CANARI snow analysis scheme in ALADIN

Final report on the work done in Meteo-France in the period
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by

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Introduction

The CANARI snow analysis scheme has been developed, updated and tested in Meteo-France in the period 2000-2001 [2,3,4]. The CANARI snow analysis scheme has been validated for different synoptic situations and over different domains (ALADIN-FR, ALADIN-BG, ARPEGE) , but never in assimilation mode.
The purpose of this work has been to touch the following topics of the CANARI snow scheme in ALADIN:

- the theoretical part of the analysis
- the data flow in the analysis
- validation of the snow scheme for cy35t2 of ALADIN over the ALADIN-France domain
- drawing conclusions and proposition for further improvements of the CANARI snow analysis scheme

Since the period of the work has been limited to 2 weeks, it is impossible to make full study of the quality of the CANARI snow scheme and its validation in assimilation mode. That is why the tests have been performed for 2 synoptic situations with snow over ALADIN-France domain in January 2009 (2009011500 and 2009011506 UTC).

I. Theoretical part of the CANARI snow analysis scheme

I.1. The CANARI snow scheme is an univariate OI scheme for the variable snow quantity [kg.m $^{-2}$] . The statistical structure is defined by the σ_b (rms model error) , σ_o (rms observation error) and the correlation function which is of the type:
$\mu (r, p) = \mu_h (r) * \mu_v (p)$
where

- $\mu_h (r) = \exp(-1/2*(r/d)^2)$ is the horizontal component of the correlation function with horizontal characteristic length d;
- $\mu_v (p) = \exp ((-1/2*(dp_{ij} /P_c))$ is the vertical component of the correlation function ; $dp_{ij} = \ln (p_j /p_i)$ is the difference between the pressures at the model and the obs points (cacova) and the pressures at the obs points (catrma) ; P_c is a vertical characteristic parameter

Since the analyzed variable does not fulfil the requirements for local homogeneity and isotropy in vertical direction, it has been decided to add the vertical component to the correlation function for the snow analysis [3]. The choice of the type of $\mu_v (p)$ as a function of pressure (in fact of lnp) has been done on the bases of the similarity with the vertical correlation functions for the other meteorological variables in CANARI and the reasonable results of our first experiments [2,3]. The values of the horizontal characteristic length d, the vertical characteristic parameter P_c and the rms model error σ_b are tunable by the relevant namelists, while the rms obs error σ_o is hard coded in the CANARI software.

I.2. The first guess is the 6-hour ALADIN forecast, which is post-processed at the obs points by the so called snow obs operator. In the recent version of the code the snow obs operator is based on the results in [5] and includes 2 terms , which represent the impacts of the post-processed surface temperature climatology and of the post-processed model temperature and the snow climatology on the model equivalent of the snow in the obs point. The results obtained in [3] have shown that there are conditions under which that way of post-processing of the model equivalent of the snow at the obs point leads to wrong results and has been recommended to replace that formula only by semi-lagrangian horizontal interpolation. The snow obs operator is defined in the routine ppobsn.F90. Unfortunately the switch off of that formula has to be done by modification of the routine itself (ppobs.F90 routine) and recompilation of the code. That is due to the fact that under the key LCLIM=T (there are always climatological files) the post-processing is always performed by the formula. To avoid that hard way of changing the formula for the first guess snow post-processing, another key will be introduced soon. Some re-investigation of the snow obs operator should be performed later to improve its accuracy under “strong” orographic constraints.

I.3. Here we should mention that there is no spatial quality control of the snow observations inside the snow analysis, but only check against the first guess snow field. The threshold value above which the snow observation is not used in the analyses is 2.5 [$kg.m^{-2}$] and is set in canali.F90 (RCSNSY=2.5). Further investigation on the snow analysis scheme should be performed to find the proper value of that parameter and to build the procedure for spatial quality control.

II. The data flow in the snow analysIs scheme

The data flow, the routines and the namelists with the settings for the snow analysis follow the CANARI documentation [1] and the reports [2,3]. Here we will put attention only on the specific features of the snow analysis.

II.1 Input of the observation data

The input data for snow are the SYNOP observations taken from the Meteo-France BDM where the observed value is the total snow depth [m]. Afterward the snow data is put into the ODB by bator. In the ODB routine bator_ecritures_mod.F90 , there is a modification of the snow data from snow depth [m] to quantity of snow [$kg.m^{-2}$] by multiplication by the constant snow density d(ensity) = 100 [$kg.m^{-3}$]. The variable snow quantity is put afterwards in ODB under NVMUMB(46) = 92 and under this NVNUMB is processed in CANARI snow analysis.
The following problems should be mentioned here:

- there could be a confusion because in varno.h NVNUMB(46) corresponds to “ 6hour snow fall (solid part)” (varno.h :// Variable numbers (varno@body). In getval_module.F90 there is a line g_sdepth = ODB_getval(h,’$sdepth’, g__sfall=ODN_getval(j,’$sfall’)). In hop.90 there is a remark (3.3.0 Surface analysis variables: snow depth (NVNUMB(25) = 71, snow fall (NVNUMB(46) = 92). When the first settings for the snow analysis were done [2], it was decided to attach the analysis variable “snow quantity (quantite de neige)” to NVNUMB(46)=92. Since then the analysis is performed for that variable under NVNUMB (46). If the snow analysis will become operational, perhaps it is better to unify the meaning of the NVNUMB(46)=92
- There is no spatial quality control of the snow quantity and in the ODB routine fcqodb_module.F90 it is necessary to add the line INTEGER(KIND=JPRM): NCUSN

.That is why it is necessary to check if all of the settings for snow quality control have been updated.

II.2 Input of the snow guess field

The snow guess field is taken from the 6-hour ALADIN forecast as ‘SURFRESERV.NEIGE ‘ in $[kg.m^{-2}]$. In Fig.1 we have presented the field
‘SURFDENSIT.NEIGE’ = snow density$[kg.m^{-3}]$ / liquid water density$[kg.m^{-3}]$)
with liquid water density = 1000 $[kg.m^{-3}]$
It could be seen from the figure that the values of ‘SURFDENSIT.NEIGE ‘$\subset$ [0.1,0.3] $[kg.m^{-3}]/[kg.m^{-3}]$ and are highest over the mountains. That corresponds to snow density $\subset$ [100, 300] $[kg.m^{-3}]$ with highest values over the mountaineous regions.
As it has been mentioned in II.1, the transformation from snow depth into snow quantity at the observation points is performed by multiplication by the constant snow density =100 $[kg.m^{-3}]$. The inconsistency between the way of definition of the snow quantity in the model and in the ODB could lead to some inconsistency between the observed and post-processed model values at the observation points especially over the mountaineous areas. In a future work it will be important to use a “variable” density to convert the observed value into a correct equivalent of snow quantity.

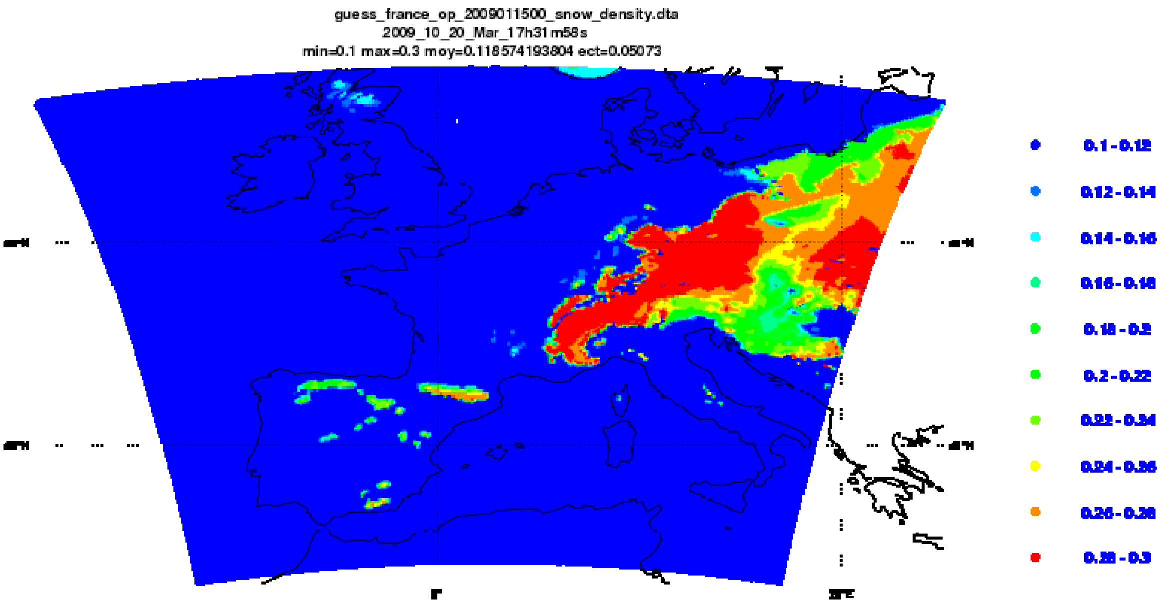


Fig. 1 ‘SURFDENSIT.NEIGE’ field used in the model

III. Validation of the snow scheme for cy35t2 of ALADIN over ALADIN-France domain

As it has been mentioned in the introductory part of this report, the validation has been performed for 2 synoptic situations (2009011500 and 2009011506 UTC). The main purpose of the validation has been to obtain some preliminary and simplified information about :

- the impact of the different obs operators in ppobsn.F90 on the quality of the snow analysis (the obs operator based on [5] and the semi-lagrangian horizontal interpolation);
- the impact of the vertical part of the correlation function on the quality of the snow analysis.

III.1 Validation of the snow scheme on the bases of the CANARI output statistics

Here should be mentioned that:

- there are 2 parameters - ORODIF,which controls the difference between the model orography at the obs point and the altitude of the observation station (in case that for some stations that difference exceeds the value of ORODIF, they would be not taken into account in the analysis) and OROLIM, which controls the altitude of the station above which the observation is not taken into account in the analysis. The default values of those parameters are 10000 [m] which allow all stations to be included in the analysis.
- there is a relaxation towards the snow climatology after the CANARI analysis of the surface fields

Since we wanted to:

- eliminate the stations for which ORODIF is too big and/or they are situated too high in the mountains, we have decreased the relevant values to ORODIF=500, OROLIM=2000;
- study the impact of the relaxation towards climatology, we have changed RCLIMCA=0.;
- study the impact of the formula of the snow obs operator, we have modified ppobsn and recompiled the code;
- study the impact of the vertical component of the correlation function, we have modified cainsu.F90 and catrma.F90 keeping only the horizontal component of the correlation function and recompiled the code again.

For each of the synoptic situations for both sets of values for ORODIF and OROLIM, we have performed the following experiments:

- FORM_CLIM - with the formula in ppobsn, RCLIMCA=0.045,full expression for the correlation function;
- FORM_NOCLIM - with the formula in ppobsn, RCLIMCA=0, full expression for the correlation function;
- NOFORM_NOCLIM - with horizontal interpolation only in ppobsn, RCLIMCA=0, full expression for the correlation function;
- NOFORM_NOCLIM_2dcor - with horizontal interpolation in ppobsn, RCLIMCA=0, only the horizontal component for the correlation function.

The results are presented in Table1. Since the number of observations for 2009011500 is rather small with comparison to the case 2009011506, we have presented in more details the results for the second case. It is seen that for the decreased values of ORODIF and OROLIM, the bigger number of observations for the case 2009011506 leads to significant decrease of the bias (OBS-MOD) and the rms error(SIGMA) both for the guess and analysis. The experiment NOFORM_NOCLIM_2dcor shows slightly smaller bias and rms error than the experiment

NOFORM_NOCLIM, but from that we can not make a strong conclusion about the impact of the full expression of the correlation function.
The conclusions that could be made from the results of the experiments in part III.1 are:

- the decrease of the values of the parameters ORODIF and OROLIM leads to decrease of the bias and rms error both for guess and analysis;
- there is no strong signal for the impact of the other components we have looked at: formula vs. noformula in the obs operator and 3d vs. 2d correlation function.

TABLE I Validation of the snow scheme for the different experiments on the bases of the CANARI output statistics

20009011500

	OROLIM=100000, ORODIF=100000 OBS-MOD/SIGMA		OROLIM=2000, ORODIF=500 OBS-MOD/SIGMA	
CASE	GUESS	ANALYSIS	GUESS	ANALYSIS
FORM_CLIM	26.901/48.361	21.838/48.232(132)	---	---
FORM_NOCLIM	26.901/48.361	21.517/48.176(132)	10.780/21.941	6.492/21.364(107)
NOFORM_NOCLIM	26.419/48.987	24.186/49.638(132)	10.193/21.180	7.585/21.177(107)
NOFORM_NOCLIM_2dcor	----	--------	10.193/21.180	7.446/21.129(107)

20009011506

			OROLIM=2000, ORODIF=500 OBS-MOD/SIGMA	
			GUESS	ANALYSIS
FORM_NOCLIM	-----	------------	3.578/12.489	1.400/11.843(651)
NOFORM_NOCLIM	----	---------	3.385/11.589	2.247/11.172(651)
NOFORM_NOCLIM_2dcor	----	--------	3.385/11.589	2.187/11.141(651)

III.2 Validation of the snow scheme on the bases of studying the increments (guess – analysis) for the different experiments

The plots of the guess and the increments (guess-anal) for the different experiments for 2009011500 and 2009011506 are presented on Fig.2-Fig.3 and on Fig.4 – Fig.5. The impact of the full definition of the correlation function is seen better on Fig.5 , where the results for 2009011506 have been presented. It is seen that in the case NOFORM_NOCLIM_2dcor the increments are spread more smoothly and over larger area than in the case NOFORM_NOCLIM with the full definition of the correlation function.

The results obtained in that paragraph show the expected more detailed distribution of the increments for the case of 3d correlation function.

Guess and the increments (guess-anal) for the different experiments for 20090115000

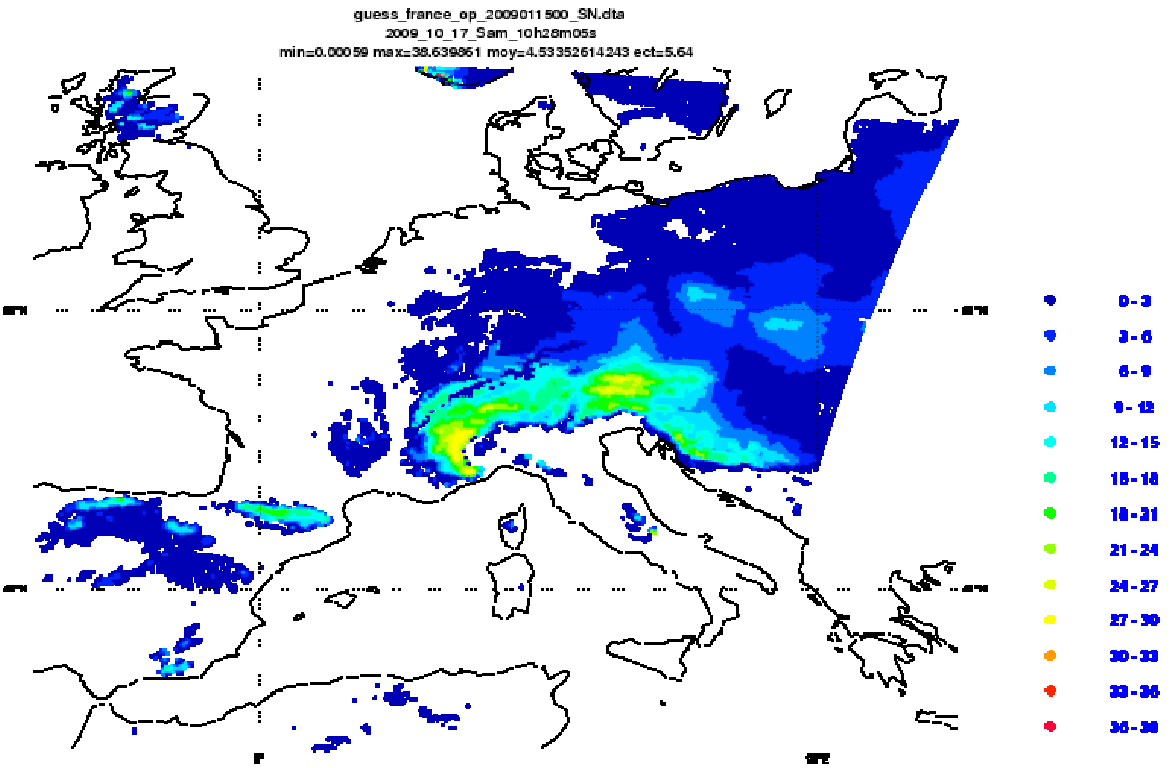
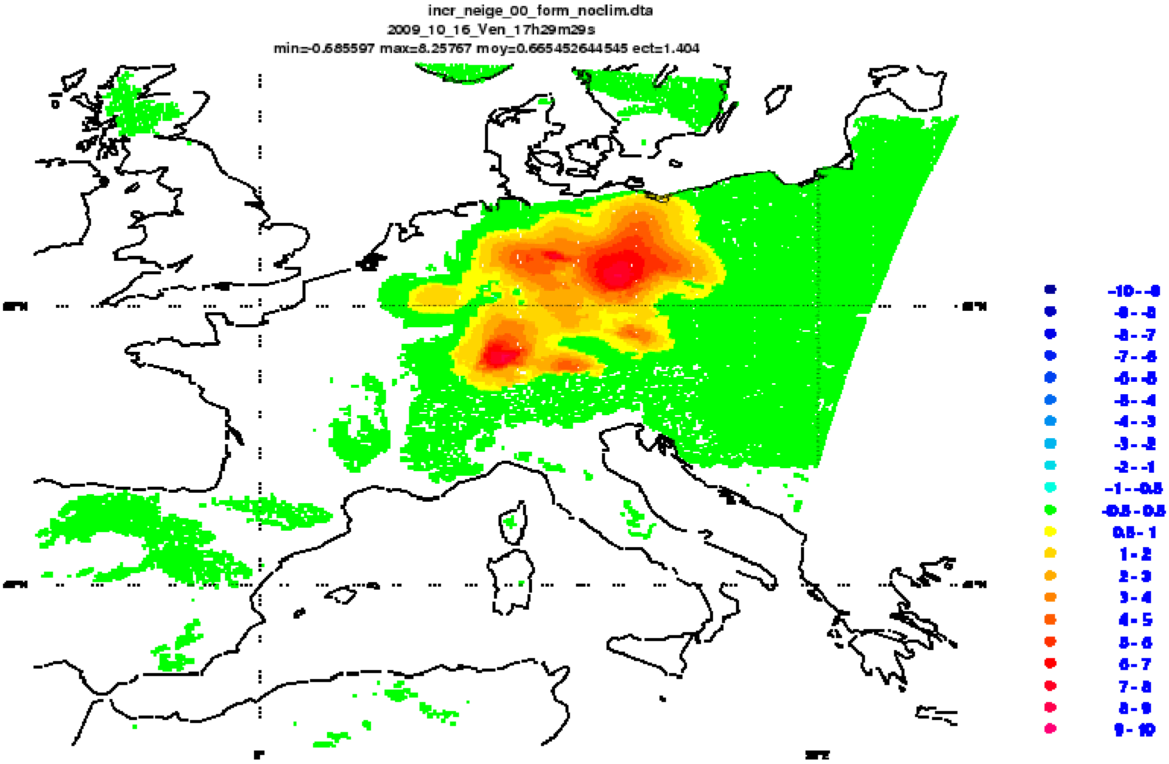
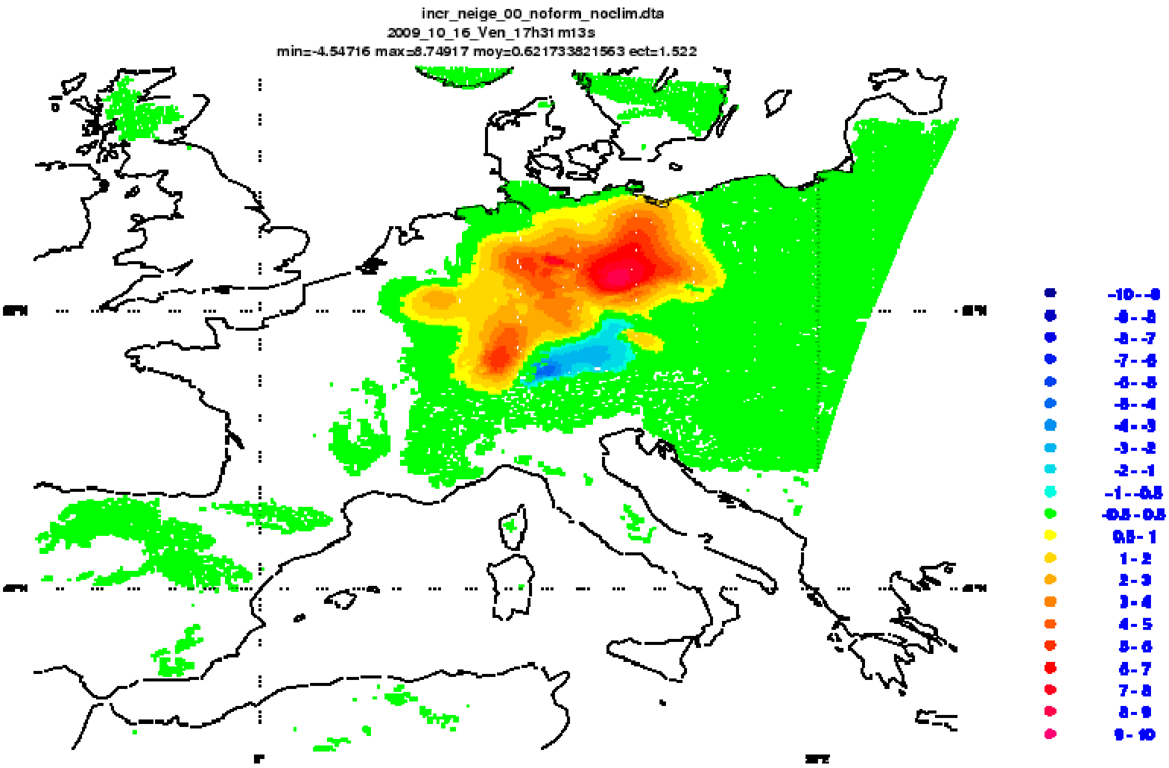


Fig 2. Guess field for 2009011500


incr_neige_00_form_noclim.dta
2009_10_16_Ven_17h29m29s
min=-0.685597 max=8.25767 moy=0.665452644545 ect=1.404
-10--9
-9--8
-8--7
-7--6
-6--5
-5--4
-4--3
-3--2
-2--1
-1--0.5
-0.5-0.5
0.5-1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10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2009_10_16_Ven_17h31m13s
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-10--9
-9--8
-8--7
-7--6
-6--5
-5--4
-4--3
-3--2
-2--1
-1--0.5
-0.5-0.5
0.5-1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10

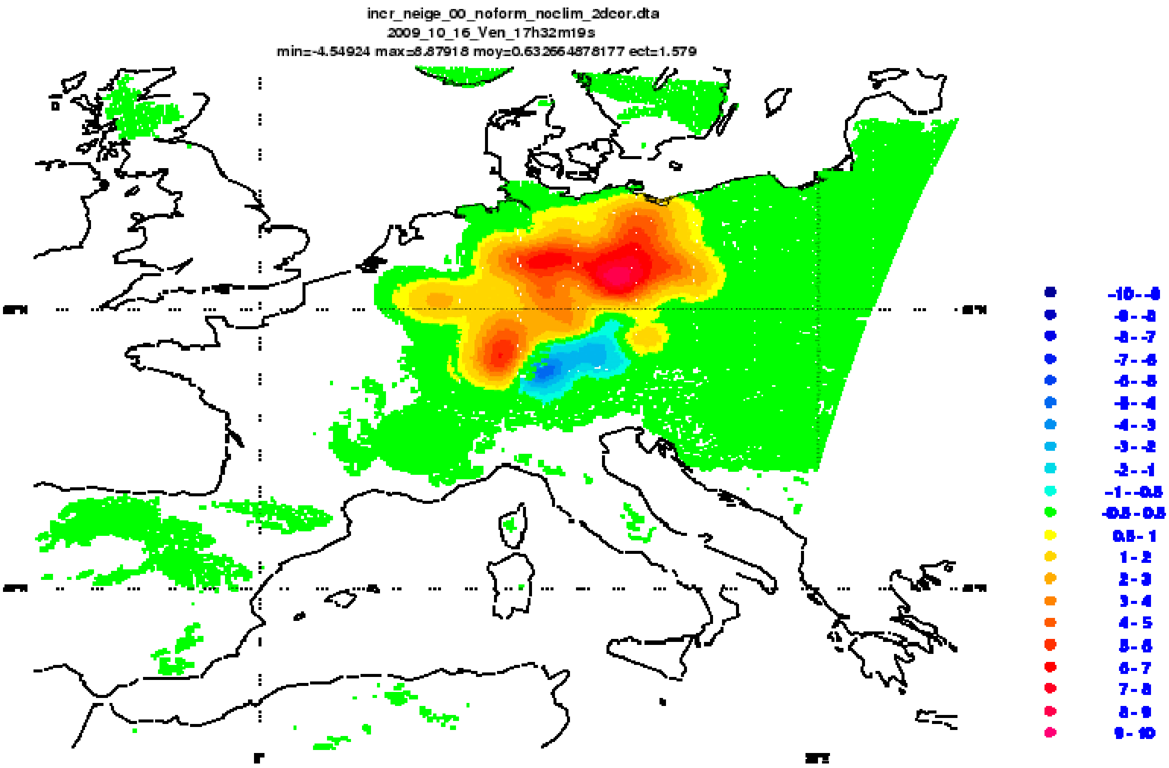


Fig.3 The increments (guess-anal) for the different experiments for 2009011500

Guess and the increments (guess-anal) for the different experiments for 20090115006

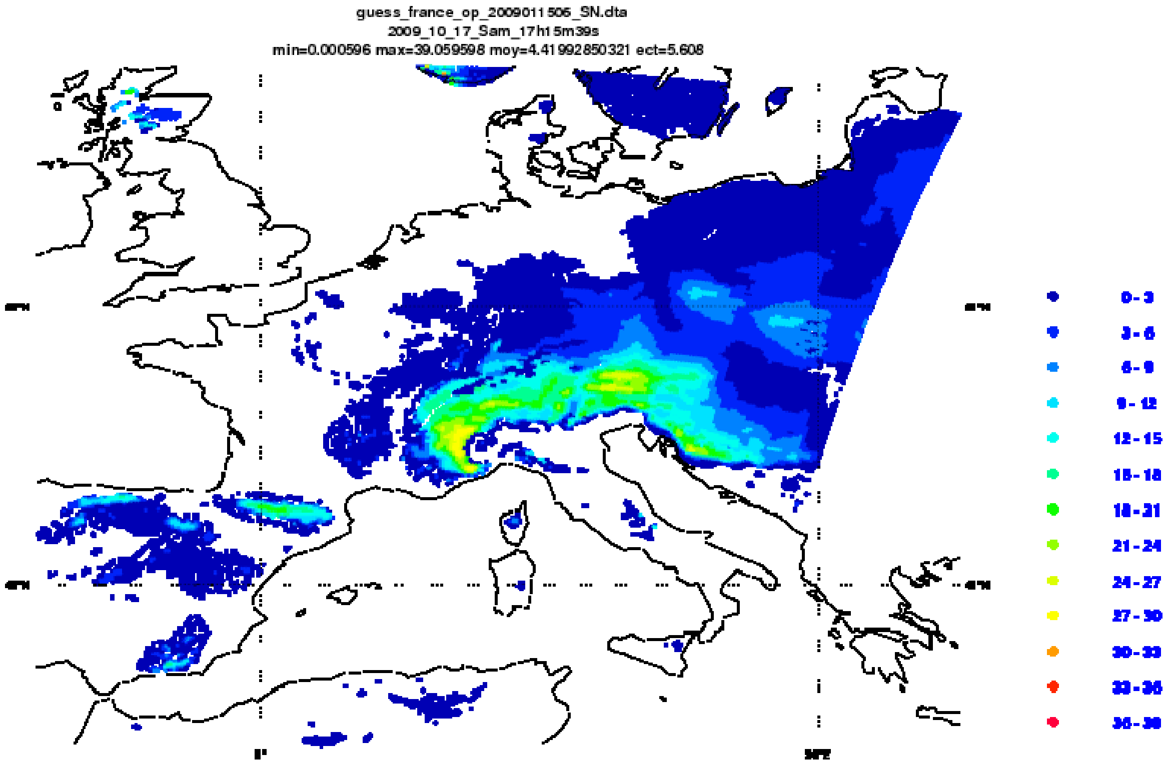
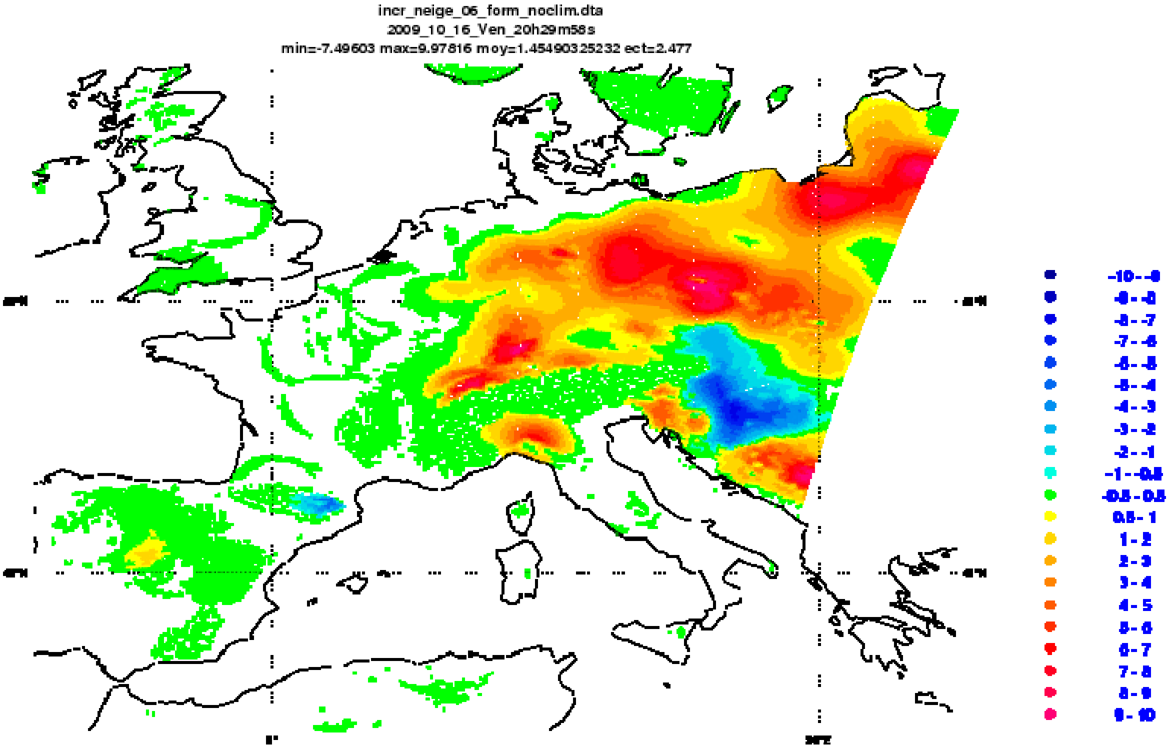


Fig.4 Guess for 2009011506


incr_neige_06_form_noclim.dta
2009_10_16_Ven_20h29m58s
min=-7.49603 max=9.97816 moy=1.45490325232 ect=2.477
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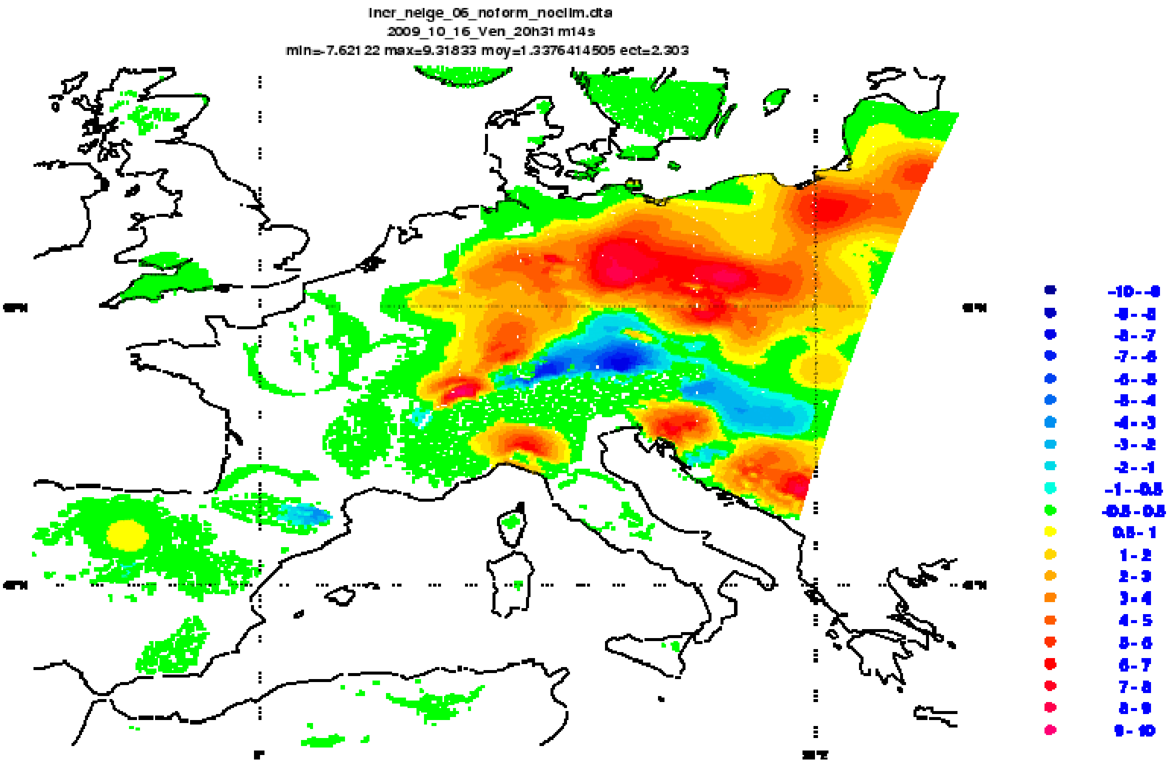
-9--8
-8--7
-7--6
-6--5
-5--4
-4--3
-3--2
-2--1
-1--0.5
-0.5-0.5
0.5-1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10


incr_neige_06_noform_noclim.dta
2009_10_16_Ven_20h31m14s
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-9--8
-8--7
-7--6
-6--5
-5--4
-4--3
-3--2
-2--1
-1--0.5
-0.5-0.5
0.5-1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10

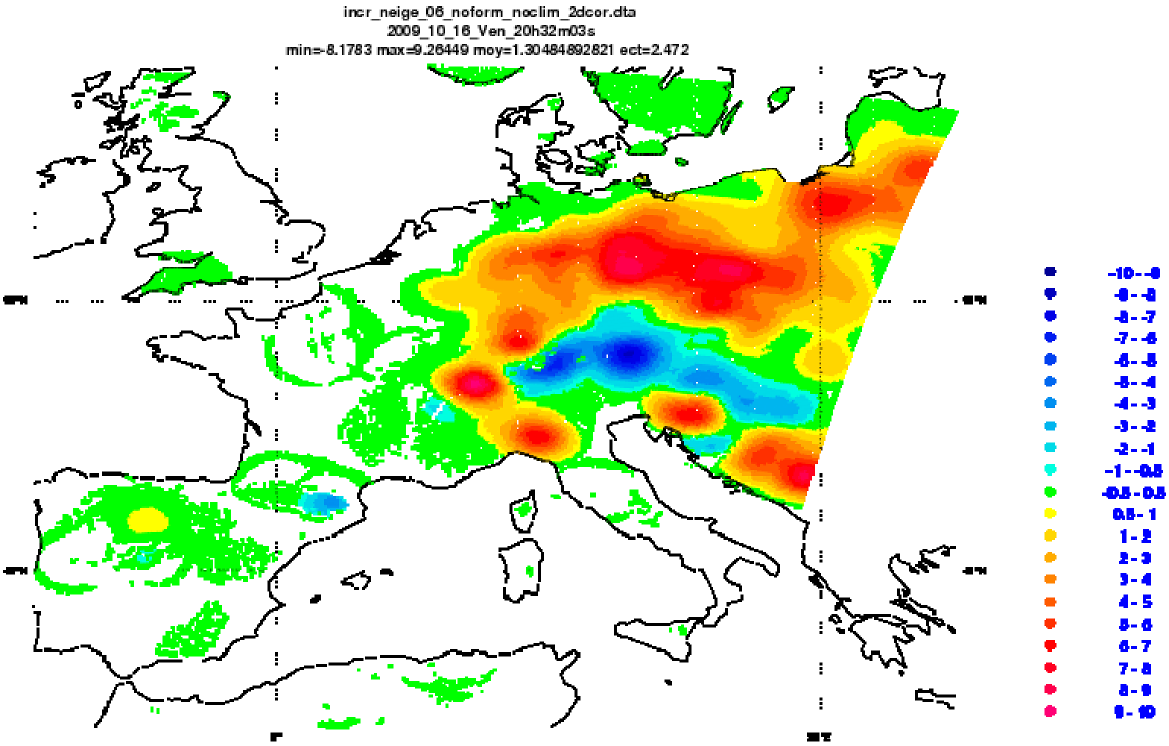

Fig.5 the increments (guess-anal) for the different experiments for 20090115006

III.3 Validation of the snow scheme on the bases of studying the analysis departures (OBS-AN) for the different experiments

Since on the bases of the plots of the distribution of the increments fields with 3d and 2d correlation function we can not make a definitive conclusion on the benefits from using the correlation function both with horizontal and vertical component, we have studied the analysis departures for the last two experiments (NOFORM_NOCLIM and NOFORM_NOCLIM_2dcor).
We worked on both synoptic situations but visualized mainly the results for 2009011506 because the number of the observations is bigger (according to WMO regulations).
On Fig.6 we have plotted the analyses departures for 2009011506 for the experiment NOFORM_NOCLIM (with 3d correlation function)

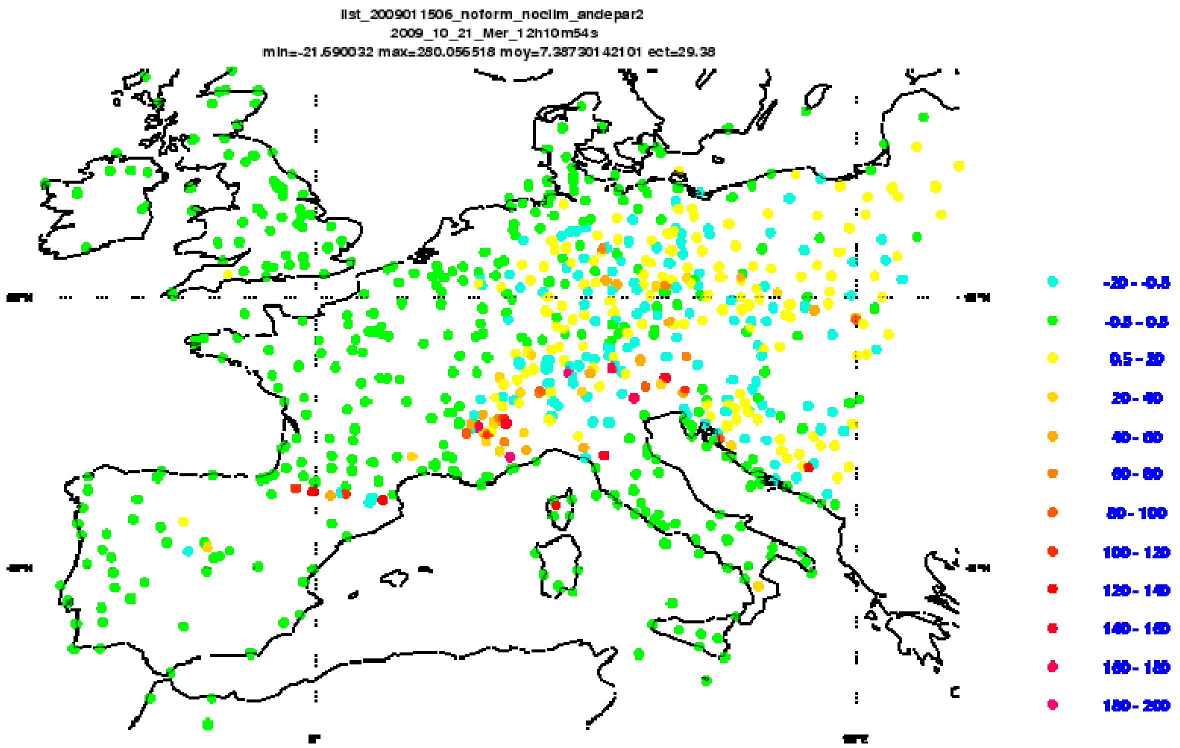

Fig.6 The analysis departures for the case NOFORM_NOCLIM

The plot with the analysis departures for the case NOFORM_NOCLIM_2dcor looked quite the same as the plot on Fig.6. That is why we have plotted the field F=NOFORM_NOCLIM_2dcor – NOFORM_NOCLIM to find the places with bigger impact of the correlation function both with horizontal and vertical components. The distribution of the field F is presented on Fig.7.
It is seen that there are such places and they are mainly over the mountainous regions (over the Alps).

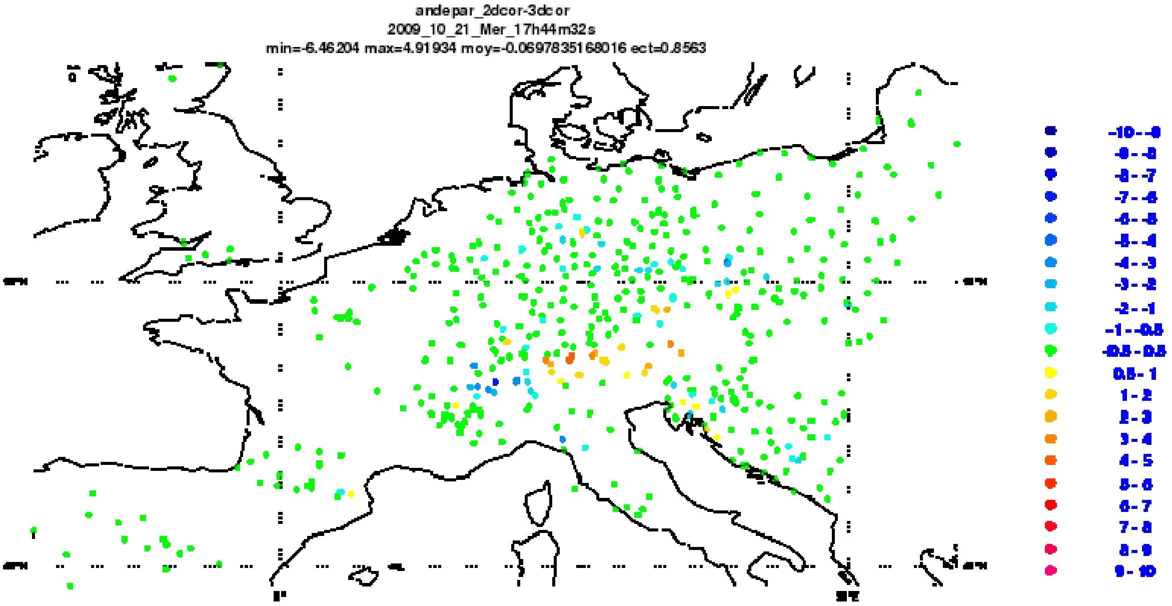

Fig.7 The difference between the observation departures for the cases NOFORM_NOCLIM and NOFORM_NOCLIM_2dcor

IV. Conclusions and proposition for further improvements of the CANARI snow analysis

The conclusions that could be made from the results of validation of the snow analysis scheme for cy35t2 over ALADIN-Fr domain are as follows:

- The snow analysis scheme gives reasonable results both from point of view of the distribution of the increments fields and of the analysis departures;
- There is no strong signal for the benefits of using the 3d correlation function when the increments fields are compared, but it seen that increments for the experiment with 2dcor are spread more smoothly and over larger area
- The distribution of the field F=NOFORM_NOCLIM_2dcor – NOFORM_NOCLIM shows the expected differences over the mountainous regions

Propositions for further work on CANARI snow analysis in ALADIN

- Further study is necessary to be performed on the snow obs operator and a new key should be introduced to change the formula for the snow obs operator inside the code without its recompilation
- It is necessary to unify the meaning of the NVNUMB(46)=92
- It is necessary to check if all of the settings for snow quality control have been updated
- It is necessary to tune the parameters of the statistical structure in the snow scheme and to test in assimilation mode.

References

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