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Verification of Operational Weather Prediction Models December 2022 to February 2023

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Verification results are also available on internal web pages

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

About this report

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

The report includes verification results for 3 Numerical Weather Prediction (NWP) models; MetCoOp ensemble 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 Klimadatavarehuset at MET. 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 shows a very small overestimation. AA25 has a very small overestimation of temperature at the North Scandinavian stations, and the mean error is only slightly below 0 for some lead times at the Svalbard stations. Still, the errors are small, indicating that the timing of the temperature changes is generally good. The temperature forecast is further improved by post processing, particularly for the shortest lead times. The improvement is larger for inland stations than coastal stations, which have less variation in temperature and smaller errors than inland stations for both MEPSctrl and post processed forecasts.

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

Wind speed is challenging to evaluate. MEPSctrl 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 post processing of wind speed was changed on 1 June 2021 by downscaling to 1km resolution to better represent local topography. The change implies that the post processed wind speed represents the mean wind speed rather than the maximum mean wind speed as before this change was introduced. 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 which this winter had mean errors very close to (and above) 0. 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. Temperature

Wintertime cold weather minima has been a challenge also this year. A case from 7 January shows that although the cloudiness is reasonably well forecast, the model temperature is not able to forecast the lowest values. Figure 1 shows a satellite image at 00 UTC. The observed temperature (top right) shows an area of temperatures less than -30°C corresponding to the cloud free area. The model clouds are shown for 12 hour lead time. The cloudiness in MEPS was well forecast. AROME-Arctic had slightly less clouds, which to some extent can explain the difference in 2m temperature from the two models.

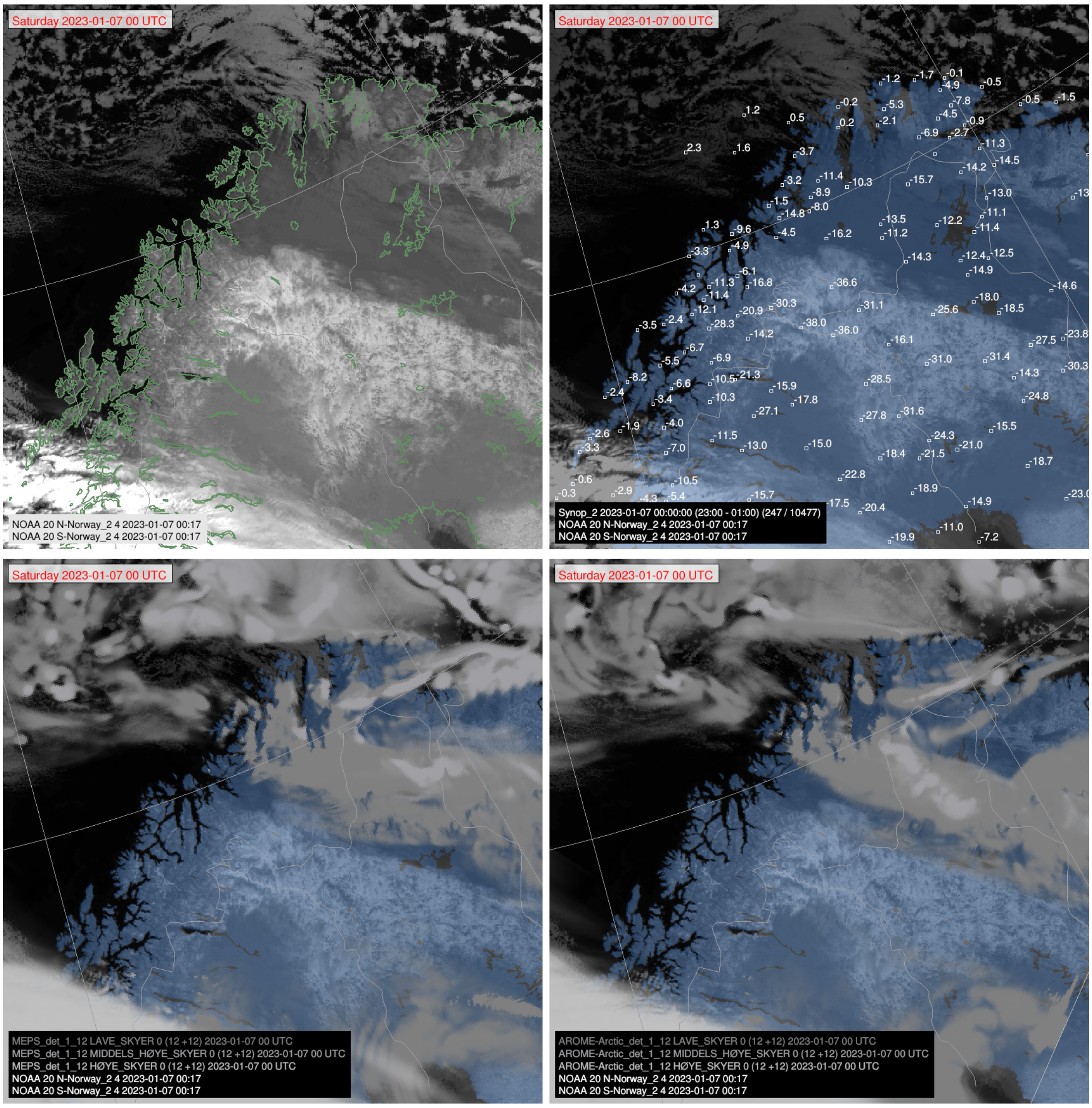


Figure 1: Satellite image from 7 January 00 UTC. The gray smooth area is low clouds. The lighter area in the middle of the picture is cloud free areas. Top left: Satellite image only. Top right: Observed temperature shown as white numbers. Bottom left: Clouds from MEPS shown as gray areas. Bottom right: Clouds from AROME-Arctic shown as gray areas.

MEPS and AROME-Arctic have a different description of the exchange of heat and momentum between the surface and lowest model level. This difference manifests itself in different 2m temperature especially in clear sky situations in the winter time. A comparison at 18 hours lead time and 0 hours lead time (figure 2) shows that both models have a better agreement with the shorter lead times. AROME-Arctic generally has slightly higher 2m temperature than MEPS.

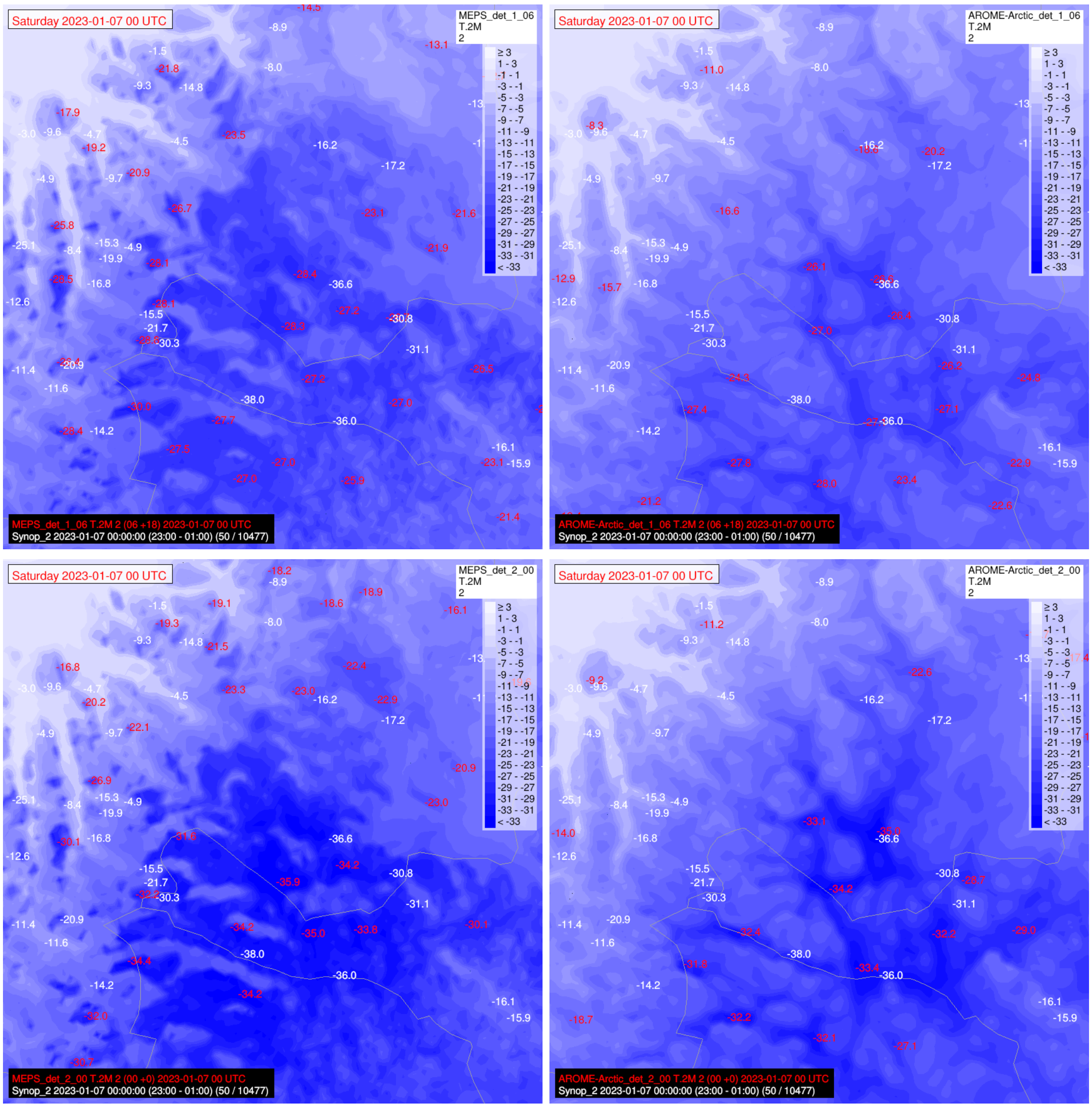


Figure 2: Model temperature from 7 January 00 UTC. Model minima are shown as red numbers and observations as white numbers. Top left: MEPS at 18 hours lead time. Top right: AROME-Arctic at 18 hours lead time. Bottom left: MEPS at 0 hours lead time. Bottom right: AROME-Arctic at 0 hours lead time.

While MEPS has a better agreement in low lying cold regions, it also shows a tendency to have very low 2m temperature at the mountain tops (figure 3). This is not seen in any observations, and may be a negative effect of the surface exchange scheme in MEPS. AROME-Arctic does not show the same contrasts as MEPS, and seems to be more in line with observations.

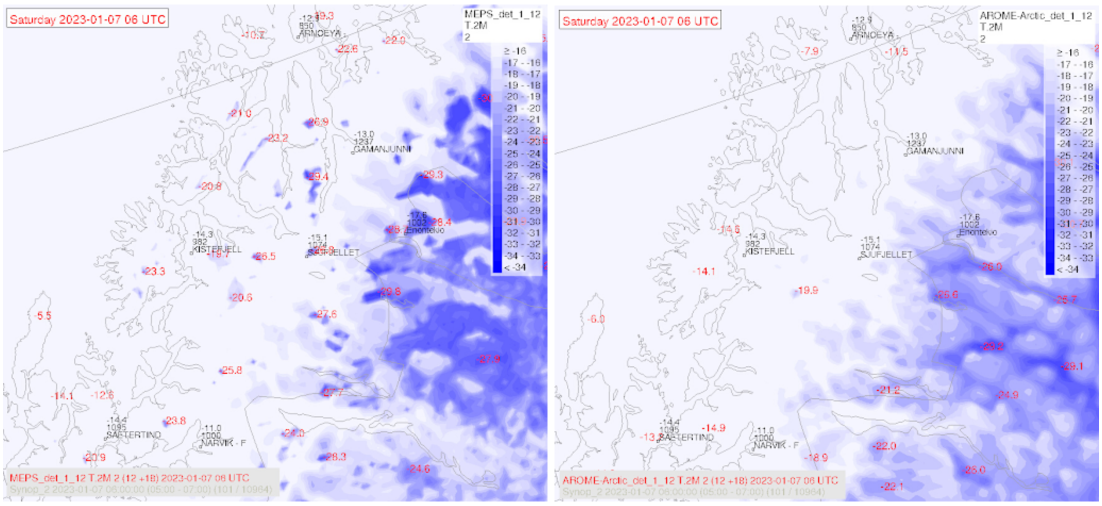


Figure 3: Model temperature from 7 January 00 UTC with 18 hours leadtime plotted against observations from mountain tops above 800m. Model minima are shown as red numbers and observations as black numbers (2m temperature, height and name). The model temperature minima in the mountains in the coastal and fjord areas are not seen in the observations. Left: MEPS. Right: AROME-Arctic.

Case 2. Precipitation

This winter has seen at least four precipitation events where the orientation of mesoscale cloud bands and associated precipitation has generated heavy snowfall over a prolonged period of time; from 12 to more than 24 hours. The cloud bands have had a movement along its axis, resulting in very high accumulated snow amounts in local areas. This has a severe impact on e.g. avalanche risk, and generally implies a forecast warning of an orange level. It is a general impression that the model reduces the amount of precipitation in the last 6 hrs, maybe more, in the prognosis, which could be a result of spin up or border issues.

On 16 December a polar low hit Andøya and Senja, and remained almost stationary for more than 24 hours. On 24 December a Polar low hit Tromsø. With regards to spatial distribution, the model had good agreement with observations from 18 to 24 hours lead time and up to the event.

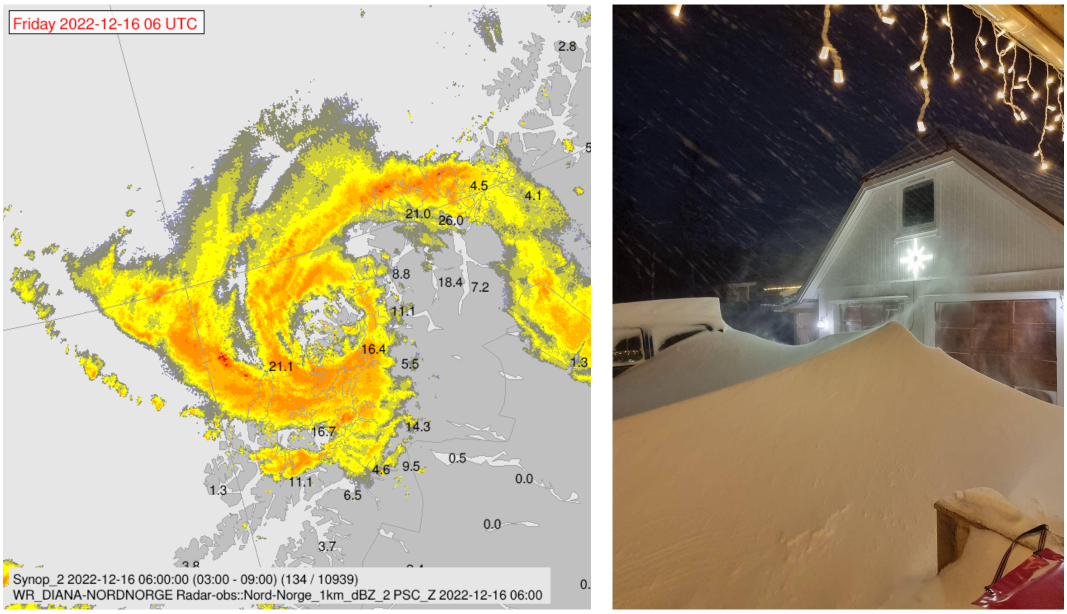


Figure 4: Left: Radar image from the Andøya low on 16 December. Right: Snow deposit at Finnsnes. Photo: Jill Maria Bjørback

Figure 4 (left) shows a radar image from the polar low at Andøya on 16 December. The low remained in this position for more than 24 hours. Note the relatively low values of observations of 24hr precipitation indicating severe undercathment at the observing stations. Unofficial reports indicated from 70 to 150 cm of local snow deposit, seen e.g. in a photo from Finnsnes. Note the snow free roof of the house, where the snow has blown clean off without settling, showing the effect of strong wind on the snow.

Figure 5 shows MSLP and 6hr precipitation from MEPS at 06 UTC in the same event. The model did not capture the low at the right position with 30 hours lead time. At 24 hours lead time the low had the right position and correct depiction of the precipitation bands. At 12 hours lead time MEPS had slightly less precipitation intensity, but the position is right. At 6 hours lead time MEPS is reducing the precipitation intensity compared to observations and earlier prognosis.

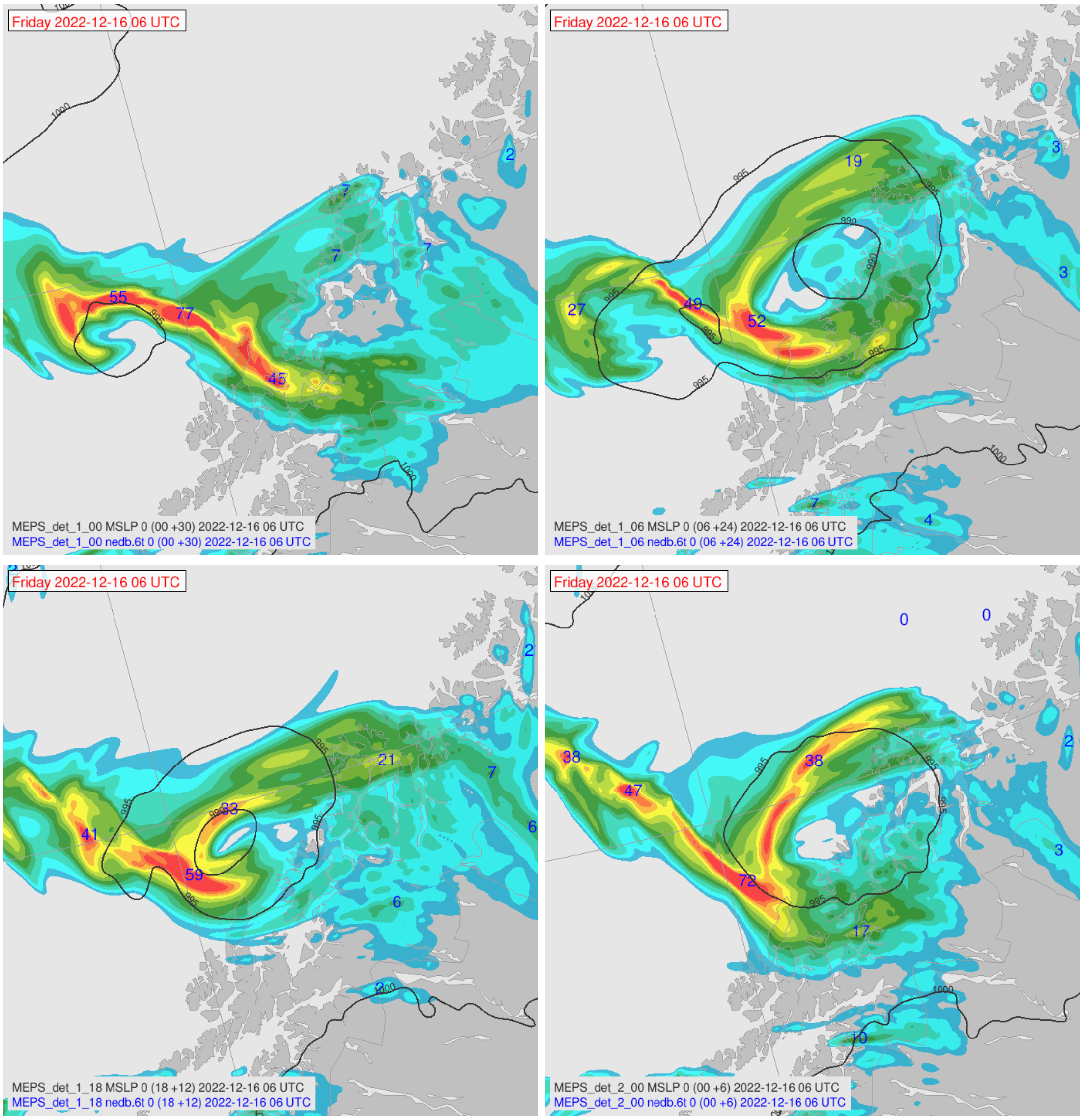


Figure 5: MSLP (black lines) and 6hr precipitation (color shading) from MEPS at 16 December 06 UTC. The blue numbers are maximum values for the precipitation. Top left: 30 hours lead time. Top right: 24 hours lead time. Bottom left: 12 hours lead time. Bottom right: 6 hours lead time.

For the polar low at Tromsø on 24 December (figure 6), MEPS also showed decreasing precipitation at short lead times.

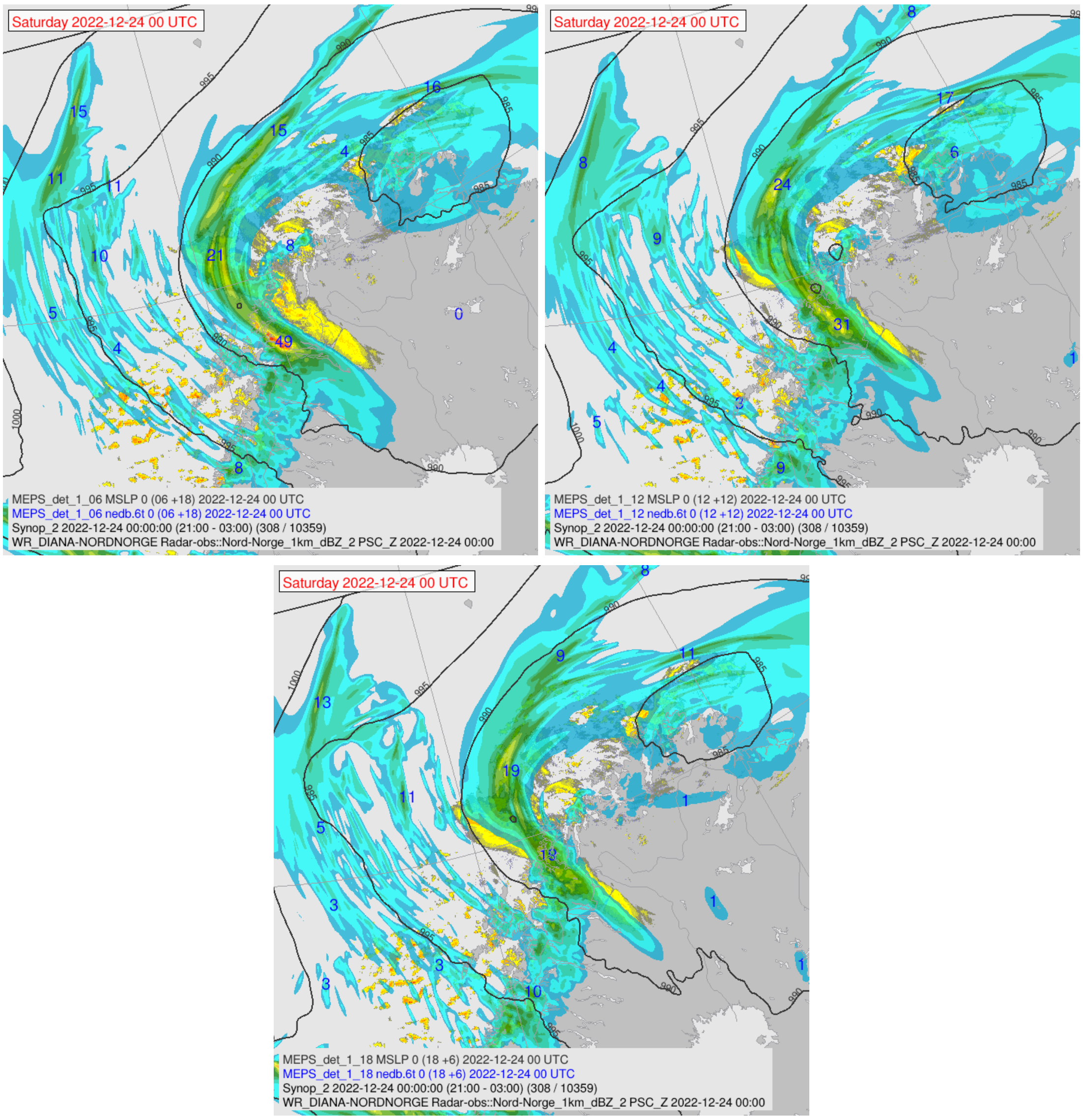
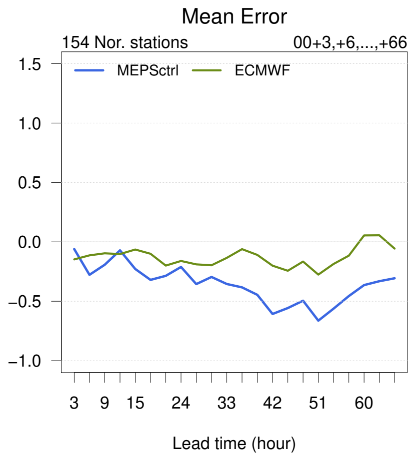
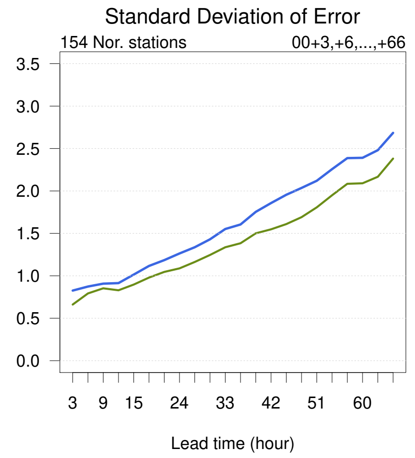
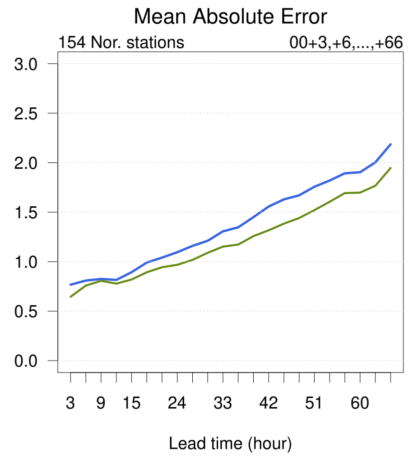


Figure 6: 6hr precipitation from MEPS (blue/green shading) overlaid the radar (yellow) with lead times 18hrs (top left) 12hrs (top right) and 6hrs (bottom) shows decreasing accumulated precipitation at the first 6hrs of the prognosis.

Summarized statistics


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


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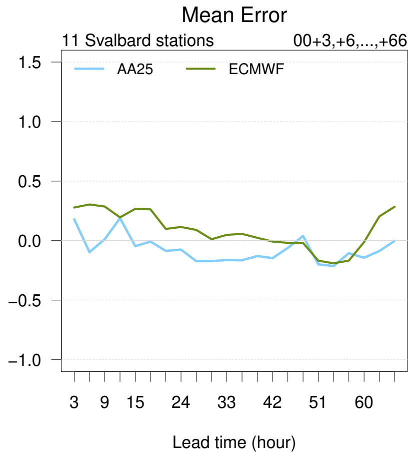
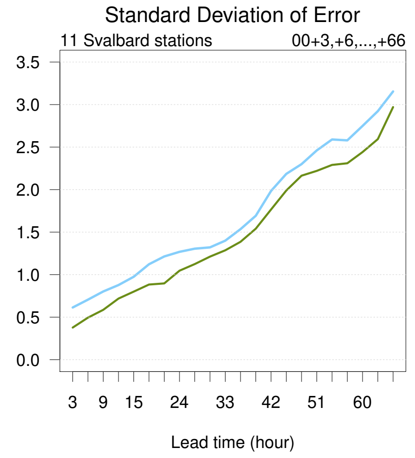
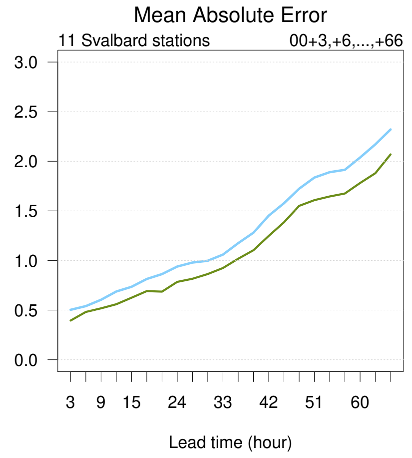
00+3,+6,...,+66
Lead time (hour)


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


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


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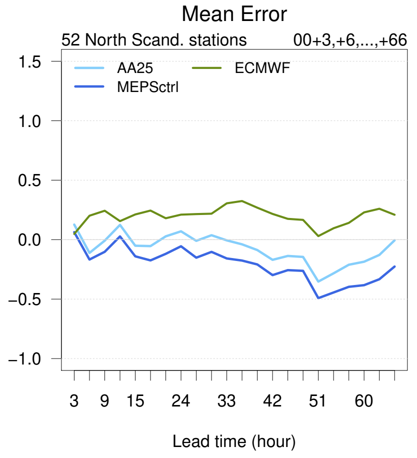
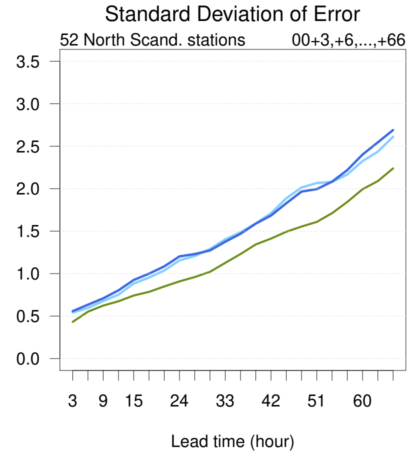
00+3,+6,...,+66
Lead time (hour)


Mean Error
52 North Scand. stations
00+3,+6,...,+66
AA25
ECMWF
MEPSctrl
Lead time (hour)


Standard Deviation of Error
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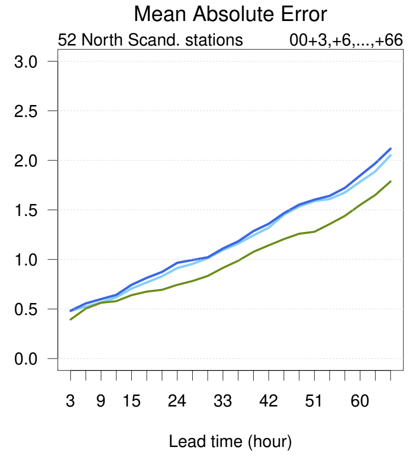
Lead time (hour)


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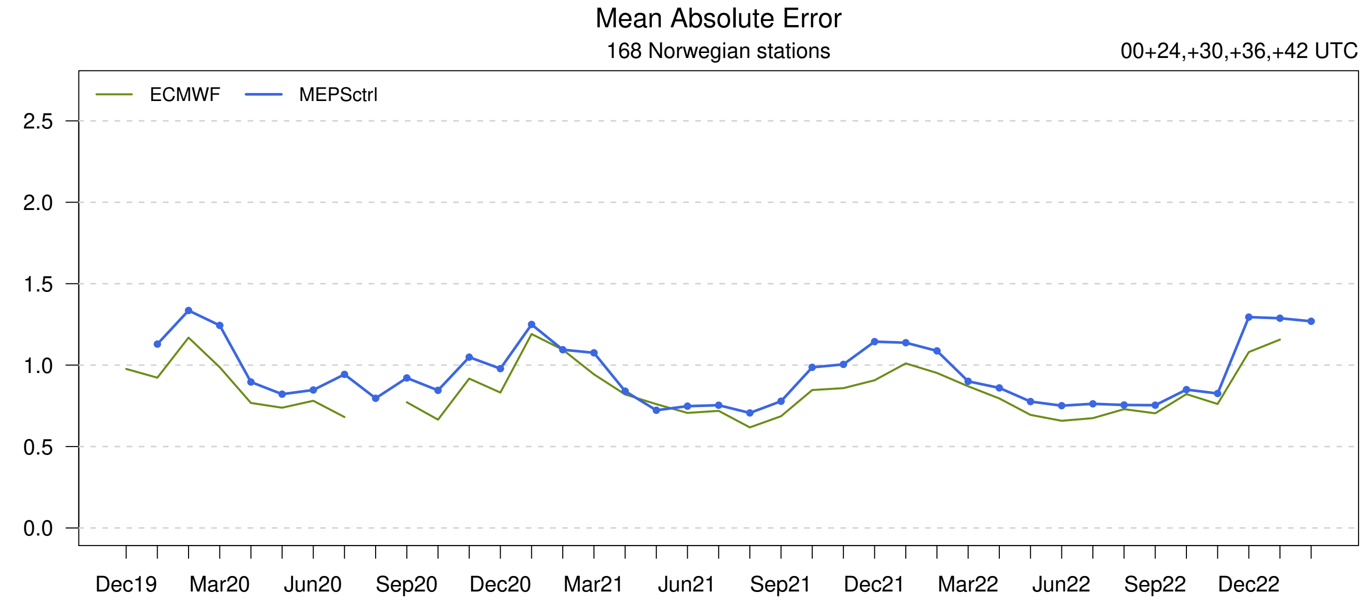
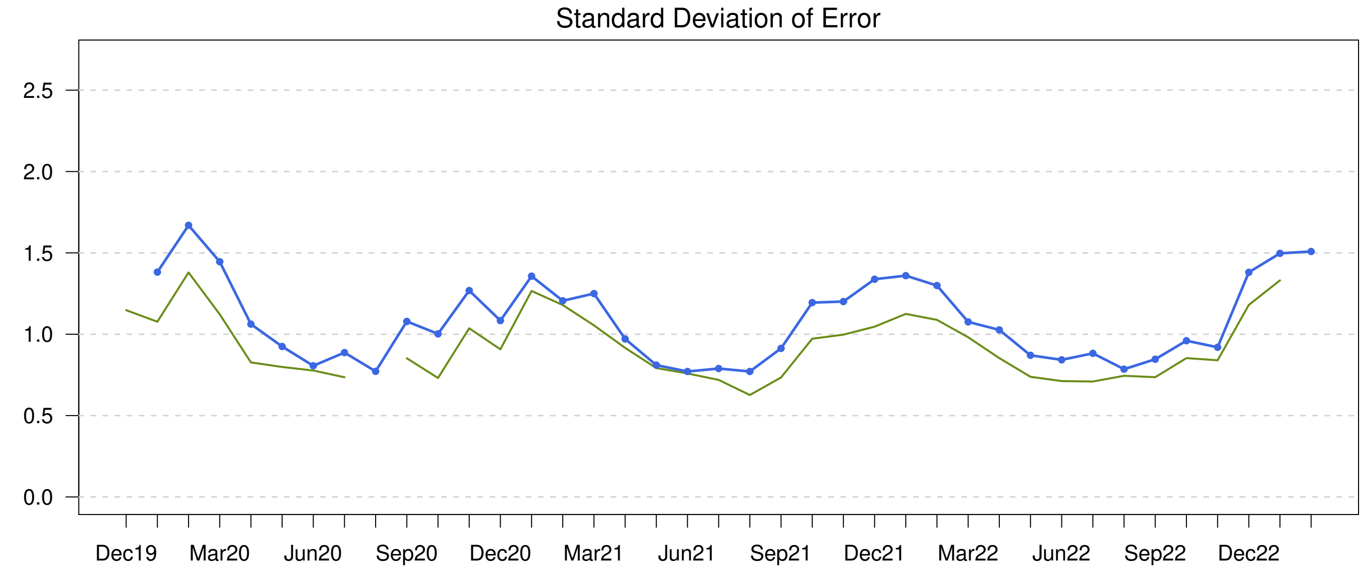
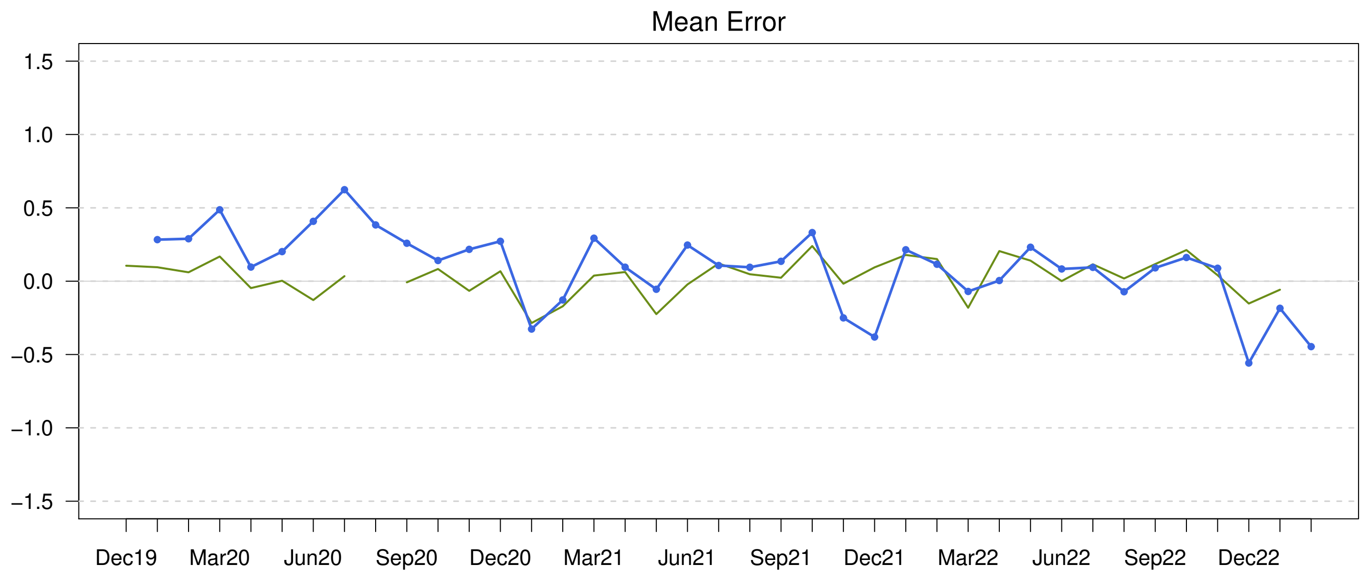
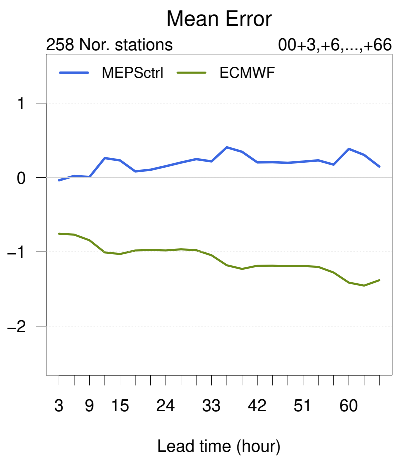
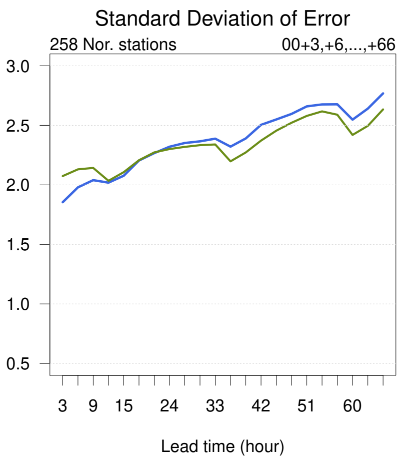
00+3,+6,...,+66
Lead time (hour)

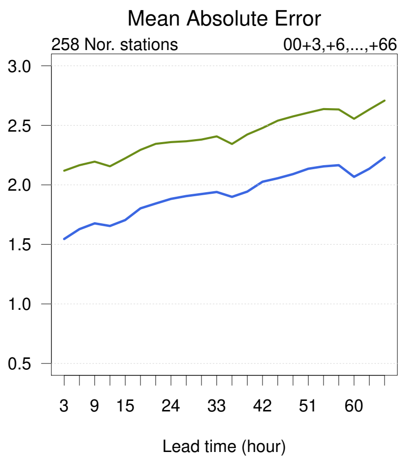

Mean Absolute Error
168 Norwegian stations
00+24,+30,+36,+42 UTC
ECMWF
MEPSctrl
2.5
2.0
1.5
1.0
0.5
0.0
Dec19 Mar20 Jun20 Sep20 Dec20 Mar21 Jun21 Sep21 Dec21 Mar22 Jun22 Sep22 Dec22

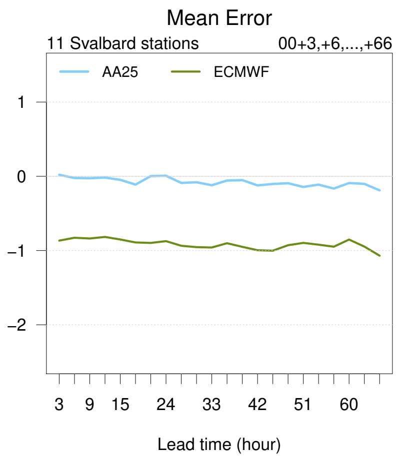

Standard Deviation of Error
2.5
2.0
1.5
1.0
0.5
0.0
Dec19 Mar20 Jun20 Sep20 Dec20 Mar21 Jun21 Sep21 Dec21 Mar22 Jun22 Sep22 Dec22

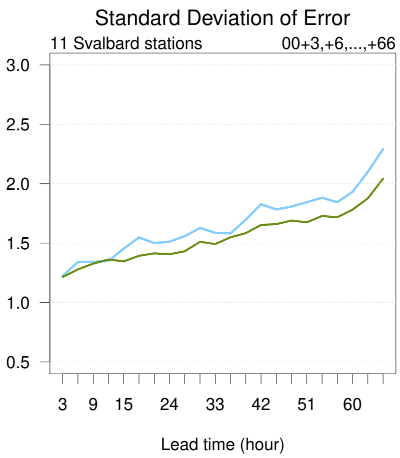

Mean Error
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
Dec19 Mar20 Jun20 Sep20 Dec20 Mar21 Jun21 Sep21 Dec21 Mar22 Jun22 Sep22 Dec22

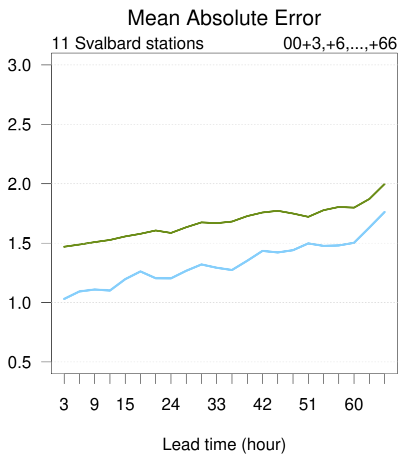

Mean Error
258 Nor. stations
00+3,+6,...,+66
MEPSctrl
ECMWF
1
0
−1
−2
3 9 15 24 33 42 51 60
Lead time (hour)

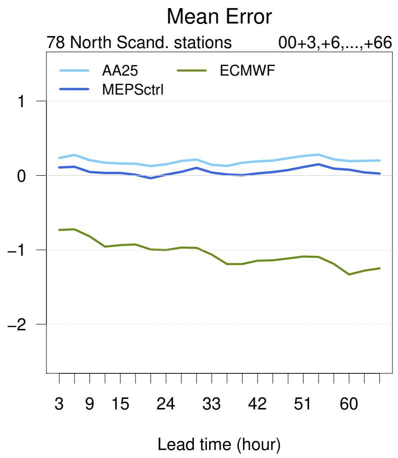

Standard Deviation of Error
258 Nor. stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)

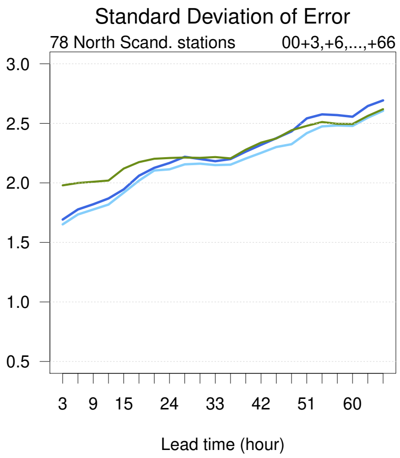

Mean Absolute Error
258 Nor. stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)

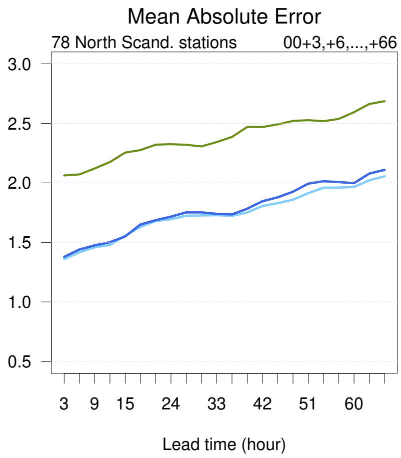

Mean Error
11 Svalbard stations
00+3,+6,...,+66
AA25
ECMWF
1
0
−1
−2
3 9 15 24 33 42 51 60
Lead time (hour)

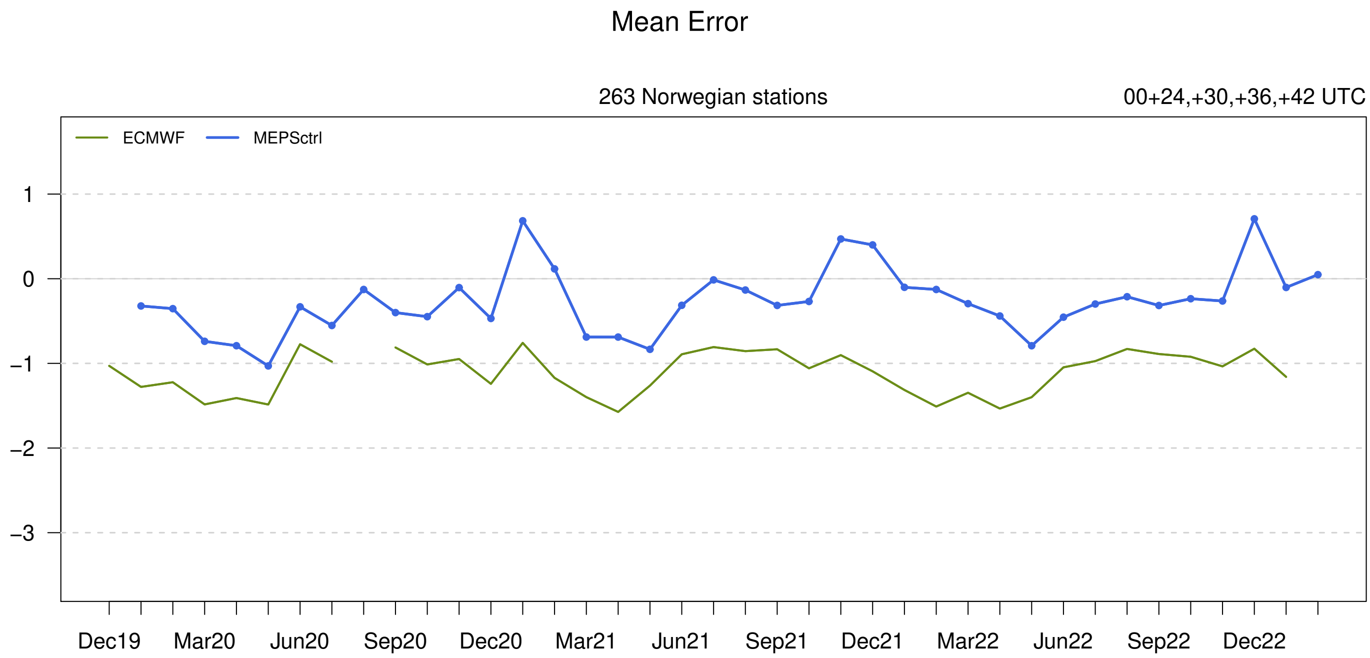

Standard Deviation of Error
11 Svalbard stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)

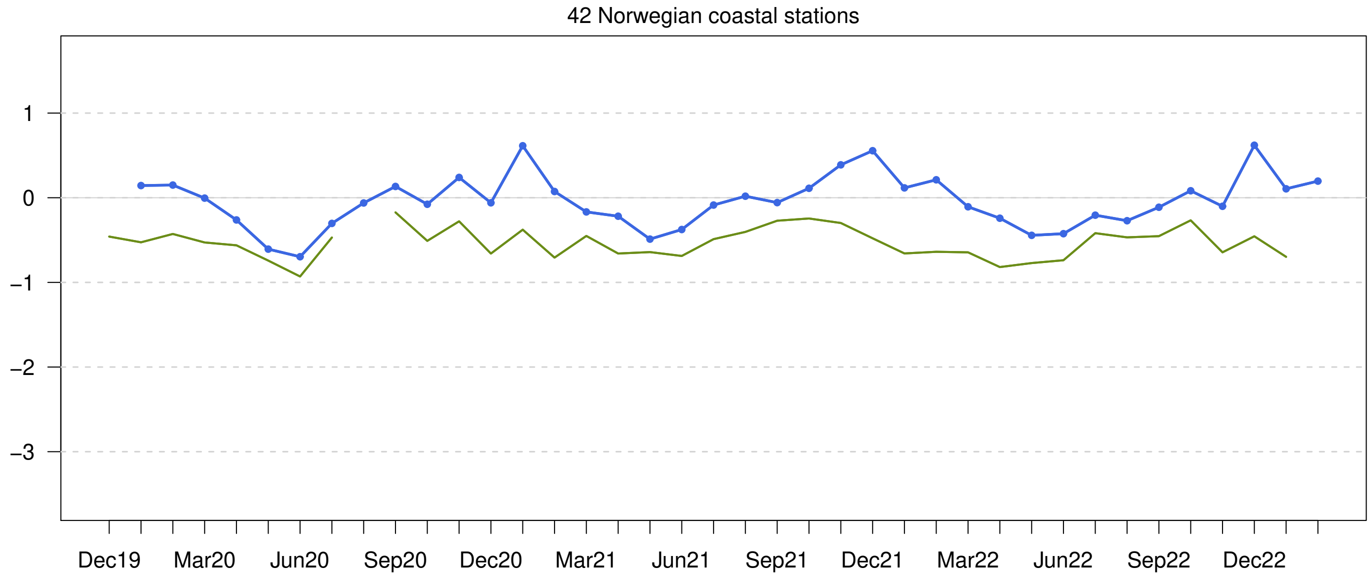

Mean Absolute Error
11 Svalbard stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)

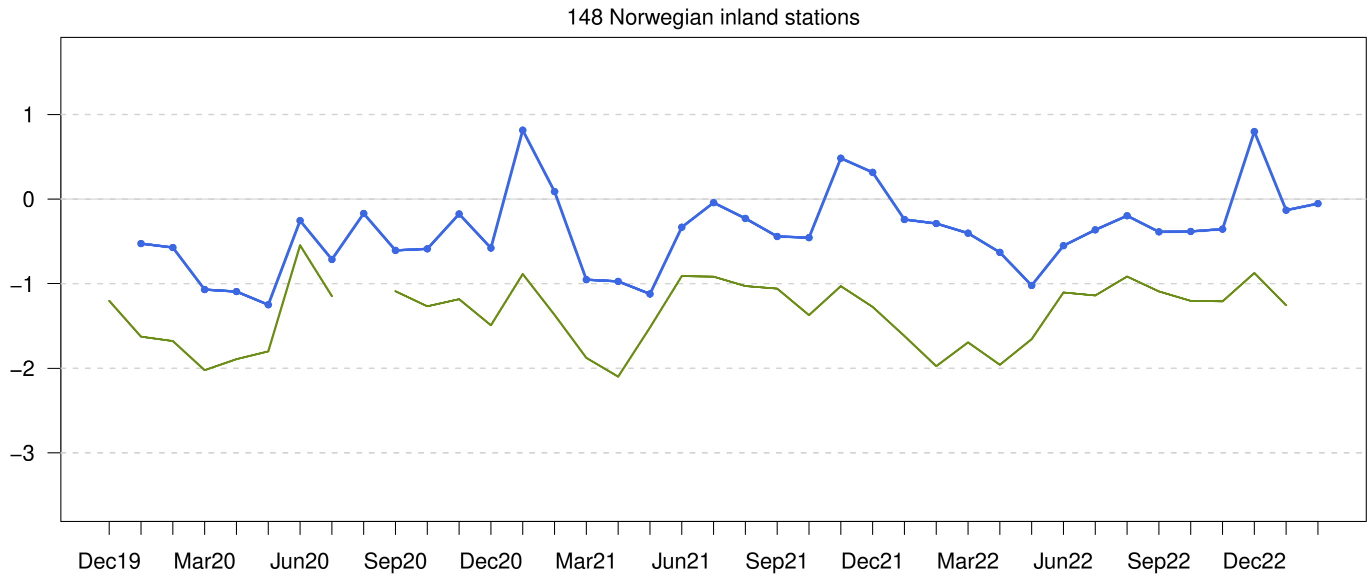

Mean Error
78 North Scand. stations
00+3,+6,...,+66
AA25
MEPSctrl
ECMWF
1
0
−1
−2
3 9 15 24 33 42 51 60
Lead time (hour)


Standard Deviation of Error
78 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)

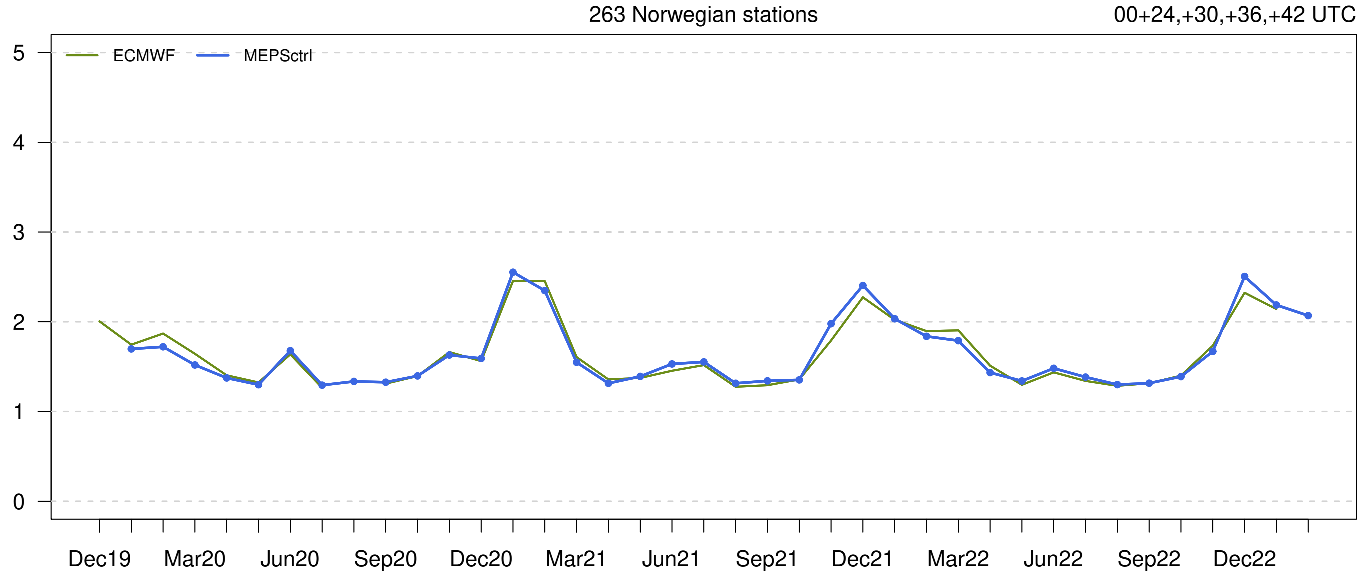

Mean Absolute Error
78 North Scand. stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)

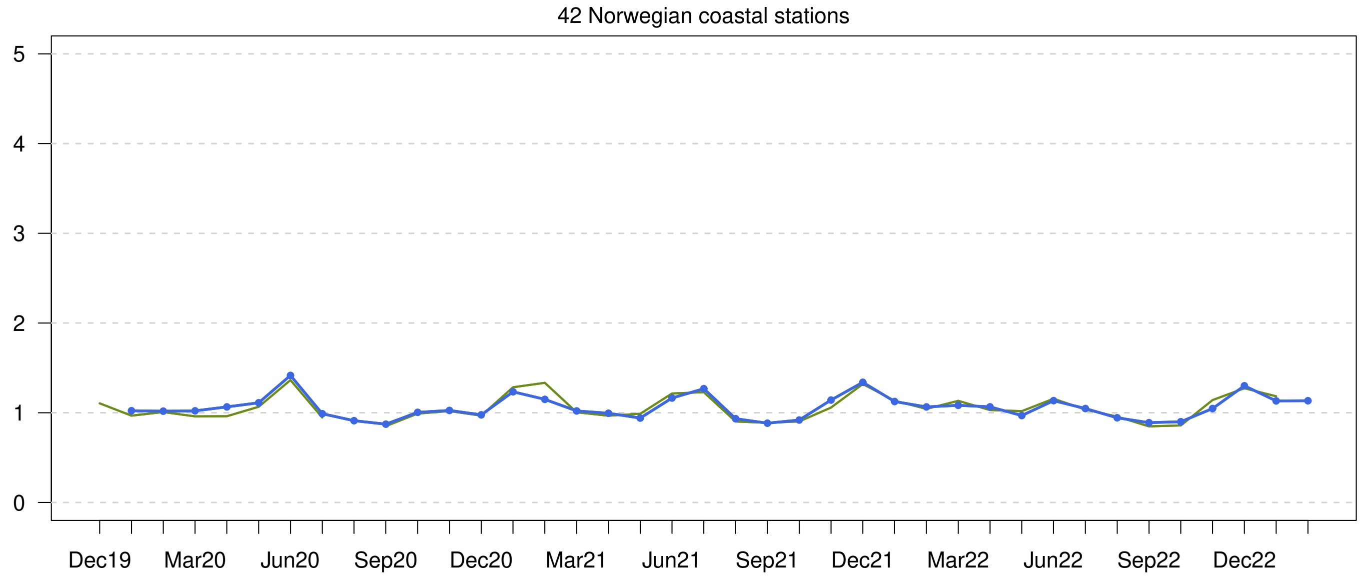

Mean Error
263 Norwegian stations
00+24,+30,+36,+42 UTC
ECMWF
MEPSctrl
1
0
−1
−2
−3
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22

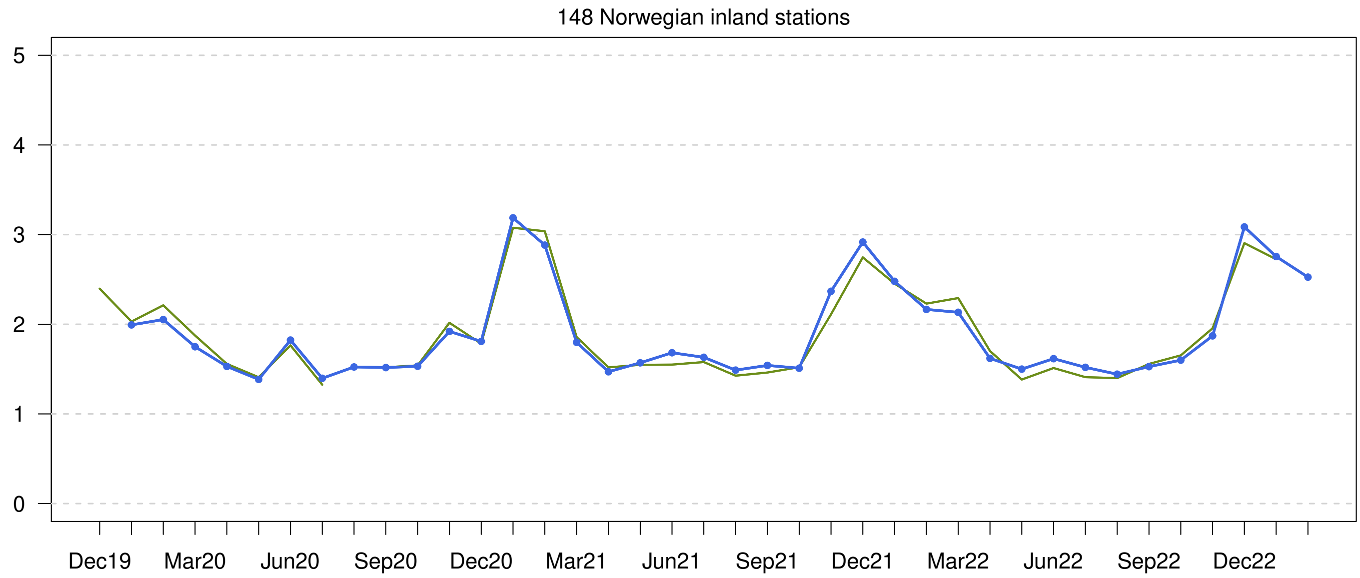

42 Norwegian coastal stations
1
0
−1
−2
−3
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22


148 Norwegian inland stations
1
0
−1
−2
−3
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22

Standard Deviation of Error

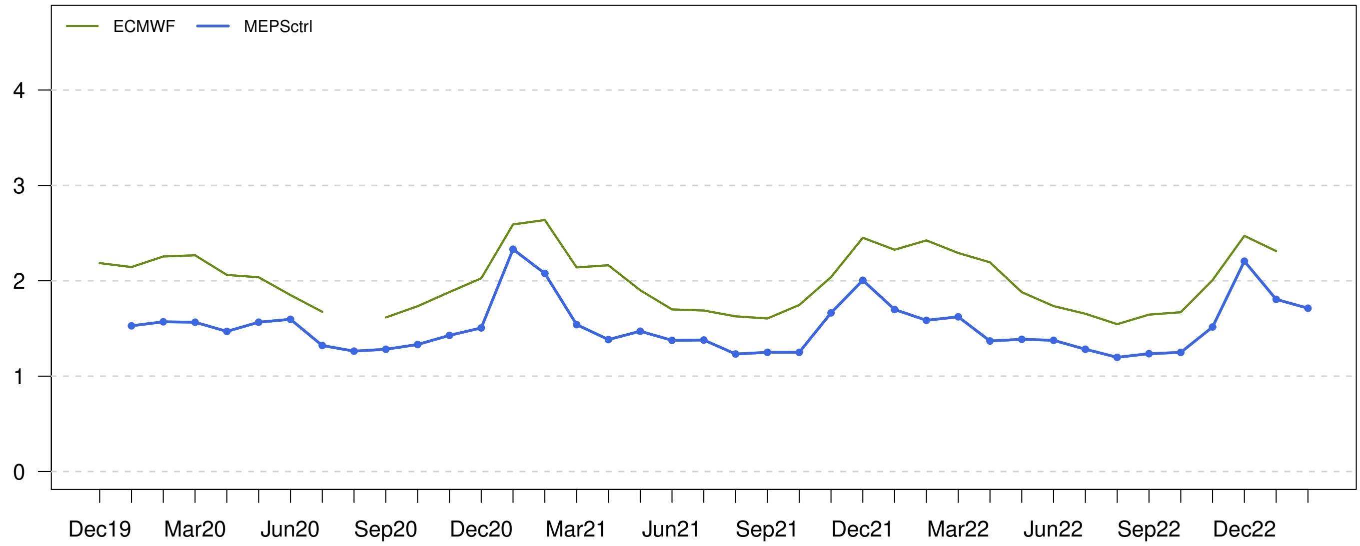




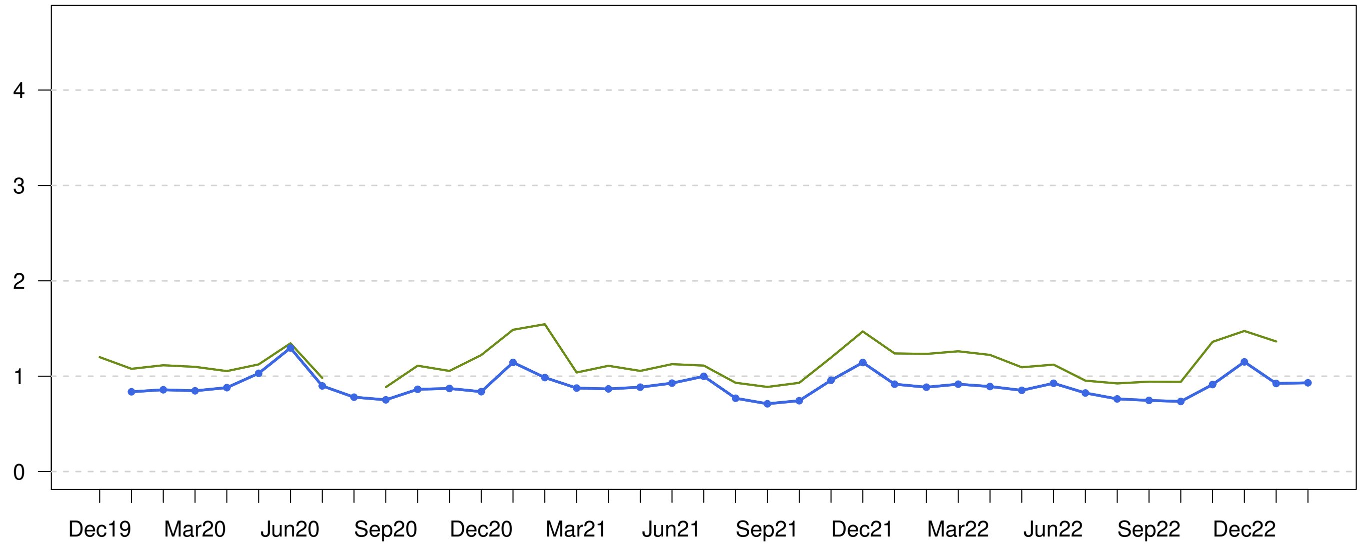


Mean Absolute Error

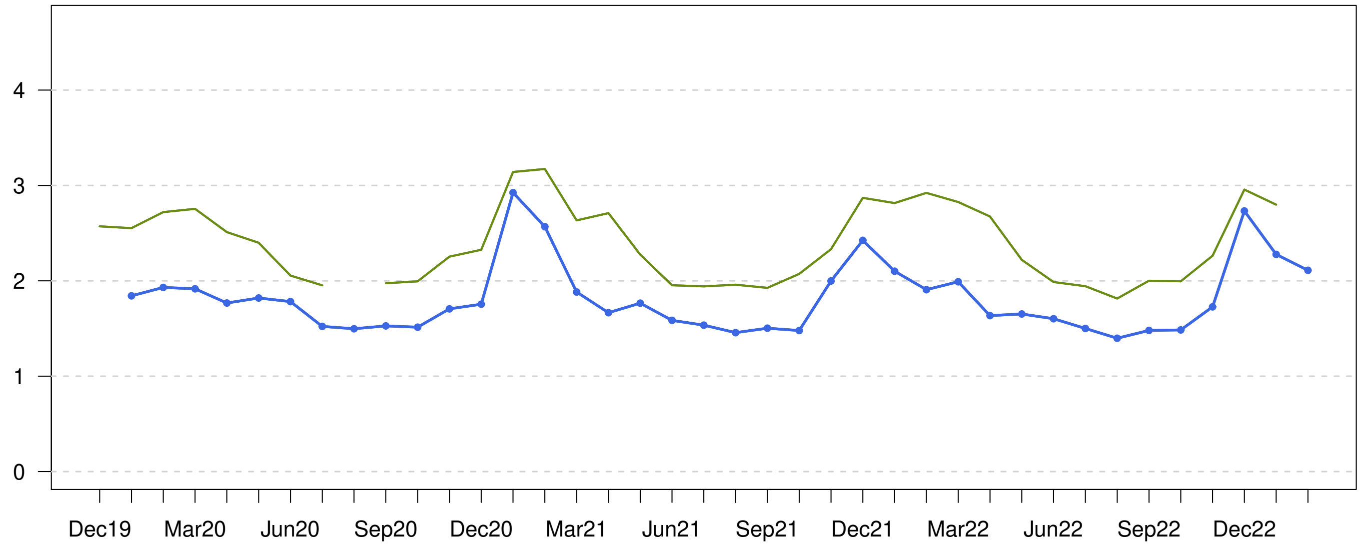
263 Norwegian stations 00+24,+30,+36,+42 UTC



42 Norwegian coastal stations

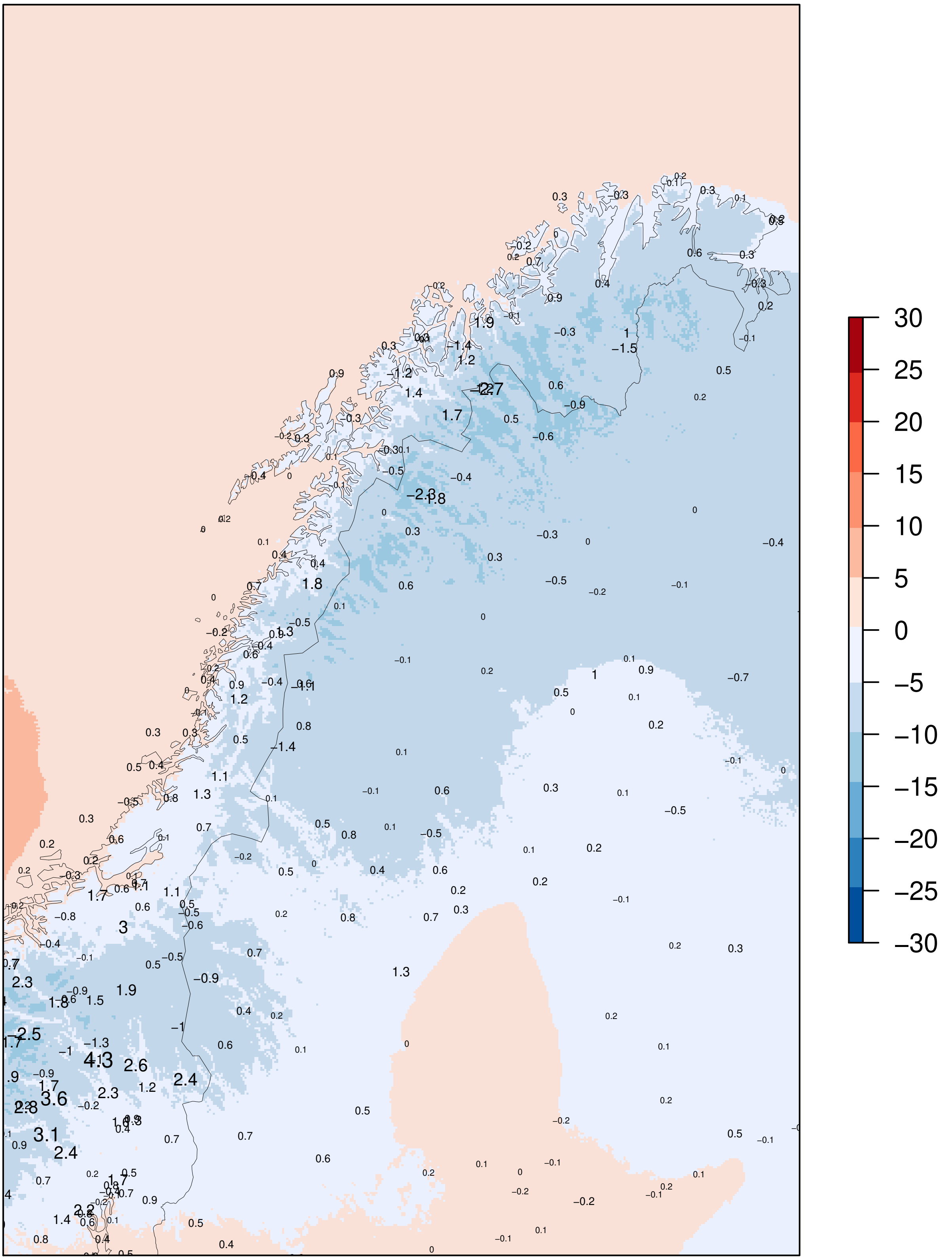


148 Norwegian inland stations

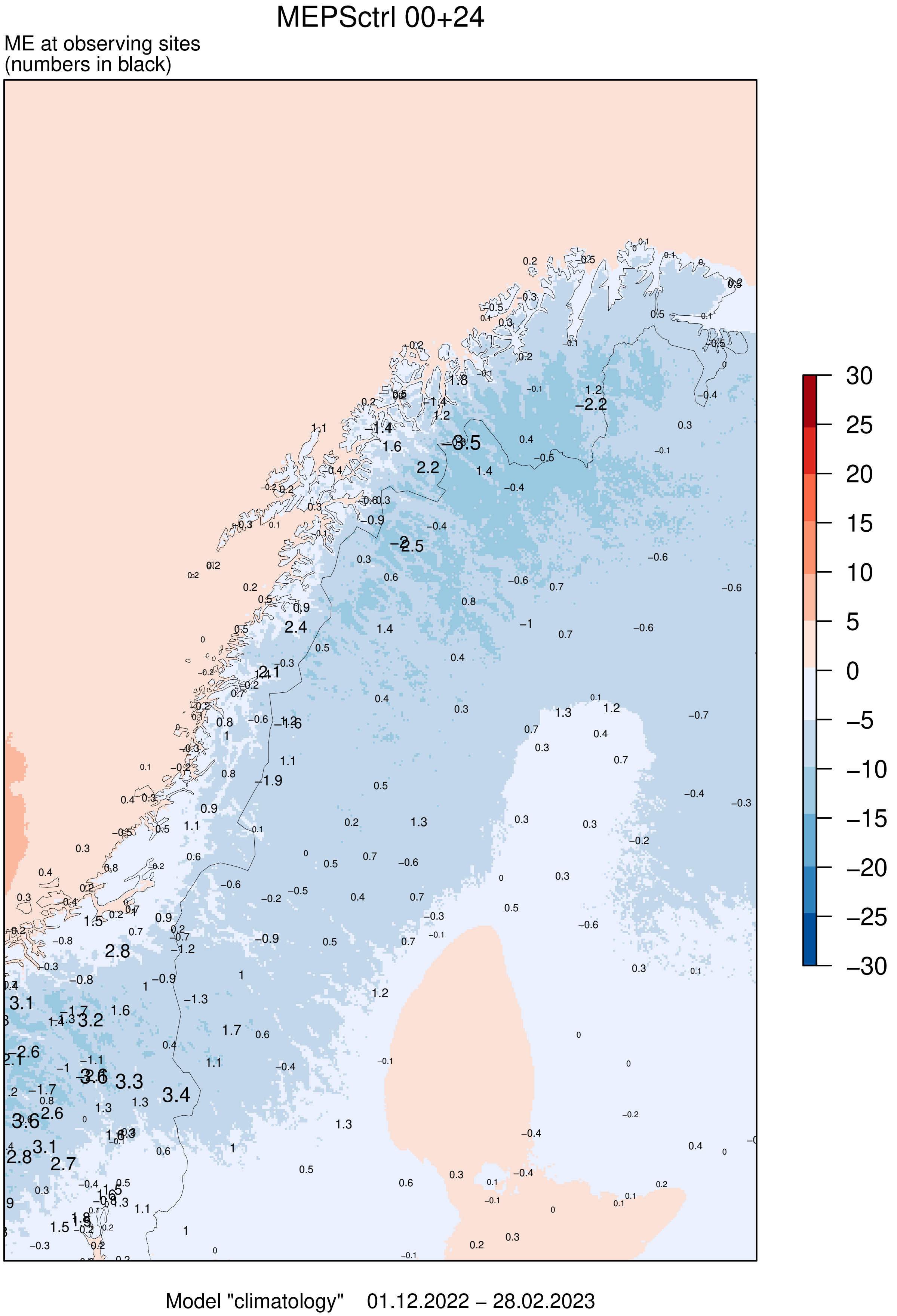


MEPSctrl 00+12

ME at observing sites
(numbers in black)

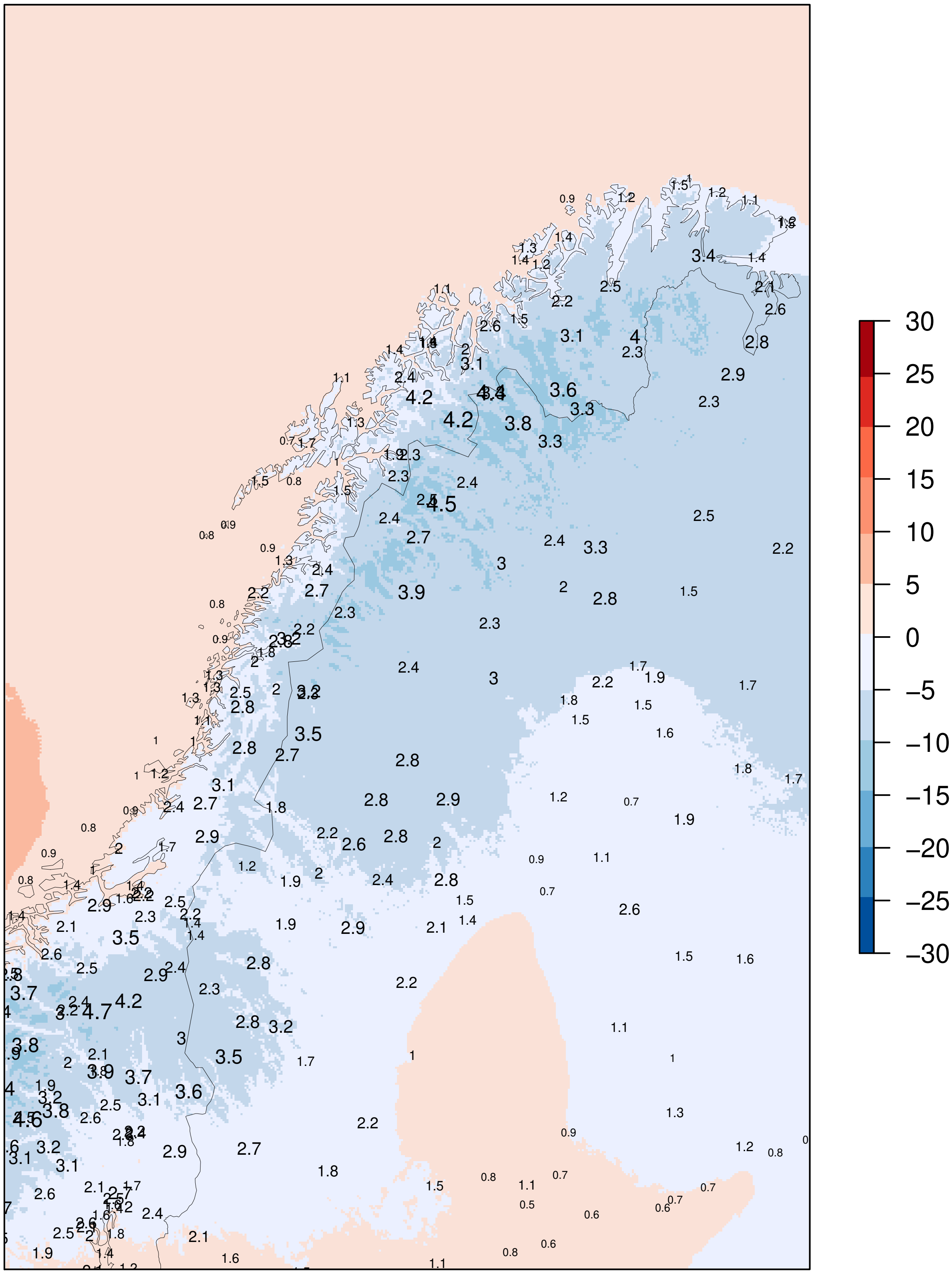


Model "climatology" 01.12.2022 – 28.02.2023


MEPSctrl 00+24
ME at observing sites
(numbers in black)
30
25
20
15
10
5
0
−5
−10
−15
−20
−25
−30
Model "climatology" 01.12.2022 – 28.02.2023

MEPSctrl 00+12

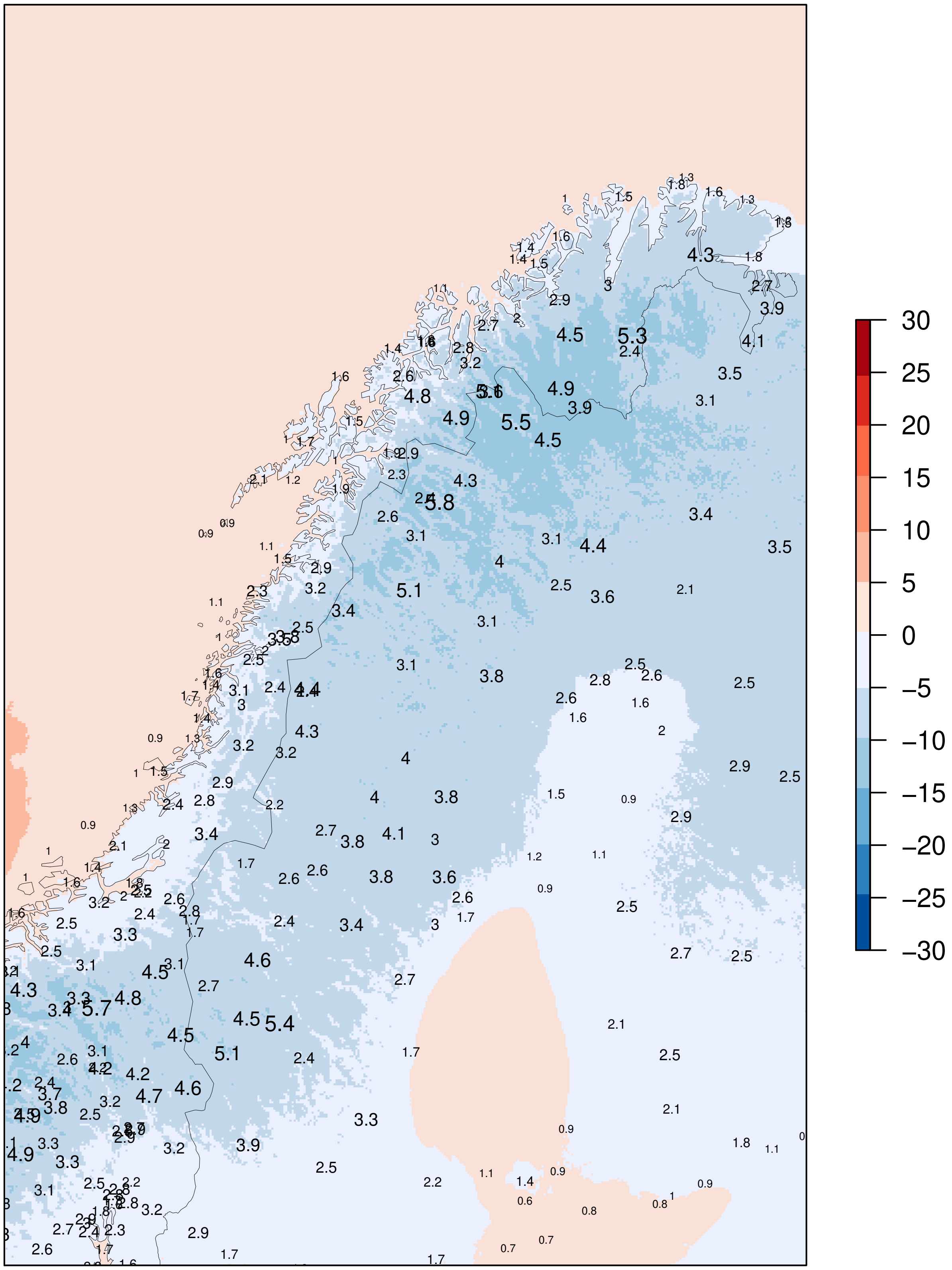
SDE at observing sites
(numbers in black)



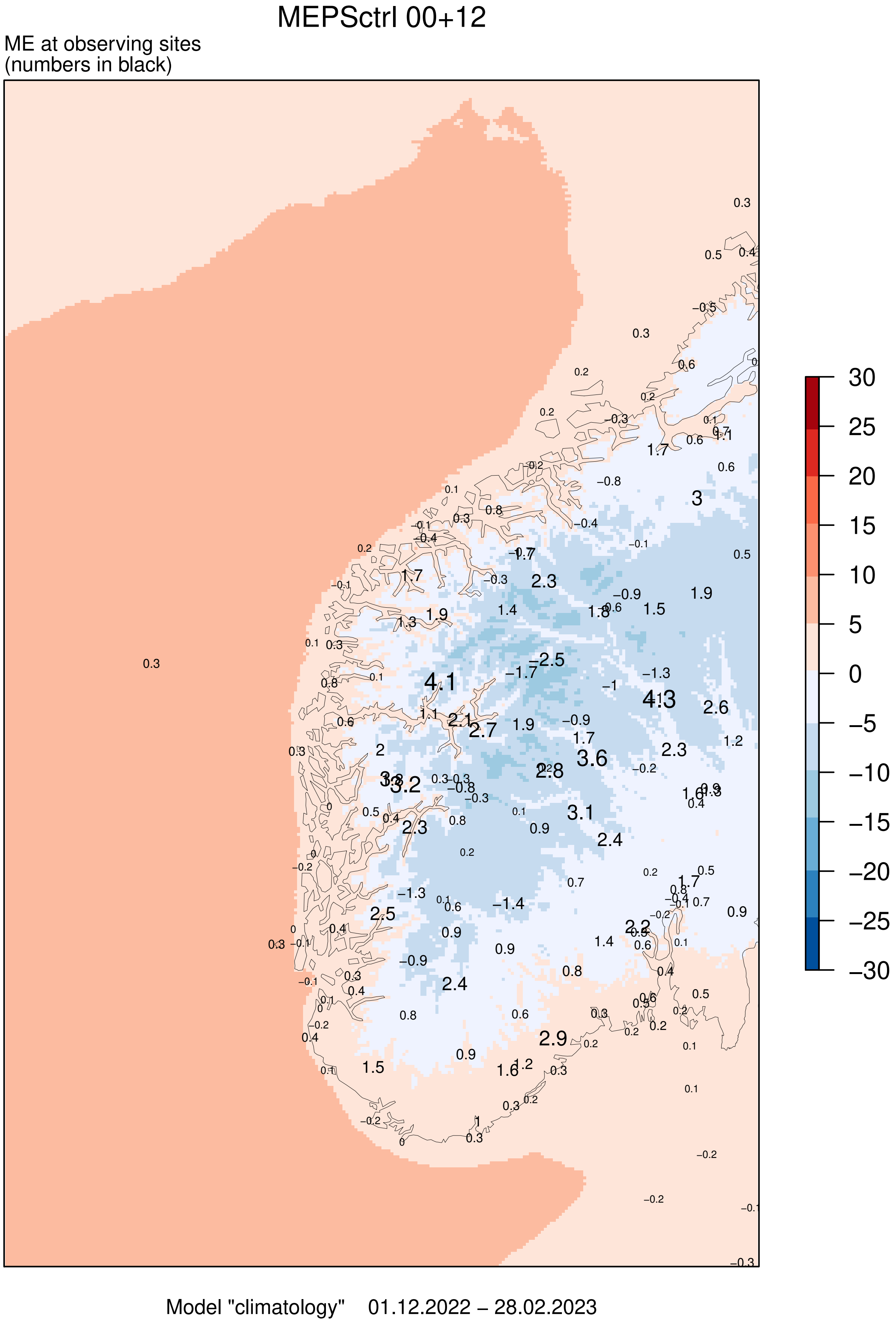
Model "climatology" 01.12.2022 – 28.02.2023

MEPSctrl 00+24

SDE at observing sites
(numbers in black)

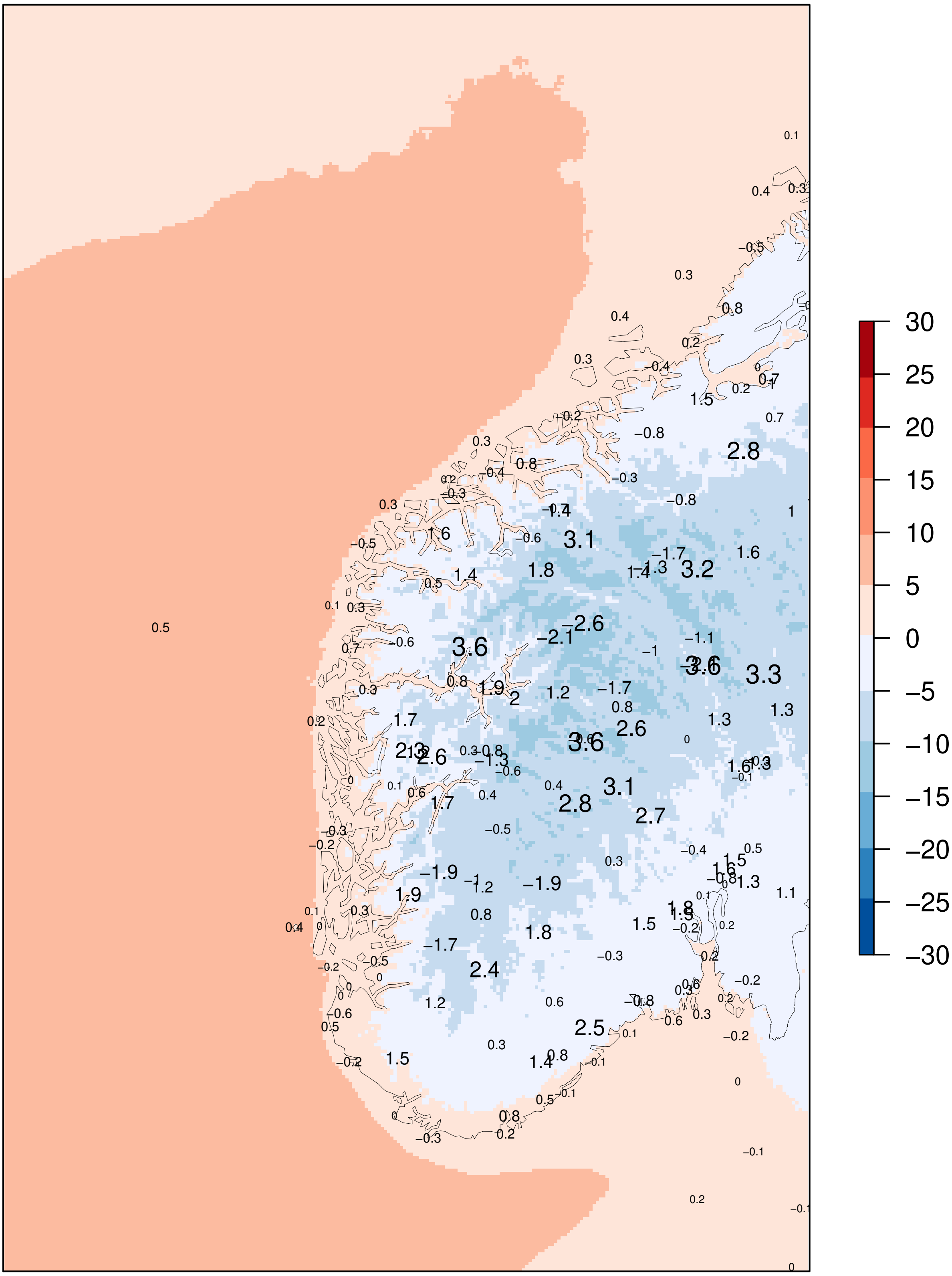


Model "climatology" 01.12.2022 – 28.02.2023


MEPSctrl 00+12
ME at observing sites
(numbers in black)
30
25
20
15
10
5
0
−5
−10
−15
−20
−25
−30
Model "climatology" 01.12.2022 – 28.02.2023

MEPSctrl 00+24

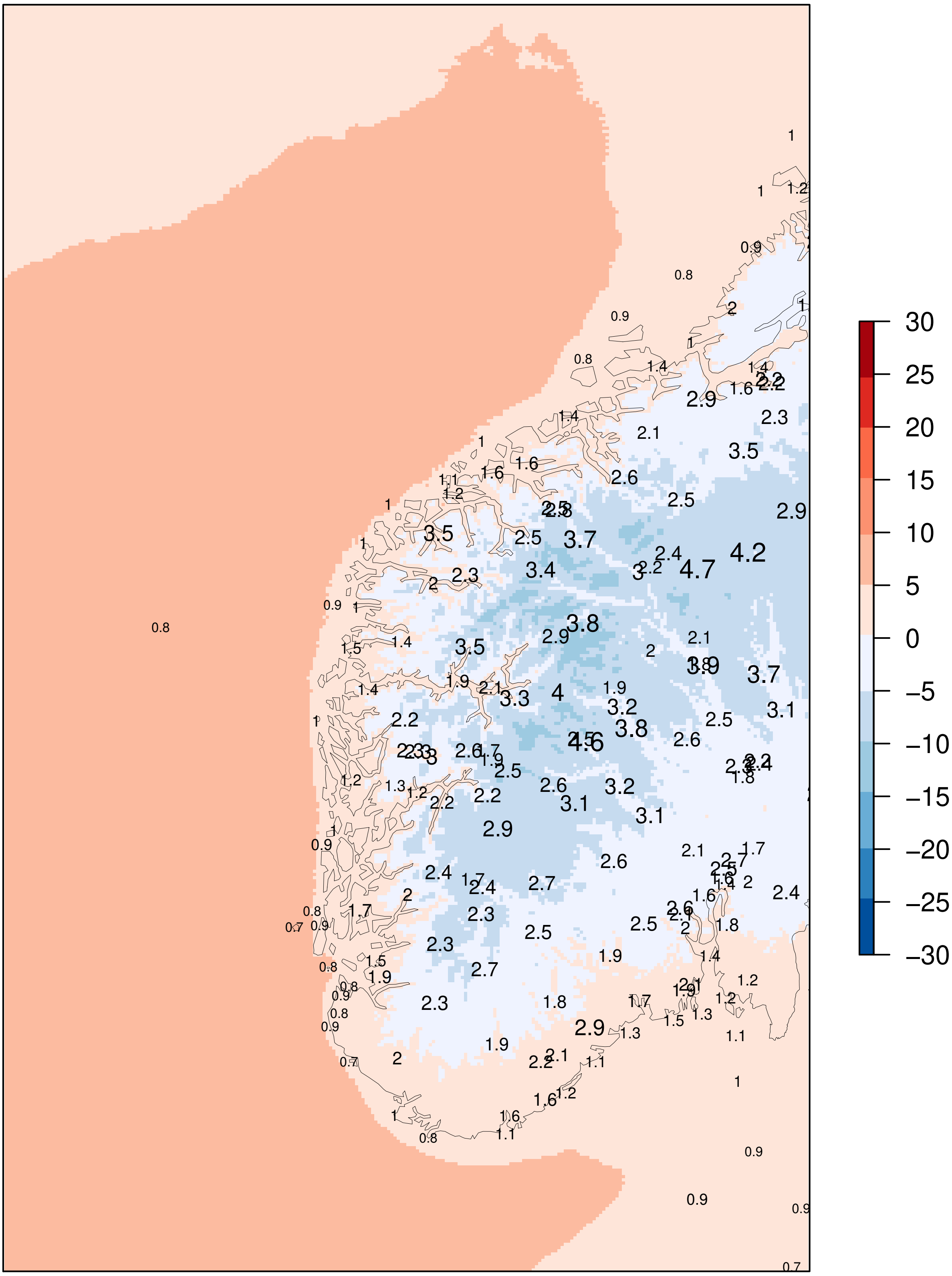
ME at observing sites
(numbers in black)



Model "climatology"   01.12.2022 – 28.02.2023

MEPSctrl 00+12

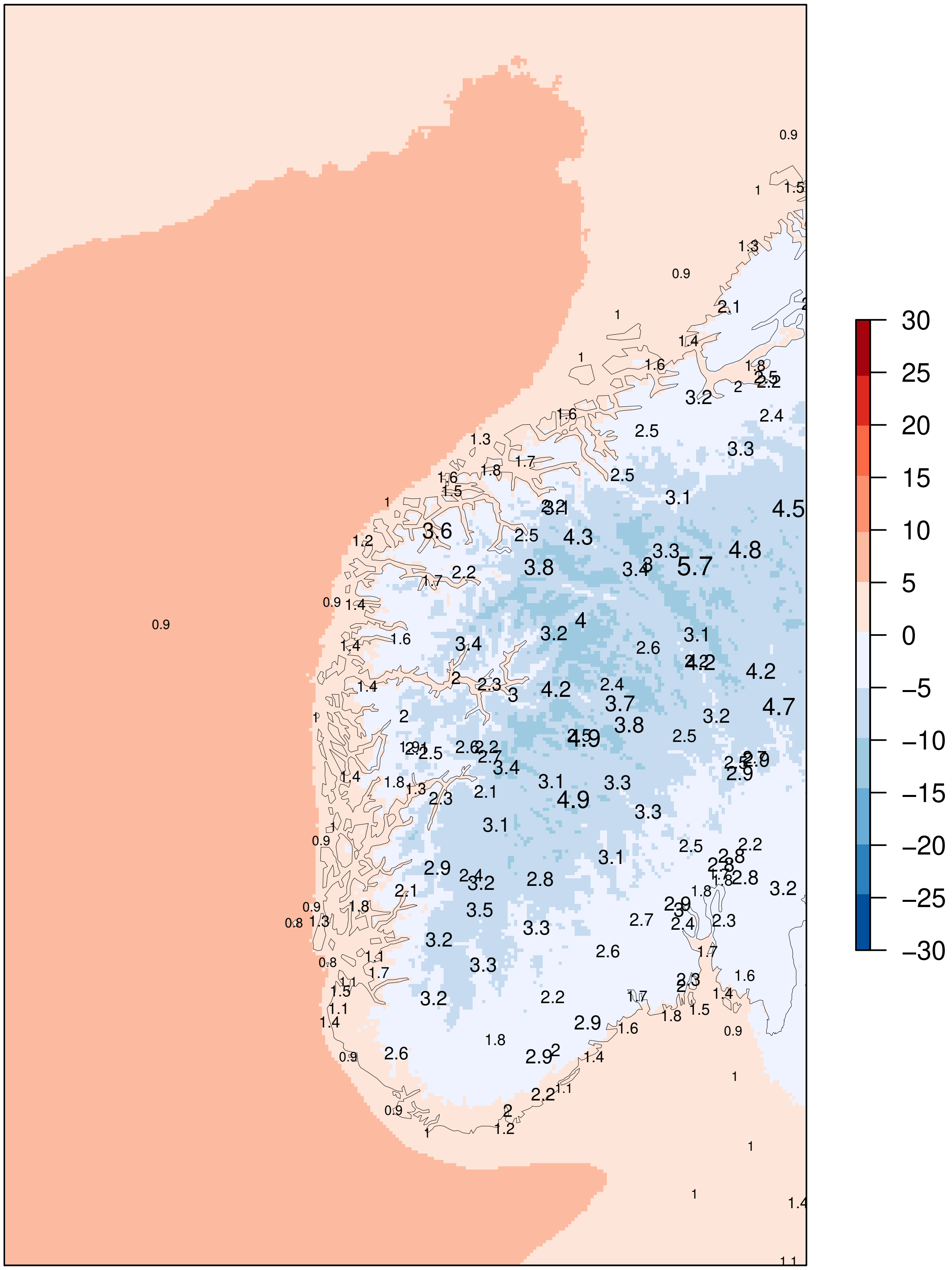
SDE at observing sites
(numbers in black)



Model "climatology" 01.12.2022 – 28.02.2023

MEPSctrl 00+24

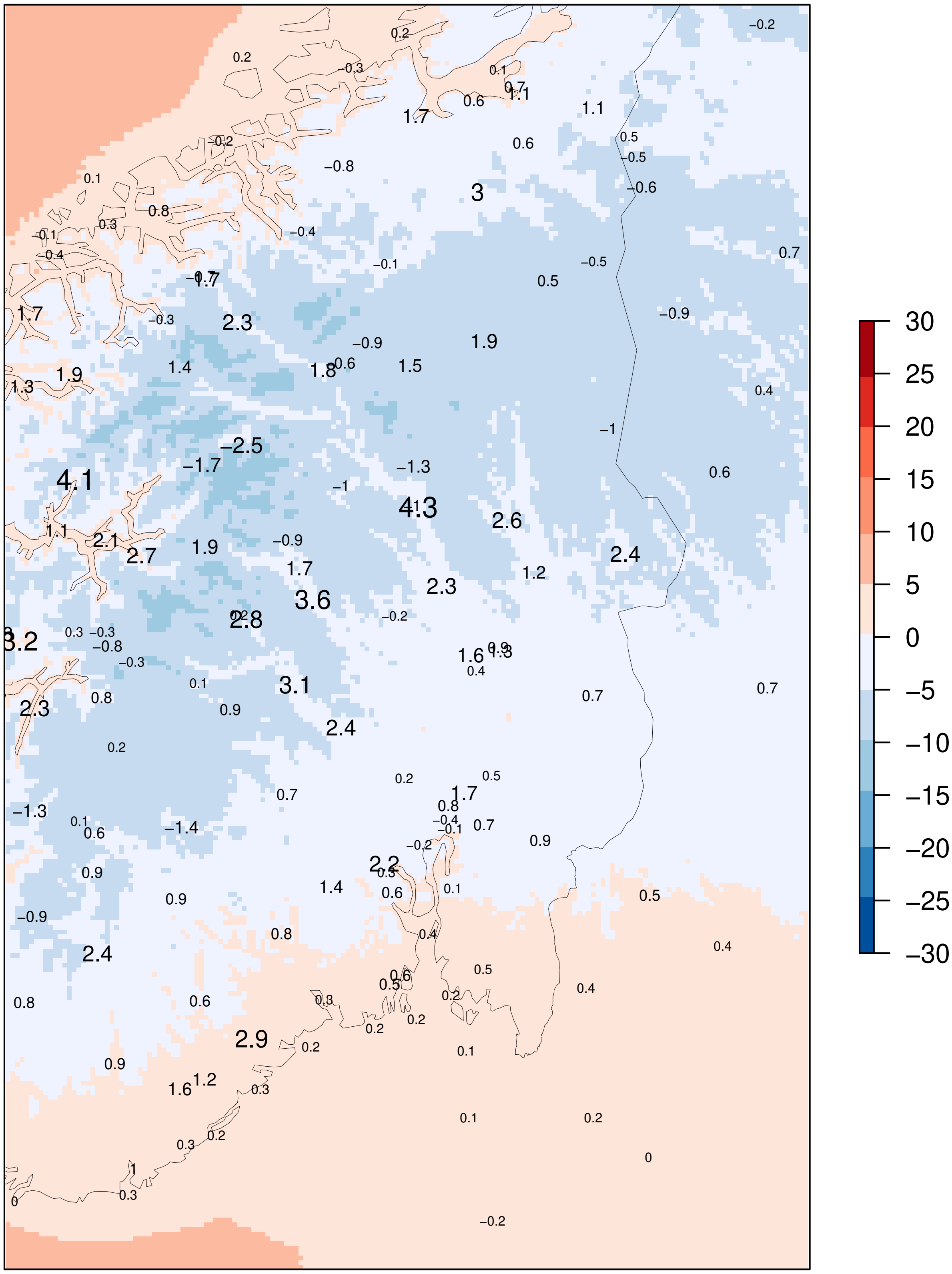
SDE at observing sites
(numbers in black)



Model "climatology" 01.12.2022 – 28.02.2023

MEPSctrl 00+12

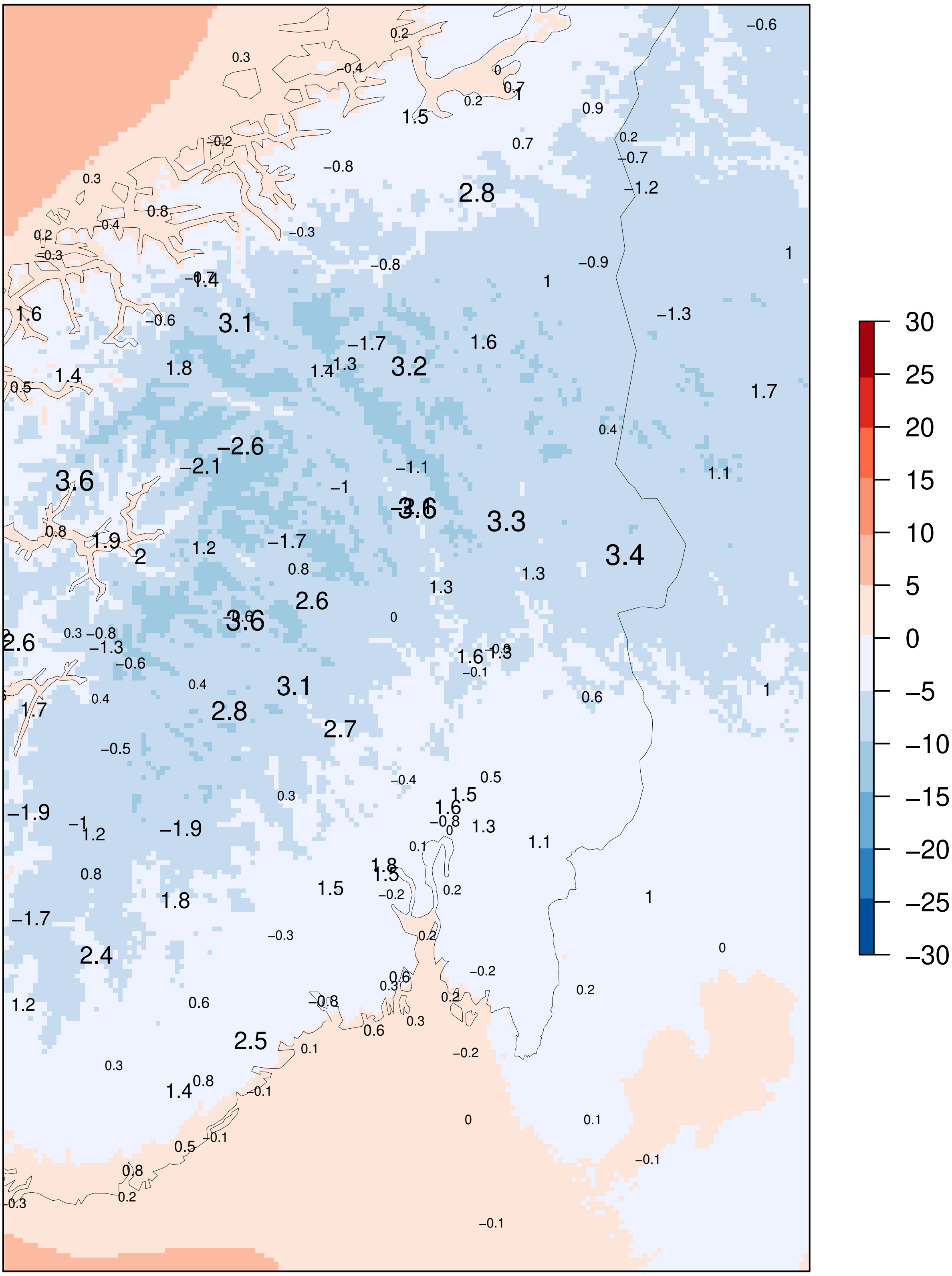
ME at observing sites
(numbers in black)



Model "climatology" 01.12.2022 – 28.02.2023

MEPSctrl 00+24

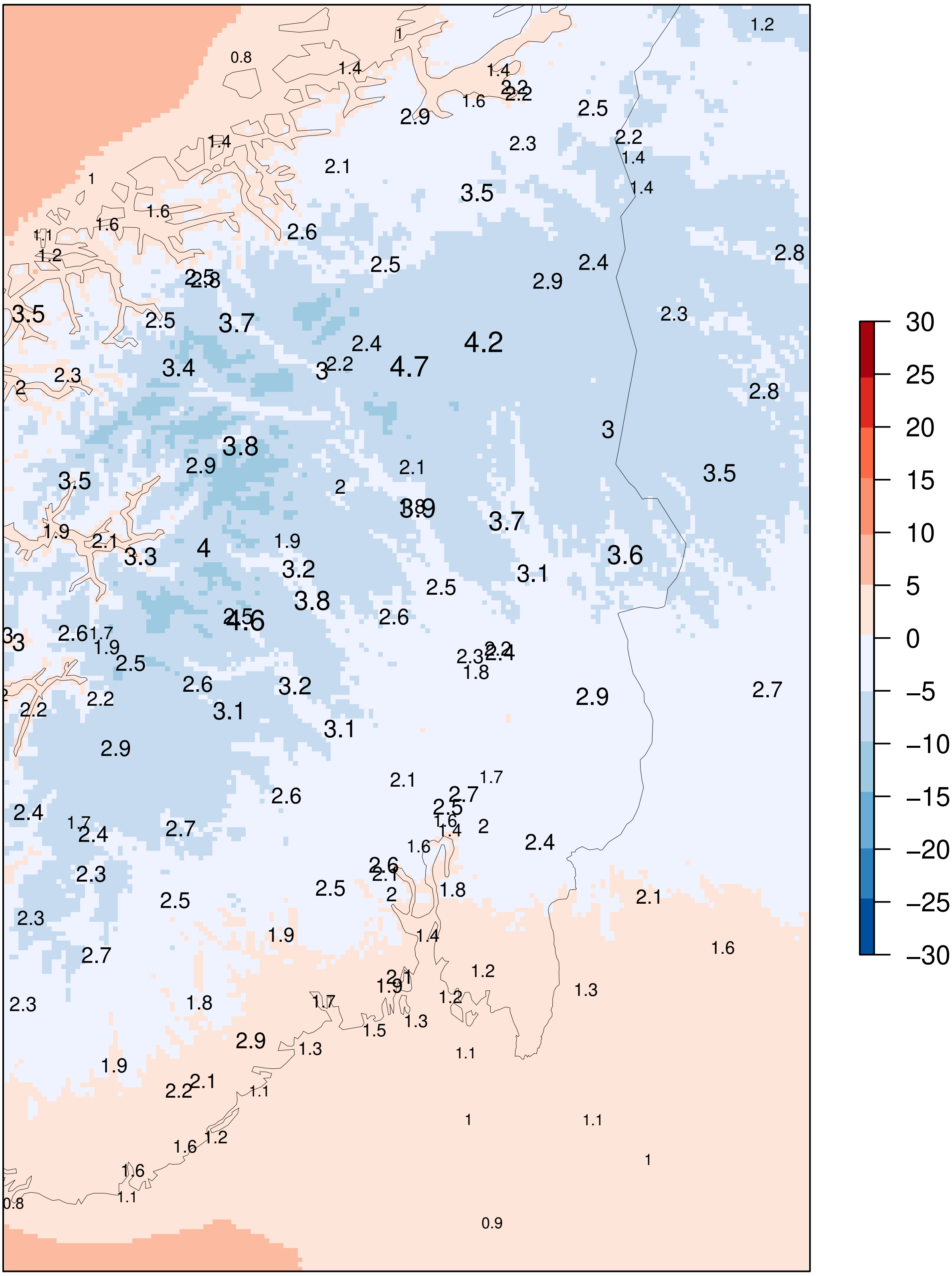
ME at observing sites
(numbers in black)



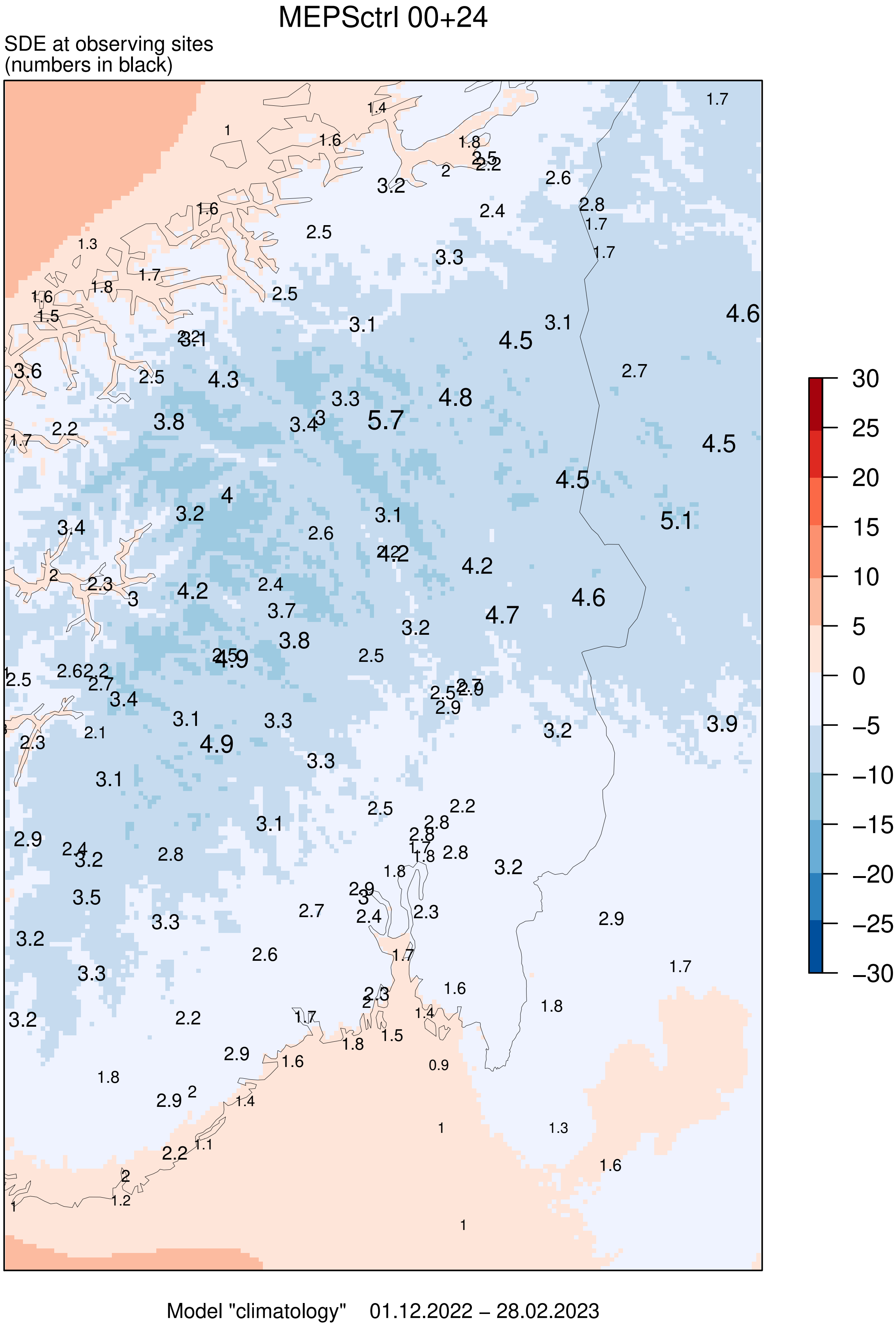
Model "climatology" 01.12.2022 – 28.02.2023

MEPSctrl 00+12

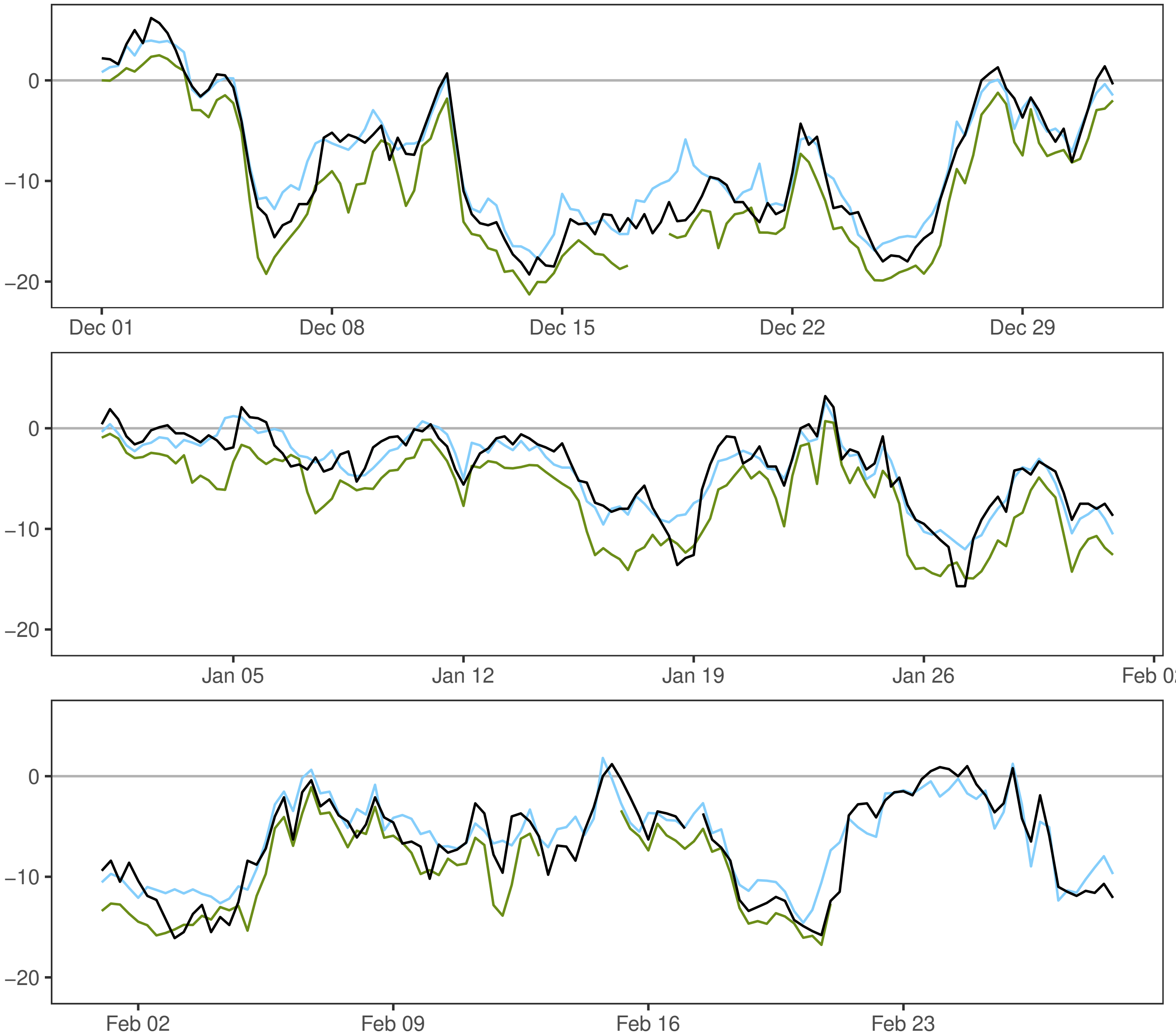
SDE at observing sites
(numbers in black)



Model "climatology" 01.12.2022 – 28.02.2023

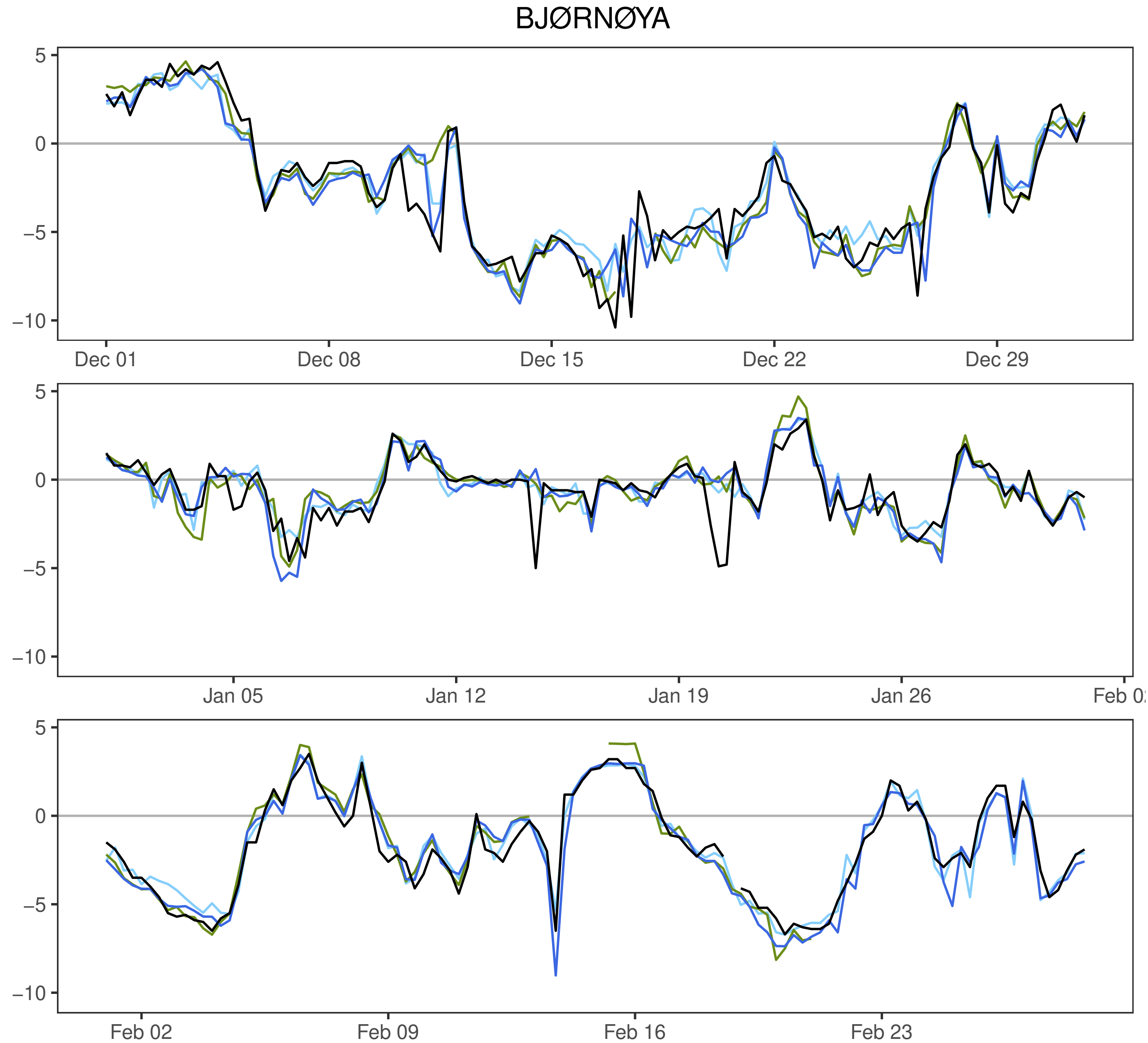

MEPSctrl 00+24
SDE at observing sites
(numbers in black)
30
25
20
15
10
5
0
−5
−10
−15
−20
−25
−30
Model "climatology" 01.12.2022 – 28.02.2023

SVALBARD LUFTHAVN



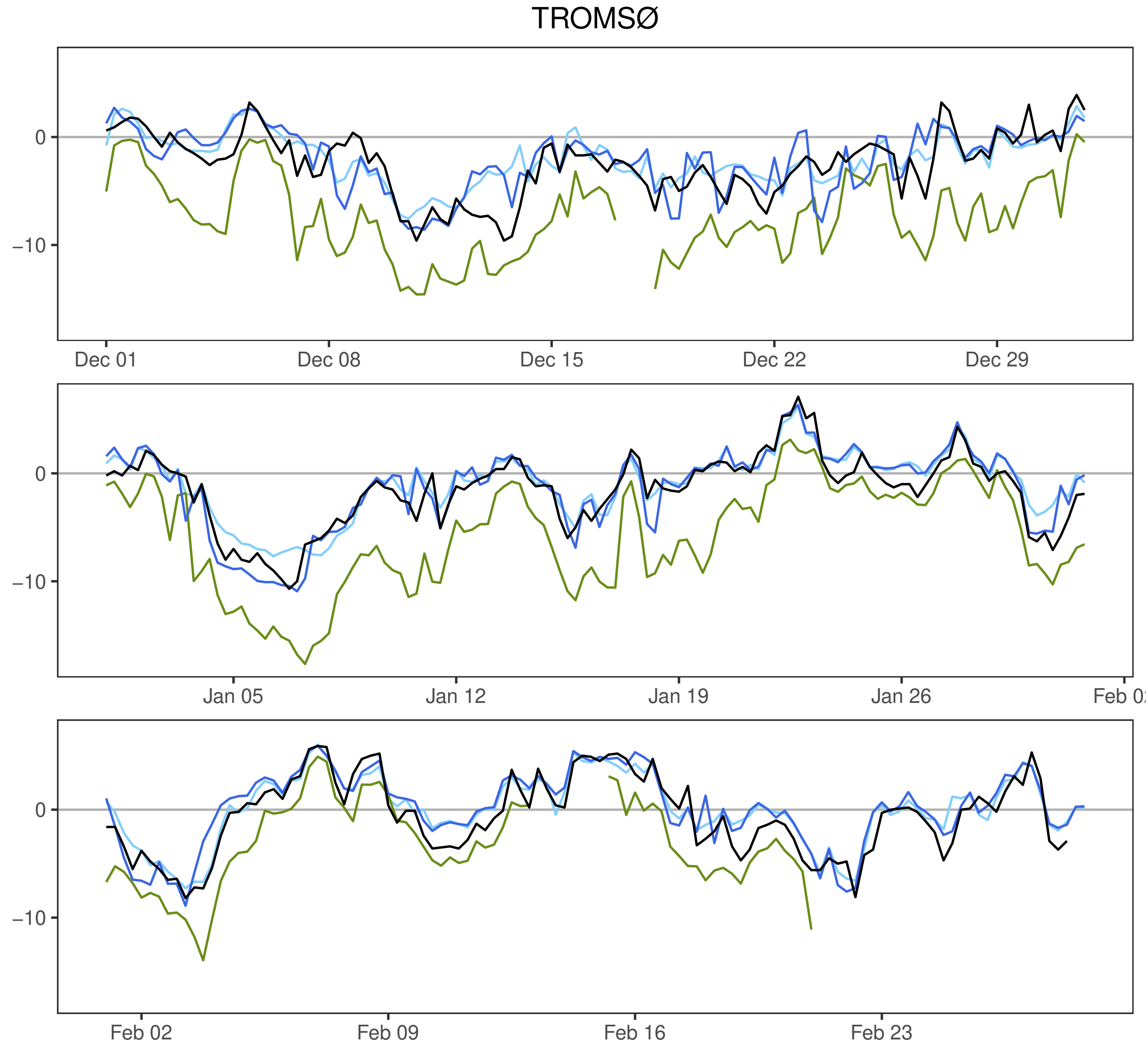
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−19.3	−6.4	6.2	5.6	359
AA25: 12+18,+24,+30,+36	−17.8	−6.0	4.0	4.8	360
ECMWF: 12+18,+24,+30,+36	−21.3	−8.9	2.5	5.6	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
AA25−synop	0.4	1.7	1.8	1.3	8.0	316
ECMWF−synop	−2.4	1.6	2.9	2.6	7.7	316



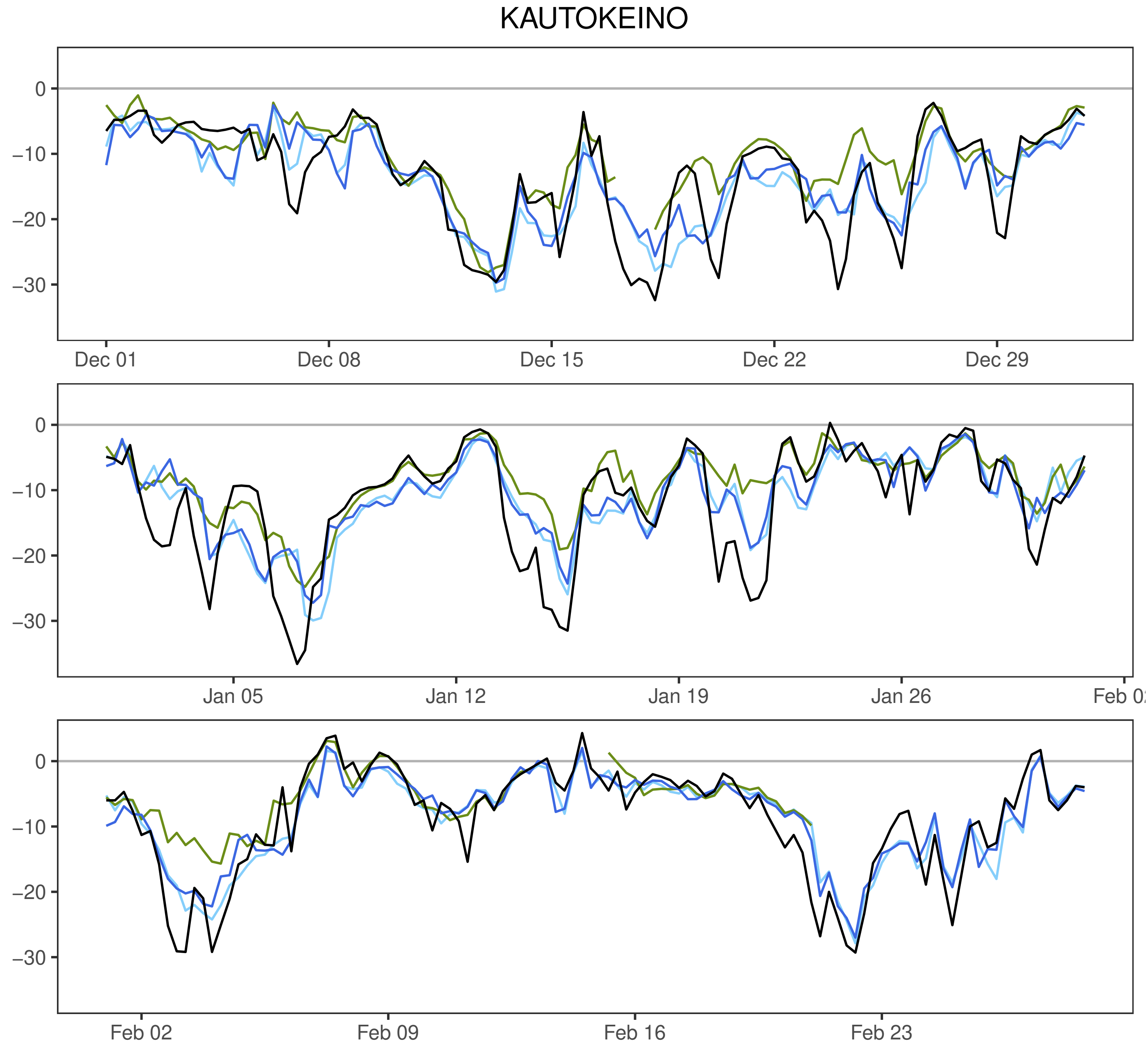
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−10.4	−1.7	4.6	2.9	359
MEPSctrl: 12+18,+24,+30,+36	−9.0	−1.8	4.2	2.9	360
AA25: 12+18,+24,+30,+36	−8.4	−1.5	4.0	2.7	360
ECMWF: 12+18,+24,+30,+36	−8.9	−1.6	4.7	3.0	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.1	1.1	1.1	0.8	5.6	316
AA25−synop	0.2	1.0	1.0	0.7	4.7	316
ECMWF−synop	0.1	1.1	1.1	0.7	6.3	316



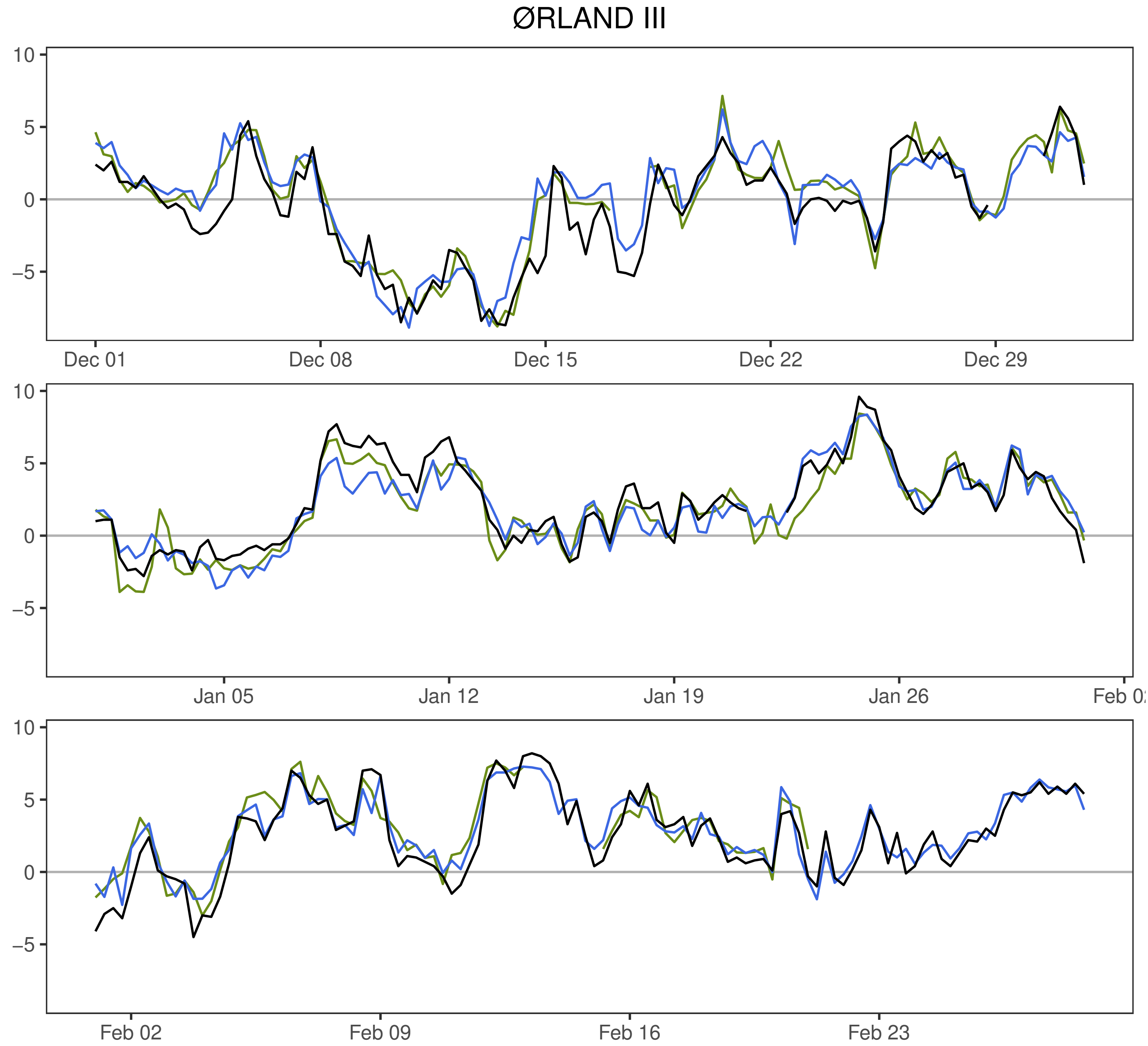
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−10.7	−1.6	7.1	3.4	359
MEPSctrl: 12+18,+24,+30,+36	−10.9	−1.1	6.3	3.5	360
AA25: 12+18,+24,+30,+36	−7.7	−1.0	6.2	2.9	360
ECMWF: 12+18,+24,+30,+36	−17.7	−5.8	4.9	4.6	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.4	1.8	1.9	1.4	6.1	317
AA25−synop	0.6	1.5	1.6	1.2	6.5	317
ECMWF−synop	−4.2	2.4	4.8	4.2	11.1	317



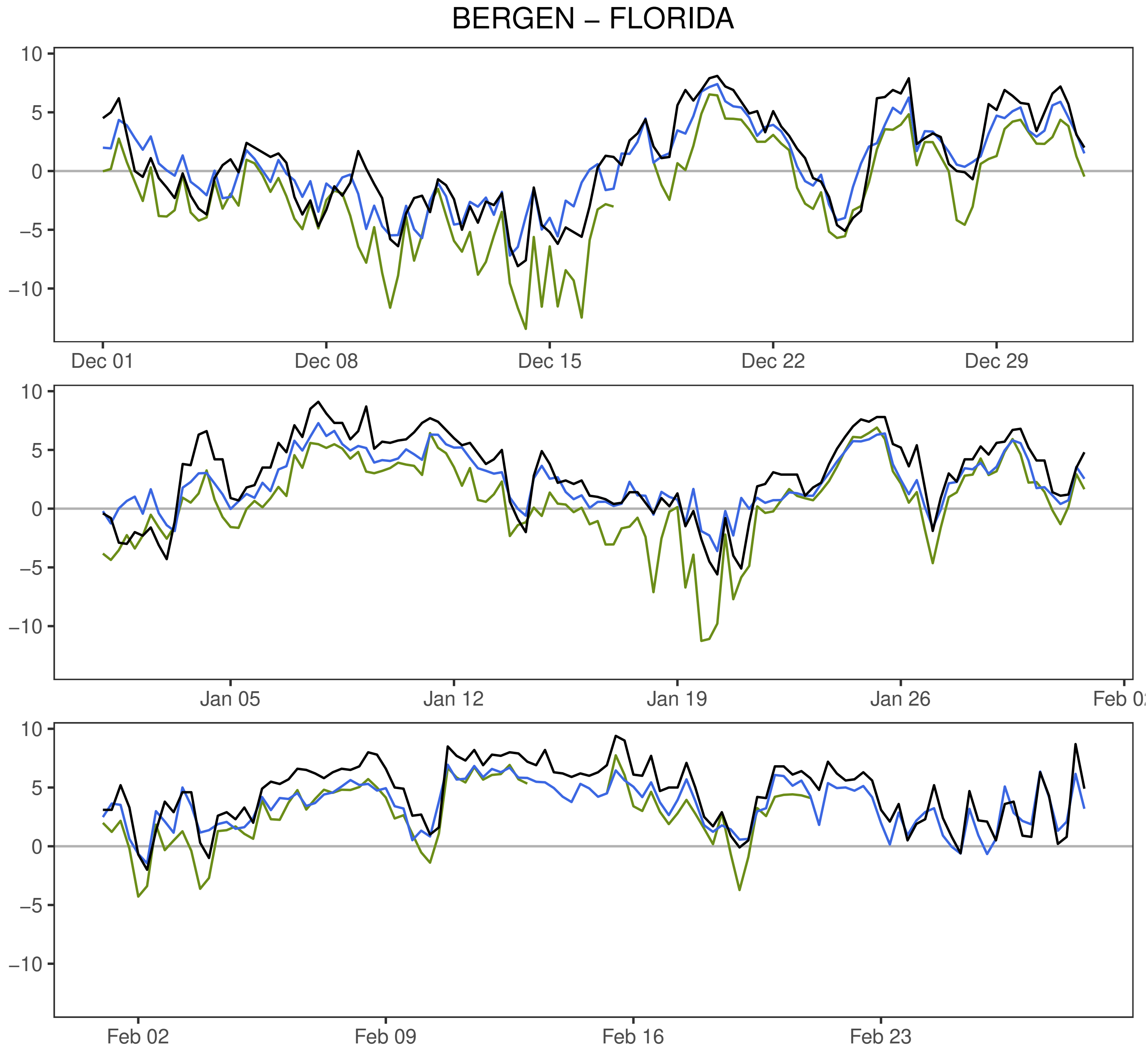
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−36.6	−11.6	4.3	8.5	360
MEPSctrl: 12+18,+24,+30,+36	−29.7	−11.1	2.3	6.4	360
AA25: 12+18,+24,+30,+36	−31.1	−11.5	1.6	6.9	360
ECMWF: 12+18,+24,+30,+36	−28.1	−8.7	3.1	5.4	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.5	4.7	4.7	3.5	15.7	317
AA25−synop	0.1	4.7	4.7	3.5	17.5	317
ECMWF−synop	2.8	4.9	5.6	3.7	18.4	317



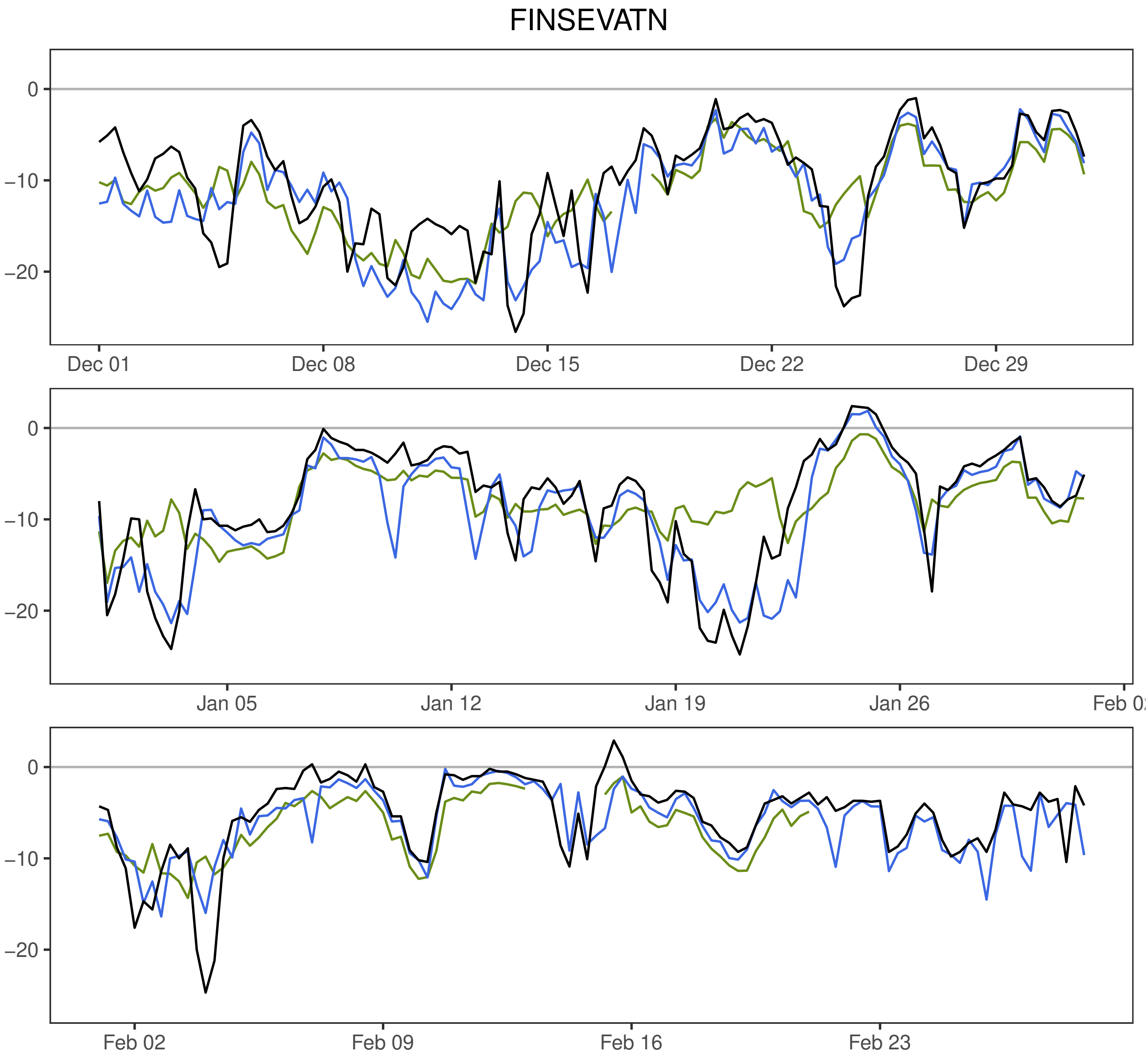
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−8.7	1.4	9.6	3.5	350
MEPSctrl: 12+18,+24,+30,+36	−8.9	1.6	8.4	3.1	360
ECMWF: 12+18,+24,+30,+36	−8.8	1.4	8.4	3.2	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.3	1.4	1.4	1.1	6.5	307
ECMWF−synop	0.2	1.3	1.3	1.0	5.1	307



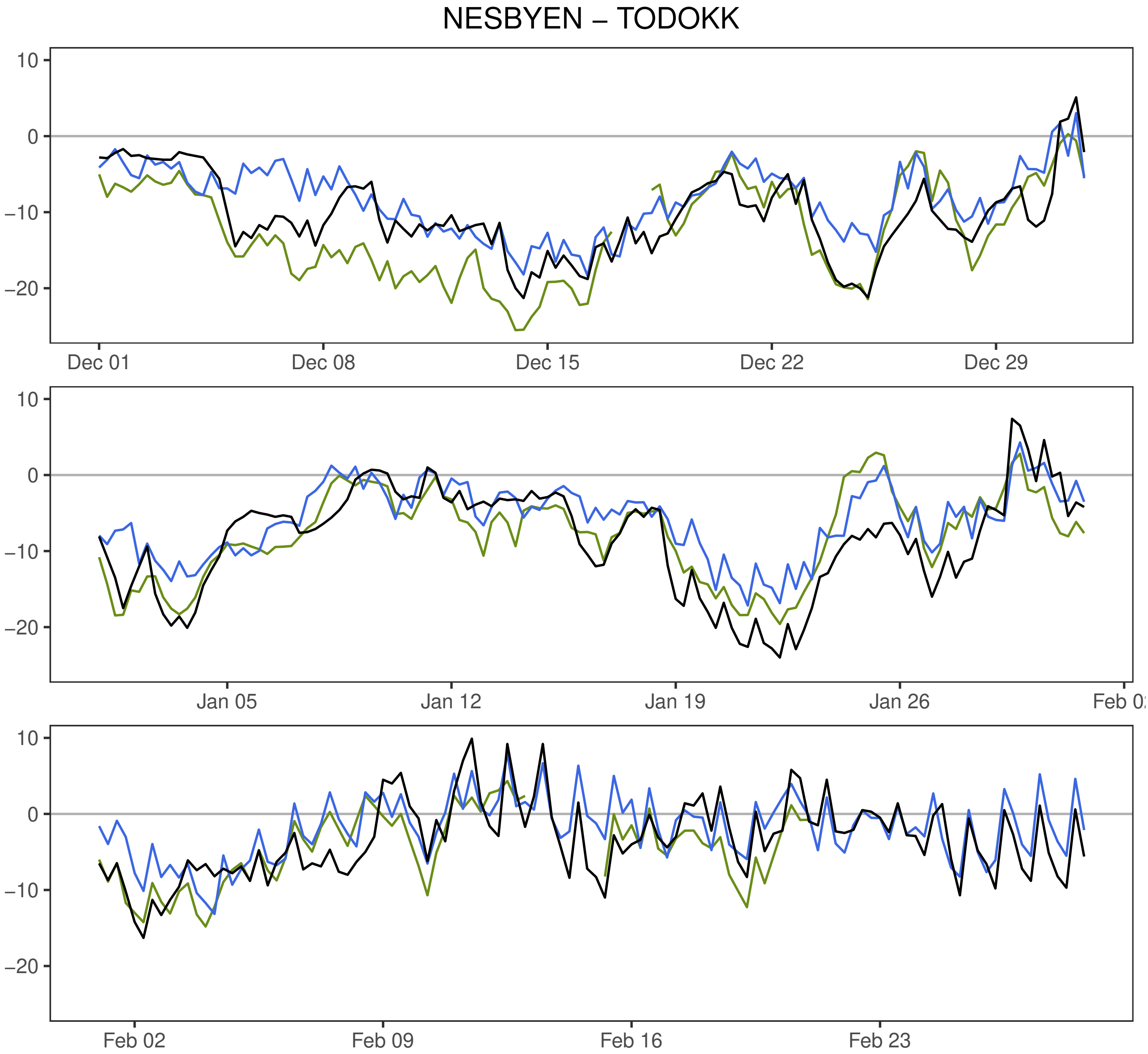
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−8.1	2.7	9.4	3.7	360
MEPSctrl: 12+18,+24,+30,+36	−7.2	2.1	7.4	2.9	360
ECMWF: 12+18,+24,+30,+36	−13.4	0.2	7.7	4.2	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.6	1.6	1.7	1.4	6.0	317
ECMWF−synop	−2.4	1.6	2.8	2.4	8.7	317



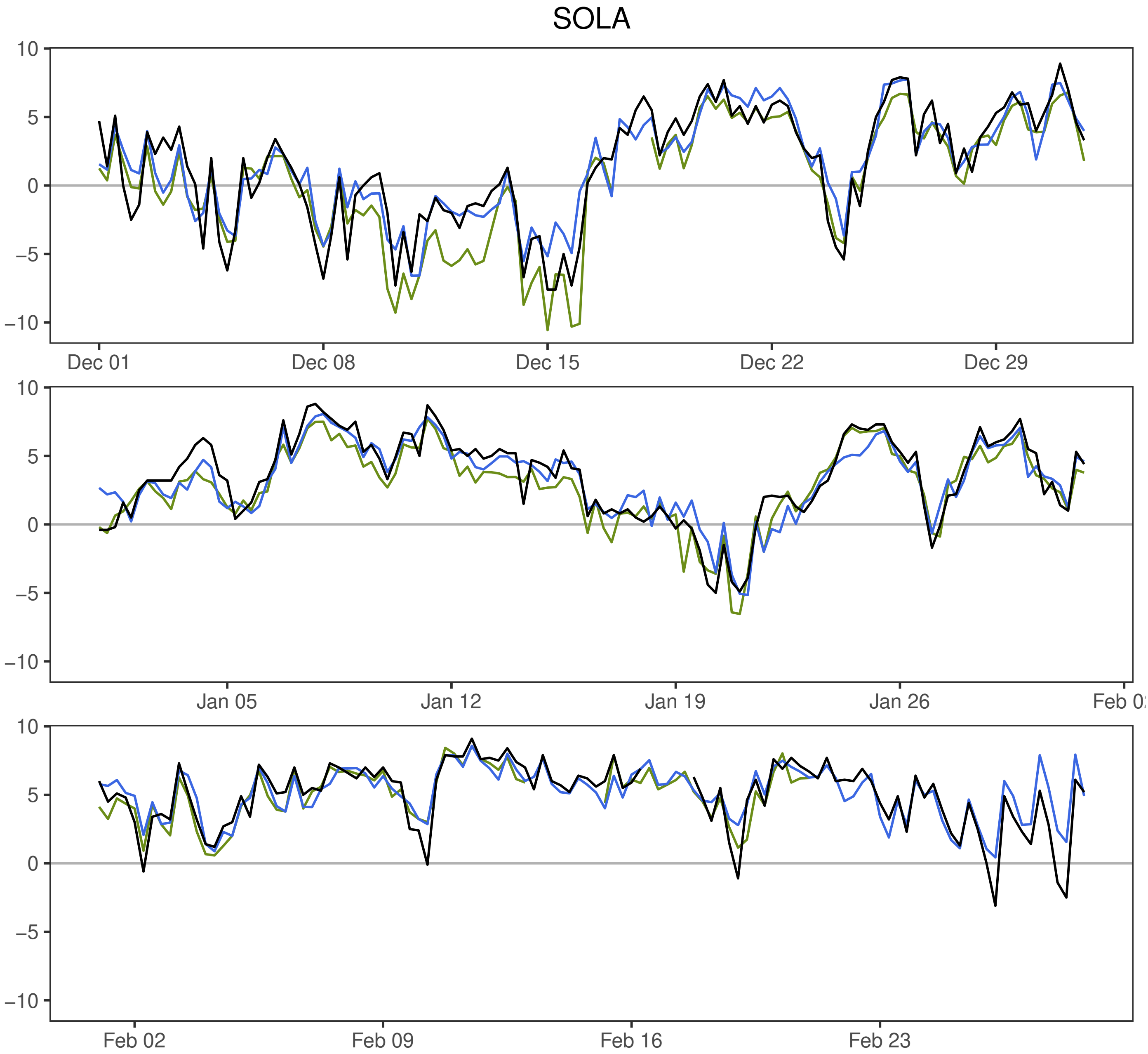
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−26.6	−8.2	2.9	6.2	360
MEPSctrl: 12+18,+24,+30,+36	−25.5	−9.3	1.9	5.9	360
ECMWF: 12+18,+24,+30,+36	−21.3	−9.2	−0.7	4.4	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−1.2	3.3	3.5	2.4	12.1	317
ECMWF−synop	−0.7	4.6	4.7	3.5	18.0	317



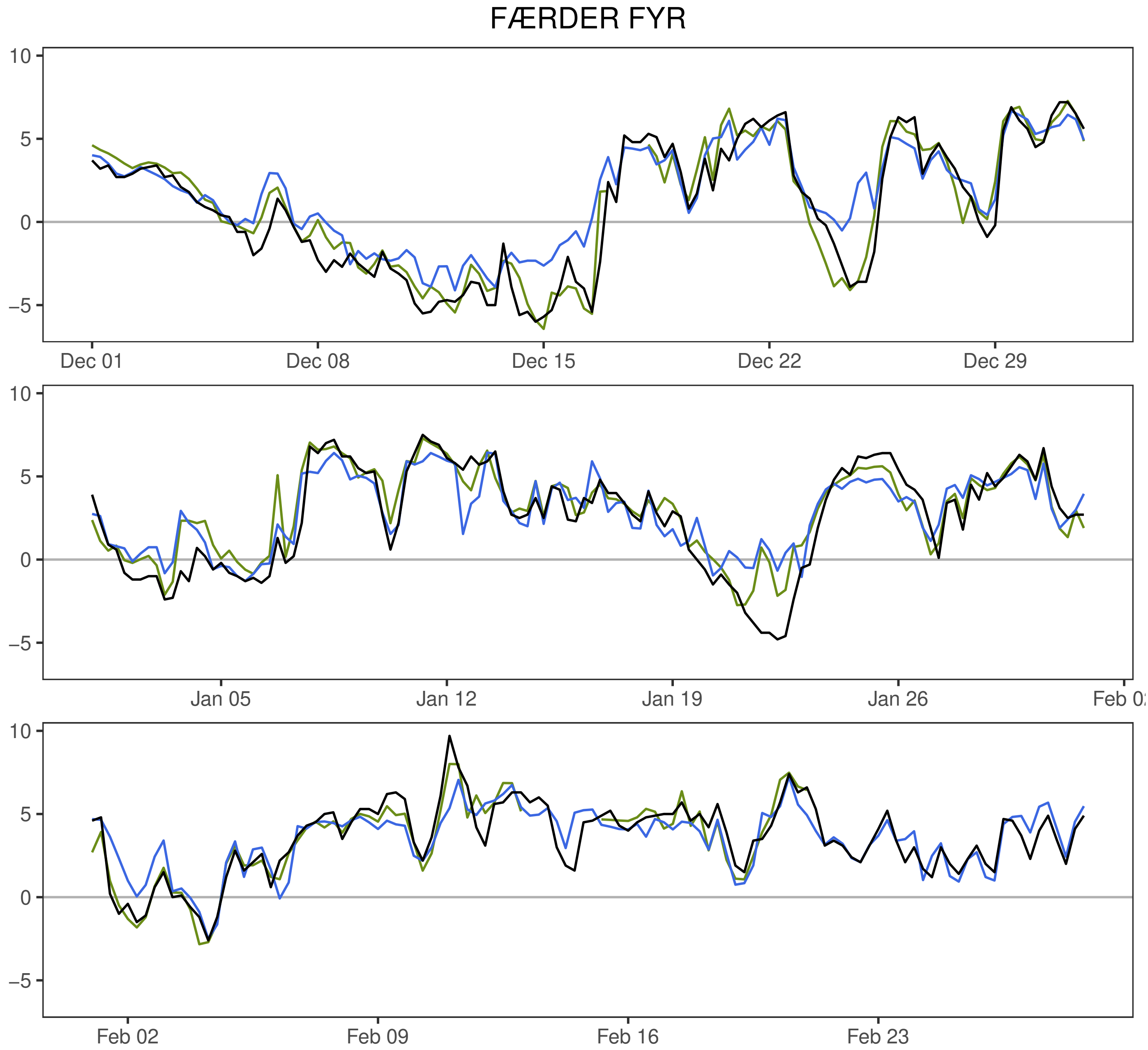
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−24.0	−7.6	9.9	6.5	360
MEPSctrl: 12+18,+24,+30,+36	−18.4	−5.5	7.9	5.1	360
ECMWF: 12+18,+24,+30,+36	−25.5	−8.9	4.3	6.5	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	2.2	3.6	4.2	3.4	10.3	317
ECMWF−synop	−0.8	4.1	4.2	3.5	11.5	317



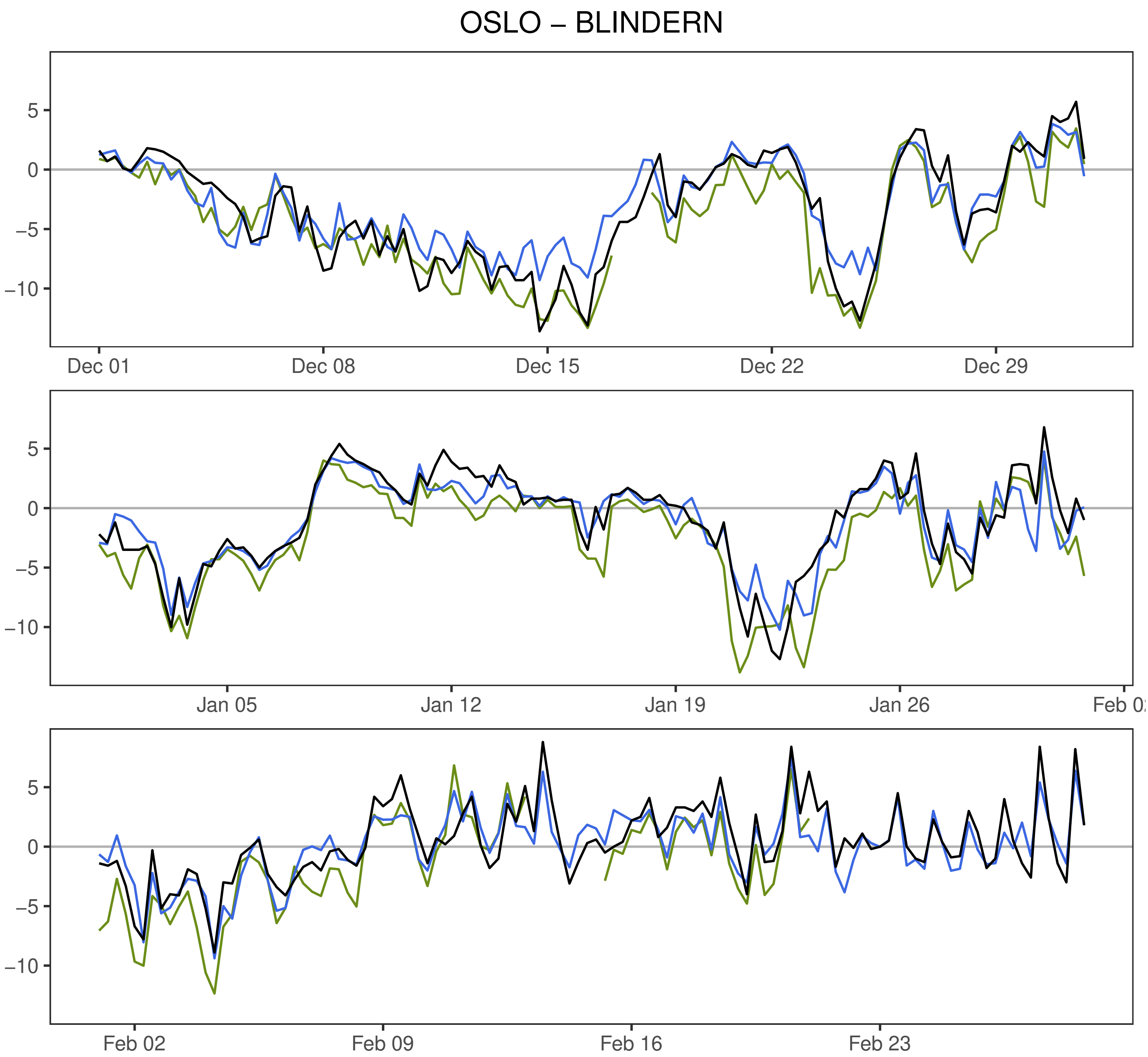
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−7.6	3.2	9.1	3.6	355
MEPSctrl: 12+18,+24,+30,+36	−6.6	3.3	8.6	3.2	360
ECMWF: 12+18,+24,+30,+36	−10.6	2.4	8.5	3.8	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.0	1.4	1.4	1.0	4.9	312
ECMWF−synop	−0.7	1.4	1.5	1.2	5.6	312



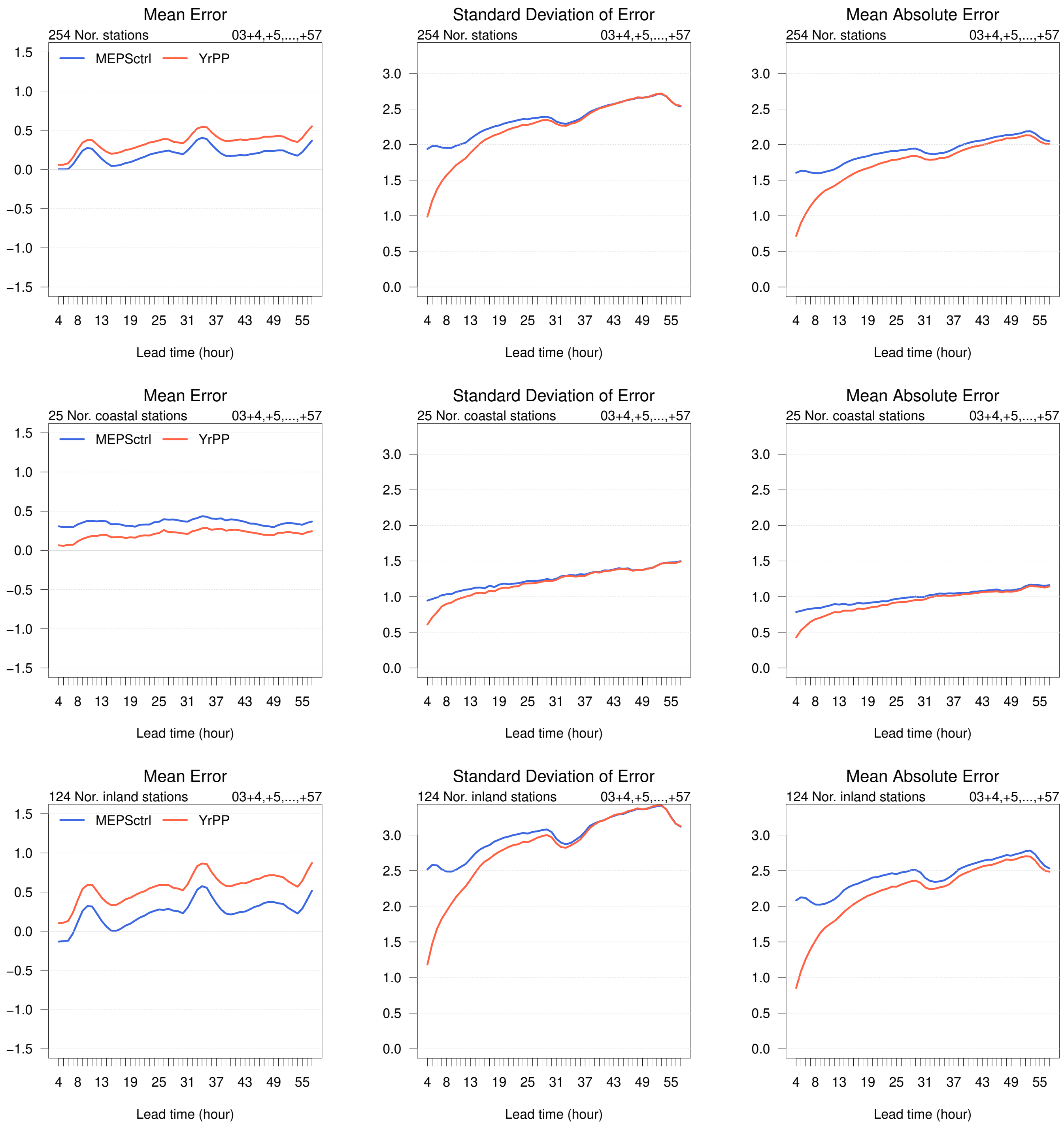
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−6.0	2.3	9.7	3.3	360
MEPSctrl: 12+18,+24,+30,+36	−4.1	2.6	7.2	2.5	360
ECMWF: 12+18,+24,+30,+36	−6.4	2.3	8.0	3.2	317

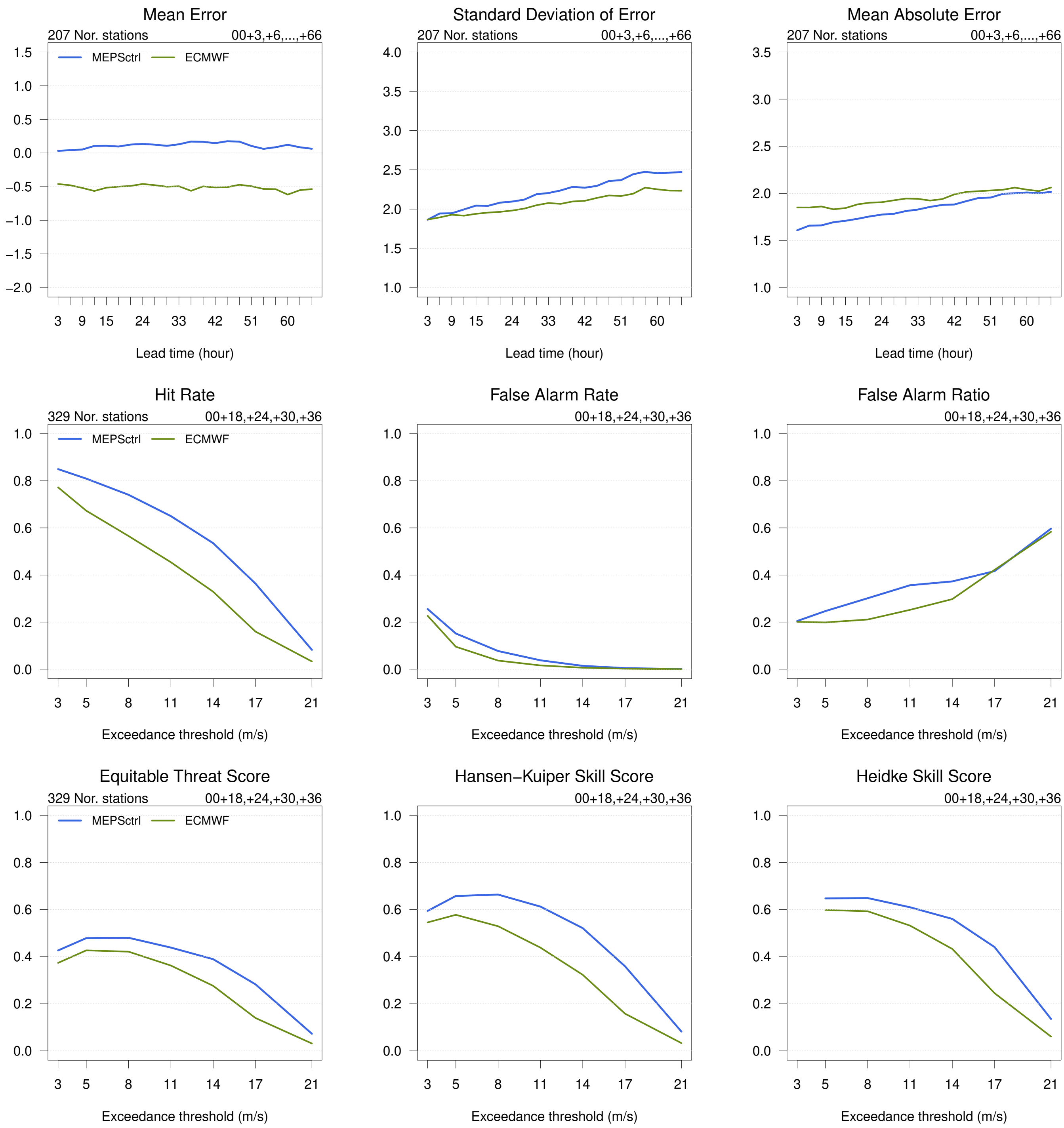
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.4	1.6	1.6	1.2	6.6	317
ECMWF−synop	0.2	1.1	1.1	0.8	5.1	317

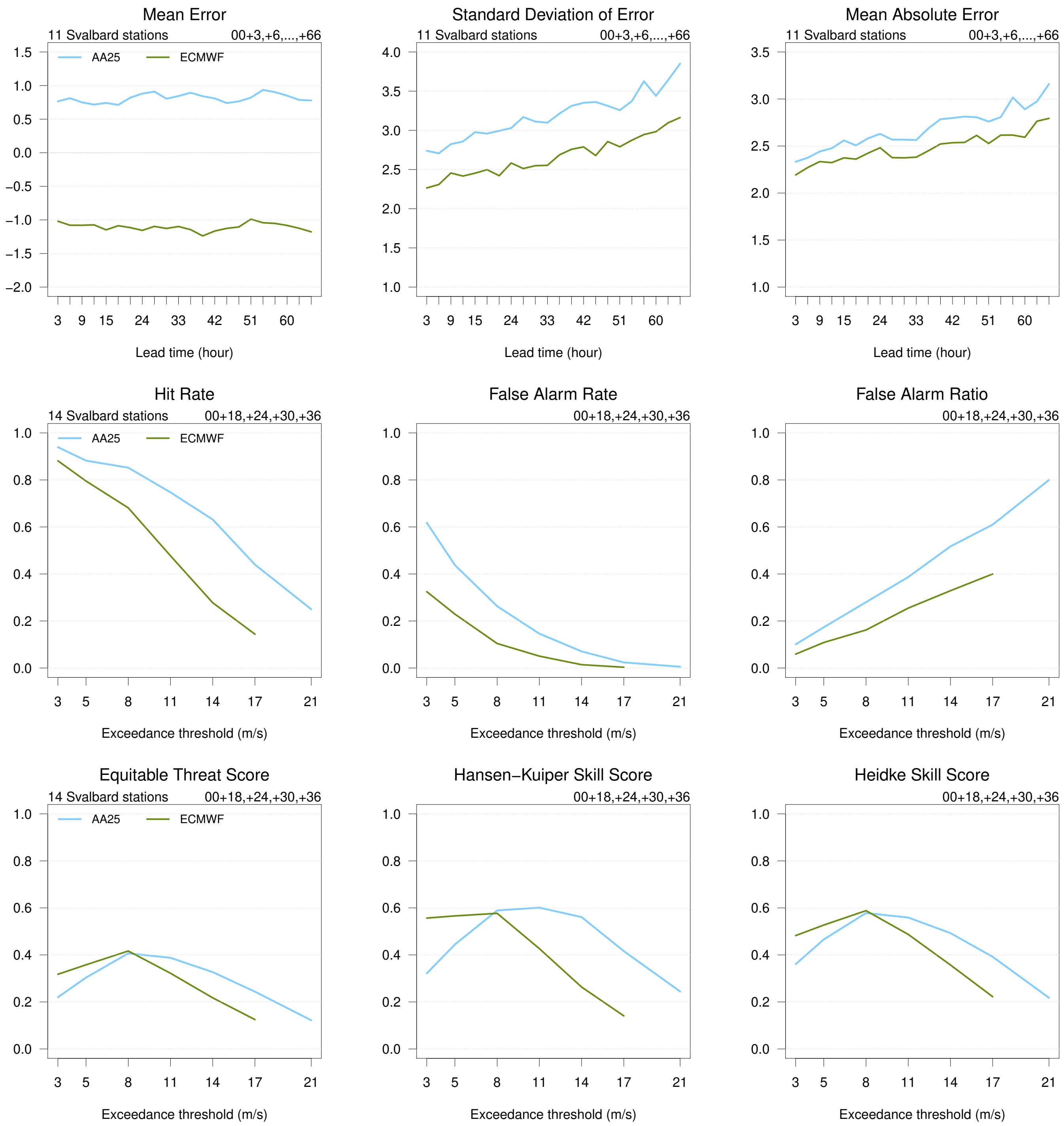


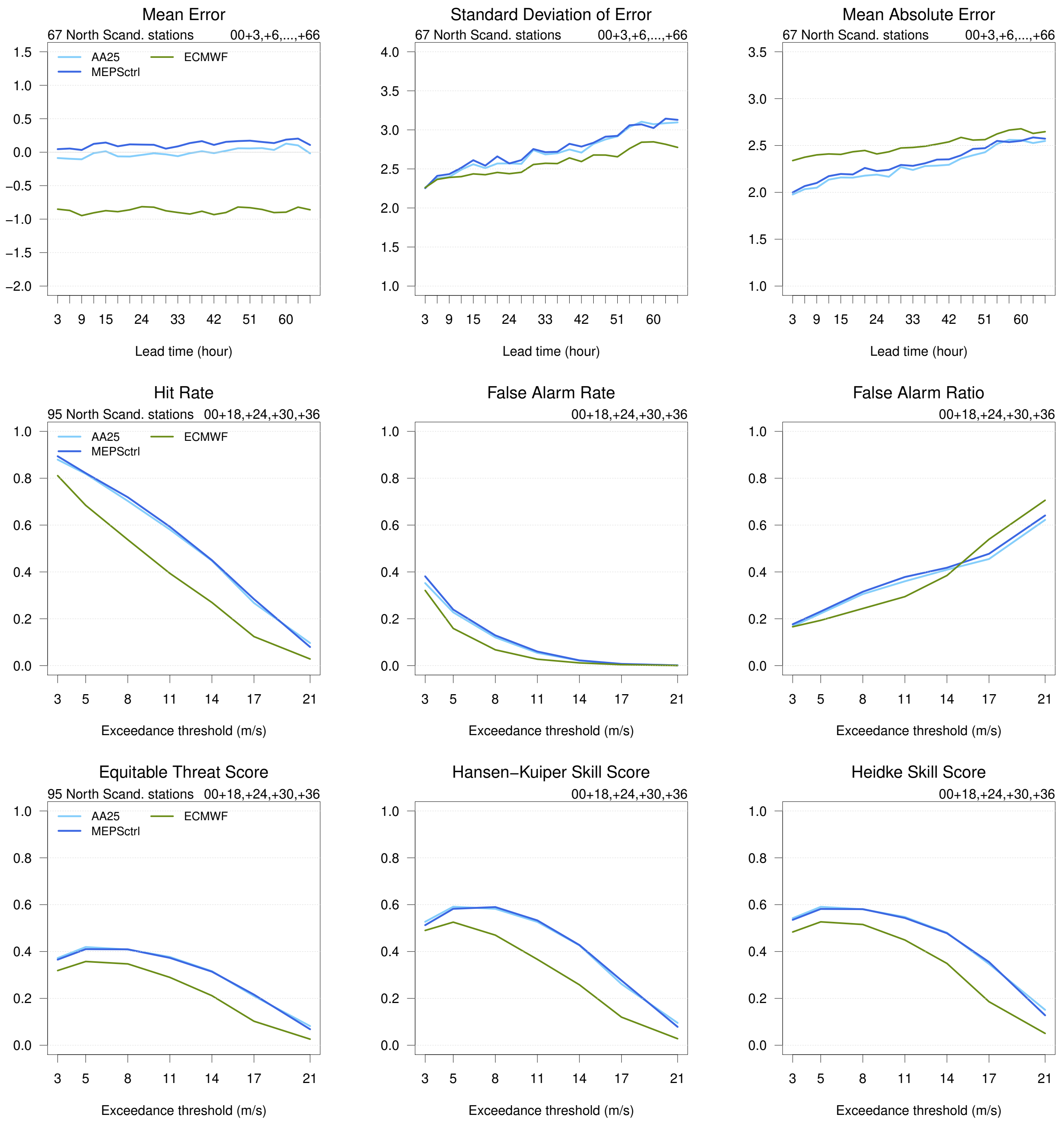
	Min	Mean	Max	Std	N
synop: 00,06,12,18	–13.6	–1.4	8.8	4.3	360
MEPSctrl: 12+18,+24,+30,+36	–10.2	–1.4	7.5	3.5	360
ECMWF: 12+18,+24,+30,+36	–13.8	–3.2	6.8	4.4	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	0.0	1.7	1.7	1.3	5.4	317
ECMWF–synop	–1.5	1.7	2.2	1.8	7.7	317

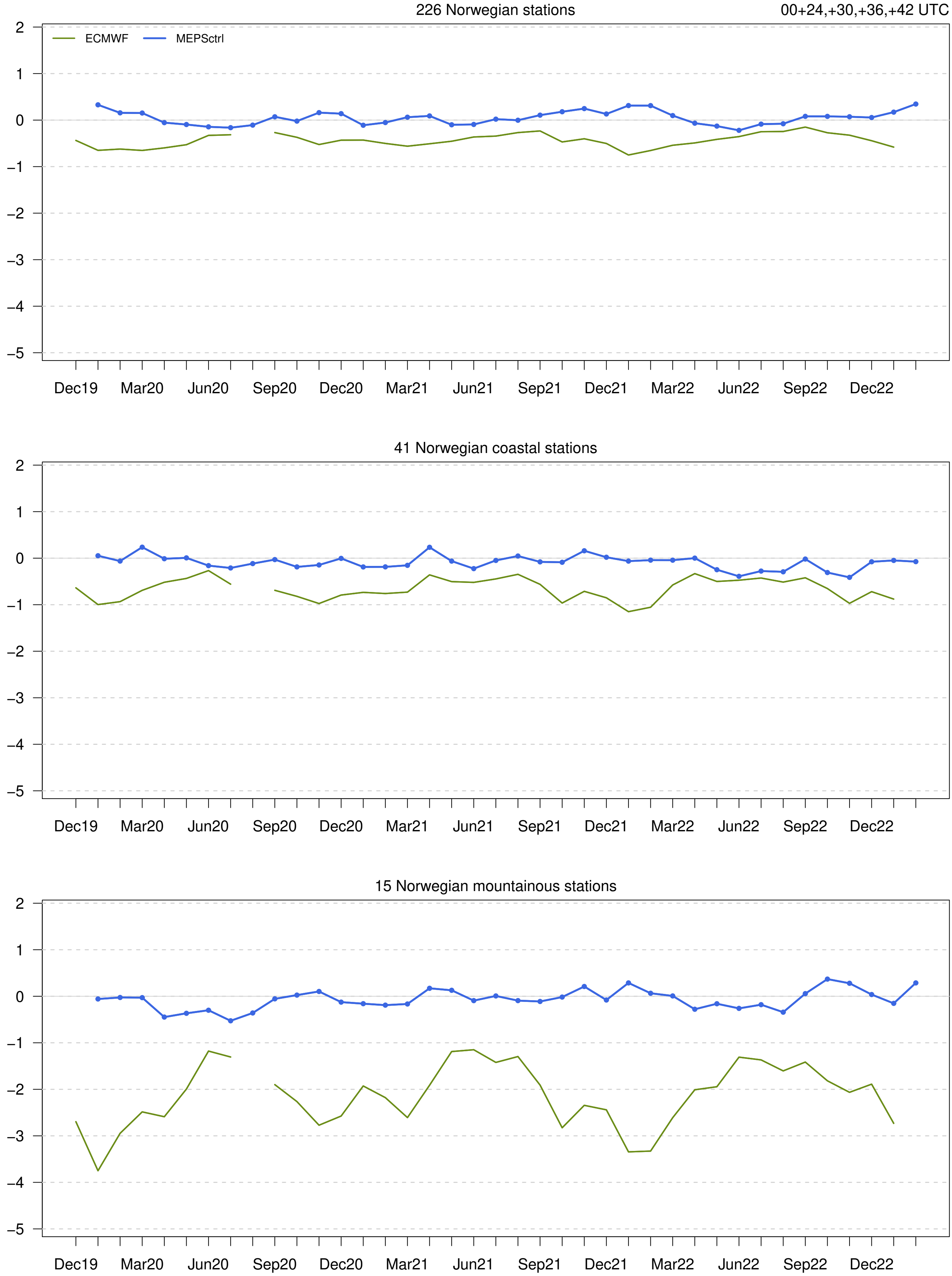

Mean Error
254 Nor. stations
03+4,+5,...,+57
MEPSctrl
YrPP
Lead time (hour)
Standard Deviation of Error
254 Nor. stations
03+4,+5,...,+57
Lead time (hour)
Mean Absolute Error
254 Nor. stations
03+4,+5,...,+57
Lead time (hour)
Mean Error
25 Nor. coastal stations
03+4,+5,...,+57
MEPSctrl
YrPP
Lead time (hour)
Standard Deviation of Error
25 Nor. coastal stations
03+4,+5,...,+57
Lead time (hour)
Mean Absolute Error
25 Nor. coastal stations
03+4,+5,...,+57
Lead time (hour)
Mean Error
124 Nor. inland stations
03+4,+5,...,+57
MEPSctrl
YrPP
Lead time (hour)
Standard Deviation of Error
124 Nor. inland stations
03+4,+5,...,+57
Lead time (hour)
Mean Absolute Error
124 Nor. inland stations
03+4,+5,...,+57
Lead time (hour)


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

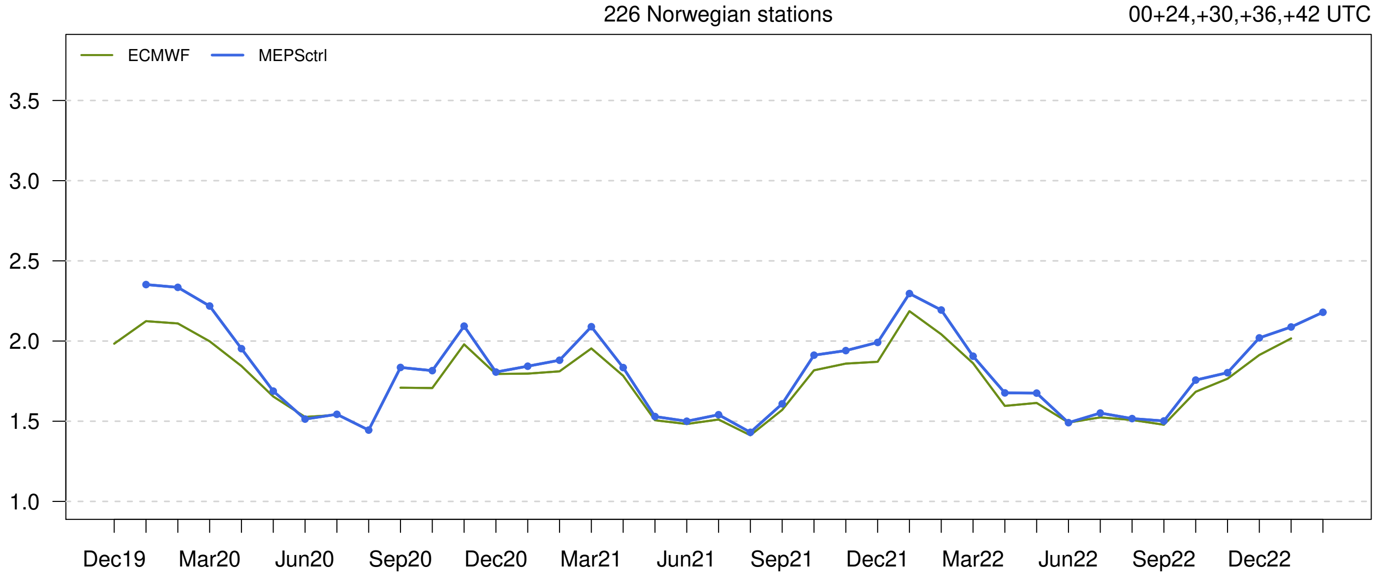

Mean Error
11 Svalbard stations
00+3,+6,...,+66
AA25
ECMWF
Lead time (hour)
Standard Deviation of Error
11 Svalbard stations
00+3,+6,...,+66
Lead time (hour)
Mean Absolute Error
11 Svalbard stations
00+3,+6,...,+66
Lead time (hour)
Hit Rate
14 Svalbard stations
00+18,+24,+30,+36
AA25
ECMWF
Exceedance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

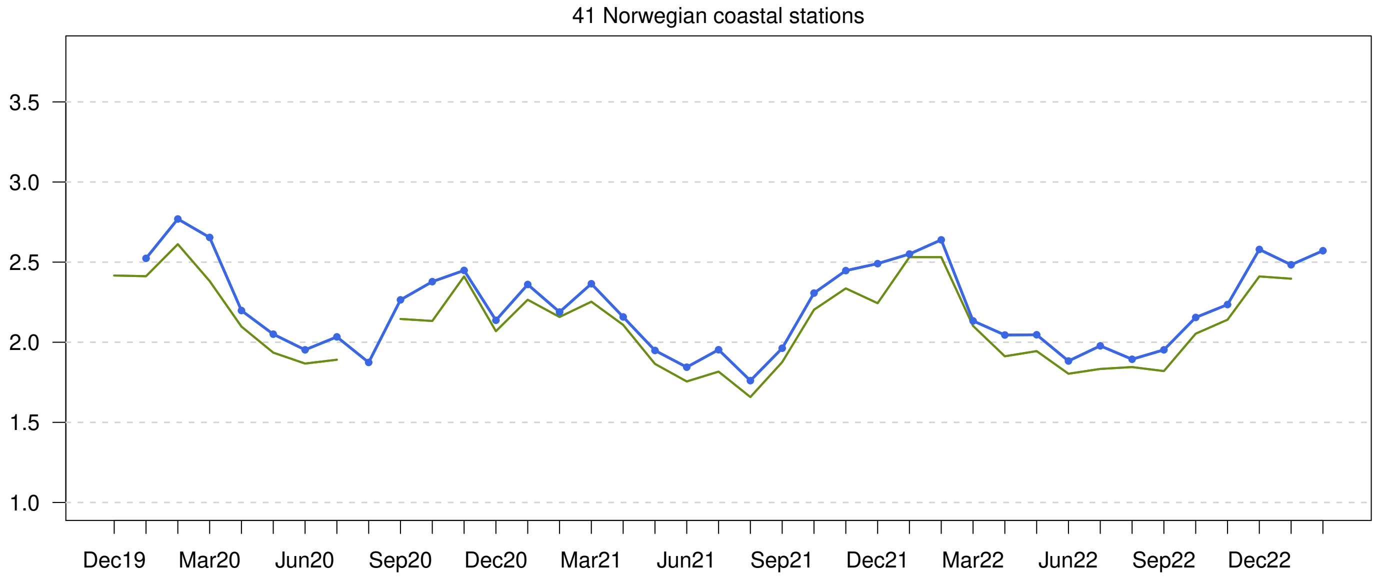

Mean Error
67 North Scand. stations 00+3,+6,...,+66
AA25
MEPSctrl
ECMWF
Lead time (hour)
Standard Deviation of Error
67 North Scand. stations 00+3,+6,...,+66
Lead time (hour)
Mean Absolute Error
67 North Scand. stations 00+3,+6,...,+66
Lead time (hour)
Hit Rate
95 North Scand. stations 00+18,+24,+30,+36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

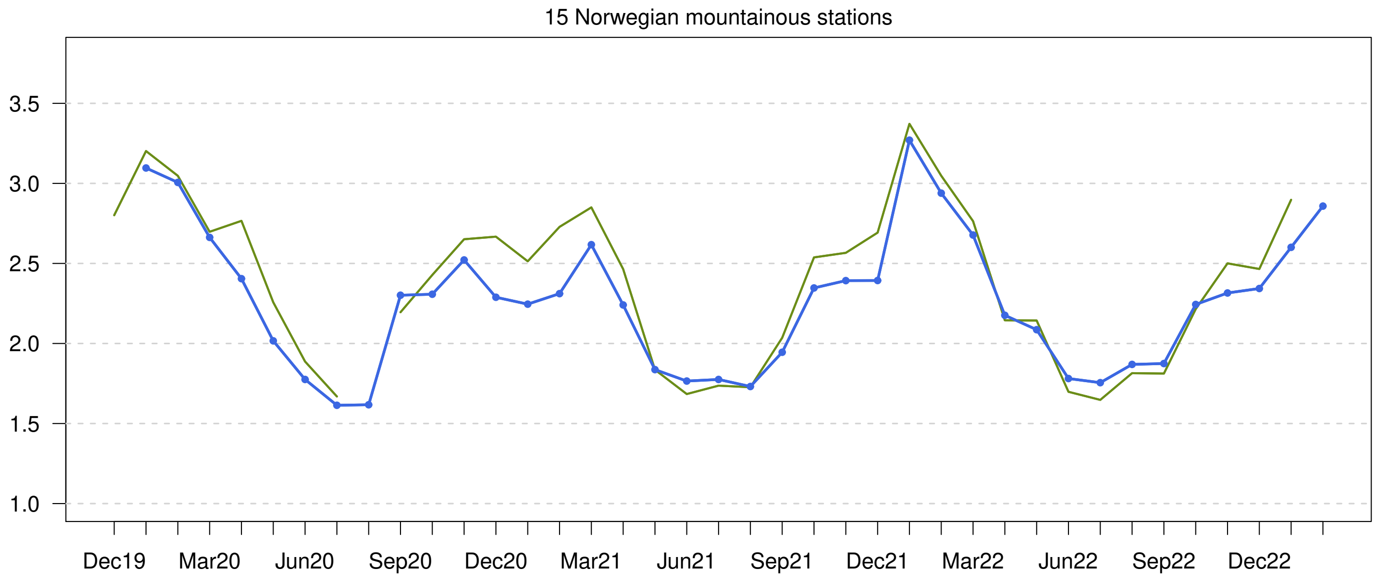
Mean Error

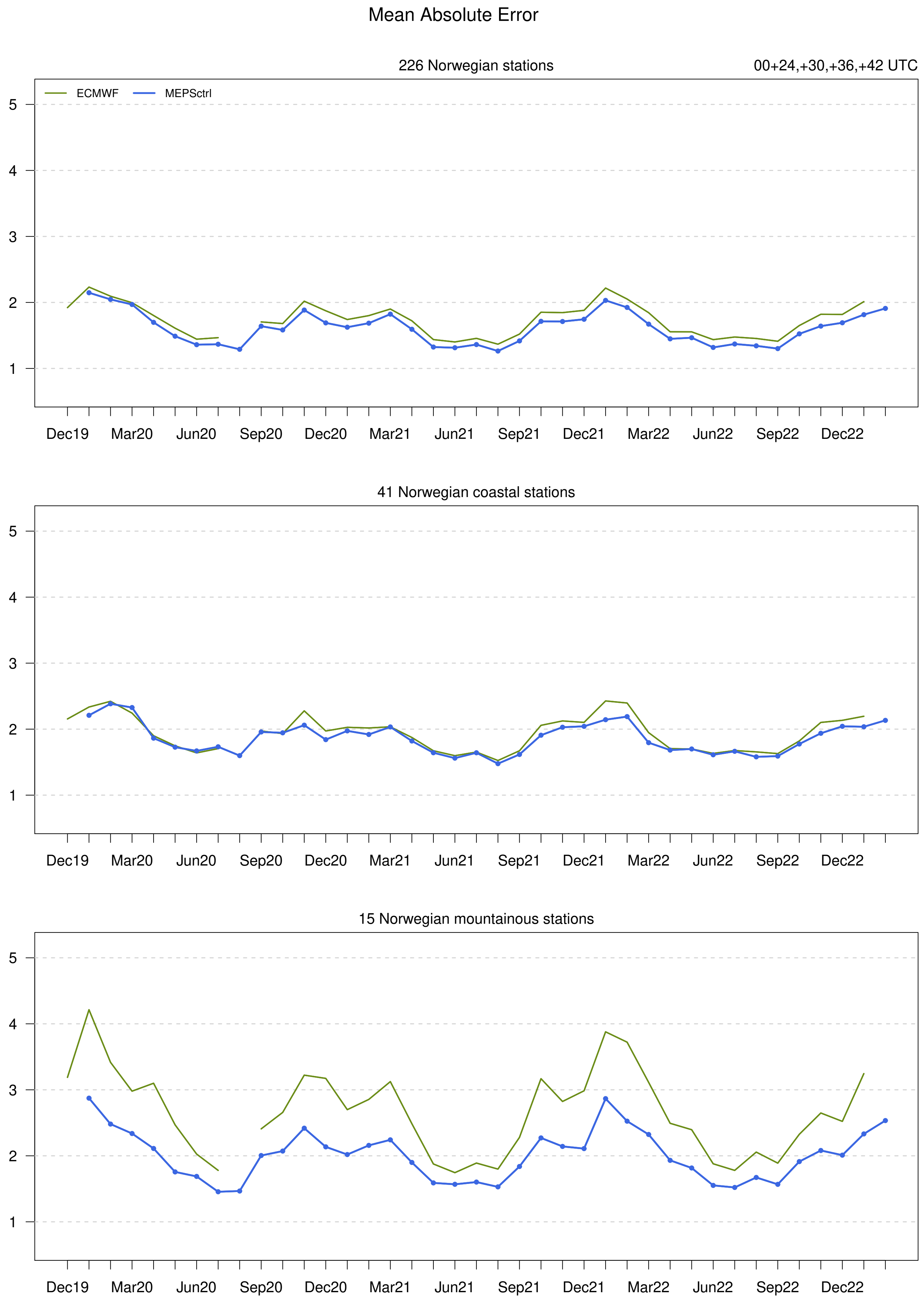

226 Norwegian stations
00+24,+30,+36,+42 UTC
ECMWF
MEPSctrl
2
1
0
−1
−2
−3
−4
−5
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
41 Norwegian coastal stations
15 Norwegian mountainous stations

Standard Deviation of Error

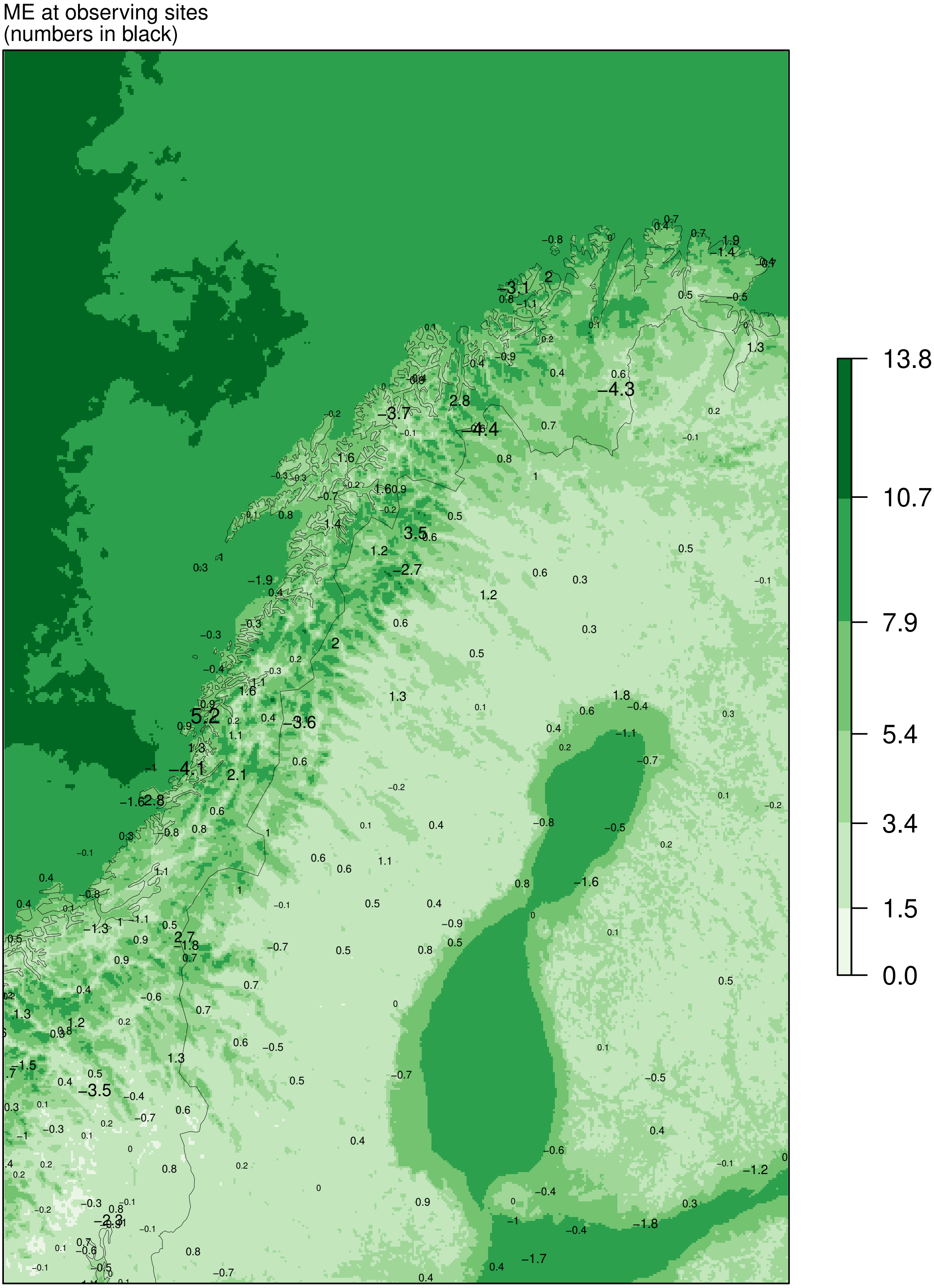







Mean Absolute Error
226 Norwegian stations
00+24,+30,+36,+42 UTC
ECMWF
MEPSctrl
1
2
3
4
5
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
41 Norwegian coastal stations
15 Norwegian mountainous stations

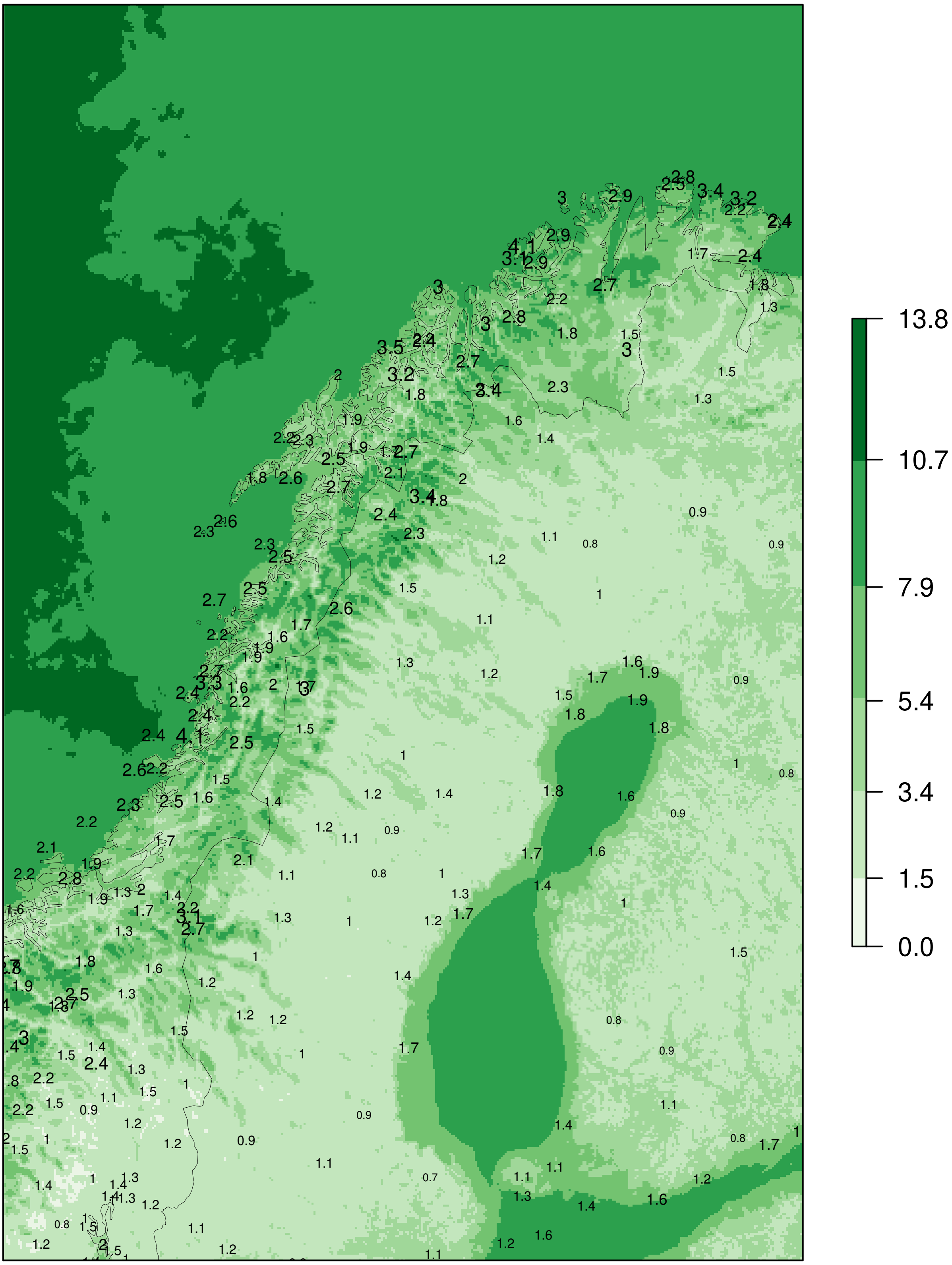
MEPSctrl 00+12



Model "climatology"   01.12.2022 – 28.02.2023

MEPSctrl 00+12

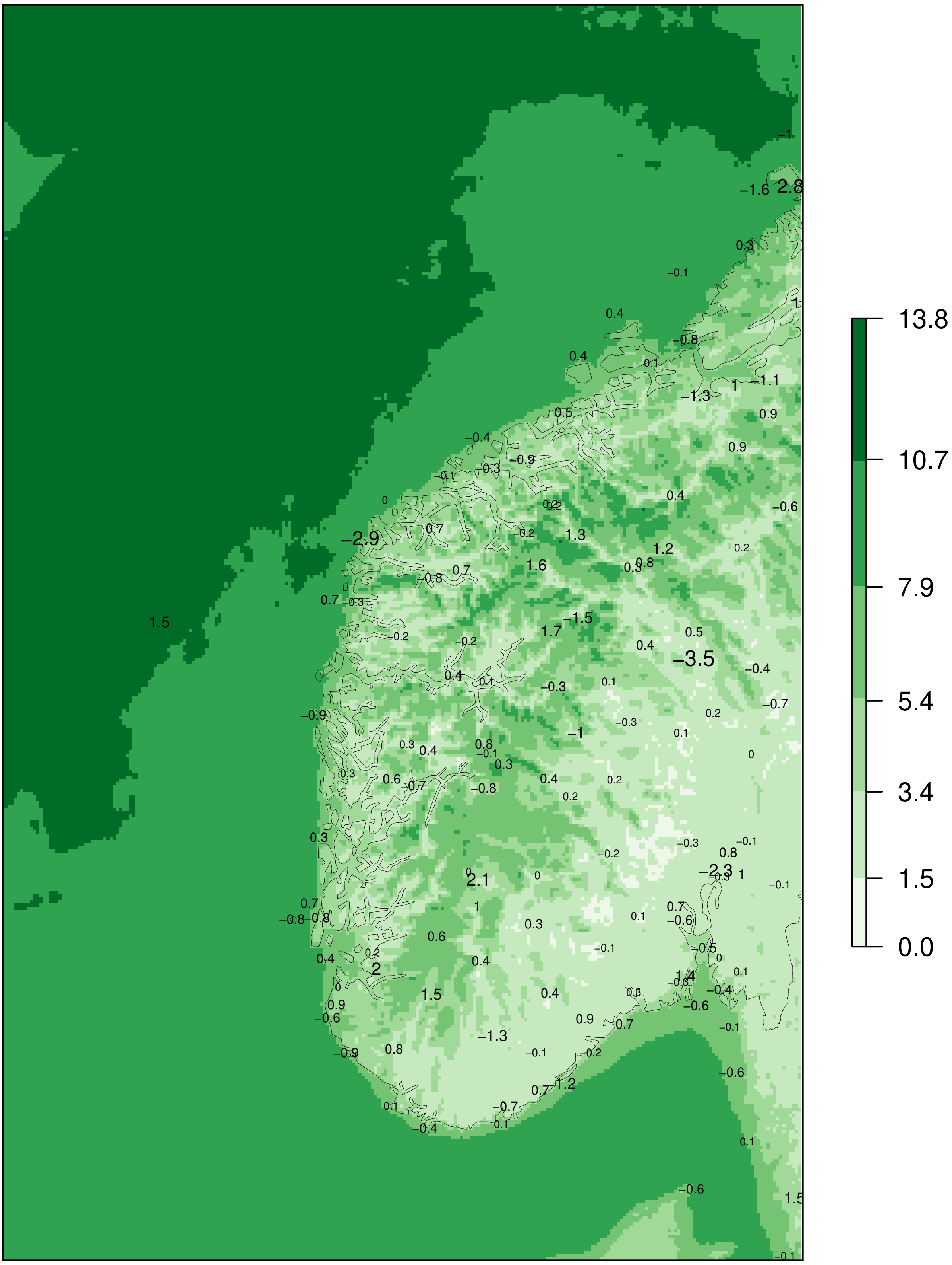
SDE at observing sites
(numbers in black)



Model "climatology"   01.12.2022 – 28.02.2023

MEPSctrl 00+12

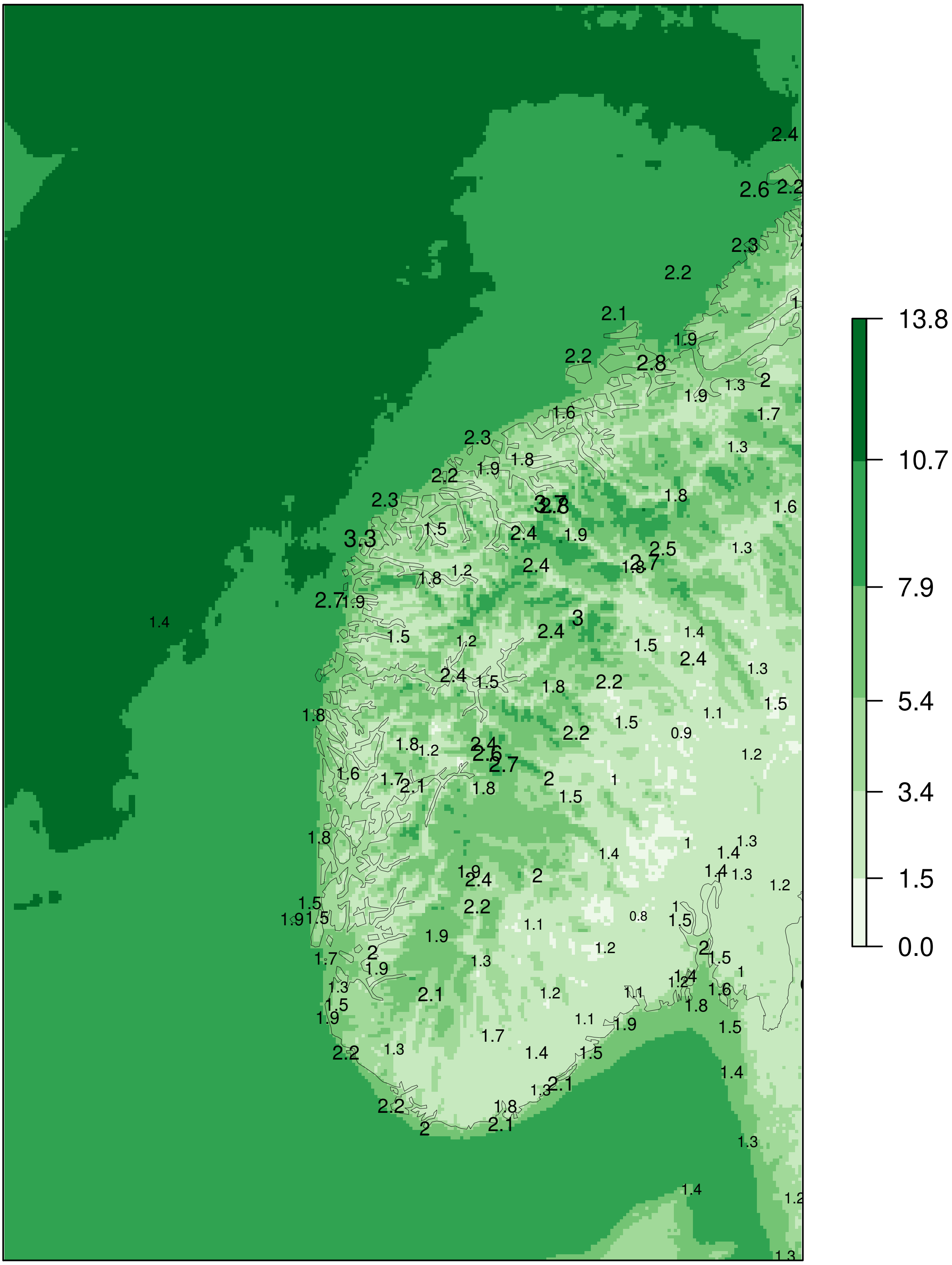
ME at observing sites
(numbers in black)



Model "climatology" 01.12.2022 – 28.02.2023

MEPSctrl 00+12

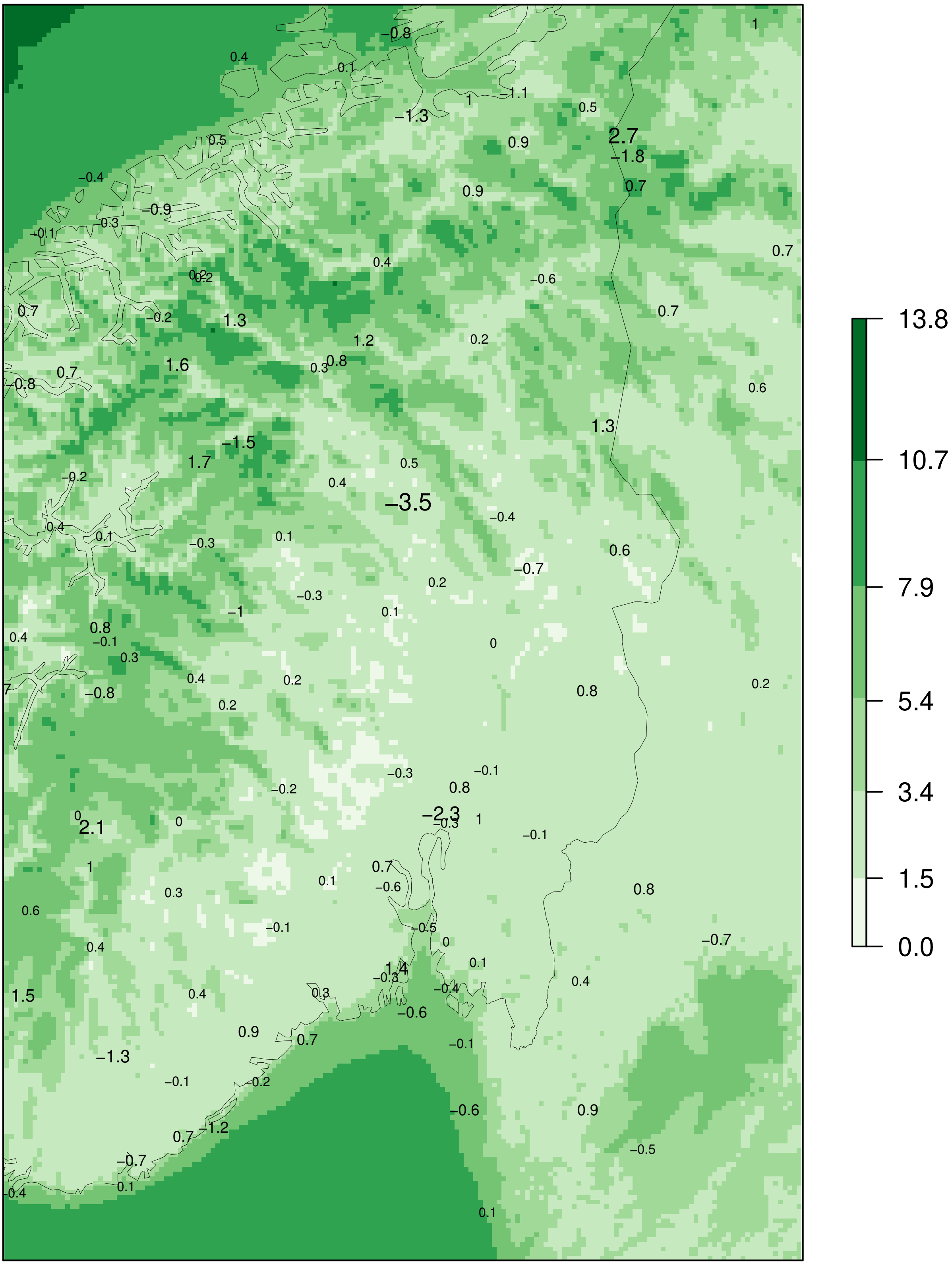
SDE at observing sites
(numbers in black)



Model "climatology" 01.12.2022 – 28.02.2023

MEPSctrl 00+12

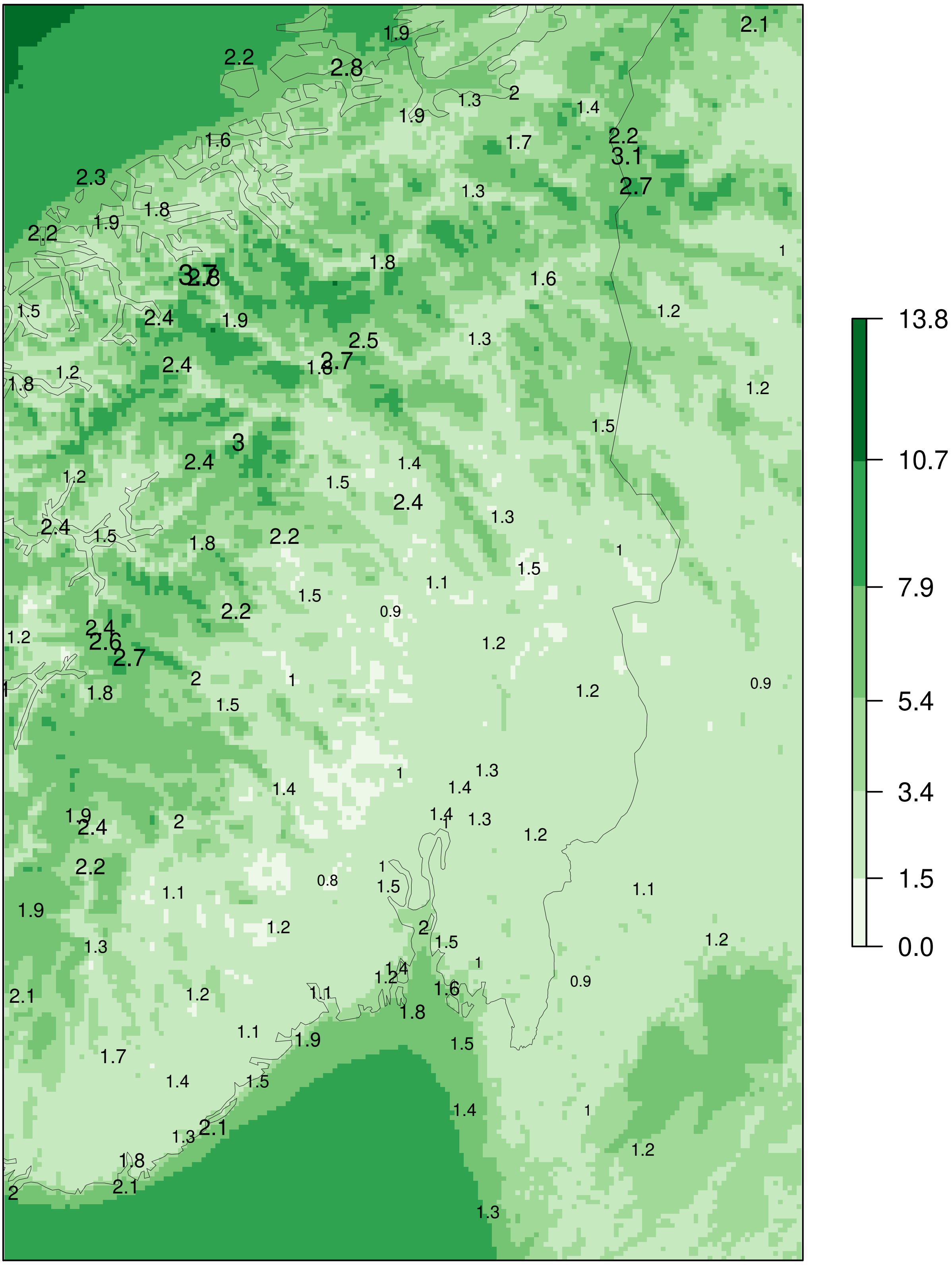
ME at observing sites
(numbers in black)



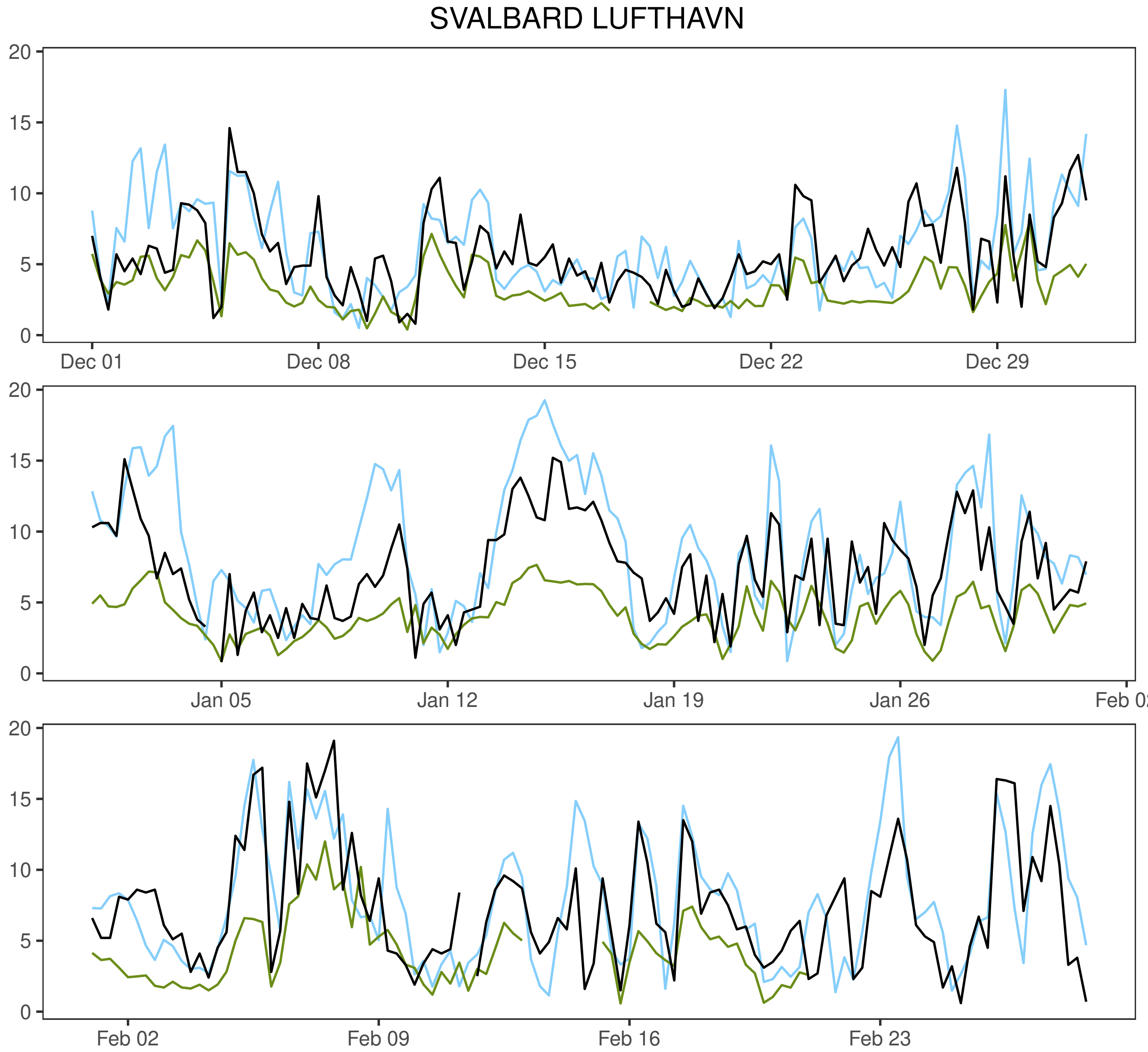
Model "climatology"   01.12.2022 – 28.02.2023

MEPSctrl 00+12

SDE at observing sites
(numbers in black)

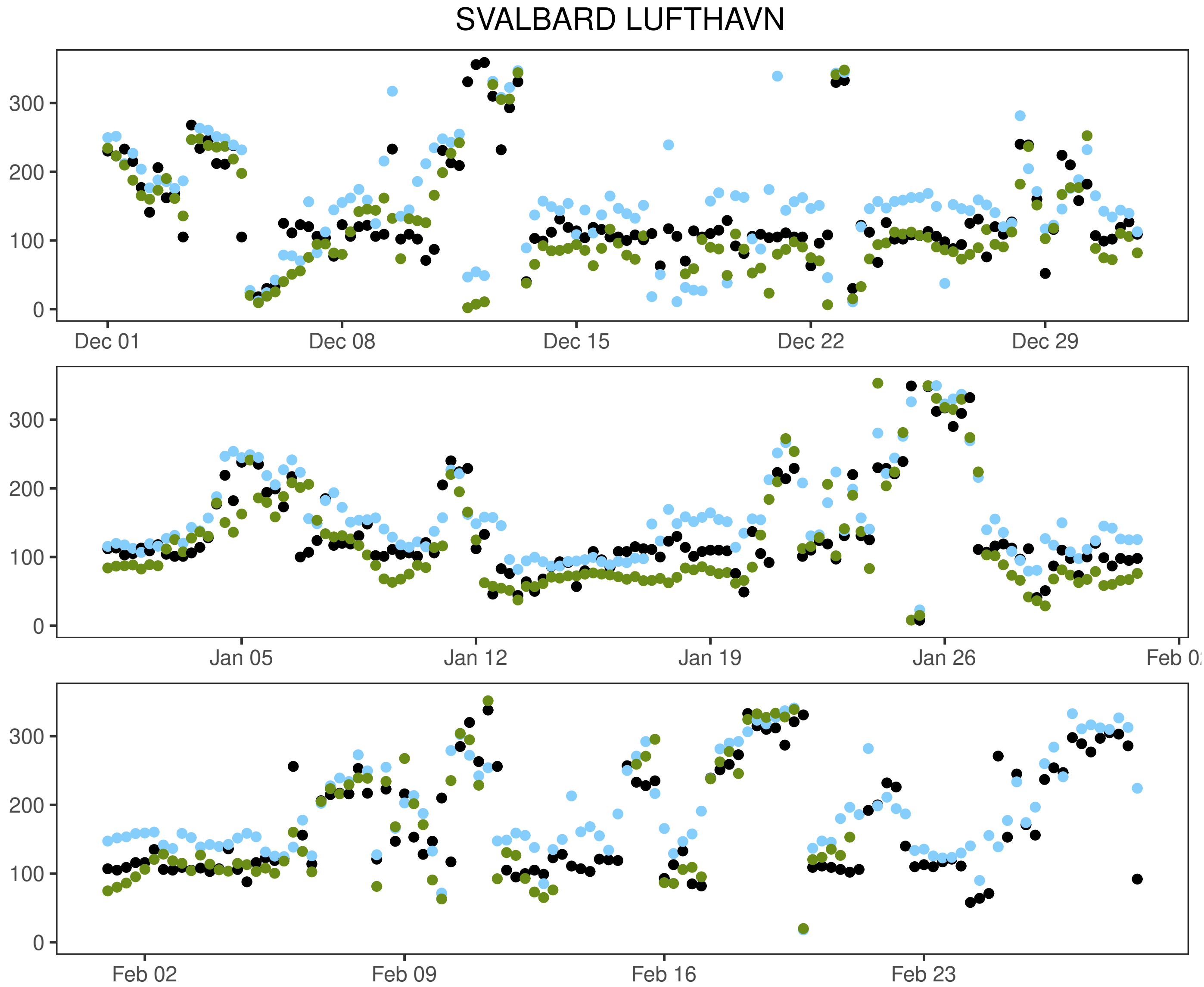


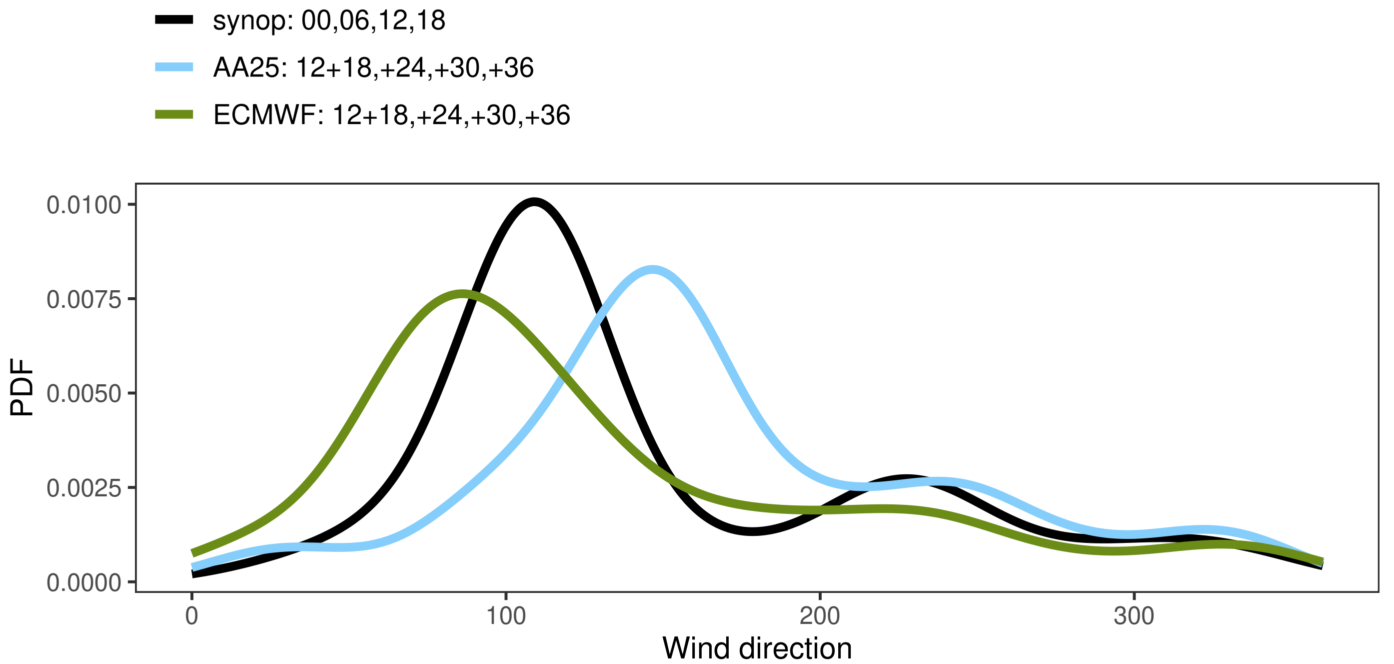
Model "climatology" 01.12.2022 – 28.02.2023

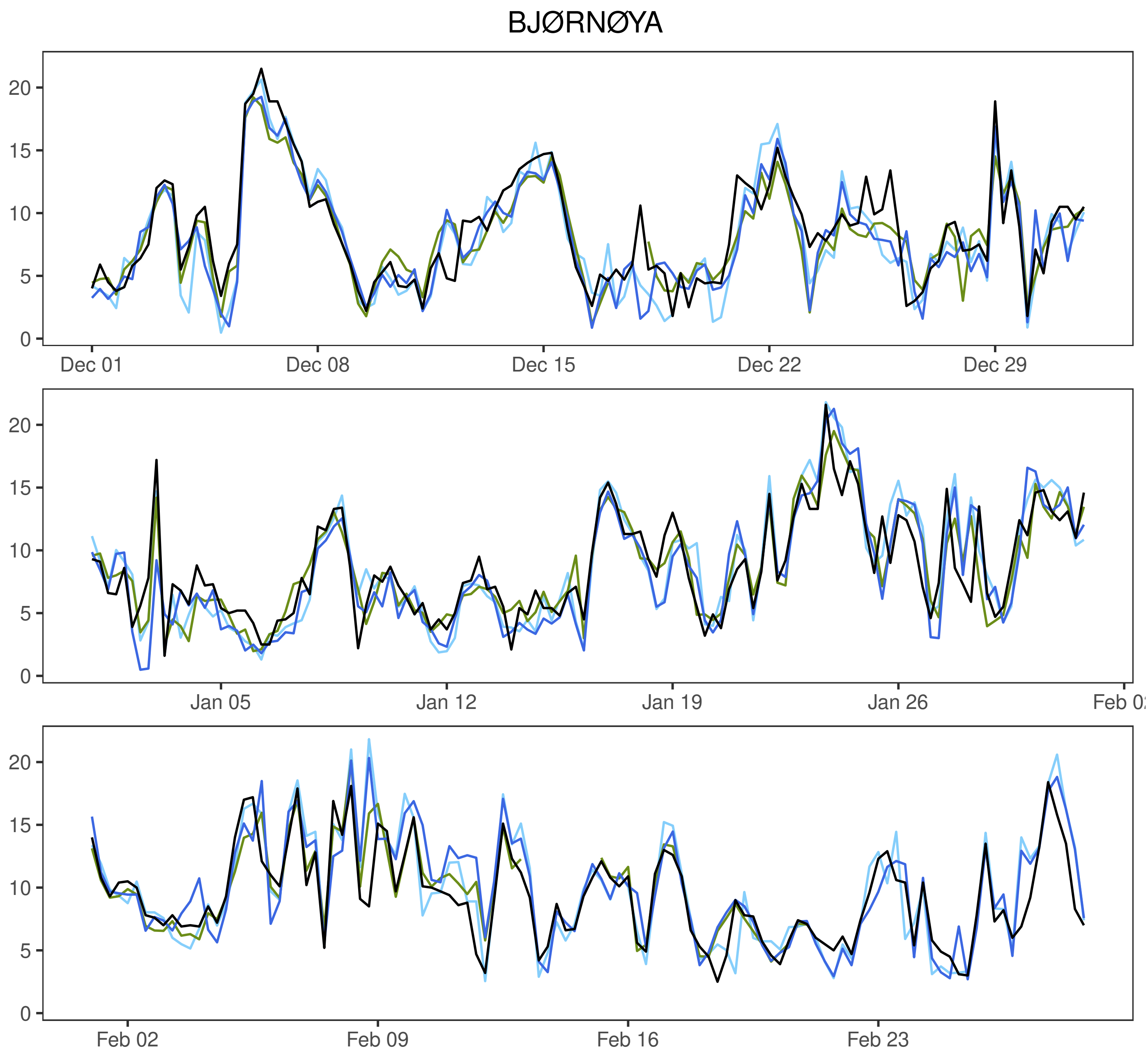


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.6	6.7	19.1	3.6	358
AA25: 12+18,+24,+30,+36	0.5	7.6	19.3	4.3	360
ECMWF: 12+18,+24,+30,+36	0.4	3.8	12.0	1.9	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
AA25−synop	0.8	2.9	3.0	2.3	10.4	315
ECMWF−synop	−2.9	2.4	3.7	3.1	10.9	315

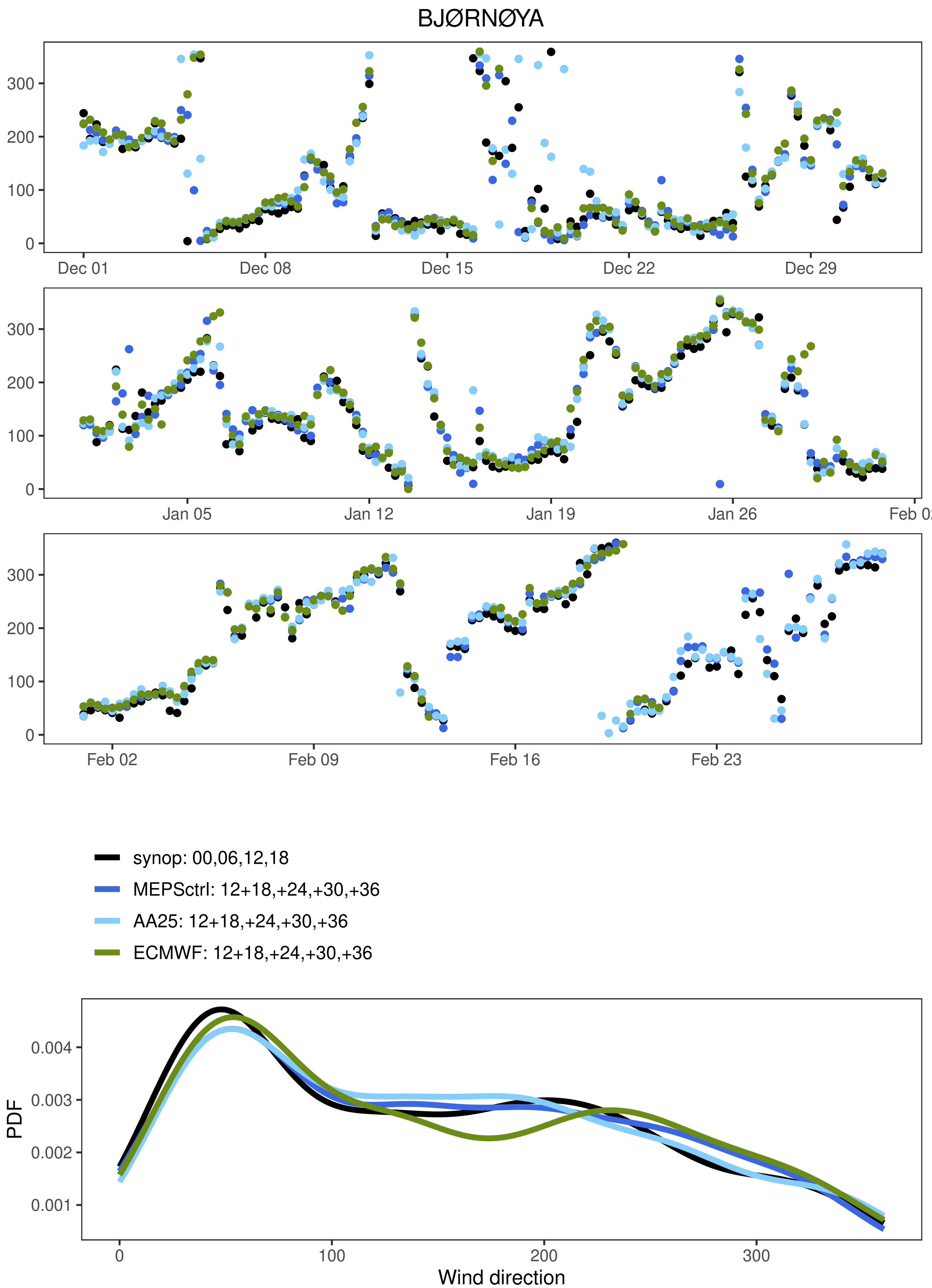

SVALBARD LUFTHAVN
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23

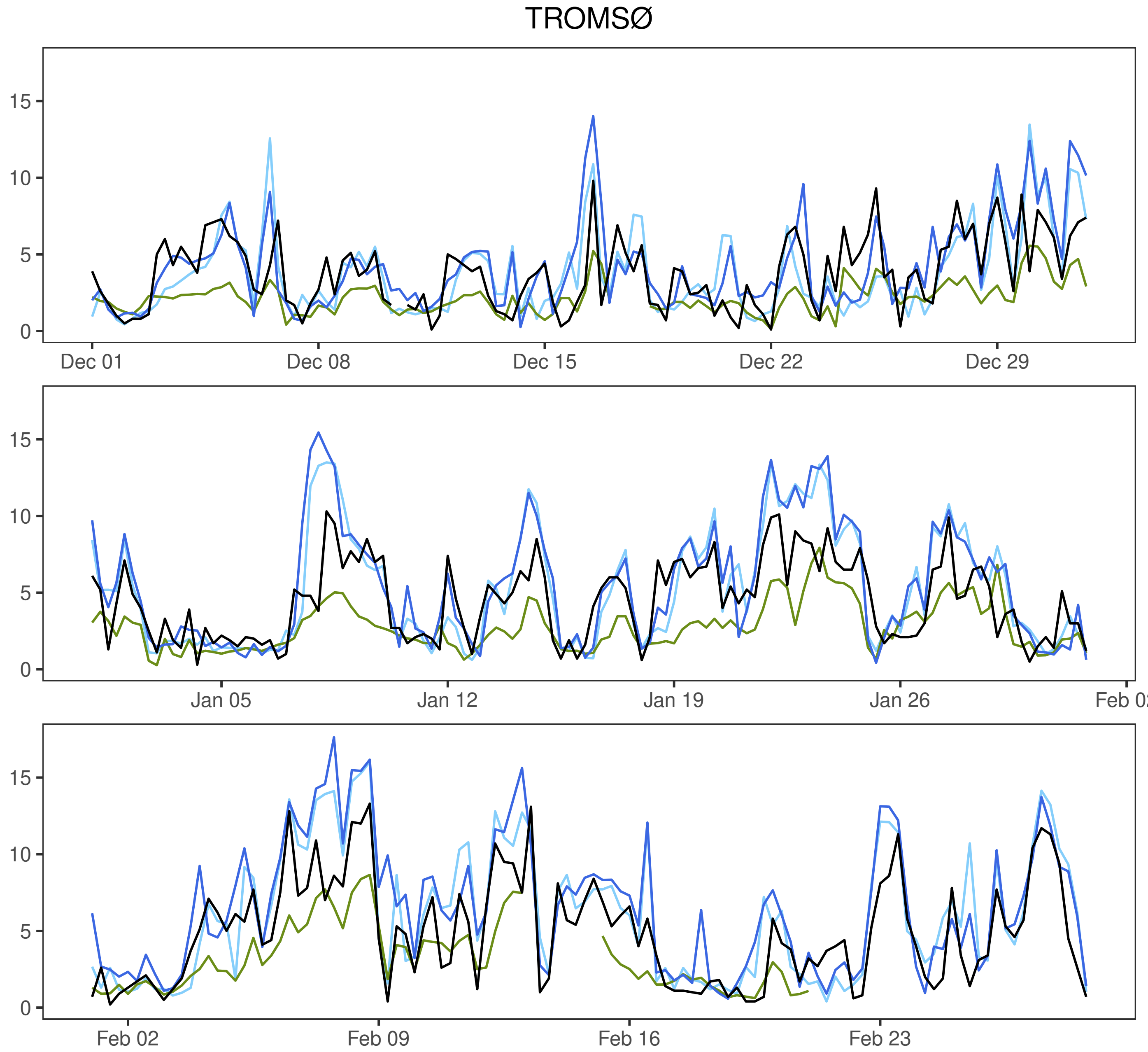

synop: 00,06,12,18
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.0100
0.0075
0.0050
0.0025
0.0000
0
100
200
300
Wind direction



	Min	Mean	Max	Std	N
synop: 00,06,12,18	1.6	8.8	21.6	4.0	360
MEPSctrl: 12+18,+24,+30,+36	0.5	8.7	21.3	4.4	360
AA25: 12+18,+24,+30,+36	0.5	8.8	21.8	4.6	360
ECMWF: 12+18,+24,+30,+36	1.1	8.8	20.1	3.8	317

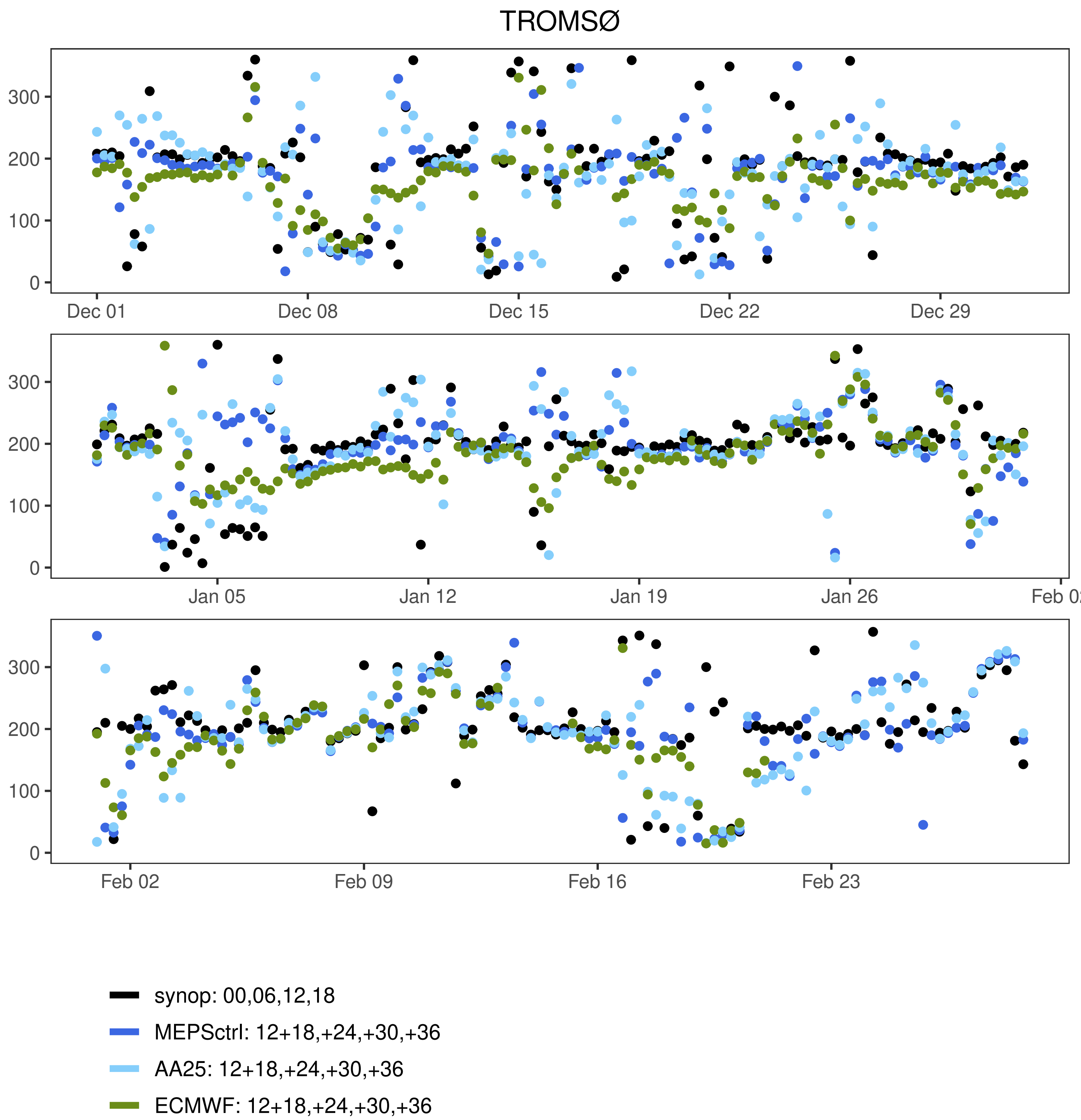
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	−0.2	2.4	2.4	1.7	11.8	317
AA25–synop	−0.1	2.3	2.3	1.7	13.3	317
ECMWF–synop	−0.1	1.9	1.9	1.4	7.4	317

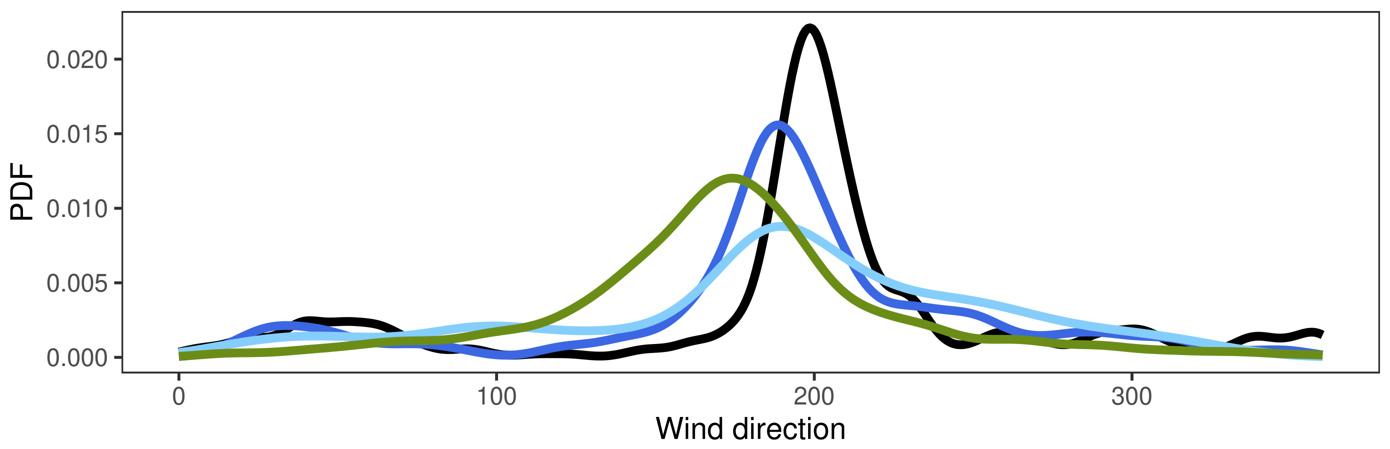

BJØRNØYA
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

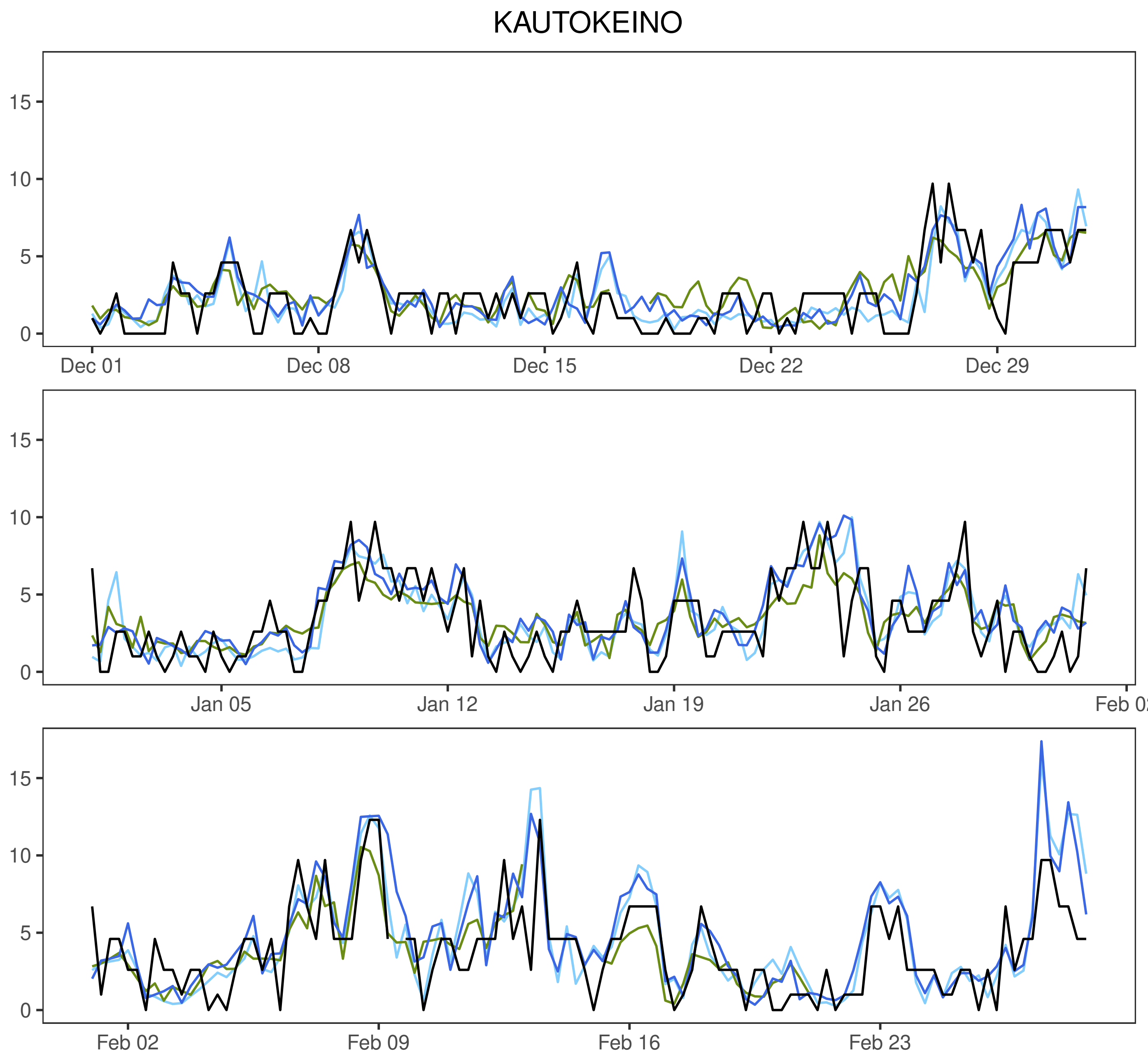


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.1	4.4	13.3	2.8	359
MEPSctrl: 12+18,+24,+30,+36	0.3	5.4	17.6	3.8	360
AA25: 12+18,+24,+30,+36	0.4	5.0	16.0	3.7	360
ECMWF: 12+18,+24,+30,+36	0.1	2.6	8.7	1.6	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	1.1	2.4	2.7	1.9	11.6	316
AA25–synop	0.6	2.3	2.4	1.7	9.6	316
ECMWF–synop	−1.6	1.9	2.4	1.9	6.8	316

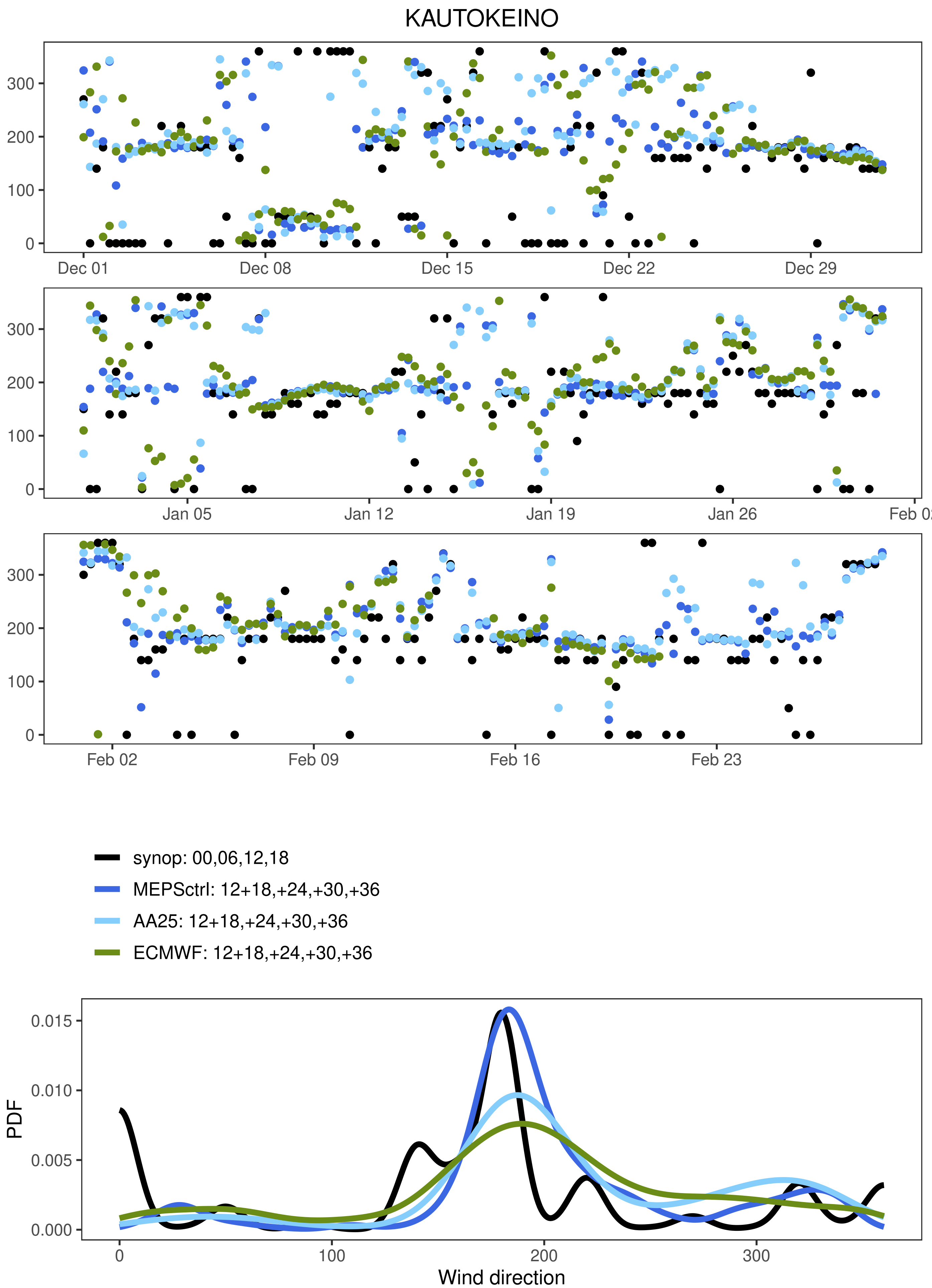

TROMSØ
0
100
200
300
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

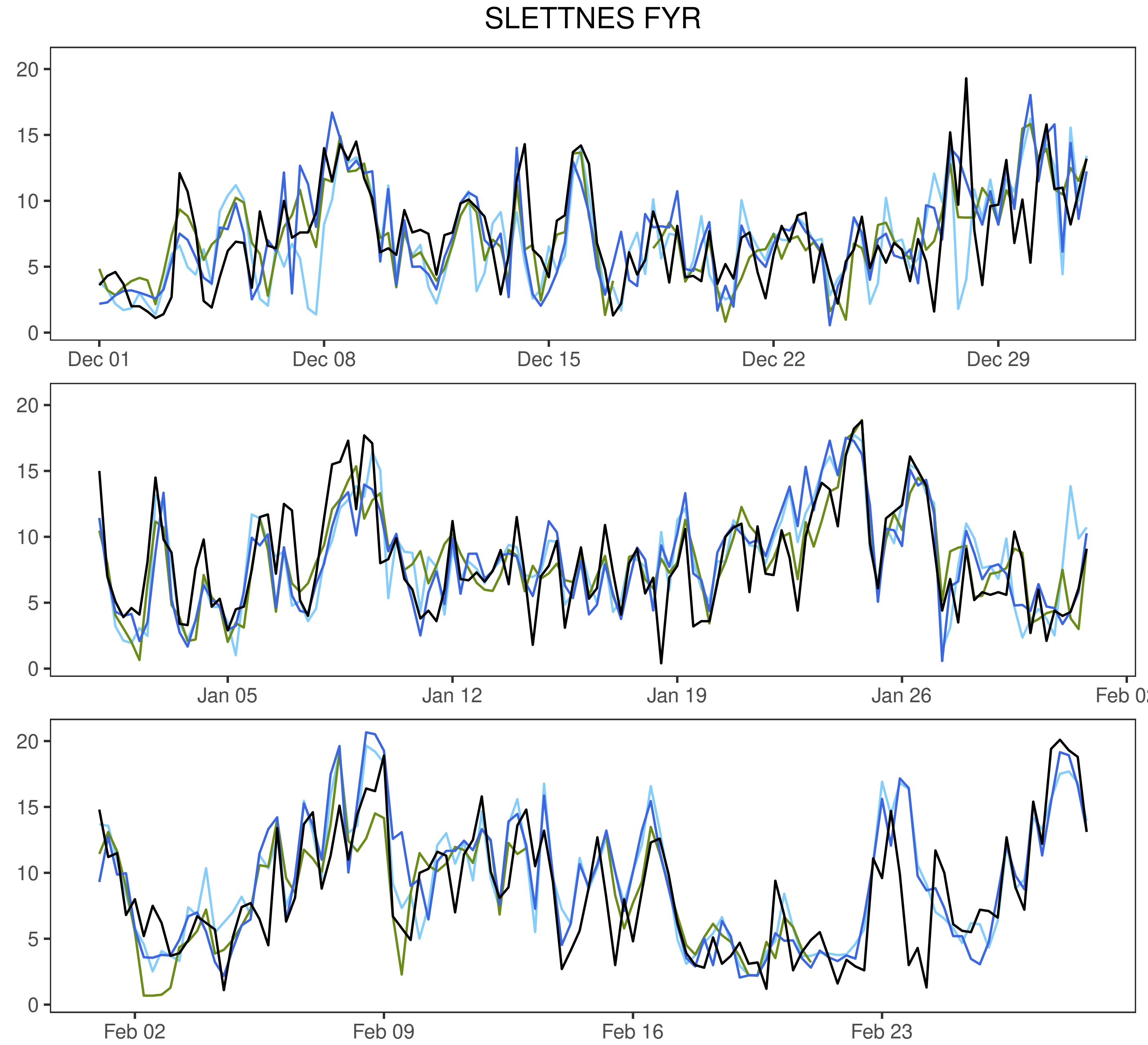

PDF
0.000
0.005
0.010
0.015
0.020
0
100
200
300
Wind direction



	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	3.1	12.3	2.6	359
MEPSctrl: 12+18,+24,+30,+36	0.3	3.7	17.4	2.7	360
AA25: 12+18,+24,+30,+36	0.2	3.5	16.1	2.8	360
ECMWF: 12+18,+24,+30,+36	0.3	3.3	10.5	1.8	317

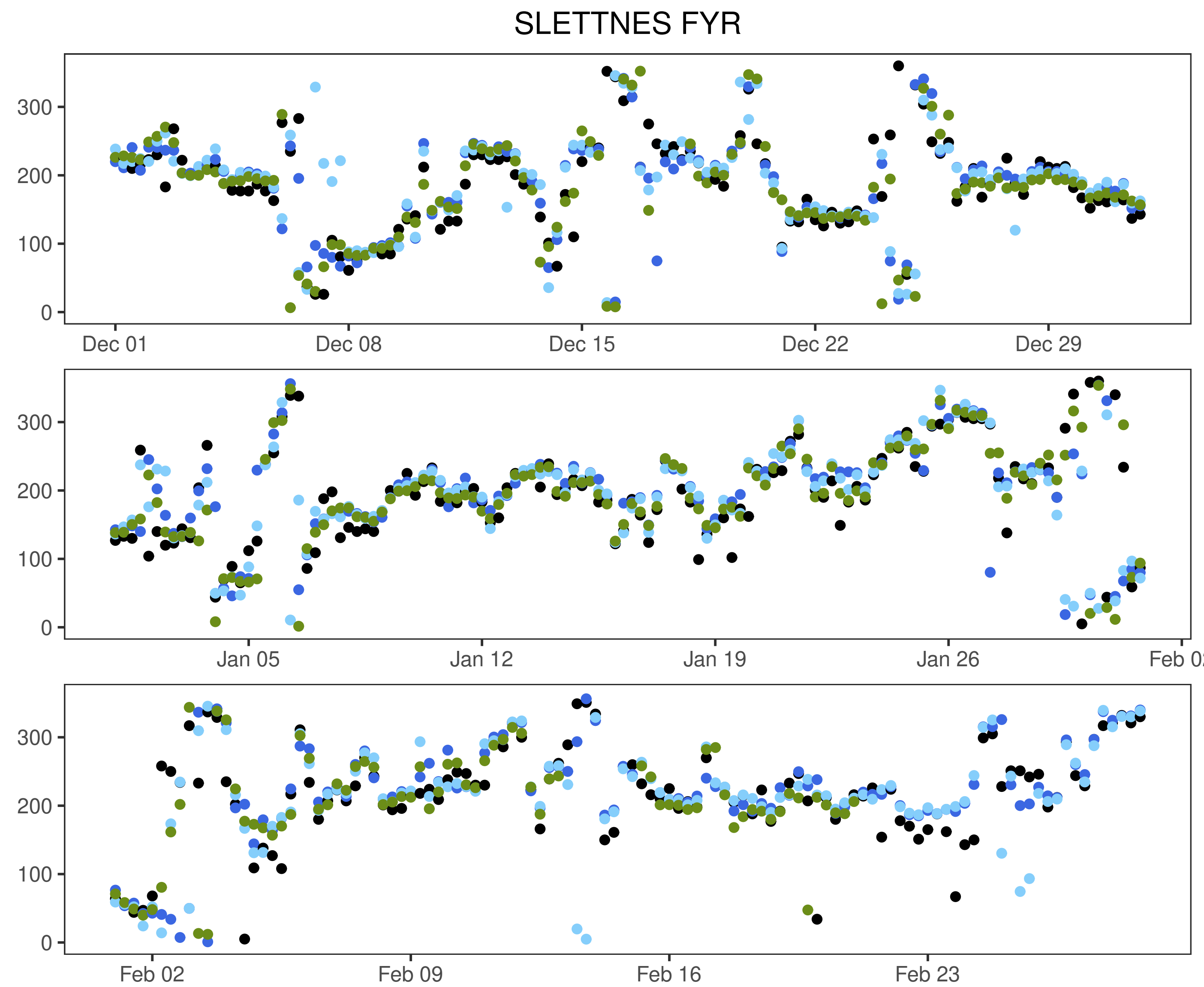
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	0.5	1.9	2.0	1.6	9.1	316
AA25–synop	0.2	1.8	1.8	1.5	6.7	316
ECMWF–synop	0.2	1.8	1.8	1.5	5.4	316

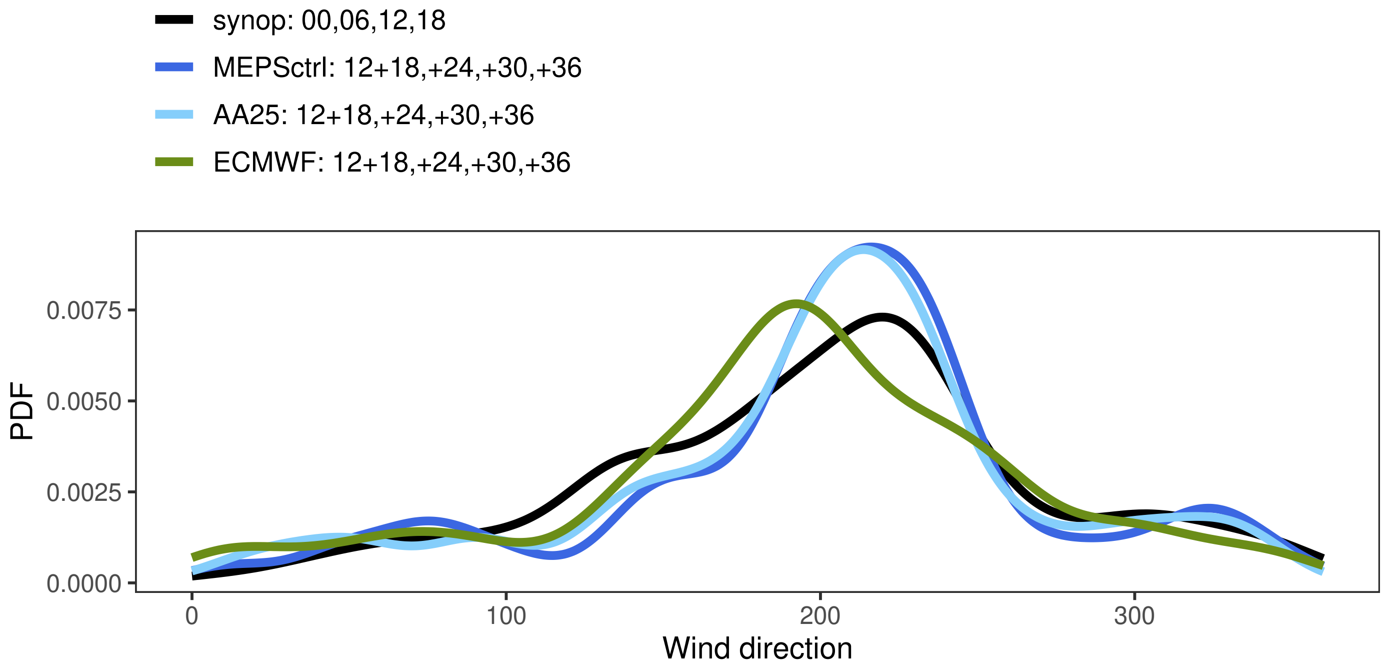

KAUTOKEINO
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.015
0.010
0.005
0.000
0
100
200
300
Wind direction

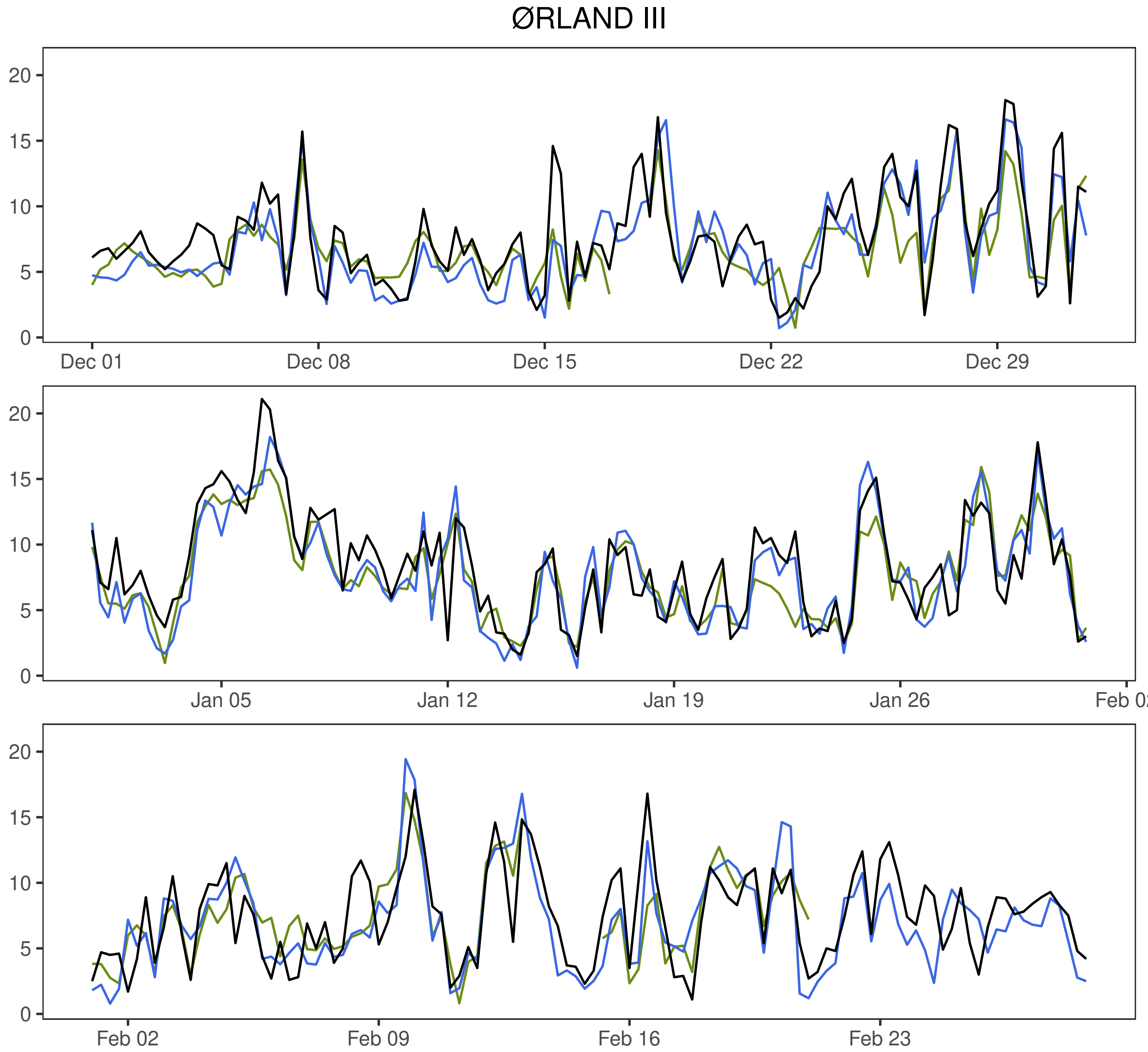


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.4	8.0	20.1	4.1	360
MEPSctrl: 12+18,+24,+30,+36	0.6	8.3	20.7	4.2	360
AA25: 12+18,+24,+30,+36	1.0	8.2	19.7	4.1	360
ECMWF: 12+18,+24,+30,+36	0.6	7.9	19.1	3.5	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	0.2	2.9	2.9	2.2	12.7	317
AA25–synop	0.2	3.2	3.2	2.4	15.3	317
ECMWF–synop	0.0	2.6	2.6	2.0	10.6	317

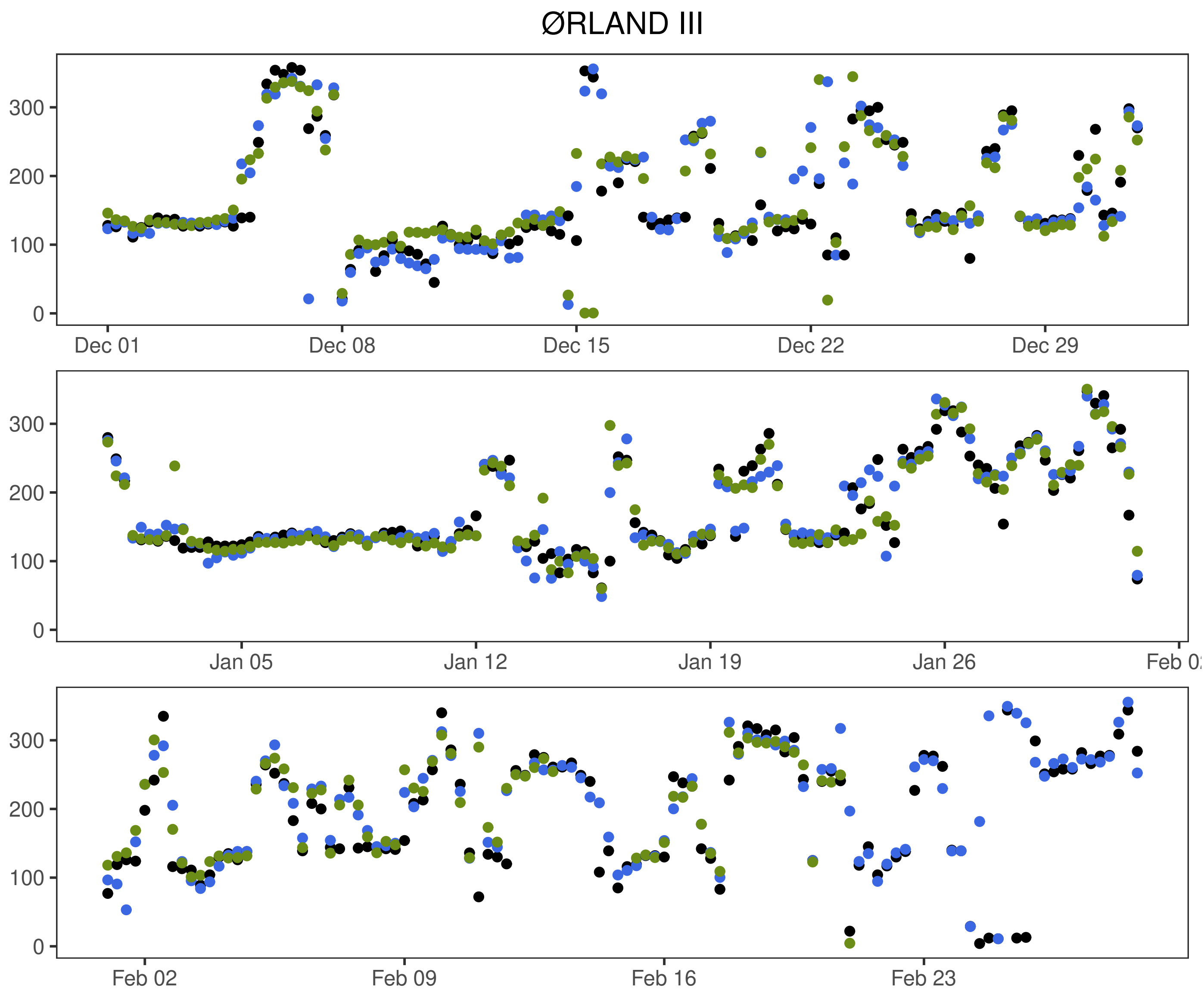

SLETTNES FYR
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23

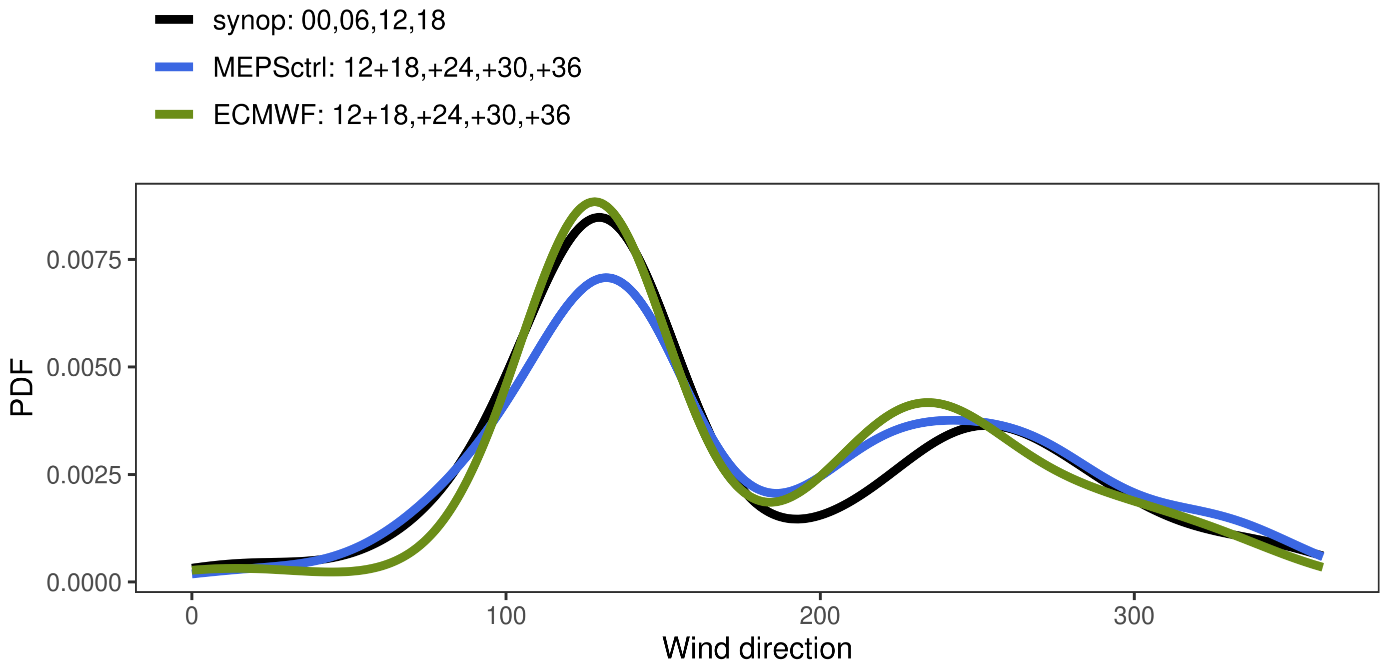

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.0075
0.0050
0.0025
0.0000
0
100
200
300
Wind direction

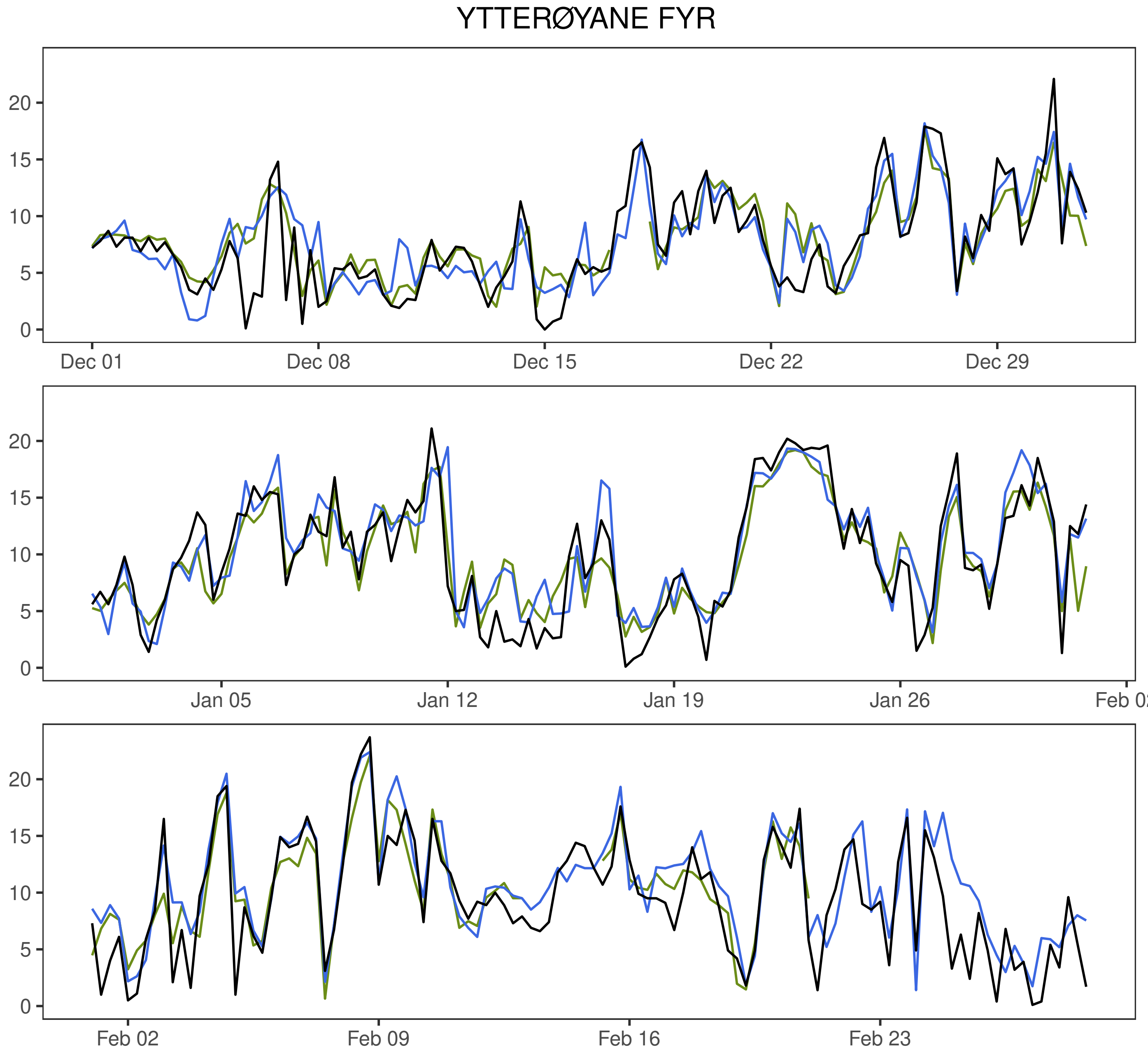


	Min	Mean	Max	Std	N
synop: 00,06,12,18	1.1	7.9	21.1	3.8	360
MEPSctrl: 12+18,+24,+30,+36	0.6	7.3	19.4	3.7	360
ECMWF: 12+18,+24,+30,+36	0.7	7.3	16.9	3.1	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.5	2.3	2.4	1.9	7.7	317
ECMWF−synop	−0.6	2.4	2.4	1.9	8.5	317

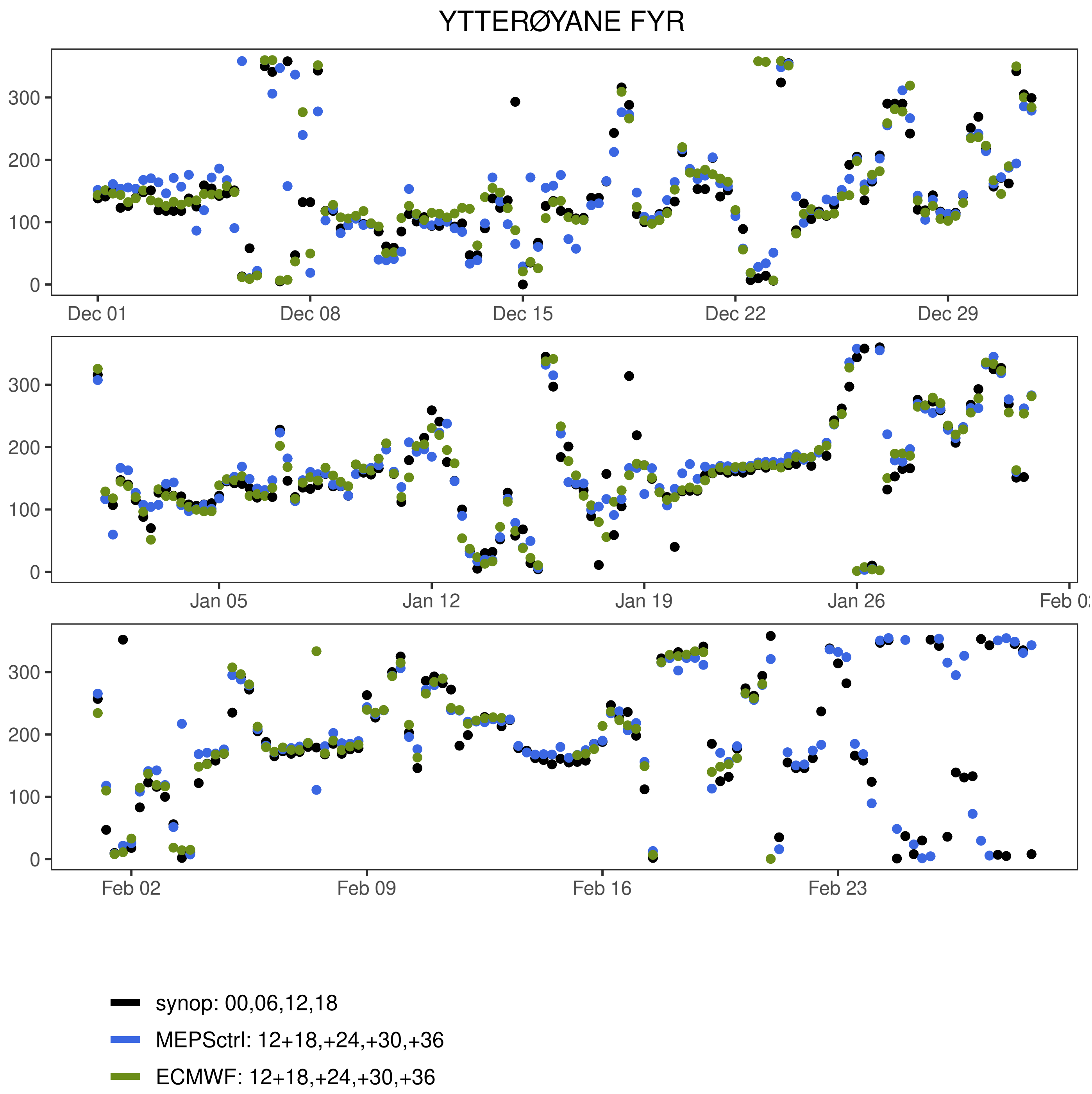

ØRLAND III
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23

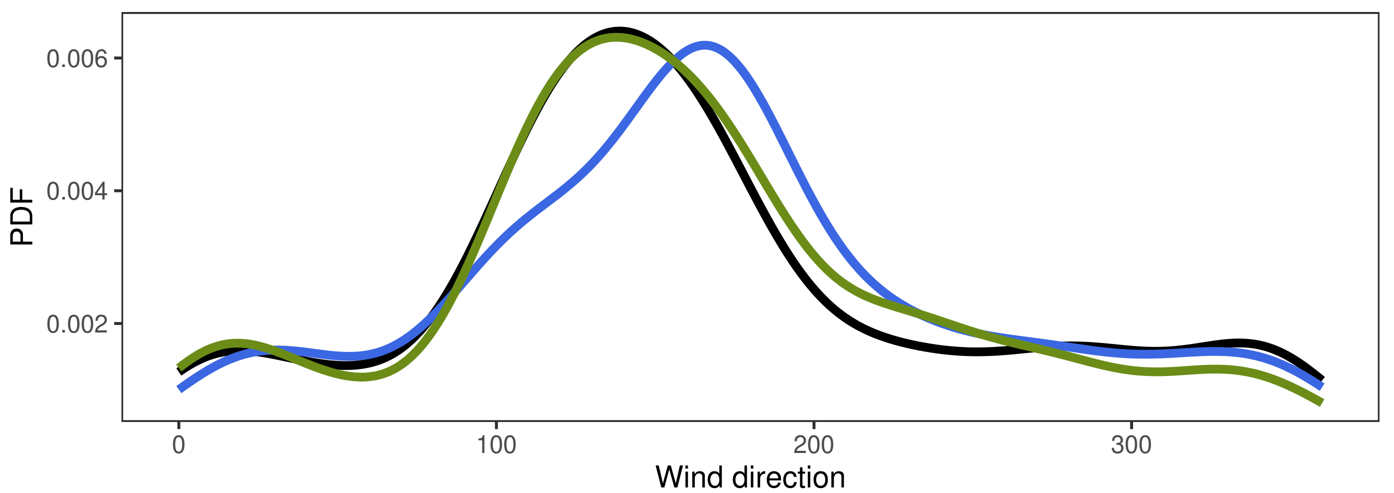

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.0075
0.0050
0.0025
0.0000
0
100
200
300
Wind direction

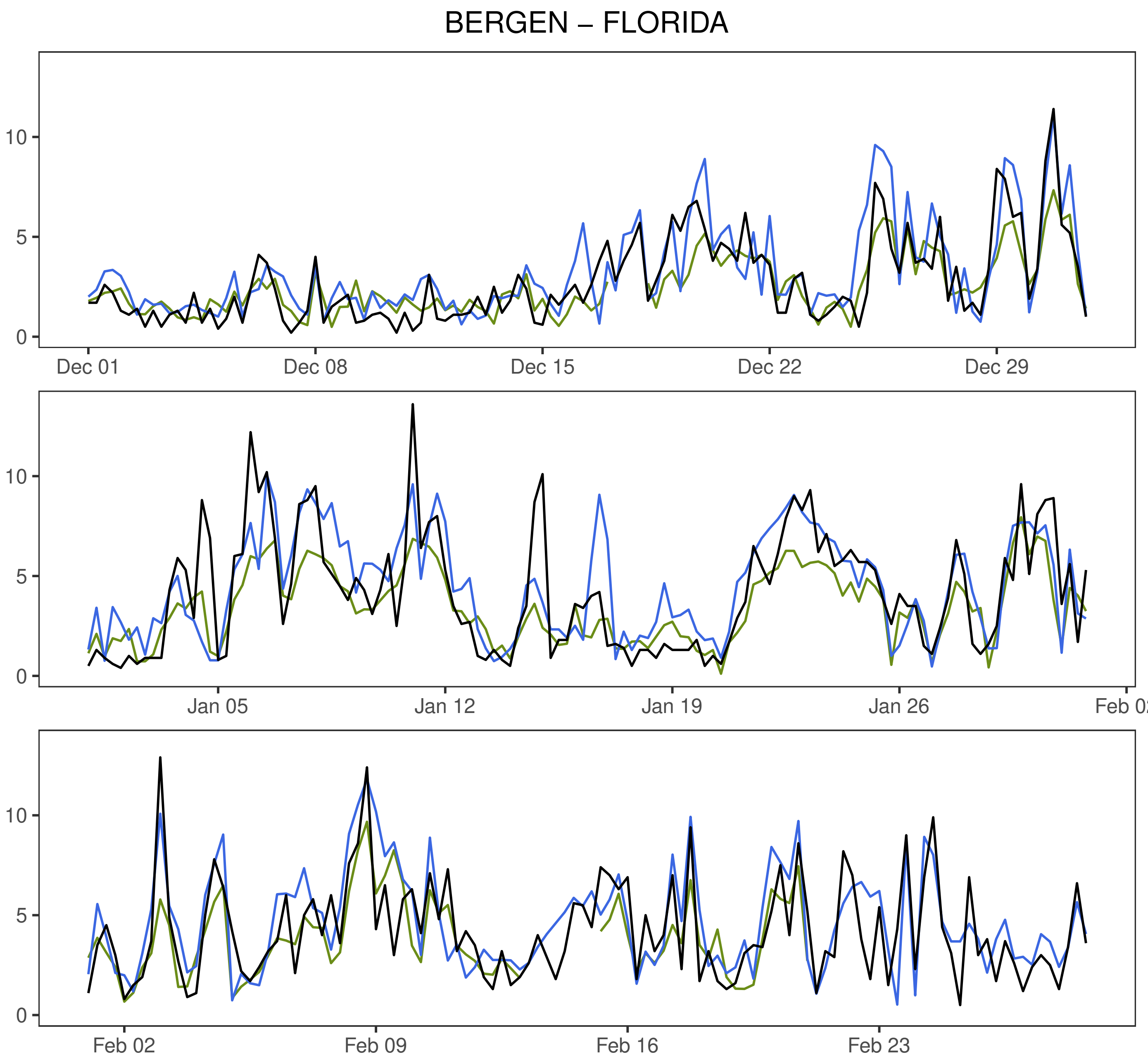


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	9.0	23.7	5.1	360
MEPSctrl: 12+18,+24,+30,+36	0.8	9.7	22.4	4.6	360
ECMWF: 12+18,+24,+30,+36	0.7	9.3	22.1	4.1	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.6	2.6	2.6	1.9	12.3	317
ECMWF−synop	0.2	2.5	2.5	1.9	8.6	317

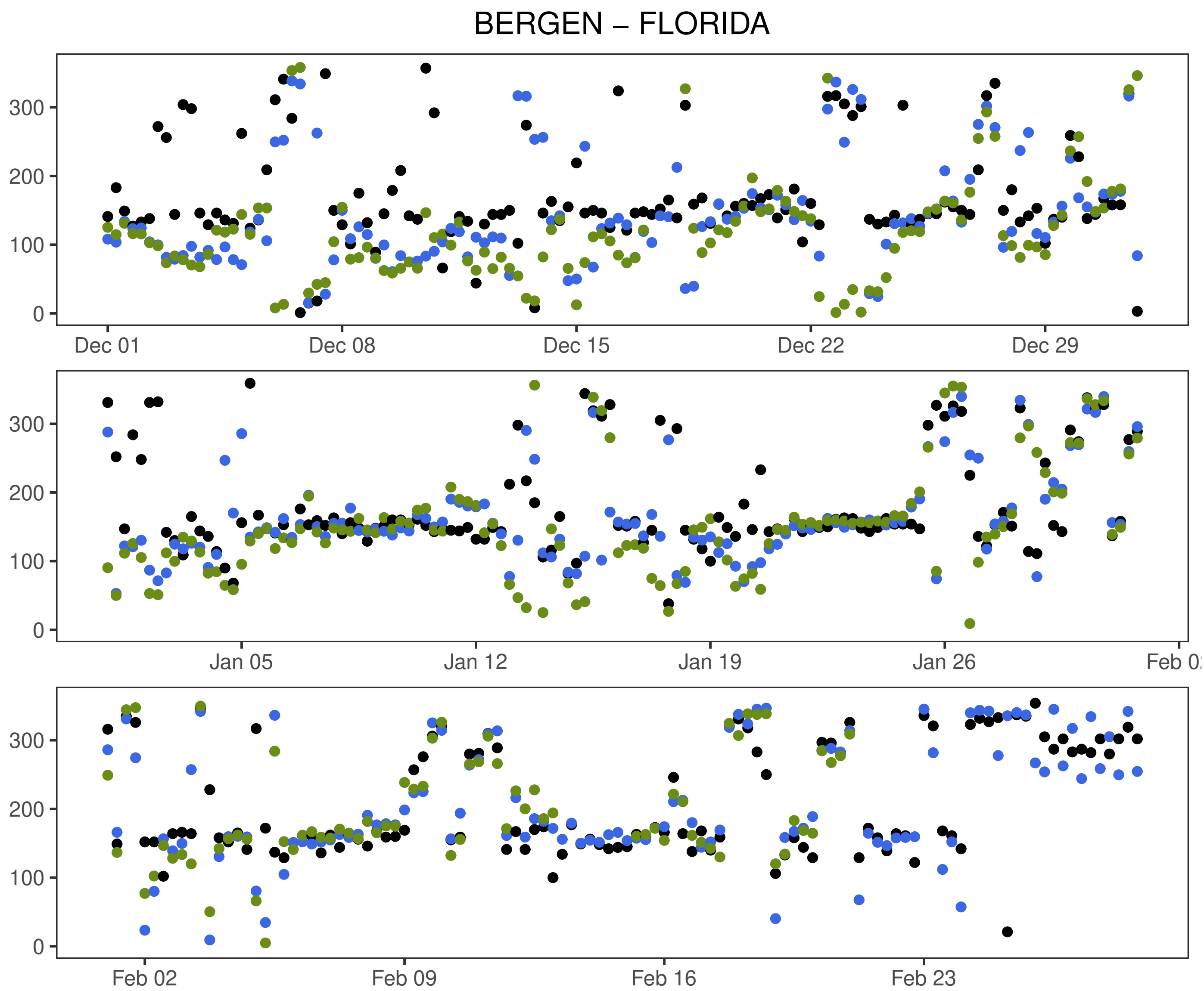

YTTERØYANE FYR
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

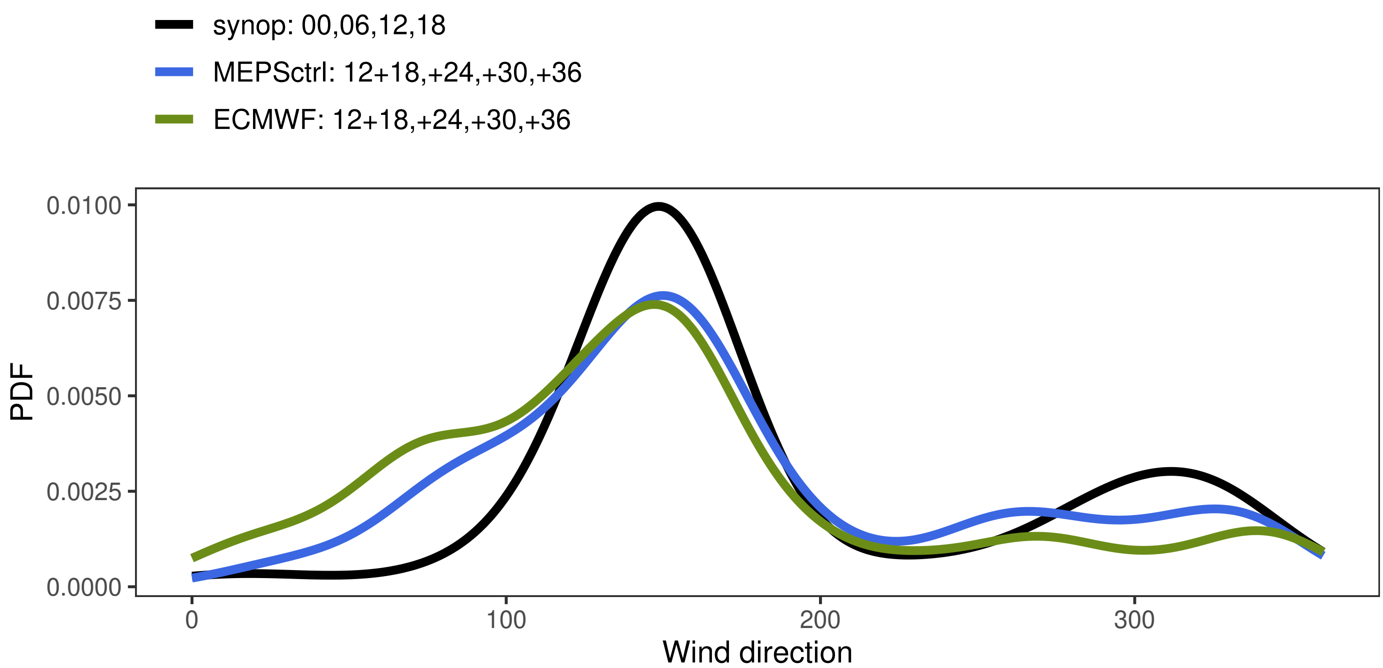

PDF
0.006
0.004
0.002
0
100
200
300
Wind direction

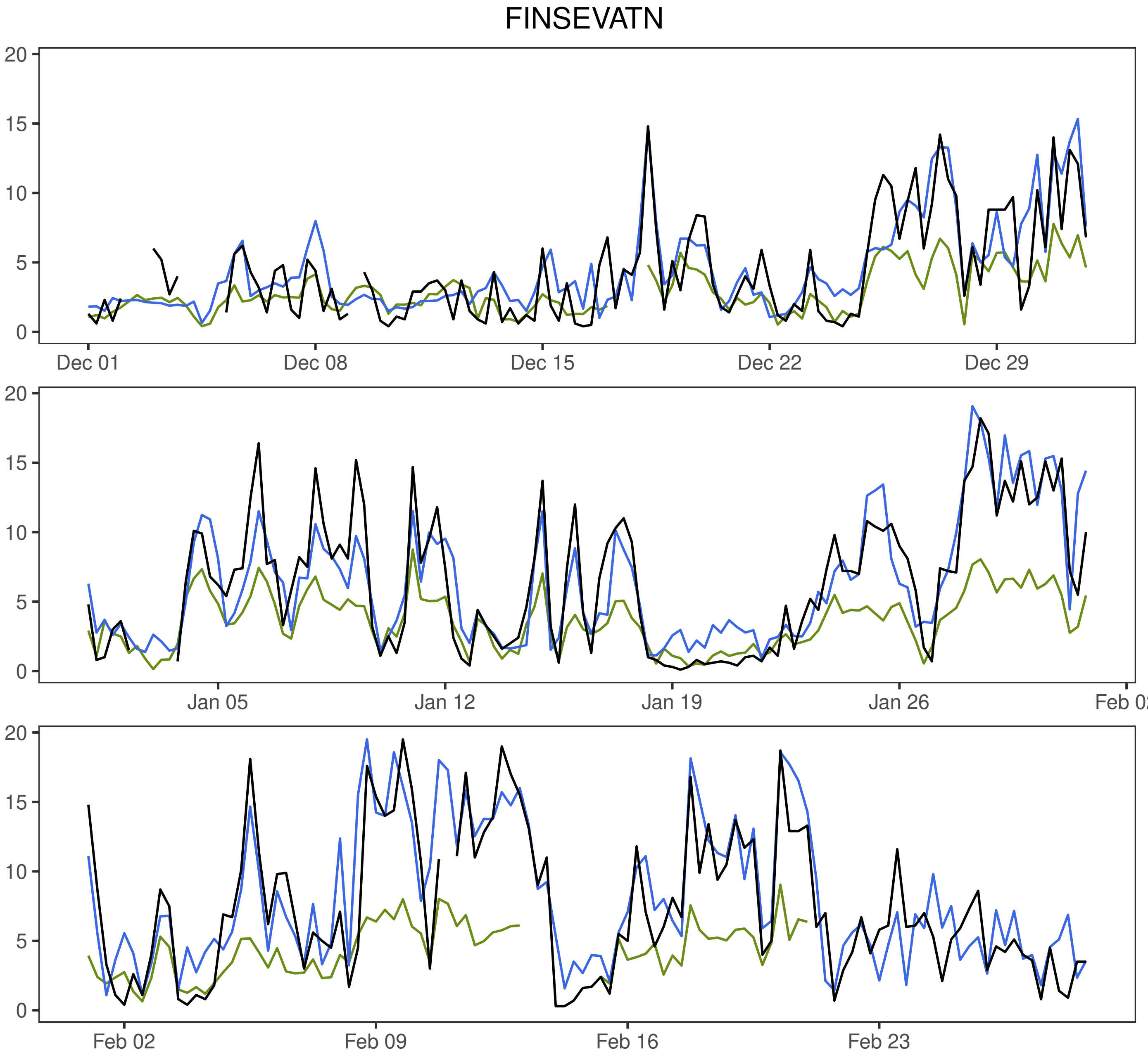


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.2	3.7	13.6	2.6	360
MEPSctrl: 12+18,+24,+30,+36	0.5	4.1	11.8	2.5	360
ECMWF: 12+18,+24,+30,+36	0.1	3.2	9.7	1.8	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	0.4	1.8	1.8	1.4	7.1	317
ECMWF–synop	–0.5	1.6	1.7	1.2	7.7	317

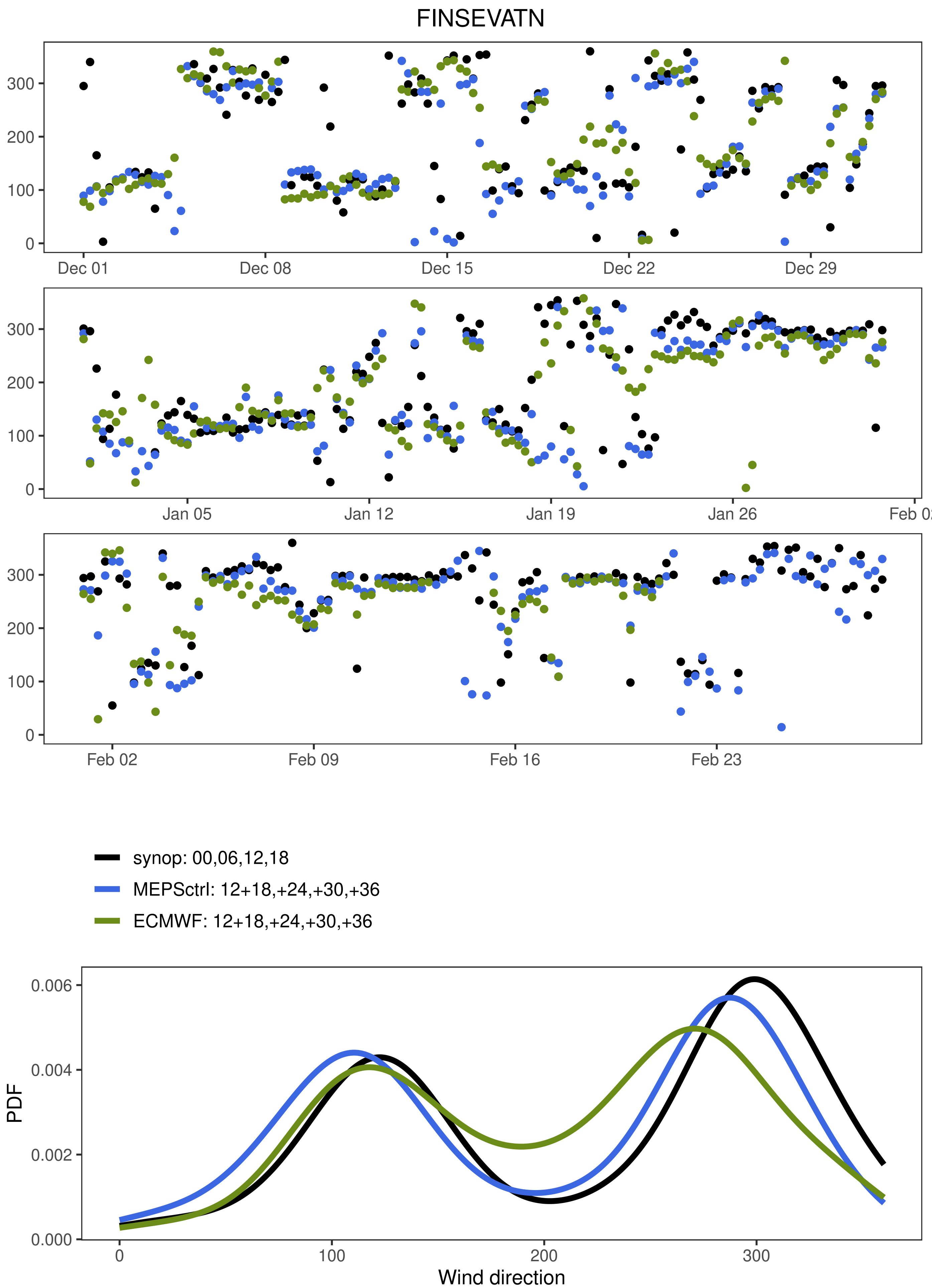

BERGEN – FLORIDA
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23

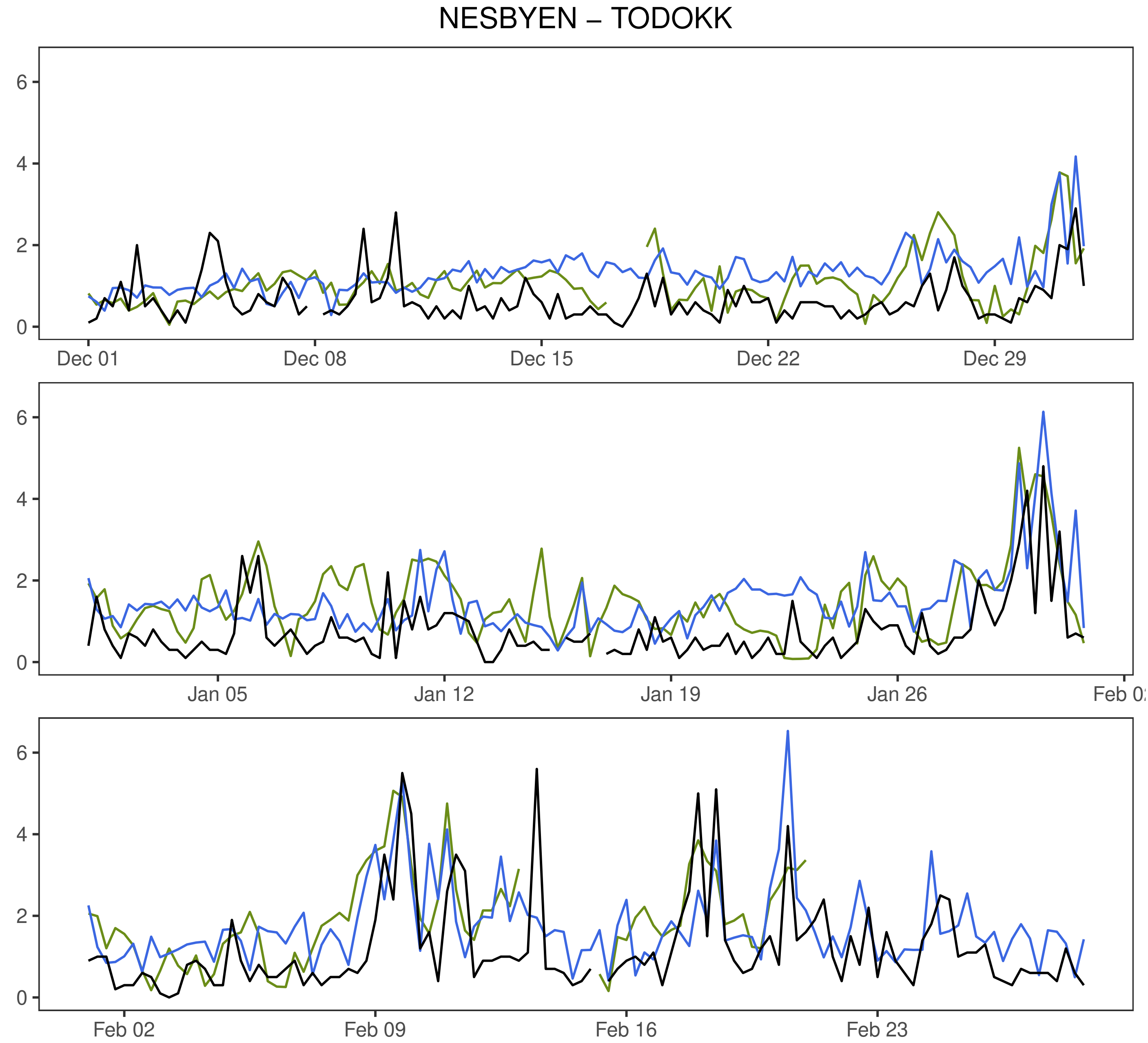

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.0100
0.0075
0.0050
0.0025
0.0000
0
100
200
300
Wind direction



	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.1	6.1	19.5	4.7	345
MEPSctrl: 12+18,+24,+30,+36	0.7	6.3	19.5	4.5	360
ECMWF: 12+18,+24,+30,+36	0.1	3.5	9.0	1.9	317

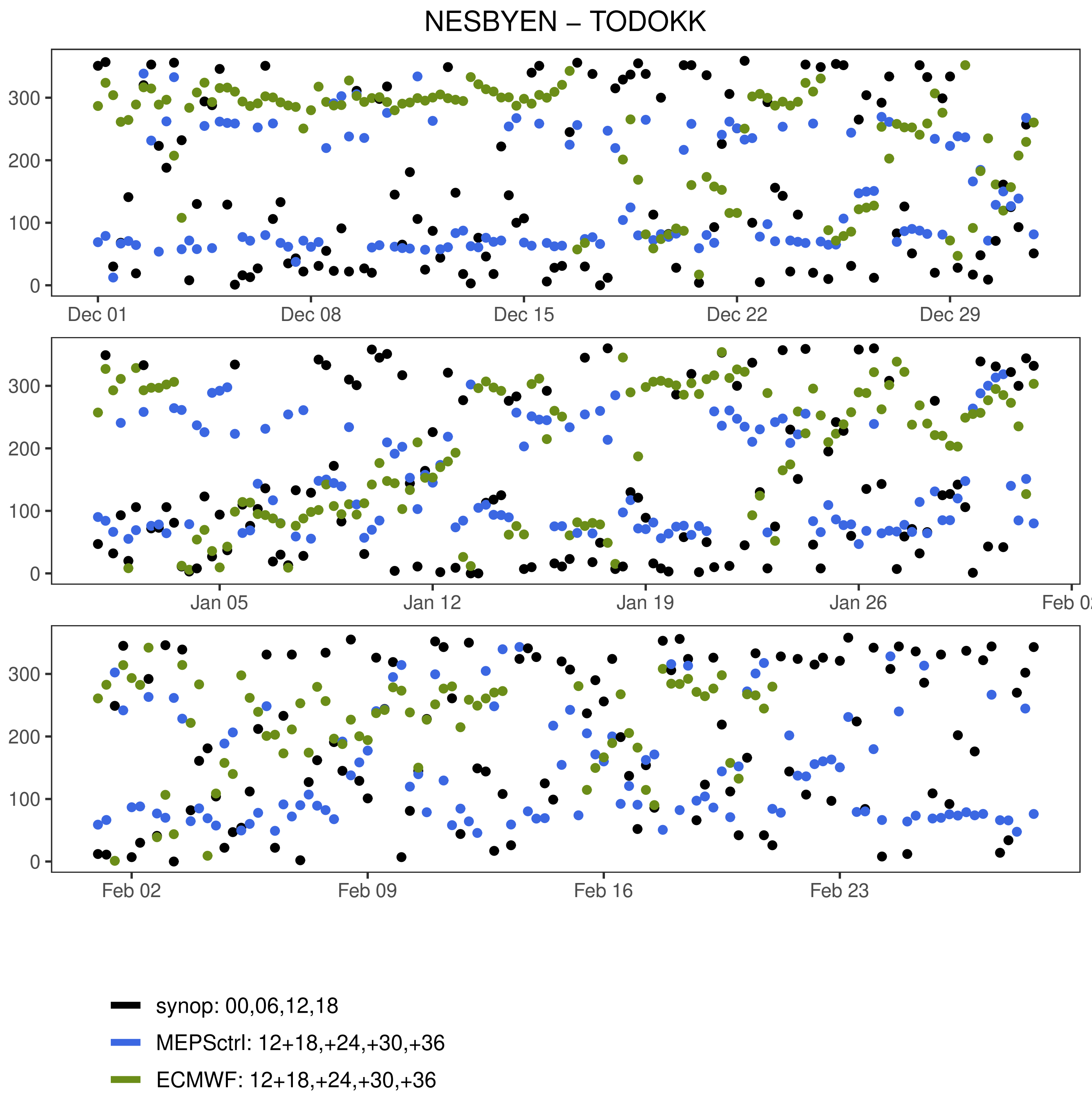
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.3	2.4	2.4	1.9	11.0	302
ECMWF−synop	−2.7	3.3	4.3	3.1	13.2	302

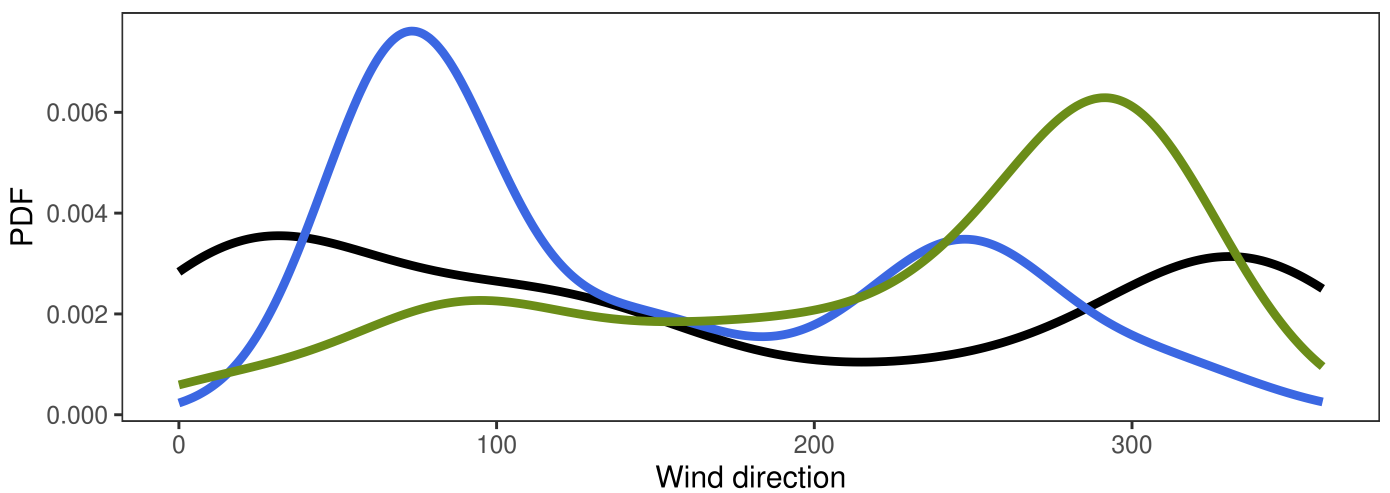

FINSEVATN
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.006
0.004
0.002
0.000
0
100
200
300
Wind direction

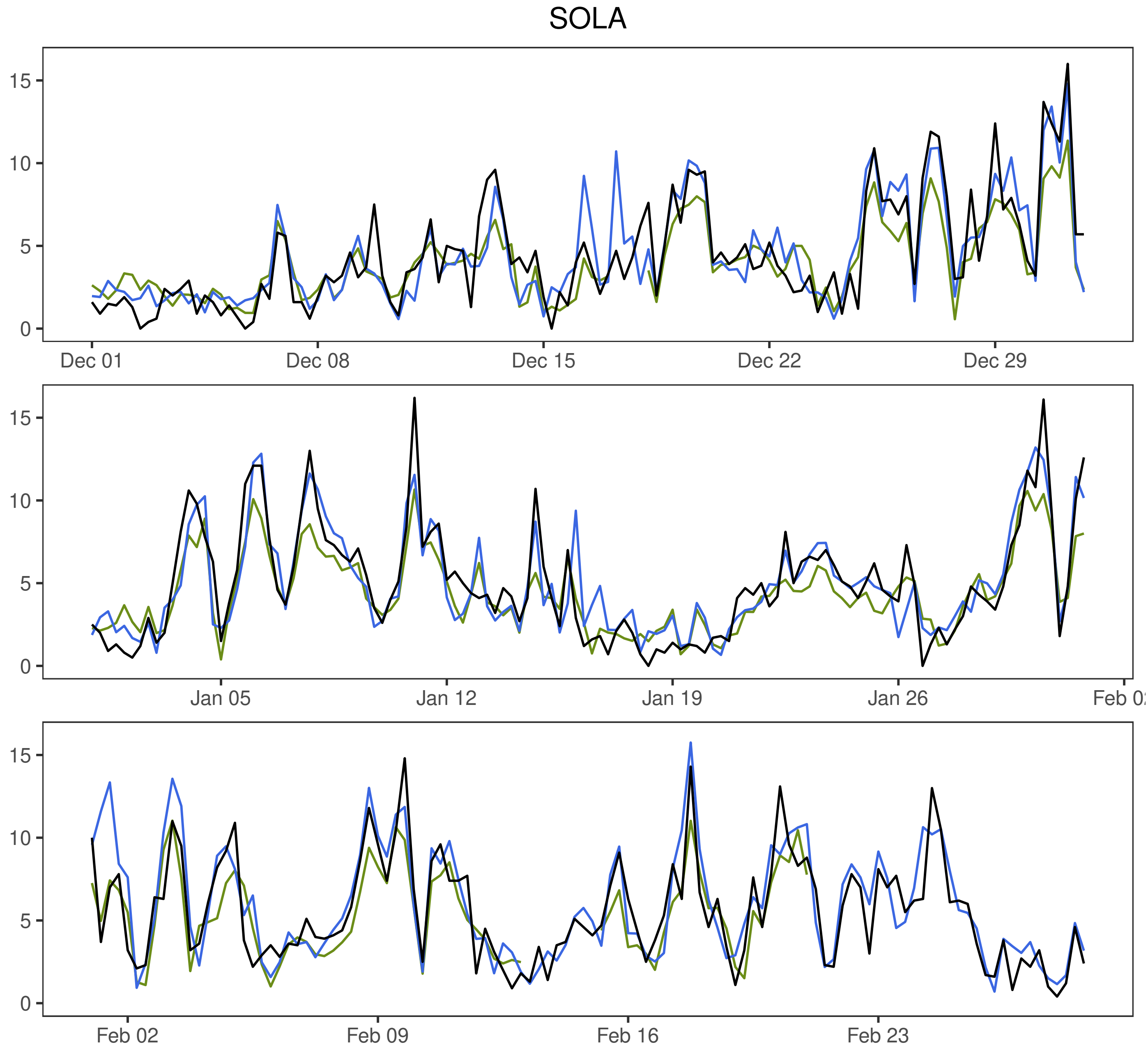


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	0.9	5.6	0.9	356
MEPSctrl: 12+18,+24,+30,+36	0.3	1.5	6.5	0.8	360
ECMWF: 12+18,+24,+30,+36	0.0	1.4	5.3	0.9	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	0.7	0.8	1.0	0.9	3.0	313
ECMWF–synop	0.6	0.8	1.0	0.8	3.4	313

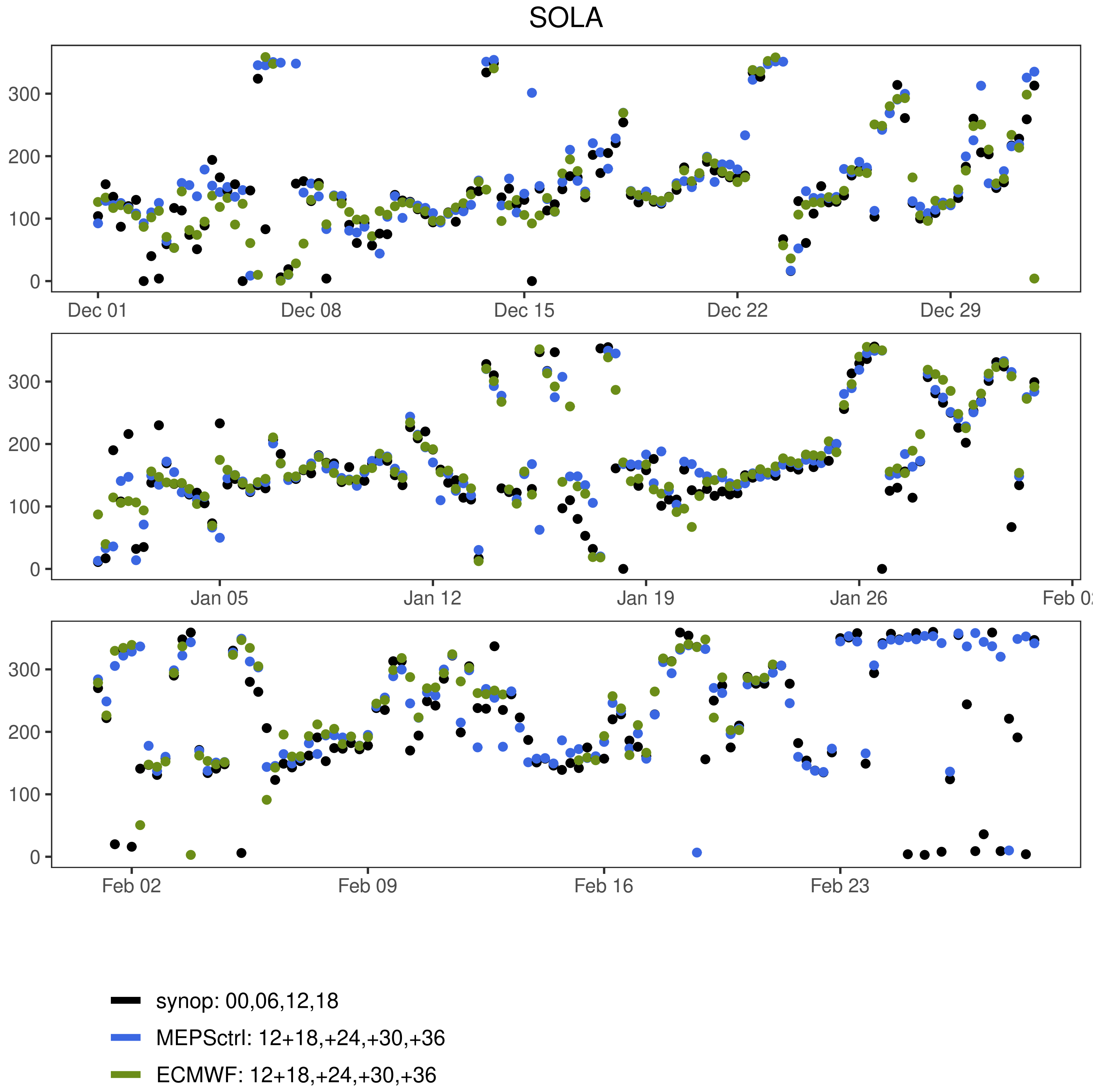

NESBYEN – TODOKK
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

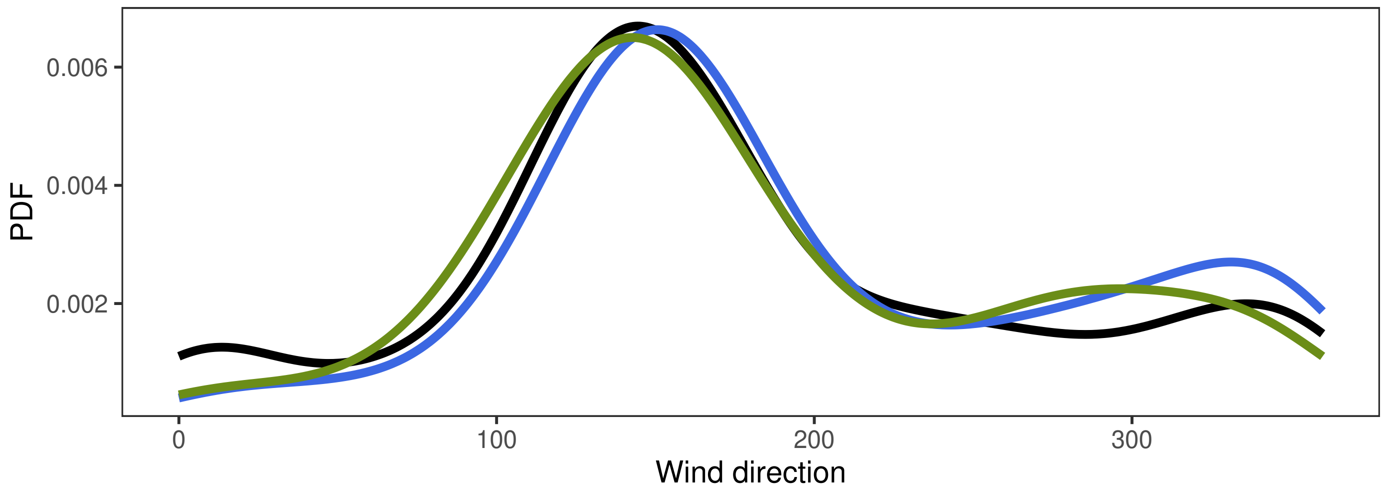

PDF
0.006
0.004
0.002
0.000
0
100
200
300
Wind direction

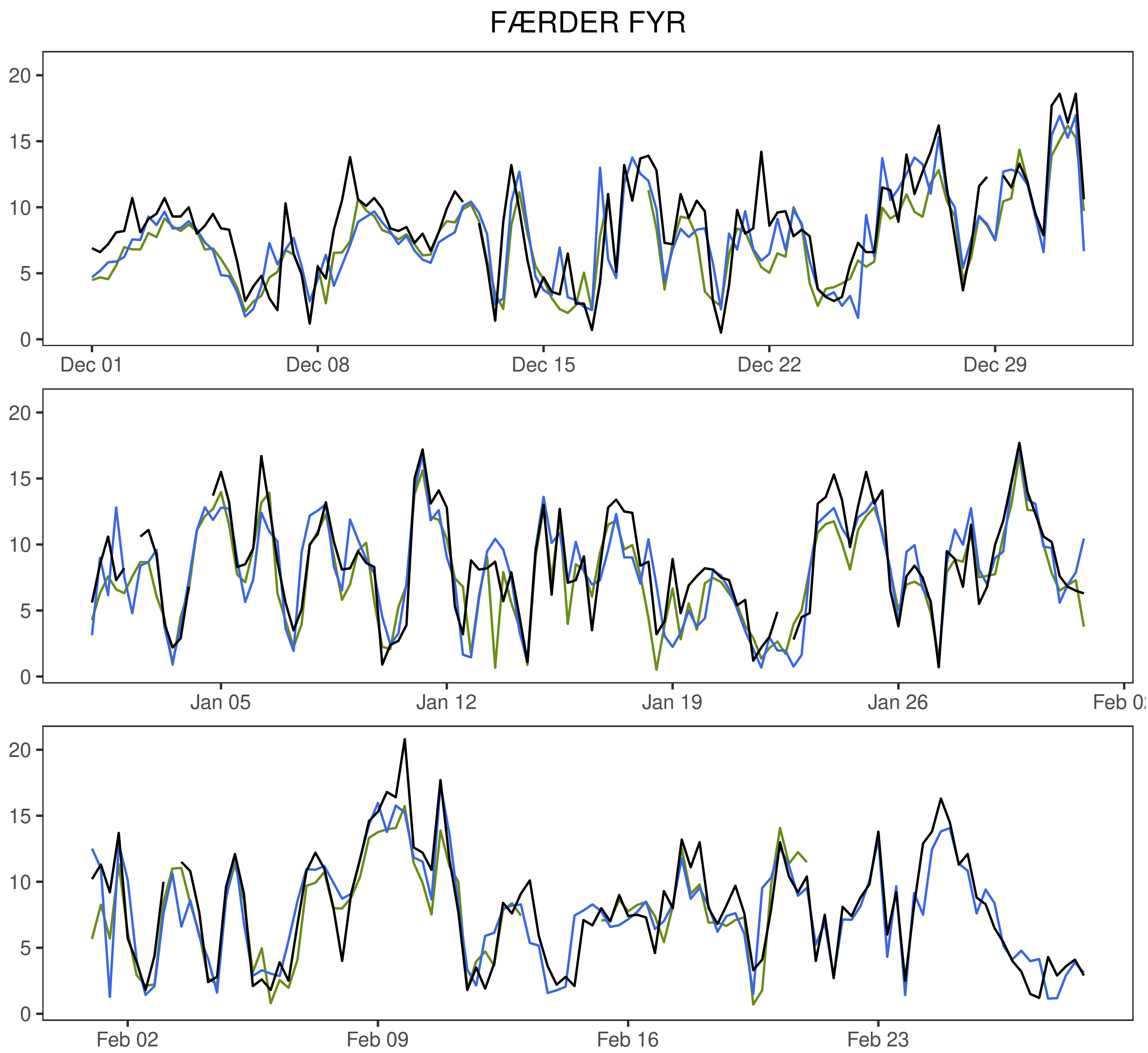


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	5.0	16.2	3.3	360
MEPSctrl: 12+18,+24,+30,+36	0.6	5.2	15.8	3.2	360
ECMWF: 12+18,+24,+30,+36	0.4	4.5	11.4	2.4	317

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.2	1.7	1.7	1.3	7.9	317
ECMWF−synop	−0.5	1.7	1.8	1.4	5.7	317

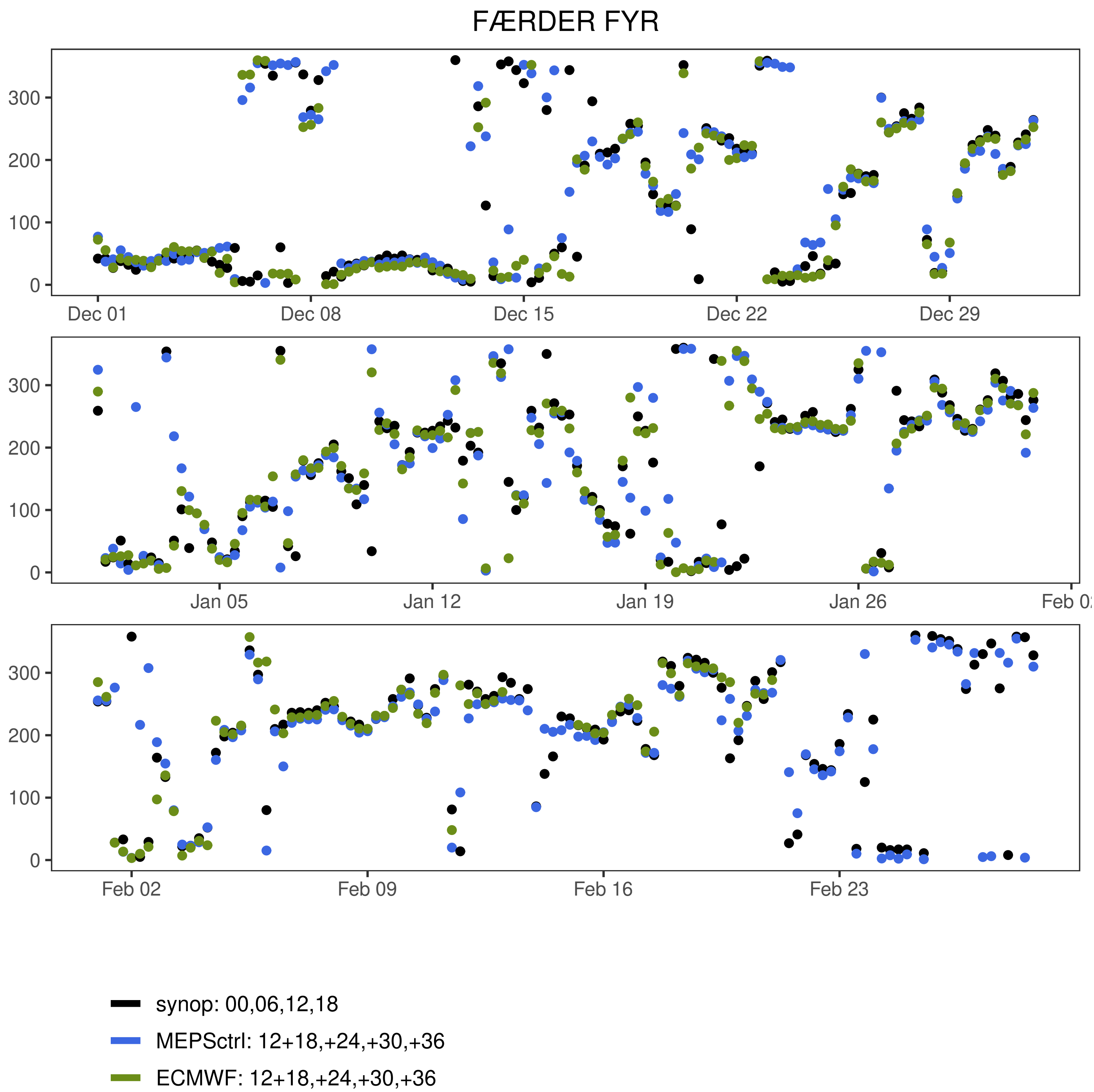

SOLA
300
200
100
0
Dec 01
Dec 08
Dec 15
Dec 22
Dec 29
Jan 05
Jan 12
Jan 19
Jan 26
Feb 02
Feb 09
Feb 16
Feb 23
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

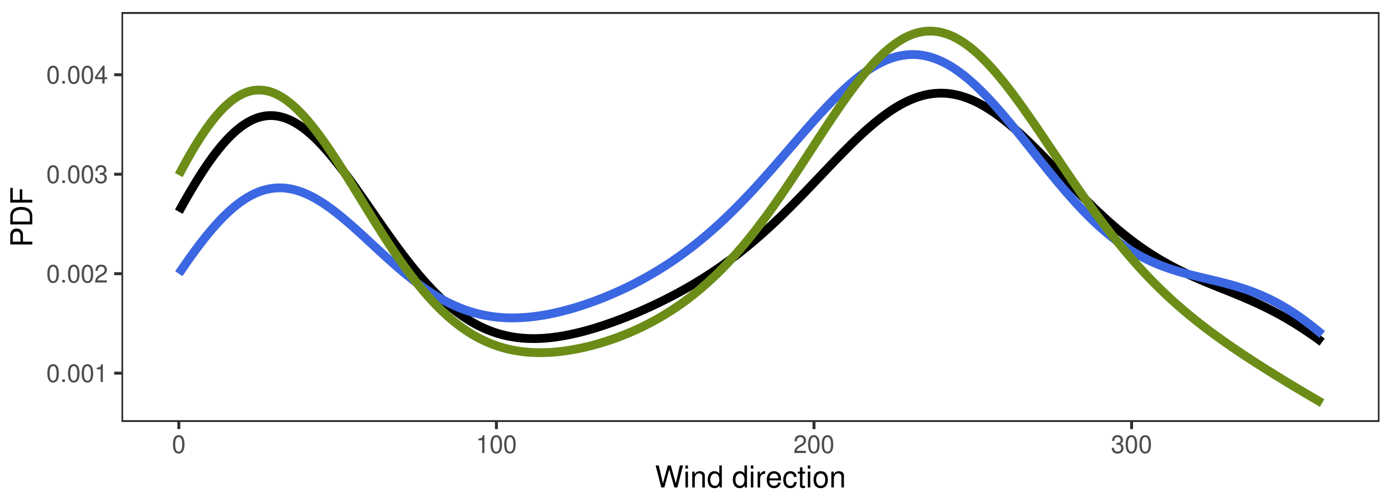

PDF
0.006
0.004
0.002
0
100
200
300
Wind direction

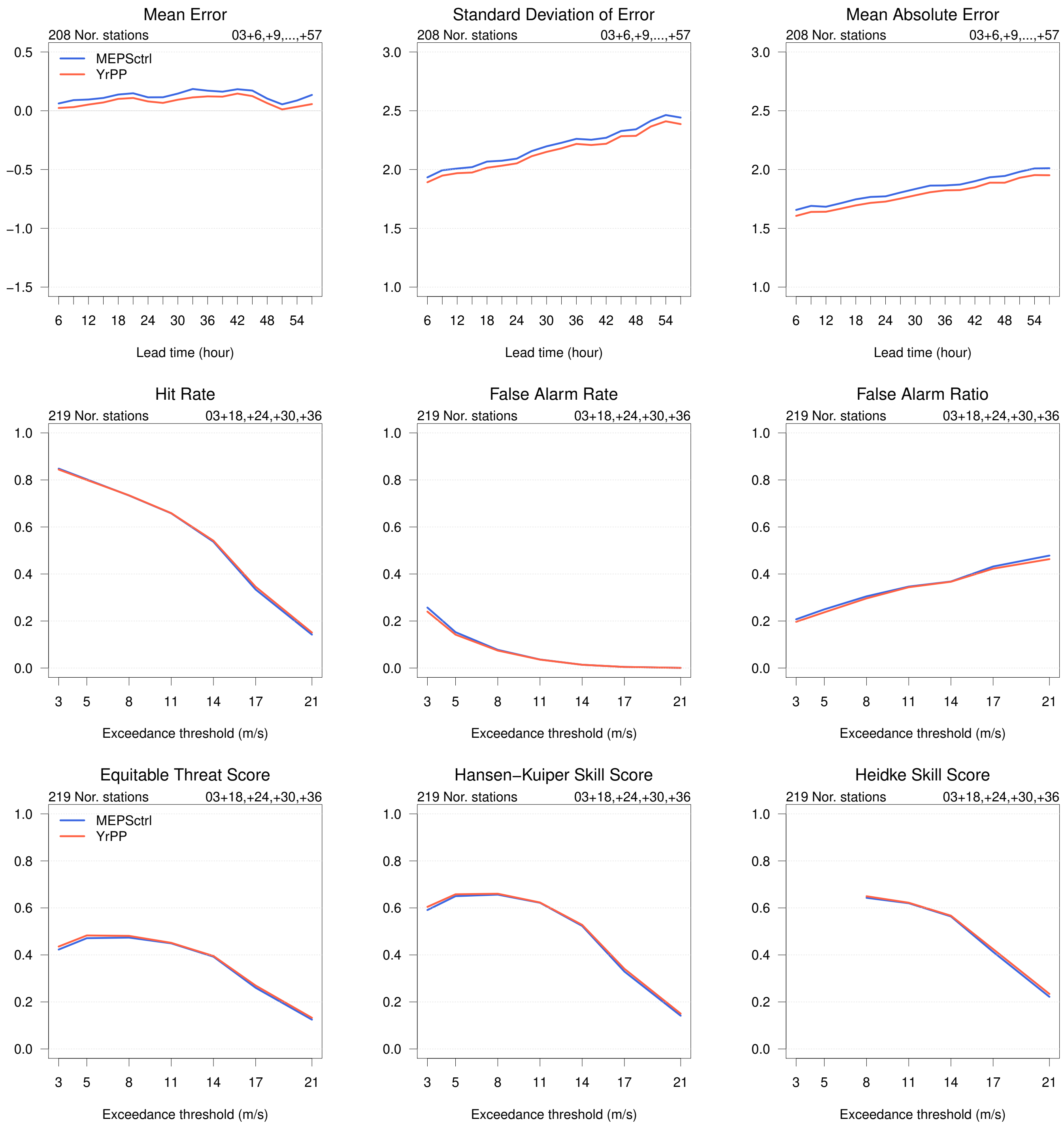


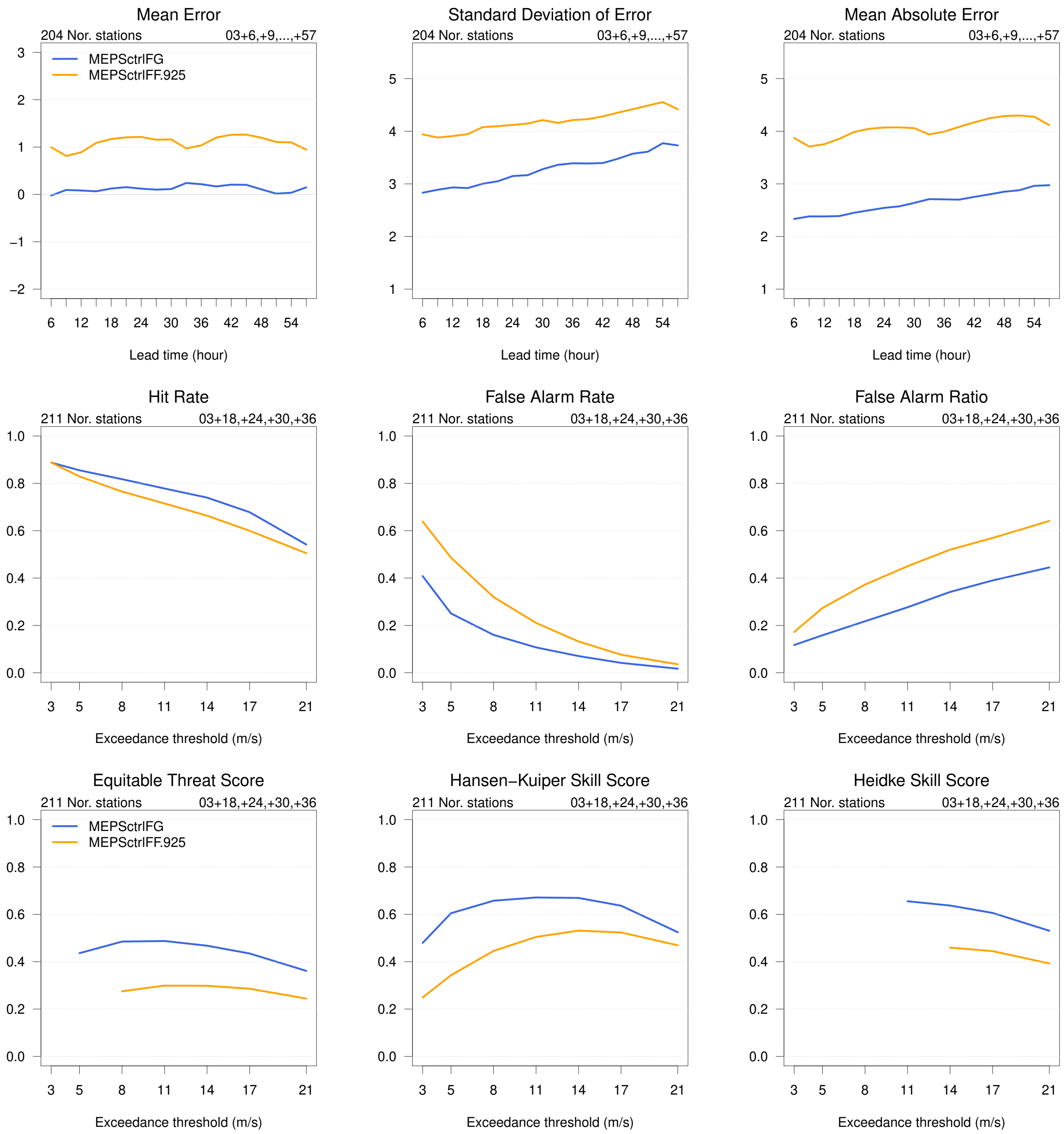
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.5	8.3	20.8	4.0	353
MEPSctrl: 12+18,+24,+30,+36	0.7	7.9	17.4	3.7	360
ECMWF: 12+18,+24,+30,+36	0.5	7.5	16.8	3.4	317

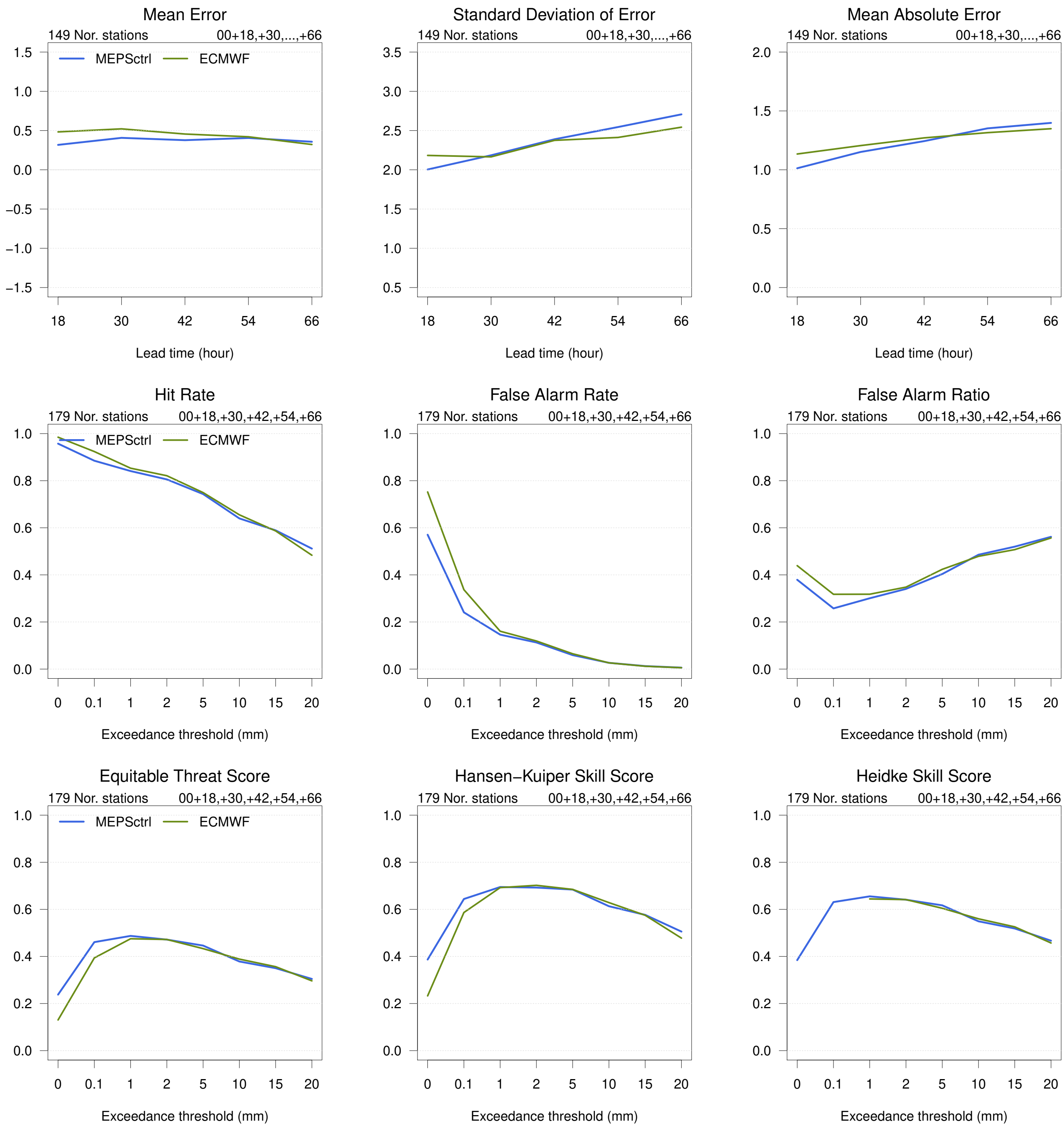
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	–0.5	2.3	2.3	1.8	8.7	310
ECMWF–synop	–1.0	1.9	2.2	1.7	8.7	310


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

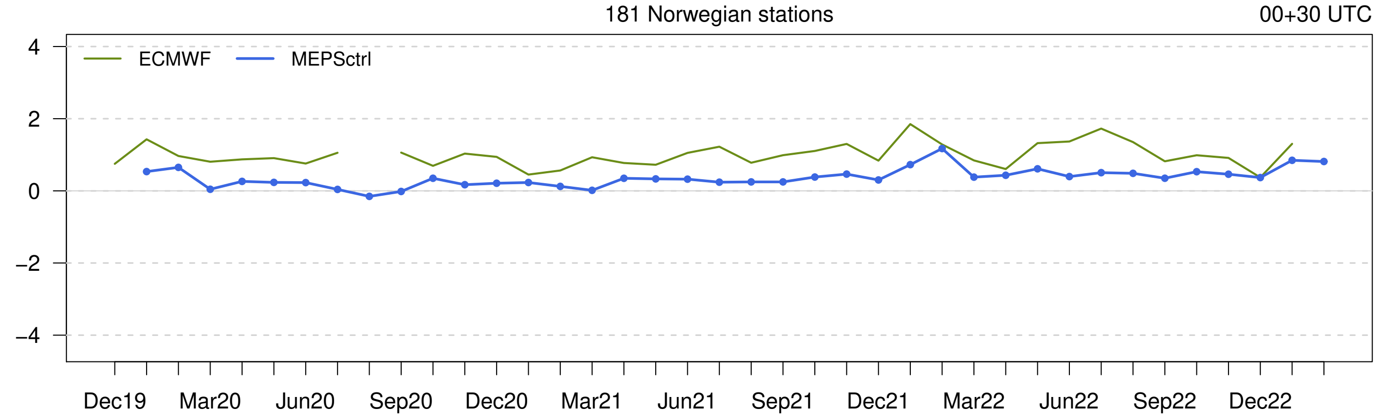

PDF
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

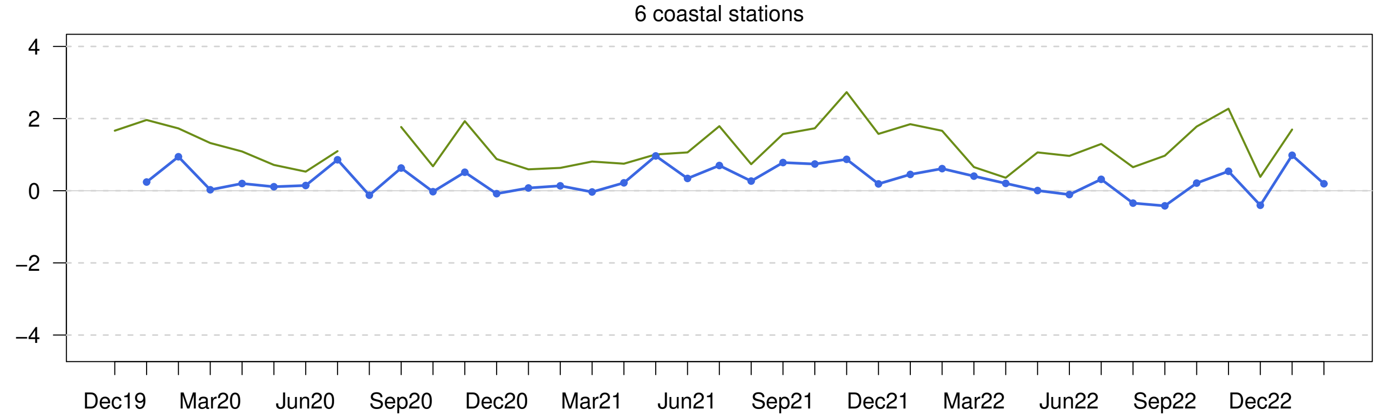

Mean Error
208 Nor. stations
03+6,+9,...,+57
MEPSctrl
YrPP
Lead time (hour)
Standard Deviation of Error
208 Nor. stations
03+6,+9,...,+57
Lead time (hour)
Mean Absolute Error
208 Nor. stations
03+6,+9,...,+57
Lead time (hour)
Hit Rate
219 Nor. stations
03+18,+24,+30,+36
Exceedance threshold (m/s)
False Alarm Rate
219 Nor. stations
03+18,+24,+30,+36
Exceedance threshold (m/s)
False Alarm Ratio
219 Nor. stations
03+18,+24,+30,+36
Exceedance threshold (m/s)
Equitable Threat Score
219 Nor. stations
03+18,+24,+30,+36
MEPSctrl
YrPP
Exceedance threshold (m/s)
Hansen−Kuiper Skill Score
219 Nor. stations
03+18,+24,+30,+36
Exceedance threshold (m/s)
Heidke Skill Score
219 Nor. stations
03+18,+24,+30,+36
Exceedance threshold (m/s)

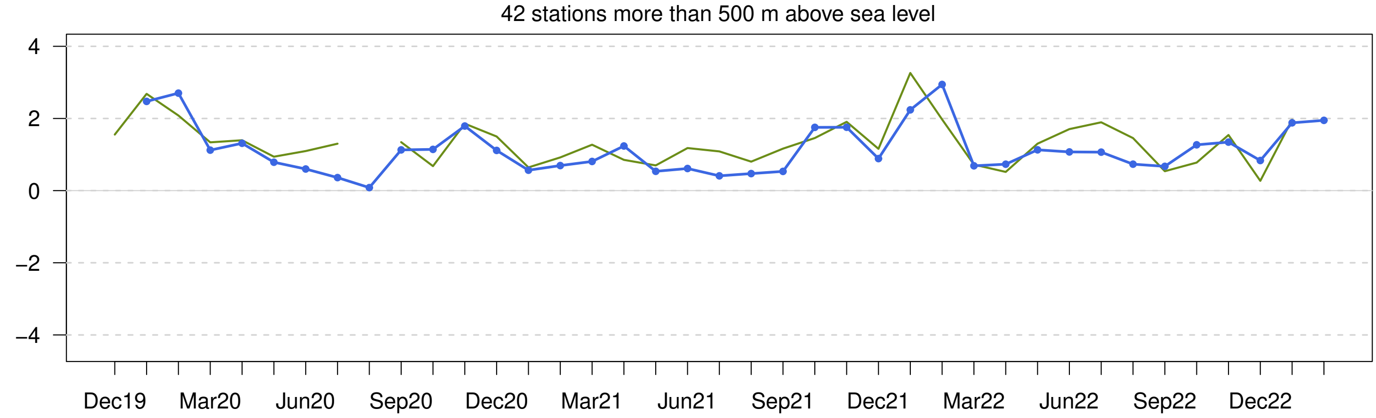

Mean Error
204 Nor. stations
03+6,+9,...,+57
MEPSctrlFG
MEPSctrlFF.925
Lead time (hour)
Standard Deviation of Error
204 Nor. stations
03+6,+9,...,+57
Lead time (hour)
Mean Absolute Error
204 Nor. stations
03+6,+9,...,+57
Lead time (hour)
Hit Rate
211 Nor. stations
03+18,+24,+30,+36
Exceedance threshold (m/s)
False Alarm Rate
211 Nor. stations
03+18,+24,+30,+36
Exceedance threshold (m/s)
False Alarm Ratio
211 Nor. stations
03+18,+24,+30,+36
Exceedance threshold (m/s)
Equitable Threat Score
211 Nor. stations
03+18,+24,+30,+36
MEPSctrlFG
MEPSctrlFF.925
Exceedance threshold (m/s)
Hansen−Kuiper Skill Score
211 Nor. stations
03+18,+24,+30,+36
Exceedance threshold (m/s)
Heidke Skill Score
211 Nor. stations
03+18,+24,+30,+36
Exceedance threshold (m/s)

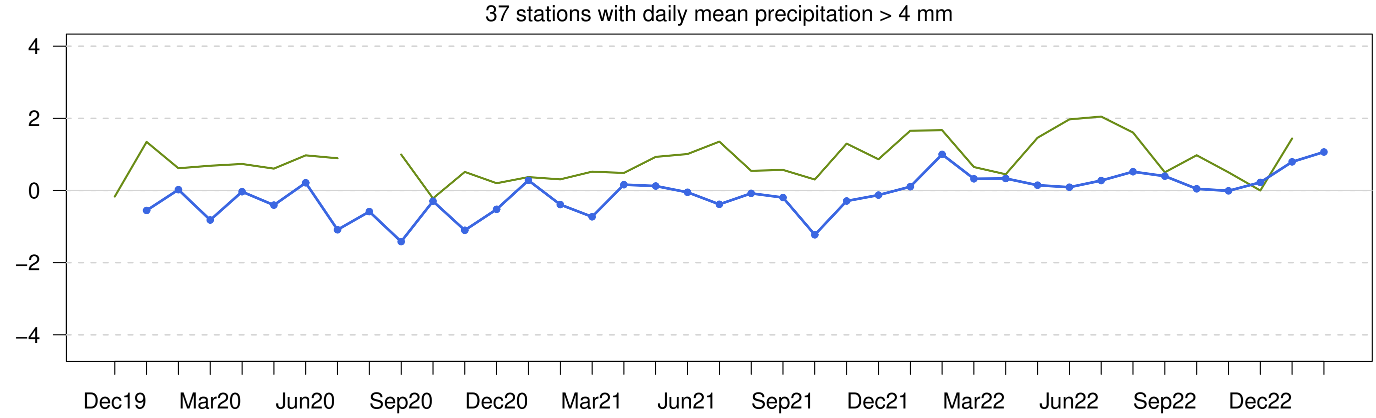

Mean Error
149 Nor. stations 00+18,+30,...,+66
MEPSctrl ECMWF
Lead time (hour)
Standard Deviation of Error
149 Nor. stations 00+18,+30,...,+66
Lead time (hour)
Mean Absolute Error
149 Nor. stations 00+18,+30,...,+66
Lead time (hour)
Hit Rate
179 Nor. stations 00+18,+30,+42,+54,+66
MEPSctrl ECMWF
Exceedance threshold (mm)
False Alarm Rate
179 Nor. stations 00+18,+30,+42,+54,+66
Exceedance threshold (mm)
False Alarm Ratio
179 Nor. stations 00+18,+30,+42,+54,+66
Exceedance threshold (mm)
Equitable Threat Score
179 Nor. stations 00+18,+30,+42,+54,+66
MEPSctrl ECMWF
Exceedance threshold (mm)
Hansen−Kuiper Skill Score
179 Nor. stations 00+18,+30,+42,+54,+66
Exceedance threshold (mm)
Heidke Skill Score
179 Nor. stations 00+18,+30,+42,+54,+66
Exceedance threshold (mm)

Mean Error

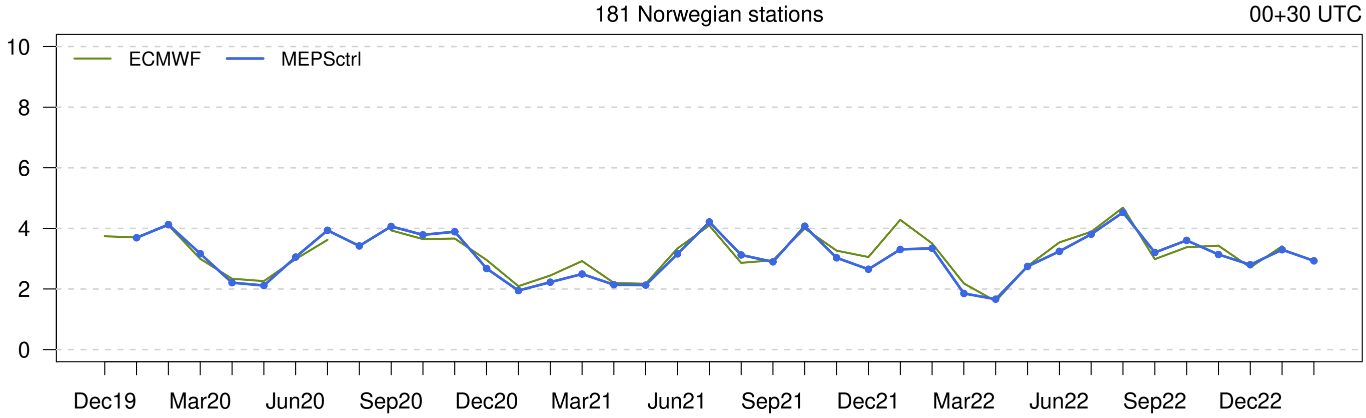

181 Norwegian stations
00+30 UTC
ECMWF
MEPSctrl
4
2
0
−2
−4
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22

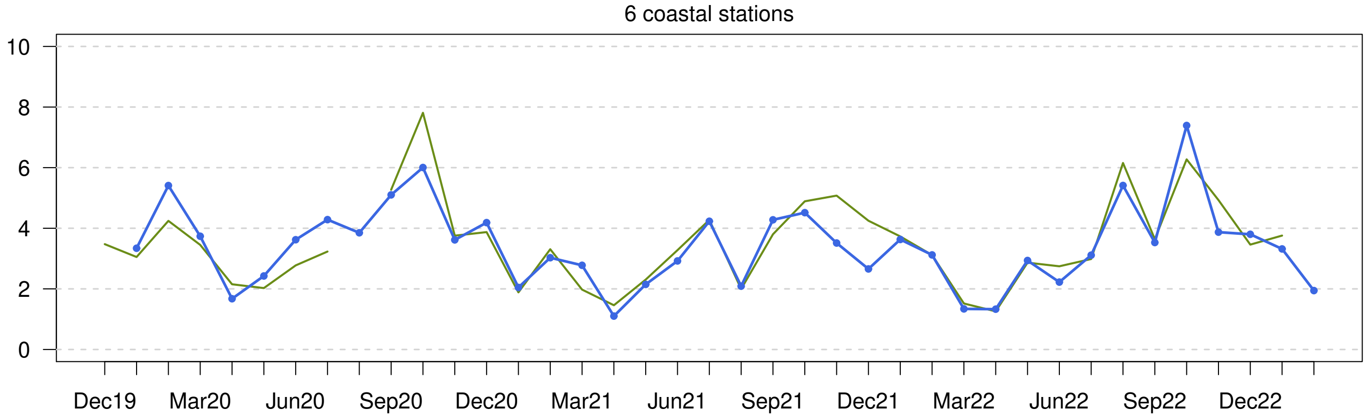

6 coastal stations
4
2
0
−2
−4
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22

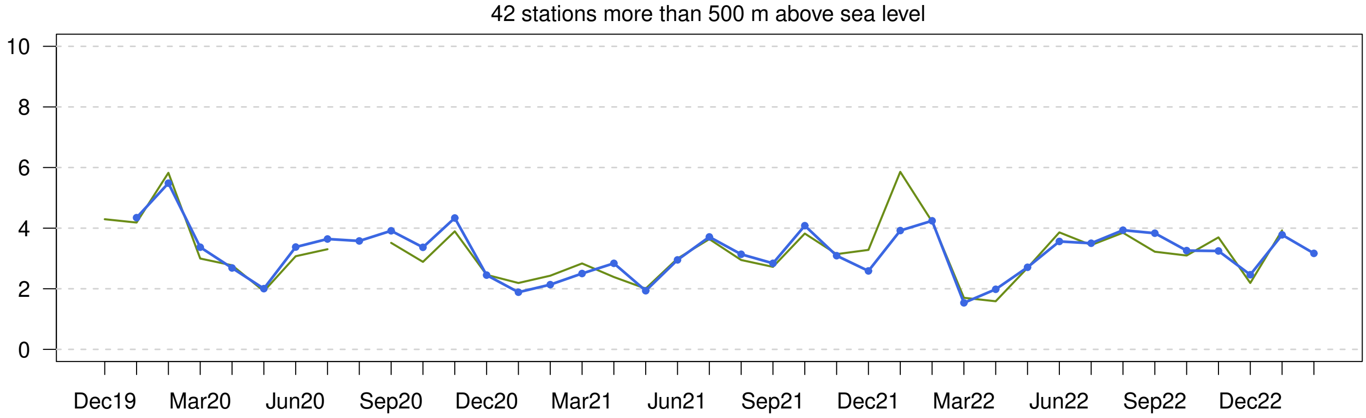

42 stations more than 500 m above sea level
4
2
0
−2
−4
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22

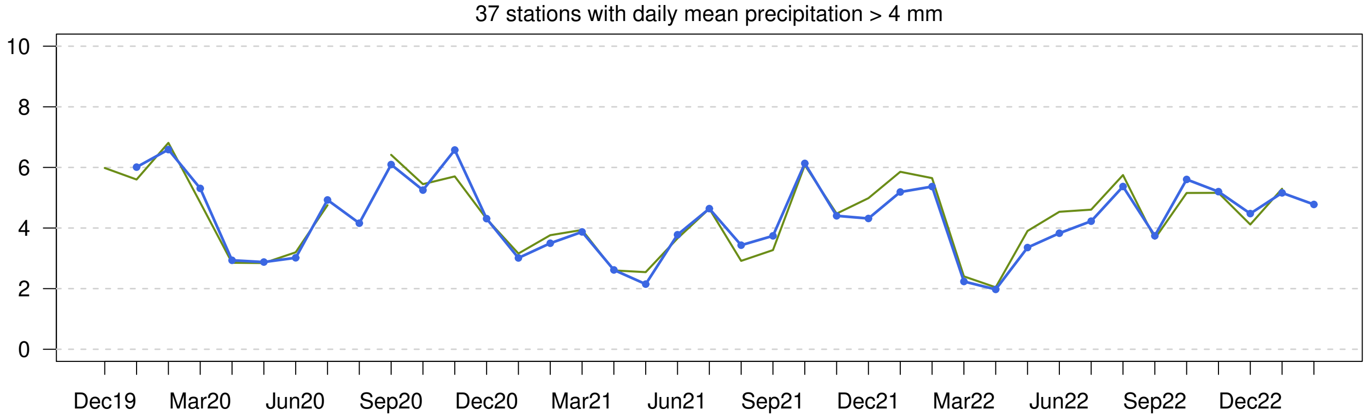

37 stations with daily mean precipitation > 4 mm
4
2
0
−2
−4
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22

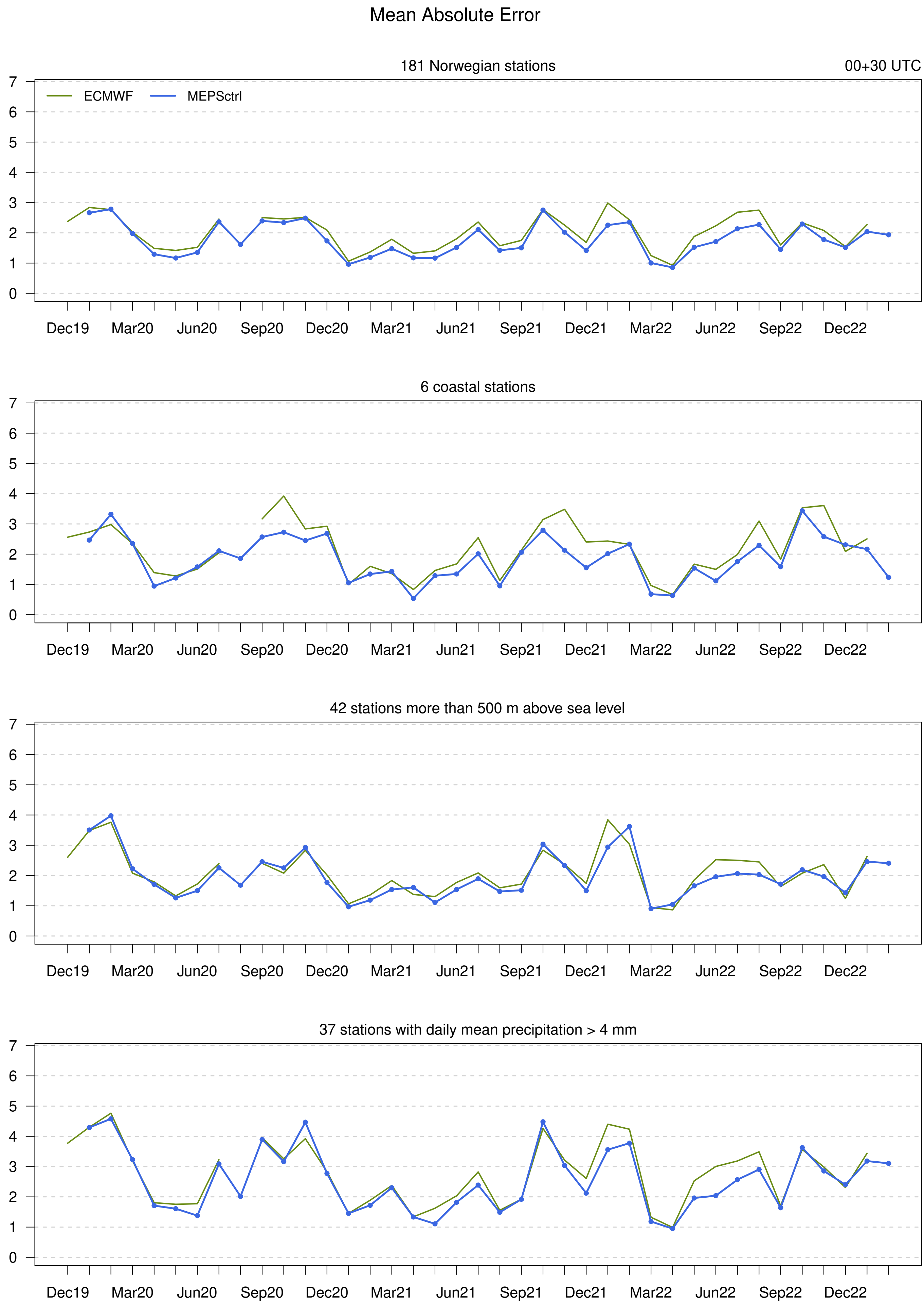
Standard Deviation of Error





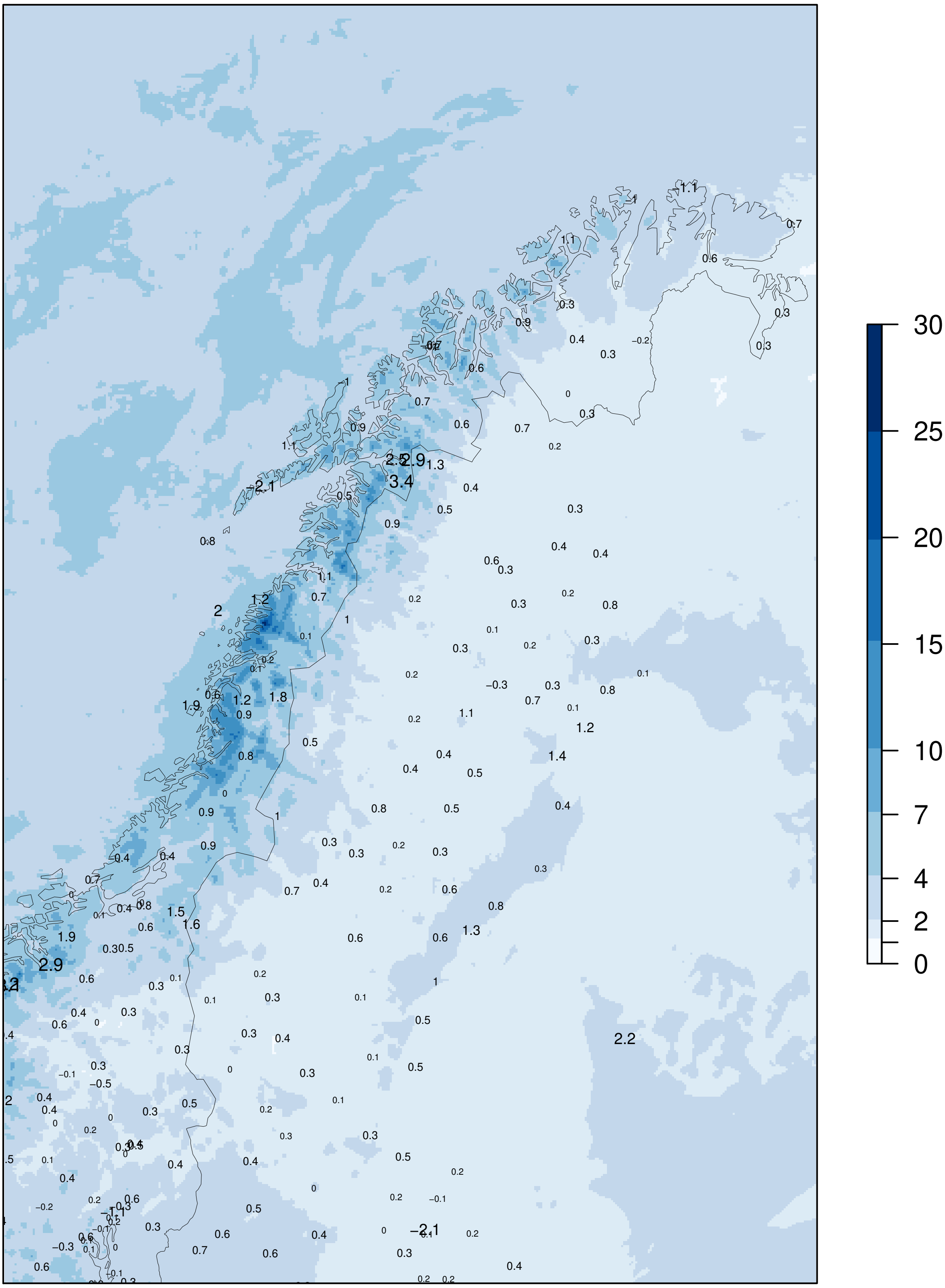





Mean Absolute Error
181 Norwegian stations
00+30 UTC
ECMWF
MEPSctrl
6 coastal stations
42 stations more than 500 m above sea level
37 stations with daily mean precipitation > 4 mm
Dec19 Mar20 Jun20 Sep20 Dec20 Mar21 Jun21 Sep21 Dec21 Mar22 Jun22 Sep22 Dec22

MEPSctrl 00+30

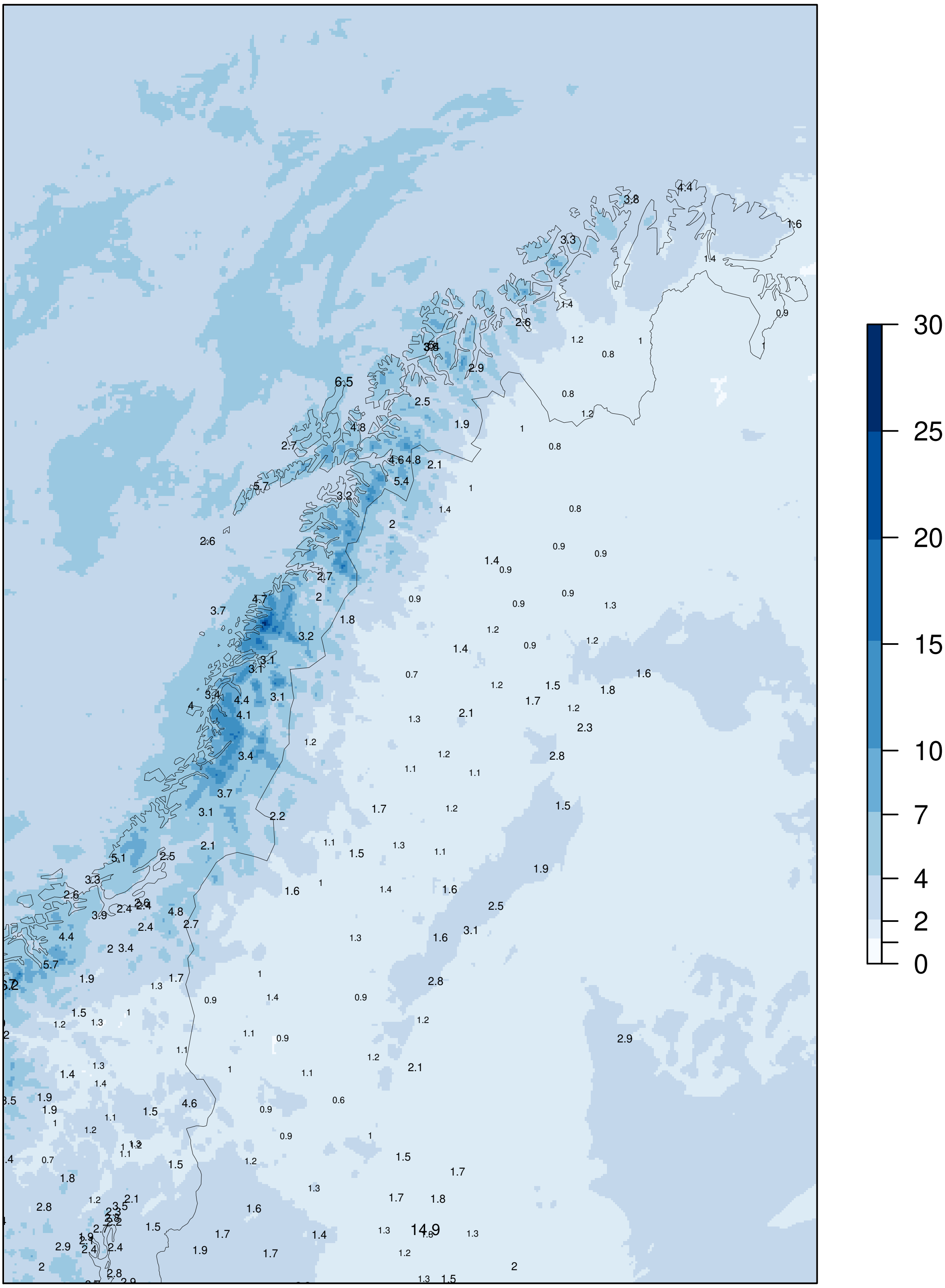
ME at observing sites
(numbers in black)



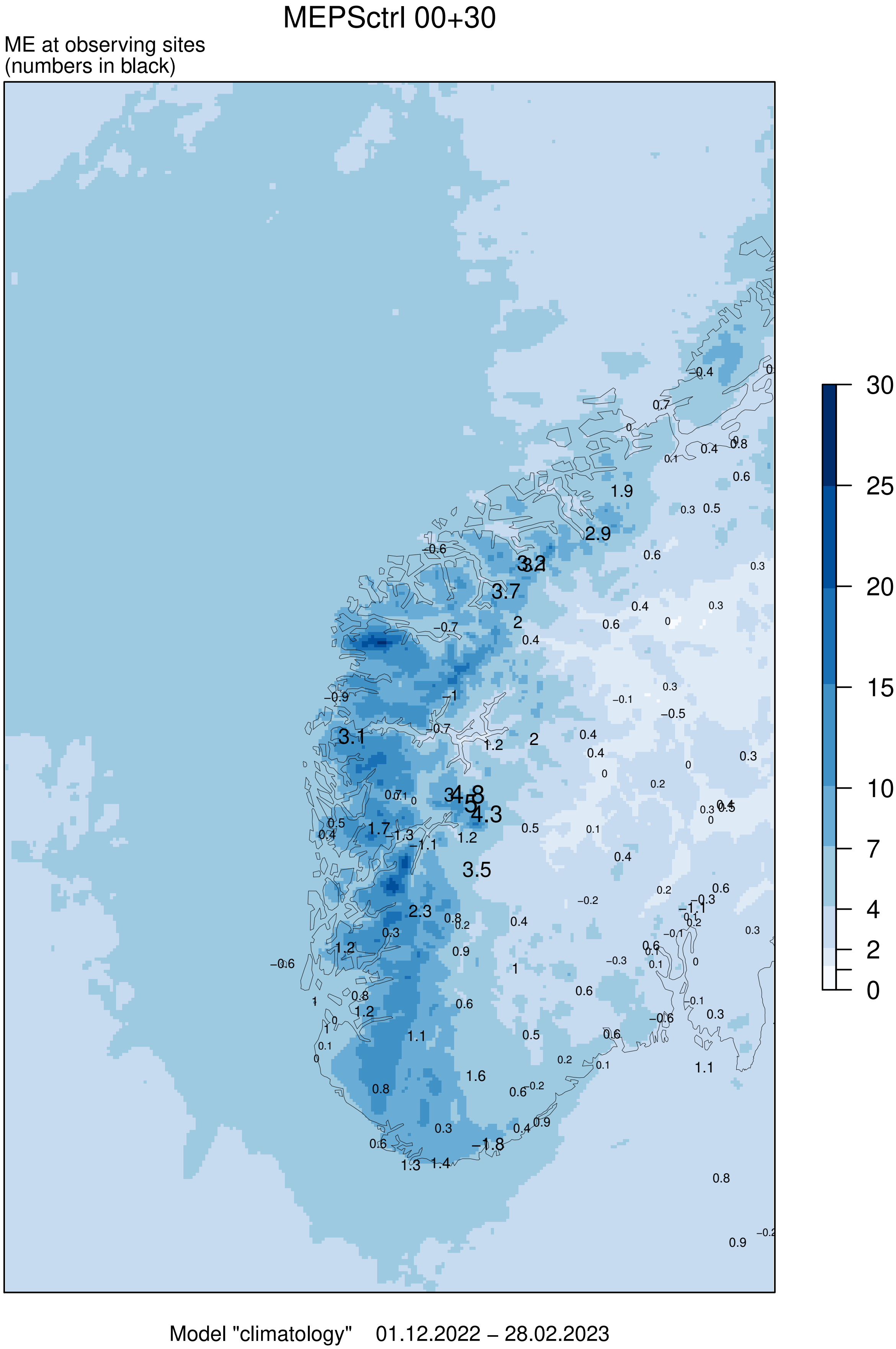
Model "climatology" 01.12.2022 – 28.02.2023

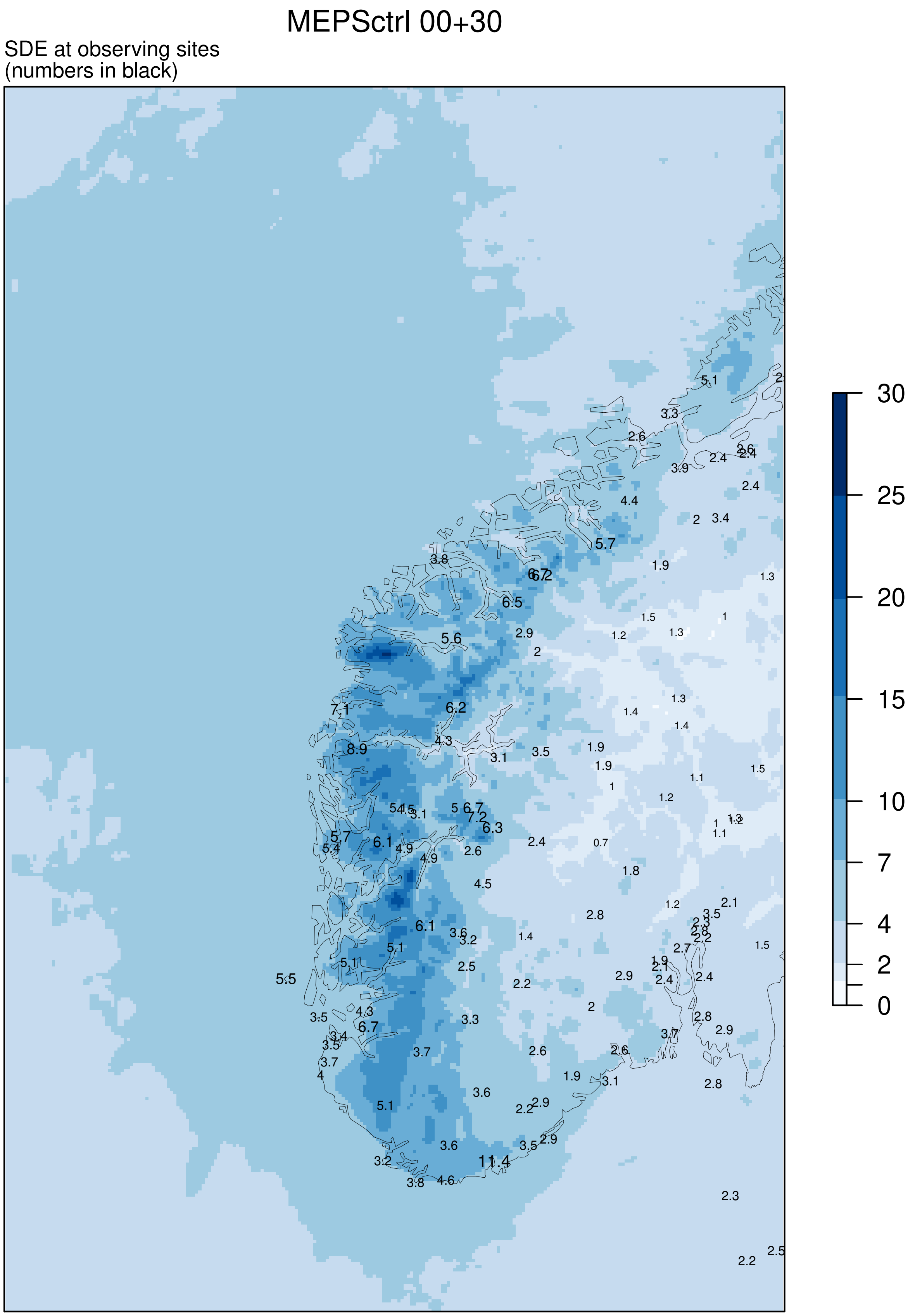
MEPSctrl 00+30

SDE at observing sites
(numbers in black)

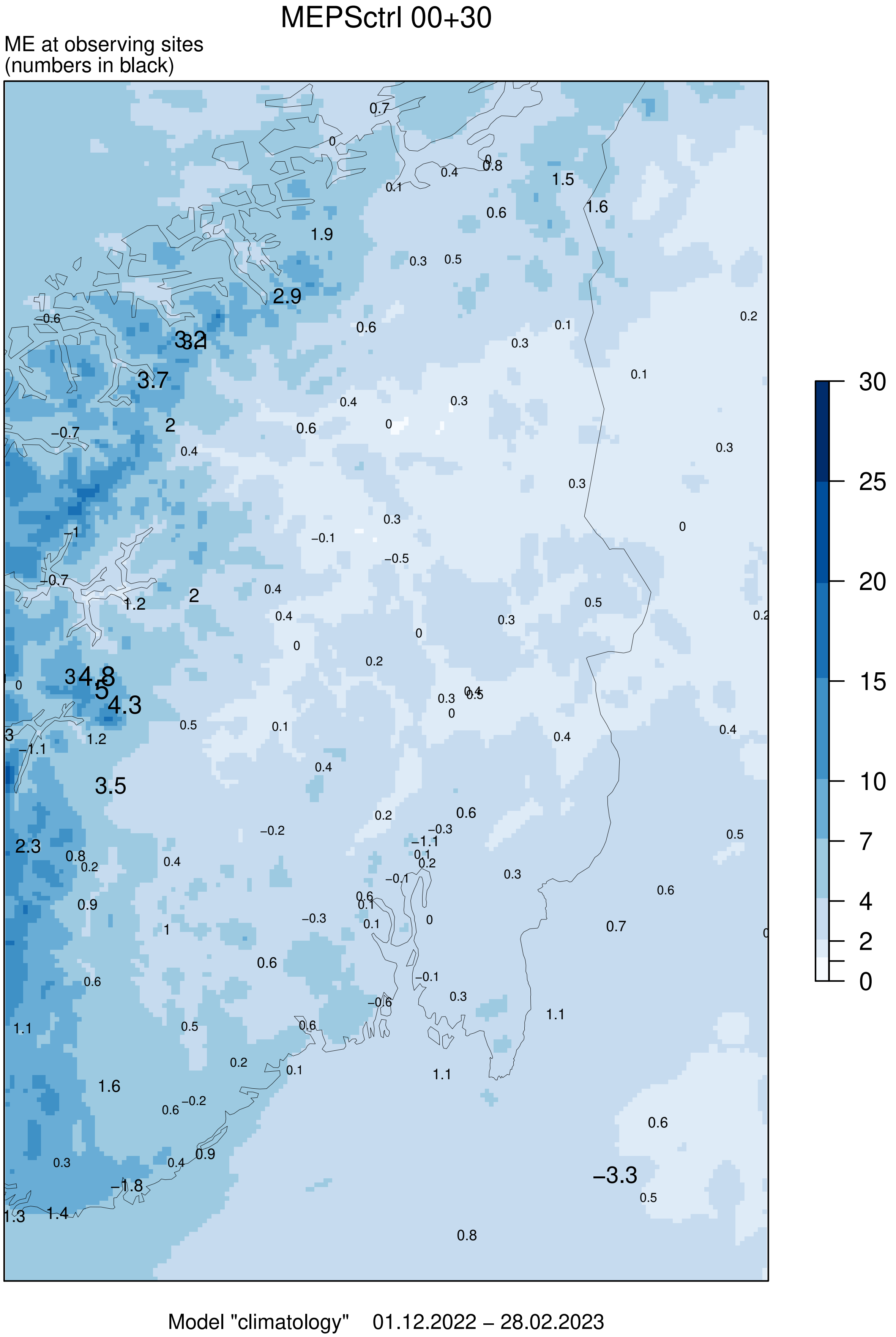


Model "climatology" 01.12.2022 – 28.02.2023


MEPSctrl 00+30
ME at observing sites
(numbers in black)
30
25
20
15
10
7
4
2
0
Model "climatology" 01.12.2022 – 28.02.2023



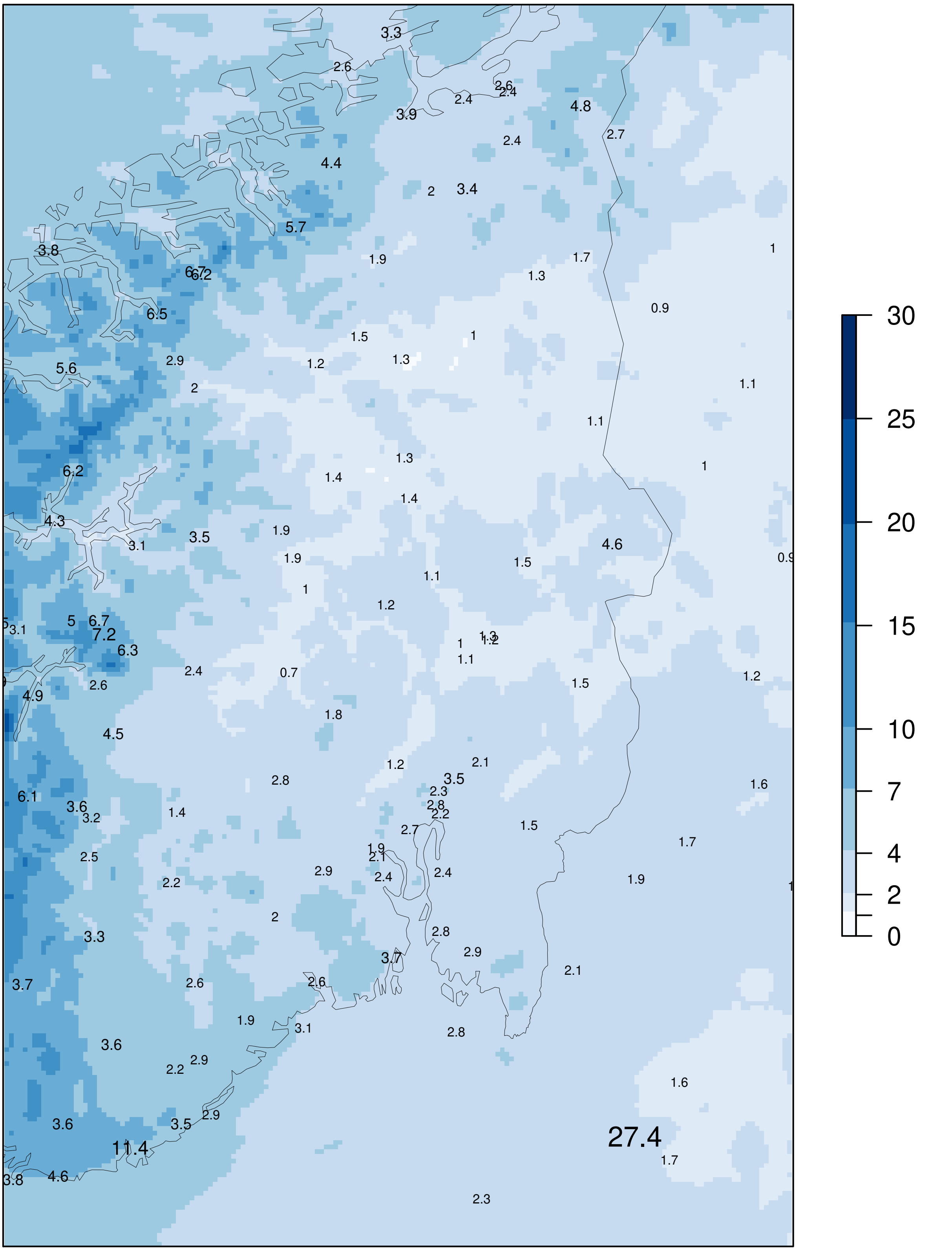
Model "climatology" 01.12.2022 – 28.02.2023



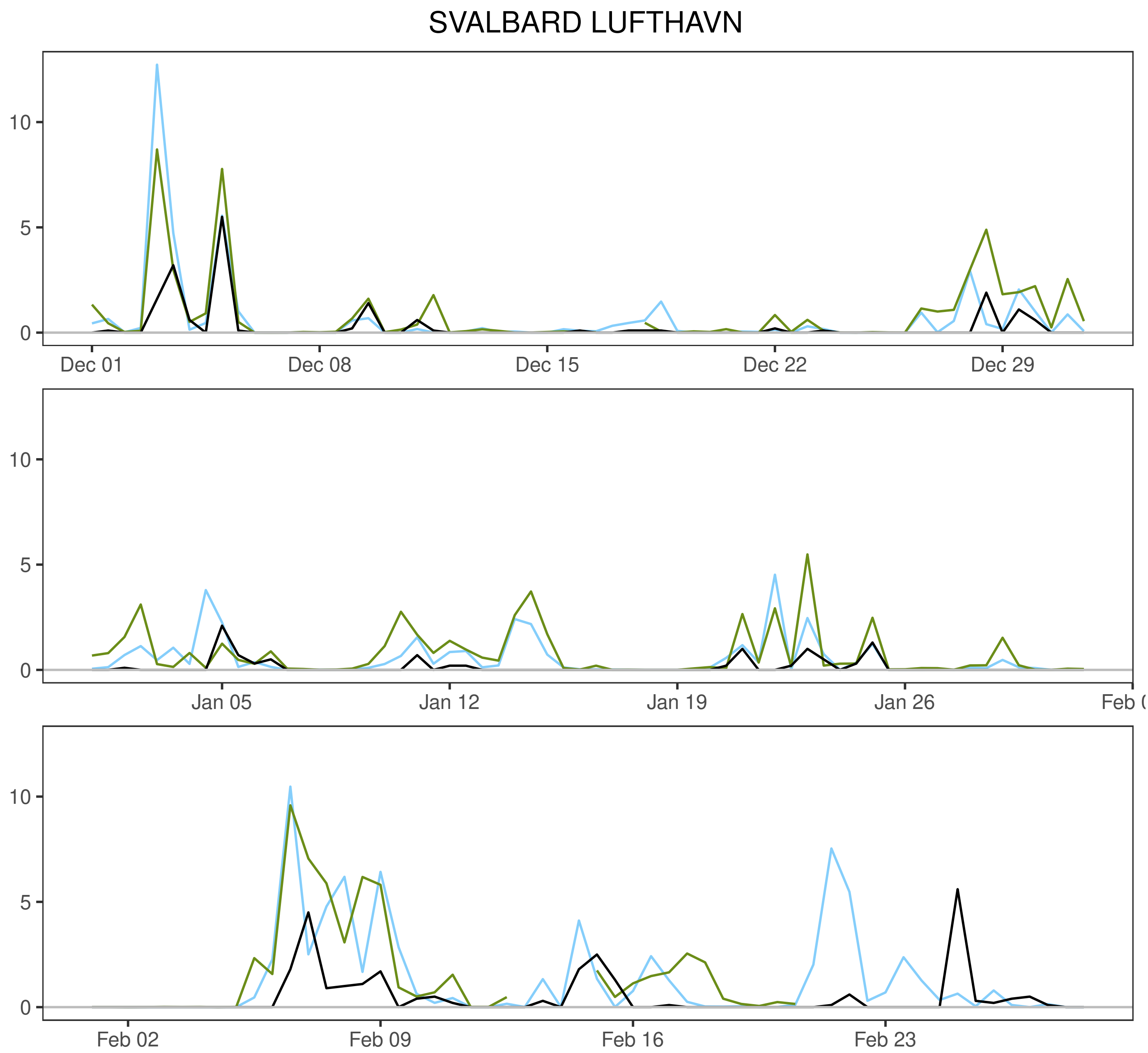
MEPSctrl 00+30
ME at observing sites
(numbers in black)
30
25
20
15
10
7
4
2
0
Model "climatology" 01.12.2022 – 28.02.2023

MEPSctrl 00+30

SDE at observing sites
(numbers in black)

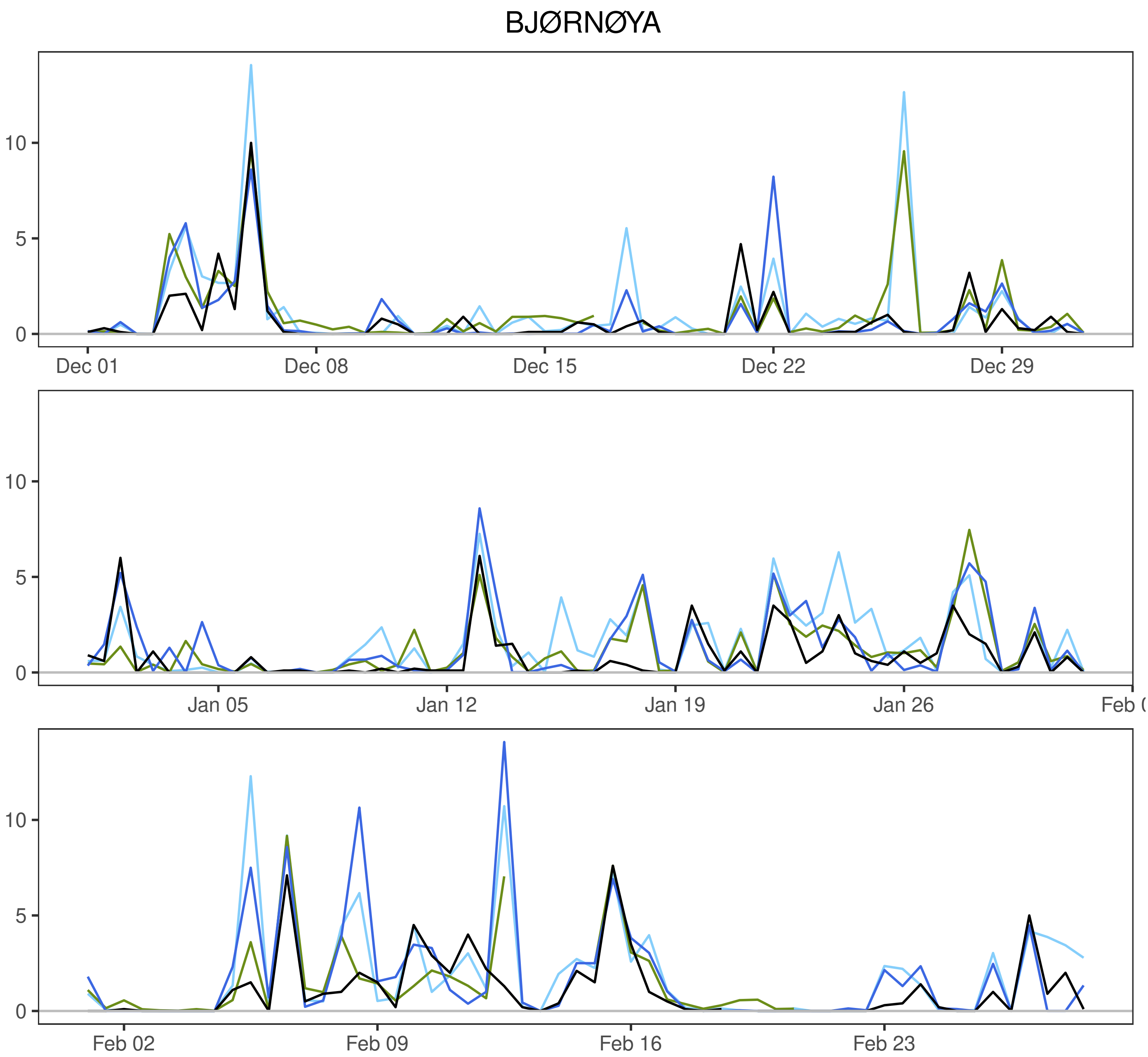


Model "climatology" 01.12.2022 – 28.02.2023



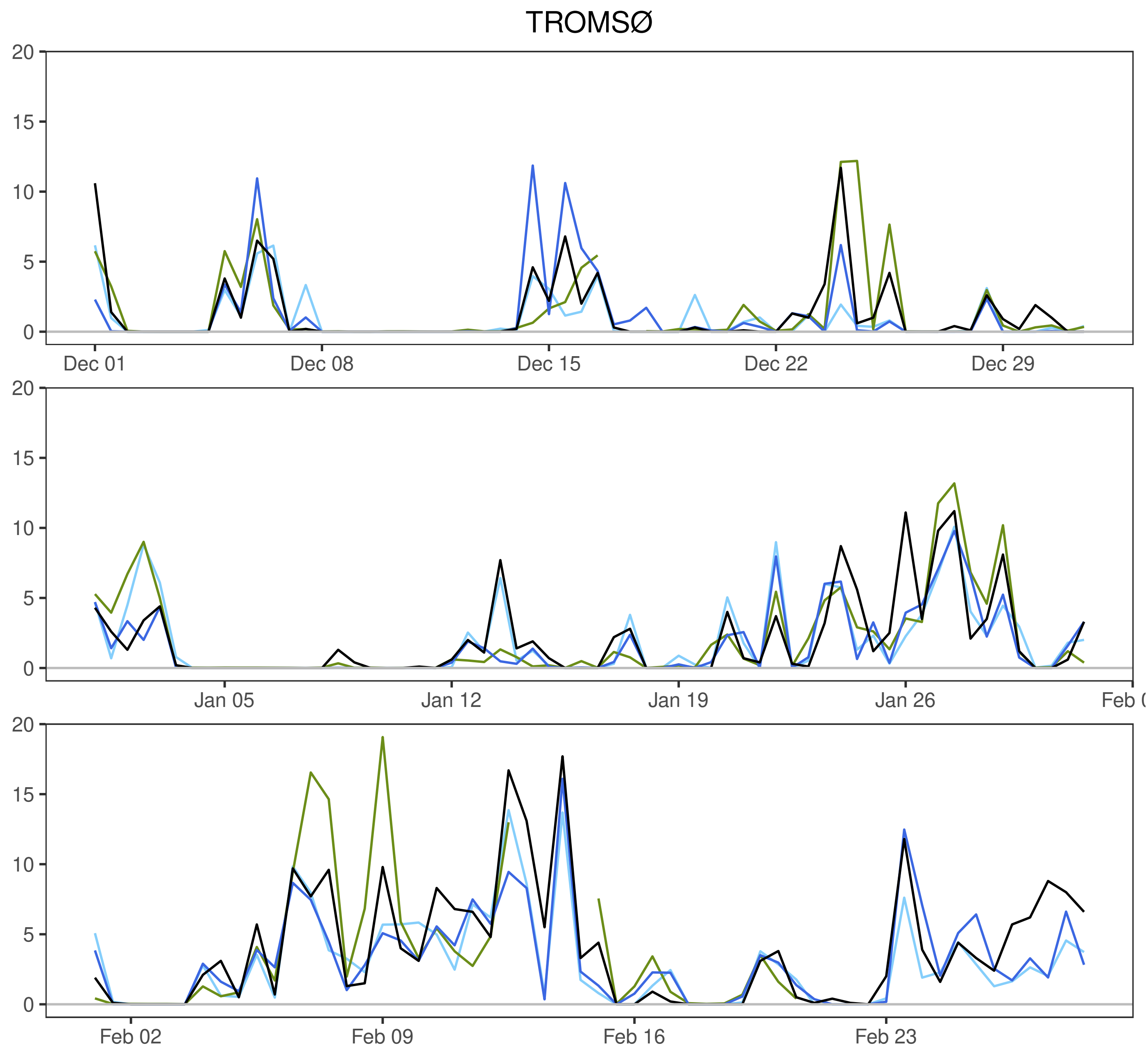
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.3	5.6	0.8	180
AA25: 12+18,+30	0.0	0.8	12.7	1.8	180
ECMWF: 12+18,+30	0.0	1.0	9.6	1.7	158

	ME	SDE	RMSE	MAE	Max.abs.err.	N
AA25−synop	0.5	1.5	1.5	0.6	11.1	158
ECMWF−synop	0.7	1.3	1.5	0.8	7.8	158



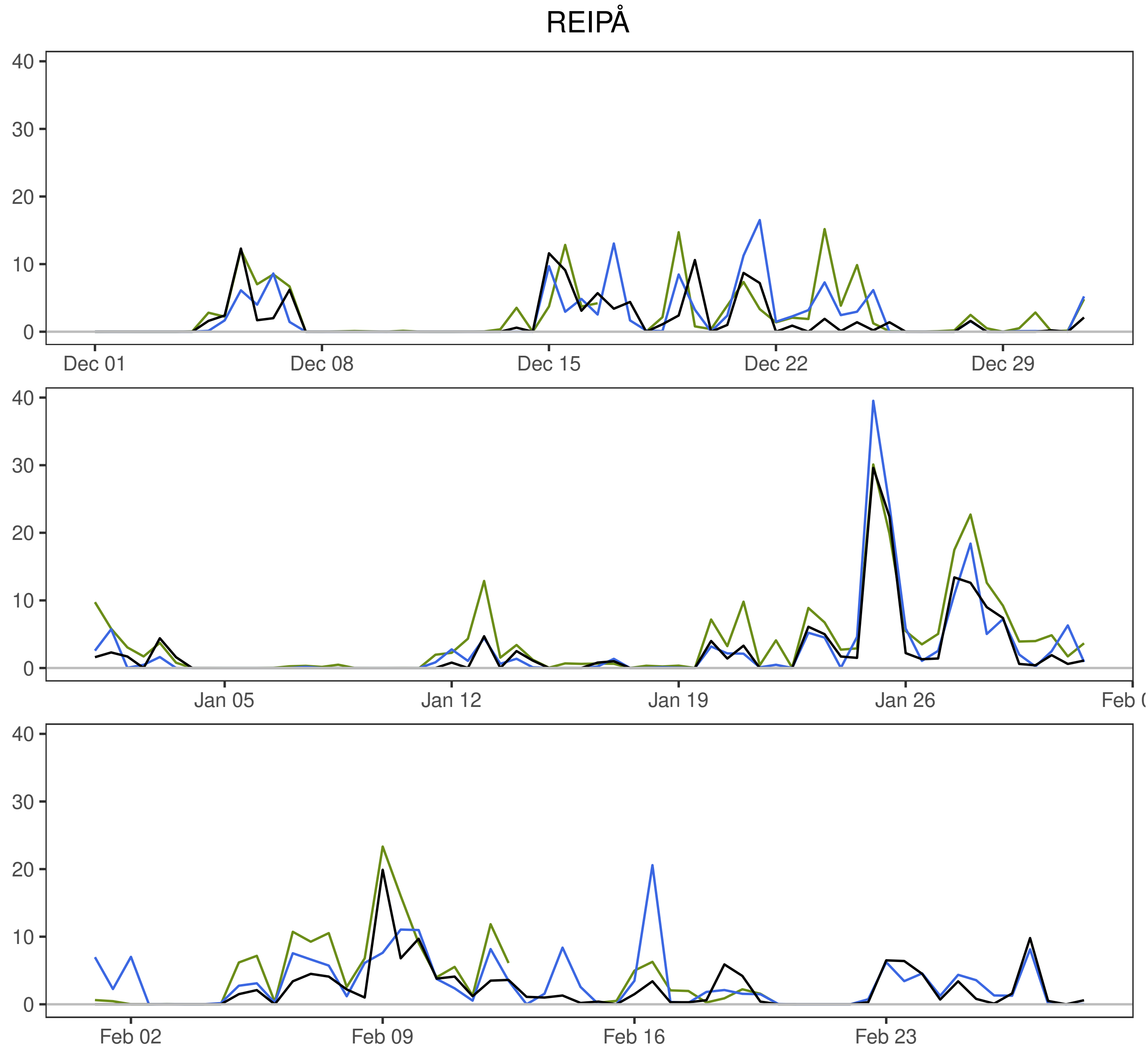
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.9	10.0	1.5	179
MEPSctrl: 12+18,+30	0.0	1.3	14.1	2.2	180
AA25: 12+18,+30	0.0	1.5	14.1	2.4	180
ECMWF: 12+18,+30	0.0	1.2	9.6	1.8	158

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.5	1.8	1.8	0.9	12.8	157
AA25−synop	0.7	1.9	2.0	1.0	12.6	157
ECMWF−synop	0.3	1.4	1.4	0.7	9.5	157



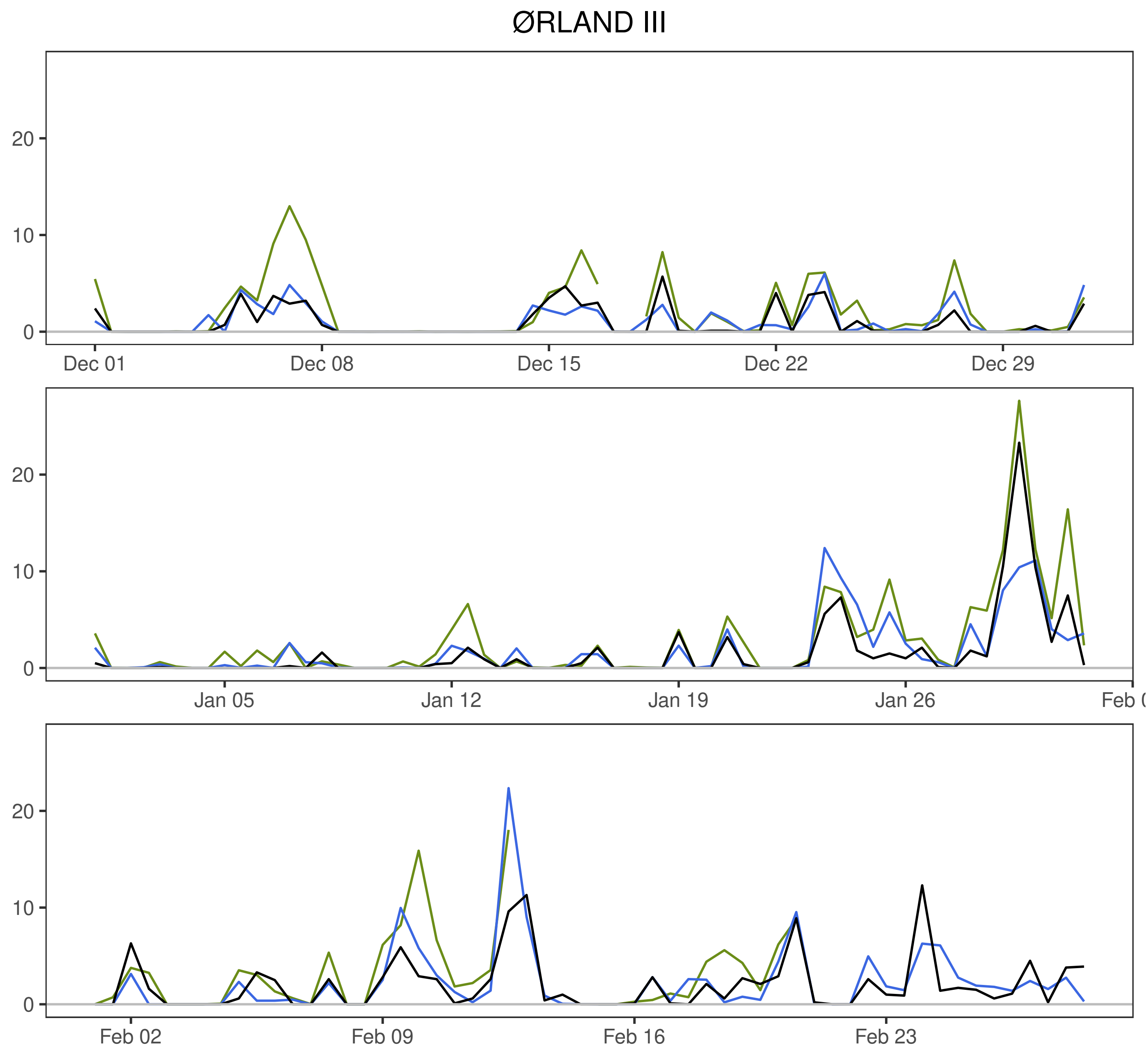
	Min	Mean	Max	Std	N
synop: 06,18	0.0	2.4	17.7	3.5	180
MEPSctrl: 12+18,+30	0.0	2.0	16.1	2.9	180
AA25: 12+18,+30	0.0	1.9	13.9	2.7	180
ECMWF: 12+18,+30	0.0	2.2	19.1	3.6	158

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.3	2.0	2.0	1.1	8.3	158
AA25−synop	−0.3	1.9	1.9	1.0	9.8	158
ECMWF−synop	0.2	2.3	2.3	1.2	11.6	158



	Min	Mean	Max	Std	N
synop: 06,18	0.0	2.1	29.6	4.0	180
MEPSctrl: 12+18,+30	0.0	2.7	39.5	4.8	180
ECMWF: 12+18,+30	0.0	3.5	30.1	5.2	158

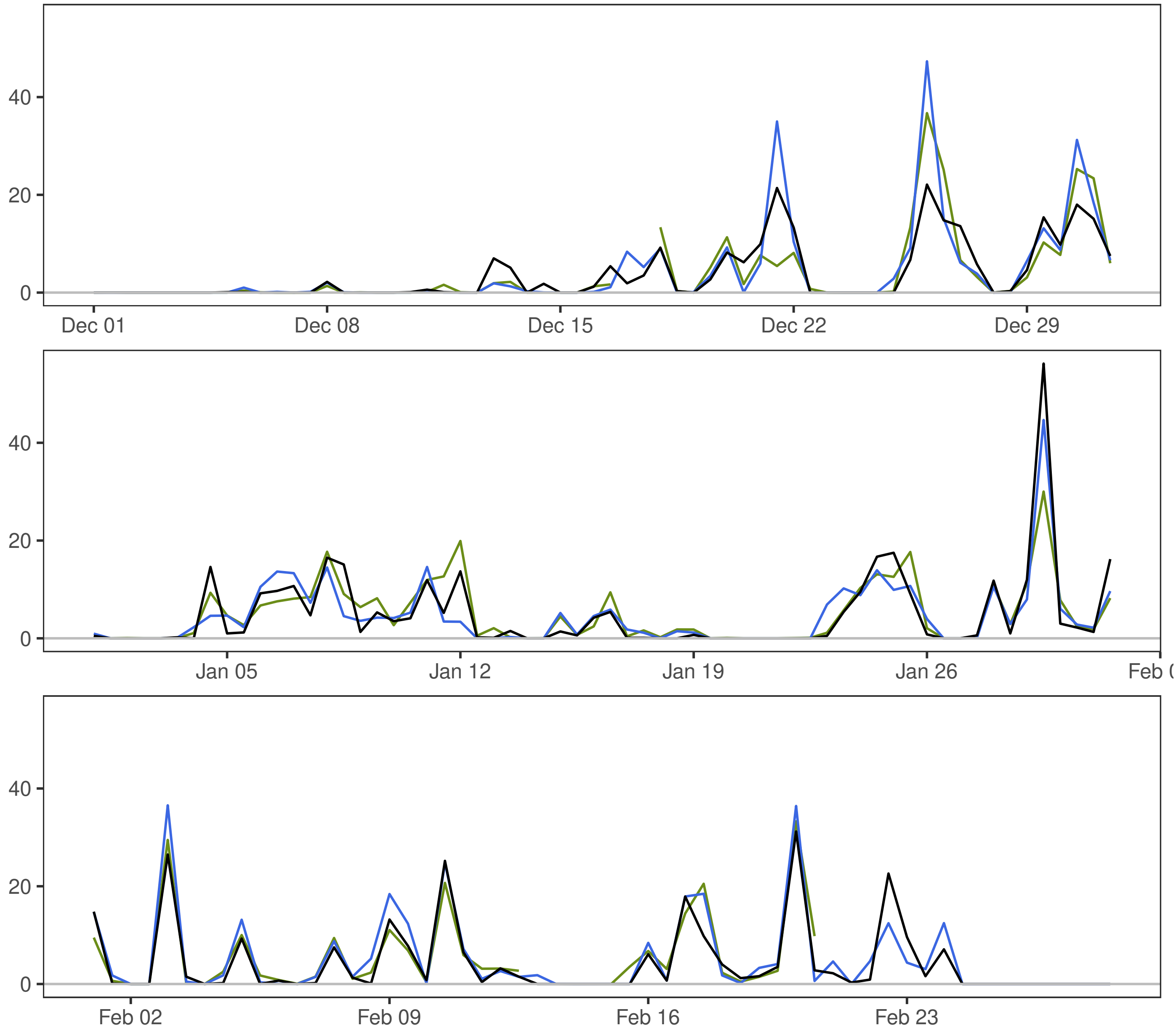
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	0.5	2.9	3.0	1.5	17.2	158
ECMWF–synop	1.3	2.9	3.2	1.8	13.3	158



	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.5	23.3	2.8	180
MEPSctrl: 12+18,+30	0.0	1.7	22.4	2.9	180
ECMWF: 12+18,+30	0.0	2.6	27.6	4.1	158

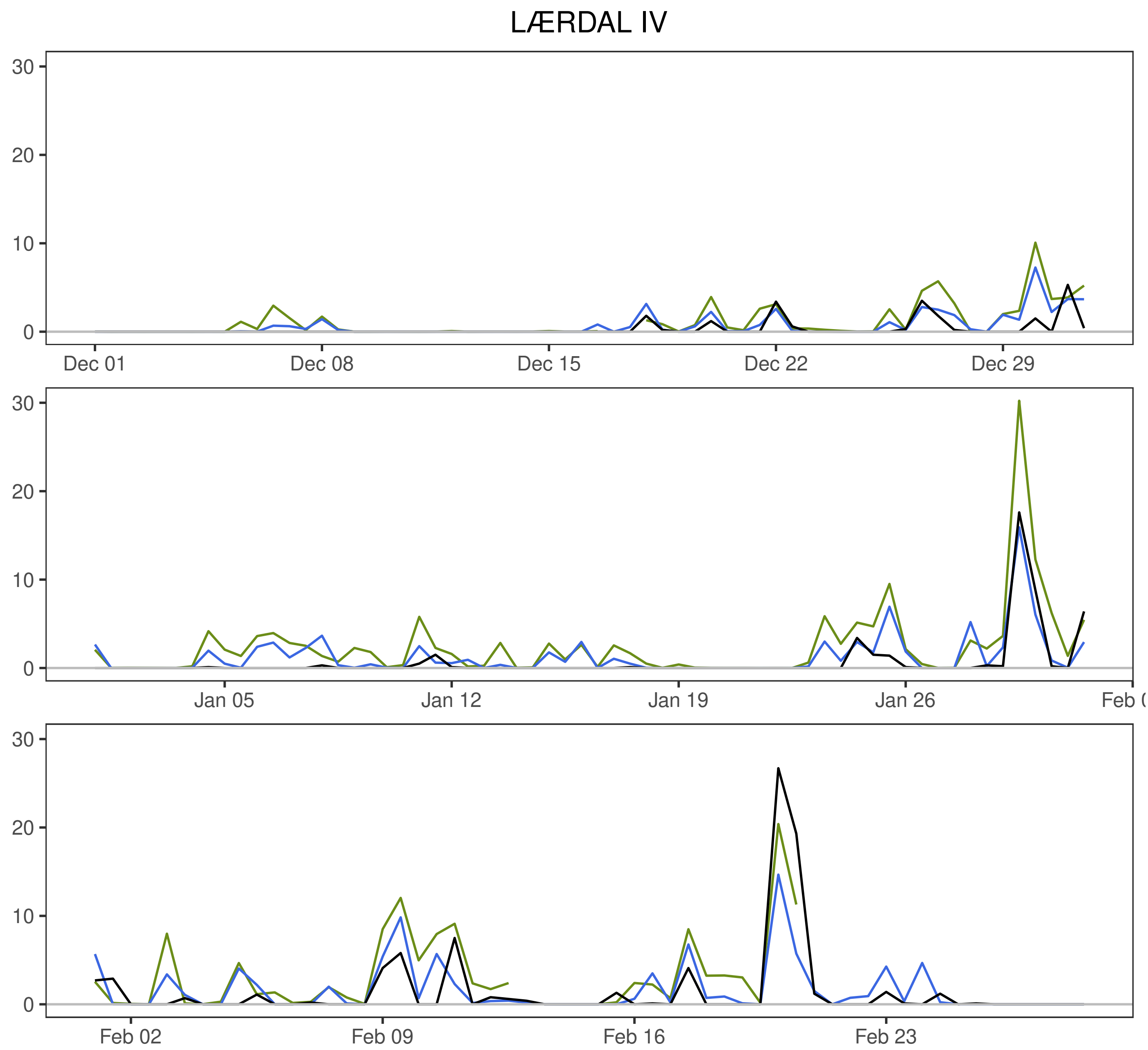
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.2	2.0	2.0	0.9	12.9	158
ECMWF−synop	1.2	2.2	2.5	1.4	13.0	158

BERGEN – FLORIDA



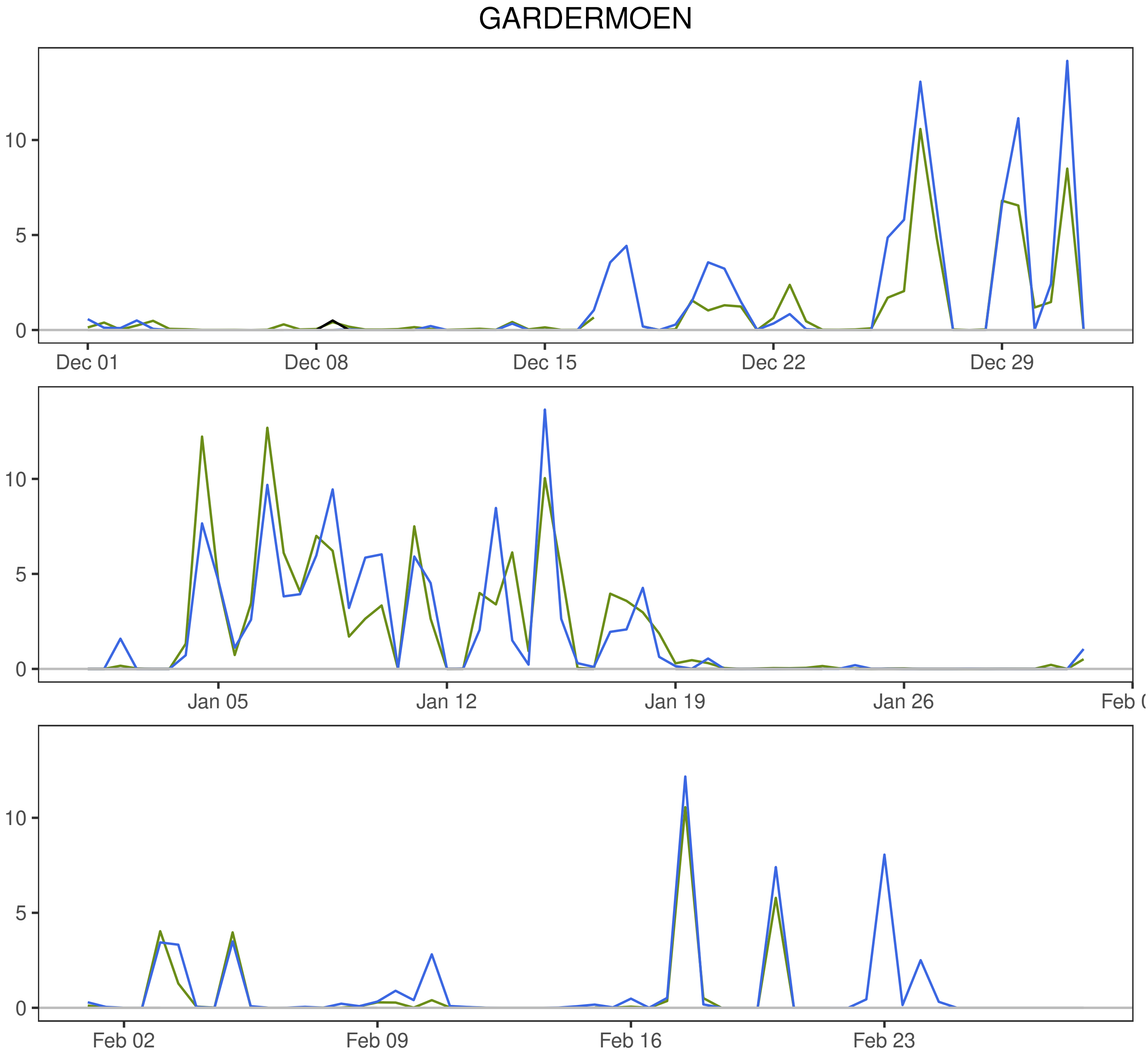
	Min	Mean	Max	Std	N
synop: 06,18	0.0	4.4	56.2	7.4	180
MEPSctrl: 12+18,+30	0.0	4.7	47.3	8.1	180
ECMWF: 12+18,+30	0.0	4.8	36.7	7.2	158

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	0.3	3.8	3.8	1.9	25.2	158
ECMWF–synop	0.1	4.0	3.9	2.1	26.2	158



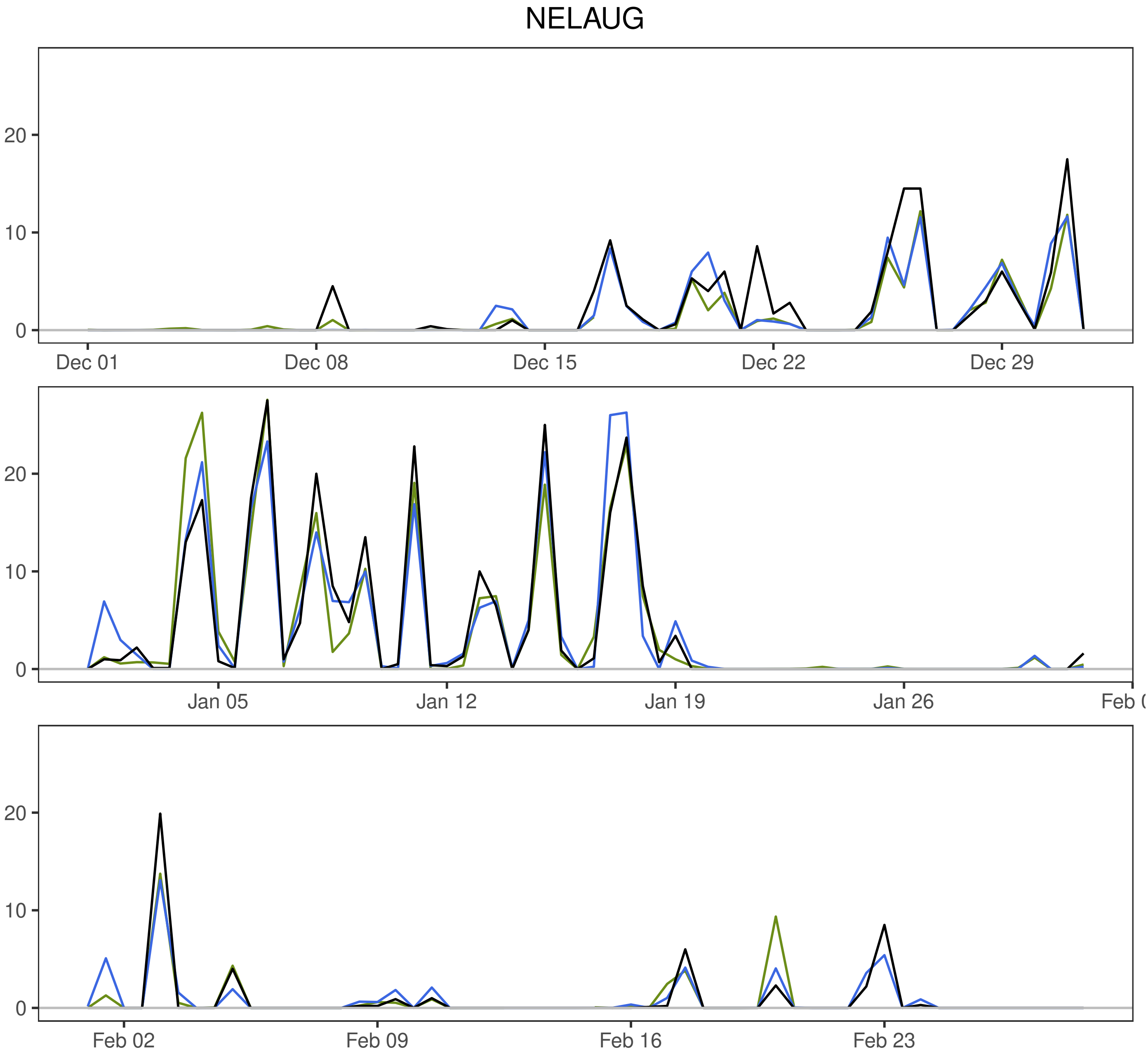
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.8	26.7	3.0	180
MEPSctrl: 12+18,+30	0.0	1.2	15.9	2.3	180
ECMWF: 12+18,+30	0.0	2.2	30.2	3.8	158

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	0.4	2.1	2.1	1.0	13.6	158
ECMWF–synop	1.3	2.3	2.7	1.6	12.6	158



	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.0	0.5	0.0	119
MEPSctrl: 12+18,+30	0.0	1.4	14.2	2.8	180
ECMWF: 12+18,+30	0.0	1.3	12.7	2.6	158

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	0.1	0.4	0.4	0.1	3.4	102
ECMWF–synop	0.1	0.4	0.4	0.1	4.0	102



	Min	Mean	Max	Std	N
synop: 06,18	0.0	2.4	27.5	5.3	180
MEPSctrl: 12+18,+30	0.0	2.3	26.3	4.9	180
ECMWF: 12+18,+30	0.0	2.3	27.6	5.2	158

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	–0.1	2.1	2.1	1.0	10.0	158
ECMWF–synop	–0.3	2.1	2.1	0.9	10.1	158