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Verification of Operational Weather Prediction Models June to August 2023

Lene Østvand, Mariken Homleid and Gunnar Noer

Husedalen. Photo: Lene Østvand.

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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 Institute (FMI) and Estonian Environment Agency (ESTEA).
AROME-Arctic (AA25)	HARMONIE with AROME physics, horizontal resolution defined by a 2.5×2.5 km^2 grid. Experimental with cycle 38h1.2 from 15 October 2015, on Yr from 14 December 2016, cycle 40h1.1 since June 2017, cycle 43h2.1 since 5 May 2021.

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

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

Post processed forecasts

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

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

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

YrPP is plotted with the color below.

The HARMONIE system

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

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

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

AROME physics

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

SURFEX as surface model

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

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

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

Data assimilation

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

Surface analysis

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

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

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

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

Upper air analysis

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

Boundary fields

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

Verification measures

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

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

Forecasts of continuous variables

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

Statistic	Acronym	Formula	Range	Optimal score
Mean Error	ME	$\frac{1}{n}\ \sum_{i=1}^{n}(f_i - o_i)$	$-\infty$ to ∞	0
Mean Absolute Error	MAE	$\frac{1}{n}\ \sum_{i=1}^{n} \mid f_i - o_i \mid$	0 to ∞	0
Standard Deviation of Error	SDE	$\left(\frac{1}{n}\sum_{i=1}^{n}(f_i - o_i - \mathrm{M}E)^2\right)^{1/2}$	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

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

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

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

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

Forecasts of categorical variables

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

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

Verification statistics for such forecasts are listed in the following table

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

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

Observations

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

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

Summary of the results

Summarized statistics show that ECMWF in general 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 diurnal variations with mainly cold biases for the Norwegian stations, but a small warm bias for night time temperature and cold bias during daytime for the North Scandinavian stations. AA25 shows a similar pattern for the North Scandinavian stations, and a cold bias for 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 shows a small effect in the mean error, while the other scores show almost identical results for MEPSctrl and YrPP.

Precipitation also shows varying results, depending on the amount and location. ECMWF has on average more precipitation than MEPS which this summer had mean errors slightly 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. Precipitation

There were several reports on missing convective precipitation from comparisons of model hourly precipitation against radar data or synoptic observations, illustrated in figure 1. Reports on missing precipitation are largely concerning either the first 6 hrs, which indicates that spin-up does have an impact on the forecasts, or at more than 24 hours lead time, indicating a more general issue with the model. There seems to be little improvement in the models ability to forecast this kind of precipitation since last year.

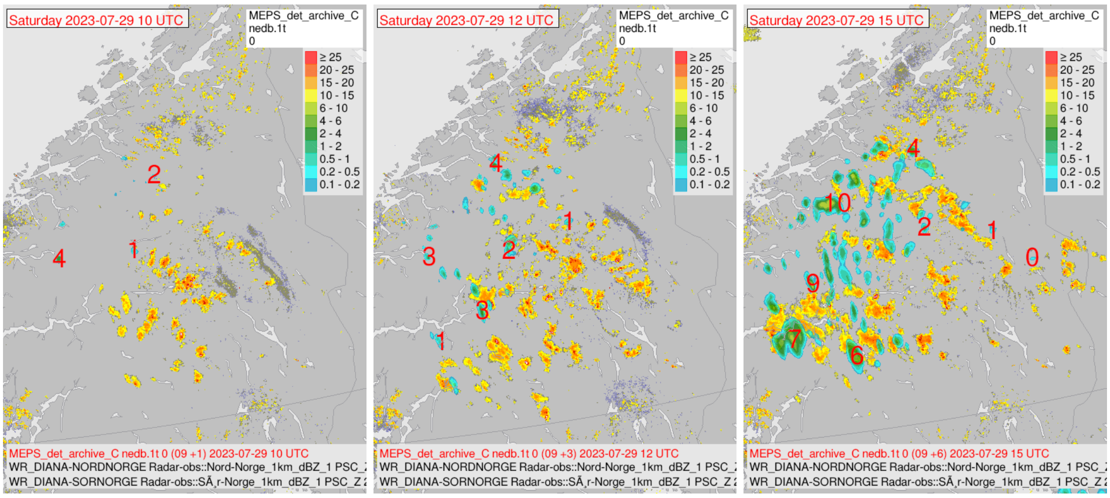


Figure 1: Example of spin-up in the model precipitation from 27 July 2023. At one hour lead time (left) there is no precipitation in the model over central Norway. At three hours lead time (middle), some of the hourly precipitation is starting to appear. At 6 hours lead time (right) the amount of precipitation in the model has stabilized at a level typical for scattered showery precipitation.

The issue of spin-up in the model was recently addressed by Thomas Nipen and Ivar Seierstad, who has run systematic tests on accumulated precipitation. Figure 2 clearly shows that severe spin-up in the model is mainly affecting the first 6 hours.

There were several events of severe frontal precipitation in this period, most notably the 'Hans' extreme rainfall event 7-9 August, where a deep low system over South-East Norway gave a mix of frontal and convective precipitation over a period of four days, and with severe flooding as a consequence. From the event report it was noted that MEPS was good in this situation, especially on days with extreme precipitation. At later stages when there were mainly scattered rain showers, the model was seen as less good. At times there were too few showers, or too low intensity, or a delayed onset of the rain. Figure 3 shows 24 hour precipitation on 9 August.

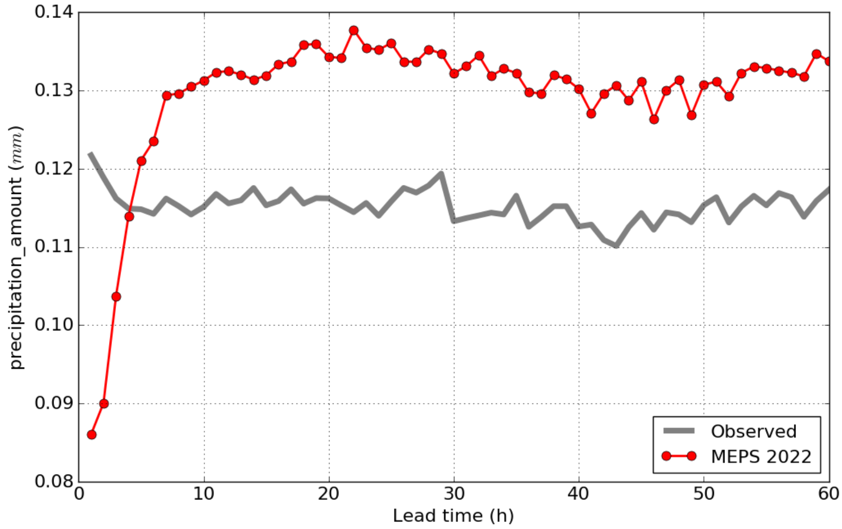


Figure 2: Average 1-hourly precipitation for all Norwegian WMO stations for 2022 with respect to lead time, for MEPS (red) and observations (grey). Illustration: Nipen/Seierstad

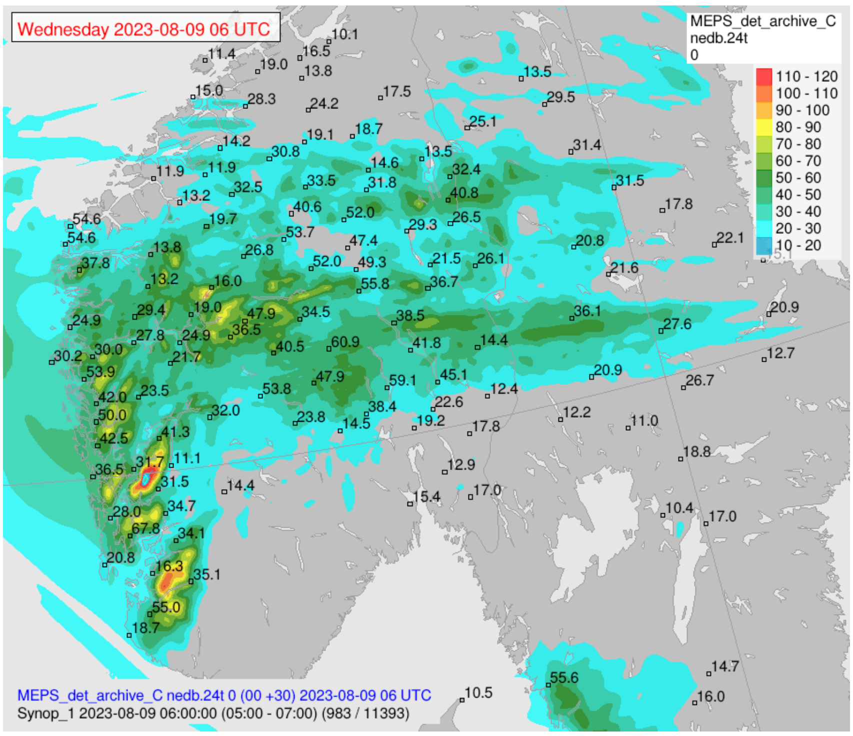


Figure 3: 24 hour precipitation (blue/green shading) plotted against observations (black) from 8 August 06 UTC to the 9 August 06 UTC from the MEPS 00 run of 8 August. Only values above 10 mm are shown. The highest values were in the mountain and glacier areas in western Norway, which is plausible, but not seen in the observations. In the more populated areas of central Norway the values from MEPS were from 20 to 70 mm, which corresponds well with the observations.

Case 2. Fog and low stratus

There were several reports on fog or low stratus. Also in this respect the models seem to have improved little since last season. The misrepresentation of fog is mainly concerning two modes: Either there is missing fog associated with advection or sea fog in complex terrain, or there is excessive areas of fog over open sea. Figure 4 shows an example of missing fog, and is probably linked to model resolution and the elevation of the model terrain being higher than in reality along the Norwegian coast.

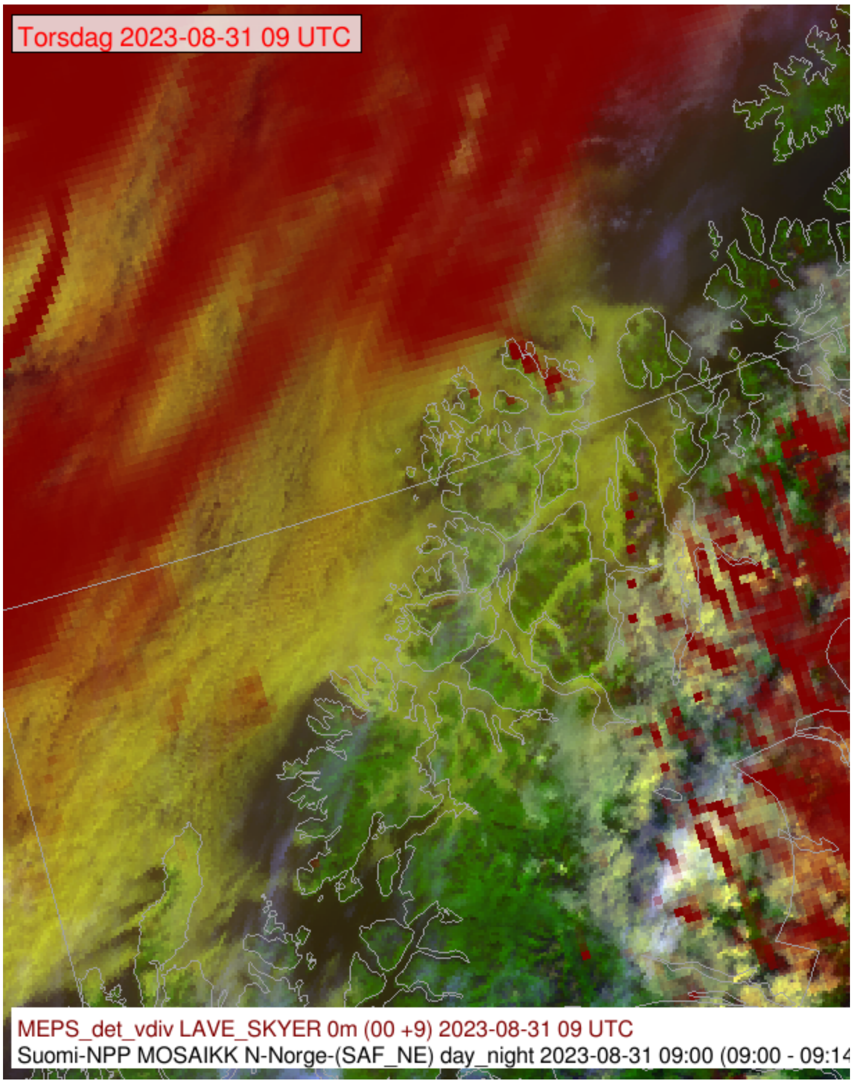


Figure 4: Coastal fog in the fjords of Troms on the 31st of August 2023. Fog and low clouds are seen here as yellowish areas in the satellite image. The red shading is MEPS 00-run low clouds with 9 hrs lead time.

The misrepresentation seen as excessive areas of fog is shown in figure 5. The precursor to this is often a small error in either 2m temperature or 2m dew point temperature of less than one degree, but enough to reach saturation. An area of fog then forms and quickly spreads out, typically in cloud free areas in between otherwise cloudy areas. This points to that the radiation balance, either from the cloud top or from the sea surface, may be an issue. The fact that the lowest model layer is often too moist, while adjacent layers further up, as indicated by low clouds, are more in line with the observed, indicates an issue with the exchange between the surface and the lowest model layer. This is also supported by soundings showing that the error in temperature or dew point temperature is mainly seen as a too strong inversion in the lowest model layer.

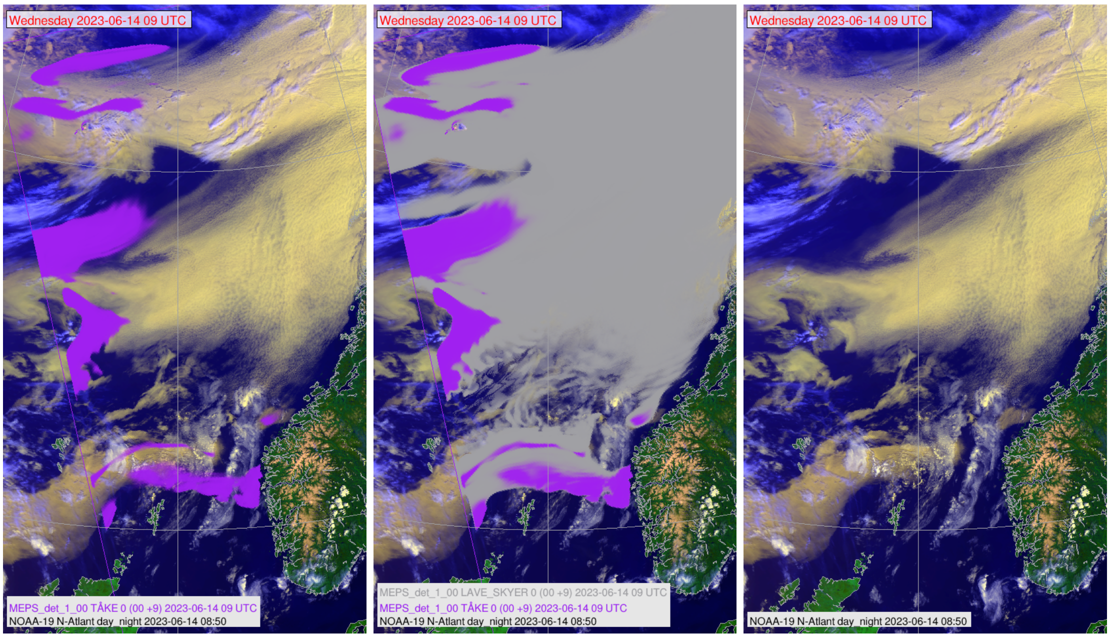


Figure 5: A typical example from 14 June shows excessive fog (violet) in MEPS in the fringes or in between actual cloud cover. Low clouds (gray) in MEPS are in good agreement with the observed low clouds.

Case 3. Wind

Wind is currently assessed as good in MEPS, but one example was noted on 11 June (figure 6). A strong kata-front passed eastwards over the coast of Troms, and strong winds of 30 m/s sustained wind was measured on a bridge outside Tromsø, and two mountain stations at 800 to 1000m height reported wind of 55 kts (28 m/s). There was quite strong wind at 1.5 km height (850 hPa) in MEPS, but the model was not able to blend this down to the surface level. MEPS indicated at most 20 kts (~10 m/s) at the surface in these locations.

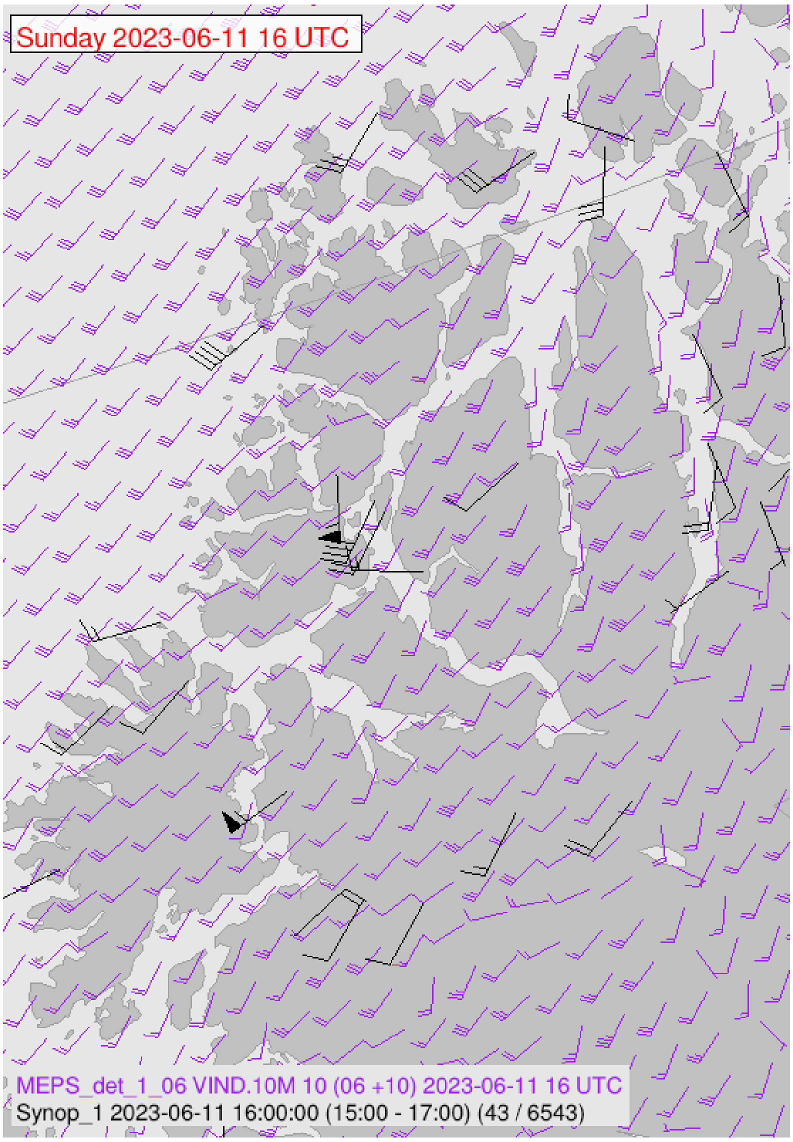
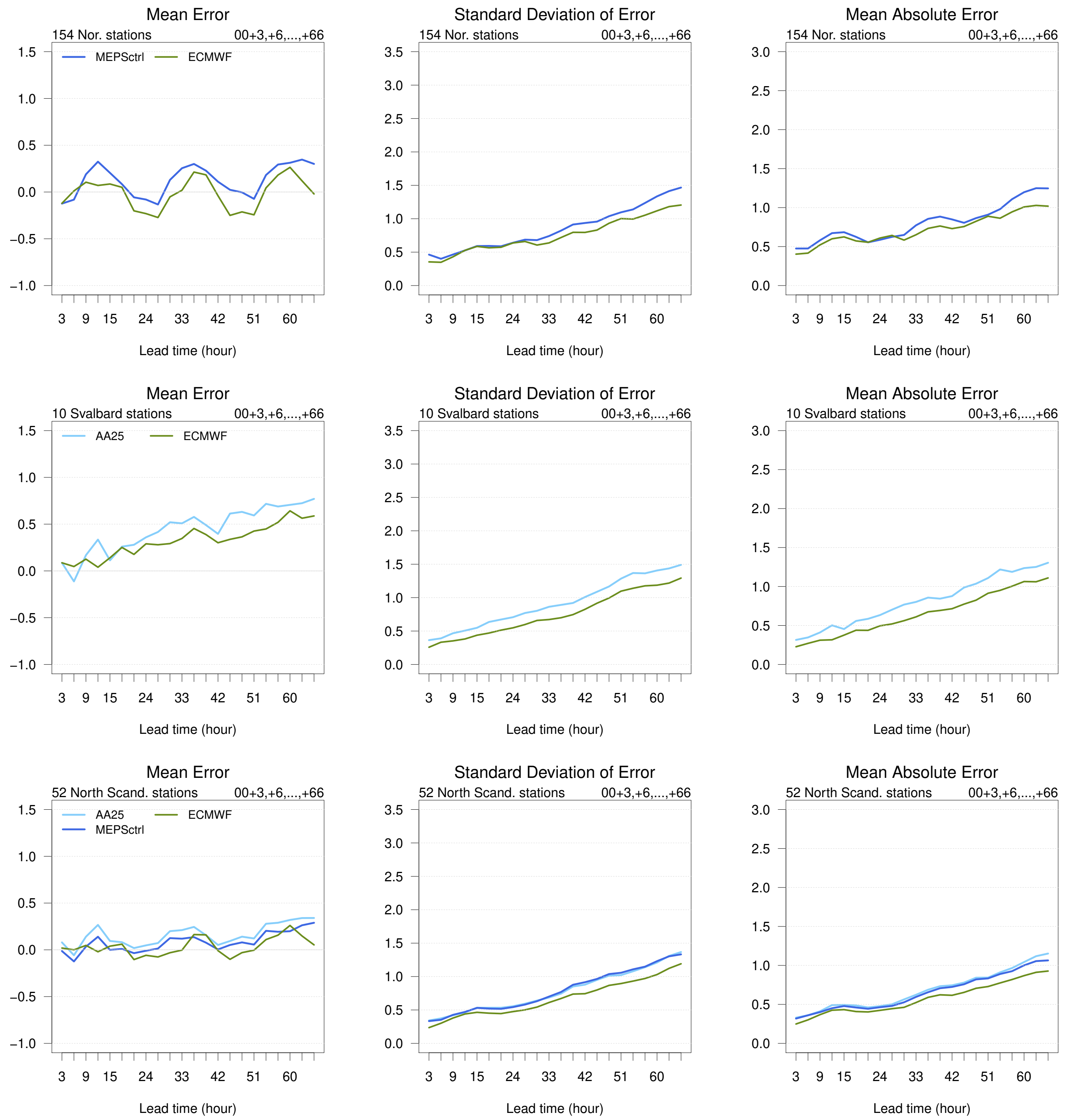


Figure 6: Wind from MEPS (violet) and synoptic observations (black) from 11 June in a strong katafront. The two observations showing 55 kts are both located at mountain tops at 800 m to 1000 m height. The observation of 31 m/s from the Tromsø brigde is not shown on this map.

Summarized statistics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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)
Mean Absolute Error
154 Nor. stations
00+3,+6,...,+66
Lead time (hour)
Mean Error
10 Svalbard stations
00+3,+6,...,+66
AA25
ECMWF
Lead time (hour)
Standard Deviation of Error
10 Svalbard stations
00+3,+6,...,+66
Lead time (hour)
Mean Absolute Error
10 Svalbard stations
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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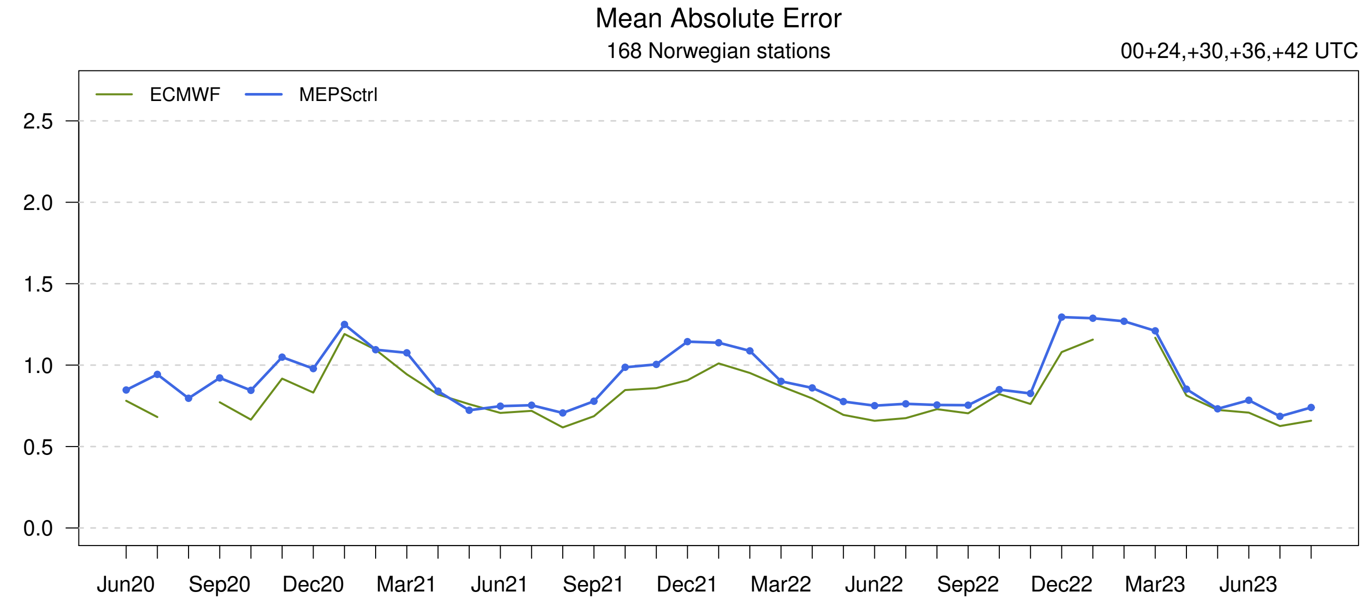
Lead time (hour)
Mean Absolute Error
52 North Scand. stations
00+3,+6,...,+66
Lead time (hour)


Mean Absolute Error
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00+24,+30,+36,+42 UTC
ECMWF
MEPSctrl
2.5
2.0
1.5
1.0
0.5
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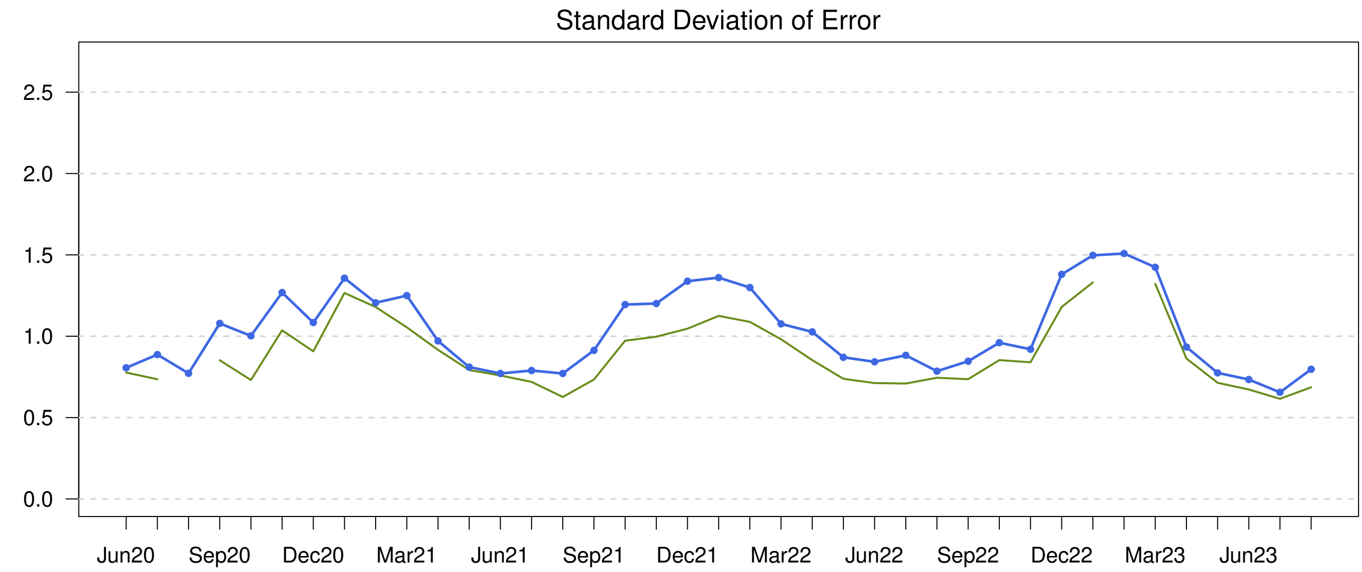
Sep22
Dec22
Mar23
Jun23


Standard Deviation of Error
2.5
2.0
1.5
1.0
0.5
0.0
Jun20
Sep20
Dec20
Mar21
Jun21
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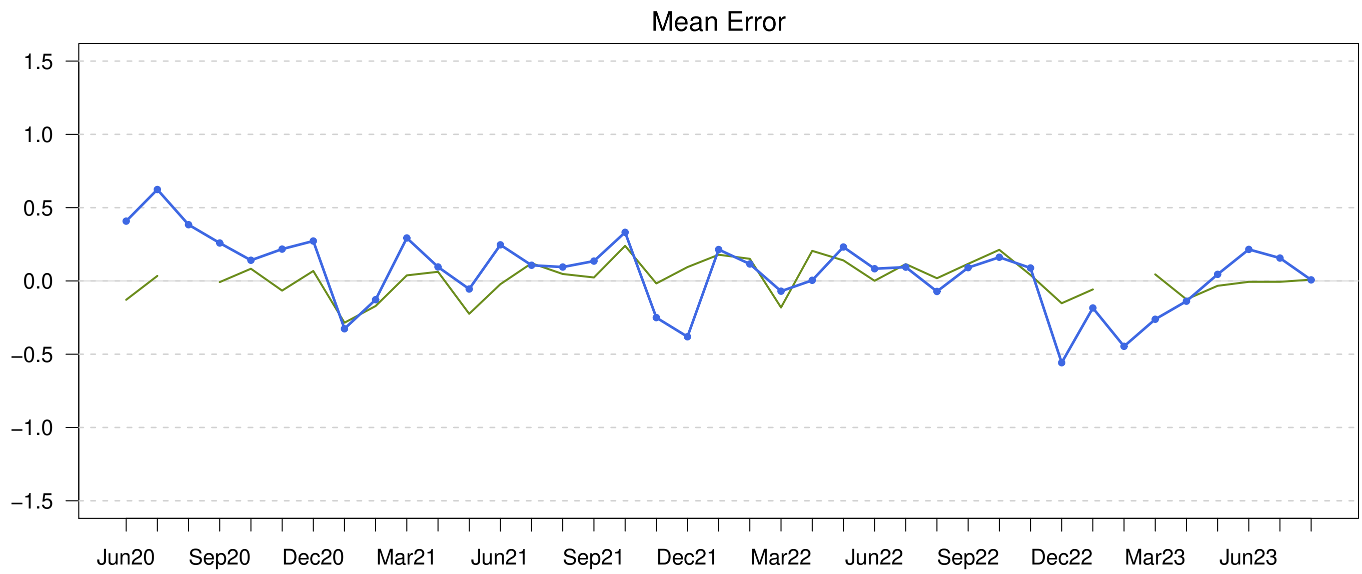
Sep22
Dec22
Mar23
Jun23


Mean Error
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
Jun20
Sep20
Dec20
Mar21
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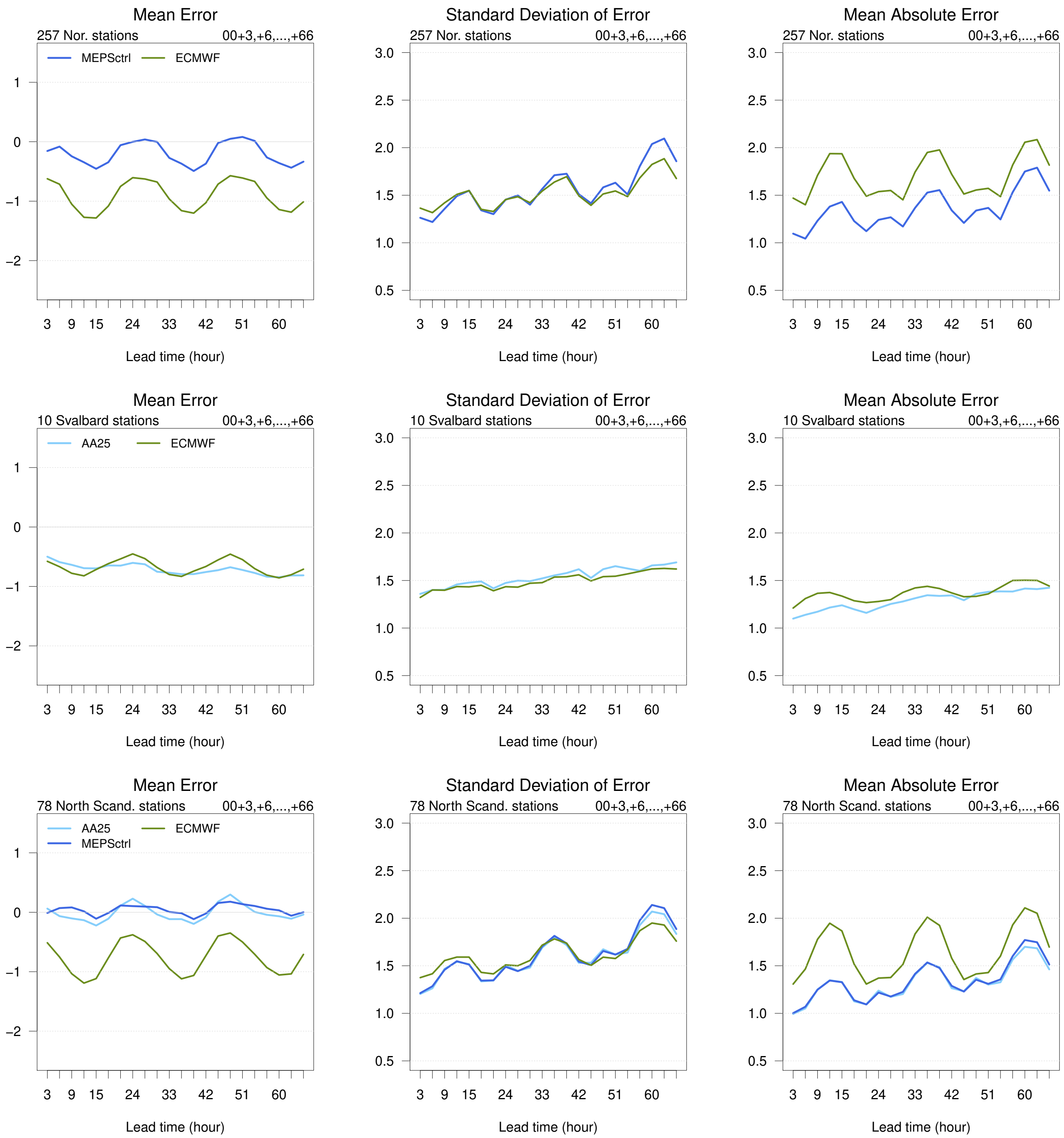
Sep22
Dec22
Mar23
Jun23


Mean Error
257 Nor. stations
00+3,+6,...,+66
MEPSctrl
ECMWF
Standard Deviation of Error
257 Nor. stations
00+3,+6,...,+66
Mean Absolute Error
257 Nor. stations
00+3,+6,...,+66
Mean Error
10 Svalbard stations
00+3,+6,...,+66
AA25
ECMWF
Standard Deviation of Error
10 Svalbard stations
00+3,+6,...,+66
Mean Absolute Error
10 Svalbard stations
00+3,+6,...,+66
Mean Error
78 North Scand. stations
00+3,+6,...,+66
AA25
MEPSctrl
ECMWF
Standard Deviation of Error
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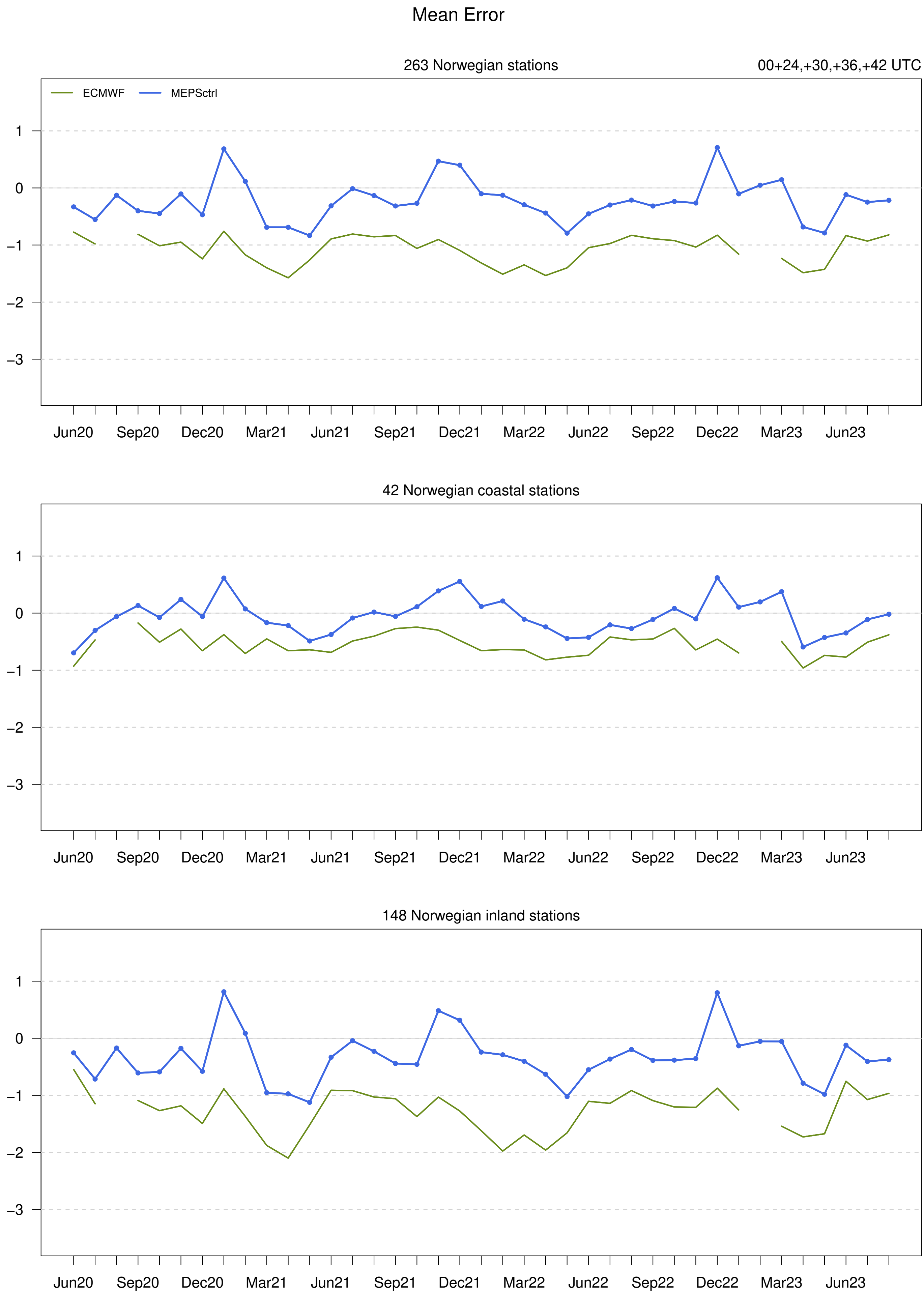
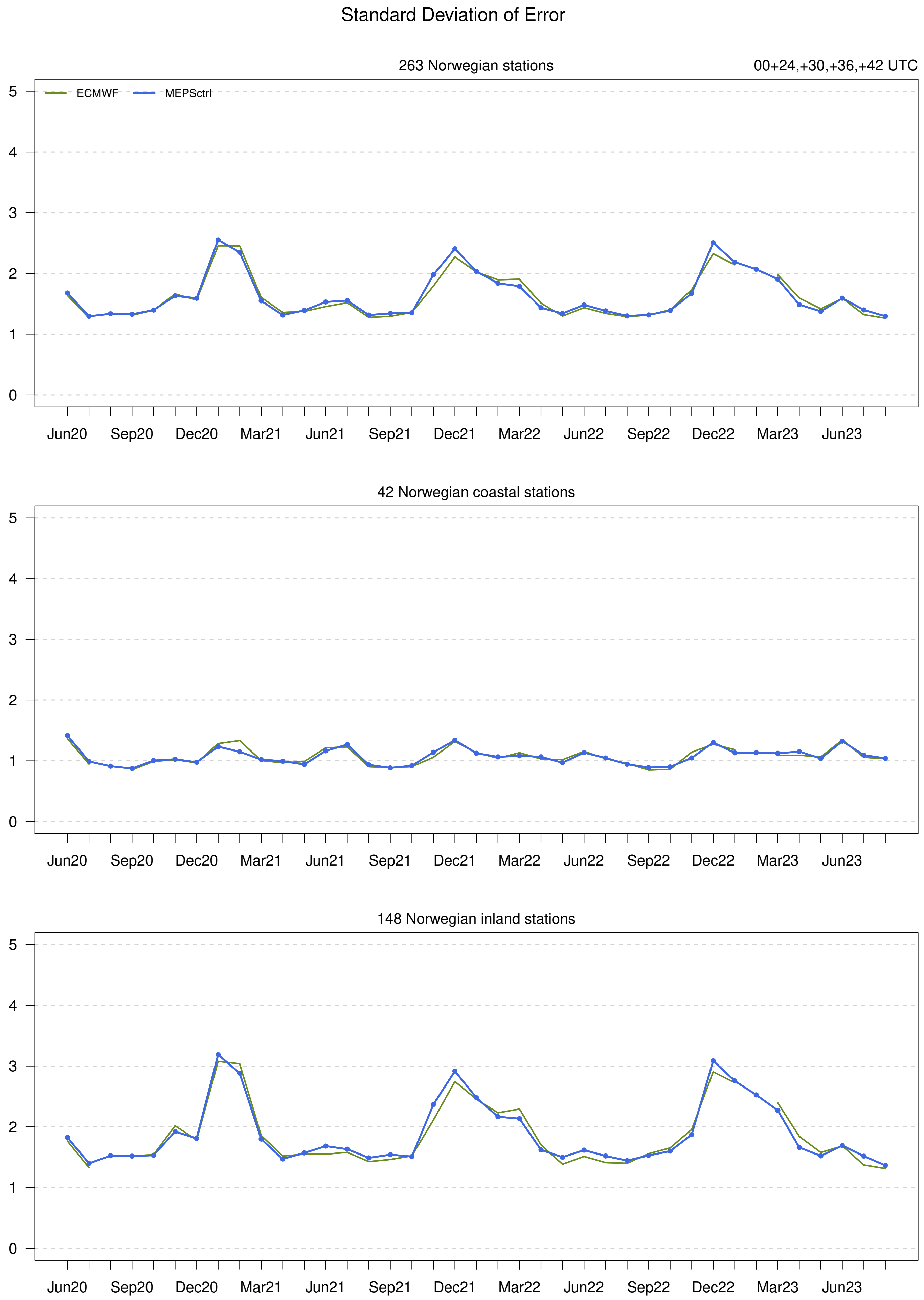
Mean Absolute Error
78 North Scand. stations
00+3,+6,...,+66
3 9 15 24 33 42 51 60
Lead time (hour)


Mean Error
263 Norwegian stations
00+24,+30,+36,+42 UTC
ECMWF
MEPSctrl
1
0
−1
−2
−3
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
42 Norwegian coastal stations
148 Norwegian inland stations



Standard Deviation of Error
263 Norwegian stations
00+24,+30,+36,+42 UTC
ECMWF
MEPSctrl
0
1
2
3
4
5
Jun20
Sep20
Dec20
Mar21
Jun21
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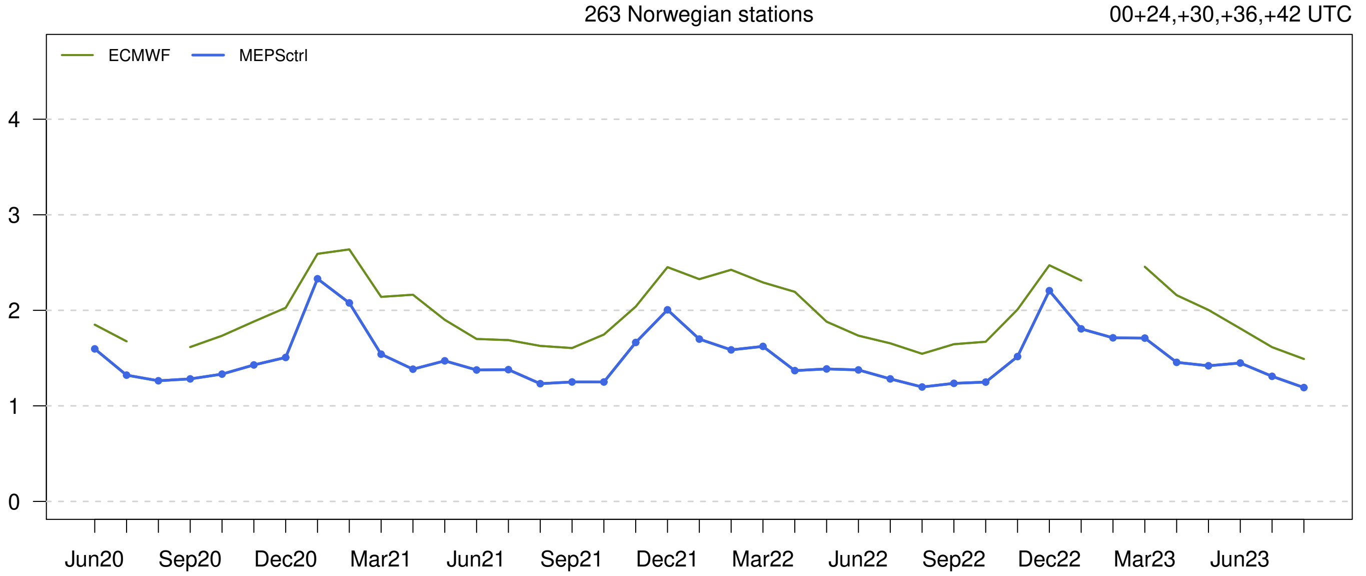
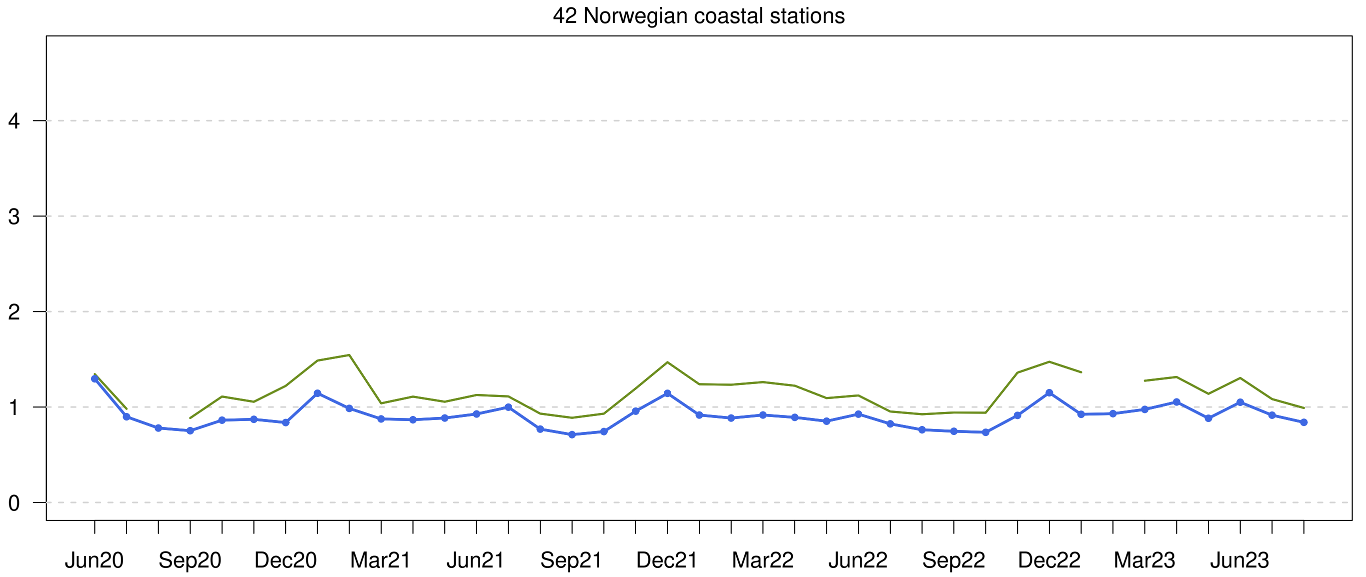
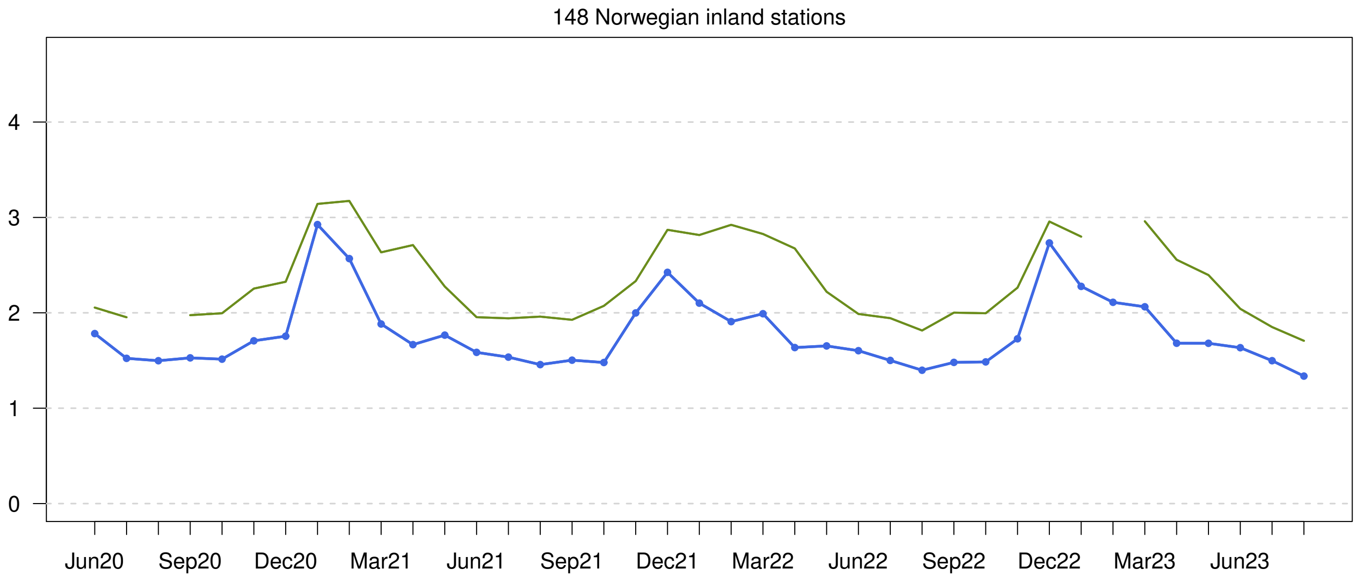
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23
42 Norwegian coastal stations
148 Norwegian inland stations

Mean Absolute Error

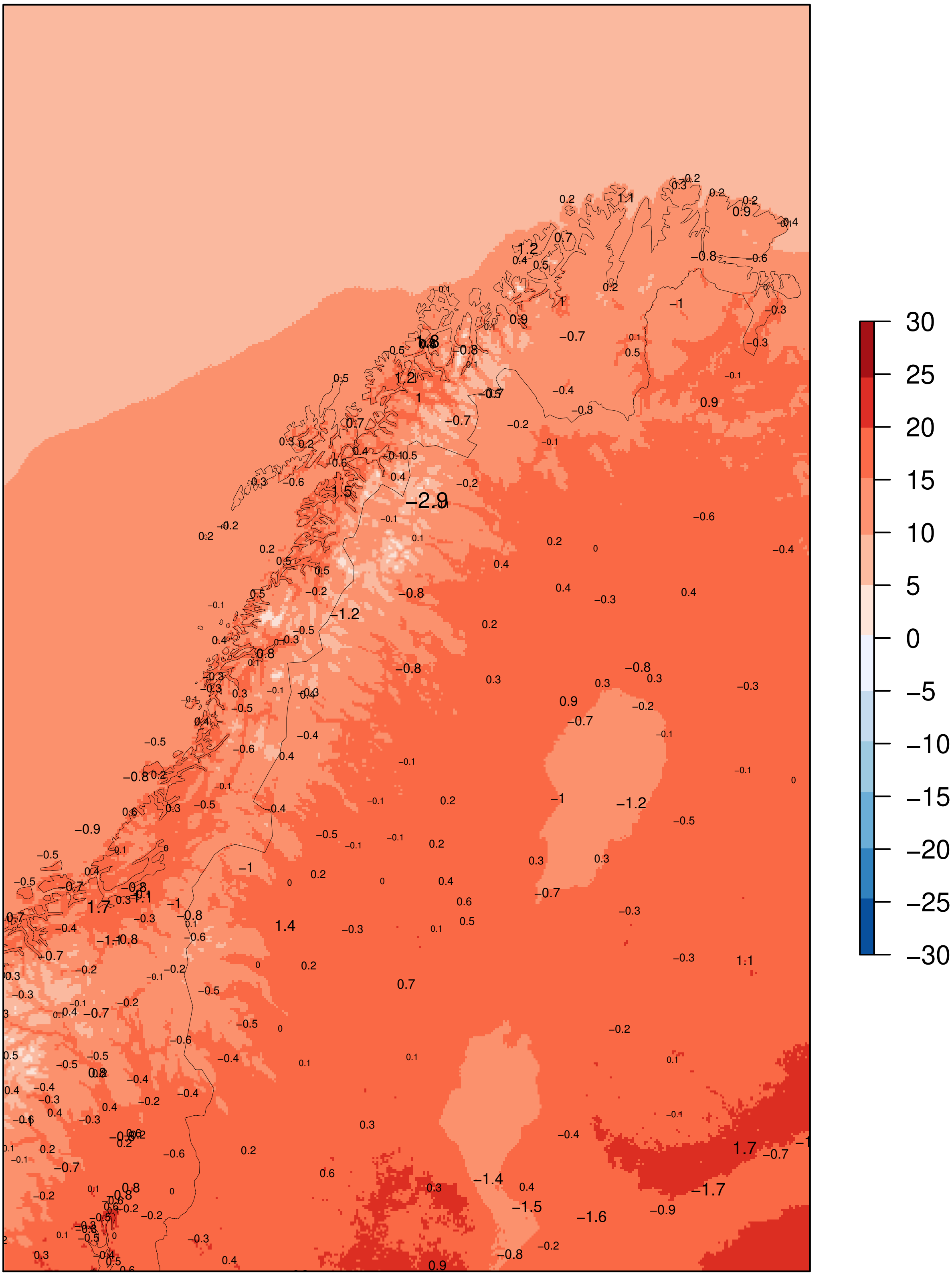






MEPSctrl 00+12

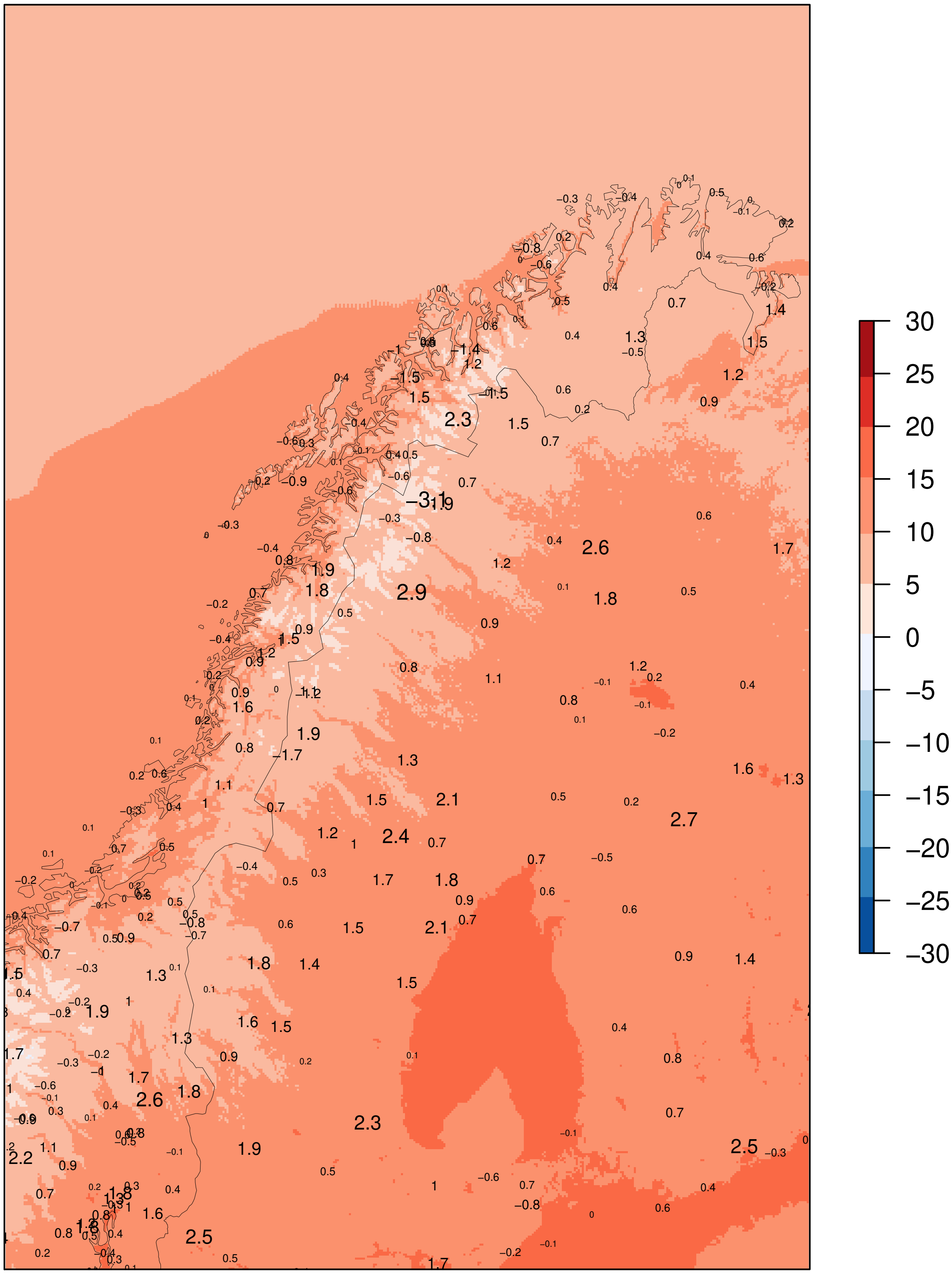
ME at observing sites
(numbers in black)



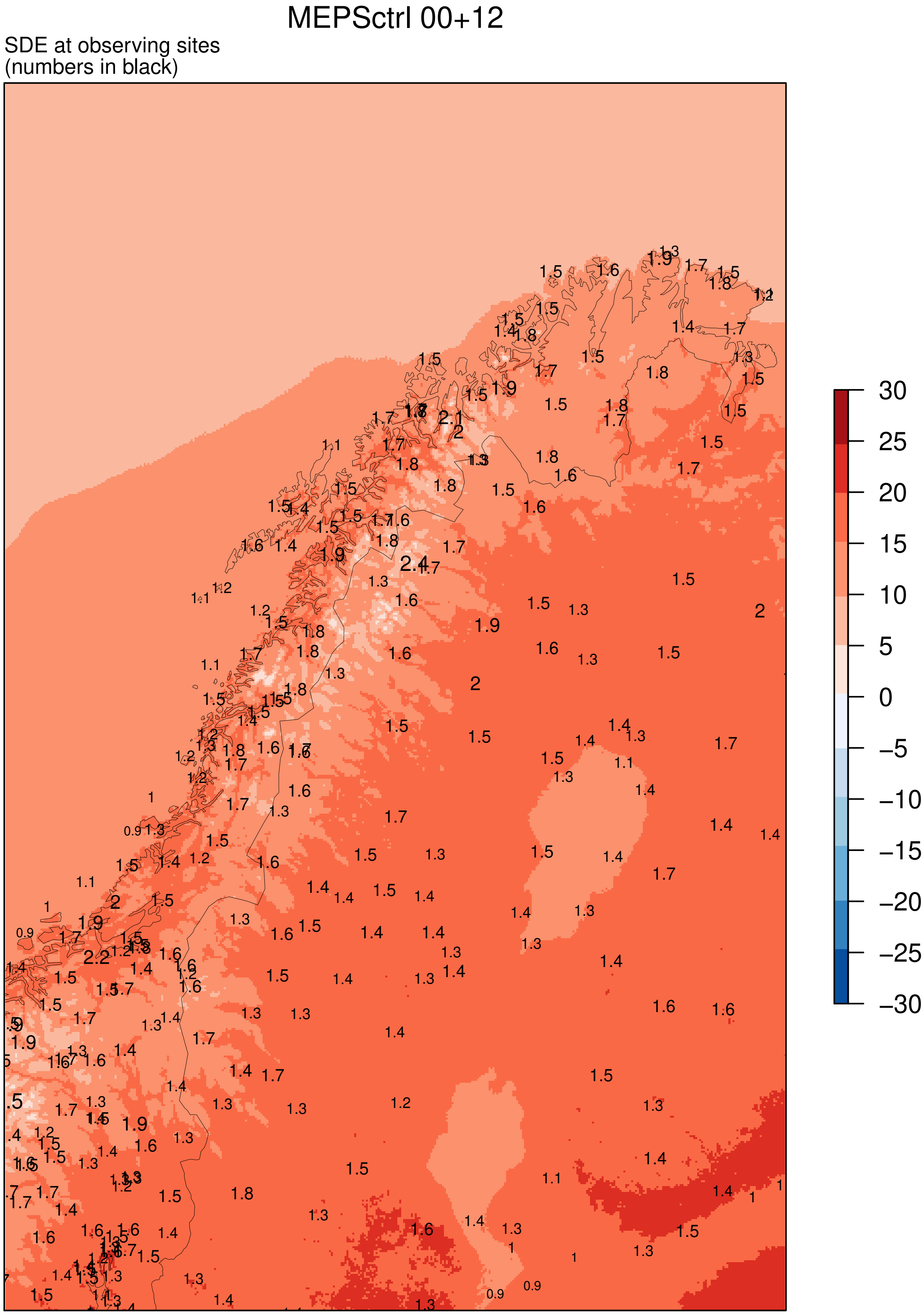
Model "climatology" 01.06.2023 – 31.08.2023

MEPSctrl 00+24

ME at observing sites
(numbers in black)



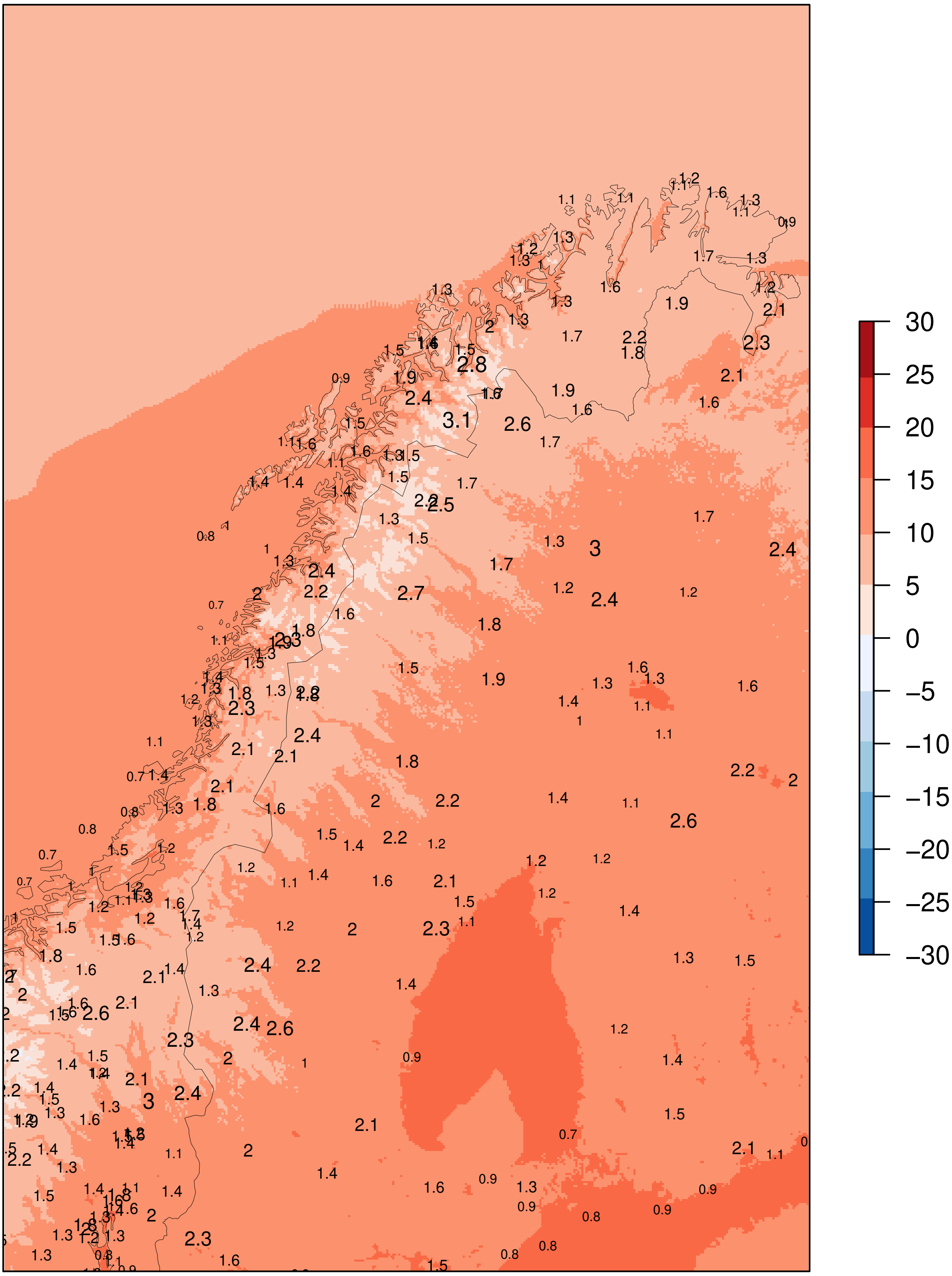
Model "climatology" 01.06.2023 – 31.08.2023



Model "climatology" 01.06.2023 – 31.08.2023

MEPSctrl 00+24

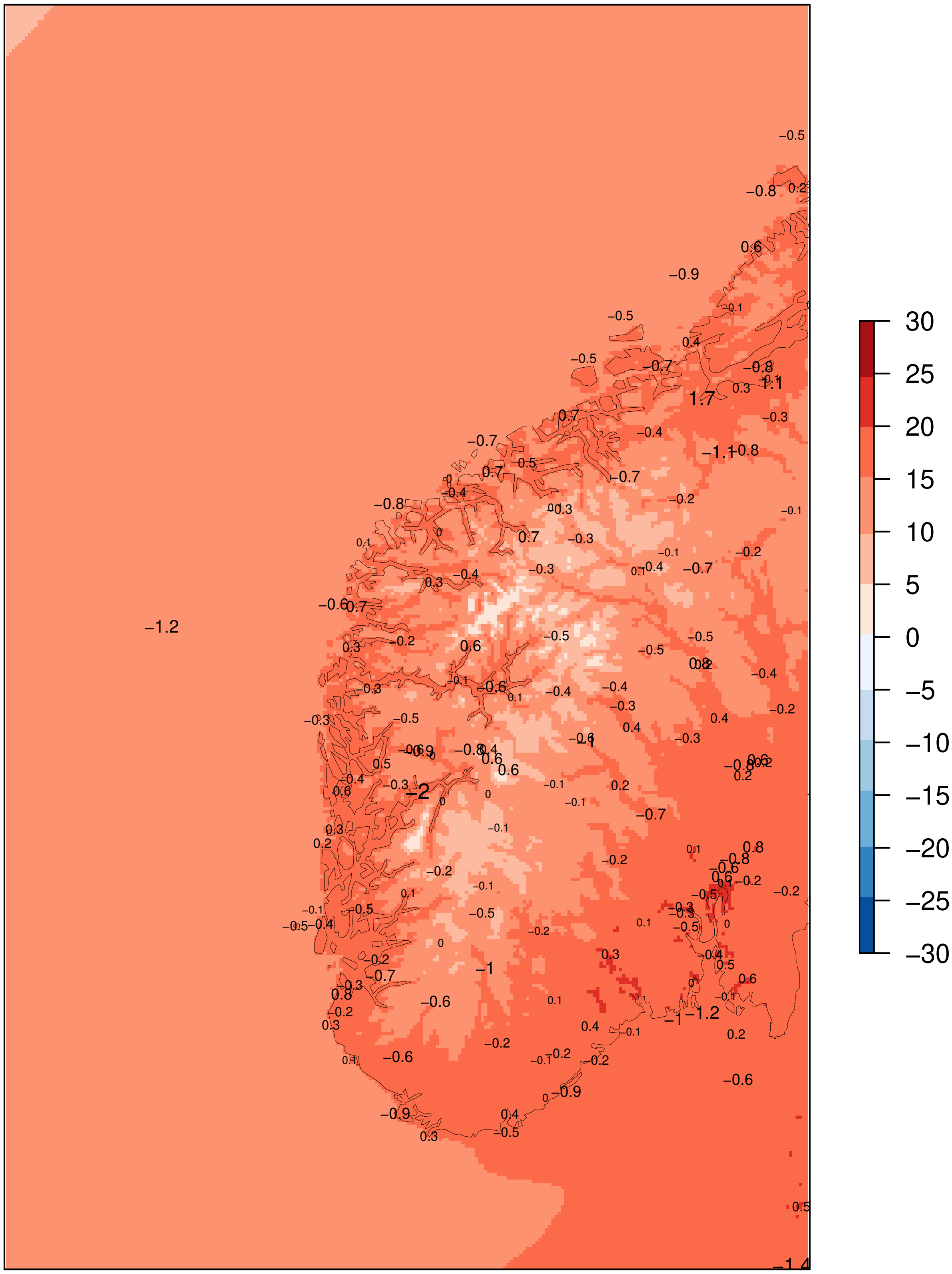
SDE at observing sites
(numbers in black)



Model "climatology" 01.06.2023 – 31.08.2023

MEPSctrl 00+12

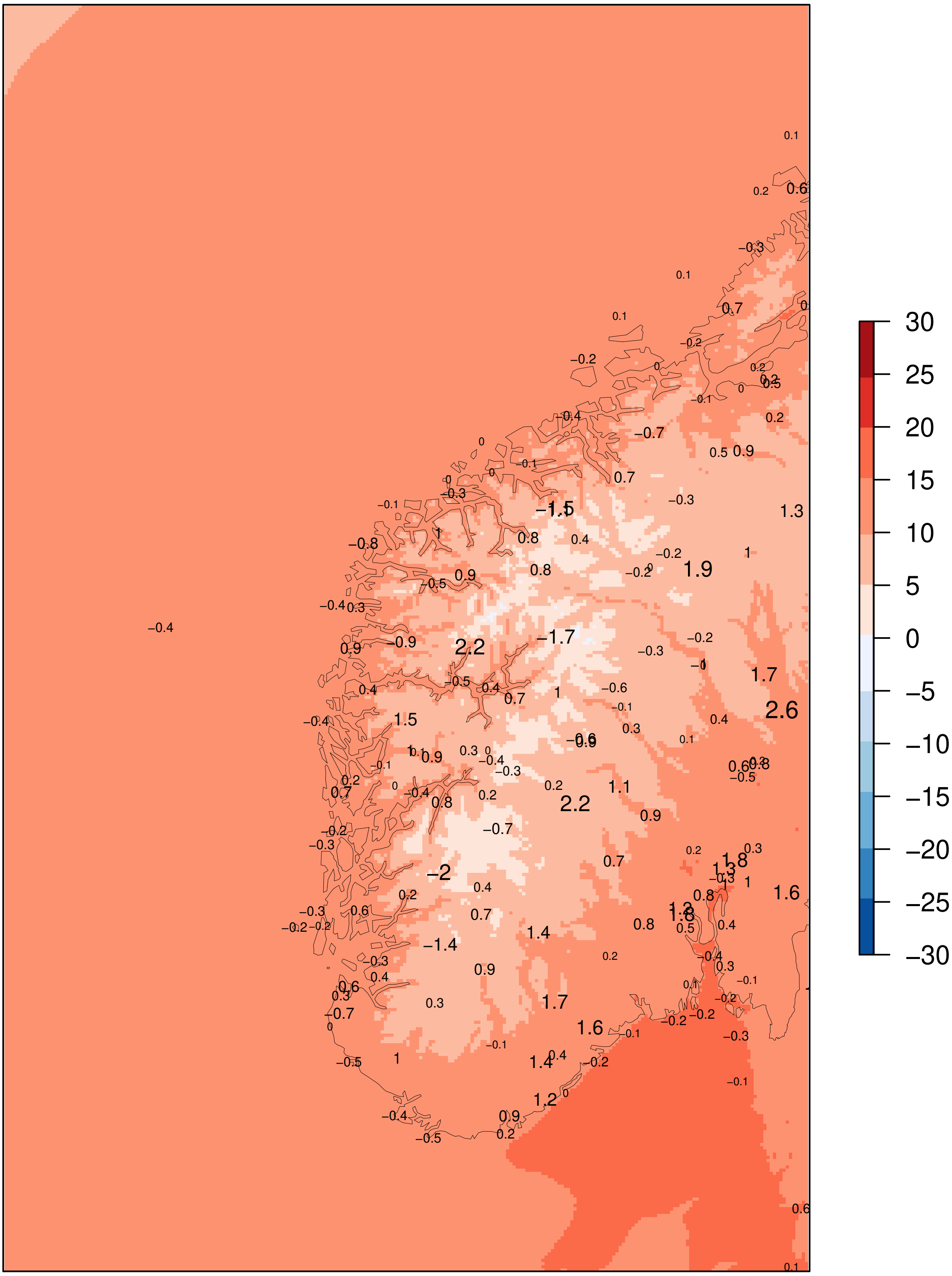
ME at observing sites
(numbers in black)



Model "climatology" 01.06.2023 – 31.08.2023

MEPSctrl 00+24

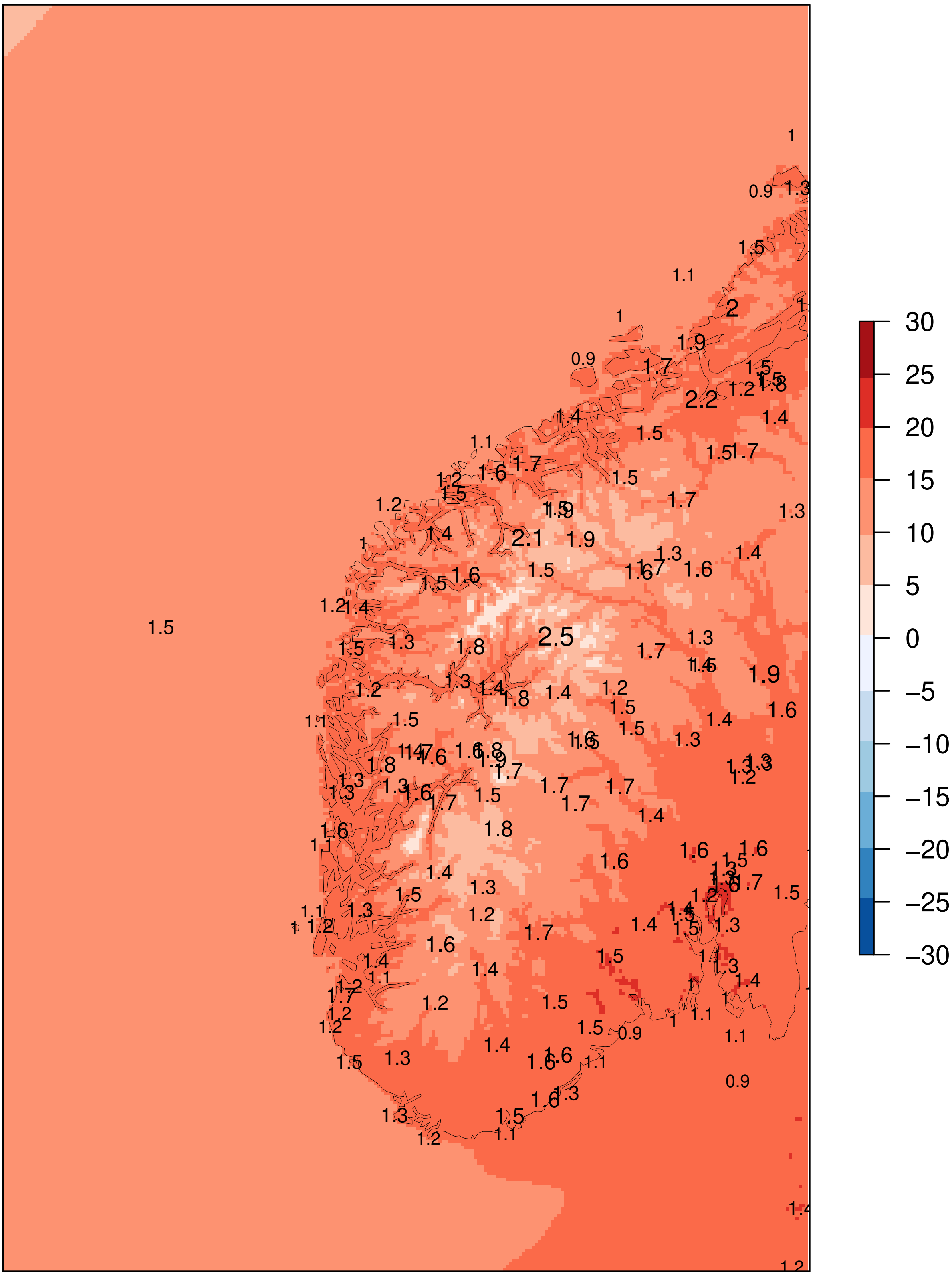
ME at observing sites
(numbers in black)



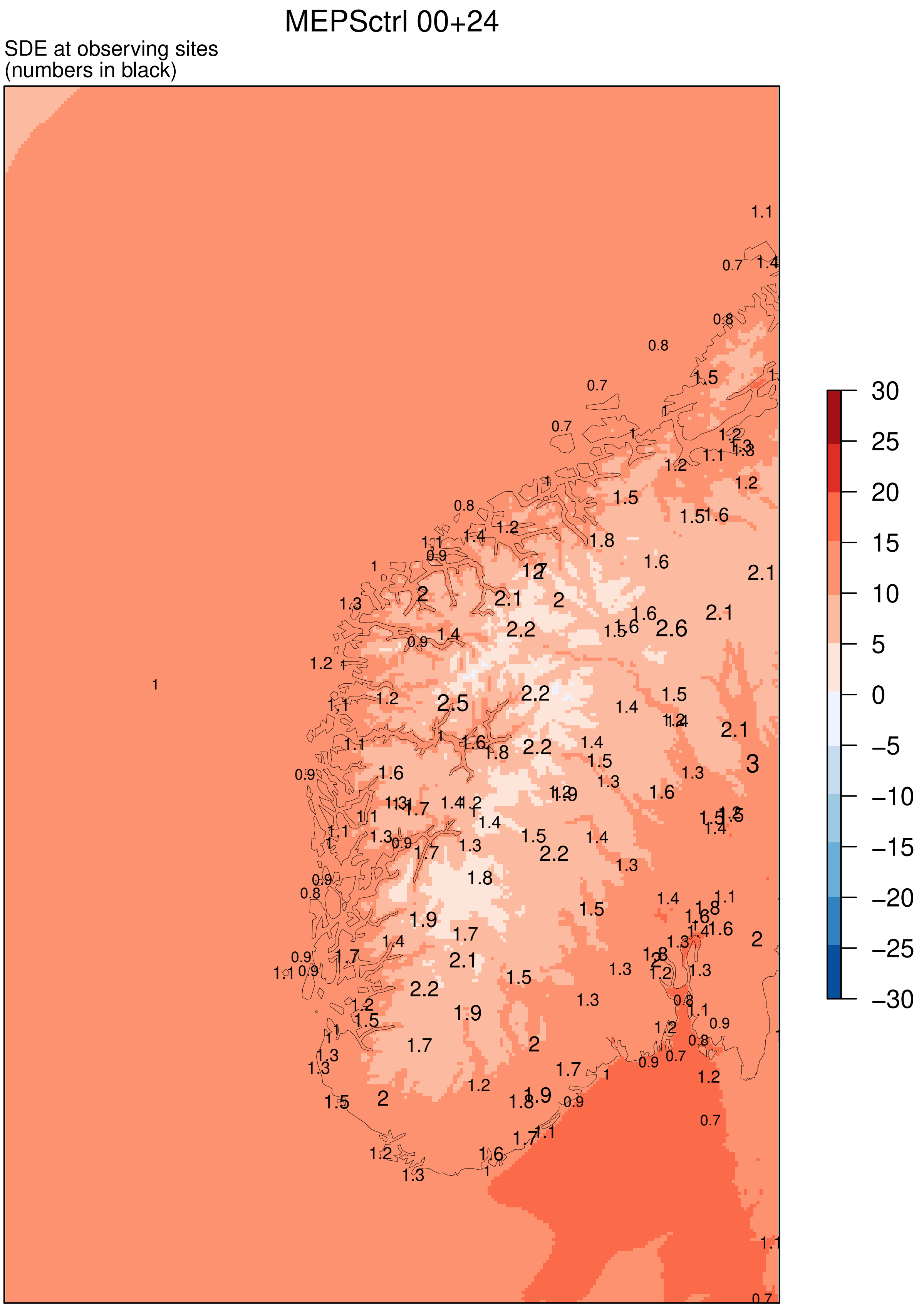
Model "climatology" 01.06.2023 – 31.08.2023

MEPSctrl 00+12

SDE at observing sites
(numbers in black)



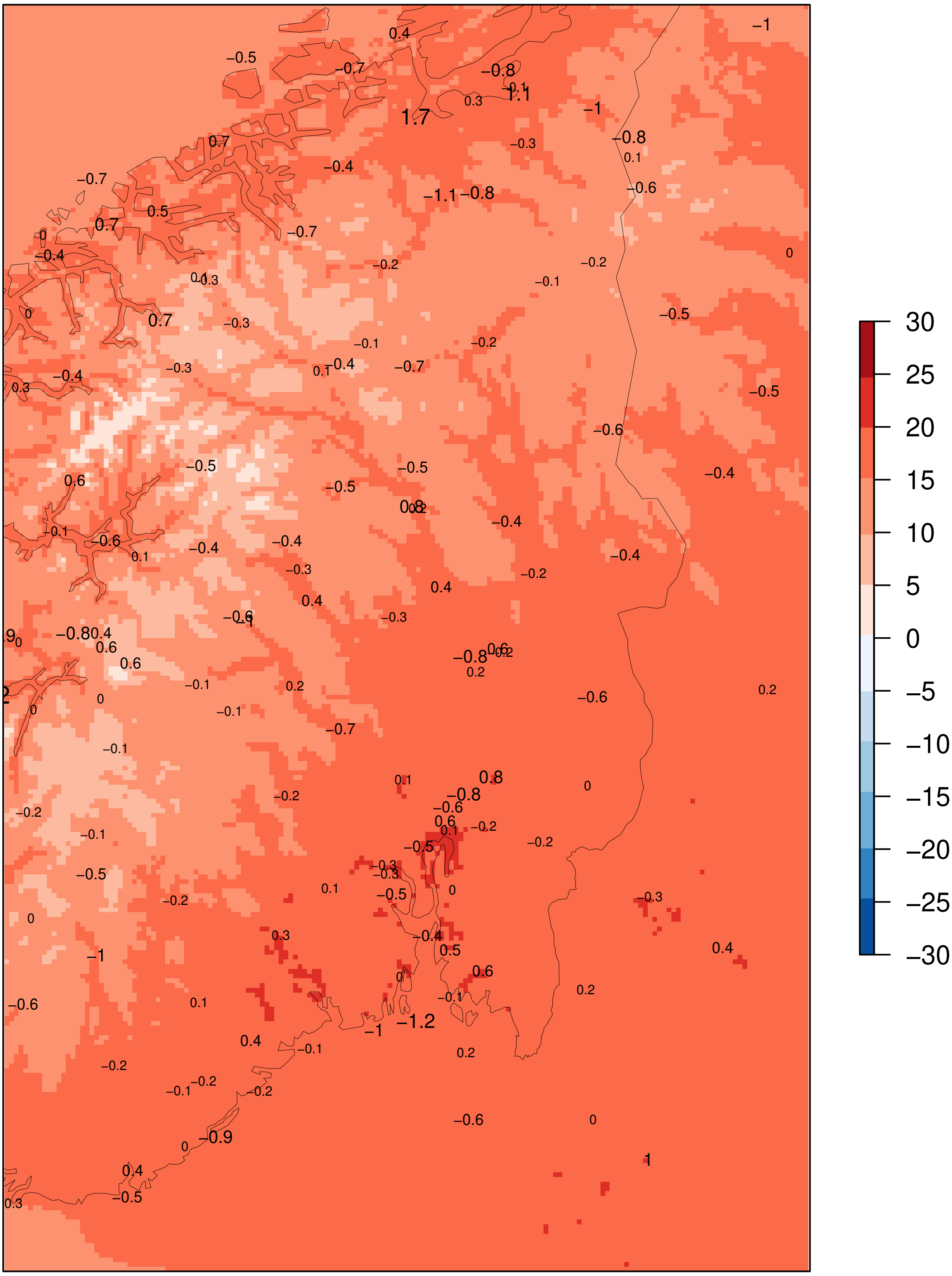
Model "climatology"   01.06.2023 – 31.08.2023



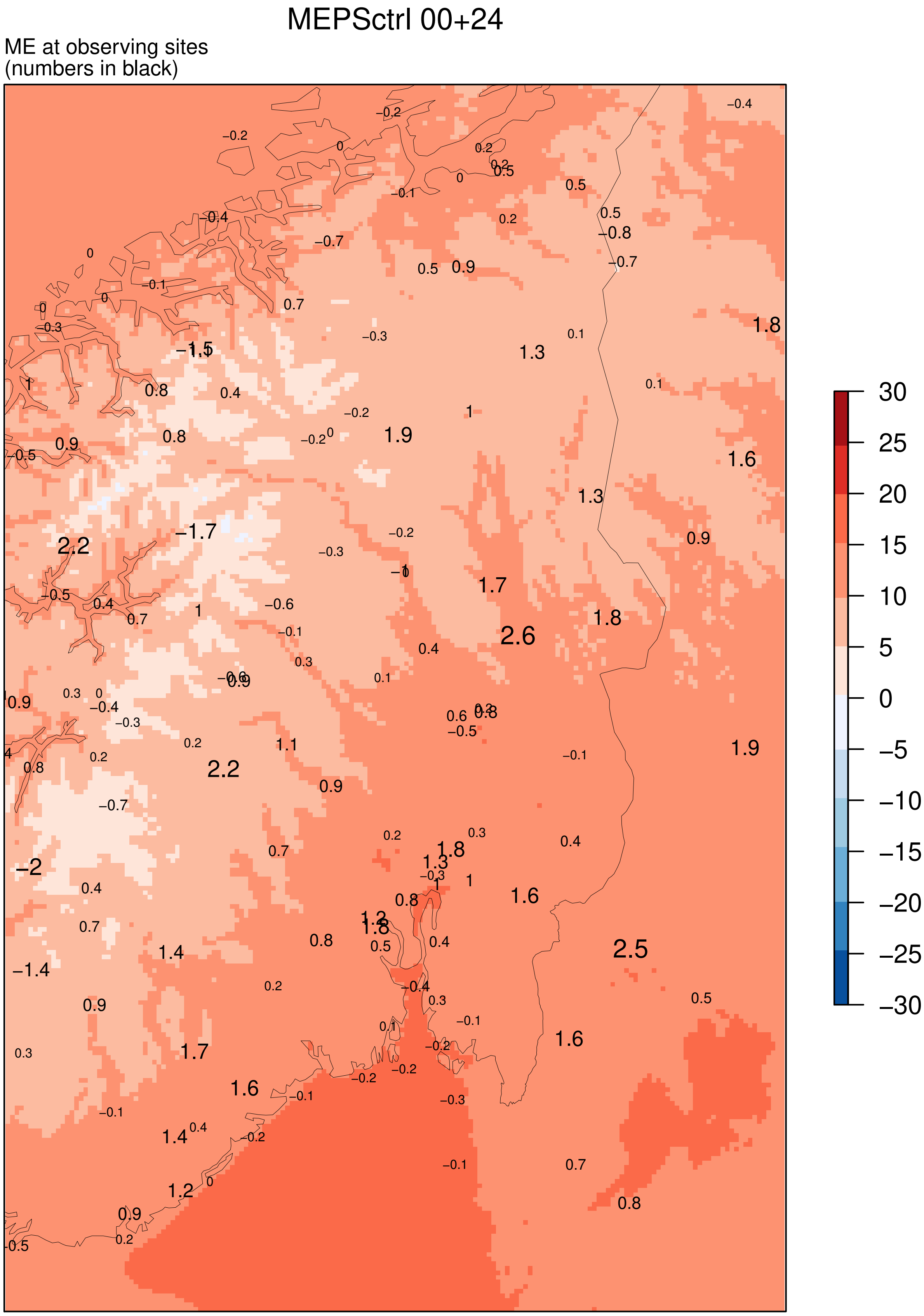
Model "climatology" 01.06.2023 – 31.08.2023

MEPSctrl 00+12

ME at observing sites
(numbers in black)



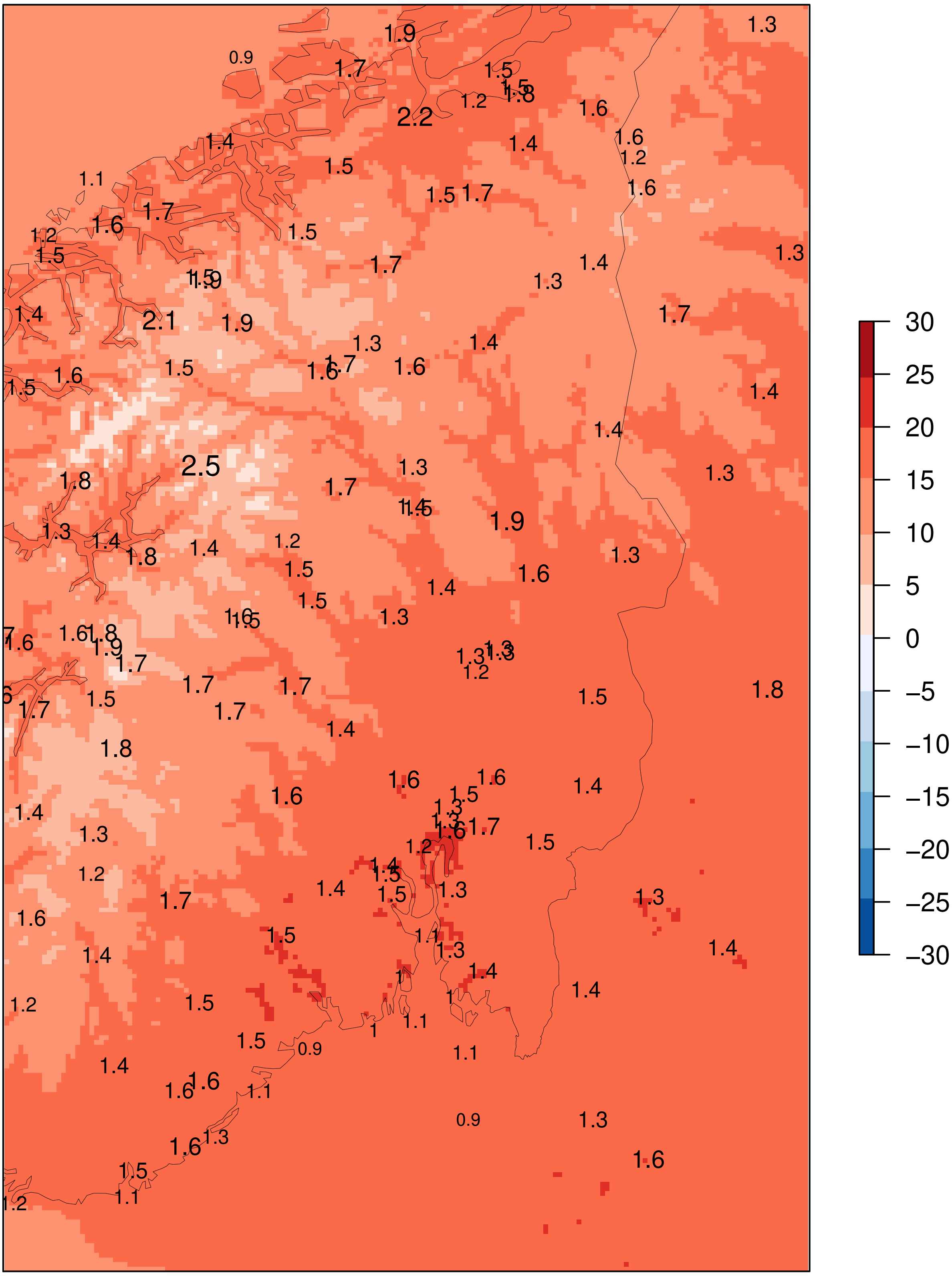
Model "climatology" 01.06.2023 – 31.08.2023



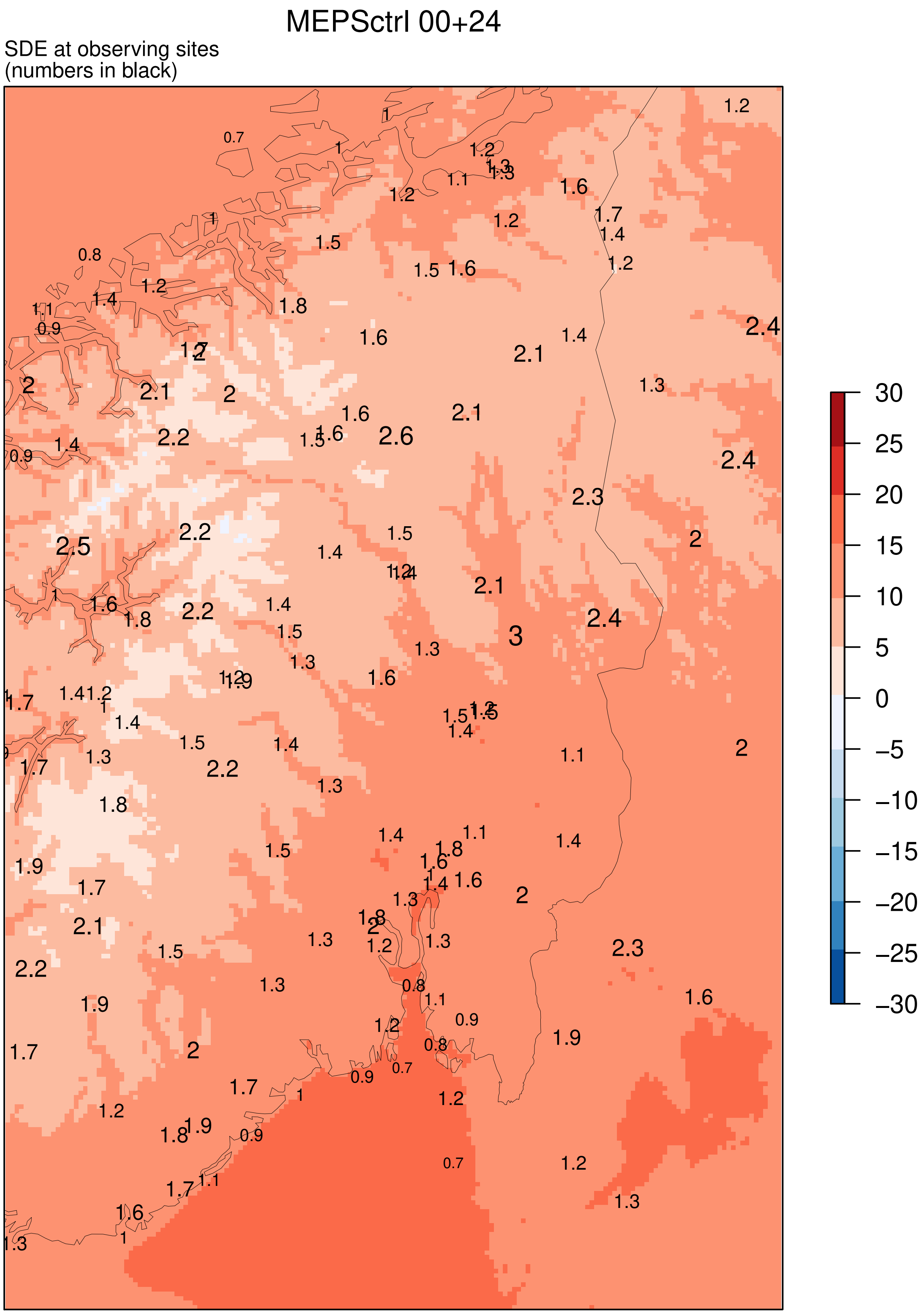
Model "climatology" 01.06.2023 – 31.08.2023

MEPSctrl 00+12

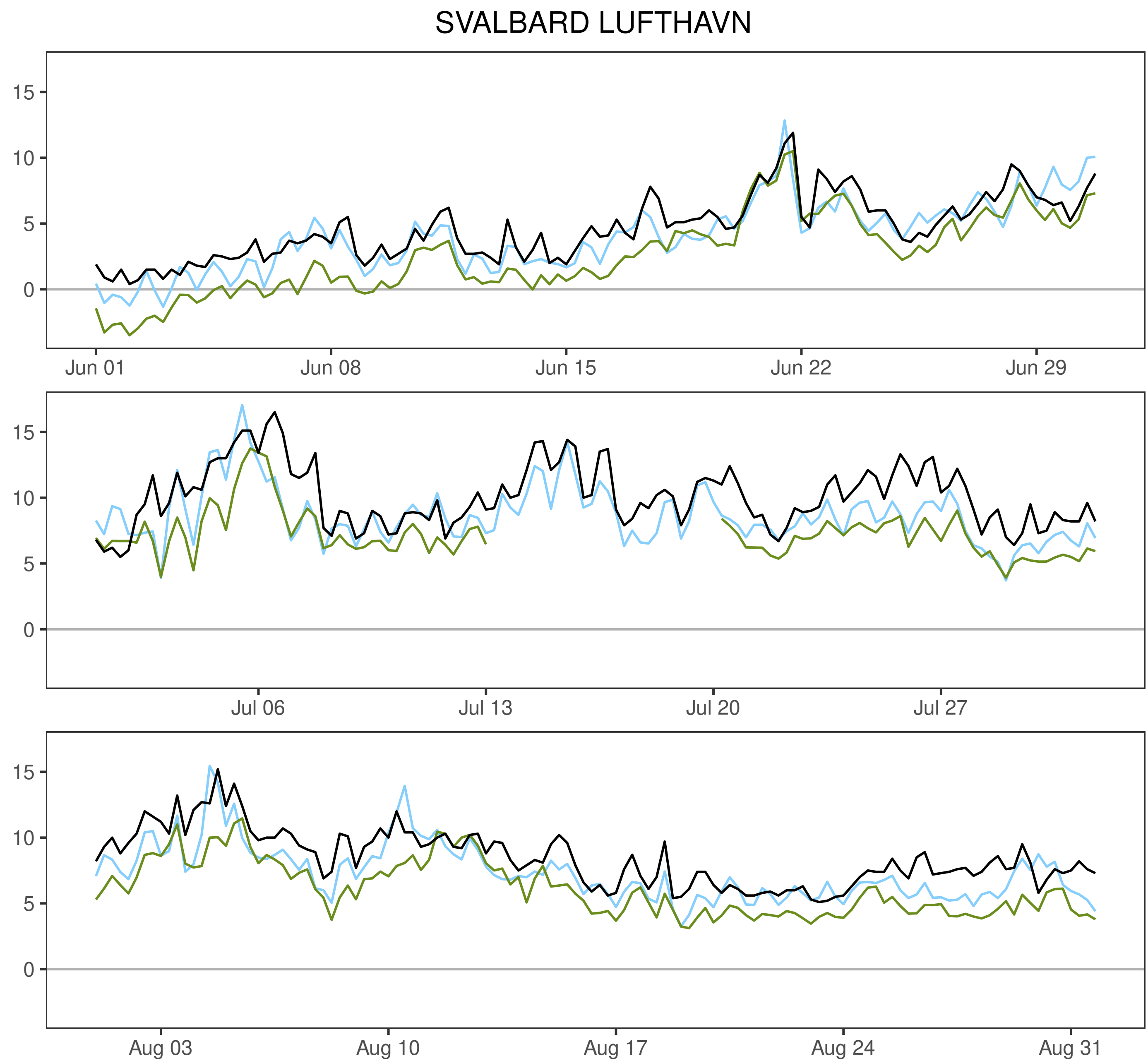
SDE at observing sites
(numbers in black)



Model "climatology" 01.06.2023 – 31.08.2023

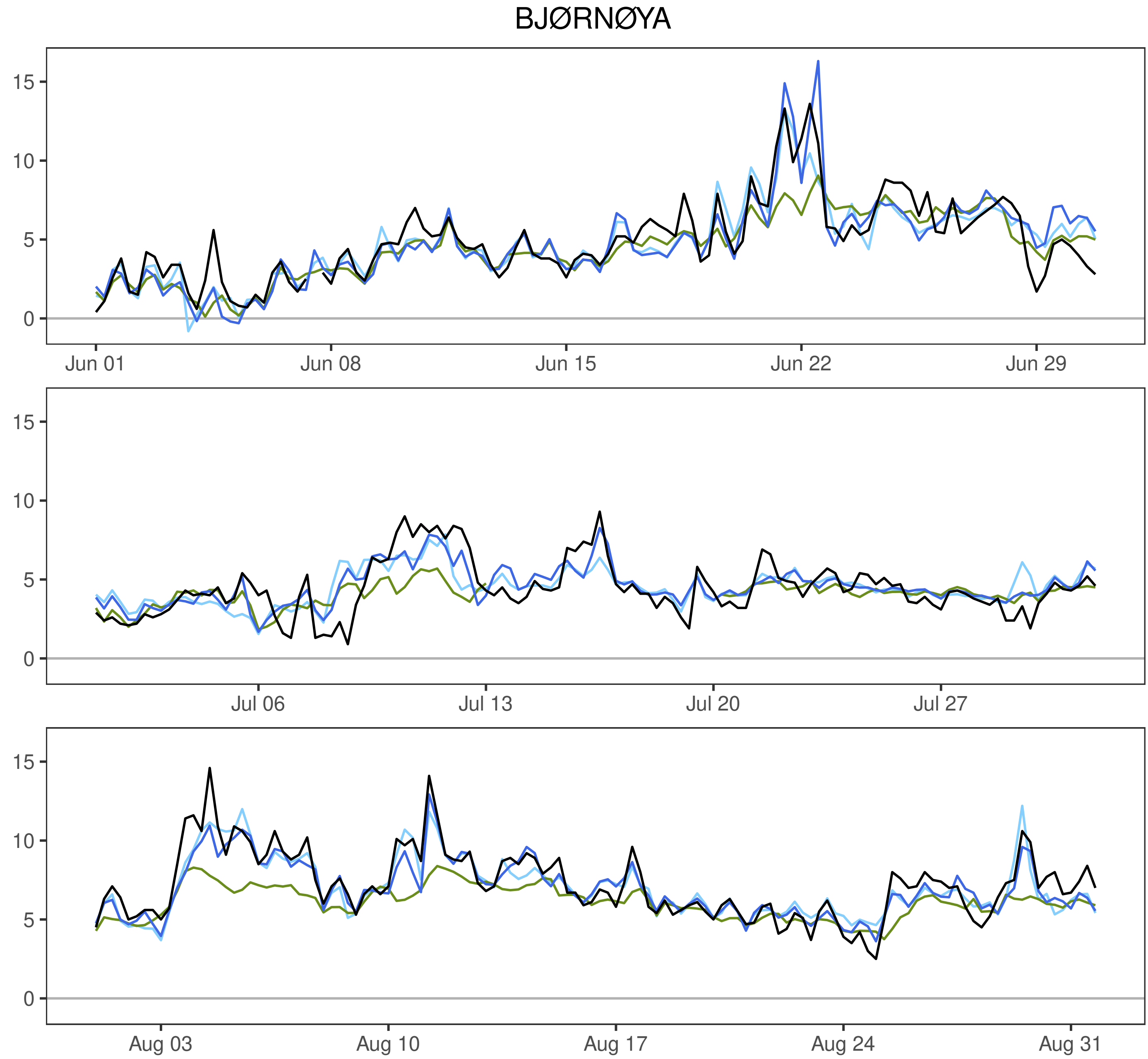


Model "climatology" 01.06.2023 – 31.08.2023



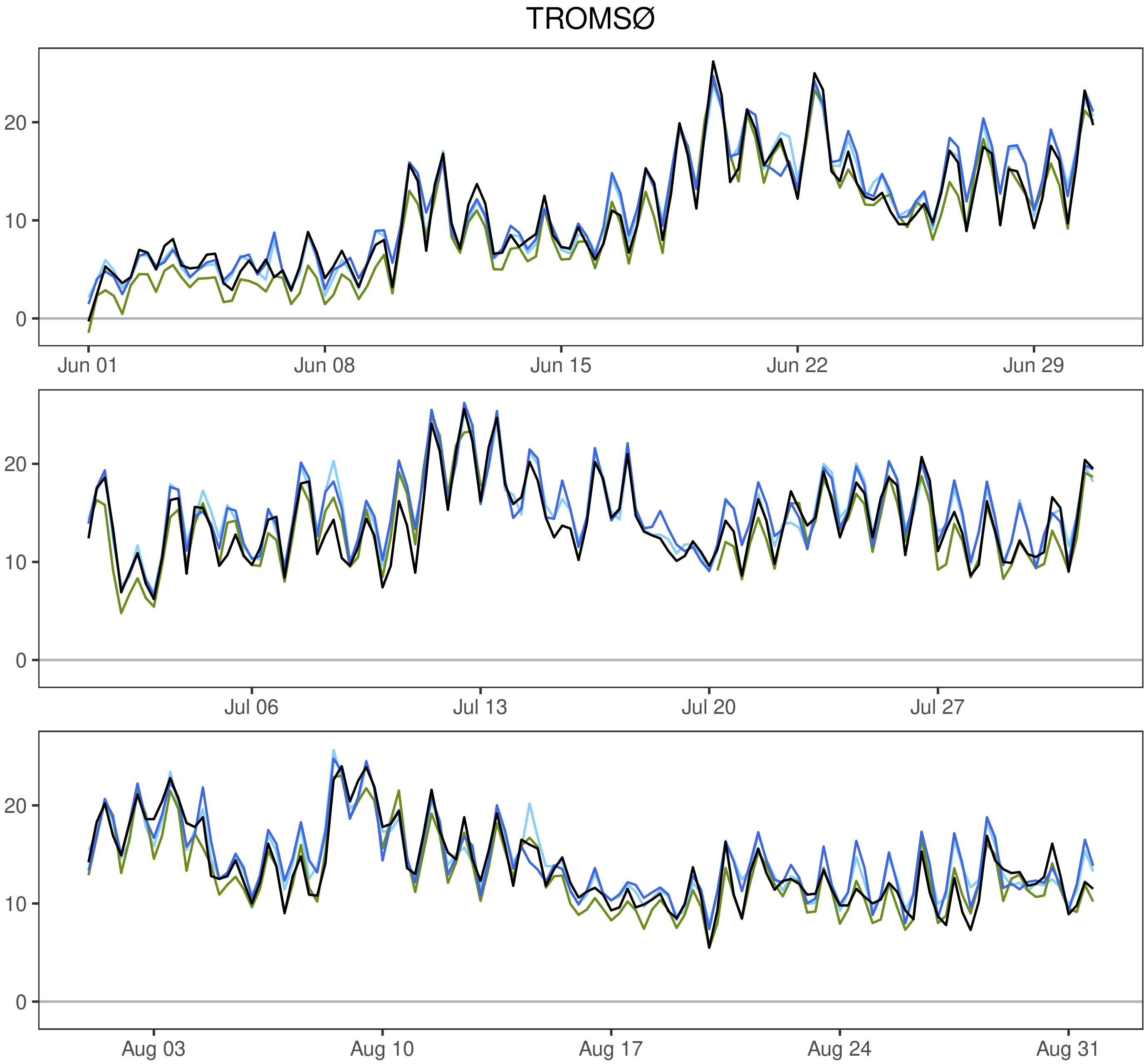
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.4	7.8	16.5	3.2	368
AA25: 12+18,+24,+30,+36	−1.3	6.7	17.0	3.0	368
ECMWF: 12+18,+24,+30,+36	−3.5	5.2	13.7	3.1	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
AA25−synop	−1.0	1.5	1.8	1.4	5.7	340
ECMWF−synop	−2.3	1.3	2.6	2.3	6.3	340



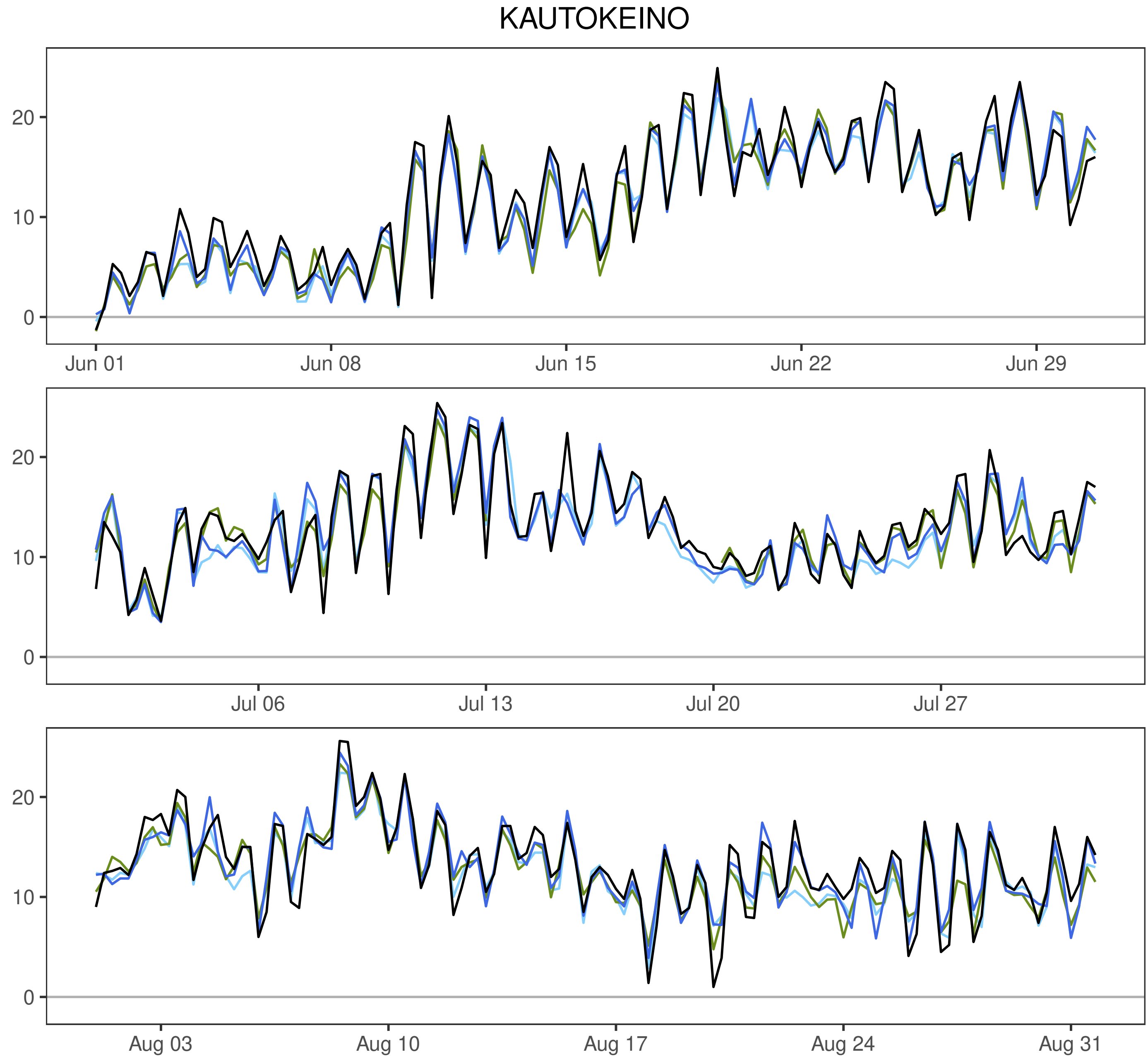
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.4	5.5	14.6	2.5	367
MEPSctrl: 12+18,+24,+30,+36	−0.3	5.4	16.3	2.2	368
AA25: 12+18,+24,+30,+36	−0.8	5.4	13.3	2.1	368
ECMWF: 12+18,+24,+30,+36	0.1	4.9	9.1	1.7	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.1	1.2	1.2	0.9	5.2	339
AA25−synop	−0.1	1.2	1.2	0.9	5.2	339
ECMWF−synop	−0.6	1.5	1.6	1.2	6.8	339



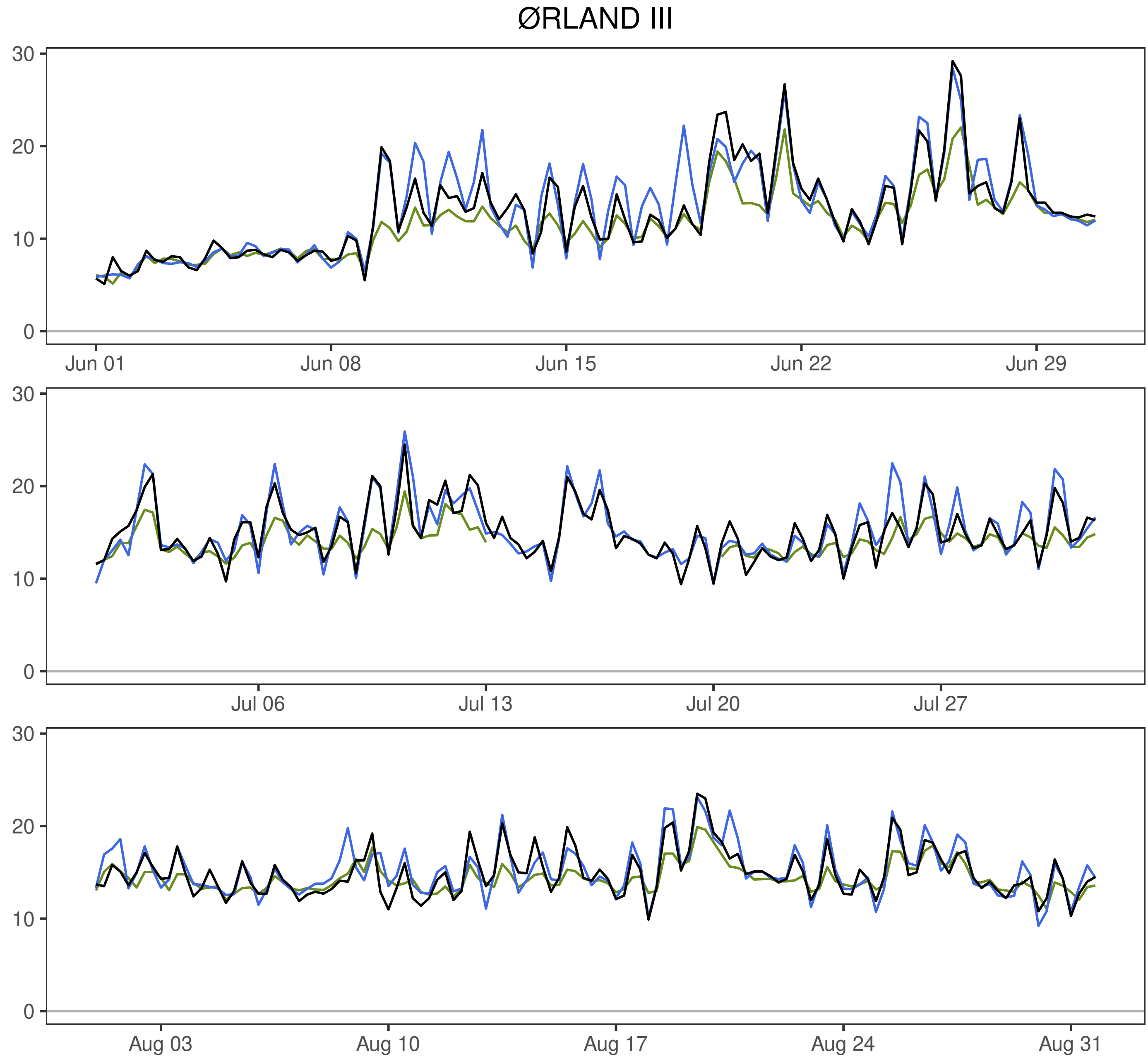
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−0.3	12.9	26.2	4.7	368
MEPSctrl: 12+18,+24,+30,+36	1.5	13.7	26.2	4.7	368
AA25: 12+18,+24,+30,+36	2.2	13.5	25.6	4.7	368
ECMWF: 12+18,+24,+30,+36	−1.5	11.9	24.9	5.0	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.8	1.6	1.8	1.4	5.1	340
AA25−synop	0.7	1.6	1.7	1.3	6.0	340
ECMWF−synop	−0.8	1.4	1.6	1.3	4.9	340



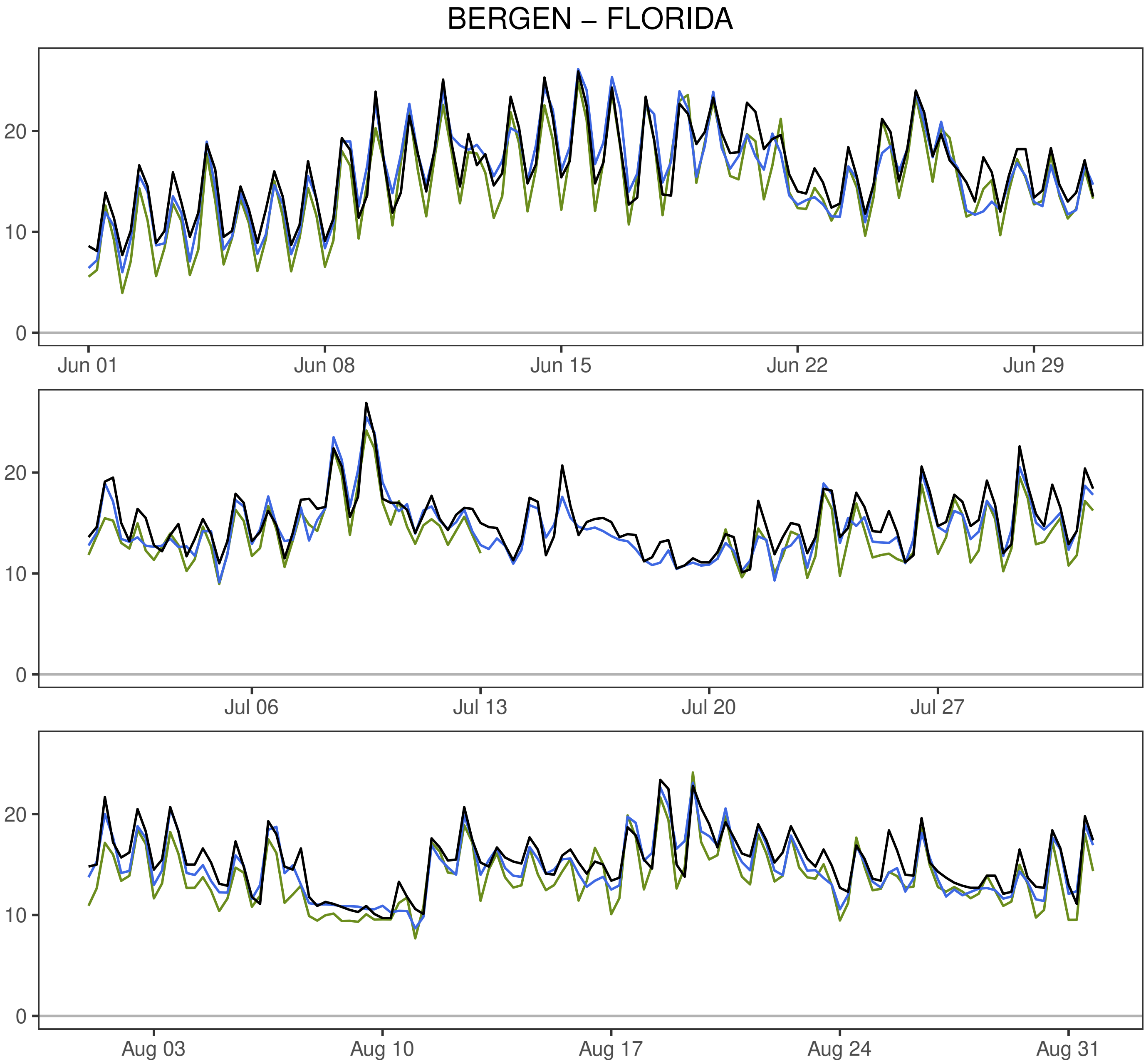
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−1.3	12.8	25.6	5.1	368
MEPSctrl: 12+18,+24,+30,+36	0.3	12.5	24.7	4.9	368
AA25: 12+18,+24,+30,+36	−0.4	12.2	23.8	4.8	368
ECMWF: 12+18,+24,+30,+36	−1.4	12.1	23.8	4.8	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.2	1.8	1.8	1.3	6.3	340
AA25−synop	−0.6	1.8	1.9	1.5	7.0	340
ECMWF−synop	−0.5	1.7	1.8	1.4	5.7	340



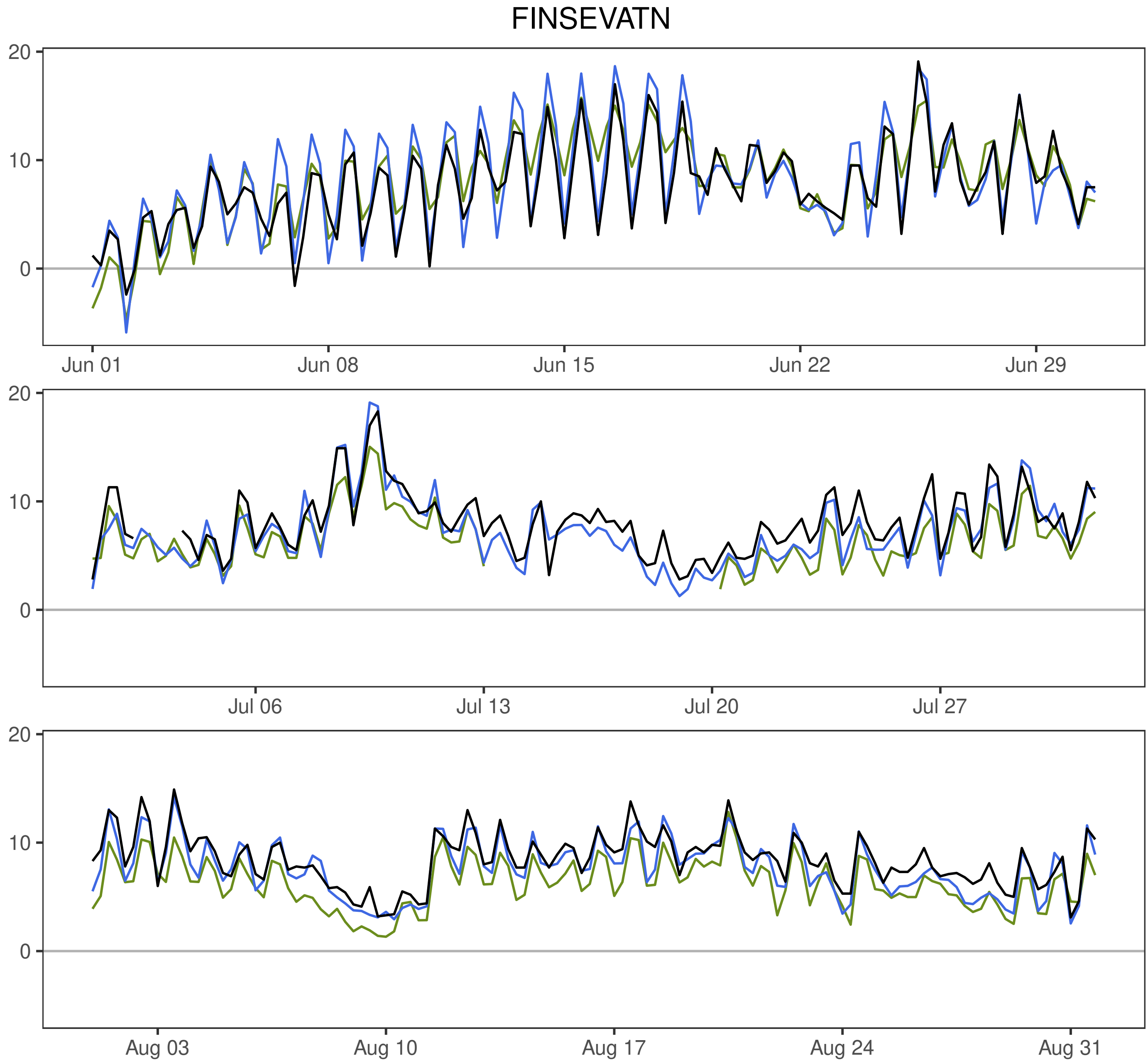
	Min	Mean	Max	Std	N
synop: 00,06,12,18	5.1	14.3	29.2	3.6	368
MEPSctrl: 12+18,+24,+30,+36	5.7	14.6	28.5	3.8	368
ECMWF: 12+18,+24,+30,+36	5.1	13.3	22.0	2.7	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.3	1.6	1.6	1.1	8.6	340
ECMWF−synop	−1.0	1.8	2.1	1.5	8.4	340



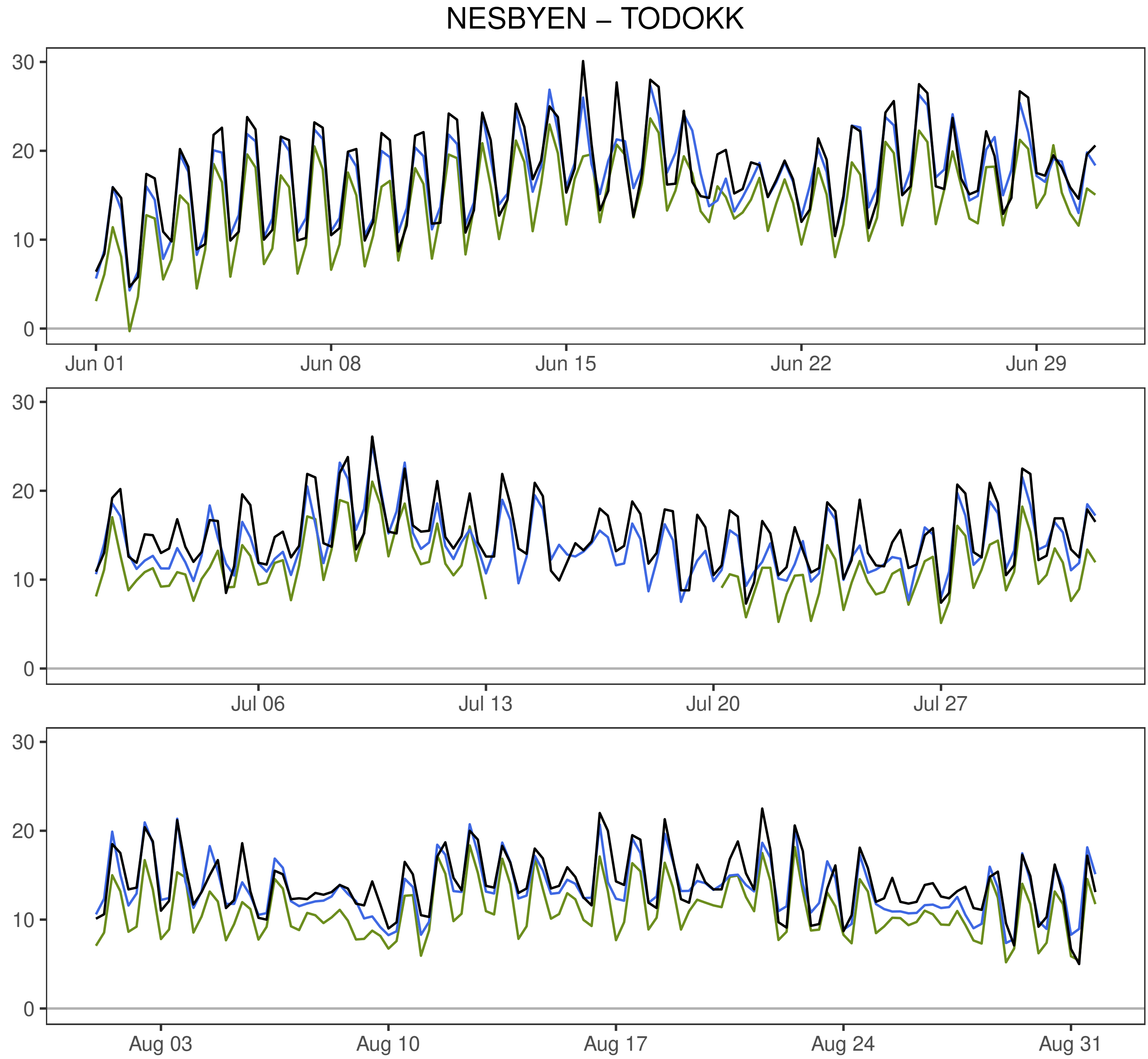
	Min	Mean	Max	Std	N
synop: 00,06,12,18	7.7	15.5	26.9	3.4	368
MEPSctrl: 12+18,+24,+30,+36	6.0	14.9	26.1	3.5	368
ECMWF: 12+18,+24,+30,+36	3.9	14.1	24.9	3.7	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	–0.6	1.4	1.5	1.2	5.4	340
ECMWF–synop	–1.5	1.3	2.0	1.7	5.0	340



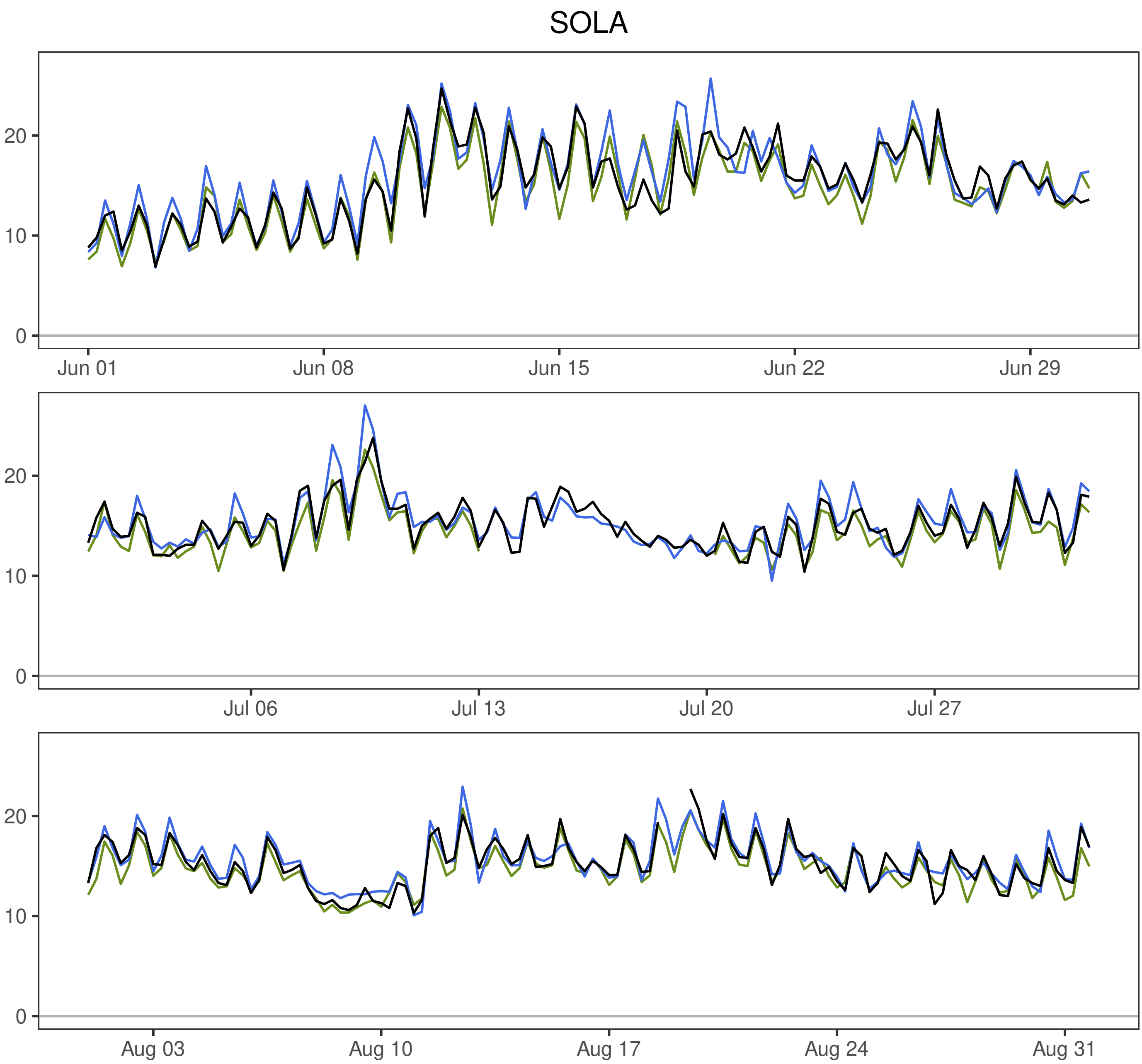
	Min	Mean	Max	Std	N
synop: 00,06,12,18	−2.4	8.0	19.1	3.2	363
MEPSctrl: 12+18,+24,+30,+36	−5.9	7.7	19.1	3.7	368
ECMWF: 12+18,+24,+30,+36	−4.8	7.1	15.8	3.2	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.3	1.6	1.6	1.3	5.9	335
ECMWF−synop	−1.1	2.0	2.3	1.9	6.8	335



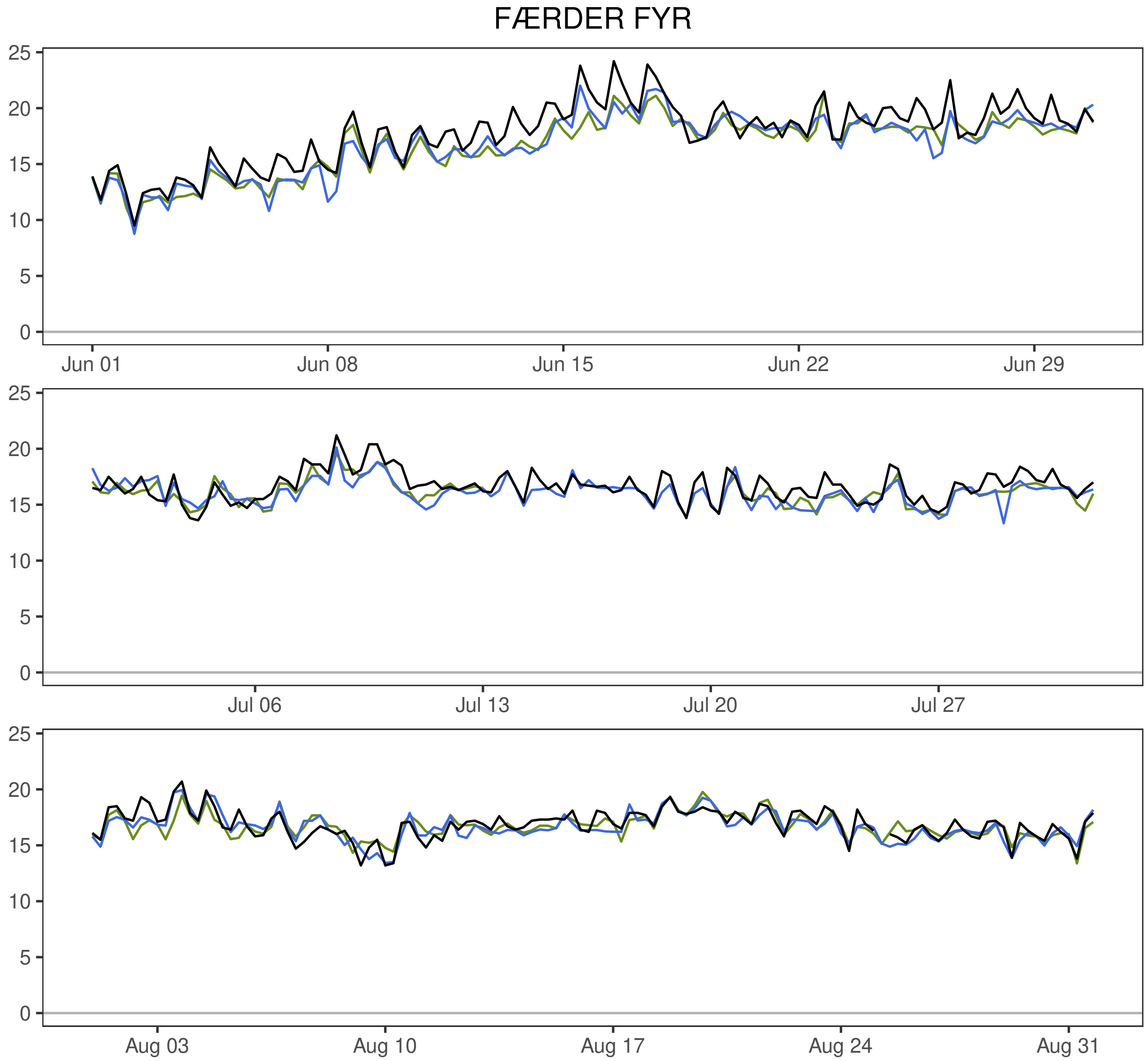
	Min	Mean	Max	Std	N
synop: 00,06,12,18	4.7	15.5	30.1	4.5	368
MEPSctrl: 12+18,+24,+30,+36	4.3	14.8	27.3	4.2	368
ECMWF: 12+18,+24,+30,+36	–0.3	12.3	23.6	4.1	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	–0.6	1.7	1.8	1.4	6.4	340
ECMWF–synop	–3.2	1.7	3.6	3.2	10.7	340



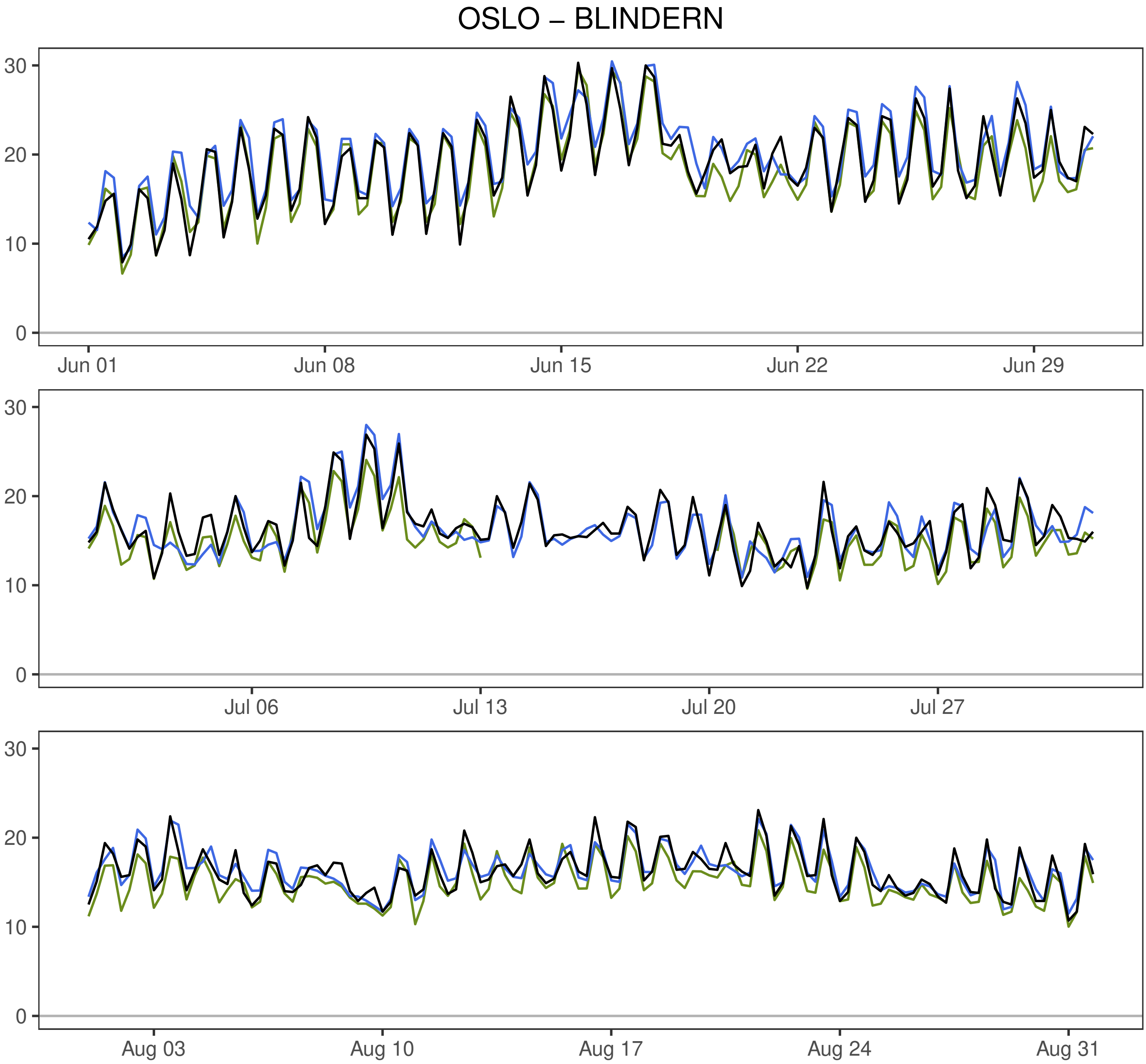
	Min	Mean	Max	Std	N
synop: 00,06,12,18	6.9	15.2	24.7	2.9	365
MEPSctrl: 12+18,+24,+30,+36	6.8	15.6	27.0	3.1	368
ECMWF: 12+18,+24,+30,+36	6.9	14.6	22.9	2.9	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.5	1.3	1.4	1.0	6.5	337
ECMWF−synop	−0.6	1.0	1.2	1.0	4.5	337



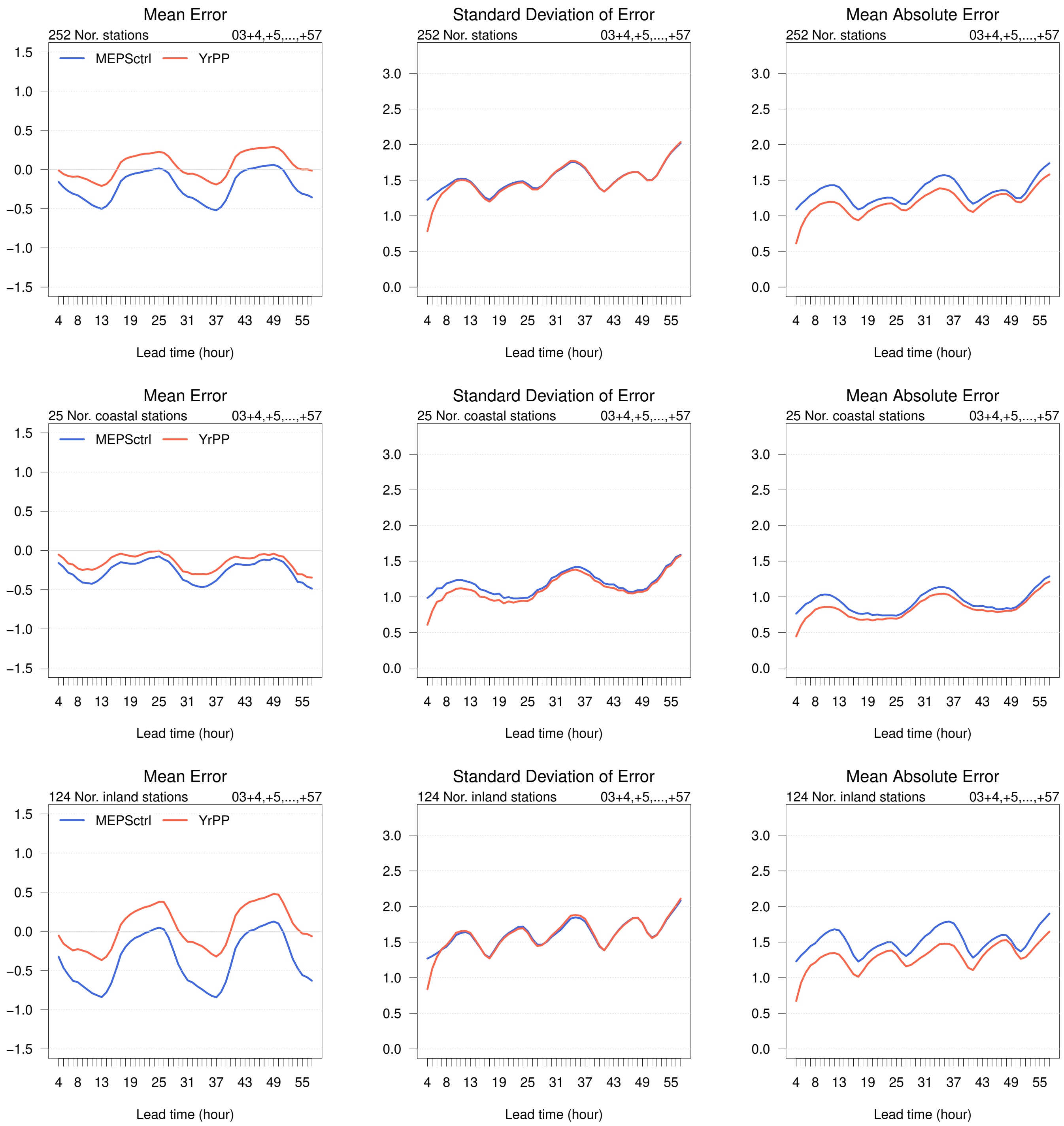
	Min	Mean	Max	Std	N
synop: 00,06,12,18	9.5	17.1	24.2	2.0	367
MEPSctrl: 12+18,+24,+30,+36	8.8	16.5	22.0	1.8	368
ECMWF: 12+18,+24,+30,+36	9.3	16.5	21.3	1.8	340

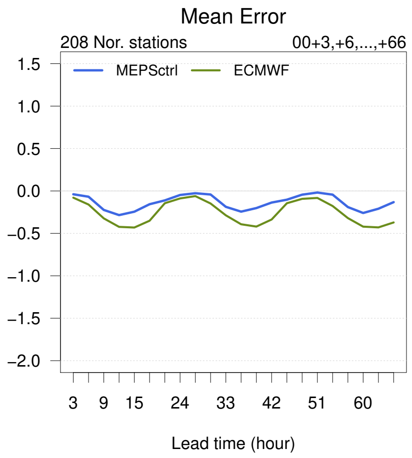
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	−0.6	1.0	1.2	0.9	3.8	339
ECMWF–synop	−0.6	1.0	1.2	0.9	5.5	339

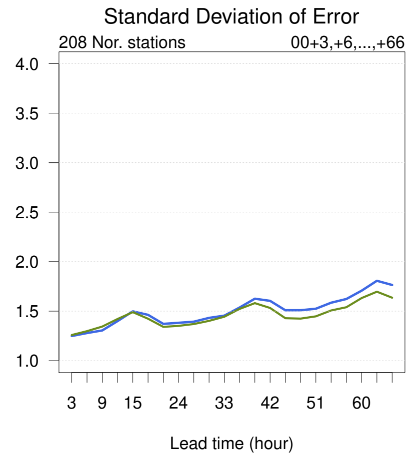


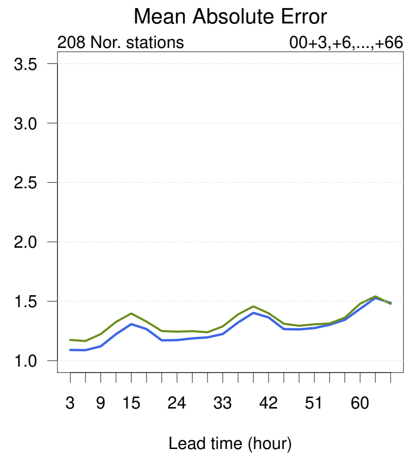
	Min	Mean	Max	Std	N
synop: 00,06,12,18	7.9	17.2	30.3	3.9	368
MEPSctrl: 12+18,+24,+30,+36	8.5	17.6	30.5	3.9	368
ECMWF: 12+18,+24,+30,+36	6.6	16.3	29.5	3.8	340

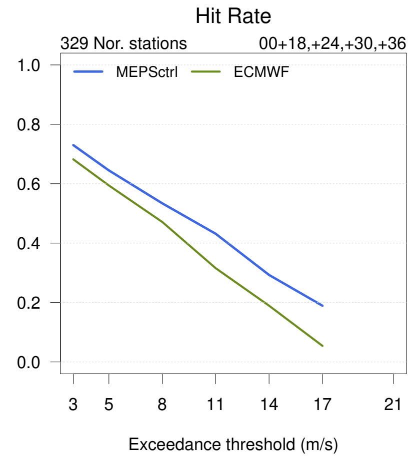
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	0.5	1.6	1.7	1.2	6.3	340
ECMWF–synop	–1.0	1.3	1.6	1.3	4.5	340

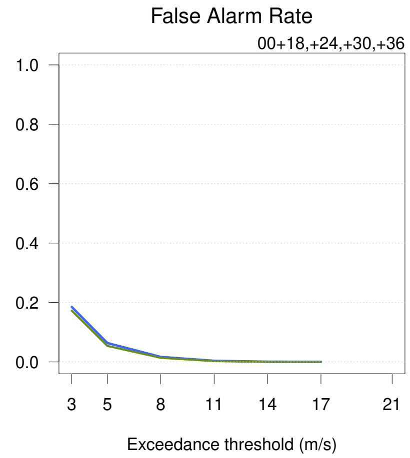

Mean Error
252 Nor. stations
03+4,+5,...,+57
MEPSctrl
YrPP
Lead time (hour)
Standard Deviation of Error
252 Nor. stations
03+4,+5,...,+57
Lead time (hour)
Mean Absolute Error
252 Nor. stations
03+4,+5,...,+57
Lead time (hour)
Mean Error
25 Nor. coastal stations
03+4,+5,...,+57
MEPSctrl
YrPP
Lead time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

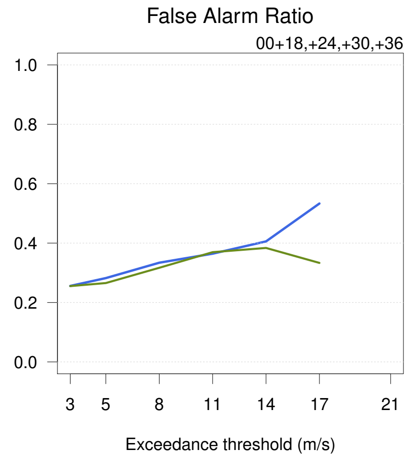

Mean Error
208 Nor. stations
00+3,+6,...,+66
MEPSctrl
ECMWF
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
3 9 15 24 33 42 51 60
Lead time (hour)

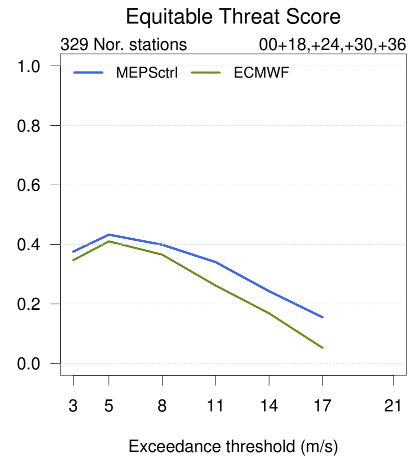

Standard Deviation of Error
208 Nor. stations
00+3,+6,...,+66
4.0
3.5
3.0
2.5
2.0
1.5
1.0
3 9 15 24 33 42 51 60
Lead time (hour)

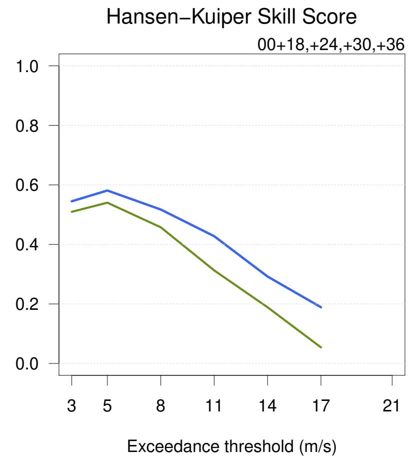

Mean Absolute Error
208 Nor. stations
00+3,+6,...,+66
3.5
3.0
2.5
2.0
1.5
1.0
3 9 15 24 33 42 51 60
Lead time (hour)

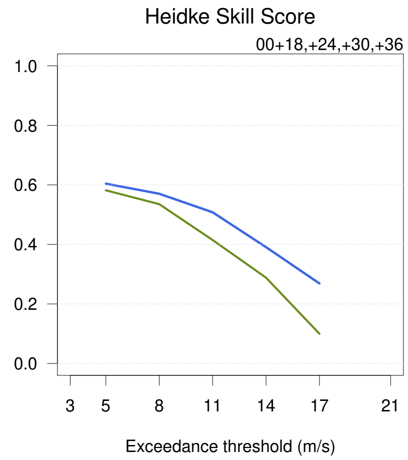

Hit Rate
329 Nor. stations
00+18,+24,+30,+36
MEPSctrl
ECMWF
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

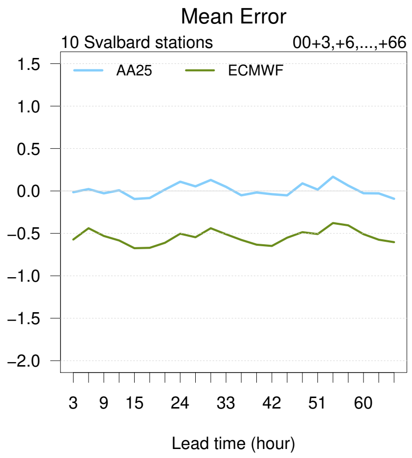

False Alarm Rate
00+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

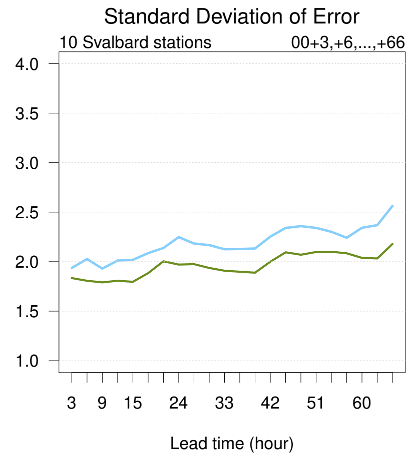

False Alarm Ratio
00+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

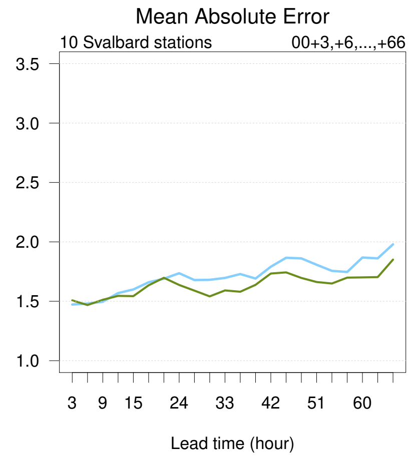

Equitable Threat Score
329 Nor. stations
00+18,+24,+30,+36
MEPSctrl
ECMWF
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

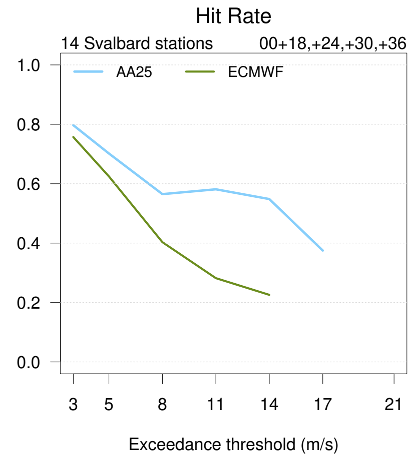

Hansen−Kuiper Skill Score
00+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

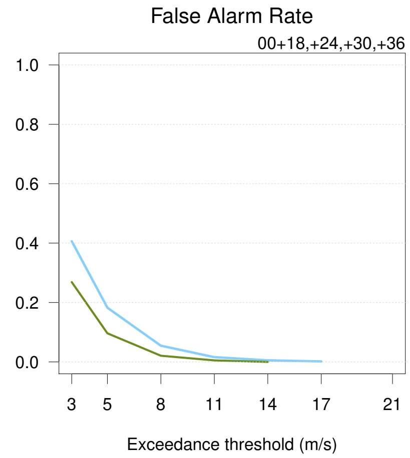

Heidke Skill Score
00+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

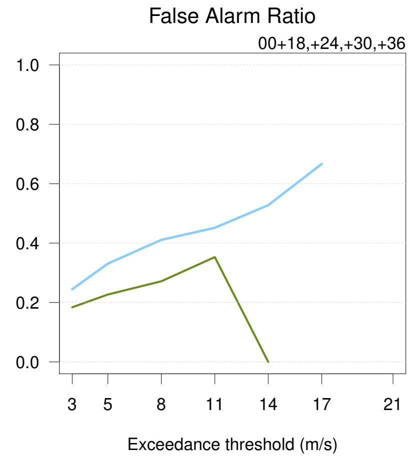

Mean Error
10 Svalbard stations
00+3,+6,...,+66
AA25
ECMWF
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
3 9 15 24 33 42 51 60
Lead time (hour)

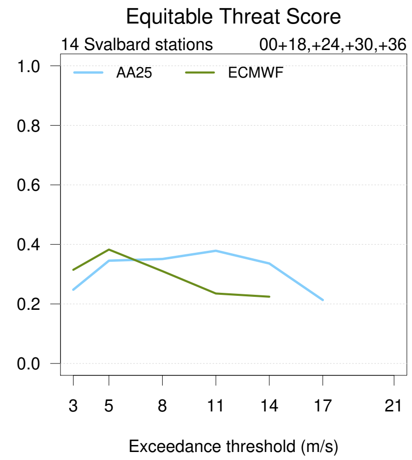

Standard Deviation of Error
10 Svalbard stations
00+3,+6,...,+66
4.0
3.5
3.0
2.5
2.0
1.5
1.0
3 9 15 24 33 42 51 60
Lead time (hour)

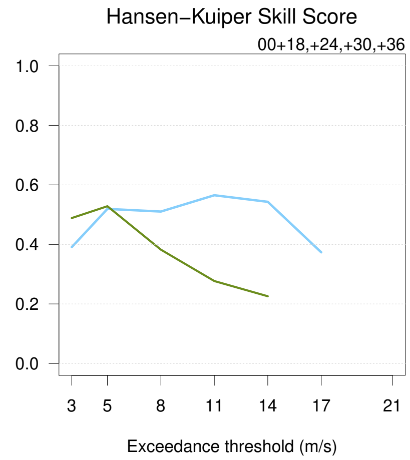

Mean Absolute Error
10 Svalbard stations
00+3,+6,...,+66
3.5
3.0
2.5
2.0
1.5
1.0
3 9 15 24 33 42 51 60
Lead time (hour)

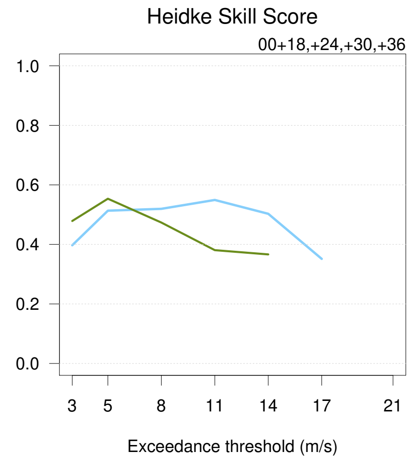

Hit Rate
14 Svalbard stations
00+18,+24,+30,+36
AA25
ECMWF
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

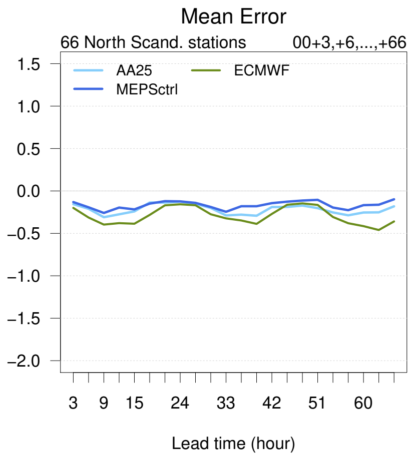

False Alarm Rate
00+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

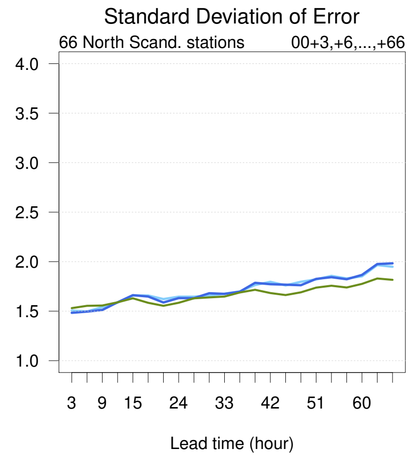

False Alarm Ratio
00+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

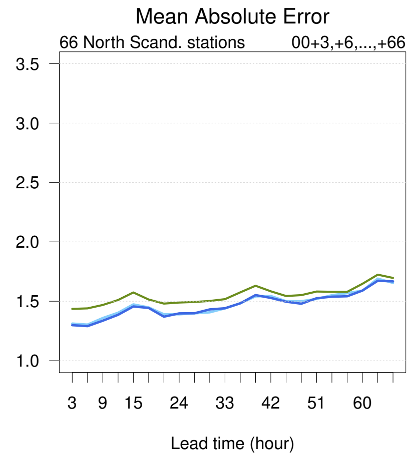

Equitable Threat Score
14 Svalbard stations
00+18,+24,+30,+36
AA25
ECMWF
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

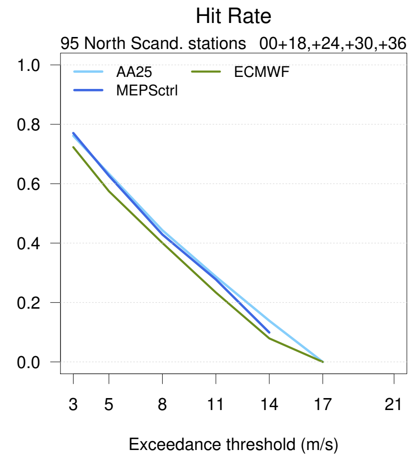

Hansen−Kuiper Skill Score
00+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

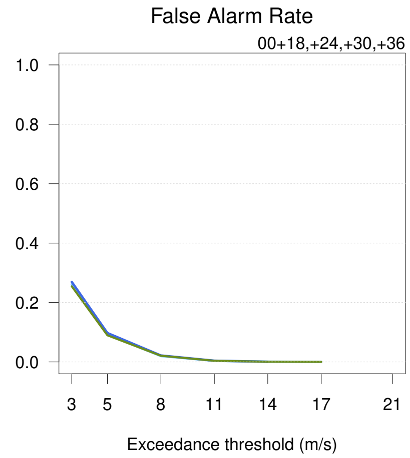

Heidke Skill Score
00+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

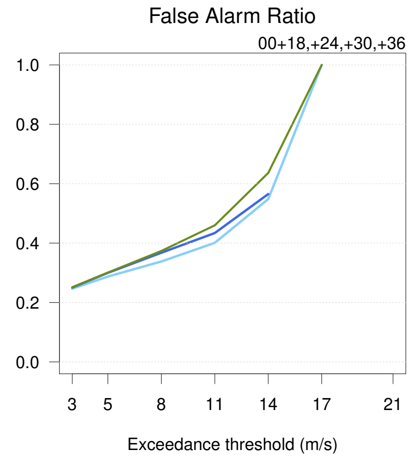

Mean Error
66 North Scand. stations
00+3,+6,...,+66
AA25
MEPSctrl
ECMWF
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
3 9 15 24 33 42 51 60
Lead time (hour)

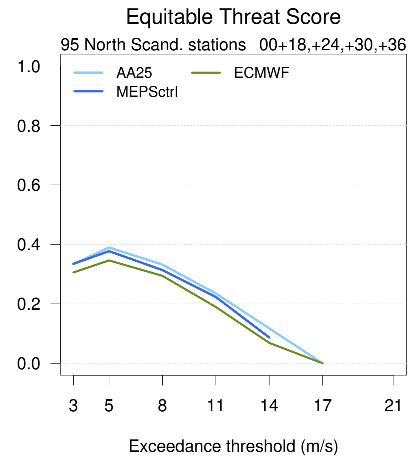

Standard Deviation of Error
66 North Scand. stations
00+3,+6,...,+66
4.0
3.5
3.0
2.5
2.0
1.5
1.0
3 9 15 24 33 42 51 60
Lead time (hour)

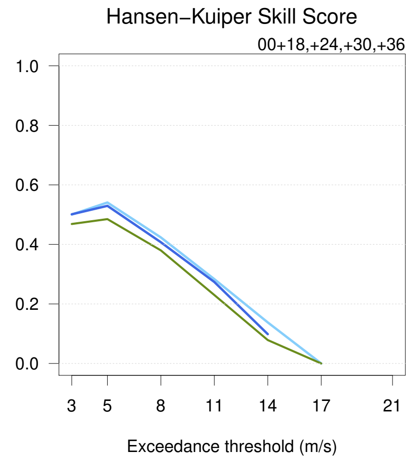

Mean Absolute Error
66 North Scand. stations
00+3,+6,...,+66
3.5
3.0
2.5
2.0
1.5
1.0
3 9 15 24 33 42 51 60
Lead time (hour)

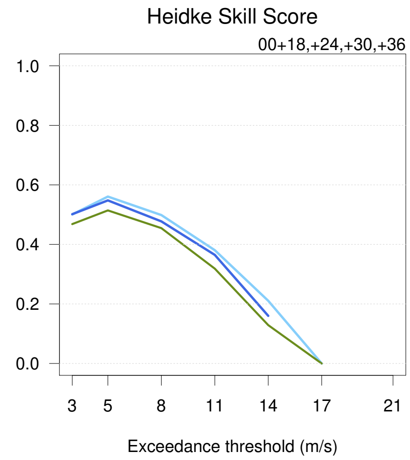

Hit Rate
95 North Scand. stations
00+18,+24,+30,+36
AA25
MEPSctrl
ECMWF
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)


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

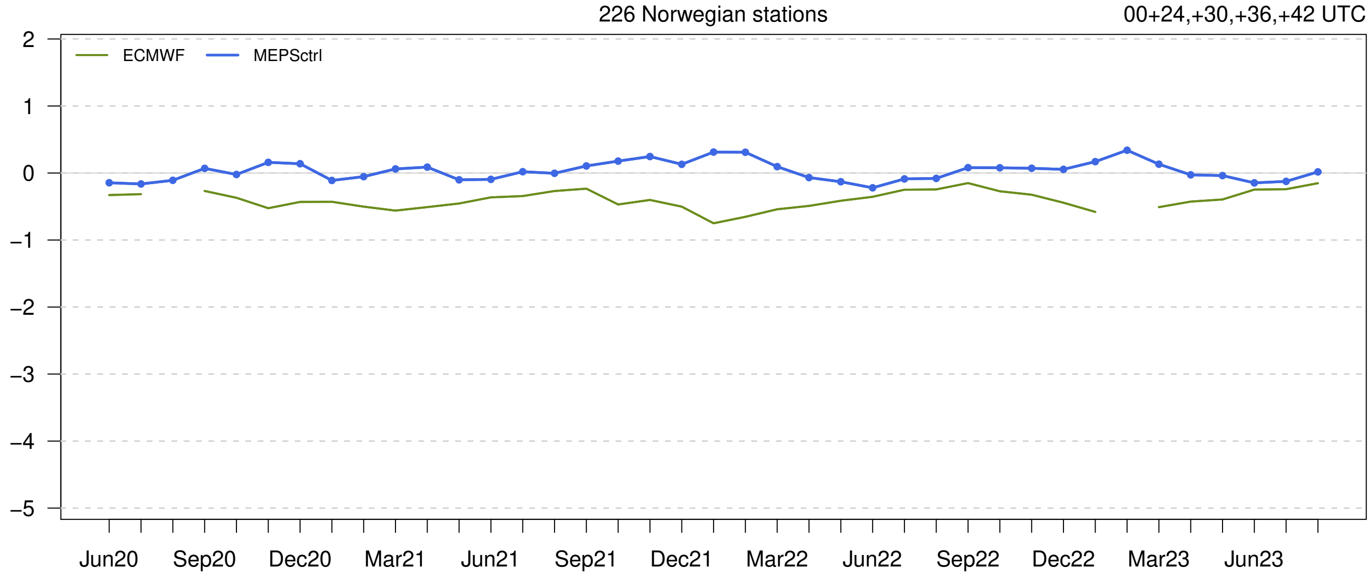

False Alarm Ratio
00+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

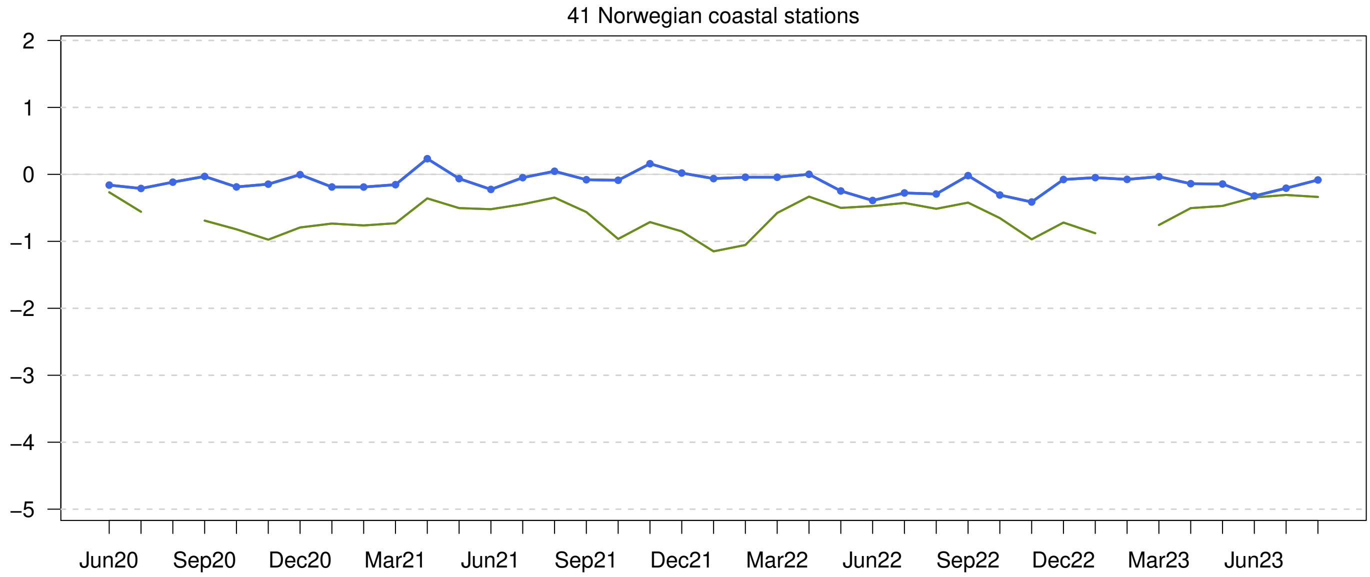

Equitable Threat Score
95 North Scand. stations
00+18,+24,+30,+36
AA25
MEPSctrl
ECMWF
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

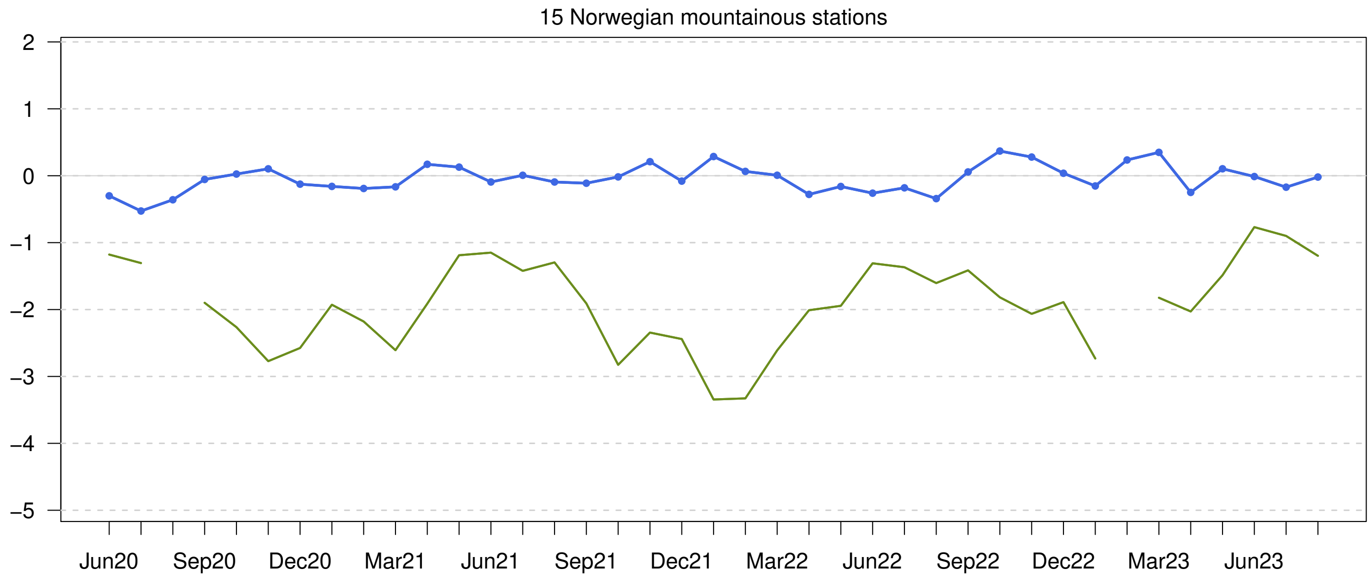

Hansen−Kuiper Skill Score
00+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)


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

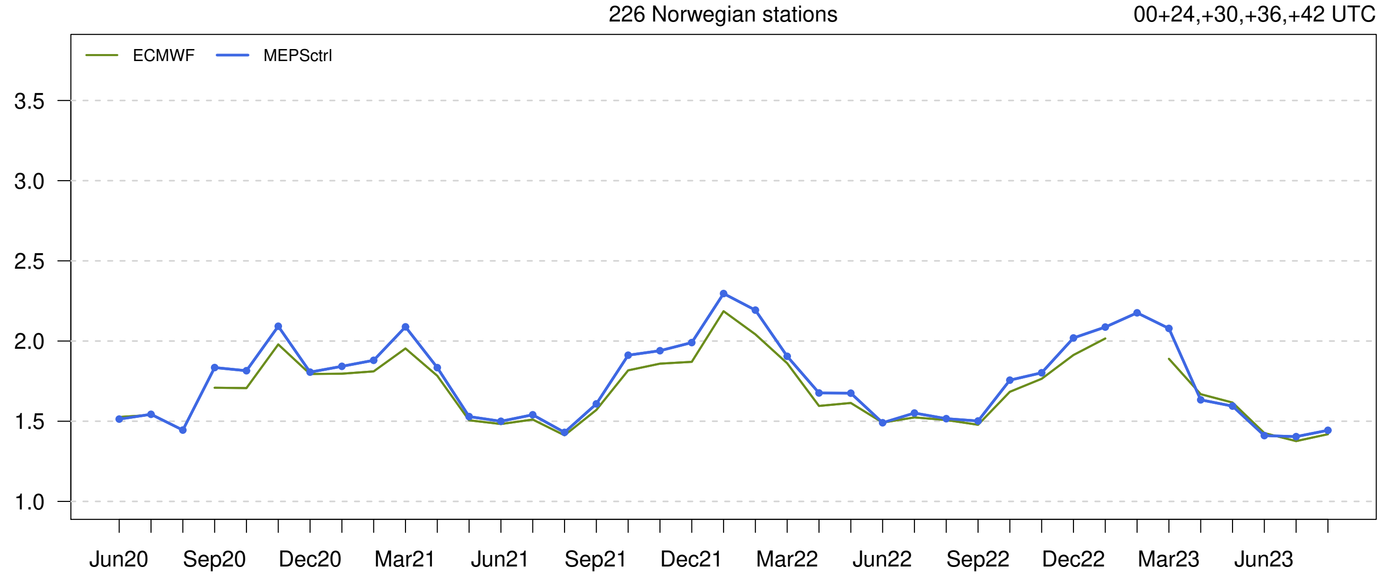
Mean Error

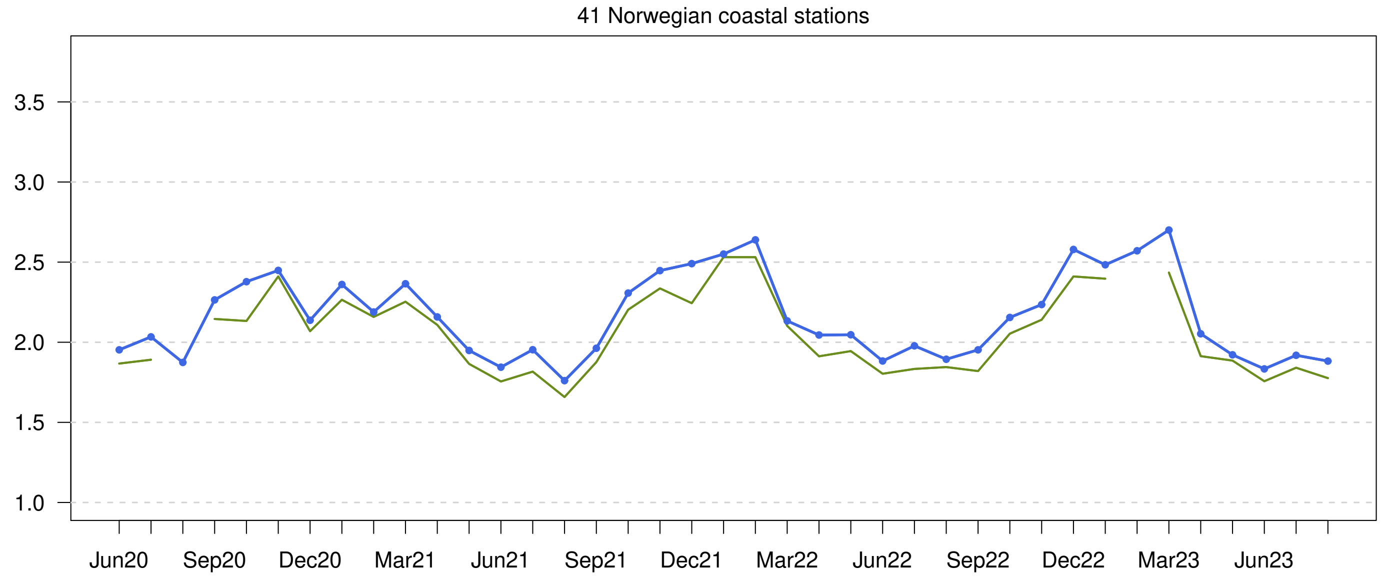

226 Norwegian stations
00+24,+30,+36,+42 UTC
ECMWF
MEPSctrl
2
1
0
−1
−2
−3
−4
−5
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23

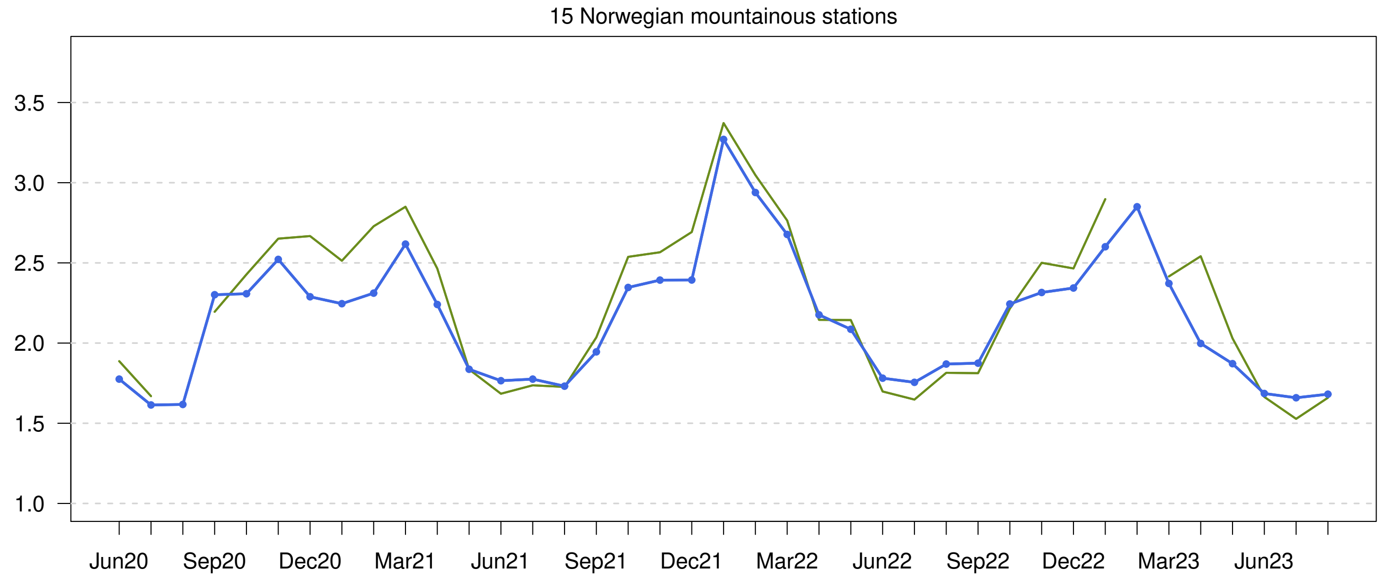

41 Norwegian coastal stations
2
1
0
−1
−2
−3
−4
−5
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23


15 Norwegian mountainous stations
2
1
0
−1
−2
−3
−4
−5
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23

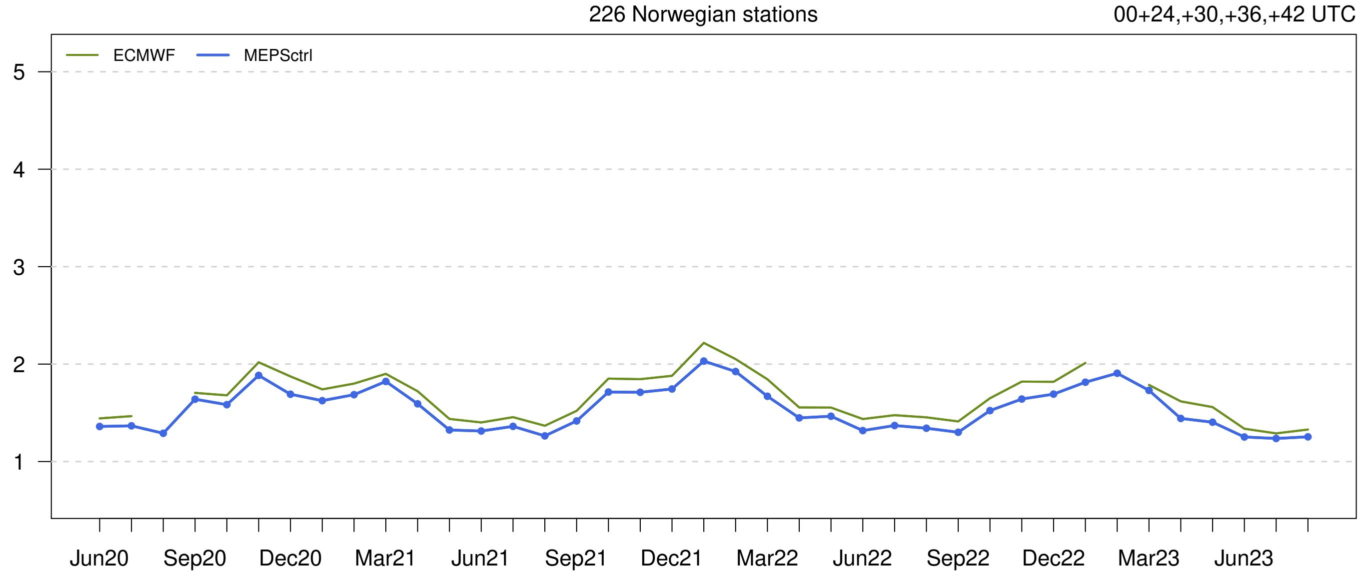
Standard Deviation of Error

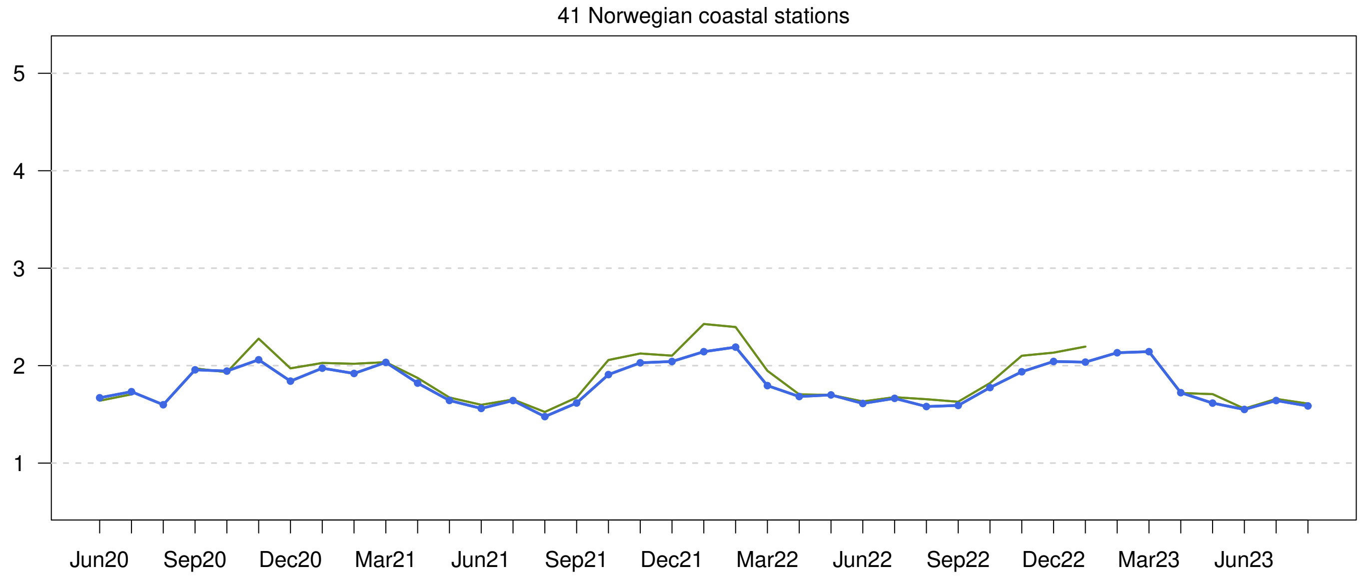


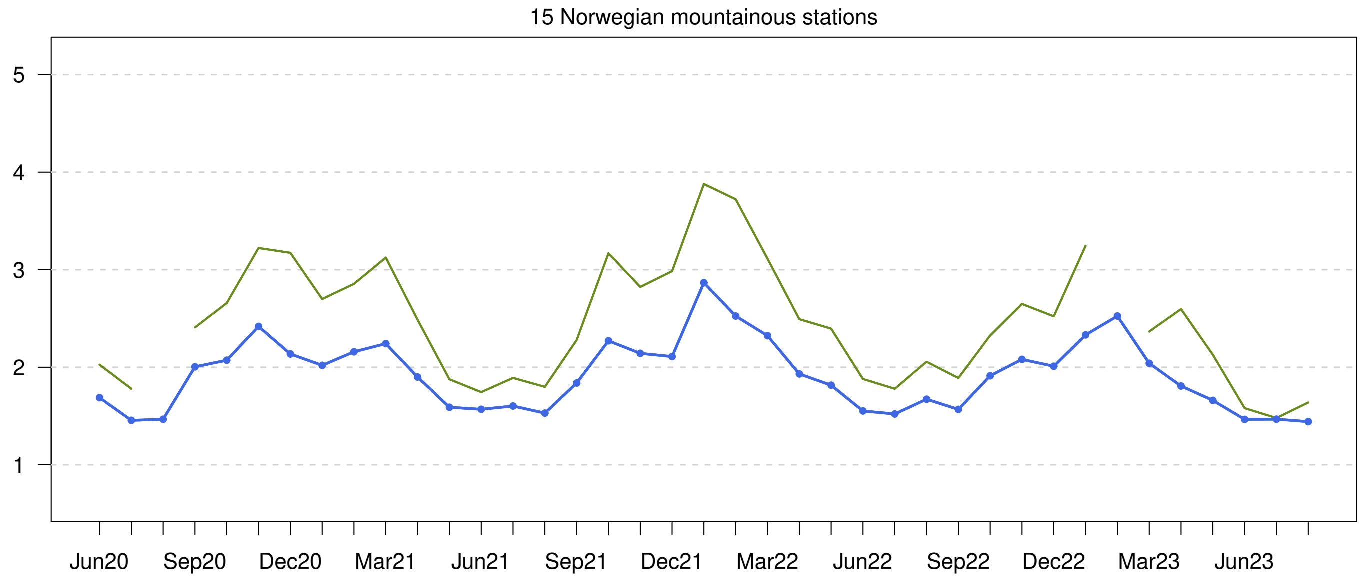


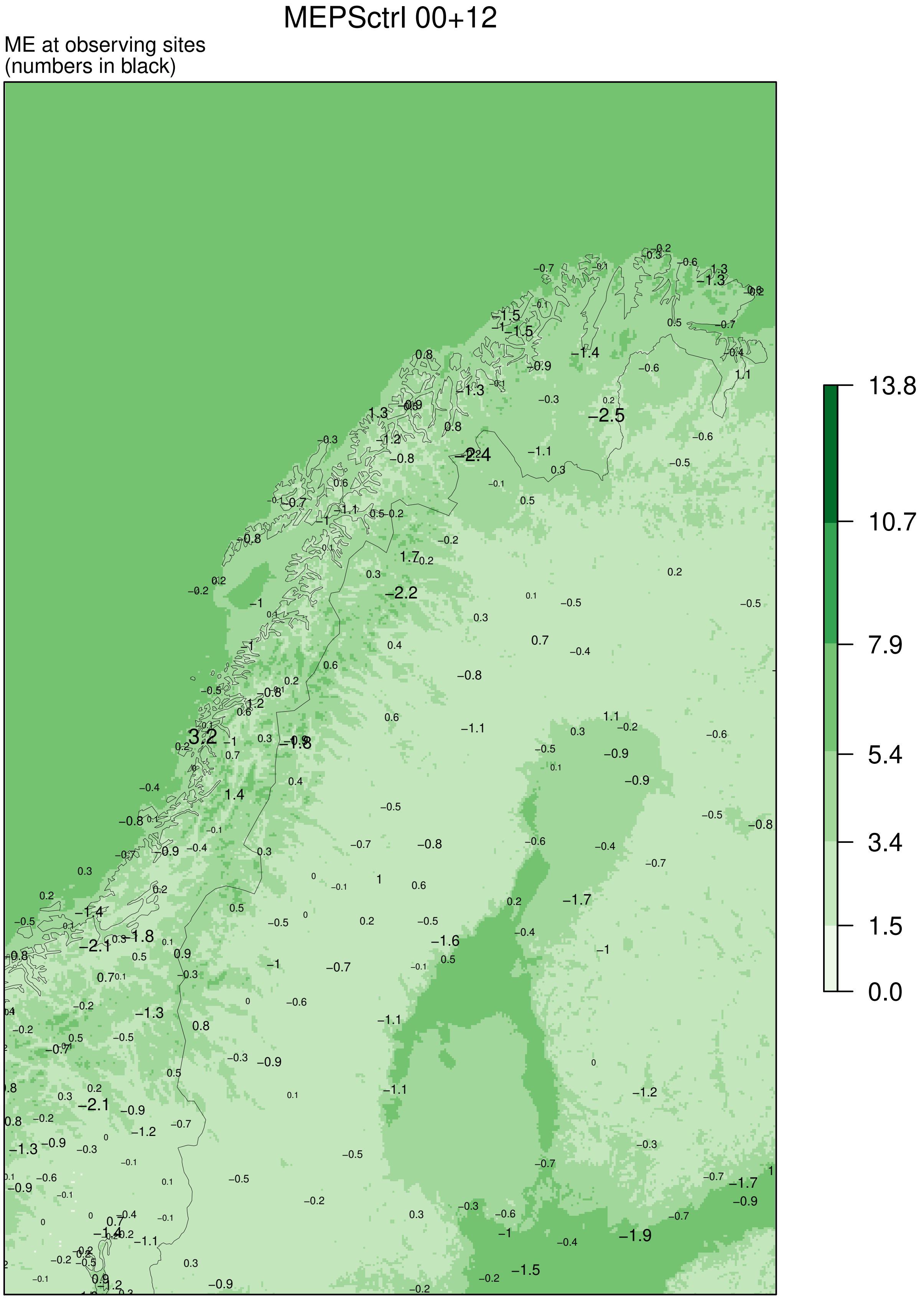


Mean Absolute Error





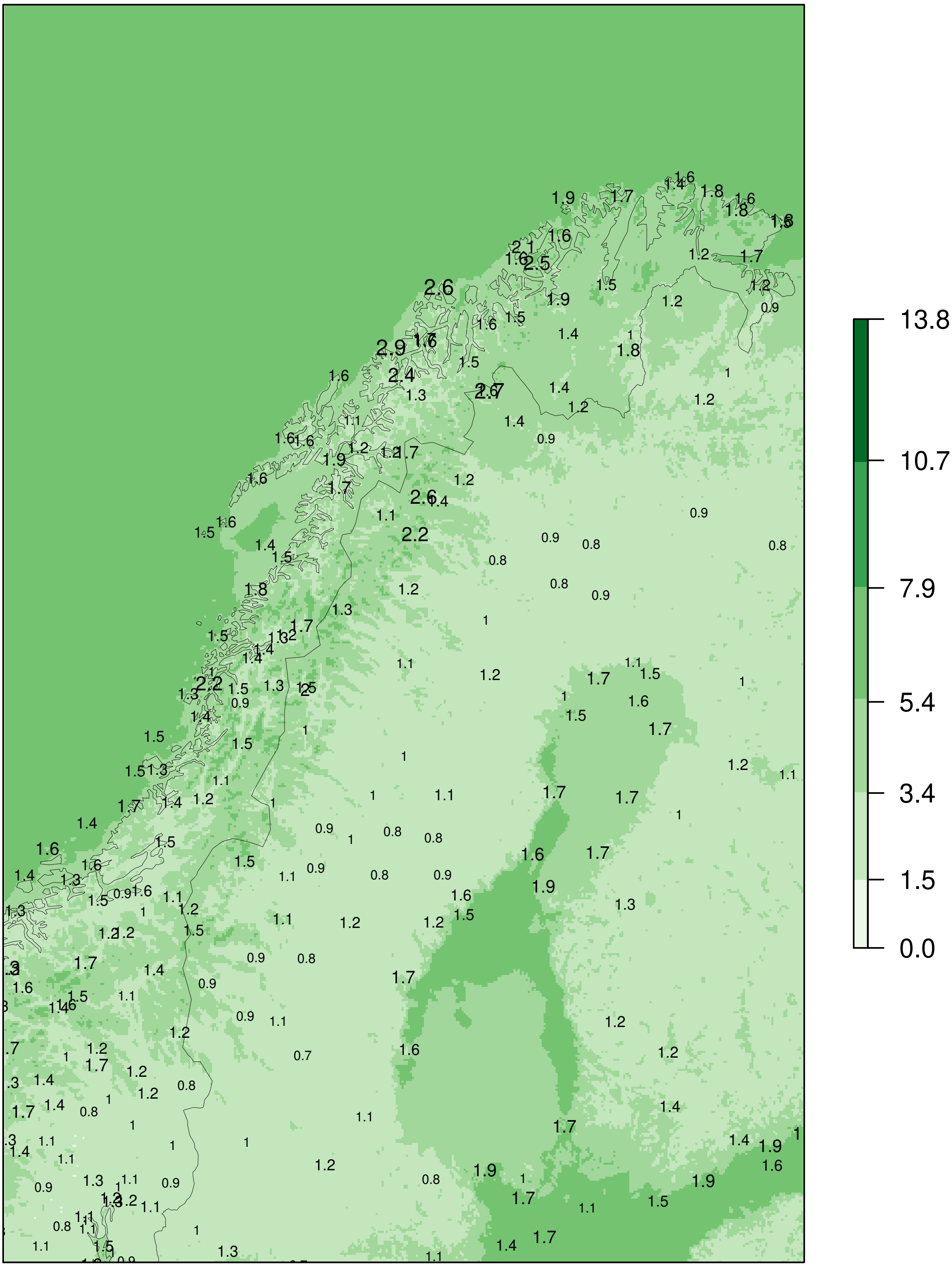




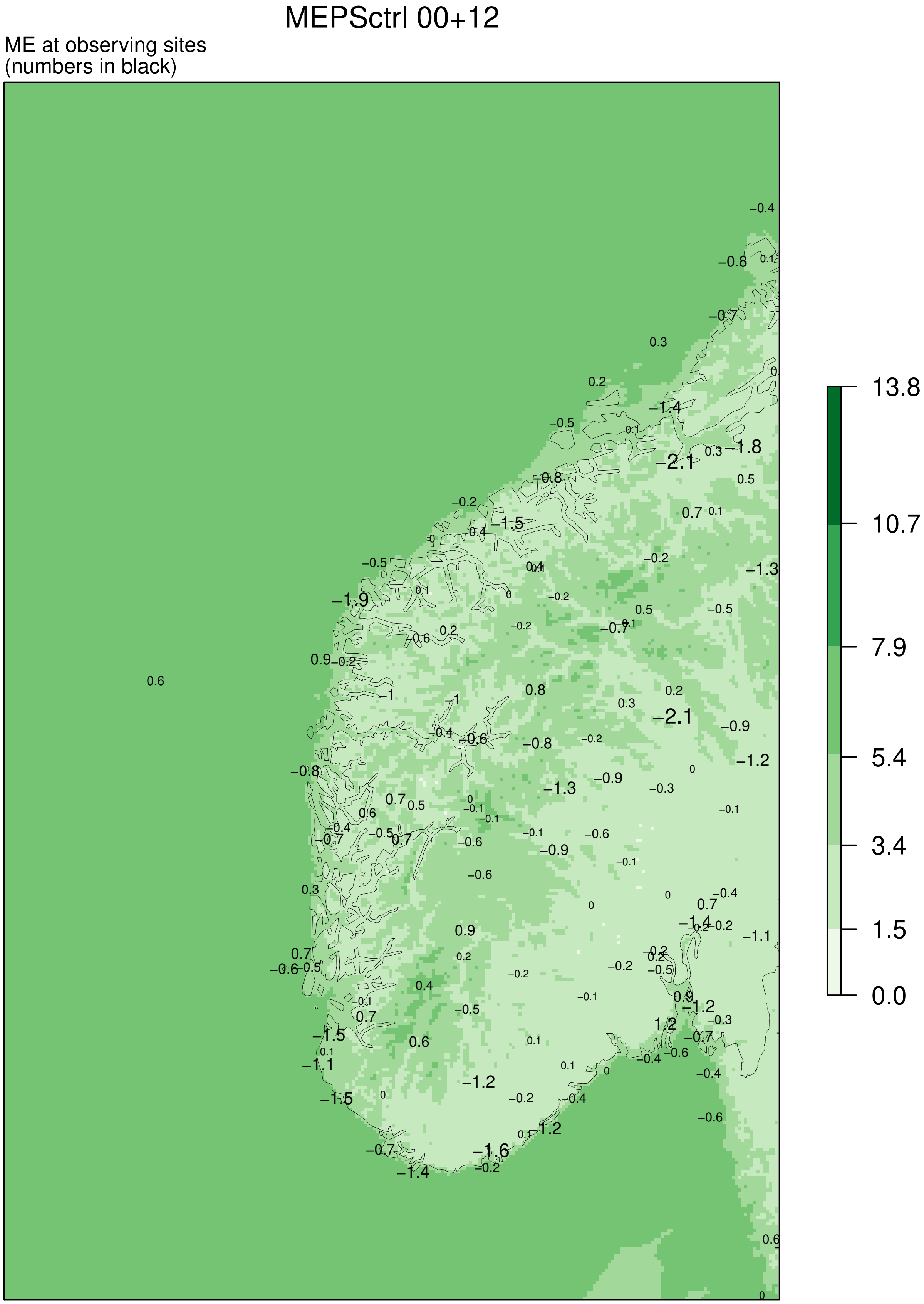
Model "climatology" 01.06.2023 – 31.08.2023

MEPSctrl 00+12

SDE at observing sites
(numbers in black)



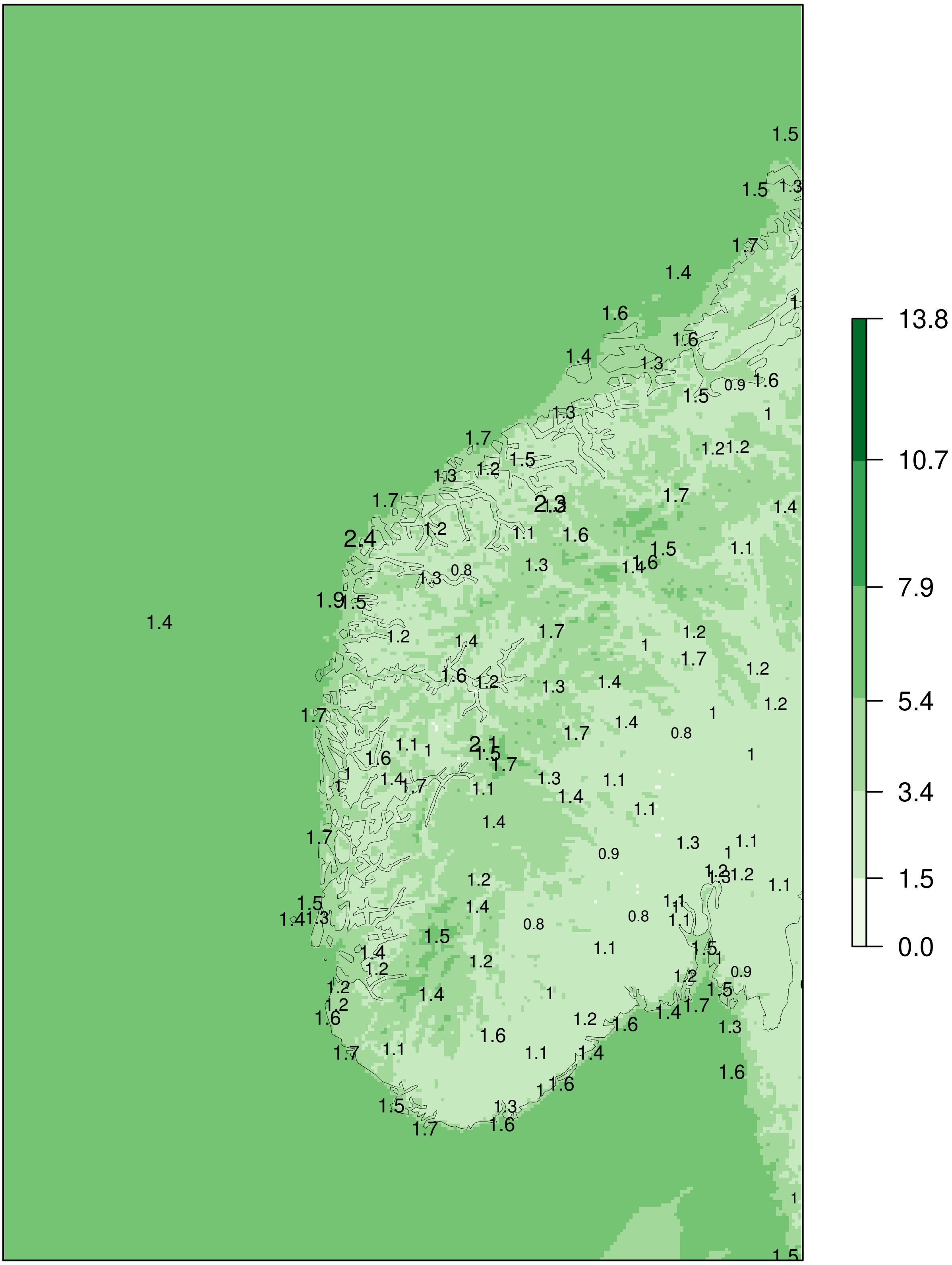
Model "climatology" 01.06.2023 – 31.08.2023



Model "climatology" 01.06.2023 – 31.08.2023

MEPSctrl 00+12

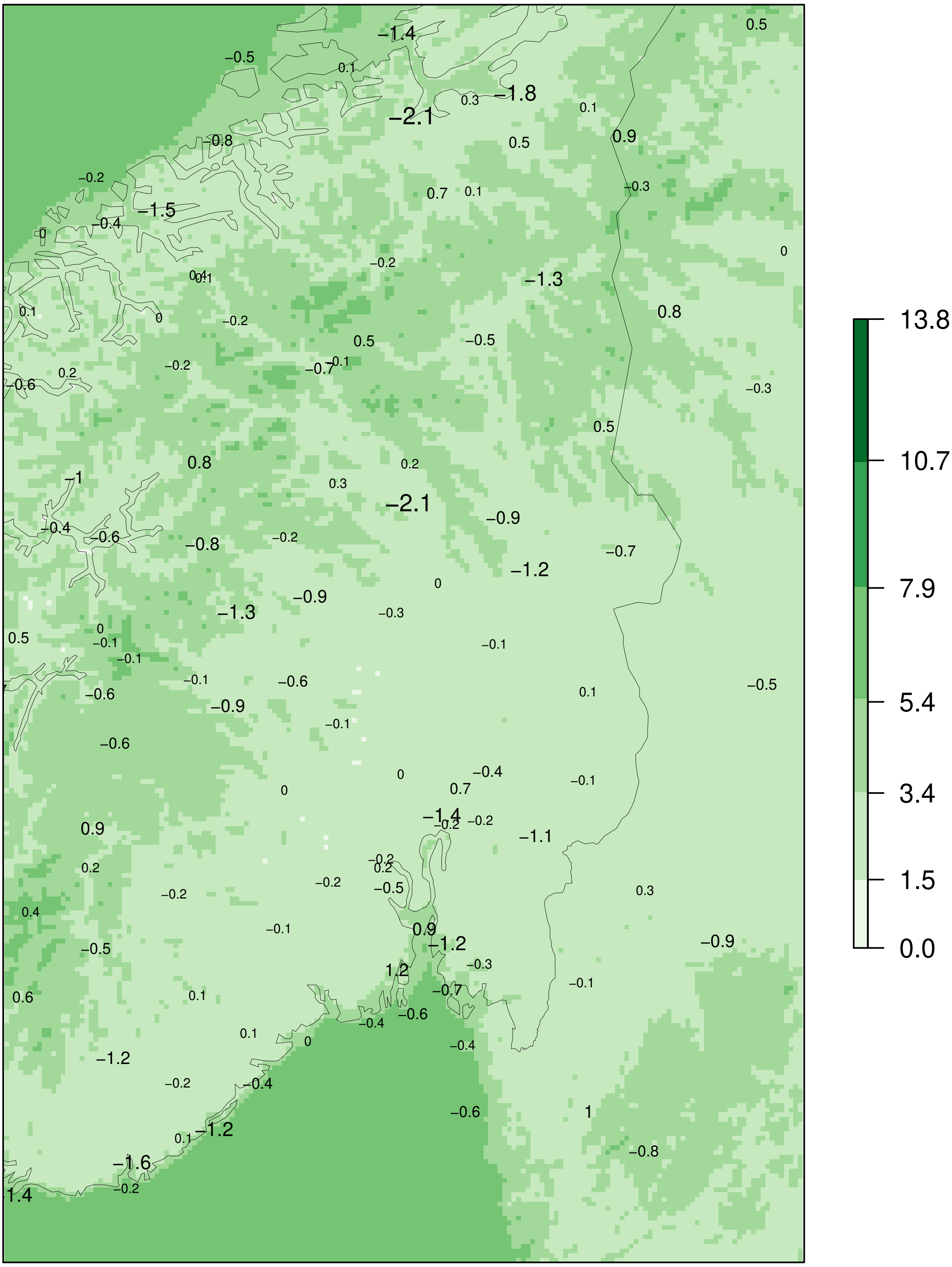
SDE at observing sites
(numbers in black)



Model "climatology" 01.06.2023 – 31.08.2023

MEPSctrl 00+12

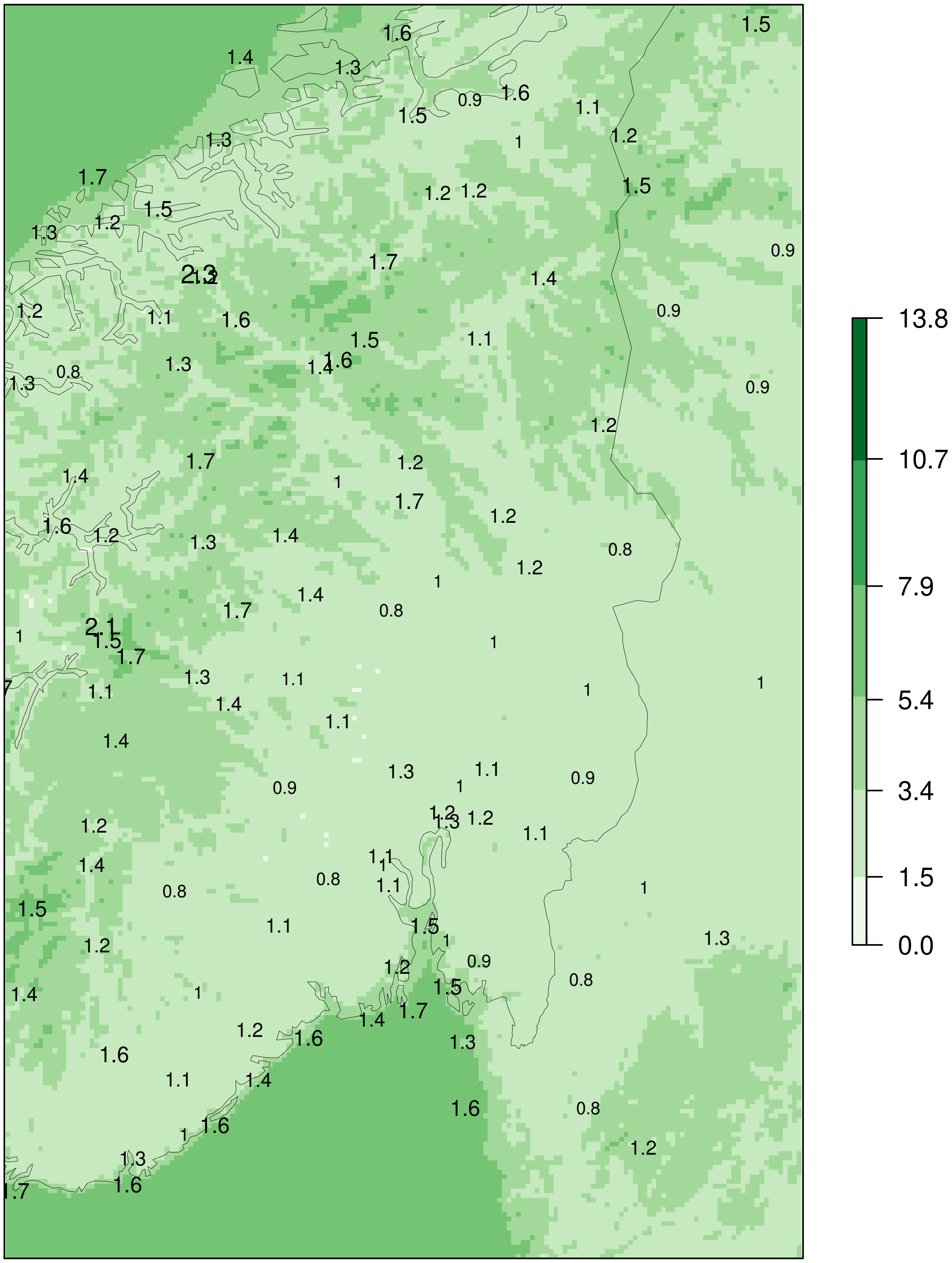
ME at observing sites
(numbers in black)



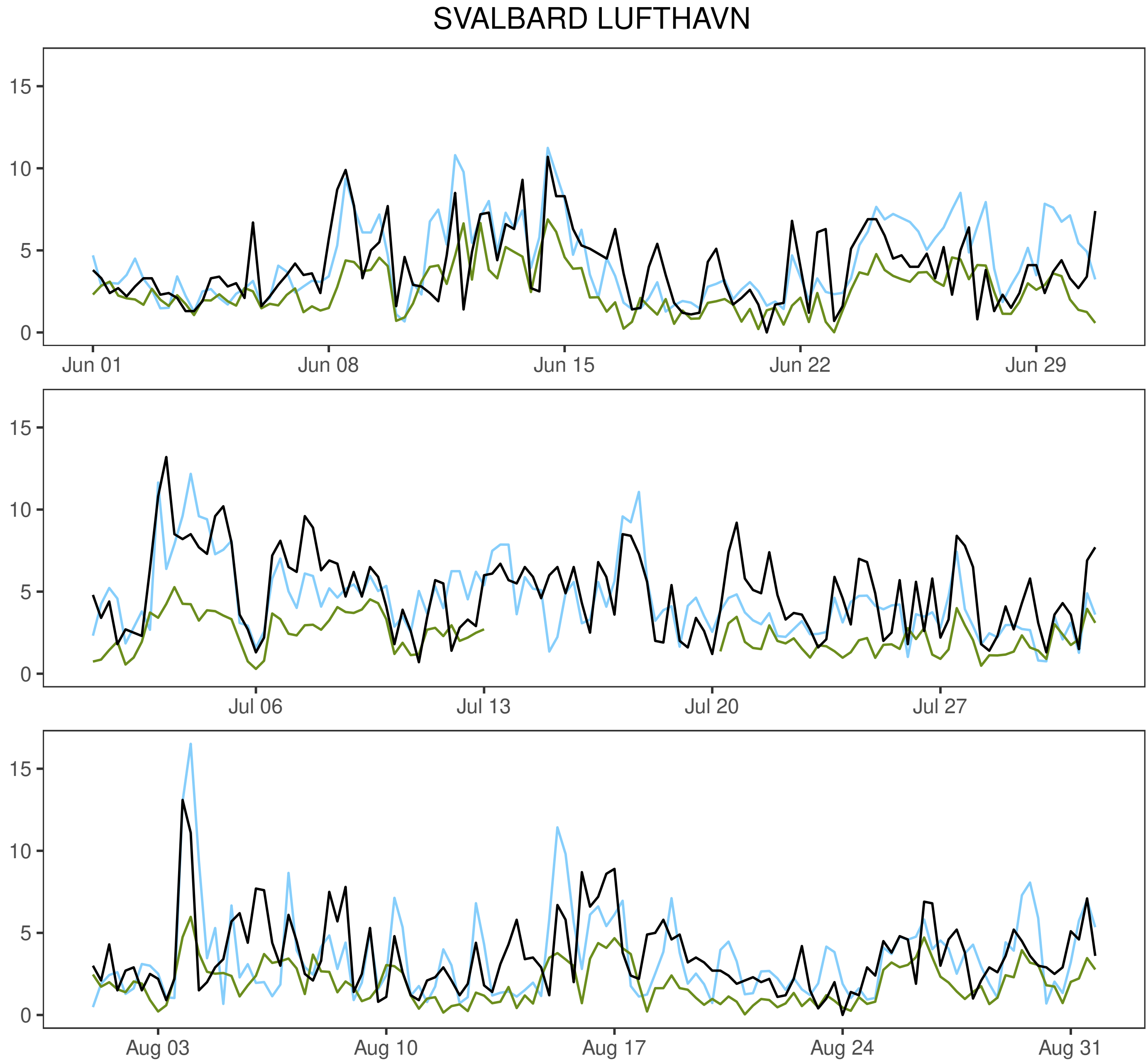
Model "climatology"   01.06.2023 – 31.08.2023

MEPSctrl 00+12

SDE at observing sites
(numbers in black)

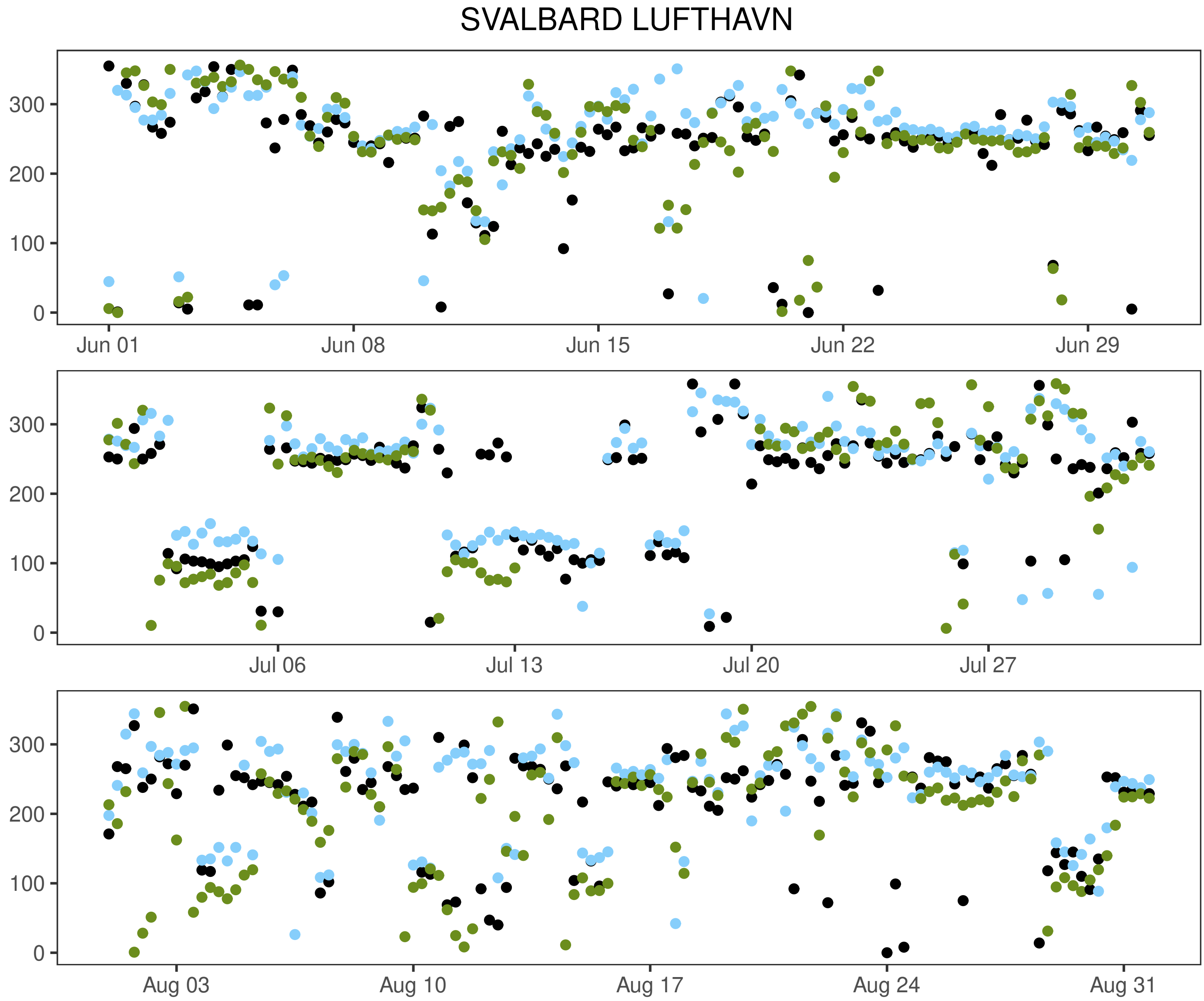


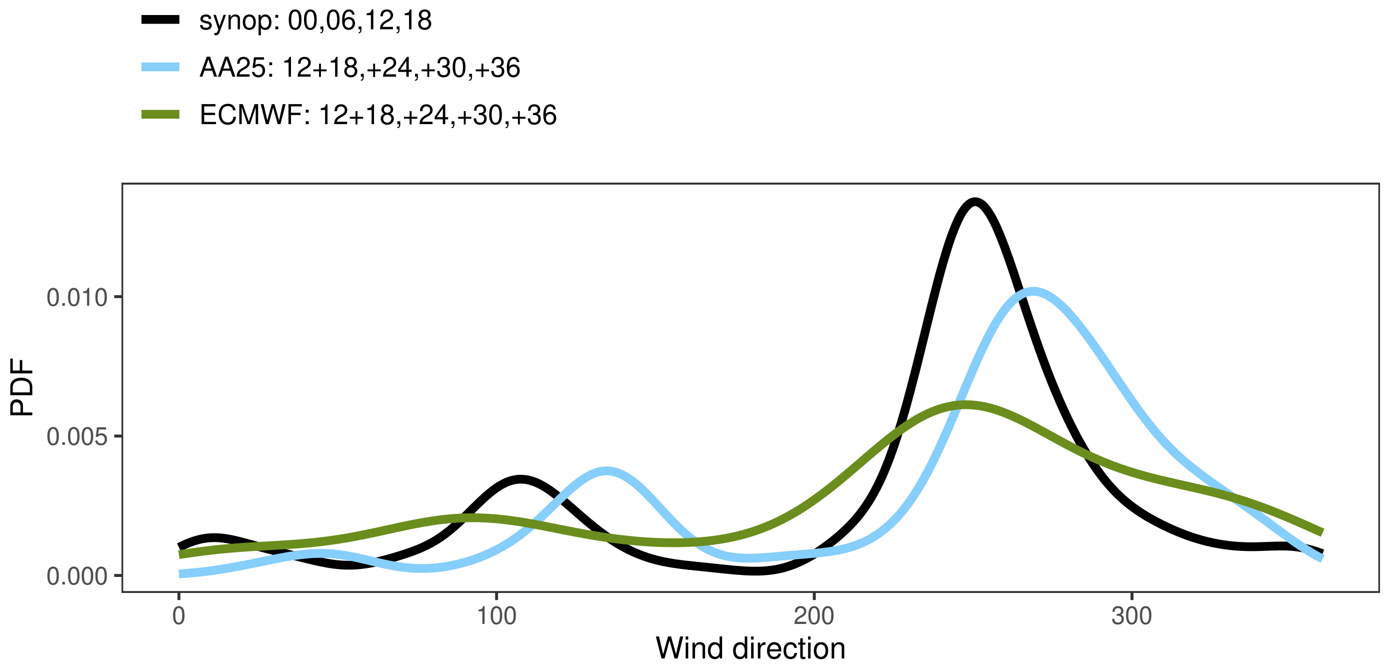
Model "climatology" 01.06.2023 – 31.08.2023

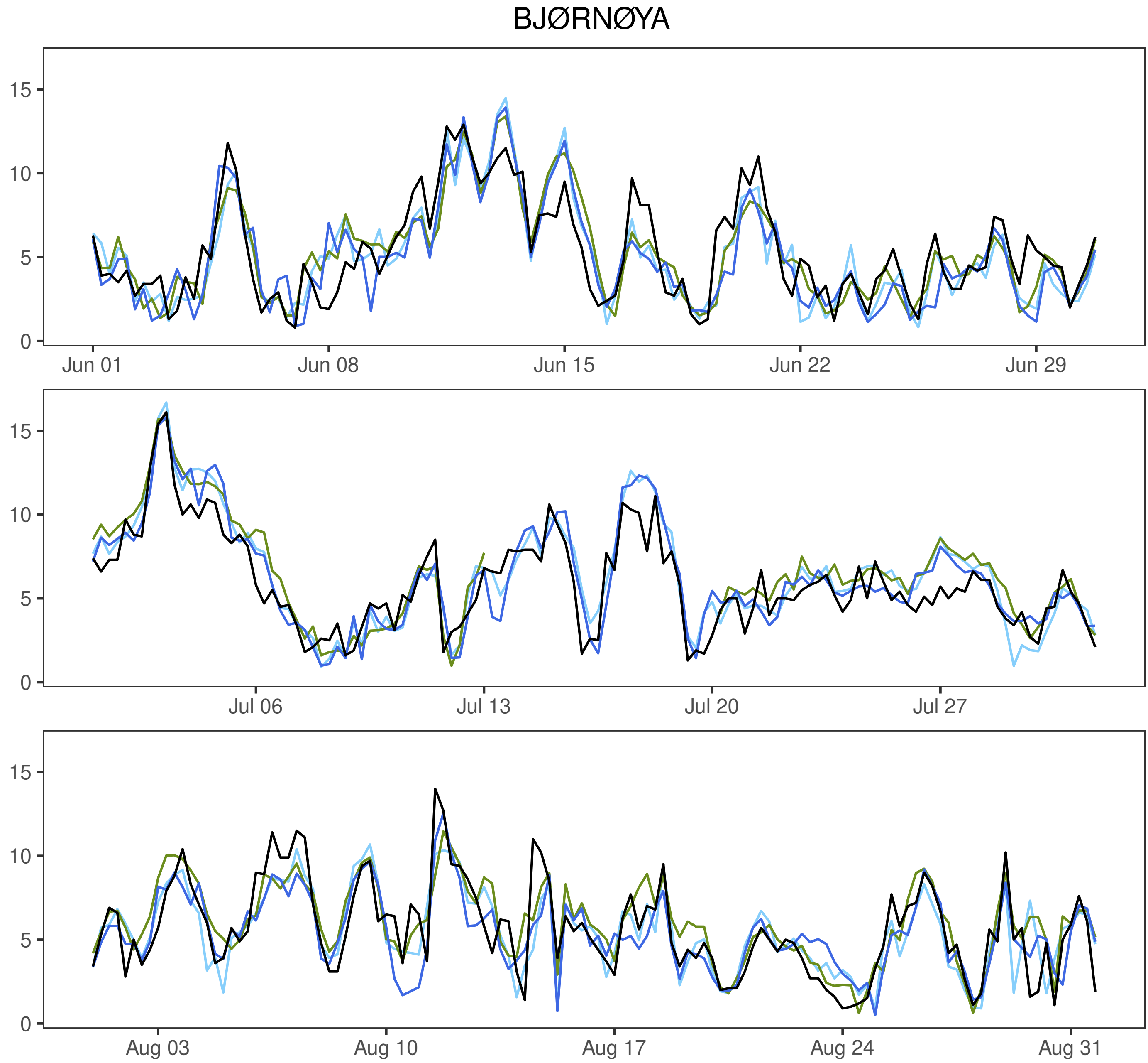


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	4.2	13.2	2.4	368
AA25: 12+18,+24,+30,+36	0.5	4.1	16.5	2.5	368
ECMWF: 12+18,+24,+30,+36	0.0	2.3	6.9	1.3	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
AA25−synop	−0.1	2.2	2.2	1.6	8.4	340
ECMWF−synop	−1.8	2.0	2.7	2.1	9.0	340

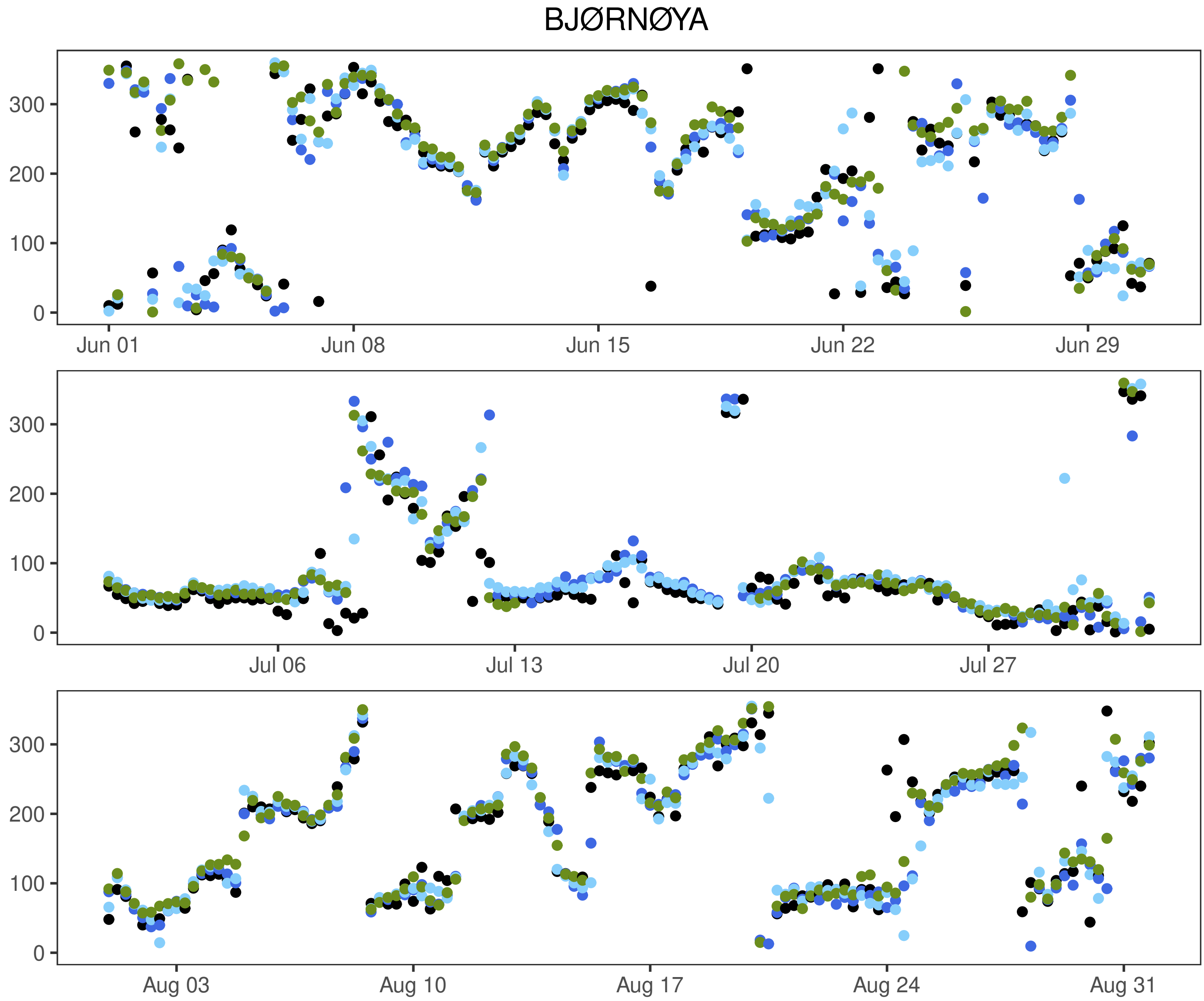

SVALBARD LUFTHAVN
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31

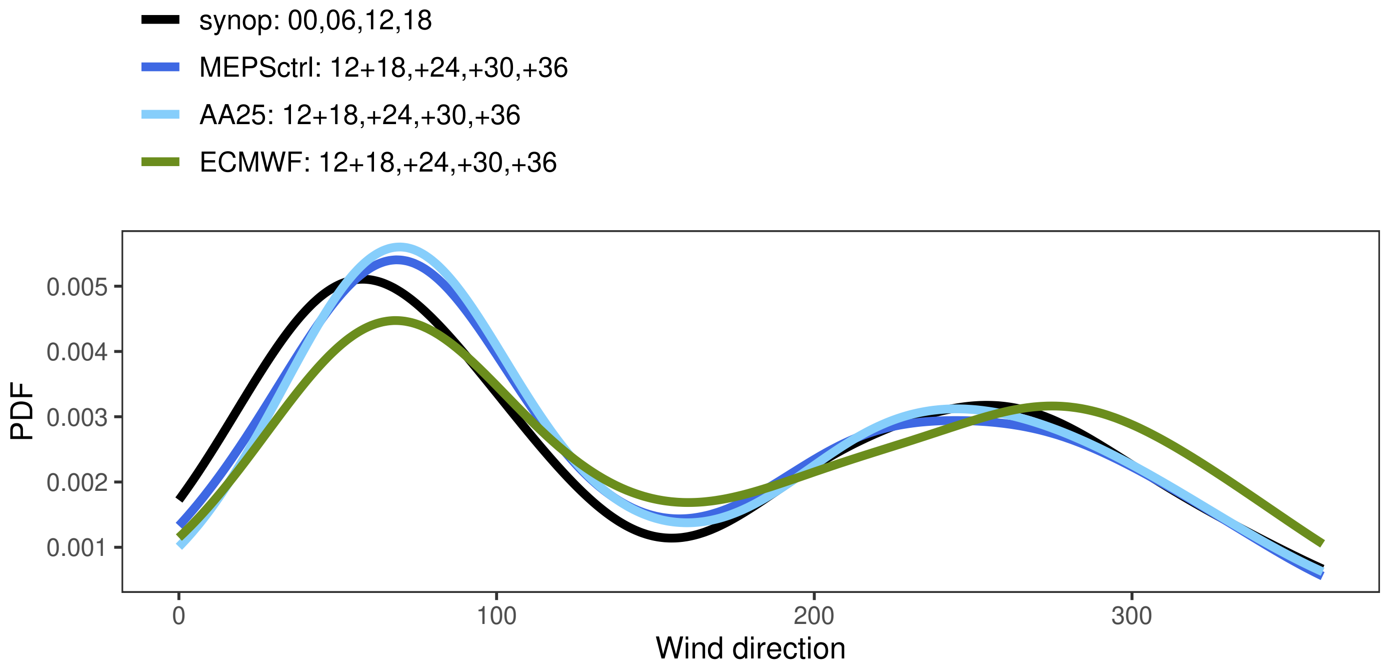

synop: 00,06,12,18
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.010
0.005
0.000
0
100
200
300
Wind direction

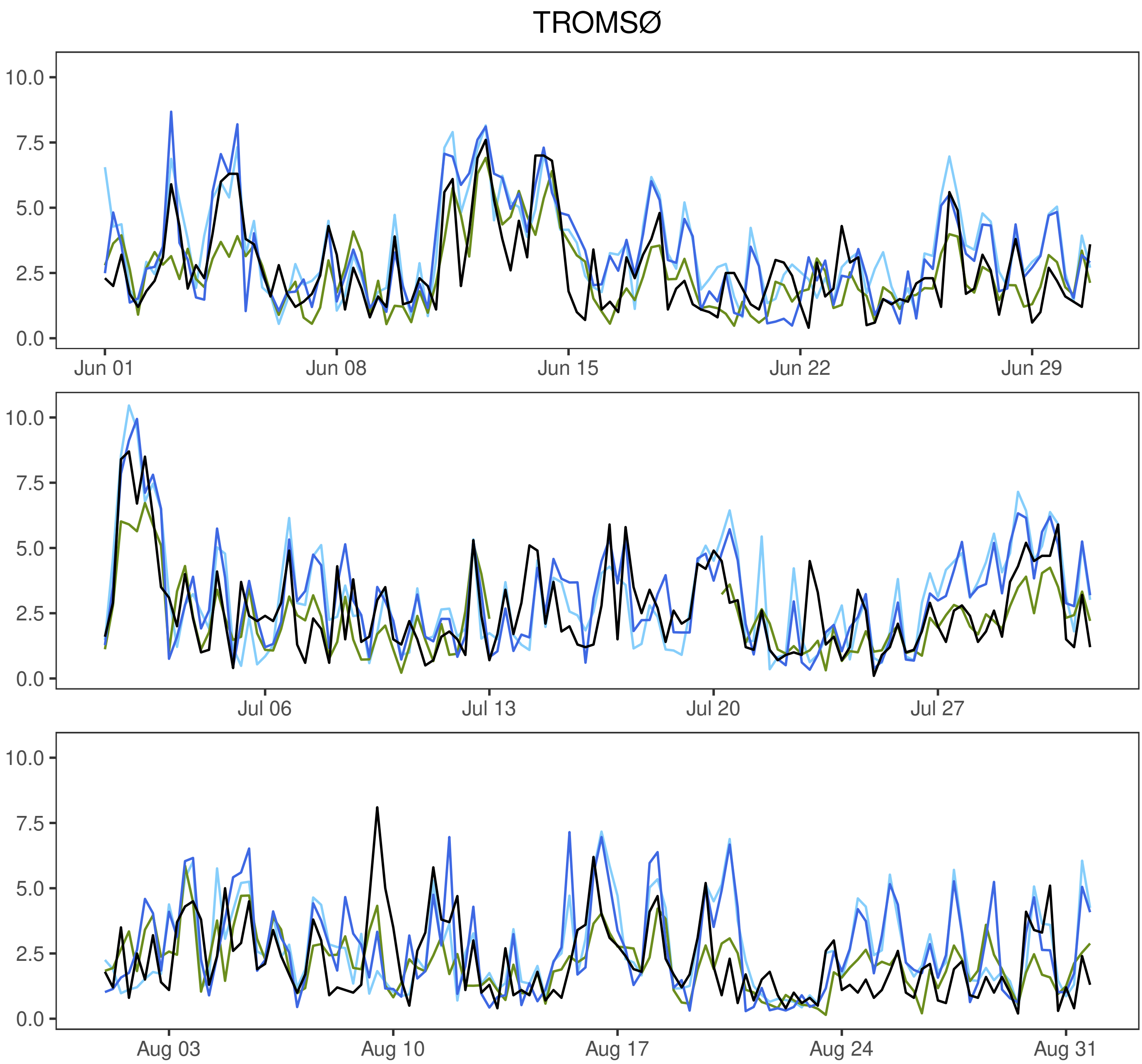


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.8	5.6	16.1	2.9	368
MEPSctrl: 12+18,+24,+30,+36	0.5	5.5	15.8	2.9	368
AA25: 12+18,+24,+30,+36	0.8	5.7	16.7	2.9	368
ECMWF: 12+18,+24,+30,+36	0.6	5.9	15.7	2.8	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	–0.1	1.6	1.6	1.3	5.2	340
AA25–synop	0.0	1.6	1.6	1.2	6.6	340
ECMWF–synop	0.3	1.6	1.6	1.3	5.2	340

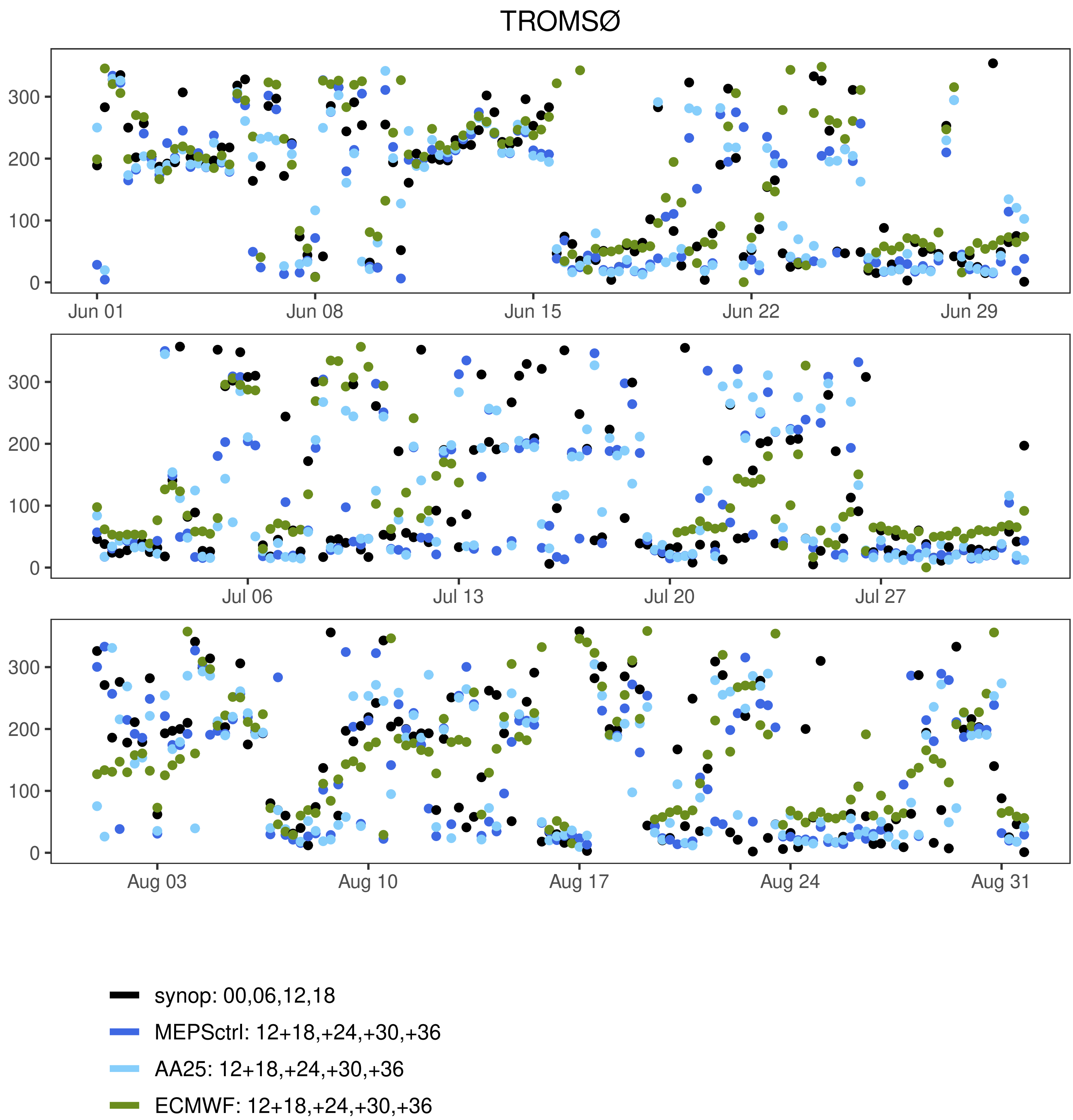

BJØRNØYA
0
100
200
300
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31

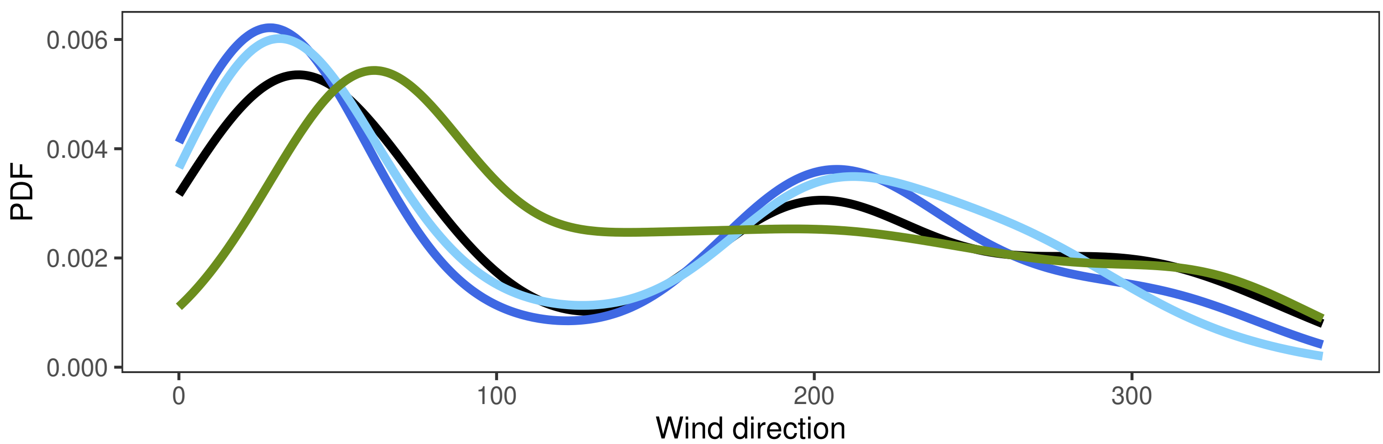

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.001
0.002
0.003
0.004
0.005
0
100
200
300
Wind direction

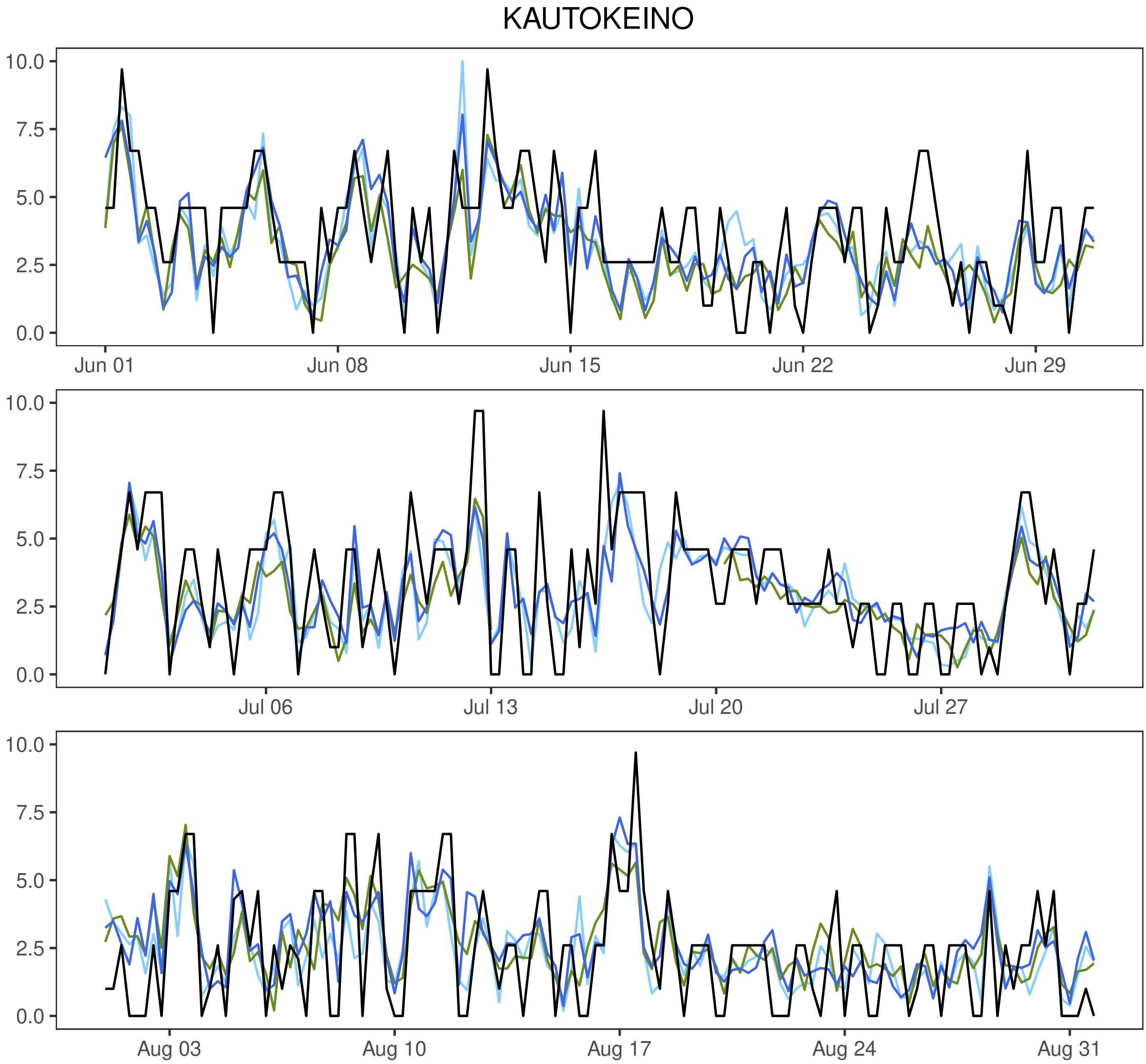


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.1	2.5	8.7	1.6	368
MEPSctrl: 12+18,+24,+30,+36	0.3	3.0	9.9	1.9	368
AA25: 12+18,+24,+30,+36	0.4	3.1	10.5	1.8	368
ECMWF: 12+18,+24,+30,+36	0.1	2.3	6.9	1.3	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	0.6	1.5	1.6	1.2	5.1	340
AA25–synop	0.7	1.5	1.6	1.3	6.3	340
ECMWF–synop	−0.2	1.2	1.3	1.0	3.8	340

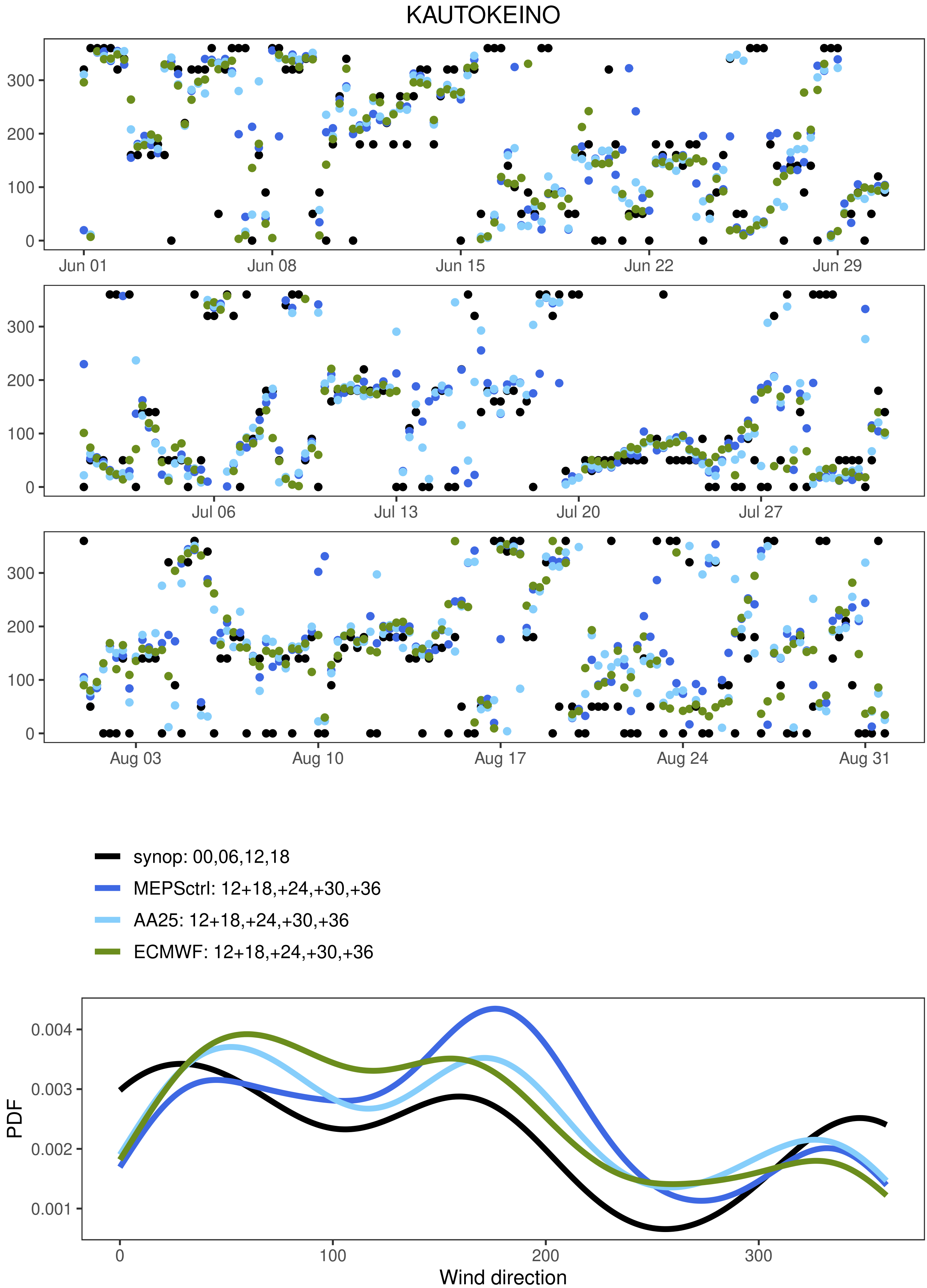

TROMSØ
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

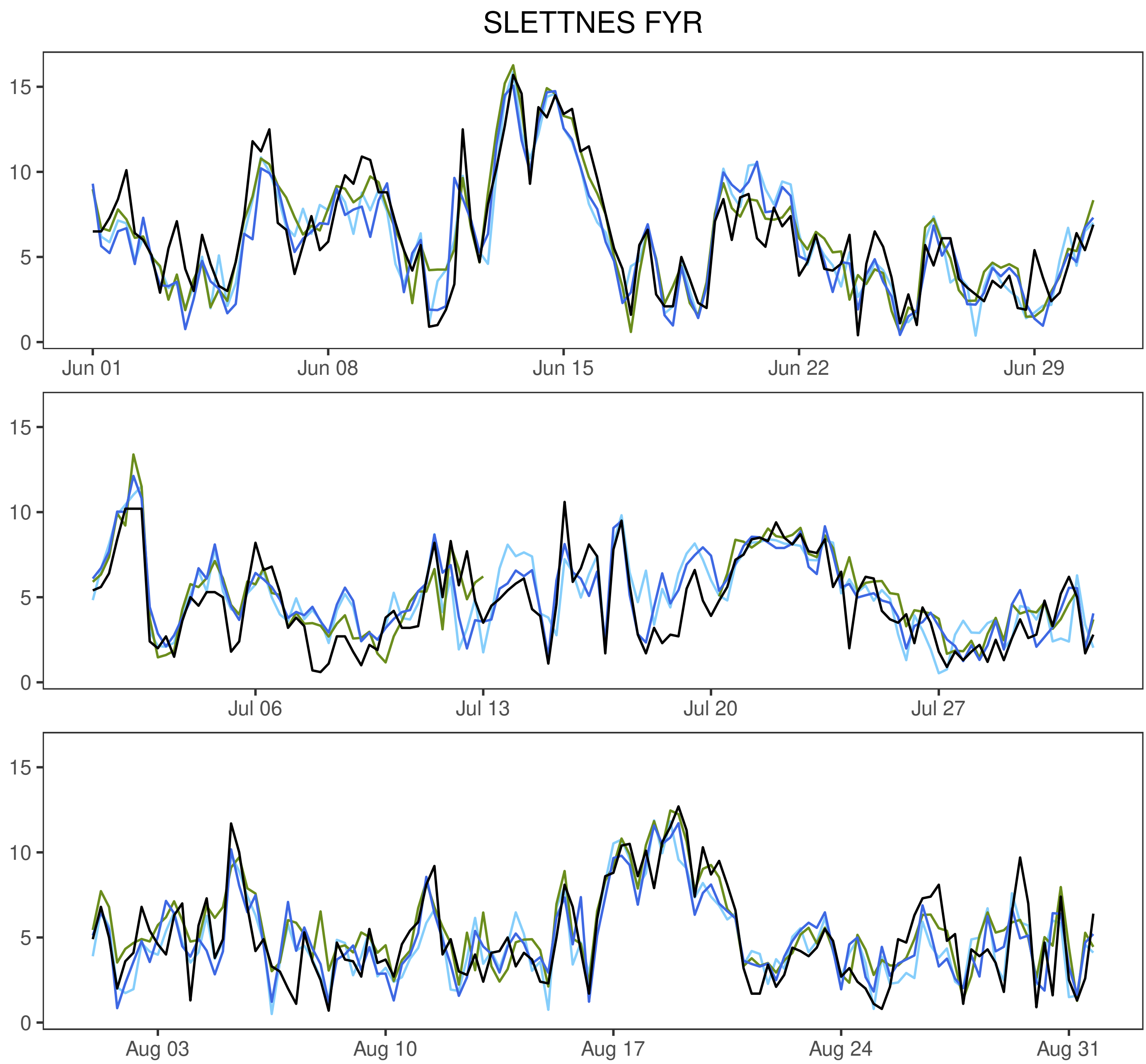

PDF
0.006
0.004
0.002
0.000
0
100
200
300
Wind direction



	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	3.1	9.7	2.2	368
MEPSctrl: 12+18,+24,+30,+36	0.4	3.0	8.0	1.6	368
AA25: 12+18,+24,+30,+36	0.2	2.9	10.0	1.6	368
ECMWF: 12+18,+24,+30,+36	0.2	2.8	7.6	1.4	340

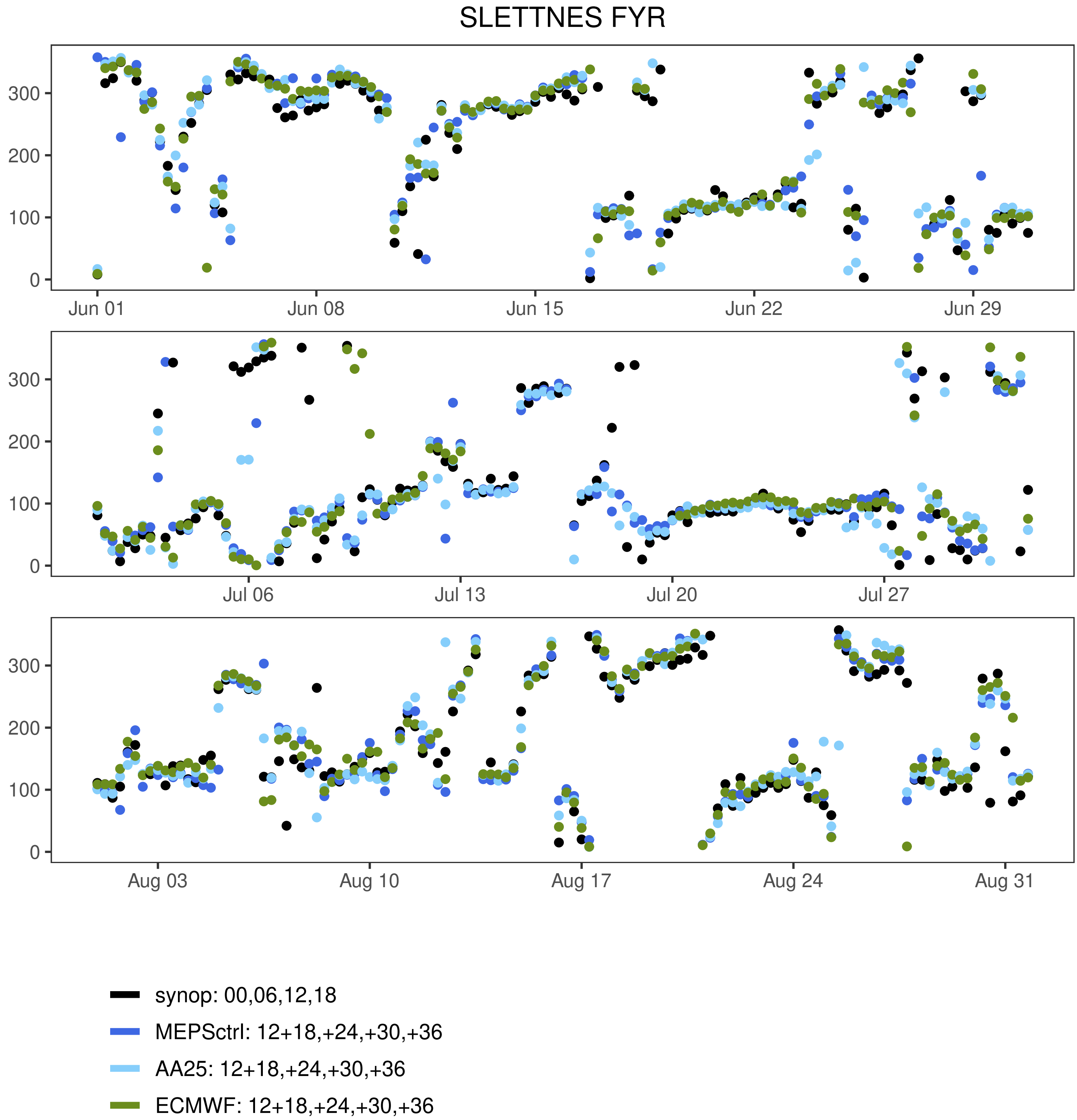
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.1	1.6	1.6	1.3	4.8	340
AA25−synop	−0.2	1.6	1.7	1.3	6.0	340
ECMWF−synop	−0.3	1.6	1.7	1.4	4.3	340

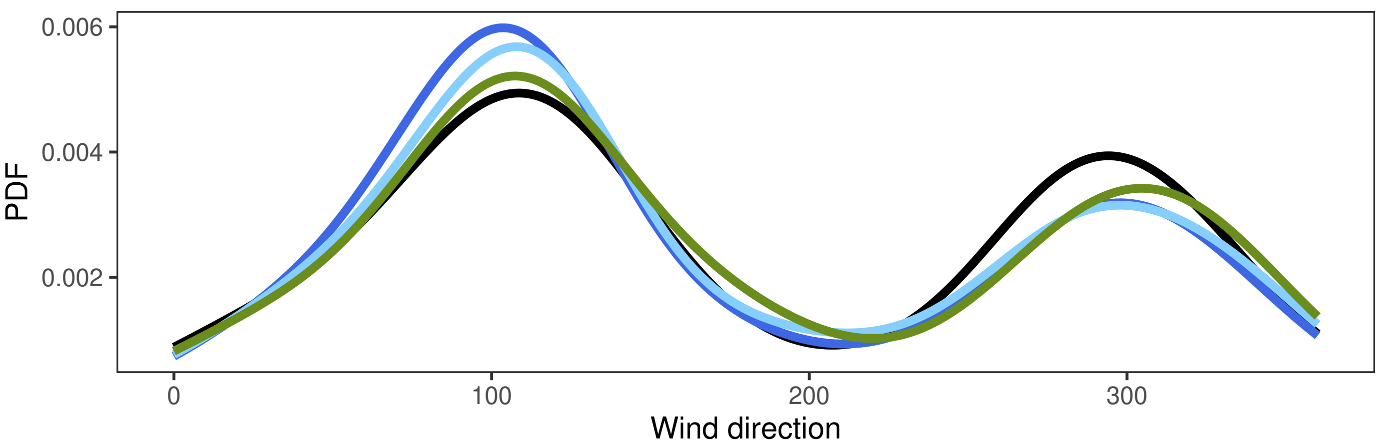

KAUTOKEINO
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.004
0.003
0.002
0.001
Wind direction

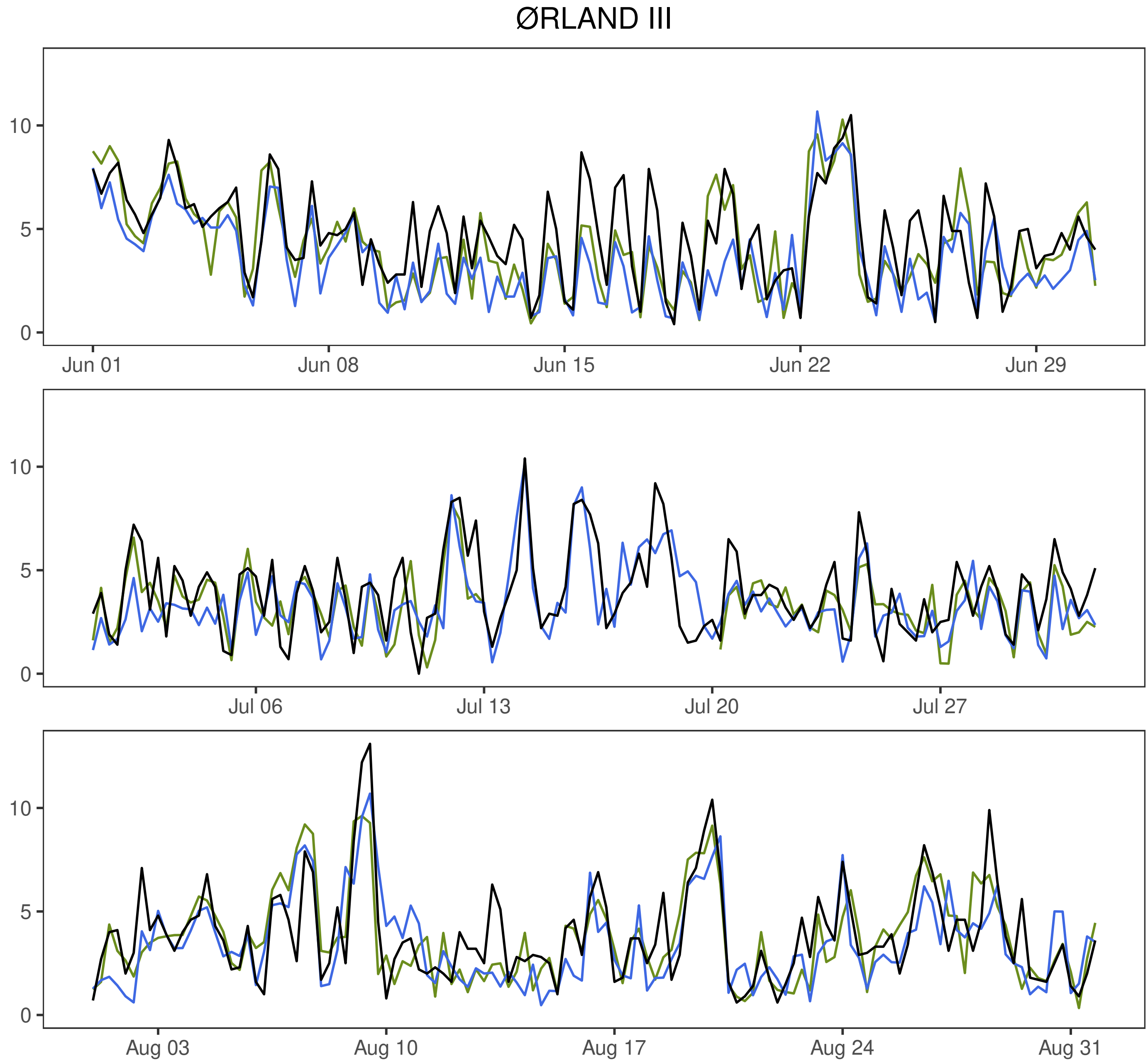


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.4	5.3	15.7	3.0	368
MEPSctrl: 12+18,+24,+30,+36	0.4	5.3	15.1	2.7	368
AA25: 12+18,+24,+30,+36	0.4	5.3	15.9	2.7	368
ECMWF: 12+18,+24,+30,+36	0.5	5.7	16.3	2.8	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.0	1.7	1.7	1.3	6.2	340
AA25−synop	−0.1	1.7	1.7	1.3	4.6	340
ECMWF−synop	0.3	1.5	1.6	1.2	5.4	340

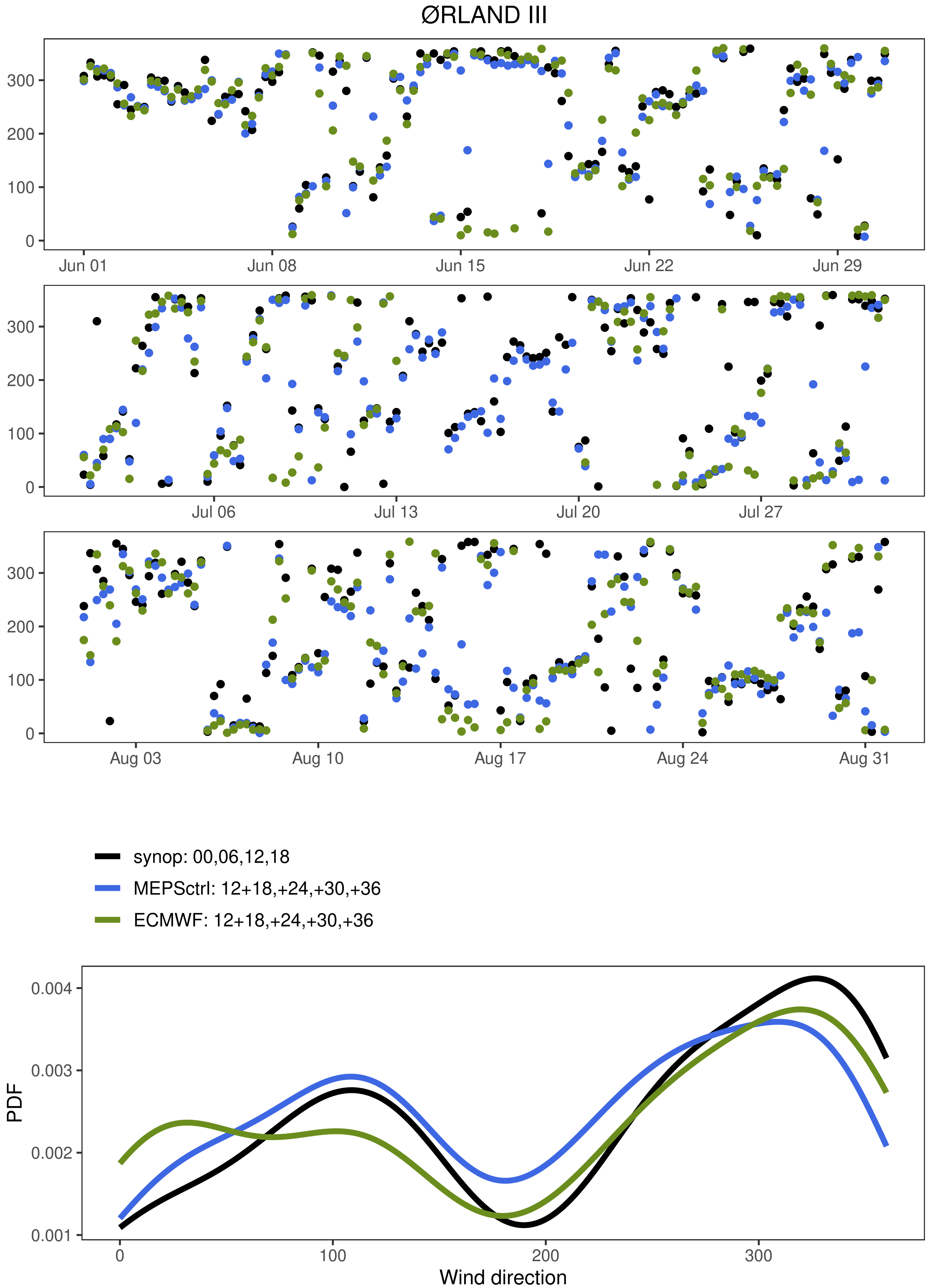

SLETTNES FYR
0
100
200
300
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

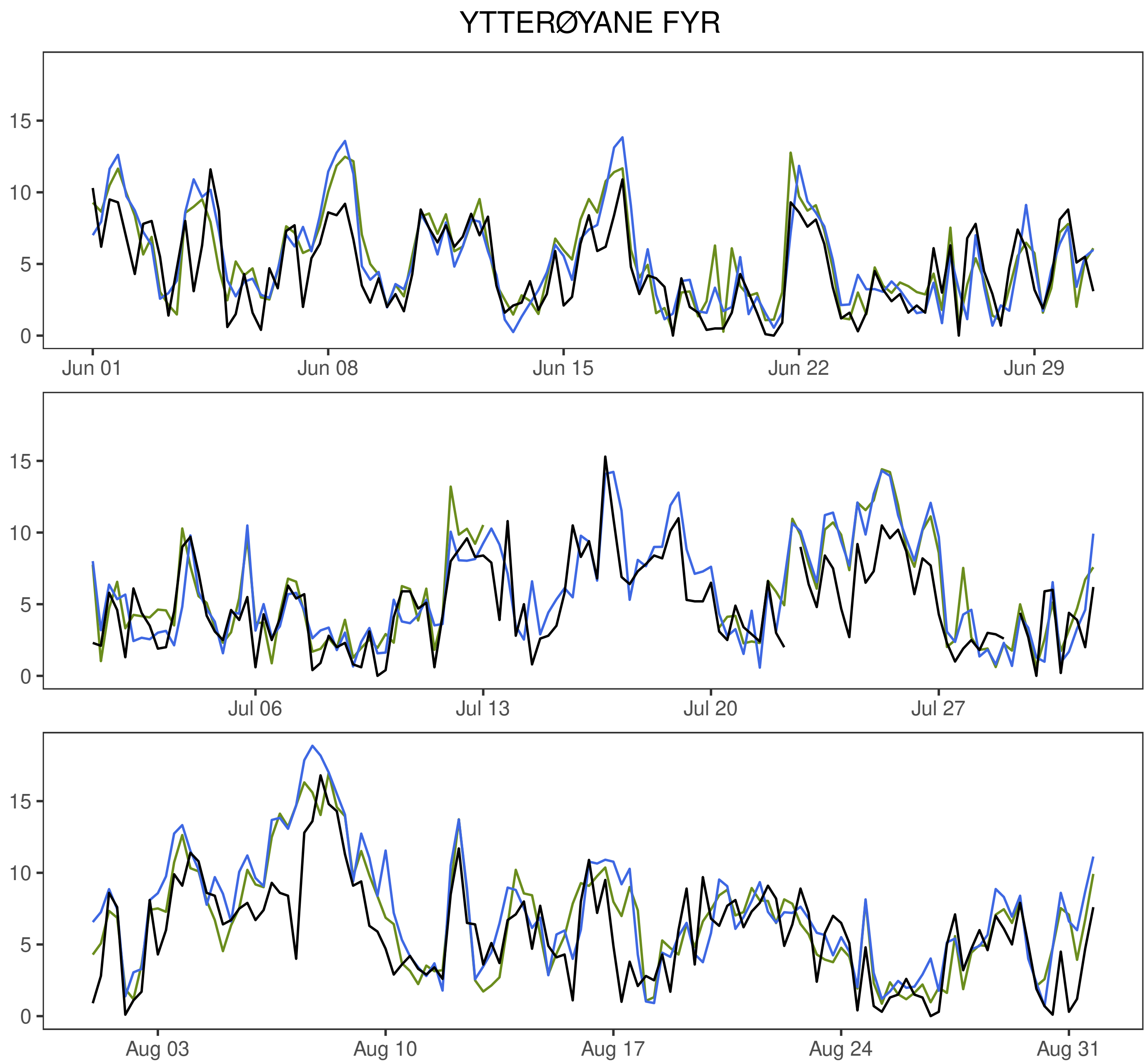

PDF
0.002
0.004
0.006
0
100
200
300
Wind direction



	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	4.2	13.1	2.2	368
MEPSctrl: 12+18,+24,+30,+36	0.5	3.5	10.7	2.0	368
ECMWF: 12+18,+24,+30,+36	0.3	3.8	10.3	2.1	340

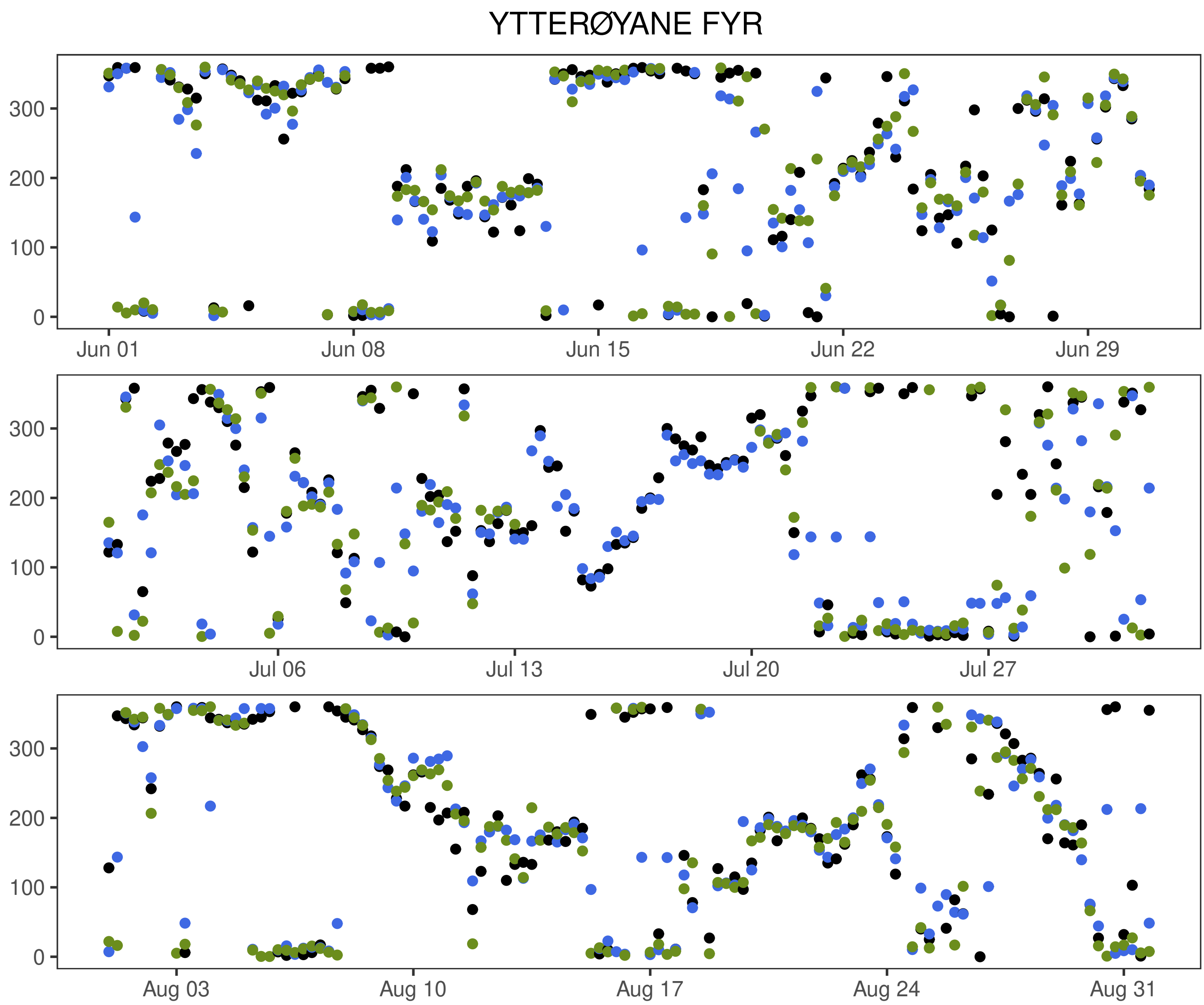
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	–0.8	1.6	1.7	1.4	5.2	340
ECMWF–synop	–0.4	1.5	1.6	1.2	5.5	340

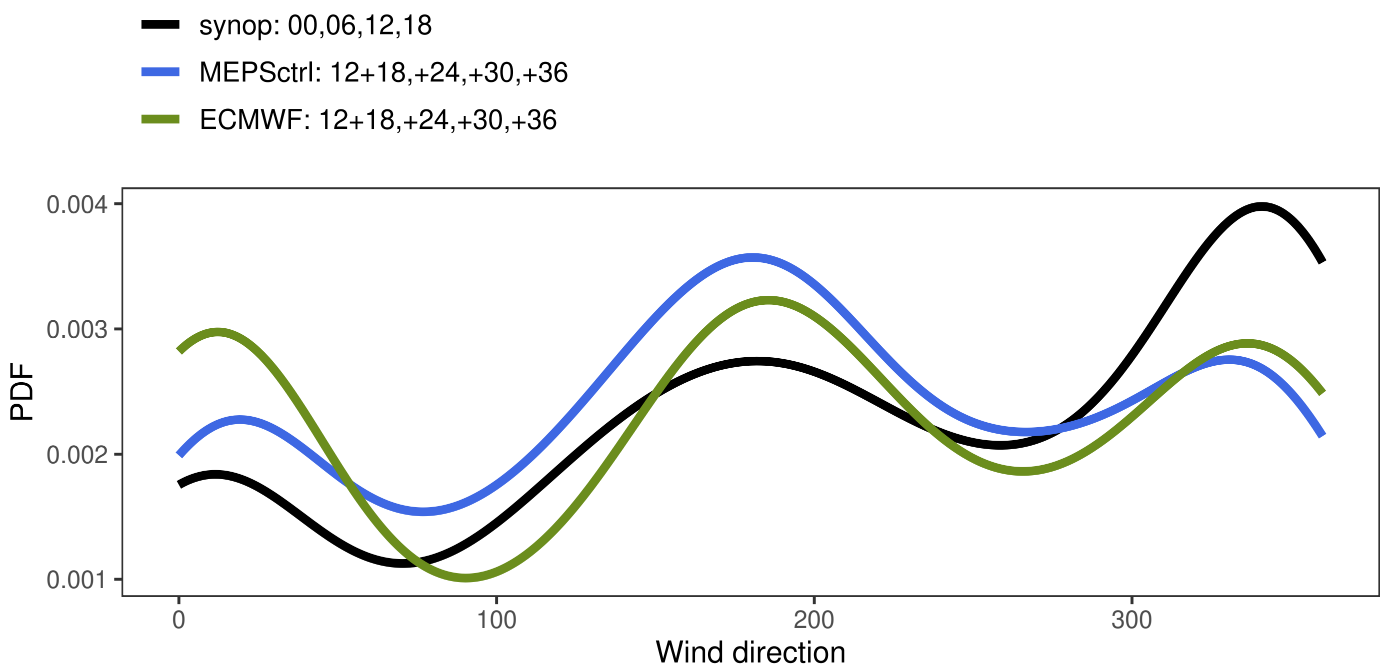

ØRLAND III
0
100
200
300
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.001
0.002
0.003
0.004
Wind direction

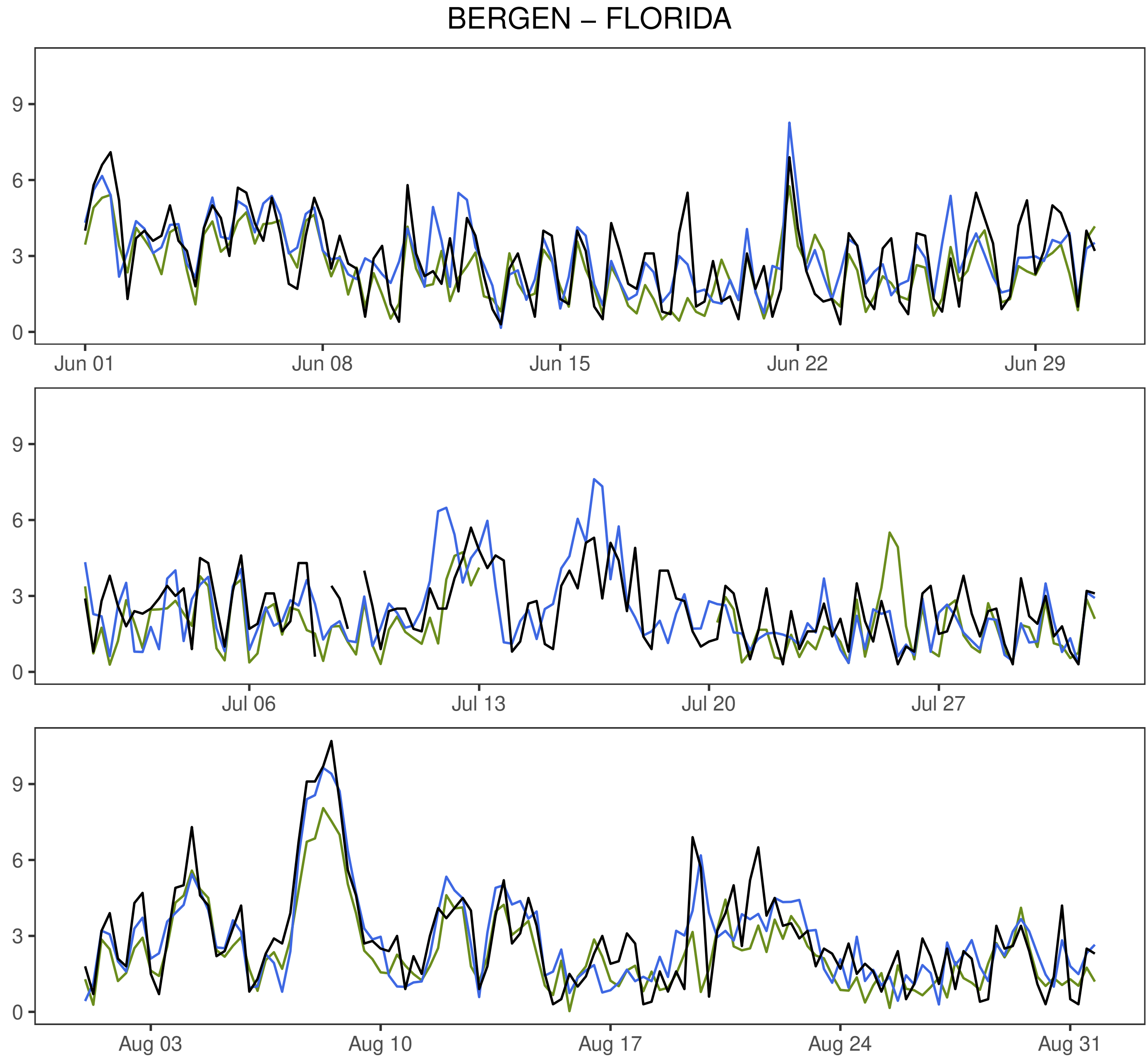


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	5.1	16.8	3.2	366
MEPSctrl: 12+18,+24,+30,+36	0.2	6.2	18.9	3.7	368
ECMWF: 12+18,+24,+30,+36	0.2	5.9	17.0	3.5	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	1.0	2.3	2.5	1.9	10.7	338
ECMWF−synop	0.9	2.1	2.3	1.8	10.7	338

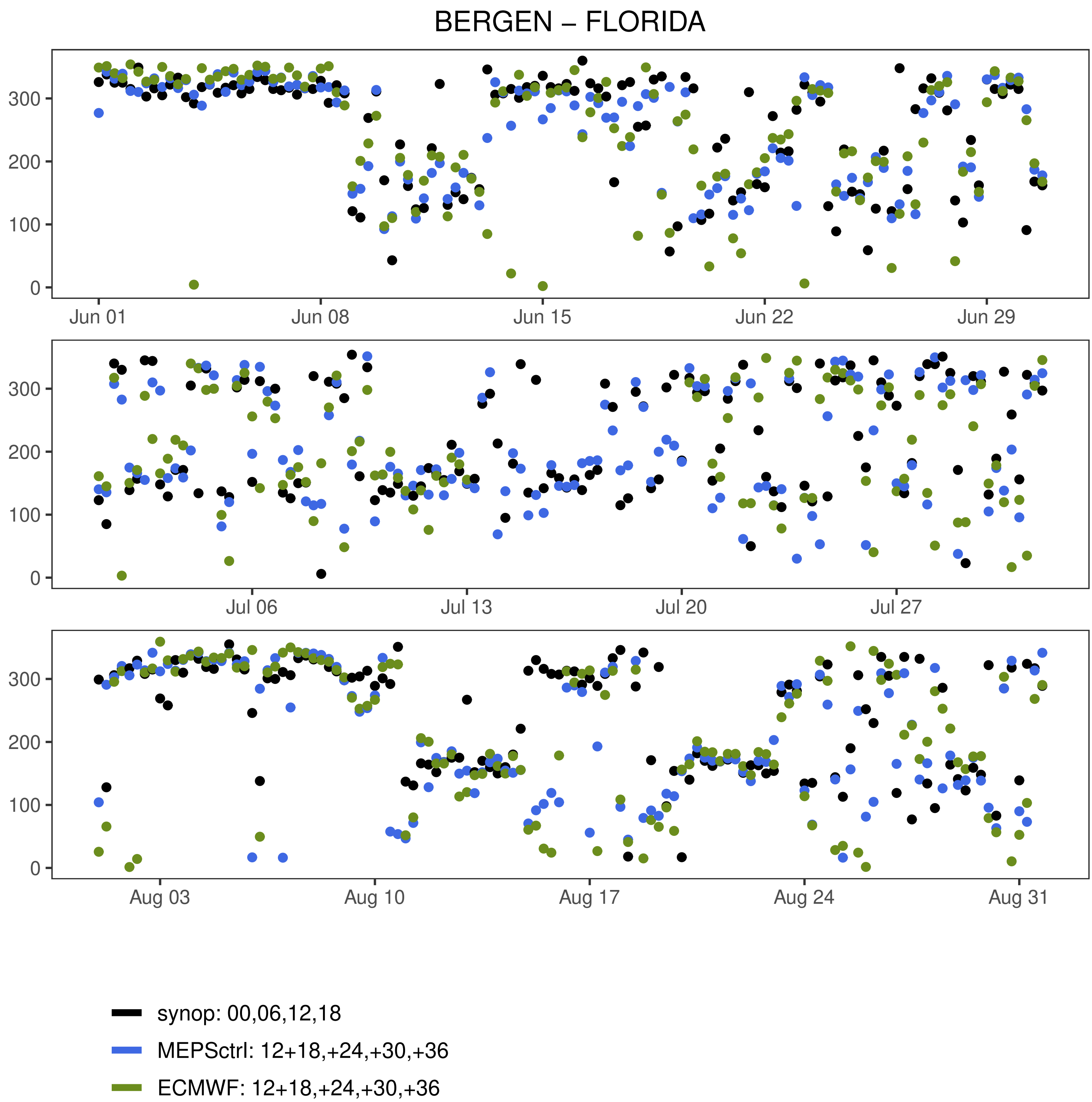

YTTERØYANE FYR
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31

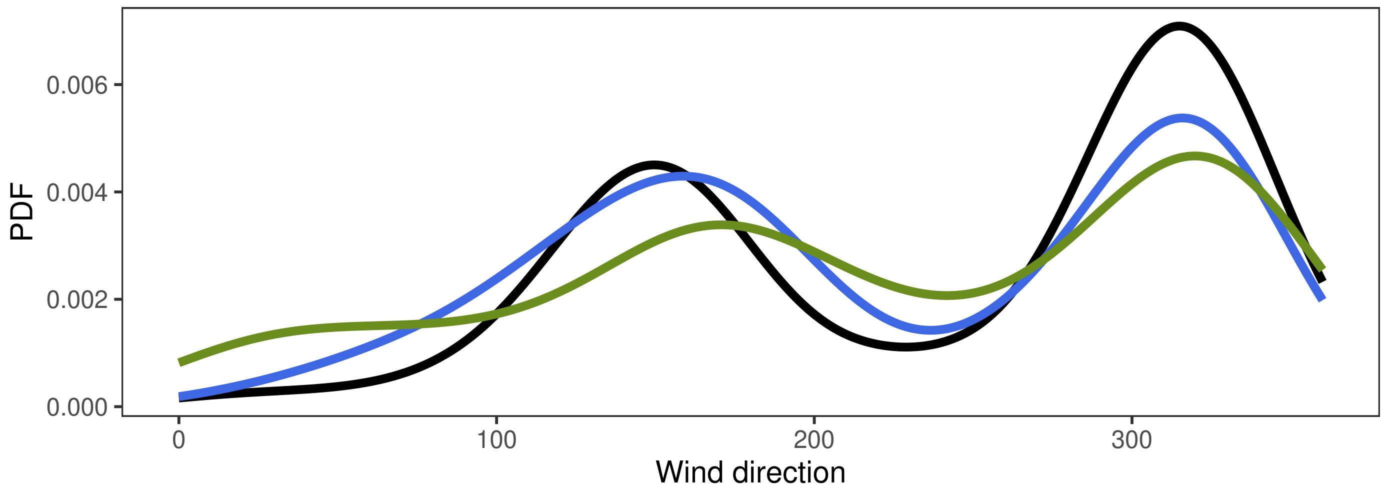

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

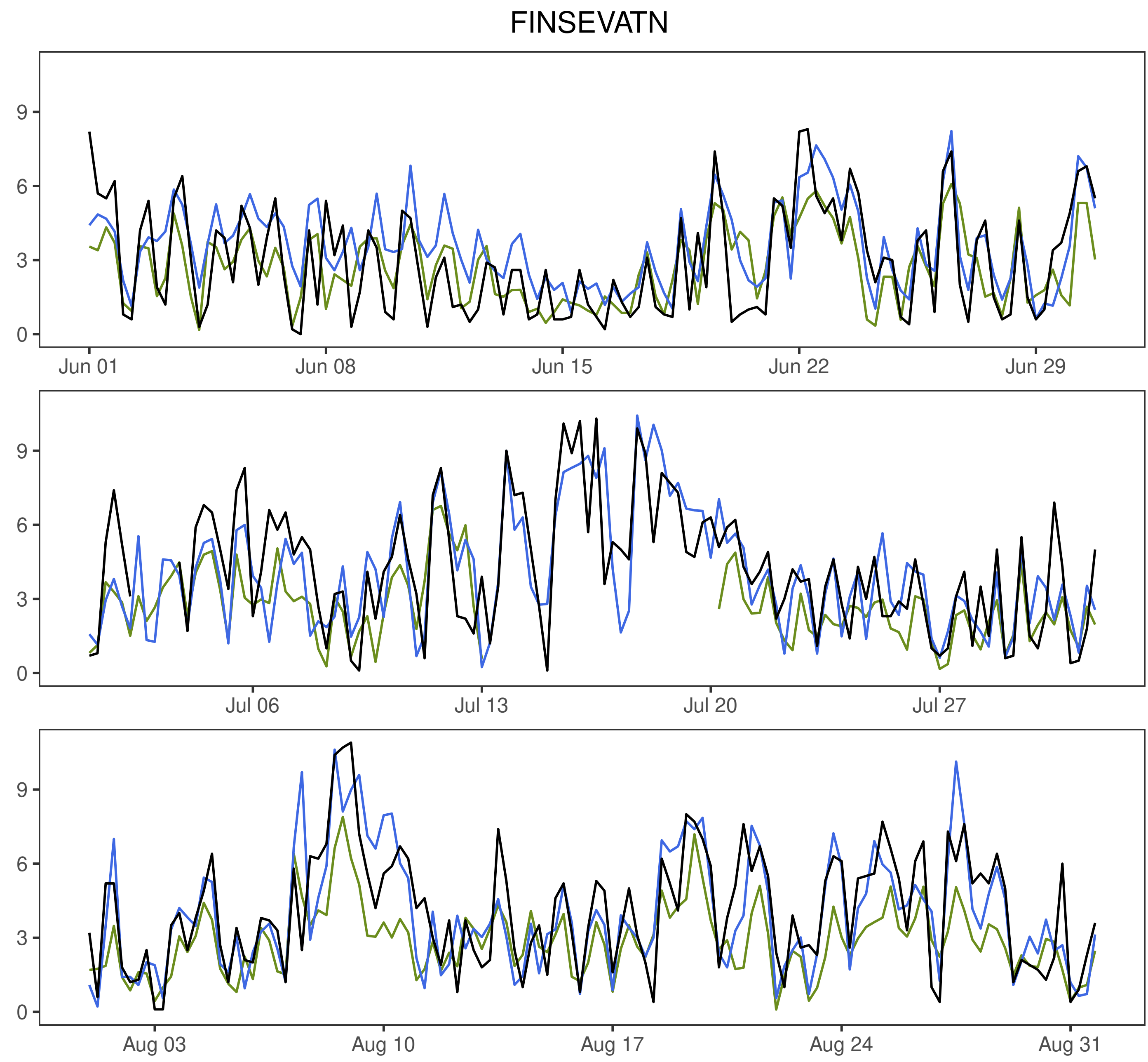


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.3	2.8	10.7	1.7	366
MEPSctrl: 12+18,+24,+30,+36	0.2	2.8	9.6	1.6	368
ECMWF: 12+18,+24,+30,+36	0.0	2.3	8.0	1.4	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	0.0	1.2	1.2	0.9	4.0	338
ECMWF–synop	–0.5	1.1	1.2	0.9	4.9	338

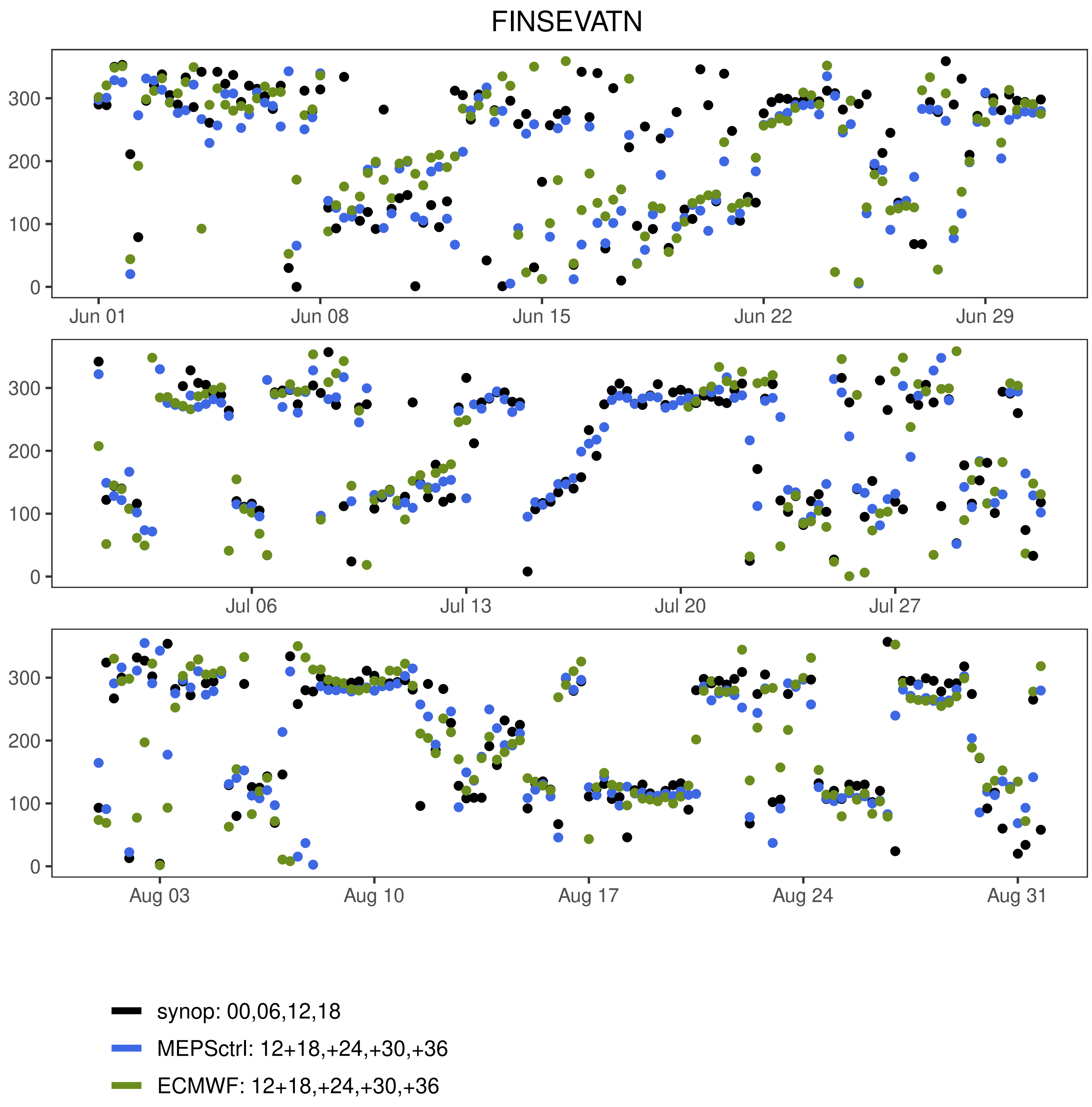

BERGEN – FLORIDA
0
100
200
300
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

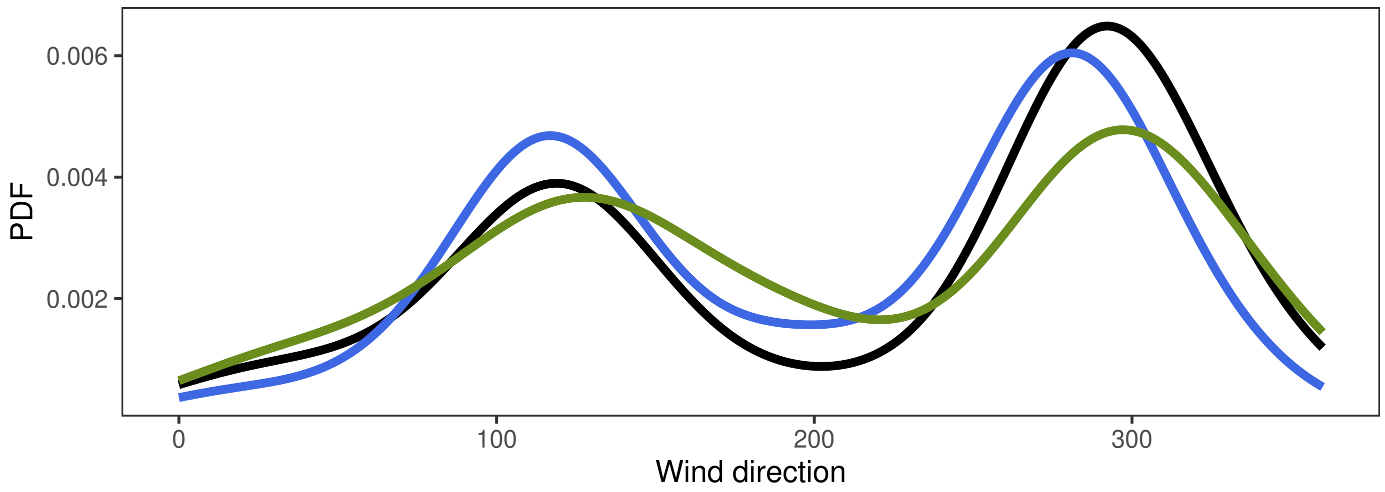

PDF
0.000
0.002
0.004
0.006
0
100
200
300
Wind direction

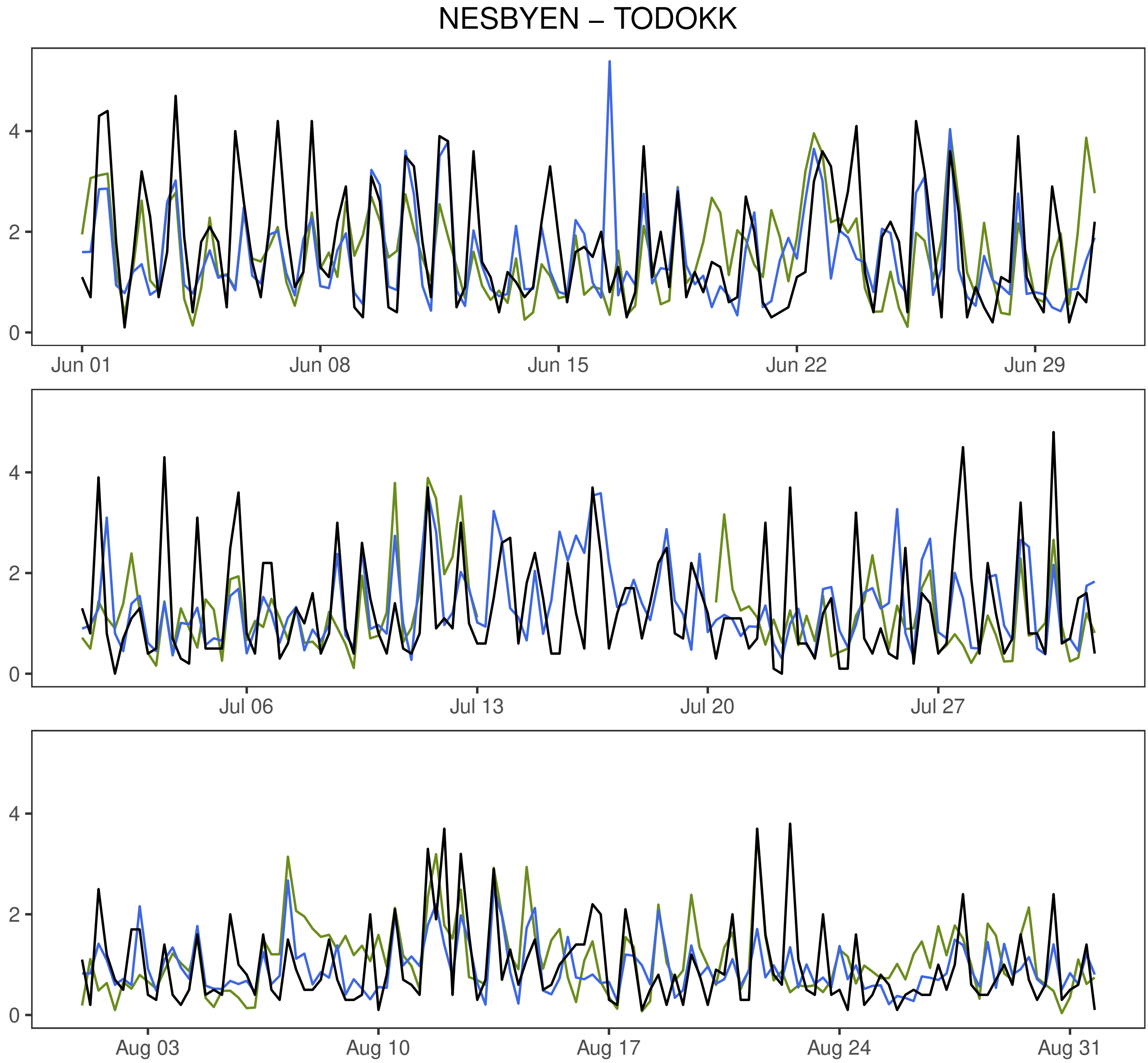


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	3.8	10.9	2.4	363
MEPSctrl: 12+18,+24,+30,+36	0.2	3.9	10.6	2.2	368
ECMWF: 12+18,+24,+30,+36	0.1	2.8	7.9	1.4	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.1	1.6	1.6	1.3	7.2	335
ECMWF−synop	−0.8	1.6	1.8	1.5	5.8	335

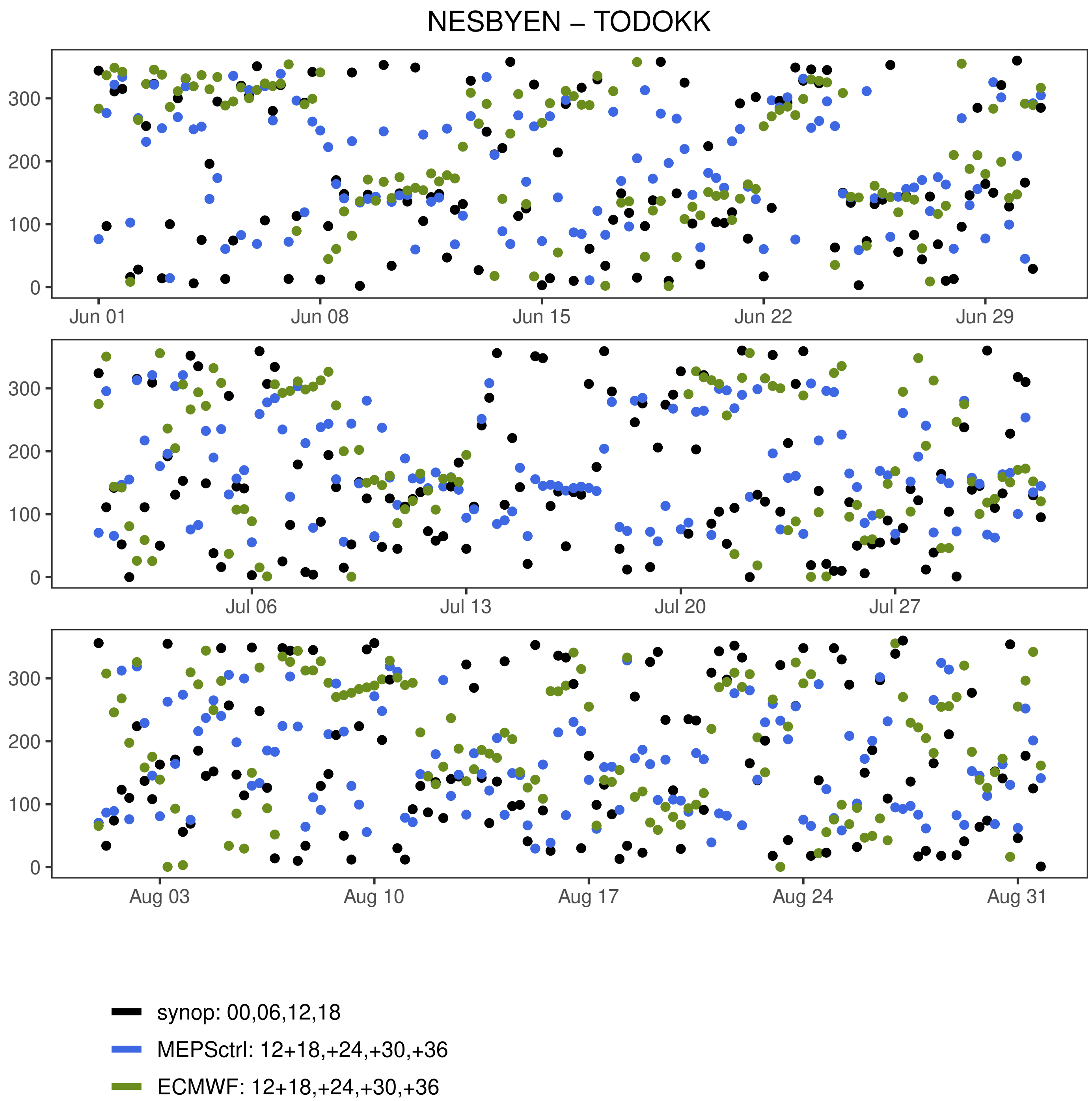

FINSEVATN
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36

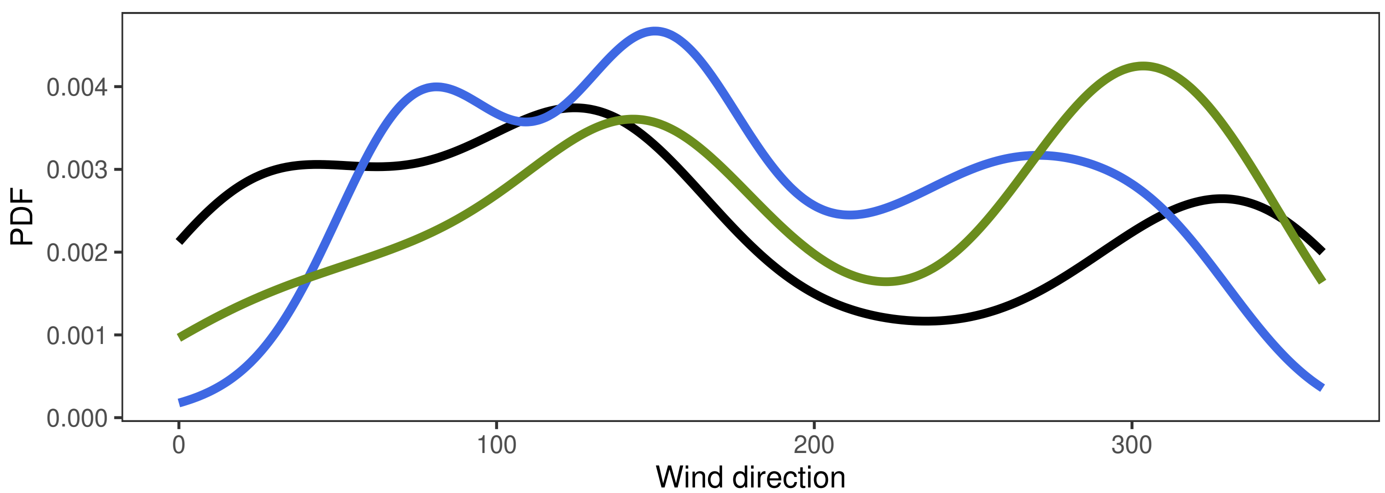

PDF
0.006
0.004
0.002
0
100
200
300
Wind direction

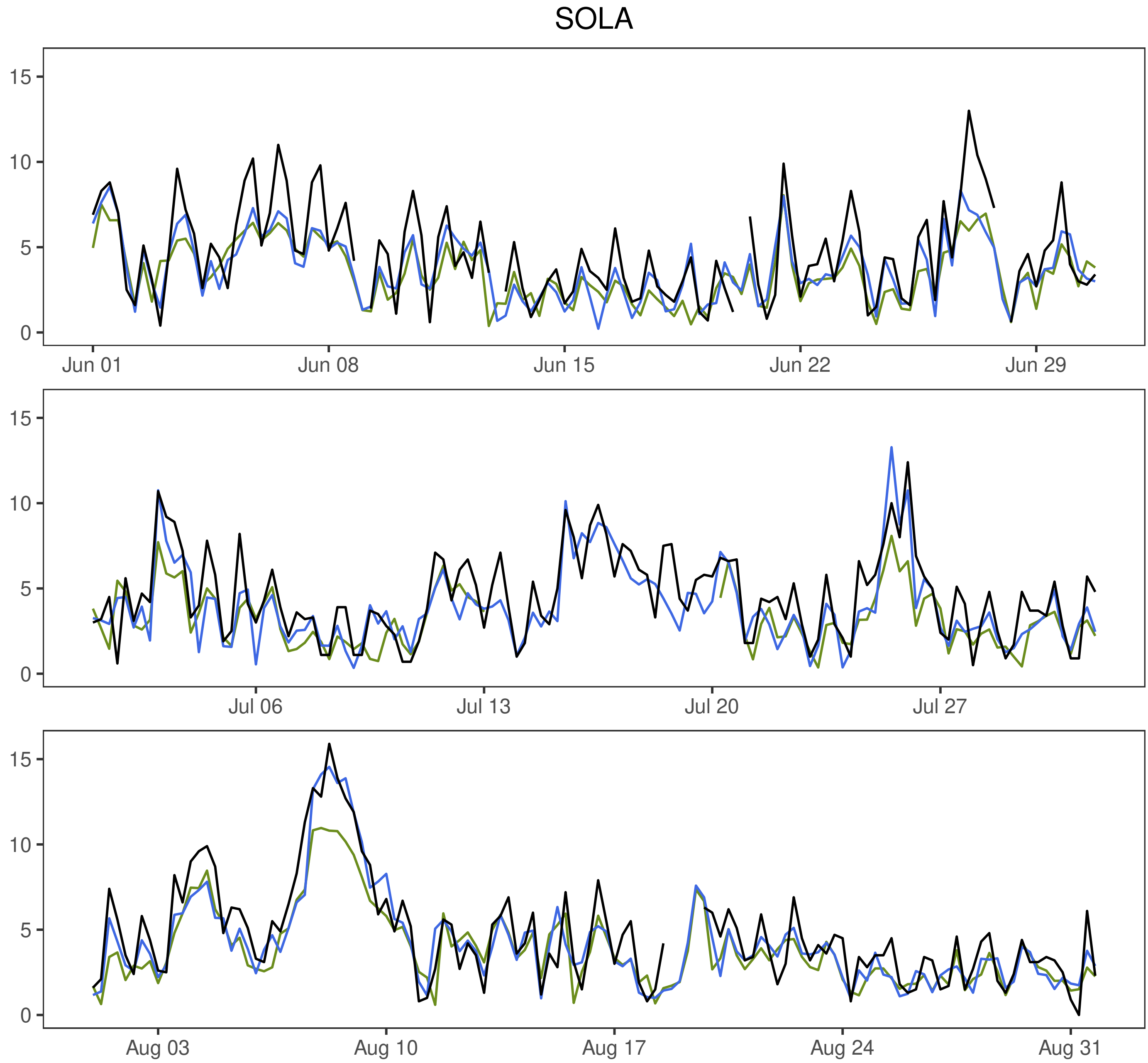


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	1.3	4.8	1.1	368
MEPSctrl: 12+18,+24,+30,+36	0.2	1.3	5.4	0.8	368
ECMWF: 12+18,+24,+30,+36	0.0	1.3	4.0	0.8	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	–0.1	0.9	0.9	0.6	4.6	340
ECMWF–synop	0.0	1.0	1.0	0.8	3.9	340

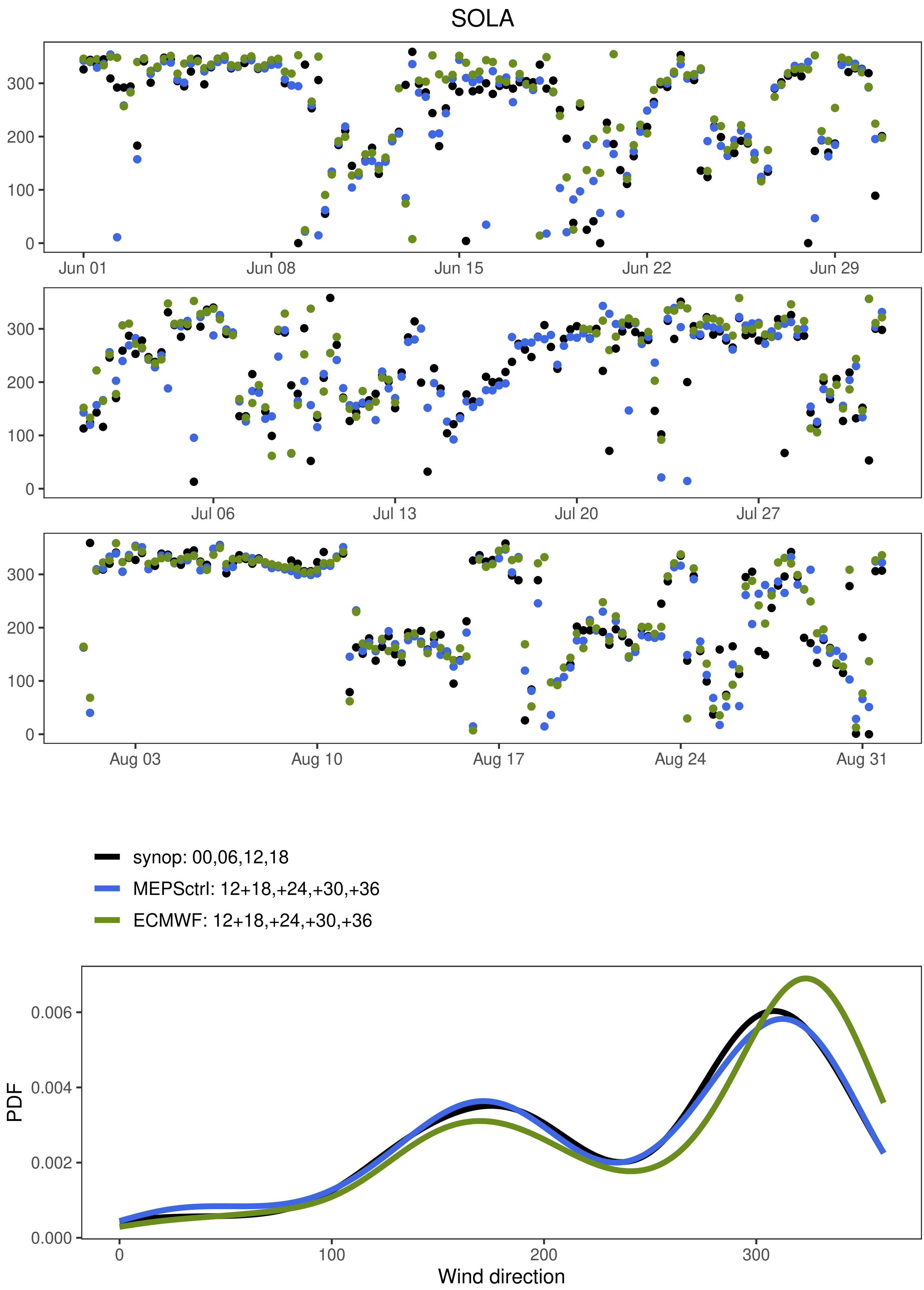

NESBYEN – TODOKK
0
100
200
300
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36


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

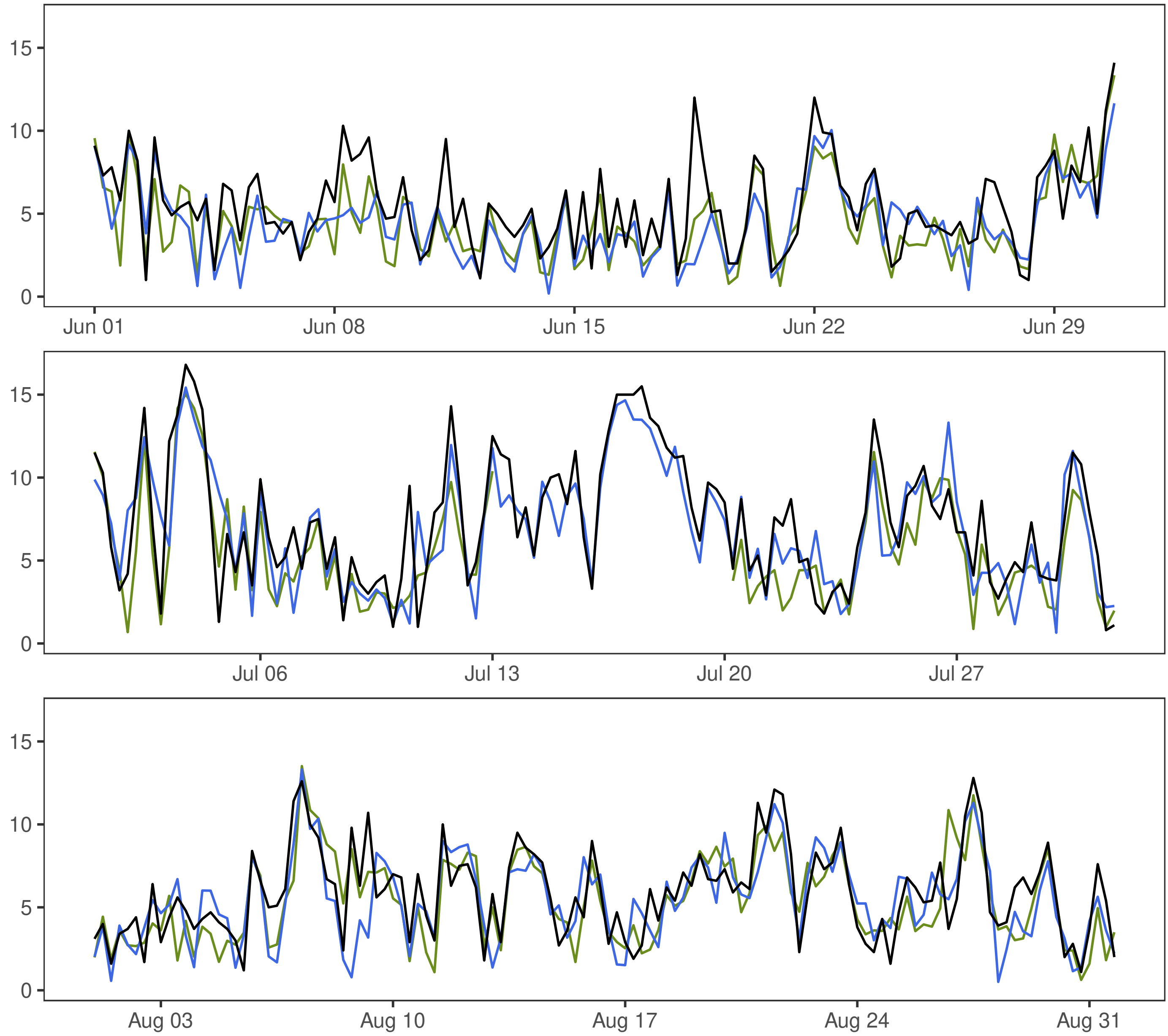


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	4.6	15.9	2.7	360
MEPSctrl: 12+18,+24,+30,+36	0.2	4.0	14.5	2.4	368
ECMWF: 12+18,+24,+30,+36	0.4	3.5	11.0	2.0	340

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.6	1.4	1.5	1.2	5.8	332
ECMWF−synop	−1.0	1.5	1.8	1.4	7.0	332

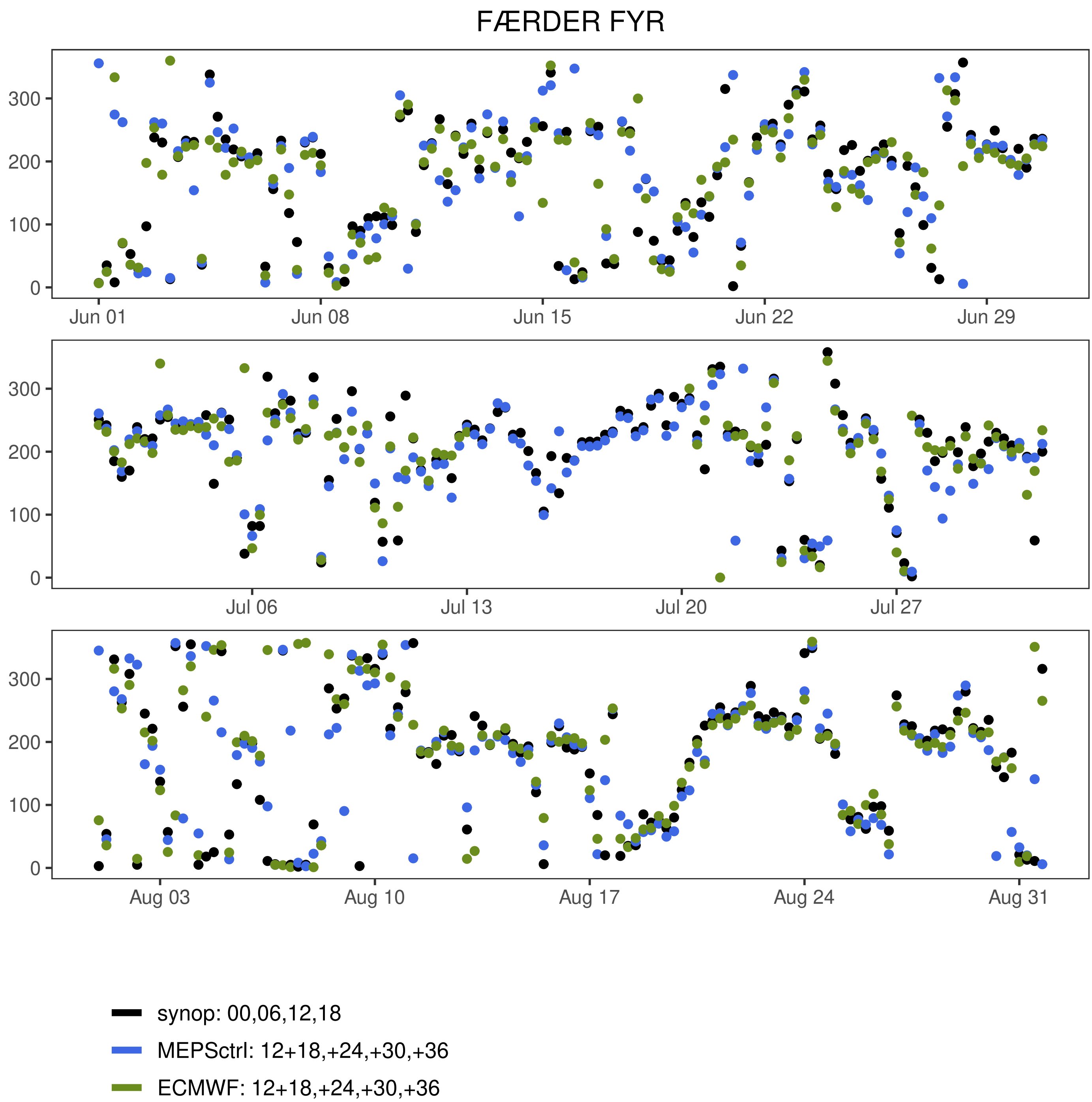

SOLA
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.006
0.004
0.002
0.000
0
100
200
300
Wind direction

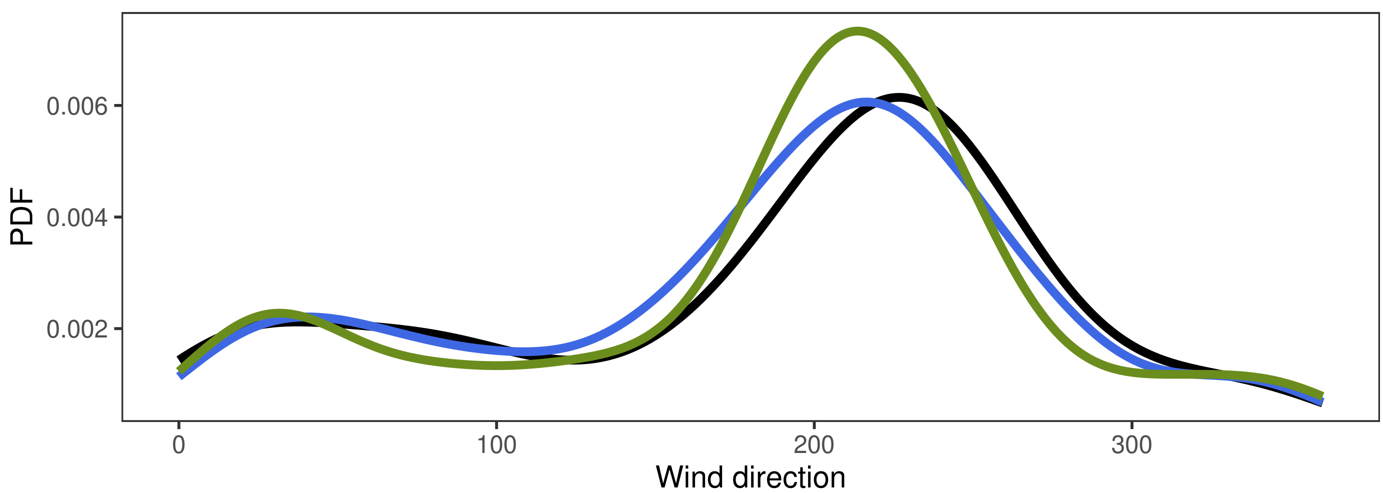
FÆRDER FYR

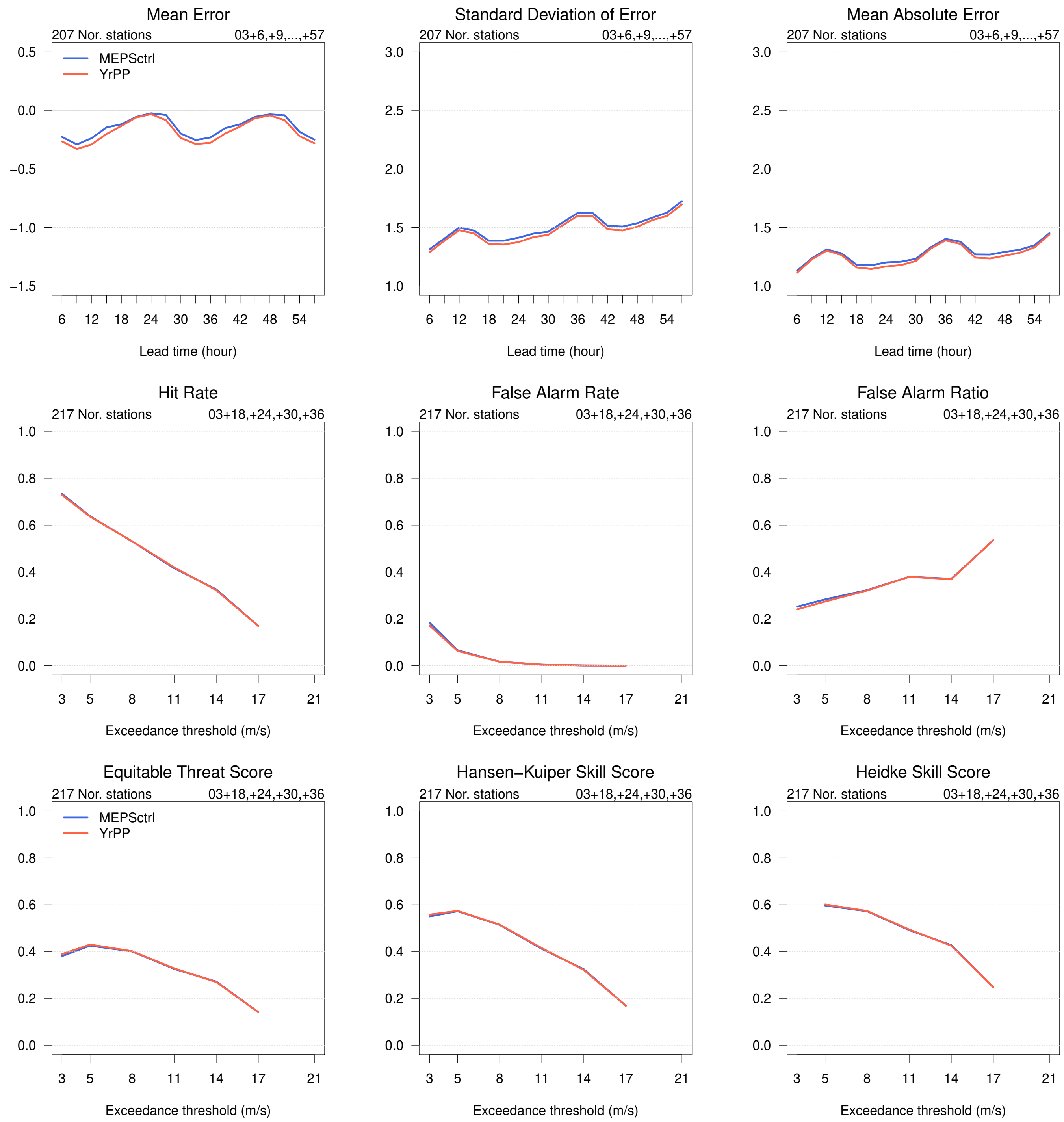


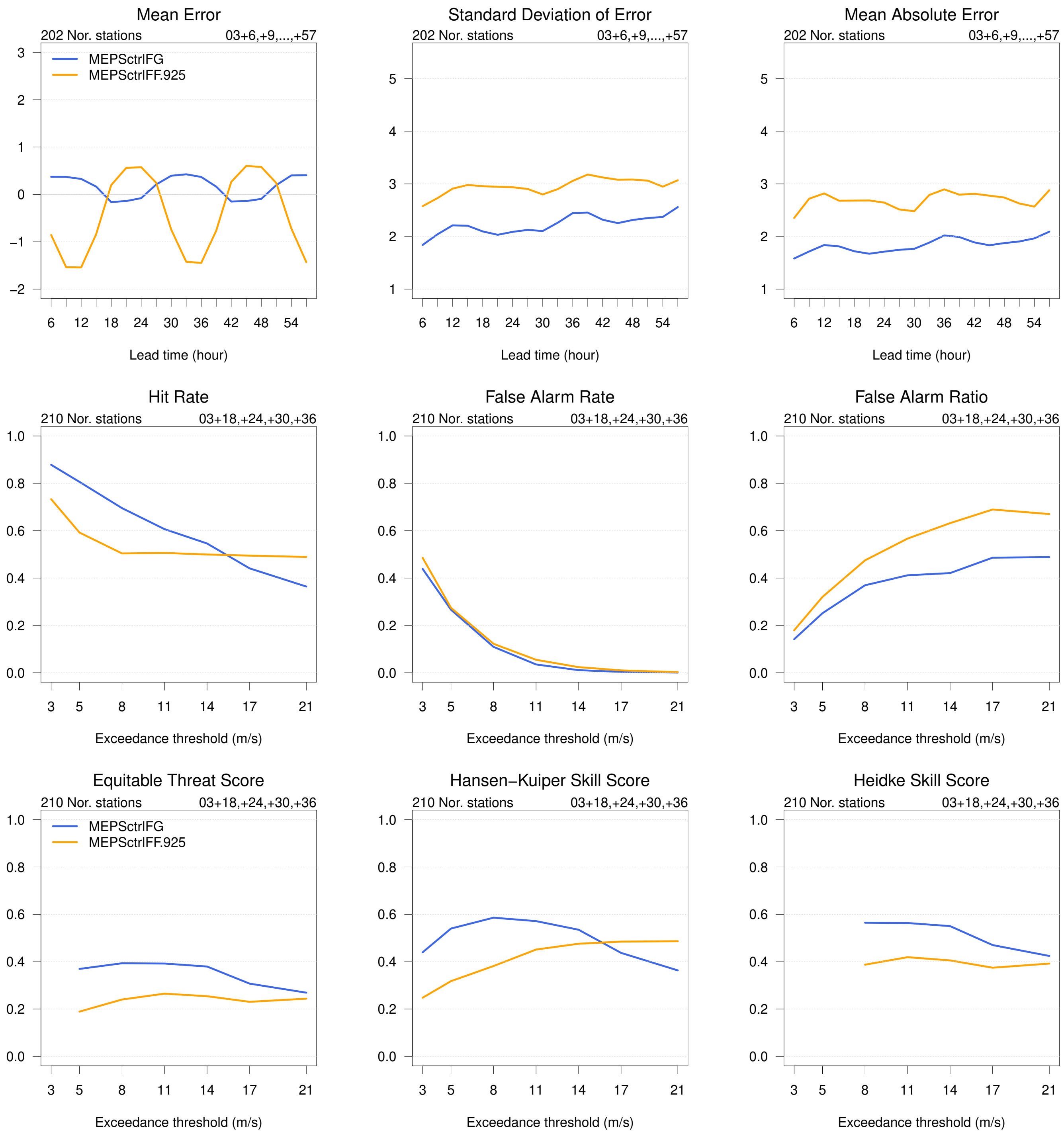
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.8	6.3	16.8	3.2	368
MEPSctrl: 12+18,+24,+30,+36	0.2	5.6	15.4	3.0	368
ECMWF: 12+18,+24,+30,+36	0.6	5.1	15.0	2.8	340

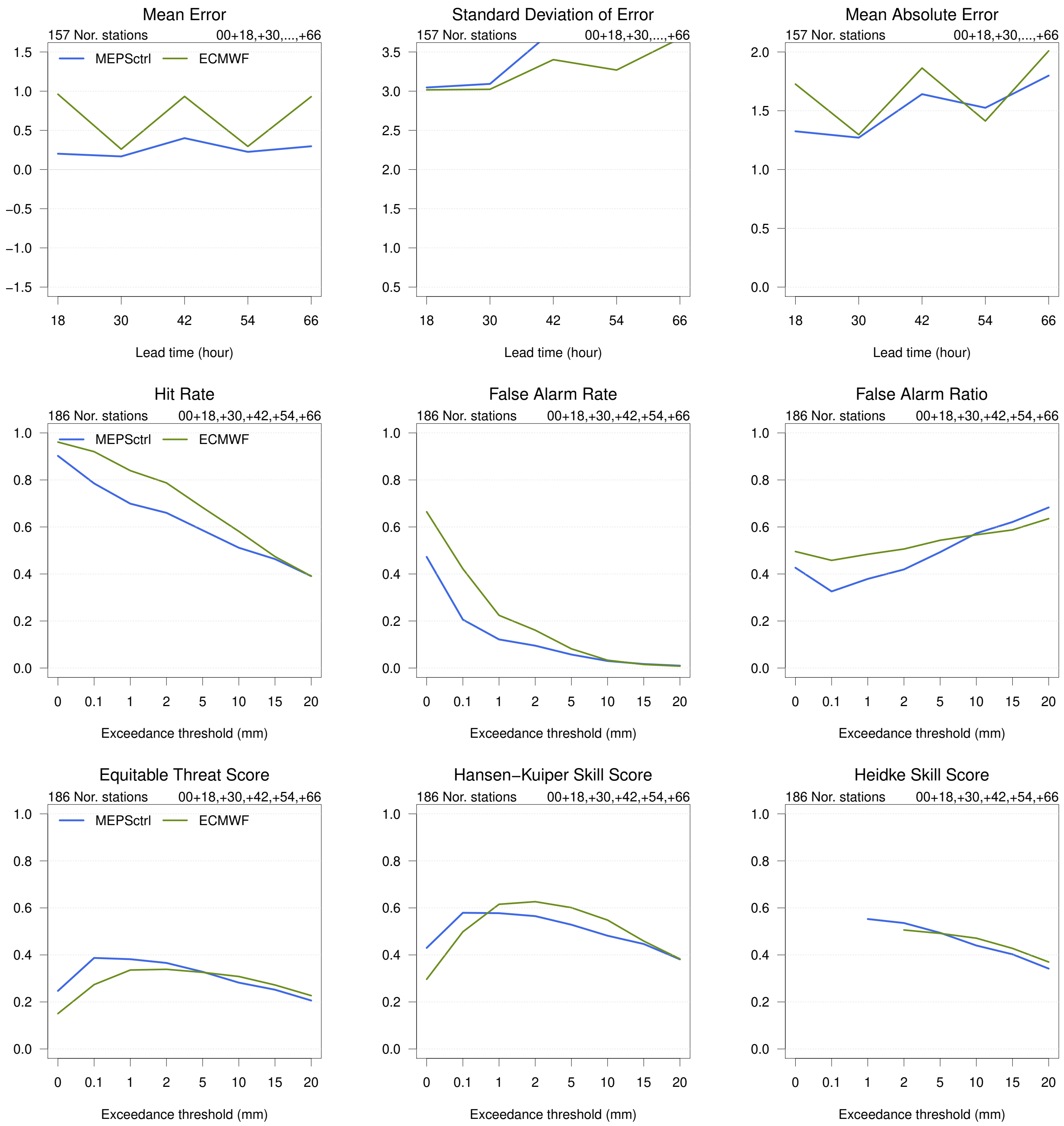
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	–0.6	2.1	2.2	1.6	10.0	340
ECMWF–synop	–0.8	1.8	1.9	1.5	7.3	340


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

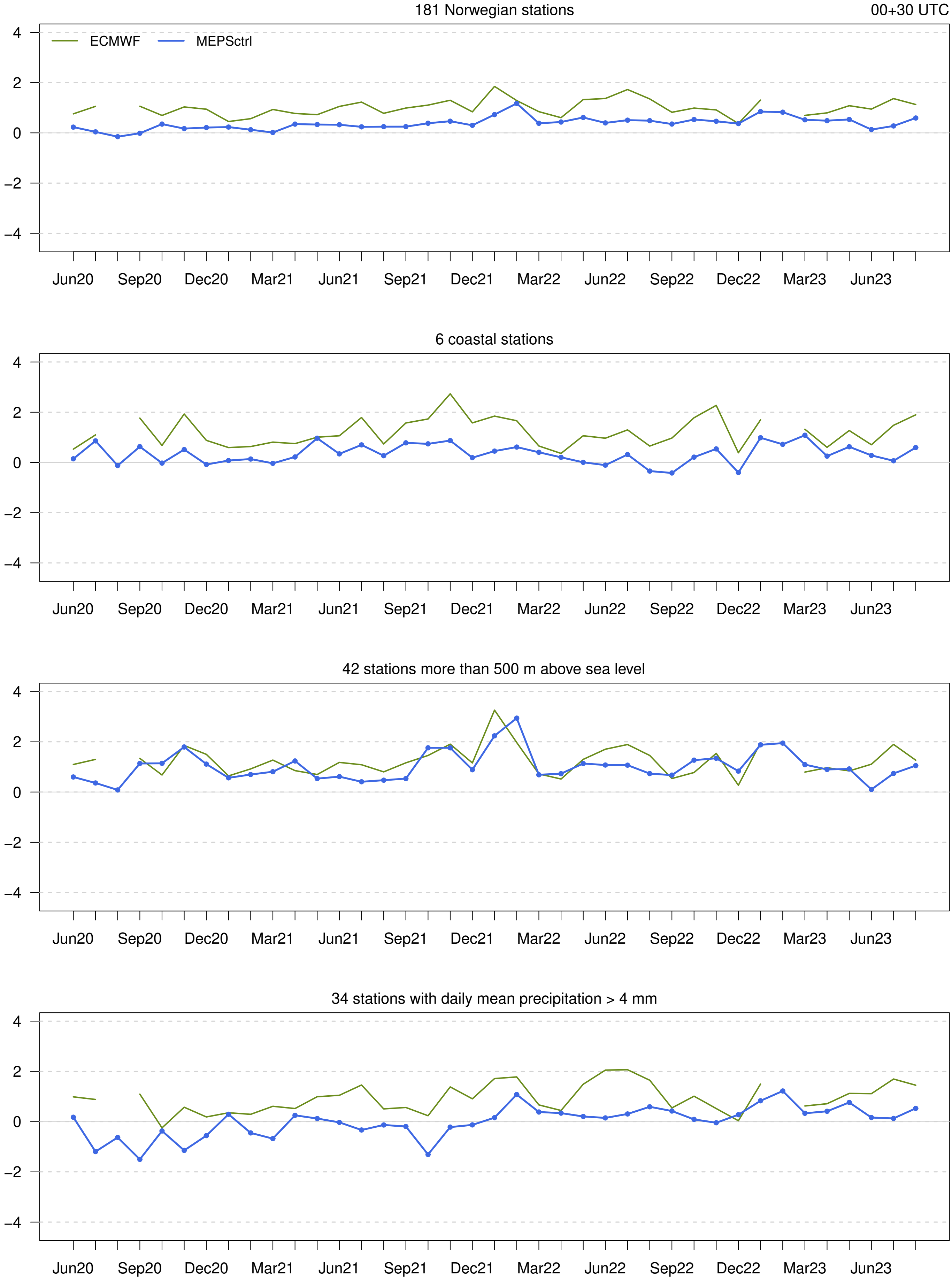

PDF
0.006
0.004
0.002
0
100
200
300
Wind direction

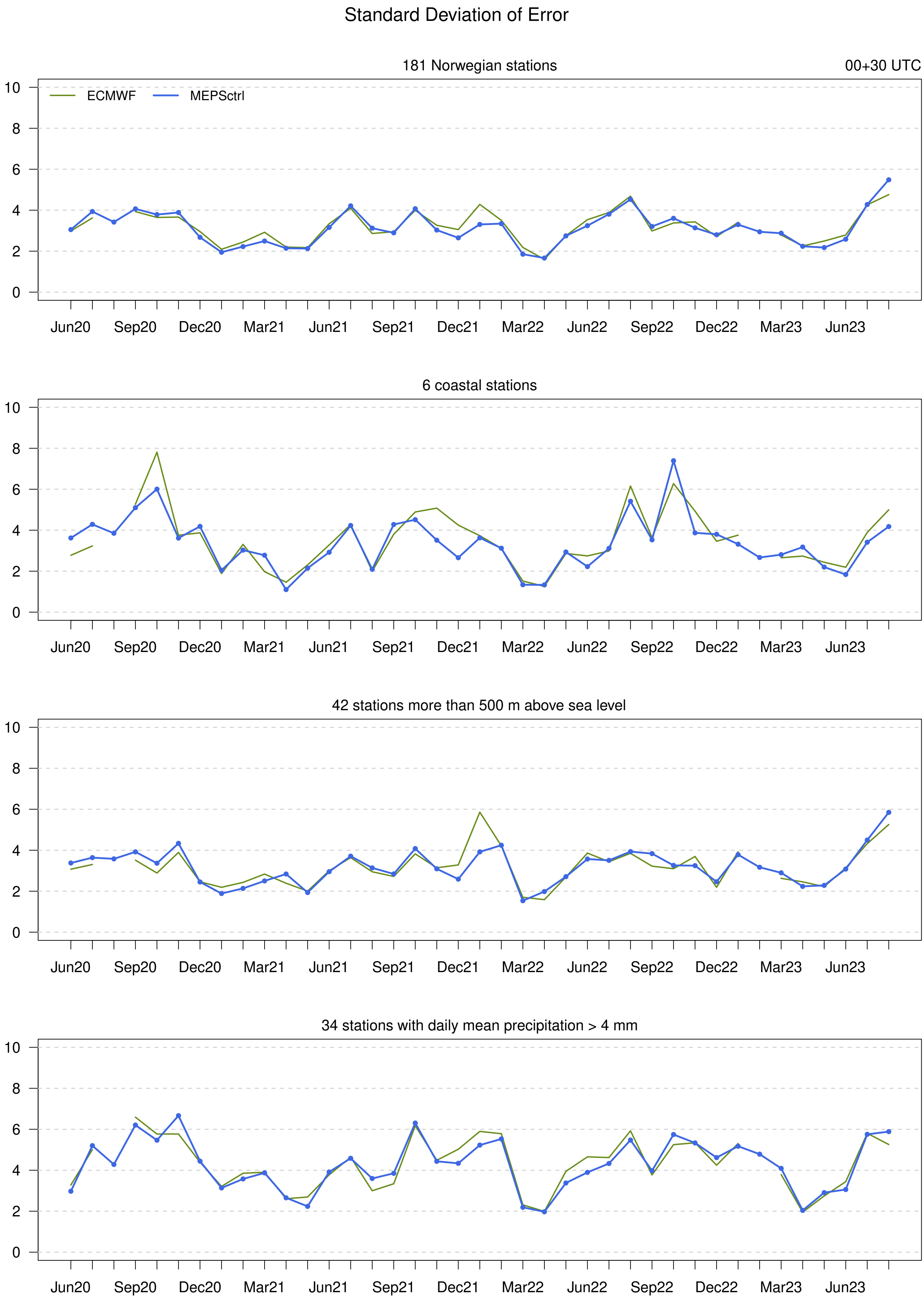

Mean Error
207 Nor. stations
03+6,+9,...,+57
MEPSctrl
YrPP
Lead time (hour)
Standard Deviation of Error
207 Nor. stations
03+6,+9,...,+57
Lead time (hour)
Mean Absolute Error
207 Nor. stations
03+6,+9,...,+57
Lead time (hour)
Hit Rate
217 Nor. stations
03+18,+24,+30,+36
Exceedance threshold (m/s)
False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


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


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

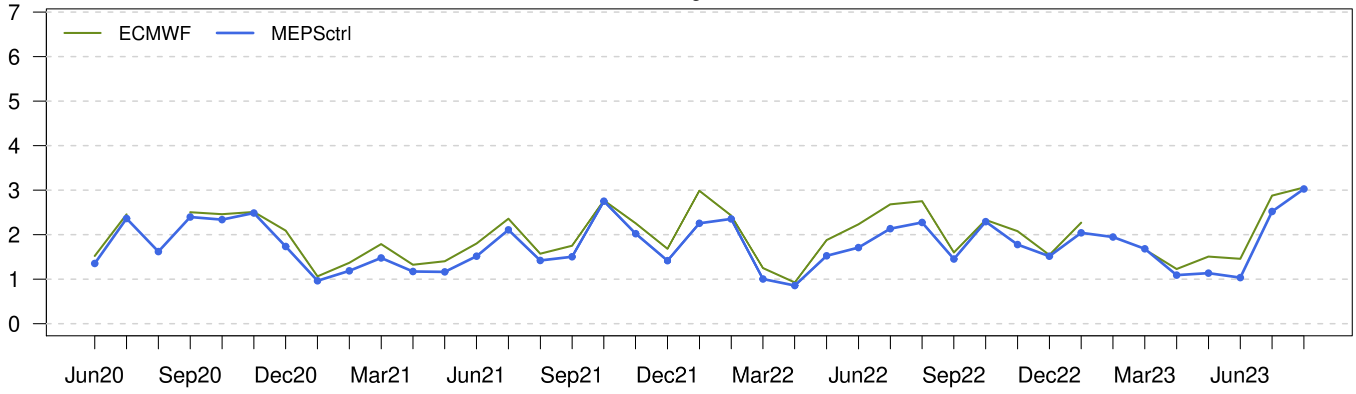
Mean Error


181 Norwegian stations
00+30 UTC
ECMWF
MEPSctrl
6 coastal stations
42 stations more than 500 m above sea level
34 stations with daily mean precipitation > 4 mm
4
2
0
−2
−4
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23

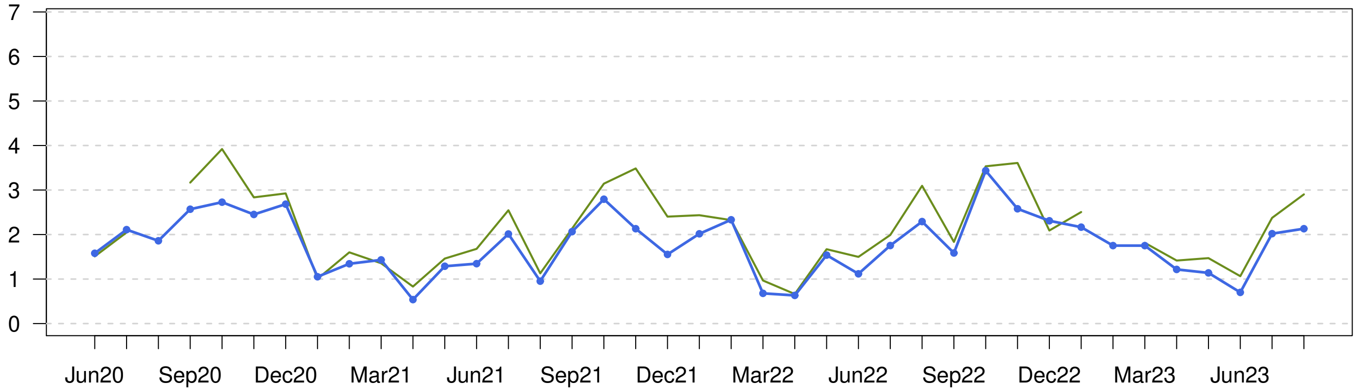

Standard Deviation of Error
181 Norwegian stations
00+30 UTC
ECMWF
MEPSctrl
6 coastal stations
42 stations more than 500 m above sea level
34 stations with daily mean precipitation > 4 mm
0
2
4
6
8
10
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22
Sep22
Dec22
Mar23
Jun23

Mean Absolute Error

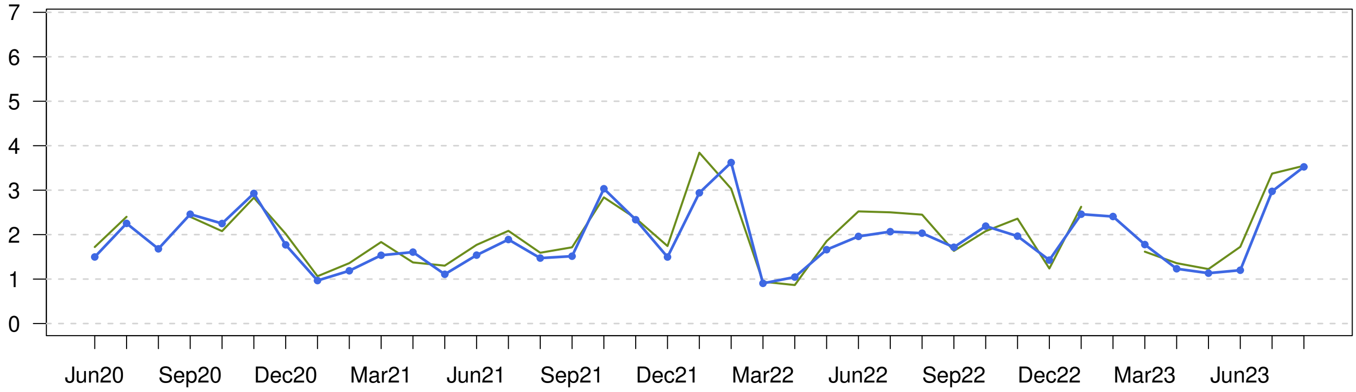
181 Norwegian stations — 00+30 UTC



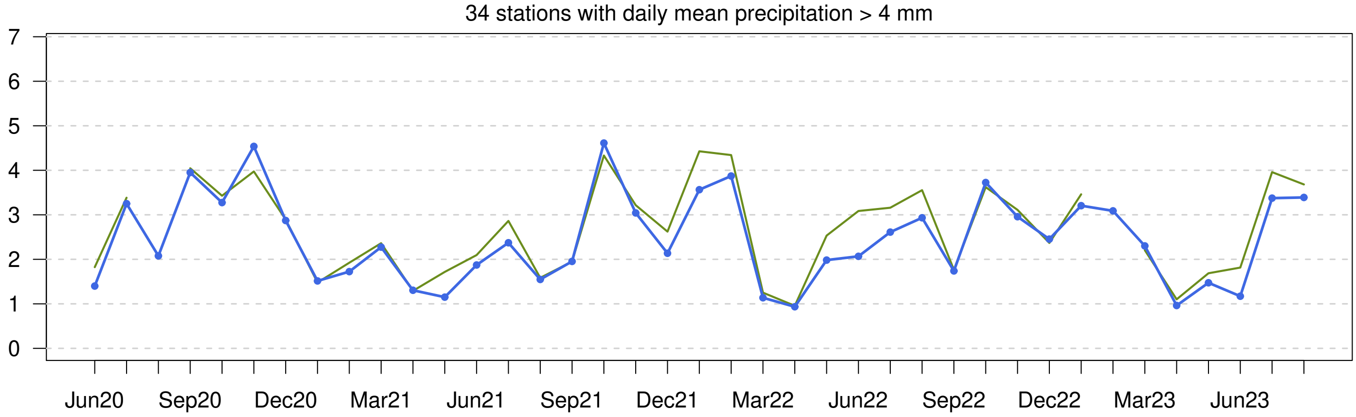
6 coastal stations



42 stations more than 500 m above sea level

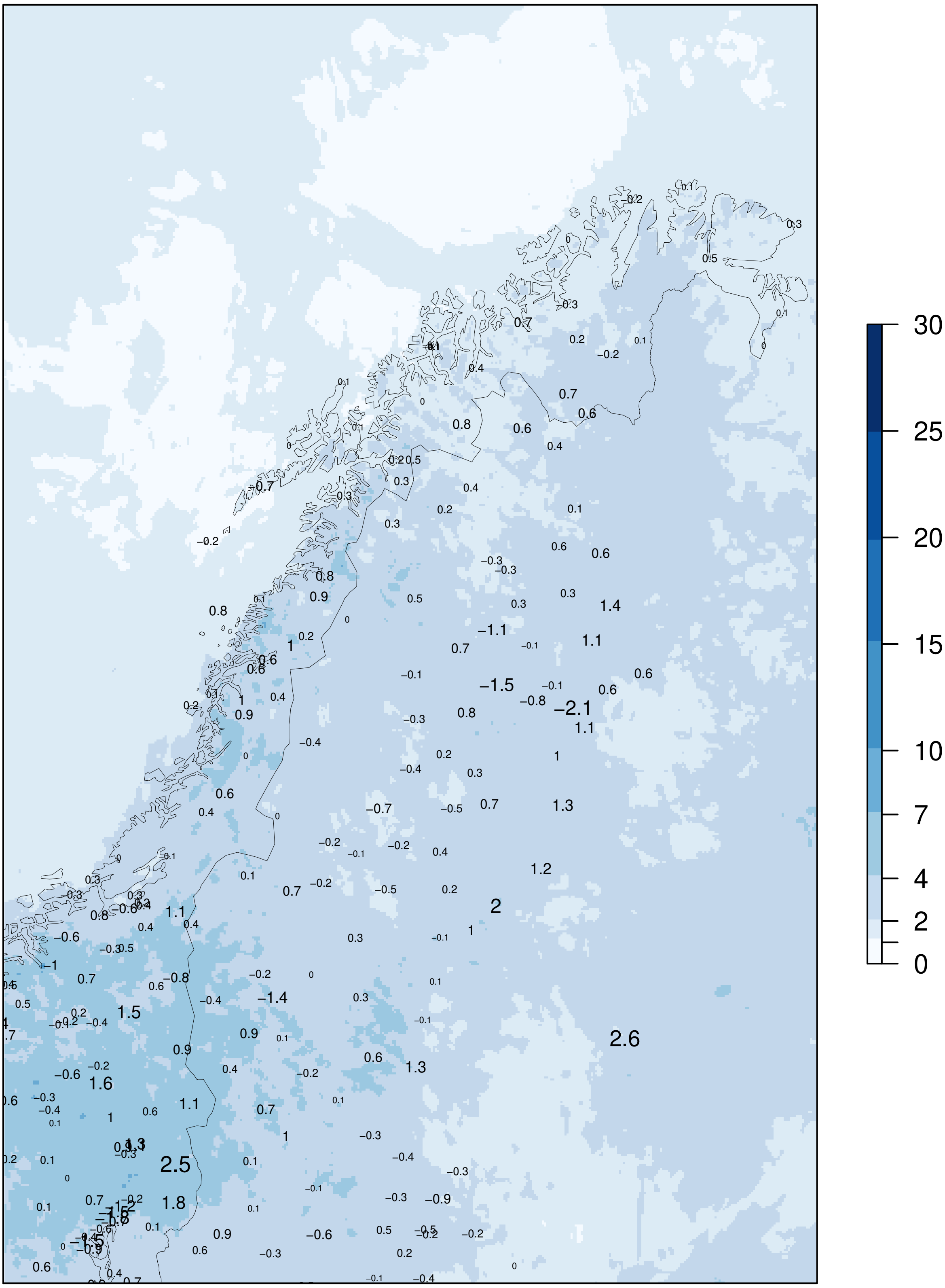


34 stations with daily mean precipitation > 4 mm



MEPSctrl 00+30

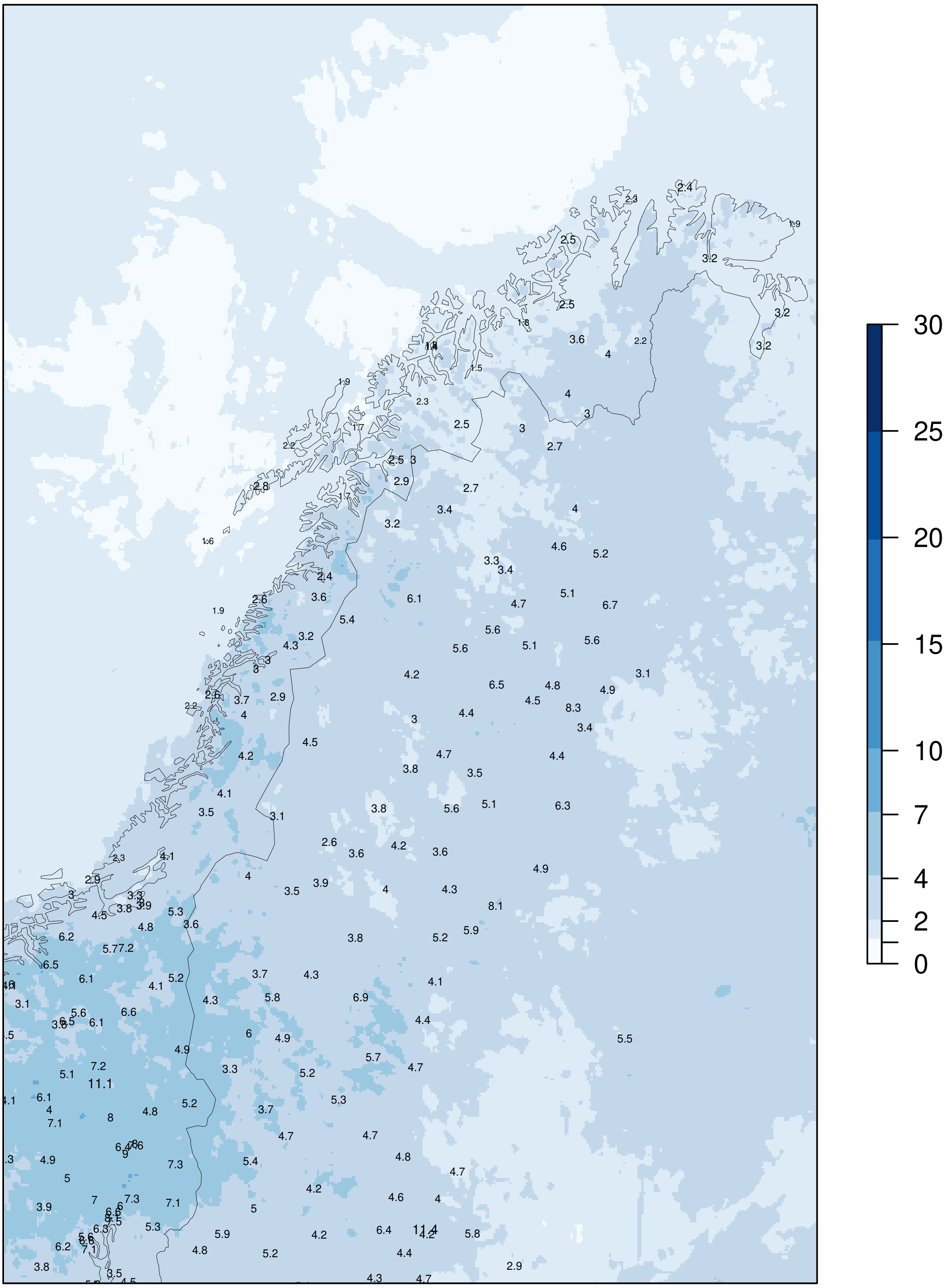
ME at observing sites
(numbers in black)



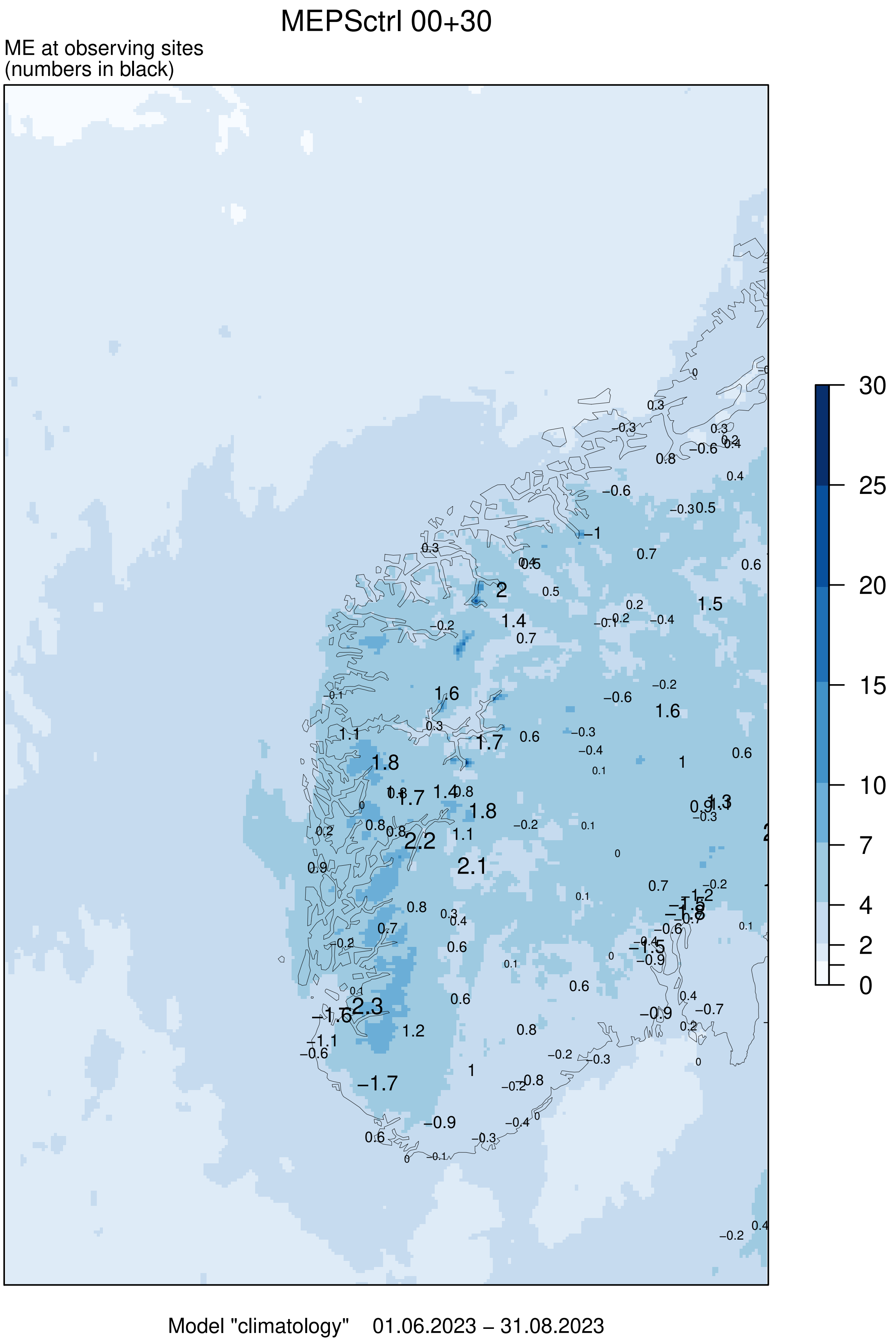
Model "climatology" 01.06.2023 – 31.08.2023

MEPSctrl 00+30

SDE at observing sites
(numbers in black)

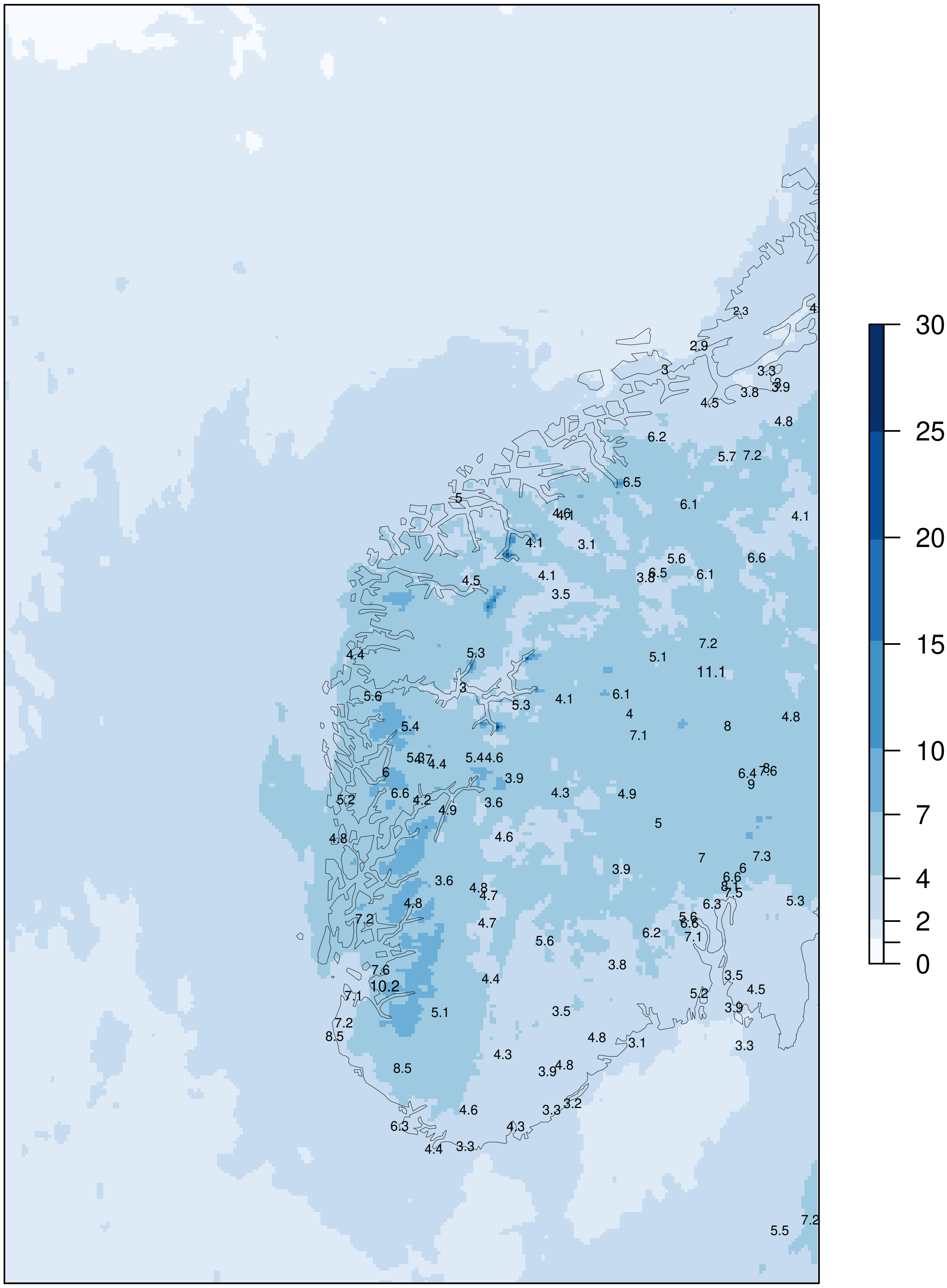


Model "climatology" 01.06.2023 – 31.08.2023


MEPSctrl 00+30
ME at observing sites
(numbers in black)
30
25
20
15
10
7
4
2
0
Model "climatology" 01.06.2023 – 31.08.2023

MEPSctrl 00+30

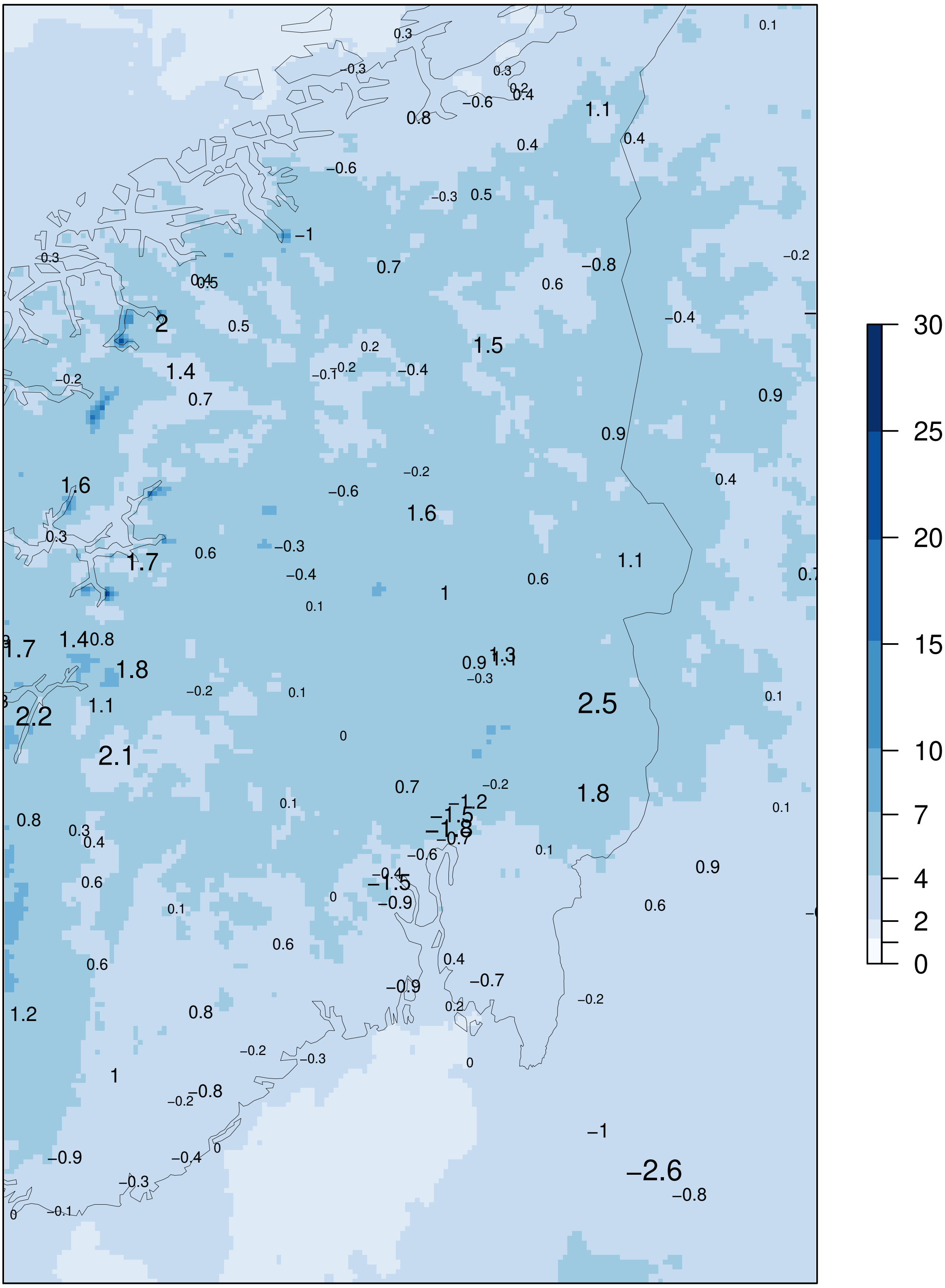
SDE at observing sites
(numbers in black)



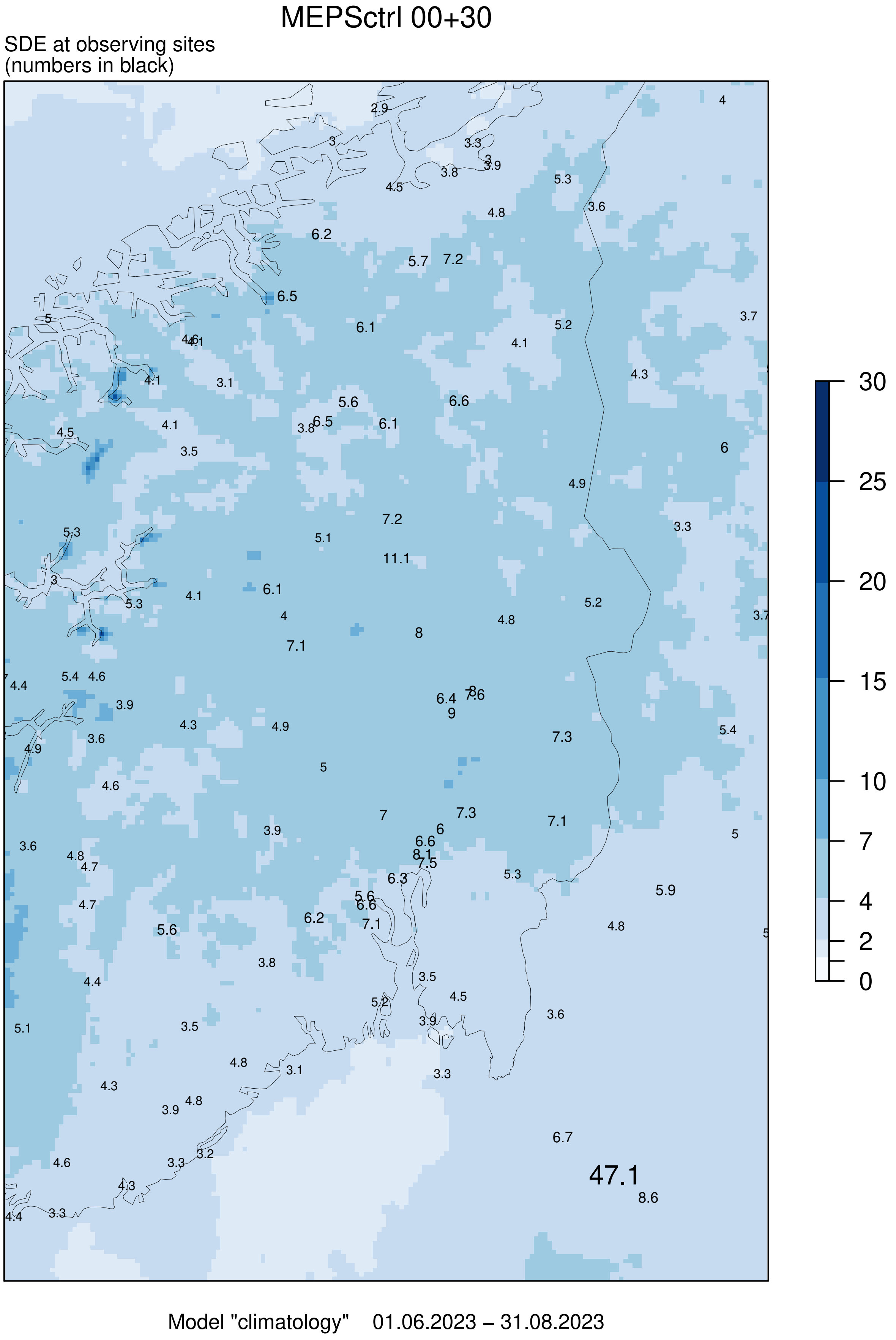
Model "climatology" 01.06.2023 – 31.08.2023

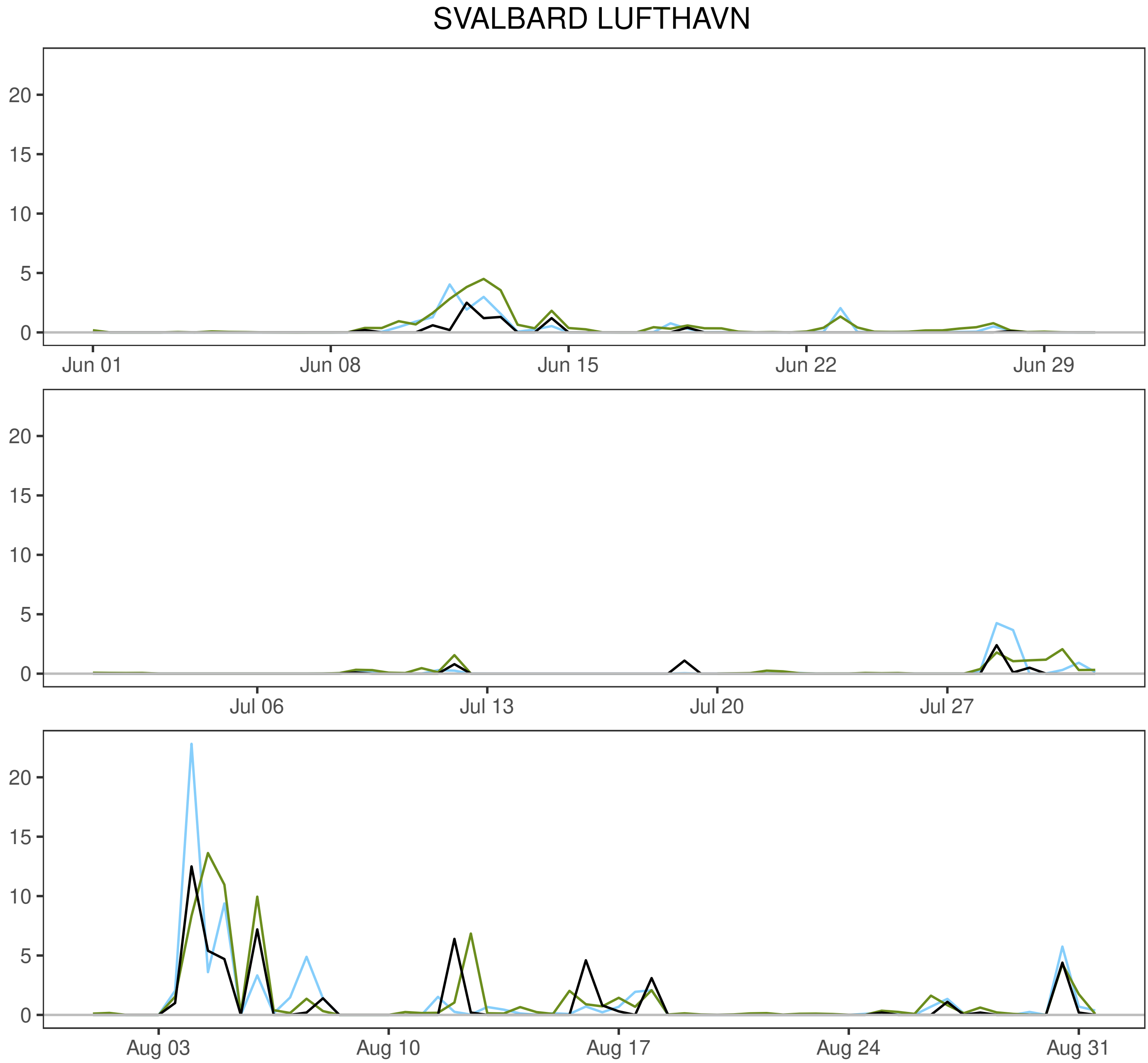
MEPSctrl 00+30

ME at observing sites
(numbers in black)



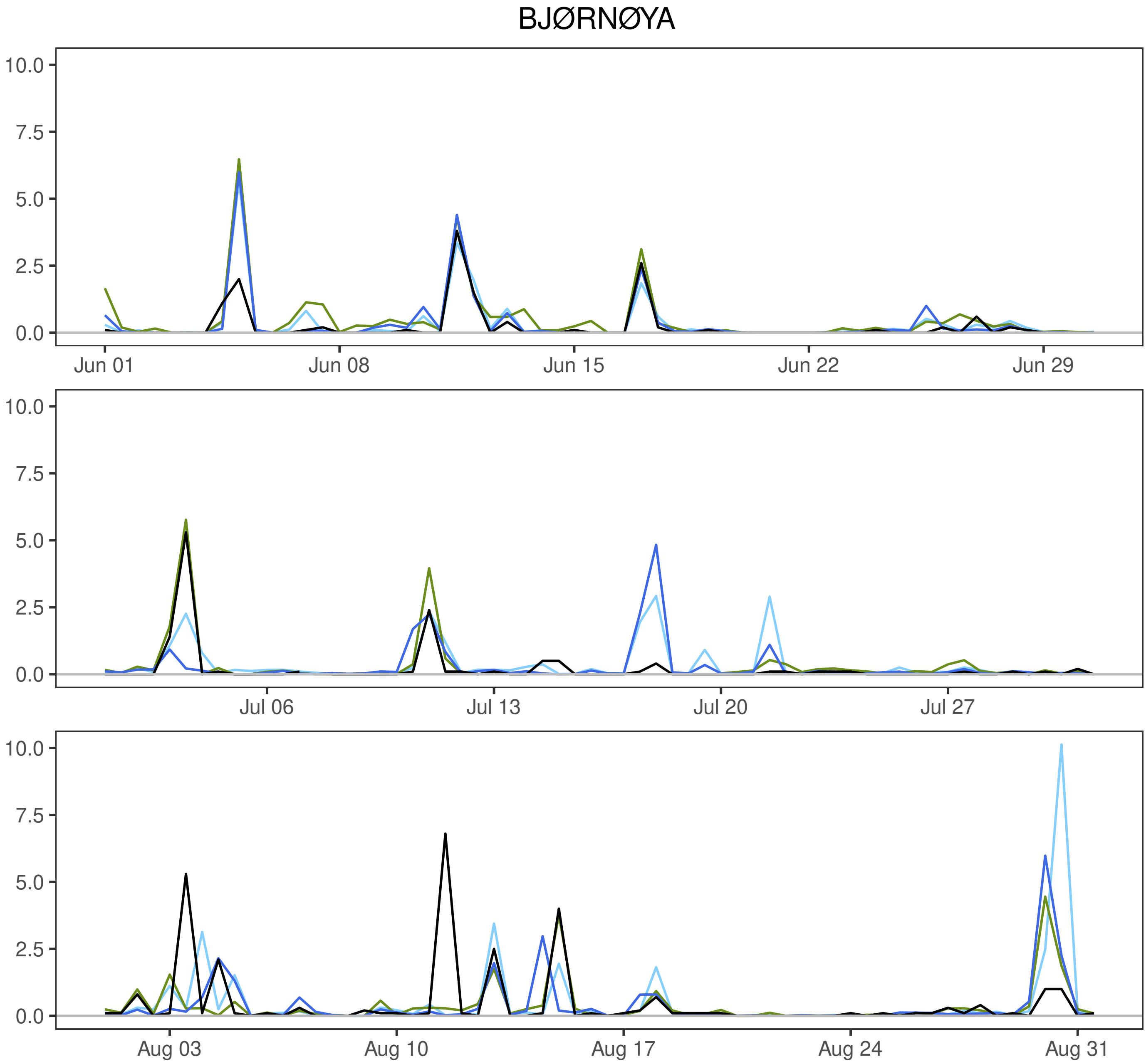
Model "climatology" 01.06.2023 – 31.08.2023


MEPSctrl 00+30
SDE at observing sites
(numbers in black)
30
25
20
15
10
7
4
2
0
Model "climatology" 01.06.2023 – 31.08.2023



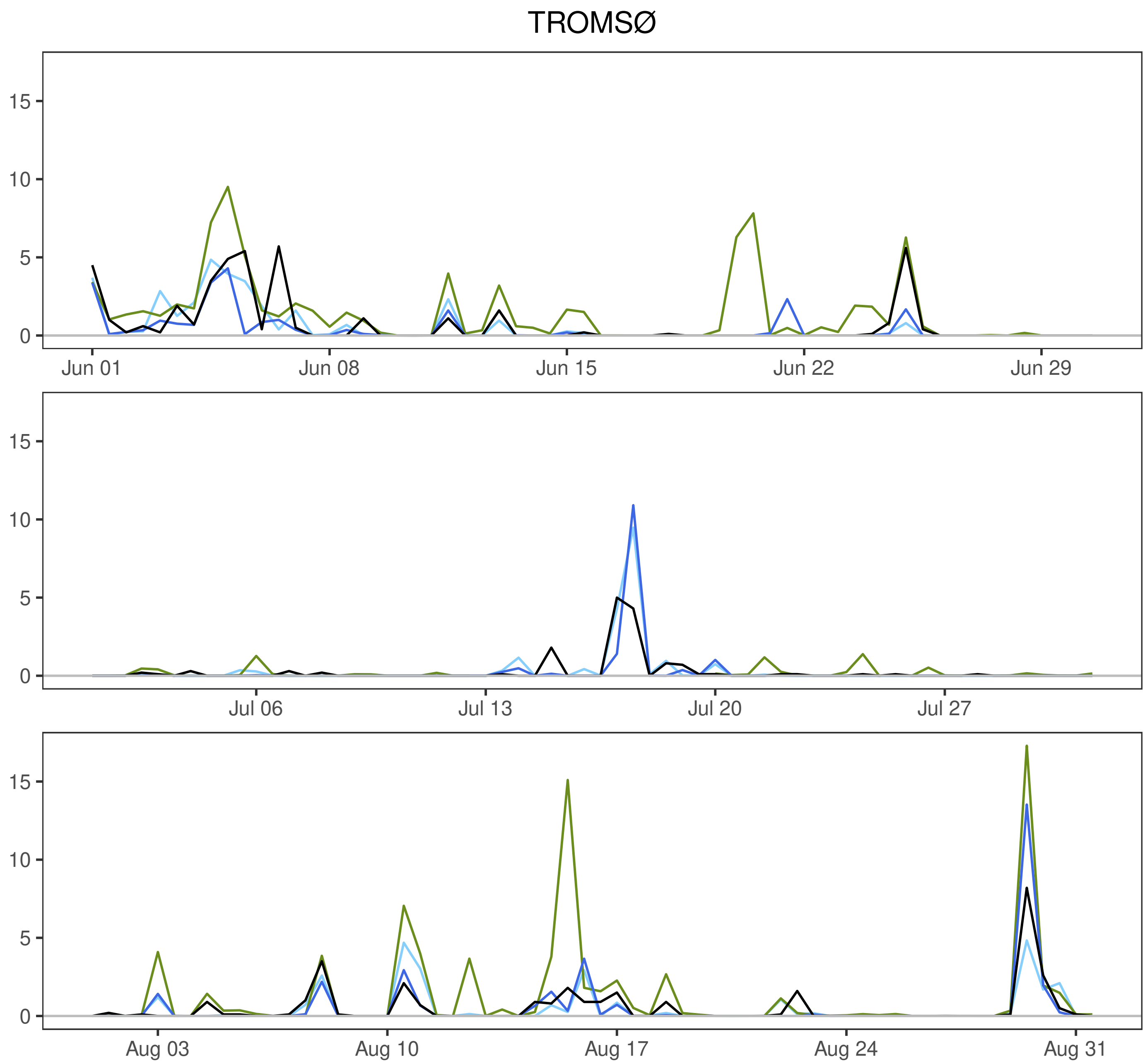
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.4	12.5	1.4	184
AA25: 12+18,+30	0.0	0.5	22.8	2.0	184
ECMWF: 12+18,+30	0.0	0.7	13.6	1.8	170

	ME	SDE	RMSE	MAE	Max.abs.err.	N
AA25–synop	0.2	1.3	1.3	0.4	10.3	170
ECMWF–synop	0.3	1.2	1.3	0.5	8.2	170



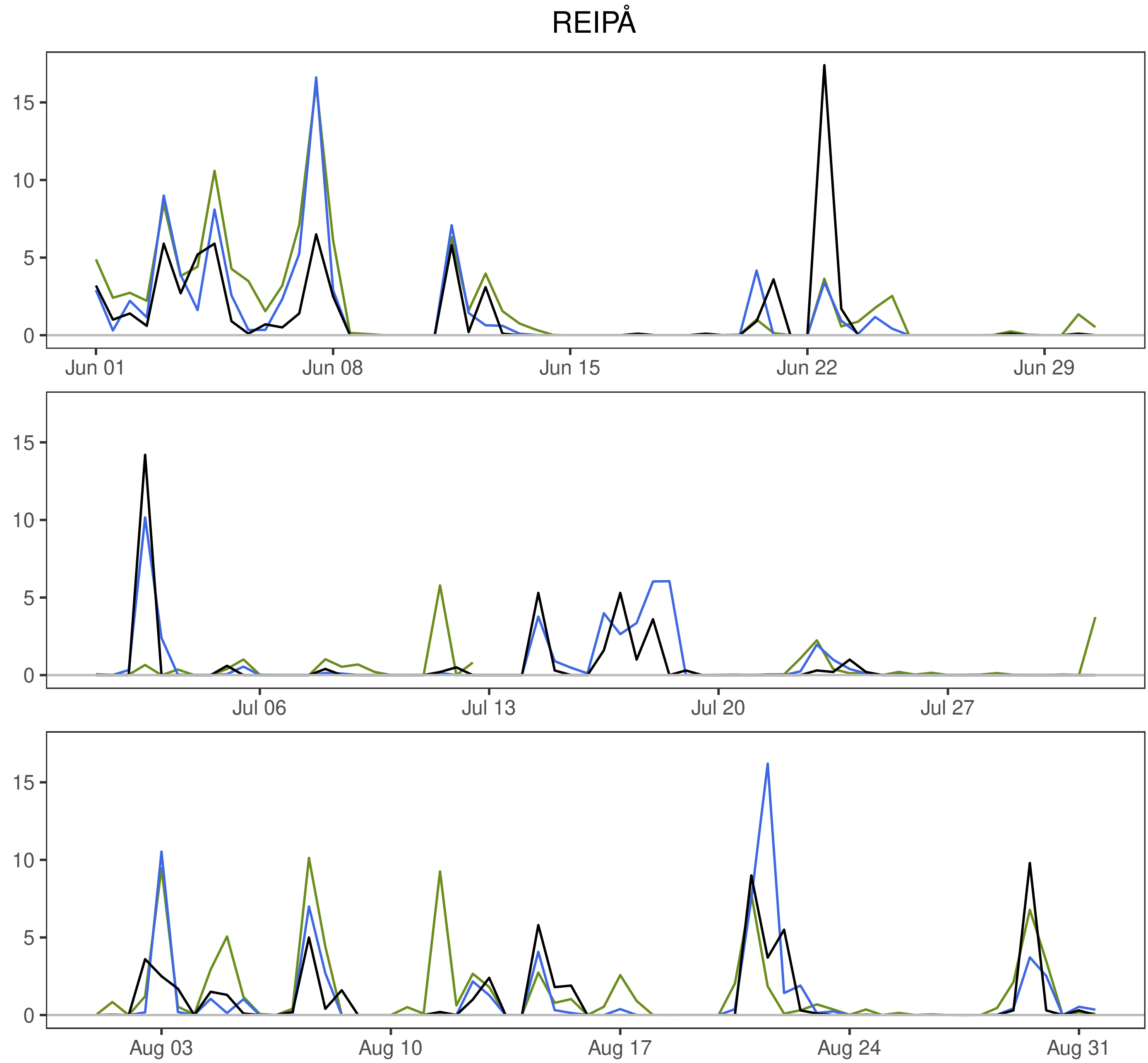
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.3	6.8	0.9	183
MEPSctrl: 12+18,+30	0.0	0.3	6.0	0.9	184
AA25: 12+18,+30	0.0	0.4	10.1	1.1	184
ECMWF: 12+18,+30	0.0	0.4	6.5	1.0	170

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.0	1.0	1.0	0.3	6.8	169
AA25−synop	0.1	1.1	1.1	0.4	9.1	169
ECMWF−synop	0.1	0.8	0.8	0.3	6.5	169



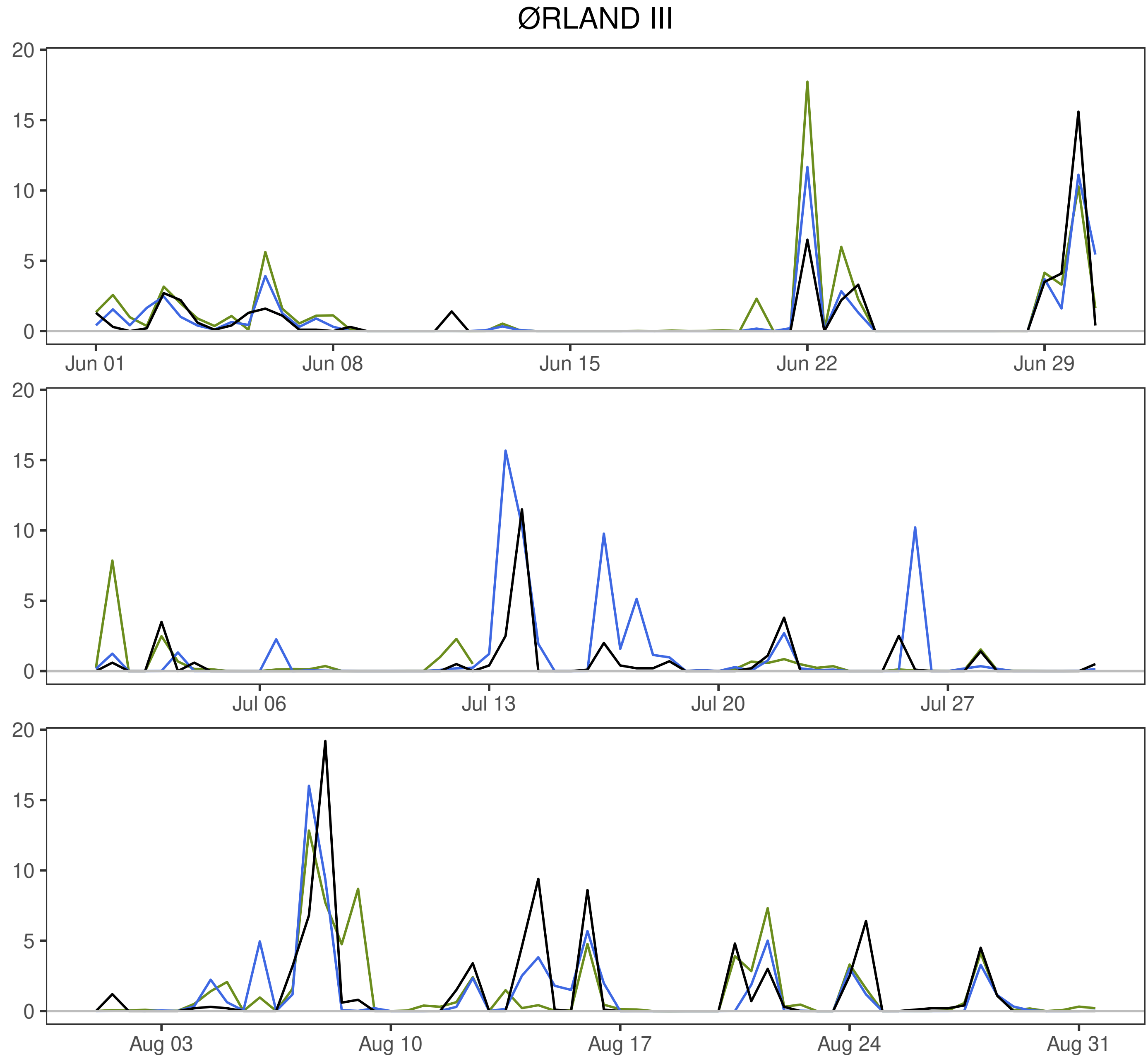
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.5	8.2	1.2	184
MEPSctrl: 12+18,+30	0.0	0.4	13.5	1.4	184
AA25: 12+18,+30	0.0	0.4	9.5	1.2	184
ECMWF: 12+18,+30	0.0	1.0	17.3	2.3	170

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	–0.1	0.9	0.9	0.3	5.3	170
AA25–synop	–0.1	0.8	0.8	0.3	5.3	170
ECMWF–synop	0.6	1.7	1.8	0.7	13.3	170



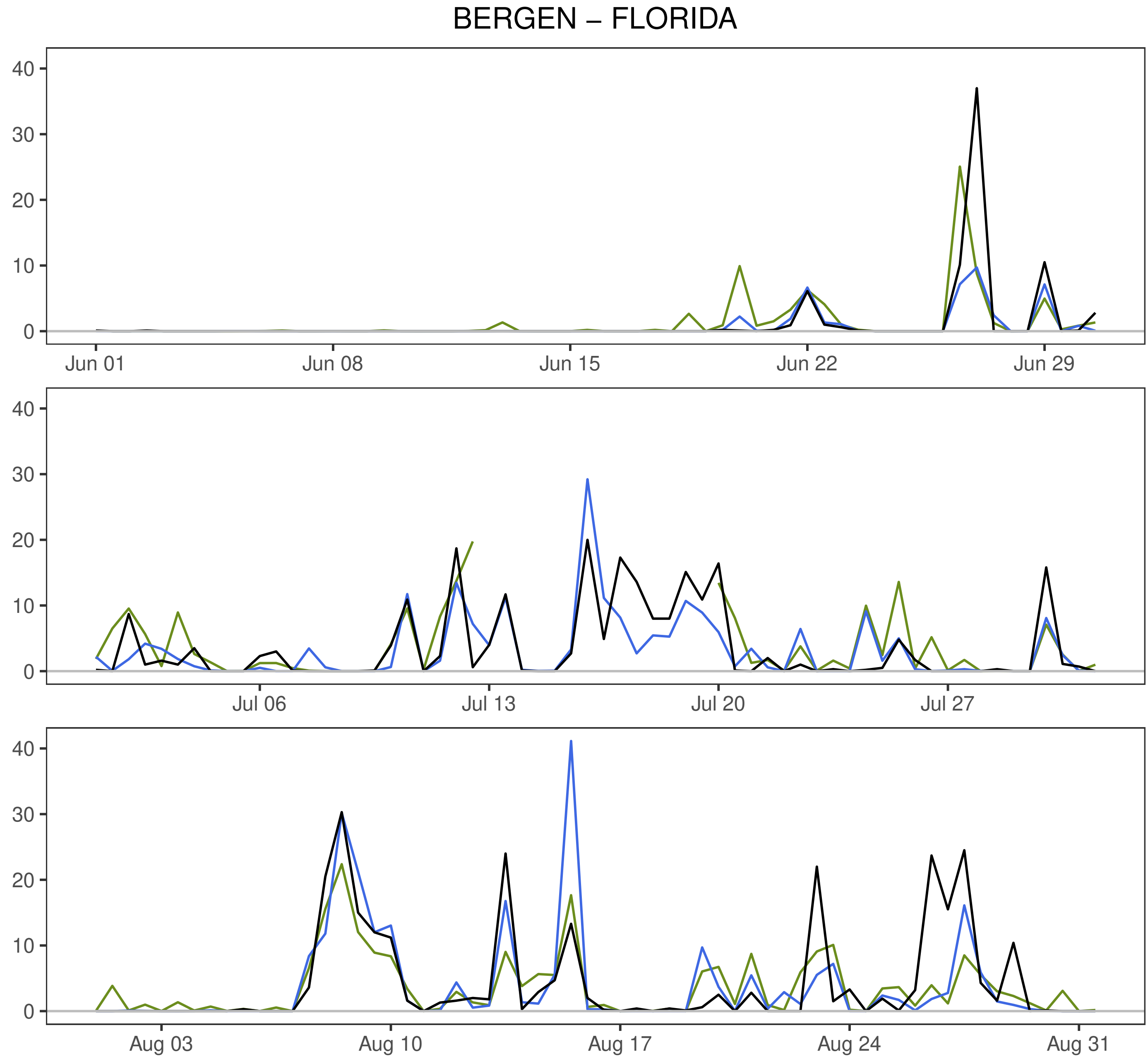
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.9	17.4	2.3	184
MEPSctrl: 12+18,+30	0.0	1.0	16.6	2.5	184
ECMWF: 12+18,+30	0.0	1.3	16.2	2.5	170

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	0.1	2.1	2.1	0.8	14.0	170
ECMWF–synop	0.4	2.3	2.4	1.1	13.8	170



	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.9	19.2	2.5	184
MEPSctrl: 12+18,+30	0.0	1.1	16.0	2.6	184
ECMWF: 12+18,+30	0.0	1.0	17.7	2.4	170

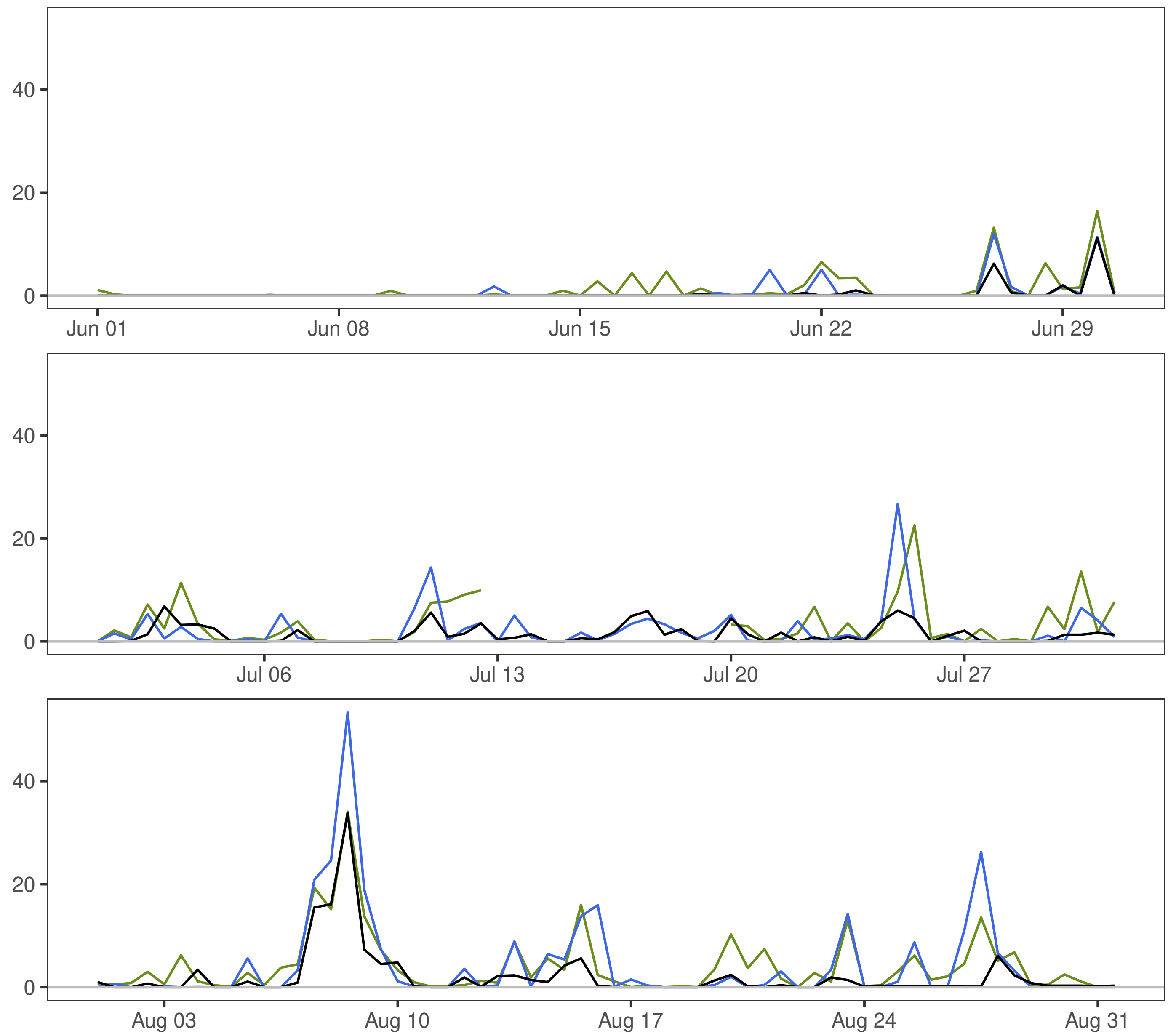
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.0	1.8	1.8	0.7	10.1	170
ECMWF−synop	0.1	2.0	2.0	0.8	11.5	170



	Min	Mean	Max	Std	N
synop: 06,18	0.0	3.0	37.0	6.3	184
MEPSctrl: 12+18,+30	0.0	2.6	41.1	5.5	184
ECMWF: 12+18,+30	0.0	2.7	25.1	4.5	170

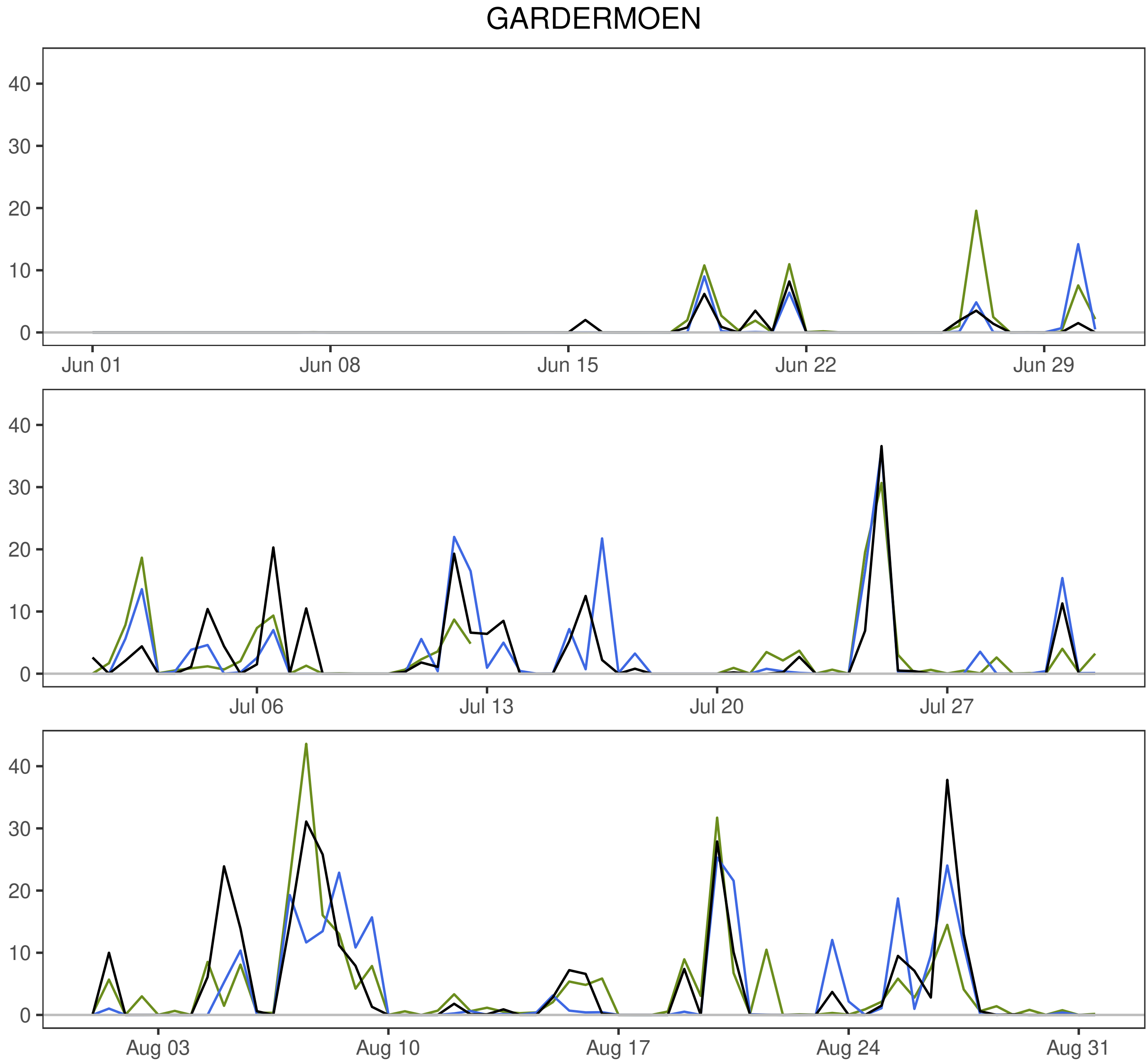
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	–0.4	4.5	4.5	1.8	27.8	170
ECMWF–synop	0.2	4.8	4.8	2.3	28.2	170

LÆRDAL IV



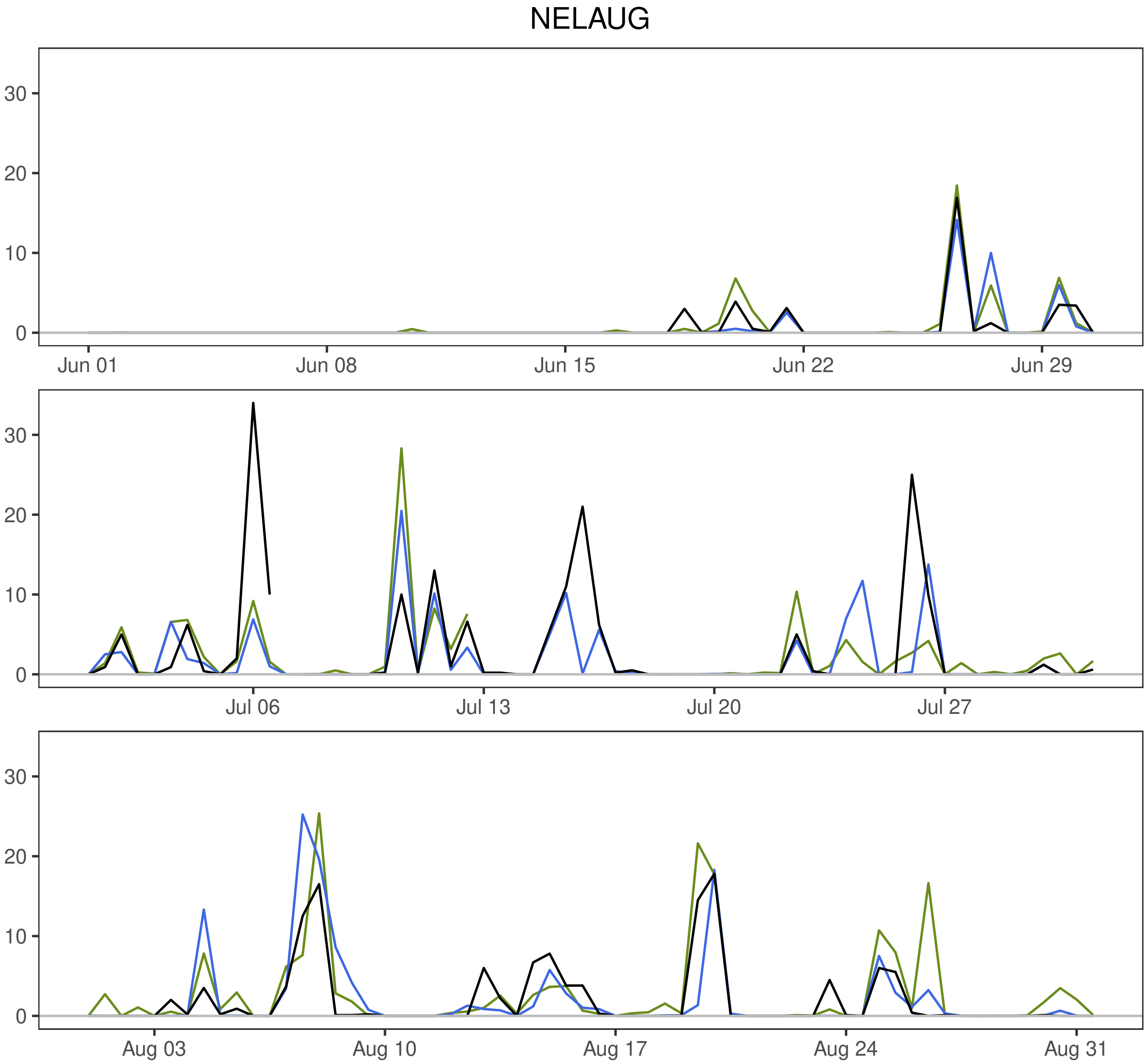
	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.3	33.8	3.4	184
MEPSctrl: 12+18,+30	0.0	2.4	53.3	6.0	184
ECMWF: 12+18,+30	0.0	2.9	34.1	4.8	170

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	1.2	4.0	4.1	1.7	26.1	170
ECMWF−synop	1.6	3.1	3.5	1.9	18.1	170



	Min	Mean	Max	Std	N
synop: 06,18	0.0	2.7	37.8	6.4	184
MEPSctrl: 12+18,+30	0.0	2.6	36.0	6.1	184
ECMWF: 12+18,+30	0.0	2.8	43.6	6.1	170

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.2	4.2	4.2	1.9	19.4	170
ECMWF−synop	0.1	4.3	4.3	2.0	23.3	170



	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.8	34.0	4.7	183
MEPSctrl: 12+18,+30	0.0	1.5	25.2	4.0	184
ECMWF: 12+18,+30	0.0	1.9	28.3	4.4	170

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	–0.2	3.9	3.9	1.4	27.1	169
ECMWF–synop	0.3	3.7	3.7	1.4	24.8	169