RESEARCH DEPARTMENT MEMORANDUM

ECMWF

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Subject: Snow analysis fixes in operations (36r1): geolocation of NOAA/NESDIS data, relaxation in NESDIS data use and timing issues

1 Introduction

Particularly cold winter conditions in 2010, with a lot of snow in the northern hemisphere, raised several issues in the operational snow analysis in the Integrated Forecasting System (IFS) cycles 35r3, 36r1 and 36r2. A snow density issue has been fixed in operation on 19 January 2010 (Balsamo and de Rosnay, 2010). Following the surface analysis re-organisation in cycle 35r3 (Vasiljevic et al., 2009), the NOAA/NESDIS (National Oceanic and Atmospheric Administration - National Environmental Satellite, Data, and Information Service) snow cover data normally used in the snow analysis at 12UTC in both the DCDA and DA analysis, was by mistake not assimilated in cycle 35r3, until it was re-activated on 19 January 2010. During these investigations several issues were also identified concerning:
- NOAA/NESDIS data geolocation in our conversion from GRIB to BUFR.
- Snow analysis computing time too long for T1279.
- Occurrence of spurious snow free patches introduced by the Cressman snow analysis,
This report addresses these three issues that have been fixed in operations (cycle 36r1) and in the e-suite (cycle 36r2) on 23 February 2010.

2 Use of NESDIS data

The use of NOAA/NESDIS snow cover data was introduced in the snow analysis in 2004 (Drusch et al., 2004). The two main ways of using NOAA/NESDIS data in the analysis are the following:
- If NOAA/NESDIS indicates snow cover while the model first guess is snow free, 10cm of snow depth is added to the background field.
- If NOAA/NESDIS is snow free and the model is snow covered, NOAA/NESDIS data enter the analysis as a pseudo-observation with zero cm of snow.

3 NOAA/NESDIS data geolocation issue

Snow cover product is delivered daily from NOAA/NESDIS in GRIB2 on a polar-stereographic grid. At the preprocessing level, ECMWF converts GRIB files to BUFR. BUFR files are used directly in the surface analysis. The GRIB to BUFR conversion programme uses four types of input files:

- NOAA/NESDIS data GRIB files that contain binary information on snow cover in the northern hemisphere (0= “no snow”and 100 = “snow”). This data is provided on a polar-stereographic grid. However the GRIB file does not contain any location information. Since the grid is particular to the NOAA/NESDIS product (contains missing pixels), it must be used together with location files provided by NOAA/NESDIS.
- Location information on latitude and longitude.
- Land sea mask is used in the conversion program to select data values over continental areas to be put in the BUFR file.
- Orography information is put in the BUFR file. It is used in the analysis to compute the altitude difference between model and observation. This determines the weighting functions used to compute analysis increments.

The output of the GRIB to BUFR conversion contains snow cover and orography. It is archived in ECFS (SNOW0001YYYYMMDDHH.DAT) and in MARS (obstype=snowcover).

Figure 1 shows the land-sea mask and orography used in the NOAA/NESDIS preprocessing and in the analysis since 2004 until February 2010. The land sea mask input file used in the GRIB to BUFR conversion is actually the orography field. It is used as a land sea mask field, masking out sea and water body points for values higher than 0.5 m. The figure 1 (top and bottom) clearly shows a shift of about 1 degree in latitude/longitude towards the south-east in the land sea mask and orography fields (same field represented with a different scale).
However, as shown in Figure 2 for two different dates in 2005 and in 2010, the NOAA/NESDIS data itself is correctly geolocated since the latitude and longitude information used for preprocessing is correct. Only the mask is shifted, giving information over sea and missing information over land. Figure 2 shows however that a few snow free points that belong to sea are located on the coastal area over land. This is due to the fact that geolocation information provided by NOAA/NESDIS gives the upper-left corner of each pixel. So, the geolocation issue mainly concerns the land sea mask and orography fields that are used to convert NOAA/NESDIS data from GRIB to BUFR.
This geolocation issue affects the snow analysis in two ways. First the orography field is wrong, so the weighting functions for observations in the analysis are wrong. Second, cases of ocean data (always defined as “no-snow”) on land in coastal areas with snow lead to increased removal of snow in coastal areas at high latitude, as clearly shown in Figure 3 on 22 February 2010.

4 Computing time issue

In addition to the geolocation error, it appeared that the snow analysis computing time was very large at T1279 (more than 2000s in wall clock time). A profiling investigation showed that the use of NOAA/NESDIS data uses most of the computing time in the two subroutines lsm_check.F90 and cres_fill1.F90. These two subroutines contain a loop on the model grid points that includes a loop on the NOAA/NESDIS data points. With the resolution increase these expensive loops were not affordable any more in the DA snow analysis. From cycle 36r1 implemented operationally on 26 January 2010 at T1279, the use of NOAA/NESDIS data was switched off in DA. This solution was not satisfactory since NOAA/NESDIS data are not used in DA anymore.

5 Snow analysis patterns issues

Artificial patterns or ”PacMan” snow shapes have been identified in the snow analysis and forecast spatial distribution. As shown in Figure 4 for different dates for North America, Siberia and Europe, the snow pattern issue has been present for several years. However the problem is more pronounced this year as pointed out in Figure 5 that shows the snow depth (in cm water equivalent) on 22 February 2010 for these three regions.

In North America, the snow free patches are located close to lakes or water bodies. Many snow free coastal points are related to the geolocation issue that put snow free data corresponding to water surfaces, on land areas. In Siberia ”PacMans” with snow excess are shown in 2005 while in 2010 snow free ”PacMans” are shown. They result from the Cressman analysis increments computation in places where only a few SYNOP data are available. In Europe, unrealistic snow free patches are present, in particular in Sweden in February 2010. These snow free patches over Europe occurred in the past few years on a regular basis. Occurrence of snow free patches in northern Sweden is unexpected in winter since it is always snow covered at this season and since NOAA/NESDIS data is in agreement with reality to indicate snow cover. In the analysis this corresponds to a quasi-snow-free ”PacMan” due to a few SYNOP reports having systematic negative increments propagated within a radius of 250km by the Cressman analysis. It results from conceptual issues in the Cressman analysis combined with lack of availability of SYNOP reports in this region.

NOAA/NESDIS data is not used in these “quasi-snow-free” ”PacMans” since a very thin amount (less than 1mm) of snow in the model First Guess prevents it from considering the model first guess as snow free.

6 Fixes implemented on 23 February 2010

In order to fix the geolocation issue we revised completely the NOAA/NESDIS data preprocessing. The geolocation latitude and longitude information was updated by using more digits to give higher precision in location information. Based on latitude and longitude information, and using the T1279 geopotential field, we generated a new orography field to be put with the NOAA/NESDIS data in the BUFR file. Since the NOAA/NESDIS geolocation indicates the upper left corner of each pixel, it is necessary to mask out the coastal areas when using the NOAA/NESDIS data at this resolution (25km). This was the purpose in the surface analysis of the lsm_check.F90 subroutine, however it was not working properly as shown by the negative analysis increments in the coastal area (Figure3). In the revised preprocessing input files are: the NOAA/NESDIS GRIB file, geolocation information, revised orography, field that contains the distance to the coast. Distance to the coast used in operations from 23 February 2010 masks out data that are less than 50 km to the coast.
Masking coastal areas at the preprocessing level allows us to stop using the subroutine lsm_check.F90 in the snow analysis. This modification leads to reduce the cost of the snow analysis by a factor 2. It solves the computing time issue of the snow analysis and we were then able to re-activate the use of NOAA/NESDIS data in the DA snow analysis at T1279 in cycle 36r1. In addition the cres_fill1.F90 was parallelised using Open MP. This modification is efficient to reduce further the cost of the analysis. It has been implemented running on one processor at the moment and it will be used with several processors in cycle 36r4.
To mitigate occurrence of snow free patches, we introduced in the Fortran code (subroutine cres_fill1.F) a relaxation in the use of NOAA/NESDIS snow cover data to a threshold of 10mm of snow depth (1mm of snow water equivalent).
These modifications were tested in research in the fb5c, fb5t and fb5u experiments before operational implementation.

The corrected snow analysis (water equivalent in cm) for 23 February 2010, is shown on Figure 7. The geolocation fix is very efficient at correcting snow free patches at high latitudes, although NOAA/NESDIS is

assimilated only once per day at 12 UTC. This is particularly the case over North America around the lakes area. Figure 8 compared to Figure 3 shows that the issue concerning negative increments in coastal areas at high latitude is solved. The quasi snow free patch in northern Sweden is snow covered after the use of NOAA/NESDIS at 12 UTC. However in this area a systematic snow removal results from the Cressman analysis and the way the weighting functions are computed when only a few observations are available. Systematic negative increments of remote observations propagates in the snow free patch at the 18 UTC, 00 UTC and 06 UTC analysis. All the others ”PacMans” snow patterns around the globe results from the Cressman analysis in case few observations are available.
This clearly shows than further improvements are necessary in the near future to: replace the Cressman analysis by a more efficient scheme, to improve the data quality Check and to address the lack of SYNOP snow depth reports received from the members states.

7 Conclusion

This reports describes the snow fixes implemented on 23 February 2010 in operations. They correct the geolocation issue in the preprocessing of the NOAA/NESDIS data and solve the computing time issue in the operational analysis at T1279. This report also investigates issues in the snow pattern, by relaxing the use of snow covered NOAA/NESDIS data. These snow fixes were very efficient to prevent the use of NESDIS data from wrongly removing snow in coastal areas and in lakes areas. By solving the computing time issue in the snow analysis these fixes also allowed us to re-activate the use of NOAA/NESDIS data in the DA analysis from 23 February 2010.

However the detailed investigation of the snow analysis also pointed out some major conceptual issues in the Cressman snow analysis used in operation. Combined with a severe lack of availability of SYNOP reports including snow depth data, this leads to have a poor unsatisfactory snow analysis in several areas around the globe, such as in Siberia or Northern Sweden. These issues will be addressed by:
- Revising the snow analysis scheme in the next IFS cycles. An Optimum Interpolation scheme will replace the Cressman analysis in 36r4. It will be combined with the EKF analysis later on through the H-SAF project.
- Investigating the availability of SYNOP snow depth reports and encourage to increase the number on the GTS.
- Improving the Quality Control in the snow analysis.
- Using higher resolution NOAA/NESDIS product (4 km instead of 25 km).

Acknowledgment

Thanks to Tim Hewson for reporting problems in the snow analysis and to Martin Miller for pointing out the ”PacMan” snow patterns in the snow analysis. Thanks to Alfred Hofstadler and to John Hodkinson for their helpful advice on the geolocation issue and for operational implementation of the modifications in the snow analysis. Thanks to Milan Dragosavac for investigating the lack of SYNOP reports over Europe.

References

Balsamo, G., and P. de Rosnay, 2010: Introduction of a fix to snow density update and re-activation of satellite snow cover in DA experiments. *ECMWF Research memorandum*, . Number 48.3/GB/1006.

Drusch, M., D. Vasilievic, and P. Viterbo, 2004: ECMWF's global snow analysis: Assessment and revision based on satellite observations. *J. Appl. Met.*, **43**, 1282–1294.

Vasiljevic, D., P. de Rosnay, and J. Haseler, 2009: New structure of the surface analysis for cycle 35r3. *ECMWF Research Memorandum 0920*, , 6pp.

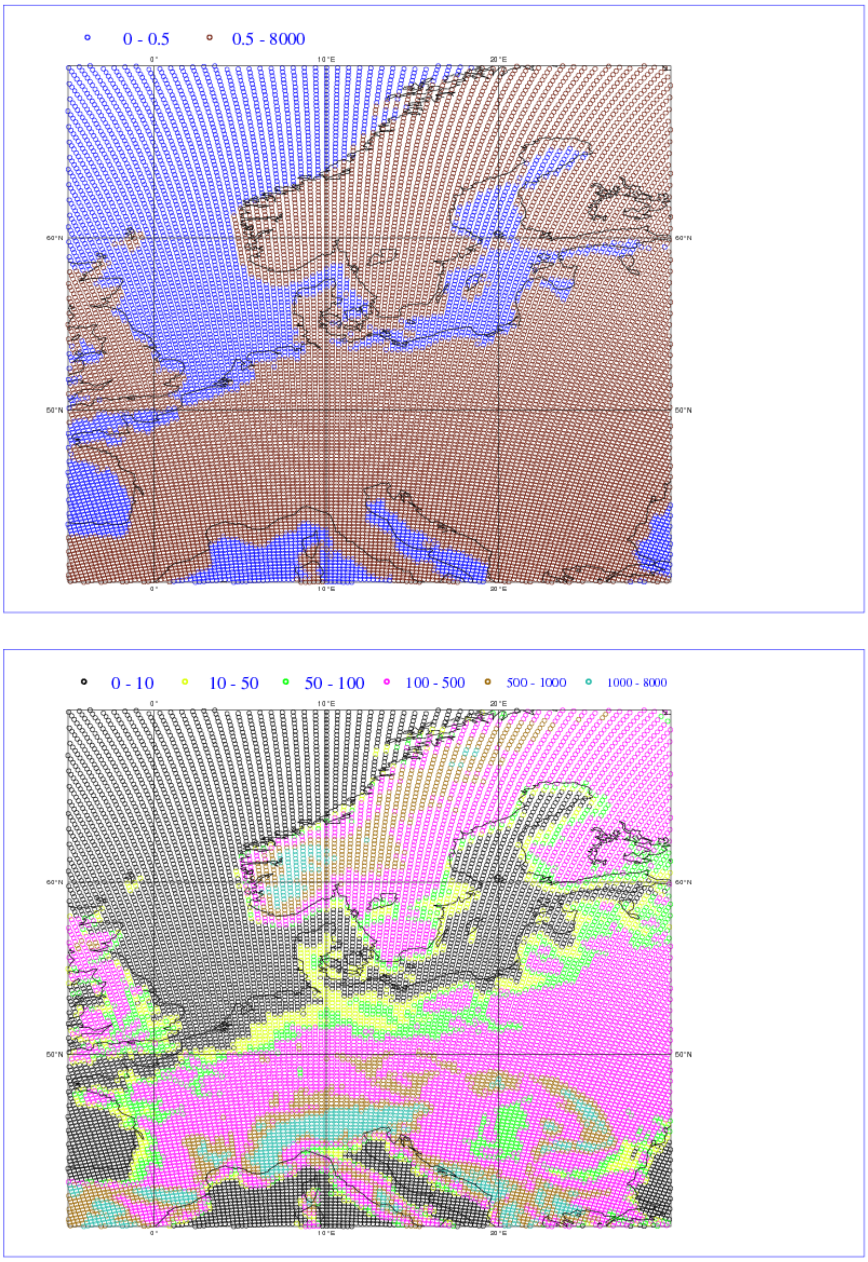
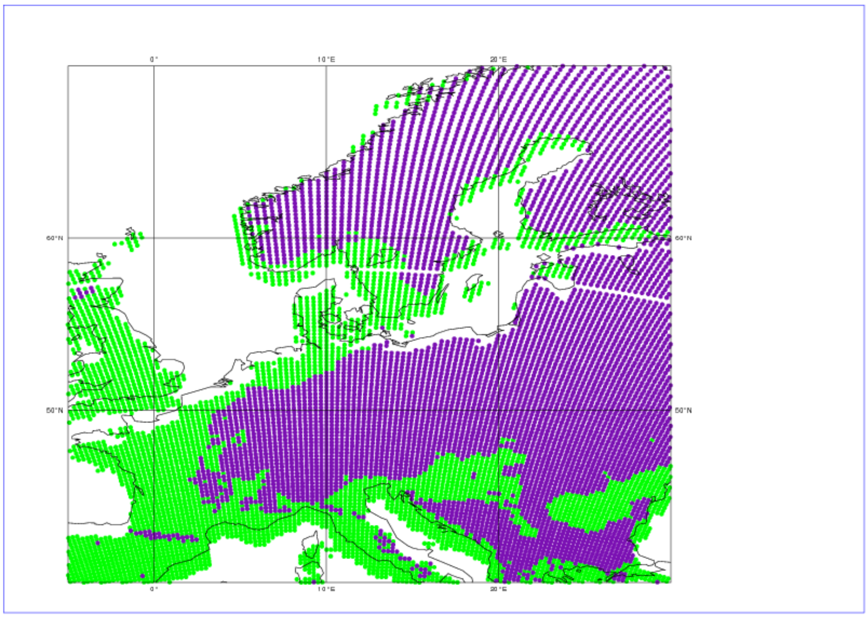


Figure 1: Land sea mask (top) and orography (bottom) used in the operational preprocessing of NOAA/NESDIS data since 2004. Land sea mask uses the orography field (geopotential divided by gravity constant; expressed in m) to mask out, at the preprocessing level, NOAA/NESDIS values below the 0.5m level.



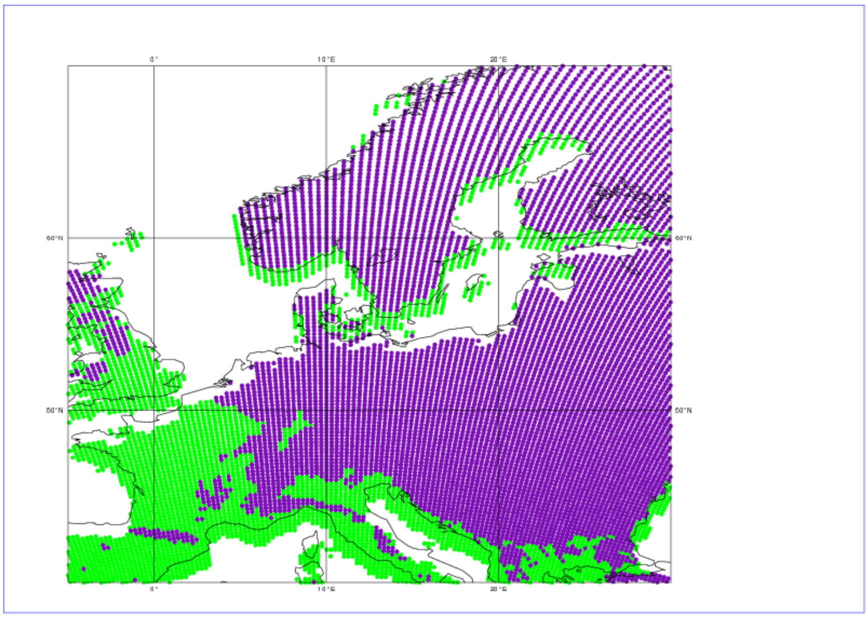


Figure 2: ECMWF NOAA/NESDIS snow cover data on 29 December 2005 (12UTC) and on 04 February 2010 (12UTC). Green represents snow free area while purple indicate snow cover of 100%.

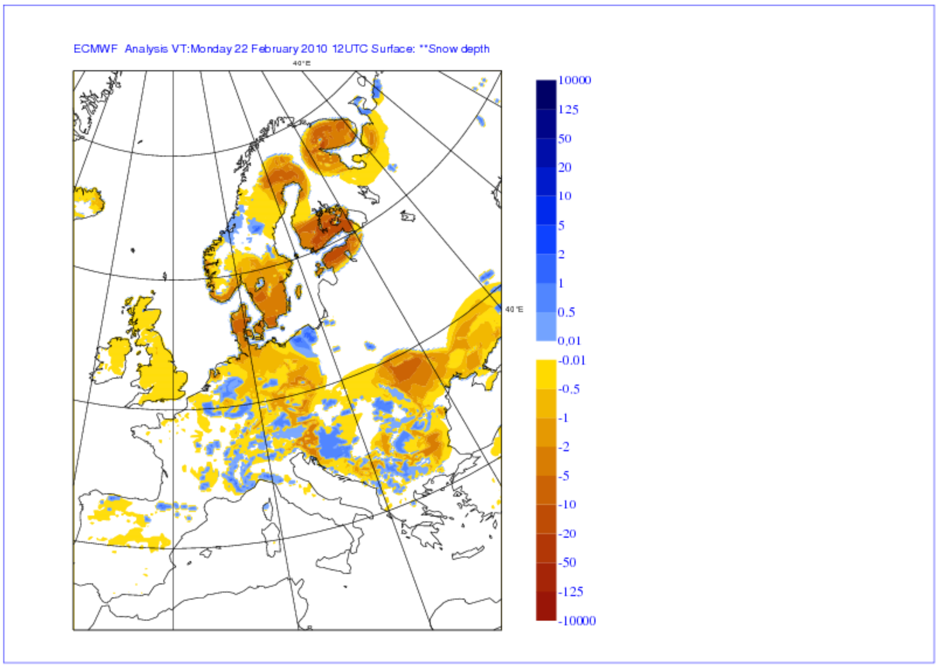


Figure 3: Operational snow analysis increment (in cm of snow water equivalent) on 22 February 2010 12UTC. Negative increments in the coastal area clearly illustrates the geolocation issue in the NOAA/NESDIS data preprocessed at ECMWF.

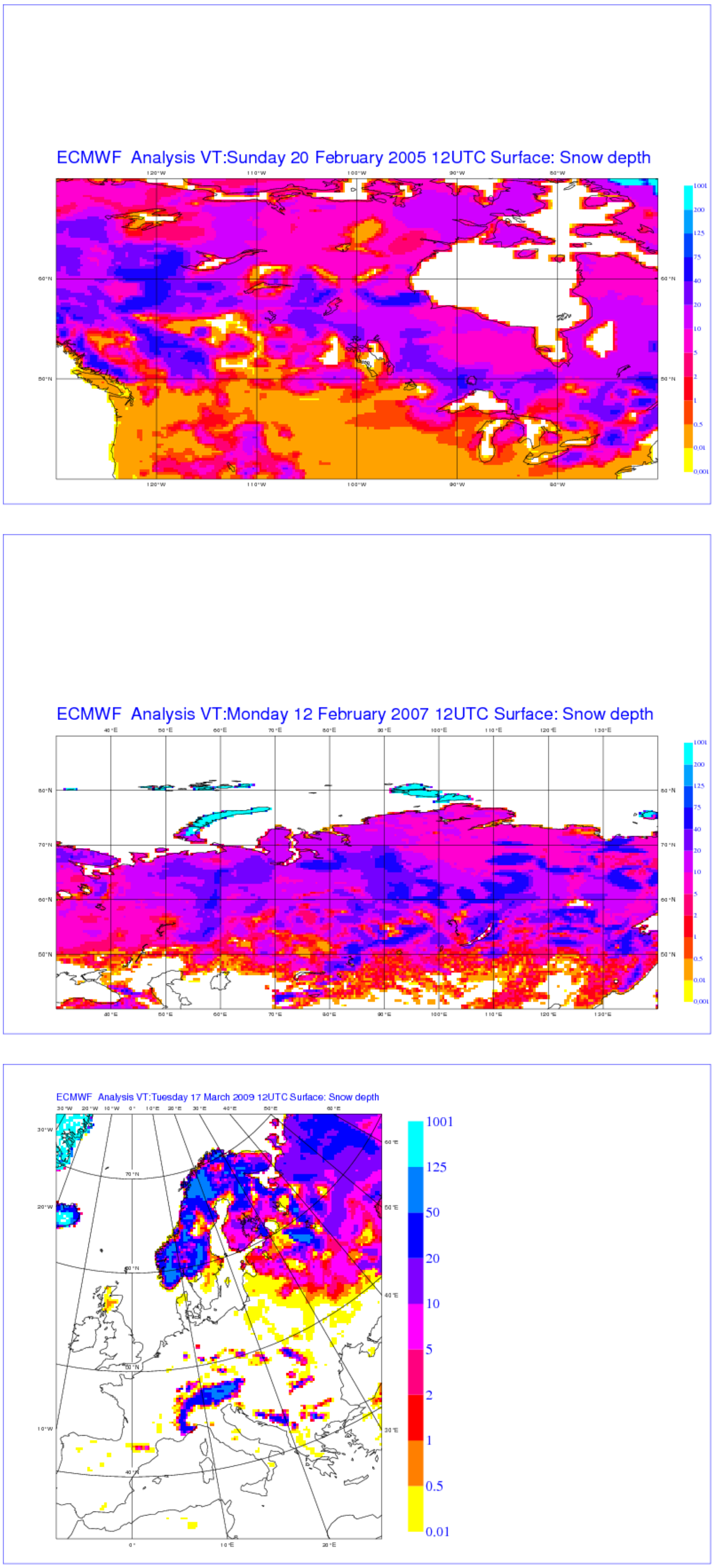


Figure 4: Operational snow analysis (in cm of snow water equivalent) on 20 February 2005 over North America (top), on 12 February 2007 over Siberia (middle), on 17 March 2009 over Europe (bottom).

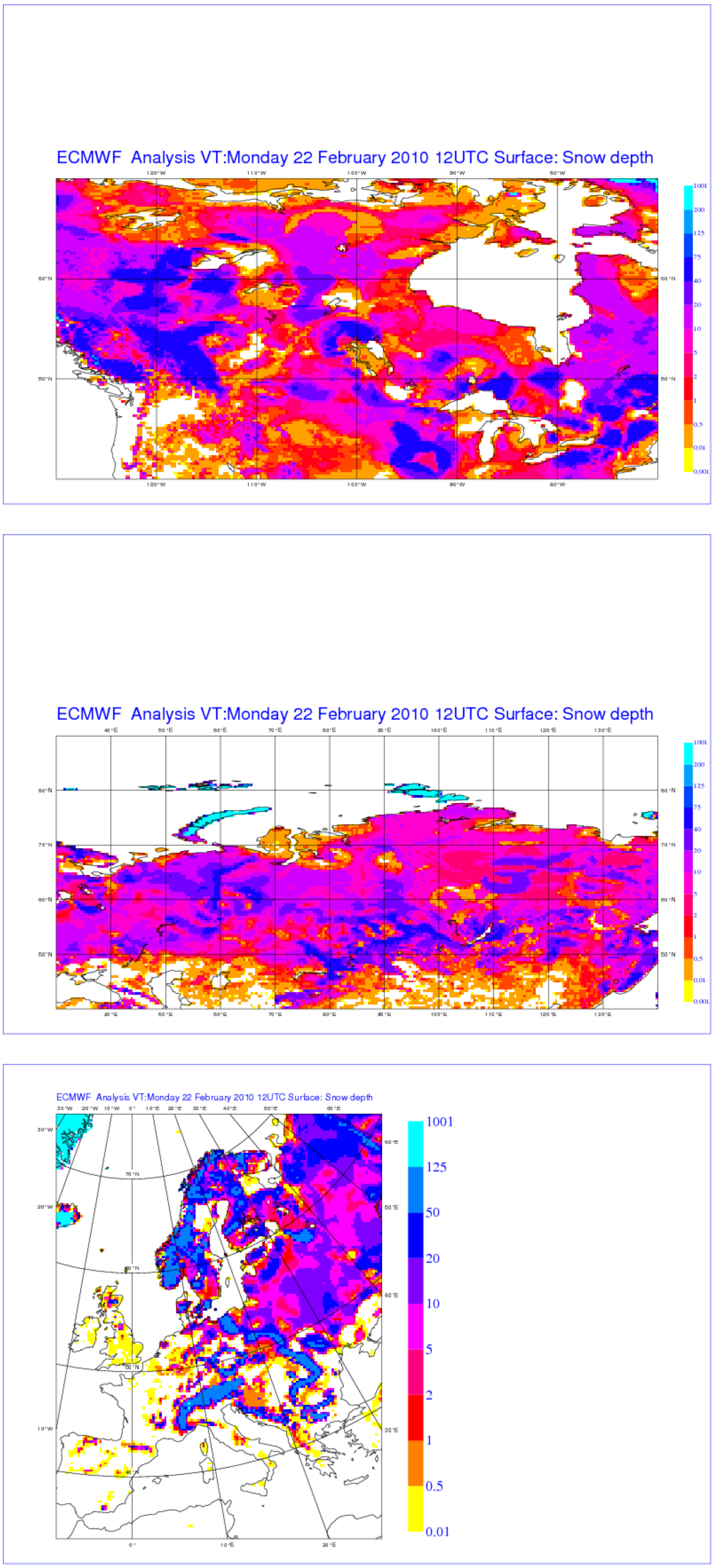
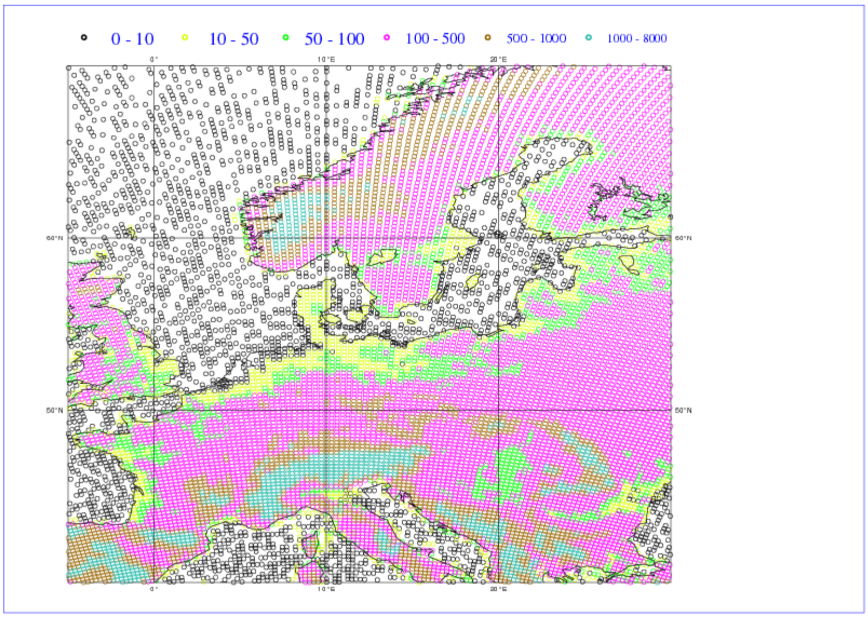


Figure 5: Operational snow analysis (in cm of snow water equivalent) on 22 February 2010 over North America (top), Siberia (middle) and Europe (bottom).



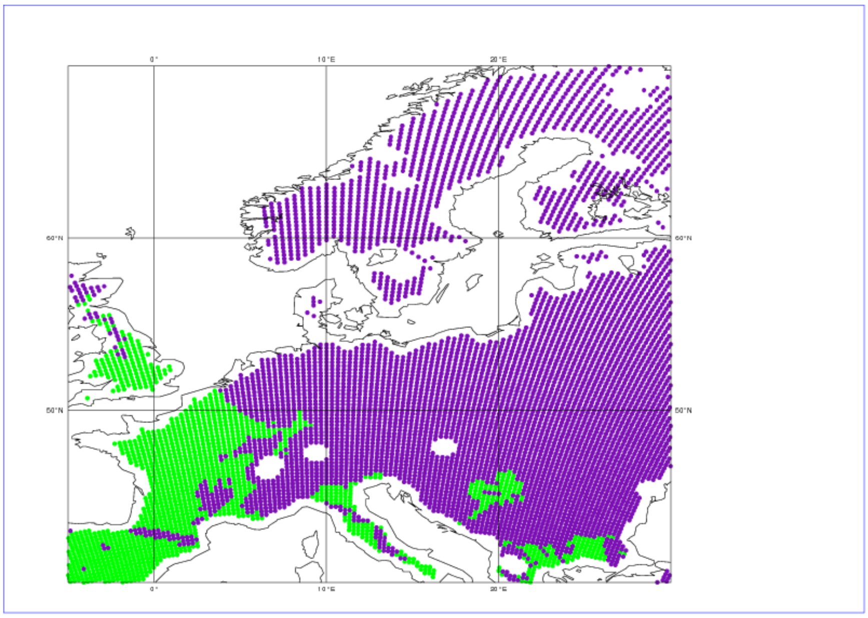


Figure 6: Corrected orography (top) in the NOAA/NESDIS BUFR files used in operations since 23 February 2010 and pre-processed NOAA/NESDIS BUFR file (bottom) used from 23 February 2010 with a 50km mask from the coast.

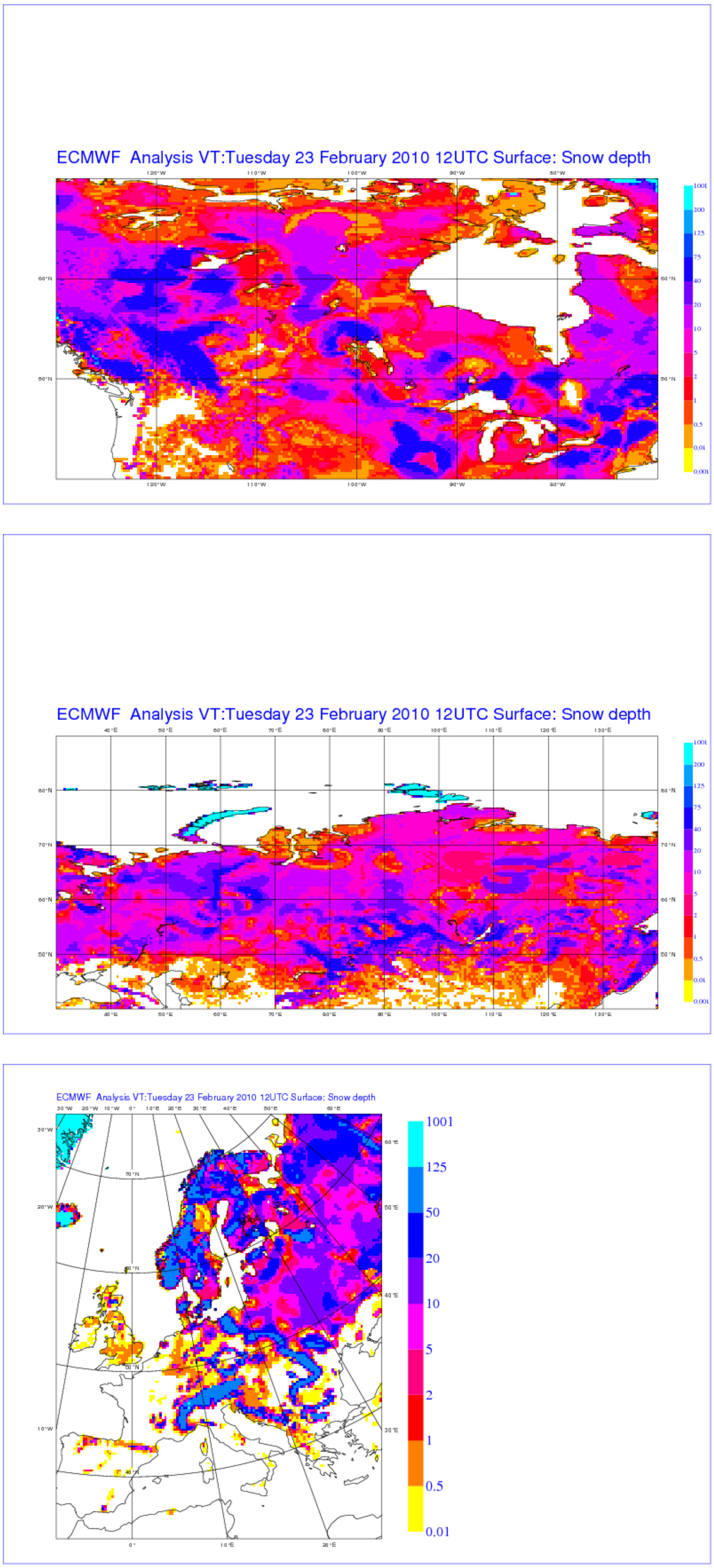


Figure 7: Operational snow analysis (in cm of snow water equivalent) on 23 February 2010 over North America (top), Siberia (middle) and Europe (bottom).

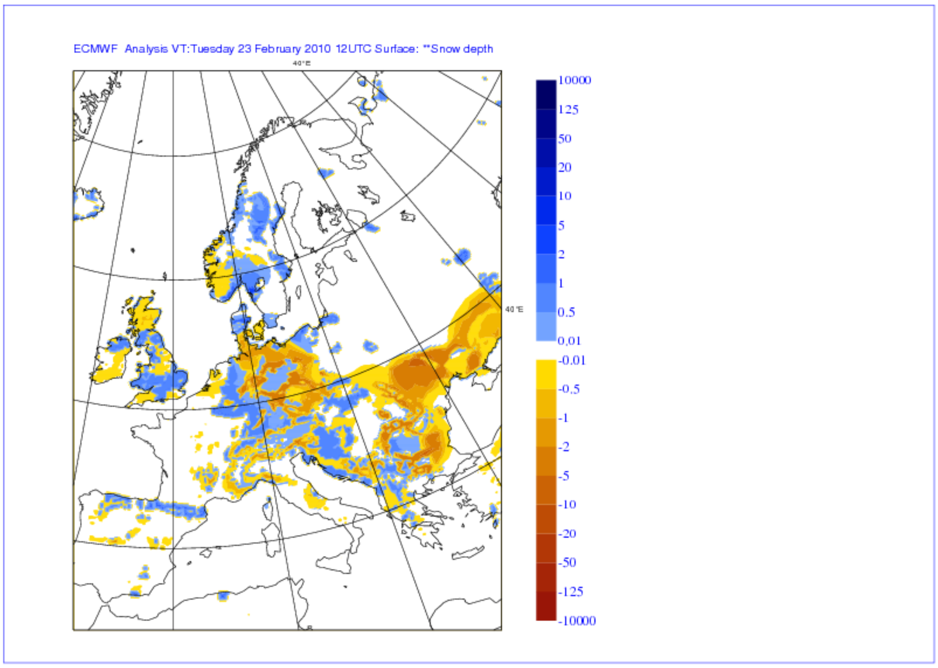


Figure 8: Operational snow analysis increment (in cm of snow water equivalent) on 23 February 2010 12UTC after the geolocation fix has been introduced.