Norwegian
Meteorological
Institute

METinfo

No. 31/2024
ISSN 1894-759X
Meteorology

Verification of Operational Weather Prediction Models December 2023 to February 2024

Lene Østvand, Bjørn Gilje Lillegraven and Gunnar Noer.
With contributions from Mariken Homleid.

Lillomarka. Photo: Lene Østvand

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More information...

Verification results are also available on internal web pages

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

About this report

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

The report includes verification results for 3 Numerical Weather Prediction (NWP) models; MetCoOp ensemble 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.

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

YrPP is plotted with the color below.

The HARMONIE system

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

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

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

AROME physics

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

SURFEX as surface model

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

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

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

Data assimilation

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

Surface analysis

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

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

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

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

Upper air analysis

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

Boundary fields

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

Verification measures

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

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

Forecasts of continuous variables

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

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

In the formula for COR the following definitions are used

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

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

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

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

Forecasts of categorical variables

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

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

Verification statistics for such forecasts are listed in the following table

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

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

Observations

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

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

Summary of the results

Summarized statistics show that ECMWF in general 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 underestimate the temperature for the different groups of stations, while MEPSctrl and AA25 show a small tendency to overestimate for most lead times. AA25 is slightly warmer than MEPSctrl for North Norwegian stations. Still, the errors are small, indicating that the timing of the temperature changes is generally good. The temperature forecast is further improved by post processing, particularly for the shortest lead times. The improvement is larger for inland stations than coastal stations, which have less variation in temperature and smaller errors than inland stations for both MEPSctrl and post processed forecasts.

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

Wind speed is challenging to evaluate. MEPSctrl clearly performs better than ECMWF over land, and particularly in the mountains, where ECMWF underestimates the speed considerably as seen in the monthly mean error and mean absolute error. The maps show that underestimation also applies to coastal stations in strong wind events. The threshold scores indicate that wind speed is better forecast for lower than for higher wind speeds for all models. 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 seen at coastal stations with increased diurnal cycle in wind speed and less underestimation during day. The mean error indicates a somewhat smaller overestimation of wind speed after post processing, while the other scores show almost identical results for MEPSctrl and YrPP.

Precipitation also shows varying results, depending on the amount and location. ECMWF has on average more precipitation than MEPS. Both have more errors for both very small amounts and very high amounts, than precipitation in the mid range.

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

Case 1. Temperatures.

One main wintertime problem that has persisted through the last years is the positive bias at very cold temperature minimum events.

One event from the 15 to 16 January is typical for the positive bias in cold nighttime inversion in the winters. MEPSctrl was here forecasting too high values of 2m temperature over a large portion of south-eastern Norway. For example the forecast for Dagali was around -20°C from MEPSctrl, while in reality the temperatures dropped as low as -34°C (figure 1).

The event developed during the evening of the 15th. The model cloudiness was quite accurate, as can be seen from figure 2, so the radiation balance must be assumed to be correct. Despite this, it seems like the model was unable to reproduce the rapid drop in temperature at the 2m level. This points to that there may be an issue with the exchange between the lowest model layers and the surface.

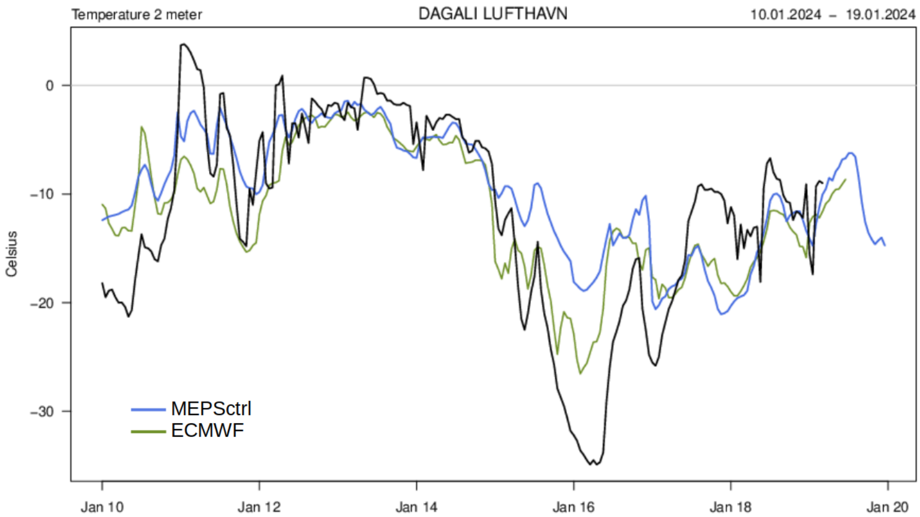


Figure 1: 2m temperatures from Dagali from 10-20 January 2024. Neither MEPS (blue) or ECMWF (green) were able to capture the temperature drop sufficiently.

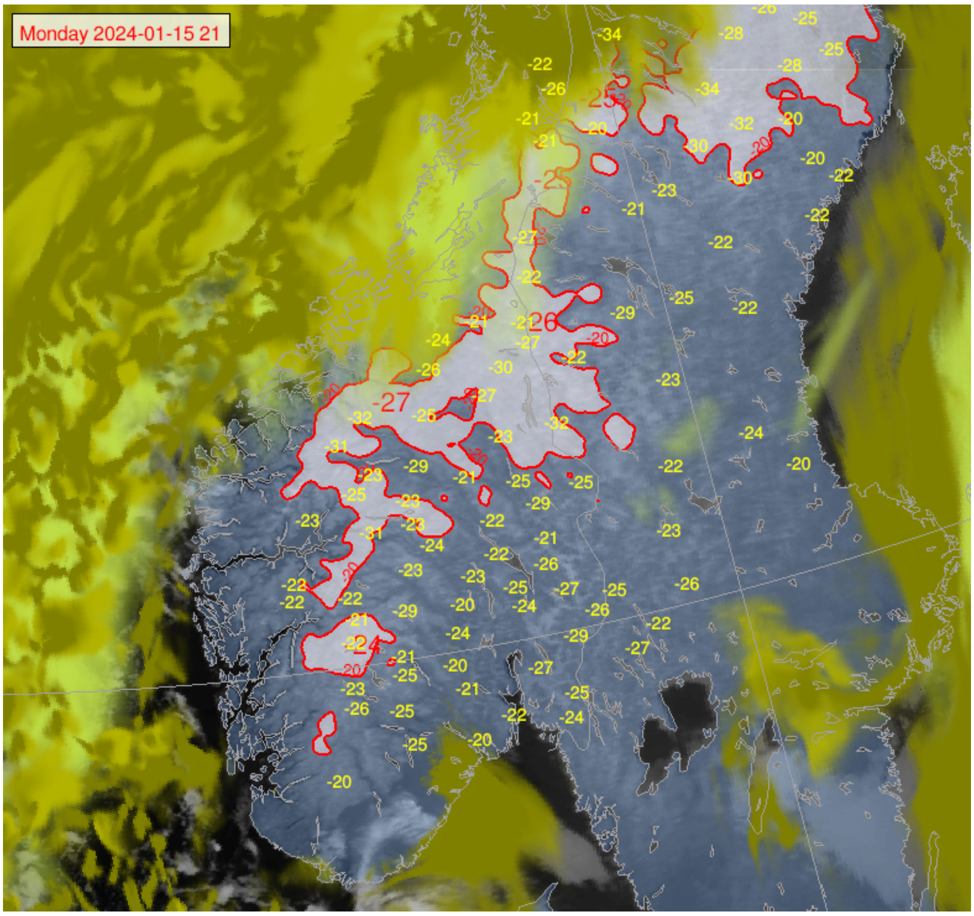


Figure 2: The model cloudiness (yellow-brown shading) with a satellite image, and MEPSctrl T2m $<$ -20°C (red) plotted against observed T2m $<$ -20°C (yellow) from the evening of the 15th of January. Ideally the model T2m and the observed should overlap if the model was correct.

Case 2. Clouds.

The most common feedback from the forecasters in this period was a lack of low or medium stratiform clouds. This has also been reported many times before. As can be seen in figure 3 (left) the model normally has good agreement with the actual clouds, but fails in the areas of high pressure and subsidence. The sounding from Oslo-Blindern in figure 3 (right) shows that while the sounding does have a saturated level and cloudiness at 0 hrs lead time, after 6 hrs it has increased the temperature too much in the mixed layer. As the moisture and dew point is almost unchanged, the model clouds dries out and clear skies are forecast.

Figure 4 shows the meteograms for Oslo-Blindern during the event, while 5 shows a comparison of cloudiness for MEPSctrl and ECMWF.

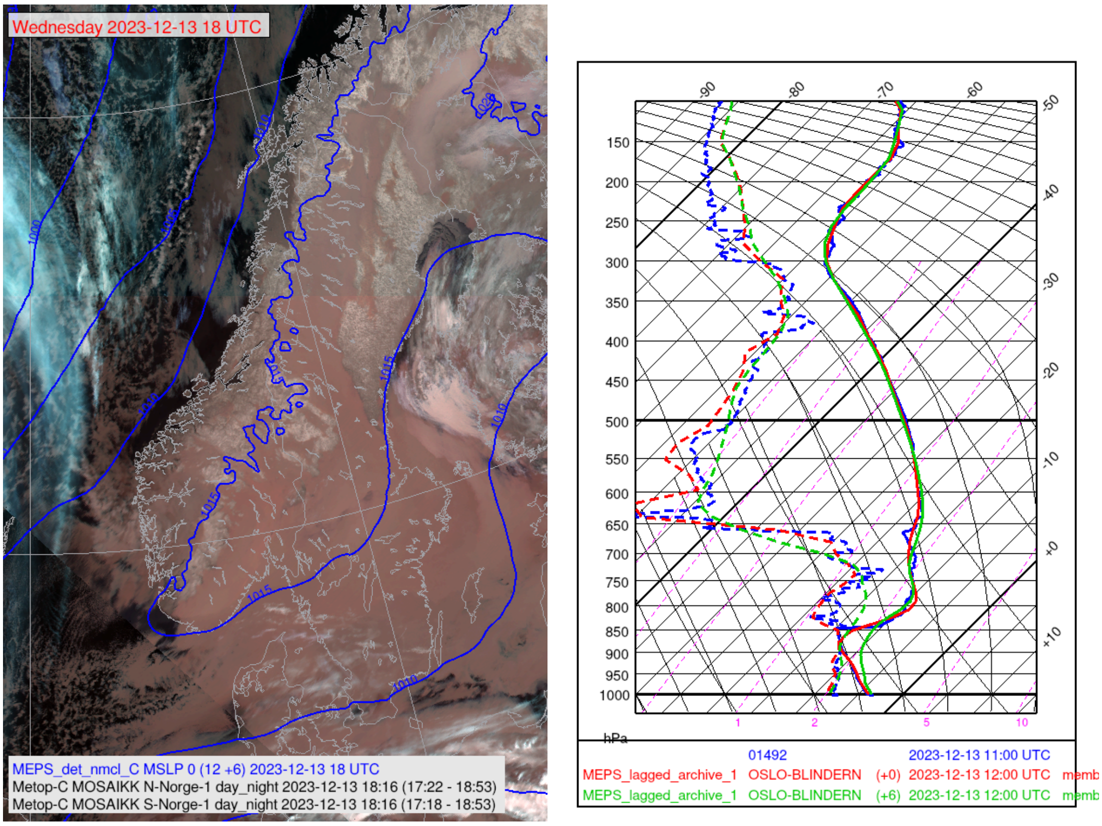


Figure 3: Low stratiform clouds are covering most of southern Scandinavia on 13 December 2023, seen as a reddish smooth area in the satellite image (left). The MSLP shows a high pressure in the central area. The sounding from Blindern (right) shows the actual sounding from 12 UTC (blue) together with a prognostic sounding from MEPS with 0 hrs (red) and 6 hrs (green) lead time. The strong inversion at 850 hPa is typical for high pressure areas and often produces thin, but compact layers of clouds.

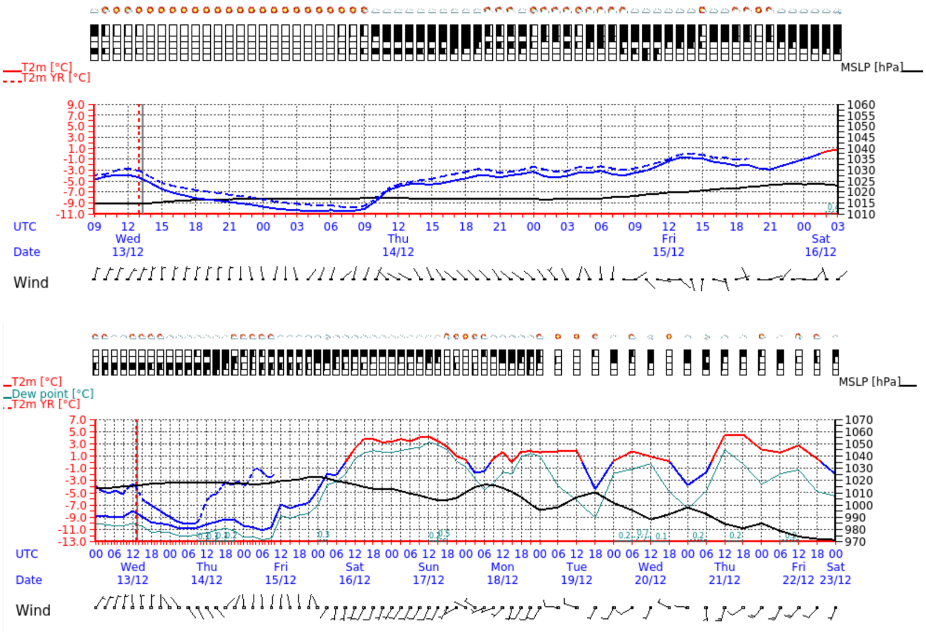


Figure 4: The event lasted almost 24 hours and had a severe impact on the perceived quality of the MET Norway forecast for this day. In the Blindern meteogram from MEPS (top) there are no clouds on the 13th. The ECMWF (bottom) has a compact layer of low clouds through the 13th.

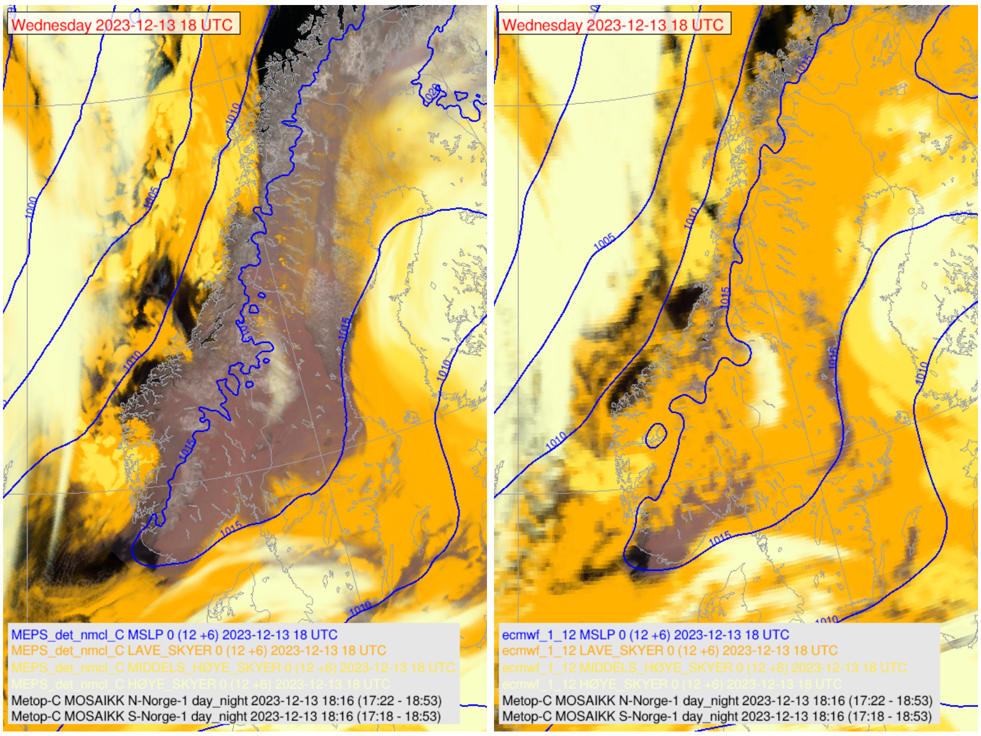


Figure 5: Comparison of MEPSctrl to ECMWF shows that the latter is much more able to reproduce the cloudiness in high pressure situations.

Case 3. Wind.

This winter was unusually calm for the most part, but one hectic week in January-February gave two severe storms in mid and northern Norway, the latter was given the name Ingunn as it was seen as an event with extreme consequences. Figure 6 shows the wind speed during pre Ingunn storm.

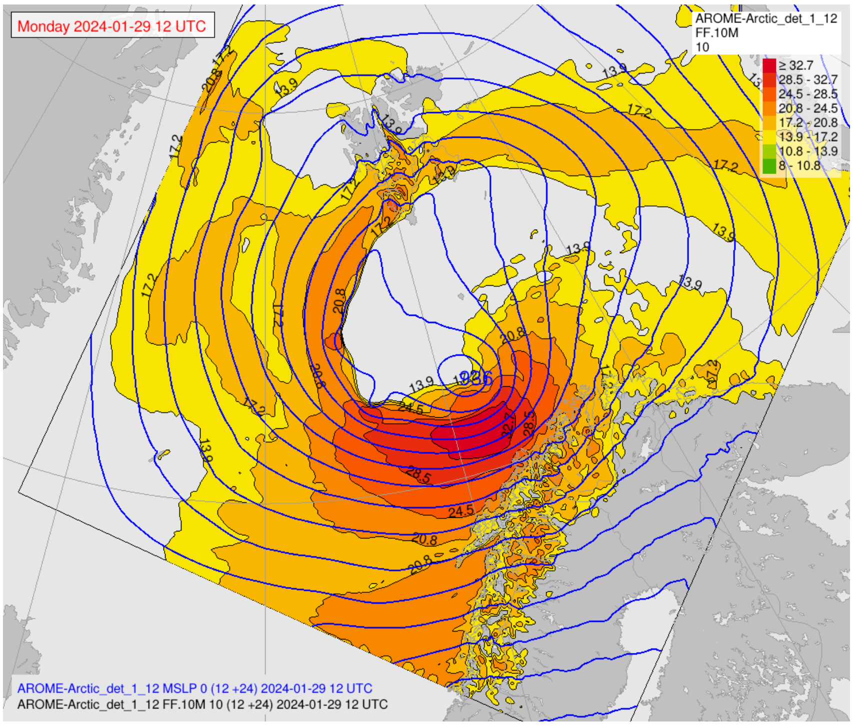


Figure 6: The pre Ingunn storm from 29 January 2024 gave hurricane force winds along the coast of Troms and Finnmark.

MEPS fared quite well in both these events, realistically reproducing winds of hurricane force in the coastal areas where it was expected. The ECMWF model consistently has a strong negative bias over land, but is generally realistic over open sea areas. This is illustrated by the timeseries at Hammerfest (figure 7) and Alta (figure 8).

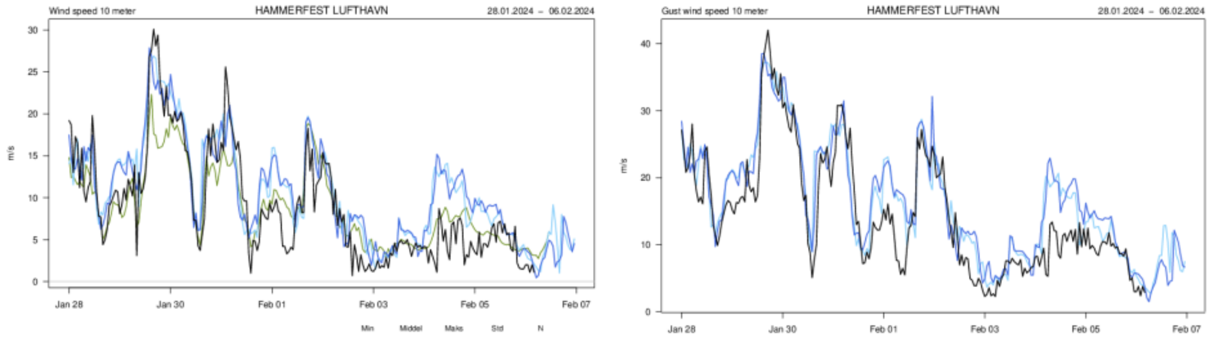


Figure 7: Plots of wind (left) and wind gusts (right) from Hammerfest, which had at most hurricane force winds on the pre Ingunn storm on the 29th January, left spike.

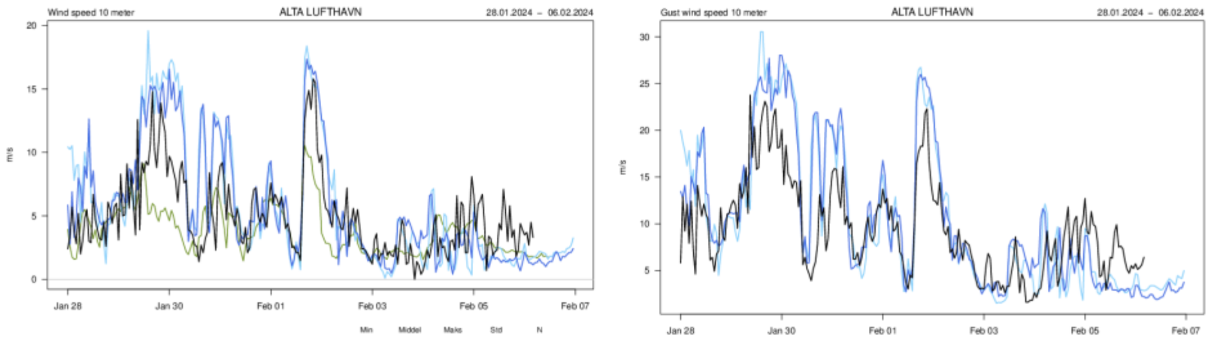
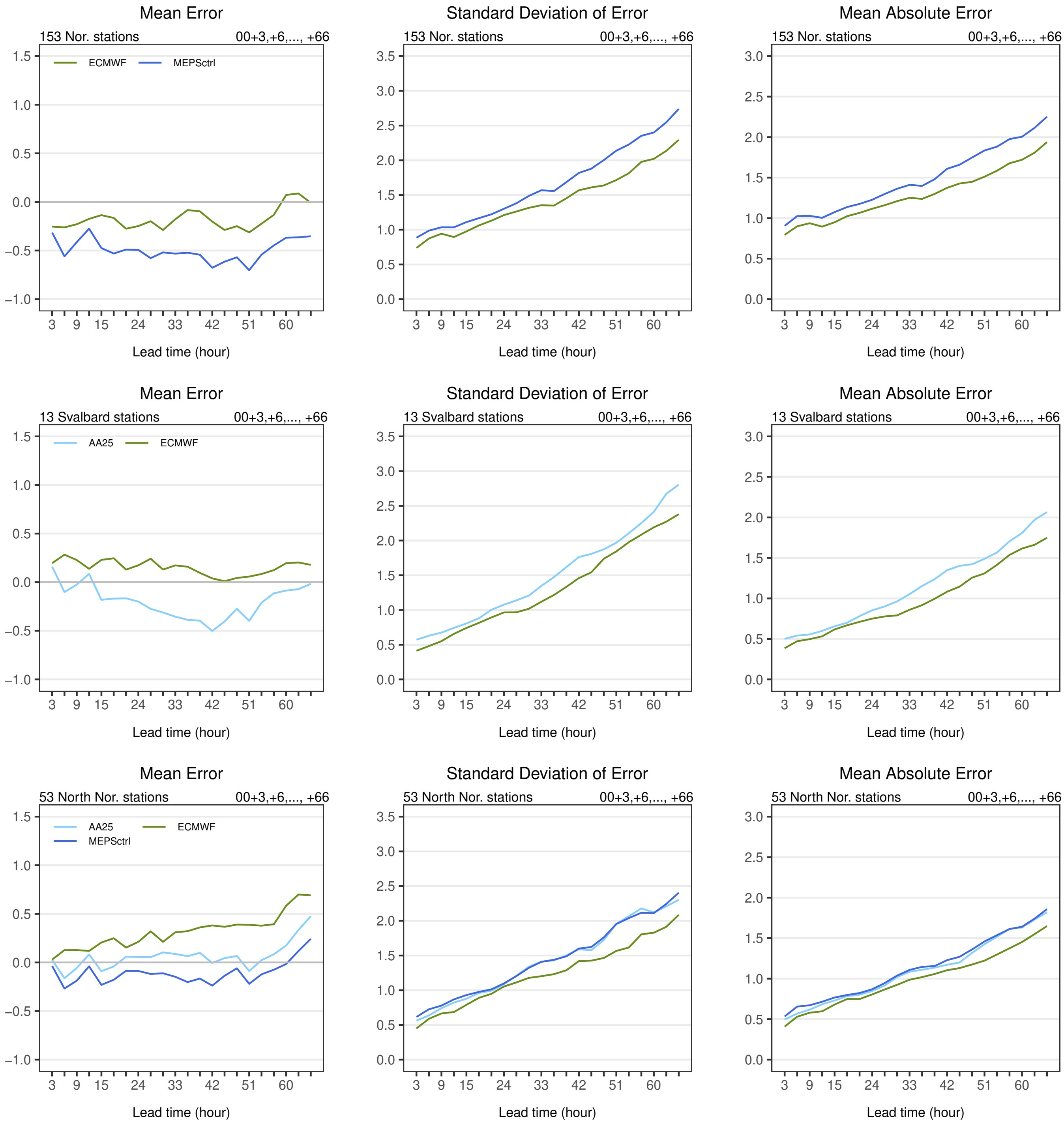
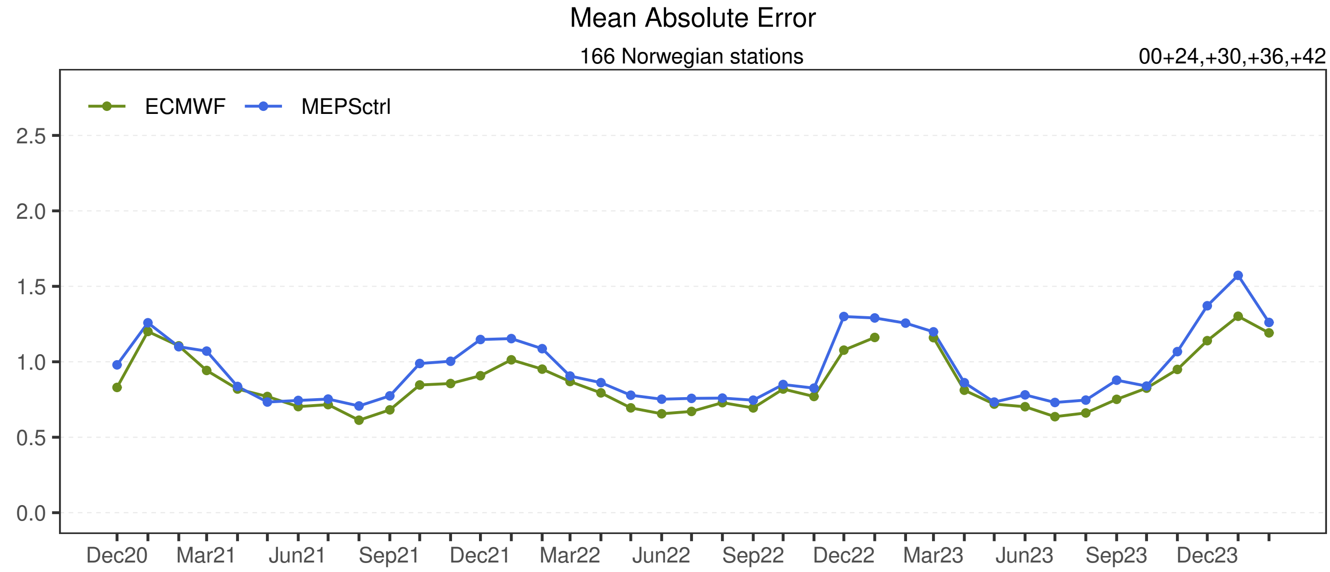


Figure 8: MEPS generally has a positive bias further inland, as can be seen from the plot from Alta which is situated further inland.

Summarized statistics


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


Mean Absolute Error
166 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
2.5
2.0
1.5
1.0
0.5
0.0
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
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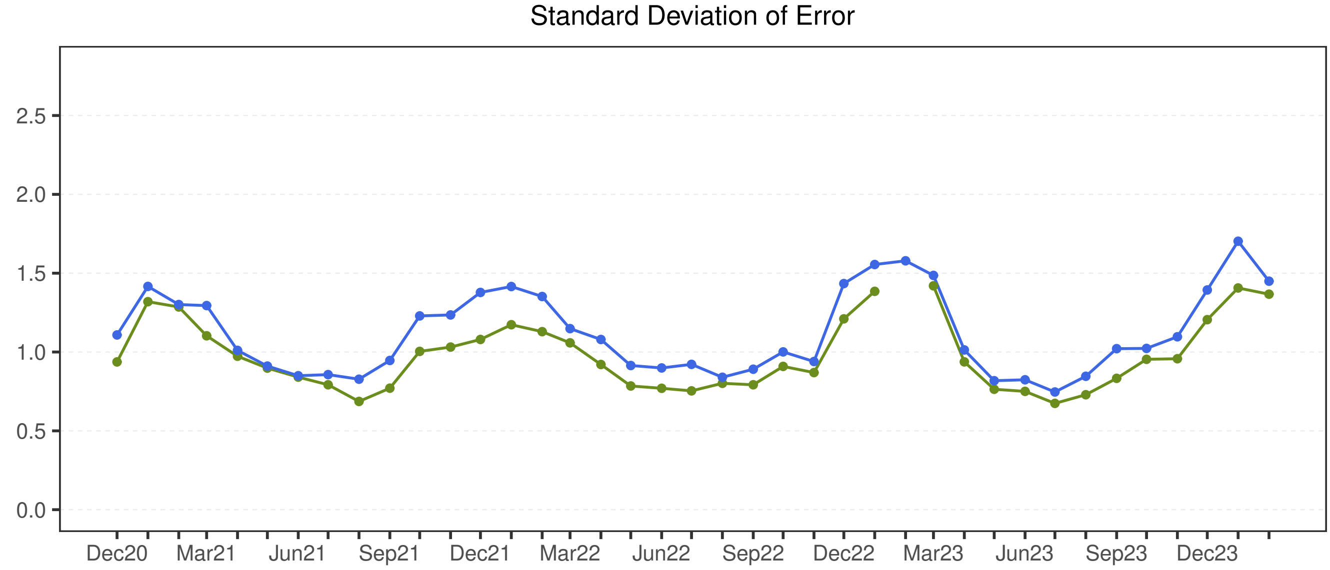
Dec22
Mar23
Jun23
Sep23
Dec23


Standard Deviation of Error
2.5
2.0
1.5
1.0
0.5
0.0
Dec20
Mar21
Jun21
Sep21
Dec21
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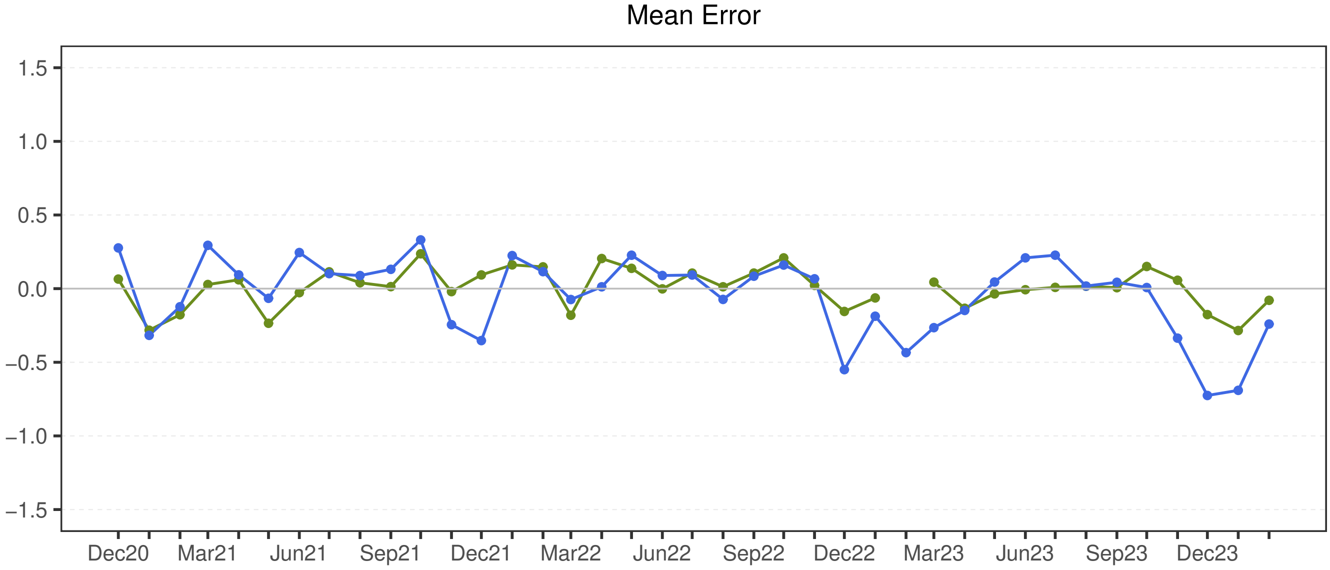
Mar23
Jun23
Sep23
Dec23


Mean Error
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
Dec20
Mar21
Jun21
Sep21
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Mar22
Jun22
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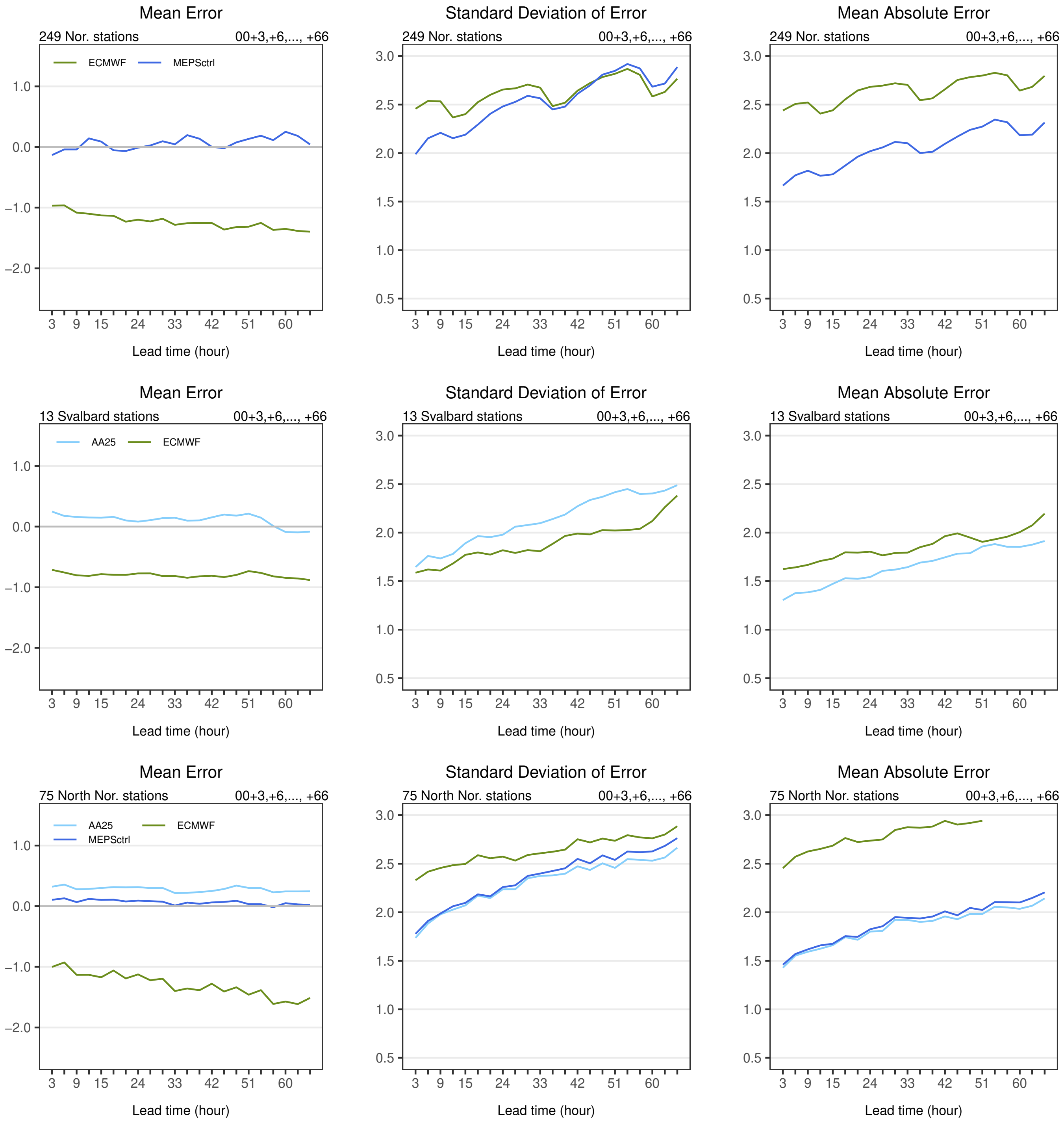
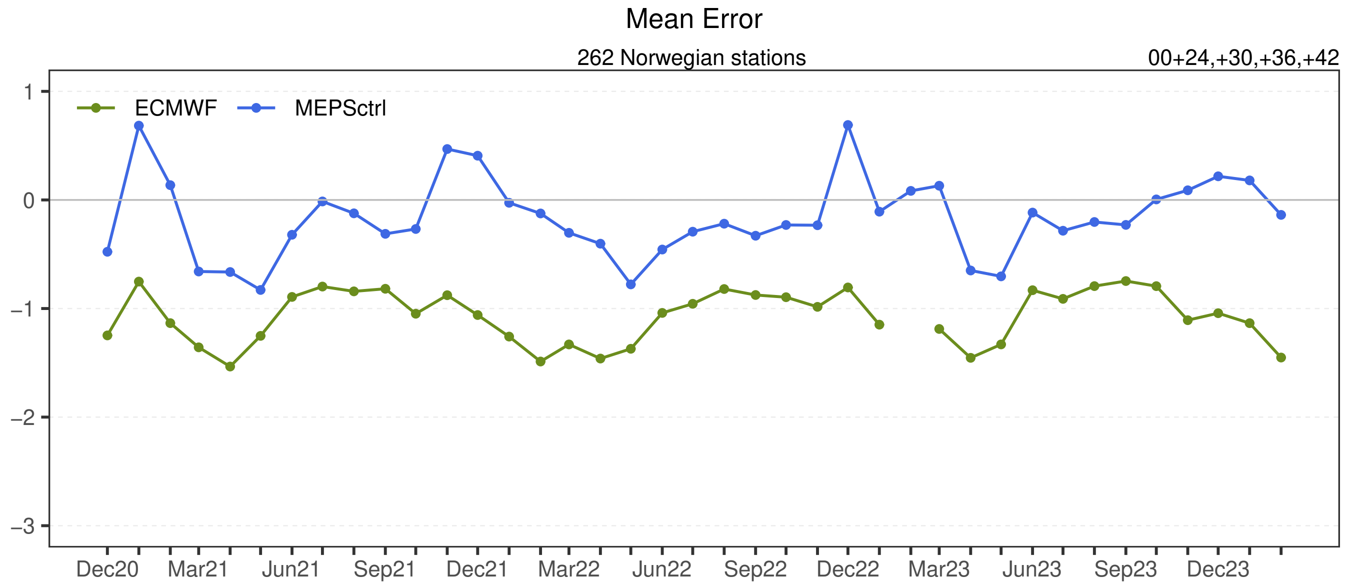
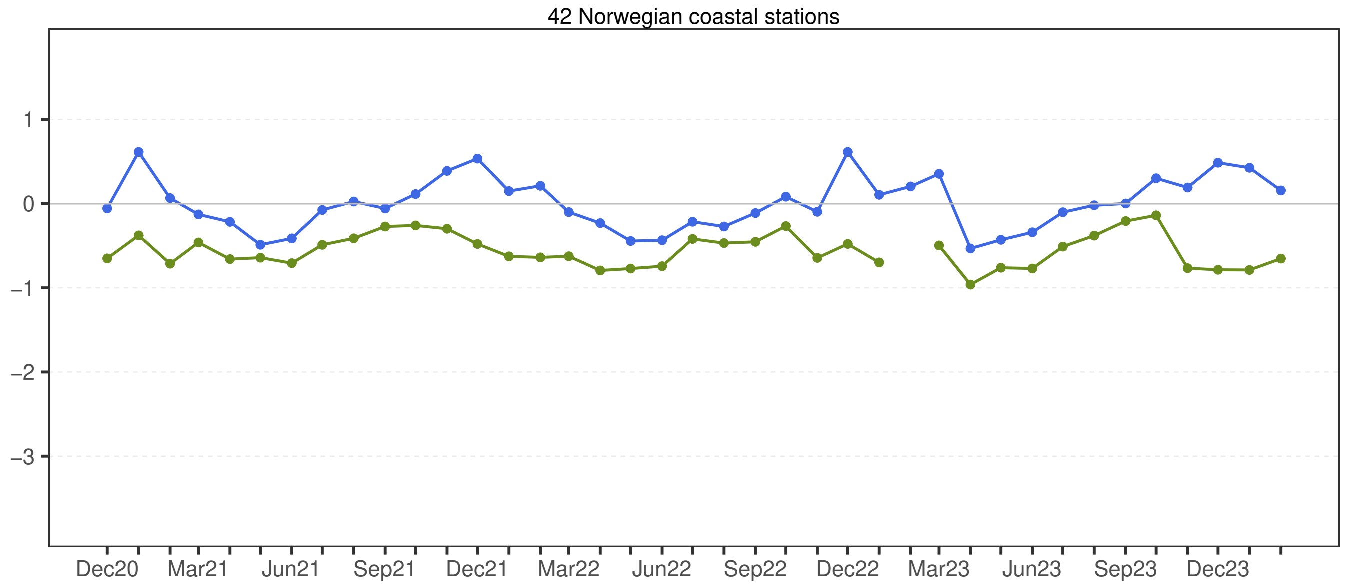
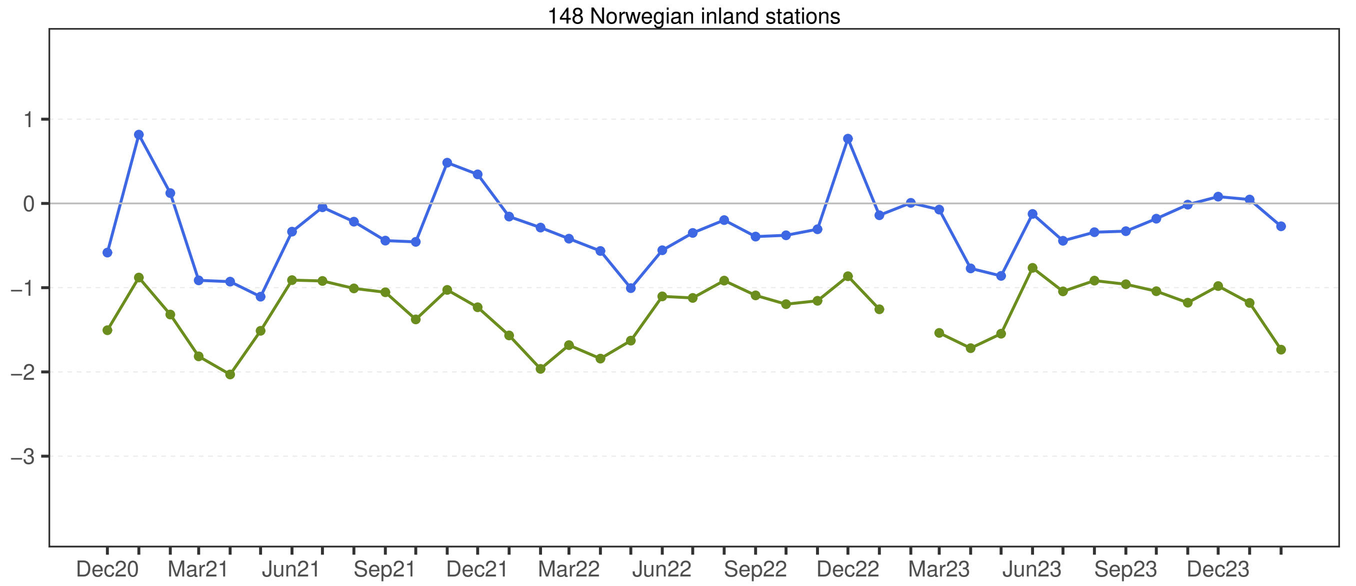
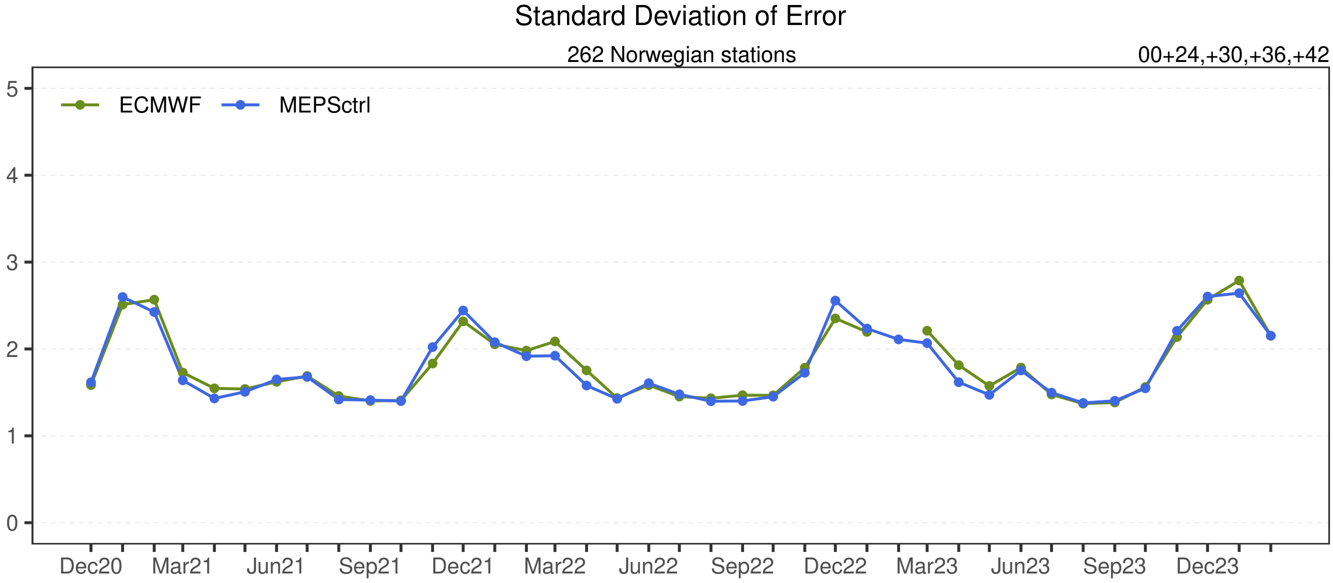
Dec22
Mar23
Jun23
Sep23
Dec23

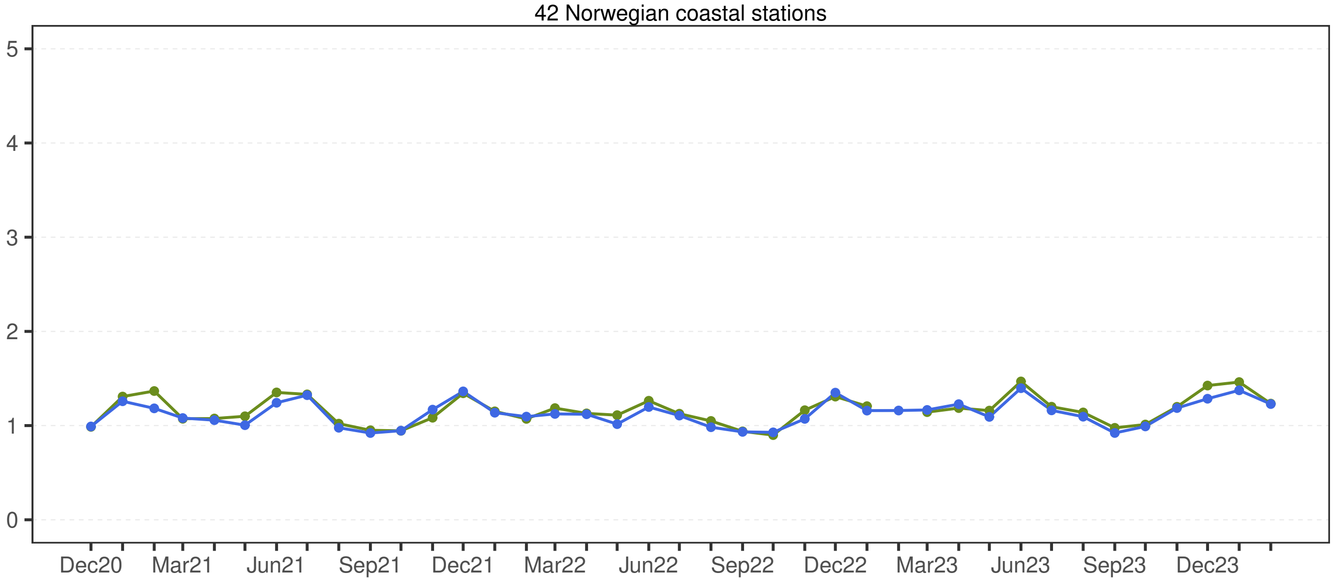

Mean Error
249 Nor. stations
00+3,+6,..., +66
ECMWF
MEPSctrl
Lead time (hour)
Standard Deviation of Error
249 Nor. stations
00+3,+6,..., +66
Lead time (hour)
Mean Absolute Error
249 Nor. stations
00+3,+6,..., +66
Lead time (hour)
Mean Error
13 Svalbard stations
00+3,+6,..., +66
AA25
ECMWF
Lead time (hour)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

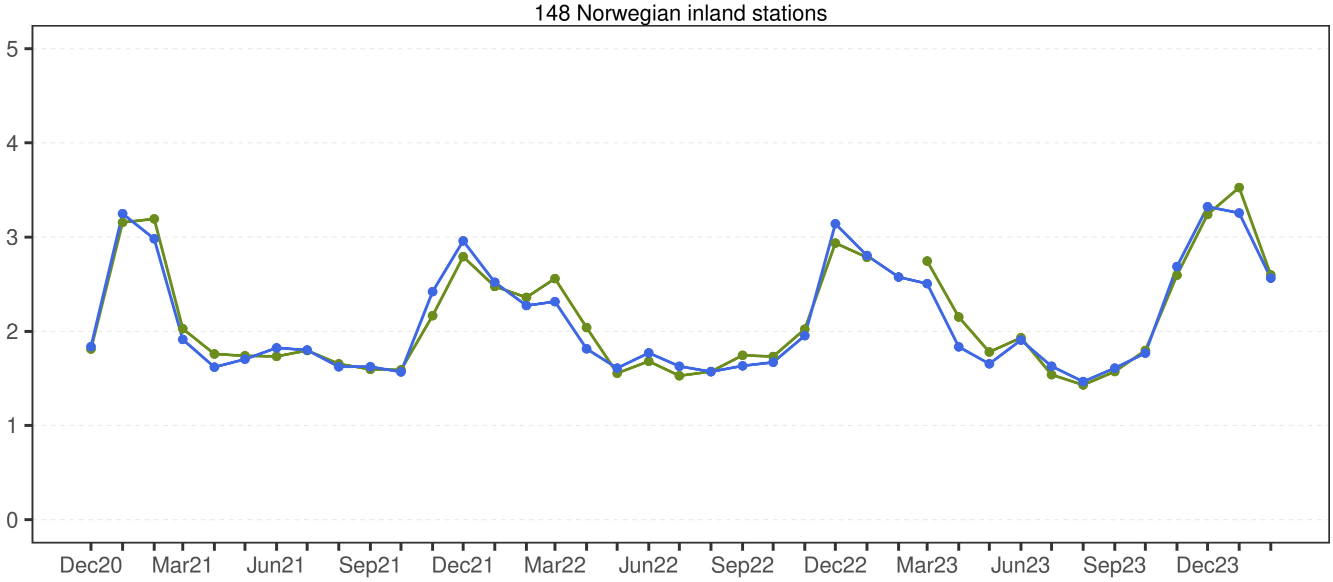

Mean Error
262 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
1
0
−1
−2
−3
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23


42 Norwegian coastal stations
1
0
−1
−2
−3
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23


148 Norwegian inland stations
1
0
−1
−2
−3
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23


Standard Deviation of Error
262 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
0
1
2
3
4
5
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23

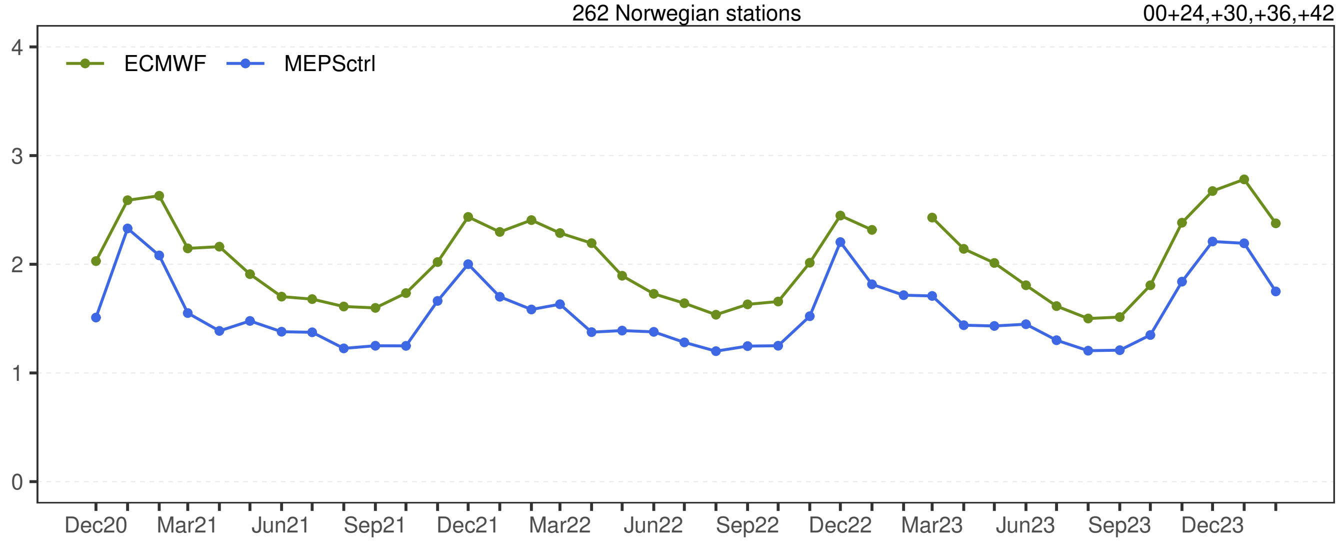

42 Norwegian coastal stations
0
1
2
3
4
5
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23


148 Norwegian inland stations
0
1
2
3
4
5
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23

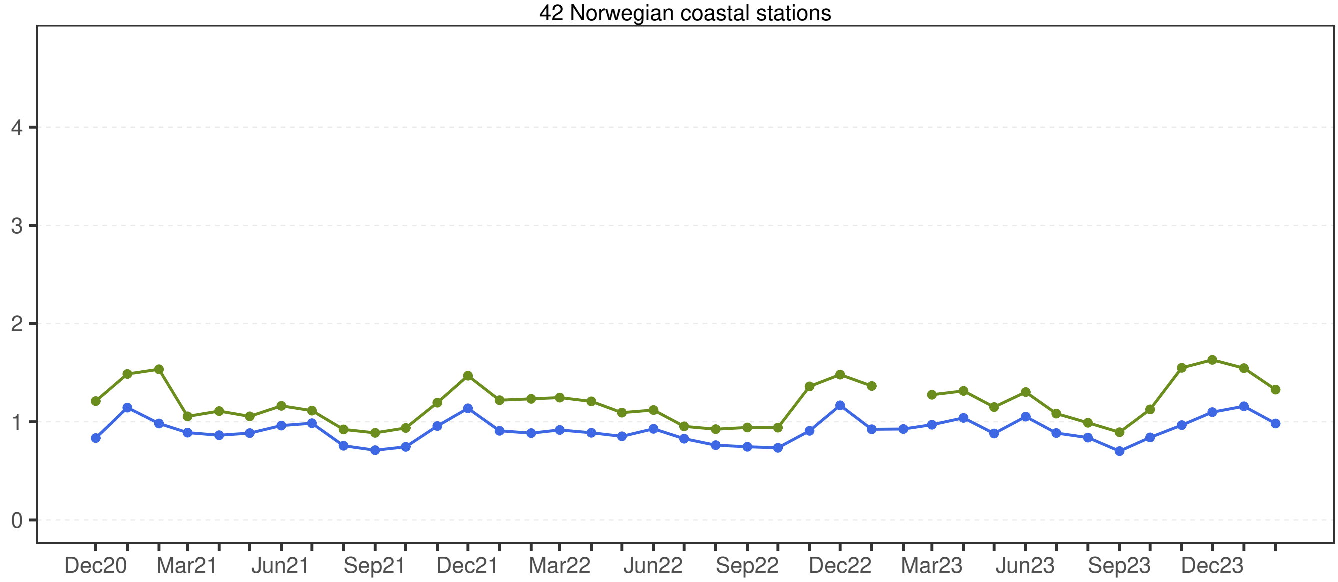
Mean Absolute Error

262 Norwegian stations

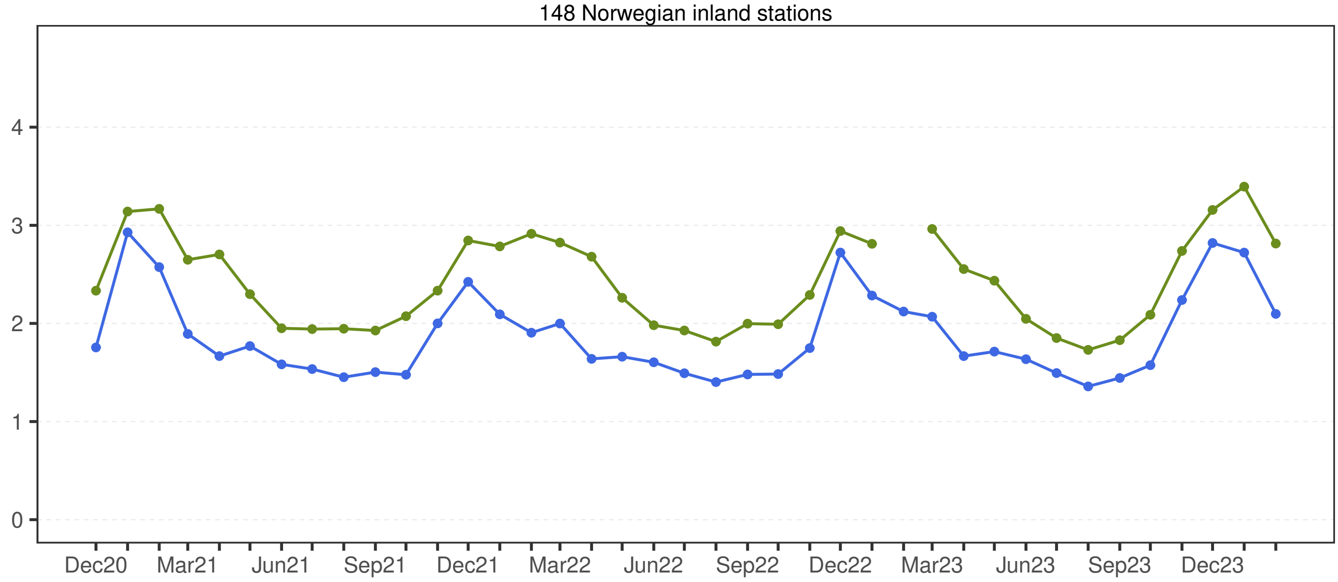
00+24,+30,+36,+42



42 Norwegian coastal stations

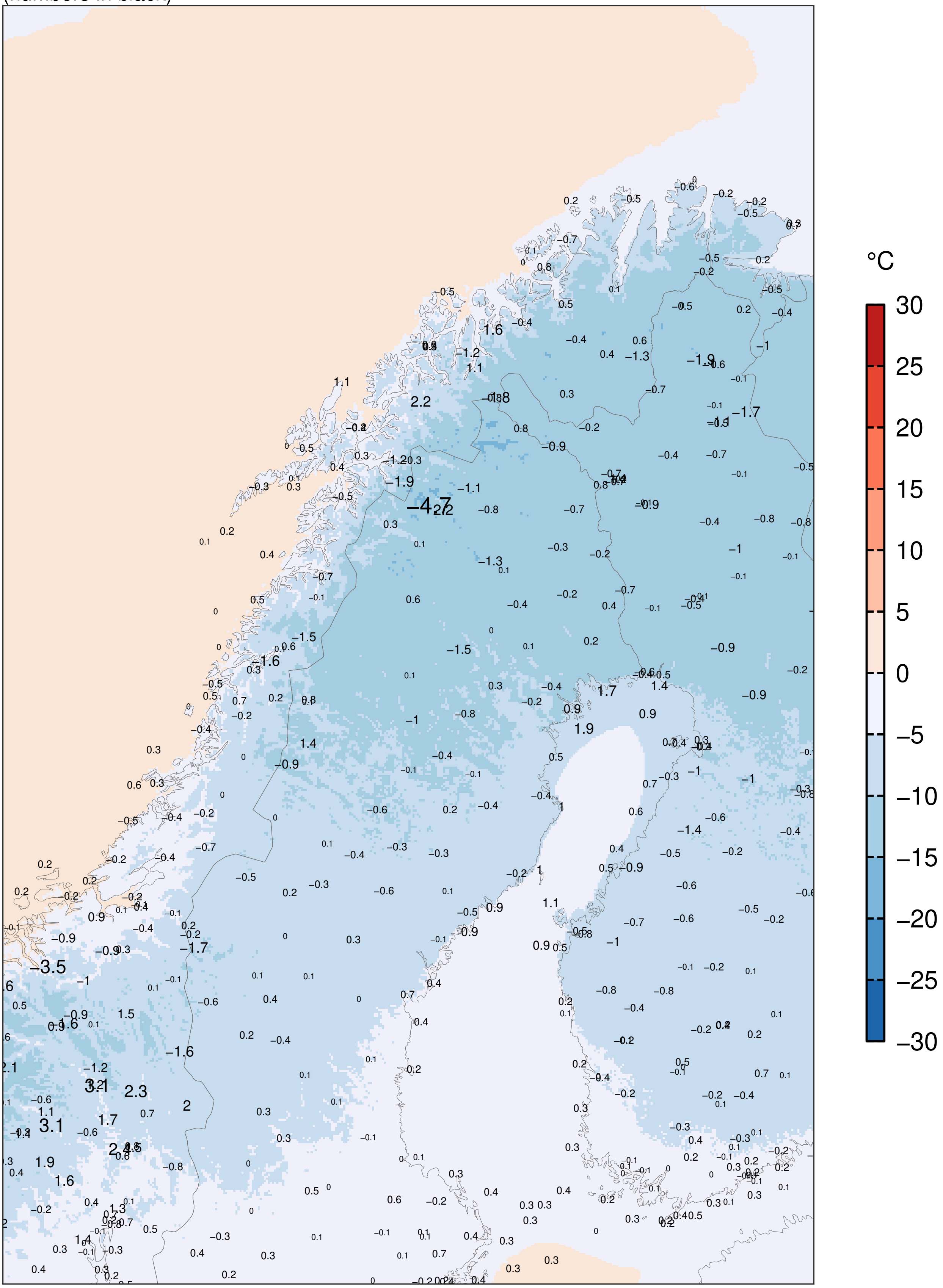


148 Norwegian inland stations



MEPSctrl 00+12

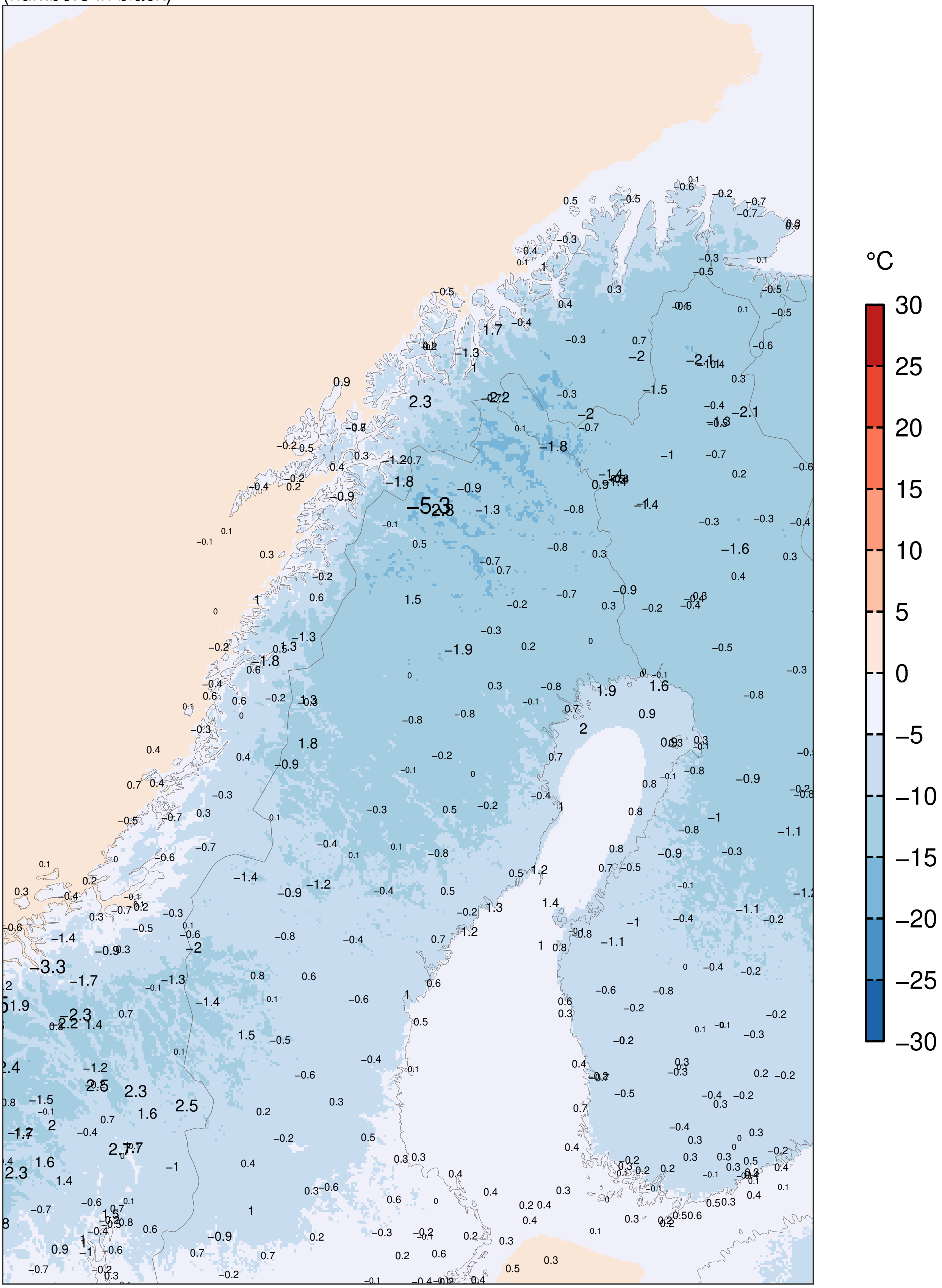
ME at observing sites
(numbers in black)



Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+24

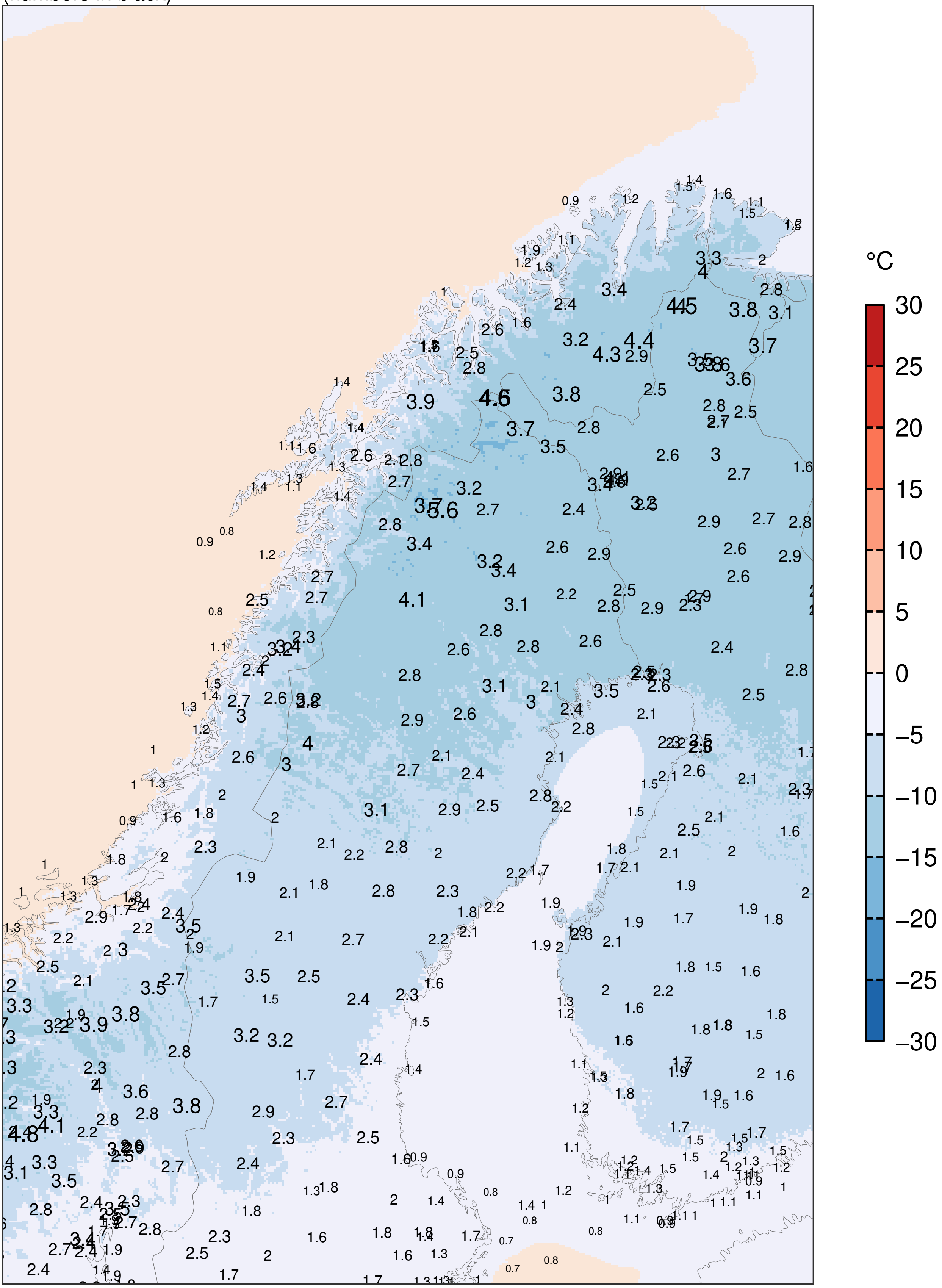
ME at observing sites
(numbers in black)



Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+12

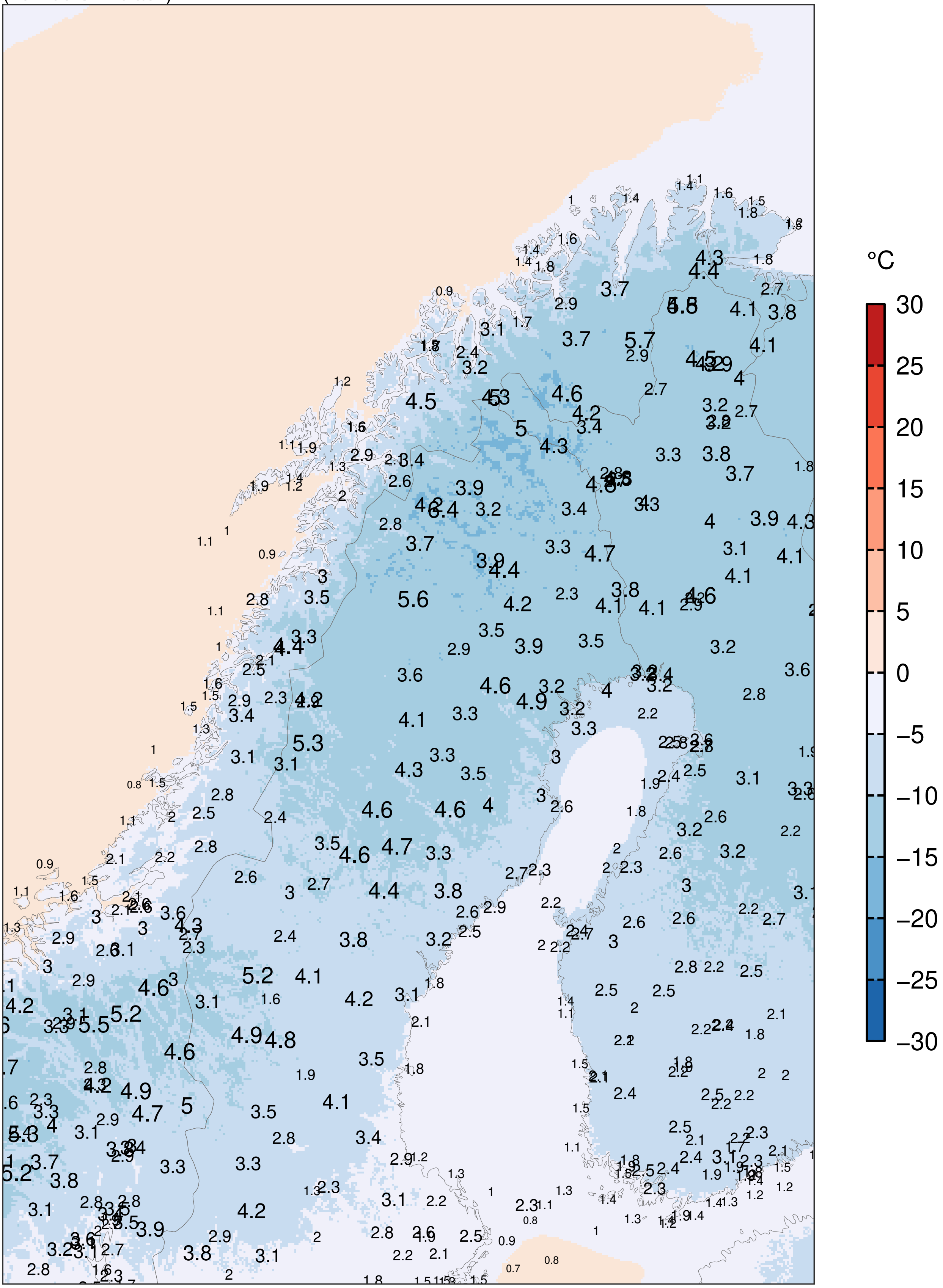
SDE at observing sites
(numbers in black)



Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+24

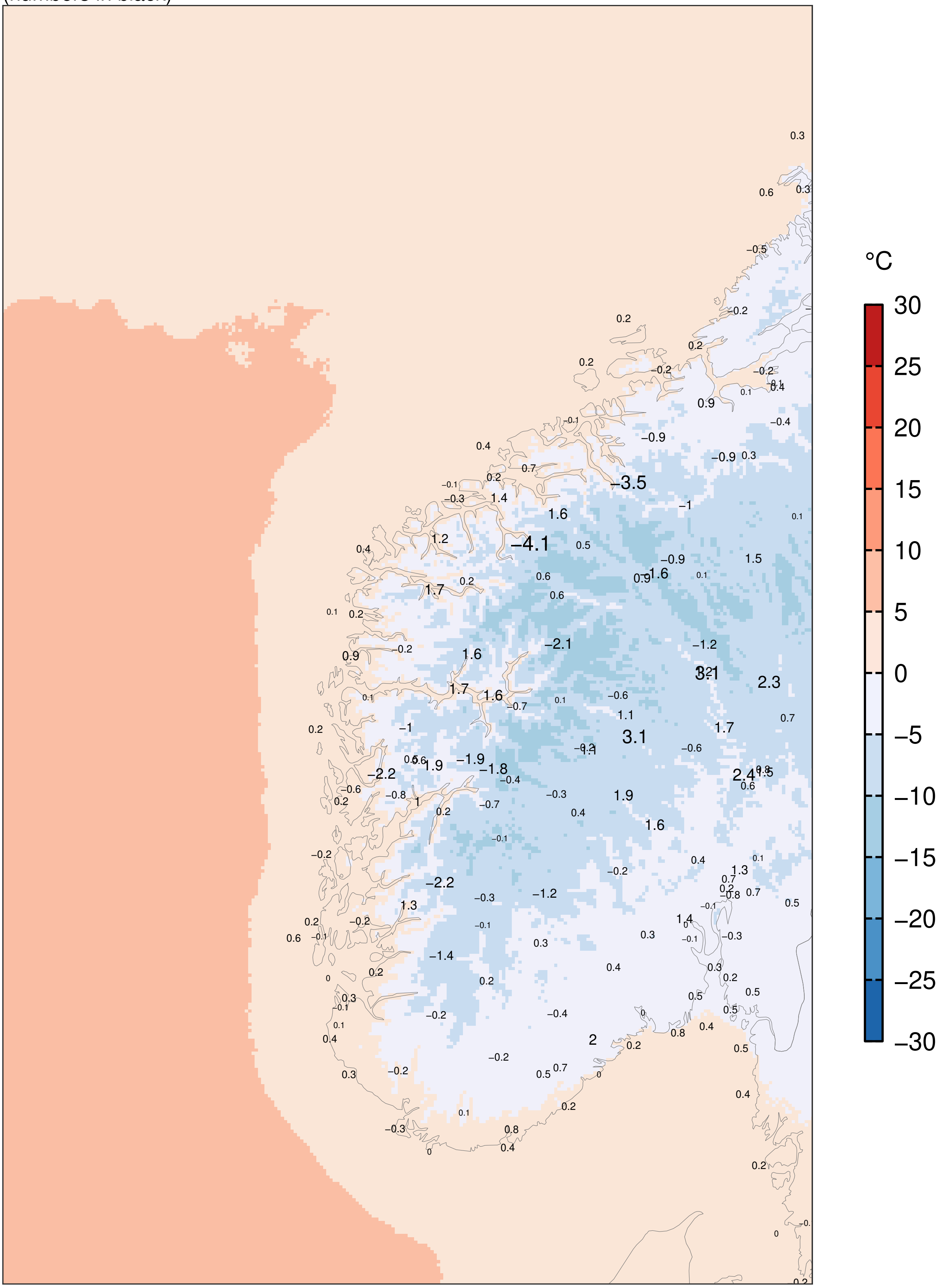
SDE at observing sites
(numbers in black)



Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+12

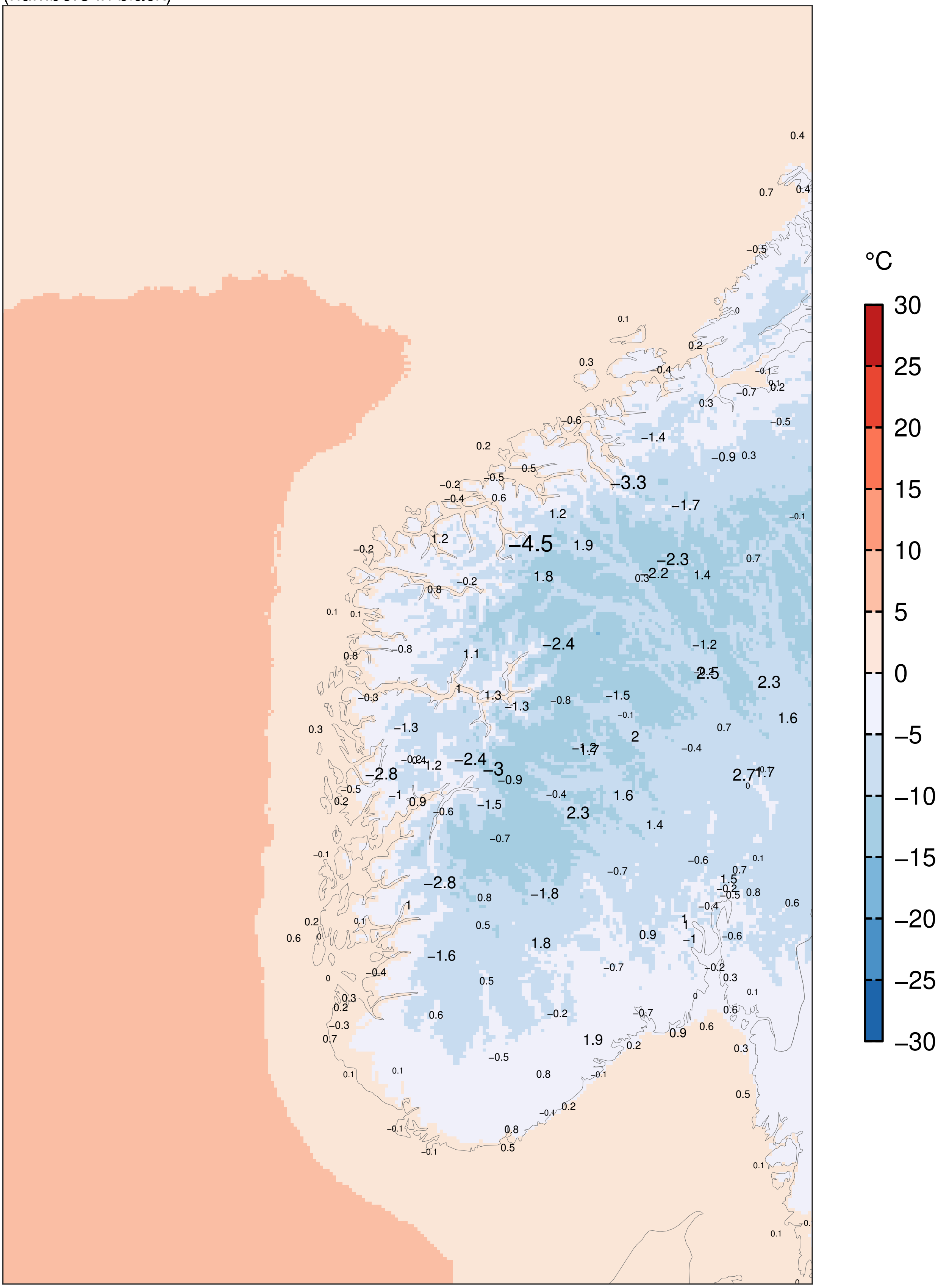
ME at observing sites
(numbers in black)



Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+24

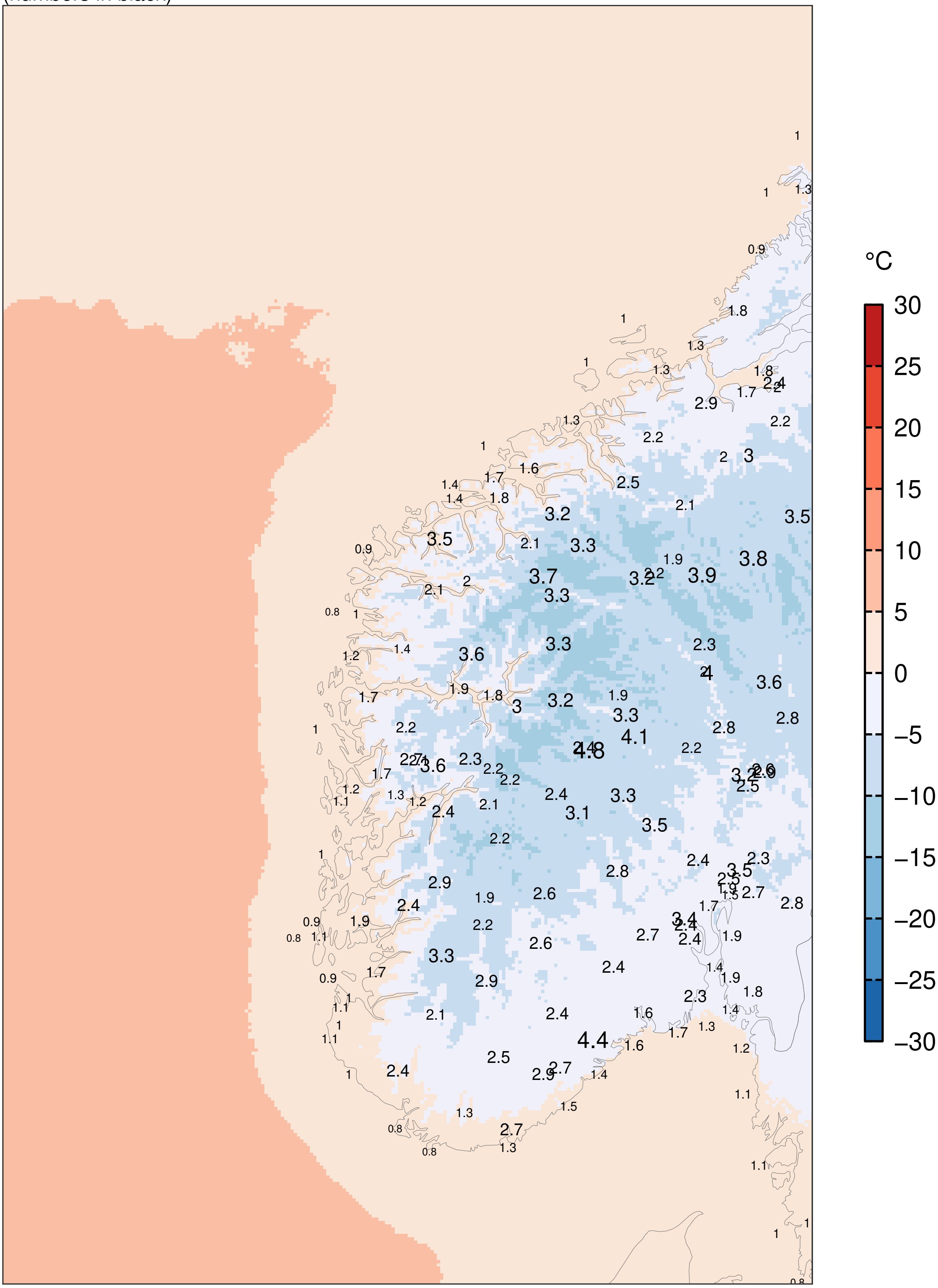
ME at observing sites
(numbers in black)



Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+12

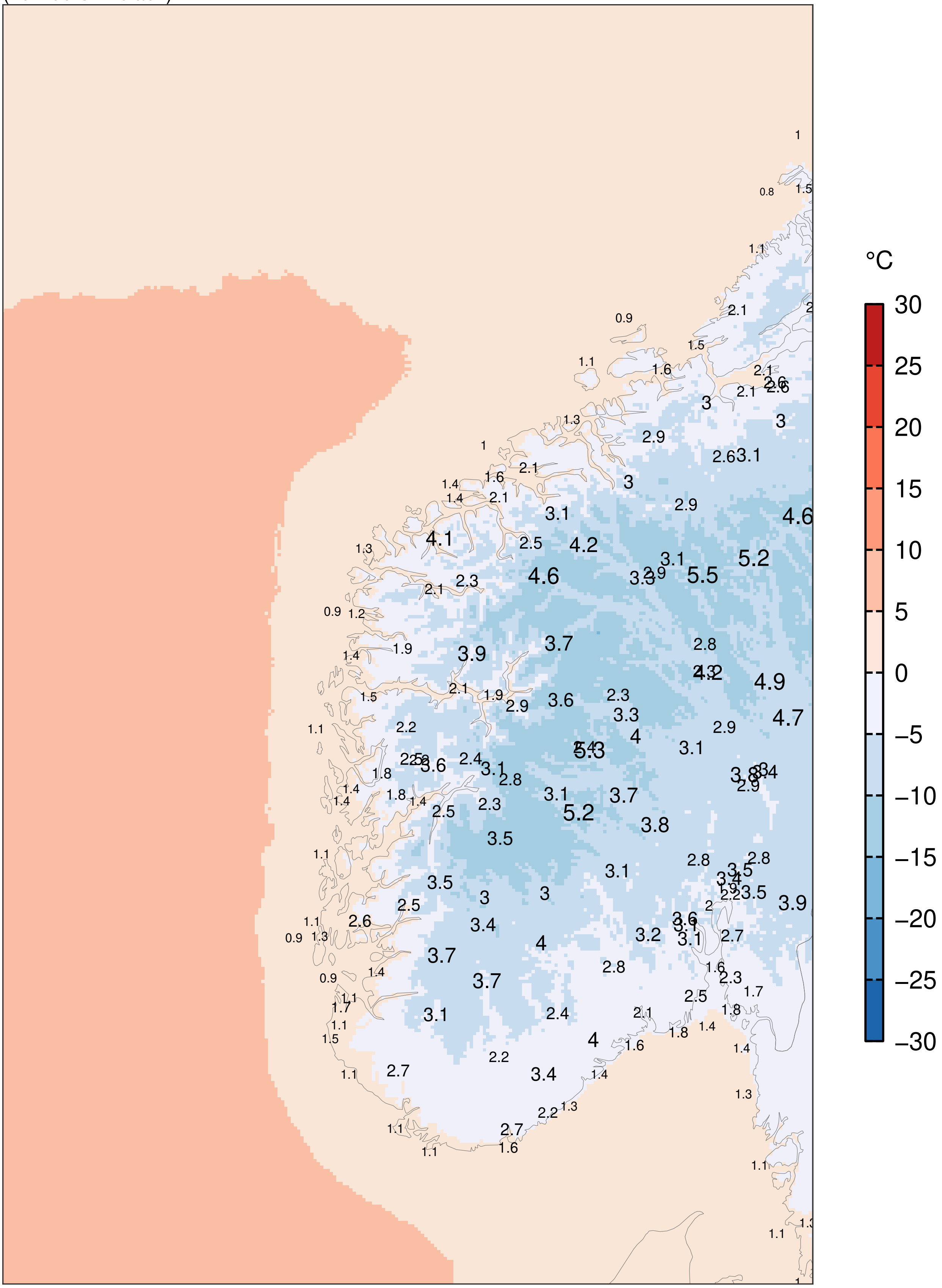
SDE at observing sites
(numbers in black)



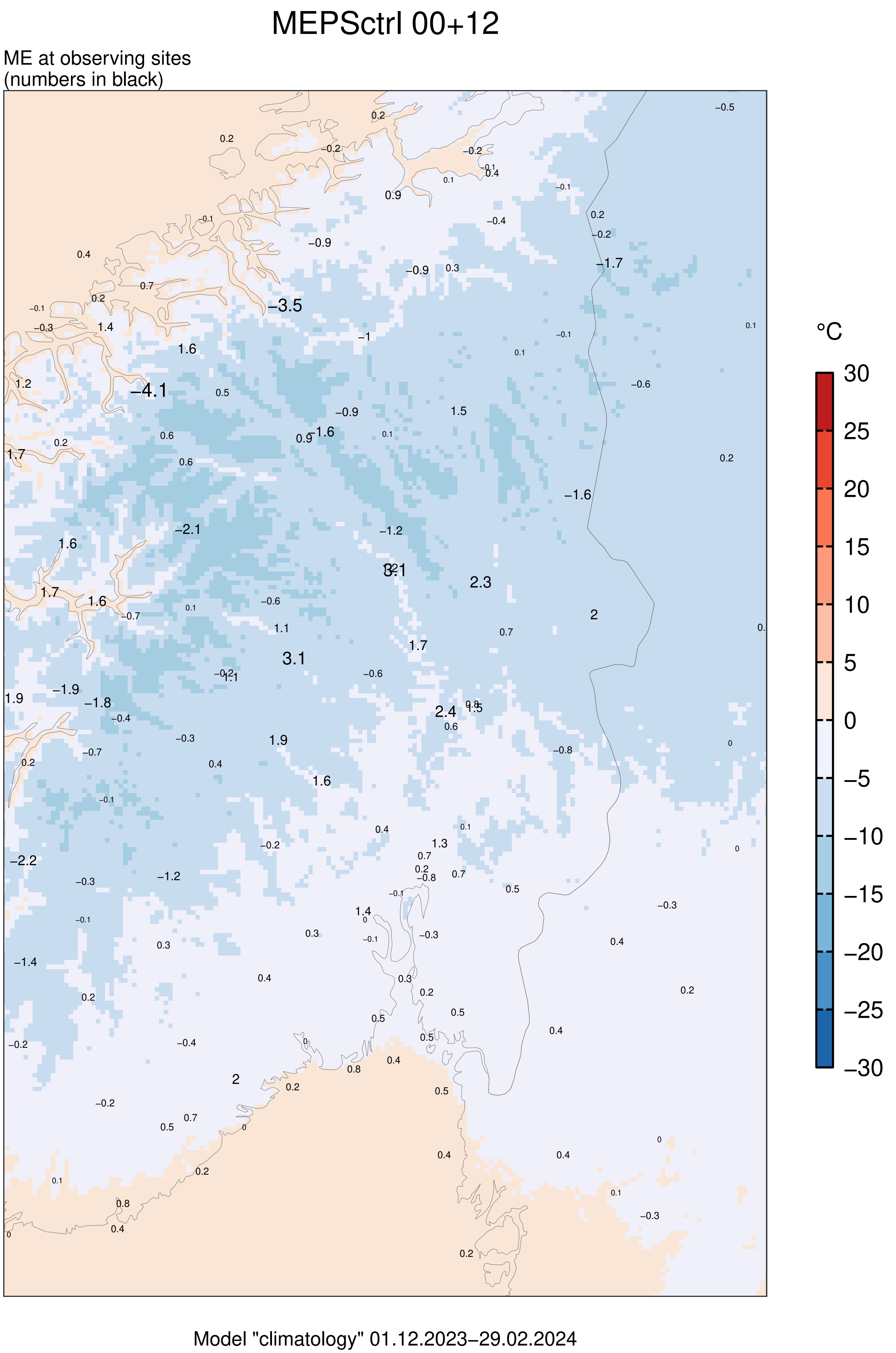
Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+24

SDE at observing sites
(numbers in black)

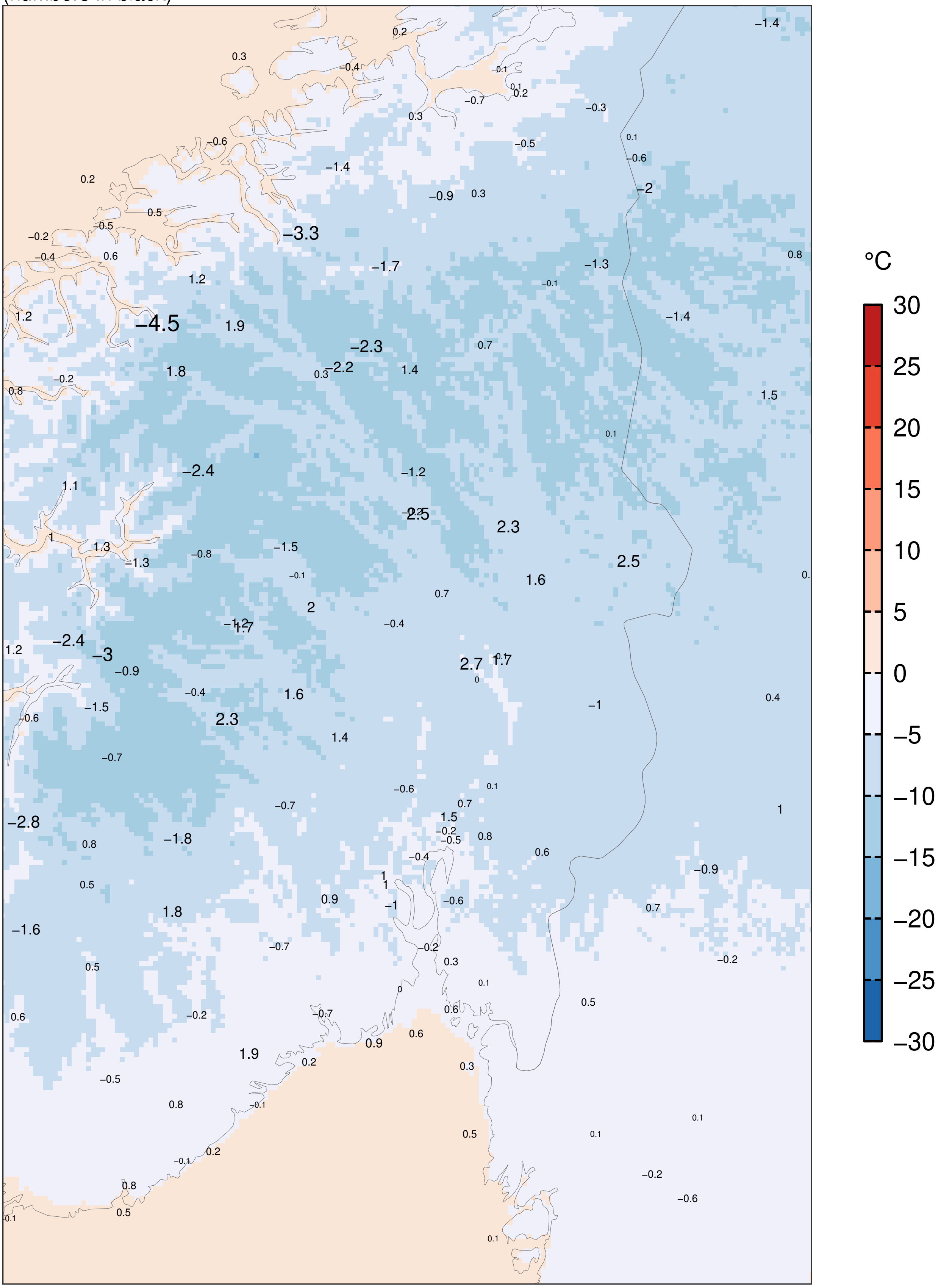


Model "climatology" 01.12.2023–29.02.2024


MEPSctrl 00+12
ME at observing sites
(numbers in black)
°C
30
25
20
15
10
5
0
−5
−10
−15
−20
−25
−30
Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+24

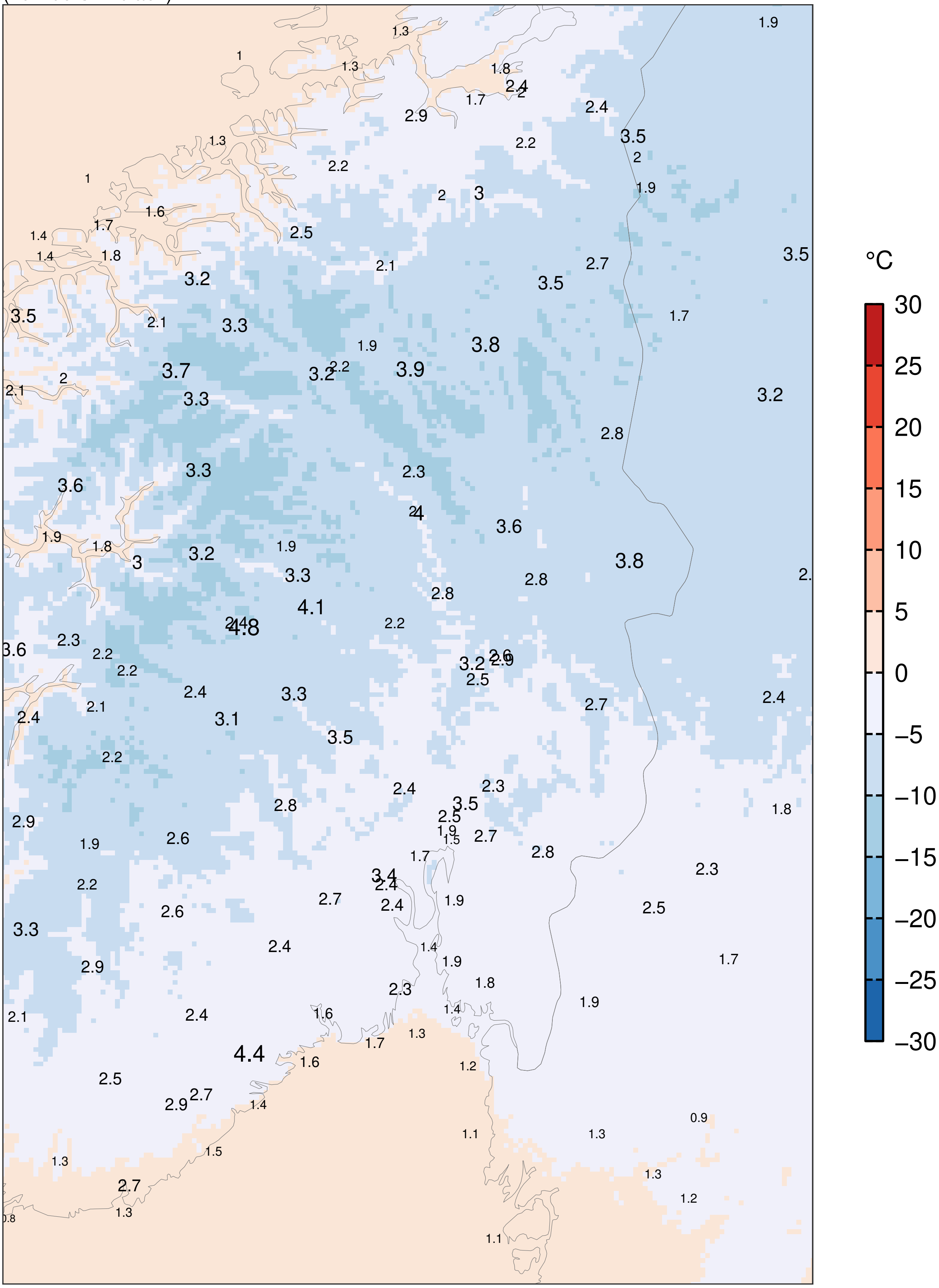
ME at observing sites
(numbers in black)



Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+12

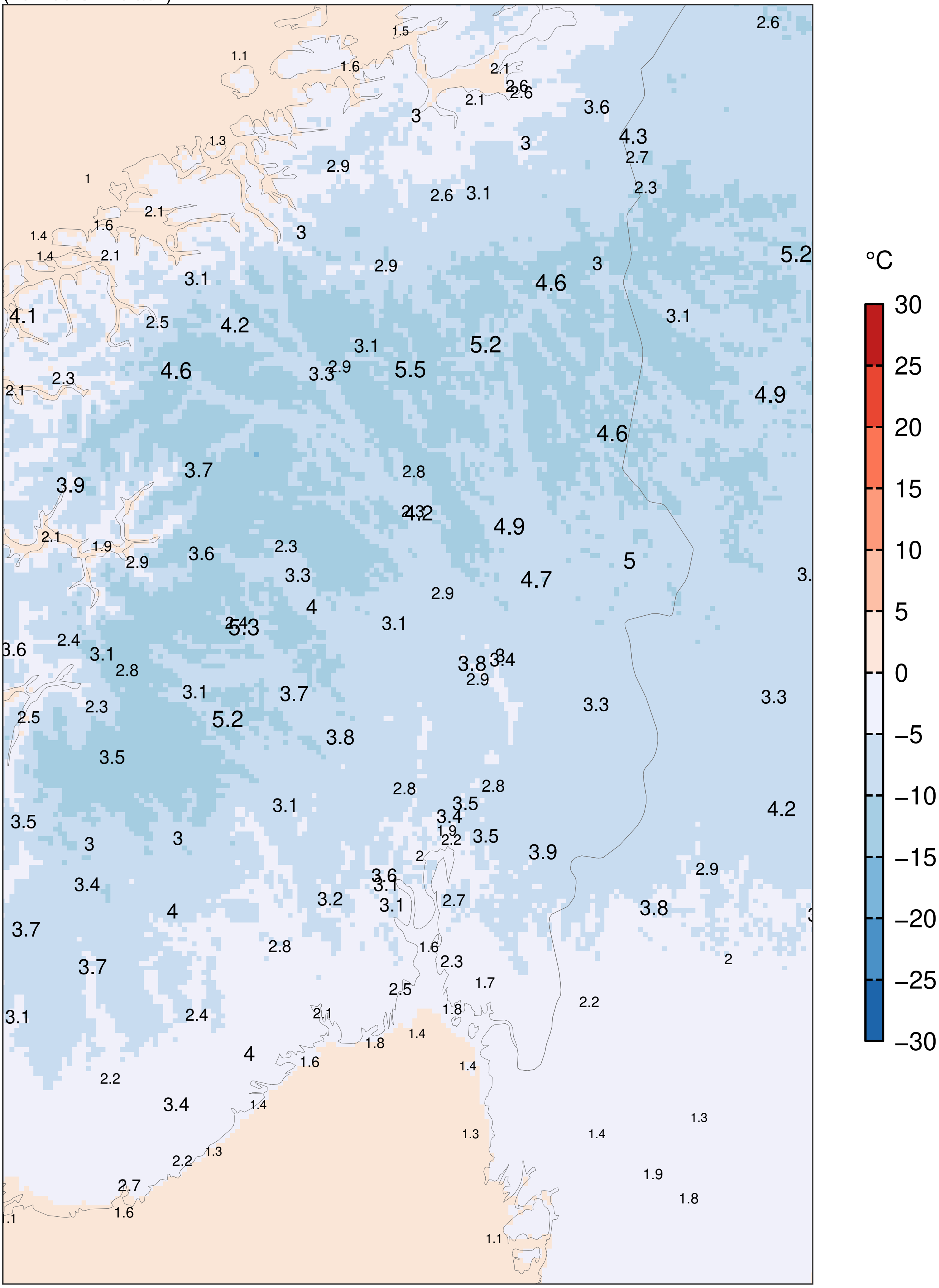
SDE at observing sites
(numbers in black)



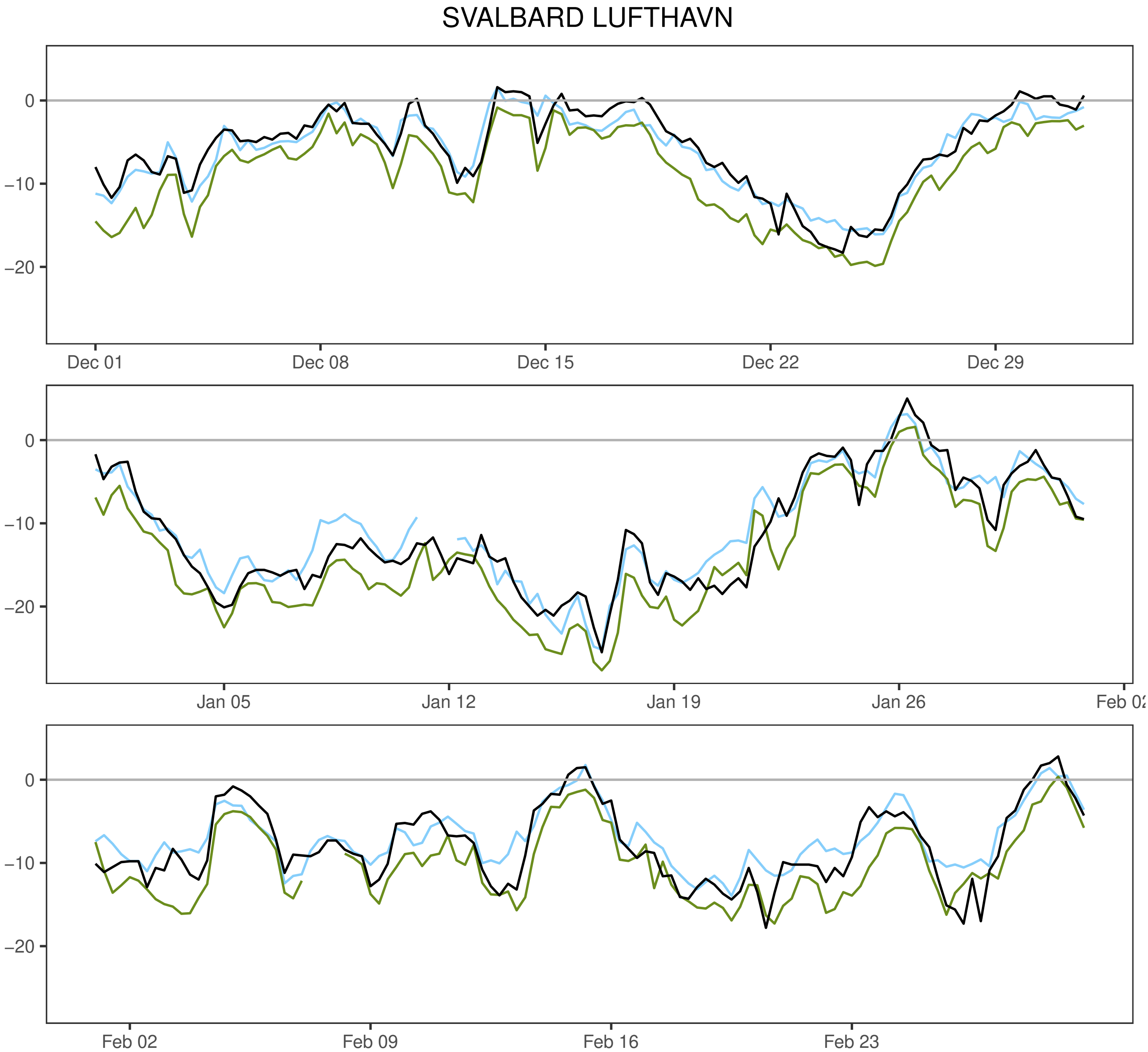
Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+24

SDE at observing sites
(numbers in black)

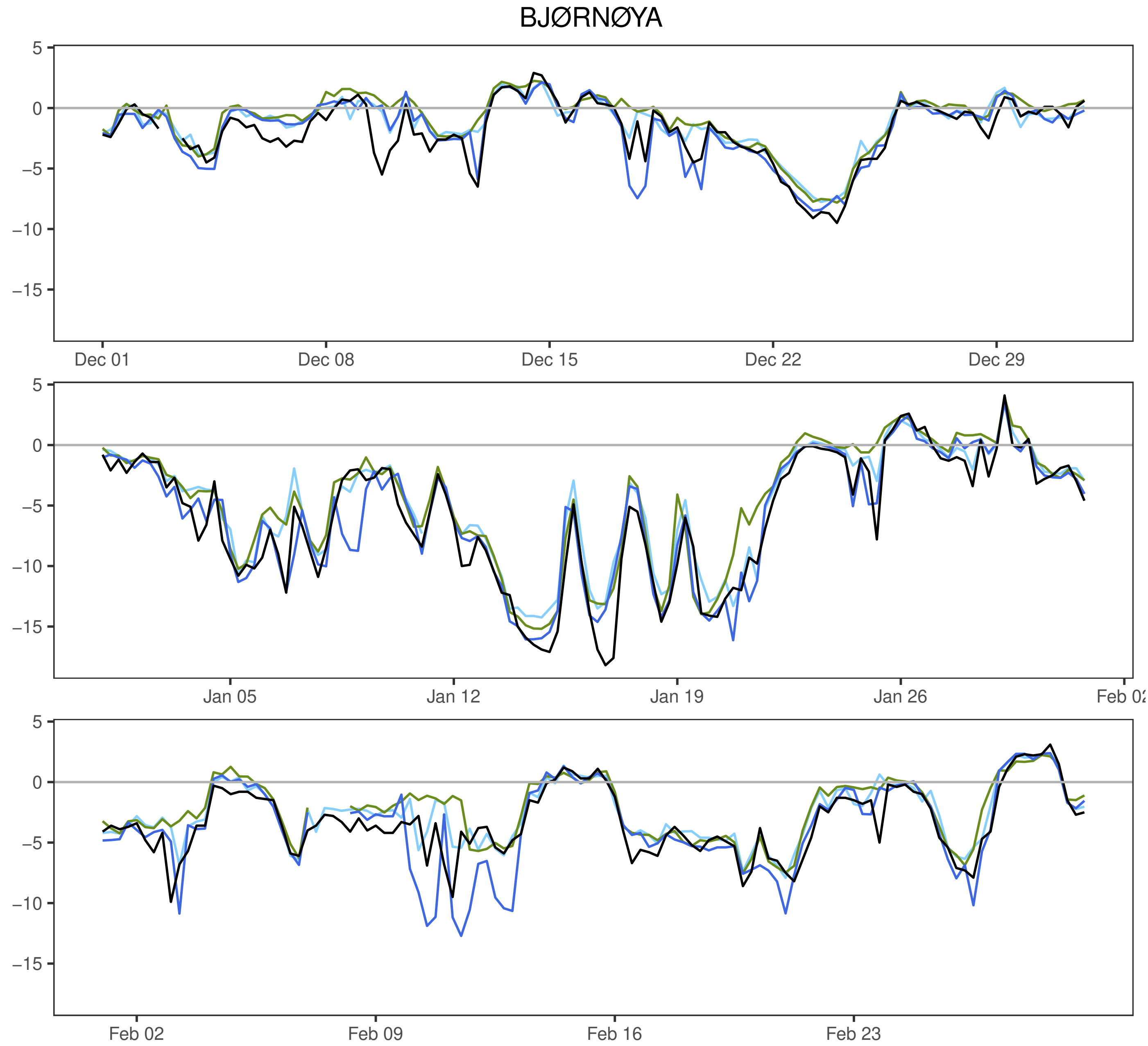


Model "climatology" 01.12.2023–29.02.2024



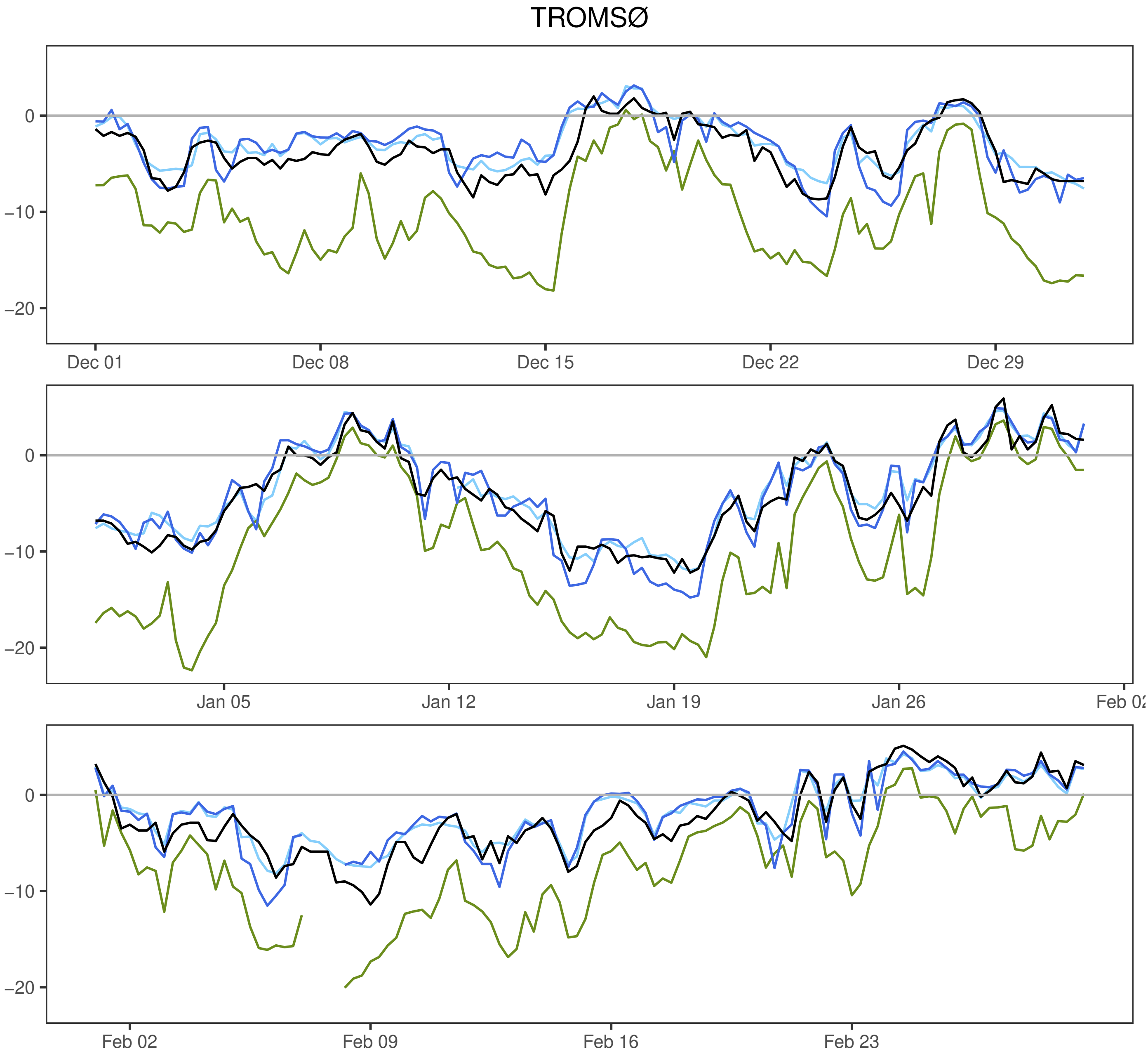
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−25.5	−8.3	5.0	6.1	364
AA25: 12+18,+24,+30,+36	−25.2	−7.9	3.1	5.4	360
ECMWF: 12+18,+24,+30,+36	−27.7	−11.0	1.6	6.1	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
AA25 – synop	0.4	2.1	2.1	1.6	7.4	356
ECMWF – synop	−2.7	2.0	3.3	2.9	8.5	356



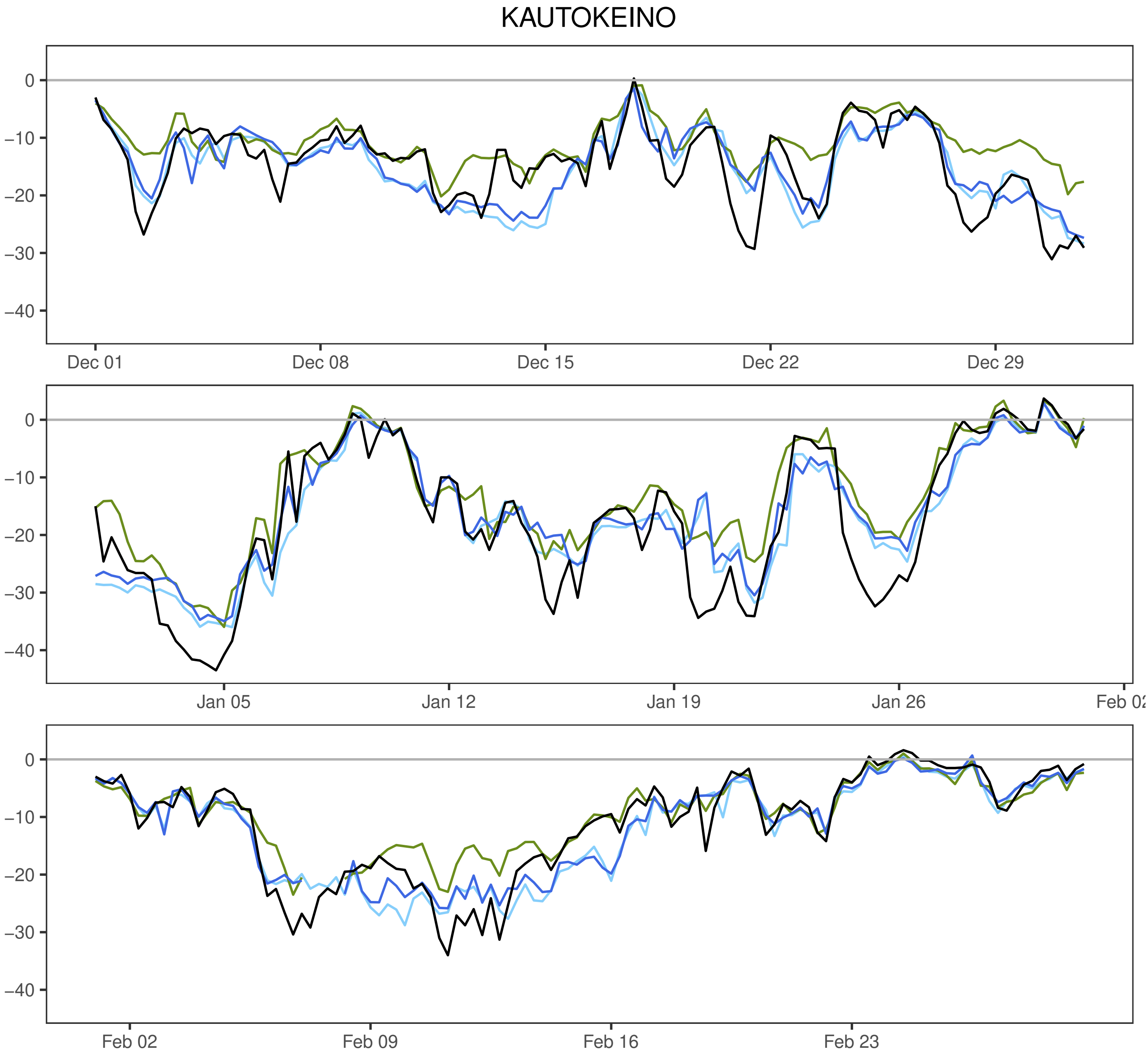
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−18.2	−3.8	4.1	4.1	362
MEPSctrl: 12+18,+24,+30,+36	−16.1	−3.8	3.5	4.3	360
AA25: 12+18,+24,+30,+36	−14.2	−2.9	3.4	3.6	360
ECMWF: 12+18,+24,+30,+36	−15.2	−2.7	3.9	3.8	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.0	1.8	1.8	1.1	8.6	354
AA25 – synop	0.8	1.3	1.6	1.1	7.9	354
ECMWF – synop	1.1	1.5	1.8	1.3	8.3	354



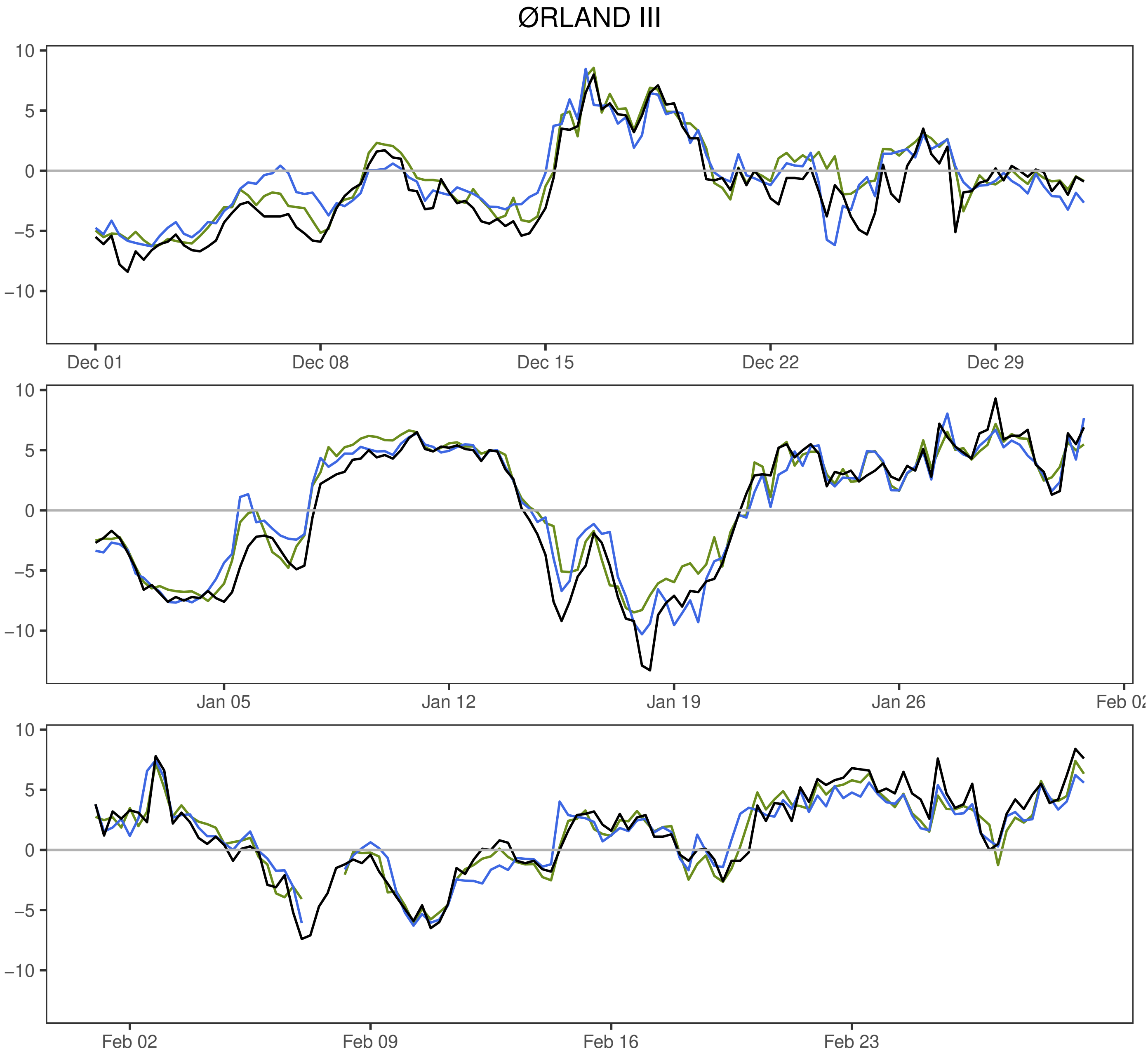
	Min	Mean	Max	Std	N
synop: 00,06,12,18	–12.2	–3.4	5.9	3.9	364
MEPSctrl: 12+18,+24,+30,+36	–14.8	–3.0	4.9	4.2	360
AA25: 12+18,+24,+30,+36	–12.0	–2.8	4.7	3.6	360
ECMWF: 12+18,+24,+30,+36	–22.4	–9.2	3.6	6.2	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.4	1.8	1.9	1.5	5.5	356
AA25 – synop	0.7	1.3	1.5	1.2	5.0	356
ECMWF – synop	–5.8	3.0	6.6	5.9	12.7	356



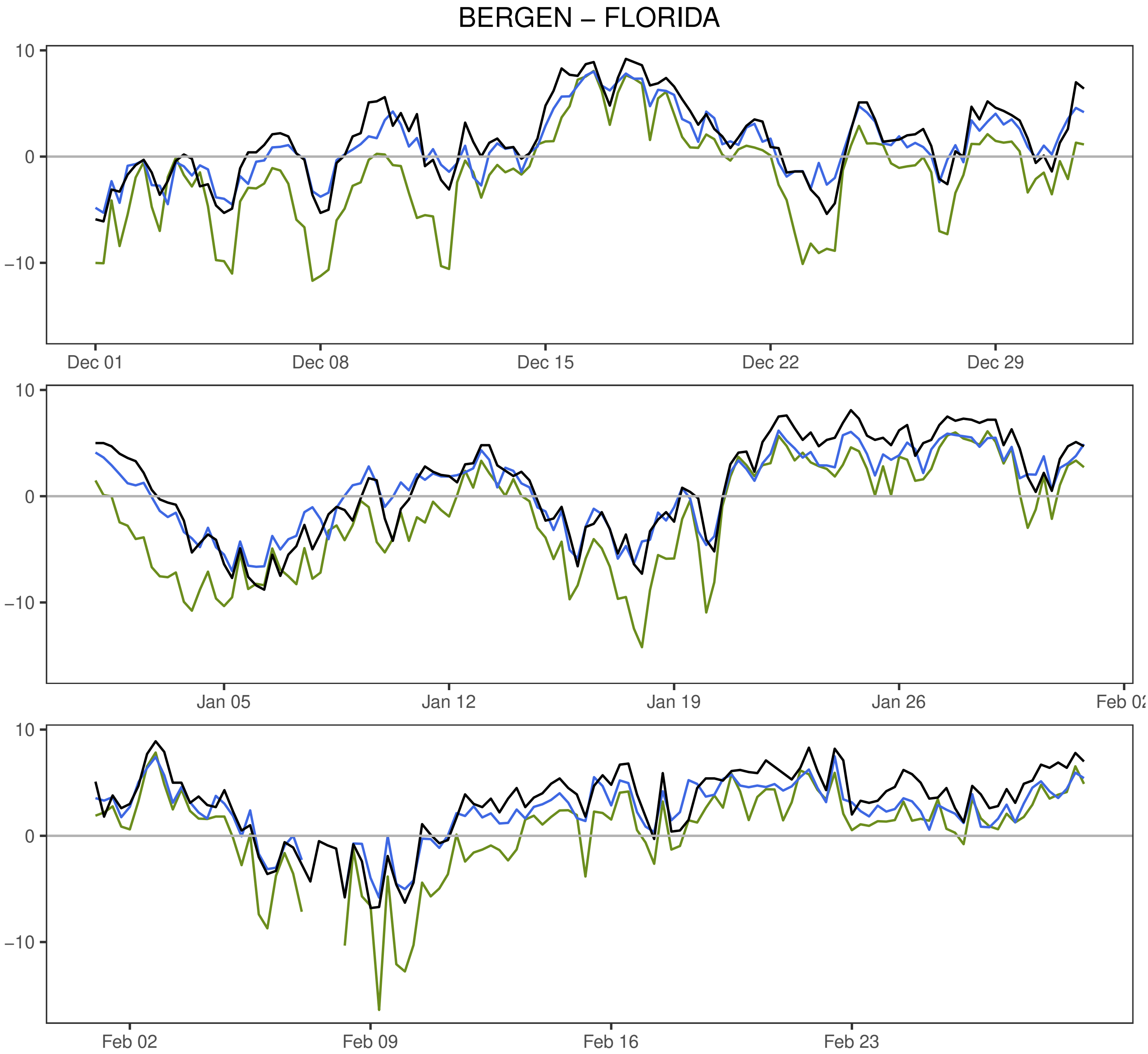
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−43.5	−14.5	3.7	10.1	364
MEPSctrl: 12+18,+24,+30,+36	−35.0	−14.1	2.9	8.3	360
AA25: 12+18,+24,+30,+36	−36.0	−14.8	3.0	8.8	360
ECMWF: 12+18,+24,+30,+36	−36.0	−11.3	3.3	7.1	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.3	4.7	4.7	3.5	20.5	356
AA25 – synop	−0.3	4.7	4.7	3.5	20.7	356
ECMWF – synop	3.2	4.5	5.6	3.9	16.6	356



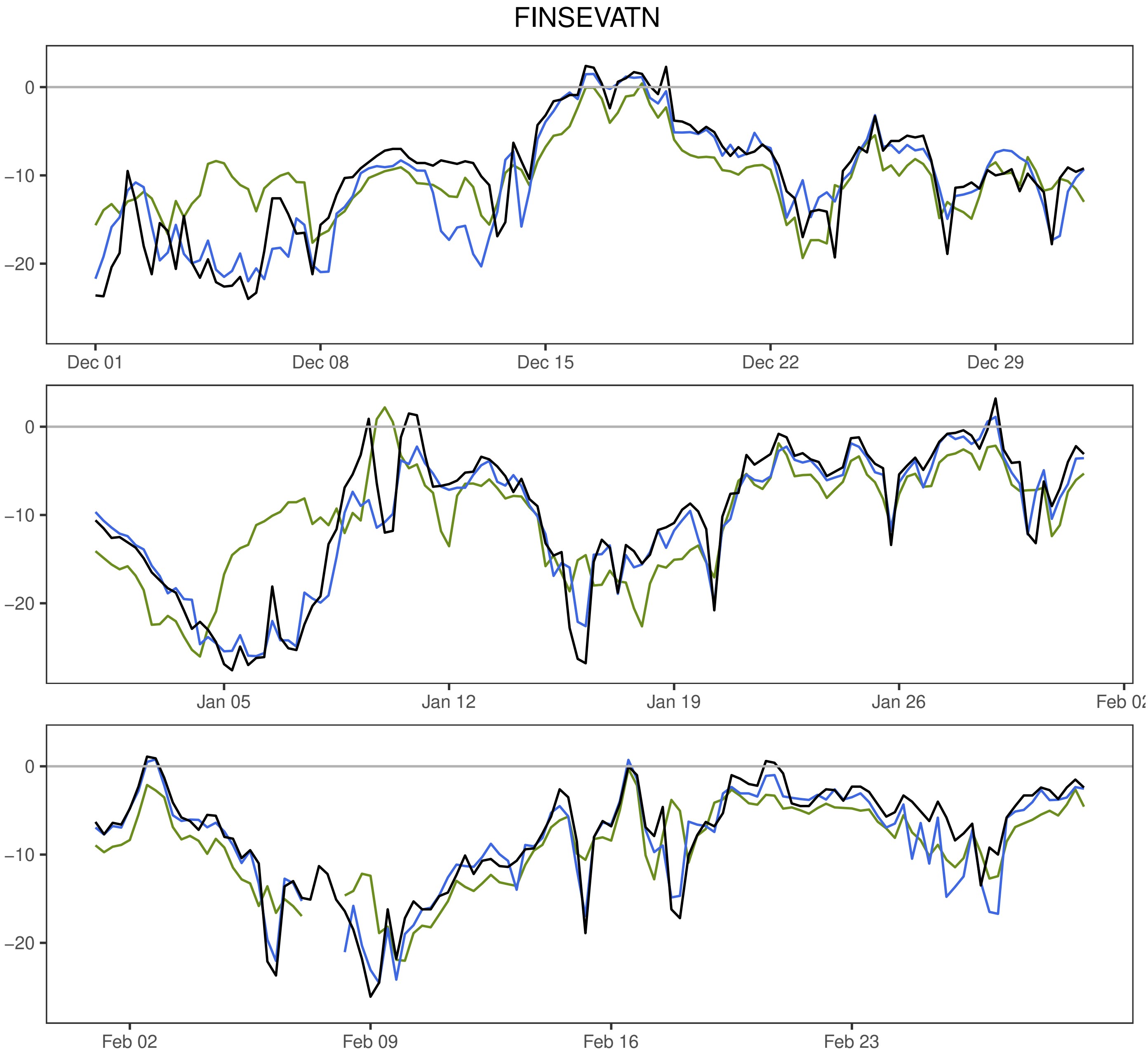
	Min	Mean	Max	Std	N
synop: 00,06,12,18	–13.3	–0.1	9.3	4.4	364
MEPSctrl: 12+18,+24,+30,+36	–10.3	0.3	8.5	3.9	360
ECMWF: 12+18,+24,+30,+36	–8.5	0.4	8.6	3.9	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.4	1.6	1.6	1.2	5.8	360
ECMWF – synop	0.5	1.4	1.4	1.1	6.3	360



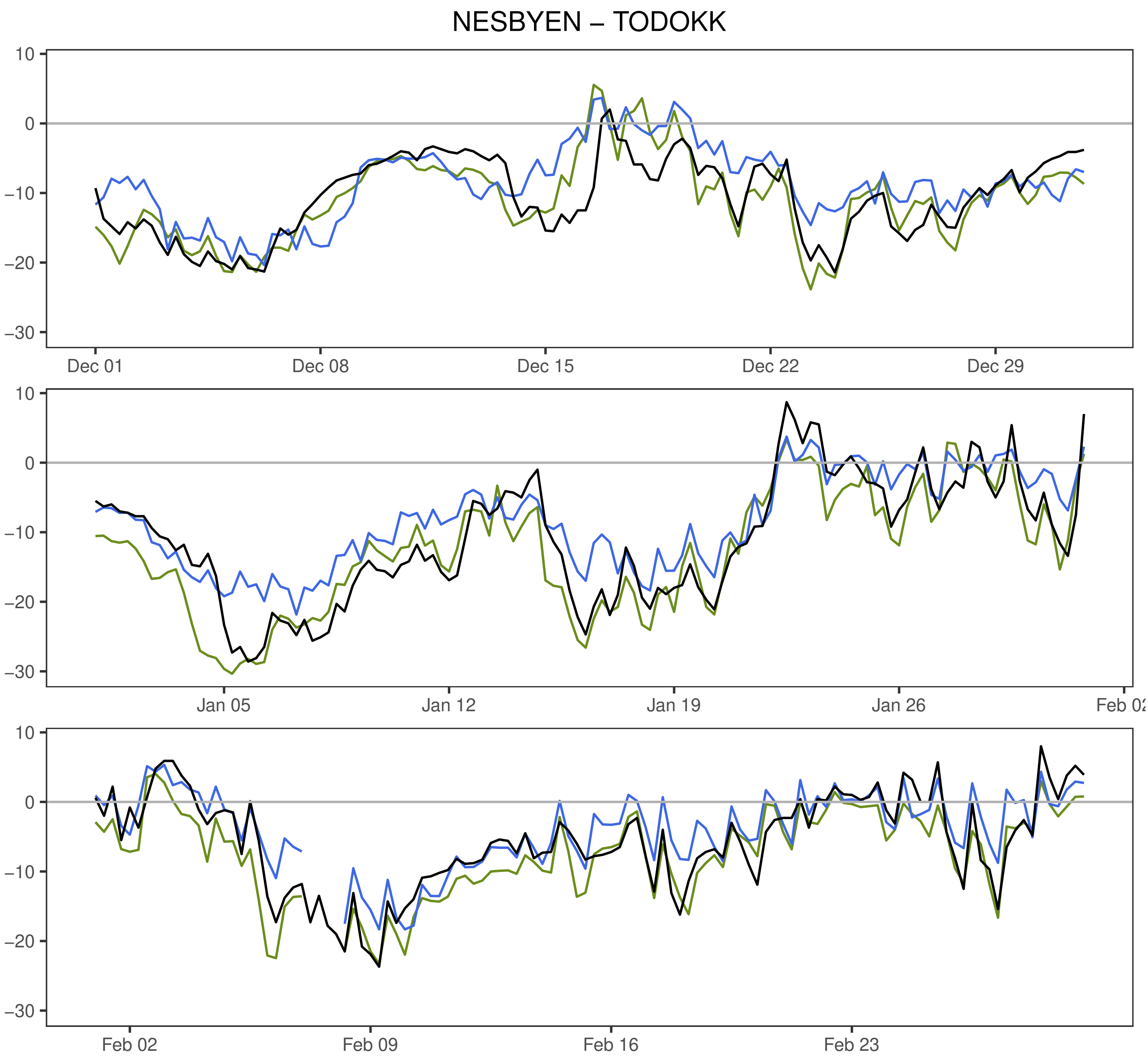
	Min	Mean	Max	Std	N
synop: 00,06,12,18	–8.8	1.8	9.2	4.0	364
MEPSctrl: 12+18,+24,+30,+36	–7.0	1.3	8.0	3.2	360
ECMWF: 12+18,+24,+30,+36	–16.4	–1.1	8.1	4.7	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.6	1.4	1.5	1.2	4.1	360
ECMWF – synop	–3.0	1.9	3.5	3.0	9.8	360



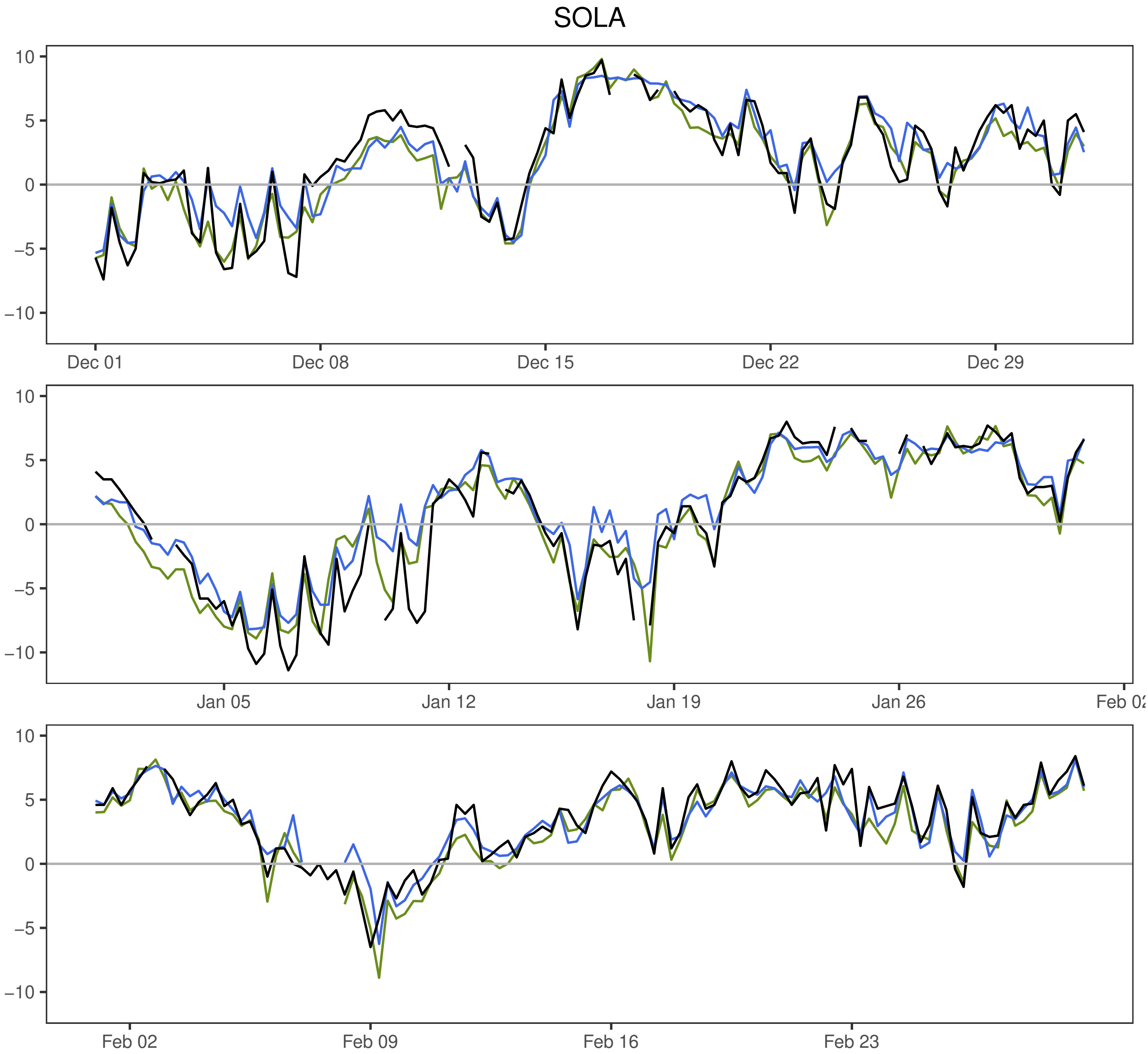
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−27.6	−9.6	3.2	7.0	364
MEPSctrl: 12+18,+24,+30,+36	−26.0	−10.1	1.5	6.5	360
ECMWF: 12+18,+24,+30,+36	−26.0	−10.0	2.2	5.0	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	−0.6	2.5	2.6	1.8	10.3	360
ECMWF – synop	−0.5	4.7	4.8	3.6	16.7	360



	Min	Mean	Max	Std	N
synop: 00,06,12,18	–28.6	–9.2	8.7	7.6	364
MEPSctrl: 12+18,+24,+30,+36	–21.8	–7.1	5.3	6.2	360
ECMWF: 12+18,+24,+30,+36	–30.3	–10.4	5.5	7.4	360

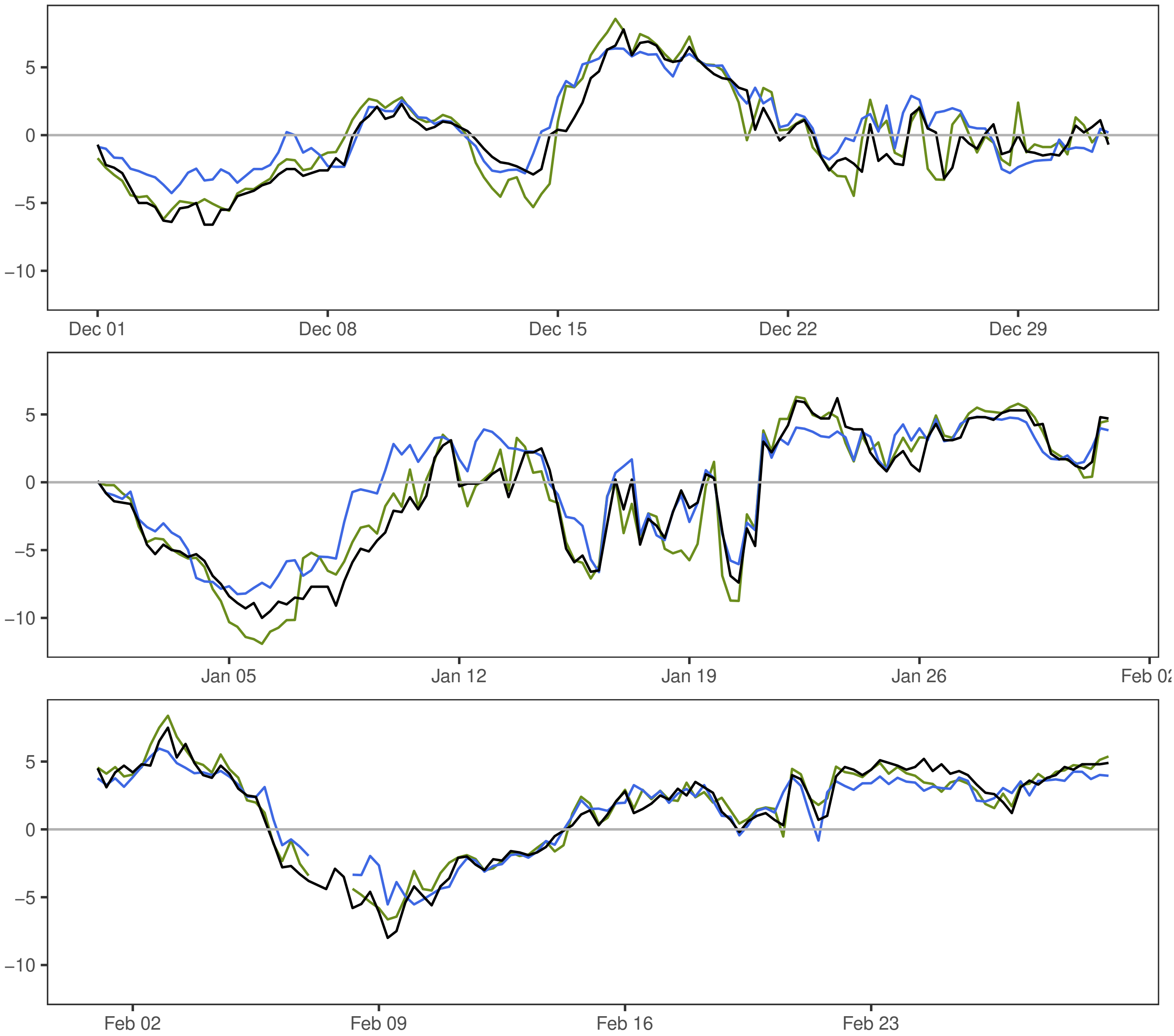
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	2.0	3.9	4.4	3.5	12.6	360
ECMWF – synop	–1.3	3.4	3.7	2.9	14.7	360



	Min	Mean	Max	Std	N
synop: 00,06,12,18	−11.4	1.9	9.7	4.5	349
MEPSctrl: 12+18,+24,+30,+36	−8.2	2.3	8.5	3.7	360
ECMWF: 12+18,+24,+30,+36	−10.7	1.6	9.8	4.1	360

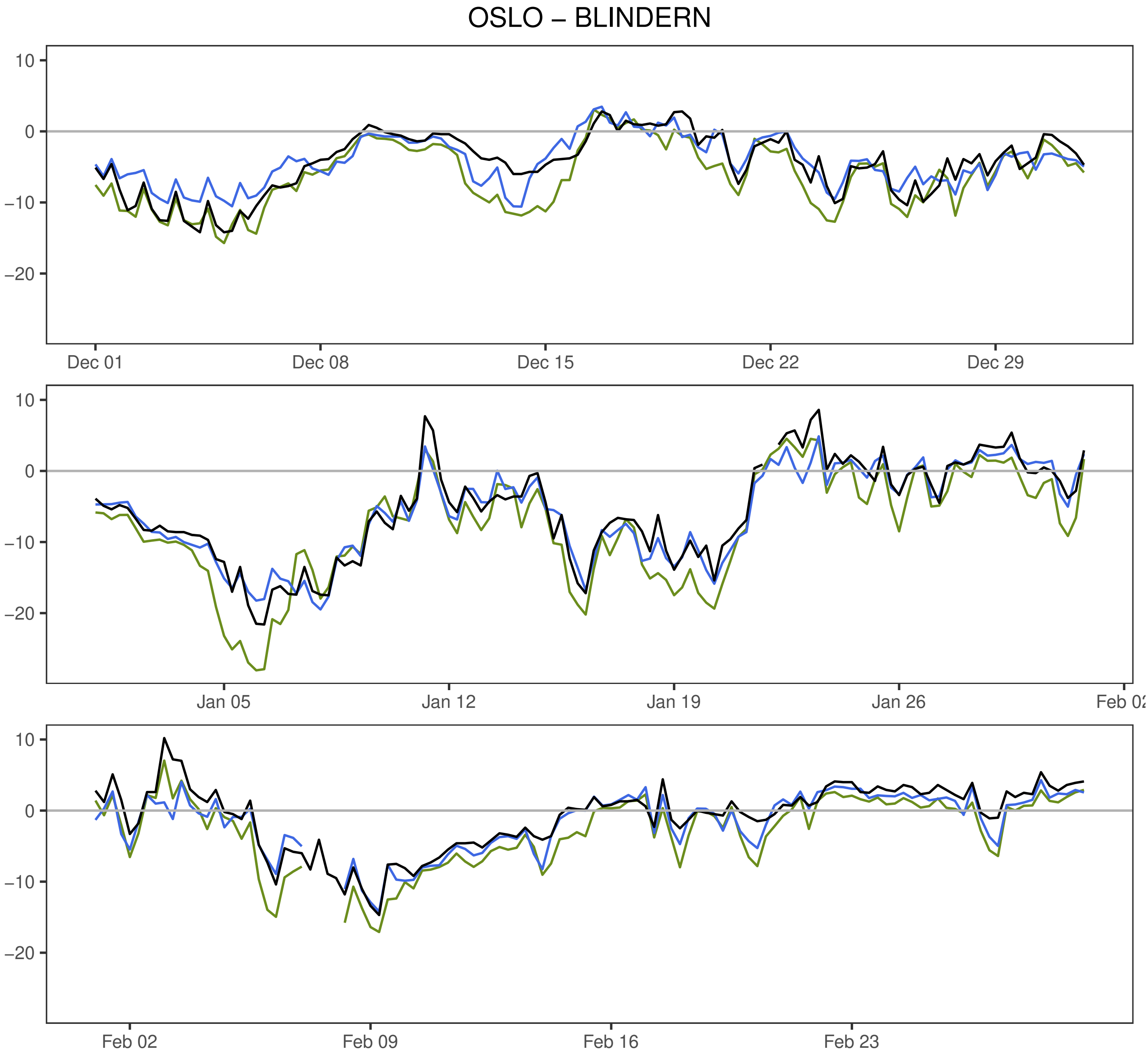
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.3	1.6	1.7	1.2	8.2	345
ECMWF – synop	−0.4	1.5	1.5	1.1	8.1	345

FÆRDER FYR



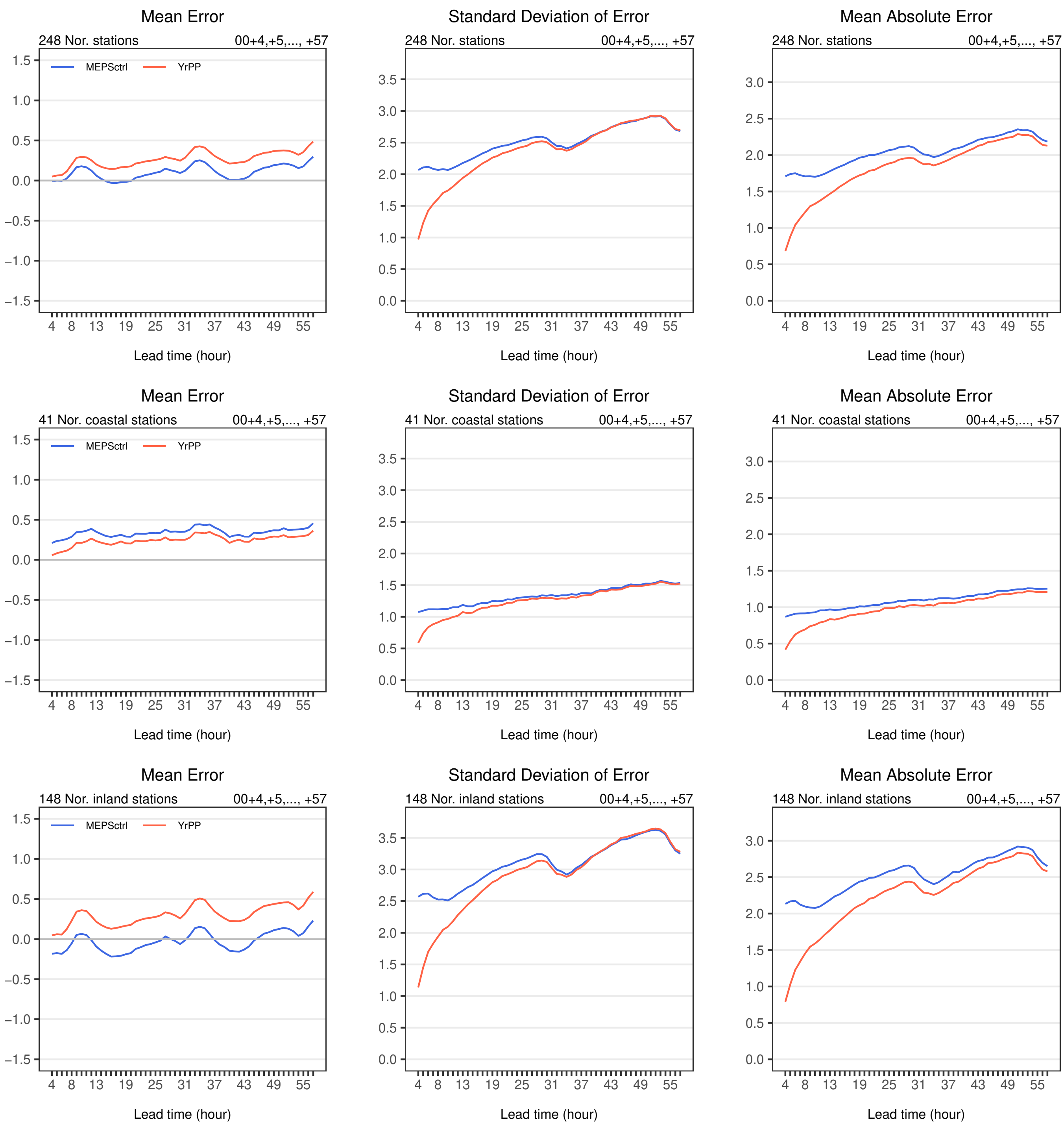
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−10.0	−0.1	7.8	3.9	364
MEPSctrl: 12+18,+24,+30,+36	−8.2	0.5	6.4	3.3	360
ECMWF: 12+18,+24,+30,+36	−11.9	0.1	8.6	4.1	360

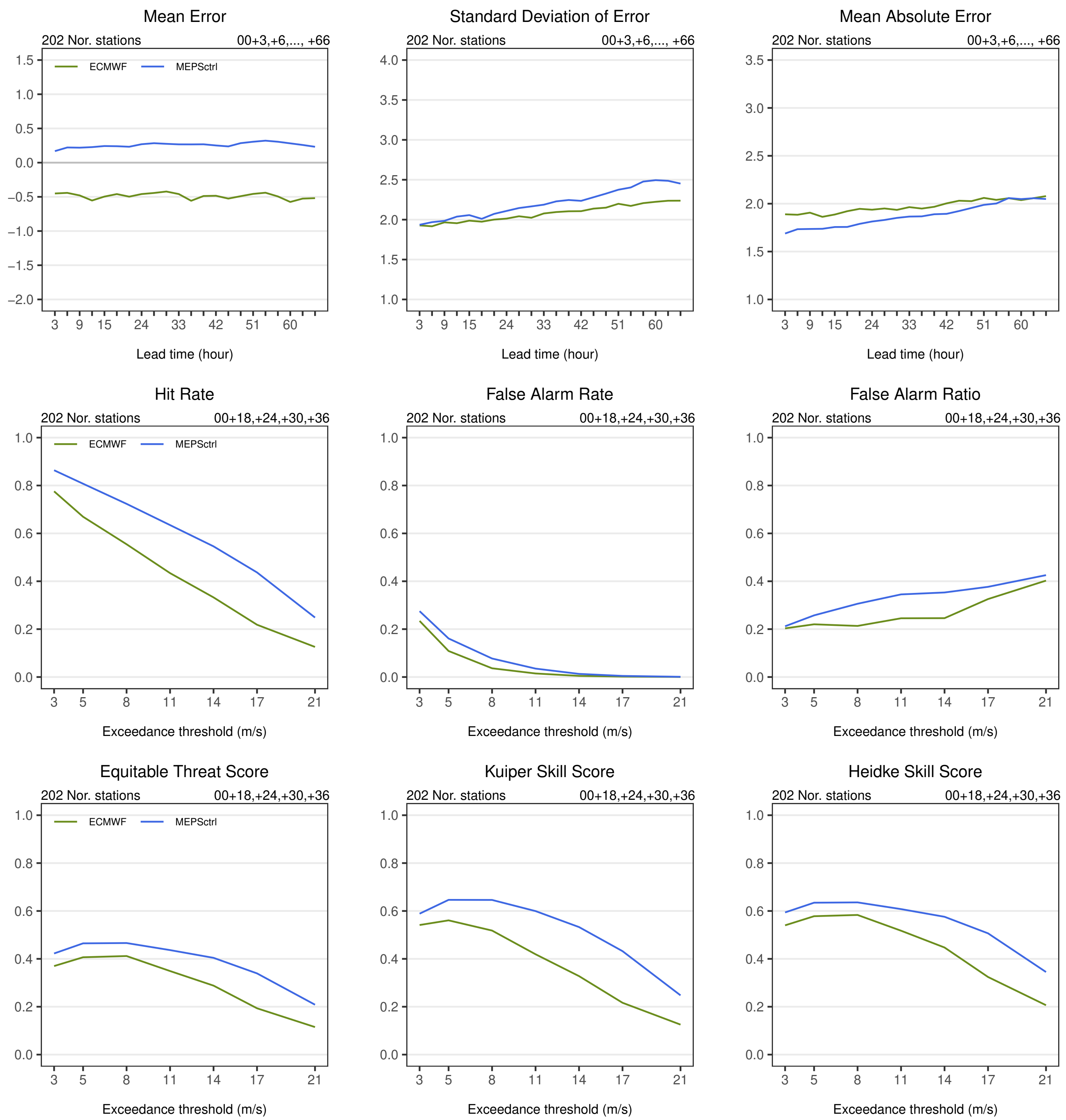
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.6	1.5	1.6	1.2	5.2	360
ECMWF – synop	0.1	1.2	1.2	0.9	4.4	360

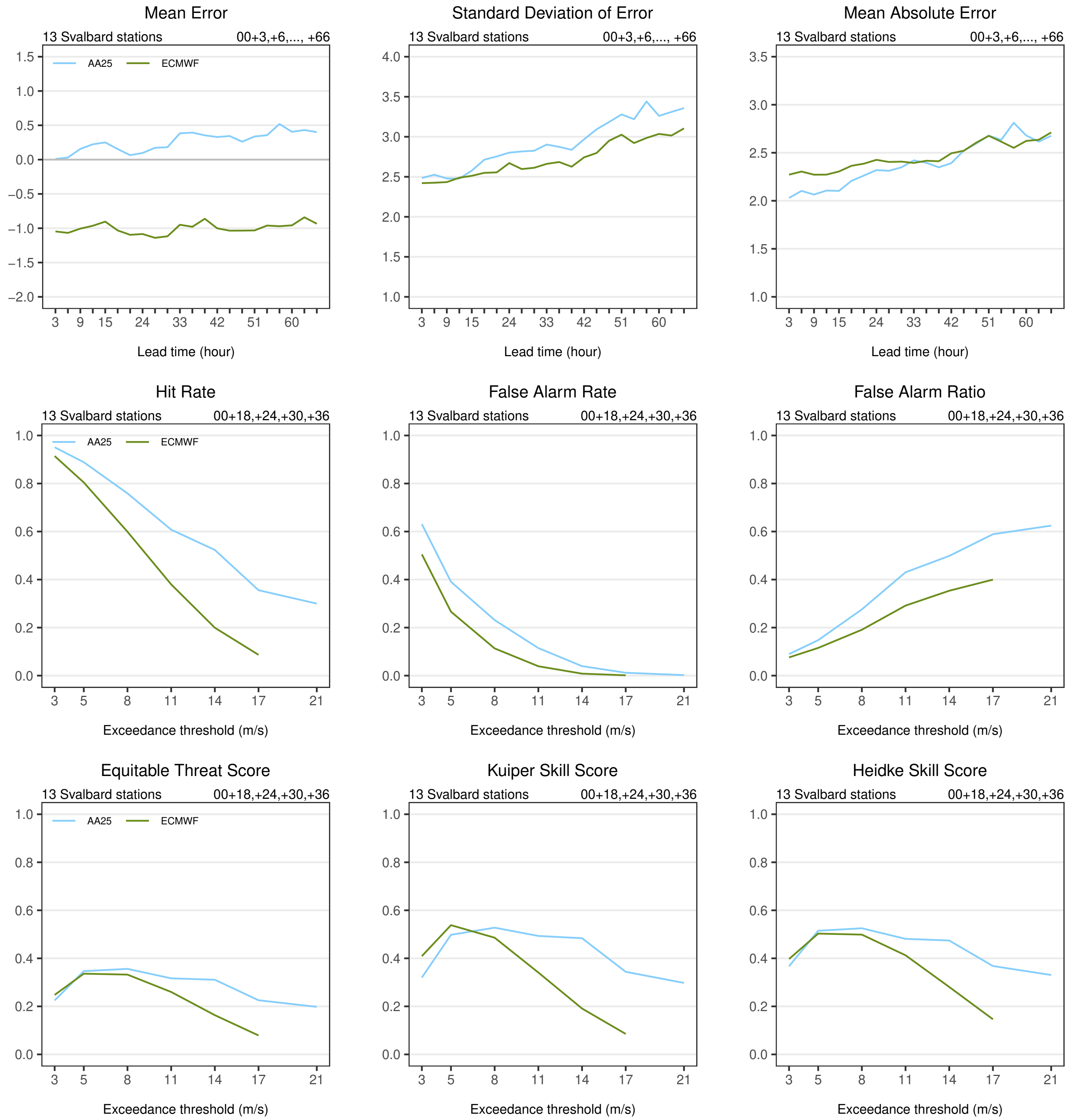


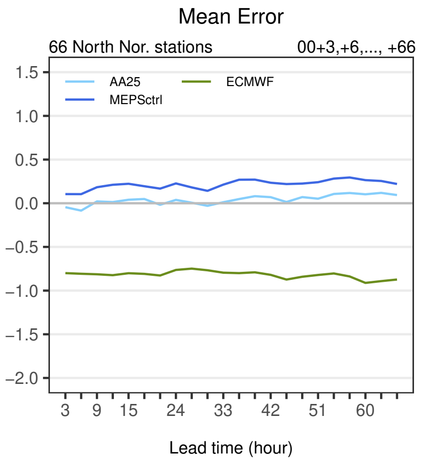
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−21.6	−3.7	10.2	5.7	363
MEPSctrl: 12+18,+24,+30,+36	−19.5	−4.0	4.9	5.1	360
ECMWF: 12+18,+24,+30,+36	−28.1	−5.8	7.0	6.2	360

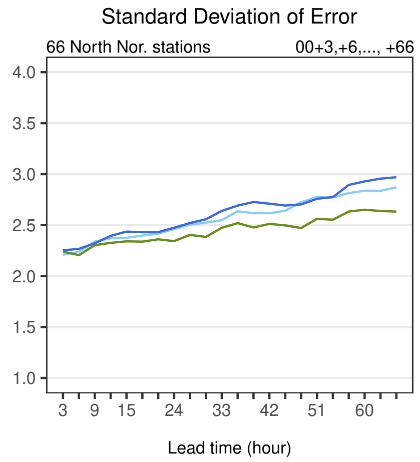
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	−0.4	2.0	2.0	1.5	9.0	359
ECMWF – synop	−2.1	2.1	3.0	2.4	10.4	359

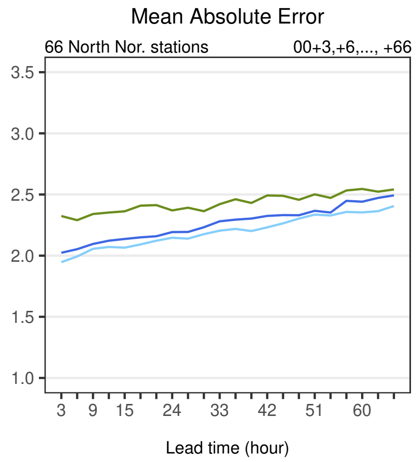

Mean Error
248 Nor. stations
00+4,+5,..., +57
MEPSctrl
YrPP
Lead time (hour)
Standard Deviation of Error
248 Nor. stations
00+4,+5,..., +57
Lead time (hour)
Mean Absolute Error
248 Nor. stations
00+4,+5,..., +57
Lead time (hour)
Mean Error
41 Nor. coastal stations
00+4,+5,..., +57
MEPSctrl
YrPP
Lead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

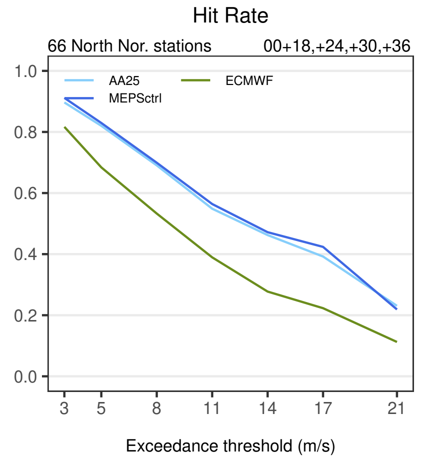

Mean Error
202 Nor. stations
00+3,+6,..., +66
ECMWF
MEPSctrl
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
3 9 15 24 33 42 51 60
Lead time (hour)
Standard Deviation of Error
202 Nor. stations
00+3,+6,..., +66
4.0
3.5
3.0
2.5
2.0
1.5
1.0
3 9 15 24 33 42 51 60
Lead time (hour)
Mean Absolute Error
202 Nor. stations
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
202 Nor. stations
00+18,+24,+30,+36
ECMWF
MEPSctrl
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
202 Nor. stations
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
202 Nor. stations
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
202 Nor. stations
00+18,+24,+30,+36
ECMWF
MEPSctrl
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)
Kuiper Skill Score
202 Nor. stations
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
202 Nor. stations
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)

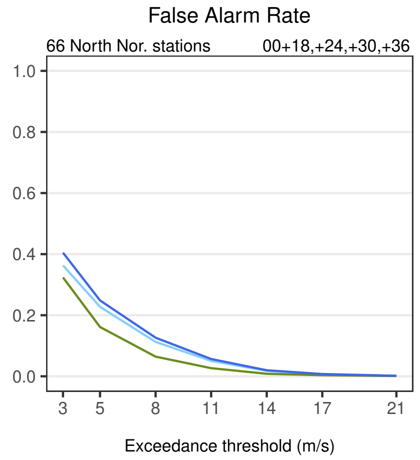

Mean Error
13 Svalbard stations
00+3,+6,..., +66
AA25
ECMWF
Lead time (hour)
Standard Deviation of Error
13 Svalbard stations
00+3,+6,..., +66
Lead time (hour)
Mean Absolute Error
13 Svalbard stations
00+3,+6,..., +66
Lead time (hour)
Hit Rate
13 Svalbard stations
00+18,+24,+30,+36
AA25
ECMWF
Exceedance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

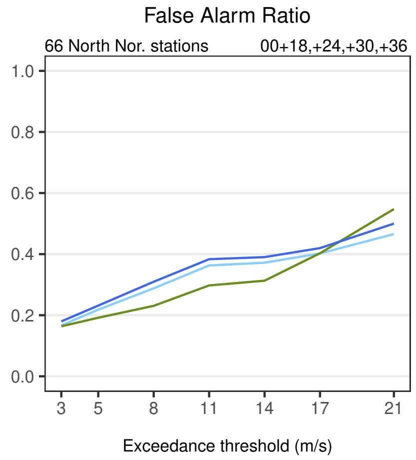

Mean Error
66 North Nor. stations
00+3,+6,..., +66
AA25
MEPSctrl
ECMWF
Lead time (hour)

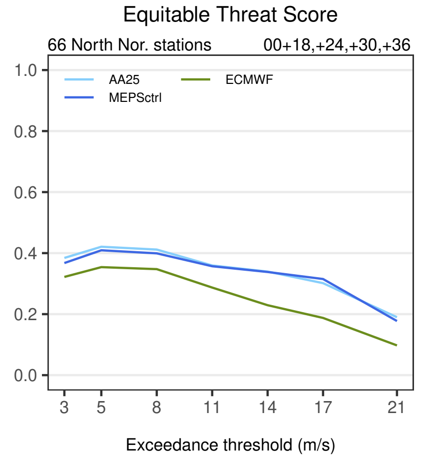

Standard Deviation of Error
66 North Nor. stations
00+3,+6,..., +66
Lead time (hour)

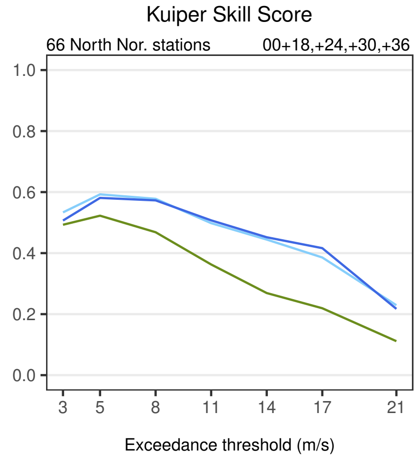

Mean Absolute Error
66 North Nor. stations
00+3,+6,..., +66
Lead time (hour)

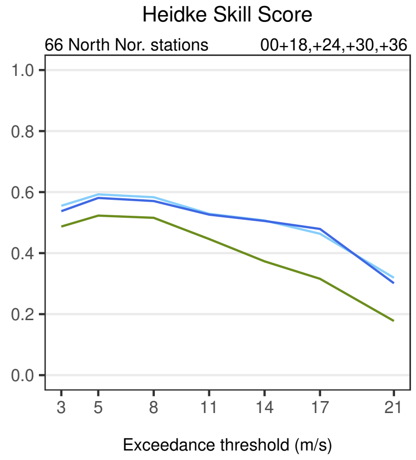

Hit Rate
66 North Nor. stations
00+18,+24,+30,+36
AA25
MEPSctrl
ECMWF
Exceedance threshold (m/s)

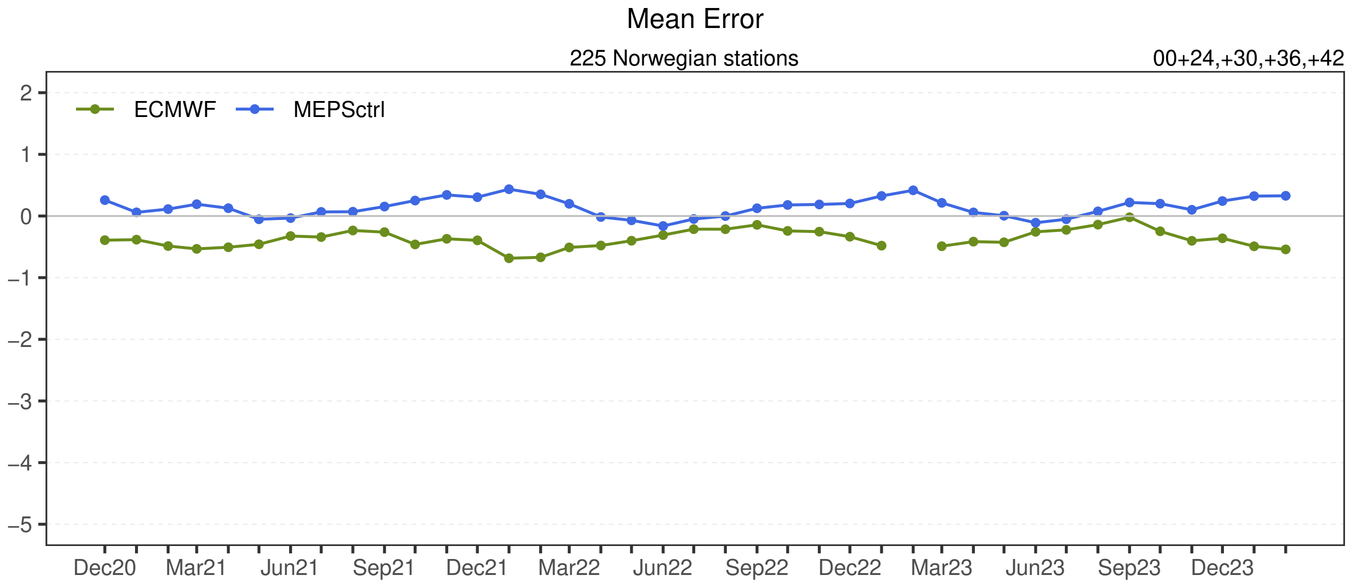

False Alarm Rate
66 North Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)

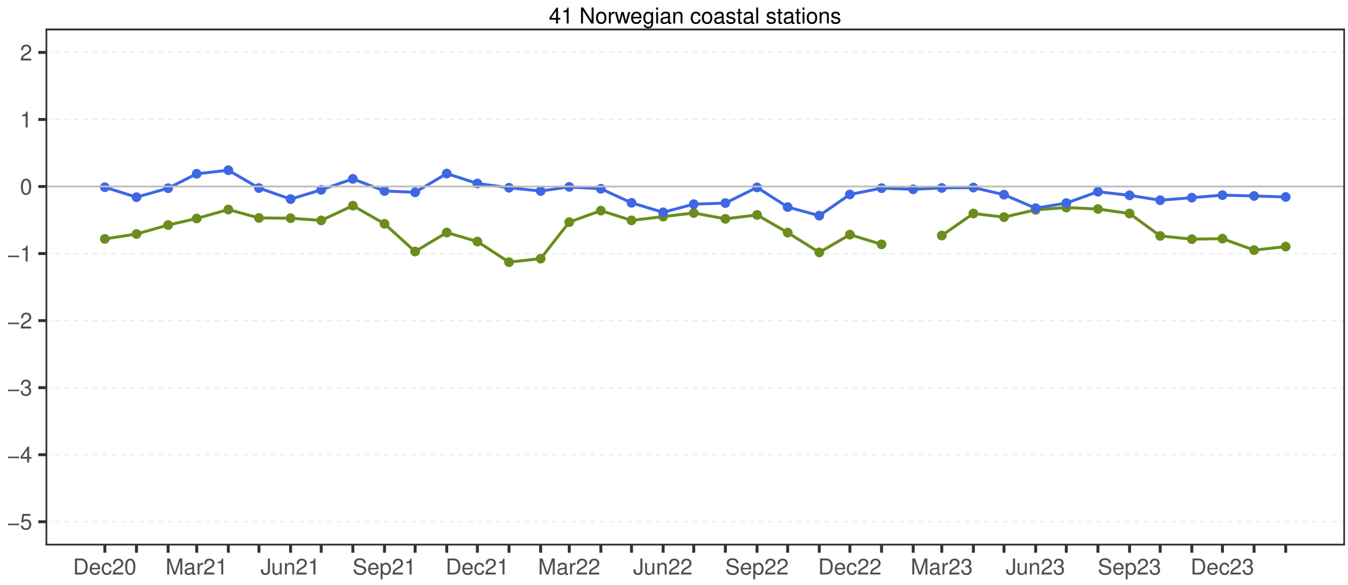

False Alarm Ratio
66 North Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)

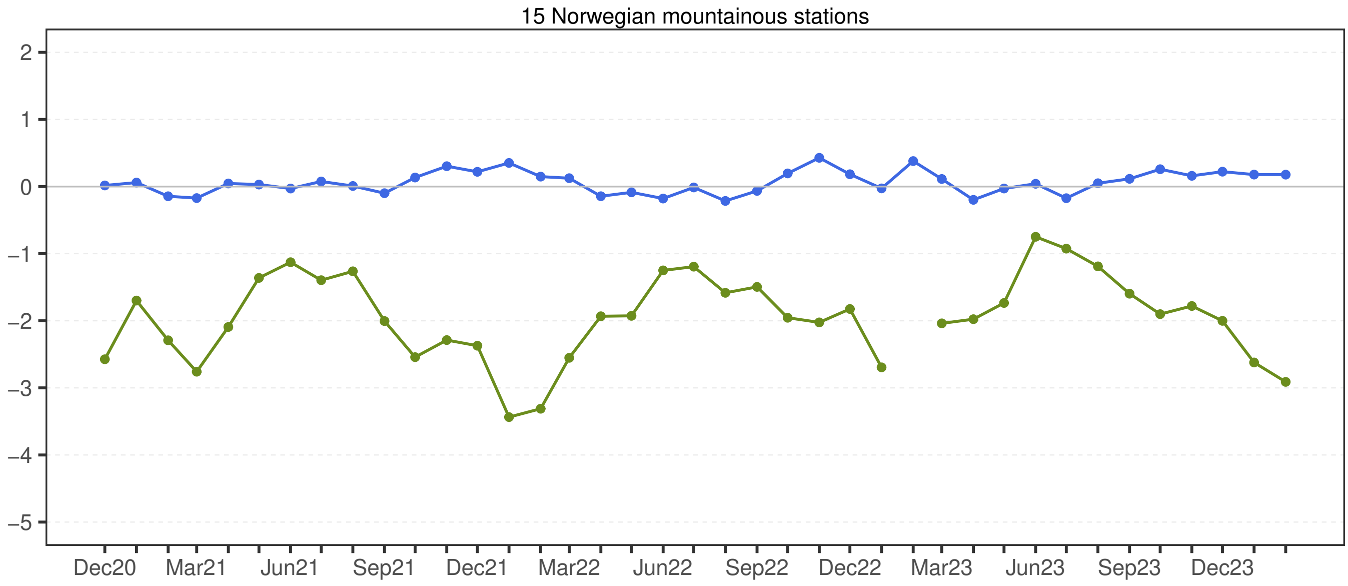

Equitable Threat Score
66 North Nor. stations
00+18,+24,+30,+36
AA25
MEPSctrl
ECMWF
Exceedance threshold (m/s)


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

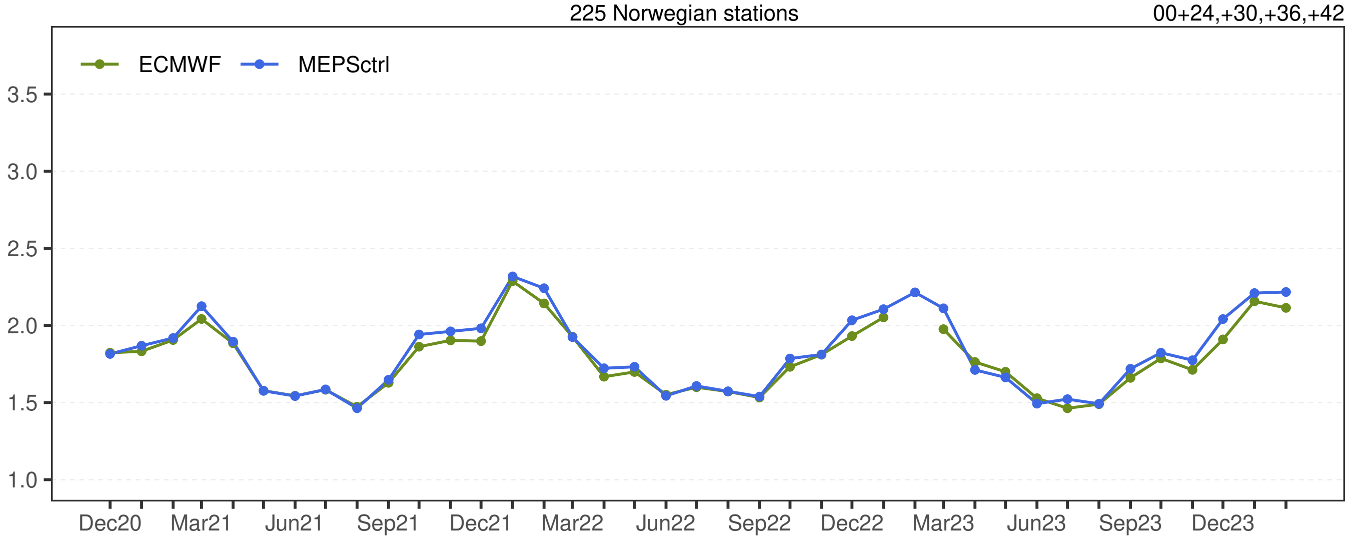

Heidke Skill Score
66 North Nor. stations
00+18,+24,+30,+36
Exceedance threshold (m/s)

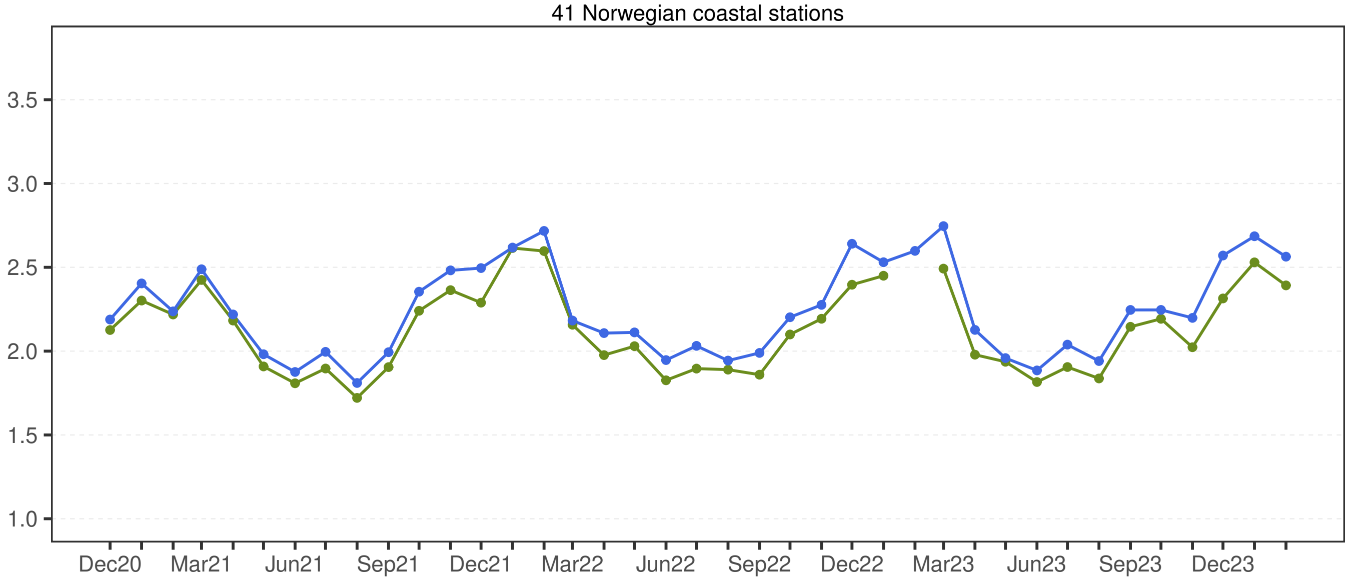

Mean Error
225 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
2
1
0
−1
−2
−3
−4
−5
Dec20 Mar21 Jun21 Sep21 Dec21 Mar22 Jun22 Sep22 Dec22 Mar23 Jun23 Sep23 Dec23

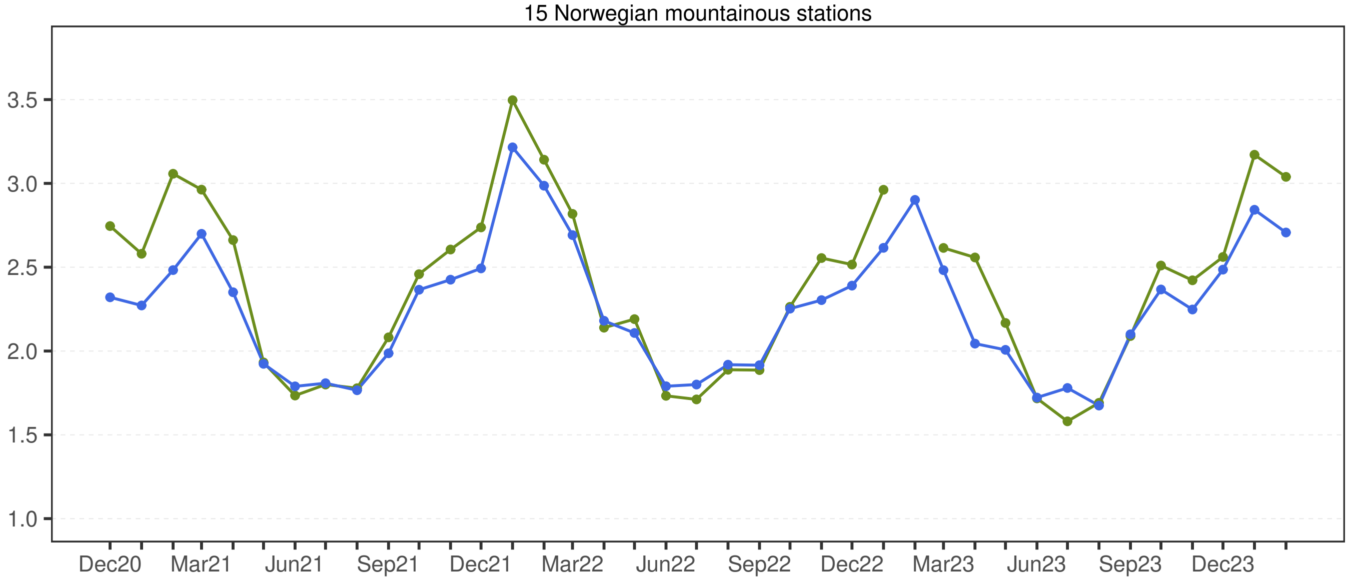

41 Norwegian coastal stations
2
1
0
−1
−2
−3
−4
−5
Dec20 Mar21 Jun21 Sep21 Dec21 Mar22 Jun22 Sep22 Dec22 Mar23 Jun23 Sep23 Dec23

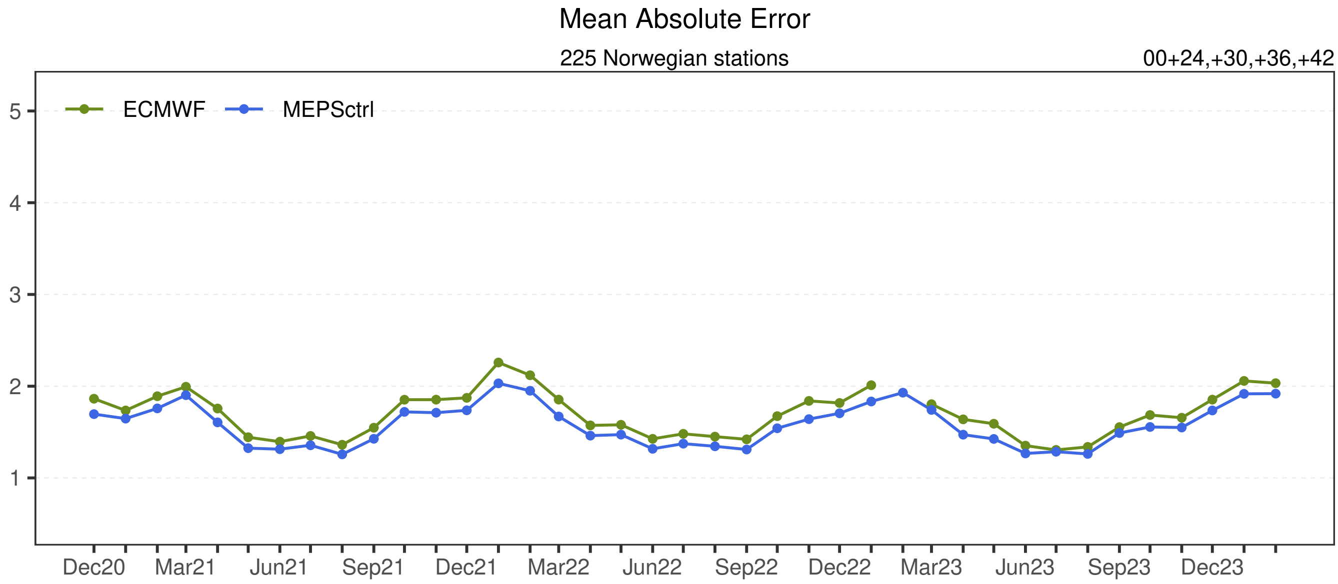

15 Norwegian mountainous stations
2
1
0
−1
−2
−3
−4
−5
Dec20 Mar21 Jun21 Sep21 Dec21 Mar22 Jun22 Sep22 Dec22 Mar23 Jun23 Sep23 Dec23

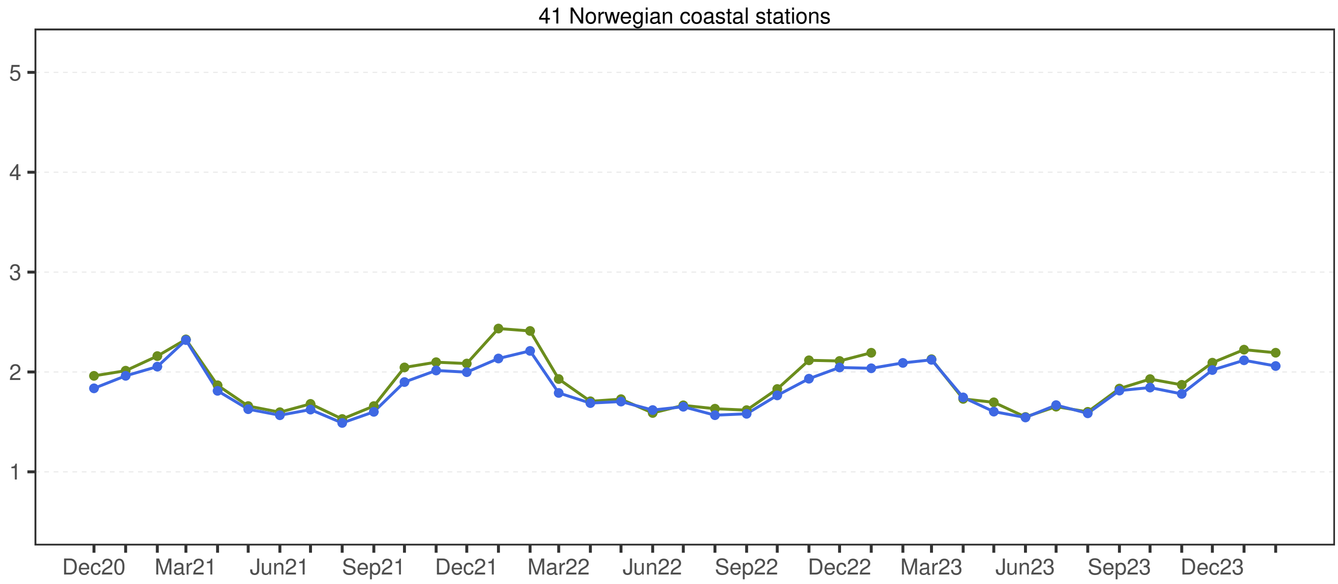
Standard Deviation of Error

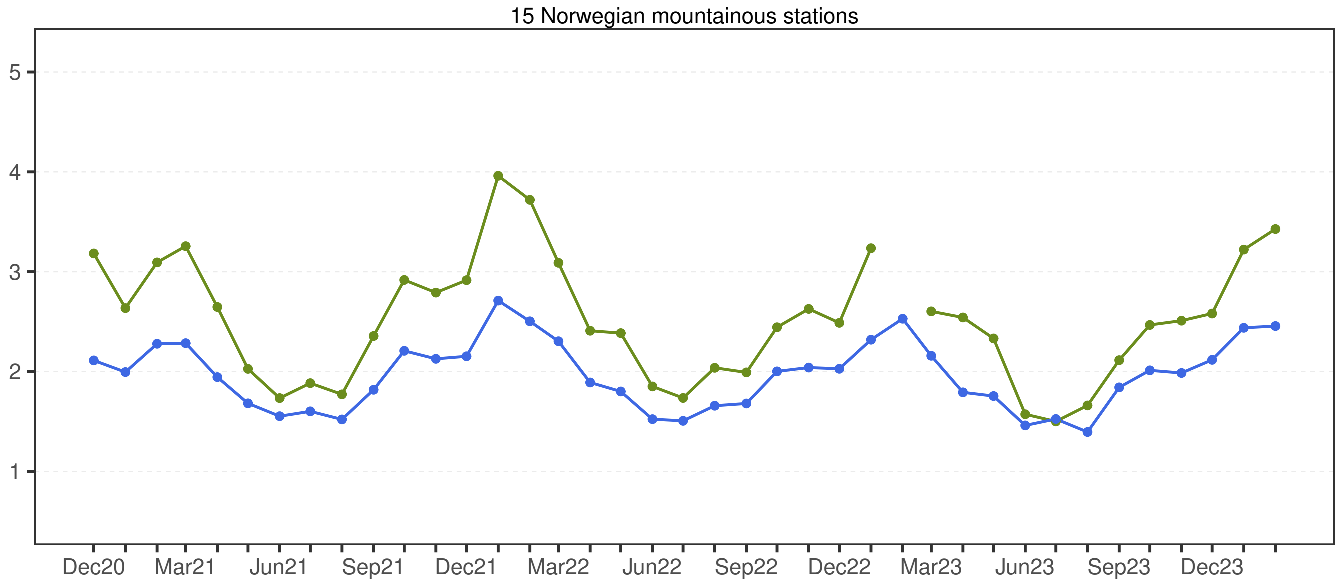


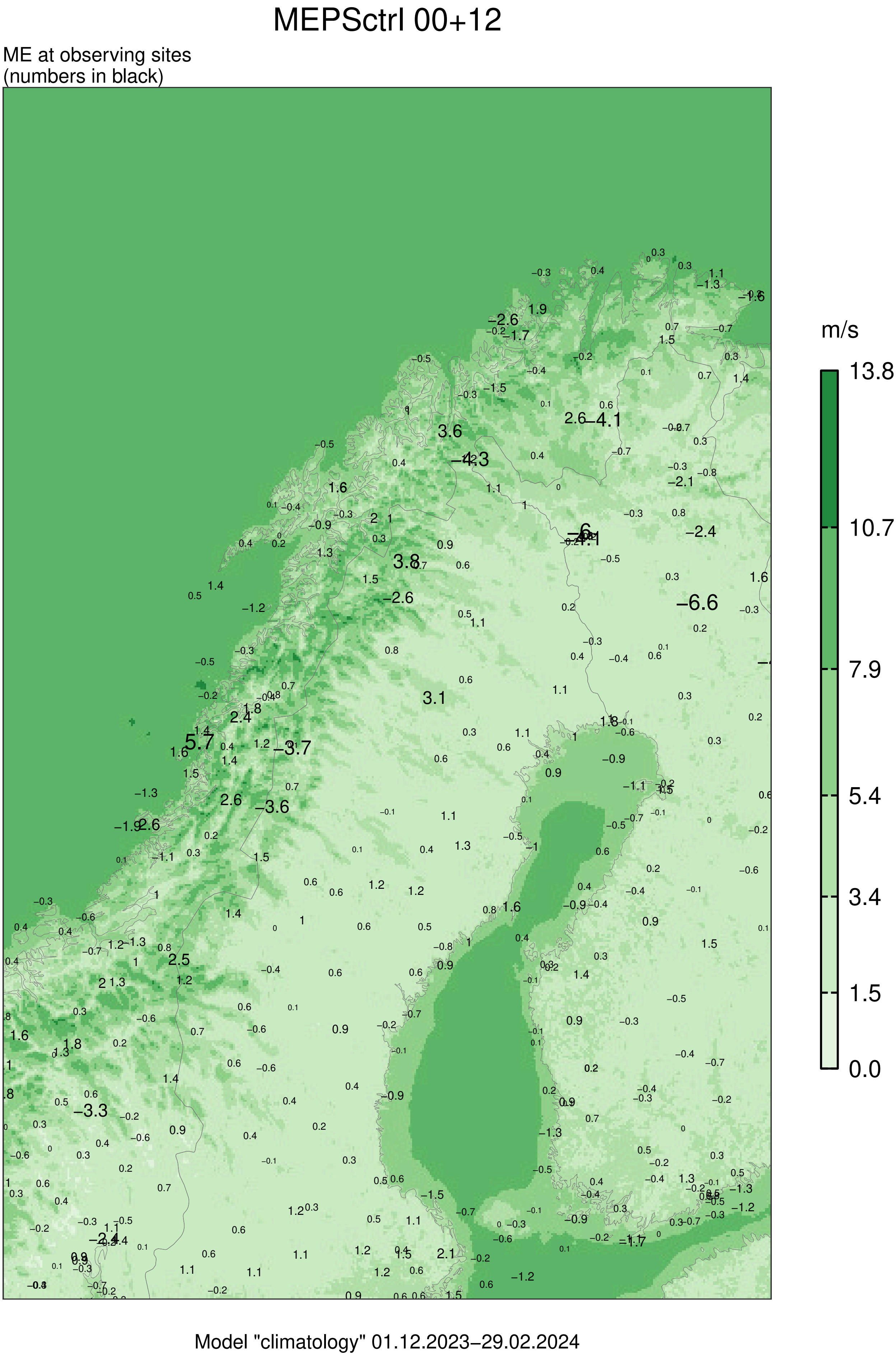





Mean Absolute Error
225 Norwegian stations
00+24,+30,+36,+42
ECMWF
MEPSctrl
5
4
3
2
1
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23

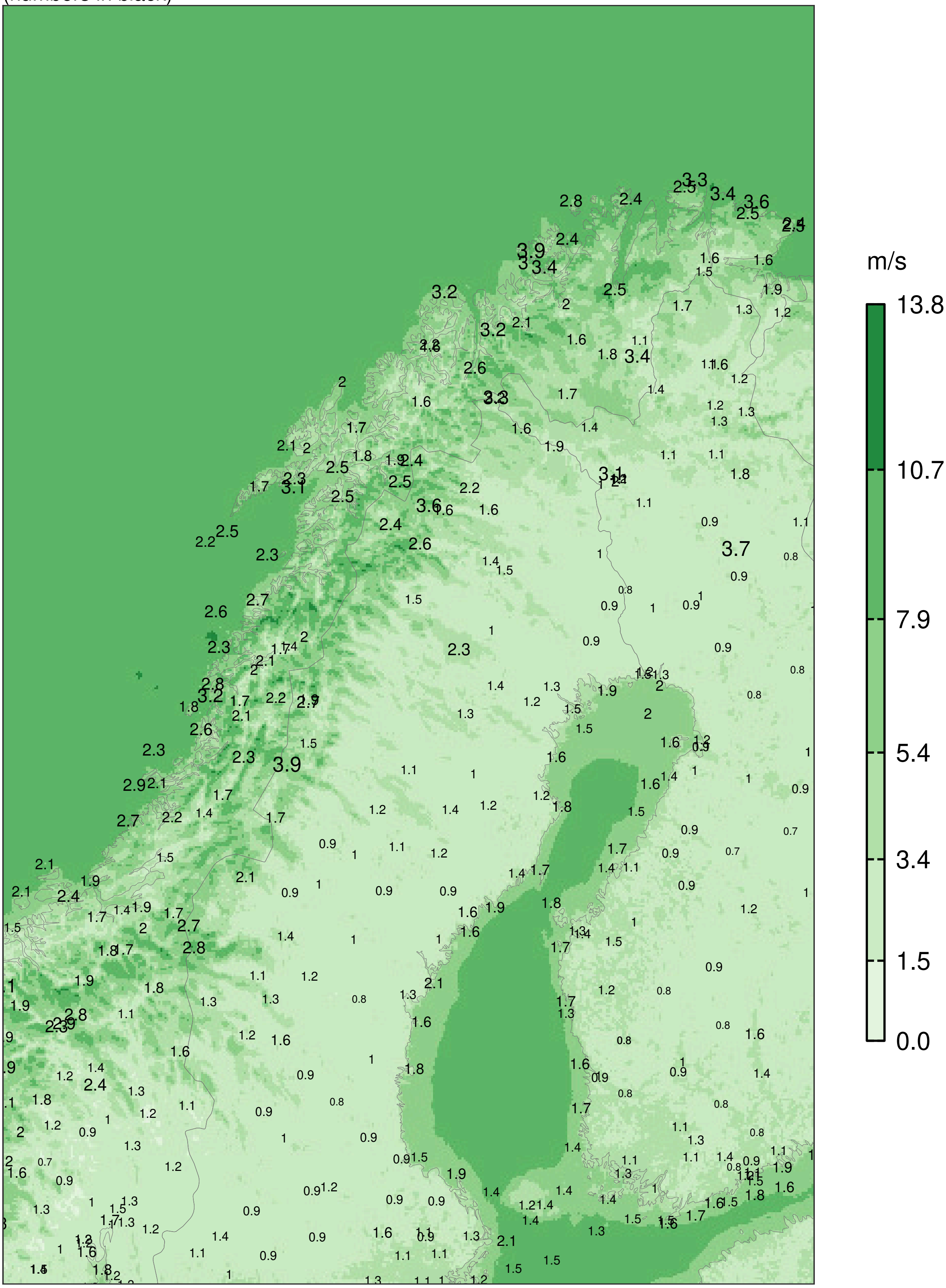

41 Norwegian coastal stations
5
4
3
2
1
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23


15 Norwegian mountainous stations
5
4
3
2
1
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23

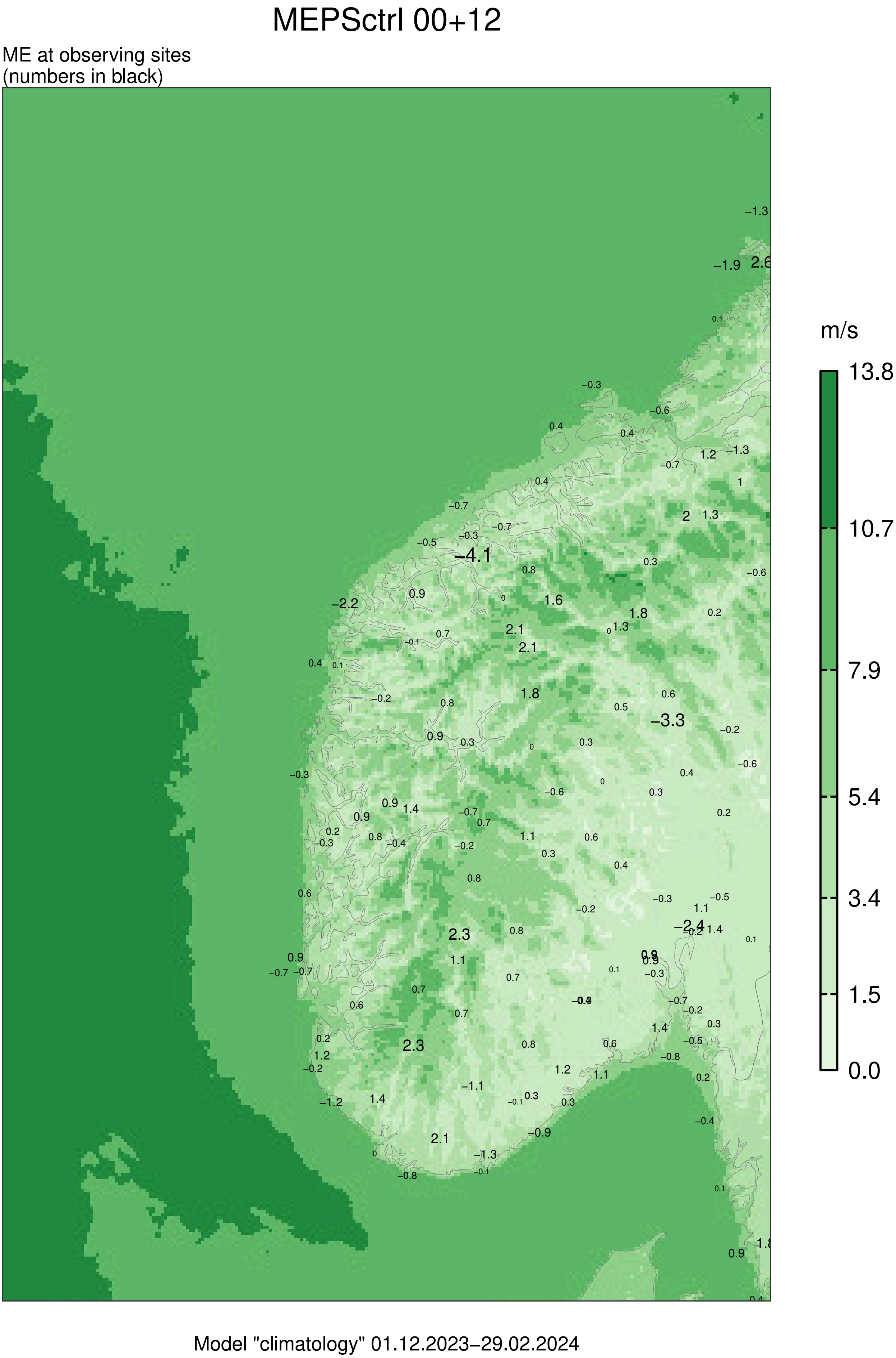

MEPSctrl 00+12
ME at observing sites
(numbers in black)
m/s
13.8
10.7
7.9
5.4
3.4
1.5
0.0
Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+12

SDE at observing sites
(numbers in black)

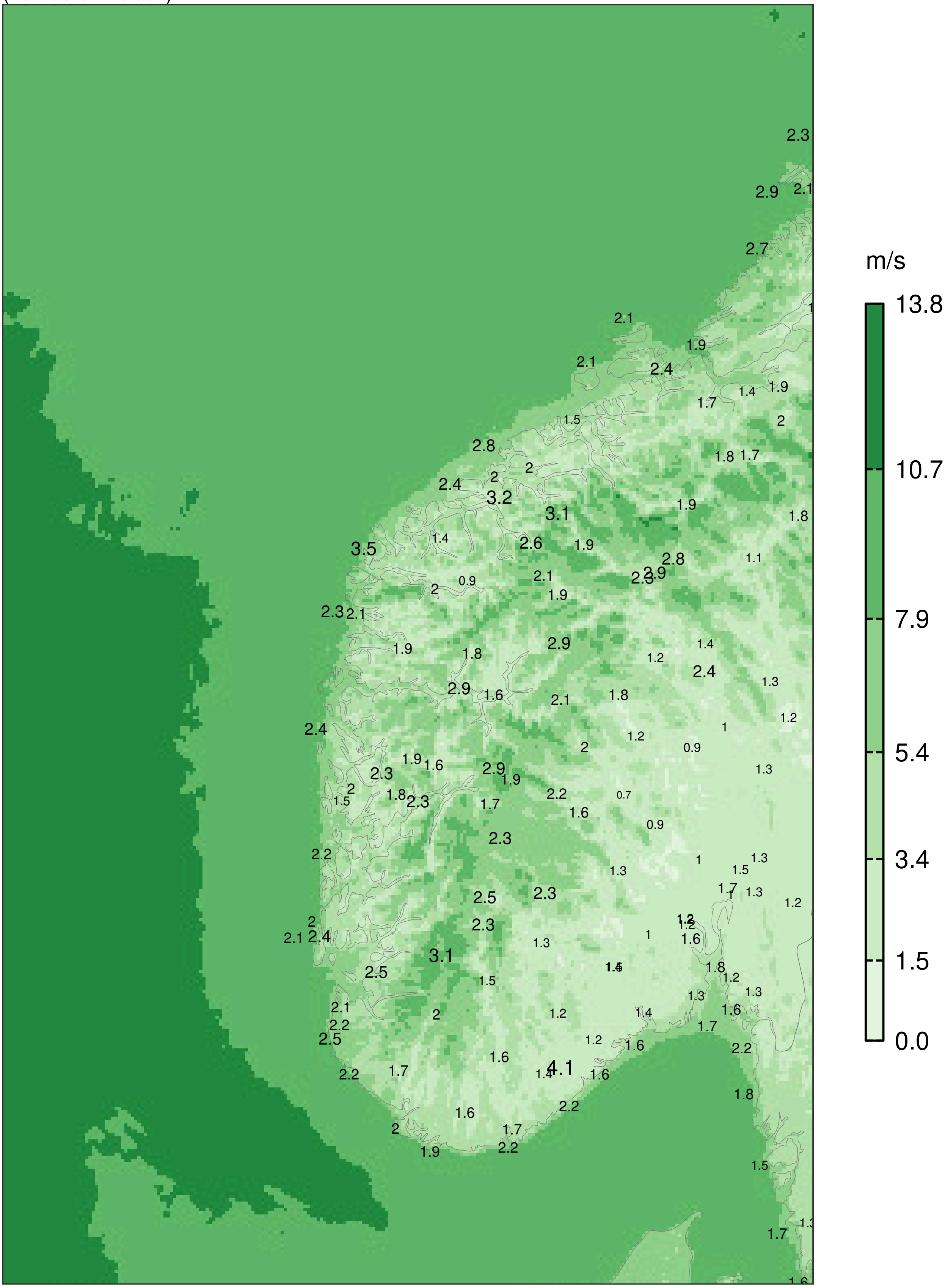


Model "climatology" 01.12.2023–29.02.2024


MEPSctrl 00+12
ME at observing sites
(numbers in black)
m/s
13.8
10.7
7.9
5.4
3.4
1.5
0.0
Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+12

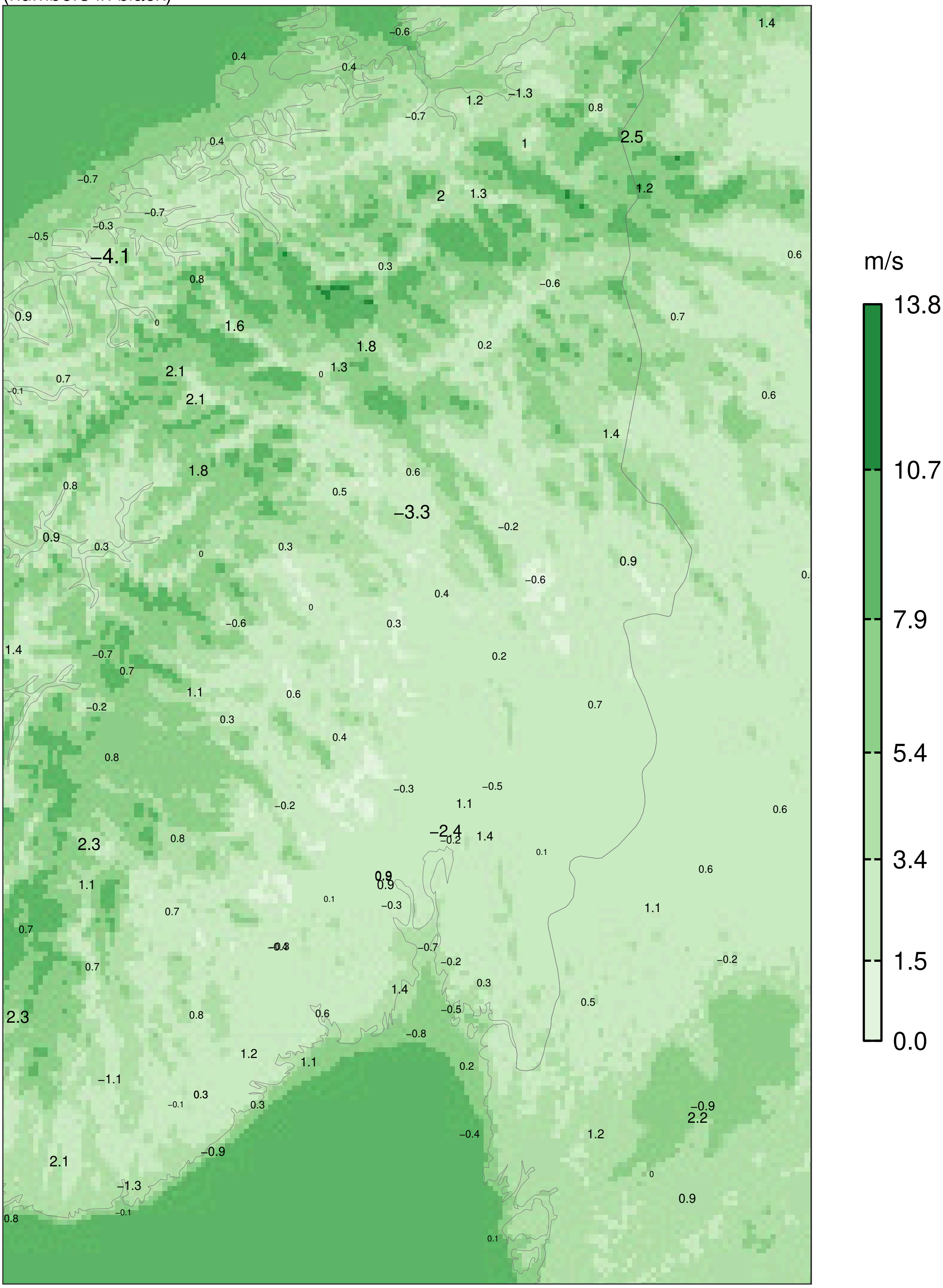
SDE at observing sites
(numbers in black)



Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+12

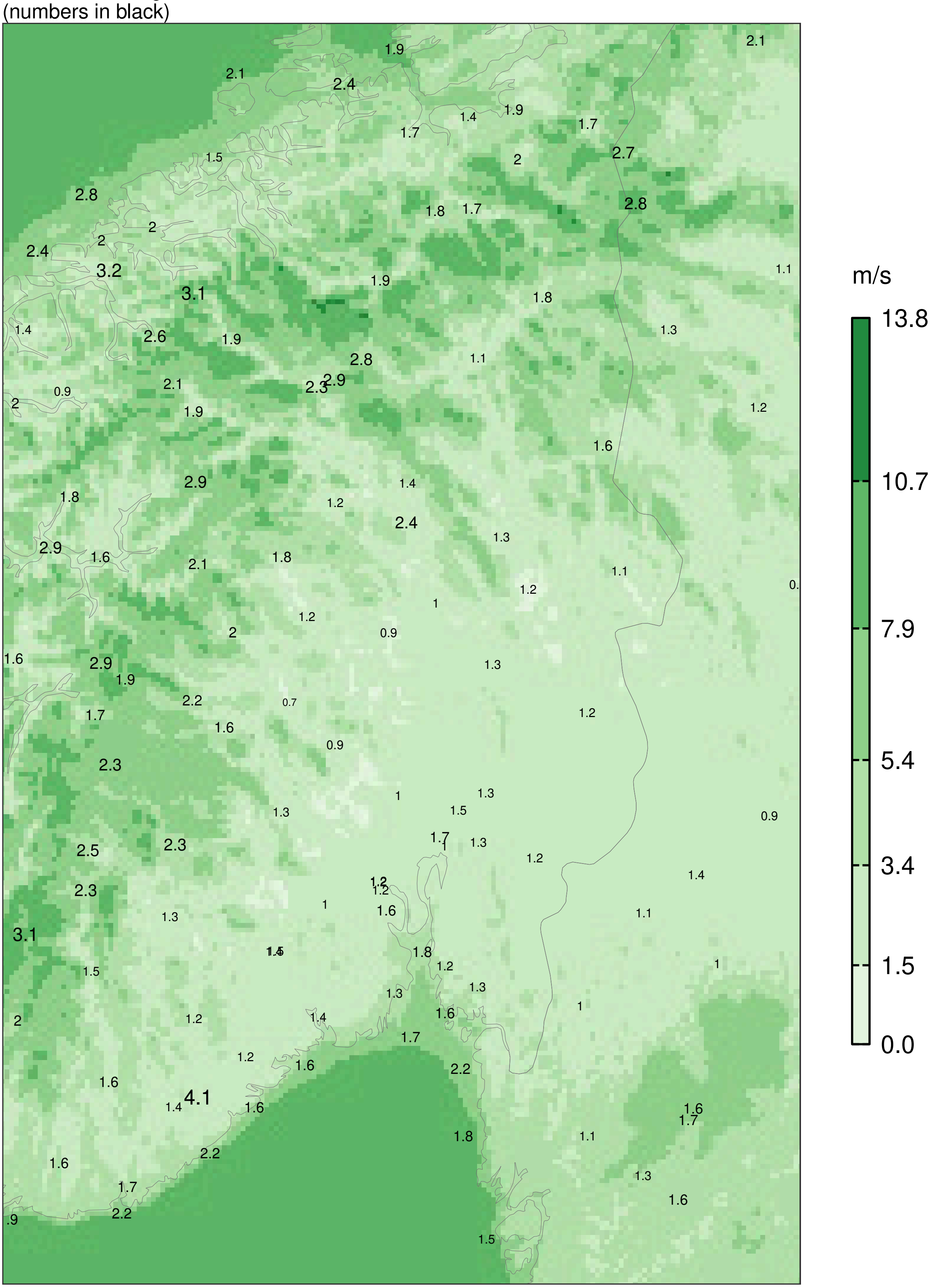
ME at observing sites
(numbers in black)



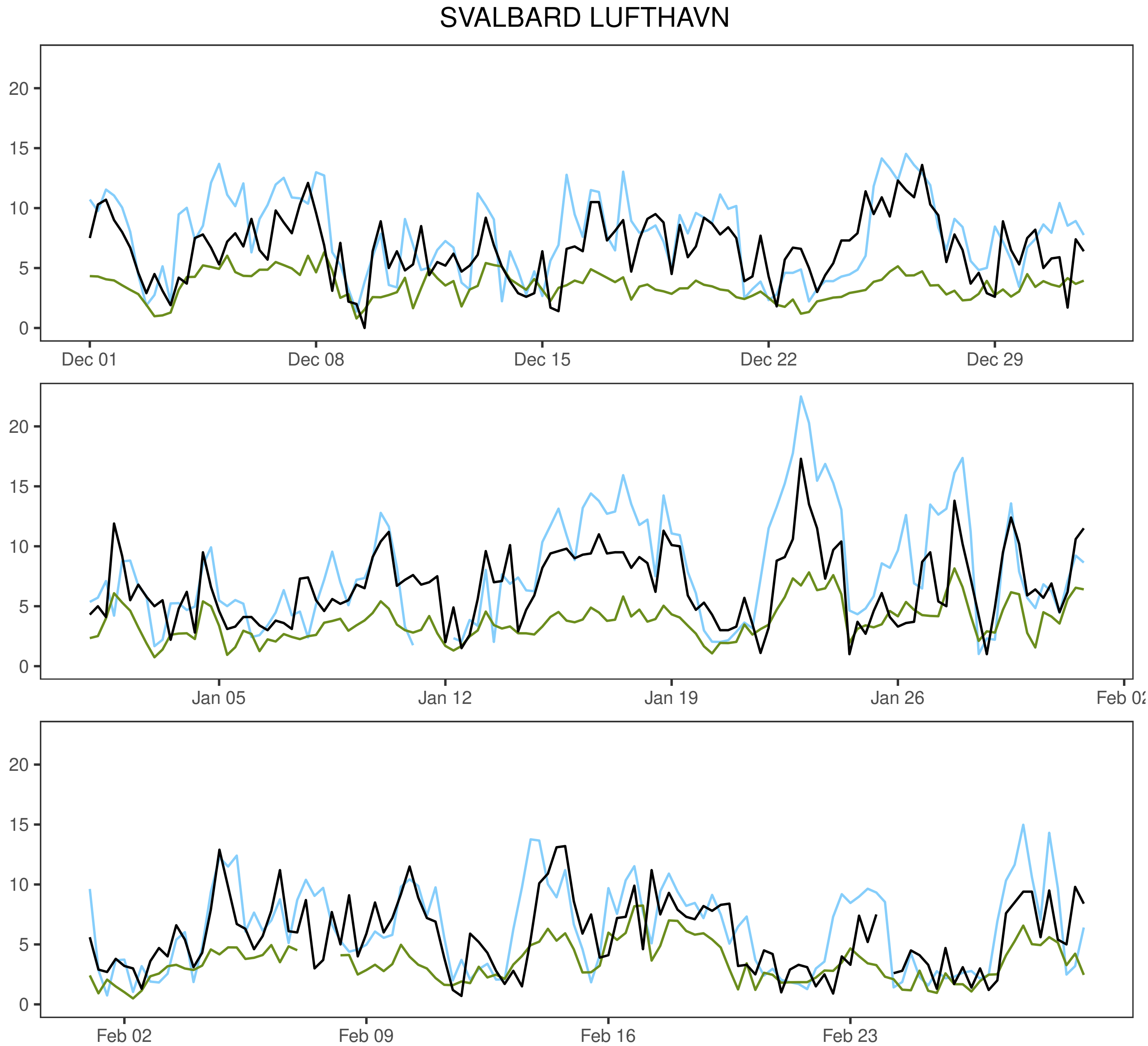
Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+12

SDE at observing sites
(numbers in black)

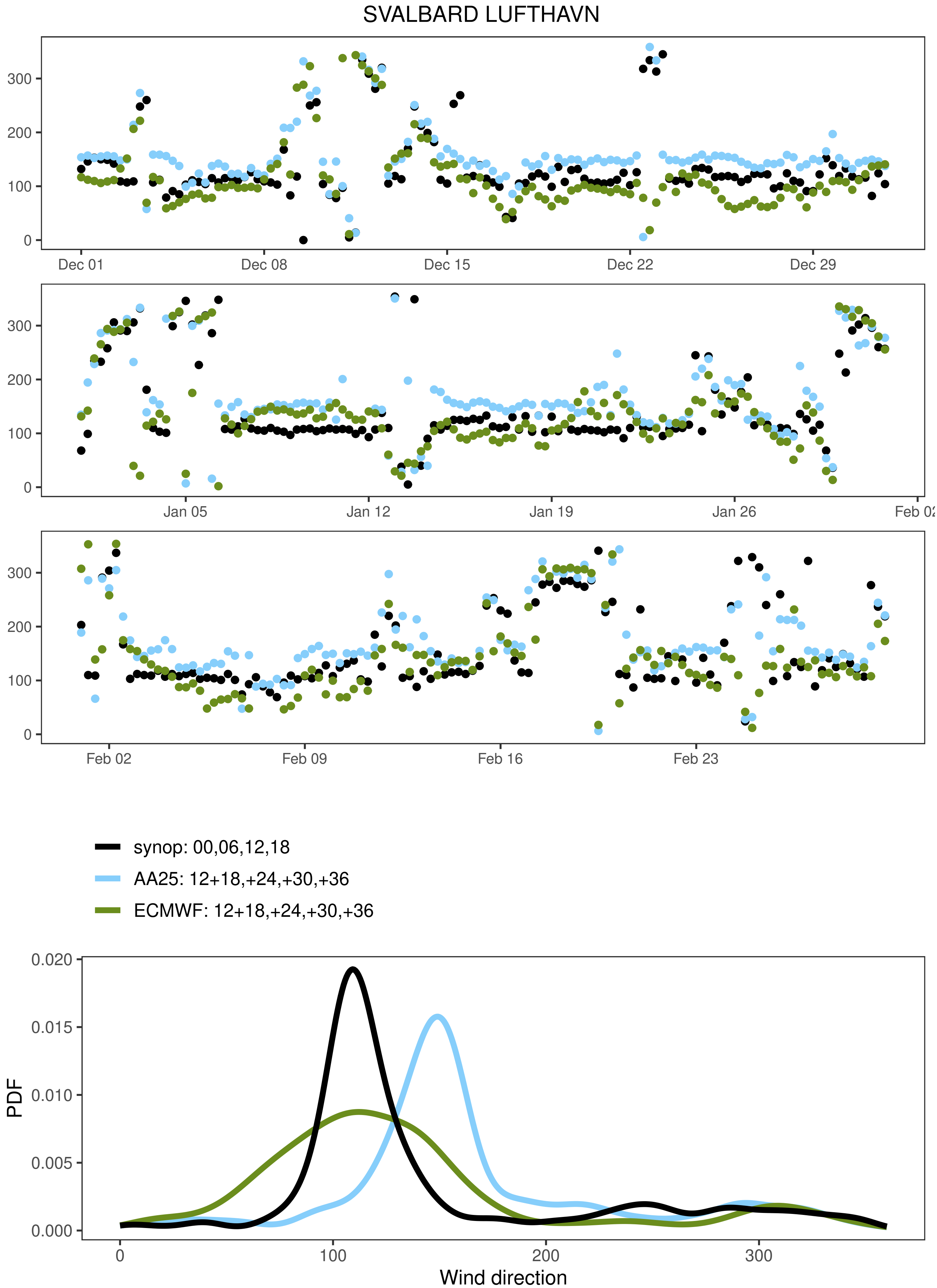


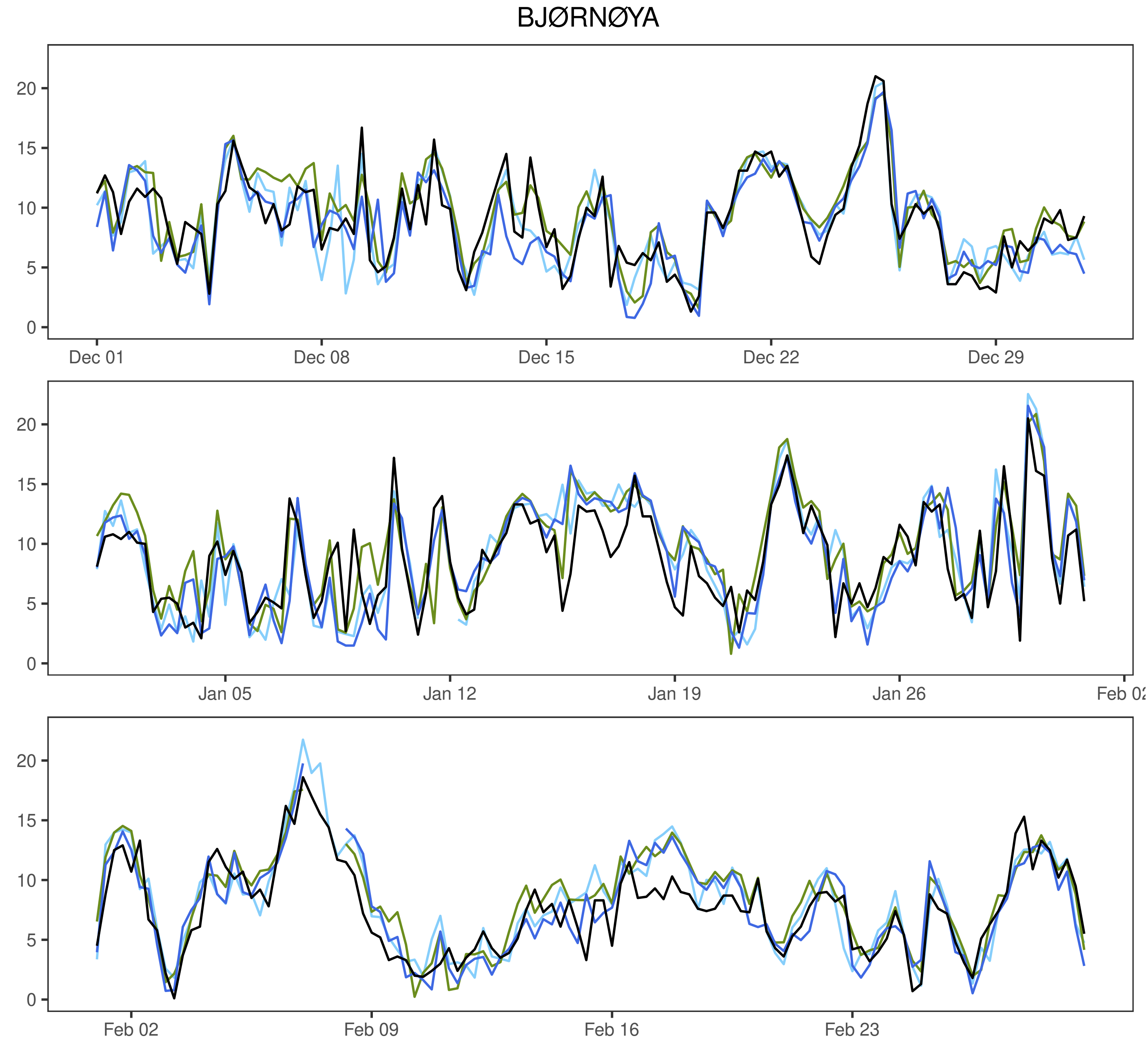
Model "climatology" 01.12.2023–29.02.2024



	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	6.3	17.3	2.9	363
AA25: 12+18,+24,+30,+36	0.7	7.3	22.5	3.9	360
ECMWF: 12+18,+24,+30,+36	0.5	3.6	8.2	1.5	360

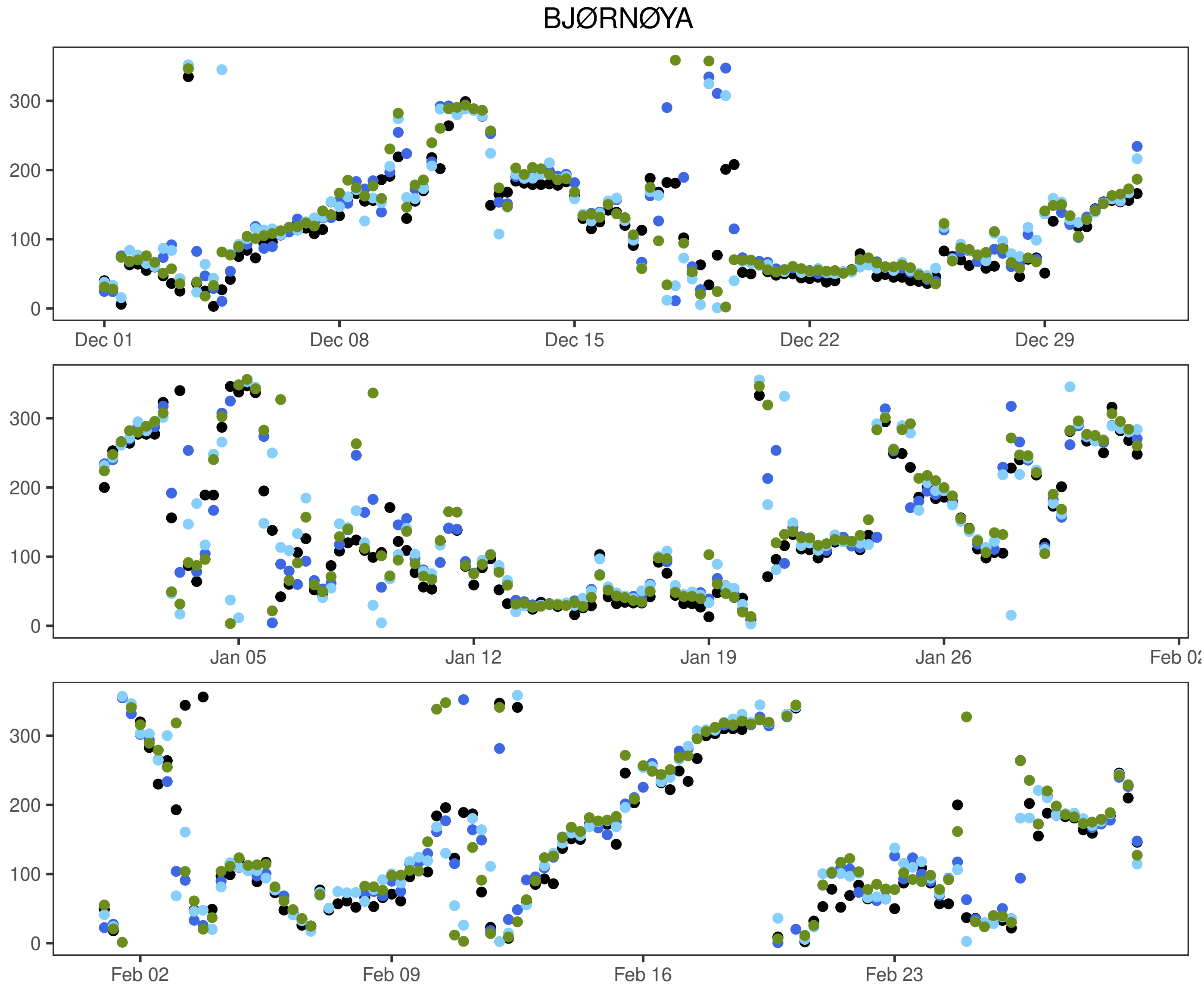
	ME	SDE	RMSE	MAE	Max.abs.err	N
AA25 – synop	1.0	2.9	3.0	2.4	9.6	355
ECMWF – synop	–2.7	2.3	3.6	3.0	10.6	355

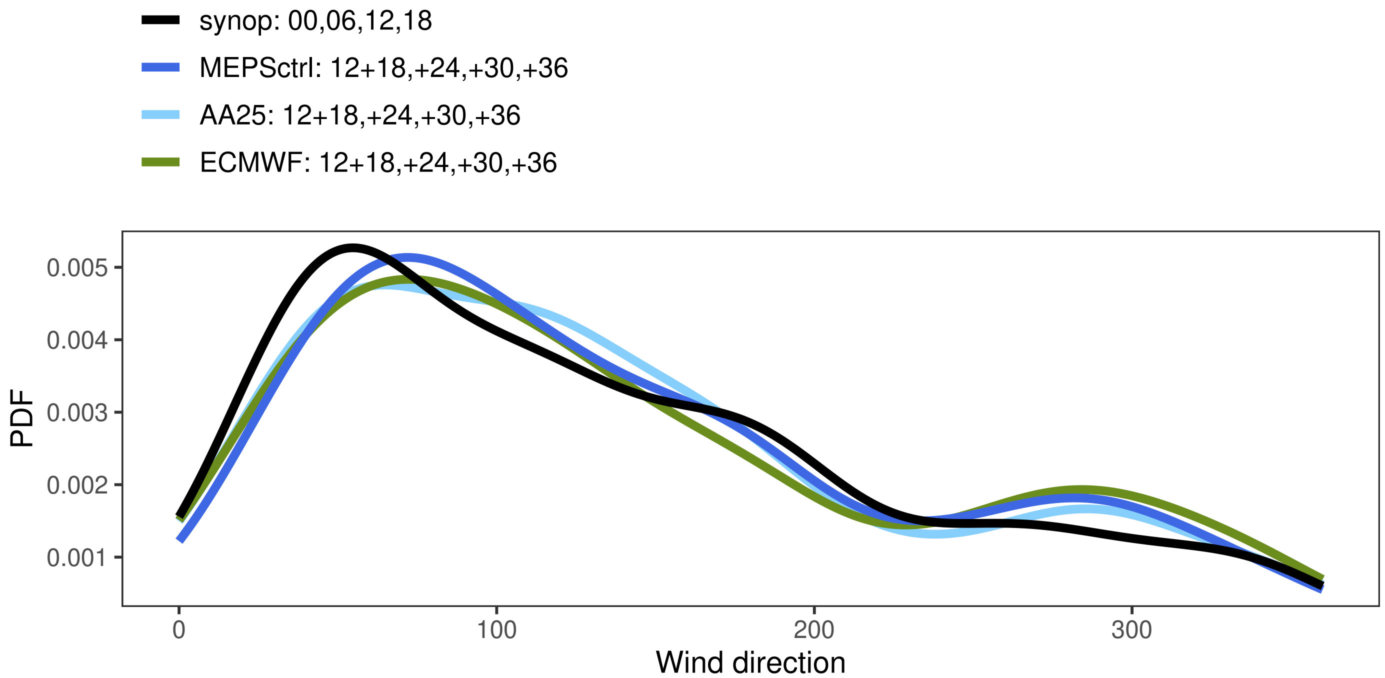

SVALBARD LUFTHAVN
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
0.020
0.015
0.010
0.005
0.000
PDF
0
100
200
300
Wind direction

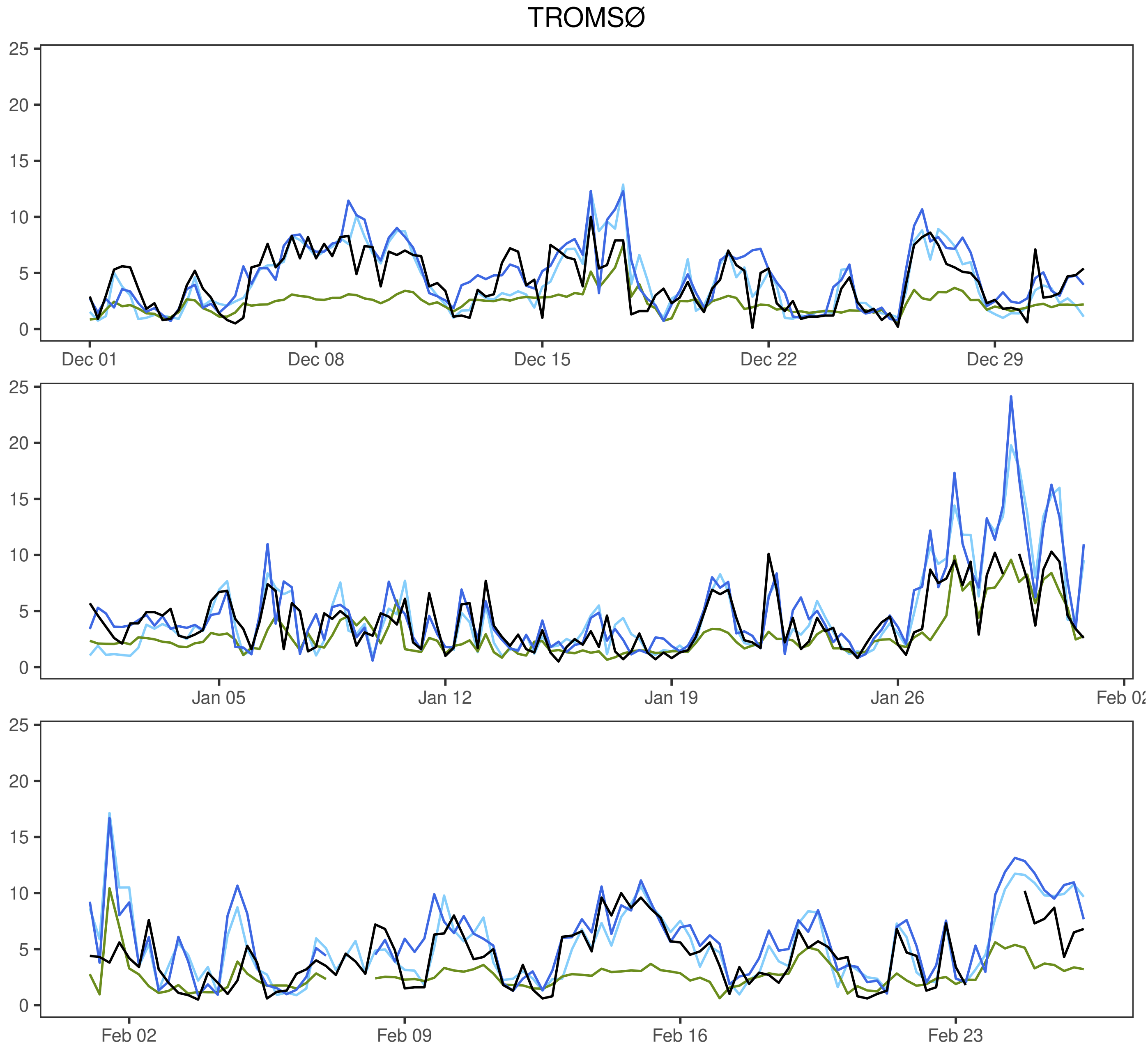


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.1	8.4	21.0	3.8	364
MEPSctrl: 12+18,+24,+30,+36	0.5	8.4	21.6	4.0	360
AA25: 12+18,+24,+30,+36	1.2	8.7	22.5	4.2	360
ECMWF: 12+18,+24,+30,+36	0.2	9.2	20.9	3.8	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.0	2.5	2.5	1.9	9.7	356
AA25 – synop	0.3	2.4	2.5	1.8	10.6	356
ECMWF – synop	0.9	2.1	2.3	1.8	8.6	356

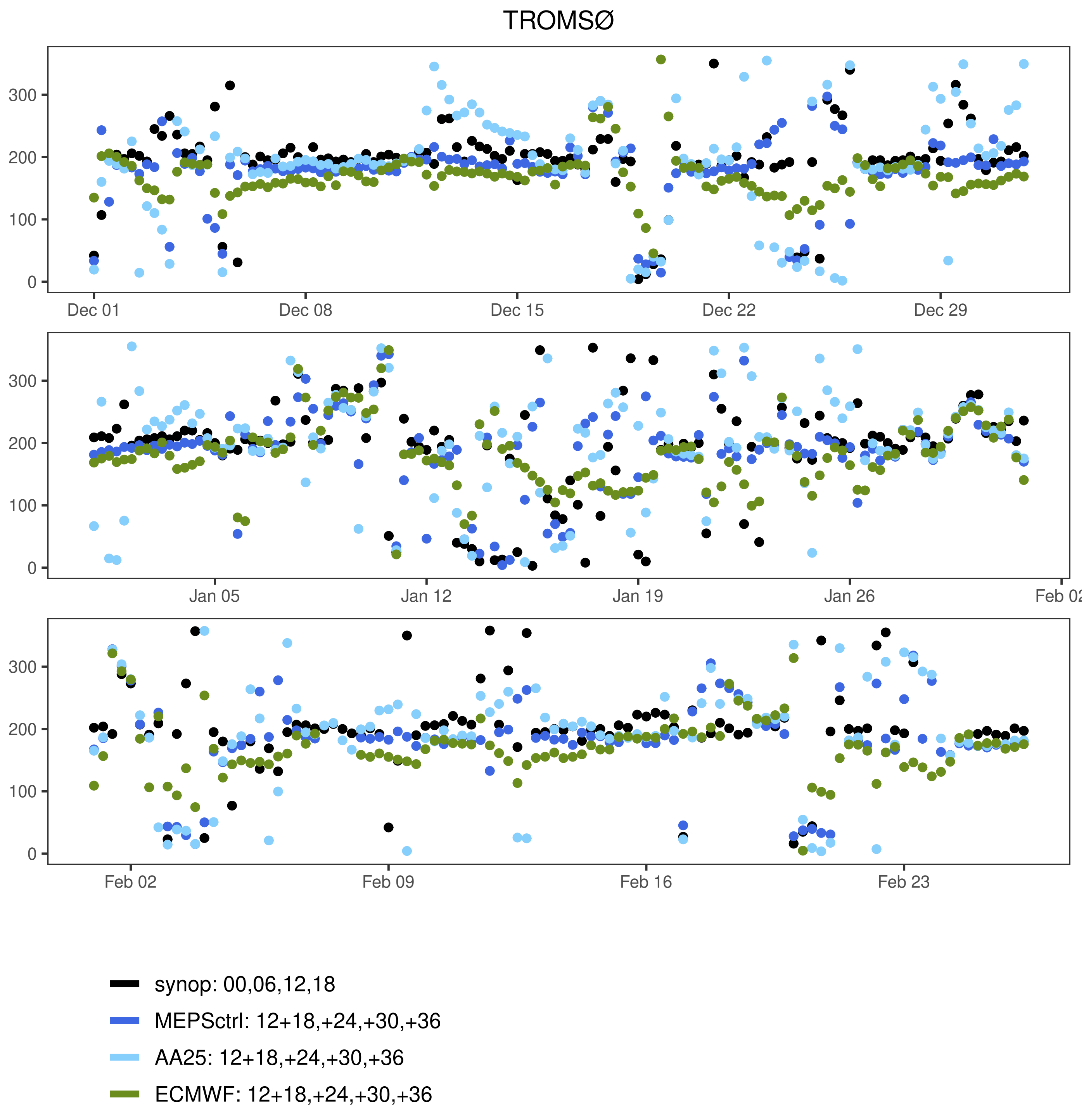

BJØRNØYA
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23

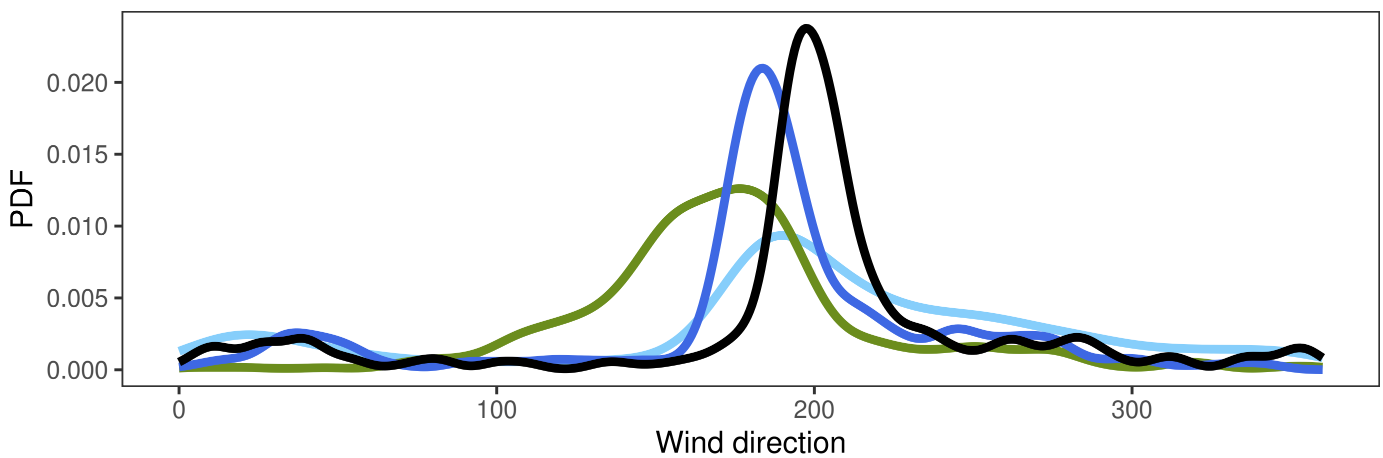

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.005
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

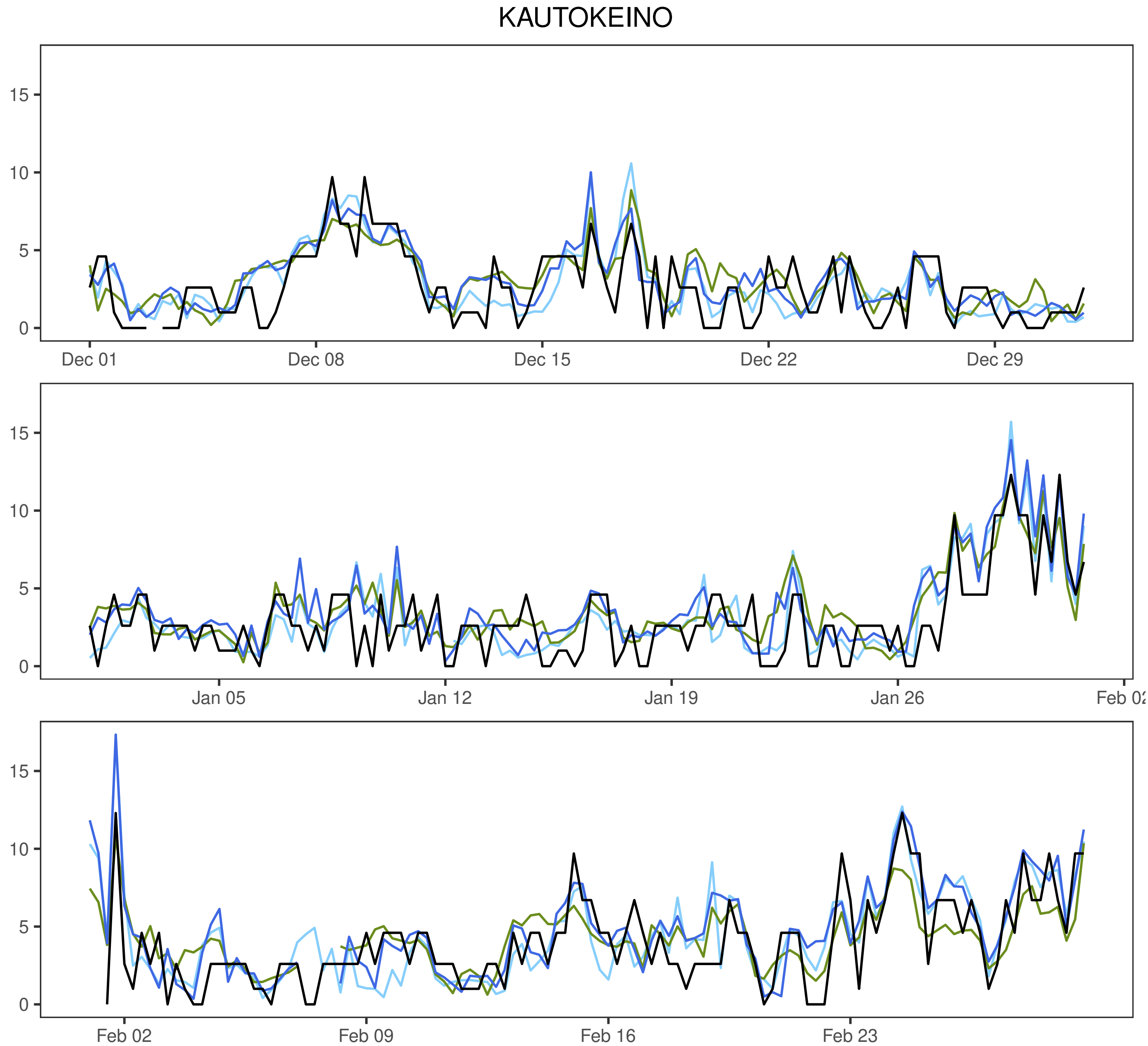


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.1	4.1	10.3	2.5	344
MEPSctrl: 12+18,+24,+30,+36	0.6	5.1	24.2	3.4	346
AA25: 12+18,+24,+30,+36	0.7	4.7	19.8	3.4	346
ECMWF: 12+18,+24,+30,+36	0.6	2.6	10.4	1.5	346

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.9	2.1	2.3	1.6	12.9	336
AA25 – synop	0.5	2.2	2.2	1.6	13.3	336
ECMWF – synop	−1.6	2.0	2.5	2.0	7.0	336

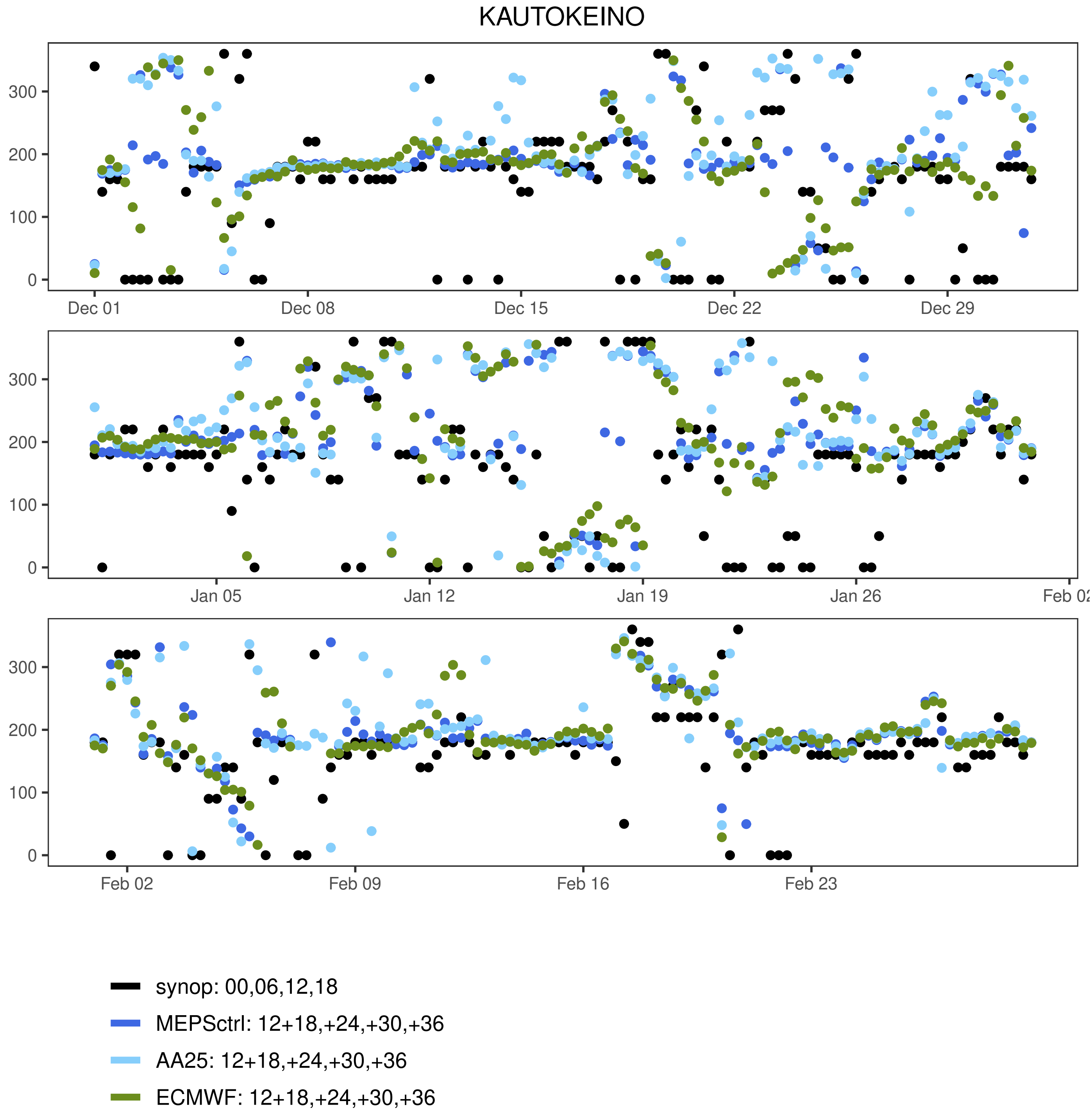

TROMSØ
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

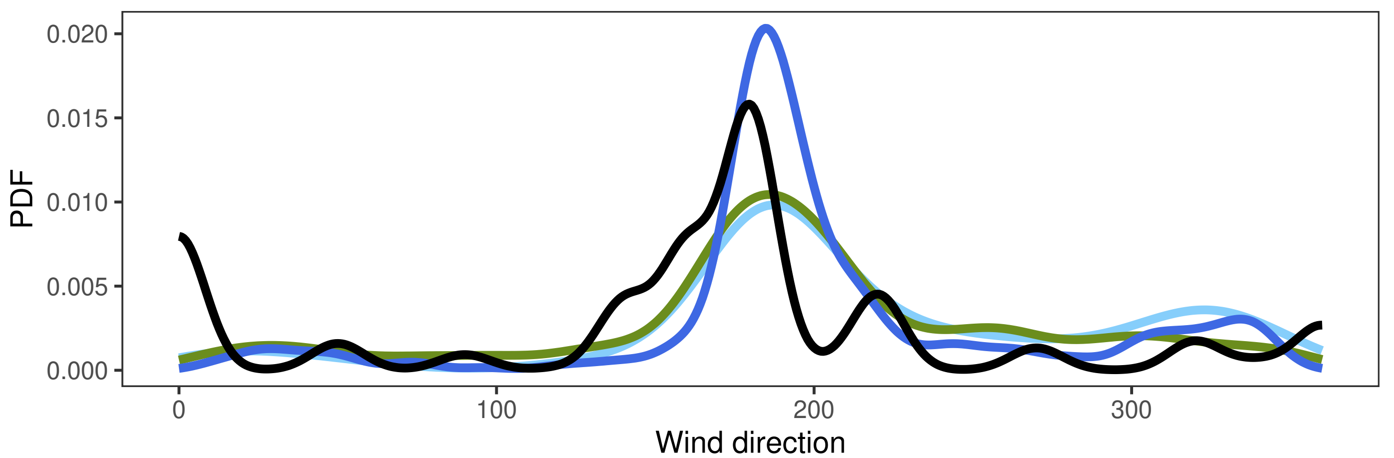

PDF
0.020
0.015
0.010
0.005
0.000
0
100
200
300
Wind direction

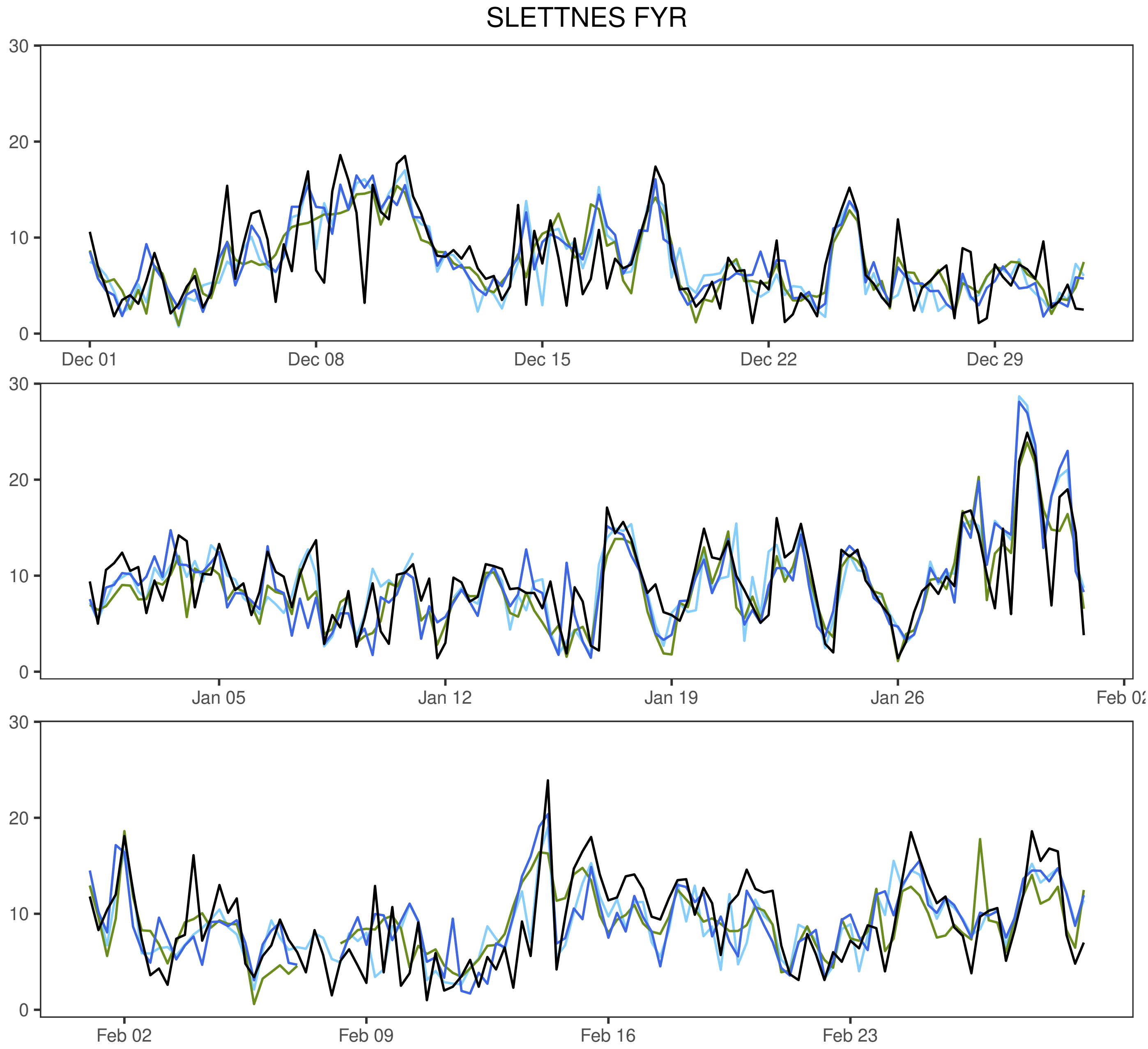


		Min	Mean	Max	Std	N
	synop: 00,06,12,18	0.0	3.2	12.3	2.6	362
	MEPSctrl: 12+18,+24,+30,+36	0.3	3.9	17.3	2.7	360
	AA25: 12+18,+24,+30,+36	0.2	3.5	17.2	2.8	360
	ECMWF: 12+18,+24,+30,+36	0.2	3.6	12.2	2.1	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.7	1.8	1.9	1.5	6.5	354
AA25 – synop	0.3	1.8	1.9	1.5	6.7	354
ECMWF – synop	0.5	1.8	1.8	1.5	5.4	354

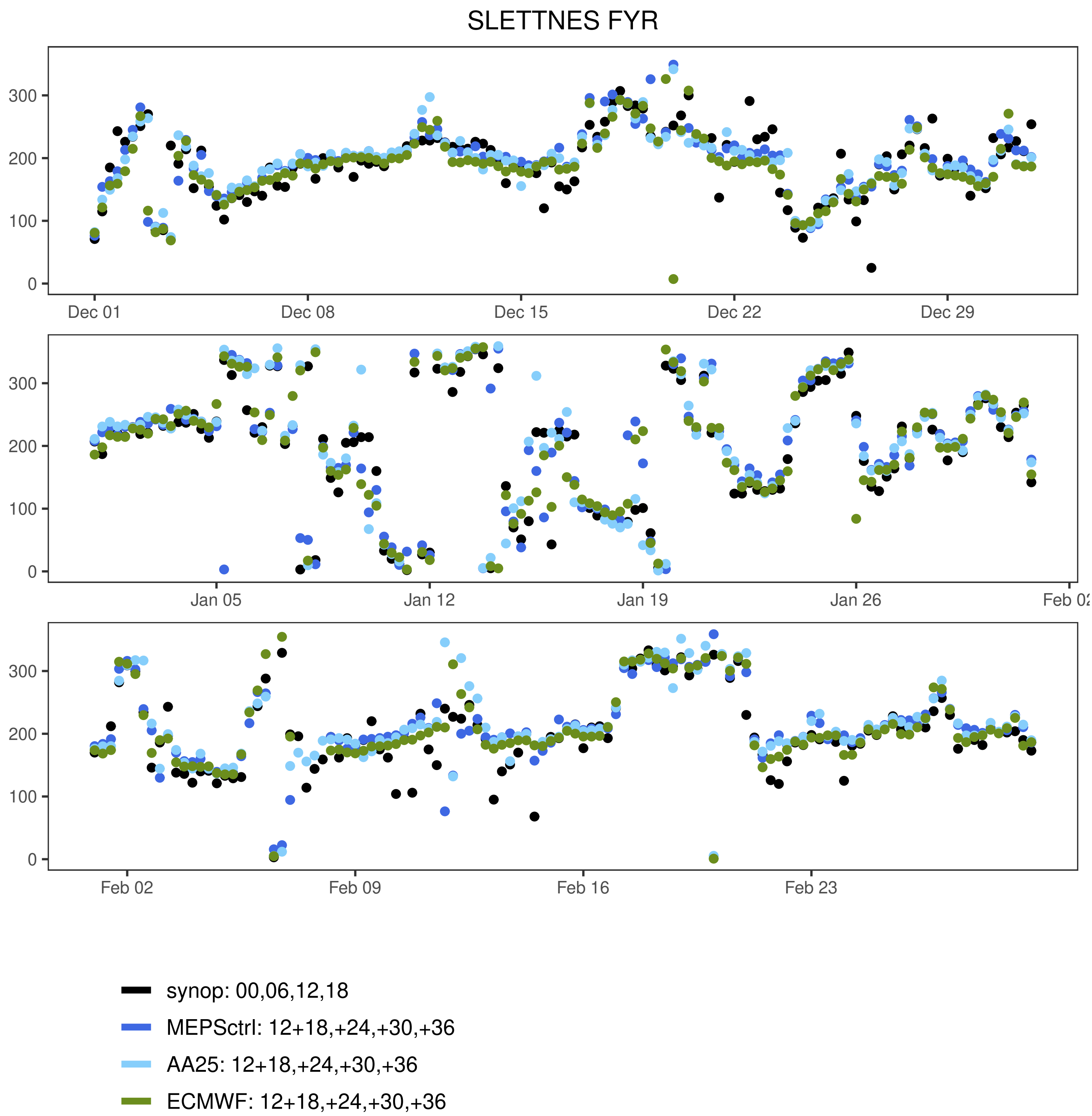

KAUTOKEINO
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

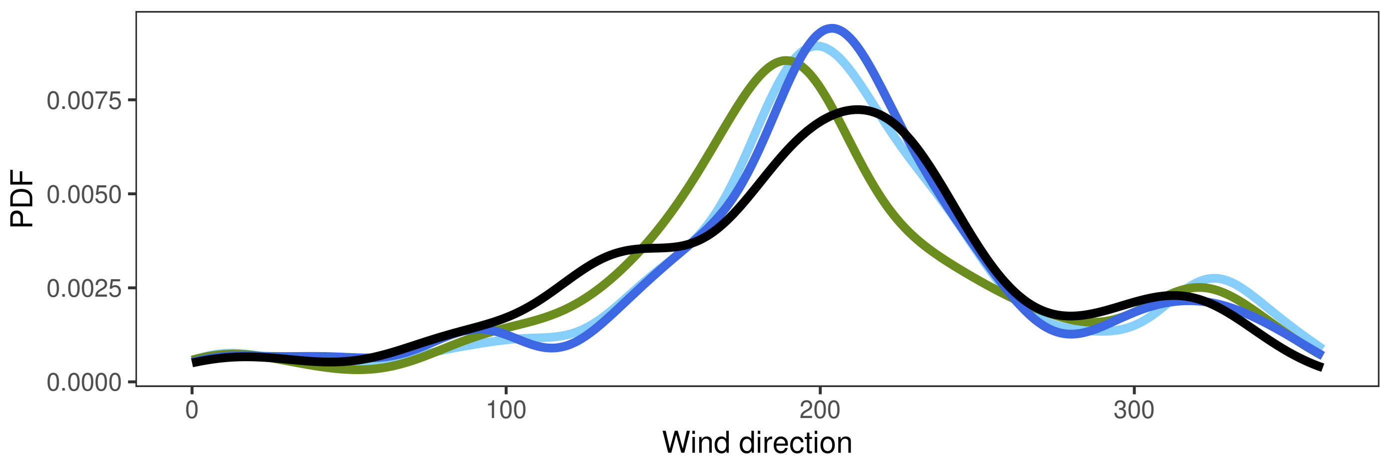

PDF
0.020
0.015
0.010
0.005
0.000
0
100
200
300
Wind direction

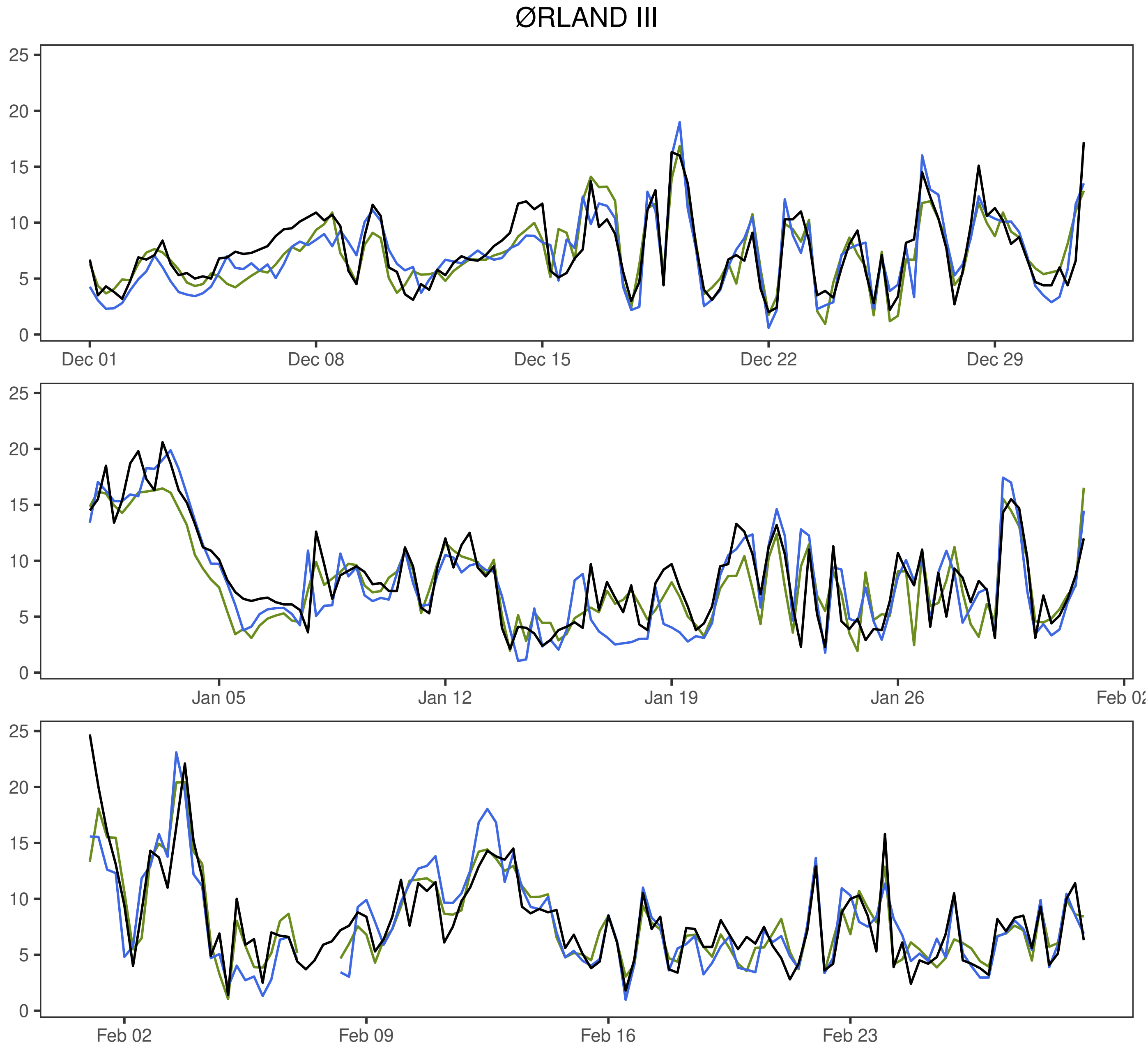


	Min	Mean	Max	Std	N
synop: 00,06,12,18	1.0	8.6	24.9	4.5	364
MEPSctrl: 12+18,+24,+30,+36	1.4	8.7	28.1	4.2	360
AA25: 12+18,+24,+30,+36	0.7	8.6	28.7	4.1	360
ECMWF: 12+18,+24,+30,+36	0.6	8.3	23.9	3.7	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.0	3.3	3.3	2.5	12.0	356
AA25 – synop	−0.1	3.1	3.1	2.4	12.9	356
ECMWF – synop	−0.3	3.0	3.0	2.3	11.4	356

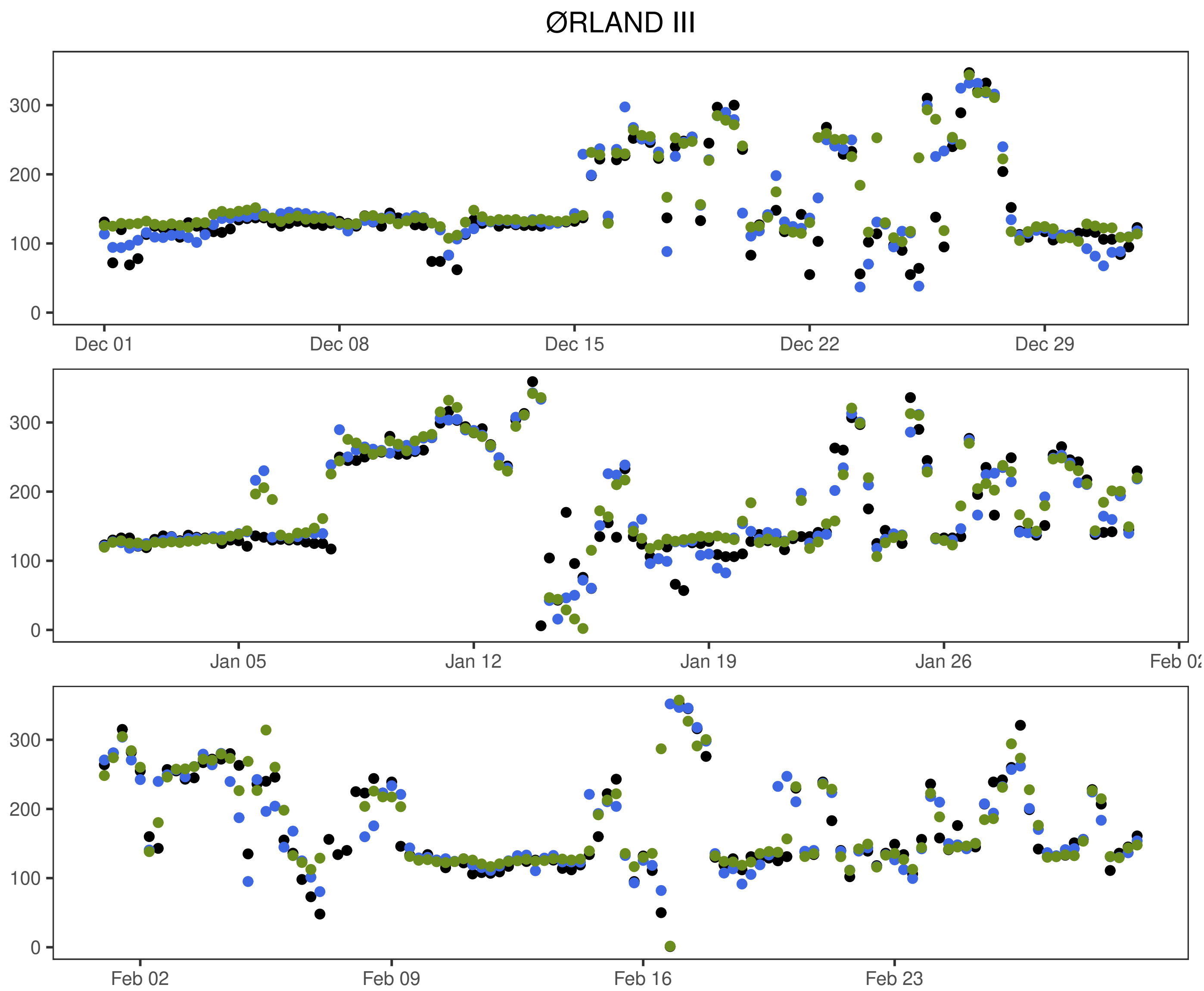

SLETTNES FYR
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

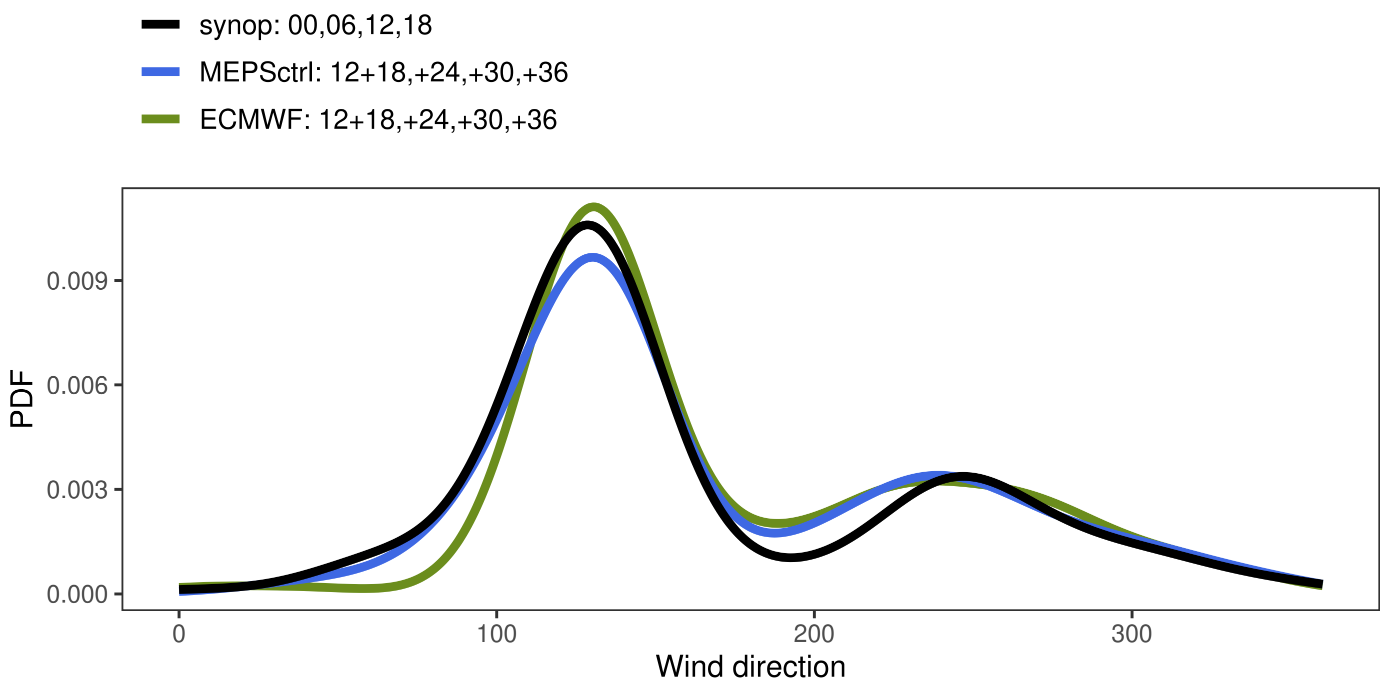

PDF
0.0075
0.0050
0.0025
0.0000
0
100
200
300
Wind direction

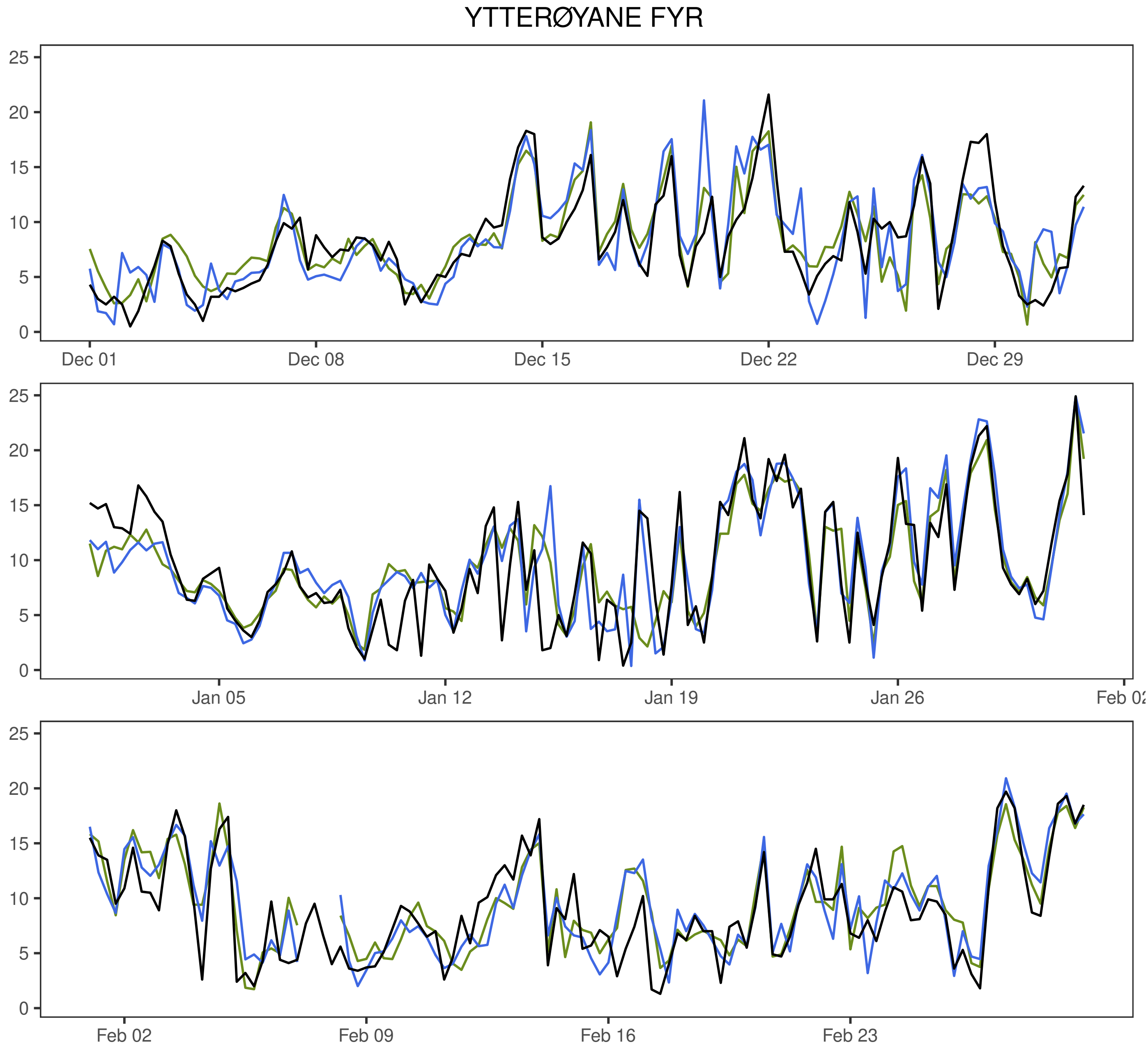


	Min	Mean	Max	Std	N
synop: 00,06,12,18	1.4	8.0	24.7	3.9	364
MEPSctrl: 12+18,+24,+30,+36	0.6	7.7	23.1	4.0	360
ECMWF: 12+18,+24,+30,+36	0.9	7.7	20.4	3.5	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.3	2.2	2.2	1.7	10.5	360
ECMWF – synop	–0.3	1.9	2.0	1.5	11.4	360

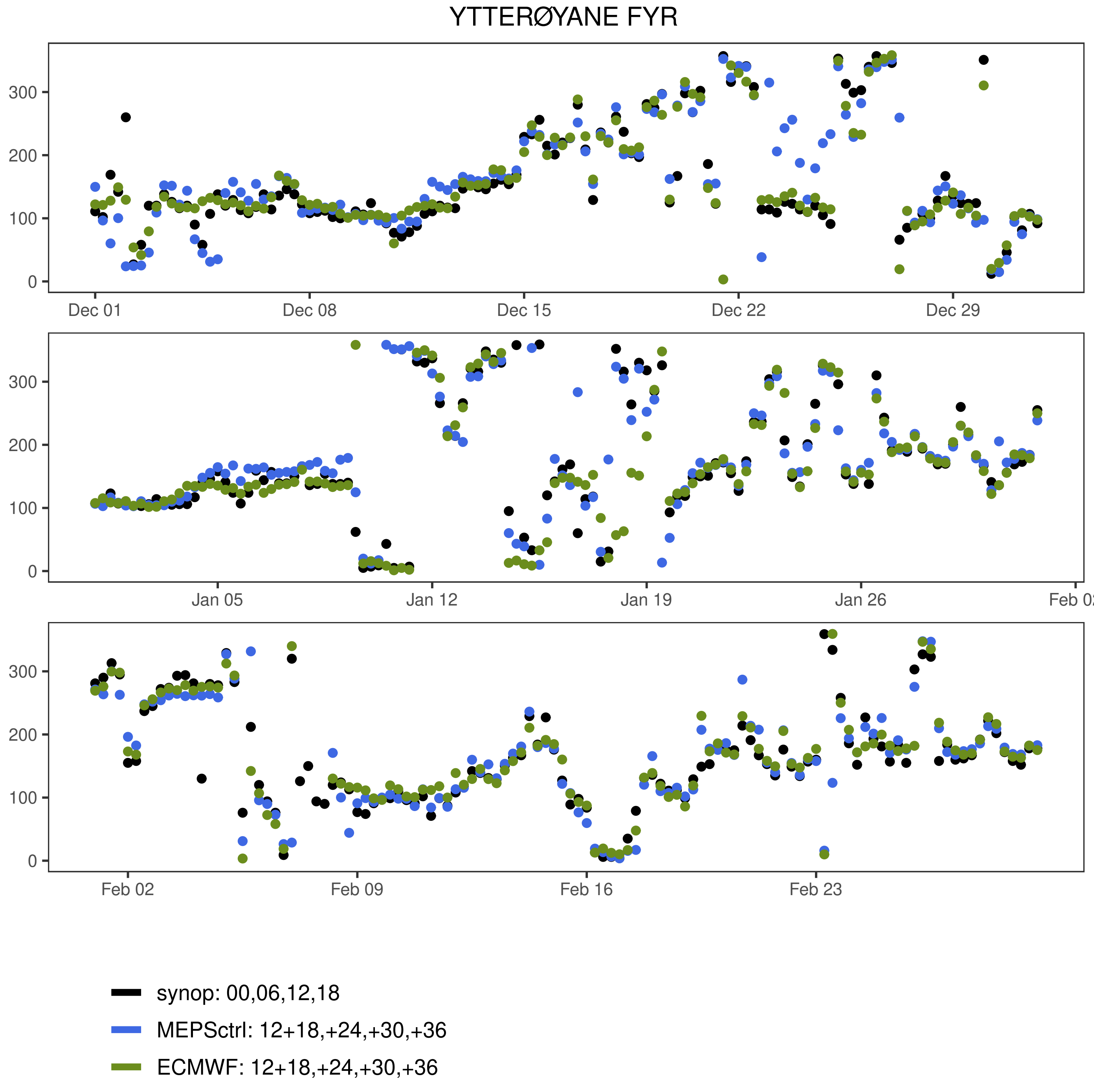

ØRLAND III
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23

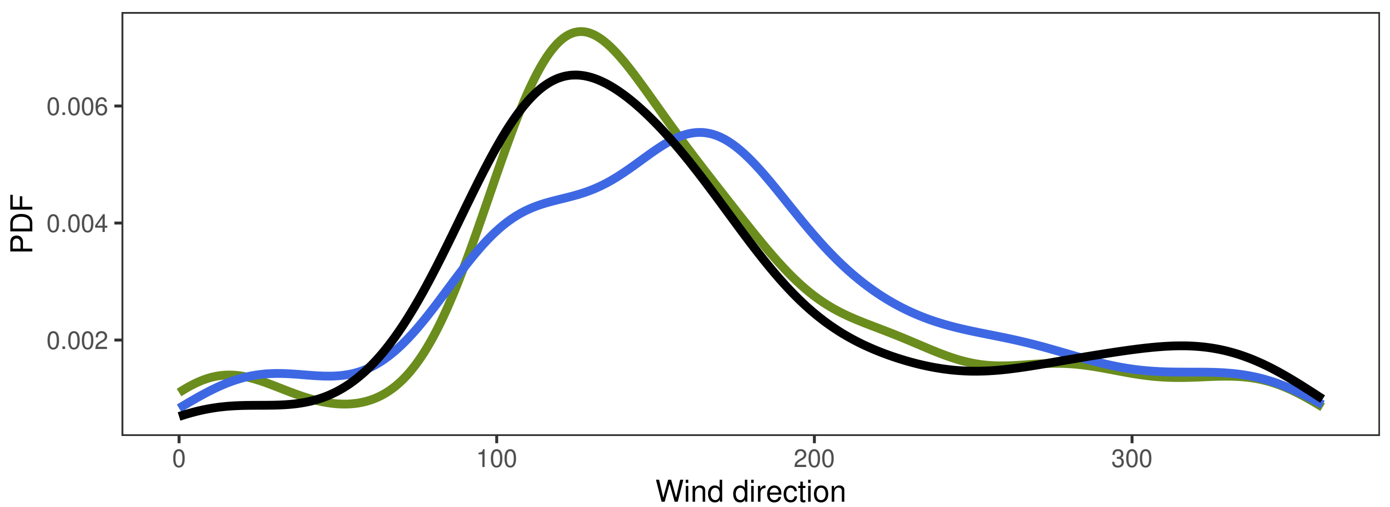

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.009
0.006
0.003
0.000
0
100
200
300
Wind direction

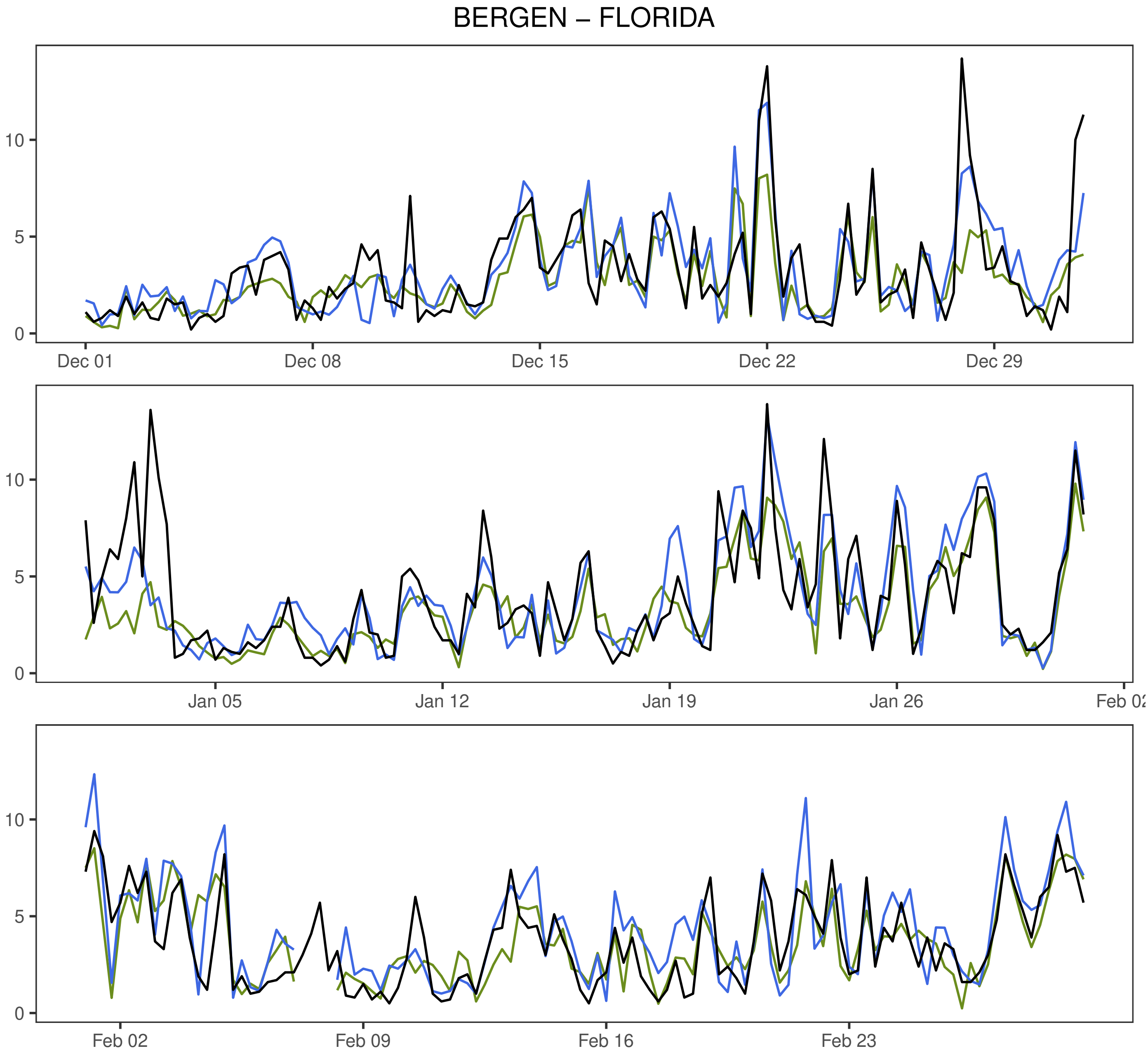


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.4	8.9	24.9	4.8	364
MEPSctrl: 12+18,+24,+30,+36	0.4	9.2	24.9	4.8	360
ECMWF: 12+18,+24,+30,+36	0.7	9.1	24.9	4.2	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.3	2.9	2.9	2.1	14.7	360
ECMWF – synop	0.2	2.7	2.7	2.0	11.7	360

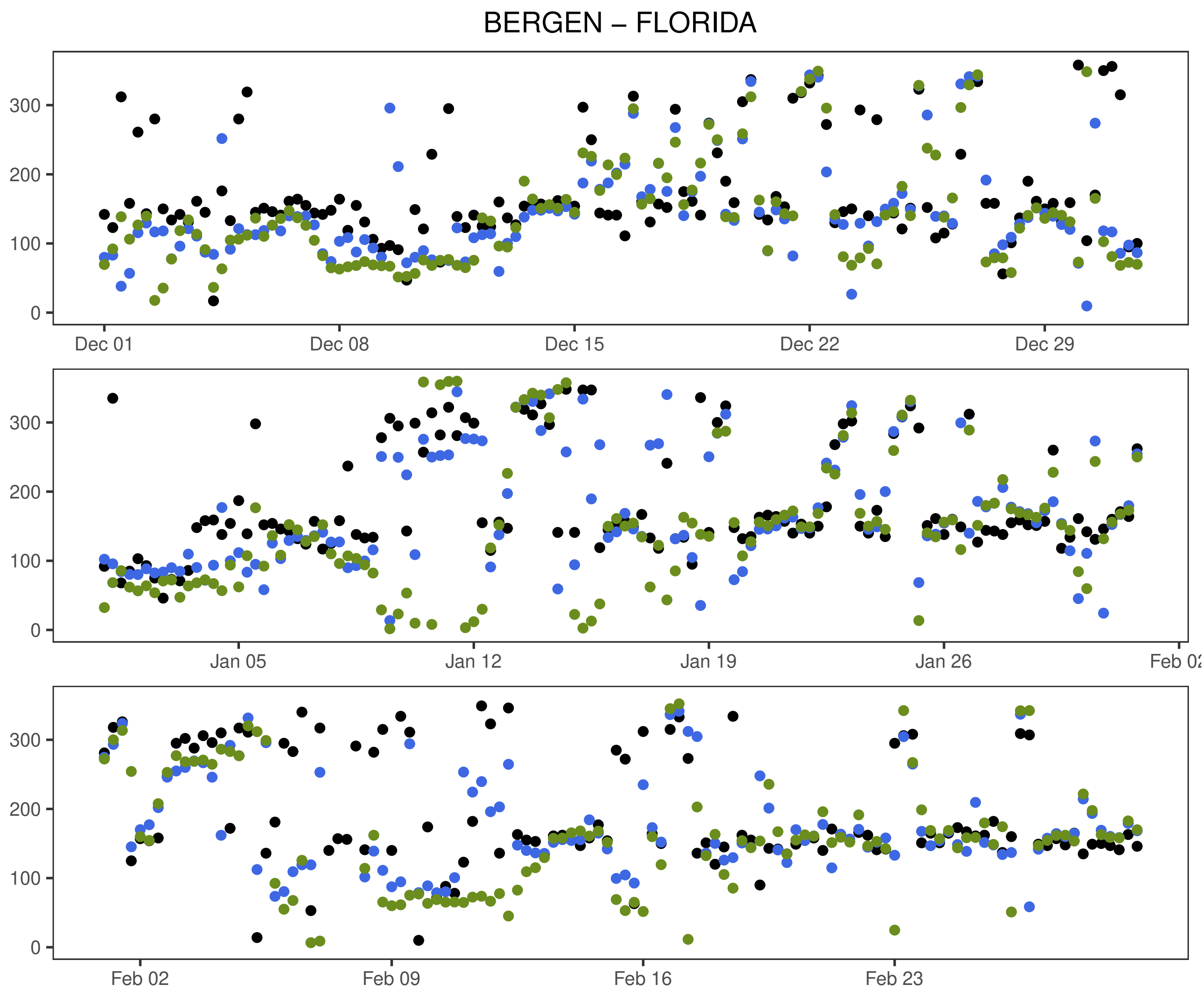

YTTERØYANE FYR
0
100
200
300
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

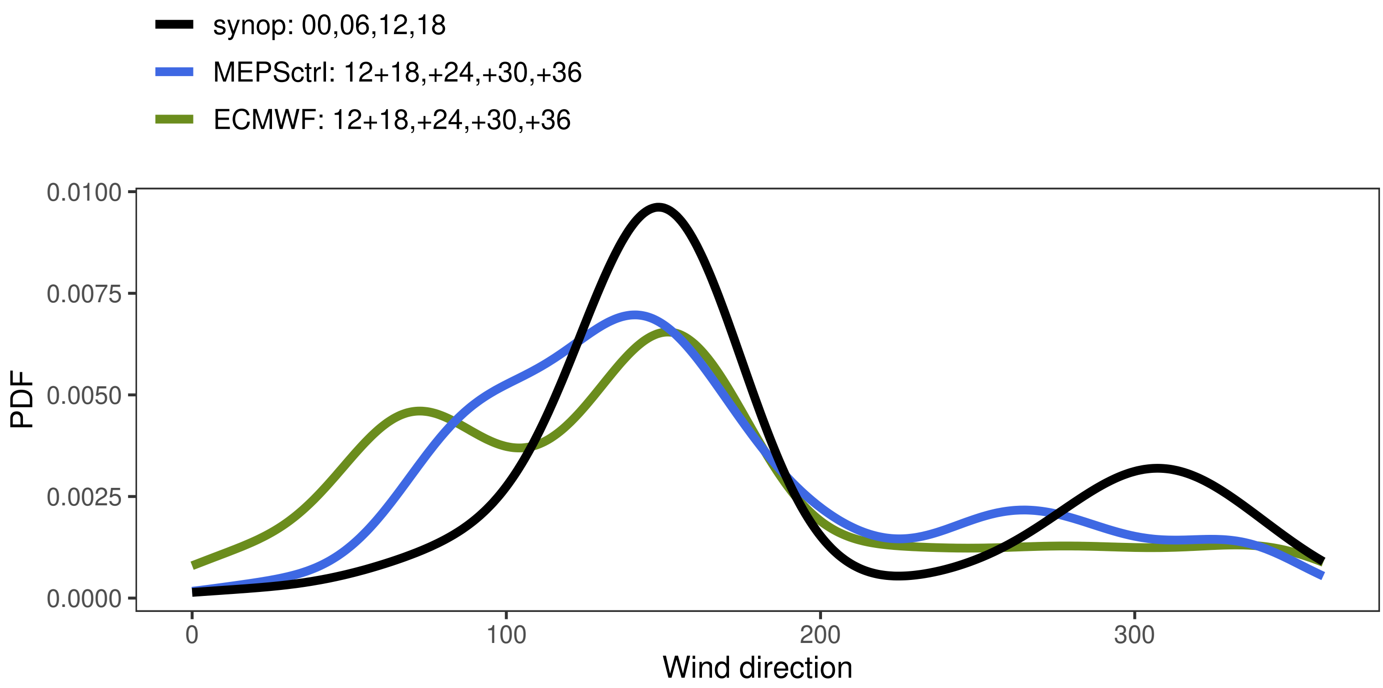

PDF
0.002
0.004
0.006
0
100
200
300
Wind direction

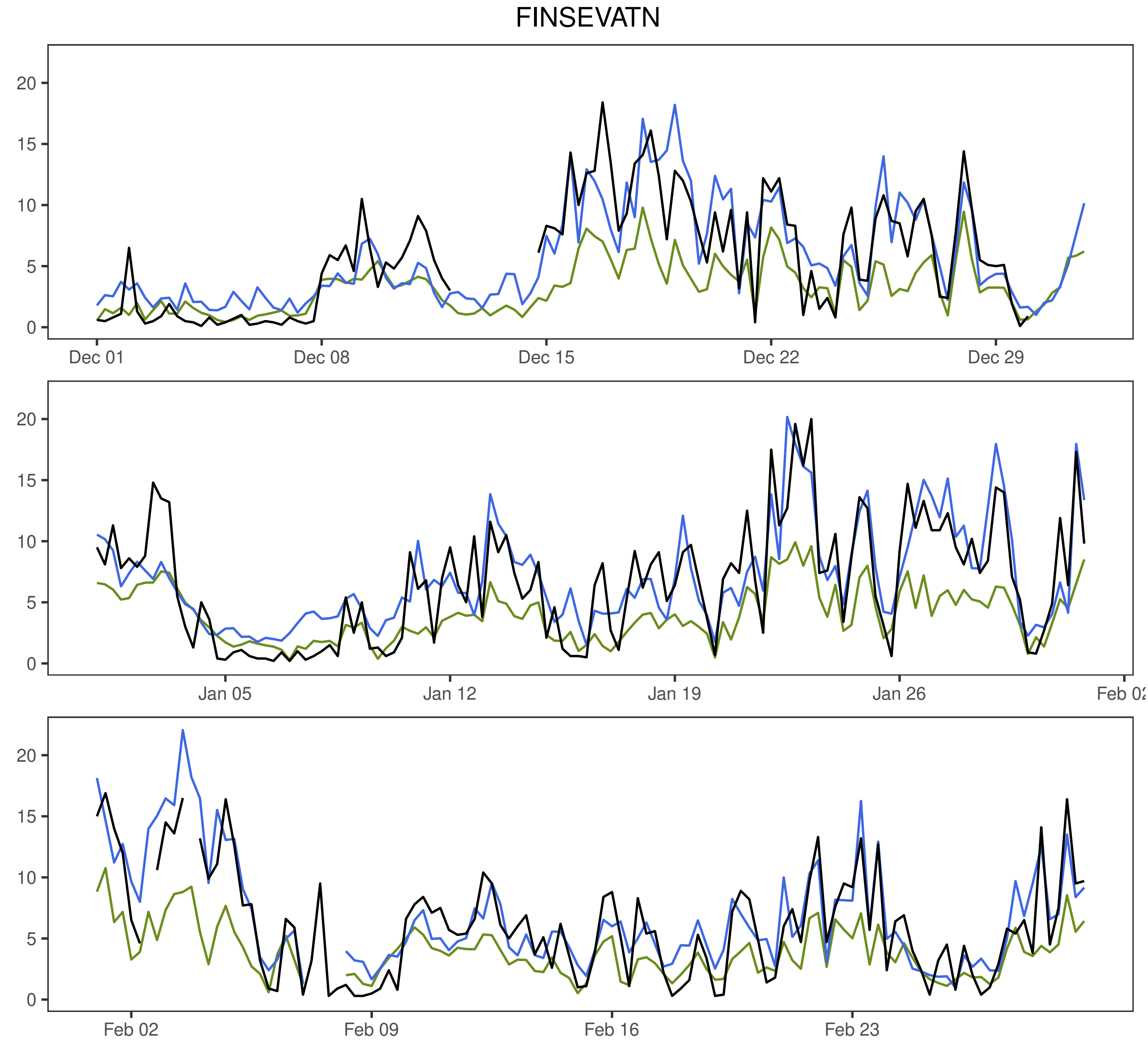


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.2	3.6	14.2	2.7	364
MEPSctrl: 12+18,+24,+30,+36	0.3	3.9	13.3	2.6	360
ECMWF: 12+18,+24,+30,+36	0.2	3.2	9.8	2.0	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.3	1.8	1.8	1.3	10.1	360
ECMWF – synop	–0.4	1.9	1.9	1.3	11.1	360

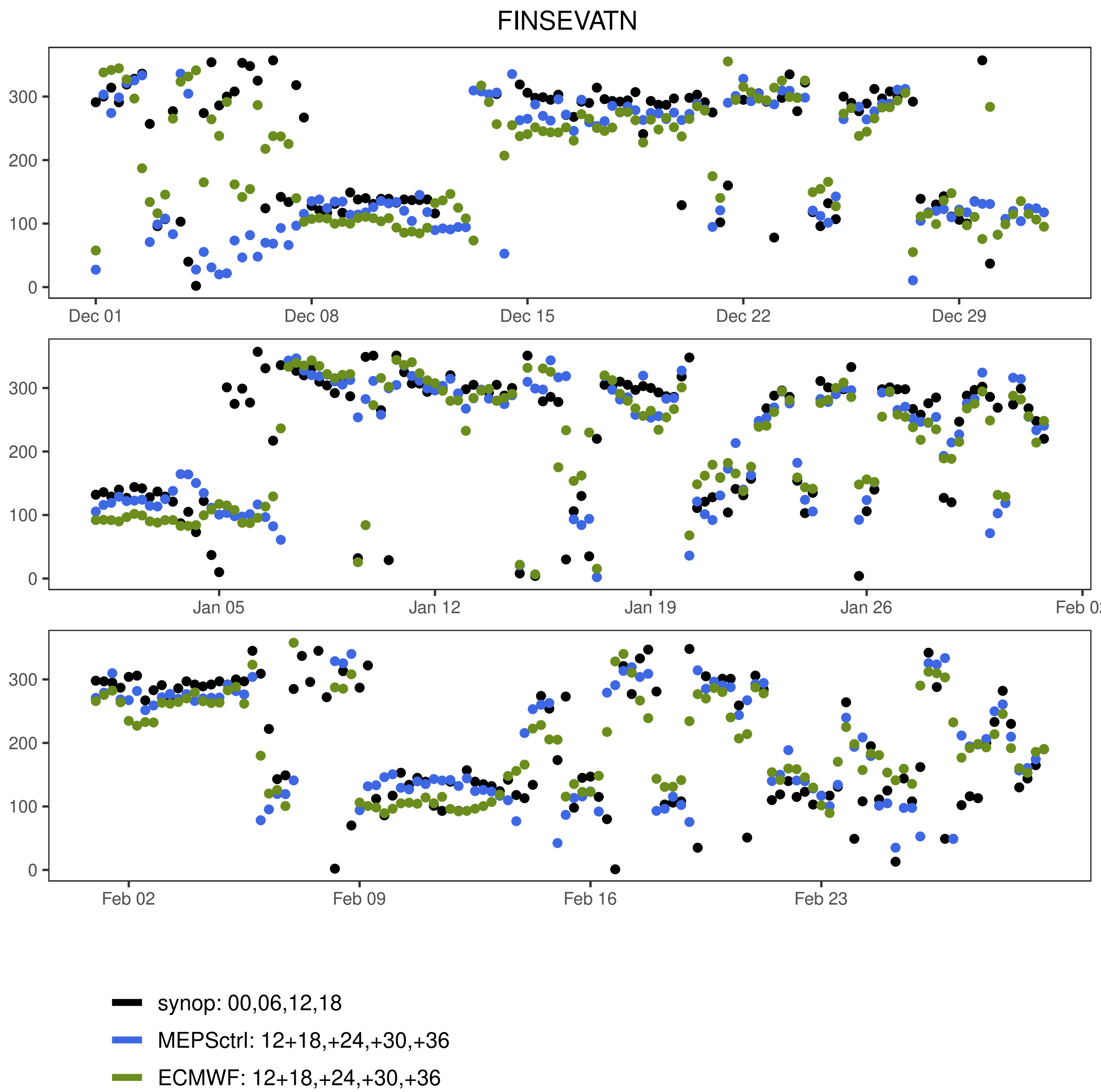

BERGEN – FLORIDA
0
100
200
300
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23

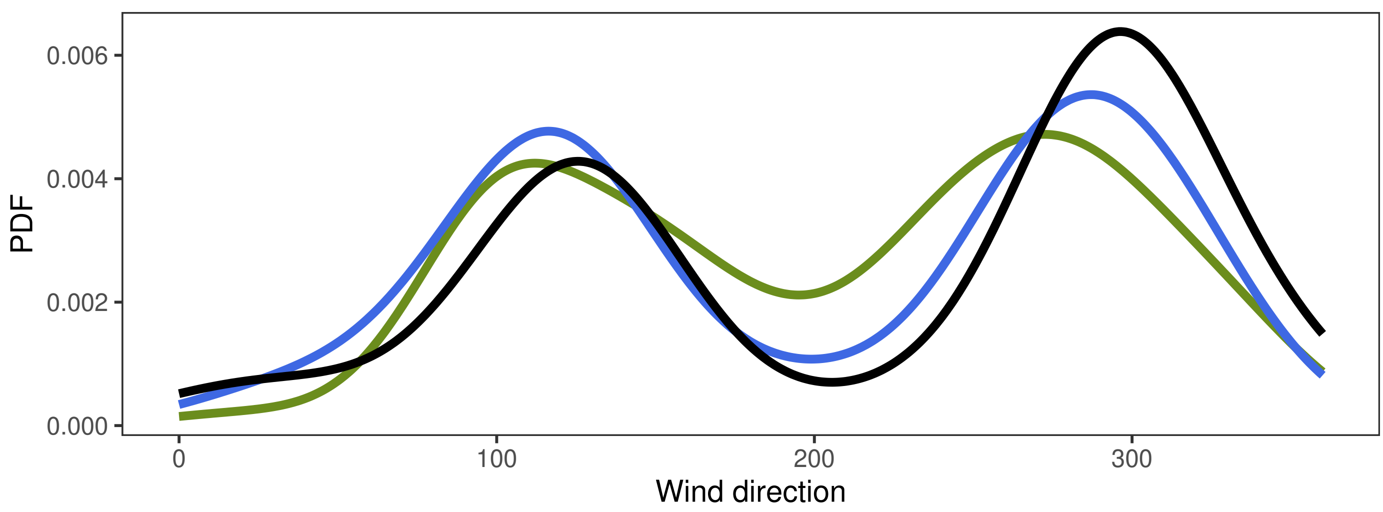

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.0000
0.0025
0.0050
0.0075
0.0100
0
100
200
300
Wind direction

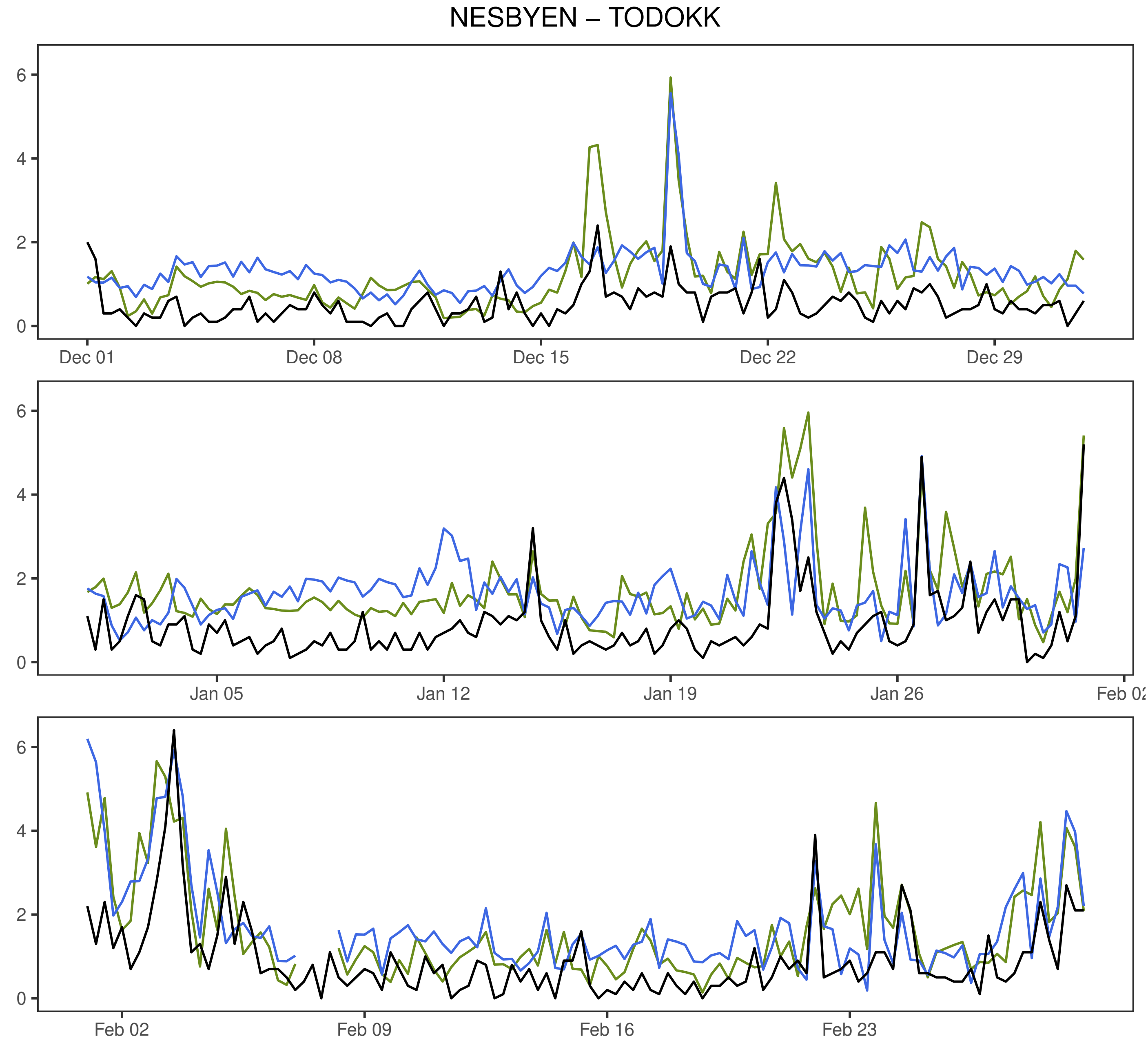


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.1	6.2	20.0	4.6	347
MEPSctrl: 12+18,+24,+30,+36	1.0	6.5	22.0	4.2	360
ECMWF: 12+18,+24,+30,+36	0.3	3.7	10.8	2.2	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.4	2.5	2.5	2.0	7.9	343
ECMWF – synop	–2.4	2.9	3.8	3.0	11.4	343

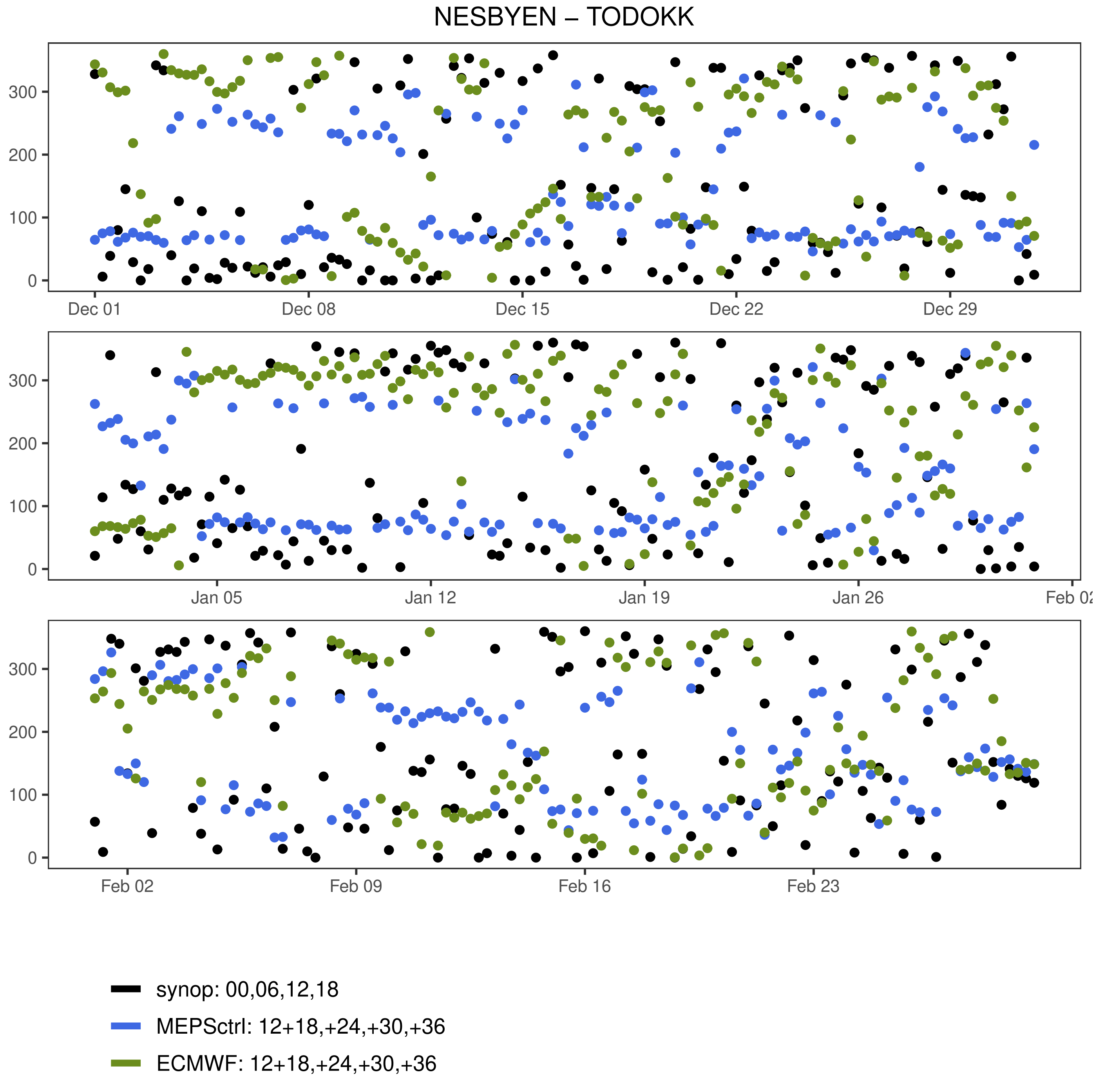

FINSEVATN
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

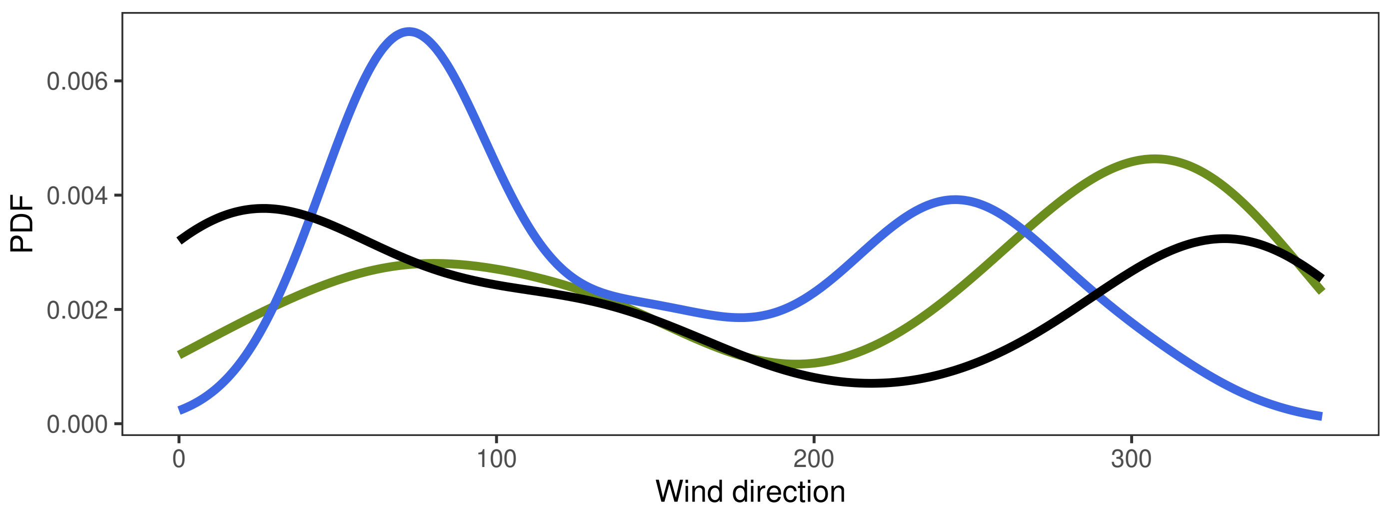

PDF
0.006
0.004
0.002
0.000
0
100
200
300
Wind direction

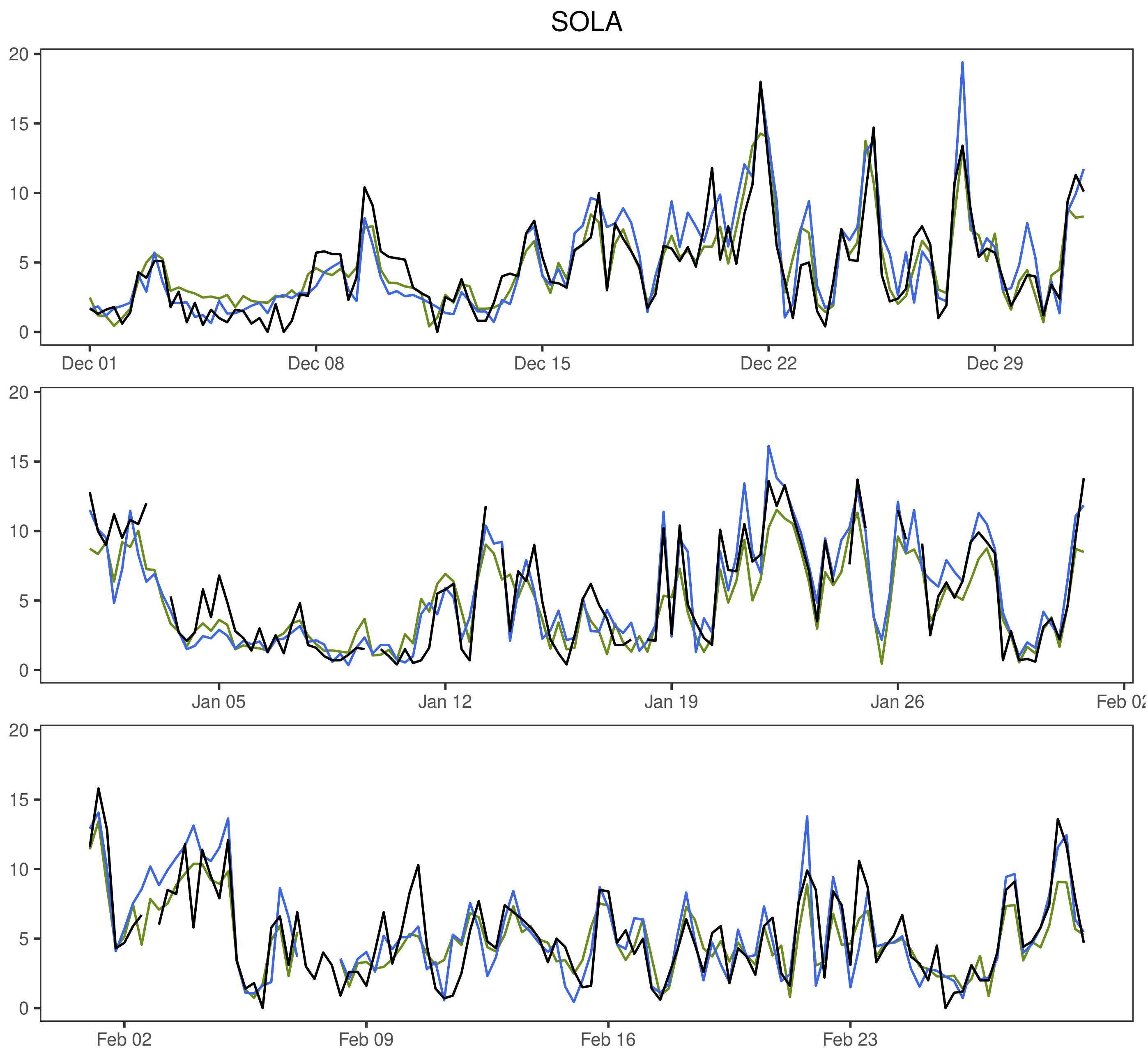


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	0.8	6.4	0.8	364
MEPSctrl: 12+18,+24,+30,+36	0.2	1.6	6.2	0.9	360
ECMWF: 12+18,+24,+30,+36	0.1	1.5	6.0	1.0	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.8	0.7	1.1	0.9	4.3	360
ECMWF – synop	0.7	0.7	1.0	0.8	4.0	360

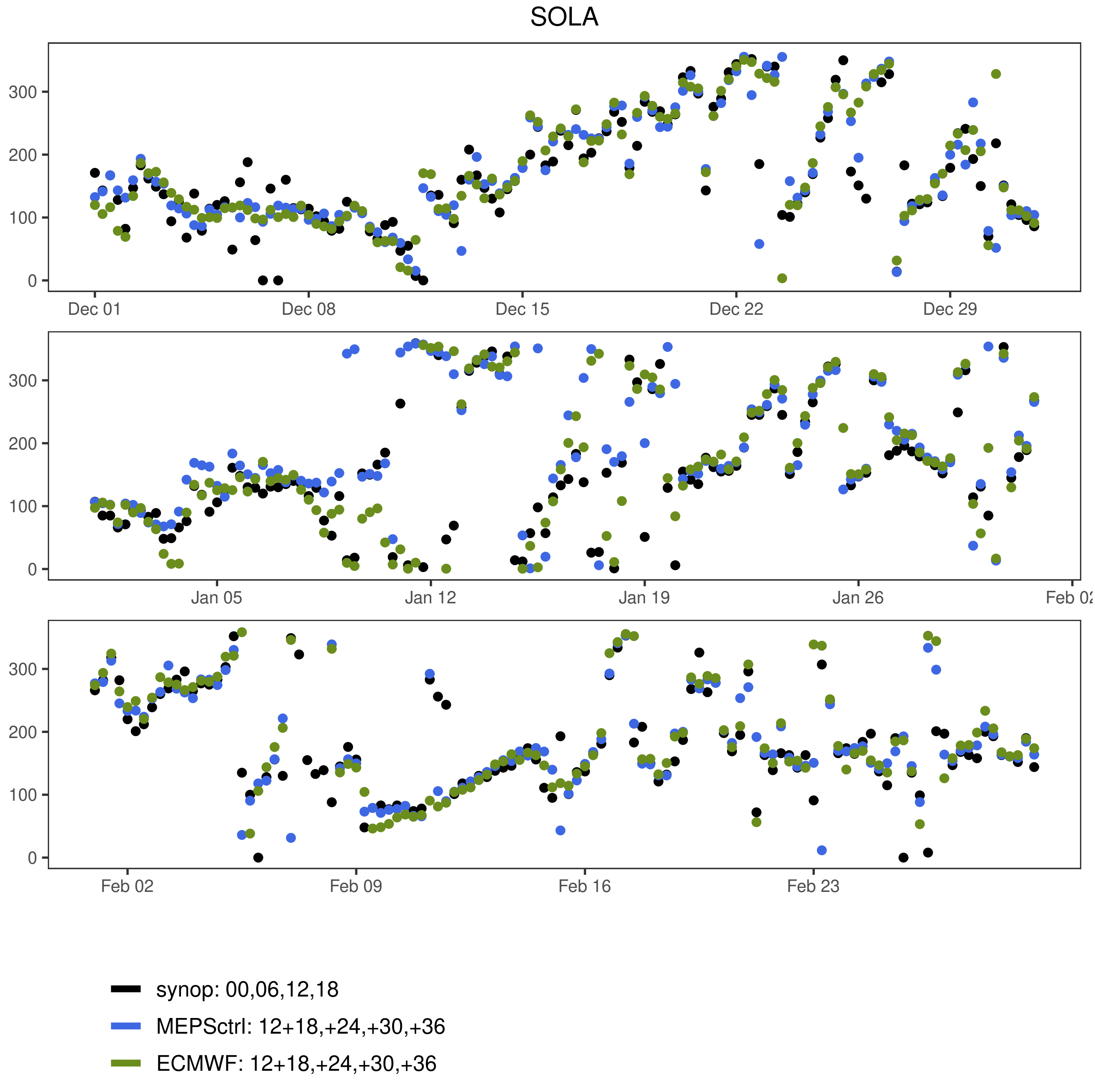

NESBYEN – TODOKK
0
100
200
300
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

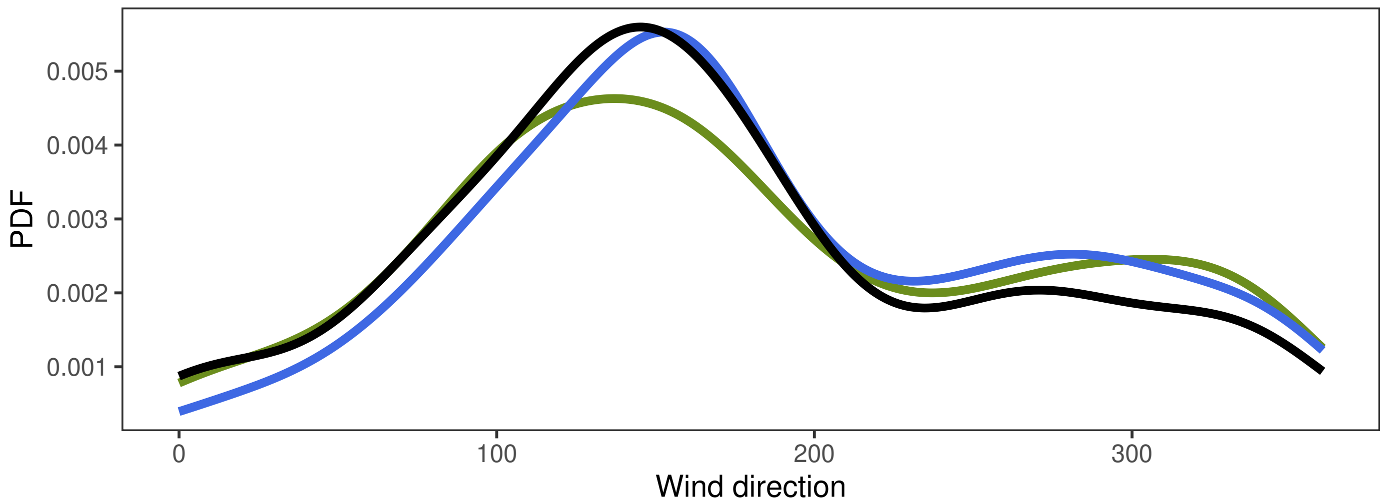

PDF
0.000
0.002
0.004
0.006
0
100
200
300
Wind direction

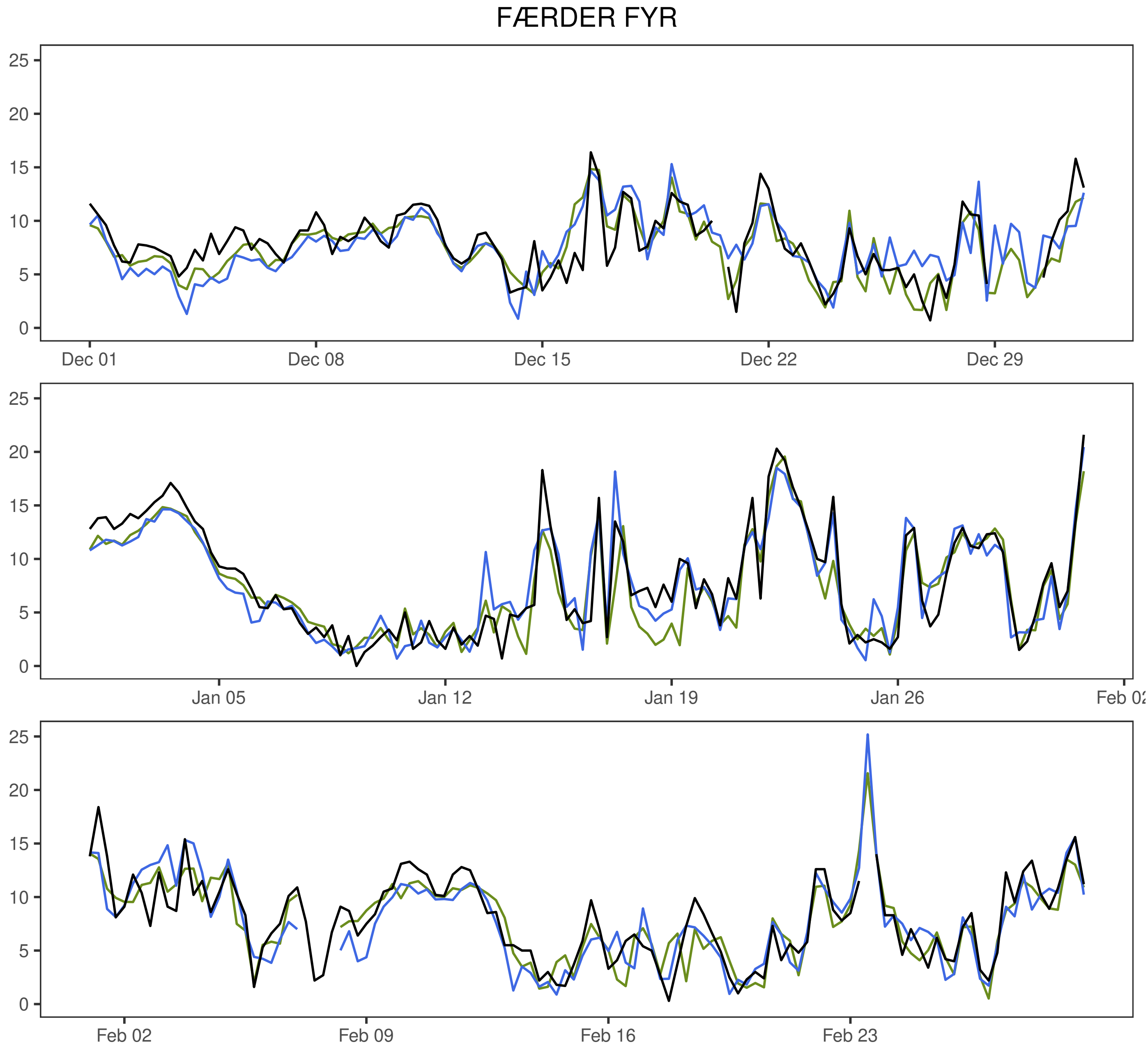


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	5.1	18.0	3.5	353
MEPSctrl: 12+18,+24,+30,+36	0.4	5.3	19.4	3.6	360
ECMWF: 12+18,+24,+30,+36	0.4	4.8	14.3	2.8	360

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.2	1.9	1.9	1.4	7.3	349
ECMWF – synop	−0.3	1.8	1.8	1.4	5.7	349

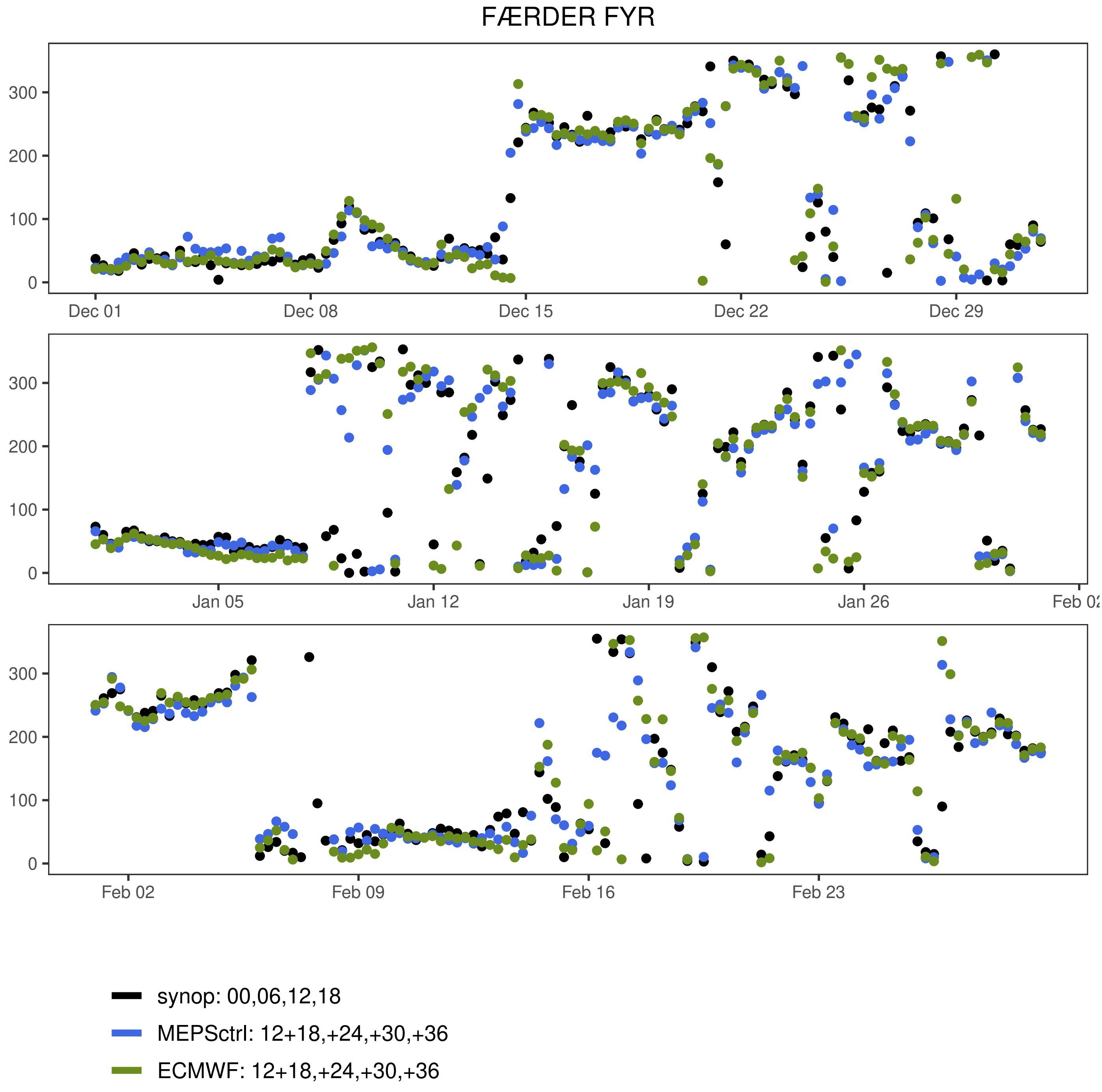

SOLA
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

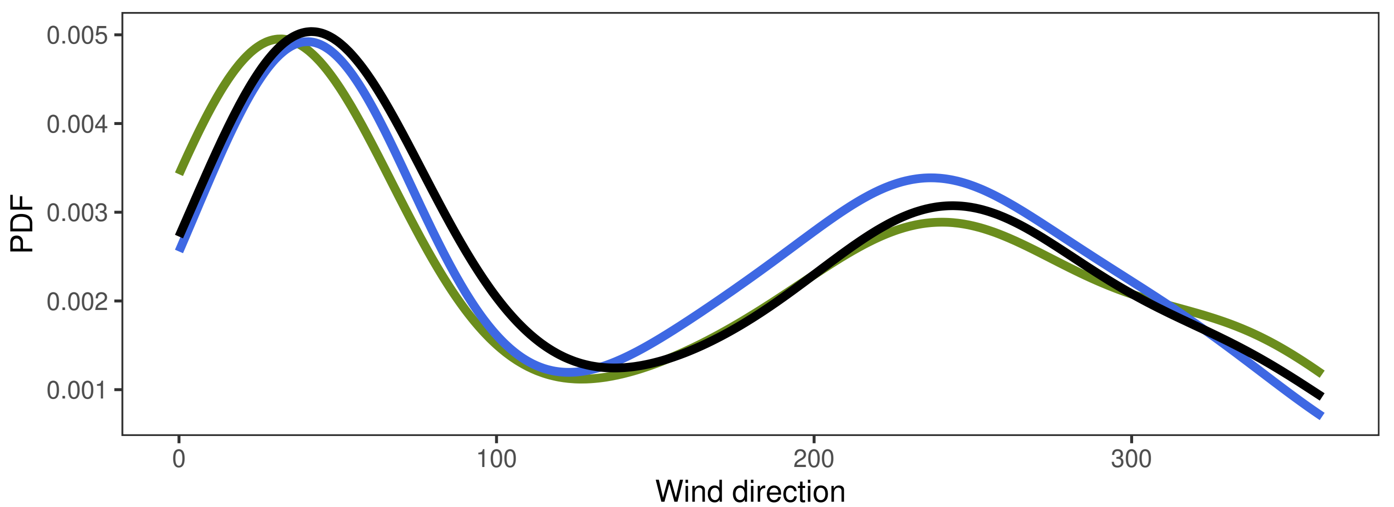

PDF
0.005
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

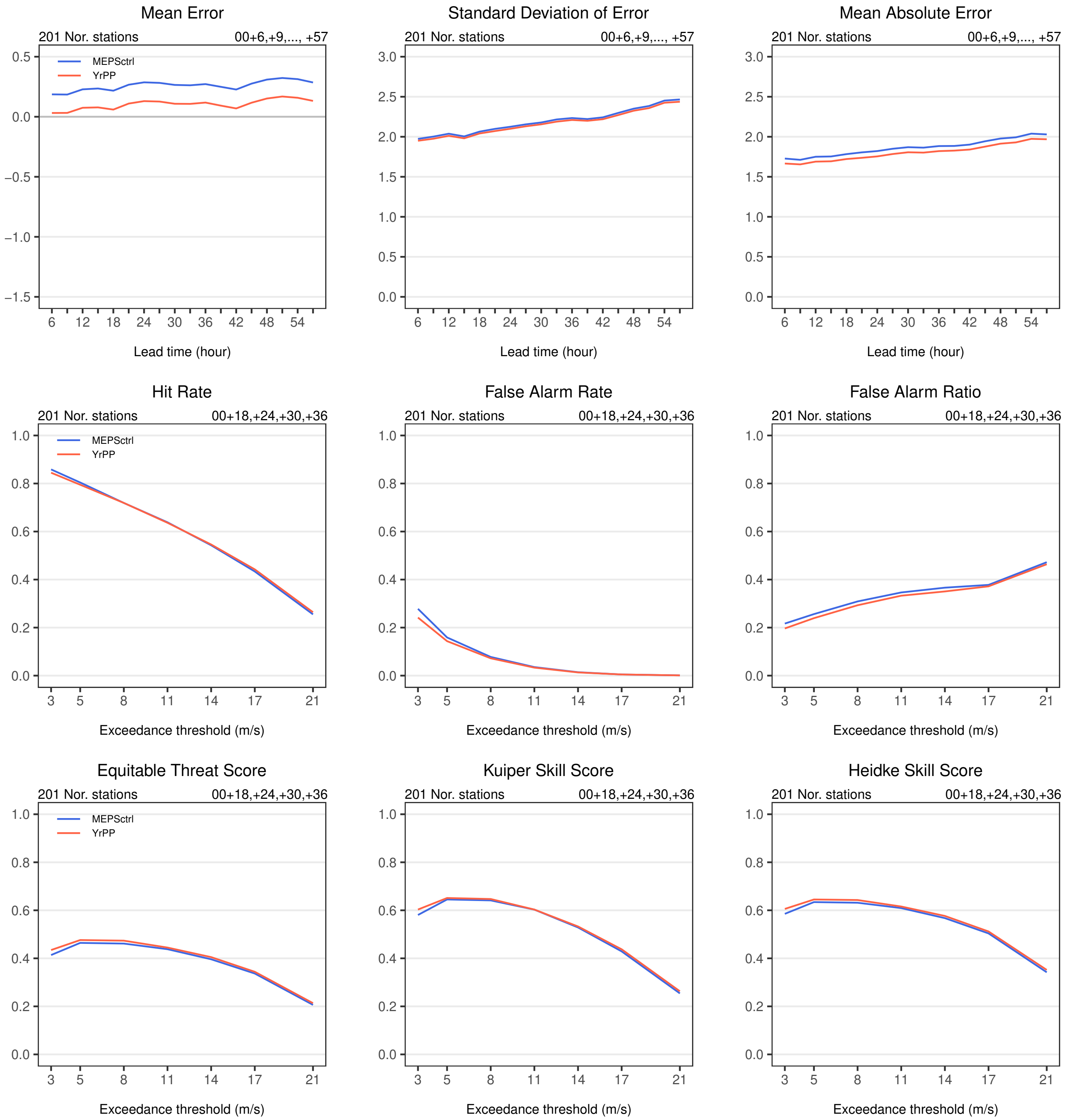


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	7.9	21.6	4.1	357
MEPSctrl: 12+18,+24,+30,+36	0.5	7.7	25.2	3.9	360
ECMWF: 12+18,+24,+30,+36	0.5	7.5	21.6	3.8	360

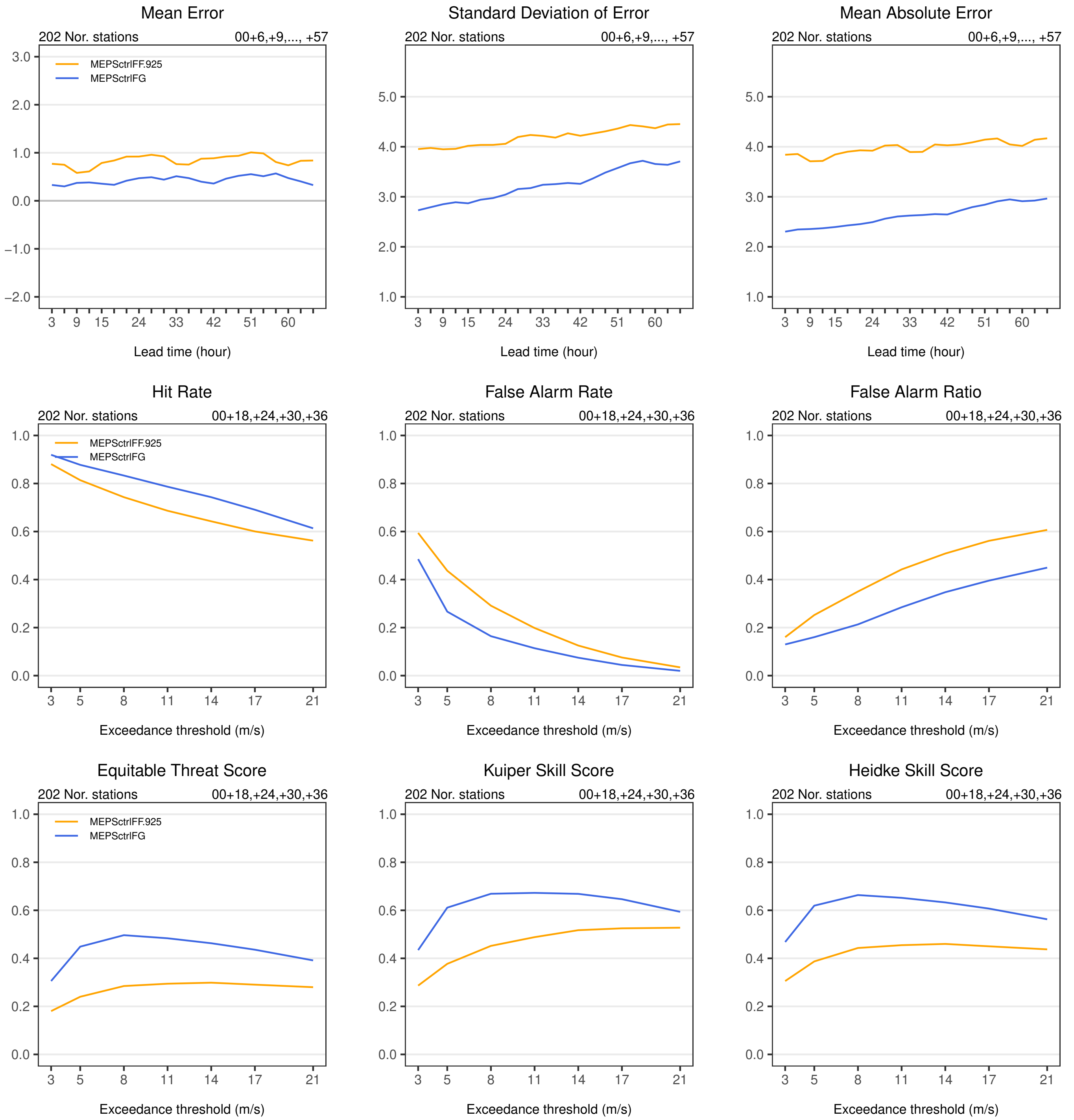
	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.3	2.1	2.1	1.6	6.4	353
ECMWF – synop	–0.4	1.9	1.9	1.5	8.1	353

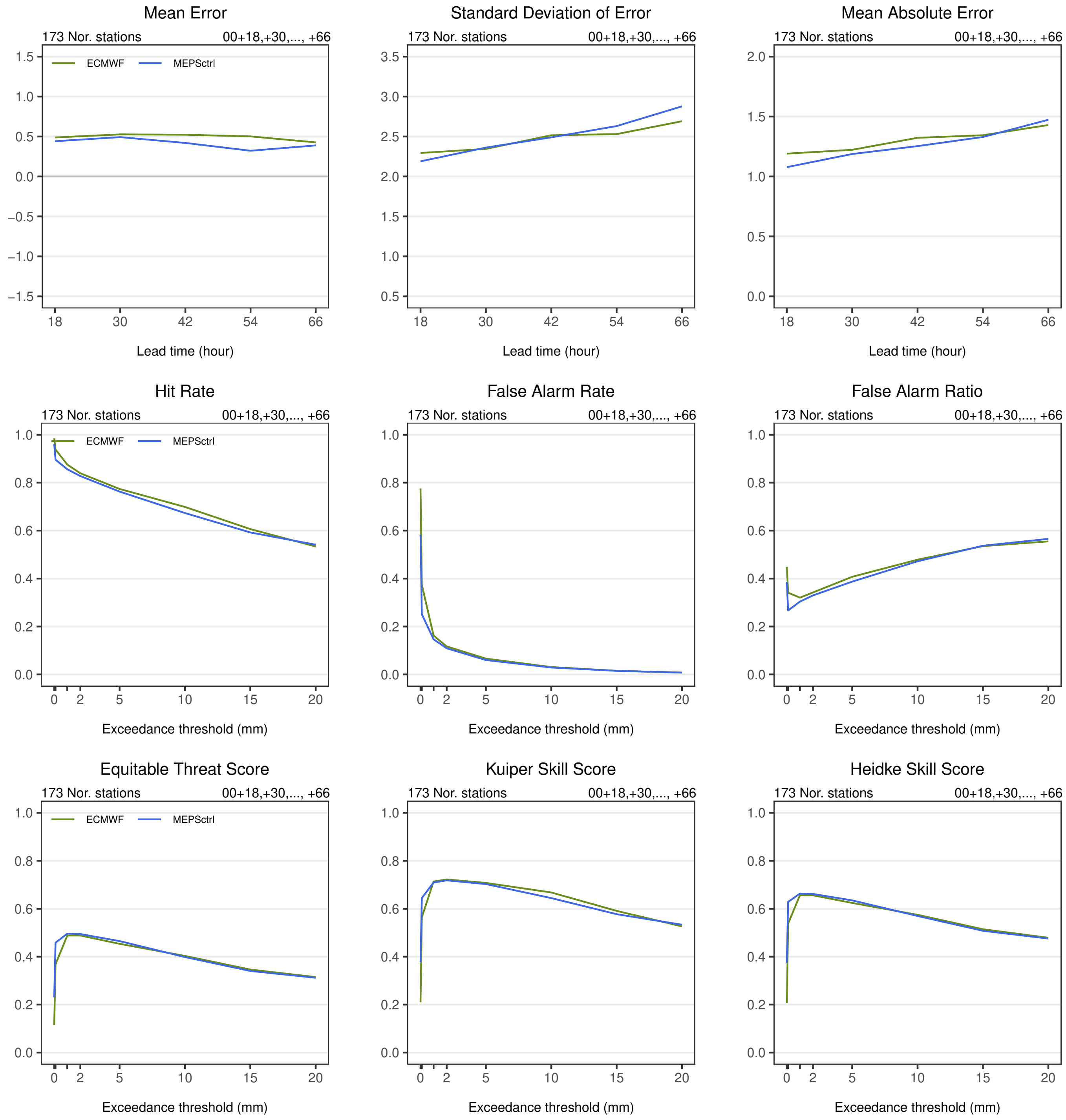

FÆRDER FYR
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

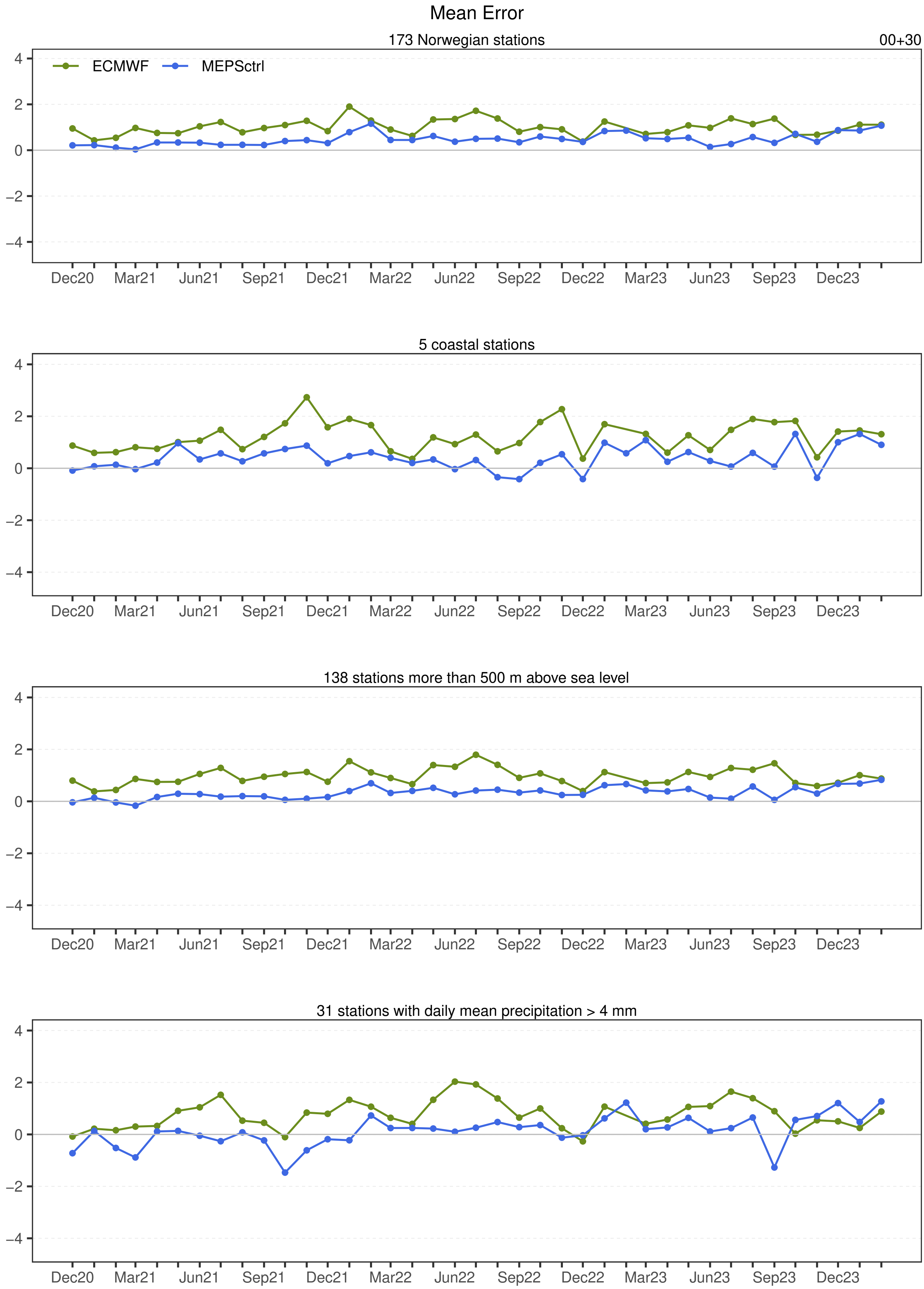

PDF
0.005
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

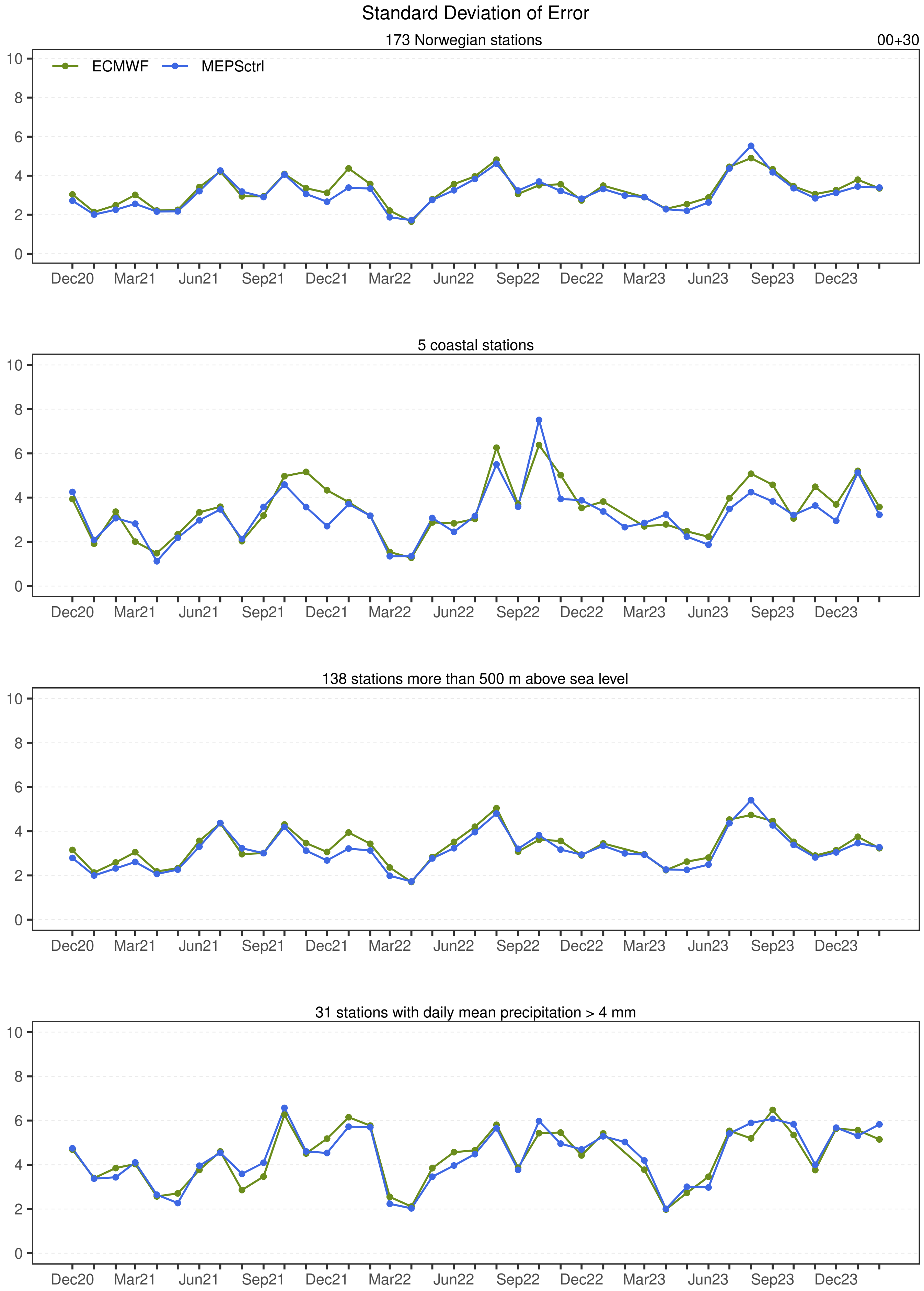

Mean Error
201 Nor. stations
00+6,+9,..., +57
MEPSctrl
YrPP
Lead time (hour)
Standard Deviation of Error
201 Nor. stations
00+6,+9,..., +57
Lead time (hour)
Mean Absolute Error
201 Nor. stations
00+6,+9,..., +57
Lead time (hour)
Hit Rate
201 Nor. stations
00+18,+24,+30,+36
MEPSctrl
YrPP
Exceedance threshold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

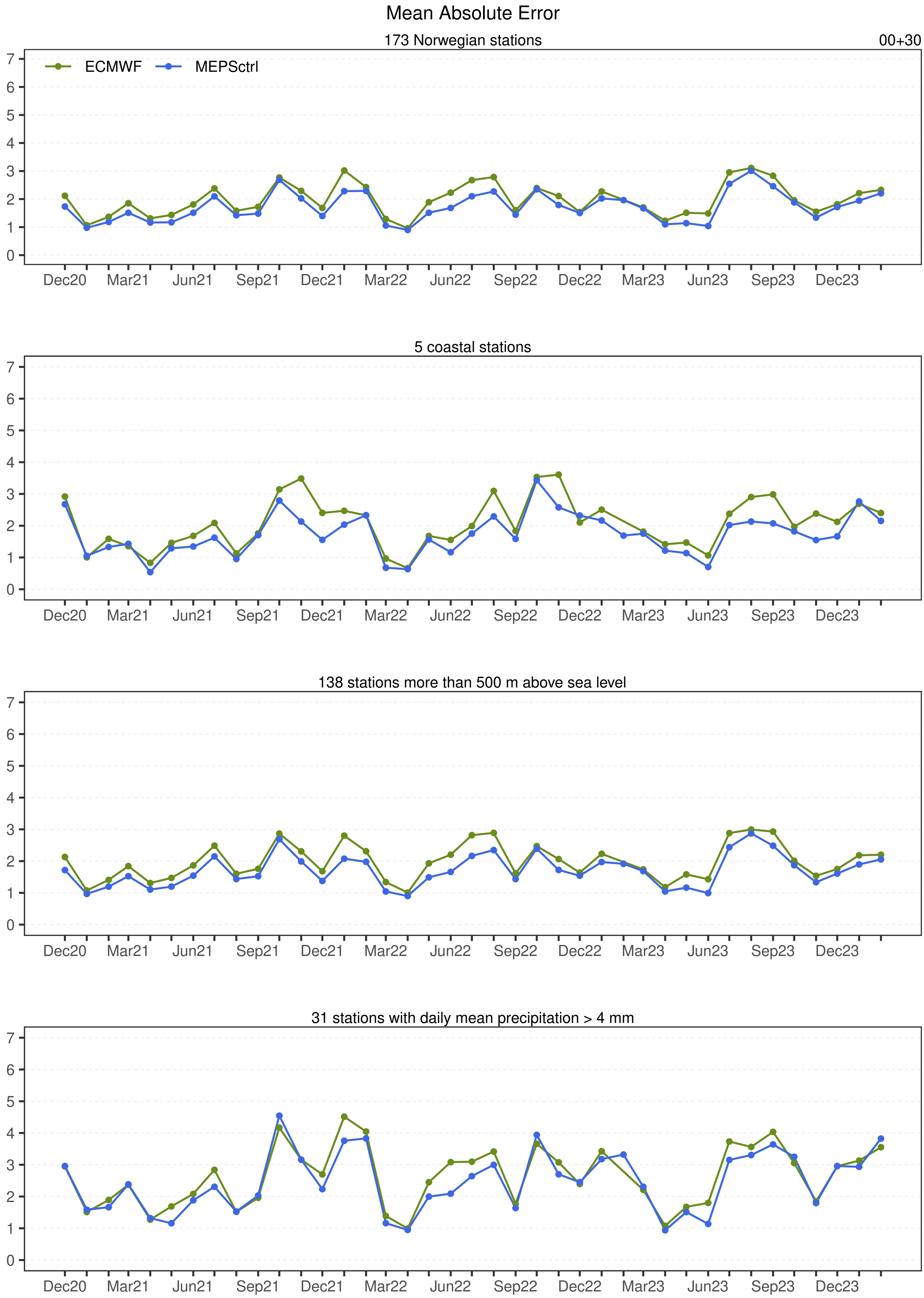
Wind gust (FG) and wind speed in 925 hpa (FF.925)

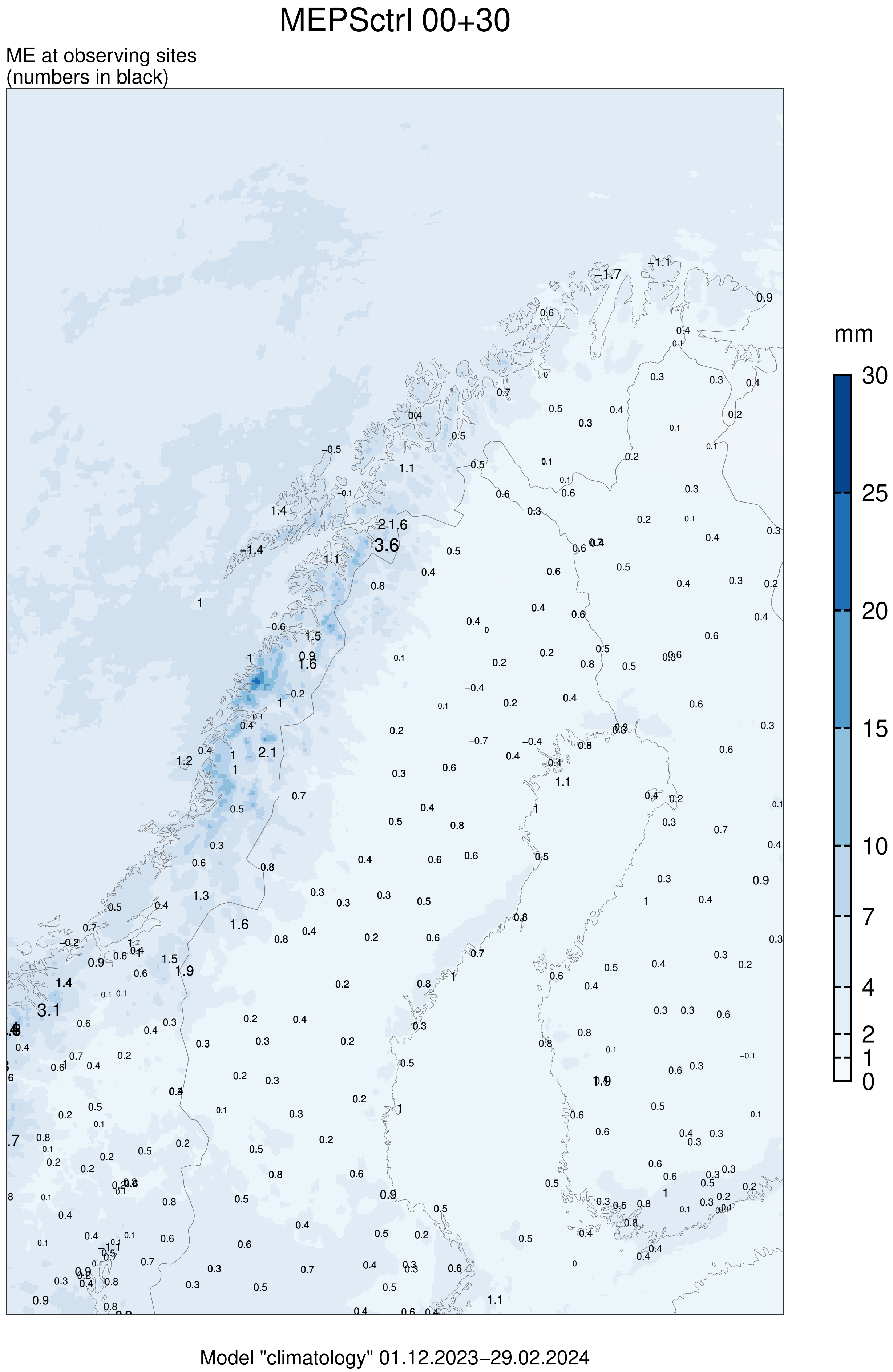


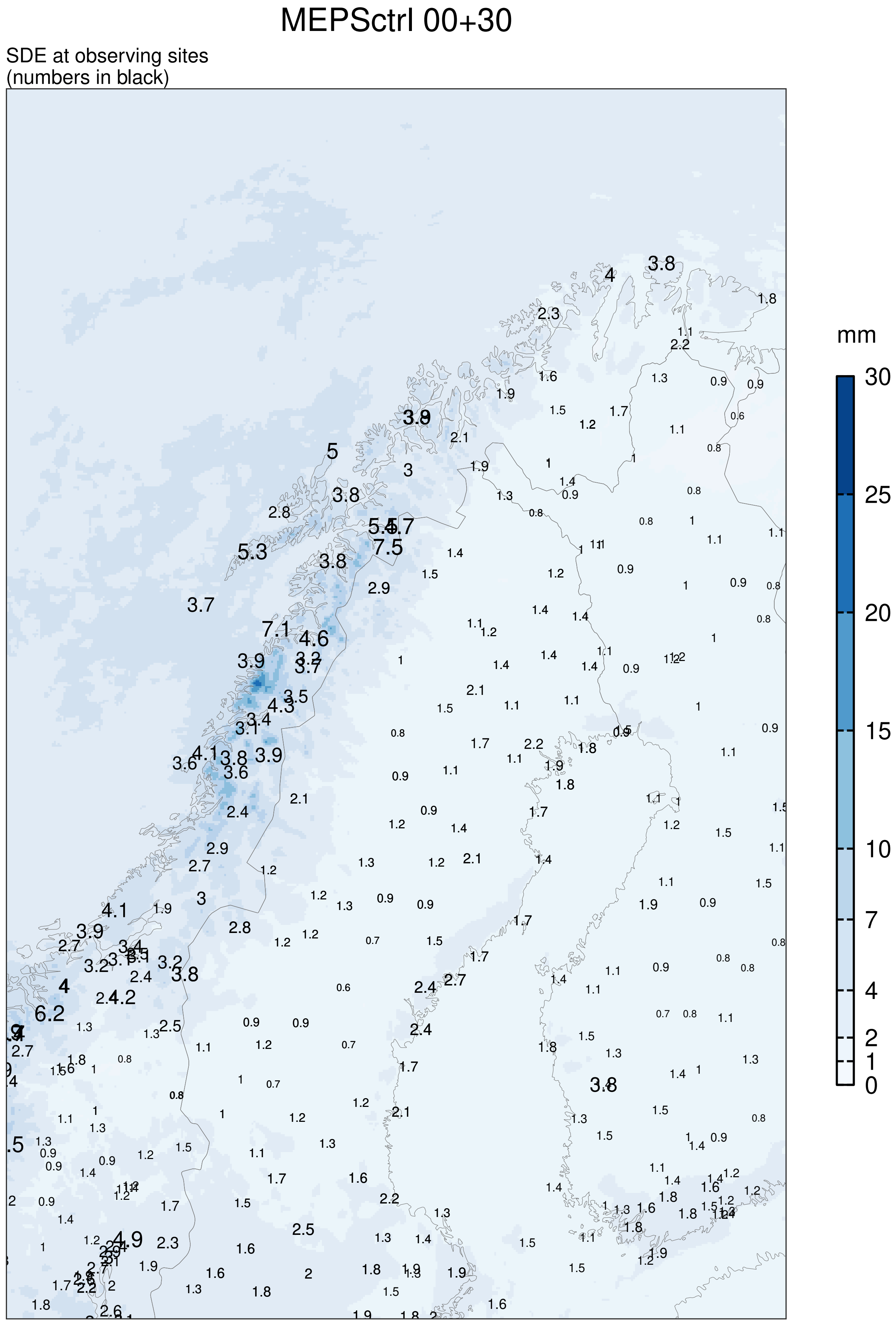

Mean Error
173 Nor. stations
00+18,+30,..., +66
ECMWF
MEPSctrl
Lead time (hour)
Standard Deviation of Error
173 Nor. stations
00+18,+30,..., +66
Lead time (hour)
Mean Absolute Error
173 Nor. stations
00+18,+30,..., +66
Lead time (hour)
Hit Rate
173 Nor. stations
00+18,+30,..., +66
ECMWF
MEPSctrl
Exceedance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


Mean Error
173 Norwegian stations
00+30
ECMWF
MEPSctrl
4
2
0
−2
−4
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23
5 coastal stations
138 stations more than 500 m above sea level
31 stations with daily mean precipitation > 4 mm


Standard Deviation of Error
173 Norwegian stations
00+30
ECMWF
MEPSctrl
5 coastal stations
138 stations more than 500 m above sea level
31 stations with daily mean precipitation > 4 mm
0
2
4
6
8
10
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
Sep23
Dec23


Mean Absolute Error
173 Norwegian stations
00+30
ECMWF
MEPSctrl
5 coastal stations
138 stations more than 500 m above sea level
31 stations with daily mean precipitation > 4 mm
Dec20 Mar21 Jun21 Sep21 Dec21 Mar22 Jun22 Sep22 Dec22 Mar23 Jun23 Sep23 Dec23

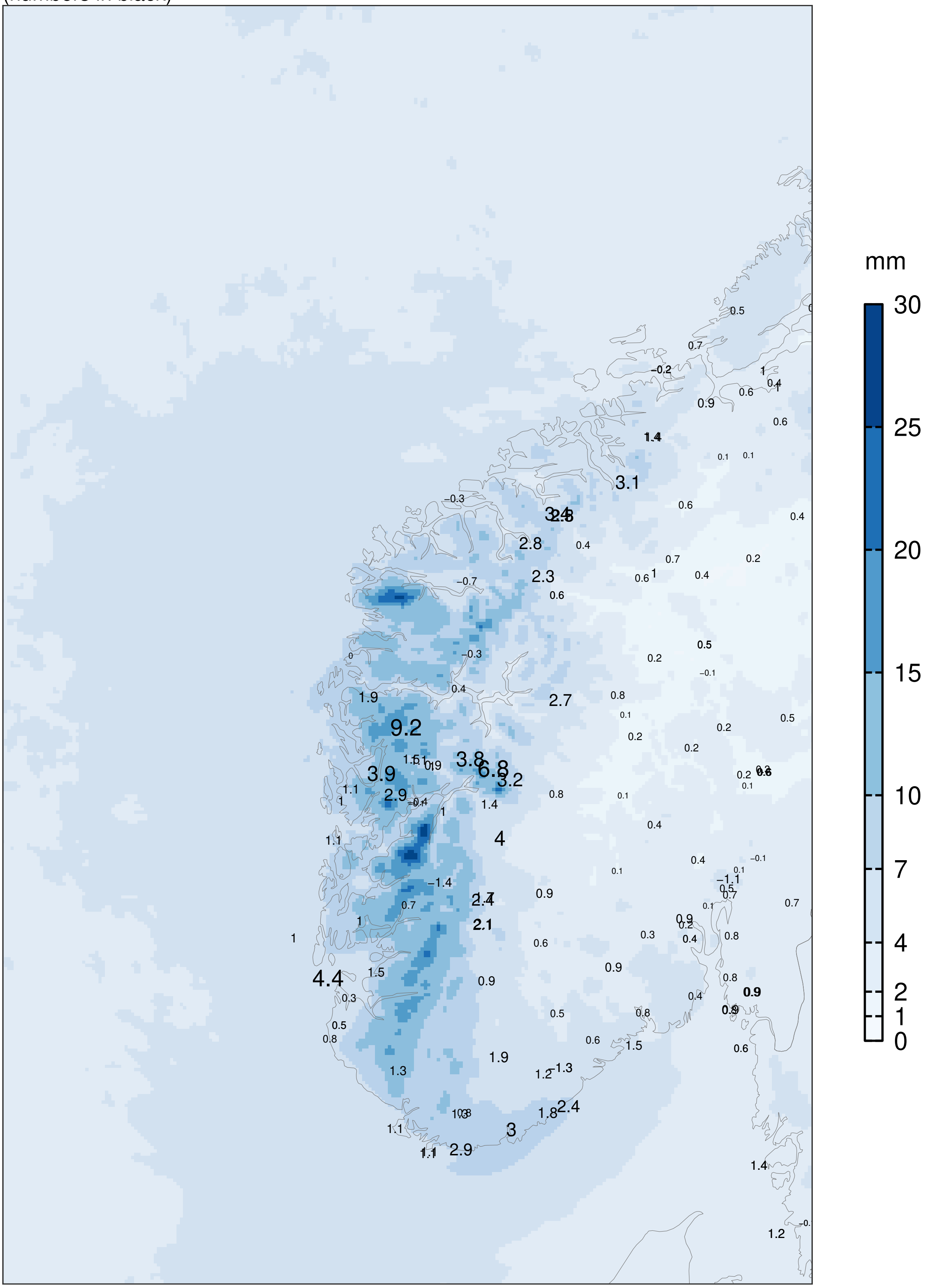

MEPSctrl 00+30
ME at observing sites
(numbers in black)
mm
30
25
20
15
10
7
4
2
1
0
Model "climatology" 01.12.2023–29.02.2024



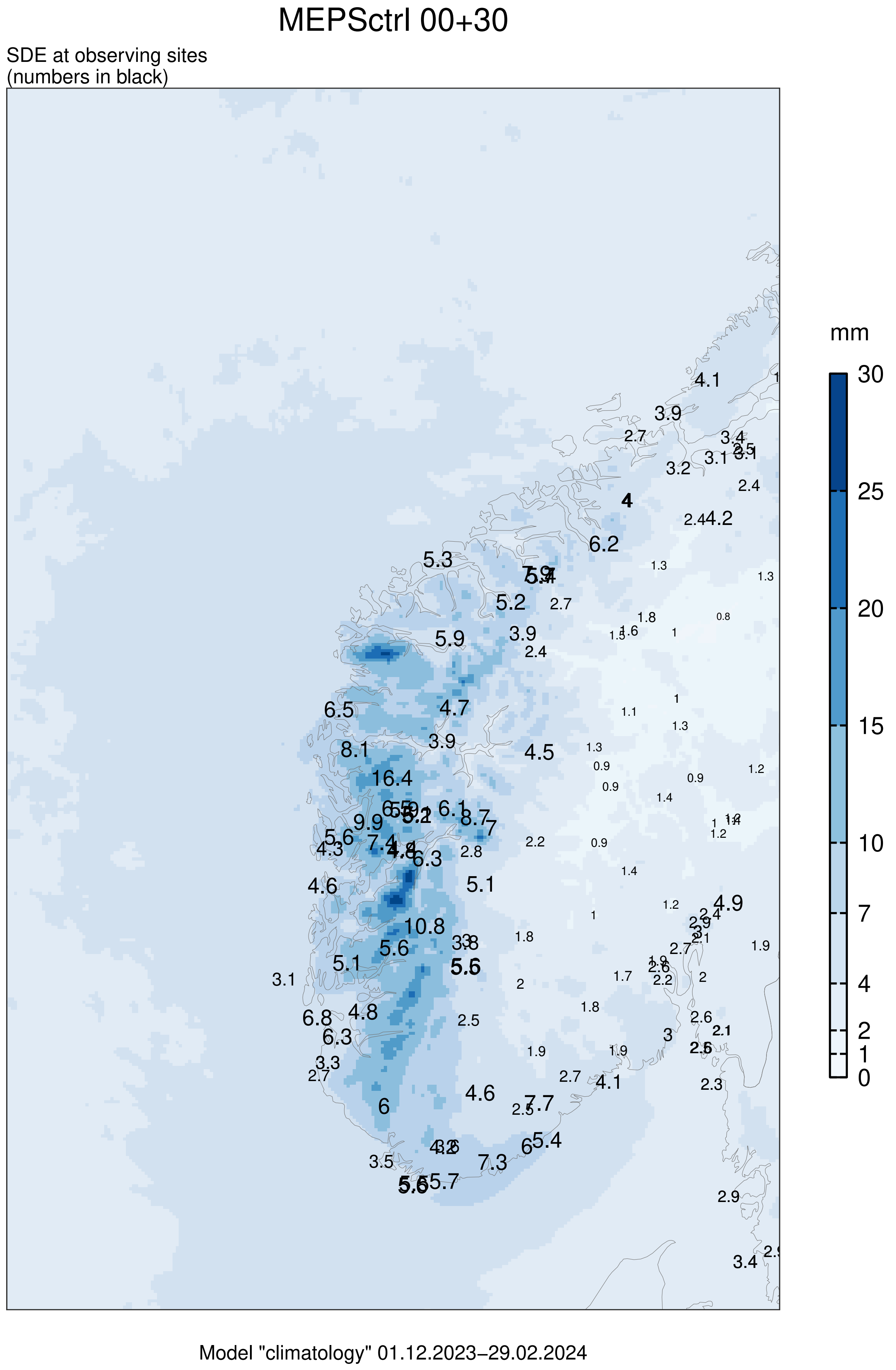
Model "climatology" 01.12.2023–29.02.2024

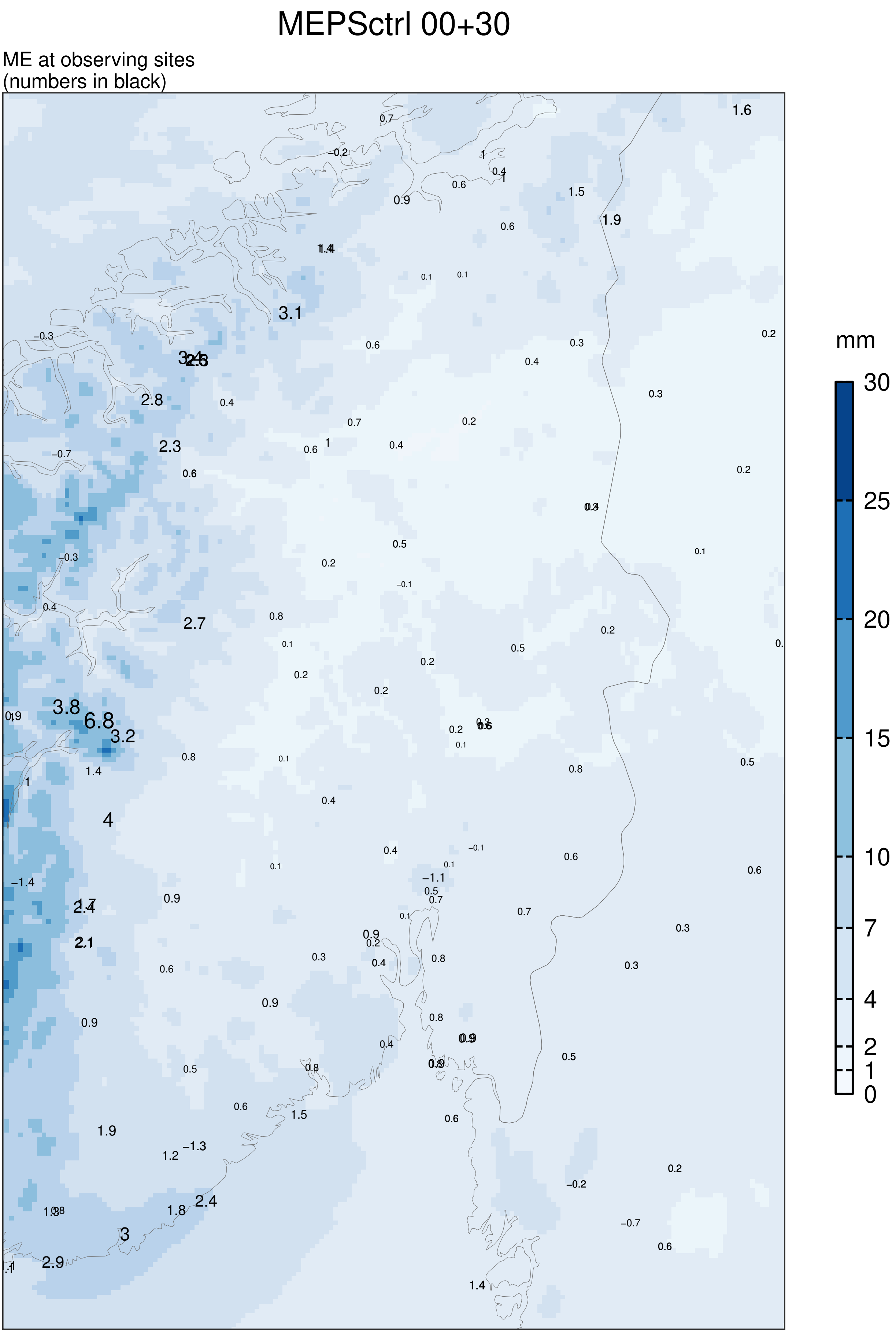
MEPSctrl 00+30

ME at observing sites
(numbers in black)



Model "climatology" 01.12.2023–29.02.2024

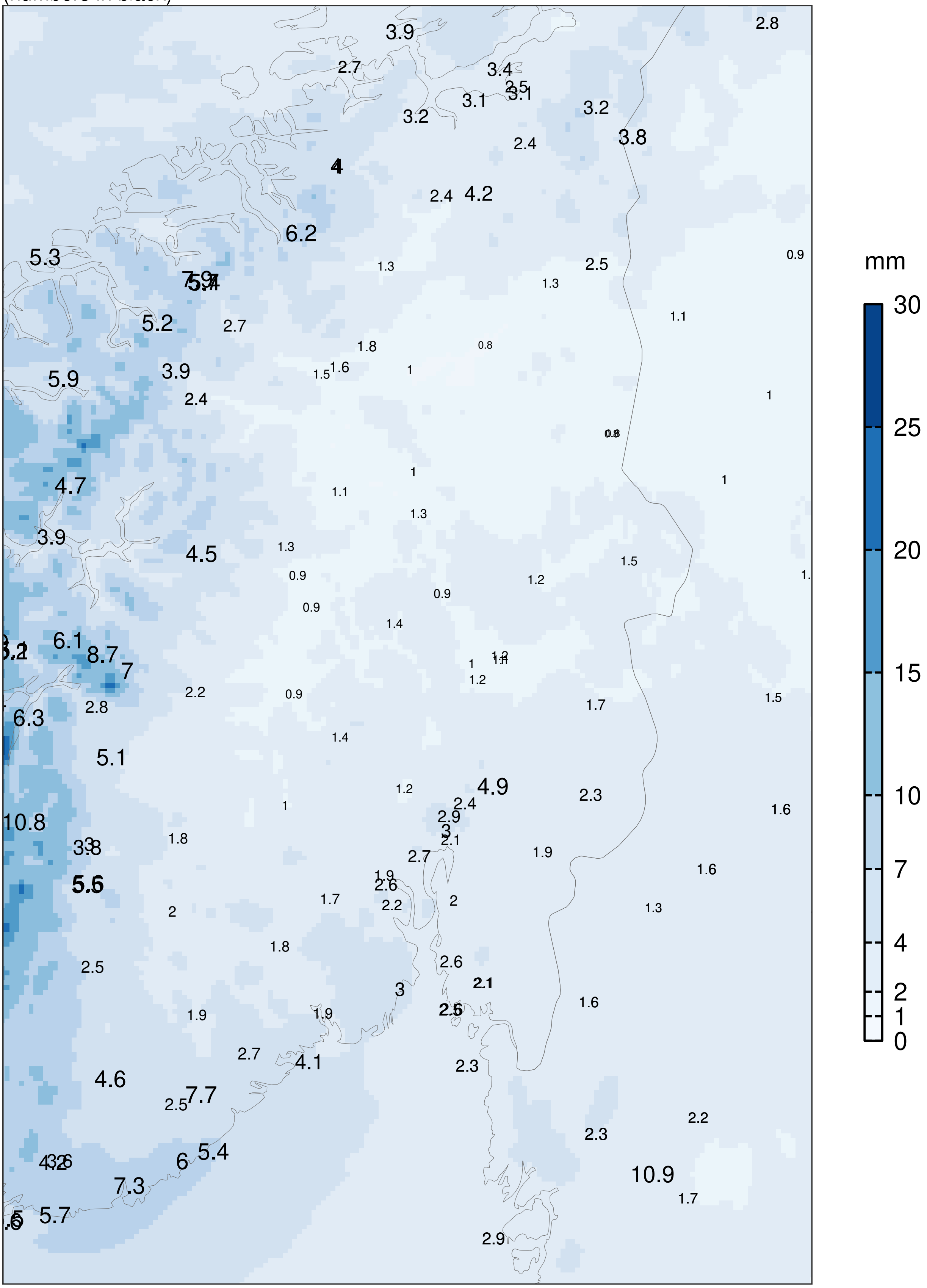

MEPSctrl 00+30
SDE at observing sites
(numbers in black)
mm
30
25
20
15
10
7
4
2
1
0
Model "climatology" 01.12.2023–29.02.2024



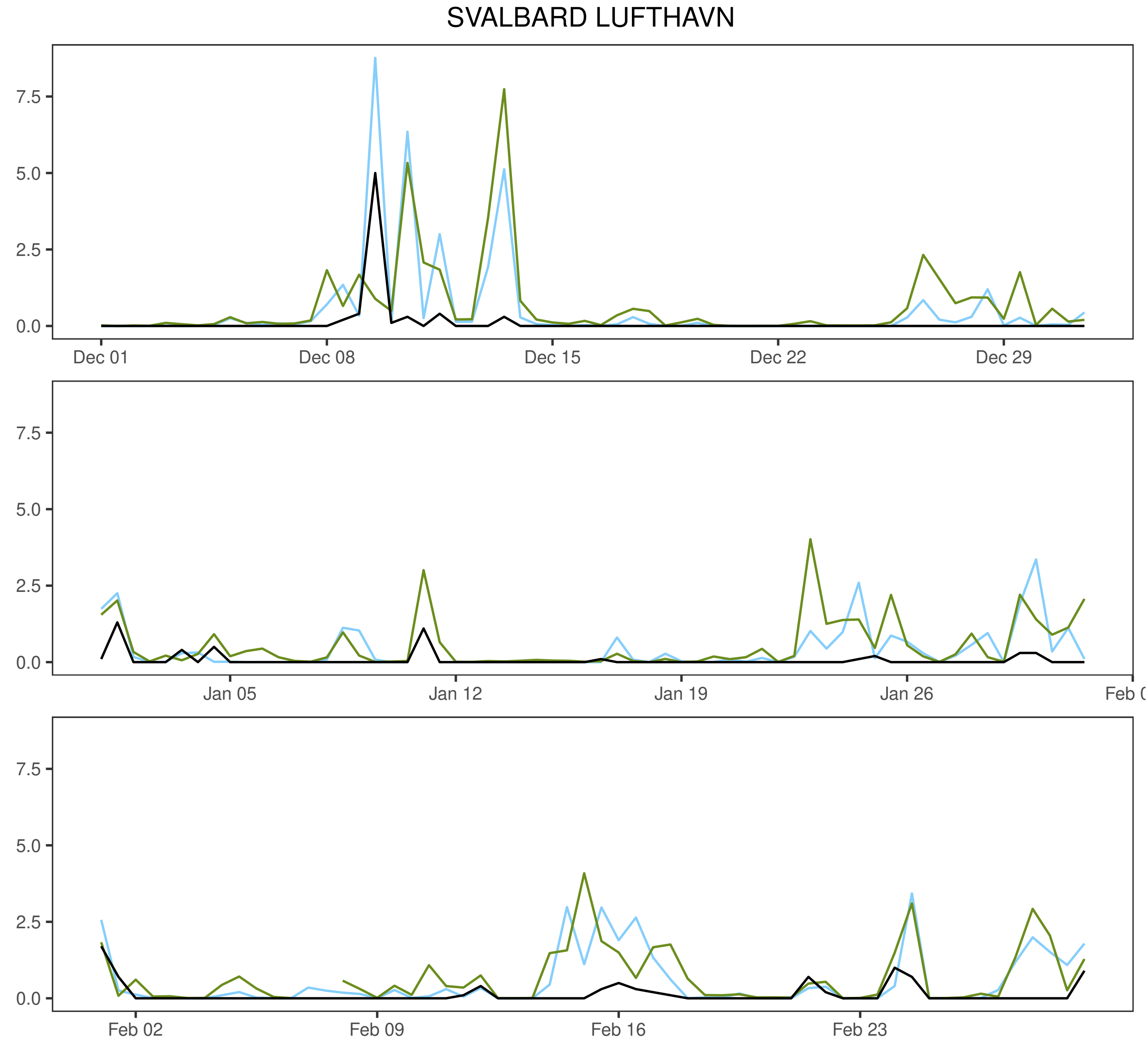
Model "climatology" 01.12.2023–29.02.2024

MEPSctrl 00+30

SDE at observing sites
(numbers in black)

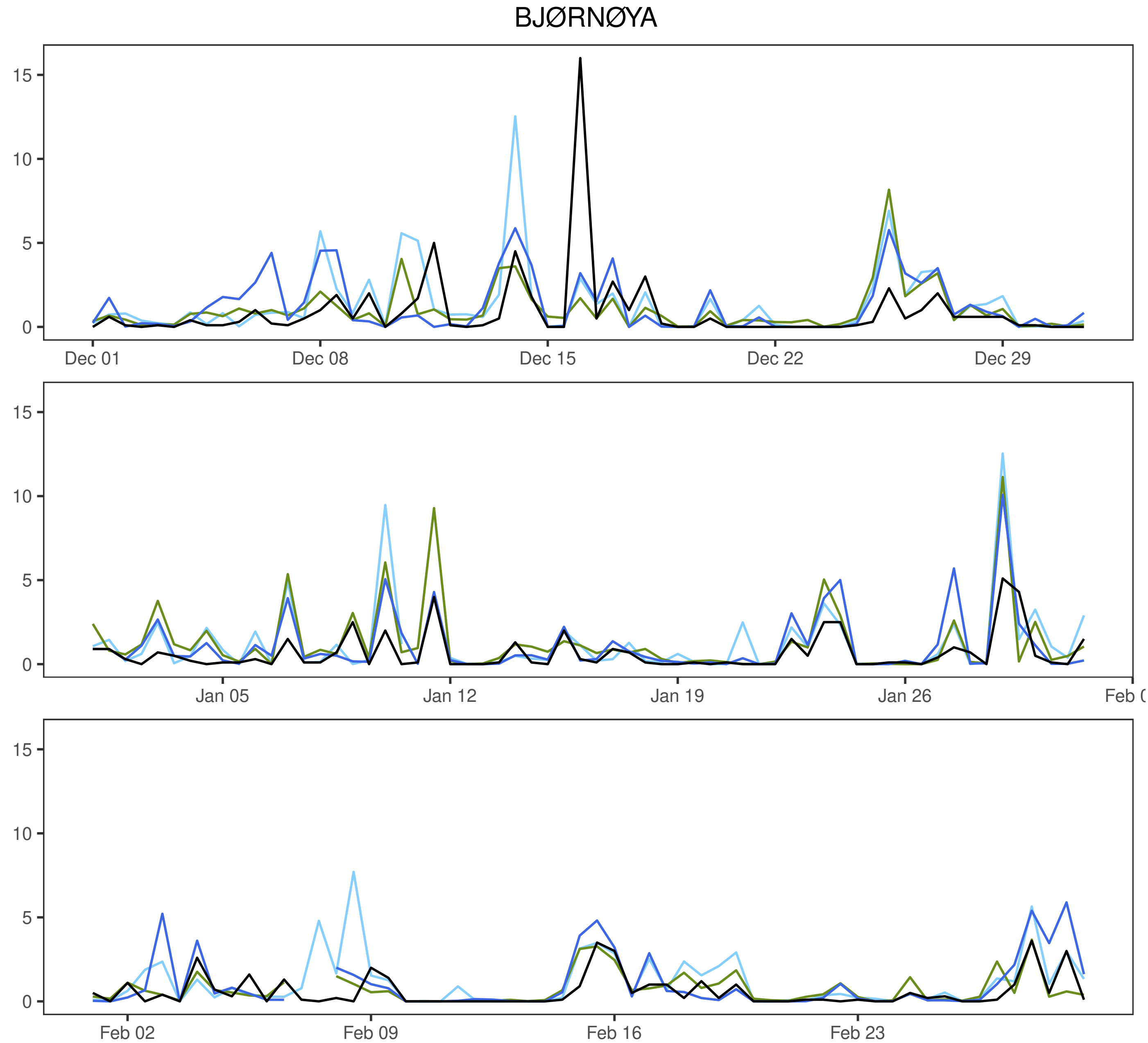


Model "climatology" 01.12.2023–29.02.2024



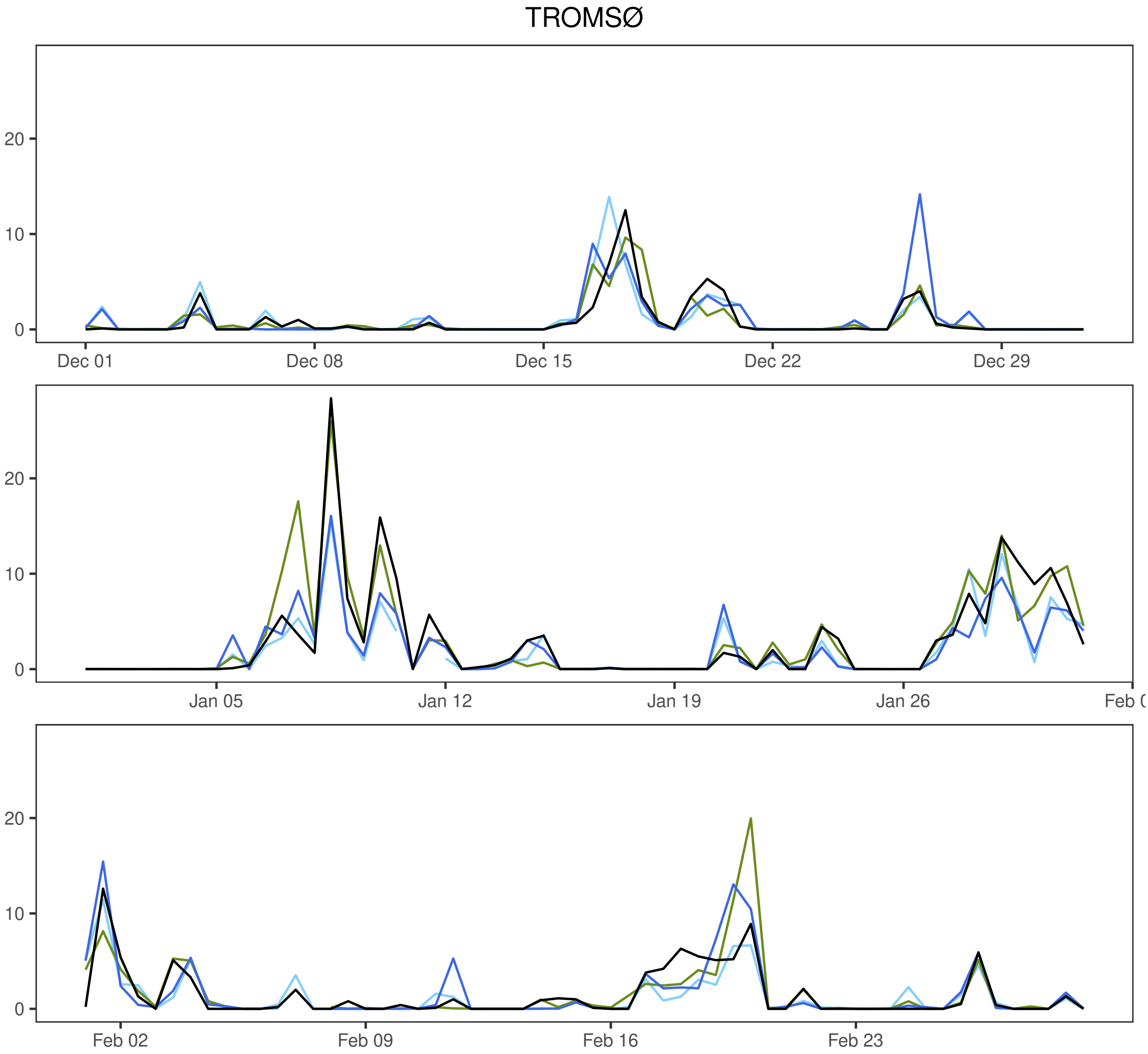
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.1	5.0	0.4	182
AA25: 12+18,+30	0.0	0.5	8.8	1.1	180
ECMWF: 12+18,+30	0.0	0.6	7.7	1.0	180

	ME	SDE	RMSE	MAE	Max.abs.err	N
AA25 – synop	0.4	0.9	1.0	0.4	6.0	178
ECMWF – synop	0.5	1.0	1.2	0.6	7.4	178



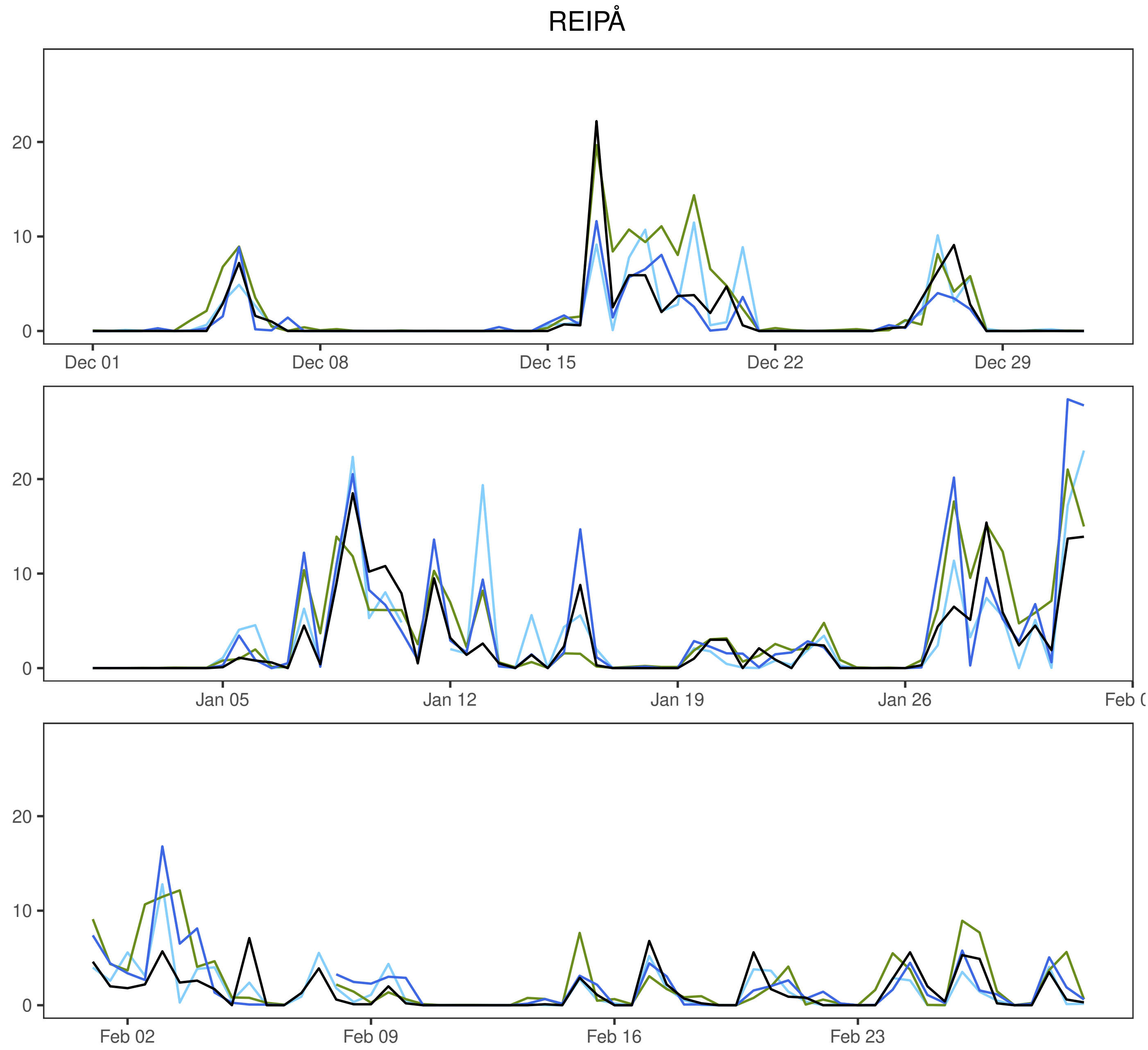
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.7	16.0	1.5	182
MEPSctrl: 12+18,+30	0.0	1.1	10.1	1.7	180
AA25: 12+18,+30	0.0	1.2	12.5	1.9	180
ECMWF: 12+18,+30	0.0	1.0	11.1	1.5	180

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.4	1.6	1.6	0.8	12.8	178
AA25 – synop	0.5	1.8	1.9	0.9	13.1	178
ECMWF – synop	0.3	1.6	1.6	0.7	14.3	178



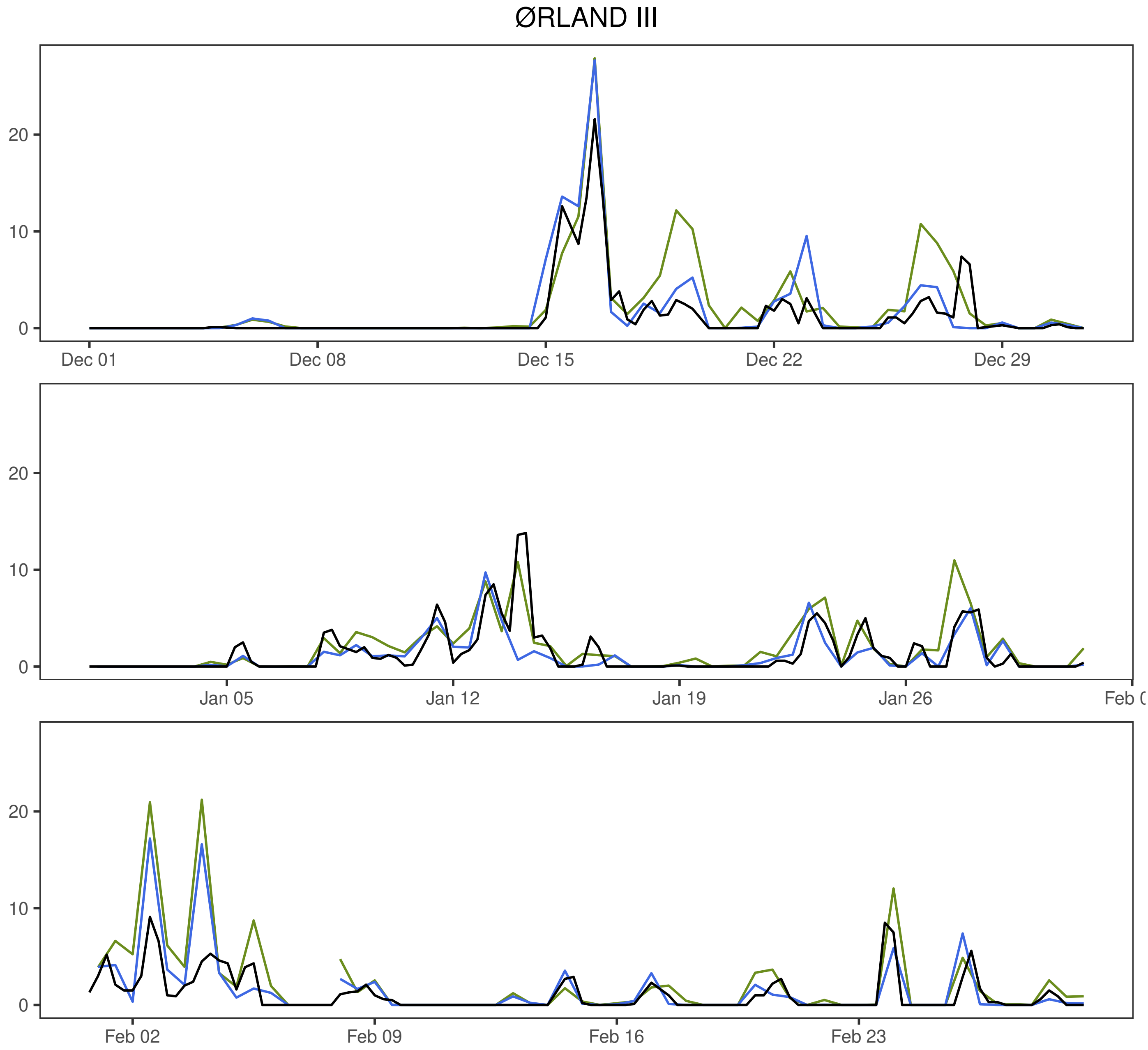
	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.8	28.4	3.6	182
MEPSctrl: 12+18,+30	0.0	1.6	16.1	3.0	180
AA25: 12+18,+30	0.0	1.4	15.4	2.6	180
ECMWF: 12+18,+30	0.0	1.9	26.0	3.8	180

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.2	2.2	2.2	1.0	12.3	178
AA25 – synop	–0.3	2.0	2.0	0.9	13.0	178
ECMWF – synop	0.1	1.9	1.9	0.8	14.0	178



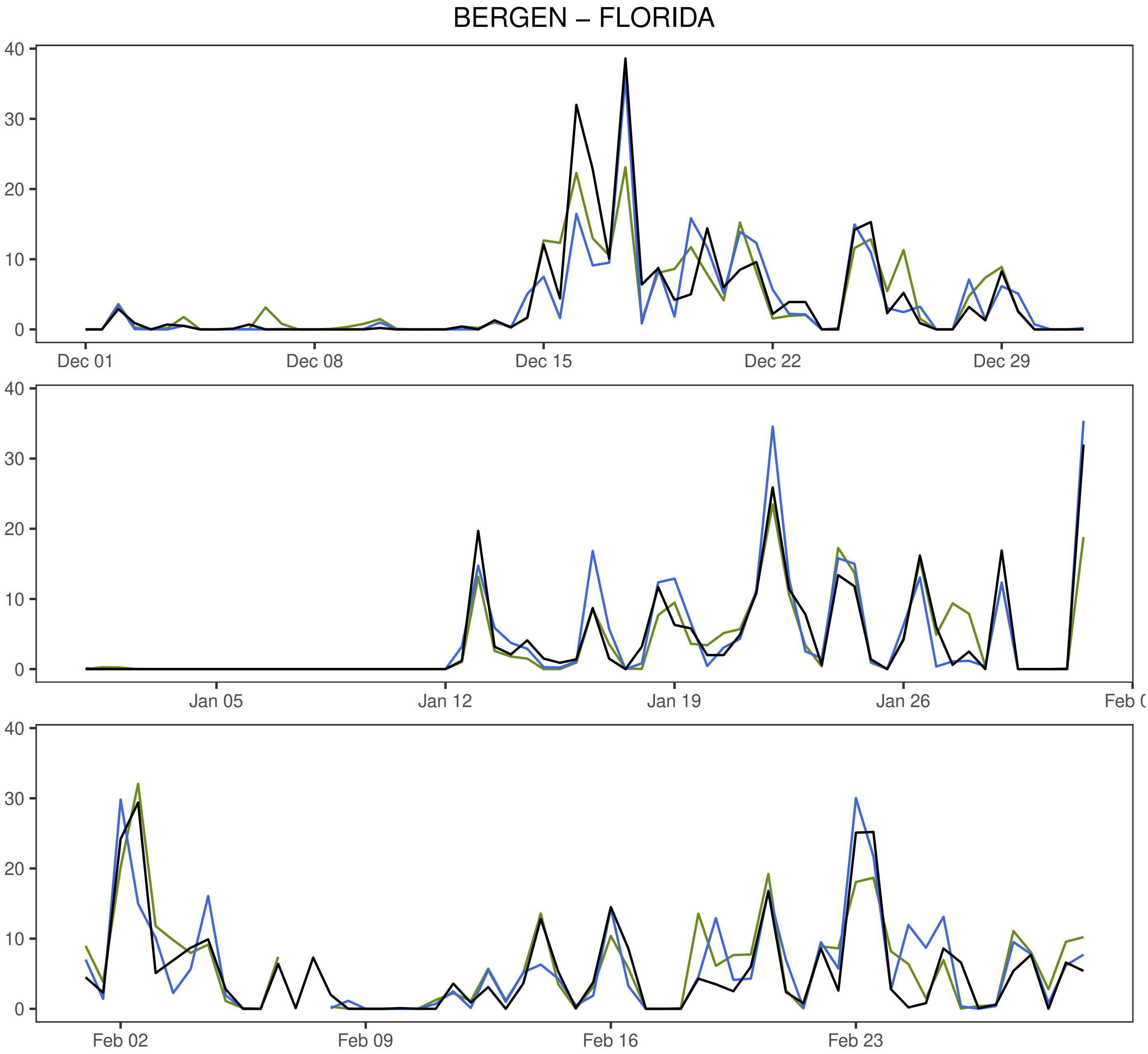
	Min	Mean	Max	Std	N
synop: 06,18	0.0	2.0	22.2	3.5	182
MEPSctrl: 12+18,+30	0.0	2.4	28.4	4.6	180
AA25: 12+18,+30	0.0	2.1	23.0	3.9	180
ECMWF: 12+18,+30	0.0	2.8	21.0	4.3	180

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.4	2.8	2.9	1.3	14.7	178
AA25 – synop	0.1	2.6	2.6	1.2	16.8	178
ECMWF – synop	0.9	2.6	2.8	1.5	11.1	178



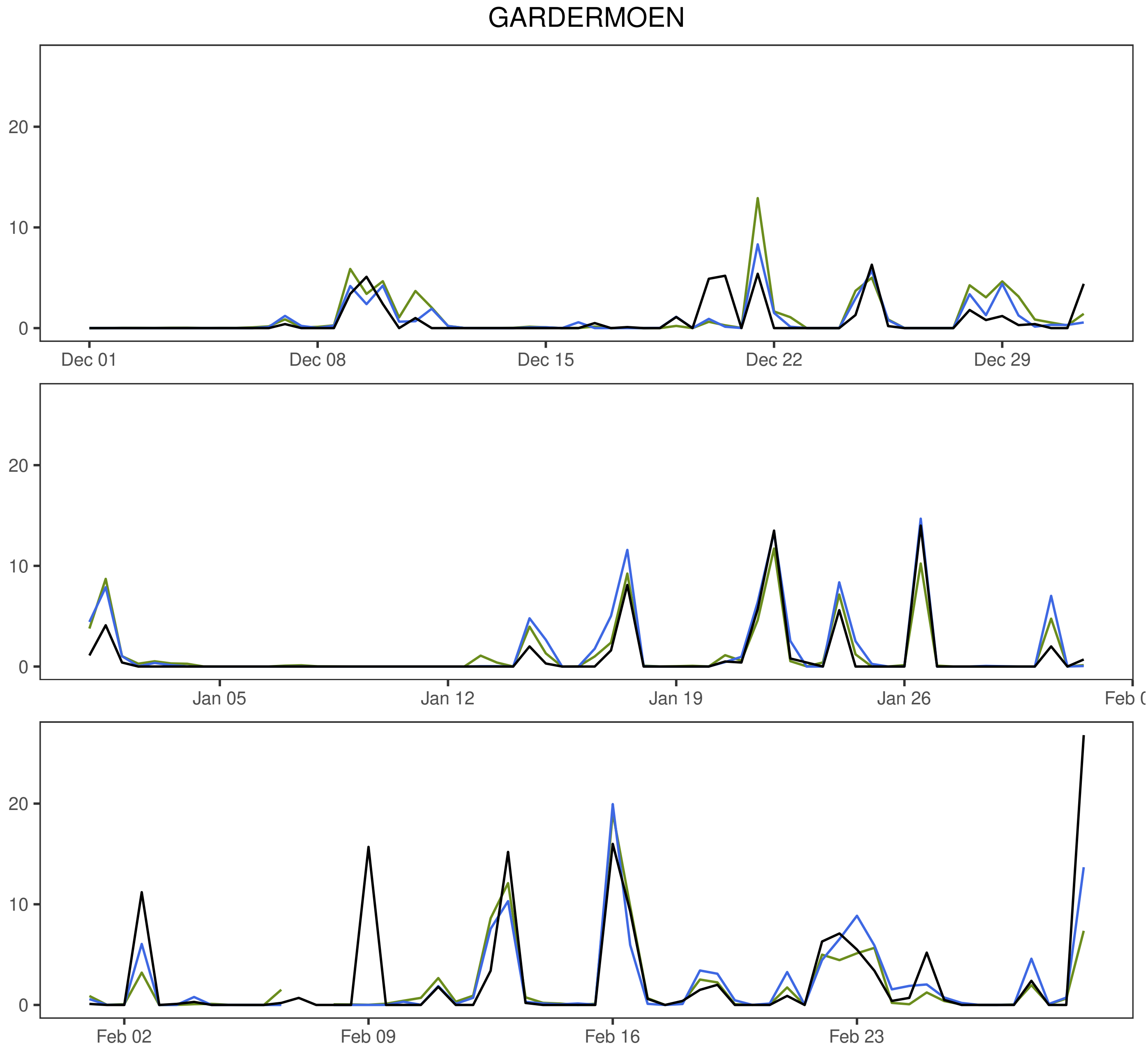
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	1.2	21.6	2.6	348
MEPSctrl: 12+18,+30	0.0	1.5	27.7	3.4	180
ECMWF: 12+18,+30	0.0	2.1	27.9	3.9	180

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.2	2.0	2.0	0.8	12.9	180
ECMWF – synop	0.9	2.4	2.5	1.2	16.7	180



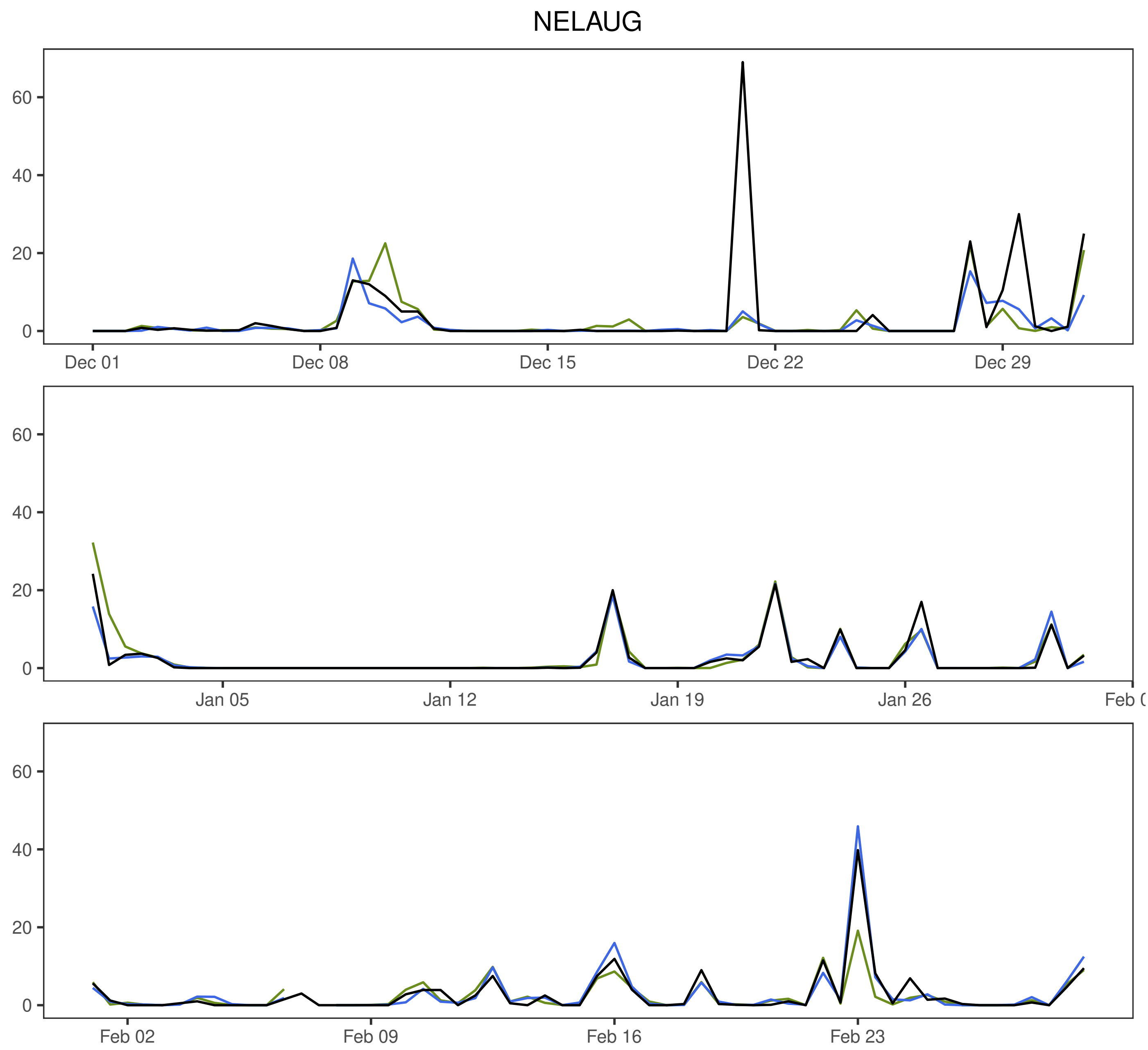
	Min	Mean	Max	Std	N
synop: 06,18	0.0	4.4	38.6	7.0	182
MEPSctrl: 12+18,+30	0.0	4.5	35.9	7.0	180
ECMWF: 12+18,+30	0.0	4.5	32.1	6.0	180

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.1	3.4	3.3	1.8	15.5	180
ECMWF – synop	0.1	3.2	3.2	1.8	15.5	180



	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.3	26.8	3.5	182
MEPSctrl: 12+18,+30	0.0	1.5	20.0	3.1	180
ECMWF: 12+18,+30	0.0	1.4	19.1	2.8	180

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	0.1	2.1	2.1	0.9	15.7	180
ECMWF – synop	0.0	2.4	2.4	0.9	19.4	180



	Min	Mean	Max	Std	N
synop: 06,12,18	0.0	2.8	69.0	7.6	183
MEPSctrl: 12+18,+30	0.0	2.2	45.9	5.1	180
ECMWF: 12+18,+30	0.0	2.4	32.2	5.0	180

	ME	SDE	RMSE	MAE	Max.abs.err	N
MEPSctrl – synop	–0.6	5.5	5.5	1.4	64.0	180
ECMWF – synop	–0.5	5.9	5.9	1.5	65.4	180