Norwegian Meteorological Institute

METinfo

No. 26/2021
ISSN 1894-759X
Meteorology

Verification of Operational Weather Prediction Models September to November 2021

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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
- https://hirlam.org/trac/wiki/CommunicationWithUsers - HARMONIE quarterly reports

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 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 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 Institue (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.

10 m wind speed 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 http://www.cnrm.meteo.fr/gmapdoc/ and http://hirlam.org/.

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.

Boundary fields

MEPS gets its boundary values (1-hourly) from the ECMWF model at approximately 16 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	$\Big(\frac{1}{n}\sum_{i=1}^{n}(f_i - o_i - \mathsf{ME})^2\Big)^{1/2}$	0 to ∞	0
Root Mean Square Error	RMSE	$\Big(\frac{1}{n}\sum_{i=1}^{n}(f_i - o_i)^2\Big)^{1/2}$	0 to ∞	0
Correlation	COR	$\frac{\frac{1}{n}\sum_{i=1}^{n}(f_i - \bar{f})(o_i - \bar{o})}{\mathsf{SD}(f)\mathsf{SD}(o)}$	-1 to 1	1

In the formula for COR the following definitions are used

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

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

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 Klimadatavarehuset at MET. Only synop stations are used. From 1 June 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 forecast 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 clearly underestimates the temperature. AA25 underestimates the temperature for Svalbard stations, while both AA25 and MEPSctrl show a slight overestimation for the North Scandinavian stations. Still, the errors are small, with mean absolute error less than 2°C, indicating that the timing of the temperature changes is generally good. The temperature forecast is further improved by post processing, although this may seem less clear from the statistics. The mean abslute error shows smaller errors for the post processed temperature than temperature from MEPSctrl, especially for inland stations. The mean error shows a small positive bias for YrPP, while MEPSctrl is more varying.

The upgrade of MEPS from cycle 40 to cycle 43 in the end of March 2021 had some effect on near surface temperatures. The new physiography data set - ECOCLIMAP Second Generation - has a new albedo data set leading to a slight increase in daytime temperatures in the summer season. The upgrade included also a change to improve the performance in stable situations, a change that in the spring worked as intended in the coldest situations, but which also reduced the temperatures in some situations and at some locations that already were too cold. A change in the radiation physics that takes the effect of thin ice clouds better into account was introduced 1 June 2021. The effect of the changes in the radiation physics can be compared to laying a “carpet” on the ground. Problems of too cold forecasts were reduced, but there has also been examples of too warm forecasts. When evaluating the combined effect of all changes in the first ”winter episode” in the end of November, it may look like the “carpet” is too thick, as the near surface temperatures were in many situations not cold enough.

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 clearly performs better than ECMWF for mountainous stations, where ECMWF underestimates the speed considerably as seen in the monthly mean error. ECMWF has also some underestimation of the wind speed at coastal stations, but lower SDE than MEPSctrl. Time series from wind exposed stations show that the strong wind events often are underestimated. The threshold scores indicate that wind speed is better forecast for lower than for higher wind speeds for all models. Otherwise, the results are ambiguous. Post processing yields in general smaller errors, but only slightly better threshold scores.

The near surface wind speeds are affected by the upgrade to cycle 43 both by modifications in the turbulence scheme and by the physiography upgrade. ECOCLIMAP Second Generation has new tree heights and a more “binary” separation between patch 1 (low vegetation) and 2 (trees). The largest effect of the change is in the autumn seen at Svalbard stations, which on average had mean error between 0.5 and 1 m/s, and at Svalbard airport 0.9 m/s. The performance of AA24 and MEPSctrl were similar with respect to wind speed when evaluated at North Scandinavian stations. Time series of wind speed and direction also shows quite impressive results, e.g. from Troll and Finsevatn.

Precipitation also shows varying results, depending on the amount and location. On average, MEPSctrl performs a little better than ECMWF, but both have more errors for both very small amounts and very high amounts than precipitation in the mid range. Both models tend to overestimate precipitation, but more so for ECMWF. The maps indicate that overestimation is more evident in areas with high amounts of precipitation.

The models generally perform better during summer months than during winter. A possible cause is that storm activity is challenging to predict accurately, and there are often more storms during fall and winter than during summer. Precipitation is an exception from this trend, as summer often comes with convective cases that are challenging to predict. AA25 and MEPSctrl show very similar results, which is expected since both are HARMONIE with AROME physics, horizontal resolution defined by a 2.5×2.5 km^2 grid.

Case studies by forecasters

In the period September to November there were altogether six reports on precipitation from the MetCoOp and Arctic domains, for three different weather types: Missing frontal or convective precipitation (3), too high maxima or stationary precipitation (2), and sensitivity to the domain border (1). In addition there were several reports on small differences between the current MEPS-prod and the new MEPS-preop, mainly that the new version is better to release precipitation closer to the coast than the MEPS-prod.

Case 1. Missing convective precipitation, 7 October 2021

Figure 1 shows a typical case of missing shallow precipitation from Troms and West Finnmark in October 2021 as seen from MEPSctrl. Similar lack of precipitation was found in all ensemble members, so EPS-based forecasts, e.g. on yr.no gave the same picture. This situation lasted from 06 UTC on 7 October till 03 UTC on the 8, and was strongly perceived as a faulty forecast by the public.

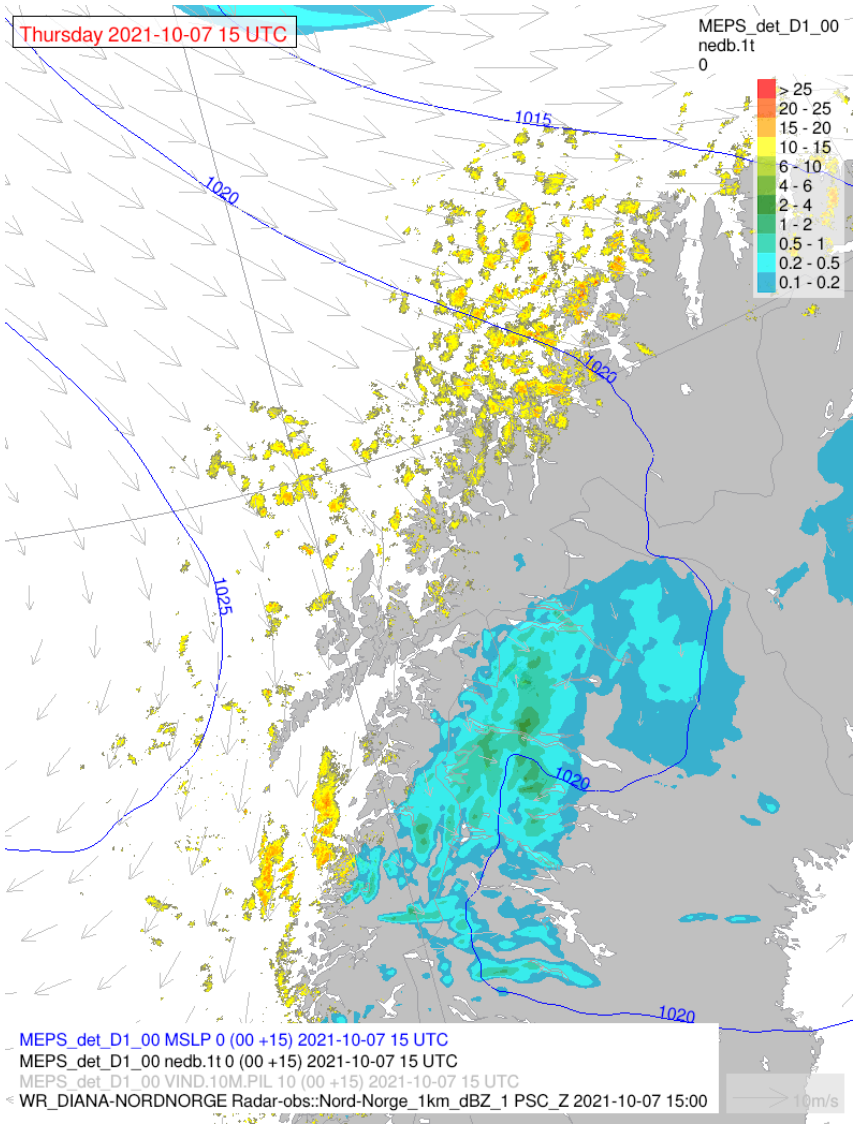


Figure 1: Typical case of missing shallow precipitation from Troms and West Finnmark in October 2021 as seen from the MEPSctrl.

Case 2. Stationary precipitation in complex topography, 12 September 2021

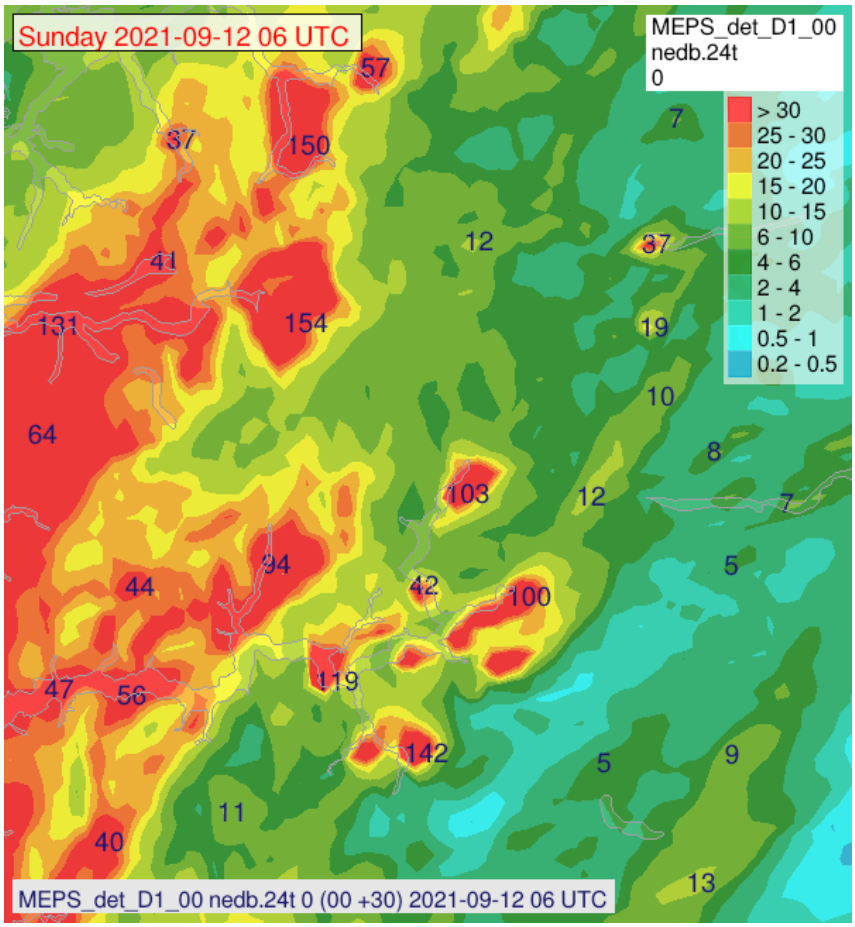


Figure 2: Stationary showers from MEPSctrl in the terrain around inner parts of the Sognefjorden.

Stationary showers from MEPSctrl in the terrain around inner parts of the Sognefjorden (figure 2) gave values of more than 100 mm/24h precipitation at some locations. This is despite the situation was quite transient, with the showers following a weak 5 to 15kt wind at 850 to 500 hPa, and moving in an easterly direction across the terrain. The wind below 850 was weak or variable. Observations (figure 3) indicated 10-20 mm in the area, although these did probably not capture the maxima in the area. The prognosed maxima had effect on the YR forecasts in populated areas like e.g. Sogndal, through an impact on the 15×15 grid for the area. According to forecasters at VpV/Bergen this has been a recurrent situation this summer.

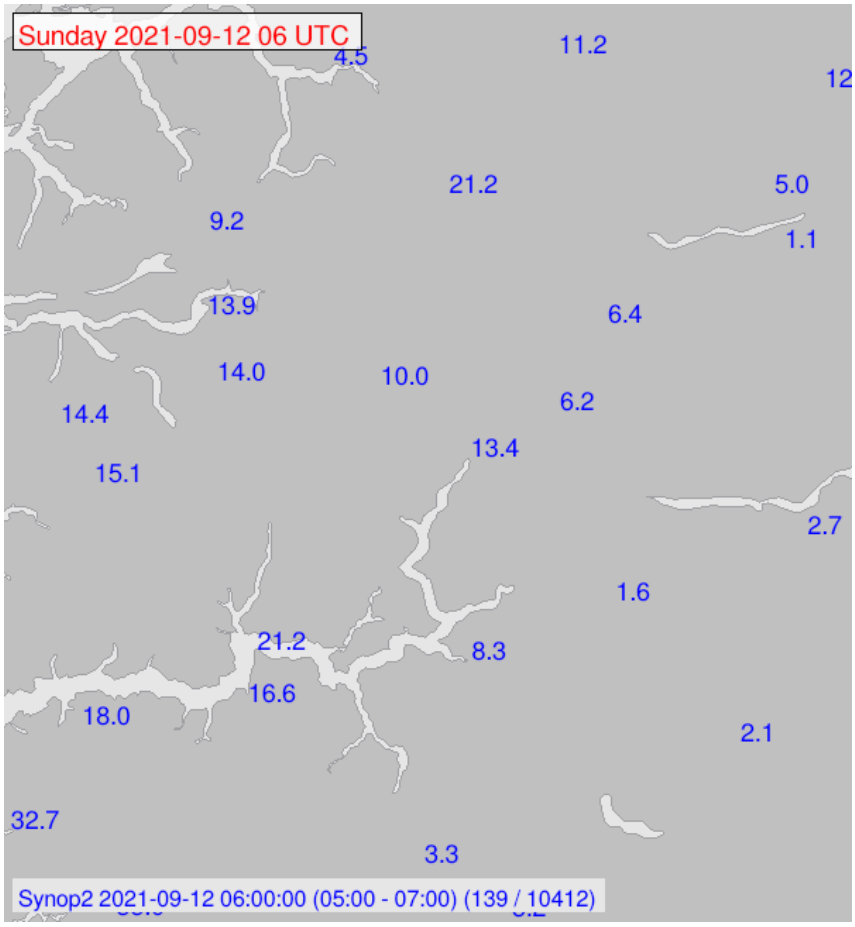


Figure 3: Observations of 24h precipitation at 06 UTC on 12 September.

Case 3. Missing precipitation due to the proximity to the domain border, 7 September 2021

On 7 September an atmospheric river formed between Iceland and Scotland, with large scale convergence at approximately 20W and a long uptake of sensible heat and moisture all the way to the coast of Trøndelag. The episode gave 105.5 mm/24h in the Fosen area. ECMWF-Hires with 30 hours lead time did forecast this precipitation quite well (figure 4), with a forecasted 103 mm in the right position. MEPS have the domain border at approximately 5E, and sets hydrometers at zero at the border. It had no precipitation for about 100 km downstream from the border, and in the Fosen area MEPSctrl had only 62mm/24hr at 30hrs lead time, thus severely underforecasting the precipitation (figure 5). Figure 6 shows the situation on 8 September.

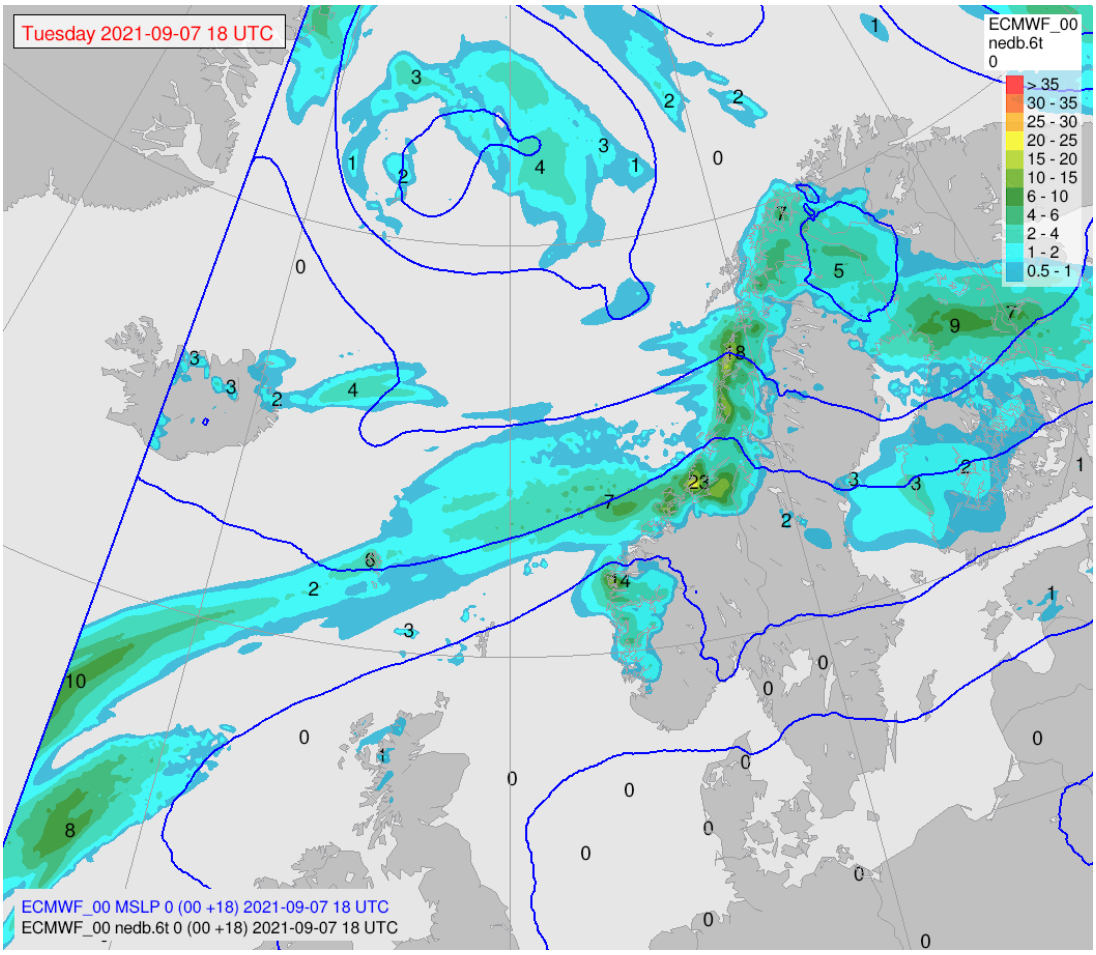


Figure 4: 6h precipitation from ECMWF-Hires with 18 hours lead time at 18 UTC on 7 September. This plot is only showing a part of the global ECMWF domain covering Scandinavia and the North Atlantic, for use at MET Norway.

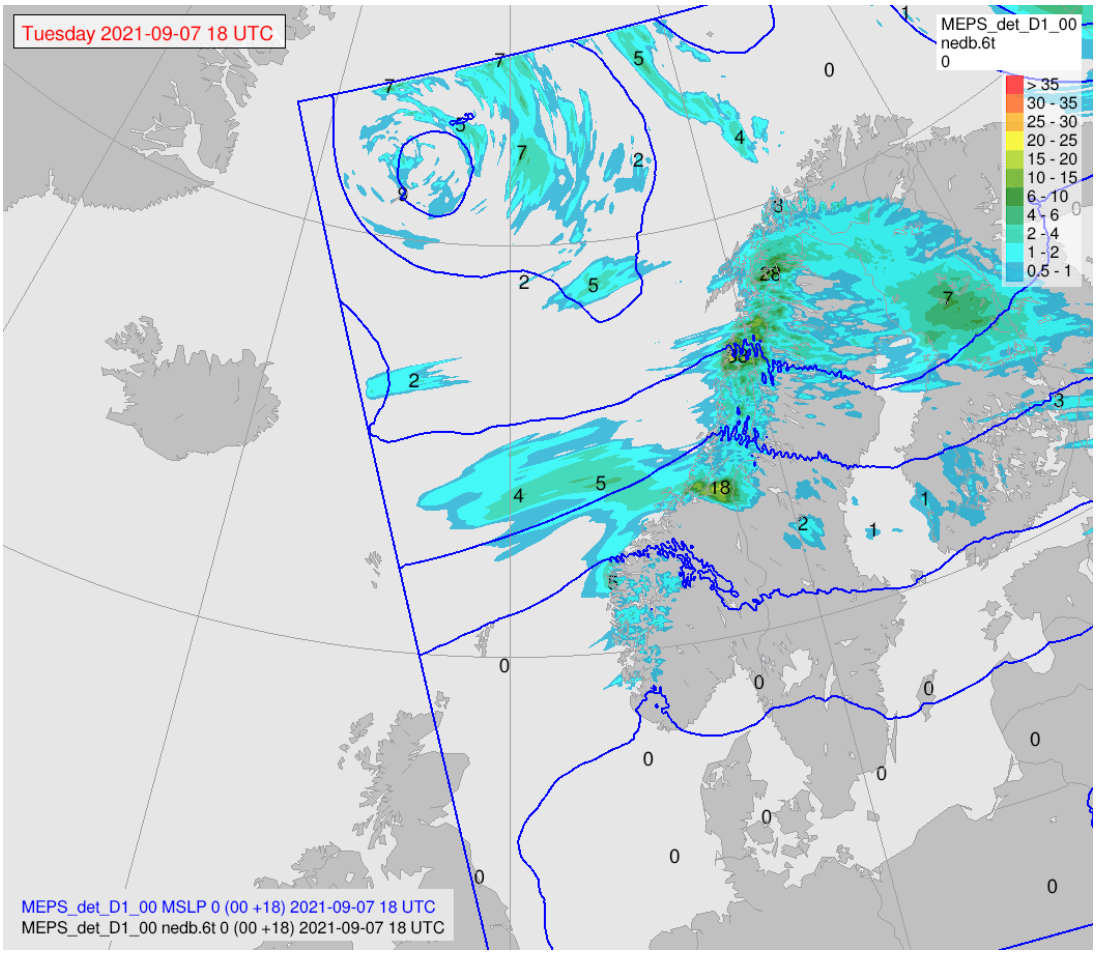


Figure 5: 6h precipitation from MEPSctrl with 18 hours lead time at 18 UTC on the 7 September.

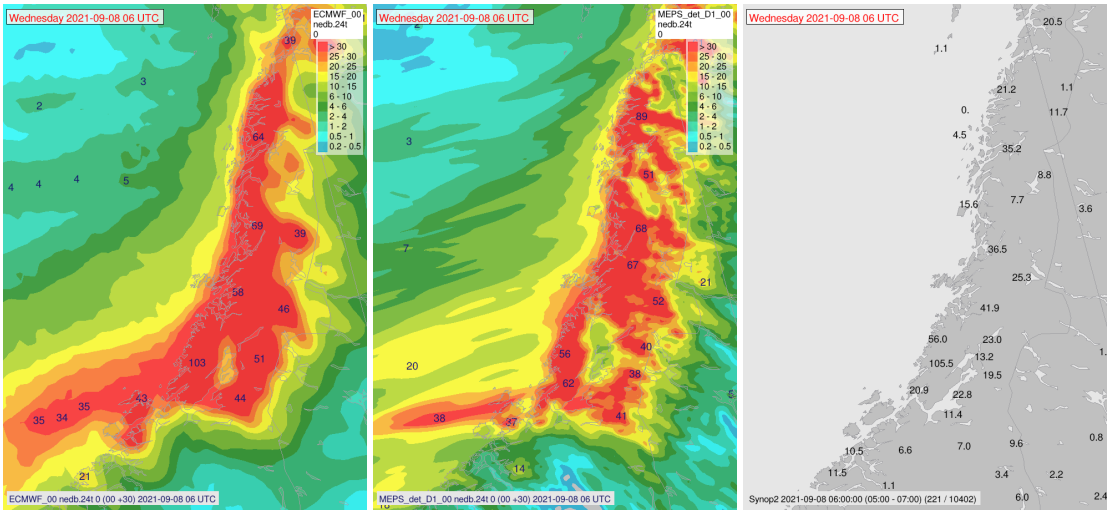
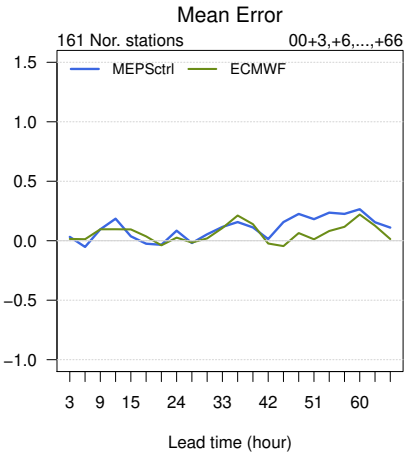
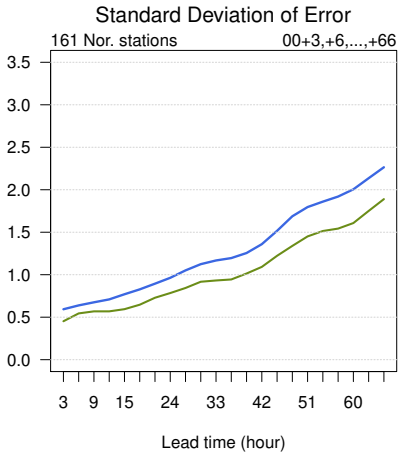
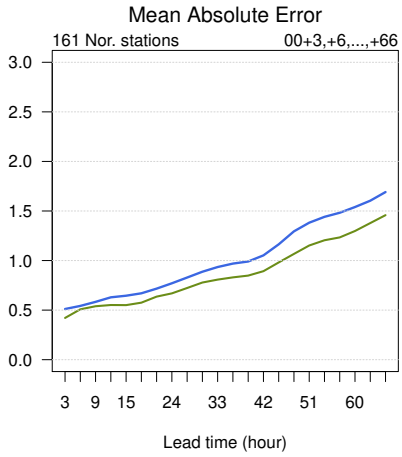


Figure 6: 24h precipitation at 06 UTC on the 8 September, from EC (left), from MEPS (middle) and observed (right).

Summarized statistics


Mean Error
161 Nor. stations
00+3,+6,...,+66
MEPSctrl
ECMWF
1.5
1.0
0.5
0.0
−0.5
−1.0
3 9 15 24 33 42 51 60
Lead time (hour)


Standard Deviation of Error
161 Nor. stations
00+3,+6,...,+66
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
3 9 15 24 33 42 51 60
Lead time (hour)


Mean Absolute Error
161 Nor. stations
00+3,+6,...,+66
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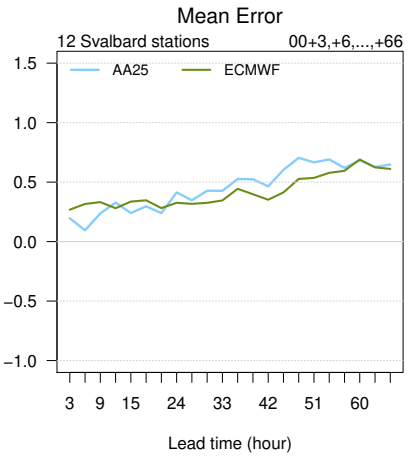
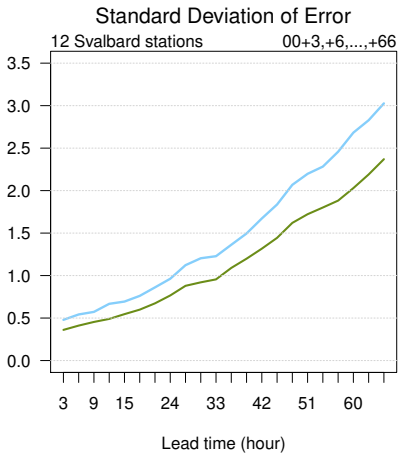
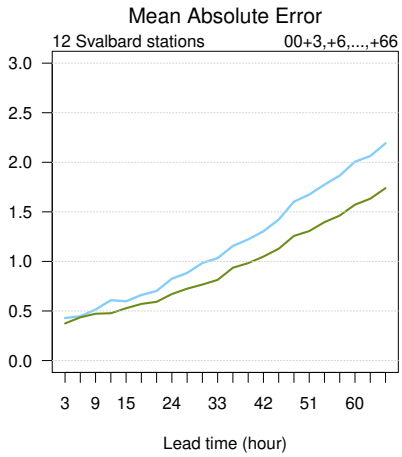
2.5
2.0
1.5
1.0
0.5
0.0
3 9 15 24 33 42 51 60
Lead time (hour)


Mean Error
12 Svalbard stations
00+3,+6,...,+66
AA25
ECMWF
1.5
1.0
0.5
0.0
−0.5
−1.0
3 9 15 24 33 42 51 60
Lead time (hour)


Standard Deviation of Error
12 Svalbard stations
00+3,+6,...,+66
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
3 9 15 24 33 42 51 60
Lead time (hour)


Mean Absolute Error
12 Svalbard stations
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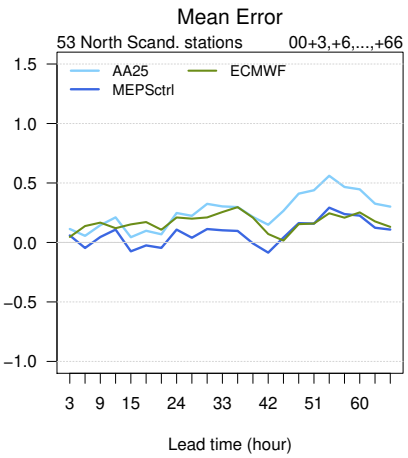
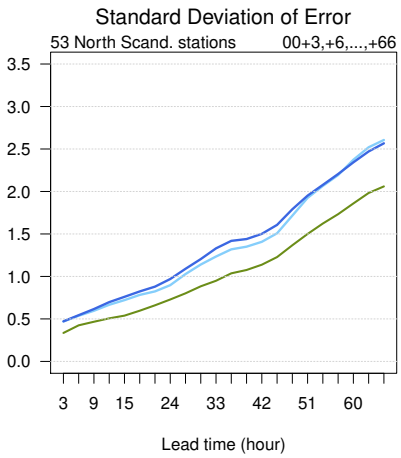
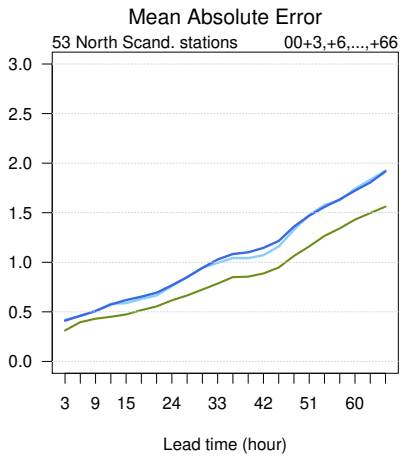
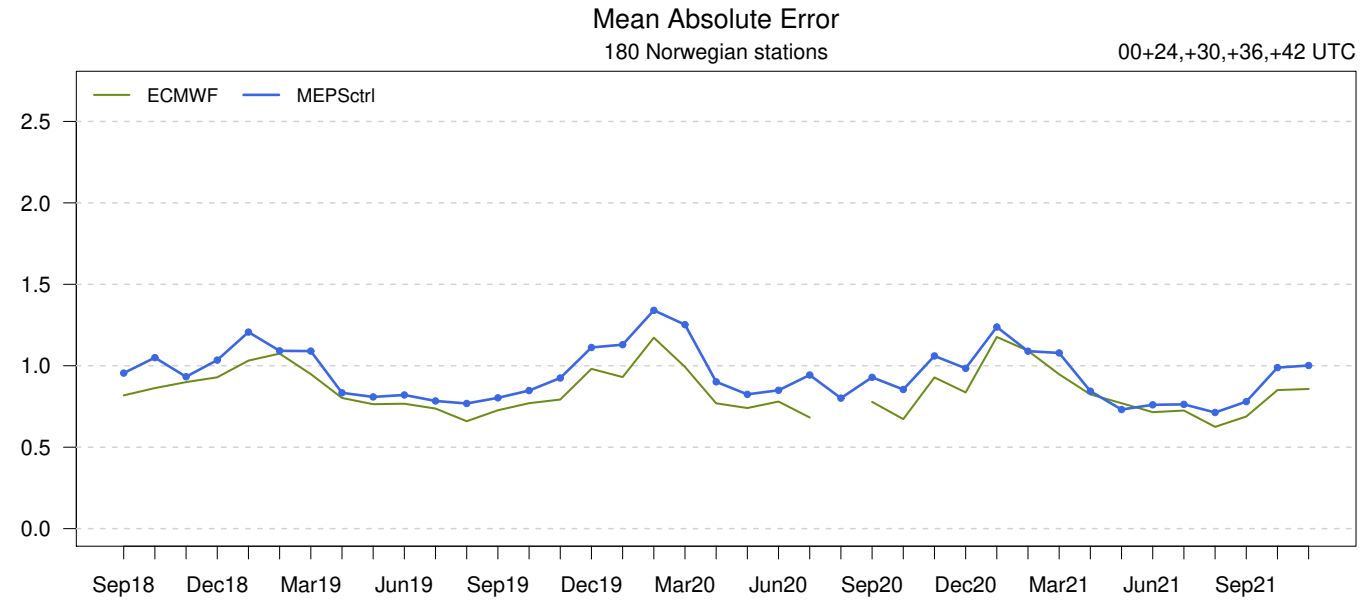
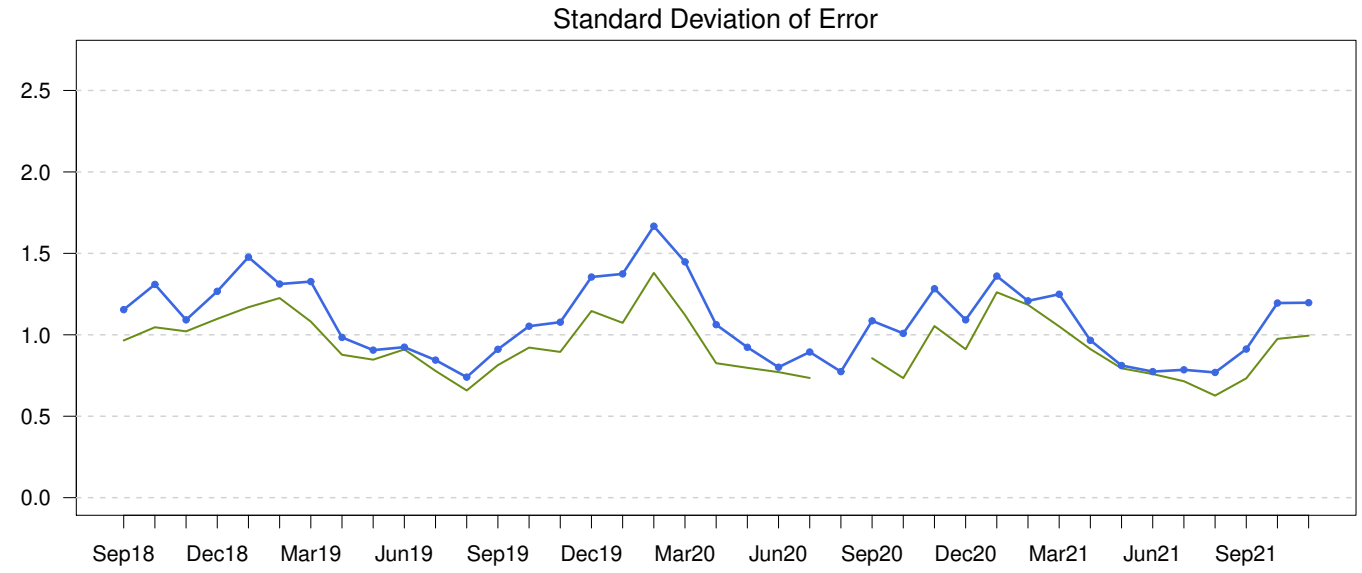
3.0
2.5
2.0
1.5
1.0
0.5
0.0
3 9 15 24 33 42 51 60
Lead time (hour)

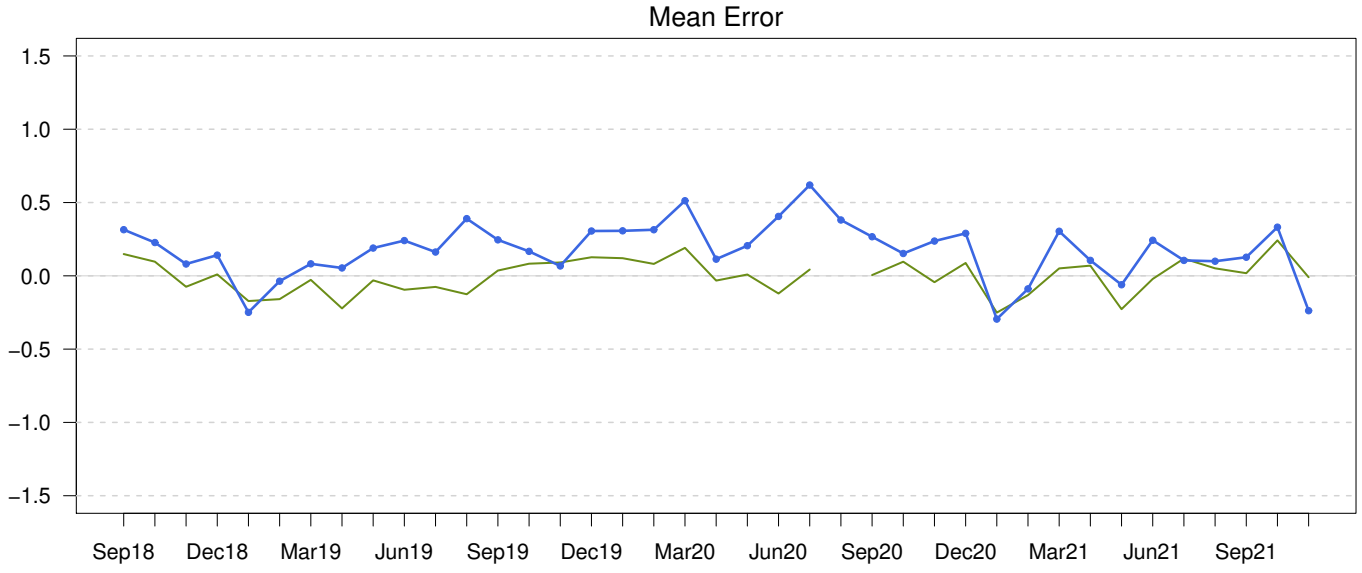

Mean Error
53 North Scand. stations
00+3,+6,...,+66
AA25
ECMWF
MEPSctrl
1.5
1.0
0.5
0.0
−0.5
−1.0
3 9 15 24 33 42 51 60
Lead time (hour)

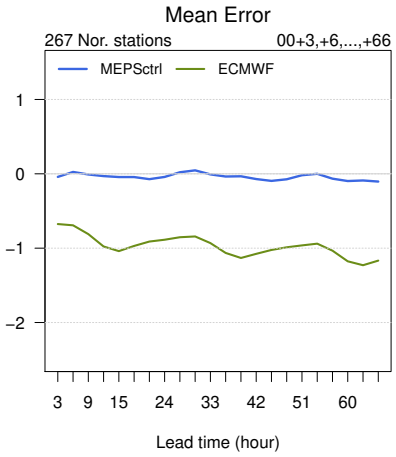

Standard Deviation of Error
53 North Scand. stations
00+3,+6,...,+66
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
3 9 15 24 33 42 51 60
Lead time (hour)

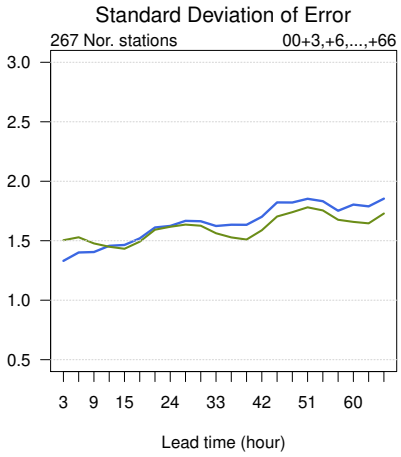

Mean Absolute Error
53 North Scand. stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
0.0
3 9 15 24 33 42 51 60
Lead time (hour)

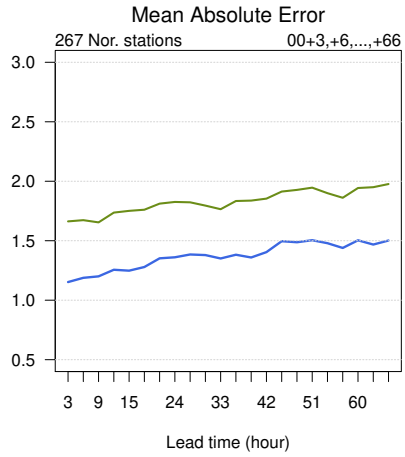

Mean Absolute Error
180 Norwegian stations
00+24,+30,+36,+42 UTC
ECMWF
MEPSctrl
2.5
2.0
1.5
1.0
0.5
0.0
Sep18
Dec18
Mar19
Jun19
Sep19
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21

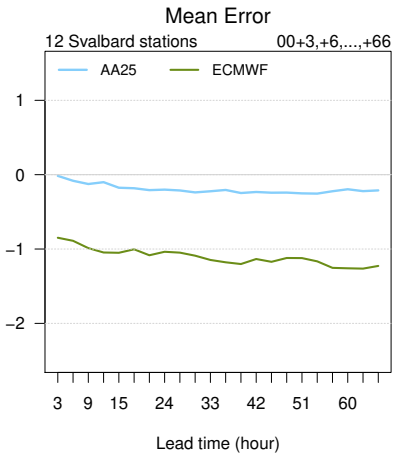

Standard Deviation of Error
2.5
2.0
1.5
1.0
0.5
0.0
Sep18
Dec18
Mar19
Jun19
Sep19
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21

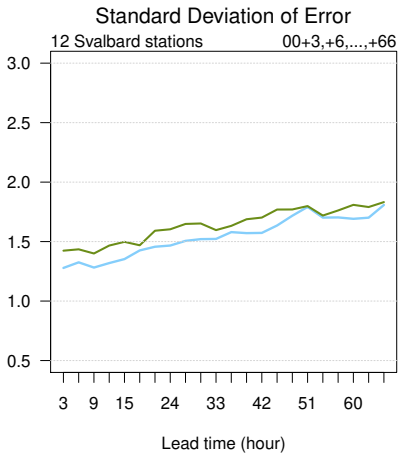

Mean Error
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
Sep18
Dec18
Mar19
Jun19
Sep19
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21

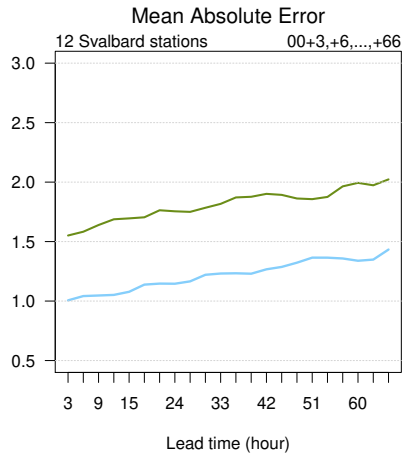

Mean Error
267 Nor. stations
00+3,+6,...,+66
MEPSctrl
ECMWF
1
0
−1
−2
3 9 15 24 33 42 51 60
Lead time (hour)

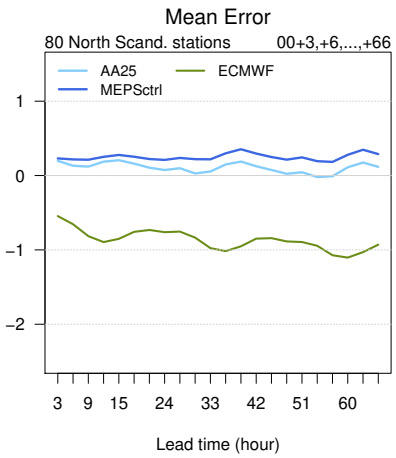

Standard Deviation of Error
267 Nor. stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)

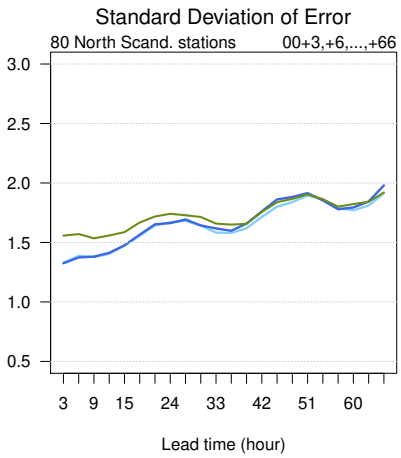

Mean Absolute Error
267 Nor. stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)

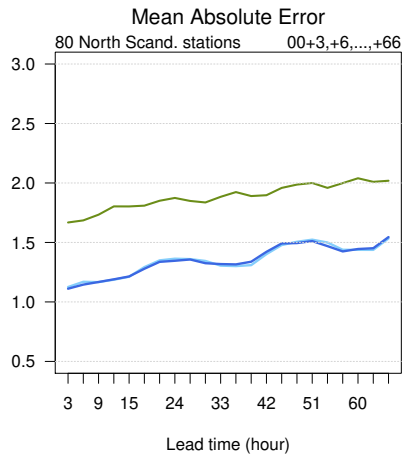

Mean Error
12 Svalbard stations
00+3,+6,...,+66
AA25
ECMWF
1
0
−1
−2
3 9 15 24 33 42 51 60
Lead time (hour)


Standard Deviation of Error
12 Svalbard stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)


Mean Absolute Error
12 Svalbard stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)

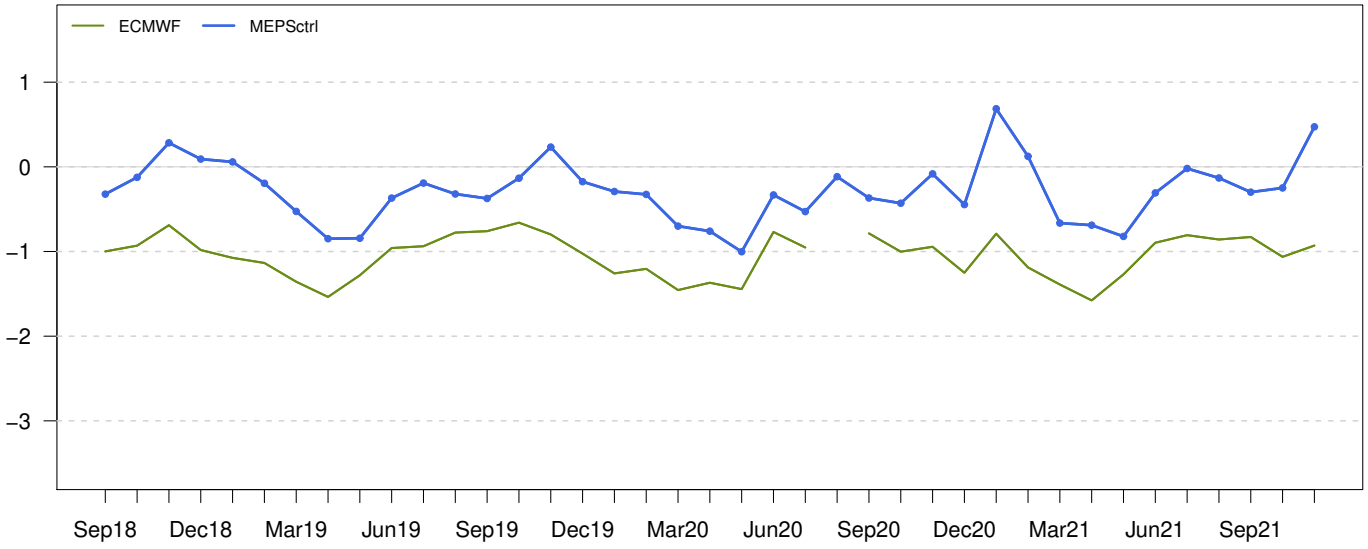

Mean Error
80 North Scand. stations
00+3,+6,...,+66
AA25
ECMWF
MEPSctrl
1
0
−1
−2
3 9 15 24 33 42 51 60
Lead time (hour)


Standard Deviation of Error
80 North Scand. stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)

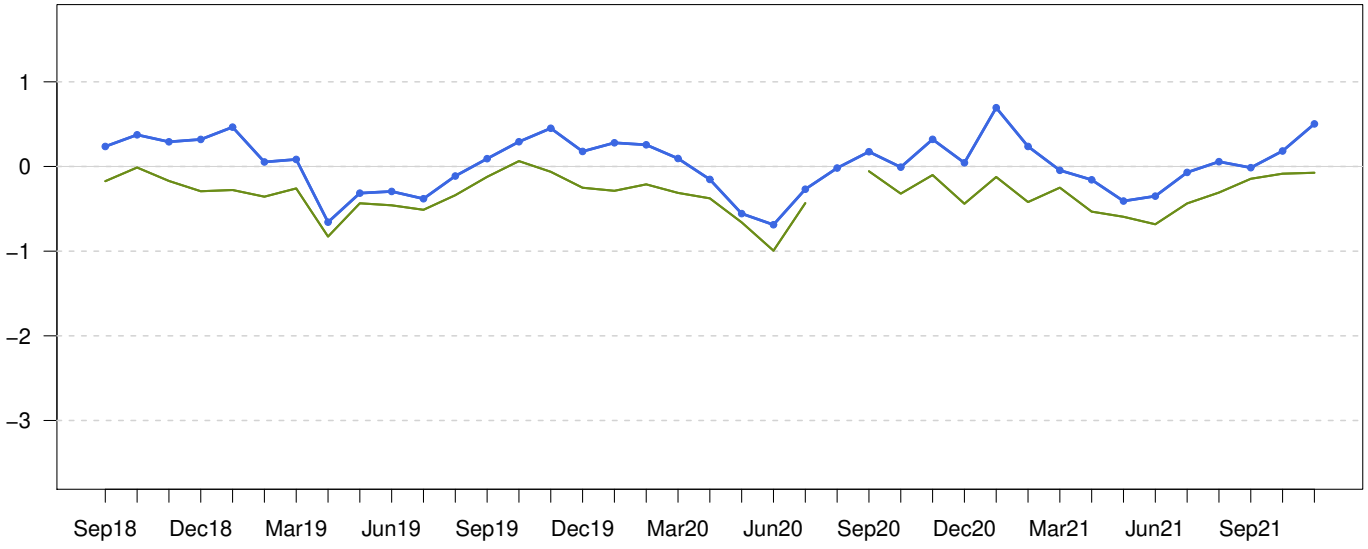

Mean Absolute Error
80 North Scand. stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)

Mean Error

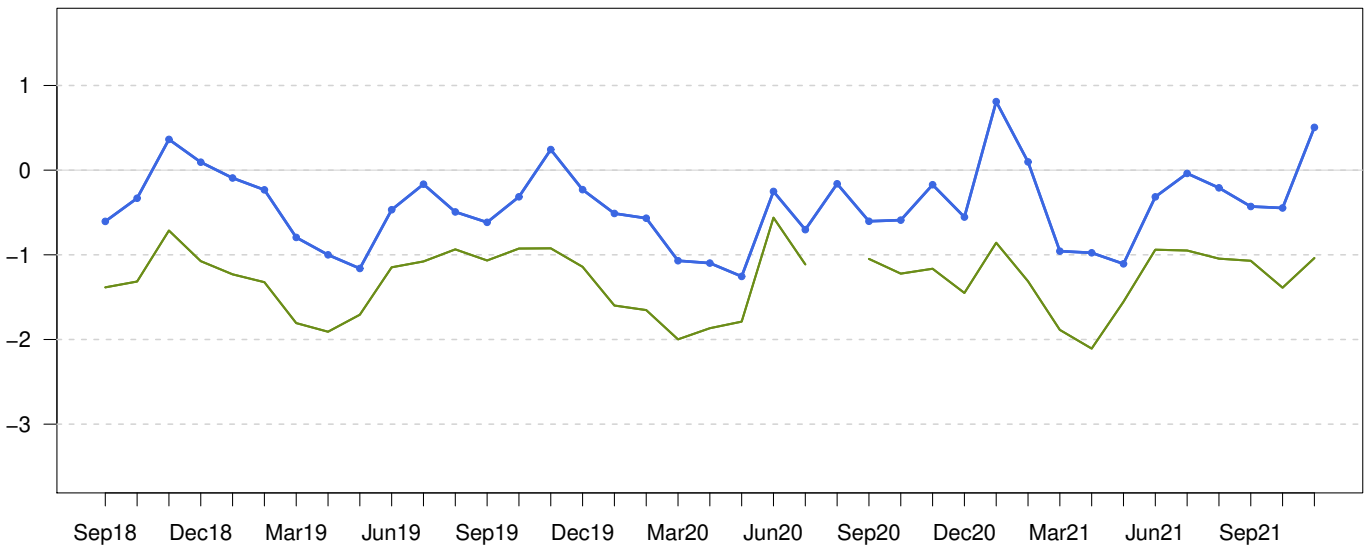
275 Norwegian stations 00+24,+30,+36,+42 UTC



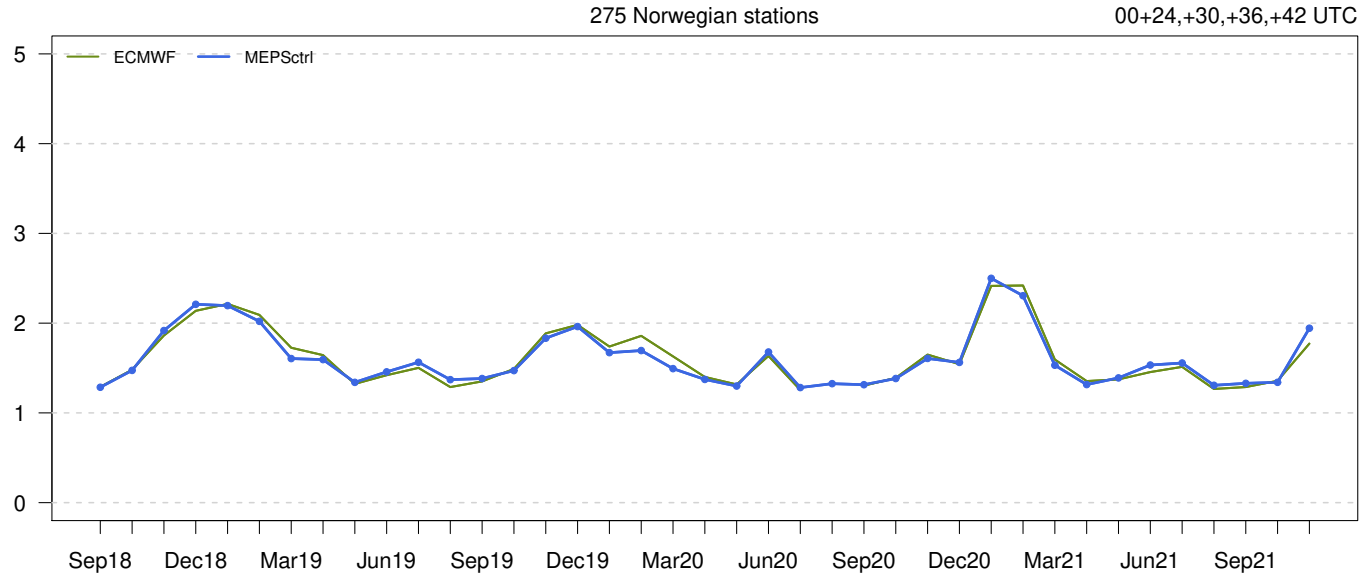
54 Norwegian coastal stations

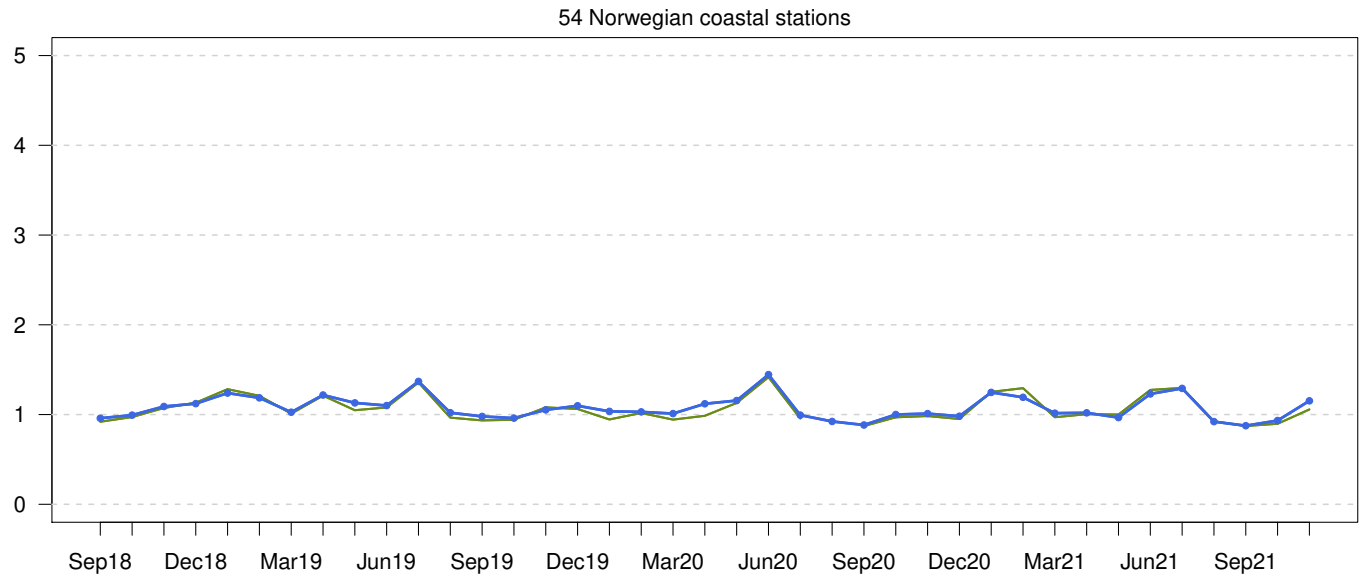


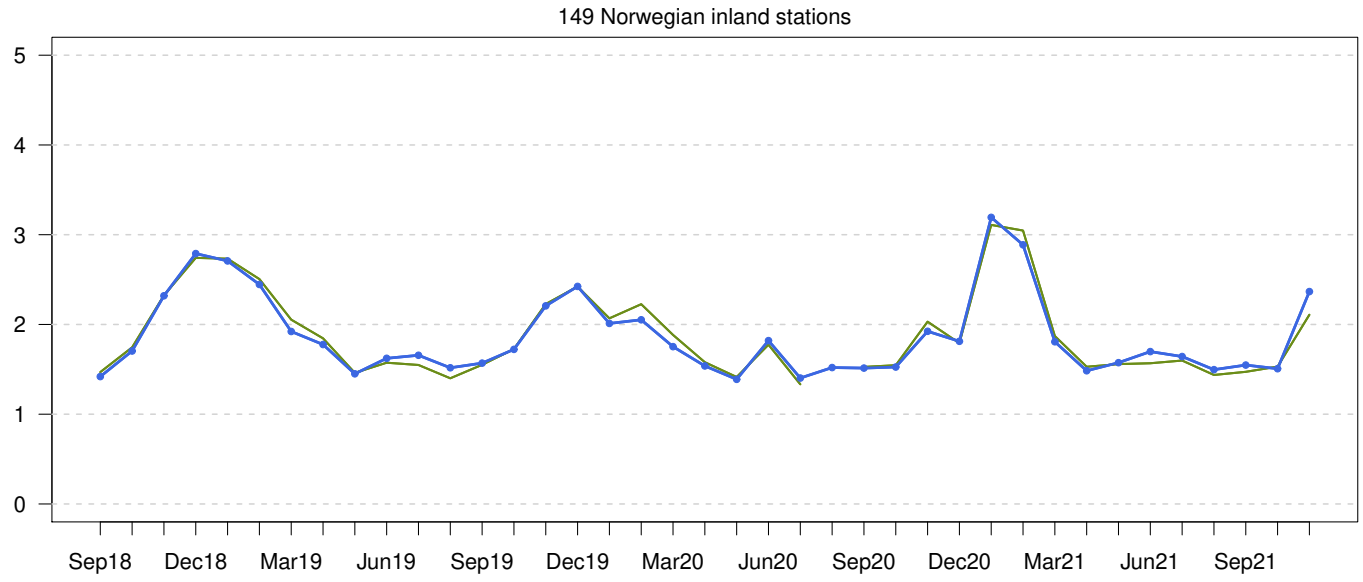
149 Norwegian inland stations



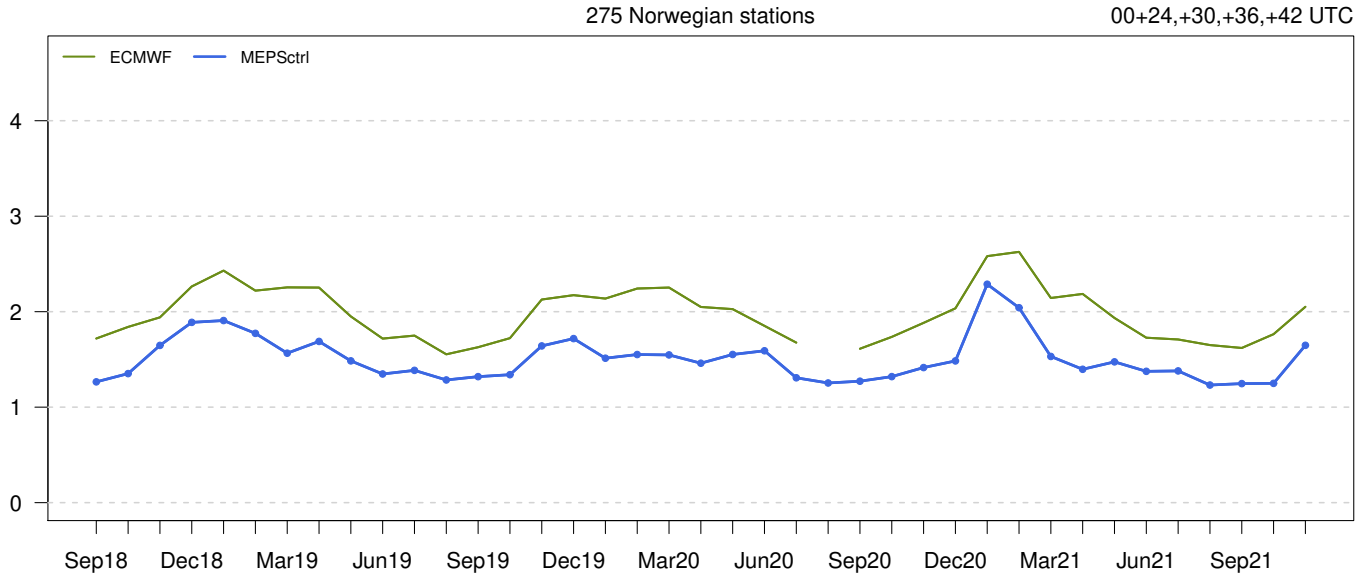
Standard Deviation of Error

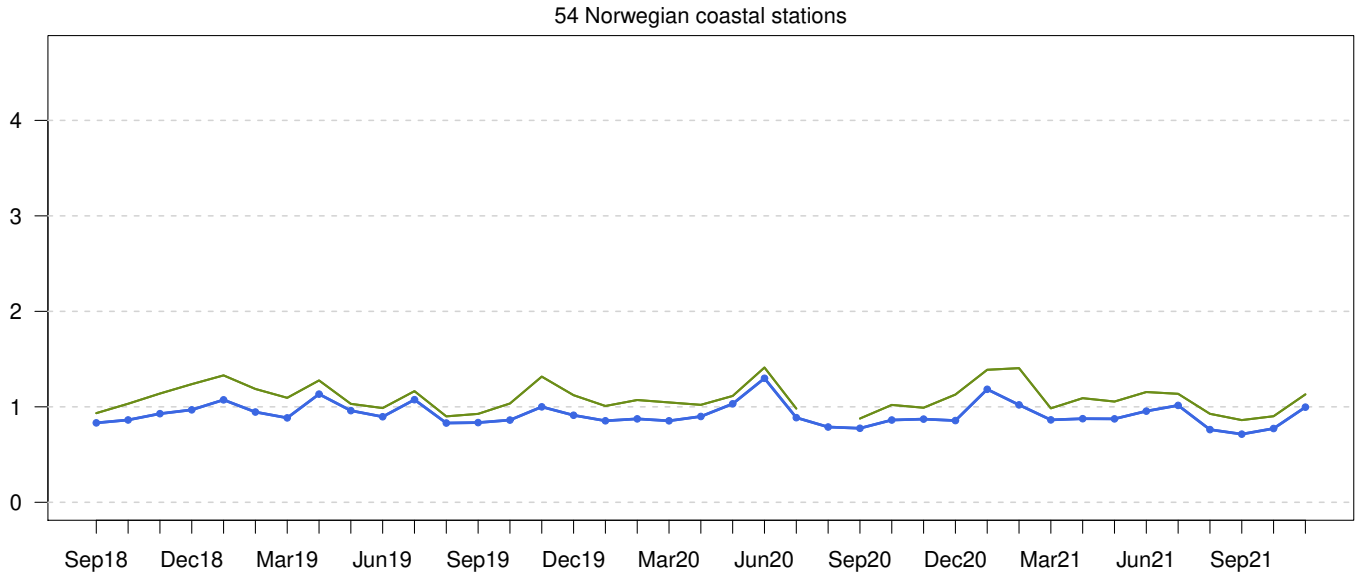


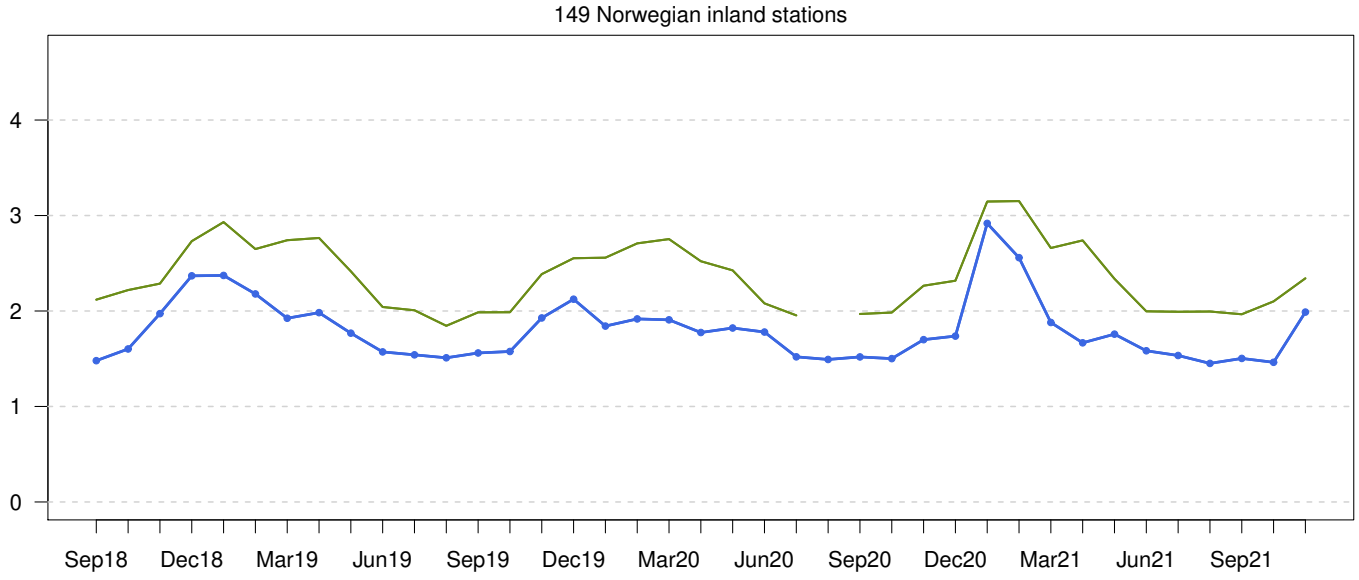




Mean Absolute Error

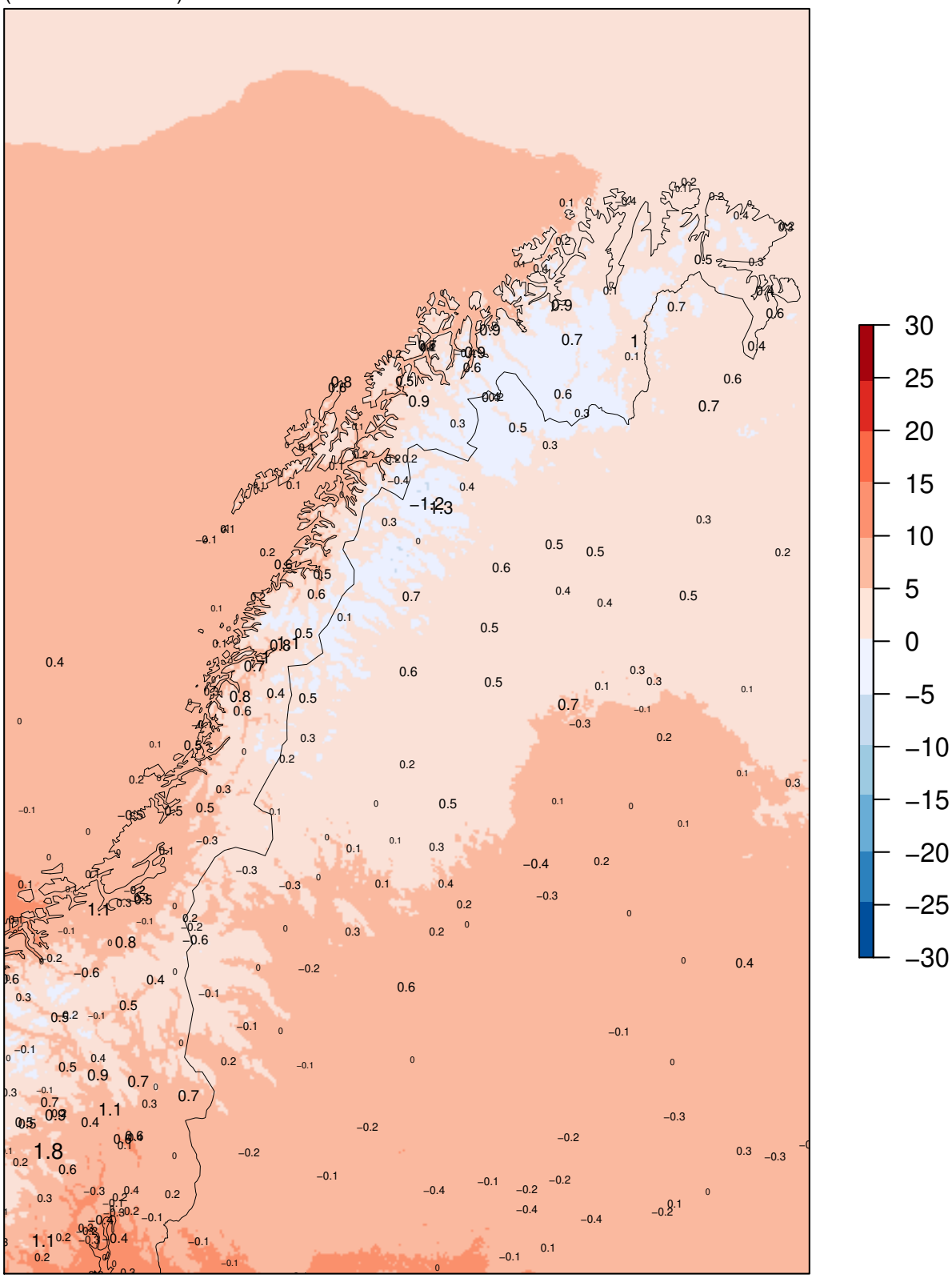






MEPSctrl 00+12

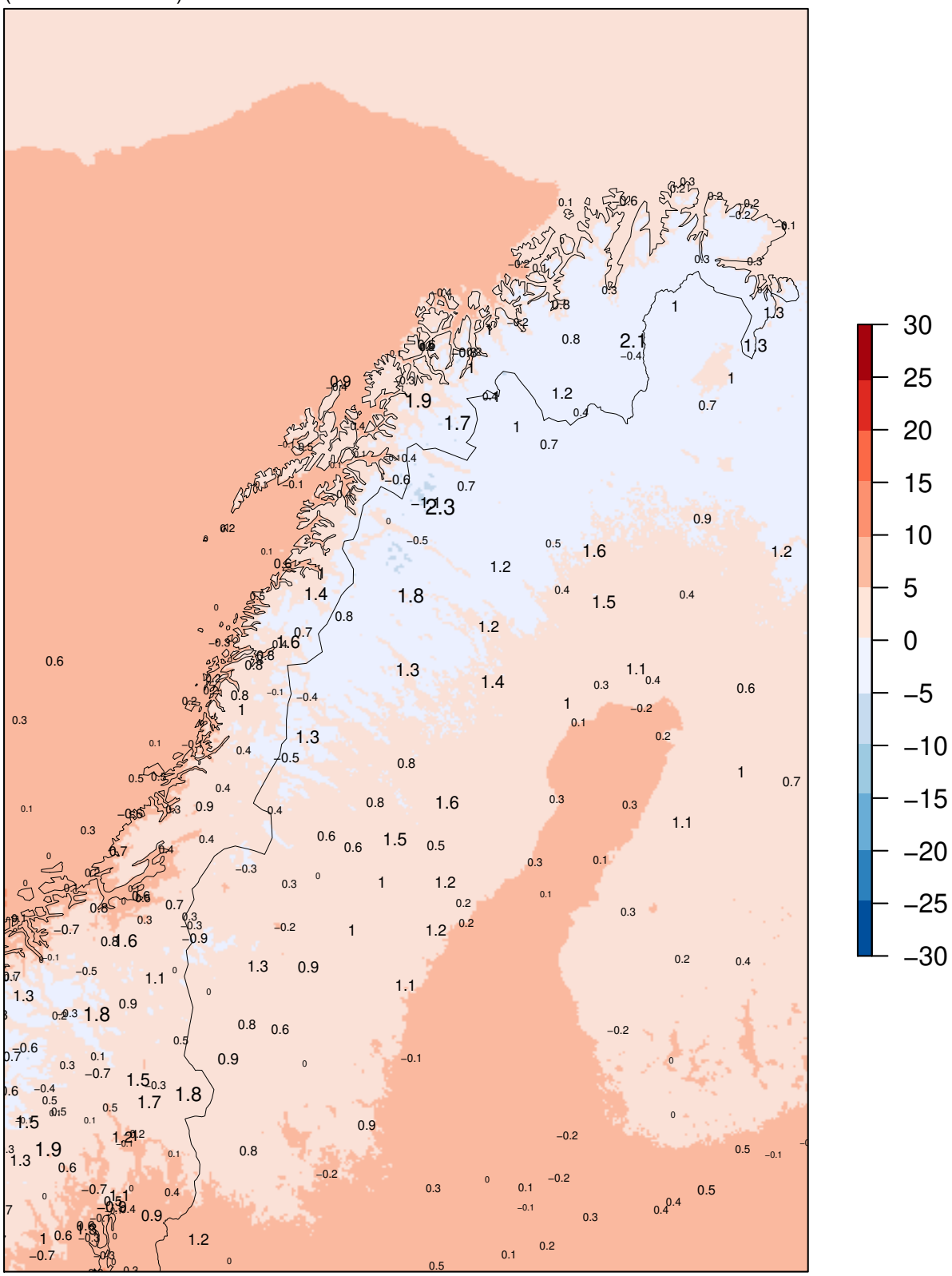
ME at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+24

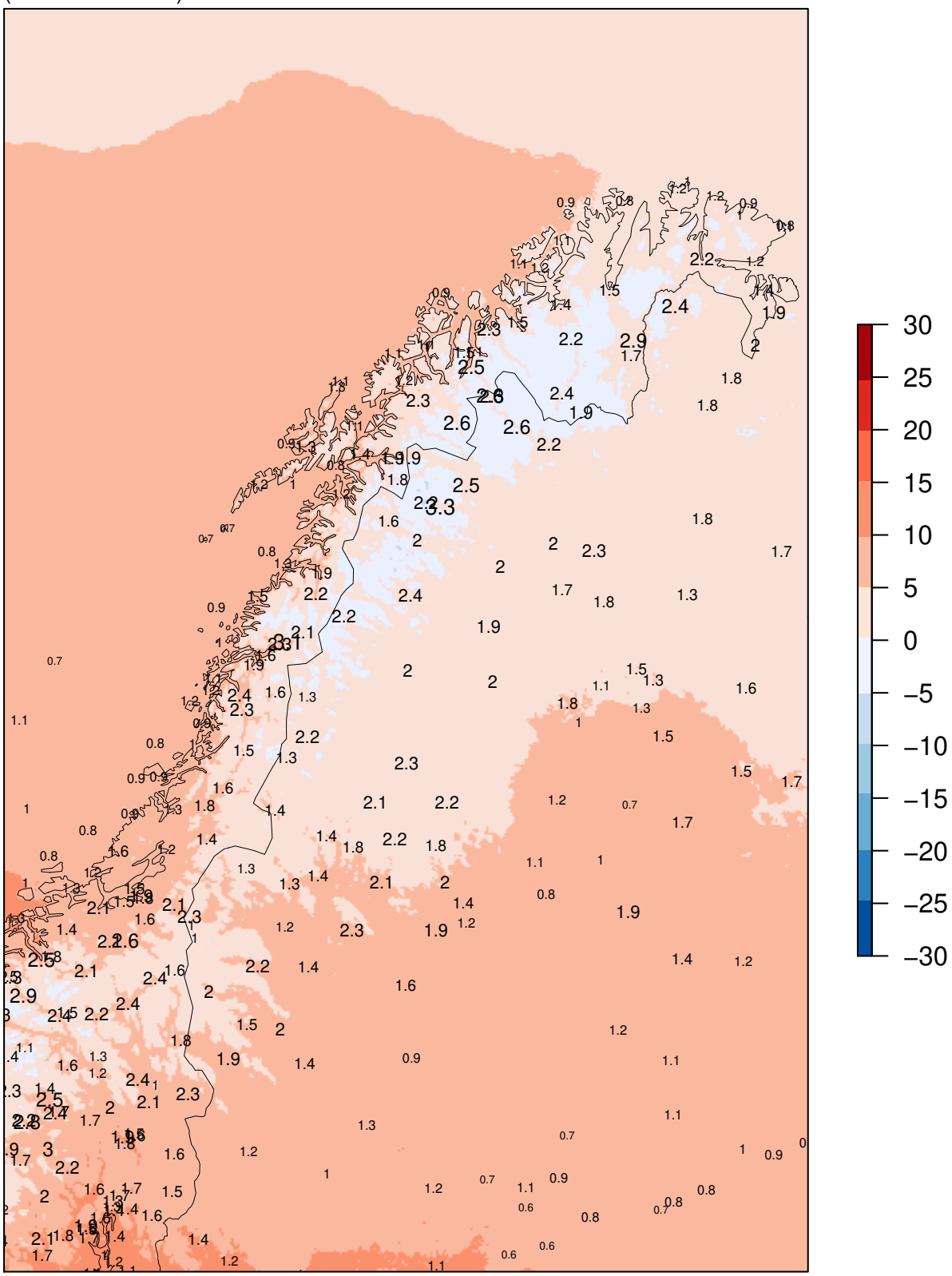
ME at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+12

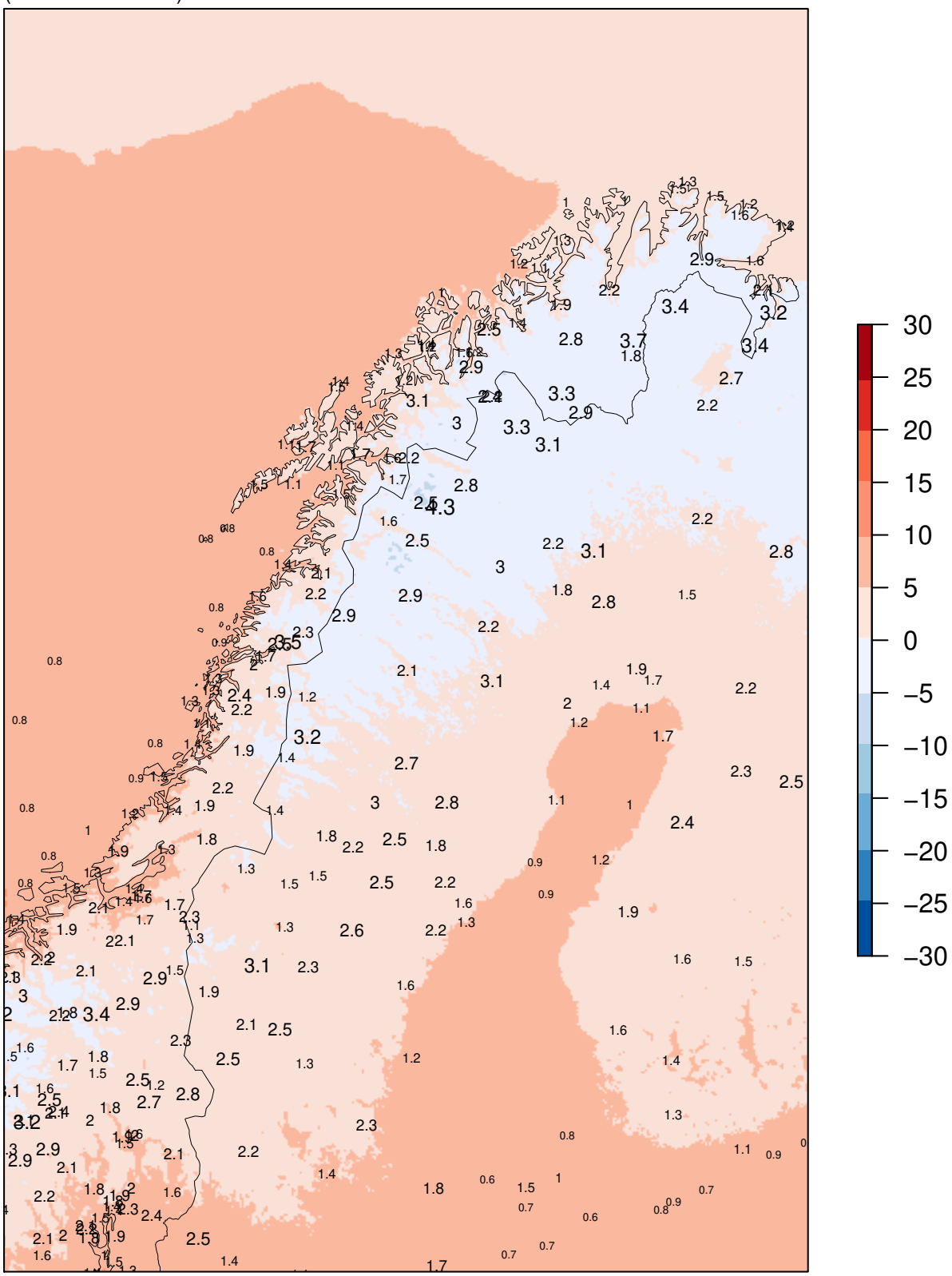
SDE at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+24

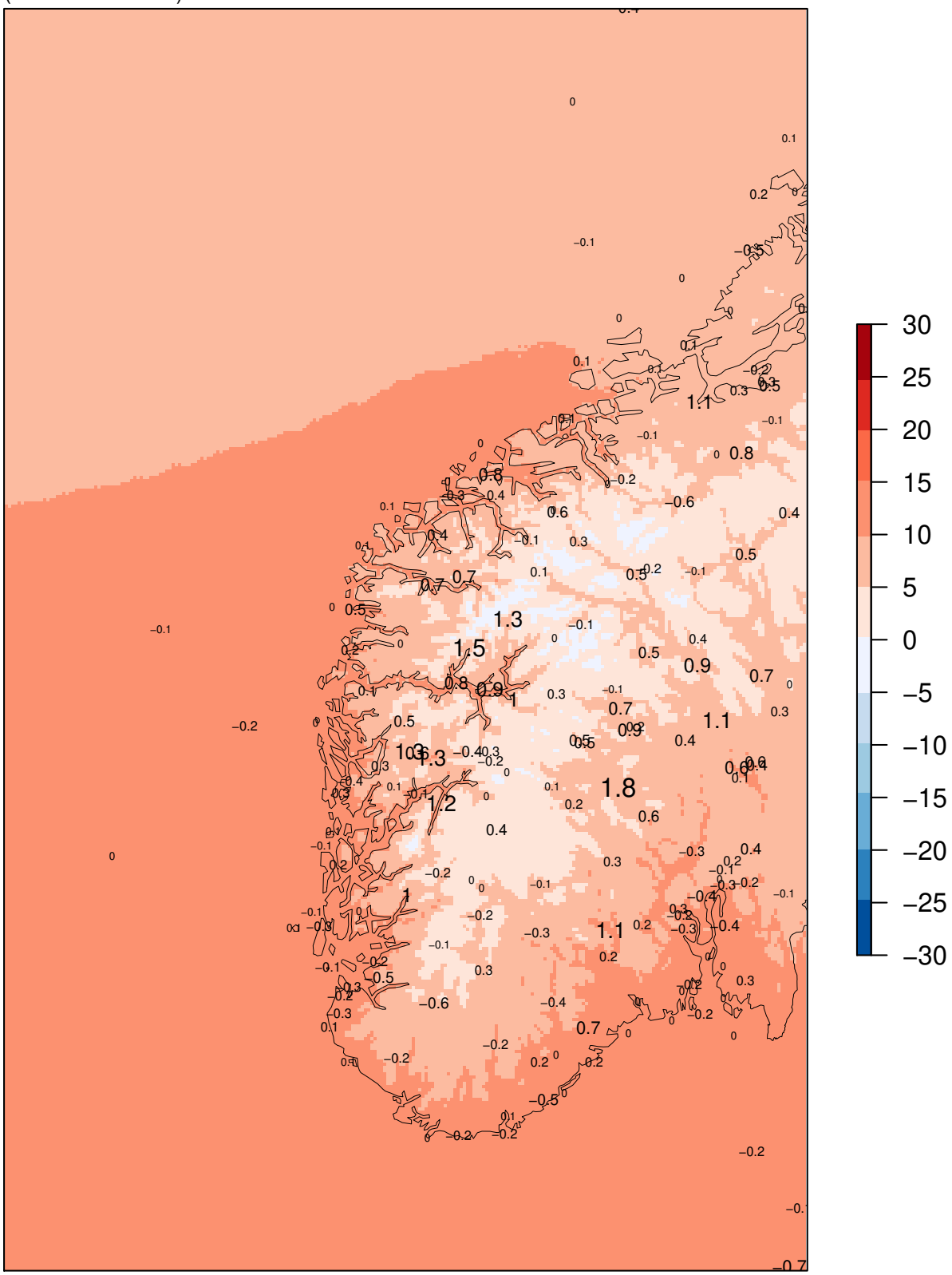
SDE at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+12

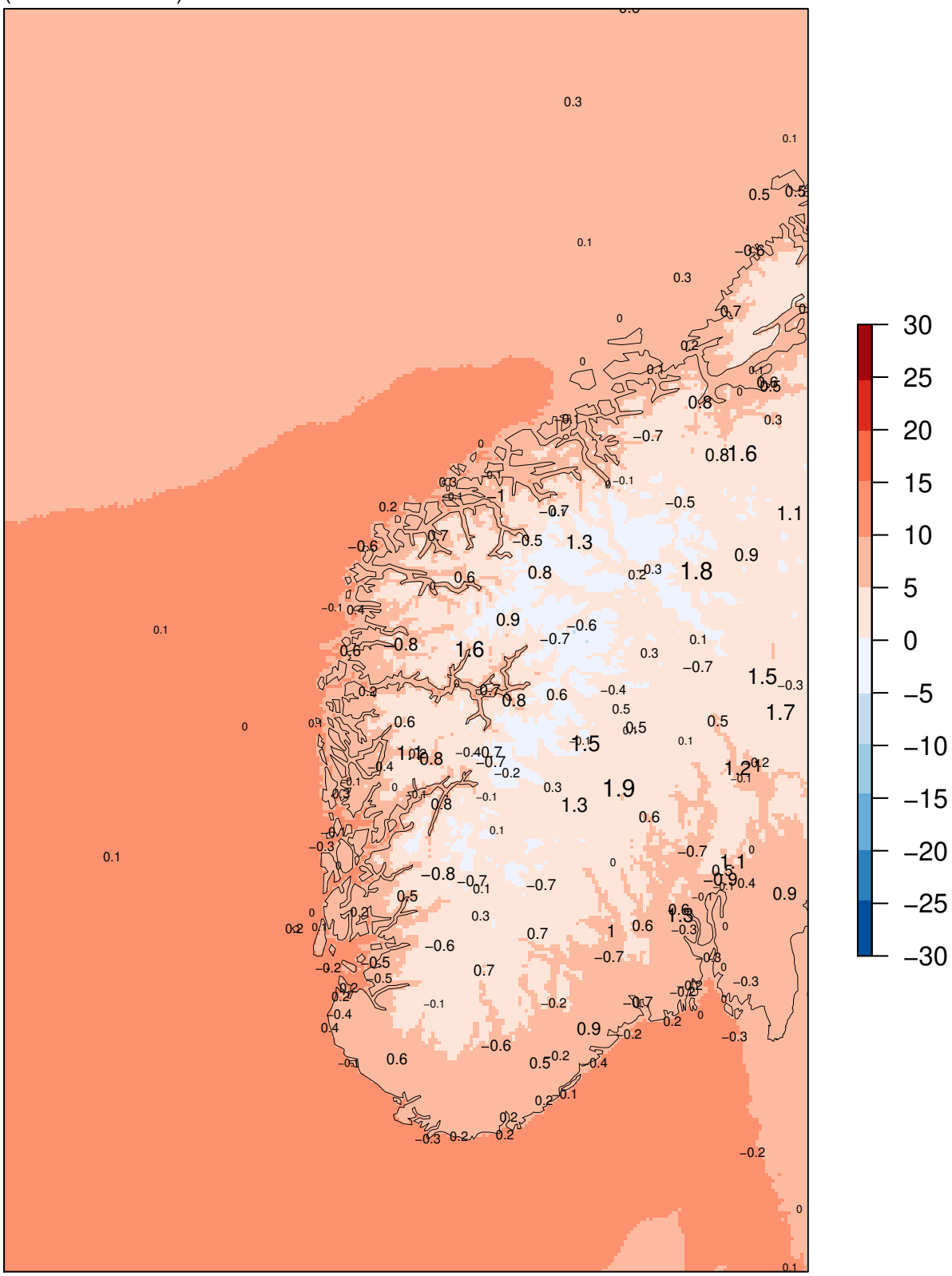
ME at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+24

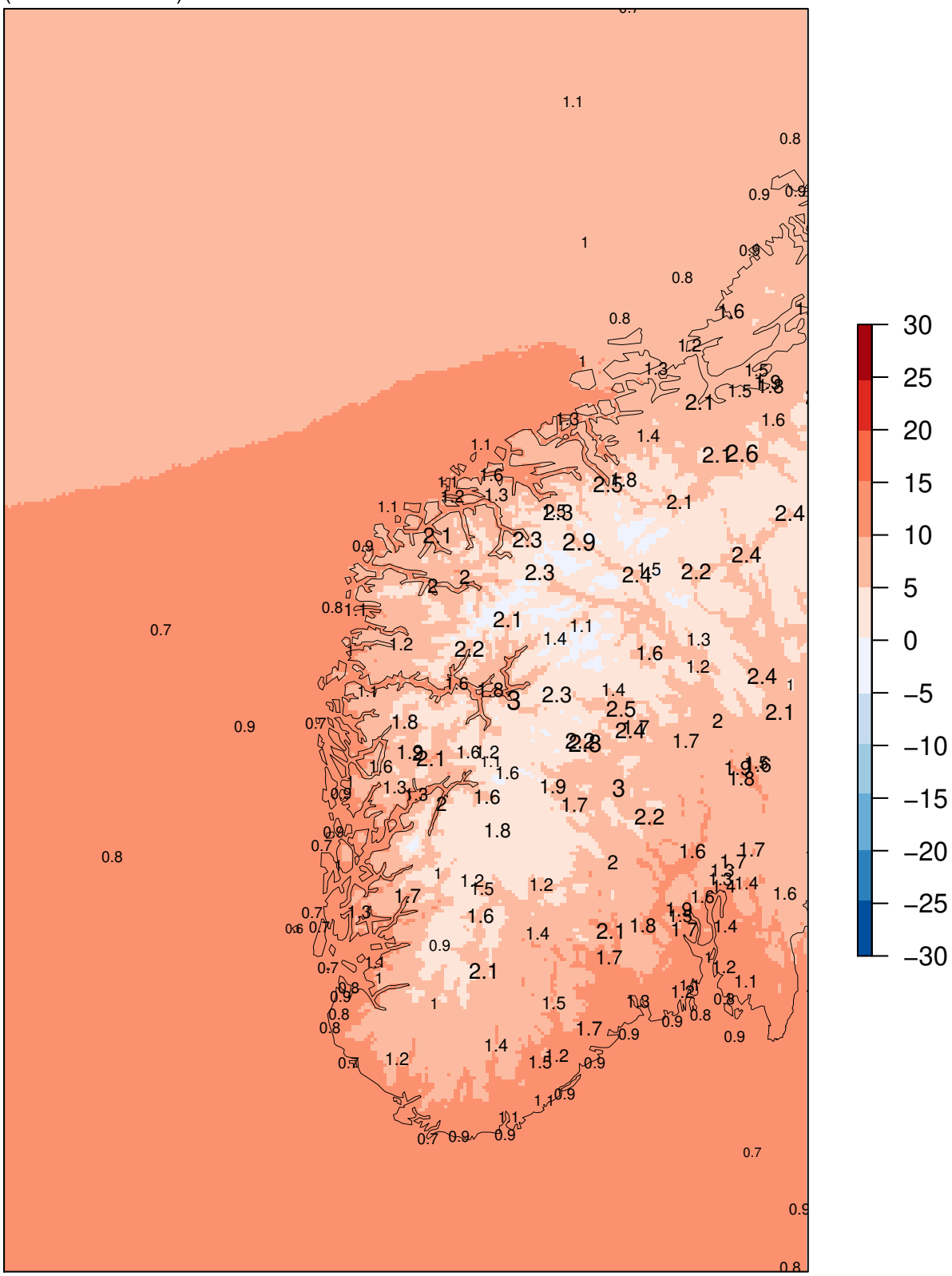
ME at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+12

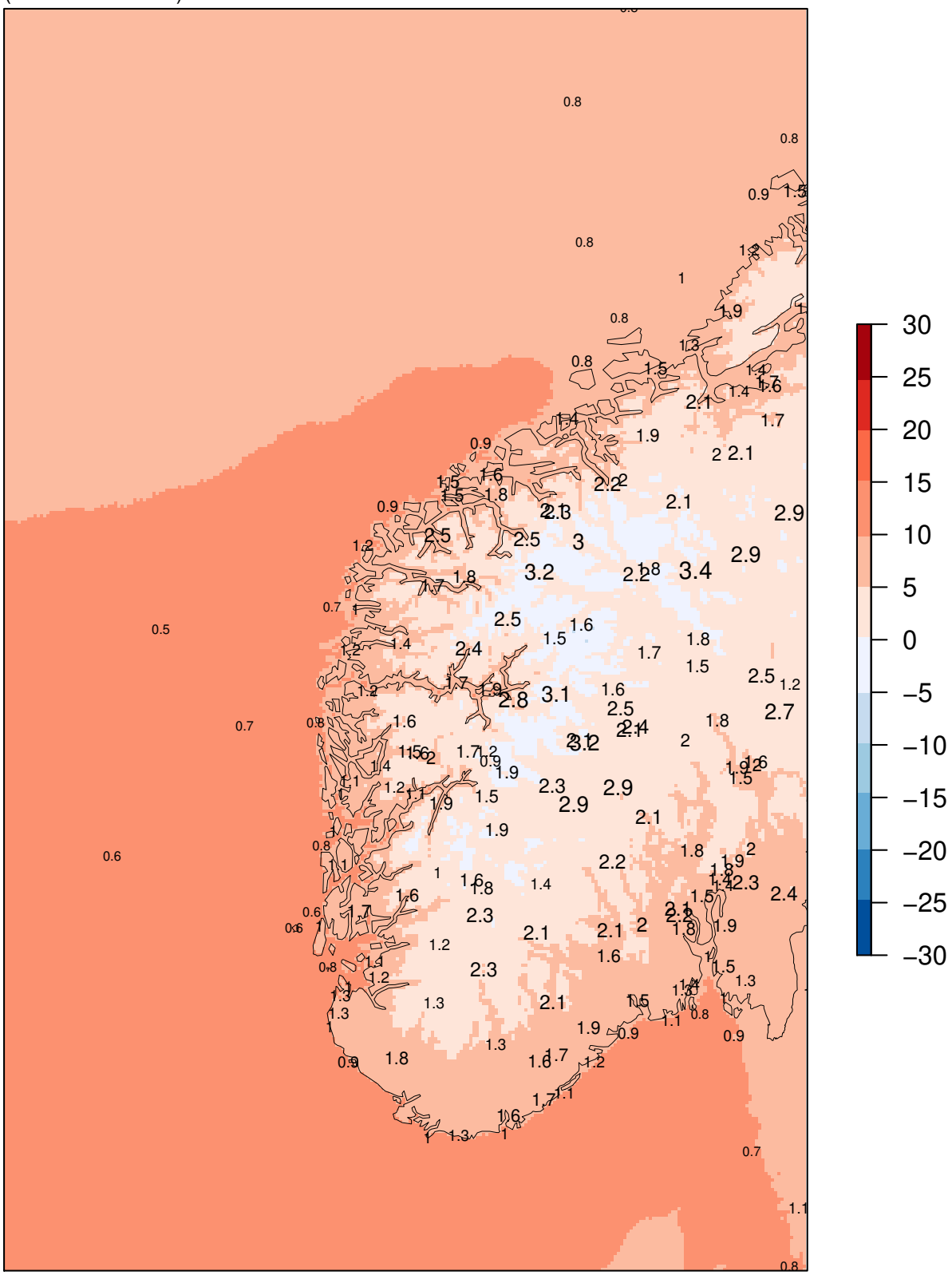
SDE at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+24

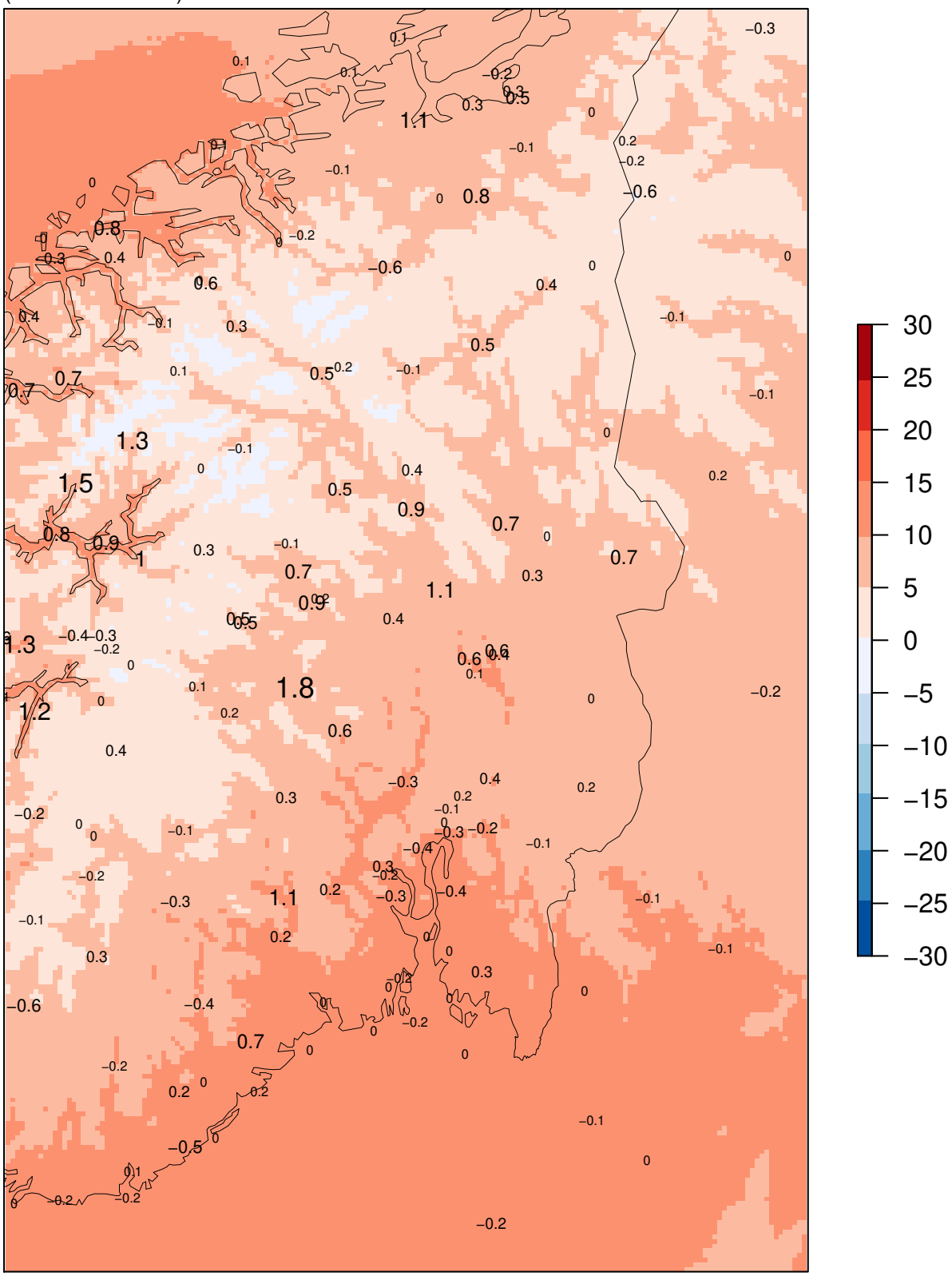
SDE at observing sites
(numbers in black)



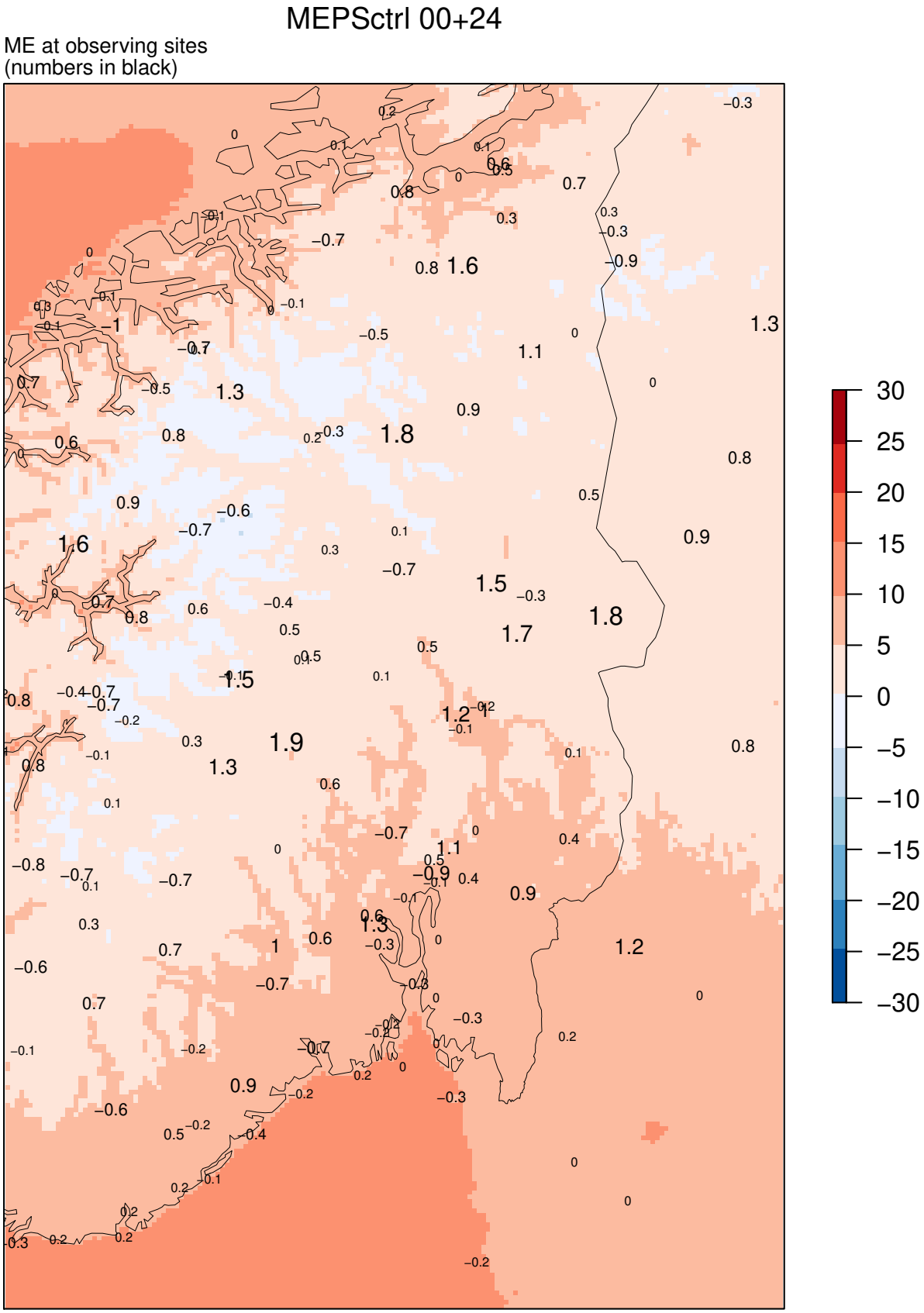
Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+12

ME at observing sites
(numbers in black)



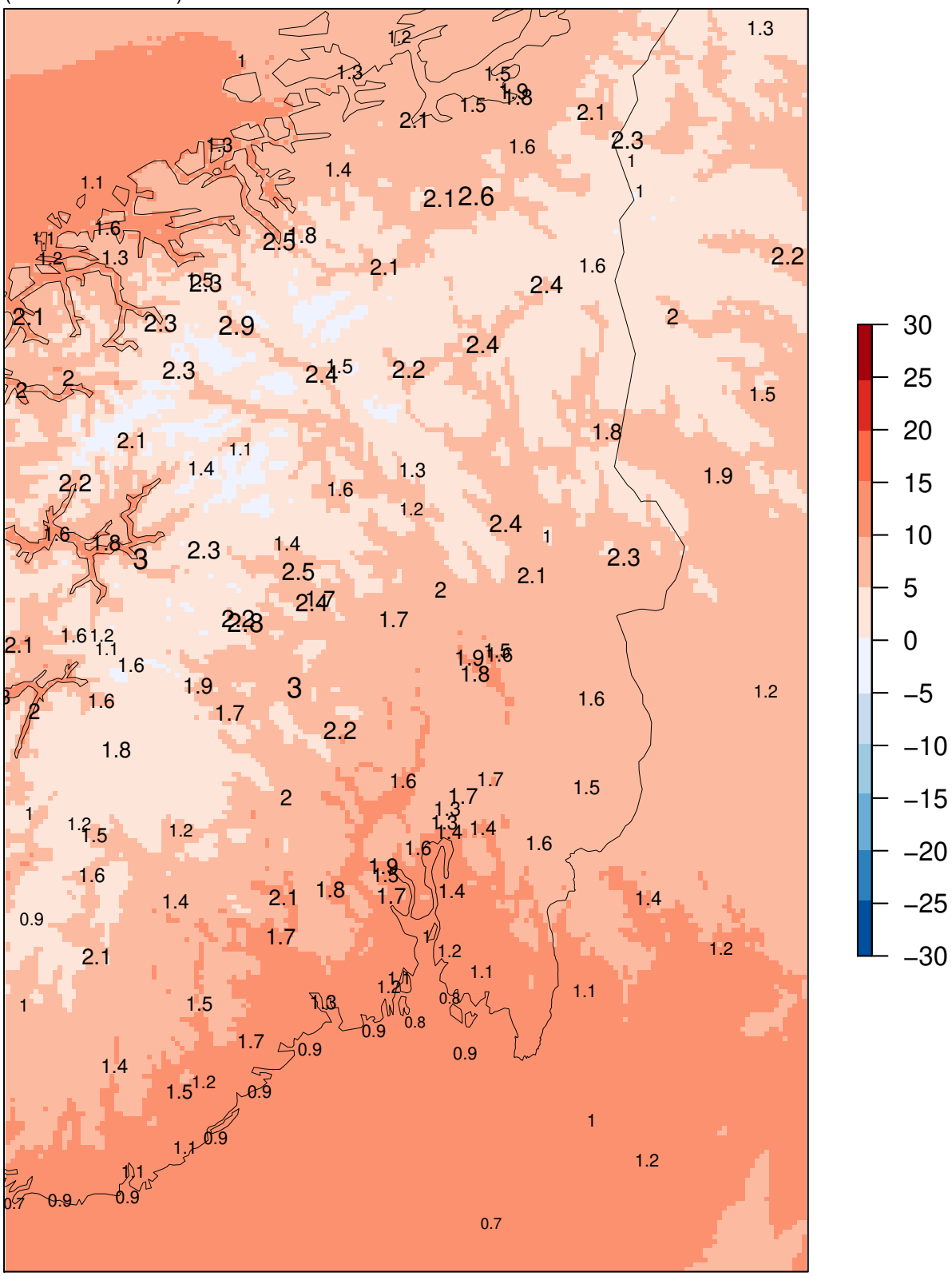
Model "climatology" 01.09.2021 – 30.11.2021



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+12

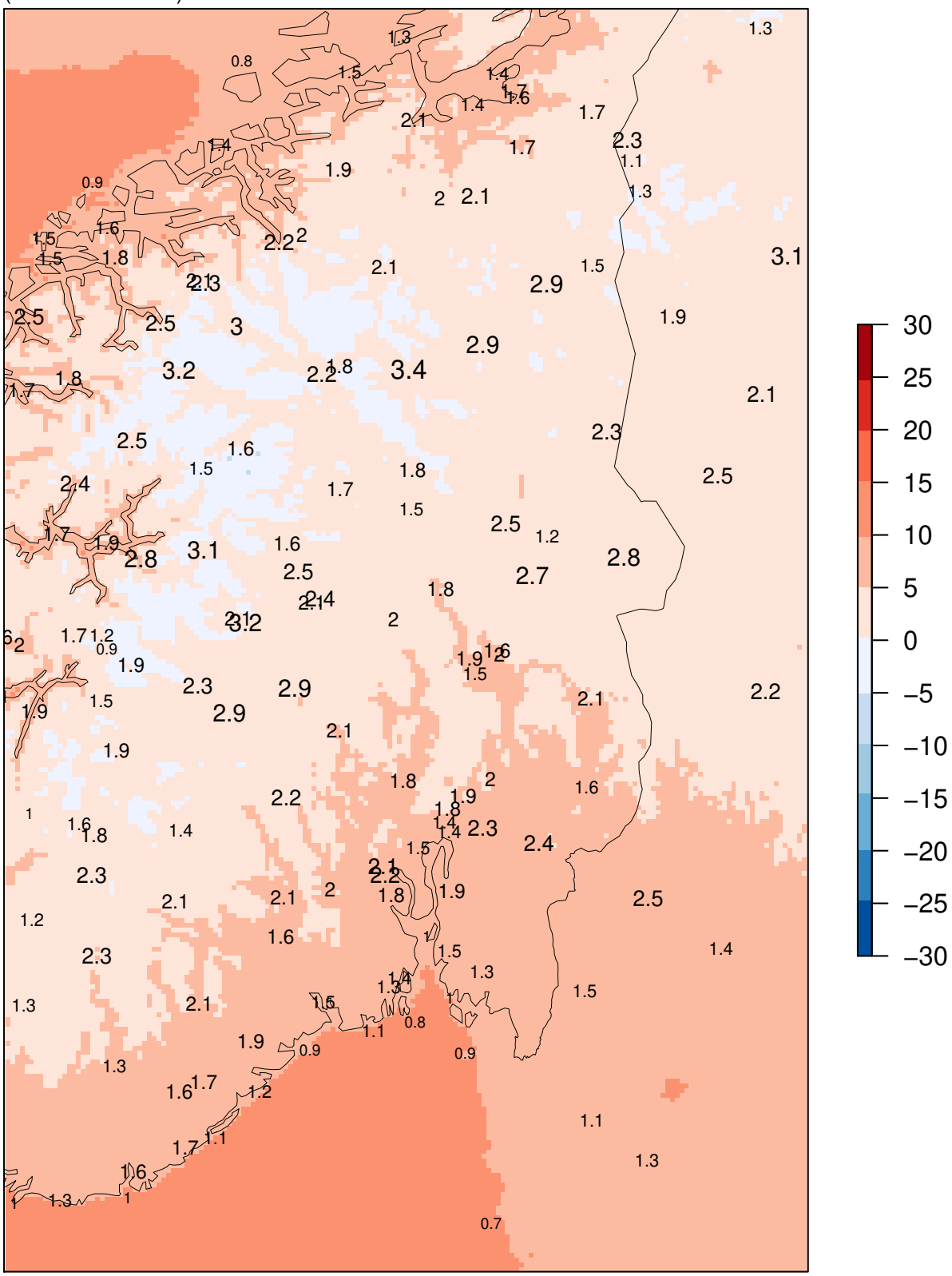
SDE at observing sites
(numbers in black)



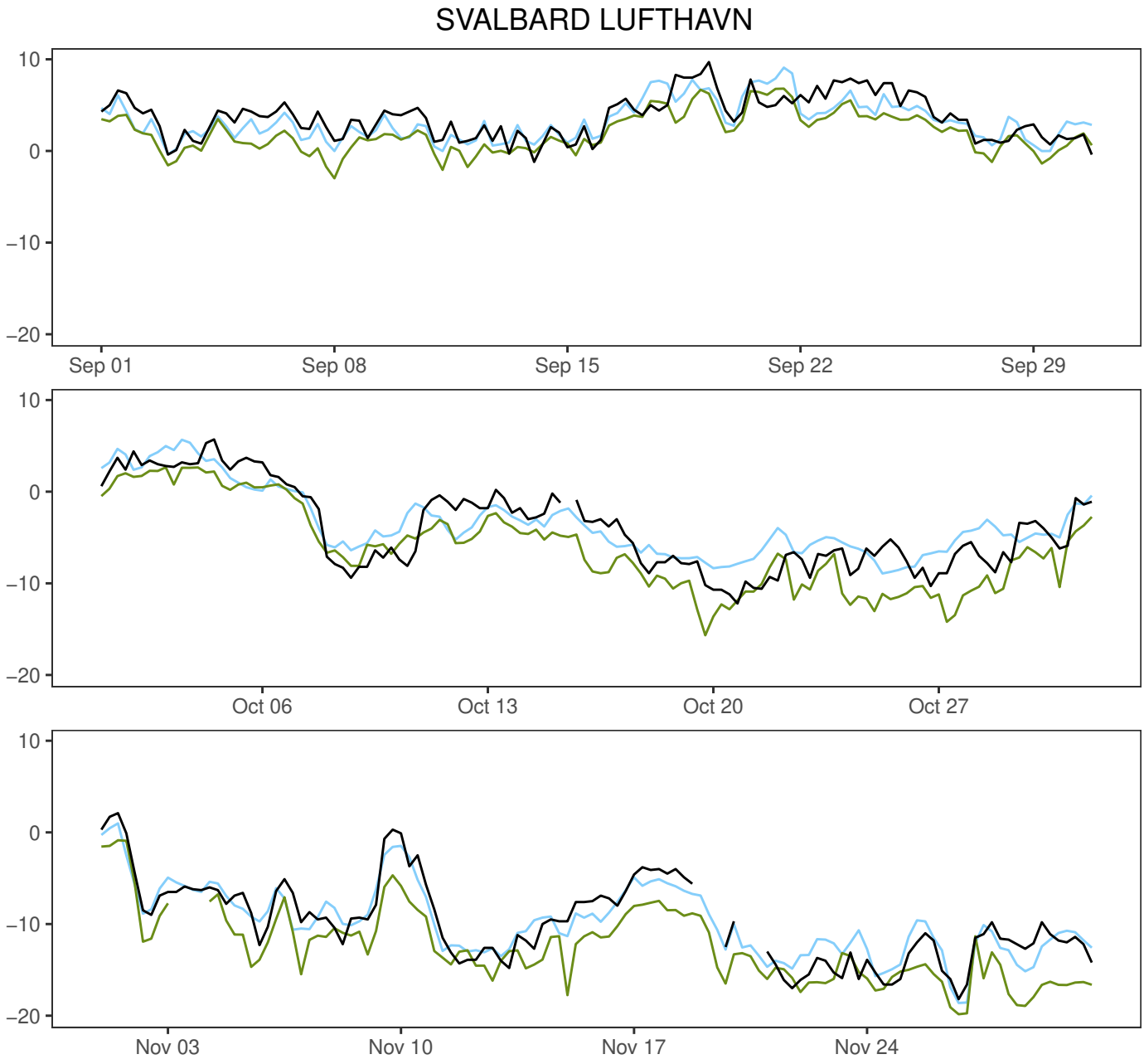
Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+24

SDE at observing sites
(numbers in black)

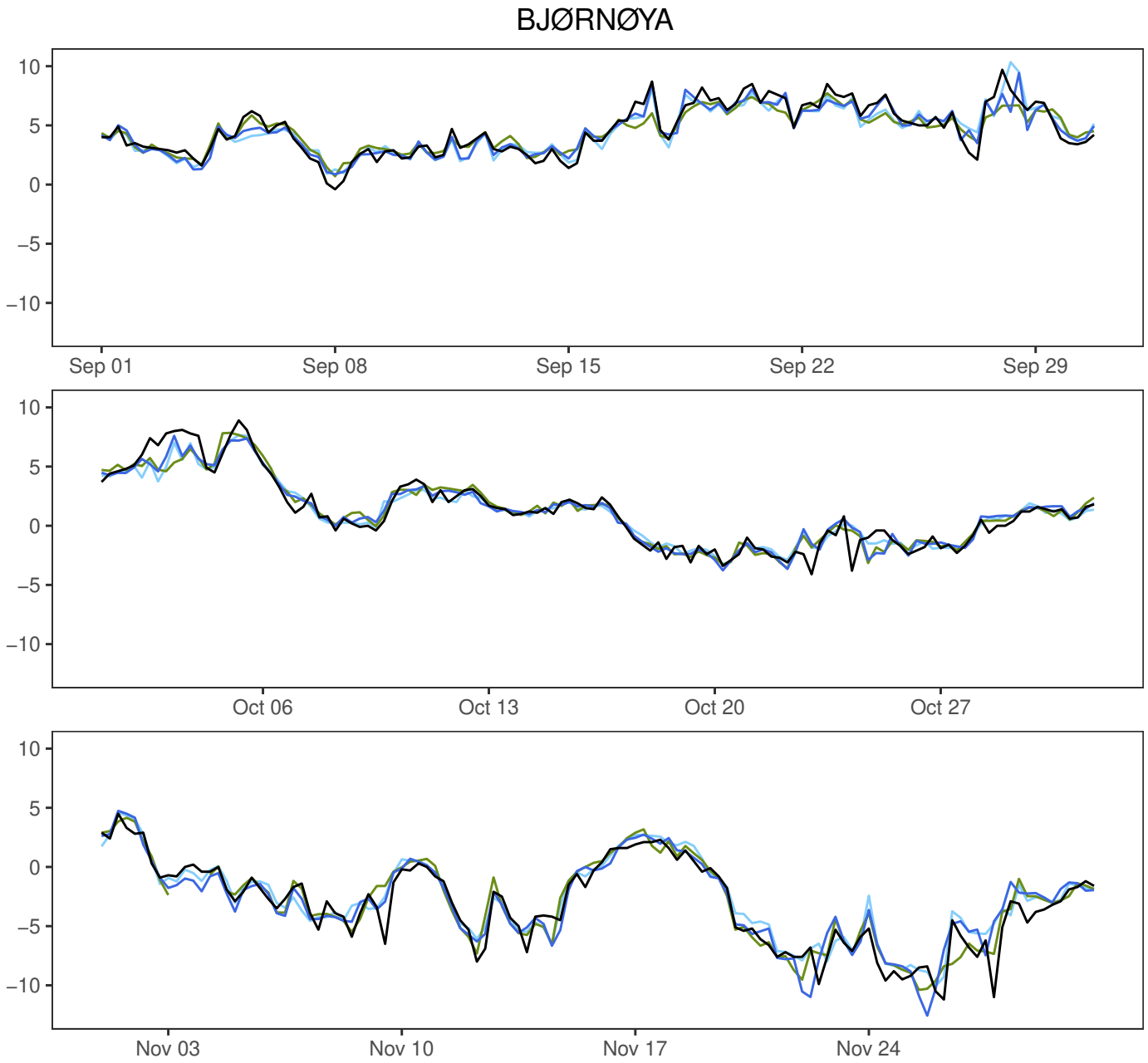


Model "climatology" 01.09.2021 – 30.11.2021



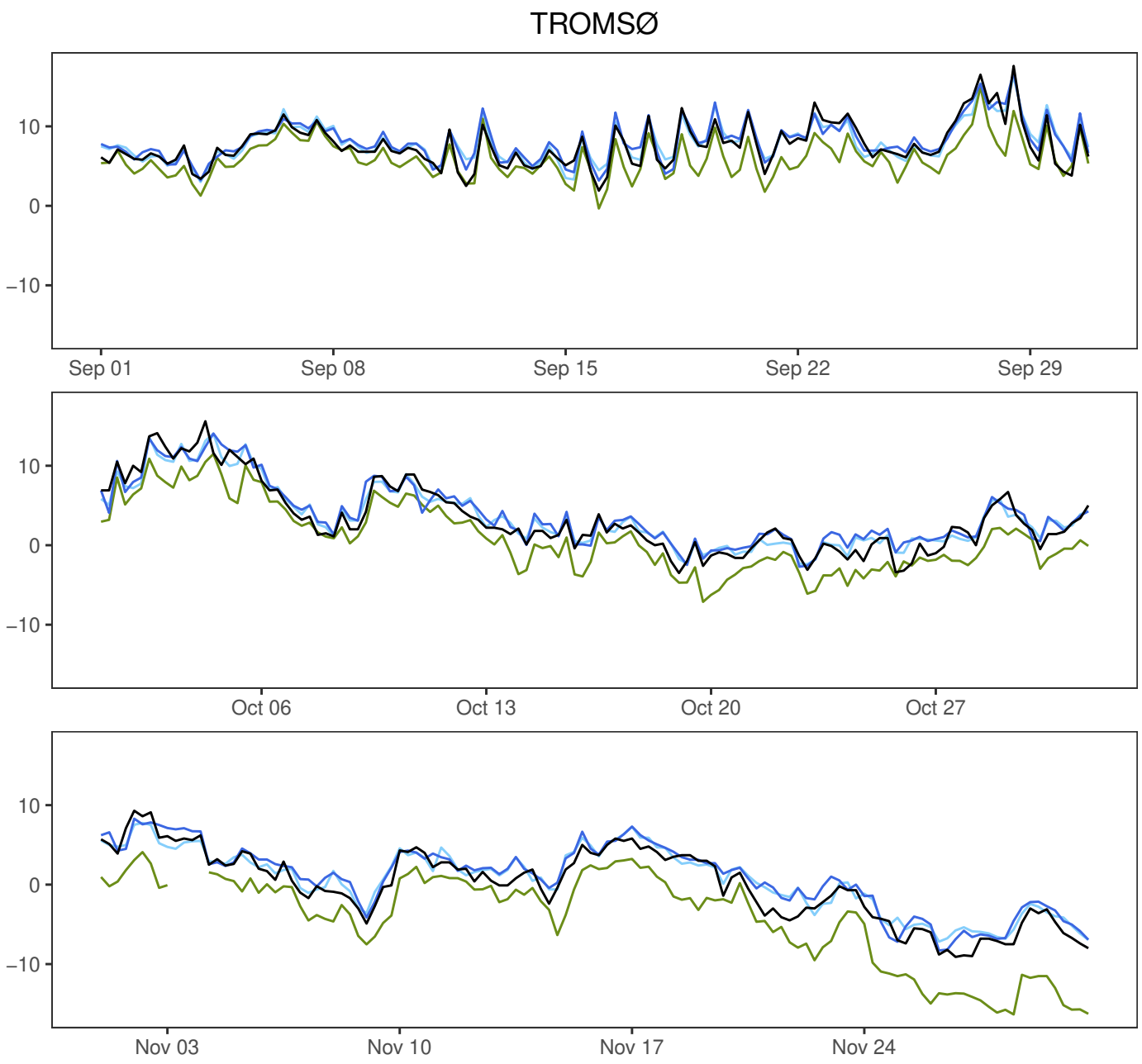
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−18.2	−3.2	9.7	6.7	357
AA25: 12+18,+24,+30,+36	−18.6	−3.3	9.1	6.2	364
ECMWF: 12+18,+24,+30,+36	−19.8	−5.5	6.8	7.0	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
AA25−synop	0.0	1.9	1.9	1.5	5.8	353
ECMWF−synop	−2.2	1.9	2.9	2.4	8.1	353



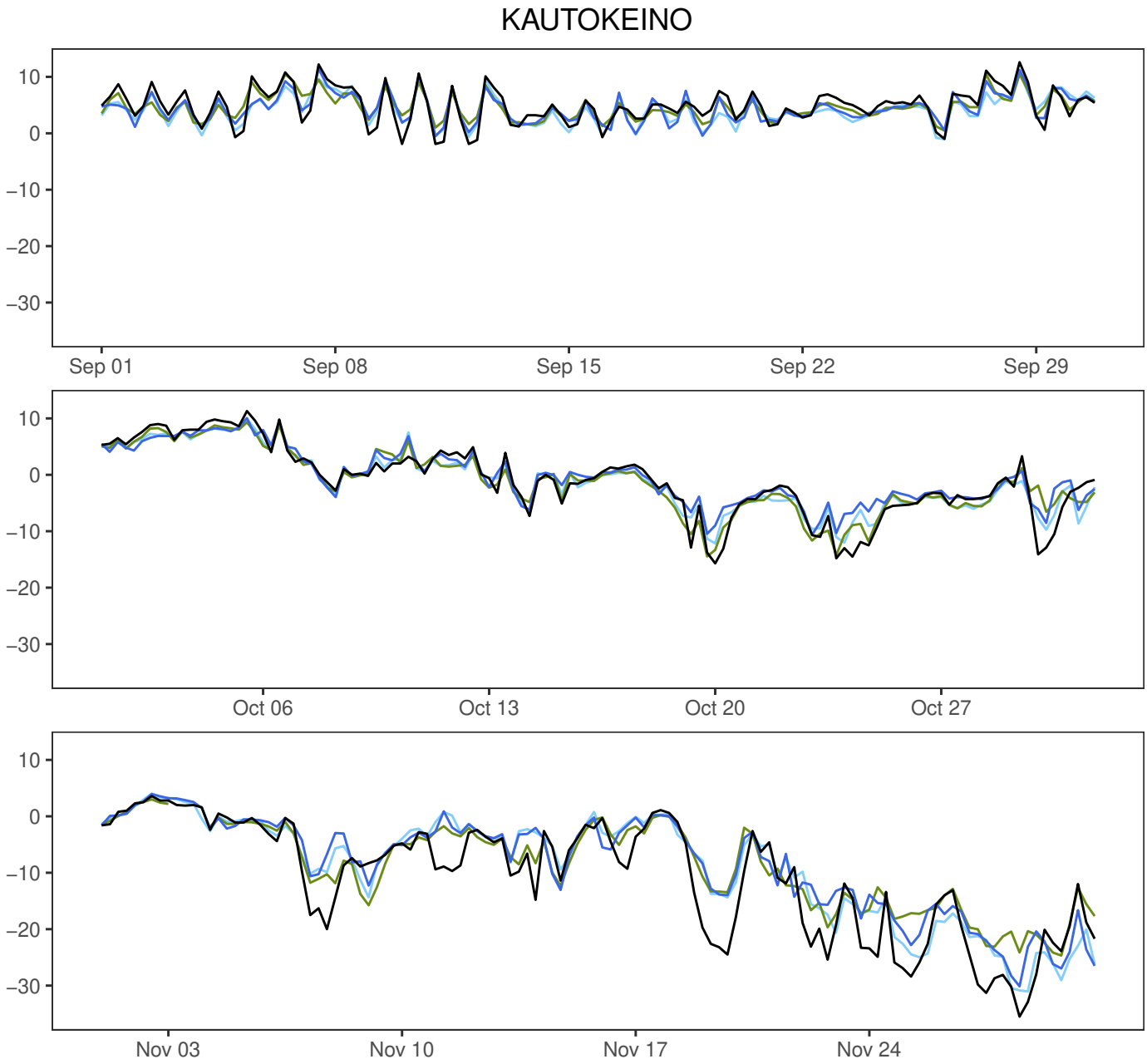
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−11.2	0.9	9.7	4.3	364
MEPSctrl: 12+18,+24,+30,+36	−12.6	0.9	9.4	4.1	364
AA25: 12+18,+24,+30,+36	−10.1	1.0	10.3	4.0	364
ECMWF: 12+18,+24,+30,+36	−10.4	0.9	7.9	4.1	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.0	1.0	1.0	0.7	6.4	360
AA25−synop	0.1	1.0	1.0	0.7	6.2	360
ECMWF−synop	0.0	1.0	1.0	0.7	4.9	360



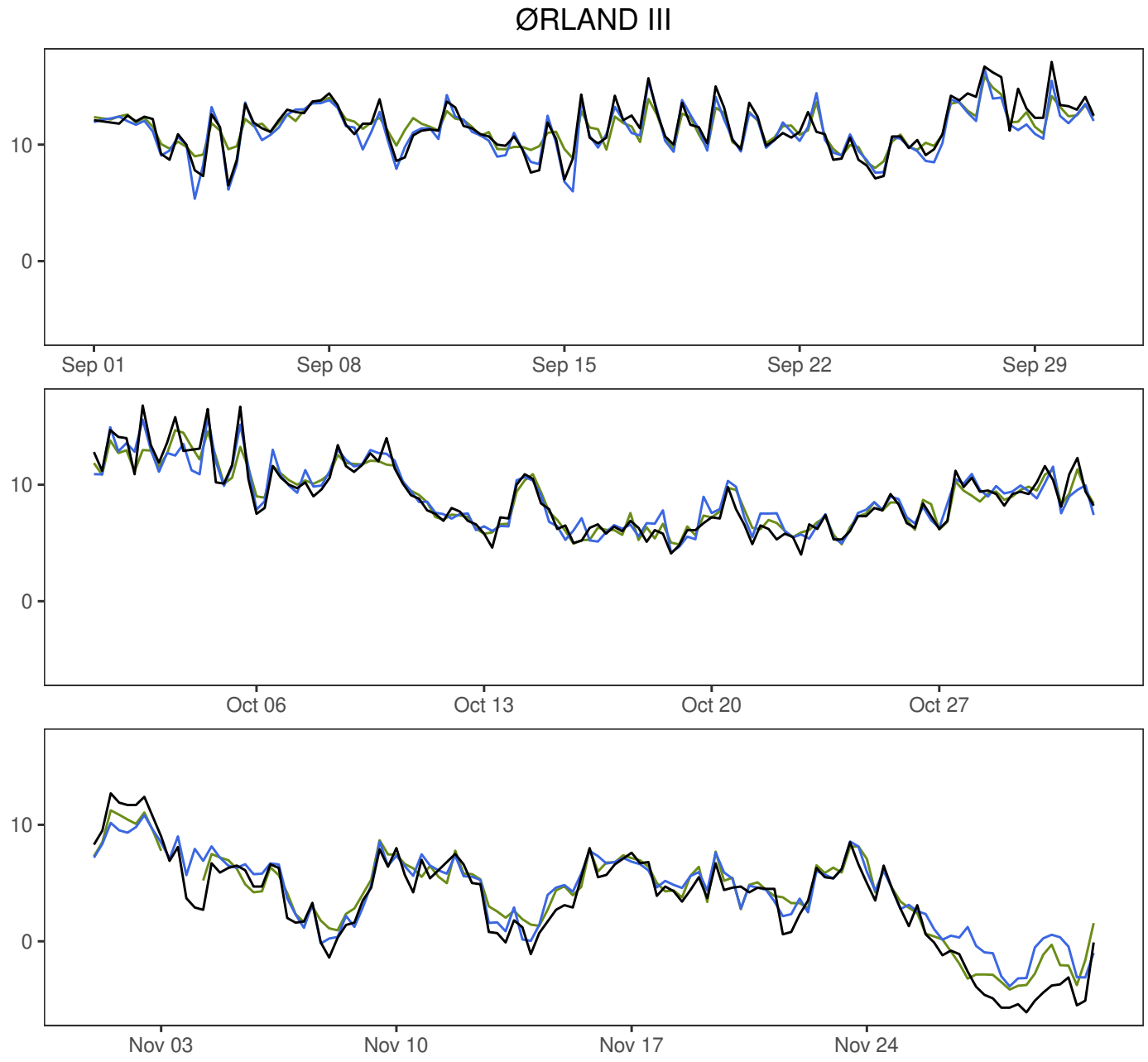
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−9.1	3.7	17.6	5.1	364
MEPSctrl: 12+18,+24,+30,+36	−8.3	4.3	16.8	4.7	364
AA25: 12+18,+24,+30,+36	−7.2	4.1	16.3	4.6	364
ECMWF: 12+18,+24,+30,+36	−16.3	0.9	15.0	6.0	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.7	1.2	1.3	1.1	4.2	360
AA25−synop	0.4	1.2	1.3	1.0	4.0	360
ECMWF−synop	−2.7	2.0	3.4	2.7	9.1	360



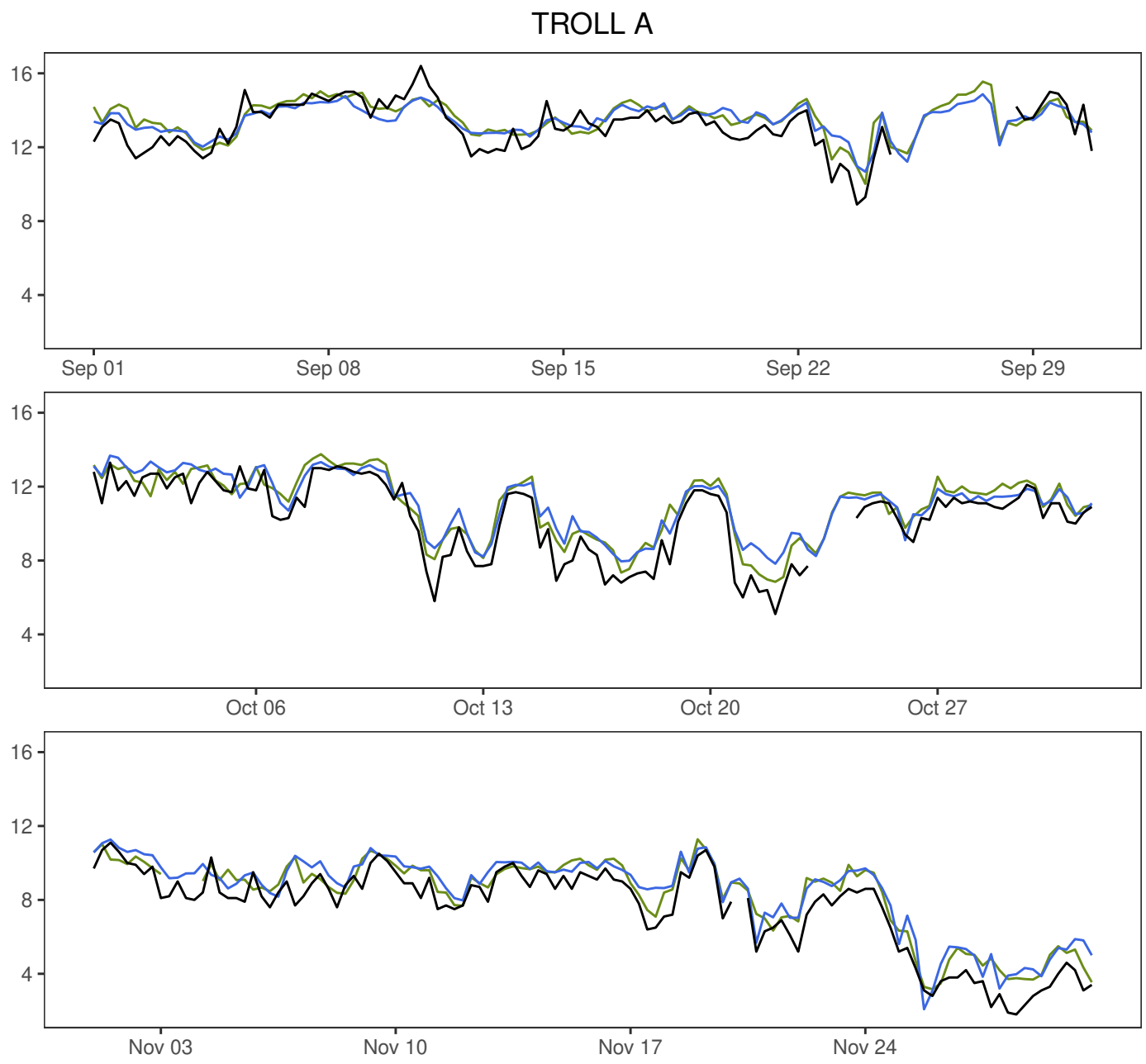
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−35.5	−2.3	12.6	9.6	364
MEPSctrl: 12+18,+24,+30,+36	−30.1	−1.5	11.4	7.9	364
AA25: 12+18,+24,+30,+36	−31.0	−2.0	11.1	8.3	364
ECMWF: 12+18,+24,+30,+36	−24.7	−1.8	10.5	7.8	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.9	3.3	3.4	2.2	13.3	360
AA25−synop	0.3	3.1	3.1	2.1	12.0	360
ECMWF−synop	0.6	3.1	3.2	2.1	12.5	360



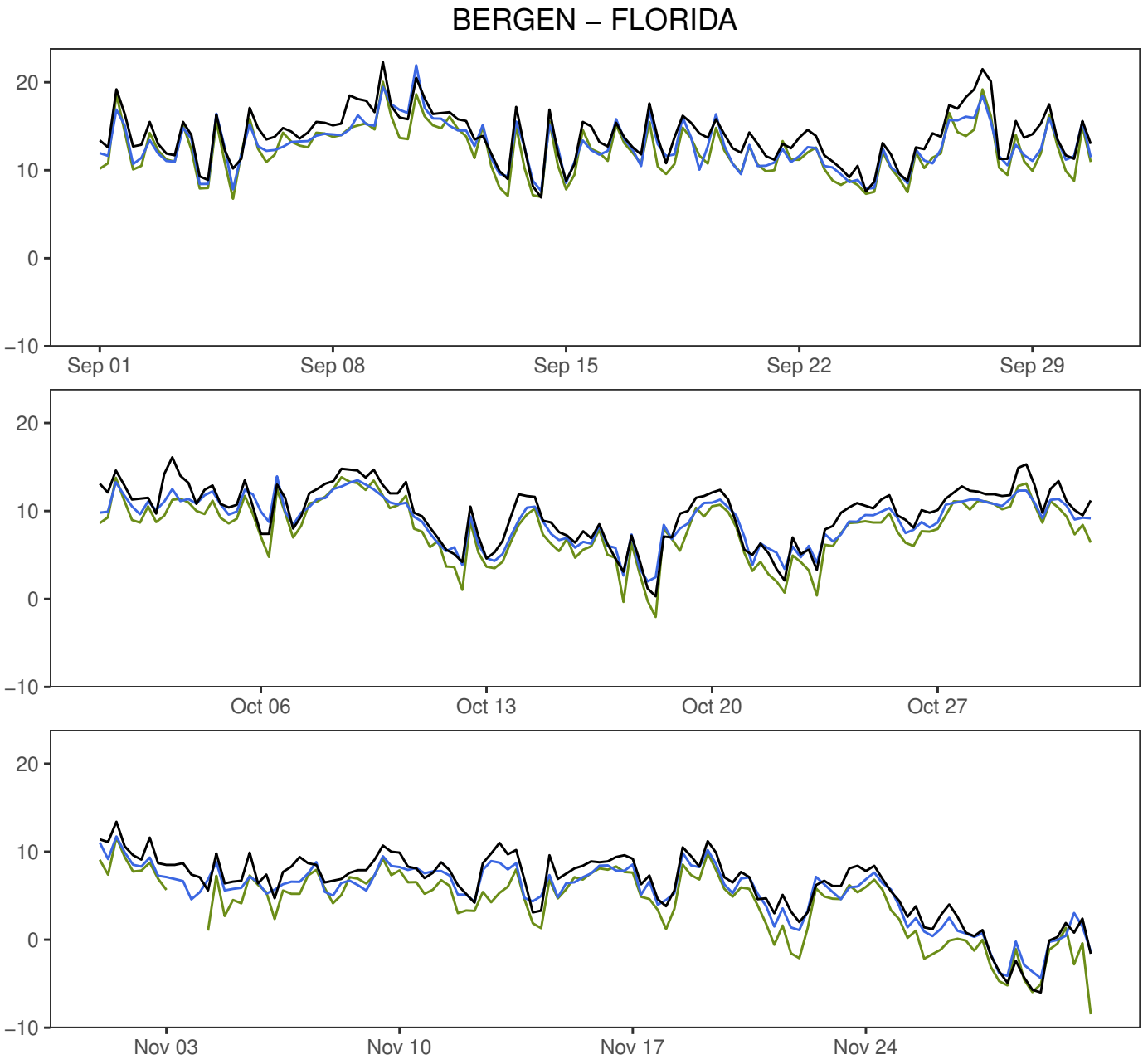
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−6.1	8.0	17.1	4.6	364
MEPSctrl: 12+18,+24,+30,+36	−3.9	8.1	16.5	3.9	364
ECMWF: 12+18,+24,+30,+36	−4.1	8.2	15.8	4.0	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.1	1.2	1.2	0.9	4.7	360
ECMWF−synop	0.2	1.1	1.1	0.8	3.8	360



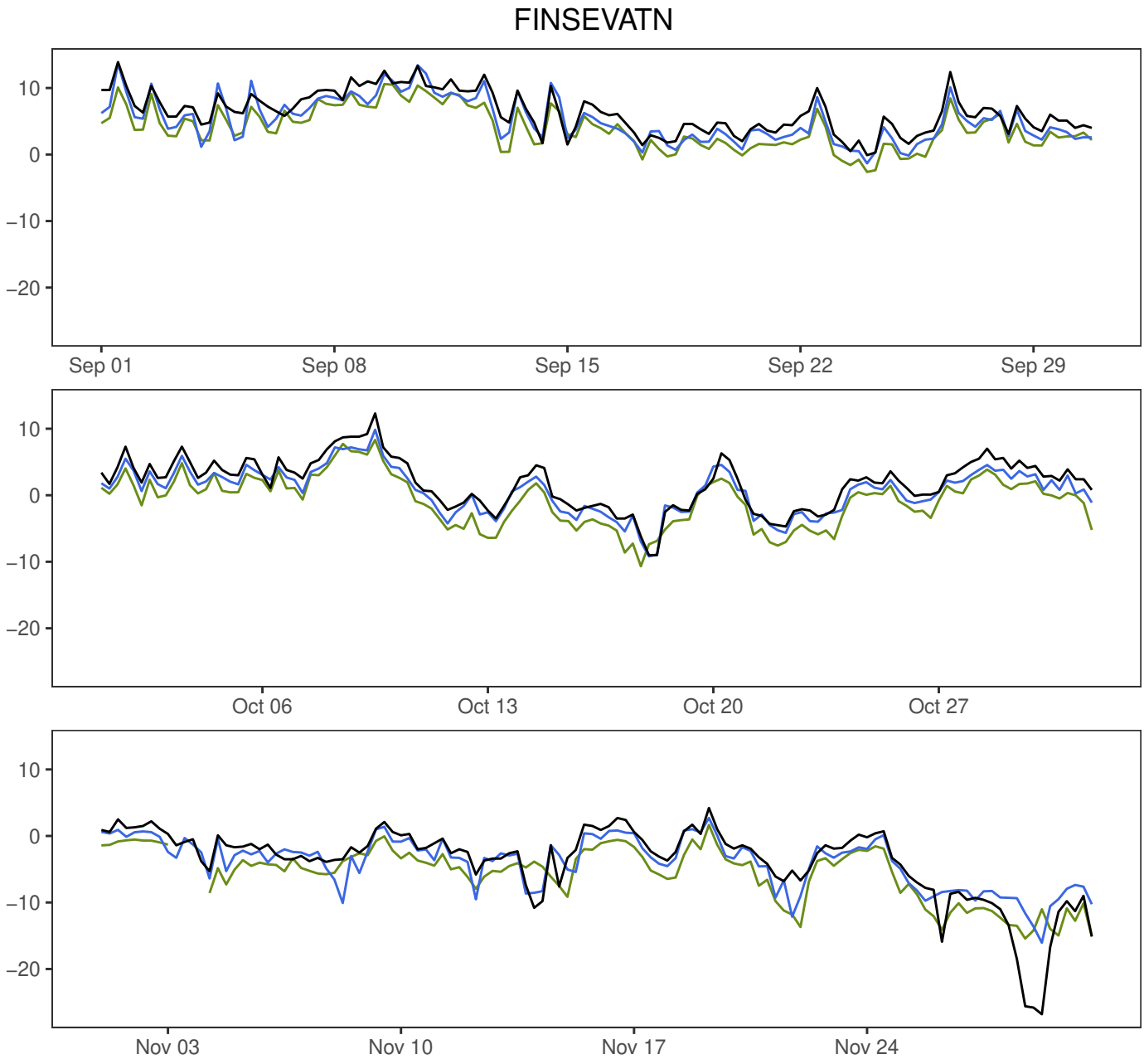
	Min	Mean	Max	Std	N
synop: 00,06,12,18	1.8	10.2	16.4	3.0	344
MEPSctrl: 12+18,+24,+30,+36	2.1	11.0	14.9	2.6	364
ECMWF: 12+18,+24,+30,+36	3.2	11.0	15.6	2.7	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.7	0.8	1.0	0.8	2.9	340
ECMWF−synop	0.6	0.7	0.9	0.8	3.2	340



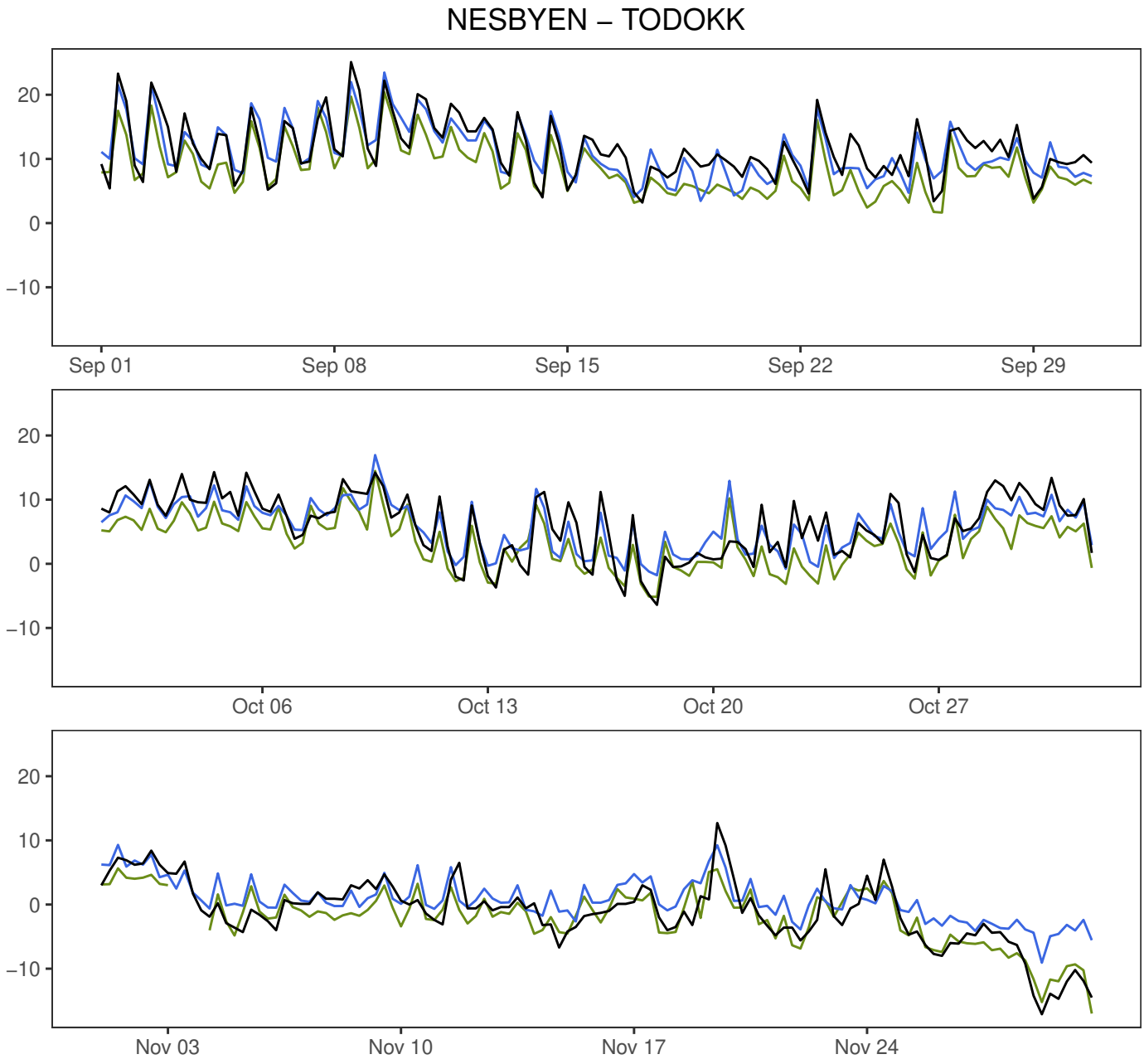
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−6.0	10.0	22.3	4.6	364
MEPSctrl: 12+18,+24,+30,+36	−4.4	9.1	21.9	4.2	364
ECMWF: 12+18,+24,+30,+36	−8.5	8.2	20.1	4.7	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.9	1.1	1.4	1.2	4.6	360
ECMWF−synop	−1.8	1.1	2.1	1.9	6.9	360



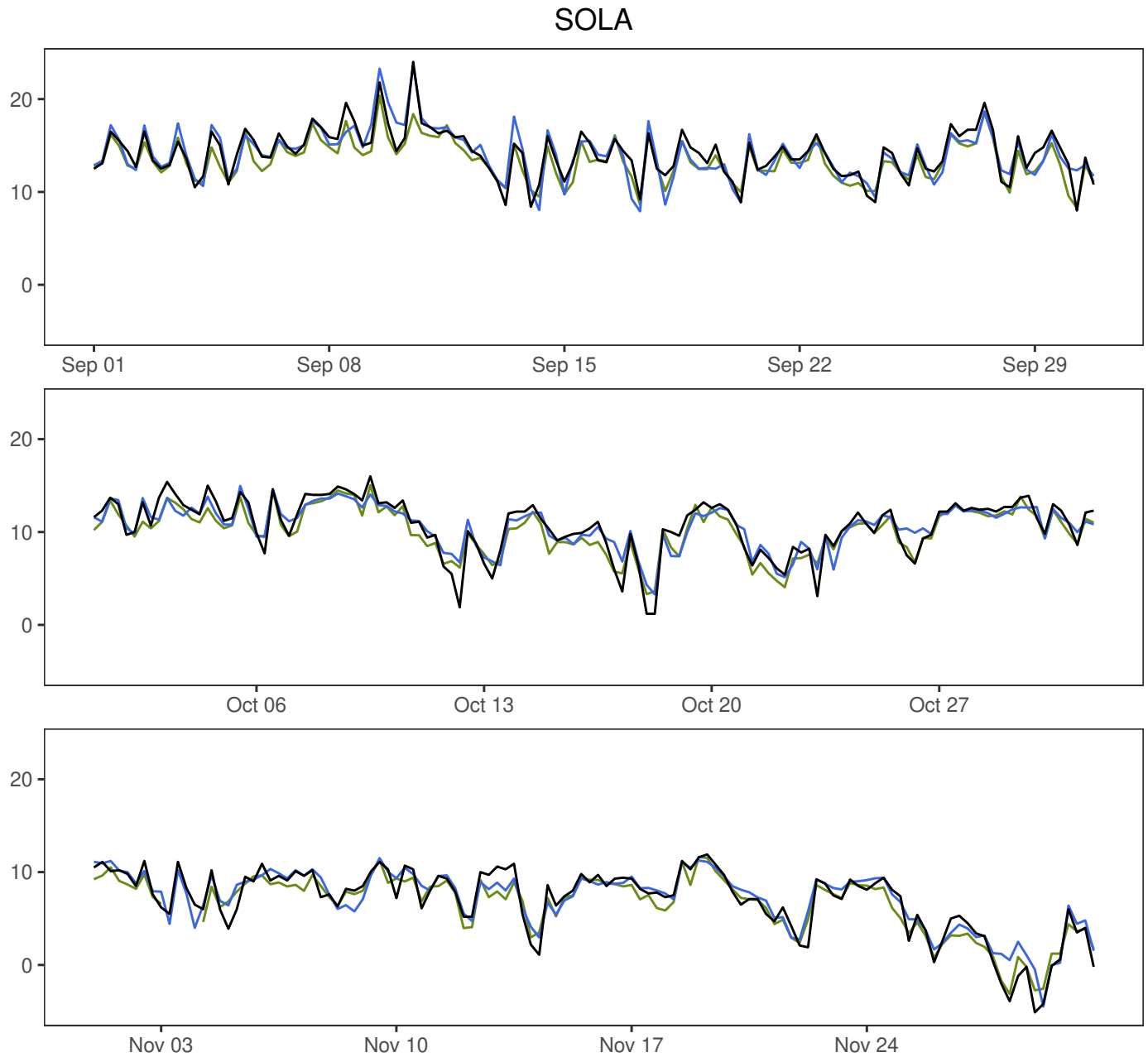
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−26.8	1.4	13.9	6.0	364
MEPSctrl: 12+18,+24,+30,+36	−16.1	0.7	13.7	5.1	364
ECMWF: 12+18,+24,+30,+36	−15.4	−0.8	10.6	5.4	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.8	1.9	2.1	1.5	14.0	360
ECMWF−synop	−2.2	2.0	3.0	2.6	15.8	360



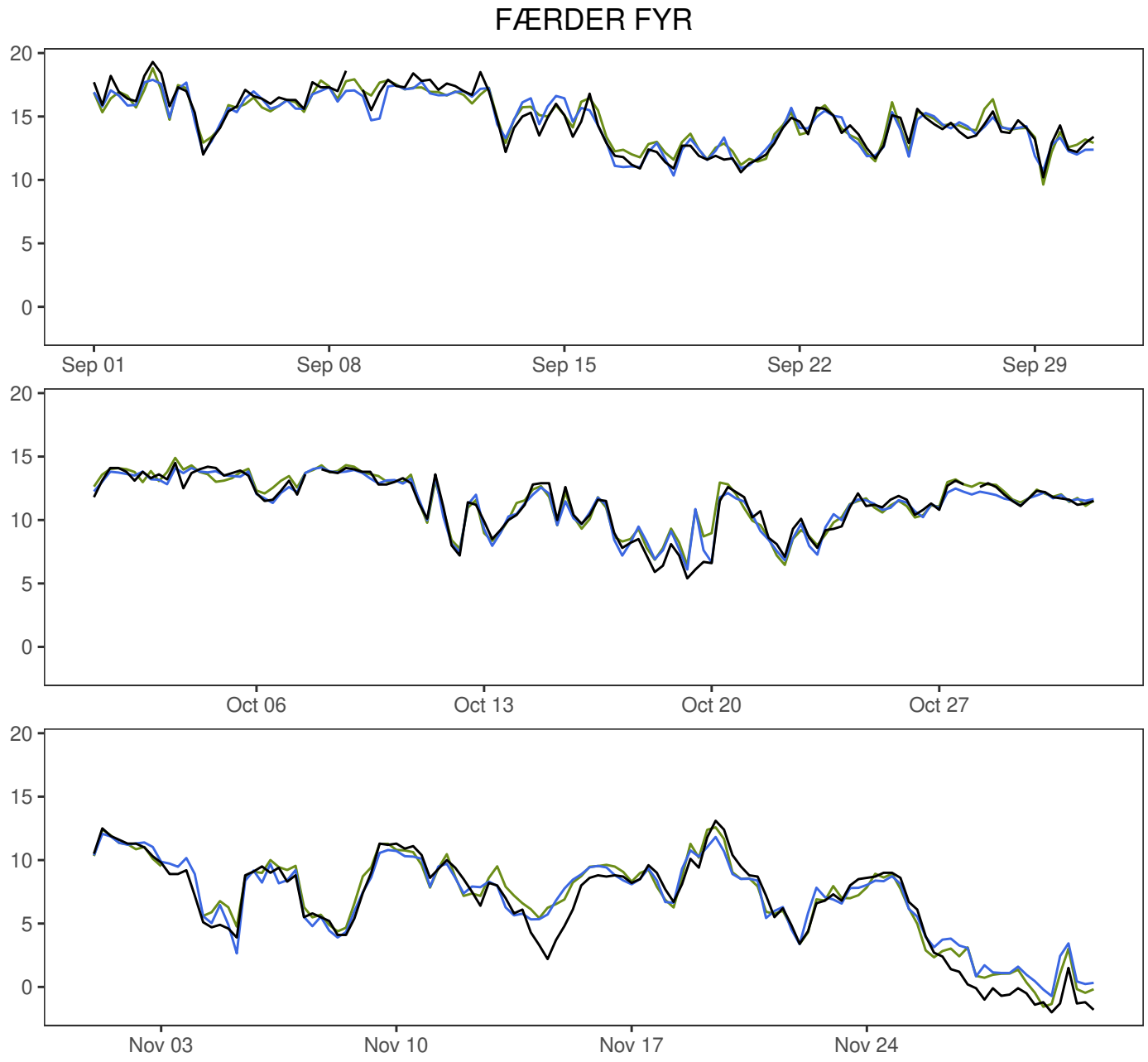
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−17.1	5.4	25.1	7.1	364
MEPSctrl: 12+18,+24,+30,+36	−9.1	5.9	23.5	5.7	364
ECMWF: 12+18,+24,+30,+36	−17.0	3.4	20.4	5.9	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.5	2.9	2.9	2.3	10.1	360
ECMWF−synop	−2.1	2.6	3.3	2.7	9.3	360



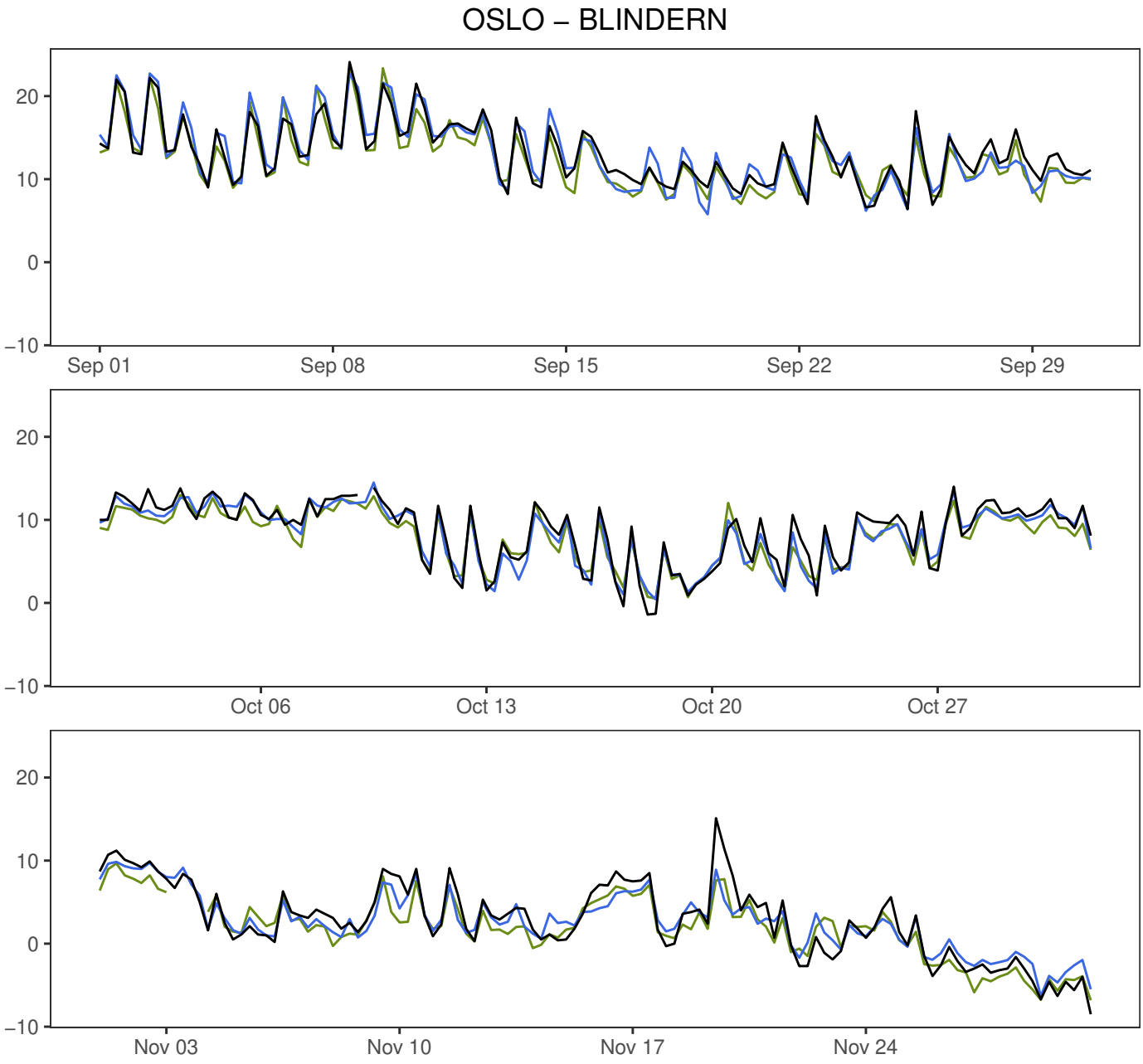
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−5.1	10.6	24.0	4.3	364
MEPSctrl: 12+18,+24,+30,+36	−4.5	10.6	23.6	3.9	364
ECMWF: 12+18,+24,+30,+36	−3.1	10.1	20.4	3.8	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.0	1.3	1.3	0.9	4.8	360
ECMWF−synop	−0.6	1.1	1.2	1.0	5.6	360



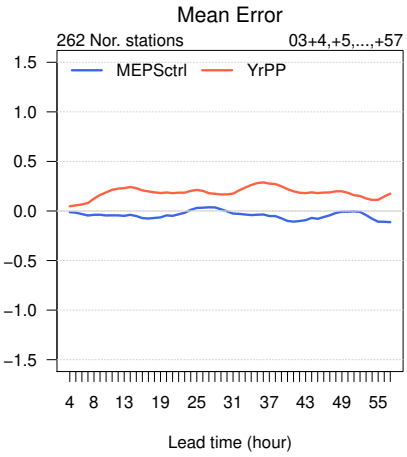
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−2.0	10.9	19.3	4.4	361
MEPSctrl: 12+18,+24,+30,+36	−0.7	11.0	17.9	4.0	364
ECMWF: 12+18,+24,+30,+36	−1.6	11.1	18.8	4.1	360

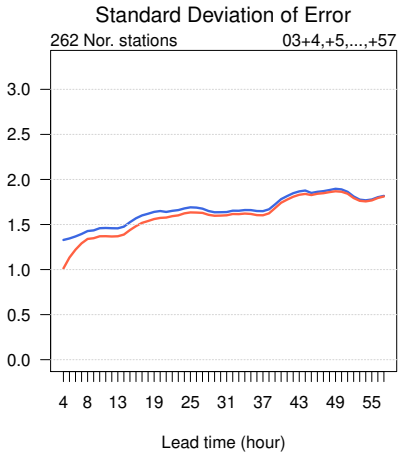
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.0	0.9	0.9	0.6	4.8	357
ECMWF−synop	0.2	0.8	0.8	0.6	4.7	357

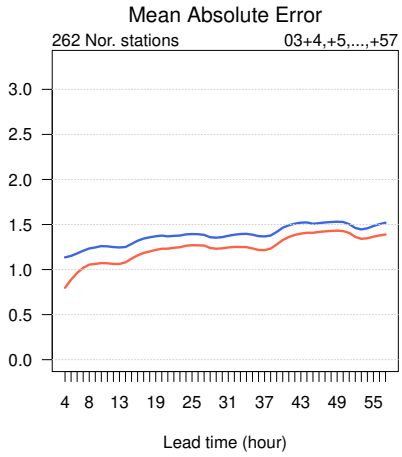


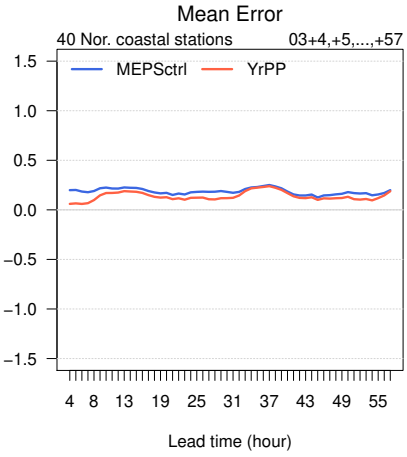
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−8.5	8.2	24.1	5.8	363
MEPSctrl: 12+18,+24,+30,+36	−6.3	8.0	22.7	5.7	364
ECMWF: 12+18,+24,+30,+36	−6.8	7.4	23.6	5.6	360

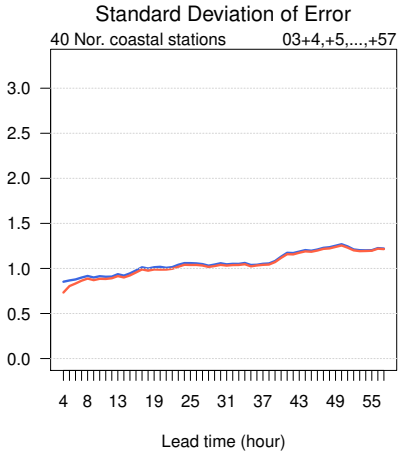
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.2	1.4	1.4	1.1	6.2	359
ECMWF−synop	−0.8	1.4	1.6	1.3	7.5	359

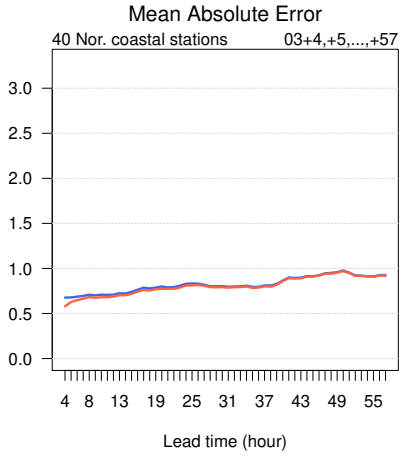

Mean Error
262 Nor. stations
03+4,+5,...,+57
MEPSctrl
YrPP
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
4 8 13 19 25 31 37 43 49 55
Lead time (hour)

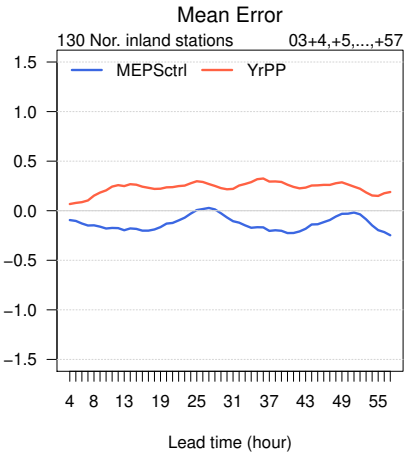

Standard Deviation of Error
262 Nor. stations
03+4,+5,...,+57
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4 8 13 19 25 31 37 43 49 55
Lead time (hour)

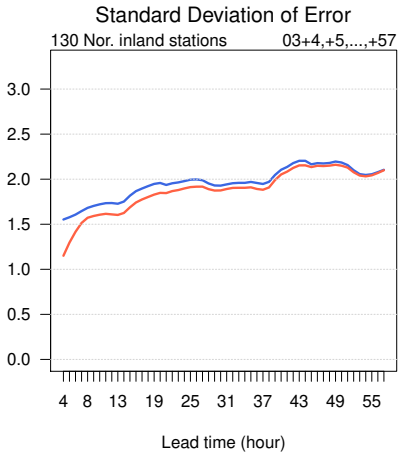

Mean Absolute Error
262 Nor. stations
03+4,+5,...,+57
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4 8 13 19 25 31 37 43 49 55
Lead time (hour)

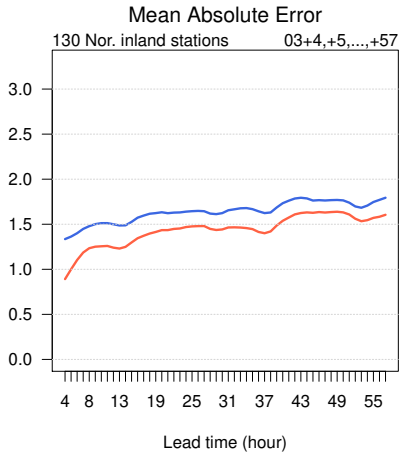

Mean Error
40 Nor. coastal stations
03+4,+5,...,+57
MEPSctrl
YrPP
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
4 8 13 19 25 31 37 43 49 55
Lead time (hour)


Standard Deviation of Error
40 Nor. coastal stations
03+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)

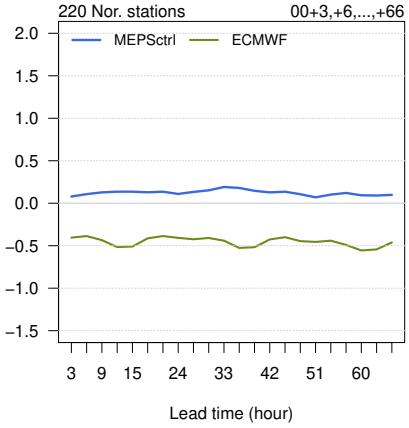

Mean Absolute Error
40 Nor. coastal stations
03+4,+5,...,+57
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4 8 13 19 25 31 37 43 49 55
Lead time (hour)


Mean Error
130 Nor. inland stations
03+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)

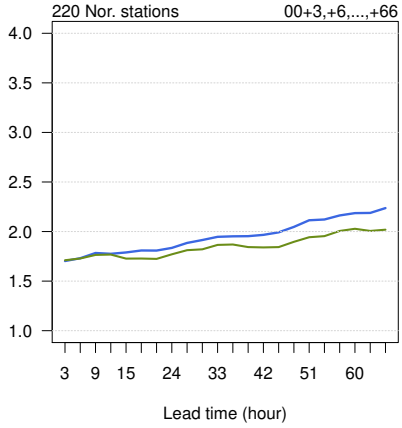

Standard Deviation of Error
130 Nor. inland stations
03+4,+5,...,+57
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4 8 13 19 25 31 37 43 49 55
Lead time (hour)


Mean Absolute Error
130 Nor. inland stations
03+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)

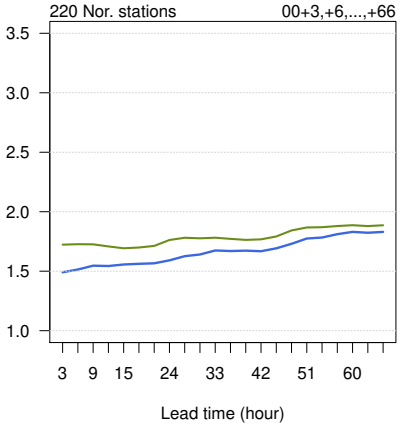
Mean Error



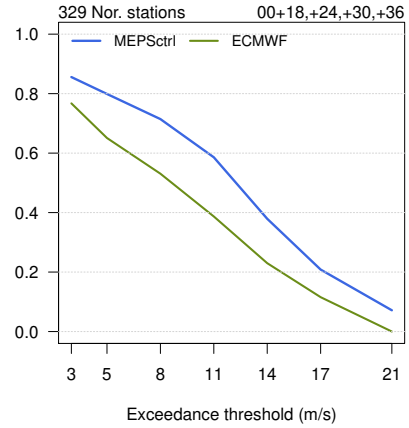
Standard Deviation of Error



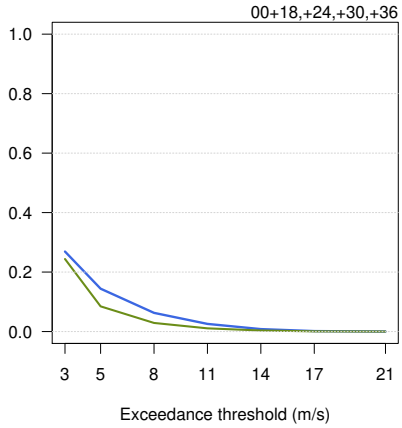
Mean Absolute Error



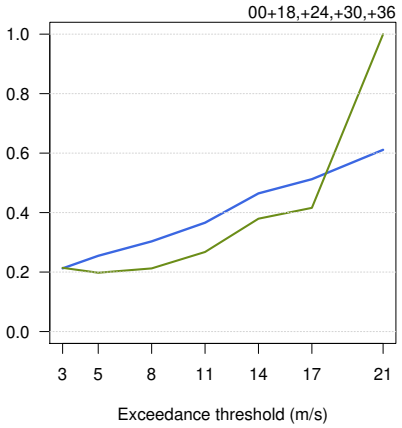
Hit Rate



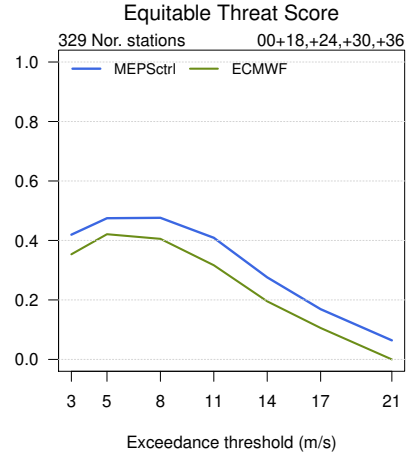
False Alarm Rate



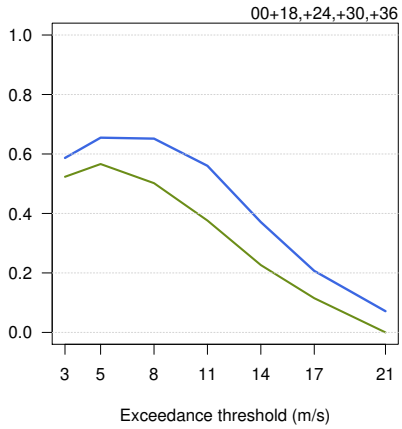
False Alarm Ratio



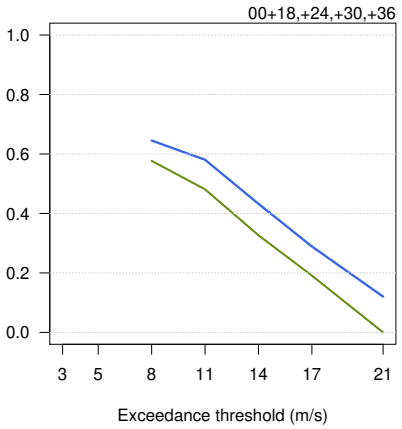
Equitable Threat Score



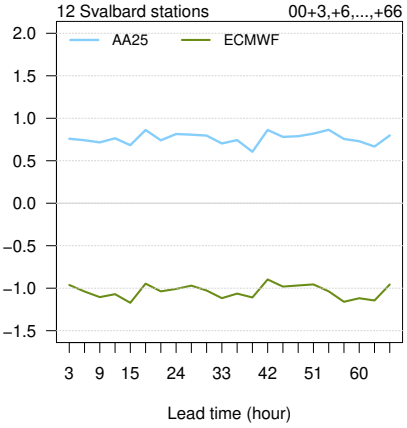
Hansen−Kuiper Skill Score



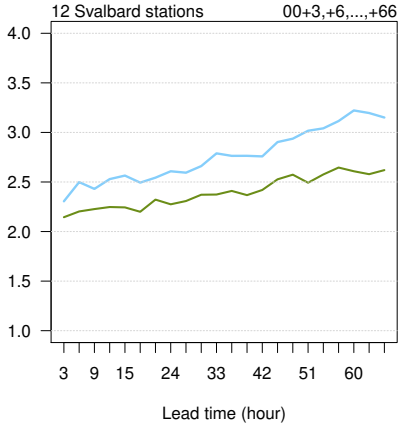
Heidke Skill Score



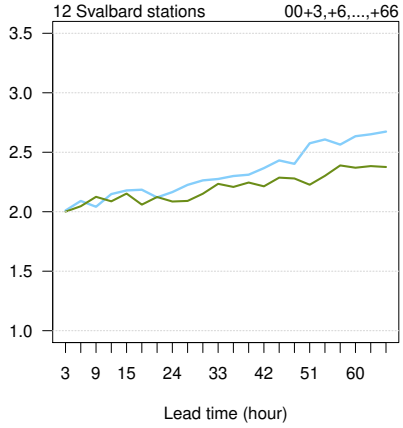
Mean Error



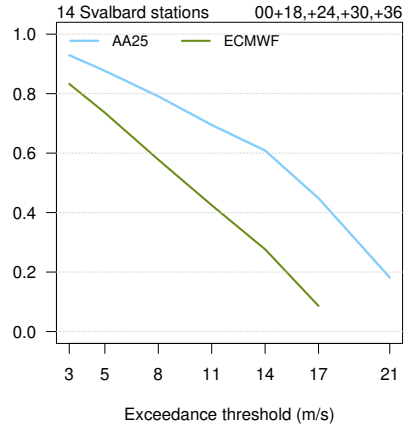
Standard Deviation of Error



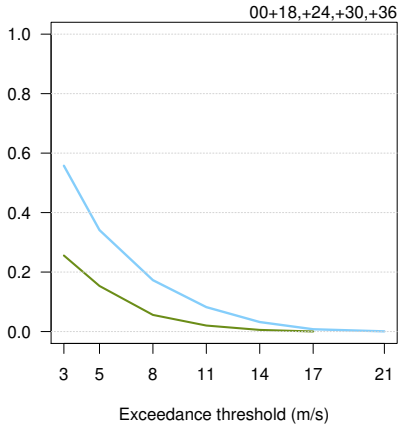
Mean Absolute Error



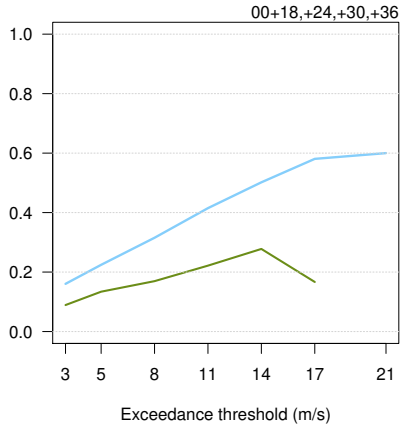
Hit Rate



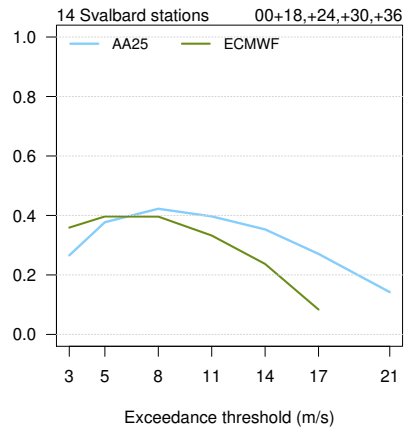
False Alarm Rate



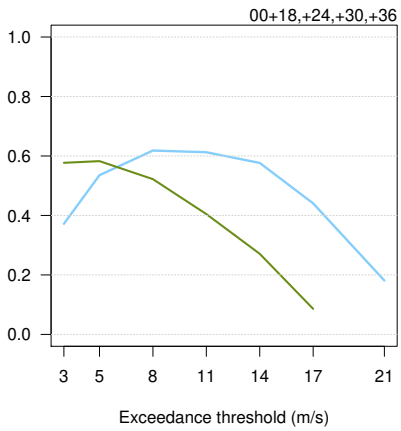
False Alarm Ratio



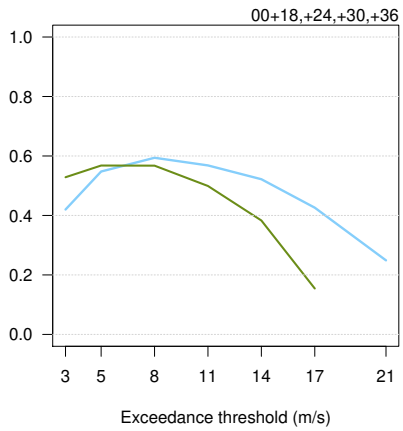
Equitable Threat Score

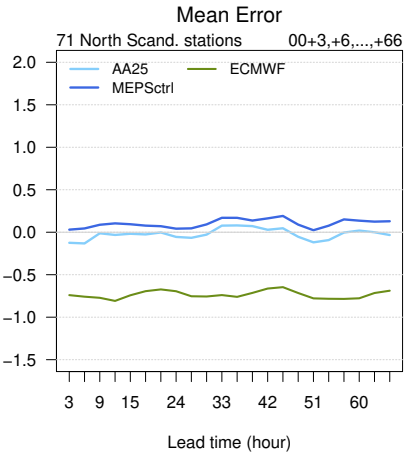


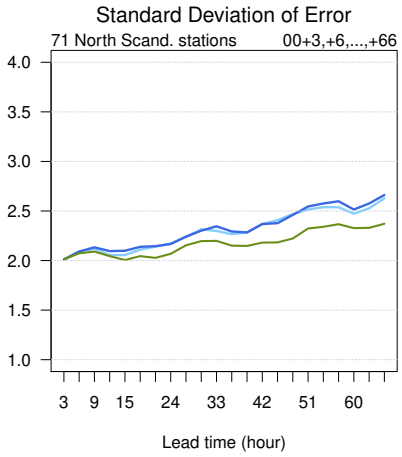
Hansen−Kuiper Skill Score

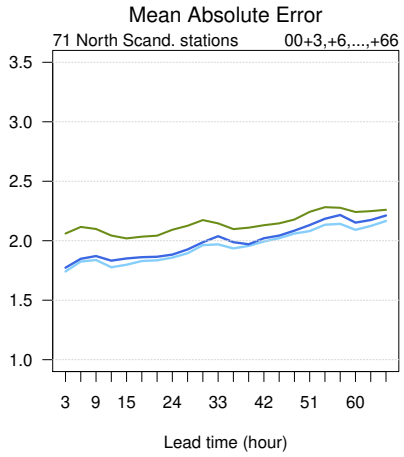


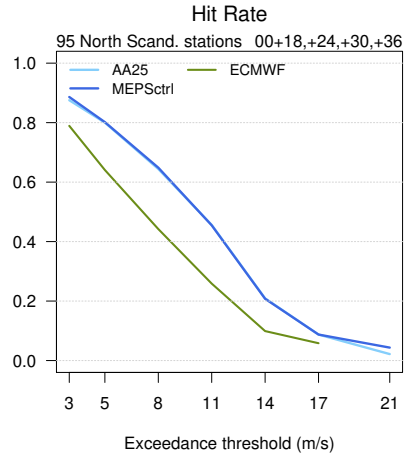
Heidke Skill Score

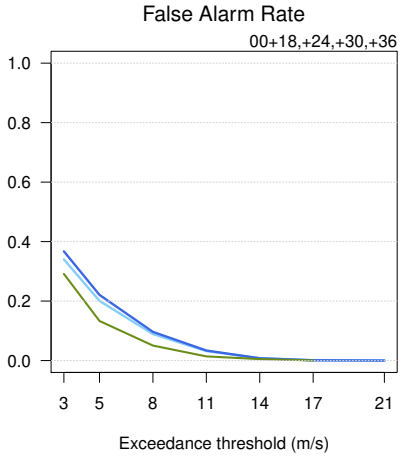


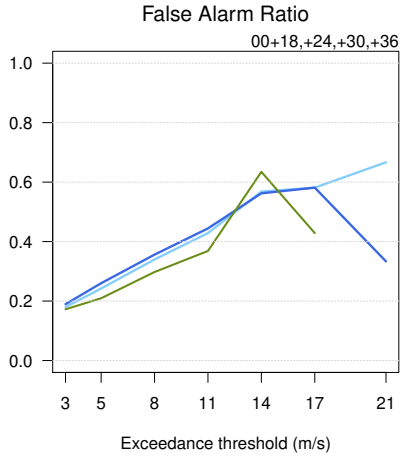

Mean Error
71 North Scand. stations 00+3,+6,...,+66
AA25
MEPSctrl
ECMWF
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
3 9 15 24 33 42 51 60
Lead time (hour)

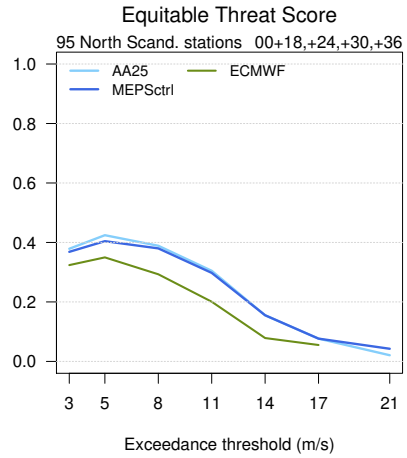

Standard Deviation of Error
71 North Scand. stations 00+3,+6,...,+66
4.0
3.5
3.0
2.5
2.0
1.5
1.0
3 9 15 24 33 42 51 60
Lead time (hour)

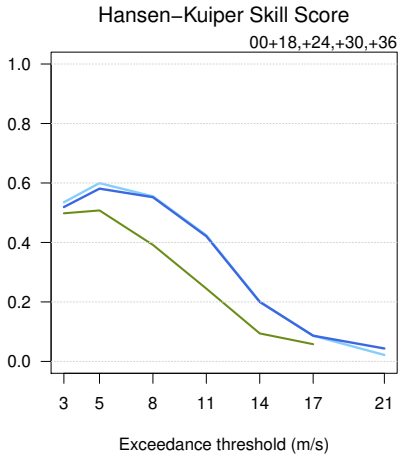

Mean Absolute Error
71 North Scand. stations 00+3,+6,...,+66
3.5
3.0
2.5
2.0
1.5
1.0
3 9 15 24 33 42 51 60
Lead time (hour)

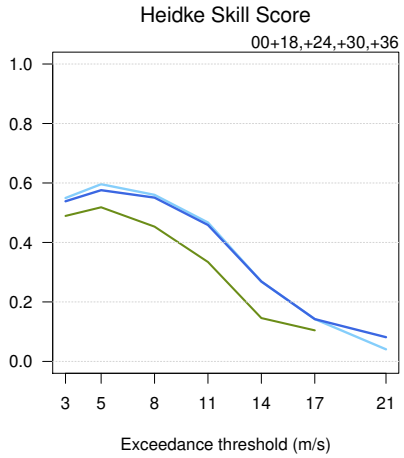

Hit Rate
95 North Scand. stations 00+18,+24,+30,+36
AA25
MEPSctrl
ECMWF
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)


False Alarm Rate
00+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

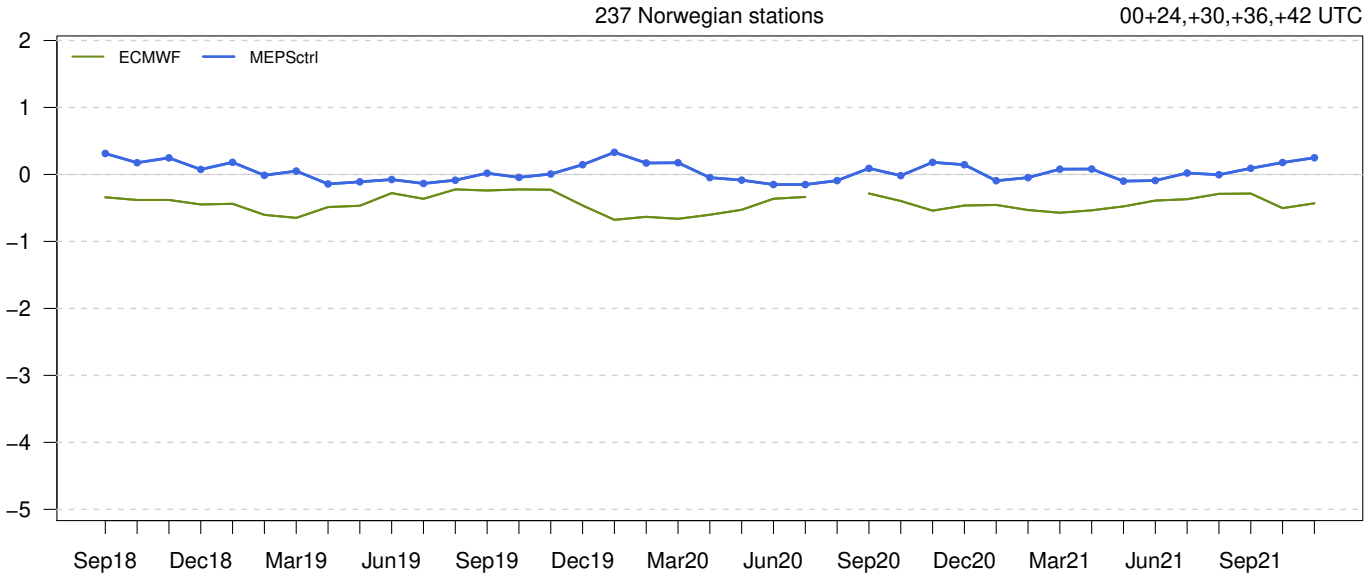

False Alarm Ratio
00+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

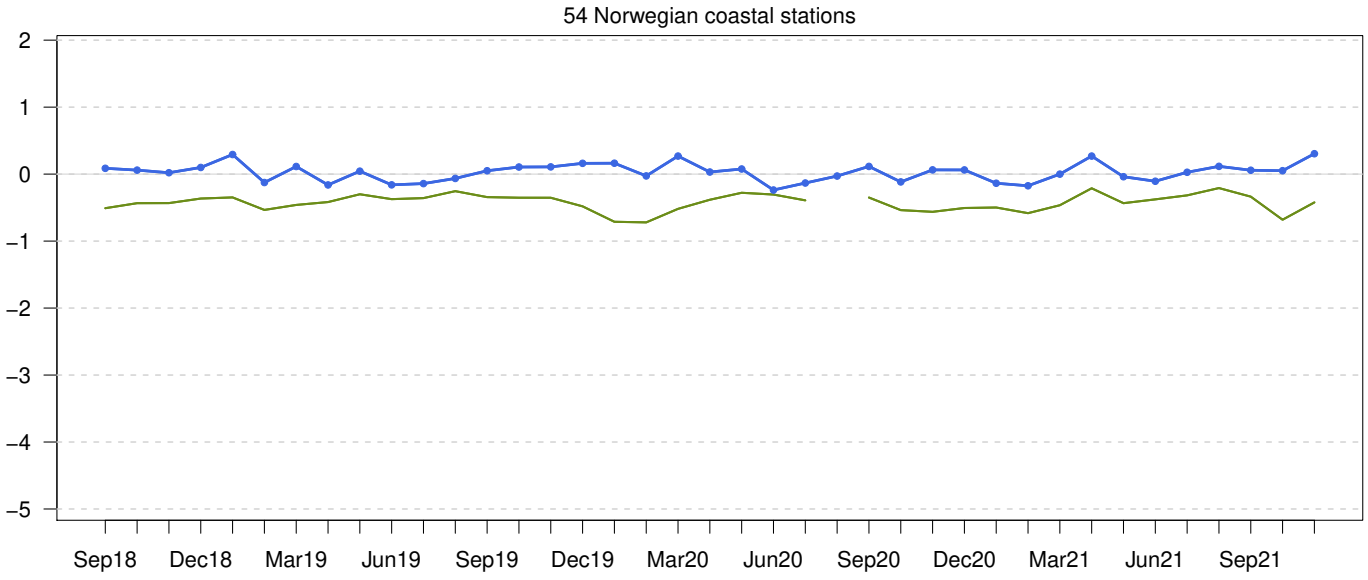

Equitable Threat Score
95 North Scand. stations 00+18,+24,+30,+36
AA25
MEPSctrl
ECMWF
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

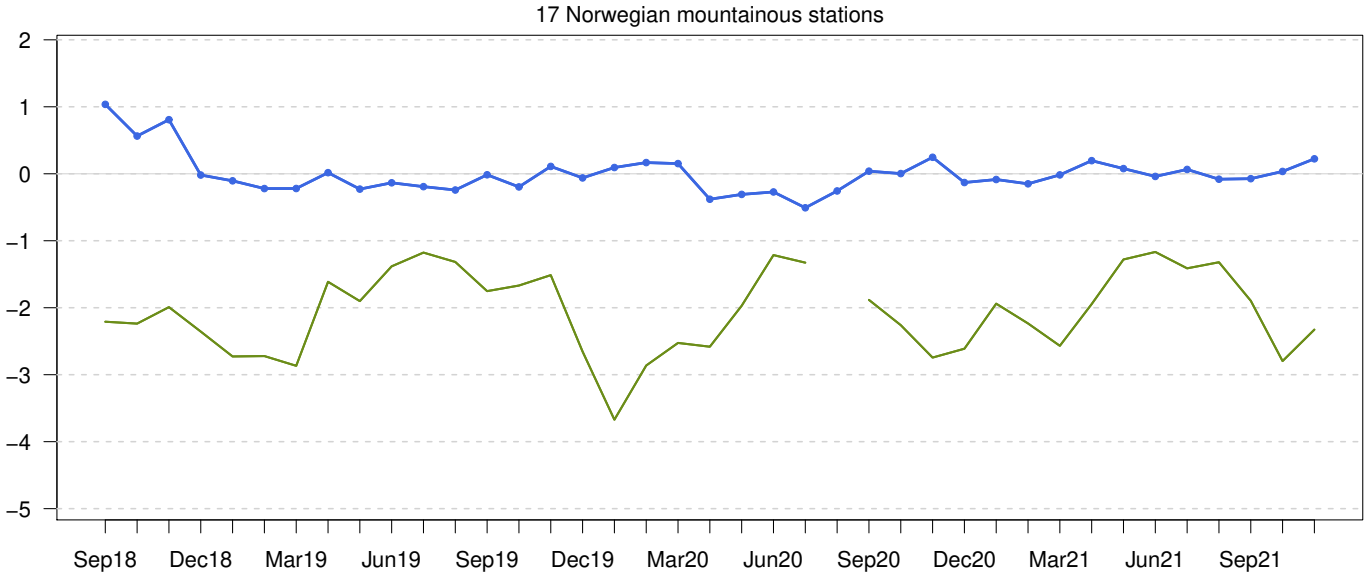

Hansen−Kuiper Skill Score
00+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)


Heidke Skill Score
00+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

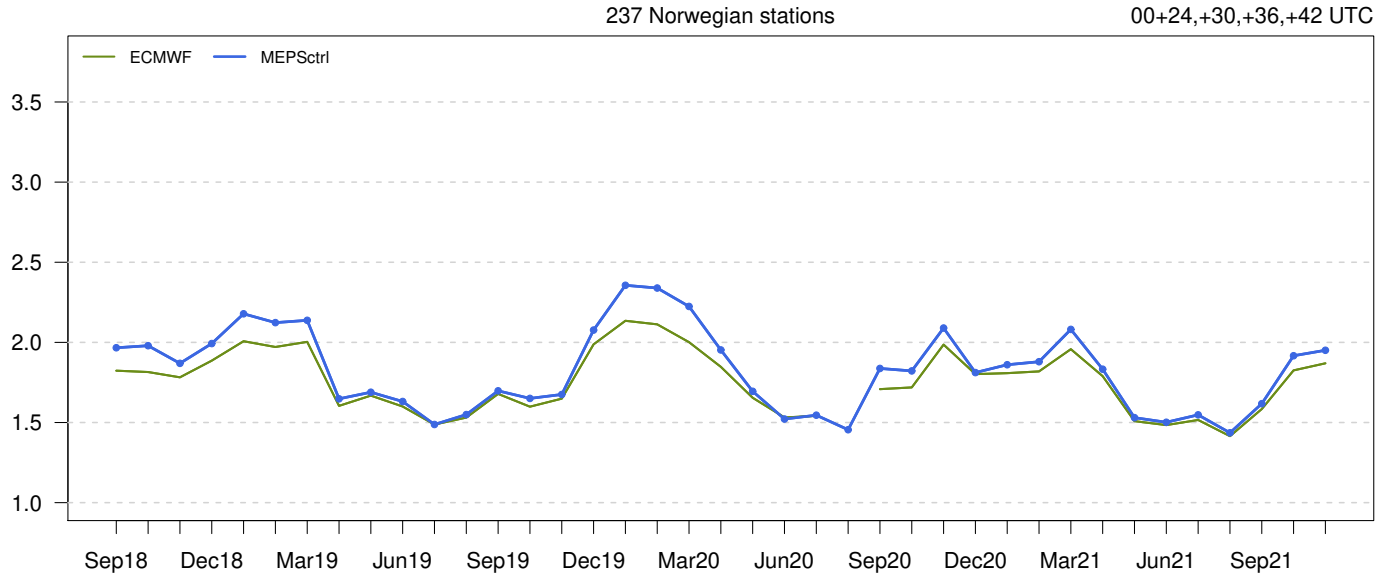
Mean Error

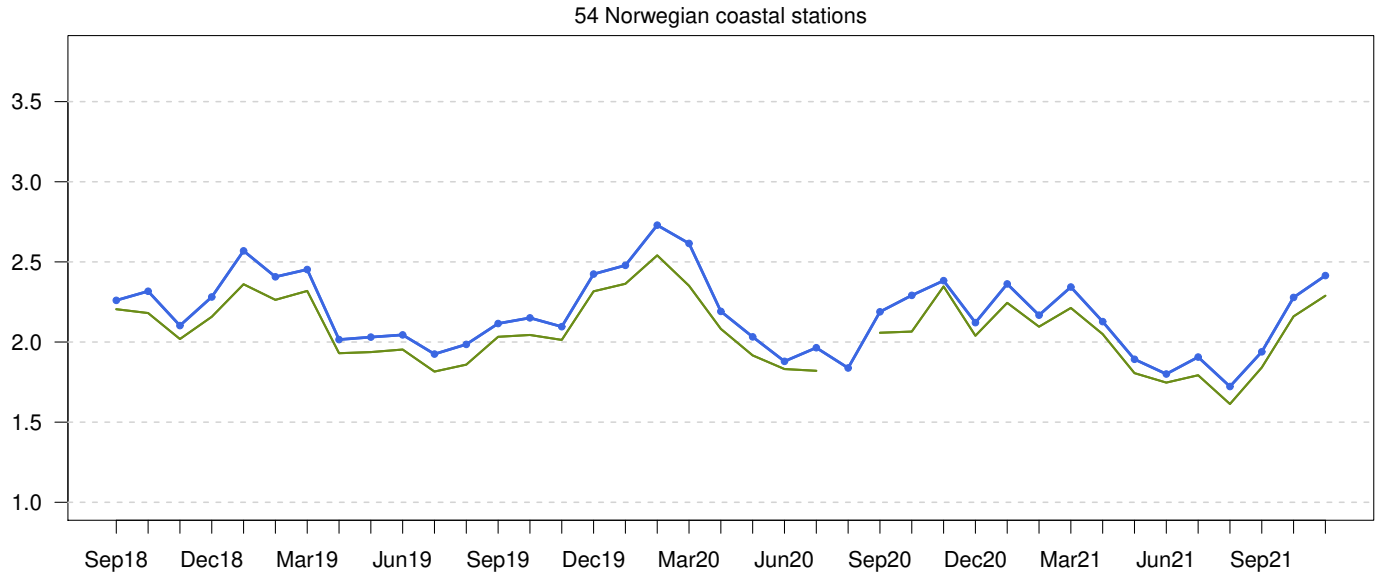

237 Norwegian stations
00+24,+30,+36,+42 UTC
ECMWF
MEPSctrl
2
1
0
−1
−2
−3
−4
−5
Sep18
Dec18
Mar19
Jun19
Sep19
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21

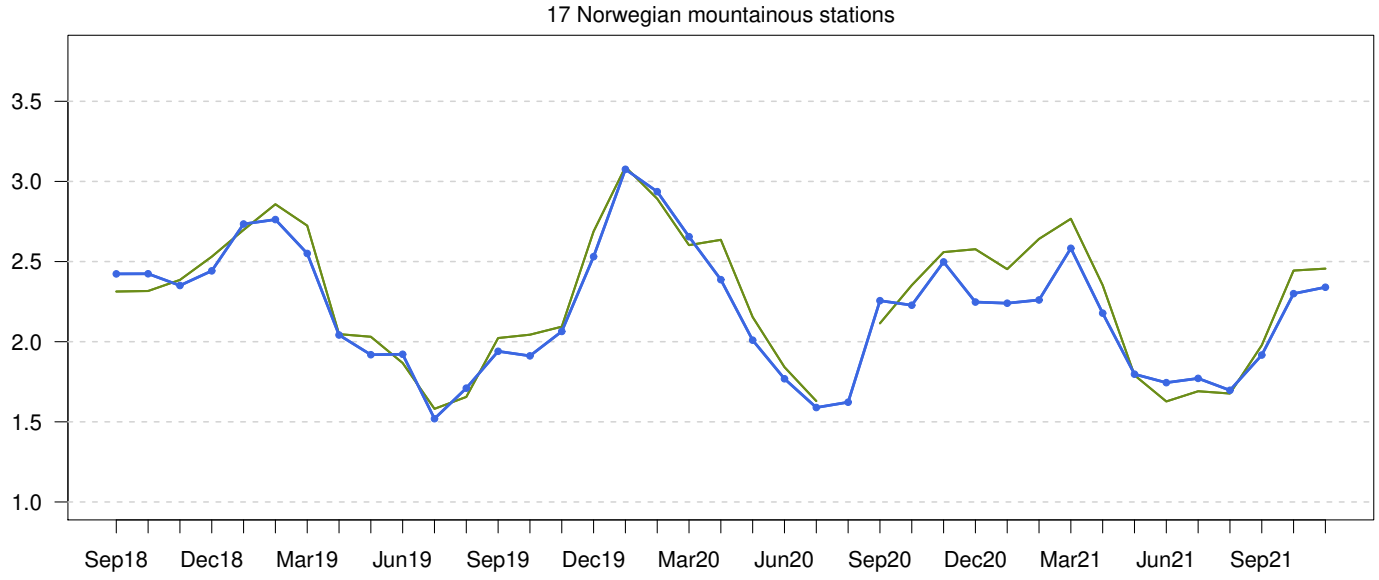

54 Norwegian coastal stations
2
1
0
−1
−2
−3
−4
−5
Sep18
Dec18
Mar19
Jun19
Sep19
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21


17 Norwegian mountainous stations
2
1
0
−1
−2
−3
−4
−5
Sep18
Dec18
Mar19
Jun19
Sep19
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21

Standard Deviation of Error

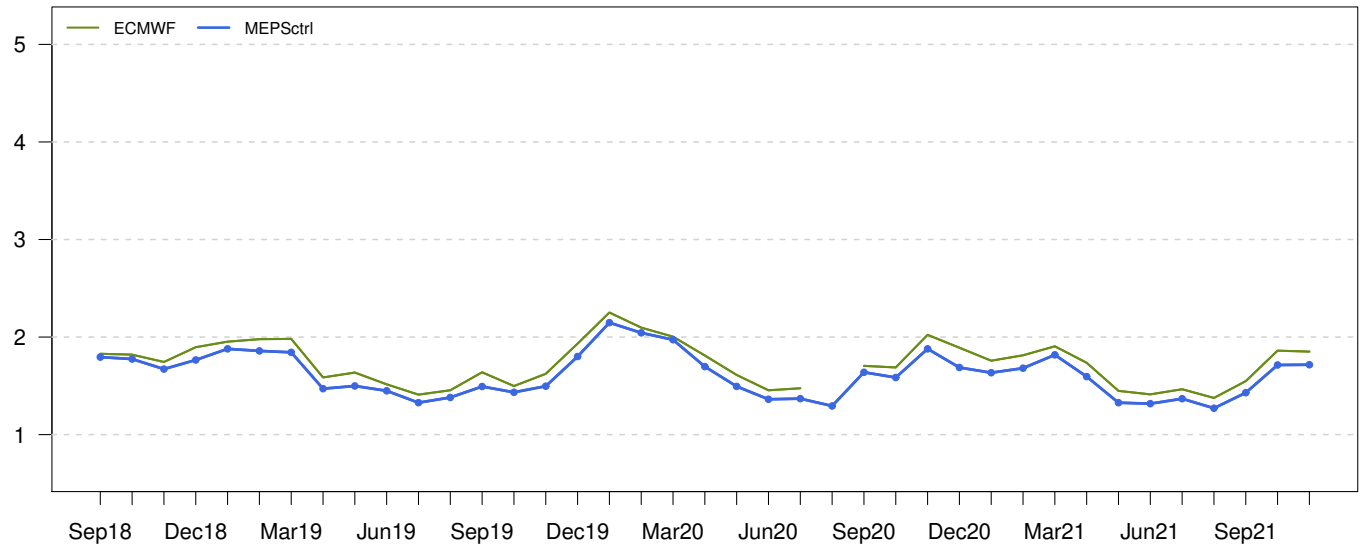




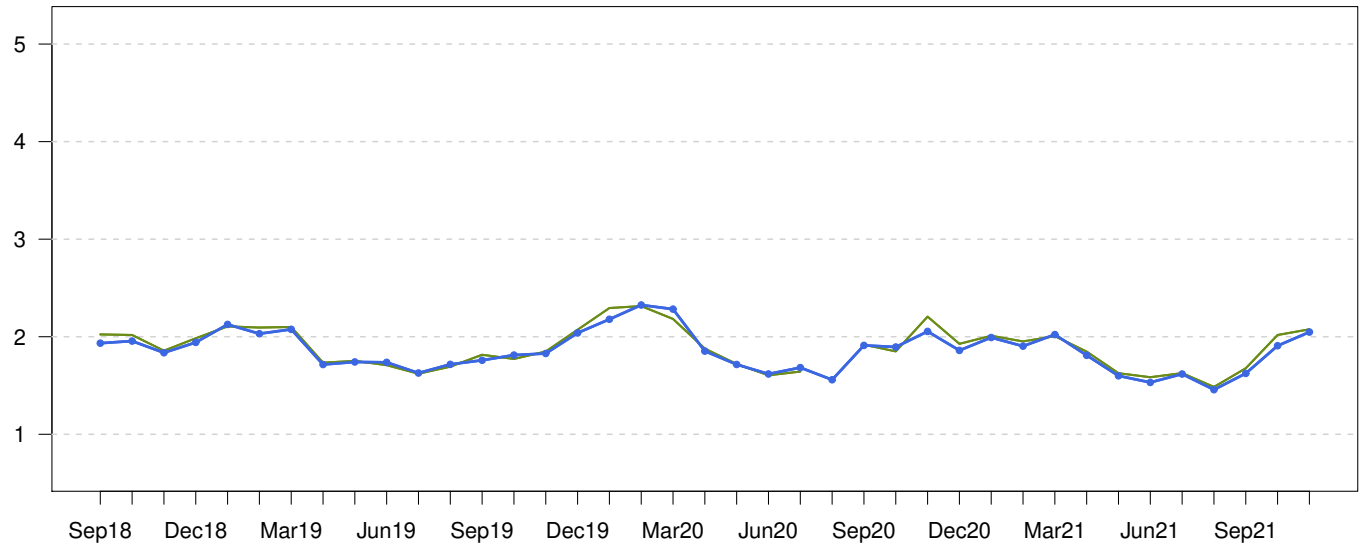


Mean Absolute Error

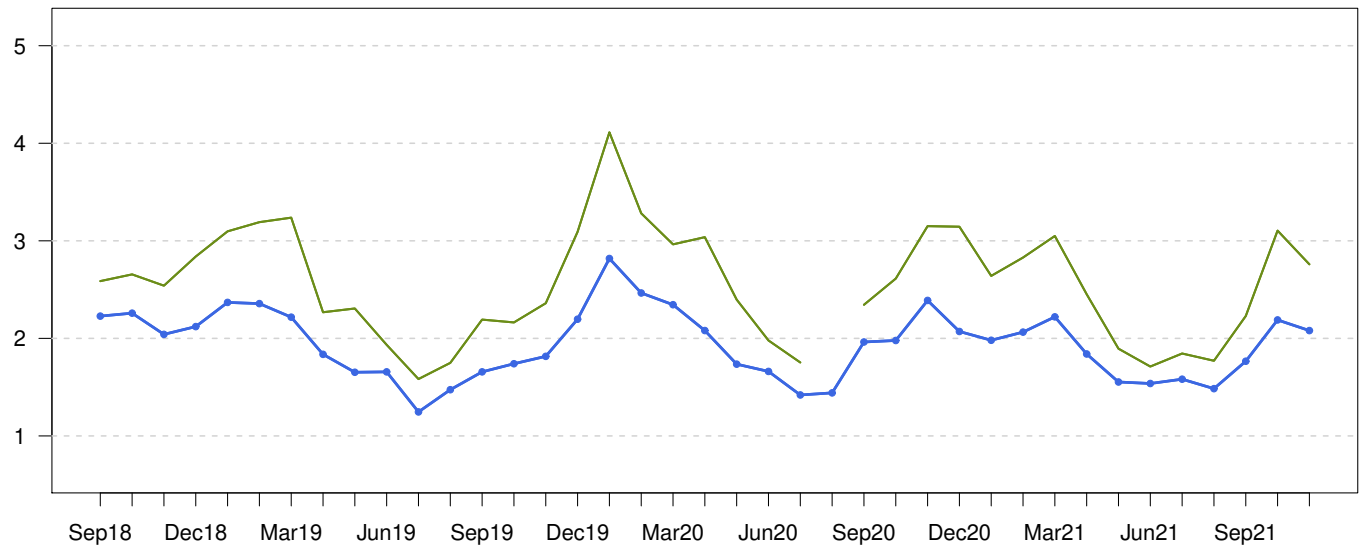
237 Norwegian stations 00+24,+30,+36,+42 UTC



54 Norwegian coastal stations

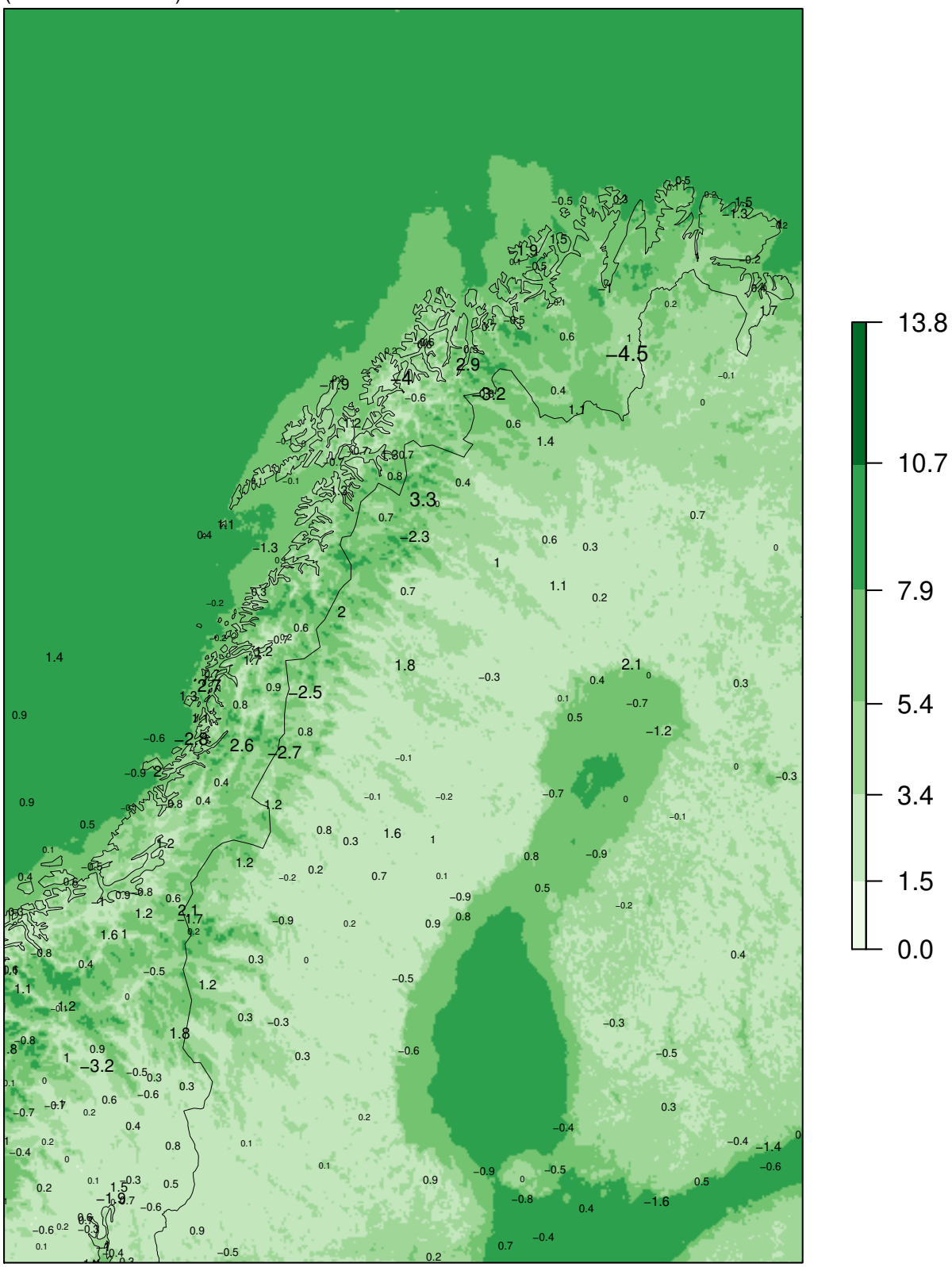


17 Norwegian mountainous stations



MEPSctrl 00+12

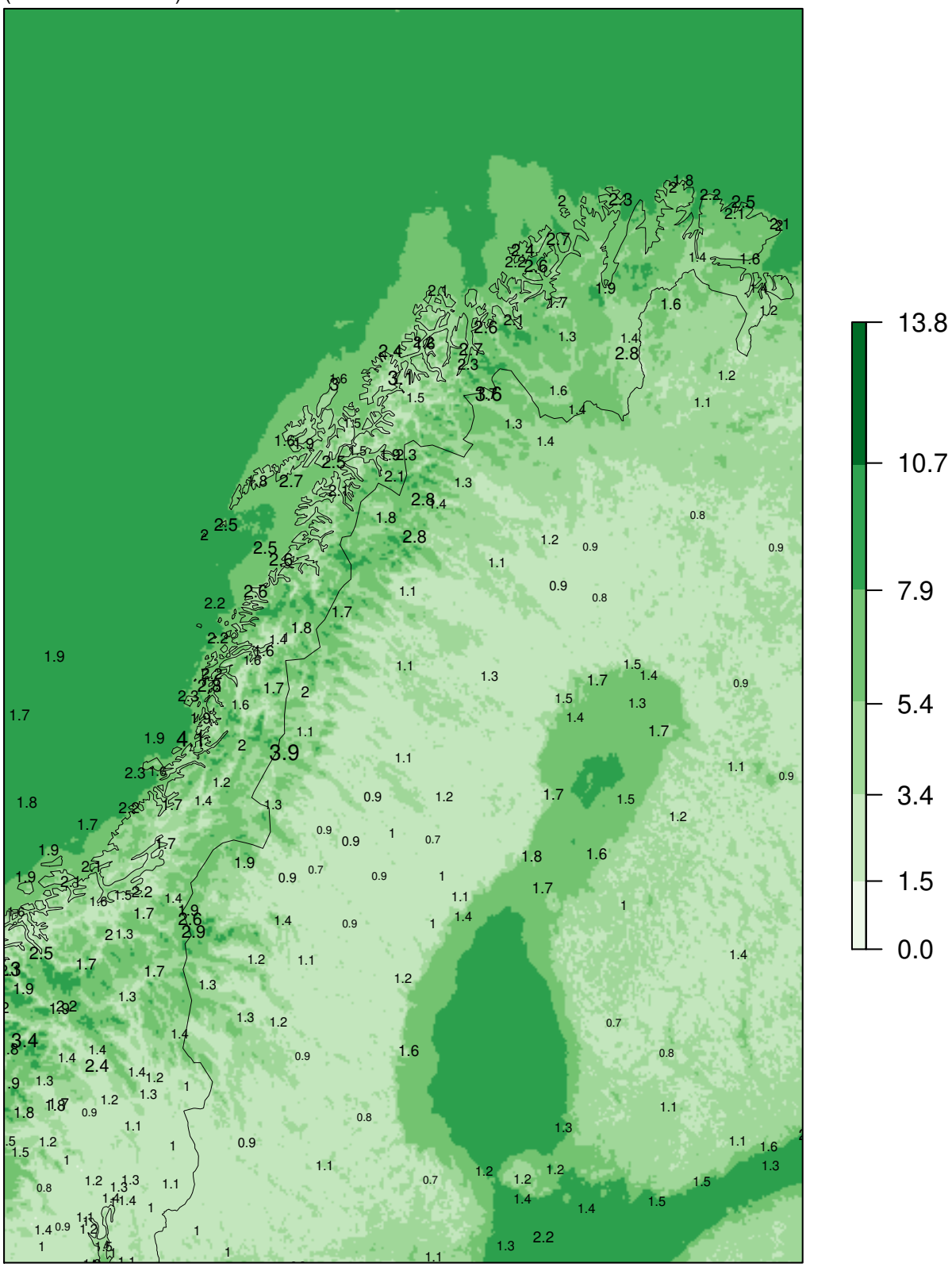
ME at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+12

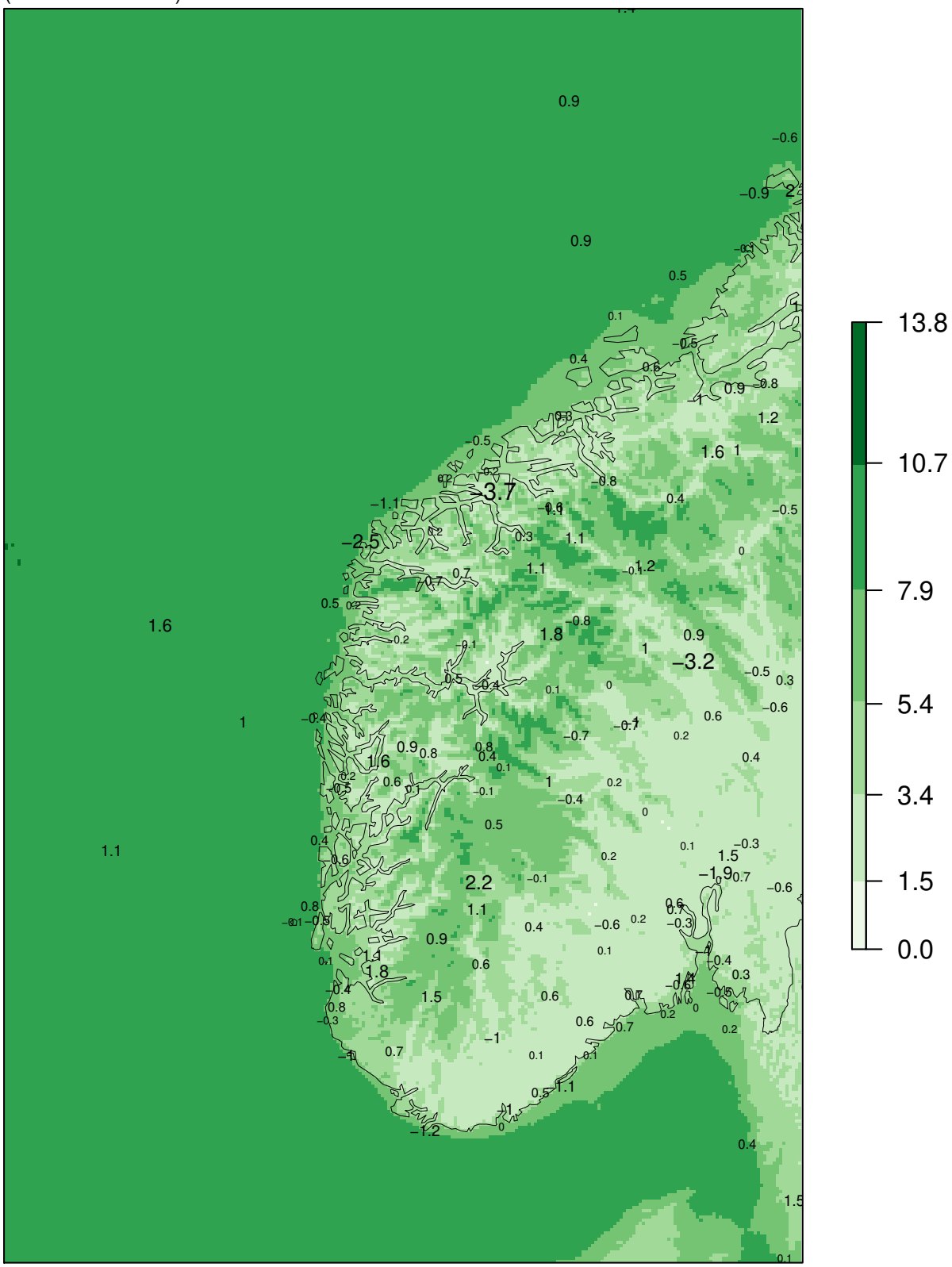
SDE at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+12

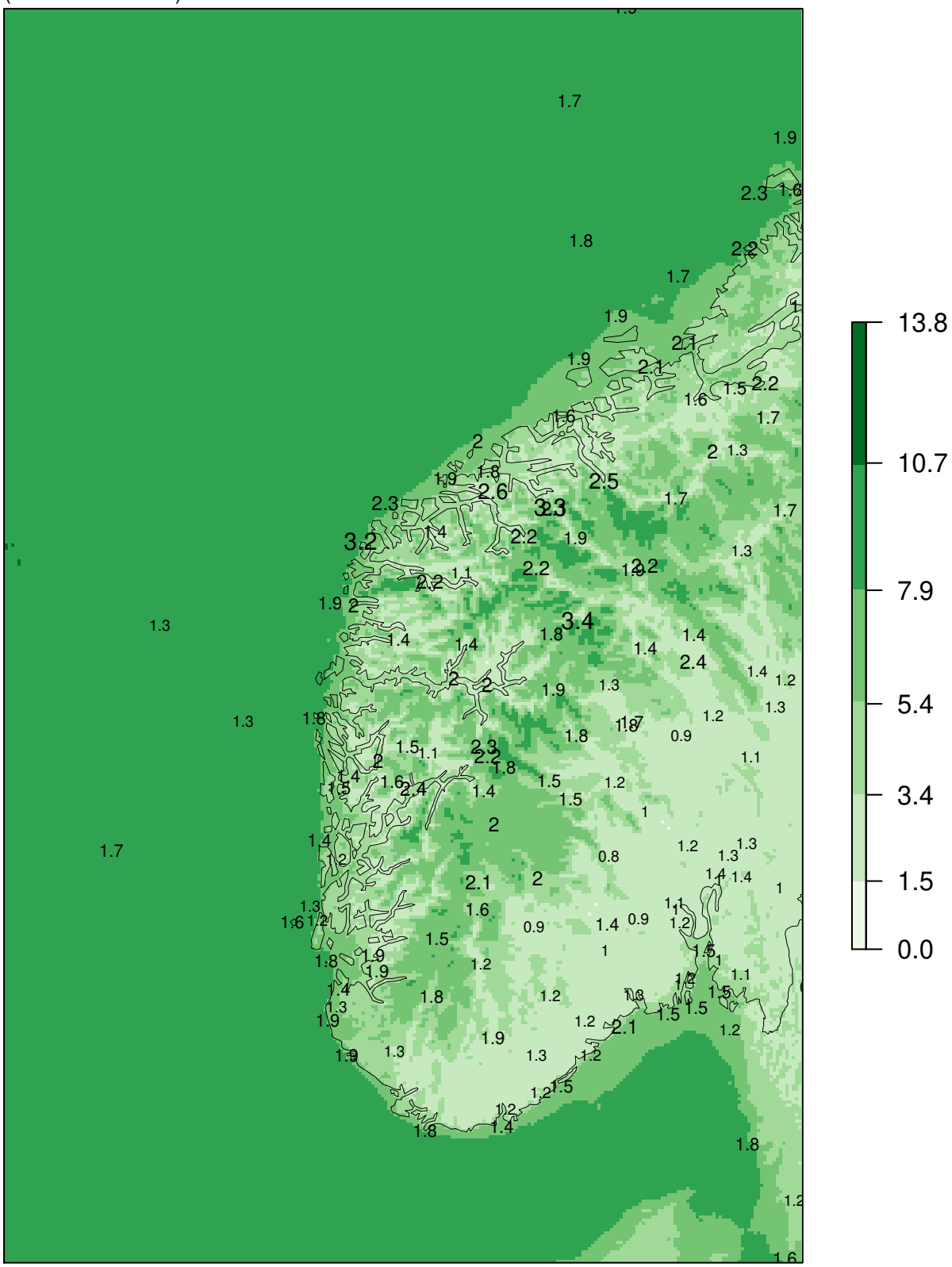
ME at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+12

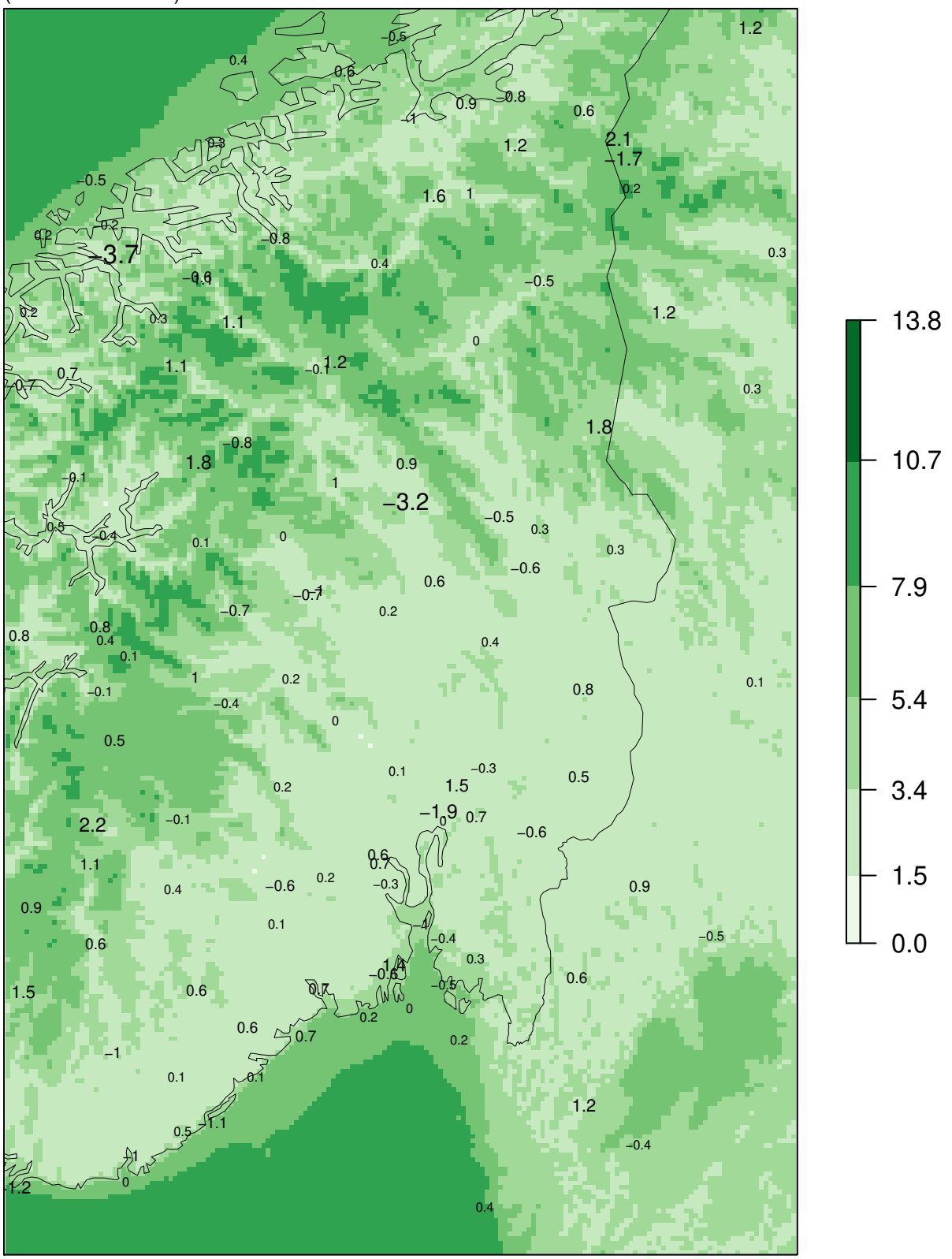
SDE at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+12

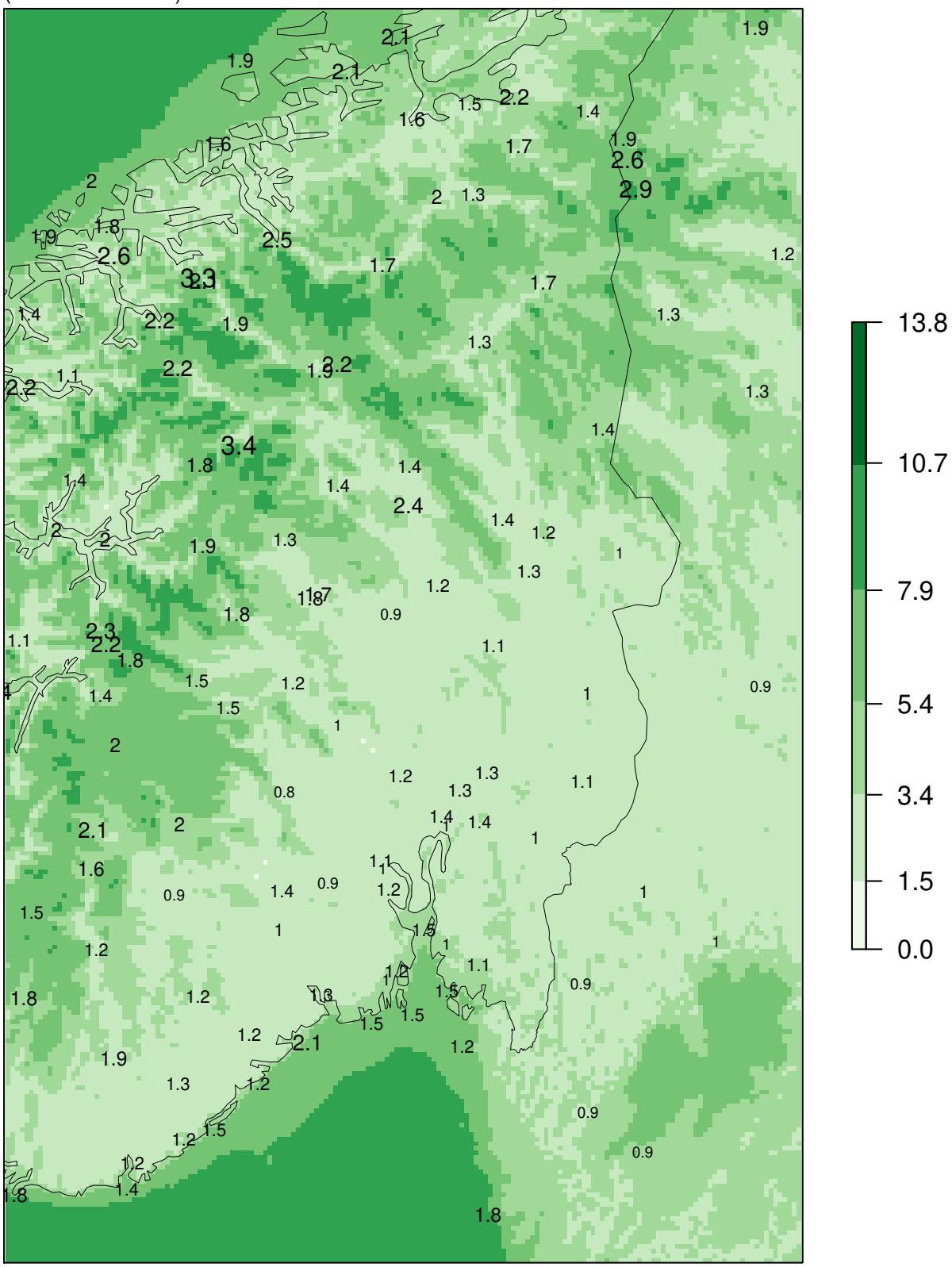
ME at observing sites
(numbers in black)



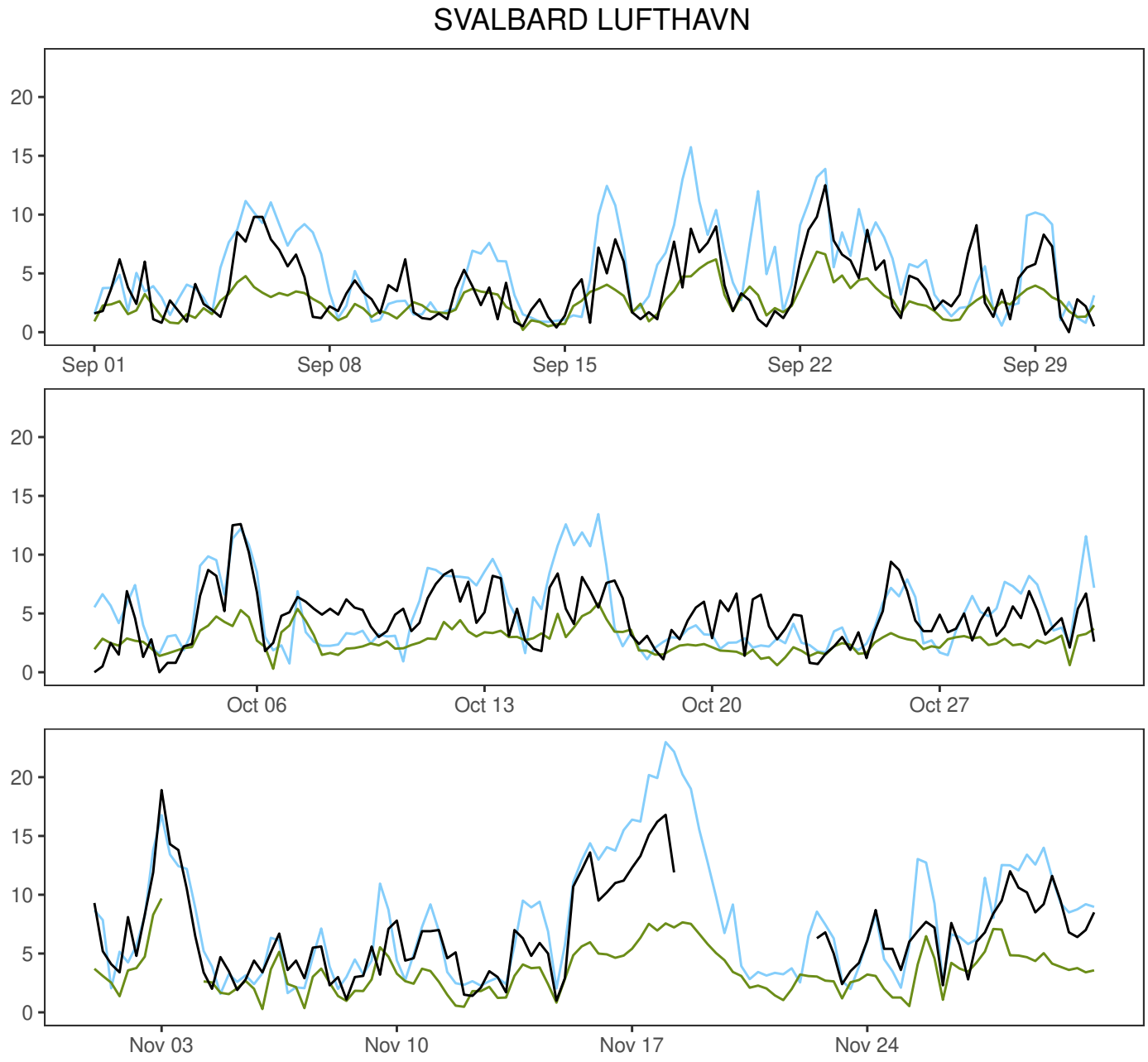
Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+12

SDE at observing sites
(numbers in black)

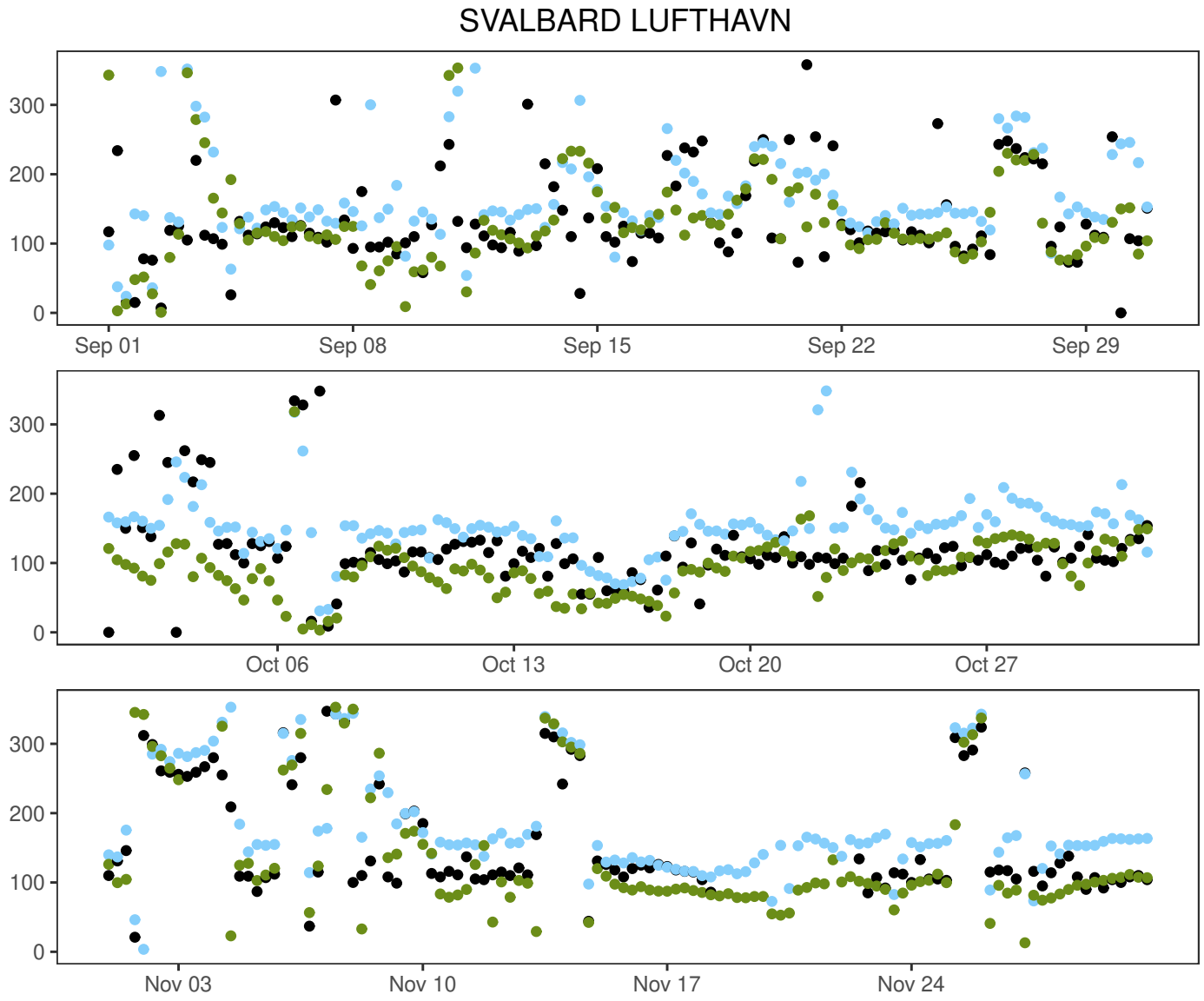


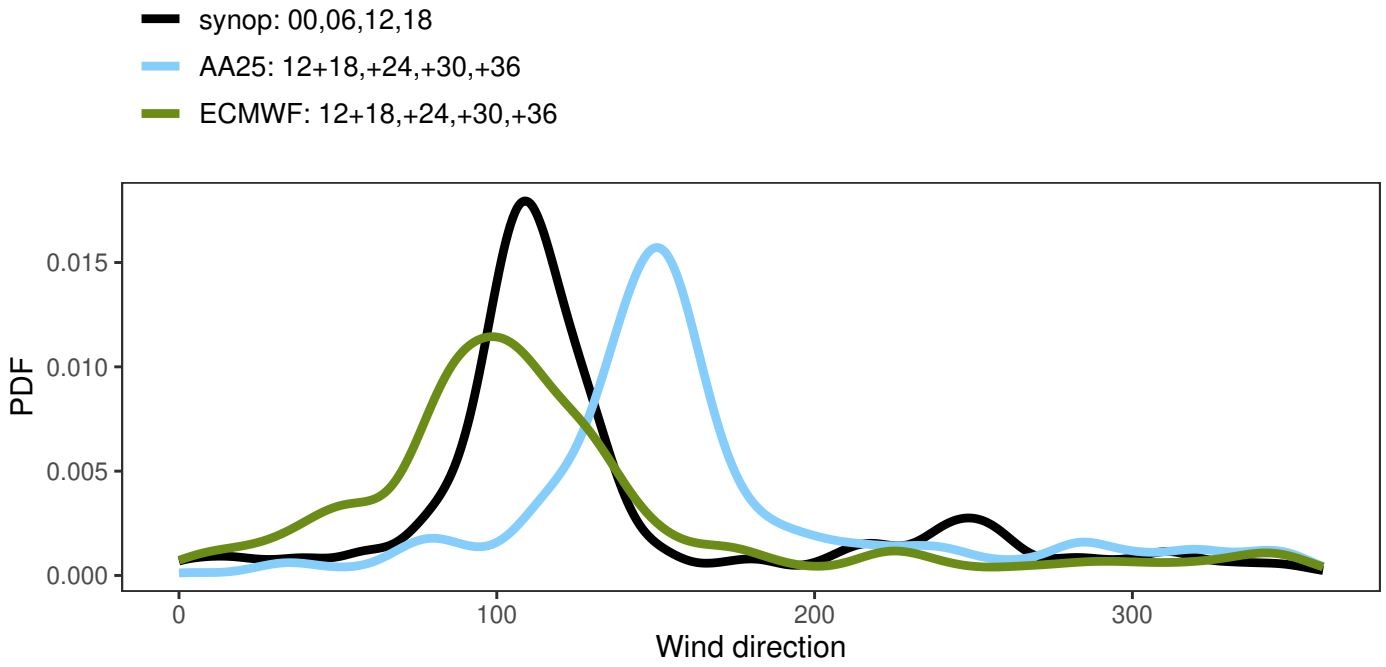
Model "climatology" 01.09.2021 – 30.11.2021



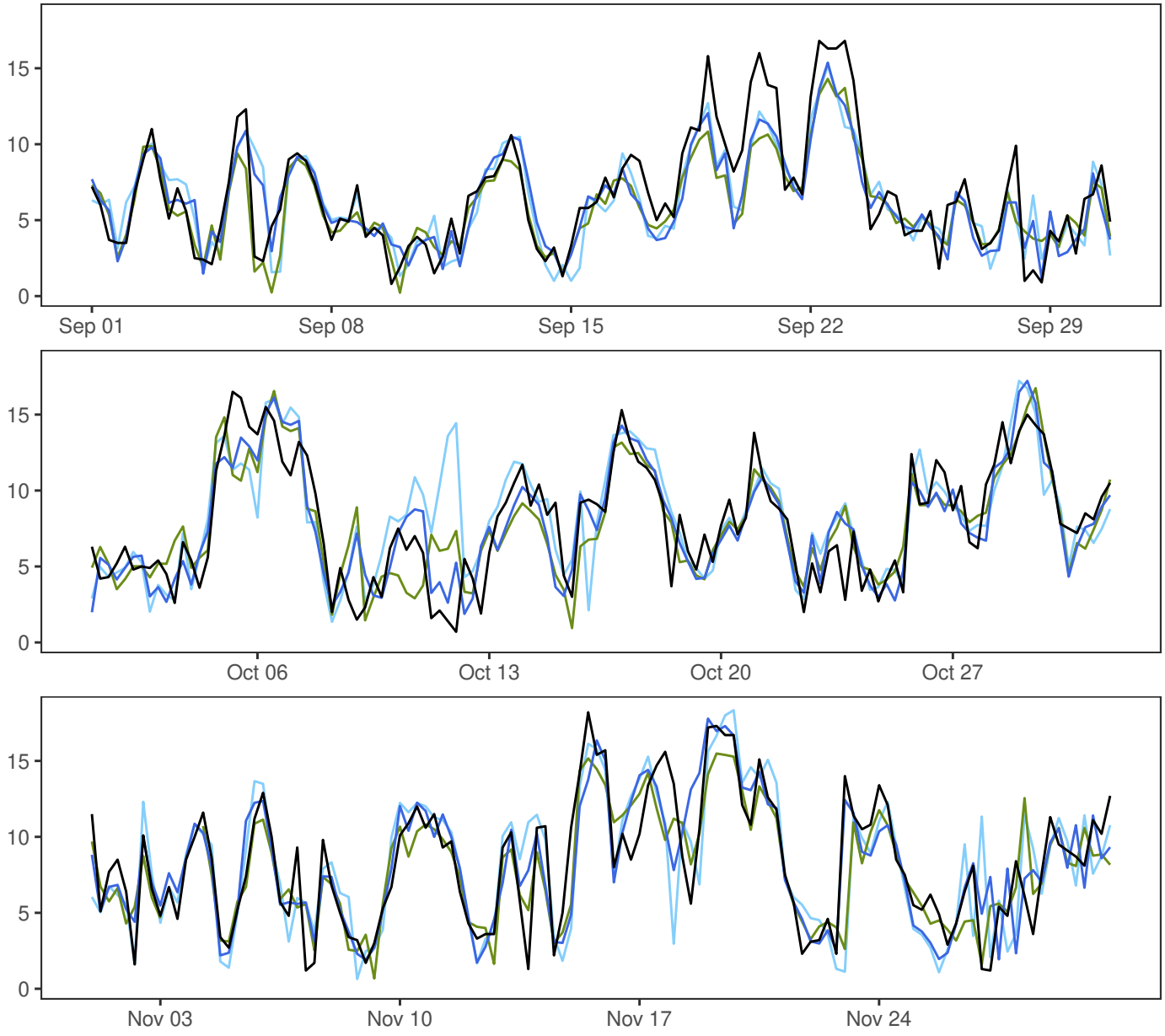
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	5.0	18.9	3.2	349
AA25: 12+18,+24,+30,+36	0.6	6.0	23.0	4.2	364
ECMWF: 12+18,+24,+30,+36	0.2	2.9	9.7	1.5	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
AA25−synop	0.9	2.6	2.7	2.1	10.9	345
ECMWF−synop	−2.0	2.2	3.0	2.4	9.2	345


SVALBARD LUFTHAVN
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

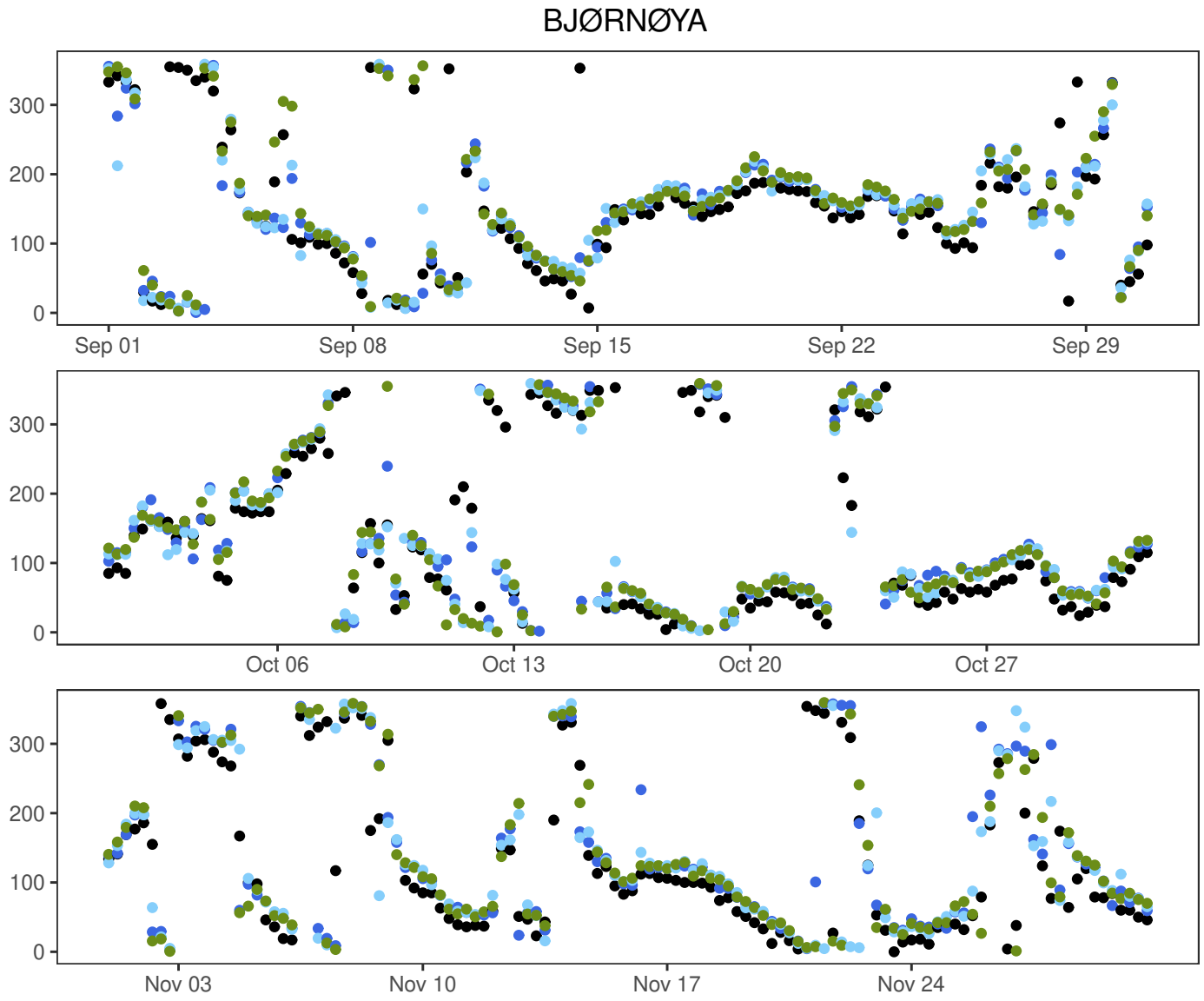

synop: 00,06,12,18
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.015
0.010
0.005
0.000
0
100
200
300
Wind direction

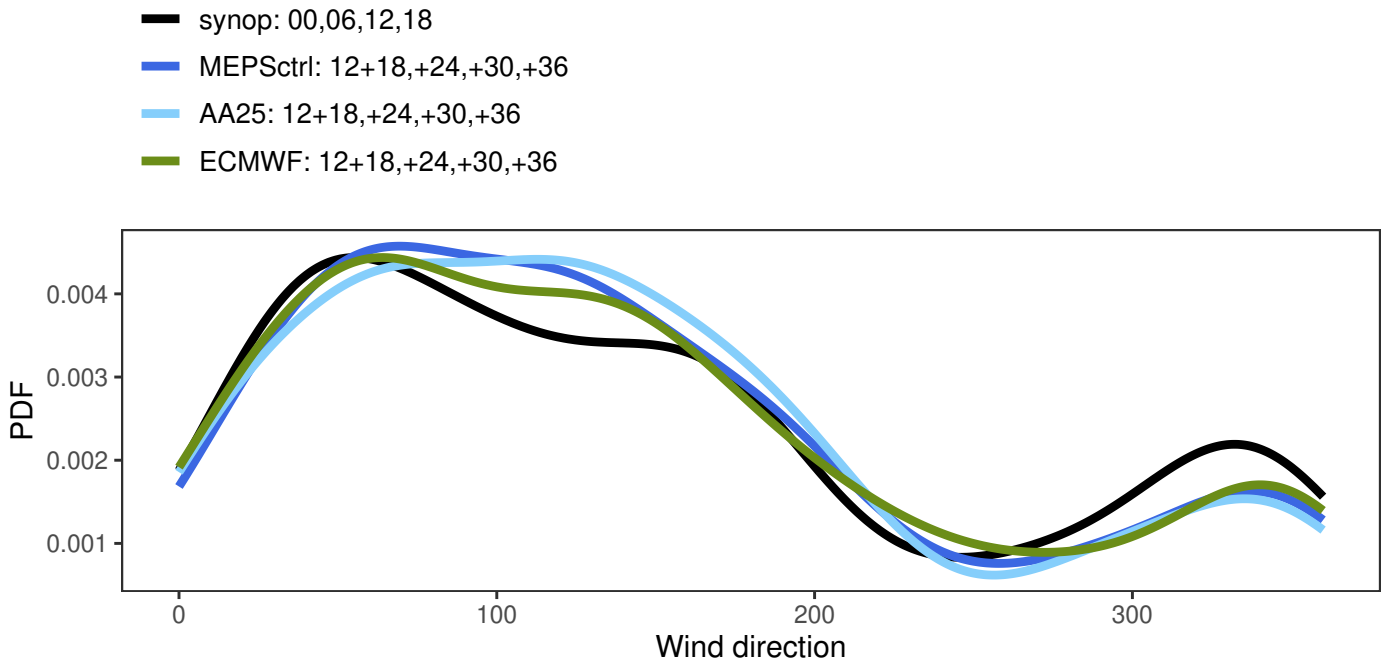
BJØRNØYA



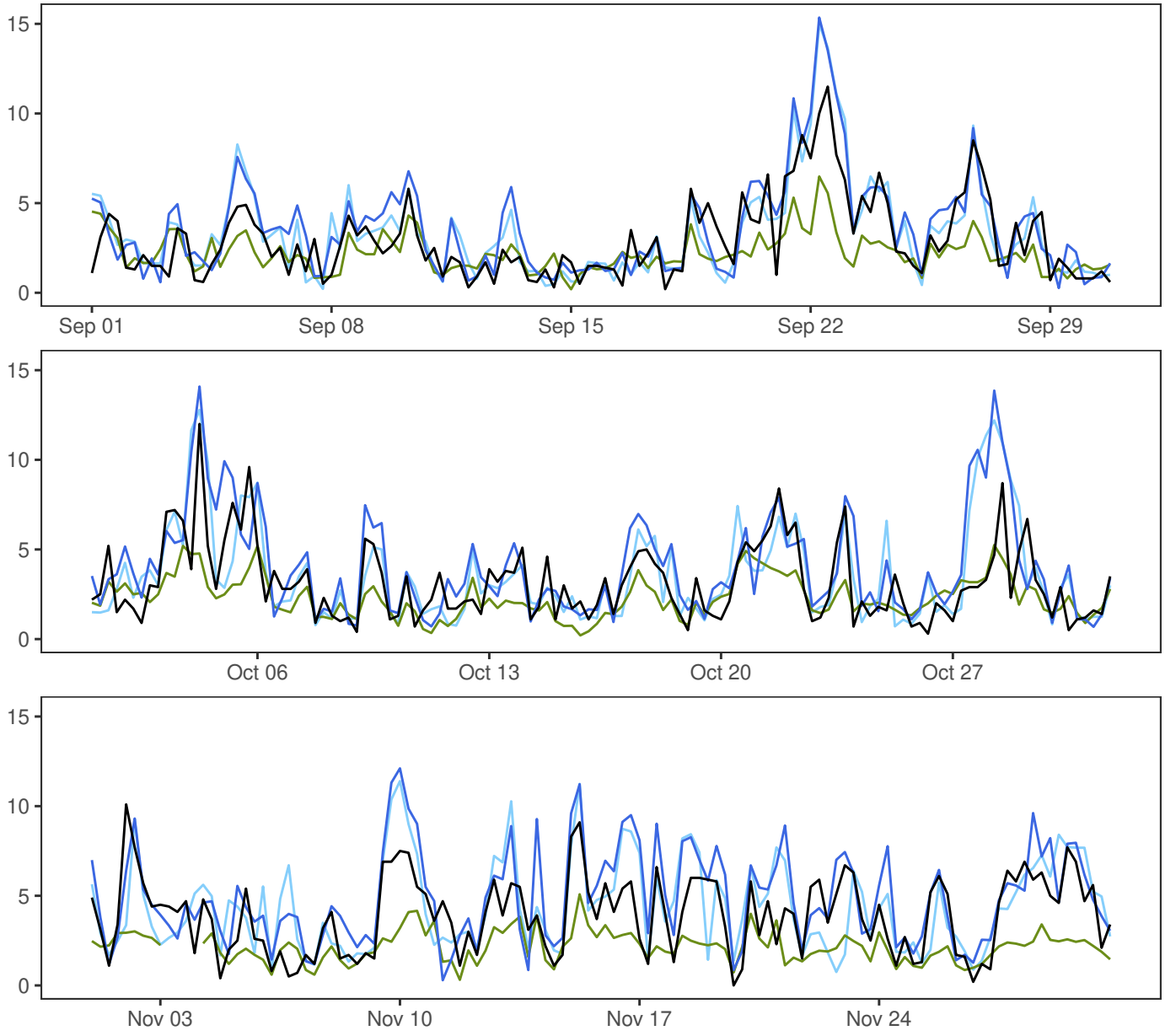
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.7	7.6	18.2	4.0	364
MEPSctrl: 12+18,+24,+30,+36	1.2	7.4	17.8	3.6	364
AA25: 12+18,+24,+30,+36	0.6	7.6	18.3	3.8	364
ECMWF: 12+18,+24,+30,+36	0.2	7.2	16.7	3.4	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.2	2.1	2.1	1.6	7.5	360
AA25−synop	0.0	2.7	2.7	1.9	13.7	360
ECMWF−synop	−0.4	2.1	2.2	1.6	11.4	360


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

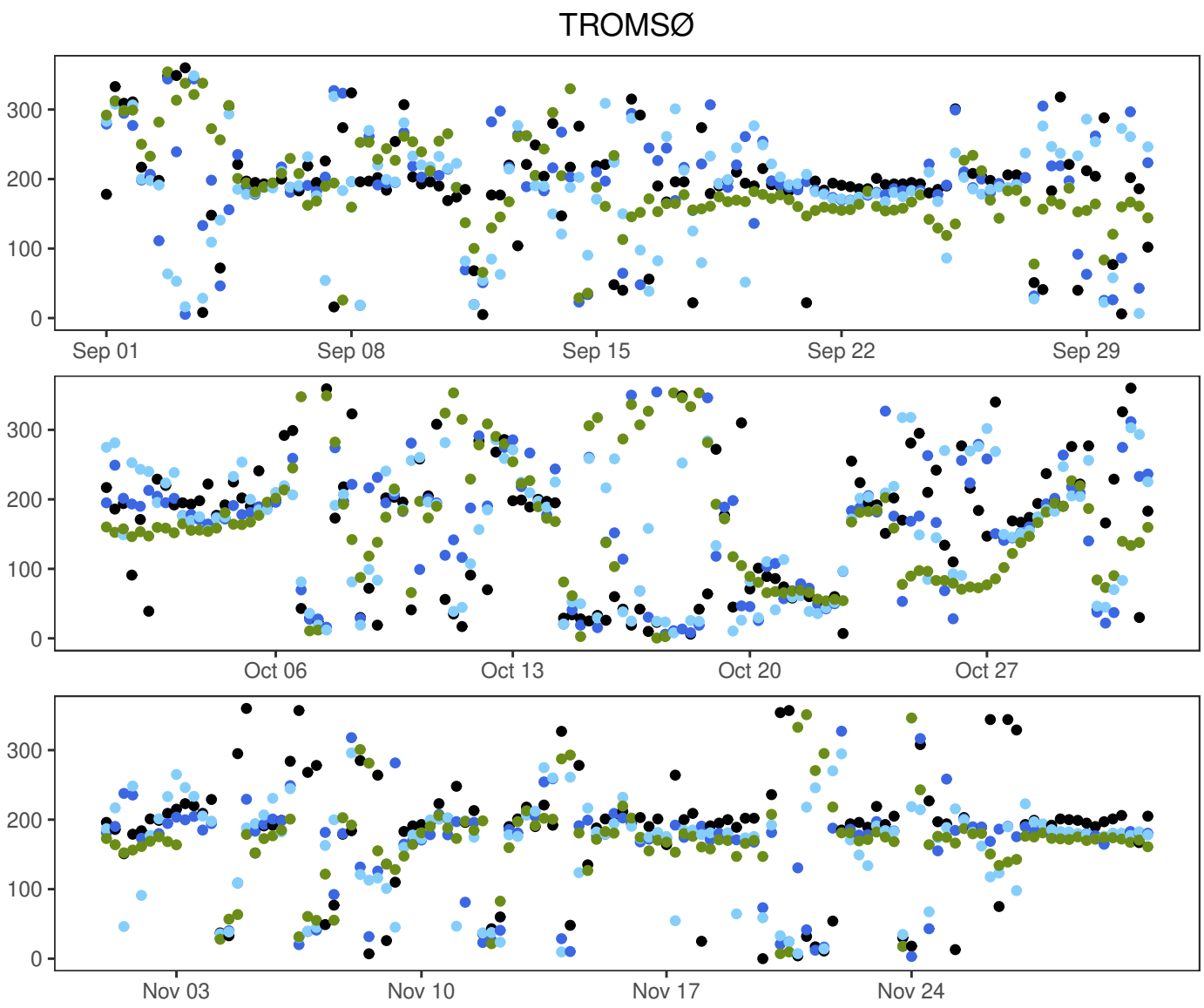

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

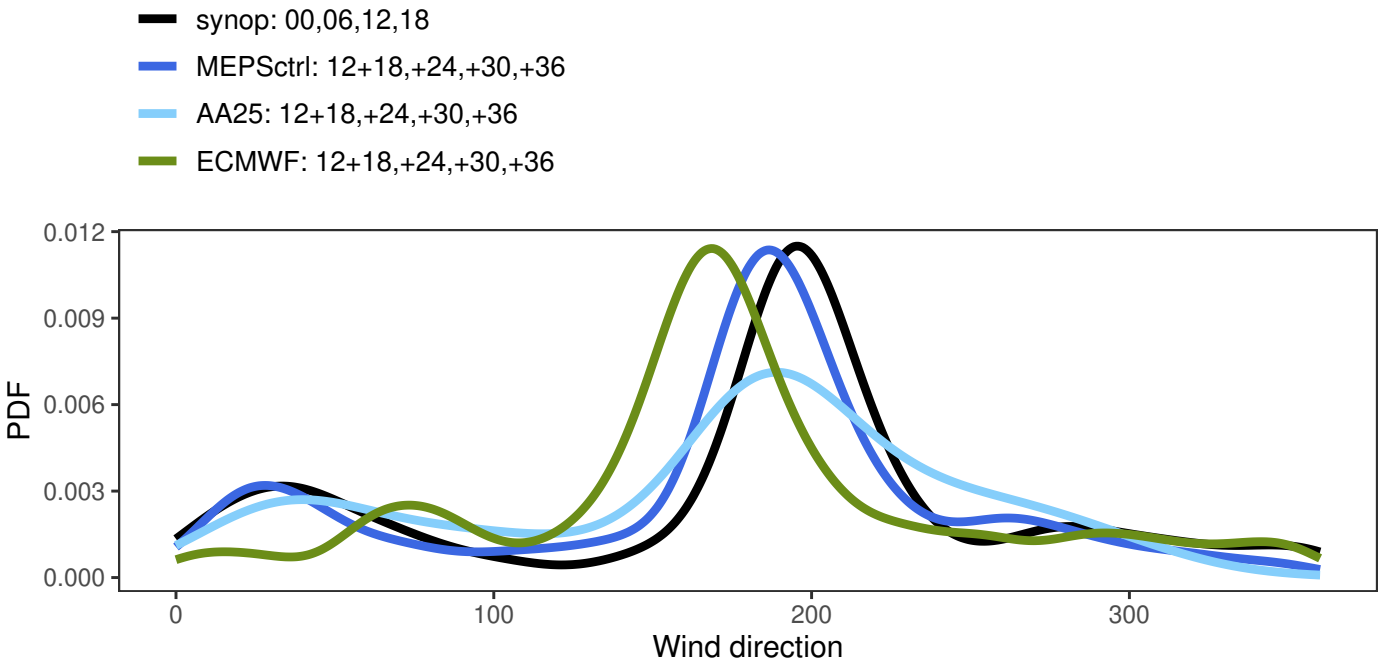
TROMSØ



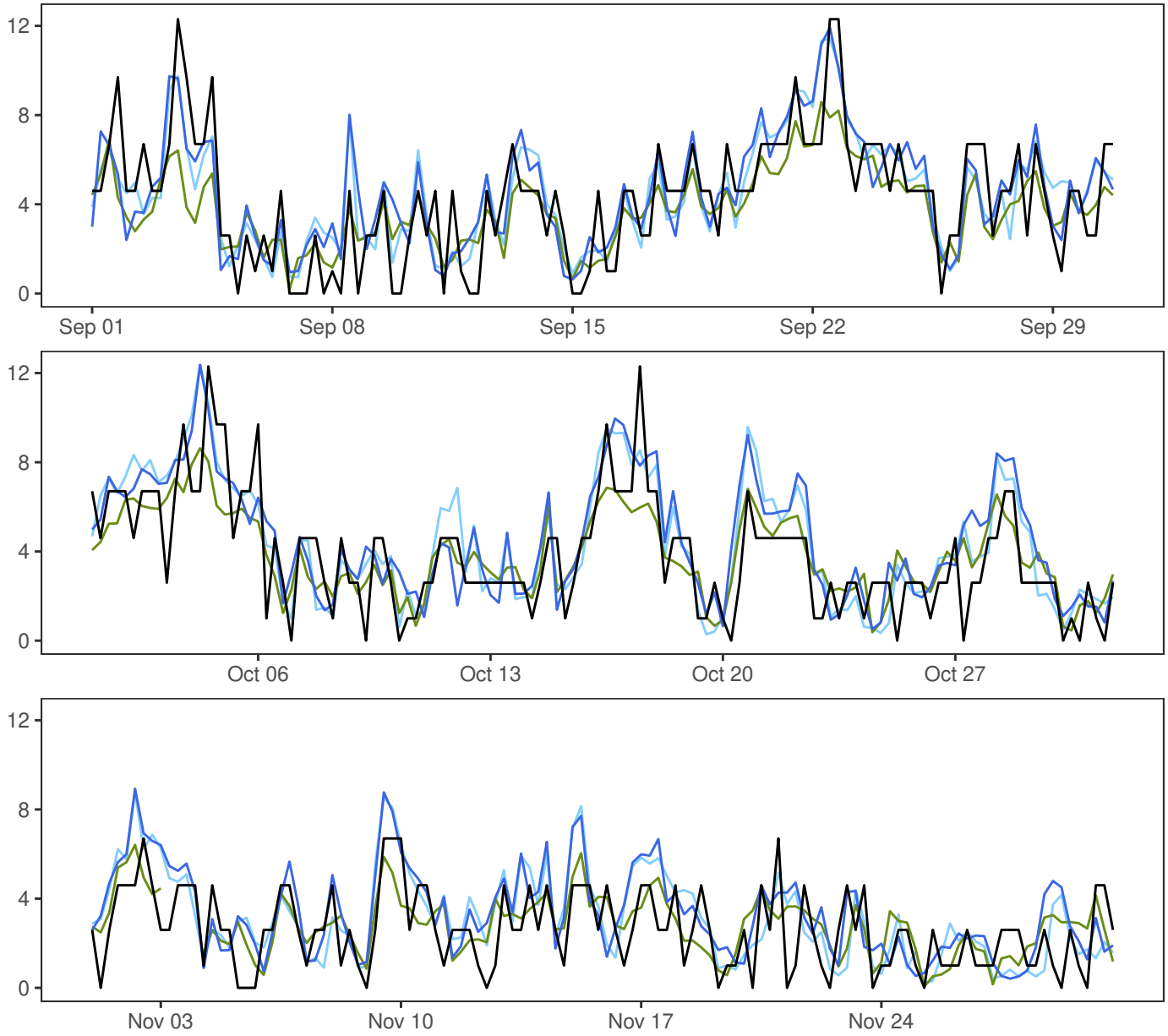
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	3.3	12.0	2.2	364
MEPSctrl: 12+18,+24,+30,+36	0.3	4.2	15.4	2.7	364
AA25: 12+18,+24,+30,+36	0.2	3.8	15.0	2.7	364
ECMWF: 12+18,+24,+30,+36	0.2	2.2	6.5	1.0	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.9	1.8	2.0	1.5	9.2	360
AA25−synop	0.4	1.9	2.0	1.4	8.1	360
ECMWF−synop	−1.1	1.7	2.1	1.5	7.2	360


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

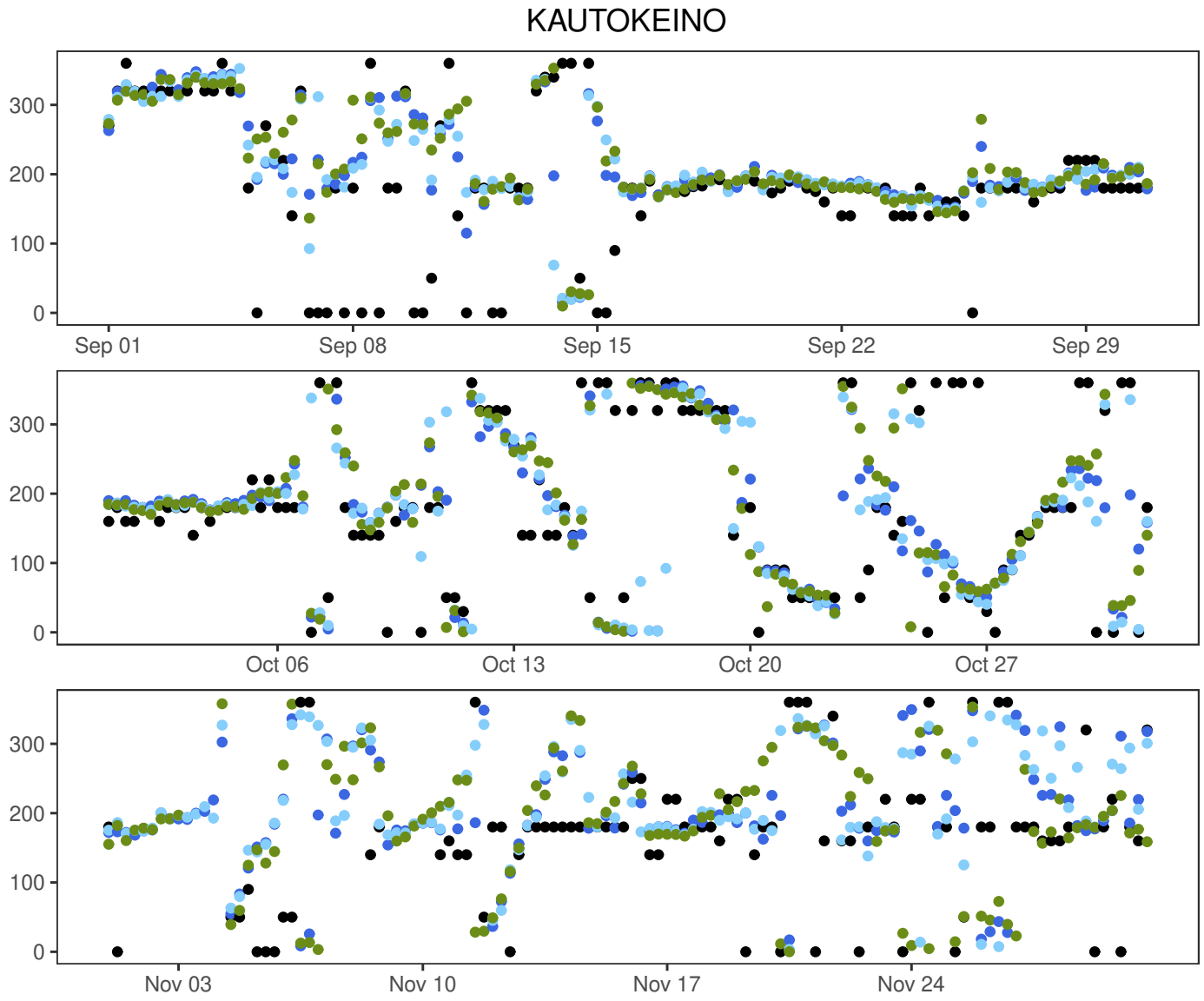

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.012
0.009
0.006
0.003
0.000
0
100
200
300
Wind direction

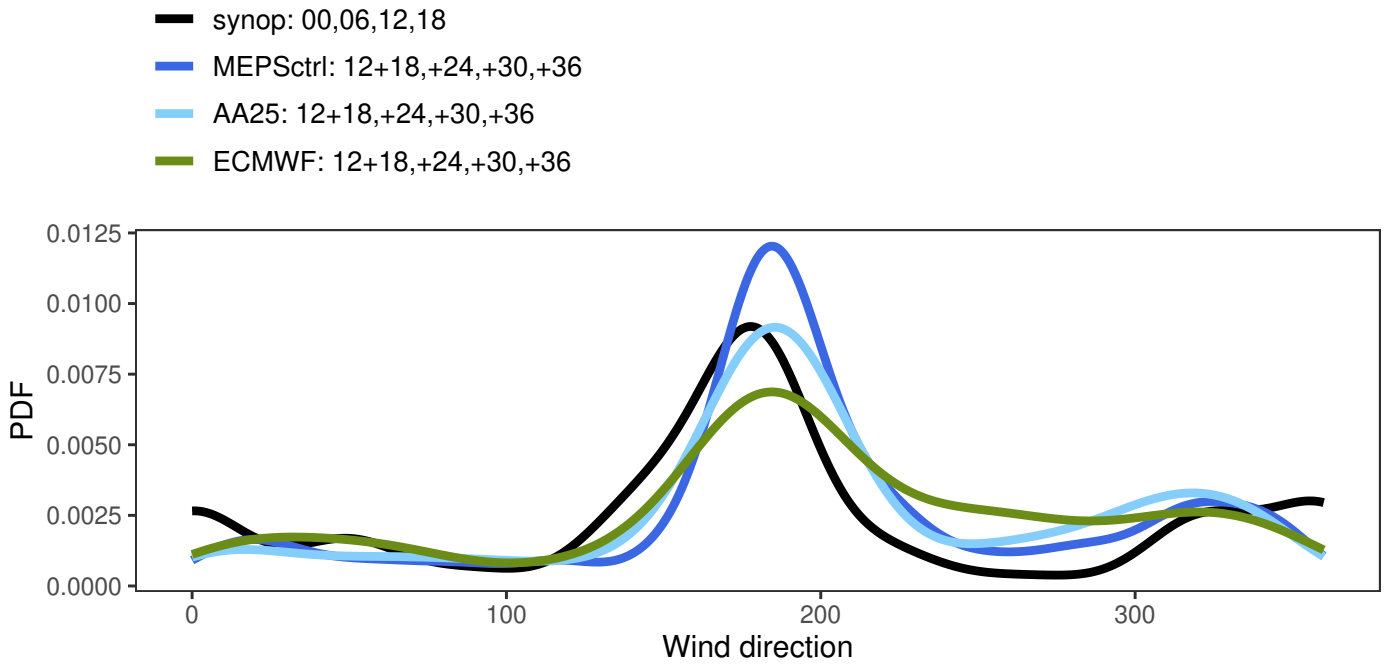
KAUTOKEINO



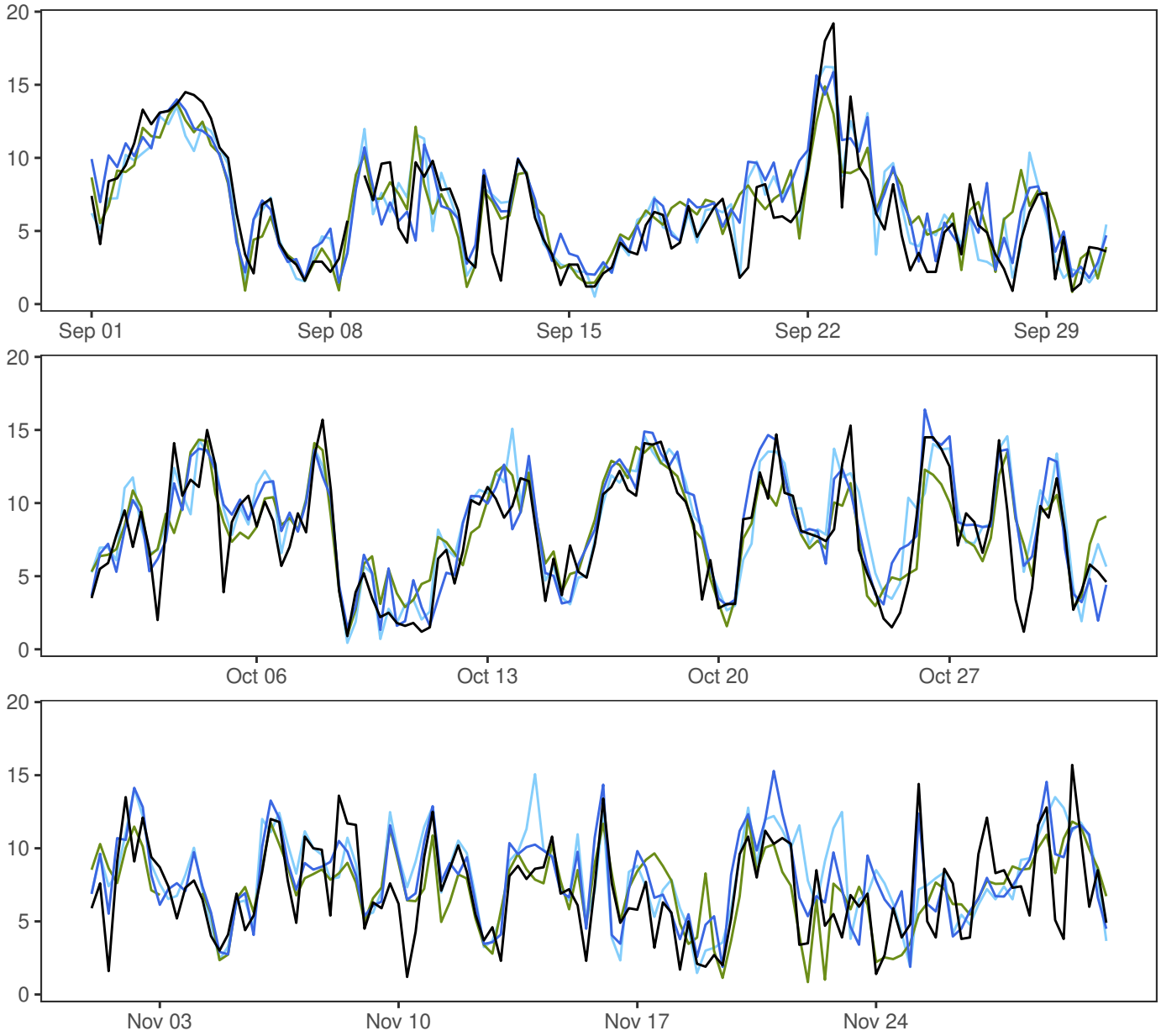
		Min	Mean	Max	Std	N
———	synop: 00,06,12,18	0.0	3.6	12.3	2.5	364
———	MEPSctrl: 12+18,+24,+30,+36	0.4	4.2	12.4	2.4	364
———	AA25: 12+18,+24,+30,+36	0.2	4.0	12.4	2.5	364
———	ECMWF: 12+18,+24,+30,+36	0.1	3.5	8.6	1.7	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.6	1.8	1.9	1.5	5.7	360
AA25−synop	0.4	1.7	1.8	1.4	5.7	360
ECMWF−synop	−0.1	1.7	1.7	1.3	6.3	360


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

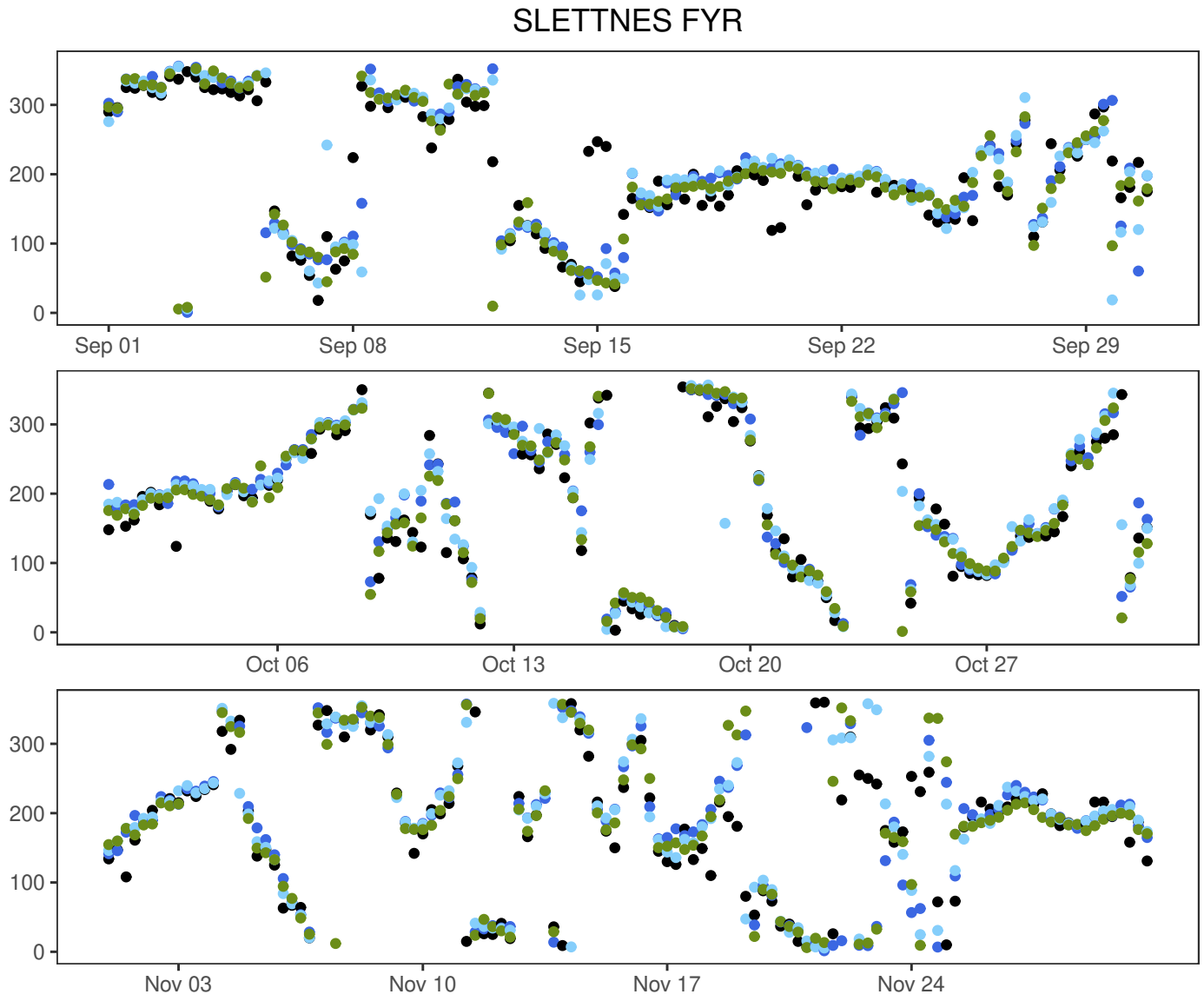

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.0125
0.0100
0.0075
0.0050
0.0025
0.0000
0
100
200
300
Wind direction

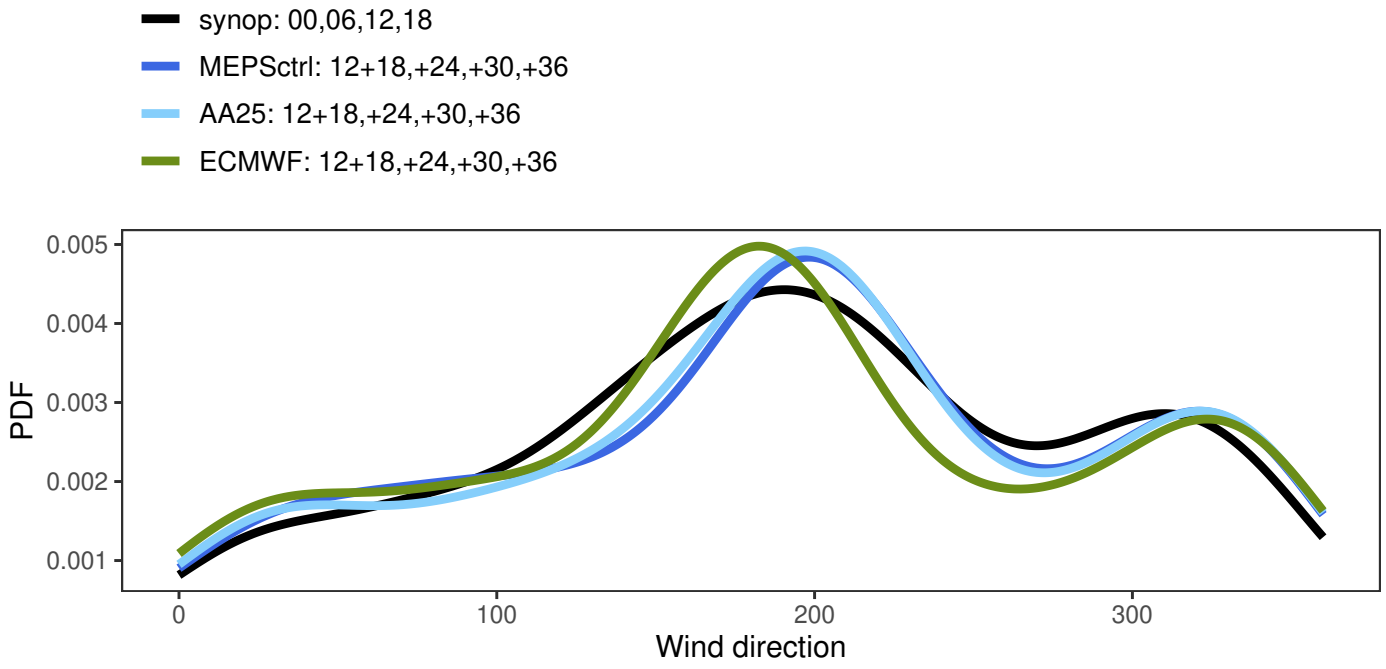
SLETTNES FYR

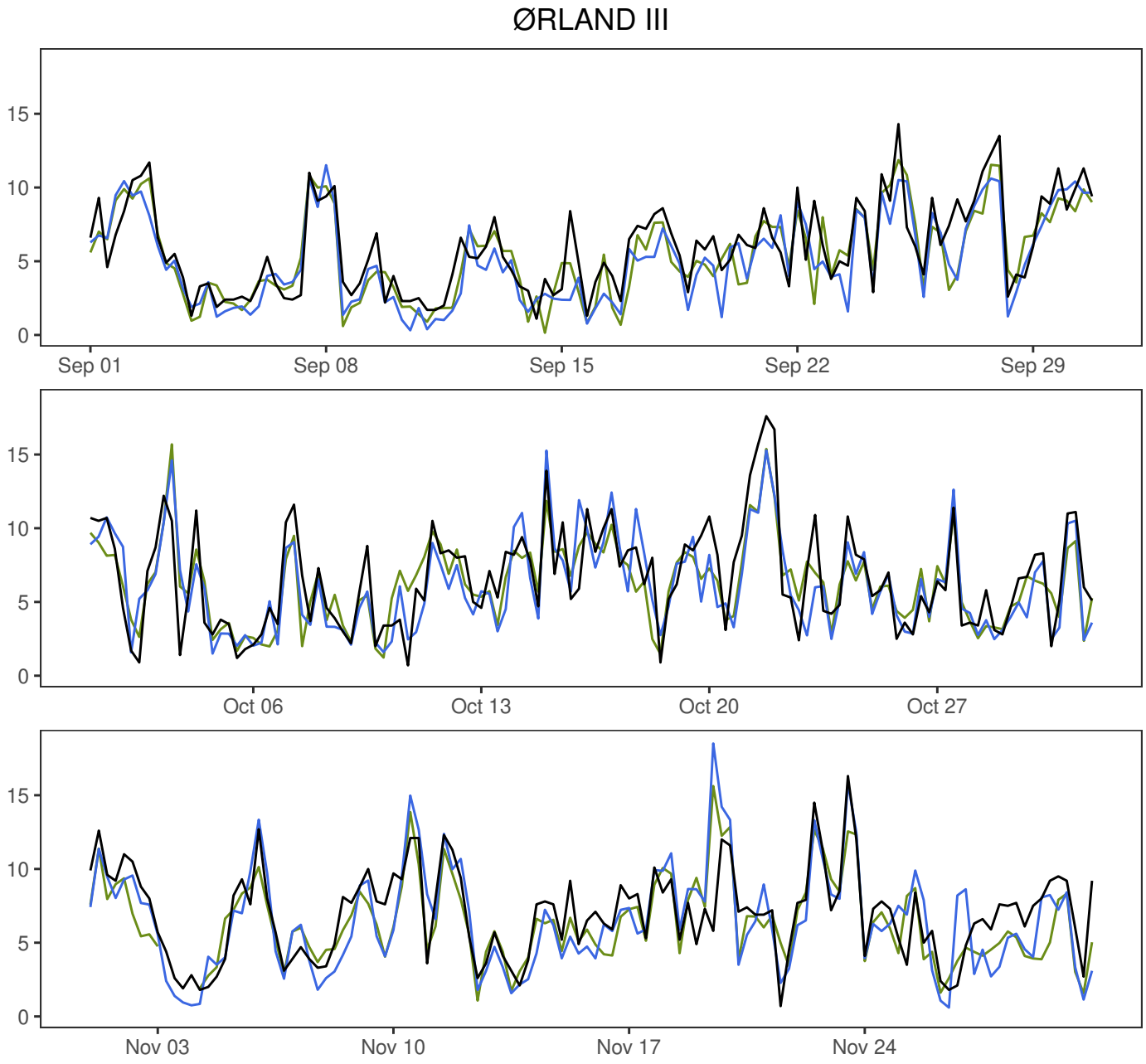


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.9	7.1	19.2	3.7	363
MEPSctrl: 12+18,+24,+30,+36	1.3	7.8	16.4	3.4	364
AA25: 12+18,+24,+30,+36	0.4	7.8	16.2	3.5	364
ECMWF: 12+18,+24,+30,+36	0.8	7.4	14.9	3.0	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.7	2.1	2.2	1.7	7.2	359
AA25−synop	0.7	2.4	2.4	1.8	9.0	359
ECMWF−synop	0.2	2.3	2.3	1.7	8.9	359

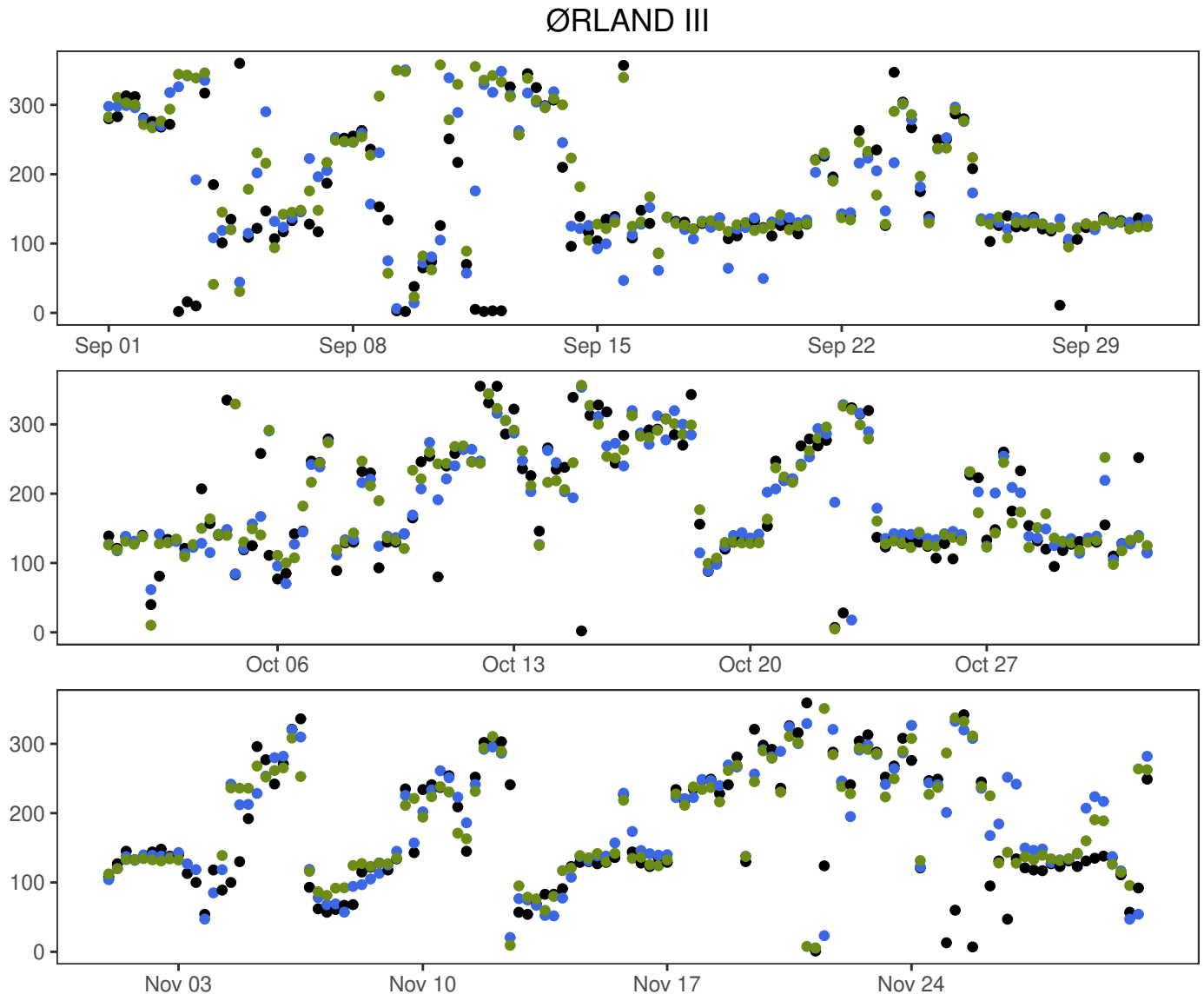

SLETTNES FYR
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24

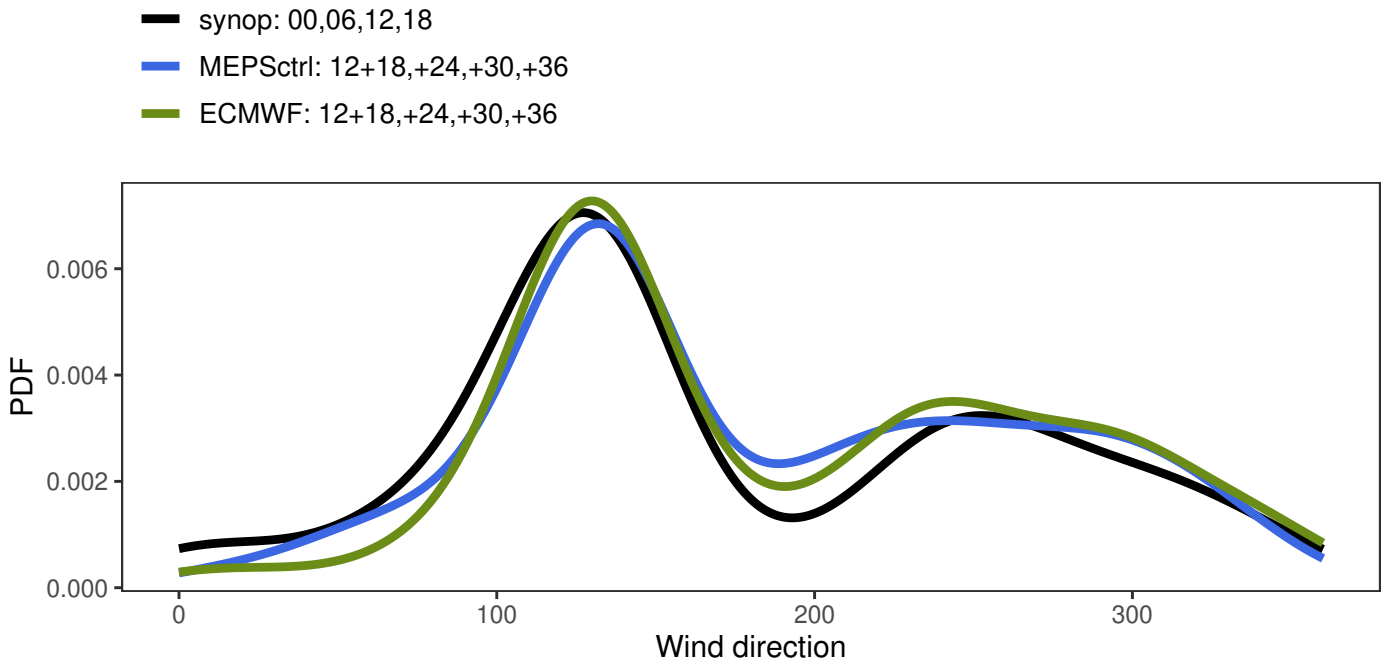

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.005
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction



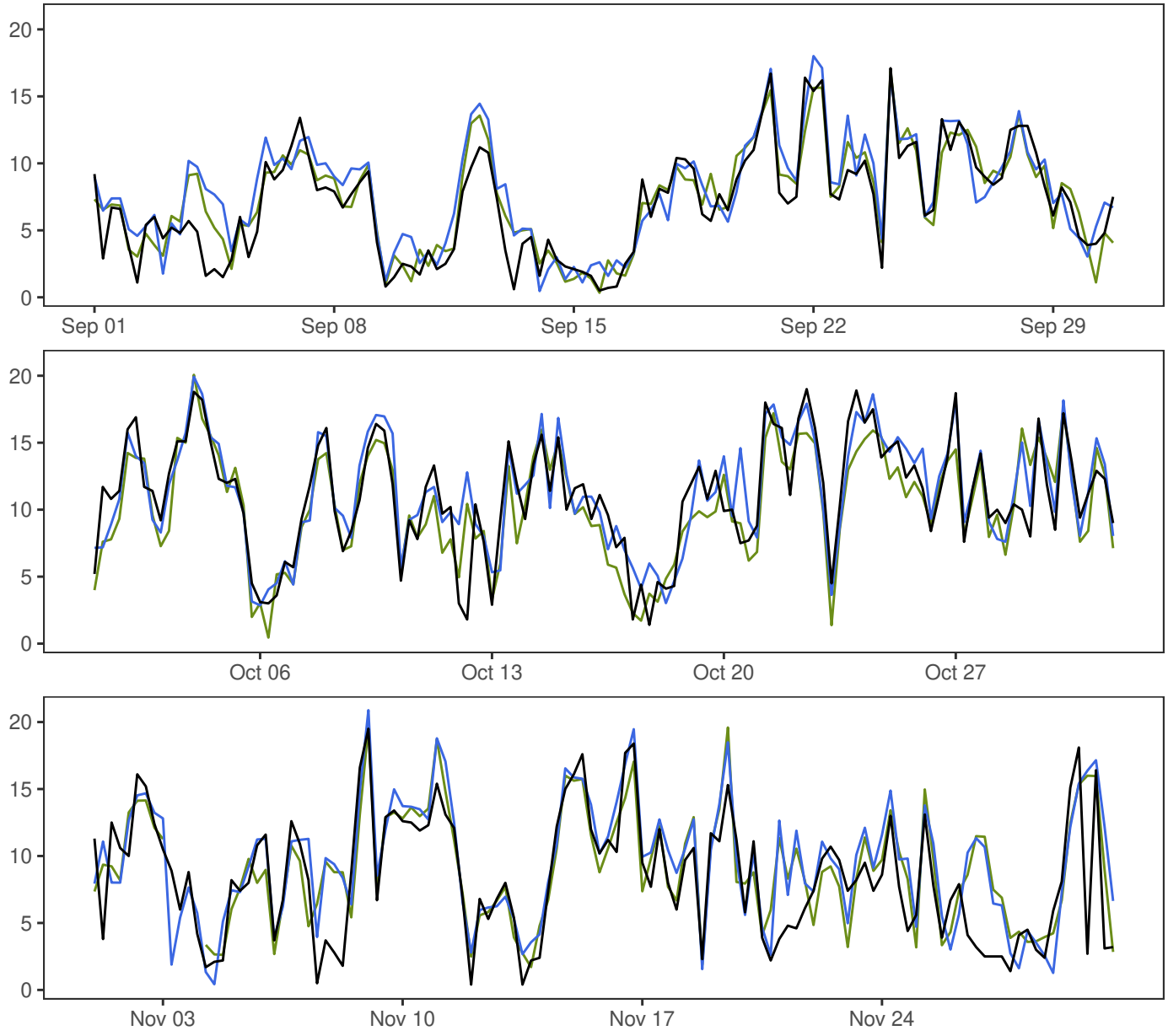
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.7	6.5	17.6	3.2	364
MEPSctrl: 12+18,+24,+30,+36	0.3	5.9	18.5	3.3	364
ECMWF: 12+18,+24,+30,+36	0.1	6.0	15.7	2.9	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.6	2.0	2.1	1.6	12.7	360
ECMWF−synop	−0.5	1.9	1.9	1.5	9.8	360


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

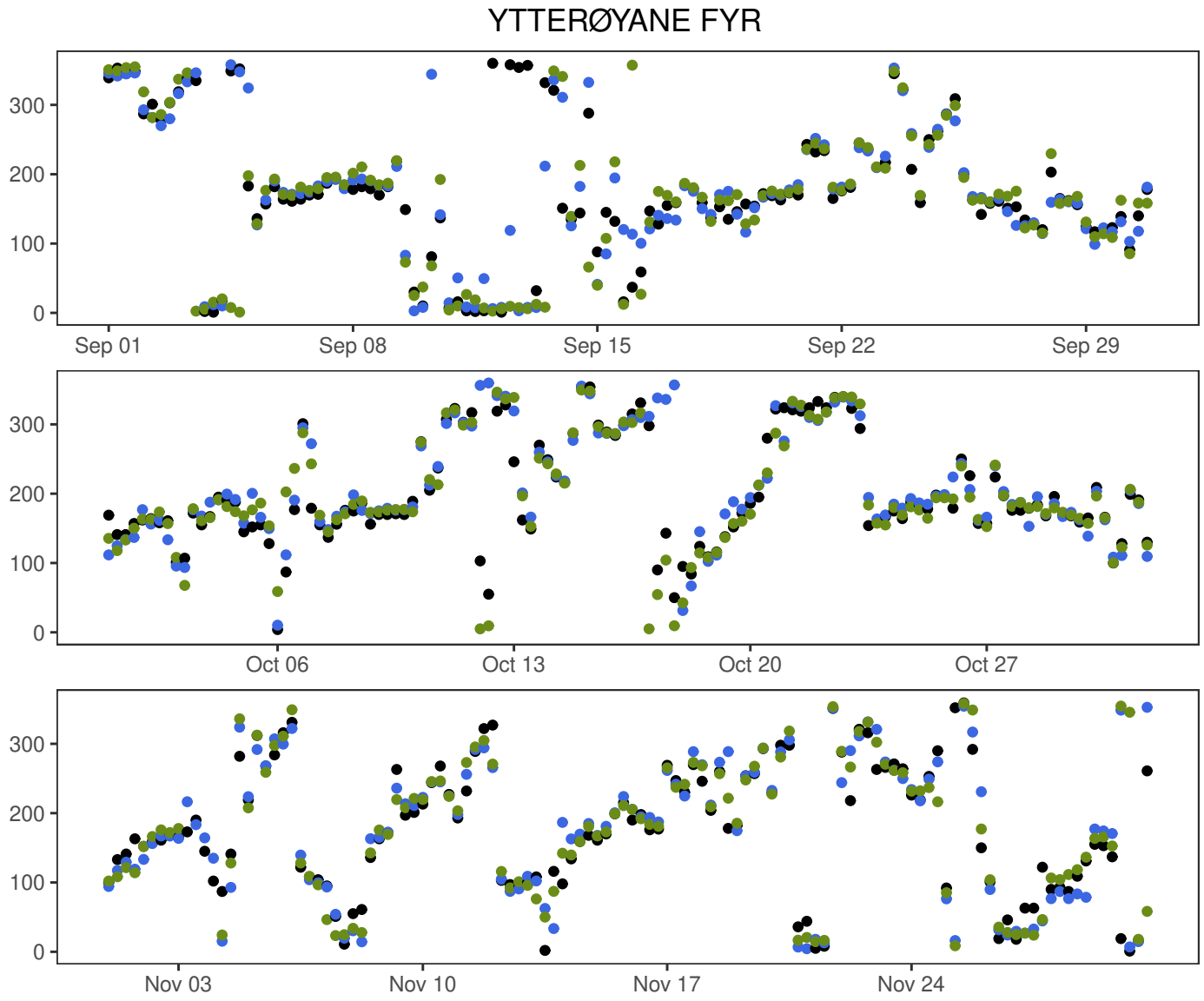

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.006
0.004
0.002
0.000
0
100
200
300
Wind direction

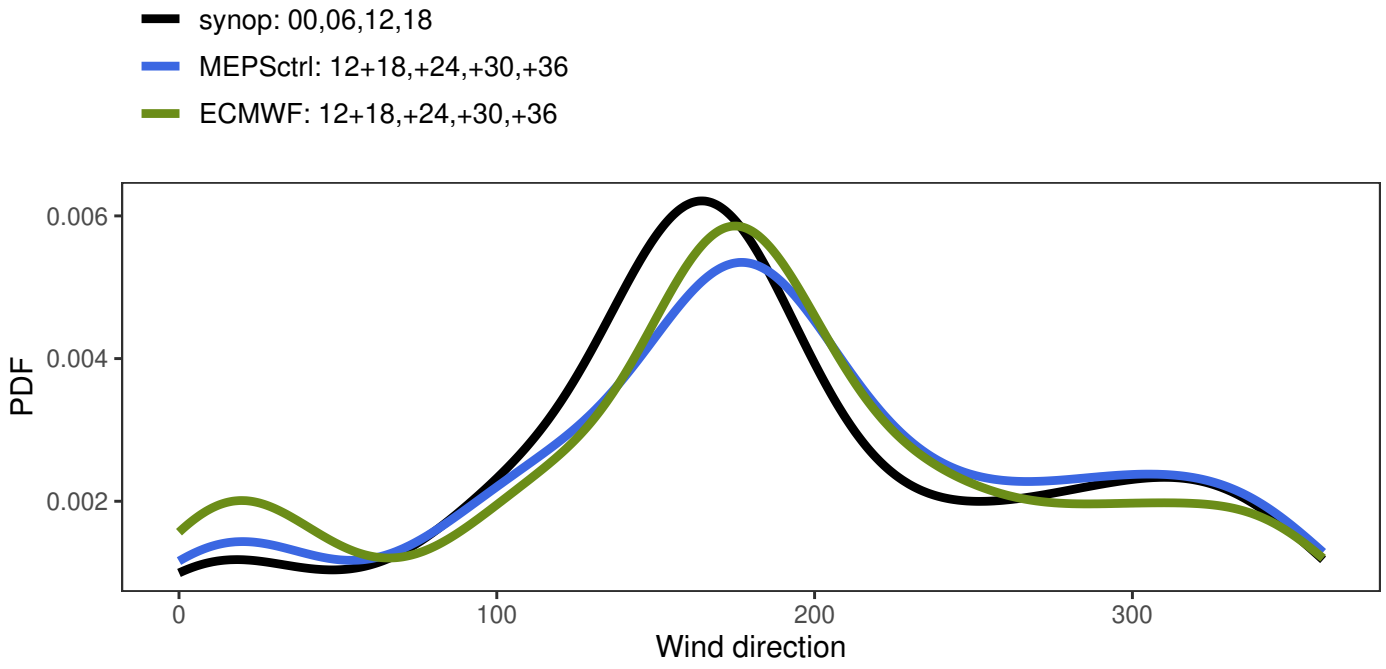
YTTERØYANE FYR

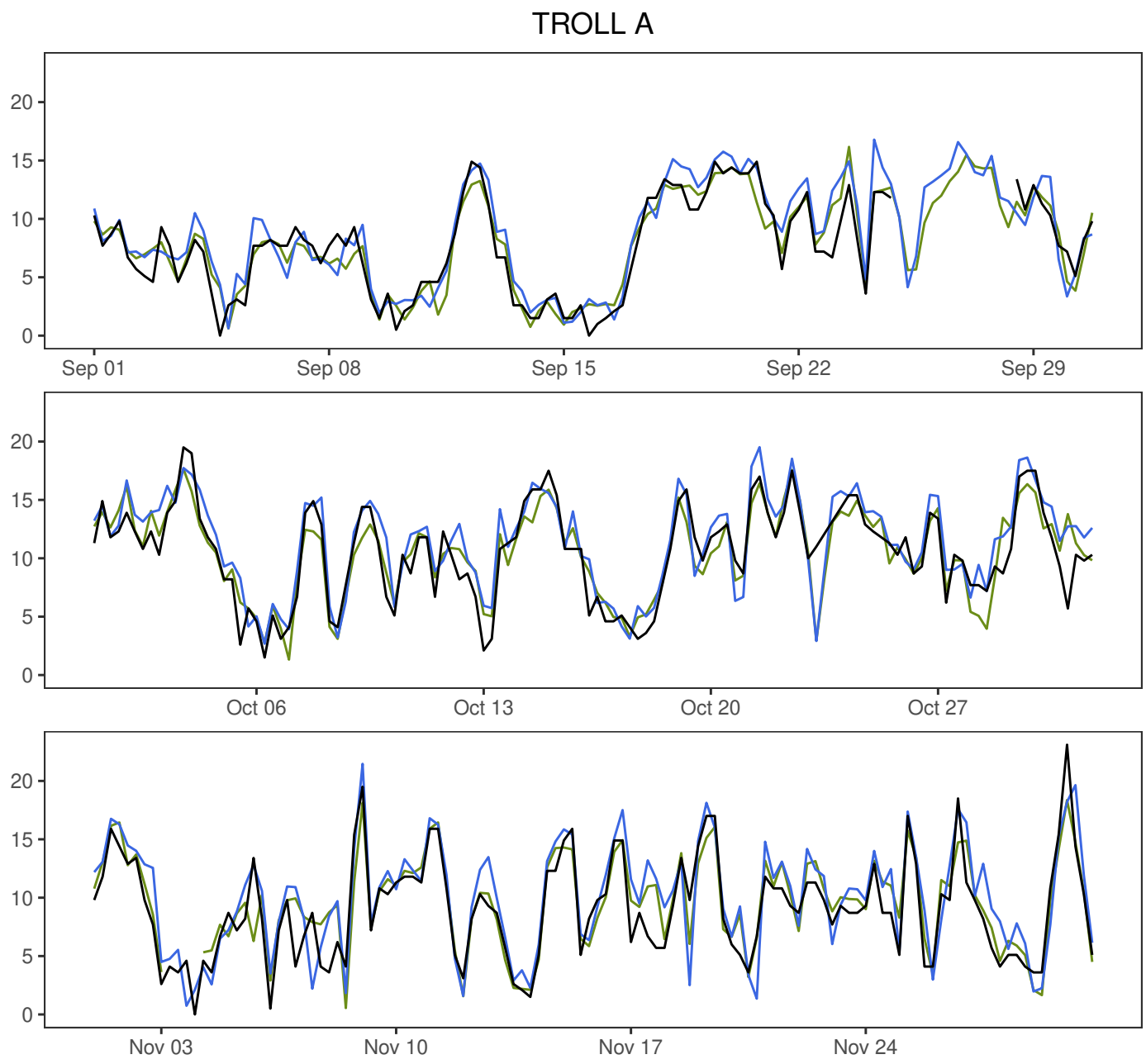


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.4	8.8	19.5	4.6	364
MEPSctrl: 12+18,+24,+30,+36	0.4	9.6	20.9	4.4	364
ECMWF: 12+18,+24,+30,+36	0.3	8.9	20.1	4.2	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.8	2.4	2.5	1.8	13.7	360
ECMWF−synop	0.1	2.4	2.4	1.7	13.3	360

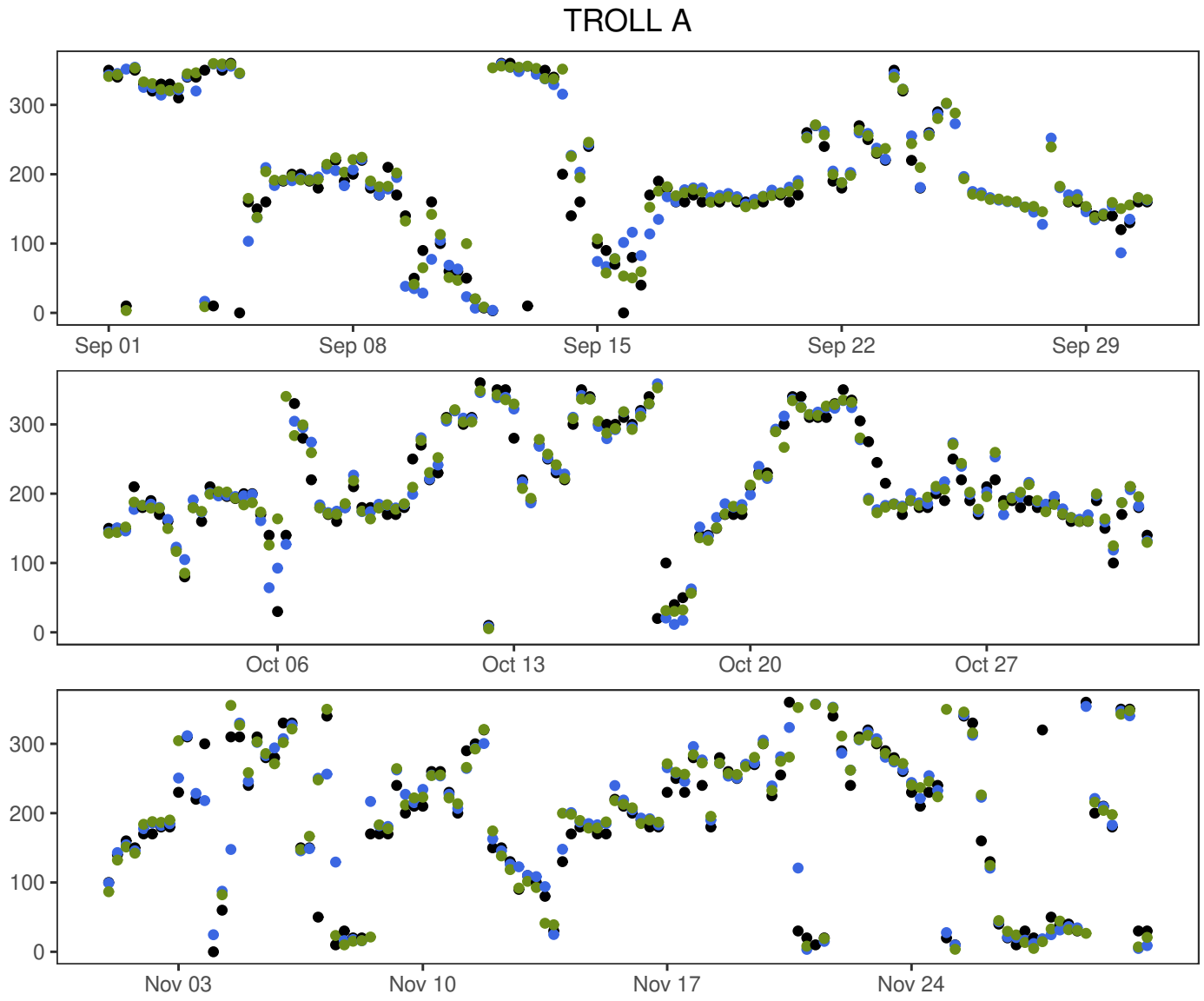

YTTERØYANE FYR
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24

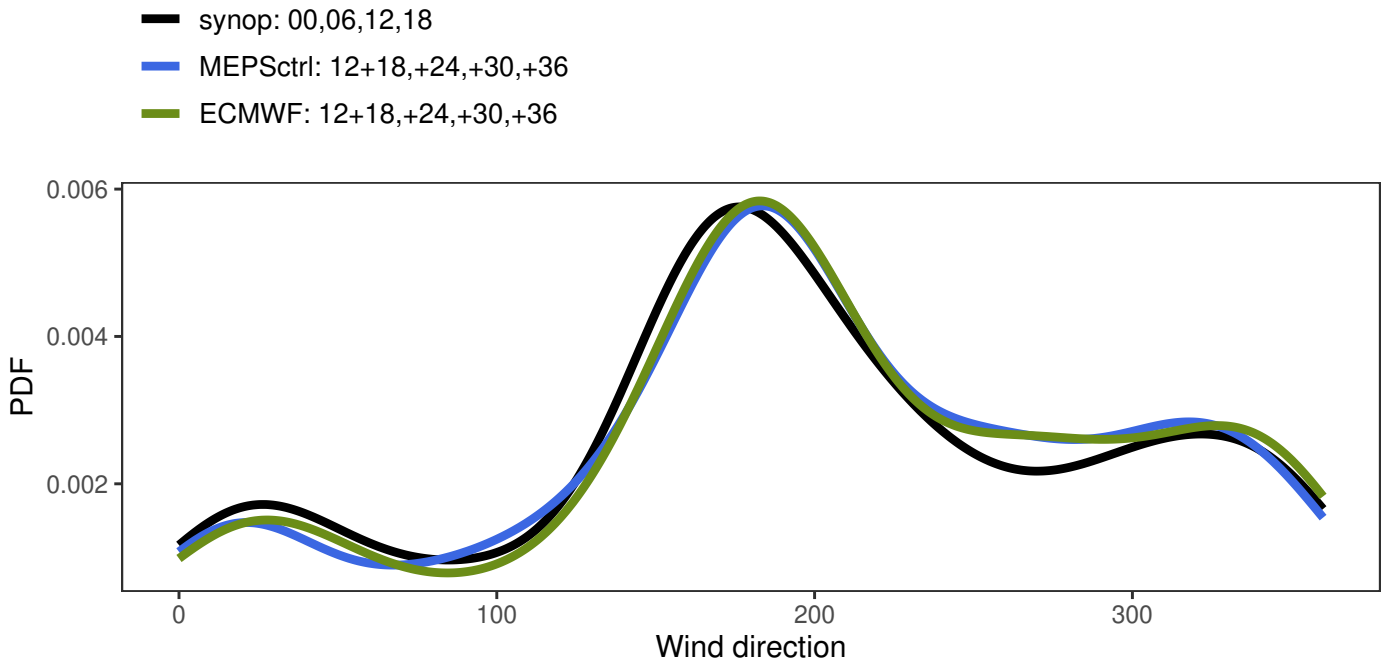

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.006
0.004
0.002
0
100
200
300
Wind direction



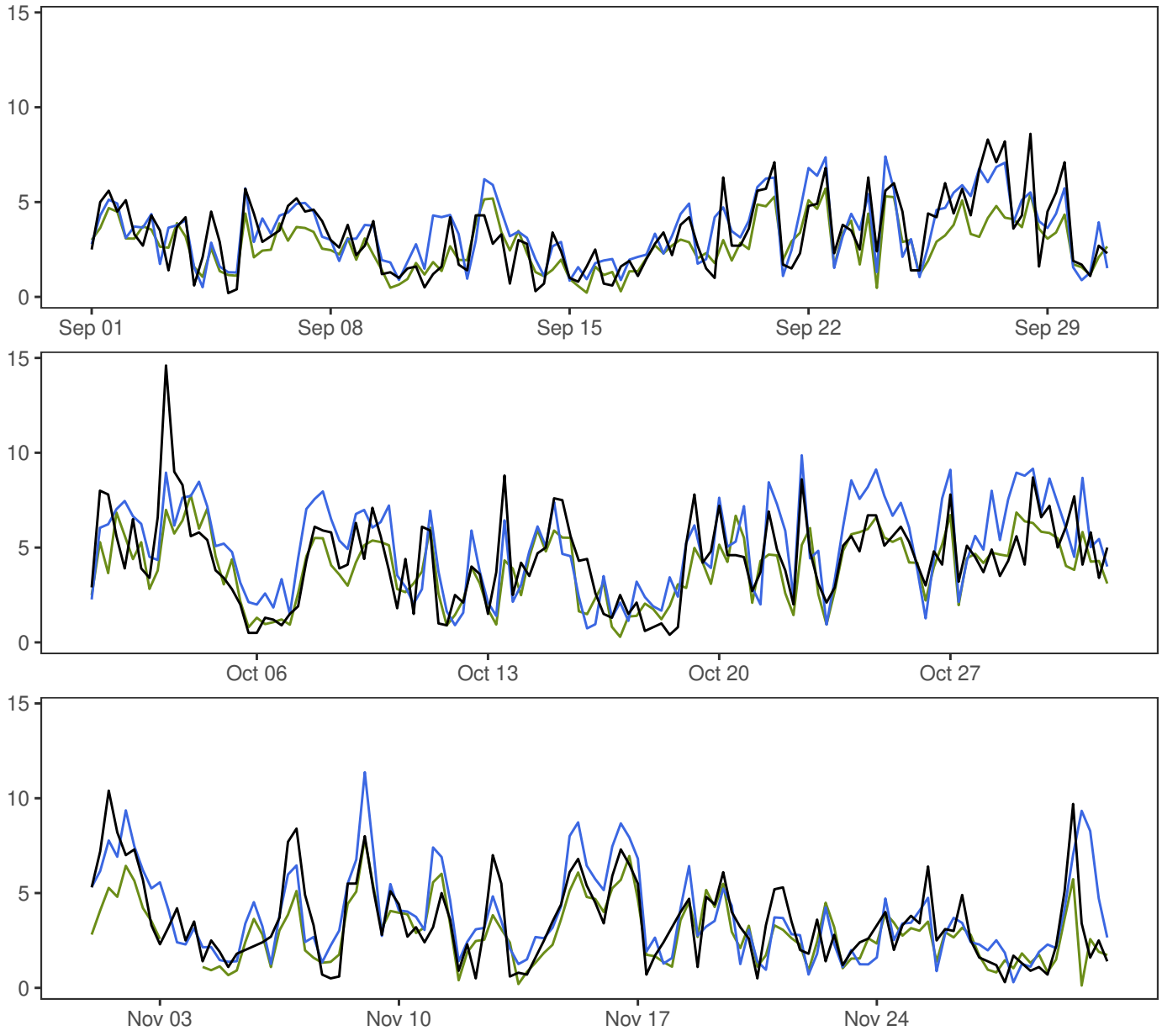
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	9.1	23.1	4.3	350
MEPSctrl: 12+18,+24,+30,+36	0.6	10.1	21.5	4.5	364
ECMWF: 12+18,+24,+30,+36	0.6	9.4	18.4	4.0	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.9	2.0	2.2	1.7	8.1	346
ECMWF−synop	0.2	1.8	1.8	1.3	8.1	346


TROLL A
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

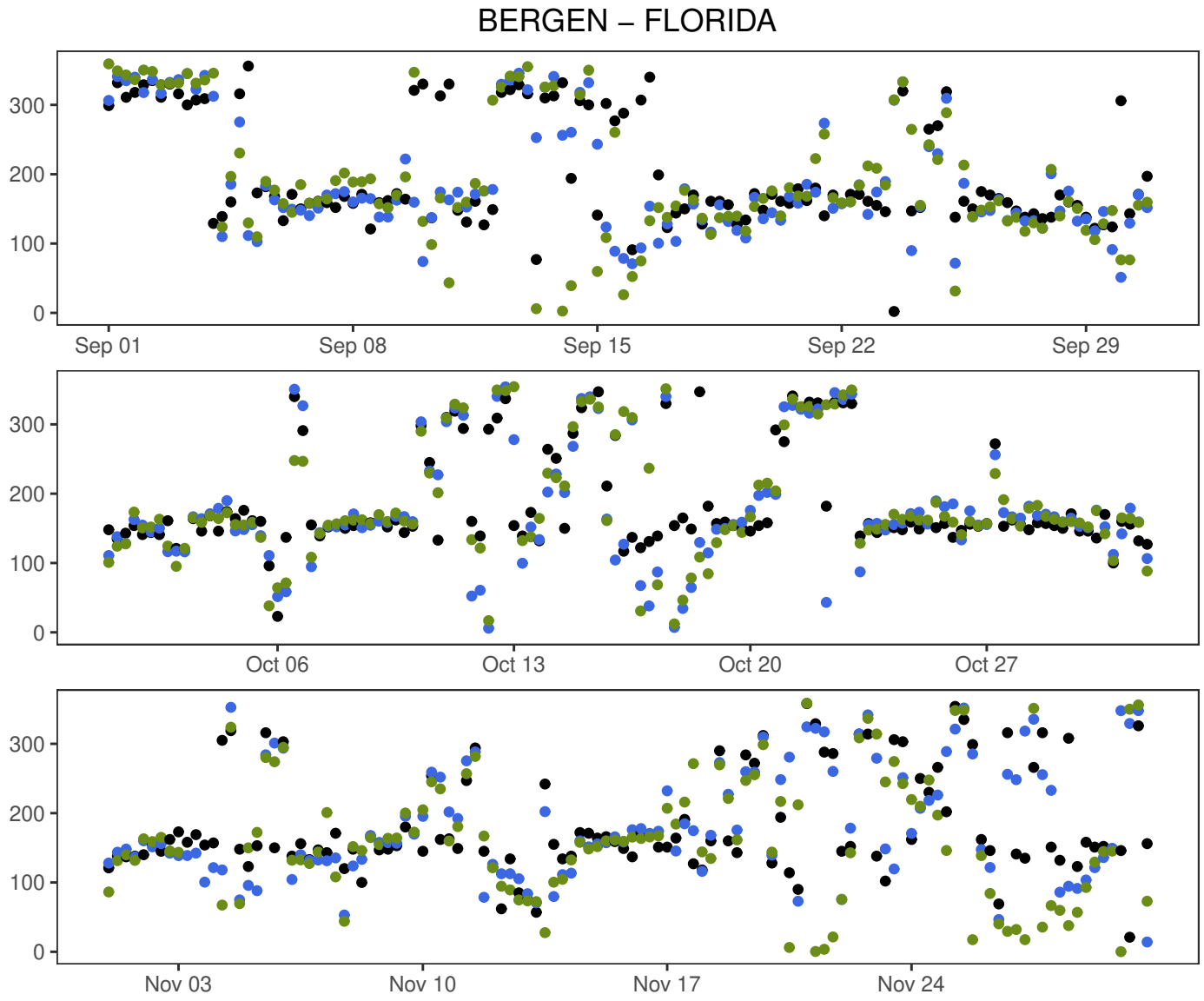

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
0.006
0.004
0.002
PDF
0
100
200
300
Wind direction

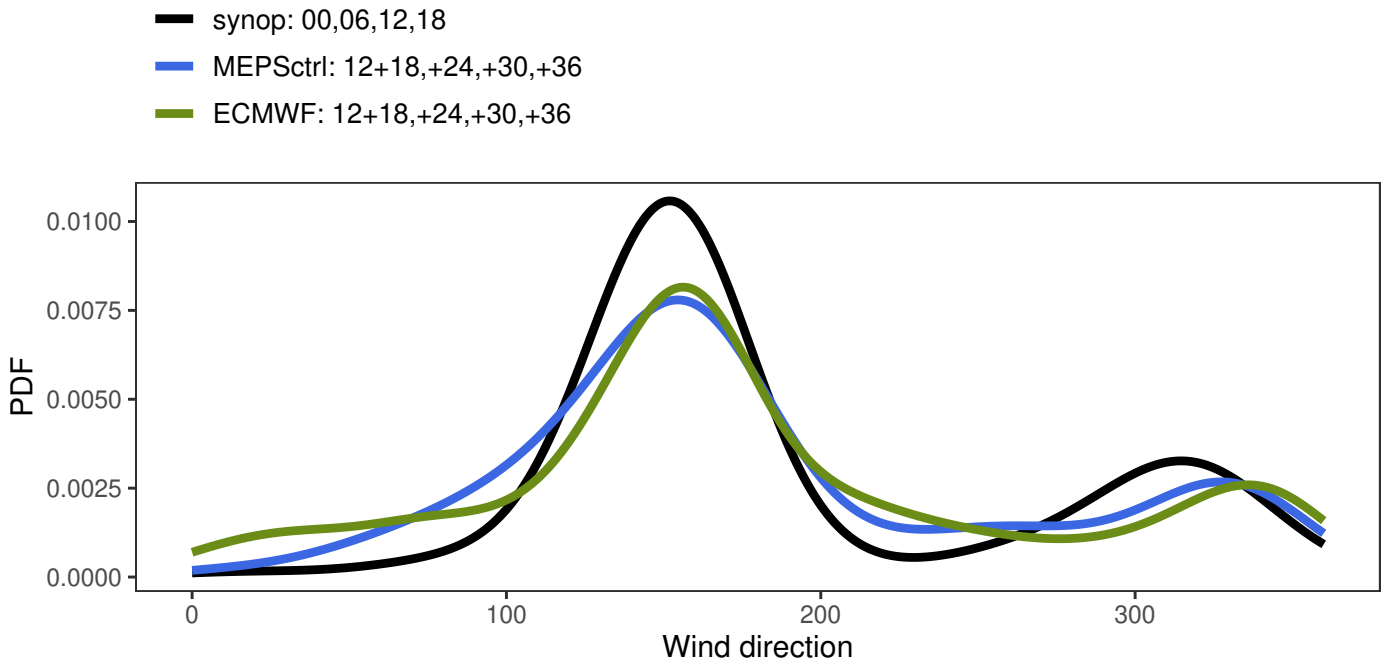
BERGEN – FLORIDA

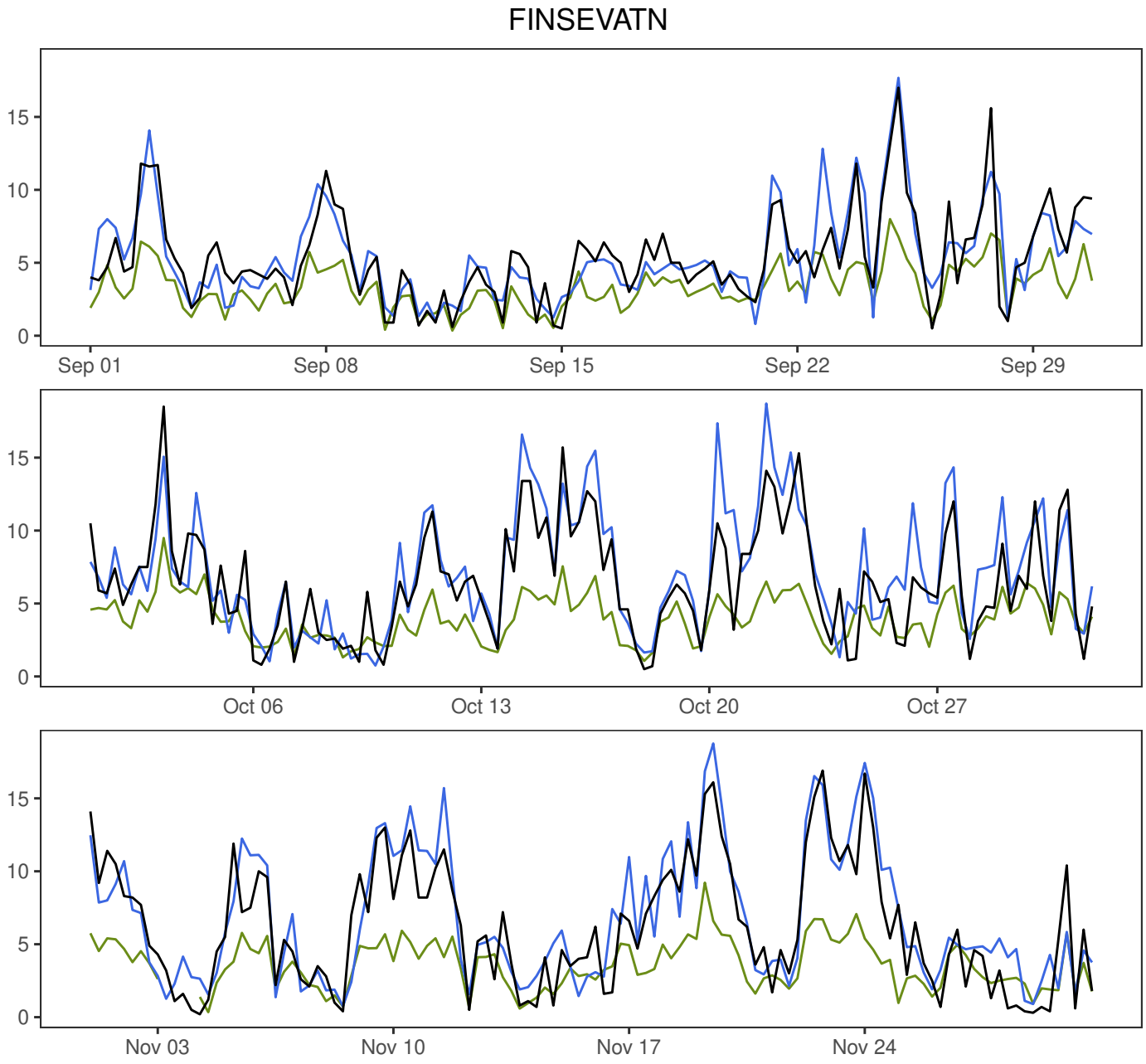


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.2	3.7	14.6	2.2	364
MEPSctrl: 12+18,+24,+30,+36	0.3	4.1	11.4	2.2	364
ECMWF: 12+18,+24,+30,+36	0.1	3.2	7.9	1.7	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	0.4	1.6	1.6	1.3	6.7	360
ECMWF–synop	–0.5	1.4	1.5	1.1	7.6	360

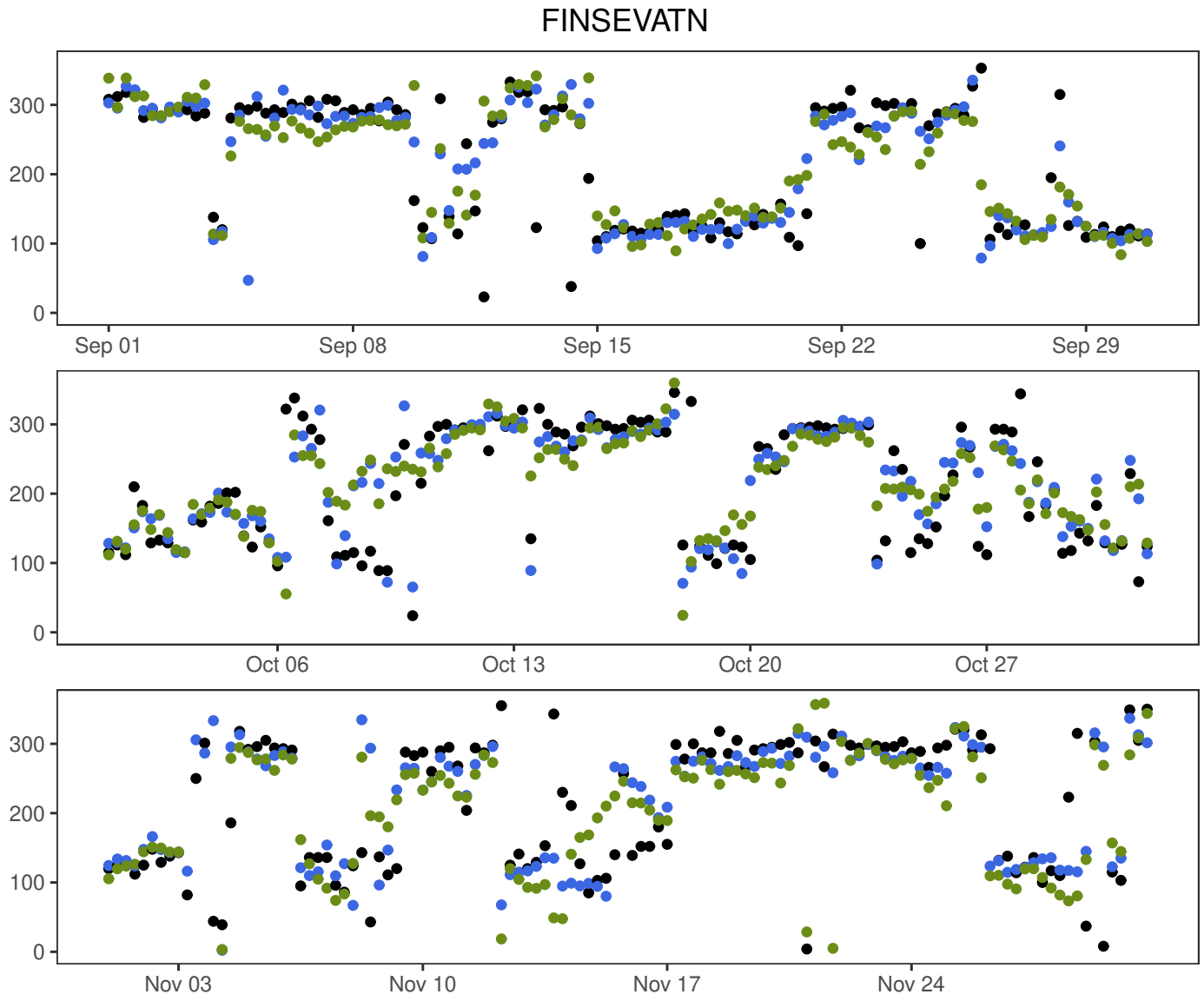

BERGEN – FLORIDA
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24

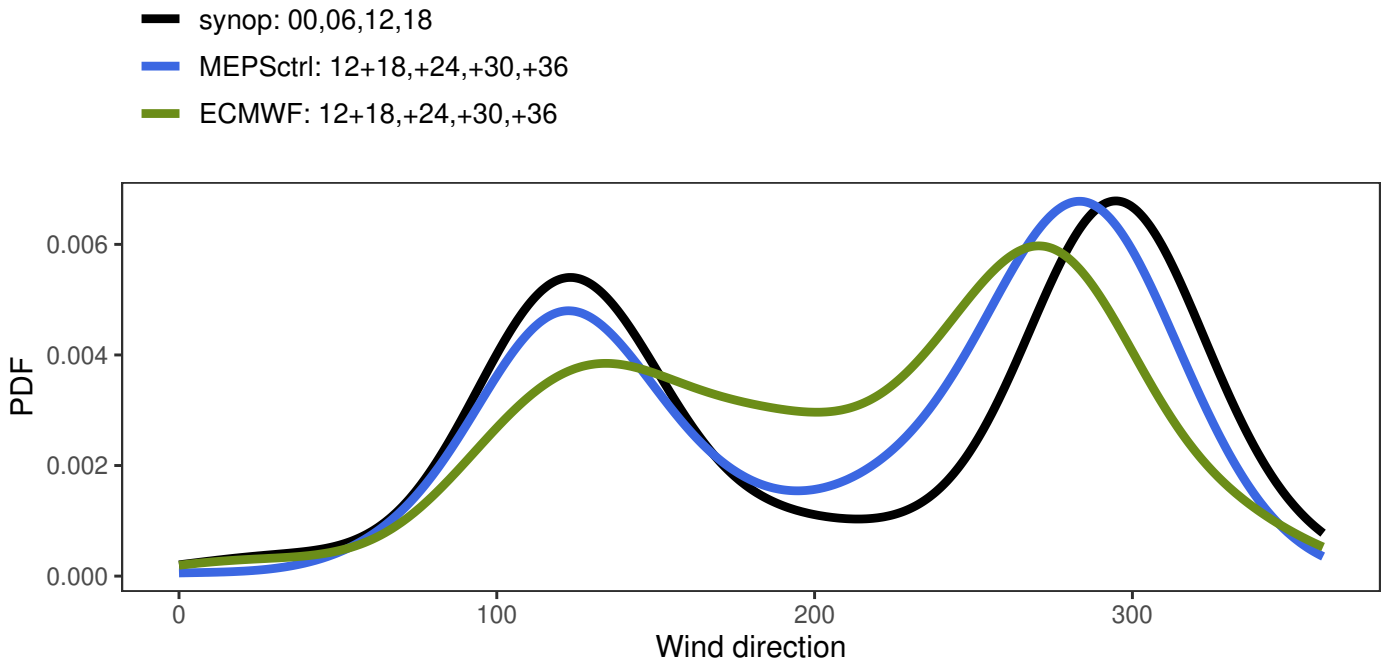

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.0100
0.0075
0.0050
0.0025
0.0000
0
100
200
300
Wind direction

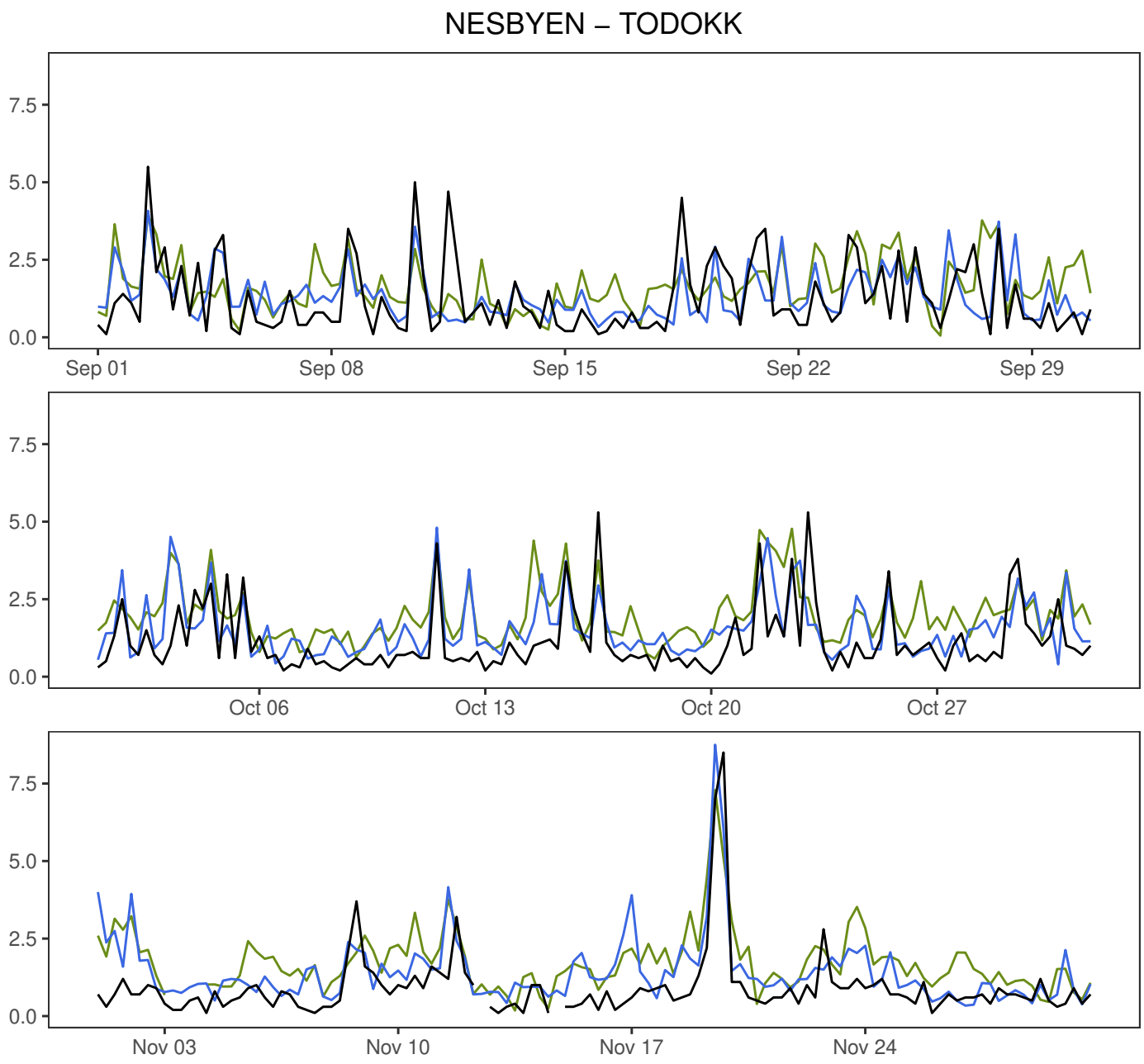


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.2	6.0	18.5	3.8	364
MEPSctrl: 12+18,+24,+30,+36	0.7	6.5	18.8	4.0	364
ECMWF: 12+18,+24,+30,+36	0.3	3.6	9.5	1.6	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.4	2.1	2.1	1.6	8.2	360
ECMWF−synop	−2.4	2.6	3.5	2.8	11.3	360

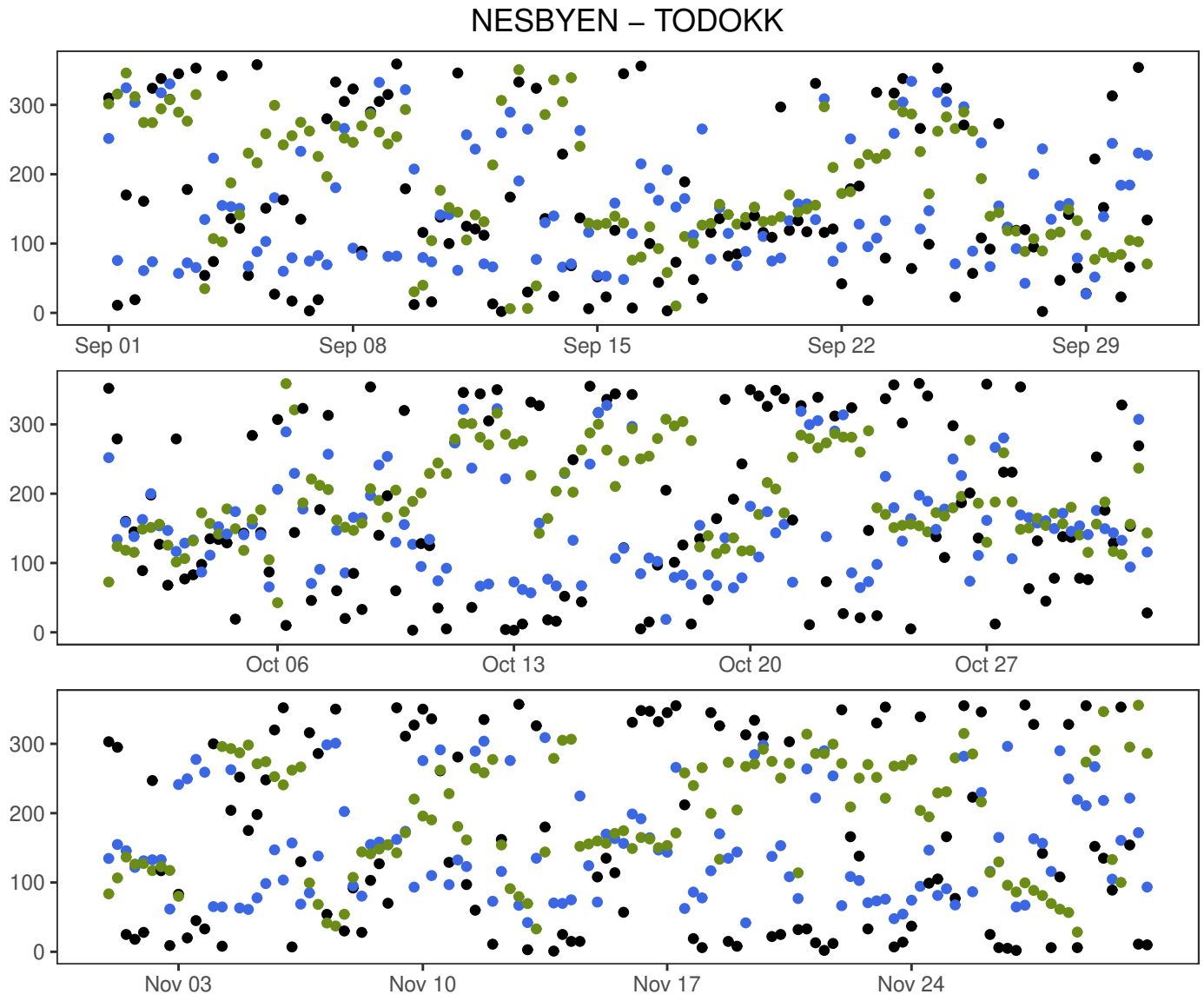

FINSEVATN
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24

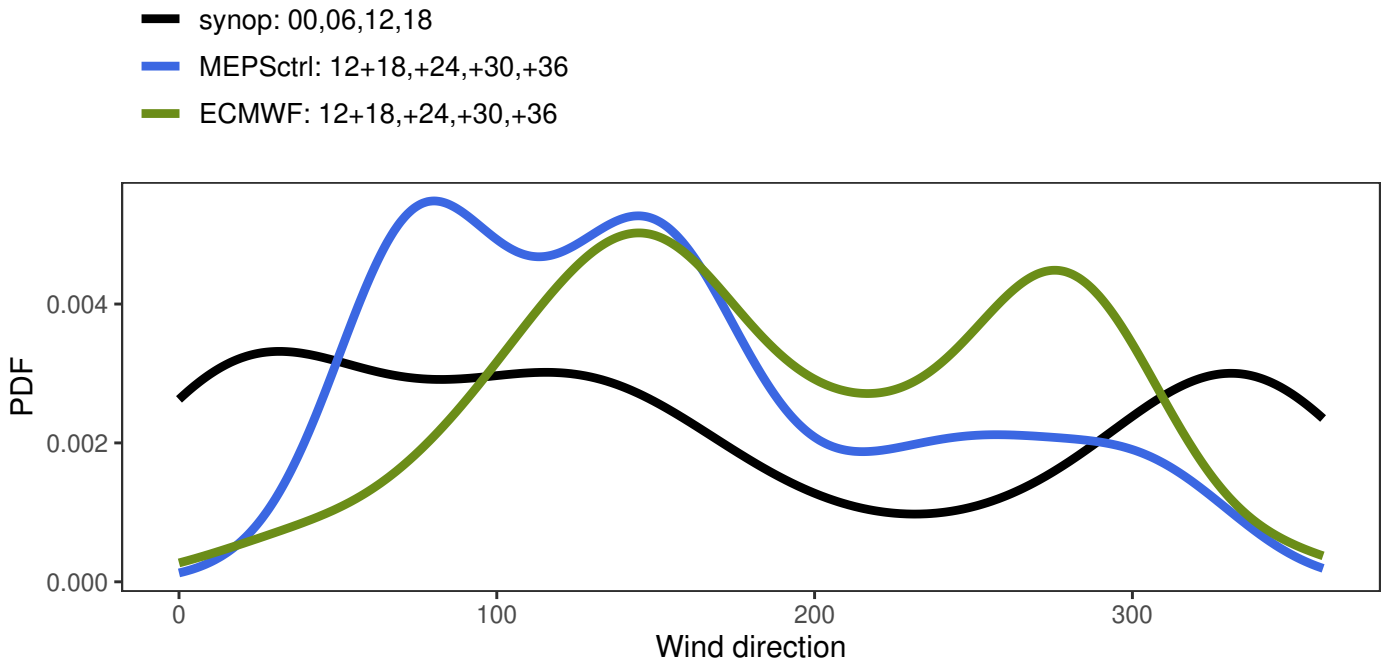

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.006
0.004
0.002
0.000
0
100
200
300
Wind direction

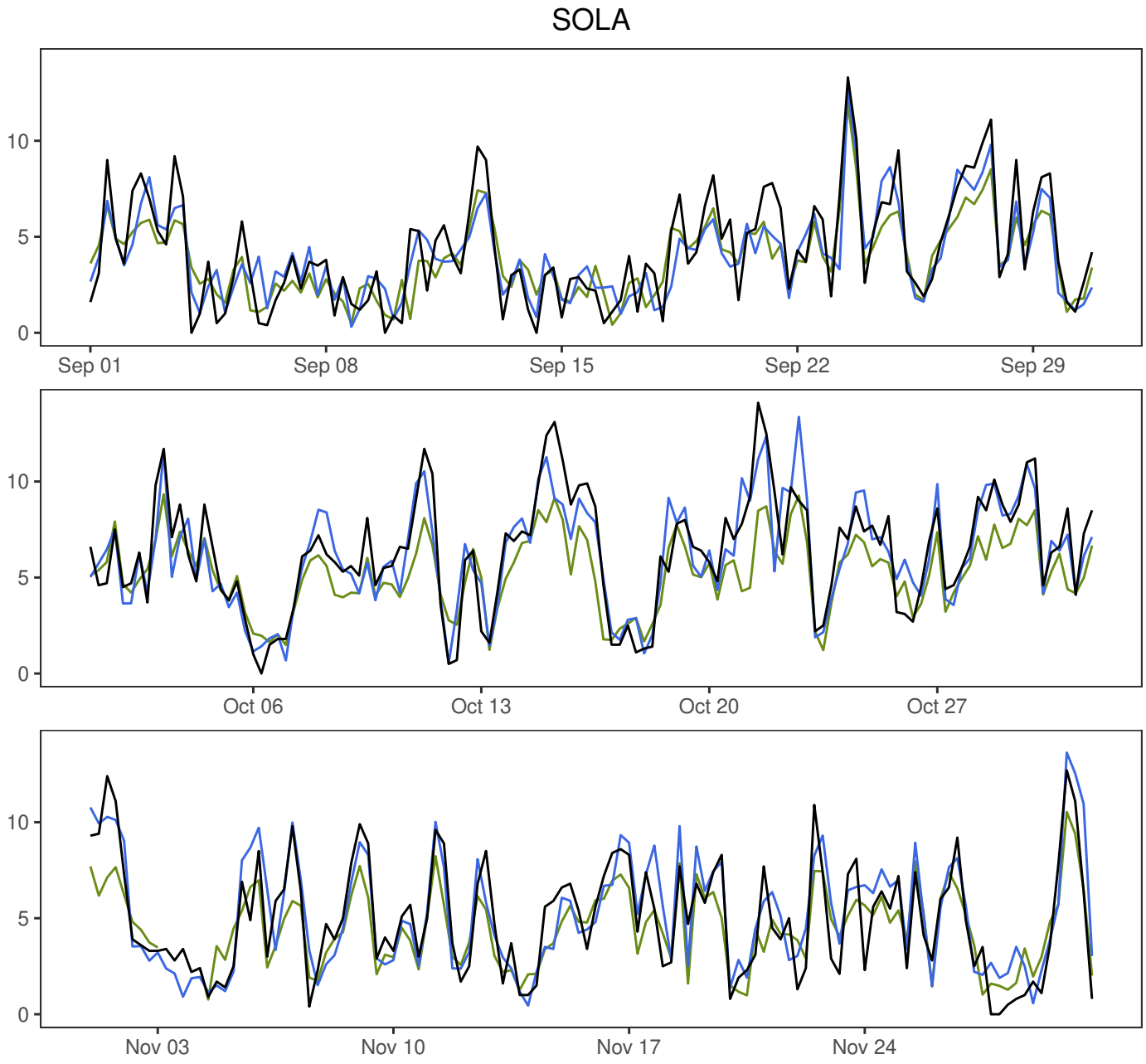


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.1	1.1	8.5	1.1	362
MEPSctrl: 12+18,+24,+30,+36	0.3	1.4	8.8	1.0	364
ECMWF: 12+18,+24,+30,+36	0.1	1.8	7.3	0.9	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.3	0.9	1.0	0.7	4.2	358
ECMWF−synop	0.7	1.0	1.2	1.0	3.4	358

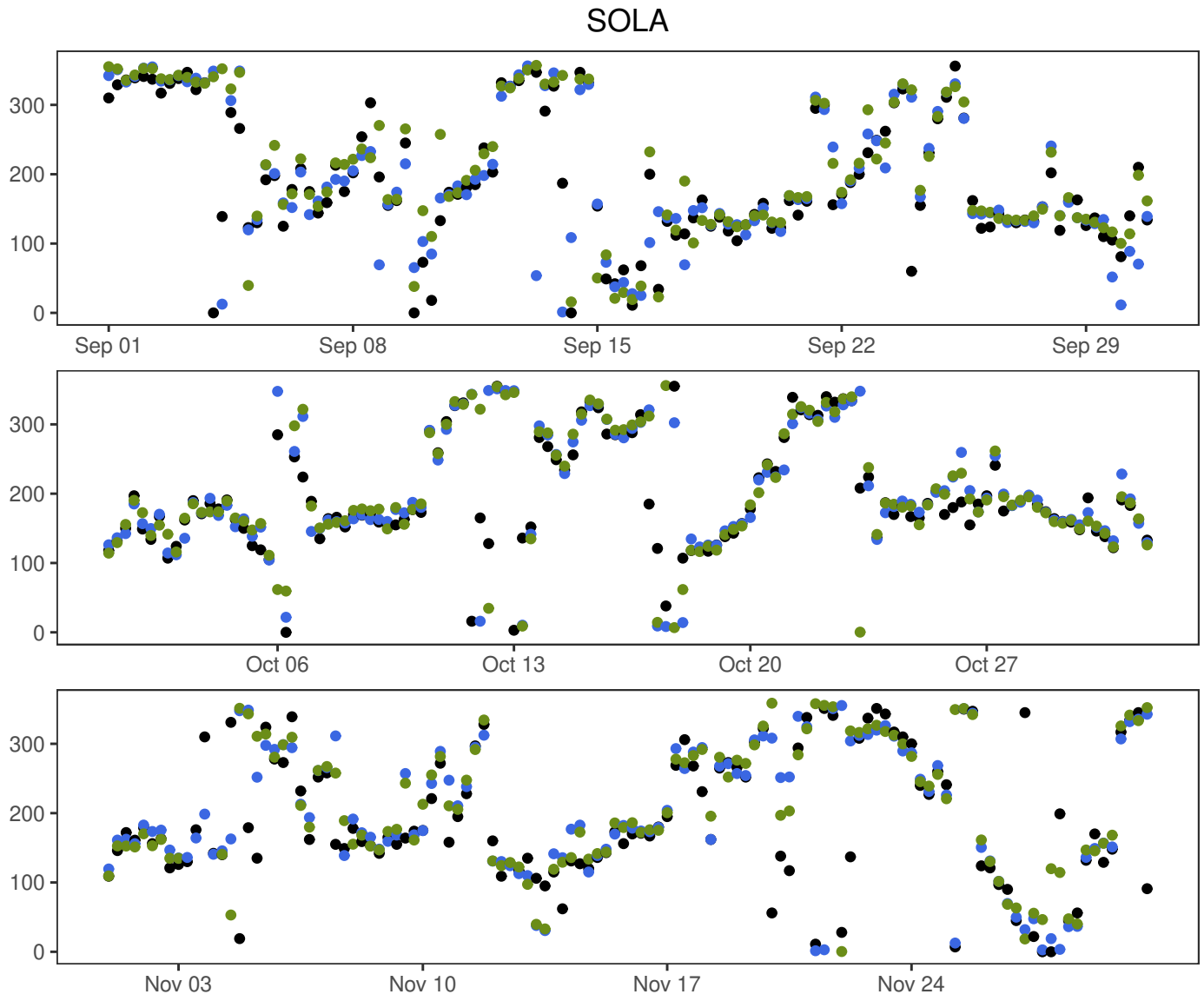

NESBYEN – TODOKK
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24

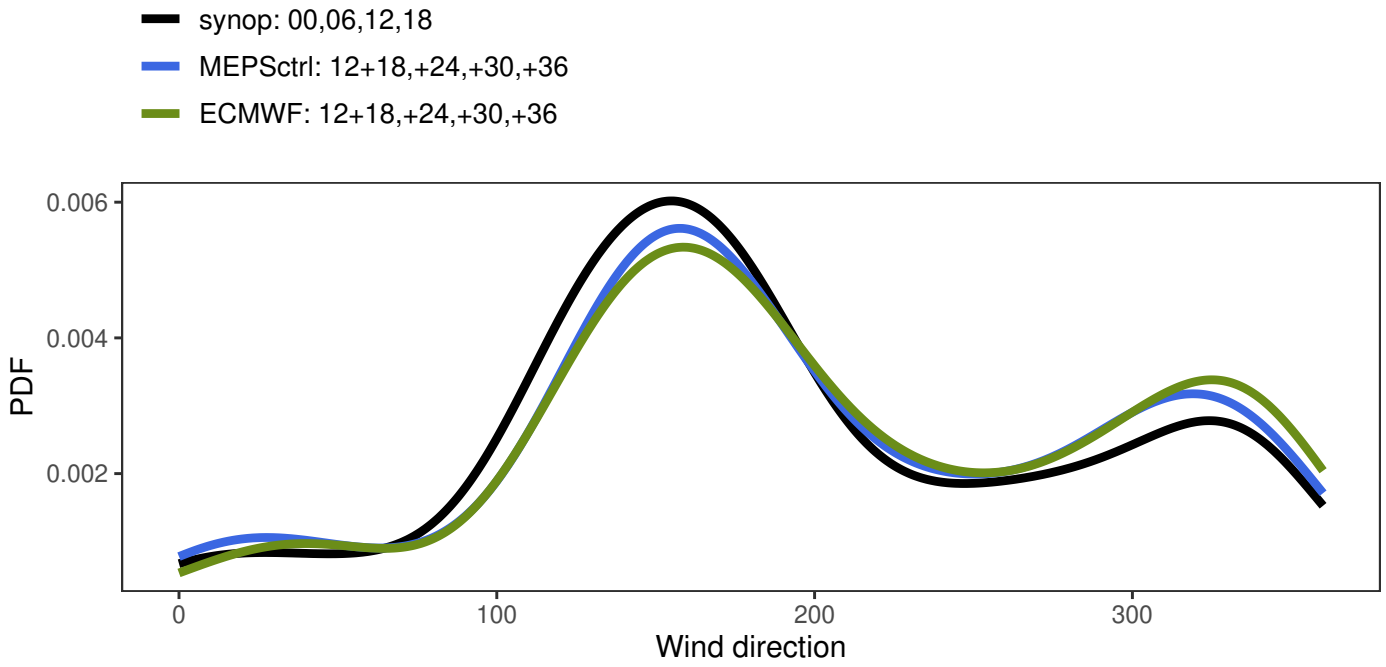

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.004
0.002
0.000
0
100
200
300
Wind direction

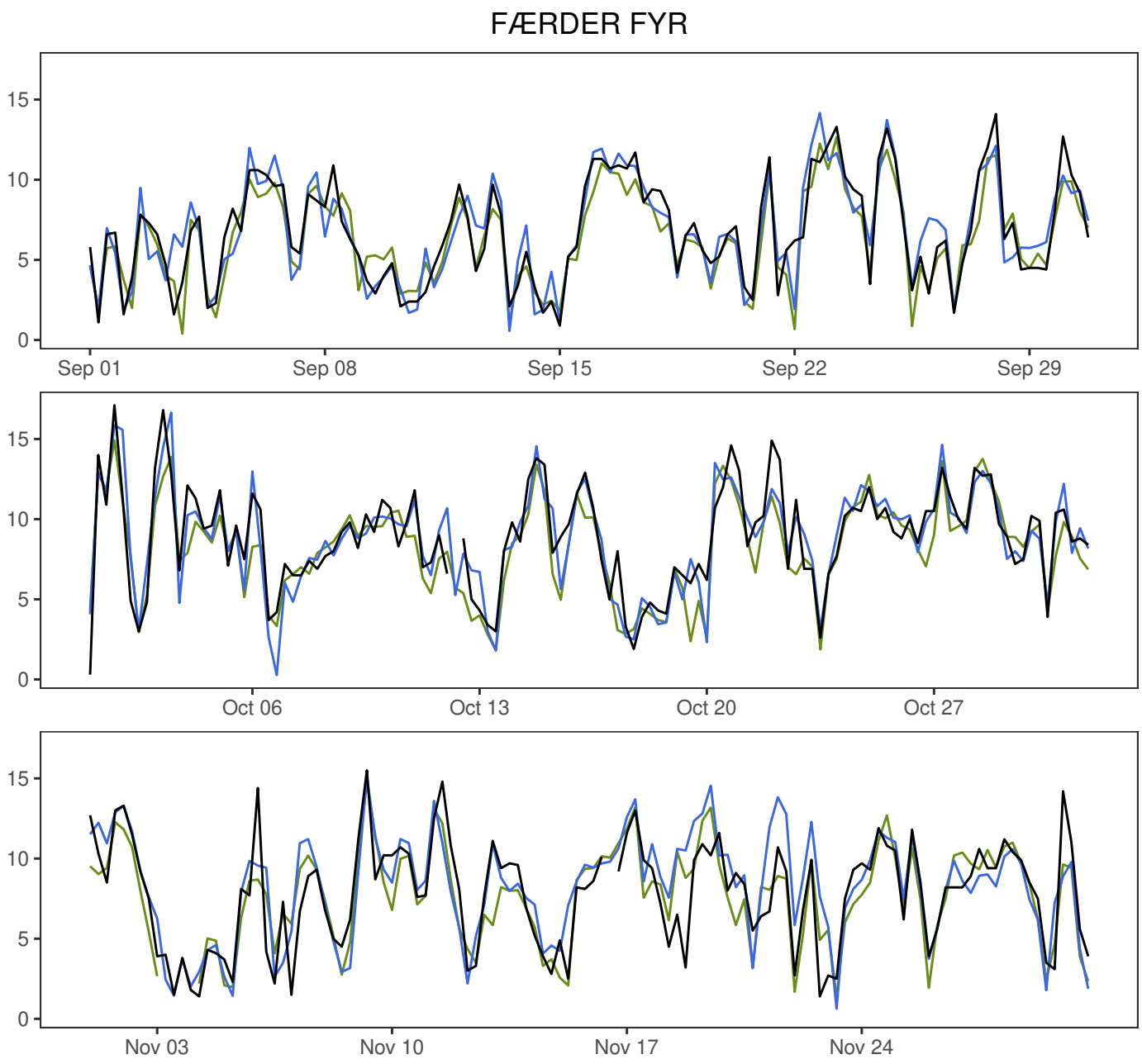


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	5.2	14.1	3.0	364
MEPSctrl: 12+18,+24,+30,+36	0.3	5.1	13.6	2.8	364
ECMWF: 12+18,+24,+30,+36	0.4	4.5	11.9	2.1	360

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.1	1.5	1.5	1.1	4.6	360
ECMWF−synop	−0.7	1.6	1.7	1.4	5.6	360

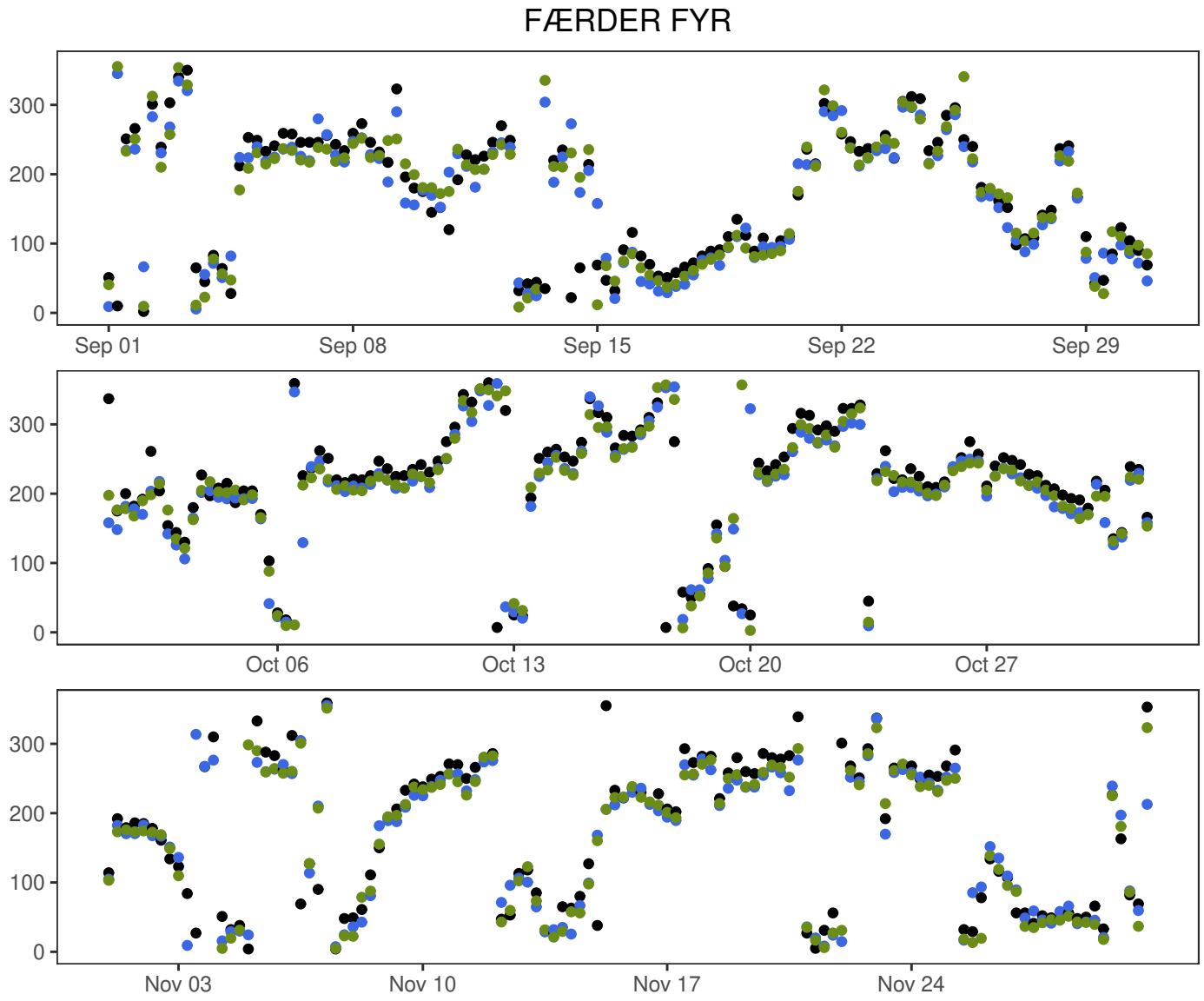

SOLA
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24

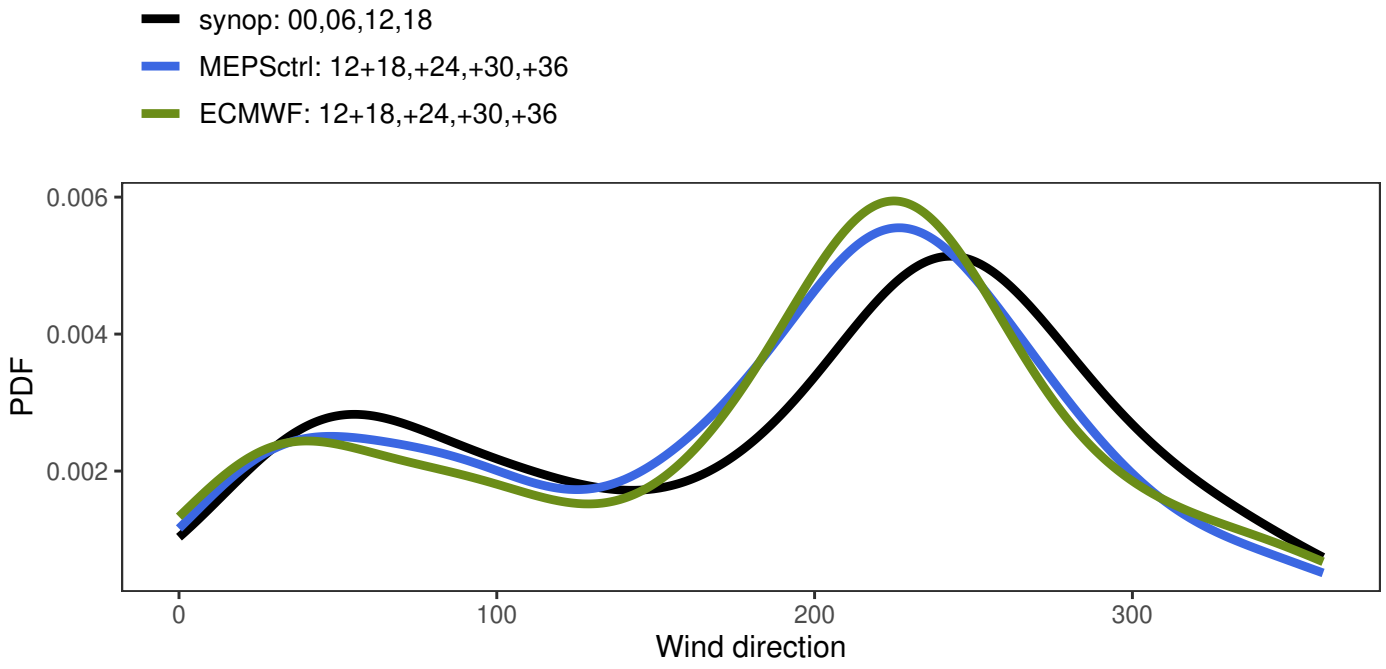

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
0.006
0.004
0.002
PDF
0
100
200
300
Wind direction



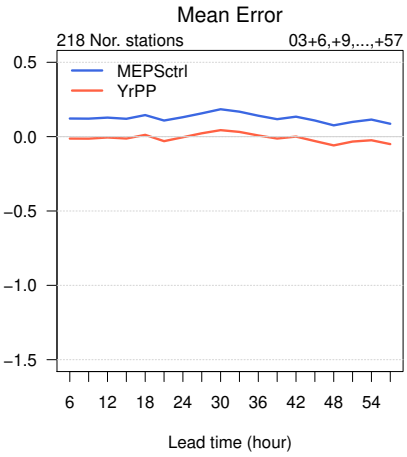
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.3	7.8	17.1	3.3	362
MEPSctrl: 12+18,+24,+30,+36	0.3	8.0	16.6	3.3	364
ECMWF: 12+18,+24,+30,+36	0.4	7.4	14.9	3.0	360

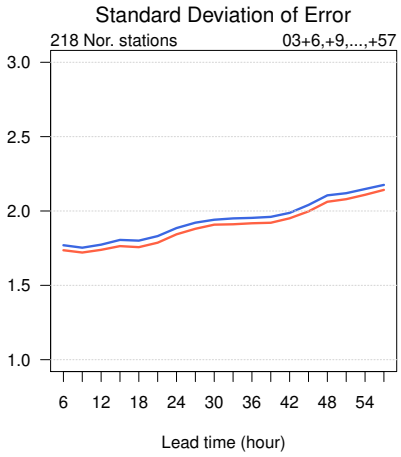
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.1	1.7	1.8	1.3	7.3	358
ECMWF−synop	−0.5	1.6	1.7	1.3	5.7	358

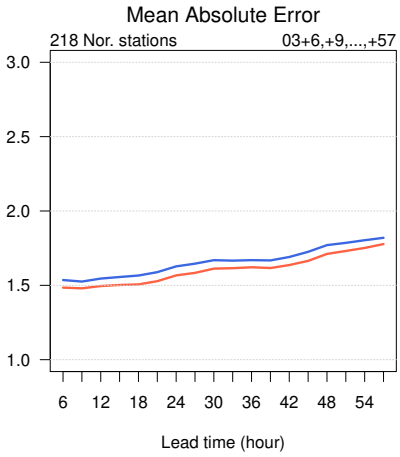

FÆRDER FYR
300
200
100
0
Sep 01
Sep 08
Sep 15
Sep 22
Sep 29
Oct 06
Oct 13
Oct 20
Oct 27
Nov 03
Nov 10
Nov 17
Nov 24

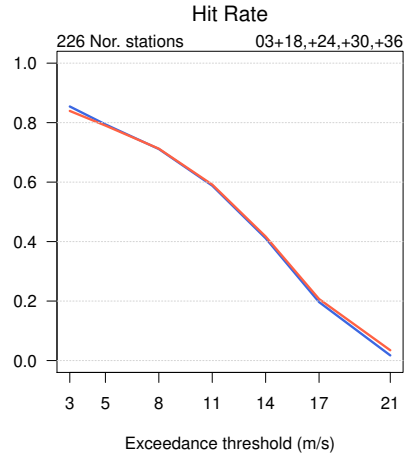

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
0.006
0.004
0.002
PDF
0
100
200
300
Wind direction

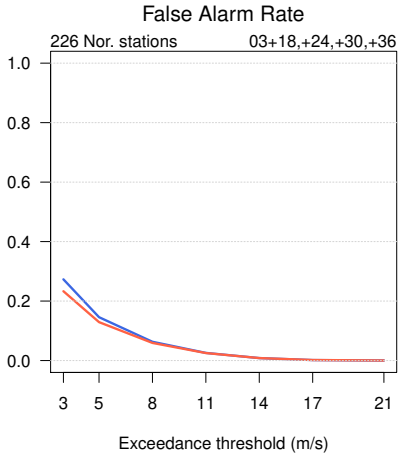
Post processed wind speed 10m (YrPP)

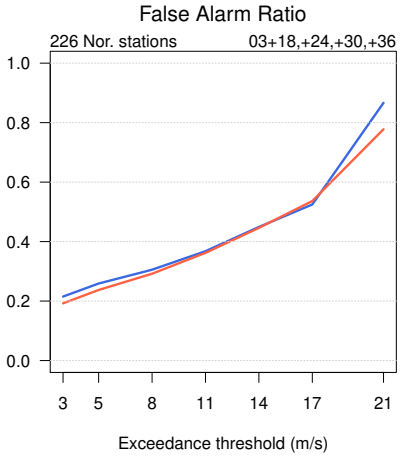


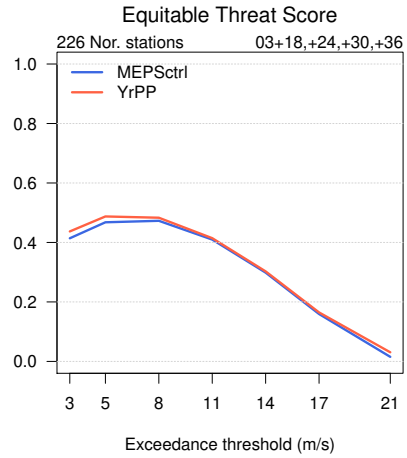


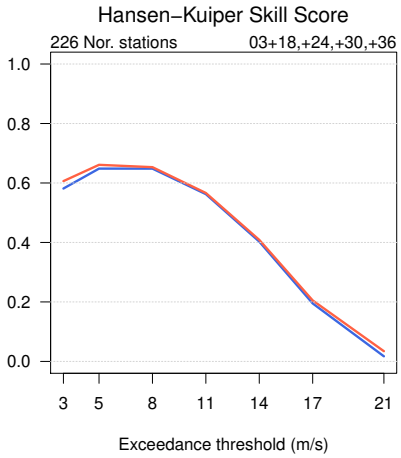


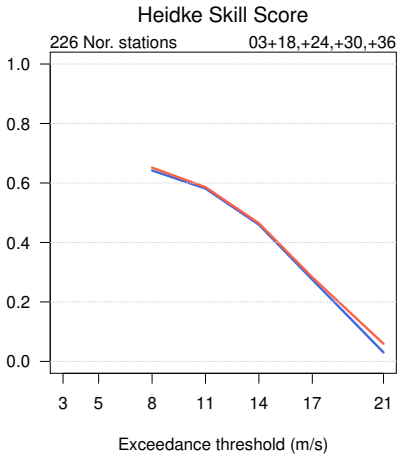




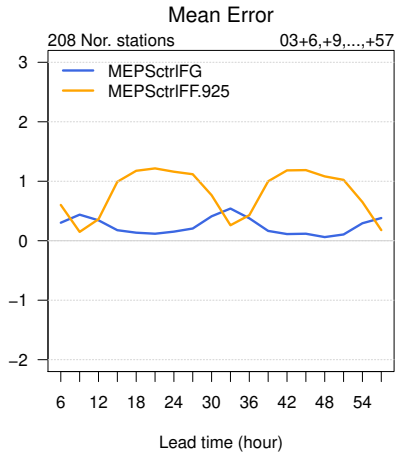


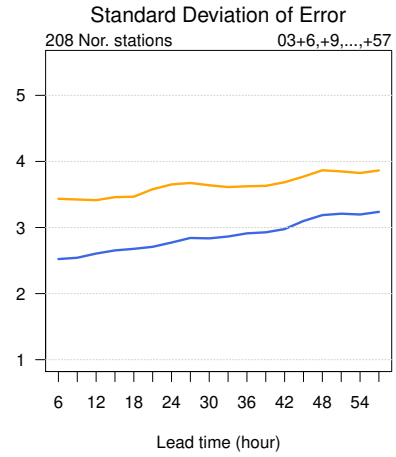


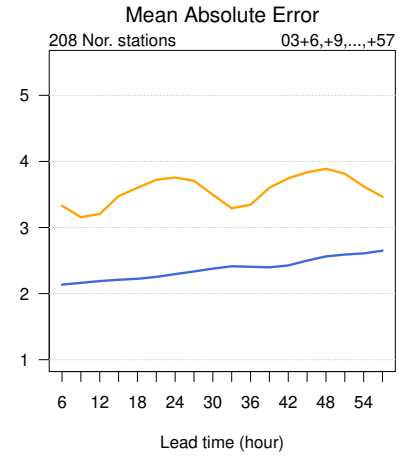


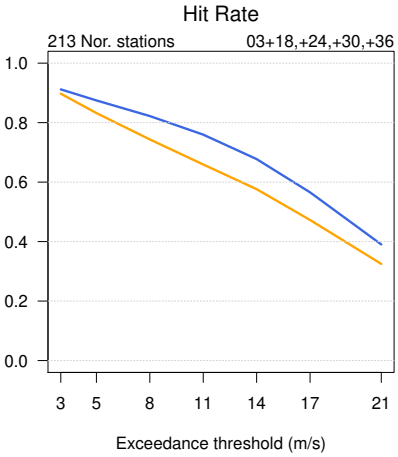


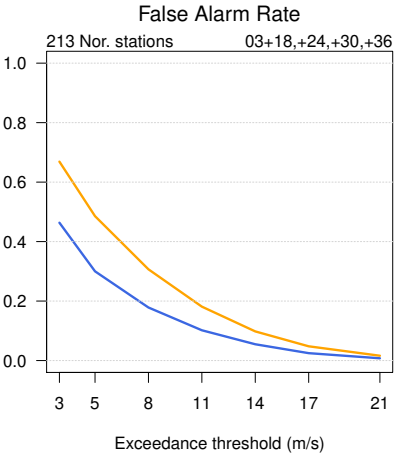
Wind gust (FG) and wind speed in 925 hpa (FF.925)

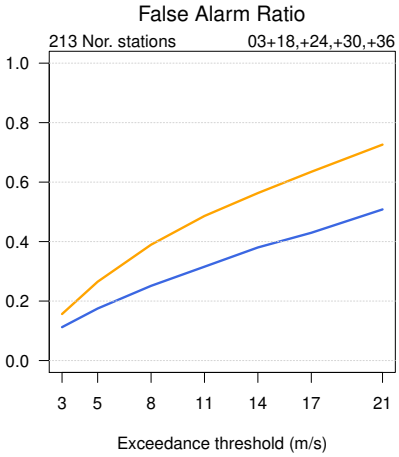


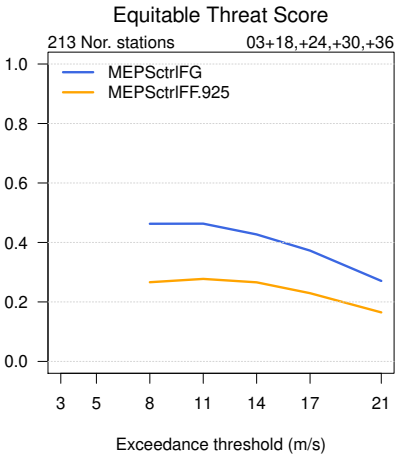


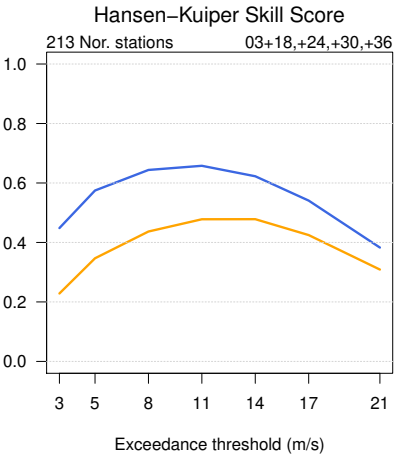


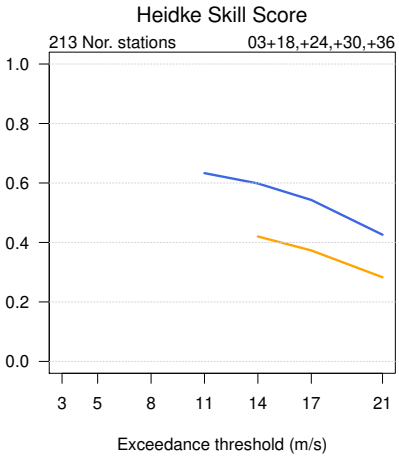


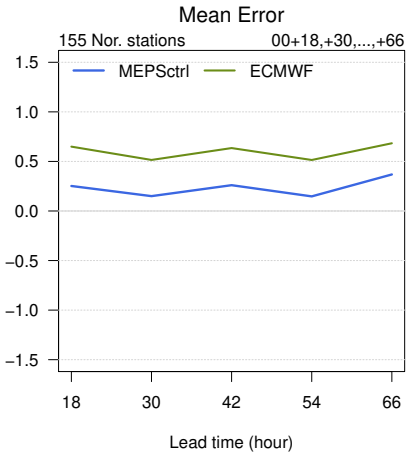


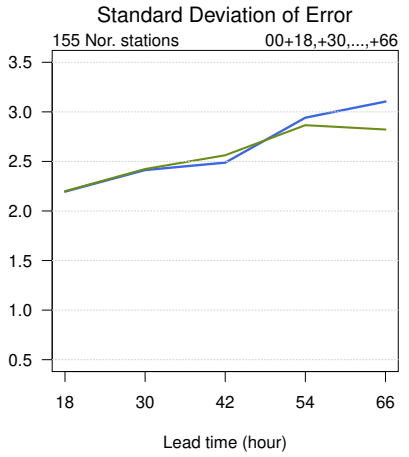


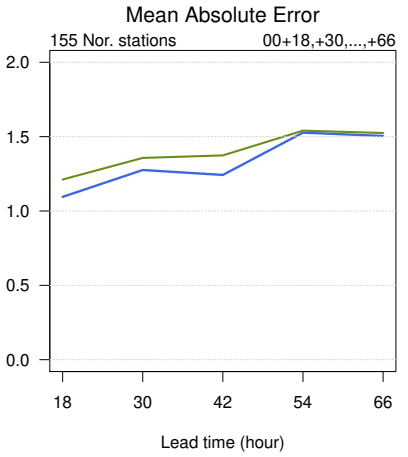


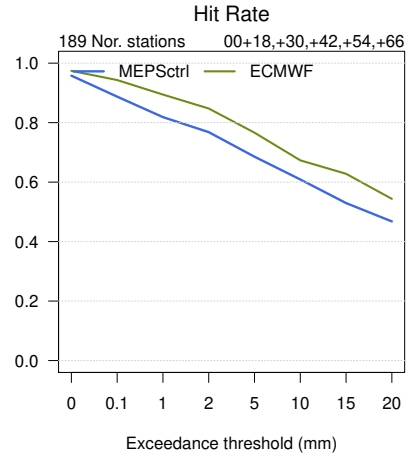


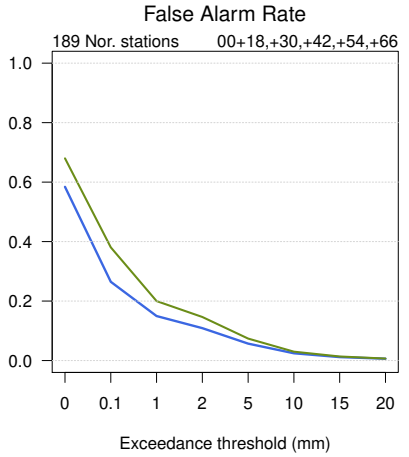


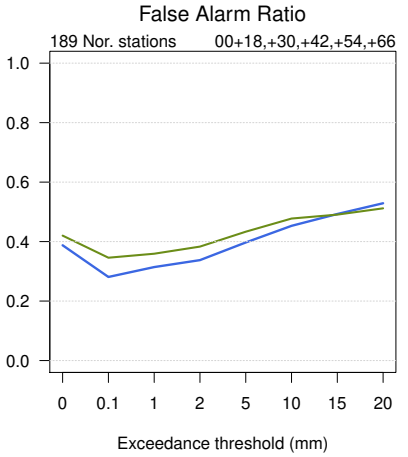

Mean Error
155 Nor. stations
00+18,+30,...,+66
MEPSctrl
ECMWF
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
18
30
42
54
66
Lead time (hour)

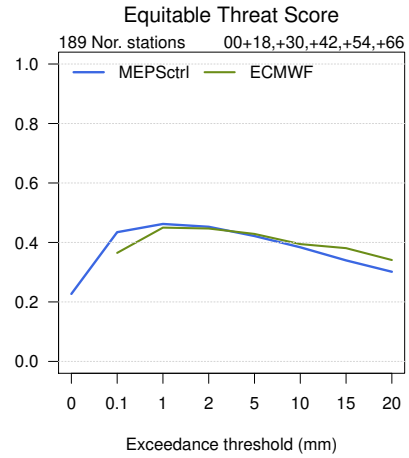

Standard Deviation of Error
155 Nor. stations
00+18,+30,...,+66
3.5
3.0
2.5
2.0
1.5
1.0
0.5
18
30
42
54
66
Lead time (hour)

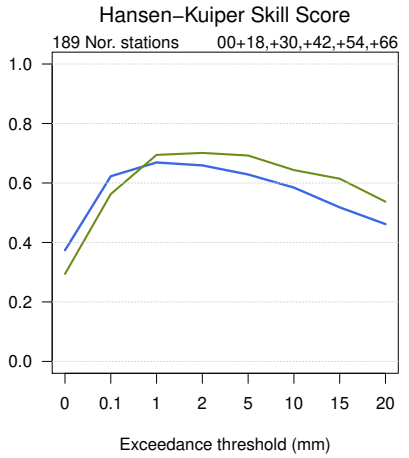

Mean Absolute Error
155 Nor. stations
00+18,+30,...,+66
2.0
1.5
1.0
0.5
0.0
18
30
42
54
66
Lead time (hour)

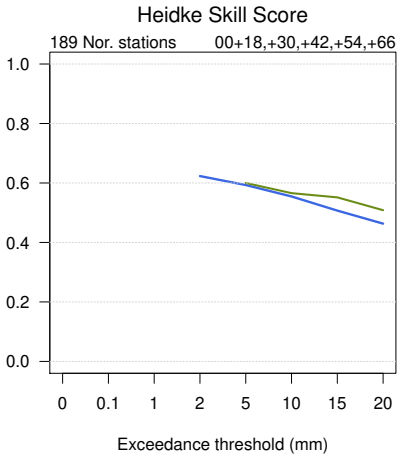

Hit Rate
189 Nor. stations
00+18,+30,+42,+54,+66
MEPSctrl
ECMWF
1.0
0.8
0.6
0.4
0.2
0.0
0
0.1
1
2
5
10
15
20
Exceedance threshold (mm)


False Alarm Rate
189 Nor. stations
00+18,+30,+42,+54,+66
1.0
0.8
0.6
0.4
0.2
0.0
0
0.1
1
2
5
10
15
20
Exceedance threshold (mm)


False Alarm Ratio
189 Nor. stations
00+18,+30,+42,+54,+66
1.0
0.8
0.6
0.4
0.2
0.0
0
0.1
1
2
5
10
15
20
Exceedance threshold (mm)

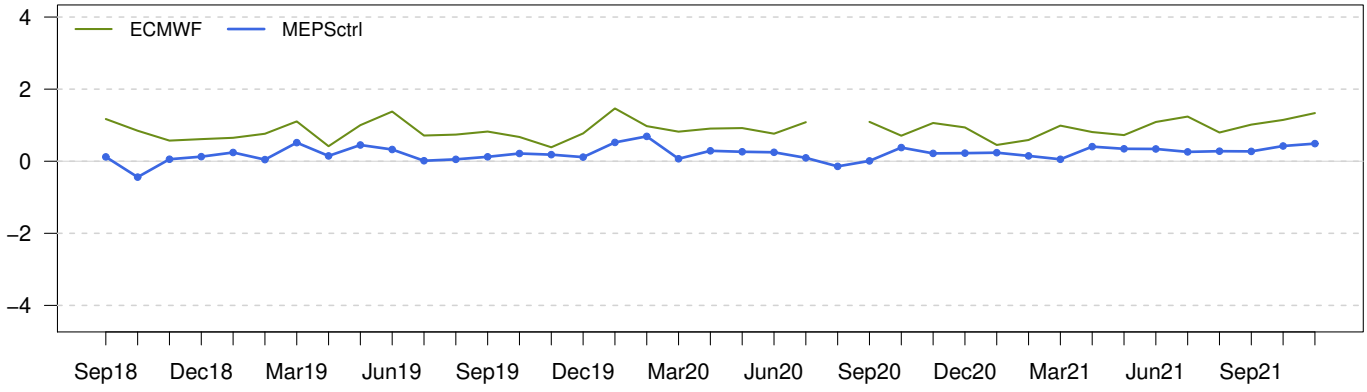

Equitable Threat Score
189 Nor. stations
00+18,+30,+42,+54,+66
MEPSctrl
ECMWF
1.0
0.8
0.6
0.4
0.2
0.0
0
0.1
1
2
5
10
15
20
Exceedance threshold (mm)


Hansen−Kuiper Skill Score
189 Nor. stations
00+18,+30,+42,+54,+66
1.0
0.8
0.6
0.4
0.2
0.0
0
0.1
1
2
5
10
15
20
Exceedance threshold (mm)

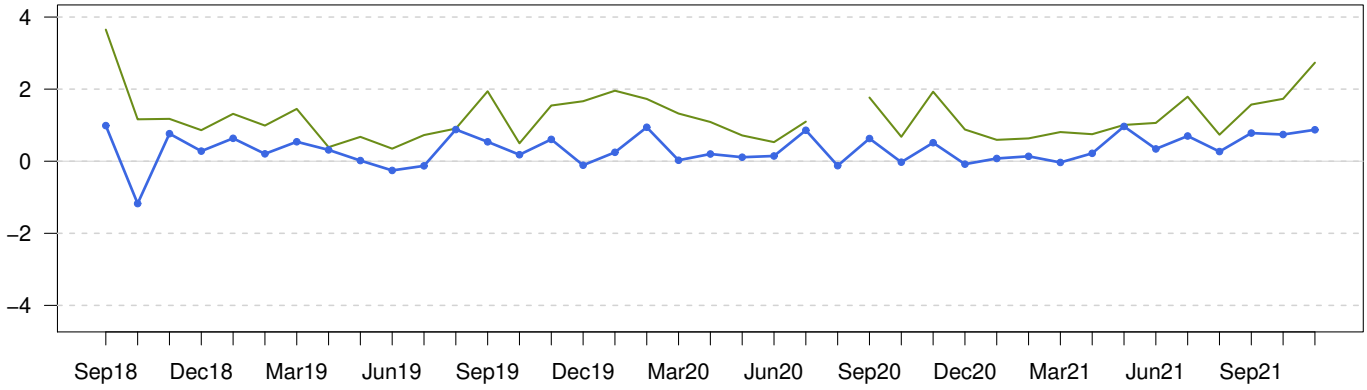

Heidke Skill Score
189 Nor. stations
00+18,+30,+42,+54,+66
1.0
0.8
0.6
0.4
0.2
0.0
0
0.1
1
2
5
10
15
20
Exceedance threshold (mm)

Mean Error

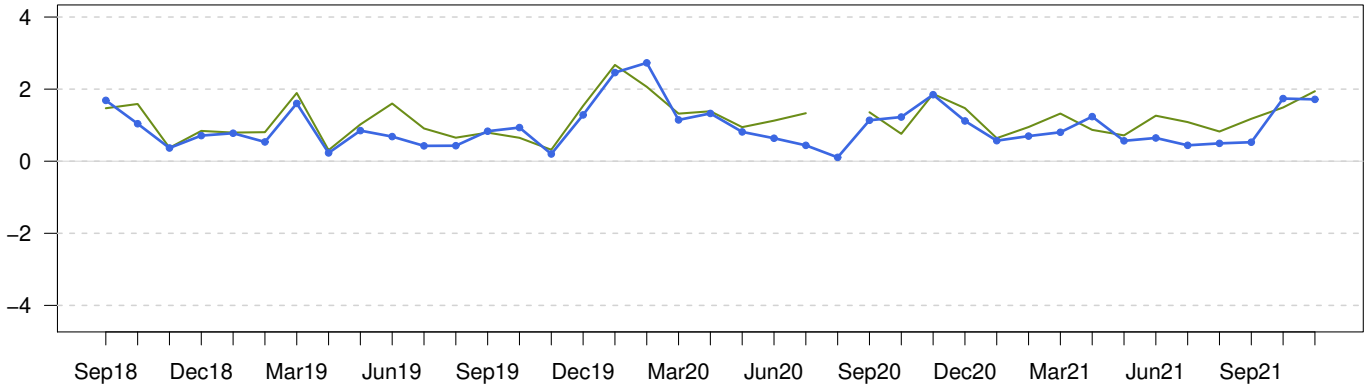
184 Norwegian stations 00+30 UTC



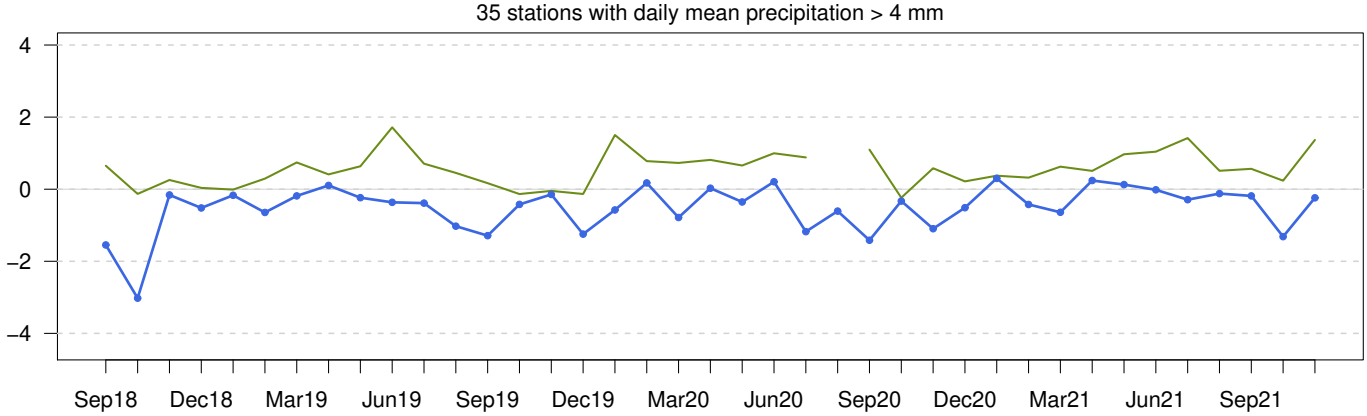
6 coastal stations



43 stations more than 500 m above sea level

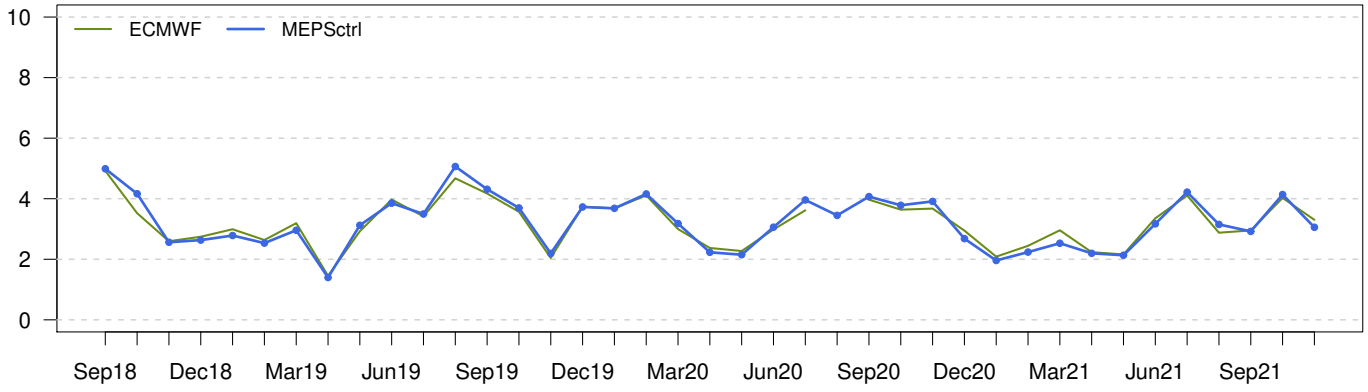


35 stations with daily mean precipitation > 4 mm

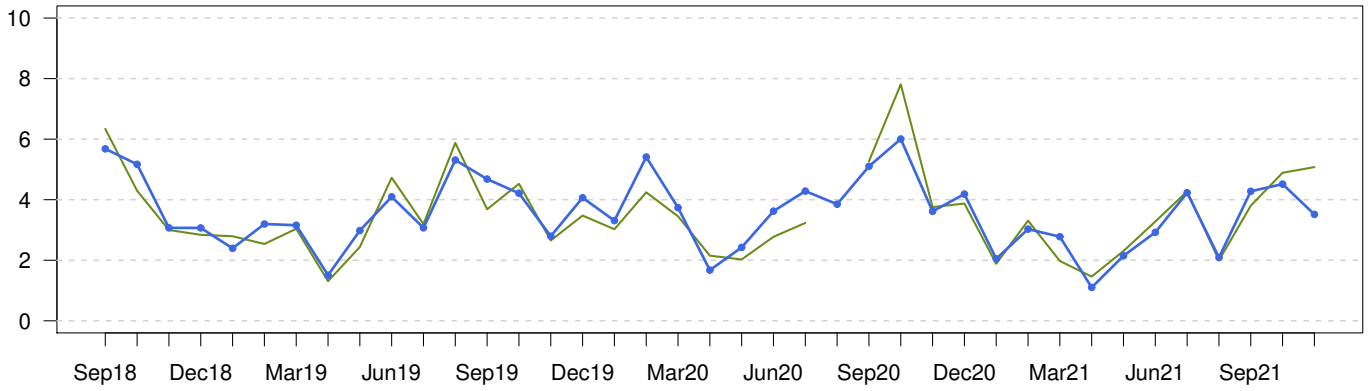


Standard Deviation of Error

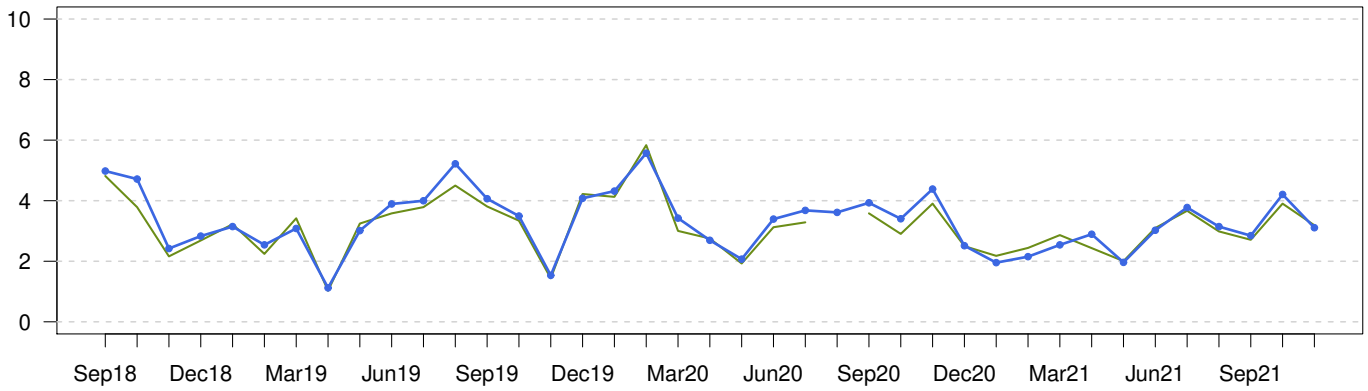
184 Norwegian stations 00+30 UTC



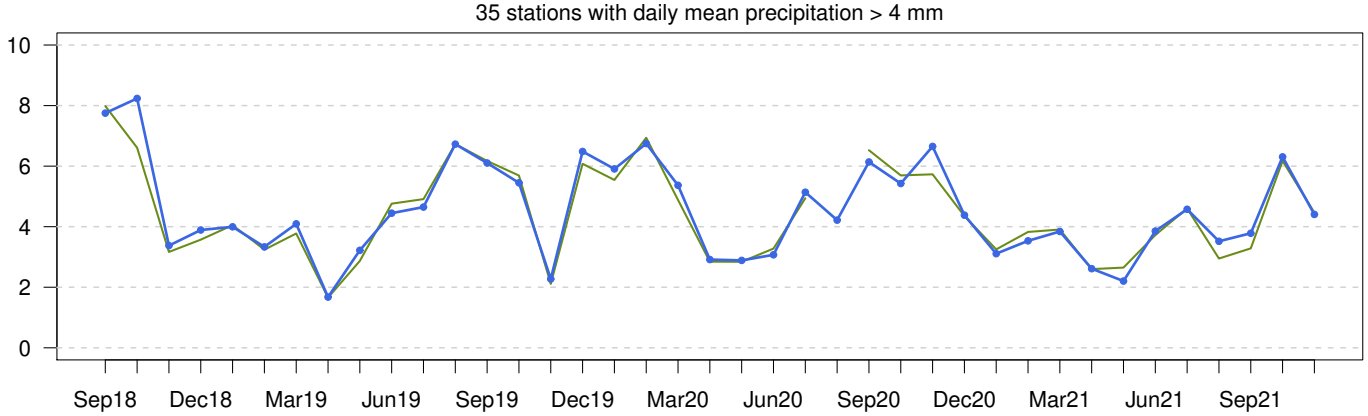
6 coastal stations



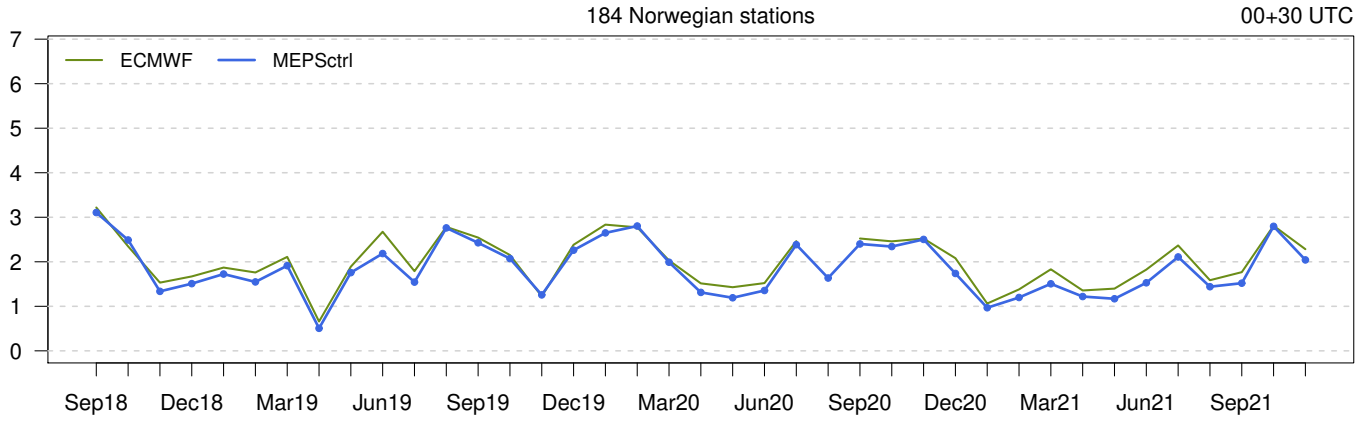
43 stations more than 500 m above sea level

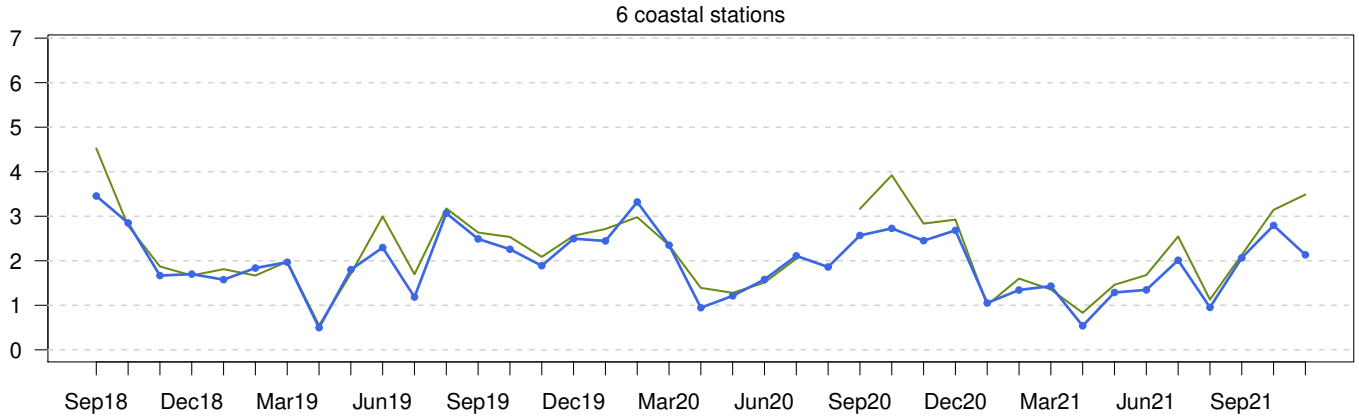


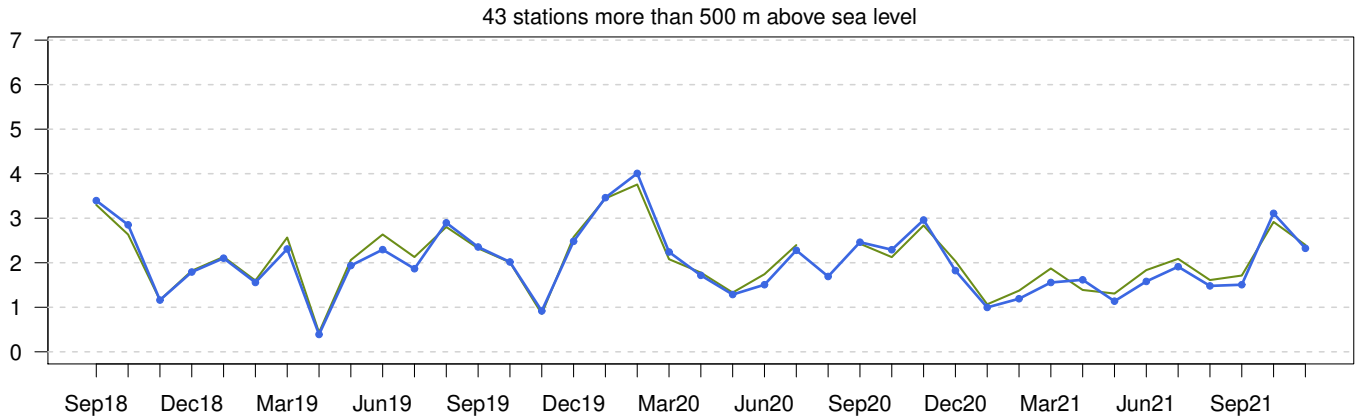
35 stations with daily mean precipitation > 4 mm

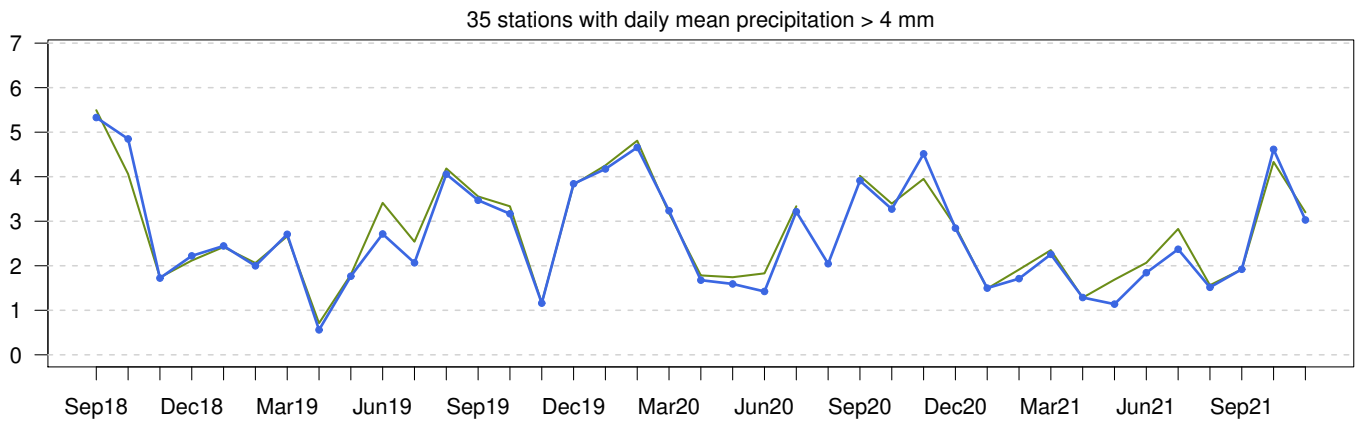


Mean Absolute Error



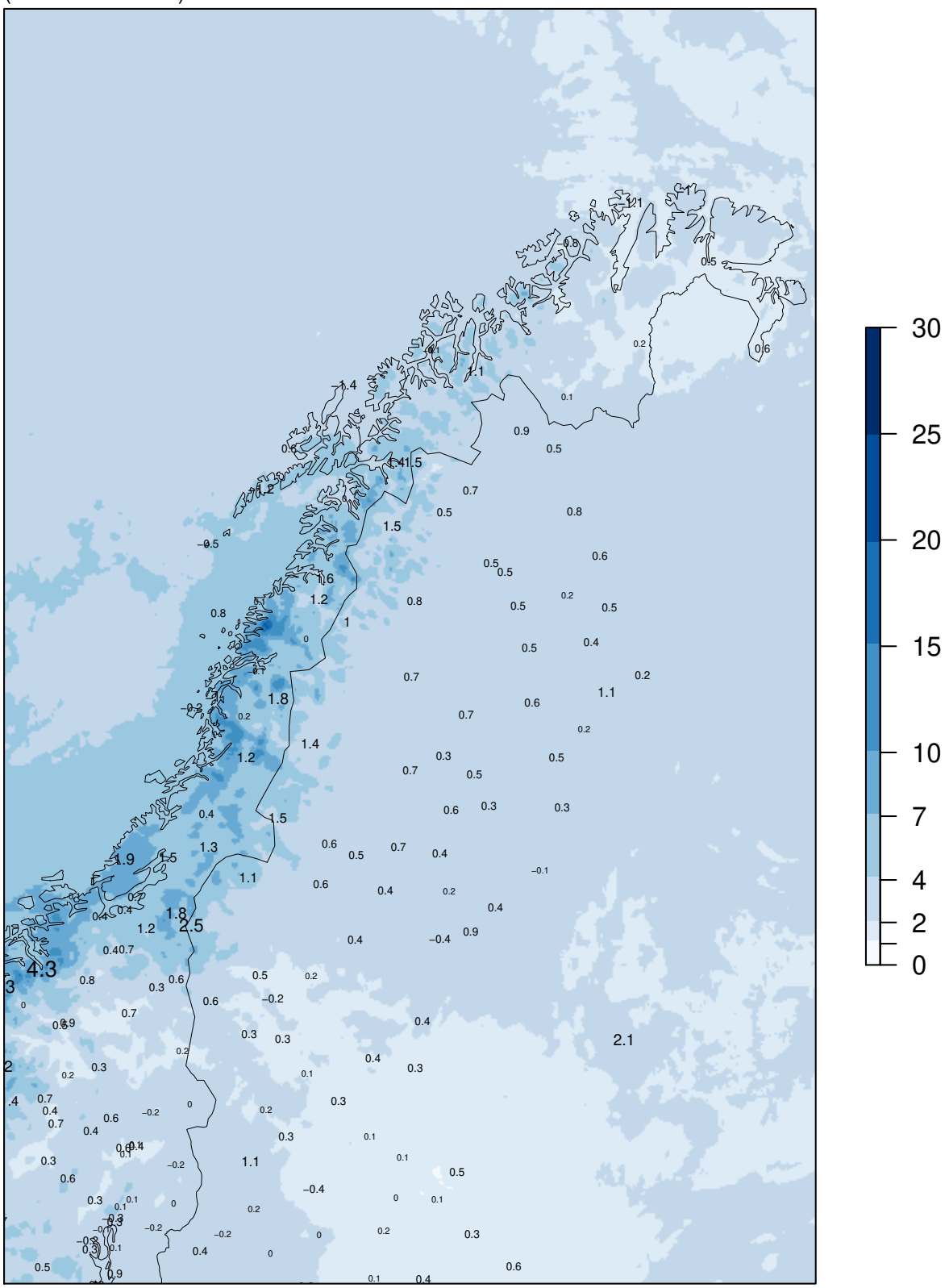






MEPSctrl 00+30

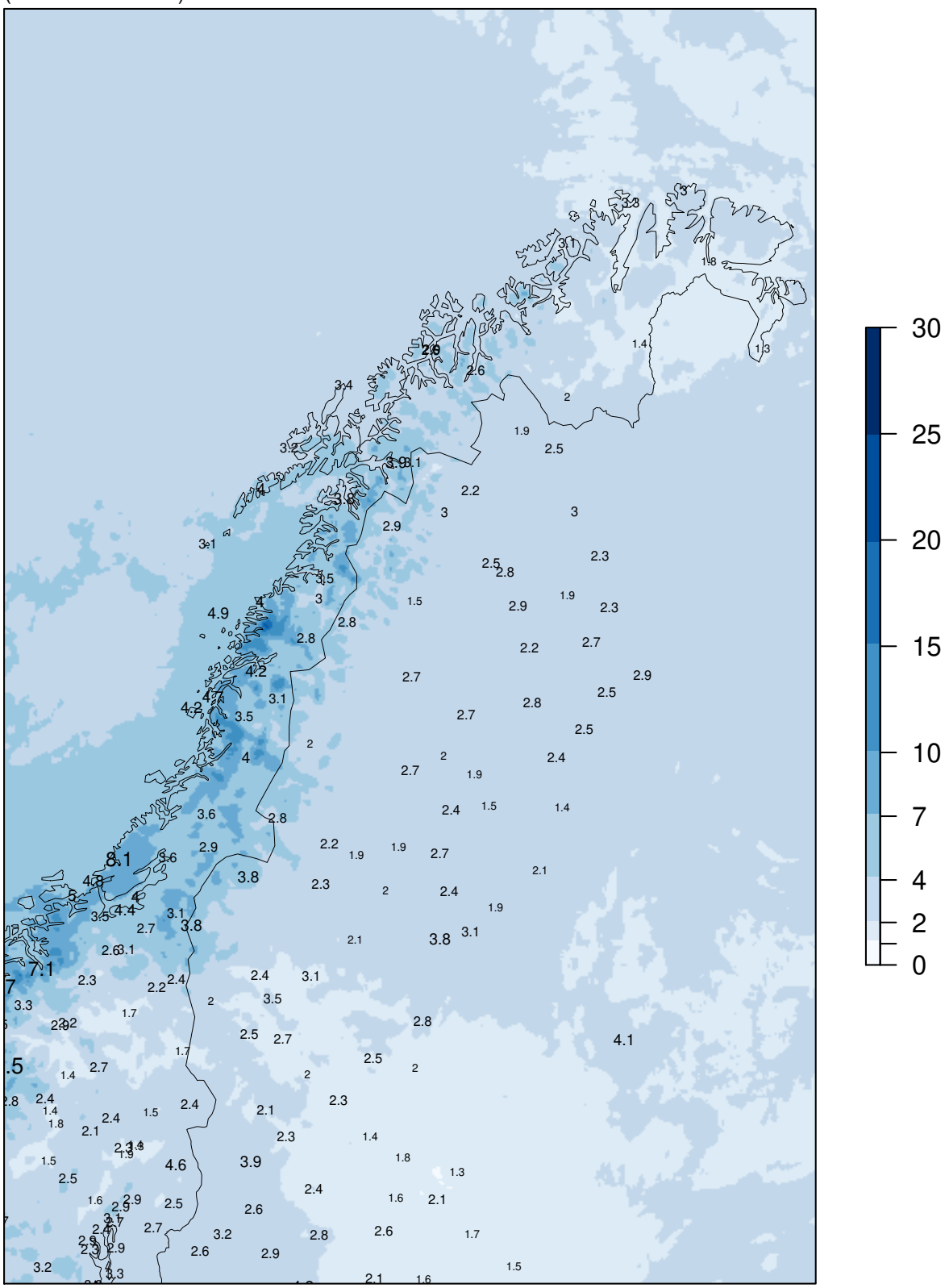
ME at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+30

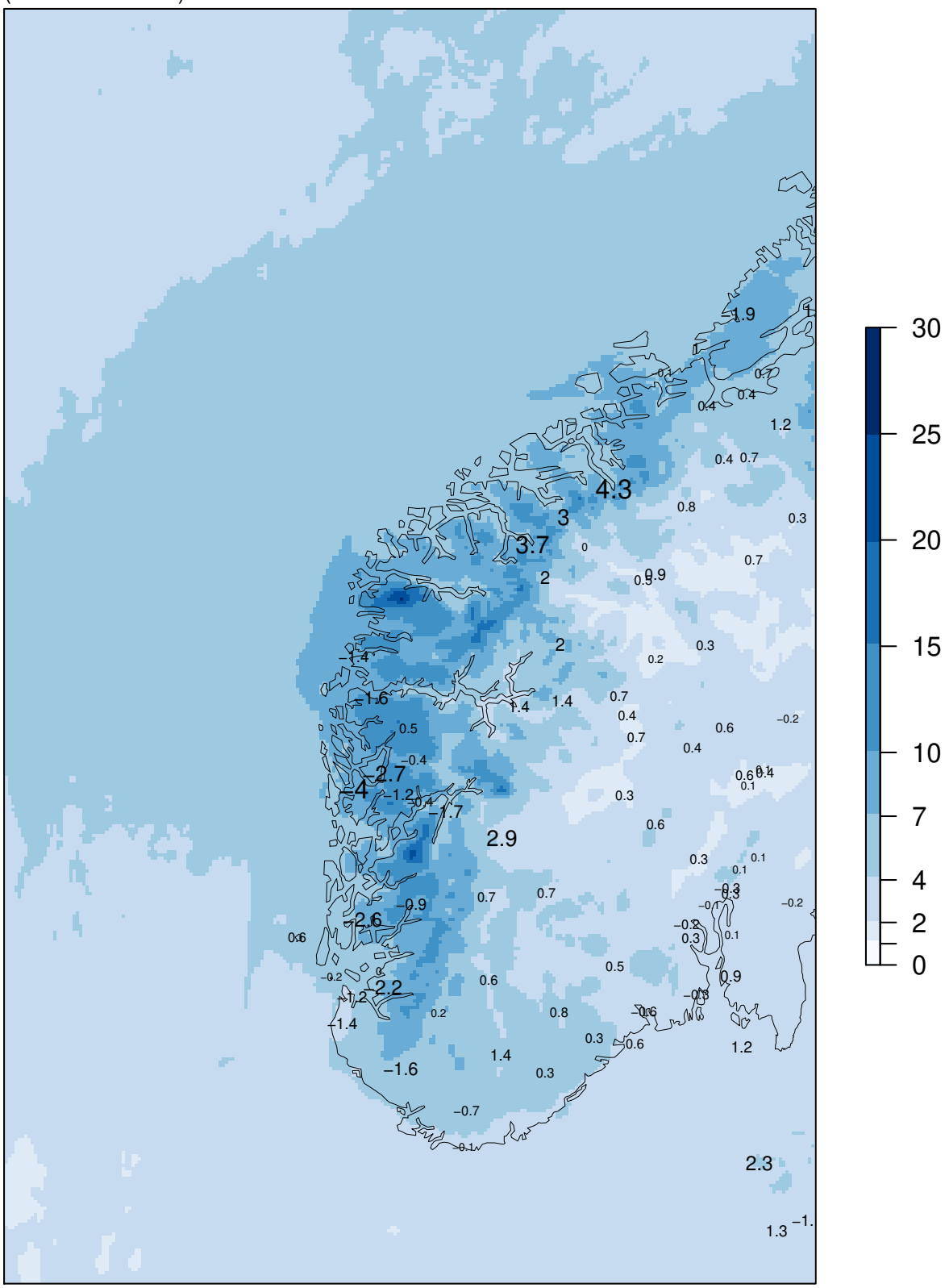
SDE at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+30

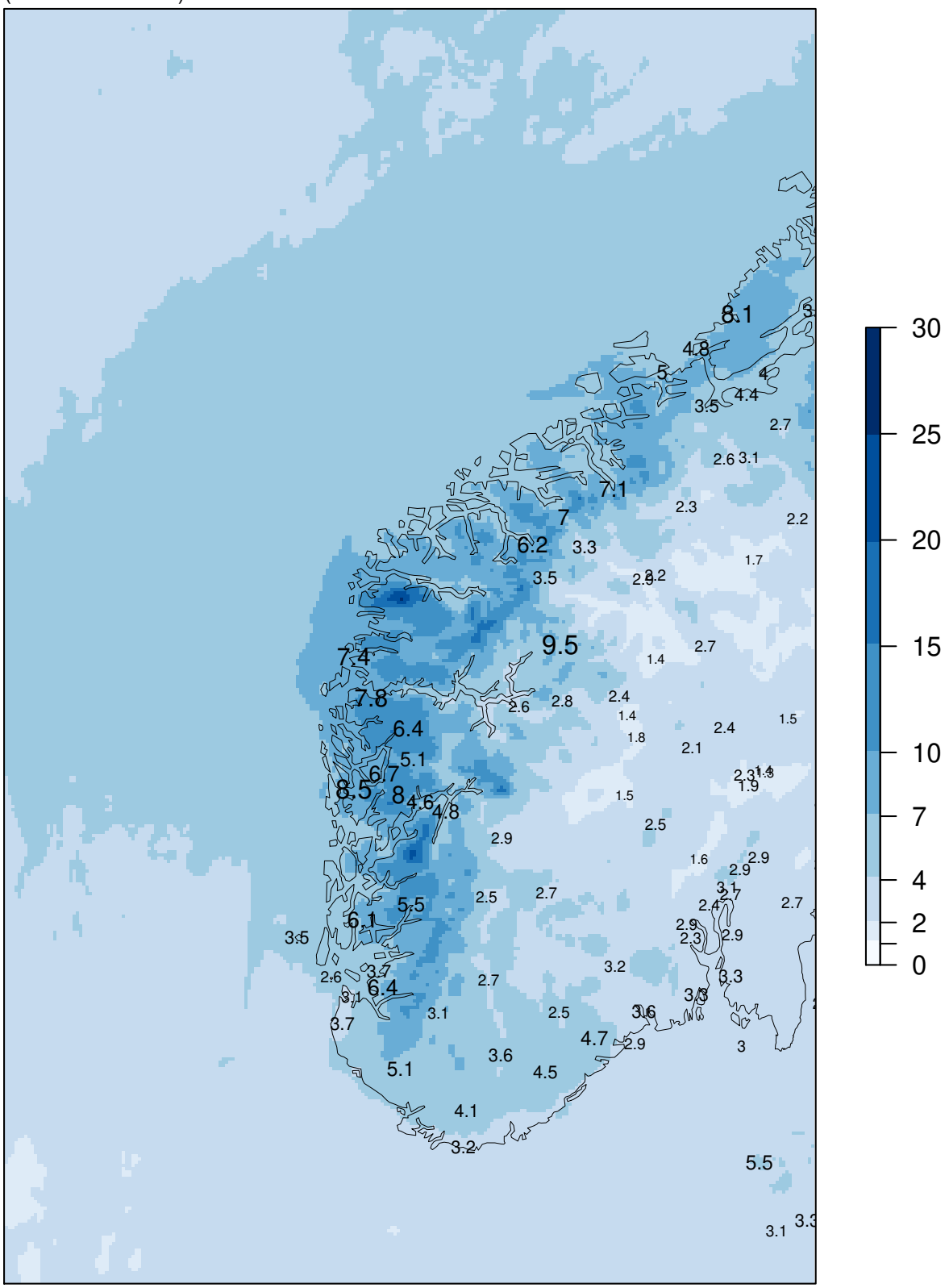
ME at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+30

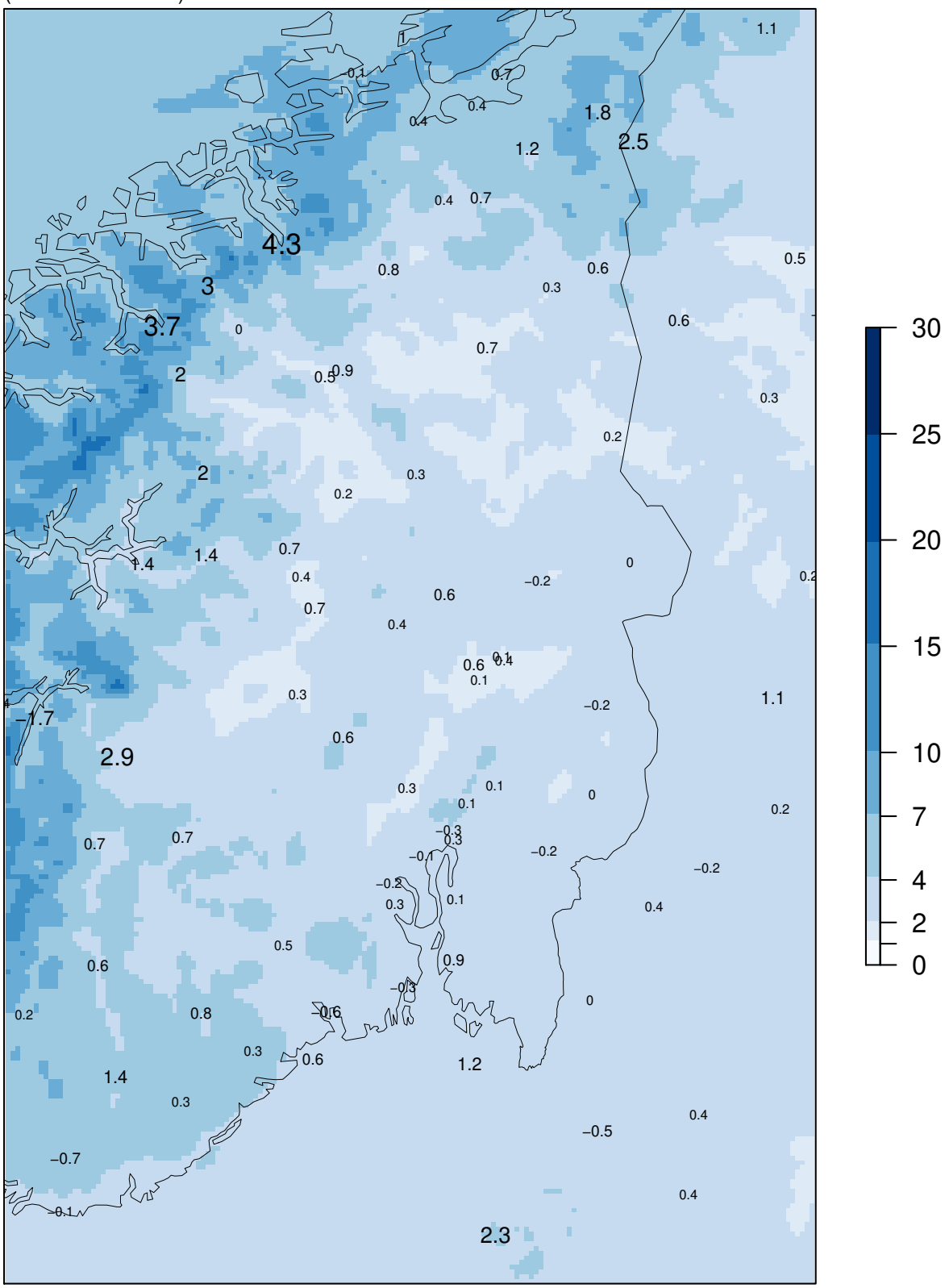
SDE at observing sites
(numbers in black)



Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+30

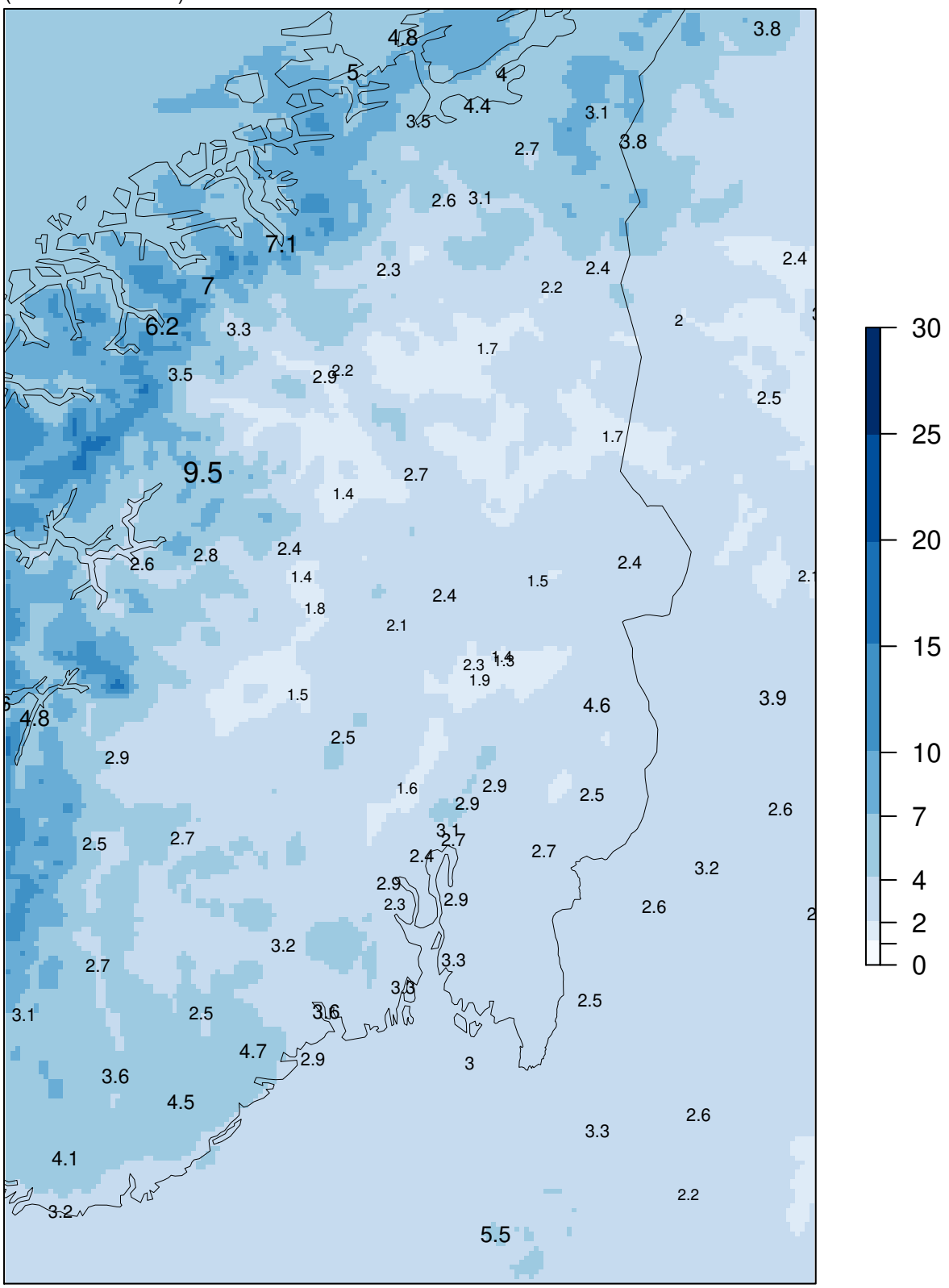
ME at observing sites
(numbers in black)



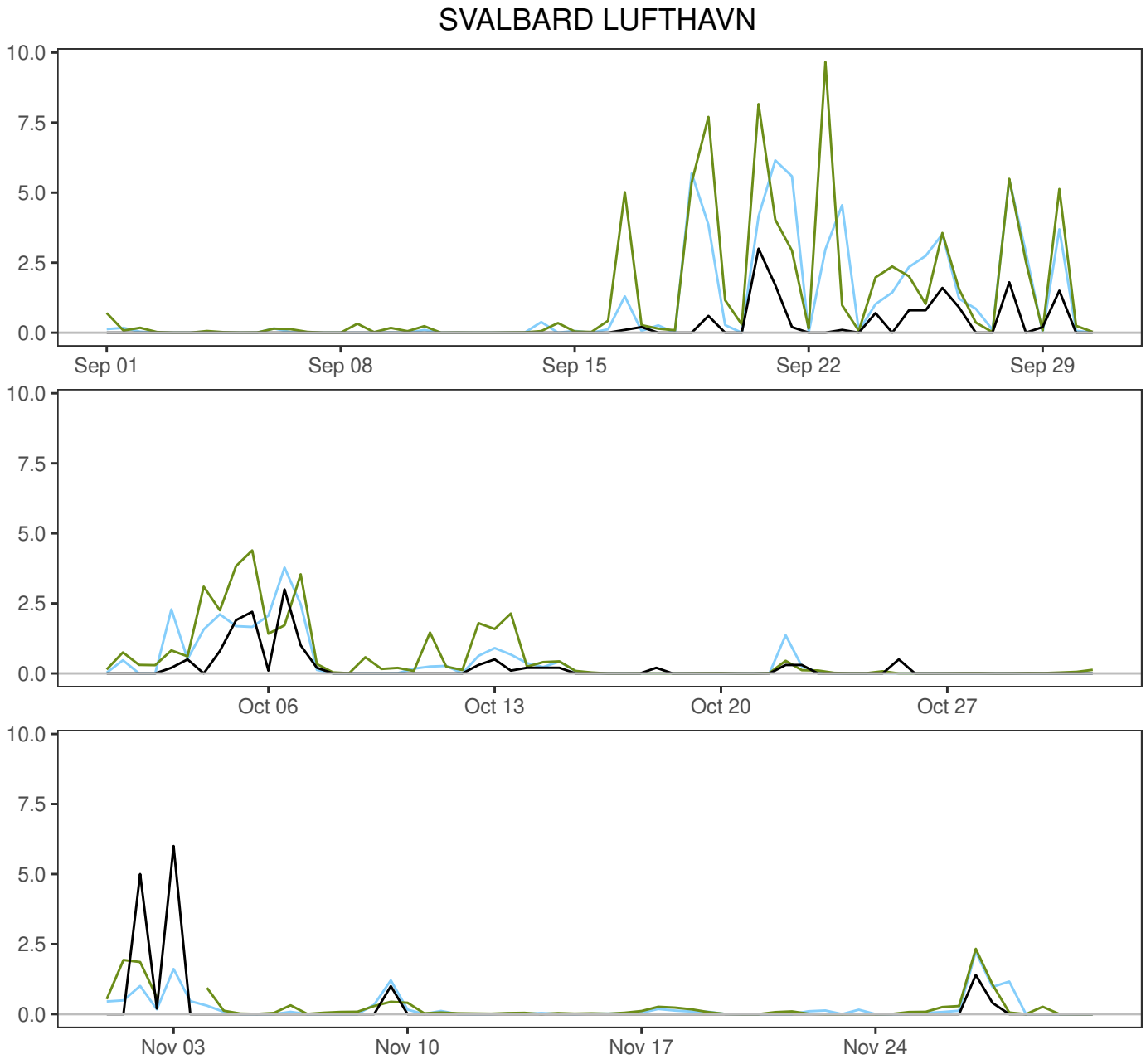
Model "climatology" 01.09.2021 – 30.11.2021

MEPSctrl 00+30

SDE at observing sites
(numbers in black)

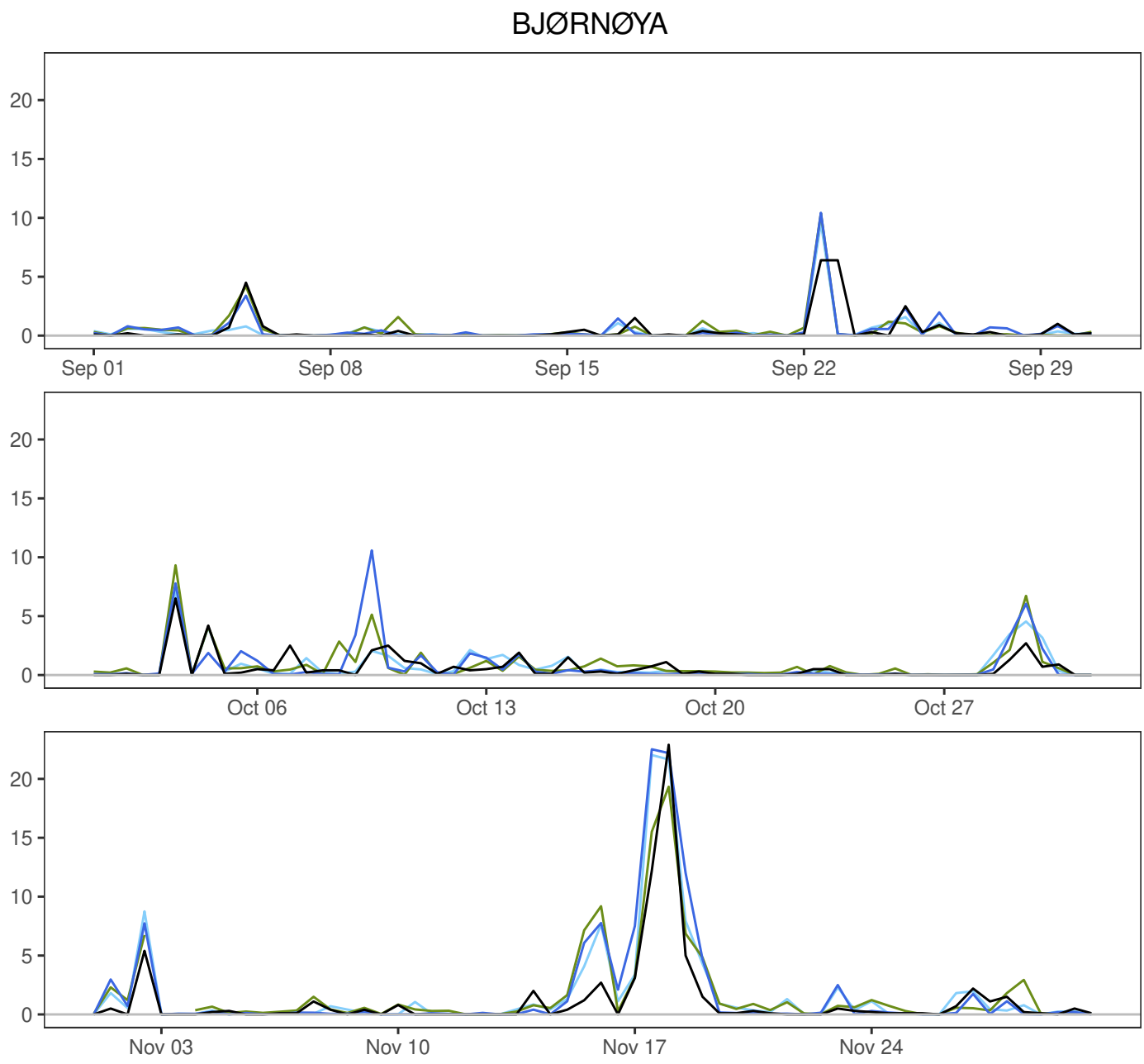


Model "climatology" 01.09.2021 – 30.11.2021



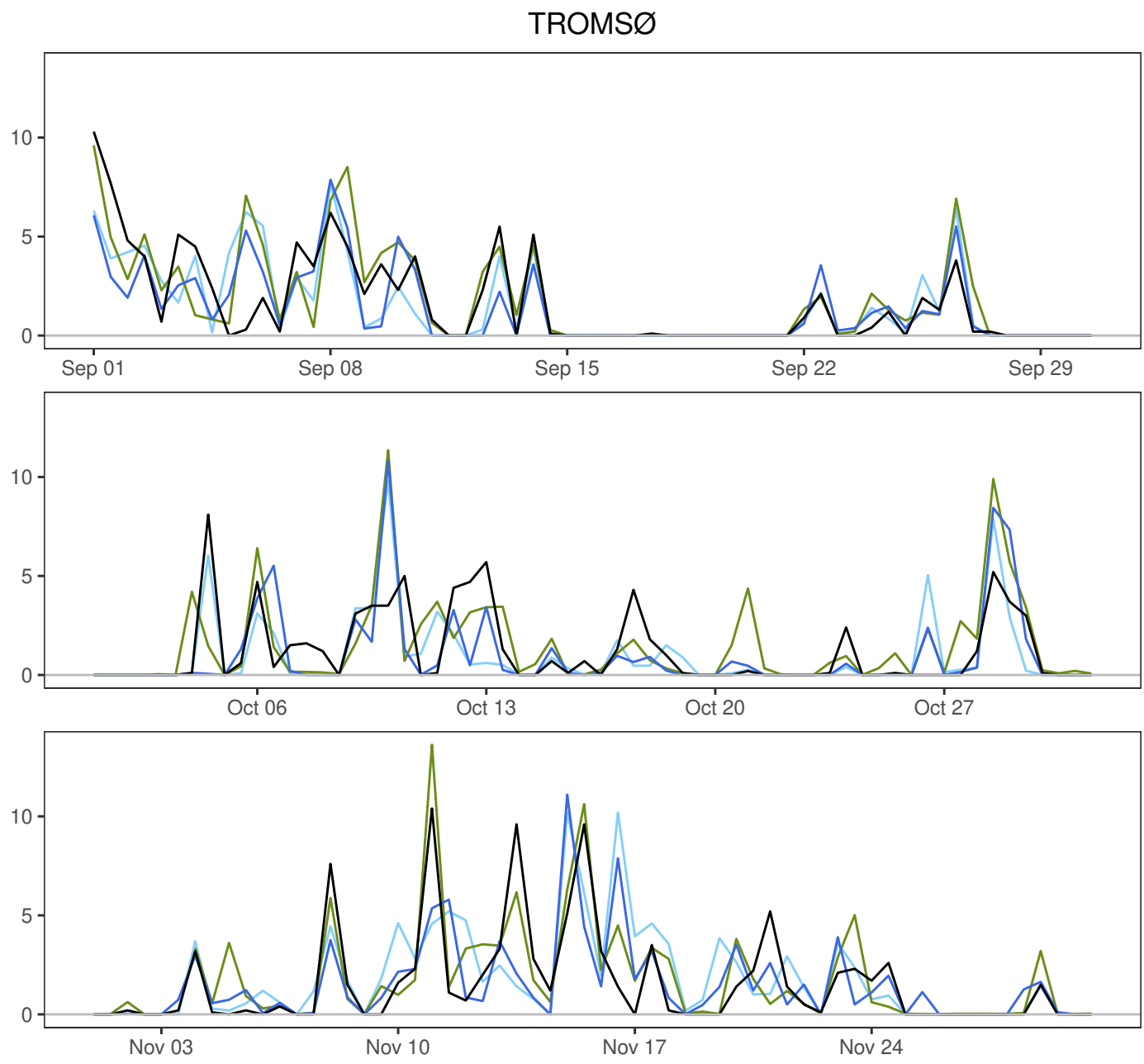
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.2	6.0	0.7	182
AA25: 12+18,+30	0.0	0.5	6.2	1.2	182
ECMWF: 12+18,+30	0.0	0.7	9.7	1.5	180

	ME	SDE	RMSE	MAE	Max.abs.err.	N
AA25−synop	0.3	1.0	1.1	0.4	5.7	180
ECMWF−synop	0.5	1.3	1.4	0.6	9.7	180



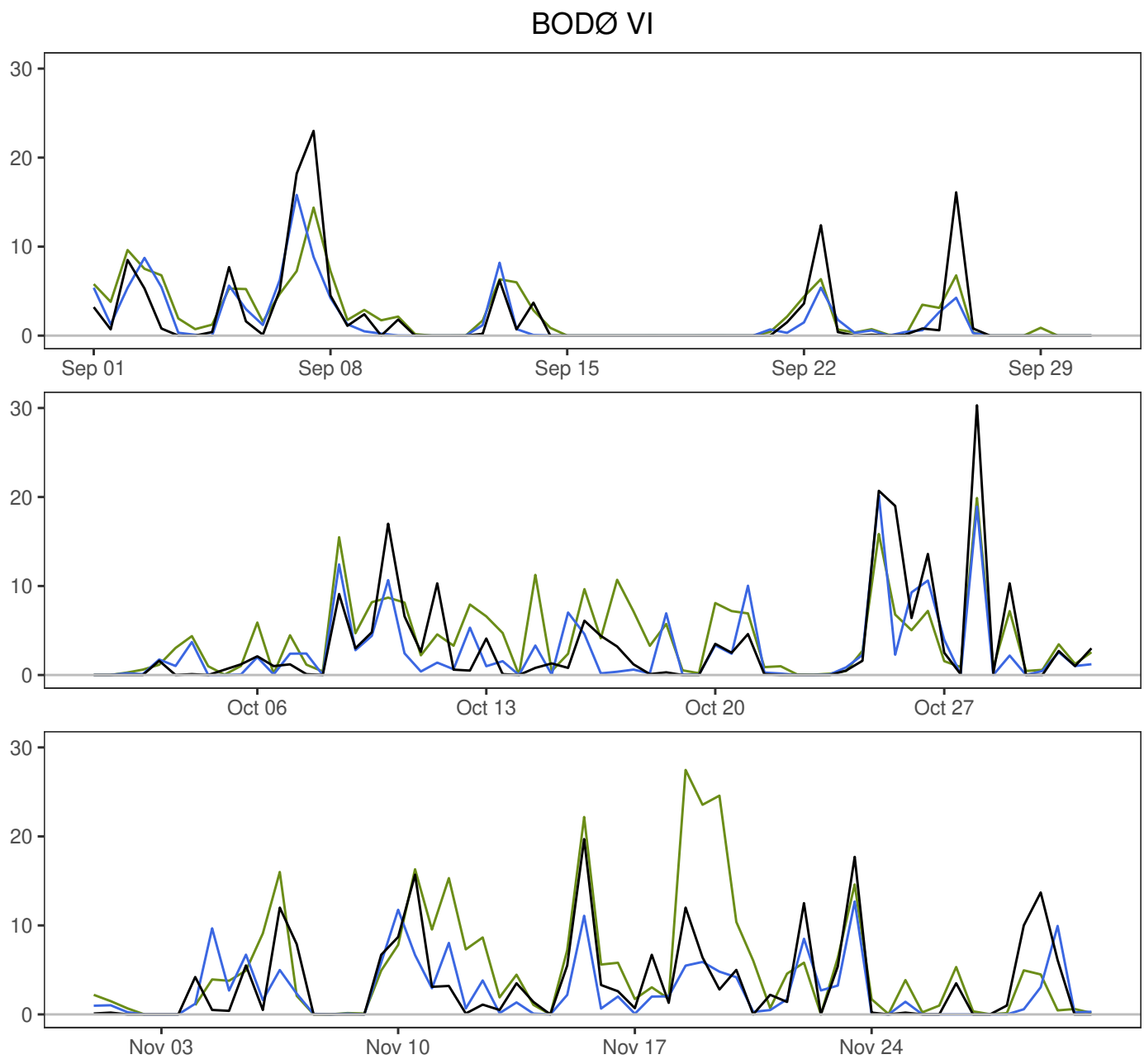
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.7	22.9	2.2	182
MEPSctrl: 12+18,+30	0.0	1.0	22.5	3.0	182
AA25: 12+18,+30	0.0	0.9	22.0	2.7	182
ECMWF: 12+18,+30	0.0	1.0	19.3	2.4	180

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.3	1.6	1.6	0.7	10.3	180
AA25−synop	0.2	1.2	1.3	0.6	9.8	180
ECMWF−synop	0.3	1.2	1.2	0.6	6.5	180



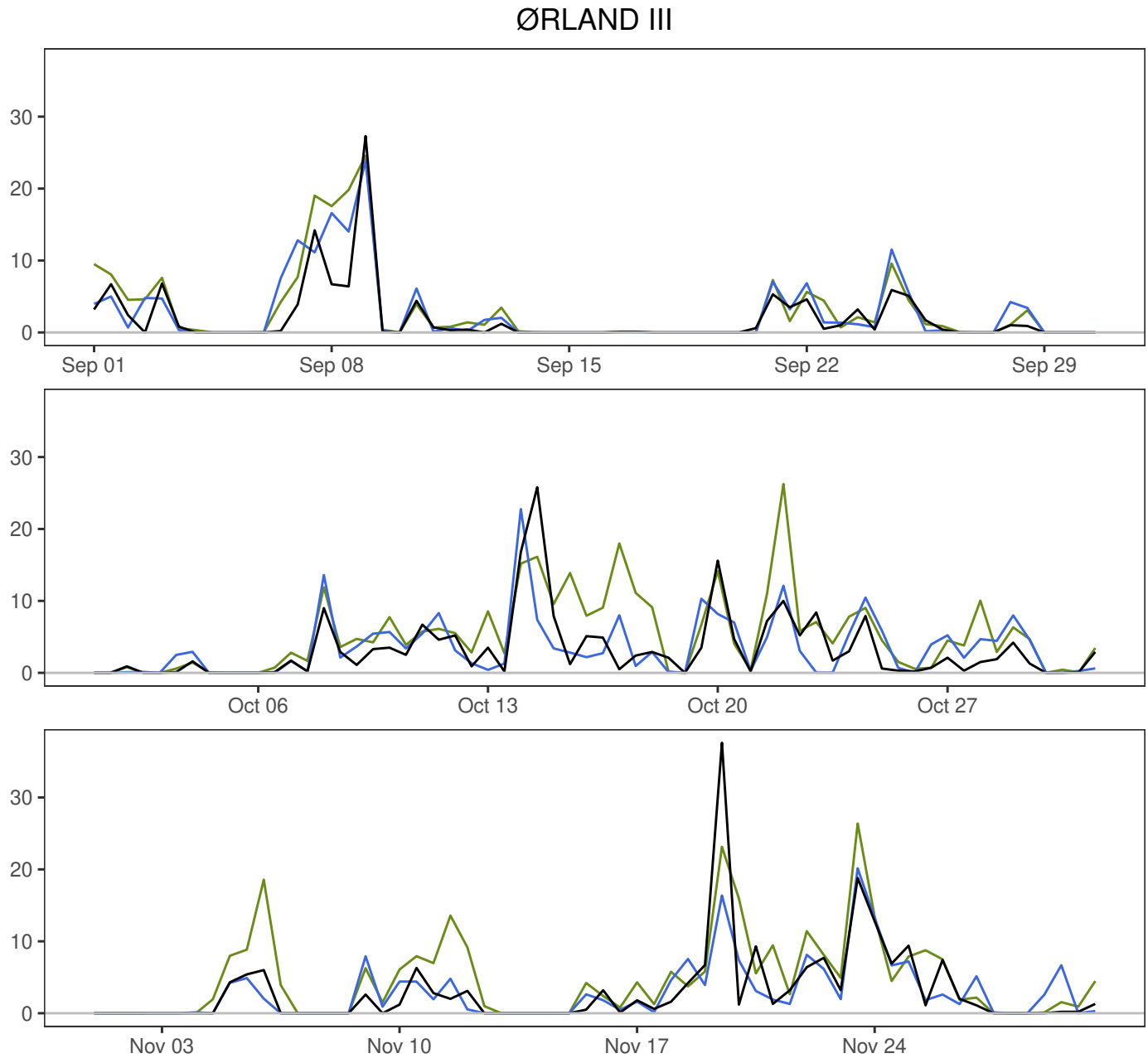
	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.5	10.4	2.2	182
MEPSctrl: 12+18,+30	0.0	1.3	11.1	2.1	182
AA25: 12+18,+30	0.0	1.4	10.2	2.1	182
ECMWF: 12+18,+30	0.0	1.7	13.6	2.4	180

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.2	1.9	1.9	1.0	8.0	180
AA25−synop	0.0	2.0	2.0	1.1	8.8	180
ECMWF−synop	0.2	1.7	1.7	1.0	7.8	180



	Min	Mean	Max	Std	N
synop: 06,18	0.0	3.0	30.3	5.2	182
MEPSctrl: 12+18,+30	0.0	2.4	20.2	3.7	182
ECMWF: 12+18,+30	0.0	4.0	27.5	5.1	180

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.7	3.4	3.4	1.9	16.7	180
ECMWF−synop	0.9	4.2	4.2	2.5	21.8	180



		Min	Mean	Max	Std	N
———	synop: 06,18	0.0	2.8	37.6	5.0	182
———	MEPSctrl: 12+18,+30	0.0	3.0	23.9	4.4	182
———	ECMWF: 12+18,+30	0.0	4.4	26.4	5.6	180

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.3	3.3	3.3	1.8	21.2	180
ECMWF−synop	1.6	3.7	4.0	2.2	17.5	180

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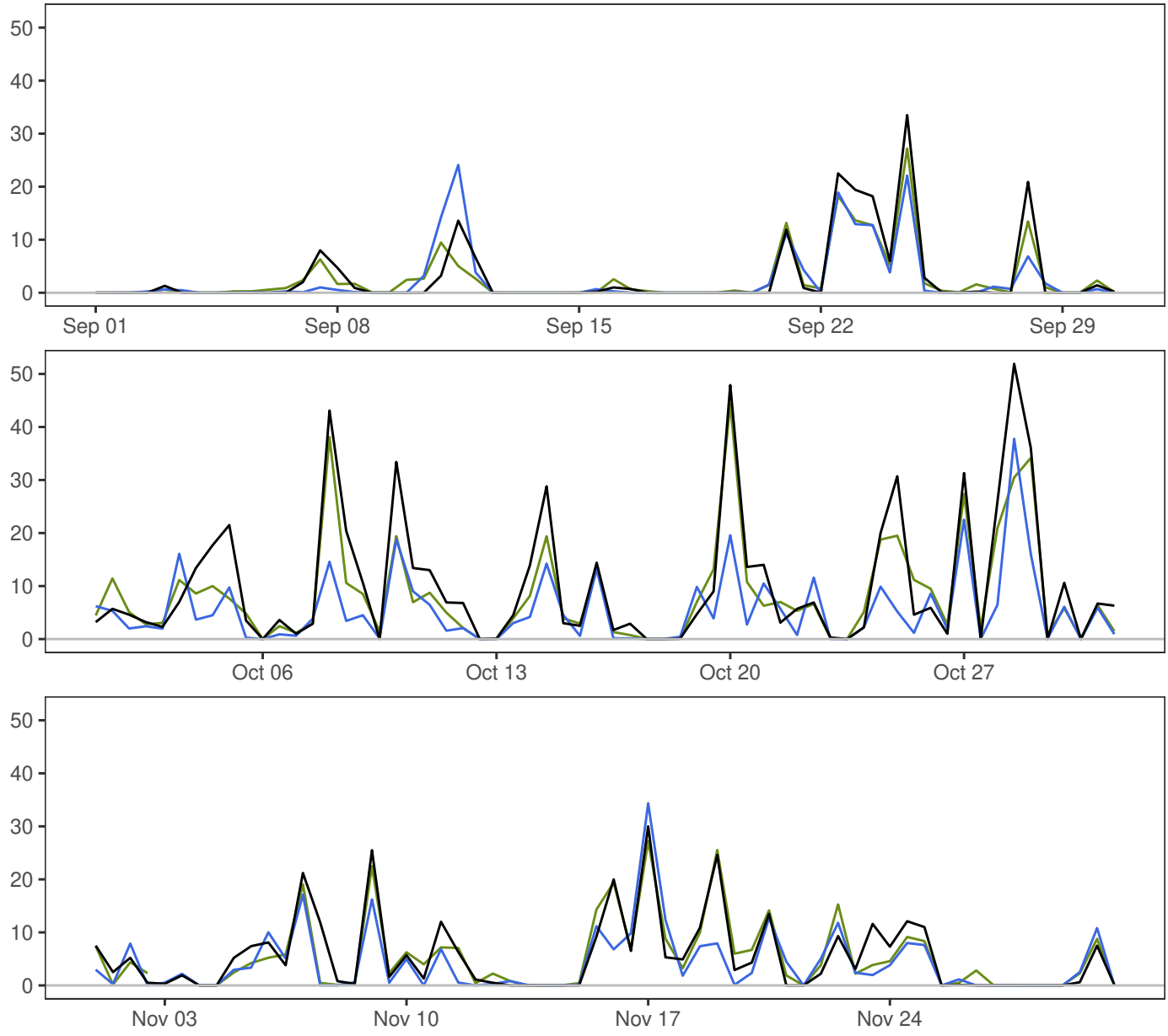
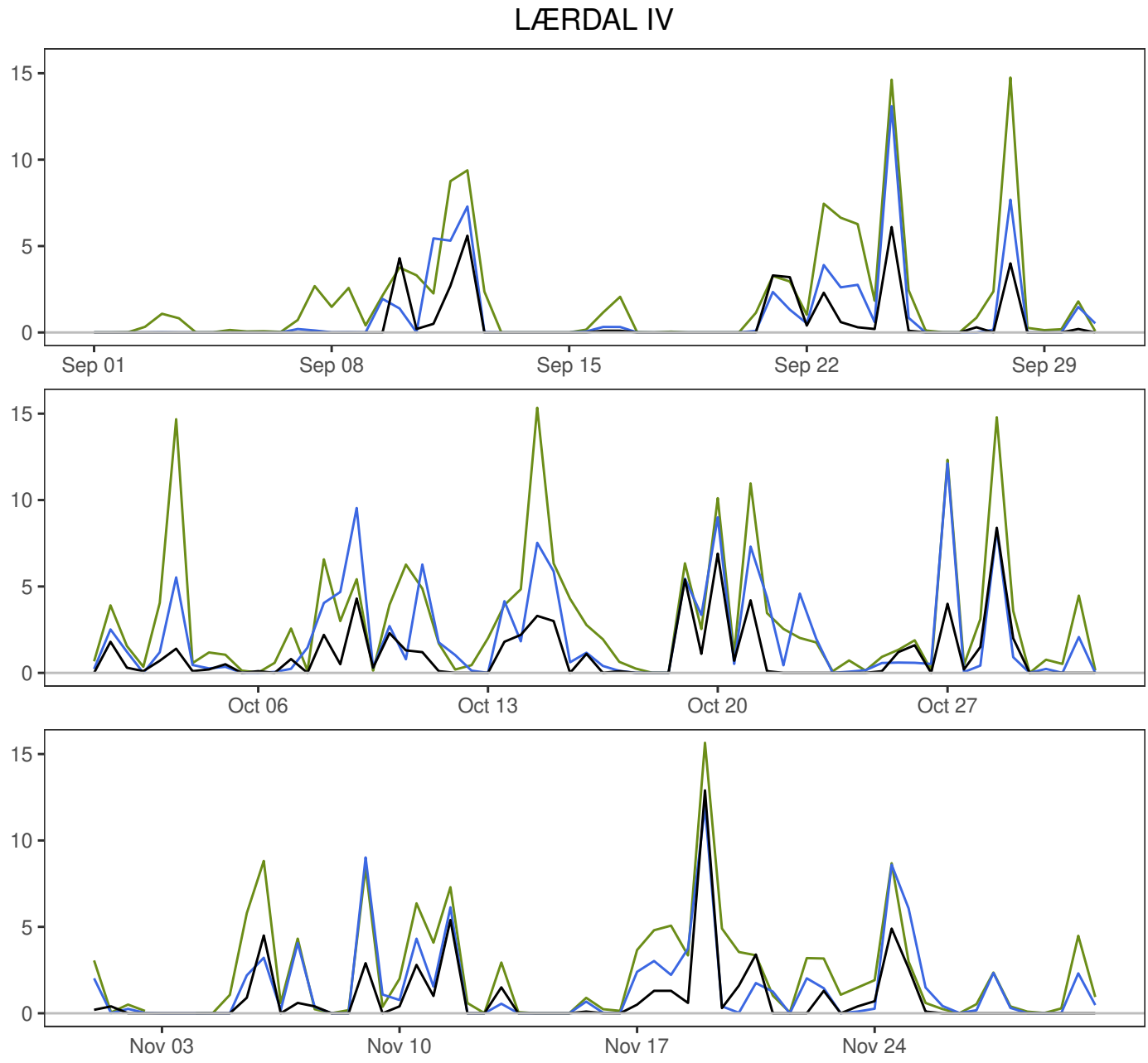


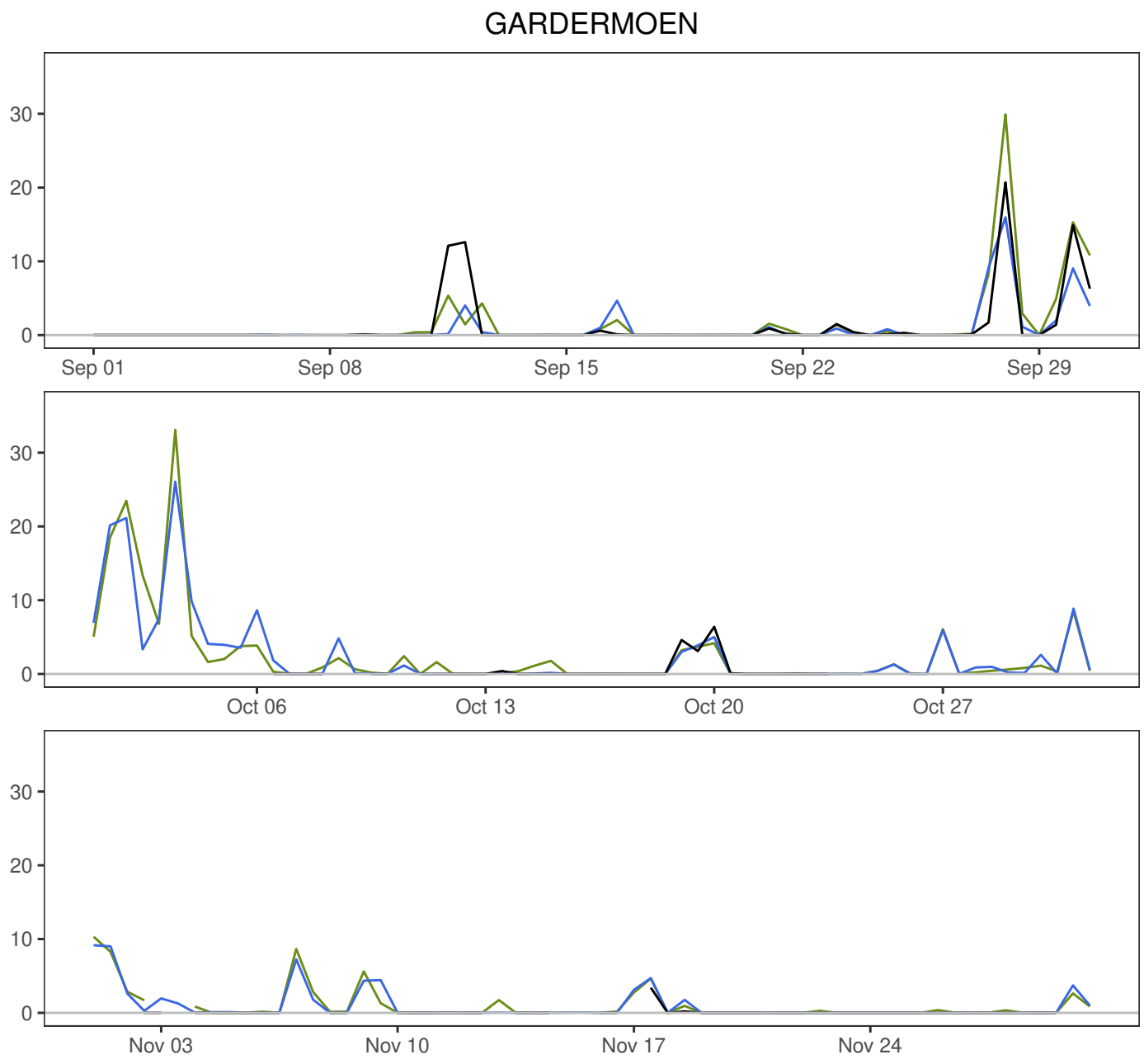
	Min	Mean	Max	Std	N
synop: 06,18	0.0	6.3	51.9	9.7	182
MEPSctrl: 12+18,+30	0.0	4.1	37.8	6.3	182
ECMWF: 12+18,+30	0.0	5.5	44.4	7.8	180

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−2.3	5.9	6.3	3.5	28.5	180
ECMWF−synop	−0.9	3.6	3.7	2.1	21.4	180



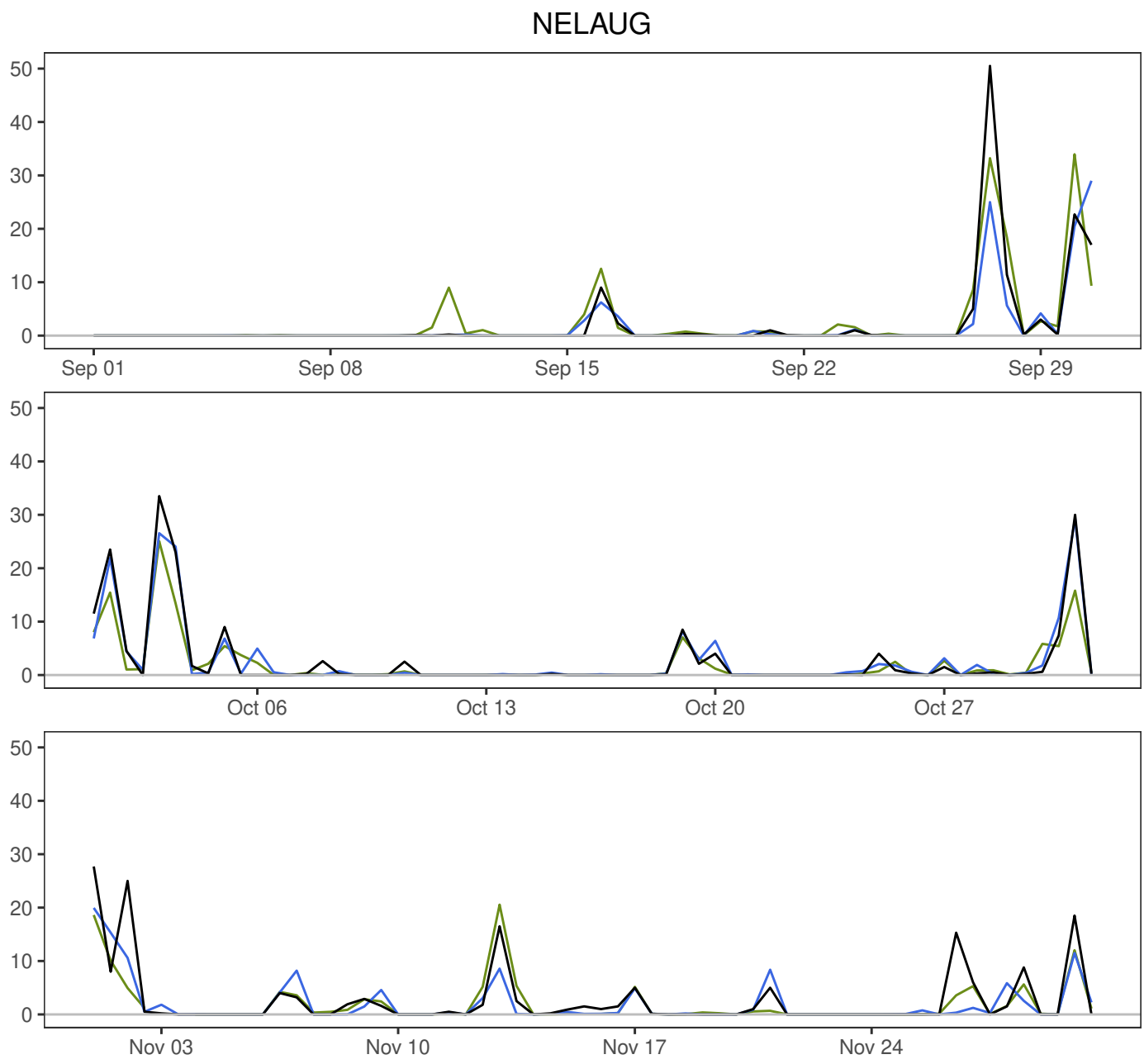
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.8	12.9	1.8	182
MEPSctrl: 12+18,+30	0.0	1.5	13.1	2.6	182
ECMWF: 12+18,+30	0.0	2.5	15.7	3.4	180

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.7	1.6	1.7	0.9	8.1	180
ECMWF−synop	1.6	2.2	2.7	1.6	13.3	180



	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.1	36.5	4.4	142
MEPSctrl: 12+18,+30	0.0	1.5	26.1	3.7	182
ECMWF: 12+18,+30	0.0	1.7	33.1	4.5	180

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.1	2.2	2.2	0.6	15.4	141
ECMWF−synop	0.2	2.4	2.4	0.7	14.6	141



	Min	Mean	Max	Std	N
synop: 06,18	0.0	2.5	50.5	6.8	182
MEPSctrl: 12+18,+30	0.0	2.2	29.3	5.5	182
ECMWF: 12+18,+30	0.0	2.2	34.0	5.3	180

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.4	3.2	3.2	1.2	25.5	180
ECMWF−synop	−0.4	3.3	3.3	1.3	20.1	180