RESEARCH DEPARTMENT
MEMORANDUM

To:	RD, FD Division and Section Heads, Evaluation Section
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Date:	28 August 2013 — File: RD13-293
Subject:	**Icelandic glacier mask update in IFS cycle 38r2**

1 Introduction

ECMWF revised the IFS glacier mask over Iceland. The new glacier mask was implemented on the fly on 8 May 2013 in the esuite 38r2, both in HRES and EDA. It became operational on 25 June 2013.
This research memorandum presents the motivations for this update and it shows the updated glacier mask at different resolutions used in operations. The implementation procedure is presented as well as results from experiments. The Icelandic glacier mask update has a local impact on surface and near surface weather parameters over Iceland. Comparisons between the esuite 38r2 and the osuite 38r1 are shown and impact on the EFI and ENS products is discussed as well as ongoing actions to account for the revised glacier mask in the re-forecast ENS. This work was conducted in close collaboration between ECMWF and the Icelandic Meteorological Office.

2 Motivations and updated glacier mask over Iceland

The Icelandic Meteorological Office (IMO) reported in 2012 systematic unrealistic cold two-metre temperature forecasts in the highland of Iceland in the ECMWF products. The bias, also present in the previous years, was particularly important in summer. It was due to an overestimation of the glacier extent in the IFS, and resulted in a permanent snow depth of 10 m (water equivalent) present in areas of Iceland which are in reality completely snow free in summer. In absence of glacier the seasonal snow cover is normally simulated in the IFS by the ECMWF snow scheme (Dutra et al , 2013) and constrained by the ECMWF land data assimilation schemes (de Rosnay et al , 2013). However, over Iceland large amount of snow reported by IMO is constrained in the IFS by the Global Land Cover Characteristics (GLCC) glacier mask used at ECMWF. IMO are running HARMONIE using ECMWF initial conditions, therefore the excessive amount of snow over Iceland also affected their HARMONIE forecasts.

IMO provided ECMWF with a 1-km glacier mask and Digital Terrain Model (DTM) data bases (Sigurðsson et al , 2013; IMO , 2004) to enable ECMWF to fix the excessive snow issue over Iceland and to reduce the cold temperature bias. The IMO glacier mask was used at ECMWF to patch the GLCC glacier mask used in the IFS. Figure 1 shows the ECMWF HRES (T1279) GLCC mask used until IFS cycle 38r1 (top left), the glacier mask provided by IMO at 1km resolution (top right) and the IFS cycle 38r2 mask patched with the IMO data (bottom left). It also shows on the bottom right the binary difference in the IFS glacier mask between cycles 38r2 and 38r1. This figure shows that the 38r2 glacier mask patched with the IMO data has a much reduced pattern compared to 38r1 and it is in good agreement with the IMO glacier.

Figures 2 to 3 show the glacier update for the ENS resolution (T639) and the EDA resolution (T399). These figures show that the revised glacier mask (based on IMO data) and the old glacier mask (based on GLCC data) differ at all resolutions used for products generation. Having a realistic glacier mask has a large local impact on snow depth and therefore on two-metre temperature forecasts. So, an action was taken to implement the use of the new glacier mask from IFS 38r2.

3 Implementation procedure

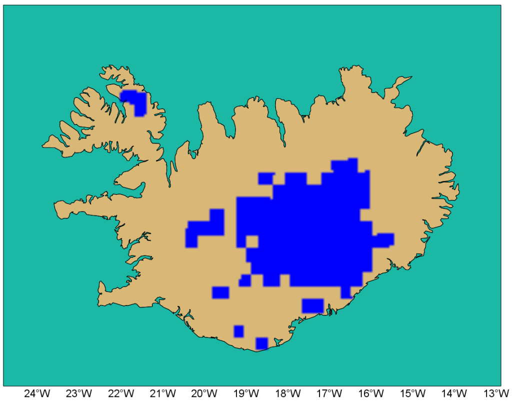
ECMWF started to work on the Icelandic glacier implementation in Autumn 2012. IFS cycle 38r1 was used in operations since June 2012 and the next operational cycle (38r2), mainly focused on vertical level increase, was being tested. The standard procedure to implement the IMO glacier mask would have been to prepare the glacier mask update and test it for implementation in IFS cycle 39r1, which RD was already working on. However this would have led to the updated glacier mask in use for operations from late autumn 2013 when cycle 39r1 becomes operational. So, the two-meter temperature issue over Iceland, which was particularly problematic for IMO in summer period, would not have been fixed for the summer 2013. Therefore, to make it possible to fix the issue in summer 2013, it was agreed to implement the fix in the esuite 38r2, on-the-fly. The implementation in the esuite was acceptable without extensive testing provided the glacier update could be shown to only have a local impact, ensuring the Icelandic snow and temperature issues were fixed. It was crucial to ensure and to check with RD experiments that the update of the Icelandic glacier had no large scale impact on the IFS cycle 38r2 scores. ERA-Interim was not modified.

Glacier mask update

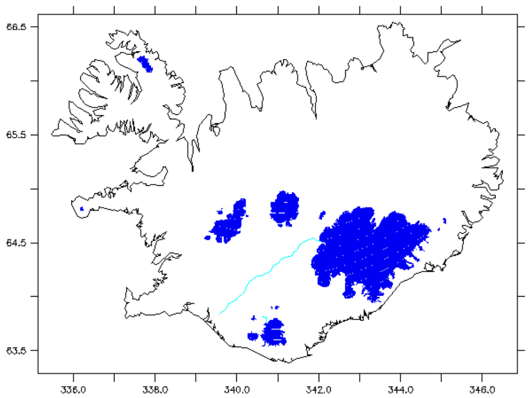
The first action was to update the climate data base on c2a, by producing, at all the IFS resolutions, patched GLCC glacier mask (file cicecap) using the IMO 1km mask (as presented in the previous section and as shown in Figures 1-3). An updated version of the glacier was made at all the other IFS resolutions (T95 to T3999), except at T42 which is too coarse to represent glacier and for which the old mask and the new mask are identical. The patch was applied in both the GLCC.1 data base currently used in operations (until IFS cycle 39r1) and the GLCC.2 data base in preparation for future implementation in IFS cycle 40r1 (Figure 4). For the latter the Icelandic fields are patched at the 1km resolution and then used into the standard interpolation procedure, leading to a slightly different result compared to 38r2 patched fields.

mask is used in the surface analysis to update snow with 10 meter of snow water equivalent for grid points where the glacier fraction is larger than 0.5 (*i.e.* in presence of glacier). Changing the glacier mask does not remove snow in areas where the glacier extent is reduced. Only the model melting processes can possibly remove the 10 m of snow water equivalent when a glacier disappears, but it would take several decades to melt such a large amount of snow at this latitude. Therefore, the second action of the implementation consisted, for both for the test experiment and for the esuite implementation, of modifying 'manually' (similarly to de Rosnay et al (2010)) the snow water equivalent field to remove snow where the new glacier mask is smaller than the old glacier. At this time of the year it is expected to have no snow, or small amount of snow in areas not covered by glaciers. So, the spurious 10 m of snow water equivalent was arbitrarily reduced to 0.06 m, with a slight spin-up expected to melt and to remove with the analysis (relying on snow cover in the absence of SYNOP snow depth report in this area) the possible excess of snow.

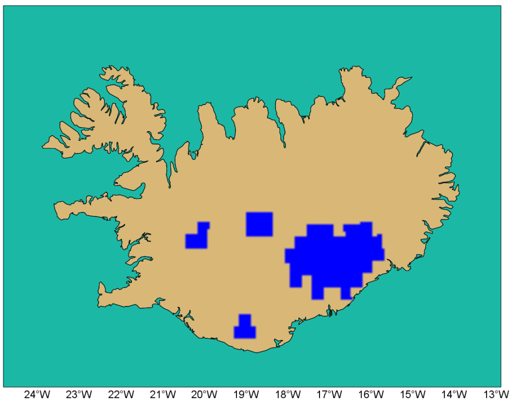
For the esuite implementation the first guess forecast on 20130507 at 18 UTC step 6, valid on 2013050800, was extracted, modified and put back to FDB. It was then used for the DCDA analysis on 20130508 at 00UTC,



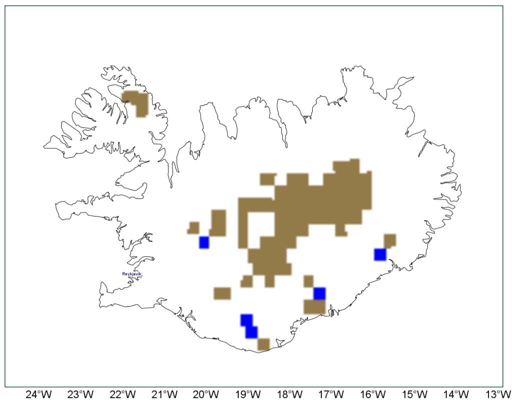
(a) IFS cycle 38r1 glacier mask



(c) IMO 1km glacier mask

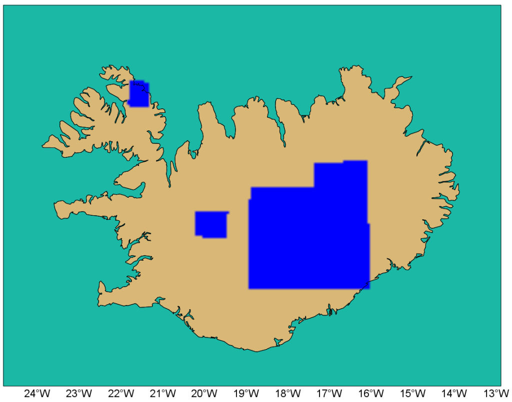


(b) Glacier mask in IFS cycle 38r2

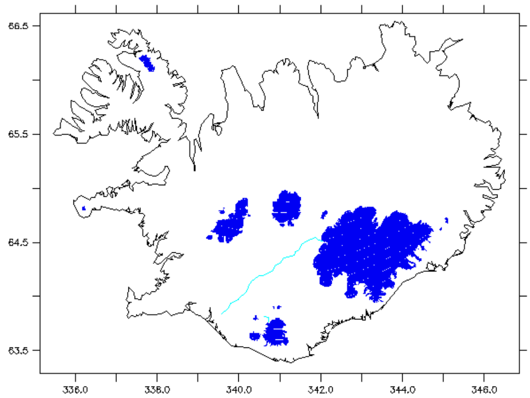


(d) Difference 38r2-38r1 glacier mask

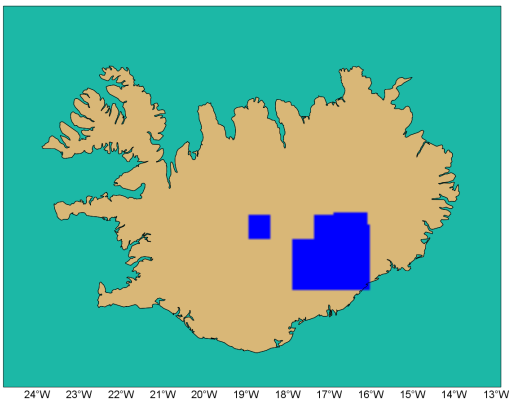
Figure 1: Glacier mask over Iceland: at T1279 from GLCC used for HRES until IFS 38r1 (top left), from the Icelandic Meteorological Office data (top right), based on the IMO data patched into the GLCC data at T1279 (bottom left). Blue indicates presence of glacier. The bottom right figure shows the binary difference in glacier mask between IFS cycle 38r2 and 38r1, with brown and blue corresponding to areas where glacier were removed or added in IFS cycle 38r2 compared to previous cycles.



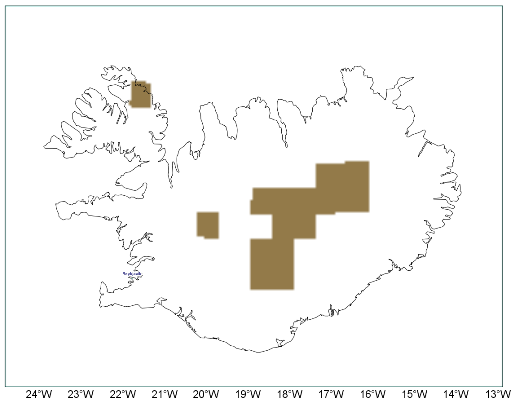
(a) IFS cycle 38r1 glacier mask



(c) IMO 1km glacier mask

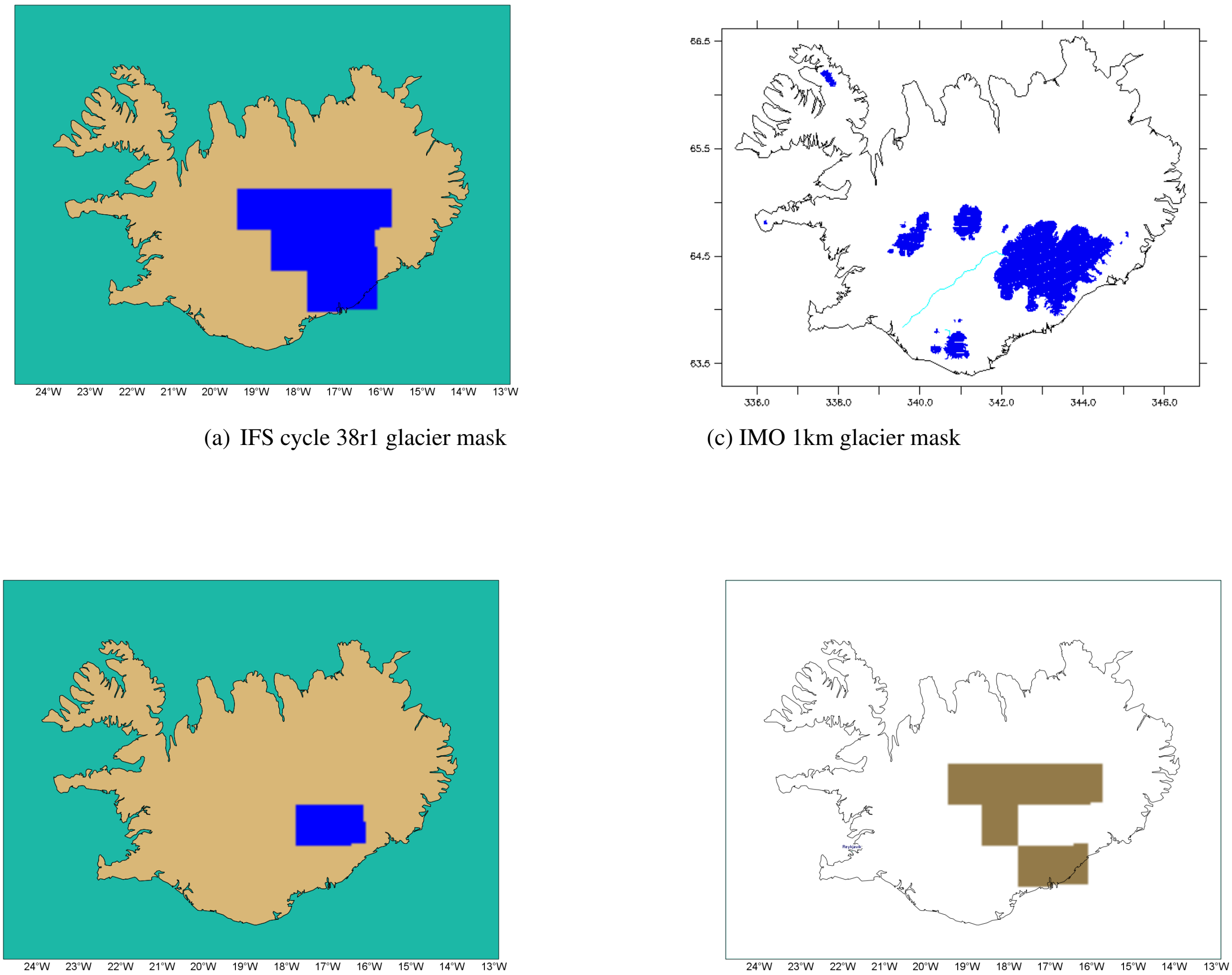


(b) Glacier mask in IFS cycle 38r2



(d) Difference 38r2-38r1 glacier mask

Figure 2: Same as Figure 1, but at the ENS resolution (T639).



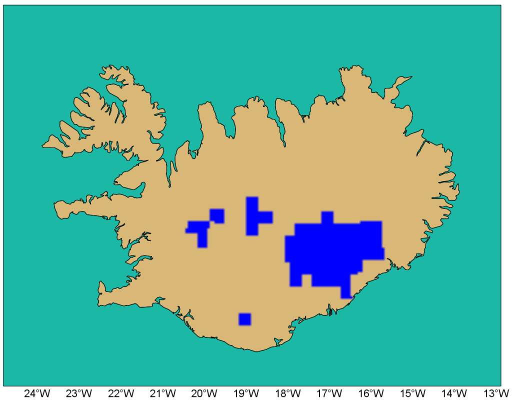
(a) IFS cycle 38r1 glacier mask

(c) IMO 1km glacier mask

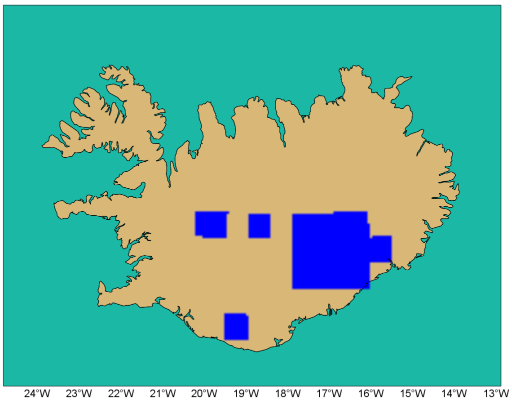
(b) Glacier mask in IFS cycle 38r2

(d) Difference 38r2-38r1 glacier mask

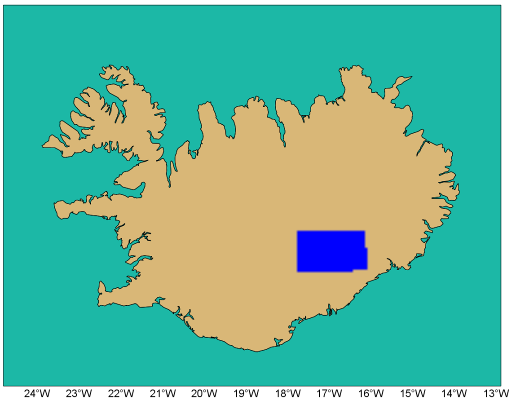
Figure 3: Same as Figure 1, but at the EDA resolution (T399).



(a) IFS cycle 40r1 glacier mask at T1279



(b) IFS cycle 40r1 glacier mask at T639



(c) IFS cycle 40r1 glacier mask at T399

Figure 4: Glacier mask over Iceland from the Icelandic Meteorological Office data patched in IFS cycle 40r1 data base at T1279 (top), T639 (middle) and T399 (bottom).

which was also the first analysis cycle for which we activated (scripts changes, see in the next paragraph) the use of the revised mask. The same procedure was applied for the HRES and for each EDA member for which the snow fields were modified individually and put back to FDB before the 00UTC analysis starts. There was no need to do any glacier update in the ENS forecasts since they rely on the operational analysis initial conditions.

Ensuring Reproducibility for 38r2

Updating a climate field on the fly in the esuite posed some reproducibility issues, both for the esuite and for experiments that RD users were running with IFS cycle 38r2. To ensure the reproducibility of IFS cycle 38r2 experiments, scripts modifications were necessary to include a switch to use the new glacier mask from the implementation date (2013 05 08 00) but to keep using the old mask before this date. In IFS 38r2 the script modifications include mklinks, ssaana and inter_fp, to pick up the right glacier mask depending on the date. So, the climate data update include both the default (old) mask file "cicecap" and the updated mask file "cicecap_iceland". This dual configuration in 38r2 ensures reproducibility of RD experiments and esuite 38r2.

Update for 39r1

IFS cycle 39r1 was not yet released when we implemented the new glacier, so the reproducibility was not an issue. Therefore, the climate data base used for 39r1, only accounts for the new version of the glacier mask, with the file 39r1 cicecap files being identical to the 38r2 cicecap_iceland files.

4 RD experiments

Before it was implemented in the esuite 38r2 the new glacier mask and the procedure described above were tested in an RD HRES (T1279) experiment for June 2012. The experiment is fvo8, with the first analysis cycle to use the revised glacier on 2012060100. It was compared to the RD control experiment fsra.

Figure 5 shows the first guess snow water equivalent valid on 2012 06 01 at 00UTC for the fvo8 experiment. It is shown on the top before modifying the snow field and on the bottom after the snow field was modified to replace 10m of snow water equivalent by a small amount of snow for grid points for which the difference between the binary mask between 38r2 and 38r1 is negative (brown area in Figure 1, bottom right). The updated snow water equivalent field, shows a 10m snow pattern in agreement with the new glacier mask (Figure 1 bottom left).

Figure 6 shows the impact, in the fourth weeks of experiment, of the revised glacier implementation on the surface temperature analysis in the soil at different depth and at the screen level. As expected, it shows warmer soil and air temperature in most areas corresponding to the reduction of the glacier extent shown in Figure 1d. For a few grid points in the southern part of Iceland, the revised glacier actually accounts for small glaciers that were not represented in the original GLCC glacier (four blue points in Figure 1d). At the location of these few grid points, the experiment fvo8 accounting for the revised glacier is locally colder than the control experiment, particularly for the first two soil layers (Figure 6, top). However apart from these few points, the overall pattern is clearly a reduction of the glacier extent (Figure 1d), leading to an increase of two-metre and soil temperature (Figure 6).

Figure 7 shows the two-metre temperature analyses (in Celsius) on 2012 06 30 at 00 UTC and 12 UTC over Iceland, for the control experiment (fsra, left) and the new glacier experiment (fvo8, right). It shows that the impact of the glacier modification is very local. SYNOP reports of screen level temperature are indicated. However they are only available in coastal areas for which the two experiment do not differ. So, they can not be used to evaluate the impact of the glacier update. The implementation strategy aimed at fixing locally the Icelandic glacier mask issue and its local impact on snow and temperature fields as requested by IMO. On Figure 8 the impact of the glacier fix is shown for Europe, for snow depth and two-metre air temperature. Figure 9 shows the large scale impact on the temperature forecasts RMSE at global scale. These two figures

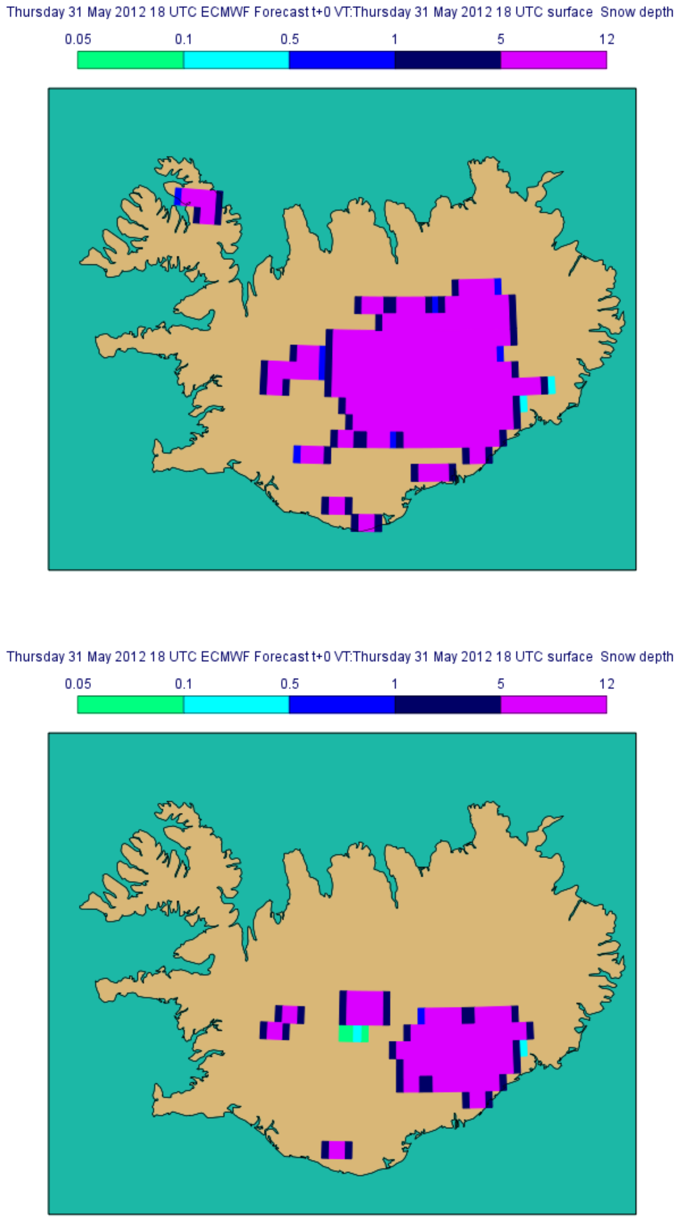
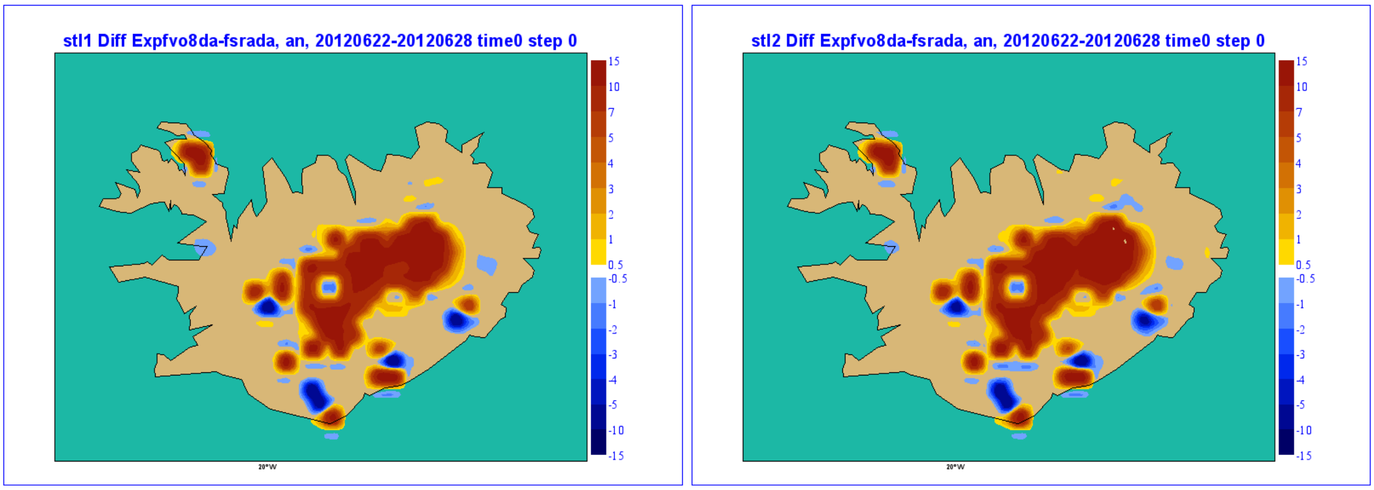
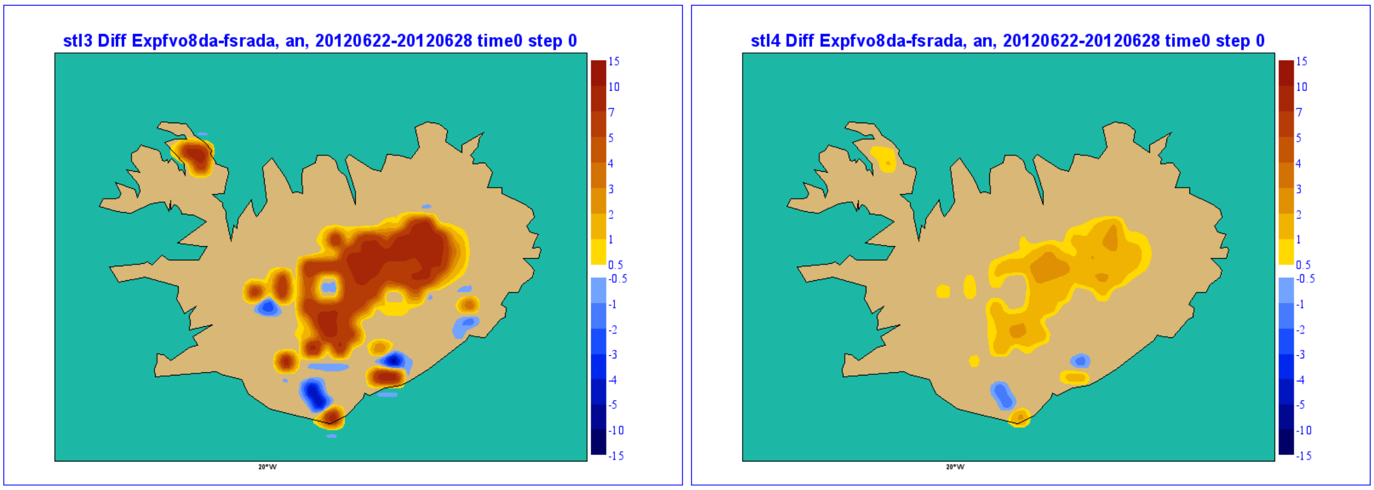


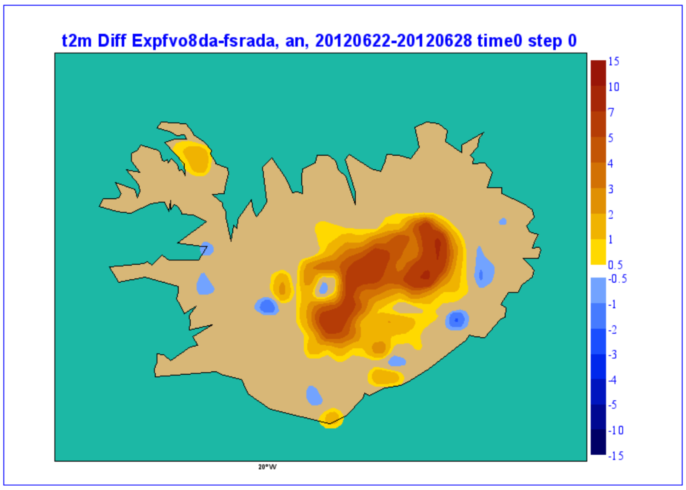
Figure 5: Snow water equivalent (in m) on 2012 05 31 at 18 UTC step 6, valid an 2012 06 01 at 00UTC, for the test experiment fvo8: before modification (top) and after the field was modified to reduce snow amount for grid points on which the new mask removed glacier (bottom). The modified field was then used as background snow depth for the 20120601 00 DCDA analysis which was also the first analysis to use the revised glacier mask.



(a) Impact on soil temperature Layer 1 (0-7cm) and Layer 2 (7-28cm)



(b) Impact on soil temperature Layer 3 (28-100cm) and Layer 4 (100-289cm)



(c) Impact on two-metre air temperature

Figure 6: Influence of the revised glacier (fvo8-fsra) on the soil and air temperature analyses (difference fsra - fvo8 in K).

confirms that the glacier fix has a local impact. As aimed with the local glacier and snow update approach implemented, it does not influence the forecasts hemispheric scores. These results confirmed the suitability of the proposed approach for implementation in the esuite 38r2 without extensive testing.

5 Esuite implementation results

The implementation in the esuite 38r2 followed the procedure described in section 3 for HRES and EDA. The first-guess forecast snow water equivalent valid on 2013050800 was modified to replace 10m of snow water equivalent by 0.06m, the climate data base on c2a was updated with the new cicecap_iceland files and the scripts were modified to pick up the new mask for analysis date larger or equal than 2013050800. The HRES patched snow depth first guess is not shown since it is very similar to the one obtained for the RD test (Figure 5). Figure 10 shows the patched first guess snow water equivalent for the esuite 38r2 EDA (T399) control member. Updated snow water equivalent shows that the 10m of snow is consistent with the new glacier mask shown in Figure 3 at the EDA resolution.

Figure 11 shows, for HRES the soil and screen level temperature differences between the esuite 38r2 and the osuite 38r1 analyses for 15-21 June 2013 (six weeks after implementation of the new glacier). In agreement with the results obtained from the RD test for June 2012, it shows large differences in soil temperature and screen level temperature. In agreement with the RD test results presented above, it shows generally much warmer conditions (up to 15 K for the soil and up to 7 K for the two-metre air temperature) with the new glacier (esuite 38r2) than with the old glacier mask (osuite 38r1). The pattern is consistent with the glacier mask difference of Figure 1 and the impact remains local over the area concerned by the glacier and subsequent snow update.

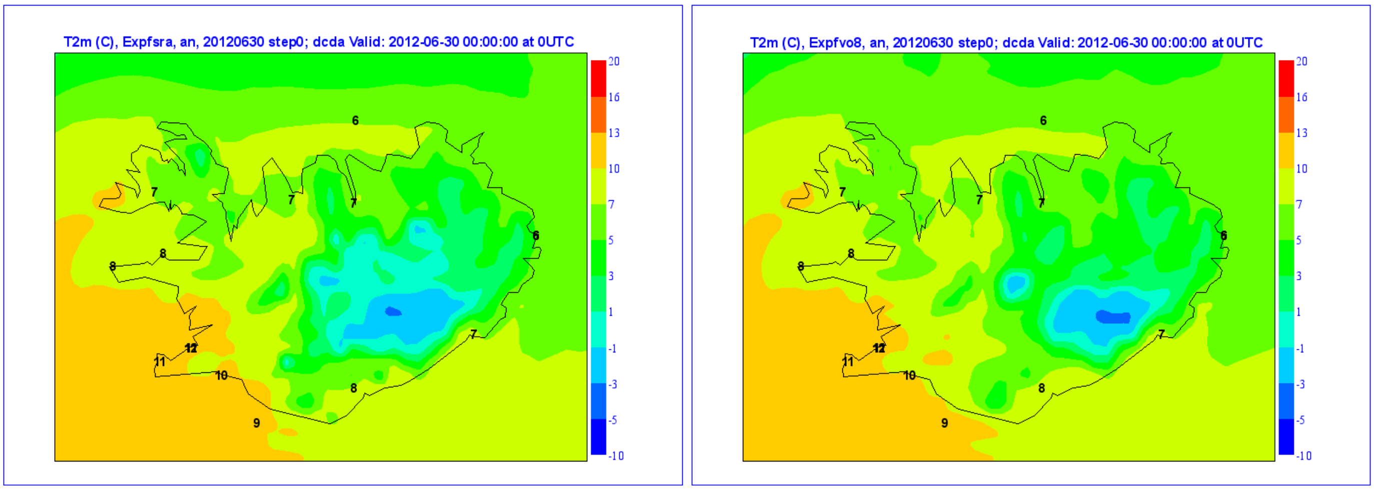
6 Initial conditions of the re-forecast ENS

Figure 12 shows the glacier extent update for the ERA-Interim and ERA-Land resolution (T255). ERA-Interim and ERA-Land currently provide initial conditions (including snow depth) to the ENS re-forecasts. For the surface initial conditions the ERA-Land simulation is used (experiment fiv8) described in Balsamo et al (2012).

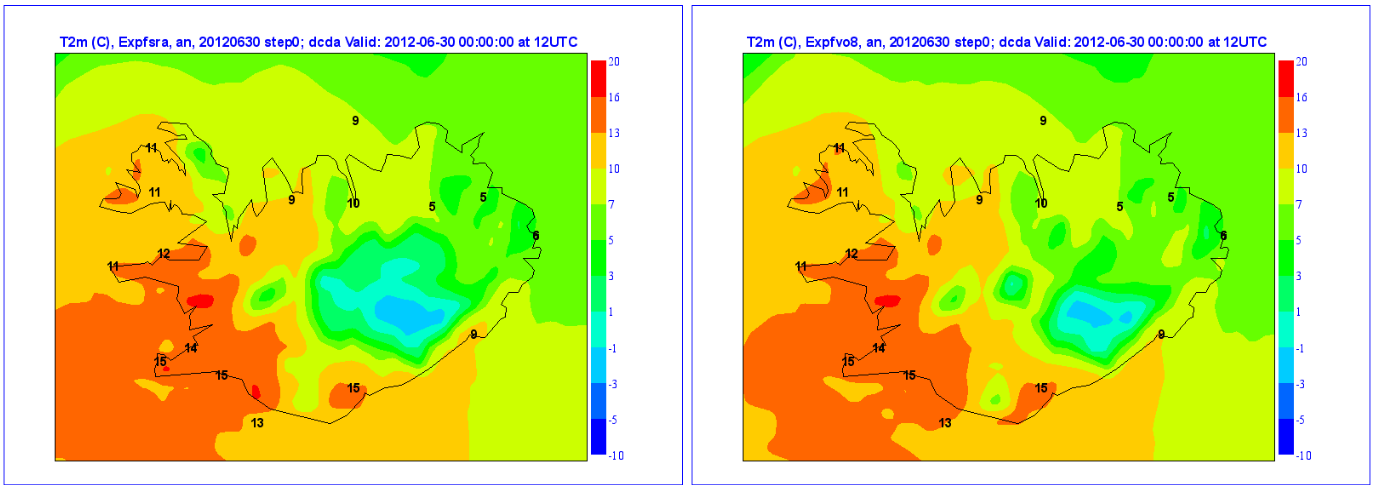
Although the re-forecasts use the operational cycle, they do not benefit from the glacier mask update because their snow water equivalent initial condition is obtained from an old cycle analysis, still using the old GLCC glacier mask. In contrast, the ENS forecasts benefit from the glacier update implemented in the operational analysis, as mentioned earlier in section 3. So, there is an inconsistency between (1) the forecast ENS, which accounts for the fixed glacier mask and (2) the re-forecast climatology, which still relies on the old mask and which causes a spurious pattern of large EFI over Iceland. This issue was highlighted in the Daily report on 19 July 2013.

To fix the re-forecasts ENS issue, ERA-Land was rerun with the snow water equivalent initial condition modified to remove spurious snow where glacier were removed over Iceland (same procedure than described above, except than in this case the T255 initial condition on 1979010100 was modified). The resulting new ERA-Land archive (fxjt) is identical to the current ERA-Land (fiv8), experiment over Iceland where the surface prognostic variables were obtained using the new glacier mask. So, it is suitable to provide land surface initial conditions for the 38r2 re-forecasts ENS.

Figure 13 shows the difference of two-metre temperature re-forecast averaged between day 5 and 11 between the ensemble mean of 15-member re-forecasts starting on 22 July 1989-1991 using the updated ERA-Land

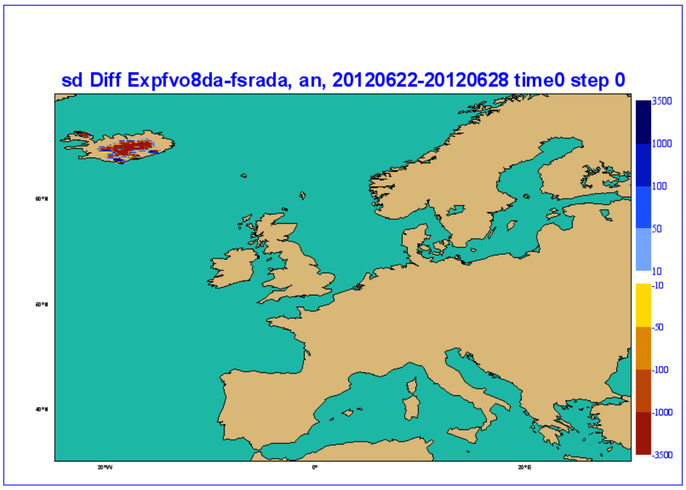


(a) 00 UTC

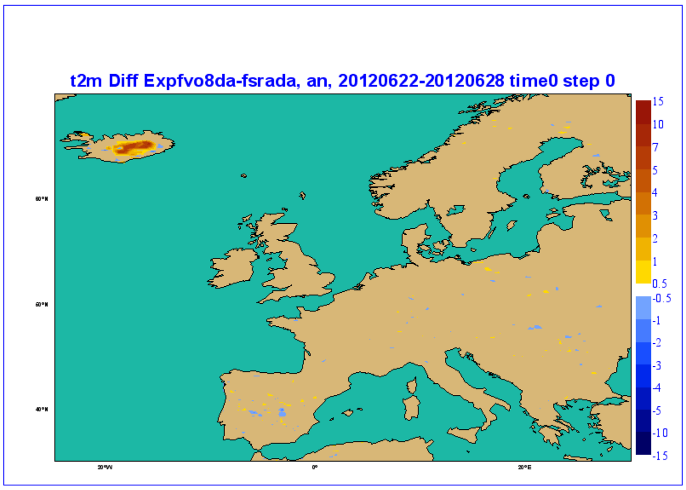


(b) 12 UTC

Figure 7: Two metre temperature analyses (Celsius) after one month of experiment for the control (left) and for the experiment using the revised glacier implementation (right), at 00 UTC (top) and 12 UTC (bottom). SYNOP reports of two-metre temperature are given in black.



(a) Snow Depth (cm)



(b) Two metre air temperature

Figure 8: Difference between the updated glacier experiment and the control (fvo8-fsra) over Europe for the last week of June 2012 (fourth week of experiment), for snow depth in cm (top) and two-metre air temperature in Celsius (bottom).

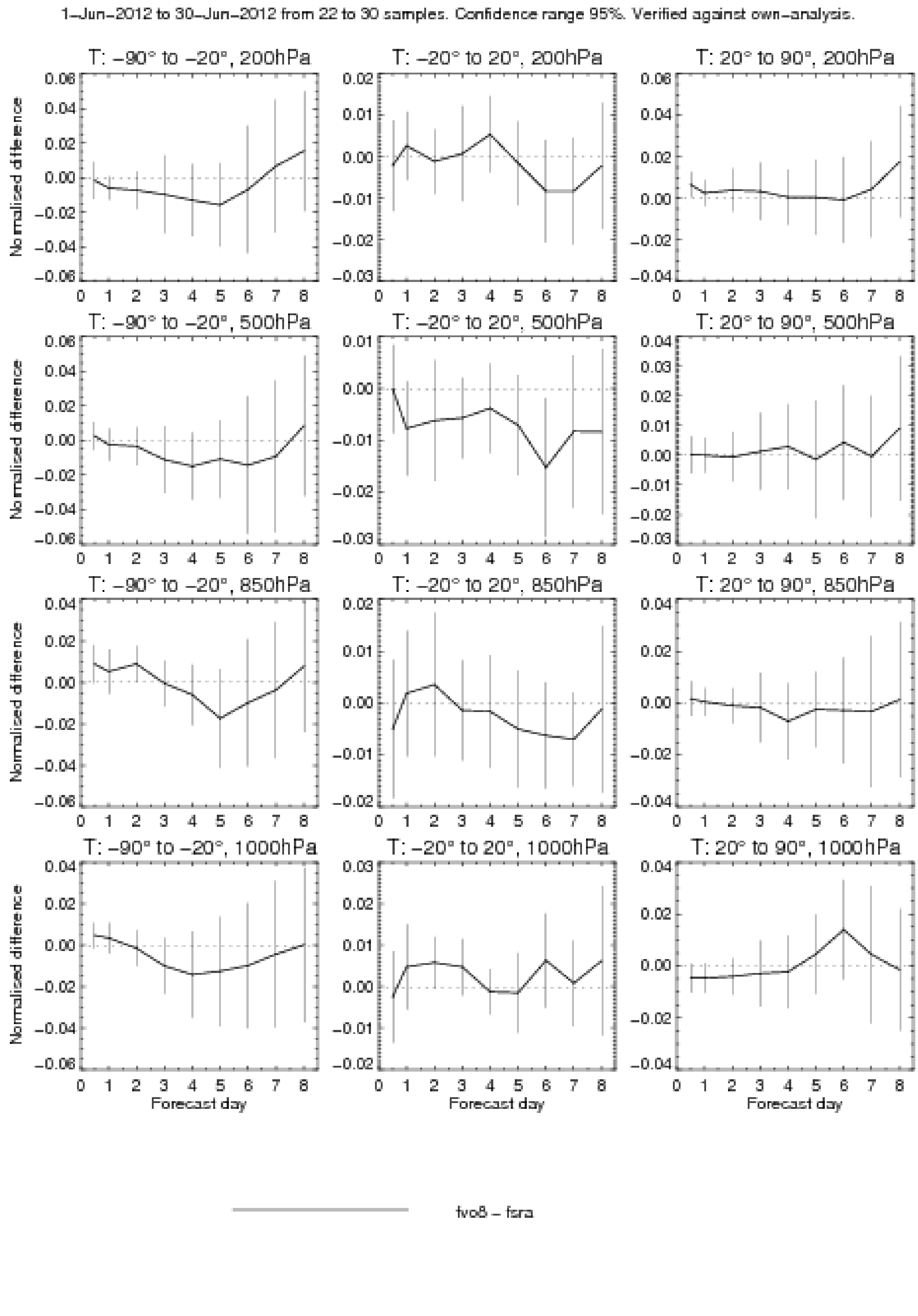


Figure 9: Impact of the new glacier mask on the forecast temperature RMSE for June 2012 (fvo8-fsra). As expected the local glacier change over Iceland only has a neutral at large scale.

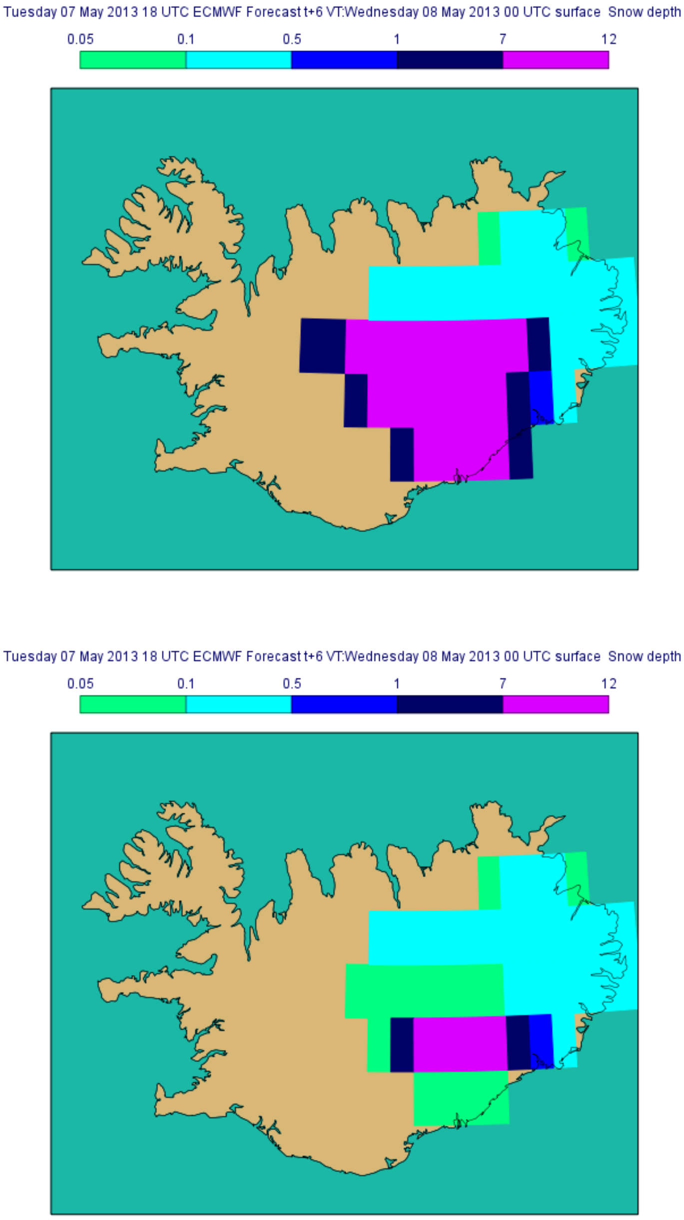
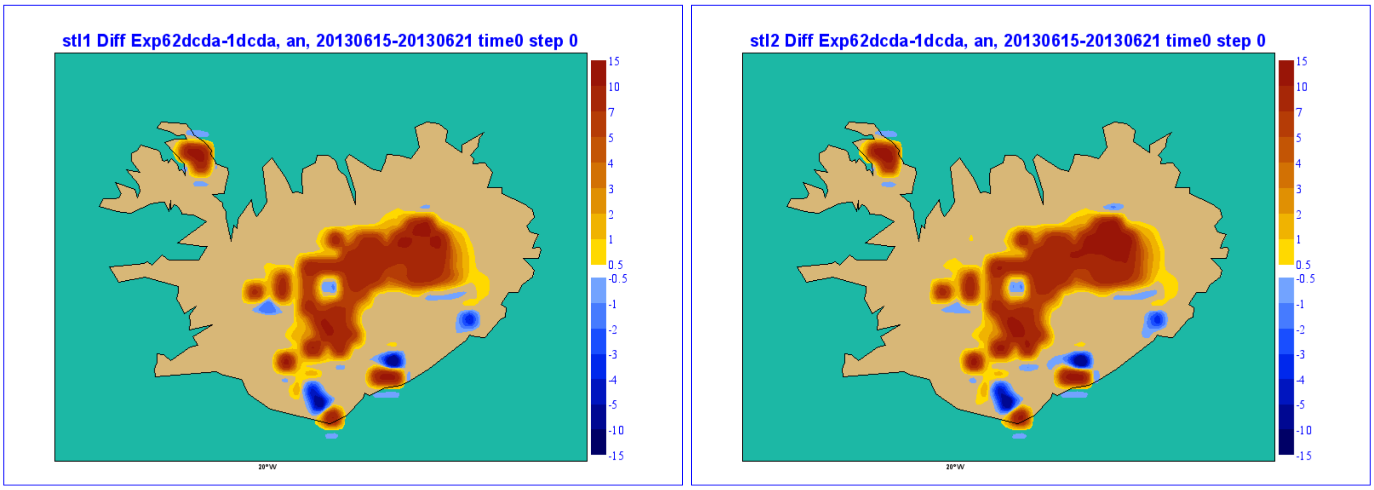
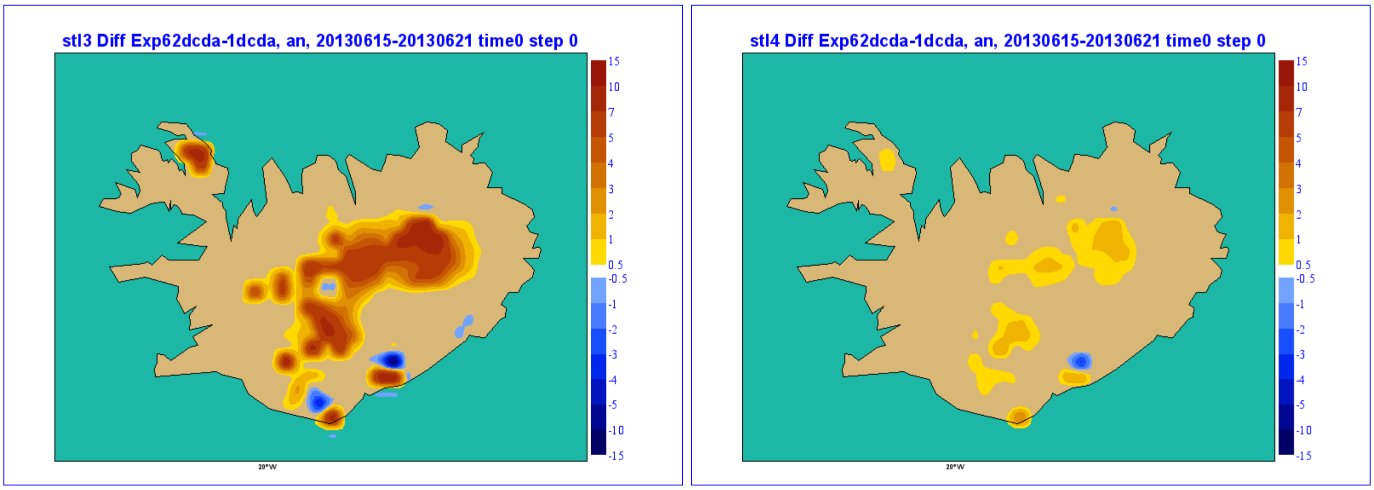


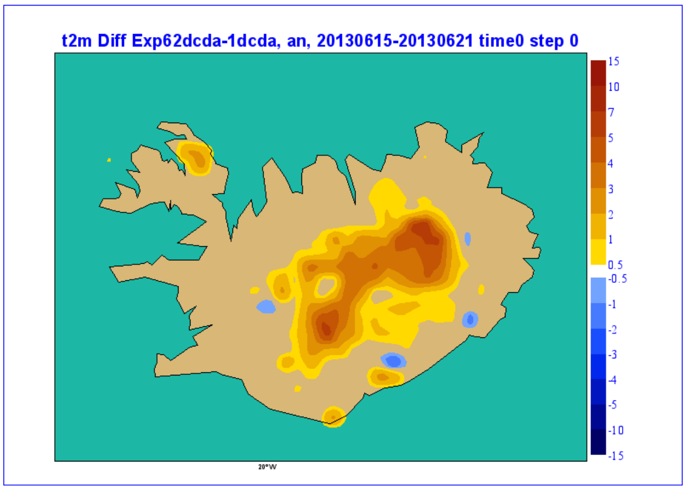
Figure 10: Snow water equivalent (in m) on 2013 05 07 at 18 UTC step 6, valid an 2013 05 08 at 00UTC, for the esuite 38r2 EDA control: before modification (top) and after the field was modified to reduce snow amount for grid points on which the new mask removed glacier (bottom). The modified field was then used as background snow depth for the 20130508 00 EDA control analysis which was also the first analysis to use the revised glacier mask. The same procedure was applied to the 10 EDA members.



(a) Impact on soil temperature Layer 1 (0-7cm) and Layer 2 (7-28cm)

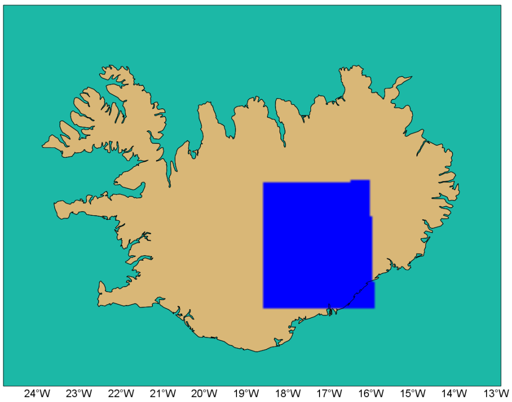


(b) Impact on soil temperature Layer 3 (28-100cm) and Layer 4 (100-289cm)

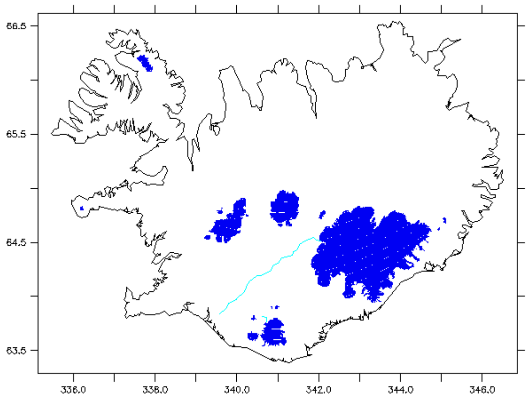


(c) Impact on two-metre air temperature

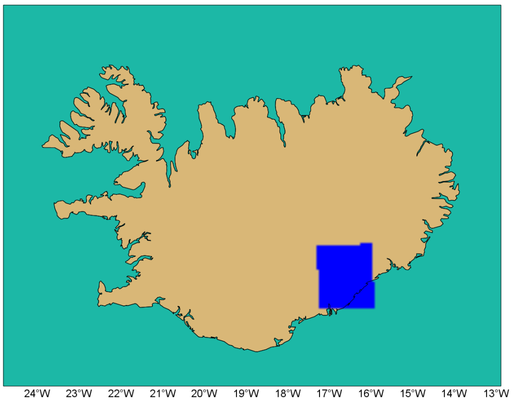
Figure 11: Influence of the revised glacier (fvo8-fsra) on the soil and air temperature analyses (difference fsra - fvo8 in K).



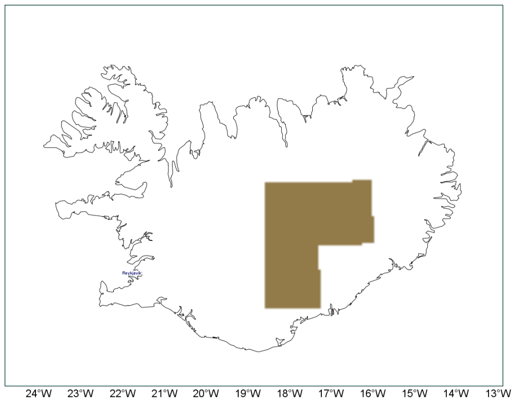
(a) IFS cycle 38r1 glacier mask



(c) IMO 1km glacier mask



(b) Glacier mask in IFS cycle 38r2



(d) Difference 38r2-38r1 glacier mask

Figure 12: Same as Figure 1, but at T255 which is the ERA-Interim and ERA-Land resolution. ERA-Interim and ERA-Land are not using IFS cycle 38r2, so they are not affected by the change, but they provide the atmospheric and surface initial conditions (including snow depth) used for the ENS re-forecast.

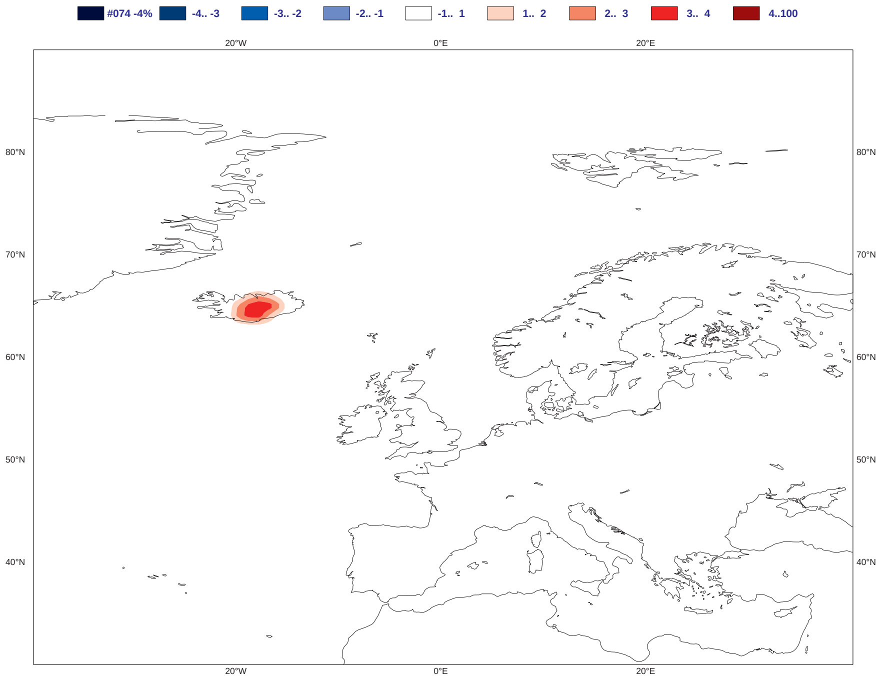


Figure 13: Two-metre temperature re-forecast difference averaged between day 5 and 11 between the ensemble mean of 15-member re-forecasts starting on 22 July 1989-1991 using the ERA-Land surface initial conditions updated with the new glacier (fxjt) and a re-forecast using the original ERA-Land surface initial conditions with the old glacier (fiv8).

surface initial conditions (fxjt) and a re-forecast using the original ERA-Land surface initial conditions (fiv8). It clearly shows that (1) Iceland is warmer with the new surface conditions, in agreement with the glacier update, (2) the impact is local over Iceland. This pattern in the re-forecasts temperature difference is consistent with the pattern obtained between the analyses using the new and old glacier, showing the relevance of the patched ERA-Land to be used to initialise the 38r2 re-forecasts.

These results support the operational use of the updated ERA-Land (class=rd, expver=fxjt) land surface conditions, instead of the current version of ERA-Land (class=rd, expver=fiv8, also archived as class=ei expver=2), to initialise the 38r2 re-forecasts.

7 Conclusion

The IFS glacier mask was revised in IFS cycle 38r2 to account for the up-to-date Icelandic Meteorological Office (IMO) mask over Iceland. The change was motivated by a request from IMO to use a more realistic glacier mask in order to improve snow depth and screen level temperature forecasts in the ECMWF products. This work has been conducted in close collaboration between ECMWF and IMO. The IMO 1-km glacier mask was used to patch the ECMWF GLCC mask over Iceland. The revised glacier mask was prepared at all resolutions. Then the implementation consisted in updating the climate data base, modifying the snow water equivalent initial conditions and changing the scripts to ensure 38r2 experiment and esuite reproducibility. The revised glacier mask was implemented in 39r1, as well as in the esuite 38r2 on 08 May 2013 at 00UTC, in HRES and EDA. Results from RD experiments and from the suite showed that the glacier update has a large local impact over Iceland where it reduces the temperature bias reported by IMO.

Although the Icelandic glacier update was effective in HRES, EDA and ENS forecasts, it was not the case in the ENS re-forecasts. The re-forecasts use land surface initial conditions from ERA-Land which was produced using the old glacier. So, a revised version of ERA-Land with patched initial conditions over Iceland in agreement with the revised glacier mask was run. Re-forecasts experiments were conducted in RD using the updated ERA-Land conditions over Iceland. Results showed that using the patched ERA-Land is suitable to initialise the re-forecast. It ensures the Icelandic glacier in the ENS re-forecasts is consistent with that of ENS forecasts, leading to reliable EFI and monthly forecasts products over Iceland. As for the HRES and EDA implementation the patch in ERA-Land is local, so that the update of ERA-Land conditions has a local impact on the re-forecasts with a neutral impact at larger scale. To ensure ECMWF is delivering reliable EFI and monthly forecasts products over Iceland, the patched ERA-Land has been used in operations since late July 2013 to initialise the ENS re-forecasts.

The implementation of the glacier update is a nice example of efficient collaboration between RD and FD and between ECMWF and its Member State IMO. This coordinated effort resulted in a consistent implementation of the revised glacier mask in the different components of the ECMWF forecasting system, whereas ensuring reproducibility of 38r2 and not perturbing the 38r2 scores. It definitely fixes a long standing issue with the Icelandic glacier representation.

Beside, the Icelandic glacier update was a very useful exercise prior to the implementation of a revised set of topographic and land-use data, where among many other modifications, we have also updated the Icelandic topography as provided by IMO together with the glacier data. Questions raised and solved to ensure consistent implementation in HRES, EDA, ENS and ENS re-forecasts will benefit the global new climate data base implementation in the next cycles.

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