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Verification of Operational Weather Prediction Models June to August 2022

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More information...

Verification results are also available on internal web pages

- https://metcoop-comm.smhi.se/ and https://metcoop.smhi.se/ - MetCoOp Web Tools - including verification and observation monitoring
- https://harp.smhi.se/ - MetCoOp verification visualized with harp
- http://verif/vmap/ - timeseries and windroses - on Google map
- https://hirlam.org/trac/wiki/CommunicationWithUsers - HARMONIE quarterly reports

About this report

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

The report includes verification results for 3 Numerical Weather Prediction (NWP) models; MetCoOp ensemble system (MEPS) covering Norway, Sweden, Finland, Denmark and the Baltic states, AROME-Arctic covering Svalbard, Novaja Semlja, Frans Josefs land and the Northern part of Scandinavia and the global ECMWF. The models are further described in the Models section. The variables verified are mean sea level pressure, temperature, wind speed and precipitation. The results are grouped by variable. A short summary of the results and cases studies by forecasters are also included.

Verification results are shown for different groups of stations: Norwegian, Svalbard and North Scandinavian. For temperature there are additional groups with Norwegian coastal and Norwegian inland stations, for wind speed Norwegian coastal and Norwegian mountainous stations, and for precipitation coastal stations, stations more than 500 m above sea level, and stations with daily mean precipitation $>$ 4 mm. For MEPSctrl statistics at the observing sites are also visualized on maps with model climatology. The text size of the statistics increases with the value. Time series with observations and available models are included for selected stations. Post processed variables are compared with MEPSctrl.

Models

The following Numerical Weather Prediction (NWP) models are verified in this report. The verification measures are plotted for each model with the colors indicated in the table below.

ECMWF	Global model (IFS) at the European Centre for Medium-Range Weather Forecasts. From 26 January 2010 horizontal resolution approximately 16×16 km^2. From 8 March 2016 cycle 41r2 with horizontal resolution about 9 km. ECMWF is available about 5 hours later than models run at MET.
MetCoOp ensemble system (MEPSctrl)	MEPS has 30 lagged ensemble members, constructed from 5 members updated hourly and run up to 66 hours. Only member 0, the control, is verified in this report. MEPS is based on HARMONIE with AROME physics and non-hydrostatic dynamics, horizontal resolution defined by a 2.5×2.5 km^2 grid. Experimental with cycle 37h1.1 from November 2012, on Yr since 1 October 2013, operational since March 2014, cycle 38h1.2 from December 2014, cycle 40h1.1 since November 2016 and cycle 43h2.1 from 23 March 2021. MEPS is run in cooperation with Swedish Meteorological and Hydrological Institute (SMHI), Finnish Meteorological Institue (FMI) and Estonian Environment Agency (ESTEA).
AROME-Arctic (AA25)	HARMONIE with AROME physics, horizontal resolution defined by a 2.5×2.5 km^2 grid. Experimental with cycle 38h1.2 from 15 October 2015, on Yr from 14 December 2016, cycle 40h1.1 since June 2017, cycle 43h2.1 since 5 May 2021.

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

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

Post processed forecasts

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

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

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 http://www.cnrm.meteo.fr/gmapdoc/ and http://hirlam.org/.

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

AROME physics

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

SURFEX as surface model

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

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

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

Data assimilation

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

Surface analysis

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

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

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

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

Upper air analysis

MEPS runs three dimensional variational (3D VAR) data assimilation using conventional observations from synop stations, ships, radiosondes and aircrafts and AMSU-A and AMSU-B/MHS data from polar orbiting NOAA and METOP satellites. GNSS were introduced 17 February 2015, radar reflectivities 16 June 2015, IASI 26 November 2015 and ASCAT 17 March 2016.

Boundary fields

MEPS gets its boundary values (1-hourly) from the ECMWF model at approximately 16 km resolution, and has currently 65 vertical levels. None of the HARMONIE configurations at MET have applied digital filter initialization (DFI).

Verification measures

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

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

Forecasts of continuous variables

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

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

In the formula for COR the following definitions are used

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

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

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

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

Forecasts of categorical variables

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

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

Verification statistics for such forecasts are listed in the following table

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

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

Observations

All observations come from Klimadatavarehuset at MET. Only synop stations are used. From 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. All models tend to underestimate the temperature for the different groups of stations, but more so for ECMWF. Still, the errors are small, indicating that the timing of the temperature changes is generally good. The upgrade of MEPS from cycle 40 to cycle 43 on 23 March 2021 had some effect on near surface temperatures. The new physiography data set - ECOCLIMAP Second Generation - has a new albedo data set leading to a slight increase in daytime temperatures in the summer season, giving less underestimation of daytime temperatures. The mean error plotted as a function of lead time shows that the temperature forecasts still are a little bit too cold during the day, but the underestimation is significantly reduced as compared to the summers before the update.

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 threshold scores indicate that wind speed is better forecast for lower than for higher wind speeds for all models. Since previous summer there are only minor changes affecting the wind. A modification introduced in January 2022, leads to a slight reduction of near surface wind speeds on summer days. The wind speed 10 m is now on average over Norwegian stations somewhat underestimated during the 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 post-processed wind speed YrPP shows results very similar to MEPSctrl for the summer season.

Precipitation also shows varying results, depending on the amount and location. ECMWF has on average more precipitation than MEPSctrl which this summer had mean errors very close to (and mainly above) 0. Evaluated by skill scores, ECMWF performs a little bit better, but both have more errors for both very small amounts and very high amounts, than precipitation in the mid range. MEPSctrl performs better than ECMWF for small amounts and no precipitation.

The models generally perform better during summer months than during winter. A possible cause is that storm activity is challenging to predict accurately, and there are 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. Low clouds June 2022

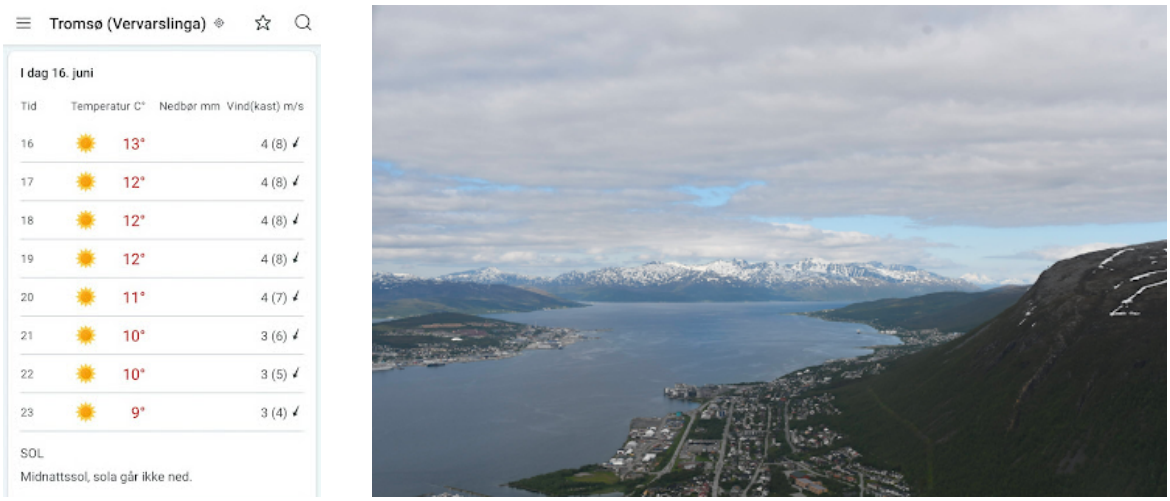


Figure 1: Forecast (left) and photo (right) from Tromsø.

Stratus layers under subsidence inversion are often not well described in the model, as illustrated in this case from 16 June 2022. As is common for these cases, there was at a high pressure ridge with a pronounced subsidence inversion at 850 hPa. The forecast for Tromsø was almost cloud free, (figure 1 left), while in reality it was almost overcast with a stratus layer at around 850 hPa (figure 1 right). The satellite image in figure 2 shows that the stratiform cloud layer covered most of Troms and Vesterålen, including Andenes. The actual sounding from Andenes (figure 3, blue line) shows that there were sharp vertical temperature gradients and a thin saturated layer at around 850 hPa, with cloud top temperature of -2.5°C. The corresponding sounding from MEPSctrl had less definition in the vertical, and was not able to reproduce the strong inversion and the saturated layer. The model was fairly accurate in the temperatures above 750 hPa, but could not resolve the details below this level, and hence missed the stratus clouds here. Figure 4 shows that the low clouds were slightly better forecast from ECMWF than from MEPSctrl in this case.

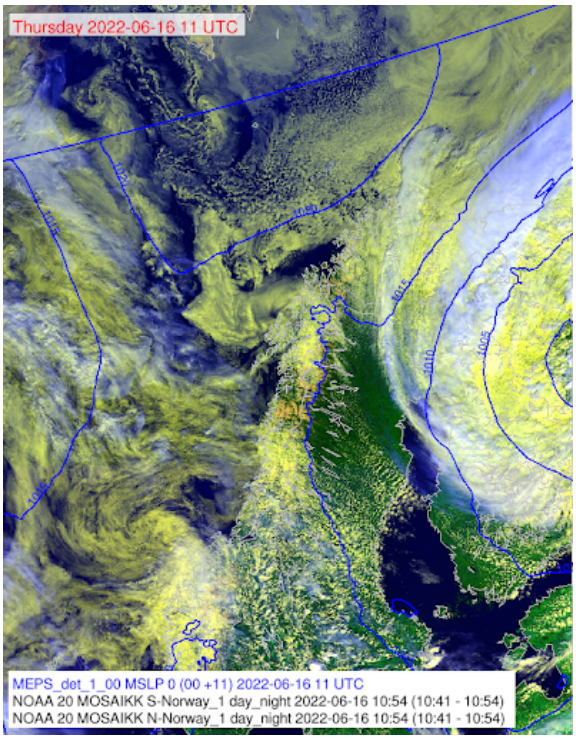


Figure 2: Satellite image of Northern Norway 16 June 11 UTC.

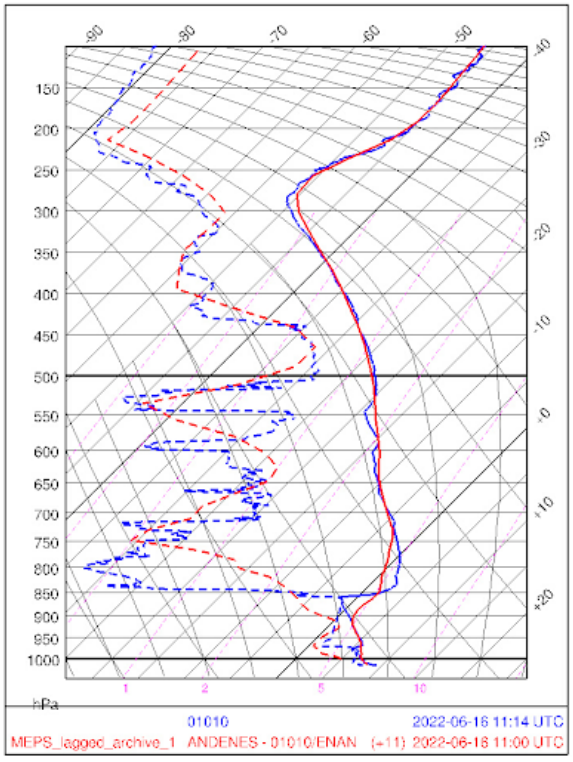
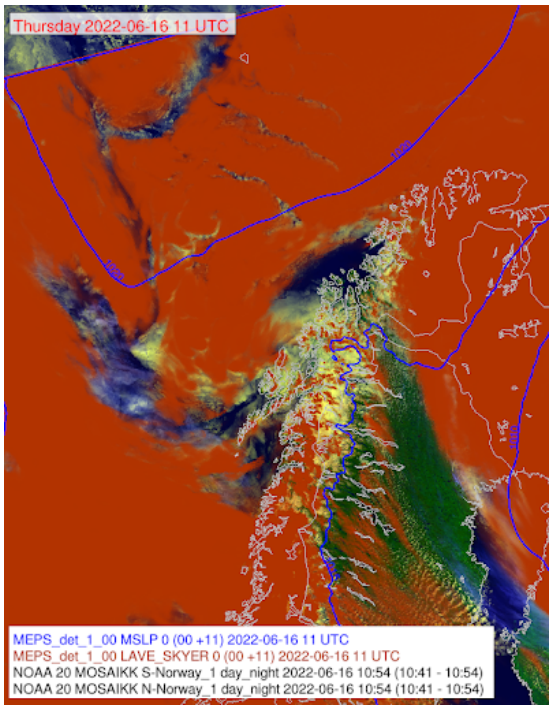


Figure 3: Temperature and sounding at Andenes 16 June 11 UTC.



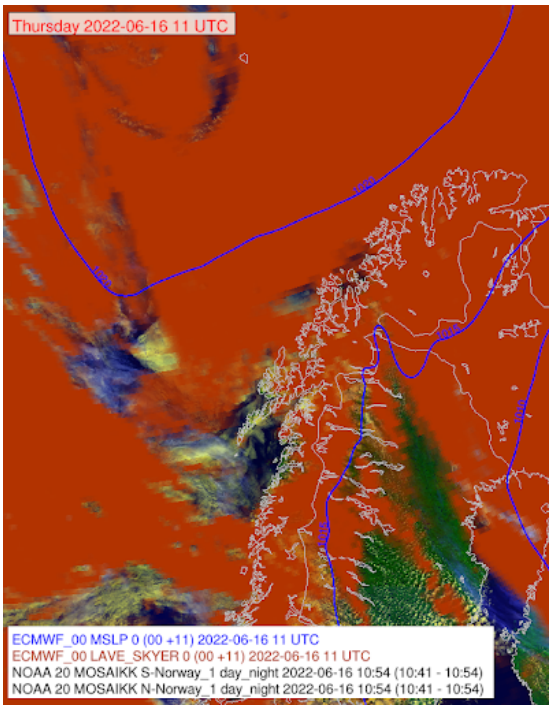


Figure 4: MSLP shown as blue lines and low clouds shown in red at 16 June 11 UTC for Northern Norway from MEPSctrl (left) and ECMWF (right).

Case 2. Precipitation August 2022

Figure 5: Heavy precipitation at Storåga, Lurøy.

High intensity precipitation is often not well forecast in MEPS. On 11 August an atmospheric river event took place in Lurøy, Nordland (figure 5) with severe floods as a result. Several meteorological observation stations (not shown on the map in figure 6) measured more than 80 mm/24 hours, most notably at Storåga, Lurøy with 170-180 mm/24 hours and at Sandnessjøen - Åsen which had 109.5 mm/24 hours. Both places are located at the coast of Nordland. Figure 6 shows that MEPSctrl gave values in the range of 60 to 90 mm in these areas, and that the maxima were placed further inland. The latter cannot be verified due to lack of observations. This case was unusual in that MEPS in several places or runs had less precipitation than the larger scale ECMWF model.

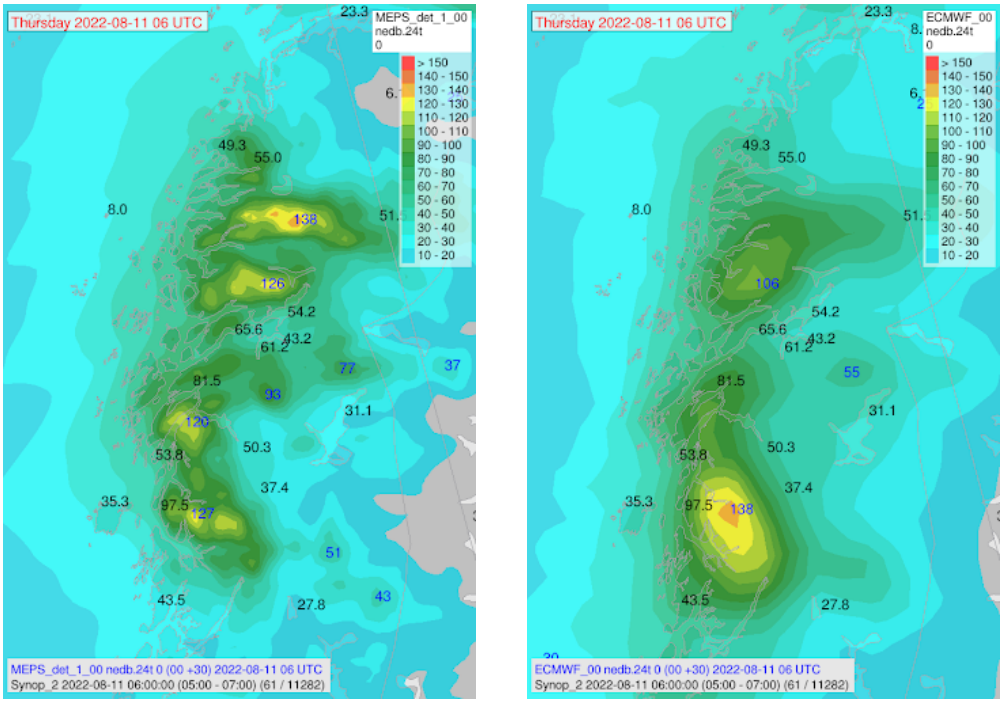


Figure 6: 24 hour accumulated precipitation forecast from MEPSctrl (left) and ECMWF (right). Synoptic are observations shown as the numbers in black (blue for maxima).

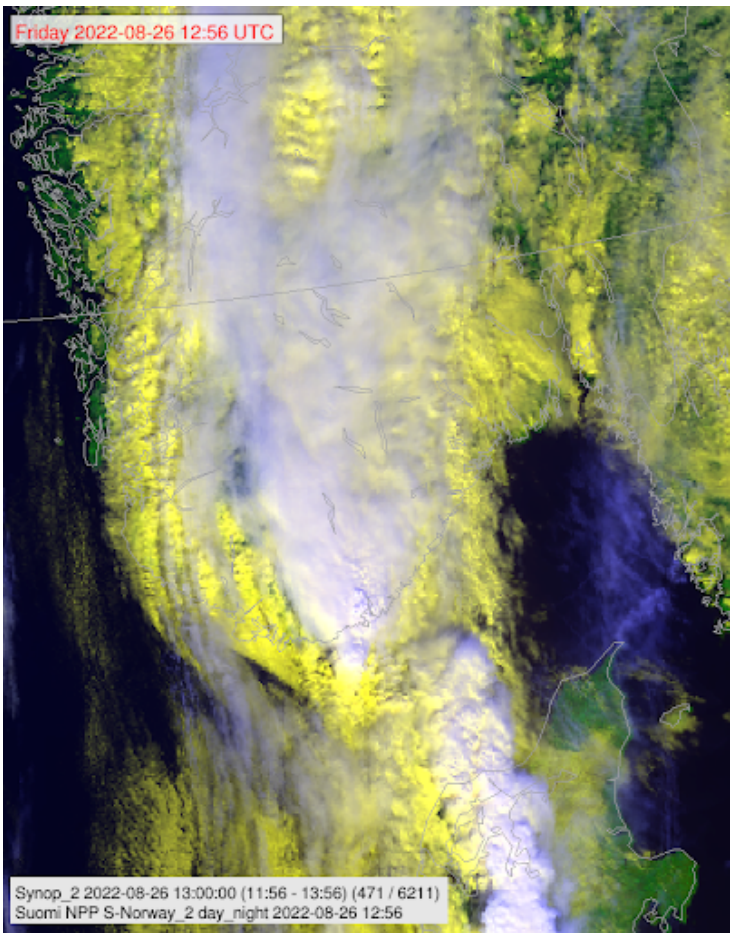


Figure 7: Satellite image 26 August 12:56 UTC.

Another example was seen on 26 August when a weather warning for heavy rain was issued for Agder and Rogaland in southern Norway. The satellite picture in figure 7 confirms a trough and deep convective clouds (bluish white) in the Agder/Kristiansand area at 12:56 UTC, that were producing heavy rain showers here. Observations from Netatmo stations (figure 8) show maximum values of 20 to 50 mm per hour when the trough passed at 14 to 15 UTC. In this period the maximum 1 hour precipitation was forecast from MEPSctrl to 2 to 8 mm/hour at 14 and 15 UTC (figure 9). An earlier maximum of 20 mm/hour was forecast for 10 UTC. Probabilities indicated a 5 to 10% chance for 25 mm/hour (figure 10), and on this basis a yellow warning was issued. Comparisons to observed values show that the precipitation maxima were severely underforecast, and an assessment of the consequences suggest that a warning of a higher level could have been justified in this case.

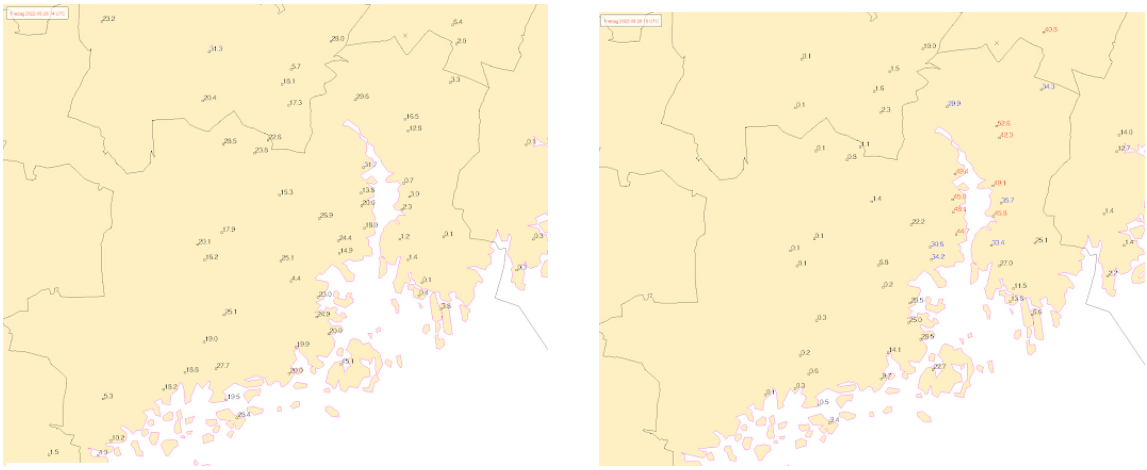


Figure 8: 1 hour precipitation from Netatmo on 26 August at 14 UTC (left) and 15 UTC (right).

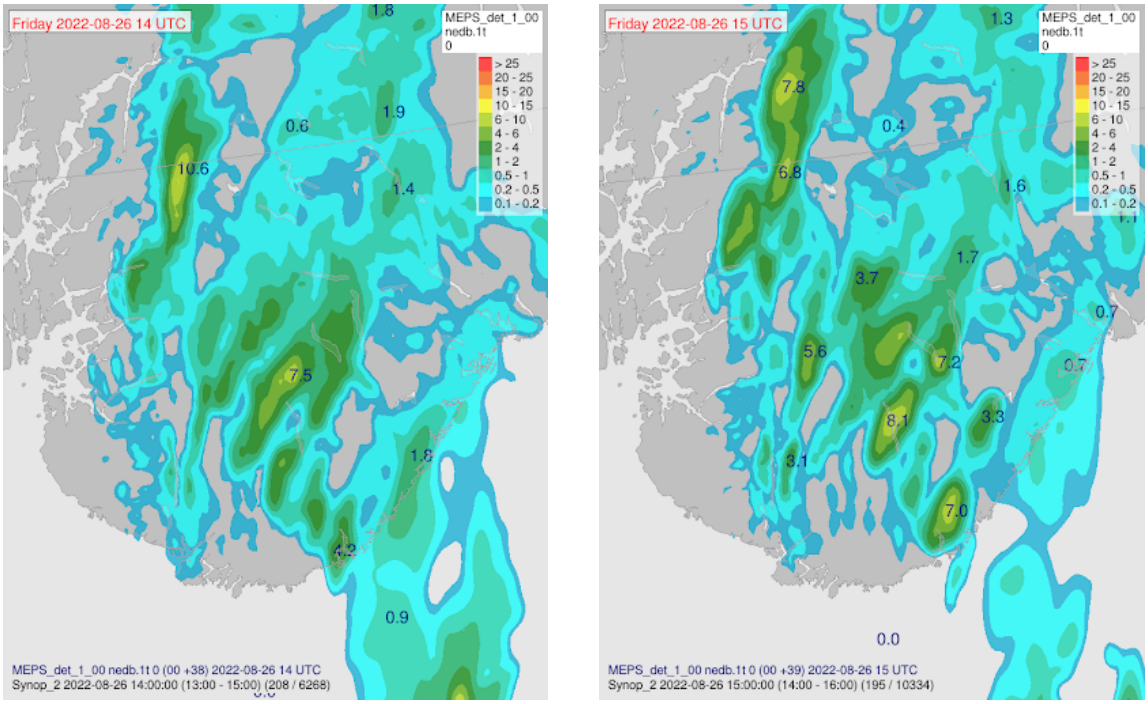


Figure 9: 1 hour precipitation from MEPSctrl on 26 August at 14 UTC (left) and 15 UTC (right). Synoptic observations are shown as black numbers.

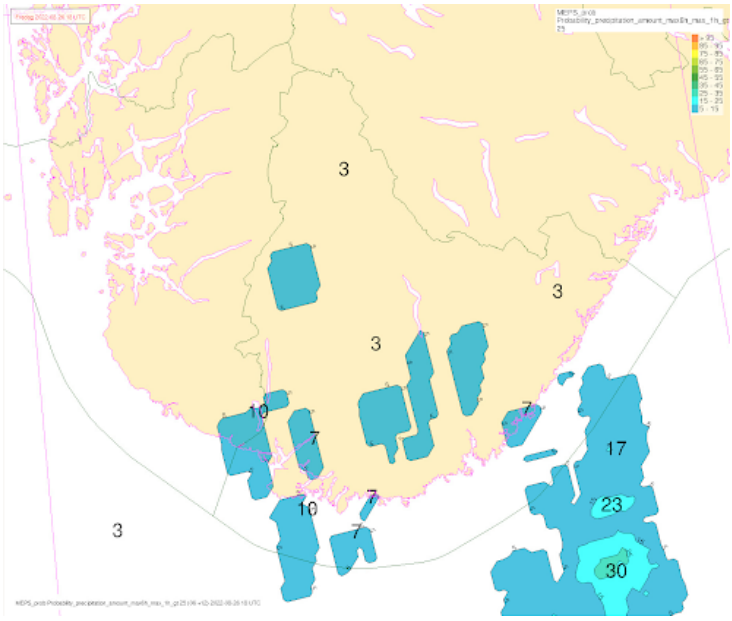
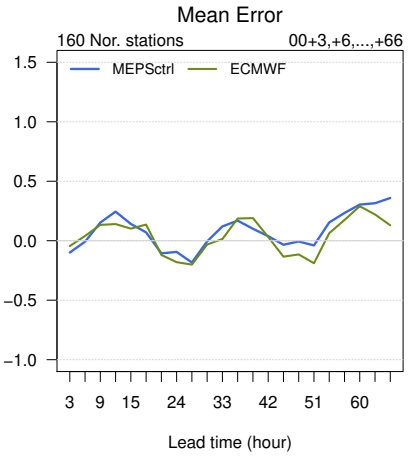
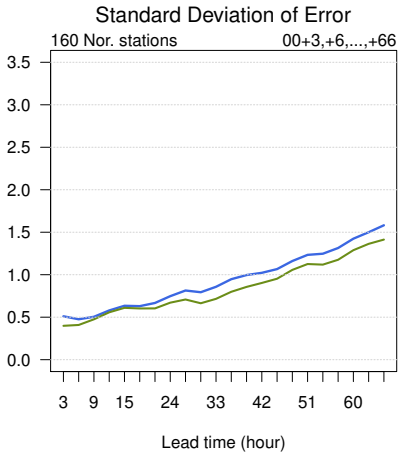
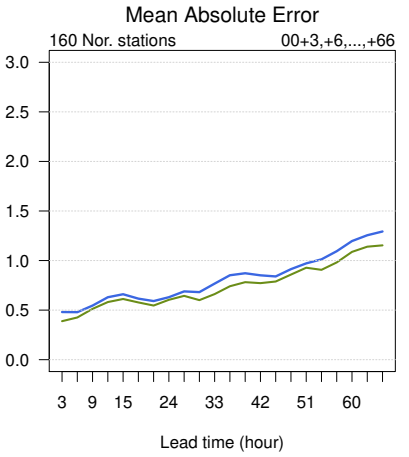


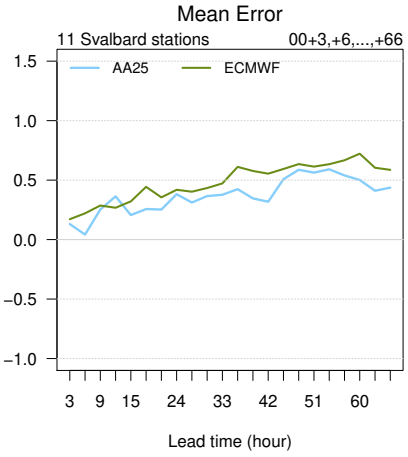
Figure 10: Probabilities of exceeding 25mm/hour from MEPSctrl.

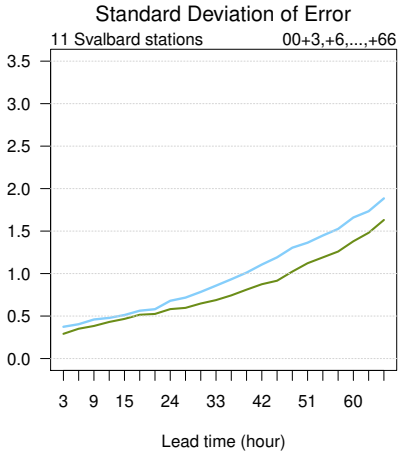
Summarized statistics

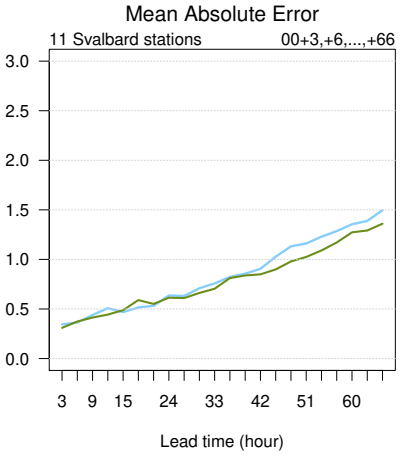

Mean Error
160 Nor. stations
00+3,+6,...,+66
MEPSctrl
ECMWF
1.5
1.0
0.5
0.0
−0.5
−1.0
3 9 15 24 33 42 51 60
Lead time (hour)

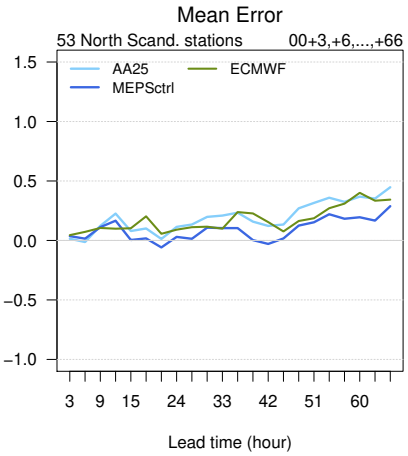

Standard Deviation of Error
160 Nor. stations
00+3,+6,...,+66
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
3 9 15 24 33 42 51 60
Lead time (hour)

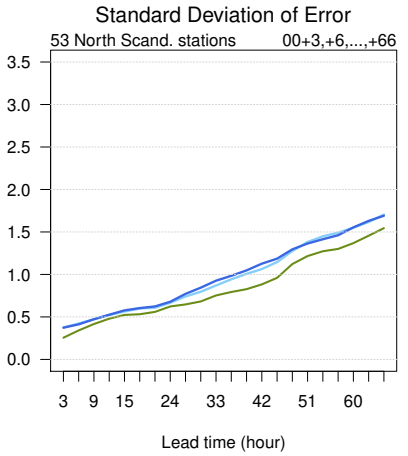

Mean Absolute Error
160 Nor. stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
0.0
3 9 15 24 33 42 51 60
Lead time (hour)

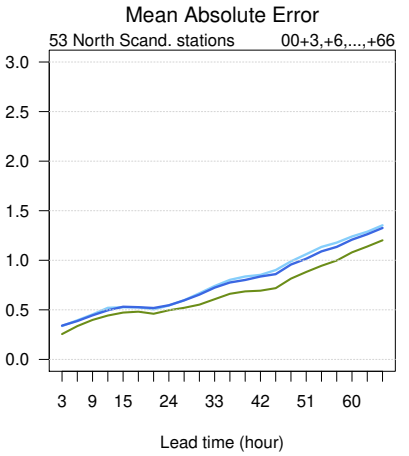

Mean Error
11 Svalbard stations
00+3,+6,...,+66
AA25
ECMWF
1.5
1.0
0.5
0.0
−0.5
−1.0
3 9 15 24 33 42 51 60
Lead time (hour)


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


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

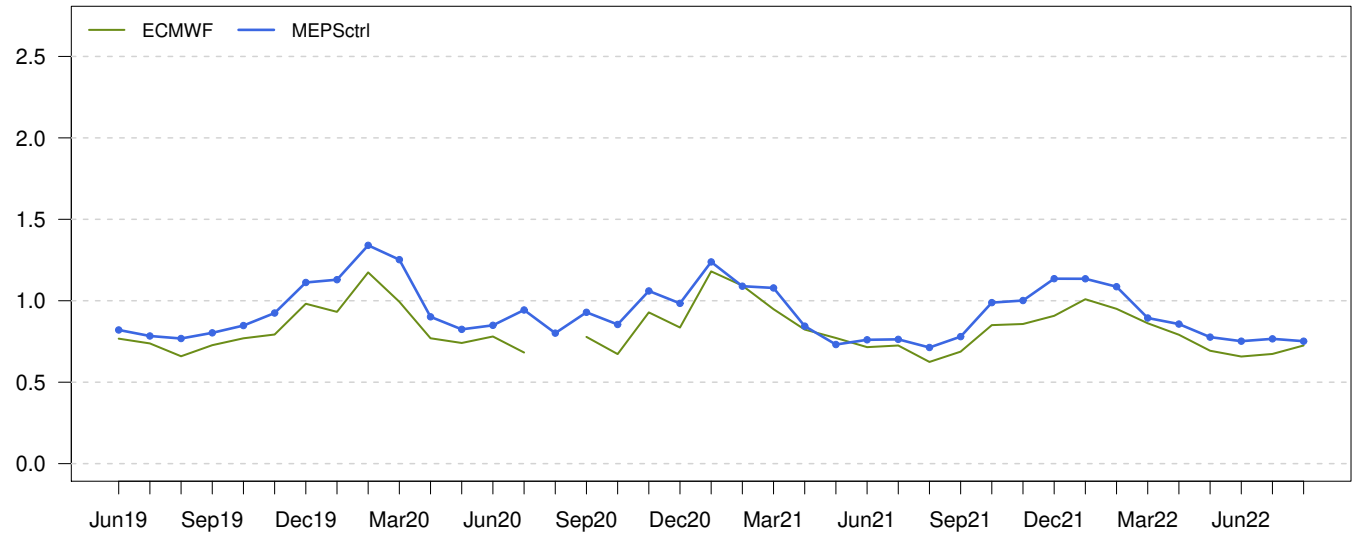

Mean Error
53 North Scand. stations
00+3,+6,...,+66
AA25
ECMWF
MEPSctrl
1.5
1.0
0.5
0.0
−0.5
−1.0
3 9 15 24 33 42 51 60
Lead time (hour)


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

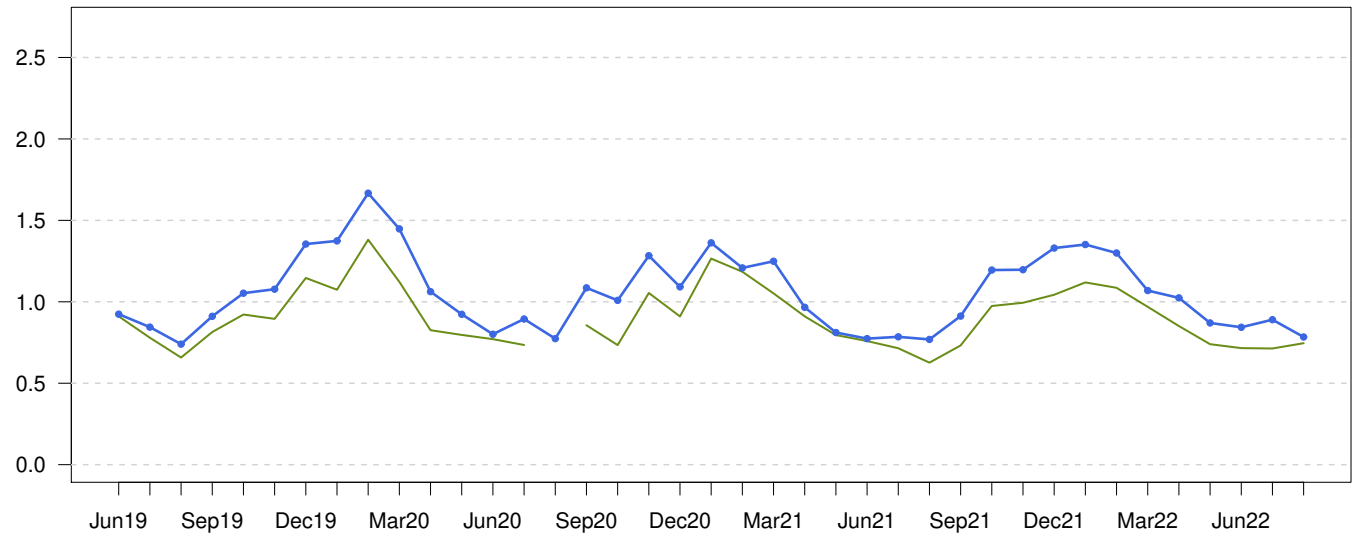

Mean Absolute Error
53 North Scand. stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
0.0
3 9 15 24 33 42 51 60
Lead time (hour)

Mean Absolute Error

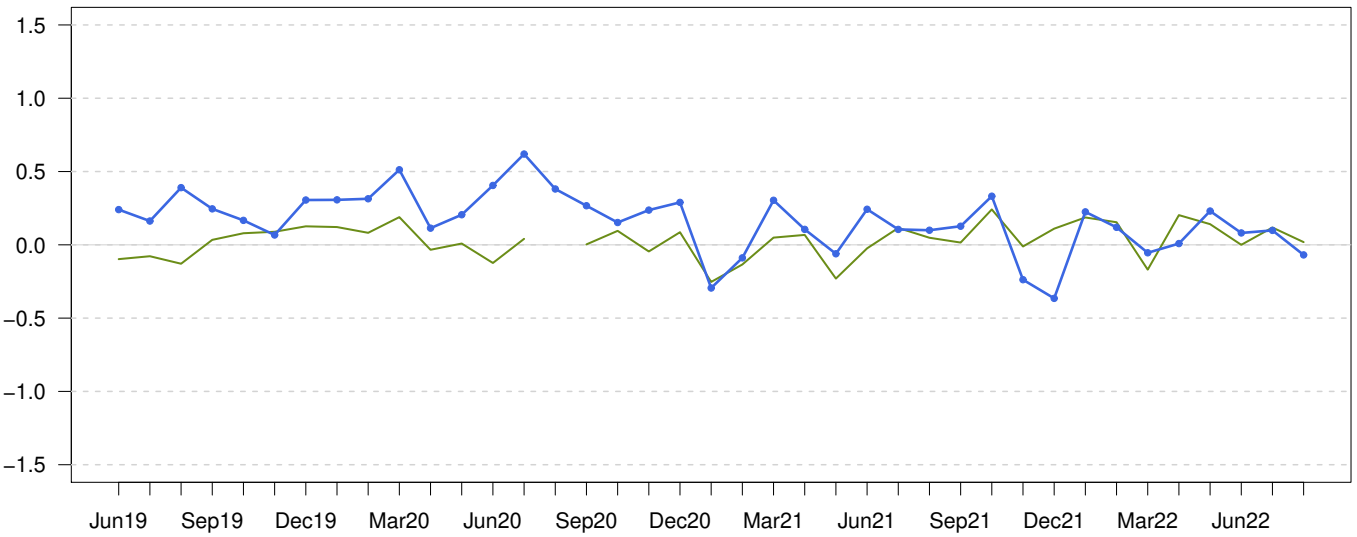
179 Norwegian stations 00+24,+30,+36,+42 UTC

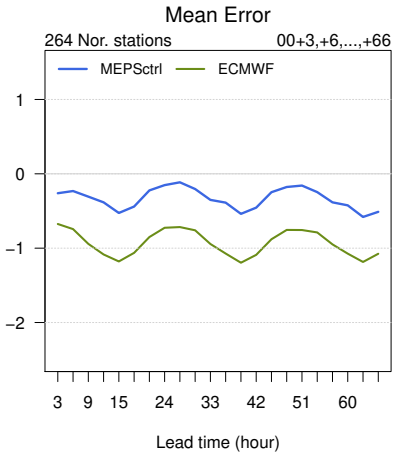


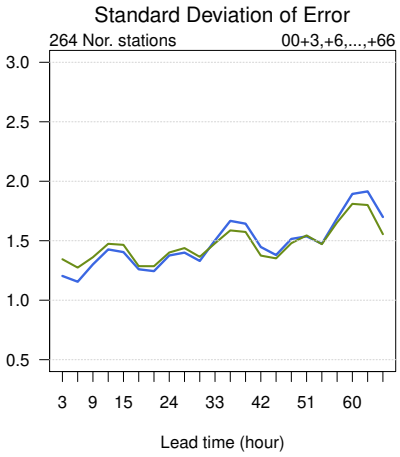
Standard Deviation of Error

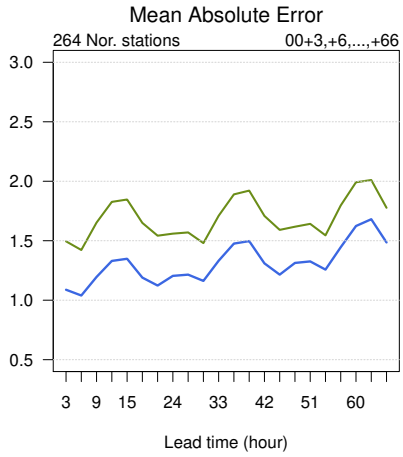


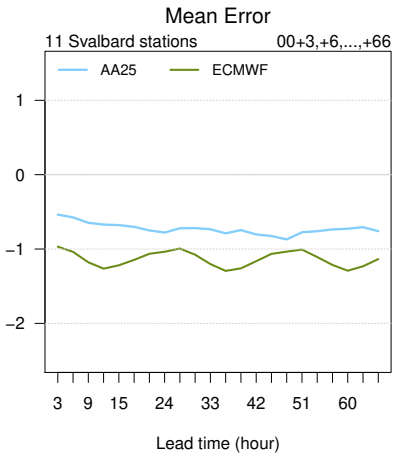
Mean Error

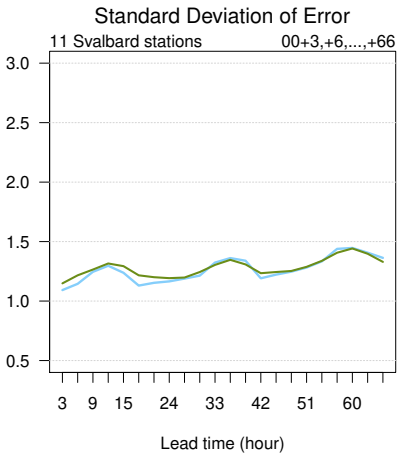


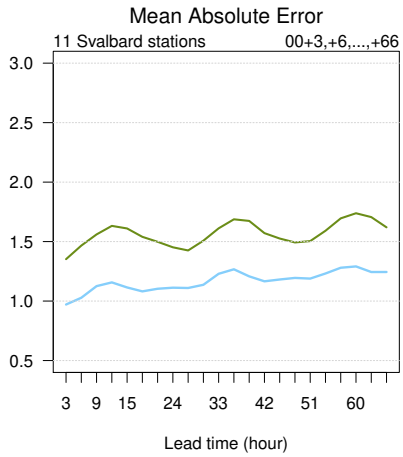

Mean Error
264 Nor. stations
00+3,+6,...,+66
MEPSctrl
ECMWF
1
0
−1
−2
3 9 15 24 33 42 51 60
Lead time (hour)

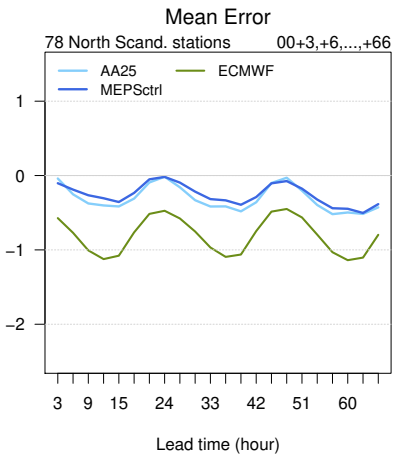

Standard Deviation of Error
264 Nor. stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)

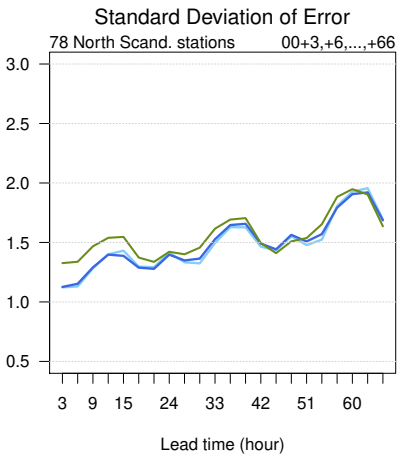

Mean Absolute Error
264 Nor. stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)

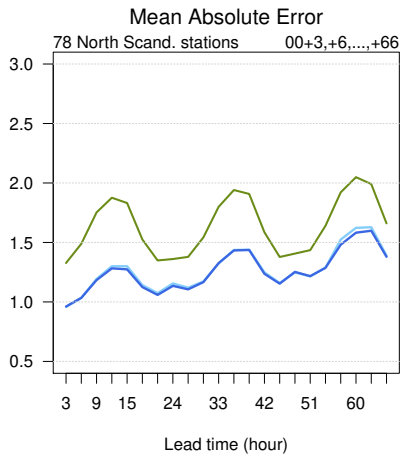

Mean Error
11 Svalbard stations
00+3,+6,...,+66
AA25
ECMWF
1
0
−1
−2
3 9 15 24 33 42 51 60
Lead time (hour)


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)

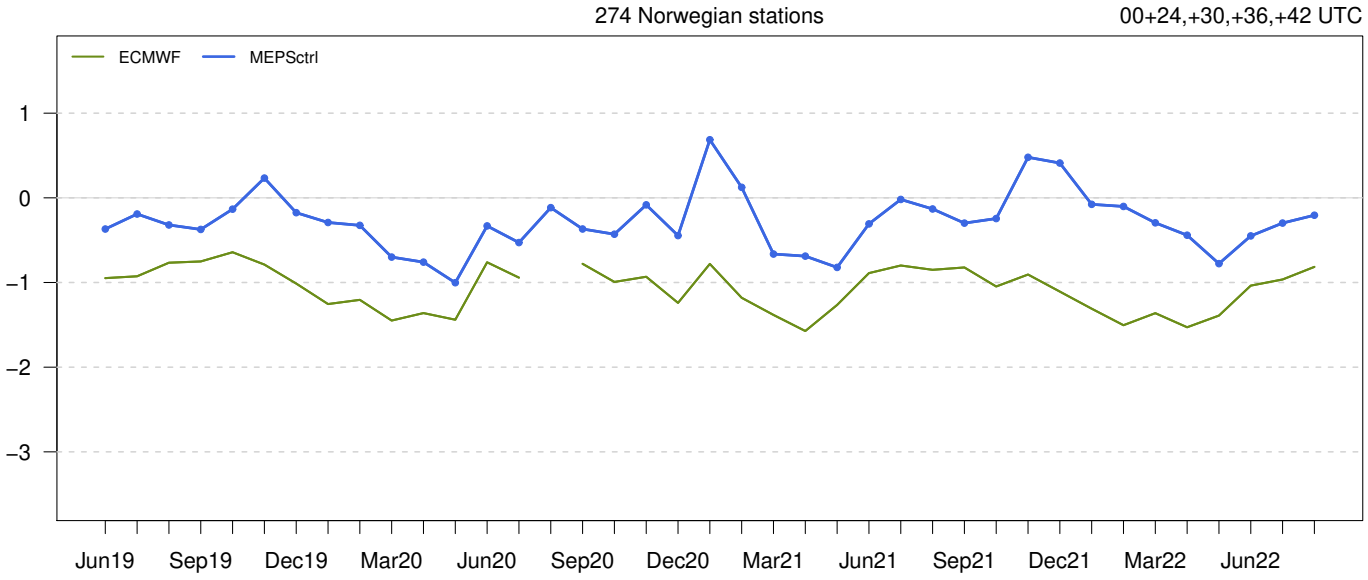

Mean Absolute Error
11 Svalbard stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)

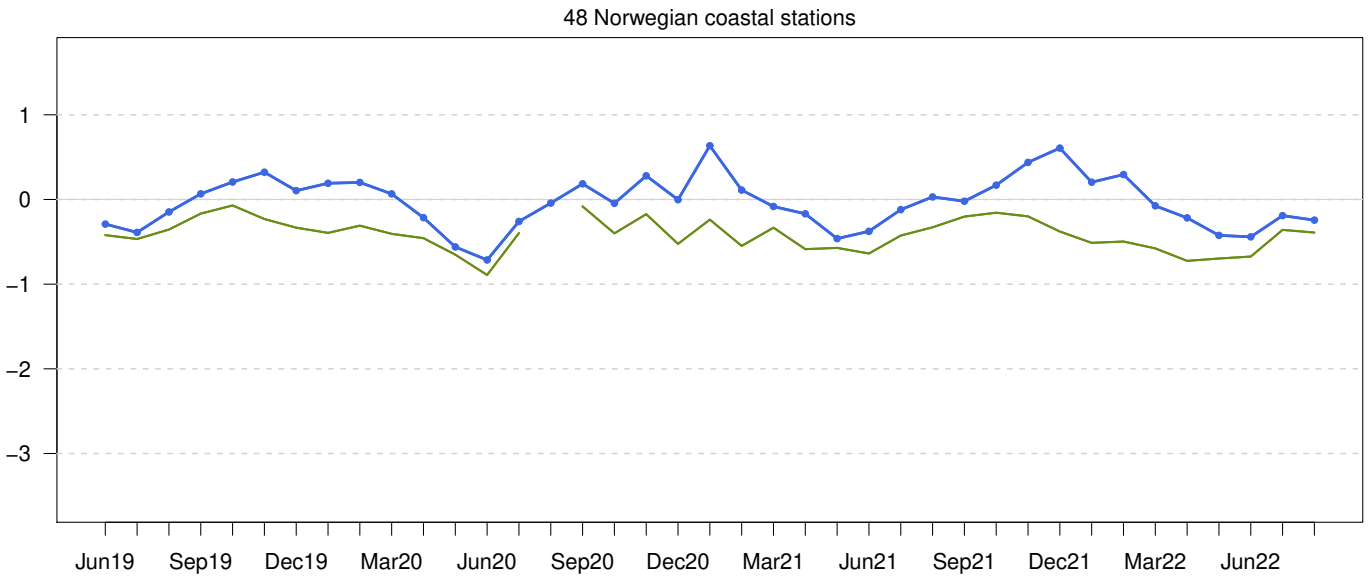

Mean Error
78 North Scand. stations
00+3,+6,...,+66
AA25
ECMWF
MEPSctrl
1
0
−1
−2
3 9 15 24 33 42 51 60
Lead time (hour)

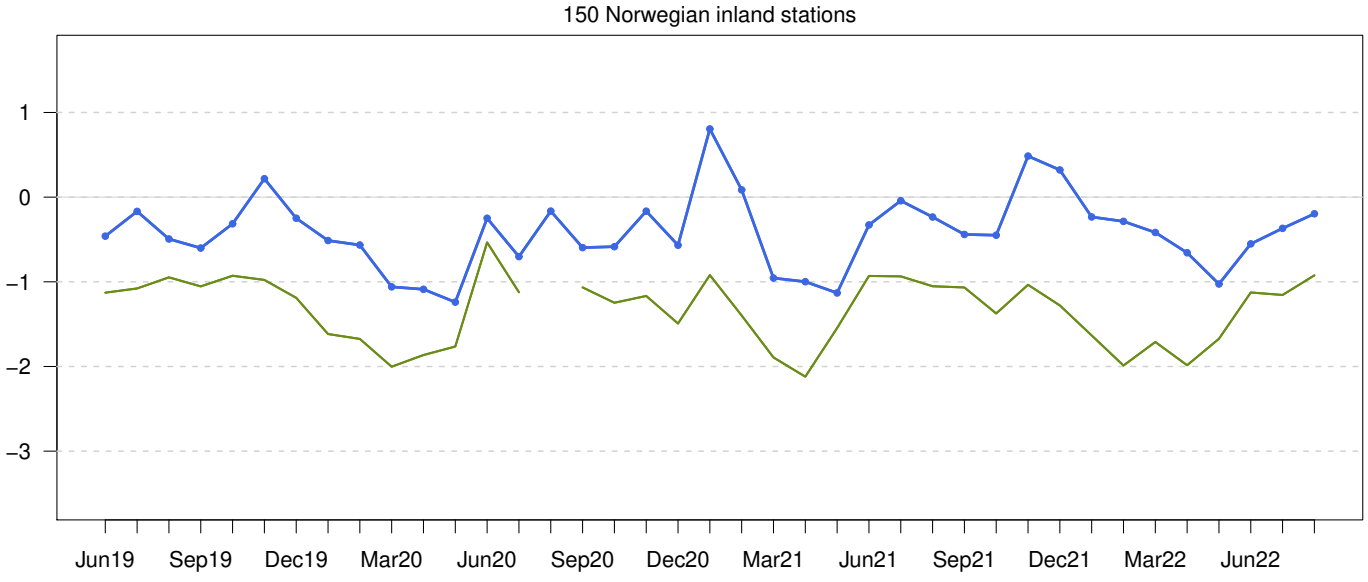

Standard Deviation of Error
78 North Scand. stations
00+3,+6,...,+66
3.0
2.5
2.0
1.5
1.0
0.5
3 9 15 24 33 42 51 60
Lead time (hour)


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)

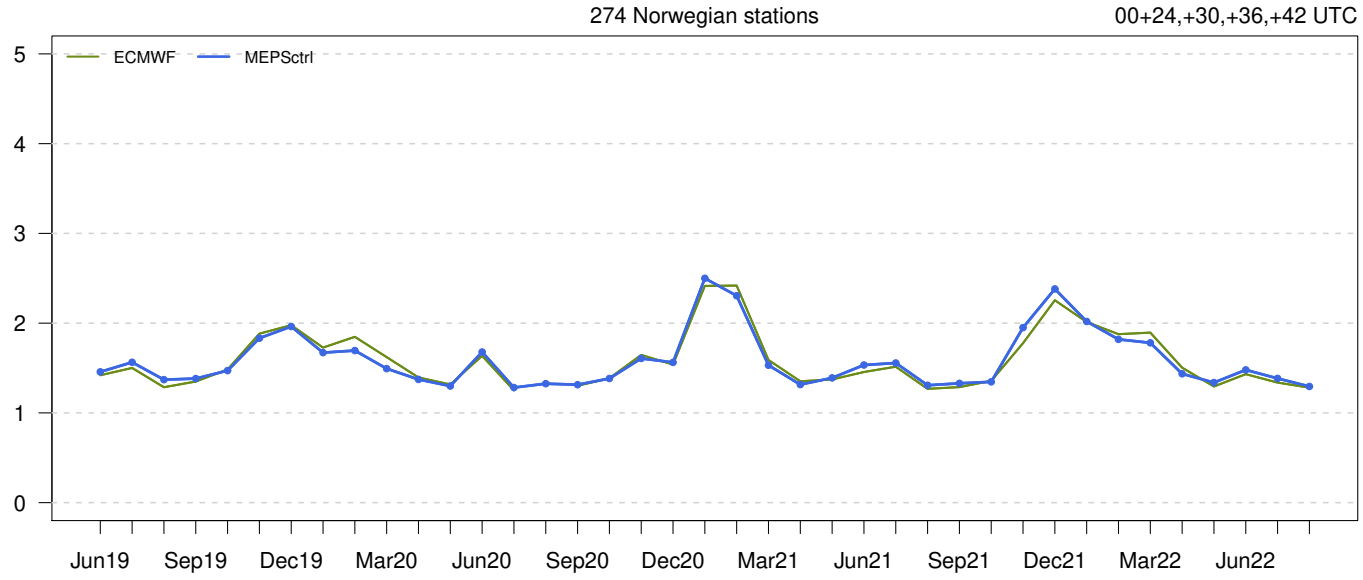
Mean Error

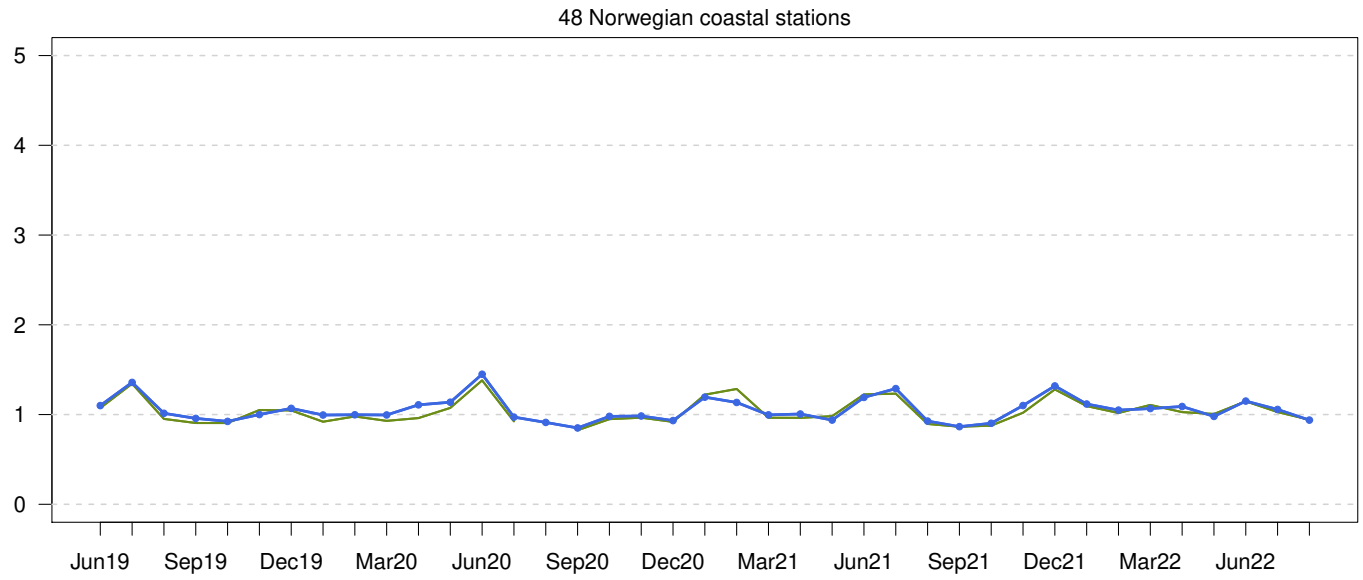

274 Norwegian stations
00+24,+30,+36,+42 UTC
ECMWF
MEPSctrl
1
0
−1
−2
−3
Jun19
Sep19
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22

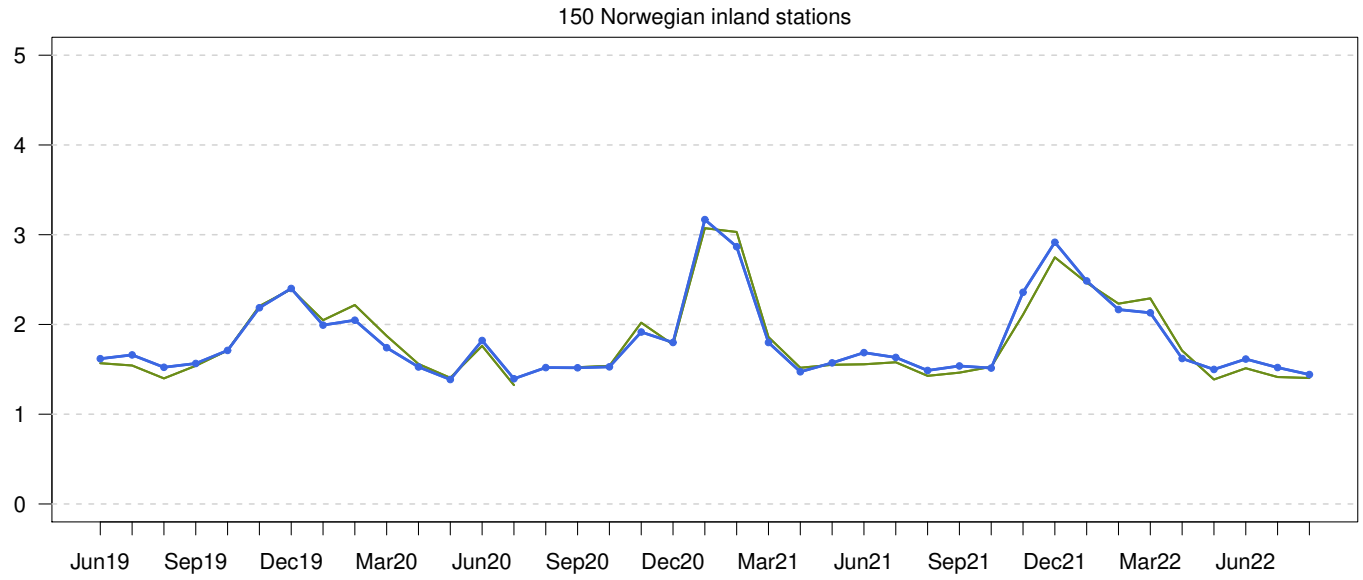

48 Norwegian coastal stations
1
0
−1
−2
−3
Jun19
Sep19
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22


150 Norwegian inland stations
1
0
−1
−2
−3
Jun19
Sep19
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22

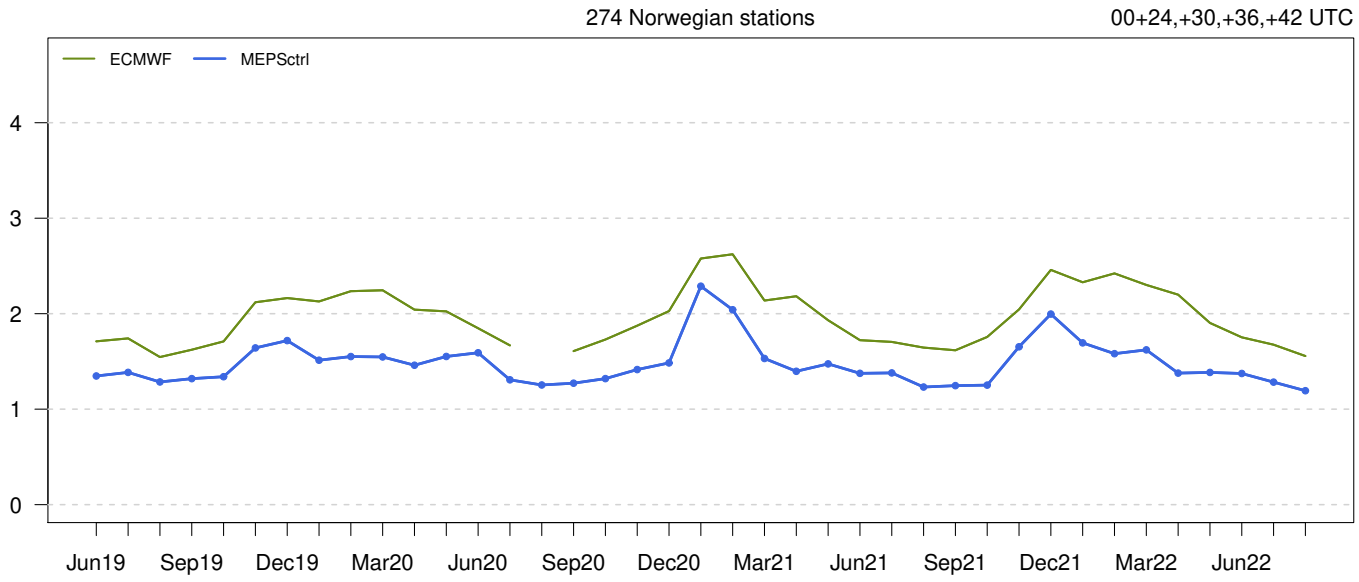
Standard Deviation of Error

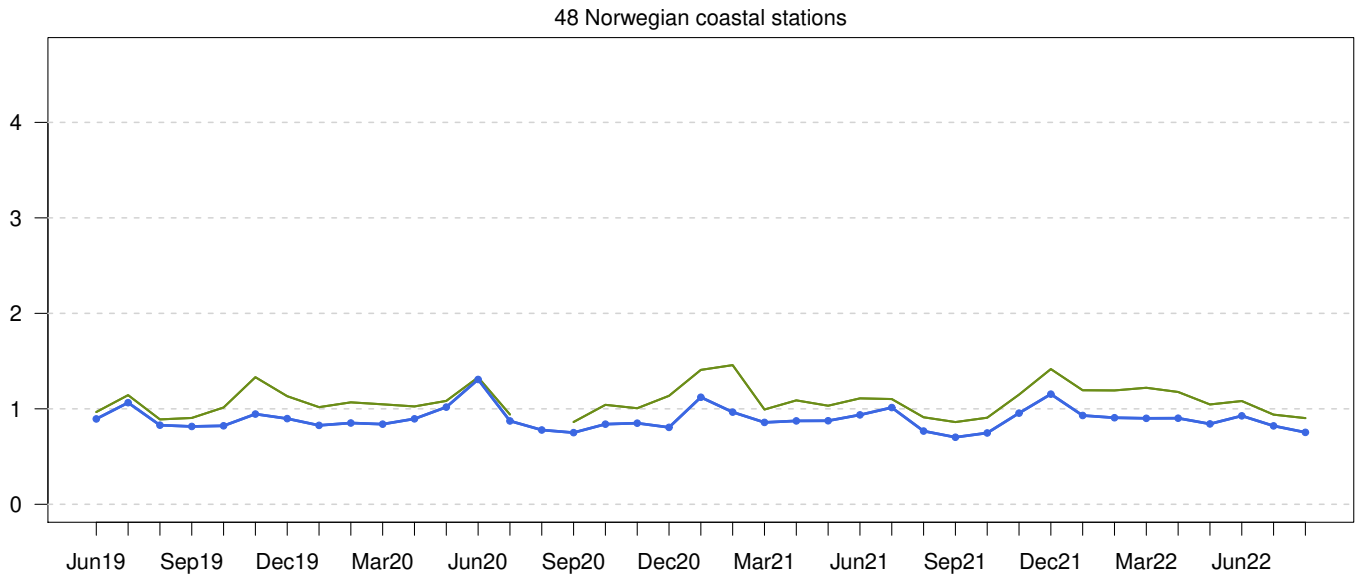


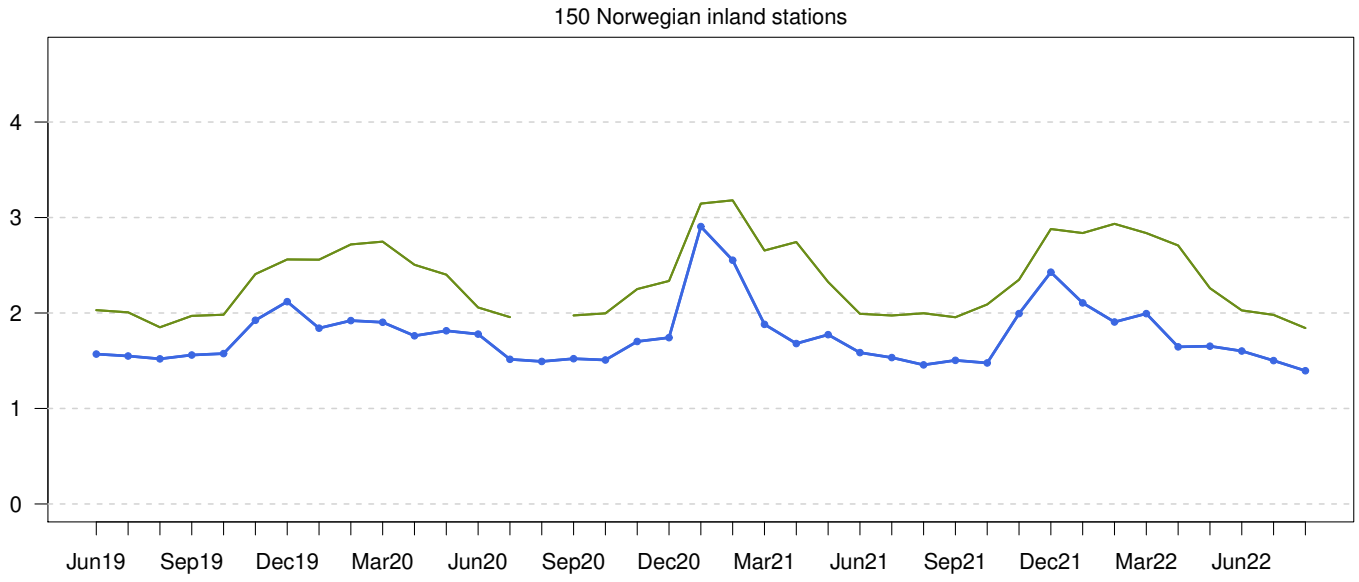




Mean Absolute Error

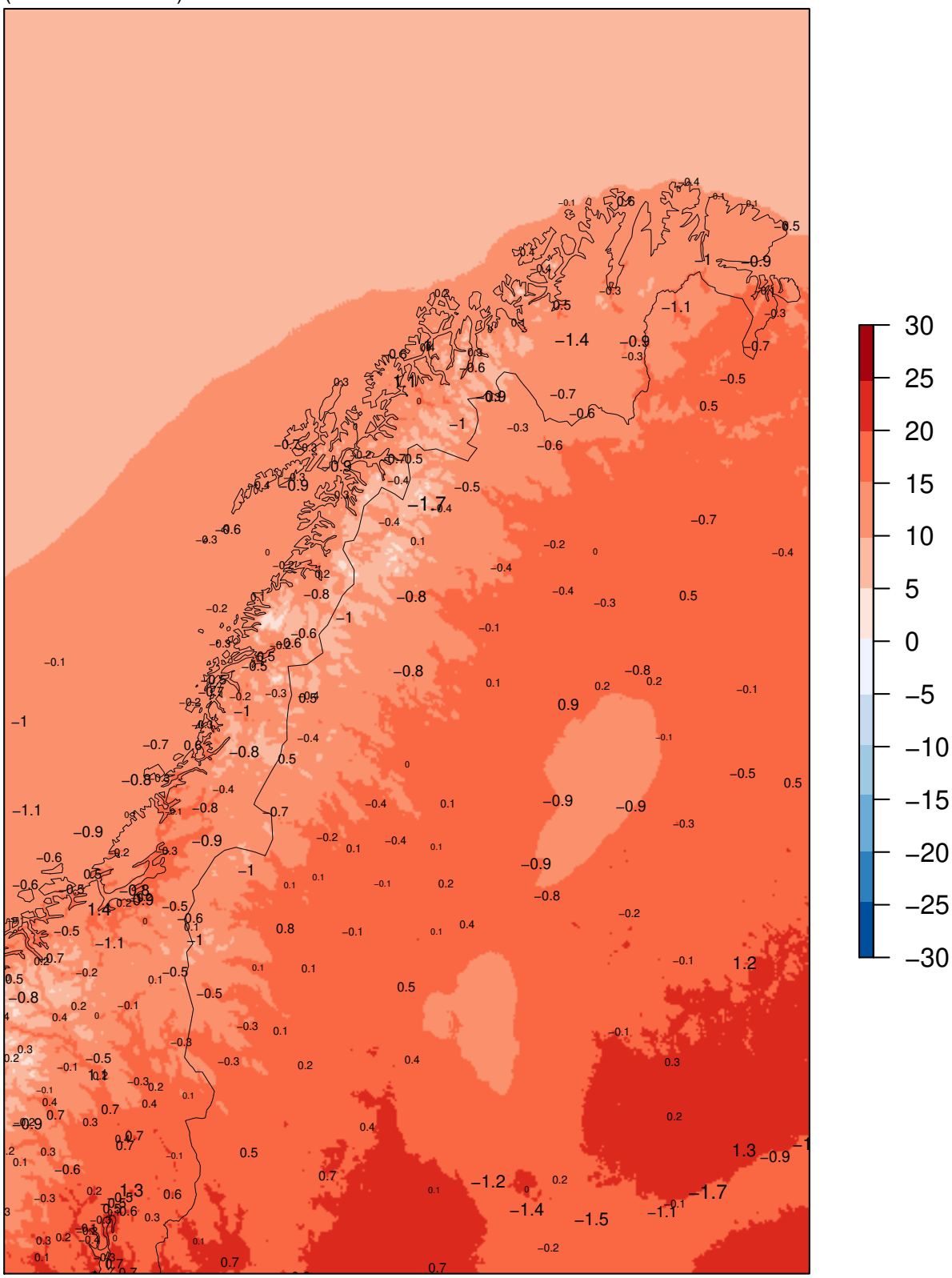






MEPSctrl 00+12

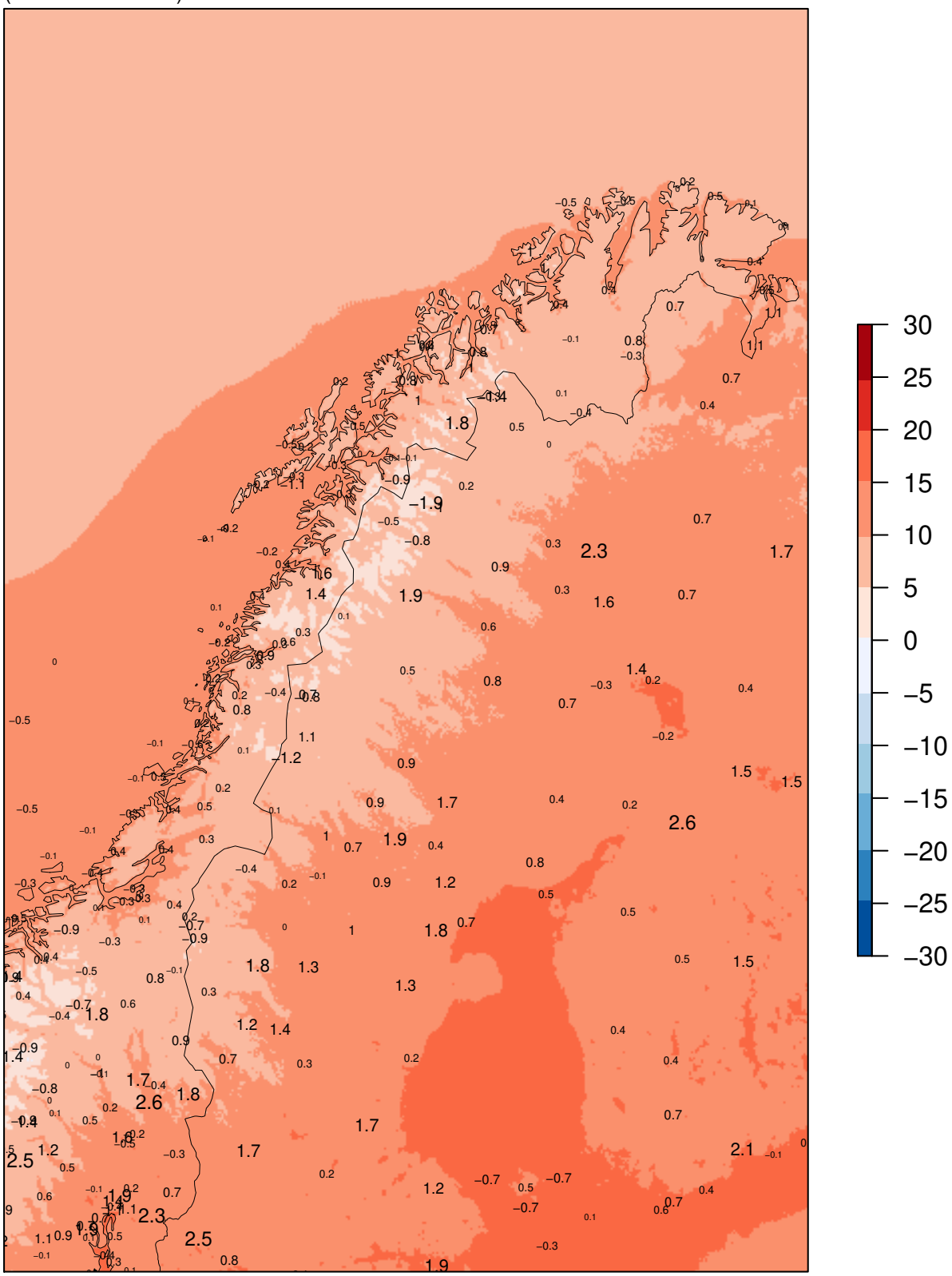
ME at observing sites
(numbers in black)



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+24

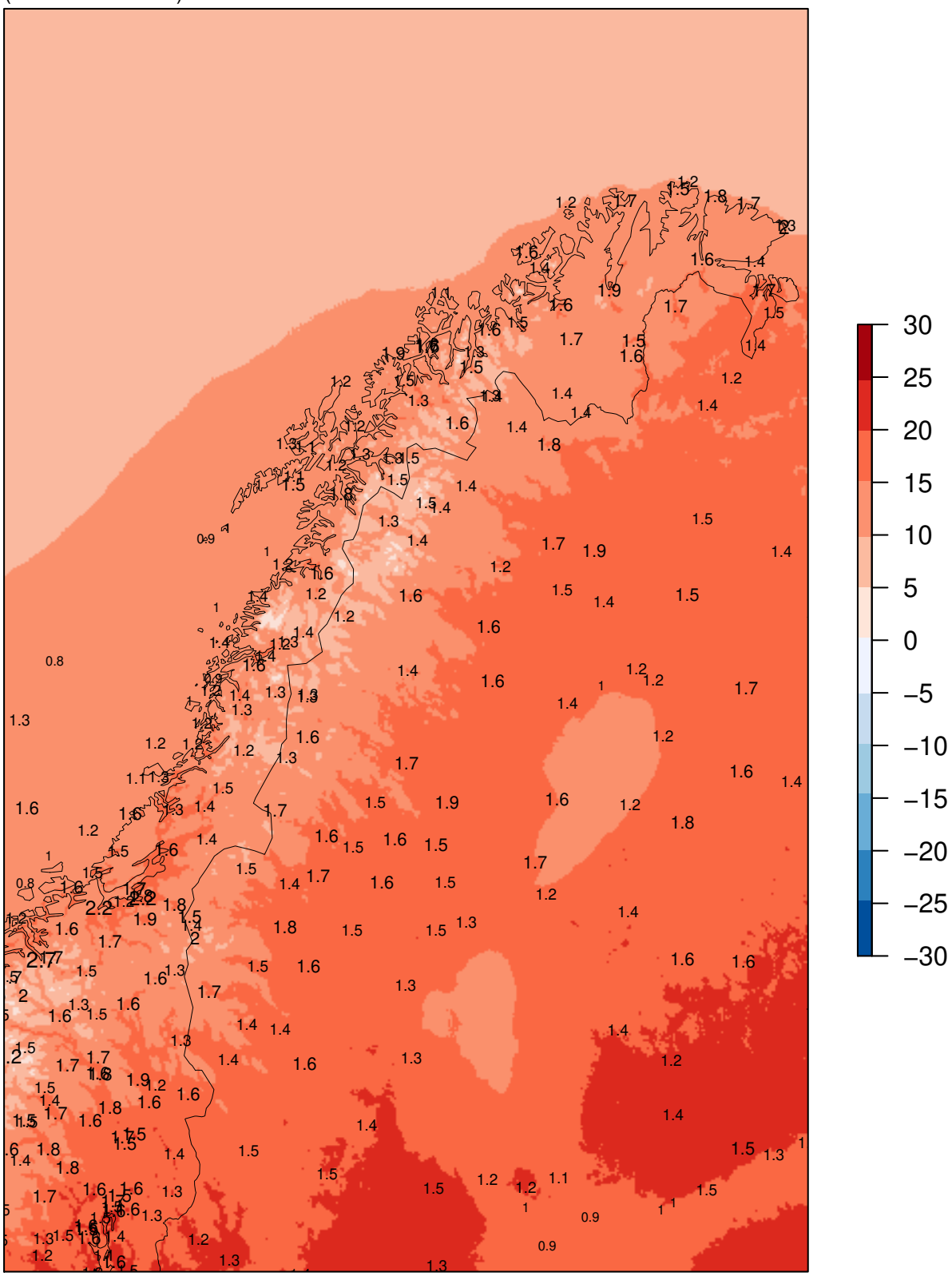
ME at observing sites
(numbers in black)



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+12

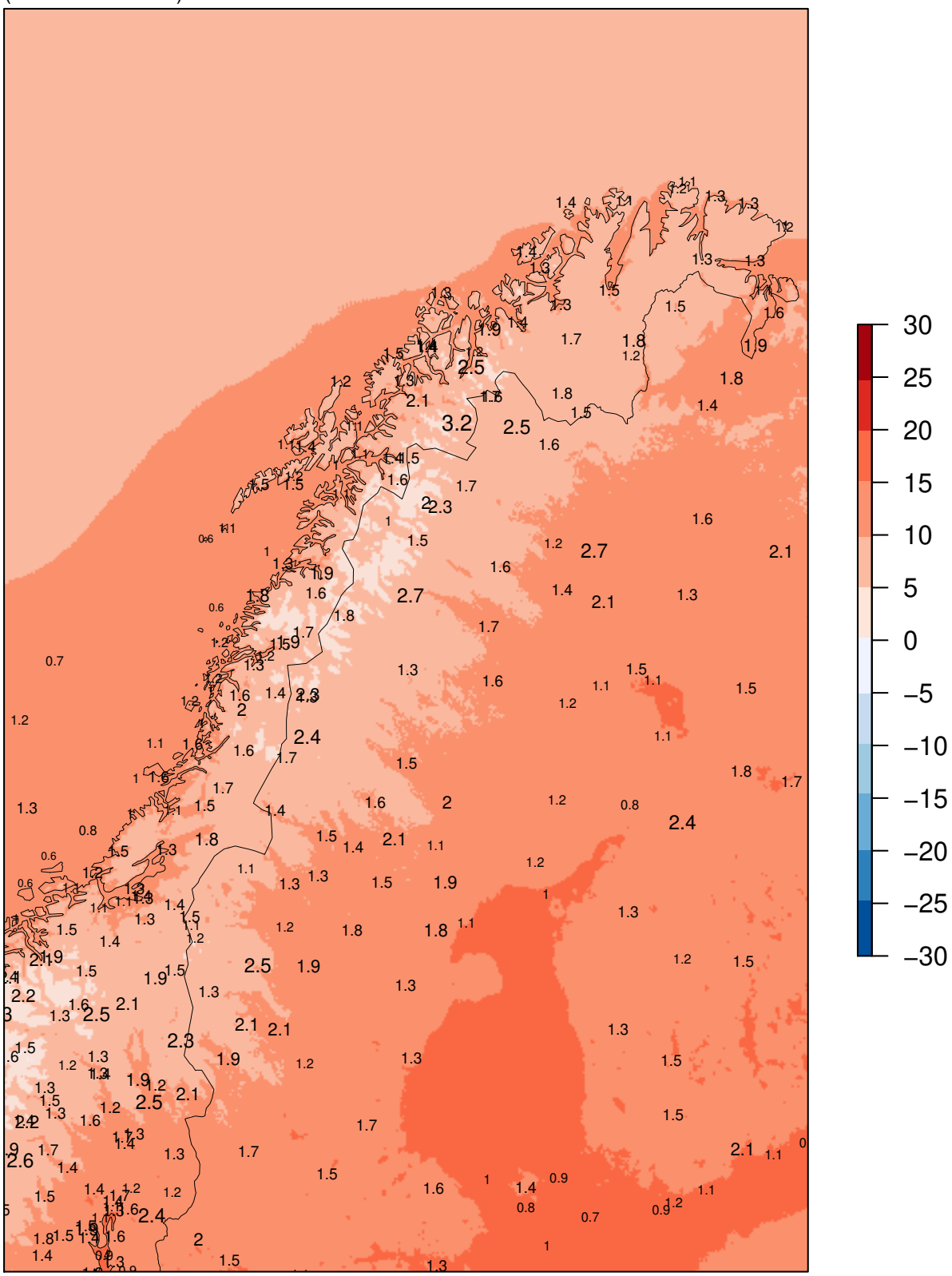
SDE at observing sites
(numbers in black)



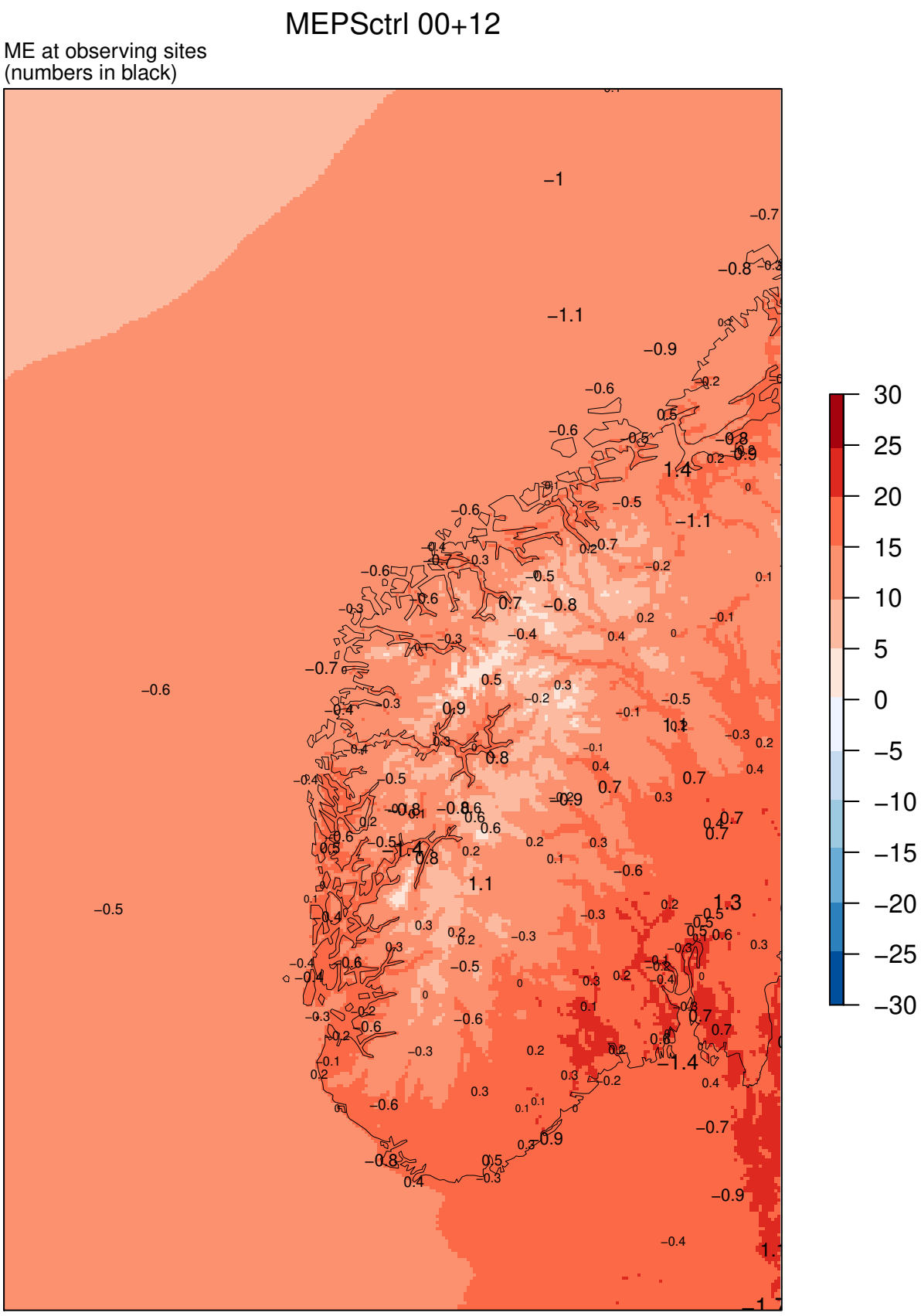
Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+24

SDE at observing sites
(numbers in black)



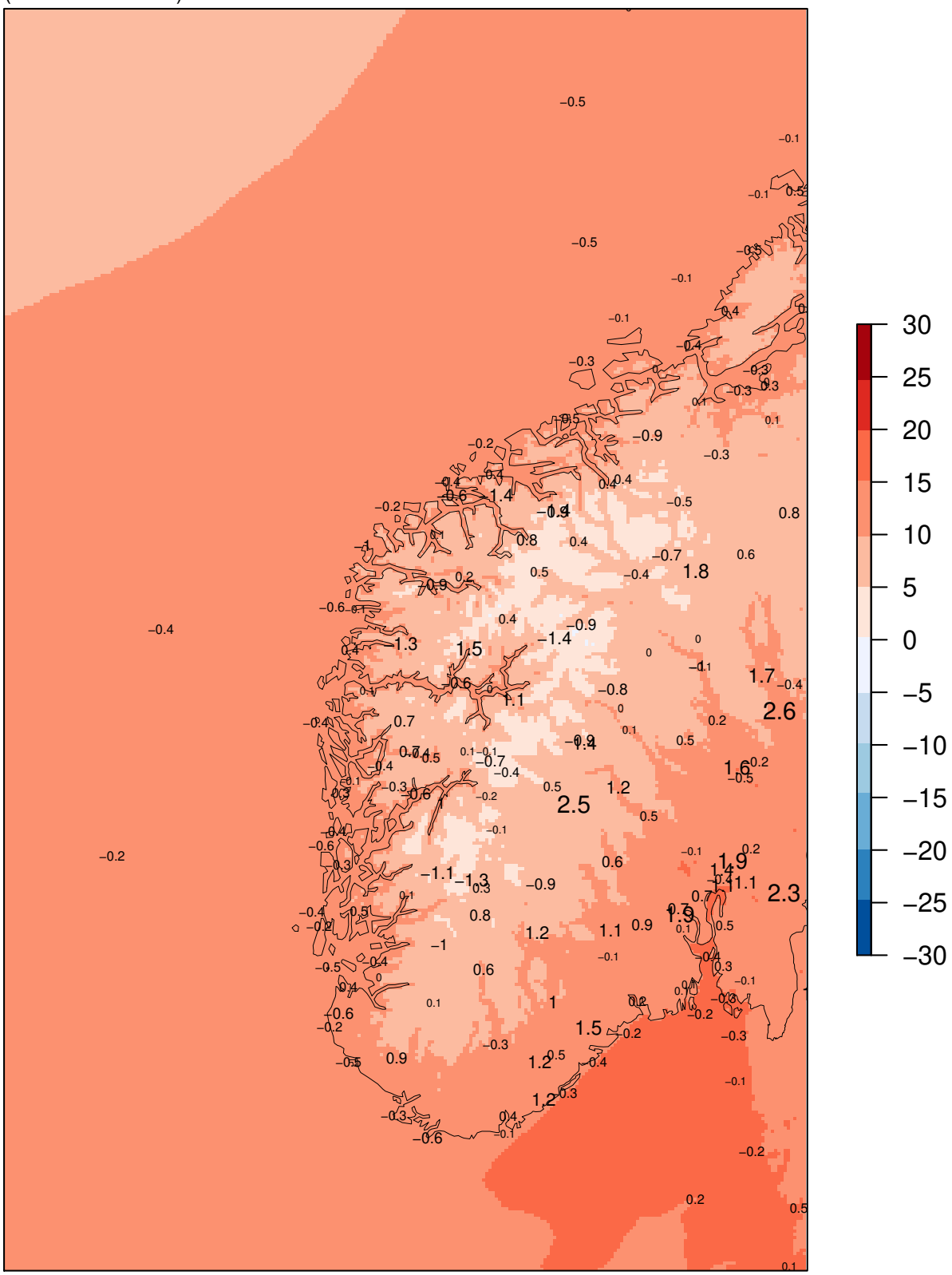
Model "climatology" 01.06.2022 – 31.08.2022



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+24

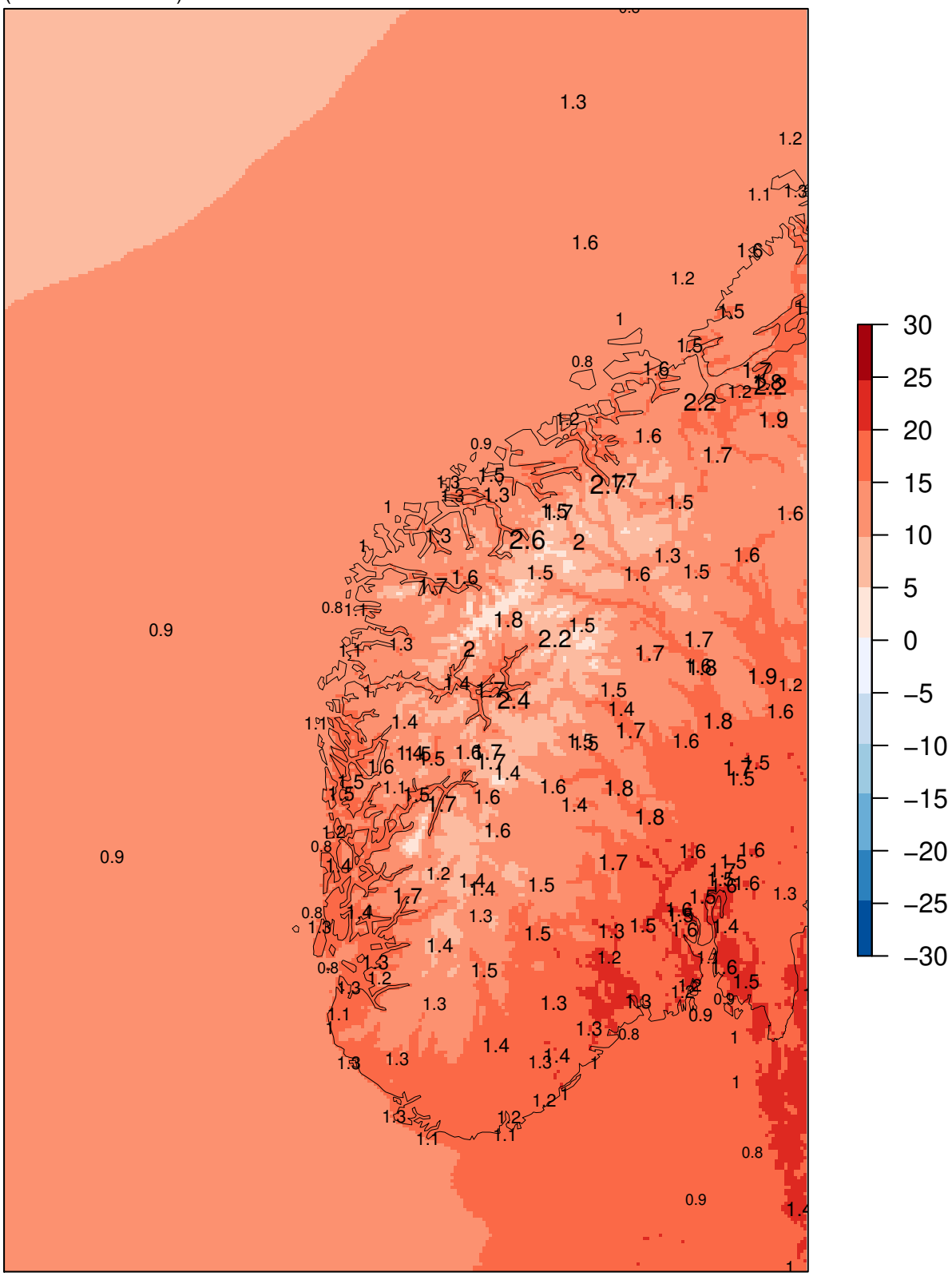
ME at observing sites
(numbers in black)



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+12

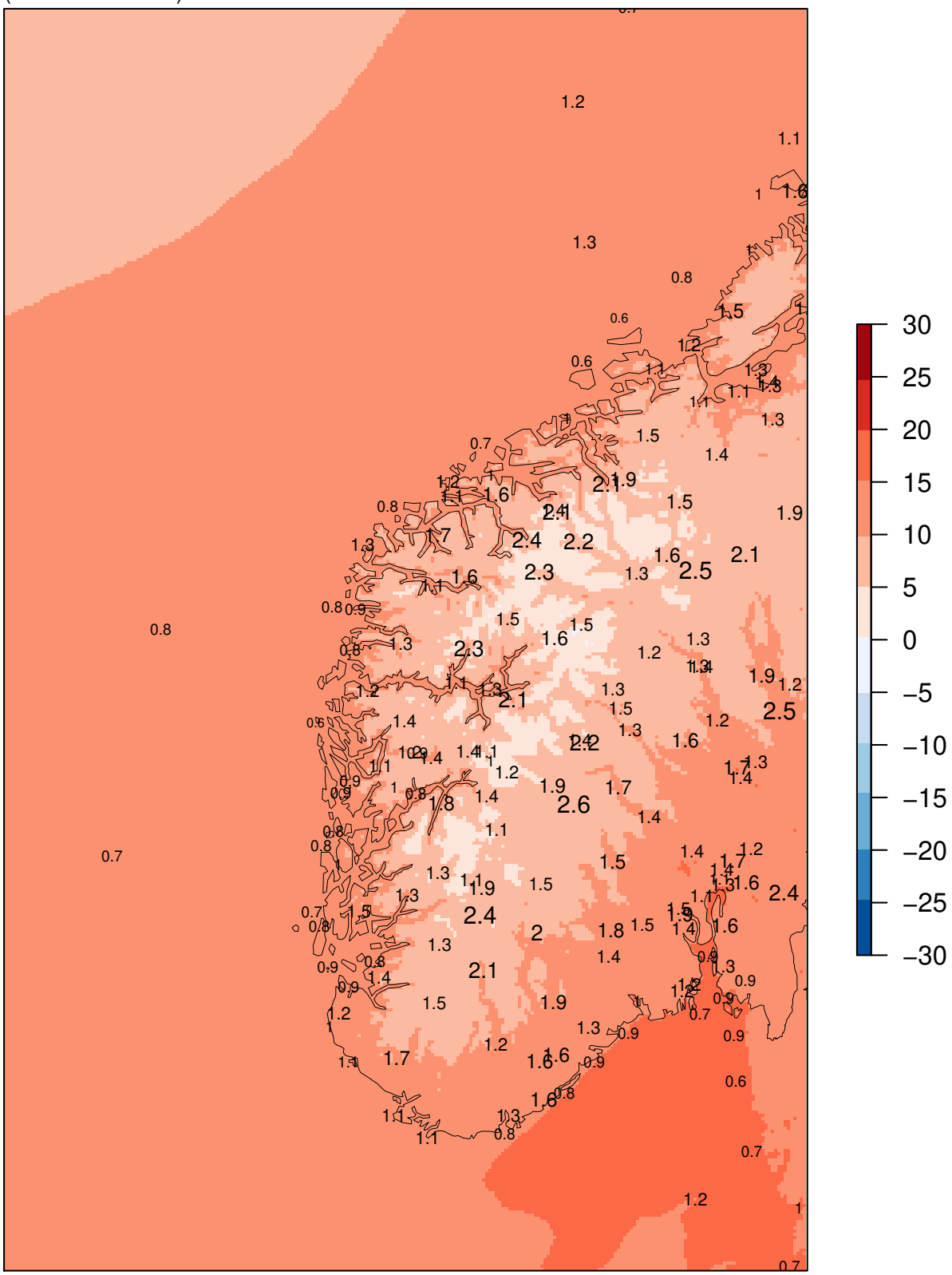
SDE at observing sites
(numbers in black)



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+24

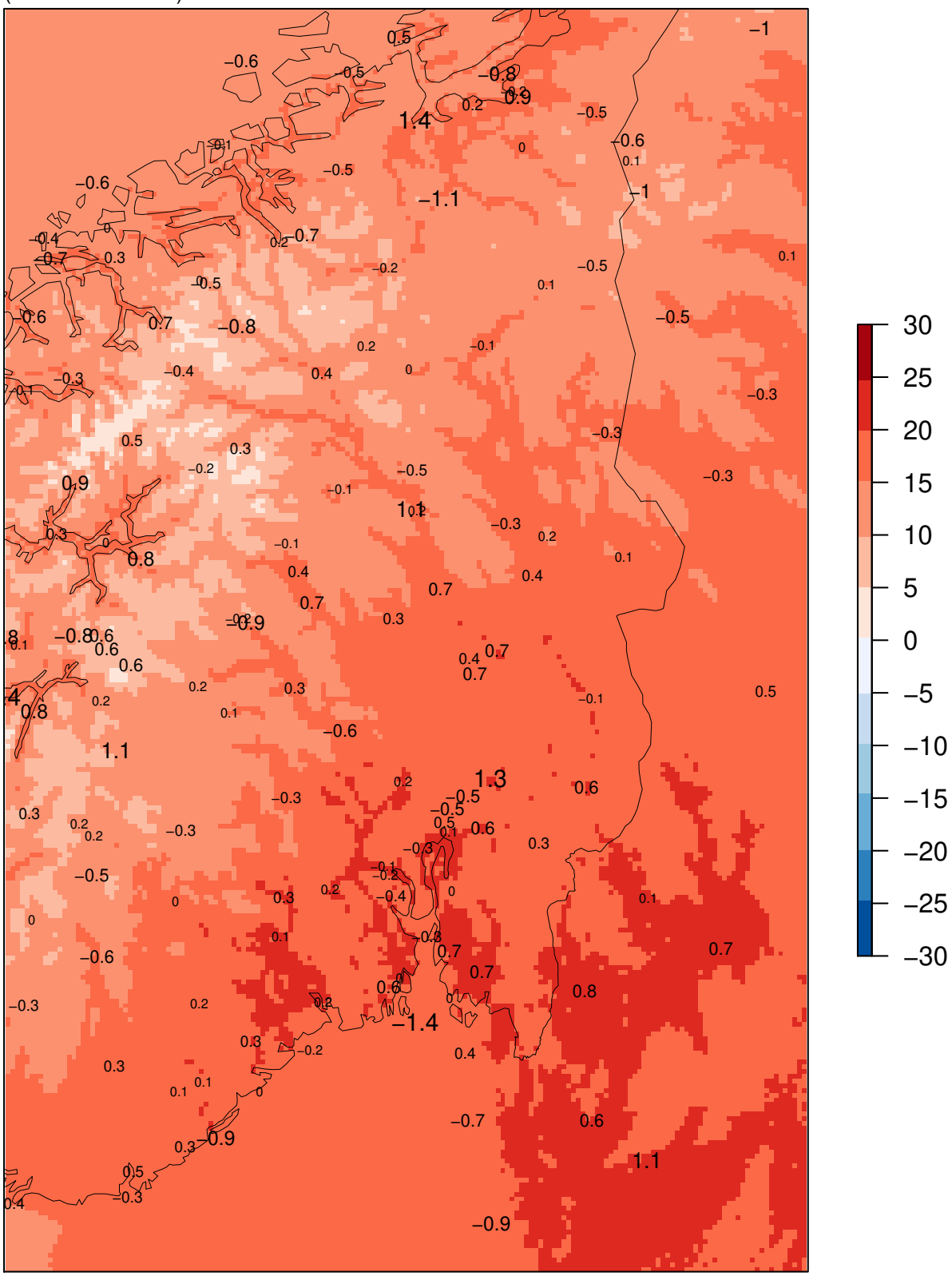
SDE at observing sites
(numbers in black)



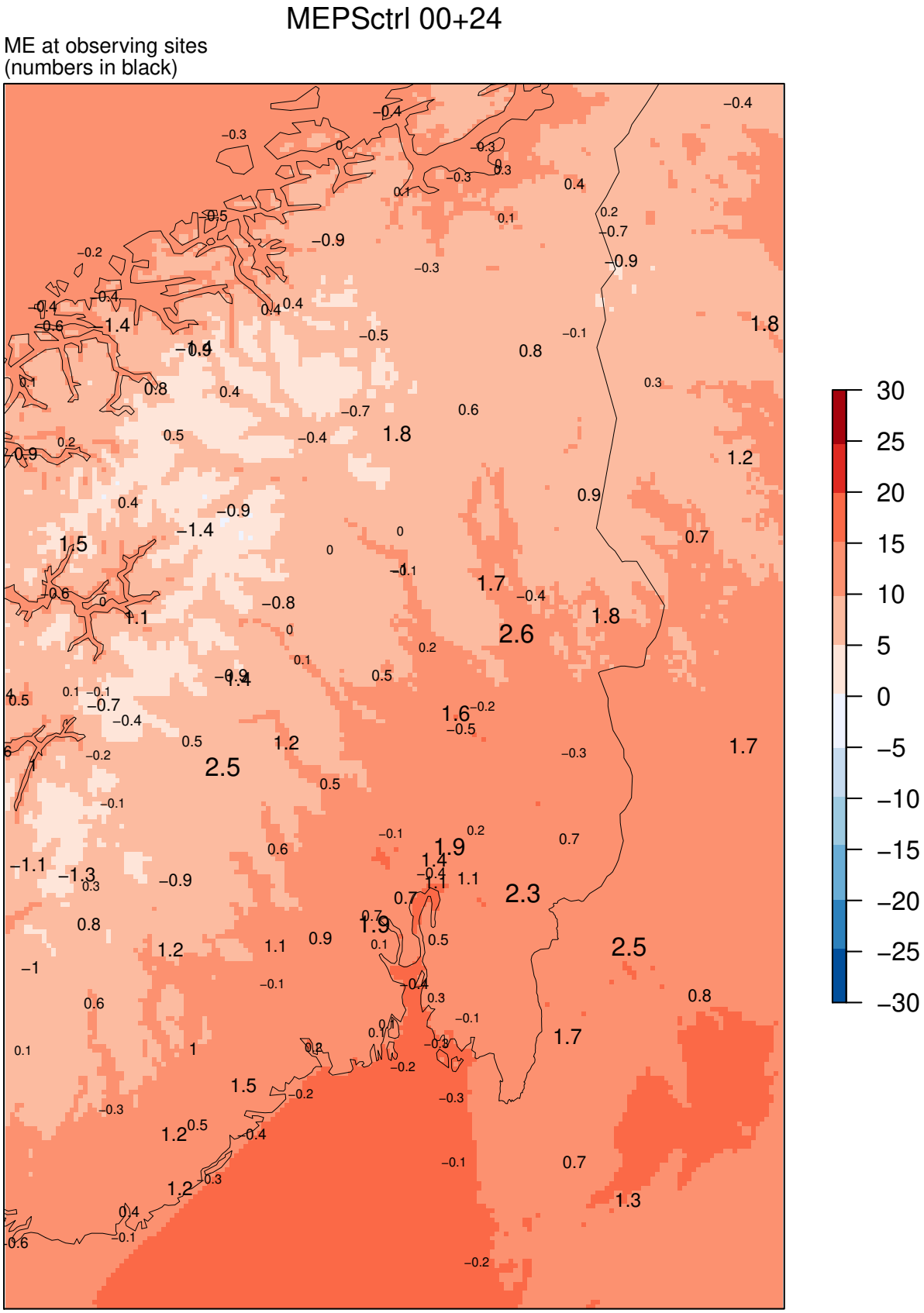
Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+12

ME at observing sites
(numbers in black)



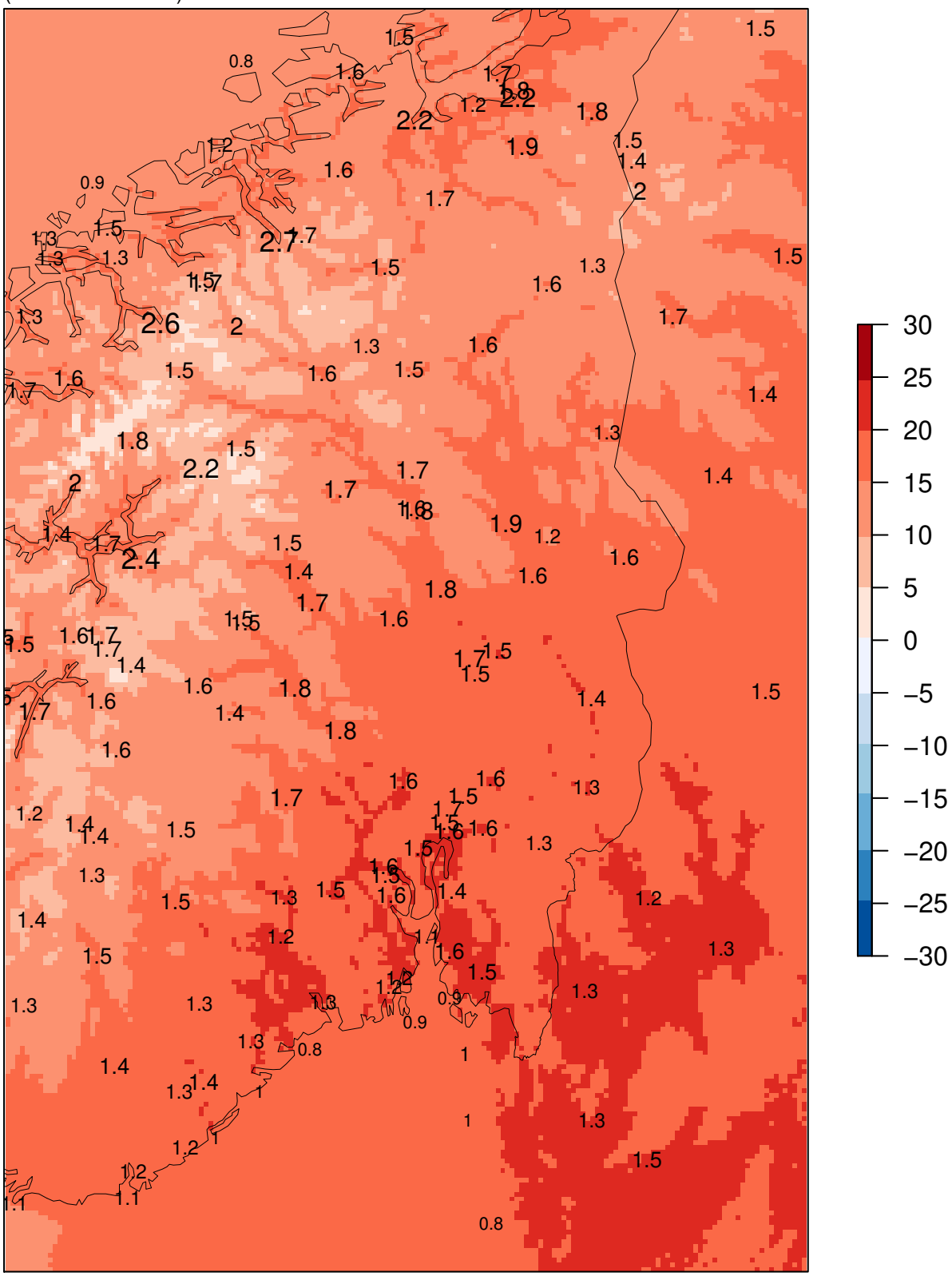
Model "climatology" 01.06.2022 – 31.08.2022



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+12

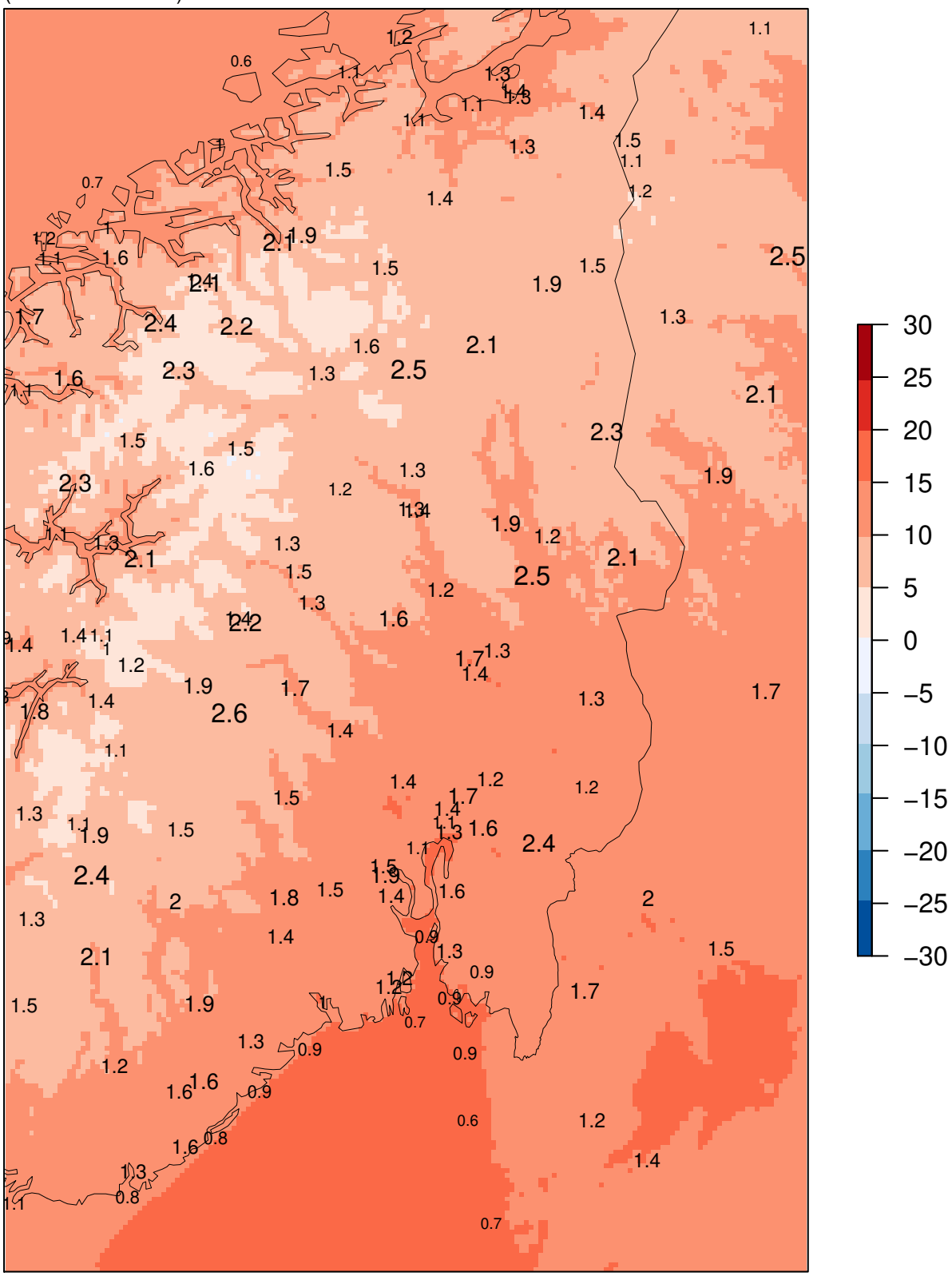
SDE at observing sites
(numbers in black)



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+24

SDE at observing sites
(numbers in black)

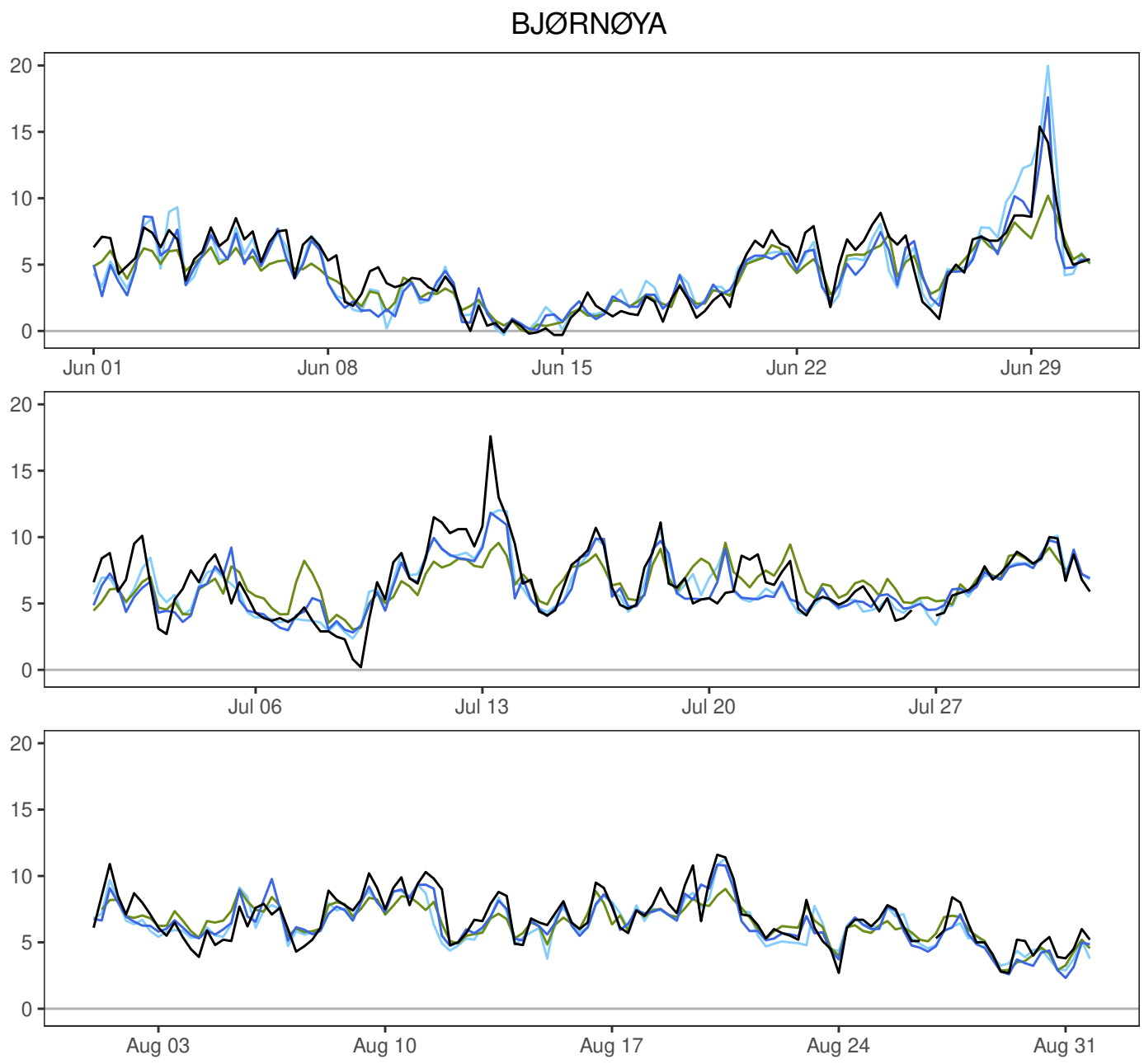


Model "climatology" 01.06.2022 – 31.08.2022

SVALBARD LUFTHAVN

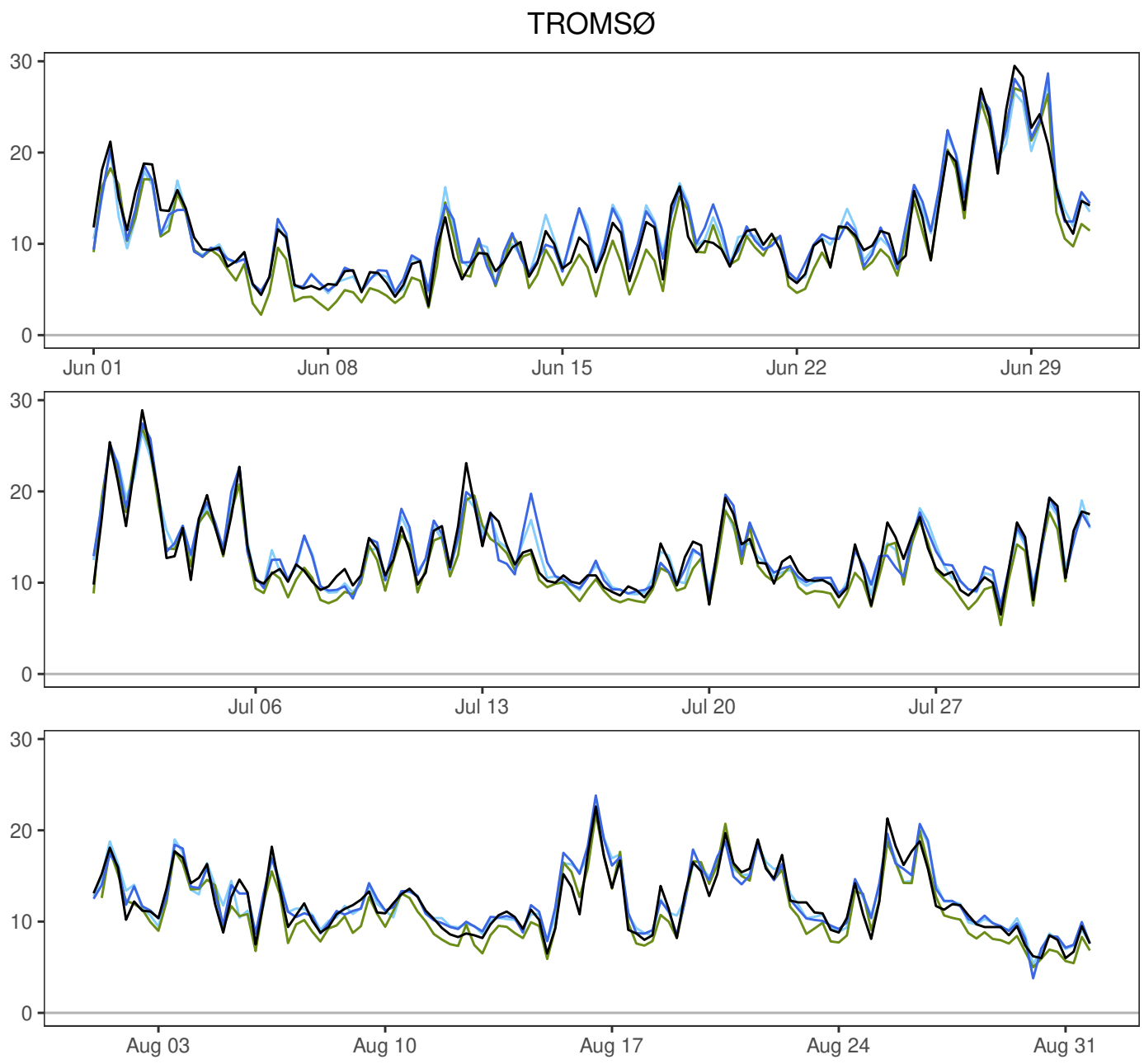
	Min	Mean	Max	Std	N
synop: 00,06,12,18	1.9	7.4	16.0	2.6	368
AA25: 12+18,+24,+30,+36	1.0	6.4	15.3	2.7	368
ECMWF: 12+18,+24,+30,+36	−0.4	4.6	12.5	2.6	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
AA25−synop	−1.0	1.3	1.6	1.3	5.9	364
ECMWF−synop	−2.7	1.4	3.1	2.8	7.4	364



	Min	Mean	Max	Std	N
synop: 00,06,12,18	−0.3	6.0	17.6	2.7	365
MEPSctrl: 12+18,+24,+30,+36	0.0	5.6	17.6	2.4	368
AA25: 12+18,+24,+30,+36	−0.3	5.7	20.0	2.5	368
ECMWF: 12+18,+24,+30,+36	−0.1	5.7	10.2	2.0	364

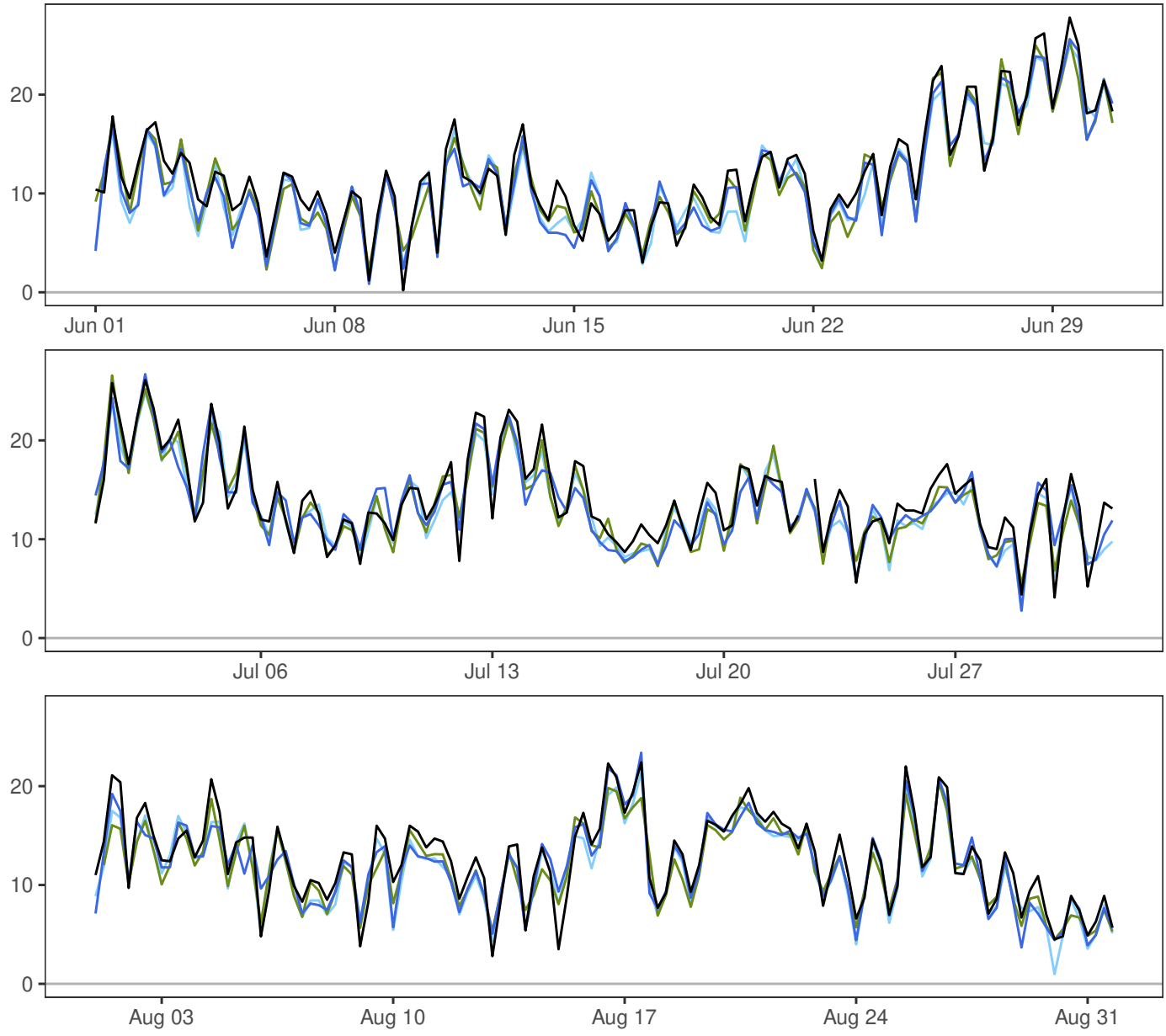
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.4	1.3	1.3	1.0	5.8	361
AA25−synop	−0.3	1.3	1.3	1.0	5.9	361
ECMWF−synop	−0.3	1.5	1.5	1.1	8.6	361



	Min	Mean	Max	Std	N
synop: 00,06,12,18	3.2	12.2	29.5	4.4	368
MEPSctrl: 12+18,+24,+30,+36	3.8	12.5	28.7	4.3	368
AA25: 12+18,+24,+30,+36	4.4	12.4	27.8	4.2	368
ECMWF: 12+18,+24,+30,+36	2.2	11.2	27.0	4.6	364

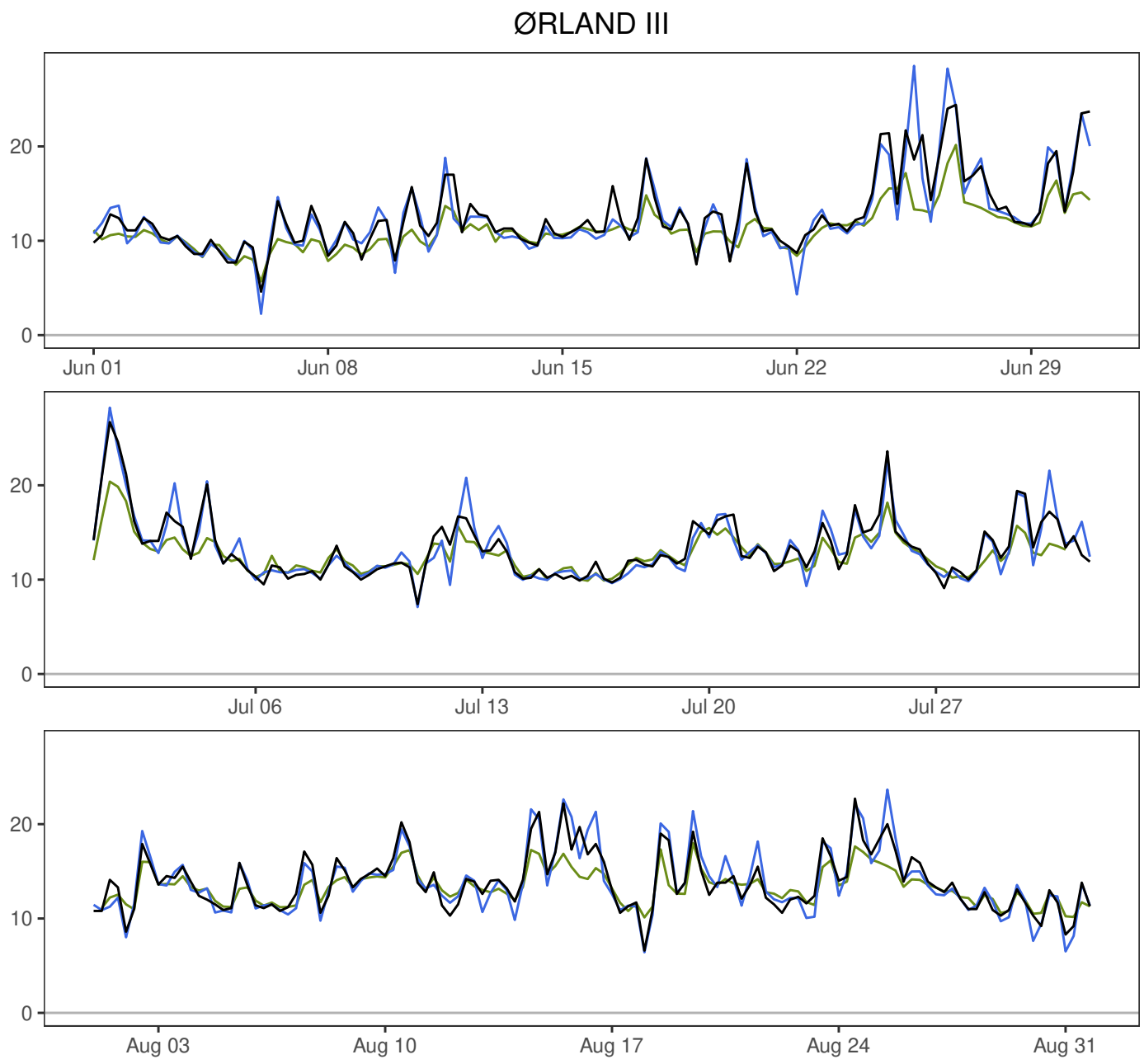
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.3	1.4	1.4	1.1	7.8	364
AA25−synop	0.2	1.4	1.4	1.1	6.9	364
ECMWF−synop	−0.9	1.2	1.5	1.3	5.5	364

KAUTOKEINO



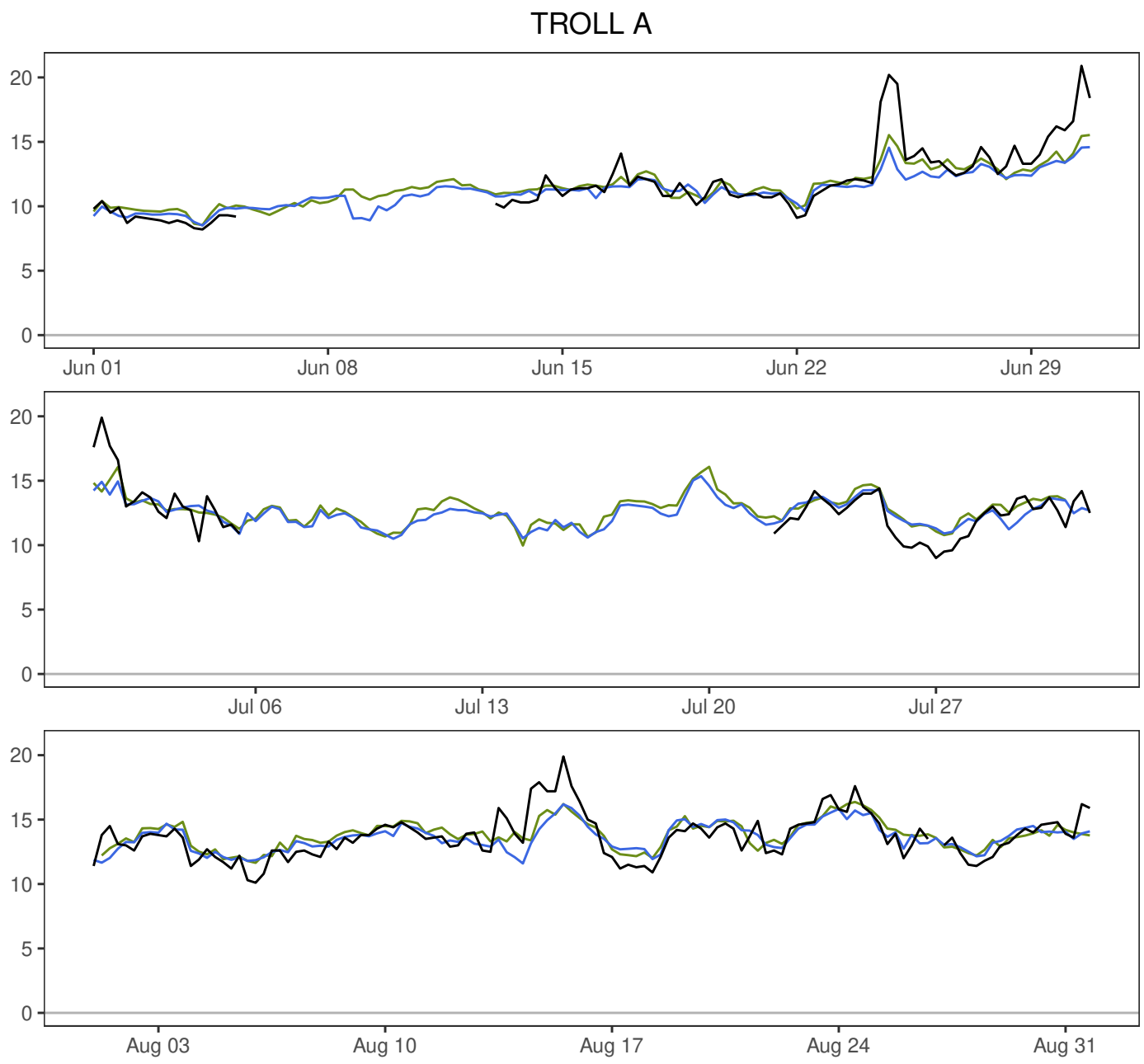
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.2	12.9	27.8	4.8	367
MEPSctrl: 12+18,+24,+30,+36	0.8	12.2	26.7	4.7	368
AA25: 12+18,+24,+30,+36	1.0	12.0	24.9	4.6	368
ECMWF: 12+18,+24,+30,+36	2.3	12.1	26.6	4.5	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.7	1.6	1.7	1.3	6.2	363
AA25−synop	−0.9	1.5	1.7	1.4	5.9	363
ECMWF−synop	−0.8	1.4	1.6	1.3	5.1	363



	Min	Mean	Max	Std	N
synop: 00,06,12,18	4.6	13.3	26.7	3.4	368
MEPSctrl: 12+18,+24,+30,+36	2.3	13.2	28.5	3.7	368
ECMWF: 12+18,+24,+30,+36	5.7	12.4	20.4	2.2	364

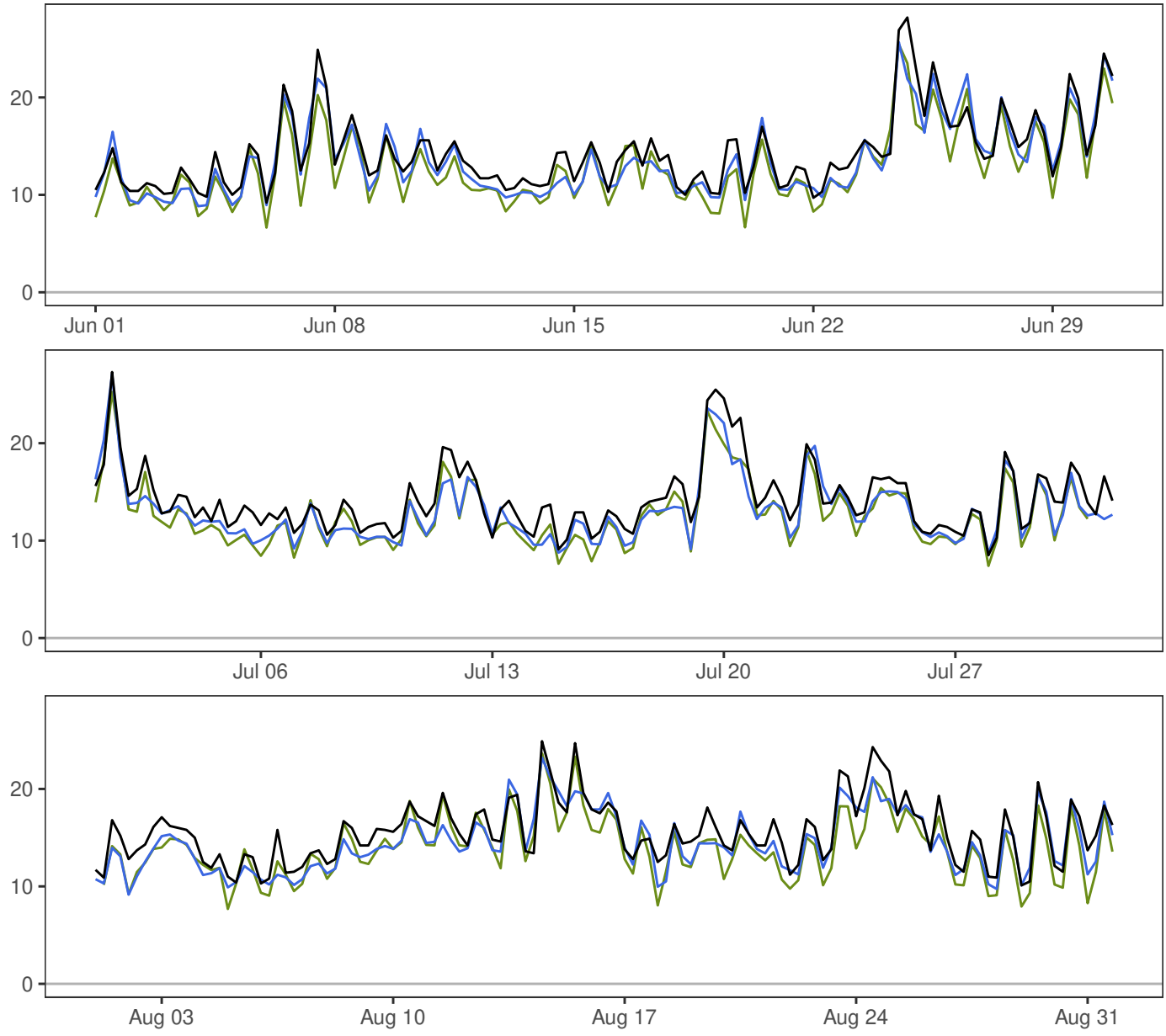
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.1	1.3	1.3	0.9	9.9	364
ECMWF−synop	−0.9	1.8	2.0	1.3	9.4	364



	Min	Mean	Max	Std	N
synop: 00,06,12,18	8.2	12.9	20.9	2.3	272
MEPSctrl: 12+18,+24,+30,+36	8.5	12.4	16.2	1.5	368
ECMWF: 12+18,+24,+30,+36	8.5	12.7	16.4	1.6	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.2	1.3	1.4	0.9	6.6	268
ECMWF−synop	0.1	1.2	1.2	0.9	5.7	268

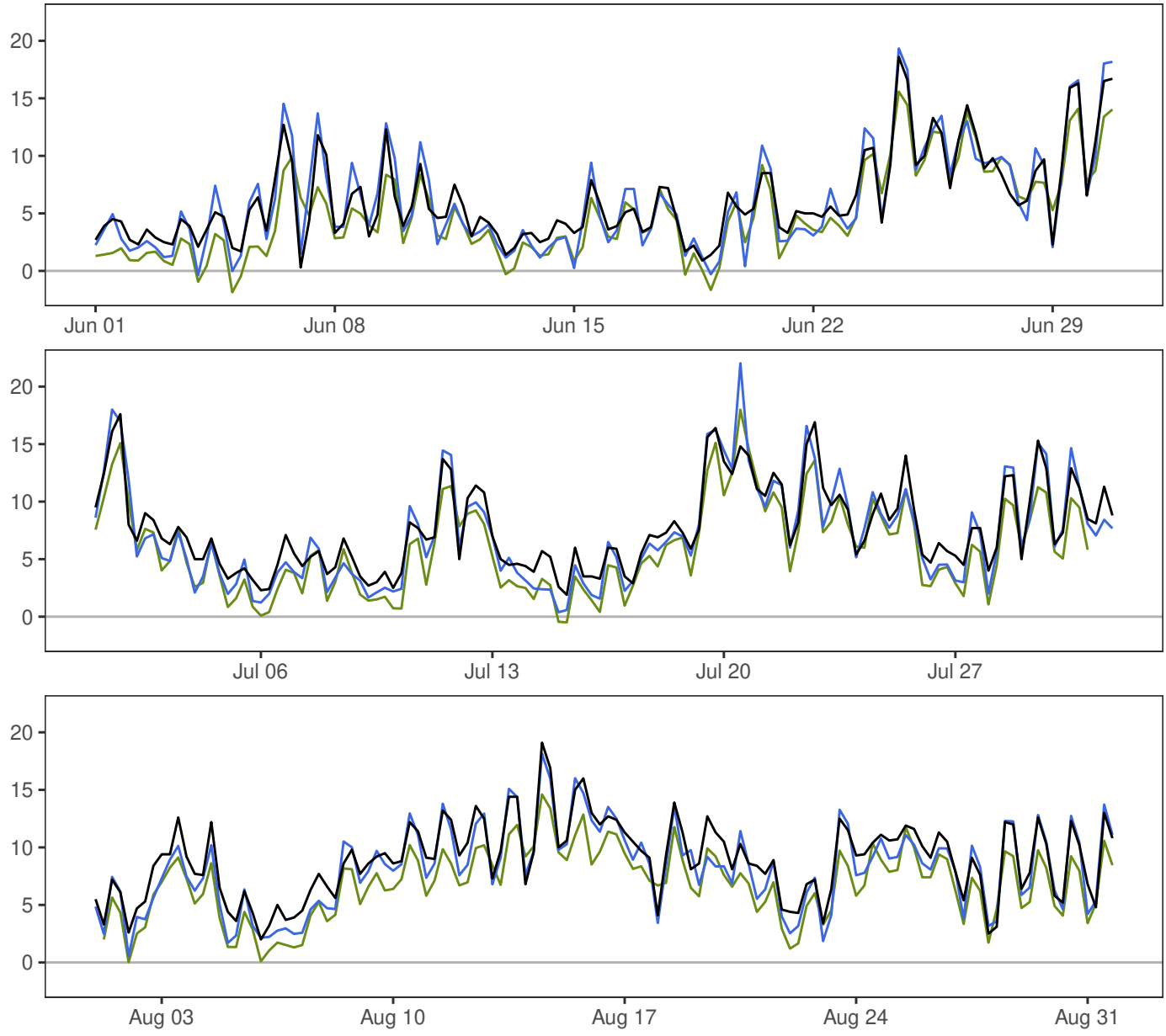
BERGEN – FLORIDA



	Min	Mean	Max	Std	N
synop: 00,06,12,18	8.5	14.7	28.2	3.5	368
MEPSctrl: 12+18,+24,+30,+36	8.7	13.7	27.1	3.4	368
ECMWF: 12+18,+24,+30,+36	6.6	13.1	25.4	3.4	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	−1.0	1.3	1.6	1.3	6.3	364
ECMWF–synop	−1.6	1.1	2.0	1.7	5.8	364

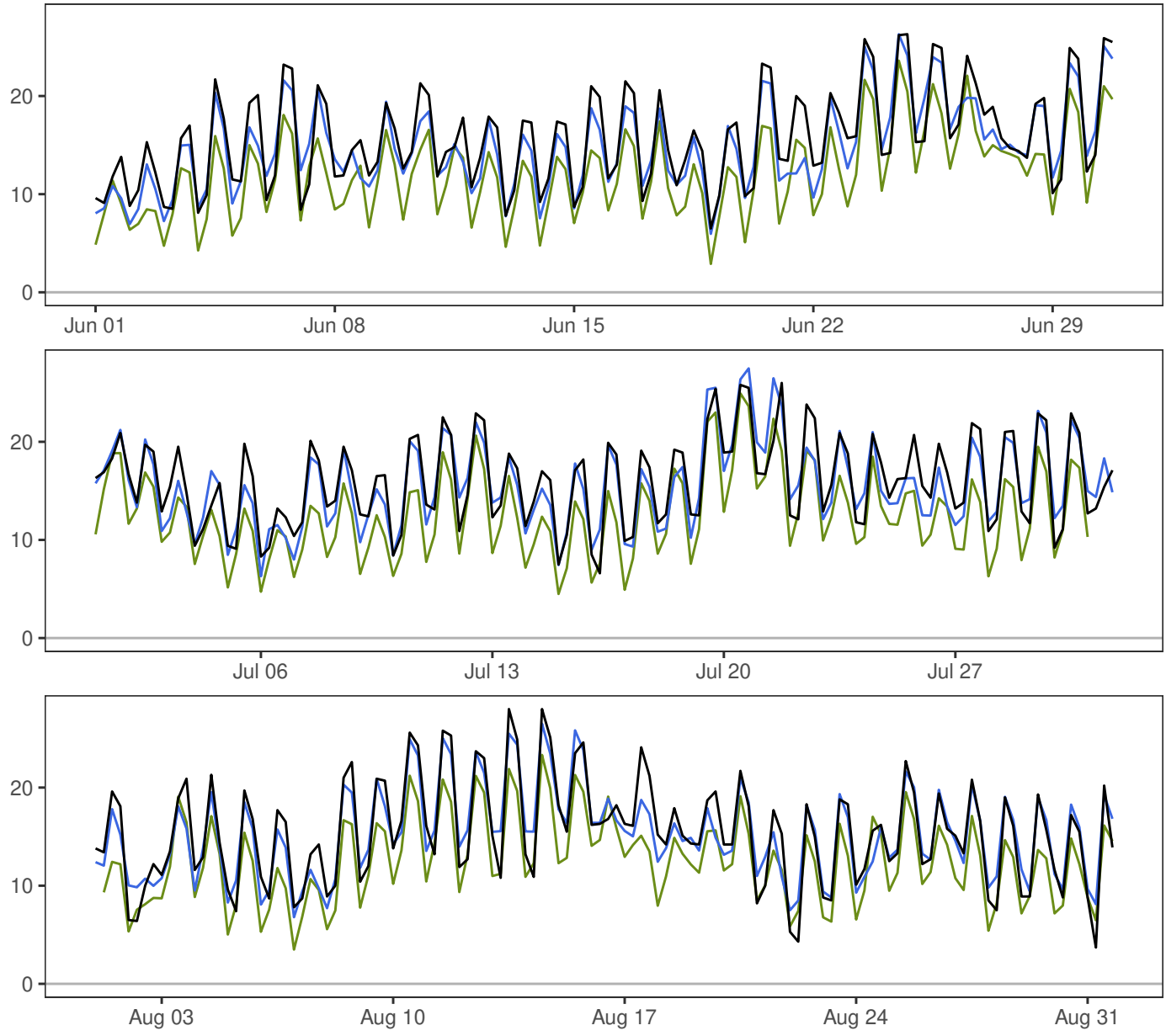
FINSEVATN



	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.3	7.6	19.1	3.8	368
MEPSctrl: 12+18,+24,+30,+36	−0.4	7.1	22.0	4.2	368
ECMWF: 12+18,+24,+30,+36	−1.9	5.9	18.0	3.7	364

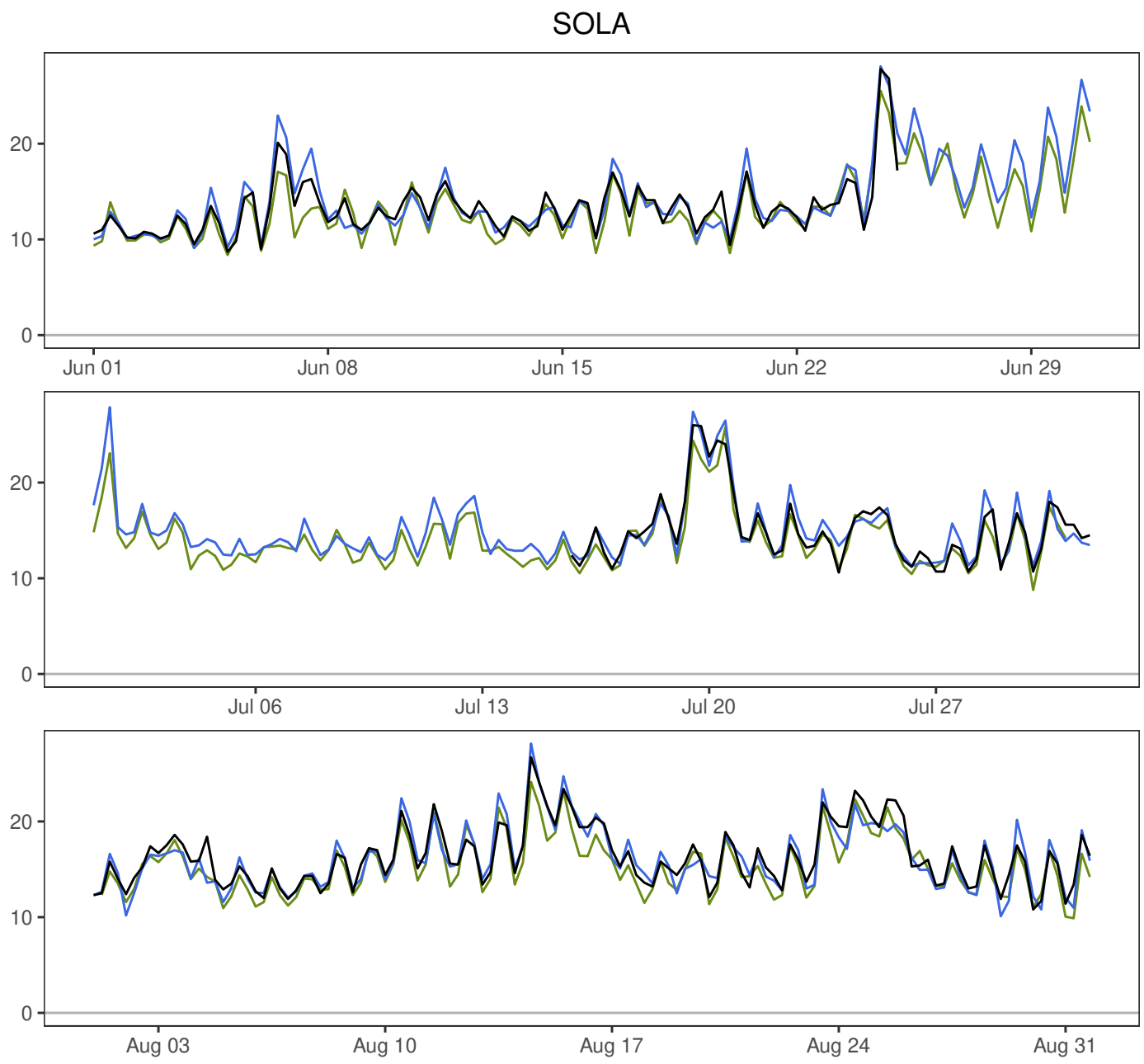
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.5	1.3	1.4	1.1	7.2	364
ECMWF−synop	−1.7	1.4	2.1	1.9	6.1	364

NESBYEN – TODOKK



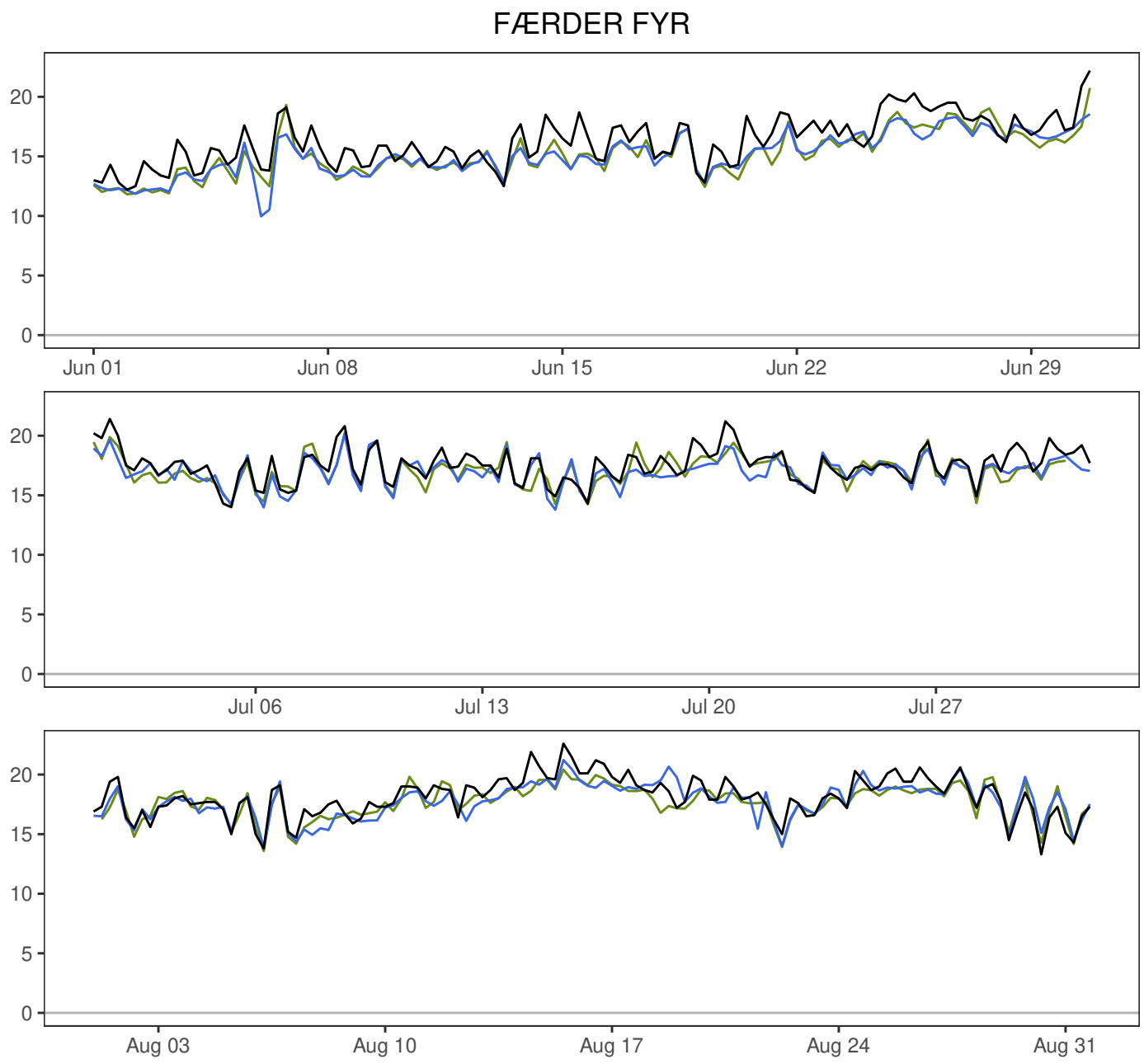
	Min	Mean	Max	Std	N
synop: 00,06,12,18	3.7	15.7	28.0	4.9	368
MEPSctrl: 12+18,+24,+30,+36	6.0	15.2	27.5	4.5	368
ECMWF: 12+18,+24,+30,+36	2.9	12.4	24.9	4.3	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	–0.5	2.0	2.1	1.6	7.9	364
ECMWF–synop	–3.3	2.1	3.9	3.4	9.0	364



	Min	Mean	Max	Std	N
synop: 00,06,12,18	8.7	15.0	27.8	3.4	286
MEPSctrl: 12+18,+24,+30,+36	9.1	15.2	28.1	3.6	368
ECMWF: 12+18,+24,+30,+36	8.4	14.2	25.8	3.2	364

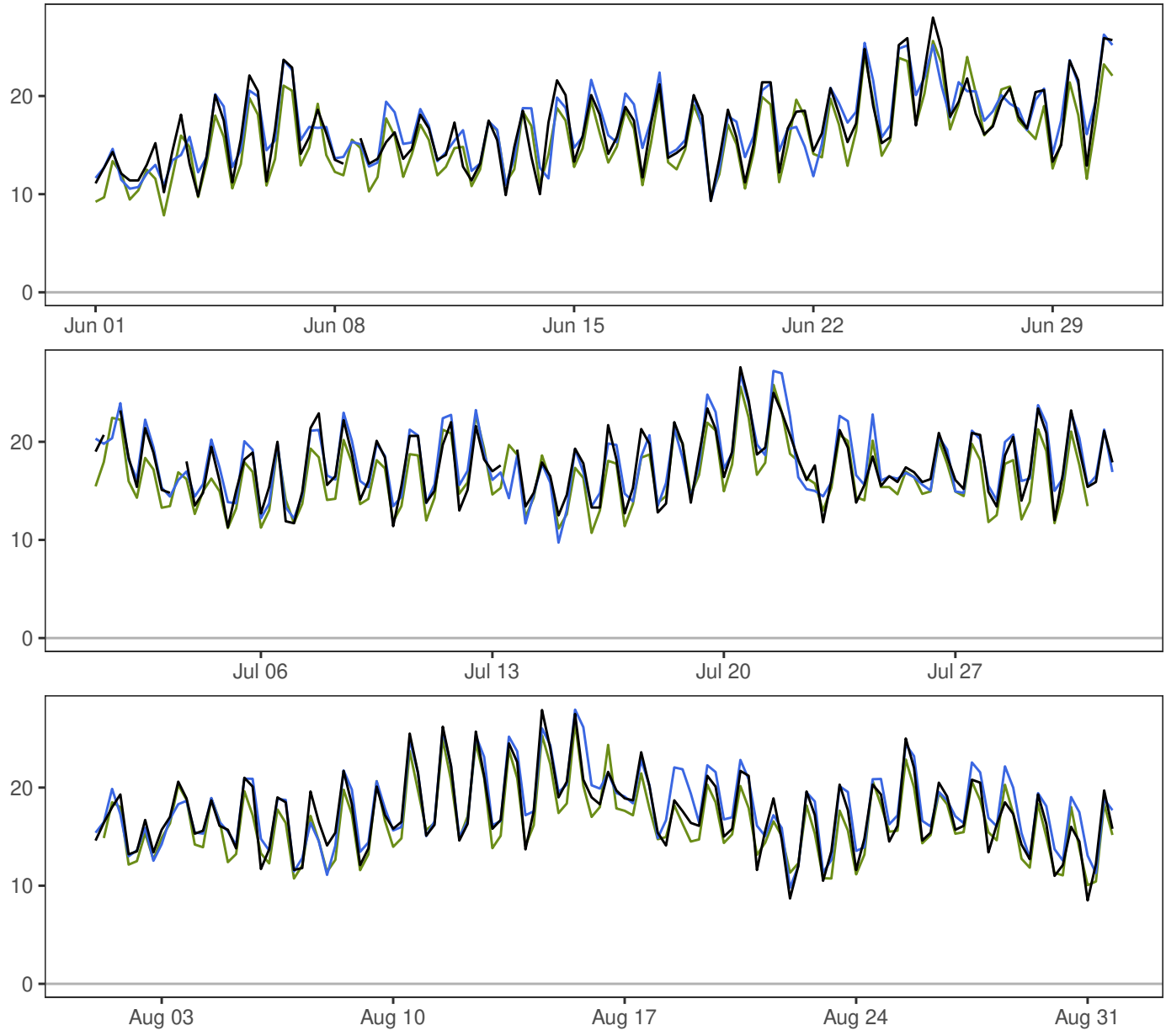
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.1	1.2	1.2	0.9	4.8	282
ECMWF−synop	−0.8	1.1	1.4	1.1	4.2	282



	Min	Mean	Max	Std	N
synop: 00,06,12,18	12.2	17.3	22.6	1.9	368
MEPSctrl: 12+18,+24,+30,+36	10.0	16.6	21.2	1.9	368
ECMWF: 12+18,+24,+30,+36	11.8	16.6	20.7	1.9	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.7	1.0	1.2	0.9	3.9	364
ECMWF−synop	−0.7	0.9	1.2	0.9	3.8	364

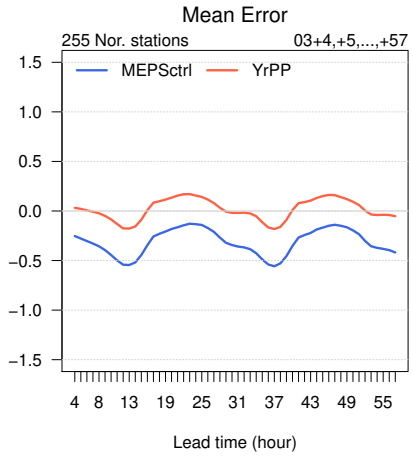
OSLO – BLINDERN

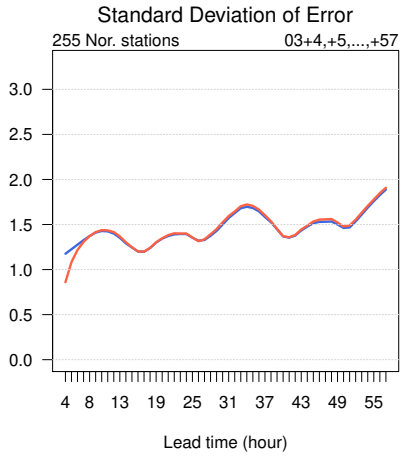


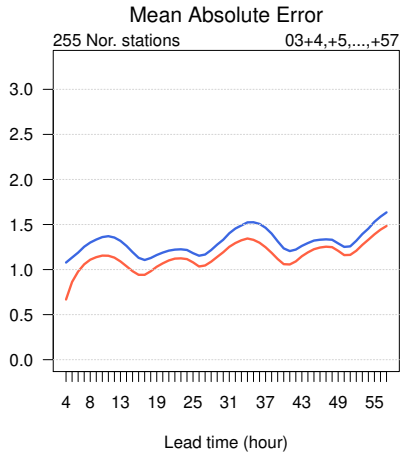
	Min	Mean	Max	Std	N
synop: 00,06,12,18	8.5	17.2	28.0	3.8	364
MEPSctrl: 12+18,+24,+30,+36	9.3	17.6	27.9	3.7	368
ECMWF: 12+18,+24,+30,+36	7.8	16.2	26.6	3.6	364

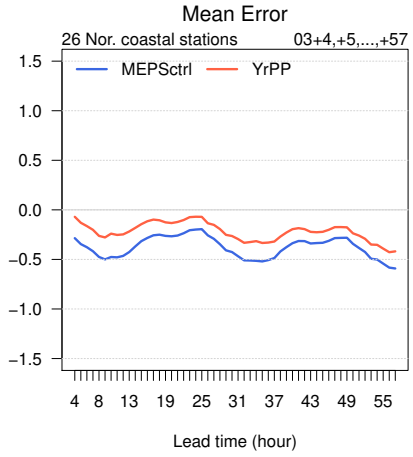
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.4	1.5	1.6	1.1	5.7	360
ECMWF−synop	−1.0	1.3	1.6	1.4	4.8	360

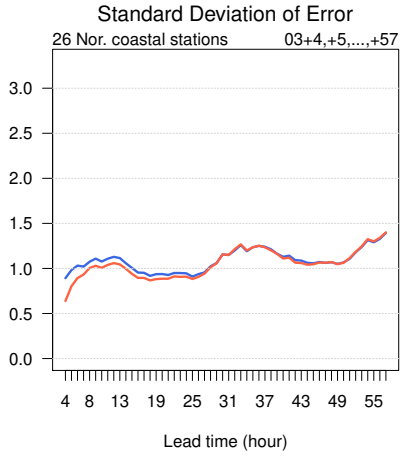
Post processed temperature 2m (YrPP)

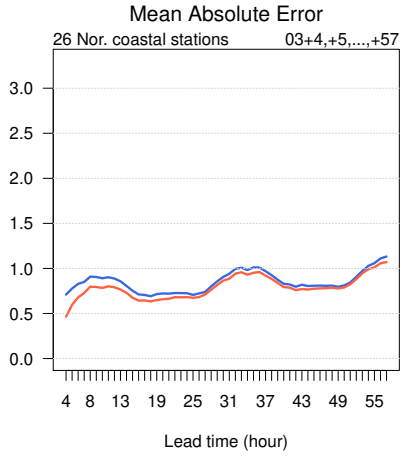


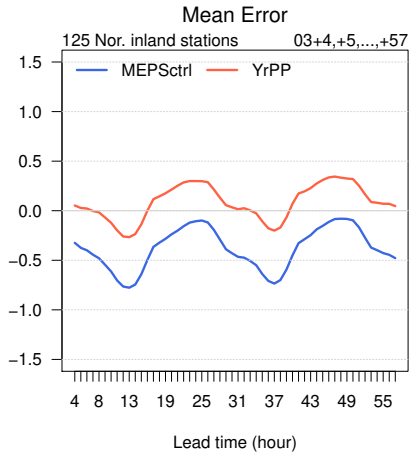


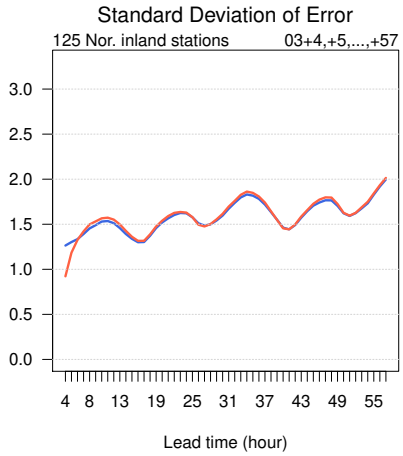


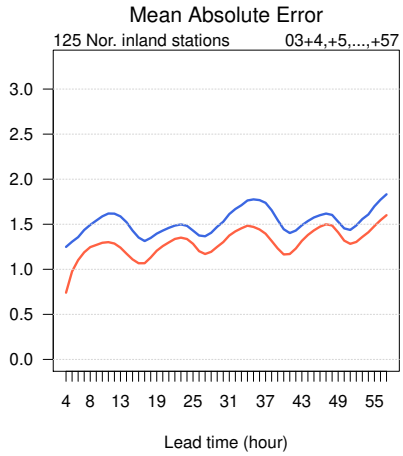




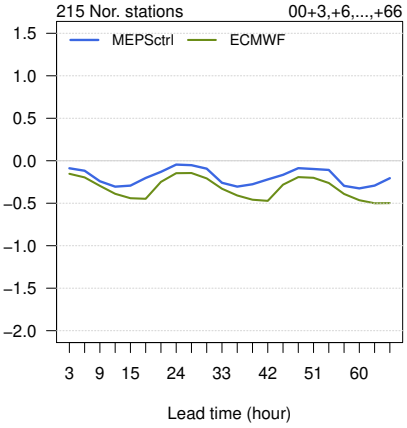




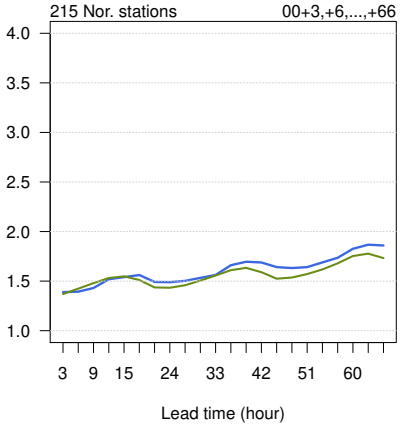




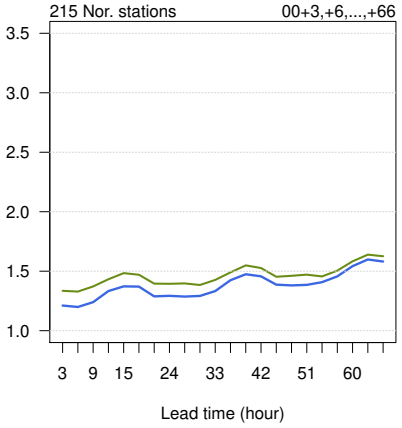
Mean Error



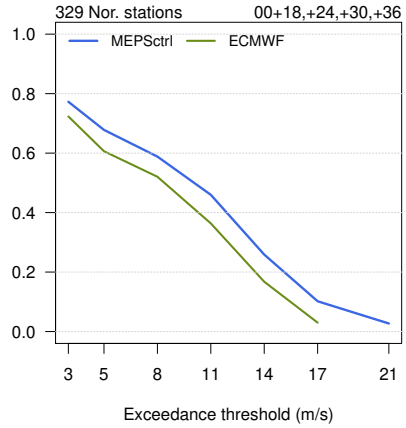
Standard Deviation of Error



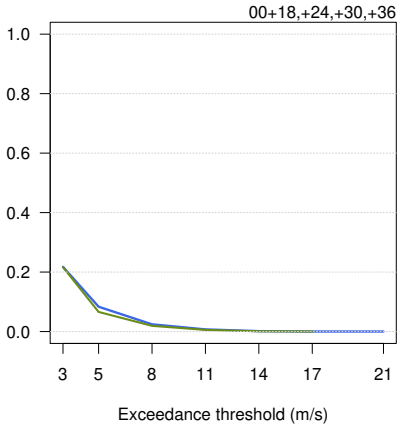
Mean Absolute Error



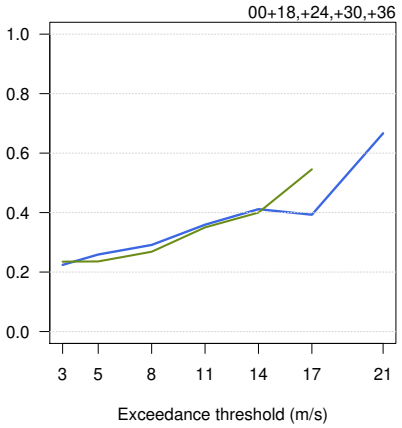
Hit Rate



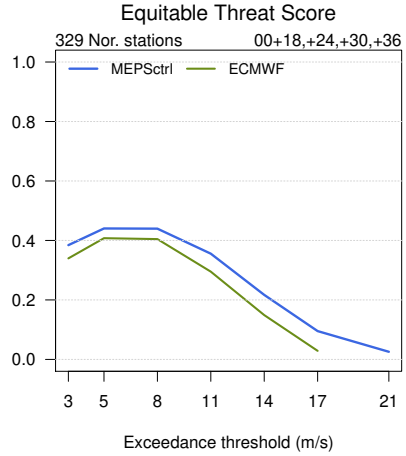
False Alarm Rate



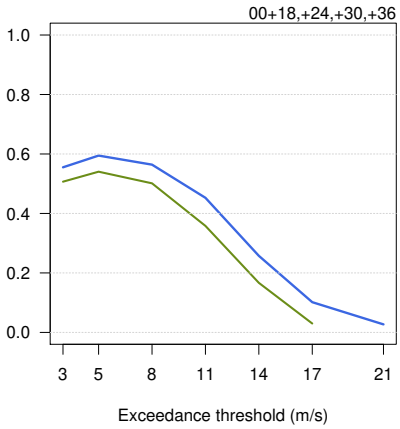
False Alarm Ratio



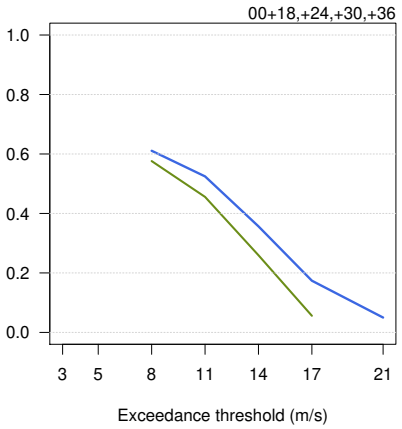
Equitable Threat Score



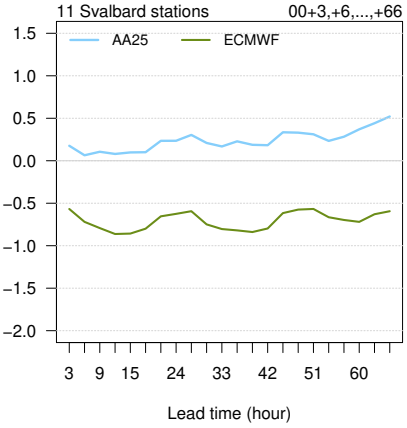
Hansen−Kuiper Skill Score



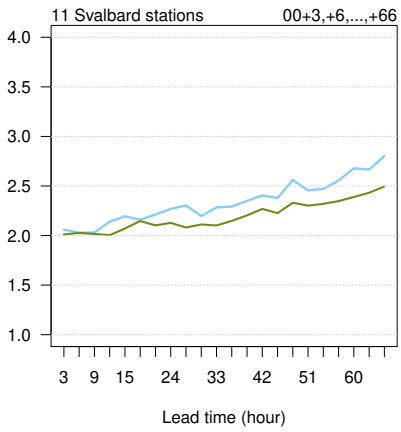
Heidke Skill Score



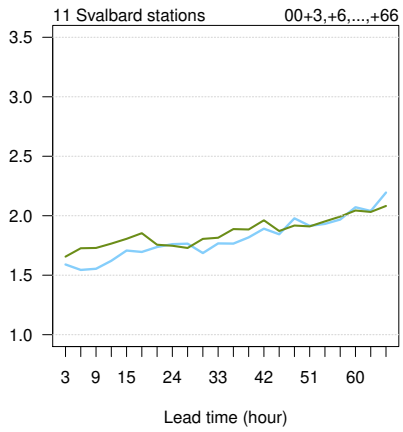
Mean Error



Standard Deviation of Error



Mean Absolute Error



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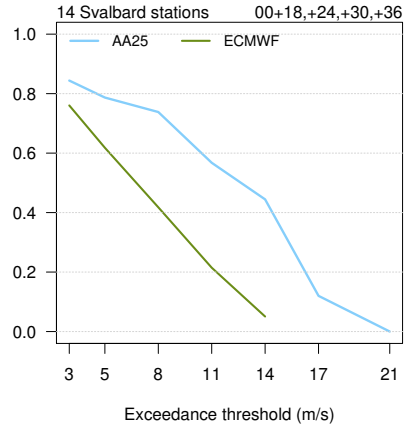
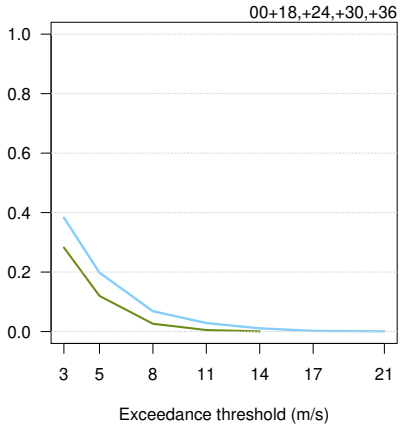
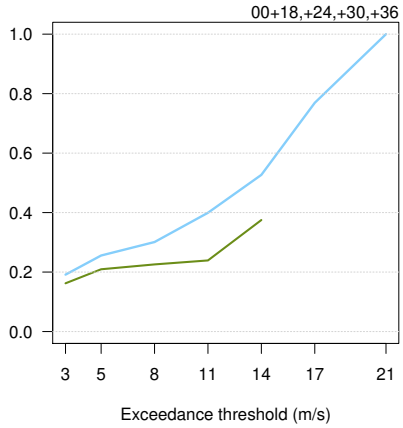


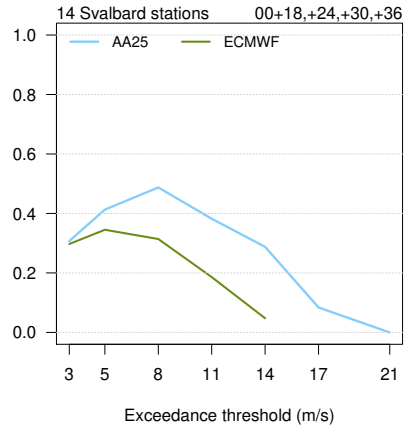
False Alarm Rate



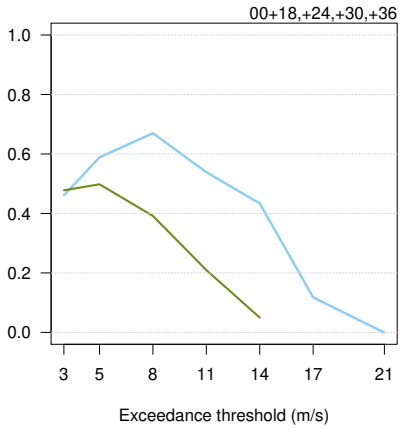
False Alarm Ratio



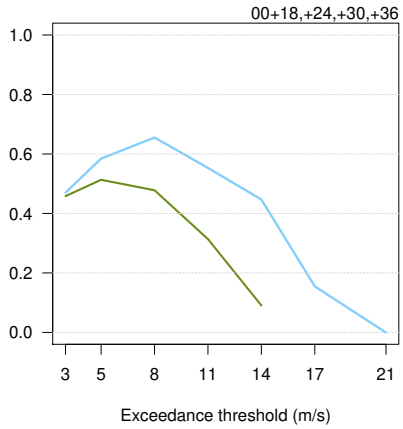
Equitable Threat Score



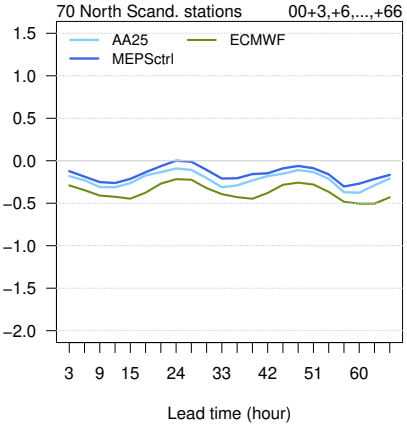
Hansen−Kuiper Skill Score



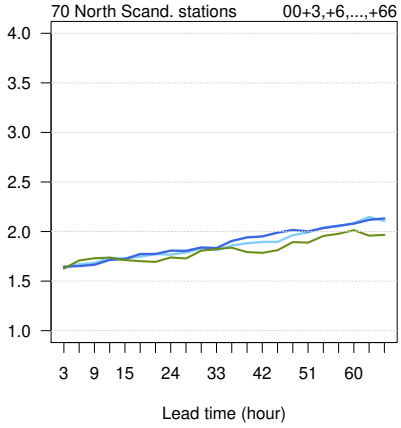
Heidke Skill Score



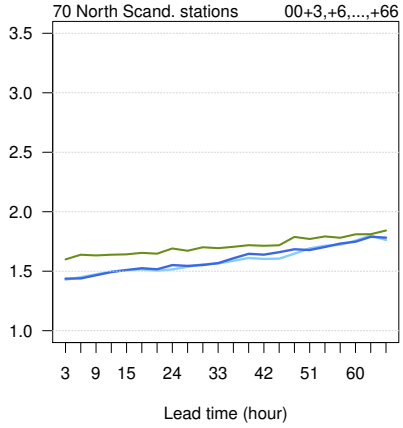
Mean Error



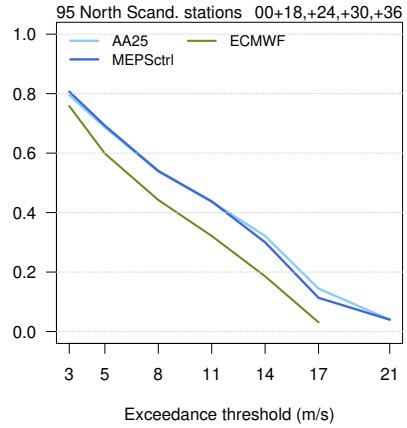
Standard Deviation of Error



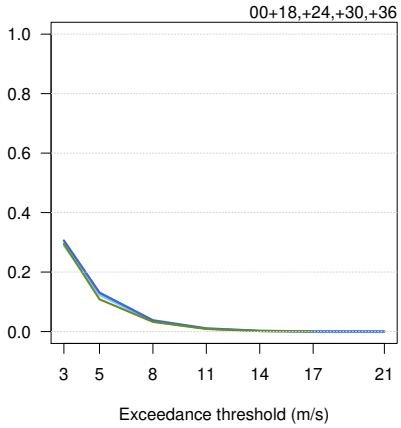
Mean Absolute Error



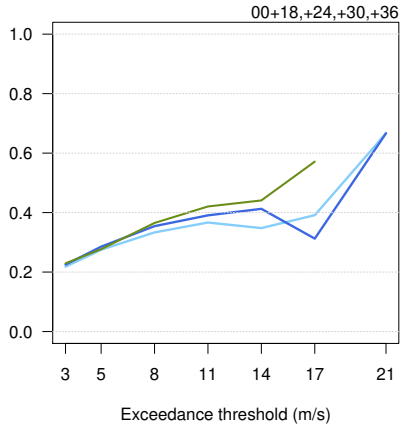
Hit Rate



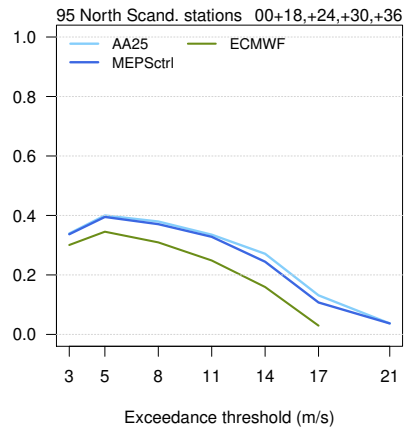
False Alarm Rate



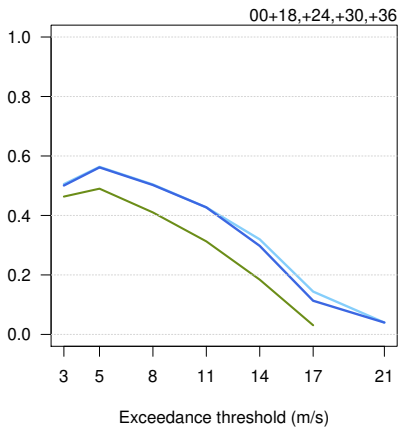
False Alarm Ratio



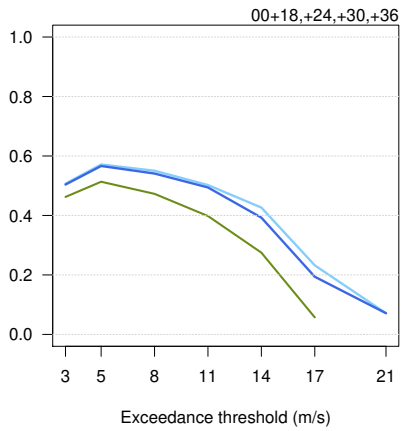
Equitable Threat Score



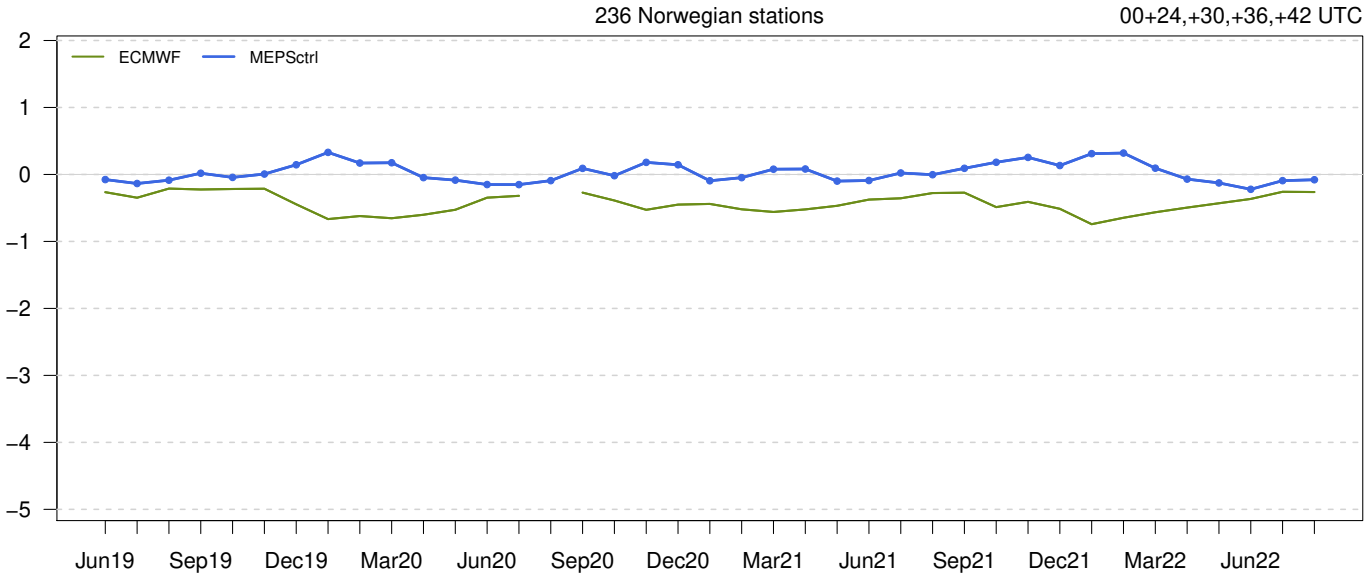
Hansen−Kuiper Skill Score

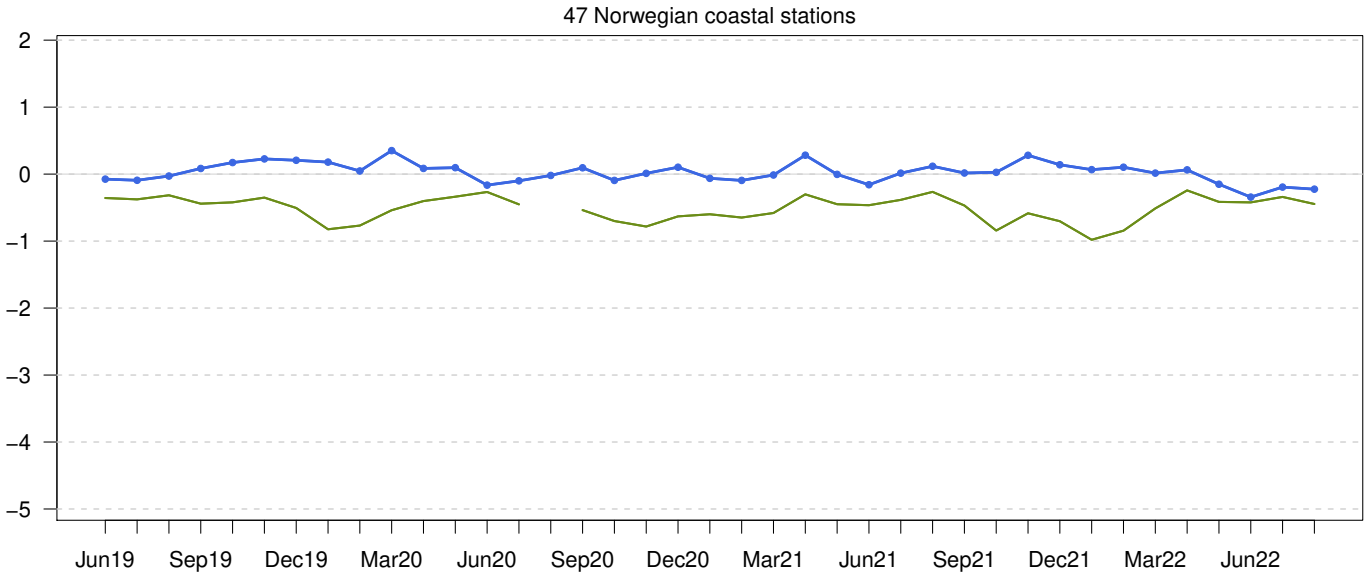


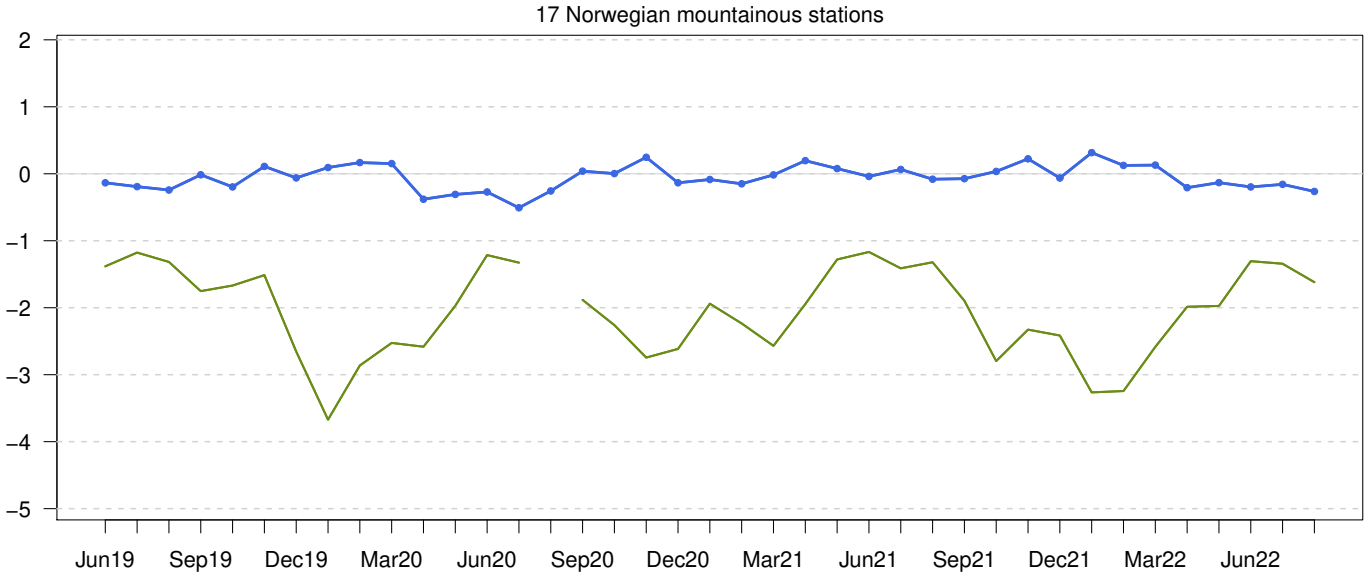
Heidke Skill Score



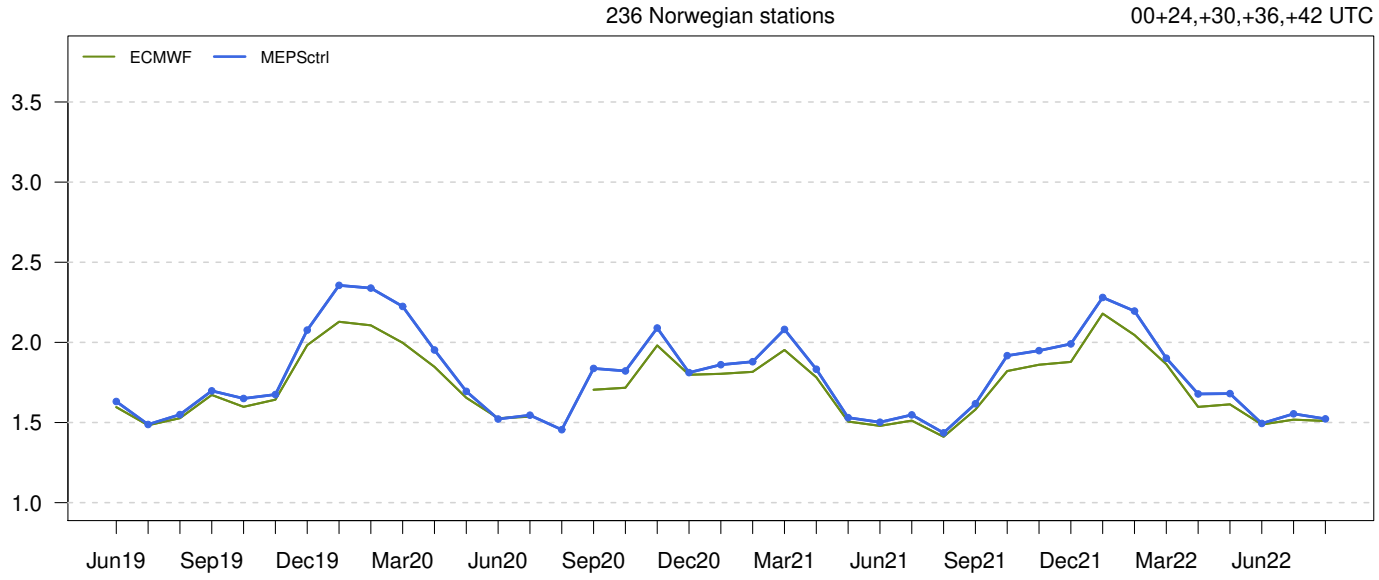
Mean Error

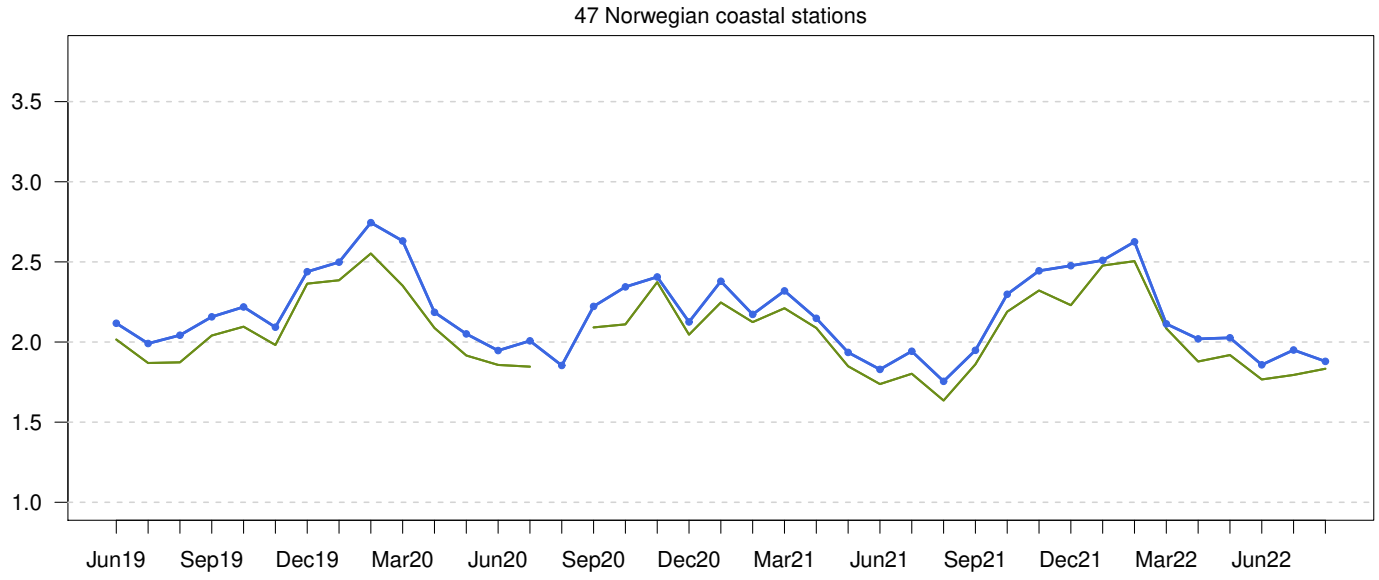

236 Norwegian stations
00+24,+30,+36,+42 UTC
ECMWF
MEPSctrl
2
1
0
−1
−2
−3
−4
−5
Jun19
Sep19
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22

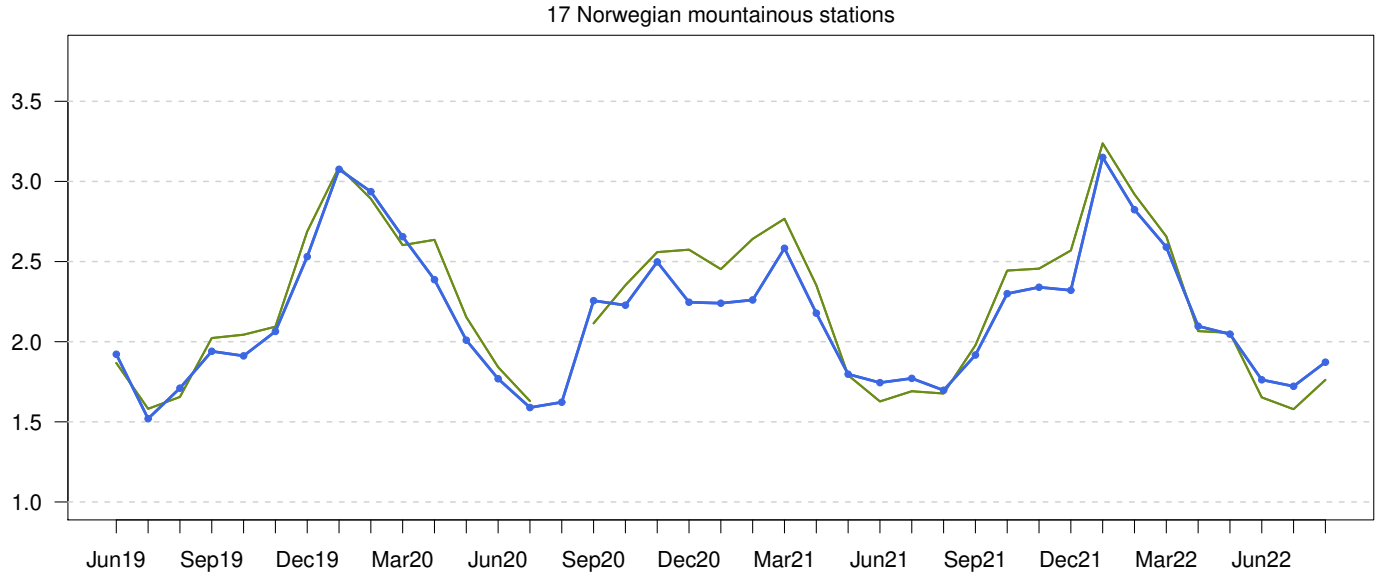

47 Norwegian coastal stations
2
1
0
−1
−2
−3
−4
−5
Jun19
Sep19
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22


17 Norwegian mountainous stations
2
1
0
−1
−2
−3
−4
−5
Jun19
Sep19
Dec19
Mar20
Jun20
Sep20
Dec20
Mar21
Jun21
Sep21
Dec21
Mar22
Jun22

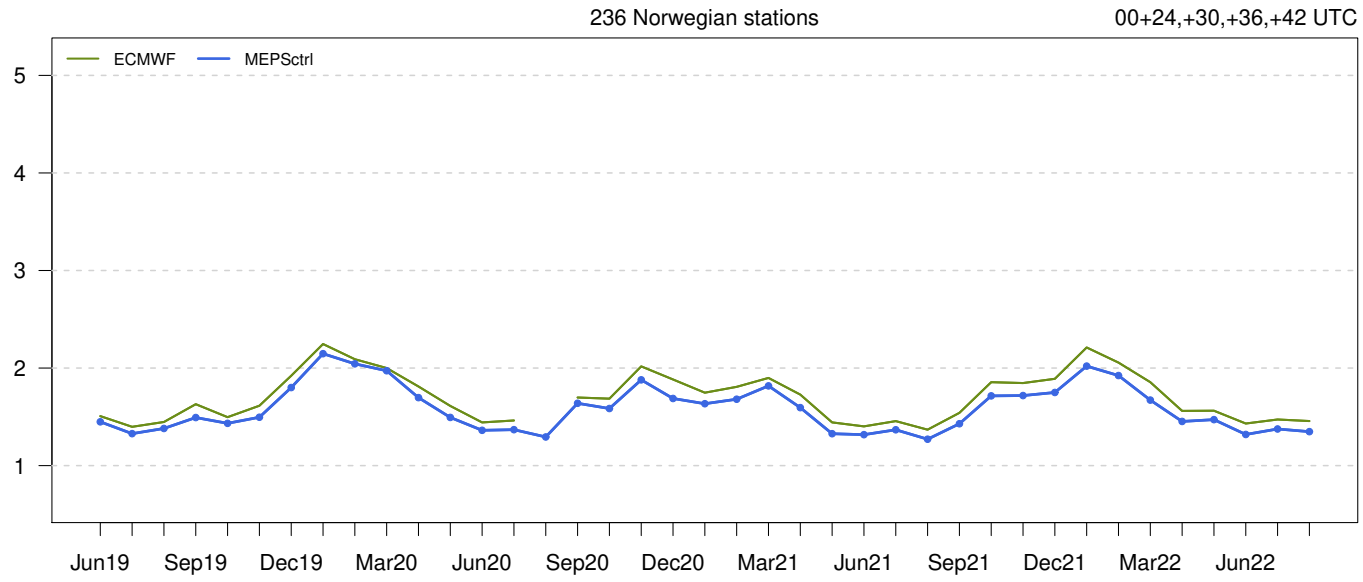
Standard Deviation of Error

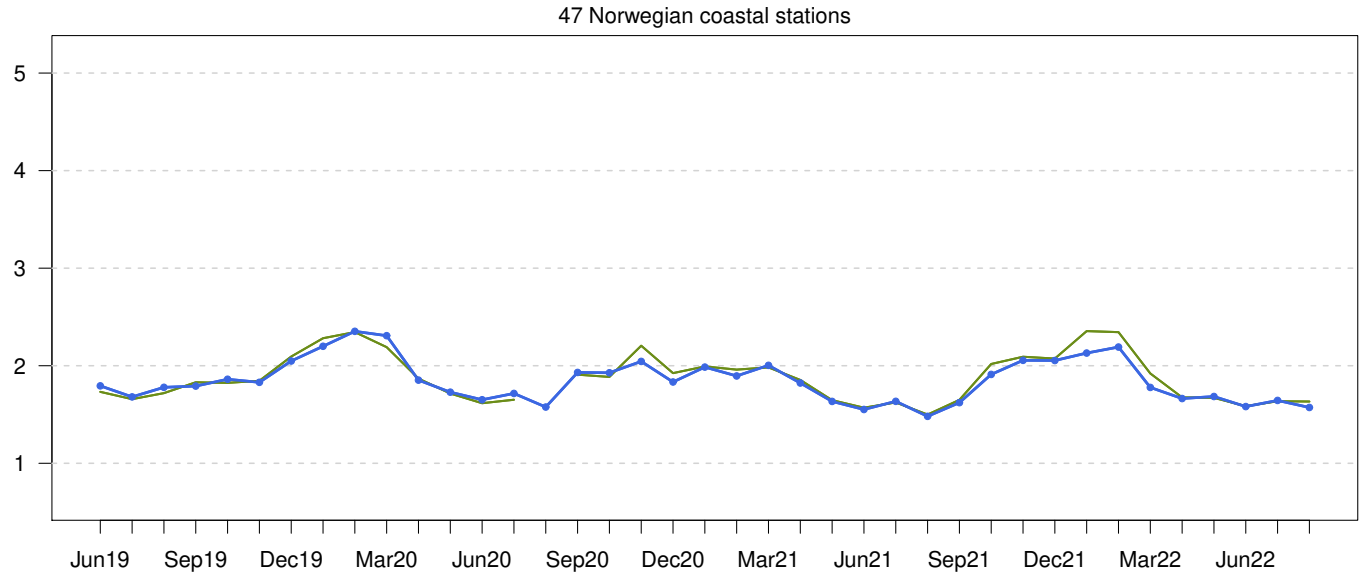


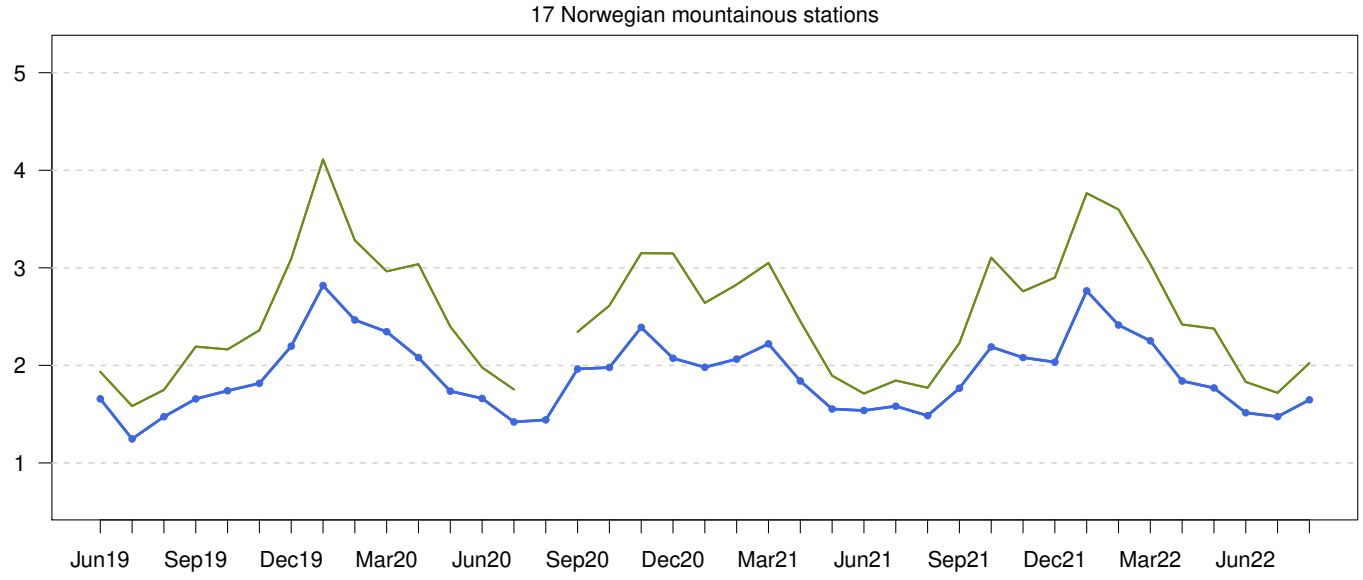




Mean Absolute Error

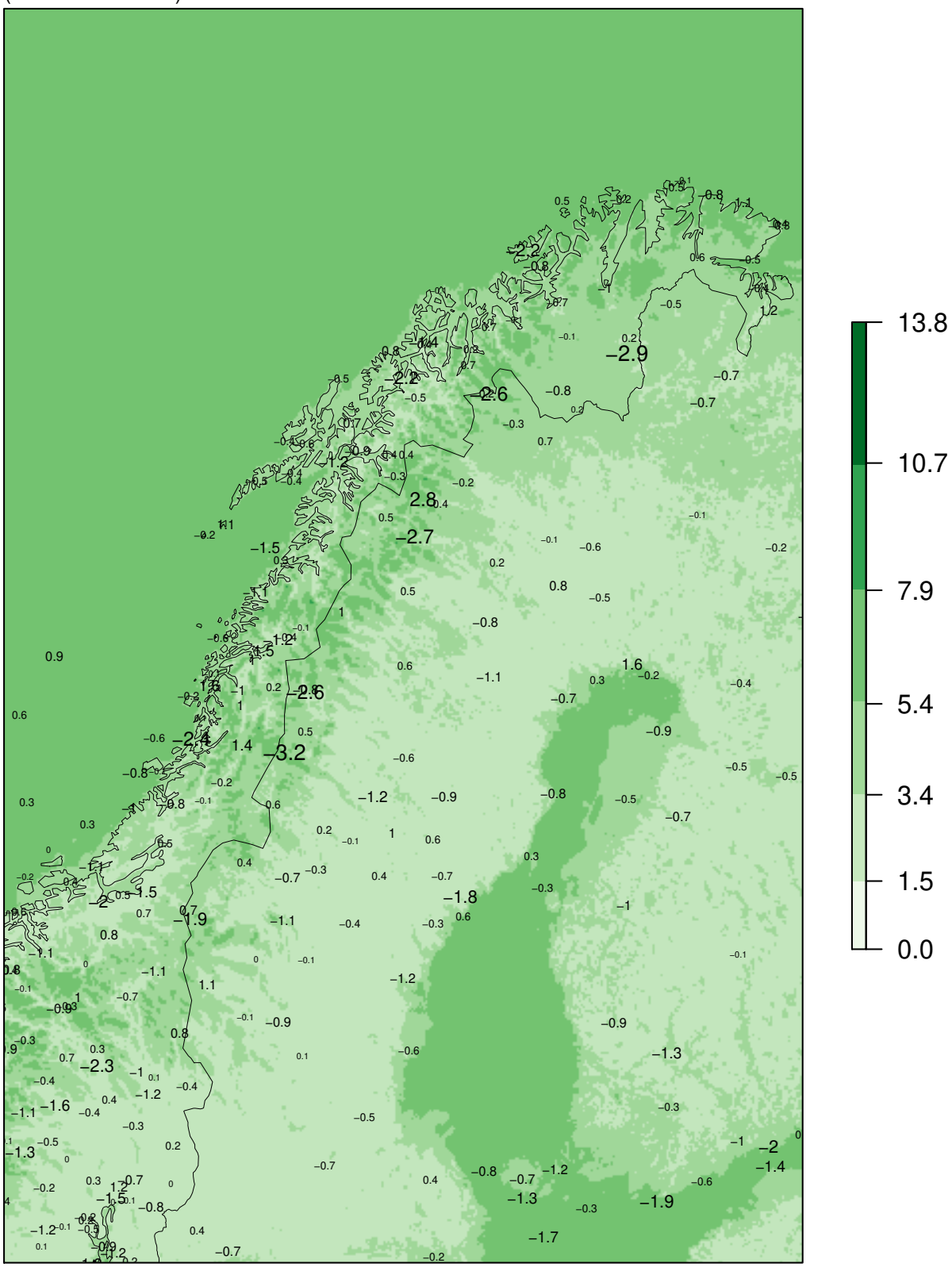






MEPSctrl 00+12

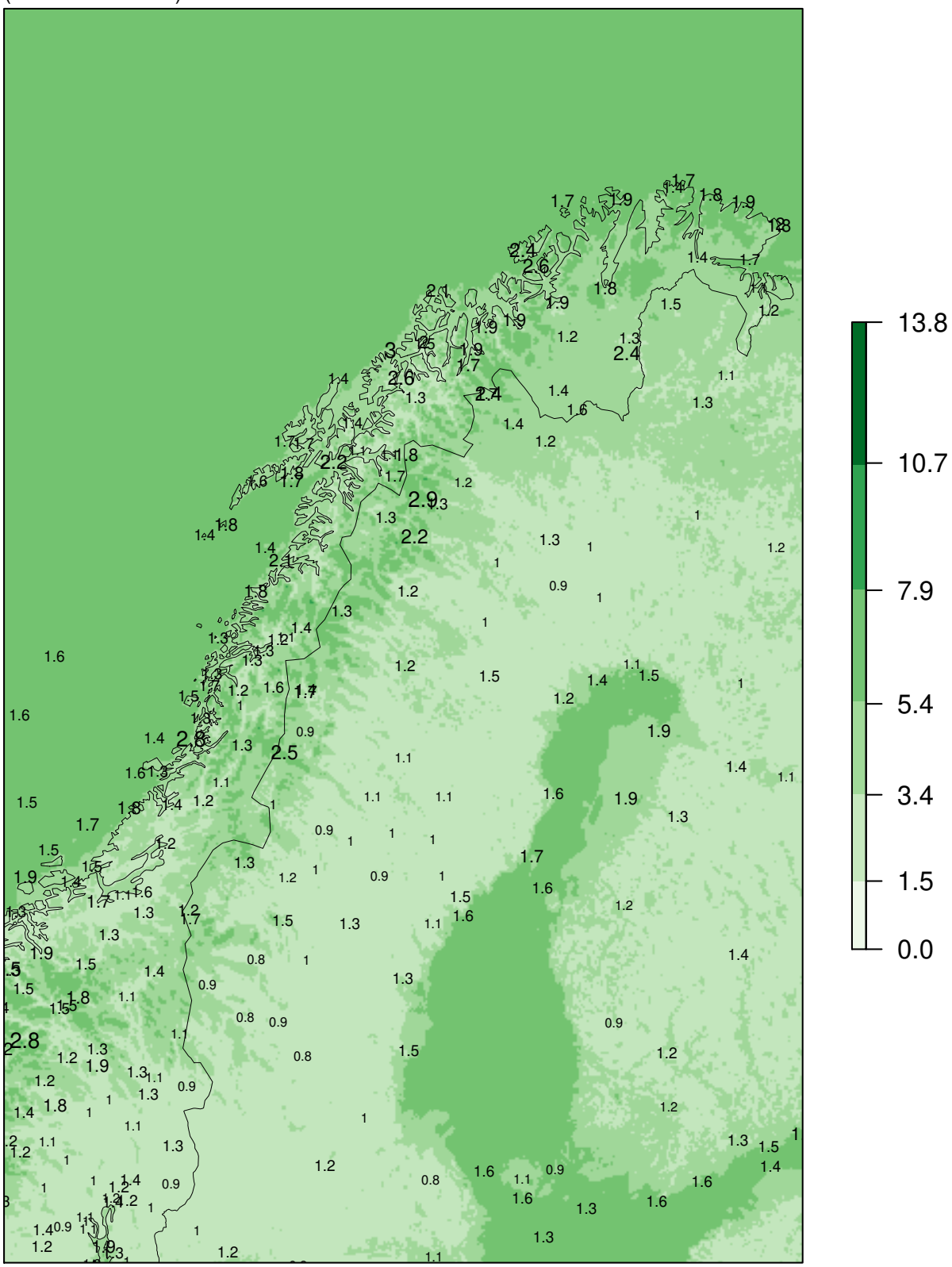
ME at observing sites
(numbers in black)



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+12

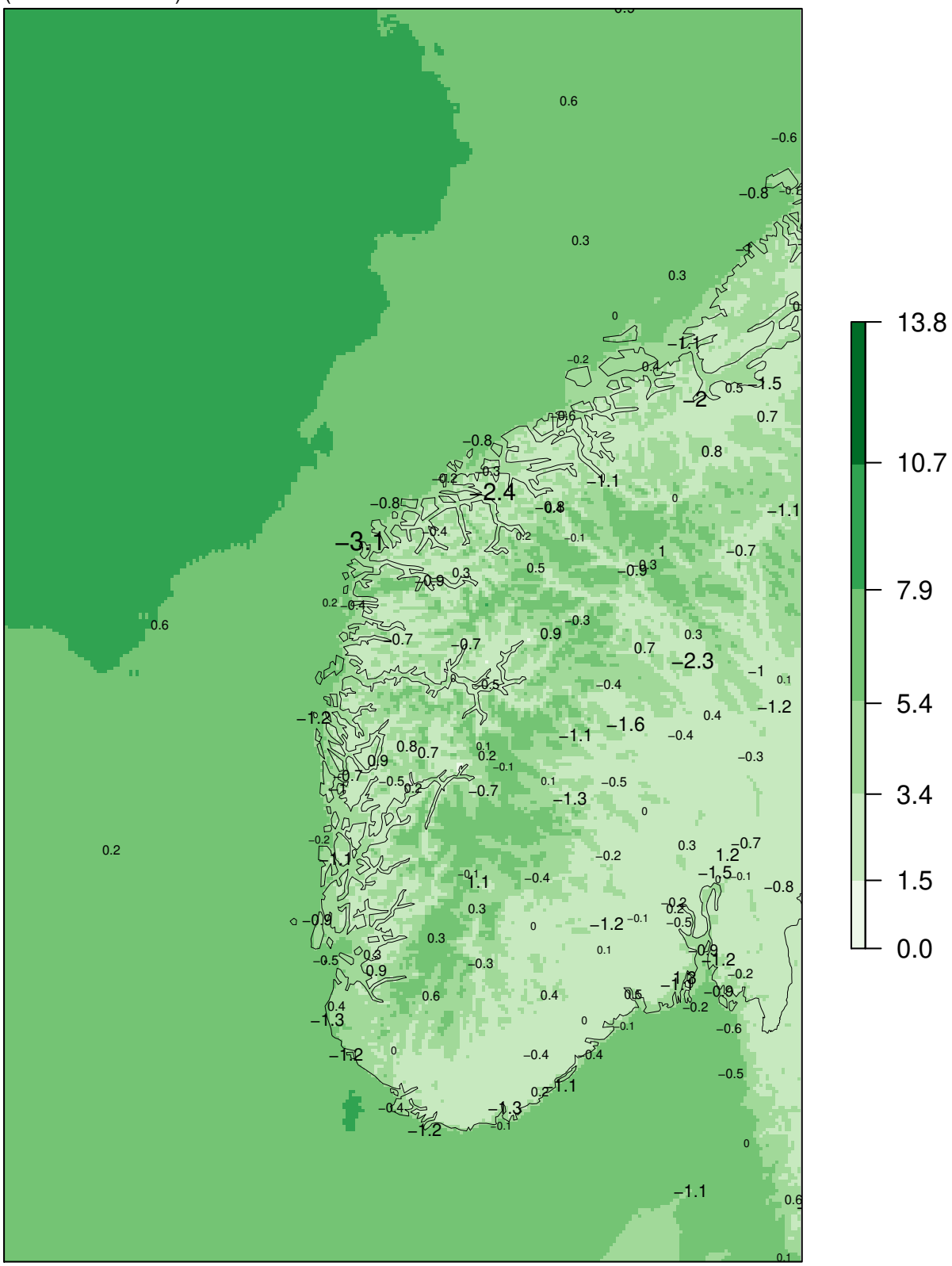
SDE at observing sites
(numbers in black)



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+12

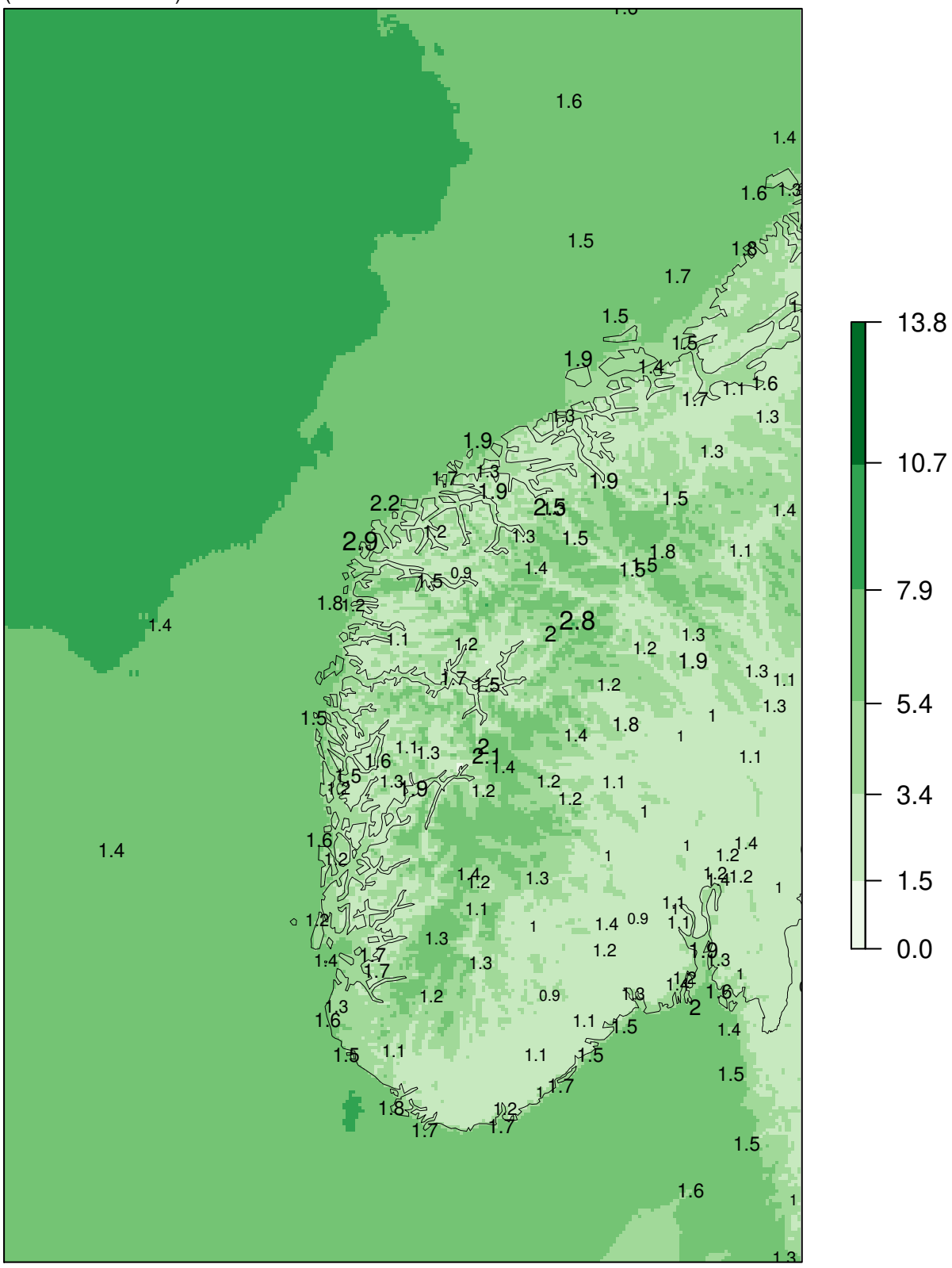
ME at observing sites
(numbers in black)



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+12

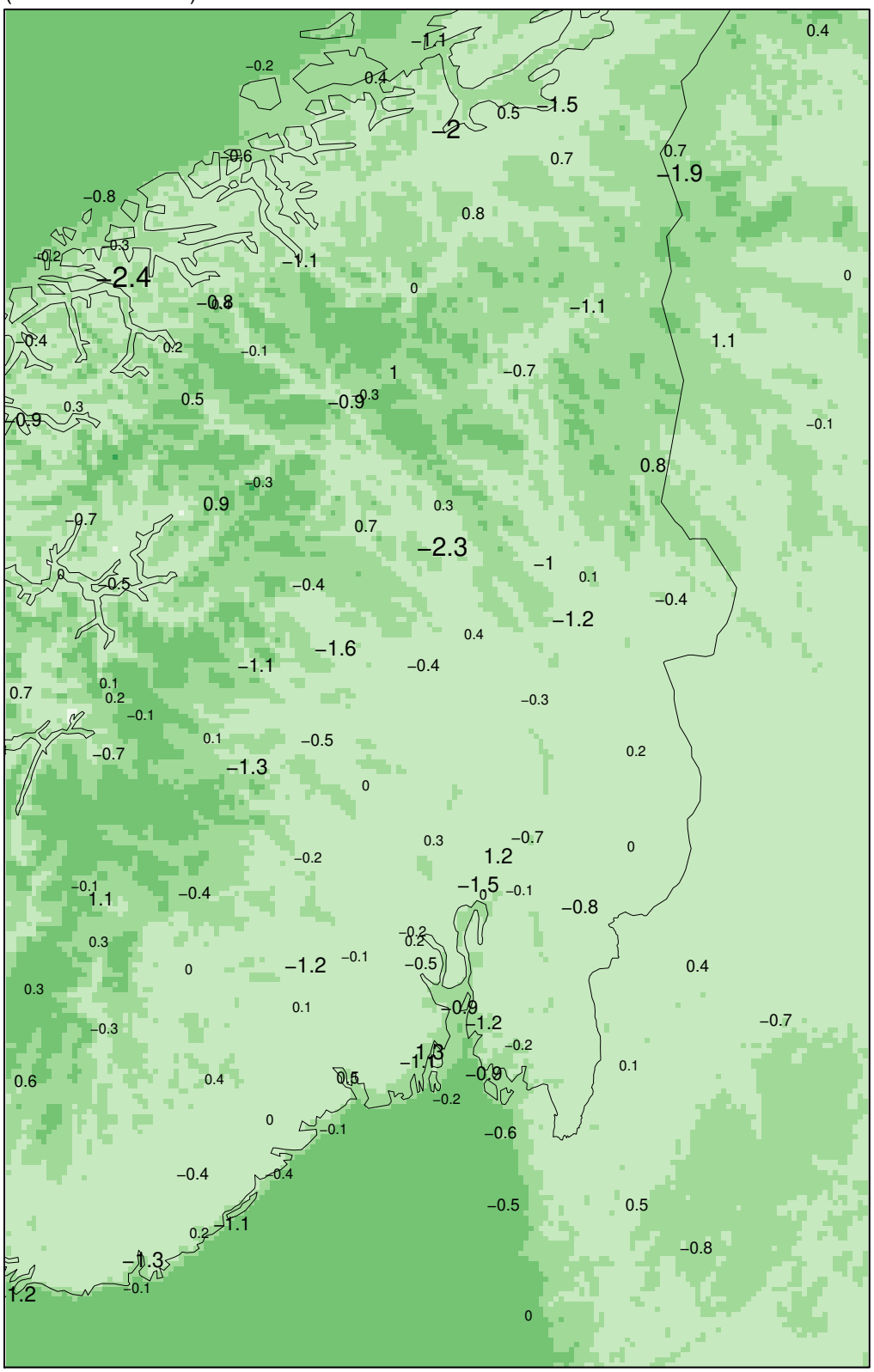
SDE at observing sites
(numbers in black)



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+12

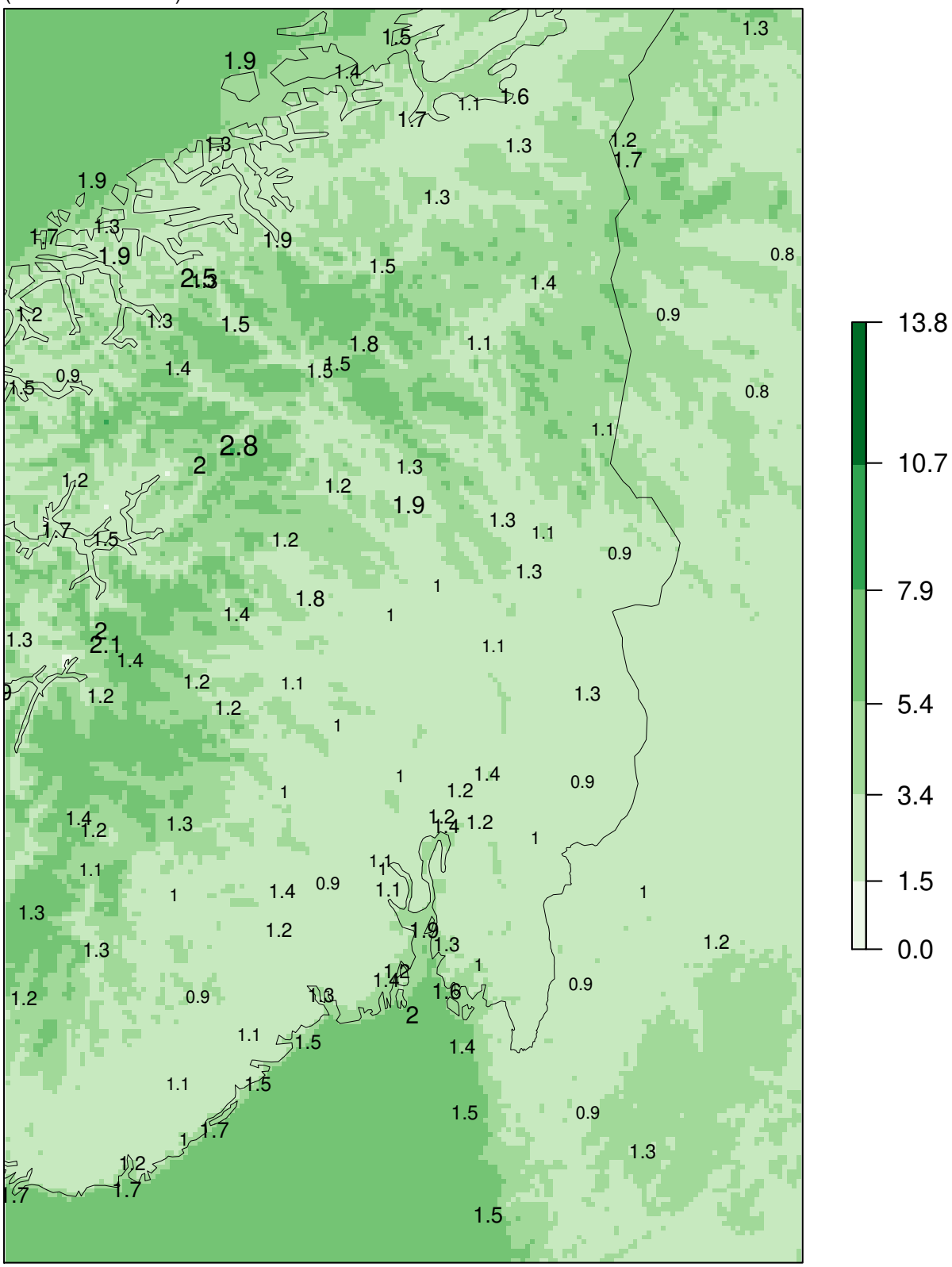
ME at observing sites
(numbers in black)



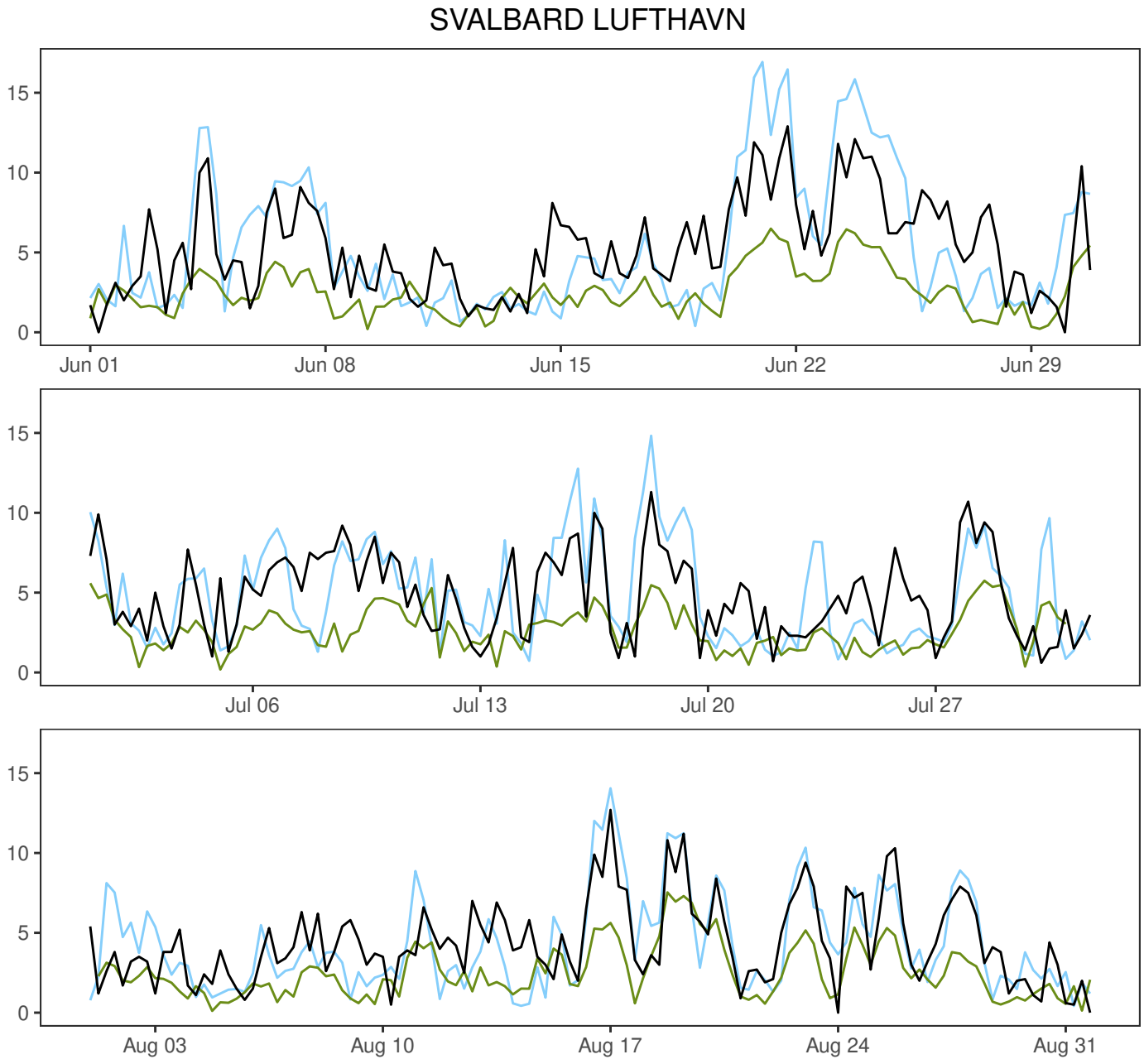
Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+12

SDE at observing sites
(numbers in black)

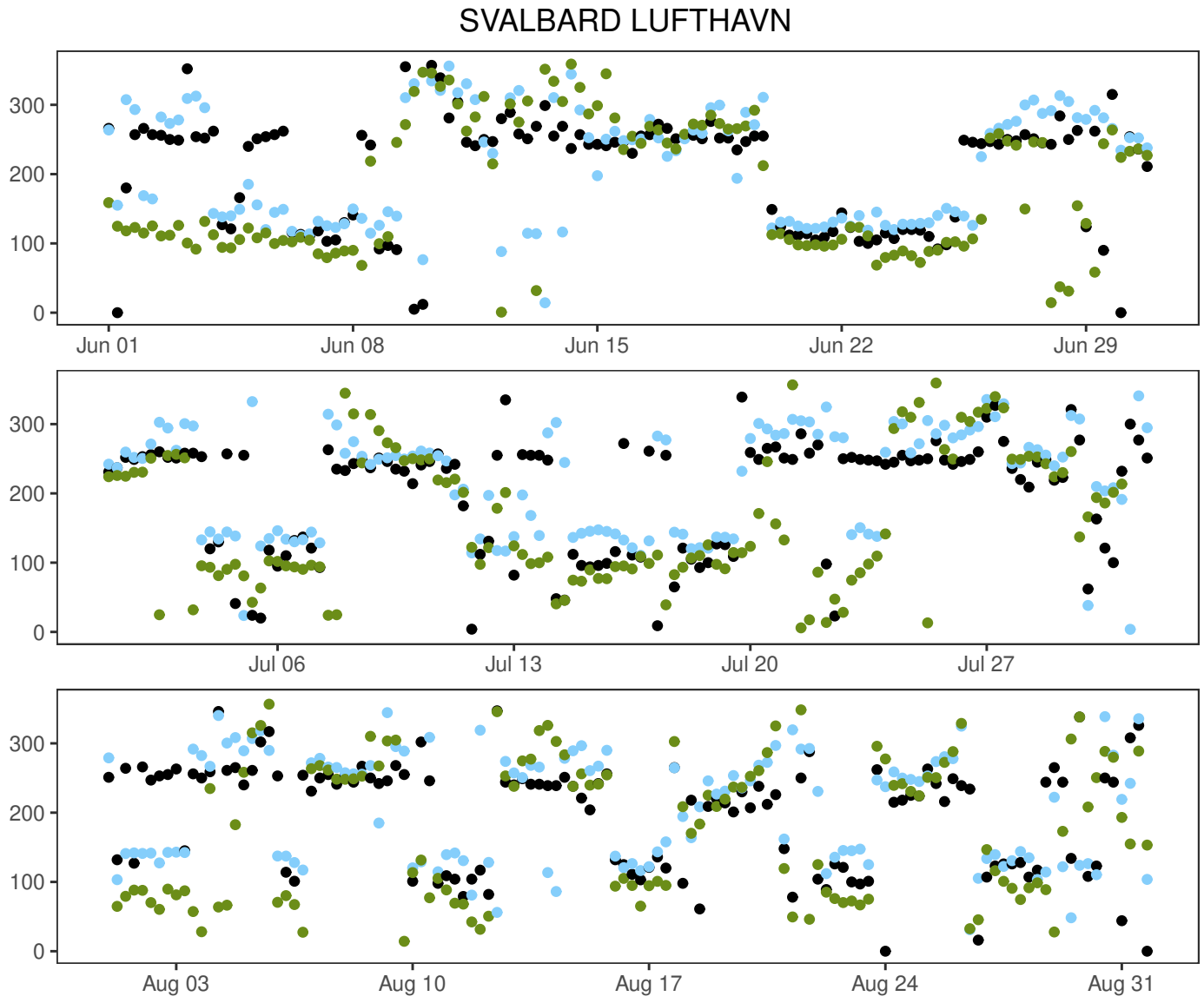


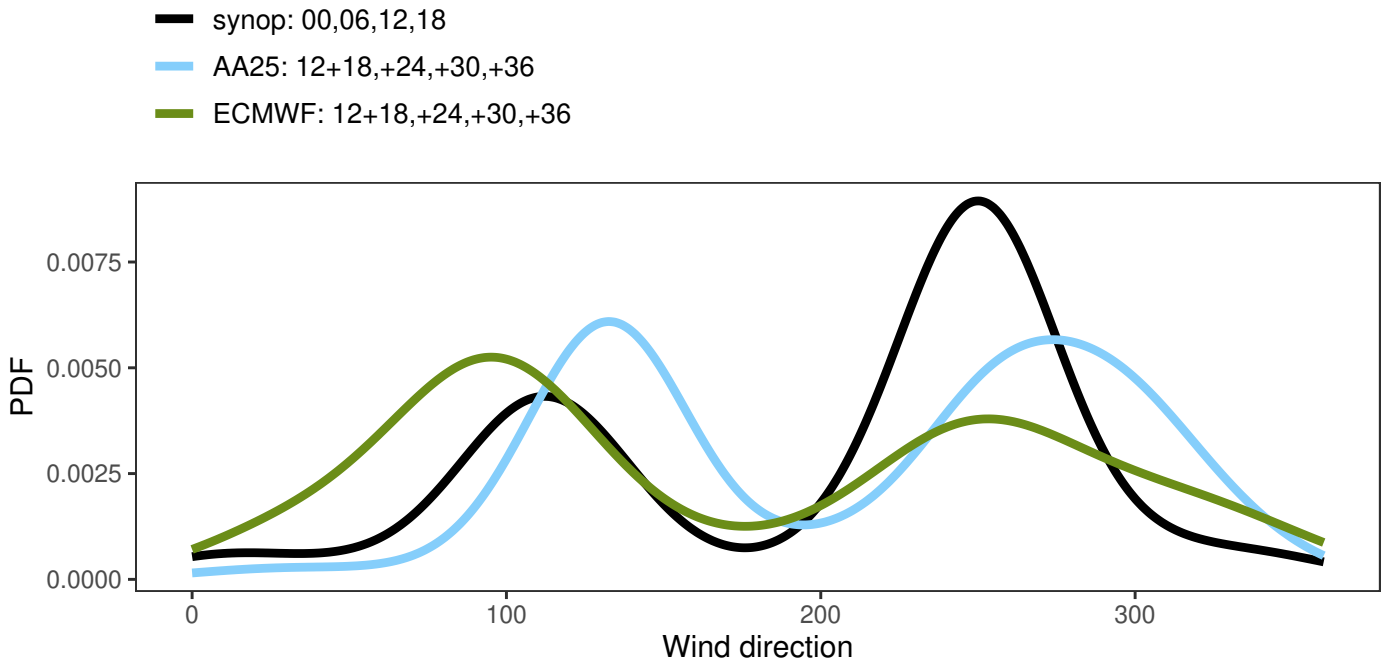
Model "climatology" 01.06.2022 – 31.08.2022

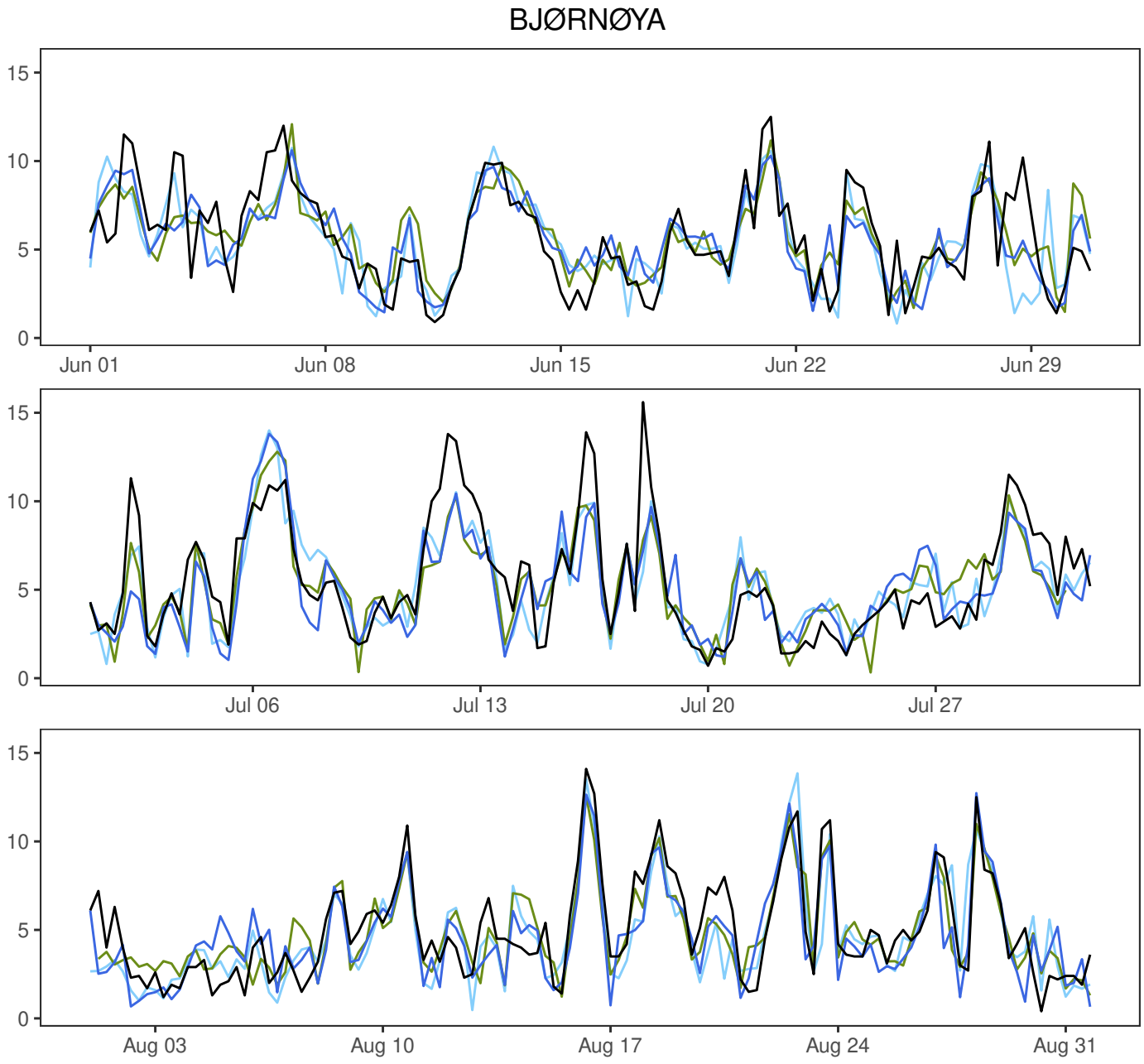


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	4.8	12.9	2.7	368
AA25: 12+18,+24,+30,+36	0.4	4.8	16.9	3.5	368
ECMWF: 12+18,+24,+30,+36	0.1	2.6	7.5	1.5	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
AA25−synop	0.0	2.6	2.6	2.0	8.2	364
ECMWF−synop	−2.3	2.1	3.1	2.6	7.9	364

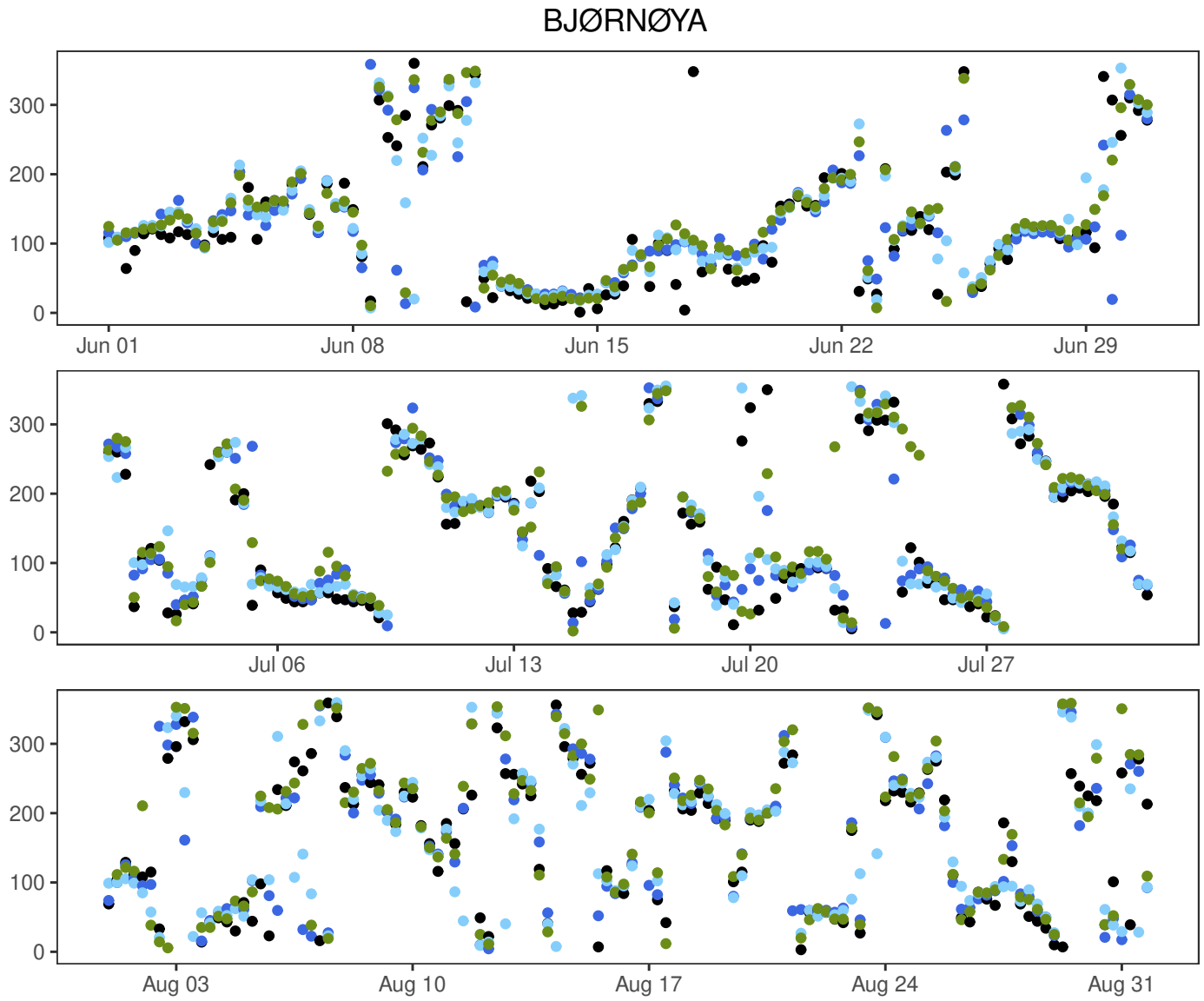

SVALBARD LUFTHAVN
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31

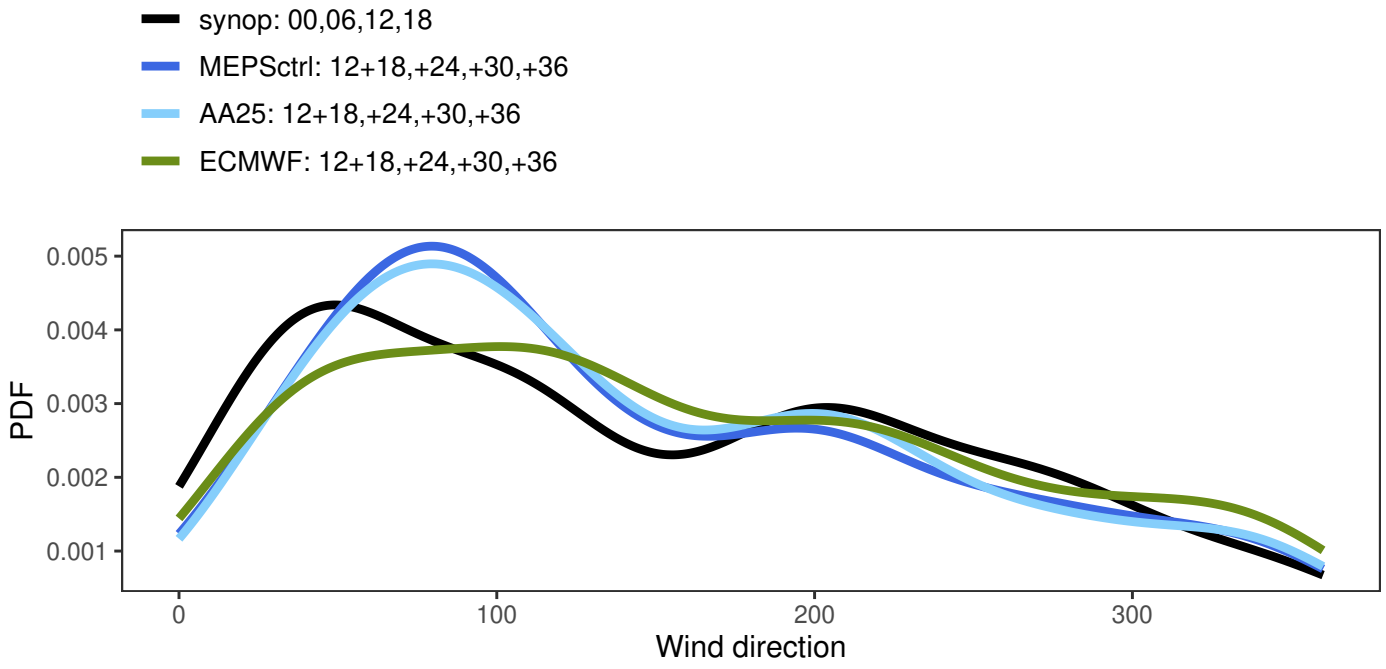

synop: 00,06,12,18
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.0075
0.0050
0.0025
0.0000
0
100
200
300
Wind direction

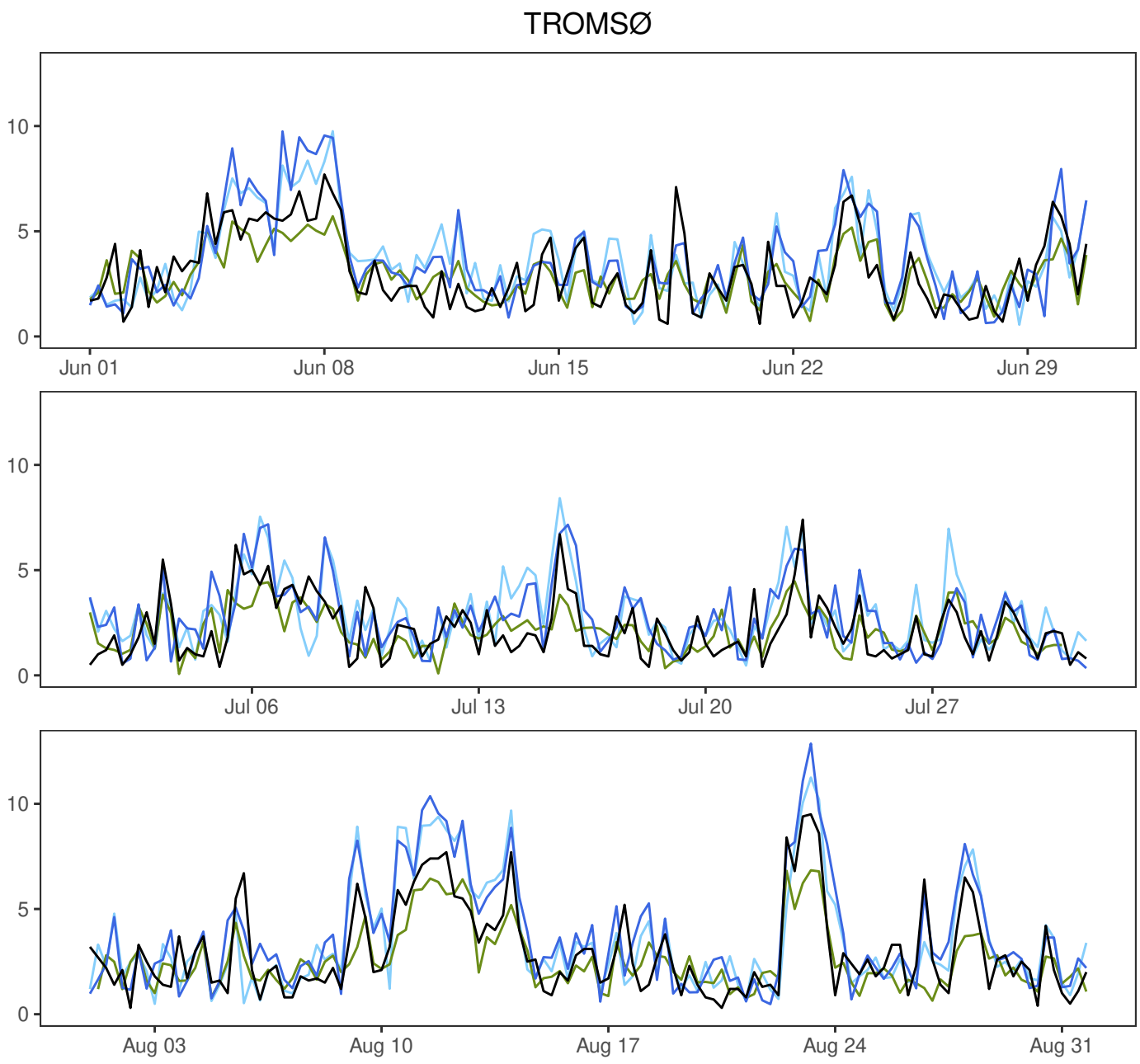


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.4	5.4	15.6	3.0	368
MEPSctrl: 12+18,+24,+30,+36	0.7	5.1	13.8	2.5	368
AA25: 12+18,+24,+30,+36	0.5	5.1	14.0	2.7	368
ECMWF: 12+18,+24,+30,+36	0.3	5.3	12.8	2.4	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.3	1.9	1.9	1.5	8.4	364
AA25−synop	−0.3	2.0	2.0	1.5	9.6	364
ECMWF−synop	−0.1	1.8	1.8	1.4	7.8	364

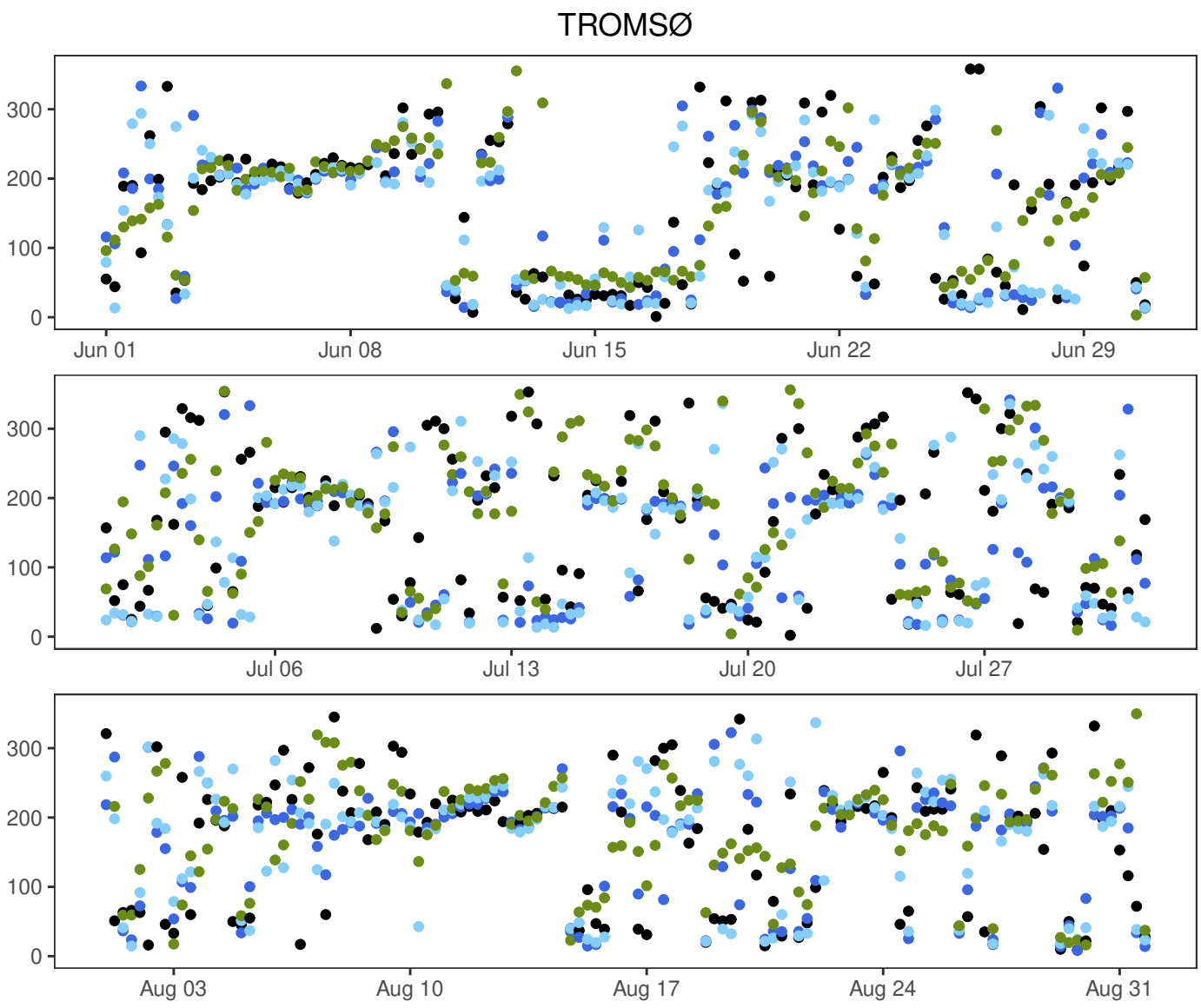

BJØRNØYA
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31

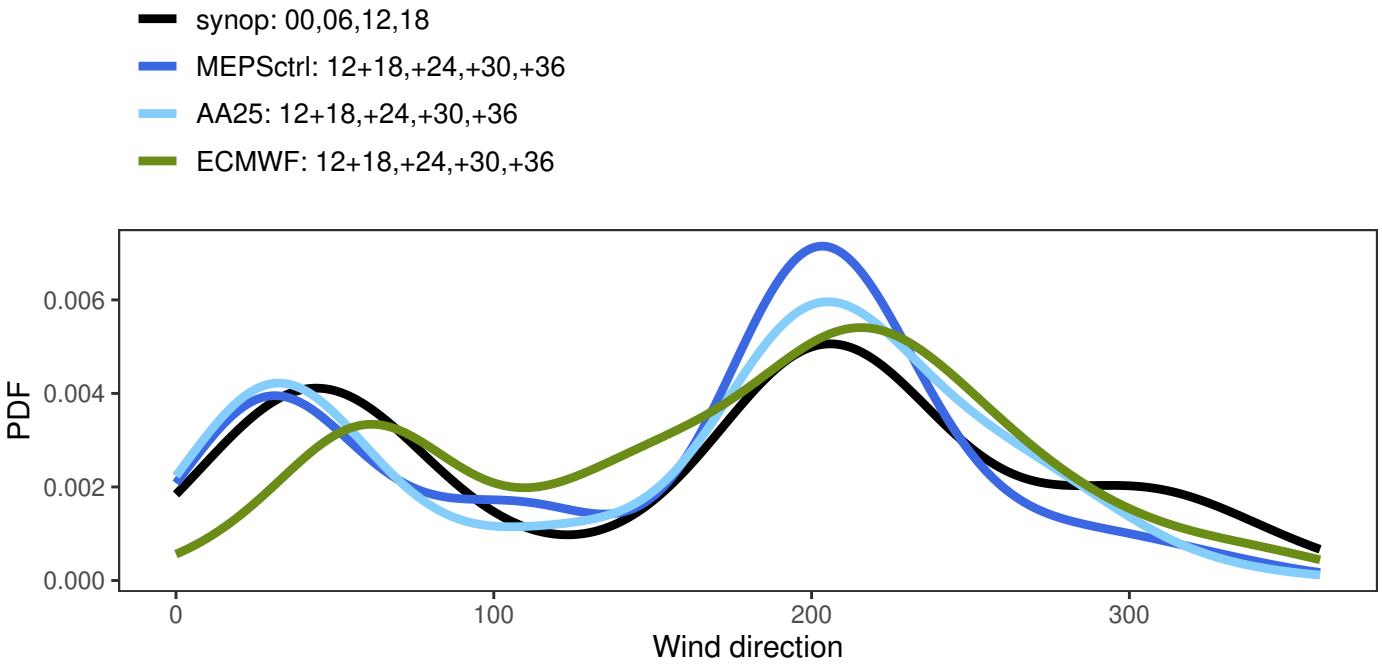

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.005
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction



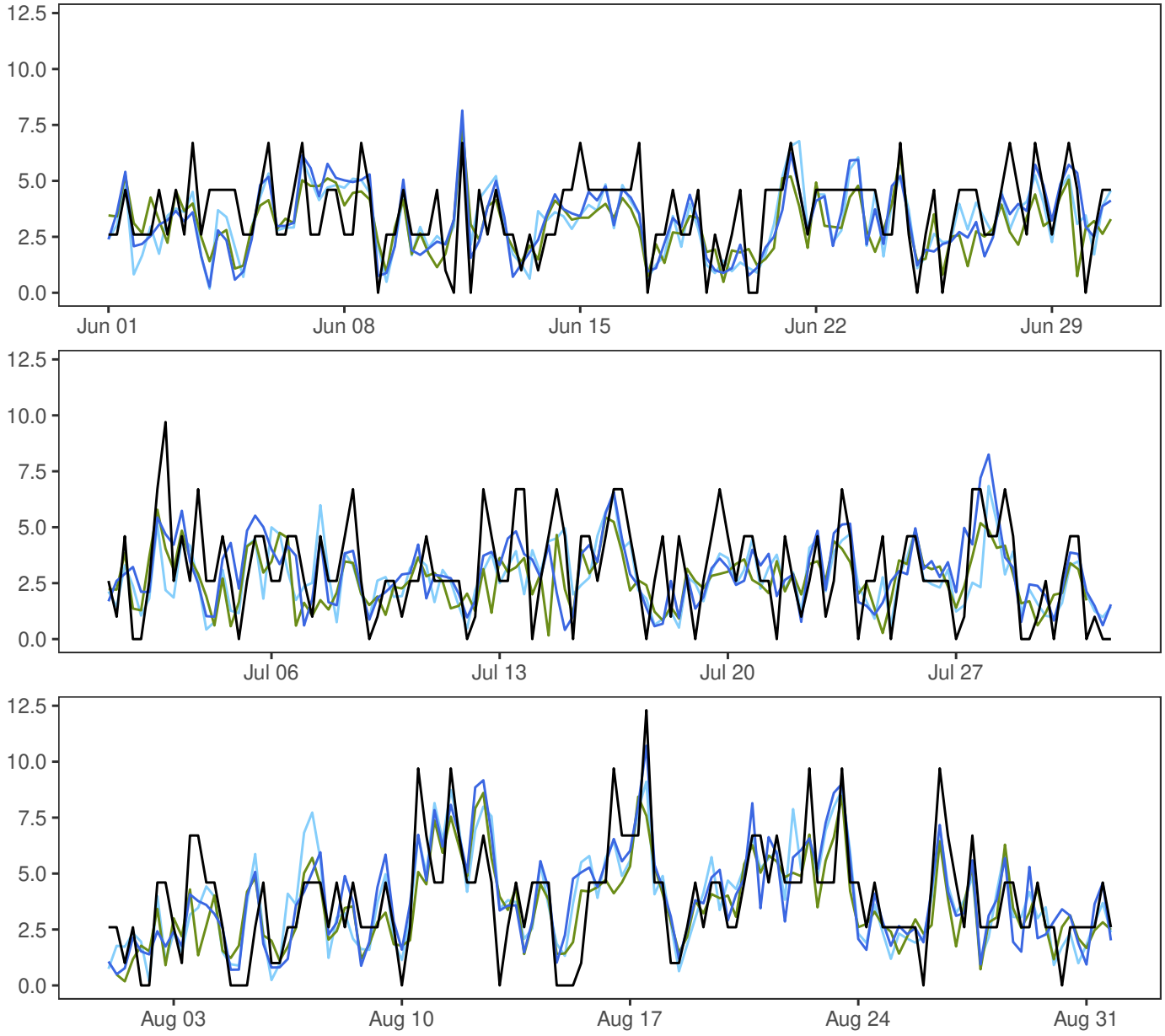
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.3	2.7	9.5	1.8	368
MEPSctrl: 12+18,+24,+30,+36	0.3	3.4	12.9	2.2	368
AA25: 12+18,+24,+30,+36	0.5	3.4	11.2	2.1	368
ECMWF: 12+18,+24,+30,+36	0.1	2.5	6.8	1.3	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.7	1.4	1.6	1.3	5.1	364
AA25−synop	0.6	1.4	1.6	1.2	6.2	364
ECMWF−synop	−0.2	1.2	1.2	0.9	5.2	364


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

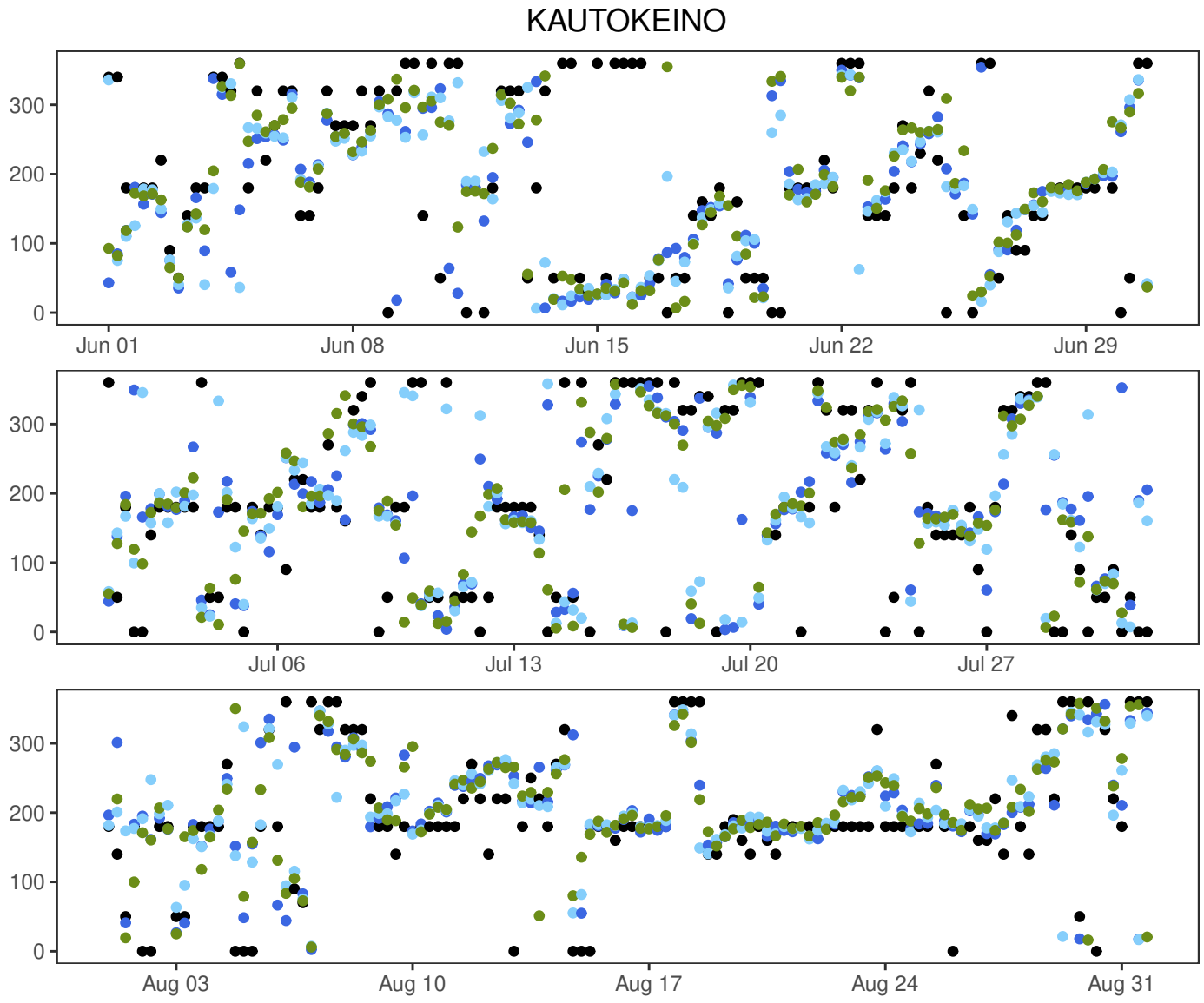

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.006
0.004
0.002
0.000
0
100
200
300
Wind direction

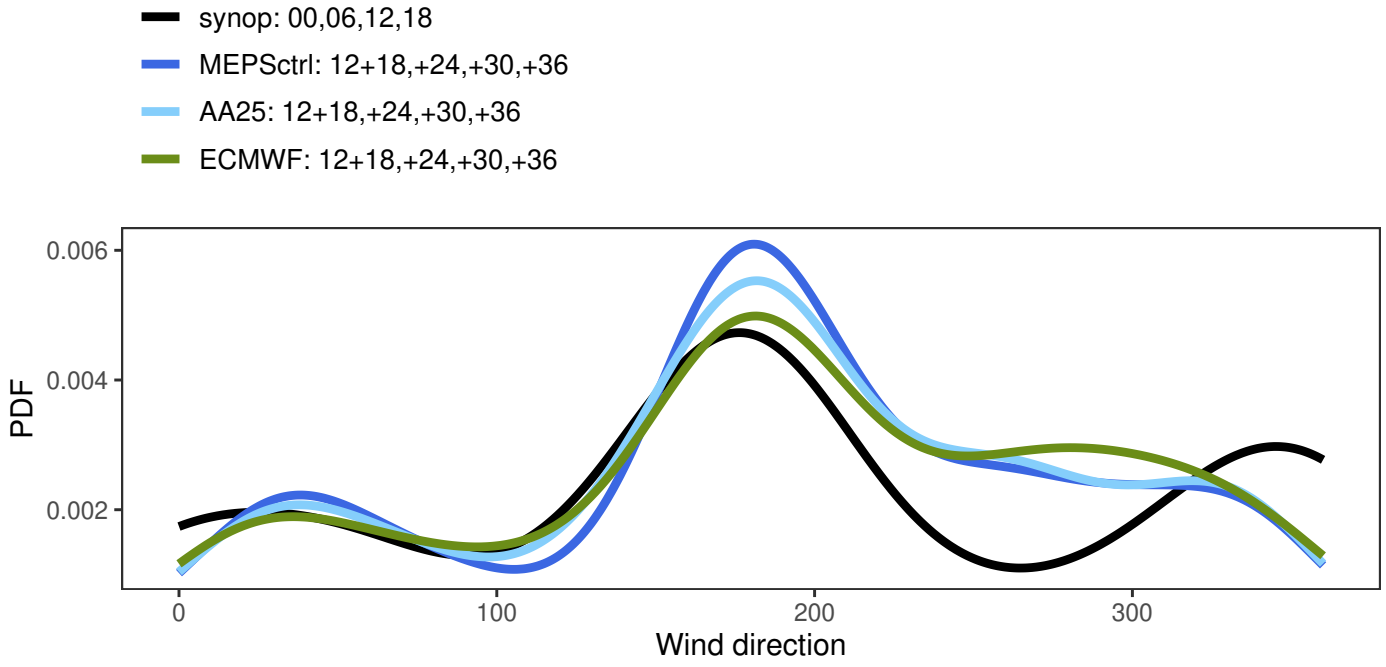
KAUTOKEINO



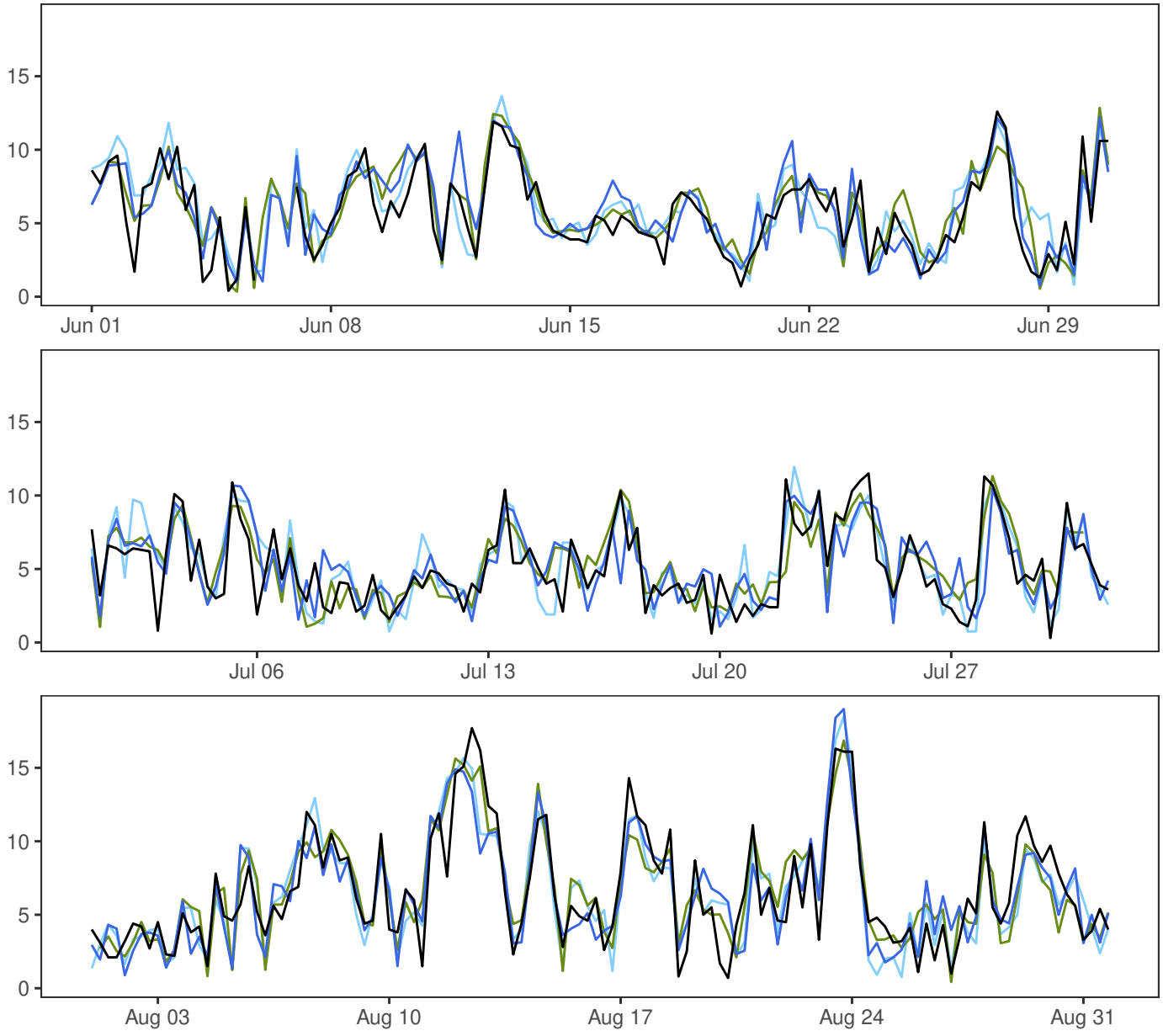
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	3.5	12.3	2.1	368
MEPSctrl: 12+18,+24,+30,+36	0.3	3.4	10.7	1.8	368
AA25: 12+18,+24,+30,+36	0.2	3.3	9.1	1.8	368
ECMWF: 12+18,+24,+30,+36	0.2	3.1	8.6	1.5	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.1	1.7	1.7	1.3	5.0	364
AA25−synop	−0.2	1.7	1.7	1.4	7.5	364
ECMWF−synop	−0.4	1.7	1.8	1.4	5.7	364


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

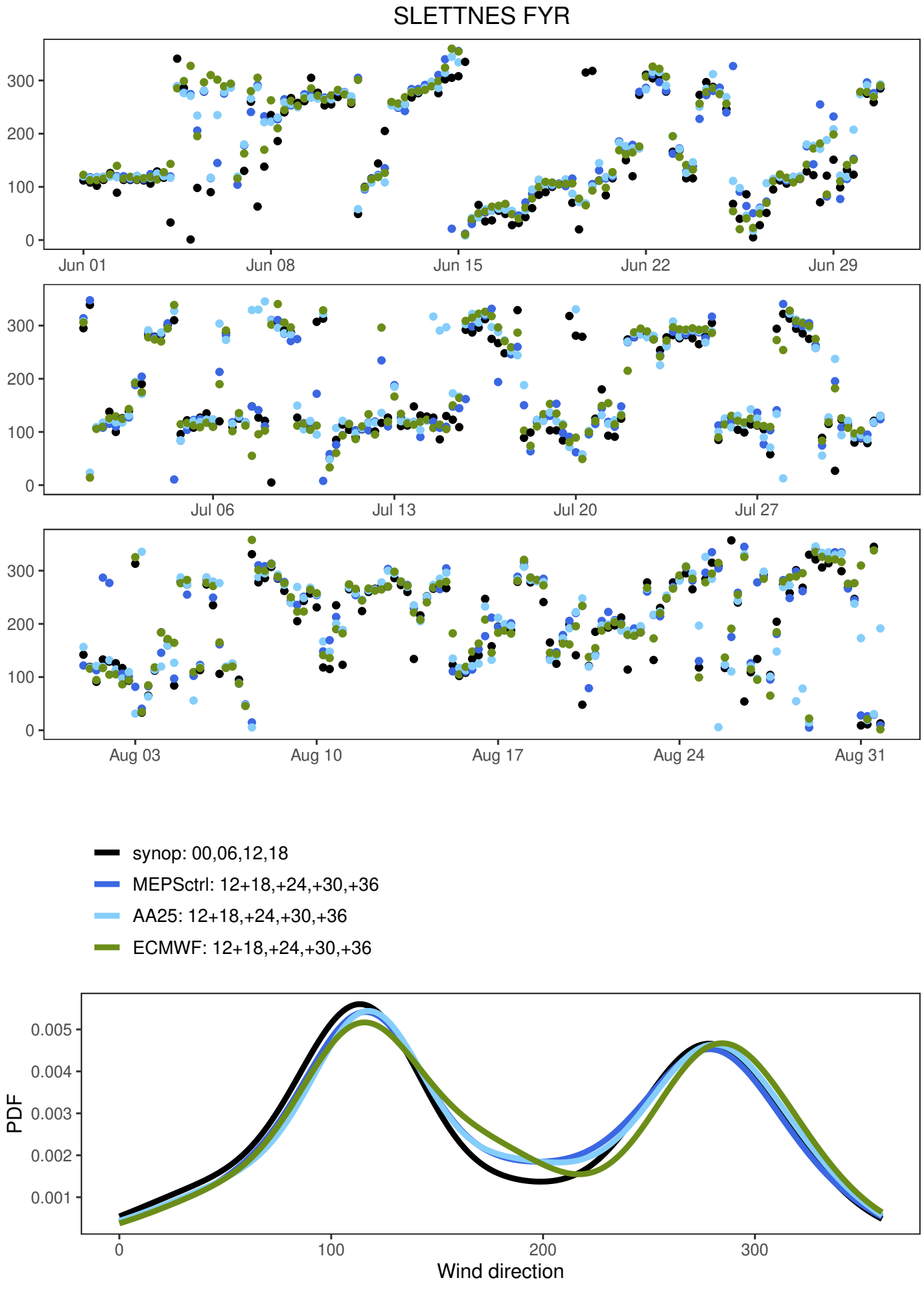

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.006
0.004
0.002
0
100
200
300
Wind direction

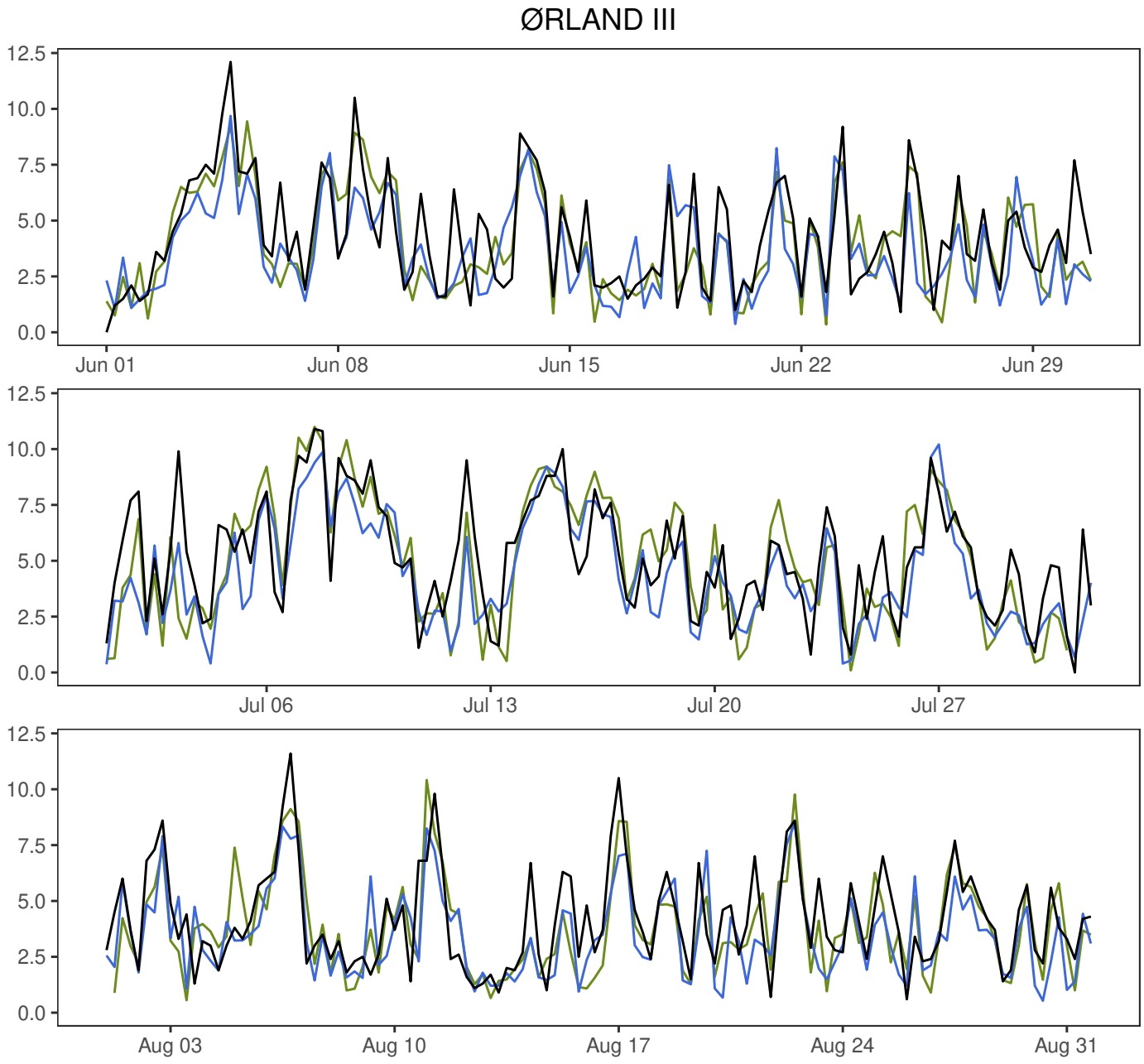
SLETTNES FYR



	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.3	5.8	17.7	3.2	364
MEPSctrl: 12+18,+24,+30,+36	0.8	5.9	19.0	3.0	368
AA25: 12+18,+24,+30,+36	0.7	6.0	18.5	3.2	368
ECMWF: 12+18,+24,+30,+36	0.3	6.0	16.9	2.9	364

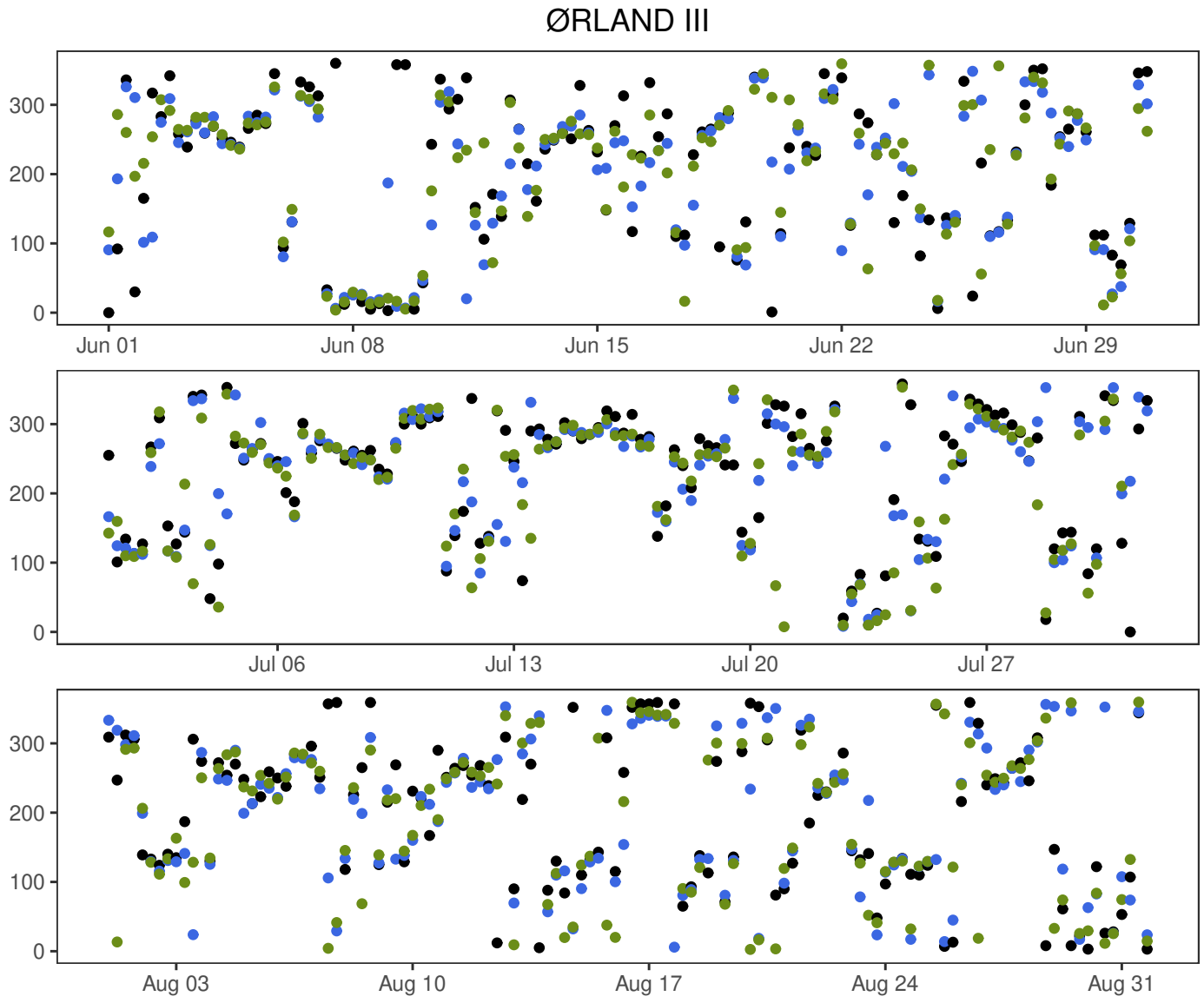
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.2	2.0	2.0	1.5	8.0	360
AA25−synop	0.2	1.9	1.9	1.5	6.7	360
ECMWF−synop	0.2	1.7	1.7	1.4	6.3	360

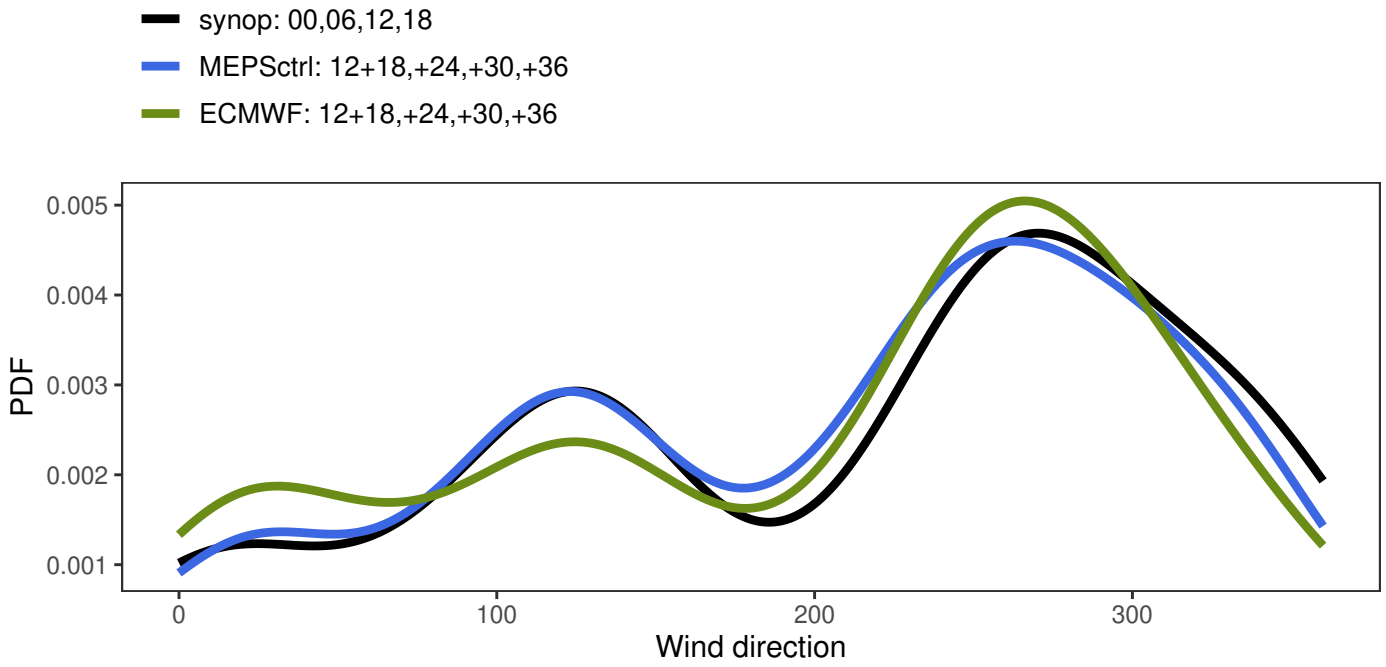

SLETTNES FYR
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31
synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
AA25: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.005
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

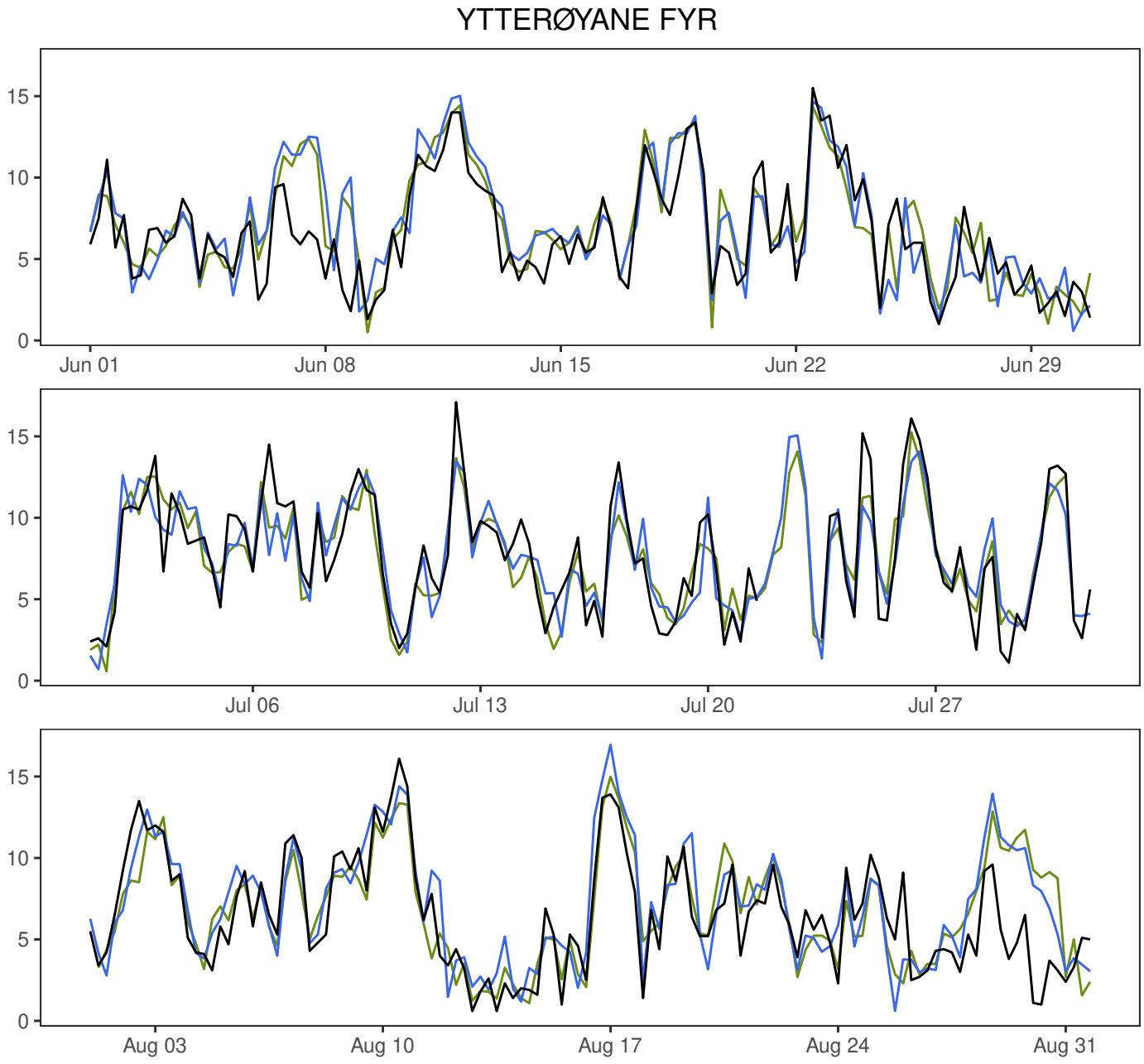


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	4.5	12.1	2.4	368
MEPSctrl: 12+18,+24,+30,+36	0.4	3.8	10.2	2.2	368
ECMWF: 12+18,+24,+30,+36	0.1	4.2	11.0	2.5	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.7	1.6	1.7	1.3	5.0	364
ECMWF−synop	−0.3	1.6	1.7	1.3	7.5	364

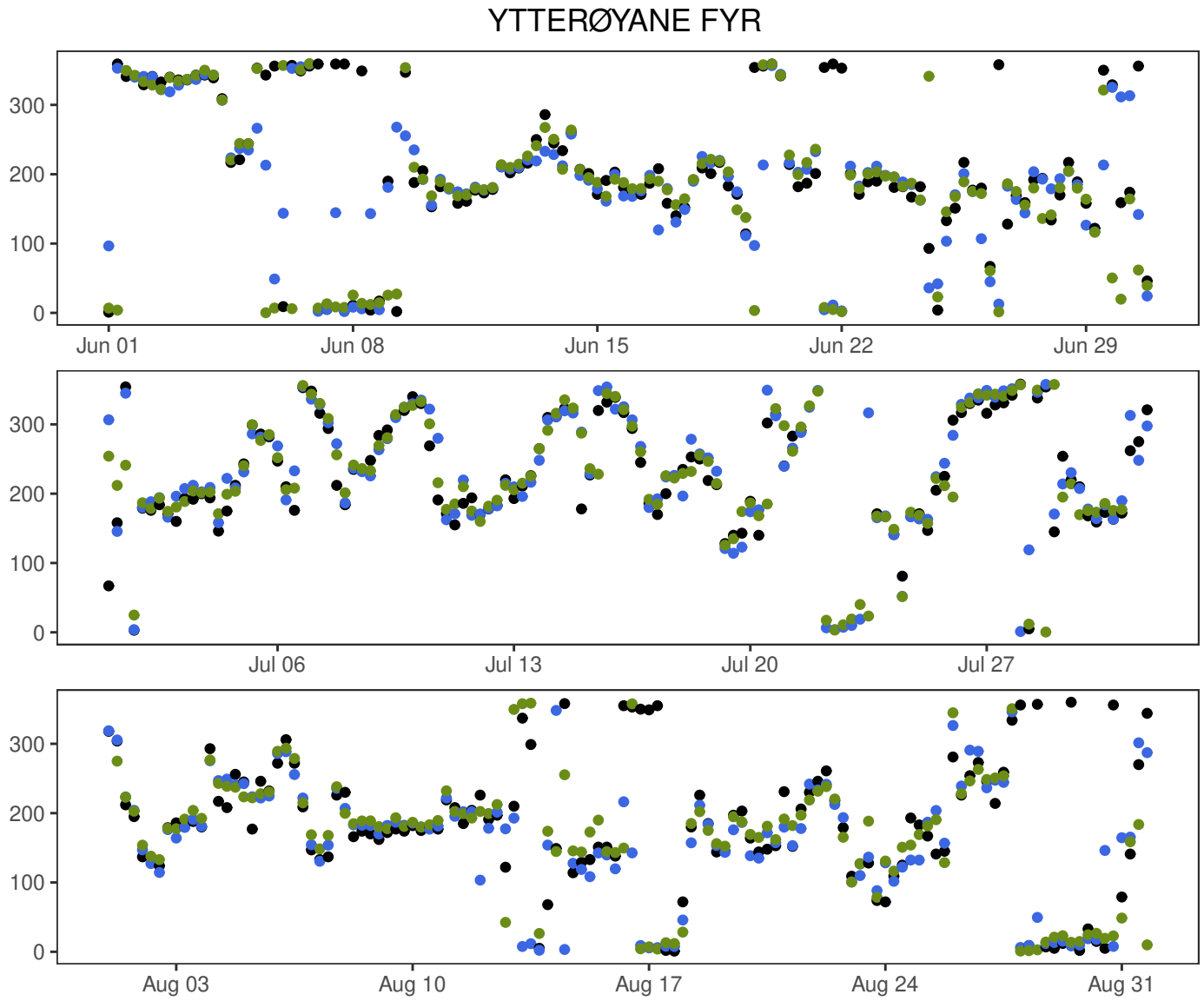

ØRLAND III
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31

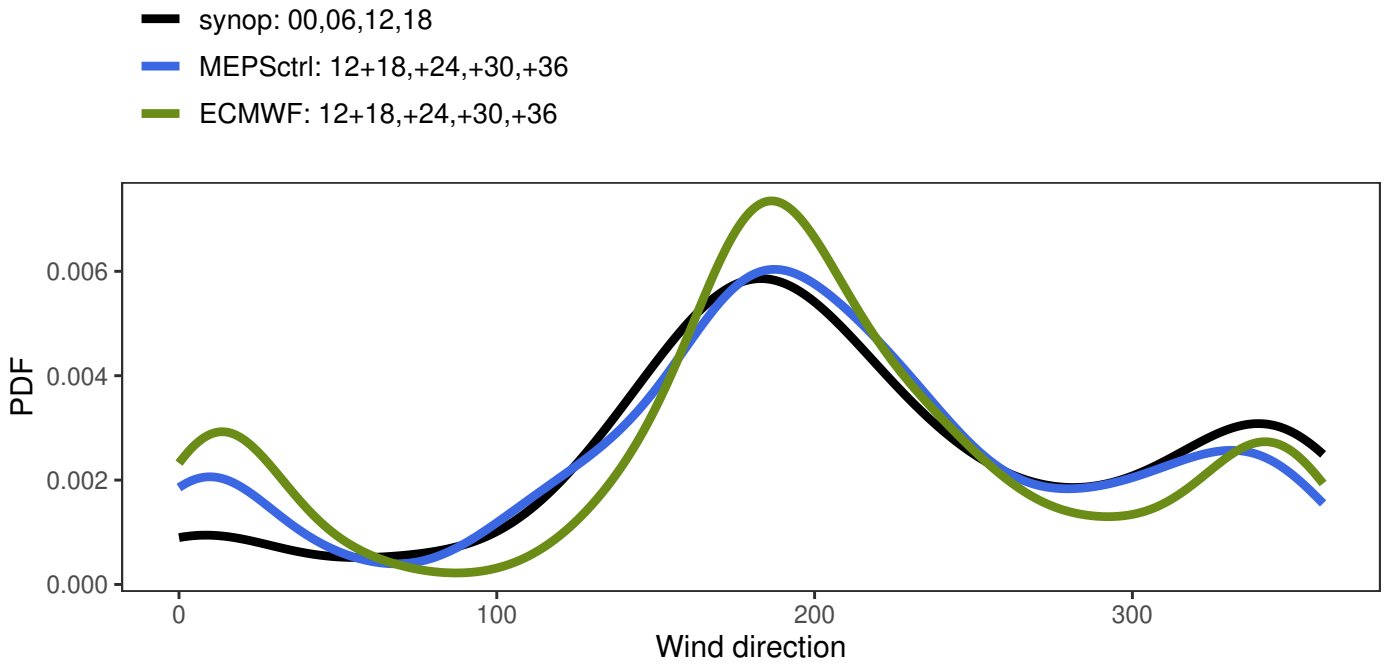

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.005
0.004
0.003
0.002
0.001
0
100
200
300
Wind direction

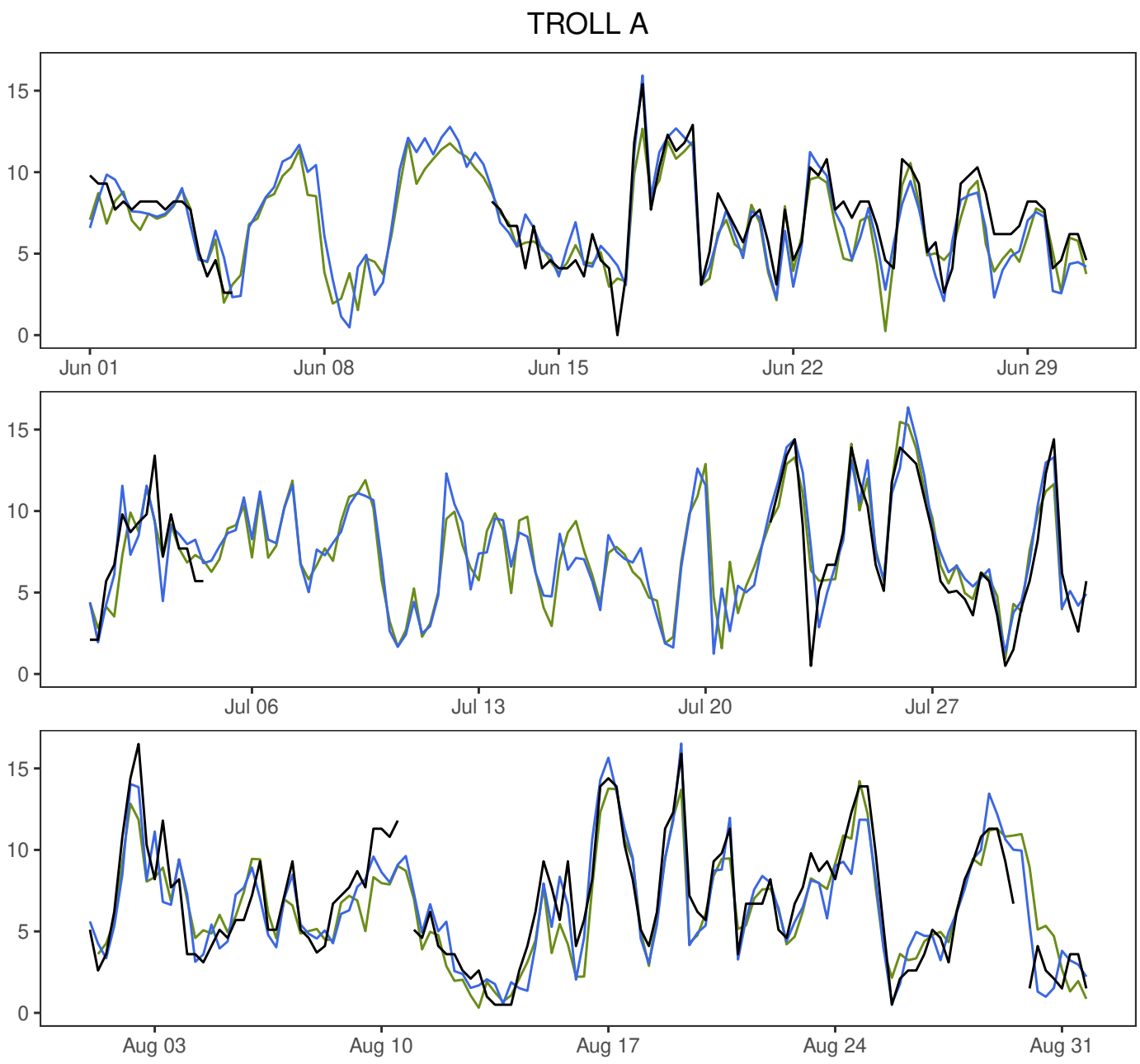


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.6	6.9	17.1	3.5	361
MEPSctrl: 12+18,+24,+30,+36	0.6	7.3	16.9	3.4	368
ECMWF: 12+18,+24,+30,+36	0.5	7.1	15.3	3.2	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.4	2.1	2.1	1.6	8.2	357
ECMWF−synop	0.2	2.0	2.0	1.5	8.2	357

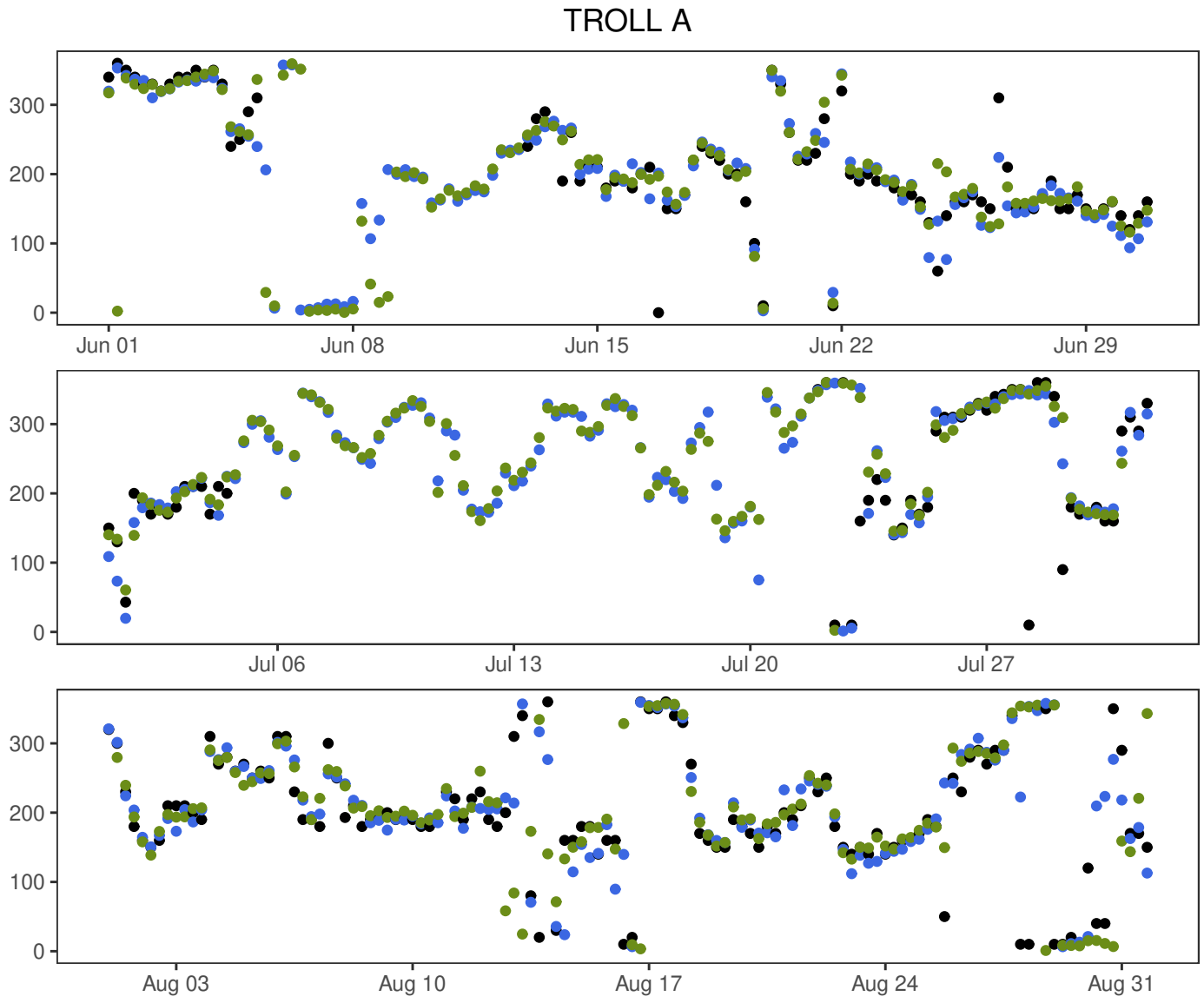

YTTERØYANE FYR
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31

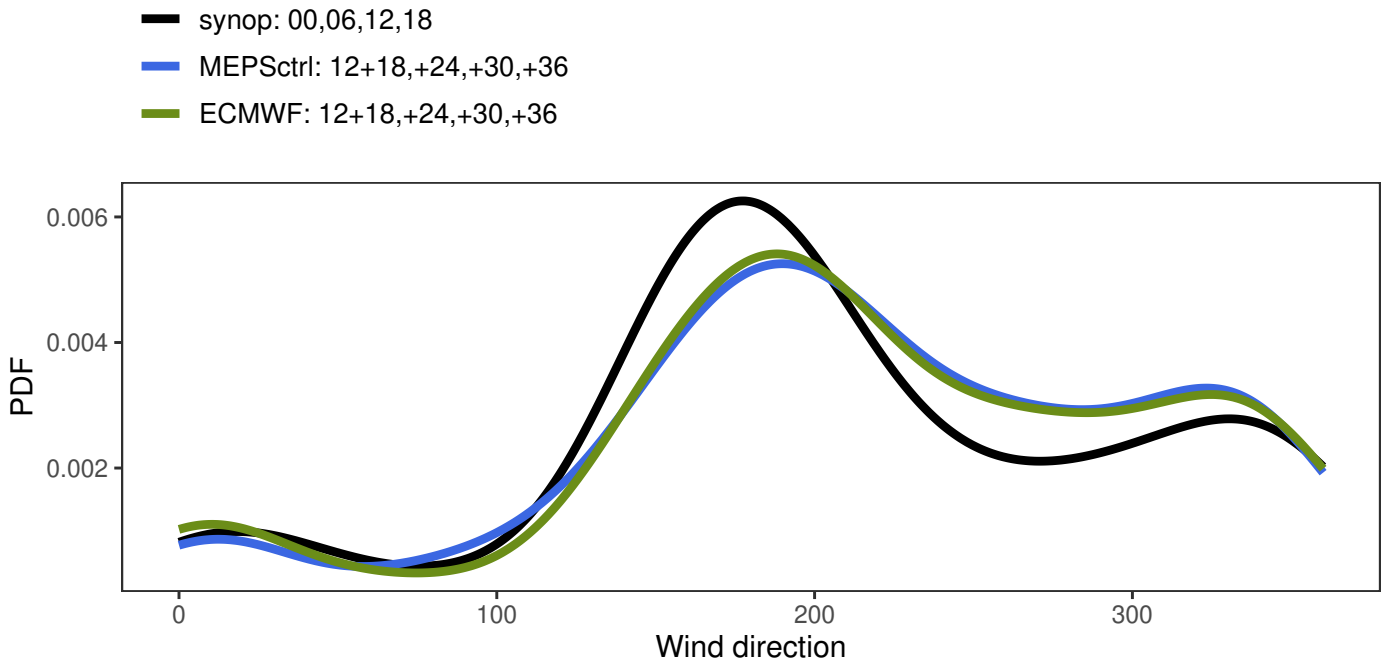

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.006
0.004
0.002
0.000
0
100
200
300
Wind direction



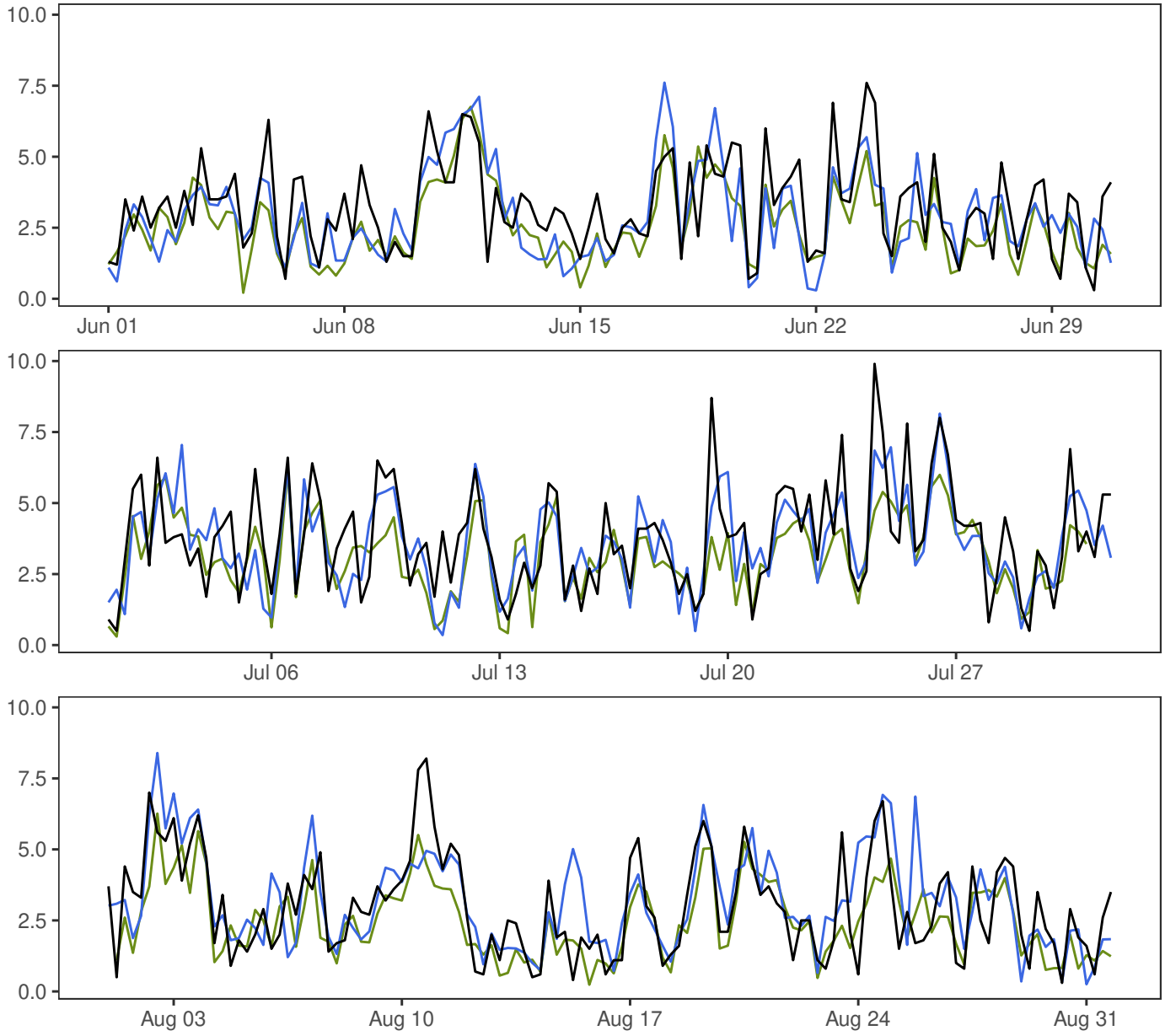
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	7.0	16.5	3.4	267
MEPSctrl: 12+18,+24,+30,+36	0.5	7.0	16.5	3.3	368
ECMWF: 12+18,+24,+30,+36	0.2	6.9	15.5	3.0	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.2	1.6	1.6	1.3	7.3	263
ECMWF−synop	−0.3	1.6	1.6	1.3	7.4	263


TROLL A
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

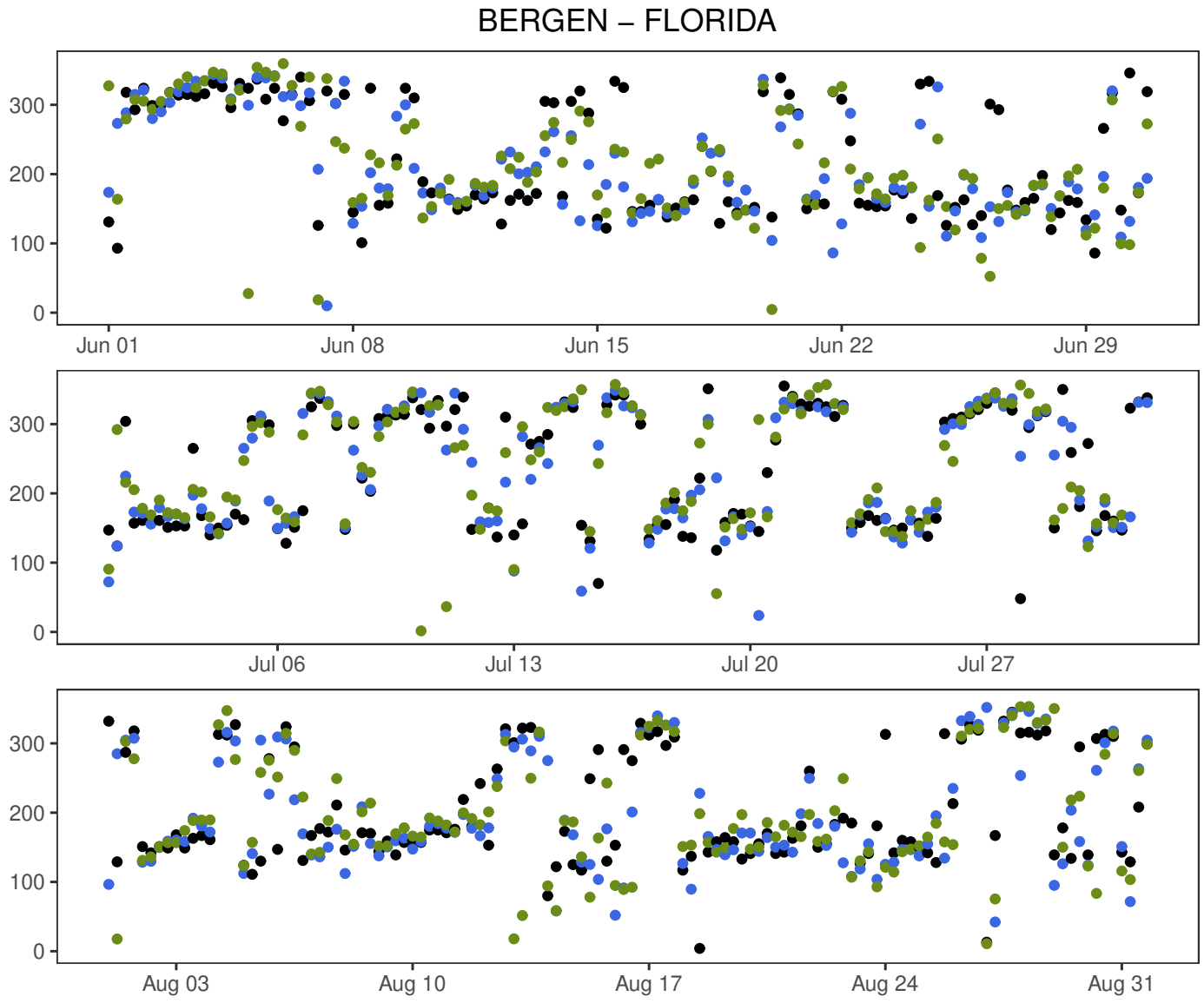

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
0.006
0.004
0.002
PDF
0
100
200
300
Wind direction

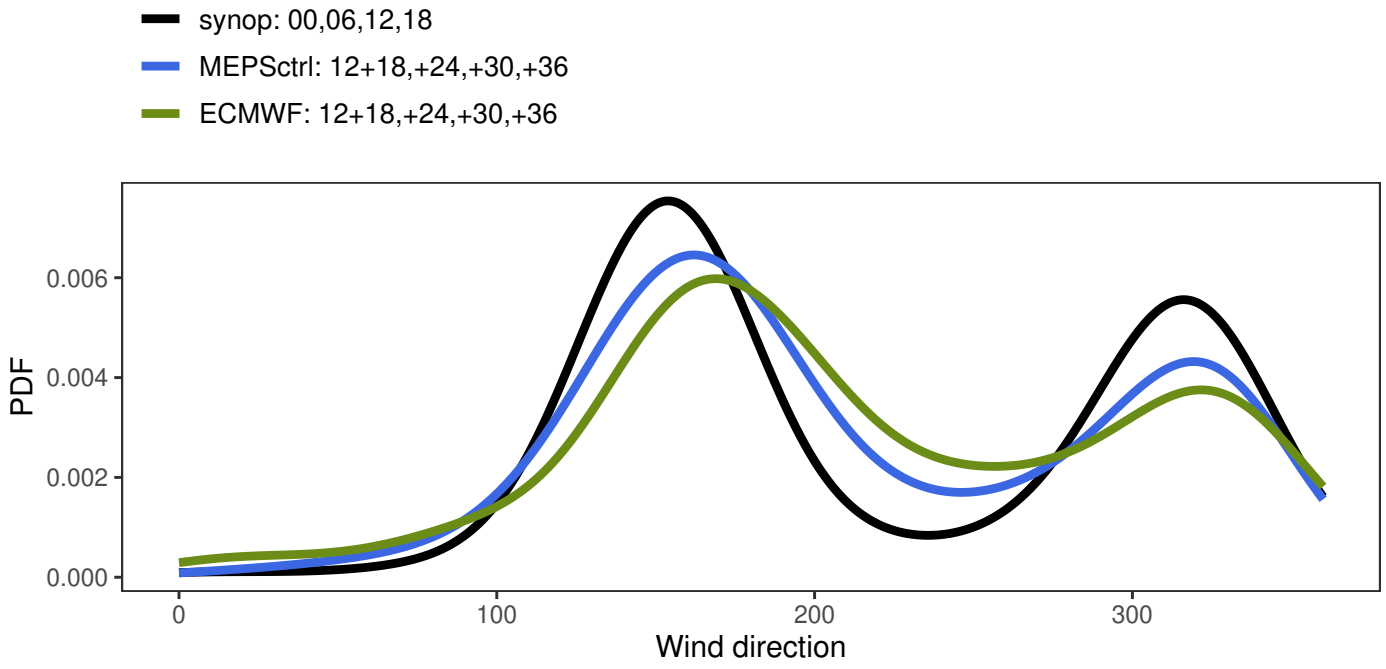
BERGEN – FLORIDA



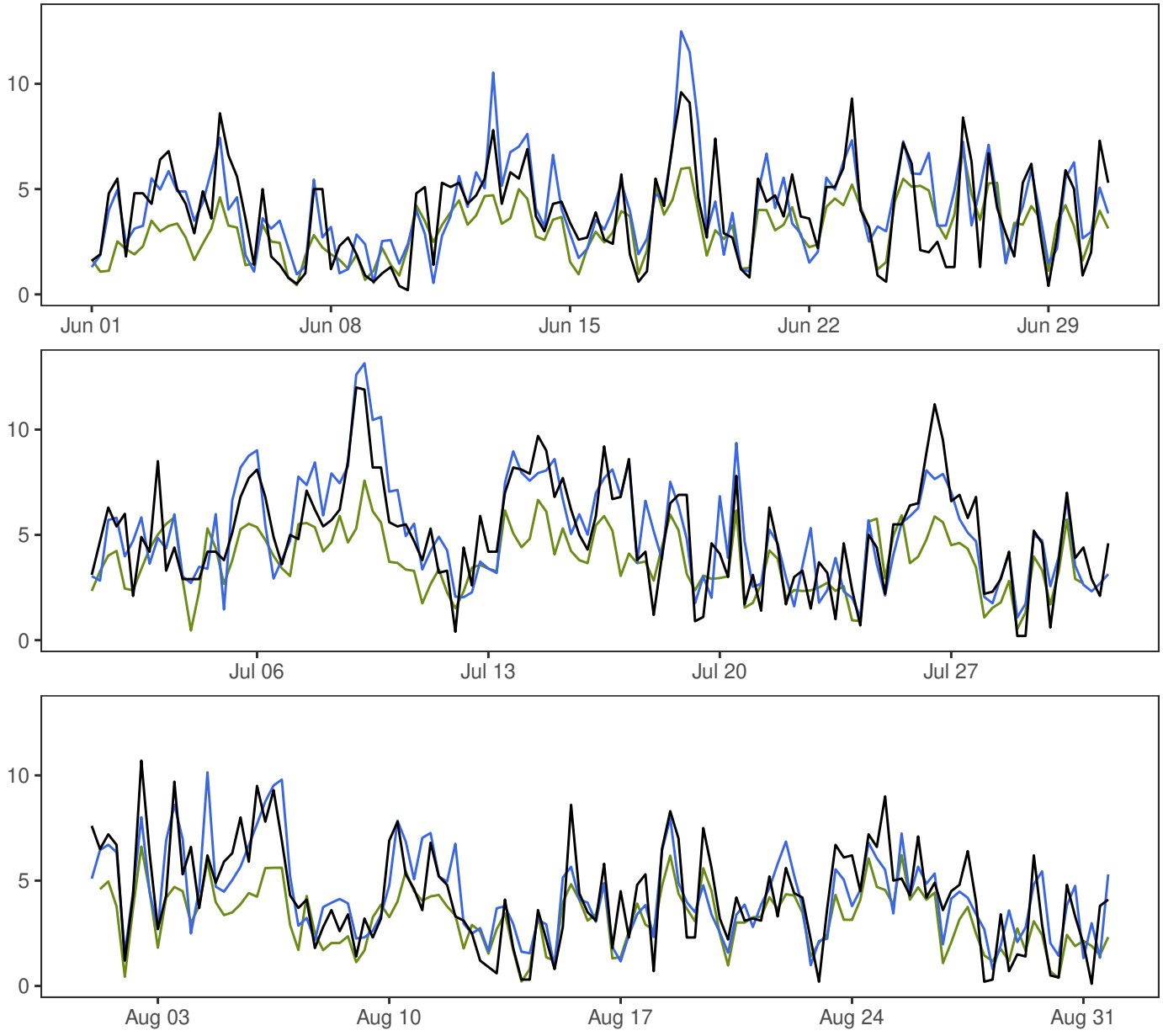
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.3	3.3	9.9	1.8	368
MEPSctrl: 12+18,+24,+30,+36	0.3	3.2	8.4	1.6	368
ECMWF: 12+18,+24,+30,+36	0.2	2.7	6.8	1.3	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl–synop	–0.1	1.4	1.4	1.1	5.2	364
ECMWF–synop	–0.6	1.2	1.3	1.0	5.2	364


BERGEN – FLORIDA
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

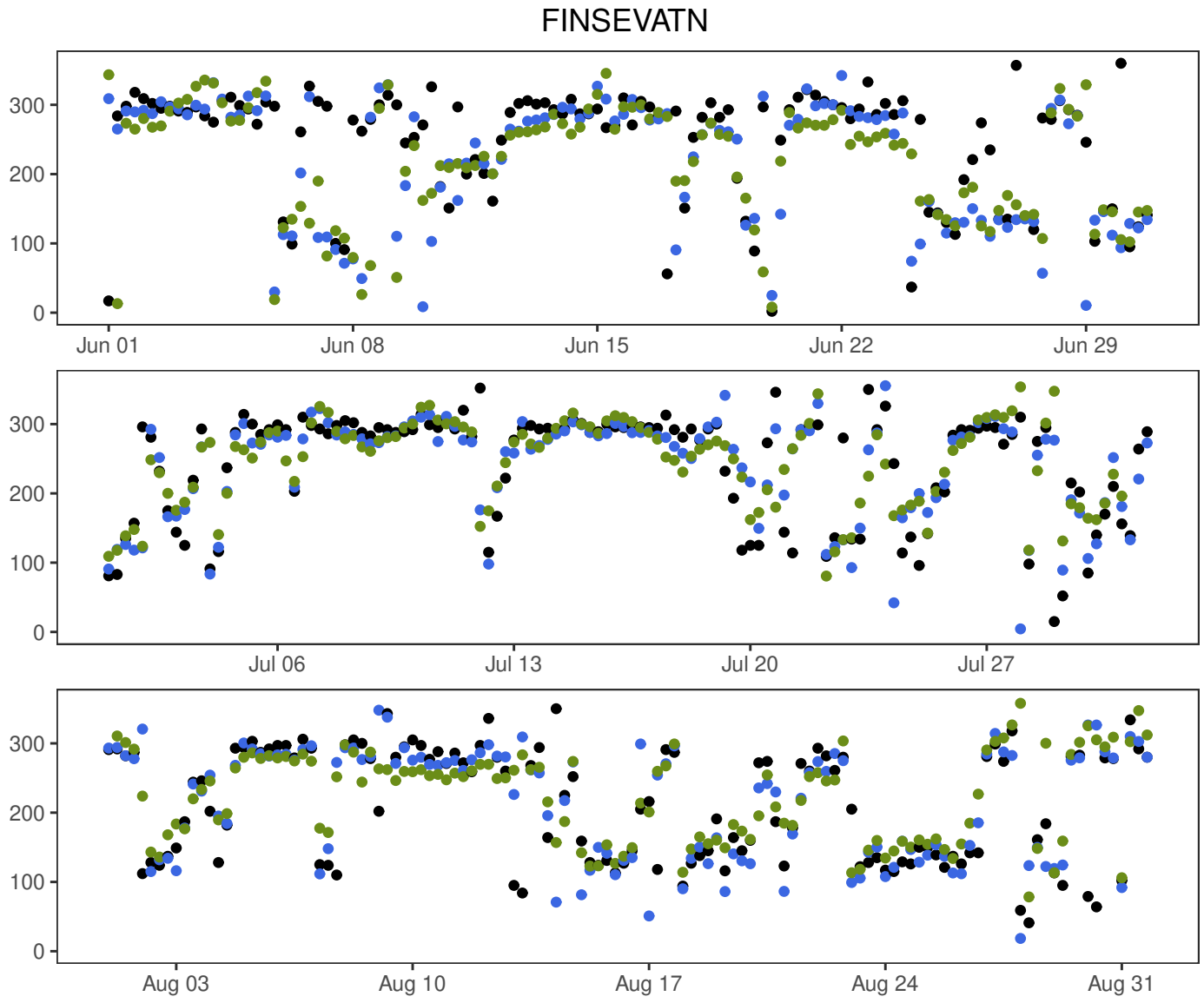

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.006
0.004
0.002
0.000
0
100
200
300
Wind direction

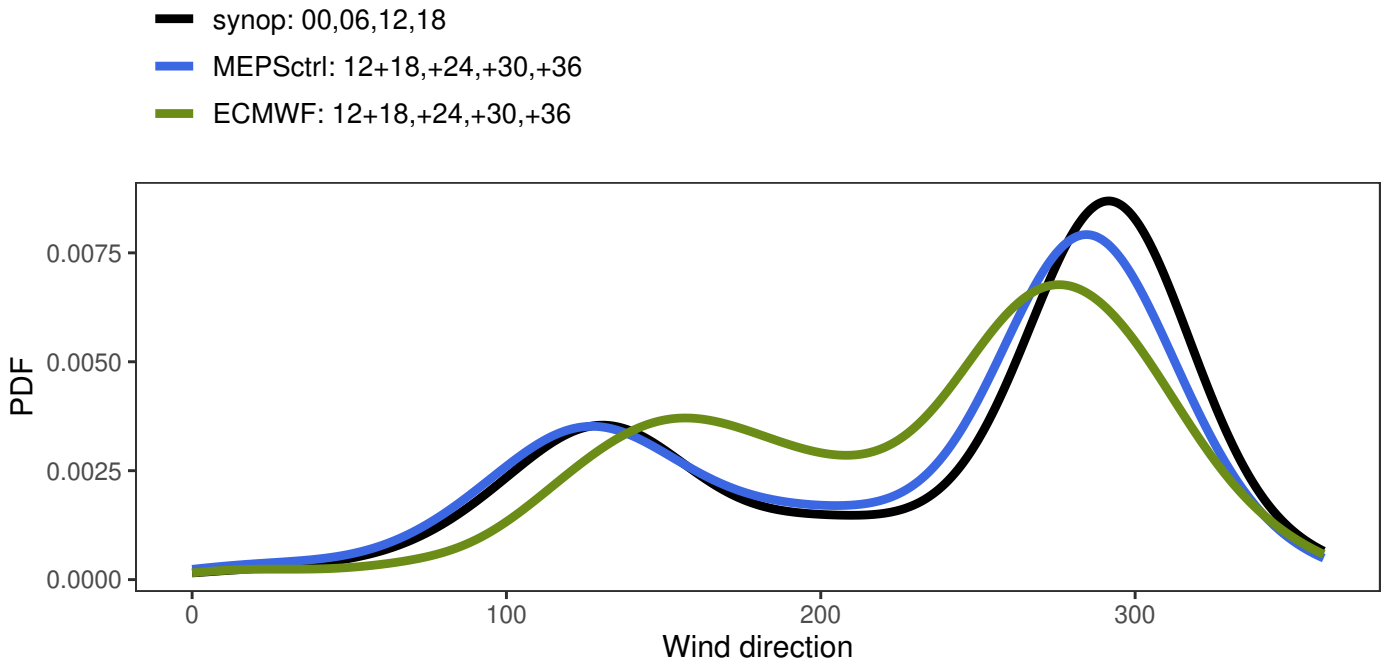
FINSEVATN

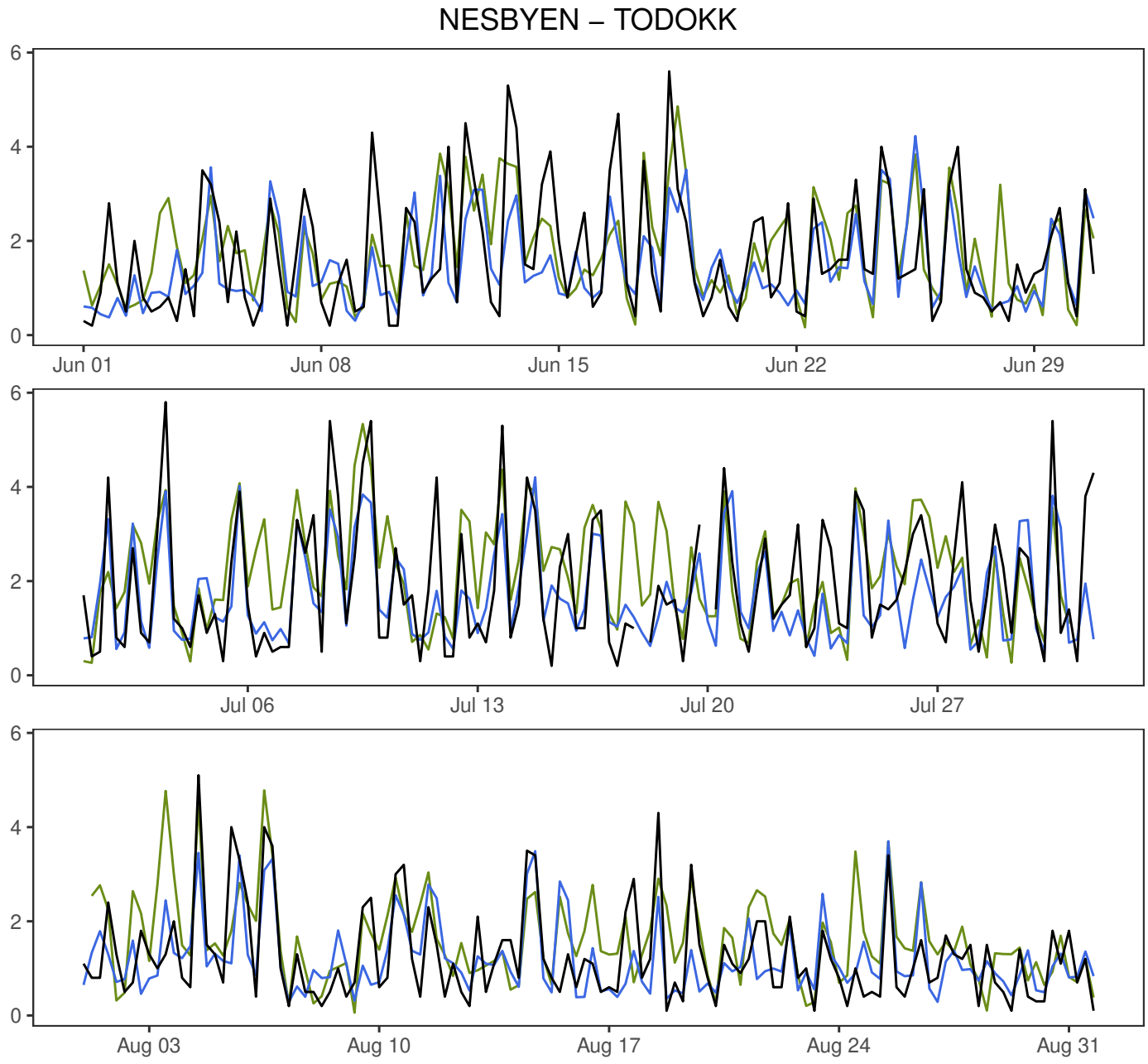


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.1	4.4	12.0	2.4	368
MEPSctrl: 12+18,+24,+30,+36	0.5	4.5	13.1	2.3	368
ECMWF: 12+18,+24,+30,+36	0.2	3.4	7.6	1.4	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.1	1.5	1.5	1.2	4.7	364
ECMWF−synop	−1.0	1.6	1.9	1.5	6.7	364

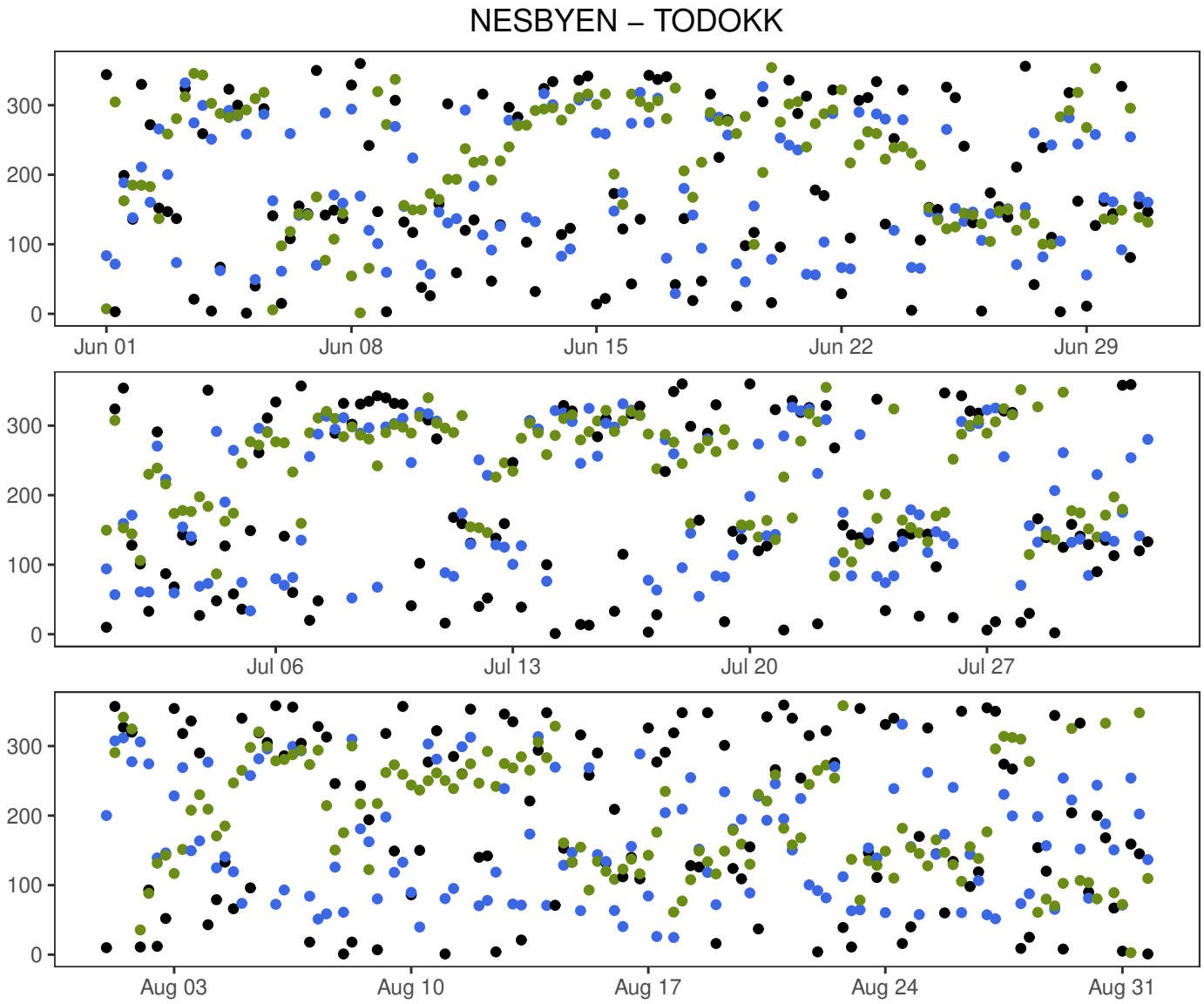

FINSEVATN
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31

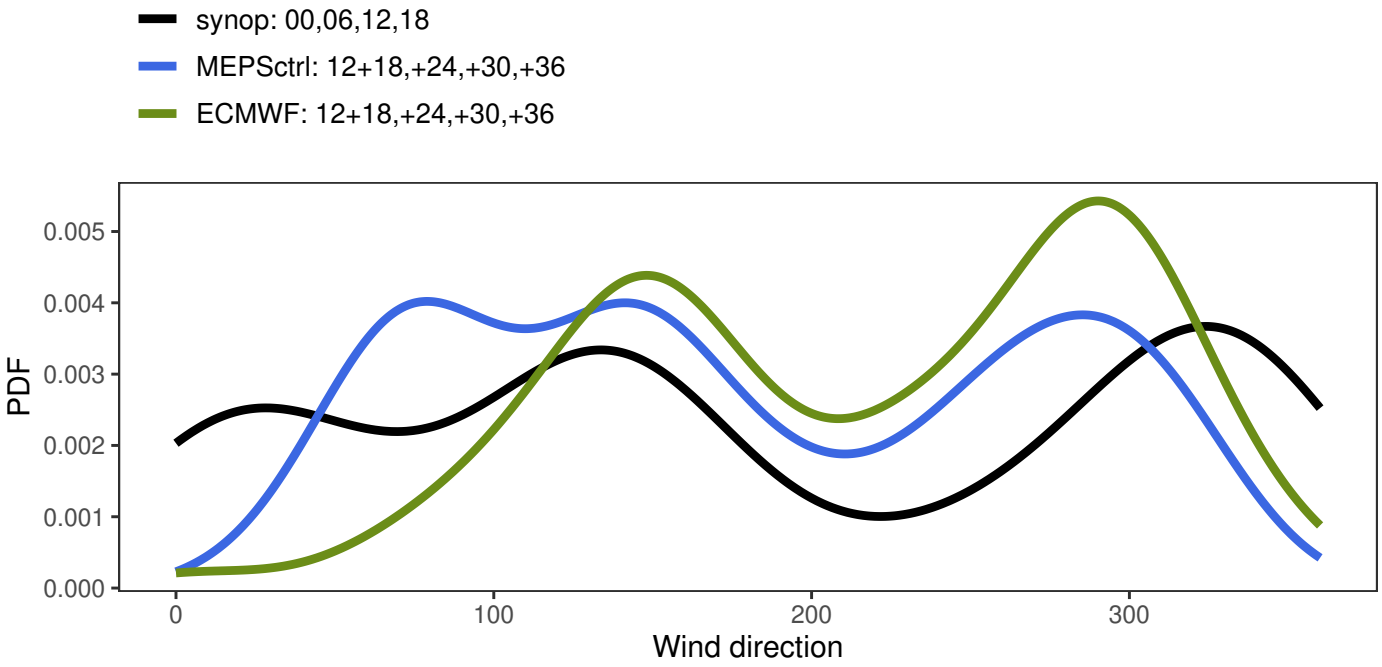

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.0075
0.0050
0.0025
0.0000
0
100
200
300
Wind direction

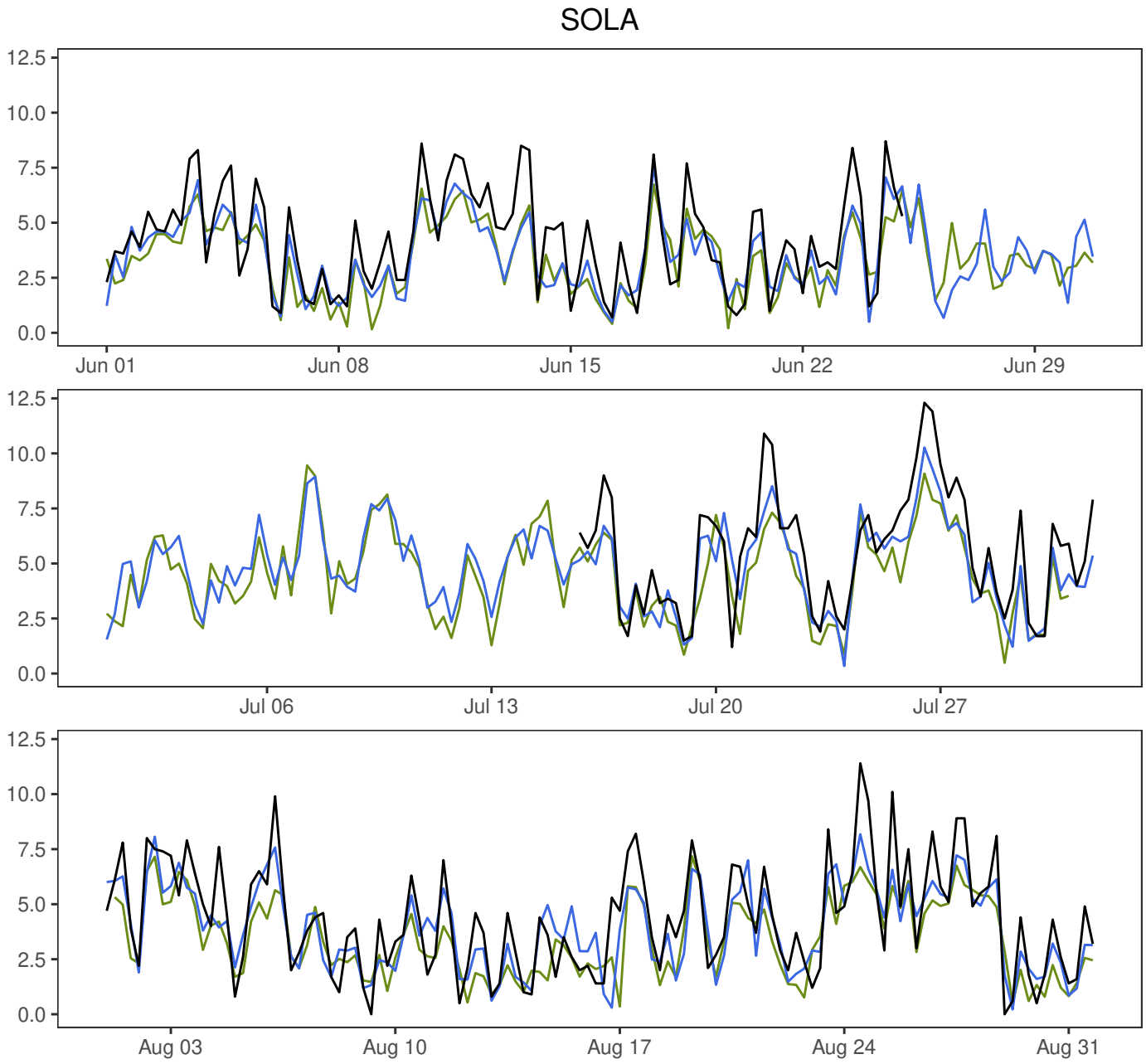


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.1	1.6	5.8	1.3	366
MEPSctrl: 12+18,+24,+30,+36	0.3	1.5	4.2	0.9	368
ECMWF: 12+18,+24,+30,+36	0.1	1.9	5.3	1.1	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.2	0.9	0.9	0.7	2.9	362
ECMWF−synop	0.2	1.0	1.0	0.8	3.5	362

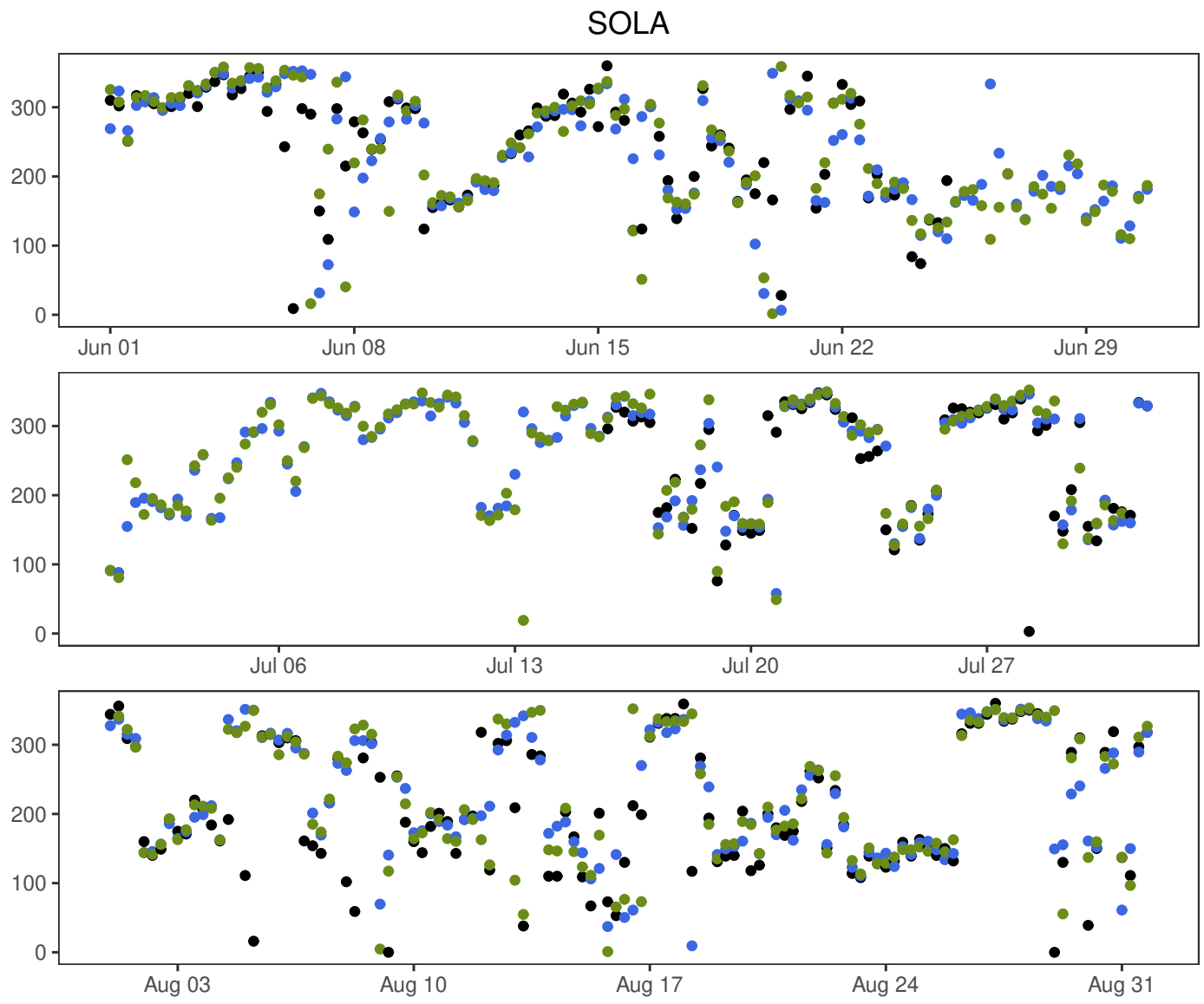

NESBYEN – TODOKK
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31

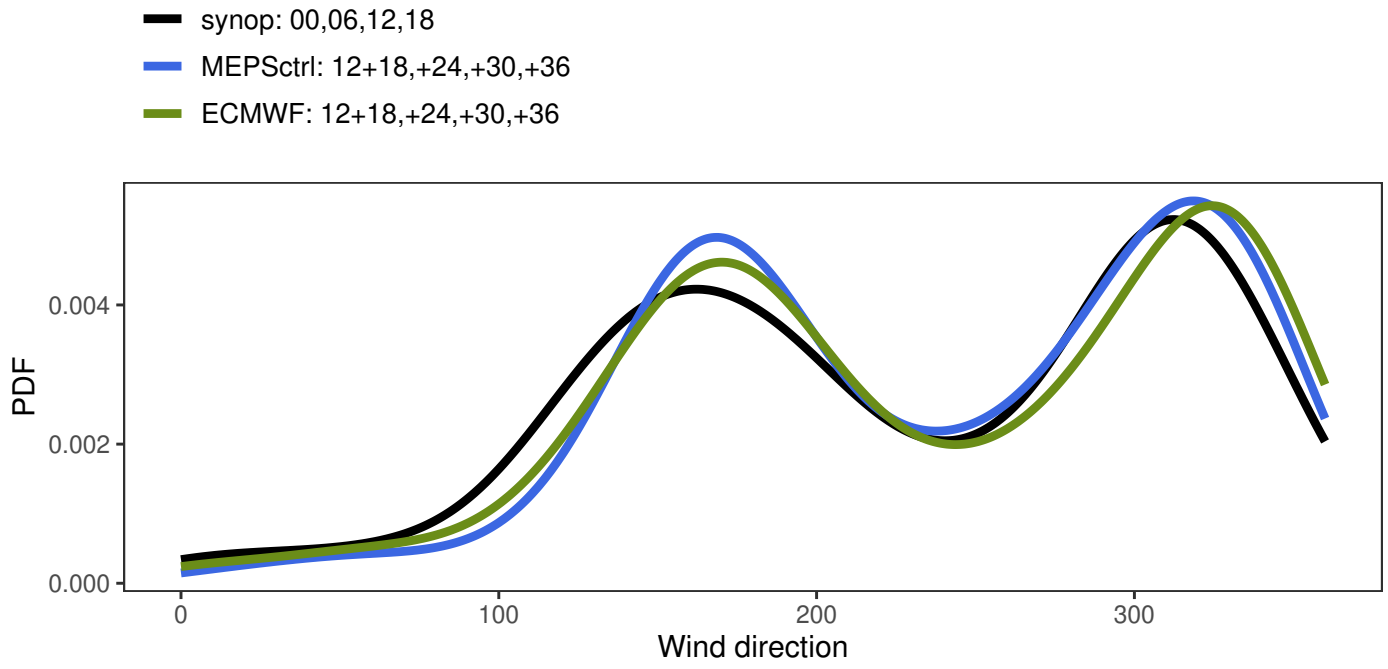

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.005
0.004
0.003
0.002
0.001
0.000
0
100
200
300
Wind direction

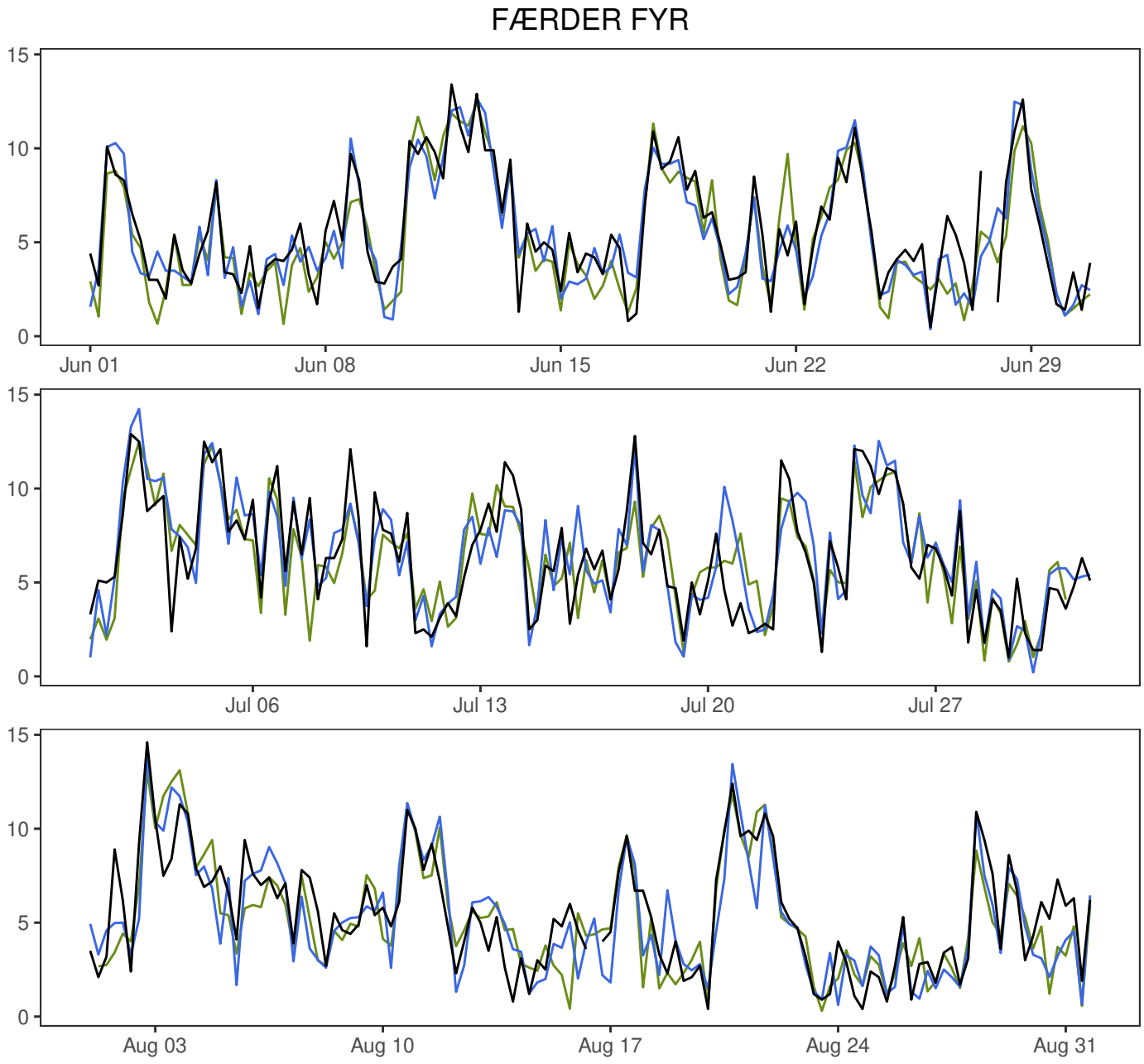


	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.0	4.6	12.3	2.5	286
MEPSctrl: 12+18,+24,+30,+36	0.2	4.1	10.3	1.9	368
ECMWF: 12+18,+24,+30,+36	0.2	3.8	9.5	1.9	364

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.6	1.2	1.4	1.1	5.0	282
ECMWF−synop	−1.0	1.3	1.6	1.3	4.7	282

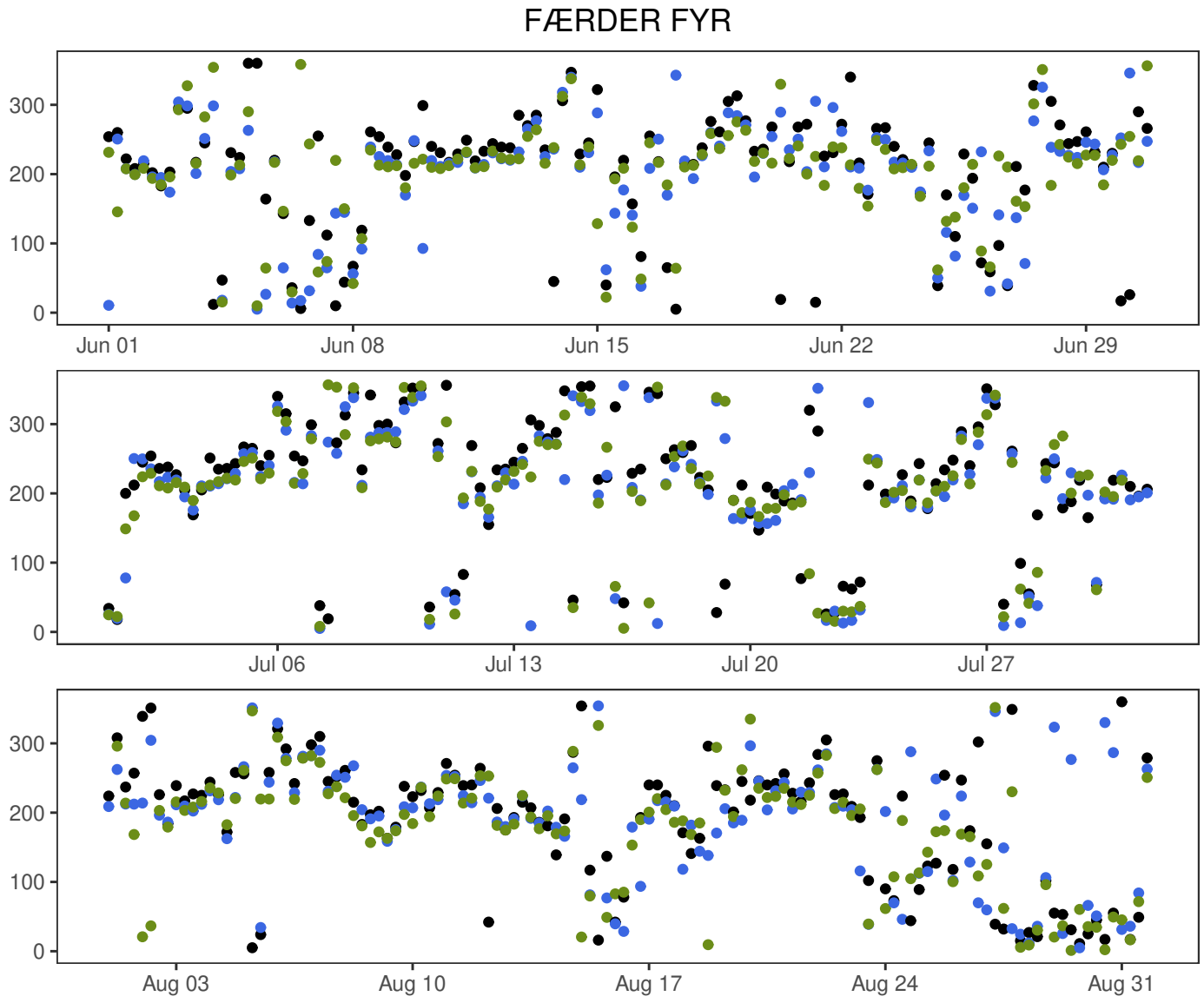

SOLA
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31

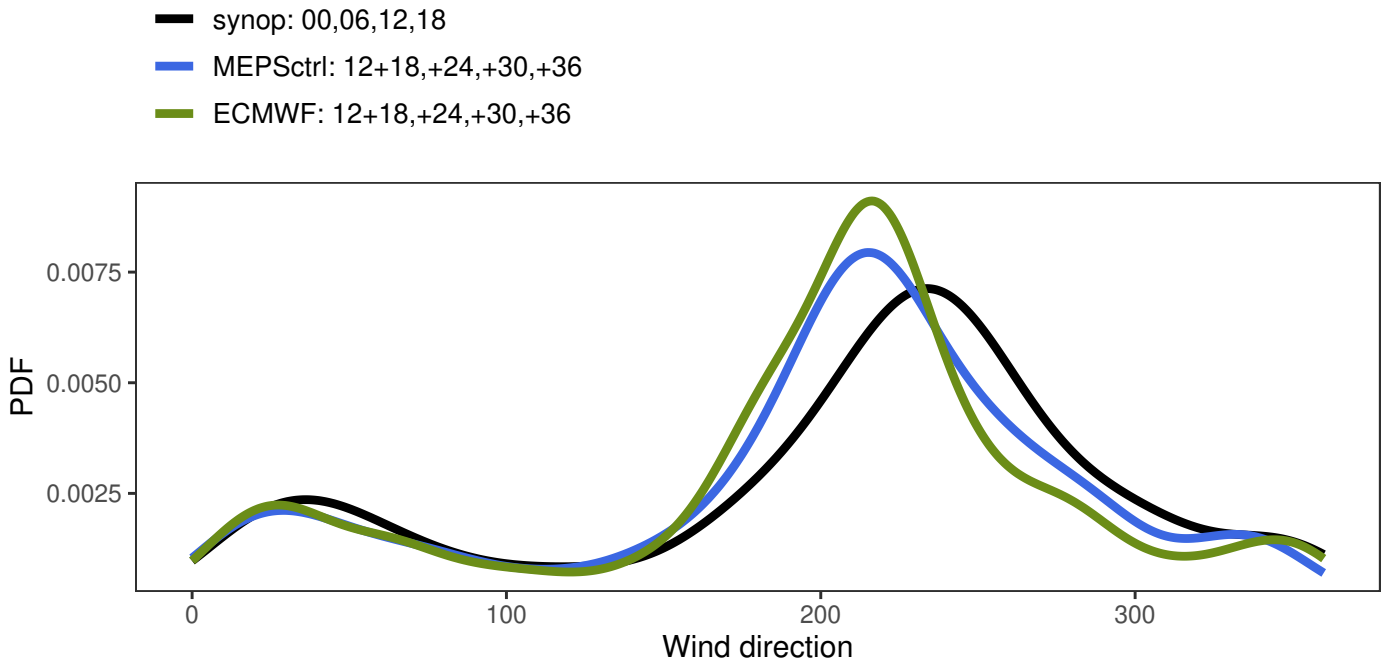

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.004
0.002
0.000
0
100
200
300
Wind direction

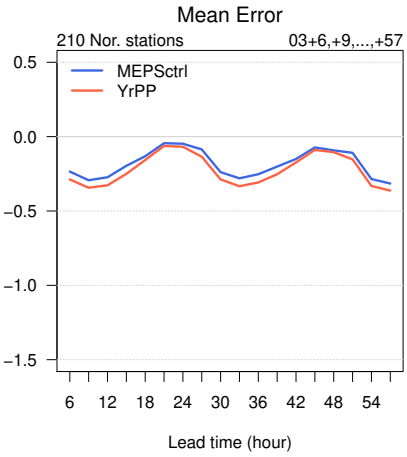


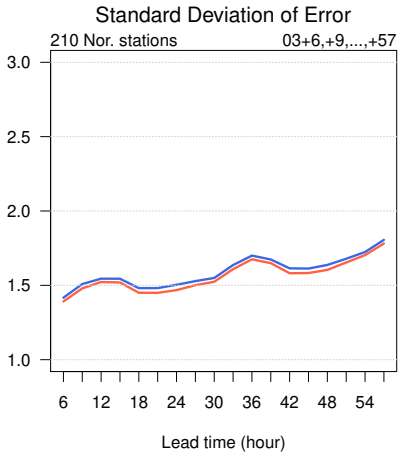
	Min	Mean	Max	Std	N
synop: 00,06,12,18	0.4	5.8	14.6	3.0	366
MEPSctrl: 12+18,+24,+30,+36	0.2	5.7	14.2	3.1	368
ECMWF: 12+18,+24,+30,+36	0.3	5.6	13.1	3.0	364

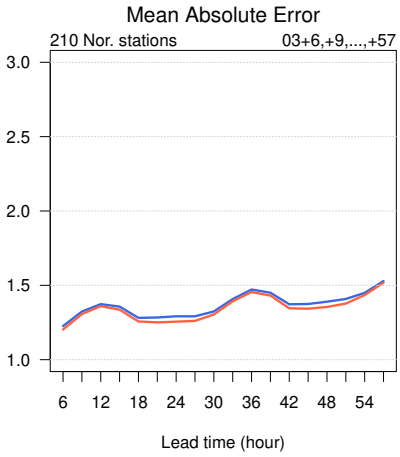
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.1	1.6	1.6	1.3	5.6	362
ECMWF−synop	−0.3	1.7	1.7	1.3	7.6	362

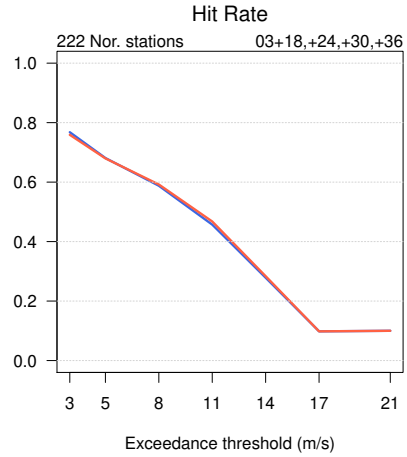

FÆRDER FYR
300
200
100
0
Jun 01
Jun 08
Jun 15
Jun 22
Jun 29
Jul 06
Jul 13
Jul 20
Jul 27
Aug 03
Aug 10
Aug 17
Aug 24
Aug 31

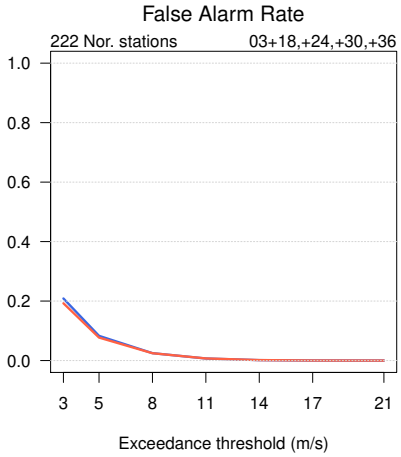

synop: 00,06,12,18
MEPSctrl: 12+18,+24,+30,+36
ECMWF: 12+18,+24,+30,+36
PDF
0.0075
0.0050
0.0025
0
100
200
300
Wind direction

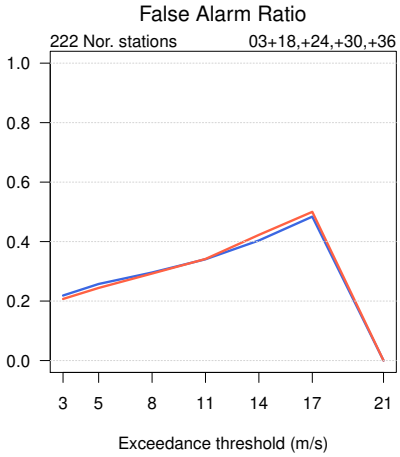

Mean Error
210 Nor. stations
03+6,+9,...,+57
MEPSctrl
YrPP
0.5
0.0
−0.5
−1.0
−1.5
6 12 18 24 30 36 42 48 54
Lead time (hour)

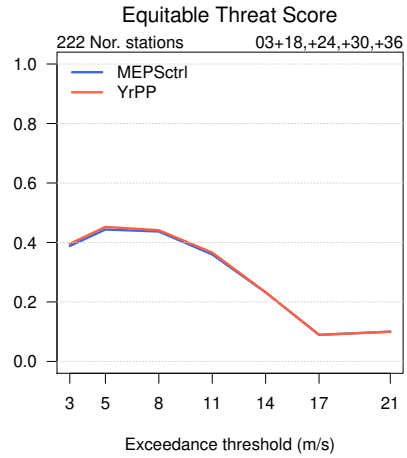

Standard Deviation of Error
210 Nor. stations
03+6,+9,...,+57
3.0
2.5
2.0
1.5
1.0
6 12 18 24 30 36 42 48 54
Lead time (hour)

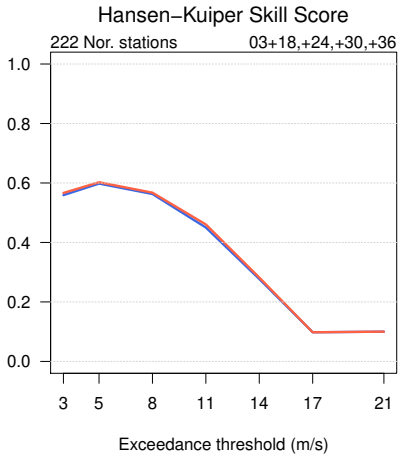

Mean Absolute Error
210 Nor. stations
03+6,+9,...,+57
3.0
2.5
2.0
1.5
1.0
6 12 18 24 30 36 42 48 54
Lead time (hour)

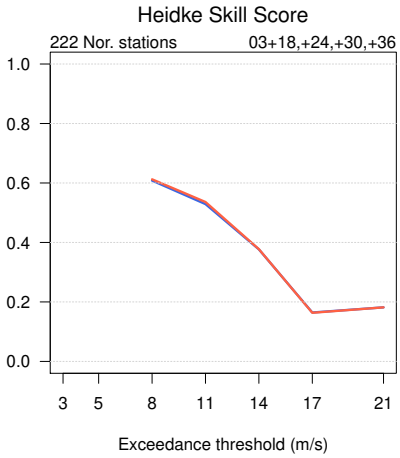

Hit Rate
222 Nor. stations
03+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)


False Alarm Rate
222 Nor. stations
03+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)

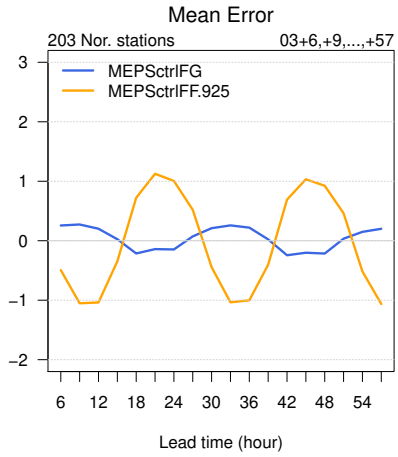

False Alarm Ratio
222 Nor. stations
03+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

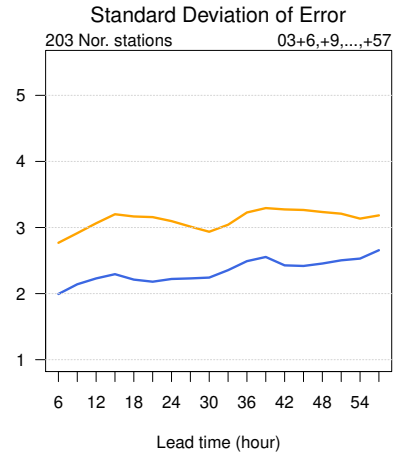

Equitable Threat Score
222 Nor. stations
03+18,+24,+30,+36
MEPSctrl
YrPP
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

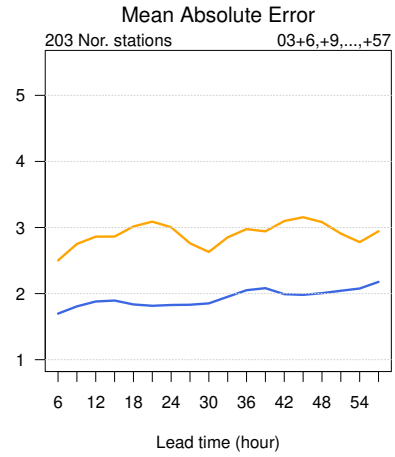

Hansen−Kuiper Skill Score
222 Nor. stations
03+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

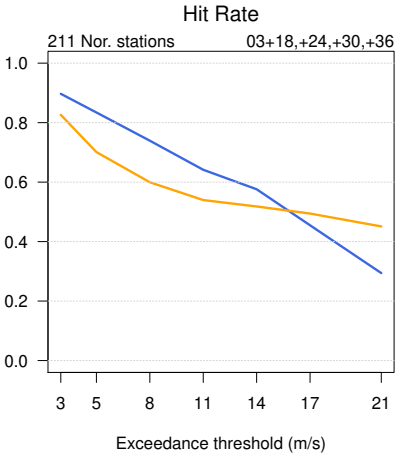

Heidke Skill Score
222 Nor. stations
03+18,+24,+30,+36
1.0
0.8
0.6
0.4
0.2
0.0
3 5 8 11 14 17 21
Exceedance threshold (m/s)

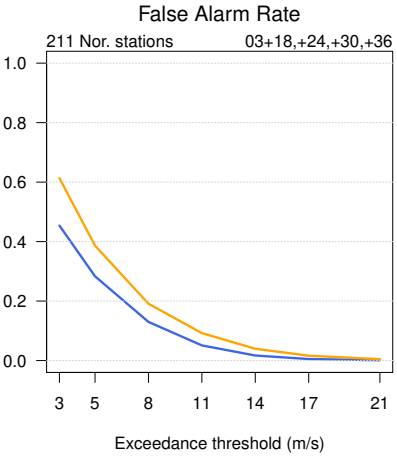
Wind gust (FG) and wind speed in 925 hpa (FF.925)

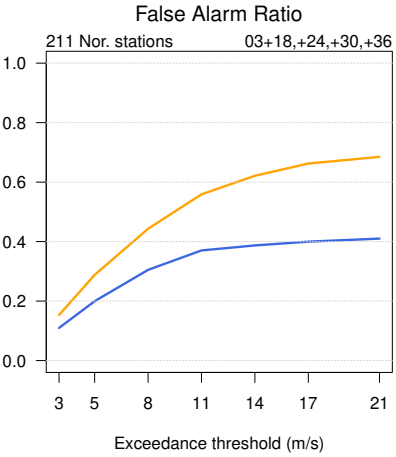


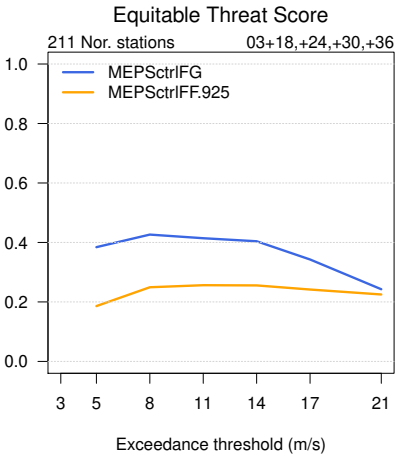


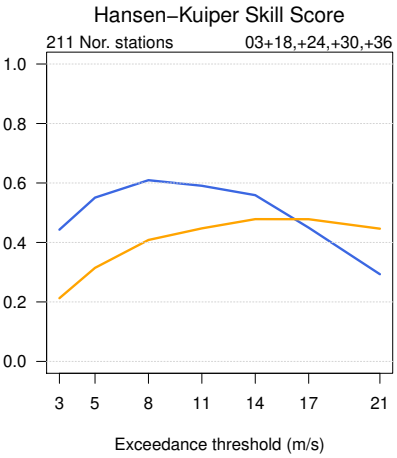


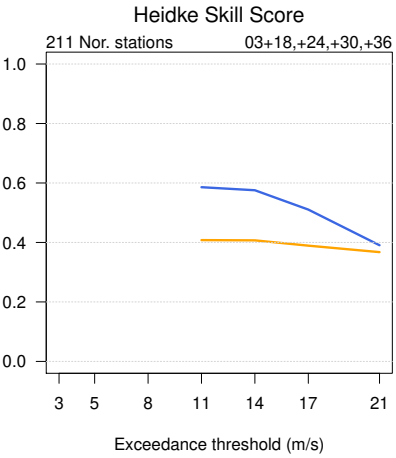


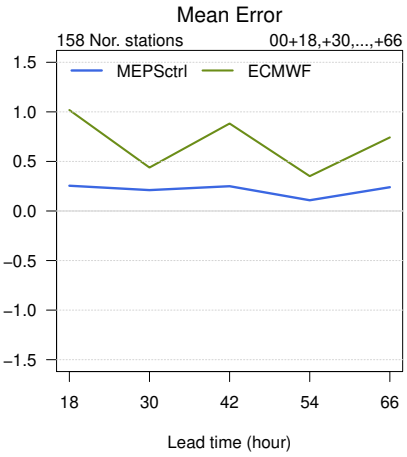


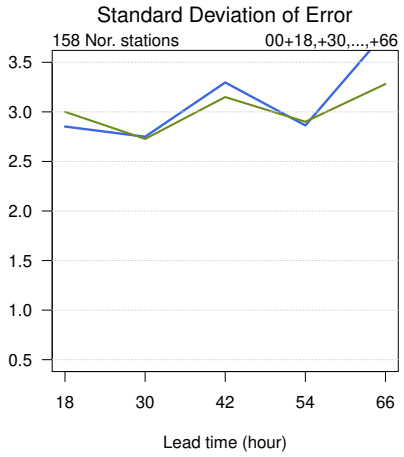


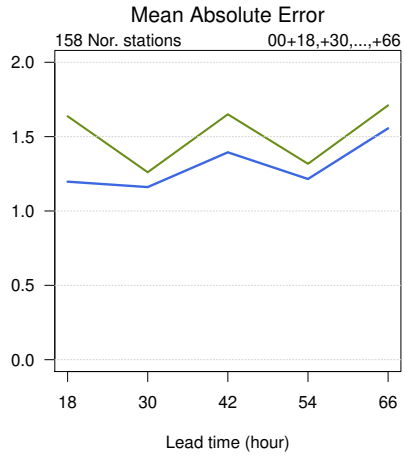


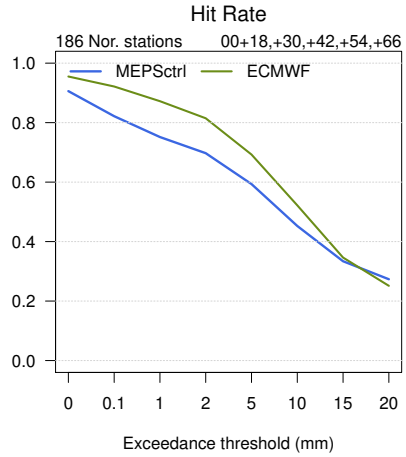


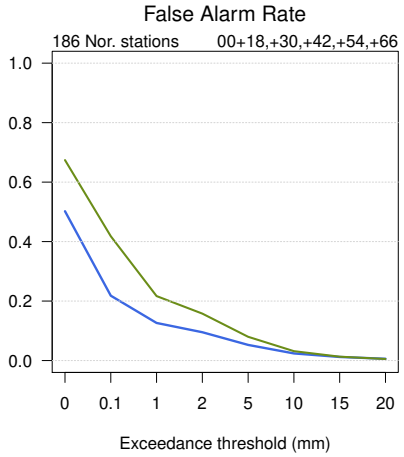


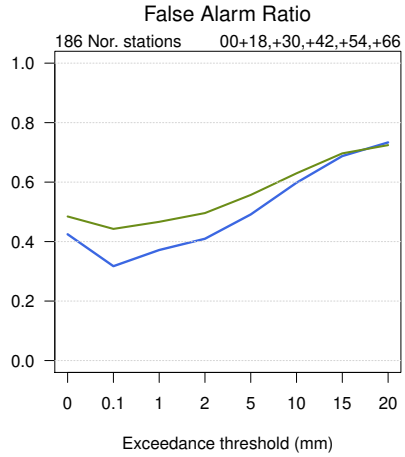

Mean Error
158 Nor. stations
00+18,+30,...,+66
MEPSctrl
ECMWF
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
18
30
42
54
66
Lead time (hour)

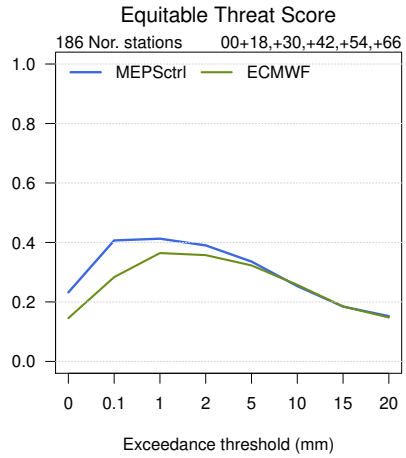

Standard Deviation of Error
158 Nor. stations
00+18,+30,...,+66
3.5
3.0
2.5
2.0
1.5
1.0
0.5
18
30
42
54
66
Lead time (hour)

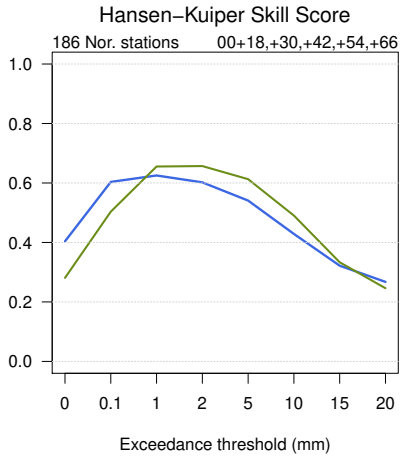

Mean Absolute Error
158 Nor. stations
00+18,+30,...,+66
2.0
1.5
1.0
0.5
0.0
18
30
42
54
66
Lead time (hour)

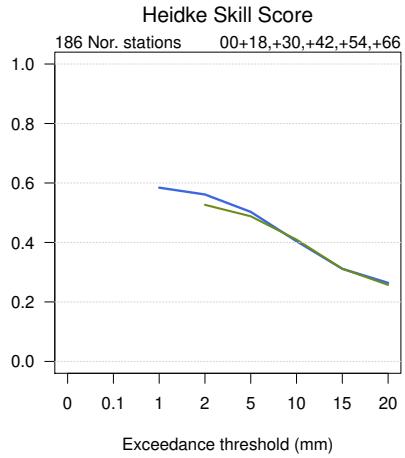

Hit Rate
186 Nor. stations
00+18,+30,+42,+54,+66
MEPSctrl
ECMWF
1.0
0.8
0.6
0.4
0.2
0.0
0
0.1
1
2
5
10
15
20
Exceedance threshold (mm)


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


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

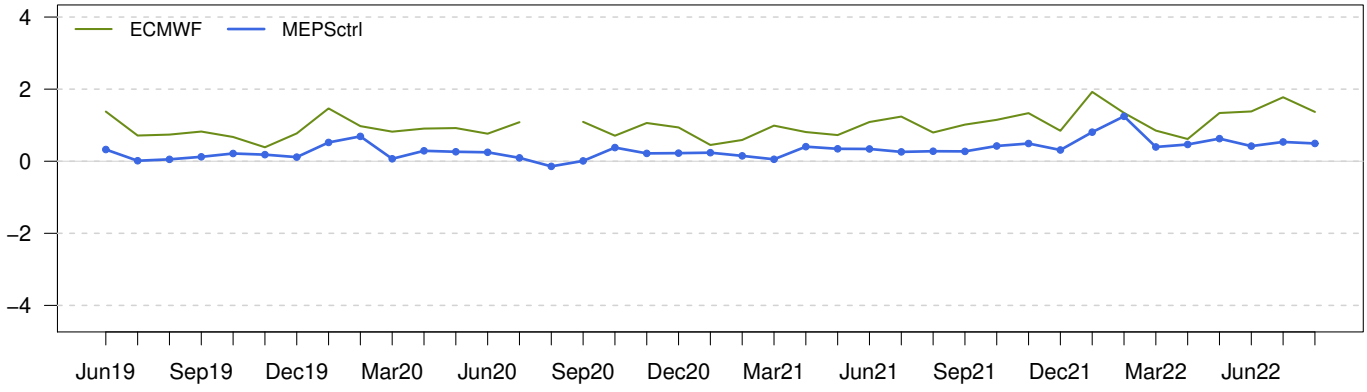

Equitable Threat Score
186 Nor. stations
00+18,+30,+42,+54,+66
MEPSctrl
ECMWF
1.0
0.8
0.6
0.4
0.2
0.0
0
0.1
1
2
5
10
15
20
Exceedance threshold (mm)


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

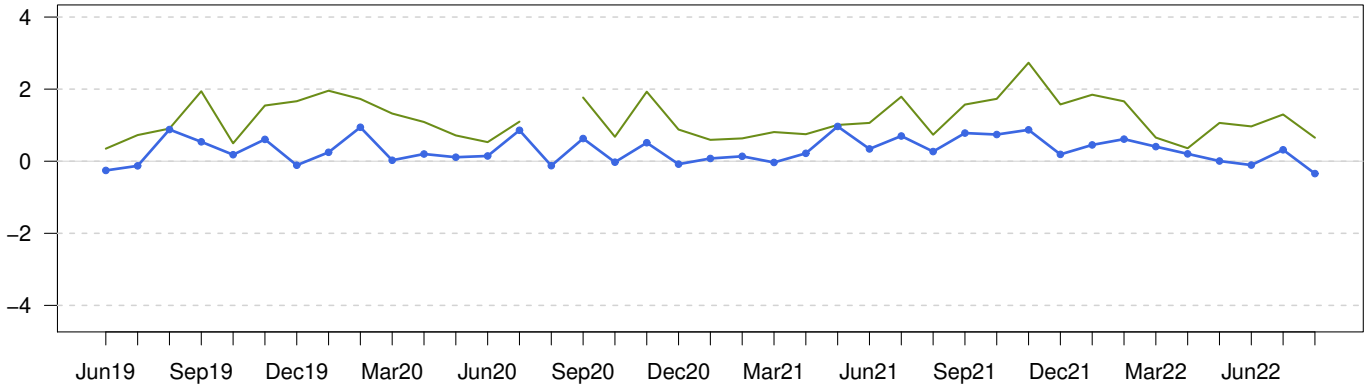

Heidke Skill Score
186 Nor. stations
00+18,+30,+42,+54,+66
1.0
0.8
0.6
0.4
0.2
0.0
0
0.1
1
2
5
10
15
20
Exceedance threshold (mm)

Mean Error

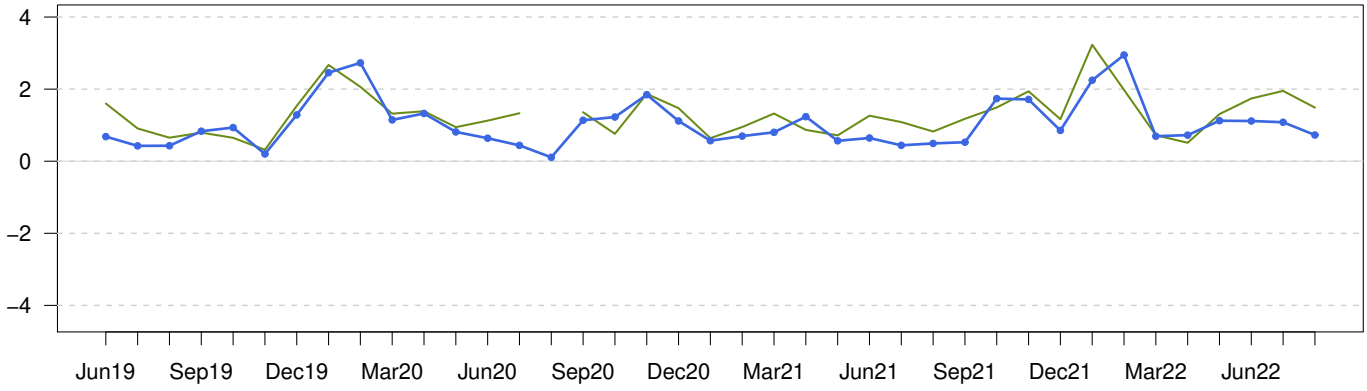
184 Norwegian stations 00+30 UTC



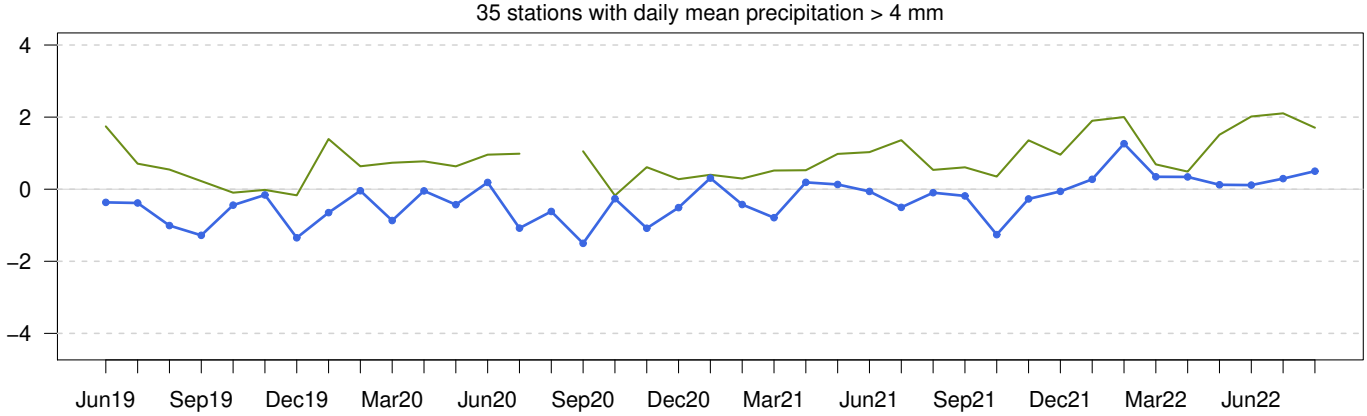
6 coastal stations



43 stations more than 500 m above sea level

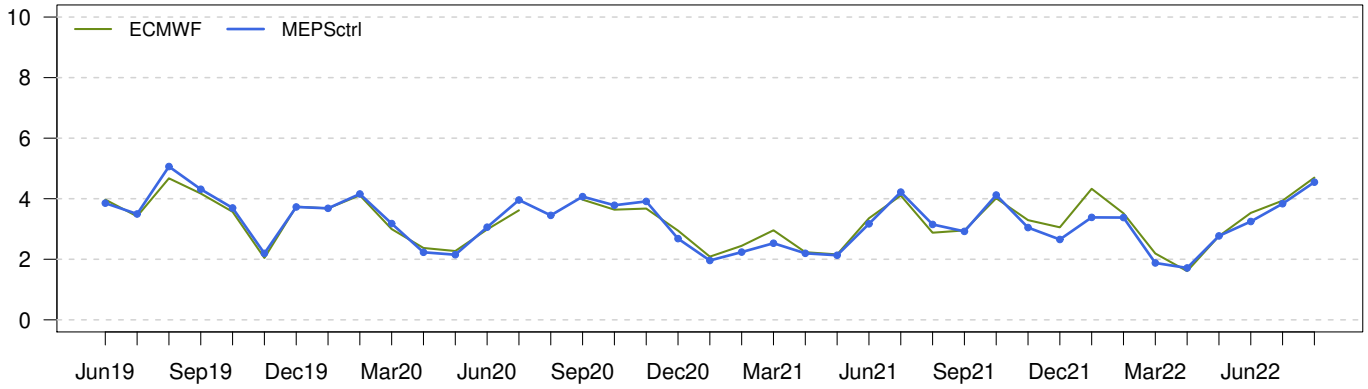


35 stations with daily mean precipitation > 4 mm

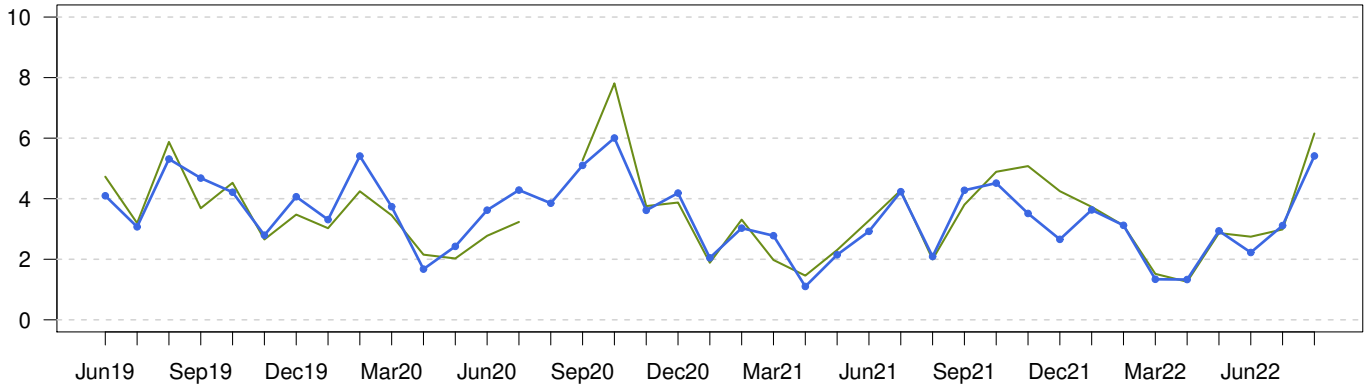


Standard Deviation of Error

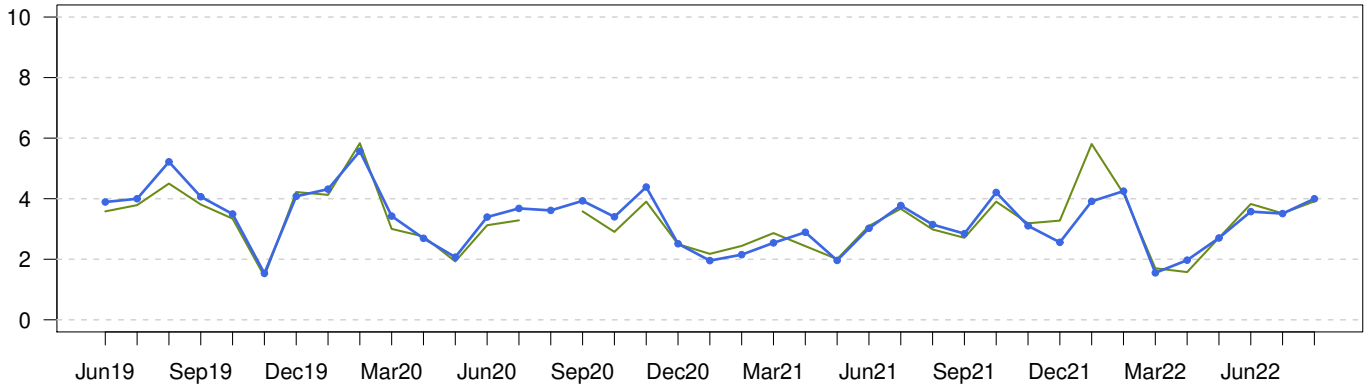
184 Norwegian stations 00+30 UTC



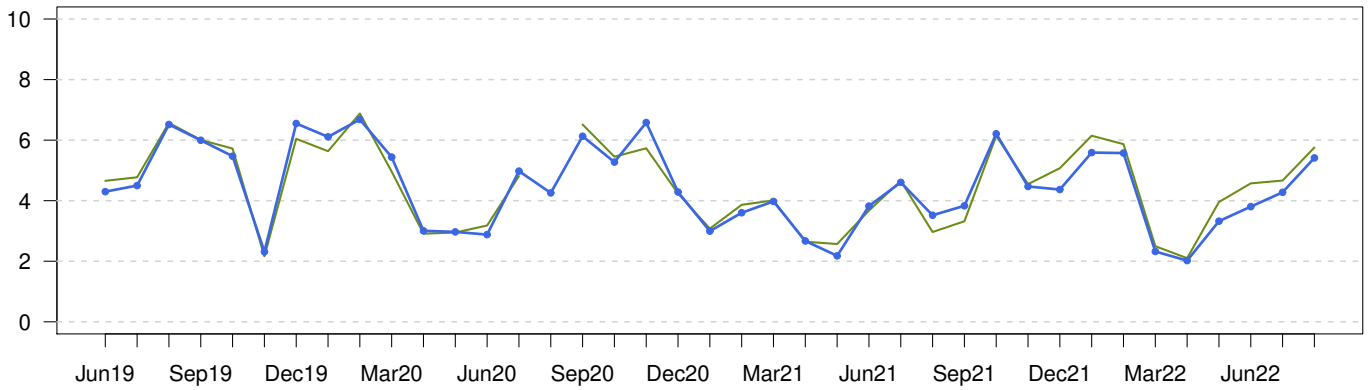
6 coastal stations



43 stations more than 500 m above sea level

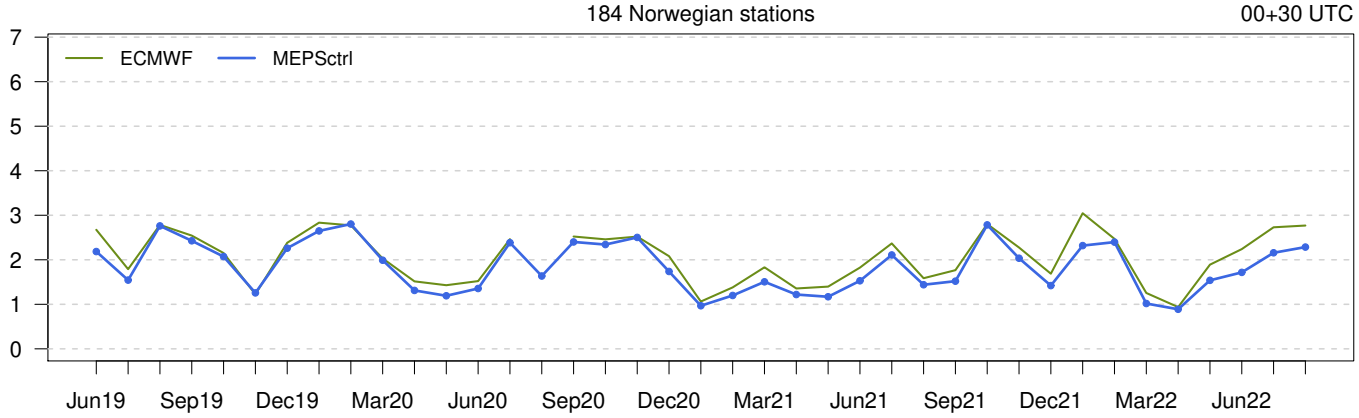


35 stations with daily mean precipitation > 4 mm

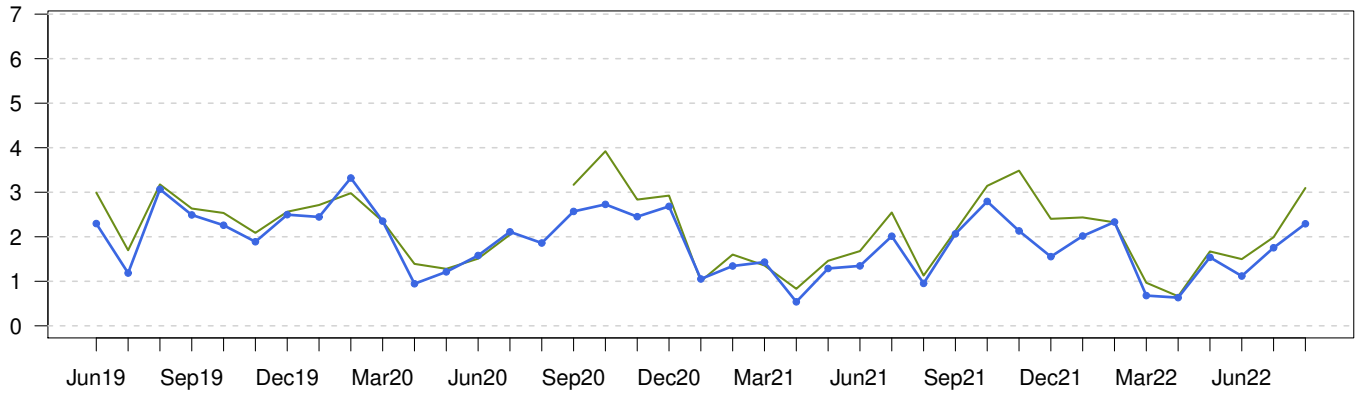


Mean Absolute Error

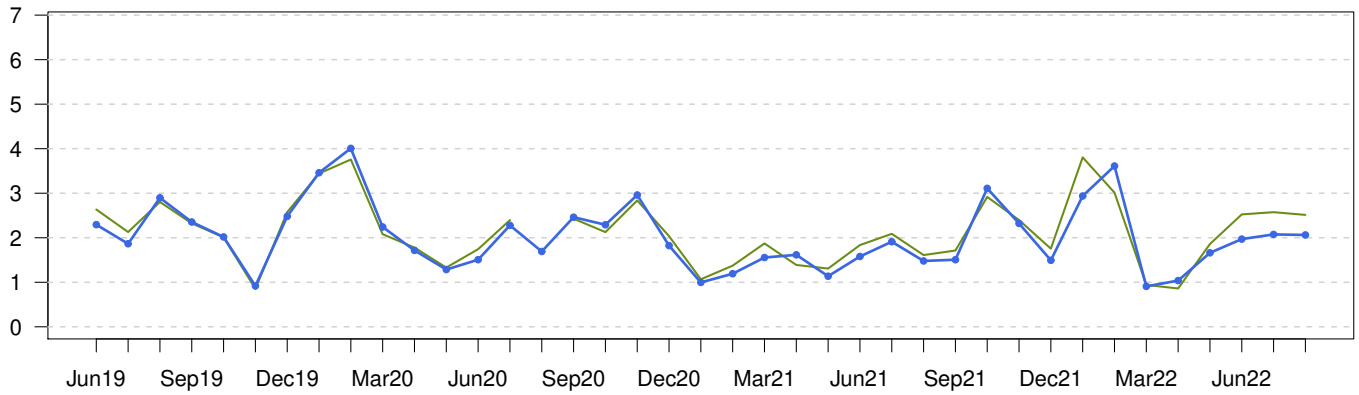
184 Norwegian stations 00+30 UTC



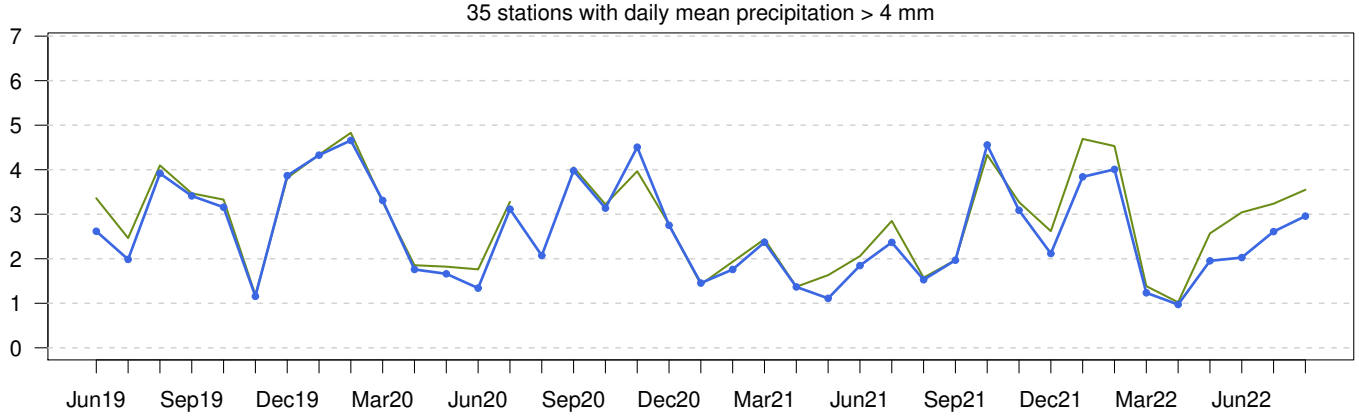
6 coastal stations



43 stations more than 500 m above sea level

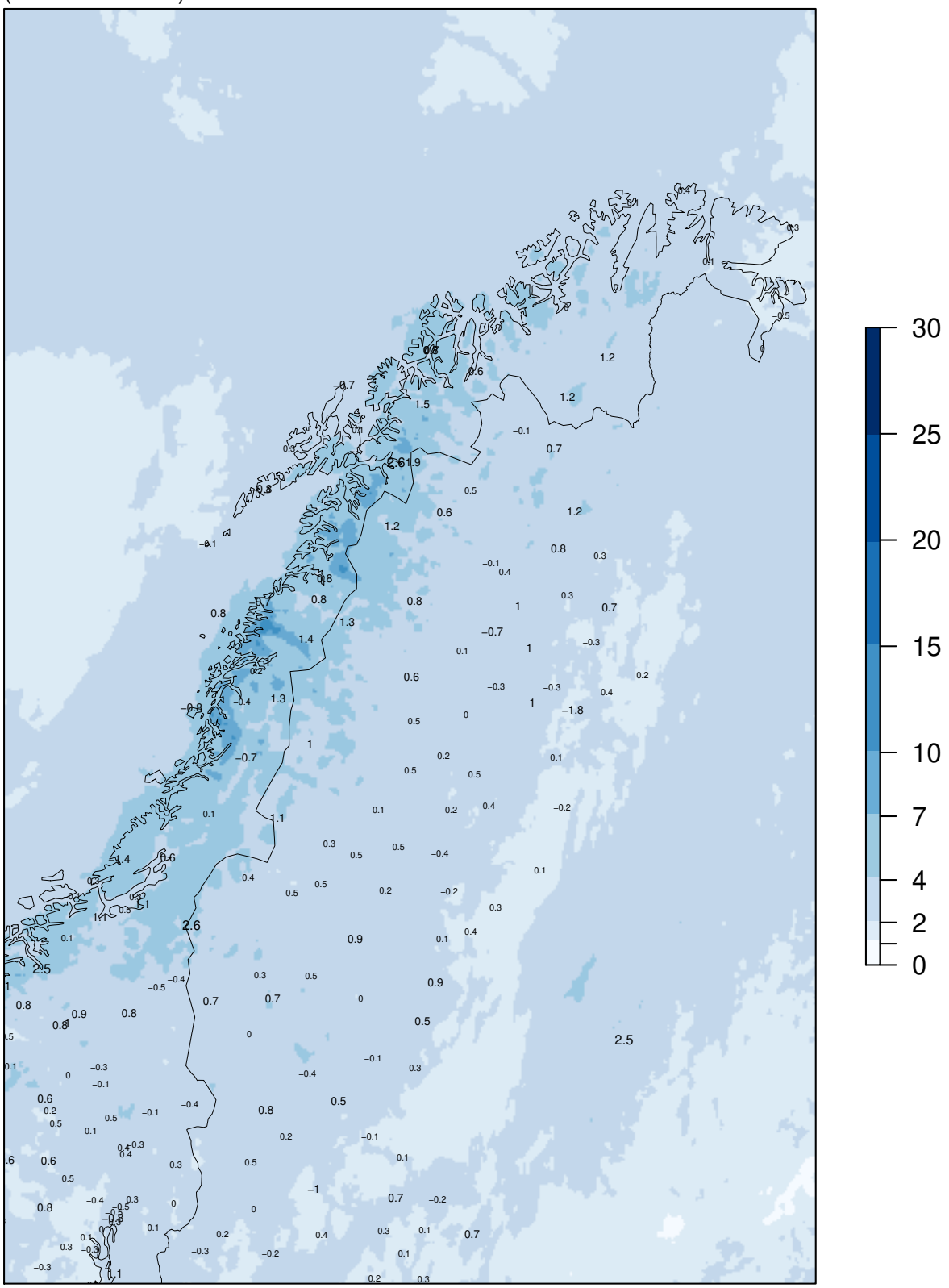


35 stations with daily mean precipitation > 4 mm



MEPSctrl 00+30

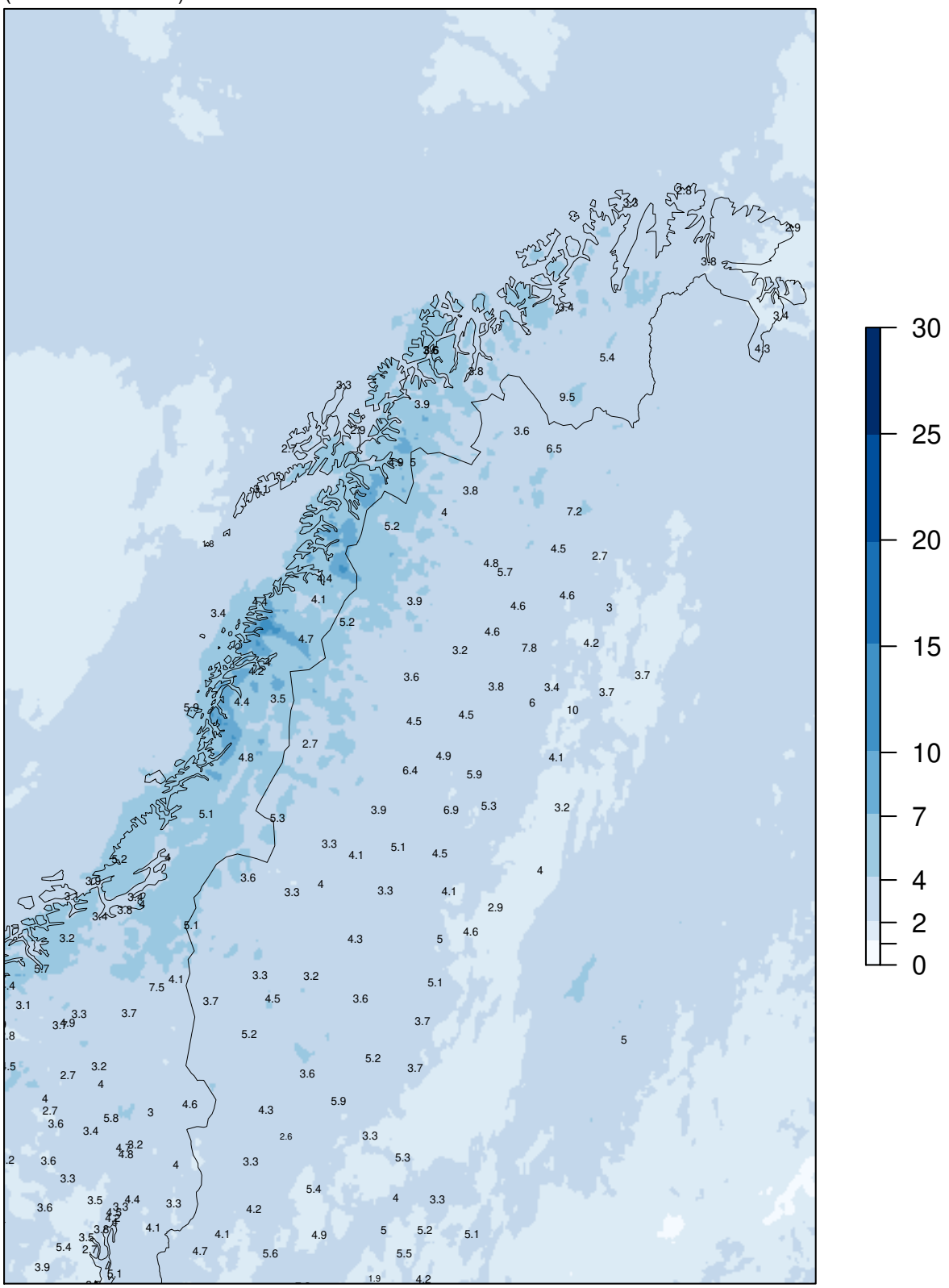
ME at observing sites
(numbers in black)



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+30

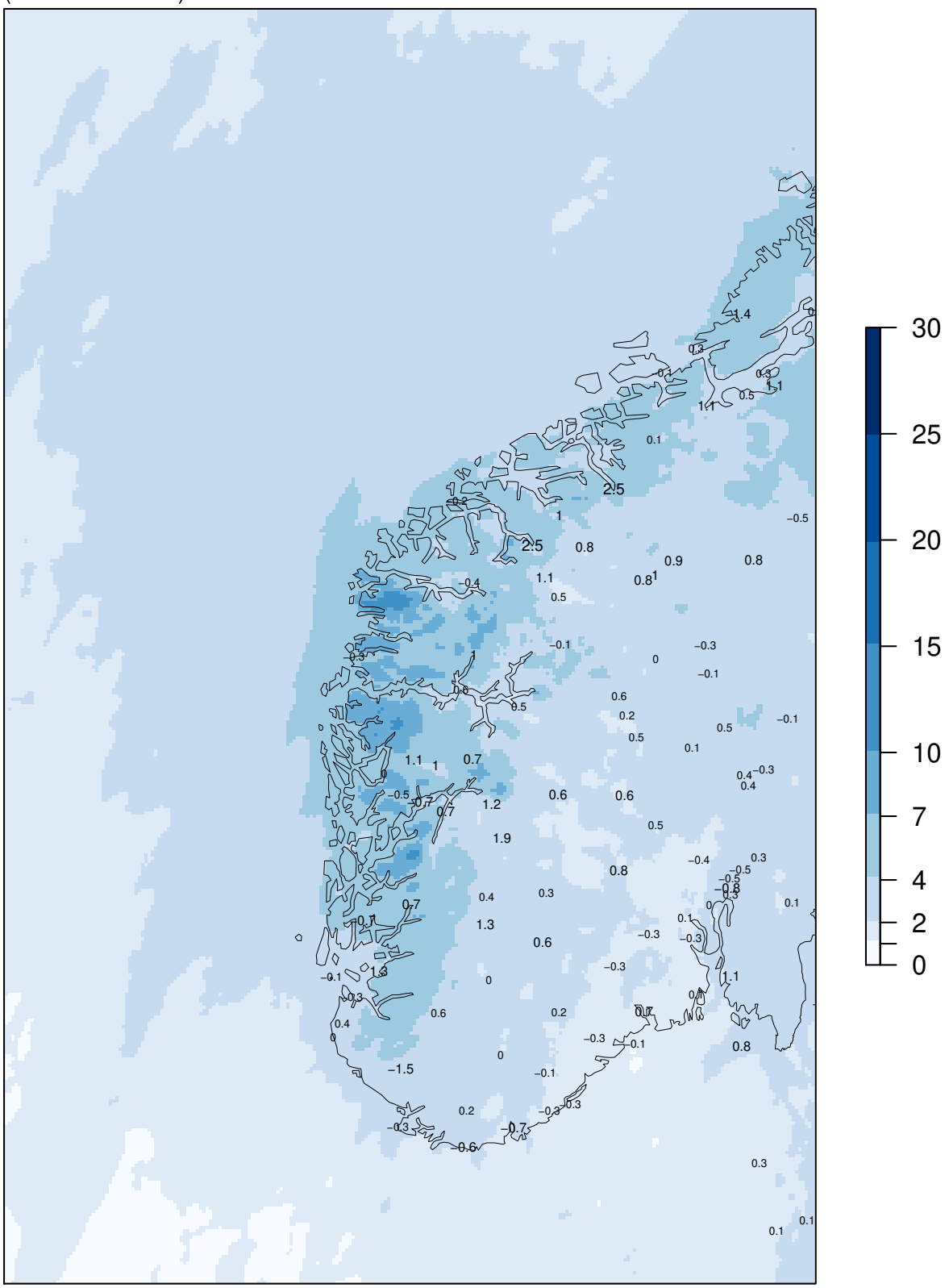
SDE at observing sites
(numbers in black)



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+30

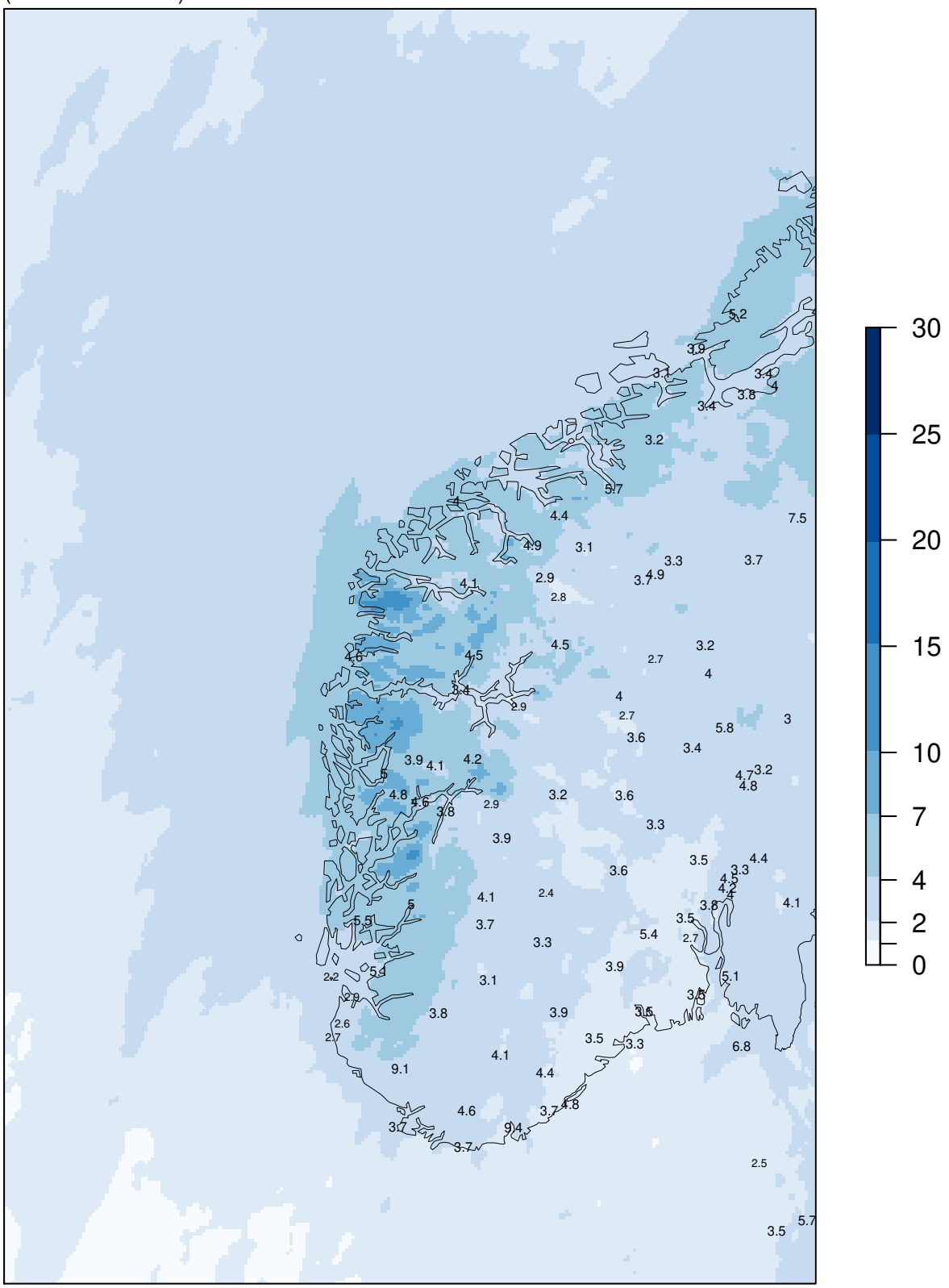
ME at observing sites
(numbers in black)



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+30

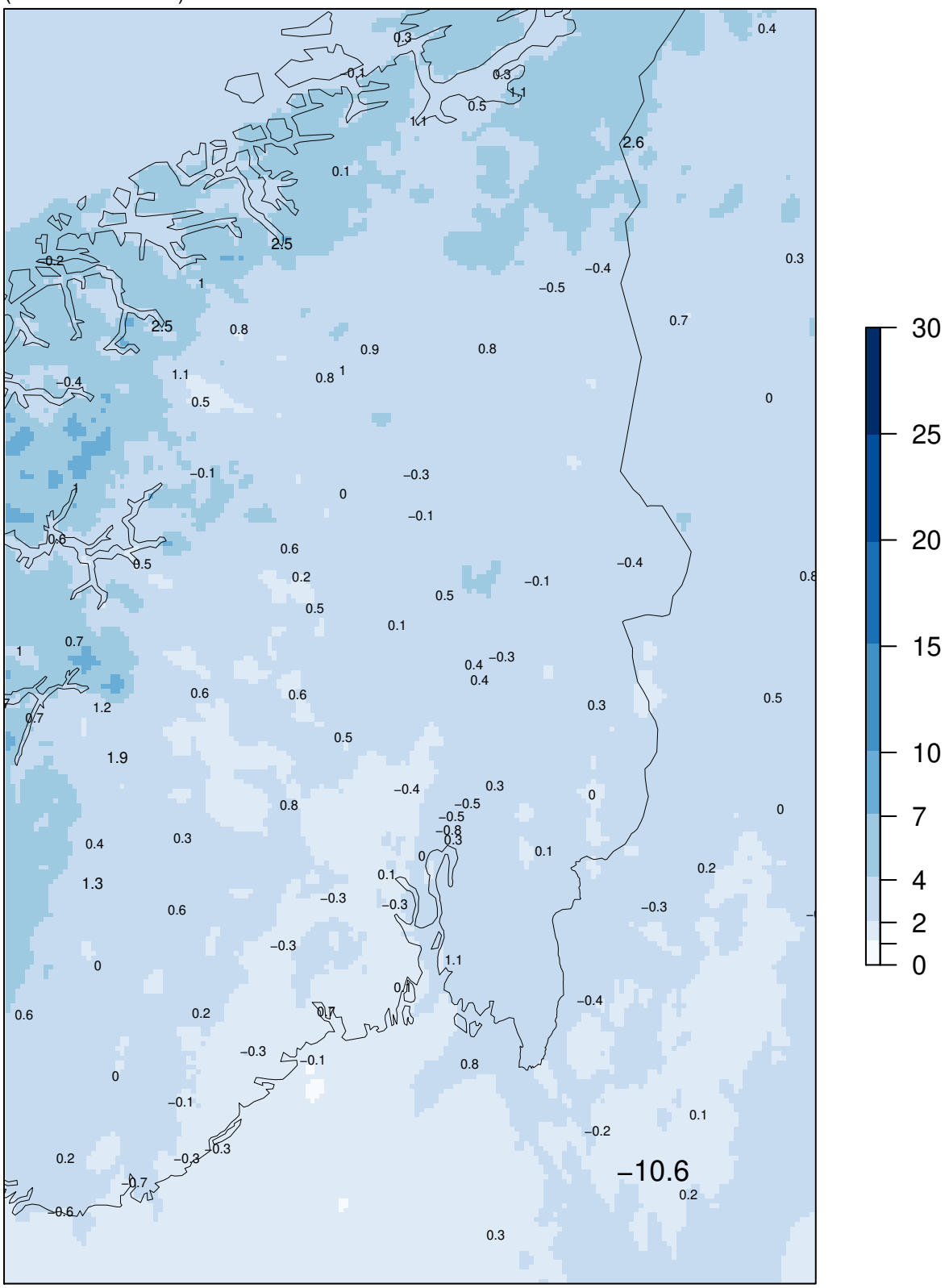
SDE at observing sites
(numbers in black)



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+30

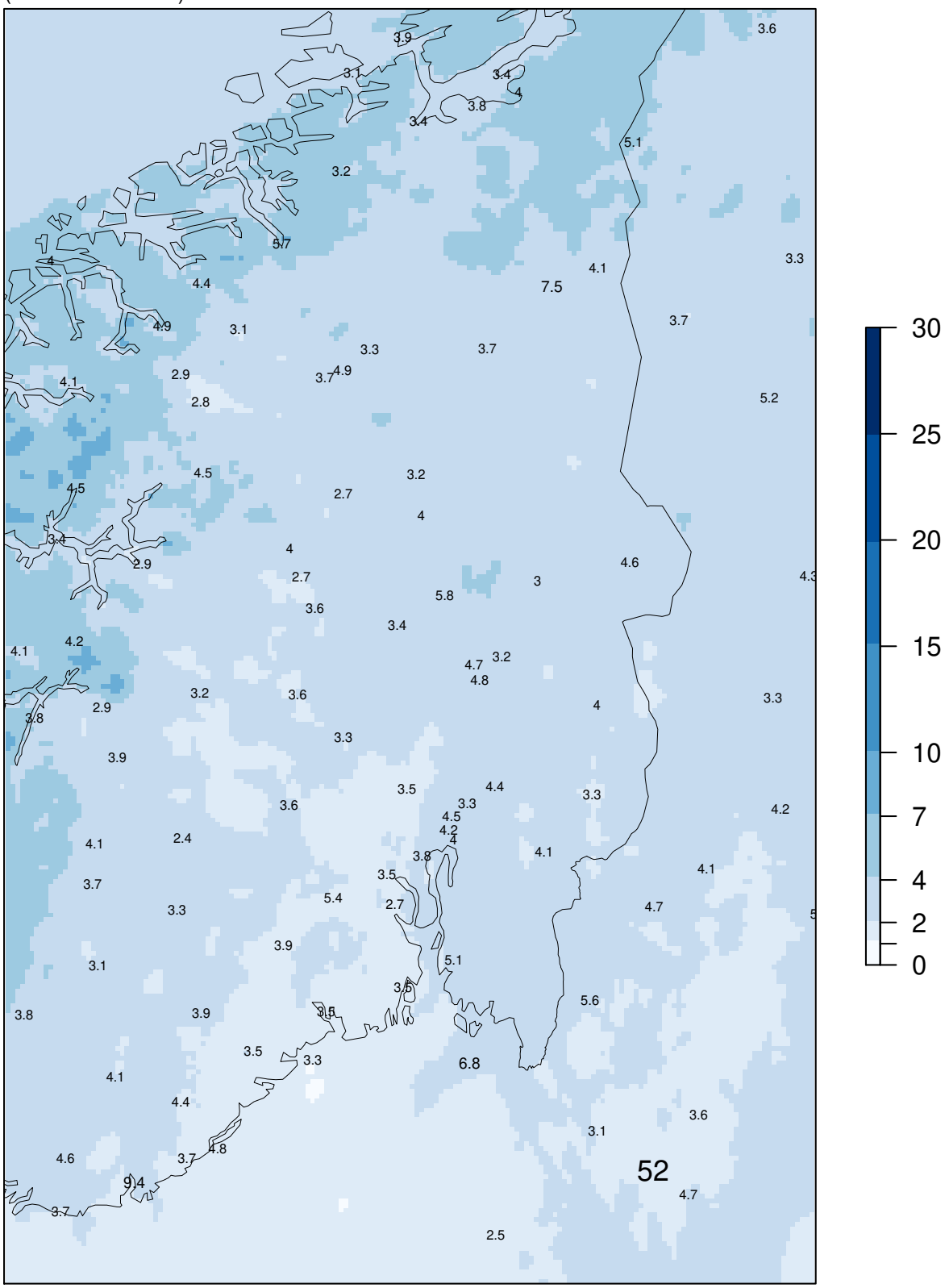
ME at observing sites
(numbers in black)



Model "climatology" 01.06.2022 – 31.08.2022

MEPSctrl 00+30

SDE at observing sites
(numbers in black)

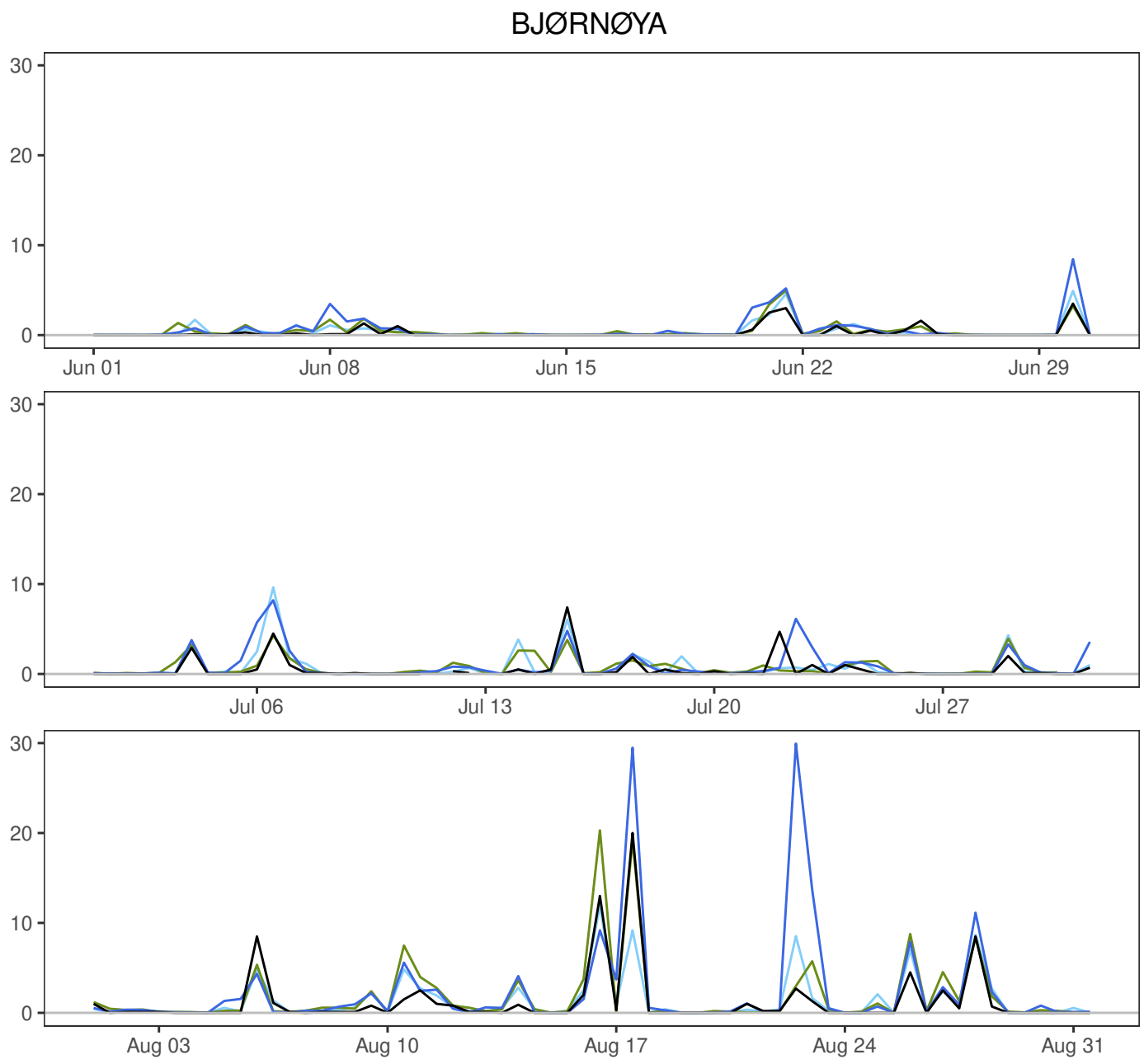


Model "climatology" 01.06.2022 – 31.08.2022

SVALBARD LUFTHAVN

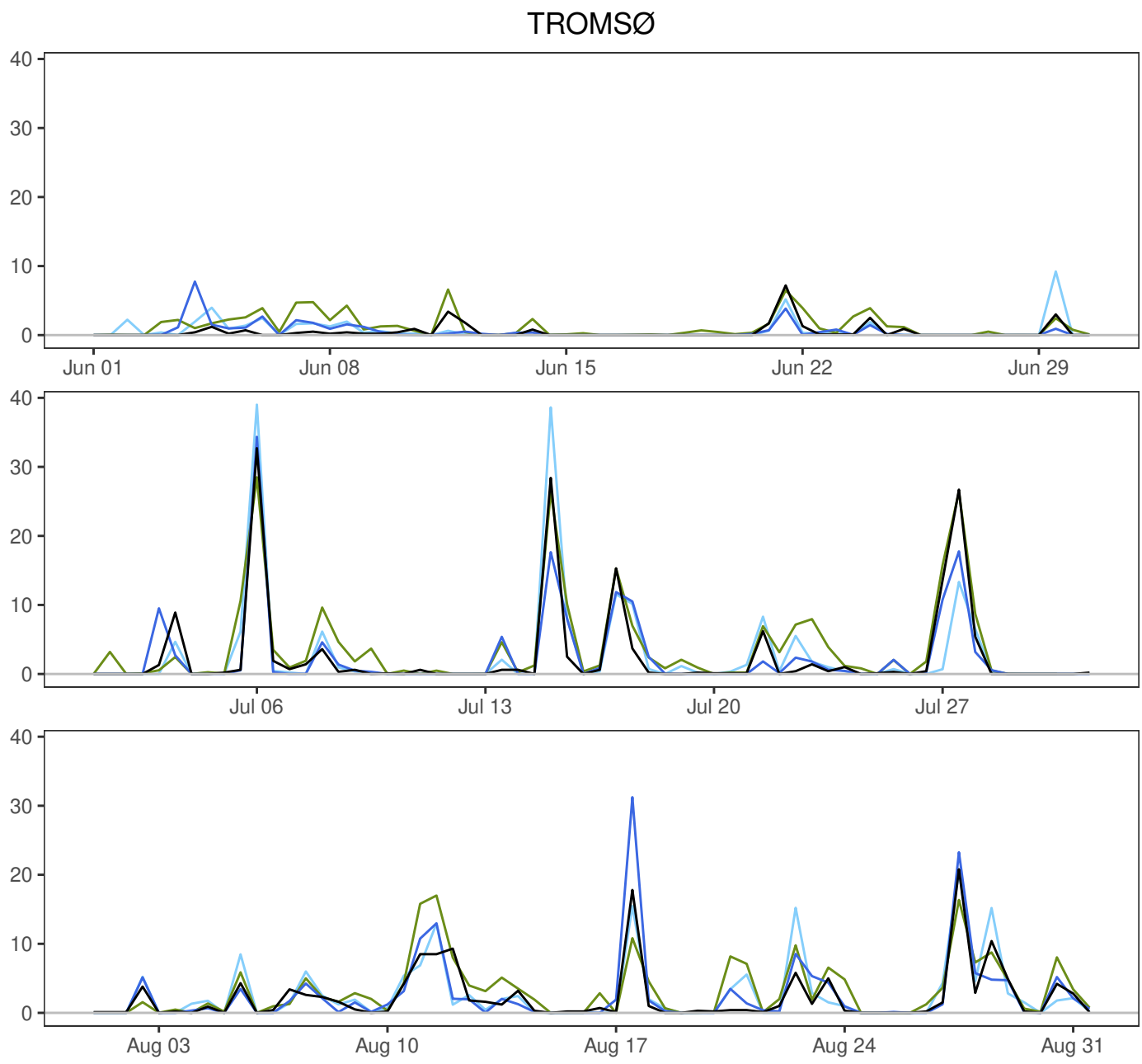
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.3	15.5	1.4	184
AA25: 12+18,+30	0.0	0.6	8.4	1.2	184
ECMWF: 12+18,+30	0.0	0.8	7.9	1.4	182

	ME	SDE	RMSE	MAE	Max.abs.err.	N
AA25−synop	0.2	1.3	1.3	0.5	11.2	182
ECMWF−synop	0.5	1.3	1.4	0.7	7.9	182



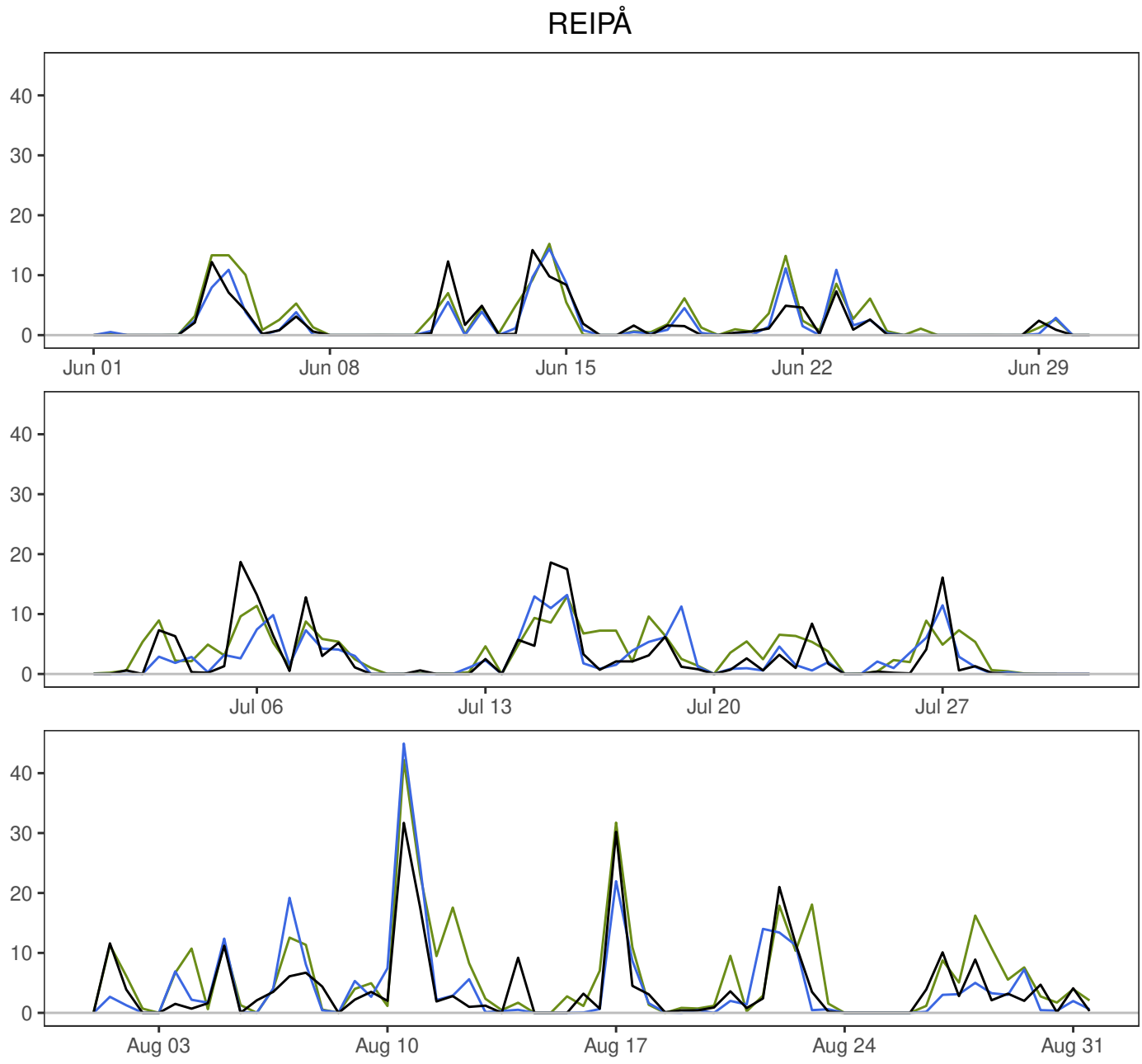
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.7	20.0	2.1	182
MEPSctrl: 12+18,+30	0.0	1.3	29.9	3.6	184
AA25: 12+18,+30	0.0	0.9	11.9	1.9	184
ECMWF: 12+18,+30	0.0	1.0	20.3	2.5	182

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.6	2.6	2.7	0.9	27.2	180
AA25−synop	0.2	1.3	1.3	0.5	10.8	180
ECMWF−synop	0.3	1.1	1.2	0.5	7.3	180



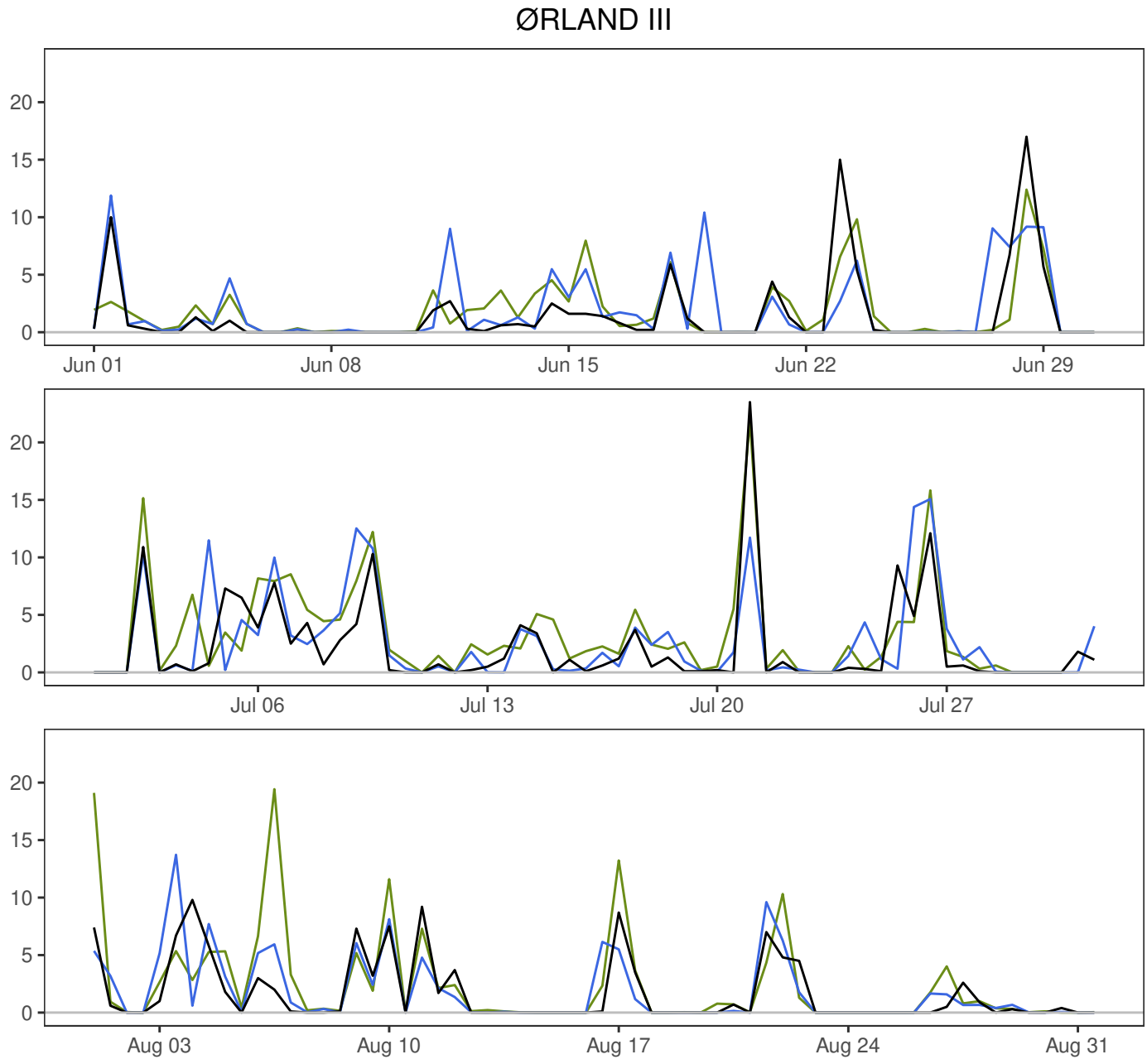
	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.8	32.7	4.7	184
MEPSctrl: 12+18,+30	0.0	1.9	34.4	4.7	184
AA25: 12+18,+30	0.0	2.1	39.0	5.1	184
ECMWF: 12+18,+30	0.0	2.8	28.5	4.7	182

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.1	2.3	2.3	1.1	13.4	182
AA25−synop	0.3	2.4	2.4	1.2	13.4	182
ECMWF−synop	1.0	2.2	2.4	1.4	10.0	182



	Min	Mean	Max	Std	N
synop: 06,18	0.0	3.0	31.7	5.2	184
MEPSctrl: 12+18,+30	0.0	3.0	44.9	5.3	184
ECMWF: 12+18,+30	0.0	4.2	42.2	5.7	182

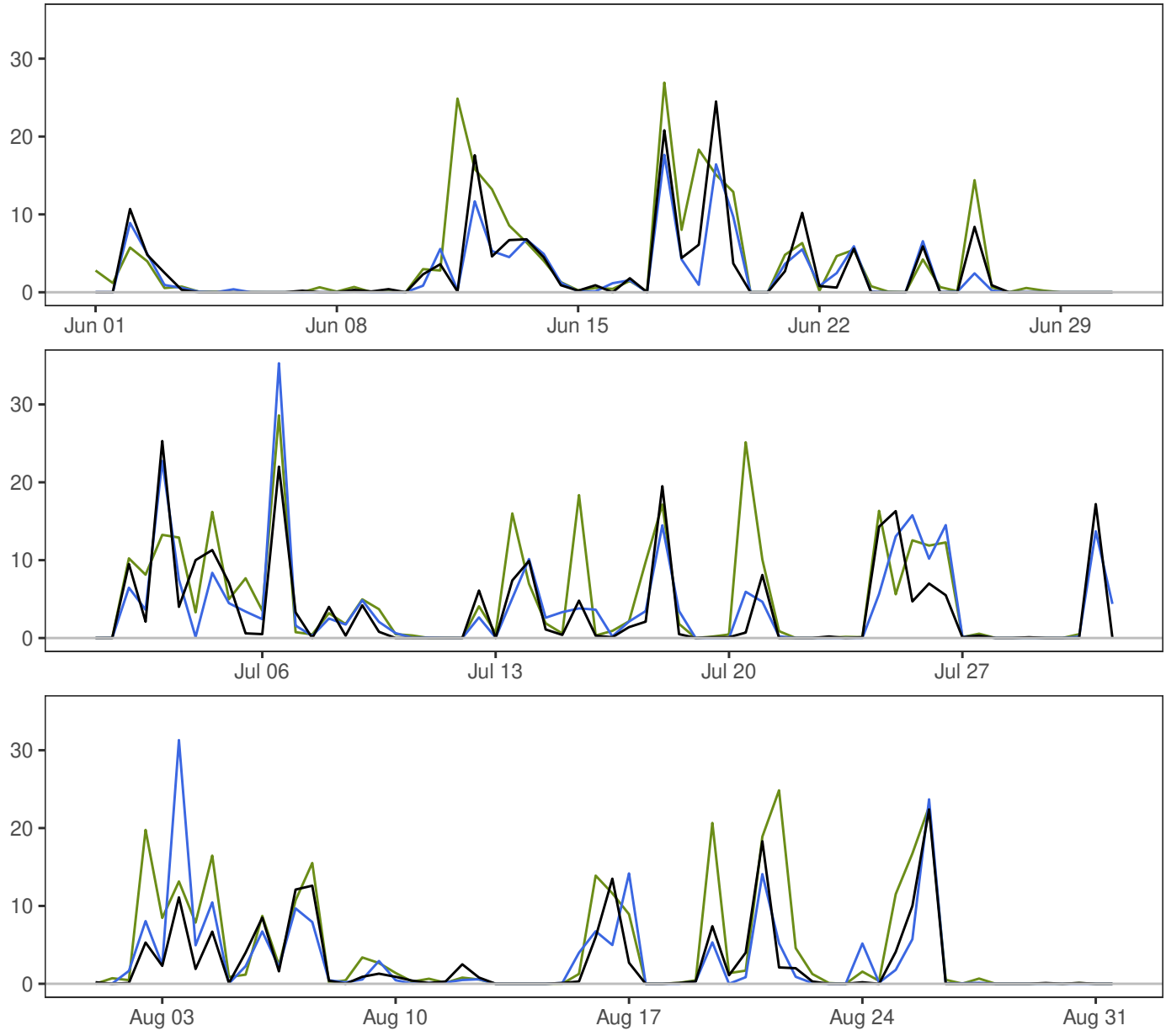
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.1	3.4	3.4	1.8	16.1	182
ECMWF−synop	1.1	3.5	3.6	2.2	14.8	182



	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.8	23.5	3.4	184
MEPSctrl: 12+18,+30	0.0	2.2	15.1	3.4	184
ECMWF: 12+18,+30	0.0	2.5	22.0	3.9	182

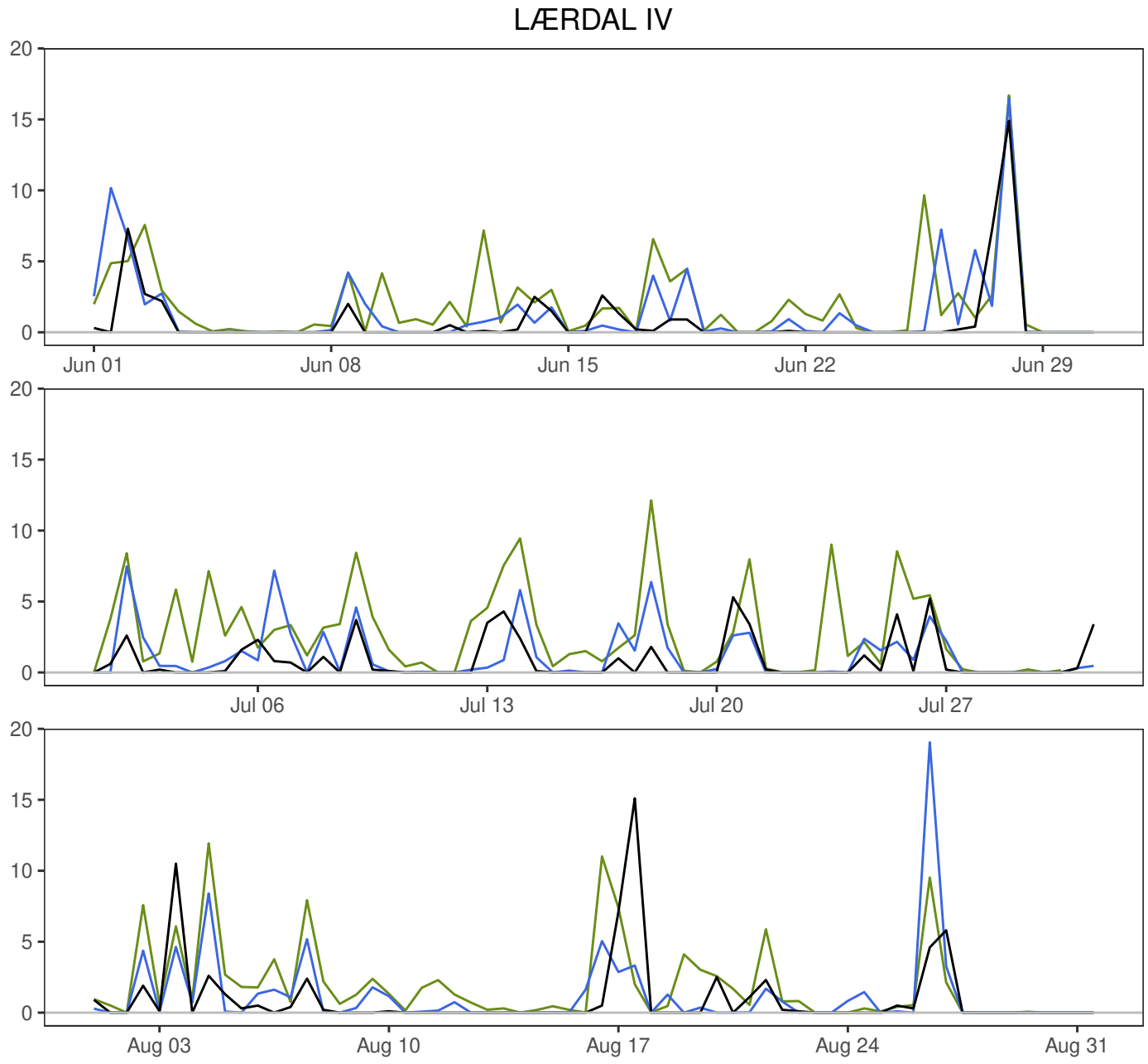
	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.3	2.8	2.8	1.4	12.3	182
ECMWF−synop	0.6	2.6	2.7	1.4	17.4	182

BERGEN – FLORIDA



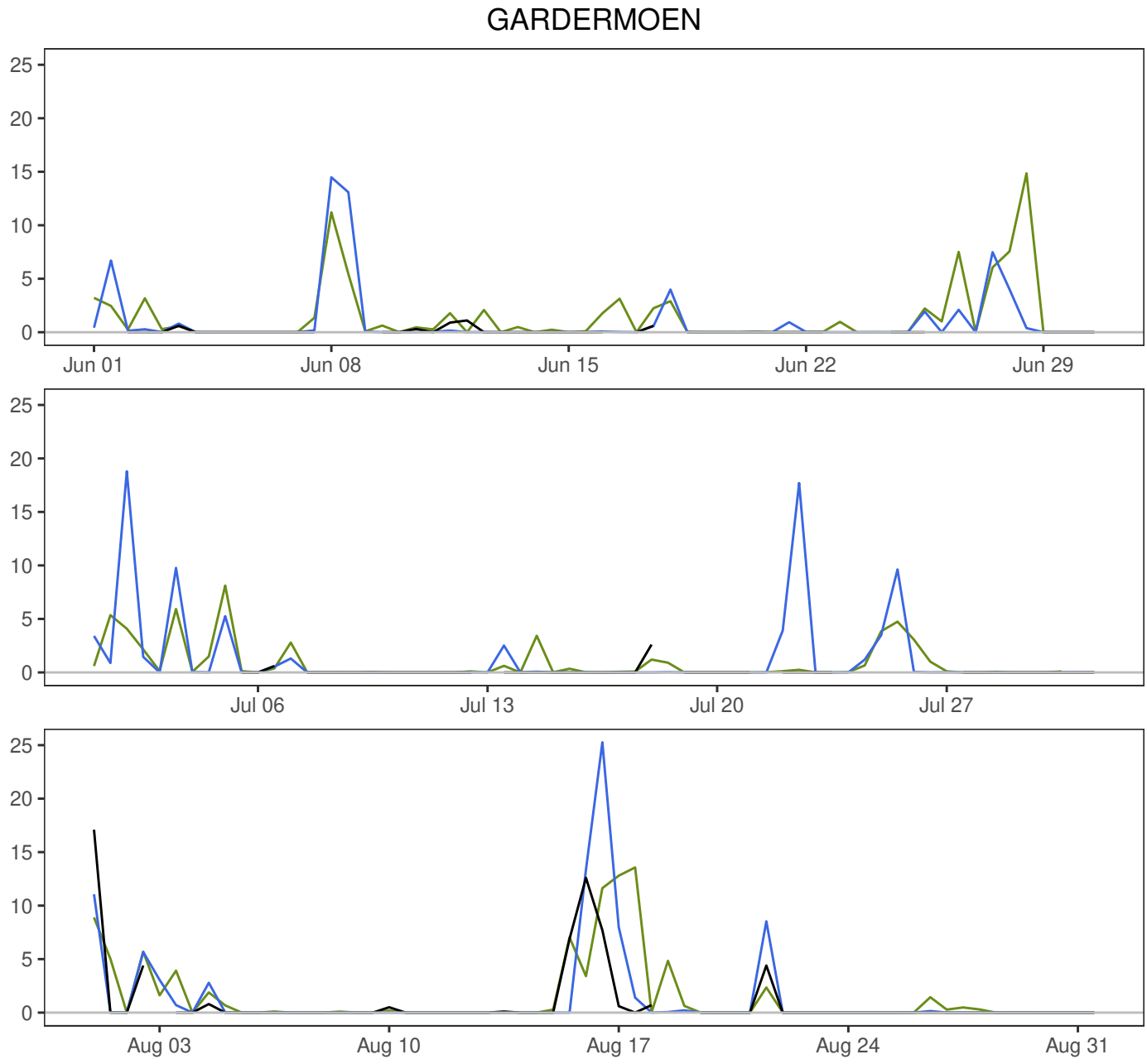
	Min	Mean	Max	Std	N
synop: 06,18	0.0	3.1	25.3	5.3	184
MEPSctrl: 12+18,+30	0.0	3.1	35.3	5.5	184
ECMWF: 12+18,+30	0.0	4.4	28.6	6.7	182

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.0	3.2	3.2	1.5	20.2	182
ECMWF−synop	1.4	4.6	4.8	2.3	24.8	182



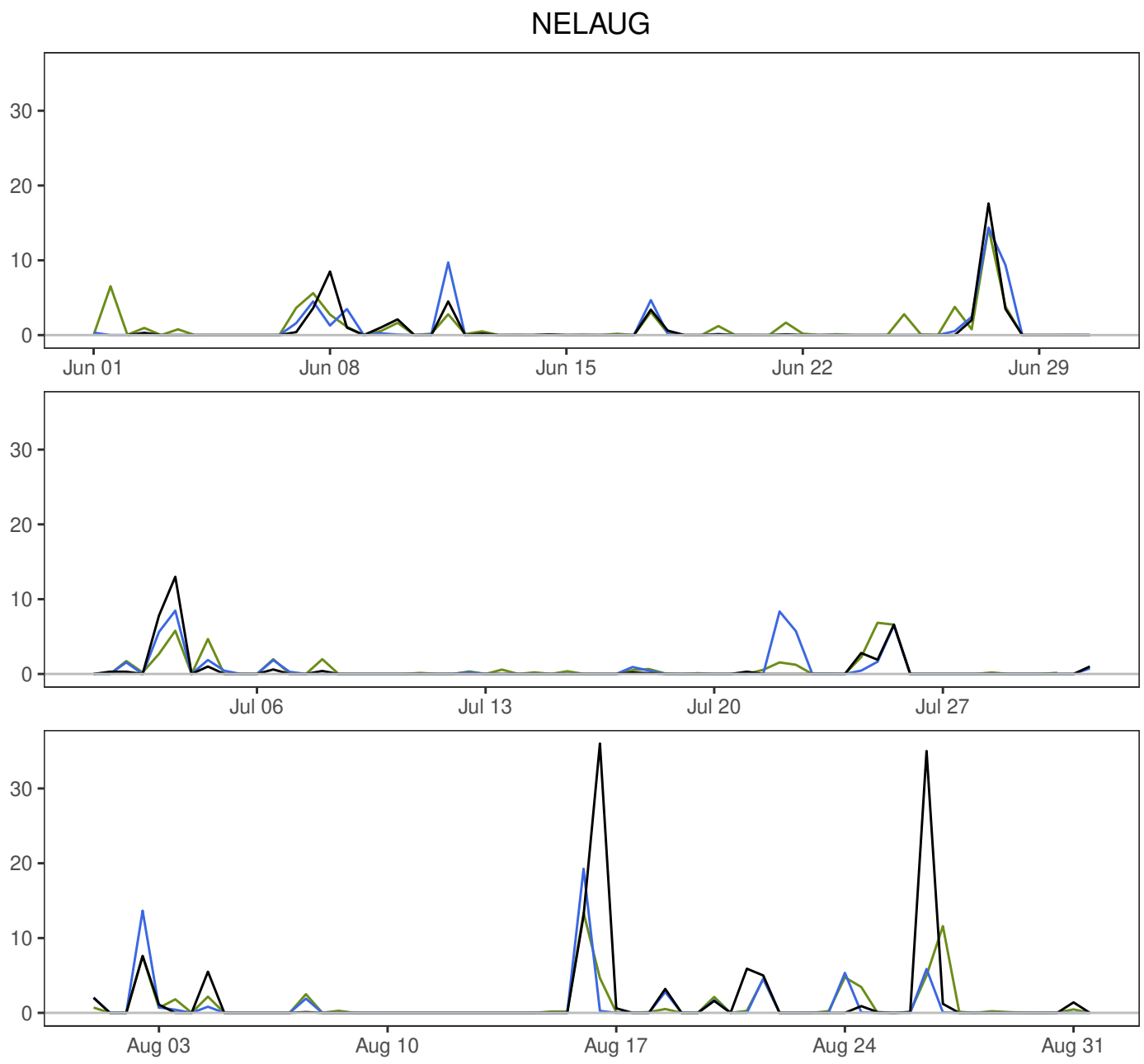
	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.9	15.1	2.2	184
MEPSctrl: 12+18,+30	0.0	1.3	19.0	2.5	184
ECMWF: 12+18,+30	0.0	2.2	16.7	2.9	182

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.4	2.3	2.3	1.1	14.4	182
ECMWF−synop	1.3	2.6	2.9	1.7	13.1	182



	Min	Mean	Max	Std	N
synop: 06,18	0.0	0.4	17.1	2.0	152
MEPSctrl: 12+18,+30	0.0	1.2	25.3	3.6	184
ECMWF: 12+18,+30	0.0	1.2	14.8	2.7	182

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	0.4	2.5	2.5	0.7	17.7	150
ECMWF−synop	0.3	2.0	2.0	0.6	13.6	150



	Min	Mean	Max	Std	N
synop: 06,18	0.0	1.1	36.0	4.3	183
MEPSctrl: 12+18,+30	0.0	0.9	19.3	2.6	184
ECMWF: 12+18,+30	0.0	0.9	14.3	2.2	182

	ME	SDE	RMSE	MAE	Max.abs.err.	N
MEPSctrl−synop	−0.3	3.8	3.8	0.9	35.7	181
ECMWF−synop	−0.2	3.6	3.6	0.9	31.3	181