Application and verification of ECMWF products 2017

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

1. Summary of major highlights

FMI's forecasts are mainly based on ECMWF. In short term forecasts we also use other models together with ECMWF such as HIRLAM and HARMONIE. We are generally very satisfied with ECMWF model and products. During the past years' we have been reporting about a few issues which have been more or less persistent from year to year, both related to 2m temperature forecasts. First is negative bias in spring especially in evenings and the other is overforecasting during cold spells. These problems still exist and are mainly related to our northern location and relatively cold climate.

2. Use and application of products

FMI's forecasts are strongly based on ECMWF deterministic and ENS products. ECMWF data is also utilised as boundary conditions for HIRLAM/HARMONIE/(in autumn MEPS with Met.no & SMHI) which are run at FMI. Usage and demand of monthly and seasonal forecasts is slowly increasing by energy customers, media and general public. Monthly and seasonal products are mainly based on ECMWF.

2.1 Post-processing of ECMWF model output

Currently forecasters' role in our production system is significant in the Scandinavian region where forecasters are postprocessing the data by making model selection(s) and necessary adjustments to model fields. European forecasts outside of the Scandinavian region are mainly based on raw ECMWF data except 2m temperature is MOS calibrated and land-sea interpolated. Global forecasts outside of European region are mainly based on raw ECMWF except the 2m temperature is Kalman corrected or calibrated by height correction and land-sea interpolation.

2.1.1 Statistical adaptation

FMI is strongly developing statistical calibration and post-processing systems. At the moment, ECMWF 2m temperature forecasts are operationally calibrated as described above. MOS calibrated ECMWF data has been in operational use in the European region since January this year. Station-specific MOS forecasts are based on a linear regression with nine predictors without predictor screening, with a four-year training period between December 2011 and September 2015. Station-specific MOS forecasts have been gridded using LAPS and from June 2017 onwards Kriging-method. The results so far have been very good (Fig 1).

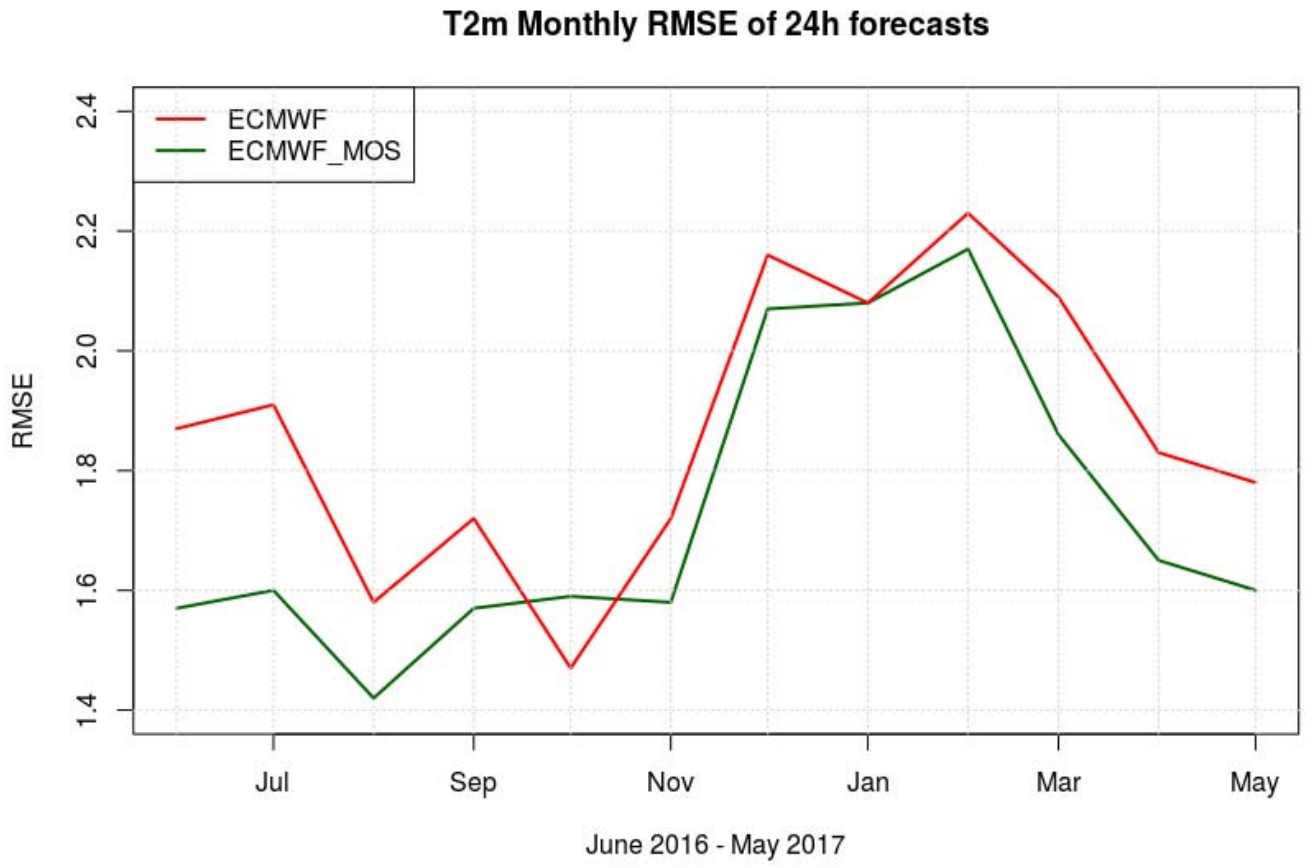

Fig 1. 24h 2m temperature forecasts' RMSE (00 and 12 UTC runs) in 30 inland weather stations in Finland.

2.1.2 Physical adaptation

ECMWF data is also utilised as boundary conditions for limited area models HIRLAM, HARMONIE which are run at FMI, dispersion and trajectory models, hydrological models (run by Finnish Environmental Institute), road condition models and wave models.

2.1.3 Derived fields

ECMWF data is used to calculate parameters that the model doesn't provide by itself e.g. probability of precipitation, probability of thunder and numerous parameters related to aviation weather.

2.2 ECMWF products

2.2.1 Use of Products

Concerning severe weather situations various ECMWF products are utilized. Based on the deterministic runs atmospheric stability indices are calculated as a part of the post-processing routines at the FMI. Moreover, the FMI meteorological workstation allows writing short scripts which enables the generation of the derived forecasting parameters (wind chill index, probability of thunder etc.).

In addition to short-range forecast ensembles ECMWF ENS products are utilized frequently. Temperature, precipitation, wind gust and CAPE ENS distributions are among the most used products. The EFI products have been found valuable in the forecasting of hazardous and harsh weather conditions around the globe when forecasters are less familiar with the local climate.

3. Verification of products

Verification information is used to monitor the quality of forecast and also to improve our forecasts.

3.1 Objective verification

The quality of FMI's weather forecasts are systematically validated. Official scores reported to the ministry of transport and communications are T2m forecast hit rate for one day and 2-5 days, predictability of precipitation based on SEEPS score and verification of wind warnings based on ROC. Besides the official scores, verification data from different data sources is widely used by weather forecasters and researchers. FMI´s verification interface gives a possibility to assess the quality of different model data and further compare different data sources

3.1.1 Direct ECMWF model output (both HRES and ENS)

ECMWF model update to version 43r1 was expected to bring significant improvements especially to 2m temperature forecasts. Forecasters have noticed some positive impact occasionally but it has not been enough to tackle all winter situations. Based on the verification results the impact is not so evident.

As mentioned earlier, during cold spells and stable conditions ECMWF has still had problems forecasting surface inversion and therefore ECMWF overforecasts 2m temperatures. Most of the winter time temperatures are in the range that are rather well forecasted by ECMWF (-15…+5 degrees), but when it's colder, model can have large forecast errors.

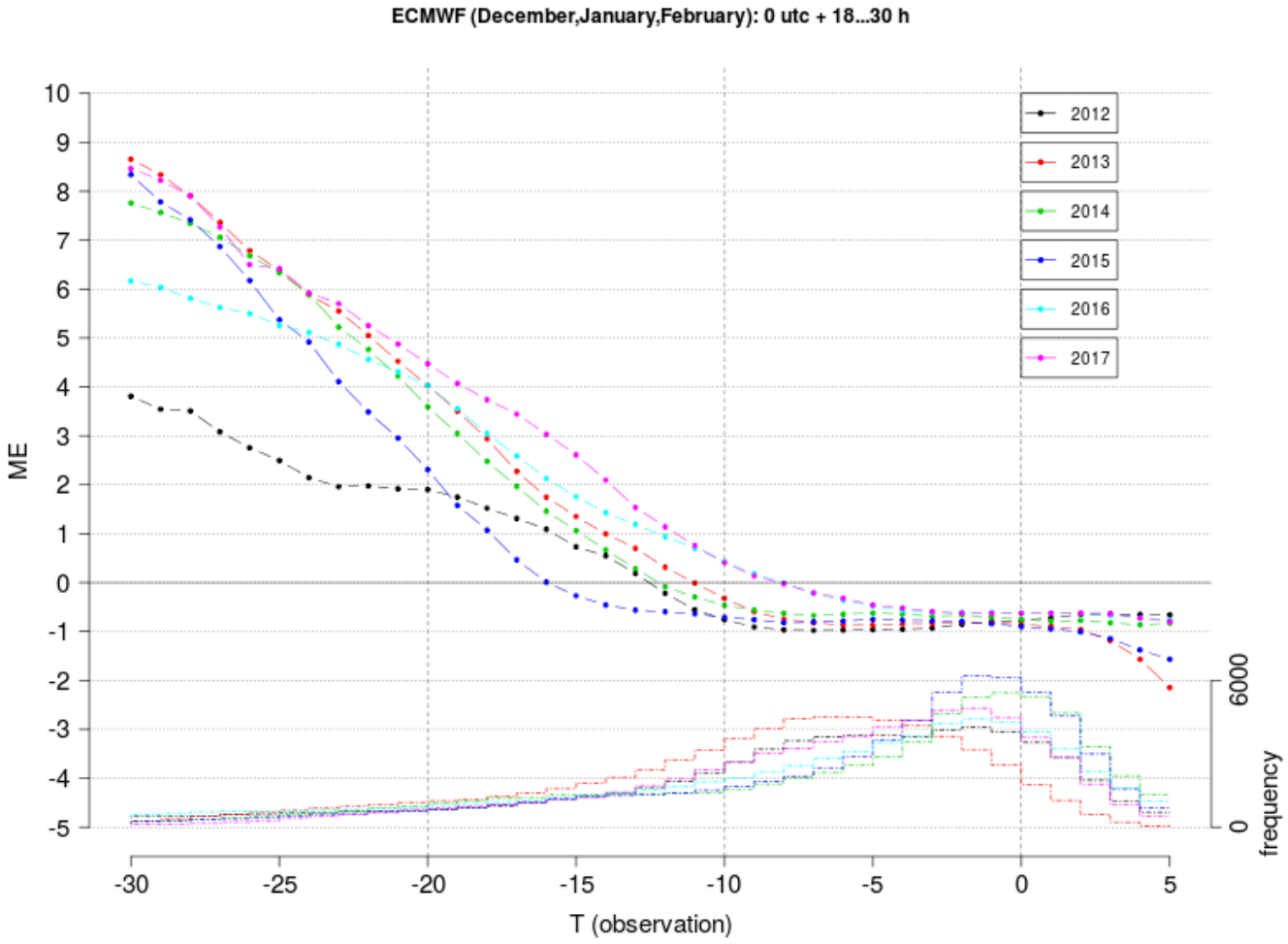

Fig 2. Mean error of 2m temperature as a function of observed temperatures (dotted lines) and amount of observations (below).

During spring ECMWF has still had negative bias in 2m temperature forecasts especially in the evenings. However this situation has gotten better from previous years but is still noticeable. This is a significant problem also for our end users, for example, Finnish Environmental Institute (SYKE) uses ECMWF products in their hydrological models to calculate flood risks. During spring time, when snow is melting, too cold evening temperatures means that flood probabilities are significantly underestimated. Our MOS calibrated ECMWF is much better in these situations.

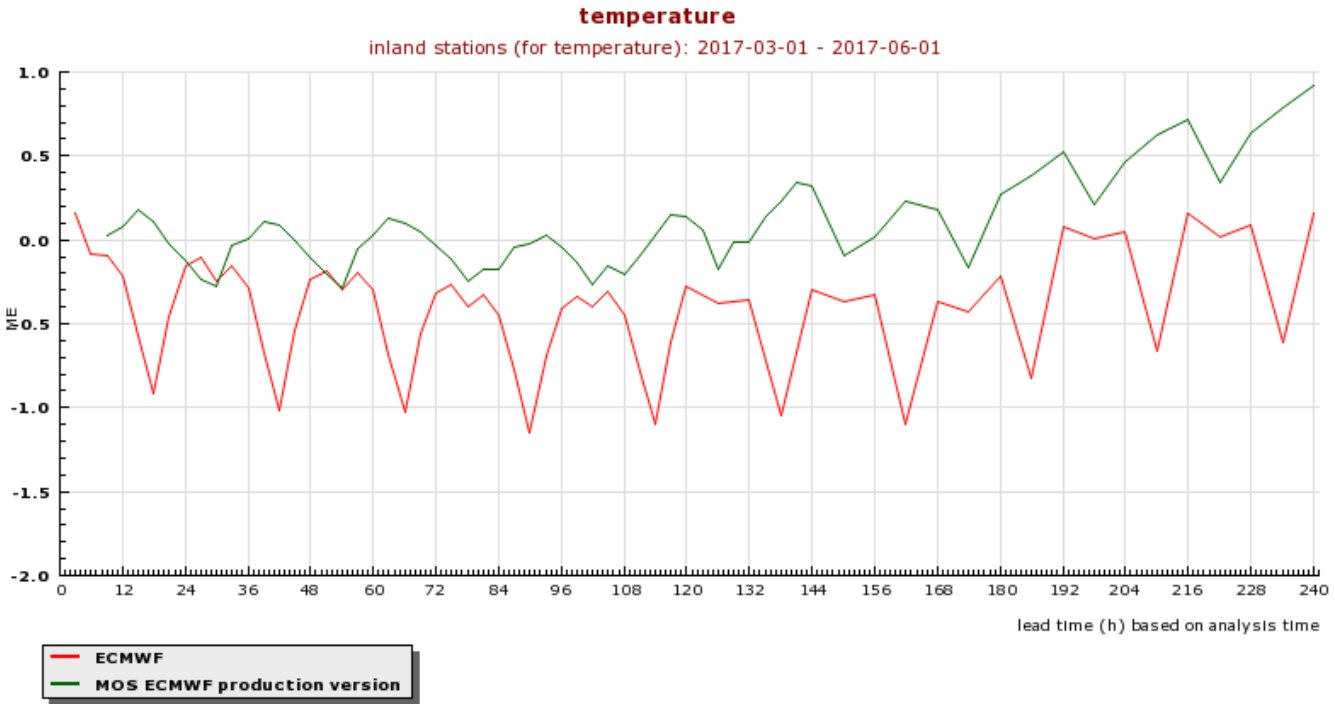

Fig 3. Mean error of 2m temperature of 00utc analysis times of spring as a function of forecast length for ECMWF (red line) and MOS calibrated ECMWF (green line) shows how MOS is able to correct the cold evening bias.

3.1.2 Post-processed products

We have started to calibrate ECMWF ensemble forecasts using 30 days training period for whole European domain (not yet operational). The method that has been used to make the calibration was the Gaussian distribution for 2 meters temperature, and the Box-Cox t-distribution for wind speed. Ensemble mean, standard deviation, and station/model elevation are used predictors in calibration equations.

Verification results (RMSE and spread) are shown in figures 4 and 5 for both raw and calibrated ensemble forecasts at Finnish stations. Calibration coefficients are calculated using data from all European stations during 30 days. At shorter lead times it can be seen that ensemble forecasts are underdispersive and calibration improves spread to be more equal to RMSE in both temperature and wind speed forecasts. Though, RMSE score is almost the same for calibrated ensemble forecasts than for raw forecasts, and for temperature forecasts when lead time is over 180 hours calibration actually worsen the RMSE.

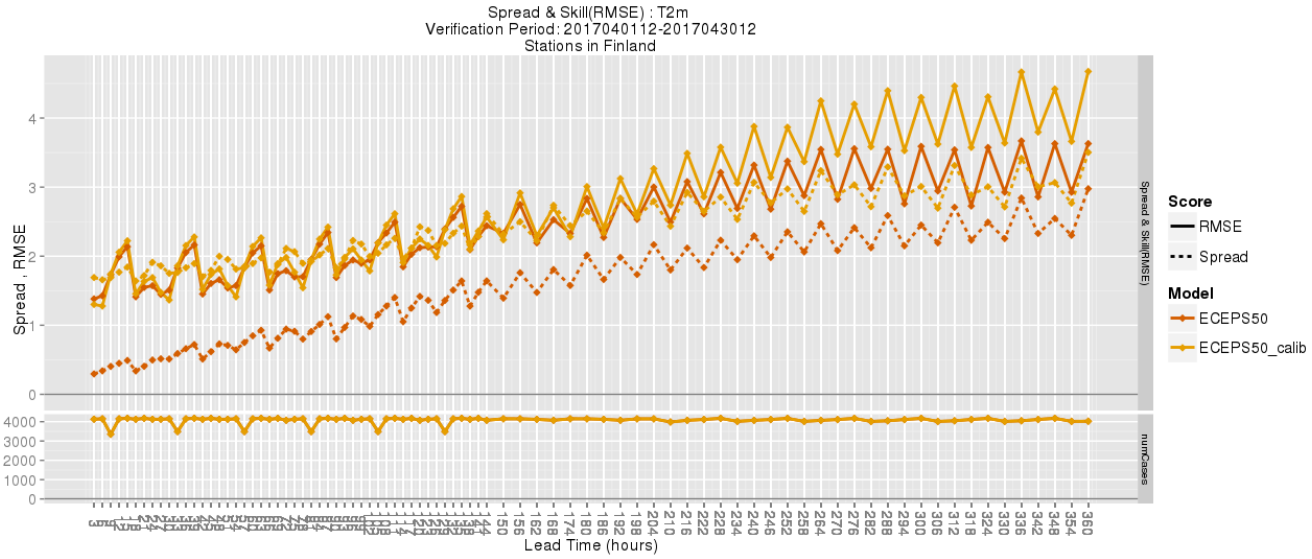

Fig 4: Verification results for 2 meters temperature forecasts

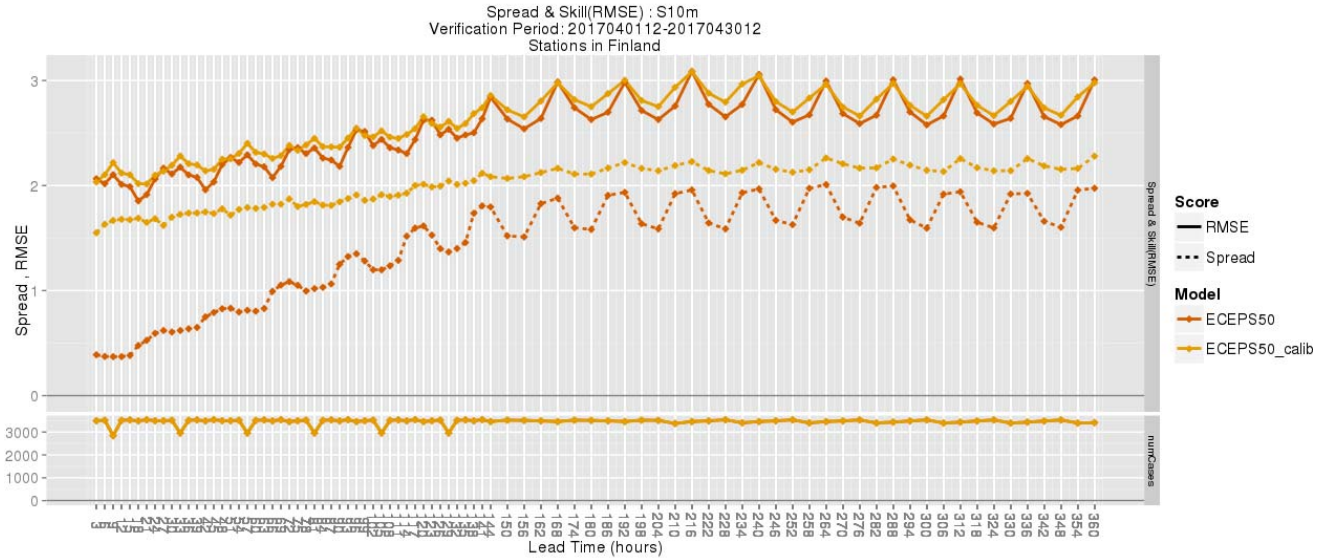

Fig 5: Verification results for 10 meters wind speed forecasts

Forecasts at Finnish stations are especially bad at mountainous areas and for wind speed forecasts also at sea areas. Calibration cannot improve these forecasts which is caused by coarse resolution. For verification (and also calibration coefficient training) forecasts are interpolated to station points.

3.1.3 End products delivered to users

FMI produces an outlook for Baltic sea ice conditions up to 6 months. Forecasted Baltic sea ice charts are produced based on seasonal forecast models, current ice situation and analog years. Charts are updated monthly from October to April and used to estimate the number of icebreakers needed in the coming months. This winter a negative NAO signal for early winter was evident in ECMWF, but it did not materialize. Sea ice extent was overestimated in forecasts from early November and December and several corrections were issued between mid December and early January following request by the customers. Positive NAO in February was well forecasted in the 46-day extended forecasts.

In addition in the project CLIPS (clips.fmi.fi) funded by Academy of Finland we develop and test climate impact outlooks for the upcoming six weeks. The focus is to raise awareness of the Finnish public of the risk and benefits related to weather impacts. The new service prototypes are developed using the ECMWF extended range weather forecast data (up to 46 days). During June 2017-May 2018 users are engaged to piloting the operational climate service products with us. The products are tailored separately for each season. Summer season's weekly forecasts include e.g. beach and sport weather outlooks, thunderstorm outlook, the probability of a sultry heat spell and e.g., blue algae conditions. For autumn we are already preparing for instance 6-week outlooks for storm exposure risk, ski-season starting point and road slipperiness. A feedback and verification system is developed to enable evaluation of the skill and usefulness of the novel outlooks. The verification of the products will be done also using ERA-Interim (or ERA5 when available) reanalysis data from ECMWF, results of verification will be provided in 2018 report. Since the services developed in CLIPS are based on ECMWF products, the project team from FMI Climate Service Centre strongly collaborates with ECMWF.

3.2 Subjective verification

3.2.1 Subjective scores

Some comments from FMI´s duty forecasters:

- 2m temperature forecasts are somewhat better in the new model version. Still room for improvement (in sunny situations too cold, nights and cold spells too warm). Also problems with spring evenings
- In Föhn-situations ECMWF is usually too cold, HIRLAM is better
- In easterly and northerly flow situations, where cloud base is widely spread, ECMWF is too warm. Normally HARMONIE is better.
- In clear sky inversion situations ECMWF sometimes creates unrealistic low level clouds when temperature and dew point curves are nearing each other near the surface.
- ECMWF low pressure development is better than in HIRLAM
- In the large scale precipitation areas ECMWF predicts too strong surface winds.

- Even when the resolution is now better precipitation areas seem to be too widely spread. Areas where we should have rain showers look like large scale precipitation areas.
- Baltic Sea's wind speed forecast are better in HIRLAM, ECMWF is often a bit weaker.
- Sea breeze's wind direction is better than earlier.
- More variations than earlier from model run to another after two to three days. Can shift from warm to cold or vice versa.
- Low level clouds are now predicted better, location and amount are more credible. This means that ECMWF is now also used in aviation forecasts earlier only HIRLAM.
- FMI's Rovaniemi's aviation office has been systematically gathering feedback from the aviation forecasters since end of February 2017 on how well models have predicted the low level clouds in northern Finland. They haven't noticed any major improvements after the new model version. From end of Feb until early June ECMWF has forecasted:
    - 11 times too much low level stratus clouds (HIRLAM's corresponding figures = 6), 78 times it has been correct (94) and 27 too small amounts (17)
        - The boundary layer was too moist and there were too much low level stratus clouds especially 25.-27. February.
        - The boundary layer has been too dry especially in March (13 cases). Also in April there where a few dry days 19.-20.4. and 26.4.
        - May was fine but again in early June too small amount of low level stratus clouds 1.6. and 4.-5.6.

4. Feedback on ECMWF "forecast user" initiatives

- "Known IFS forecast issues" page – (https://software.ecmwf.int/wiki/display/FCST/Known+IFS+forecasting+issues)
    - It is good to be able to check which bugs and weaknesses have already been reported and what is their "correction" status.
- "Severe event catalogue" (https://software.ecmwf.int/wiki/display/FCST/Severe+Event+Catalogue).
    - Good reminder that this page exist. Hasn't yet been used very much.