Application and Verification of ECMWF Products 2019

Finnish Meteorological Institute – compiled by Weather and Safety Centre with help of several FMI's experts

1. Summary of major highlights

We have seen steady improvement in model performance and ECMWF data is widely used at FMI. ECMWF has improved its handling of low clouds during the past two years. ECMWF is still many times too dry in the lower atmosphere, but compared to the situation couple of years ago, these too dry situations have become more and more rare. ECMWF has shown its greatest improvements in low pressure situations. In the past, the model had often too high cloud base heights in the old dissipating low pressure centers. The greatest weakness of ECMWF in aviation forecasting is forecasting of (radiation) fogs and handling of visibility output in general. However, in subjective verification done in Kuopio regional office, ECMWF was often the best model in aviation forecasting during February, March and April 2018.

ECMWF still has problems with cold temperatures and the diurnal variation related to T2m during spring/summer. High wind speeds are also underestimated. Similar problems can be seen in ENS probabilities. Gusts over lakes during winter (stable situation) are too weak. In addition rain areas are too wide and some "jumpiness" can be seen between 00 and 12utc model runs. Weekly forecasts tend to be too similar with current weather

2. Use and application of products

2.1 Direct Use of ECMWF Products

ECMWF products are widely used in our weather service, research side and by our customers. ECMWF deterministic and ENS products are utilised in our forecasts. ECMWF data is also used as boundary conditions for Hirlam/Harmonie. The ice services in FMI uses ECMWF extended and long-range forecasts of sea ice in operative manner to predict sea ice extent in the Baltic Sea.

2.2 Other uses of ECMWF output

2.2.1 Post-processing

European forecasts outside of the Scandinavian region are mainly based on raw ECMWF data except for T2m which is MOS-calibrated (Model Output Statistics), height-corrected and land-sea interpolated. Also precipitation type is postprocessed from ECMWF fields and adjusted using MOS 2m temperature. Global forecasts outside of European region are mainly based on raw ECMWF data except for the 2m temperature, where some corrections have been made.

3. Verification of ECMWF products

The deterministic ECMWF is overforecasting the low wind speeds slightly (fig. 1). For high wind speeds the model is underforecasting in total. The negative bias for high wind speeds during winter can roughly be estimated to be about 5m/s. Wind gusts (fig 1) are mainly overforecasted, but the strongest gusts are underforecasted. There's also a diurnal bias in wind speed forecasts, where night-time winds are in general overforecasted and daytime often underforecasted.

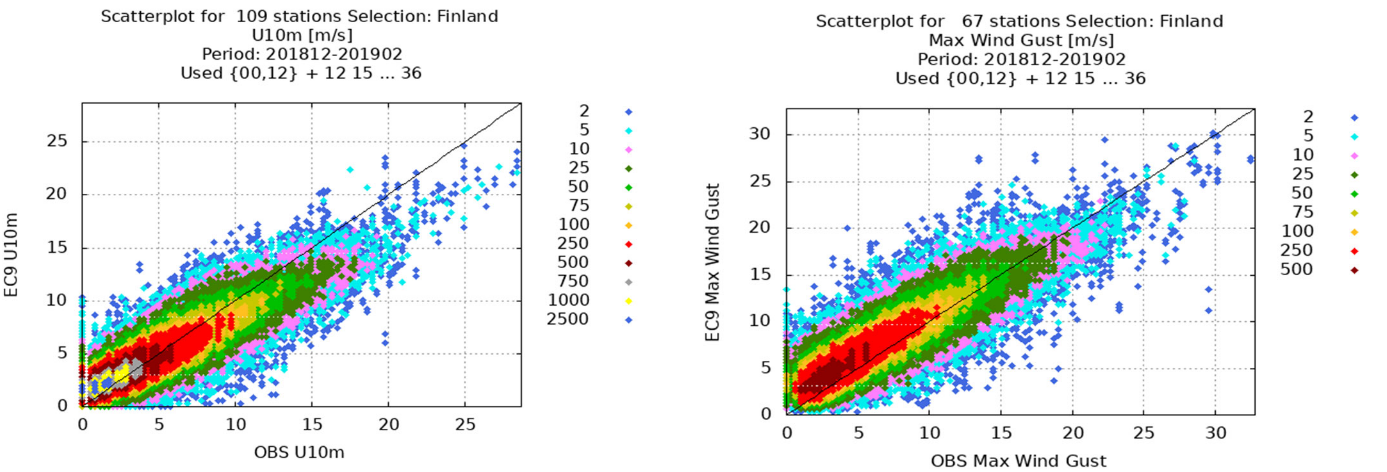


Fig 1. Scatterplots for 10m wind speeds on left and Max wind gust [m/s] on right for Finnish observation stations in winter DJF 18/19 and for leadtimes 12...36h.

There is a significant warm bias in T2m forecasts in very cold temperatures during winter in Finland (Fig 2). This is a significant problem in our northern climate where very cold temperatures are frequently measured. Warm bias in T2m is often related to shallow and strong surface inversions which ECMWF is unable to forecast to be strong enough. Statistical postprocessing (MOS) is improving ECMWF T2m forecasts, but the warm bias in cold temperatures still exists during winter. More information about this in the section below. The visibility is often forecasted to be better than observed (Fig 2) and fogs are frequently missed in model forecasts.

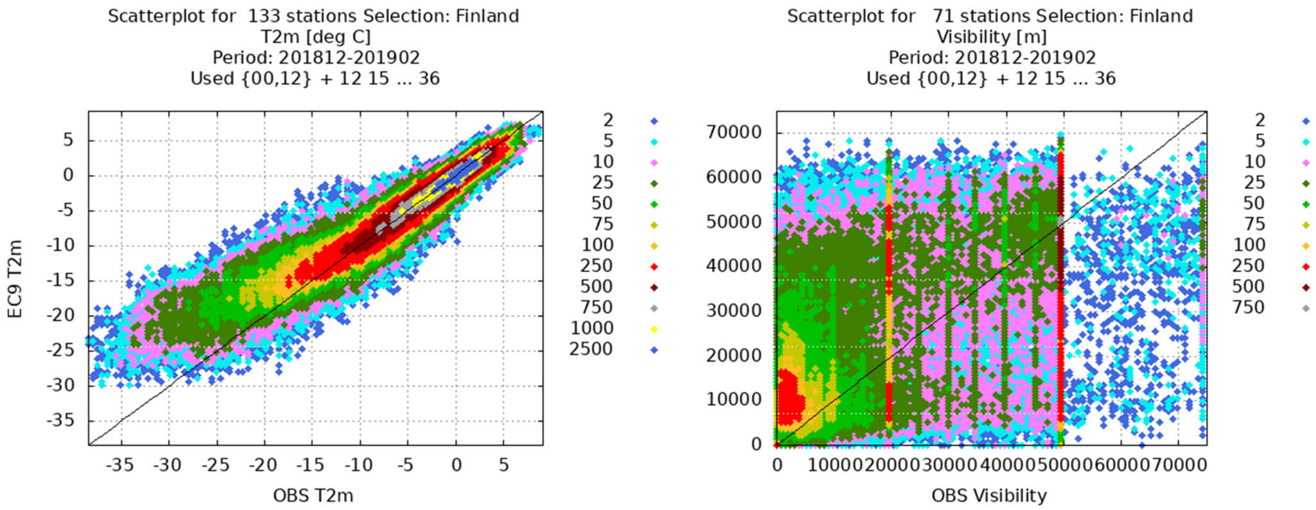


Fig 2. Scatterplots for T2m [Celsius] and visibility [m] during winter DJF 18/19 for ECMWF and leadtimes 12...36h.

A master thesis was done to study the possible relationships between model variables and the forecast error in T2m. Density plots for model data collected from 5 previous winters and for southern, central and northern Finland separately from relative short forecast leadtimes (<48h) were plotted for 5 different bias categories seen in fig. 3. The yellow curve indicates that the forecast has been "good enough" and the error is ±5 degrees. The red colours indicate the model overforecasting temperatures >5 degrees. Model overforecasting the T2m was most usual error during wintertime and it was most frequent in northern Finland where the coldest temperatures are measured. For most variables there wasn't a clear distinction in bias categories to be seen in density plots, but some features could be found. In fig. 3 are some results for southern Finland where it can be seen that when model overforecasts temperatures the 10m wind speeds are low and the T950hPa is very cold, but for the skin temperature the curves mainly overlap and most profound is the yellow curve that indicates relatively good forecasts. The coldest skin temperatures are forecasted for the cases when the model tends to underforecast also the 2m temperatures.

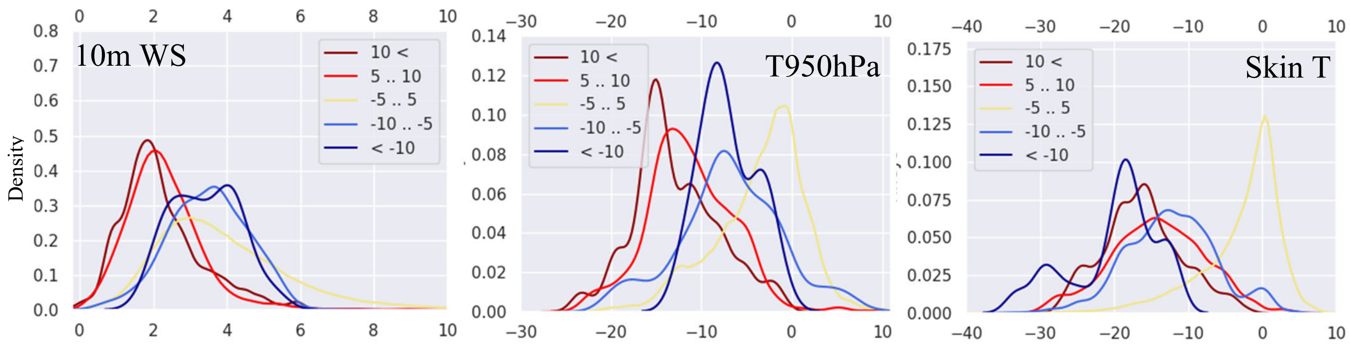


Fig 3. Density plots for 10m wind speed, temperature at 950hPa and the skin temperature for 5 different bias categories, where blue curves indicate model underforecasting and the red curves indicate model overforecasting T2m. The results are for southern Finland.

3.1 Objective verification

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

Ensemble verification

FMI has LAM-EPS system MEPS in collaboration with other countries. MEPS has 10 members, horizontal resolution of 2.5km, calculation area is roughly Northern Europe and it uses ECMWF data for boundary conditions. In general MEPS is better compared to ECMWF EPS in temperature, wind forecasts and often for precipitation (Fig. 4). ECMWF was better in humidity forecasts during April, because MEPS had strong spring time bias.

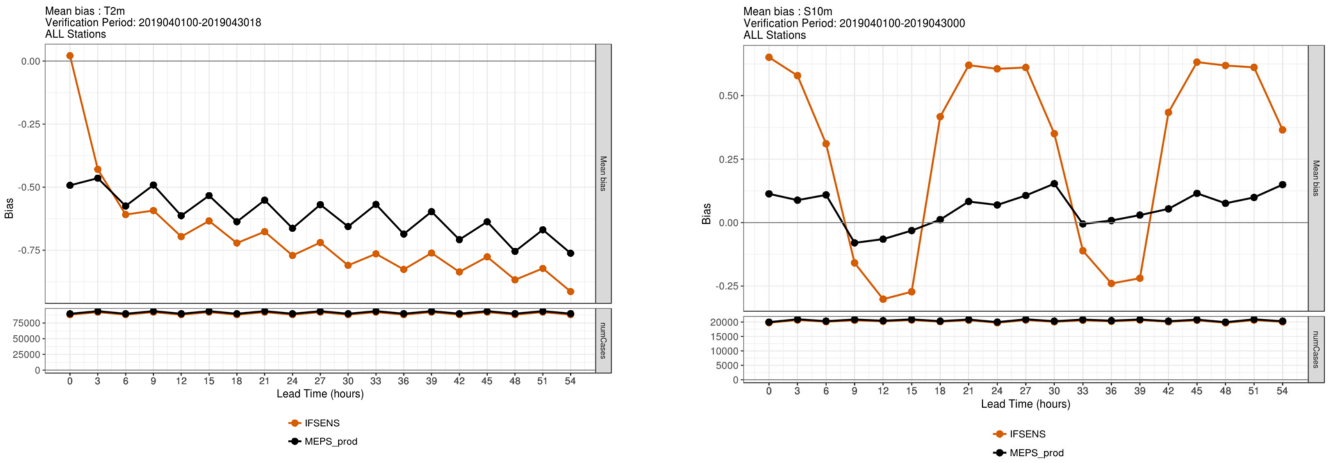


Fig 4. Mean bias for T2m [Celsius] and wind speed [m/s] in April 2019 for MEPS (black curve) and ECMWF EPS (brown curve). Results are for Northern Europe

3.1.2 Post-processed products and end products delivered to users

The calibration of ECMWF ensemble forecasts (temperature and wind) have been tested and used within the EU-project I-REACT, and now FMI is starting to use operational calibration for ECMWF-ENS temperature forecasts. The calibration methods that are used are Gaussian distribution for temperature and Box-Cox t-distribution for wind speed forecasts. Calibration coefficients are calculated using data from all European stations from past 30 days, and coefficients are updated once a week. Separate values are estimated for each lead time and analysis time. In addition to ensemble mean and standard deviation, the station/model elevation is used as predictor in calibration model.

Verification results indicate that calibration method that we have used improves ensemble forecasts on the average over the calibrated area but locally there might be areas where calibration reduces the forecast skill. Figure 5 shows the verification results (Spread and Skill) at Finnish stations for raw and calibrated T2m forecasts in April 2019. The calibration corrects the underdispersion of ensemble forecast quite well and improves also the RMSE at all lead times. Figure 6 shows that in January 2019 raw ECMWF-ENS temperature forecasts have large positive bias in Northern Sweden and Finland (overforecasting of very cold temperatures). Calibration improves the model bias over the calibration area on average but in Northern part the bias is even larger after calibration (Fig. 6 right). We have concluded that when dispersion or bias errors are systematic over the Europe, our calibration method is able to improve ensemble forecasts.

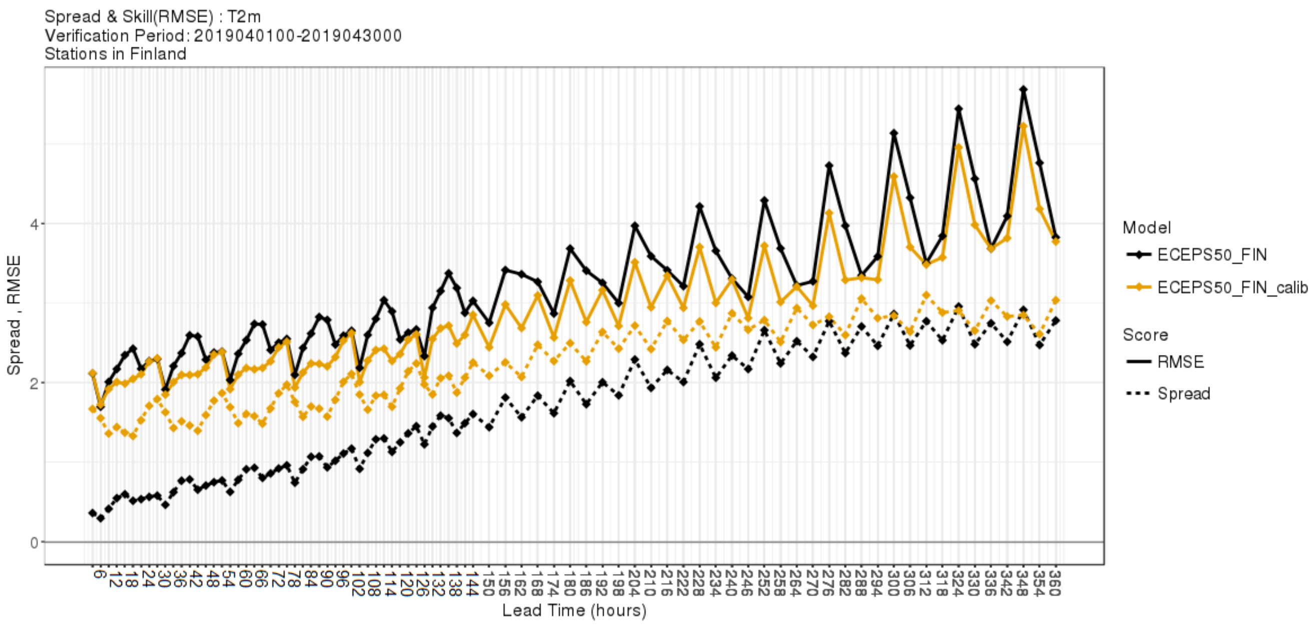


Fig 5: Spread and skill (RMSE) for temperature forecasts at Finnish stations in April 2019

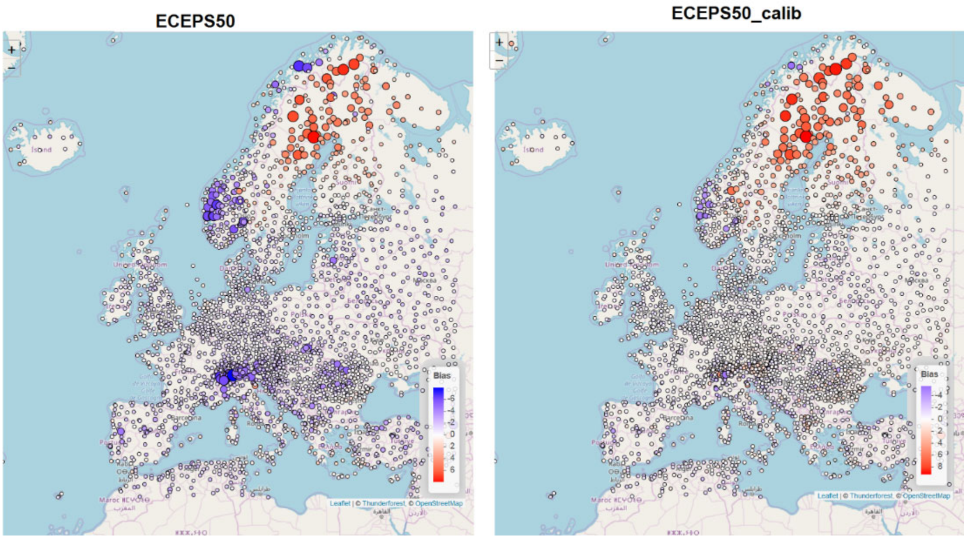


Fig 6: Station based mean bias for raw (left) and calibrated (right) temperature forecasts in January 2019. (Note that scale differs between figures.)

3.1.3 Monthly and Seasonal forecasts

The ERF forecasts of the sea ice extent at the Baltic Sea show predictive skill but seem to have a problem with the initial condition. The analysis of satellite images that is, in a winter time, daily made by ice experts gives a substantially larger ice extent than the week 1 sea ice extent of the forecasts (Figure 7). This leads to the whole 6-week forecast staying well below the real ice extent. This issue could be avoided by using more accurate observed sea ice concentration and extend information for initial conditions, such as FMI-BAL-SEAICE that can be obtained from CMEMS service (product *SEAICE_BAL_SEAICE_L4_NRT_OBSERVATIONS_011_004)*.

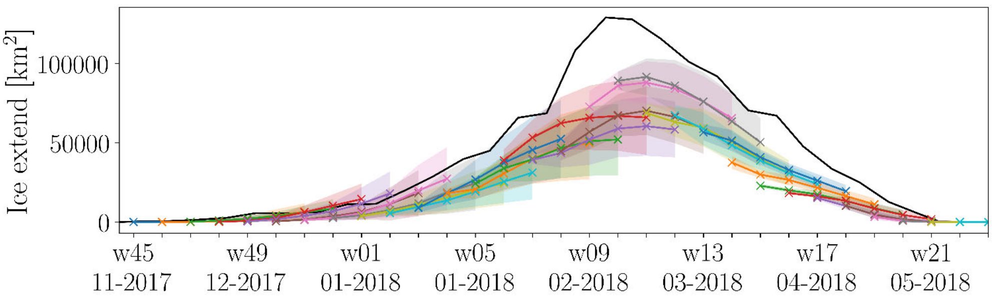


Figure 7. Weekly mean of sea ice extent at the Baltic Sea in winter 2017-2018 as analysed from satellite data (black line) and forecasted by the ERFs (colourful lines with ensemble spread).

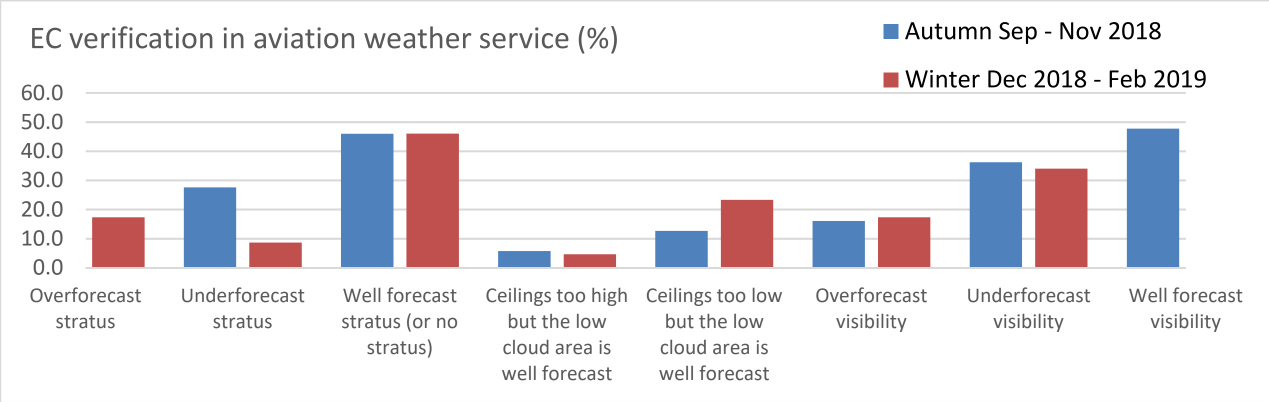
3.2 Subjective verification

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

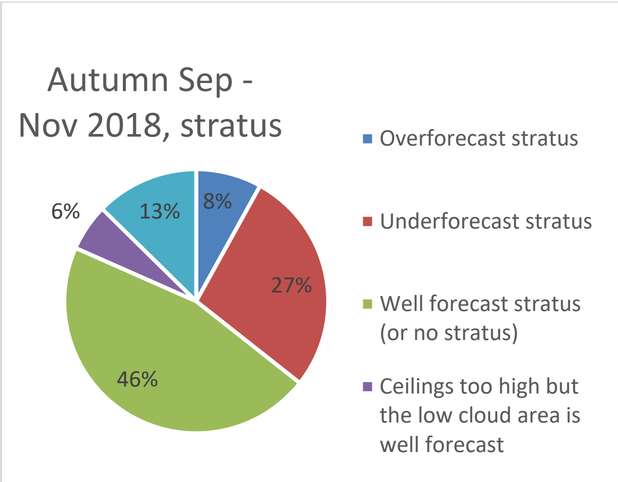
In this analysis, the model's success with stratus and (FMI postprocessed) visibility are compared to observations (METARs and AUTO-METARs) is reviewed. This verification summary is based on daily subjective verification performed by the aviation forecaster on duty at one timestep (04Z). The forecast lead time is 24 hours in this analysis.

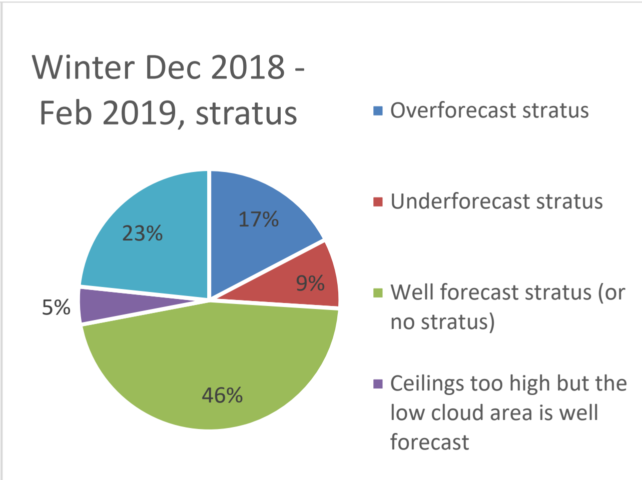
In the following results, success with stratus has been divided into five groups and for visibility there are three groups as explained below. Finland has been divided into northern and southern part and the stratus and visibility are reviewed separately for both parts. Verification has been analysed separately for winter and autumn.

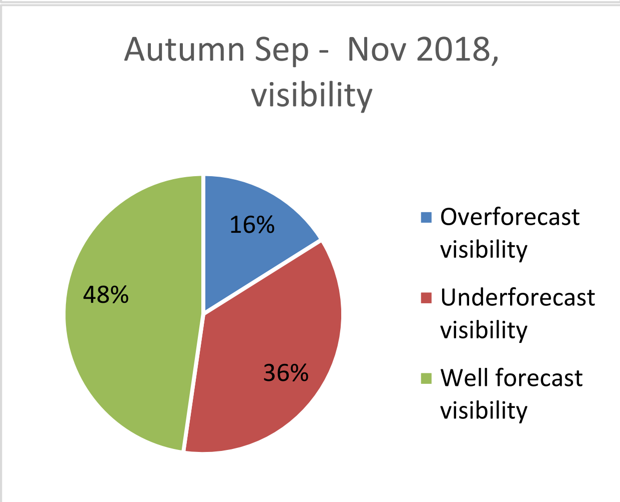
Results:

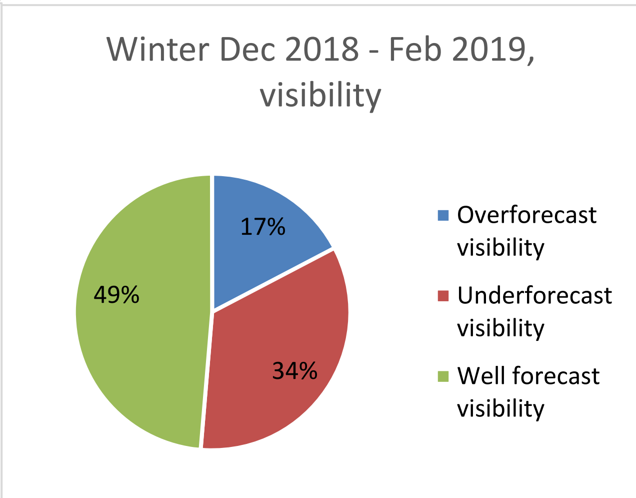


- About 45-50 % of the cases were well forecasted for both stratus and visibility
- In the autumn the model underforecasted (=too few) stratus and during wintertime overforecasted (=too much) it
- For visibility there wasn't much difference between autumn and winter. About 35 % of the time the model has too low visibilities.









ECMWF performance related to severe weather

The overall ECMWF performance regarding deep moist convection is rather good. Most of the time ECMWF seems to provide quite balanced forecasts regarding the main ingredients for thunderstorm development. Generally BL moisture seems to be the trickiest one as it often shows large variability between different NWP models. EMCWF performs generally quite well, but shows a slight tendency to overly dry BL compared to observations. Too dry BL moisture forecasts are most usually seen during spring time.

ECMWF's convective precipitation forecasts are not very good and they often show overly large areas of precipitation compared to reality. The model is unable to forecast the motion of convective features, which stands out especially in strongly sheared situations where thunderstorms move very fast, sometimes even quite far downstream from the precipitation area indicated by the model. Precipitation forecasts in elevated convection are difficult for ECMWF

In highly unstable situations these kind of problems can sometimes affect even the next day forecasts. Long-lived and large mesoscale convective systems can produce very large area of precipitation and cloudiness that could survive for the next day and cause large errors to for example temperature forecasts. MCS:s of this scale can have noticeable effect even to synoptic scale weather situation. In principle, it should be possible for a global model (and ECMWF) to catch up with MCS's and their effects of this scale (spatial and temporal).

These above mentioned issues are of course mainly related to normal characteristics for a global hydrostatic model which do not resolve deep moist convection, but uses parameterization instead. This is something that every forecaster should know in order to use ECMWF wisely and efficiently in deep moist convection forecasting. Better forecasting results can be achieved by ingredients based approach rather than using heavily parameterized parameters like convective precipitation intensity.

3.2.2 Case studies

Spring temperatures

During end of April we noticed that ECMWF had significant problems with too cold day temperatures especially in the eastern Finland and Lapland (example from eastern Finland in Fig.8). We have been speculating the reason for this: is it e.g. because of the colder climate in the east or this year's fast spring development? One thing that might also have a role is snow observations' impact to the model. E.g. during this observed situation snow depth dropped from 30cm to 0 cm during the period of 23.-29.4.2019 in Joensuu. However we know that during spring even when the observation shows 30cm it means that e.g. fields and all open areas are snowless, so could this have a "cold" impact to the forecast?

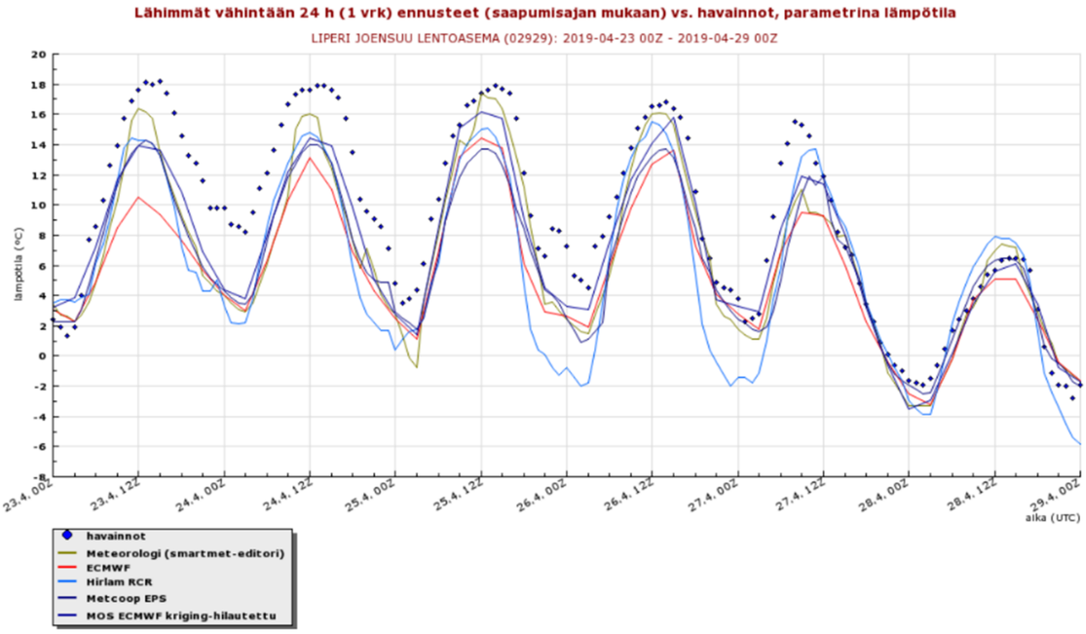


Fig 8. Example of too cold temperatures 22.-29.4.2019 in Liperi, Joensuu (eastern Finland). Dots: observations, Green: meteorologist, Red: ECMWF, Lightest blue: Hirlam RCR, Darkest blue: MEPS, Blue: Kriging interpolated MOS corrected ECMWF