Application and Verification of ECMWF Products 2019

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1. Summary of major highlights

Products and data from ECMWF 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. MET Norway no longer runs any atmospheric models outside of Scandinavia, so the forecasters depend on the daily forecasts from ECMWF to see what is coming across the Atlantic, and to forecast weather past day 3. ecCharts has this year become the official backup system for the operational forecasters.
The BC project provides boundary values for MET Norway's 2 Limited Area models for the atmosphere: AROME-MetCoOp Ensemble Prediction System (MEPS) and AROME-Arctic. EC HRES and/or ENS are also driving several downstream models like dispersion models for air pollutants and volcanic ash, chemical weather forecasting, ocean state and storm surge models. Monthly and seasonal forecasts are distributed to selected customers, and used internally as a support for the forecasters on duty. Several end users are using data from ECMWF more or less directly.

2. Use and application of products

2.1 Direct Use of ECMWF Products

ECMWF products - both disseminated and on the ECMWF website - are highly valuable in operational short range forecasting and indispensable in medium range forecasting. Disseminated parameters are available to the operational forecasters in the Diana visualisation tool. HRES parameters are presented as horizontal maps, vertical profiles and cross sections, and as time series/meteograms. ENS single member parameters and probabilities are presented as horizontal fields. The ensemble spread in t2m, z500 and precipitation is also visualized as time series/meteograms.

Monthly and seasonal forecasts are used as background information by the operational forecasters. Extended range anomaly maps of 2m temperature and precipitation are distributed, with a few additional words from the forecasters, to users within the energy supply industry and flood forecasting authorities.

Multi Parameter EFI, EFI/SOT web maps
Forecasters and researchers meet twice a week to the 'Extreme Weather Outlook' 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.

ecCharts / My Dashboard has become the official backup system for the duty forecasters at MET Norway
Since vertical profiles was introduced in 2018, ecCharts contains all necessary functionality to make it a complete backup system for the duty forecasters at MET Norway. During autumn 2018 all operational forecasters have been trained in using ecCharts and creating their own dashboard at https://www.ecmwf.int/en/forecasts/dashboard. The system is easy to use, but ecCharts is sometimes a bit slow. The Dashboard function is therefore an essential part of this system.

ecCharts: Precipitation type, possibility of Freezing Rain
Based on the positive experiences from last winter, the meteogram for Precipitation Type is now recommended for use in both aviation and general forecasting for the winter season. Freezing rain is challenging for road and air traffic, and this product has shown some skill in predicting freezing rain events several days in advance.

ecCharts: Point Rainfall product
The new Point Rainfall product released in March 2019 has already proven to give reliable signals of heavy convection in Scandinavia. Combined with lightning strike probability it is becoming a popular product in situations with high convective activity. The 95 and 99 percentile of the Point Rainfall compares well with signals from the local MEPS forecasts, and also with rain gauge recordings. Forecasters welcome this product because it picks up signals up to 5 days in advance.

First glance on the New extended range (monthly) test products:
The products showed on https://confluence.ecmwf.int/display/FCST/Test+products are not yet widely known nor used at MET Norway, but they look very promising. The Medium and Extended range trajectory plots will probably be more useful during the next winter season. Also the extended range regime product seems to be a nice supplement to the anomaly maps.

2.2 Other uses of ECMWF output

2.2.1 Post-processing

Public medium range forecasts (3-10 days) for Norwegian locations, as presented on www.yr.no, are based on EC ENS. Both a consensus forecast and probabilities are generated. For Norwegian locations there is currently a statistical calibration of air temperature (at 2m), precipitation, and wind speed (at 10m).

- A quantile-quantile method is used for air temperature, with climatology from a high resolution limited area model as reference. From late 2017 an additional regression-based calibration method is implemented on EC-ENS, to deal with the large biases along Norway's intricate coastline.
- The precipitation calibration ia a combination of logistic regression and fitting of a gamma distribution. This procedure accounts for 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.

Forecasts on www.yr.no for locations outside Norway are based on ECMWF HRES with some simple altitude corrections.

2.2.2 Derived fields

The EC-ENS reforecasts have been used as input in a weather generator. The generator creates synthetic weather sequences and is used in hydropower production planning. All reforecasts made since the model upgrade in 2016 have been compiled into a large database of 15-day weather segments. These segments are joined stochastically to create arbitrarily long and arbitrarily many weather scenarios.

2.2.3 Modelling

EC HRES provides lateral boundary values for the AROME-MetCoOp Ensemble Prediction System (MEPS) and the limited area atmospheric model AROME-Arctic (both have 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.

MET Norway's regional Storm Surge forecast model (ROMS) has 51 members, each driven by surface pressure and wind stress from EC-ENS. The change from deterministic to ensemble approach made last winter has proven to give more consistent warnings for high sea surface levels along the Norwegian coast. In CMEMS, MET Norway runs the TOPAZ ocean and sea ice model, which utilises EC-HRES wind and air temperature forecasts, to produce daily updated 10-day ocean forecasts for the Arctic Ocean.

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.

The EMEP air quality model uses meteorological data from EC-HRES 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 from 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. Since 2018, MET Norway provides operationally local air-pollution forecasts at a resolution of 50m in Norway, downscaling CAMS output with MEPS meteorology and local emissions in the uEMEP model.

3. Verification of ECMWF products

3.1 Objective verification

3.1.1 Direct ECMWF model output (both HRES and ENS), and other NWP models

EC HRES does not produce sufficiently strong surface winds. The same is the case for EC ENS. Large negative 10m wind mean errors for the 5 mountainous stations demonstrate that the wind speed is too weak in mountainous regions, but the results have improved slightly since the release of IFS Cycle 41r2 in 2016. Along the coastline the wind speed forecasts are unbiased or slightly underestimated. 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 3 years, most probably as a result of the increased resolution in IFS cycle 41r2 released in March 2016.

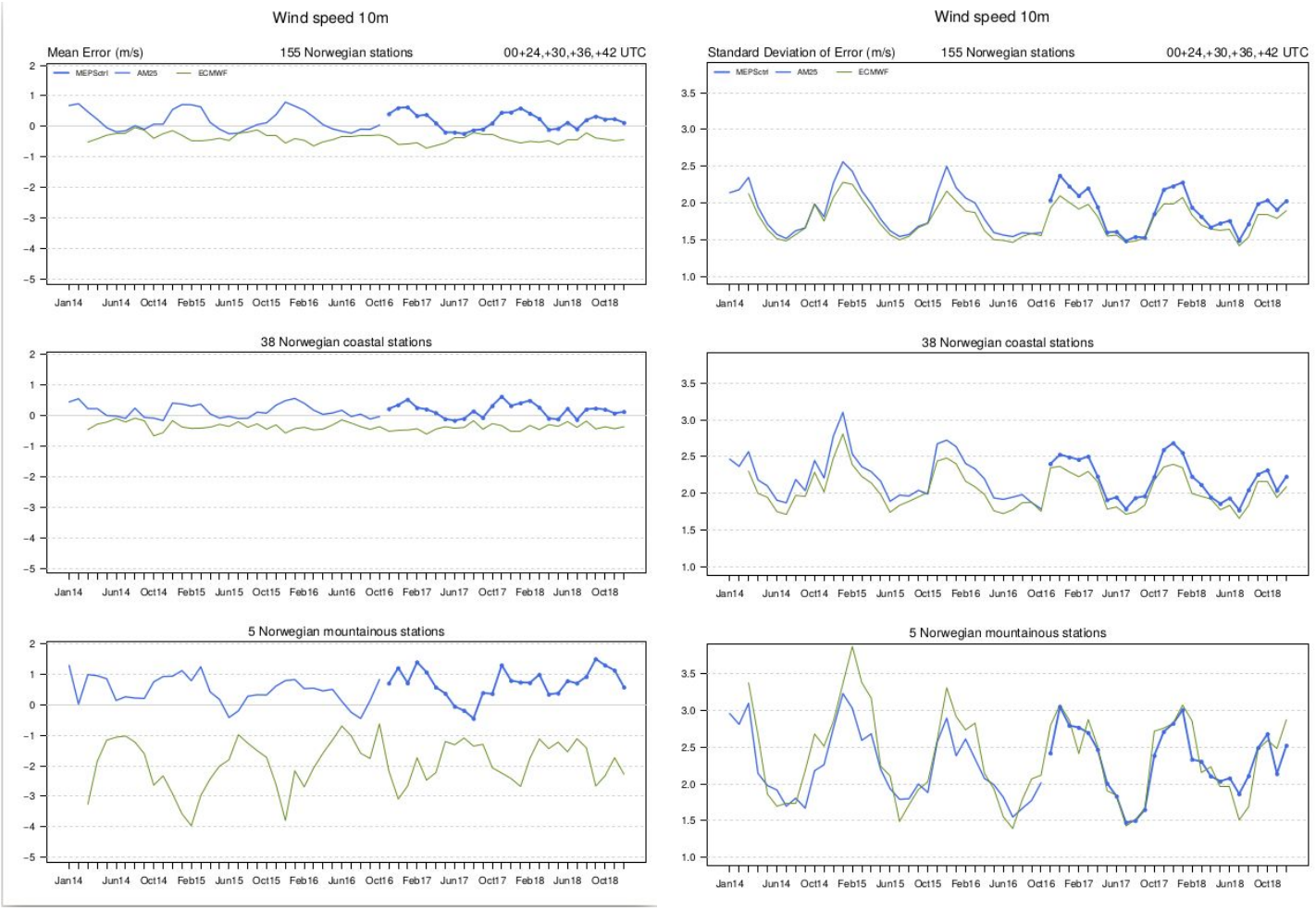

Fig.1 Monthly mean errors (LEFT) and Standard Deviation of errors (RIGHT) from January 2014 to October 2018, 00+24,+30,+36,+42 10 m wind speed forecasts. EC HRES (olive), MEPS-ctrl (dark_blue) , AROME_MetCoOp (blue)

3.1.2 Post-processed products and end products delivered to users

As can be seen in figure 2, the forecasts of 2m temperature was significantly improved with IFS Cycle 41r2 in March 2016. However, there is still a negative bias in both EC HRES and EC ENS (most pronounced inland in winter, and along the coast in summer, even though it still can get too cold in single 'fjord areas' like the area near Tromsø in winter). For end-users on yr.no, we therefore need to apply some statistical calibration on the EC-ENS temperature forecasts.

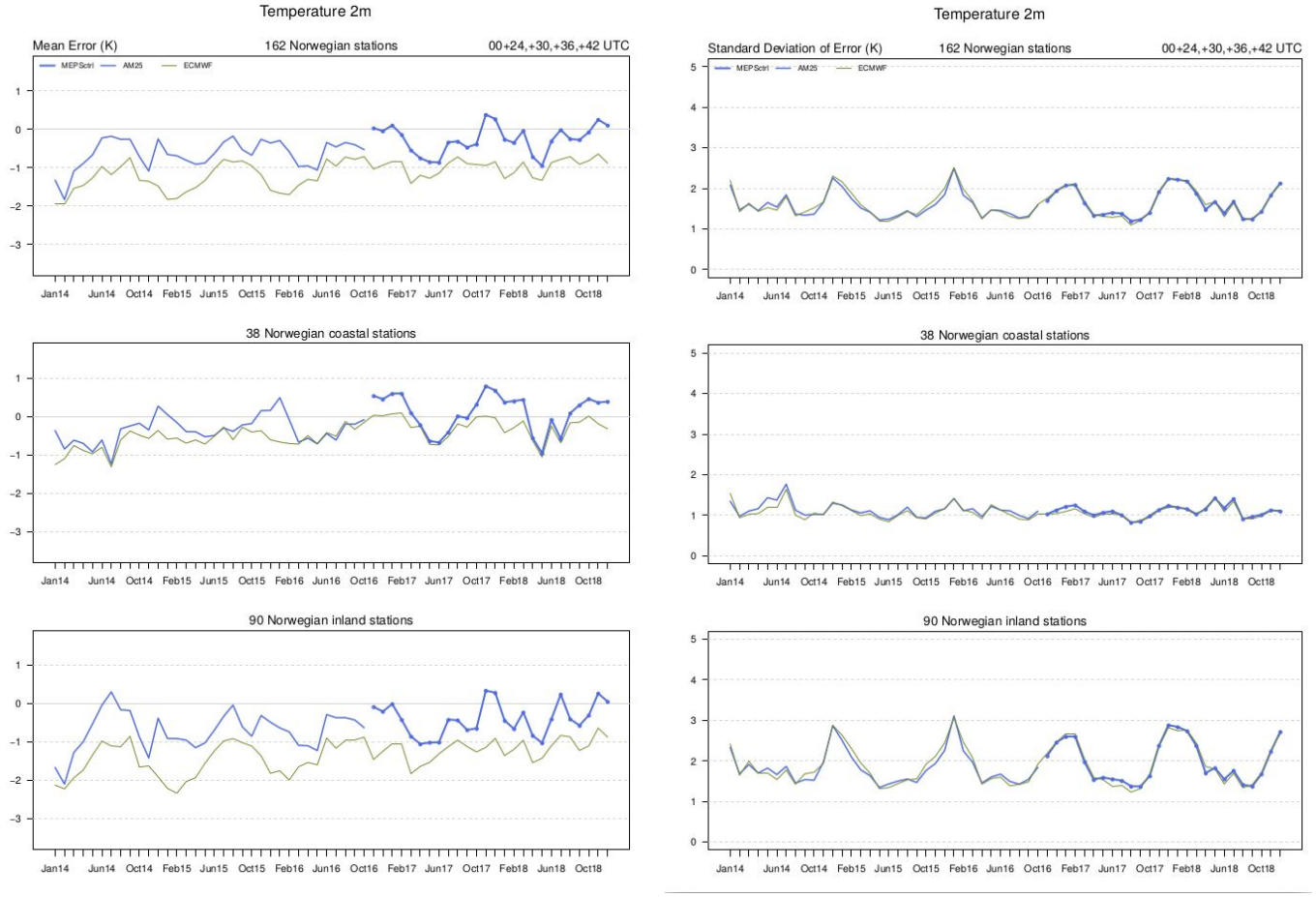

Fig.2 Monthly mean errors (LEFT) and Standard Deviation of errors (RIGHT) from January 2014 to October 2018, 00+24,+30,+36,+42 2 m temperature forecasts. EC HRES (olive), MEPS-ctrl (dark_blue) , AROME_MetCoOp (blue)

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.
- If EC-HRES is jumpy early in the forecast, EC-ENS is usually jumpy as well. This makes it hard to estimate uncertainties using EC-ENS early in the forecast period (but that is probably how the system is intended to work?).
- (Winter) Convection over sea is generally better predicted by EC-HRES than MEPS wrt horizontal extent. Forecasters also appreciate that EC-HRES shows potential showers/precipitation over larger areas over land, compared to very limited and specific horizontal extent of the showers in MEPS.
- Low clouds are generally better predicted in EC-HRES than in the local MEPS. This is especially true in situations with on-shore winds, where MEPS tends to be too dry on the coast.
- EC-HRES is over-forecasting snowfall. The fraction of snow is too high, and the horizontal extent is too large.
- 10m wind in complex terrain is seriously underestimated by EC HRES and ENS. 850 hPa wind is generally more useful.
- 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).

3.2.2 Case studies

Heavy snowfall and strong winds South Norway, 17 March 2019

The signals of an oncoming heavy weather incident were picked up by the EFI/SOT products 5 days before the incident. Action was discussed at the 'Extreme Weather Brief' on Thursday 14.march, 3 days before the incident. In this case the ensemble forecasts were exceptionally sharp and consistent, which contributed to early warnings of the Snowy Sunday.

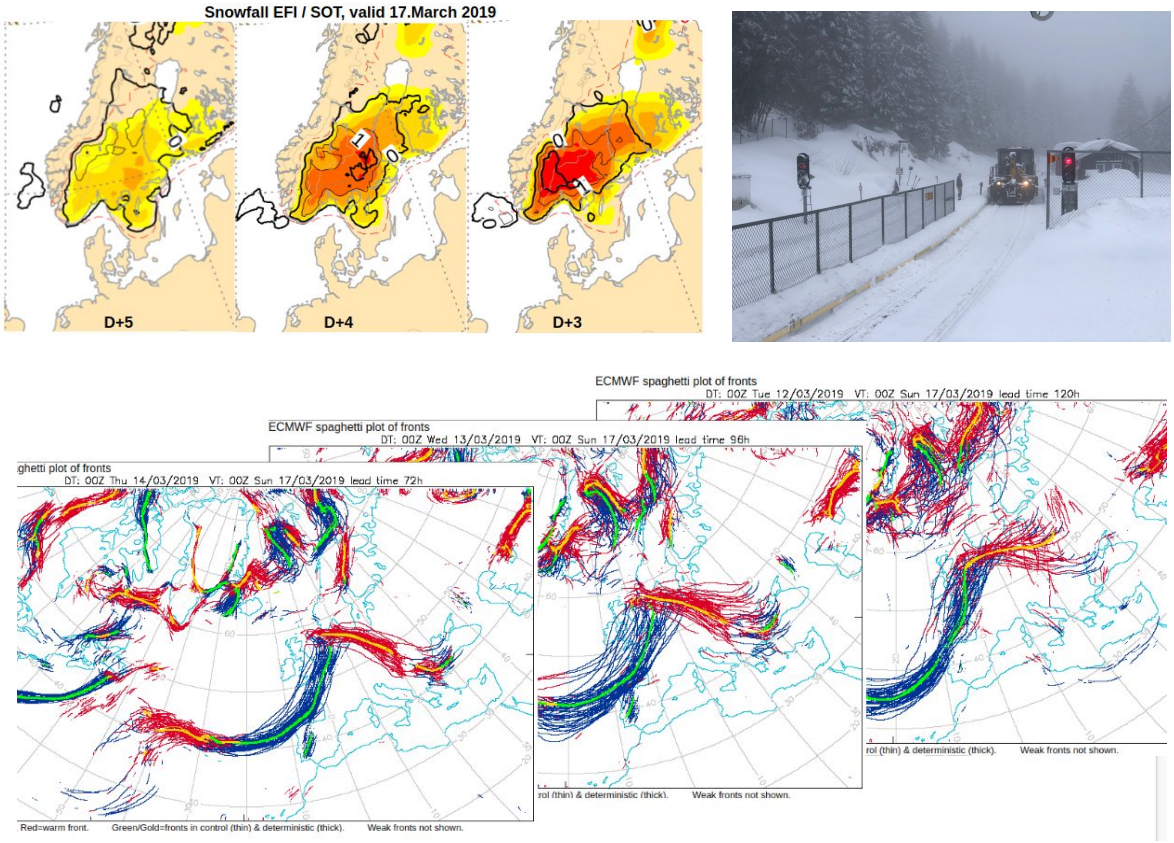

Fig.3 TOP LEFT: Increasingly higher signals in the EFI/SOT index for snowfall, from the 00-forecasts 5, 4 and 3 days ahead. TOP RIGHT: The snow caused disruptions in traffic all over South-Eastern Norway. LOWER PANEL: Front animation plots from the 00-forecasts 5, 4 and 3 days ahead of the incident. These plots are a big help for the forecasters as they efficiently visualize the spread in the ensemble.

4. Requests for additional output

EFI/SOT for IVT/ Integrated Water Vapour Transport

Hydroelectric power reservoirs play an important role in flood prevention in Norway, as the reservoirs will stall water and give sufficient room in the downstream river string to cope with any added inflow from rain and/or snow melt. It takes some days (2-5) to prepare for heavy inflow in a catchment area, as dam levels must be adjusted and any 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.

Legend on maps saved to 'My Dashboard'
When saving a map product from ecCharts to 'My Dashboard' we would like to save the legend as well. 'My Dashboard' / ecCharts is now the backup visualisation system for the duty forecasters at MET Norway, should the local systems fail. 'My Dashboard' is a very nice and efficient way to compile our most-used products, but the beautifully coloured maps are of limited use as a forecasting tool without a corresponding legend.

5. Feedback on ECMWF "forecast user" initiatives

The new Forecast User Guide has been promoted internally at MET Norway and is well known to the users of ECMWF products. It is seen as a big improvement from the previous versions, and also seems to be updated whenever necessary. Much appreciated!

The rest of the Forecast User Portal is rarely or never used by users at MET Norway.