Application and verification of ECMWF products 2018

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1. Summary of major highlights

ECMWF products are widely used throughout the Norwegian Meteorological Institute (MET Norway). Forecasters use HRES and ENS fields to make weather forecasts for the public and for customers. The BC project provides boundary values for the AROME-MetCoOp Ensemble System (MEPS) and AROME-Arctic Limited Area Model. EC HRES is also used for several downstream models like chemical weather forecasting, as well as ash and radioactivity emergency transport modelling. EC HRES and ENS also drive models for ocean state and storm surge, give input to statistical methods and calibration, and are used more or less directly by end uses. Monthly and seasonal forecasts are distributed to selected customers, and used internally as a support for the forecasters on duty.

2. Use and application of products

2.1 Post-processing of ECMWF model output

2.1.1 Statistical adaptation

ECMWF ENS is the basis for the public medium range forecasts (3-10 days) for locations in Norway, presented on www.yr.no. Both a consensus forecast and probabilities are generated. ECMWF HRES is used for locations outside Norway. For Norwegian locations there is currently a statistical calibration of air temperature (at 2m), precipitation, and wind speed (at 10m).

- For air temperature a quantile-quantile method is used with climatology from a limited area model as reference. From late 2017 have implemented an additional regression-based calibration method on EC-ENS for dealing with the large biases along Norway's intricate coastline.
- The precipitation calibration is done using a combination of a logistic regression and fitting a gamma distribution. This procedure accounts for the lack of spread in the ensemble, ensuring that the presented probabilities for precipitation are reliable.
- The wind speed calibration is performed using quantile-quantile mapping against a high resolution (2.5 km) model.

2.1.2 Physical adaptation

ECMWF HRES provides lateral boundary values for MEPS and the limited area atmospheric models AROME-Arctic model (2.5 km horizontal resolution, based on Harmonie, covering Scandinavia and Svalbard) at 00, 06, 12 and 18 UTC. Scaled Lagged Average Forecast (SLAF) is used for initial and lateral boundary perturbations to the MEPS.

Meteorological data from the daily dissemination from ECMWF are used operationally in the EMEP air quality model to forecast and analyze air pollution levels in Europe (Copernicus Atmosphere Monitoring Service, led by ECMWF) and in East Asia (AirQuip project, funded by the Research Council of Norway). The daily forecasts and analyses include ozone, particulate matter, NO2 and other health relevant air pollutants, as well as pollen. Within CAMS, the daily dissemination of ECMWF is also used to calculate in so-called source-receptor matrices for air pollution. In these calculations, contributions of air pollution to cities in Europe are estimated, distinguishing between the contribution of air pollution from the city itself, from the country and from other countries in Europe.

Meteorological data from ECMWF are not verified directly during our production, but output from the air quality model is evaluated continuously against near-real time measurements from all over Europe and East Asia. These evaluations can reveal deficiencies in meteorological data that have a strong influence on air pollution, such as surface winds, boundary layer height and precipitation.

IFS Cycle 40r1 model hindcast runs are performed by MET Norway on ECMWF HPCs (PrepIFS) with support from ECMWF staff creating a consistent meteorological dataset to support work on air pollution trend studies for the EMEP project under the Convention for Long Range Transport of Air Pollution (CLRTAP) and other related projects. The model is run on global domain, 60 vertical levels with 0.1 deg (T1279) horizontal resolution and is adapted to extract also extra parameters (3D - humidity, cloud cover, precipitation and convection) to support specifically the chemical transport modelling. These hind cast runs are used as input to the European air pollution model runs for trends (years 2000-2017) and source receptor matrices ('blame matrices'), which are published on www.emep.int.

From the winter 2017/2018 the Norwegian regional Storm Surge forecast model (ROMS) is running in ensemble mode, with 51 members driven by surface pressure and wind stress from EC-ENS. The change from deterministic to ensemble approach to storm surge forecasting is expected to give more consistent warnings for high sea surface levels along the Norwegian coast.

ECMWF HRES and/or ENS is also used in forcing of other Wave- and Ocean models, Drift models for the ocean, and as input to dispersion models for volcanic ash and nuclear emissions to the atmosphere.

2.1.3 Derived fields

On the website yr.no, MET Norway provide location-specific forecasts up to 10 days. In the medium range, the forecast is a combination of a consensus forecast and a probabilistic forecast, both based on EC-ENS. This forecast used to be accompanied by a text with ‘The forecaster’s comment’, but as this is no longer the case, the yr.no graphical product is currently the only public medium range forecast issued by MET Norway.

To achieve a smooth transition from the short range forecasts (based on MEPS/AROME-Arctic) we rely on the ECMWF re-forecasts to provide a reliable model climatology. These reruns of the current operational ENS are very important, especially close up to major model upgrades, as they quickly provide a large training data set for statistical post processing.

To the end-users on yr.no, uncertainty is indicated for weather, temperature and wind in terms of green, yellow and red markers. Probability forecasts comprise the 10, 25, 75 and 90 percentiles for temperature and 6-hourly precipitation, see for example http://www.yr.no/place/Norway/Oslo/Oslo/Oslo/long.html.

EFI, SOT and probability maps for selected weather parameters based on ENS are presented in the meteorological visualisation system Diana, and used daily by forecasters when communicating with media and cooperating partners and customers.

2.2 ECMWF products

2.2.1 Use of Products

EcCharts: Precipitation type, in particular possibility of Freezing Rain
The past winter has seen a handful events of long-lasting freezing rain which has been challenging for road and air traffic. The new meteogram product for Precipitation Type has shown some skill in predicting these events several days in advance. Based on the positive experience from this winter, the products may be recommended as a standard tool in both aviation and general forecasting for the coming winter season.

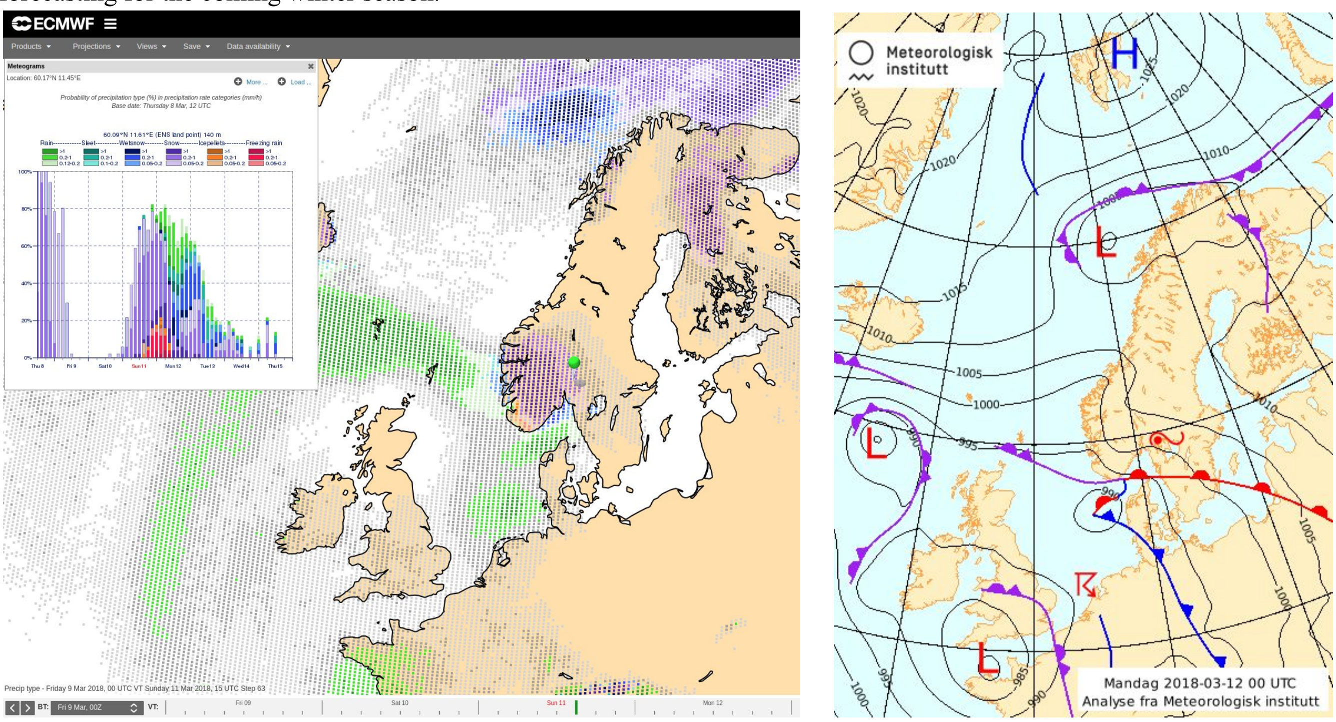

Fig.1 Case from 8.March 2018 showing the skill of the ‘Precipitation Type’ product. Left: forecast issued on March 5th, indicating significant probability of freezing rain (red columns in the histogram). Right: analysis for 8.March 2018t.

Multi Parameter EFI, EFI/SOT web maps

Forecasters and researchers meet twice a week for an 'Extreme Weather Outlook' discussion/brief in the weather room. When relevant, the brief is also attended by the Flood forecasting service (NVE). The discussions are based on the easy accessible web-maps of Multi Parameter EFI from ECMWF, along with relevant EFI/SOT and standard weather parameters. These briefs have proven valuable for identifying possible severe weather events during the coming week, and for mobilizing extra forecasting staff to handle the situations properly.

2.2.2 Product requests

- **EFI/SOT snowfall, more than 24h?**

  "I would like to see snowfall EFI/SOT accumulations for 2, 3 and more days, just like we get for total precipitation" Long-lasting snowfall strain the resources on road maintenance crews, and causes disruptions in people's' lives. It is of high value to be able to forecast heavy snowfall well in advance.

- **A Graphics archive?**

  "If there had been a graphics archive, say going back some (6 ?) months, EFI/SOT plots would be a standard element in all my reports on severe weather cases."

  Historical forecasts in graphical form is requested by researchers and forecasters. 10 days pass quickly and by the time you sit down to write your Severe Weather report the plots are gone from the web.

- **EFI/SOT for IVT/ Integrated Water Vapour Transport**

  Most of the rivers in Norway are regulated by power reservoirs. They play an important role in flood prevention as the reservoirs will stall water and give sufficient room in the downstream river string to cope with the added inflow from rain and/or snow melt. It takes some days (2-5) to prepare for heavy inflow in the catchment area, and the spill water must have time to pass by the affected part of river string before the heavy rain sets in. Sharp and reliable forecasts for long-lasting, heavy precipitation is therefore essential for being able to make preparations and prevent devastating flooding, and to minimize income loss due to forced spilling of water. Early warning for long-lasting (often orographically enhanced) precipitation is therefore even more important than for intense short-time rainfall, and we welcome the efforts by ECMWF to produce EFI/SOT indices for IVT.

3. Verification of products

3.1 Objective verification

3.1.1 Direct ECMWF model output (both HRES and ENS)

Figure 2 shows the a selection of scores for 10 m wind speed from last winter (Dec 17-Feb 18), verified against stations in Northern Scandinavia. It is clear that EC HRES does not produce sufficiently strong surface winds. The same is the case for EC ENS. However, the overall scores for ECMWF have improved slightly compared to the results prior to March 2016, most probably as a result of the increased resolution in IFS cycle 41r2.

More results can be found in Homleid & Tveter, 2018: Verification of Operational Weather Prediction Models December 2017 to February 2018.

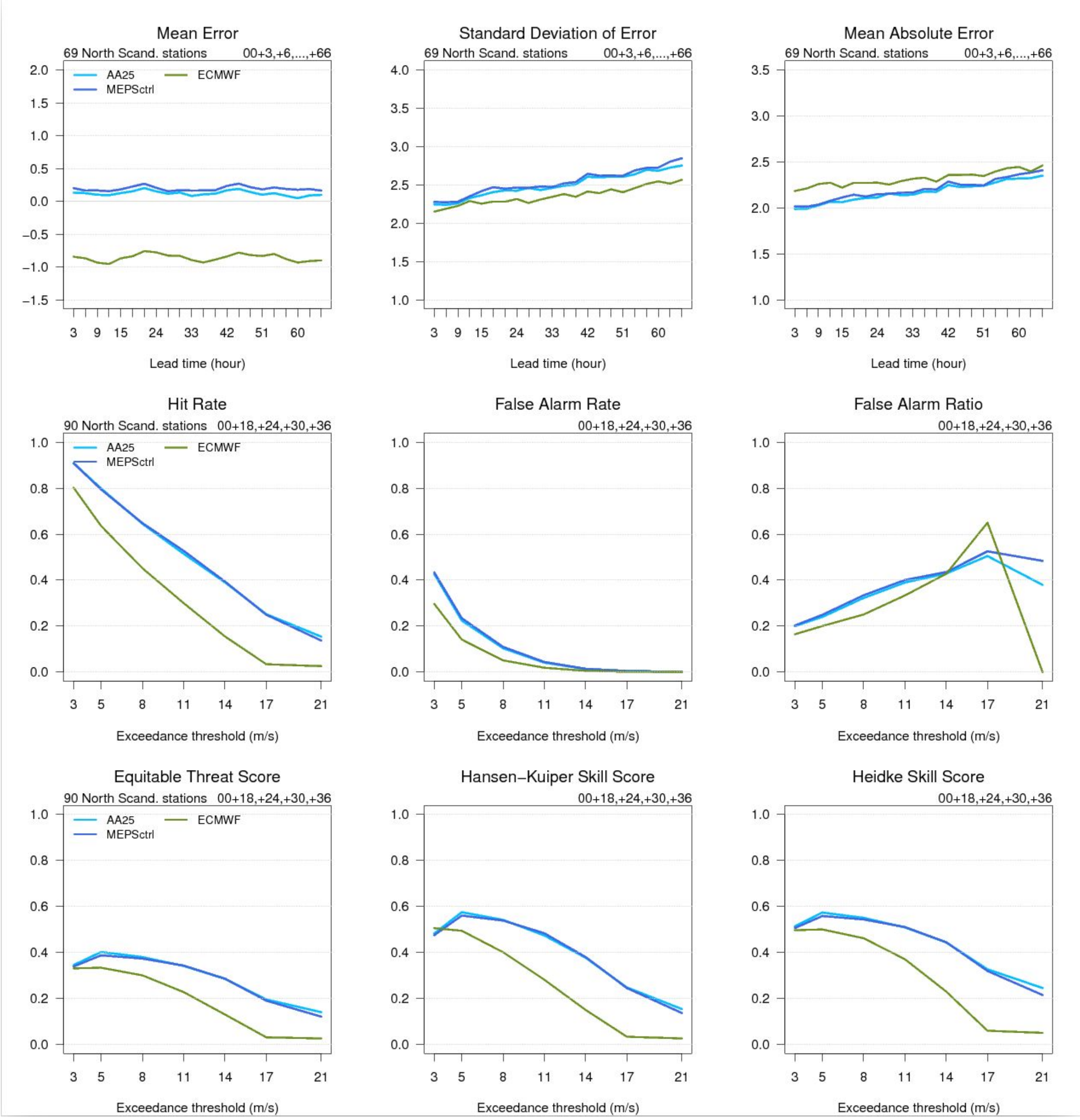

Fig.2 Standard skill scores for 00+3-66h **10 metre wind** forecasts for the winter 2017/2018**.** EC HRES (olive), MEPS-cntrl/AROME-MetCoOp (blue), AROME-Arctic (cyan)

3.1.2 ECMWF model output compared to other NWP models

Examples of 10 m wind speed forecast verification of EC HRES compared to various versions of MEPS/AROME-MetCoOp are given in figures 3 and 4, showing time series of monthly mean and standard deviation of errors from October 2014 to December 2017. The results are averaged over various selections of stations. Large negative mean errors for the 5 mountainous stations demonstrate that the wind speed is too weak in mountainous regions, but the results have improved during the last 1-2 winter seasons. Along the coastline the wind speed forecasts were unbiased or slightly underestimated (Figure 3).

Figure 4 shows that all models have similar quality of the 10 metre wind speed with respect to standard deviation of errors. The ECMWF SDE scores in the mountains have improved significantly the last 1-2 years, most probably as a result of the increased resolution in IFS cycle 41r2 released in March 2016.

3.1.3 Post-processed products

As reported last year, the forecasts of 2m temperature in winter was significantly improved with IFS Cycle 41r2. However, there is still a bias in both EC HRES and EC ENS along the coast. For end-users on yr.no, we therefore still need to apply some statistical calibration on the EC-ENS temperature forecasts. In the autumn the method for statistical calibration of 10m wind speed will be updated. We will then use both 10m and 100m wind speed from the EC-ENS in the quantile-mapping. The 100m wind speed has been shown to be more robustly correlated with the 10m wind speed from our high resolution model (Arome 2.5 km) in the mountain areas. Due to the underforecasting of 10m wind speed the 100m from EC-ENS in general verifies better inland for higher wind speeds.

3.1.4 End products delivered to users

3.2 Subjective verification

3.2.1 Subjective scores (including evaluation of confidence indices when available)

Some comments on EC HRES / EC ENS from the duty forecasters at MET Norway:

- The synoptic situation is usually very well predicted up to 3-4 days.
- SOT/EFI are powerful tools in forecasting severe weather 24-84h ahead
- 10m wind in complex terrain is seriously underestimated by EC HRES and ENS. 850 hPa wind is generally more useful.
- HRES has too much precipitation is concentrated on the cold fronts in summer, and too little on the squall lines in the warm air ahead of the front. Over-all amounts seem OK.
- 2m temperature maximas are too low in summer (even though the air masses are warm and the temperature in 850 hPa indicates temperatures well above climate values).
- The highest rainfall amounts are better predicted by the local MEPS than by EC HRES/ENS. However HRES and ENS sometimes over-predict orographic rainfall in warm sectors. This rarely happened before March 2016 (IFS cycle 41r2)

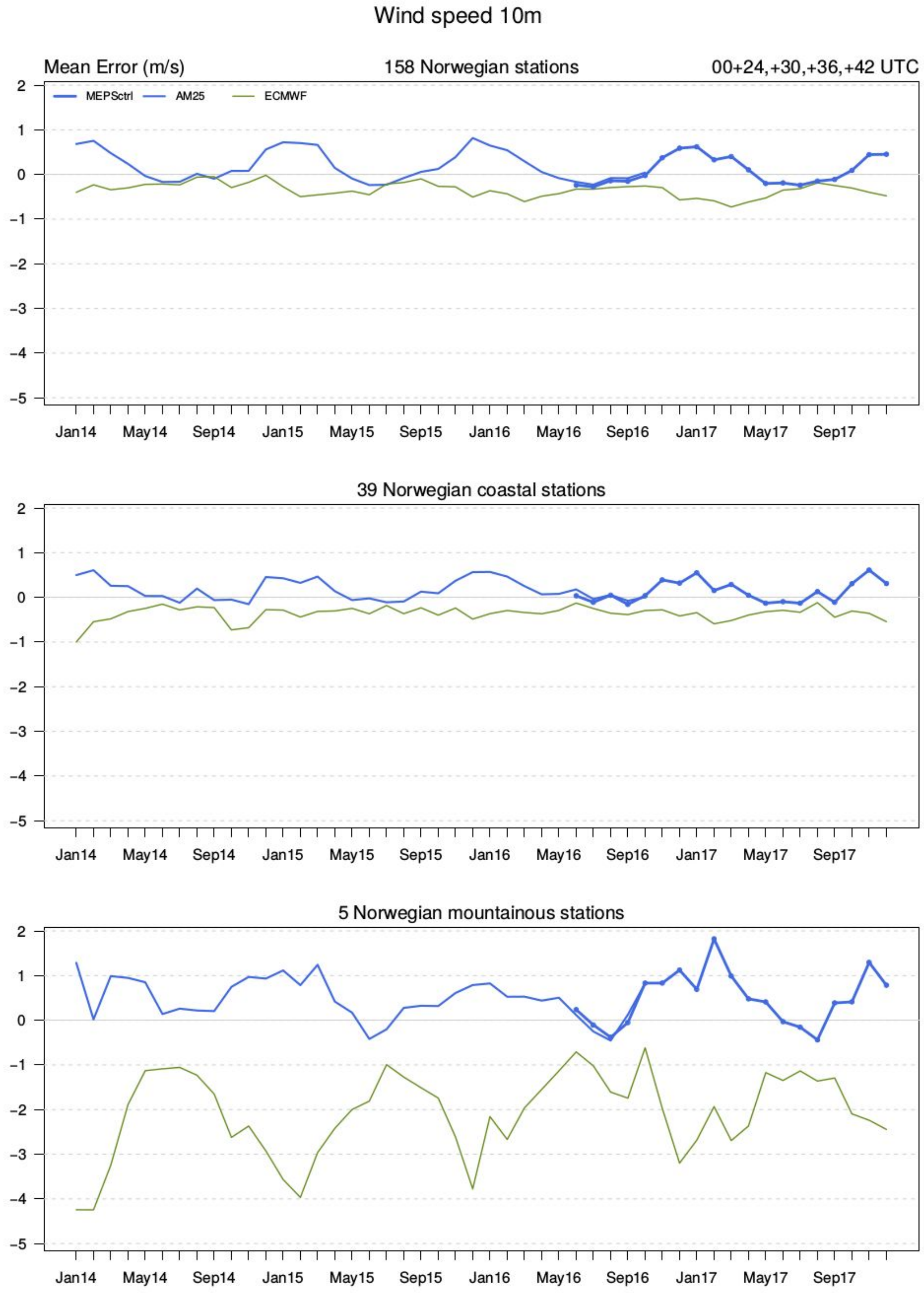

Fig.3 Monthly mean errors from October 2014 to December 2017, 00+24,+30,+36,+42 **10 m wind speed** forecasts. EC HRES (olive), MEPS-cntrl (dark_blue) , AROME_MetCoOp (blue) .

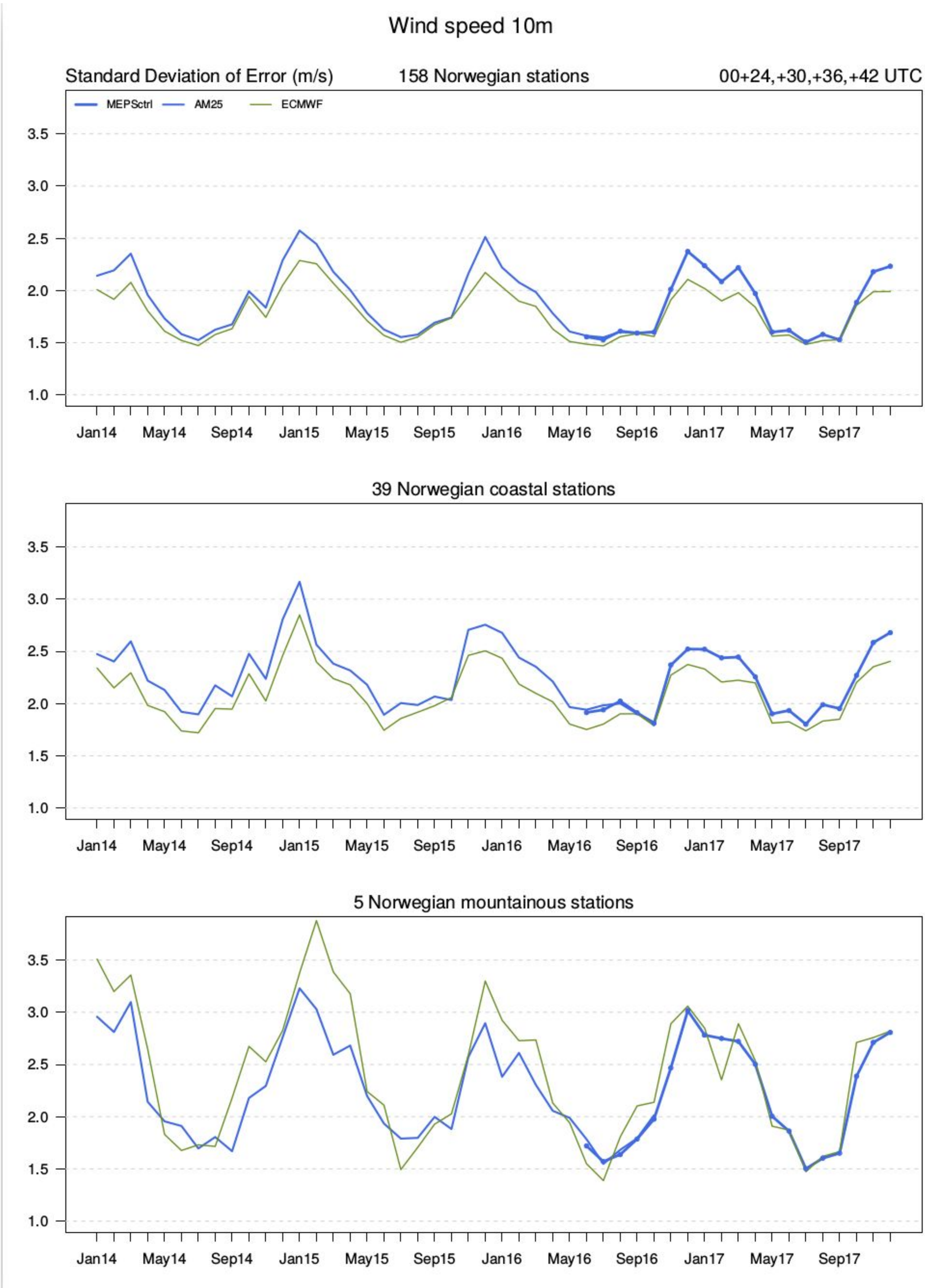

Fig.4 Monthly standard deviation of errors from October 2014 to December 2017, 00+24,+30,+36,+42 **10 m wind speed** forecasts. EC HRES (olive), MEPS-cntrl (dark_blue) , AROME_MetCoOp (blue) .

3.2.2 Case studies

October flooding, South Norway

The first weekend of October 2017 the south part of Norway saw two extreme rain events in two consecutive days. Some locations measured close to 300 mm during the two events. The results were massive river and surface flooding with extensive damage to infrastructure and private properties.

As shown in figure 6, EC HRES slightly underestimated the highest precipitation amounts, but still the wettest signal was in roughly the correct location. The highest (and most correct) predictions were from forecasts issued 1-2 days prior to the event. ECMWF EFI and SOT for Total Precipitation showed consistent wet signals 3-4 days ahead and were valuable tools in forecasting this severe rain event (figure 7).

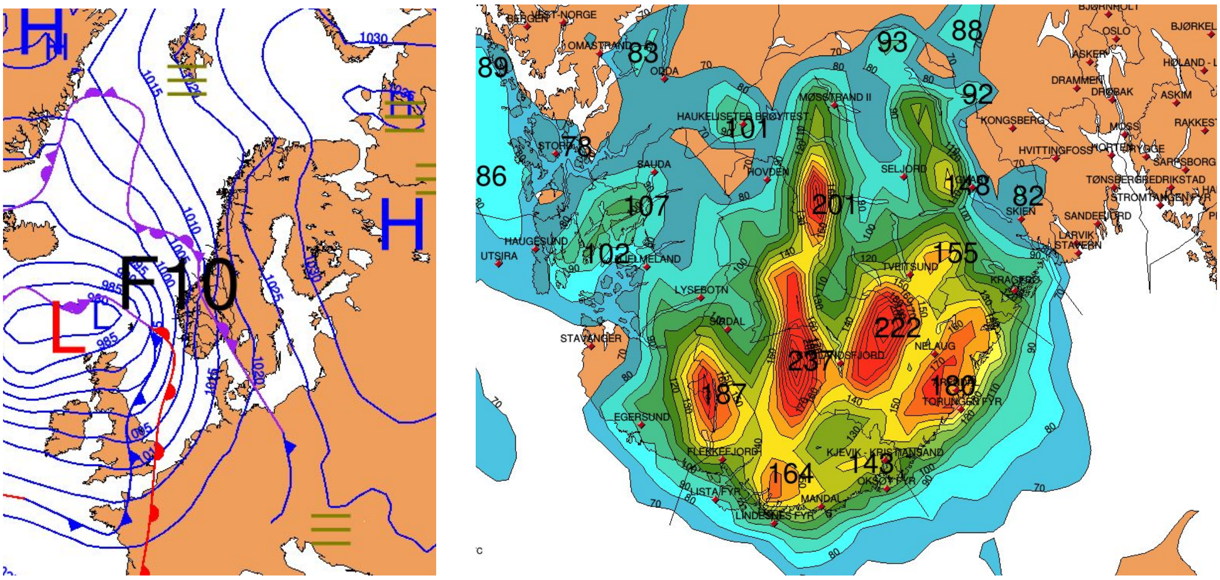

Fig.5 Left: surface analysis from 2 October 2017, showing the double fronts lined up near South Norway. Right: Precipitation from 30 September to 2 October (72 hours accumulation) as forecasted from EC HRES initiated 29 September 00Z.

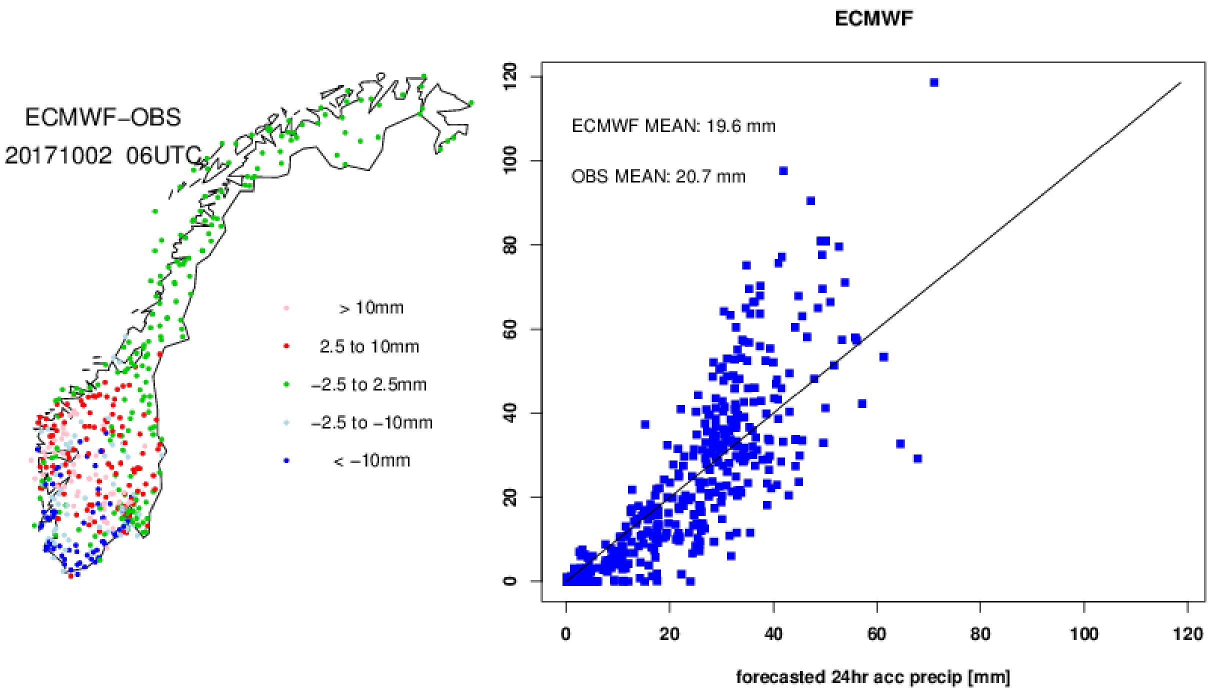

Fig.6 Left: Distribution of forecast bias. Right: Scatterplot, both comparing forecasted 24h precipitation with observations from rain gauges for the period 1-2 october. EC HRES forecast from 1.October 00Z. Similar patterns are seen for 2-3 October.

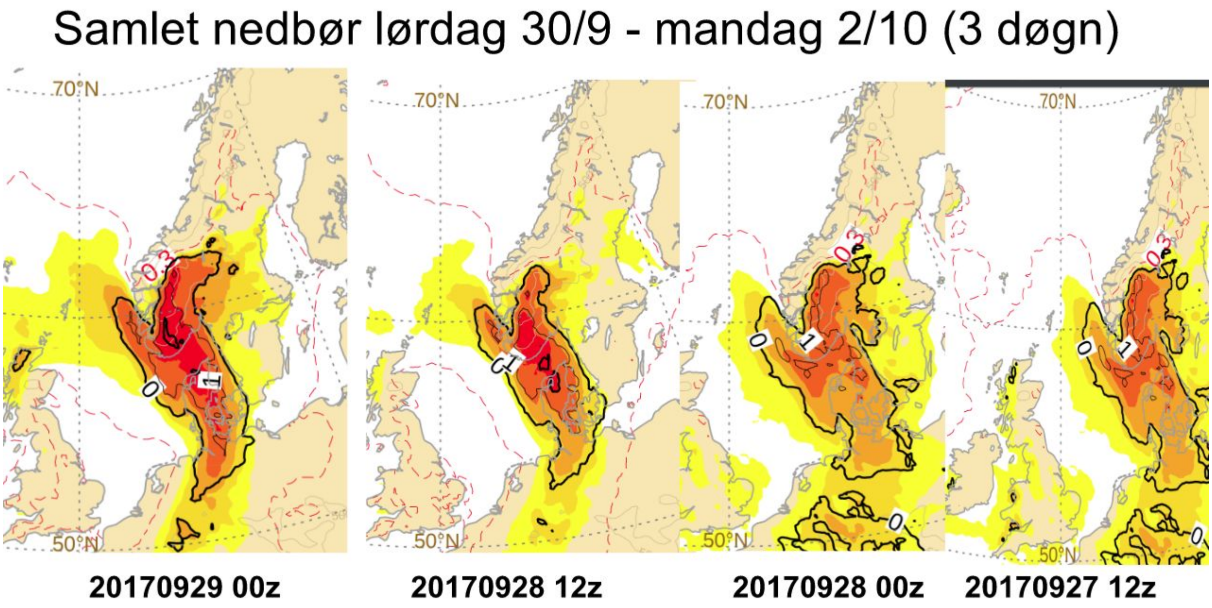

Fig.7 EFI/SOT maps of 3 day's accumulated rainfall for the period Saturday 30 September - Monday 2 October 2017. The panel shows forecasts from four consecutive ENS runs leading up to the event.

4. Feedback on ECMWF "forecast user" initiatives

The "Forecast User Portal" is still not very much used by the personnel at MET Norway, mainly because people are not aware of its existence. The new web-based "Forecast User Guide" looks promising, and already several of the forecasters have visited the User Guide for references and guidance on how to interpret the web products. The sections on EC WEB and EcCharts are excellent, but needs to be continually updated, for instance with information on vertical profiles in EcCharts. A section listing 'recently added products' would probably be a good addition to the User Guide in time, to make it easier to find & learn to use newly added functionality.

5. References to relevant publications

Homleid, M and **F. T. Tveter**, 2017: Verification of Operational Weather Prediction Models September to November 2017. http://www.met.no/publikasjoner/met-info

Gislefoss, K, et al, 2017: Nedbørhendelsen i Agderfylkene 30 september - 2 oktober 2017. http://www.met.no/publikasjoner/met-info (in Norwegian)