Environnement Canada
Centre météorologique canadien

Environment Canada
Canadian Meteorological Centre

Processing of Atmospheric Motion Vectors Observations at the Canadian Meteorological Centre

Version 3.7

March 2016

Revision history		
Version	**Date**	**Remarks**
1.0	2003/05	First version
1.1	2003/06	Change of GMS-5 by GOES-P SATOBS
2.0	2004/09	- Addition of MODIS Polar winds - Change from SATOBS to BUFR files from JMA - Tuning of selection - Observations files ready for 4DVar
3.0	2005/01	4DVar processing for the global analyses
3.1	2005/12	MTSAT-1R and METEOSAT-8
3.2	2008/01	Satellites updates & GOES 3.9 µm
3.3	2009/03	Includes MODIS DB from Tromso, Fairbanks and McMurdo
3.4	2011/03	New satellites and Strato2b version
3.5	2013/06	Addition of AVHRR polar winds NOAA 15-19 and METOP2
3.6	2013/11	Addition of global MeteoSat10 and polar winds METOP1
3.7	2015/12 2016/03	-Addition of METSAT8 in cases when METSAT10 is not operational -Replacement of MTSAT-2 with Himawari-8 -Addition of NPP

Note: The date in the table above represents the date of revision of the document and not the implementation date.

1. Introduction

The document is a summary of the processing of atmospheric motion vectors (AMVs) observations in the CMC assimilation system. Some technical aspects of the processing are discussed but without going in the details.

History of AMVs observations usage:

In December 2001, a new selection of satellite winds was implemented at the same time as many other modifications to the analysis. GOES satellite observations from NESDIS BUFR coded bulletins were added. SATOB format METEOSAT observations from EUMETSAT were replaced by a selection from the expanded low-resolution (ELW) BUFR bulletins. The quality indicators, MPEF QI and NESDIS RFF, are used in the screening and thinning procedures. Quality thresholds were determined from observation minus background statistics. The quality control of the observations was improved with the introduction of variational quality control and the addition of an asymmetric test for satellite winds. Also, the weight given to the satwinds was increased by lowering the observation error. Note: More information about QI thresholds and observation errors is given in Appendix A.

In December 2002, EUMETSAT kept only the IR-channel winds in the ELW bulletins, visible and water vapour winds were eliminated. More information about the different channels defined by Satellite derived wind computation method is given in Appendix B. In March 2003, high resolution water vapour, HWW, and visible, HRV, bulletins from EUMETSAT were included in the operational system in replacement of the lost low resolution observations.

In April 2003, GOES-12 replaces GOES-08 winds.

In June 2003, GOES-9 replaces GMS-5 winds.

In September 2004, we started using the BUFR bulletins from JMA containing the observations of GOES-9, instead of the SATOBS format files. The MODIS polar winds were added. The fine tuning of the observations selection included among other things, the inclusion of water vapour in clear air observations. The observations errors are specified in 10 layers and there is a tightening of the QC.

In January 2005, 4DVar processing was added for the global assimilation system. The number of AMVs assimilated in the 4DVar is more than double the number of observations in the 3DVar.

In July 2005, MTSAT-1R data replaces observations derived from GOES-9.

In December 2005, METEOSAT-8 data replaces METEOSAT-7 winds.

In June 2006, GOES-11 replaces GOES-10.

In February 2007, METEOSAT-7 replaces METEOSAT-5.

In April 2007, METEOSAT-9 replaces METEOSAT-8.

In December 2007, winds observations derived from the GOES 3.9 μm channel are added to the selection of observations.

In March 2009, Direct Broadcast MODIS observations from Tromso, Norway; Fairbanks, Alaska and McMurdo, Antarctica, were added to the selection of observations.

In April 2010, GOES-13 data replaces GOES-12

In August 2010, MTSAT-2 replaces MTSAT-1R

In May 2011, modify selection criteria with the implementation of Strato2b assimilation: elimination of clear-air wv data and threshold of O-P values

In February 2013, the polar winds observations produced by Advanced Very High Resolution Radiometer AVHRR instruments, NOAA 15-19 and METOP2 (METOP-A) are added to the selection of observations

In April 2013, METEOSAT-10 replaces METEOSAT-9 as global winds.

In November 2013, METOP-1 (METOP-B)

In December 2015, addition of METSAT8 in cases when METSAT10 is not operational

In March 2016, NPP was added as polar winds and Himawari-8 replaced MTSAT-2.

Note: A list of AMV types assimilated currently at CMC is given in Appendix C

2. Flowchart of processing

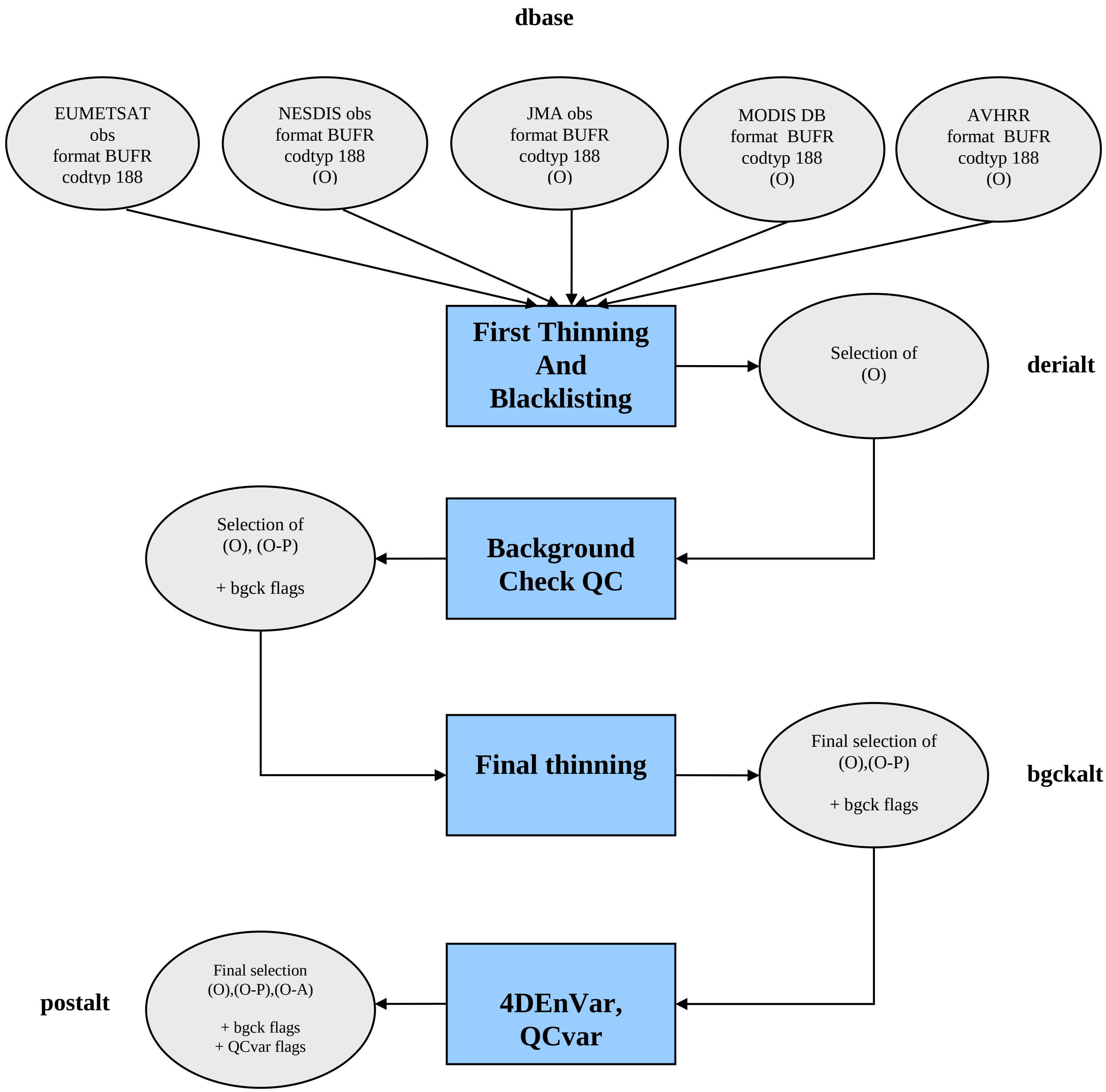

Figure 1: AMVs observations processing; Operational branch, last file is in postalt directory.

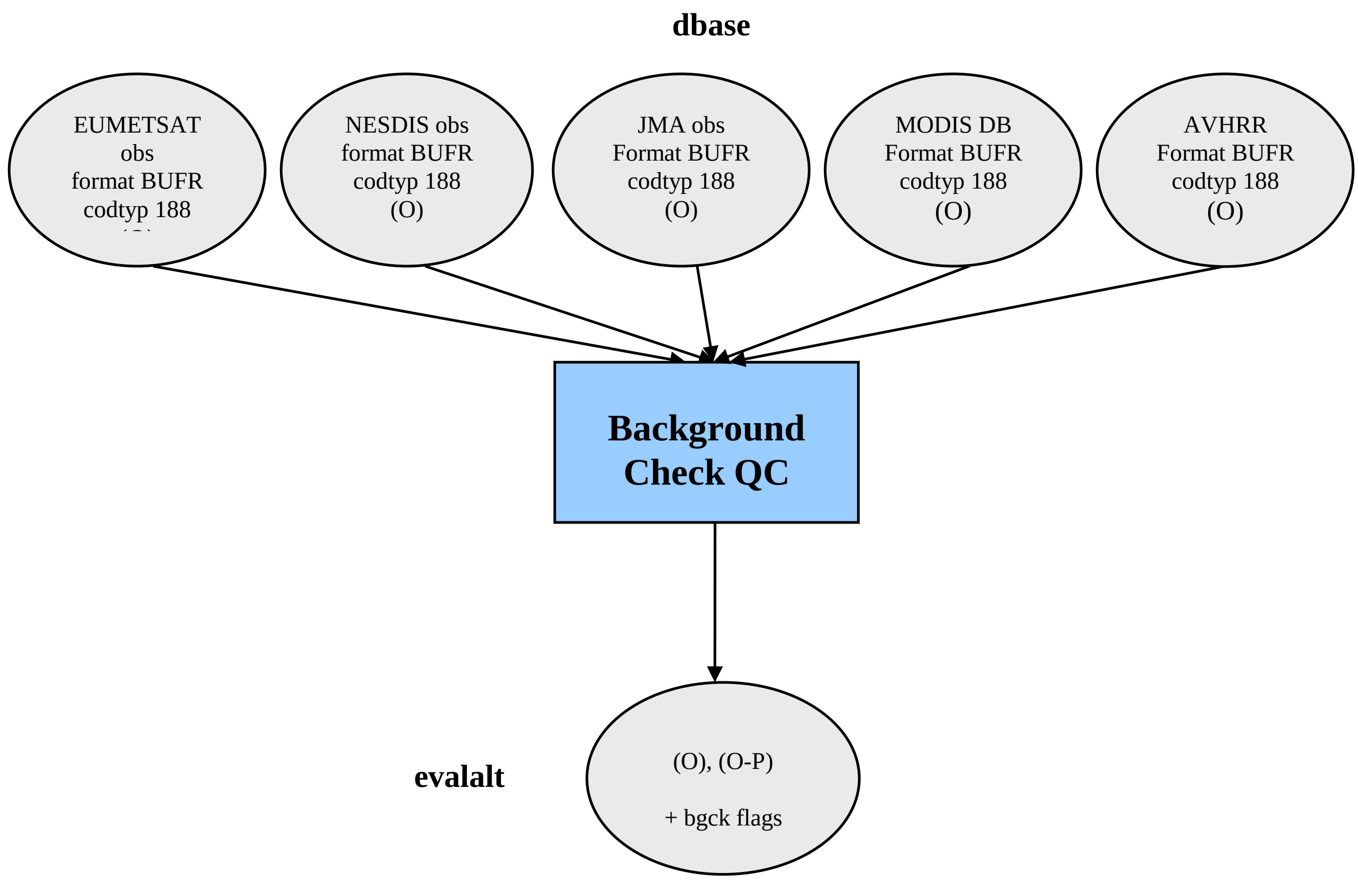

Figure 2: AMVs observations processing, evaluation and monitoring branch, last file (sw_qc file) is in evalalt/g2 directory.   These files include all decoded observations for monitoring and evaluation purposes, even the observations not included in the analysis.

3. Observations details

CMC Codtyp 188

From the evaluation process for the implementation of NPP and Himawari-8 in the parallel run, the number of observations that CMC receives is estimated to be around ~13 100 000 AMVs per day. The number of assimilated observations is around ~ 292 000 AMVs per day.

From EUMETSAT:

Bulletins: METEOSAT WVW, ELW, HWW, HRV
WMO Headers: IUCN, IUCS, IXCN, IXCS : #1-29
Satellites: METEOSAT-7 & 10

Bulletins:
WMO Headers: IEVX01 EUMC IEVX01 EUMP
Satellites: METOP-1 & 2

From NOAA/NESDIS:

GOES High density winds
WMO headers: J[A-T]CX[0-9][0-9] KNES
Satellites: GOES-13 & 15

MODIS Polar winds
WMO headers: J[I,B,L,F]CX01 KNES
Satellites: Terra and Aqua

AVHRR Polar winds
WMO headers: JCVX91 JCVX92 JCVX94 JCVX95 KNES
Satellites NOAA 15-19 and METOP2

The NPP data are not received through the GTS, but files are downloaded directly from the NESDIS FTP server.

From JMA:

MTSAT winds
WMO headers: IUCN, IUCS
Satellite: MTSAT-2

From JMA:

Himawari 8 winds
WMO headers: IXCN, IXCS
Satellite: Himawari 8

From CIMSS:

Tromso, Norway: MODIS DB, TERRA winds
Fairbanks, Alaska: MODIS DB, TERRA winds
McMurdo, Antarctica: MODIS DB, TERRA and AQUA winds
Rothera, Antarctica: AVHRR NOAA 16-19
Barrow, Alaska: AVHRR NOAA 16-19

4. Processing details

Grouped data

The thinning programs have been modified in order to handle AMV grouped data. From now and on, the **grouped data** for AMVs are being used instead of ungrouped ones in order to avoid reaching the maximum of records in a BURP file that is 262144. Before for ungrouped data the BURP file had one record for one observation, whereas now for grouped data the BURP file has one record with many observations.

First Thinning

The AMV decoder at MSC reads the BUFR files and creates dbase files in BURP format. AMV's dbase keeps observations in grouped records. BURP codtyp for satwinds data is 188. The program **deriv.thinning0_satwinds.f90** was written originally from Real Sarrazin and it is modified for reading and writing grouped observations.

Figure 3 explains the process of first thinning. Program **deriv.thinning0_satwinds.f90** is written in Fortran90 and uses the Fortran BURP_MODULE interface to access and create BURP files. More information for BURP_MODULE interface can be found here: http://iweb.cmc.ec.gc.ca/~afsdcvs/ftn90_burp/

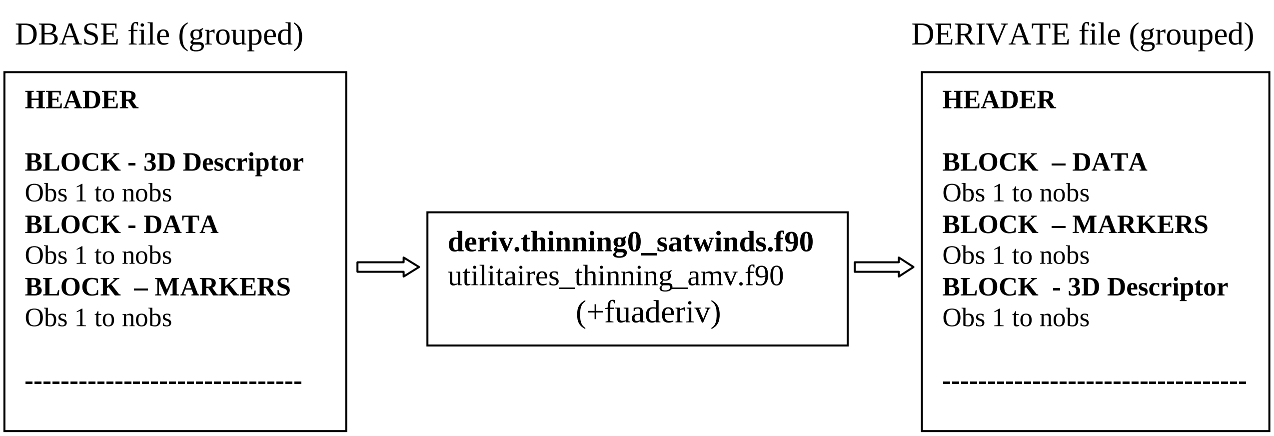

Figure 3: Transformation of AMVs (grouped) dbase file into (grouped) derivate file by program **deriv.thinning0_satwinds.f90**

To compile the program:
s.compile -src utilitaires_thinning_amv.f90 deriv.thinning0_satwinds.f90 -o deriv.thinning0_satwinds -librmn rmn -libappl burp_module

domain: . ssmuse-sh -d rpn/libs/15.2

usage : deriv.thinning0_satwinds -inburp file_in -outburp file_out -date $date -landmask mganal_alt -deltmax 180 -hourly

-inburp the input file from dbase in grouped formed
-outburp the output file or derivate file in grouped form
-date specifies the date of the dbase file in Julian format
-landmask mganal_alt
-deltmax 180 (minutes)
-hourly treating hourly data

Here is an example for date 2016030306_ in dbase for geostationary satellites and for polar satellites. For geostationary satellites file, the number of valid records is 11209 (file size of 98MB of disk space), whereas for the output file the number of records is 7350 (file size of 20MB). For the same date for polar satellites file, the number of valid records is 1787 (file size of 17MB of disk space), whereas for the output file the number of records is 937 (file size of 3MB).

The program **deriv.fuaderiv** is used to add the record domain and change the btype in burp files. The command line for program **deriv.fuaderiv** is:

deriv.fuaderiv_1.4 -ixburp file1 -oxburp file2 -date $date -run G2

The overview of the algorithm for program deriv.thinning0_satwinds.f90 is given below. Figure 6 represents a flowchart of this algorithm.

Step1 : Information gathering, QC and selection based on observation time

1) Initialization for variables and constants

2) Gather information from 3D-DESCRIPTOR and DATA blocks of the report

3) Open input file

4) Scan the input file (Scan1, Figure 6) to look for the date of the record, the number of reports and the number of maximum observations by using **pointer ref_rpt**;

6) Scanning reports (Scan 2, Figure 6) by using the pointer **ref_rpt**

7) Check satellite: Call subroutine **check_satellite**, count the number of reports and save them in **n_rep_in**

8) For grouped data, specified the elements for 3D -DESCRIPTOR and DATA blocks; if the data are not grouped then there is one observation for one report: if(.not.lgrouped) elev = 1; If the data are grouped, count the number of observations, get the values for the elements in 3D - DESCRIPTOR and DATA blocks. Add the number of observations for input file in **n_obs_in**

9) If **(sat_geostationary)** is true then call subroutine **thin_0_geostationary**, else call subroutine **thin_0_polar**

10) Save obs in **select_obs**; if observation are missing record them in **n_missing**

11) Calculate the number of observations per report for the output file
12) Open the new Burp file for output file to write later

Step 2: Create derivate file

1) Scanning reports by using the pointer ref_rpt
2) Check satellite as in Step1 -task 7
3) Create New Report parameters
4) Initialize the new report for writing
5) Write valid reports to the new BURP file (derivate file)
6) Output statistics
7) Cleanup and free memory

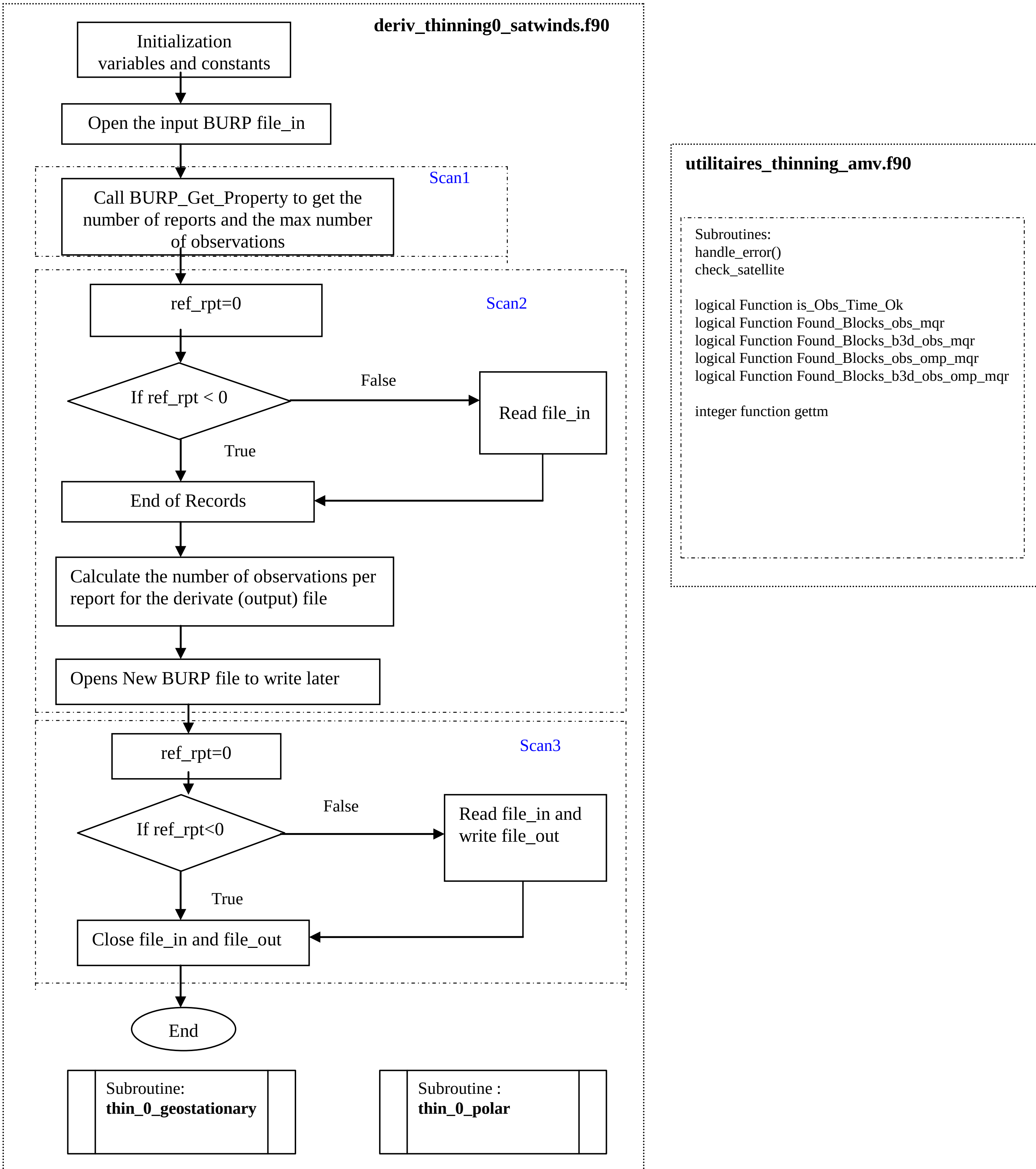

Figure 6: Flowchart of algorithm for program **deriv.thinning0_satwinds.f90**

Figure 7, 8 give examples of the statistics output by the program for AMV's respectively for geostationary and polar satellites for date 2016030306. Figure 7 shows that from a total number of 1,508,444 observations for geostationary satellites only 304,206 observations will be written in the derivate file. A large number of observations (1,204,238) are being rejected due to thinning rules. Figure 8 shows the number of observations in dbase files for polar satellites. From a total of 91069 observations, only 44015 observations will be written in the derivate file. In these examples, one can observe clearly that there are more observations provided from geostationary satellites than from polar satellites.

```
DELTMAX =          180
 on traite les donnees horaires
 temps hhmm de la date en argument :         600
 Nombre de rapport et max obs :        11209        2316


            Number of satellites reports =      10595


                  Number of obs in  =    1508444
                  Number of obs out =     304206
                Number of obs not out =    1204238

           Number of xenith angle reject =      89081
               Number of time reject =          0
              Number of method reject =      76774
             Number of pressure reject =      93581
               Number of speed reject =      3104
              Number of quality reject =     712131
             Number of landmask reject =      27639
            Number of frequency reject =     201928

            Total number of AMV rejects =    1204238


   Number of records by satellite in the input

                              nb goes w =     242836
                              nb goes e =     277284
                            nb meteosat w =     247697
                            nb meteosat e =      59230
                             nb japan sat =     681397

                              nb Terra =          0
                               nb Aqua =          0
                               nb NOAA =          0
                                nb NPP =          0
                              nb METOP =          0
```

Figure 7: Example of output statistics from program deriv.thinning0_satwinds.f90 for geostationary satellites for date 2016030306

```
DELTMAX =          180
 on traite les donnees horaires
 temps hhmm de la date en argument :          600
 Nombre de rapport et max obs :        1787        2480


                Number of satellites reports =       1213


                     Number of obs in  =      91069
                     Number of obs out =      44015
                   Number of obs not out =      47054

               Number of xenith angle reject =          0
                   Number of time reject =          0
                  Number of method reject =          0
                 Number of pressure reject =      22033
                   Number of speed reject =       1695
                  Number of quality reject =      10272
                 Number of landmask reject =      13054
                Number of frequency reject =          0

               Total number of AMV rejects =      47054


    Number of records by satellite in the input

                                  nb goes w =          0
                                  nb goes e =          0
                                nb meteosat w =          0
                                nb meteosat e =          0
                                 nb japan sat =          0

                                  nb Terra =       5899
                                   nb Aqua =      19233
                                   nb NOAA =       7210
                                    nb NPP =      14945
                           nb METOP =      43782
```

Figure 8: Example of output statistics from program deriv.thinning0_satwinds.f90 for polar satellites for date 2016030306

Here are given more details about the data selection from the First Thinning procedure.

For geostationary satellites:

An observation is removed if:

- level is: above 700 hPa for VI, below 400 hPa for WV
- wind speed: below 3.0 m/s
- satellite angle: > 55°
- quality indicator: below threshold
- land mask: over land and north of 20°N, over land south of 20°N and below 400 hPa
    - (25°N instead of 20°N for METEOSAT data)
- for METEOSAT-9, canal 6 & 12 data is removed, even hours data is removed
- WV in clear-air

For EUMETSAT and JMA data, a quality indicator (QI) value of 0.85 is used as threshold.

For NESDIS data, the recursive filter flag (RFF) is used as threshold as follow:

	< 400 hPa	**401-700 hPa**	**> 700 hPa**
extra-tropics	0.65	0.70	0.75
Tropics	0.70	0.75	0.80

For the MODIS and AVHRR polar winds:

An observation is removed if:

- level is: below 700 hPa for IR, below 550 hPa for WV
- wind speed: below 3.0 m/s
- quality indicator: below threshold (RFF of 0.6)
- land mask: over land and below 400 hPa

Himawari-8

AMV MTSAT-2 is replaced by Himawari-8. In order to maintain an equivalent volume of data comparable with MTSAT-2, the data of Himarwari-8 that are taken into account are from IR, VIS and only one channel from WV having the quality index QI larger than 97.

Background Check

The objective of the background check is to identify observations with gross errors. It is a comparison between the observed elements and the same elements from the analysis first guess (6-hour forecast) interpolated at the observation location. In the background quality check, the background departure is considered suspect when it exceeds its expected variance by more than predefined multiples.

Final Thinning

Any wind observation rejected by the background check is removed. In addition for the geostationary satellites, the wind observation is removed if the vector difference between O and P is greater than 7.5 m/s above 400 hPa, 6.0 m/s between 700 and 400 hPa and 4.0 m/s below 700 hPa.

A spatial thinning of AMV data noted as **Final thinning** in Figure1 is done before their assimilation into the 4DEnVar analysis systems. The final thinning is carried out after the background check. In the spatial thinning, only one observation is kept by pressure layer and by 1.5° X 1.5° horizontal boxes for stationary satellites and 180 km boxes for the polar winds. The pressure layers are centred on the following pressures: 1000, 925, 850, 700, 500, 400, 300, 250, 200, 150 and 100 hPa. The priority is given to: first observations closest to the analysis time, secondly observations with the maximum QI value. For the 4DEnVar, the spatial thinning is done for each time step of the background fields in the 6-hour assimilation period, currently the time-bins are 15 minutes. A few details about the model used in the Global Deterministic Prediction System and the assimilation method are given in Appendix D. The program **bgck.thinning1_satwinds.f90** was written originally from Réal Sarrazin and it is modified for reading and writing grouped observations. Figure 9 explains the process of final thinning. Program **bgck.thinning1_satwinds.f90** is written in Fortran90 and uses the Fortran BURP_MODULE interface to access and create BURP files. For more information for BURP_MODULE interface can be found here: http://iweb.cmc.ec.gc.ca/~afsdcvs/ftn90_burp/

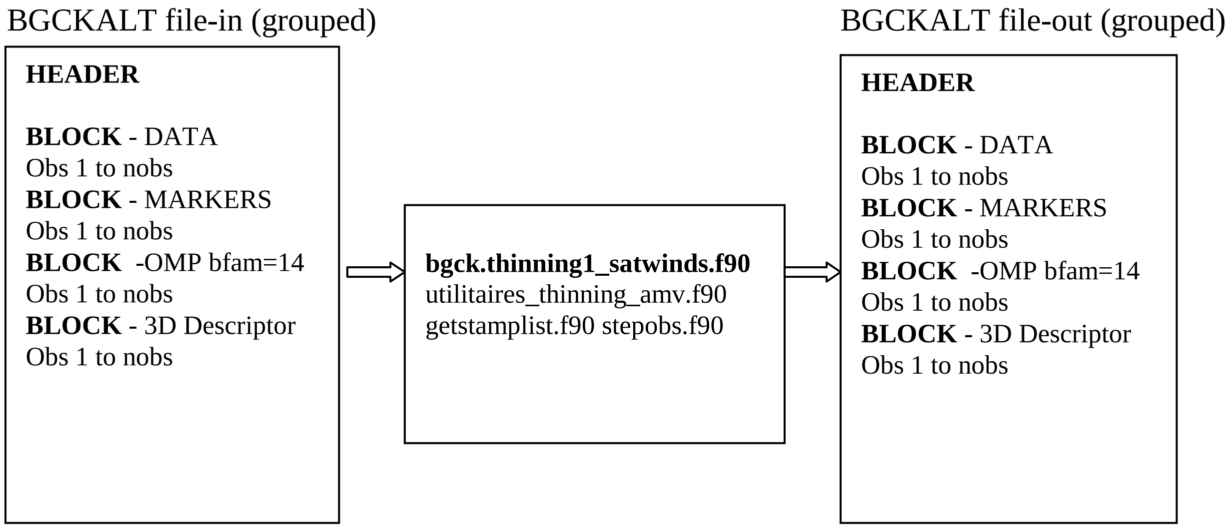

Figure 9: Transformation of AMVs bgckalt file-in (grouped) into bgckalt file-out (grouped) by program bgck.thinning1_satwinds.f90

To compile the program:

s.compile -src utilitaires_thinning_amv.f90 getstamplist.f90 stepobs.f90 bgck.thinning1_satwinds.f90 -o deriv.thinning0_satwinds -librmn rmn -libappl burp_module

domain: . ssmuse-sh -d rpn/libs/15.2

usage : bgck.thinning1_satwinds -inburp file_in -step 0.25 -deltmax 180 -deltax1 75 -deltax2 180 -outburp file_out

-inburp burp observation file-in
-step 0.25 specifies the stepobs in hours
-deltmax 180 is the time window per bin
-deltax1 75 2X75=150 1.5 deg; indicates the resolution for geostationary satellites
-deltax2 180 (km), indicates the resolution used for polar satellites
-outburp burp file of selected observations

Here is an overview of algorithm of **bgck.thinning1_satwinds.f90**. Figure 10 represents a flowchart of this algorithm.

Step 1: Information gathering, QC and selection based on observation time

1) Initialization for variables and constants

2) Gather information from 3D-DESCRIPTOR, DATA and OMP (bfam=14) blocks of the report

3) Open input file

4) Scan the input file (Scan1, Figure 10); loop for the number of reports **nb_rpts** to get the information for date, time and number of reports from the header that has (stnid_l = =>BGCKALT"); **nb_obs_max** is a temporary variable that records the number of maximal observations. **nb_obs_in(k) = elev** is one -dimensional matrix that records the number of observations for each report.

5) Allocate memory for **keep_obs** (nb_rpts*nb_obs_max) **array**, that is initialized with logic values as false. This array keeps a true value for the observations that are being written in the output .

6) Loop on both geostationary and polar satellites; Find latitude bands of boxes grid

7) Scanning (Scan2, Figure 10) reports by using the pointer ref_rpt; The number of reports is counted before the subroutine **check satellite**, n_rep_in = n_rep_in + 1 ;

8) For grouped data, specify the elements for 3D-DESCRIPTOR, DATA, OMP and MARKERS blocks; if the data are not grouped then there is one observations for one record: if(.not.lgrouped) elev = 1; If the data are grouped, count the number of observations, get the values for the elements in 3D –DESCRIPTOR, DATA, OMP and MARKERS blocks . Array **obs_pos** = n_rep_in*nb_obs_max + jt, defines the position of a specific observation in **keep_obs** array.

9) If **(sat_geostationary)** is true then call **thin_1_geostationary**, else call subroutine **thin_1_polar**

10) Count missing observations in **n_missing**

11) Calculate the number of observations per report for the output file:

n_obs_out - variable representing the total number of observations to be written out

n_obs_in - total number of observations read from the input file

nb_obs_out - array - number of observation to be written out for each report

obs_pos - calculate the position of each observation in **keep_obs** array

if(keep_obs(obs_pos)) – if value is true then observation is counted to be written in the output file

tthcount - total number of observations not to be written in the output file

12) Open the new BURP file for output file to write later

Step 2: Create output file

1) Scanning (Scan3, Figure 10) reports by using the pointer **ref_rpt**

2) Check satellite as in Step1 1-task 7,

3) Create New Report parameters

4) Initialize the new report for writing

5) Write valid reports to the new BURP file

6) Output statistics

7) Cleanup and free memory

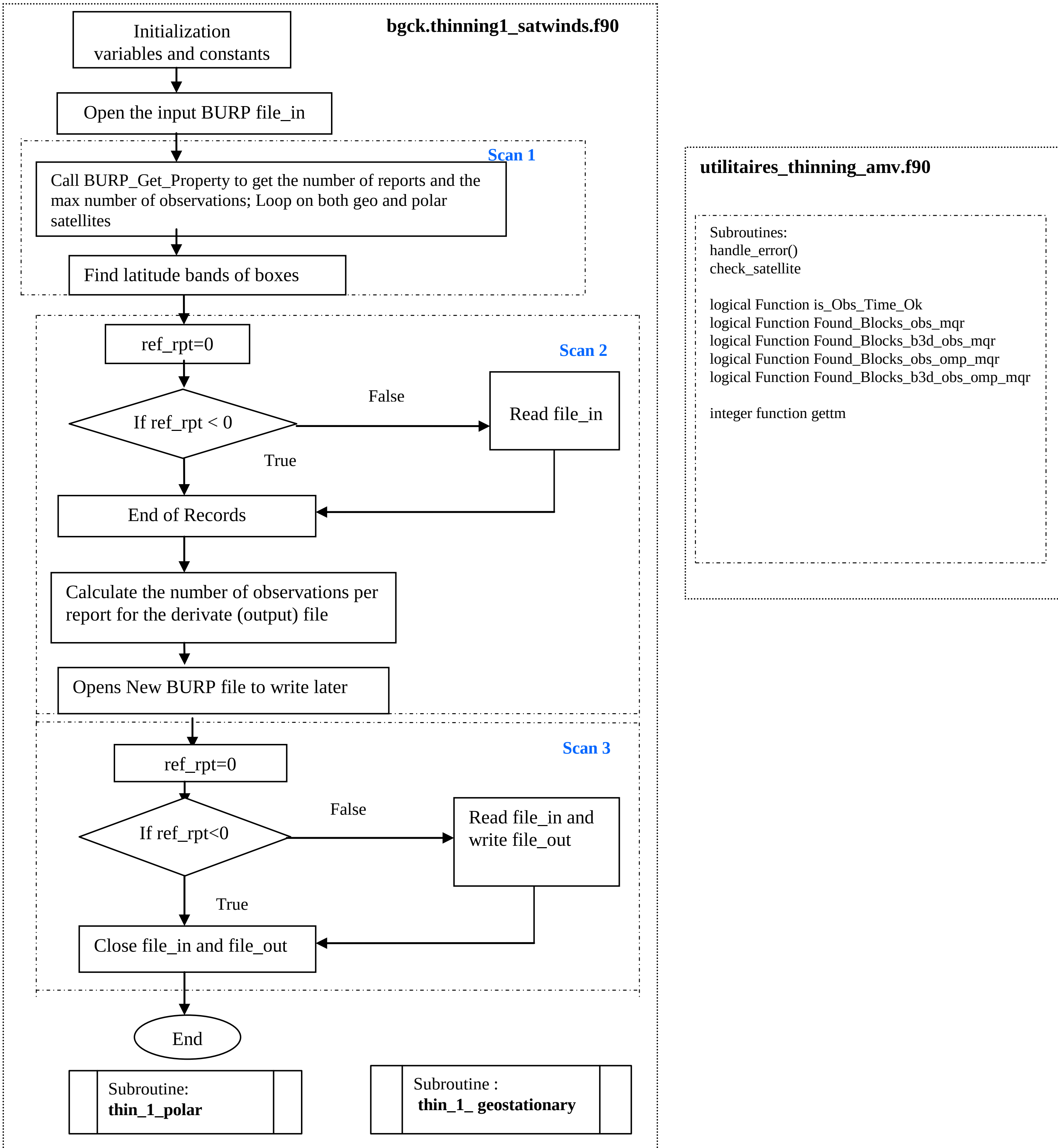

Figure 10: Flowchart of algorithm for program bgck.thinning1_satwinds.f90

Figure 11 gives an example of the statistics output from the program **bgck.thinning1_satwinds.f90** for date 2015010100 for both geostationary and polar satellites. From a total of 214679 observations only 43863 observations will be assimilated.

```
STEP =   0.250000000000000       hours
 DELTMAX =          180
 deltax1 =    1.500000     deg
 deltax2 =          180 km
        Date et temps du resume :      20150101          0
      Nombre de rapport et max obs :          4569         755

       Processing geostationary data


          Processing polar data

              number of input observations     214679

                    nb goes w =      51147
                    nb goes e =     49304
                  nb meteosat w =     35388
                  nb meteosat e =      7201
                   nb japan sat =     49160

                    nb Terra =       3524
                     nb Aqua =       4402
                     nb NOAA =        209
                      nb NPP =          0
                    nb METOP =      14344

              Number satellites reports =       4569
                 Number of obs in  =     214679
                 Number of obs out =      43863
  Number of reject outside time window, BGCK and thinning          0     19145    151671
                Total number of reject =     170816

              number of observations kept      43863

                    nb goes w =       9722
                    nb goes e =       8506
                  nb meteosat w =       9341
                  nb meteosat e =       3039
                   nb japan sat =       8157

                    nb Terra =        780
                     nb Aqua =        599
                     nb NOAA =        118
                      nb NPP =          0
                    nb METOP =       3601
```

Figure 11: Example of output statistics from program **bgck.thinning1_satwinds.f90**

The main change between the **First thinning** and the **Final thinning** lies on the thinning rules. The **First thinning** selects the observation depending on the criteria for derivation method, pressure, speed, angle, quality indices, land mask and frequency. All those criteria are found in the subroutines: **thin_0_polar** and **thin_0_geostationary**. The **Final thinning** does a spatial thinning of AMV data according to criteria specified in subroutines: **thin_1_polar** and **thin_1_geostationary**. In the subroutine thin_1_geostationary the criteria for not keeping any observation in two touching boxes of half resolution is applied.

Variational QC

This is the last stage of the quality control, it is done at the same time than the variational analysis. Each observation is given an a-priori probability of gross error (PGE) base on the characteristics and past statistics of that type of observation. Then, at each iteration of the analysis process, an a-posteriori PGE is given to the observation based on the departure with the preliminary analysis for that iteration. The observation cost function is modified by a factor based on the PGE. An observation with an high PGE is given a weight of near zero in the analysis. Observation with a PGE > 0.75 are flagged as rejected in the observation file.

An asymmetric test for the quality control of satellite winds is included in the variational quality control. The test essentially holds some satellite wind reports, those with wind speeds less than the background wind speed, to a higher standard of quality. The rationale is to compensate for the well-known wind speed bias due to the averaging in space and time inherent in the atmospheric motion vectors generated by tracking features with satellites. The variational quality control method is made asymmetric by altering the specification of the prior probability of gross error, A, as follows:

$$A_{new} = k\,A_{old} \qquad \text{for } \nu_o < \nu_b$$
$$A_{new} = A_{old} \qquad \text{for } \nu_o \geq \nu_b$$

where ν_o is the observed wind speed (m/s), ν_b is the wind speed of the background at the location of the observation, and k, chosen empirically, is $0.7\nu_b$. Choosing k to be proportional to ν_b ensures that the variational quality control will be more stringent where the wind speeds are higher, i.e. near jets, where a biased wind speed report can do the most harm. Since the higher wind speed regions are our main concern, the application of the asymmetric test is limited to the extratropical upper troposphere.

Appendix A: QI thresholds and Observation errors

QI thresholds

			extratropics			tropics		
			HL	ML	LL	HL	ML	LL
Meteosat-7/9	QI1	ALL	85	85	85	85	85	85
GOES-11/13	RFF	ALL	65	70	75	70	75	80
Terra and Aqua	RFF	ALL	60	60	-	-	-	-
Himawari-8	QI1	ALL	98	98	98	98	98	98

tropics: 20S-20N
extratropics: polewards of 20S/N

hl: 10-400 hPa
ml: 400-700 hPa
ll: 700-1000 hPa

QI1 - EUMETSAT QI with first guess check
QI2 - EUMETSAT QI without first guess check
RFF - Recursive Filter Function (CIMSS/NESDIS)

For information on how the quality indicators are formulated see Holmlund (1998, *Weather Forecasting* **13** 1093-1104) and Hayden and Purser (1995, *Journal of Applied Meteorology* **34** 3-15).

Observation errors

Observation errors are currently standard for all satellites, all wind types:

	Level (hPa)	1000	850	700	500	400	300	250	200	150	100
Error (m/s)	All	2.5	2.5	3.0	4.0	4.5	5.0	5.5	5.5	5.5	6.0

Appendix B: Satellite derived wind computation method

The different channels are defined by element 002023 from WMO BUFR table

0'02'023 - Satellite derived wind computation method
C 002023
0 Reserved
1 Wind derived from cloud motion observed in the infrared channel
2 Wind derived from cloud motion observed in the visible channel
3 Wind derived from cloud motion observed in the water vapour channel
4 Wind derived from motion observed in a combination of spectral channels
5 Wind derived from motion observed in the water vapour channel in clear air
6 Wind derived from motion observed in the ozone channel
7 Wind derived from motion observed in water vapour channel (cloud or clear air not specified)
13 Root-mean-square
15 Missing value
8-12, 14 Reserved

Appendix C: List of AMV types currently assimilated at CMC

- Meteosat-10 IR, VIS 0.8, WV 6.2
- Meteosat-7 IR, VIS, WV
- GOES-15 IR 3.9 IR 10.7, VIS, WV
- GOES-13 IR 3.9 IR 10.7, VIS, WV
- NESDIS MODIS Terra IR, WV
- NESDIS MODIS Aqua IR, WV
- direct broadcast MODIS from Tromso, Fairbanks and McMurdo
- AVHRR NOAA-15/18/19 IR, WV
- EUMETSAT Metop-A IR
- EUMETSAT Metop-B IR
- NPP IR, VIS
- Himawari-8 IR, VIS, WV 6.9

Appendix D: Information about current CMC Global model and the assimilation method

CMC Global model physical characteristics

- Grid-point model 2x1287x417 Yin-Yang horizontal grid
- Horizontal resolution: ~25 km
- Vertical resolution: 80 levels

Data assimilation method

- 4DEnVar, 6-h data assimilation window, 4DIAU, 0.45° x 0.45° increment resolution
- Time window: T ± 3 hr, analysis times (T): 00, 06, 12, 18 Z
- Time constraints (model runtime):
    - Early analysis and forecast run: T+3 hr, forecast at 00 and 12Z only.
    - Update analysis run: ~T+9 hr at 00 and 12Z, T+6 hr at 06 and 18Z.
    - 25 slots in the 6-h window.