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Processing of SSMIS Radiances at the Canadian Meteorological Centre

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Revision history			
Version	Date	Author/modifications	Remarks
1.0	2007/12/06	S. Macpherson	First version
1.1	2008/04/08	S. Macpherson	Minor modifications and additions
1.2	2008/07/25	S. Macpherson	Edits for new UPP v.2 data from NESDIS
1.3	2009/03/04	S. Macpherson	Few corrections to part 2.
1.4	2010/06/22	S. Macpherson	Updated.
1.5	2010/10/04	S. Macpherson	Updates and added Appendix A. Updated flow chart (Figure 1).
1.6	2010/10/25	S. Macpherson	Added Appendix B (Data remapping and averaging). Some minor additions and modifications.
1.7	2010/12/07	S. Macpherson	Updated section on UK Met Office UPP averaging code (for recent code modifications).
1.8	2011/01/26	S. Macpherson	Few minor edits. Added info on QC flag bits set by programs.
1.9	2011/04/07	S. Macpherson	A few updates, mostly related to UPP averaging and asc/desc bias.
2.0	2011/04/18	S. Macpherson	Fixed error in Table 3 (TOPO height limit for ch. 4)
2.1	2013/04/16	S. Macpherson	Modifications related to new OPS assmilation of data from satellites F17, F18. Updated processing flow chart (Figure 1) and weighting chart (Figure 2). Modified Table 3. Removed references to GEM-STRATO and old GEM (58 level).

1. *Introduction*

In this document a detailed description of the processing of SSMIS radiances prior to assimilation is given. These steps include averaging, quality control, calculation of the innovation, application of the bias corrections, the background check, and data thinning.

The SSMIS instrument onboard U.S. Department of Defense DMSP satellites F16, F17, and F18 has 24 microwave channels. Seven channels are similar to the 7 SSM/I instrument imager channels onboard DMSP satellites F13, F14, and F15. Measurements from these channels are sensitive to surface characteristics (e.g., skin temperature, emissivity, ice/snow cover), cloud, precipitation and integrated water vapour. Radiance data for these channels are only assimilated over open water, where the surface emissivity (and its variability with surface wind speed) is well known.

The remaining 17 channels are sounding channels similar to those of the NOAA AMSU-A and AMSU-B/MHS instruments. Data from these channels provide temperature and humidity information from the lower troposphere to the upper mesosphere (80 km).

A more detailed description of the SSMIS channels is given in Section 2. The processing of SSMIS radiances for the 7 SSM/I-like imager channels is based on that done for SSM/I (as described in the document *Processing of SSM/I Radiances at the Canadian Meteorological Centre*), while processing of the sounding channels is based on that done for AMSU-A and AMSU-B/MHS (as described in *Processing of ATOVS radiances at the Canadian Meteorological Centre*).

A flowchart on the following page (Figure 1) provides an overview of the SSMIS data processing as described in Sections 3 to 7. Program details (such as source code locations and input arguments) are found in Appendix A. Details on SSMIS data remapping and averaging are found in Appendix B.

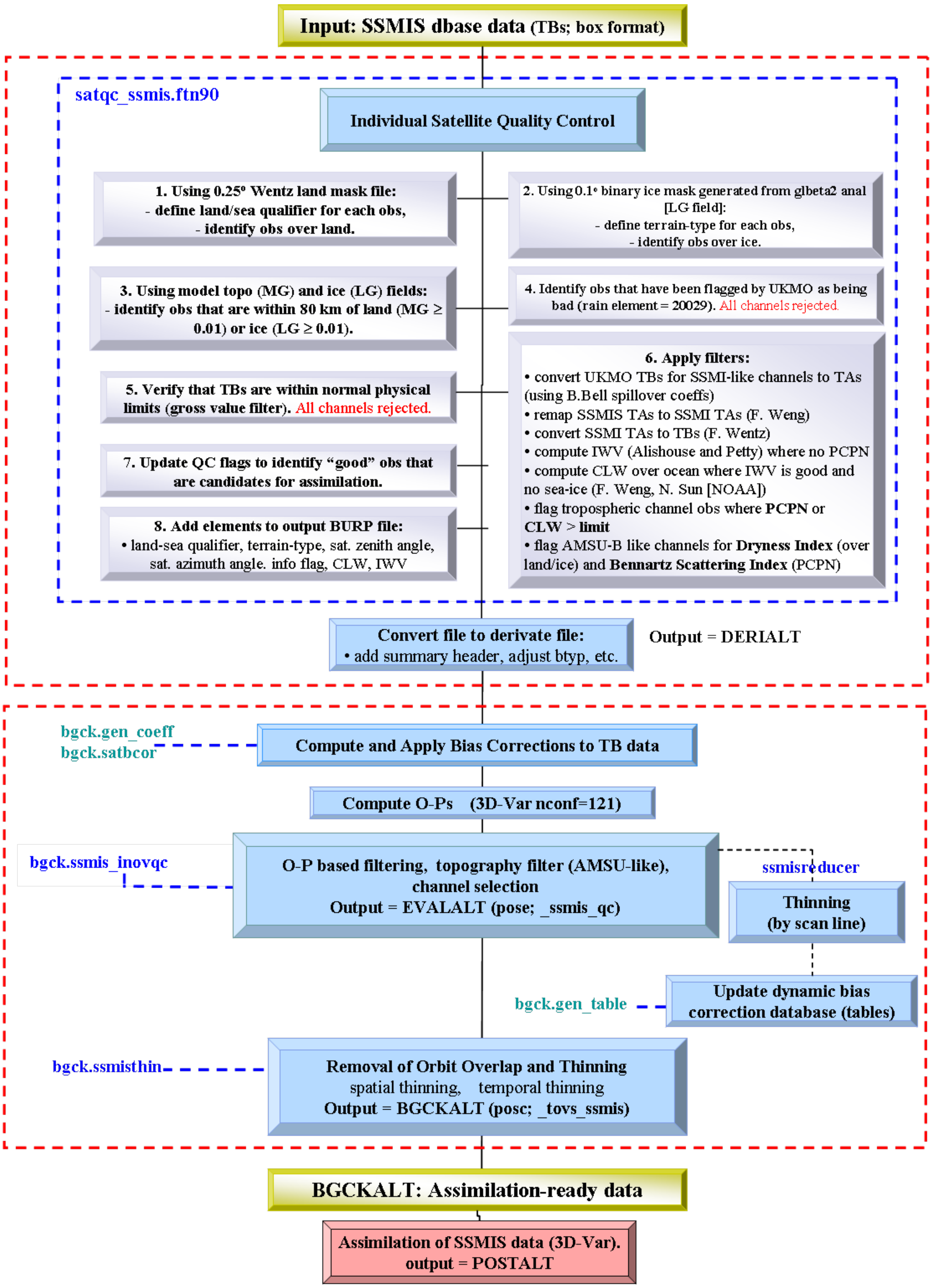

Figure 1. Flow chart of SSMIS data processing.

2. *SSMIS Brightness Temperatures (TB)*

The SSMIS (Special Sensor Microwave Imager Sounder) is a conically-scanning microwave radiometer onboard U.S. Defense Meteorological Satellite Program (DMSP) satellites beginning with DMSP satellite F16 launched in October 2003. The SSMIS data are received at the CMC in BUFR format from NOAA/NESDIS who receive the files from the Naval Research Laboratory (NRL) in Monterey, CA. The BUFR data include "orbit format" brightness temperatures (TB) for 24 microwave channels with frequencies of 19 to 183 GHz. These data have been preprocessed by NRL with the SSMIS **Unified Preprocessing Package** (UPP) developed by the UK Met Office and NRL.

The **preprocessing** (starting with UPP version 2) includes:

1. conversion of antenna temperatures (TA) to brightness temperatures (TB);
2. correcting data affected by solar intrusions into the warm load calibration target;
3. correcting TB for thermal emissions from the instrument's reflector;
4. flagging data (with a "rain flag") that fail preliminary quality control (includes some precipitation-affected data);
5. remapping data from all channels to the 60 scan positions of the Lower Atmospheric Sounding (LAS) channels (1-7,24) (see Appendix B);
6. (until August 2009) spatial averaging of data to reduce noise characteristics (primarily in LAS channels); since August 2009, averaging is applied by the end-user with a stand-alone program provided by the UK Met Office (see item (a) in Appendix A and also Appendix B).

Items 2 and 3 are necessary to correct data contaminated by the specified instrument design flaws for satellites F16 and F17. These design flaws were largely corrected starting with satellite F18. However, radiance data from F18 (primarily data from the temperature sounding channels) are affected by significant warm and cold bias errors that vary with ascending/descending mode, latitude and season. These bias errors are related to radiation emitted from black Teflon tape that is heated by the sun. The bias errors should be corrected in a future version of the UPP. Until then, the CMC satellite radiance bias correction system must be used to correct the data.

Beginning with UPP version 2, most "rain flagged" data points are points affected by moderate to heavy precipitation. In UPP version 1, the rain flag was also used to flag data affected by solar intrusions and reflector emissions, which were not corrected in this version.

The UK Met Office SSMIS UPP data averaging program is applied to the SSMIS BUFR files received from NESDIS to reduce noise levels in the temperature sounding channel radiance data. The BUFR "orbit" format data are then converted to the local "box" BURP format where the TB observations are grouped into 5° by 5° latitude boxes (with the `regrup` program), with each BURP file record containing data for one box. (Information on the BURP format can be found in the CMC internal document "*Description_en_BURP.pdf*"). The ascending/descending qualifier (BURP element 008075) is also computed at this stage, using the variation of latitude with time as found in the raw BUFR files.

The SSMIS microwave channels are listed in Table 1. Remapped data are available at the resolution of the LAS channels 1-7 (37.5 km) (see Appendix B). For surface-sensitive channels, only data over open water are assimilated due to the high complexity of modeling emissivity over land and ice surfaces. Also, because clouds and precipitation are not defined for the forward model, data in cloudy and precipitating conditions are rejected for all imager channels and for the tropospheric sounding channels. Note that the polarity of channels 1-5 for satellite F16 is V as opposed to the actual design specification (H) found on the other satellites.

LAS channels are highlighted in yellow in Table 1. Upper atmospheric temperature sounding (UAS) channels are highlighted in blue. AMSU-B/MHS like humidity sounding channels are highlighted in green, while SSM/I like imaging channels are highlighted in pink-purple.

Weighting (transmittance) functions for the LAS and UAS channels are shown in Figure 2. The height of maximum weight for a channel indicates the level of peak sensitivity for that channel.

Table 1. SSMIS Channel Description

Channel	Frequency (GHz) / Polarization	1st IF (MHz)	2nd IF (MHz)	Equivalent AMSU or SSMI Channel	SFC	CLD / PCPN
1	50.300 H [2]	0	0	AMSU-A 3	X	X
2	52.800 H [2]	0	0	AMSU-A 4	X	X
3	53.596 H [2]	0	0	AMSU-A 5	X	X
4	54.400 H [2]	0	0	AMSU-A 6	X[1]	X
5	55.500 H [2]	0	0	AMSU-A 8		
6	57.290 RC	0	0	AMSU-A 9		
7	59.400 RC	0	0	AMSU-A 10		
8	150.000 H	1250.	0	AMSU-B 2	X	X
9	183.310 H	6600.	0	AMSU-B 5	X	X
10	183.310 H	3000.	0	AMSU-B 4		X
11	183.310 H	1000.	0	AMSU-B 3		X
12	19.350 H	0	0	**SSM/I 2**	X	X
13	19.350 V	0	0	**SSM/I 1**	X	X
14	22.235 V	0	0	**SSM/I 3**	X	X
15	37.000 H	0	0	**SSM/I 5**	X	X
16	37.000 V	0	0	**SSM/I 4**	X	X
17	91.655 V	900.	0	**SSM/I 6** AMSU-A 15	X	X
18	91.655 H	900.	0	**SSM/I 7** AMSU-B 1	X	X
19	63.283248 RC	285.27	0			
20	60.792668 RC	357.89	0			
21	60.792668 RC	357.89	2.0			
22	60.792668 RC	357.89	5.5	AMSU-A 14		
23	60.792668 RC	357.89	16.0	AMSU-A 13		
24	60.792668 RC	357.89	50.0	AMSU-A 11, 12		

- Channels sensitive to the surface and to clouds/precipitation are indicated by an X in columns “SFC” and “CLD/PCPN” respectively. SFC channels are assimilated over open water only. Cloud/precipitation detection algorithms are used to filter CLD/PCPN channels.
- Channels 19 to 22 have weighting functions peaking in the upper stratosphere and mesosphere, so data from these channels are affected by oxygen (O_2) splitting from earth’s magnetic field (the Zeeman Effect), which is not modeled well in some forward models (i.e., radiative transfer models such as RTTOV).
- Equivalent AMSU-A, AMSU-B/MHS, or SSM/I channels for SSMIS channels 1-18 have the same or similar frequencies. Equivalent for UAS channels 19-24 means similar heights for maximum sensitivity (weighting function peaks).

[1] Channel sensitivity to the surface is very small, so there is an option in **satqc_ssmis.ftn90** (Section 3) to assimilate this channel over both land and open water.

[2] Measured polarity on satellite F16 is actually **V** (by mistake)

3. *Satellite Quality Control – satqc_ssmis.ftn90*

The first stage of SSMIS data quality control (QC) includes the removal of bad brightness temperature (TB) data, data flagged by the UPP as unusable (Section 2), removal of observations over land/ice and in clouds/precipitation for selected channels, plus other data filtering as described below. In this section, words like "removal", "rejection" and "filtering" mean setting data QC flag **bit 7** in the output BURP file so the data will not be selected for assimilation (e.g. by assimilation system background check program *bgck.ssmis_inovqc* [section 6]). The primary filters are described below.

3.1. Removal of data flagged by UKMO ("rain" flag)

Data for all channels are rejected for points where the UKMO rain flag is "on". The rain flag (element 20029 in the data BURP file) indicates observation points that have been flagged in preprocessing item 4 listed in Section 2.

3.2. Removal of bad data

All TB data are checked for gross errors using the expected range of TB. If a bad TB is detected for any channel at a particular location, data from all channels are rejected for that location.

3.3. Removal of observations over land (surface sensitive channels only: 1-3, 8-9, 12-18)

Observations are interpolated to a 0.25° resolution land-mask to identify and remove those points that are over land. This land-mask (the Wentz land-mask) is also used to define the land/sea qualifier for each observation point (element 008012), which is required by the 3D-Var assimilation scheme.

3.4. Removal of observations over sea-ice/ice (surface sensitive channels only: 1-3, 8-9, 12-18)

Similar to the last step, the remaining observations are interpolated to a 0.1° resolution binary ice-mask to remove those points that are over sea-ice/ice. This global ice field is derived from a 0.3° resolution ice-mask generated daily by the operational G6 final global surface run executed at 00 UTC. The G600 run uses SSM/I observations together with other Canadian Ice Service data to create the ice-mask (appears as LG field in RPN standard files archived at *operation.analyses.glbsfc6*). The 0.1° binary ice-mask is also used to define the terrain-type for each observation point (element 013039), which is required by the 3D-Var assimilation scheme.

3.5. Sea-ice/ice/land consistency check (surface sensitive channels only: 1-3, 8-9, 12-18)

In this step a check is performed to verify that the observation points retained to this point remain only over open-ocean areas with respect to the land- and ice- masks used by the global model. The static model land-mask (MG field) and the daily updated model ice-masks (LG field) are extracted from the *operation.analyses.glbeta2* standard files. The objective of this check is to ensure that none of the observation points that remain are within a sufficiently small distance from land or ice to be contaminated. To do so, an artificial grid of dimensions 5 grid points by 5 grid points, and with a grid spacing of 40 km is centred over each observation. All of the grid points within this box are then interpolated to the model land- and ice-masks. If the largest interpolated MG value indicates greater than or equal to 1% of land, or the largest interpolated LG value indicates greater than or equal to 1% of ice, then the observation is removed. The dimensions of the box ensure that no observation is within 80 km of ice or land after this filter is applied.

3.6. Compute Integrated Water Vapour (IWV) (over open water only)

Brightness temperatures (TB) from the SSM/I-like channels are used to compute IWV and cloud liquid water path (CLWP) (see section 3.7). The code that does this was designed for TB data from the SSM/I instrument, so SSMIS TB data must first be converted to equivalent SSM/I TB values by the following 3-step process:

(a) SSMIS TB are converted back to the original antenna temperatures (TA) by reverse application of the UPP spillover coefficients used to get TB from TA
(b) SSMIS TA are remapped to SSM/I TA (with code developed by Ninghai Sun and Banghua Yan from NOAA/NESDIS)
(c) SSM/I TA are converted to SSM/I TB (with a routine developed by G. Deblonde (MRD/ARMA), based on original code by F. Wentz)

Then, using a regression technique (Alishouse et al. 1990; Petty 1990; Colton and Poe, 1994) developed for SSM/I data, IWV is computed from the SSM/I TB. For those observations flagged by the precipitation screen (Alishouse et al. 1990), the IWV values are set to missing. Observations with an IWV value outside the range 0 kg m^{-2} to 80 kg m^{-2} are removed. The IWV data are added to the information (INFO) blocks in the SSMIS data file as new element 013208. Note that different options for computing IWV and converting TA to TB can be selected via the **ALG_OPTN** argument to the program – see Appendix A for details. The above description applies when "–ALG_OPTN fwentz" (the default value) is used.

3.7. Compute Cloud Liquid Water Path (CLWP) and remove "cloudy points" (over open water only, AMSU-A-like channels 1-4 , SSM/I-like channels 12-18)

Where IWV is not missing, CLWP is calculated from the remapped/converted SSM/I-like channel brightness temperatures obtained in step 3.6 using a regression algorithm by F. Weng (Weng and Grody, 1994) and coded by Ninghai Sun (NOAA/NESDIS). For SSM/I-like channels (12-18), observations with a CLWP value greater than 0.02 kg m^{-2} are removed. For AMSU-A-like channels, a limit of 0.10 kg m^{-2} is applied for channel 1, and 0.30 kg m^{-2} for channels 2-4. Cloud filtering for AMSU-B like channels 8-11 is done later using the innovations (O−P) for channel 8 (Section 6). The CLWP data are added to the information (INFO) blocks in the SSMIS data file as new element 013209.

3.8. Filter AMSU-B-like channel data as done for ATOVS AMSU-B/MHS (SSMIS channels 8-11)

The algorithm for scattering index developed by Bennartz et al. (1999) is used to detect and remove precipitation affected TB data for channels 8 to 11. The Bennartz Scattering Index (BSI) is computed from channels 8 and 18 brightness temperatures. BSI values of 40, 15, and 0 are applied as limits (maximum values) over sea-ice, sea, and land respectively to filter channels 8-11. In addition, TB data for channels 9-11 are filtered in very dry conditions over land (mostly in polar regions) as there is a significant surface contribution in such cases. The difference between the observed TB of channels 11 and 9 is used as a dryness index, and limits (maximum values) of -20K, -10K and 0K are applied for filtering channels 9, 10 and 11 respectively. Note that no attempt is made to account for differences between the SSMIS and AMSU-B instruments when computing these indices or applying the limits. In other words, the same algorithms and limits used for AMSU-B are applied here, substituting unmodified SSMIS channel 8, 9, 11 and 18 TB for AMSU-B channel 2, 5, 3 and 1 TB respectively. However, the quantity and locations of the rejected data from this filter appear reasonable. (Note that the Alishouse precipitation screen [Section 3.6] is only available over open water, and cannot be used to filter AMSU-B like channels over land.)

For the filters described in sections 3.6 to 3.8, various quantities and indices (e.g. IWV, CLWP, BSI) are computed from the TB data. As described in Section 5, TB data have biases with respect to the model background state. These “global” biases are found to vary with scan position as well as channel. The variation of the global biases with scan position must be removed before quantities such as CLWP and BSI are computed from the TB data. Otherwise, the amount of data filtered will depend on scan position. This is especially true for CLWP filtering of SSM/I-like channels, where the CLWP threshold is very low (0.02 kg $m^{-2)}$. In this case, the number of TB observations filtered for extreme scan position 60 is about half the number filtered for central scan position 30 when the variation of the global biases with scan position is not removed. The variation of global bias with scan position will be referred to as the “scan position bias” (SPB).

Scan position biases (SPB) are removed from the TB data by using information contained in the SSMIS bias correction coefficient file (see Section 5). This file contains the global biases (mean O−P) for each channel as a function of scan position, called the “global scan position bias” (GSPB). It is assumed that the SPB for the central scan position (30) is zero. For the remaining scan positions, the difference in GSPB from the scan position 30 GSPB defines the SPB. The SPB are than applied to the TB data to remove the variability of the biases with scan position. Note that these corrections are applied internally for filtering steps 3.6 to 3.8. The actual TB data in the output file remain uncorrected. Complete bias corrections to the TB data are applied later on (Section 5).

$SPB_{sp} = GSPB_{sp} - GSPB_{30}$ for scan position (*sp*) = 1 to 60

$TB_{sp}^{¿} = TB_{sp} - SPB_{sp}$ where $TB_{sp}^{¿}$ is the TB adjusted for scan position *sp*

Note that removal of scan position bias is optional and is controlled via the **SPADJUST** and **IRBC** arguments to the program (see Appendix A).

Finally, an **information integer** (info flag) is added to all INFO blocks in the SSMIS data file as new element 002183. Different bits are set ON in the info flag at various steps in the QC/filtering for monitoring the performance of the various filters. Table 2 gives the meaning for each ON (set) bit in the info flag integer. See the sections listed in the table for details. Note that the info flag is added for information purposes only. It is not used by other processing programs or in the data assimilation system.

Table 2. Meaning of set (ON) bits in the information (info) flag integer (element 002183).

Bit	Meaning	Section
0	Open water point (not over or near land or sea-ice)	3.3−3.5
1	CLWP > limit used to filter SSM/I-like channels 12-18	3.7
2	CLWP > limit used to filter channel 1 (like AMSU-A ch. 3)	3.7
3	CLWP > limit used to filter channels 2-4 (like AMSU-A ch. 4-6)	3.7
4	Precipitation detected from IWV routine	3.6
5	IWV outside normal range (0−80 kg m^{-2})	3.6
6	Bennartz Scattering Index > limit (for AMSU-B like ch. 8-11)	3.8
7	Dryness Index > limit for channel 9	3.8
8	Dryness Index > limit for channel 10	3.8
9	Dryness Index > limit for channel 11	3.8
10	UK Met Rain Flag is 1 (all channels rejected)	3.1
11	Gross TB error detected (all channels rejected)	3.2

The previous quality control operations are performed outside the background check step since there is no reliance on the model background. The following steps describe the background check performed on SSMIS data during an assimilation cycle, which is executed by the script **BGCKSSMIS.int** in the Kuklos environment and by **bgck.ssmisbgck** in the OCM environment.

4. *Bias Correction*

The first step in the background check is bias correction. Biases naturally exist between satellite observations (O) and the model state equivalents from 3-9h forecasts or trials (P). Prior to assimilating the data, it is imperative that these biases are removed so that adjustments made to the model fields by the assimilation of the observations reflect differences other than those that are strictly systematic. Biases are determined from TB O-P collected over a period of time, as described below, and can be related to certain “predictors” derived from data in the observation and/or forecast files.

For SSMIS TB data, the biases are separated into two components – one that depends on scan position only, and so global in nature, and one which is dependent upon air-mass characteristics. The global scan position bias is the main component and is easily computed from an ensemble mean of an innovation (O−P) data set. The smaller second component is addressed by developing a set of regression coefficients correlating the O−P (predictands) to the air-mass type using model air-mass type predictors, following Harris and Kelly, 2001:

- Geopotential thickness of the layer 1000 hPa to 300 hPa ($GZ_{300}-GZ_{1000}$),
- Geopotential thickness of the layer 200 hPa to 50 hPa ($GZ_{50}-GZ_{200}$),
- Geopotential thickness of the layer 50 hPa to 5 hPa ($GZ_{5}-GZ_{50}$),
- Geopotential thickness of the layer 10 hPa to 1 hPa ($GZ_{1}-GZ_{10}$).

where GZ_P, the geopotential height of the P (hPa) pressure level, are taken from the trial (P) file.

The unified satellite radiance dynamic bias correction scheme developed by Stephen Macpherson (ARMA) is described here. A detailed description of this scheme can be found in the CMC techinical document *Unified Satellite Radiance Bias Correction System*. The basic operation of this scheme can be described by the following 6 steps:

1. Global and air-mass bias correction components are determined using as input a series of SQLite table files previously generated for each 6 hour assimilation period (step 6 below). All tables available over the last 7 days are used (normally 28 table files). A minimum of 8 table files (2 days) are required to activate the dynamic correction scheme (this primarily applies to the launch of new assimilation experiments). A static correction scheme is applied if the number of tables is less than 8. The name of the program that generates the bias correction components from table files is **bgck.gen_coeff**. The output bias correction coefficient file is an ASCII file containing the global scan position biases (mean O−P for each scan position and channel) as well as the regression coefficients and constant for the air-mass correction component.
2. Information in the bias correction coefficient file created in step 1 is applied with GZ from the trial field (the predictors) to perform the bias correction of the TB data. The name of this program is **bgck.satbcor**.
3. TB innovations (O-P) are produced using 3D-Var in O-P mode (see Section 5).
4. Final QC is performed based on the magnitude of the innovations (see Section 6).
5. Data are thinned by scan line to reduce the size of the input file for the next step (table file generation). This significantly reduces the computer time, memory, and disk space requirements (smaller table files) for the bias correction scheme. The thinning program is **ssmisreducer**. A recommended thinning of one in five scan lines reduces data volume by 80%.
6. The program **bgck.gen_table** produces the SQLite table file for the current 6 hour period from the thinned data file from step 5. The table file contains TB O−P for each channel (O = <u>uncorrected</u> TB) and values of the associated predictors (thicknesses) from the trial GZ fields. Only data that have passed all QC and filtering to this point are included.

Note that the period for bias determination and coefficient file generation (last 7 days) and the minimum number of table files or cases (8) can be changed in the Kuklos interface **BGCKSSMIS.int**. Note also that the static bias correction scheme uses a bias correction file called *coeff_file_ssmis* copied from the “statsat” directory (the directory where the error statistics files *stats_ssmis_errtot* and *stats_tovs* are stored). This file must exist for the beginning period of experimental assimilation cycles when the number of cases is less than 8. If not, then the TB data will not be corrected for this starting period.

A radiosonde mask file can be applied to weight the data used for determining the bias corrections (argument in program **bgck.gen_coeff**) according to the proximity of the data points to upper air stations. Greater weight is given to table data closer to radiosonde stations, due to greater confidence in the background state (P) in the O−P.

In the application of the complete bias correction (consisting of the global scan position component and the air-mass component) in step 2, flags in the data BURP file are used to indicate that the observations and their innovations have been corrected. Uncorrected data are not assimilated in 3D-Var. Corrections for all observations are also stored in the BURP file (element 012233), so that they can be reversed to obtain the original uncorrected TB data. For example, the bias corrections are read and applied to obtain uncorrected O−P in the program **bgck.gen_table** in step 6 above.

Finally it should be noted that the unified bias correction system allows for correction type (e.g., dynamic/static or complete/scan-position-only) and predictors (up to 6) to be specified separately and uniquely for each channel of an instrument. Different types of predictors are available including the standard airmass predictors, the TB itself, and quantities related to view angle.

5. *Computation of the Innovations (O−P)*

The bias-corrected data containing observations over the 6h analysis window are next fed into the 3D-Var program (3D-Var NCONF=121 for "O−P mode"), along with trial (3−9h model forecast) fields valid for the same 6h time period, to determine the innovations (i.e. O−Ps), which are computed using the following relation:

$$O-P=y-H(x)$$

where: *y* is *O*, the observed brightness temperature (TB),
x is the model state from the trial closest to the observation time,
H is the non-linear observation operator
H(x) is *P*, the model equivalent (simulated) value of TB.

The forward operator *H* maps the model state into observation space. The radiative transfer model RTTOV is used to produce model TB from the model state for operator *H*. Application of the operator *H* involves the following three operations:

1. horizontal interpolation of the model state to the SSMIS observation points,
2. vertical interpolation of model temperature and natural logarithm of the model specific humidity from the model levels to 40 RTTOV pressure levels (1013 to 0.1 hPa),
3. computation of the model brightness temperatures using the RTTOV fast radiative transfer model.

The RTTOV radiative transfer model was developed by the EUMETSAT Satellite Application Facility on Numerical Weather Prediction (NWPSAF). More information is available at the web address: http://research.metoffice.gov.uk/research/interproj/nwpsaf/rtm/. The required input to RTTOV for cloud-free radiance computation consists of model state profiles (*x*) of temperature and humidity at the observation locations, as well as surface (skin) temperature and wind-speed (over water). Additional profiles can be specified for ozone, CO_2, cloud liquid or ice, and aerosols. Tangent linear (TL) and adjoint (AD) versions of RTTOV are used for variational assimilation (3D-Var or 4D-Var).

6. *Quality Control of the Corrected Innovations – bgck.ssmis_inovqc.ftn90*

This program does the final QC to prepare the SSMIS data for assimilation. First, any data that have QC flag bit 7 set from the first QC program *bgck.satqc_ssmis* (section 3) are flagged to be rejected for assimilation by setting QC flag bit 9, and no further checks on the data are done.

For data that have passed the first stage of QC (section 3), bias-corrected innovations (O-P) are screened to determine those observations that differ significantly from the background field (considered rogue outliers). It is desirable to remove these data since they might degrade the analysis. The 'total error statistics' are employed to identify the outliers. The 'total error statistics' are comprised of standard deviations of the bias-corrected innovations for each of the channels, and are found in the ASCII file *stats_ssmis_errtot*. The error statistics are typically computed over a fixed period (e.g. 3 weeks) using only "good" observations that passed the QC.

An outlier is identified as an innovation (O−P) whose magnitude is greater than or equal to *F* times the total error statistics (σ) for that channel, where the rogue factor *F* depends on the channel considered. Values of *F* for the 24 SSMIS channels are given in Table 3. The same rogue factors are applied for the equivalent AMSU and SSM/I channels. Outliers are flagged for omission from the assimilation process by setting data QC flag bit 9 (and bit 16).

Channel selection is also performed at this QC stage, whereby the “UTIL” column in the file *stats_ssmis_errtot* defines for each satellite which channels are to be assimilated. (Note that the file *stats_tovs_assim* is used for this purpose in the AMSU filtering program.) Data QC flag bit 11 is set for data from unselected channels. Bit 11 is also set for data that are not bias corrected (bit 6 OFF).

Additional QC filtering is done in this step for the AMSU-A and AMSU-B like sounding channels, namely:

- rejection of channels 2−4 if channel 1 fails rogue check
- rejection of channels 8−11 if channel 8 $|O-P| \geq 5K$ (pseudo cloud filter)
- rejection of channels 4, 9, 10, 11 if model surface height above sea level (ASL) at the observation location is too high (topography check)

Data QC flag bit 9 (and bit 16) are set for the data rejected by these checks.

The topography (TOPO) check is done for some sounding channels because over high terrain the surface contribution may be non-zero due to peak response of these channels at low levels. Data QC flag bit 9 (and bit 18) are set for TOPO rejected data.

Details on this stage of QC can be found in Table 3.

Table 3. Final Quality Control and Channel Selection

Chan	Equivalent Channel	rogue factor *F* (for *Fσ*)	TOPO height limit (m ASL)	Other	Assim
1	AMSU-A 3	2			
2	AMSU-A 4	3		CH1	N
3	AMSU-A 5	4		CH1	N
4	AMSU-A 6	4	250[1]	CH1[2]	N
5	AMSU-A 8	4			N
6	AMSU-A 9	4			N
7	AMSU-A 10	4			N
8	AMSU-B 2	2		CH8	N
9	AMSU-B 5	4	1000[3]	CH8	N
10	AMSU-B 4	4	2000	CH8	N
11	AMSU-B 3	4	2500	CH8	N
12	**SSM/I 2**	2			Y
13	**SSM/I 1**	2			Y
14	**SSM/I 3**	2			Y
15	**SSM/I 5**	2			Y
16	**SSM/I 4**	2			Y
17	**SSM/I 6** AMSU-A 15	2			Y
18	**SSM/I 7** AMSU-B 1	2			Y
19		3			ABVS**
20		3			ABVS**
21		3			N **
22	AMSU-A 14	3			N **
23	AMSU-A 13	3			N
24	AMSU-A 11,12	3			N

- **rogue factor *F***: reject if $|O-P| \geq F\sigma$, where σ = total error statistics
- **TOPO height limit**: reject if model surface height > TOPO height limit (m)
- **Assim**: Y = channel assimilated
  N = channel not currently assimilated (but could be in future)
  ABVS = channel weighting function peaks above GEM top (0.1 hPa)
  ** = channel sensitive to mesosphere Zeeman effect
- **Other**:
  - CH1: reject if channel 1 $|O-P|$ fails rogue check
  - CH8: reject if channel 8 $|O-P| \geq 5K$ (pseudo-cloud filter)

[1] if the channel is assimilated over both land and open water; low value means little data over land
[2] if the channel is assimilated over open water only (option is set in *satqc_ssmis* [variable *ipc*=4])
[3] the check is done anyway, even though this channel is currently not assimilated over land

7. *Data thinning and sorting – bgck.ssmisthin.ftn90*

7.1. Obtaining a single layer of observations (3D-Var only)

Due to the overlap of orbits within a 6 hour time frame, either from different satellites or from the same satellite over higher latitudes, measures must be taken to obtain a single layer of observations over the globe. This process is referred to as blending. To eliminate the overlap, first an equal-area grid of 100 km resolution is applied across the earth's surface (IDELTA1 argument supplies actual resolution value to program, see Appendix A). Within each grid box, the group of observations (from a particular orbit) that are determined to be closest to the central time are identified and retained, while the rest of the observations in that box are removed.

In the case of a 4D-Var assimilation cycle, this filter is not applied since the 45 min width of the nine assimilation sub-windows assures that overlap is unlikely. In the case that it does occur, the better choice of 2 or more available orbits is somewhat arbitrary since neither will be very far from the local central time of the assimilation sub-window. Note that the filter is also not applied in the case of 3D-Var FGAT assimilation. The assimilation mode is determined from the value of variable *dstepob*s in the background check 3D-Var namelist file for the innovation computation step (Section 5). If the value is not equal to 6h, then 4D-Var or 3D-Var FGAT assimilation is assumed.

7.2. Thinning the data

Prior to assimilating the final observation set, it is necessary to thin the data further to avoid a high correlation of observation error and overwhelming the assimilation system. To do this, an equal-area grid of 150 km resolution is employed (IDELTA2 argument supplies actual resolution value to program, see Appendix A). For each grid box we select only 1 observation - that which is the closest to the centre of the box. Also, we impose the condition that the point retained must be within 40 km of the centre of the box. This is done to eliminate the incidence whereby points in neighbouring boxes are selected by the algorithm, despite each being far from its own box centre. Because the two points are near one another, this would result in a more densely packed observation field than desired.

In the case of preparing for assimilation using the 4D-Var or 3D-Var FGAT scheme, this selection process is performed separately for each 45 assimilation sub-period. A grid box may then have multiple observations after thinning, as long as they occur in different sub-periods, which means that more observations are available for assimilation.

8. *Assimilation of SSMIS Data*

The typical average number of observations **per channel** available in a 6 hour period for processing (dbase) and accepted for assimilation (after QC, background check and thinning [150 km]) is provided in the table below.

Table 4. Number of SSMIS observations (per channel)

Satellite	Before Processing (dbase)	Ready For Assimilation (BGCKALT)			
		SSM/I	TROPA	TROPB	UPPER
DMSP F16	750,000	1700	n/a	n/a	n/a
DMSP F17	750,000	1700	n/a	n/a	n/a
DMSP F18	750,000	1400	n/a	n/a	n/a

SSM/I: SSM/I like (Channels 12-18) [open water, **CLW<0.02 kg m^{-2}**]
TROPA: AMSU-A like in troposphere (Channels 2-4) [open water, **CLW<0.30 kg m^{-2}**]
TROPB: AMSU-B like (Channels 8-9 / 10-11) [channels 8-9 open water only, channels 10-11 water/land]
UPPER: Channels peaking above tropopause (Channels 5-7, 23-24)

Notes:

- only SSM/I-like channel data (channels 12-18) are currently assimilated
- number of thinned data points (Δx=150 km) is about 10, 000 (99% of the data points are removed by the thinning)
- the cloud/precip filter removes about 30% of the observations for SSM/I-like channels
- the land/sea filter removes about 50 % of the observations for SSM/I-like channels
- precentage of data rejected due to the rain flag is about 5%
- upper atmosphere channels 19-22 are currently not considered for assimilation (due to Zeeman effect and transmittance above model top of 0.1 hPa)

Figure 2 shows the weighting functions for the 13 temperature sounding channels of the SSMIS instrument. Also shown is the current 80-level GEM model top which represents to top-most layer of the analysis grid used to assimilate satellite radiance data.

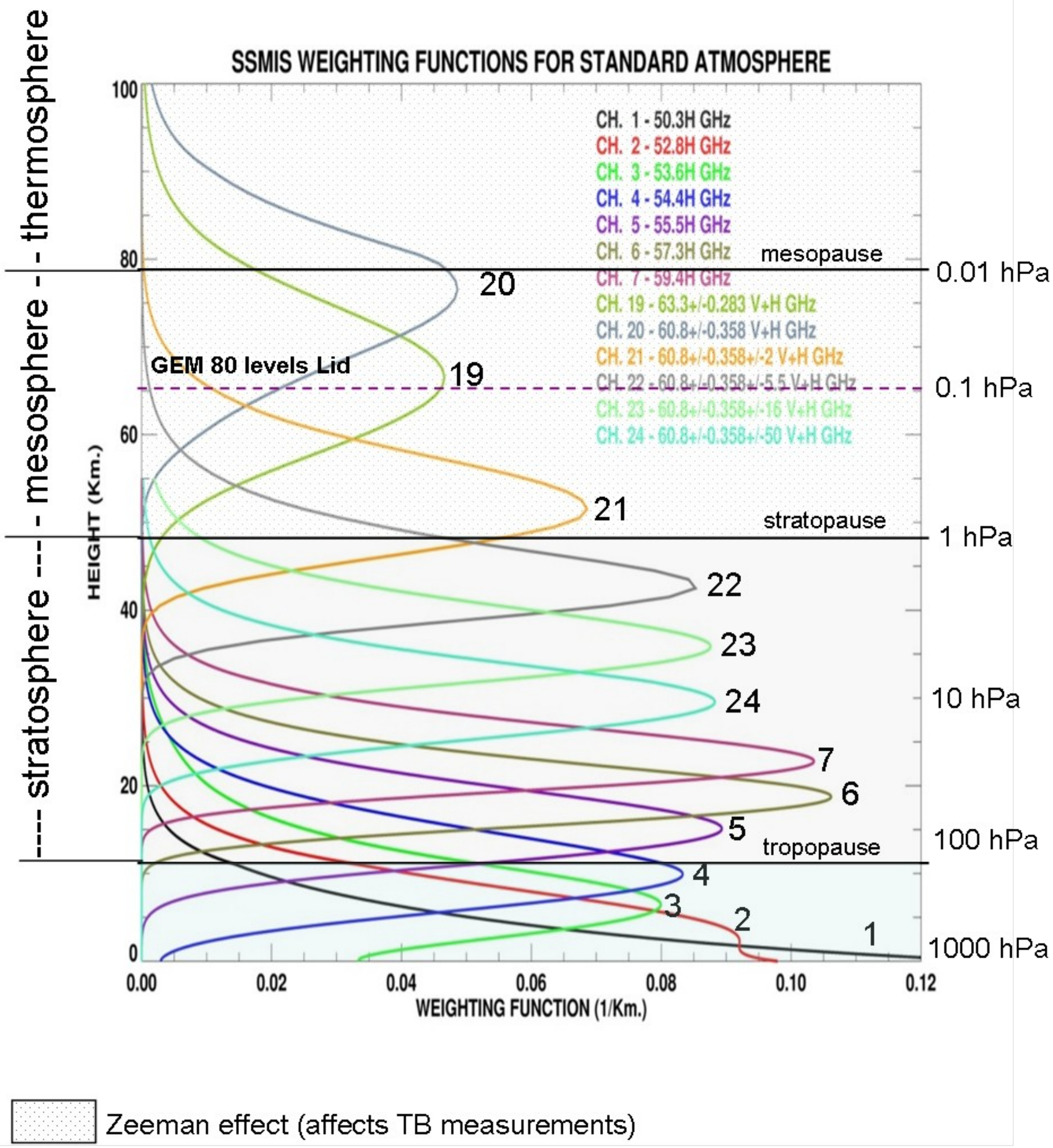

Figure 2. SSMIS Weighting Functions (temperature sounding channels)

9. *References*

Alishouse, J. C., S.A. Snyder, J. Vongsathorn, and R. R. Ferraro, 1990. Determination of oceanic total precipitable water from the SSM/I. *IEEE Trans. Geosci. Remote Sens*., **28**, 811-816.

Bennartz, R., A. Thoss, A. Dybbroe and D.B. Michelson, 1999: Precipitation Analysis from AMSU, Nowcasting SAF, *Swedish Meteorological and Hydrological Institute, Visiting Scientist Report***, November 1999**.

Colton M.C. and G. A. Poe, 1994. Shared Processing Program, Defense Meteorological Satellite Program, Special Sensor Microware/Imager Algorithm Symposium, June 8-10, 1993. *Bull. Amer. Meteor. Soc.*, **75**, 1663-1669.

Harris, B. A. and G. Kelly, 2001. A satellite radiance bias correction scheme for data assimilation, *J. R. Meteorol. Soc.*, **127**, 1453-1468.

Petty, G. W., 1990. On the response of the SSM/I for atmospheric parameter retrievals. Ph. D. thesis, University of Washington, 252 pp.

Weng, F. and N. C. Grody, 1994. Retrieval of cloud liquid water using the Special Sensor Microwave Imager. *J. Geophys. Res.*, **99,** 14493–14502.

10. *Appendix A: Program Details*

(a) UK Met Office data averaging program

The SSMIS radiance (BT) data from the temperature sounding channels must be averaged to reduce noise levels before they can be assimilated. Prior to August 2009, this was done (for all channels) by the SSMIS Unified Preprocessor Package (UPP) that generates the raw BUFR files that CMC receives from NESDIS. In August 2009, this part of the UPP code was removed and made a separate stand-alone program. Nigel Atkinson of the UK Met Office has provided CMC with the program. Note that this program takes as input the raw UPP SSMIS data BUFR files (prefix=NPR.TDUP) that CMC receives from NESDIS. In the box below is a copy of an e-mail from Nigel that explains how to install and run the program. The program TAR archive file referred to in the message below is located here:

`/users/dor/arma/mac/home1/ssmis/upp_avg_ukmet_NEW/`**`ssmis_upp.tar`**

If you unpack the attached tar file then it will create the following directory structure:

```
SSMIS_PP/
    /data
        /coeffs
    /docs
        /guides
    /src
        /MetDB_BUFR15.0
        /ssmis_upp
```

First build the **/MetDB_BUFR15.0** library. Go to that directory, choose your compiler (we recommend either ifort or gfortran) and select the appropriate Makefile. Currently ifort is selected; if you want to change to gfortran then change the link:

```
ln -sf Makefile_BUFRrelease_linux_gfortran Makefile
```

(If file `Makefile_BUFRrelease_linux_gfortran` is missing, you can copy it from /users/dor/arma/mac/home1/ssmis/upp_avg_ukmet_NEW/SSMIS_PP/src/MetDB_BUFR15.0)

Build the library using `make`.

Then go to the **/ssmis_upp** directory. Edit the Makefile to select the appropriate compiler.

Replace the following 3 files

```
   SSMISMod_UPP.f90
   SSMISMod_UPP_Average.f90
   SSMISMod_UPP_DoAveraging.f90
```

with the newer ones found in the TAR archive directory

```
  /users/dor/arma/mac/home1/ssmis/upp_avg_ukmet_NEW/
```

This fixes a problem with missing orbit sections in the output BUFR file.

Then

```
make
make install
```

This will create a run directory **SSMIS_PP/run_UPP** containing links to the executable, the BUFR tables, the averaging data file and the namelist file. By default it uses the 50km averaging specification, but you can change this is you want to by linking to one of the other coefficient files in **data/coeffs**. Also, averaging is applied to all channels by default, but this can be changed by editing the namelist file.

To run, place your incoming BUFR file in the `run_UPP` directory and create a file UPP_WORKLIST containing the name of that file. Then run
`./SSMIS_UPP_PREPROCESSOR.exe`

Output file will be called UPP_BUFR_FILE_AV.BUFR. You can rename it as required.

Nigel Atkinson AAPP manager
Met Office FitzRoy Road Exeter EX1 3PB United Kingdom
Tel: +44 (0)1392 884528 Fax: +44 (0)1392 885681

There is a reference document included in the TAR package that describes how to install and run the program. It is

```
../SSMIS_PP/docs/guides/NWPSAF-MO-UD-025_SSMIS_UPP.pdf
```

A namelist file called `UPP_AUXILIARY.nl` is used to specify what channels are to be averaged. The file is also used to set options for keeping the original rain flag and surface type for each data point when averaging is applied. The default namelist file (for averaging all channels) is found in the directory

```
/SSMIS_PP/src/ssmis_upp/
```

and is copied to the program work directory

```
/SSMIS_PP/run_upp/
```

when the program is installed. The namelist file in the work directory can be edited to apply selective data averaging (see reference document for details). The recommended settings are

```
&UPP_ToBeAveraged
ChannelsToBeAveraged = 1,2,3,4,5,6,7,19,20,21,22,23,24
SetAveragedRainFlags = .FALSE.
SetSurfaceDiscrepancy= .FALSE.
```

which averages data from the temperature sounding channels only while retaining the original rain flags and surface types.

Any questions or comments can be directed to Nigel (contact information is in e-mail copied above).

A script that runs the program can be found here:

```
/users/dor/arma/mac/home1/scripts/ade/bgck.ssmis_avg
```

The UK Met Office has a SSMIS UPP web page as well:

http://research.metoffice.gov.uk/research/interproj/nwpsaf/ssmis_pp/

(b) satqc_ssmis

The Fortran90 source code for ***satqc_ssmis*** is located here:

```
/users/dor/arma/mac/home1/ssmis/processing/satqc_ssmis/
```

The script to compile the code (AIX on the IBM) is (in the same directory):

```
do_rcomp_ibm.sh
```

An example of a script that prepares a derialt BURP file from an SSMIS dbase BURP file is:

```
/users/dor/arma/mac/home1/ssmis/processing/gen_derivSSMIS/
do_gen_derivSSMIS_mpi.ksh
```

which uses the following job (in the same directory) to run ***satqc_ssmis***

```
job_satqc_ssmis_mpi.ksh
```

Note that, in addition to the input dbase BURP file, the following input files are required by the program:

i. **Wentz surface mask file**
This file can be found here:
`/users/dor/arma/mac/home1/ssmis/processing/toolbox/wentz_surf.std`

ii. **MG field (ocean/continent mask)**
This file can be found here:
`/users/dor/arma/mac/home1/ssmis/processing/toolbox/MG_field_801x600`
It can alternatively be extracted from any operations global G2 analysis file (see **iii** below).

iii. **LG field (continuous ice fraction)**
The LG field is extracted (with *editfst*) from the operations 00Z global G2 analyses which can be found here:
`/cnfs/ops/production/gridpt/dbase/anal/glbhyb2/`

iv. **binary ice mask file**
This file is generated from the 00Z LG field (item **iii** above). The program used to do this is
`/usr/local/env/afsisio/programs/bgck.genice`
e.g. `bgck.genice -imice` *`LG_file`* `-osice bicefil -date g600`
Note that the name of this file must be **`bicefil`** and it must be copied to the working directory used when running the program ***satqc_ssmis***.

The MG field and LG field (items **ii** and **iii**) are comibined in one standard file (using *editfst*) for input to the program *satqc_ssmis.*

The arguments for the program are:

-L	name of listing file (default is STDOUT)
-IXENT	input dbase SSMIS BURP file
-OXSRT	output SSMIS BURP file ready for conversion to type derialt

-WNTZFILE	Wentz surface mask standard file (item (**i**) above)	
-MGLGFILE	combined MG+LG fields standard file (items (**ii**) and (**iii**) above)	
-ALG_OPTN	option for computing integrated water vapour (IWV) from BTs	
	=**fwentz** (default)	use Alishouse and Petty algorithm (also Wentz SSM/I Ta→Tb conversion)
	=fweng	use Weng algorithm (also Weng SSM/I Ta→Tb conversion)
	=nsun	use N. Sun algorithm with Weng SSM/I Ta→Tb conversion
-SPADJUST	=**non**	no scan position bias adjustment to BT data (default)
	=oui	adjust BT data for scan position biases using old style standard file (FST) bias correction coefficient file
	=new	adjust BT data for scan position biases using new (unified bias correction system) ASCII bias correction coefficient file
-IRBC	name of SSMIS bias correction coefficicent file (required when oui/new specified for **SPADJUST** argument.)	

(c) ssmis_inovqc

The Fortran90 source code for ***ssmis_inovqc*** is located here:

```
/users/dor/arma/mac/home1/SatRadDBC/bgck/ssmis_inovqc/
```

Arguments are:

-IXENT	input BURP file (must contain O-P data blocks added by 3D-Var [O-P mode])	
-OXSRT	output BURP file with QC data flag bits set	
-ISSTAT	SSMIS stats file (e.g. *stats_ssmis_errtot*) containing error stats (from monitoring of Std O-P) for each channel of each satellite plus the "UTIL" channel selection flag.	
-IRGEO	std file with 3D GZ field from trial file (used to get model topography MT)	
-ETIKRESU	eitket (string) for resume record of output file e.g., ">>BGCKALT"	
-RESETQC	=oui/**non**	reset all QC flags to "0" before updating them (default=non)
-DEBUG	=oui/**non**	debug mode (default=non)

(d) ssmisthin

The Fortran90 source code for ***ssmisthin*** is located here:

```
/users/dor/arma/mac/home1/ssmis/processing/ssmisthin/
```

Arguments (with default values in **bold**) are:

-IXENT input BURP data file
-OXSRT output BURP data file (thinned)
-BLEND =**oui** remove overlapping data from all satellites (for 3D-thinning)
non no blending (e.g. for 4D thinning)
If **DSTEPOBS** is not equal to 6.0d0, **BLEND** is forced to "non".
-THINDAT =**oui** thin data spatially (using dx = value of **IDELTA2**)
non no spatial thinning
-IDELTA1 equal-area grid resolution (km) for global grid used to blend observations from different satellites (**BLEND**=oui); default = **100 km**
-IDELTA2 desired spatial thinning *dx* (km) (**THINDAT**=oui); default = **250 km**
-PACDT[1] determines width of time slot *dt* (sec.) within which obs pts are retained when blending data from multiple satellites (**BLEND**=oui); default=**2000 sec.**
-DSTEPOBS data thinning time step (hours) (e.g. **6.0d0** for 3D-thinning, 0.75d0 for 4D-thinning)

[1] In each equal-area grid box, the observation closest to the analysis time is selected. All observations that are not within *dt* seconds of this observation are discarded. If multiple observations remain (from different satellites), the one closest to the analysis time is retained.

(e) ssmisreducer

The Fortran90 source code for ***ssmisreducer*** is:

```
/users/dor/arma/mac/home1/ssmis/processing/ssmisreducer/tovsreducer.ftn90
```

This program can be applied to any TOVS data (AMSU, SSM/I or SSMIS) and so the source file is also called *tovsreducer.ftn90*. This program is used to perform simple data volume reduction for TOVS data in BURP files. An example of its' application is in the generation of SQLite bias correction database tables from BURP file data (see flowchart in Fig. 1). The program is used to reduce the volume of data in the unthinned evalalt SSMIS data BURP file before conversion to SQLite database (with program *burp2rdb*). In data files with scan line information, the data can be reduced by keeping every 1 in *N* scan lines, where *N* is an input argument. A scan position skip factor *M* can also be specified, where every 1 in *M* scan positions is retained. Alternatively, a percentage reduction can be specified if scan line or scan position information is not available (e.g. SSM/I).

Arguments (with default values in **bold**) are:

-IXENT input BURP file
-OXSRT output BURP file (volume reduced data)
-DEBUG OUI or **NON**
-SKIPFOV scan position skip factor *M*, e.g. **1**, 5, 10
-SKIPSCL scan line skip factor *N*, e.g. **1**, 5, 10, 20
-PERCOBS used in place of SKIPFOV/SKIPSCL to specifiy percentage of data to keep
-NOREDUCE latitude (deg) ; poleward of this latitude (N/S) data reduction is reduced by ½. If the –NOREDUCE key is specified alone, a latitude of 59 deg is used.

Default is **99 deg** = **equal reduction over globe**.

-INSTRUM instrument (e.g. AMSUA, SSMI, SSMIS). ***NOT USED YET***.

The **NOREDUCE** option is useful when the data being reduced are heavily pre-filtered over polar regions, such as is the case for data from surface sensitive channels (e.g. SSM/I). In this case, we want less data reduction in the polar regions such that the global distribution of the retained data is more uniform over the globe.

CAUTION: Do not reduce data by scan position (with **-SKIPFOV**) if data for all scan positions is needed in the data-reduced files. An example of such a case is in the generation of SQLite tables mentioned above, where the table data are used to compute scan position dependent biases for bias correction.

11. *Appendix B: Data Remapping and Averaging*

The SSMIS data stream comprises data from four microwave instrument subtypes on the satellite, each associated with a subset of the total of 24 SSMIS channels: the lower atmospheric sounding channels (LAS); the upper atmospheric sounding (UAS) channels; the imaging (IMA) channels and the environmental (ENV) channels (see Table 5). These data streams are produced from seperate feeds on SSMIS and are **not** co-located.

The SSMIS brightness temperatures (Tb) for UAS, IMA, and ENV channels are **remapped** by the SSMIS pre-processor (UPP) to the grid defined by the LAS observations. This is done by computing, at each LAS data point, the weighted sum of Tb from the 4 nearest neighbors of the subtype being remapped, as shown in Fig. 3 below (for ENV channels).

Before August 2009, the UPP also performed spatial **data averaging**. This averaging was primarily intended to reduce noise in the AMSU-A like (i.e., LAS+UAS) sounding channel Tb data to acceptable (for assimilation) levels, but was also applied to the remapped IMA and ENV channel Tb data. The weighted average of Tb from up to 200 data points in a circular domain centred at a given point replaces the original Tb at the point, producing a “smoothed” Tb data field (see Fig. 4). The effective resolution of averaged data is 50 km. Obviously, averaging will be somewhat sub-optimal at the scan edges and at the beginning and end of each orbit, where less data are available for averaging.

As mentioned above, since August 2009 this data averaging is no longer part of the UPP run at NRL in Monterey that produces the SSMIS BUFR files received at CMC (via NESDIS). This part of the UPP was made a separate stand-alone program (available from the UK Met Office) that can be run by the user (CMC). By default it applies the 50 km averaging specification to data from all channels in raw SSMIS data BUFR files but this can be changed by the user. The averaging specification can be changed by linking to different averaging coefficient file, while selective data averaging (for a subset of channels such as the LAS and UAS channels) is managed through a namelist file. See Appendix A (section 10 (a)) for details.

Starting in **March 2011**, CMC activated the UK Met Office SSMIS UPP data averaging program in the development branch of the ADE “remote” rawdata to dbase stream. Only data from the LAS and UAS channels are averaged.

Table 5. SSMIS Channels by Instrument Subtype

Chan	Frequency (GHz)	Subtype	Sample Spacing (km)
1	50.300 H	LAS	37.5
2	52.800 H	LAS	37.5
3	53.596 H	LAS	37.5
4	54.400 H	LAS	37.5
5	55.500 H	LAS	37.5
6	57.290	LAS	37.5
7	59.400	LAS	37.5
24	60.793	LAS	37.5
8	150.000 H	IMA	12.5
9	183.310 H	IMA	12.5
10	183.310 H	IMA	12.5
11	183.310 H	IMA	12.5
17	91.655 V	IMA	12.5
18	91.655 H	IMA	12.5
12	19.350 H	ENV	25
13	19.350 V	ENV	25
14	22.235 V	ENV	25
15	37.000 H	ENV	25
16	37.000 V	ENV	25
19	63.283	UAS	75
20	60.793	UAS	75
21	60.793	UAS	75
22	60.793	UAS	75
23	60.793	UAS	75

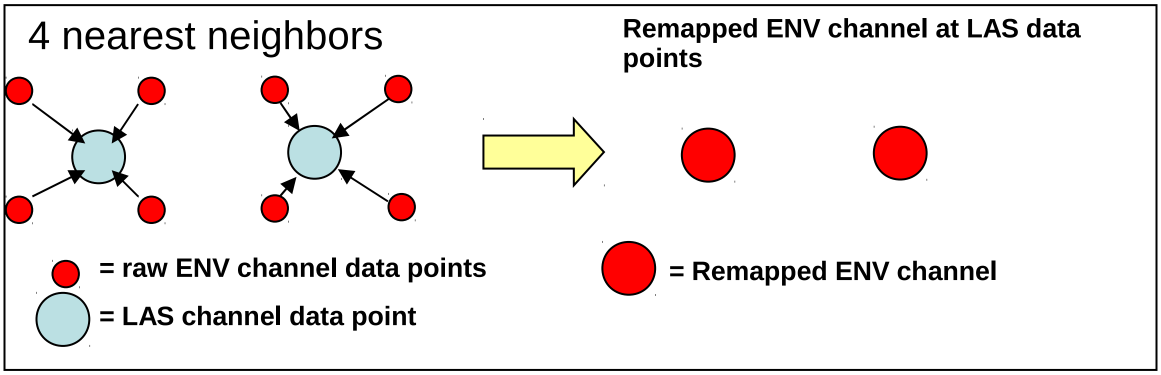

Figure 3. Remapping of ENV channel data to LAS channel grid

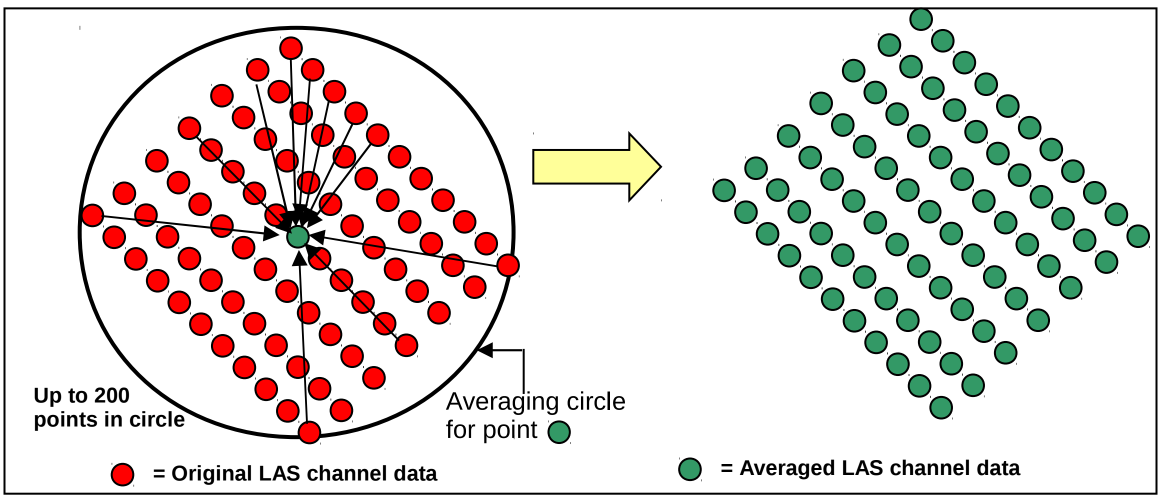

Figure 4. Data averaging of SSMIS Tb data (shown for LAS channel data)