# Application and Verification of ECMWF Products 2021

Icelandic Meteorological Office (www.vedur.is) – Bolli Pálmason and Guðrún Nína Petersen

## 1. Summary of major highlights

At the Icelandic Meteorological Office (IMO) ECMWF HRES output is used as boundary conditions for limited-area modelling (LAM) and directly for forecasts from 72 hours to 168 hours. HRES wind speed over land has a significant negative bias in strong winds, but the winds over the ocean are reliable. HRES 2-m temperature is post-processed for local weather forecasts and HRES 10-m wind speed for the whole domain. ENS is used for forecasts for up to three weeks but also for likelihood of extreme events. EFI for extreme precipitation is considered quite reliable.

## 2. Use and application of products

### 2.1 Direct Use of ECMWF Products

ECMWF products are used for a wide range of forecasts. For day 1 to day 3 (up to 66 hours) HRES is used together with operational LAM forecasts for writing of text forecasts and impact-based warnings. For day 4 to 7 and impact-based warnings up to day 5 mainly HRES and ENS are used. EFI is used to identify events of extreme precipitation in Iceland, that is usually linked to frontal passage rather than convective precipitation. The wave model is used for warnings of storm surges.

Every week a three-week forecast is produced based on ENS, using the Open Charts products. The decision of ECMWF to make the charts on the website free-to-access has not changed how IMO uses the charts but has in some ways made the use easier as login is not required.

### 2.2 Other uses of ECMWF output

#### *2.2.1 Post-processing*

The 2-m temperature direct model output (DMO) of HRES has a cold bias, on average 0.8-1.0°C, but less during the warmest months. A recursive statistical post-processing method (*bcor*) based on Boi (2006) is applied to point forecasts where observations are available and published on the IMO website.

10-m wind speed HRES DMO is too low over land, especially during windy conditions. This results in for example a large decrease in forecasted wind speed when moving from LAM wind speed to HRES wind speed on day 3. To decrease this error a simple post-processing filter is applied, using HRES wind speed at 10 and 100 m, with the weighing depending on the wind speed at 100 m. *Figure 1* shows a comparison of the post-processed field and the DMO of HARMONIE-AROME IGB as well as HRES DMO at 10 m and 100 m, a 24-hour forecasts valid 26 June 2021 00 UTC. Clearly the HRES post-processed field has increased wind speed in regions over land compared to 10-m DMO, and in better agreement with the LAM output. Such post-processed fields are now published on the website of IMO. See verification in section 3.1.

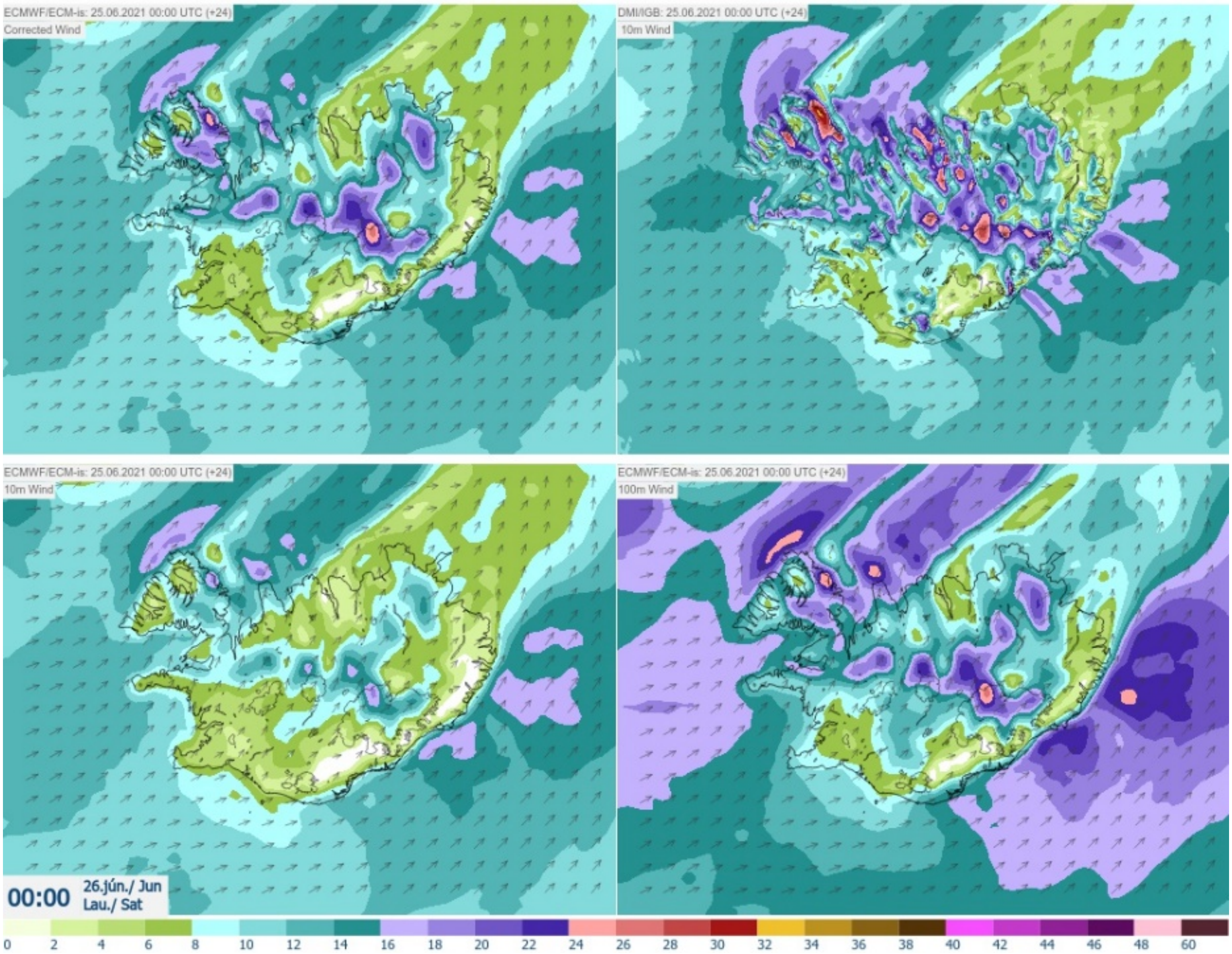



*Figure 1. A comparison of 10-m wind speed. HRES post-processed (top left), HARMONIE-AROME IGB DMO (top right), HRES 10-m DMO (bottom left) and HRES 100-m DMO (bottom right). 24-hour forecasts valid on 26 June 2021 00 UTC.*

### 2.2.2 Derived fields

IMO produces charts of DMO 10-m wind speed, 2-m temperature, mean sea level pressure and precipitation, that are an intrinsic part of the official website, as well as local weather forecasts for over 140 locations. HRES output is used for the forecasting range 75—168 hours. HRES output is also published in the IMO weather app. In addition, IMO has an extensive internal forecasting charts website where several fields from the available NWP models are visualised. Over 70 chart types are produced from HRES, varying from charts of traditional surface parameters to surface fluxes, divergence and potential vorticity aloft. In addition, EPS products, ensemble mean, standard deviation and probabilities, for 500 hPa geopotential height, mean sea level pressure, 850 hPa temperature, 10-m wind speed and precipitation, for an area covering Iceland and the surrounding seas, are visualised as well as the EPS cluster scenario over the North Atlantic, see Figure 2. Furthermore, meteograms for a few locations in Iceland and by the coast are produced. Maps of several field of forecasted weekly anomalies, such as mean sea level pressure, 500-1000 hPa thickness and SST, are produced from the extended range forecasts as well as EFI and SOT for 2-m temperature, 10-m wind speed/gust and 24-hour precipitation.

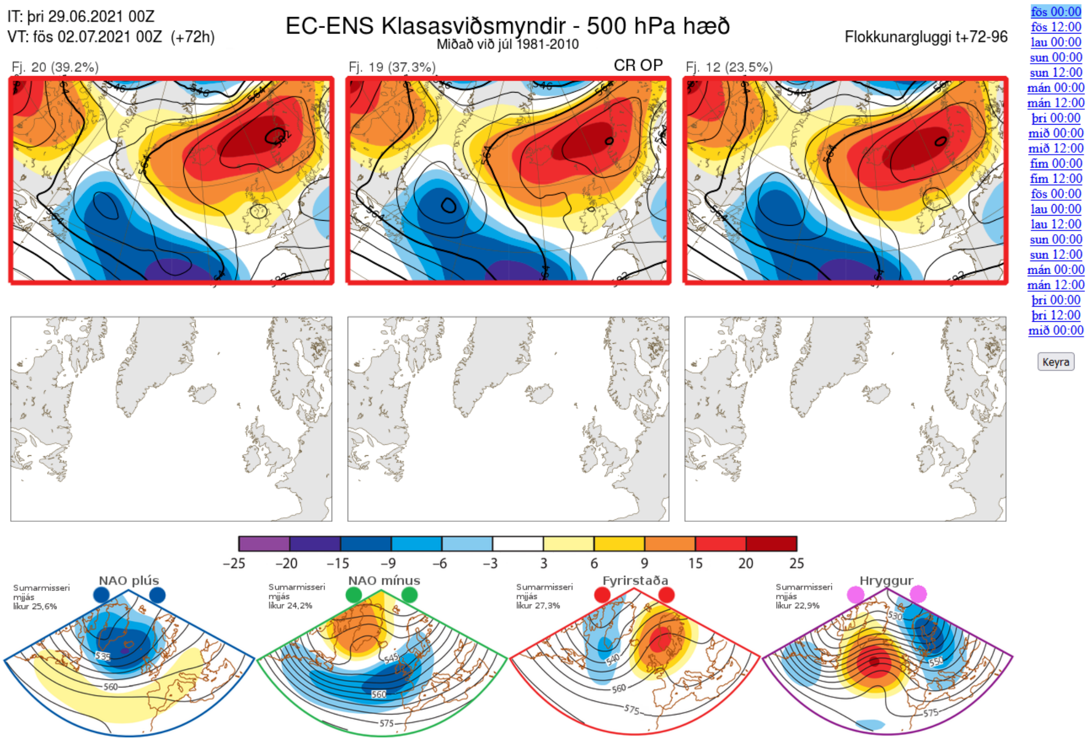



*Figure 2. Cluster scenario as visualized on the internal forecasting website of IMO. The time bar on the right is used to scroll through the whole forecasting time.*

#### *2.2.3 Modelling*

HRES is used as lateral boundary conditions (LBC) for the LAM HARMONIE-AROME IGB (Iceland-Greenland) that the Danish Meteorological Office runs for the region, in cooperation with IMO. This is the operational NWP LAM model of IMO. In addition, IMO runs semi-operationally the same NWP model but a different version and for a smaller domain, for 2.5 km (harmonie) and 750 m (hm750m), with lateral boundary conditions from HRES and HARMONIE-AROME 2.5 km, respectively. Two dispersion models run operationally, daily for a few volcanoes when eruptions are not on-going and additionally for other volcanoes in case of an imminent or on-going eruption. For tephra forecasts the model NAME is used and CALPUFF for volcanic gas. Both models use HRES data as initial and boundary conditions.

## 3. Verification of ECMWF products

### 3.1 Objective verification

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

Verifications of 2-m temperature and 10-m windspeed for November 2020 for hm750m, IGB and HRES and for the same parameters but for June 2021 for hm750m, harmonie and HRES are shown in Figure 3 and Figure 4, respectively. Take notice of similar negative temperature bias (ME) for all the models, but windspeed has a positive bias for the HARMONIE-AROME models, both hm750 and IGB, while HRES has a big negative bias. Verifications show improvements in temperature and wind speed forecasts for the hectometre scale hm750m run. ECMWF HRES fails in most extreme wind events.

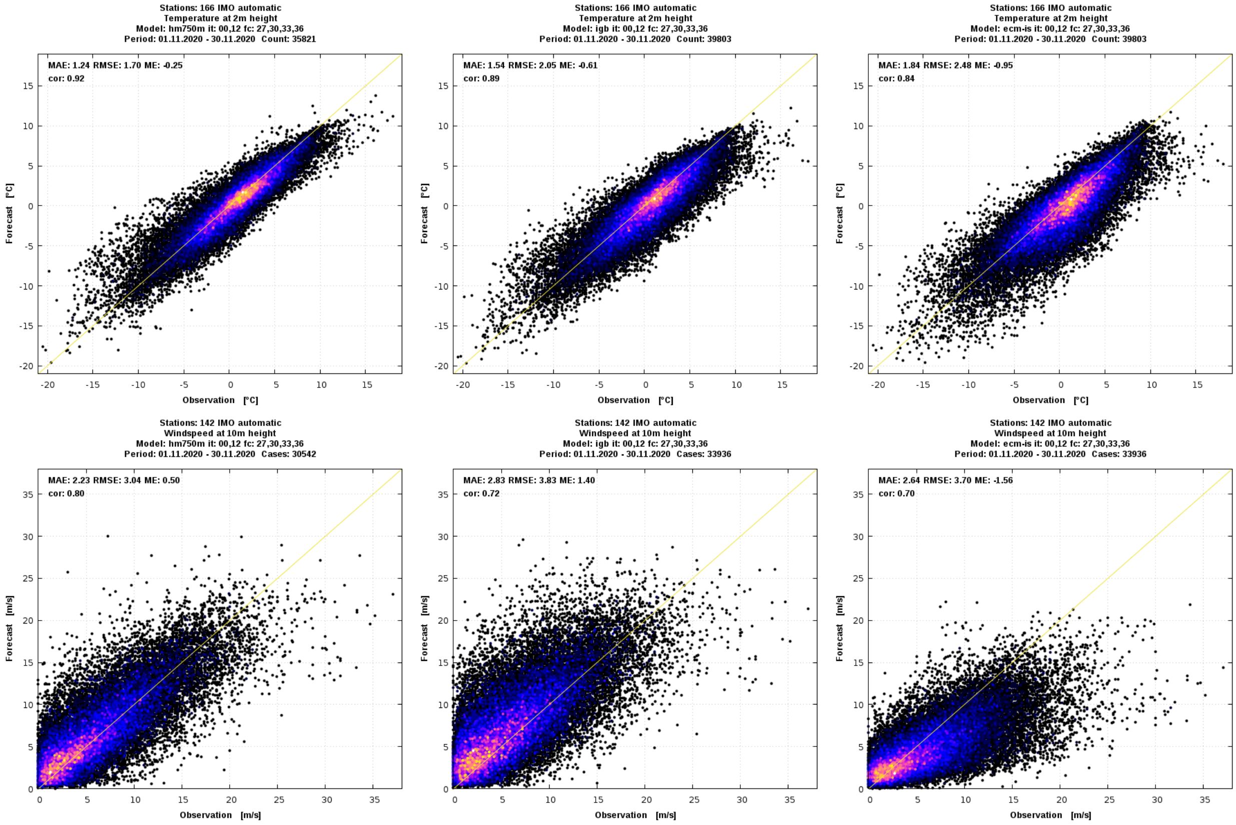



*Figure 3. Forecast verifications of 2-m temperature (top) and 10 m wind speed (bottom) for the month of November 2020. hm750m (left), IGB (centre) and HRES (right).*

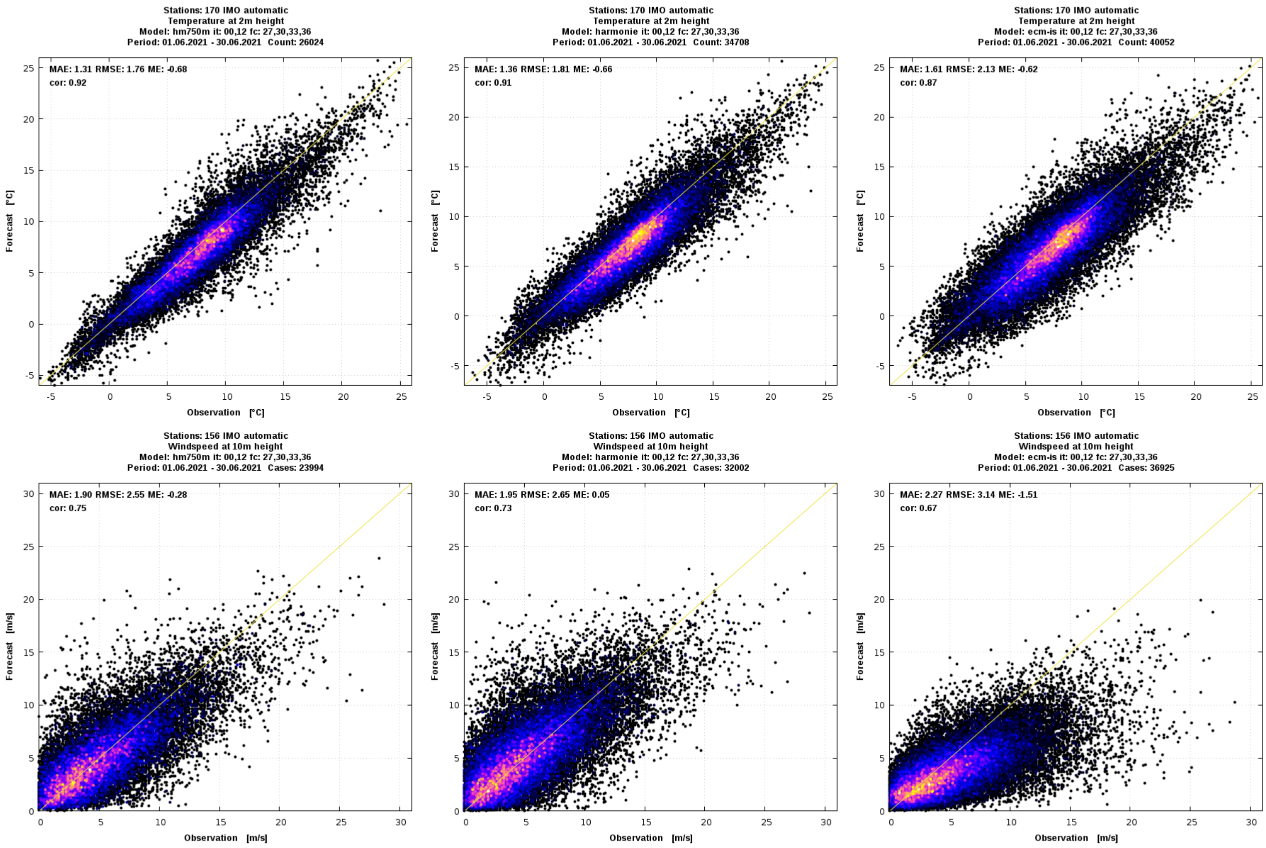



*Figure 4. Forecast verification for 2-m temperature (top) and 10-m wind speed (bottom) for the month of June 2021. hm750m (left), harmonie (centre) and HRES (right).*

### 3.1.2 Post-processed products and end products delivered to users

The post-processing of HRES DMO 2-m temperature and 10-m wind speed improves the forecasts significantly. Figure 5 shows scatterplots of observed values and 27—36-hour forecasts, DMO on the left and post-processed on the right, for both variables for January 2021. The *bcor* post-processing of temperature results in RMSE decreasing by 0.6°C and the bias is removed. For wind speed RMSE decreases by 0.6 m/s and the bias goes down to 0.1 m/s. The post-processing also results in wind speed forecasts frequently exceeding 20 m/s while that is rare for HRES DMO. The *bcor* method for 2-m temperature is applied for both the HRES and the HARMONIE-AROME runs.

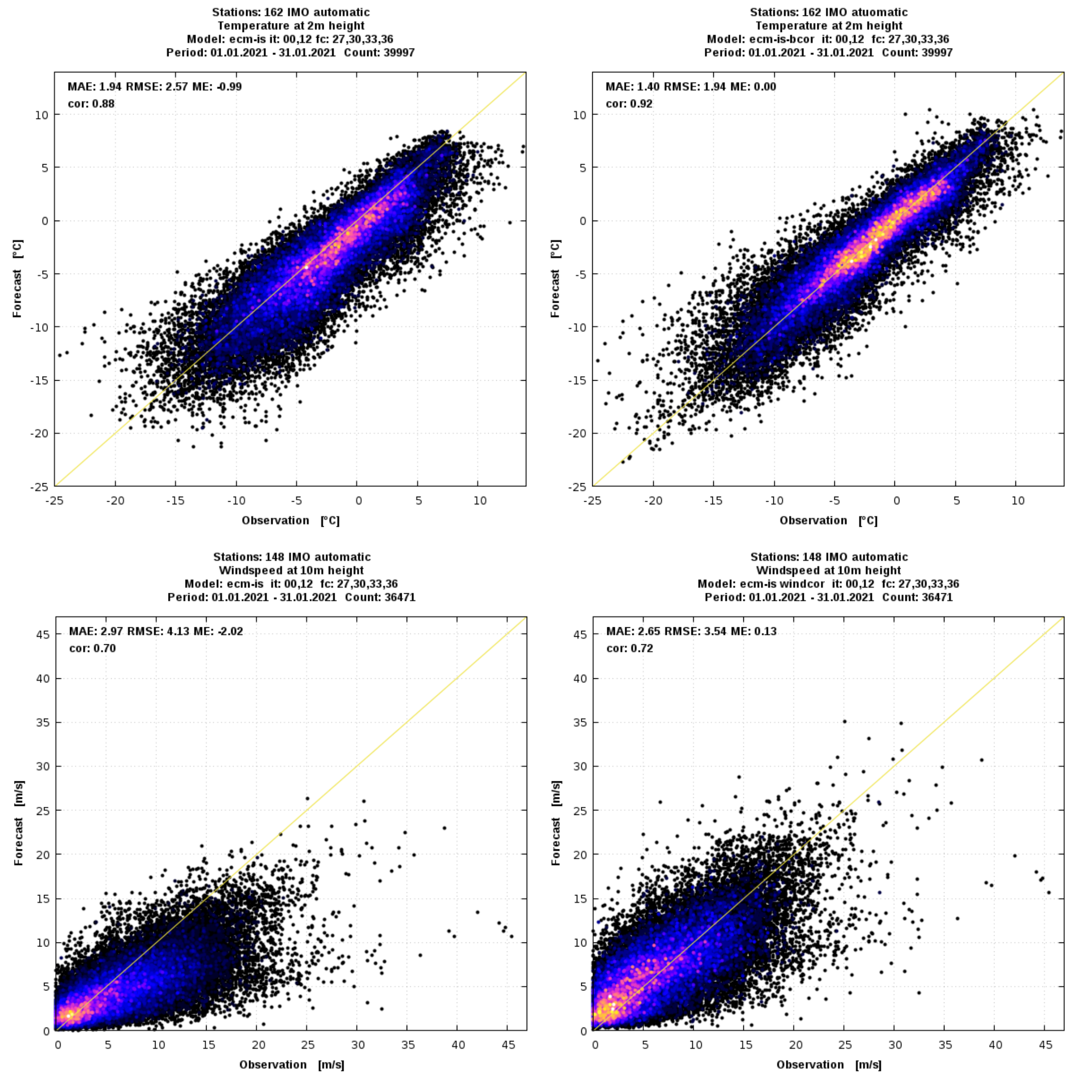



*Figure 5. Scatterplots of observed and forecasted 2-m temperature (top) and 10-m wind speed (bottom). Left: HRES DMO. Right: HRES post-processed. Forecast length 27-36 hours and forecast period January 2021.*

#### 3.1.3 Monthly and Seasonal forecasts

N/A

## 3.2 Subjective verification

### 3.2.1 Subjective scores

N/A.

### 3.2.2 Case studies

Every year Iceland experiences a few extreme weather events. Wind events are the most common, but precipitation events often have larger societal impact.

A major weather event occurred 10-12 December 2019 with widespread societal impact. A deep cyclone moved northward along the eastern coast of Iceland resulting in observed wind speed of over 26 m/s in large part of eastern, northern and western Iceland. Temperature was around freezing level resulting in precipitation falling as snow or sleet in the northeastern part of the country. Also, a large amount of snow fell in southern Iceland. Icing accumulated on electrical wires and structures causing electrical disturbances and outtakes, the longest lasted three days. One person died and several horses and sheep. Wind damages were reported in many locations and storm surge damages by the north and northeast coast. A few snow avalanches were reported. Weather warnings based on EPS EFI and SOT were issued days in advance (see Figure 6). They played a major role in minimizing damages and accidents.

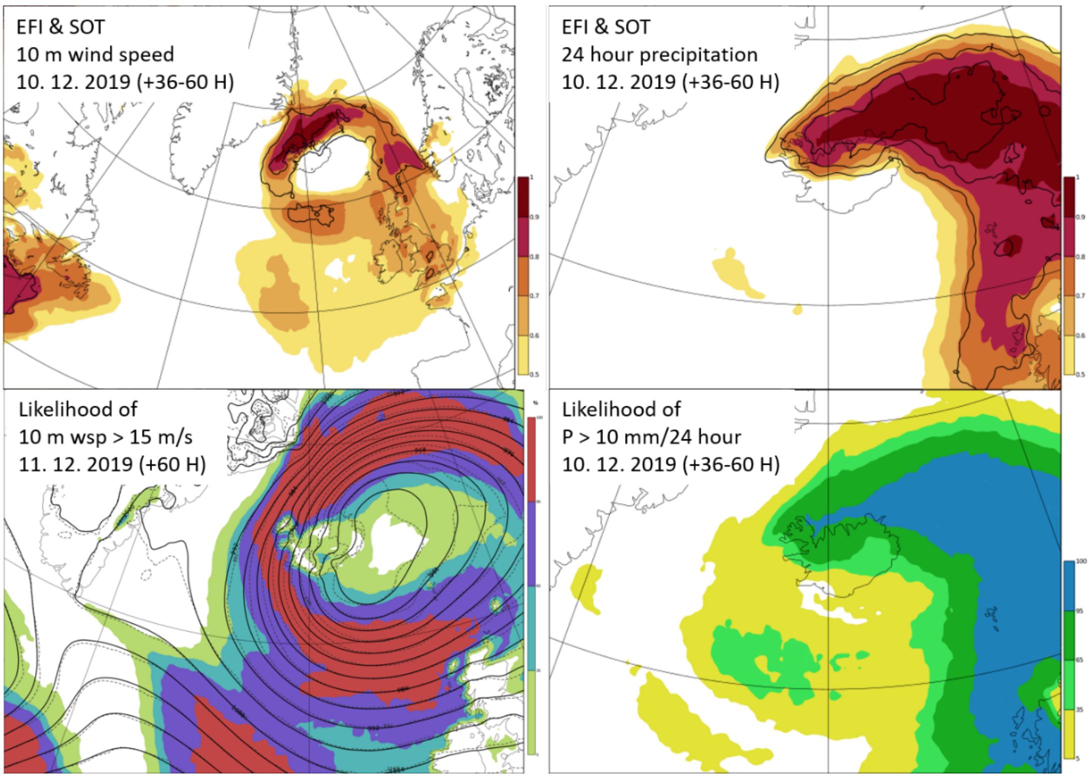



*Figure 6. EFI & SOT of 10-m wind speed and 24-hour accumulated precipitation as well as the likelihood of wind speed exceeding 15 m/s and precipitation 10 mm/24 hours in the weather event of 10-12 December 2019.*

In December 2020 a record was broken in 5-day accumulated precipitation in Iceland. In Seyðisfjörður village, E-Iceland, the observed 5-day precipitation for the period 14—18 December was 569 mm. This record precipitation fell as rain in the mountains below about 400 m adding water to already rain-soaked ground from a lesser precipitation events during 10 – 12 December, increasing the risk of landslides. The IMO issued a warning on 13 December and from the 15 – 18 December large mudslides fell into the village, destroying 14 houses. Figure 7 shows a comparison of the observed rainfall and the simulated by HRES and HARMONIE-AROME models. Although HRES unsurprisingly underpredicted the rainfall by over 300 mm, as this is a region with very complex orography, the precipitation pattern was correct (Figure 8).

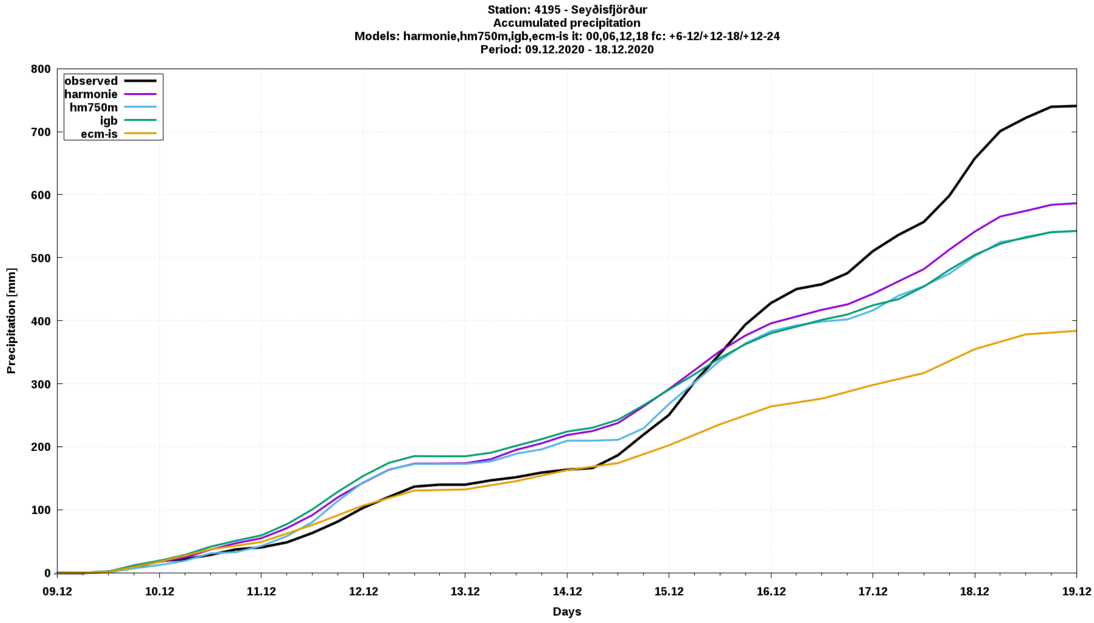



*Figure 7. Accumulated precipitation in Seyðisfjörður 9—19 December 2020. Observations in black, HRES in yellow and HARMONIE-AROME models in blue and purple. For HRES 12—24-hour forecasts and for HARMONIE-AROME models 6—12, 12—18-hour forecasts.*

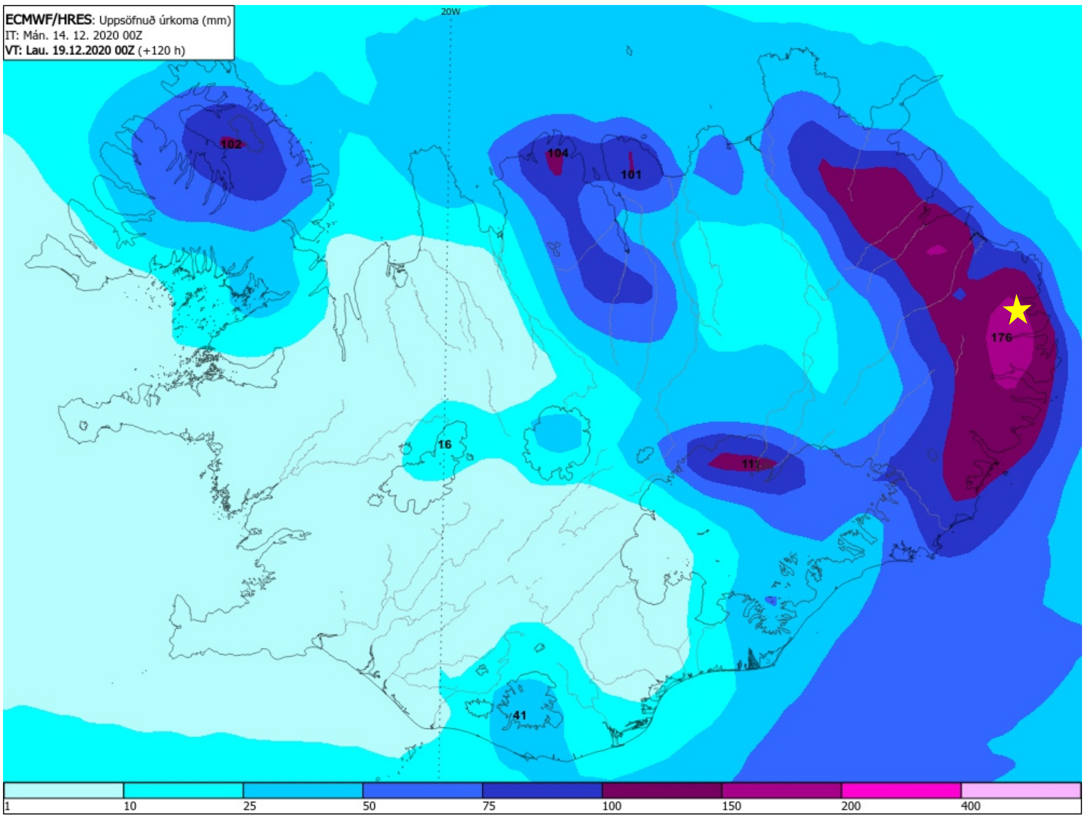
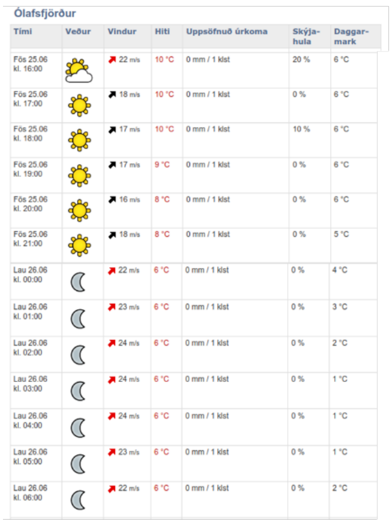


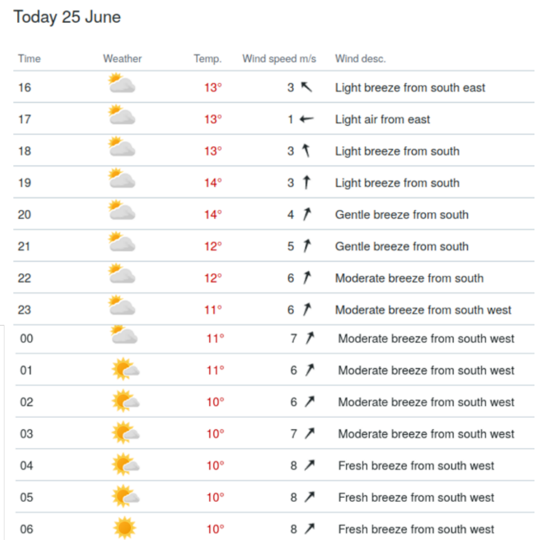

*Figure 8. 120-hour accumulated precipitation, forecast valid 19 December2020, 00 UTC. The location of the weather stations where 569 mm were observed is marked with a star.*

Although IMO post-processes HRES 10-m wind speed and uses for its application, the underprediction of strong winds over land in HRES DMO is a problem. Many users of weather forecasts in Iceland use the Norwegian website yr.no where HRES DMO is published for regions outside Met Norway's forecasting area, for the whole forecasting period. In stormy conditions these users are oblivious to the hazard and may e.g. decide on driving in areas where it should be avoided. Figure 9 shows a comparison of the weather forecasts available to the general public for Ólafsfjörður, N-Iceland, valid for 25—26 June 2021, from the IMO website and yr.no. There is a significant difference in the forecasts, at the IMO website forecasted winds are up to 24 m/s while at yr.no the winds do not exceed 10 m/s. Orange coloured wind warnings were in place for the region. An improvement in HRES winds over land would improve the safety of the public in Iceland by decreasing this difference and thus making the use of websites, such as yr.no, more reliable in hazardous winds.



Ólafsfjörður

| Tími | Veður | Vindur | Hiti | Uppsöfnuð úrkoma | Skýja-hula | Daggar-mark |
|---|---|---|---|---|---|---|
| Fös 25.06 kl. 16:00 | | 22 m/s | 10 °C | 0 mm / 1 klst | 20 % | 6 °C |
| Fös 25.06 kl. 17:00 | | 18 m/s | 10 °C | 0 mm / 1 klst | 0 % | 6 °C |
| Fös 25.06 kl. 18:00 | | 17 m/s | 10 °C | 0 mm / 1 klst | 10 % | 6 °C |
| Fös 25.06 kl. 19:00 | | 17 m/s | 9 °C | 0 mm / 1 klst | 0 % | 6 °C |
| Fös 25.06 kl. 20:00 | | 16 m/s | 8 °C | 0 mm / 1 klst | 0 % | 6 °C |
| Fös 25.06 kl. 21:00 | | 18 m/s | 8 °C | 0 mm / 1 klst | 0 % | 5 °C |
| Lau 26.06 kl. 00:00 | | 22 m/s | 6 °C | 0 mm / 1 klst | 0 % | 4 °C |
| Lau 26.06 kl. 01:00 | | 23 m/s | 6 °C | 0 mm / 1 klst | 0 % | 3 °C |
| Lau 26.06 kl. 02:00 | | 24 m/s | 6 °C | 0 mm / 1 klst | 0 % | 2 °C |
| Lau 26.06 kl. 03:00 | | 24 m/s | 6 °C | 0 mm / 1 klst | 0 % | 1 °C |
| Lau 26.06 kl. 04:00 | | 24 m/s | 6 °C | 0 mm / 1 klst | 0 % | 1 °C |
| Lau 26.06 kl. 05:00 | | 23 m/s | 6 °C | 0 mm / 1 klst | 0 % | 1 °C |
| Lau 26.06 kl. 06:00 | | 22 m/s | 6 °C | 0 mm / 1 klst | 0 % | 2 °C |



Today 25 June

| Time | Weather | Temp. | Wind speed m/s | Wind desc. |
|---|---|---|---|---|
| 16 | | 13° | 3 | Light breeze from south east |
| 17 | | 13° | 1 | Light air from east |
| 18 | | 13° | 3 | Light breeze from south |
| 19 | | 14° | 3 | Light breeze from south |
| 20 | | 14° | 4 | Gentle breeze from south |
| 21 | | 12° | 5 | Gentle breeze from south |
| 22 | | 12° | 6 | Moderate breeze from south |
| 23 | | 11° | 6 | Moderate breeze from south west |
| 00 | | 11° | 7 | Moderate breeze from south west |
| 01 | | 11° | 6 | Moderate breeze from south west |
| 02 | | 10° | 6 | Moderate breeze from south west |
| 03 | | 10° | 7 | Moderate breeze from south west |
| 04 | | 10° | 8 | Fresh breeze from south west |
| 05 | | 10° | 8 | Fresh breeze from south west |
| 06 | | 10° | 8 | Fresh breeze from south west |

*Figure 9. A comparison of the weather forecast for Ólafsfjörður, N-Iceland, valid 25-26 June 2021. Left: HARMONIE-IGB forecast as published on vedur.is, the IMO website. Right: HRES forecast as published on yr.no.*

## 4. Requests for additional output

IMO does not request any additional output but asks ECMWF to investigate if the roughness of Iceland can be reduced in such a way as to decrease the negative wind bias.

## 5. References to relevant publications

**Boi, P.** 2006: A statistical method for forecasting extreme daily temperatures using ECMWF 2-m temperatures and ground station measurements. *Met. Apps*, 11: 245–251. doi:10.1017/S1350482704001318