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Verification of Operational Weather Prediction Models September to November 2024

Bjørn Gilje Lillegraven, Gunnar Noer and Lene Østvand

Iskoras, Finnmarksvidda. Photo: Bjørn Gilje Lillegraven

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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 ensemble runs. 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

		event observed	
		yes	no
event forecasted	yes	a	b
	no	c	d

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 all the different groups of stations, while MEPSctrl has a bias around zero for the Norwegian stations and a slight overestimation for the North Scandianiavian stations. AA25 has a very small overestimation of temperature at the North Scandinavian stations, similar to MEPSctrl, while very slightly underestimating the temperature at the Svalbard stations. 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 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, but the difference is smaller for the autumn than the summer months. 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 the undercatchment of observed snow. This is the case when there is strong wind in combination with snow, which is often the case especially in Northern Norway and in the mountainous areas in Southern Norway. It is suspected that the models are too dry in the coastal and fjord areas, 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 what is actually the case. AA25 and MEPSctrl show very similar results, which is expected since both are HARMONIE models with AROME physics and a horizontal resolution defined by a 2.5×2.5 km^2 grid.

Case studies by forecasters

Case 1. Convective precipitation

There were several reports of missing convective precipitation this period. One example in Rogaland from September 4th shows that even in cases with heavy precipitation the MEPSctrl model often misses in both location and intensity.

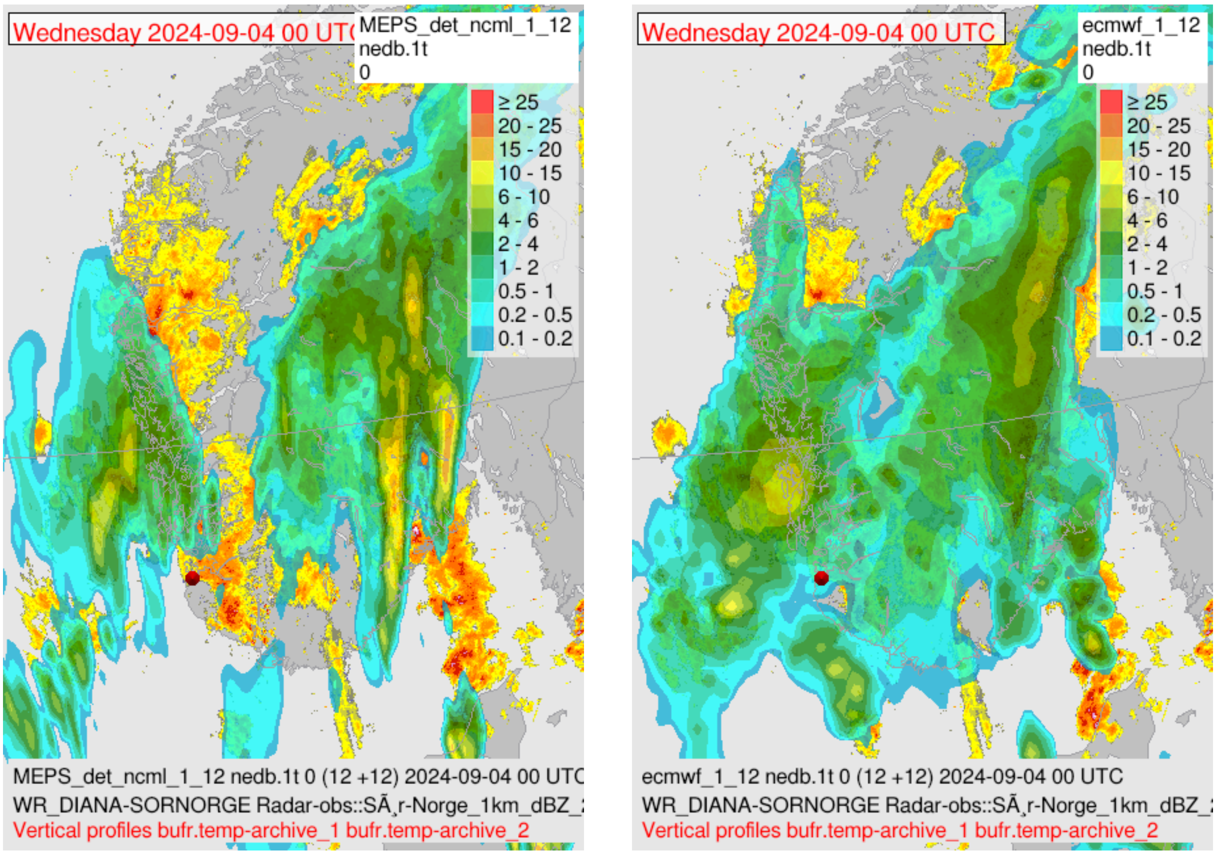


Figure 1: 1hr precipitation from MEPSctrl (left) and ECMWF (right) overlaid a radar image from 00 UTC on the 4th of September. The red dot marks the location of Sola.

Figure 1 shows the 1-hour precipitation from MEPSctrl and ECMWF at 00 UTC compared to the radar precipitation at that time. MEPSctrl was not able to reproduce the observed heavy showers south of Stavanger or in Northern Denmark, while ECMWF did to a certain degree. Since in this case ECMWF had a better fit, the problem with MEPSctrl could not lie in the analysis or boundary conditions, but rather in the physics or parameterisation schemes used in the model.

A comparison of the sounding from the MEPSctrl to an actual sounding at Sola airport near Stavanger (figure 2) from 00 UTC shows that the model had a good fit for the temperature and dew point temperature. It also shows that the model had a correct depth of instability. While MEPSctrl captured some of the precipitation near Sola, there were large areas of underforecasted precipitation in close vicinity.

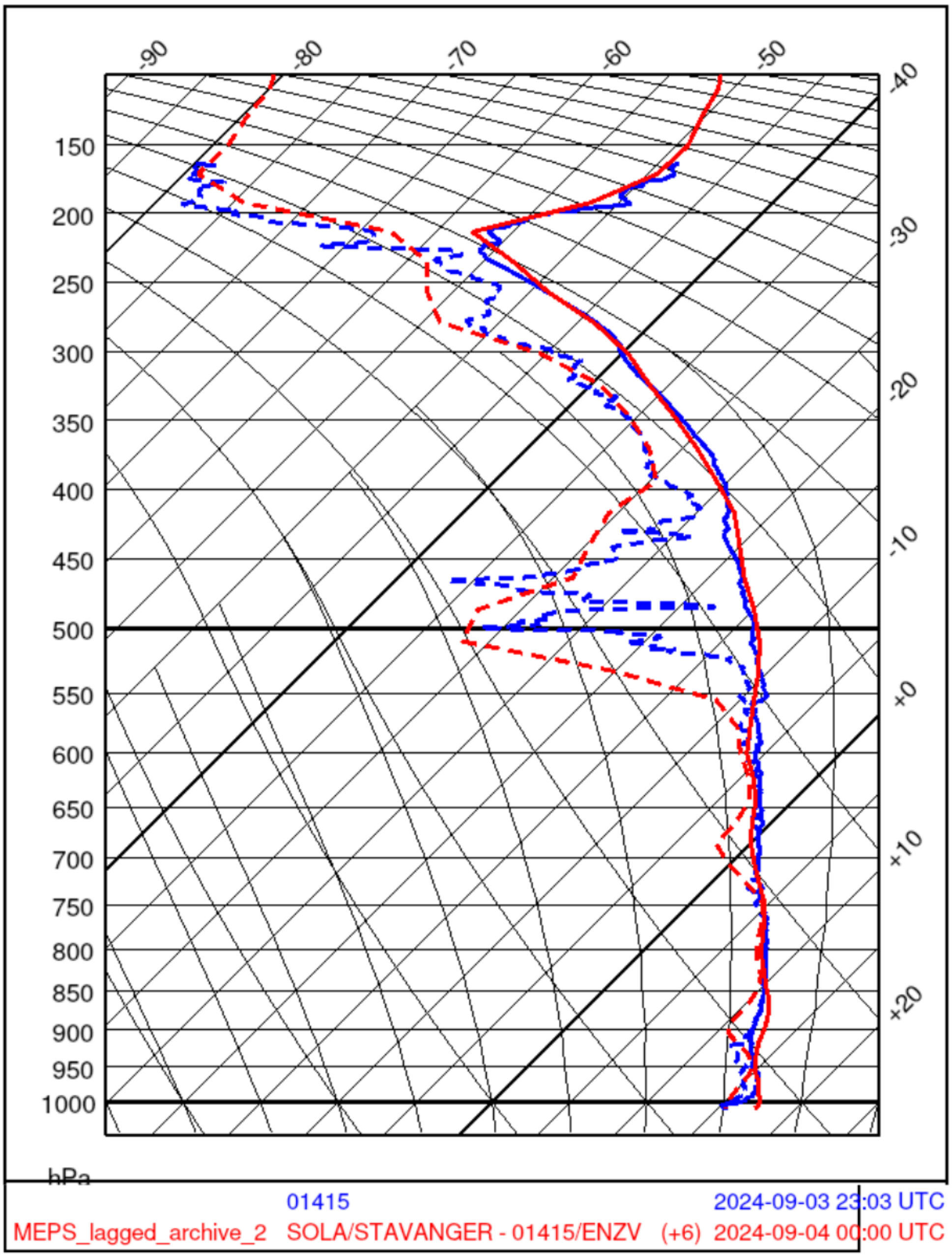


Figure 2: The prognostic sounding from MEPSctrl (red) compared to an actual sounding (blue) from 00 UTC on the 4th of September.

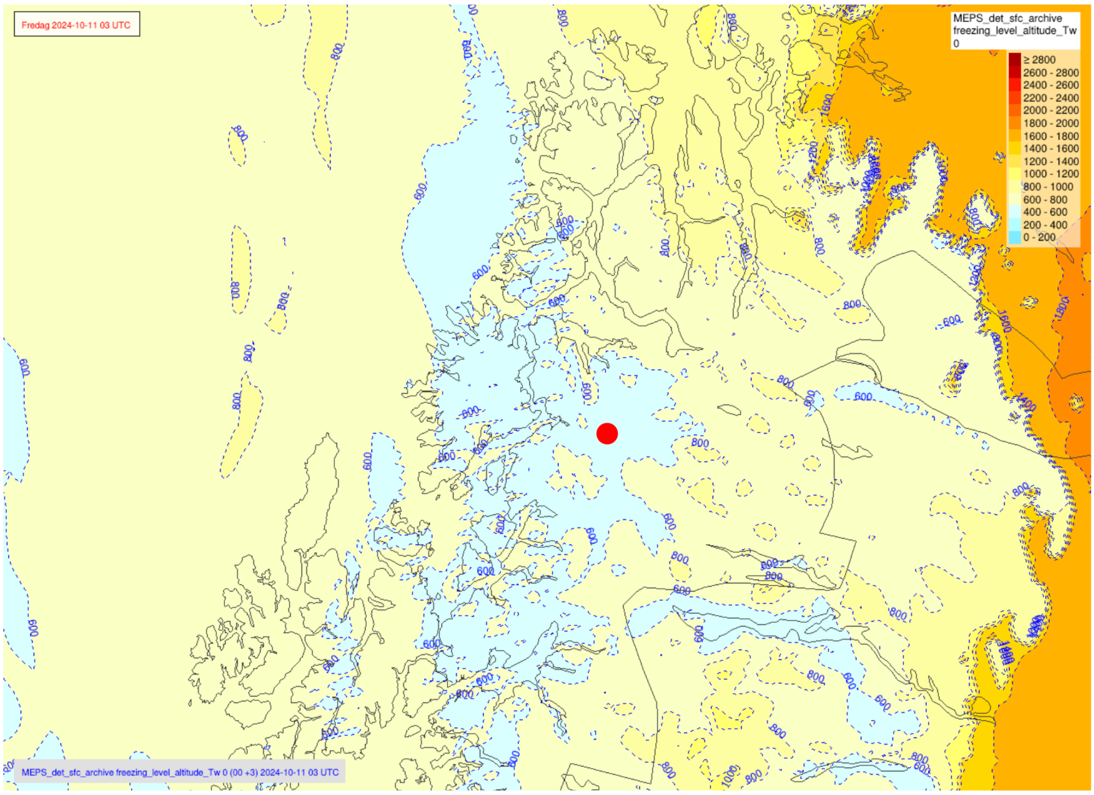
Case 2. Precipitation phase

This case from October 11th illustrates the challenges of forecasting the precipitation phase in near-freezing conditions. This autumn there were multiple reports from our meteorologists of the models forecasting rain when the observed precipitation came as snow. As seen many times before, inaccuracies in the vertical temperature profile at the lowest model layers of the NWP models continue to cause incorrect forecasts.

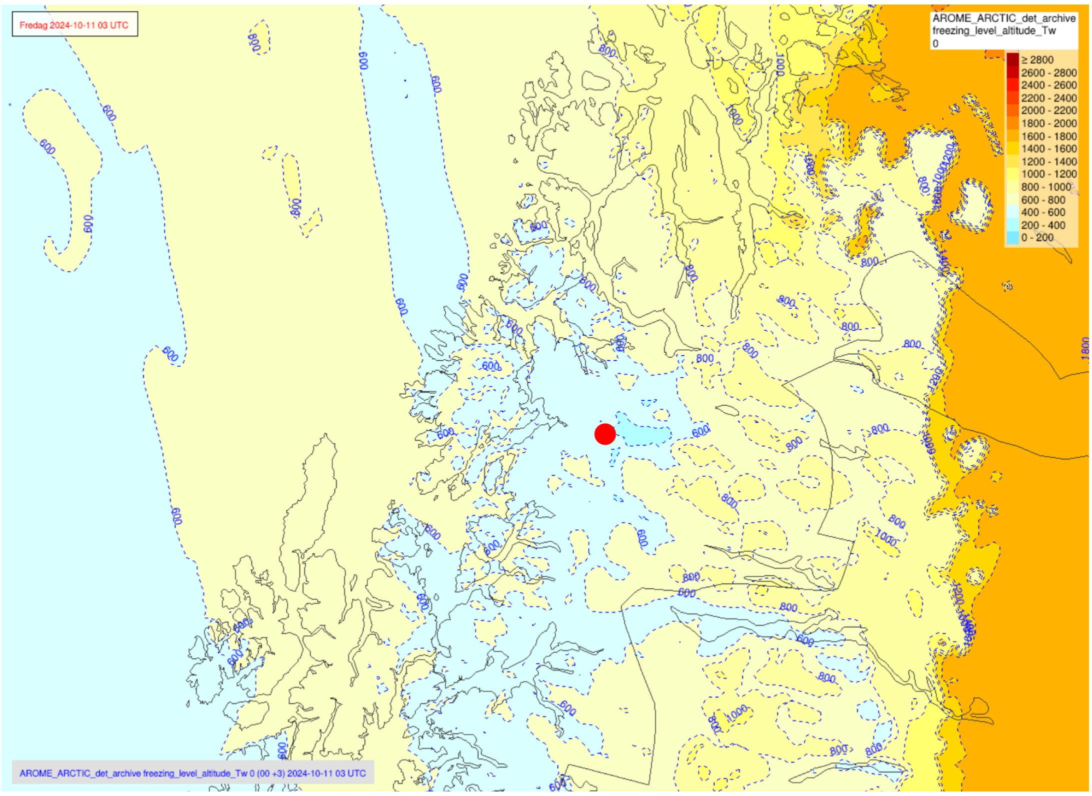
In this situation there were relatively warm airmasses aloft and if the temperature profiles from the models had been accurate, the precipitation form in a place like Bardufoss (77 masl) would have been rain, not snow, as the freezing level in the models was around 550 masl at the time of the observed snowfall (figure 3). At 03 UTC the observed T2m at Bardufoss was 0°C, while MEPSctrl and AROME Arctic (AA25) had temperatures of +2-3°C (figure 4). ECMWF was also too warm at Bardufoss in this case, which is often seen in these stable situations. However, ECMWF was closer to the observed T2m, but this is due to the ECMWF model on average being too cold, especially during winter for most of Norway.

At the same time a front was laying quite stable over the area and the winds near the surface were weak. This led to cooling and limited mixing in a stable atmosphere. It is therefore reasonable to assume that the issue here is the excessive mixing in the boundary layer causing a lack of stability of the lowest parts of the atmosphere. This lack of congruency between the observations and models is often also found in clear weather conditions during winter, especially in deeper valleys where cold air is being trapped. For such cases, the model resolution is also a factor due to the topography not being resolved properly, but the excessive near-surface mixing is often found to be the main issue.

In this particular situation AA25 is slightly colder than MEPSctrl, probably resulting from the fact that AA uses XRIMAX=0 while MEPSctrl uses XRIMAX=0.2. XRIMAX is the maximum Richardson number, which is both a turbulence indicator and an index of stability. Lower values indicate a higher degree of turbulence. This means that in AA there is forced mixing between the surface and the atmosphere, while there in MEPSctrl is more of a decoupling between the two. The T2m is therefore often lower in these situations in AA25 than MEPSctrl, due to less mixing from above and more influence from the surface. That being said, both models generally perform rather poorly under these conditions.



(a)



(b)

Figure 3: Freezing level altitudes from MEPSctrl (a) and AROME Arctic (b) at 03 UTC on October 11th. The location of Bardufoss is marked with a red dot.

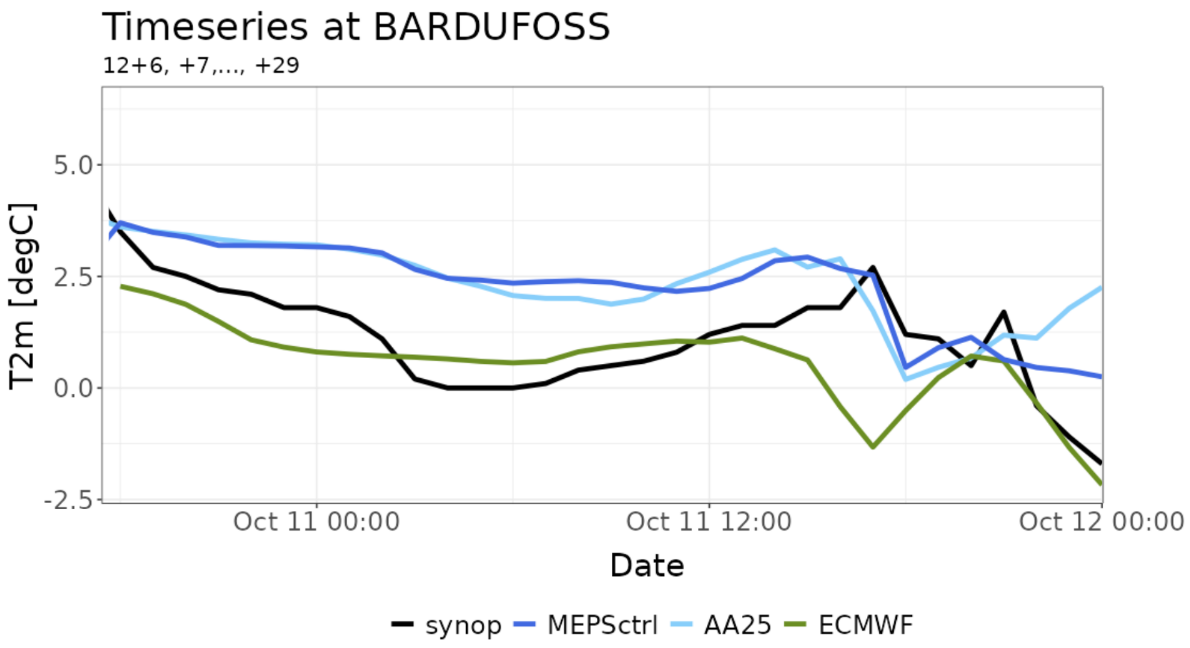


Figure 4: Timeseries of T2m (°C) at Bardufoss. Observations in black, MEPSctrl in dark blue, AROME Arctic in light blue and ECMWF in green.

Case 3. Missing fog

Fog can be a challenge to forecast, and this was definitely the case on the 10th of November. Parts of Trøndelag and Møre and Romsdal had widespread fog that day, and at Værnes airport (ENVA) near Trondheim the fog was particularly persistent and thick, even becoming freezing when the temperature dropped below 0°C. The fog resulted in many canceled landings and departures from Værnes and affected thousands of people this Sunday. The fog at Værnes persisted from 04 UTC to 22 UTC, according to METAR observations at ENVA.

During the evening of the 9th and the night of the 10th of November, the surface temperature dropped quite rapidly at Værnes. This happened due to near cloud free conditions and calm winds, causing cooling of the ground due to outgoing longwave radiation. This, in turn, caused the formation of radiation fog. Neither MEPSctrl nor the ECMWF model captured the strong temperature inversion near the ground. The satellite image in figure 5 shows that the Trondheimsfjord near Værnes (marked with a red dot) was covered in fog (showing up as slightly yellow), while neither of the models had fog in that area (bright yellow fields).

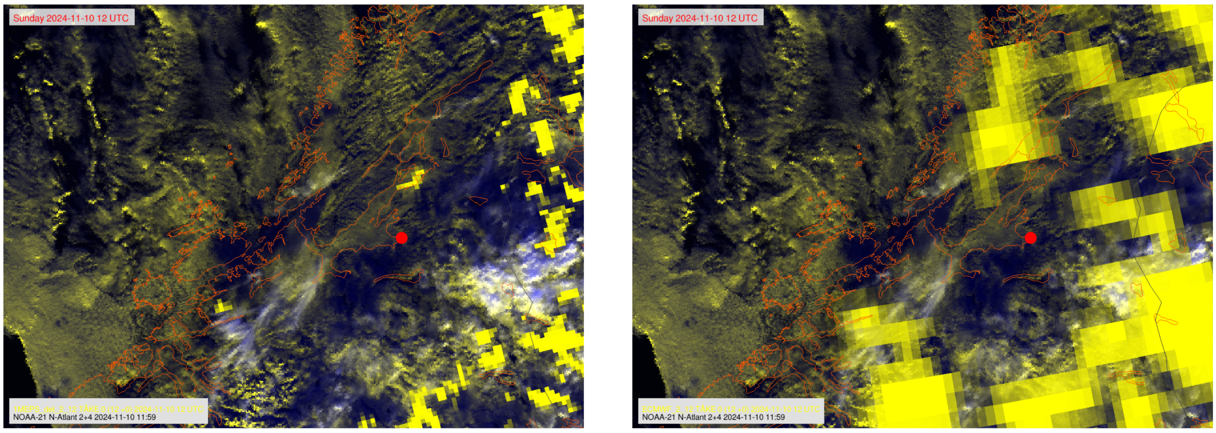


Figure 5: Fog from the MEPSctrl (left) and ECMWF (right) models at 12 UTC November 10th in bright yellow, layered on top of a satellite image from 11:59 UTC. The red dot marks the location of Værnes Airport (ENVA).

The timeseries of temperature (figure 6) shows that at the time of the fog forming, 04 UTC, the two-meter temperature (T2m) from both models is too high, and thus the dew point depression becomes too large for fog to form. The MEPSctrl model had a more accurate cloud cover after midnight, as seen by the sinking temperature throughout the night in figure 6, than ECMWF, but was still not cooling the ground as much as observed. The timeseries of wind (figure 7) also shows that MEPSctrl had more wind than observed both before and around the time of the fog forming. This causes more mixing in the layers near the ground, contributing to the lack of fog persisting in the model. ECMWF on the other hand had weaker winds, but more clouds after midnight (not shown). This can be seen in the temperature rise for ECMWF in figure 6 around 03 UTC, which coincides with the time of the low cloud layer appearing in the model over ENVA.

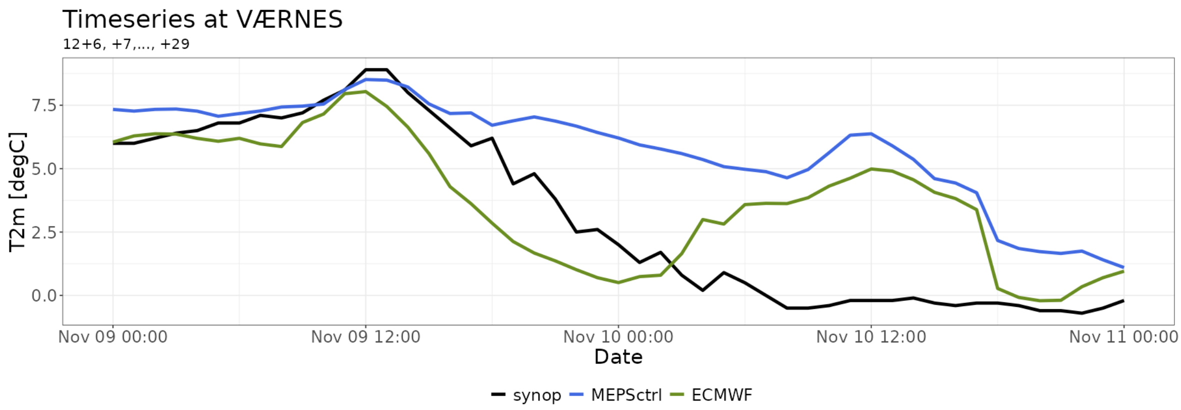


Figure 6: Timeseries of two-meter temperature (°C) at Værnes airport. Observations in black, MEPSctrl in blue and ECMWF in green.

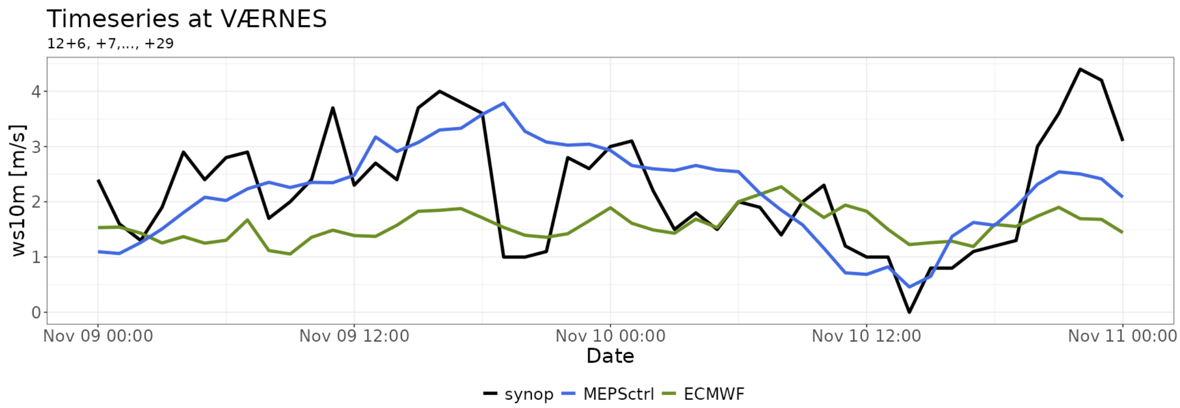
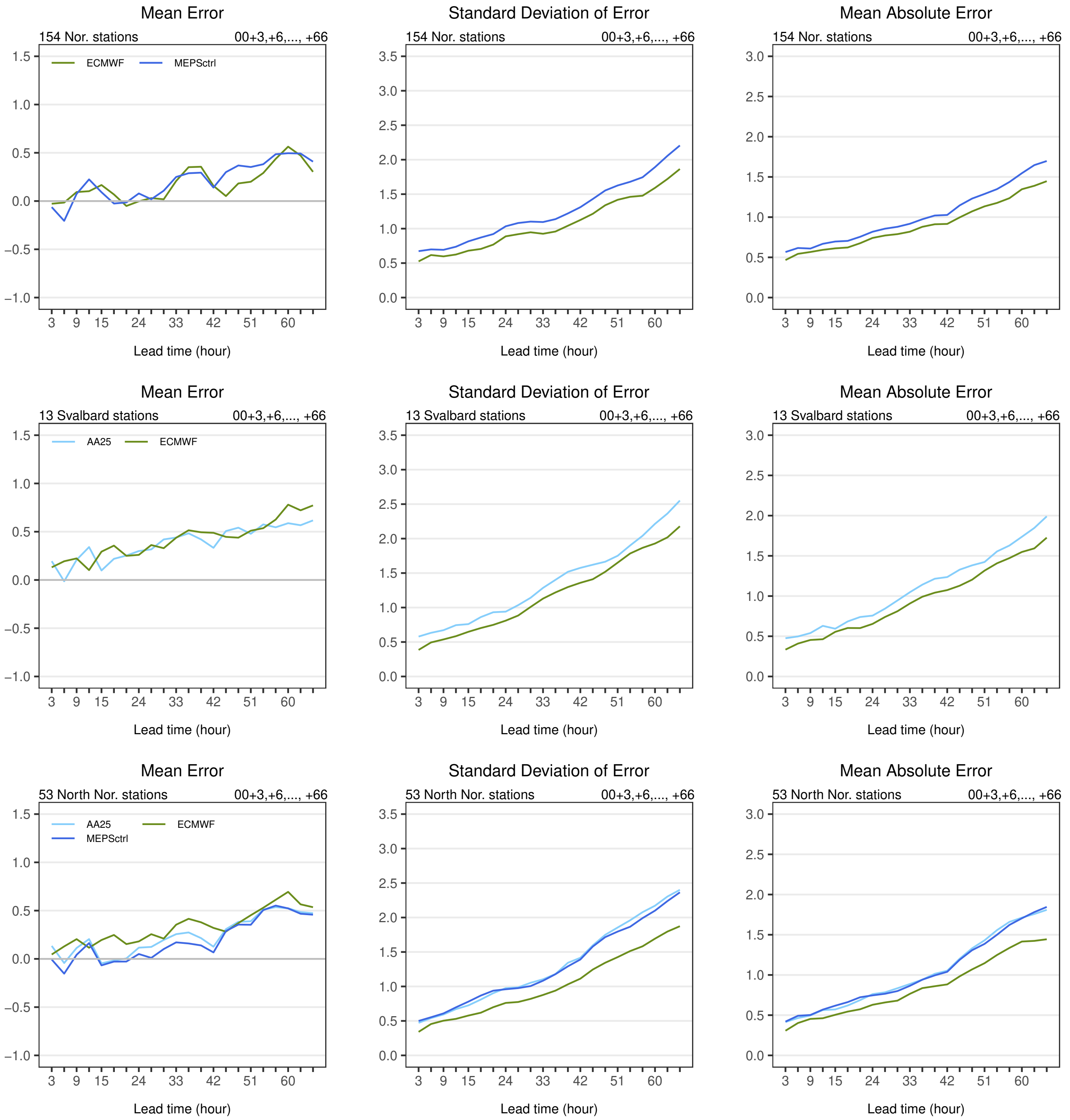
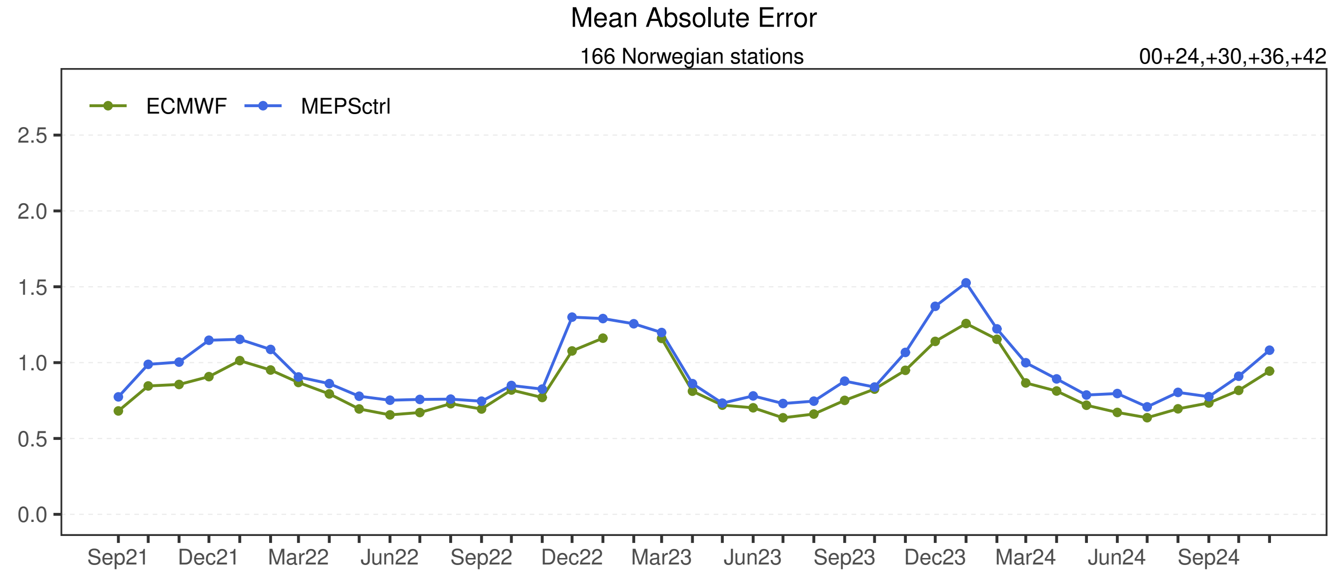
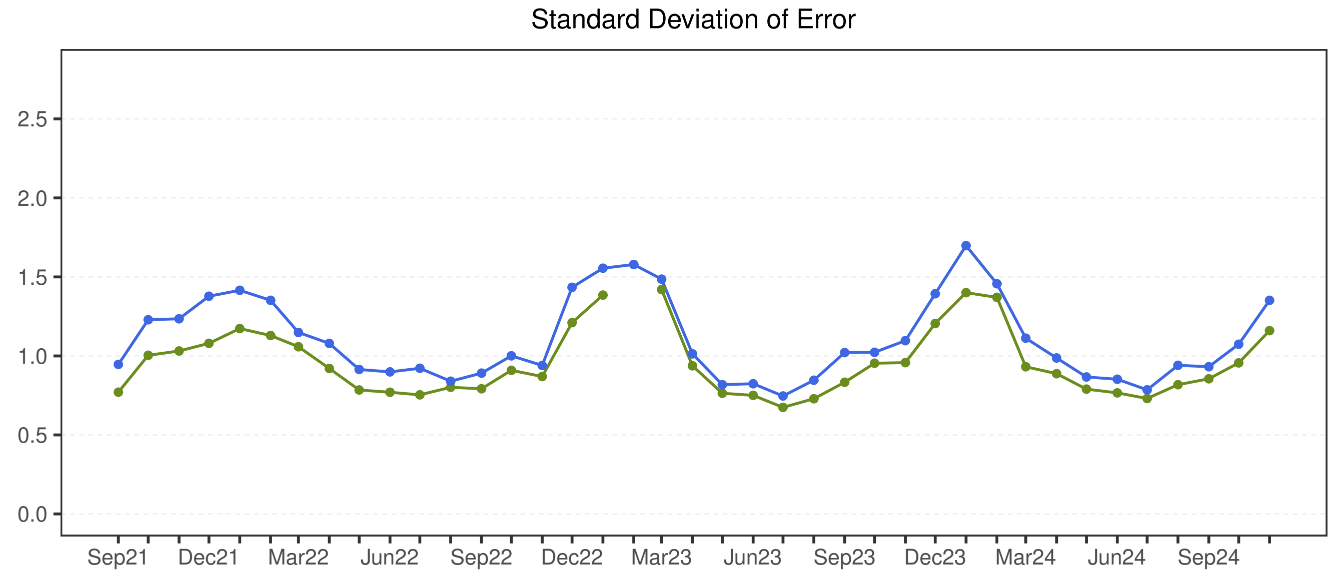


Figure 7: Timeseries of wind speed (m/s) at Værnes airport. Observations in black, MEPSctrl in blue and ECMWF in green.

Summarized statistics


Mean Error
154 Nor. stations
00+3,+6,..., +66
ECMWF
MEPSctrl
Lead time (hour)
Standard Deviation of Error
154 Nor. stations
00+3,+6,..., +66
Lead time (hour)
Mean Absolute Error
154 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
53 North Nor. stations
00+3,+6,..., +66
AA25
ECMWF
MEPSctrl
Lead time (hour)
Standard Deviation of Error
53 North Nor. stations
00+3,+6,..., +66
Lead time (hour)
Mean Absolute Error
53 North Nor. stations
00+3,+6,..., +66
Lead time (hour)


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
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24
Sep24


Standard Deviation of Error
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2.0
1.5
1.0
0.5
0.0
Sep21
Dec21
Mar22
Jun22
Sep22
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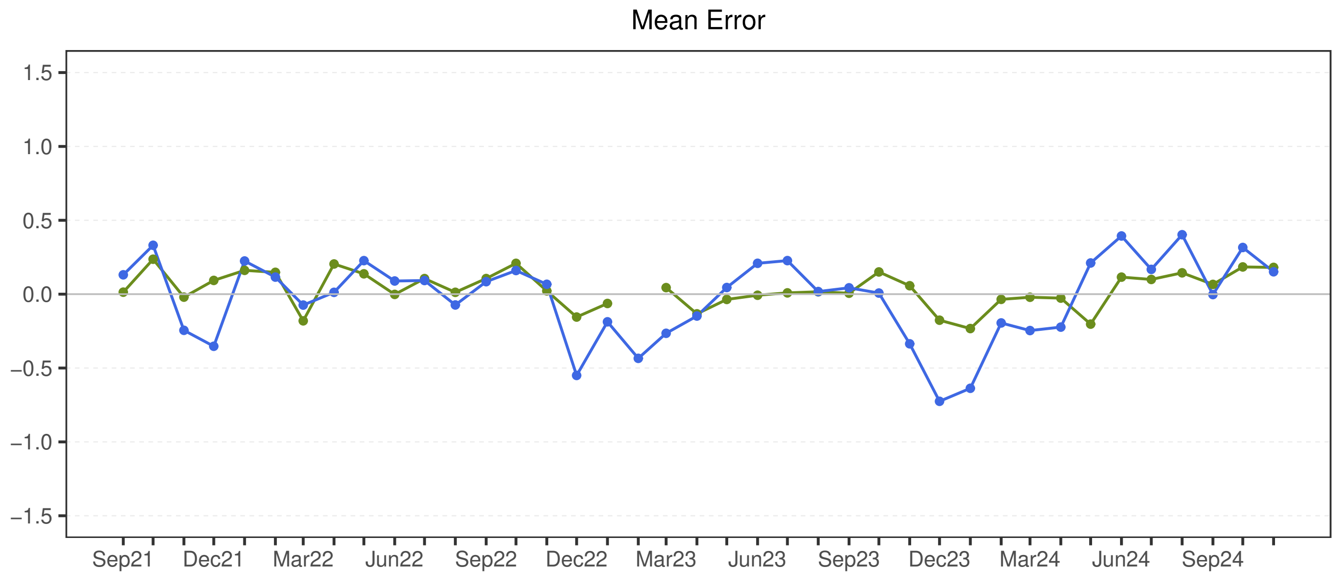
Dec23
Mar24
Jun24
Sep24


Mean Error
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1.0
0.5
0.0
−0.5
−1.0
−1.5
Sep21
Dec21
Mar22
Jun22
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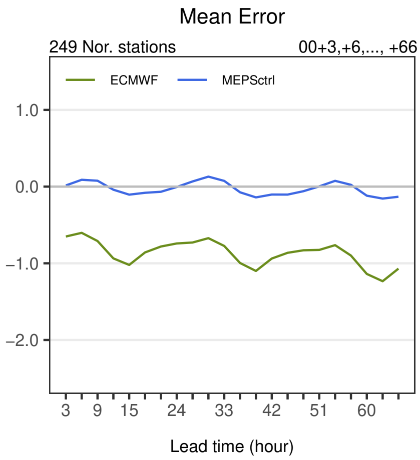
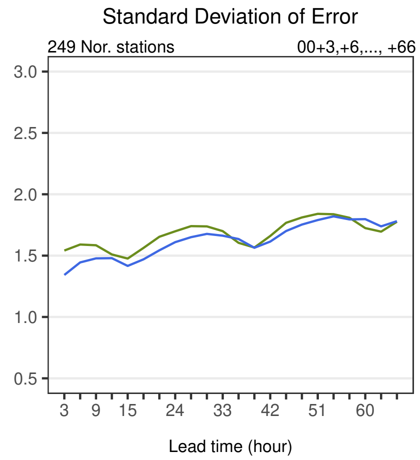
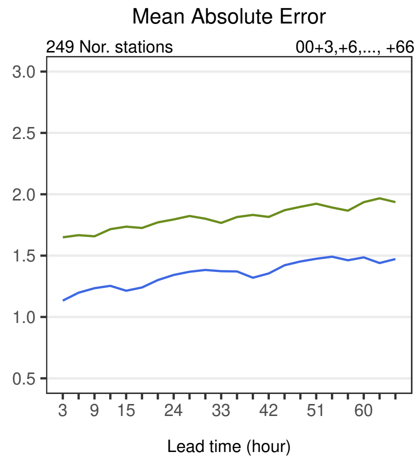
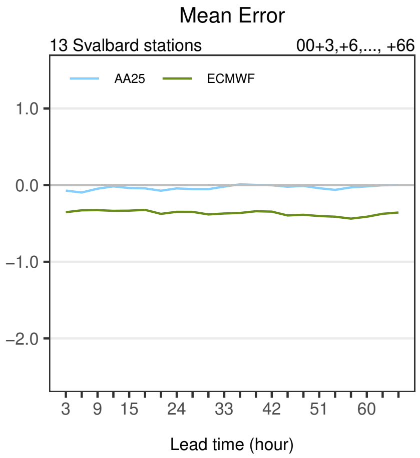
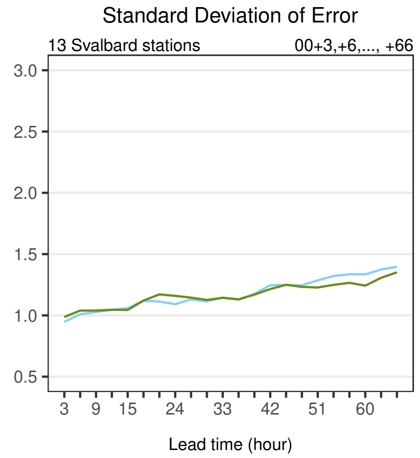
Dec23
Mar24
Jun24
Sep24

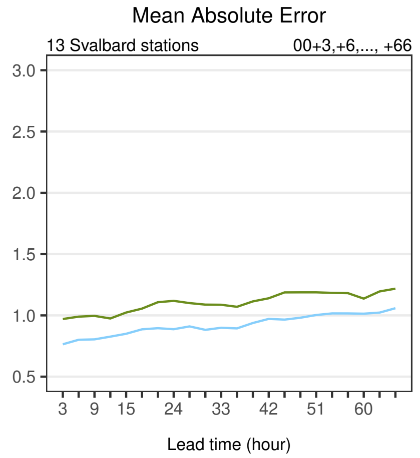

Mean Error
249 Nor. stations
00+3,+6,..., +66
ECMWF
MEPSctrl
Lead time (hour)

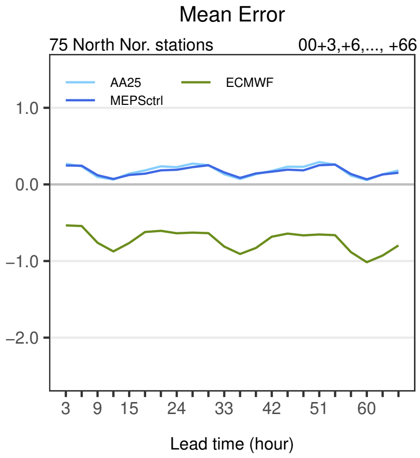

Standard Deviation of Error
249 Nor. stations
00+3,+6,..., +66
Lead time (hour)

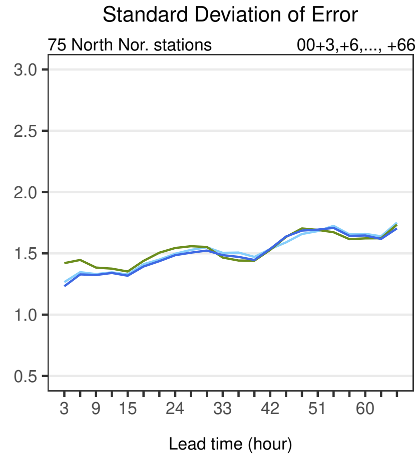

Mean Absolute Error
249 Nor. stations
00+3,+6,..., +66
Lead time (hour)

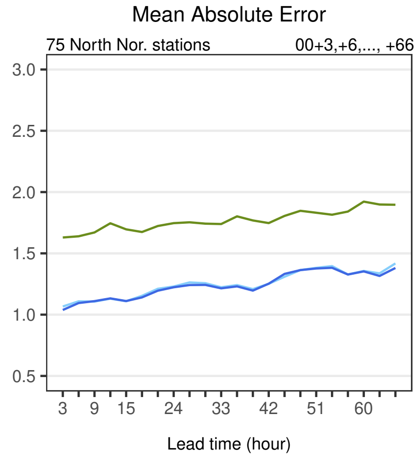

Mean Error
13 Svalbard stations
00+3,+6,..., +66
AA25
ECMWF
Lead time (hour)

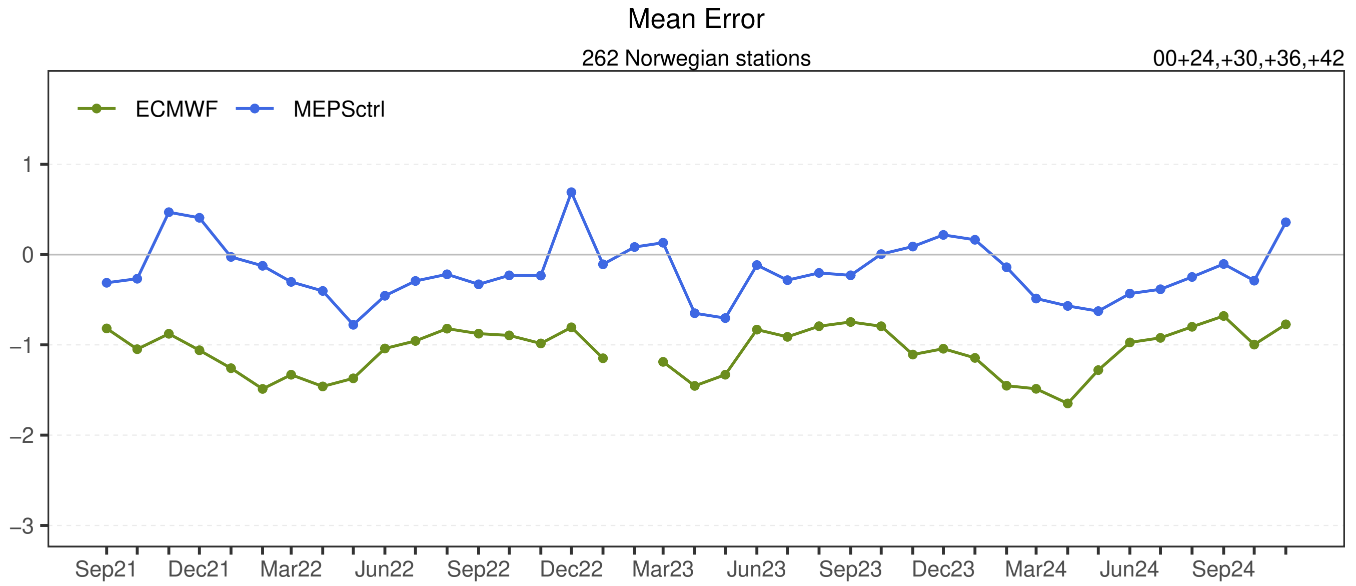

Standard Deviation of Error
13 Svalbard stations
00+3,+6,..., +66
Lead time (hour)

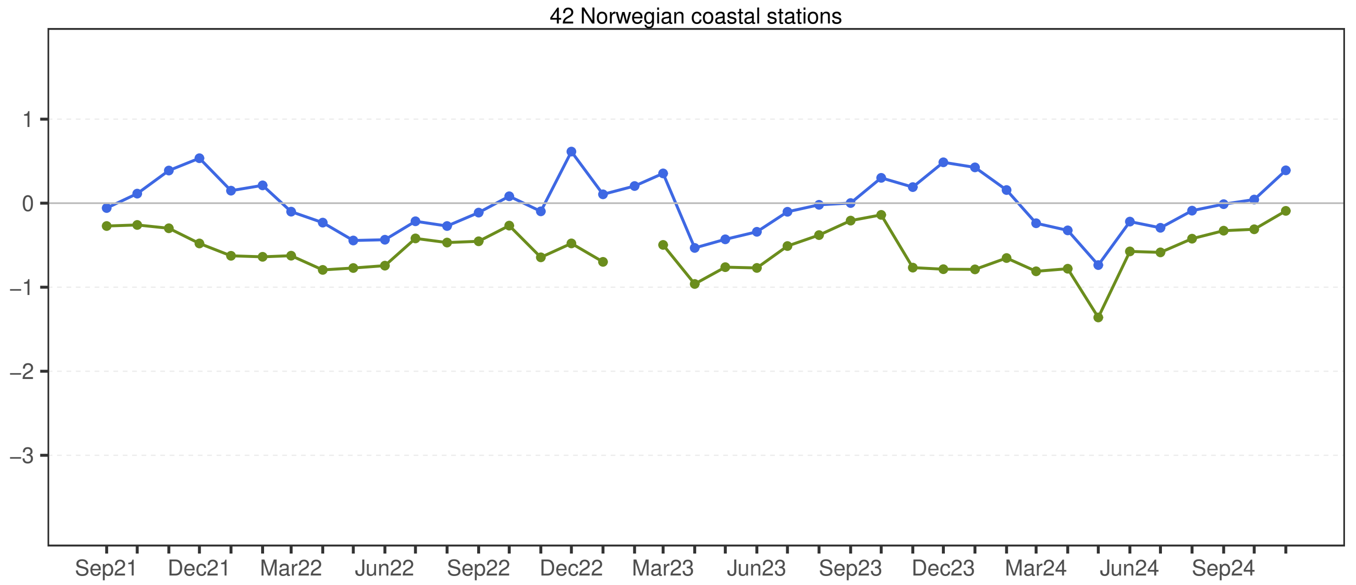

Mean Absolute Error
13 Svalbard stations
00+3,+6,..., +66
Lead time (hour)

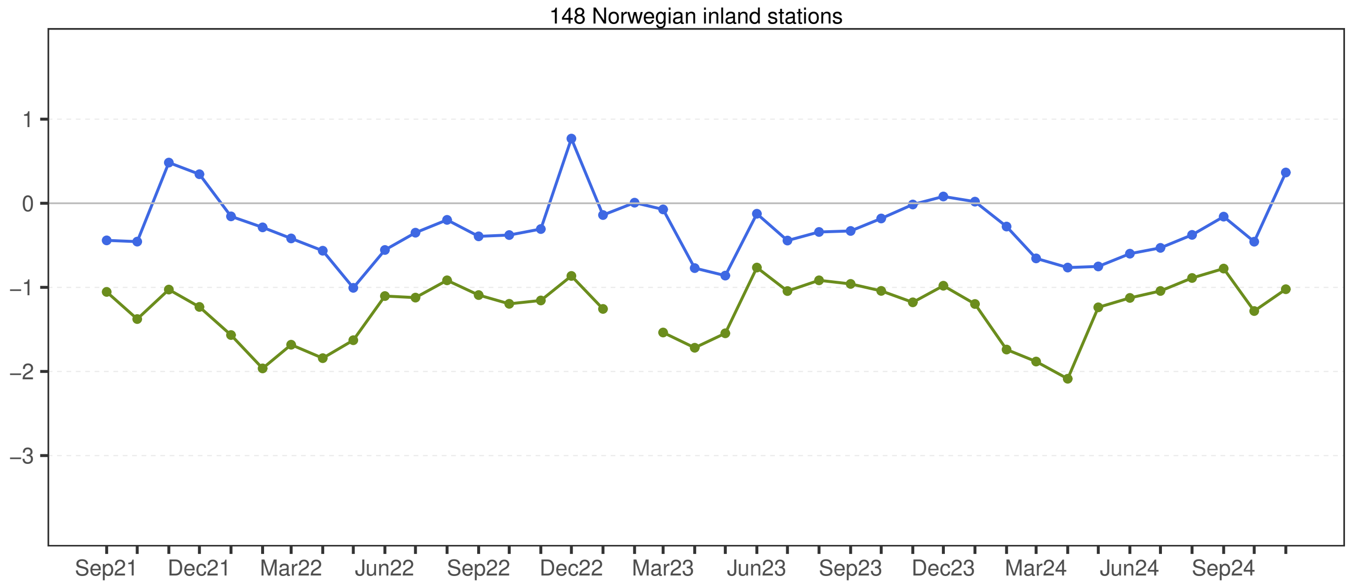

Mean Error
75 North Nor. stations
00+3,+6,..., +66
AA25
ECMWF
MEPSctrl
Lead time (hour)


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

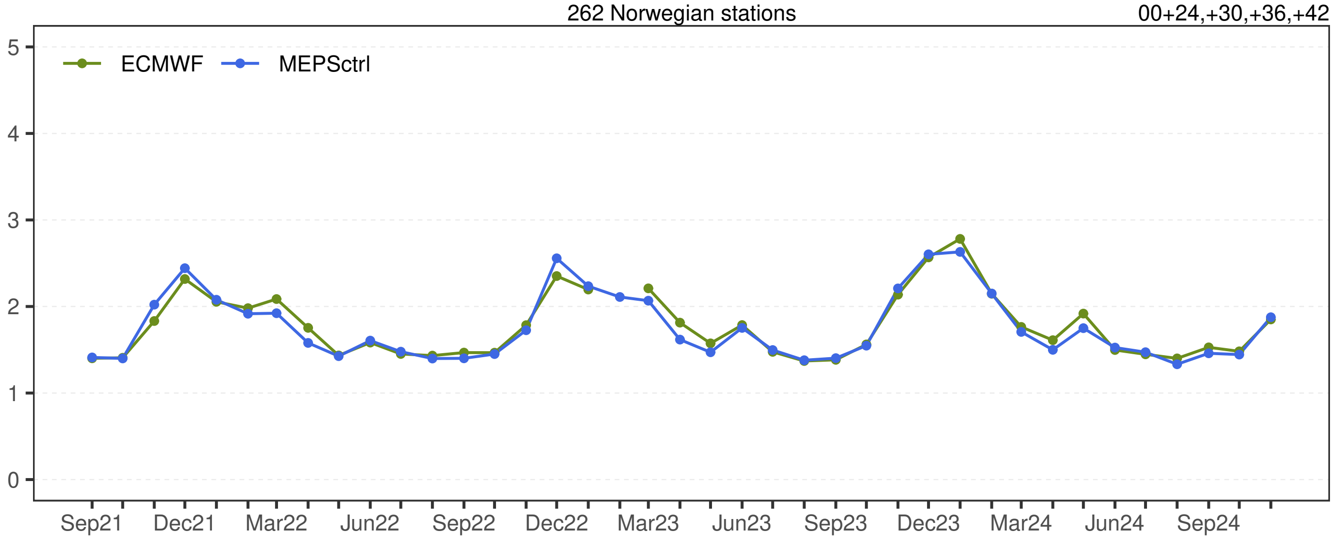

Mean Absolute Error
75 North Nor. stations
00+3,+6,..., +66
Lead time (hour)

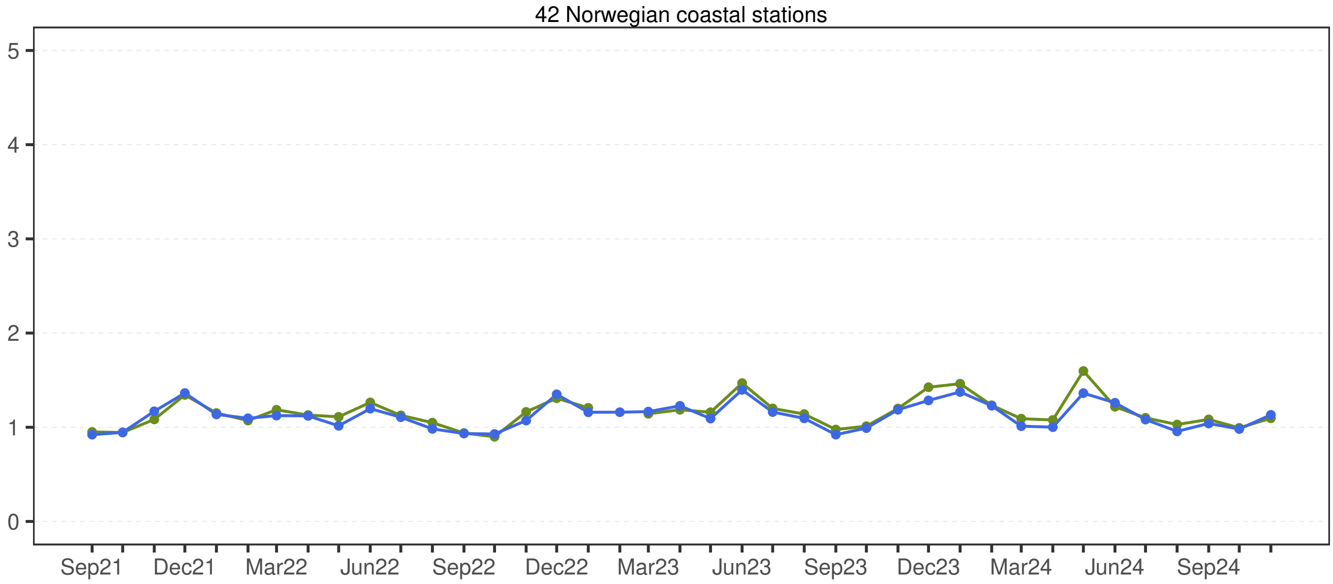

Mean Error
262 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
1
0
−1
−2
−3
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24
Sep24

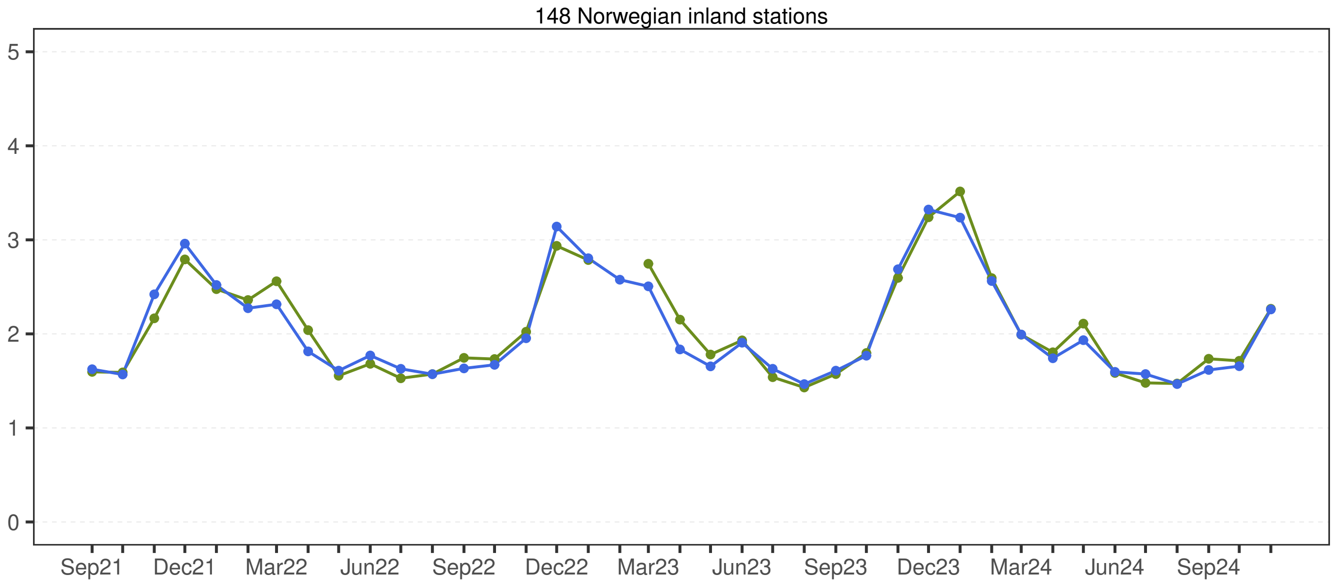

42 Norwegian coastal stations
1
0
−1
−2
−3
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24
Sep24

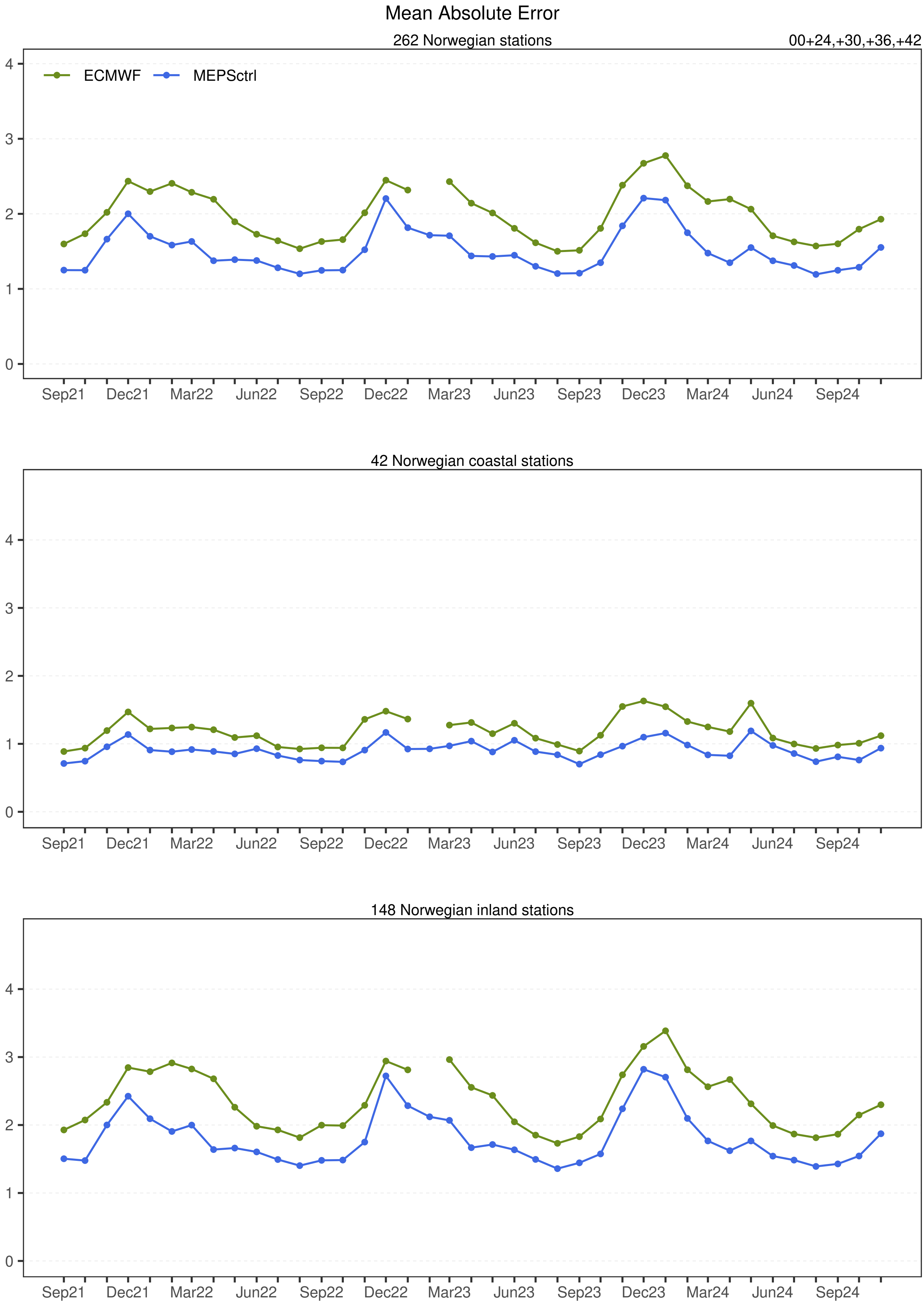

148 Norwegian inland stations
1
0
−1
−2
−3
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24
Sep24

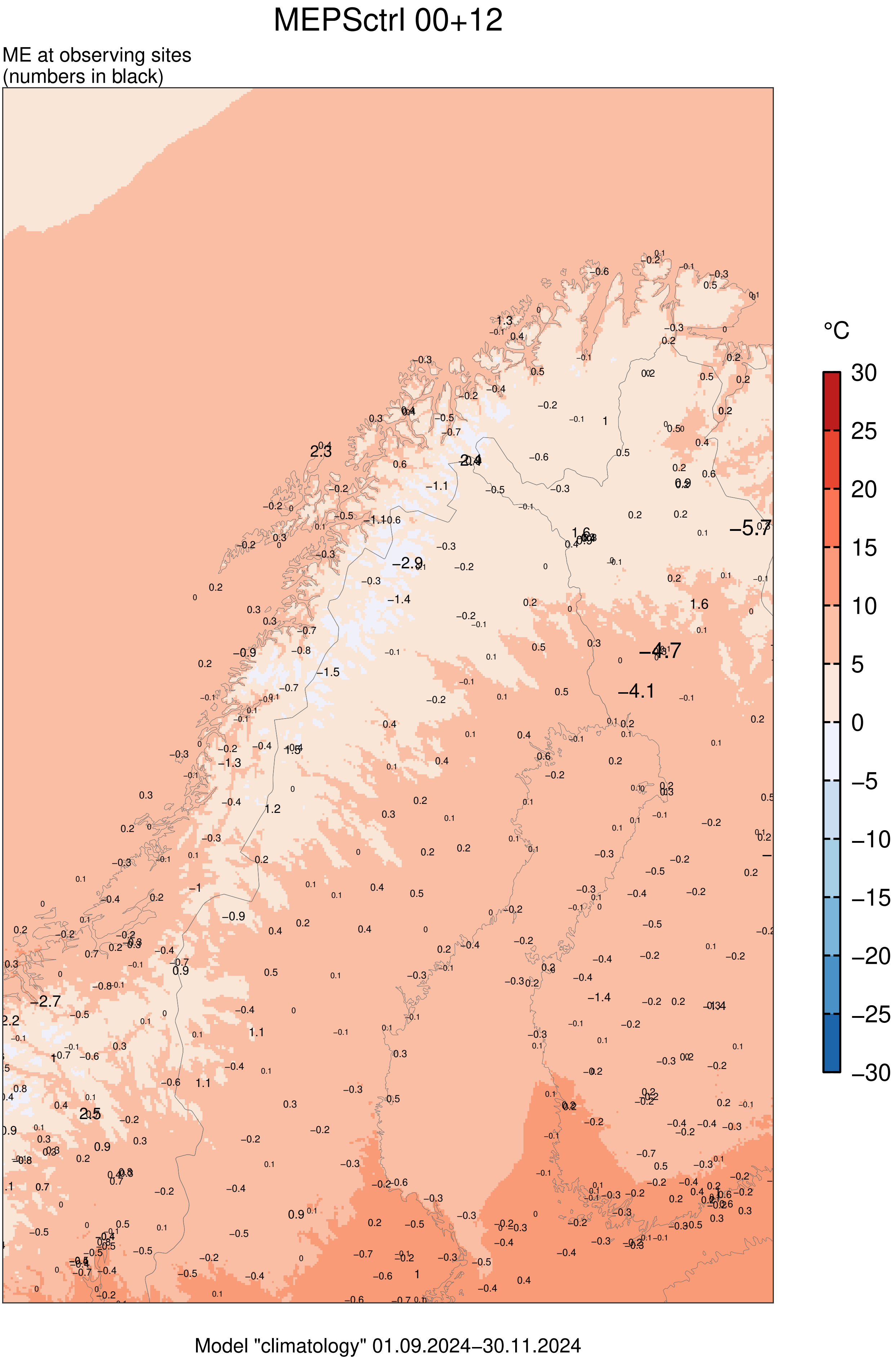
Standard Deviation of Error

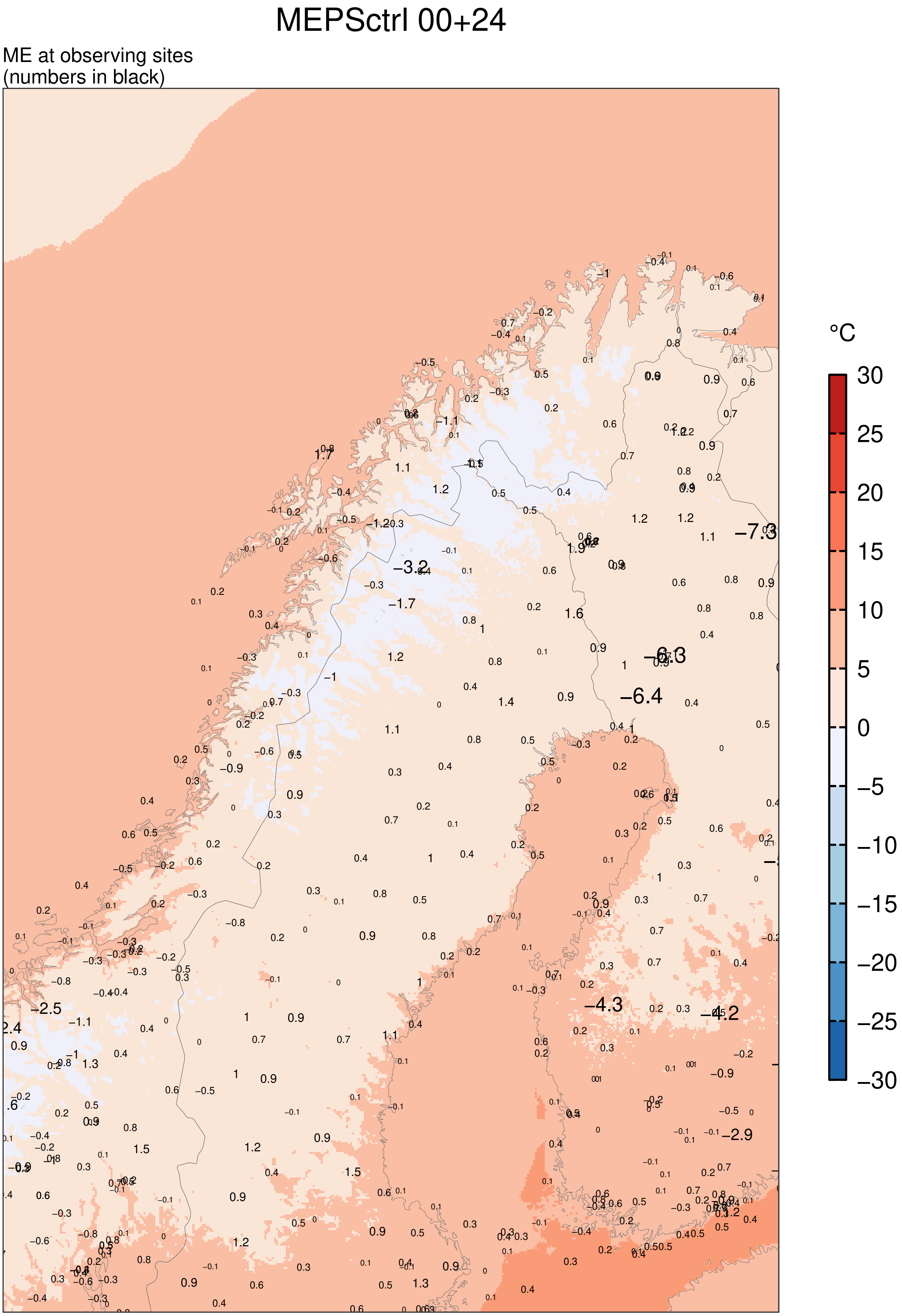







Mean Absolute Error
262 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
0 1 2 3 4
Sep21 Dec21 Mar22 Jun22 Sep22 Dec22 Mar23 Jun23 Sep23 Dec23 Mar24 Jun24 Sep24
42 Norwegian coastal stations
0 1 2 3 4
Sep21 Dec21 Mar22 Jun22 Sep22 Dec22 Mar23 Jun23 Sep23 Dec23 Mar24 Jun24 Sep24
148 Norwegian inland stations
0 1 2 3 4
Sep21 Dec21 Mar22 Jun22 Sep22 Dec22 Mar23 Jun23 Sep23 Dec23 Mar24 Jun24 Sep24

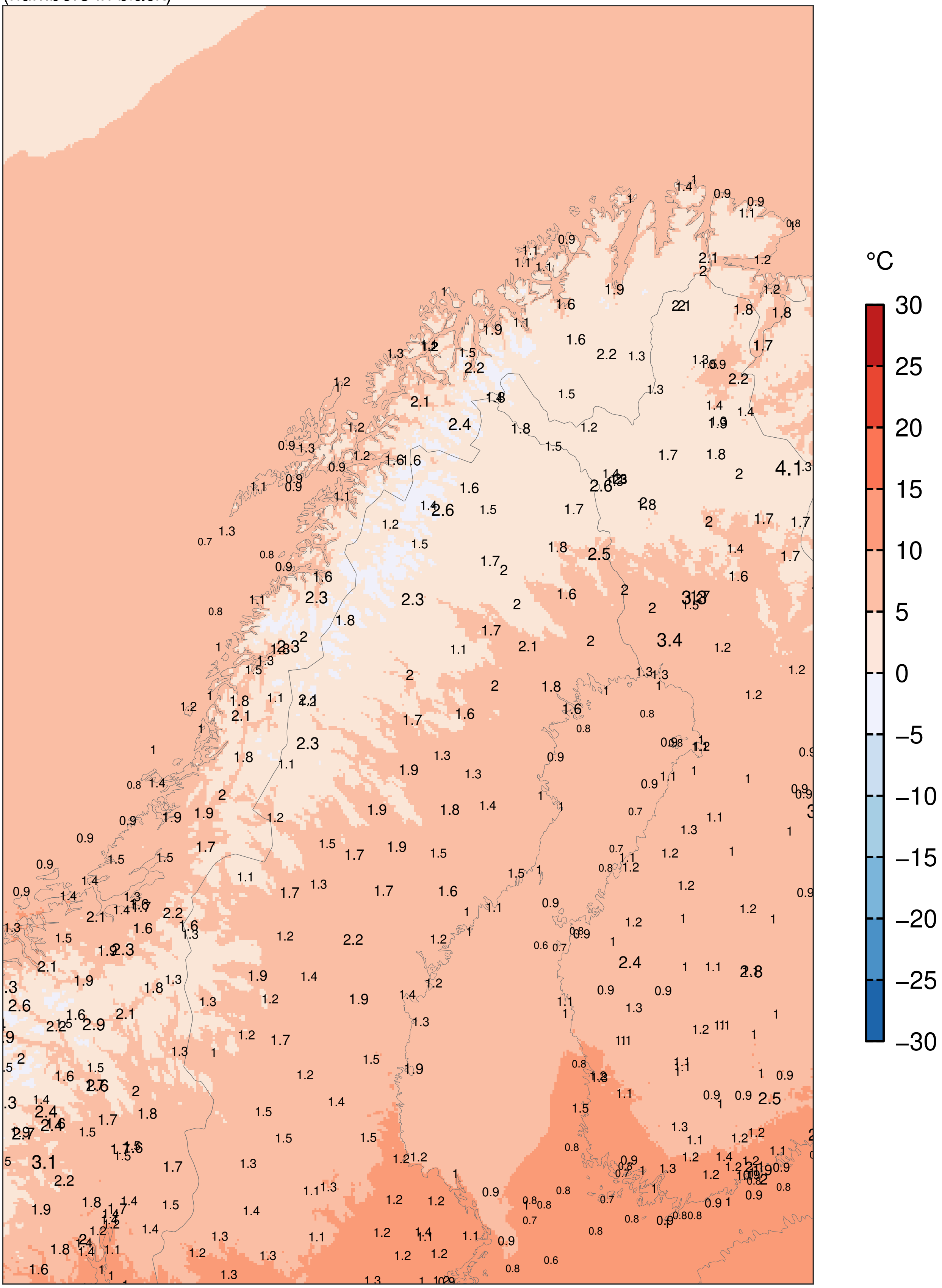

MEPSctrl 00+12
ME at observing sites
(numbers in black)
°C
30
25
20
15
10
5
0
–5
–10
–15
–20
–25
–30
Model "climatology" 01.09.2024–30.11.2024



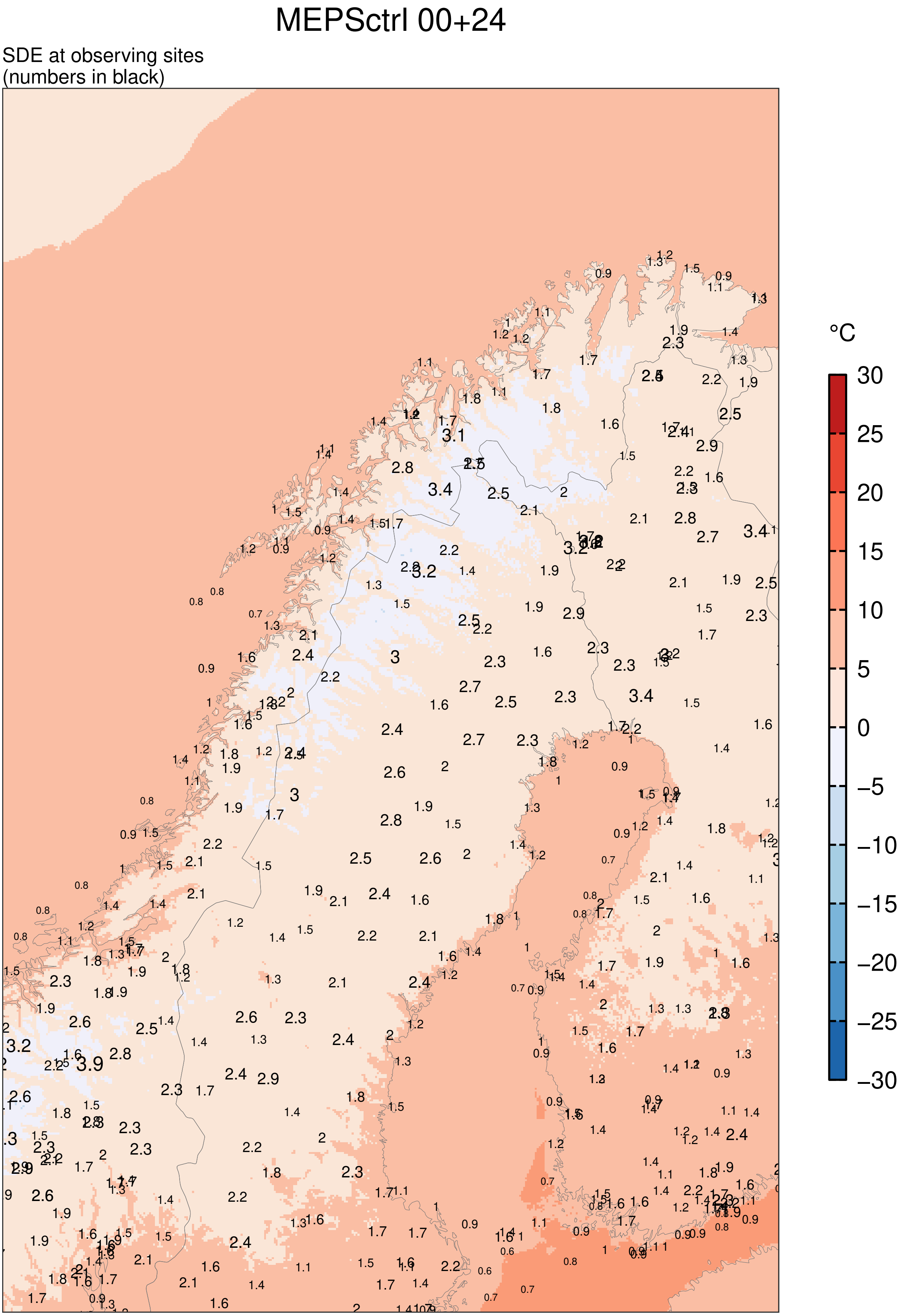
Model "climatology" 01.09.2024–30.11.2024

MEPSctrl 00+12

SDE at observing sites
(numbers in black)



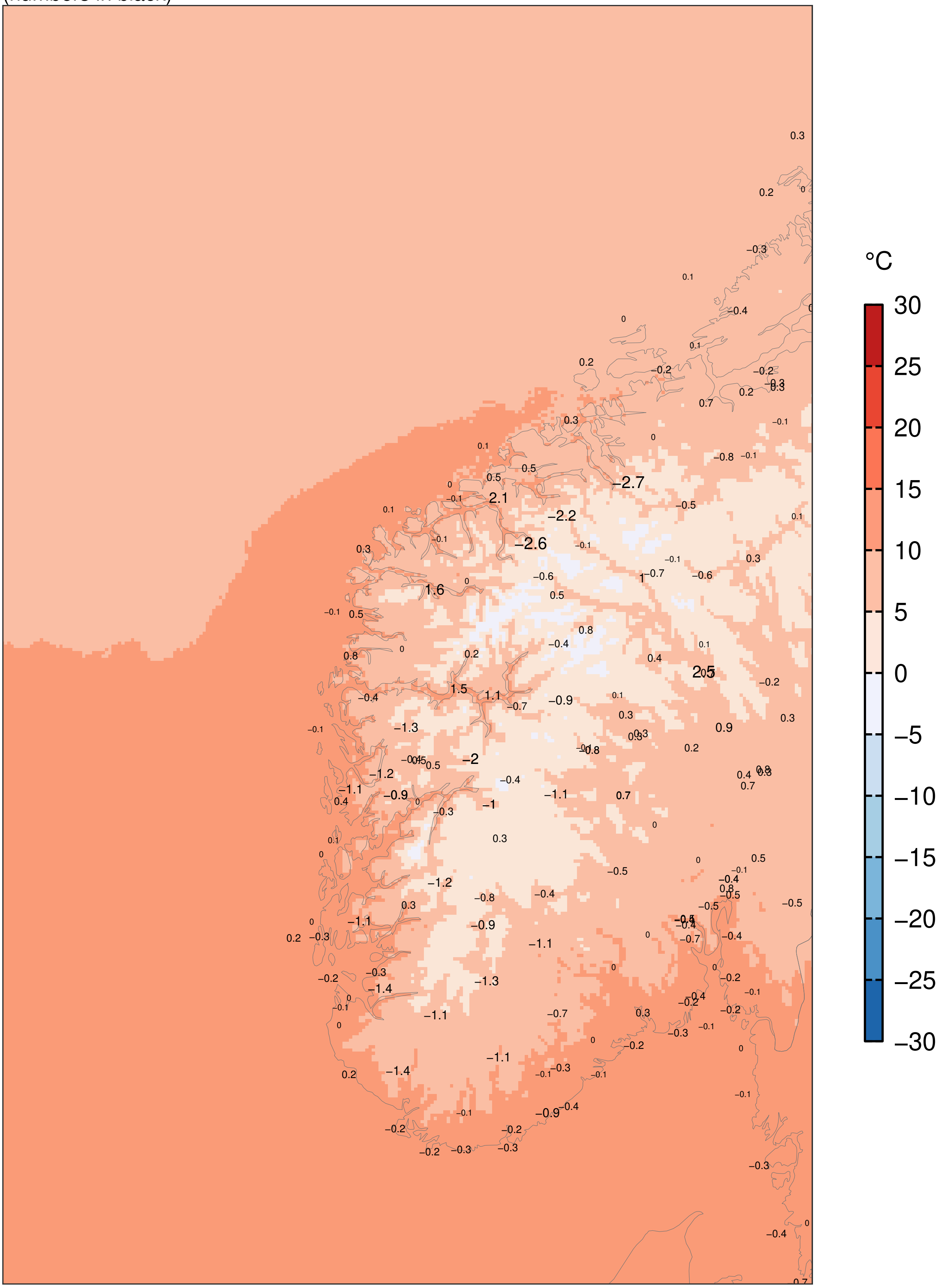
Model "climatology" 01.09.2024–30.11.2024



Model "climatology" 01.09.2024–30.11.2024

MEPSctrl 00+12

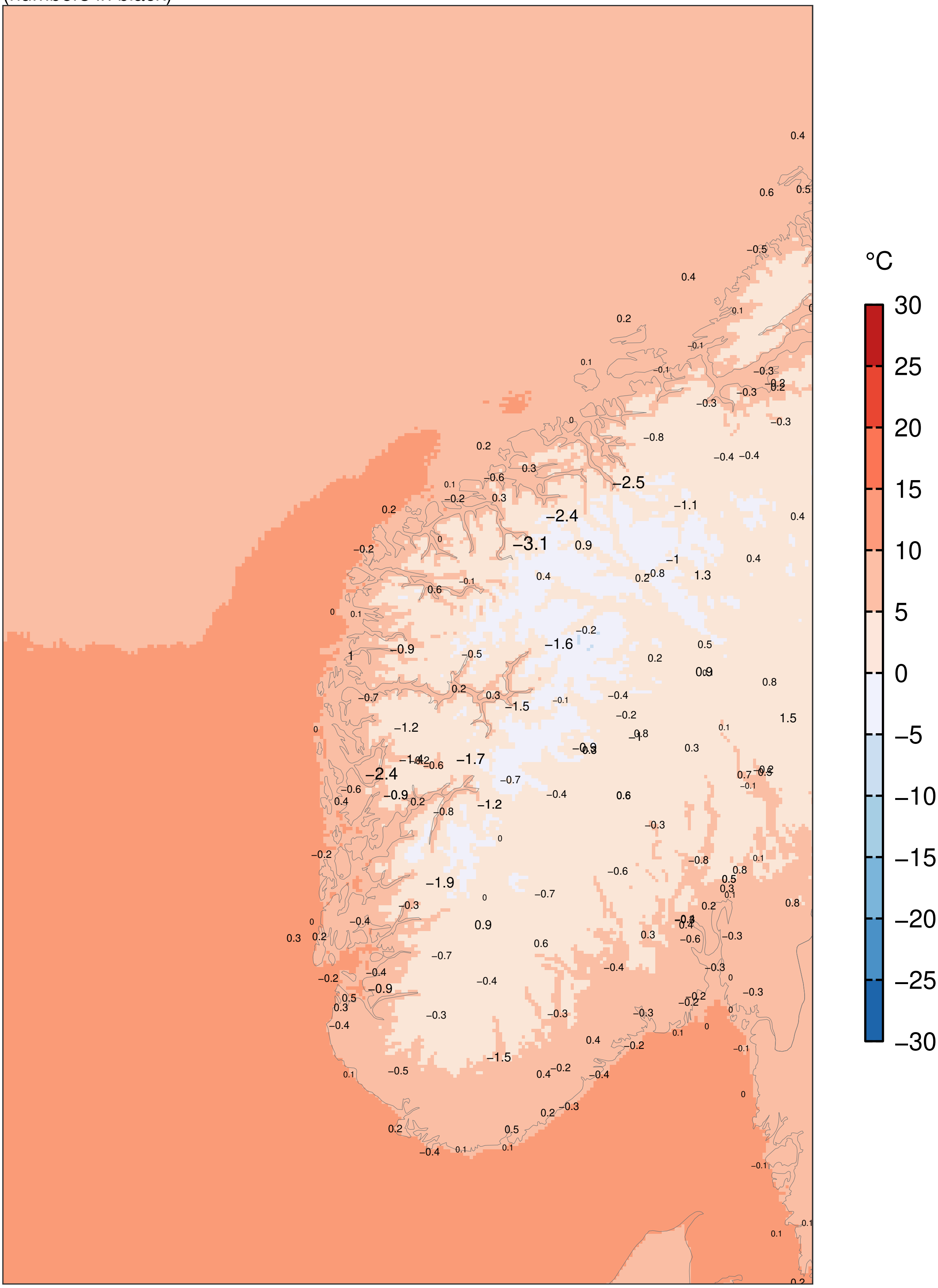
ME at observing sites
(numbers in black)



Model "climatology" 01.09.2024–30.11.2024

MEPSctrl 00+24

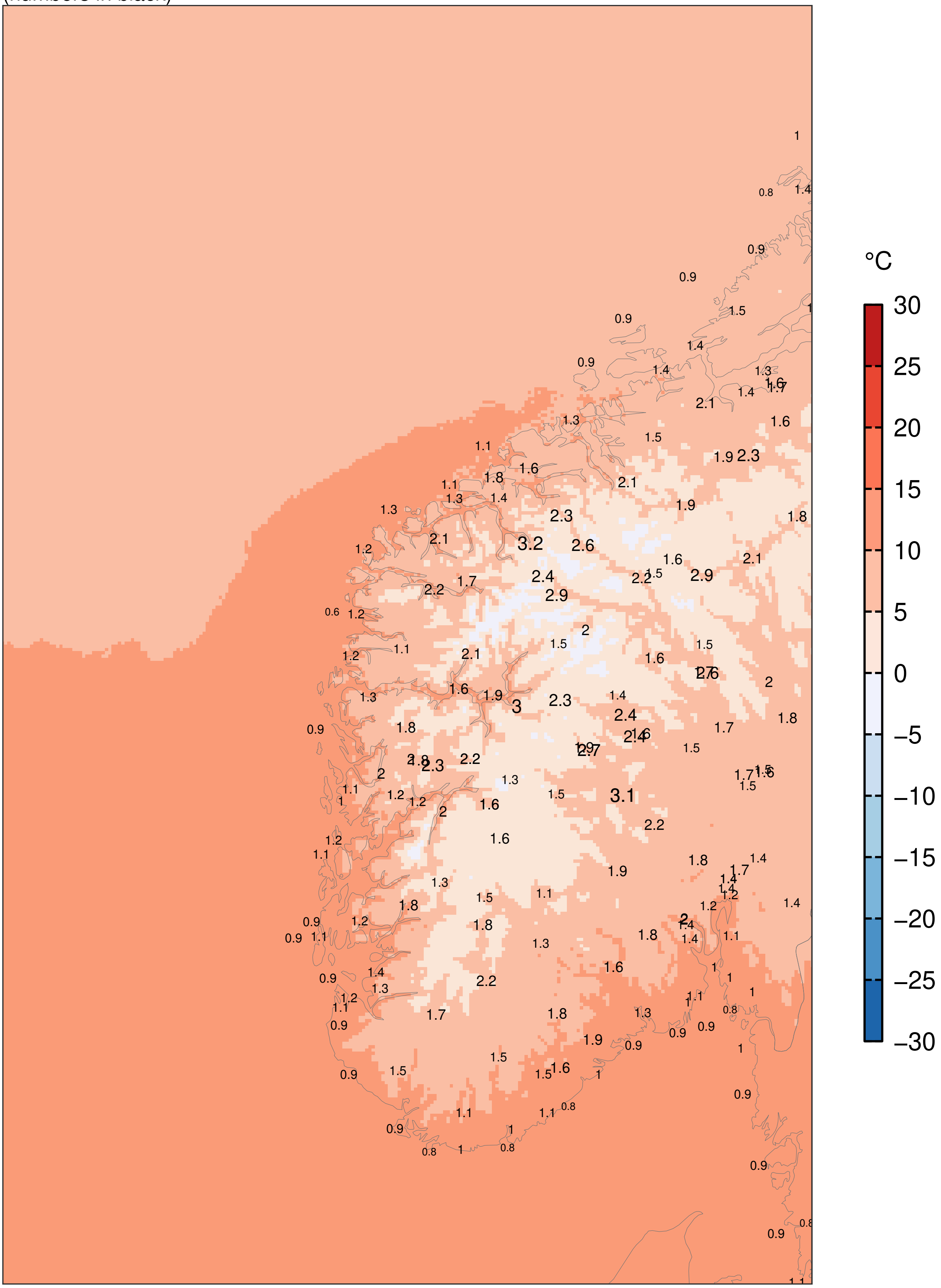
ME at observing sites
(numbers in black)



Model "climatology" 01.09.2024–30.11.2024

MEPSctrl 00+12

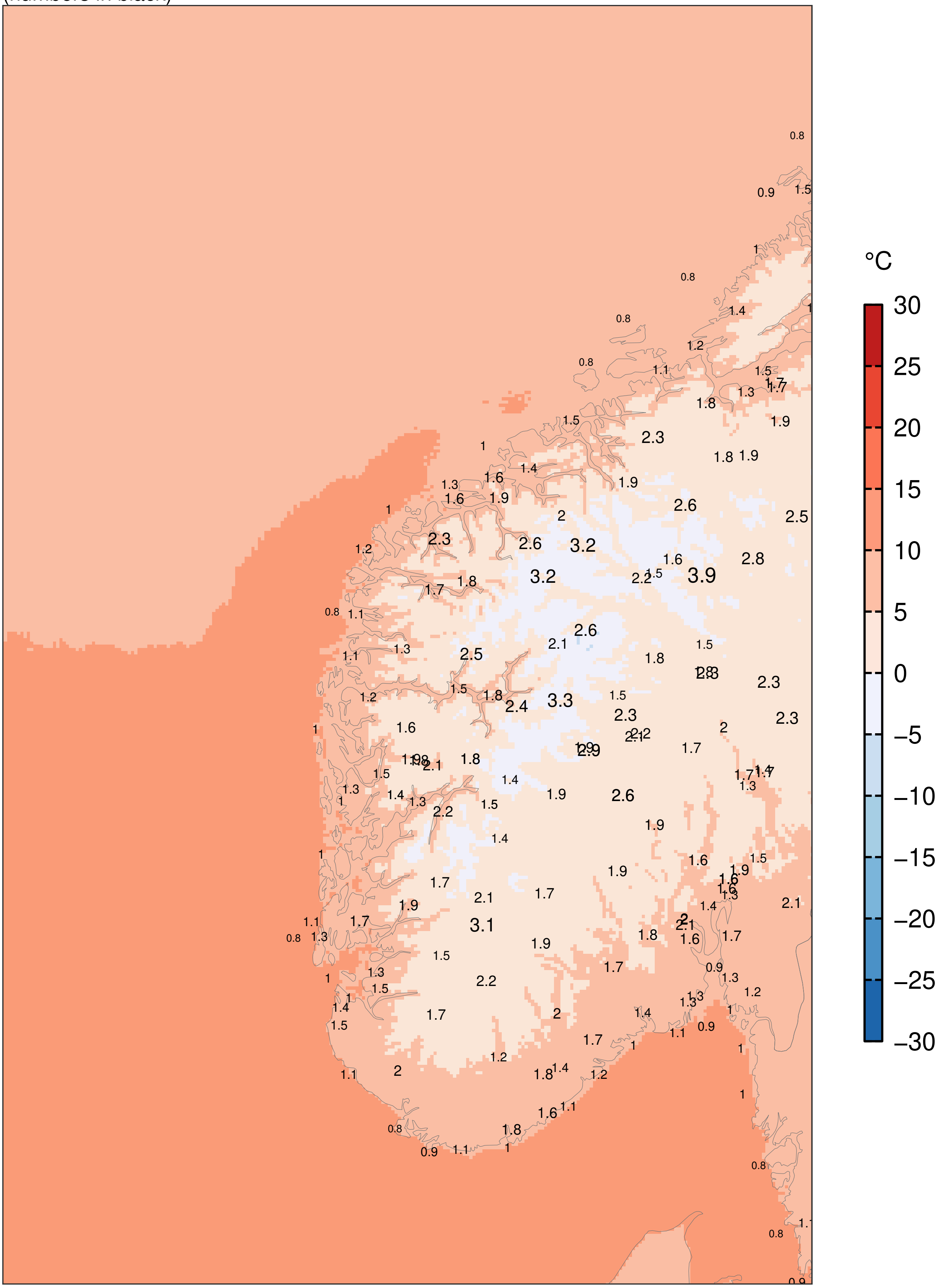
SDE at observing sites
(numbers in black)



Model "climatology" 01.09.2024–30.11.2024

MEPSctrl 00+24

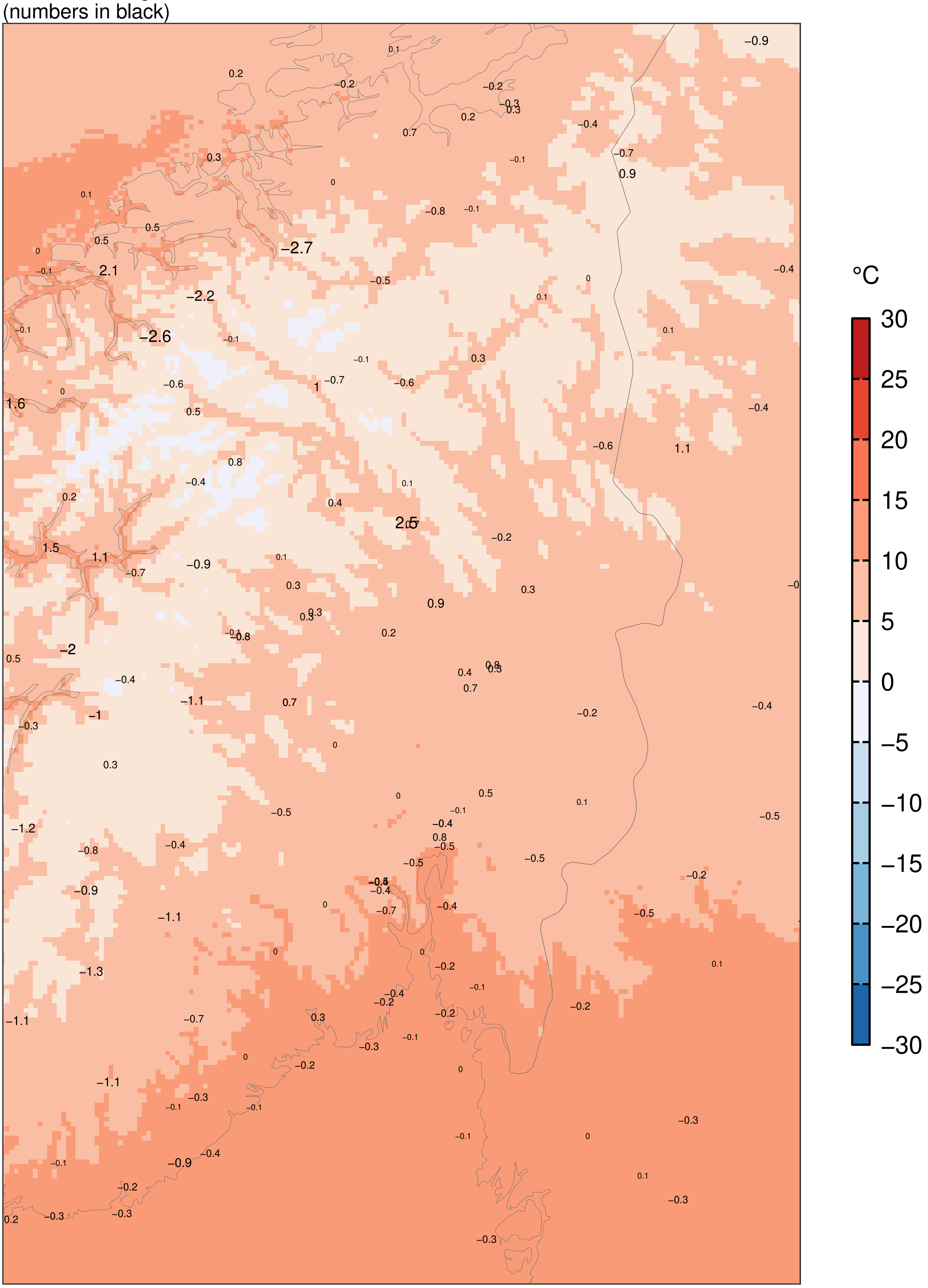
SDE at observing sites
(numbers in black)



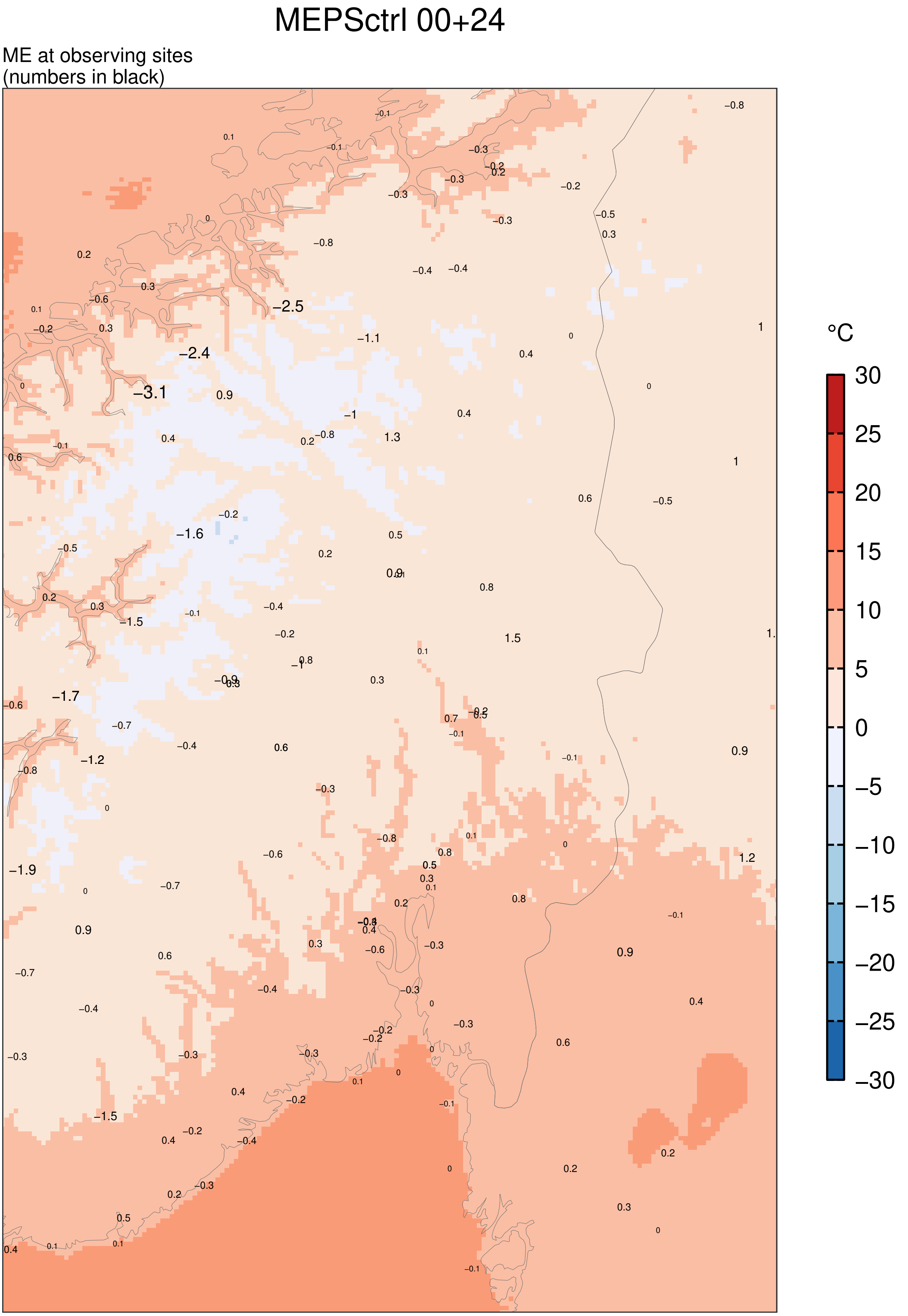
Model "climatology" 01.09.2024–30.11.2024

MEPSctrl 00+12

ME at observing sites
(numbers in black)



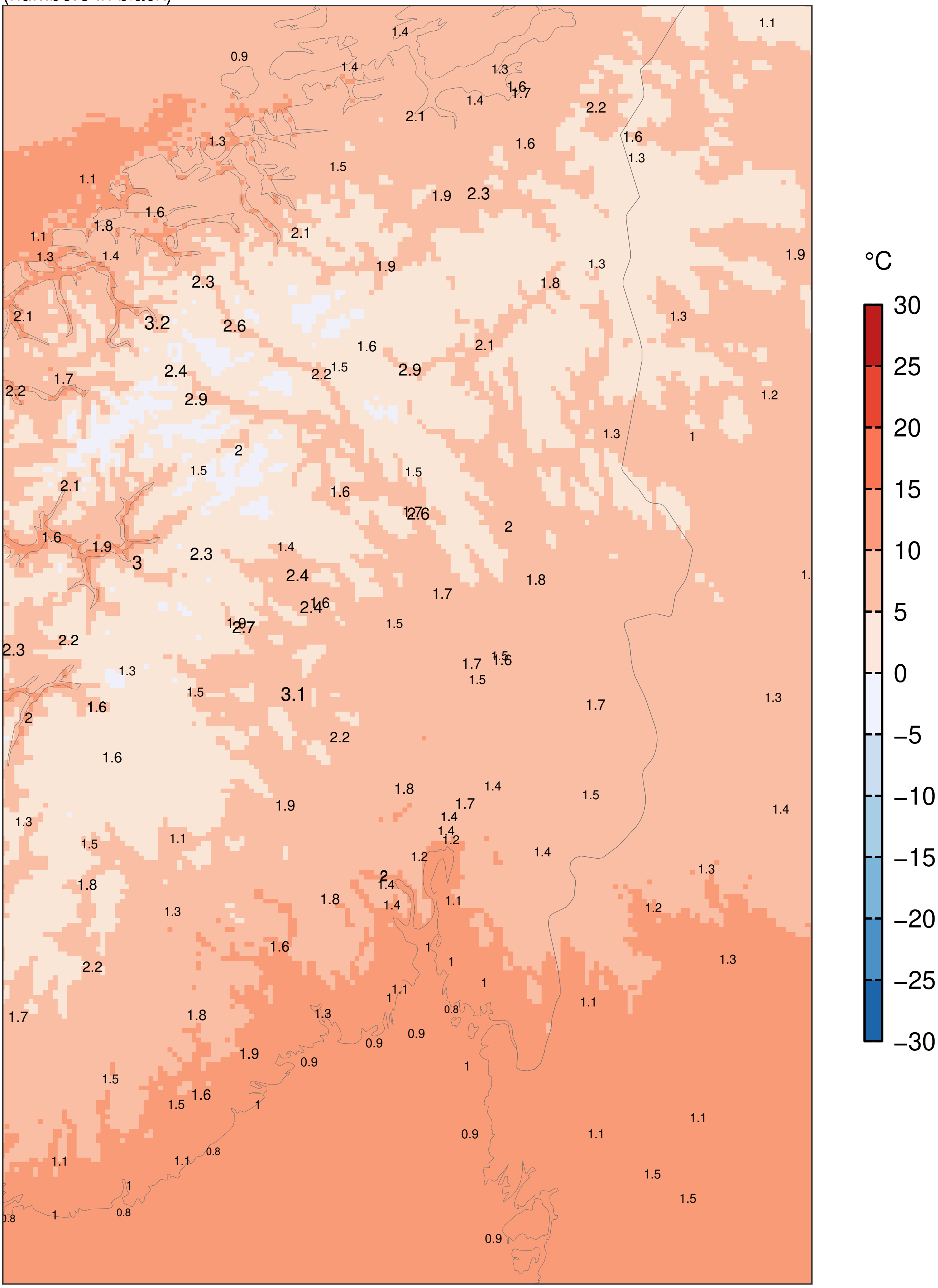
Model "climatology" 01.09.2024–30.11.2024



Model "climatology" 01.09.2024–30.11.2024

MEPSctrl 00+12

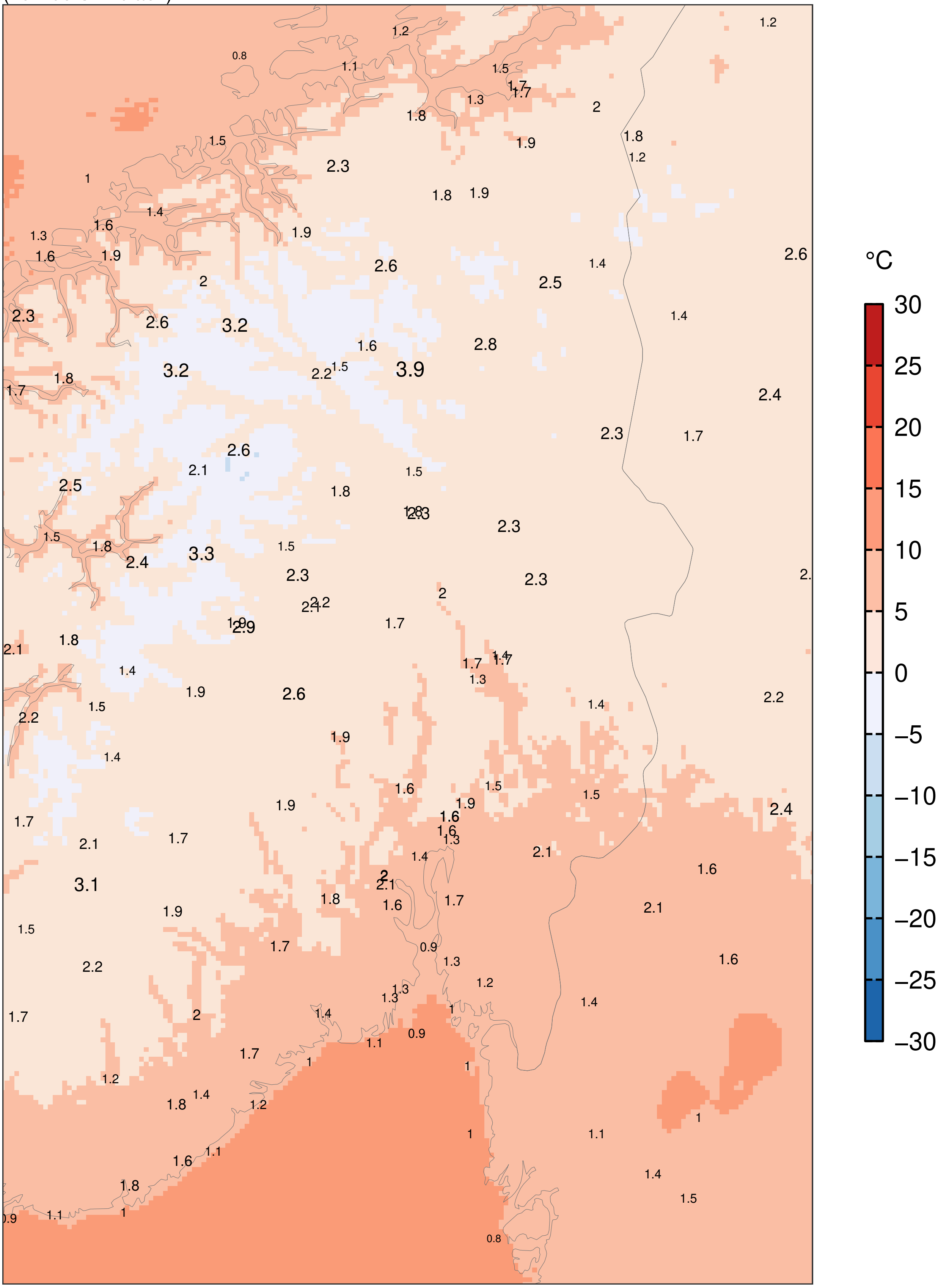
SDE at observing sites
(numbers in black)



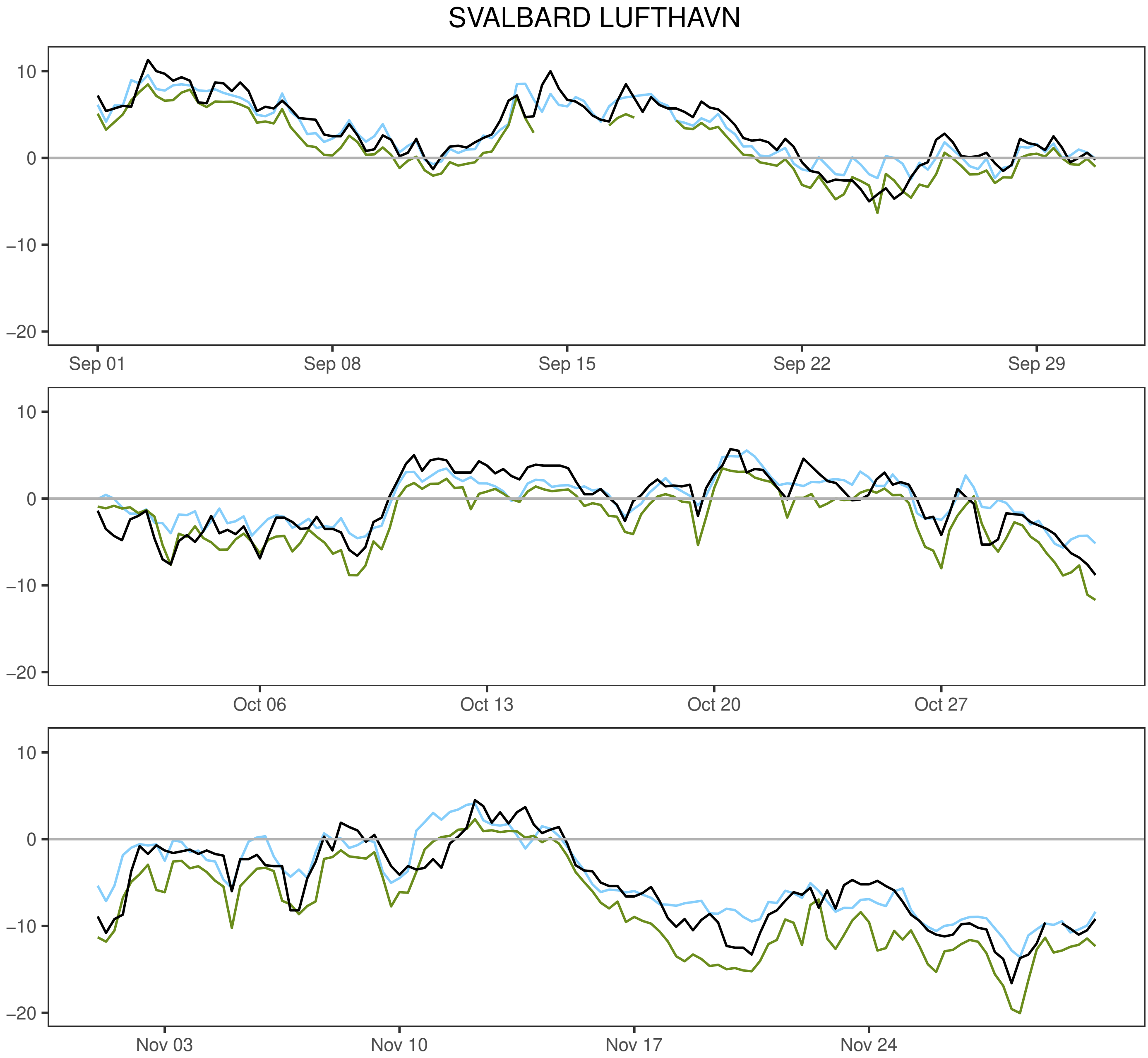
Model "climatology" 01.09.2024–30.11.2024

MEPSctrl 00+24

SDE at observing sites
(numbers in black)

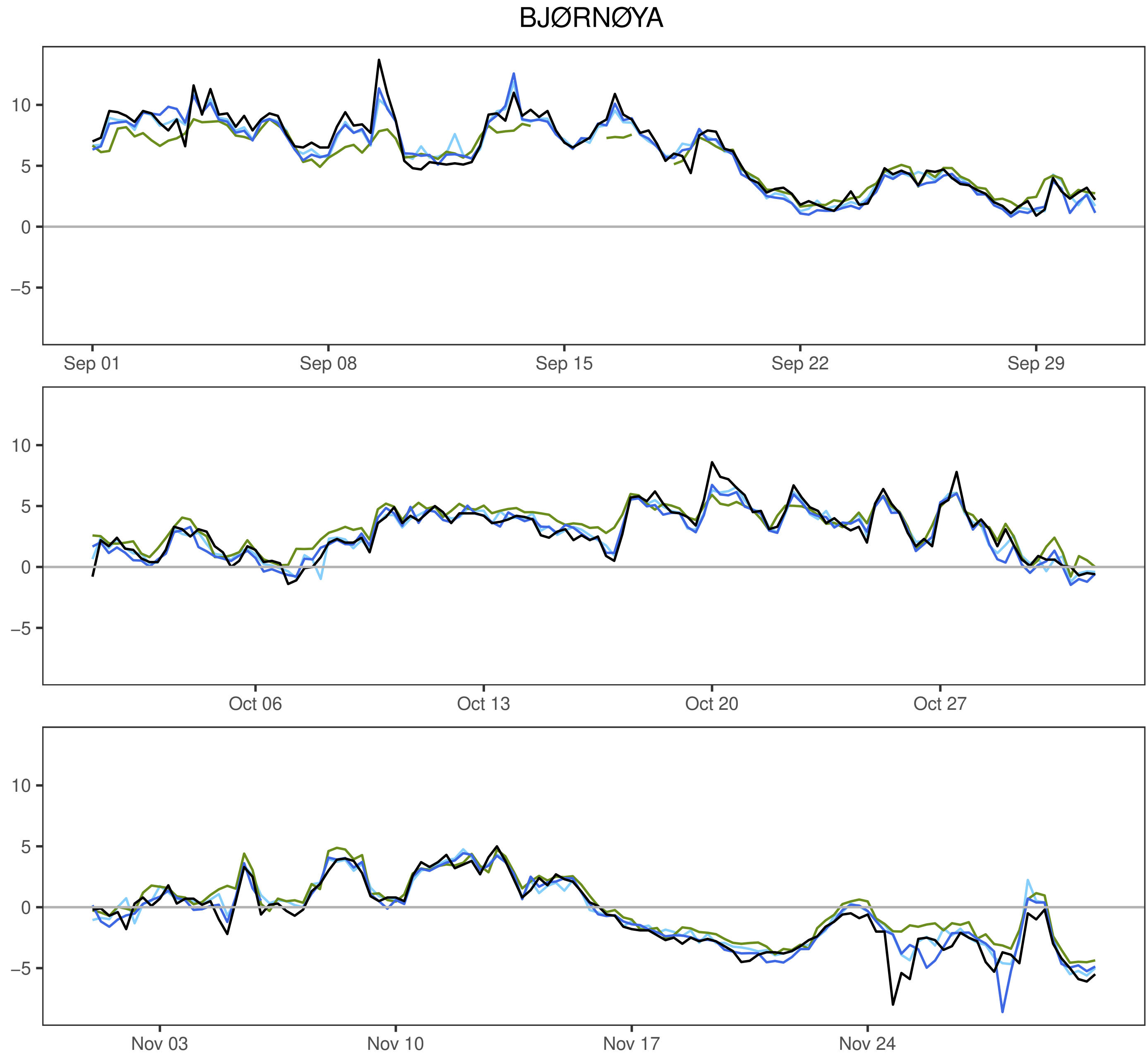


Model "climatology" 01.09.2024–30.11.2024



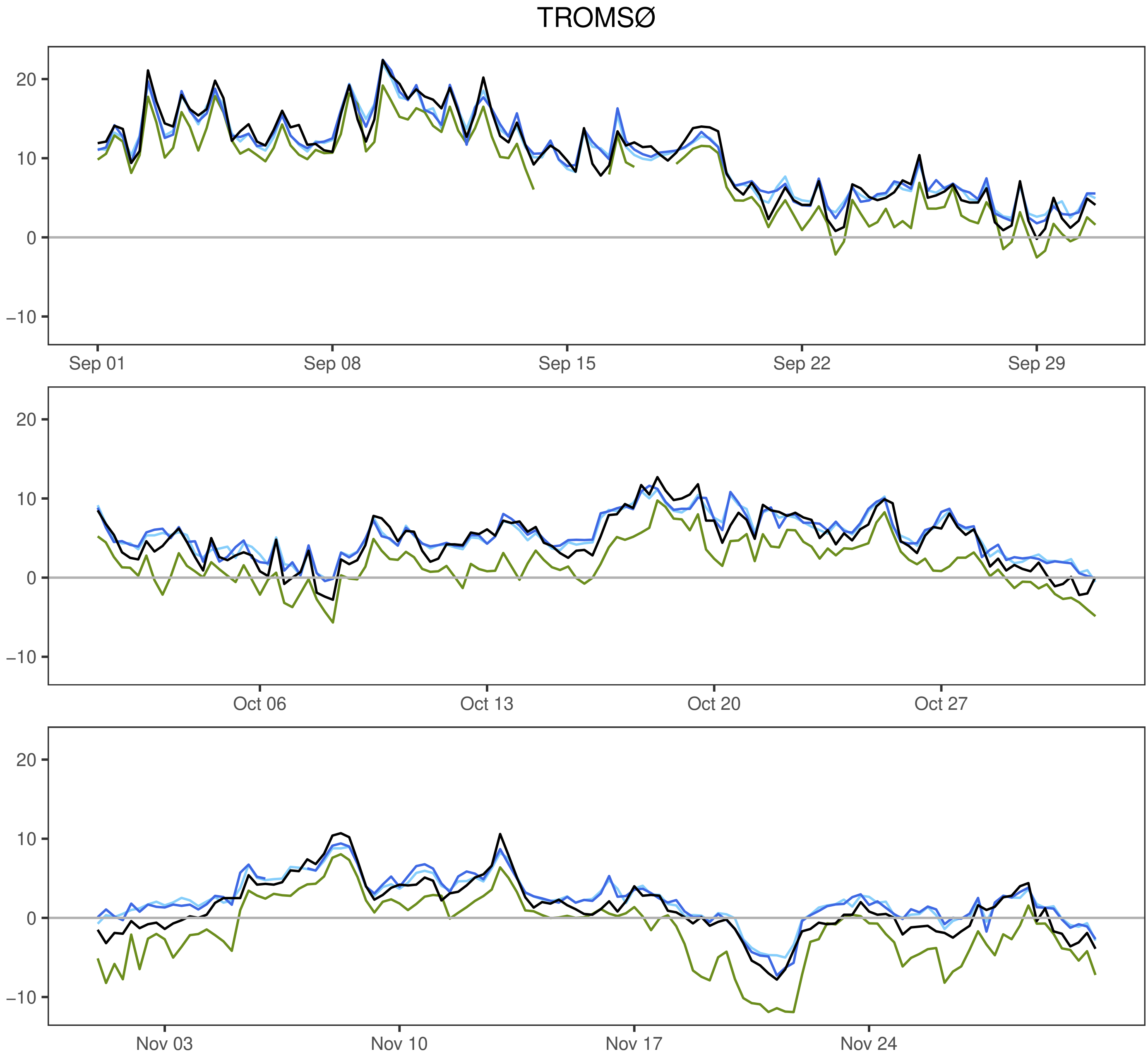
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−16.6	−0.9	11.3	5.3	363
AA25: 12+18,+24,+30,+36	−13.6	−0.6	9.6	4.7	364
ECMWF: 12+18,+24,+30,+36	−20.0	−3.1	8.5	5.6	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
AA25 – synop	0.3	1.8	1.8	1.4	6.9	351
ECMWF – synop	−1.9	1.6	2.5	2.2	8.0	351



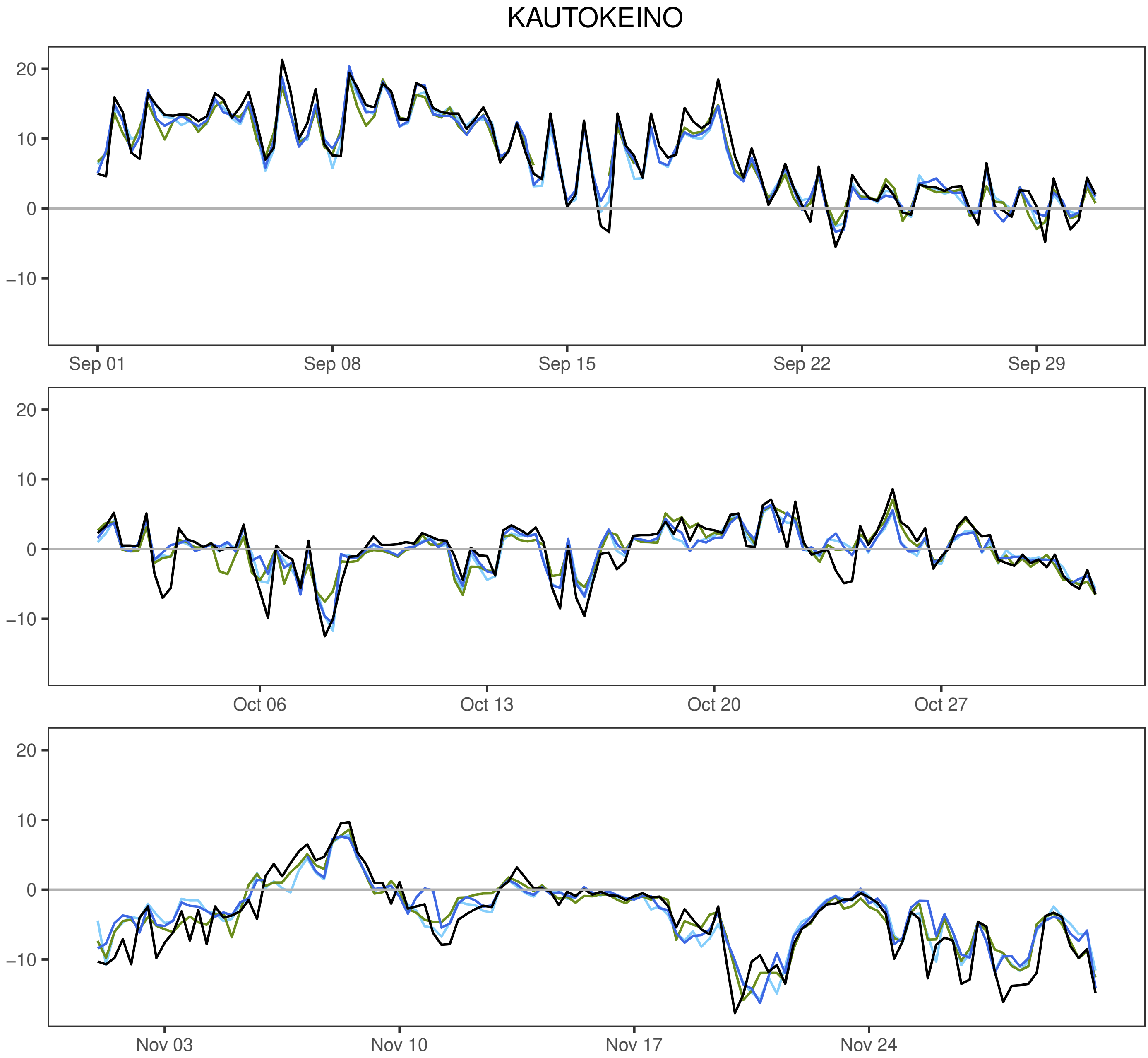
	Min	Mean	Max	Std	N
synop: 00,06,12,18	–8.0	2.8	13.7	3.8	364
MEPSctrl: 12+18,+24,+30,+36	–8.6	2.7	12.6	3.7	360
AA25: 12+18,+24,+30,+36	–5.6	2.8	11.9	3.6	364
ECMWF: 12+18,+24,+30,+36	–4.6	2.9	8.8	3.1	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.1	0.8	0.9	0.6	5.8	348
AA25 – synop	0.0	0.8	0.8	0.5	5.7	348
ECMWF – synop	0.2	1.2	1.2	0.9	6.0	348



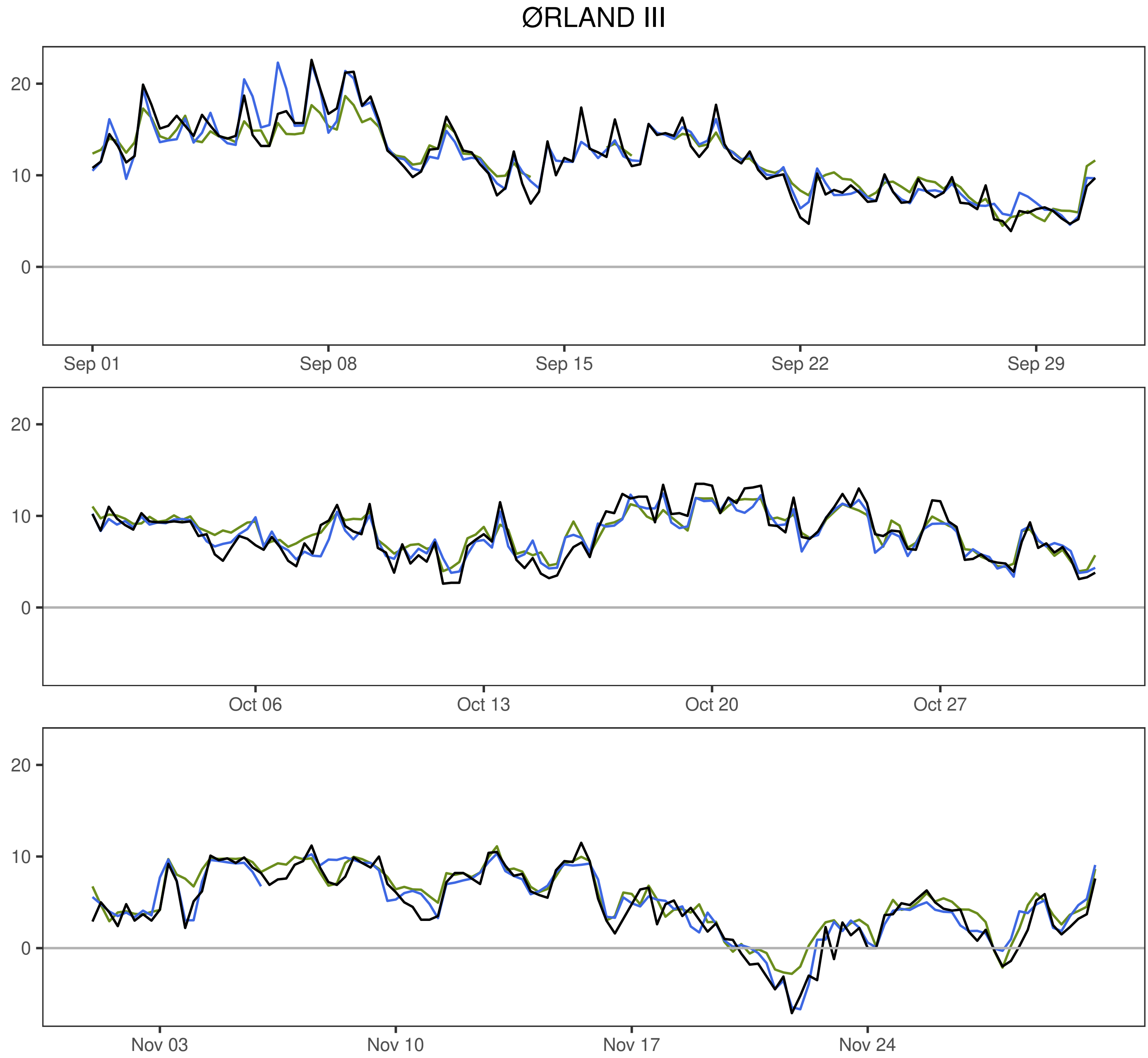
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−7.8	5.5	22.4	5.6	364
MEPSctrl: 12+18,+24,+30,+36	−7.3	6.1	22.4	5.1	360
AA25: 12+18,+24,+30,+36	−5.0	6.0	21.9	4.9	364
ECMWF: 12+18,+24,+30,+36	−11.9	2.6	19.2	5.9	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.6	1.3	1.4	1.1	4.3	348
AA25 – synop	0.5	1.3	1.4	1.1	3.8	348
ECMWF – synop	−2.7	1.5	3.1	2.7	7.8	348



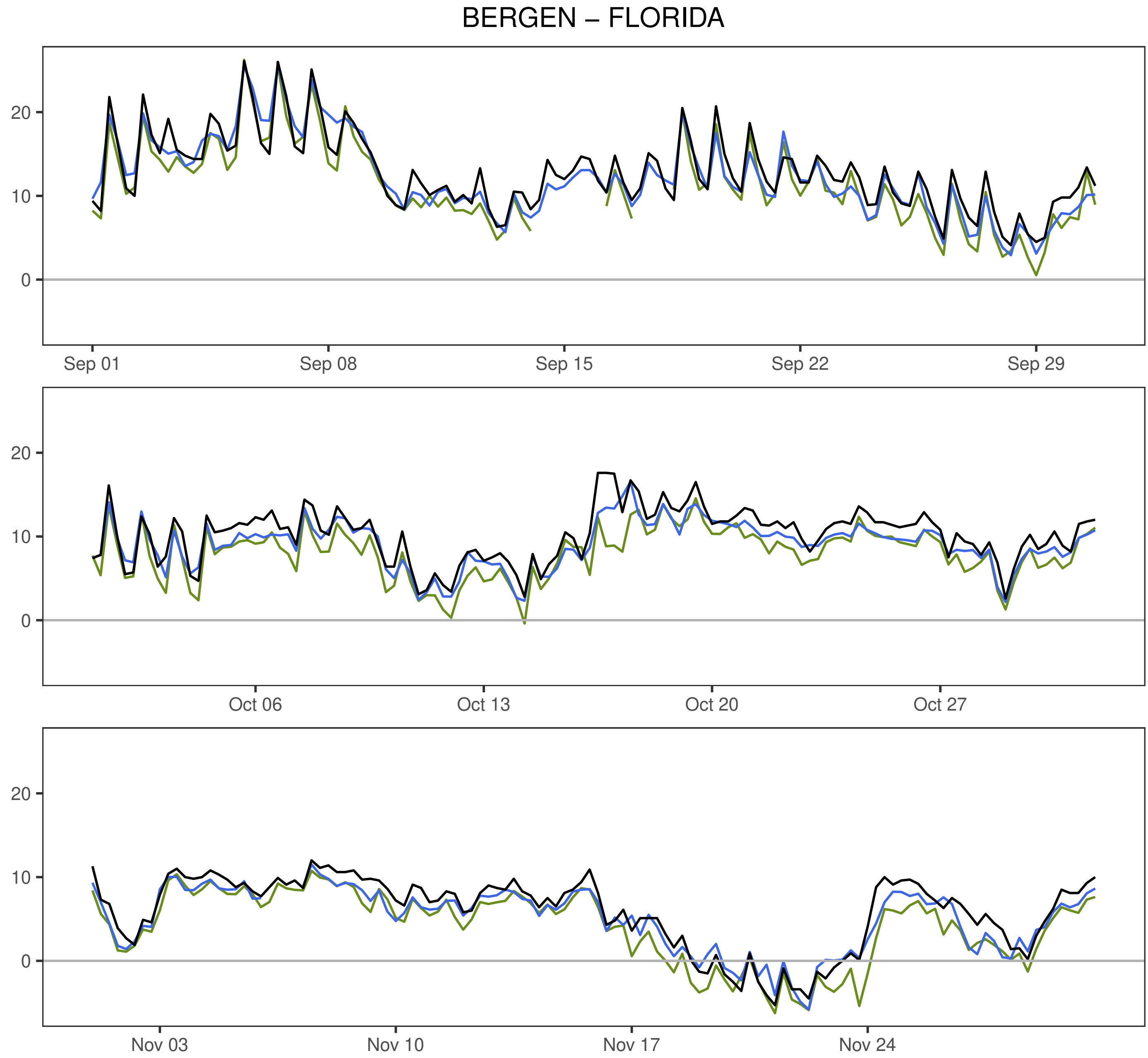
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−17.7	1.2	21.3	7.3	364
MEPSctrl: 12+18,+24,+30,+36	−16.2	1.4	20.4	6.4	360
AA25: 12+18,+24,+30,+36	−15.7	1.2	19.1	6.4	364
ECMWF: 12+18,+24,+30,+36	−15.8	1.1	18.5	6.4	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.2	2.1	2.1	1.5	11.1	348
AA25 – synop	0.0	2.1	2.1	1.5	7.2	348
ECMWF – synop	0.1	2.1	2.1	1.5	8.1	348



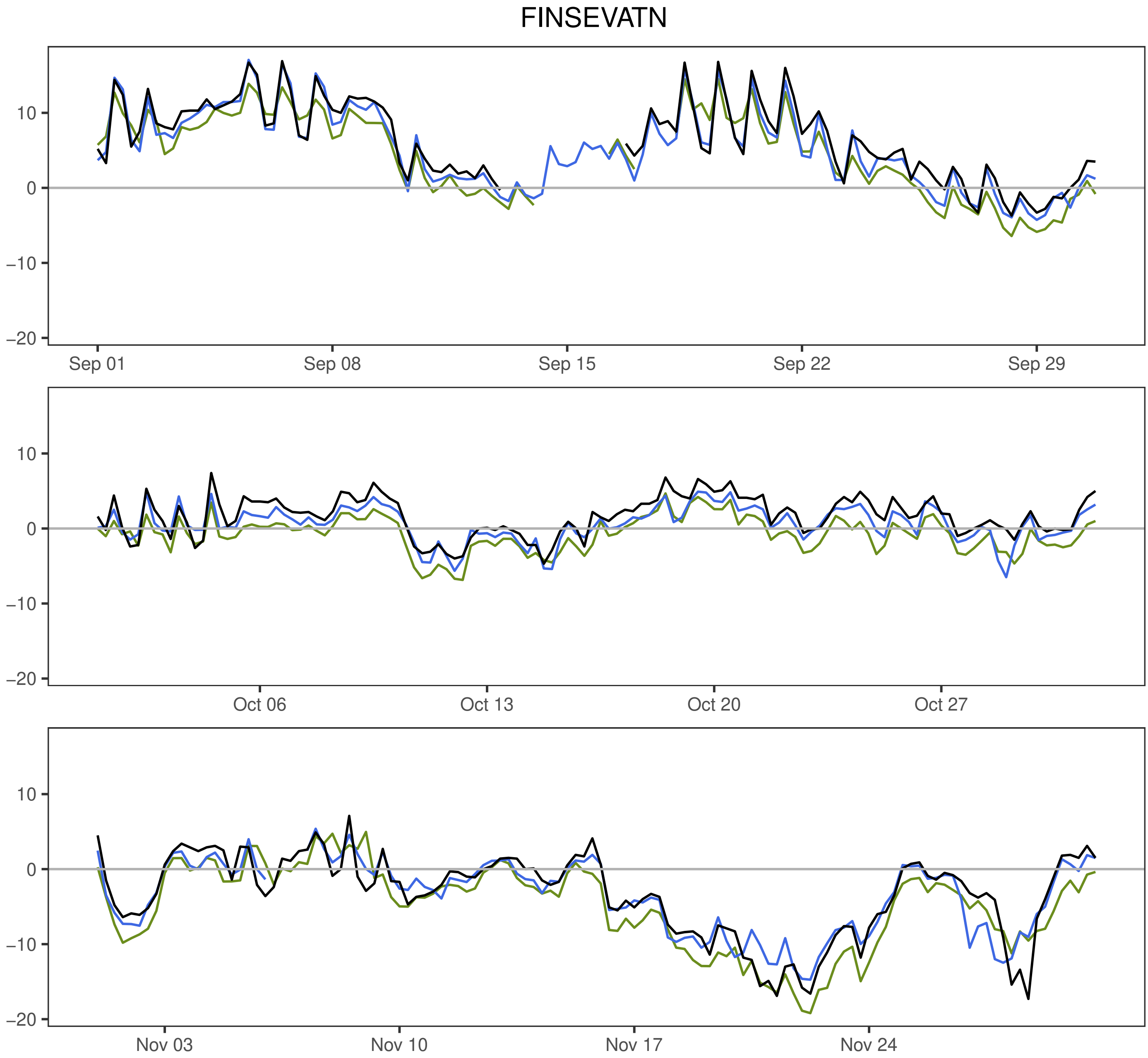
	Min	Mean	Max	Std	N
synop: 00,06,12,18	–7.1	8.1	22.6	4.7	364
MEPSctrl: 12+18,+24,+30,+36	–6.7	8.2	22.3	4.4	360
ECMWF: 12+18,+24,+30,+36	–2.8	8.3	18.7	3.9	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.1	1.3	1.3	0.9	5.6	348
ECMWF – synop	0.3	1.4	1.4	1.1	5.4	348



	Min	Mean	Max	Std	N
synop: 00,06,12,18	–5.3	9.6	26.1	4.9	364
MEPSctrl: 12+18,+24,+30,+36	–5.8	8.8	25.6	4.8	360
ECMWF: 12+18,+24,+30,+36	–6.2	7.7	26.2	5.1	352

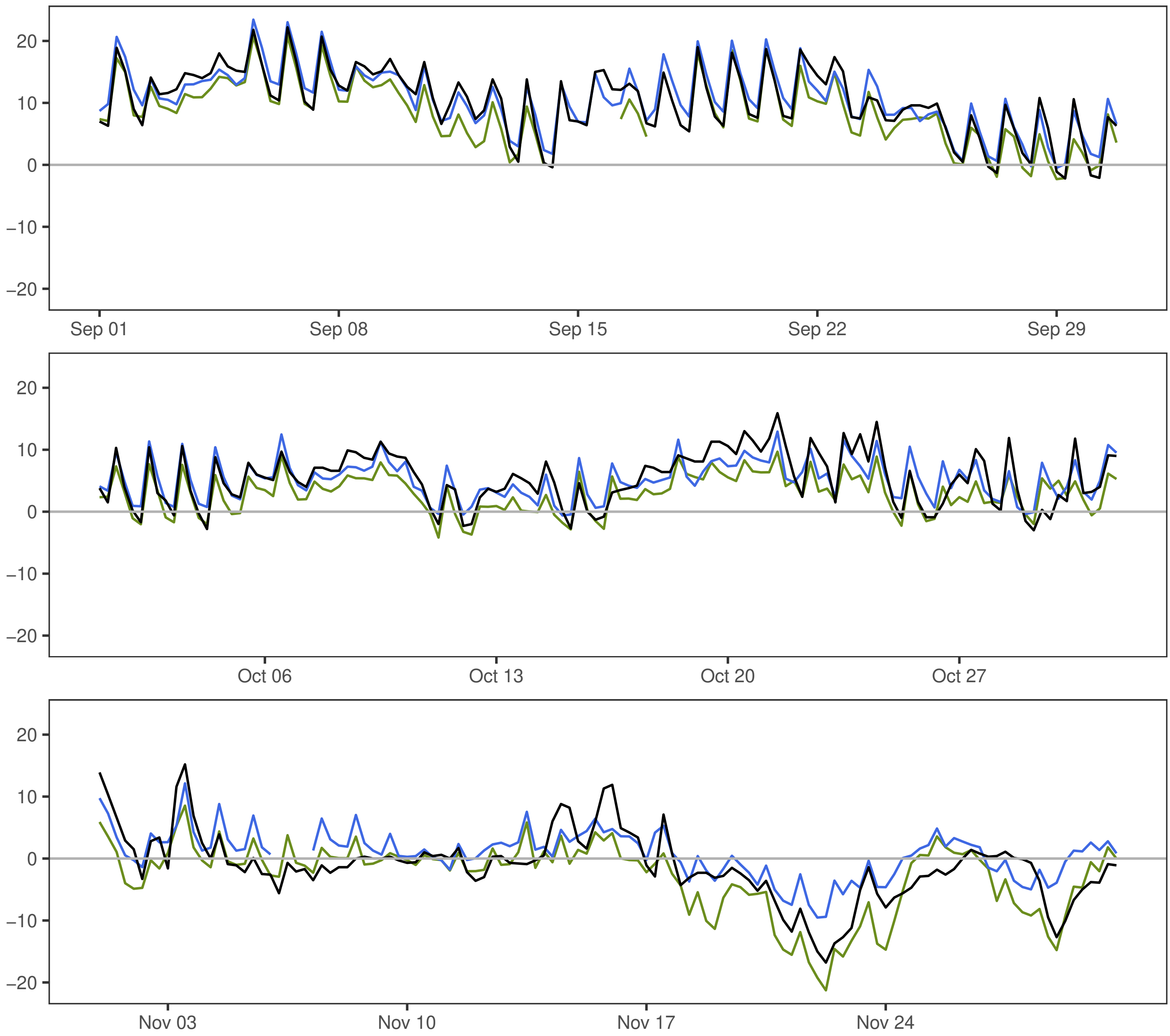
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.8	1.4	1.6	1.3	4.8	348
ECMWF – synop	–1.9	1.3	2.3	1.9	8.8	348



	Min	Mean	Max	Std	N
synop: 00,06,12,18	−17.3	1.4	16.9	6.1	350
MEPSctrl: 12+18,+24,+30,+36	−14.7	0.8	17.1	5.6	360
ECMWF: 12+18,+24,+30,+36	−19.2	−0.6	14.5	6.0	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	−0.7	1.6	1.8	1.3	8.3	342
ECMWF – synop	−1.9	1.9	2.7	2.4	7.9	342

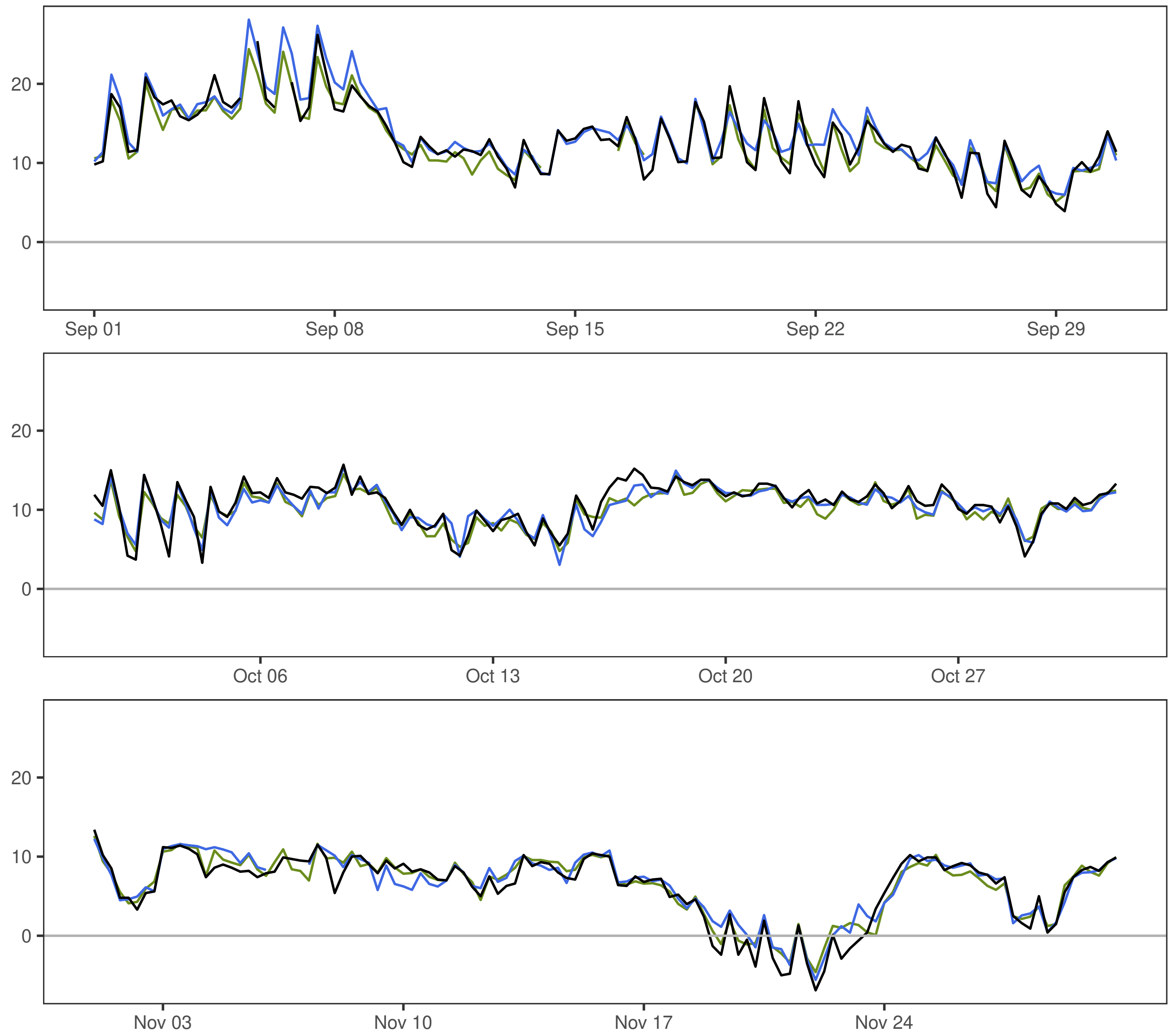
NESBYEN – TODOKK



	Min	Mean	Max	Std	N
synop: 00,06,12,18	–16.8	4.8	22.2	7.0	364
MEPSctrl: 12+18,+24,+30,+36	–9.5	5.6	23.4	5.8	360
ECMWF: 12+18,+24,+30,+36	–21.3	2.6	20.8	6.7	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.7	2.9	3.0	2.3	10.1	348
ECMWF – synop	–2.1	2.7	3.4	2.7	9.0	348

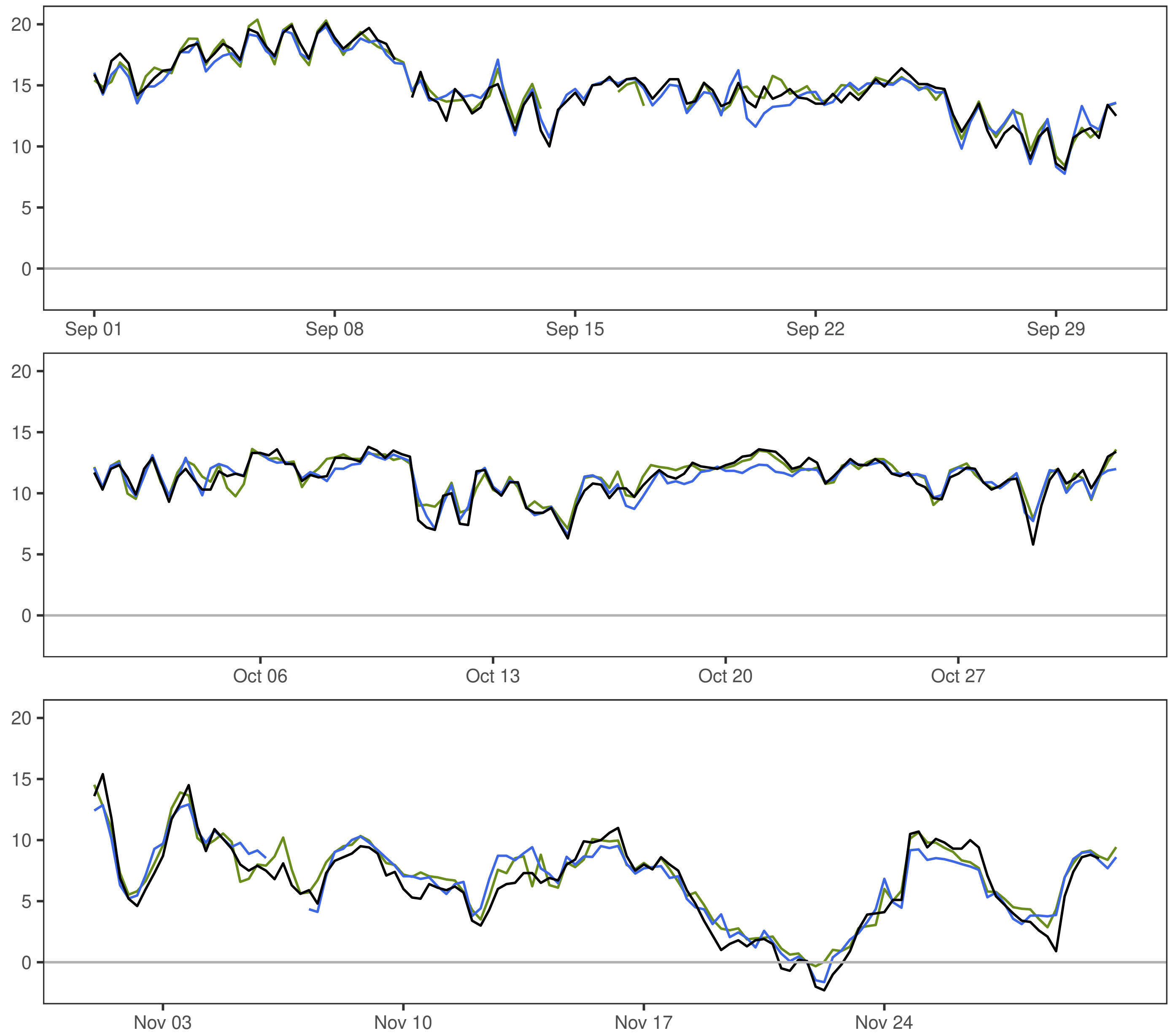
SOLA



	Min	Mean	Max	Std	N
synop: 00,06,12,18	−6.9	9.9	26.2	4.7	362
MEPSctrl: 12+18,+24,+30,+36	−5.6	10.3	28.1	4.7	360
ECMWF: 12+18,+24,+30,+36	−4.6	9.7	24.4	4.3	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.2	1.4	1.4	1.0	4.7	346
ECMWF – synop	−0.2	1.2	1.3	1.0	4.7	346

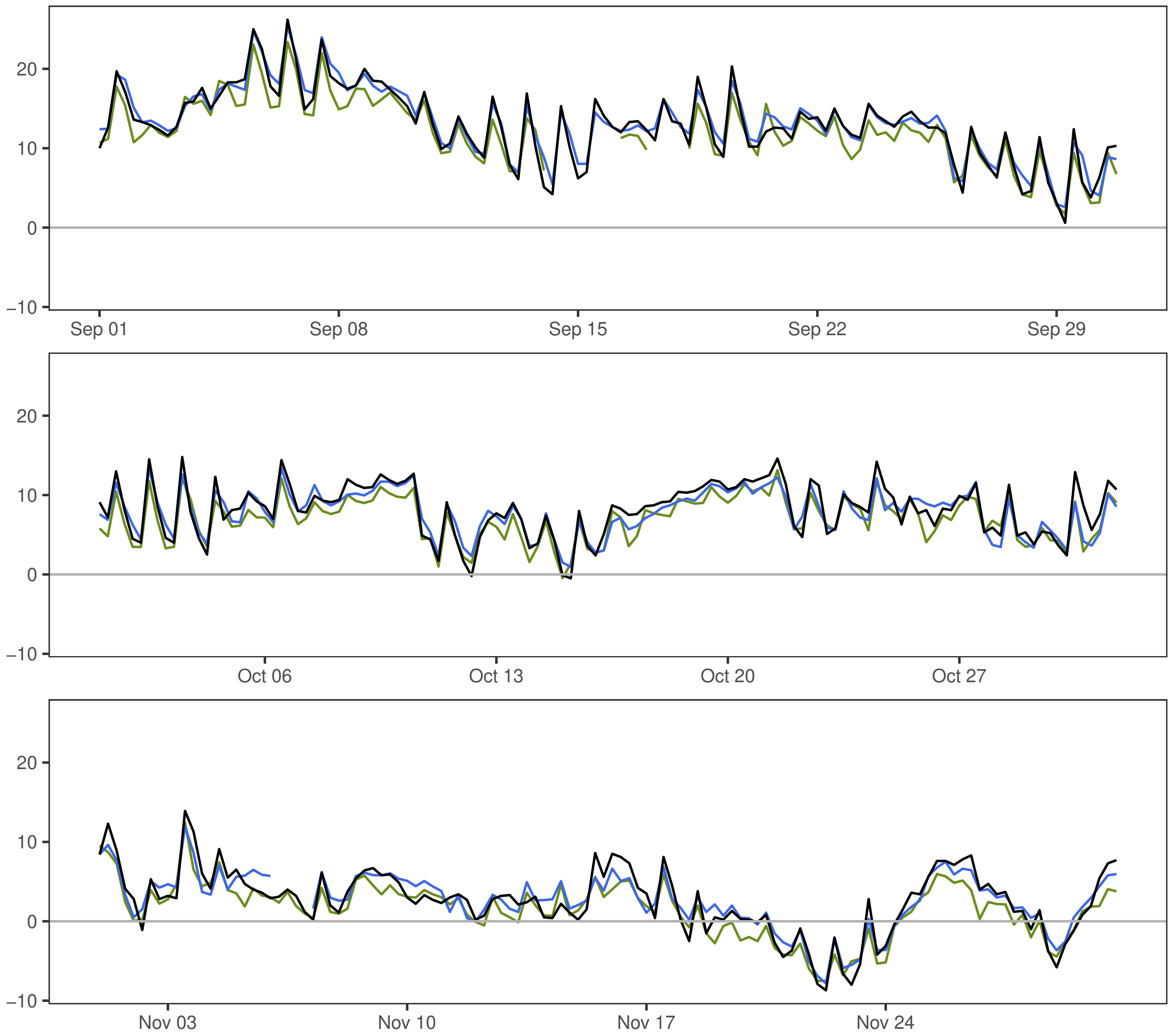
FÆRDER FYR



	Min	Mean	Max	Std	N
synop: 00,06,12,18	–2.3	10.8	20.1	4.3	362
MEPSctrl: 12+18,+24,+30,+36	–1.6	10.9	19.8	4.1	360
ECMWF: 12+18,+24,+30,+36	–0.3	10.9	20.4	4.1	352

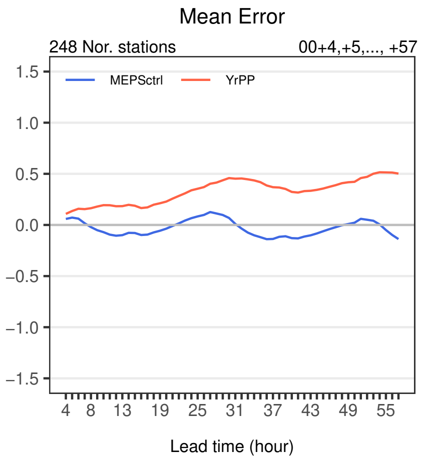
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.0	0.9	0.9	0.7	3.0	346
ECMWF – synop	0.2	0.8	0.8	0.6	3.4	346

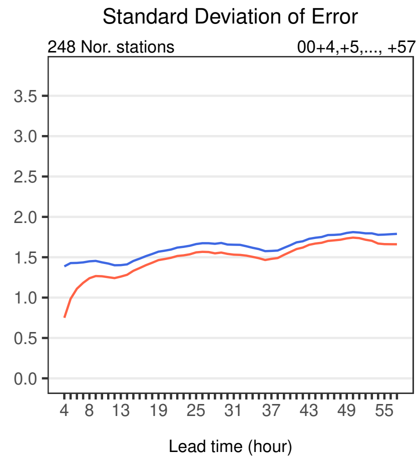
OSLO – BLINDERN

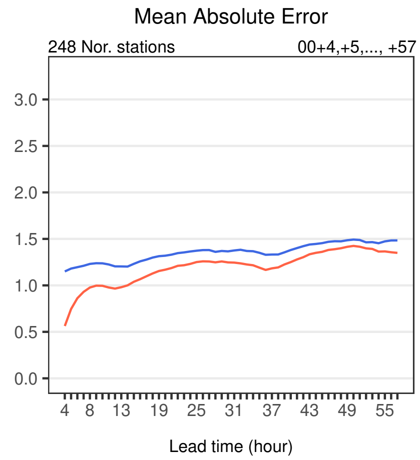


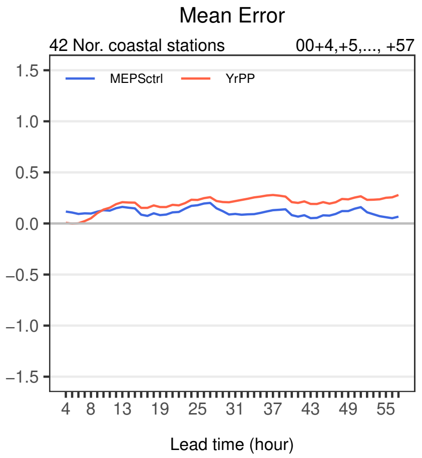
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−8.7	7.9	26.2	5.9	364
MEPSctrl: 12+18,+24,+30,+36	−7.8	8.0	25.4	5.6	360
ECMWF: 12+18,+24,+30,+36	−7.5	6.7	23.4	5.5	352

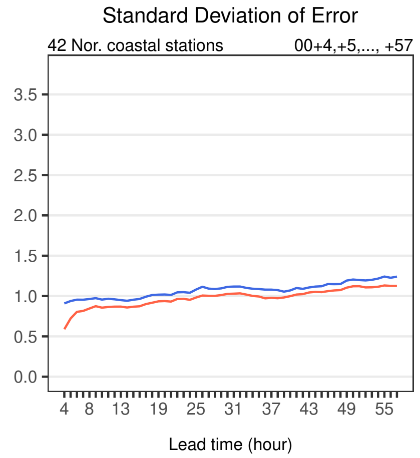
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.0	1.3	1.3	1.1	4.5	348
ECMWF – synop	−1.1	1.4	1.8	1.5	5.8	348

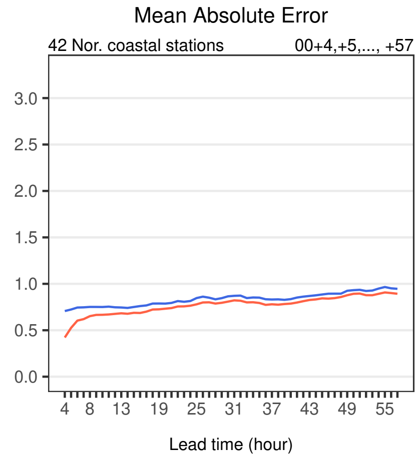

Mean Error
248 Nor. stations
00+4,+5,..., +57
MEPSctrl
YrPP
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
4 8 13 19 25 31 37 43 49 55
Lead time (hour)

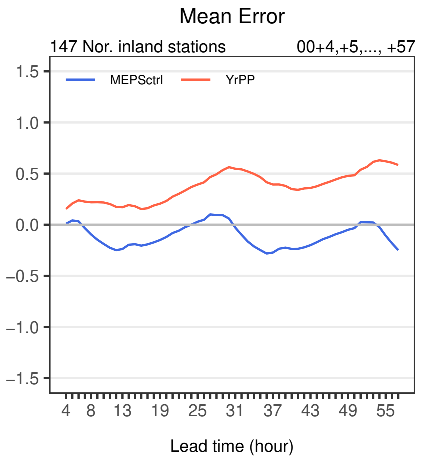

Standard Deviation of Error
248 Nor. stations
00+4,+5,..., +57
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4 8 13 19 25 31 37 43 49 55
Lead time (hour)

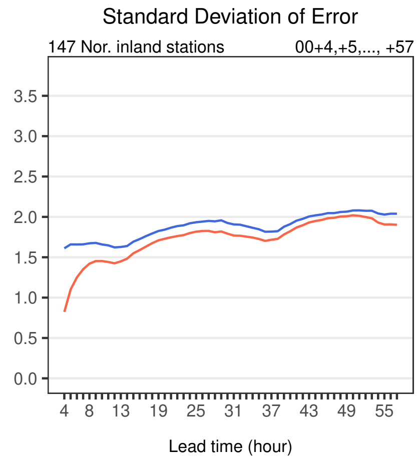

Mean Absolute Error
248 Nor. stations
00+4,+5,..., +57
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4 8 13 19 25 31 37 43 49 55
Lead time (hour)

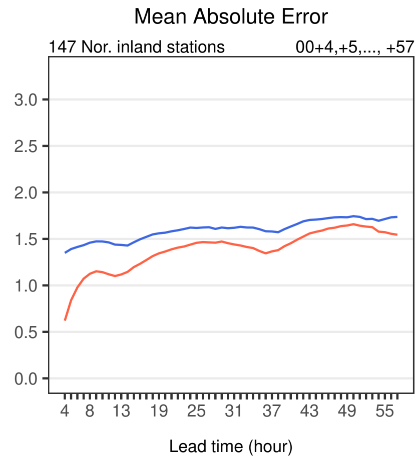

Mean Error
42 Nor. coastal stations
00+4,+5,..., +57
MEPSctrl
YrPP
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
4 8 13 19 25 31 37 43 49 55
Lead time (hour)

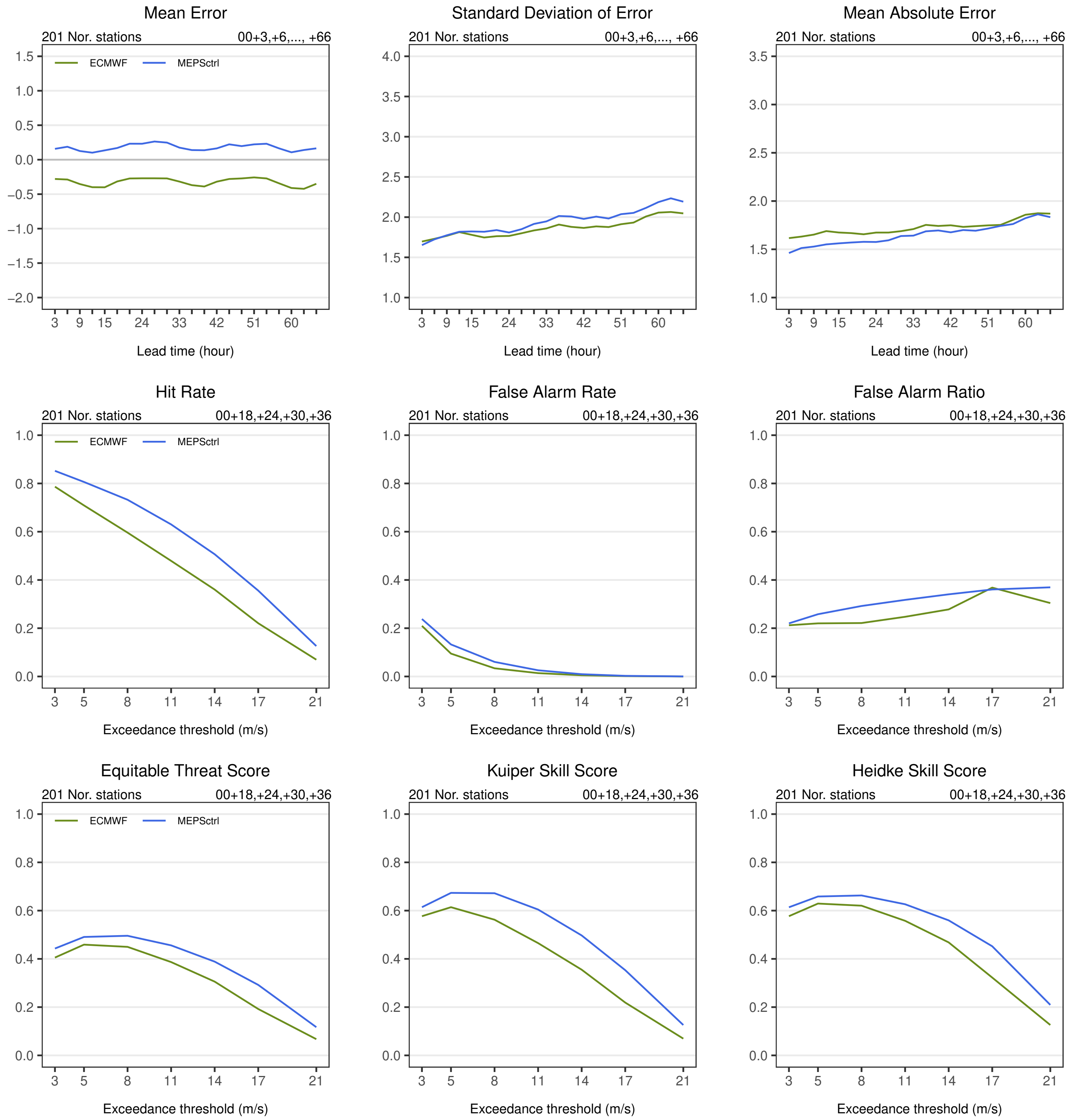

Standard Deviation of Error
42 Nor. coastal stations
00+4,+5,..., +57
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4 8 13 19 25 31 37 43 49 55
Lead time (hour)

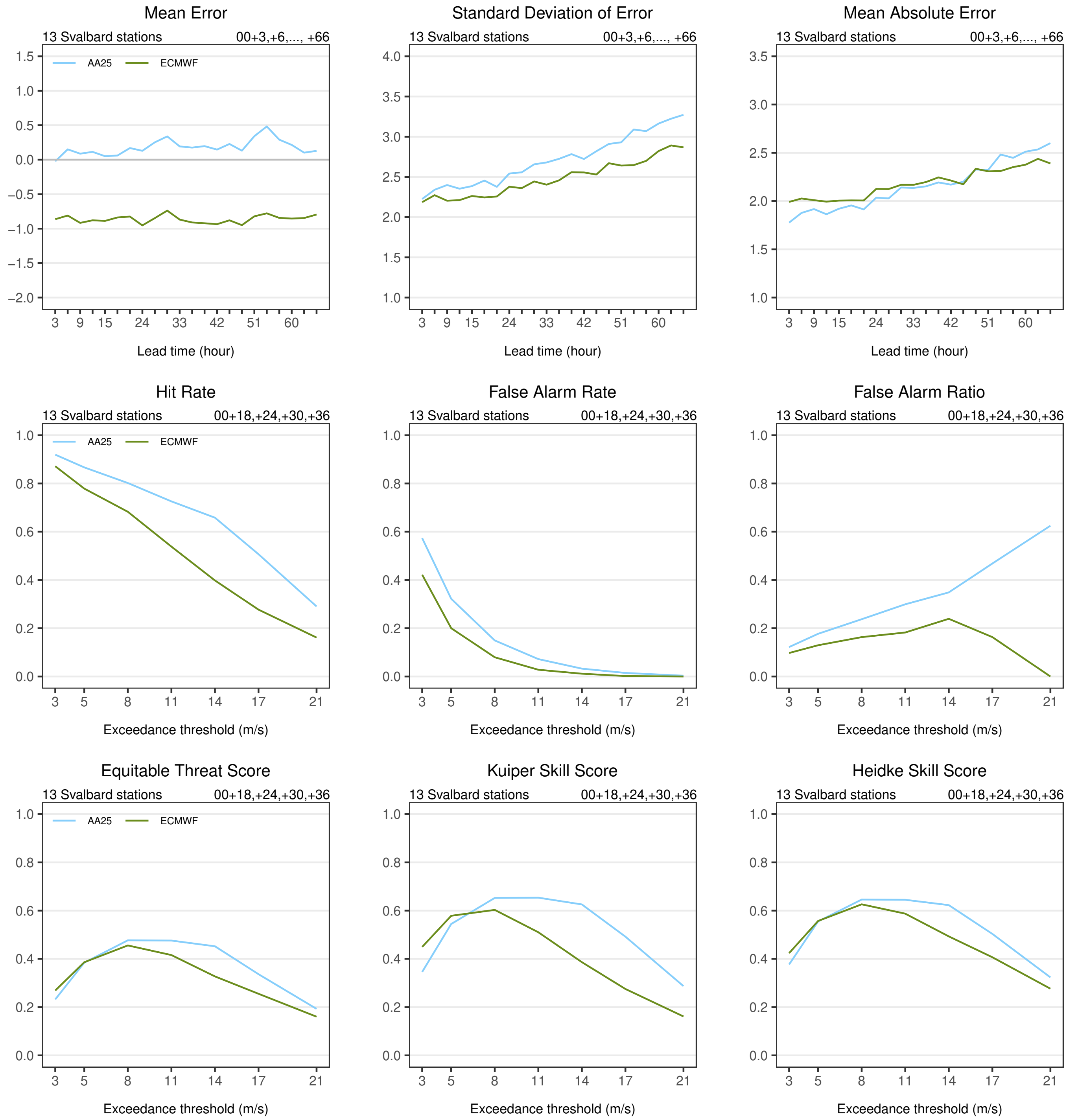

Mean Absolute Error
42 Nor. coastal stations
00+4,+5,..., +57
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4 8 13 19 25 31 37 43 49 55
Lead time (hour)

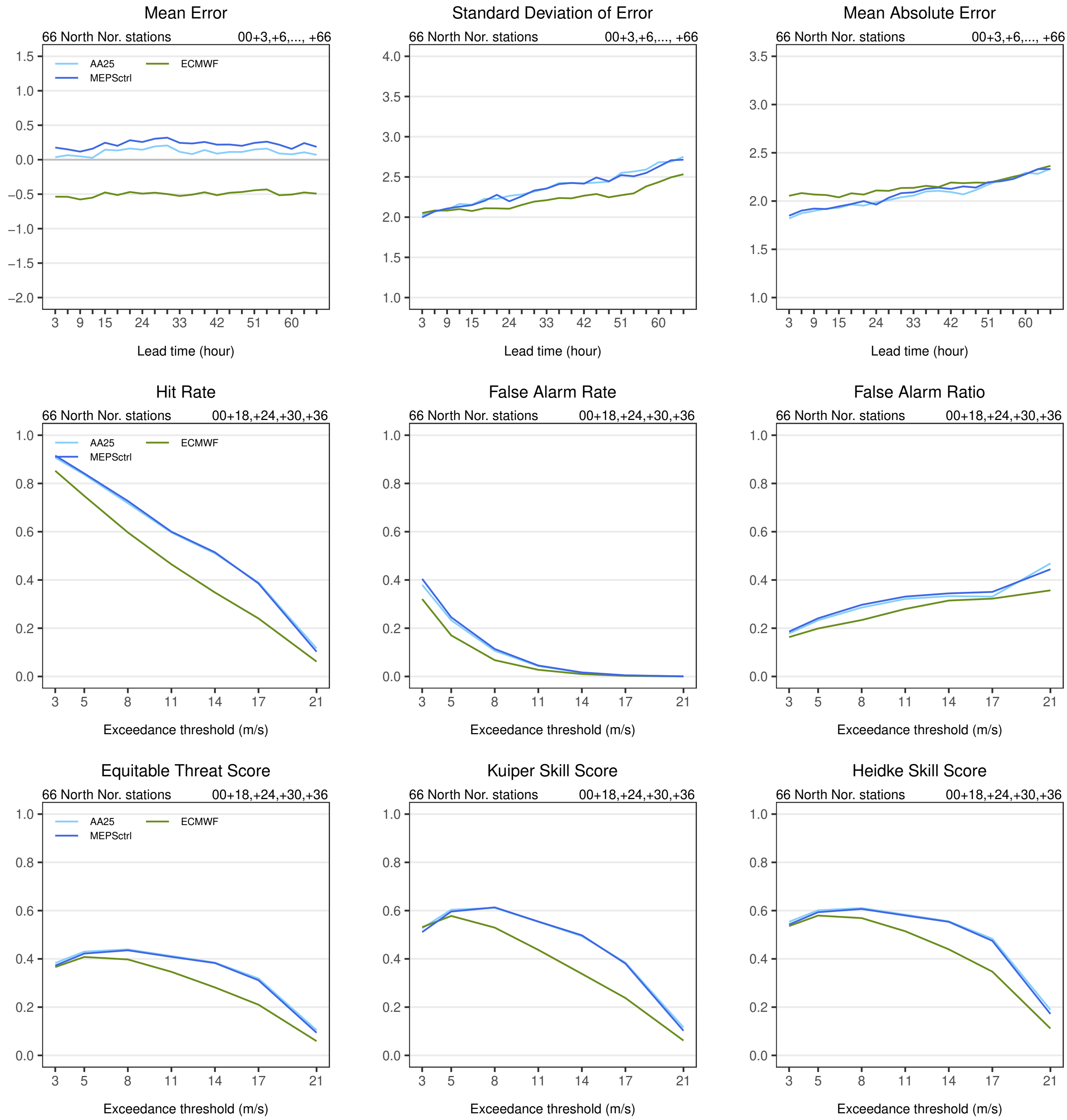

Mean Error
147 Nor. inland stations
00+4,+5,..., +57
MEPSctrl
YrPP
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
4 8 13 19 25 31 37 43 49 55
Lead time (hour)

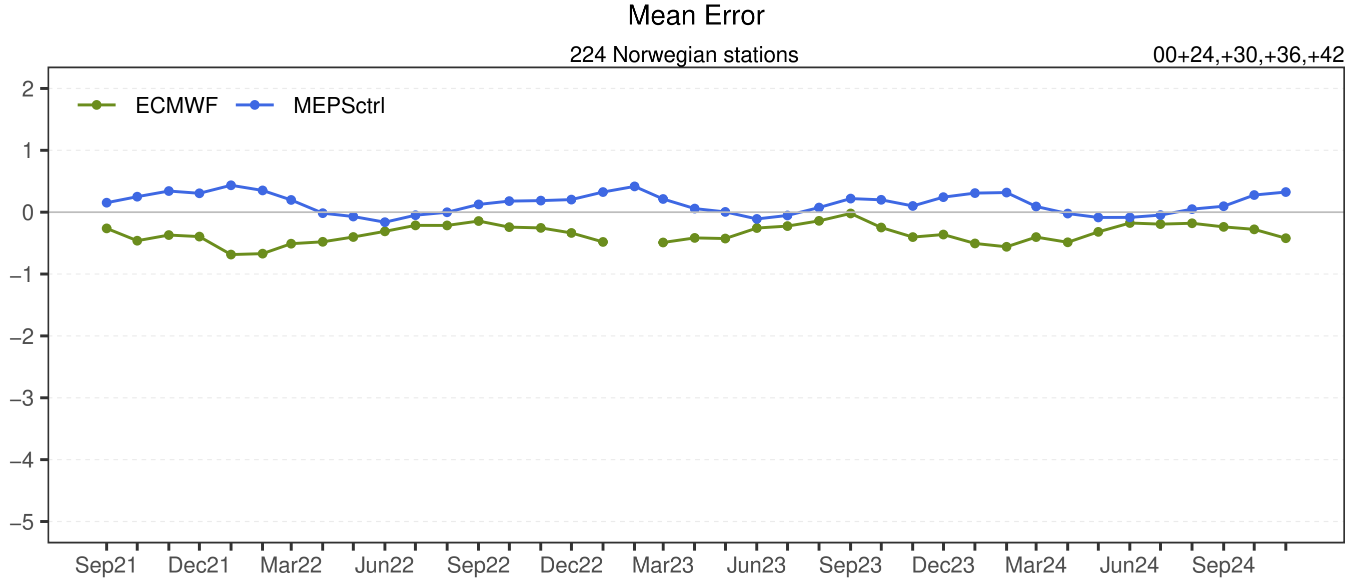

Standard Deviation of Error
147 Nor. inland stations
00+4,+5,..., +57
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4 8 13 19 25 31 37 43 49 55
Lead time (hour)

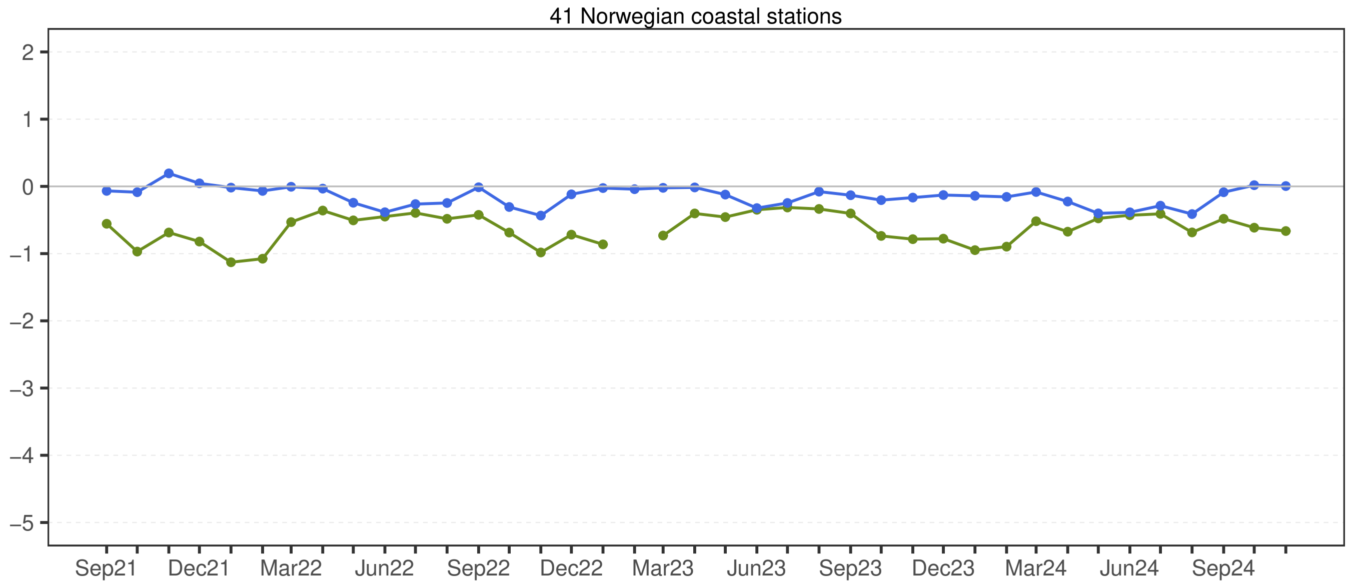

Mean Absolute Error
147 Nor. inland stations
00+4,+5,..., +57
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4 8 13 19 25 31 37 43 49 55
Lead time (hour)

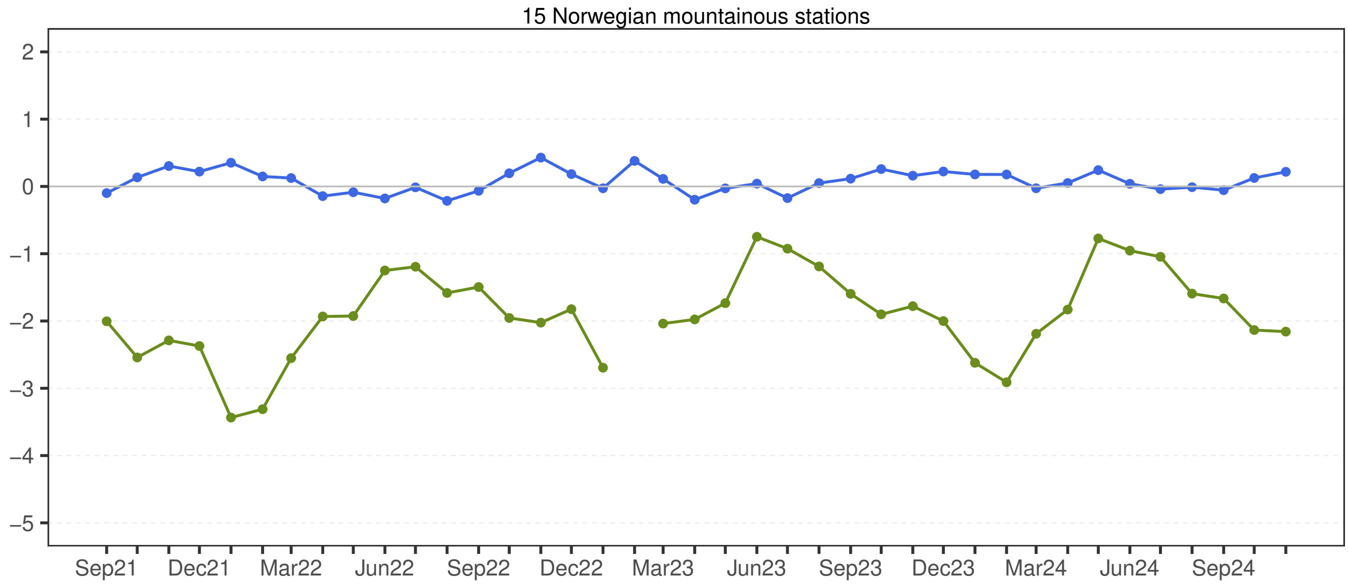

Mean Error
201 Nor. stations
00+3,+6,..., +66
ECMWF
MEPSctrl
Lead time (hour)
Standard Deviation of Error
201 Nor. stations
00+3,+6,..., +66
Lead time (hour)
Mean Absolute Error
201 Nor. stations
00+3,+6,..., +66
Lead time (hour)
Hit Rate
201 Nor. stations
00+18,+24,+30,+36
ECMWF
MEPSctrl
Exceedance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

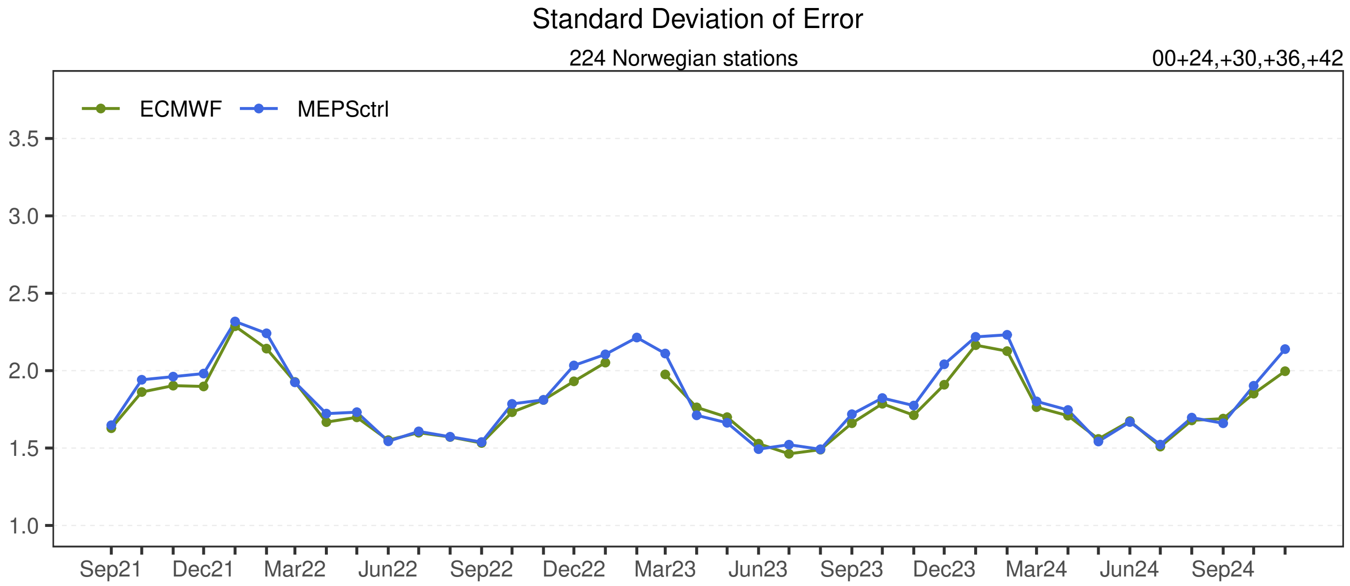

Mean Error
13 Svalbard stations
00+3,+6,..., +66
AA25
ECMWF
Lead time (hour)
Standard Deviation of Error
13 Svalbard stations
00+3,+6,..., +66
Lead time (hour)
Mean Absolute Error
13 Svalbard stations
00+3,+6,..., +66
Lead time (hour)
Hit Rate
13 Svalbard stations
00+18,+24,+30,+36
AA25
ECMWF
Exceedance 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)

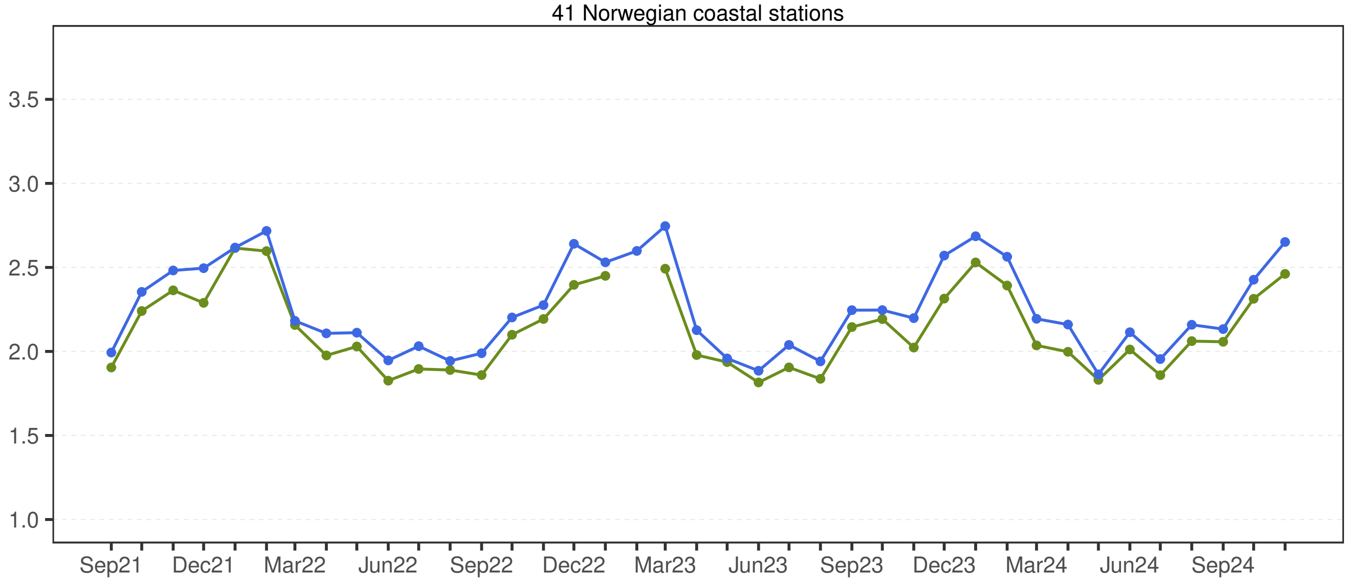

Mean Error
66 North Nor. stations
00+3,+6,..., +66
AA25
MEPSctrl
ECMWF
Lead time (hour)
Standard Deviation of Error
66 North Nor. stations
00+3,+6,..., +66
Lead time (hour)
Mean Absolute Error
66 North Nor. stations
00+3,+6,..., +66
Lead time (hour)
Hit Rate
66 North Nor. stations
00+18,+24,+30,+36
AA25
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)

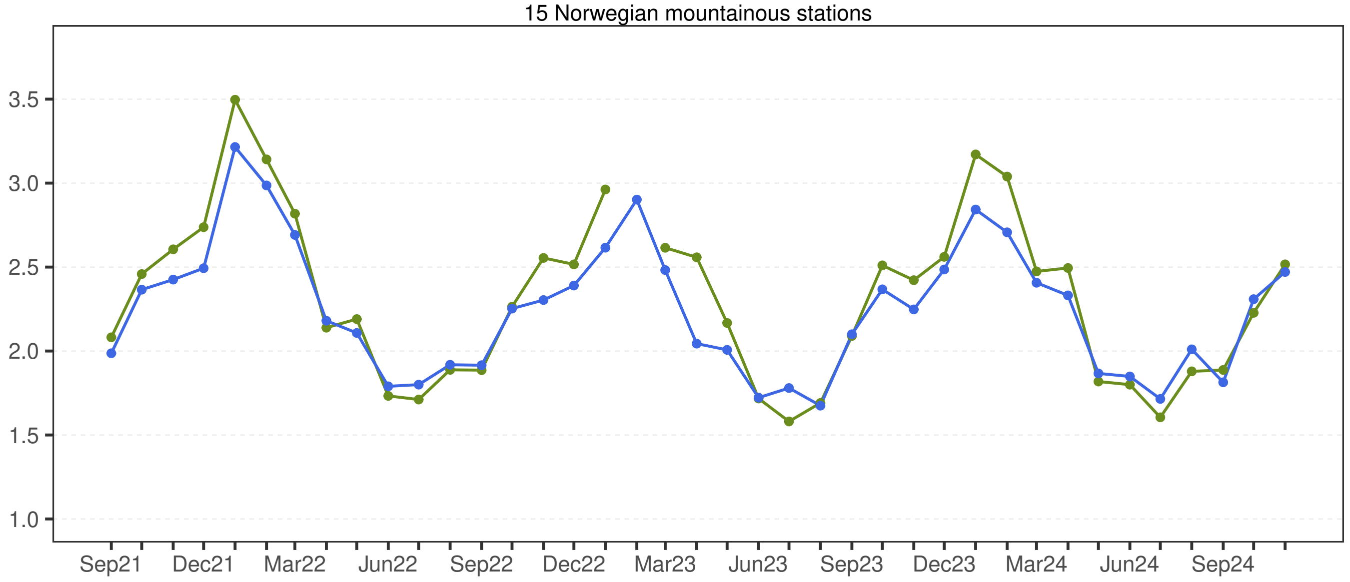

Mean Error
224 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
2
1
0
−1
−2
−3
−4
−5
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24
Sep24


41 Norwegian coastal stations
2
1
0
−1
−2
−3
−4
−5
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24
Sep24

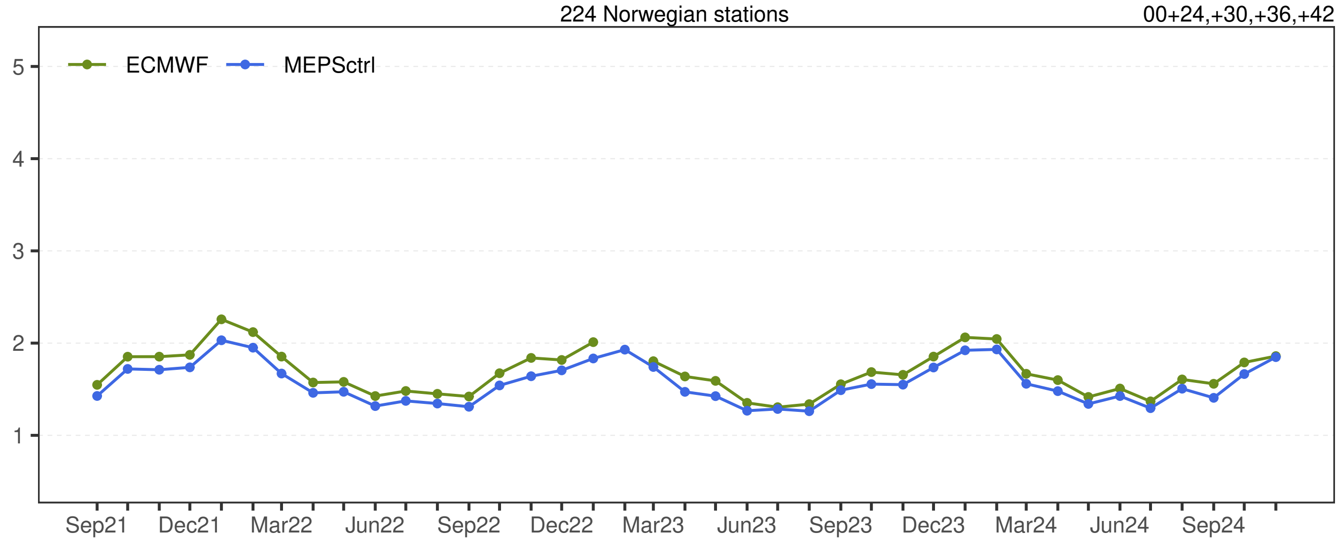

15 Norwegian mountainous stations
2
1
0
−1
−2
−3
−4
−5
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24
Sep24

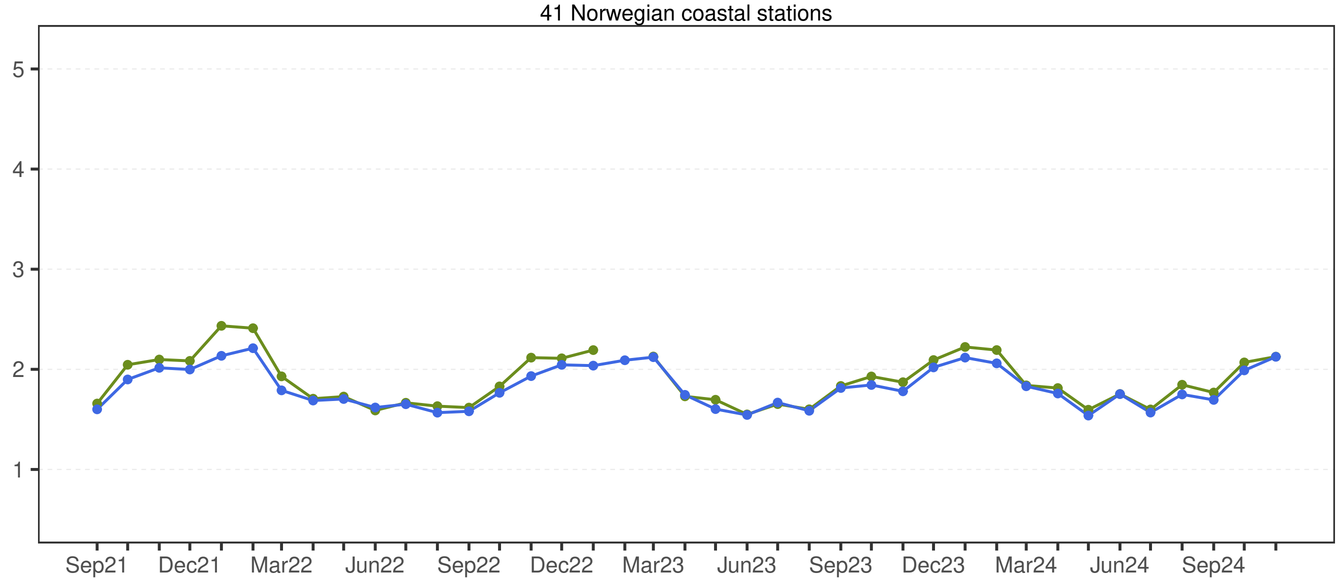

Standard Deviation of Error
224 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
3.5
3.0
2.5
2.0
1.5
1.0
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24
Sep24

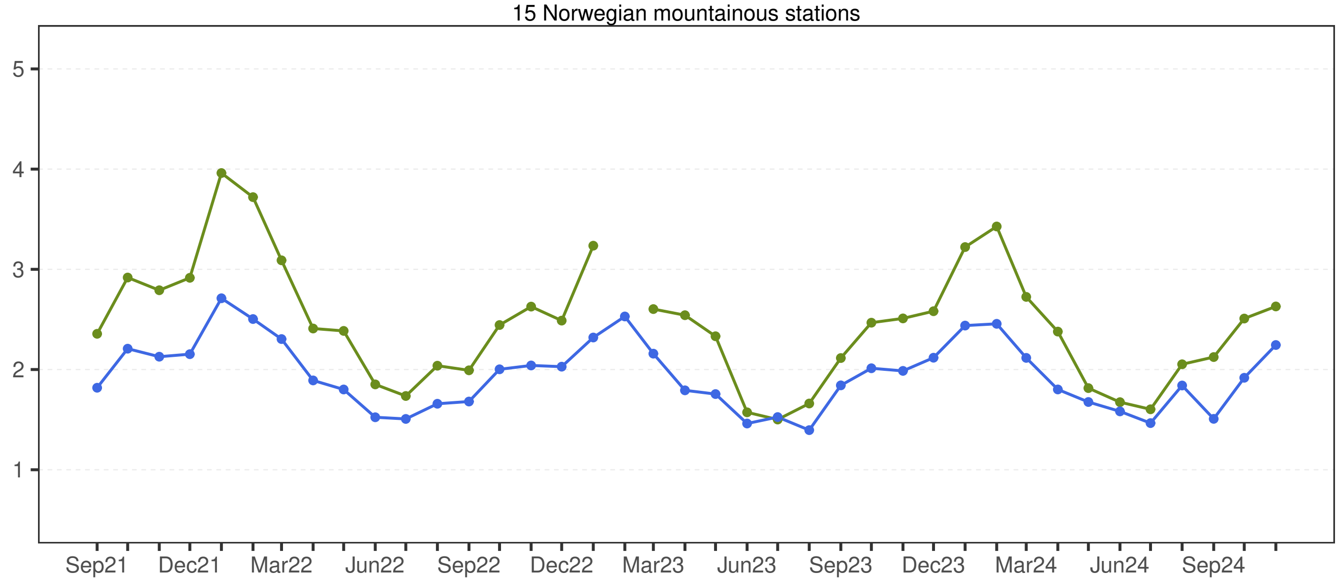

41 Norwegian coastal stations
3.5
3.0
2.5
2.0
1.5
1.0
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24
Sep24


15 Norwegian mountainous stations
3.5
3.0
2.5
2.0
1.5
1.0
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24
Sep24

Mean Absolute Error

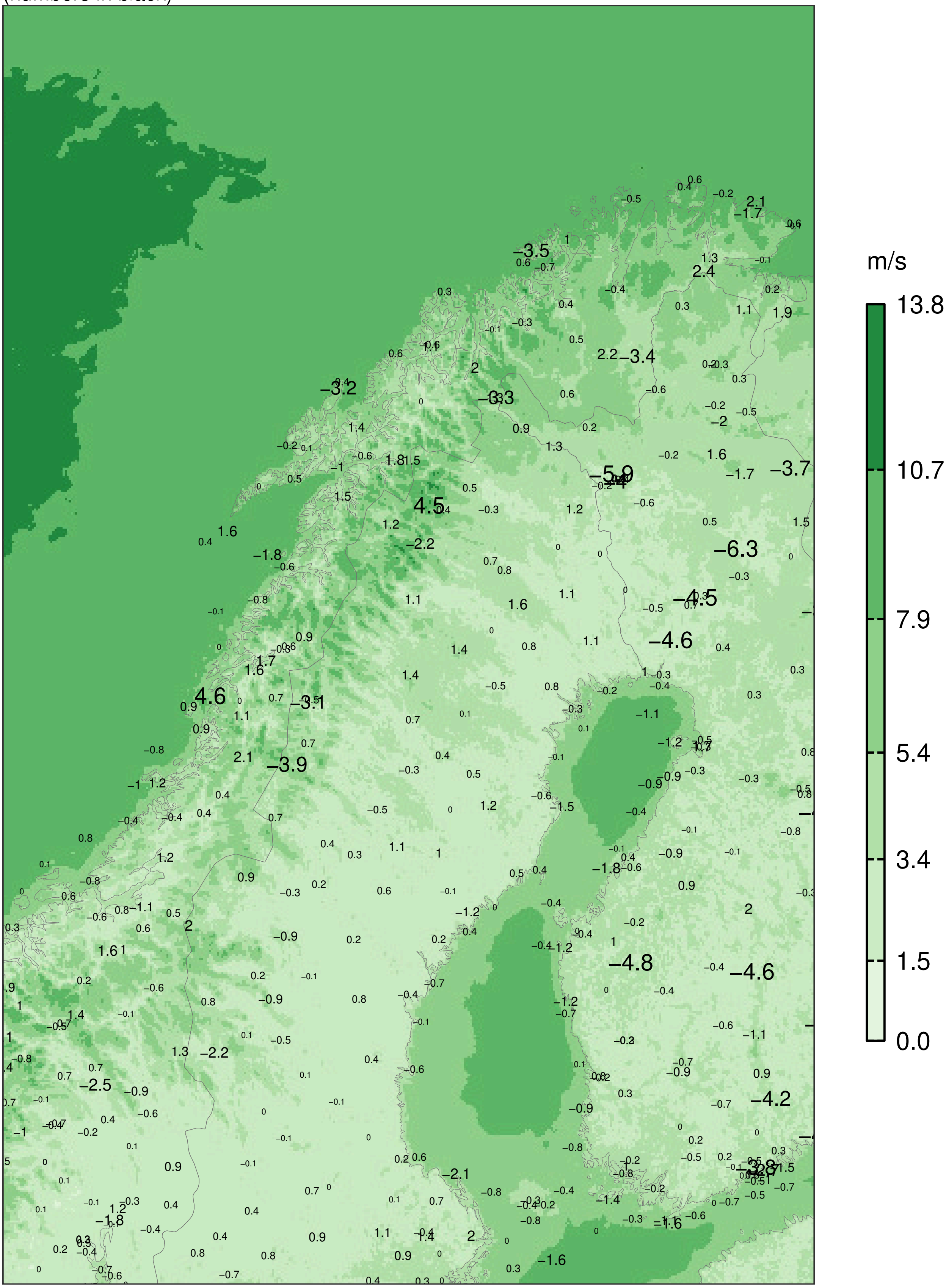




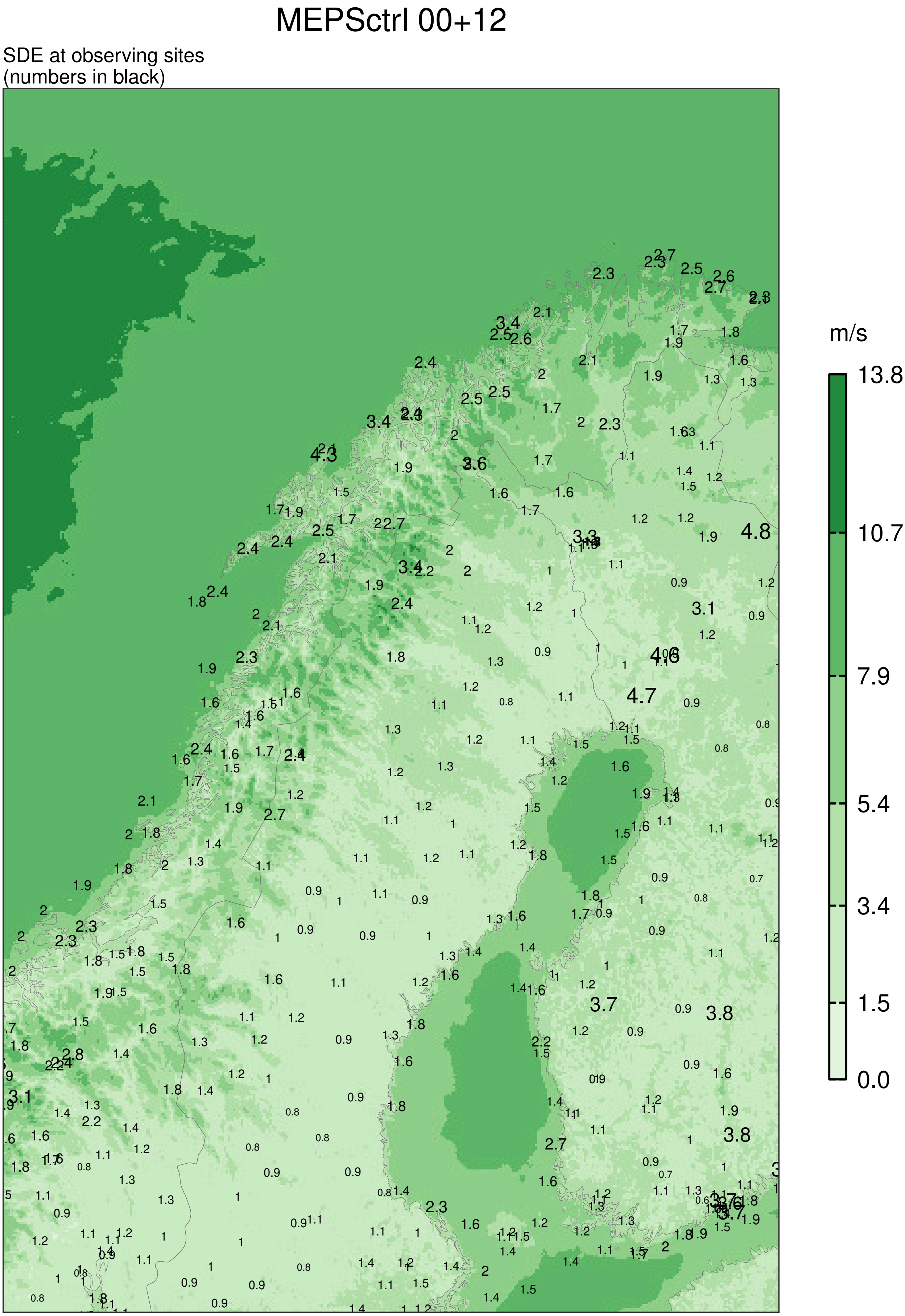


MEPSctrl 00+12

ME at observing sites
(numbers in black)



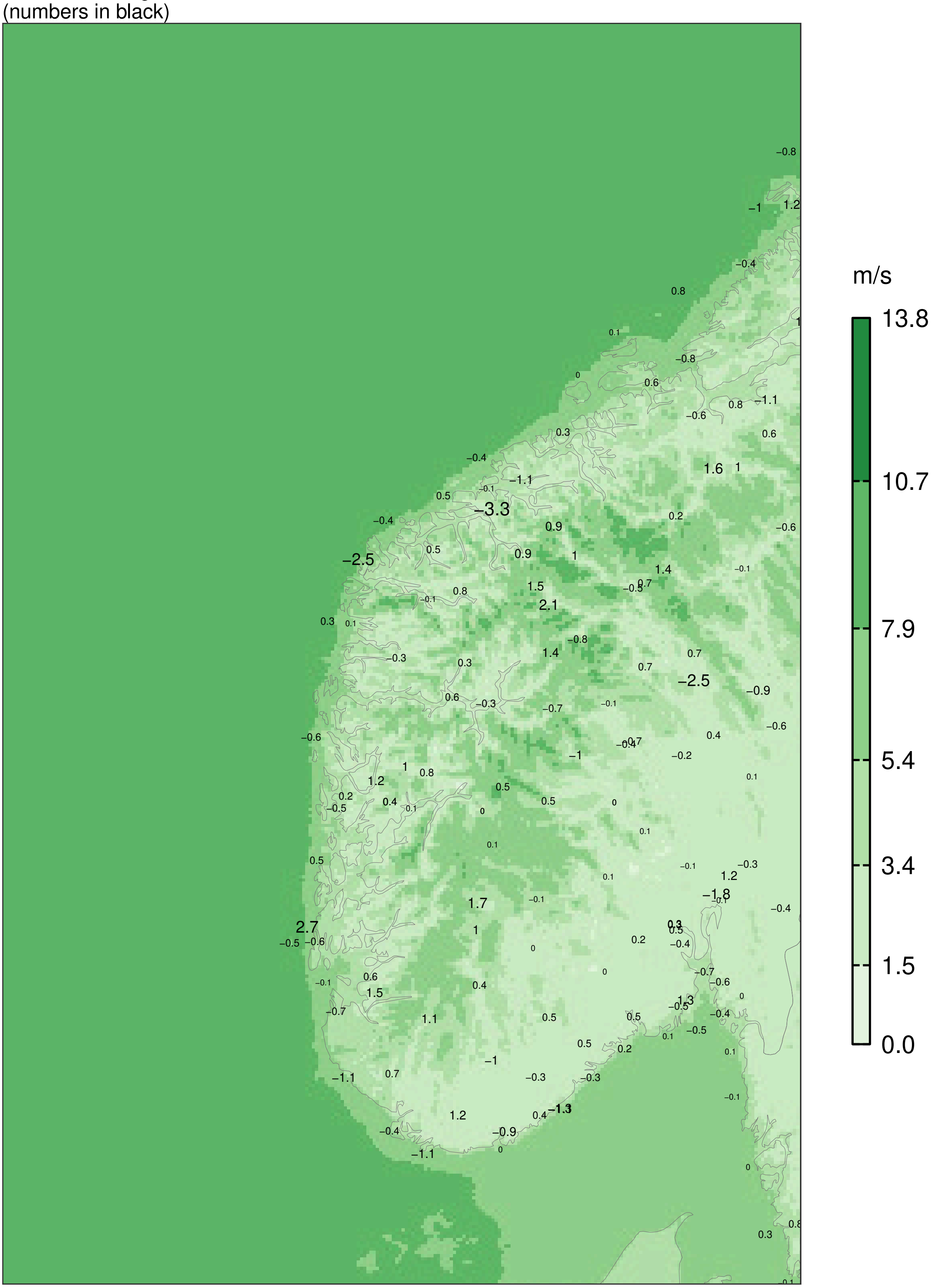
Model "climatology" 01.09.2024–30.11.2024



Model "climatology" 01.09.2024–30.11.2024

MEPSctrl 00+12

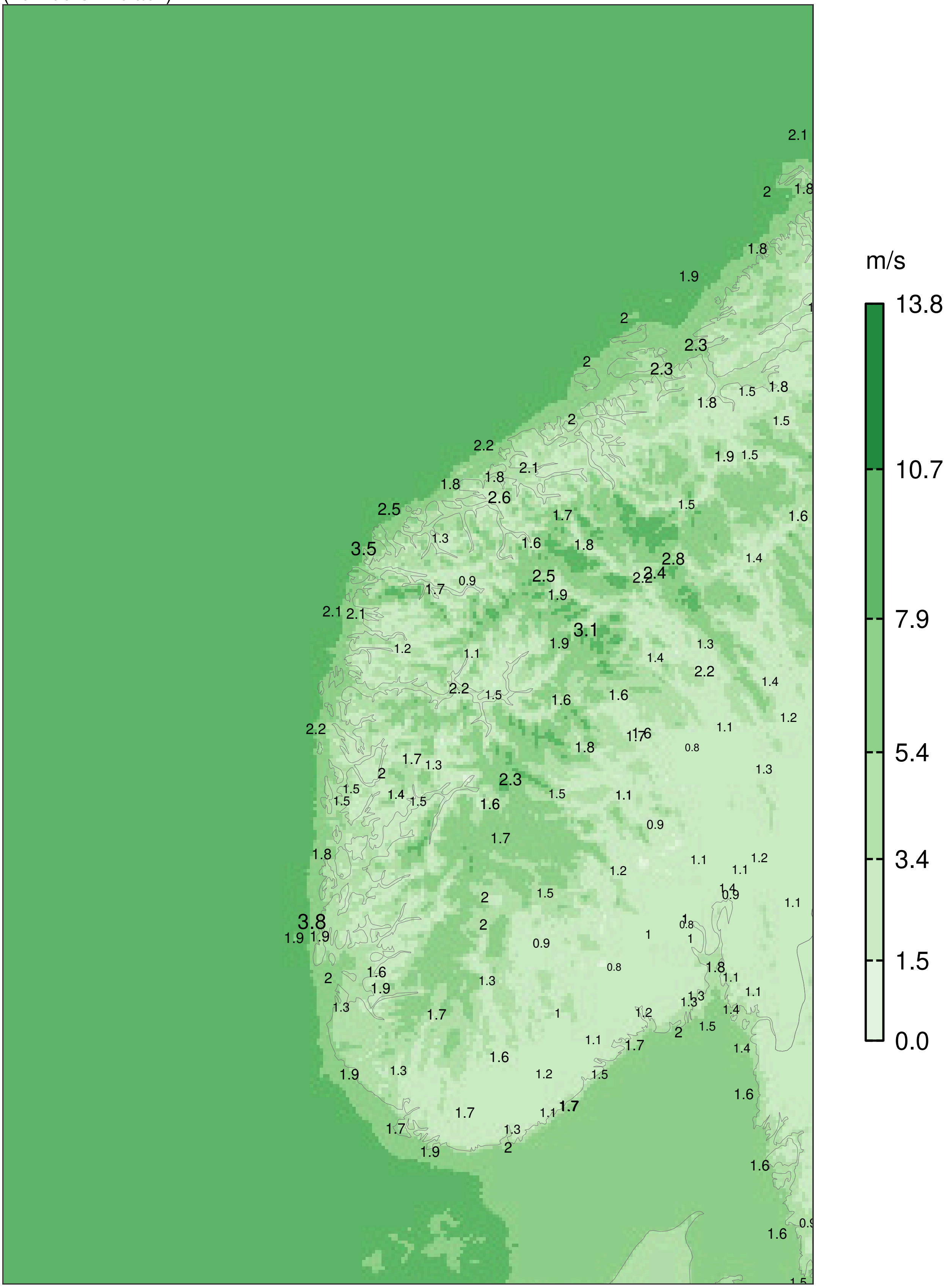
ME at observing sites
(numbers in black)



Model "climatology" 01.09.2024–30.11.2024

MEPSctrl 00+12

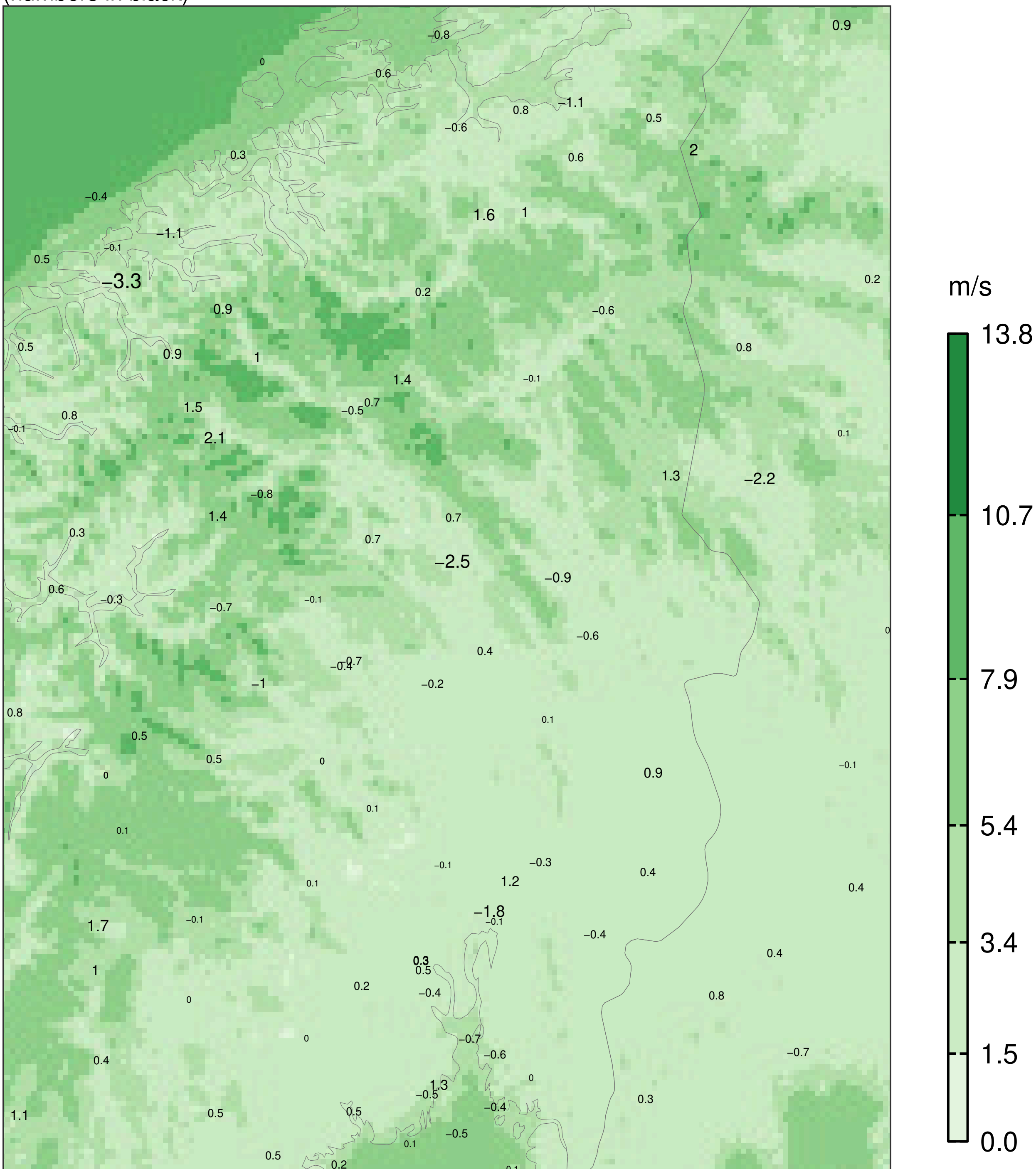
SDE at observing sites
(numbers in black)



Model "climatology" 01.09.2024–30.11.2024

MEPSctrl 00+12

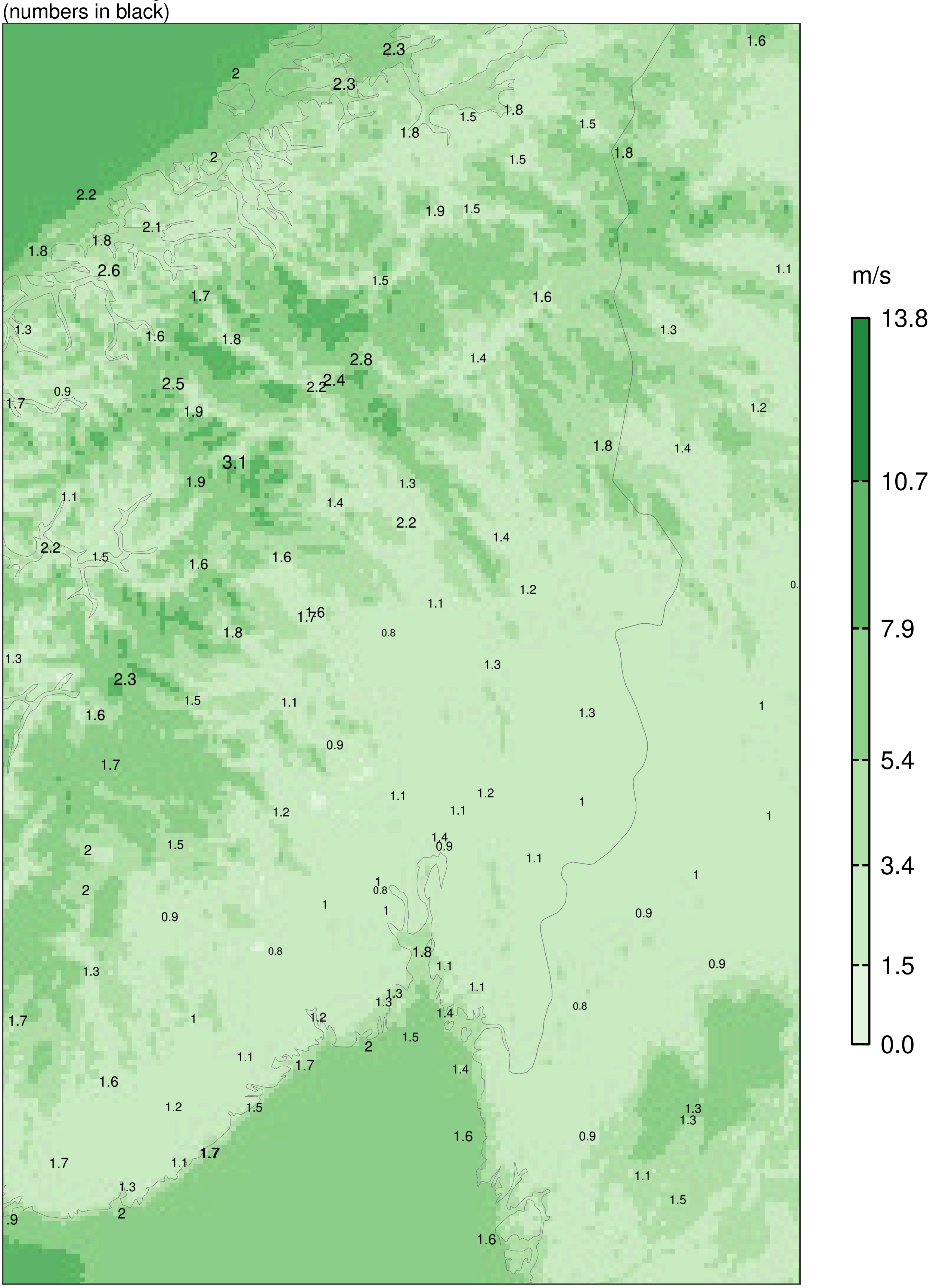
ME at observing sites
(numbers in black)



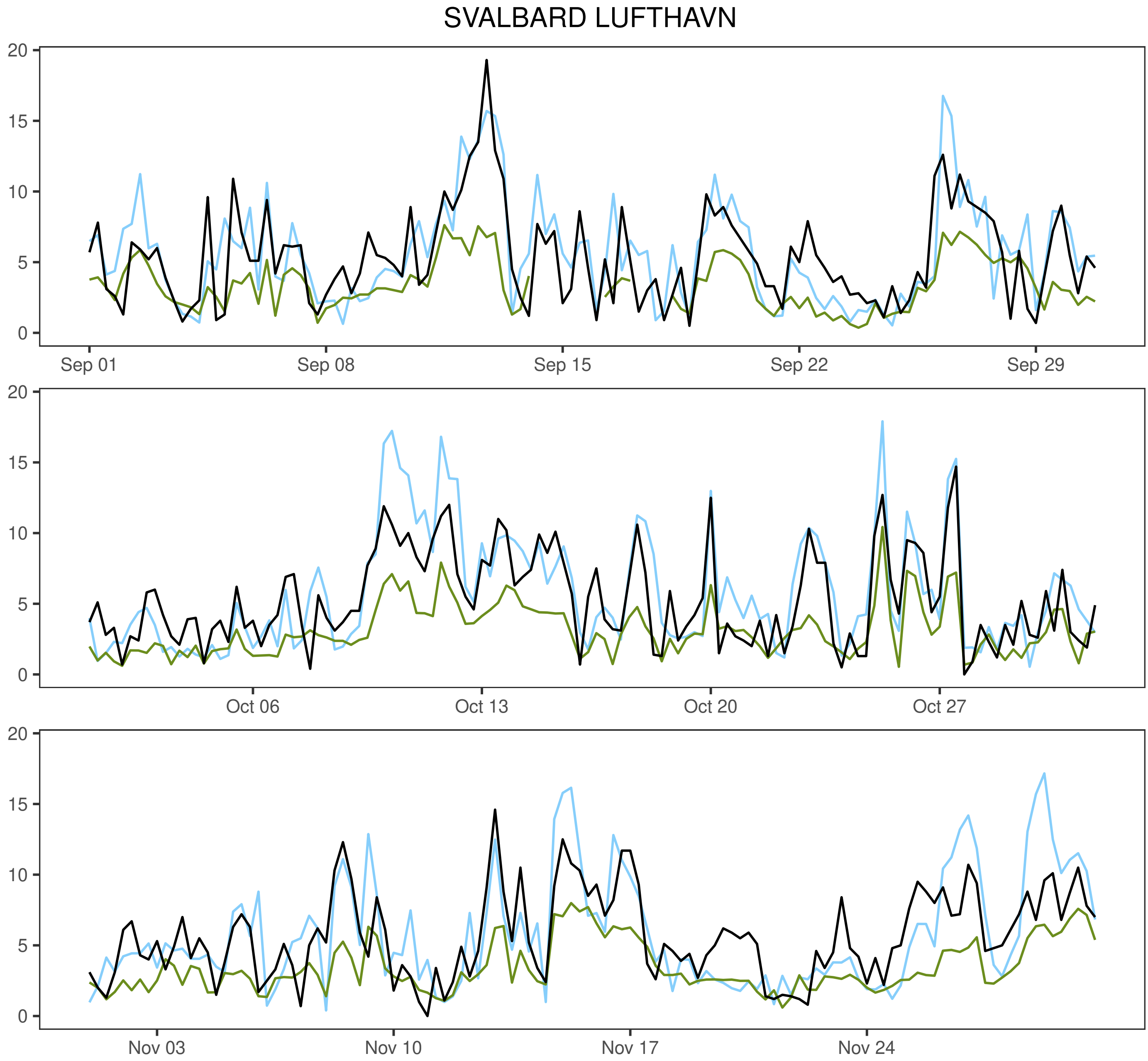
Model "climatology" 01.09.2024–30.11.2024

MEPSctrl 00+12

SDE at observing sites
(numbers in black)

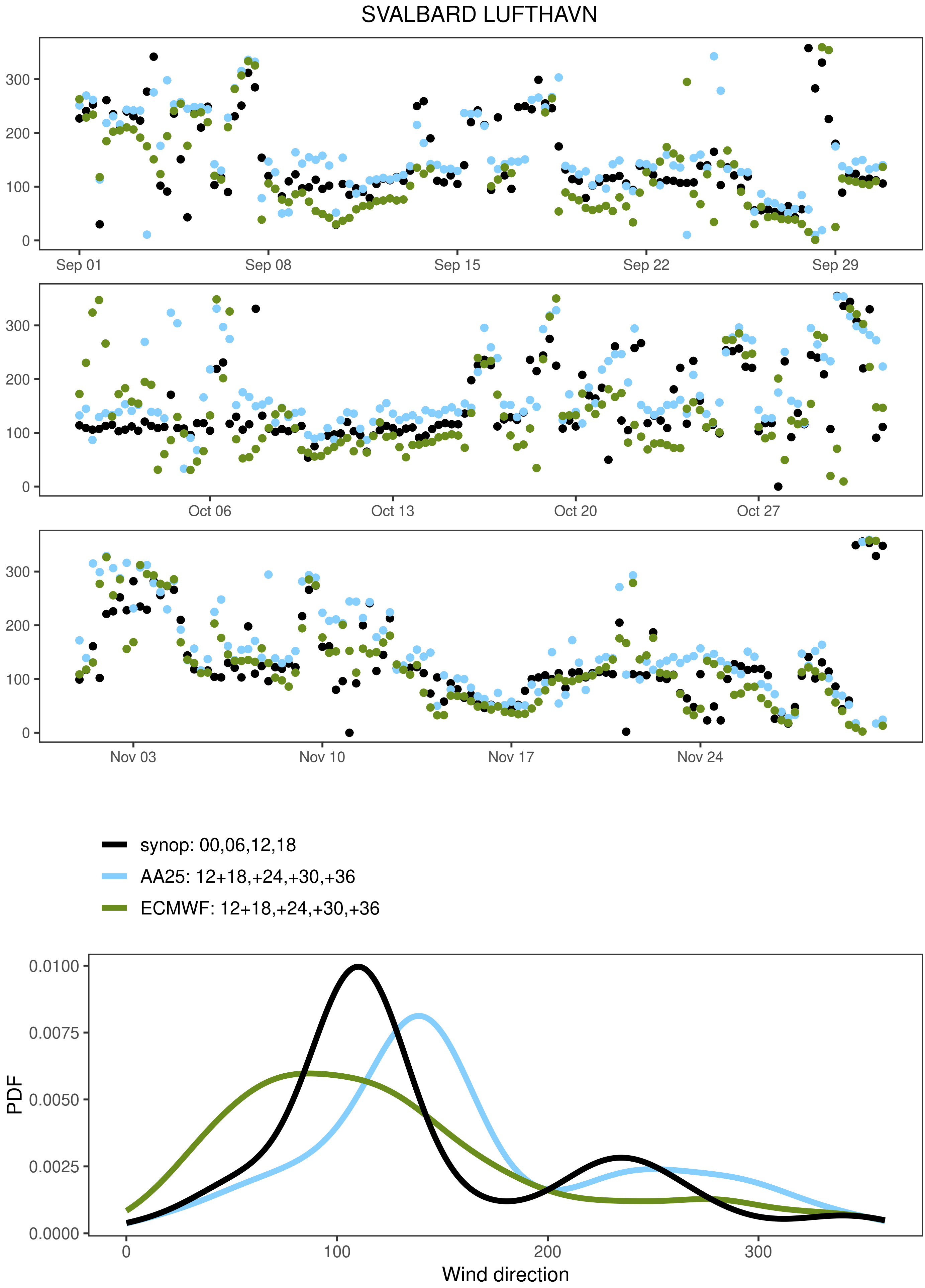


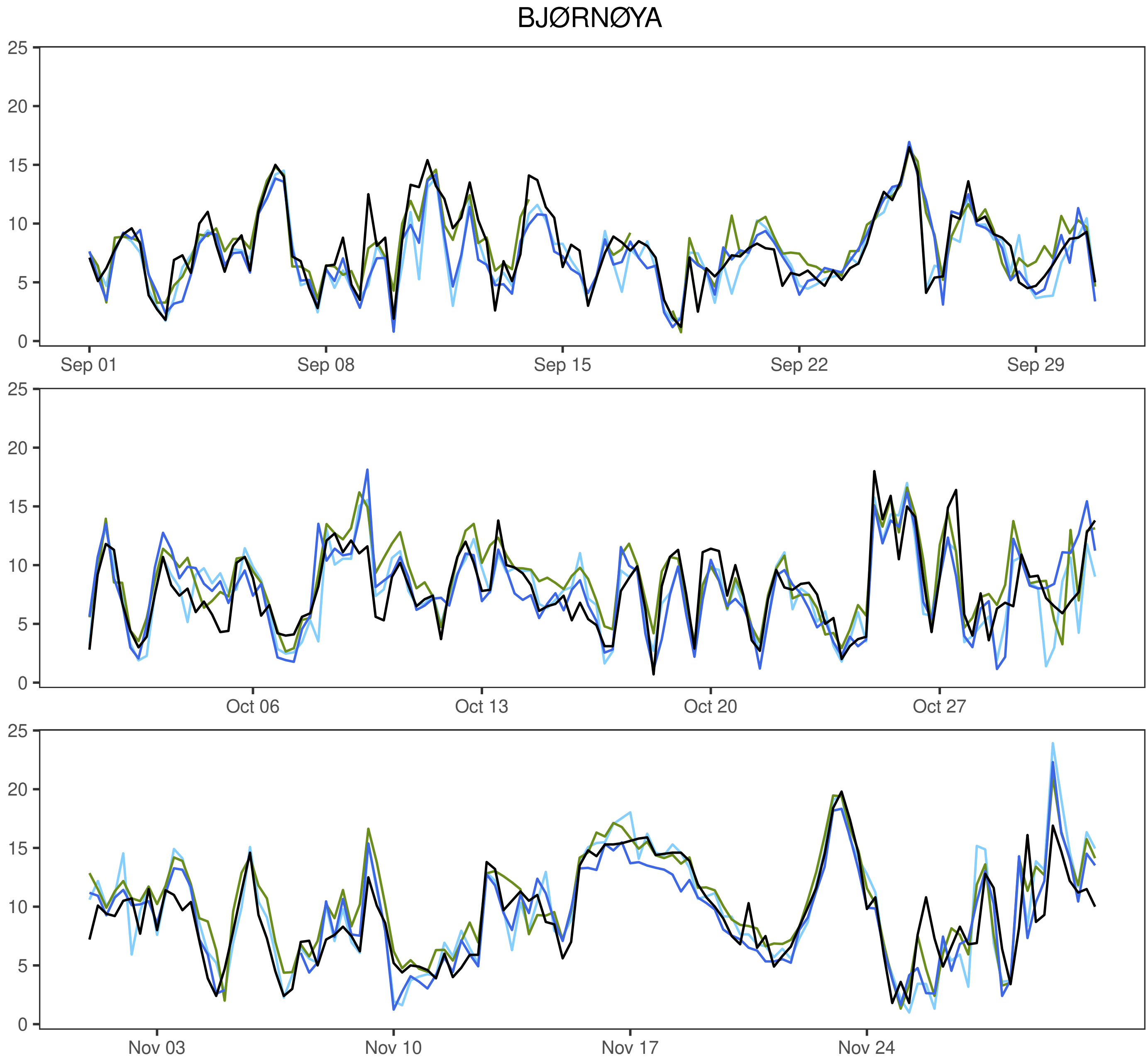
Model "climatology" 01.09.2024–30.11.2024



	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	5.4	19.3	3.2	364
AA25: 12+18,+24,+30,+36	0.4	5.7	17.9	3.9	364
ECMWF: 12+18,+24,+30,+36	0.4	3.3	10.4	1.8	352

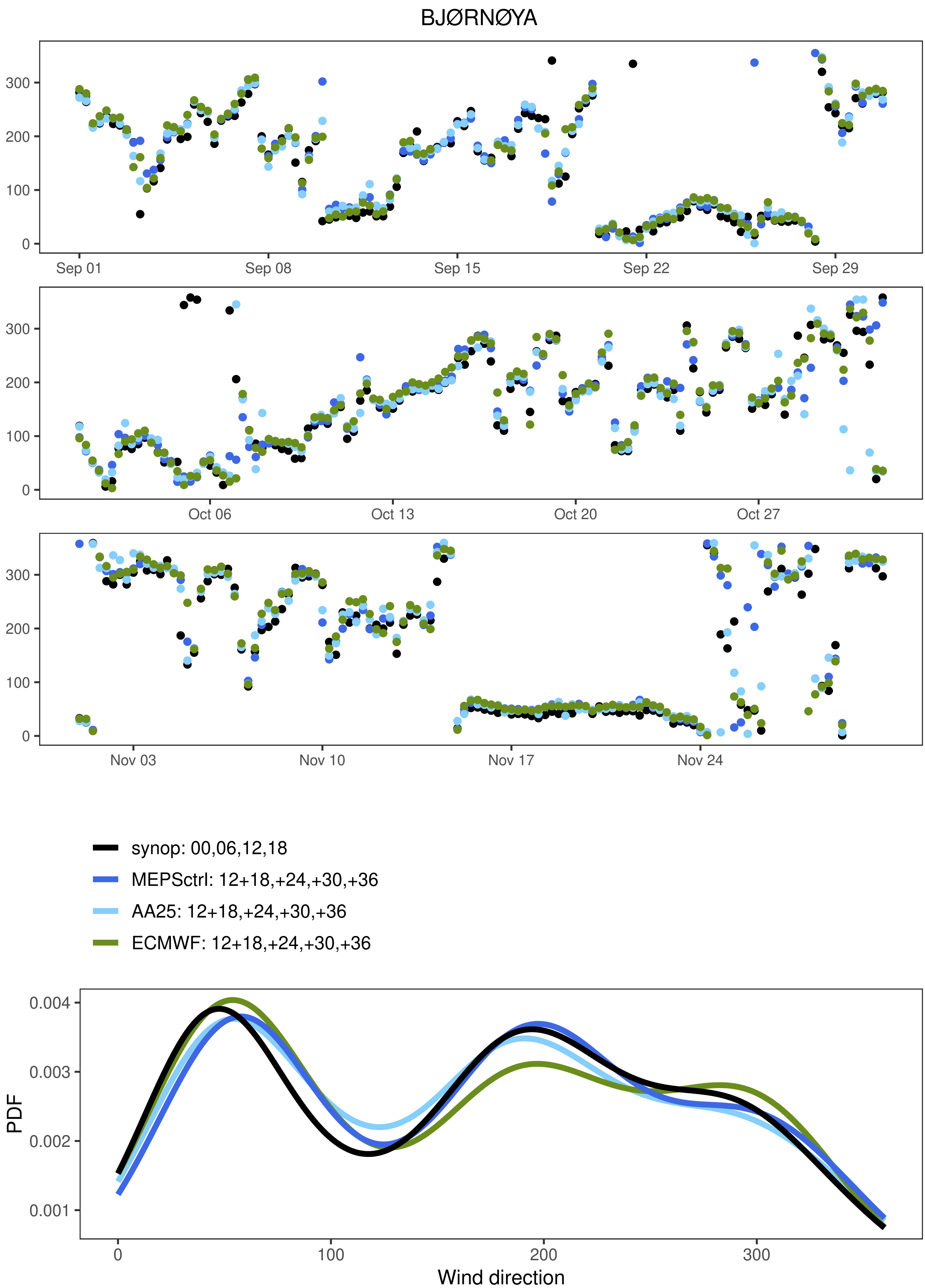
	ME	SDE	RMSE	MAE	Max.abs.err	N
AA25 – synop	0.3	2.6	2.6	2.0	8.9	352
ECMWF – synop	−2.2	2.2	3.1	2.5	12.5	352

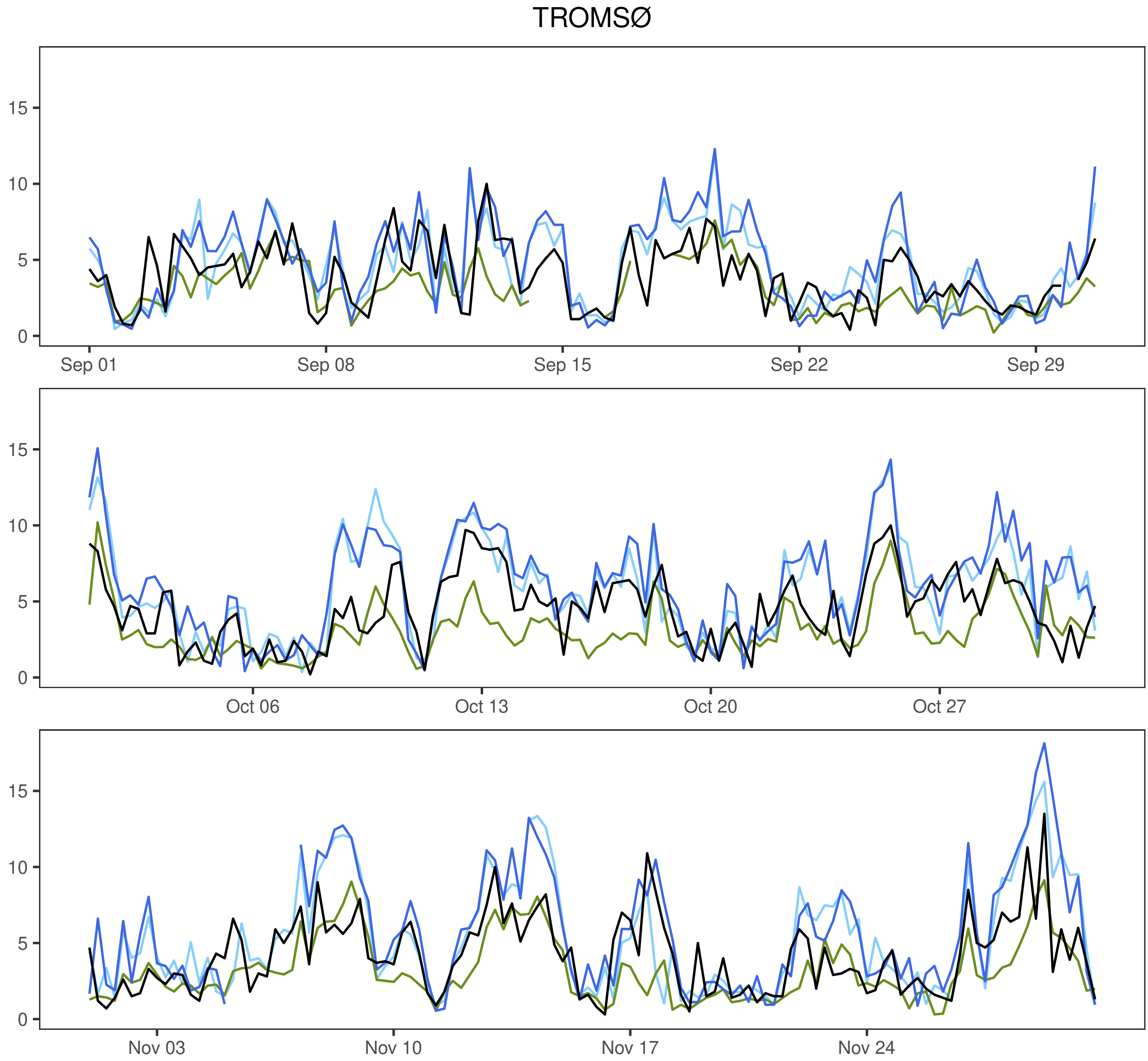

SVALBARD LUFTHAVN
0
100
200
300
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24
synop: 00,06,12,18
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.0000
0.0025
0.0050
0.0075
0.0100
Wind direction



	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.7	8.4	19.8	3.6	364
MEPSctrl: 12+18,+24,+30,+36	0.8	8.2	22.3	3.7	356
AA25: 12+18,+24,+30,+36	1.0	8.2	23.9	3.9	364
ECMWF: 12+18,+24,+30,+36	0.7	9.2	21.1	3.5	352

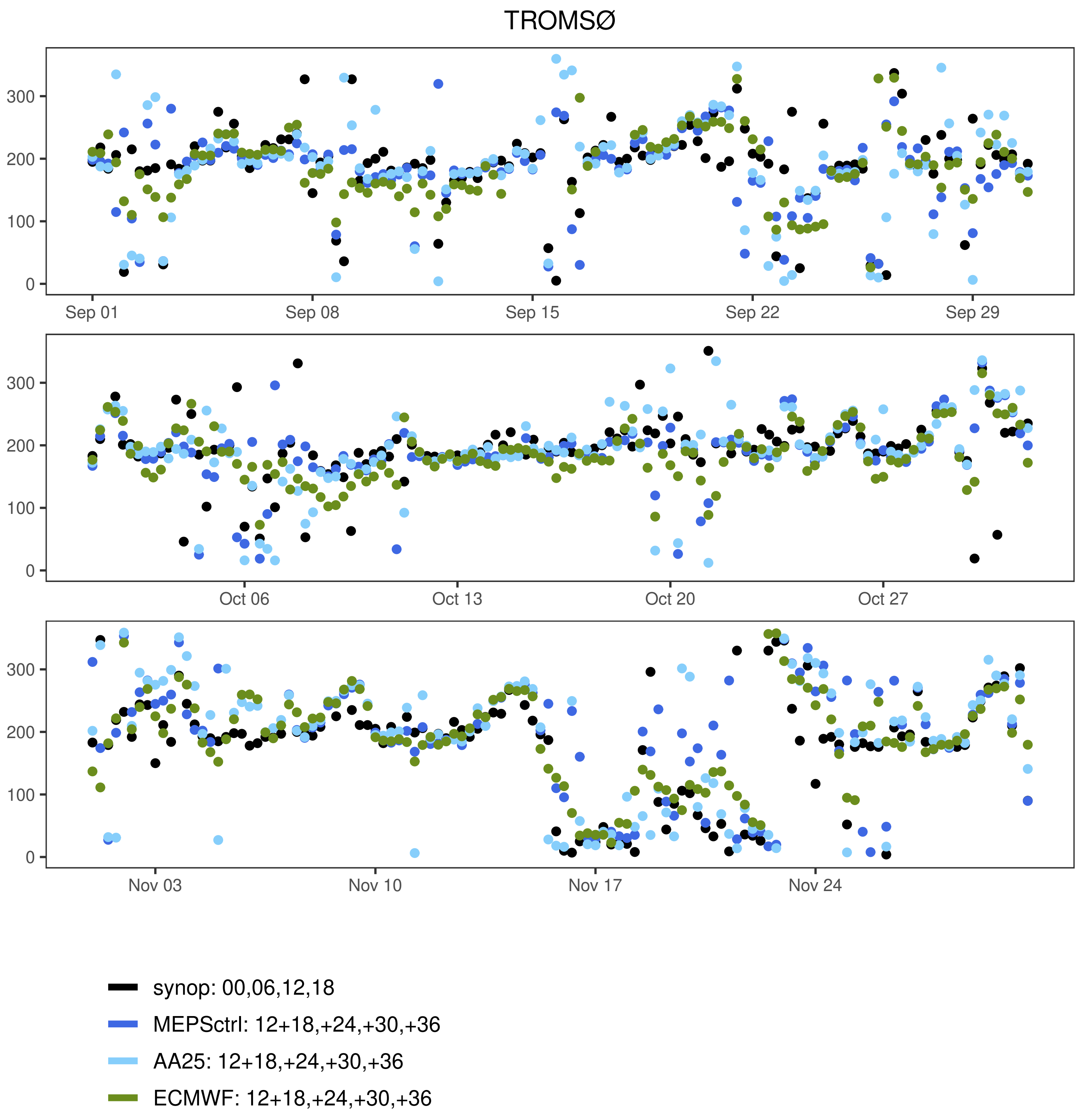
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	−0.2	2.2	2.2	1.6	8.8	344
AA25 – synop	−0.1	2.3	2.3	1.7	8.3	344
ECMWF – synop	0.8	1.9	2.1	1.6	7.3	344


BJØRNØYA
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

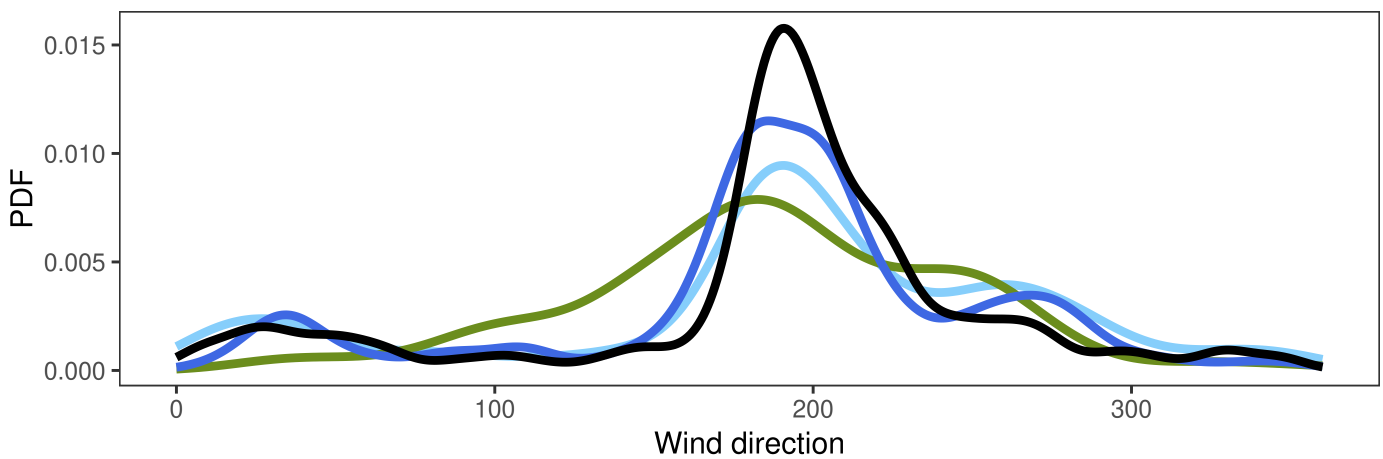


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.2	4.2	13.5	2.3	363
MEPSctrl: 12+18,+24,+30,+36	0.4	5.6	18.1	3.4	356
AA25: 12+18,+24,+30,+36	0.3	5.3	15.6	3.1	364
ECMWF: 12+18,+24,+30,+36	0.2	3.1	10.2	1.8	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	1.4	2.3	2.7	2.0	11.5	343
AA25 – synop	1.1	2.2	2.5	1.8	8.8	343
ECMWF – synop	−1.1	1.7	2.1	1.6	9.3	343

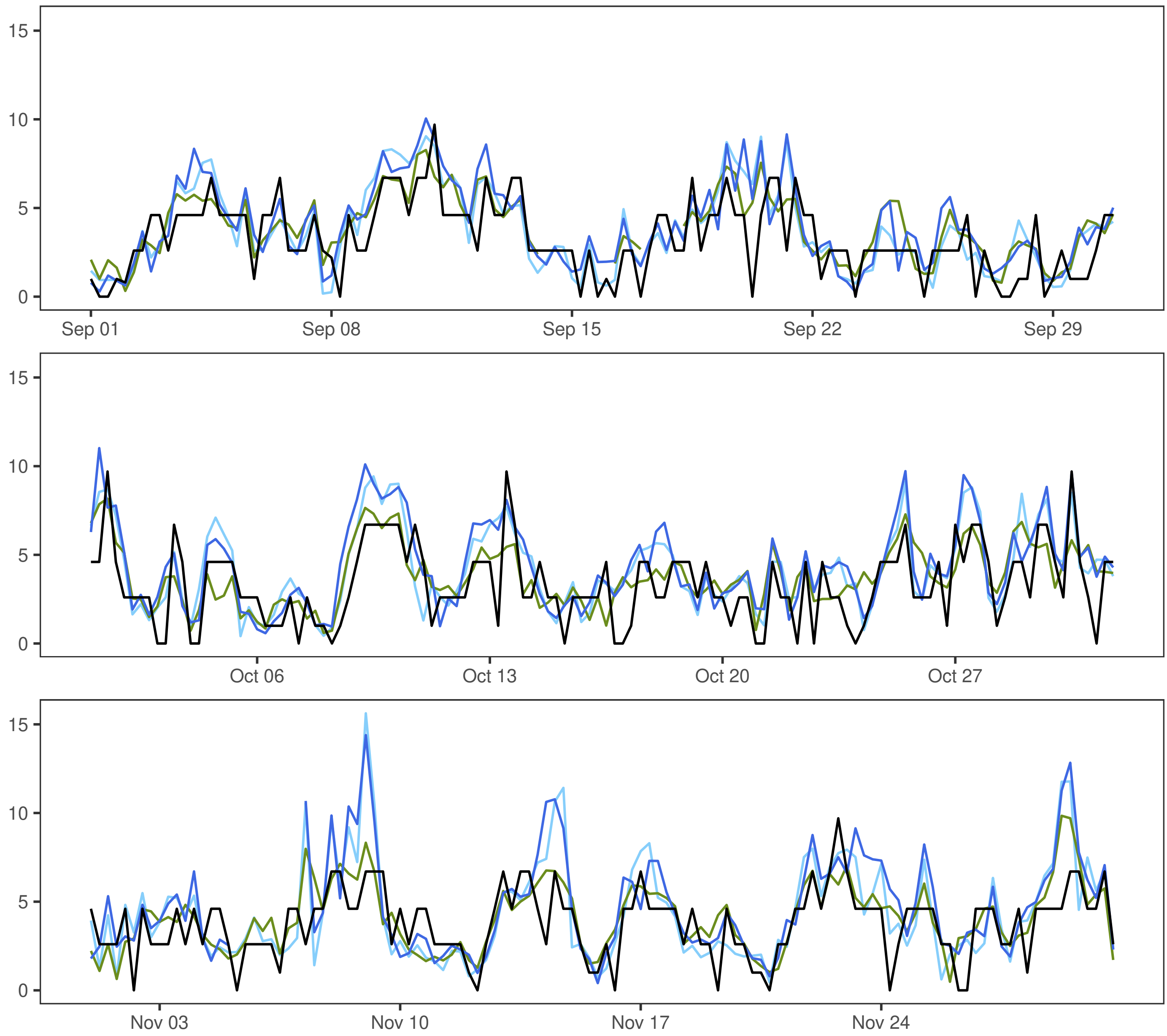


TROMSØ
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36



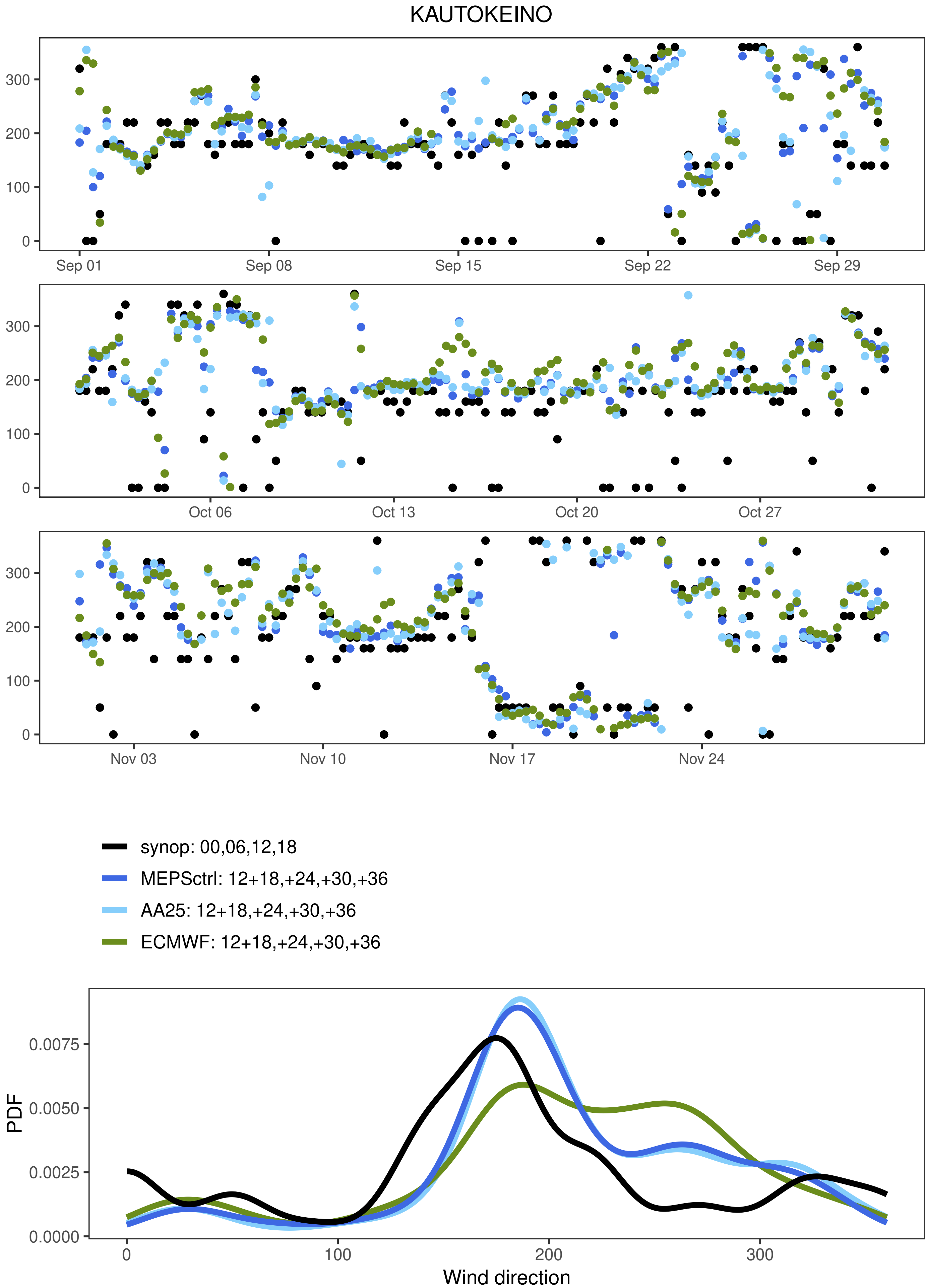
PDF
0.015
0.010
0.005
0.000
0
100
200
300
Wind direction

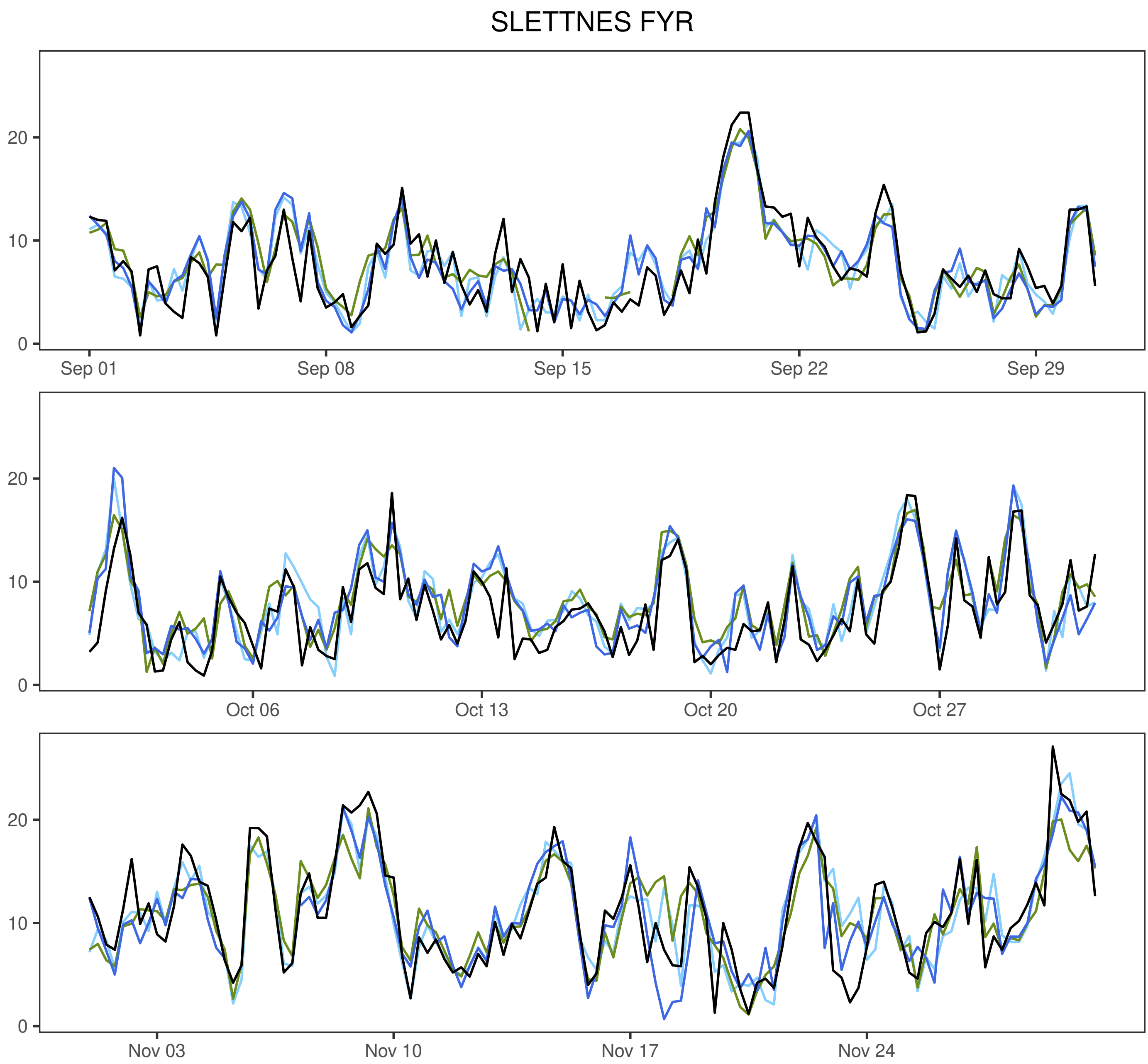
KAUTOKEINO



	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	3.5	9.7	2.1	364
MEPSctrl: 12+18,+24,+30,+36	0.3	4.4	14.4	2.5	356
AA25: 12+18,+24,+30,+36	0.2	4.1	15.6	2.5	364
ECMWF: 12+18,+24,+30,+36	0.3	3.9	9.8	1.8	352

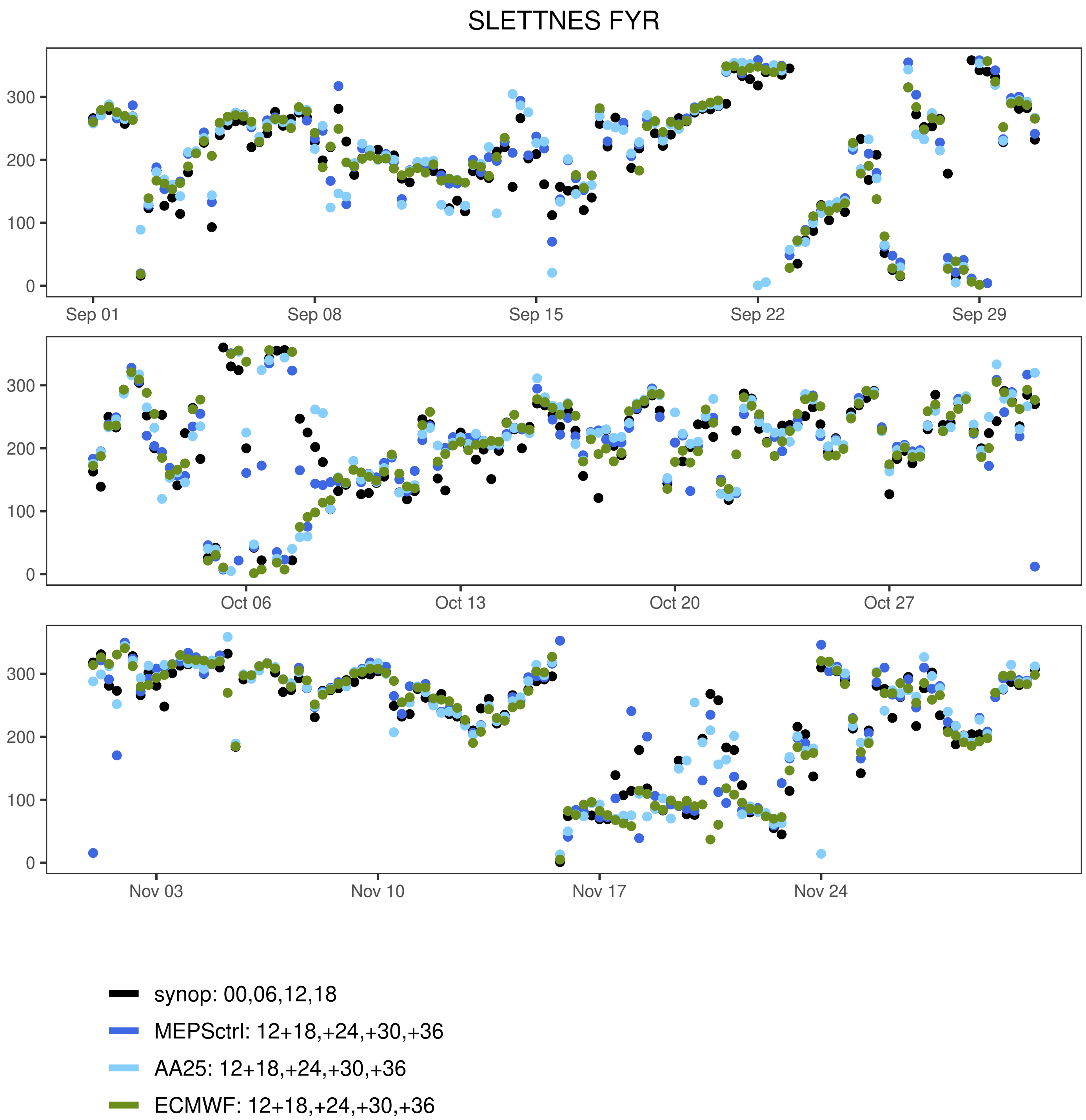
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	1.0	2.0	2.2	1.7	8.1	344
AA25 – synop	0.7	1.9	2.1	1.6	8.9	344
ECMWF – synop	0.4	1.6	1.7	1.3	5.4	344

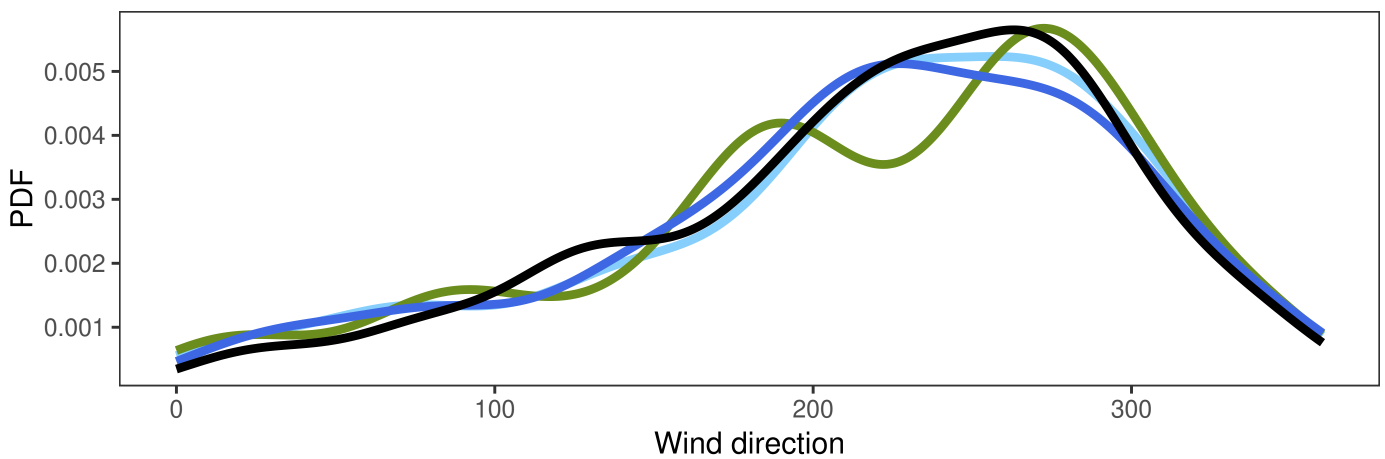

KAUTOKEINO
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.0075
0.0050
0.0025
0.0000
0
100
200
300
Wind direction



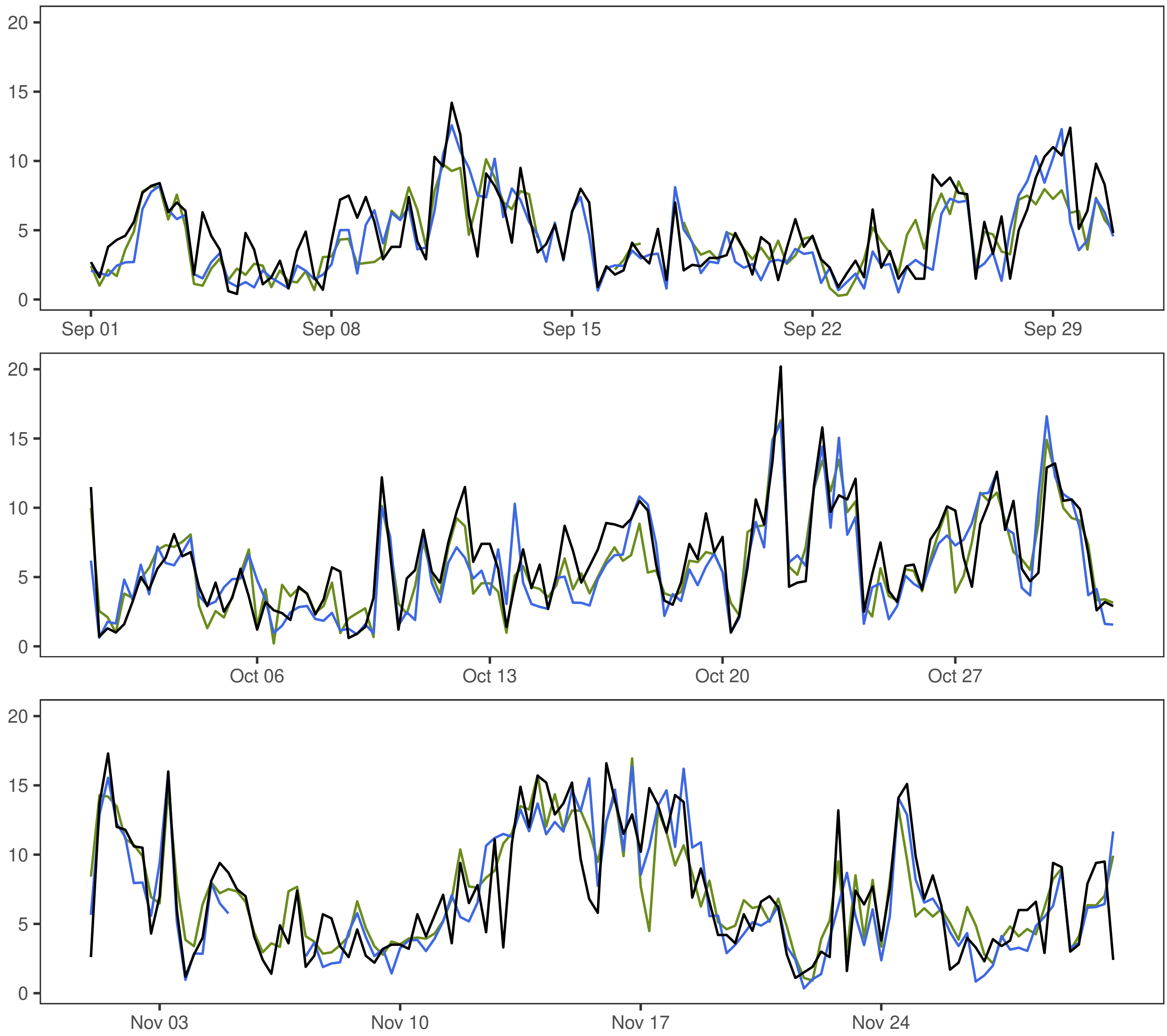
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.8	8.6	27.1	5.0	364
MEPSctrl: 12+18,+24,+30,+36	0.7	8.8	22.3	4.5	356
AA25: 12+18,+24,+30,+36	0.9	8.9	24.5	4.6	364
ECMWF: 12+18,+24,+30,+36	1.1	9.2	21.1	4.1	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.3	2.6	2.6	2.0	8.8	344
AA25 – synop	0.4	2.6	2.7	2.1	9.9	344
ECMWF – synop	0.5	2.6	2.6	2.0	7.9	344


SLETTNES FYR
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

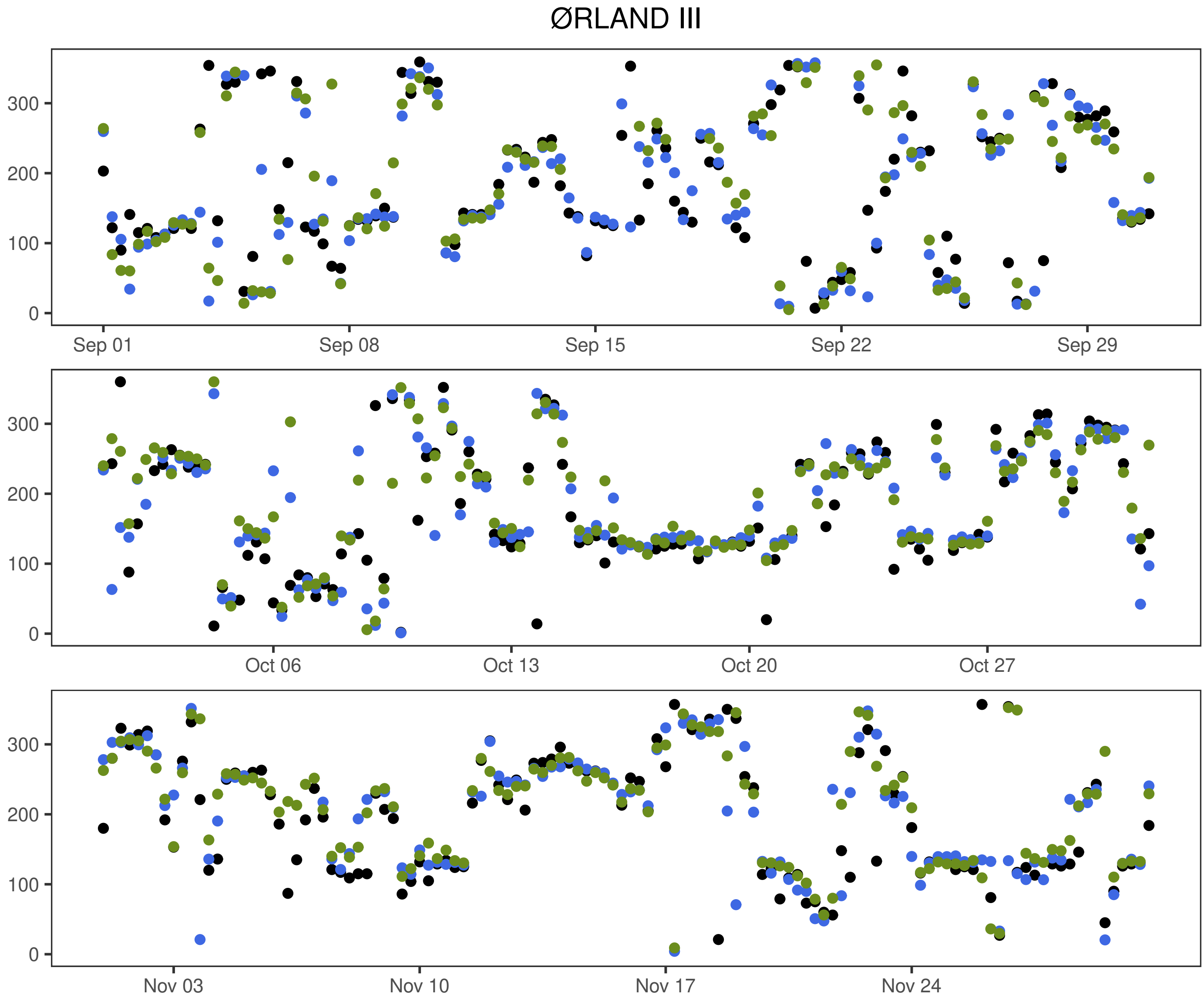

PDF
0.005
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

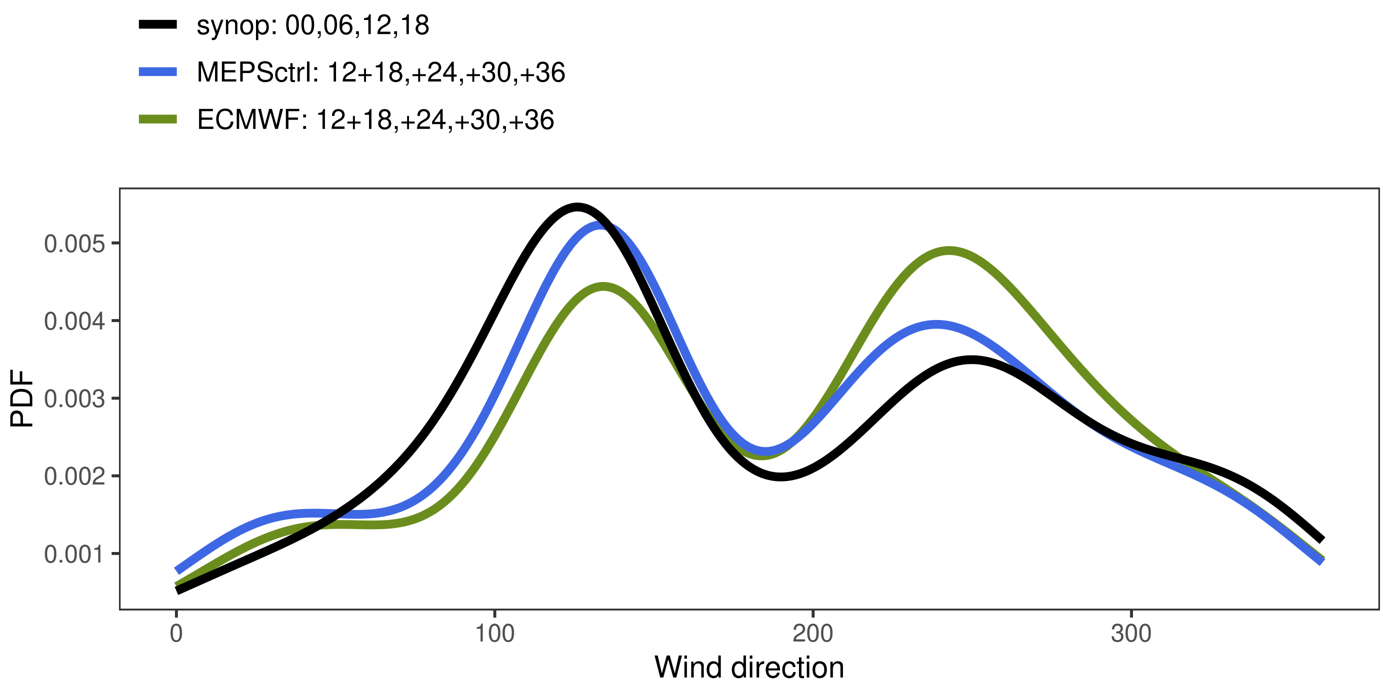
ØRLAND III

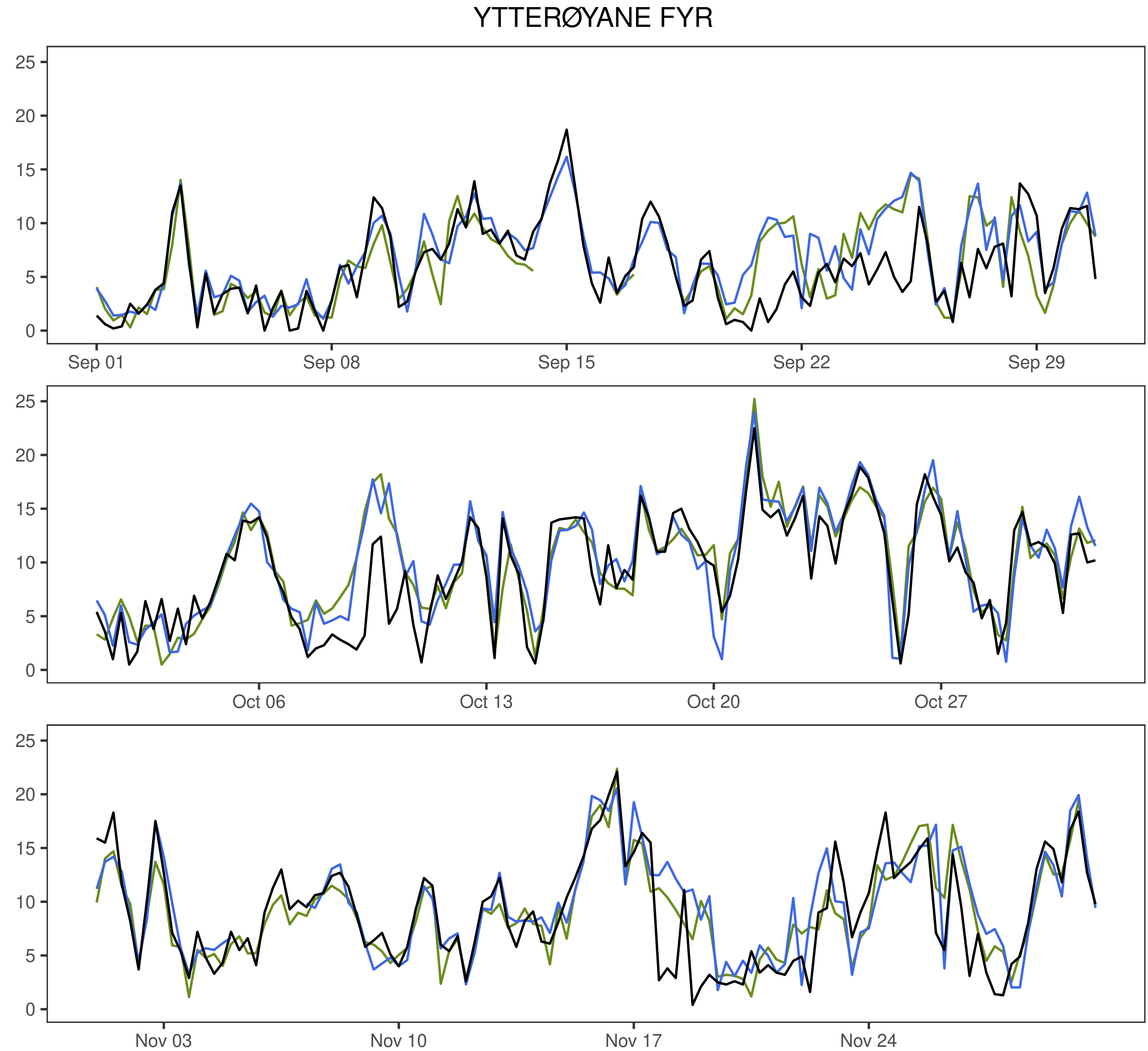


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.4	6.1	20.2	3.7	364
MEPSctrl: 12+18,+24,+30,+36	0.3	5.6	16.6	3.7	356
ECMWF: 12+18,+24,+30,+36	0.2	5.9	16.9	3.3	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.5	2.2	2.3	1.7	9.3	344
ECMWF – synop	–0.3	2.1	2.1	1.6	10.3	344

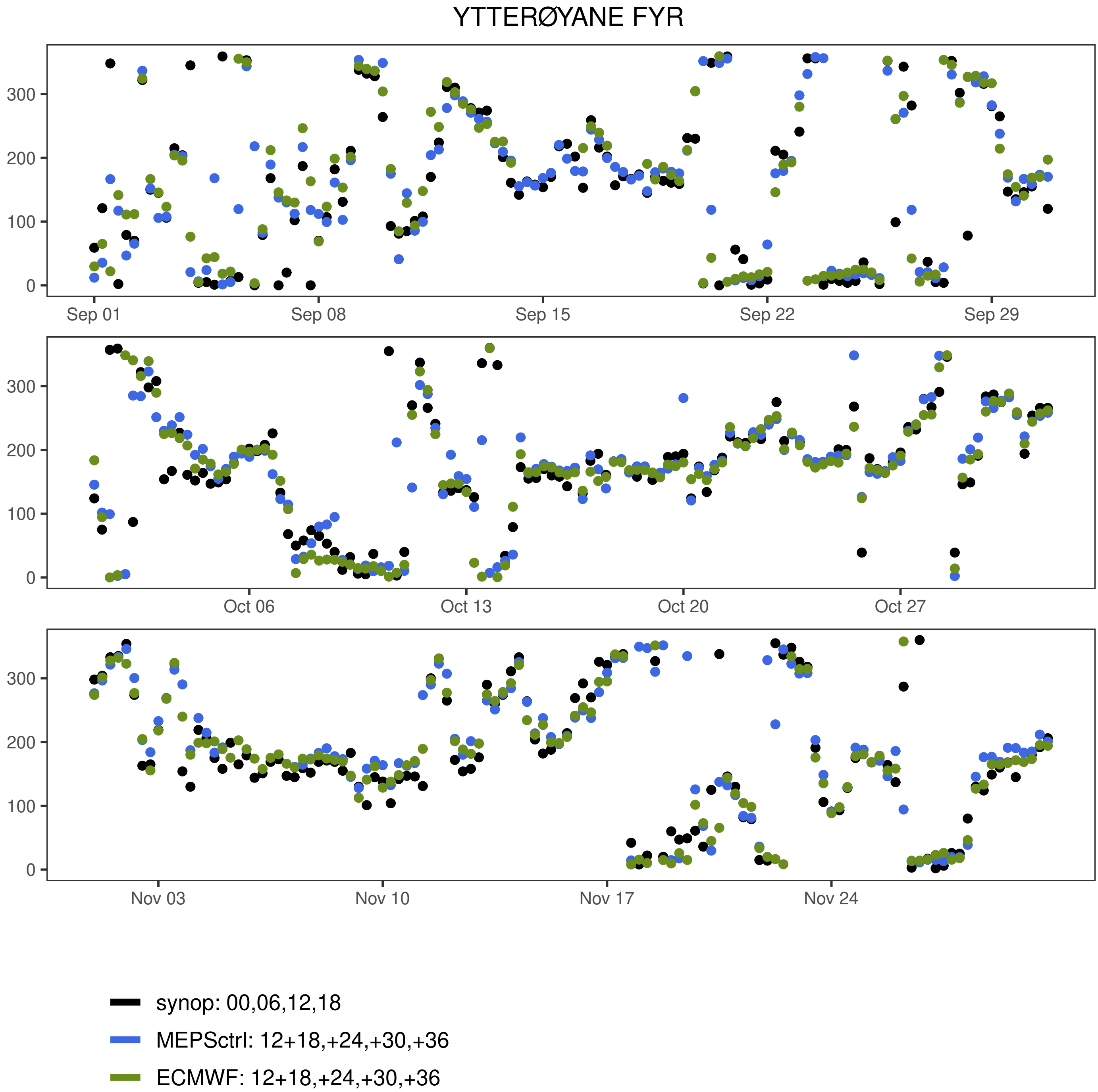

ØRLAND III
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24

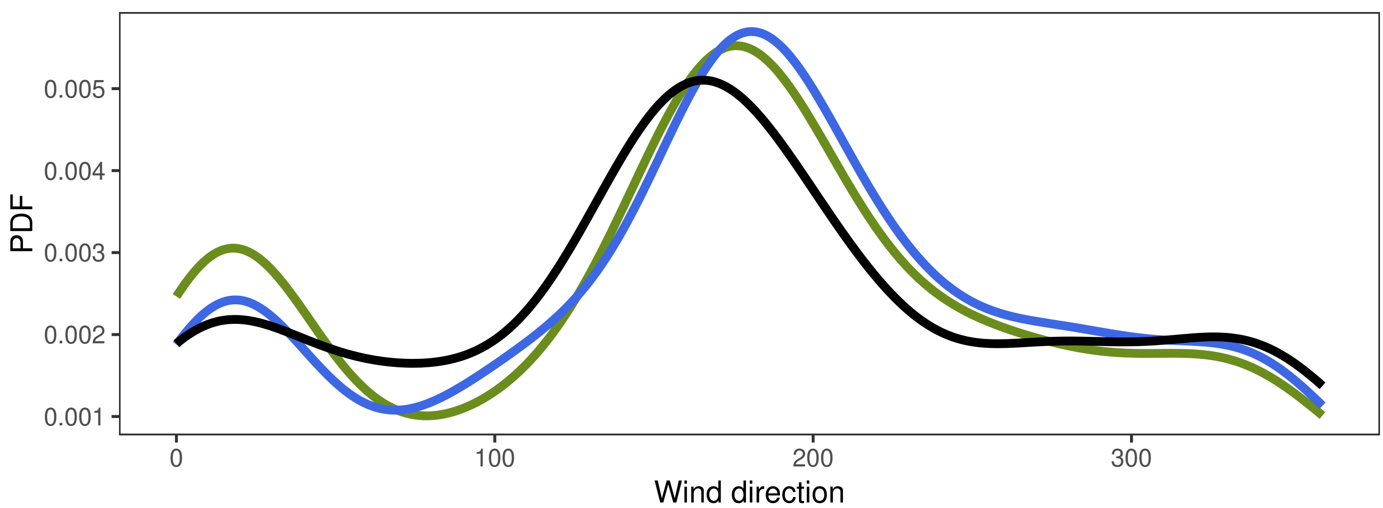

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.005
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

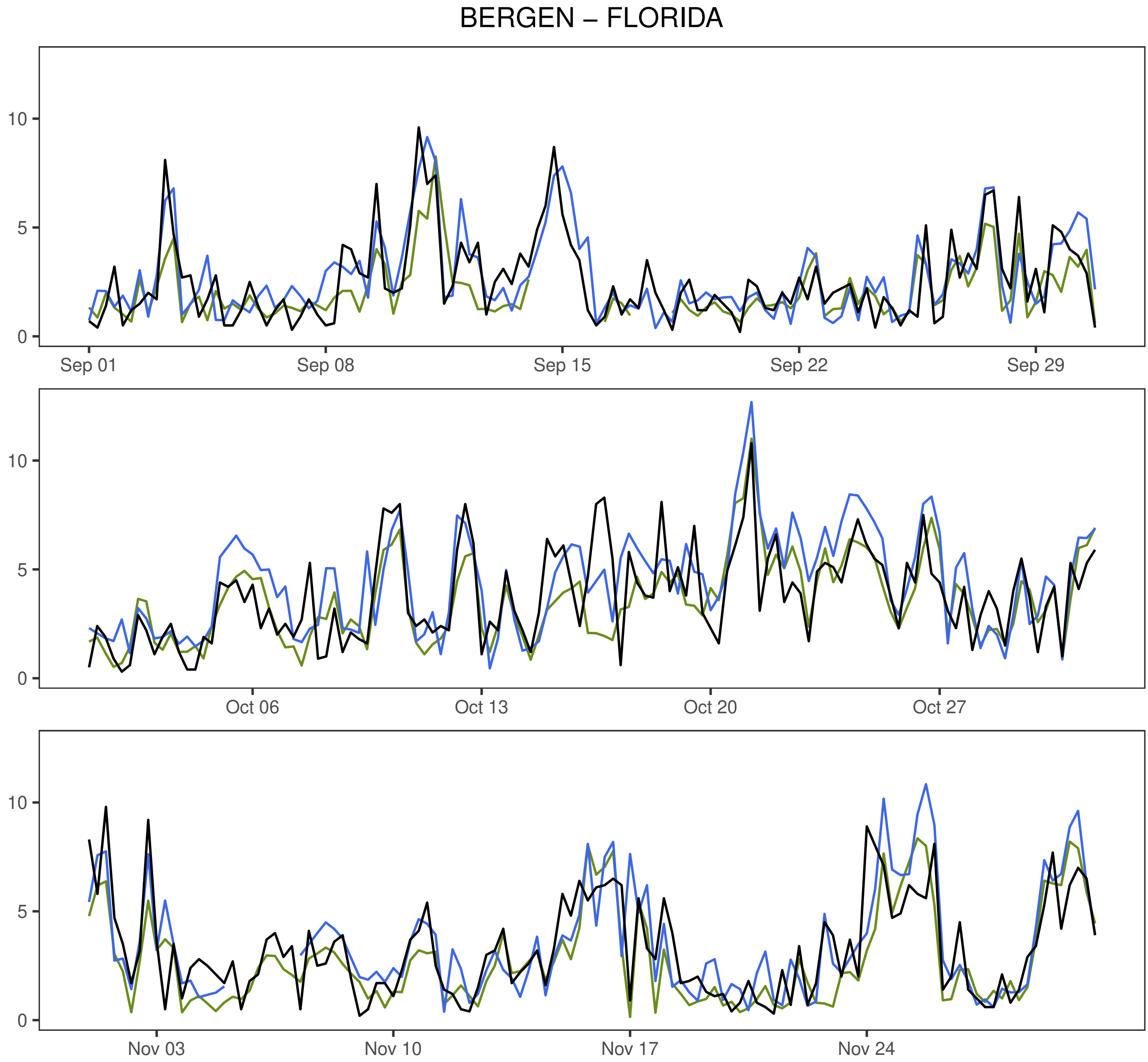


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	8.1	22.5	4.9	364
MEPSctrl: 12+18,+24,+30,+36	0.8	8.9	24.0	4.7	356
ECMWF: 12+18,+24,+30,+36	0.3	8.5	25.2	4.6	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.9	2.9	3.1	2.1	13.1	344
ECMWF – synop	0.5	2.9	2.9	2.1	11.5	344

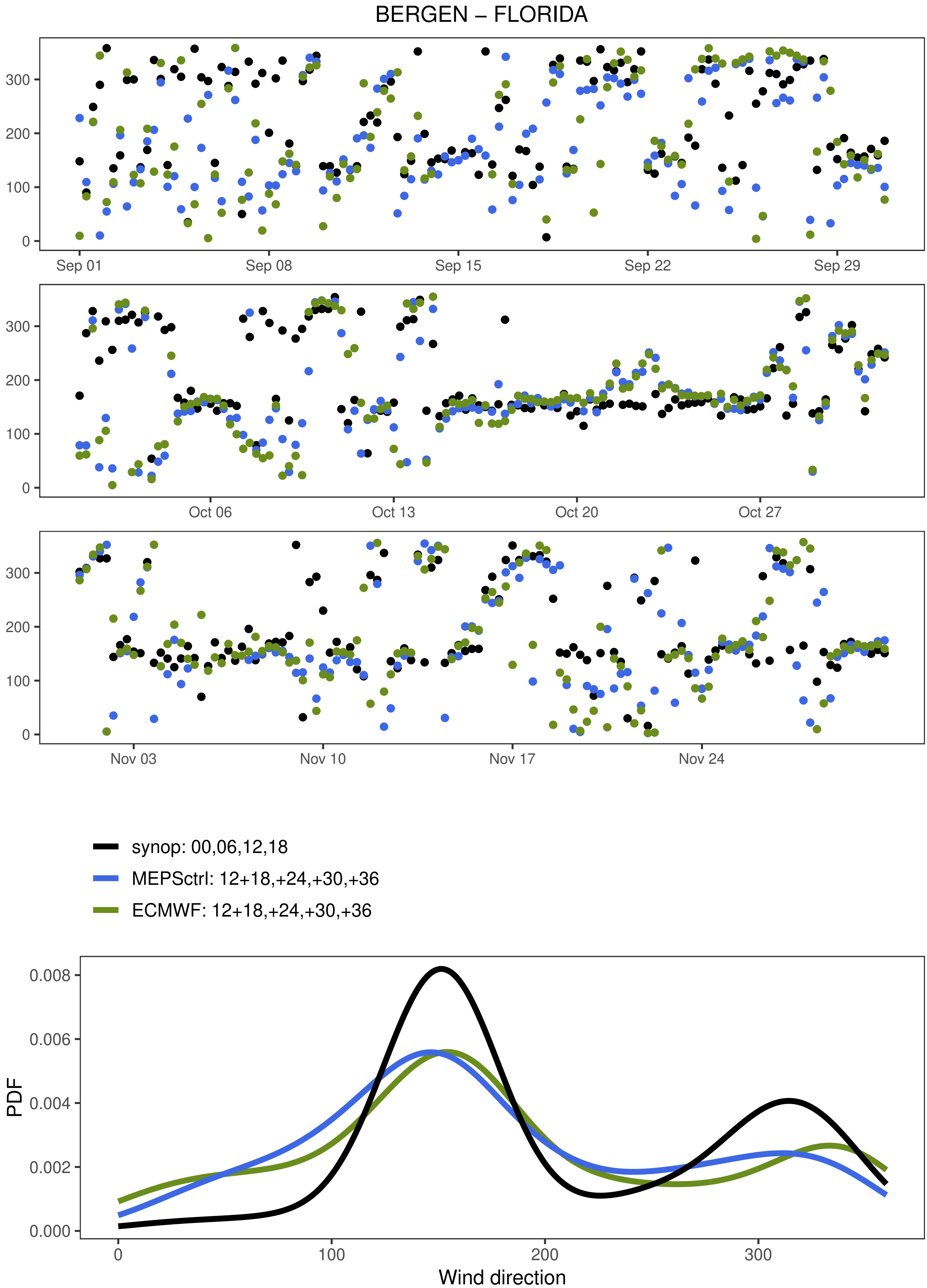

YTTERØYANE FYR
0
100
200
300
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

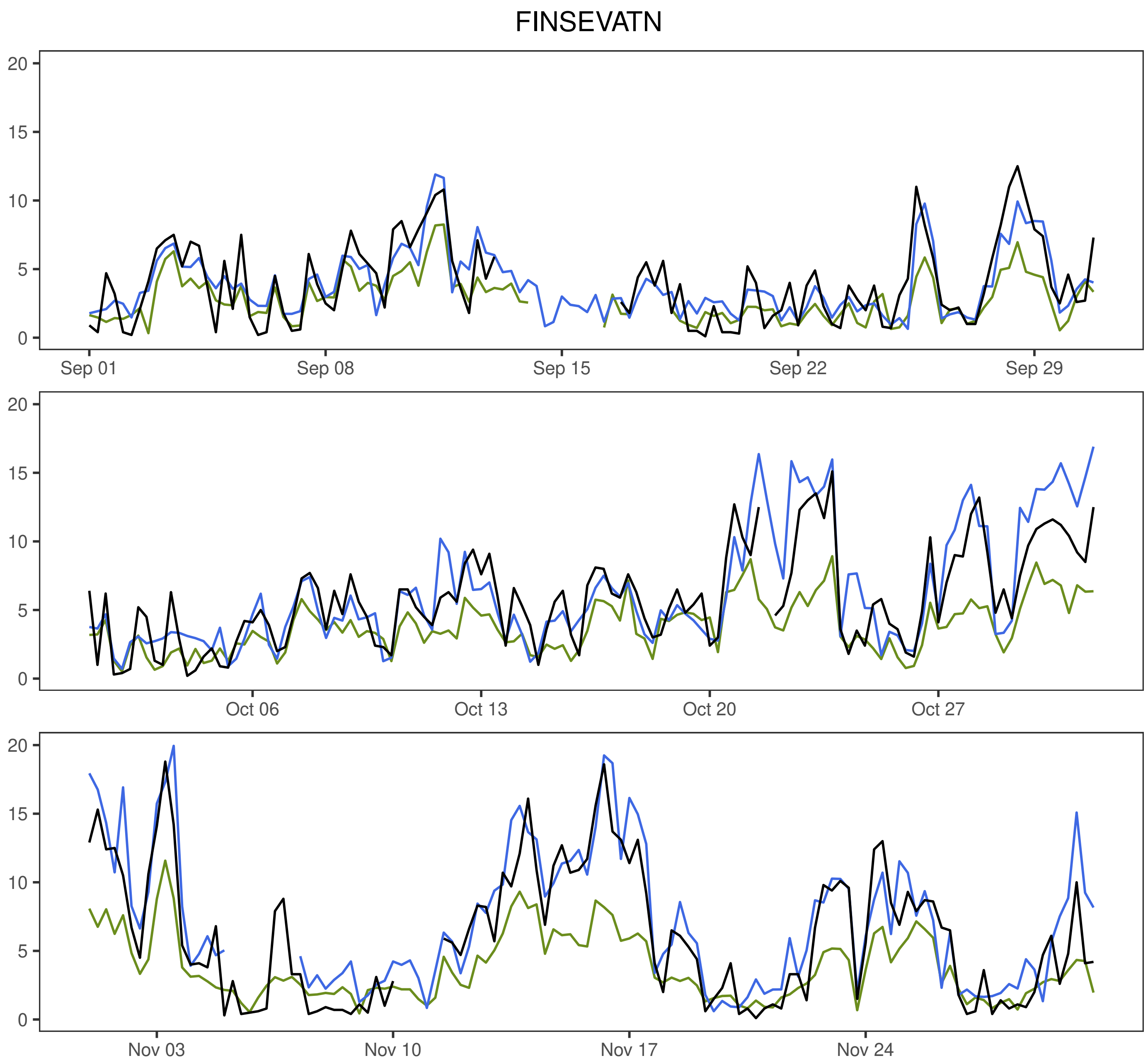

PDF
0.001
0.002
0.003
0.004
0.005
0
100
200
300
Wind direction



	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.2	3.2	10.8	2.2	364
MEPSctrl: 12+18,+24,+30,+36	0.4	3.6	12.7	2.3	356
ECMWF: 12+18,+24,+30,+36	0.1	2.8	11.0	1.9	352

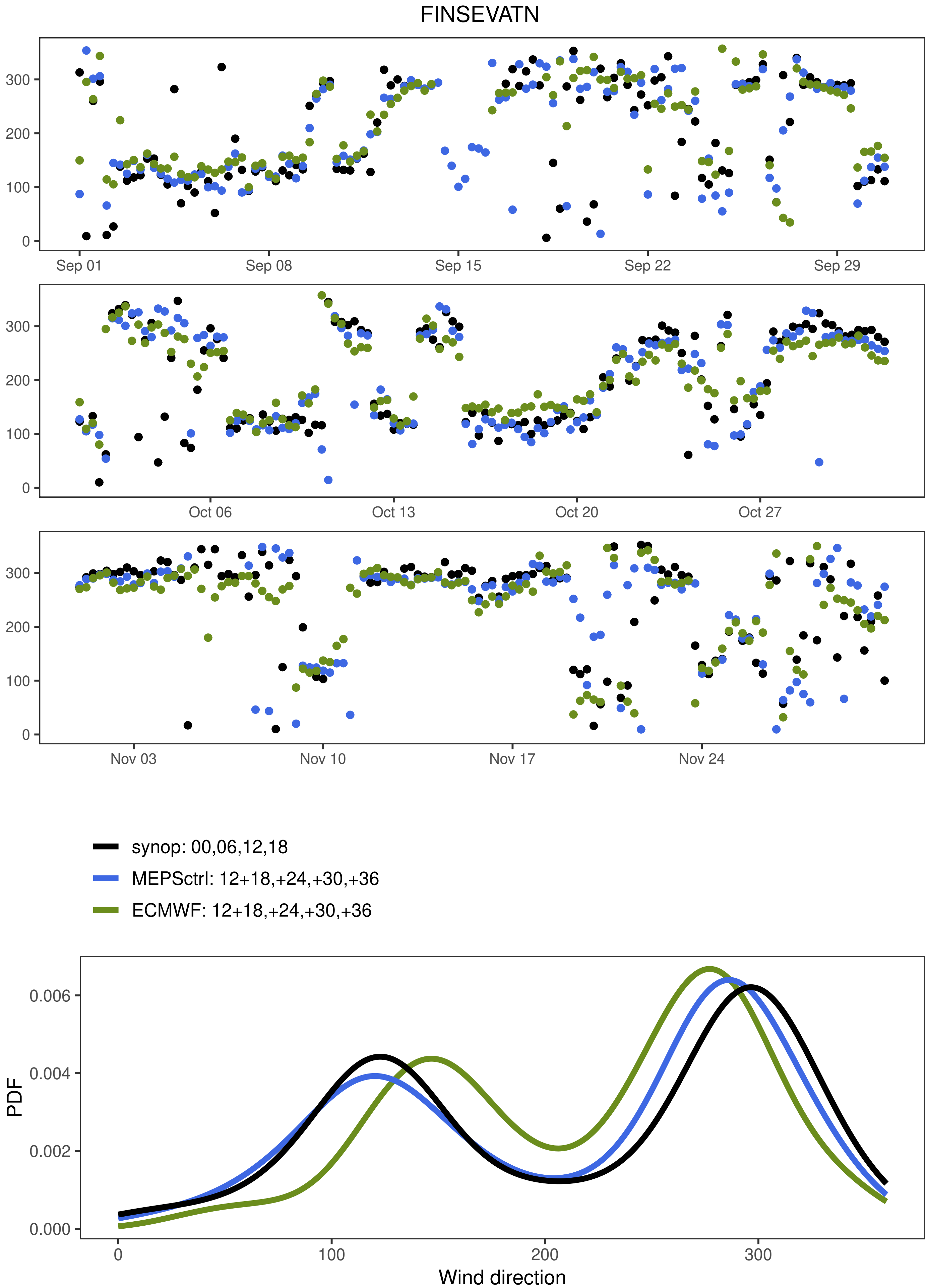
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.4	1.6	1.6	1.3	6.7	344
ECMWF – synop	−0.4	1.5	1.5	1.1	6.4	344

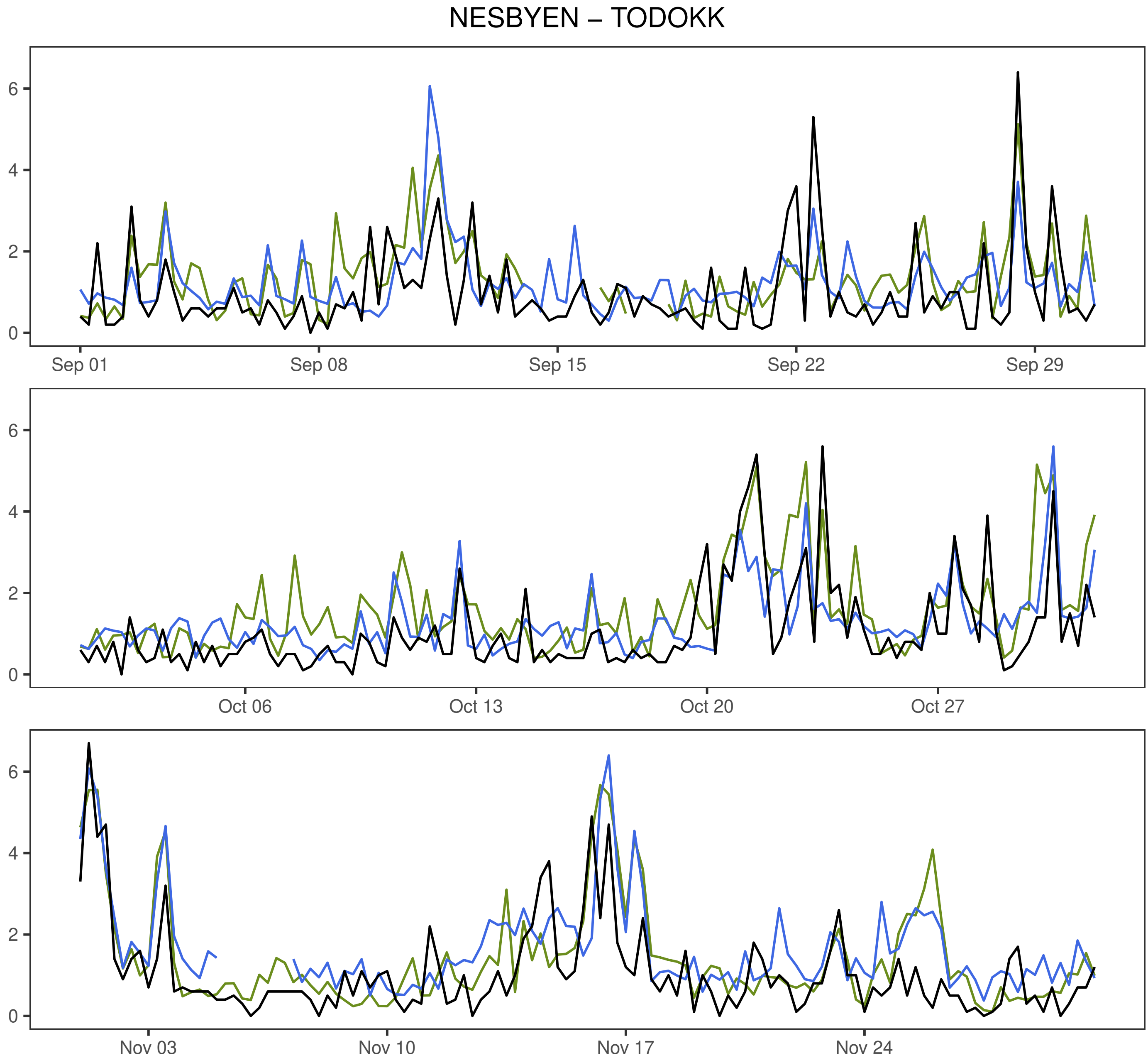

BERGEN – FLORIDA
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.008
0.006
0.004
0.002
0.000
0
100
200
300
Wind direction



	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.1	5.4	18.8	3.9	344
MEPSctrl: 12+18,+24,+30,+36	0.6	5.8	19.9	4.2	356
ECMWF: 12+18,+24,+30,+36	0.3	3.5	11.6	2.1	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.5	2.1	2.2	1.7	8.1	332
ECMWF – synop	−1.9	2.3	3.0	2.3	10.4	332

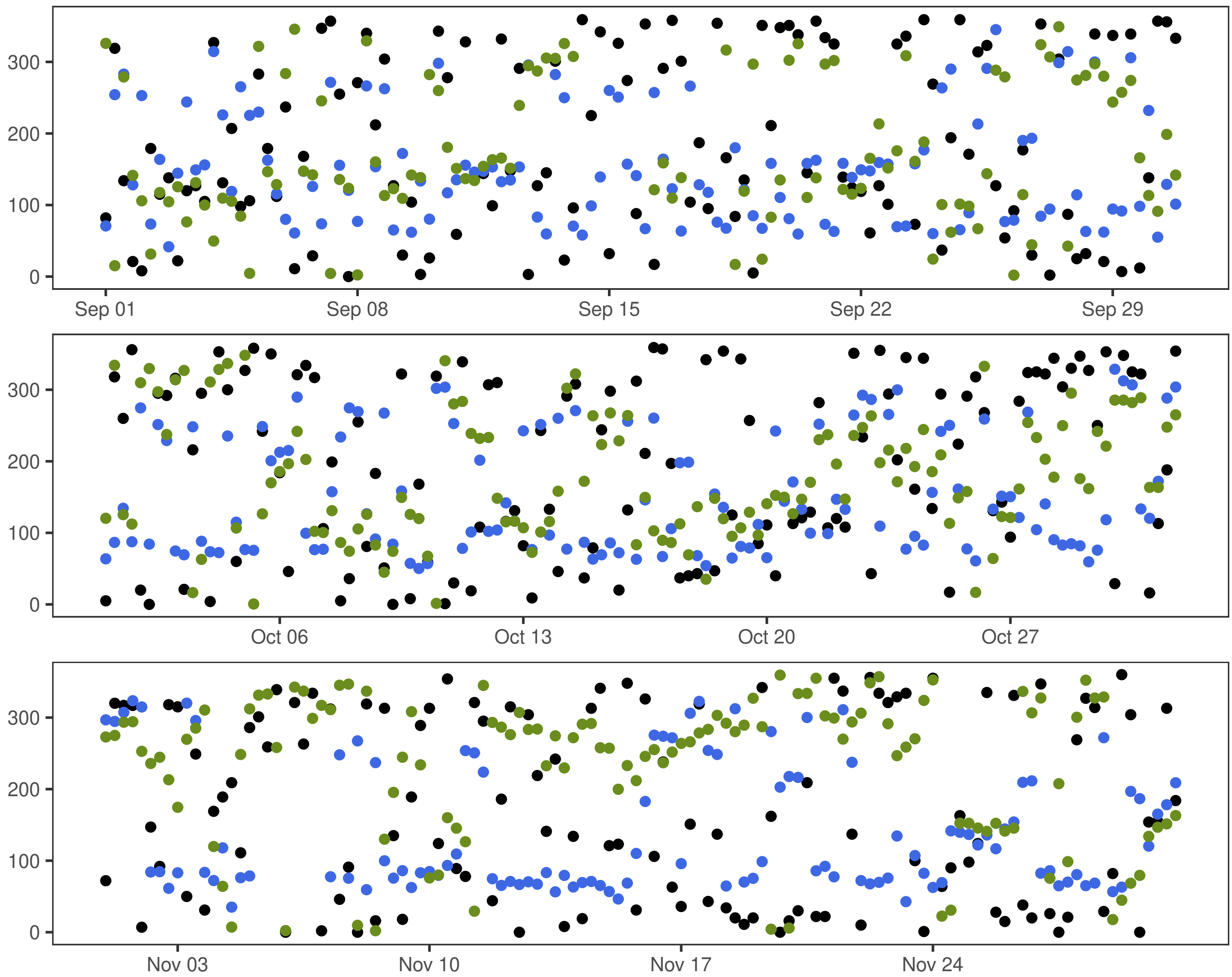

FINSEVATN
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.000
0.002
0.004
0.006
0
100
200
300
Wind direction

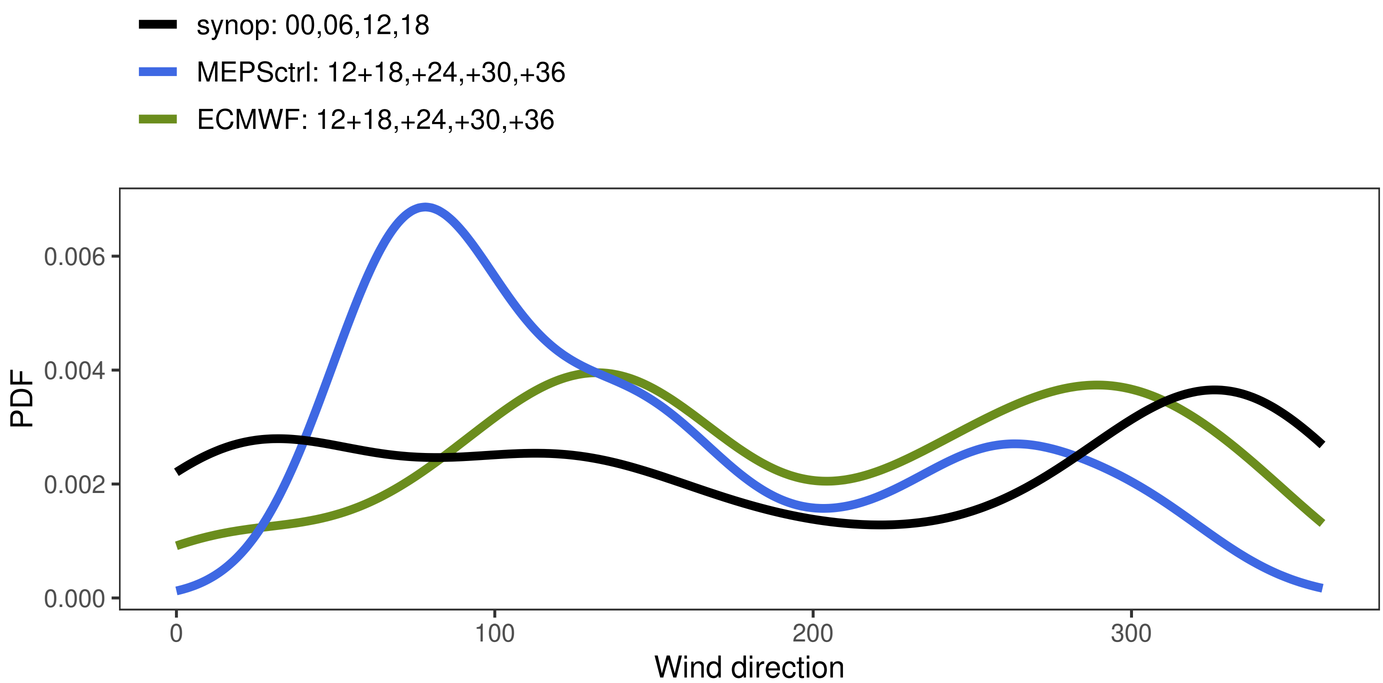


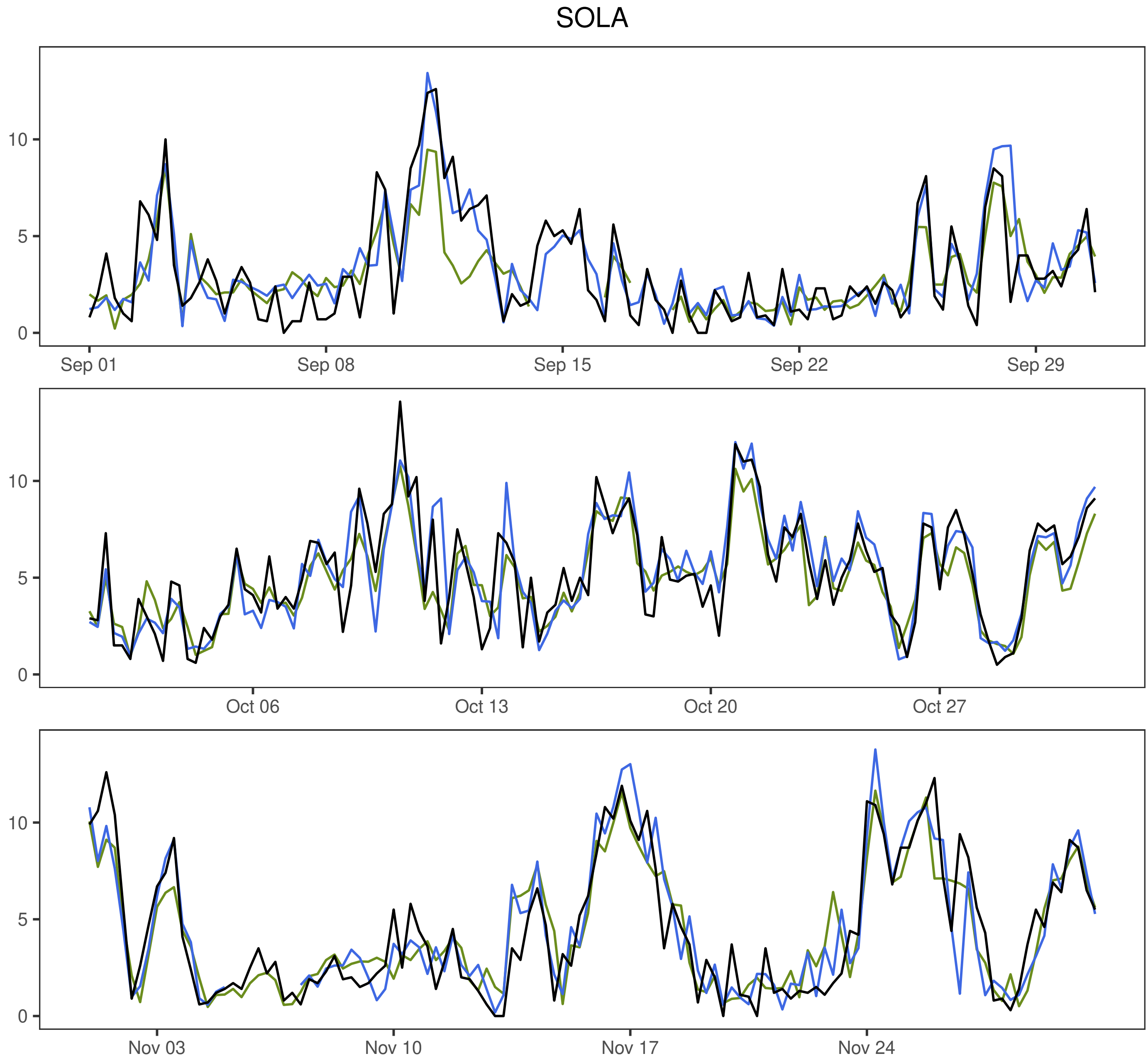
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	1.0	6.7	1.1	364
MEPSctrl: 12+18,+24,+30,+36	0.3	1.4	6.4	1.0	356
ECMWF: 12+18,+24,+30,+36	0.1	1.5	5.7	1.1	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.3	0.9	1.0	0.8	3.9	344
ECMWF – synop	0.4	0.9	1.0	0.7	4.0	344

NESBYEN – TODOKK

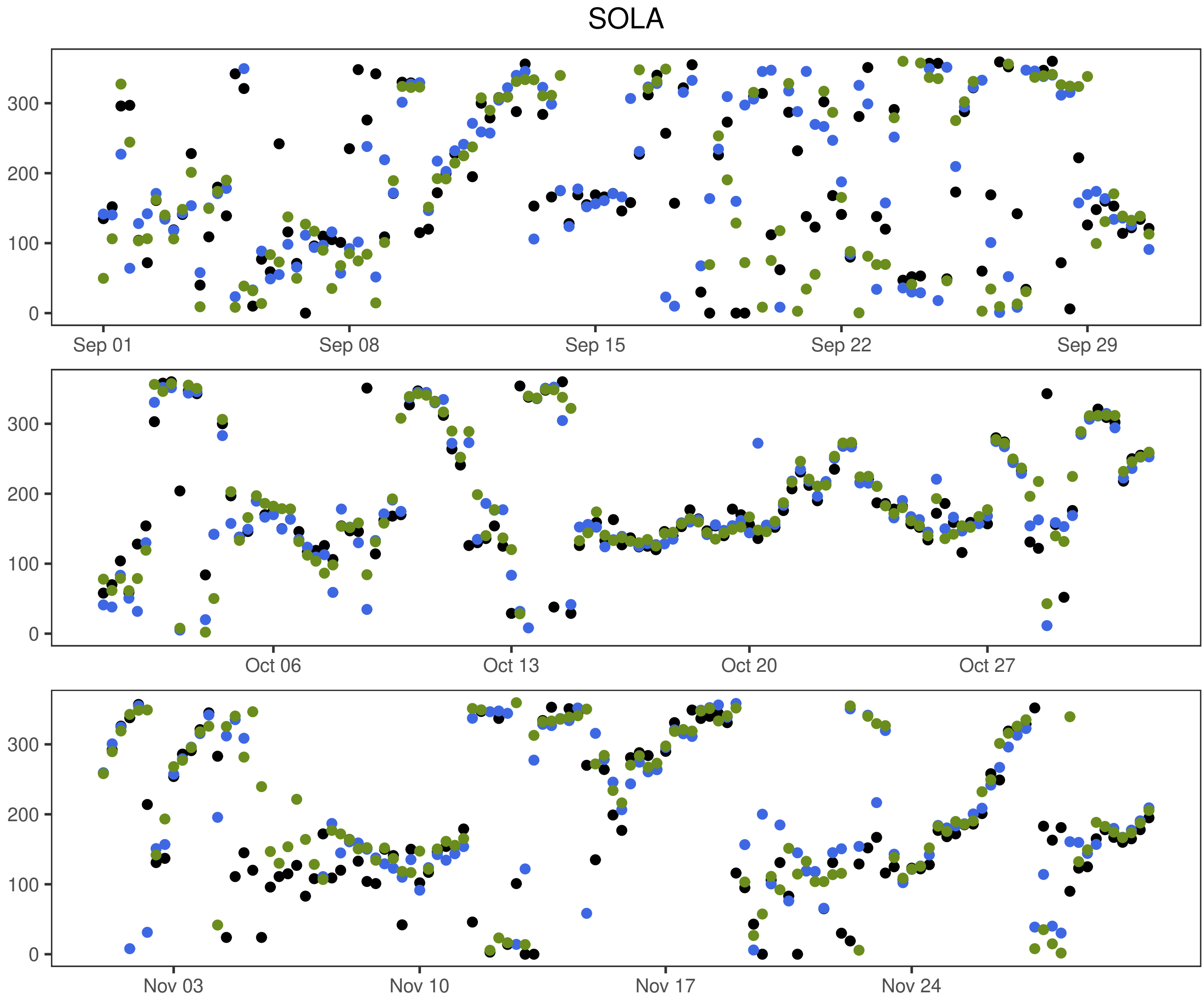


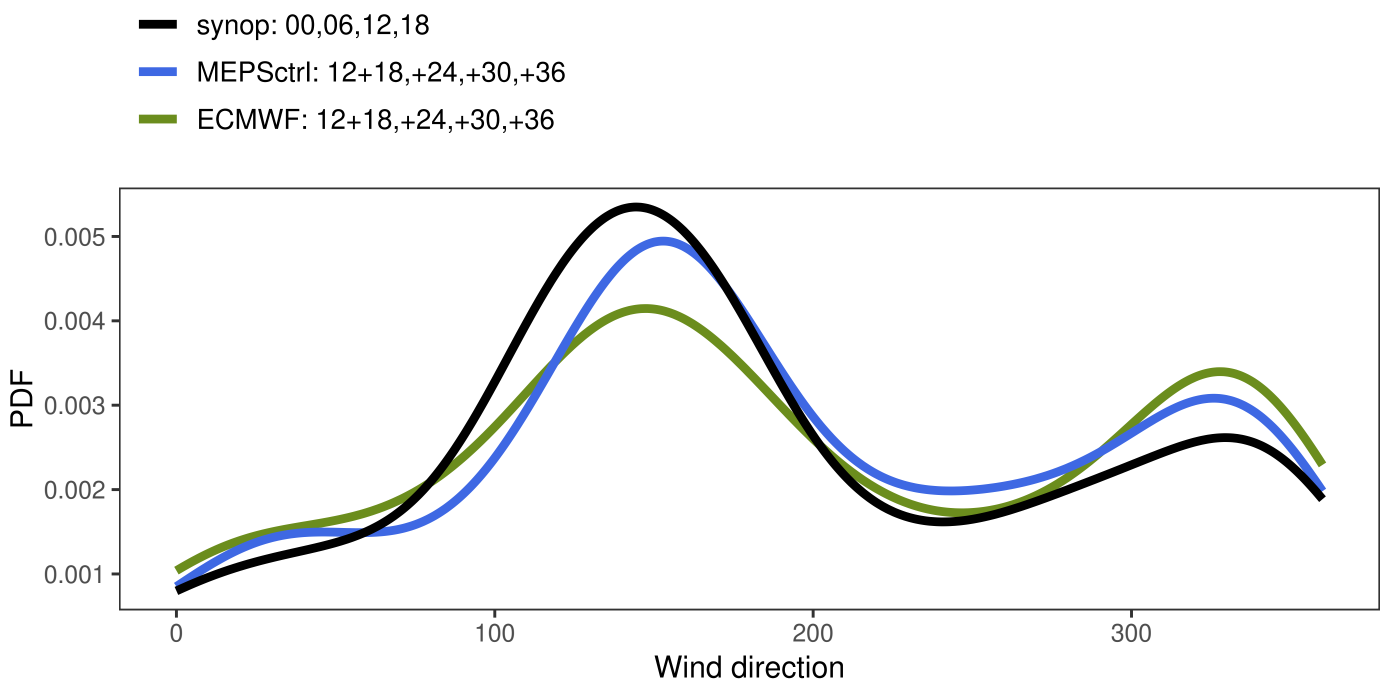




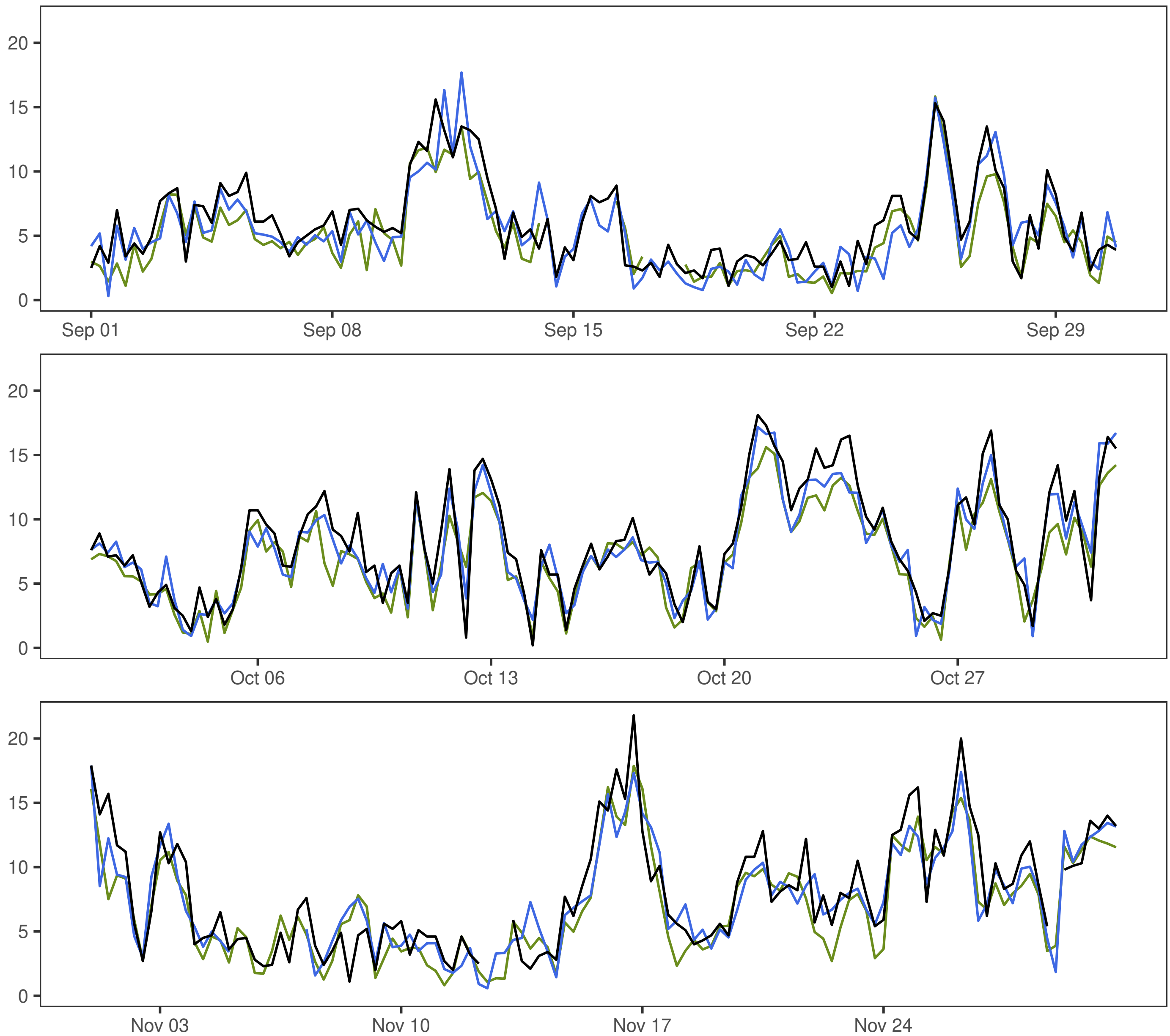
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	4.3	14.1	3.1	364
MEPSctrl: 12+18,+24,+30,+36	0.2	4.4	13.8	3.0	356
ECMWF: 12+18,+24,+30,+36	0.2	4.1	11.6	2.5	352

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.1	1.6	1.6	1.1	8.2	344
ECMWF – synop	–0.2	1.6	1.6	1.2	5.6	344


SOLA
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24

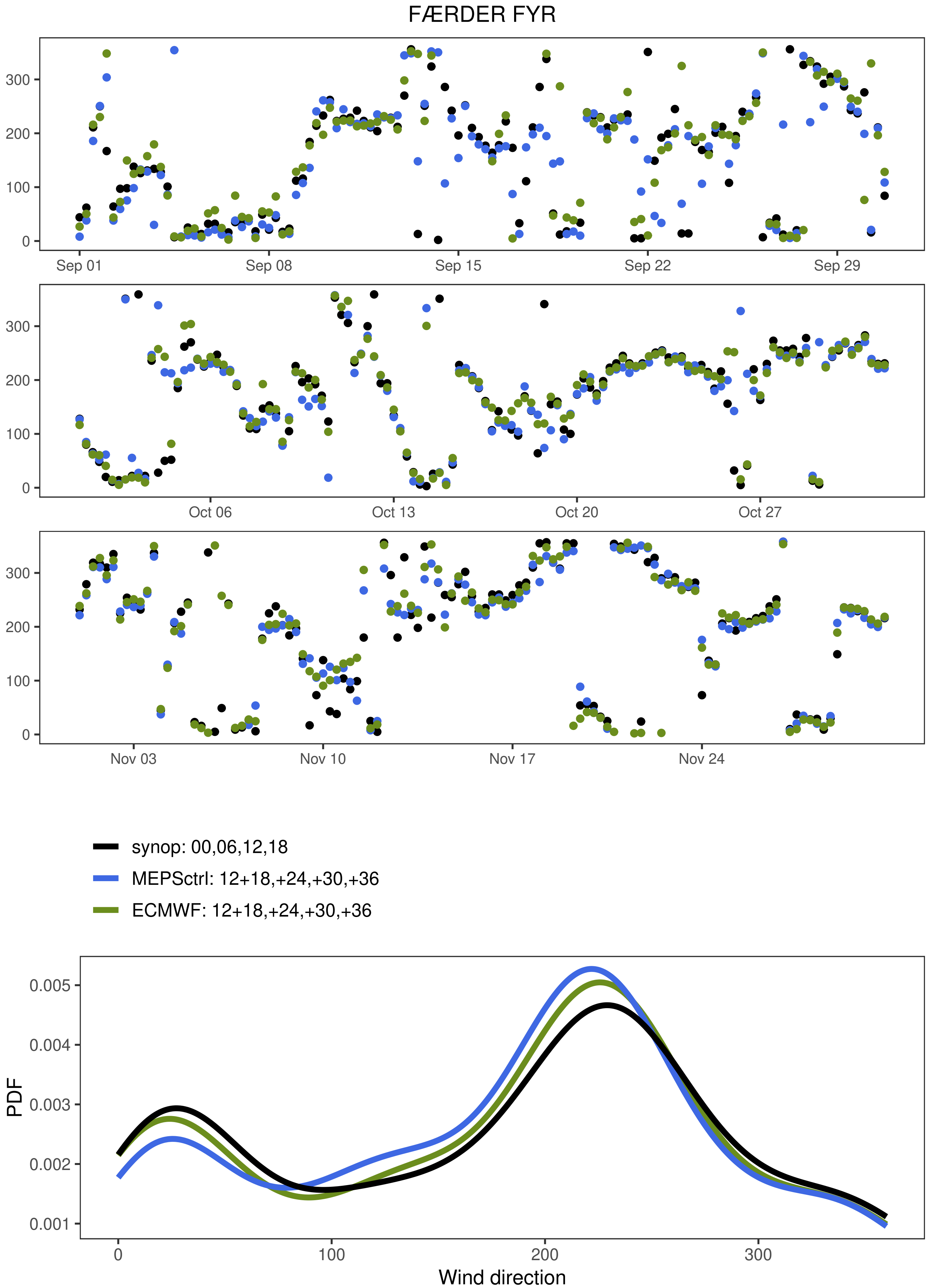

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.005
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

FÆRDER FYR

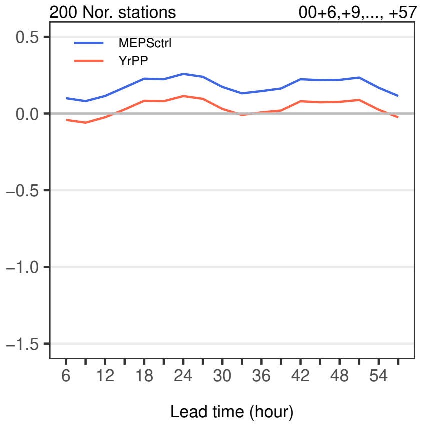


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.2	7.4	21.8	4.2	361
MEPSctrl: 12+18,+24,+30,+36	0.3	7.0	17.9	3.8	356
ECMWF: 12+18,+24,+30,+36	0.5	6.4	17.9	3.7	352

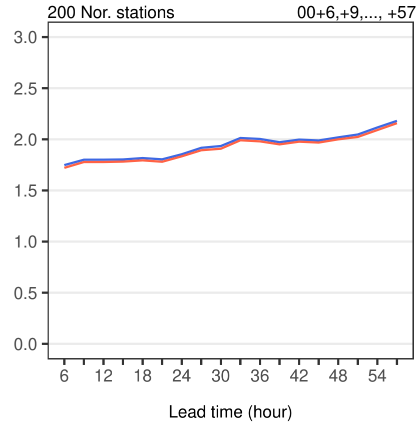
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.5	1.7	1.8	1.4	6.7	341
ECMWF – synop	–1.0	1.7	2.0	1.5	8.2	341


FÆRDER FYR
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24
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

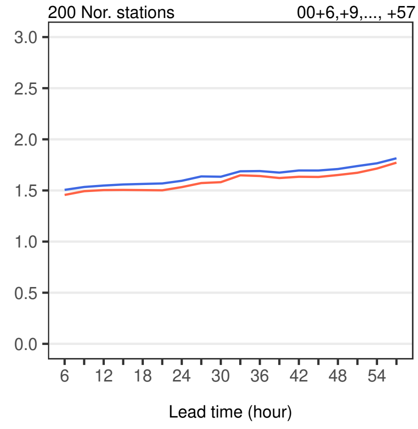
Mean Error



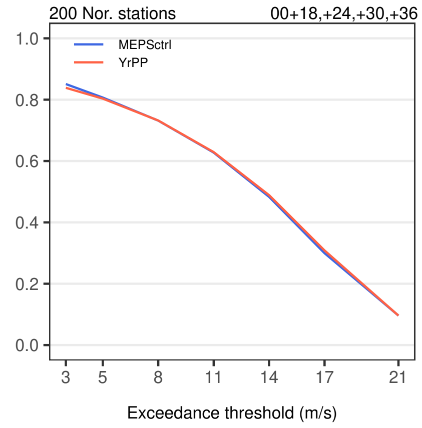
Standard Deviation of Error



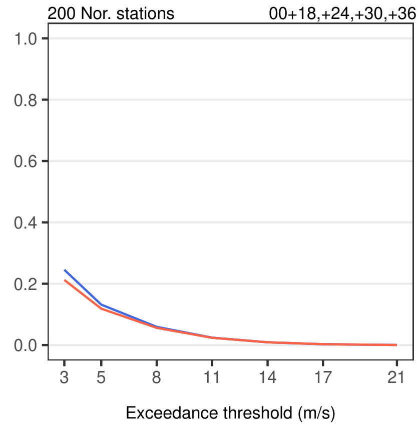
Mean Absolute Error



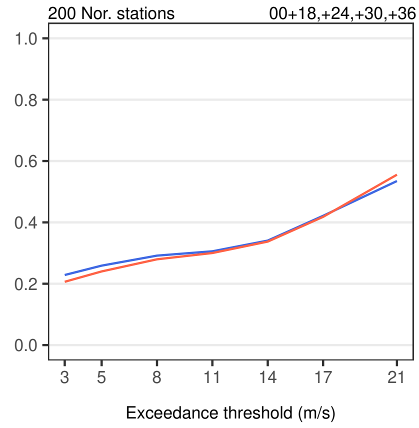
Hit Rate



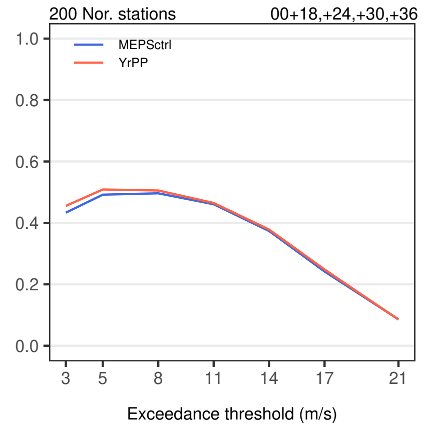
False Alarm Rate



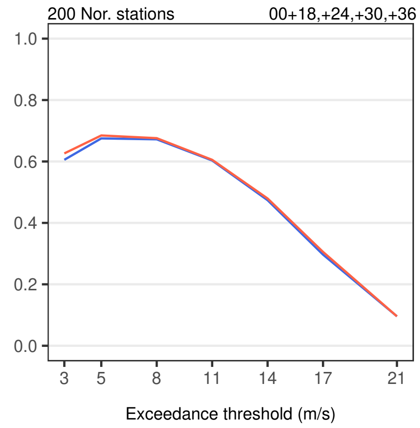
False Alarm Ratio



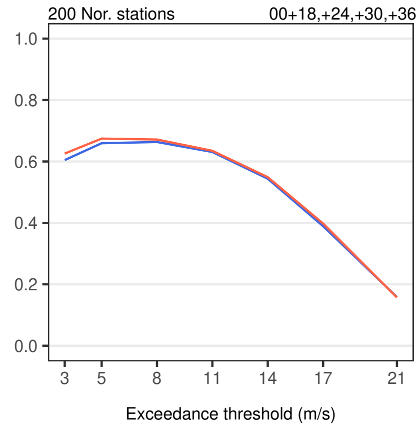
Equitable Threat Score



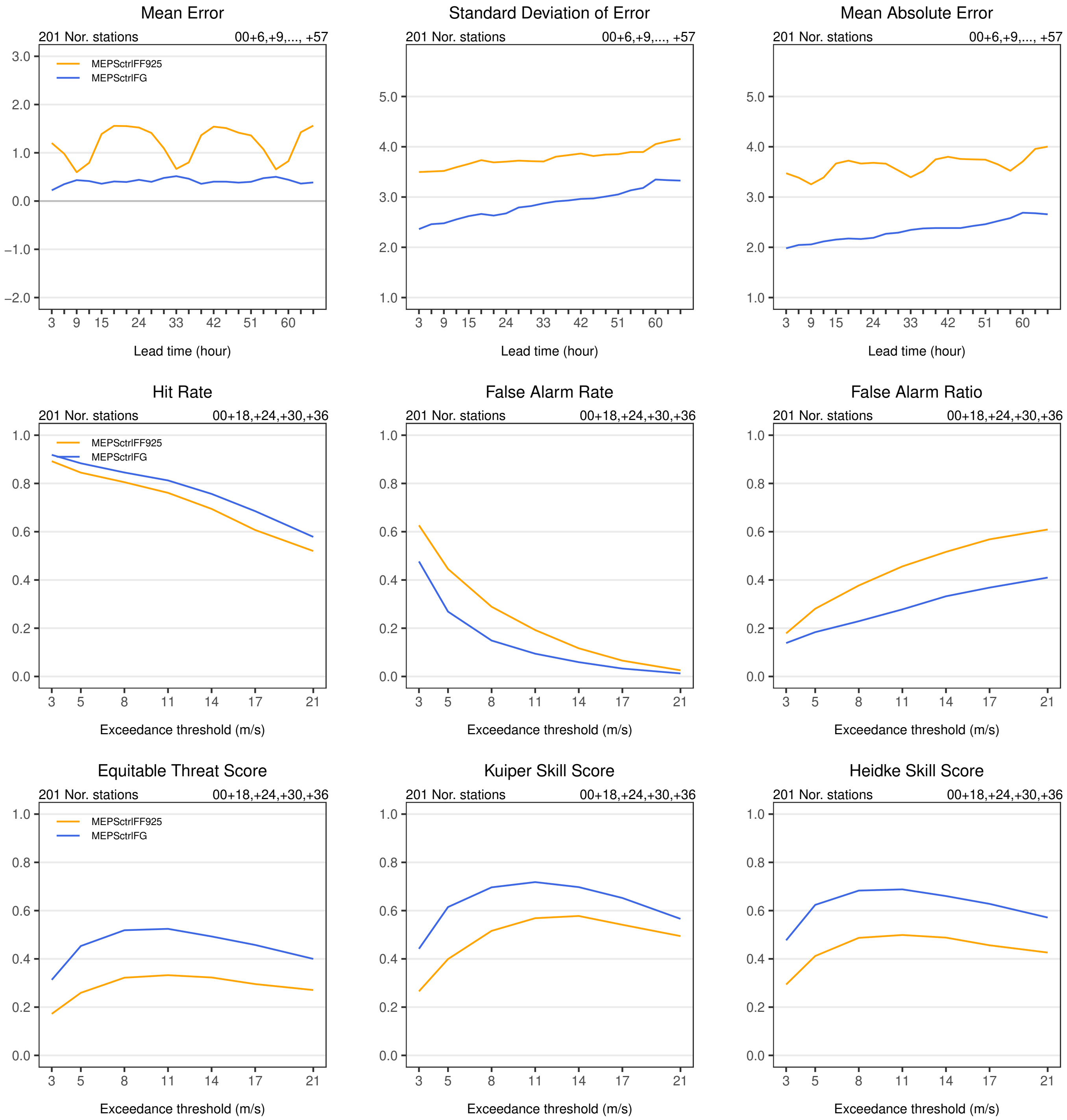
Kuiper Skill Score

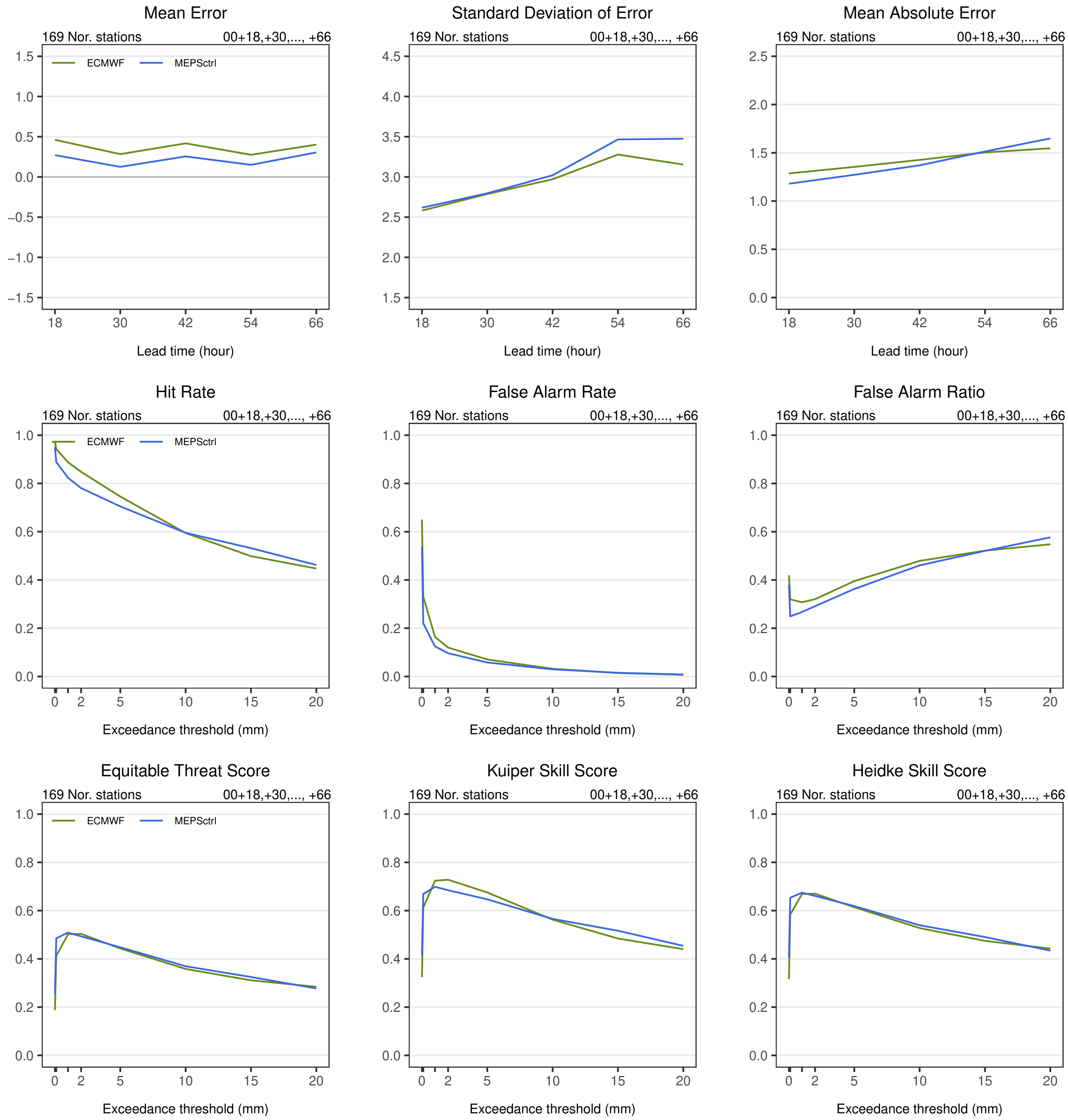


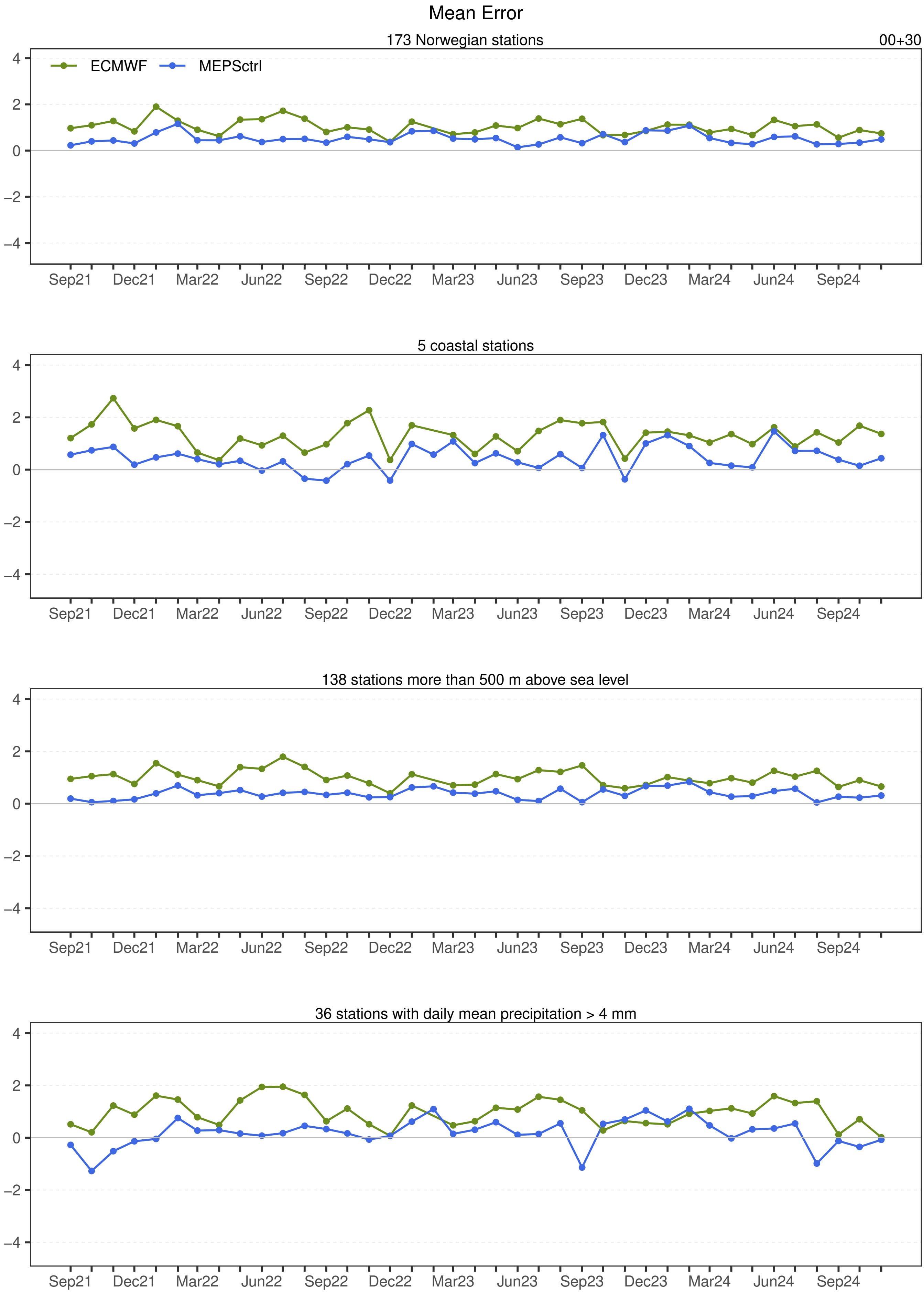
Heidke Skill Score



Wind gust (FG) and wind speed in 925 hpa (FF.925)

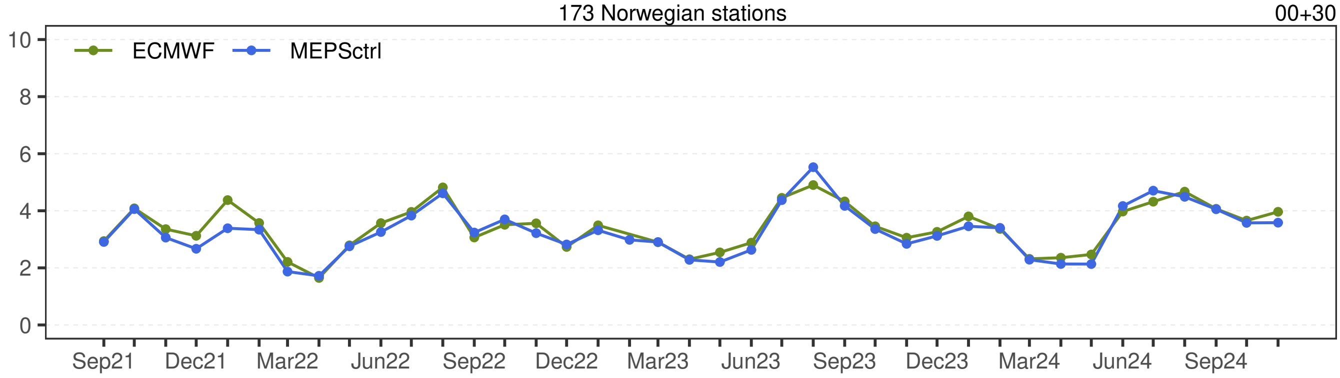



Mean Error
169 Nor. stations
00+18,+30,..., +66
ECMWF
MEPSctrl
Lead time (hour)
Standard Deviation of Error
169 Nor. stations
00+18,+30,..., +66
Lead time (hour)
Mean Absolute Error
169 Nor. stations
00+18,+30,..., +66
Lead time (hour)
Hit Rate
169 Nor. stations
00+18,+30,..., +66
ECMWF
MEPSctrl
Exceedance 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)

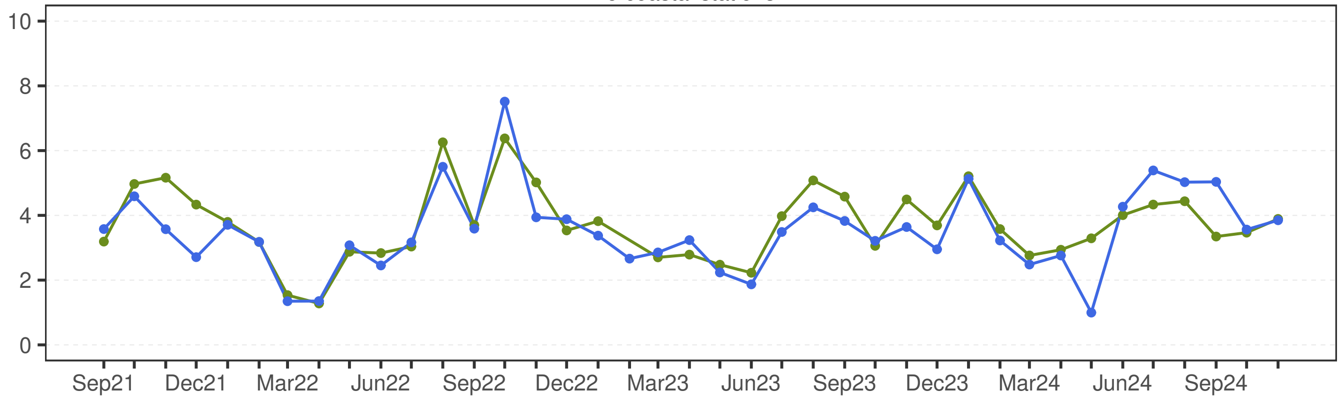

Mean Error
173 Norwegian stations
00+30
ECMWF
MEPSctrl
4
2
0
−2
−4
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24
Sep24
5 coastal stations
138 stations more than 500 m above sea level
36 stations with daily mean precipitation > 4 mm

Standard Deviation of Error

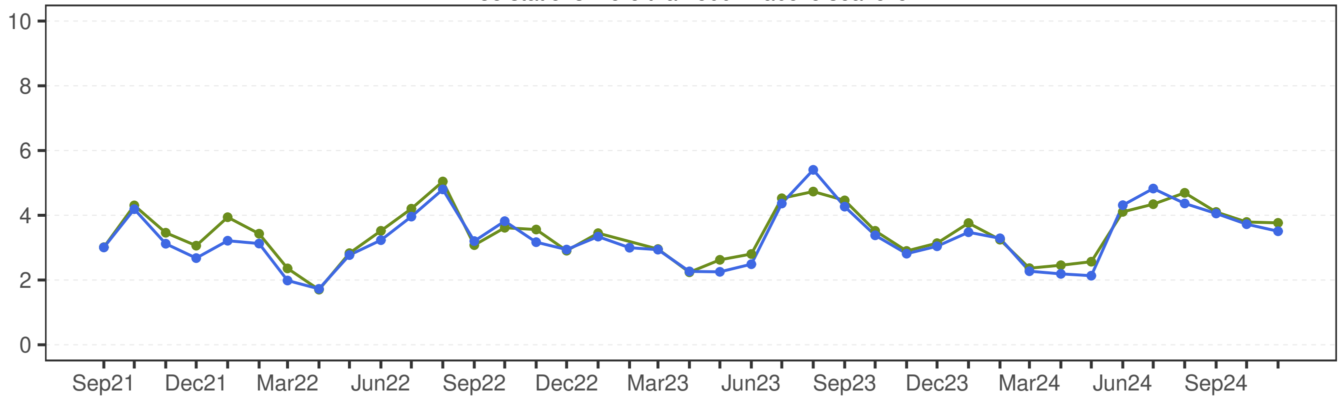
173 Norwegian stations 00+30



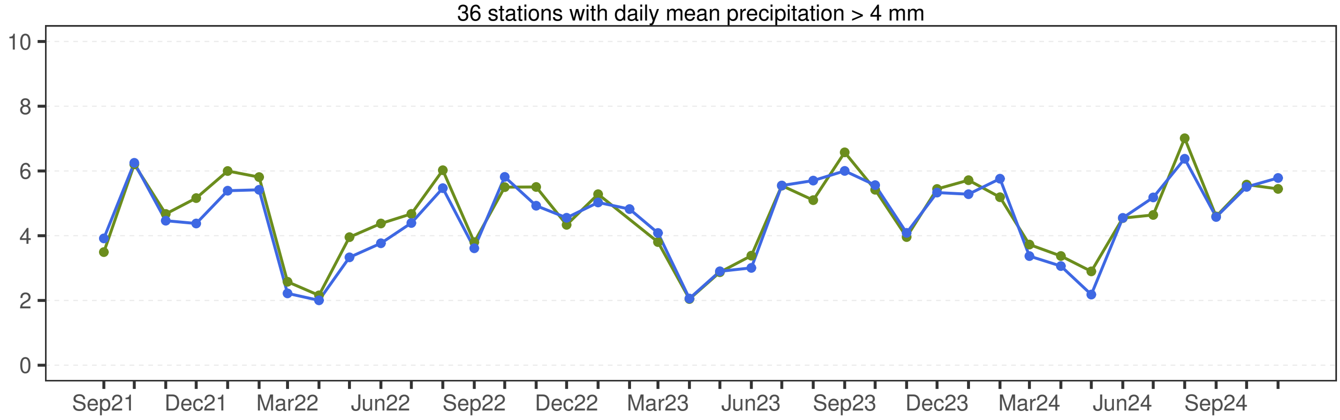
5 coastal stations

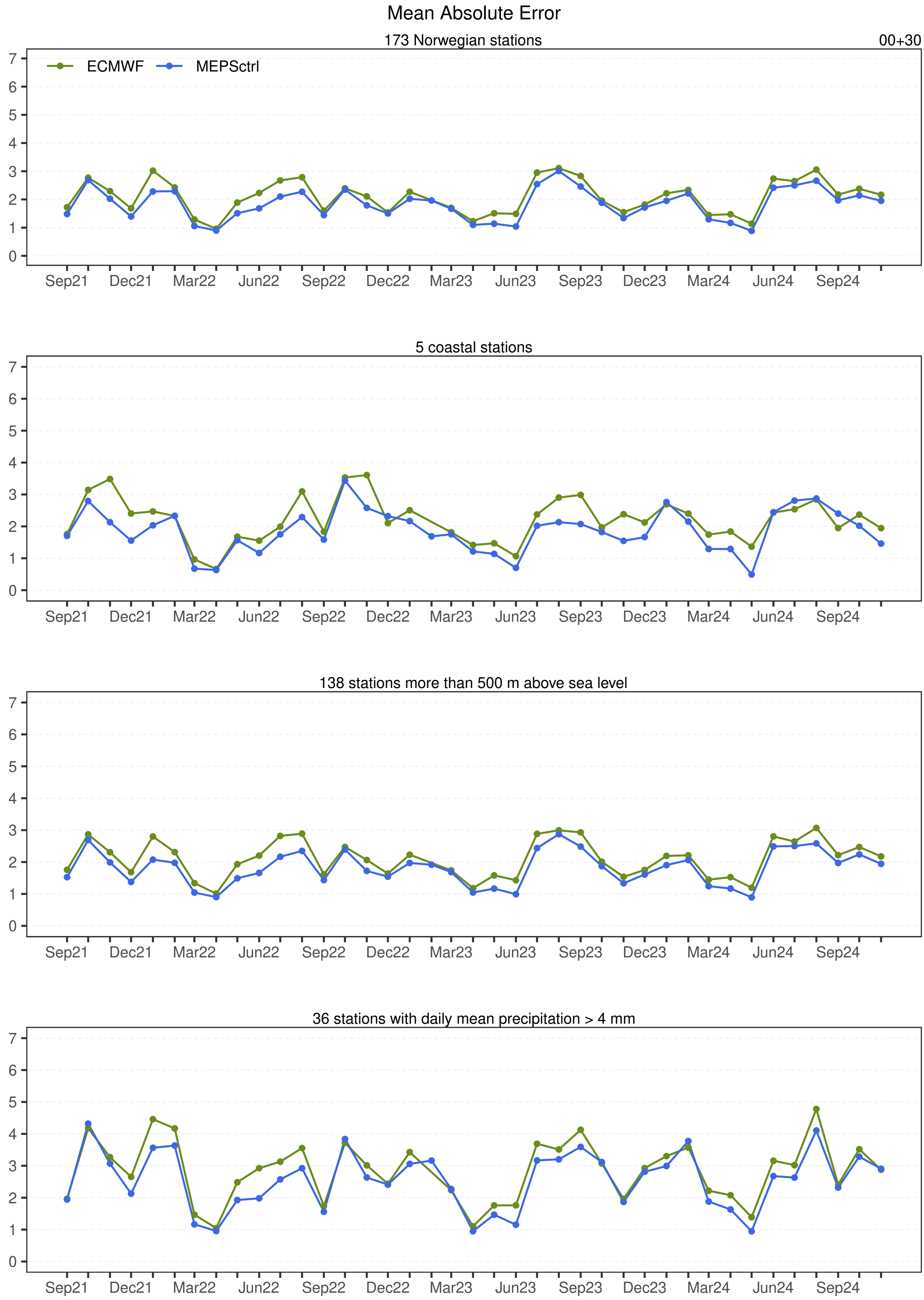


138 stations more than 500 m above sea level



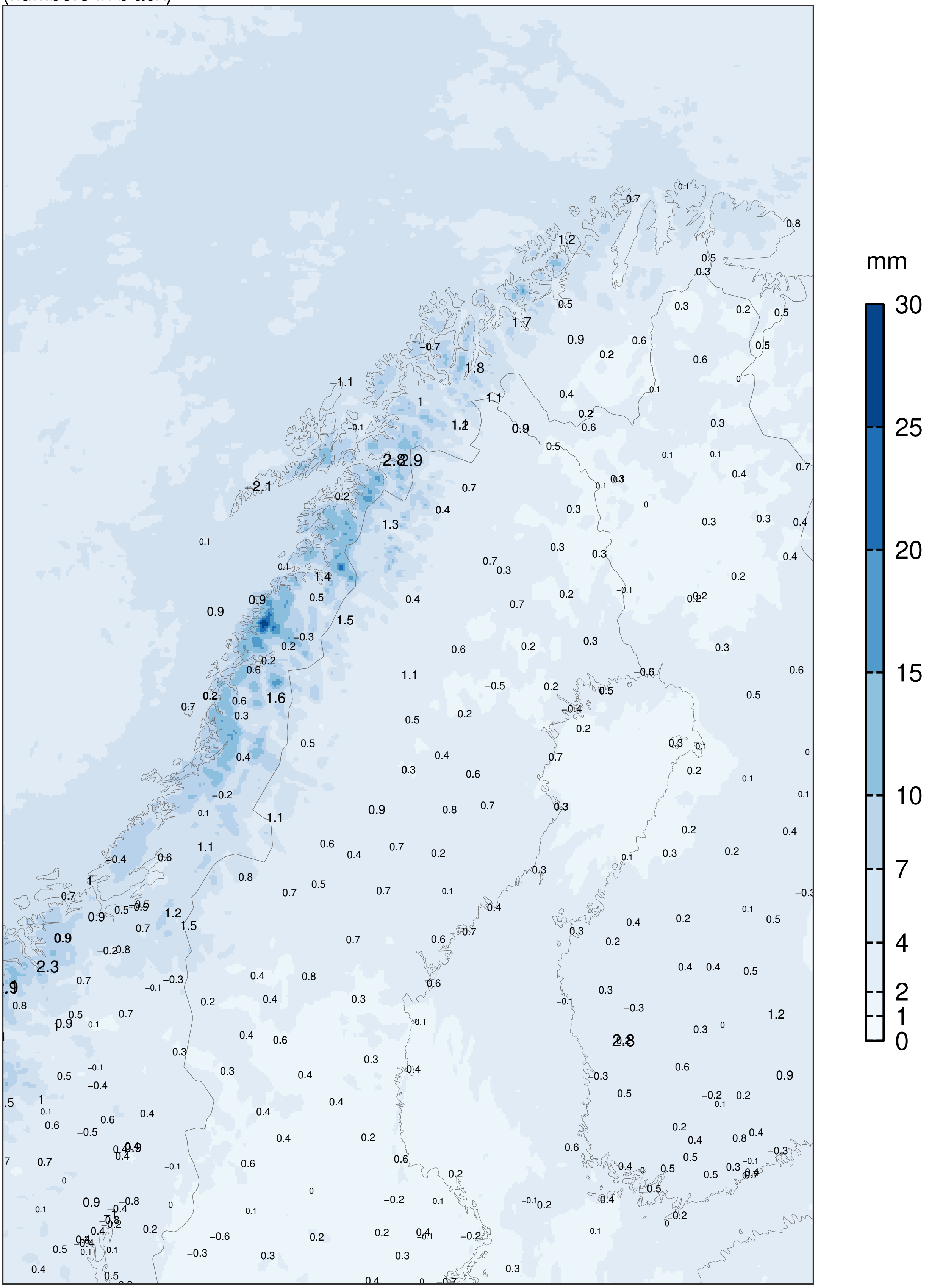
36 stations with daily mean precipitation > 4 mm




Mean Absolute Error
173 Norwegian stations
00+30
ECMWF
MEPSctrl
0
1
2
3
4
5
6
7
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
Mar24
Jun24
Sep24
5 coastal stations
138 stations more than 500 m above sea level
36 stations with daily mean precipitation > 4 mm

MEPSctrl 00+30

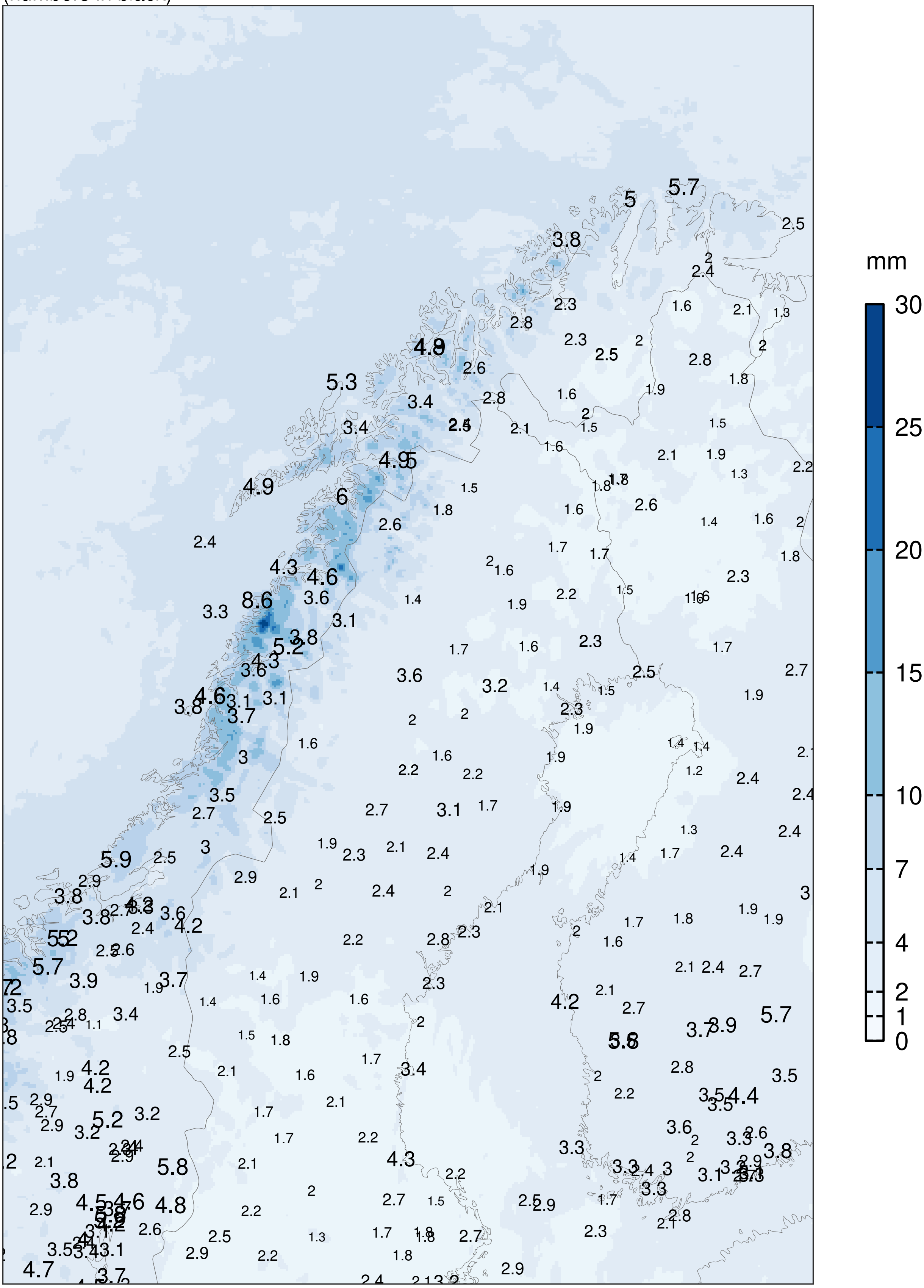
ME at observing sites
(numbers in black)



Model "climatology" 01.09.2024–30.11.2024

MEPSctrl 00+30

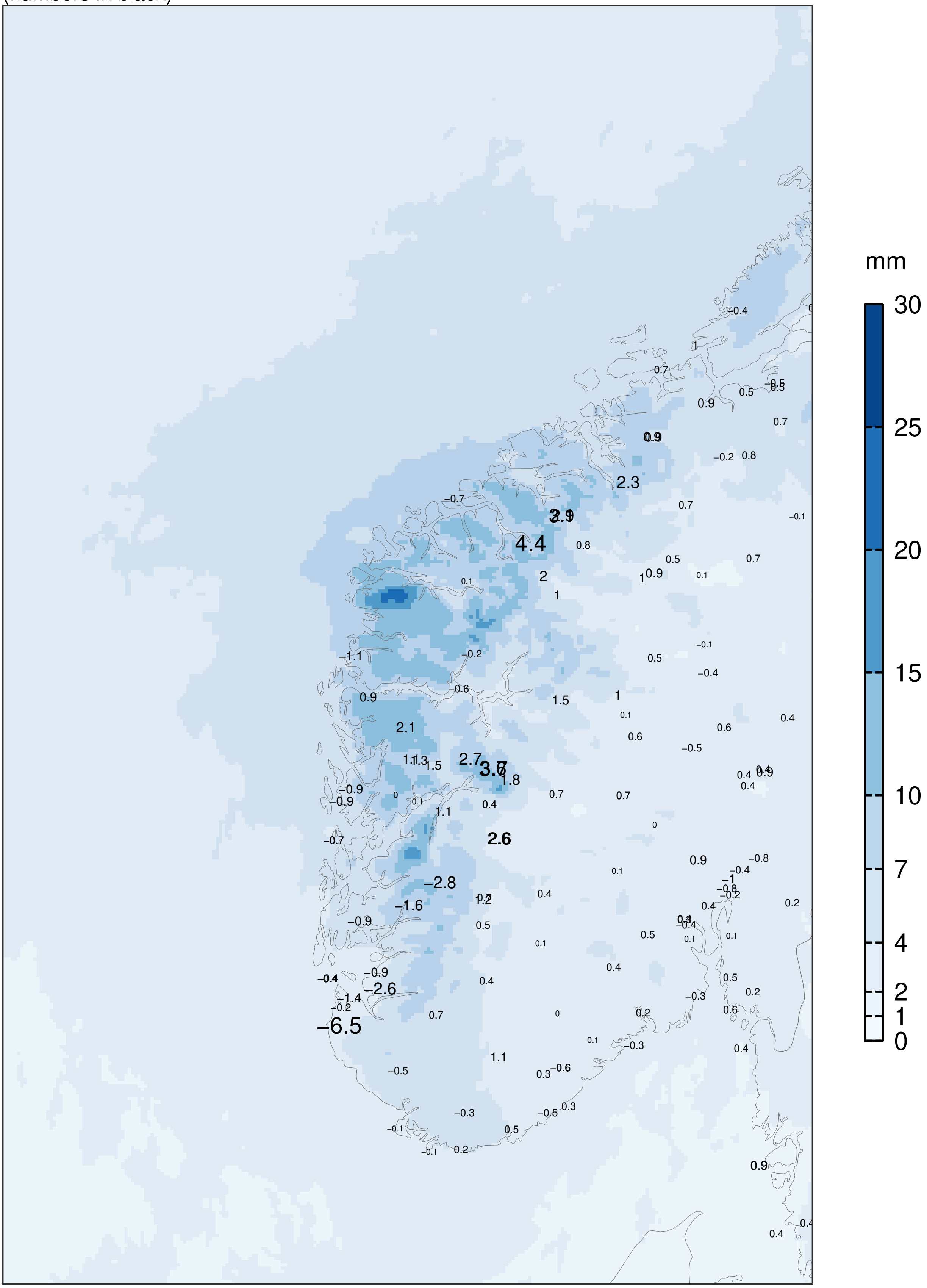
SDE at observing sites
(numbers in black)



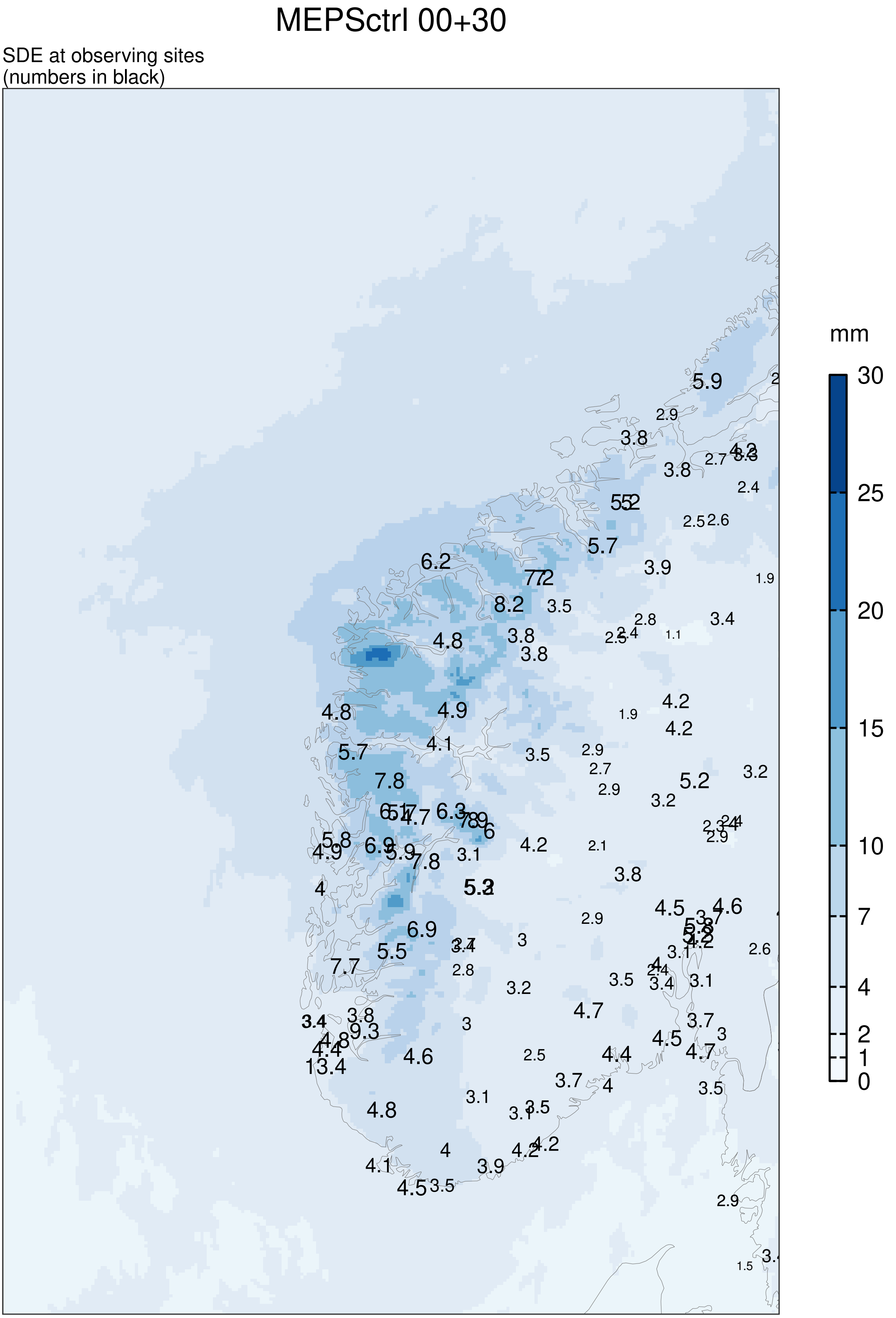
Model "climatology" 01.09.2024–30.11.2024

MEPSctrl 00+30

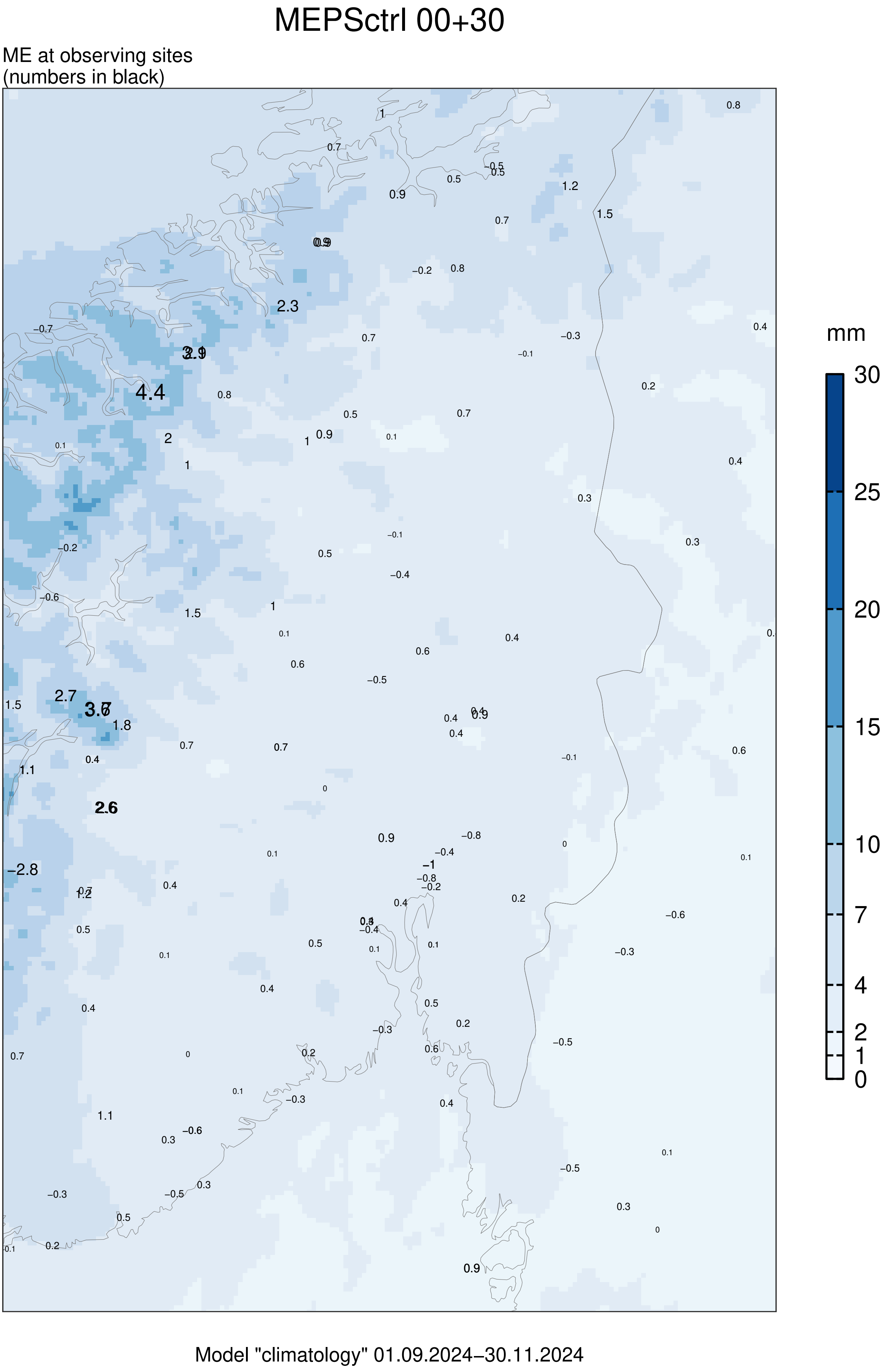
ME at observing sites
(numbers in black)

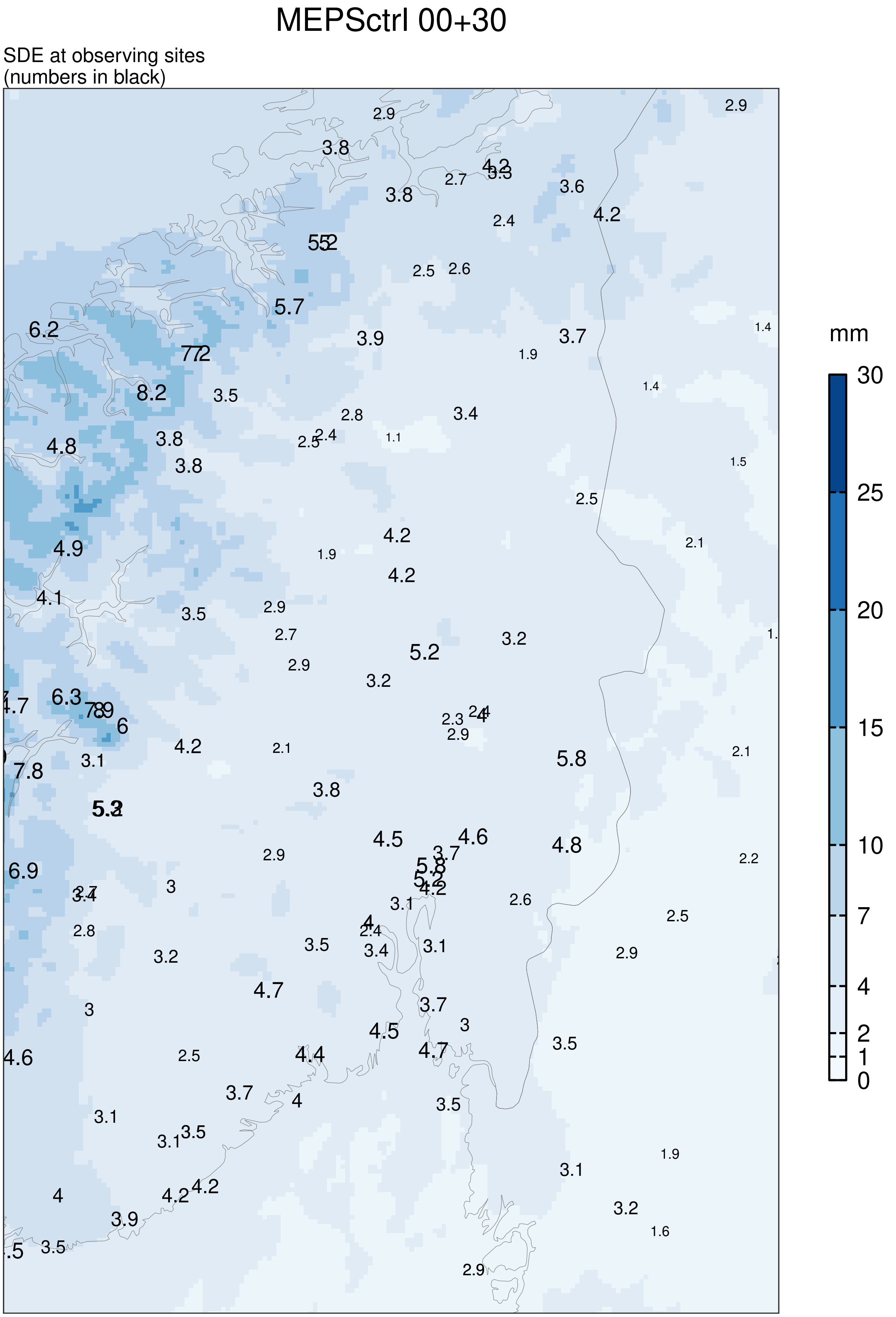


Model "climatology" 01.09.2024–30.11.2024

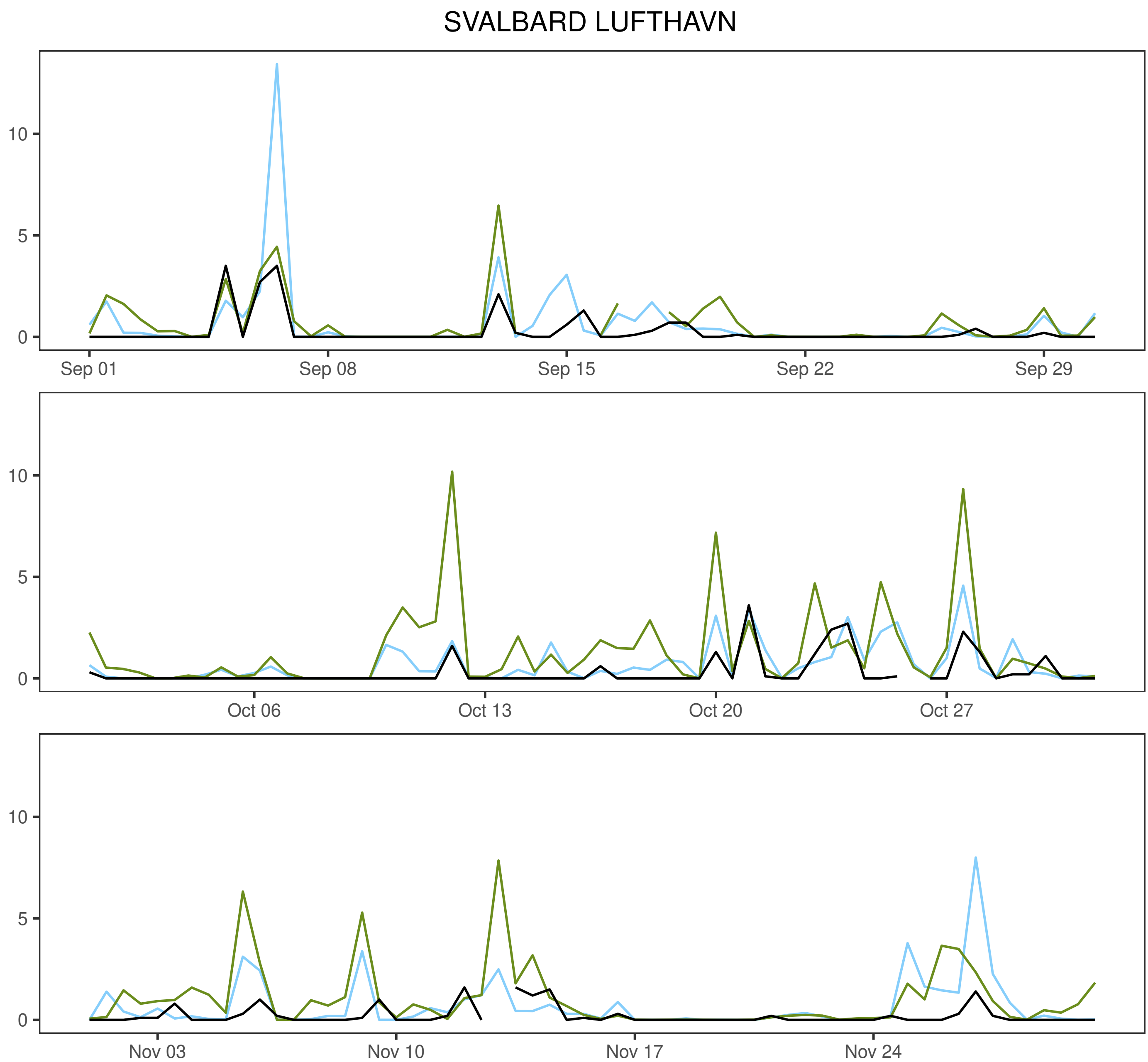


Model "climatology" 01.09.2024–30.11.2024


MEPSctrl 00+30
ME at observing sites
(numbers in black)
mm
30
25
20
15
10
7
4
2
1
0
Model "climatology" 01.09.2024–30.11.2024

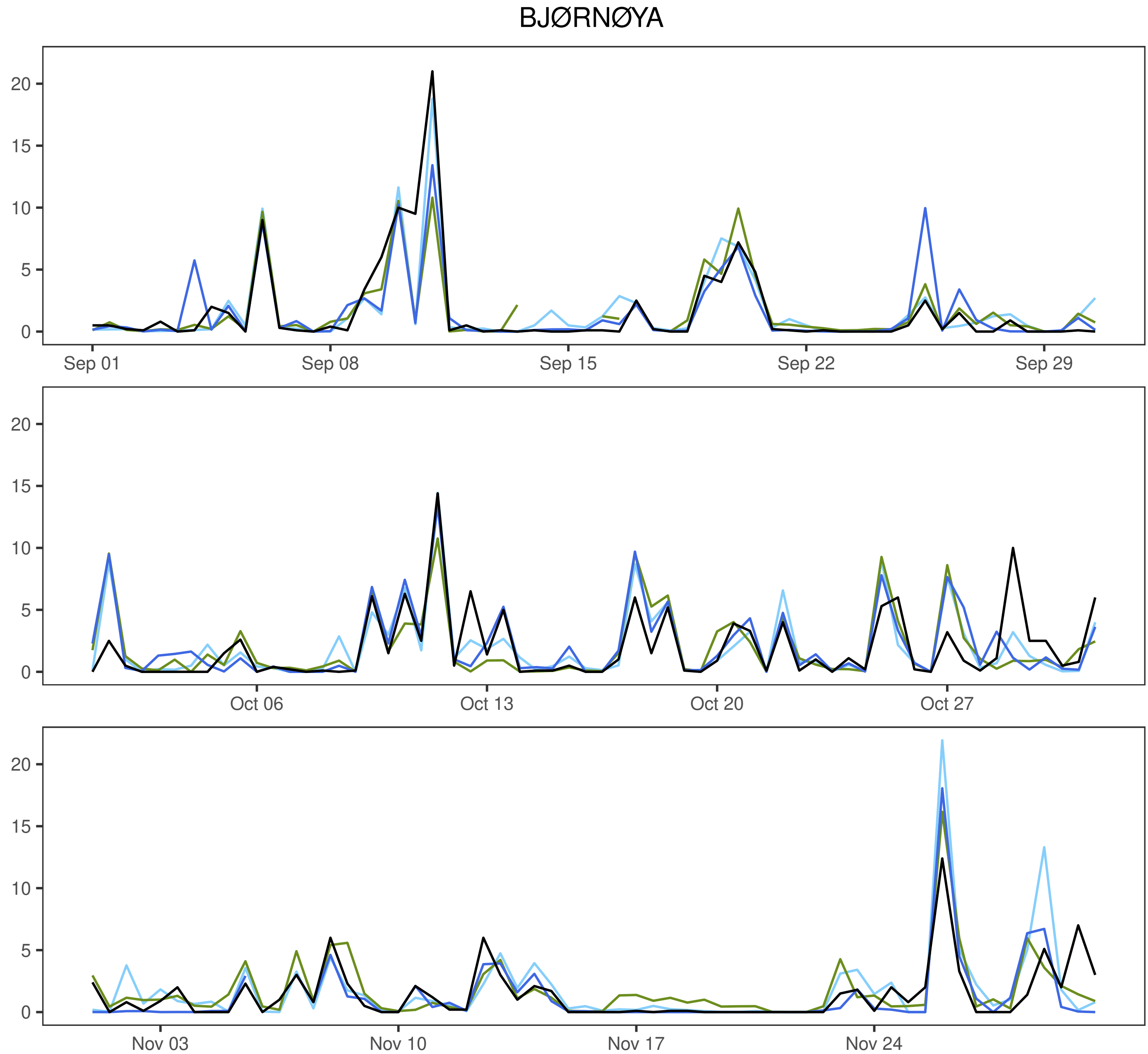


Model "climatology" 01.09.2024–30.11.2024



	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.3	3.6	0.7	180
AA25: 12+18,+30	0.0	0.7	13.4	1.4	182
ECMWF: 12+18,+30	0.0	1.0	10.2	1.7	176

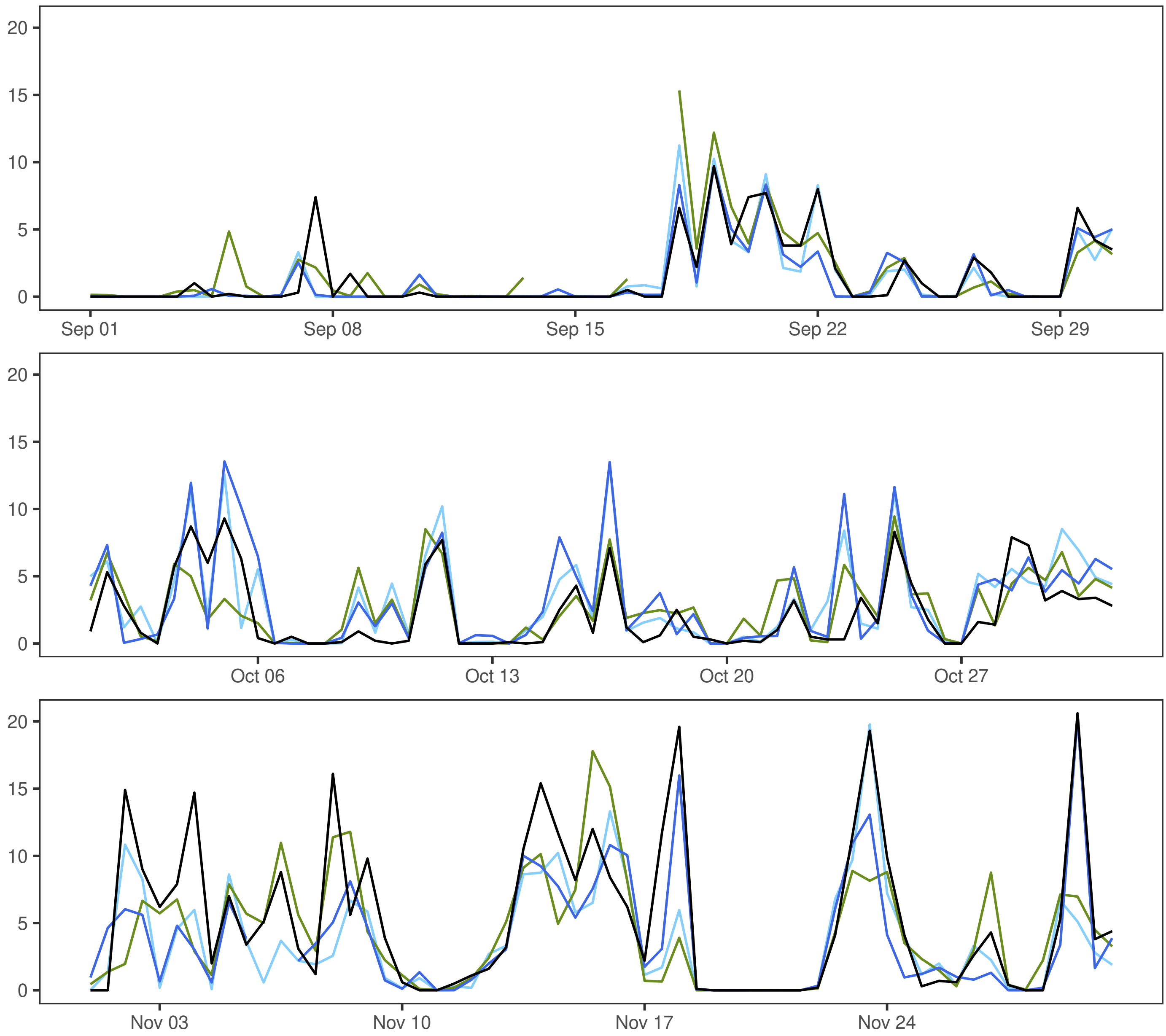
	ME	SDE	RMSE	MAE	Max.abs.err	N
AA25 – synop	0.4	1.1	1.2	0.5	9.9	174
ECMWF – synop	0.7	1.4	1.6	0.8	8.6	174



	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.6	21.0	2.9	182
MEPSctrl: 12+18,+30	0.0	1.7	18.1	2.9	180
AA25: 12+18,+30	0.0	1.8	21.9	3.2	182
ECMWF: 12+18,+30	0.0	1.8	16.2	2.7	176

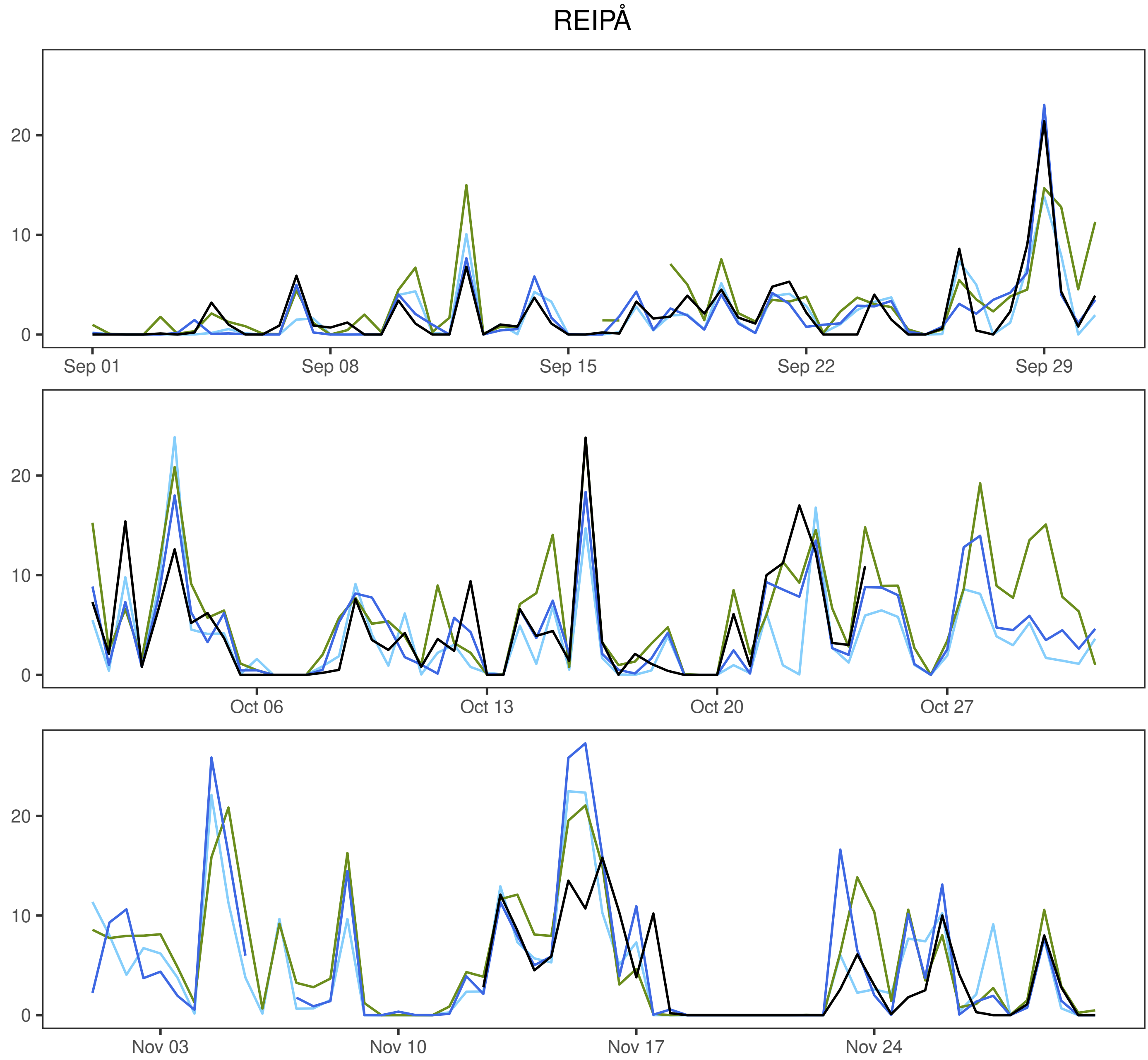
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.0	2.0	2.0	1.1	8.9	174
AA25 – synop	0.2	1.9	2.0	1.1	9.5	174
ECMWF – synop	0.1	2.0	2.0	1.1	10.2	174

TROMSØ



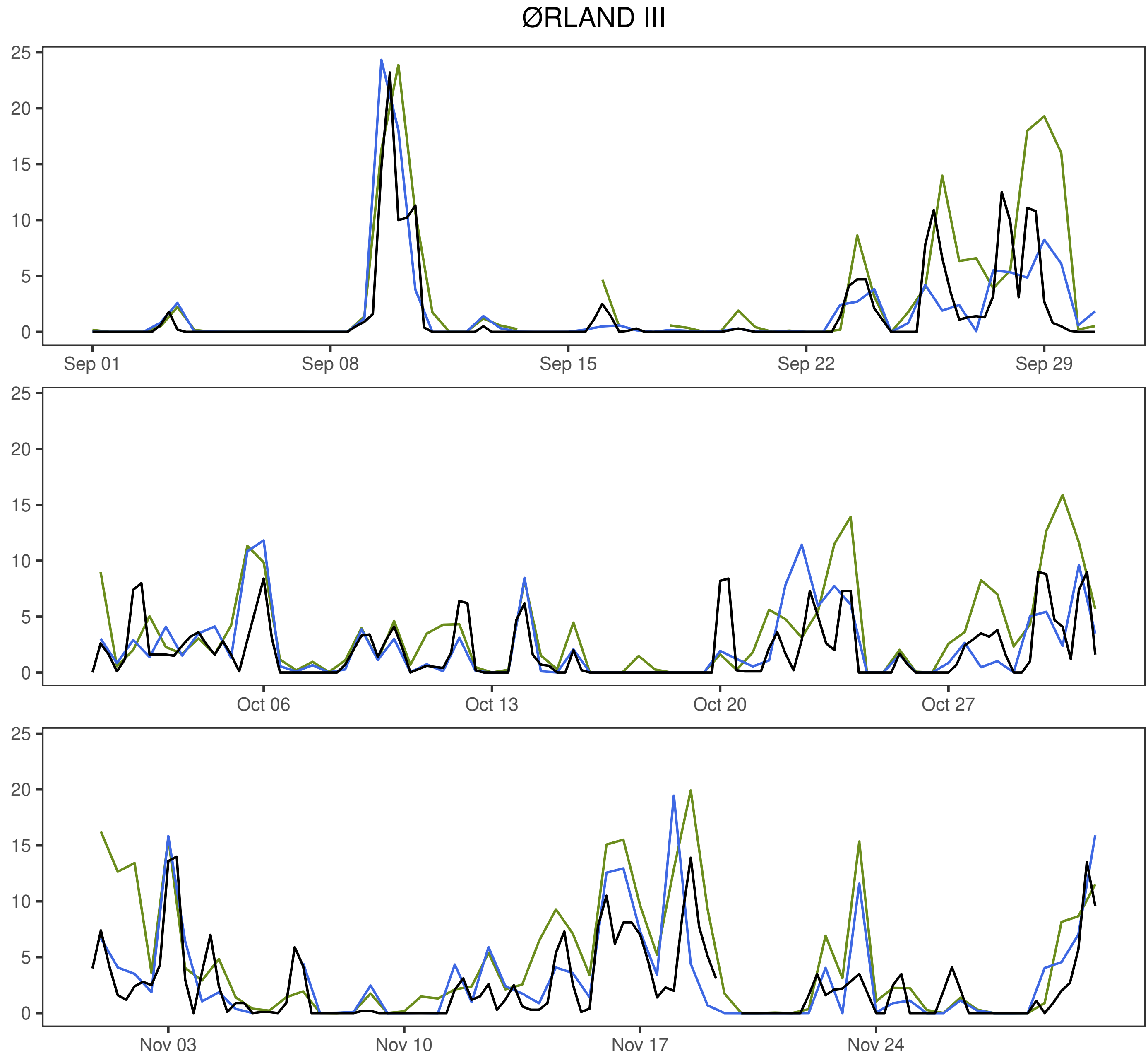
	Min	Mean	Max	Std	N
synop: 06,18	0.0	3.0	20.6	4.3	182
MEPSctrl: 12+18,+30	0.0	2.8	20.3	3.7	180
AA25: 12+18,+30	0.0	2.7	19.8	3.5	182
ECMWF: 12+18,+30	0.0	3.0	17.8	3.4	176

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	−0.2	2.8	2.8	1.7	11.7	174
AA25 – synop	−0.3	3.0	3.0	1.6	15.5	174
ECMWF – synop	−0.2	3.2	3.2	1.7	15.7	174



	Min	Mean	Max	Std	N
synop: 06,18	0.0	3.3	23.8	4.5	145
MEPSctrl: 12+18,+30	0.0	3.8	27.3	5.2	180
AA25: 12+18,+30	0.0	3.2	23.9	4.6	182
ECMWF: 12+18,+30	0.0	4.9	23.8	5.3	176

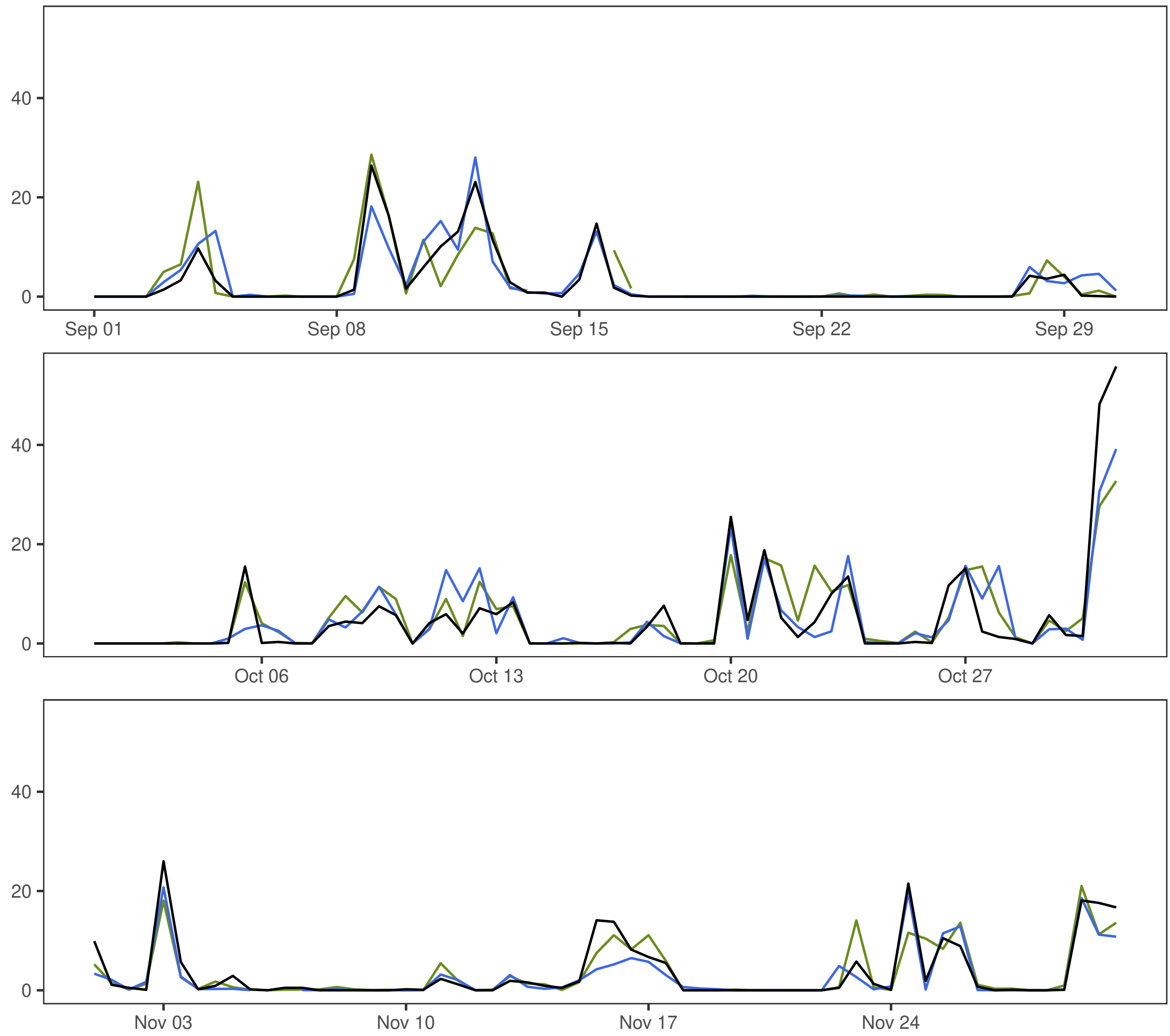
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.2	3.2	3.2	1.7	16.6	139
AA25 – synop	−0.3	3.4	3.4	1.9	17.0	139
ECMWF – synop	1.0	3.3	3.4	2.2	10.3	139



	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	2.0	23.2	3.3	343
MEPSctrl: 12+18,+30	0.0	2.4	24.3	4.0	180
ECMWF: 12+18,+30	0.0	3.8	23.9	5.1	176

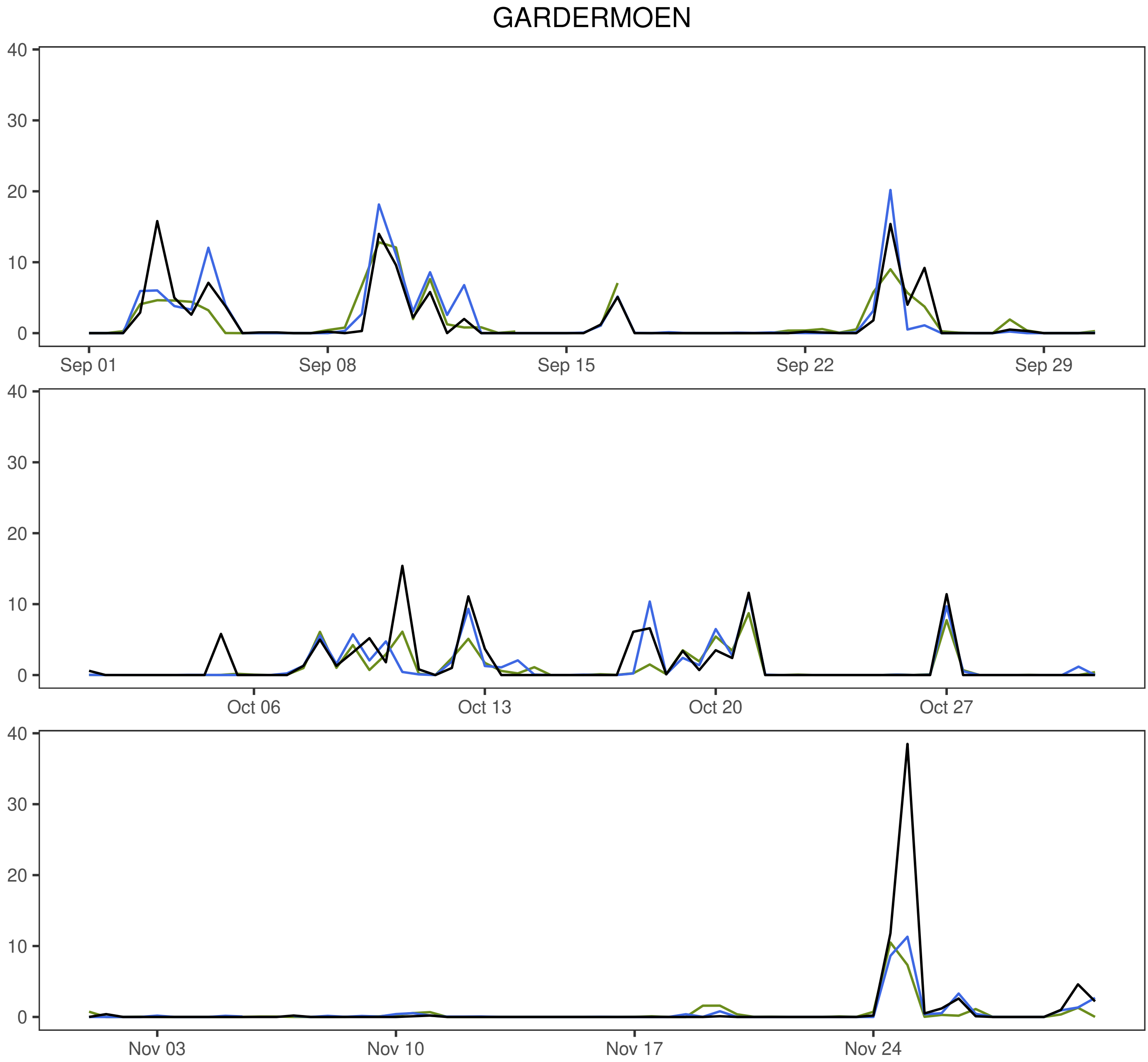
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.5	2.8	2.9	1.5	17.5	173
ECMWF – synop	1.8	3.4	3.8	2.2	16.6	173

BERGEN – FLORIDA



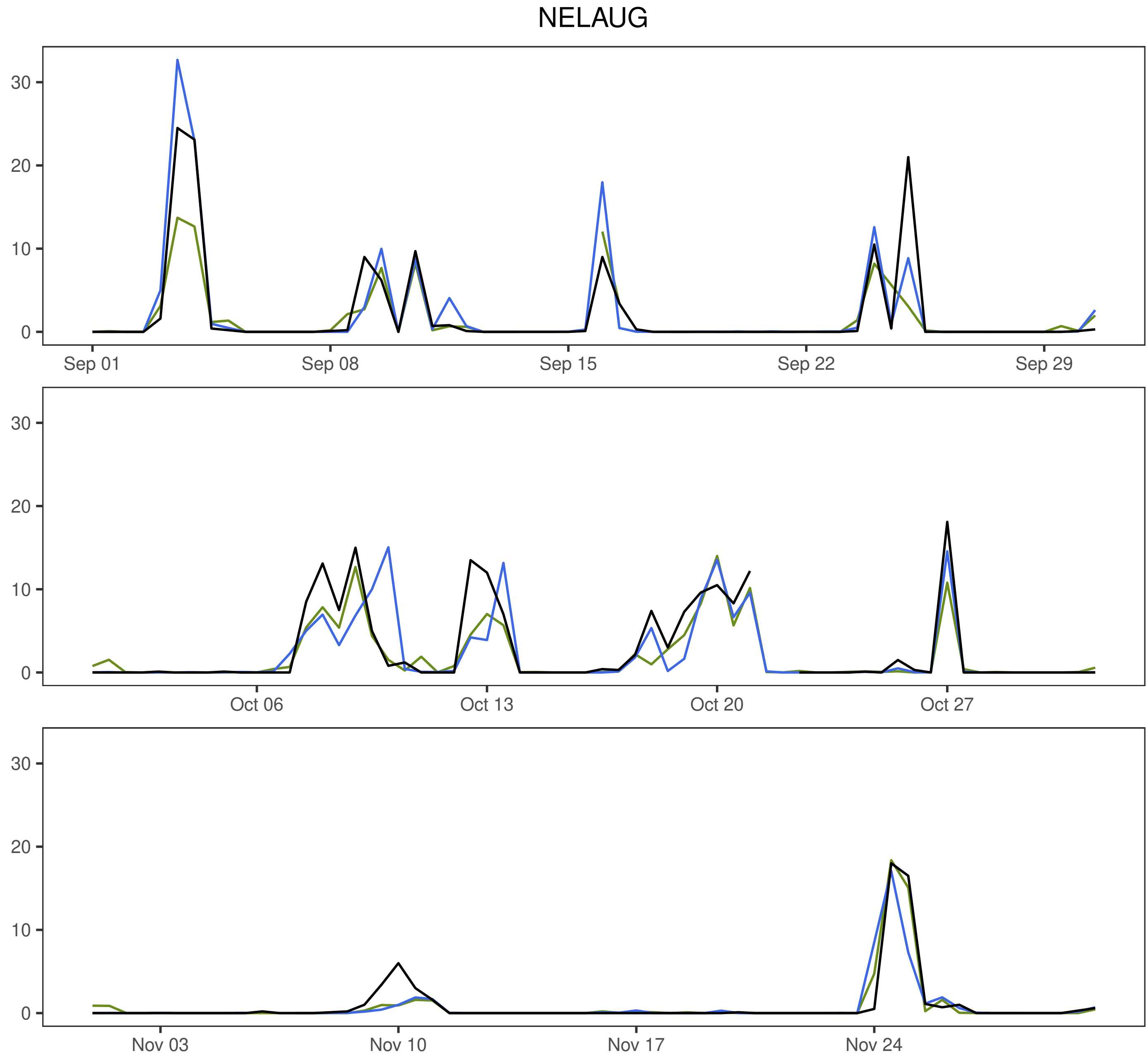
	Min	Mean	Max	Std	N
synop: 06,18	0.0	3.8	55.8	7.6	182
MEPSctrl: 12+18,+30	0.0	3.6	39.2	6.3	180
ECMWF: 12+18,+30	0.0	3.9	32.7	6.2	176

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.2	3.6	3.6	1.8	17.5	174
ECMWF – synop	0.1	4.0	4.0	1.9	23.1	174



	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.5	38.5	4.2	182
MEPSctrl: 12+18,+30	0.0	1.3	20.2	3.2	180
ECMWF: 12+18,+30	0.0	1.1	12.8	2.4	176

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.2	2.9	2.9	0.9	27.2	174
ECMWF – synop	–0.4	3.0	3.0	1.0	31.2	174



	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.9	24.5	4.6	180
MEPSctrl: 12+18,+30	0.0	1.7	32.7	4.5	180
ECMWF: 12+18,+30	0.0	1.5	18.4	3.3	176

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.2	2.7	2.7	1.1	14.2	172
ECMWF – synop	–0.5	2.4	2.4	0.9	17.9	172