RESEARCH DEPARTMENT MEMORANDUM

To:	D, HR, HO, RD Division and Section Heads, PA/DA sections		
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From:	Gianpaolo Balsamo and Patricia de Rosnay		
Date:	29 January 2010		
Subject:	**Introduction of a fix to snow density update and re-activation of satellite snow cover in DA experiments**	File:	R483/GB/1006

The abundance of snow at our latitudes early this winter has highlighted a few snow-related problems in data rich areas which have been fixed or have generated actions detailed in the following 3 points:

1. Snow density update

An error in the update of snow density has been uncovered in cases when new snow is added by the snow analysis. The snow density is a model variable which hasn't got an equivalent observation in the GTS (among the routine observations), however it is of crucial importance in mapping the snow water equivalent (or snow mass) into snow depth which can be observed at various SYNOP locations and it is used in the snow analysis as detailed in Drusch et al., (2004). In the past cycles (CY35R2 and CY35R3) the snow density parameterization has been improved by considering more physical processes acting on the compaction and metamorphism of the snowpack. The description of the set of changes is available in the ECMWF tech. memo. 607 by Dutra et al. (2009).

The update of snow density is also performed in subsequent assimilation cycles at script level when new snow is added by the analysis. In fact, when a snow increment is applied on a previously snow-free land surface, the snow density is unknown (lack of a first guess). The model snow density operator introduced since CY35R2 has been adopted to provide a first guess for snow density when new snow has been added by the analysis. The snow density in this case can be between 100 and 400 kg/m3 depending on previous meteorological conditions with the value of 100 kg/m3 being adopted for cold/calm conditions.

The mask needed for applying the snow density increment had been erroneously obtained. A snow density increment had therefore been applied on larger areas than originally intended and also on pre-existing snow. This error produced a densification of the snow-pack (Figure 1) at places where previous snow was already present, with occasional overestimation of the overall snow mass. The snow analysis has been very efficient to constrain those errors and limit the impact in the forecast with an increase snow water equivalent added by the analysis (Figure 2).

Such high values of snow density had the effect of reducing a cold bias in night-time temperature locally (Figure 3, Eastern Europe), although this is an artefact due to compensating errors in combination with a stable boundary layer. A physically-based improvement addressing night-time strong inversions has been already proposed by Köhler et al. (2009) for CY36R3.

This correlation of snow density and temperature is the consequence of a more diffusive snowpack, allowing stronger coupling to soil temperatures, which results into a warming of the near-surface atmosphere over night. However, unrealistically high snow densities can also lead to a snow melting delay producing a cooling (Figure 3, e.g. France).

Impact of snow density correction in an RD experiment:

The density update has been by fixed correcting the formula in the script (scripts/gen/ssaana) and a month long RD assimilation test at T799 in parallel to the operational model has proven the fix is already effective after few days of assimilation cycles.

Focusing on the Europe snow event at the beginning of January 2010, the density is correctly modelled around 150 kg/m3 as expected for a snowfall in cold condition (correcting the previous values around 400 kg/m3). As a result the snow water equivalent is reduced while the snow-depth is unchanged (strongly constrained by the analysis in presence of SYNOPs snow depth reports).

2. NOAA-NESDIS satellite snow cover

2) Following the re-organization of the surface analysis code introduced by CY35R3 (Vasiljevic et al. 2009), allowing the future implementation of a surface Extended Kalman Filter and an offline surface analysis suite, the NESDIS snow cover product (http://www.natice.noaa.gov/ims/), normally included in the 12 UTC snow analysis, has not been assimilated. This was due to a mismatch in the path of the file pointing to the previous surface analysis structure. Given that NESDIS snow product can be occasionally missing, the error did not cause any apparent disruption to the system while limiting the capabilities to remove/add snow seen from satellite.

Reactivation of satellite snow cover:

A fix has been introduced in “script/gen/fetchobs”. Since this file can be absent for short period of time (and it is assimilated only at 12 UTC) an alert to operations (by email) is being introduced at script level in order to signal the lack of the NESDIS product and prevent long disruptions happening.

Geo-referencing and time-referencing issues have been discovered which affect the GRIB file encoding and have been pointed out also to NOAA. A report detailing these problems, which have been affecting the snow analysis since 2004, will be issued later together with a revision of the Cressman snow analysis.

3. SYNOP snow-depth reports from Member States

The lack of SYNOPs reporting snow depth in Europe and the consequent inability for ECMWF to correct snow related errors have triggered some actions from KNMI in Holland (contact: Sander Tjim) who have started to send snow depth reports attached to the SYNOP message from January 2010. SYNOP snow-depth remains the most important observation to correct and constrain the model evolution of snow on the ground.

Analysing in more details the number and the location of SYNOP reports entering the snow analysis it appears that several automatic stations are not correctly entering into the analysis and also that incorrect SYNOP reports may be assimilated generating strange snow-free patterns (appearing as broken LPs!). These issues are object of further investigations and will be included in a follow-on report.

Further experiments, parallel to the e-suite at T1279 have confirmed the impact of the snow changes detailed in point 1 and point 2 which motivated the introduction of the fixes in the e-suite in time for the CY36R1 operational implementation.

Interpreting IFS snow forecasts:

The presence of small amounts of snow on the ground (below 10 mm of water equivalent) should be carefully evaluated. This quantity (SD, gribcode 141) always refers to the model grid-box average as well as the snow density (RSN, gribcode=33) and the other snow variables (temperature and albedo).

The actual snow depth and snow cover can be calculated as the forecast model accounts also for fractional snow cover. Also the IFS model do not represent non-natural surfaces such as roads, concrete or buildings, therefore the modelled snow refers to open vegetated areas.

The snow depth is often obtained by rule-of-thumb multiplying the snow water equivalent by a factor 10 (or 12 in the UK following inch/foot ratio) to obtain a rough estimate of snow depth for a given precipitation.

This method is rather efficient for freshly deposited snow (when the snow density is close to 100 kg/m3), however for melting conditions the snow density gets higher, and the above rule is misleading. The snow depth is correctly calculated as:

$$Snow\_Depth = Snow\_Water\_Equivalent * (Water\_density / Snow\_density) \quad (1)$$

The fractional snow cover is a simple function of snow depth and it is assumed to cover 100% of the gridbox for a snow depth of 15cm or more and going linearly to zero for smaller amounts. This can be expressed based on (1) by the formula.

$$Snow\_Cover = \min [1, (Snow\_Depth / 0.15)] \quad (2)$$

Therefore, with high snow density at the end of a cold season (e.g. 400 kg/m3) a given snow mass (e.g. 20 mm of water equivalent) may result in a reduced gidbox average snow depth (of 5cm) and therefore the snow on the ground will occupy only a minor fraction (in this case 1/3 of the grid-box).

Snow depth and snow cover, as calculated following (1) and (2), are reported for the same case in figure 4 and 5. It is recommended to evaluate the presence of snow on the ground (particularly for low amounts) by plotting both the snow cover and the snow fraction.

Acknowledgements

We’d like to thank Tim Hewson for early notification of the presence of high values of snow density compared with derived estimates during the UK exceptional snow event (5 January 2010), and Robert Mureau and Sander Tijm (KNMI) for reporting the Netherlands snow issue and taking actions at observational level. Martin Miller is acknowledged for pointing out to strange patterns in the Siberian and US snow extent. Thanks to Anna Ghelli for the weather parameters diagnostics and to Anton Beljaars and Lars Isaksen for helpful discussions. Finally we would like to thank Jan Haseler for helpful iterations on the experiments.

References

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M. Köhler, A. Beljaars, G. Balsamo and A. Ghelli, 2009: Adjustment to diffusion in stable layers near the surface and impact on T2m. ECMWF RD memo 962.

D Vasiljevic, P de Rosnay and J Haseler, 2009: New structure of the surface analysis for cycle 35r3, CMWF RD memo 960.

Figures:

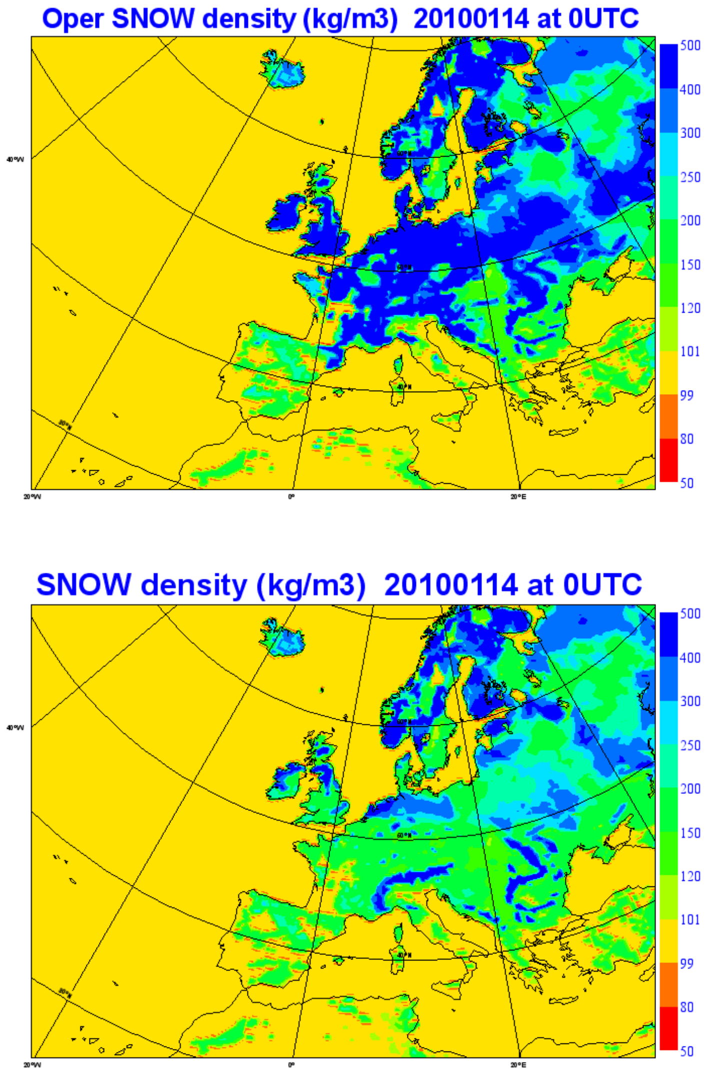

Figure 1: Snow density: operational model T799 (upper panel), RD experiment (lower panel).

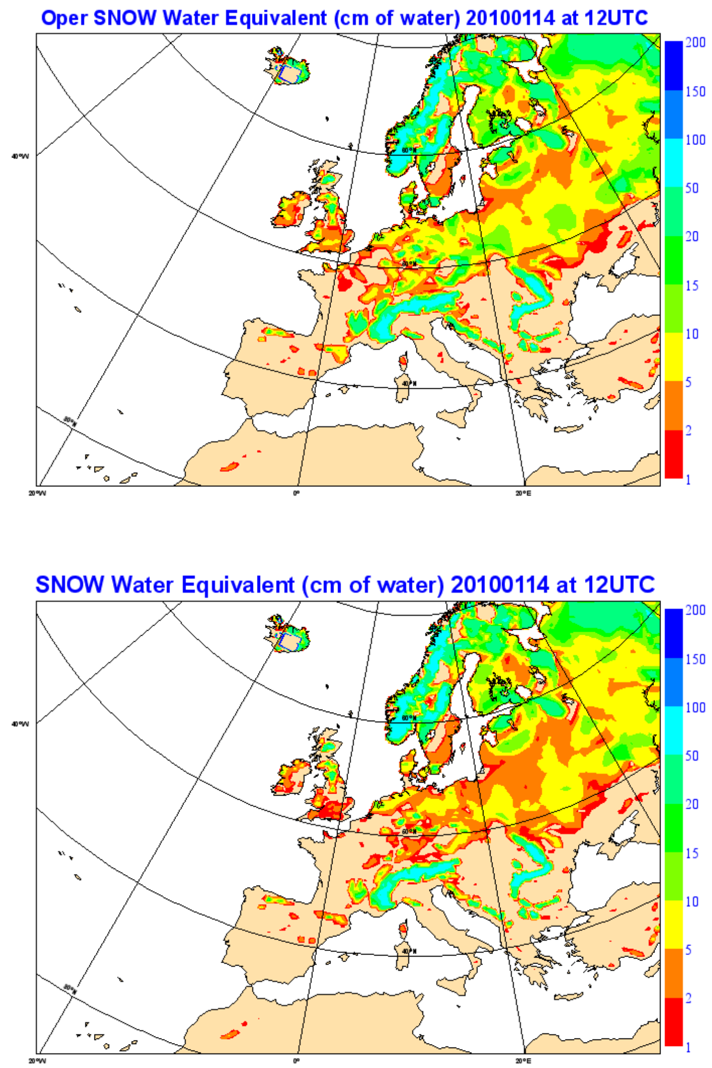

Figure 2: Snow water equivalent: operational model T799 (upper panel), RD experiment (lower panel).

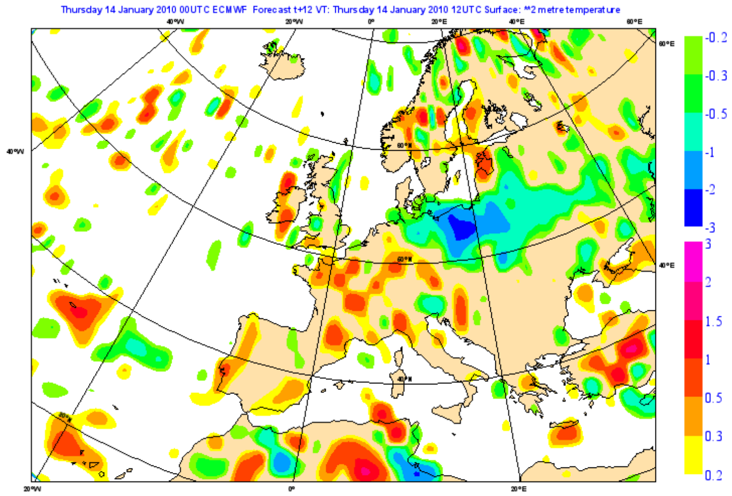

Figure 3: Difference in FC+12-hour 2m temperature (RD exp - OPER)

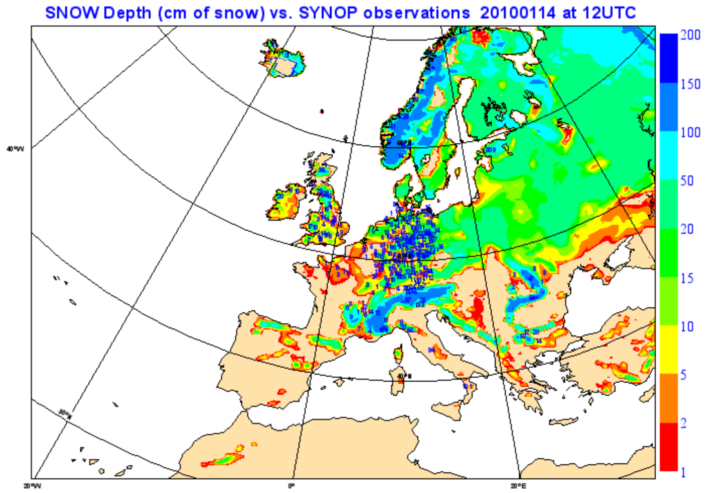

Figure 4: Snow depth as calculated from eq. 1. This quantity can be directly compared to SYNOP reports.

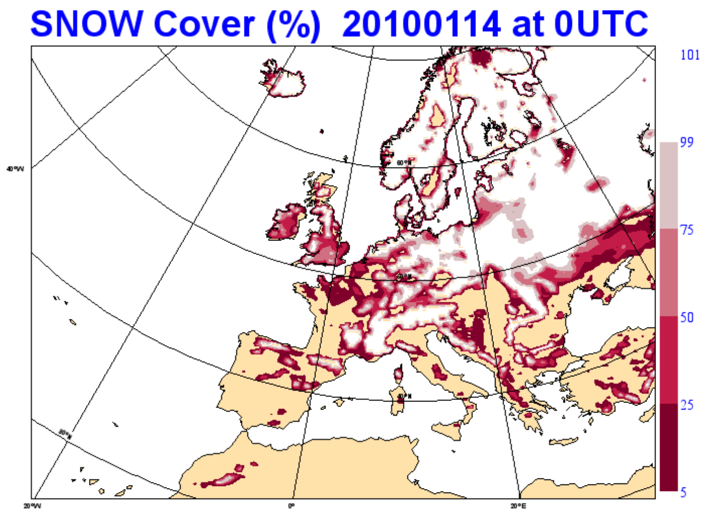

Figure 5: Snow cover (expressed in %) as calculated from eq. 2.