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SSALTO

ALGORITHM DEFINITION, ACCURACY AND SPECIFICATION
VOLUME 3 : CMA RADIOMETER LEVEL 1B PROCESSING

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Issue	Update	Date	Modifications	Visa
0	0	30th July, 1998	Document creation	
1	0	9th April, 199	Accounting for the algorithms specifications and for conclusions of the Jason-1 SWT meeting (Keystone, October 1998), and for TBC/TBD removal	
2	0	2nd Nov., 1999	Correction of minor errors pointed out during the software development phase, and accounting for SWT comments (Boston, June 1999)	
3	0	14th April, 2000	Modification of the definition of the antenna temperature quality flag in the input JMR Level 1.0 product : it is now a two-state flag (0 = valid, 1 = invalid) instead of the previously defined three-state flag (0 = valid, 1 = thermistor temperature invalid, 2 = count invalid)	
3	1	05th January, 2001	Correction of an error in the JMR surface type calculation (Dmin has to be multiplied by 60 to be compatible with minutes units).	
3	2	04th July, 2001	Update of RAD_PHY_TEM_01 provided by C. Ruf	

ABBREVIATIONS

Sigle	Definition
ADA	Algorithm Definition and Accuracy
ADx	Applicable Document x
CLS	Collecte Localisation Satellites
CMA	Centre Multi-missions Altimètre
CNES	Centre National d'Etudes Spatiales
DAD	Dynamic Auxiliary Data
JPL	Jet Propulsion Laboratory
RDx	Reference Document x
SAD	Static Auxiliary Data
SSALTO	Segment Sol Altimétrie et Orbitographie
SWT	Science Working Team
TBC	To Be Confirmed

TBD	To Be Defined
UTC	Universal Time Coordinate

APPLICABLE AND REFERENCE DOCUMENTS

Reference		Document title
TP2-SB-J0-102-CNES	AD1	JASON-1 Science and Operational Requirements
SMM-ST-M2-EA-10658-CN	AD2	CMA Requirements Specification
SMM-SP-M-EA-10879-CN	AD3	SSALTO Products Specifications - Volume 1: JASON-1 User Products
TP2-SB-J0-459-CNES	AD4	JASON-1 Products Description
SMM-ST-M1-EA-31023-CLS	AD5	JMR Level 1.0 data product
SMM-ST-M2-EA-11010-CN	AD6	Algorithms Definition, Accuracy and Specification Volume 9: CMA Mechanisms
SMM-IF-M/JRAD-EA-11871-CN	AD7	Interface specifications between SSALTO and the radiometer experts
SMM-IF-M2-EA-20207-CN	AD8	SSALTO internal Interfaces specification : CMA (CAL & TEC products)
JPL D-7075, Rev. A	RD1	TOPEX Ground System Science Algorithm Specification
SMM-SP-M2-EA-32011-CLS	RD2	Processing steps for the computation and control of the CMA production parameters

TBC AND TBD LIST

TBC/TBD	Section	Brief description
/	/	/

CONTENTS

1. INTRODUCTION

This document is aimed at defining and specifying the main functions of the nominal Level 1b processing of the JASON-1 Microwave Radiometer (JMR) data.

Regarding the JASON-1 mission, the highest level requirements placed by the JASON Science Working Team upon the JASON project to meet the scientific and operational objectives of the mission are listed in AD1, and the requirements aimed at defining the CMA facility inside the SSALTO system are established in AD2.

The JMR level 1b processing starts from the JMR level 1.0 product (see AD5), and generates the JMR level 1b product, the content of which is given in the appendix 1.

As previously mentioned, this document deals with both the definition of the radiometer level 1b processing and the specification of its main functions.

Definition of the radiometer level 1b processing

The definition of the radiometer level 1b processing consists of the identification and the description of its main functions. It will provide the reader with an overview of the processing and a global understanding of the algorithms.

Specifications of the radiometer level 1b processing

Regarding the specifications of the radiometer level 1b processing, two kinds of algorithms are distinguished:

- The “scientific” algorithms, which represent the core of the processing
- The other algorithms, which will be called the “data management” algorithms, ensuring functions such as:
  - To get the input data
  - To prepare the data to be processed (for example to select the orbit data set requested to compute the location of each altimeter measurement)
  - To perform unit conversions or changes in reference systems
  - To perform general checks (relevant for example to the presence of input files, to the data conformity or to the compatibility of input data with the data set to be processed)
  - To build the output product(s)
  - To manage the processing

The scientific algorithms are specified in this document and in AD6 for the mechanisms, which represent the functions common to several algorithms or the functions frequently requested within an algorithm. The data management algorithms, which strongly depend on the format of the input and output data, are specified in RD2 (and AD6 for the corresponding mechanisms, if any). The complete set of specifications (to be associated with the corresponding interfaces documents) is intended for the team in charge of the software development.

Conventions

The radiometer level 1b processing is represented in this document as a linear set of functions which are aimed at building a set of radiometer level 1b parameters from a set of level 1.0 parameters. This representation has been chosen for historical reasons in order to ease the understanding of the overall processing, but it does not anticipate the organization or the sequencing of the algorithms within the CMA processor.

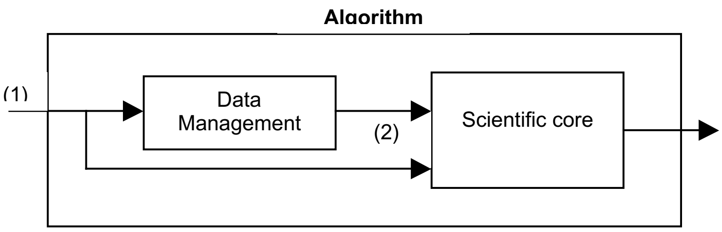
Organization of the document

- The interfaces of the processing (input and output data) are defined in section 2.
- The Radiometer Level 1b processing algorithms are described in section 3.

The description of the processing consists of:

- An overview of the overall processing (brief description of the processing and list of functions).
- The definition and the specification of the algorithms, using the following items:
  - Name and identifier of the algorithm
  - Heritage
  - Function
  - Applicability to the various procedures
  - Algorithm definition:
    - Input data
    - Output data
    - Mathematical statement
  - Algorithm specification:
    - Input data
    - Output data
    - Processing
  - Accuracy (if any)
  - Comments (if any)
  - References (if any)

As previously mentioned, only the scientific core of each algorithm is specified in this document. For each algorithm, the input data (1) identified in the "Algorithm definition" section corresponds to the input data required for the global processing (Data Management and Scientific Core), while the input data (2) identified in the "Algorithm specification" section corresponds to the data requested for the scientific core only.



The general information necessary for a global understanding of the algorithm within the overall processing is provided in the “Algorithm definition” sections.

The detailed information required by the team in charge of the software development is provided in the “Algorithm specification” sections, which precisely define the scientific part (i.e. the core) of the algorithms.

Basic rules

The following basic rules are applied to the specification of the algorithms:

- The specifications of an algorithm are always relevant to the processing of a single data point and not to a set of data points
- Elementary functions, which are common to several algorithms (also called "mechanisms"), are specified in AD6.
- The input and output data are always identified by a precise description, an explicit name (that could be used in the coding phase), a unit and, if necessary, a reference system
- Regarding the errors that may occur during the processing functions (for example, negative argument for logarithmic or square root functions), the algorithms systematically output an execution status. The building and the management of this information will be defined during the architectural design of the software.
- Regarding the representation of tables, the following conventions are used :
  - $X[N_1:N_2]$ represents a one-dimension table whose elements are X(i) (or X_i) with $i \in [N_1, N_2]$
  - $X[N_1:N_2][M_1:M_2]$ represents a two-dimension table whose elements are X(i,j) (or X_{ij}) with $i \in [N_1,N_2]$ and $j \in [M_1,M_2]$
  - And so on

2. INPUT AND OUTPUT DATA

2.1. INPUT DATA

Two types of input data may be discriminated (see AD2):

- "Product" data, which correspond to measurements performed by the JMR:
  - JMR level 1.0 parameters.
- Auxiliary data, which may be dynamic or static:
  - Dynamic auxiliary data are the time-varying data
  - Static auxiliary data are constant data.

The JMR dataset on input represents a sequential set of measurements.

2.1.1. PRODUCT DATA

The JMR level 1.0 parameters are described in AD5.

2.1.2. AUXILIARY DATA

- **Dynamic auxiliary data:**

  None

- **Static auxiliary data:**

  Static auxiliary data for JMR level 1b processing consist of:

  – The JMR instrumental characterization data, described in AD7

  – The following data described in AD8:

    * Processing parameters (all the constant parameters used in the processing)

    * Land/sea mask file

2.2. OUTPUT DATA

The JMR level 1b processing outputs one set of level 1b parameters that are structured in exactly the same sequence as the set of level 1.0 input parameters.

The JASON-1 JMR Level 1b parameters consist of the JMR level 1.0 parameters required on input of the level 2 processing and of the parameters computed by the JMR level 1b algorithms.

These parameters are considered as intermediate parameters within a global processing of the radiometer (and altimeter) measurements from level 1.0 (see AD5) to Level 2 (see AD3).

A list of these parameters is given in appendix 1.

3. JMR PROCESSING

3.1. PROCESSING OVERVIEW

3.1.1. BRIEF DESCRIPTION

A brief overview of the main functions of the JMR processing is given in this section. A more detailed description is provided in section 3.2.

- The overflown surface type is determined accounting for the antenna pattern characteristics.
- The main beam brightness temperature is computed for each channel from the corresponding antenna temperature and corrections for the antenna pattern are applied.
- For each channel, the main beam brightness temperatures are averaged along-track to equalize the different channel footprints along the satellite ground track.

3.1.2. LIST OF FUNCTIONS

A list of the functions of the JMR level 1b processing is given in **Figure 1**.

FUNCTION
GEN_ENV_SUR_03 - To determine the JMR surface type
RAD_PHY_TEM_01 - To compute the main beam brightness temperatures
RAD_COM_TEM_01 - To equalize the channel footprints along the spacecraft groundtrack

Figure 1: Functions of the JMR level 1b processing

3.2. FUNCTIONS

A detailed description of the functions of the JMR level 1b processing is given in this section.

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GEN_ENV_SUR_03 - To determine the JMR surface type

DEFINITION, ACCURACY AND SPECIFICATION

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FUNCTION

To determine if the surface type corresponding to the JMR measurement is over land or over ocean. Two surface types are derived. The first one is intended to flag the JMR brightness temperatures for their use in the along-track equalization procedure. The second one is intended to flag the JMR path delay.

HERITAGE

ERS-1, ERS-2

ALGORITHM DEFINITION

Input data

- Product data:
  - Latitude and longitude of the 1-s measurement.
- Computed data: None
- Dynamic auxiliary data: None
- Static auxiliary data:
  - Land/sea mask file
  - Processing parameters:
    - The characteristics of the reference ellipsoid (semi-major axis, flattening)
  - Radiometer characterization data :
    - The radial ground distance from the sub-satellite point along nadir at which land contamination would be sufficient to corrupt the subsequent path delay estimate by approximately 0.5 cm (used to flag the path delay)
    - The radial ground distance from the sub-satellite point along nadir from which land contamination of path delay is lower with along-track averaging than without (used to flag the JMR main beam brightness temperatures for their proper selection in the along-track averaging procedure).

Output data

- Surface type of JMR measurement for path delay flag
- Surface type of JMR measurement for main beam brightness temperatures flag

Mathematical statement

The mathematical statement is detailed in Ruf, 1999a. From the antenna pattern characteristics and an approximate path delay retrieval algorithm, a single radial ground distance from the sub-satellite point along nadir can be estimated at which land contamination would be sufficient to corrupt the subsequent path delay estimate by approximately 5 mm. This distance is 50 km. It is therefore recommended that path delay retrievals within 50 km of land be flagged as possibly contaminated. On the other hand, as path delay retrievals at distances from land greater than approximately 25 km have lower error with along track averaging than without, it is also recommended that brightness temperature samples be eliminated from the along track averaging algorithm when they are within 25 km from land. This 25-km distance is different from the 50-km distance at which the path delay algorithm begins to degrade. The difference is due to the fact that, even with degraded performance, it is still preferable to maintain along track averaging between 25 and 50 km from land in order to maximize the partial cancellation of brightness temperature errors in the path delay algorithm. The present algorithm thus outputs two JMR surface type flags. The first one acts as a path delay quality flag : it corresponds to the 50-km distance. The second one is only used for proper selection of main beam brightness temperatures in the along track averaging algorithm : it corresponds to the 25-km distance.

Each of these two distances is translated into the number of grid points of the land/sea mask file to include in a search for land presence around the location of the JMR measurement (note that the same land/sea mask file is used in the altimeter processing to determine the surface type for the altimeter). The percentage of grid points within this search area that are set to “continental ice” or “land” is then determined. Subsequent computations will assume that if this percentage is > 0, then the measurement is contaminated by land.

ALGORITHM SPECIFICATION

Input data

- Latitude of the JMR measurement : Lat_JMR (degree)
- Longitude of the JMR measurement : Lon_JMR (degree)
- Land/sea mask :
  - Number of grid points in the longitude axis : Land_Sea_Nb_Lon (/)
  - Number of grid points in the latitude axis : Land_Sea_Nb_Lat (/)
  - Map : Land_Sea[0:Land_Sea_Nb_Lon-1, 0:Land_Sea_Nb_Lat-1] (m)
  - Latitude step : Land_Sea_Lat_Step (minute)
  - Longitude step : Land_Sea_Lon_Step (minute)
  - First latitude : Land_Sea_Lat_First (minute)
  - First longitude : Land_Sea_Lon_First (minute,[0,360x60[)
- The characteristics of the reference ellipsoid:
  - Semi major axis : SM_Axis (m)
  - Flattening : Flattening (/)
- The radial ground distance from the sub-satellite point along nadir, at which land contamination would be sufficient to corrupt the subsequent path delay estimate by approximately 5 mm : Dmin_PD (m)

- The radial ground distance from the sub-satellite point along nadir, from which land contamination of path delay is lower with along-track averaging than without : Dmin_TB (m)

Output data

- Surface type for path delay land contamination [(1)] : JMR_PD_Surf_Type (/)
- Surface type for main beam brightness temperatures land contamination[(2)] : JMR_TB_Surf_Type (/)
- Execution status

Processing

- Determine the indexes of the southwestern corner of the land/sea mask cell that contains the JMR measurement, using mechanism "GEN_MEC_GRI_01 - Cell identification",

  the input parameters of which are:

  - X = Lon_JMR x 60
  - Y = Lat_JMR x 60
  - DX = Land_Sea_Lon_Step
  - DY = Land_Sea_Lat_Step
  - Xfir = Land_Sea_Lon_First
  - Yfir = Land_Sea_Lat_First
  - Nb_Ptx = Land_Sea_Nb_Lon
  - Nb_Pty = Land_Sea_Nb_Lat
  - Xcyc = 360 x 60
  - Ycyc = 0
  - Xcut = 0
  - Ycut = 0

  And the output parameters of which are:

  - The indexes of the four grid points surrounding the (Lon_JMR, Lat_JMR) point: I_Left, I_Right, J_Low, J_Up
  - The weights of these points: W(0) = W_LL; W(1)=W_LR; W(2)= W_UL; W(3)= W_UR
  - The execution status.
- Dmin(0) = Dmin_TB (1)
- Dmin(1) = Dmin_PD (2)

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(1) The surface type value is the percentage of grid points set to "continental ice" or "land" within the distance Dmin_PD

(2) The surface type value is the percentage of grid points set to "continental ice" or "land" within the distance Dmin_TB

- For I = 0 to 1 (i.e., for the two distances Dmin_TB and Dmin_PD) :
  - Compute the number of grid points in latitude and longitude to consider in the land/sea mask, to include in a search for land presence around the location of the JMR measurement :
    - $\text{Nb\_Grid\_Lat} = \text{CEIL}\left[\frac{\text{Dmin(I)} * 60}{(\text{Land\_Sea\_Lat\_Step} * 111320)}\right]$ (3)
    - $\text{Nb\_Grid\_Lon} = \text{CEIL}\left[\frac{\text{Dmin(I)} * 60}{\left(\text{Land\_Sea\_Lon\_Step} * 111320 * \cos\left(\text{Lat\_JMR} * \frac{\pi}{180}\right)\right)}\right]$ (4)

    Where CEIL(x) is the function that computes the smallest integer greater than or equal to x.
  - I_Left_JMR = I_Left – Nb_Grid_Lon (5)
  - I_Right_JMR = I_Right + Nb_Grid_Lon (6)
  - If I_Left_JMR < 0, then :
    - I_Left_JMR = I_Left_JMR + Land_Sea_Nb_Lon (7)
    - I_Right_JMR = I_Right_JMR + Land_Sea_Nb_Lon (8)
  - Nb_Pts_Grid_Land = 0 (9)
  - Nb_Pts_Grid = 0 (10)
  - For I_Grid = I_Left_JMR to I_Right_JMR :
    - If I_Grid > Land_Sea_Nb_Lon – 1, then :
      - ◊ I_Grid2 = I_Grid – Land_Sea_Nb_Lon (11)

      Else :
      - ◊ I_Grid2 = I_Grid (12)
    - Lon_Grid_Point = Land_Sea_Lon_First + I_Grid2 ∗ Land_Sea_Lon_Step (13)
    - For J_Grid = J_Low – Nb_Grid_Lat to J_Up + Nb_Grid_Lat :
      - ◊ Lat_Grid_Point = Land_Sea_Lat_First + J_Grid ∗ Land_Sea_Lat_Step (14)
      - ◊ Computing the ground distance between the JMR measurement and the grid point, using mechanism "GEN_MEC_MIS_01 – Ground distance between two points",

        the input parameters of which are :

        ⇒ Lat1 = Lat_JMR

        ⇒ Lon1 = Lon_JMR

        ⇒ Lat2 = Lat_Grid_point

        ⇒ Lon2 = Lon_Grid_point

        ⇒ The semi major axis of the reference ellipsoid : SM_Axis (m)

        ⇒ The flattening of the reference ellipsoid : Flattening (/)

and the output parameters of which are :

⇒ The ground distance D

⇒ The execution status

◊ Counting the number of grid points set to “continental ice” or “land” within the radius Dmin(I) :

⇒ If (D < Dmin(I)), then :

→ Nb_Pts_Grid = Nb_Pts_Grid + 1 (15)

→ If [Land_Sea(I_Grid2, J_Grid) is set to “continental ice” or is set to “land”] then :

Nb_Pts_Grid_Land = Nb_Pts_Grid_Land + 1 (16)

– $$\text{JMR\_Surf\_Type(I)} = 100. * \frac{\text{Nb\_Pts\_Grid\_Land}}{\text{Nb\_Pts\_Grid}} \quad (17)$$

- JMR_TB_Surf_Type = JMR_Surf_Type(0) (18)
- JMR_PD_Surf_Type = JMR_Surf_Type(1) (19)

ACCURACY

The errors in the JMR surface type are caused by errors in the land/sea mask itself, and by all the assumptions taken for calculating Dmin (e.g. Dmin is not a constant but is actually some unknown function of land surface temperature).

COMMENTS

None

REFERENCES

Ruf, C.S., 1999a : Jason Microwave Radiometer – Land Contamination of Path Delay Retrieval. 22 February 1999

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RAD_PHY_TEM_01 - To compute the main beam brightness temperatures

DEFINITION, ACCURACY AND SPECIFICATION

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FUNCTION

To compute the JMR brightness temperatures by applying an antenna pattern correction (APC) to the measured antenna temperatures.

HERITAGE

TOPEX/POSEIDON Microwave Radiometer

ALGORITHM DEFINITION

Input data

- Product data:
  - For each 1-s JMR measurement:
    - Latitude of the measurement.
    - Averaged (1-s) antenna temperature for each of three channels, T_{Ai}
    - Antenna temperature quality flag for each of three channels.
- Computed data: None
- Dynamic auxiliary data: None
- Static auxiliary data:
  - Radiometer characterization data :
    - Beam sidelobe fractions for each of three JMR frequencies (2 values, b_i (on-Earth), and c_i (off-Earth) for each of 3 frequencies). These are computed from Ball Aerospace Corp. indoor antenna range measurements of the complete patterns and confirmed by principle plane measurements at the JPL outdoor range.
    - Three tables of constant, linear and quadratic coefficients relating the mean brightness temperature of the Earth, T_{ei}, to the antenna temperature T_{ai}, at each of three JMR frequencies, as functions of latitude. These are computed from island radiosonde data calculations.
    - Effective cosmic background brightness temperature, T_{ci}, at each of three JMR frequencies (3 values).

Output data

For each 1-s JMR measurement:

- Main beam brightness temperature (T_{mbi}) at each of three JMR frequencies (3 values).

Mathematical statement

The mathematical statement is detailed in Ruf (1999b), and Ruf and Keihm (2000). If the antenna temperature quality flag is set to "state 2 (invalid)" (i.e. T_{Ai} = 0), then T_{mbi} = 0, else the main beam brightness temperature for channel i, T_{mbi}, is computed for each channel from antenna temperature T_{ai}, using simplified beam pattern parameters:

$$T_{mbi} = \frac{(T_{Ai} - b_i T_{ei} - c_i T_{ci})}{(1 - b_i - c_i)} \qquad (1)$$

where: T_{Ai} is the input antenna temperature for channel i
T_{ei} is the effective on-Earth sidelobe brightness temperature for channel i
T_{ci} is the effective cosmic background brightness temperature for channel i
b_i is the on-Earth sidelobe fraction for channel i
c_i is the off-Earth sidelobe fraction for channel i

T_{mbi} is the average brightness temperature within the main beam. The boundary of the main beam is defined as the angle from beam center at which the beam power drops to the roughly uniform level of the far sidelobes, and is determined from antenna range measurements at each of the JMR frequencies.

In (1), the mean brightness temperature of the Earth, T_{ei}, is calculated from the T_{Ai} value using the tabulated constant, linear and quadratic coefficients, the latitude of which is the closest to the latitude of the JMR measurement.

ALGORITHM SPECIFICATION

Warning: The selection of the coefficients corresponding to the 23.8 GHz channel in operation is considered as a "data management" algorithm (see section 1). It is specified in RD2.

Input data

- Latitude of the JMR measurement : Lat_JMR (degree)
- Averaged (1-s) antenna temperatures (3 values) : TA[0:2] (K)
- Antenna temperature quality flags (3 values) : TA_Qual_Flag[0:2] (/)
- Number of points in the tables of coefficients : Coef_T_Earth_Nbpts (/)
- Step in latitude of tables of coefficients : Coef_T_Earth_Lat_Step (degrees)
- First latitude of tables of coefficients : Coef_T_Earth_Lat_First (degrees)
- Table of constant coefficients for T_{ei} calculation : Coef_T_Earth0[0:2][0:Coef_T_Earth_Nbpts-1] (K)
- Table of linear coefficients for T_{ei} calculation : Coef_T_Earth1[0:2][0:Coef_T_Earth_Nbpts-1] (/)
- Table of quadratic coefficients for T_{ei} calculation : Coef_T_Earth2[0:2][0:Coef_T_Earth_Nbpts-1] (K^{-1})
- Effective cosmic background brightness temperature : T_Cosmic[0:2] (K)
- On-Earth sidelobe fraction : Fraction_Earth[0:2] (/)
- Off-Earth sidelobe fraction : Fraction_Cosmic[0:2] (/)

Output data

- Main-beam brightness temperature : TMB[0:2] (K)
- Execution status

Processing

For i = 0 to 2 (i representing the channel number):

- If TA_Qual_Flag(i) = 1, then:

  $$TMB(i) = 0 \quad (1)$$

- Else:

  – $$Index\_Lat = NINT\left(\frac{Lat\_JMR - Coef\_T\_Earth\_Lat\_First}{Coef\_T\_Earth\_Lat\_Step}\right) \quad (2)$$

  Where NINT represents the function which rounds its real argument to the nearest integer value.

  – $$Coef\_T\_Earth0\_Clos(i) = Coef\_T\_Earth0(i, Index\_Lat) \quad (3)$$

  – $$Coef\_T\_Earth1\_Clos(i) = Coef\_T\_Earth1(i, Index\_Lat) \quad (4)$$

  – $$Coef\_T\_Earth2\_Clos(i) = Coef\_T\_Earth2(i, Index\_Lat) \quad (5)$$

  – $$T\_Earth\_Clos(i) = Coef\_T\_Earth0\_Clos(i) + TA(i) * Coef\_T\_Earth1\_Clos(i) + [TA(i)]^2 * Coef\_T\_Earth2\_Clos(i) \quad (6)$$

  – $$TMB(i) = \frac{TA(i) - Fraction\_Earth * T\_Earth\_Clos(i) - Fraction\_Cosmic * T\_Cosmic(i)}{1 - Fraction\_Earth - Fraction\_Cosmic} \quad (7)$$

ACCURACY

- With the assumption that the T_a calibration accuracy and the beam parameter accuracies are comparable to those of the TOPEX Microwave Radiometer (Ruf et al., 1995; Janssen et al., 1995), the resultant T_{mb} accuracy for the JMR channels is estimated to be 0.8-1.0K.
- The antenna temperature T_a to brightness temperature T_b conversion is most accurate over ocean surfaces. However, T_b values obtained over land (with slightly diminished accuracy) should be retained in the data record. They could prove useful for other (non-ocean) purposes.
- Candidate values for Coef_T_Earth_Nbpts, Coef_T_Earth_Lat_First and Coef_T_Earth_Lat_Step are 29, -70 degrees and 5 degrees respectively.

COMMENTS

The formulation of the JMR brightness temperature algorithm is close to that of the TOPEX Microwave Radiometer (Janssen et al., 1995).

REFERENCES

- Janssen, M. A., C. S. Ruf, and S. J. Keihm, TOPEX/Poseidon microwave radiometer (TMR): II. Antenna pattern correction and brightness temperature algorithm, IEEE Trans. Geosci. Remote Sensing, 33, 138-146, Jan. 1995.
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RAD_COM_TEM_01 - To equalize the channel footprints along the spacecraft groundtrack

DEFINITION, ACCURACY AND SPECIFICATION

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FUNCTION

To approximately equalize the effective JMR beam dimensions along the spacecraft track.

HERITAGE

TOPEX/POSEIDON Microwave Radiometer

ALGORITHM DEFINITION

Input data

- Product data:
  - For each 1-s JMR measurement number k:
    - The following data corresponding to JMR measurements (k-j), j = 1 to 4 :
      - ◊ Time-tag of measurement k-j
      - ◊ Antenna temperature quality flag for each of three channels
    - The following data corresponding to JMR measurements (k+j), j = 1 to 4 :
      - ◊ Time-tag of measurement k+j
      - ◊ Antenna temperature quality flag for each of three channels
    - Antenna temperature quality flag for each of three channels.
- Computed data:
  - For each 1-s JMR measurement number k:
    - The main beam brightness temperature for each of three channels i, $T_{mbi}(k)$, from "RAD_PHY_TEM_01 - To compute the main beam brightness temperatures".
    - The surface type JMR_TB_Surf_Type(k), from "GEN_ENV_SUR_03 - To determine the JMR surface type"
    - The following data corresponding to JMR measurements (k-j), j = 1 to 4 :
      - ◊ The main beam brightness temperatures for the 23.8 and 34 GHz channels (i = 1 to 2), $T_{mbi}(k-j)$, from "RAD_PHY_TEM_01 - To compute the main beam brightness temperatures".
      - ◊ The surface type JMR_TB_Surf_Type(k-j), from "GEN_ENV_SUR_03 - To determine the JMR surface type".
    - The following data corresponding to JMR measurements (k+j), j = 1 to 4 :
      - ◊ The main beam brightness temperatures for the 23.8 and 34 GHz channels (i = 1 to 2), $T_{mbi}(k+j)$, from "RAD_PHY_TEM_01 - To compute the main beam brightness temperatures".
      - ◊ The surface type JMR_TB_Surf_Type(k+j), from "GEN_ENV_SUR_03 - To determine the JMR surface type".

- Dynamic auxiliary data: None
- Static auxiliary data:
  - Radiometer characterization data : 8 sets of 5 weighting coefficients a_0, a_1, a_2, a_3, and a_4, for the 23.8 GHz channel and for the 34 GHz channel. Each set corresponds to one of the following configurations of missing samples (sample 0 is the sample where the along-track average is to be computed) :
    - No missing samples
    - sample ±4 missing
    - sample ±3 missing
    - sample ±2 missing
    - sample ±1 missing
    - sample 0 missing
    - samples ±4 and ±3 missing
    - samples ±4 and ±3 and ±2 missing

    The wording “missing sample” means that the measurement is either physically missing (i.e., there is a time gap), or that the measurement is present (a time tag has been made) but its antenna temperature quality flag = 1 because the digital counts were set to 0, or that the measurement surface type indicates that the measurement is contaminated by land.

Output data

For each 1-s JMR measurement:

- Nadir brightness temperature T_b, equalized in effective along-track beam size, at each of three JMR frequencies (3 values)

Mathematical statement

The mathematical statement is detailed in Ruf (1999b). Over ocean only, this algorithm averages successive 23.8 GHz and 34 GHz T_{mbi} measurements to approximately provide footprint sizes equal to the footprint size of the 18.7 GHz channel along the spacecraft track:

$$T_{bi}(k) = a_0\, T_{mbi}(k) + \sum_{j=1}^{j=+4} a_{ij}\,[T_{mbi}(k+j) + T_{mbi}(k-j)] \qquad (1)$$

Where $T_{bi}(k)$ is the along-track averaged brightness temperature for channel 23.8 or 34 GHz. For channel 18.7 GHz, no along-track averaging is performed (i.e., $T_{bi} = T_{mbi}$).

The coefficients a_{ij} are determined from the principal plane measurements made at JPL. Note that the along-track averaging expressed in equation (1) includes both “uptrack” and “downtrack” T_{mb} values, giving a weighting which is spatially balanced around the nadir position of time tag k. For each measurement k, the appropriate set of coefficients a_{ij} is selected according to the occurrence of so-called “missing” samples T_{mbi} (i.e., either physically missing samples, or non valid samples (antenna temperature quality flag not equal to 0), or samples contaminated by land). If $T_{mbi}(k+j)$ is declared missing, then both $T_{mbi}(k+j)$ and $T_{mbi}(k-j)$ are not included in the averaging.

ALGORITHM SPECIFICATION

Input data

- Numbers of measurements involved in the along-track weighting : N_W (/)
- Weighting coefficients for each of 8 configurations of missing samples and for each of two channels (i = 0 for 23.8 GHz and i = 1 for 34 GHz) : Coef_W[0:7][0:1][0:N_W-1] (/)

  Coef_W(0)[0:1][0:N_W-1] corresponds to the case “no missing samples”

  Coef_W(1)[0:1][0:N_W-1] corresponds to the case “sample ±4 missing”

  Coef_W(2)[0:1][0:N_W-1] corresponds to the case “sample ±3 missing”

  Coef_W(3)[0:1][0:N_W-1] corresponds to the case “sample ±2 missing”

  Coef_W(4)[0:1][0:N_W-1] corresponds to the case “sample ±1 missing”

  Coef_W(5)[0:1][0:N_W-1] corresponds to the case “sample 0 missing”

  Coef_W(6)[0:1][0:N_W-1] corresponds to the case “samples ±4 and ±3 missing”

  Coef_W(7)[0:1][0:N_W-1] corresponds to the case “samples ±4 and ±3 and ±2 missing”
- Number of JMR measurements for the whole JMR sequence : N_Mes_JMR (/)
- Main beam brightness temperatures of the whole JMR sequence : TMB[0:2][0:N_Mes_JMR-1] (K)
  - i = 0 : 18.7 GHz channel
  - i = 1 : 23.8 GHz channel
  - i = 2 : 34 GHz channel
- JMR time tags for the whole JMR sequence : JMR_Time[0:N_Mes_JMR-1] (1)
- Antenna temperature quality flags for the whole JMR sequence : TA_Qual_Flag[0:2][0:N_Mes_JMR-1] (/)
- JMR surface types for the whole JMR sequence : JMR_TB_Surf_Type[0:N_Mes_JMR-1](/)
- Time interval between two consecutive JMR measurements : Dt_No_Gap_JMR (s)

Output data

- Equalized along-track brightness temperatures of the whole JMR sequence : TB[0:2][0:N_Mes_JMR-1] (K)
- Execution status

(1) Seconds ellapsed since 01/01/1950 0 h.

Processing

Warning: The selection of the weighting coefficients corresponding to the 23.8 GHz channel in operation is considered as a "data management" algorithm (see section 1). It is specified in RD2.

It is convenient to perform a first processing step which consists of identifying existing measurement gaps and replacing them with fictive measurements, to work with a JMR measurement series with no gap. In a second processing step, for each measurement number k where the along-track average has to be computed, the weighting coefficients are selected according to the configuration of missing samples.

First step : filling the gaps with fictive measurements

- k1 = 0 (1)
- $Nb\_Mes\_Tot = \dfrac{JMR\_Time(Nb\_Mes\_JMR - 1) - JMR\_Time(0)}{Dt\_No\_Gap\_JMR} + 1$ (2)
- For k = 0 to Nb_Mes_JMR - 1
  - JMR_Time_No_Gap(k1) = JMR_Time(k) (3)
  - JMR_TB_Surf_Type_No_Gap(k1) = JMR_TB_Surf_Type(k) (4)
  - TA_Qual_Flag_No_Gap(0)(k1) = TA_Qual_Flag(0)(k) (5)
  - TA_Qual_Flag_No_Gap(1)(k1) = TA_Qual_Flag(1)(k) (6)
  - TA_Qual_Flag_No_Gap(2)(k1) = TA_Qual_Flag(2)(k) (7)
  - TMB_No_Gap(0)(k1) = TMB(0)(k) (8)
  - TMB_No_Gap(1)(k1) = TMB(1)(k) (9)
  - TMB_No_Gap(2)(k1) = TMB(2)(k) (10)
  - Ind_Presence(k1) = 1 (11)
  - If k < Nb_Mes_JMR-1 then :
    - $Nb\_Mes\_Miss = \dfrac{JMR\_Time(k+1) - JMR\_Time(k)}{Dt\_No\_Gap\_JMR} - 1$ (12)
  - If Nb_Mes_Miss > 0, then
    - For n = 1, Nb_Mes_Miss
      - ◊ JMR_Time_No_Gap(k1+n) = JMR_Time(k1) + n∗Dt_No_Gap_JMR (13)
      - ◊ Ind_Presence(k1+n) = -1 (14)
      - ◊ JMR_TB_Surf_Type_No_Gap(k1+n) = 100. (15)
      - ◊ TMB_No_Gap(0)(k1+n) = 0. (16)
      - ◊ TMB_No_Gap(1)(k1+n) = 0. (17)
      - ◊ TMB_No_Gap(2)(k1+n) = 0. (18)
      - ◊ TA_Qual_Flag_No_Gap(0)(k1+n) = 1 (19)
      - ◊ TA_Qual_Flag_No_Gap(1)(k1+n) = 1 (20)

◊ TA_Qual_Flag_No_Gap(2)(k1+n) = 1 (21)

– k1 = k1 + Nb_Mes_Miss + 1 (22)

Second step : selection of the proper set of coefficients and along-track averaging

- j1 = 0 (23)
- For k = 0 to Nb_Mes_Tot -1
  - TB_No_Gap(0)(k) = TMB_No_Gap(0)(k) (24)
  - If JMR_TB_Surf_Type_No_Gap(k) > 0 ("land" measurement), or if TA_Qual_Flag_No_Gap(0)(k) = 1 ("invalid measurement"), then the hereafter described averaging processing is not performed (i.e., TB_No_Gap(i)(k) = TMB_No_Gap(i)(k), i = 1 to 2).
  - If k = 0 OR k = Nb_Mes_Tot - 1, then :
    - ∗ For i = 0 to 1
      - ◊ TB_No_Gap(i+1)(k) = TMB_No_Gap(i+1)(k) (25)
  - If k = 1 OR k = Nb_Mes_Tot - 2, then :

    For i = 0 to 1

    - ∗ Miss_Sample_4 = 1 (26)
    - ∗ Miss_Sample_3 = 1 (27)
    - ∗ Miss_Sample_2 = 1 (28)
    - ∗ If { [Ind_Presence(k-1) = -1] OR [Ind_Presence(k+1) = -1]

      OR [JMR_TB_Surf_Type_No_Gap(k-1) > 0] OR [JMR_TB_Surf_Type_No_Gap(k+1) > 0]

      OR [TA_Qual_Flag_No_Gap(i+1)(k-1) = 1] OR [TA_Qual_Flag_No_Gap(i+1)(k+1) = 1] } then :

      ◊ Miss_Sample_1 = 1 (29)

      Else

      ◊ Miss_Sample_1 = 0 (30)
    - ∗ If Miss_Sample_1 = 1, then :

      ◊ TB_No_Gap(i+1)(k) = TMB_No_Gap(i+1)(k)

      Else :

      ◊ For N = 0 to N_W-1

      ⇒ Coef_W_Sel(i)(N) = Coef_W(7)(i)(N) (32)

      ◊ TB_No_Gap(i+1)(k) = Coef_W_Sel(i)(0) ∗ TMB_No_Gap(i+1)(k)

      + Coef_W_Sel(i)(1) ∗ [TMB_No_Gap(i+1)(k-1) + TMB_No_Gap(i+1)(k+1)] (33)

– If k = 2 OR k = Nb_Mes_Tot - 3, then :

For i = 0 to 1

∗ Miss_Sample_4 = 1 (34)

∗ Miss_Sample_3 = 1 (35)

∗ If { [Ind_Presence(k-1) = -1] OR [Ind_Presence(k+1) = -1]

OR [JMR_TB_Surf_Type_No_Gap(k-1) > 0] OR [JMR_TB_Surf_Type_No_Gap(k+1) > 0]

OR [TA_Qual_Flag_No_Gap(i+1)(k-1) = 1] OR [TA_Qual_Flag_No_Gap(i+1)(k+1) = 1] } then :

◊ Miss_Sample_1 = 1 (36)

Else

◊ Miss_Sample_1 = 0 (37)

∗ If { [Ind_Presence(k-2) = -1] OR [Ind_Presence(k+2) = -1]

OR [JMR_TB_Surf_Type_No_Gap(k-2) > 0] OR [JMR_TB_Surf_Type_No_Gap(k+2) > 0]

OR [TA_Qual_Flag_No_Gap(i+1)(k-2) = 1] OR [TA_Qual_Flag_No_Gap(i+1)(k+2) = 1] } then :

◊ Miss_Sample_2 = 1 (38)

Else

◊ Miss_Sample_2 = 0 (39)

∗ If Miss_Sample_2 = 1 AND Miss_Sample_1 = 0, then :

◊ For N = 0 to N_W-1

Coef_W_Sel(i)(N) = Coef_W(7)(i)(N) (40)

◊ TB_No_Gap(i+1)(k) = Coef_W_Sel(i)(0) ∗ TMB_No_Gap(i+1)(k)

+ Coef_W_Sel(i)(1) ∗ [TMB_No_Gap(i+1)(k-1) + TMB_No_Gap(i+1)(k+1)] (41)

Else if Miss_Sample_1 = 0 AND Miss_Sample_2 = 0, then :

◊ For N = 0 to N_W-1

Coef_W_Sel(i)(N) = Coef_W(6)(i)(N) (42)

◊ TB_No_Gap(i+1)(k) = Coef_W_Sel(i)(0) ∗ TMB_No_Gap(i+1)(k)

+ Coef_W_Sel(i)(1) ∗ [TMB_No_Gap(i+1)(k-1) + TMB_No_Gap(i+1)(k+1)]

+ Coef_W_Sel(i)(2) ∗ [TMB_No_Gap(i+1)(k-2) + TMB_No_Gap(i+1)(k+2)] (43)

Else :

◊ TB_No_Gap(i+1)(k) = TMB_No_Gap(i+1)(k) (44)

– If k = 3 OR k = Nb_Mes_Tot - 4, then :

For i = 0 to 1

∗ Miss_Sample_4 = 1 (45)

∗ If { [Ind_Presence(k-1) = -1] OR [Ind_Presence(k+1) = -1]

OR [JMR_TB_Surf_Type_No_Gap(k-1) > 0] OR [JMR_TB_Surf_Type_No_Gap(k+1) > 0]

OR [TA_Qual_Flag_No_Gap(i+1)(k-1) = 1] OR [TA_Qual_Flag_No_Gap(i+1)(k+1) = 1] } then :

◊ Miss_Sample_1 = 1 (46)

Else

◊ Miss_Sample_1 = 0 (47)

∗ If { [Ind_Presence(k-2) = -1] OR [Ind_Presence(k+2) = -1]

OR [JMR_TB_Surf_Type_No_Gap(k-2) > 0] OR [JMR_TB_Surf_Type_No_Gap(k+2) > 0]

OR [TA_Qual_Flag_No_Gap(i+1)(k-2) = 1] OR [TA_Qual_Flag_No_Gap(i+1)(k+2) = 1] } then :

◊ Miss_Sample_2 = 1 (48)

Else

◊ Miss_Sample_2 = 0 (49)

∗ If { [Ind_Presence(k-3) = -1] OR [Ind_Presence(k+3) = -1]

OR [JMR_TB_Surf_Type_No_Gap(k-3) > 0] OR [JMR_TB_Surf_Type_No_Gap(k+3) > 0]

OR [TA_Qual_Flag_No_Gap(i+1)(k-3) = 1] OR [TA_Qual_Flag_No_Gap(i+1)(k+3) = 1] } then :

◊ Miss_Sample_3 = 1 (50)

Else

◊ Miss_Sample_3 = 0 (51)

∗ If Miss_Sample_3 = 1 AND Miss_Sample_2 = 1 AND Miss_Sample_1 = 0, then :

◊ For N = 0 to N_W-1

Coef_W_Sel(i)(N) = Coef_W(7)(i)(N) (52)

◊ TB_No_Gap(i+1)(k) = Coef_W_Sel(i)(0) ∗ TMB_No_Gap(i+1)(k)

+ Coef_W_Sel(i)(1) ∗ [TMB_No_Gap(i+1)(k-1) + TMB_No_Gap(i+1)(k+1)] (53)

Else If Miss_Sample_3 = 1 AND Miss_Sample_2 = 0 AND Miss_Sample_1 = 0, then :

◊ For N = 0 to N_W-1

Coef_W_Sel(i)(N) = Coef_W(6)(i)(N) (54)

◊ TB_No_Gap(i+1)(k) = Coef_W_Sel(i)(0) ∗ TMB_No_Gap(i+1)(k)

+ Coef_W_Sel(i)(1) ∗ [TMB_No_Gap(i+1)(k-1) + TMB_No_Gap(i+1)(k+1)]

+ Coef_W_Sel(i)(2) ∗ [TMB_No_Gap(i+1)(k-2) + TMB_No_Gap(i+1)(k+2)] (55)

Else If Miss_Sample_3 = 0 AND Miss_Sample_2 = 0 AND Miss_Sample_1 = 0, then :

◊ For N = 0 to N_W-1

Coef_W_Sel(i)(N) = Coef_W(1)(i)(N) (56)

◊ TB_No_Gap(i+1)(k) = Coef_W_Sel(i)(0) ∗ TMB_No_Gap(i+1)(k)

+ Coef_W_Sel(i)(1) ∗ [TMB_No_Gap(i+1)(k-1) + TMB_No_Gap(i+1)(k+1)]

+ Coef_W_Sel(i)(2) ∗ [TMB_No_Gap(i+1)(k-2) + TMB_No_Gap(i+1)(k+2)]

+ Coef_W_Sel(i)(3) ∗ [TMB_No_Gap(i+1)(k-3) + TMB_No_Gap(i+1)(k+3)] (57)

Else :

◊ TB_No_Gap(i+1)(k) = TMB_No_Gap(i+1)(k) (58)

– If k > 3 AND k < Nb_Mes_Tot – 4, then :

<u>For i = 0 to 1</u>

∗ If { [Ind_Presence(k-1) = -1] OR [Ind_Presence(k+1) = -1]

OR [JMR_TB_Surf_Type_No_Gap(k-1) > 0] OR [JMR_TB_Surf_Type_No_Gap(k+1) > 0]

OR [TA_Qual_Flag_No_Gap(i+1)(k-1) = 1] OR [TA_Qual_Flag_No_Gap(i+1)(k+1) = 1] } then :

◊ Miss_Sample_1 = 1 (59)

Else

◊ Miss_Sample_1 = 0 (60)

∗ If { [Ind_Presence(k-2) = -1] OR [Ind_Presence(k+2) = -1]

OR [JMR_TB_Surf_Type_No_Gap(k-2) > 0] OR [JMR_TB_Surf_Type_No_Gap(k+2) > 0]

OR [TA_Qual_Flag_No_Gap(i+1)(k-2) = 1] OR [TA_Qual_Flag_No_Gap(i+1)(k+2) = 1] } then :

◊ Miss_Sample_2 = 1 (61)

Else

◊ Miss_Sample_2 = 0 (62)

* If { [Ind_Presence(k-3) = -1] OR [Ind_Presence(k+3) = -1]
  OR [JMR_TB_Surf_Type_No_Gap(k-3) > 0] OR [JMR_TB_Surf_Type_No_Gap(k+3) > 0]
  OR [TA_Qual_Flag_No_Gap(i+1)(k-3) = 1] OR [TA_Qual_Flag_No_Gap(i+1)(k+3) = 1] } then :

  ◊ Miss_Sample_3 = 1 (63)

  Else

  ◊ Miss_Sample_3 = 0 (64)

* If { [Ind_Presence(k-4) = -1] OR [Ind_Presence(k+4) = -1]
  OR [JMR_TB_Surf_Type_No_Gap(k-4) > 0] OR [JMR_TB_Surf_Type_No_Gap(k+4) > 0]
  OR [TA_Qual_Flag_No_Gap(i+1)(k-4) = 1] OR [TA_Qual_Flag_No_Gap(i+1)(k+4) = 1] } then :

  ◊ Miss_Sample_4 = 1 (65)

  Else

  ◊ Miss_Sample_4 = 0 (66)

* If Miss_Sample_4 = 1 AND Miss_Sample_3 = 1 AND Miss_Sample_2 = 1 AND Miss_Sample_1 = 0, then :

  ◊ For N = 0 to N_W-1

  Coef_W_Sel(i)(N) = Coef_W(7)(i)(N) (67)

  Else If Miss_Sample_4 = 1 AND Miss_Sample_3 = 1 AND Miss_Sample_2 = 0 AND Miss_Sample_1 = 0, then :

  ◊ For N = 0 to N_W-1

  Coef_W_Sel(i)(N) = Coef_W(6)(i)(N) (68)

  Else If Miss_Sample_4 = 1 AND Miss_Sample_3 = 0 AND Miss_Sample_2 = 0 AND Miss_Sample_1 = 0, then :

  ◊ For N = 0 to N_W-1

  Coef_W_Sel(i)(N) = Coef_W(1)(i)(N) (69)

  Else If Miss_Sample_4 = 0 AND Miss_Sample_3 = 0 AND Miss_Sample_2 = 0 AND Miss_Sample_1 = 0, then :

  ◊ For N = 0 to N_W-1

  Coef_W_Sel(i)(N) = Coef_W(0)(i)(N) (70)

Else If Miss_Sample_4 = 0 AND Miss_Sample_3 = 1 AND Miss_Sample_2 = 0 AND Miss_Sample_1 = 0, then :

◊ For N = 0 to N_W-1

Coef_W_Sel(i)(N) = Coef_W(2)(i)(N) (71)

Else If Miss_Sample_4 = 0 AND Miss_Sample_3 = 0 AND Miss_Sample_2 = 1 AND Miss_Sample_1 = 0, then :

◊ For N = 0 to N_W-1

Coef_W_Sel(i)(N) = Coef_W(3)(i)(N) (72)

Else If Miss_Sample_4 = 0 AND Miss_Sample_3 = 0 AND Miss_Sample_2 = 0 AND Miss_Sample_1 = 1, then :

◊ For N = 0 to N_W-1

Coef_W_Sel(i)(N) = Coef_W(4)(i)(N) (73)

Else :

◊ Coef_W_Sel(i)(0) = 1 (74)

◊ For N = 1 to N_W - 1

Coef_W_Sel(i)(N) = 0 (75)

∗ TB_No_Gap(i+1)(k) = Coef_W_Sel(i)(0) ∗ TMB_No_Gap(i+1)(k)

+ Coef_W_Sel(i)(1) ∗ [TMB_No_Gap(i+1)(k-1) + TMB_No_Gap(i+1)(k+1)]

+ Coef_W_Sel(i)(2) ∗ [TMB_No_Gap(i+1)(k-2) + TMB_No_Gap(i+1)(k+2)]

+ Coef_W_Sel(i)(3) ∗ [TMB_No_Gap(i+1)(k-3) + TMB_No_Gap(i+1)(k+3)]

+ Coef_W_Sel(i)(4) ∗ [TMB_No_Gap(i+1)(k-4) + TMB_No_Gap(i+1)(k+4)] (76)

– If Ind_Presence(k) = 1, then :

∗ For i = 0 to 2

◊ TB(i)(j1) = TB_No_Gap(i)(k) (77)

∗ j1 = j1 + 1 (78)

ACCURACY

See in RD1 the error analysis due to near beam effects in the TMR brightness temperature calculation.

COMMENTS

The formulation of the JMR brightness temperature algorithm is an improvement of that of the TOPEX Microwave Radiometer (Janssen et al., 1995).

Note that the case "missing sample 0" is not considered here although it is mentioned in Ruf (1999b) and associate weighting coefficients are available. The reason is that if 23.8 GHz or 34 GHz sample is declared "missing" at measurement number k, the 18.7 GHz sample is also missing for the same reason. In such a case, the along track averaging is not performed (i.e., TB(i) = T_{mb}(i), i = 0 to 2).

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Appendix 1

JMR level 1b parameters

The JMR Level 1b parameters corresponding to a 1-s measurement are given hereafter:

- TAI time of the middle of the 1-s averaged JMR measurement, in seconds elapsed since SSALTO internal reference date.
- Latitude of the 1-s averaged JMR measurement
- Longitude of the 1-s averaged JMR measurement
- JMR mode flag (0: JMR mode , 1: JMR mode 2)
- 23.8 GHz channel in operation flag (OC_k) (0 : two channels “off”, 2: channel 2 “on”, 3: channel 3 “on”)
- For i = 1 to 3, j = 1 to 3, j running first:
  - Renormalized reference load count, channel i, noise diode j (R_{ij})
  - Renormalized antenna count with noise injected, channel i, noise diode j (N_{ij})
  - Renormalized antenna count without noise injected, channel i, noise diode j (S_{ij})
- Feedhorn thermistor 1 temperature (T_1)
- Feedhorn thermistor 2 temperature (T_2)
- Noise source 1 temperature (T_3)
- Noise source 2 temperature (T_4)
- For i = 1 to 4:
  - Waveguide thermistor 1 temperature, channel i (T_{i+4})
- For i = 1 to 4:
  - Waveguide thermistor 2 temperature, channel i (T_{i+8})
- For i = 1 to 4:
  - Reference load thermistor temperature, channel i (T_{i+12})
- Temperatures quality flag (TQF_k). This is a 16-bit bitfield (one bit per temperature, $2^0 \rightarrow T_1$
- For i = 1 to 4, j = 1 to 3, j running first:
  - Corrected noise source temperature, channel i, noise diode j (T_{Nij})
- Radiometer counts validity flag (VF_k). This is a 16-bit bitfield. The bits 2^0 to 2^8 correspond to the nine validity flags VF_{ij} , each flag representing one radiometer elementary measurement (made of a set of three counts, from reference load, antenna with noise diode on, and antenna with noise diode off) ($2^0 \rightarrow R_{i1}$, $2^1 \rightarrow N_{i1}$, ..., $2^8 \rightarrow S_{i3}$)
- For i = 1 to 3:
  - Zero offset (Z_i)
- For i = 1 to 3, j = 1 to 3, j running first:
  - System noise temperature ($Tsys_{ij}$)

- For i = 1 to 3, j = 1 to 3, j running first:
  - 330-ms individual antenna temperature, channel i, noise diode j (T_{Aij})
- For i = 1 to 3, j = 1 to 3, j running first:
  - 330-ms individual antenna temperature quality flag, channel i, noise diode j
- For i = 1 to 3:
  - 1-s averaged antenna temperature, channel i (T_{Ai})
- For i = 1 to 3:
  - Number of averaged individual antenna temperatures, channel i
- For i = 1 to 3:
  - 1-s averaged antenna temperature quality flag, channel i
- For i = 1 to 3:
  - Main beam brightness temperature, channel i (T_{mbi})
- Surface type (= 0 if no path delay contamination by land, > 0 otherwise) (JMR_PD_Surf_Type)
- For i = 1 to 3:
  - Along-track averaged brightness temperature, channel i (T_{bi})

Reference document : **SMM-ST-M2-EA-11004-CN**

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