I.32.

UPDATE AND VALIDATION OF SNOW ANALYSIS IN CANARI/ALADIN

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

15 February - 30 March 2000

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.

Before discussing the results, obtained with the experiments with that real synoptic situation, we should remind that for the real snow data we have not performed study of the:

- statistical model parameters (obs. and guess rms errors, characteristic length, etc.),
- parameters that are set in formula (2).

In that sense, the results, obtained in that paragraph, should be considered as preliminary and the conclusions should be drawn mainly from the point of view of the general agreement with the results, obtained in the single_obs experiment.

The results of **ful_obs_noForm** experiment are presented in **Appendix 3, Fig. 10 - Fig. 13**.
From the output statistics (Fig. 10) it could be seen that 3 observations have been rejected after checking against the guess and there are coherent indications for the positive impact of the snow analysis:

- the histogram with the distribution of the residuals before and after the analysis (guess and analysis residuals, averaged over all observations) shows a tendency to reduce the normalised model departure from observation;
- the bias (OBS-MOD) and the rms error (SIGMA) after the analysis are smaller than the bias and the rms before it;
- mean SIGA/SIGP < 1 shows that the a posteriori model error resulting from the analysis is smaller than the a priori model error assigned to the guess.

The increments field (Fig.13) shows a well pronounced area of closed contours over the region with significant values of snow quantity and noise like pattern over the rest of the area.

The results of the **ful_obs_Form** experiment are presented in **Appendix 4 , Fig. 14 - Fig. 17**
From the output statistics (Fig. 14) could be seen that:

- the rejected observations are 6 ;
- there is still tendency for decreasing the bias and the rms error after the analysis , none the less the values of the bias and the rms error themselves are surprisingly high in comparison with the ful_obs_noForm case.

The increment field (Fig. 17) shows less pronounced differences between guess and analysis compared to the ful_obs_noForm case. That could be interpreted as smaller impact of the observations on the guess.

IV. CONCLUSIONS

As seen from the figures, the main goal of the work has been achieved - there is a working CANARI/ALADIN snow analysis scheme, which has been tested within the environment of the single_obs experiment. The results obtained in single_obs experiment have shown the expected and coherent outputs from the different routines of CANARI. The results obtained in ful_set experiment have shown that:

- it is necessary to study the statistical structure model for the snow analysis;
- the parameters in the formula for postprocessing the model equivalent of the snow quantity should be tuned;
- it would be interesting to have in ARPEGE/ALADIN an independent climatology of snow (the current one was obtained with one year of assimilation in truncation T79);
- some research is necessary to be done for assimilating other kinds of observations (snow fall, liquid precipitation, etc.) to enlarge the present input data set.

Besides these recommendations for further study of the snow analysis, it is worth mentioning that:

- QC of snow data is still an open question;
- the correct writing/reading of the snow data should be done in Mandalay.

ACKNOWLEDGMENTS

The authors would like to thank V. Casse for his helpful suggestions at the beginning of that work. We are indebted to Ph. Caille for his help in preparing the cmafoc files for the snow analysis. Many thanks to F. Taillefer for her recommendations while we modified the routines and to P. Moll for the discussion of the results. We are also grateful to V. Casse, J. Jerman and G. Radnoti for their reports on diagpack which have been used as a guideline in our work.

References

Cassé, V., 1998: Canari statistical model, version 03/98 (Personal communications)

Urban, B., 1996: Coherent Observation Operators for Surface Data Assimilation with Application to Snow Depth. Journal of Applied Meteorology, vol. 35, No 2, February 1996

APPENDIX 1

LIST OF THE MODIFIED MODULES AND ROUTINES TAKEN FROM CY22T1_bf

I. MODULES in alphabetic order

- **qaeteo.F90** - module that contains the array with obs rms errors
  The value of JPEOPO (the number of parameters for which the rms obs error is available) has been changed
  INTEGER_M, PARAMETER :: JPEOPO=6
- **qakeki.F90** - module with position of the individual QC flags
  flag for snow analysis has been added
  NCUSN 30 code d'utilisation analyse SN
  INTEGER_M :: NCUSN
- **qacoss.F90**
  horizontal characteristic length for snow has been added
  !* XPOHSN : PORTEE HORIZONTALE POUR LA NEIGE SN**
  REAL_B :: XPOSHSN(-JPBLS:JPBLS+1)
- **qacost.F90**
  QPOHSN has been added
  REAL_B :: QPOHSN(JPTASM)
- **qastat.h**
  horizontal correlation function for snow has been added
  !NEIGE SN
  REAL_B :: FRHSNSN
  FRHSNSN(PD2,POZ) = FH(PH2,POZ)

II ROUTINES in alphabetic order

- **cabane.F90** - routine for intialization of the statistical model
  XPOSHSN has been initialized
  XPOHSN = REF_A_SN * ZCOEF
- **cabiyo.F90** - routine for initialization of the observation rms error arrays for each type of observation
  the rms observation error for snow has neen added
  ECTERO(NSYNOP, 6, 1) = 5.0_JPRB
- **cacova.F90** - routine for calculation of the correlations and co-variances
  correlation matrix for snow has been added
  ZH2SN = QPOHSN(KTASK) ** 2
  PCOREL(IY, IX, 1) = FRHSNSN(PDSELS(IPRE,JSEL),ZH2SN)

- **caffar.F90**

  QC flag for snow has been added

  IFLG = KBIT1OU0(IFLG,IVAL,NCUSN)

- **cainsu.F90** - routine for determination of the statistical model

  QPOHSN has been determined

  QPOHSN(KTASK) = XPOHSN(ILATR) * PSTRET(2)

  QPOHSN(KTASK)= (XPOHSN(ILATS)*ZPOS+ XPOHSN(ILATN)*ZPON * PSTRET(2)

- **calico.F90** - routine for initialization of the obs rms error in ROBSAR

  rms for snow has been initialized

  ```
  ELSEIF ( INOVAR == NVNUMB(46) ) THEN
     IOPARO = 6
  ```

- **canada.F90** -

  QC flag for snow have been added

  ```
  ELSEIF ( LDFLAI(JPPXSN) ) THEN
     IBP = NCUSN
  ```

- **canali.F90** - routine for initialization of the namelist used in the OI scheme CANARI

  the QC for snow has been switched off as a temporary decision

  ```
  IF (LAECHK.AND.LAESNM) THEN
  WRITE(NULOUT,*) ' --> NO QC FOR SNOW '
   CALL ABOR1 (' ** ROUTINE CANALI - TEMPORARY NO QC FOR
  SNOW ** ')
  ```

- **canami.F90** - routine for initialization of the predictants and predictors

  ```
  !IPRPK(1,NKSN) = NVNUMB(25) ! snow depth
  !IPRPK(2,NKSN) = NVNUMB(34) !RRliqui
  !IPRPK(3,NKSN) = NVNUMB(46) !RRsnow
  !INBK(NKSN) = 3
  !temporary solution
  IPRPK(1,NKSN) = NVNUMB(46 ) ! quantity of snow
  INBK(NKSN) = 1

  ...........
  !IPRPA(1,NASN) = NVNUMB(25) ! snow depth
  !IPRPA(2,NASN) = NVNUMB(34) !RRliqui
  !IPRPA(3,NASN) = NVNUMB(46) !RRsnow
  !INBA(NASN) = 3
  !temporary solution
  IPRPA(1,NASN) = NVNUMB(46 ) ! quantity of snow
  INBA(NASN) = 1
  ```

- **carnak.F90 -** routine for QC
  the line excluding QC of snow has been commented
  !IF (JJK == NKSN) IINMS(INBMS) = JPPXHU
- **casino.F90** - routine for initialization of the variables connected with the obs used in CANARI
  Initialization of module QAKEKI - QC flag for snow has been initialized
  NCUSN = 30
- **caspia.F90** - searching the predictors in the array ldflaj
  the line, replacing JPPXSN with JPPHU has been commented
  !IF (ICODY == JPPXSN) ICODY=JPPHU
- **castro.F90** - routine for efective selection of the observations used in CANARI
  The routine has been modified by Ph. Caille. Due to problems in writing / reading of snow data in cmafoc file (the value of snow quantity is devided by 100), temporary solution has been found and correct reading of the snow value has been put here instead of in Mandalay .USE YOMCMBDY and YOMVNB have been added

```
!PC
  IHLN = INTREA ( ROBSAR (IADO+NCMHLN) )
  IBLN  = INTREA ( ROBSAR (IADO+NCMBLN) )
  INLV = INTREA ( ROBSAR(IADO+NCMNLV) )
  DO JW=1, INLV
     IADW = IADO + IHLN + (JW-1)*IBLN
     IVNM = INTREA ( ROBSAR(IADW+NCMVNM) )
     IF ( IVNM == NVNUMB(46) ) ROBSAR (IADW+NCMVAR) =
                                 ROBSAR (IADW+NCMVAR) * &
      &100._JPRB
  ENDDO
!PC
```

- **catrma.F90** - construction of the matrix of the linear system
  calculation of the covariances for snow has been added - new paragraph 9

```
ZH2SN = QPOHSN(KTASK) **2
..........

- 9 - Calcul des covariances entre les predicteurs SN
      et les predicteurs autres (SN)
IPRX = JPPYSN
DO JSEX 1, KNSELS(IPRX)
   IX = IX + 1
   IY = IX
   IADX = KASELS (IPRX,JSEX)
   ZFG(IX) = ROBSAR (IADX+NCMFGE)
```

```
    IPRY = JPPYSN
    DO JSEY = JSEX + 1, KNSELS (IPRY)
        IY = IY + 1
        PCOVAR(IY,IX) = FRHSNSN(ZDIST2(IX,IY),ZH2SN)
    ENDDO
  ENDDO
```

- **capito.F90** - routine for summary printouts
  the expression for the obs rms for NSYNOP has been changed;
  FORMATS 1211 and **1212** have been changed

```
IF ( LLMPTO(NSYNOP) ) THEN
  WRITE (KUNIT,1211)
  WRITE(KUNIT,1201)
  WRITE(KUNIT,1212) ECTERO(NSYNOP,1,1,1)/RG,&
     &ECTERO(NSYNOP,1,2,1),ECTERO(NSYNOP,1,3,1),&
     &ECTERO(NSYNOP,1,4,1),&
     &ECTERO(NSYNOP,1,6,1)
  ..................
ENDIF
```

- capotx.F90 - the routine for surface analysis
  LAESNM excluded from the if for calling CACLSI

```
IF (LAET2M .OR. LAEH2M .OR. LAEV1M .OR. LAEICS) THEN
   CALL CACLSI(KNBPT,NPROMA,PUT,PVT,PTT,PQT,ZPSPS,PGM,PGP)
ENDIF
```

- **caviar.F90** - statistics for the utilization of the observations in CANARI
  the QC flag for snow has been added

```
INTEGER_M :: IUTILT(10)
IUTILT(10) = KBITLU(IFLG,NCUSN,1)
IUTILT(4) = MAX(..,..,..,..,..,..,..,..,.., IUTILT(10))
```

- **caviso.F90** - routine for visualisation of the observations
  QC flag for snow has been added

```
ICQU( 9) = KBITLU(IFLG,NCUSN,)
```

- **ppobsn.F90** - routine for snow analysis
  the formula for postprocessing of the model equivalent of the snow quantity has been changed

```
PXPP(JROF,1,1) = ZSNS(JROF)
```

APPENDIX 2

DESCRIPTION OF THE FIGURES IN APPENDIX 2 - SINGLE_OBS EXPERIMENT FOR 2000/03/01/00 UTC

1.Fig.1Output statistics
2.Fig.2 The snow clim file for February
3. Fig.3 The snow clim file for March
4. Fig.4 The guess snow field ($kg.m^{-2}$)
5. Fig.5 The analysed snow field (same unit)
6. Fig.6 The increments field (same unit)
7. Fig.7 The analysis snow field for the T2_FALSE experiment (same unit)
8. Fig. 8 The increments field for T2_FALSE experiment (same unit)
9. Fig.9 The increments field for T2_FALSE_all experiment (same unit)
   Contour interval - 1 ($kg.m^{-2}$)

```
OUTPUT STATISTICS - SINGLE OBS EXPERIMENT

 sig_SST    sig_snow   sig_T2     sig_H2     sig_V1
     0.80       5.00       3.00       0.30       6.00
 ref_a_SST  ref_a_snow ref_a_T2   ref_a_H2   ref_a_VOR1/DIV1
 300000.00   50000.00   50000.00   50000.00   50000.00   50000.00

                                  ****************************************************
                                  *   ECARTS-TYPES D'ERREURS D'OBSERVATION UTILISES   *
                                  ****************************************************

 Unites :   niveaux pression         en hPa
 ------     geopotentiel             en m
            temperature              en degres
            vent                     en m/s
            humidite relative        de 0 a 1
            epaisseur de couche      en m
            SST                      en degres
            quantite de neige        en kg/m**2

 Messages SYNOP, SHIP, etc...     (NSYNOP)
 ----------------------------
                          Z         T        u/v       Hu        SST       SN
         SYNOP          8.00      1.40      2.00      0.10                5.00
         SHIP           8.00      1.40      3.00      0.10      1.50

     ************************
     *    Debut de CAVISO    *
     ************************


 ************************************
 *   Type d'observation numero 1    *
 ************************************

           Observation numero     1

           ONM    BOX OTP ----OCH----   LAT     LON      DAT       ETM    SID      ALT    NLV
Loco          1 110   1  1       3  11  44.83   1.00 20000301   3027 Snow_Fr   100.    1

VNM RDFL fina cq K cq E lino cod.uti.   PPP      PRL     PIO    VAR    OMF    OMN    FOE FGE  FGC1 FGC2
 92 0000 0000 0000 0000 0000 00000000 101020.0   ---    11.5  10.00    ---    ---   5.00 ---  --- ---
```

```
 ******************************************
 * Impression des diagnostics des residus *
 ******************************************

nombre total de wagons :         1

QUANTITE DE NEIGE

 0.2 0.4 0.6 0.8 1.0 1.2 1.4  1.6  1.8  2.0  2.2  2.4  2.6  2.8  3.0  3.2  3.4  3.6  3.8  4.0  4.2  4.4

   0   0   0   0   0   0   0    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0100.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0100.0100.0100.0100.0100.0100.0100.0100.0100.0100.0100.0100.0100.0100.0100.0

 WAGONS REJETES :      0 (  0.0% )  plus    0 ELIMINES (  0.0% )   -  LISTE NOIRE (     0 ) :    0 ELIMINES et
    0 REJETES (  0.0% )

Statistiques supplementaires
----------------------------

          Type d'observations numero  1

  QUANTITE DE NEIGE           OBS-MOD =   10.000 SIGMA =     0.001 (00001)

     ************************
     *    Debut de CAVISO    *
     ************************

 ***********************************
 *   Type d'observation numero 1   *
 ***********************************

          Observation numero     1

          ONM    BOX OTP ----OCH----    LAT      LON     DAT      ETM   SID      ALT   NLV
Loco          1 110  1  1      3  11  44.83     1.00 20000301   3027 Snow_Fr   100.   1

VNM RDFL fina cq K cq E lino cod.uti.   PPP       PRL  PIO    VAR    OMF    OMN   FOE   FGE   FGC1  FGC2

 92 0000 1000 0000 1000 0000 00000000 101020.0    ---  11.5   10.00  10.00   ---  5.00  5.00  1.41  ---
```

```
***************************
*    Debut de CAVISO      *
***************************

************************************
*   Type d'observation numero 1   *
************************************

        Observation numero    1

       ONM   BOX OTP ----OCH----   LAT     LON     DAT      ETM   SID      ALT   NLV
Loco     1 110  1  1      3  11  44.83    1.00 20000301   3027 Snow_Fr  100.   1

VNM RDFL fina cq K cq E lino cod.uti.   PPP      PRL   PIO    VAR    OMF     OMN   FOE   FGE  FGC1  FGC2

 92 0000 1000 0000 1000 0000 00000000 101020.0   ---   11.5   10.00   10.00   ---   5.00  5.00 1.41  ---
```

Renseignements fournis par CAIDGU pour le champ SN GUESS sur 76729 points

niv.	moyenne	ecart-type	minimum	lat.	lon.	maximum	lat.	lon.
1	0.1278E+00	0.1658E+01	0.0000E+00	33.14	348.16	0.8910E+02	58.63	6.76

Renseignements fournis par CAIDGU pour le champ SN ANALYSE sur 76729 points

niv.	moyenne	ecart-type	minimum	lat.	lon.	maximum	lat.	lon.
1	0.1368E+00	0.1665E+01	0.0000E+00	33.14	348.16	0.8910E+02	58.63	6.76

Renseignements fournis par CAIDGU pour le champ SN TAILLE SL sur 76729 points

niv.	moyenne	ecart-type	minimum	lat.	lon.	maximum	lat.	lon.
1	0.4105E-02	0.6394E-01	0.0000E+00	33.14	348.16	0.1000E+01	43.96	0.84

Renseignements fournis par CAIDGU pour le champ SN RES ANA sur 76729 points

niv.	moyenne	ecart-type	minimum	lat.	lon.	maximum	lat.	lon.
1	0.8959E-02	0.1595E+00	0.0000E+00	33.14	348.16	0.4974E+01	44.85	0.94

```
Renseignements fournis par CAIDGU pour le champ SN SIGA/SIGP     sur  76729 points
 ----------------------------------------------------------------------------------------------
| niv.     moyenne    ecart-type     minimum      lat.      lon.       maximum     lat.     lon.  |
 ----------------------------------------------------------------------------------------------
|  1  | 0.9997E+00 | 0.6296E-02 | 0.7107E+00 |  44.85 |    0.94 | 0.1000E+01 |  33.14 | 348.16 |
 ----------------------------------------------------------------------------------------------

     ************************
     *   Debut de CAVISO    *
     ************************

*********************************
*   Type d'observation numero 1   *
*********************************

          Observation numero     1

          ONM   BOX OTP ----OCH----    LAT      LON     DAT        ETM    SID       ALT    NLV
Loco          1 110  1  1     3  11  44.83    1.00 20000301    3027 Snow_Fr   100.    1

VNM RDFL fina cq K cq E lino cod.uti.    PPP      PRL   PIO    VAR    OMF    OMN   FOE  FGE  FGC1   FGC2

 92 0000 1000 0000 1000 0000 00000000 101020.0    ---   11.5   10.00  10.00   ---   5.00 5.00  1.41   ---

   Impression des diagnostics des residus *
  ******************************************

nombre total de wagons :         1

           Type d'observations numero  1

QUANTITE DE NEIGE

  0.2 0.4 0.6  0.8  1.0  1.2  1.4  1.6  1.8  2.0  2.2  2.4  2.6  2.8  3.0  3.2  3.4  3.6  3.8  4.0  4.2  4.4

    0   0   0    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0.0 0.0 0.0100.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0 0.0 0.0100.0100.0100.0100.0 100.0100.0100.0100.0100.0100.0100.0100.0100.0100.0100.0100.0100.0100.0100.0

 WAGONS REJETES :    0 (  0.0% )  plus   0 ELIMINES (  0.0% )   -  LISTE NOIRE (    0 ) :    0 ELIMINES  et
    0 REJETES (  0.0% )
```

```
Statistiques supplementaires
----------------------------

          Type d'observations numero  1

  QUANTITE DE NEIGE              OBS-MOD =    5.042 SIGMA =    0.001 (00001)

     *************************
     *    Debut de CAVISO    *
     *************************

***********************************
*   Type d'observation numero 1   *
***********************************

          Observation numero    1

          ONM    BOX OTP ----OCH----   LAT     LON      DAT      ETM    SID      ALT    NLV
Loco           1 110  1   1     3  11  44.83   1.00 20000301   3027 Snow_Fr   100.    1

VNM RDFL fina cq K cq E lino cod.uti.   PPP      PRL   PIO   VAR   OMF   OMN   FOE   FGE  FGC1  FGC2

 92 0000 1000 0000 1000 0000 00000000 101020.0   ---   11.5  10.00 10.00 5.04  5.00  5.00 1.41  ---
```

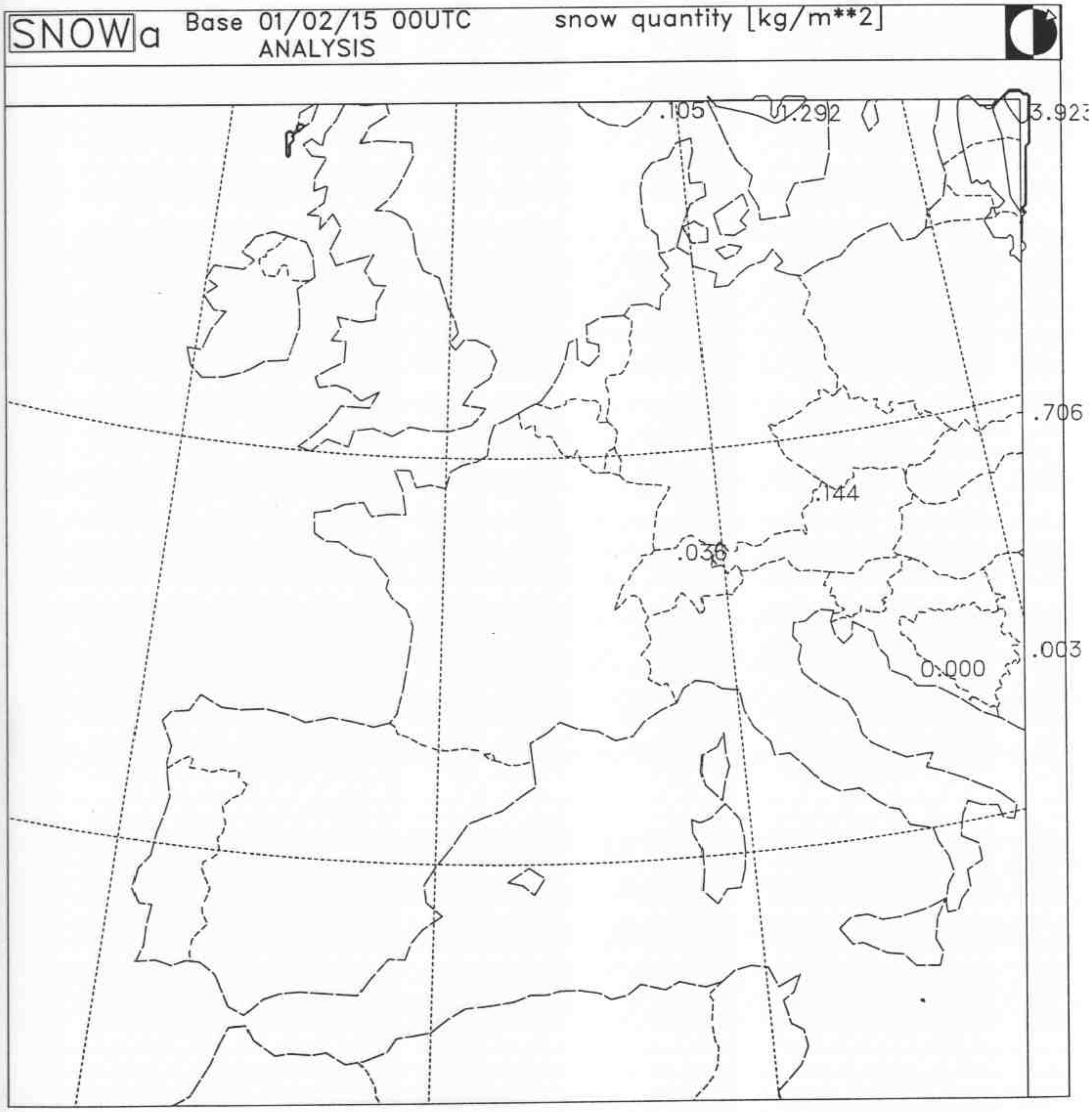

SNOW a
Base 01/02/15 00UTC
ANALYSIS
snow quantity [kg/m**2]
.105
1.292
3.923
.706
.144
.036
.003
0.000

Fig. 2

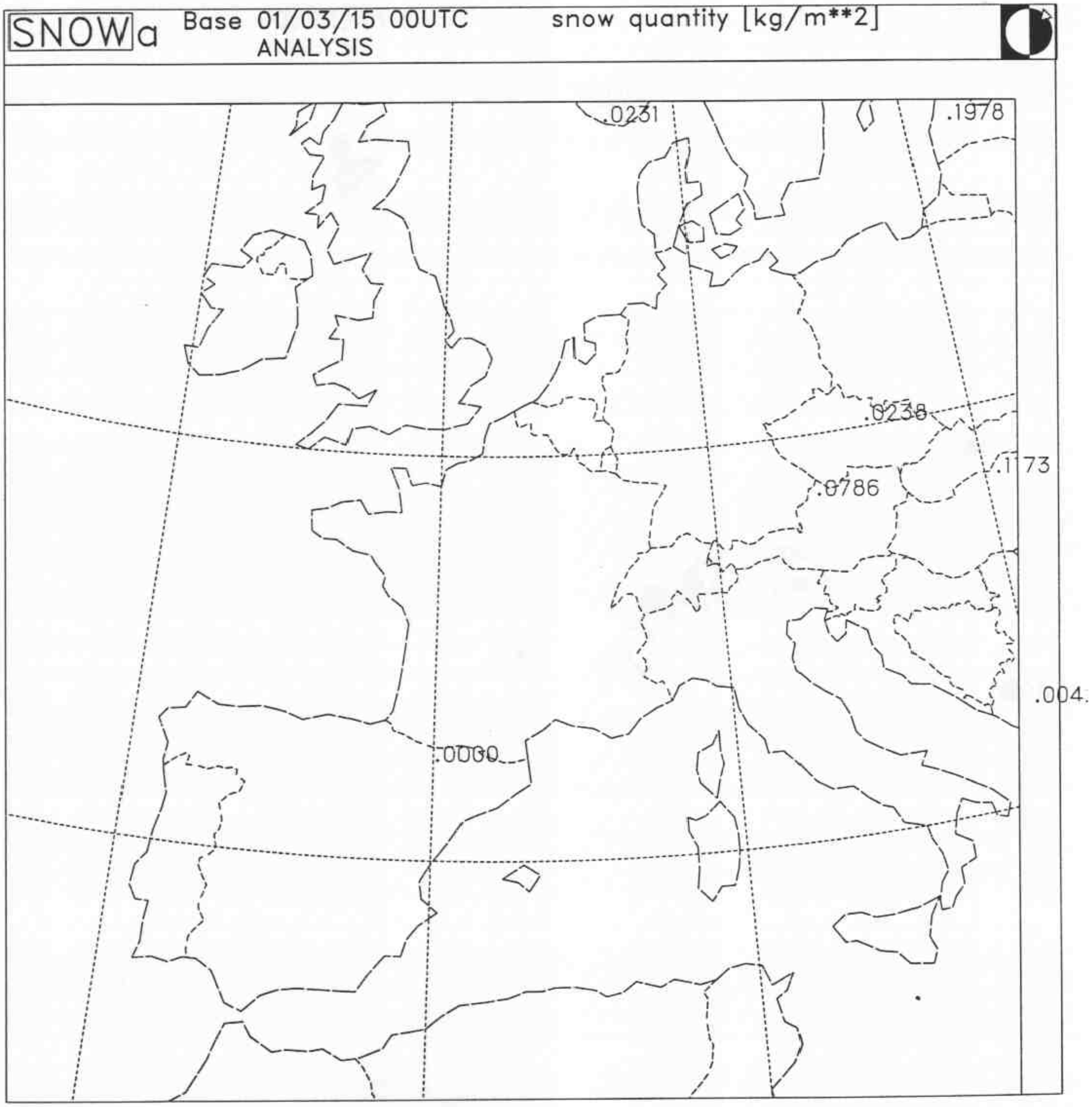

SNOWa
Base 01/03/15 00UTC
ANALYSIS
snow quantity [kg/m**2]
.0231
.1978
.0238
.1173
.0786
.004
.0000

Fig. 3

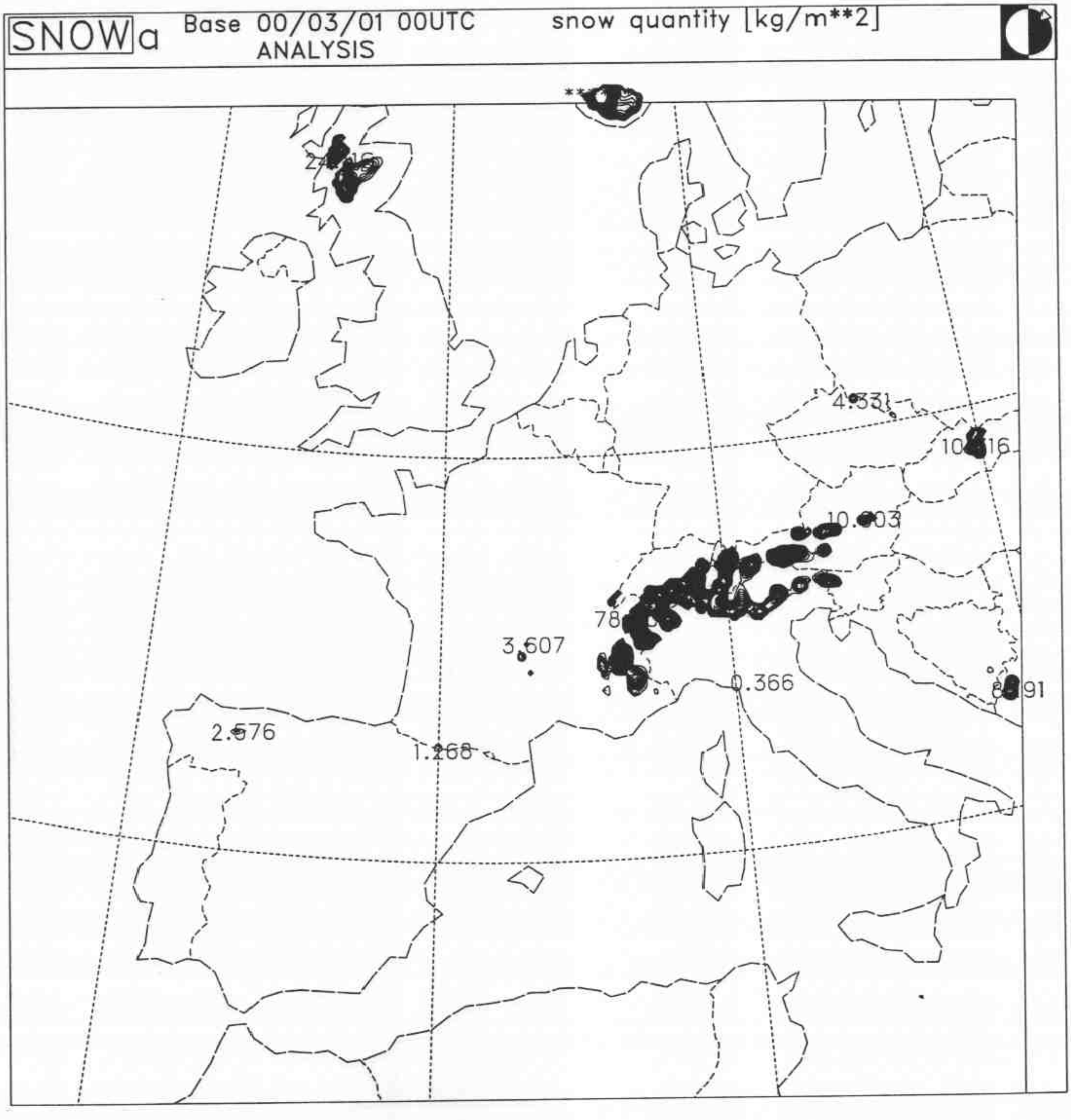

SNOWa
Base 00/03/01 00UTC
ANALYSIS
snow quantity [kg/m**2]
4.331
3.607
0.366
2.576

Fig. 4

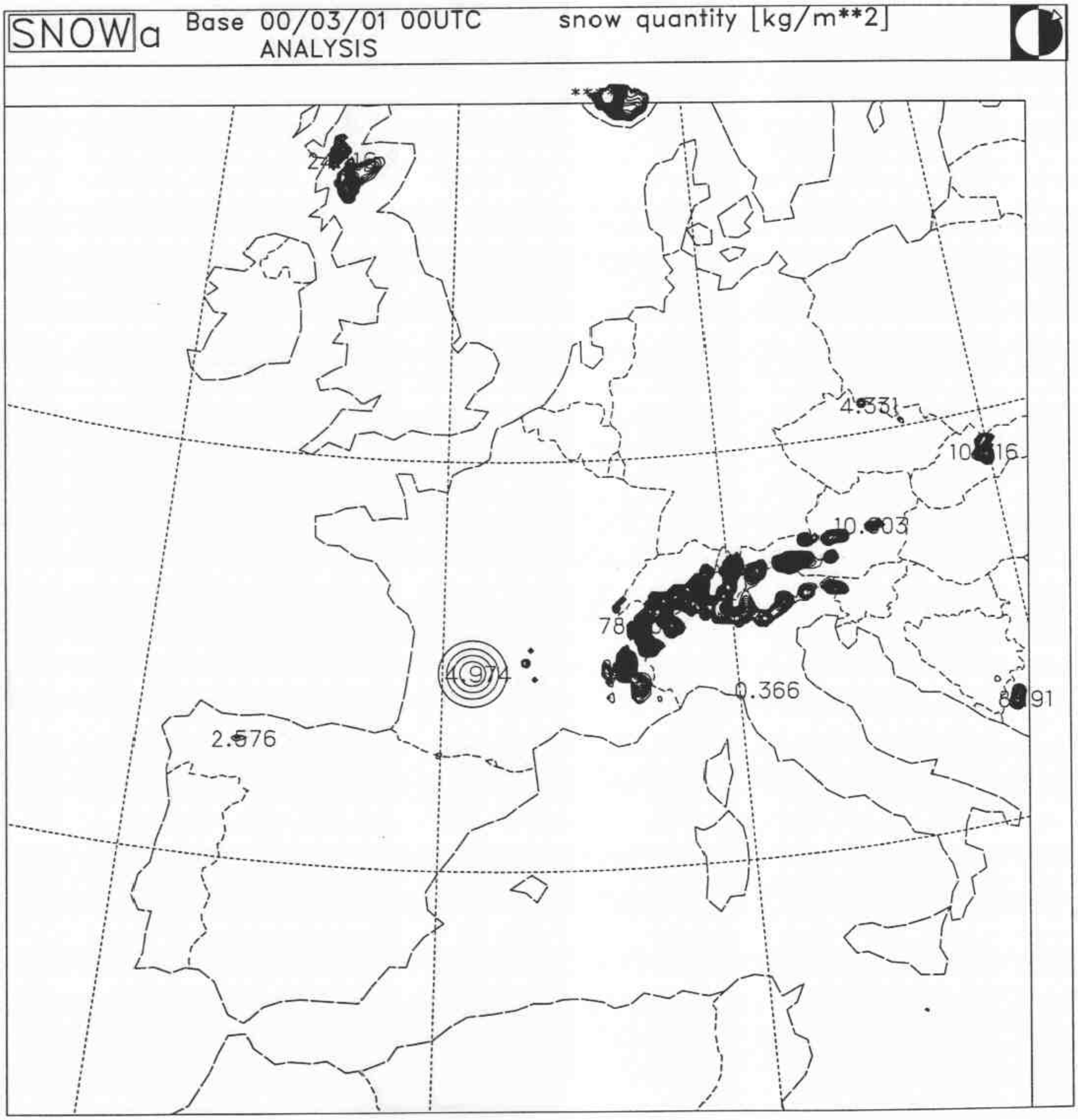

SNOW a
Base 00/03/01 00UTC
ANALYSIS
snow quantity [kg/m**2]
10.003
0.366
2.576

Fig. 5

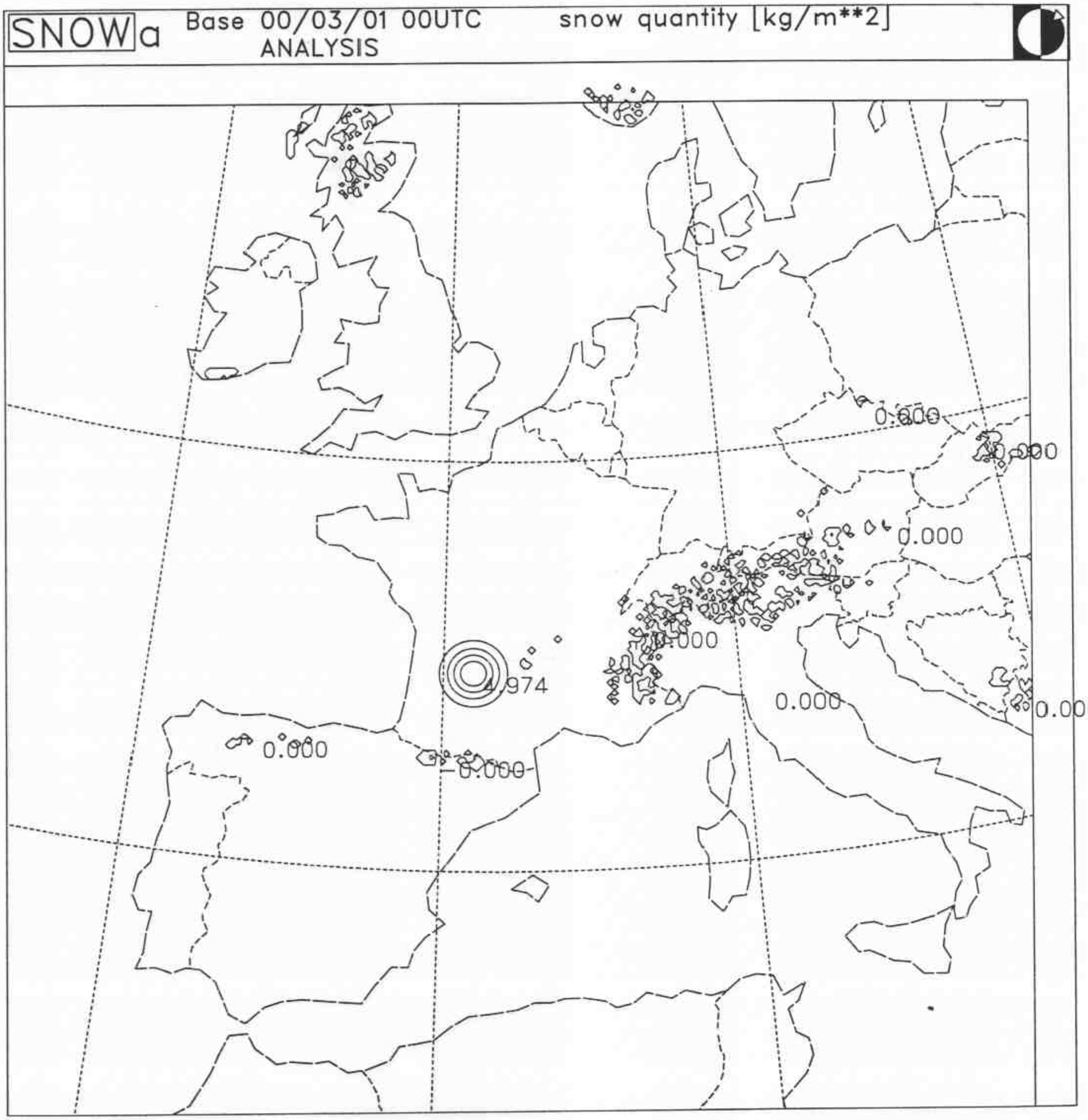
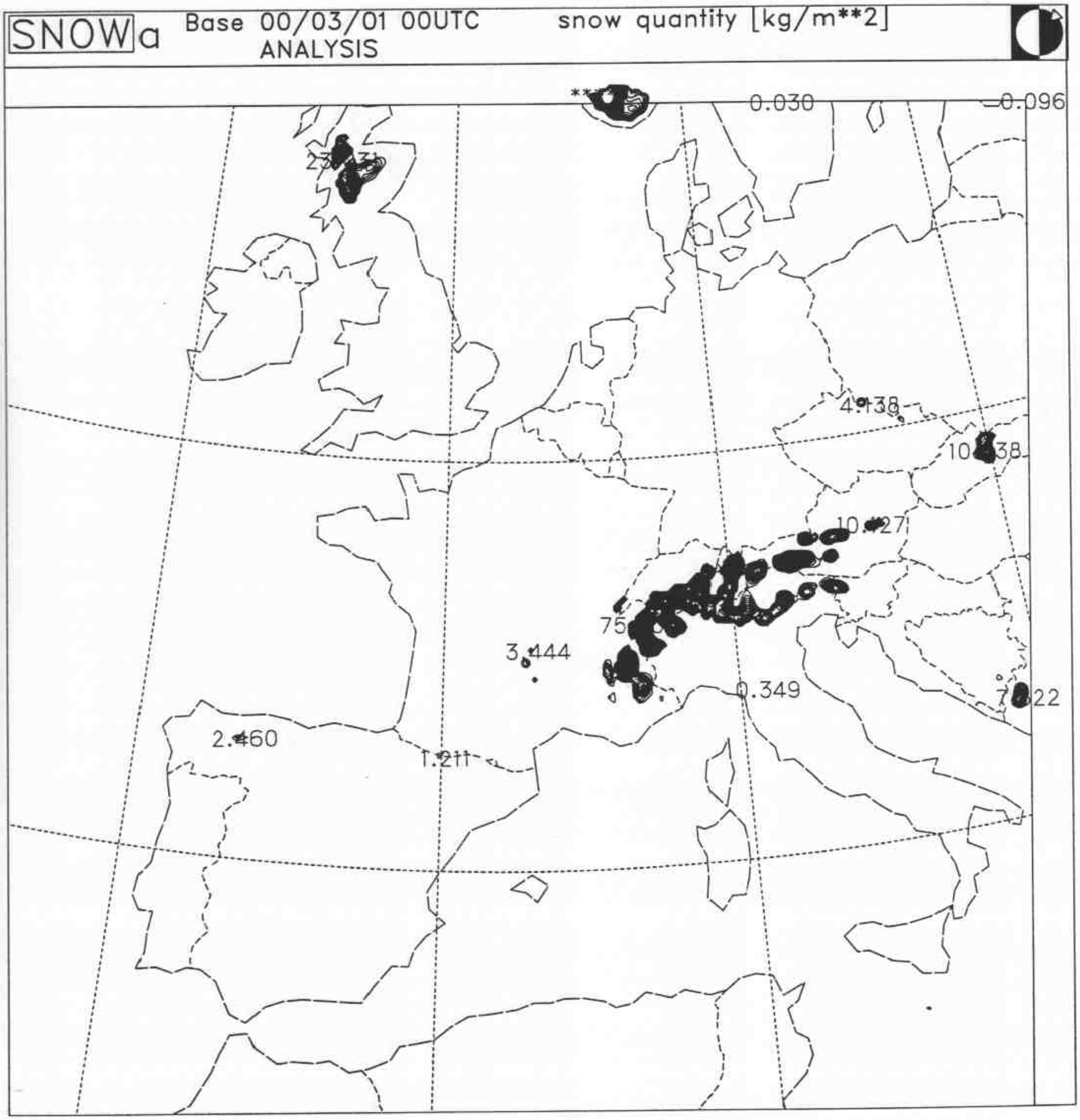

SNOWa
Base 00/03/01 00UTC
ANALYSIS
snow quantity [kg/m**2]
0.000
0.000
0.000
0.000
4.974
0.000
0.000
0.000
0.000

Fig.6



SNOW a
Base 00/03/01 00UTC
ANALYSIS
snow quantity [kg/m**2]
0.030
0.096
4.138
10.438
10.427
75
3.444
0.349
7.22
2.460
1.211

Fig. 7

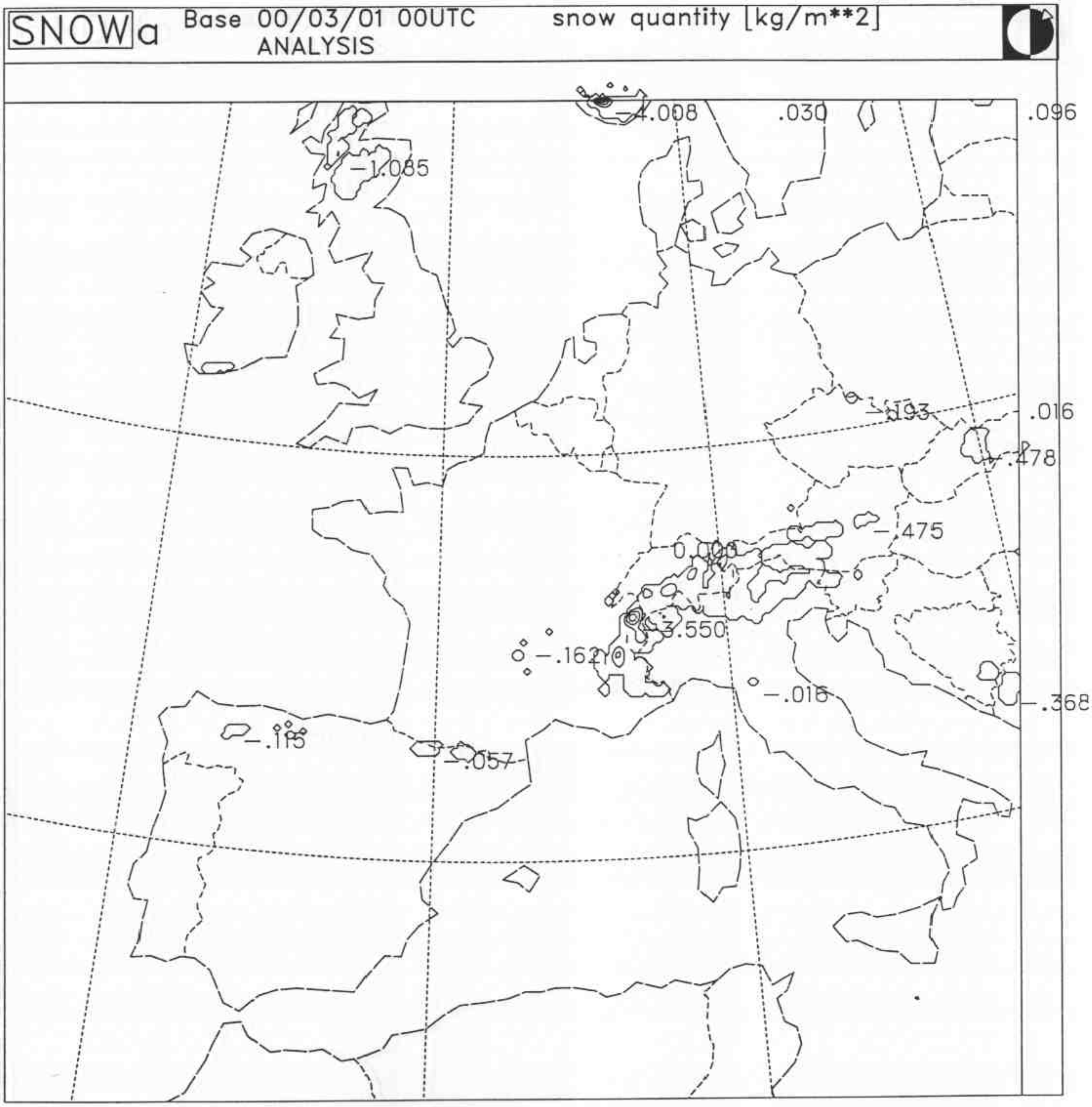

SNOWa
Base 00/03/01 00UTC
ANALYSIS
snow quantity [kg/m**2]
.008
.030
.096
1.085
.193
.016
.478
.475
3.550
.162
.016
.368
.115
.057

Fig. 8

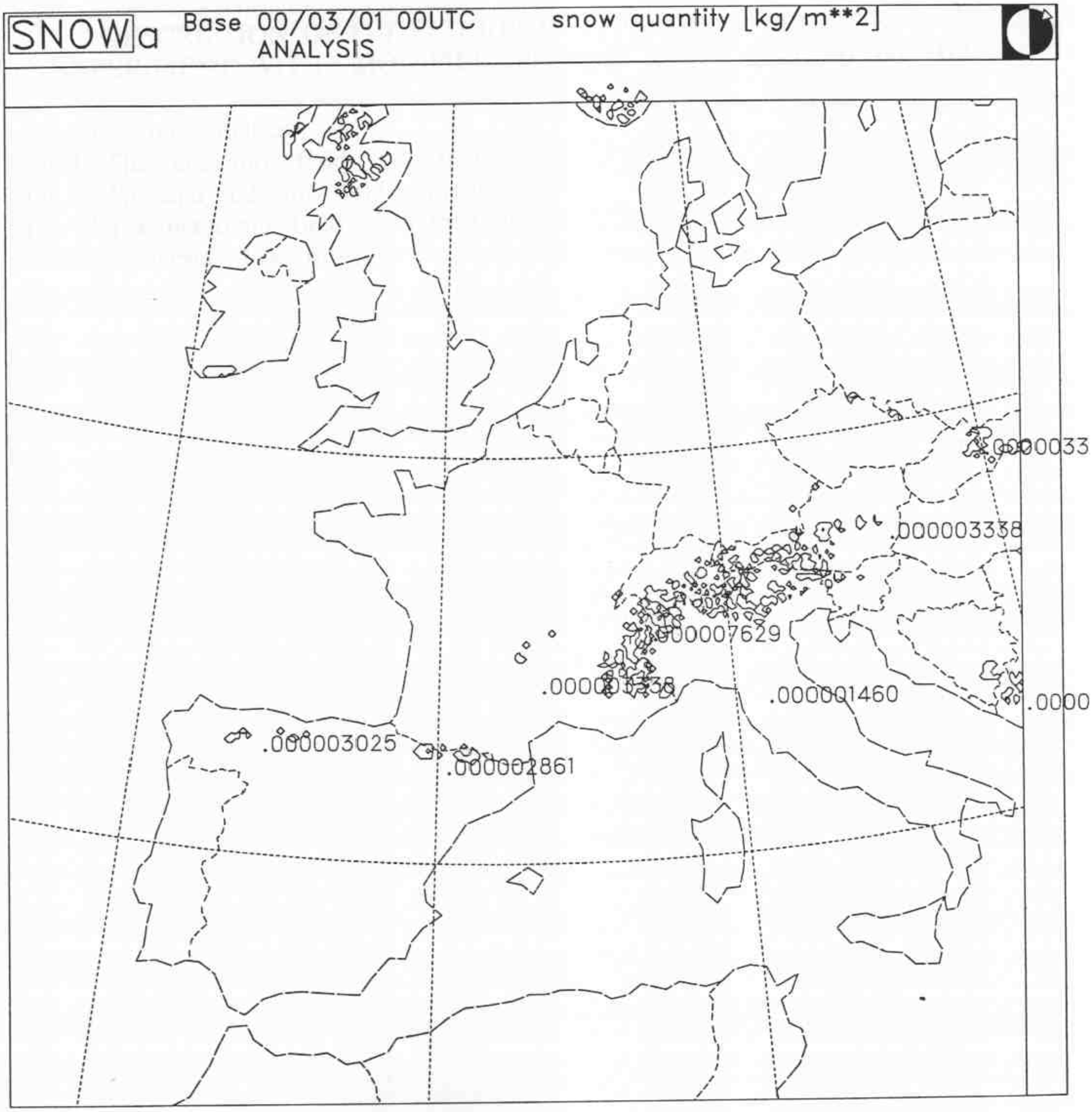

SNOW a
Base 00/03/01 00UTC
ANALYSIS
snow quantity [kg/m**2]
.000003338
.000007629
.000001460
.000003025
.000002861

Fig. 9

APPENDIX 3

DESCRIPTION OF THE FIGURES IN APPENDIX 2 - FULL_OBS EXPERIMENT WITH MODIFIED PPOBSN FOR 2000/03/01/00 UTC

1.Fig.10 Output statistics
2.Fig.11 The guess snow field (kg.m^{-2})
2.Fig.12 The analysed snow field (same unit)
3.Fig.13 The increments field (same unit)
Contour interval - 1 (kg.m^{-2})

OUTPUT STATISTICS - FULL_OBS EXPERIMENT - PPOBSN MODIFIED

BEFORE ANALYSES

QUANTITE DE NEIGE

0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.(
12	4	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	(
54.5	18.2	0.0	0.0	4.5	4.5	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.(
54.5	72.7	72.7	72.7	77.3	81.8	81.8	81.8	86.4	86.4	86.4	86.4	86.4	86.4	86.4	86.4	90.9	90.(

WAGONS REJETES : 3 (13.6%) plus 0 ELIMINES (0.0%) - LISTE NOIRE (0
) : 0 ELIMINES et 0
REJETES (0.0%)

Statistiques supplementaires

Type d'observations numero 1

GEOPOTENTIEL	OBS-MOD = -16.214	SIGMA =	88.618	(01076)
HUMIDITE RELATIVE A 2M	OBS-MOD = -0.001	SIGMA =	0.090	(01497)
TEMPERATURE A 2M	OBS-MOD = 0.119	SIGMA =	1.190	(01566)
TAUX DE PRECIPITATIONS	OBS-MOD = 0.000	SIGMA =	0.001	(01030)
QUANTITE DE NEIGE	OBS-MOD = -6.305	SIGMA =	14.146	(00022)
VENT U A 10M	OBS-MOD = 0.256	SIGMA =	3.213	(00072)
VENT V A 10M	OBS-MOD = -0.266	SIGMA =	3.807	(00072)
NON REPERTORIE	OBS-MOD = 0.001	SIGMA =	0.001	(00836)

Renseignements fournis par CAIDGU pour le champ SN GUESS sur 76729 points

niv.	moyenne	ecart-type	minimum	lat.	lon.	maximum	lat.
1	0.1278E+00	0.1658E+01	0.0000E+00	33.14	348.16	0.8910E+02	58.63

Renseignements fournis par CAIDGU pour le champ SN ANALYSE sur 76729 points

niv.	moyenne	ecart-type	minimum	lat.	lon.	maximum	lat.
1	0.1230E+00	0.1581E+01	0.0000E+00	33.14	348.16	0.8910E+02	58.63

Renseignements fournis par CAIDGU pour le champ SN TAILLE SL sur 76729 points

niv.	moyenne	ecart-type	minimum	lat.	lon.	maximum	lat.
1	0.5409E-01	0.3692E+00	0.0000E+00	33.14	348.16	0.7000E+01	44.81

Renseignements fournis par CAIDGU pour le champ SN RES ANA sur 76729 points

niv.	moyenne	ecart-type	minimum	lat.	lon.	maximum	lat.
1	-.1502E-01	0.2467E+00	-.6706E+01	45.41	6.65	0.7823E+00	42.72

Renseignements fournis par CAIDGU pour le champ SN SIGA/SIGP sur 76729 points

niv.	moyenne	ecart-type	minimum	lat.	lon.	maximum	lat.
1	0.9967E+00	0.2586E-01	0.5323E+00	45.18	5.74	0.1000E+01	33.14

AFTER ANALYSES

QUANTITE DE NEIGE

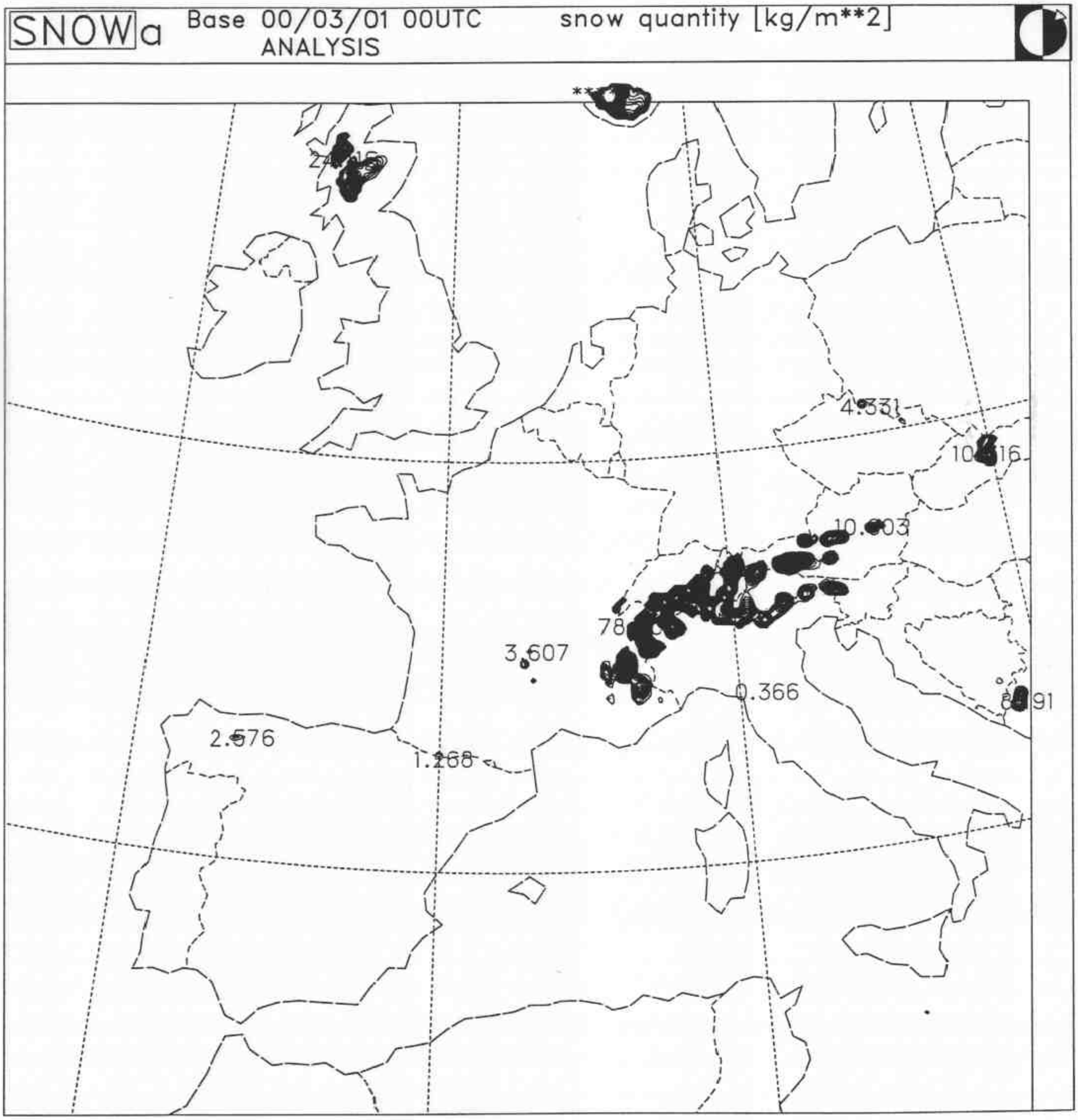
0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.
15	1	2	1	0	0	0	0	0	0	0	0	0	1	0	1	0	[illegible]
68.2	4.5	9.1	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	4.5	0.0	0.
68.2	72.7	81.8	86.4	86.4	86.4	86.4	86.4	86.4	86.4	86.4	86.4	86.4	90.9	90.9	95.5	95.5	95

WAGONS REJETES : 3 (13.6%) plus 0 ELIMINES (0.0%) - LISTE NOIRE (0
) : 0 ELIMINES et 0
REJETES (0.0%)

Statistiques supplementaires

Type d'observations numero 1

GEOPOTENTIEL	OBS-MOD =	-16.214	SIGMA =	88.618	(01076)
HUMIDITE RELATIVE A 2M	OBS-MOD =	-0.001	SIGMA =	0.090	(01497)
TEMPERATURE A 2M	OBS-MOD =	0.120	SIGMA =	1.189	(01566)
TAUX DE PRECIPITATIONS	OBS-MOD =	0.000	SIGMA =	0.001	(01030)
QUANTITE DE NEIGE	OBS-MOD =	-5.018	SIGMA =	12.955	(00022)
VENT U A 10M	OBS-MOD =	0.258	SIGMA =	3.213	(00072)
VENT V A 10M	OBS-MOD =	-0.266	SIGMA =	3.807	(00072)
NON REPERTORIE	OBS-MOD =	0.001	SIGMA =	0.001	(00836)



SNOW a
Base 00/03/01 00UTC
ANALYSIS
snow quantity [kg/m**2]
3.607
0.366
2.576
1.268

Fig. 11

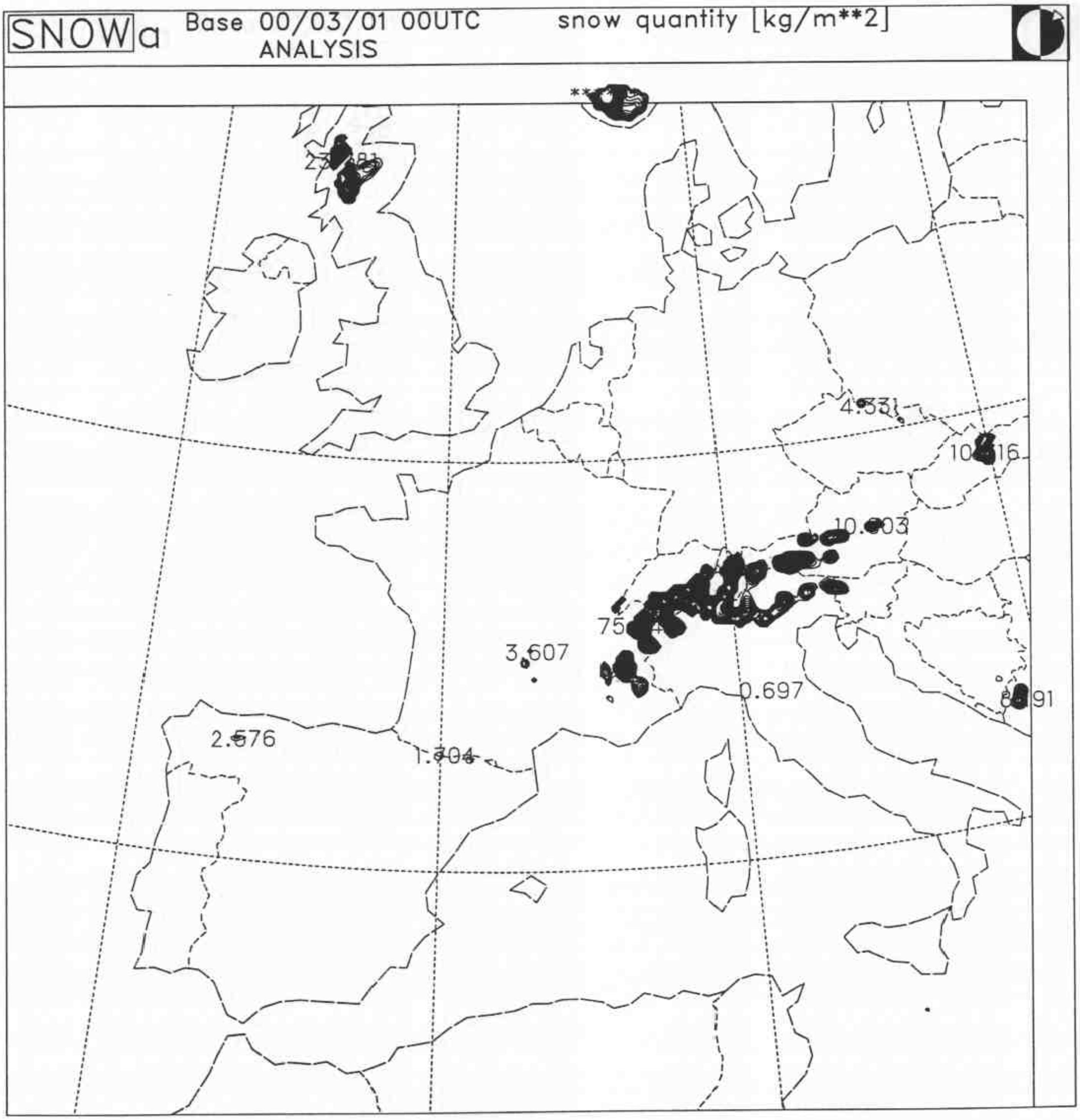

SNOW a
Base 00/03/01 00UTC
ANALYSIS
snow quantity [kg/m**2]
4.331
10.003
3.607
0.697
2.576
1.704

Fig. 12

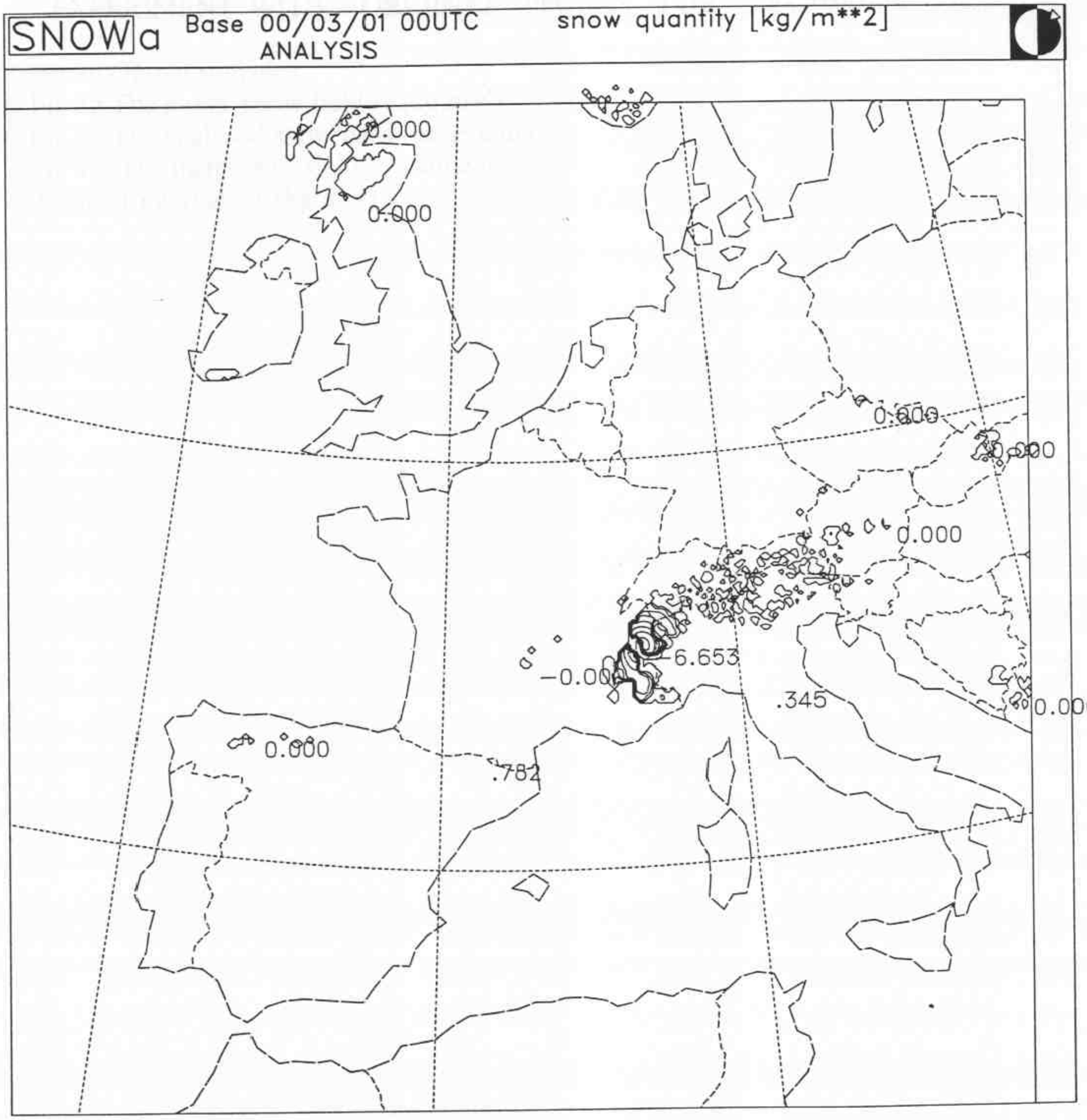

SNOW a
Base 00/03/01 00UTC
ANALYSIS
snow quantity [kg/m**2]
0.000
0.000
0.000
0.000
0.000
6.653
-0.00
.345
0.000
0.000
.782

Fig.13

APPENDIX 4

DESCRIPTION OF THE FIGURES IN APPENDIX 2 - FULL_OBS
EXPERIMENT WITH ORIGINAL PPOBSN FOR 2000/03/01/00 UTC

1.Fig.14 Output statistics
2.Fig.15 The guess snow field (kg.m^{-2})
2.Fig.16 The analysed snow field (same unit)
3.Fig 17 The increments field (same unit)
Contour interval - 1 (kg.m^{-2})

OUTPUT STATISTICS - FULL_OBS EXPERIMENT

BEFORE ANALYSES

QUANTITE DE NEIGE

0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6
5	3	6	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1
22.7	13.6	27.3	4.5	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5
22.7	36.4	63.6	68.2	68.2	72.7	72.7	72.7	72.7	72.7	72.7	72.7	72.7	72.7	72.7	72.7	72.7	77.3

WAGONS REJETES : 6 (27.3%) plus 0 ELIMINES (0.0%) - LISTE NOIRE
(0) : 0 ELIMINES et 0 REJETES (0.0%)

Statistiques supplementaires

Type d'observations numero 1

GEOPOTENTIEL	OBS-MOD = -16.214	SIGMA = 88.618	(01076)
HUMIDITE RELATIVE A 2M	OBS-MOD = -0.001	SIGMA = 0.090	(01497)
TEMPERATURE A 2M	OBS-MOD = 0.119	SIGMA = 1.190	(01566)
TAUX DE PRECIPITATIONS	OBS-MOD = 0.000	SIGMA = 0.001	(01030)
QUANTITE DE NEIGE	OBS-MOD = -32.698	SIGMA = 67.077	(00022)
VENT U A 10M	OBS-MOD = 0.256	SIGMA = 3.213	(00072)
VENT V A 10M	OBS-MOD = -0.266	SIGMA = 3.807	(00072)
NON REPERTORIE	OBS-MOD = 0.001	SIGMA = 0.001	(00836)

Renseignements fournis par CAIDGU pour le champ SN GUESS sur 76729 points

niv.	moyenne	ecart-type	minimum	lat.	lon.	maximum	lat.
1	0.1278E+00	0.1658E+01	0.0000E+00	33.14	348.16	0.8910E+02	58.63

Renseignements fournis par CAIDGU pour le champ SN ANALYSE sur 76729 points

niv.	moyenne	ecart-type	minimum	lat.	lon.	maximum	lat.
1	0.1225E+00	0.1627E+01	0.0000E+00	33.14	348.16	0.8910E+02	58.63

Renseignements fournis par CAIDGU pour le champ SN TAILLE SL sur 76729 points

niv.	moyenne	ecart-type	minimum	lat.	lon.	maximum	lat.
1	0.4254E-01	0.2723E+00	0.0000E+00	33.14	348.16	0.4000E+01	44.73

Renseignements fournis par CAIDGU pour le champ SN RES ANA sur 76729 points

niv.	moyenne	ecart-type	minimum	lat.	lon.	maximum	lat.
1	-.2464E-01	0.2029E+00	-.4337E+01	44.78	6.85	0.0000E+00	33.14

Renseignements fournis par CAIDGU pour le champ SN SIGA/SIGP sur 76729 points

niv.	moyenne	ecart-type	minimum	lat.	lon.	maximum	lat.
1	0.9972E+00	0.2234E-01	0.5393E+00	45.18	5.62	0.1000E+01	33.14

AFTER ANALYSES

QUANTITE DE NEIGE

0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.
7	3	4	2	0	0	0	0	0	0	0	1	0	0	0	0	0	(
31.8	13.6	18.2	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.(
31.8	45.5	63.6	72.7	72.7	72.7	72.7	72.7	72.7	72.7	72.7	77.3	77.3	77.3	77.3	77.3	77.3	77.

WAGONS REJETES : 5 (22.7%) plus 0 ELIMINES (0.0%) - LISTE NOIRE (0) : (
REJETES (0.0%)

Statistiques supplementaires

Type d'observations numero 1

GEOPOTENTIEL	OBS-MOD =	-16.214	SIGMA =	88.618	(01076)
HUMIDITE RELATIVE A 2M	OBS-MOD =	-0.001	SIGMA =	0.090	(01497)
TEMPERATURE A 2M	OBS-MOD =	0.120	SIGMA =	1.189	(01566)
TAUX DE PRECIPITATIONS	OBS-MOD =	0.000	SIGMA =	0.001	(01030)
QUANTITE DE NEIGE	OBS-MOD =	-29.637	SIGMA =	65.317	(00022)
VENT U A 10M	OBS-MOD =	0.258	SIGMA =	3.213	(00072)
VENT V A 10M	OBS-MOD =	-0.266	SIGMA =	3.807	(00072)
NON REPERTORIE	OBS-MOD =	0.001	SIGMA =	0.001	(00836)

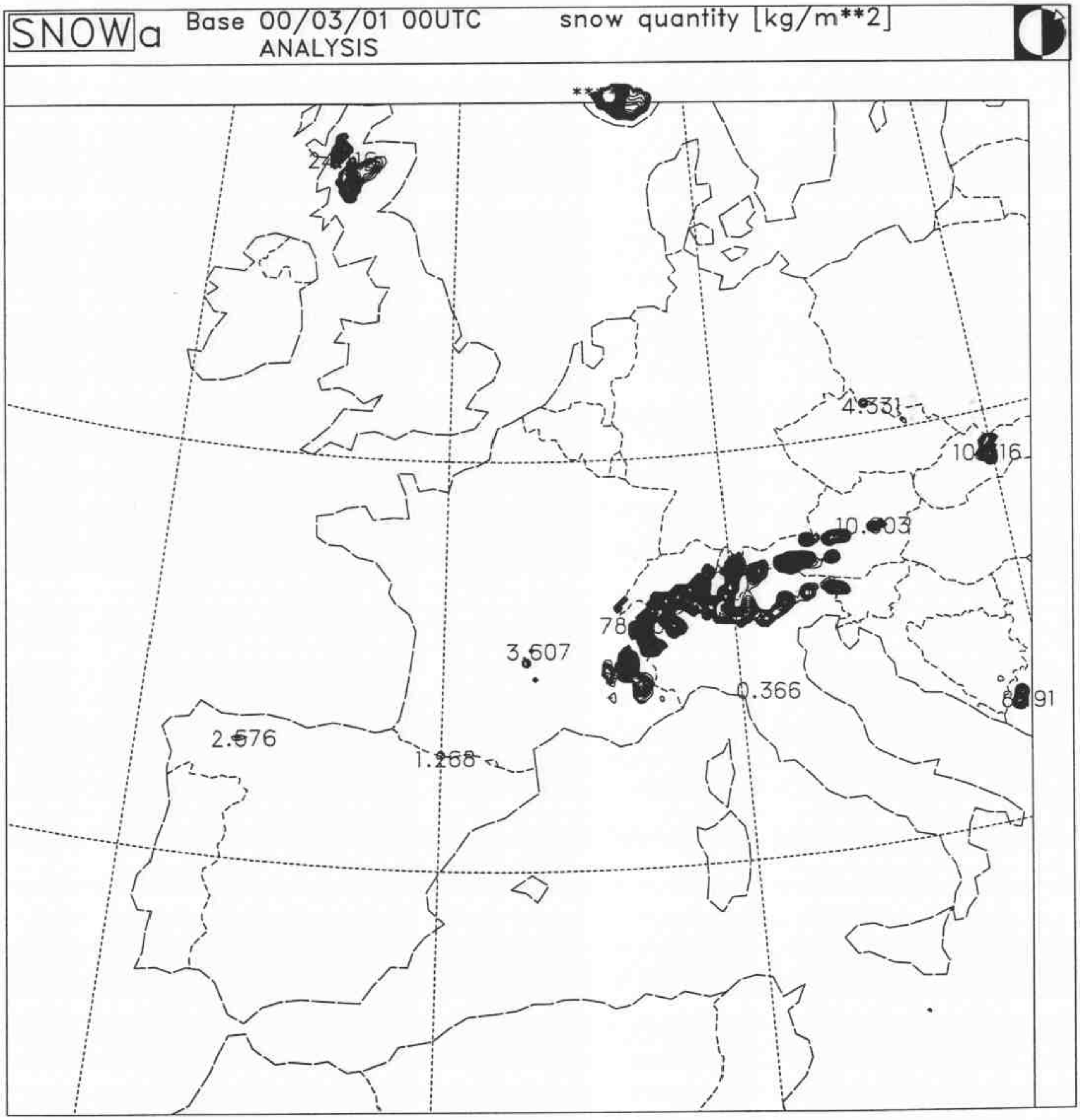

SNOW a
Base 00/03/01 00UTC
ANALYSIS
snow quantity [kg/m**2]
4.331
3.607
0.366
2.576
1.268

Fig. 15

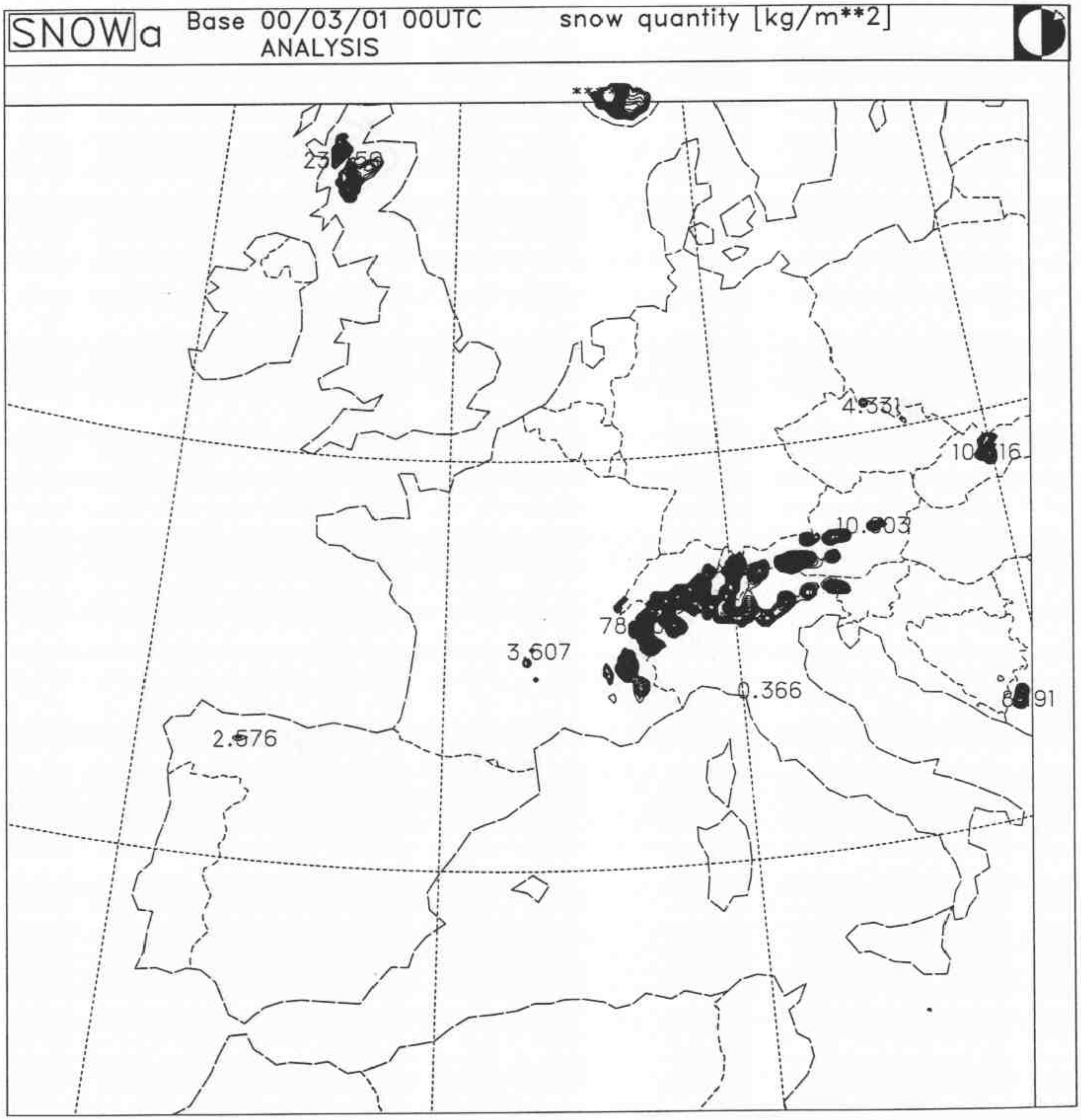
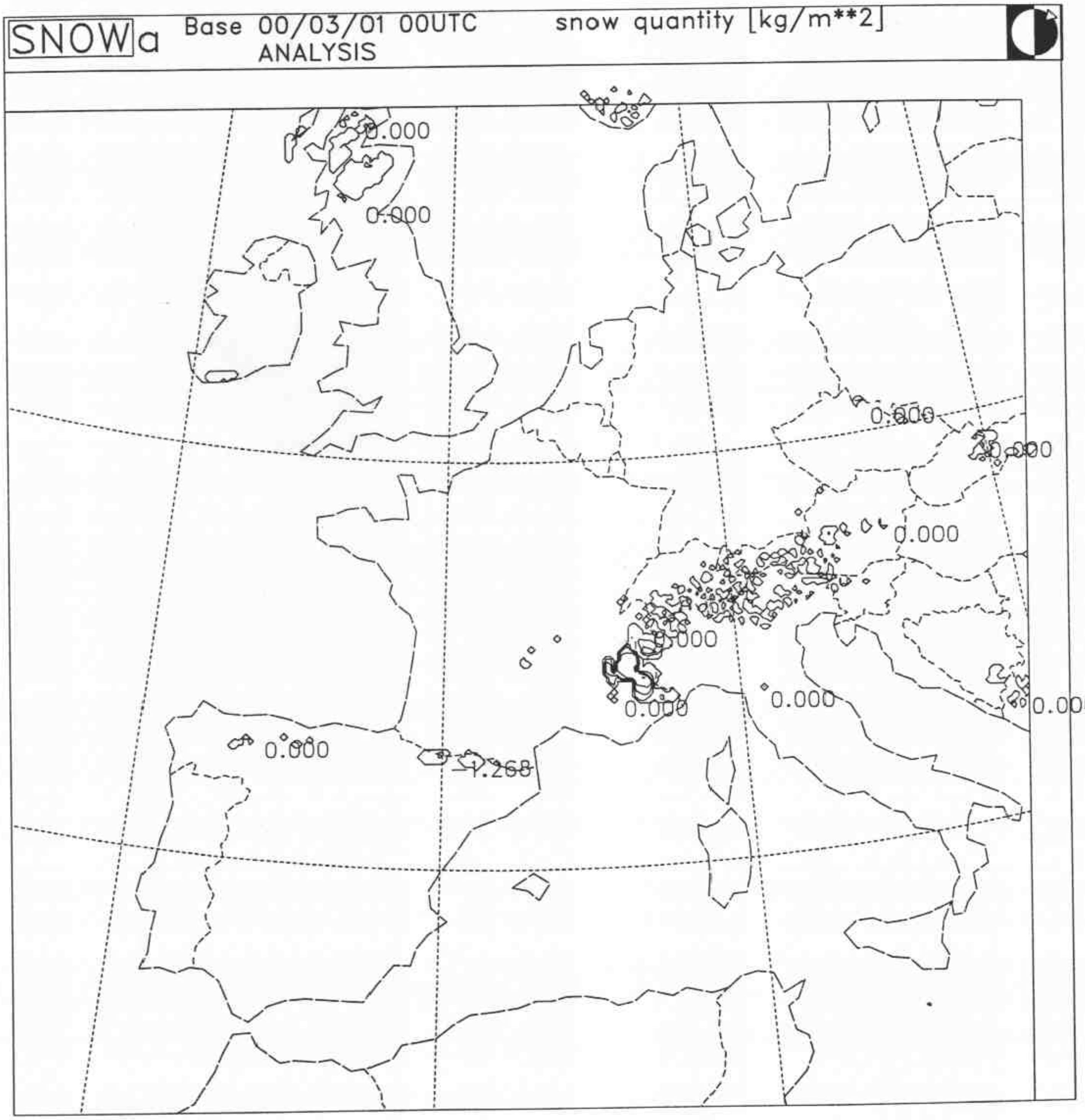

SNOWa
Base 00/03/01 00UTC
ANALYSIS
snow quantity [kg/m**2]
3.607
2.576
0.366
78

Fig. 16



SNOWa
Base 00/03/01 00UTC
ANALYSIS
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0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
1.268

Fig. 17