03, 06, 09, 12, 15, 18 and 21 UTC.

Surface analysis

Surface analysis is performed by CANARI (Code d'Analyse Nécessaire à ARPEGE pour ses Rejets et son Initialisation) (Taillefer, 2002). The analysis method is Optimal Interpolation and only conventional synoptic observations are used. 2 meter temperature and relative humidity observations are used to update the surface and soil temperature and moisture.

The snow analysis is also performed with CANARI in analogy with the HIRLAM snow analysis. Snow depth observations are used to update Snow Water Equivalent. The snow fields are analysed only at 06 UTC as there are very few snow depth observations at 00, 03, 09, 12, 15, 18 and 21.

The Sea Surface Temperature (SST) and Sea Ice Concentration (SIC) is not analysed, but taken from the boundaries. ECMWF uses the OSTIA (Operational Sea Surface Temperature and Sea Ice Analysis) product, including SST from UK Met Office and SIC from MET. SST and SIC for the Baltic Sea have since 26 November 2015 been taken from ocean models run at SMHI; first HIROMB and since 26 April 2017 NEMO.

The surface temperature over sea ice was taken from the boundary model and remained unchanged through the forecast. A simple thermodynamical sea ice scheme (SICE) giving prognostic sea ice temperatures in 4 fixed layers was introduced 26 November 2015.

Upper air analysis

MEPS runs three dimensional variational (3D VAR) data assimilation using conventional observations from synop stations, ships, radiosondes and aircrafts and AMSU-A and AMSU-B/MHS data from polar orbiting NOAA and METOP satellites. GNSS were introduced 17 February 2015, radar reflectivities 16 June 2015, IASI 26 November 2015 and ASCAT 17 March 2016. Mode-S EHS, AMSU-A and MHS from METOP-C satellite were introduced June 2020, METOP-C IASI (deactivation of METOP-A IASI), June 2021, radar radial wind observations and German radars, June 2022.

Boundary fields

MEPS gets its boundary values (1-hourly) from the ECMWF model at approximately 9 km resolution, and has currently 65 vertical levels. None of the HARMONIE configurations at MET have applied digital filter initialization (DFI).

Verification measures

All model forecasts in this report are verified against observations by interpolating (linear) the grid based forecasts to the observational sites. As a consequence, it should be noted that it is the models' abilities to forecast the observations that is being quantifed and assessed. Thus, there is no attempt in this report to verify area averaged precipitation for example.

Verification is carried out both for raw and categorized forecasts. In the following, let $f_1, ..., f_n$ denote the forecasts and $o_1, ..., o_n$ the corresponding observations.

Forecasts of continuous variables

The verification statistics applied to continuous variables are defined in the table below.

Statistic	Acronym	Formula	Range	Optimal score
Mean Error	ME	$\frac{1}{n} \sum_{i=1}^{n}(f_i - o_i)$	$-\infty$ to ∞	0
Mean Absolute Error	MAE	$\frac{1}{n} \sum_{i=1}^{n} \mid f_i - o_i \mid$	0 to ∞	0
Standard Deviation of Error	SDE	$\left(\frac{1}{n} \sum_{i=1}^{n}(f_i - o_i - \mathrm{ME})^2 \right)^{1/2}$	0 to ∞	0
Root Mean Square Error	RMSE	$\left(\frac{1}{n} \sum_{i=1}^{n}(f_i - o_i)^2 \right)^{1/2}$	0 to ∞	0
Correlation	COR	$\frac{\frac{1}{n}\sum_{i=1}^{n}(f_i - \bar{f})(o_i - \bar{o})}{\mathrm{SD}(f)\mathrm{SD}(o)}$	-1 to 1	1

In the formula for COR the following definitions are used

$$\bar{f} = \frac{1}{n}\sum_{i=1}^{n} f_i, \qquad \bar{o} = \frac{1}{n}\sum_{i=1}^{n} o_i$$

$$\mathrm{SD}(f) = \Big(\frac{1}{n}\sum_{i=1}^{n}(f_i - \bar{f})^2\Big)^{1/2}, \qquad \mathrm{SD}(o) = \Big(\frac{1}{n}\sum_{i=1}^{n}(o_i - \bar{o})^2\Big)^{1/2}$$

for the means and standard deviations of the forecasts and observations.

For wind direction the probability density function (PDF) is used to show the distribution of observed and forecast wind directions. The PDF used here is a kernel density estimate, which is a smoothed version of the histogram.

Forecasts of categorical variables

All variables in this report are continuous in raw form, but it is possible to categorize them and verify these. For example, wind speed above a given threshold could be of interest which would result in two possible outcomes (yes and no). The verification is then completely summarized by a contingency table as the one shown below

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">event observed</td></tr>
<tr><td>yes</td><td>no</td></tr>
<tr><td rowspan="2">event forecasted</td><td>yes</td><td>a</td><td>b</td></tr>
<tr><td>no</td><td>c</td><td>d</td></tr>
</table>

Verification statistics for such forecasts are listed in the following table

Statistic	Acronym	Formula	Range	Optimal score
Hit rate	HR	$\frac{a}{a+c}$	0 to 1	1
False alarm rate	F	$\frac{b}{b+d}$	0 to 1	0
False alarm ratio	FAR	$\frac{b}{a+b}$	0 to 1	0
Equitable threat score	ETS	$\frac{a-ar}{a+b+c-ar}$	$-1/3$ to 1	1 (0 = no skill)
Hanssen-Kuipers skill score	KSS	HR - F	-1 to 1	1 (0 = no skill)
Heidke skill score	HSS	$\frac{(a+d)/n-ssf}{1-ssf}$	$-\infty$ to 1	1 (0 = no skill)

In the formula for ETS $ar = (a+b)(a+c)/n$.
In the formula for HSS the score for the standard forecast $ssf = [(a+b)(a+c)+(b+d)(c+d)]/n^2$.

Observations

All observations come from frost.met.no. Only synop stations are used. From June 1 2021, both the model wind speed and the post-processed wind speed are verified against mean wind observations, FF. The model wind gust is verified against the observed wind gust, FG. FF and FG are defined as follows:

- FF: Wind speed (10 meters above ground) - defined as the mean value for the last 10 minutes before the time of the observation.
- FG: Gust wind speed (10 m above ground) - defined as highest gust wind speed (3 second mean) the last 10 minutes before the time of the observation.

Summary of the results

Summarized statistics show that ECMWF in general forecasts sea level pressure better than MEPSctrl/AA25, but the errors are small for both.

Temperature is on average better forecast by MEPSctrl/AA25 than ECMWF. ECMWF underestimates the temperature for the different groups of stations, and while MEPSctrl also underestimates the temperature, it is a very small underestimation. AA25 has a very small underestimation of temperature at the North Scandinavian stations, similar to MEPSctrl, while the negative mean error it has for the Svalbard stations is similar to that of the ECMWF model. Still, the errors are small, indicating that the timing of the temperature changes is generally good. The temperature forecast is further improved by post processing, particularly for the shortest lead times. The improvement is larger for inland stations than coastal stations, which have less variation in temperature and smaller errors than inland stations for both MEPSctrl and post processed forecasts.

For wind speed and precipitation, a larger number of verification scores is used to assess model quality, including threshold statistics.

Wind speed is challenging to evaluate. MEPSctrl performs better than ECMWF over land, and particularly in the mountains, where ECMWF underestimates the speed considerably as seen in the monthly mean error and mean absolute error. AA25 performs considerably better than ECMWF for the Svalbard stations. The threshold scores indicate that wind speed is better forecast for lower than for higher wind speeds for all models. The post-processing of wind speed shows a small effect in the mean error, while the other scores show almost identical results for MEPSctrl and YrPP.

Precipitation also shows varying results, depending on the amount and location. ECMWF has on average more precipitation than MEPSctrl which this summer had mean errors very close to (and above) 0. Both have more errors for both very small and very high amounts, than for precipitation in the mid range.

For temperature and wind, the monthly scores for the last three years show that the models generally perform better during summer months than during winter. A possible cause is that storm activity is challenging to predict accurately, and that there are often more storms with high wind speeds during fall and winter than during summer. Precipitation does not have clear seasonal patterns. Convective cases that are challenging to predict may occur with different frequency for different months and years. A challenge with verification of precipitation that occurs during winter is undercatchment of observed snow, especially in coastal areas. It is suspected that the models are too dry here, but the undercatchment leads to cases where the observations give an impression that there is better fit in the models with regards to precipitation than is actually the case. AA25 and MEPSctrl show very similar results, which is expected since both are HARMONIE with AROME physics and a horizontal resolution defined by a 2.5×2.5 km^2 grid.

Case studies by forecasters

Case 1. Missing clouds

Missing cloud cover is a recurring complaint from yr.no's users, especially during summer. A sky full of clouds is of course disappointing when you are expecting sunny and cloud free conditions. This was the case for a frustrated man from the southern coast of Norway calling in to one of our meteorologists on the 30th of July.

The cloud cover forecast found on yr.no for lead times up to 66 hours is based on the MEPS model, which on this day forecast more or less no clouds in the area circled in figure 1. It seems that in this case the ECMWF model is able to forecast the lower clouds under the subsidence inversion better than MEPS at the coast of the eastern part of southern Norway. Both the model fields (figure 2) and the prognostic sounding from Lyngør fyr (figure 3) shows ECMWF having more clouds in the forecast than MEPS.

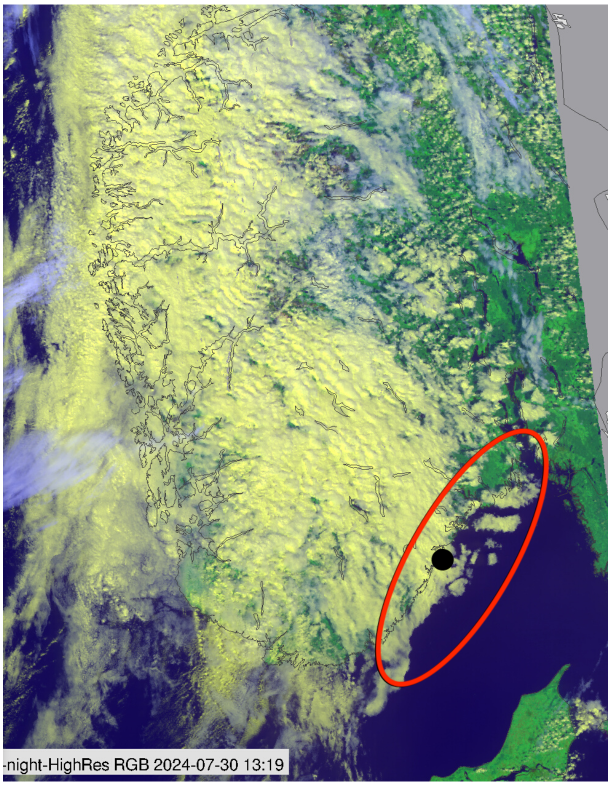


Figure 1: Satellite image from 13.19 UTC July 30th. The red ellipse marks the area of missing clouds in the model and the black dot marks the position of Lyngør fyr.

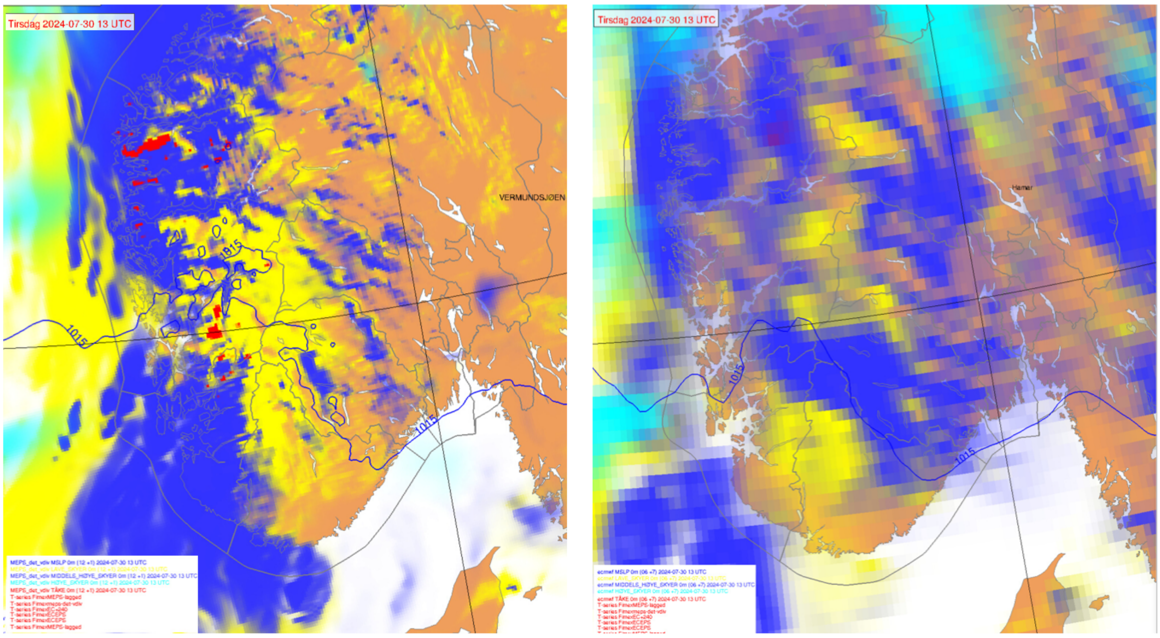


Figure 2: Cloud cover from MEPS (left) and ECMWF (right) at 13.00 UTC July 30th (yellow = low clouds, dark blue = mid range clouds, light blue = high clouds).

MEPS does not seem to capture the humidity and temperature under 700 hPa as well as ECMWF, which has a smaller dew point depression in the heights where the clouds occur. The cloud top temperature above Lyngør fyr at 12.00 UTC was around +1°C (found from satellite imagery), at around 10,000 ft (based on the prognostic soundings in figure 3). ECMWF clearly has a more prominent indication of a cloud layer at this height than MEPS (dew point temperatures of around -2°C for EC and -5°C for MEPS).

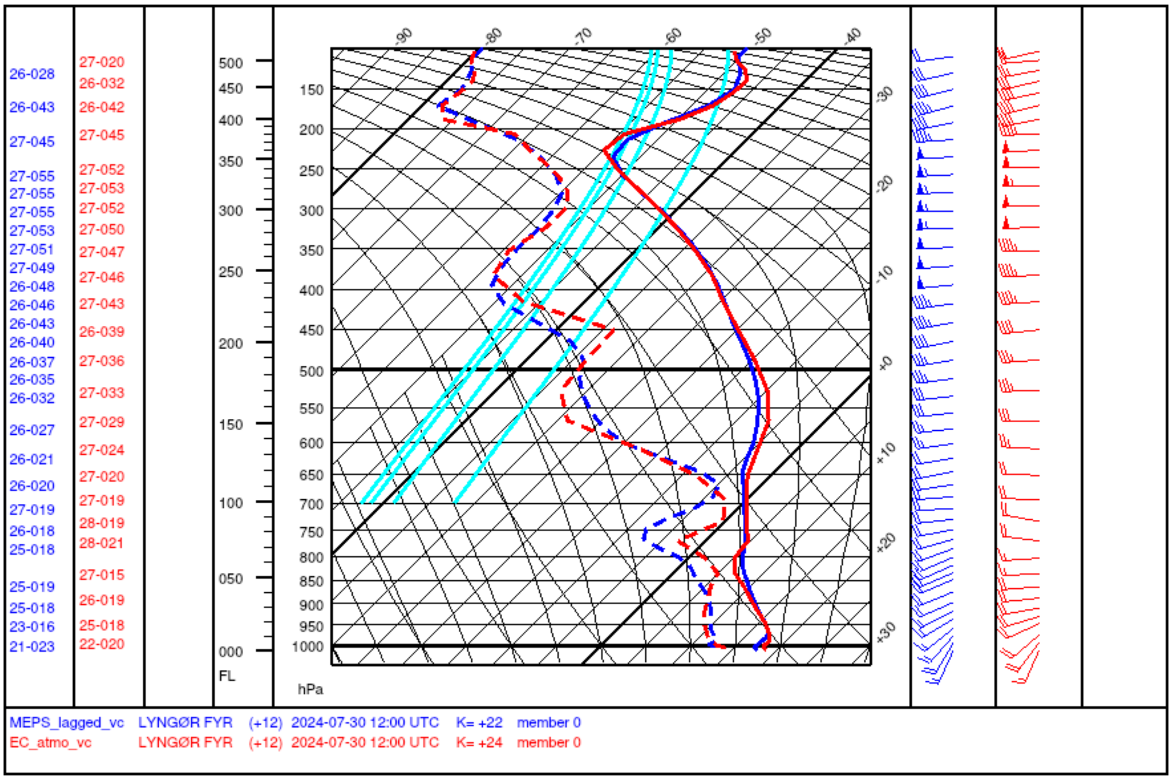


Figure 3: Prognostic sounding from Lyngør fyr at 12.00 UTC July 30th. The blue graph shows the sounding from MEPS and the red one shows ECMWF's sounding.

Case 2. Missing precipitation and thunderstorms

This case was captured by an aviation meteorologist on night shift duty in Bergen on the 24th of August. One of the tasks that night was making forecasts for some of the Norwegian oil rigs in the North Sea. Early in the night there was a case of rain showers and thunderstorms being detected in the North Sea without the MEPS model forecasting it. The showers were, however, captured rather well with the ECMWF model. Figure 4 shows the situation at 00 UTC.

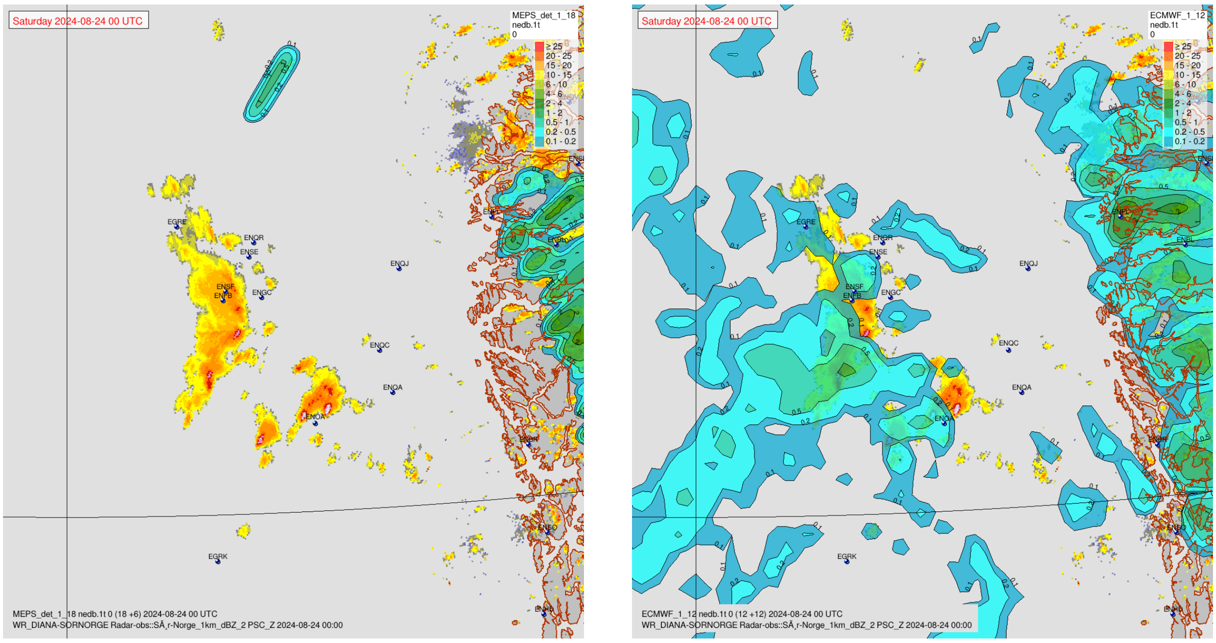


Figure 4: 1h model precipitation (blue/green) from MEPSctrl 18 UTC+06 (left) and ECMWF 12 UTC +12 (right) alongside the radar precipitation (yellow/orange) at 00 UTC August 24th in the North Sea. The small blue dots are Norwegian and British oil rigs.

This case shows, as often before, that MEPS is too dry under certain circumstances. It also showcases ECMWF's tendency to be too wet. When forecasting convective precipitation as in this case, the meteorologists use a wide variety of tools to make the best predictions. On shorter timescales, like a few hours, radar and satellite imagery is of great importance, but on longer timescales one has to rely more on the model.

As mentioned, this episode also came with thunderstorms which is of great importance for the helicopters transporting personnel to and from the oil rigs. These thunderstorms were not captured well by MEPS either, contributing to what already was a challenging situation for the forecaster on duty. Figure 5 shows that the thunder index from MEPS forecasts no potential for thunder in an area where there were many registered lightning strikes.

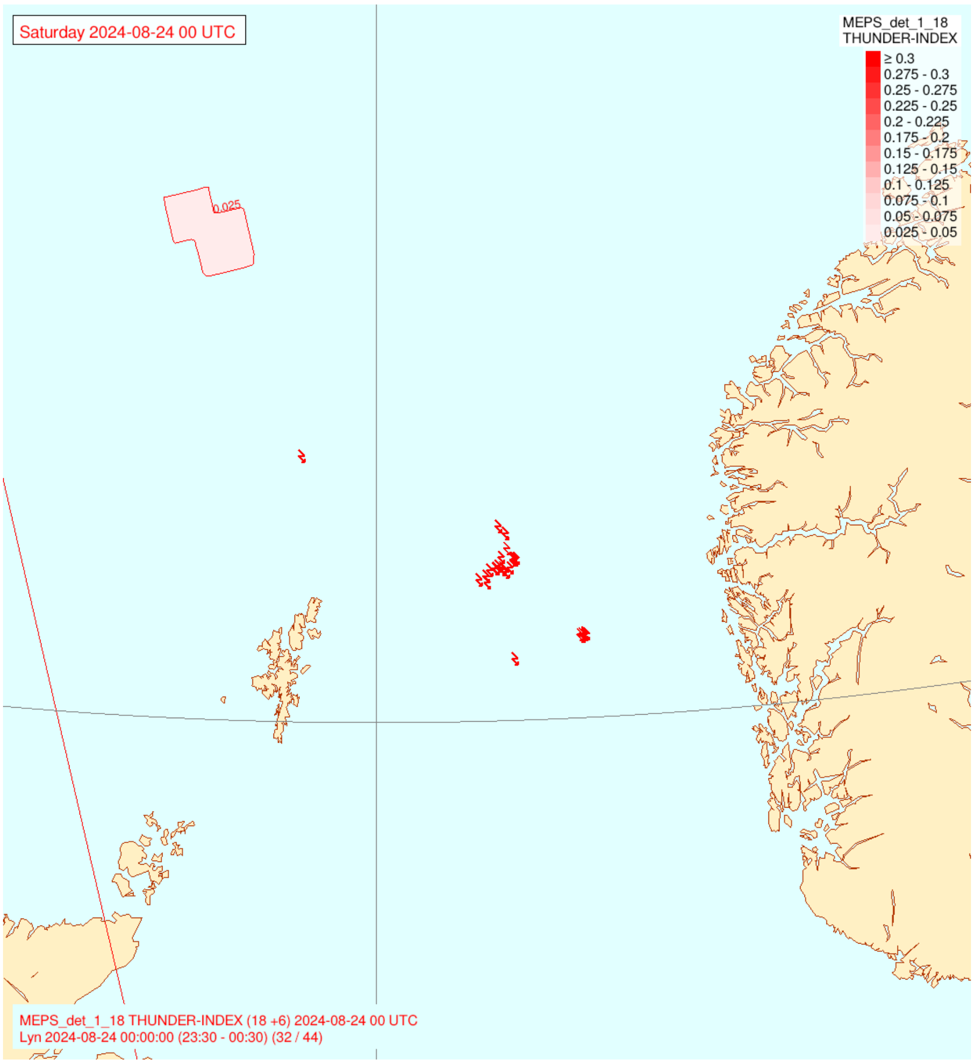


Figure 5: Registered lightning activity, marked by red thunder symbols, between 23.30 UTC August 23rd and 00.30 UTC August 24th and the forecast from the MEPS thunder index at 00 UTC August 24th in light red.

The reasoning for the severe underforecasting of both precipitation and lightning activity by MEPS in this case is likely complicated, but it seems clear that MEPS fails to capture the deep convection actually present in the North Sea around 00 UTC. The prognostic sounding from the oil rig Gullfaks C (figure 6) shows a clearly unstable atmosphere. There is reason to believe that MEPS here underestimates the potential of deep convection and therefore concludes that the cloud tops, and thus the convective potential, are much lower than the reality. Unfortunately, we have neither any actual soundings or prognostic ones from ECMWF to compare the one from MEPS to in this case.

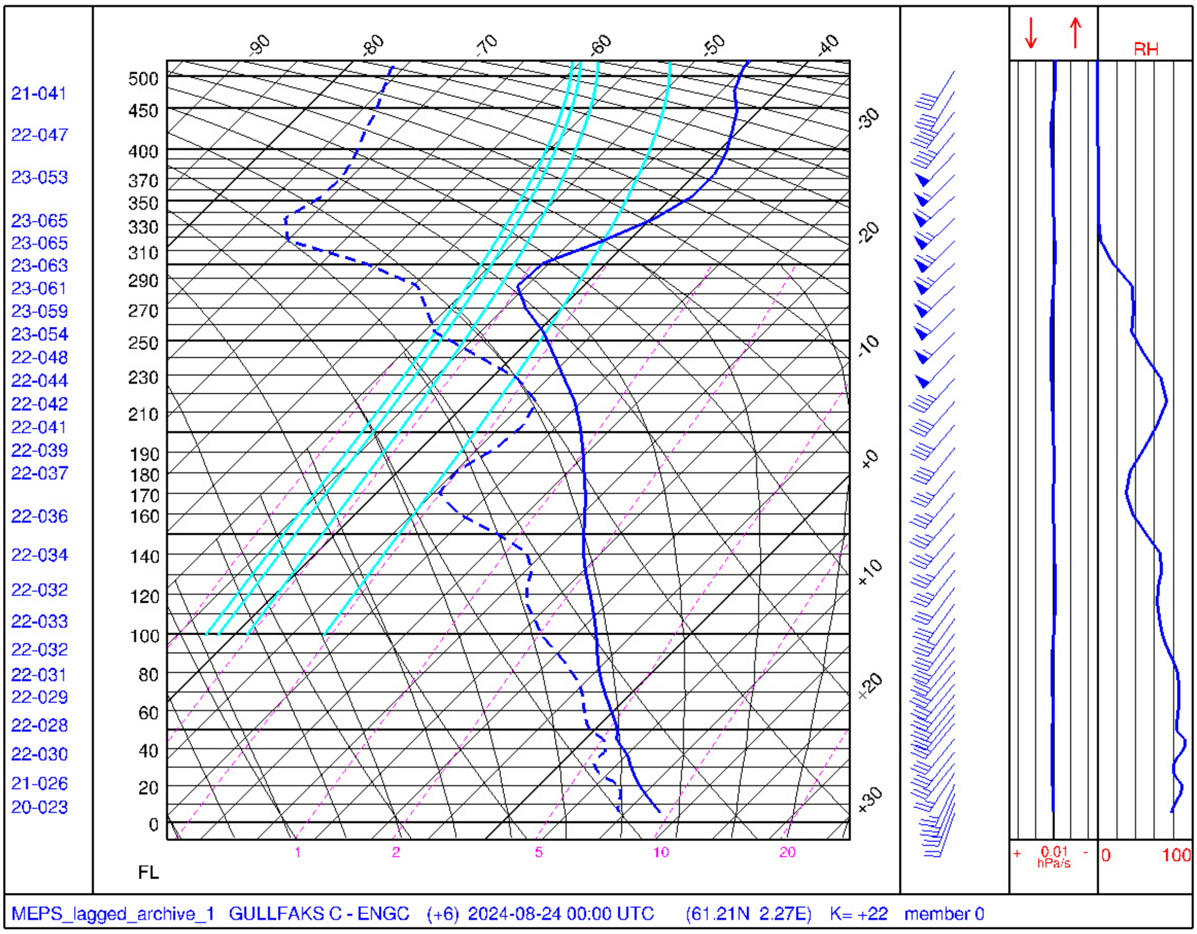


Figure 6: Prognostic sounding from MEPSctrl at 00 UTC August 24th.

Case 3. Fog

In this case we wanted to highlight an improvement in the preoperational Arome Arctic model versus the operational model. This case from August 8th illustrates differences in the two models' forecasts of fog over the ocean near Svalbard in the Norwegian Sea and the Barents Sea. Ocean fog is most prominent in summer, and our meteorologists have gotten to experience the models' tendency to exaggerate the extent of the fog and low cloud cover in recent months. Therefore it is gratifying to see that there is some hope for improvement when looking at the preoperational Arome Arctic model.

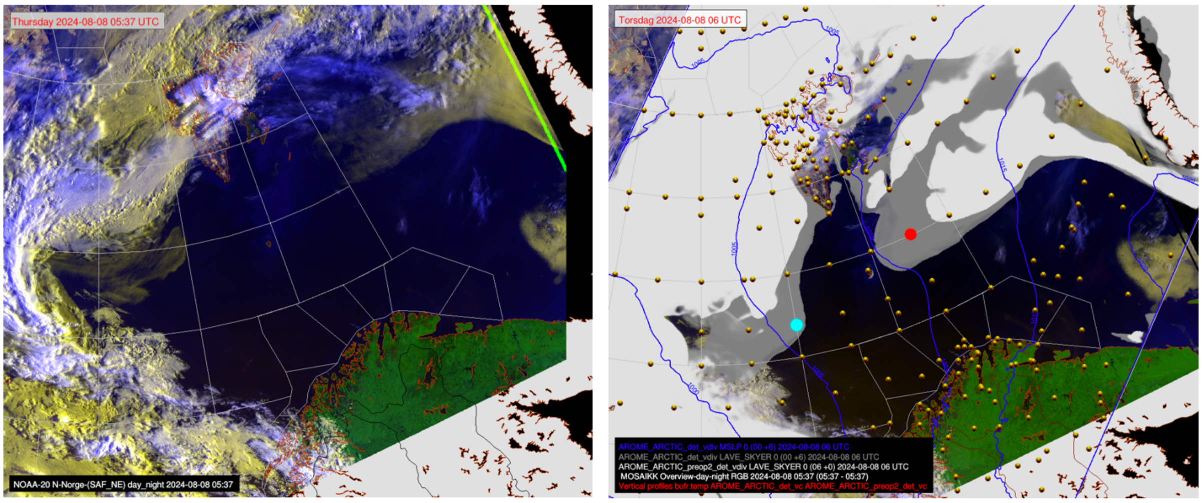


Figure 7: Left: satellite image at 05.37 UTC August 8th. Right: low clouds from the operational Arome Arctic model in dark gray and the preoperational Arome Arctic in light gray at 06 UTC. The red and cyan colored dots show the position of the soundings at 75°N 25°E and 73.5°N 10°E, respectively.

The satellite image in figure 7 shows the extent of the fog/low clouds in a yellow color. Although still overforecasting, the preoperational model predicts the extent of the ocean fog and low clouds significantly better than the model used operationally (figure 7, right panel). Looking at the the soundings from the red and cyan colored dots in figure 7, both located in an area where Arome Arctic prod has low clouds and Arome Arctic preop does not, it is clear that the models yield different results.

Figure 8 shows that while the operational model forecasts a solid cloud layer from the surface up to a few hundred feet, while the preoperational model correctly forecasts cloud free conditions. It seems that the operational model cools the air at the top of the cloud layer too much, resulting in saturation and the production of a solid cloud layer. It is not clear whether the cooling or the fog occurred first, but the most common is for the false fog to appear near areas of already existing fog, expanding the horizontal extent too far. It is worth noting that the sea surface temperature (SST) from the preoperational model is slightly higher than the operational one, which in conditions where fog formation is a possibility could be the decisive factor for whether the model predicts fog or not.

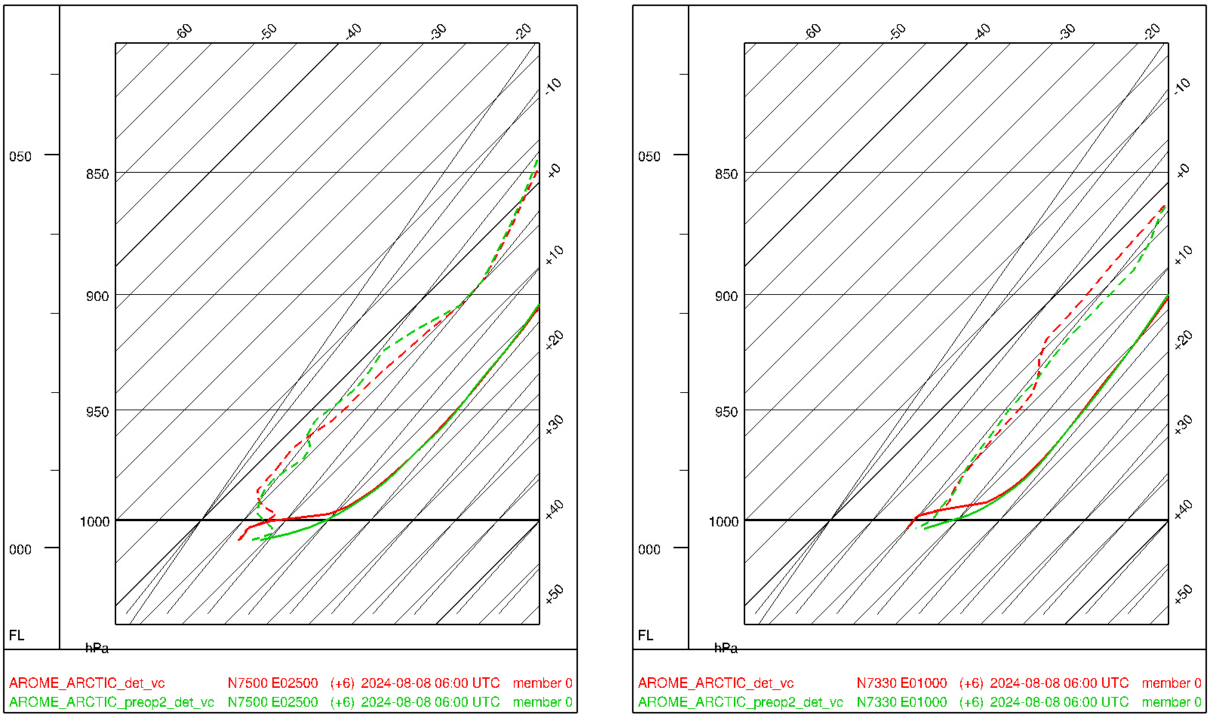
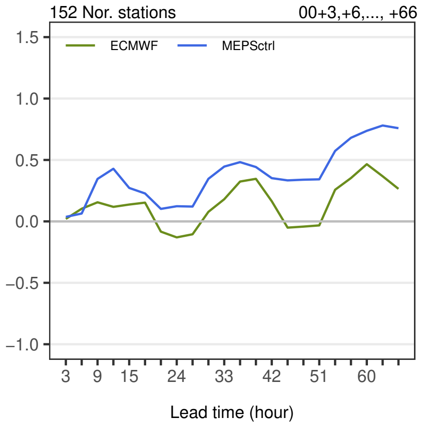


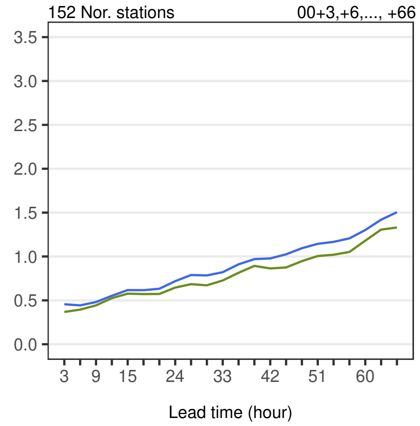
Figure 8: Prognostic soundings near the surface for 75°N 25°E and 73.5°N 10°E, with the operational soundings from Arome Arctic in red and from the preoperational Arome Arctic model in green.

Summarized statistics

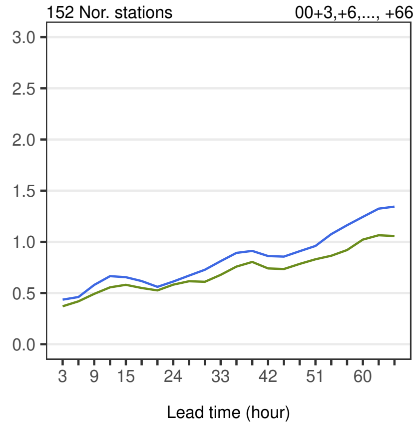
Mean Error



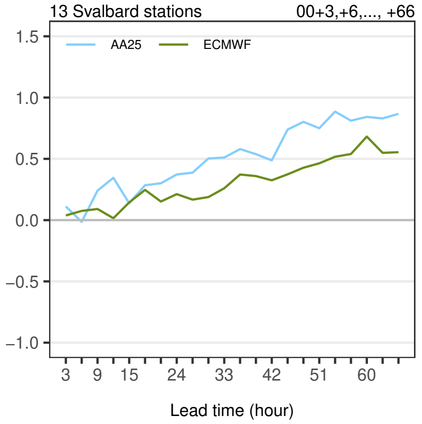
Standard Deviation of Error



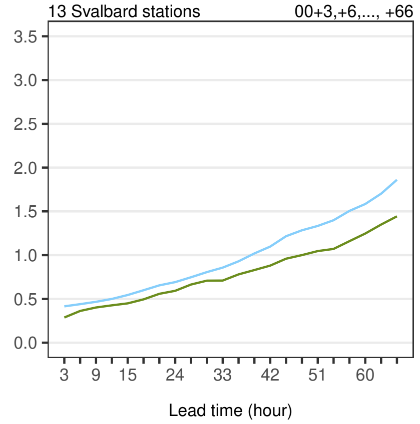
Mean Absolute Error



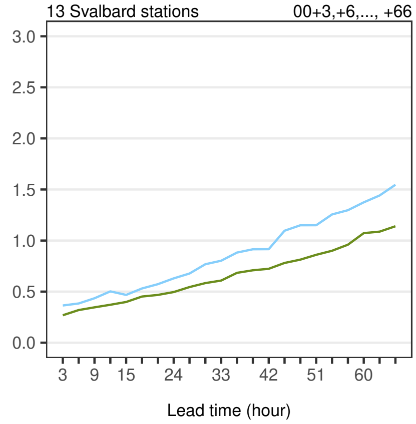
Mean Error



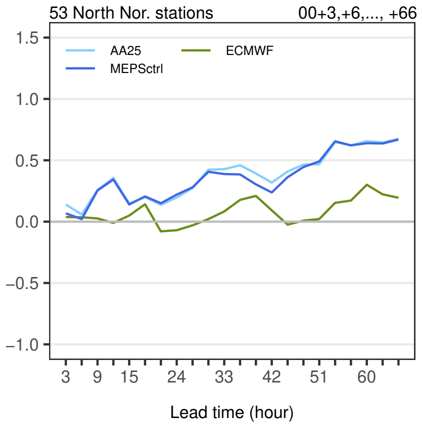
Standard Deviation of Error



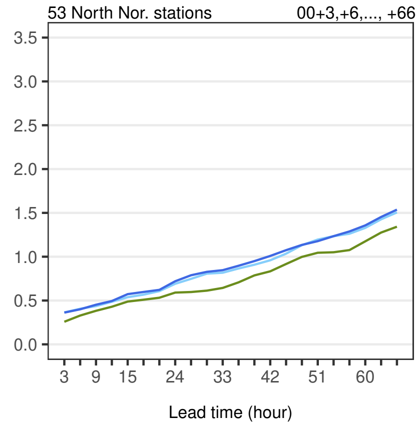
Mean Absolute Error



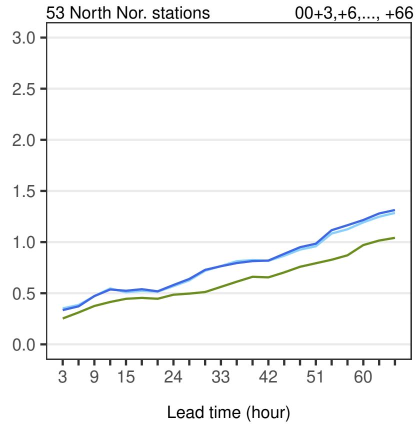
Mean Error

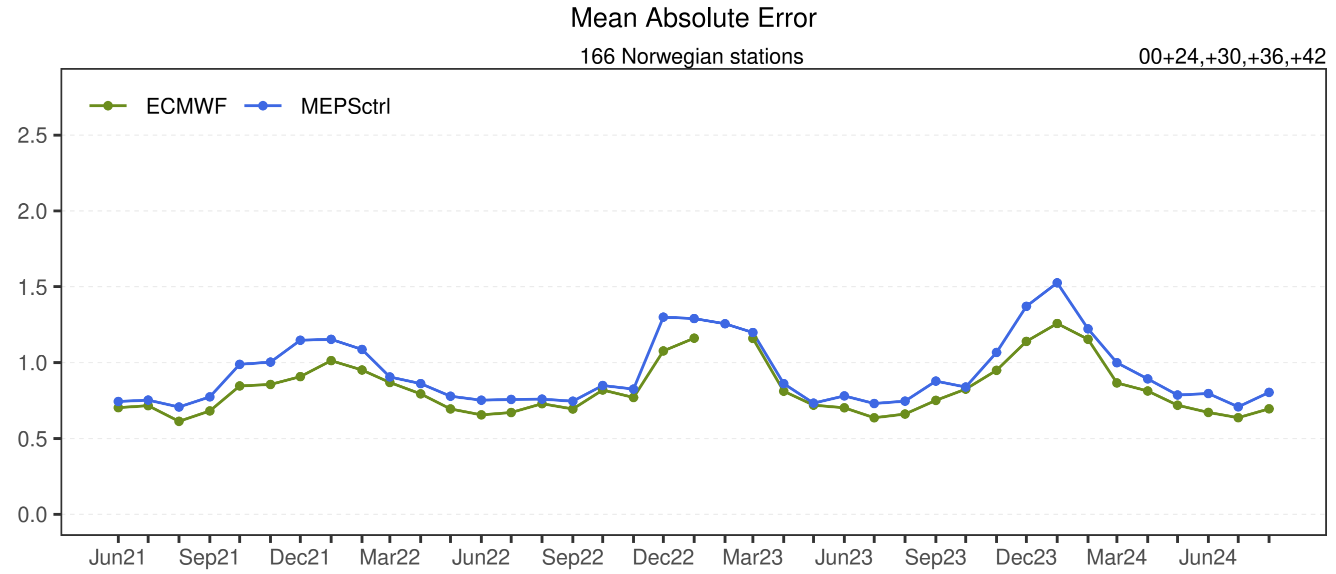


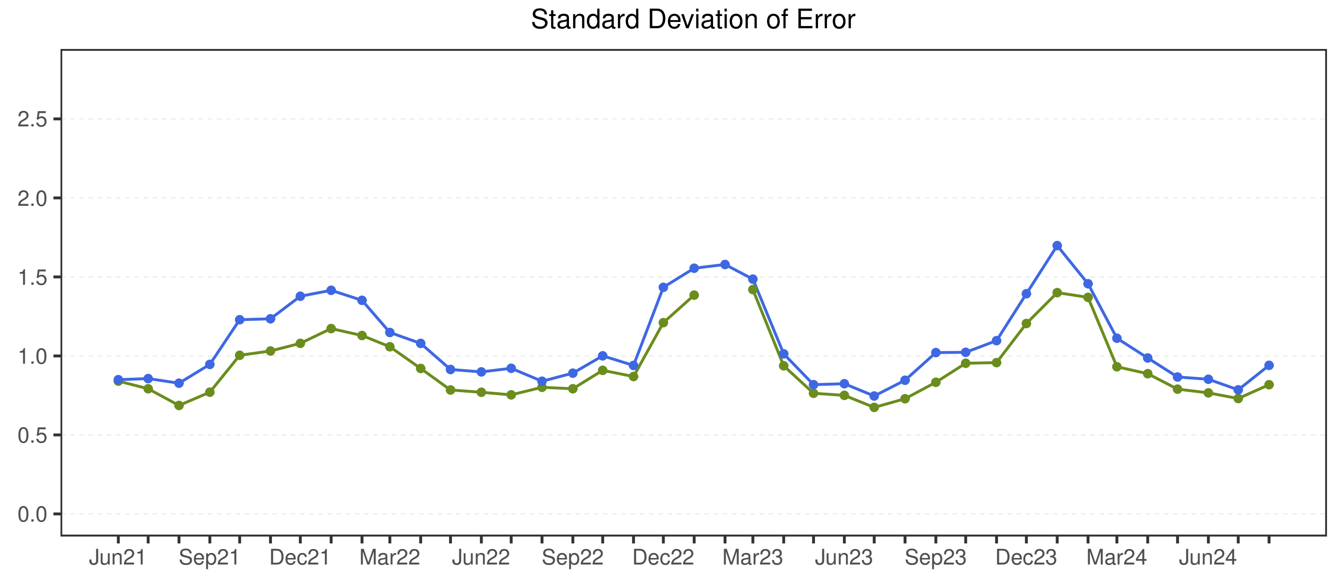
Standard Deviation of Error

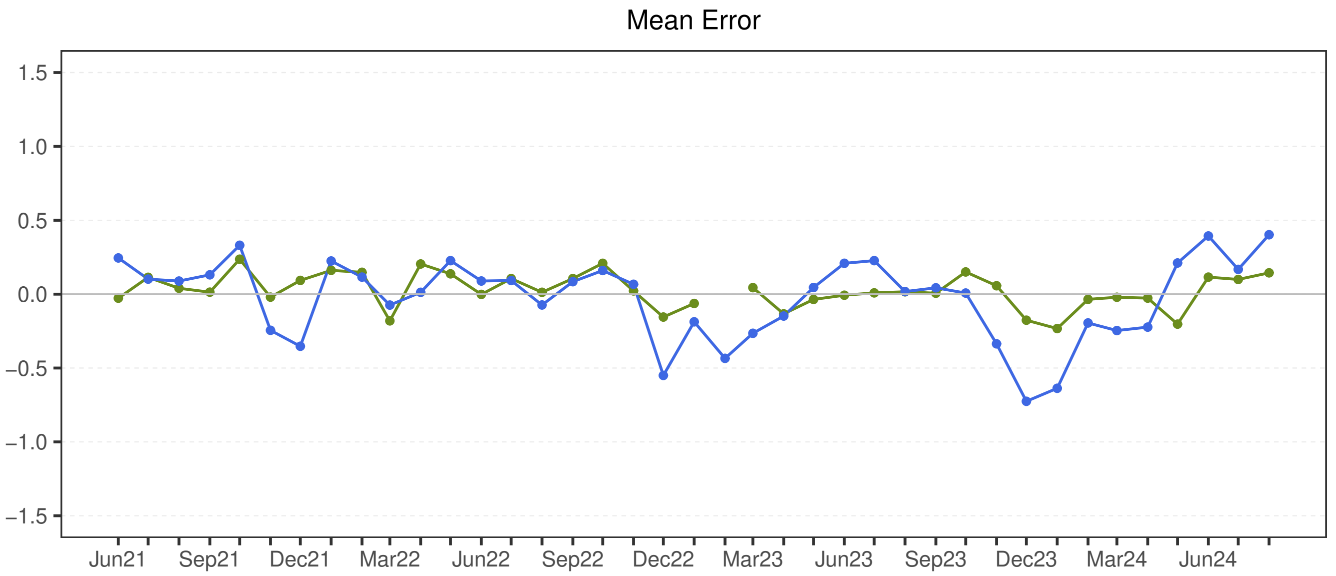


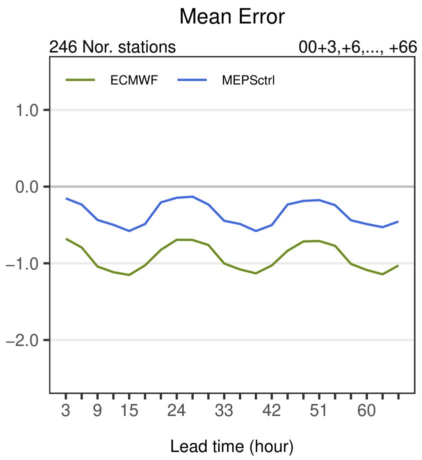
Mean Absolute Error

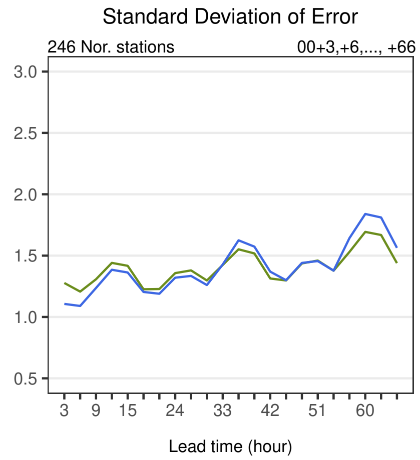


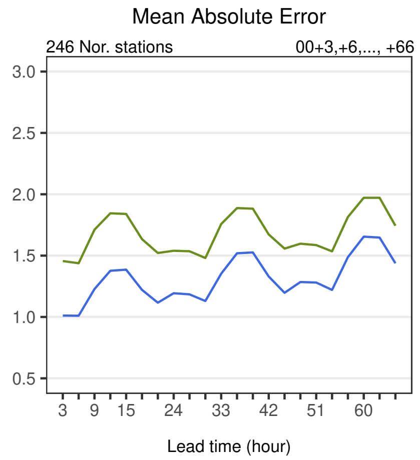

Mean Absolute Error
166 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
2.5
2.0
1.5
1.0
0.5
0.0
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24

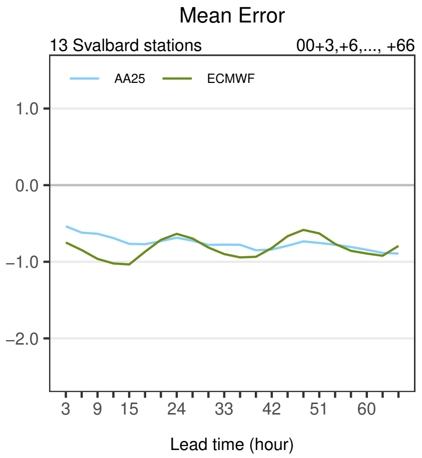

Standard Deviation of Error
2.5
2.0
1.5
1.0
0.5
0.0
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24

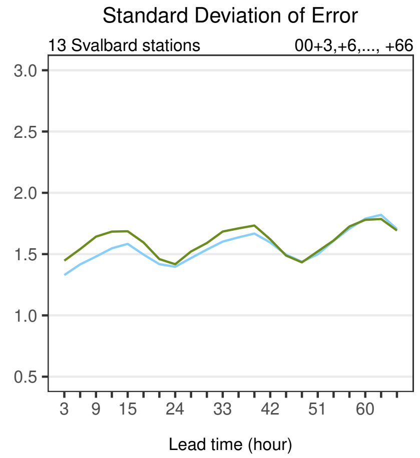

Mean Error
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24

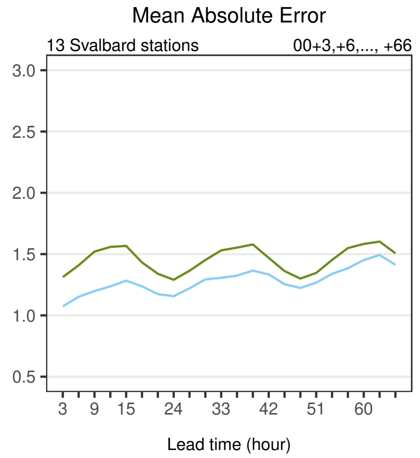

Mean Error
246 Nor. stations
00+3,+6,..., +66
ECMWF
MEPSctrl
Lead time (hour)

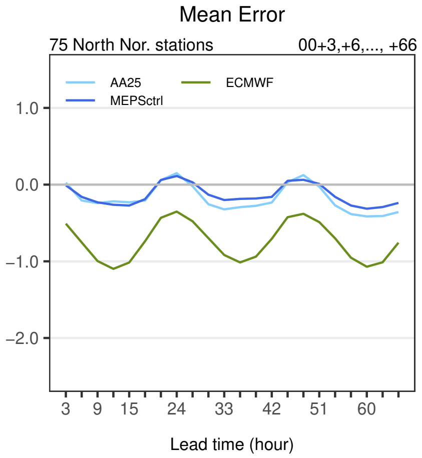

Standard Deviation of Error
246 Nor. stations
00+3,+6,..., +66
Lead time (hour)

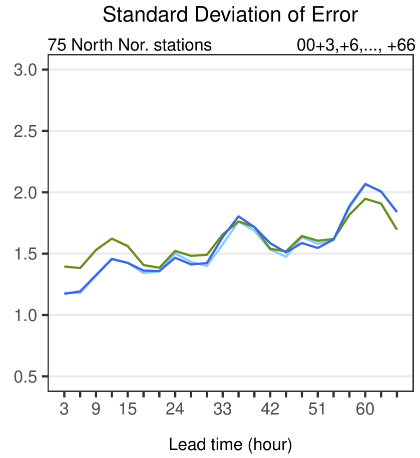

Mean Absolute Error
246 Nor. stations
00+3,+6,..., +66
Lead time (hour)

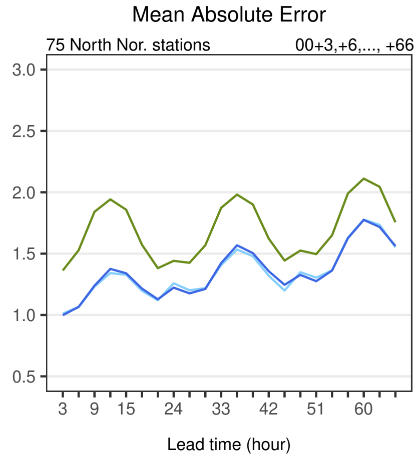

Mean Error
13 Svalbard stations
00+3,+6,..., +66
AA25
ECMWF
Lead time (hour)

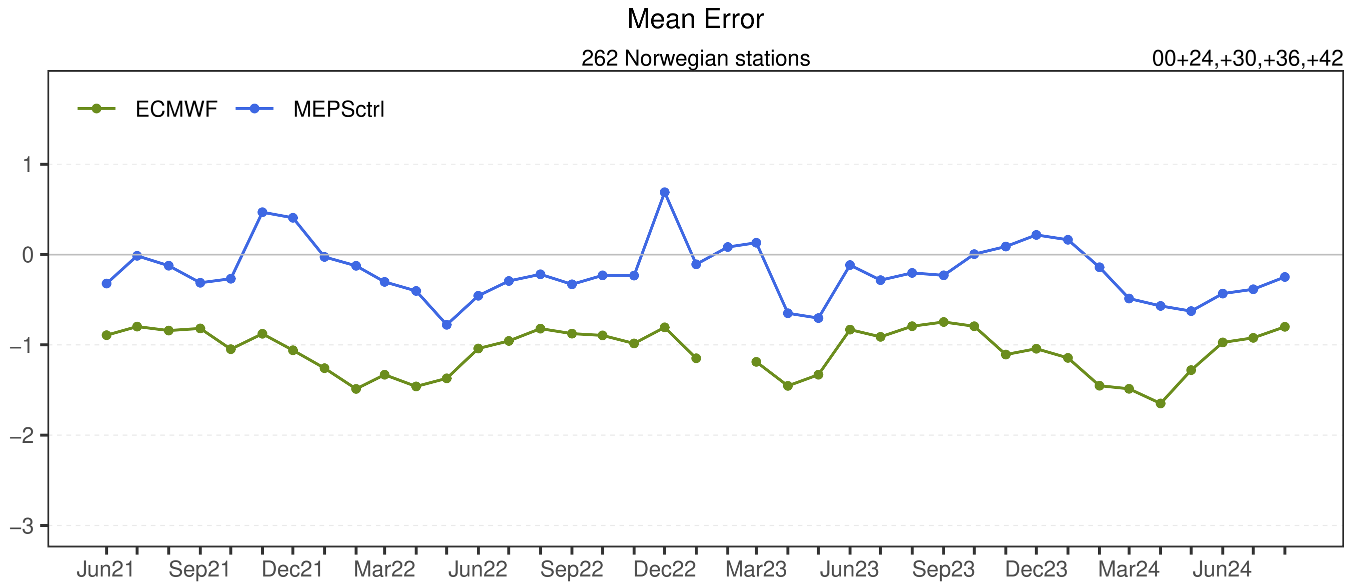

Standard Deviation of Error
13 Svalbard stations
00+3,+6,..., +66
Lead time (hour)

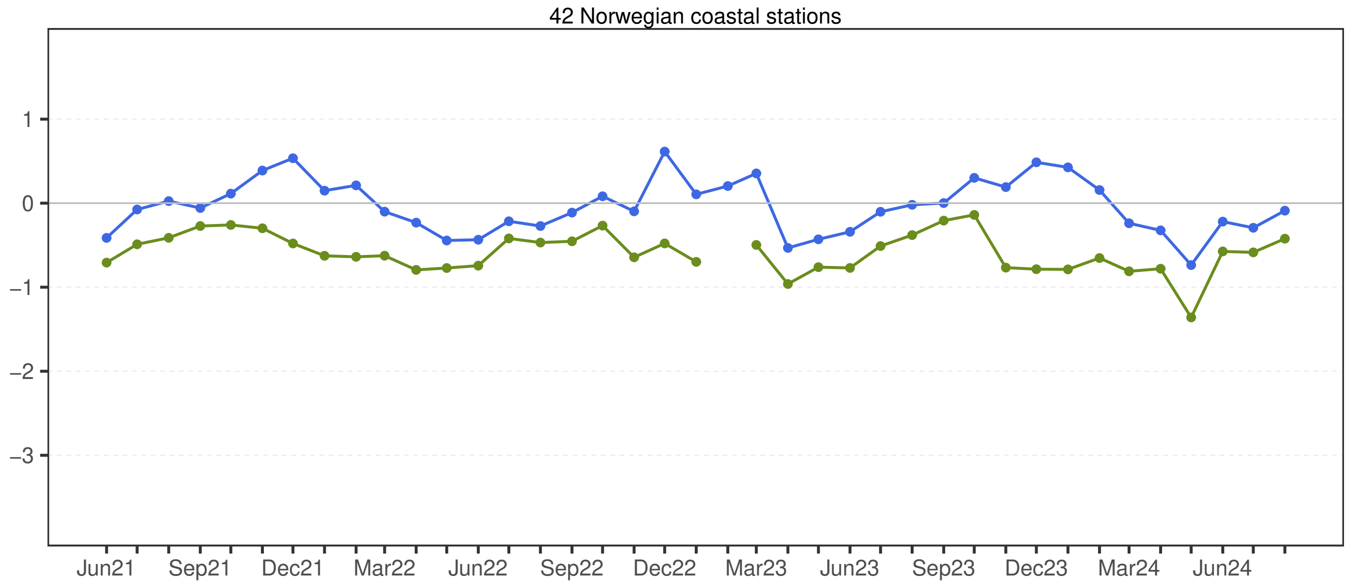

Mean Absolute Error
13 Svalbard stations
00+3,+6,..., +66
Lead time (hour)

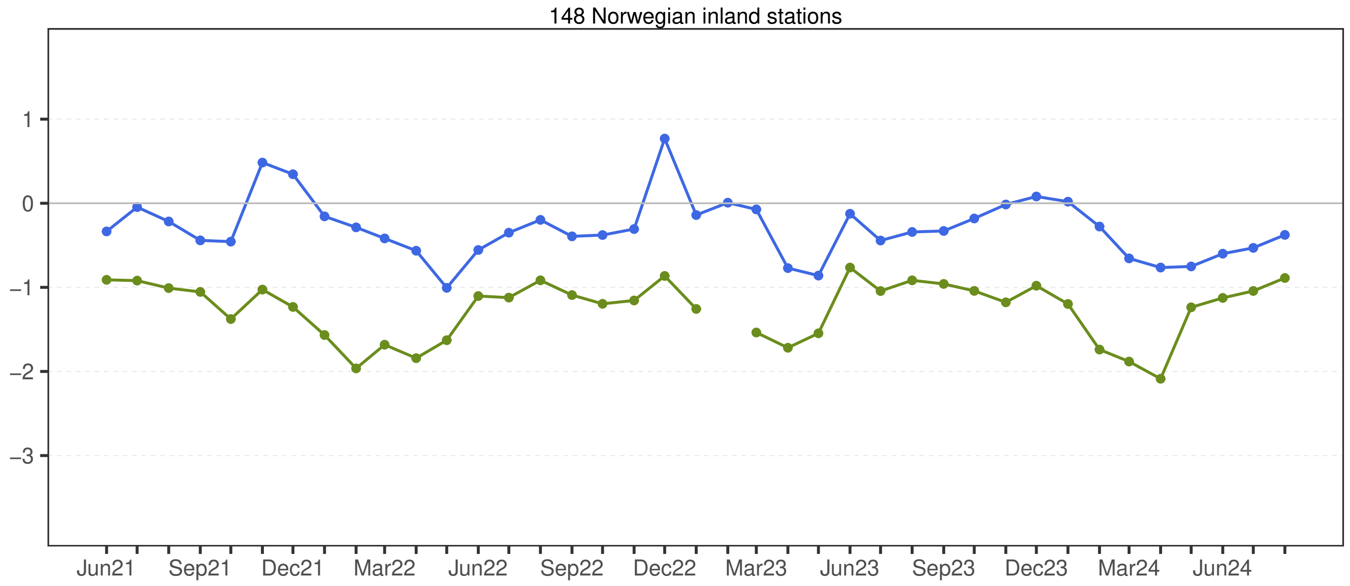

Mean Error
75 North Nor. stations
00+3,+6,..., +66
AA25
ECMWF
MEPSctrl
Lead time (hour)

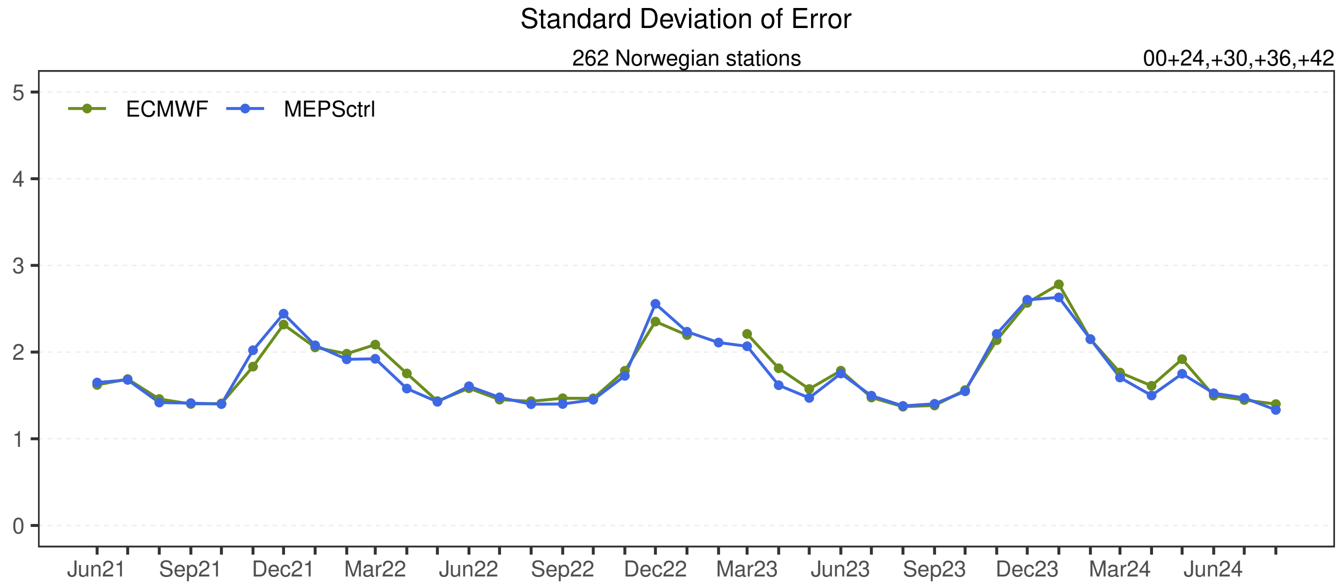

Standard Deviation of Error
75 North Nor. stations
00+3,+6,..., +66
Lead time (hour)


Mean Absolute Error
75 North Nor. stations
00+3,+6,..., +66
Lead time (hour)


Mean Error
262 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
1
0
−1
−2
−3
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24


42 Norwegian coastal stations
1
0
−1
−2
−3
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24


148 Norwegian inland stations
1
0
−1
−2
−3
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24


Standard Deviation of Error
262 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
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Mar23
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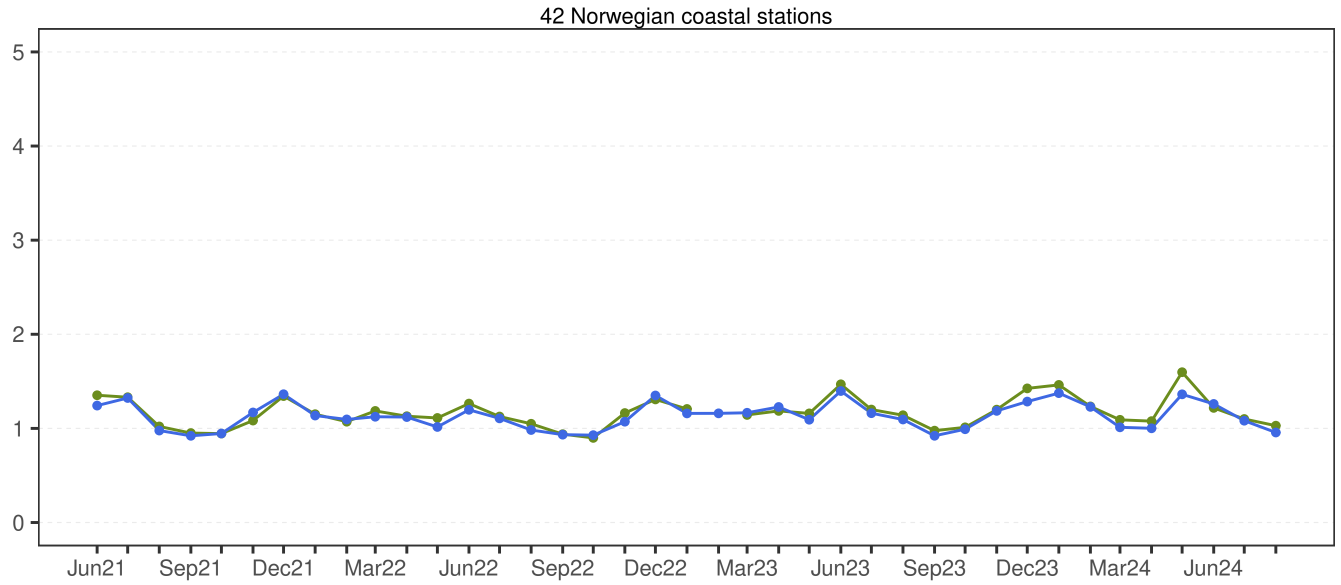
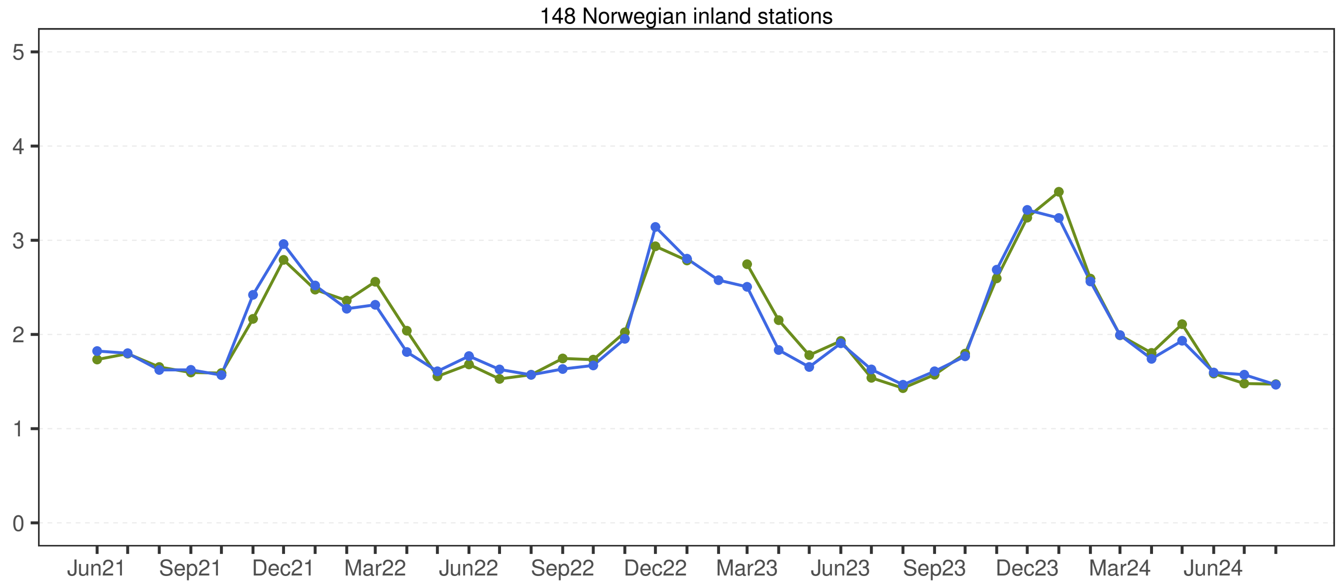
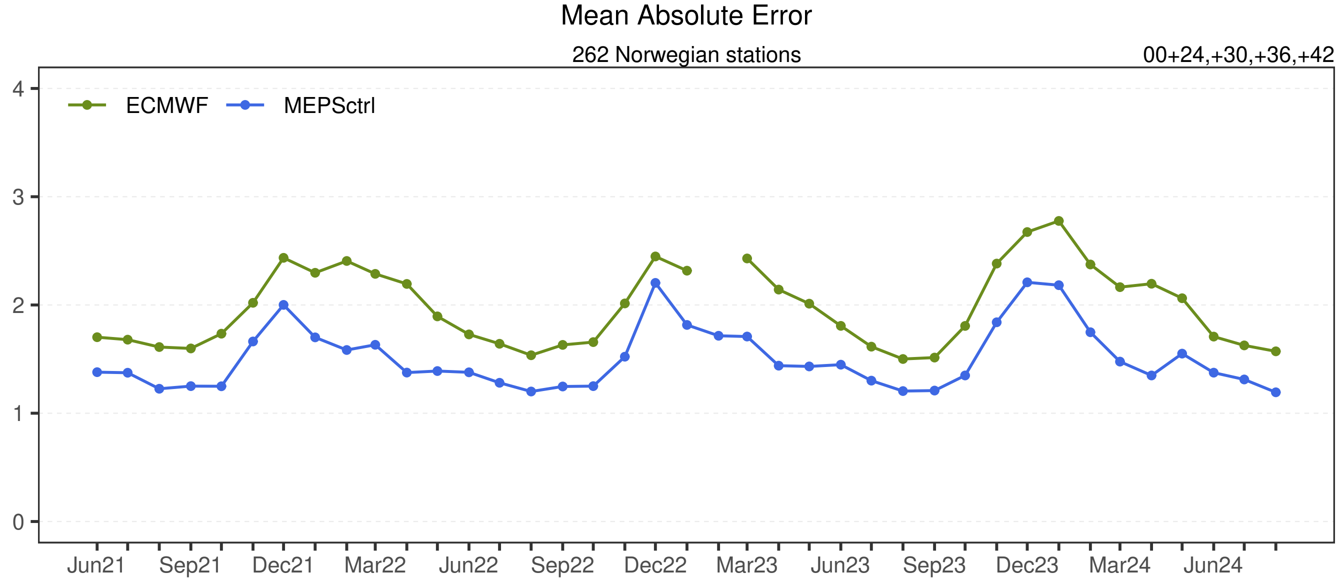
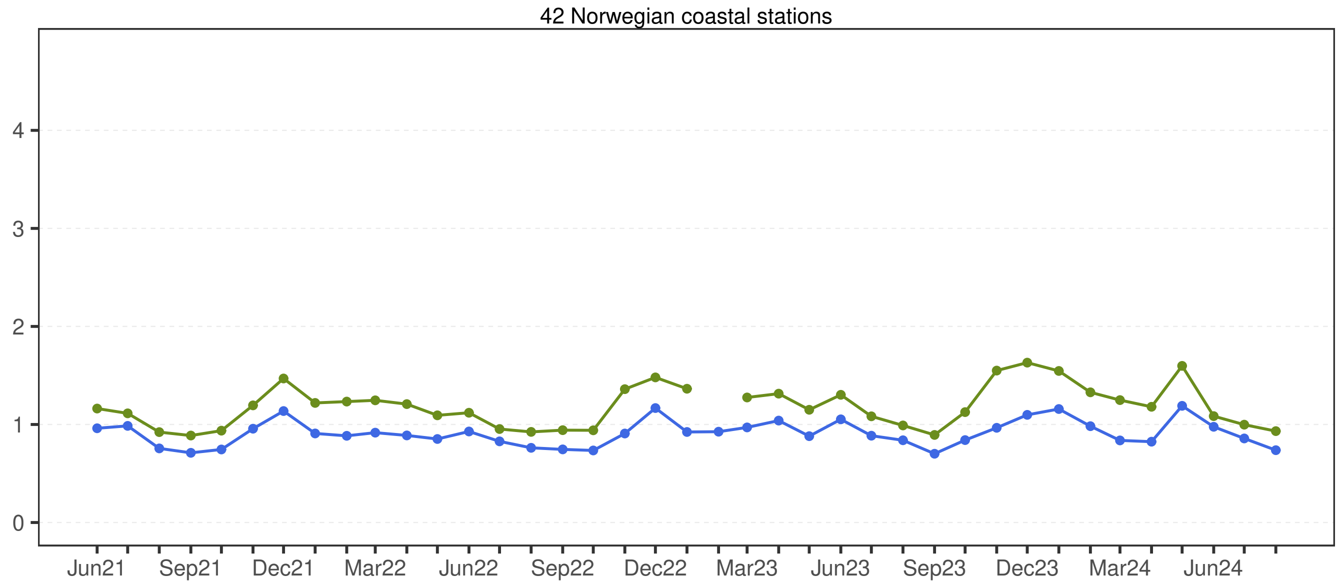
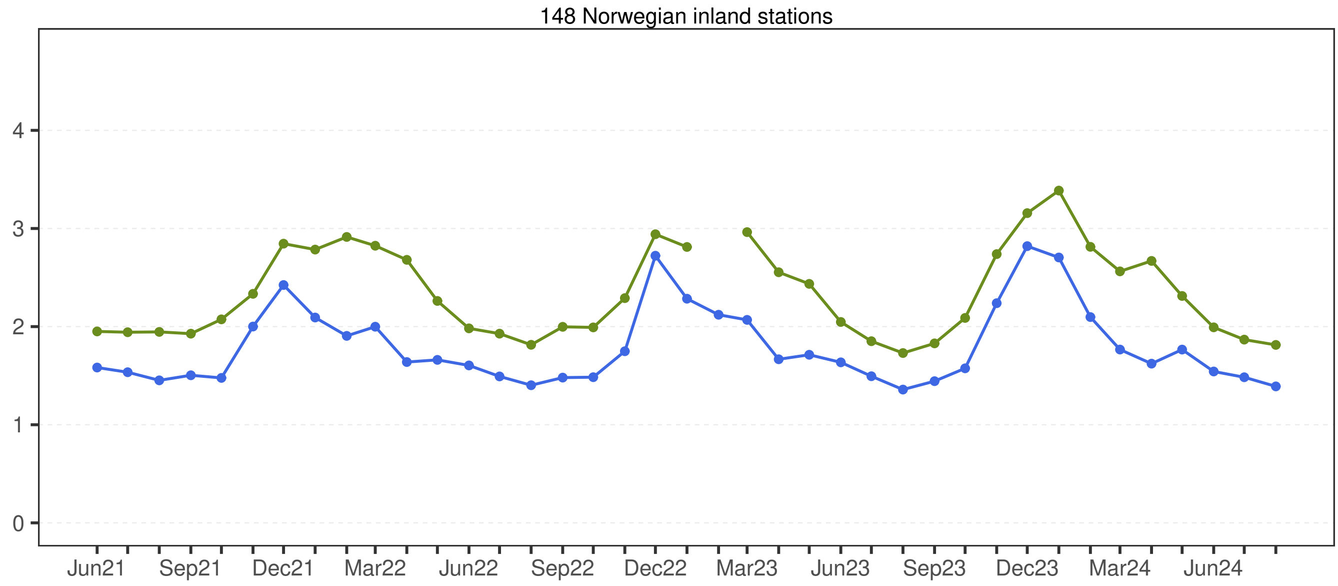
Sep23
Dec23
Mar24
Jun24

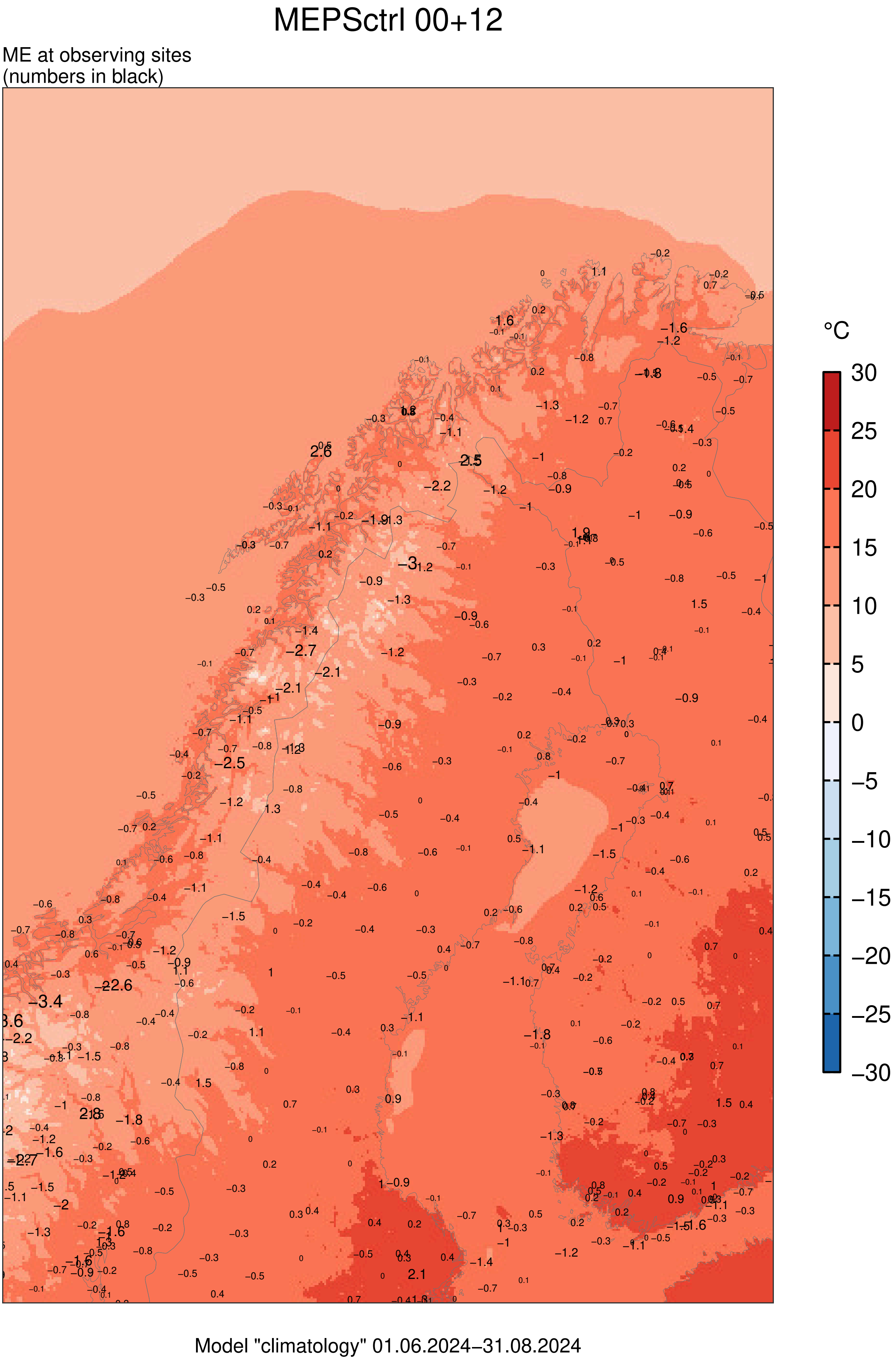

42 Norwegian coastal stations
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24


148 Norwegian inland stations
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24


Mean Absolute Error
262 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
0
1
2
3
4
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24

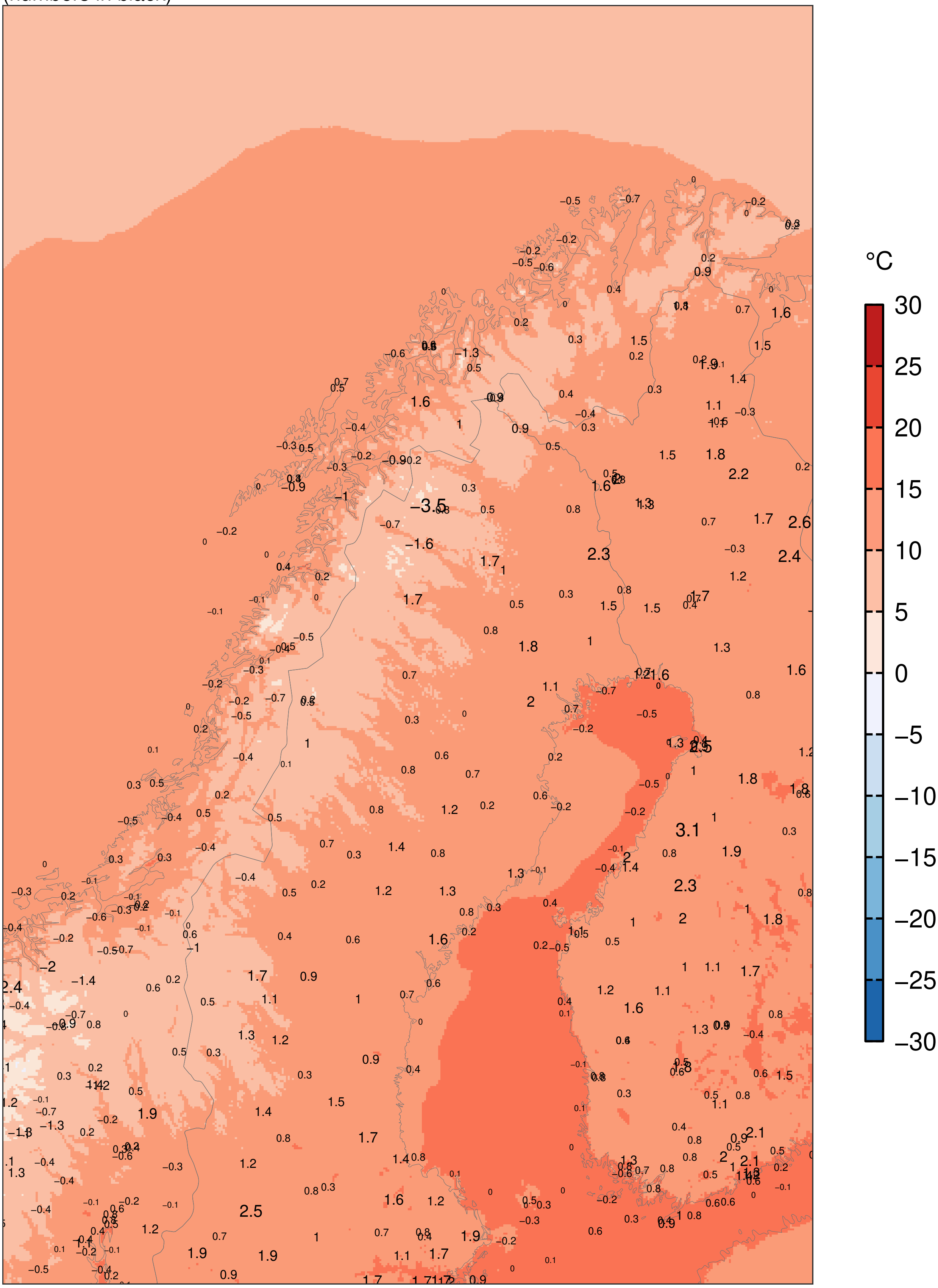

42 Norwegian coastal stations
0
1
2
3
4
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24


148 Norwegian inland stations
0
1
2
3
4
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24

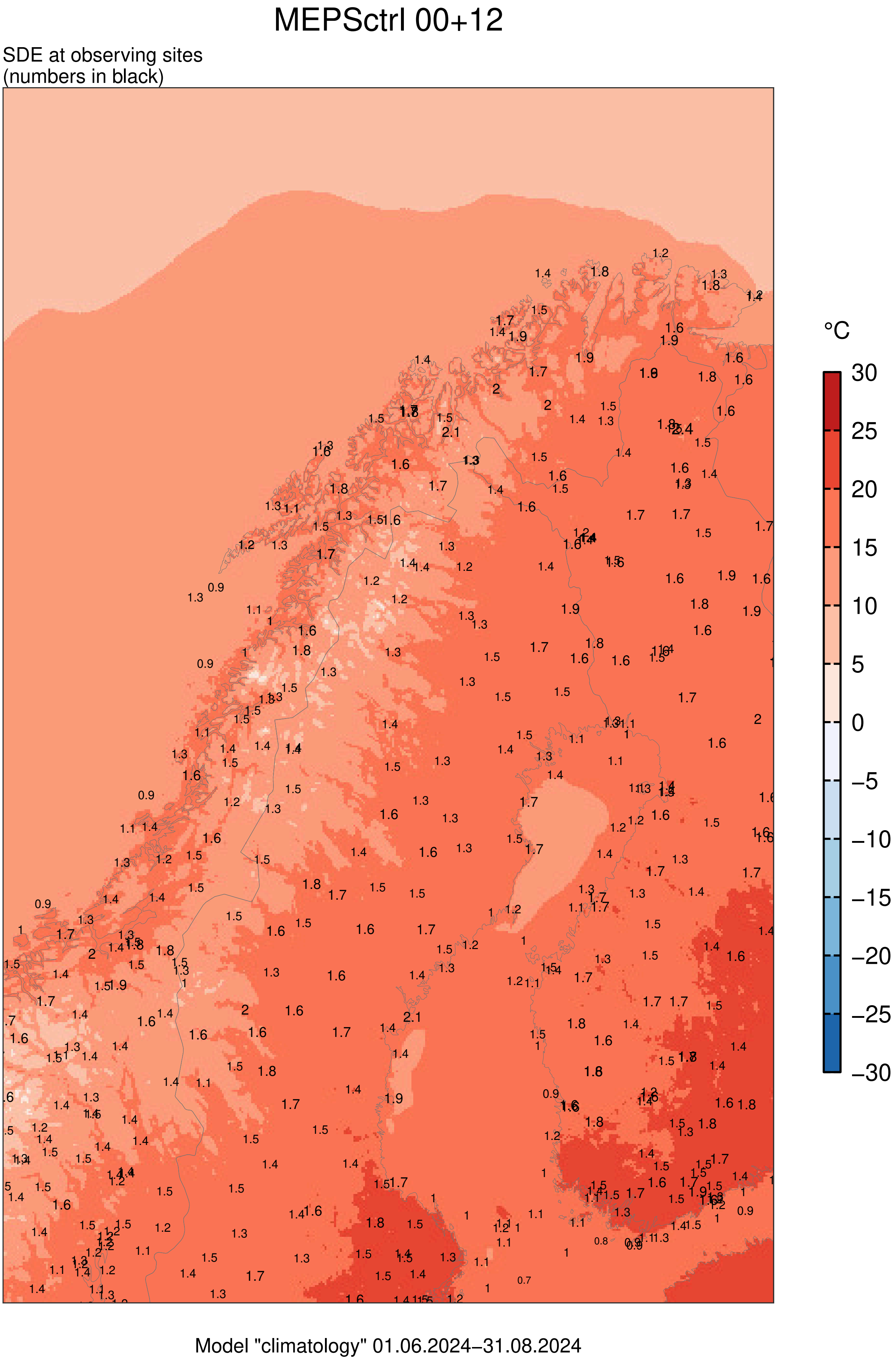

MEPSctrl 00+12
ME at observing sites
(numbers in black)
°C
30
25
20
15
10
5
0
−5
−10
−15
−20
−25
−30
Model "climatology" 01.06.2024–31.08.2024

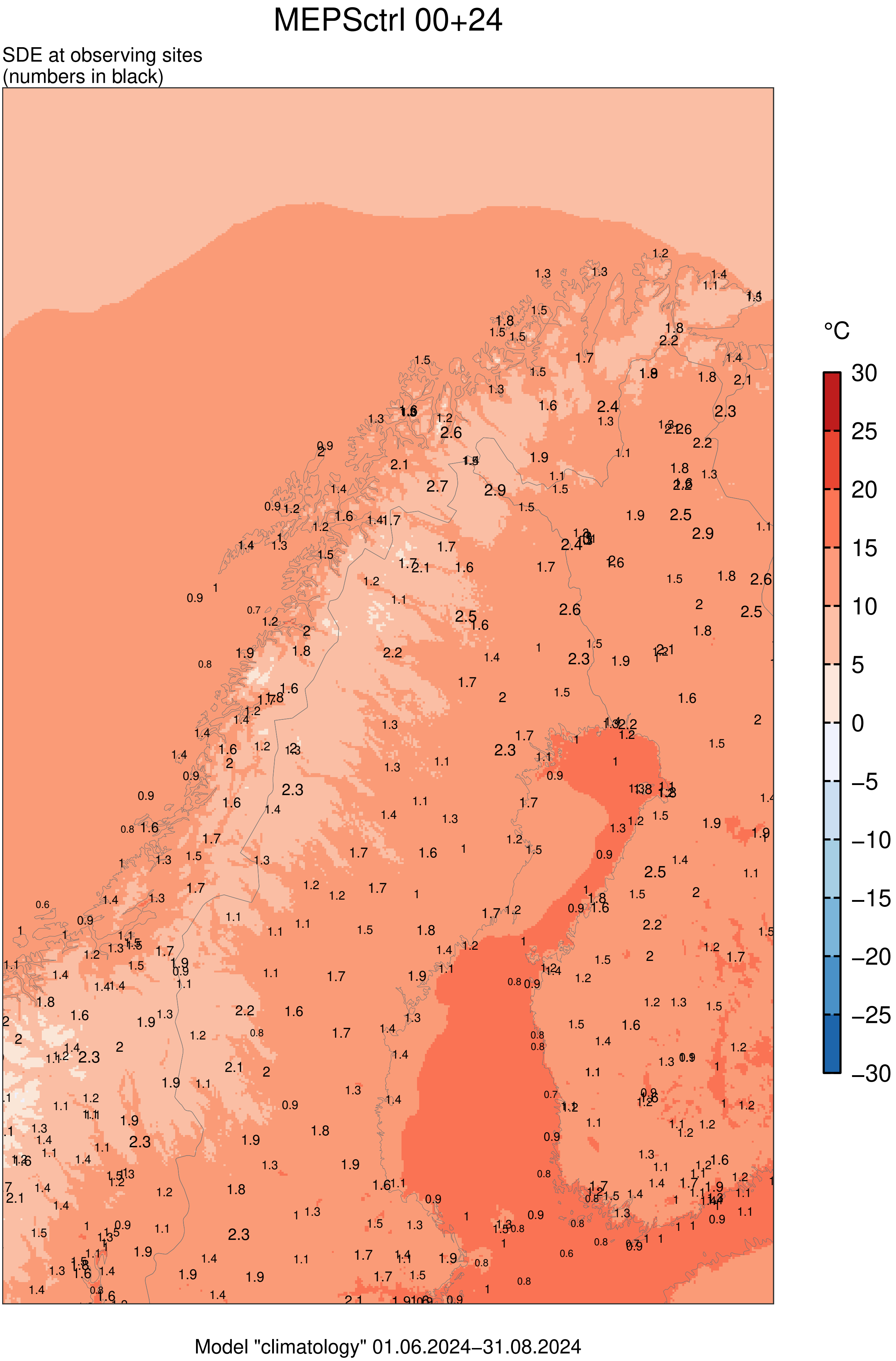
MEPSctrl 00+24

ME at observing sites
(numbers in black)



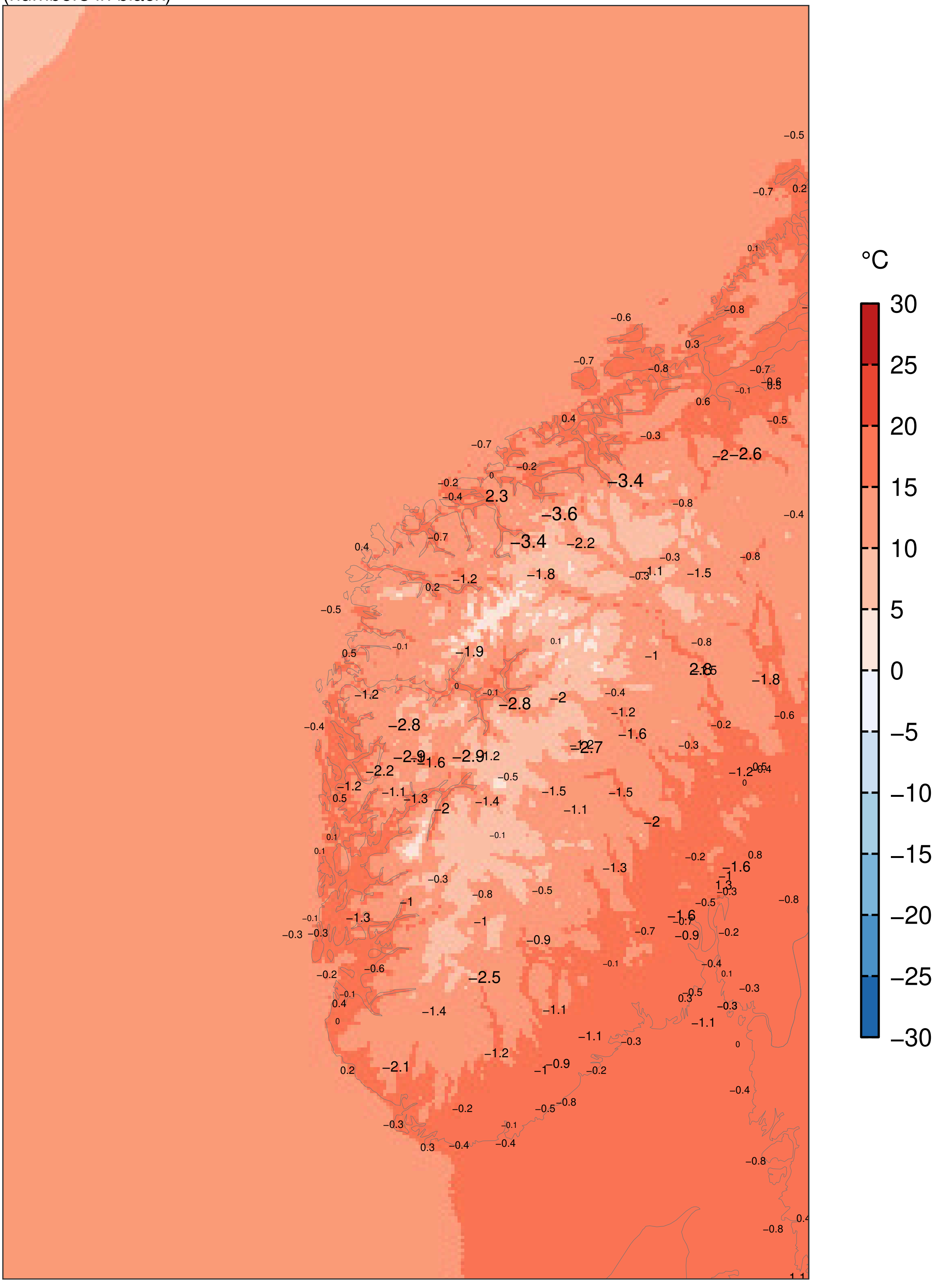
Model "climatology" 01.06.2024–31.08.2024


MEPSctrl 00+12
SDE at observing sites
(numbers in black)
°C
30
25
20
15
10
5
0
−5
−10
−15
−20
−25
−30
Model "climatology" 01.06.2024–31.08.2024


MEPSctrl 00+24
SDE at observing sites
(numbers in black)
°C
30
25
20
15
10
5
0
−5
−10
−15
−20
−25
−30
Model "climatology" 01.06.2024–31.08.2024

MEPSctrl 00+12

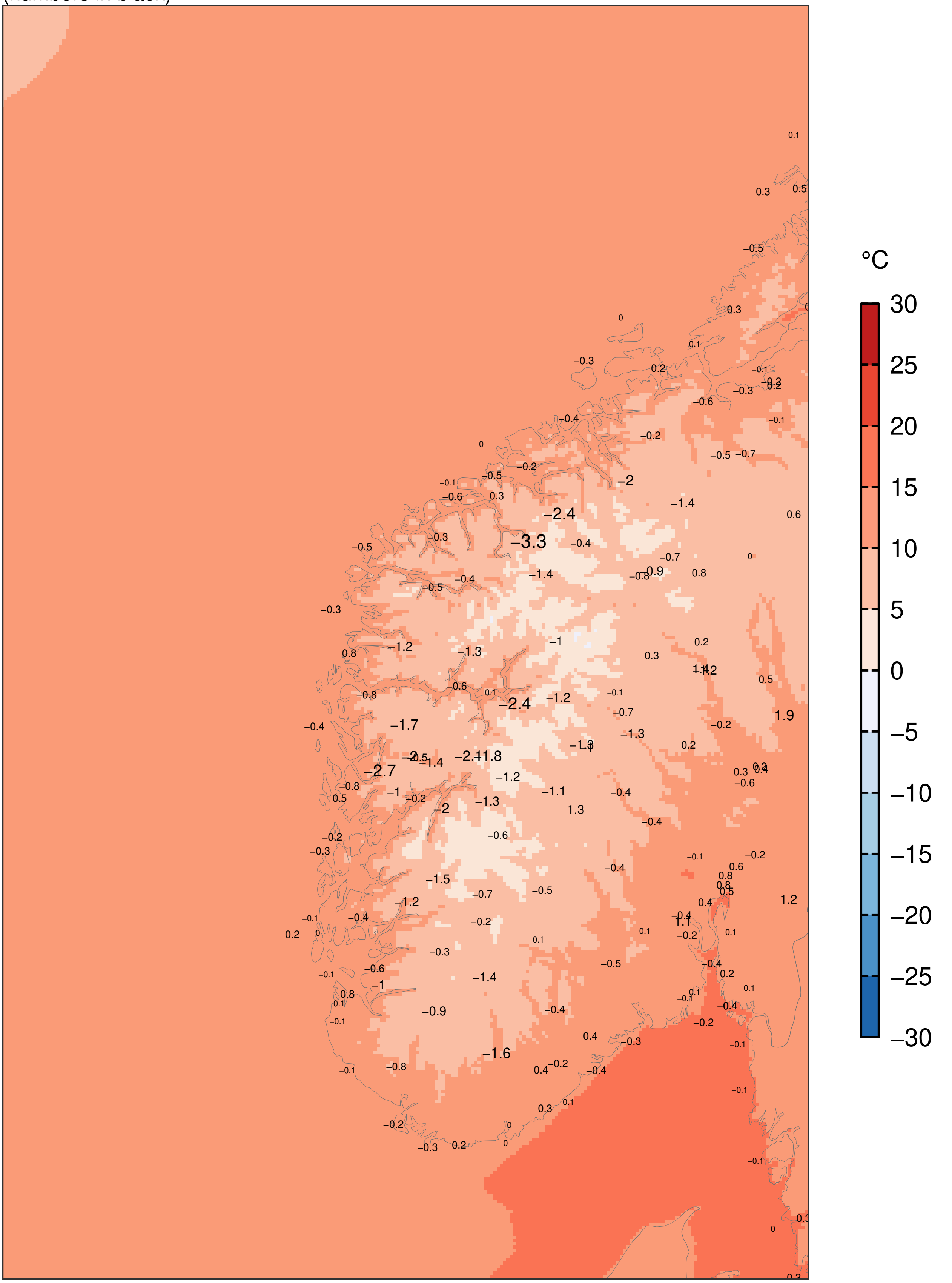
ME at observing sites
(numbers in black)



Model "climatology" 01.06.2024–31.08.2024

MEPSctrl 00+24

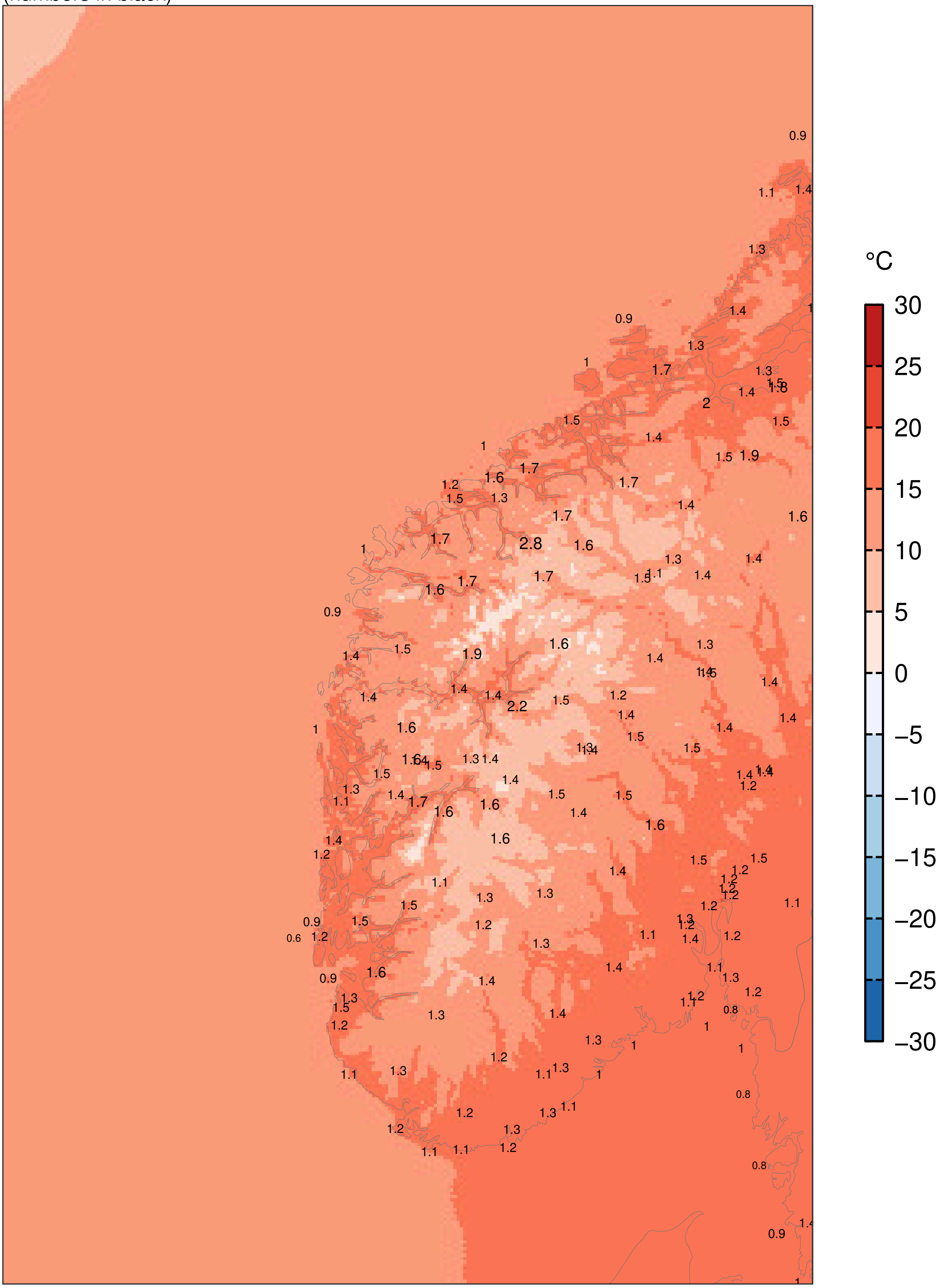
ME at observing sites
(numbers in black)



Model "climatology" 01.06.2024–31.08.2024

MEPSctrl 00+12

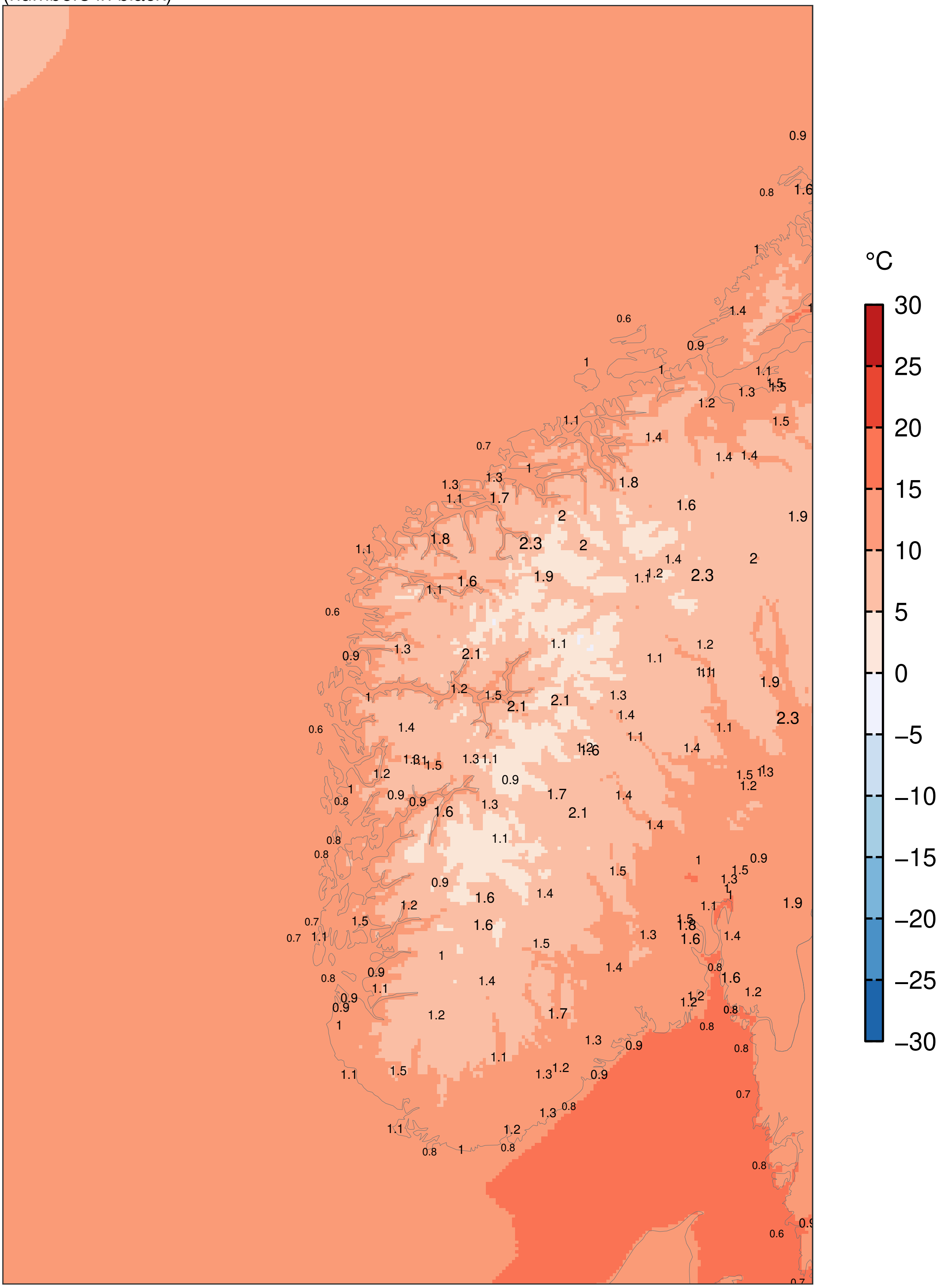
SDE at observing sites
(numbers in black)



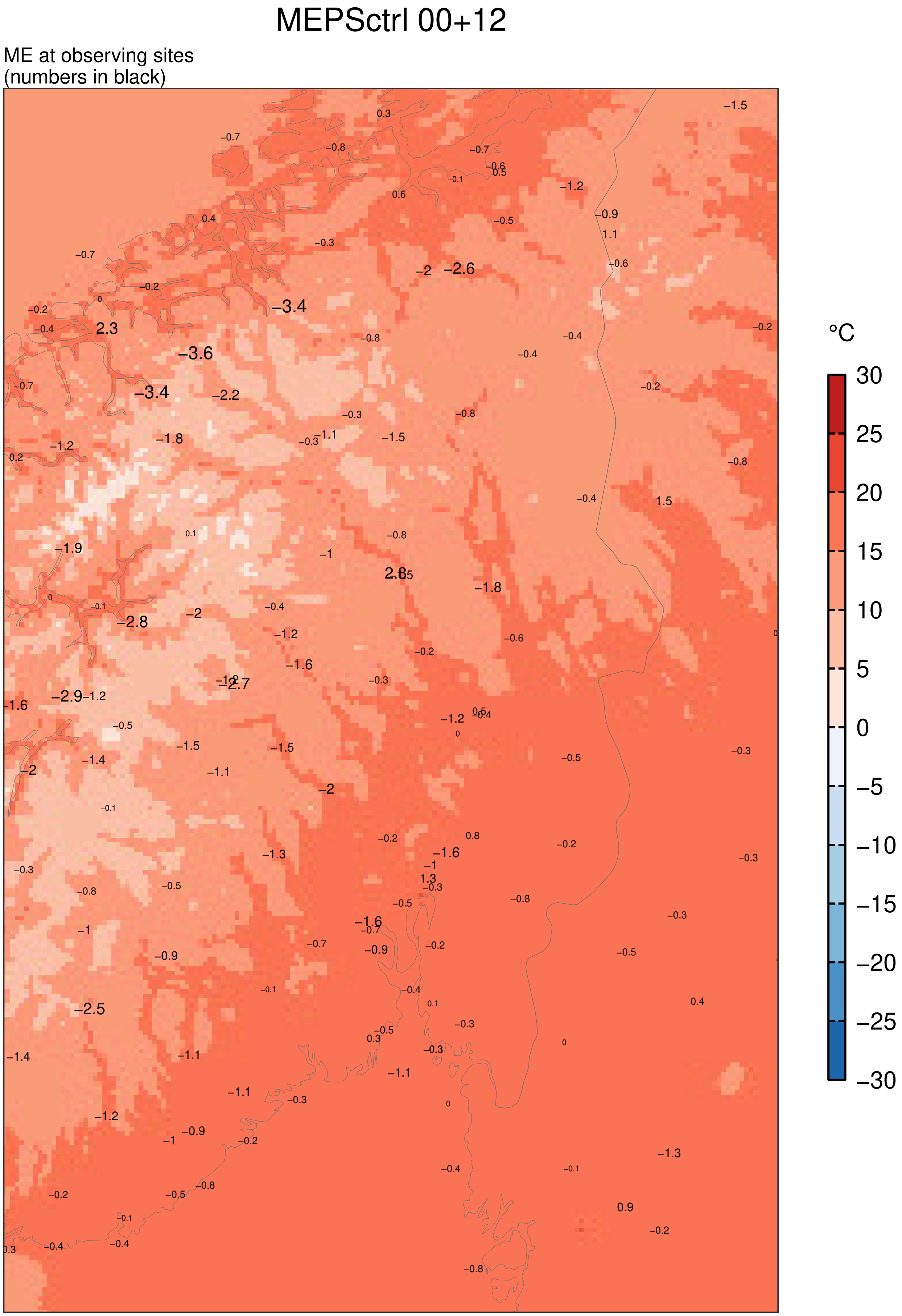
Model "climatology" 01.06.2024–31.08.2024

MEPSctrl 00+24

SDE at observing sites
(numbers in black)



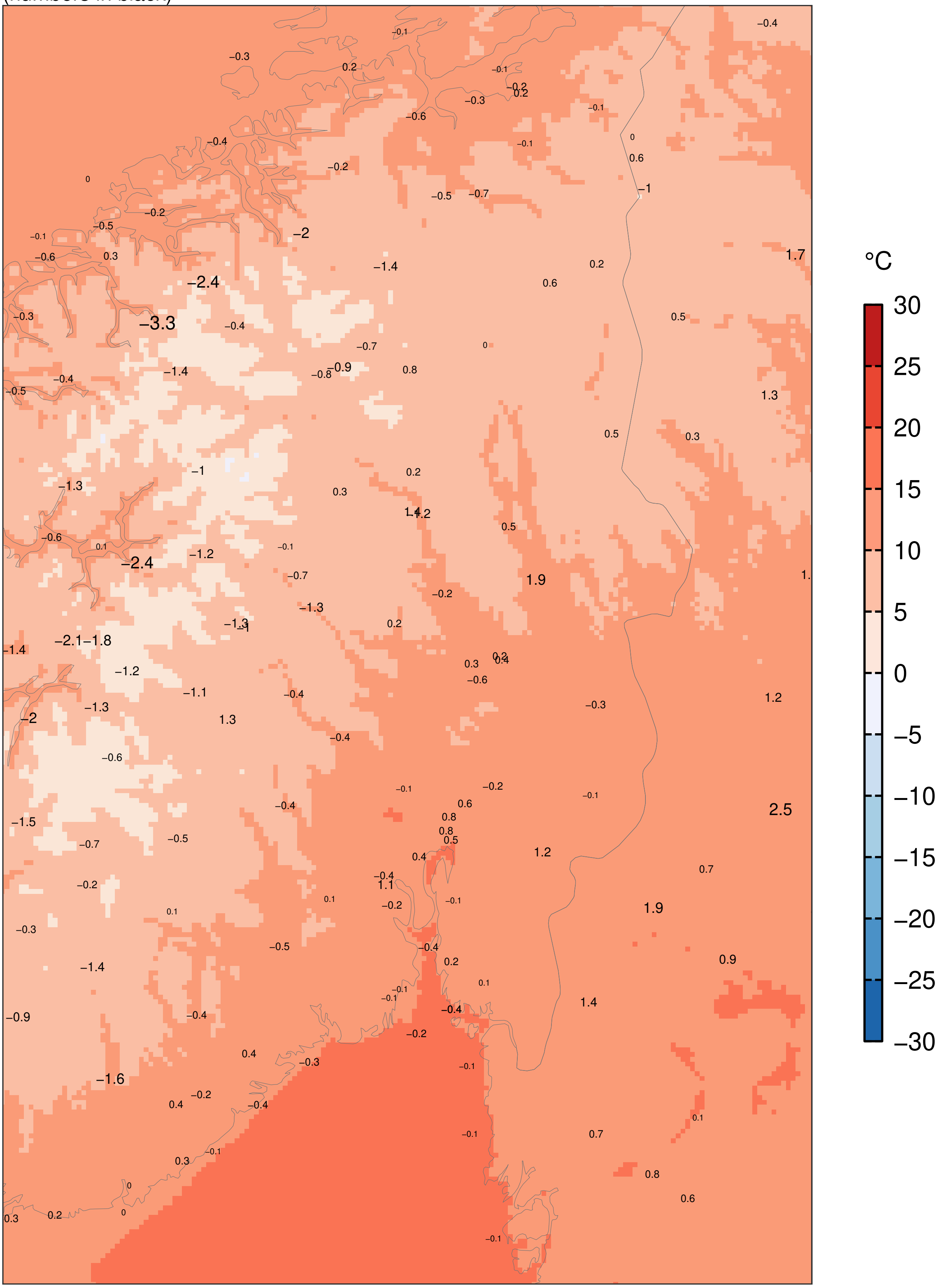
Model "climatology" 01.06.2024–31.08.2024



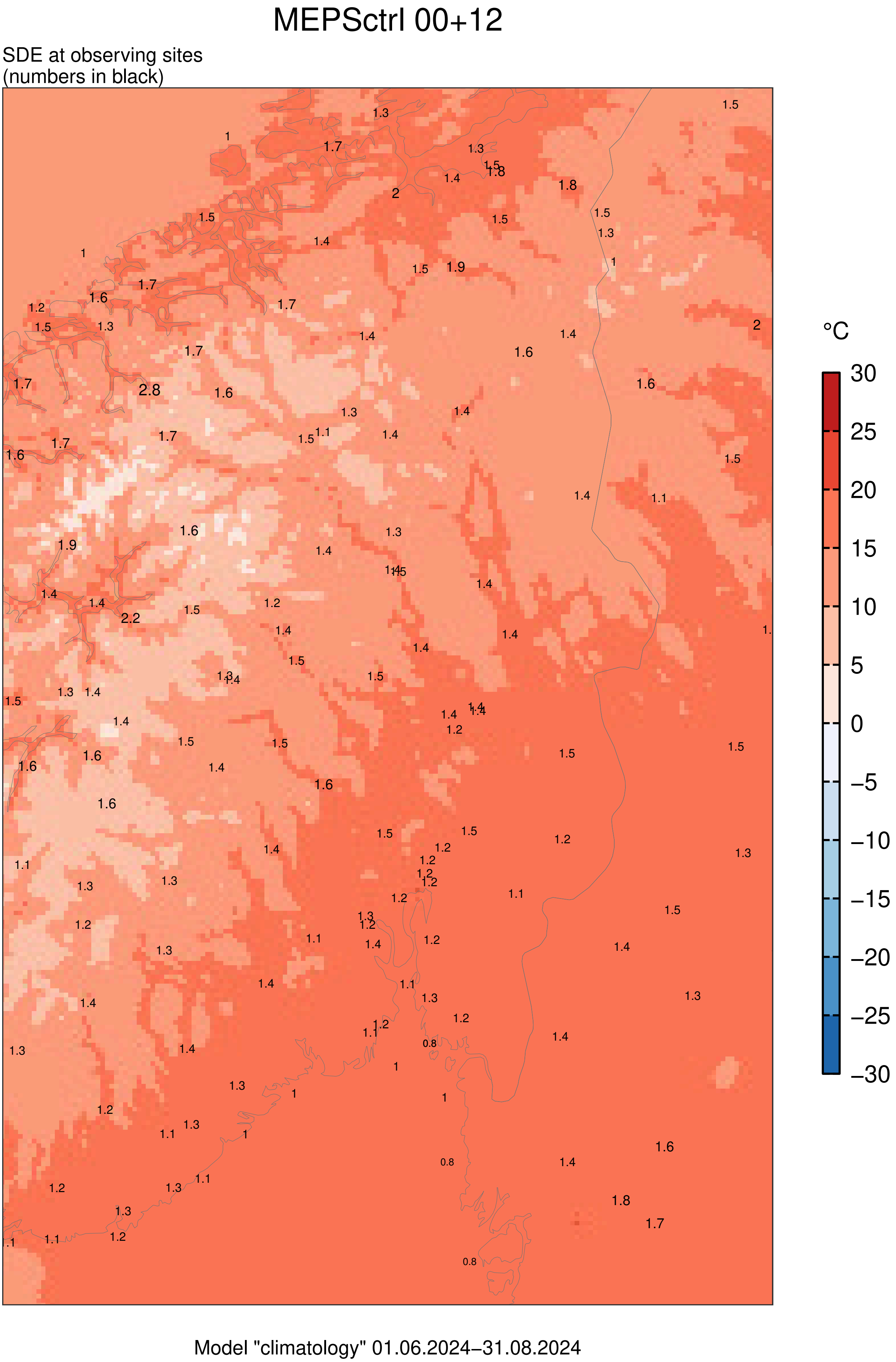
Model "climatology" 01.06.2024–31.08.2024

MEPSctrl 00+24

ME at observing sites
(numbers in black)

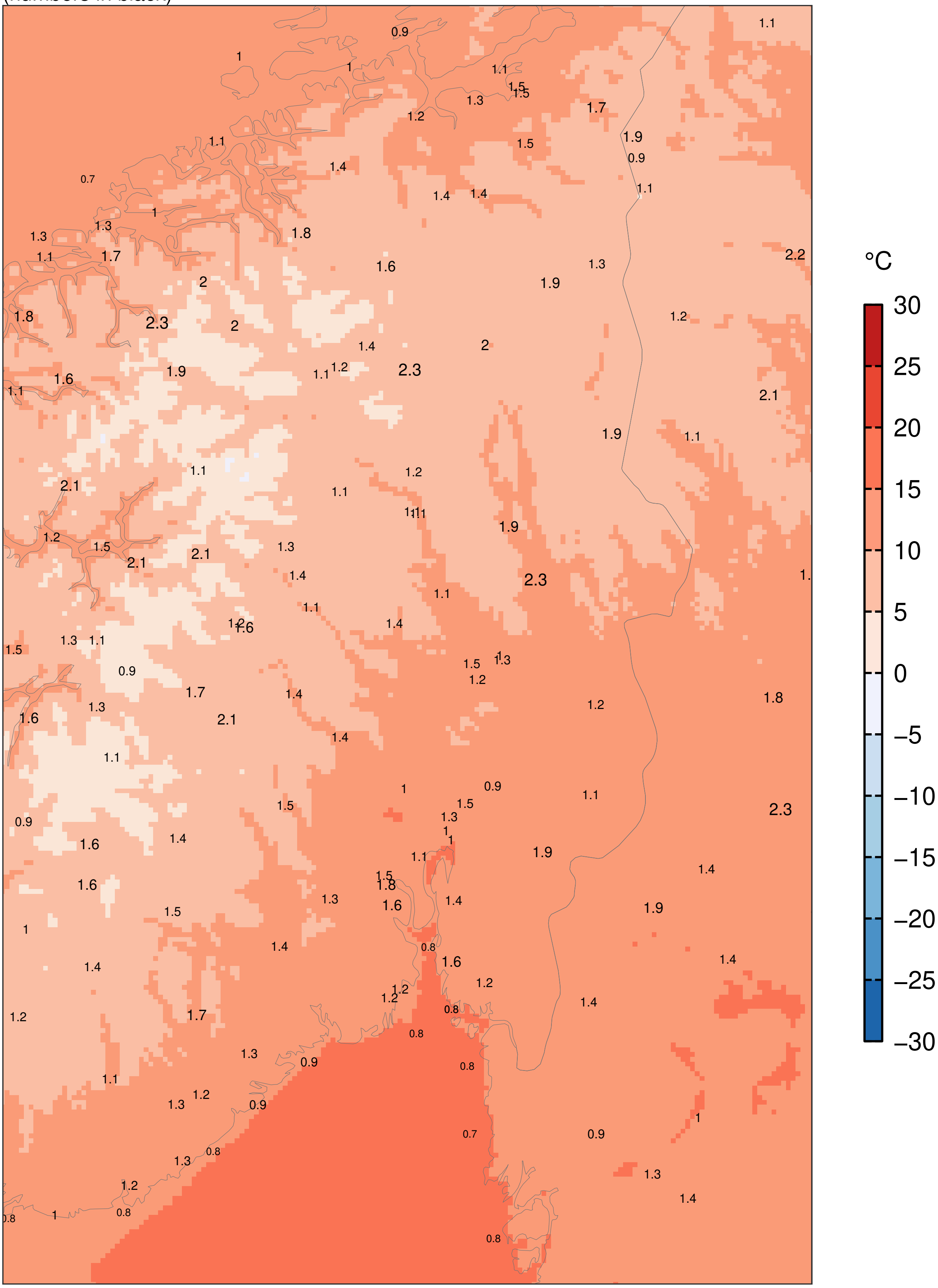


Model "climatology" 01.06.2024–31.08.2024

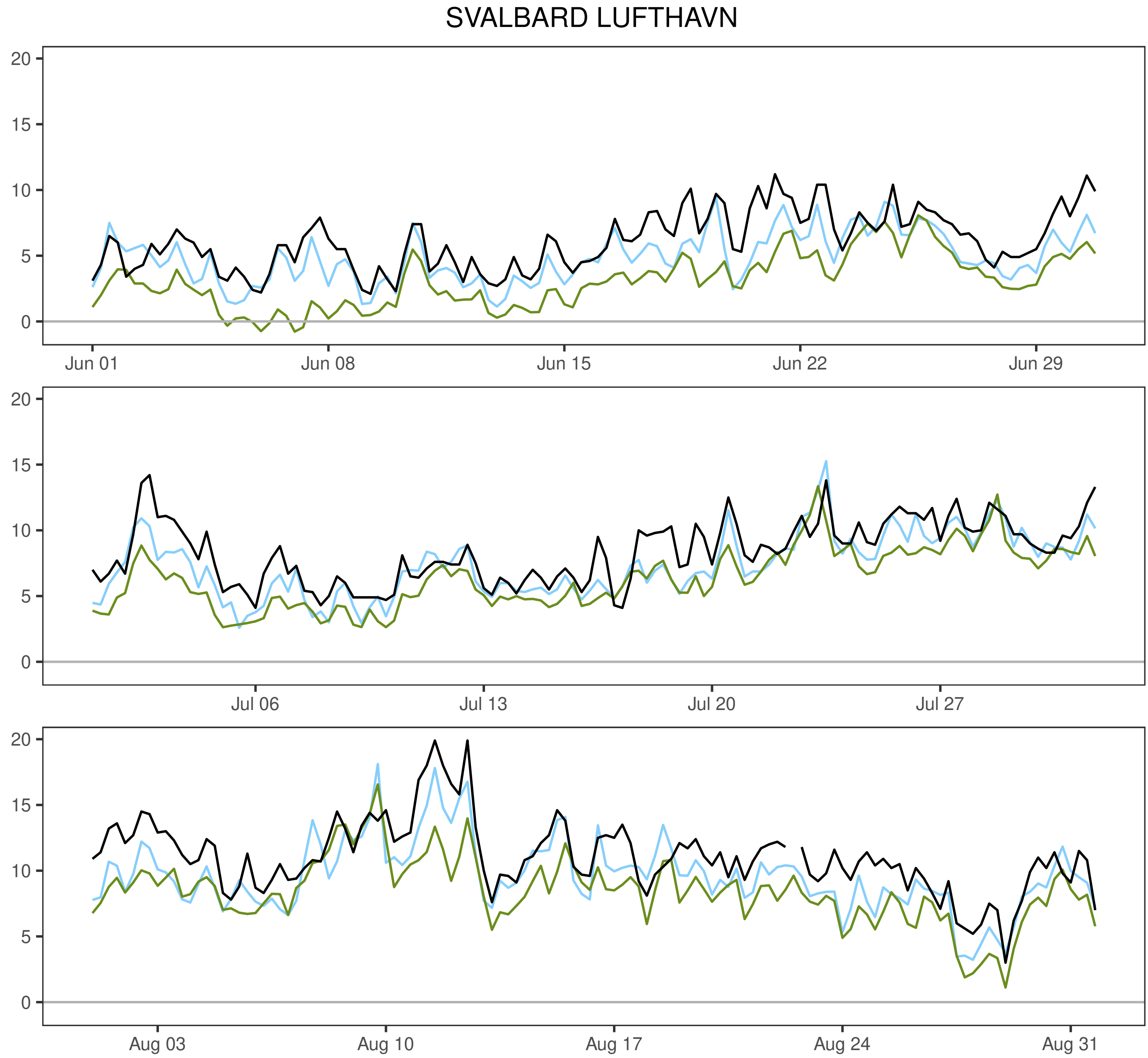

MEPSctrl 00+12
SDE at observing sites
(numbers in black)
°C
30
25
20
15
10
5
0
−5
−10
−15
−20
−25
−30
Model "climatology" 01.06.2024–31.08.2024

MEPSctrl 00+24

SDE at observing sites
(numbers in black)

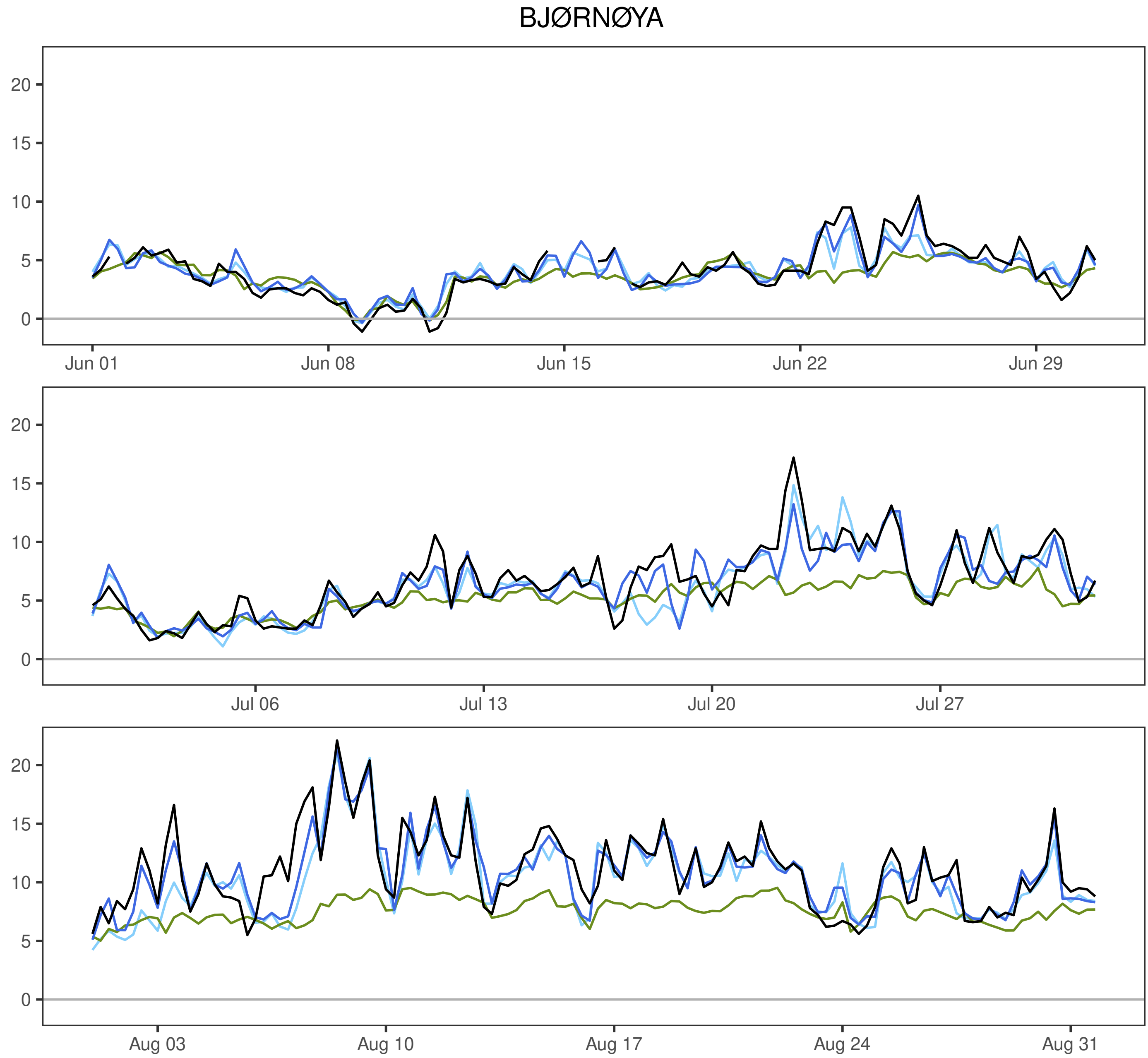


Model "climatology" 01.06.2024–31.08.2024



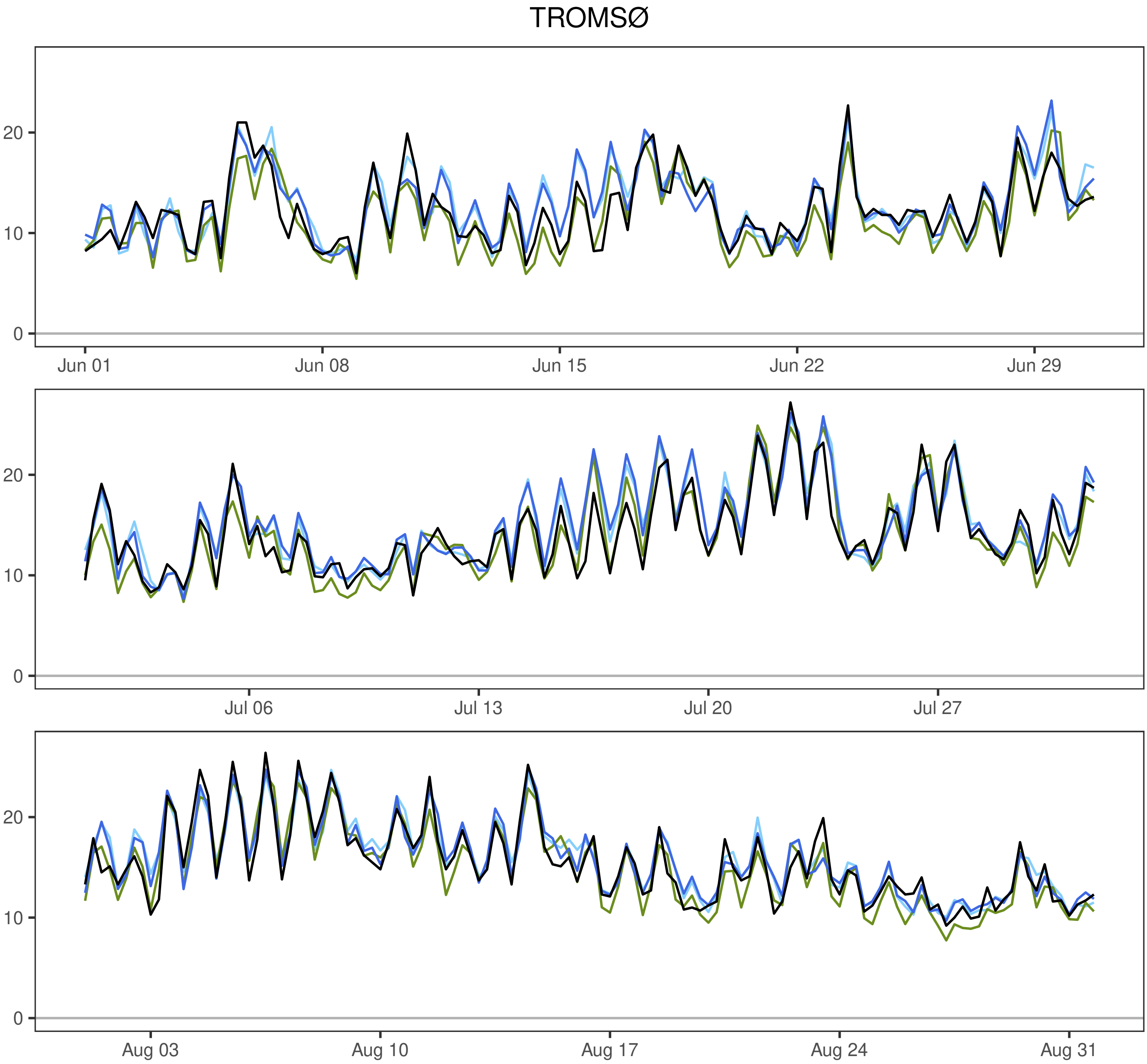
	Min	Mean	Max	Std	N
synop: 00,06,12,18	2.1	8.5	19.9	3.2	367
AA25: 12+18,+24,+30,+36	1.1	7.3	18.1	3.0	368
ECMWF: 12+18,+24,+30,+36	–0.8	6.0	16.6	3.2	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
AA25 – synop	–1.2	1.4	1.9	1.5	4.9	367
ECMWF – synop	–2.5	1.6	3.0	2.6	7.4	367



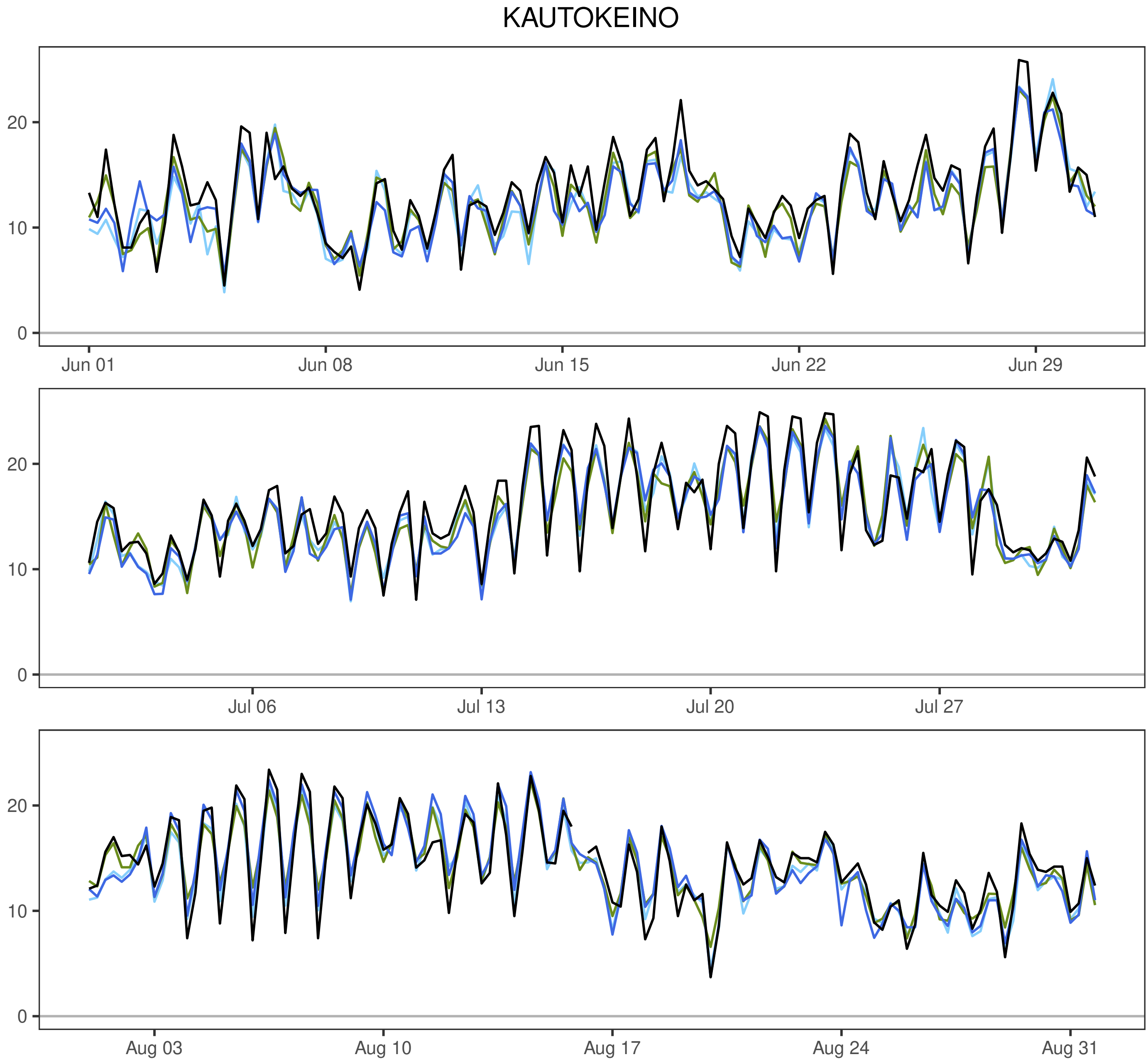
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−1.1	7.3	22.1	4.1	363
MEPSctrl: 12+18,+24,+30,+36	−0.3	7.1	21.6	3.7	368
AA25: 12+18,+24,+30,+36	−0.4	6.9	21.0	3.7	368
ECMWF: 12+18,+24,+30,+36	−0.1	5.5	9.5	2.0	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	−0.2	1.4	1.4	1.0	5.4	363
AA25 – synop	−0.4	1.6	1.7	1.1	7.2	363
ECMWF – synop	−1.9	2.5	3.1	2.2	13.2	363



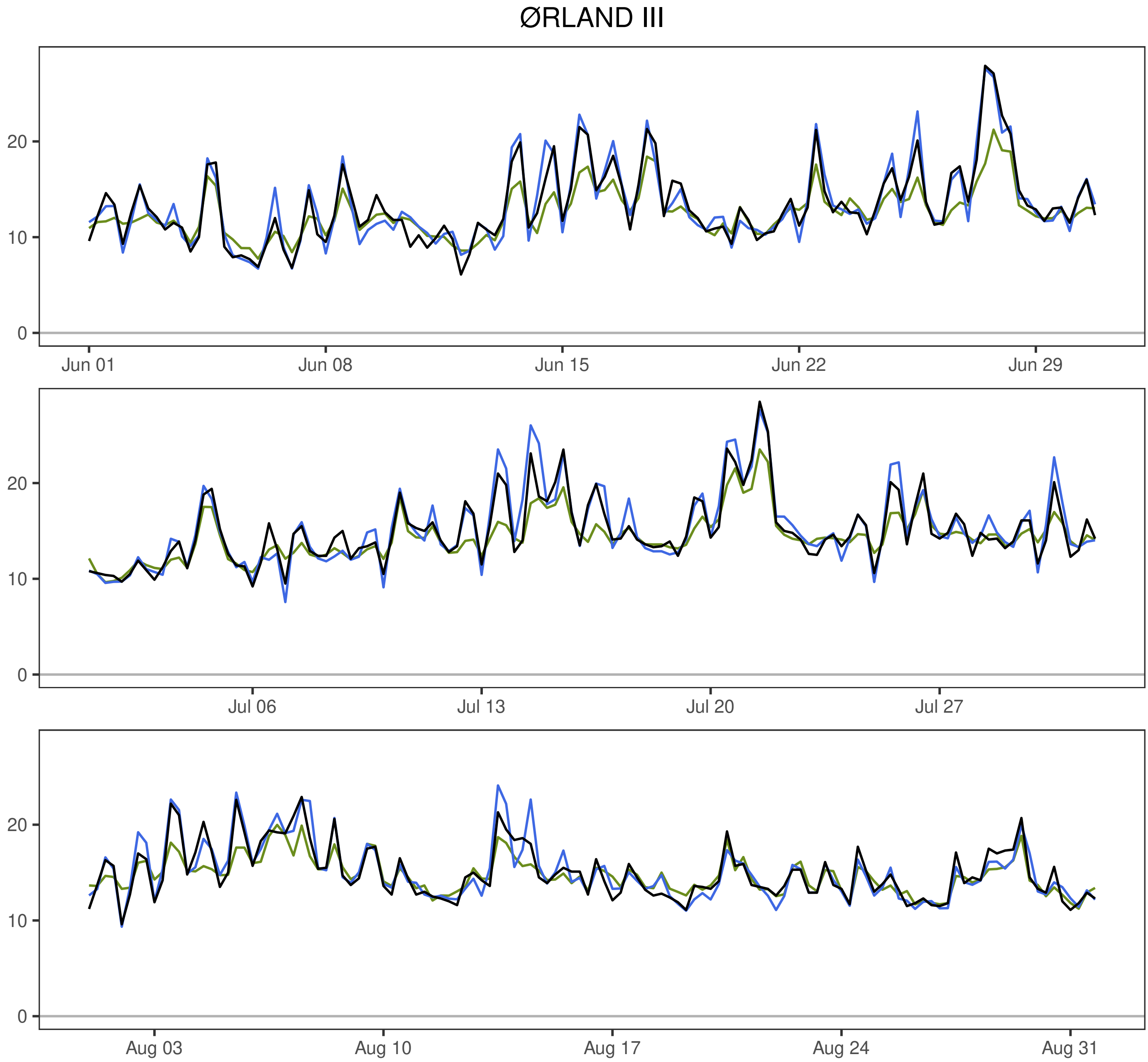
	Min	Mean	Max	Std	N
synop: 00,06,12,18	6.0	14.1	27.2	4.0	368
MEPSctrl: 12+18,+24,+30,+36	6.6	14.7	26.1	4.0	368
AA25: 12+18,+24,+30,+36	7.4	14.7	25.6	3.9	368
ECMWF: 12+18,+24,+30,+36	5.4	13.5	24.9	4.2	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.6	1.6	1.7	1.3	5.9	368
AA25 – synop	0.6	1.7	1.8	1.4	7.2	368
ECMWF – synop	−0.5	1.6	1.6	1.3	6.1	368



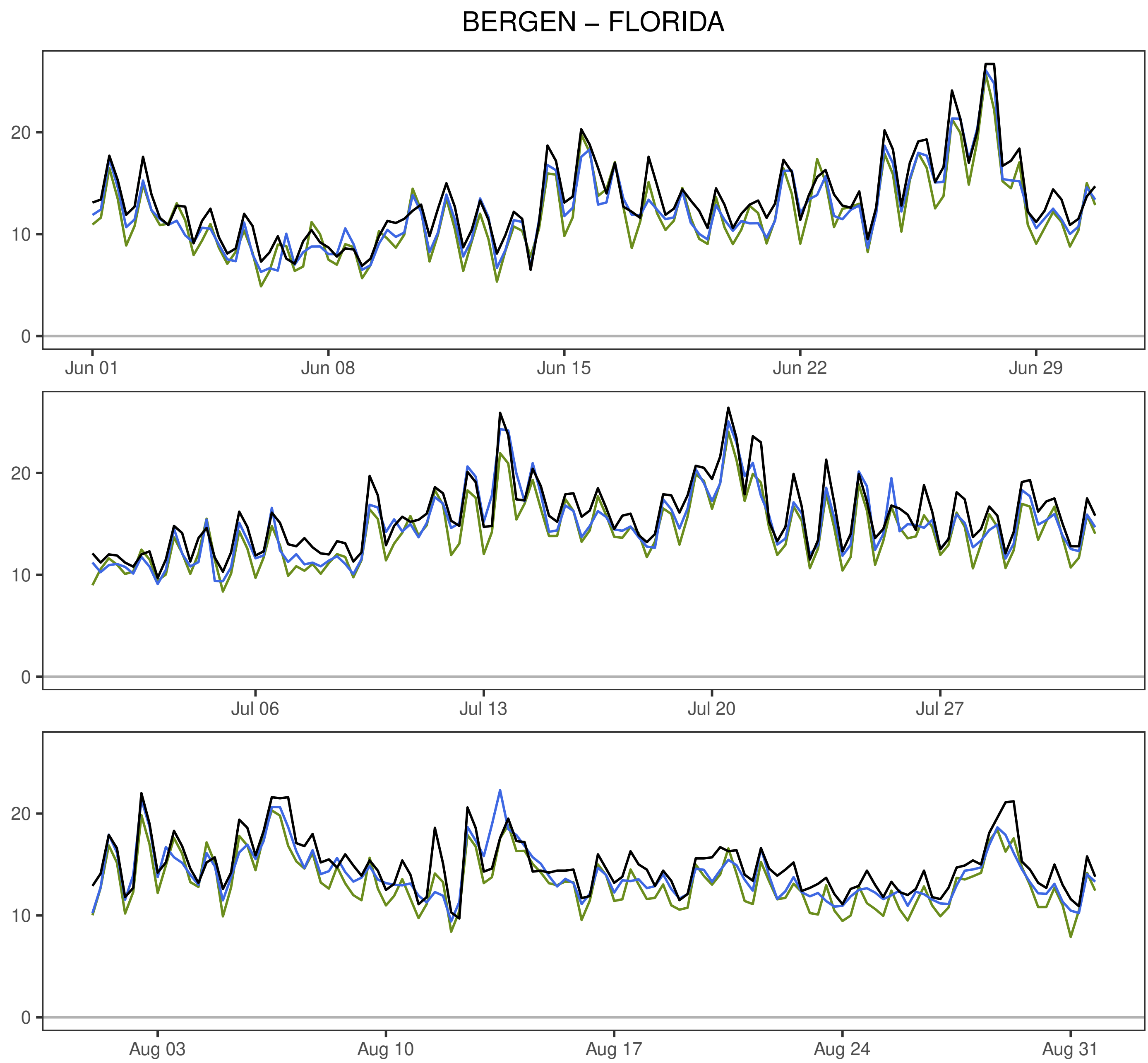
	Min	Mean	Max	Std	N
synop: 00,06,12,18	3.7	14.5	25.9	4.4	367
MEPSctrl: 12+18,+24,+30,+36	3.8	14.0	23.6	4.1	368
AA25: 12+18,+24,+30,+36	3.9	13.9	24.1	4.0	368
ECMWF: 12+18,+24,+30,+36	4.5	14.0	24.3	3.8	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.6	1.7	1.8	1.5	5.6	367
AA25 – synop	–0.7	1.7	1.8	1.4	6.8	367
ECMWF – synop	–0.5	1.7	1.7	1.4	5.0	367



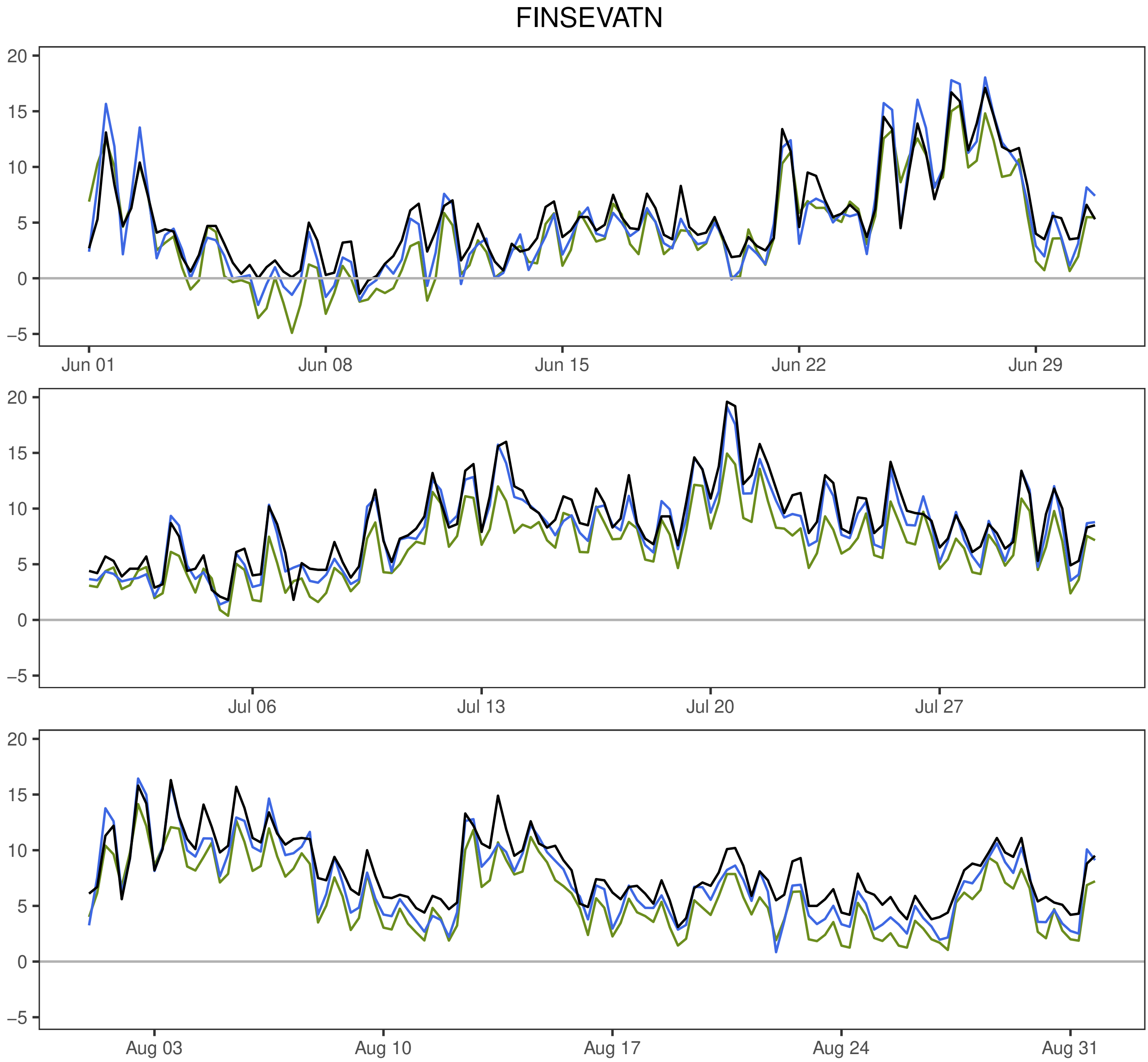
	Min	Mean	Max	Std	N
synop: 00,06,12,18	6.1	14.5	28.5	3.5	368
MEPSctrl: 12+18,+24,+30,+36	6.7	14.6	27.6	3.8	368
ECMWF: 12+18,+24,+30,+36	7.7	13.9	23.5	2.4	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.1	1.2	1.2	0.9	5.5	368
ECMWF – synop	–0.6	1.7	1.8	1.2	10.2	368



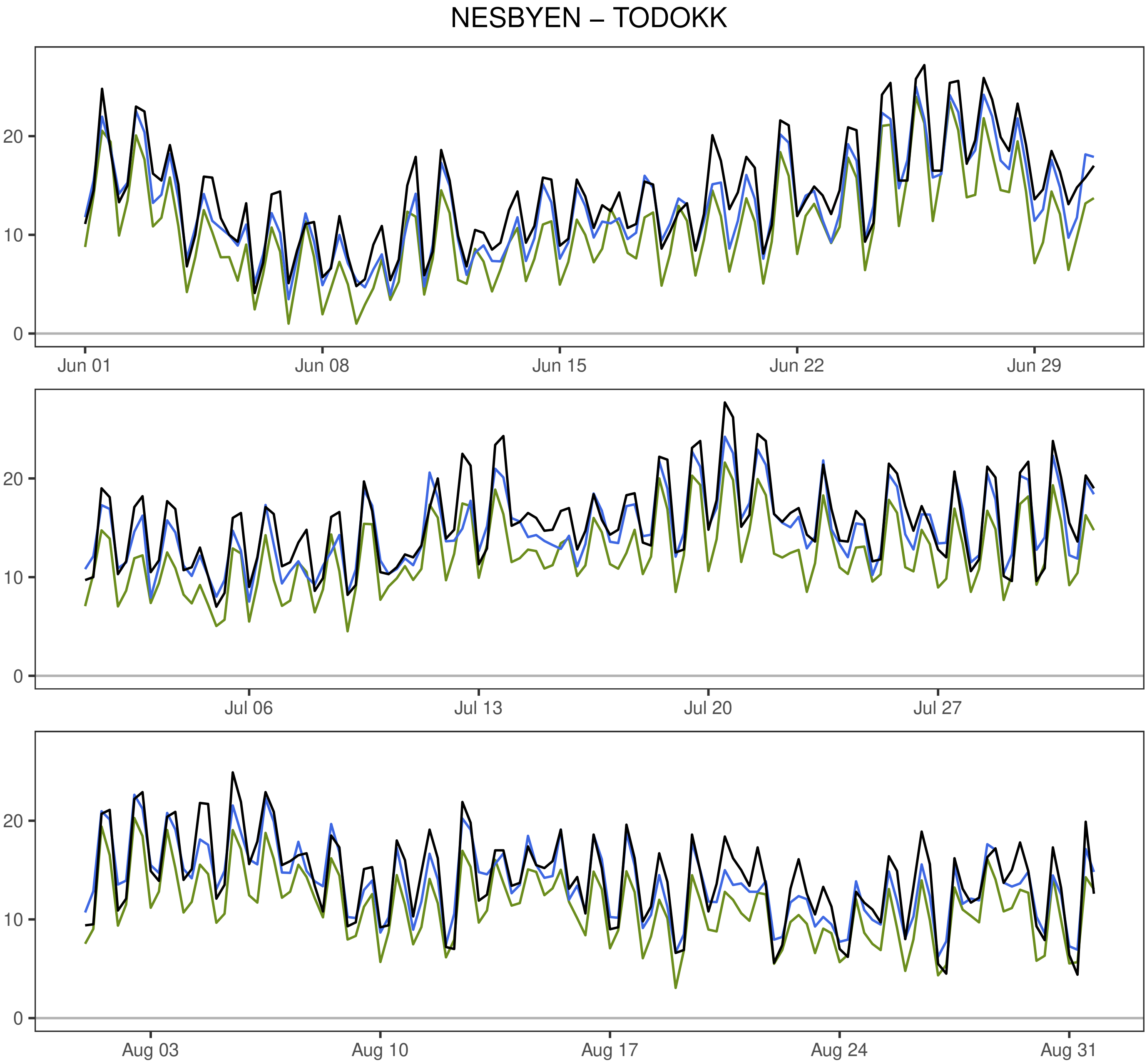
	Min	Mean	Max	Std	N
synop: 00,06,12,18	6.5	14.6	26.7	3.4	368
MEPSctrl: 12+18,+24,+30,+36	6.3	13.7	26.1	3.4	368
ECMWF: 12+18,+24,+30,+36	4.9	13.1	25.7	3.3	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.9	1.2	1.5	1.2	6.3	368
ECMWF – synop	–1.5	1.1	1.9	1.6	4.8	368



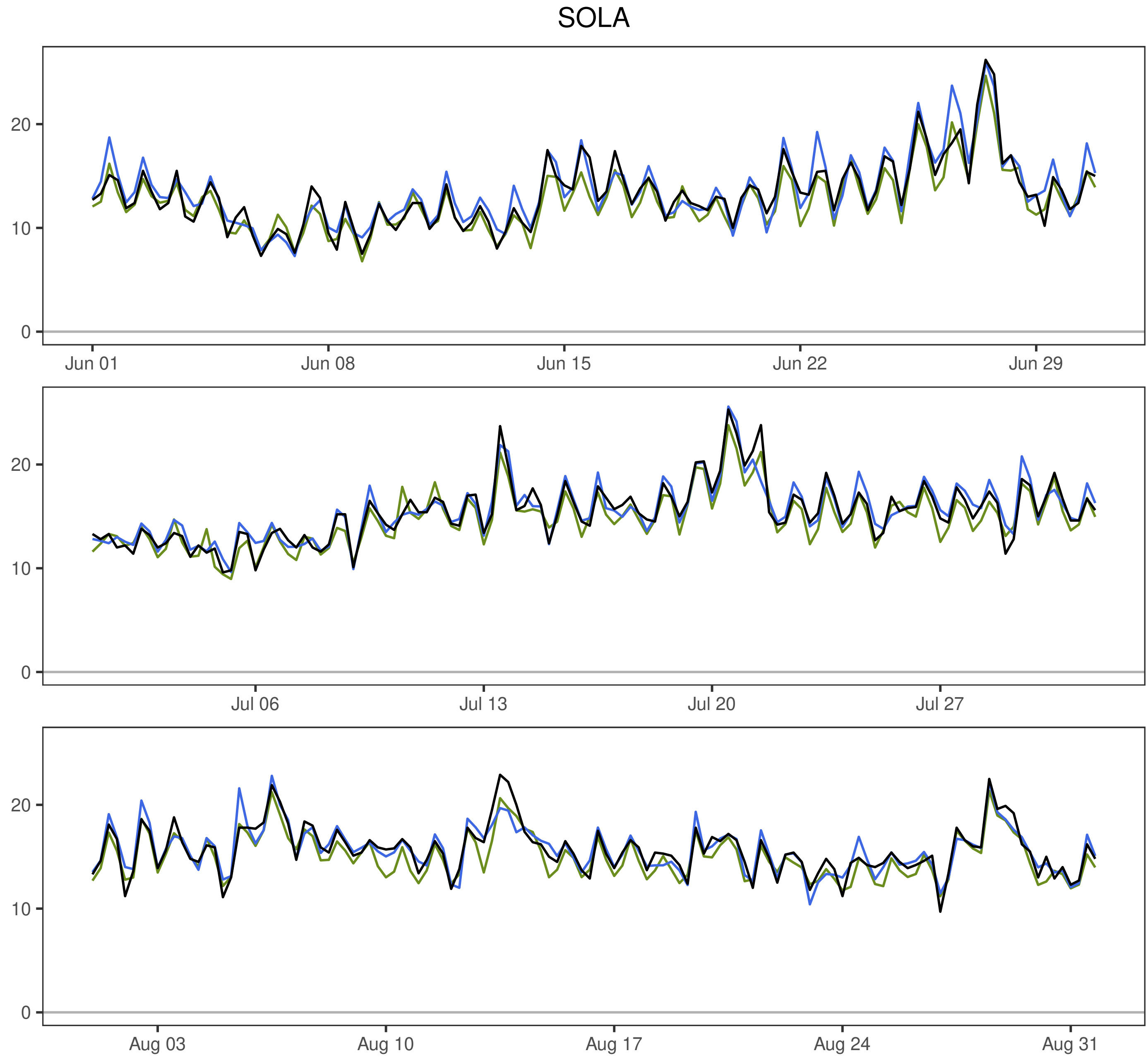
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−1.4	7.4	19.6	3.8	368
MEPSctrl: 12+18,+24,+30,+36	−2.4	6.7	19.1	4.1	368
ECMWF: 12+18,+24,+30,+36	−4.9	5.6	15.5	3.7	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	−0.7	1.1	1.3	1.1	4.7	368
ECMWF – synop	−1.9	1.3	2.3	2.0	5.3	368



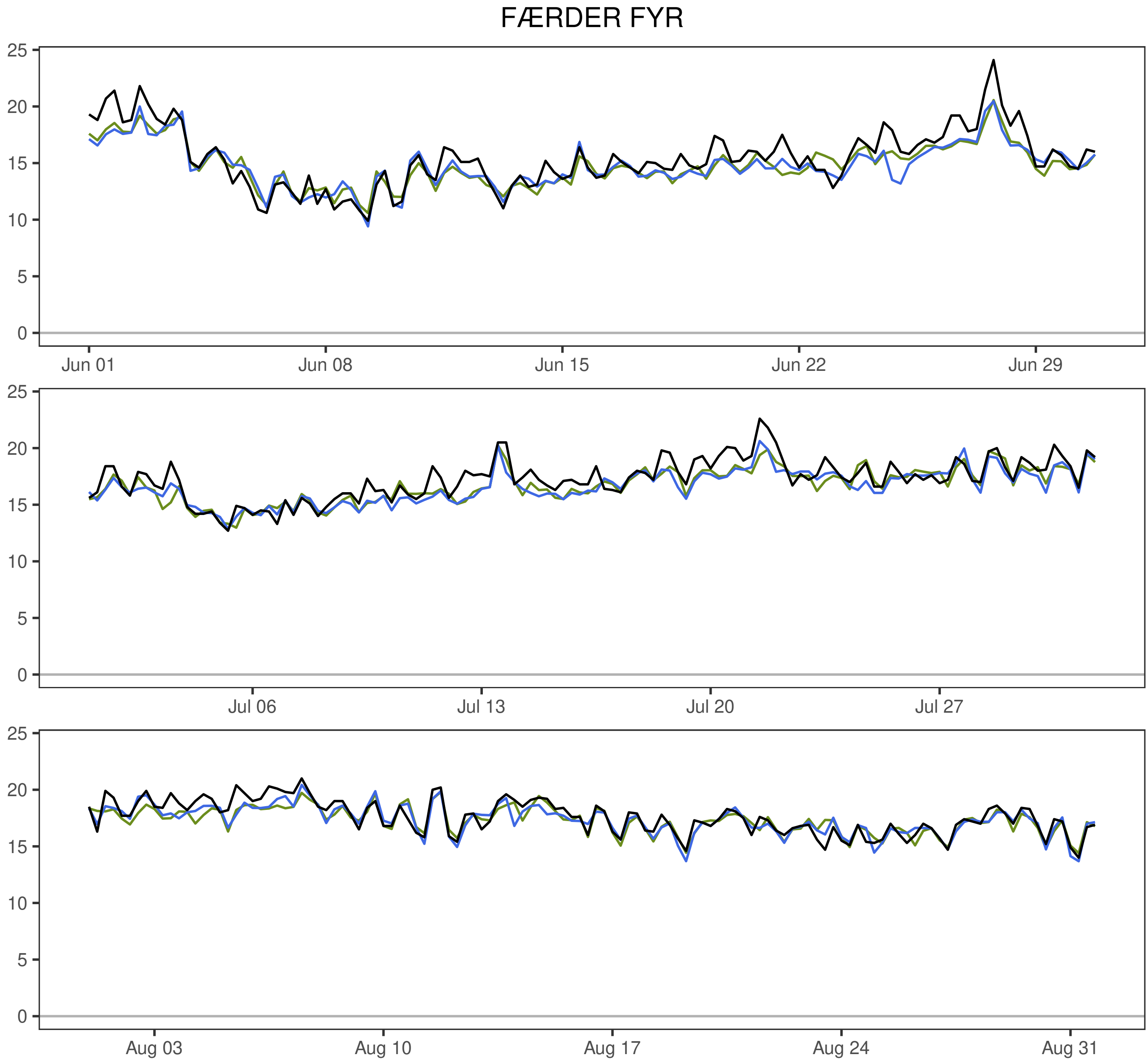
	Min	Mean	Max	Std	N
synop: 00,06,12,18	4.1	14.6	27.7	4.8	368
MEPSctrl: 12+18,+24,+30,+36	3.5	13.8	25.0	4.2	368
ECMWF: 12+18,+24,+30,+36	1.0	11.5	24.0	4.2	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.8	1.7	1.9	1.5	7.6	368
ECMWF – synop	–3.2	1.6	3.6	3.2	7.9	368



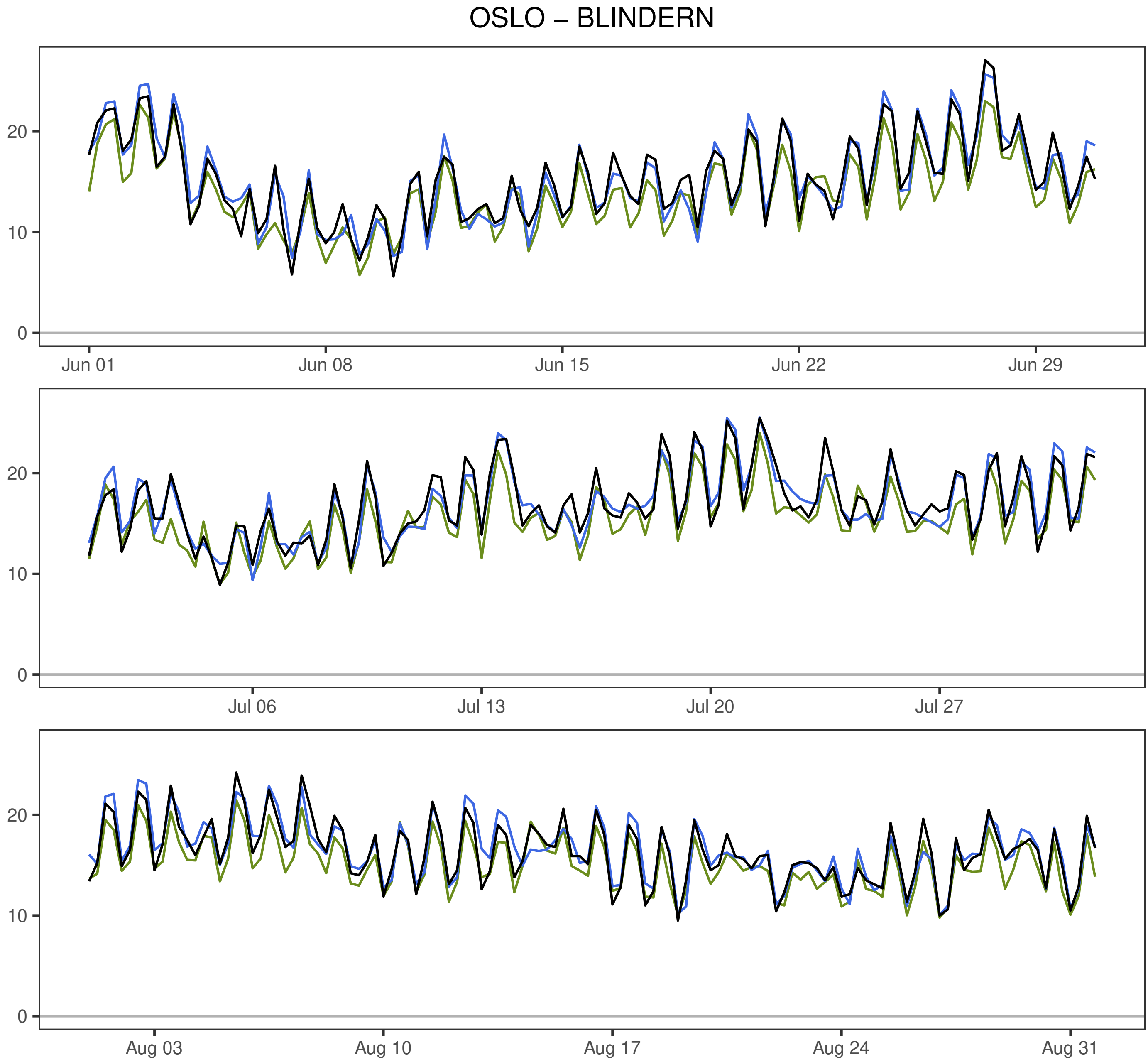
	Min	Mean	Max	Std	N
synop: 00,06,12,18	7.3	14.8	26.2	3.0	368
MEPSctrl: 12+18,+24,+30,+36	7.3	15.0	26.0	3.0	368
ECMWF: 12+18,+24,+30,+36	6.8	14.1	24.7	2.8	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.2	1.1	1.1	0.8	5.5	368
ECMWF – synop	−0.6	0.9	1.1	0.9	3.8	368



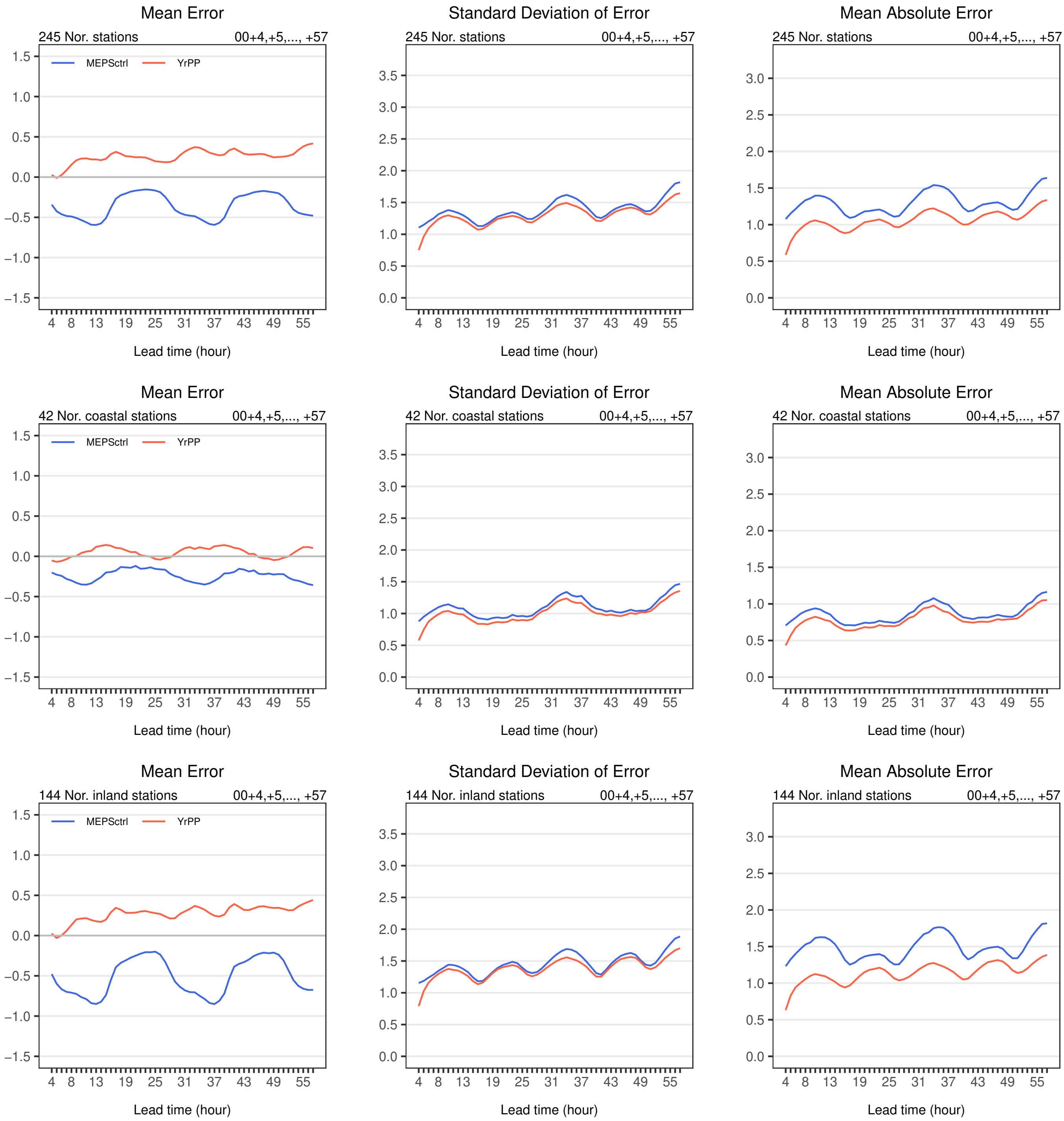
	Min	Mean	Max	Std	N
synop: 00,06,12,18	9.9	16.8	24.1	2.2	368
MEPSctrl: 12+18,+24,+30,+36	9.4	16.3	20.6	1.9	368
ECMWF: 12+18,+24,+30,+36	10.6	16.3	20.6	1.9	368

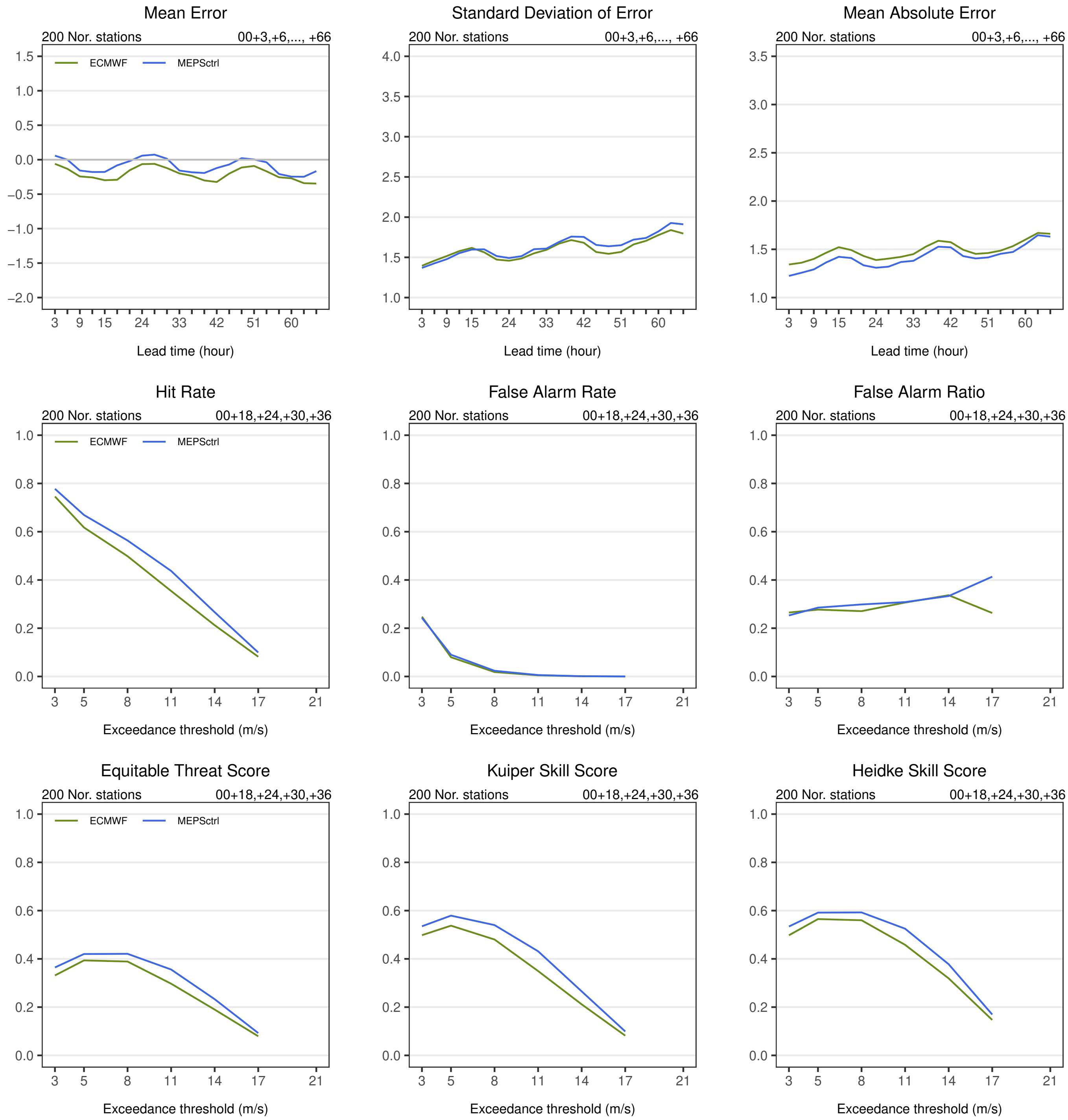
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.5	1.0	1.1	0.8	4.4	368
ECMWF – synop	–0.5	1.0	1.1	0.8	3.6	368

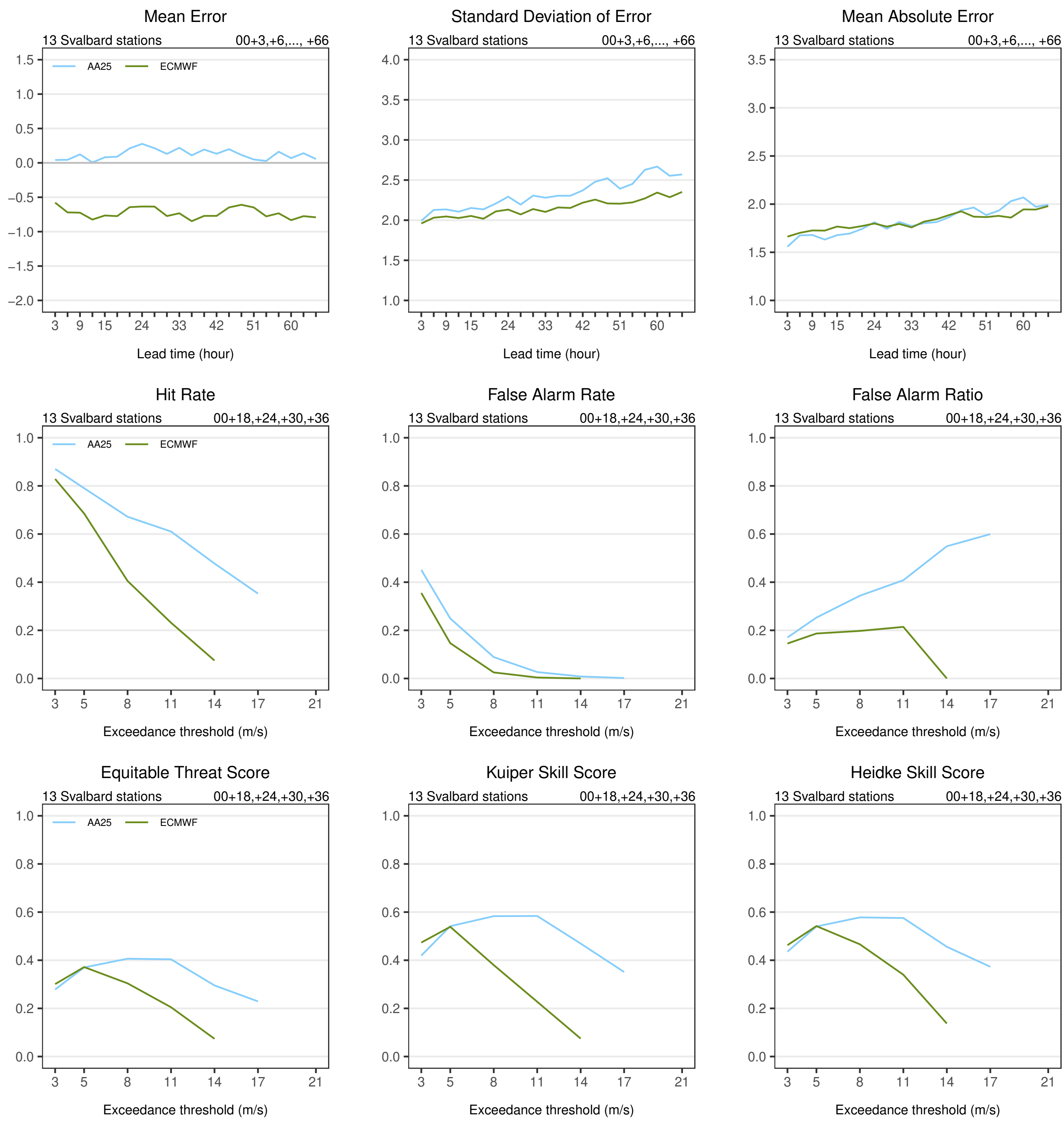


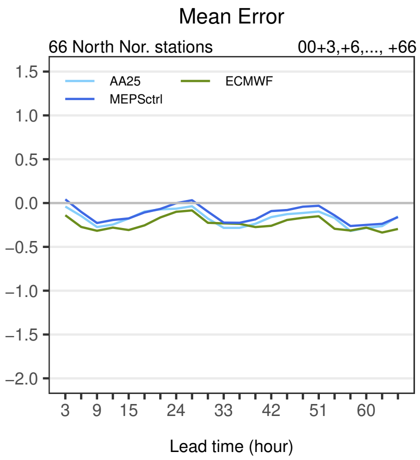
	Min	Mean	Max	Std	N
synop: 00,06,12,18	5.6	16.2	27.1	3.7	368
MEPSctrl: 12+18,+24,+30,+36	7.5	16.3	25.7	3.7	368
ECMWF: 12+18,+24,+30,+36	5.7	14.9	24.0	3.3	368

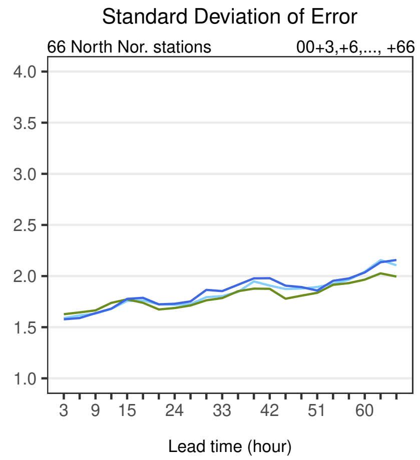
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.1	1.2	1.2	0.9	4.0	368
ECMWF – synop	–1.3	1.2	1.7	1.5	5.7	368

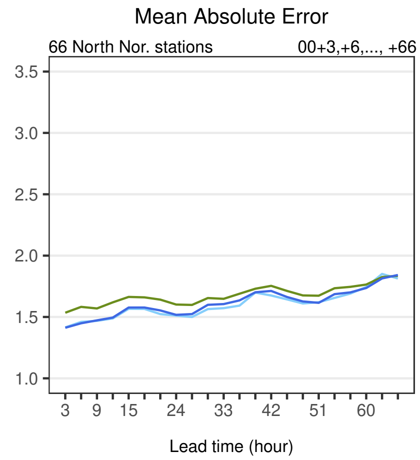

Mean Error
245 Nor. stations
00+4,+5,..., +57
MEPSctrl
YrPP
Lead time (hour)
Standard Deviation of Error
245 Nor. stations
00+4,+5,..., +57
Lead time (hour)
Mean Absolute Error
245 Nor. stations
00+4,+5,..., +57
Lead time (hour)
Mean Error
42 Nor. coastal stations
00+4,+5,..., +57
MEPSctrl
YrPP
Lead time (hour)
Standard Deviation of Error
42 Nor. coastal stations
00+4,+5,..., +57
Lead time (hour)
Mean Absolute Error
42 Nor. coastal stations
00+4,+5,..., +57
Lead time (hour)
Mean Error
144 Nor. inland stations
00+4,+5,..., +57
MEPSctrl
YrPP
Lead time (hour)
Standard Deviation of Error
144 Nor. inland stations
00+4,+5,..., +57
Lead time (hour)
Mean Absolute Error
144 Nor. inland stations
00+4,+5,..., +57
Lead time (hour)

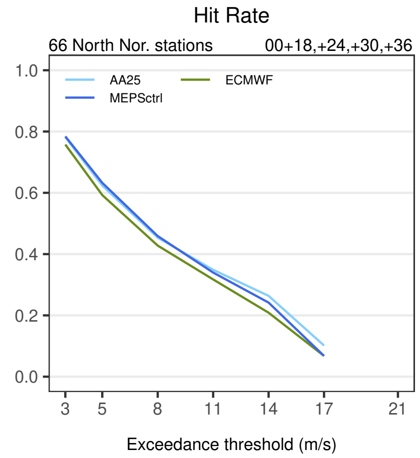

Mean Error
Standard Deviation of Error
Mean Absolute Error
200 Nor. stations
00+3,+6,..., +66
Lead time (hour)
Hit Rate
False Alarm Rate
False Alarm Ratio
200 Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)
Equitable Threat Score
Kuiper Skill Score
Heidke Skill Score
ECMWF
MEPSctrl

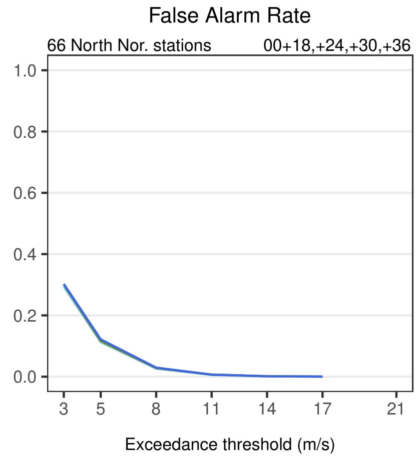

Mean Error
13 Svalbard stations
00+3,+6,..., +66
AA25
ECMWF
Lead time (hour)
Standard Deviation of Error
13 Svalbard stations
00+3,+6,..., +66
Lead time (hour)
Mean Absolute Error
13 Svalbard stations
00+3,+6,..., +66
Lead time (hour)
Hit Rate
13 Svalbard stations
00+18,+24,+30,+36
AA25
ECMWF
Exceedance threshold (m/s)
False Alarm Rate
13 Svalbard stations
00+18,+24,+30,+36
Exceedance threshold (m/s)
False Alarm Ratio
13 Svalbard stations
00+18,+24,+30,+36
Exceedance threshold (m/s)
Equitable Threat Score
13 Svalbard stations
00+18,+24,+30,+36
AA25
ECMWF
Exceedance threshold (m/s)
Kuiper Skill Score
13 Svalbard stations
00+18,+24,+30,+36
Exceedance threshold (m/s)
Heidke Skill Score
13 Svalbard stations
00+18,+24,+30,+36
Exceedance threshold (m/s)

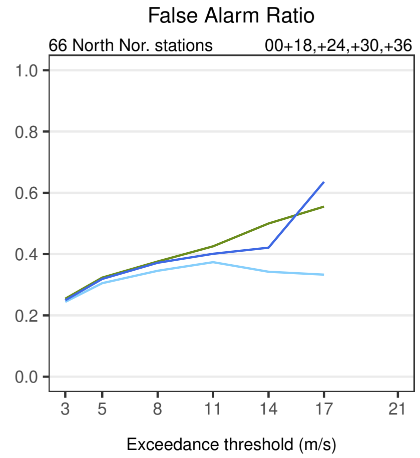

Mean Error
66 North Nor. stations
00+3,+6,..., +66
AA25
MEPSctrl
ECMWF
Lead time (hour)

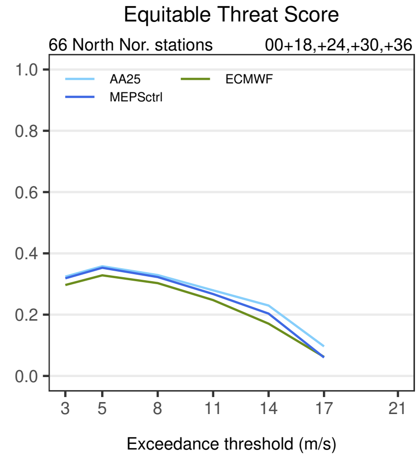

Standard Deviation of Error
66 North Nor. stations
00+3,+6,..., +66
Lead time (hour)

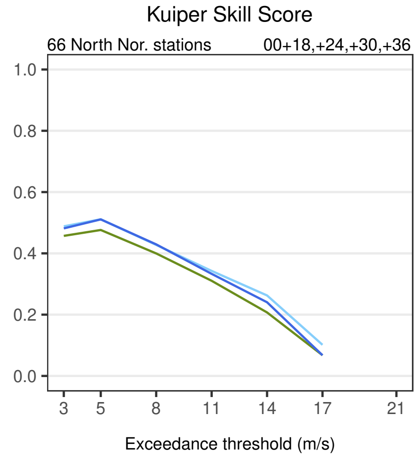

Mean Absolute Error
66 North Nor. stations
00+3,+6,..., +66
Lead time (hour)

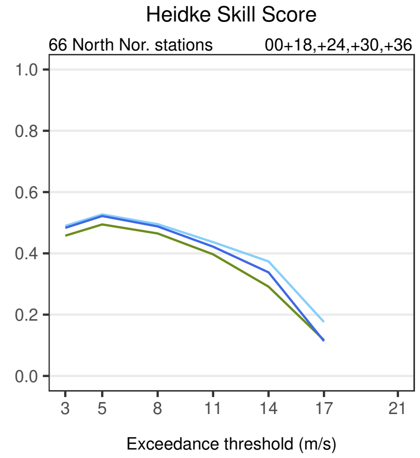

Hit Rate
66 North Nor. stations
00+18,+24,+30,+36
AA25
MEPSctrl
ECMWF
Exceedance threshold (m/s)

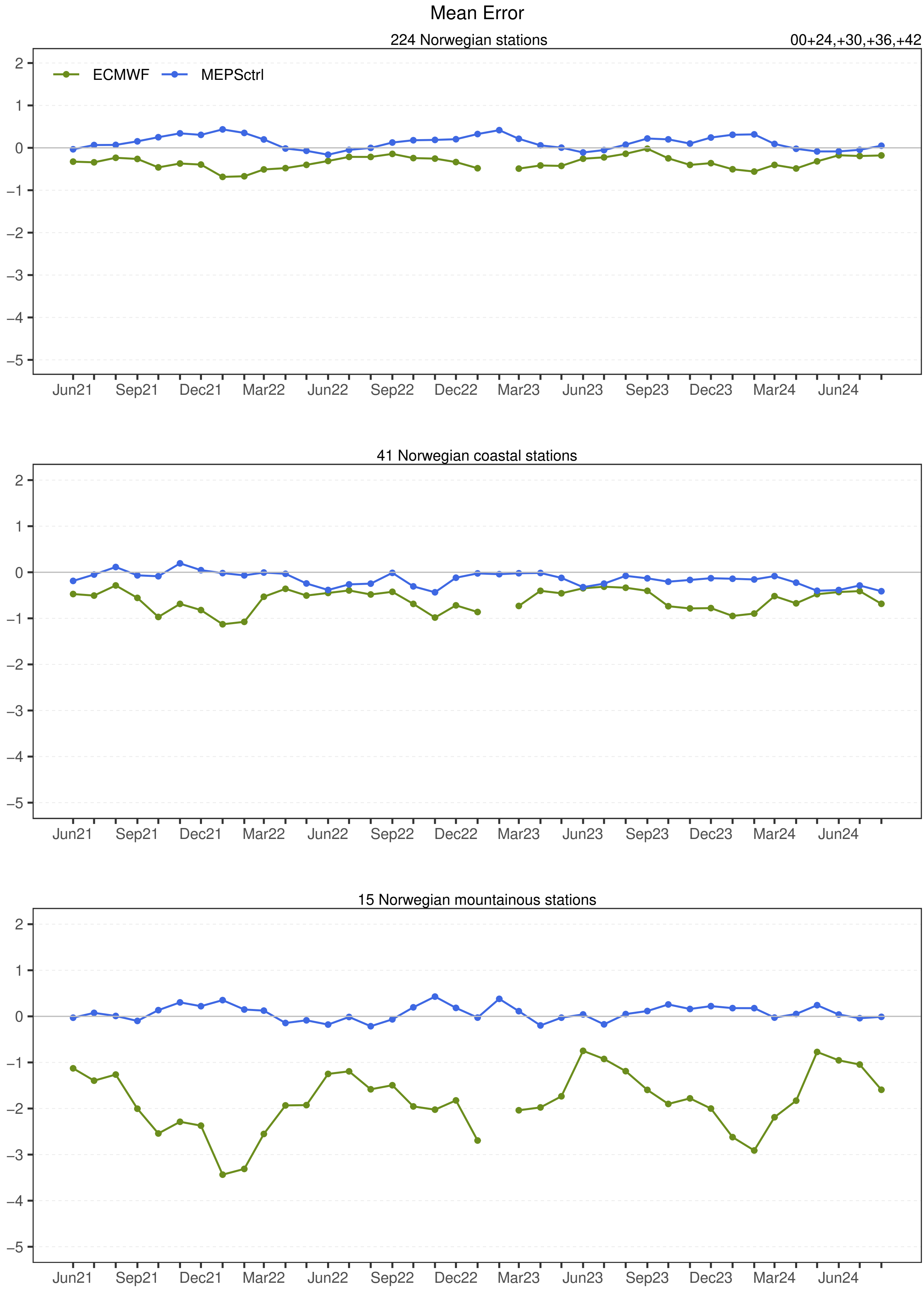

False Alarm Rate
66 North Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)

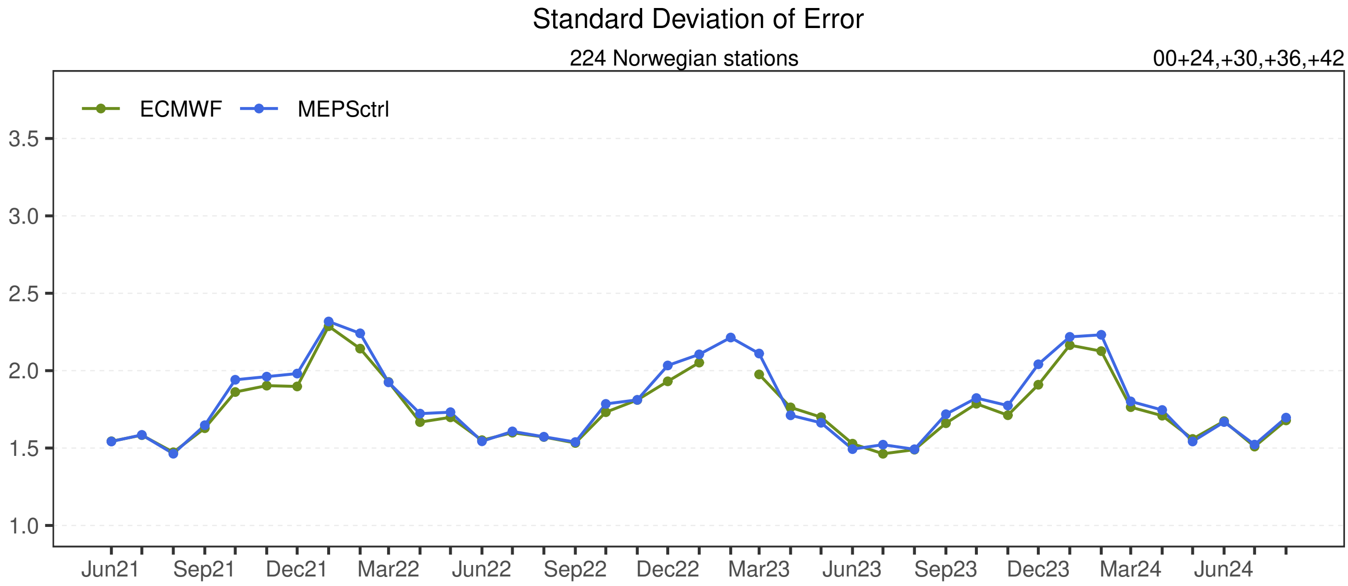

False Alarm Ratio
66 North Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)

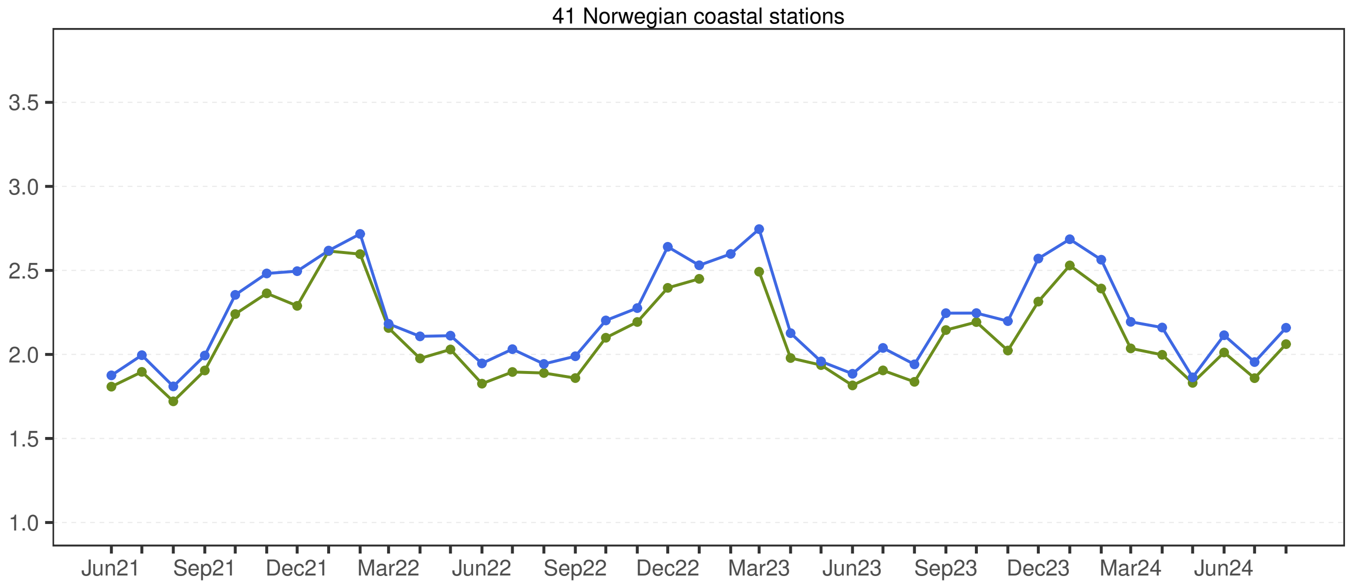

Equitable Threat Score
66 North Nor. stations
00+18,+24,+30,+36
AA25
MEPSctrl
ECMWF
Exceedance threshold (m/s)

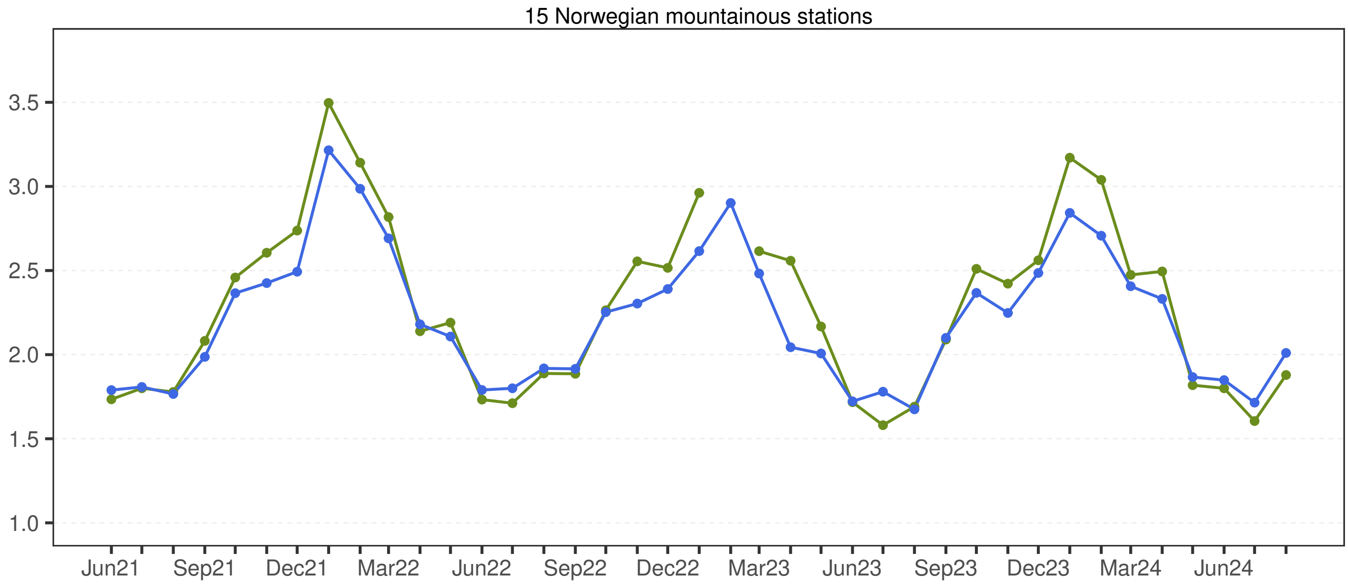

Kuiper Skill Score
66 North Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)

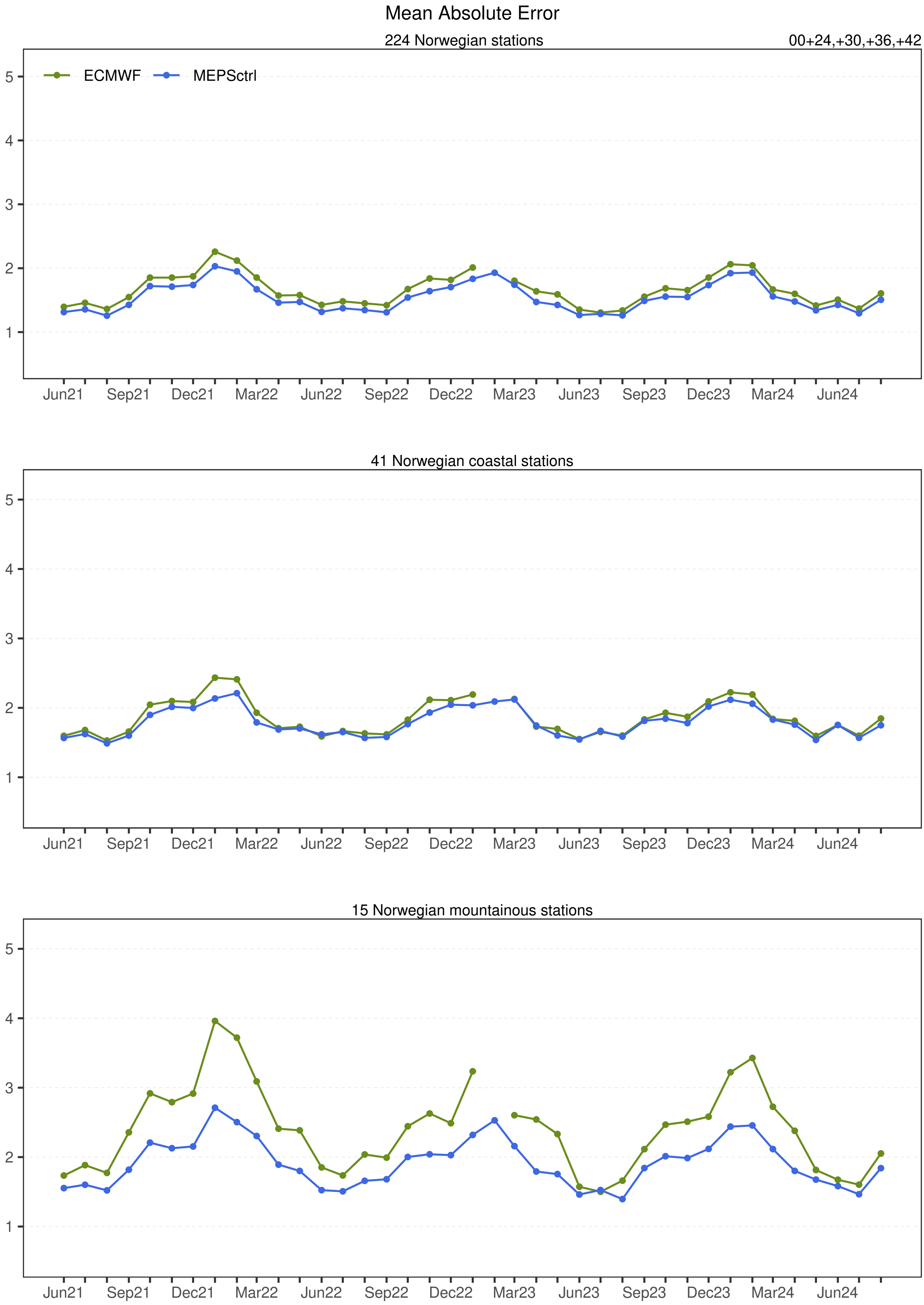

Heidke Skill Score
66 North Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)


Mean Error
224 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
2
1
0
−1
−2
−3
−4
−5
Jun21 Sep21 Dec21 Mar22 Jun22 Sep22 Dec22 Mar23 Jun23 Sep23 Dec23 Mar24 Jun24
41 Norwegian coastal stations
15 Norwegian mountainous stations


Standard Deviation of Error
224 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
3.5
3.0
2.5
2.0
1.5
1.0
Jun21 Sep21 Dec21 Mar22 Jun22 Sep22 Dec22 Mar23 Jun23 Sep23 Dec23 Mar24 Jun24

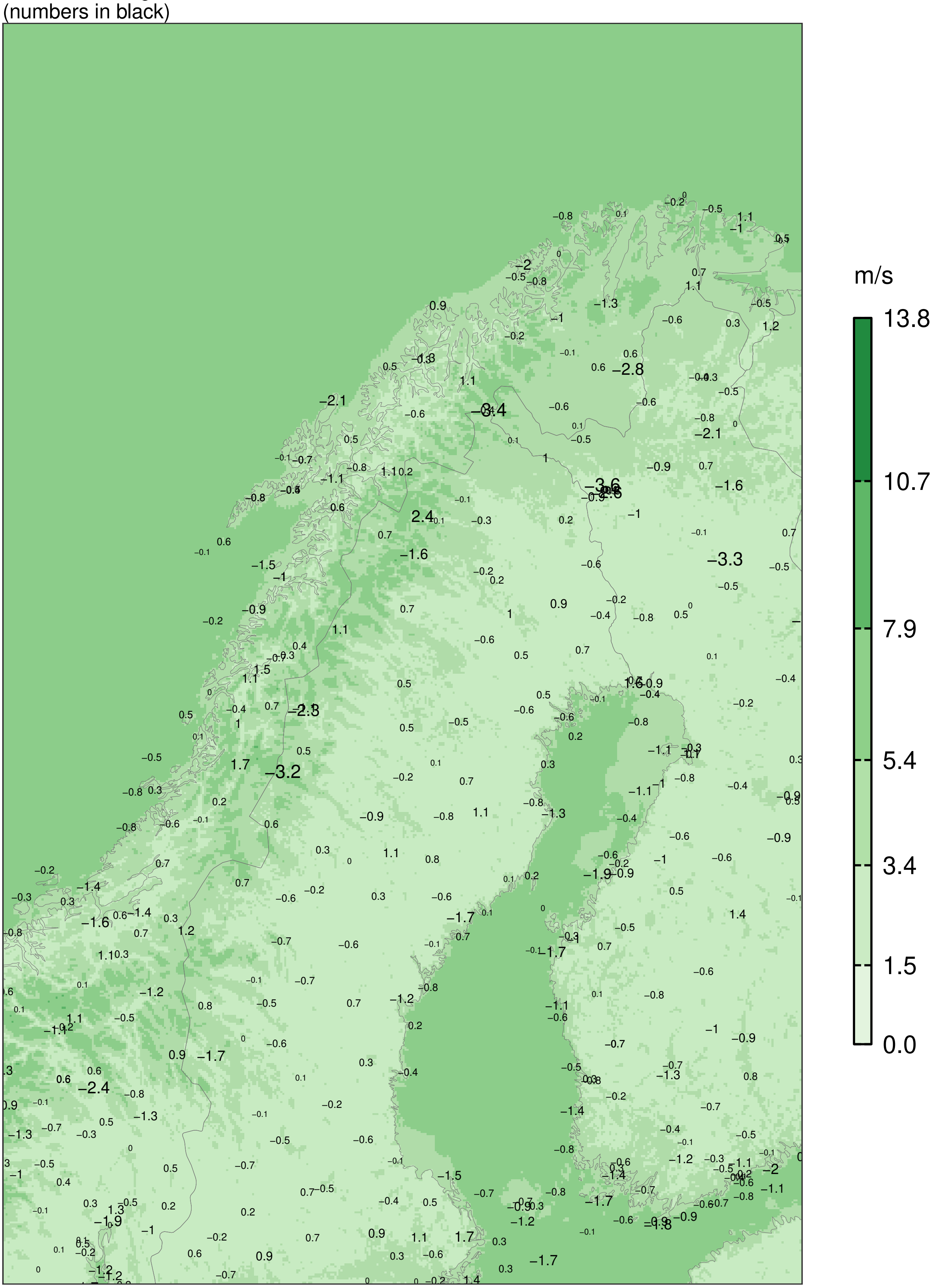

41 Norwegian coastal stations
3.5
3.0
2.5
2.0
1.5
1.0
Jun21 Sep21 Dec21 Mar22 Jun22 Sep22 Dec22 Mar23 Jun23 Sep23 Dec23 Mar24 Jun24


15 Norwegian mountainous stations
3.5
3.0
2.5
2.0
1.5
1.0
Jun21 Sep21 Dec21 Mar22 Jun22 Sep22 Dec22 Mar23 Jun23 Sep23 Dec23 Mar24 Jun24


Mean Absolute Error
224 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
41 Norwegian coastal stations
15 Norwegian mountainous stations
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24

MEPSctrl 00+12

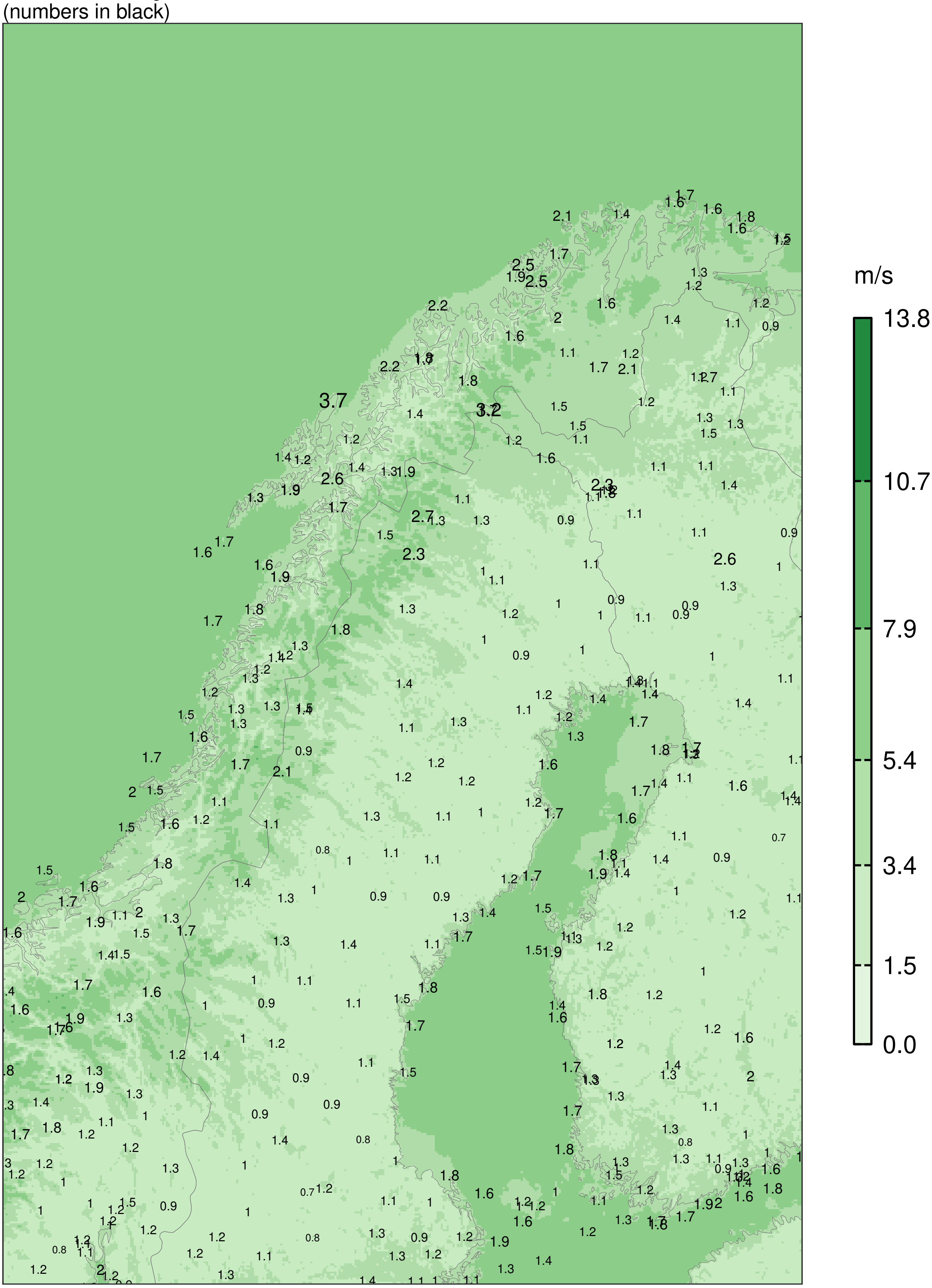
ME at observing sites
(numbers in black)



Model "climatology" 01.06.2024–31.08.2024

MEPSctrl 00+12

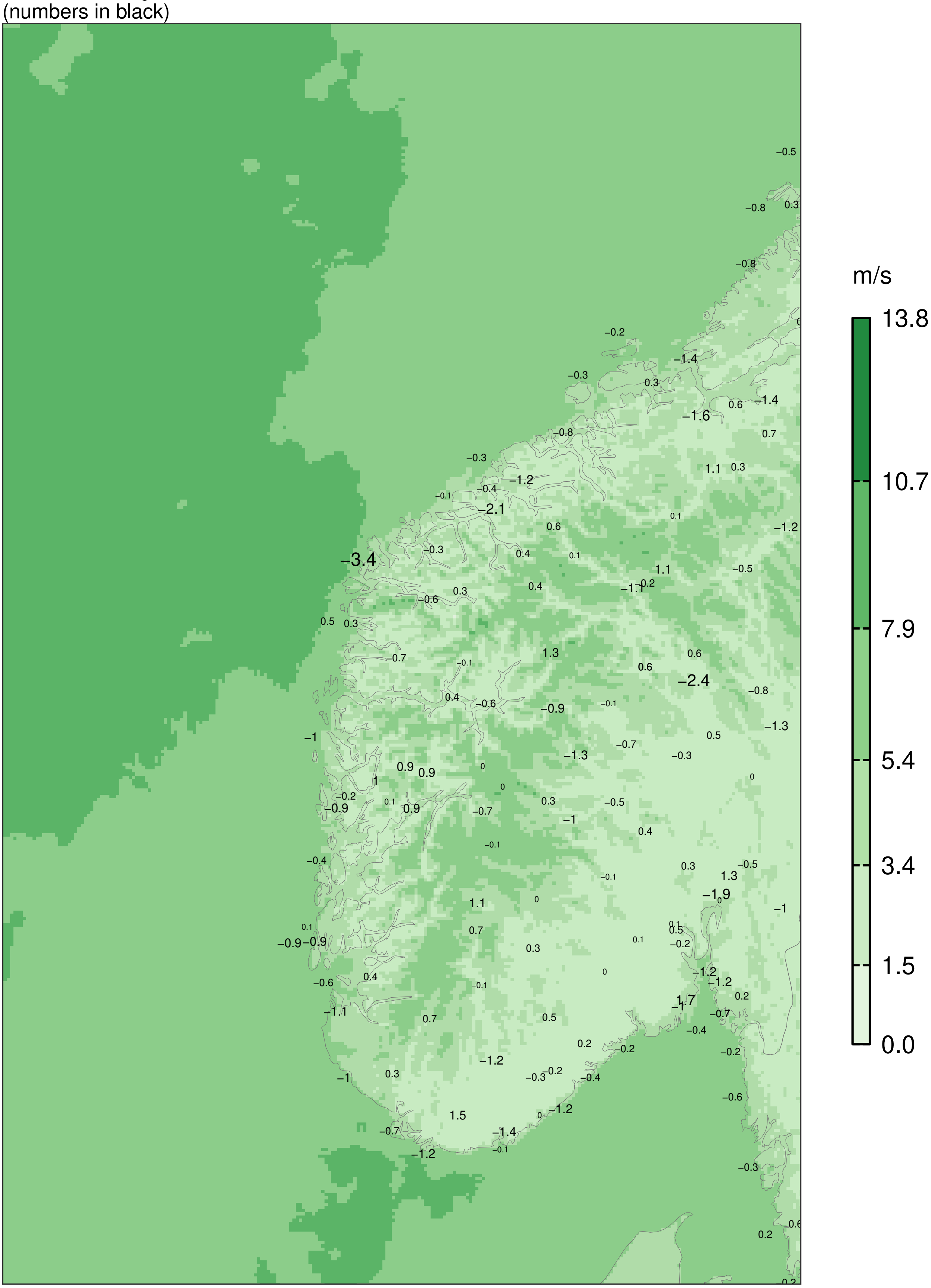
SDE at observing sites
(numbers in black)



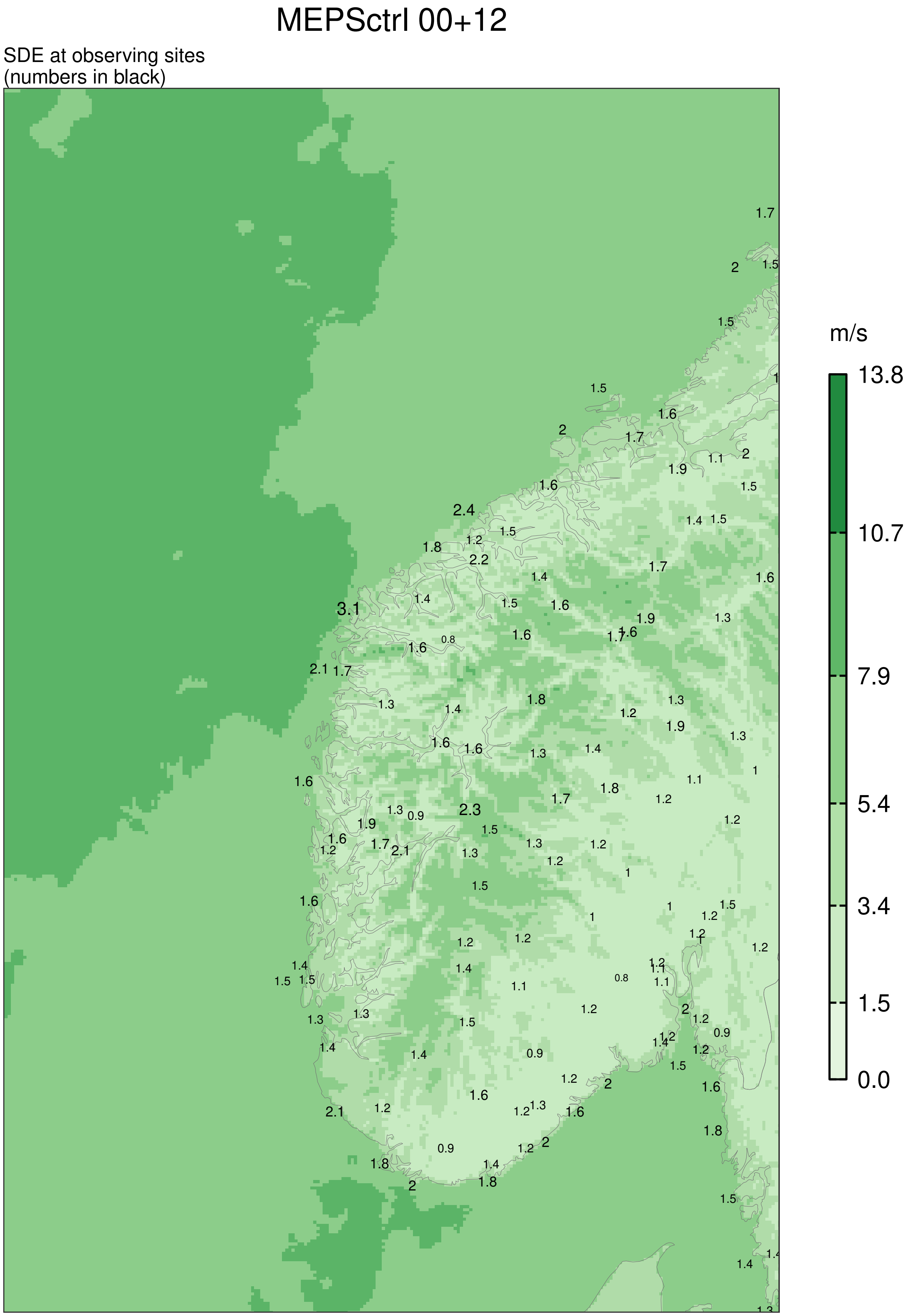
Model "climatology" 01.06.2024–31.08.2024

MEPSctrl 00+12

ME at observing sites
(numbers in black)



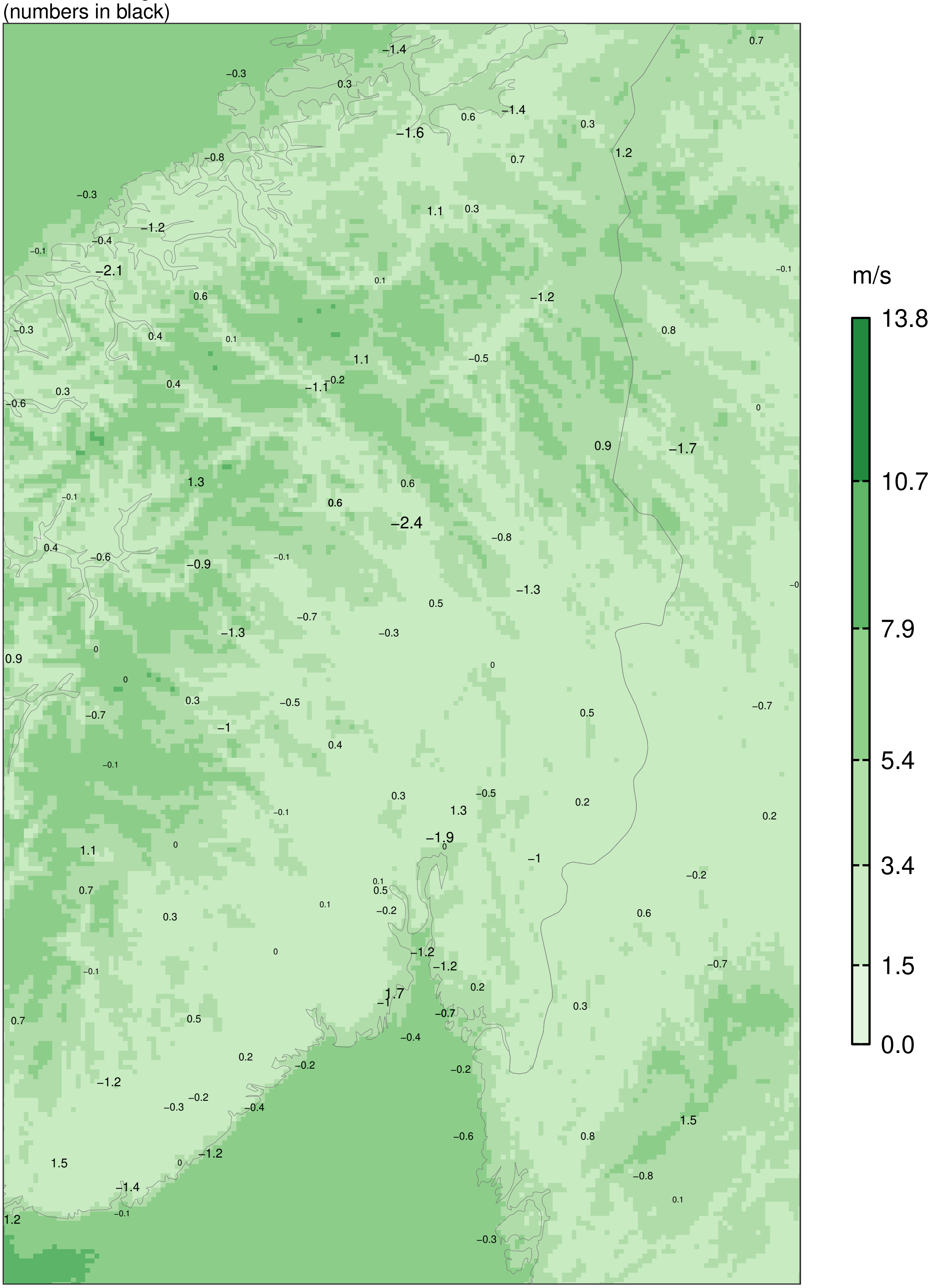
Model "climatology" 01.06.2024–31.08.2024



Model "climatology" 01.06.2024–31.08.2024

MEPSctrl 00+12

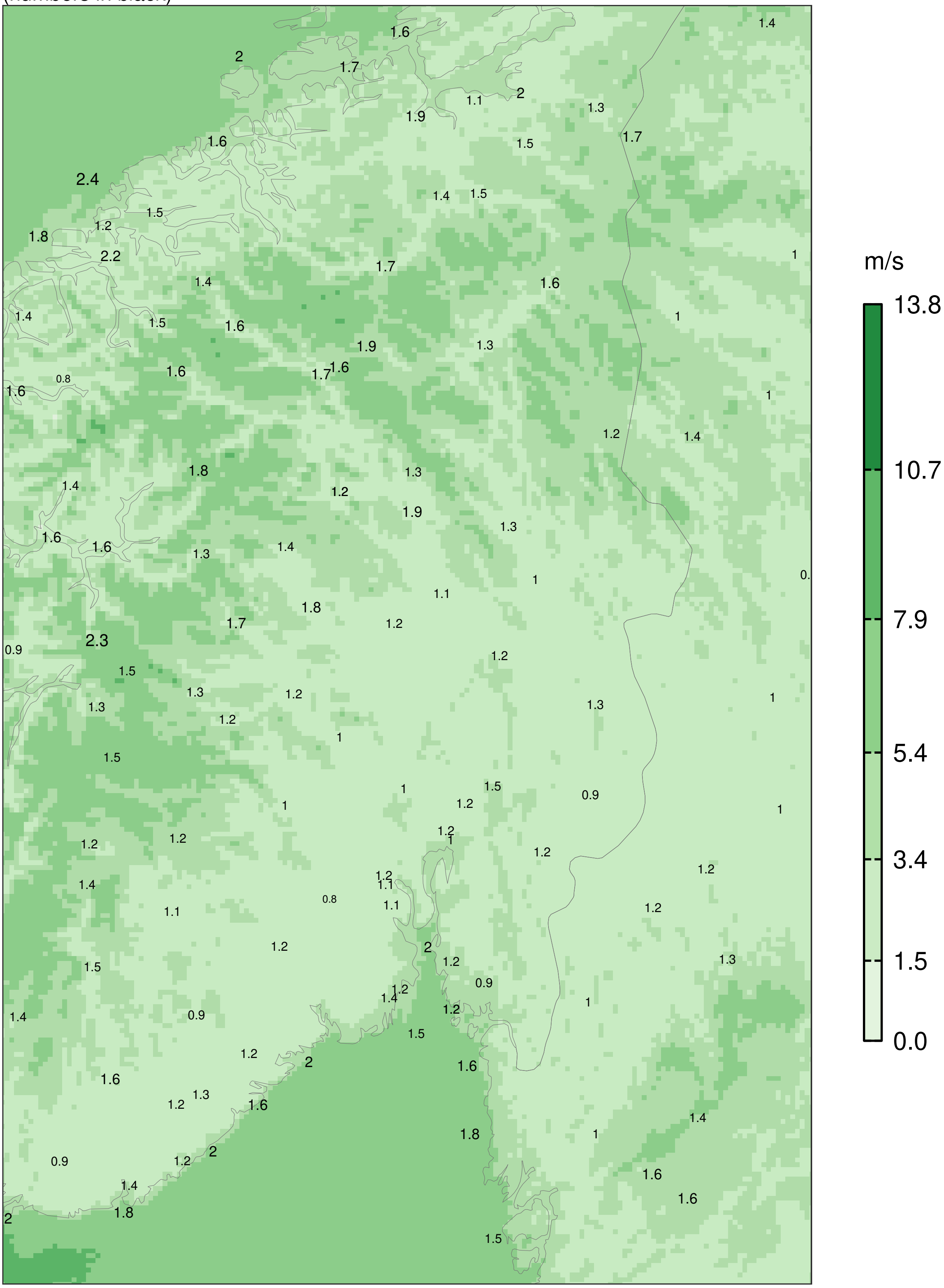
ME at observing sites
(numbers in black)



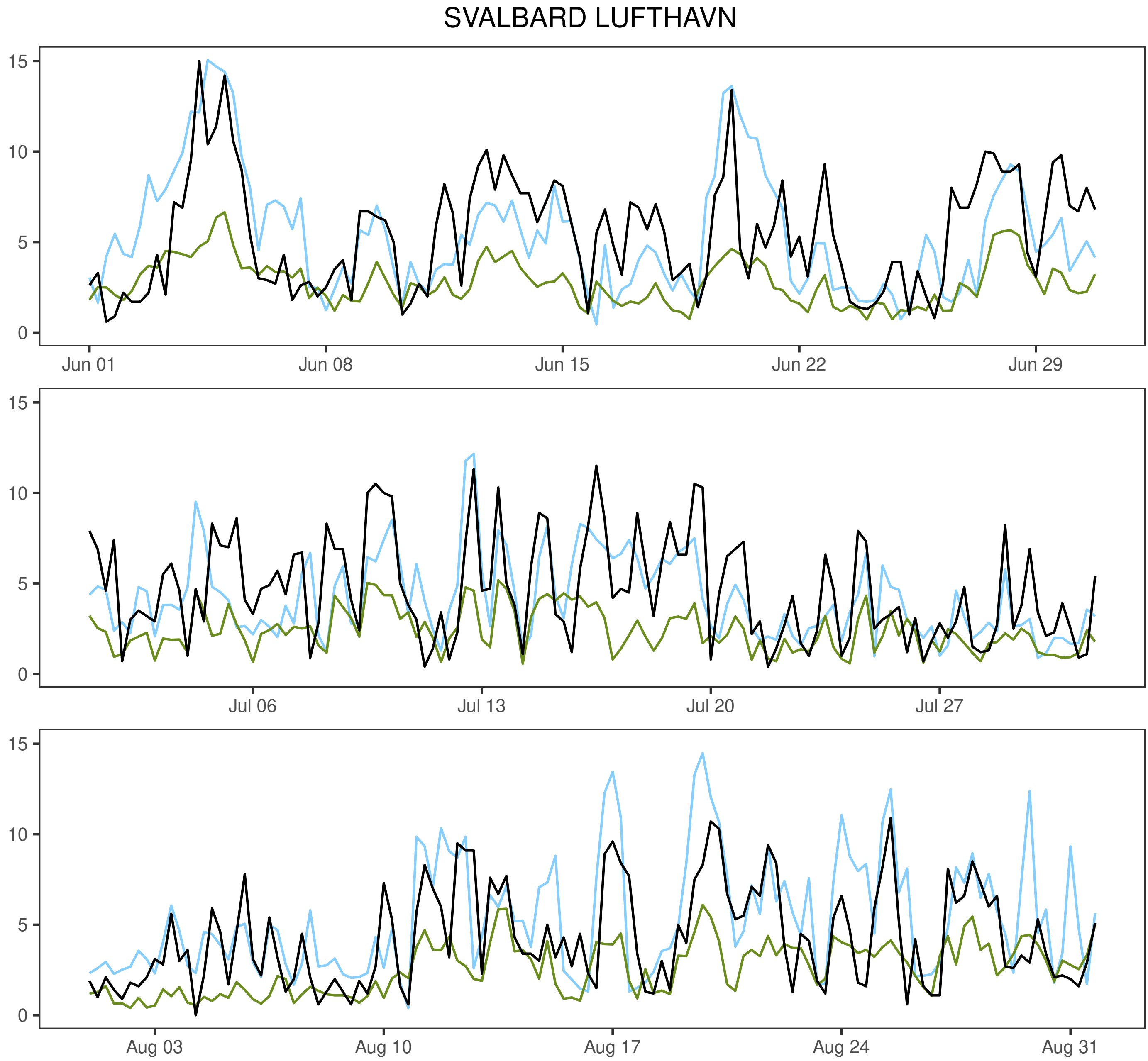
Model "climatology" 01.06.2024–31.08.2024

MEPSctrl 00+12

SDE at observing sites
(numbers in black)

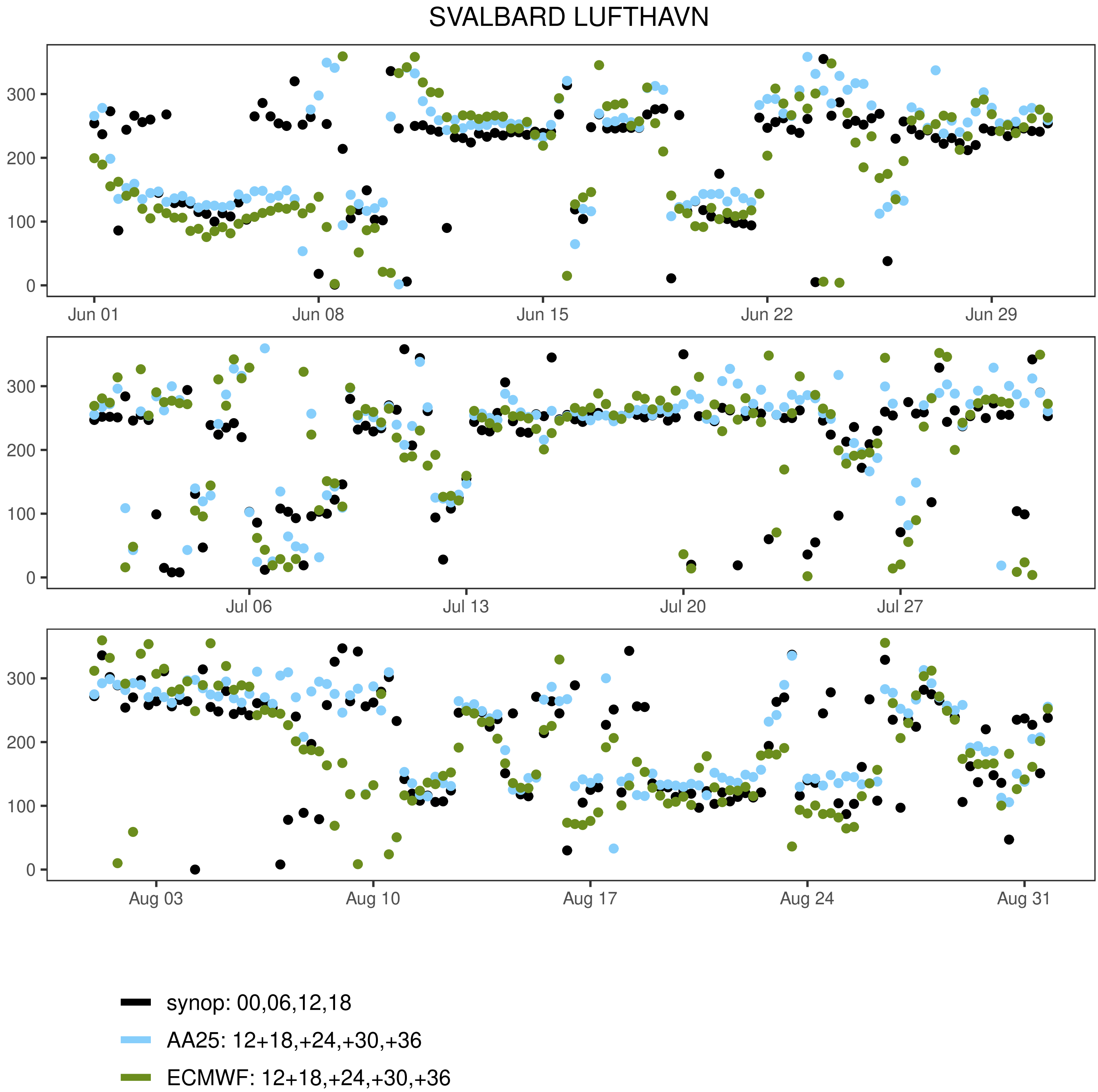


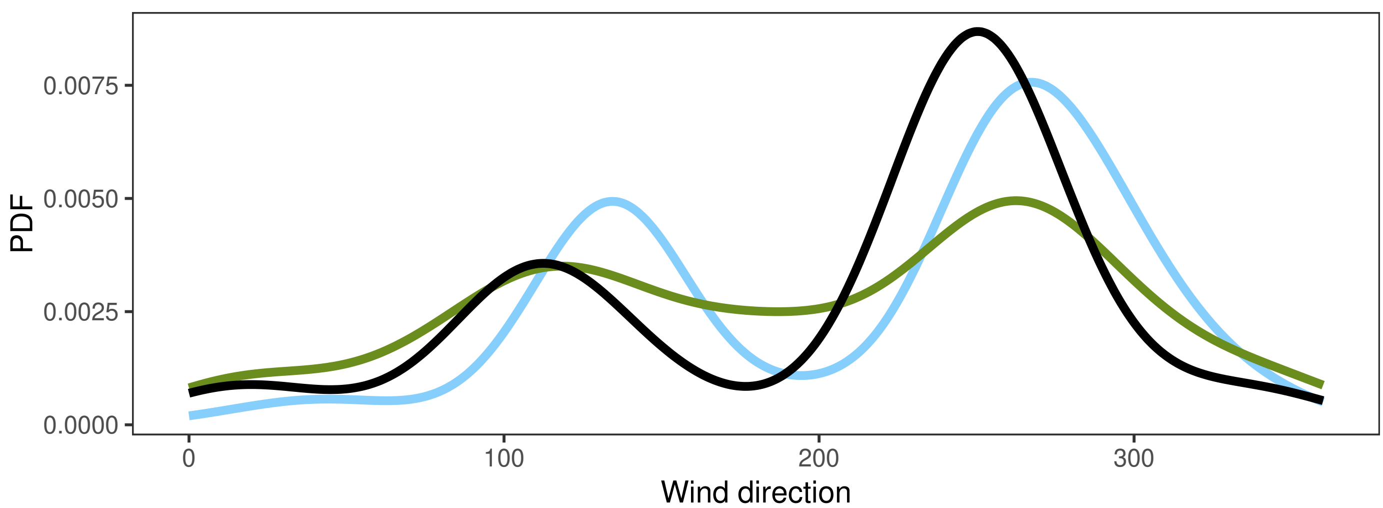
Model "climatology" 01.06.2024–31.08.2024

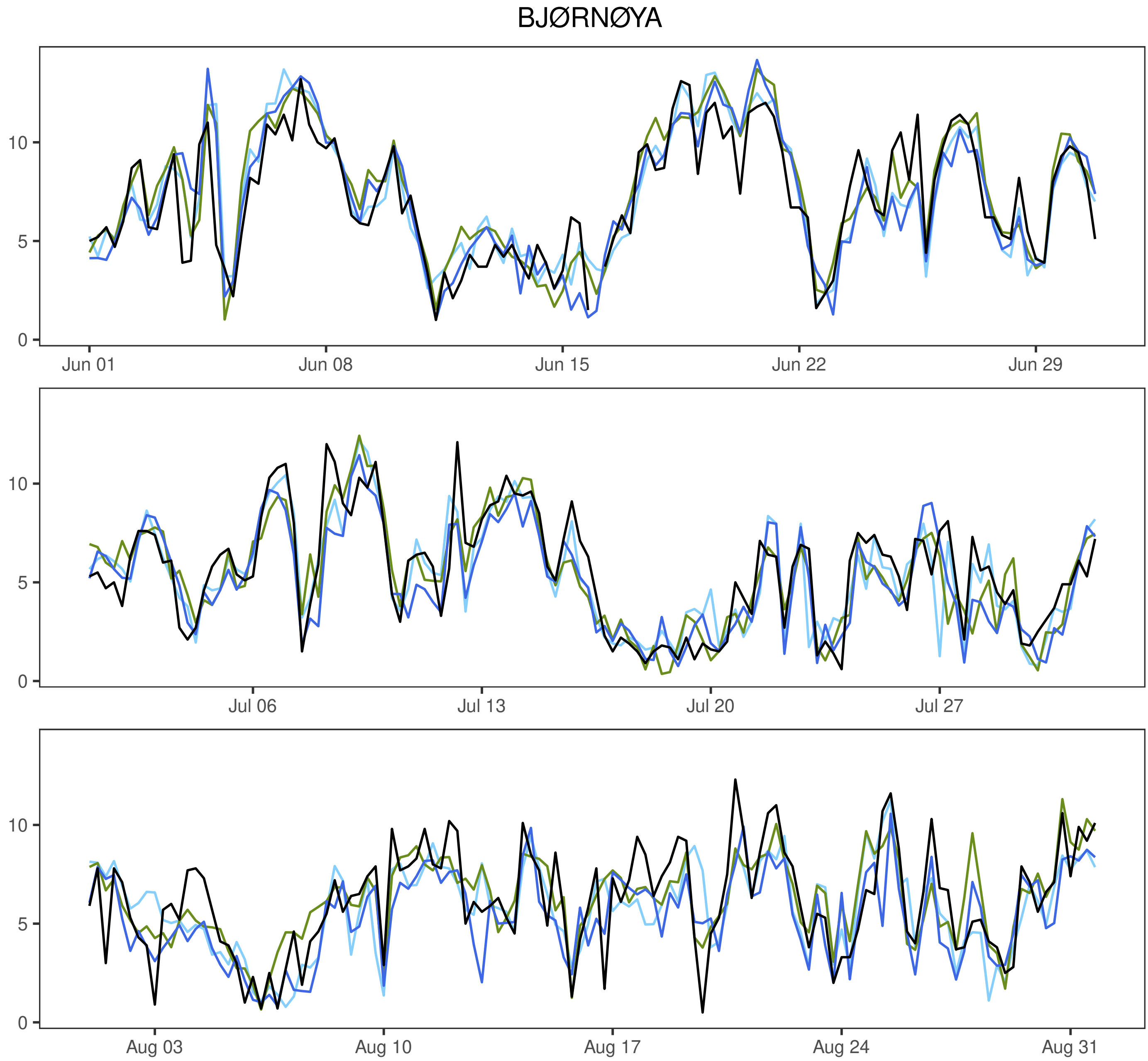


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	4.8	15.0	2.9	368
AA25: 12+18,+24,+30,+36	0.4	5.0	15.1	3.0	368
ECMWF: 12+18,+24,+30,+36	0.4	2.6	6.7	1.3	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
AA25 – synop	0.2	2.7	2.7	2.1	9.5	368
ECMWF – synop	−2.2	2.4	3.3	2.6	10.3	368

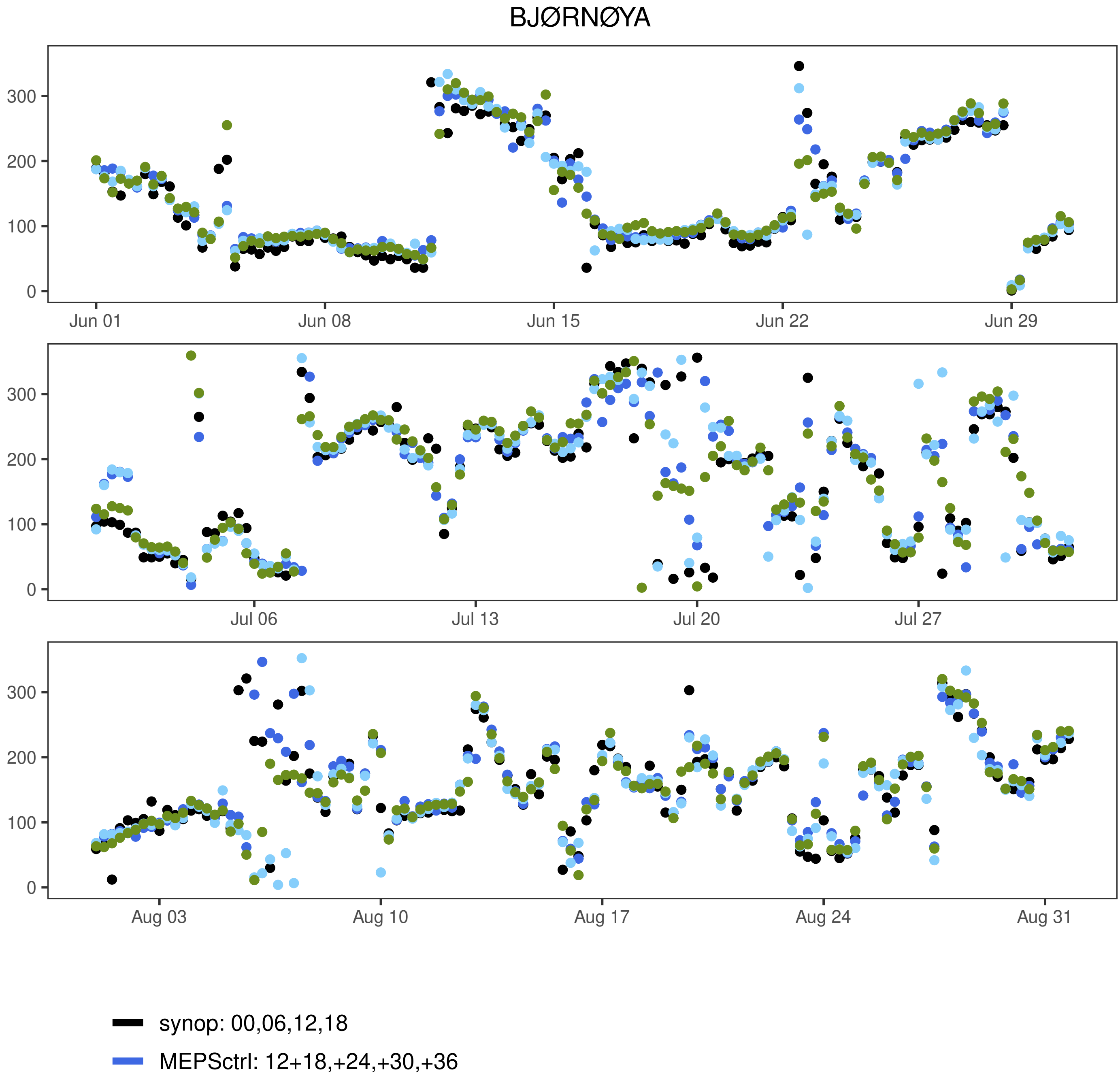

SVALBARD LUFTHAVN
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

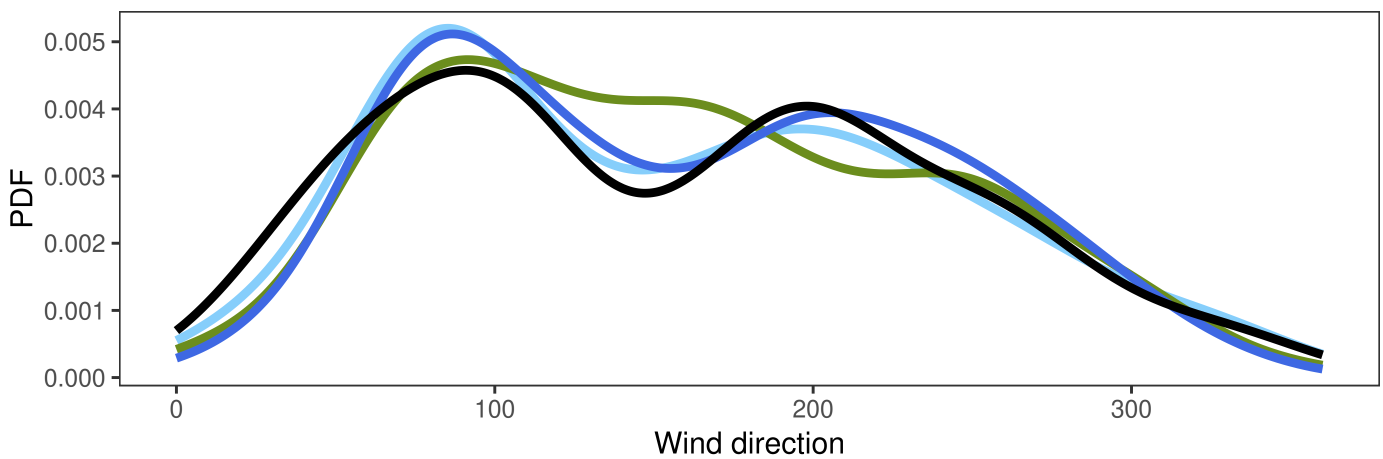

PDF
0.0075
0.0050
0.0025
0.0000
0
100
200
300
Wind direction

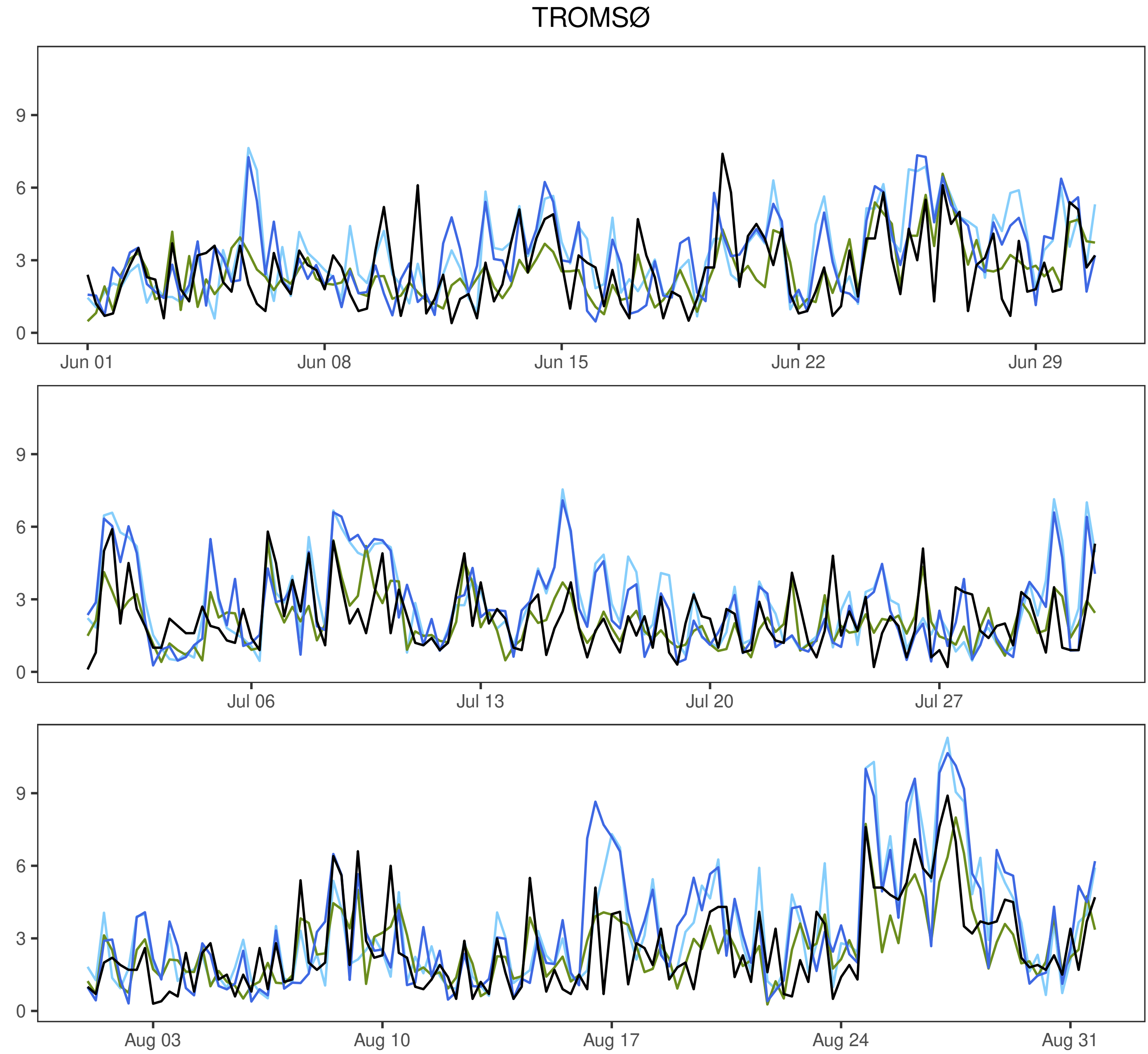


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.5	6.3	13.2	2.9	367
MEPSctrl: 12+18,+24,+30,+36	0.8	5.9	14.2	2.9	368
AA25: 12+18,+24,+30,+36	0.8	6.2	13.7	2.8	368
ECMWF: 12+18,+24,+30,+36	0.4	6.4	13.7	2.8	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.4	1.7	1.7	1.3	5.8	367
AA25 – synop	–0.1	1.7	1.7	1.3	7.2	367
ECMWF – synop	0.1	1.6	1.6	1.2	6.2	367

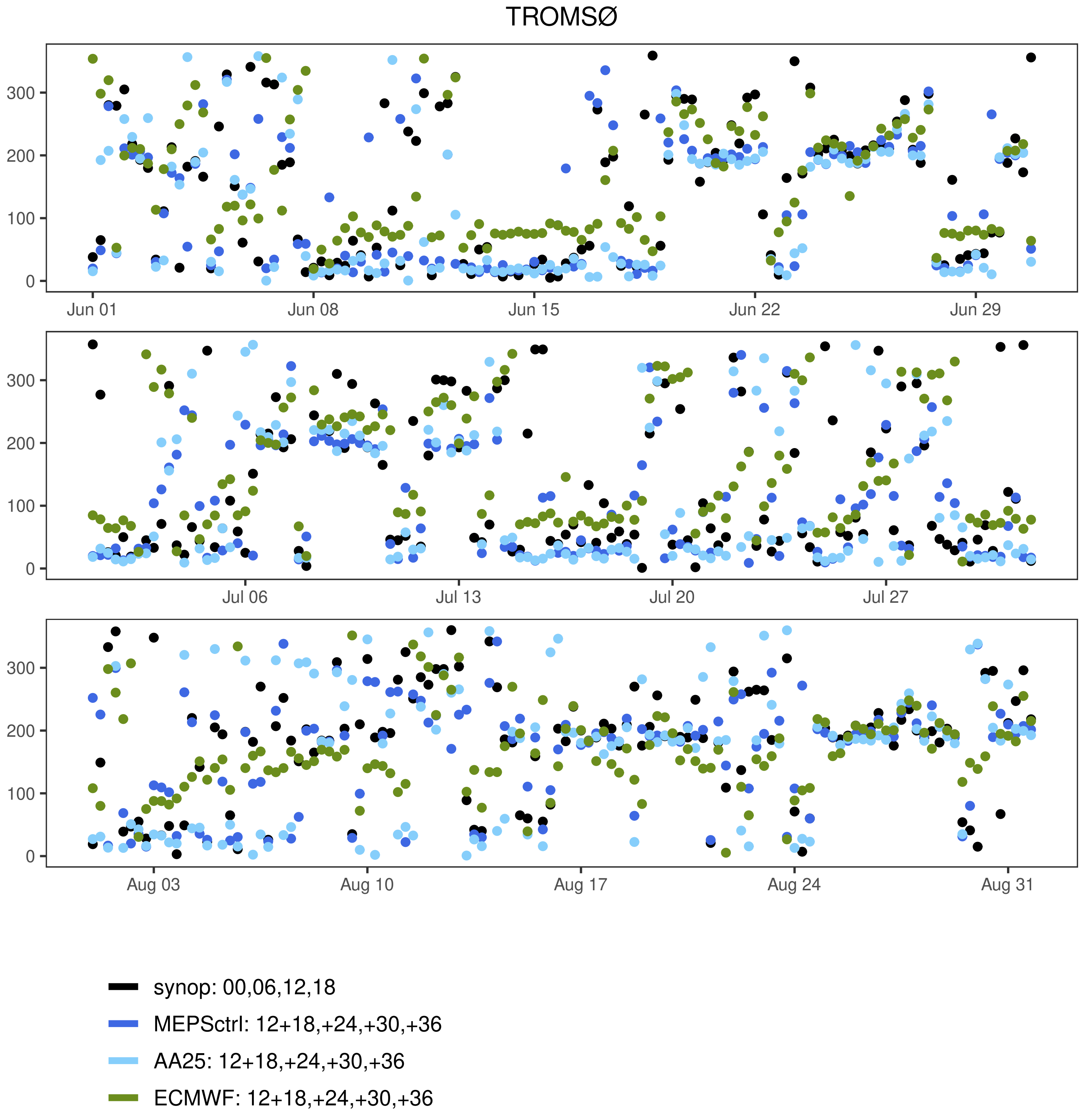

BJØRNØYA
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

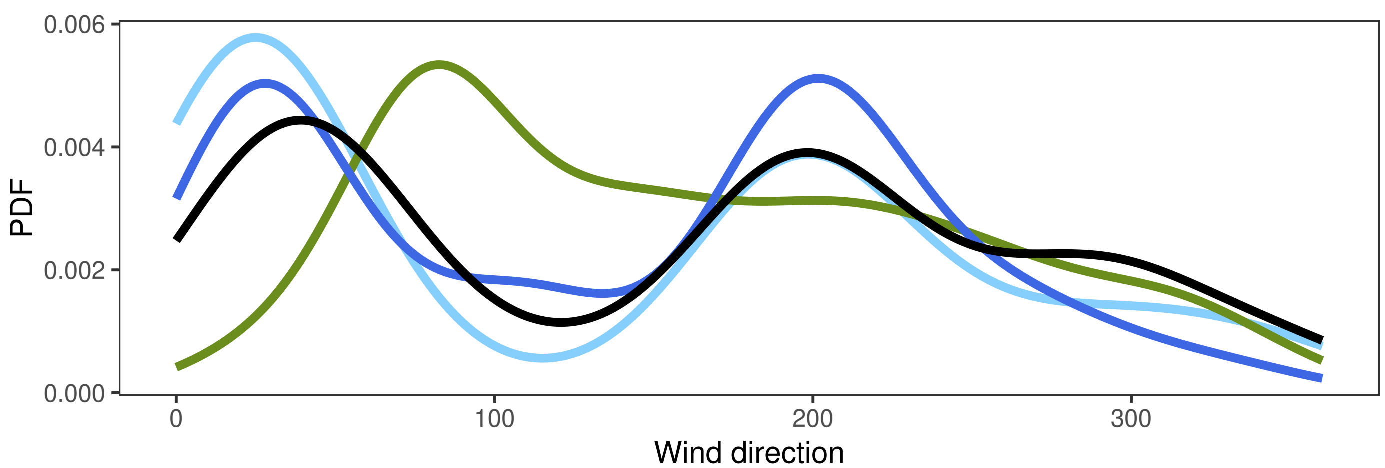

PDF
0.005
0.004
0.003
0.002
0.001
0.000
0
100
200
300
Wind direction

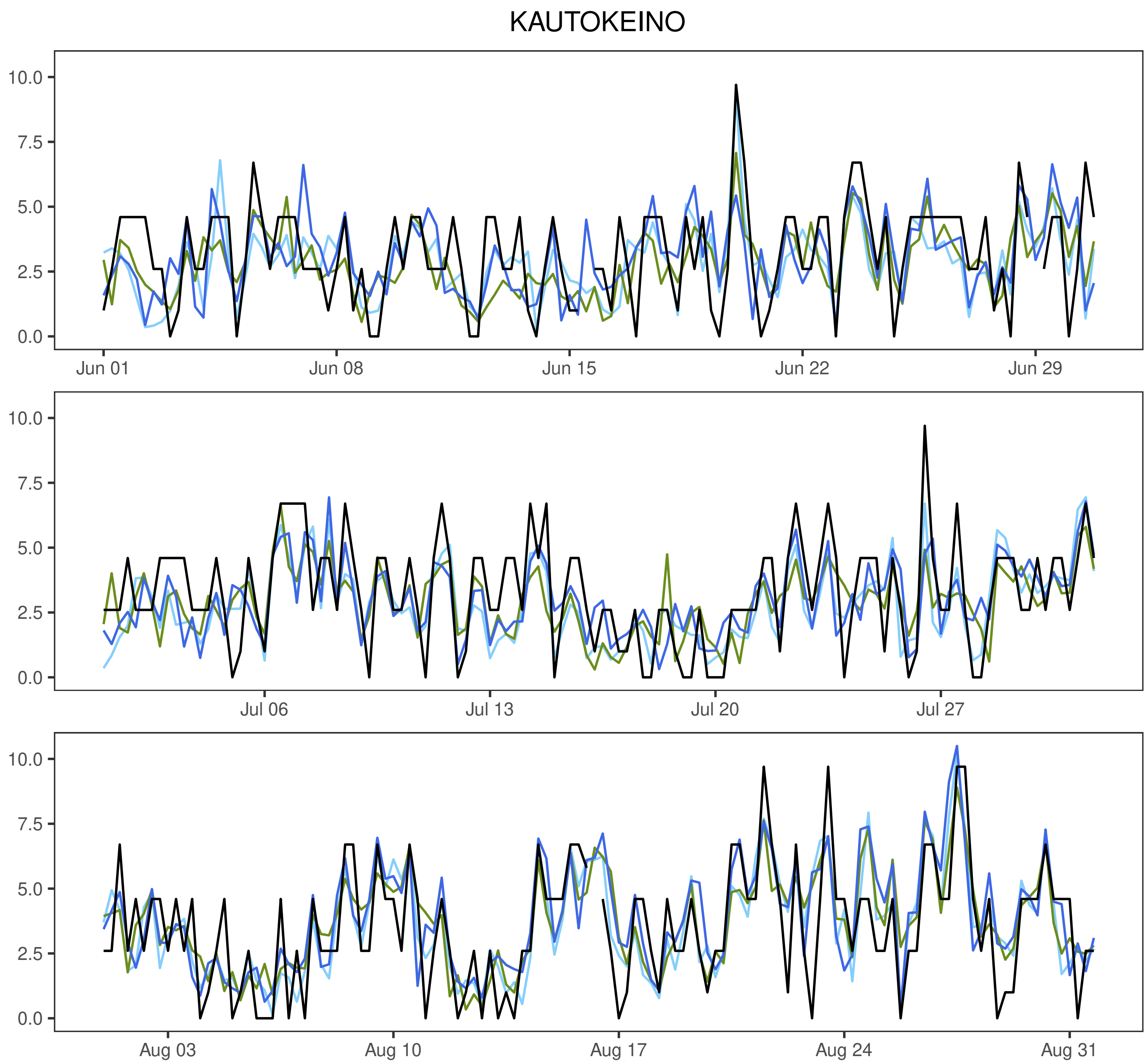


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.1	2.5	8.9	1.6	368
MEPSctrl: 12+18,+24,+30,+36	0.3	3.1	10.7	2.0	368
AA25: 12+18,+24,+30,+36	0.5	3.1	11.3	2.0	368
ECMWF: 12+18,+24,+30,+36	0.3	2.4	8.0	1.2	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.6	1.7	1.8	1.3	7.0	368
AA25 – synop	0.7	1.6	1.8	1.3	5.6	368
ECMWF – synop	−0.1	1.2	1.2	1.0	4.4	368

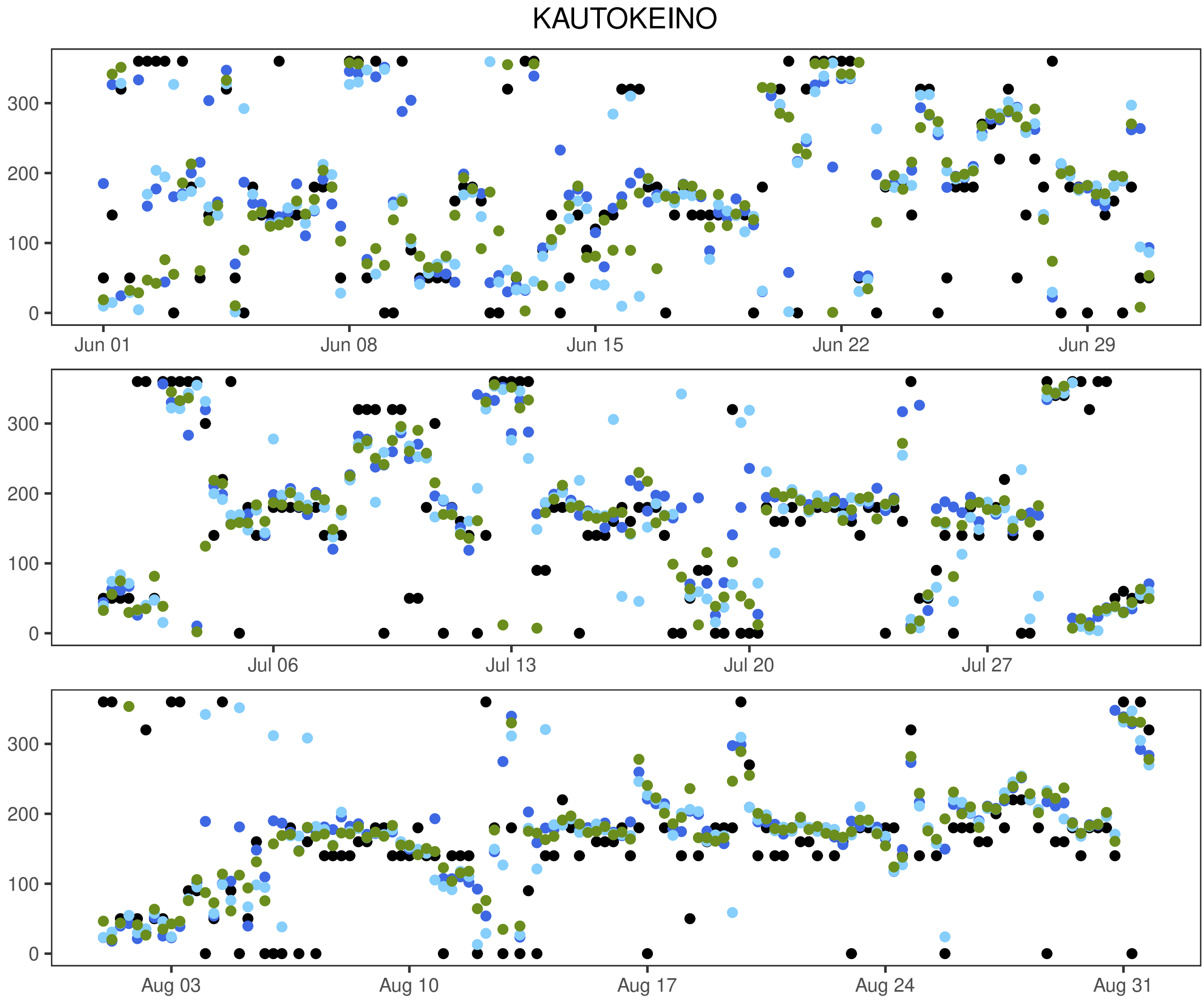

TROMSØ
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36


0.006
0.004
0.002
0.000
PDF
0
100
200
300
Wind direction

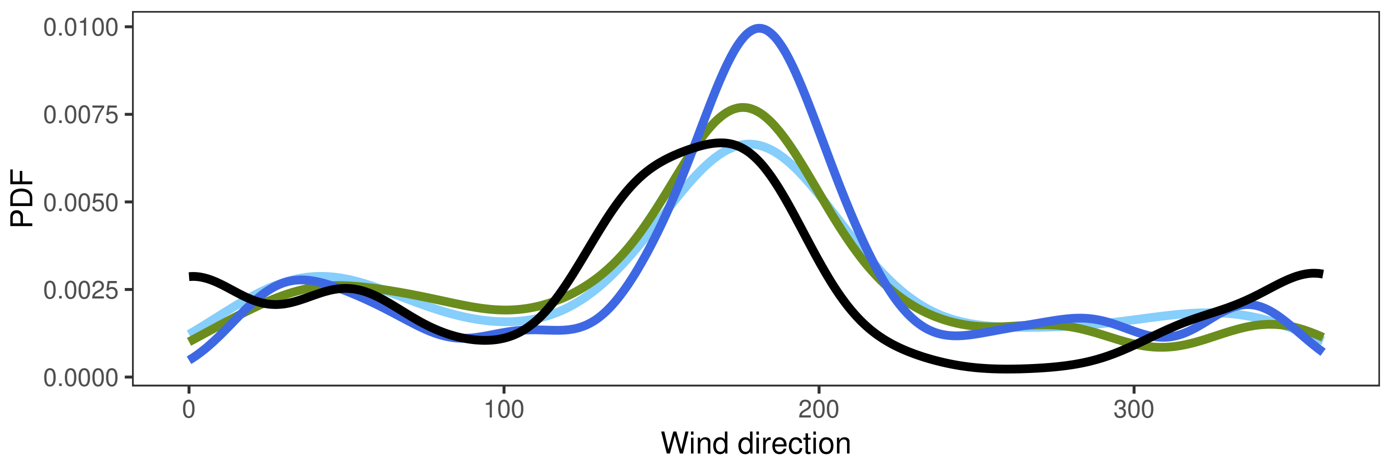


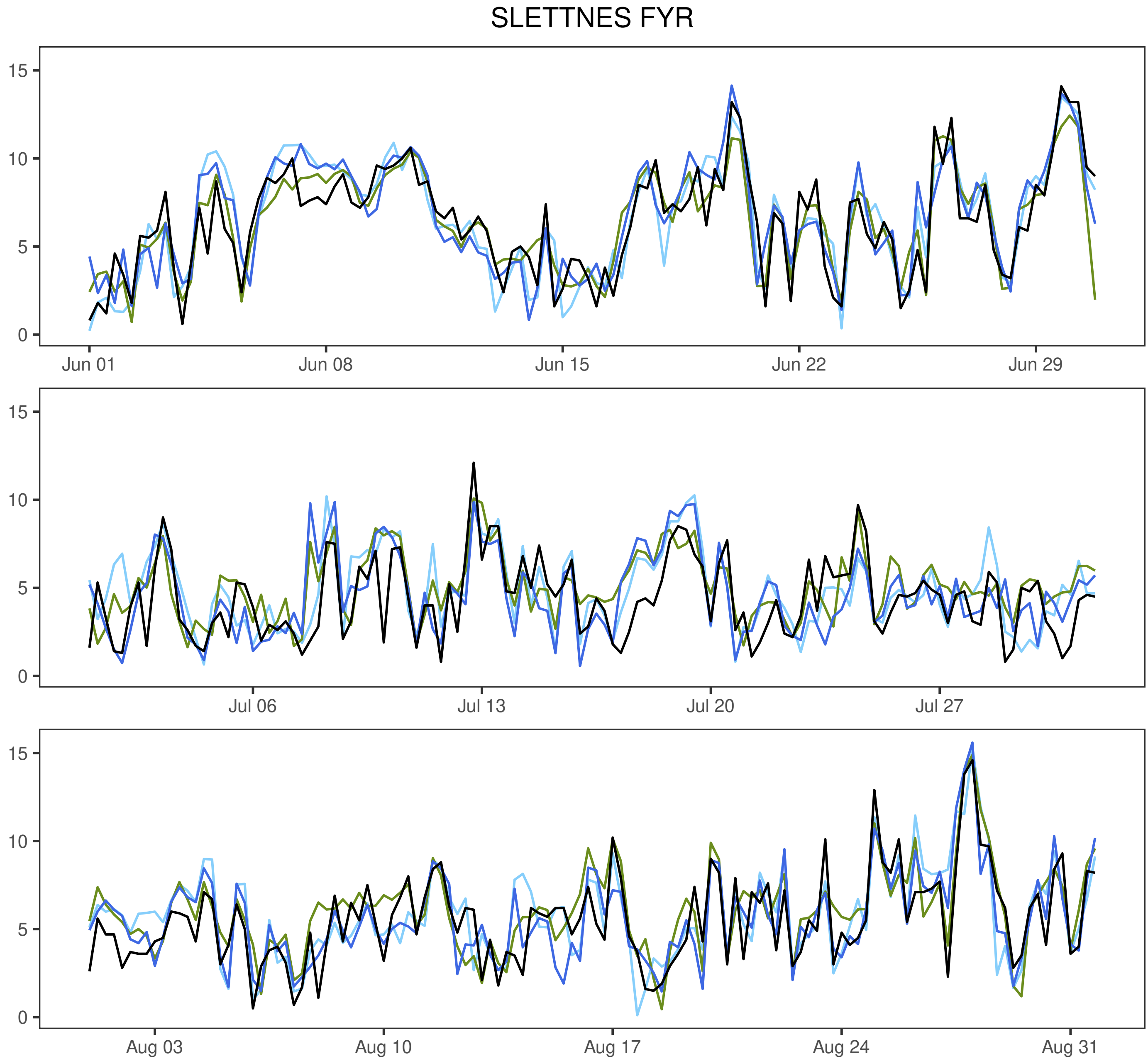
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	3.3	9.7	2.1	365
MEPSctrl: 12+18,+24,+30,+36	0.3	3.3	10.5	1.7	368
AA25: 12+18,+24,+30,+36	0.1	3.1	10.2	1.7	368
ECMWF: 12+18,+24,+30,+36	0.3	3.2	8.9	1.5	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.0	1.7	1.7	1.3	5.7	365
AA25 – synop	−0.2	1.6	1.6	1.3	6.0	365
ECMWF – synop	−0.2	1.6	1.6	1.3	5.1	365



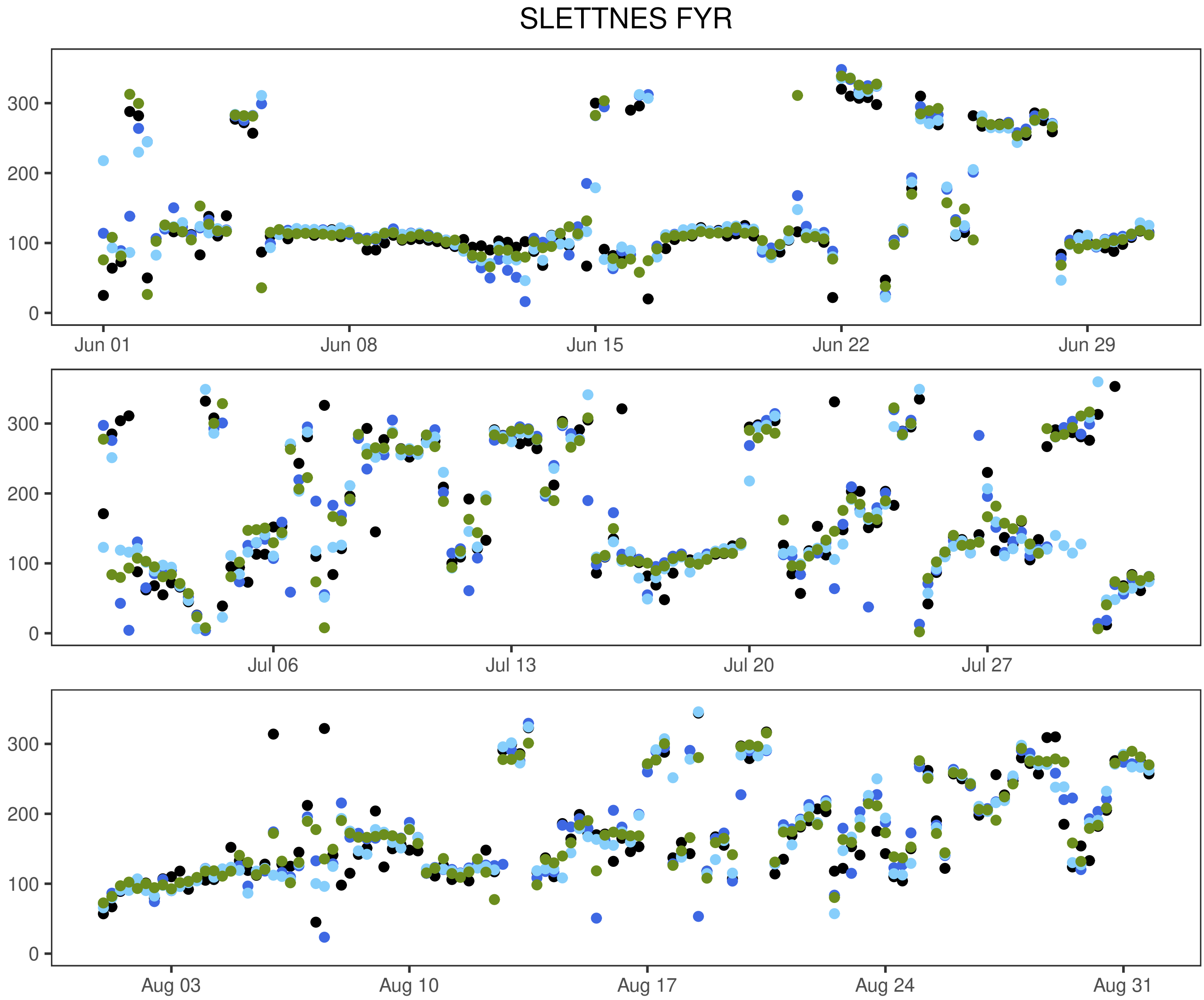
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

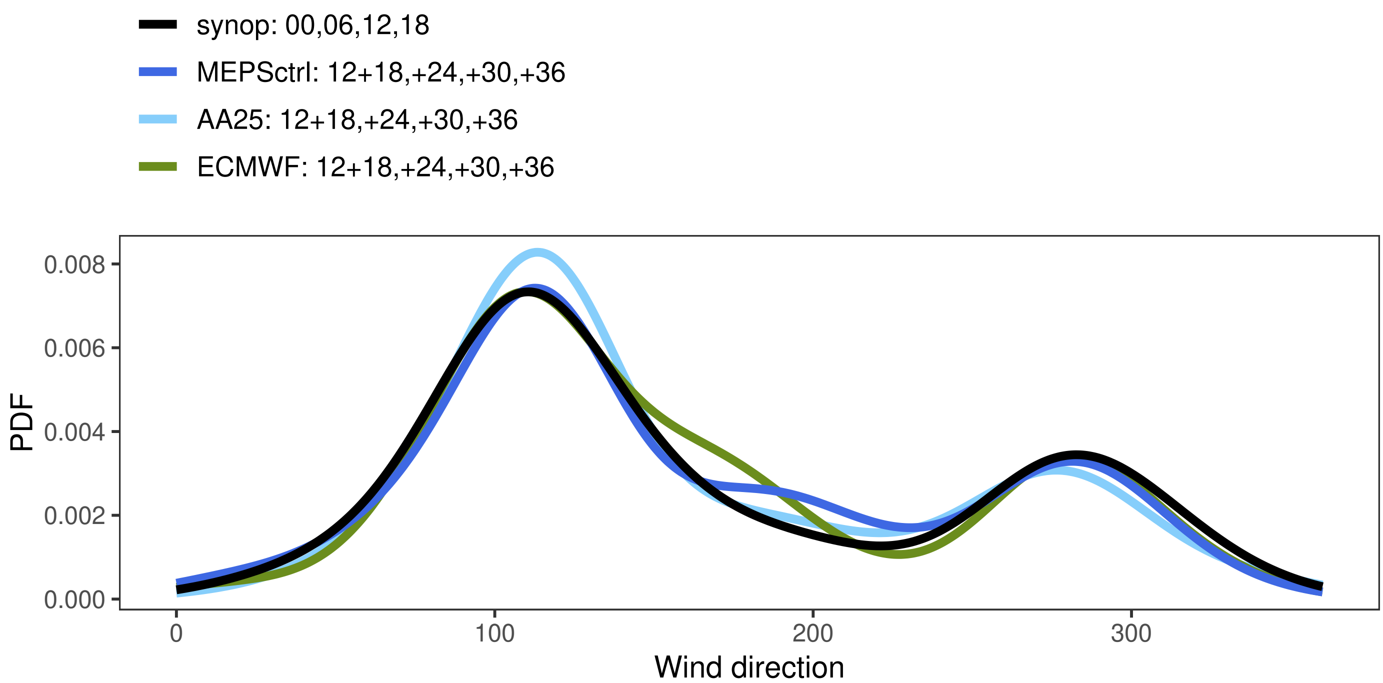


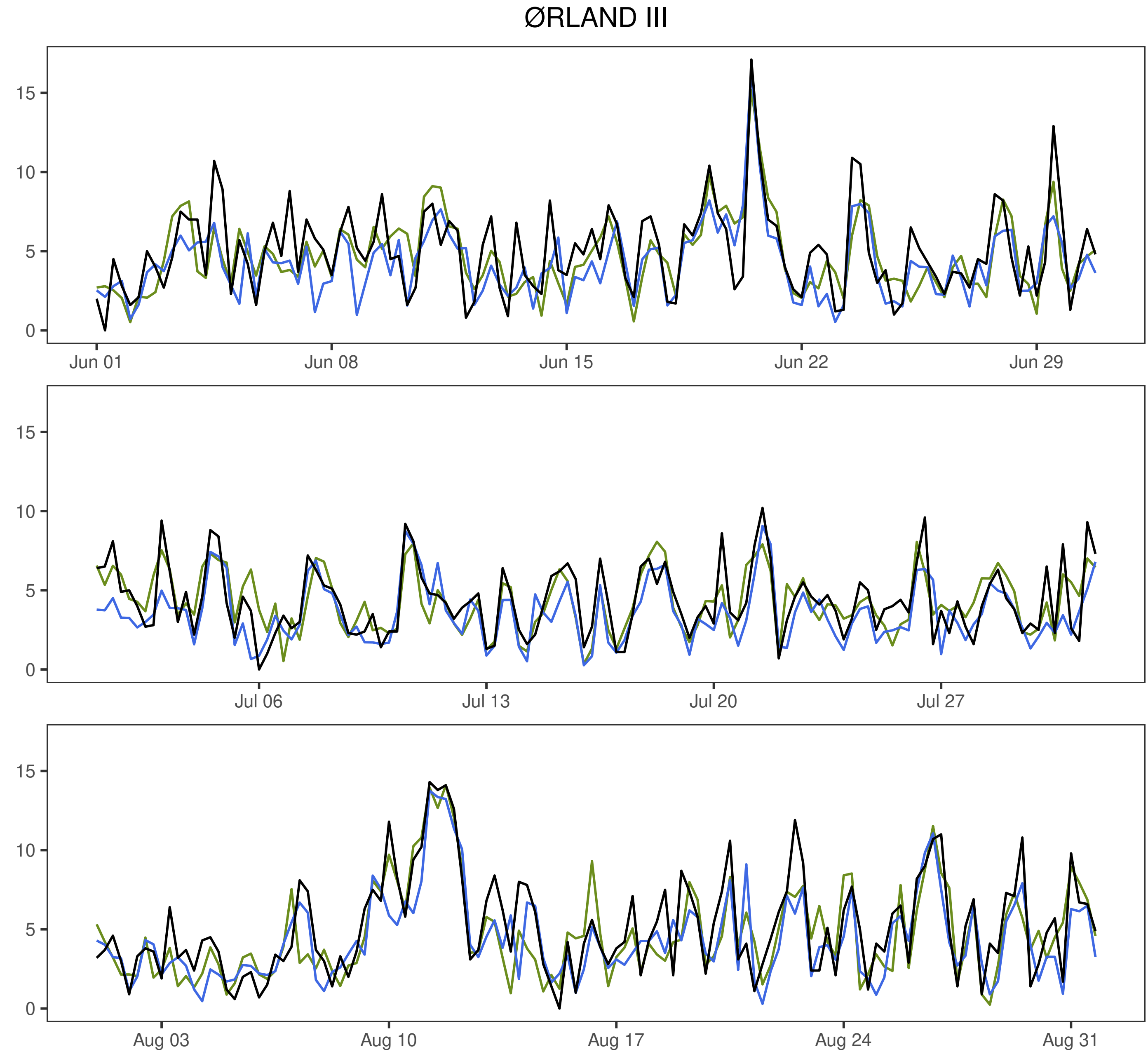


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.5	5.4	14.6	2.7	368
MEPSctrl: 12+18,+24,+30,+36	0.6	5.6	15.6	2.7	368
AA25: 12+18,+24,+30,+36	0.1	5.8	15.3	2.8	368
ECMWF: 12+18,+24,+30,+36	0.5	5.9	14.9	2.4	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.2	1.8	1.8	1.4	7.8	368
AA25 – synop	0.3	1.8	1.8	1.4	6.4	368
ECMWF – synop	0.4	1.6	1.7	1.3	7.0	368

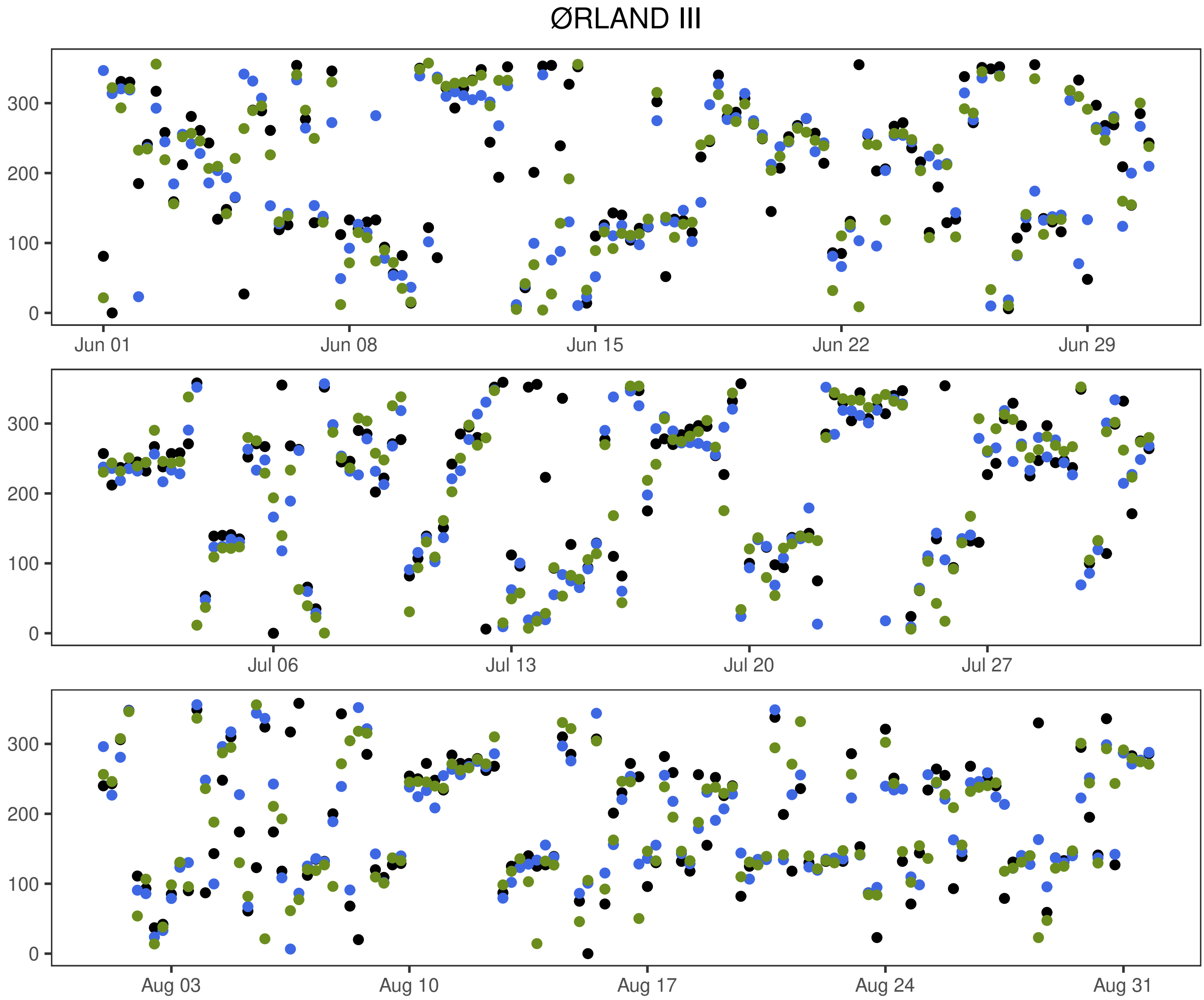

SLETTNES FYR
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31

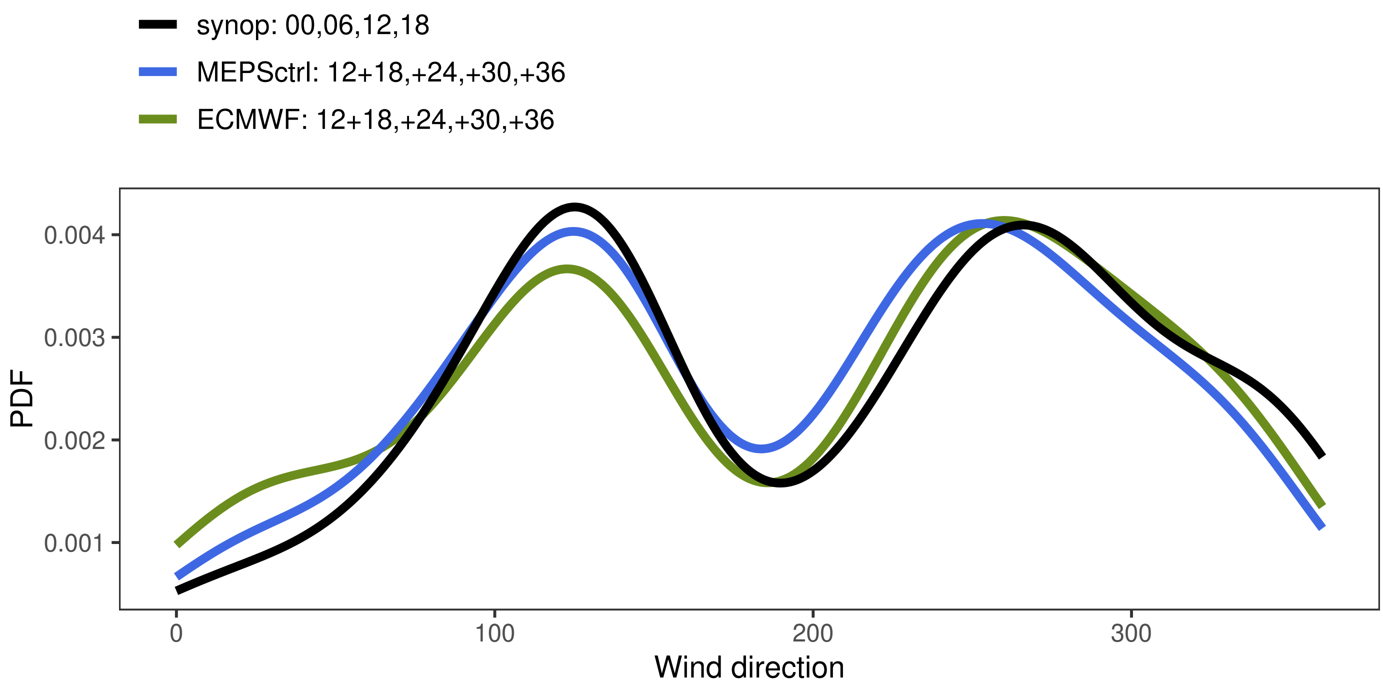

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.008
0.006
0.004
0.002
0.000
0
100
200
300
Wind direction

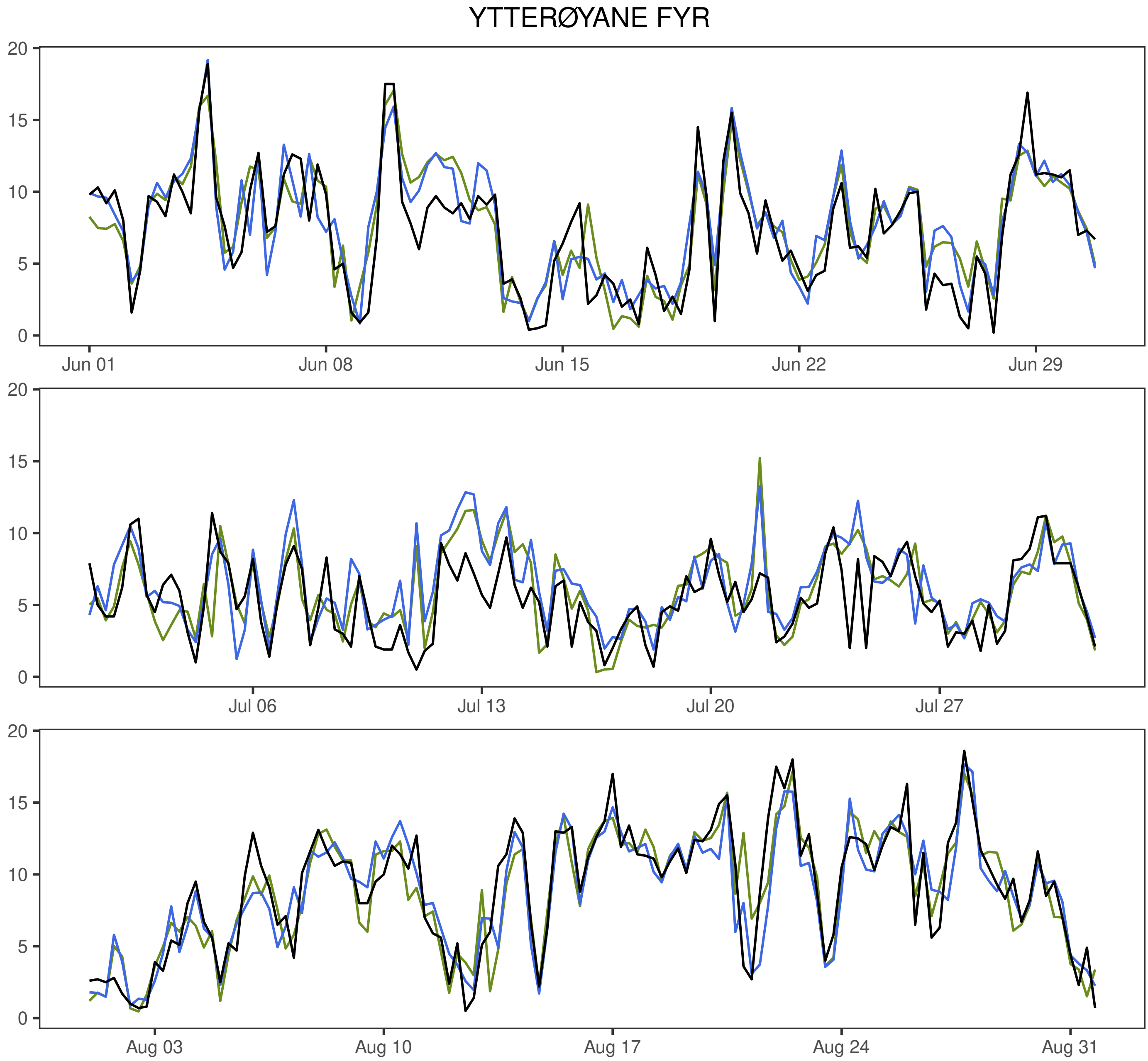


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	4.8	17.1	2.7	368
MEPSctrl: 12+18,+24,+30,+36	0.3	4.1	16.4	2.3	368
ECMWF: 12+18,+24,+30,+36	0.2	4.6	15.2	2.4	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.8	1.7	1.9	1.4	6.1	368
ECMWF – synop	–0.3	1.8	1.8	1.4	5.2	368

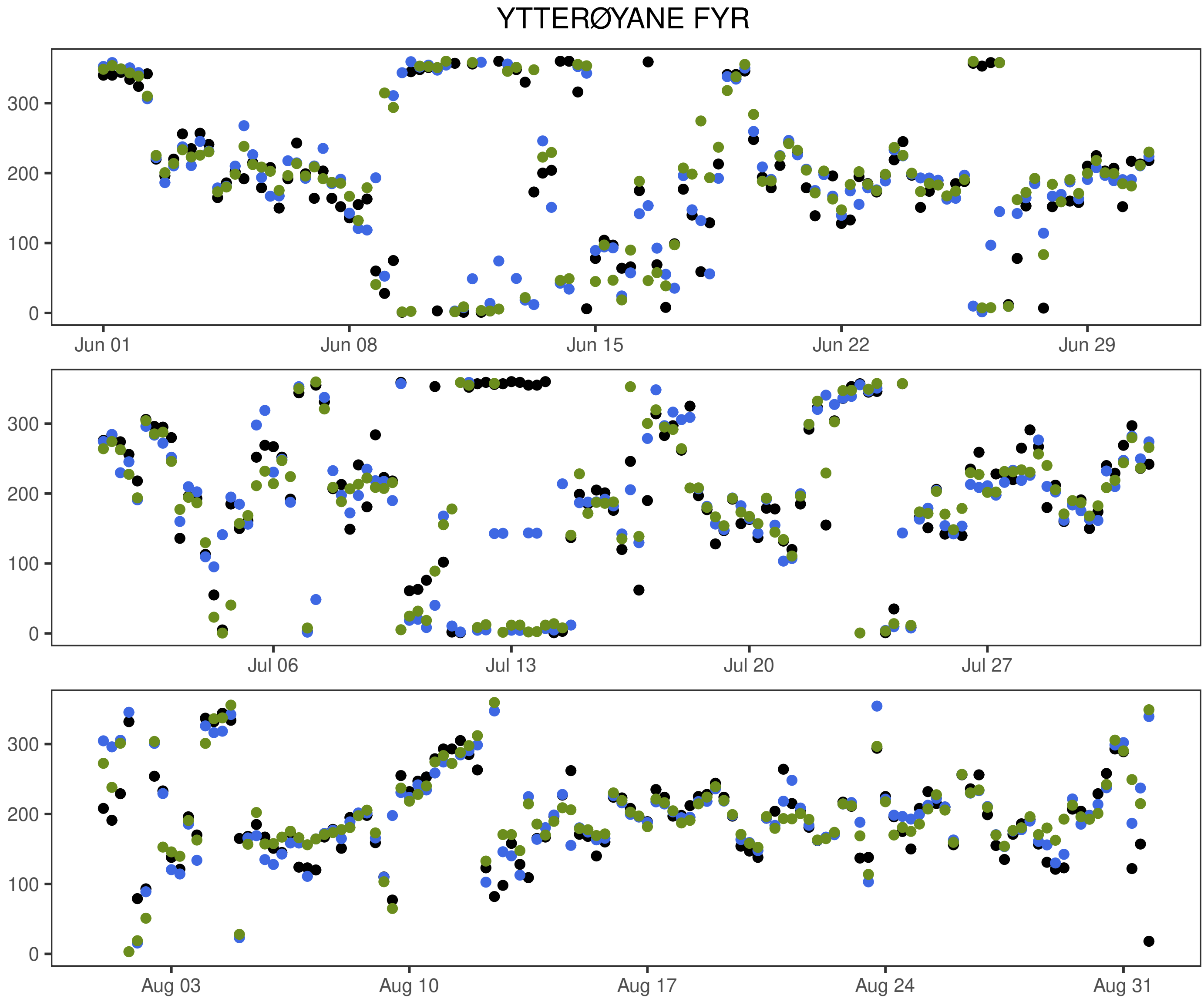

ØRLAND III
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31

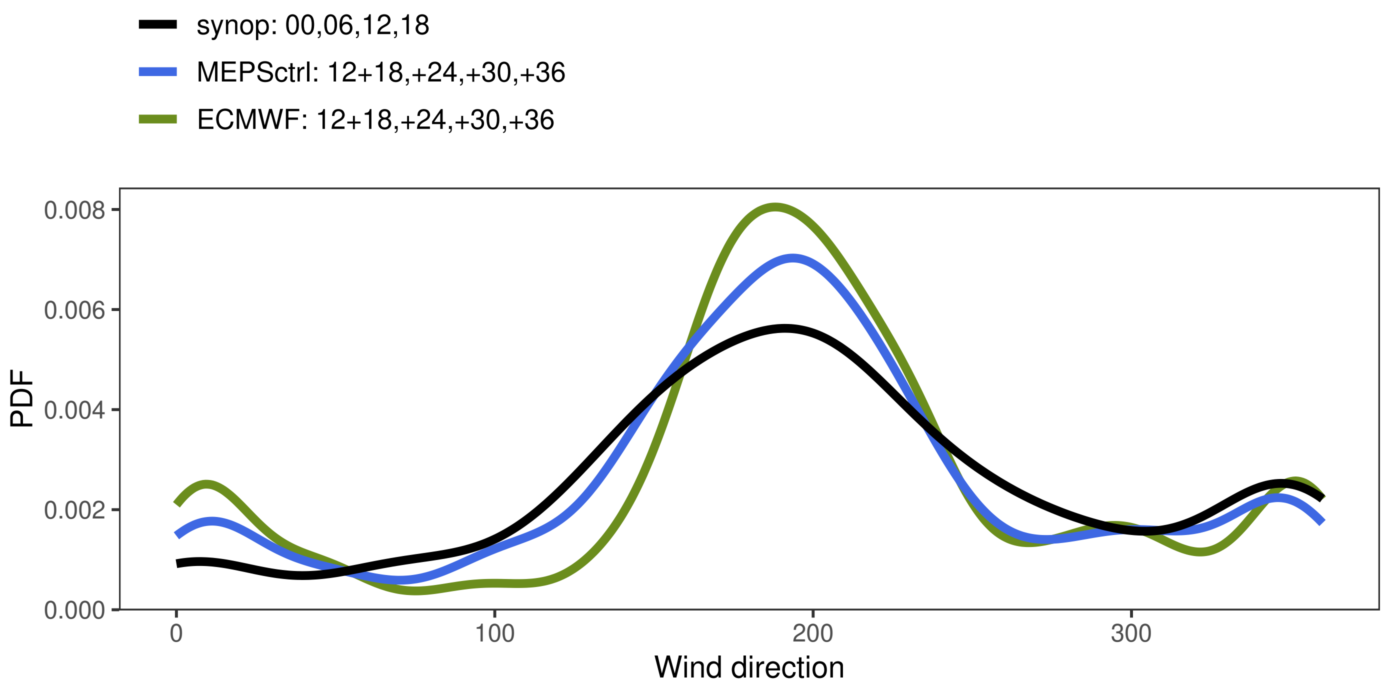

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

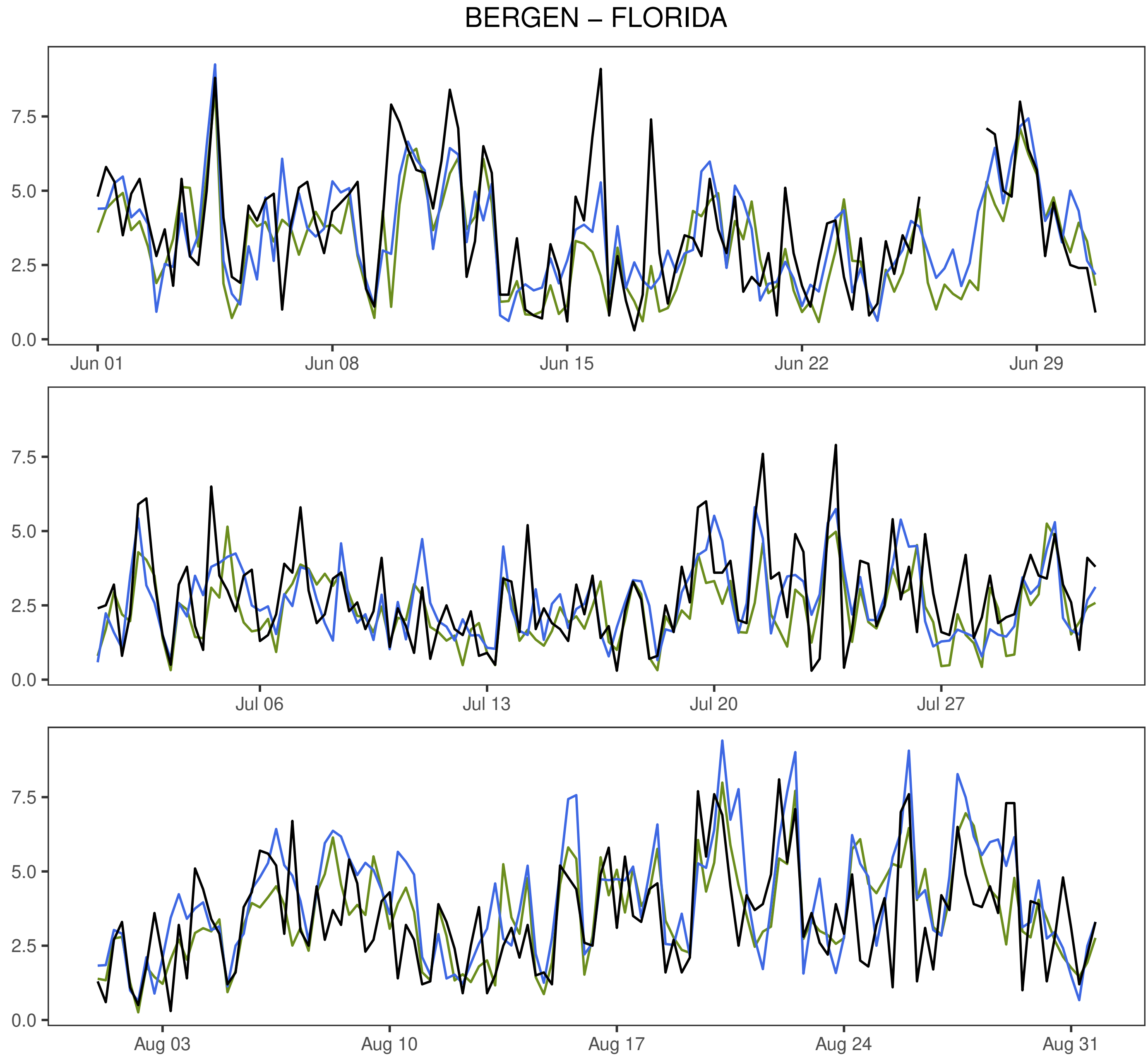


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.2	7.3	18.9	4.0	368
MEPSctrl: 12+18,+24,+30,+36	0.8	7.7	19.2	3.6	368
ECMWF: 12+18,+24,+30,+36	0.3	7.5	17.2	3.7	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.4	2.1	2.2	1.6	10.2	368
ECMWF – synop	0.3	2.1	2.1	1.6	9.3	368

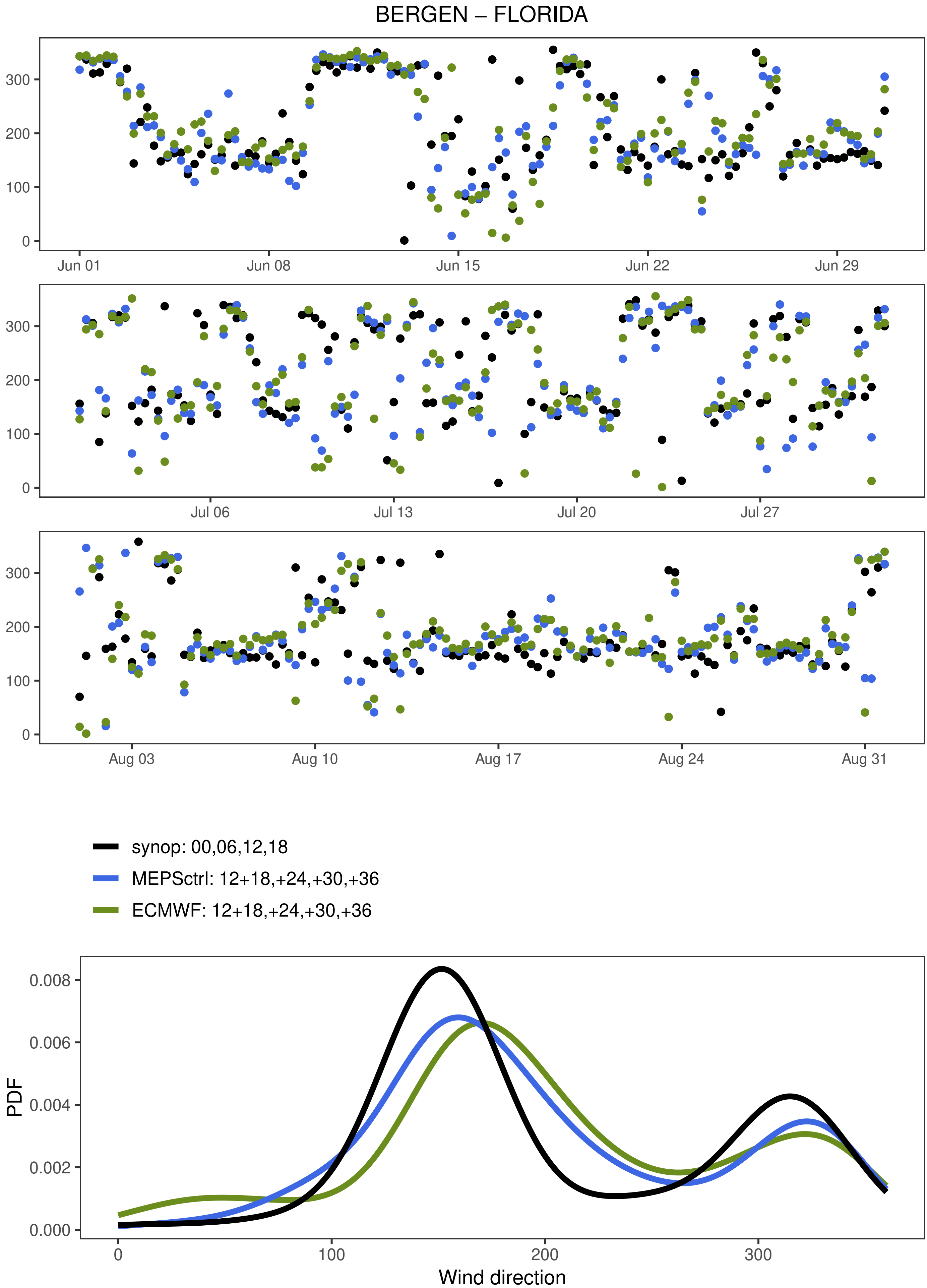

YTTERØYANE FYR
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31


synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.008
0.006
0.004
0.002
0.000
0
100
200
300
Wind direction

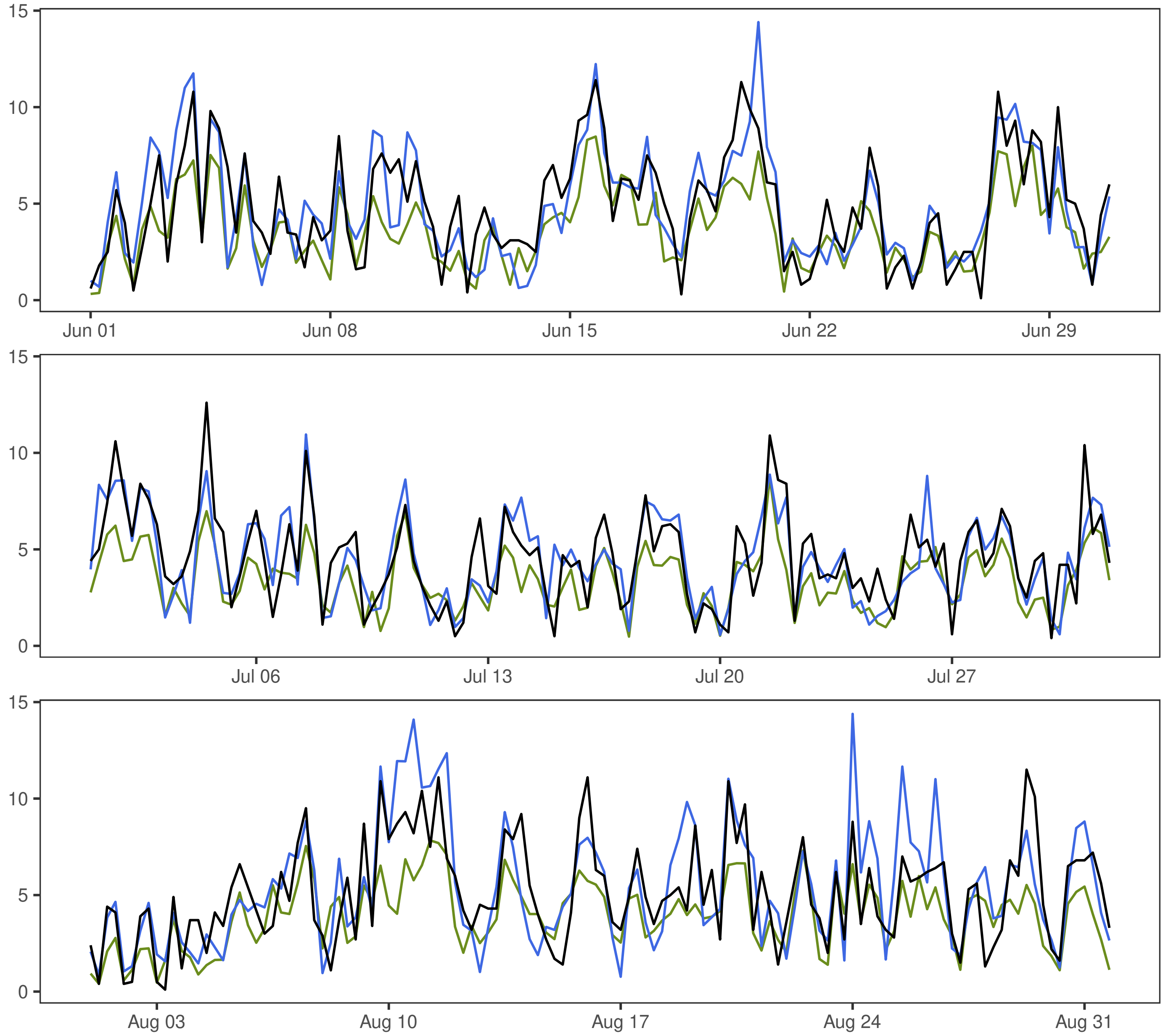


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.3	3.3	9.1	1.8	361
MEPSctrl: 12+18,+24,+30,+36	0.6	3.4	9.4	1.7	368
ECMWF: 12+18,+24,+30,+36	0.3	3.0	8.4	1.5	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.1	1.5	1.5	1.2	5.7	361
ECMWF – synop	−0.3	1.4	1.5	1.1	7.0	361

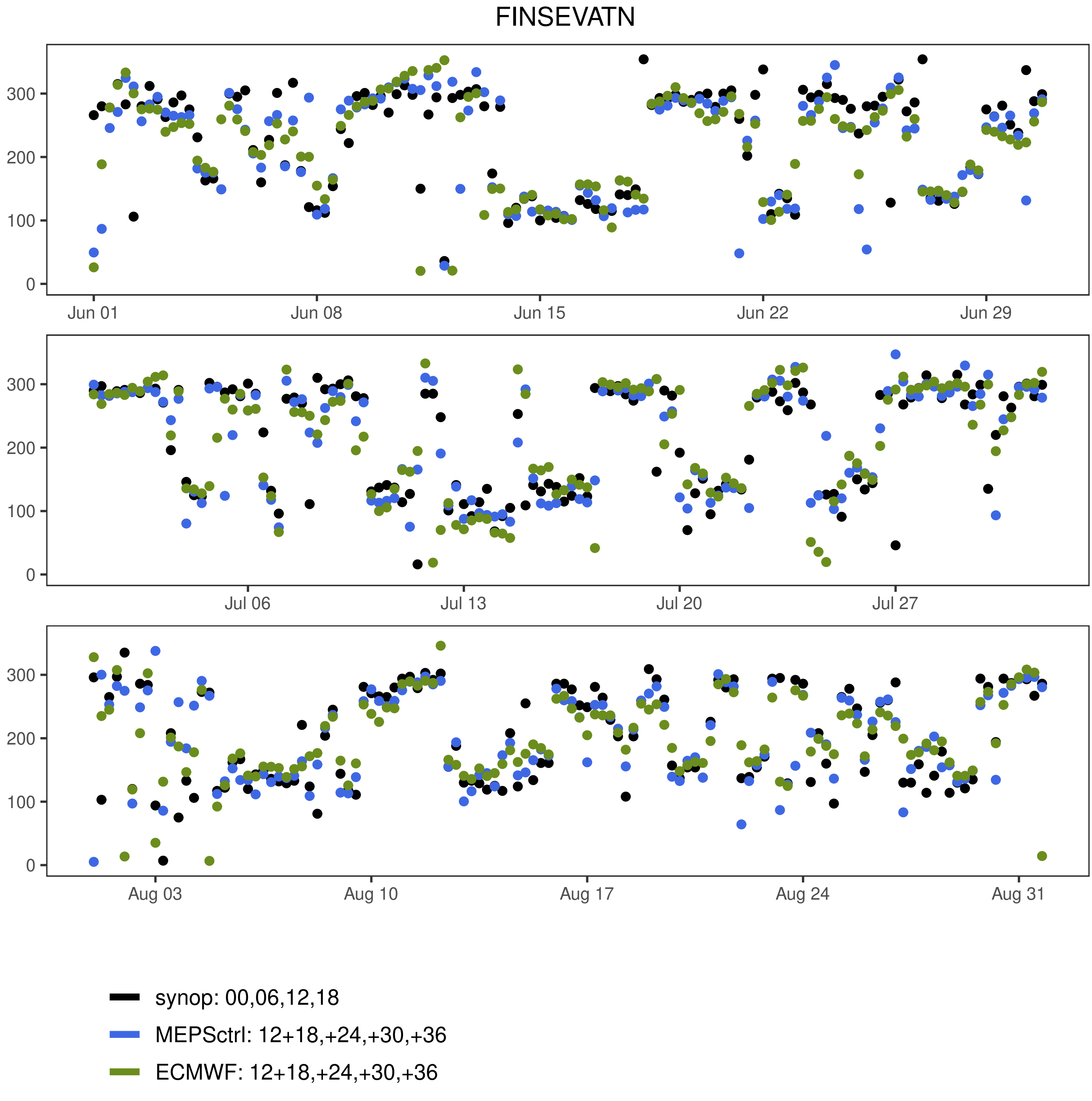

BERGEN – FLORIDA
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.008
0.006
0.004
0.002
0.000
0
100
200
300
Wind direction

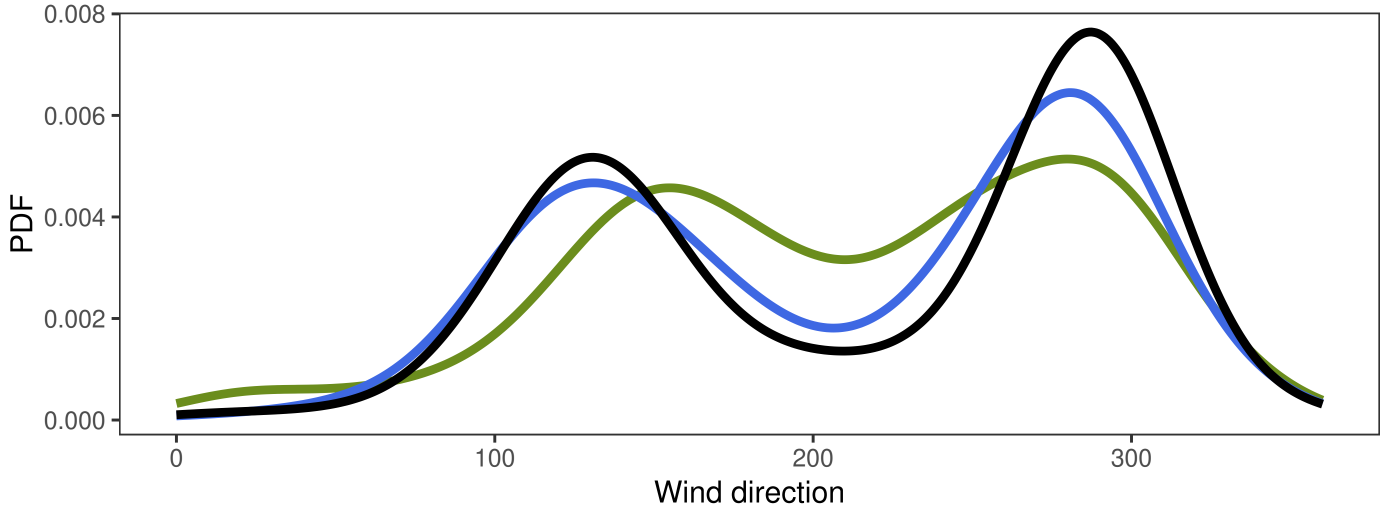
FINSEVATN

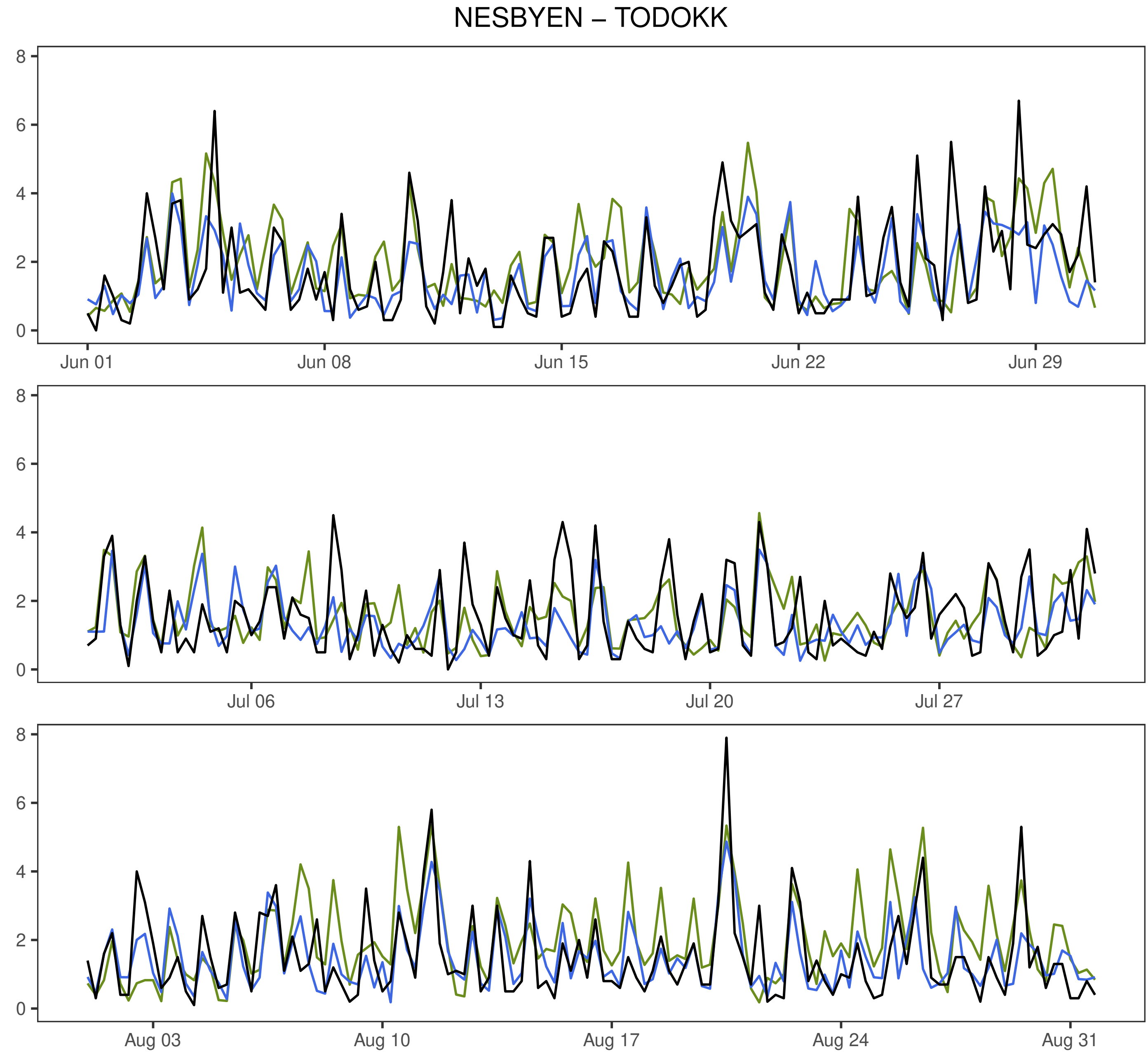


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.1	4.8	12.6	2.6	368
MEPSctrl: 12+18,+24,+30,+36	0.6	4.9	14.4	2.8	368
ECMWF: 12+18,+24,+30,+36	0.3	3.7	8.7	1.8	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.0	1.8	1.8	1.4	5.9	368
ECMWF – synop	–1.2	1.6	2.0	1.6	6.0	368

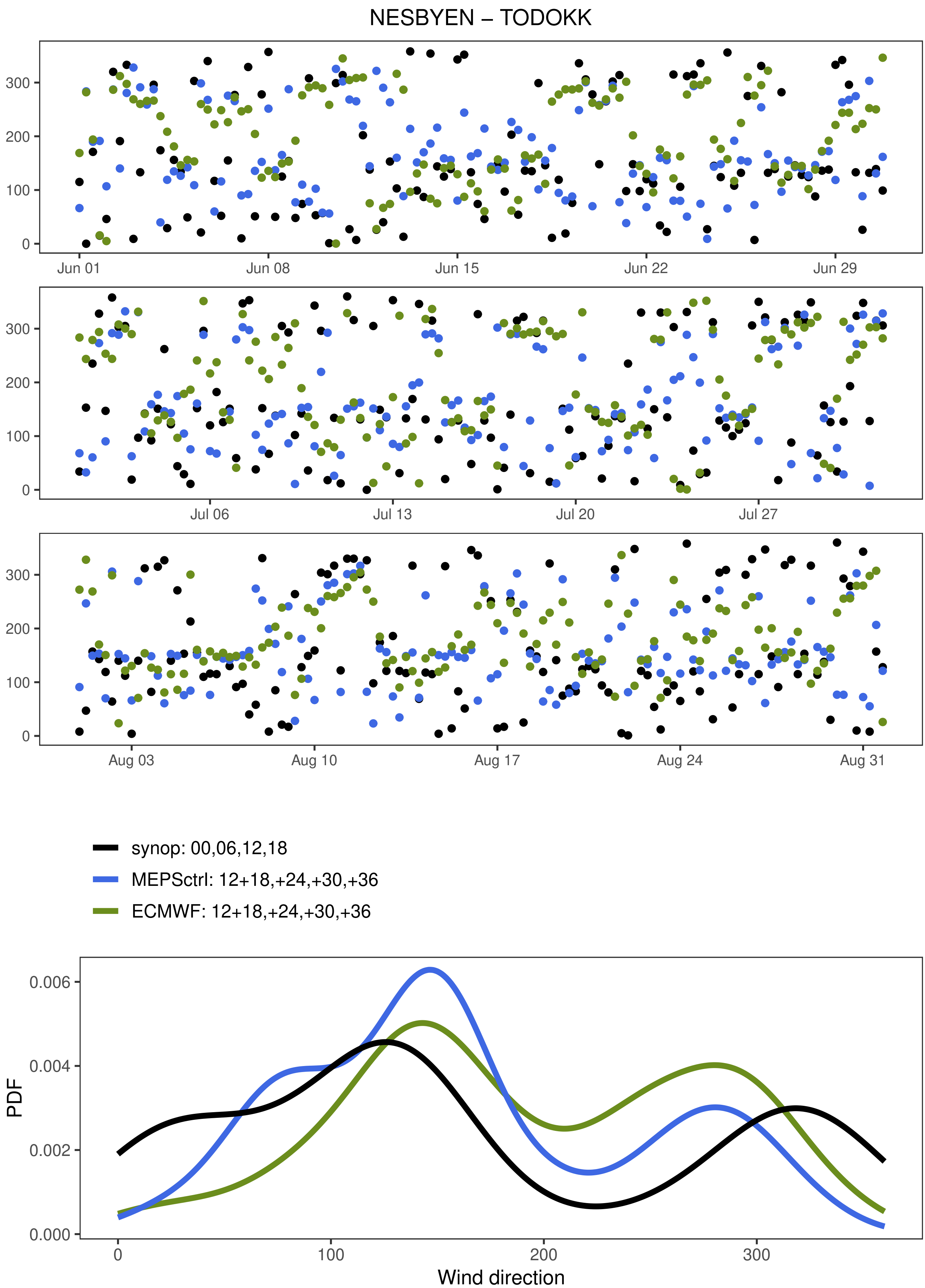

FINSEVATN
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

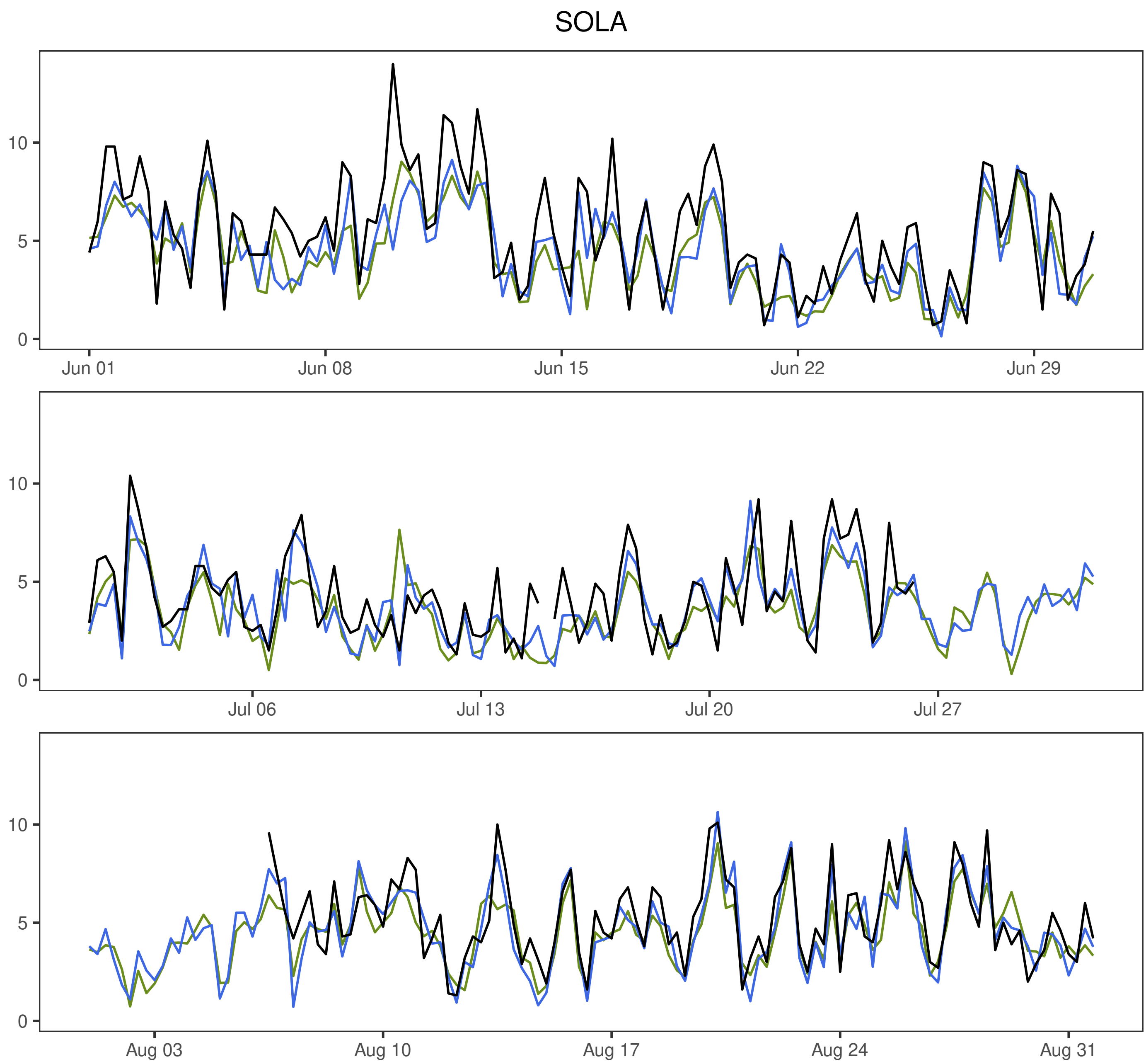

0.008
0.006
0.004
0.002
0.000
PDF
0
100
200
300
Wind direction



	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	1.6	7.9	1.3	368
MEPSctrl: 12+18,+24,+30,+36	0.2	1.5	4.9	0.9	368
ECMWF: 12+18,+24,+30,+36	0.2	1.9	5.5	1.1	368

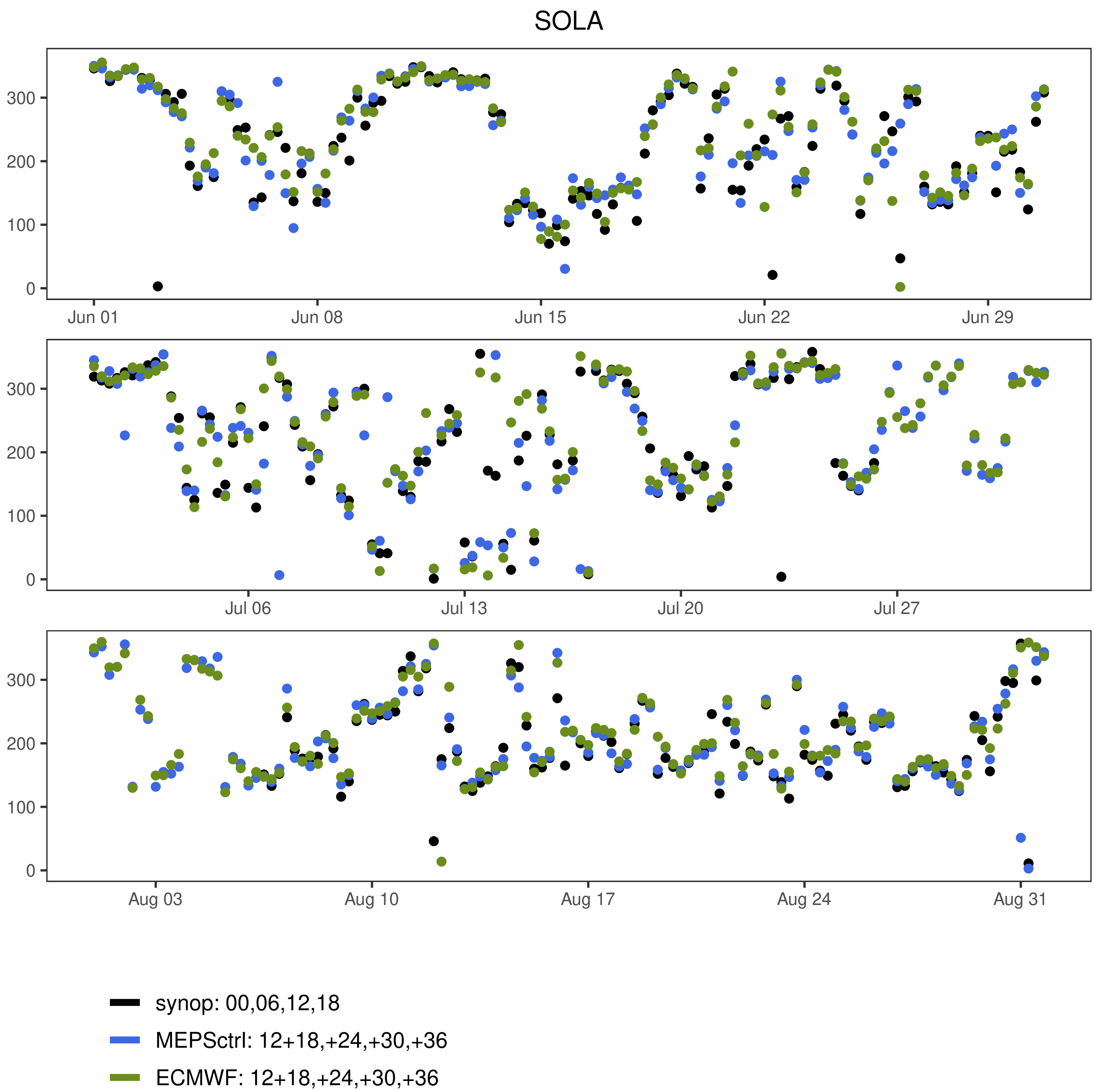
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.1	1.0	1.0	0.7	3.9	368
ECMWF – synop	0.2	1.1	1.1	0.9	5.0	368

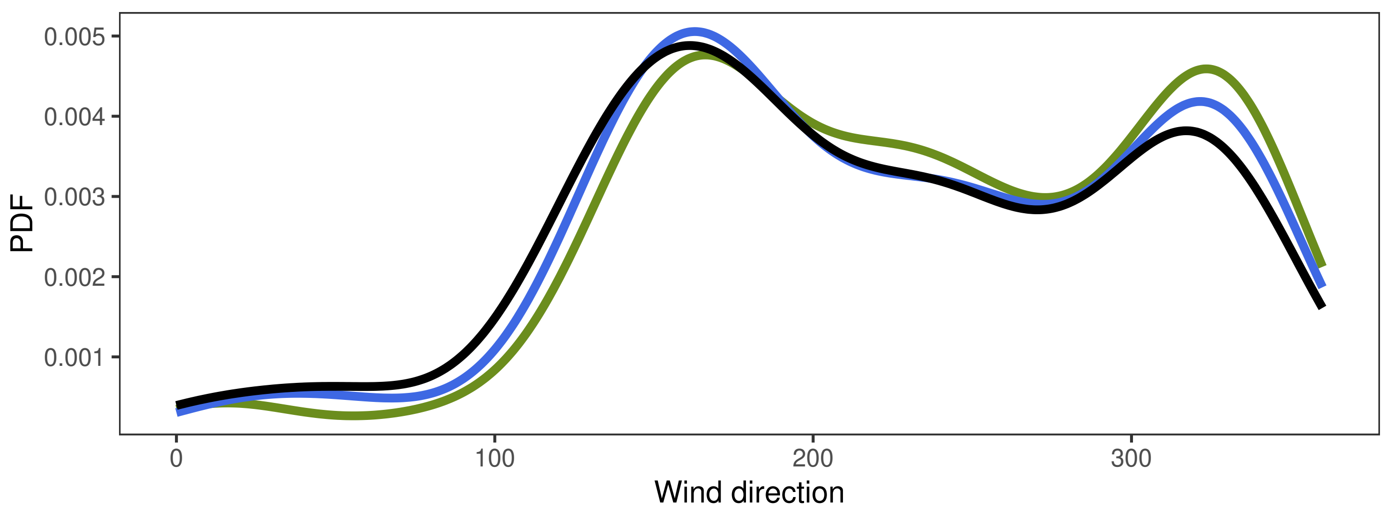

NESBYEN – TODOKK
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
0.006
0.004
0.002
0.000
PDF
0
100
200
300
Wind direction

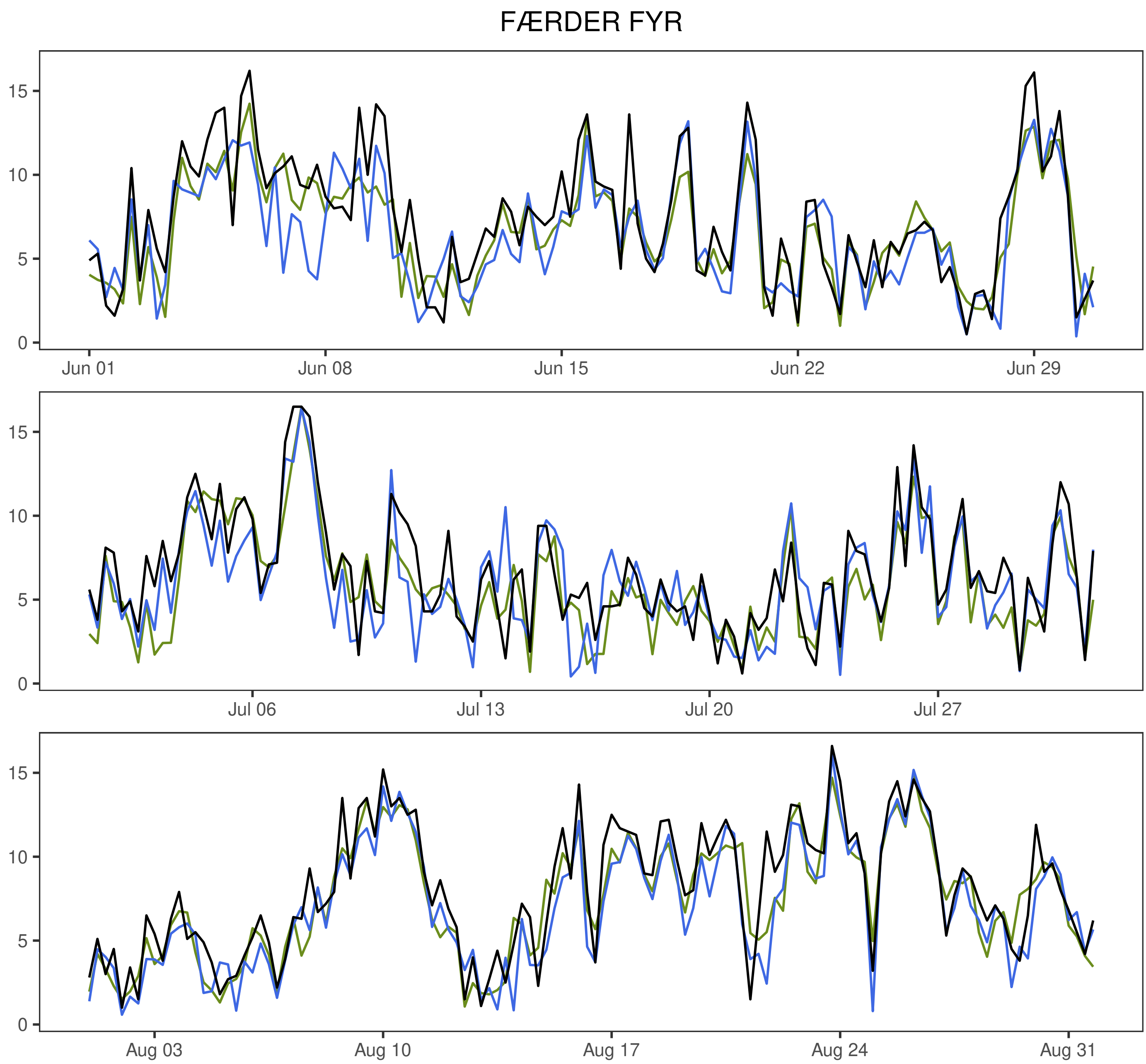


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.7	5.0	14.0	2.4	323
MEPSctrl: 12+18,+24,+30,+36	0.1	4.3	10.6	2.0	368
ECMWF: 12+18,+24,+30,+36	0.3	4.1	9.1	1.8	368

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	−0.6	1.4	1.5	1.2	9.4	323
ECMWF – synop	−0.9	1.4	1.7	1.3	6.9	323

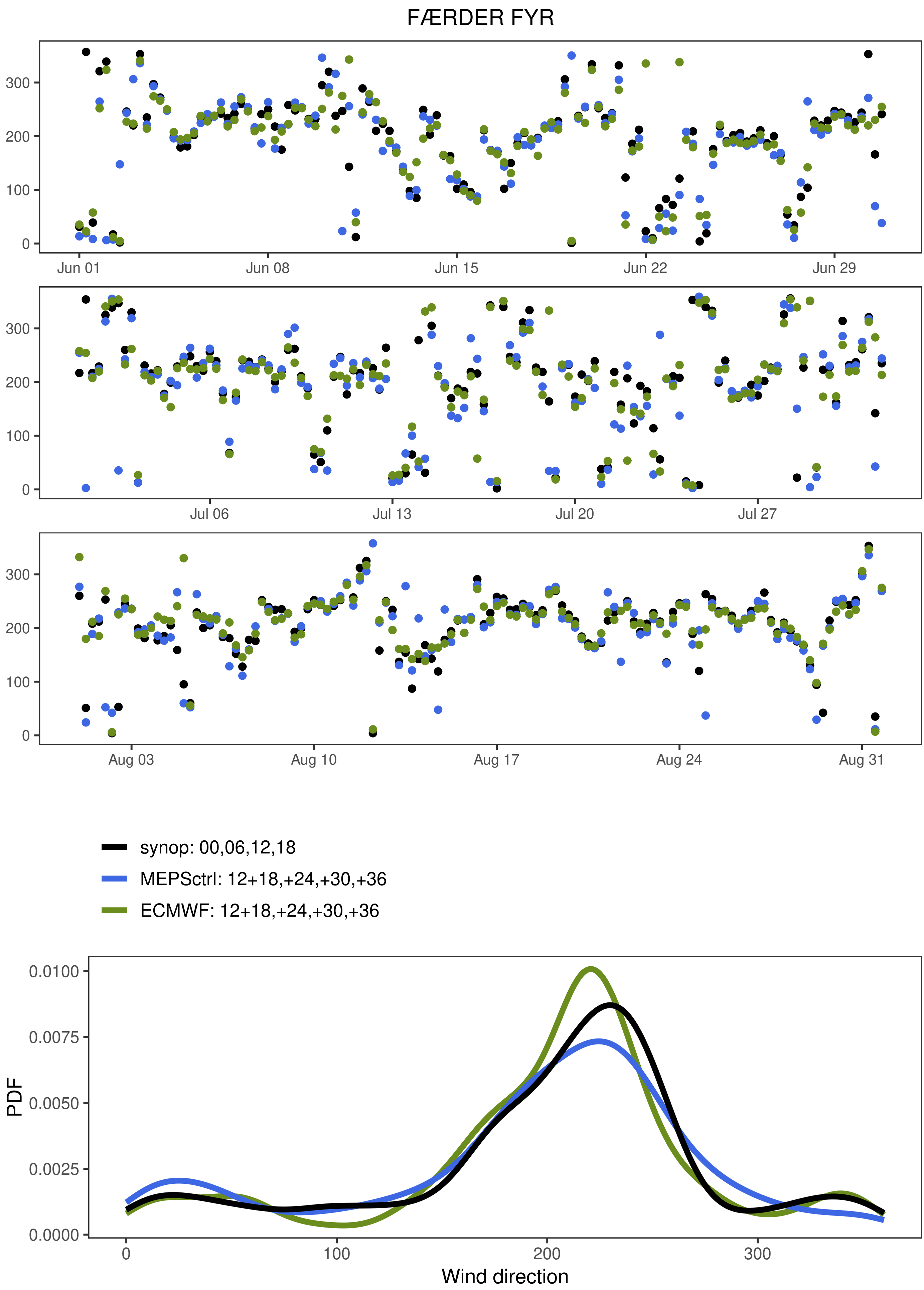

SOLA
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

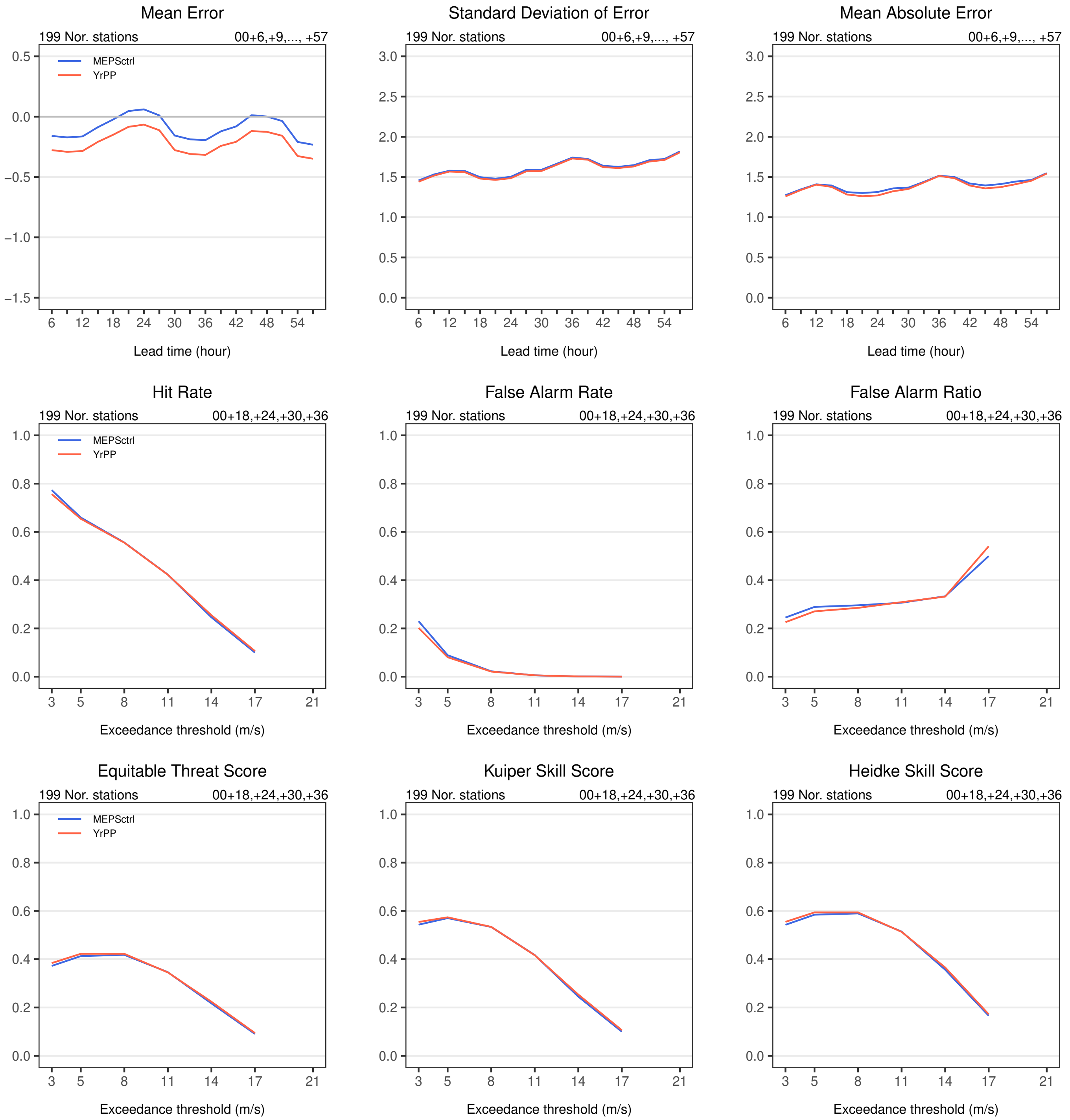

PDF
0.005
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

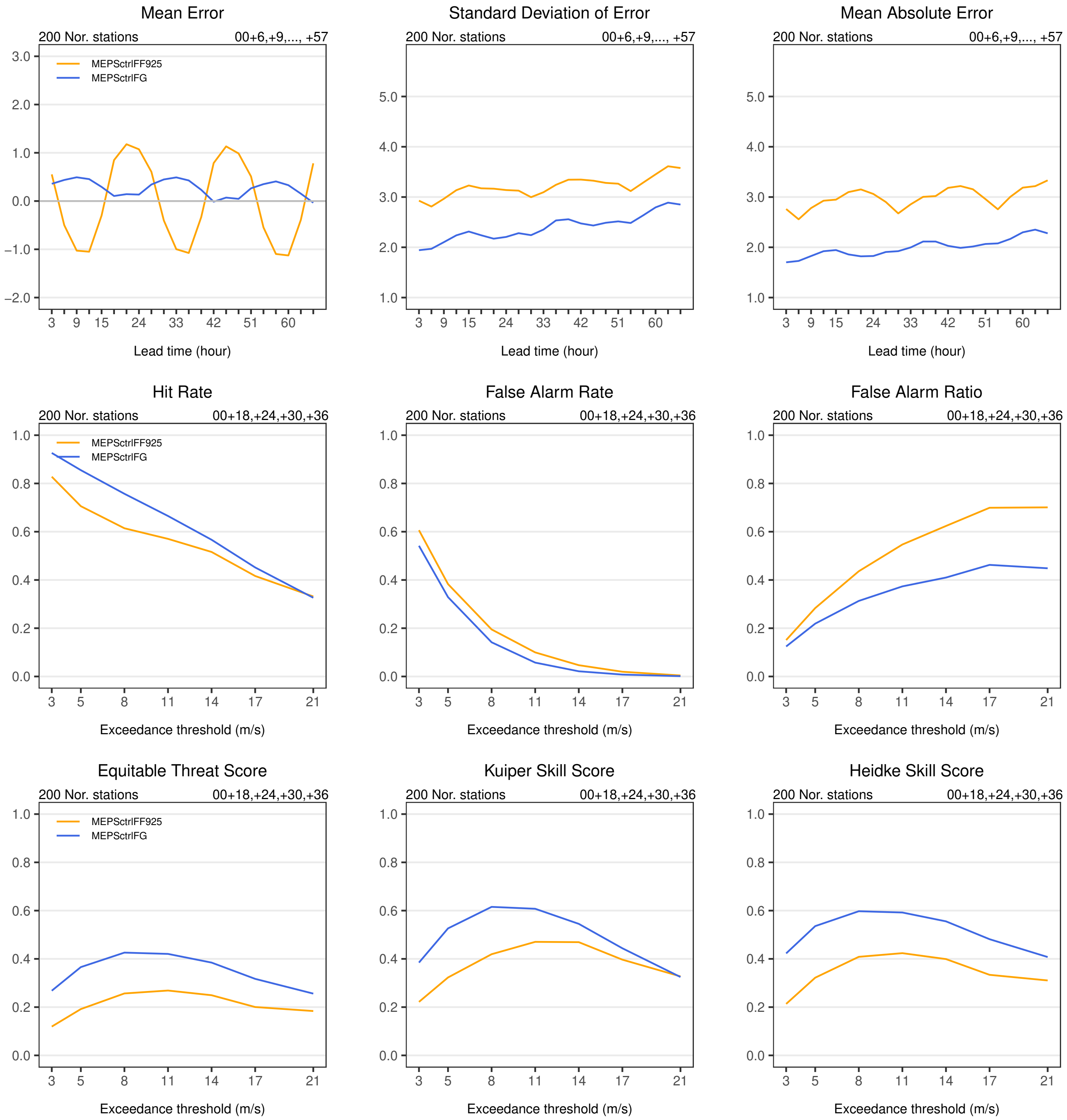


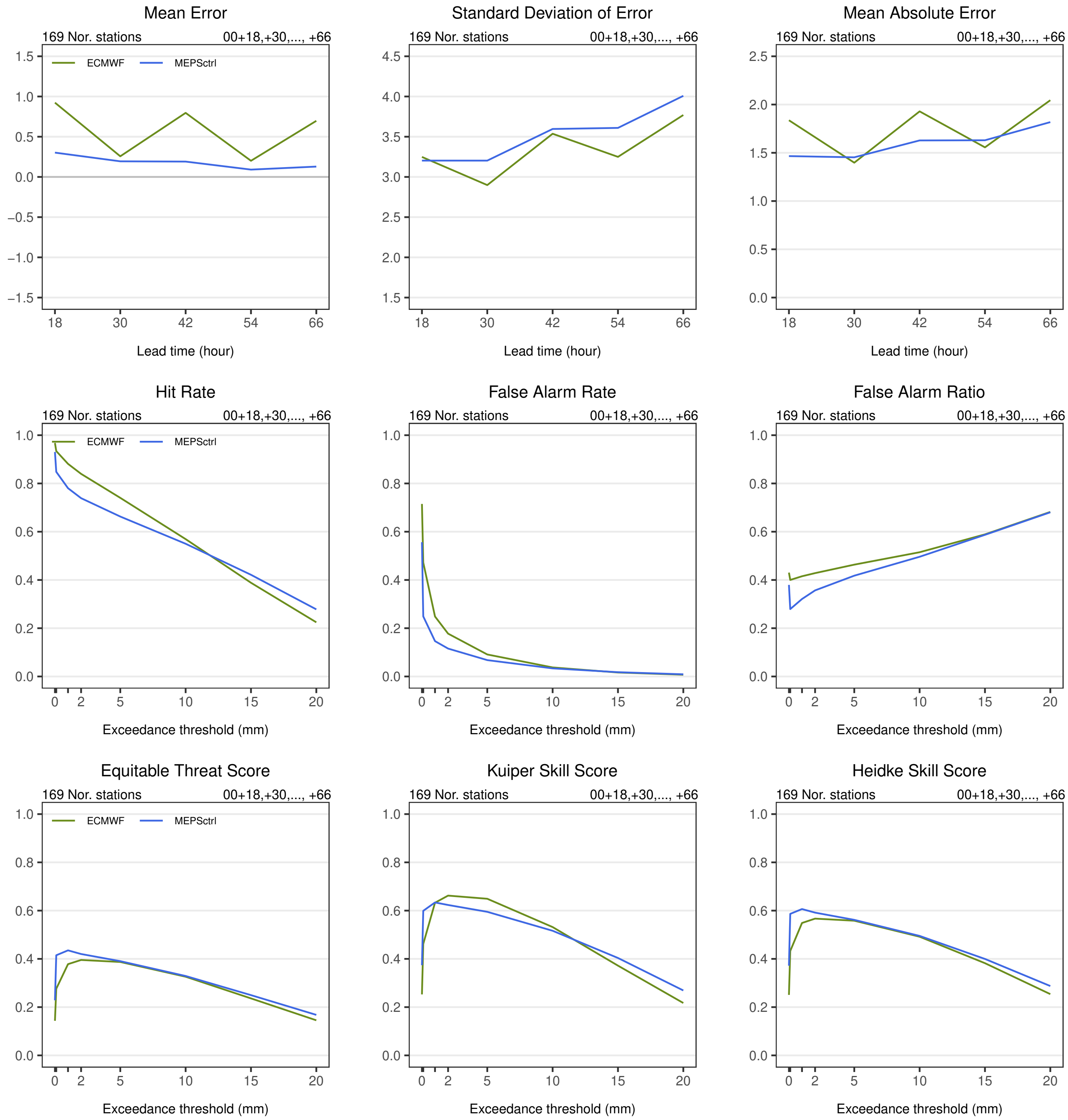
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.5	7.3	16.6	3.7	368
MEPSctrl: 12+18,+24,+30,+36	0.4	6.5	16.4	3.4	368
ECMWF: 12+18,+24,+30,+36	0.7	6.6	16.5	3.3	368

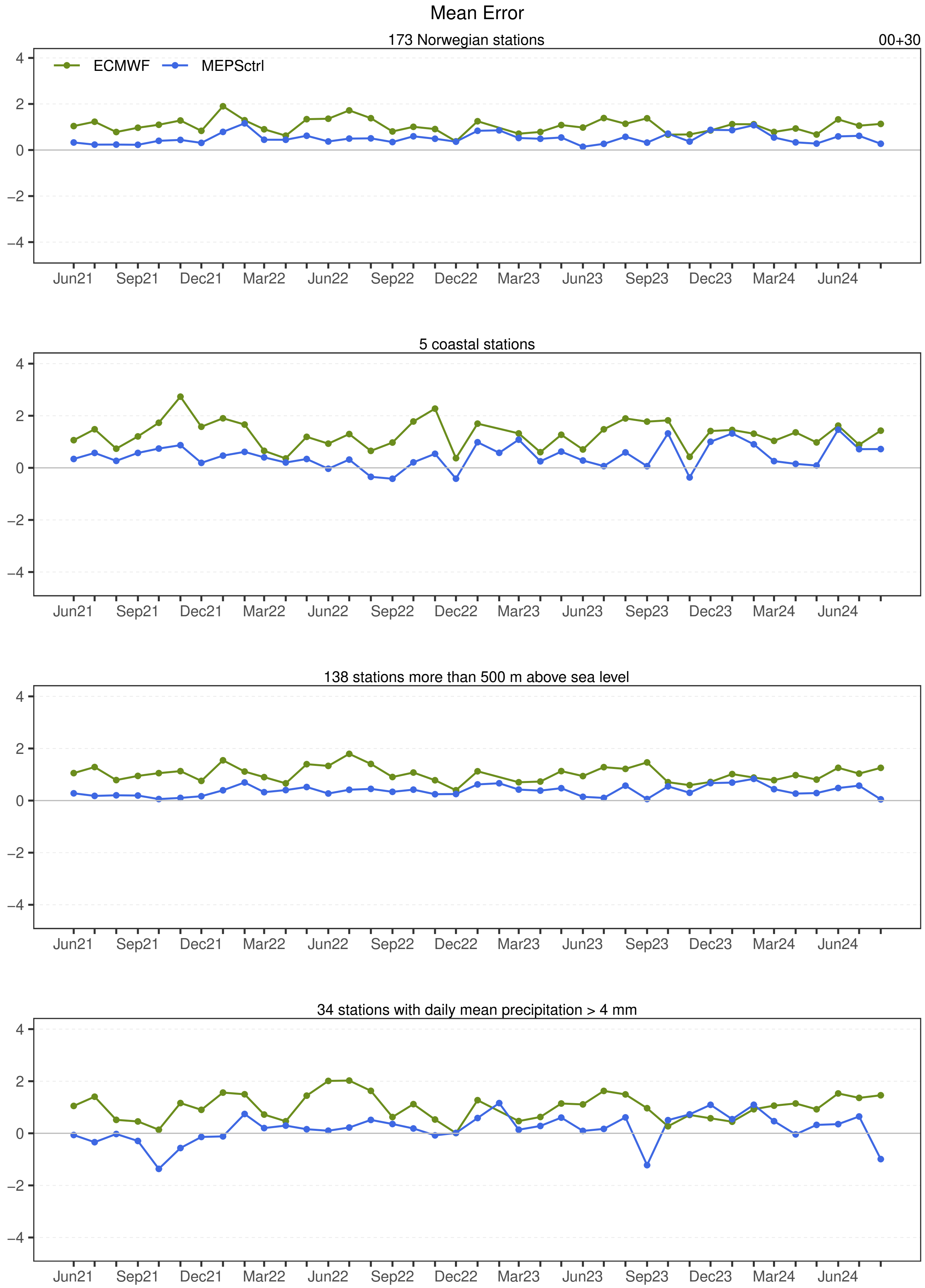
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.8	1.9	2.1	1.6	9.1	368
ECMWF – synop	–0.7	1.6	1.8	1.4	6.1	368

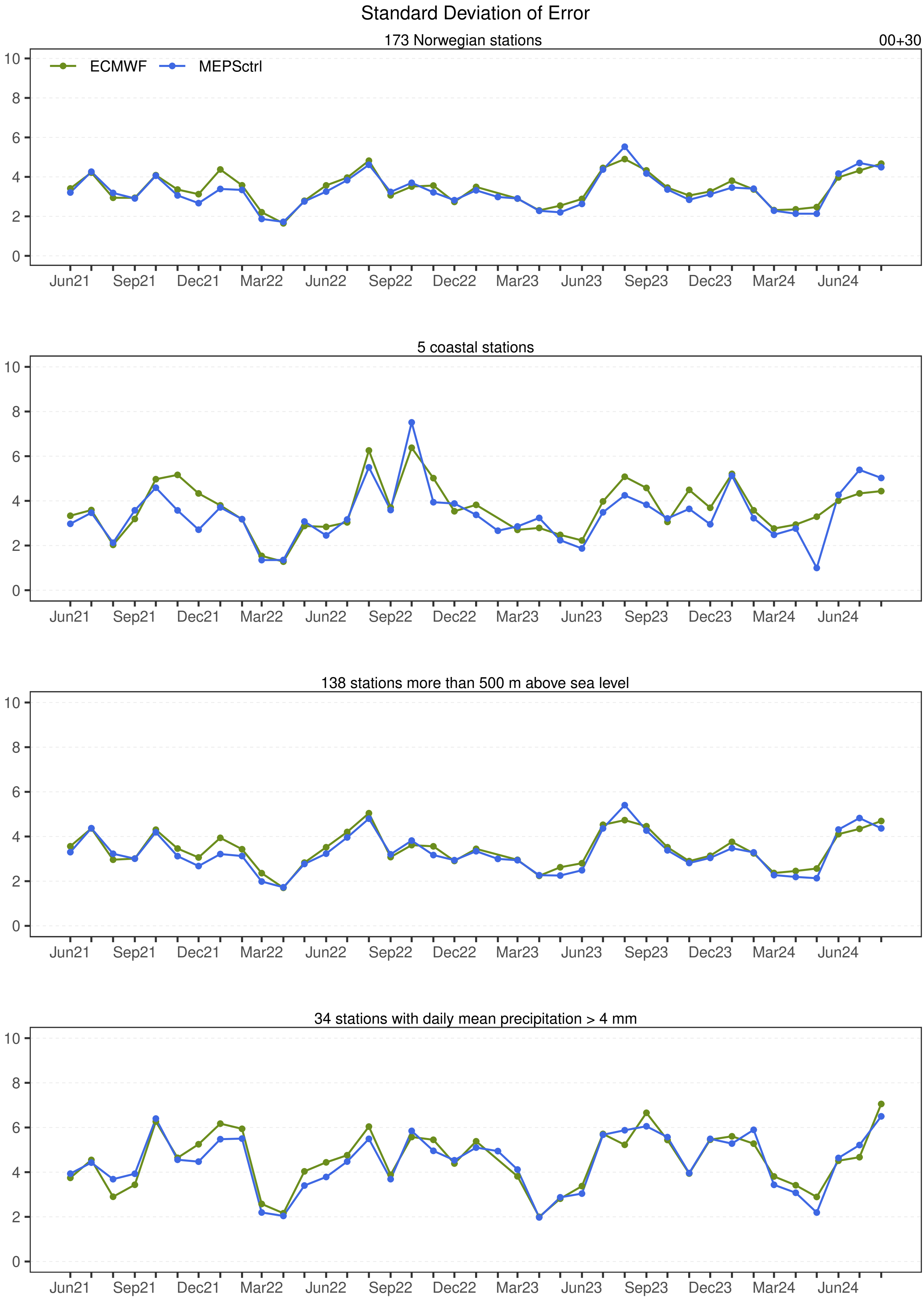

FÆRDER FYR
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.0100
0.0075
0.0050
0.0025
0.0000
0
100
200
300
Wind direction

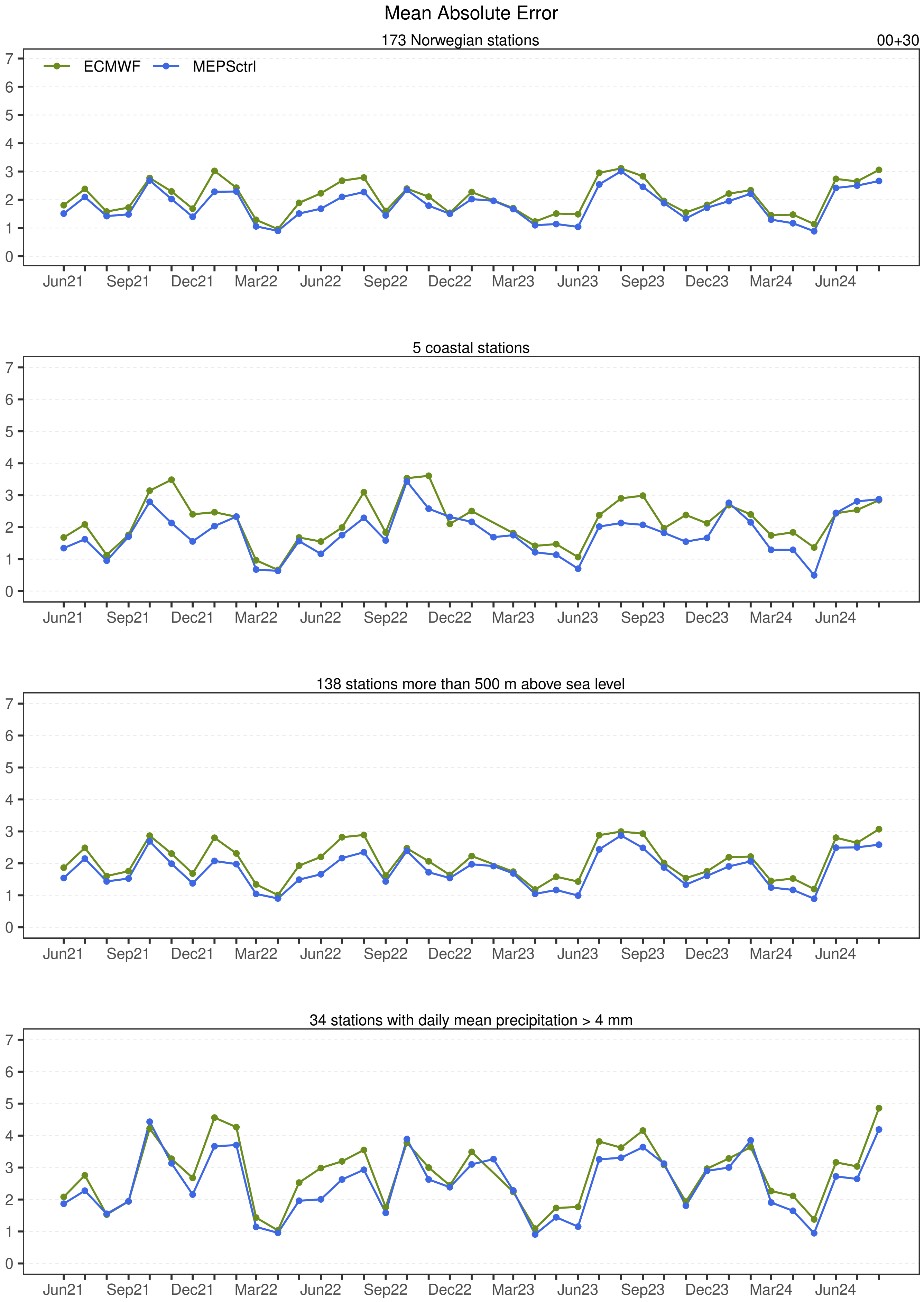

Mean Error
199 Nor. stations
00+6,+9,..., +57
MEPSctrl
YrPP
Lead time (hour)
Standard Deviation of Error
199 Nor. stations
00+6,+9,..., +57
Lead time (hour)
Mean Absolute Error
199 Nor. stations
00+6,+9,..., +57
Lead time (hour)
Hit Rate
199 Nor. stations
00+18,+24,+30,+36
MEPSctrl
YrPP
Exceedance threshold (m/s)
False Alarm Rate
199 Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)
False Alarm Ratio
199 Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)
Equitable Threat Score
199 Nor. stations
00+18,+24,+30,+36
MEPSctrl
YrPP
Exceedance threshold (m/s)
Kuiper Skill Score
199 Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)
Heidke Skill Score
199 Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)


Mean Error
200 Nor. stations
00+6,+9,..., +57
MEPSctrlFF925
MEPSctrlFG
Lead time (hour)
Standard Deviation of Error
200 Nor. stations
00+6,+9,..., +57
Lead time (hour)
Mean Absolute Error
200 Nor. stations
00+6,+9,..., +57
Lead time (hour)
Hit Rate
200 Nor. stations
00+18,+24,+30,+36
MEPSctrlFF925
MEPSctrlFG
Exceedance threshold (m/s)
False Alarm Rate
200 Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)
False Alarm Ratio
200 Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)
Equitable Threat Score
200 Nor. stations
00+18,+24,+30,+36
MEPSctrlFF925
MEPSctrlFG
Exceedance threshold (m/s)
Kuiper Skill Score
200 Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)
Heidke Skill Score
200 Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)


Mean Error
169 Nor. stations
00+18,+30,..., +66
ECMWF
MEPSctrl
Lead time (hour)
Standard Deviation of Error
169 Nor. stations
00+18,+30,..., +66
Lead time (hour)
Mean Absolute Error
169 Nor. stations
00+18,+30,..., +66
Lead time (hour)
Hit Rate
169 Nor. stations
00+18,+30,..., +66
ECMWF
MEPSctrl
Exceedance threshold (mm)
False Alarm Rate
169 Nor. stations
00+18,+30,..., +66
Exceedance threshold (mm)
False Alarm Ratio
169 Nor. stations
00+18,+30,..., +66
Exceedance threshold (mm)
Equitable Threat Score
169 Nor. stations
00+18,+30,..., +66
ECMWF
MEPSctrl
Exceedance threshold (mm)
Kuiper Skill Score
169 Nor. stations
00+18,+30,..., +66
Exceedance threshold (mm)
Heidke Skill Score
169 Nor. stations
00+18,+30,..., +66
Exceedance threshold (mm)

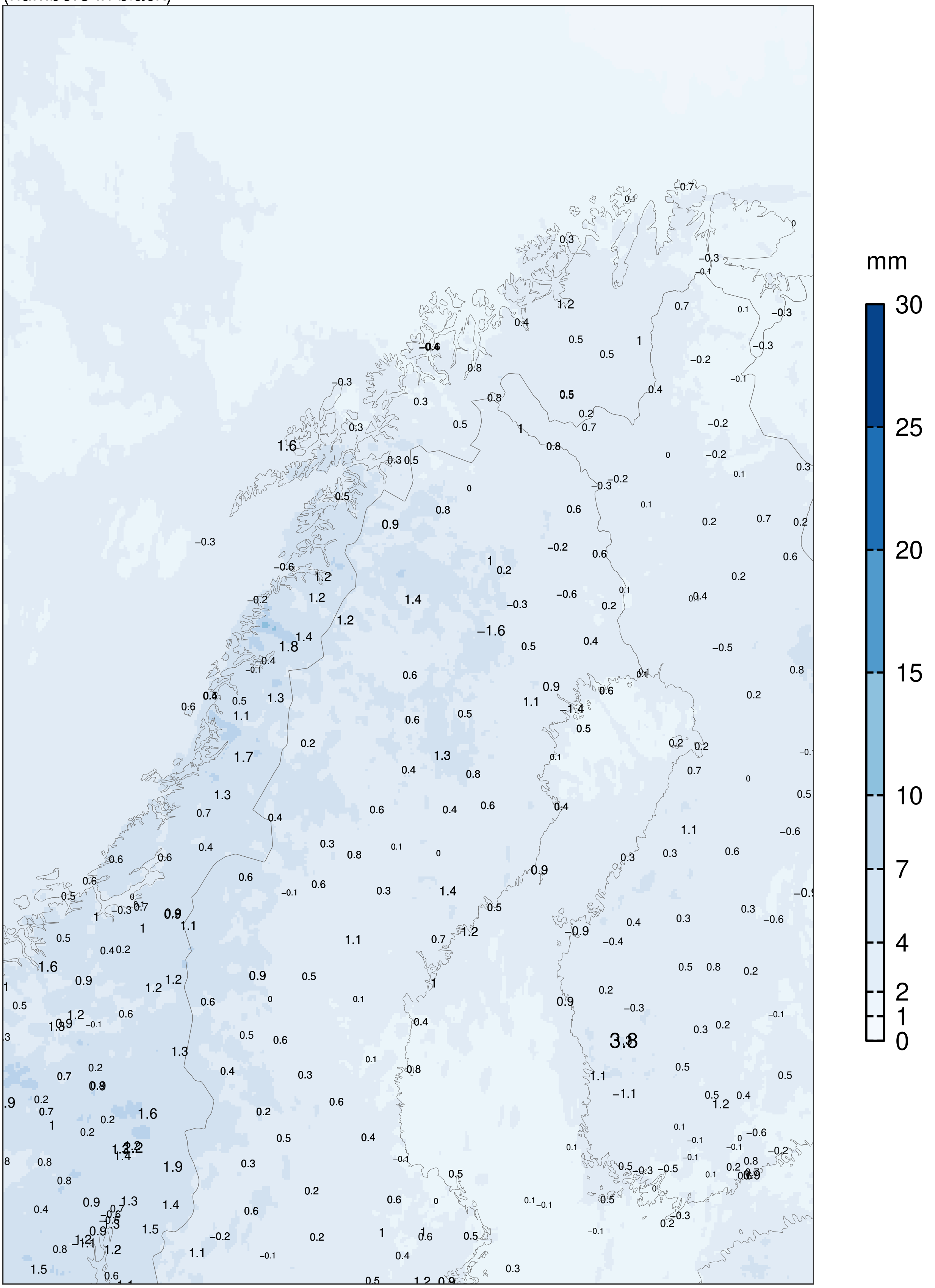

Mean Error
173 Norwegian stations
00+30
ECMWF
MEPSctrl
5 coastal stations
138 stations more than 500 m above sea level
34 stations with daily mean precipitation > 4 mm
4
2
0
−2
−4
Jun21 Sep21 Dec21 Mar22 Jun22 Sep22 Dec22 Mar23 Jun23 Sep23 Dec23 Mar24 Jun24


Standard Deviation of Error
173 Norwegian stations
00+30
ECMWF
MEPSctrl
5 coastal stations
138 stations more than 500 m above sea level
34 stations with daily mean precipitation > 4 mm
0
2
4
6
8
10
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24


Mean Absolute Error
173 Norwegian stations
00+30
ECMWF
MEPSctrl
5 coastal stations
138 stations more than 500 m above sea level
34 stations with daily mean precipitation > 4 mm
0
1
2
3
4
5
6
7
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24

MEPSctrl 00+30

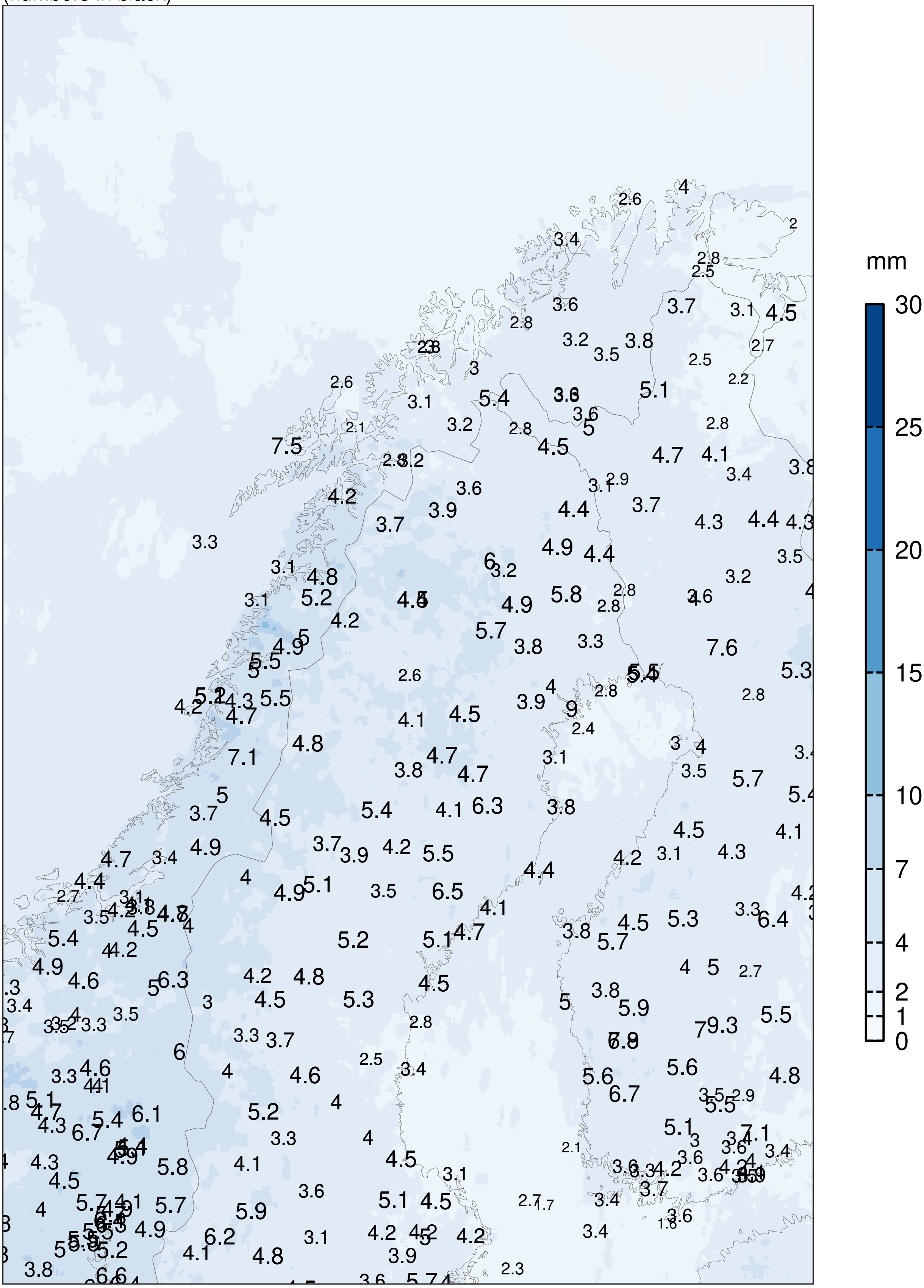
ME at observing sites
(numbers in black)



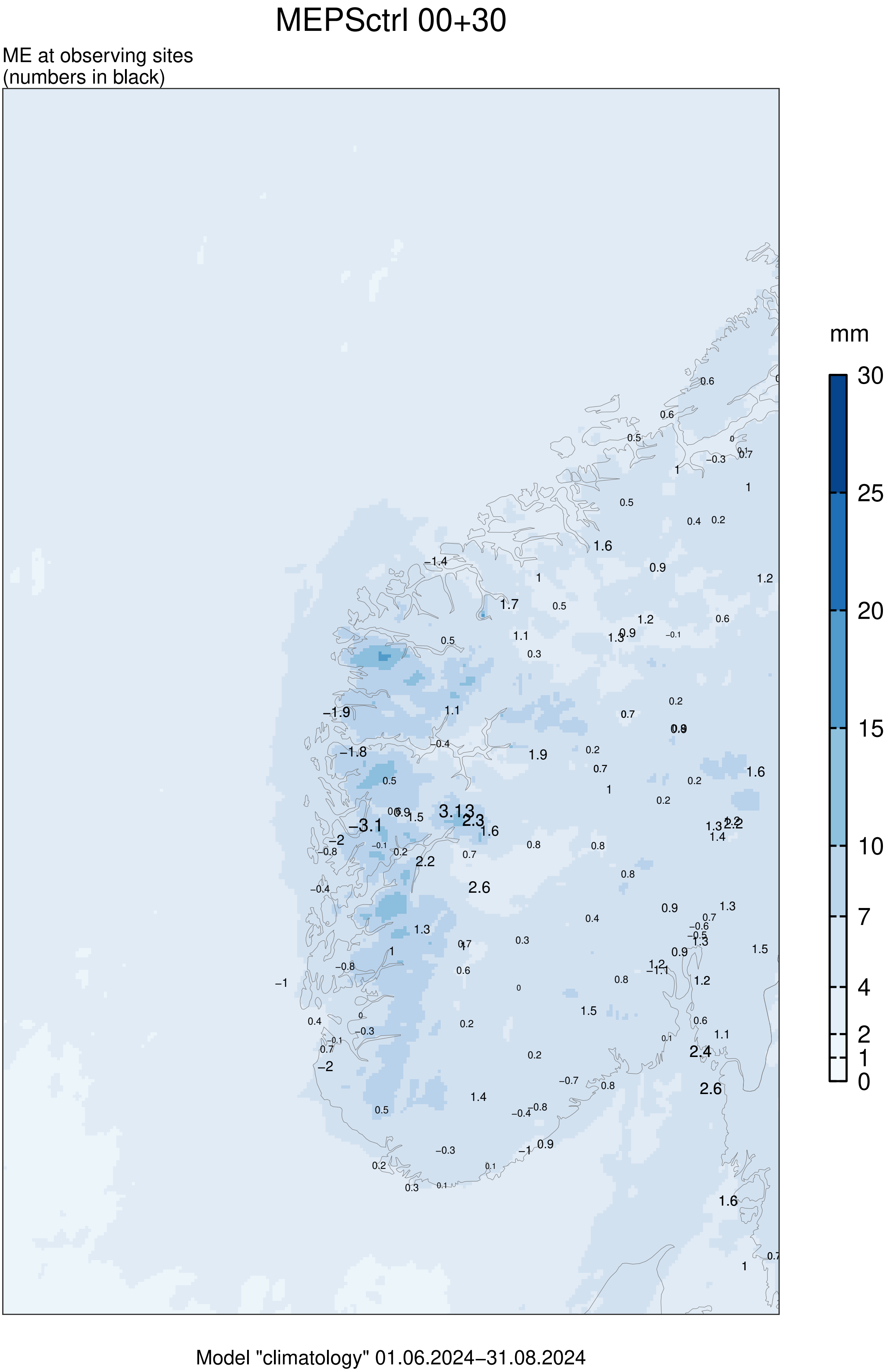
Model "climatology" 01.06.2024–31.08.2024

MEPSctrl 00+30

SDE at observing sites
(numbers in black)

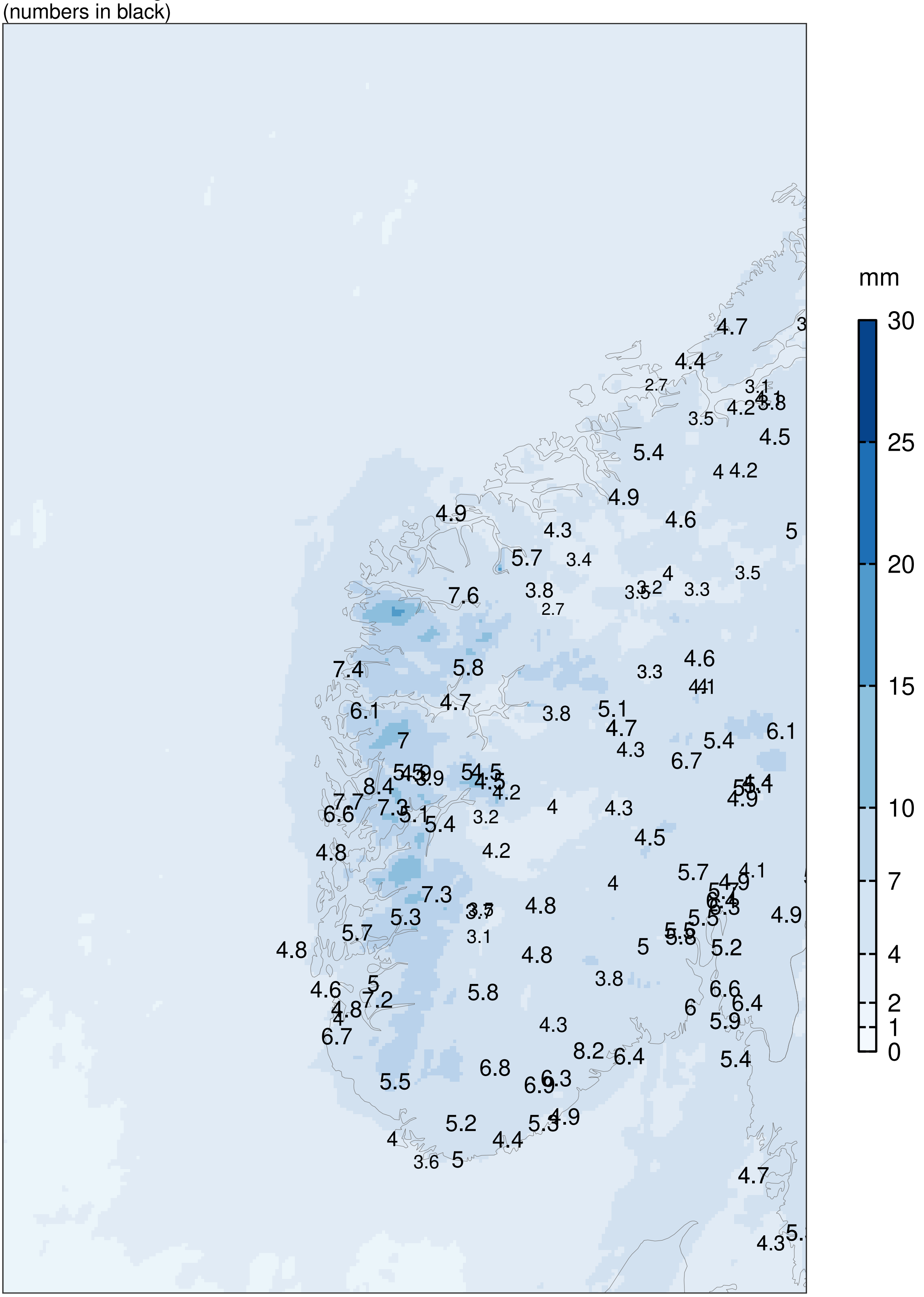


Model "climatology" 01.06.2024–31.08.2024


MEPSctrl 00+30
ME at observing sites
(numbers in black)
mm
30
25
20
15
10
7
4
2
1
0
Model "climatology" 01.06.2024–31.08.2024

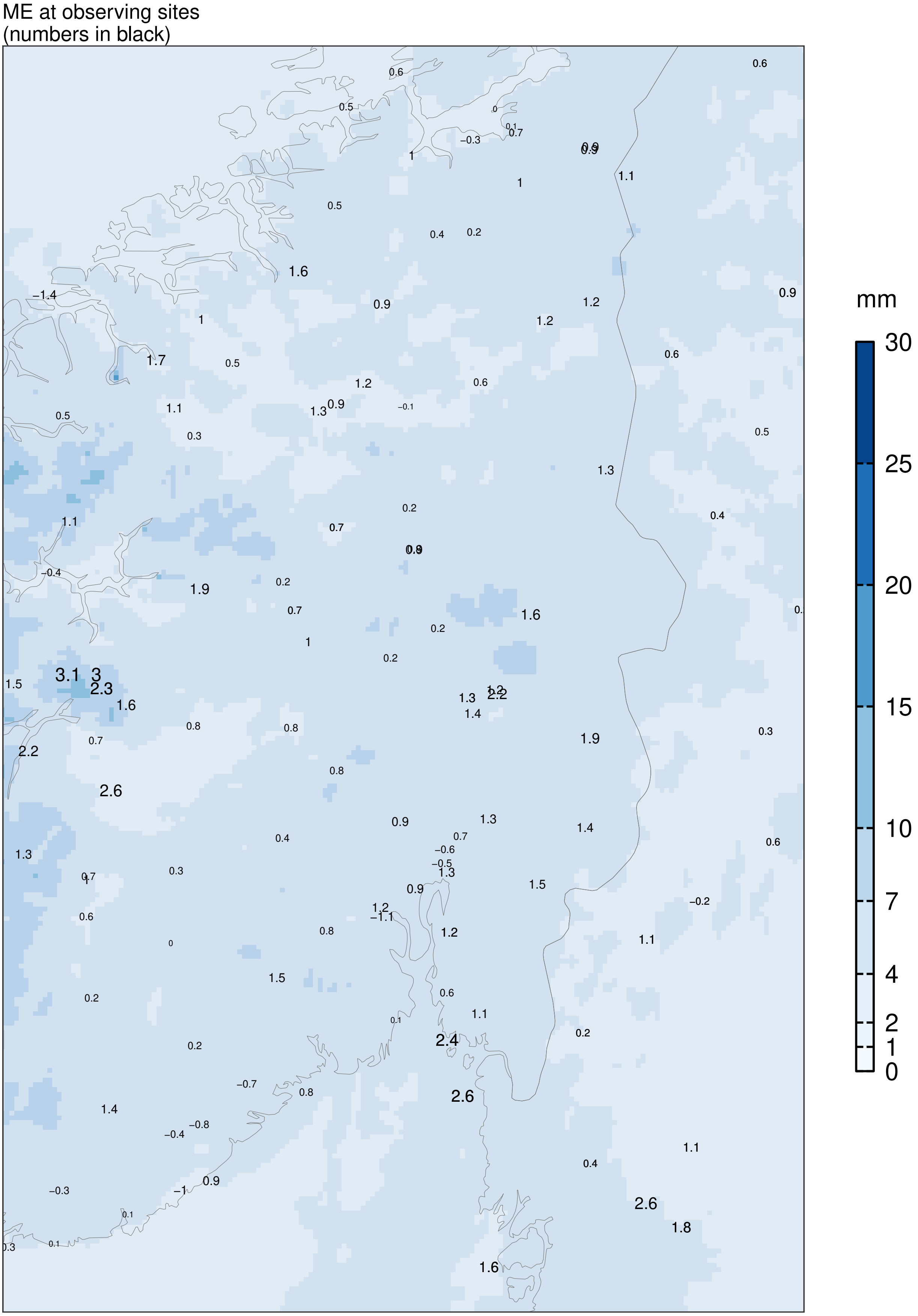
MEPSctrl 00+30

SDE at observing sites
(numbers in black)



Model "climatology" 01.06.2024–31.08.2024

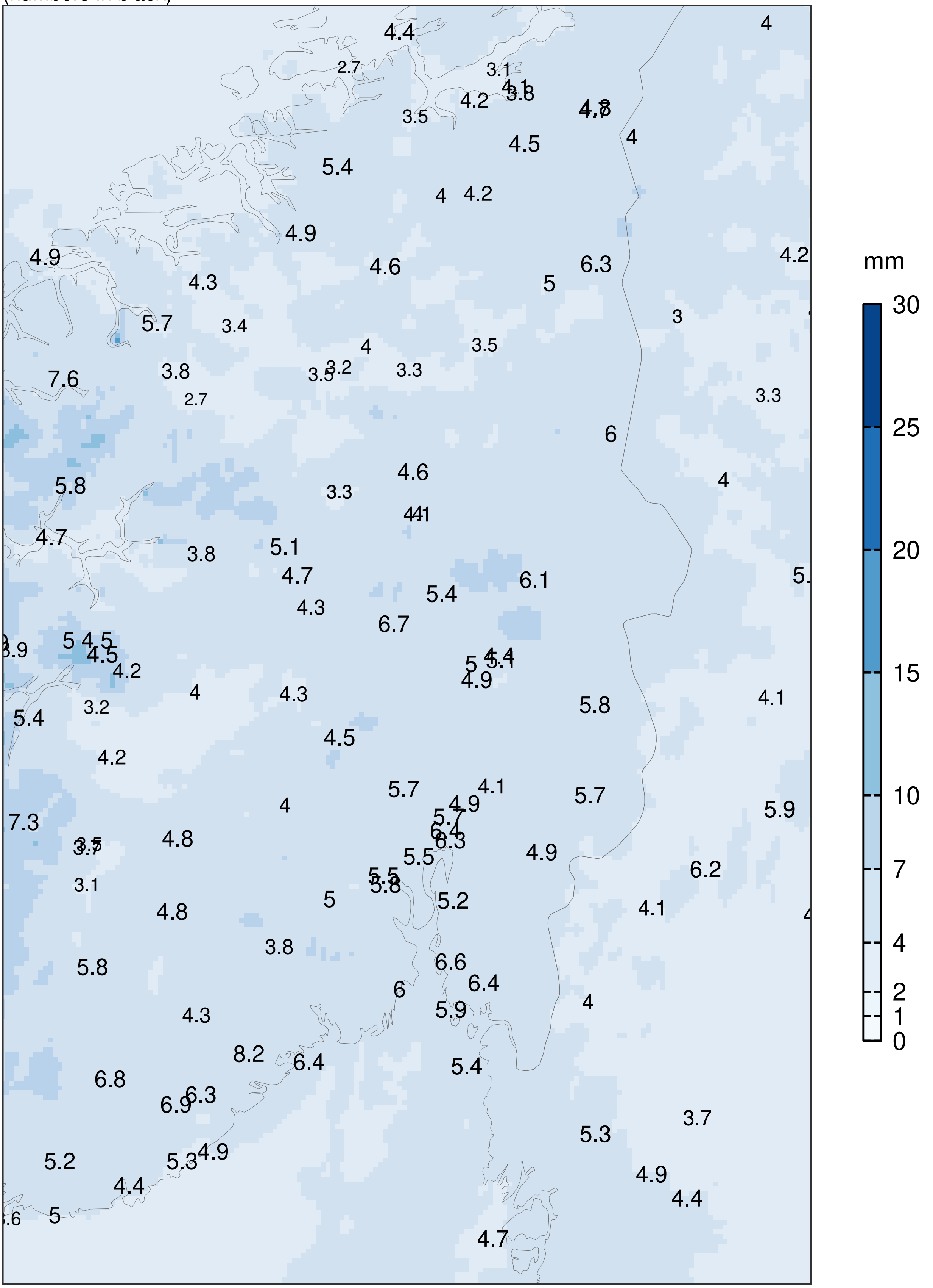
MEPSctrl 00+30



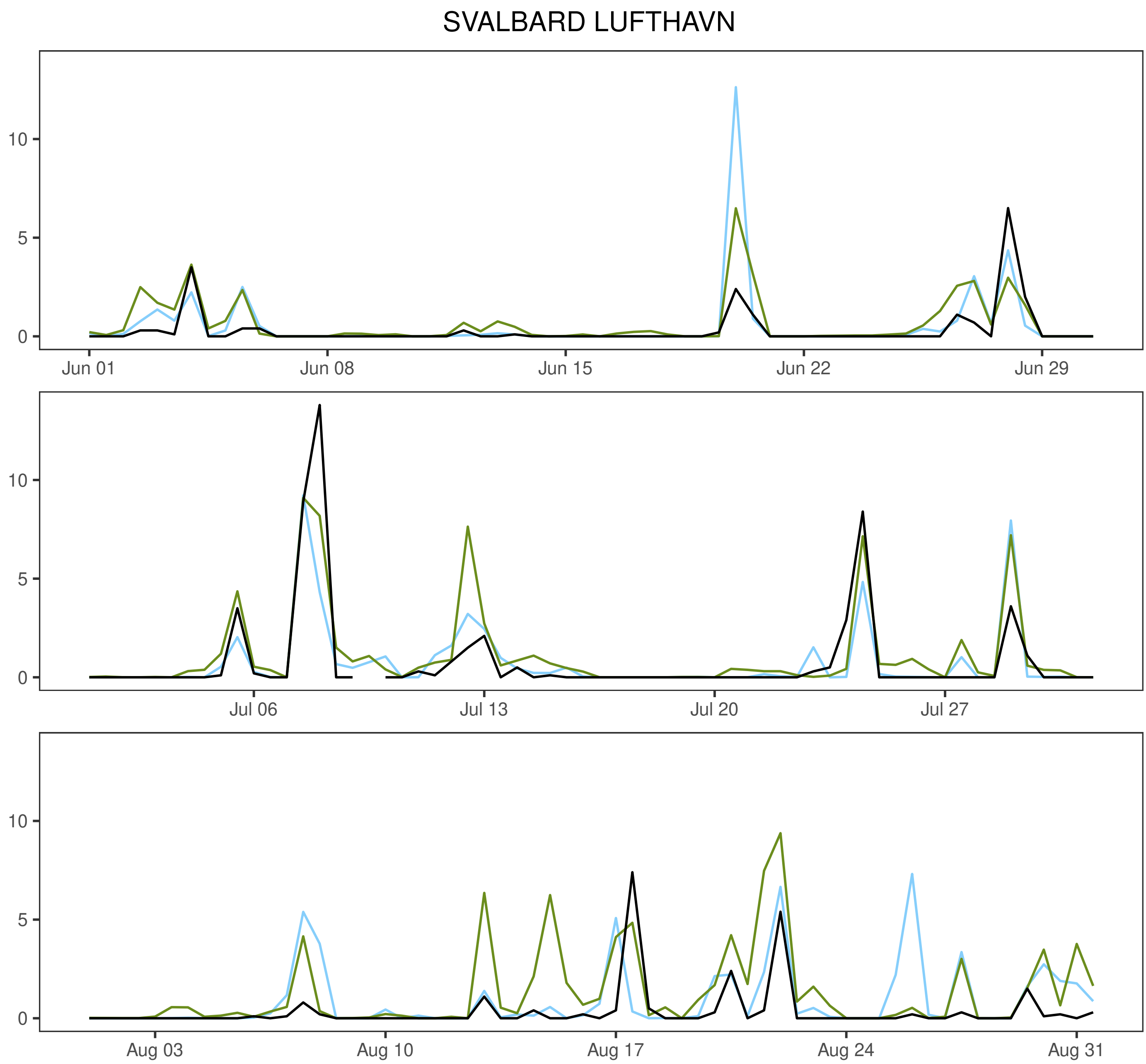
Model "climatology" 01.06.2024–31.08.2024

MEPSctrl 00+30

SDE at observing sites
(numbers in black)

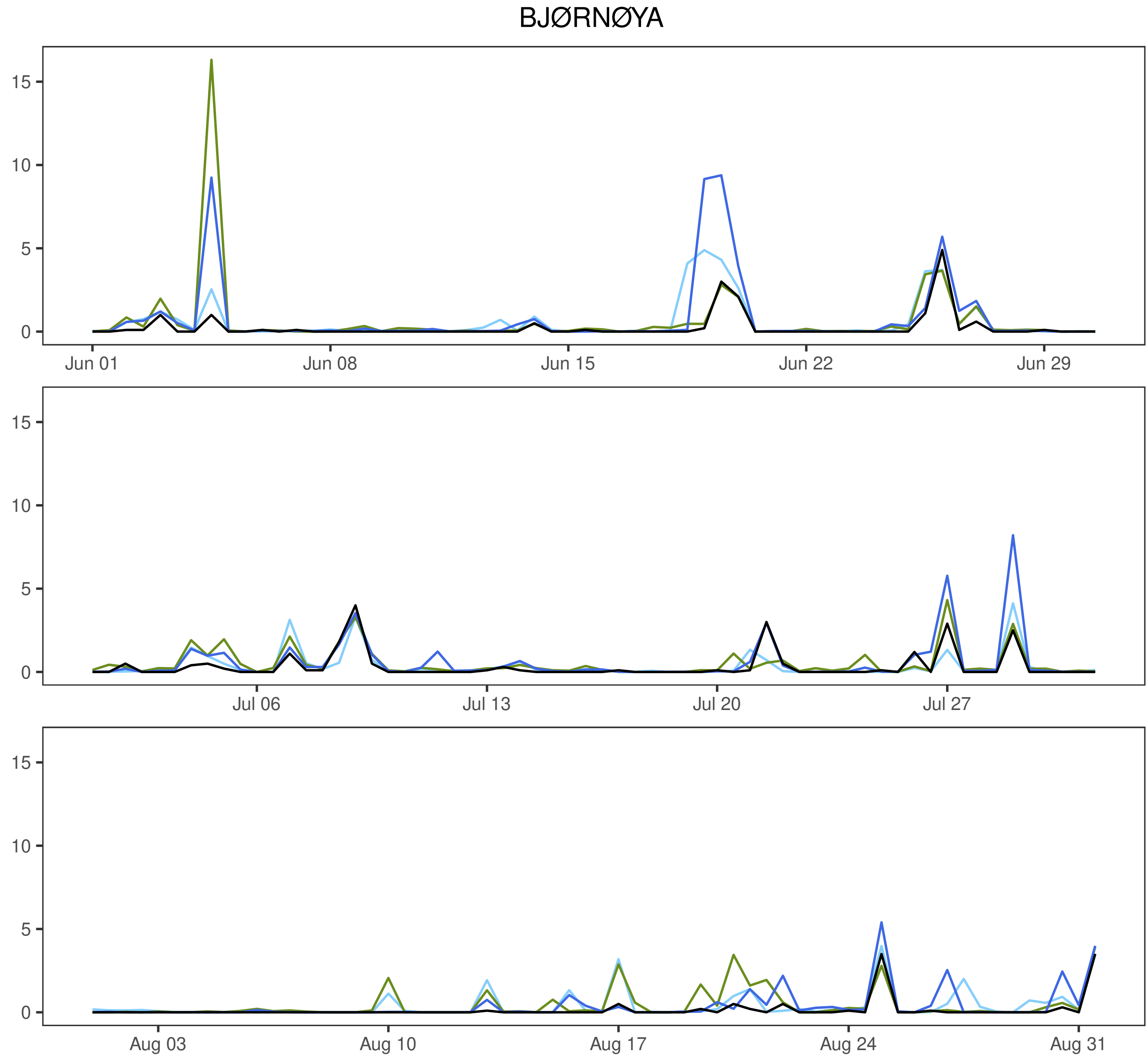


Model "climatology" 01.06.2024–31.08.2024



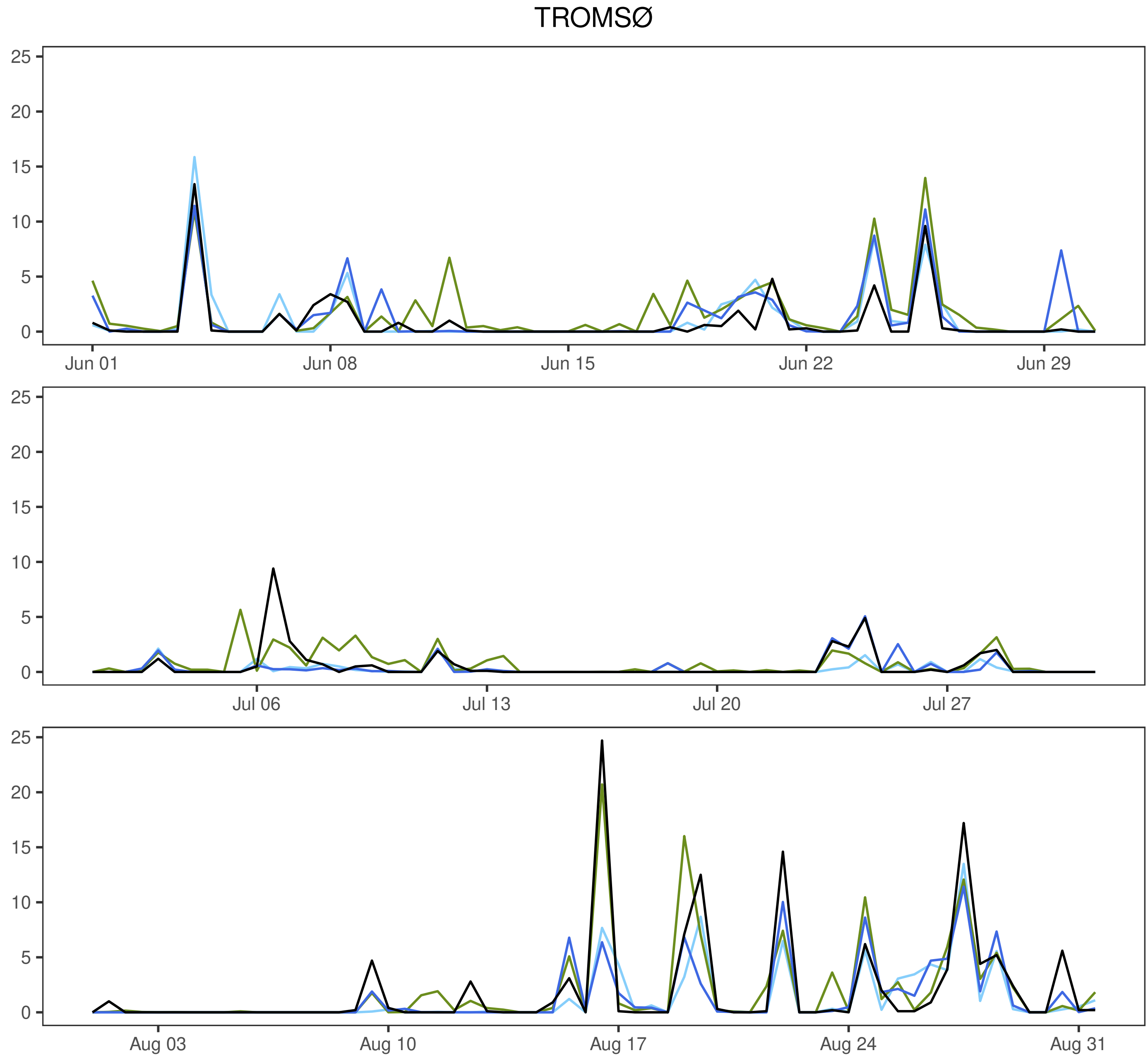
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.5	13.8	1.7	183
AA25: 12+18,+30	0.0	0.7	12.6	1.7	184
ECMWF: 12+18,+30	0.0	1.0	9.4	1.9	184

	ME	SDE	RMSE	MAE	Max.abs.err	N
AA25 – synop	0.2	1.6	1.6	0.6	10.2	183
ECMWF – synop	0.5	1.4	1.4	0.7	7.1	183



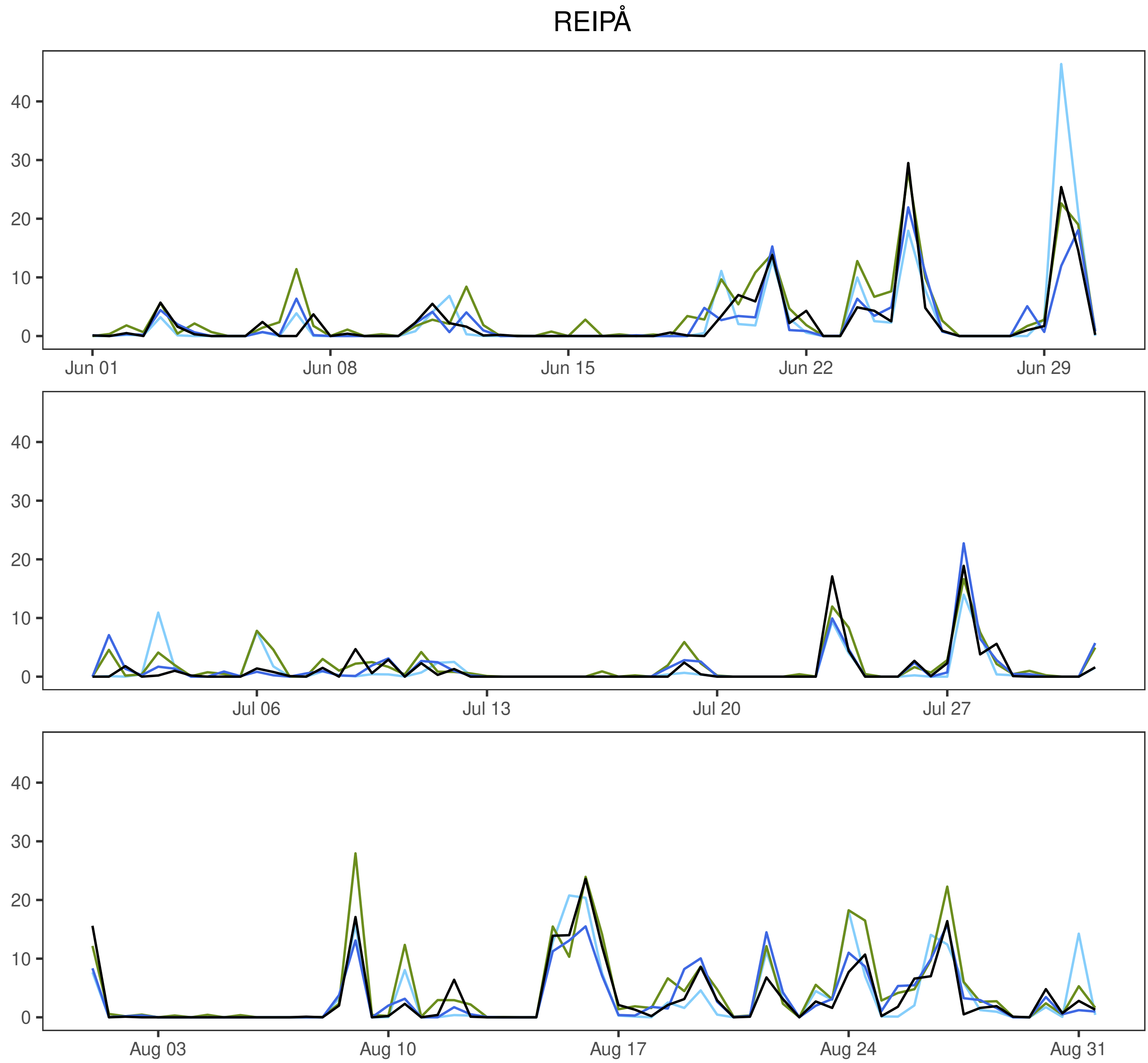
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.2	4.9	0.8	184
MEPSctrl: 12+18,+30	0.0	0.6	9.4	1.6	184
AA25: 12+18,+30	0.0	0.5	4.9	1.0	184
ECMWF: 12+18,+30	0.0	0.5	16.3	1.4	184

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.4	1.2	1.2	0.4	9.0	184
AA25 – synop	0.2	0.7	0.7	0.3	4.7	184
ECMWF – synop	0.3	1.2	1.3	0.4	15.3	184



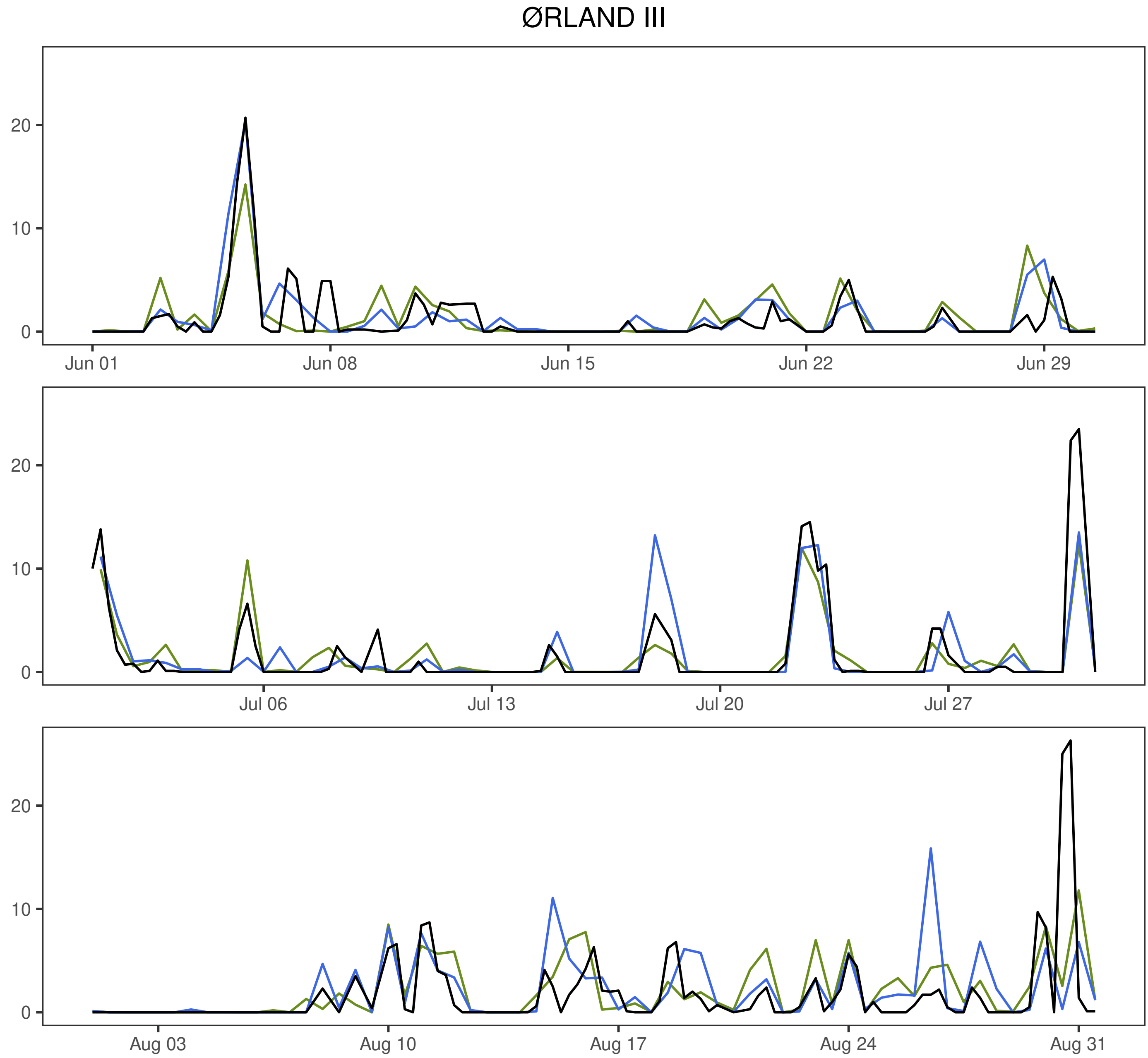
	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.1	24.7	3.1	184
MEPSctrl: 12+18,+30	0.0	1.0	11.4	2.3	184
AA25: 12+18,+30	0.0	0.9	15.9	2.2	184
ECMWF: 12+18,+30	0.0	1.5	20.7	2.9	184

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.1	2.1	2.1	0.8	18.3	184
AA25 – synop	–0.3	2.0	2.0	0.8	17.0	184
ECMWF – synop	0.3	1.8	1.8	1.0	8.9	184



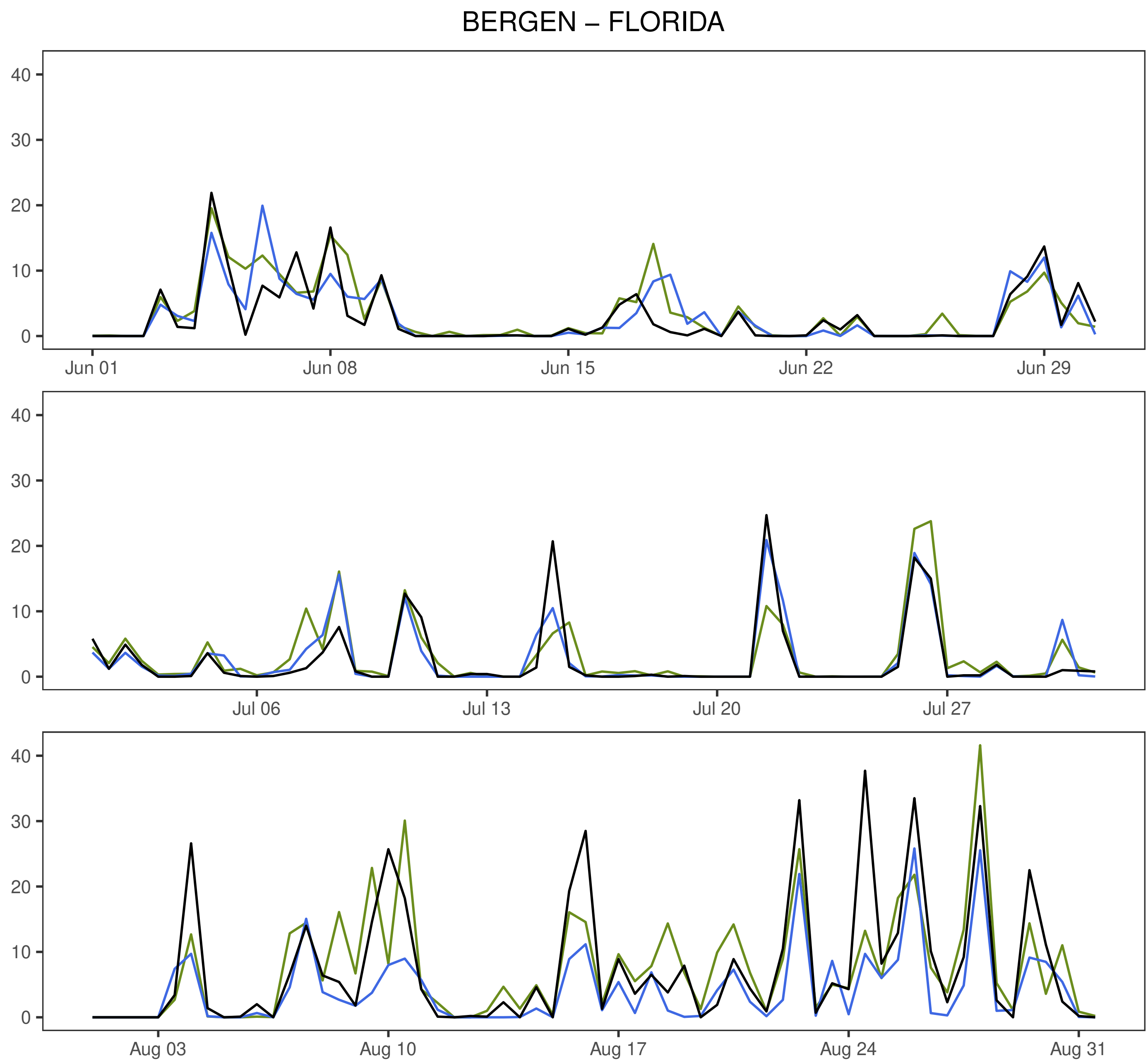
	Min	Mean	Max	Std	N
synop: 06,18	0.0	2.4	29.5	4.9	184
MEPSctrl: 12+18,+30	0.0	2.4	22.7	4.2	184
AA25: 12+18,+30	0.0	2.4	46.4	5.5	184
ECMWF: 12+18,+30	0.0	3.3	28.1	5.5	184

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.0	2.3	2.3	1.2	13.4	184
AA25 – synop	0.0	3.2	3.1	1.5	21.0	184
ECMWF – synop	1.0	2.5	2.6	1.5	11.4	184



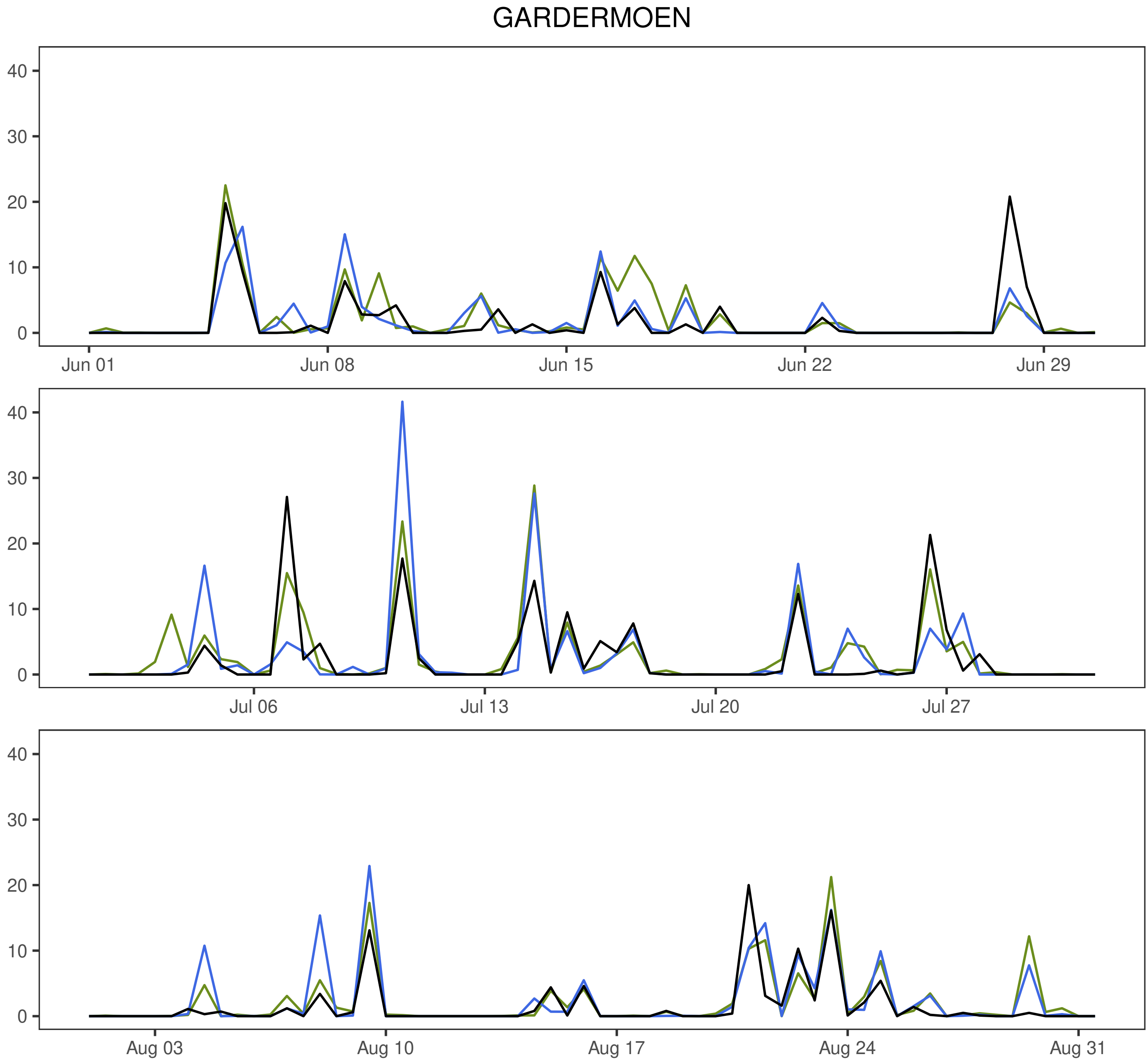
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	1.6	26.3	3.7	327
MEPSctrl: 12+18,+30	0.0	1.7	20.3	3.3	184
ECMWF: 12+18,+30	0.0	1.7	14.2	2.8	184

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.3	2.9	2.9	1.2	24.7	184
ECMWF – synop	0.2	2.6	2.6	1.2	22.5	184



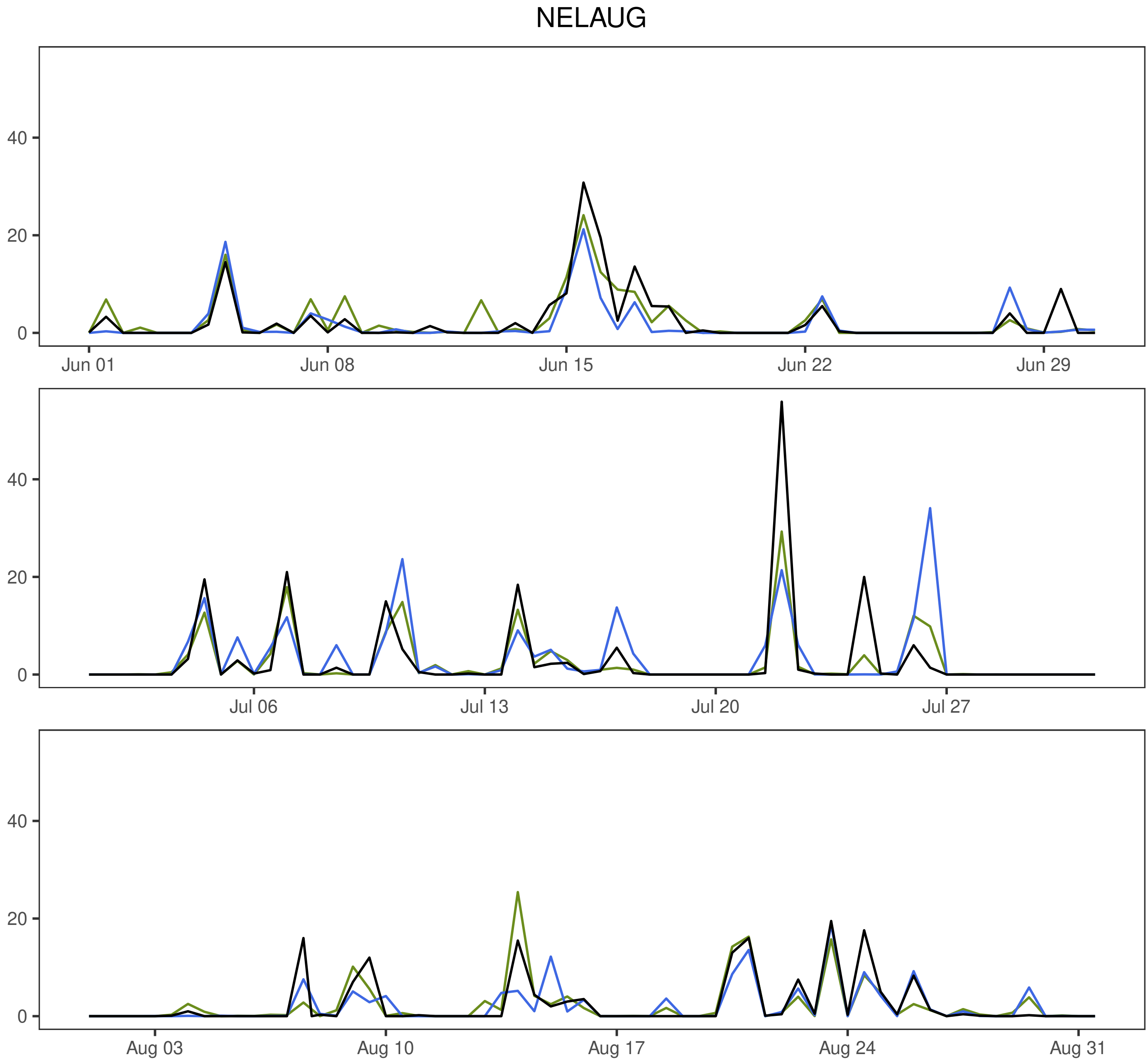
	Min	Mean	Max	Std	N
synop: 06,18	0.0	4.3	37.7	7.4	184
MEPSctrl: 12+18,+30	0.0	3.3	25.8	5.1	184
ECMWF: 12+18,+30	0.0	4.7	41.6	6.6	184

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–1.0	4.4	4.5	2.2	28.0	184
ECMWF – synop	0.4	4.5	4.5	2.4	24.5	184



	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.9	27.1	4.5	184
MEPSctrl: 12+18,+30	0.0	2.3	41.6	5.3	184
ECMWF: 12+18,+30	0.0	2.4	28.8	4.8	184

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.4	4.1	4.1	1.7	23.9	184
ECMWF – synop	0.5	3.0	3.0	1.4	16.2	184



	Min	Mean	Max	Std	N
synop: 00,06,18	0.0	2.6	55.9	6.5	185
MEPSctrl: 12+18,+30	0.0	2.4	34.1	5.0	184
ECMWF: 12+18,+30	0.0	2.4	29.3	4.9	184

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.3	5.0	5.0	2.0	34.5	184
ECMWF – synop	–0.2	3.5	3.5	1.5	26.6	184