I.32.

UPDATE AND VALIDATION OF SNOW ANALYSIS IN CANARI/ALADIN

Final report based on the work done in METEO-FRANCE during the time

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by

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INTRODUCTION

The purpose of the work is to update and validate the snow analysis in CANARI/Aladin , developed in Météo-France/CNRM/GMAP. This goal has been achieved by modifications of the modules and the routines listed in **Appendix 1**.

The report intends to present :

- the basic ideas of the snow analysis in the frame of CANARI,
- the desciption of the experiments with the snow analysis scheme and the obtained results,
- conclusions drawn on the basis of the obtained results.

The experiments have been done with ALADIN-FRANCE , CY22T1AL12 libraries. The variable, which has been analysed, is the snow quantity (kg.m^{-2}).

I. Basic ideas of snow analysis in the frame of CANARI

Being part of the CANARI scheme, the snow analysis scheme is based on the principles of the OI (Optimal Interpolation), namely: at any point i the analysed variable A_i is presented as a sum of the first guess G_i (6 hour forecast) at the same point and a weighted sum of the observed increments (obs - guess) in the nearest K surrounding observation points.

$$A_i = G_i + \sum_{k=1}^{K} W_{ik} \left[O_k - G_k \right] \qquad (1)$$

The weights W_{ik} minimize the analyses errors . Applying the technique of the OI, the optimal weight vector is

$$\underline{W_i} = \left[\underline{\underline{G}} + \underline{\underline{O}} \right]^{-1} \underline{G_i}$$

where:

$\underline{W_i}$ – *column vector of weights Wik*

$\underline{\underline{G}}$ – *prediction error covariances matrix*

$\underline{\underline{O}}$ – *observation error covariances matrix*

As far as the snow quantity is not a generally continuous variable and snow analysis not widely used, the definition of the model equivalent of the snow observations, as well as the determination of the statistical model (horizontal correlation function, prediction and observation error covariance matrices) is still a matter of studying.

Following V. Cassé (1998) here we have made the following assumptions for the analysed variable and the parameters of the statistical model :

- the variable, that would be analysed , would be the snow quantity ($kg.m^{-2}$), defined as NVNUMB(46) = 92 in NCMVNM /CMAFOC data base;
- the variable is locally continuous, homogeneous and isotropic and the statistical structure for the other surface elements analysed in CANARI, could be applied for the snow analysis as well;
- the horizontal correlation function is $\exp(-1/2*(r/d)^{-2})$ with r being the horizontal distance between any 2 points with characteristic length d ;
- the horizontal characteristic length d is 50 000 m ;
- the horizontal correlation function is defined only between points with snow observations i.e. the snow analysis is performed only on the base of snow observations;
- the rms observation error is equal to the rms guess error and is 5 $kg.m^{-2}$ (or 5 mm liquid water equivalent of the snow quantity).

For the guess field we have used the coupling ARPEGE file and the model equivalent of the snow observation at the observation points is defined in the routine **ppobsn.F90**, following the approach proposed in Urban (1996) . The basic idea in that approach is to modify the model equivalent of snow according to snow climatology as well as model and climatology temperature, in order to avoid snow where temperatures are higher than 3°C. In its formulation the "weights" attributed to climatology and model have somewhat changed from the original version (Urban, 1996) due to unexpected sensitivity of the coefficients to model resolution (Urban, personal communication). Here is the last version of the post-processed snow quantity (*PXPP* in $kg.m^{-2}$) as it is coded in ARPEGE (which probably needs to be revised):

$$PXPP = P_1\max\left(0;TR-ZTCLIMA\right)+P_2\max\left(0;TR-ZTOBS\right)\cdot\left(ZSNS-ZCCLISN\right) \qquad (2)$$

where *ZTCLIMA* and *ZTOBS* are climatology and model temperature at the observation point respectively, i.e. climatology temperature reduced to the observation altitude with respect to the standard temperature gradient ($-6.5.10^{-3}$ $K.m^{-1}$) and last model level temperature reduced to the observation altitude according to the model temperature gradient. $TR = 276$ K is the temperature threshold above which snow is prohibited. *ZCCLISN* and *ZSNS* are the snow quantities in $kg.m^{-2}$ derived from climatology and model (guess or analysis) respectively, $P_1 = 1/2$ ($kg.m^{-2}.K^{-1}$) , $P_2 = 1/3$ (K^{-1}).

For implementation of the snow analysis scheme within the frame of CANARI/ ALADIN it has been necessary to modify some modules and routines, listed in **Appendix 1**. The changes concerned the definition of:

- the statistical model for the snow analysis,
- the predictors for the analysis of snow quantity,
- QC flags for the snow analysis, none the less the QC itself has not been performed and checked during the experiments.

Here should be mentioned the modifications in the routine **castro.F90** done by Ph. Caille. Due to problems in writing / reading of snow data in cmafoc file (the value of snow quantity is devided by 100 for historic reasons) temporary solution has been found and the correct reading of the snow value has been performed here, not in Mandalay. There were changes in some routines for visualization of the output results. The experiments have been made with LMESSP=.F..

With the parameters described above, we have performed on vpp5000 two types of experiments:

- single_obs experiment - to study the impact of a perturbed snow value in one single point over the whole field,
- full_obs experiment - to see the results of the CANARI snow analysis for a real synoptic situation.

II. Single-obs experiment

The single-obs experiment for 2000/03/01/00 UTC has been performed following the steps:

- prepation of a cmafoc file with Mandalay (~mrpa657/script_2000/man/script_1obs_sn) :
  - input : ASCII file on kami ~mrpa657/script_2000/man/file1obsSND with snow quantity of 10 $kg.m^{-2}$ or 10 mm equivalent of liquid water.
  - output: cmafoc file on kami ~mrpa657/CMAFOC_SND

- snow analysis with CANARI/ALADIN (~mrpa657/script_2000/script701_fr_1obs)
  - input: FILEOBS = ~mrpa657/CMAFOC_SND
    FILECLIM = /cnrm_2/mrpe/mrpe601/clim/chgt_extension/FRAN_r03
    FILECLI2 = /cnrm_2/mrpe/mrpe601/clim/chgt_extension/FRAN_r02
    FILEGUESS = / chaine/mxpt/mxpt001/france/03/COUPL0000.r0
    DCST = ~mxpt001/arpege/france/oper/const/autres
    DIRNAM = ~mrpa657/Namel/E701
  - output: $WORKDIR/00030100/analyse_surf_france; guess_oper_france; cma_oper; cmafoc_omg_surf_france

The results of the single_obs experiment performed with the namelist **namel_ analyse_surf** are presented in **Appendix 2, Fig. 1 - Fig. 6.**
Here should be noted that to get coherent outputs from the different analysis routines (diagnostics from **cancer.F90** and **caidgu.F90**), the **ppobsn.F90** routine has been modified. The postprocessed model equivalent of the snow quantity has not been calculated by formula (2), but simply has been put equal to the guess (respectively analysed) value ZSNS.
This routine is called twice - first time for calculating the observation departures (obs - guess) before analysis and second time for calculating the differences (obs - an) for the historical file after the analysis. The implementation of that formula for calculating the obs departures is reasonable, because it takes into account the impact of the difference between the altitude at the obs point and the model orography at the same point. In our experiment we have not done any tuning of the parameters in the formula and the question of evaluating that impact is still open. But for calculating the differences (obs-an) that formula has driven to misleading results: for that simulated case, the postprocessed temperature at the lowest model level at the observation point exceeded the critical value, defined in the second term of formula (2) and the postprocessed value of the snow was 0 instead of the analysed value ZSNS.

The output statistics from the listing of the single_obs experiment is presented on Fig. 1. It could be seen that:
- the observation error model for the snow is initialized and the obs rms error is equal to the guess error;
- for that case the guess at the obs point is 0 and the obs departure from the guess is 10 mm;
- there is a coherence between the outputs from the routines **caviso.F90** (OMF is 10) and **cancer.F90** (OBS-MOD = 10);
- the max difference between the analysis and the guess is apprx. 5 mm as could be expected from the assumption for equality of the obs and guess error (max SN RES ANA is 0.4974E+01);

- after the analysis OMN (observation departure from analysis) is 5.042 and OBS-MOD is 5.04.

The conclusion that could be drawn from Fig. 1 is that the outputs from the snow analysis in this single observation experiment are correct and coherent.

On Fig. 2 - Fig. 4 the clim files for February and March and the guess snow field for 2000/03/01/00 are presented. The snow analysis field is presented on Fig. 5, while the increments field is presented on Fig. 6. As it could be seen, the impact of the single obs is well pronounced over an area of order of the characteristic length of the snow analysis. The max value of the increments on the picture corresponds to the relevant value in the output statistics discussed above.
To study the reason for the noise-like distribution of the increments over the areas with snow, we have performed the following experiments:

- in the obs point the initial observed value of snow has been put to zero and LAESNM=.T.
  The increments field has had the same structure, which means that it is not due to a correlation with the single-obs data. We have not presented here the relevant picture.
- in the obs point there has been defined T2 instead of snow quantity and the namelist **namel_analyse_surf** has been modified with putting **LAESNM=.F.** That experiment (**T2_FALSE**) corresponds to the operational run where the initial snow is produced by the physics of the model. When there is no snow analyses (**LAESNM = .F.**), there is a relaxation towards the climatology and snow melting, if the temperature is higher than 273.16 K. The analysis and the increment fields are presented on Fig.7 - Fig.8 . It is seen that in that case, instead of noise, there is a signal-like structure over the area with the max snow amount.
- same as previous experiment with **namel_analyse_surf** modified with **LAEICS=.F., RCLIMCA=0., RCLISST=0**. With that experiment (**T2_FALSE_all**) we tried to have "analysis without observations" and to have guess and analysis fields as close as possible. The increments field is presented on Fig. 9. It is seen that the values of the non-zero increments are of 10E-05 order and the structure is the same as in the initial single-obs experiment. The verification of the differences between the guess and analysis fields by editfield_64 (E.Bazile) has shown that these differences are not produced by the graphical software, but present in the historical files. Perhaps they are due to the compression and decompression used for reading and writing of the files.

The main conclusions drawn on the bases of the experiments described above could be summarized as:

- the initial settings and the modifications of the commons and routines concerning the snow analysis have been done consistently;

- the results of the single obs experiment have shown the expected distribution of the increments when the observation error is set to be equal to the guess error;
- the distribution of the non-zero increments could be considered as a noise due to the way of processing the fields;
- for that experiment it is necessary to keep **ppobsn.F90** modified i.e. PXPP = ZSNS to get coherent output from the analysis routines (**cancer.F90** and **caviso.F90**).

III. Ful_obs experiment

The ful_obs experiment for has been done with ~mrpa657/script_2000/script701_fr:

- input: FILEOBS = ~mrpa657/cmafoc_new_2000030100
  FILECLIM = /cnrm_2/mrpe/mrpe601/clim/chgt_extension/FRAN_r03
  FILECLI2 = /cnrm_2/mrpe/mrpe601/clim/chgt_extension/FRAN_r02
  FILEGUESS = / chaine/mxpt/mxpt001/france/03/COUPL0000.r0
  DCST = ~mxpt001/arpege/france/oper/const/autres
  DIRNAM = ~mrpa657/Namel/E701
- output: $WORKDIR/00030100/analyse_oper_france; guess_oper_france; cma_oper; cmafoc_omg_surf_france

The input data for that experiment consisted in snow observations from 25 observation points. As these observations are not used in the standard ARPEGE configuration, they were not available in the cmafoc file. A screening has therefore been performed from the complete observation file (obsob). Over the whole globe and for this particular date 679 observations of snow (NVNUMB(46)=92) have been gathered together, amongst which 141 observations were redundant. Over a slightly larger area [60N , 30N ; 20W ; 25E] including the ALADIN FRANCE region, FILEOBS contains 104 observations of snow amongst which only 25 observations are kept by the system; the redundancy of the other observations is probably due to the different sources of observations. Note that the proportion of redundant data is much higher over Europe than over the whole globe (76% against 21%).

The ful_obs experiment has been performed considering 2 cases, which differ in the way of defining the observation departures (obs - guess):

- case with the modified **ppobsn.F90** in the sense , described in the previous section, which would hereafter be referred to as **ful_obs_noForm** case,
- case with the original form of **ppobsn.F90** hereafter referred to as **ful_obs_Form** case.