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File: SO-UM-BEC-0007-remapISEA-0.3.pdf , version 1.0

Title: remapISEA User Manual.

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Date: 06/03/2012

remapISEA User Manual.

Abstract: `remapISEA` interpolates some SMOS georeferenced products to be expressed in a regular latitude-longitude grid. The resulting netCDF file contains the desired SMOS products fields expressed as a function of latitude and longitude. This file can also include helpful information about the interpolation process for each interpolated variable: The number of ISEA grid points used to interpolate each resulting value and its variance.

1 Purpose and procedure

The SMOS products are computed and distributed in the ISEA 4H8 and 4H9 grids [DEI04] as well as in 100x100 km and 200x200 km grids. The ISEA family of grids ensures a minimum distortion of the areas in the globe, but the most popular libraries and software still are unable to operate with them. The purpose of *remapISEA* is to provide a fast and confidence tool to convert the SMOS georeferenced products, expressed in the ISEA 4H9, ISEA 4H8, 100x100 km or 200x200 km grids, to the well known rectangular grids based on a regular latitude-longitude mesh.

The procedure used to interpolate SMOS products from their original grid to the desired regular lat-lon grid is described in [MB11]. The method of interpolation is based on average the values contained in each resulting cell but keeping, as much as possible, the statistical significance of the average. This one is accomplished by expanding the distance of influence of each original grid point along longitude as the inverse of the cosine of the latitude.

In case of converting sea products, the corresponding sea identification for each cell is activated internally. In this case, for a given cell, only grid points that belong to seas *connected* to the sea of the cell are included to compute the average in this cell. Table 1 and map 1 show the predefined seas, their limits and the connection among them.

Sea name	Acronym	is connected with...
Atlantic Ocean	ATL	SIN, ANT, ARC
Pacific Ocean	PAC	SIN, ANT, ARC, JAP
North Indic Ocean	NIN	ARA, BEN,SIN
South Indic Ocean	SIN	ATL, PAC, ANT, NIN
Mediterranean Sea	MED	-
Baltic Sea	BAL	-
Black Sea	BLA	-
Red Sea	RED	-
Persian Gulf	PER	-
Hudson Bay	HUD	-
Antarctic Ocean	ANT	ATL, PAC, SIN
Arctic Ocean	ARC	ATL, PAC
Japan Sea	JAP	PAC
Arabian Sea	ARA	NIN
Bengal Sea	BEN	NIN

Table 1: Seas and oceans recognised by *remapISEA*

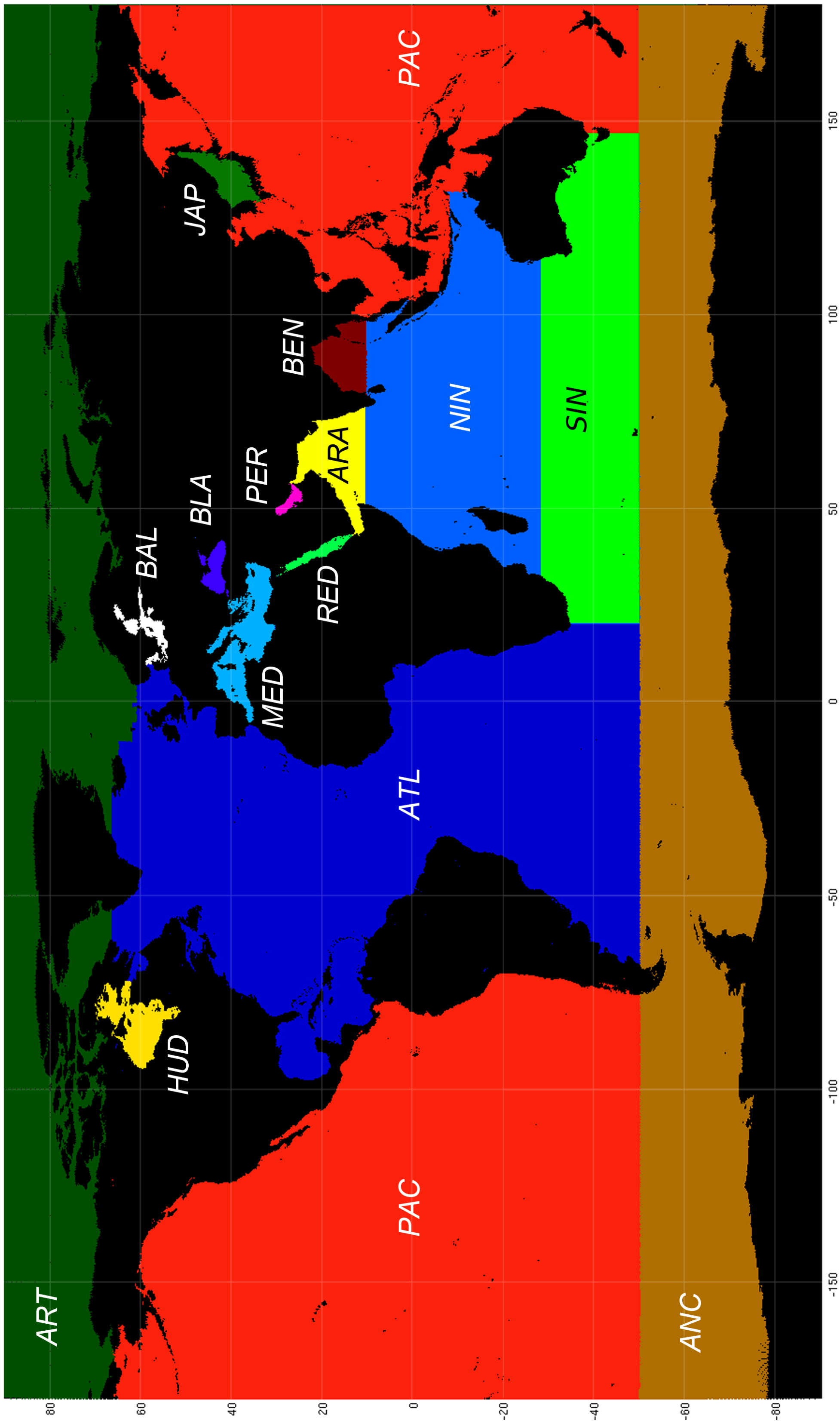


Figure 1: Seas limits and acronyms

2 The products

RemapIsea can convert to lat-lon grid the following SMOS products:

- Browse Brightness Temperature L1 data (BWLF1C/BWSF1C/BWSD1C/BWLD1C)
- Sea Surface Salinity Level 2 User Data Product (OSUDP2)
- Soil Moisture Level 2 User Data Product (SMUDP2)
- Sea Surface Salinity Level 3 User Data Product (M___Oxxxxn $n = \{1, 3, 4, 5\}$)
- Soil Moisture Level 3 User Data Product (M___Lxxxxn $n = \{1, 3, 4, 5\}$)

These ones are georeferenced products and the resulting netCDF file contains dimensions lat (latitude) and lon (longitude). The extracted fields are expressed as functions of these dimensions. The fields that can be extracted from products are the following (see [IND10], [IND11] and [GMV11] for a complete description of these fields):

`Browse Brightness Temperature L1 data (BWLF1C/BWSF1C/BWSD1C/BWLD1C).`

`Altitude`	Local altitude taken from GETASSE30
`BT_Value_HH`	Brightness Temperature. HH polarisation
`BT_Value_VV`	Brightness Temperature. VV polarisation
`BT_Value_ReHV`	Brightness Temperature. Real part of HV polarisation
`BT_Value_ImHV`	Brightness Temperature. Imaginary part of HV polarisation
`Pixel_Radiometric_Accuracy_HH`	Error accuracy measurement in Brightness Temperature. HH polarisation
`Pixel_Radiometric_Accuracy_VV`	Error accuracy measurement in Brightness Temperature. VV polarisation
`Pixel_Radiometric_Accuracy_ReHV`	Error accuracy measurement in Brightness Temperature. Real part of HV polarisation
`Pixel_Radiometric_Accuracy_ImHV`	Error accuracy measurement in Brightness Temperature. Imaginary part of HV polarisation

Sea Surface Salinity Level 2 User Data Product (OSUDP2).

SSS1	Sea Surface Salinity using roughness model 1
Sigma_SSS1	Theoretical uncertainty computed from SSS1
SSS2	Sea Surface Salinity using roughness model 2
Sigma_SSS2	Theoretical uncertainty computed from SSS2
SSS3	Sea Surface Salinity using roughness model 3
Sigma_SSS3	Theoretical uncertainty computed from SSS3
A_card	Effective Acard retrieved with minimalist model
Sigma_Acard	Theoretical uncertainty computed for Acard
WS	10m neutral wind module derived from ECMWF UN10 and VN10
Sigma_WS	Theoretical uncertainty associated to WS
SST	Sea Surface Temperature from ECMWF
Sigma_SST	Theoretical uncertainty associated to SST
Tb_42_5H	Brightness Temperature at surface level for 42.5° incidence angle derived with default forward model and retrieved geophysical parameter. H polarisation
Sigma_Tb_42_5H	Uncertainty for brightness Temperature at surface level for 42.5° incidence angle derived with default forward model and retrieved geophysical parameter. H polarisation
Tb_42_5V	Brightness Temperature at surface level for 42.5° incidence angle derived with default forward model and retrieved geophysical parameter. V polarisation
Sigma_Tb_42_5V	Uncertainty for brightness Temperature at surface level for 42.5° incidence angle derived with default forward model and retrieved geophysical parameter. V polarisation
Tb_42_5X	Brightness Temperature at surface level for 42.5° incidence angle derived with default forward model and retrieved geophysical parameter. X polarisation
Sigma_Tb_42_5X	Uncertainty for brightness Temperature at surface level for 42.5° incidence angle derived with default forward model and retrieved geophysical parameter. X polarisation
Tb_42_5Y	Brightness Temperature at surface level for 42.5° incidence angle derived with default forward model and retrieved geophysical parameter. Y polarisation
Sigma_Tb_42_5Y	Uncertainty for brightness Temperature at surface level for 42.5° incidence angle derived with default forward model and retrieved geophysical parameter. Y polarisation

Soil Moisture Level 2 User Data Product (SMUDP2).

Altitude	Local altitude taken from GETASSE30
Soil_Moisture	Retrieved soil moisture value
Soil_Moisture_DQX	DQX for Soil Moisture
Optical_Thickness_Nad	Nadir optical thickness estimate for vegetation layer
Optical_Thickness_Nad_DQX	DQX for nadir optical thicknes
Surface_Temperature	Surface temperature
Surface_Temperature_DQX	DQX for surface temperature
TTH	Optical thickness coefficient for polarisation H
TTH_DQX	DQX for TTH
RTT	Ratio of optical thickness coefficients TTH/TTV
RTT_DQX	DQX for RTT
Scattering_Albedo_H	Scattering albedo for horizontal polarisation
Scattering_Albedo_H_DQX	DQX for scattering albedo
DIFF_Albedos	Difference of albedos Wh-Wv
DIFF_Albedos_DQX	DQX for difference of albedos
Rougness_Param	Roughness parameter estimate
Rougness_Param_DQX	DQX for roughness parameter estimate
Dielect_Const_MD_RE	Real part of the dielectric constant from MD retrieval
Dielect_Const_MD_RE_DQX	DQX for real part of the dielectric constant from MD retrieval
Dielect_Const_MD_IM	Imaginary part of the dielectric constant from MD retrieval
Dielect_Const_MD_IM_DQX	DQX for imaginary part of the dielectric constant from MD retrieval
Dielect_Const_Non_MD_RE	Real part of the dielectric constant from retrieval models other than MD
Dielect_Const_Non_MD_RE_DQX	DQX for real part of the dielectric constant from retrieval models other than MD
Dielect_Const_Non_MD_IM	Imaginary part of the dielectric constant from retrieval models other than MD
Dielect_Const_Non_MD_IM_DQX	DQX for imaginary part of the dielectric constant from retrieval models other than MD
TB_ASL_Theta_B_H	Surface level brightness temperature computed from forward model. Incidence angle 42.5°. H polarisation
TB_ASL_Theta_B_H_DQX	DQX for surface level brightness temperature computed from forward model. Incidence angle 42.5°. H polarisation
TB_ASL_Theta_B_V	Surface level brightness temperature computed from forward model. Incidence angle 42.5°. V polarisation
TB_ASL_Theta_B_V_DQX	DQX for surface level brightness temperature computed from forward model. Incidence angle 42.5°. V polarisation
TB_TOA_Theta_B_H	Top of atmosphere brightness temperature computed from forward model. Incidence angle 42.5°. H polarisation
TB_TOA_Theta_B_H_DQX	DQX for top of atmosphere brightness temperature computed from forward model. Inc. an. 42.5°. H polarisation
TB_TOA_Theta_B_V	Top of atmosphere brightness temperature computed from forward model. Incidence angle 42.5°. V polarisation
TB_TOA_Theta_B_V_DQX	DQX for top of atmosphere brightness temperature computed from forward model. Inc. an. 42.5°. V polarisation

Sea Surface Salinity Level 3 User Data Product (M___Oxxxxn $n = \{1, 3, 4, 5\}$).

SSS1	Sea Surface salinity using roughness model 1
Var_L2_SSS1	Variance of input SSS1 values contributing to the output SSS1 values
Anomaly_SSS1	Difference between the absolute value and a predefined temporal mean
Error_SSS1	Theoretical uncertainty computed for SSS1
Nr_measurements_SSS1	Number of input SSS1 values contributing to the output SSS1 values
Reference_SSS1	Predefined mean value
Error_Reference_SSS1	Theoretical uncertainty of predefined mean value
SSS2	Sea Surface salinity using roughness model 2
Var_L2_SSS2	Variance of input SSS2 values contributing to the output SSS2 values
Anomaly_SSS2	Difference between the absolute value and a predefined temporal mean
Error_SSS2	Theoretical uncertainty computed for SSS2
Nr_measurements_SSS2	Number of input SSS2 values contributing to the output SSS2 values
Reference_SSS2	Predefined mean value
Error_Reference_SSS2	Theoretical uncertainty of predefined mean value
SSS3	Sea Surface salinity using roughness model 3
Var_L2_SSS3	Variance of input SSS3 values contributing to the output SSS3 values
Anomaly_SSS3	Difference between the absolute value and a predefined temporal mean
Error_SSS3	Theoretical uncertainty computed for SSS3
Nr_measurements_SSS3	Number of input SSS3 values contributing to the output SSS3 values
Reference_SSS3	Predefined mean value
Error_Reference_SSS3	Theoretical uncertainty of predefined mean value
Background	Background Salinity Value
Error_Background	Error of the Background Salinity Value

Soil Moisture Level 3 User Data Product (M__Lxxxxn $n = \{1, 3, 4, 5\}$)	
Altitude	Local altitude taken from GETASSE30
Soil_Moisture	Soil Moisture (SM)
SM_Var_L2	Variance of input SM values contributing to the output value
SM_Anomaly	Difference between the absolute value and a predefined temporal mean
SM_Error	Theoretical uncertainty computed for soil moisture
SM_Reference	Predefined mean value
SM_Error_Reference	Theoretical uncertainty of predefined temporal mean
SM_Nr_measurements	Number of input values contributing to the output values.
Optical_Thickness	Optical Thickness
OT_Var_L2	Variance of input Optical Thickness used values
OT_Anomaly	Optical Thickness anomaly
OT_Error	Optical Thickness uncertainty
OT_Reference	Optical Thickness predefined mean value
OT_Error_Reference	Optical Thickness predefined mean value uncertainty
OT_Nr_measurements	Number of L2 Optical Thickness used values
Vegetation_Water_Content	Vegetation Water Content
Soil_Roughness	Soil Roughness
SR_Var_L2	Variance of L2 SR used values
SR_Error	Soil Roughness uncertainty
SR_Reference	Soil Roughness predefined mean value
SR_Error_Reference	Soil Roughness predefined mean value uncertainty
SR_Nr_measurements	Number of L2 SR used values
Dielectric_Constant_Real	Real part of Dielectric Constant (DCR)
DCR_Var_L2	Variance of L2 DCR used values
DCR_Anomaly	DCR anomaly
DCR_Error	DCR uncertainty
DCR_Reference	DCR predefined mean value
DCR_Error_Reference	Real part of Dielectric Constant predefined mean value uncertainty
DCR_Nr_measurements	Number of L2 DCR used values
Dielectric_Constant_Imag	Imaginary part of Dielectric Constant (DCI)
DCI_Var_L2	Variance of L2 DCI used values
DCI_Anomaly	DCI anomaly
DCI_Error	DCI uncertainty
DCI_Reference	DCI predefined mean value
DCI_Error_Reference	DCI predefined mean value uncertainty
DCI_Nr_measurements	Number of L2 DCI used values

3 Advanced issues

remapISEA takes some decisions automatically. Thus, the values for mesh size provided by the user (`-incLon` and `-incLat`) are slightly modified if, according to the geospatial coverage of the product, they don't generate a grid with an integer number of cells. Another automatic decision concerns to the connection between seas. As have been mentioned before, for a given cell which center belongs to a given sea (see figure 1) only grid points that belongs to a sea connected to this one (see table 1) will contribute to the average value of the cell.

Nevertheless, *remapISEA* admits some additional parameters that allow to the user to improve the resulting remapped data.

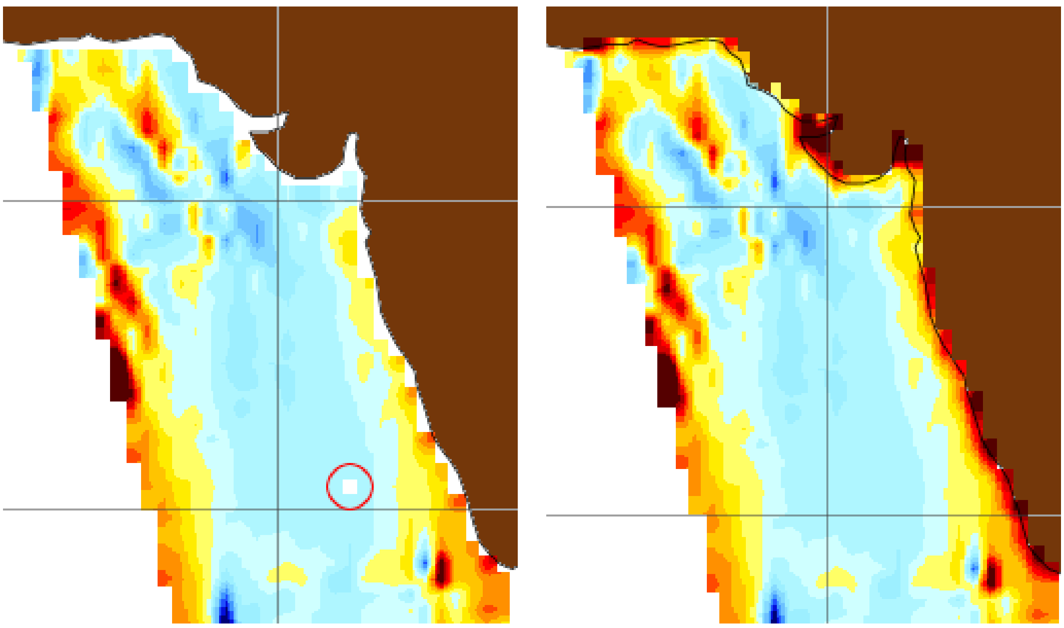
Area of interest

By default, the resulting netCDF file covers the same region as the original product file. Nevertheless, it is possible to change the resulting area defining the desired latitude and longitude ranges by means of `lat` and/or `lon` parameters. These parameters accept two values separated by commas: The first value stands for the initial value of the corresponding coordinate whereas the second one fixes its final value. For instance `-lat=-30,-20 -lon=-10,10` restricts the output netCDF file to the region included in the rectangle defined by $(30S, 10W) - (20S, 10E)$.

Coast

Coast can be adjusted by means of the option `-land`. This parameter establishes the minimum percentage of land contained in a cell to consider this cell as land. For example, `-land=5` means that cells containing a 5% of land or more, are considered as land. Note that, following this definition, sea products will be void if `-land=0` is defined. Therefore, in this case, *remapISEA* stops its execution and warns about the convenience in increasing the value of `land` parameter. The default value of this parameter is 10%.

Note that with low values of `land` some holes can appear in sea products (see figure 2). In the same way, some values can be shown in oceans when converting land products. Don't be surprised, these zones corresponds to small islands that probably will not be drawn in your maps.



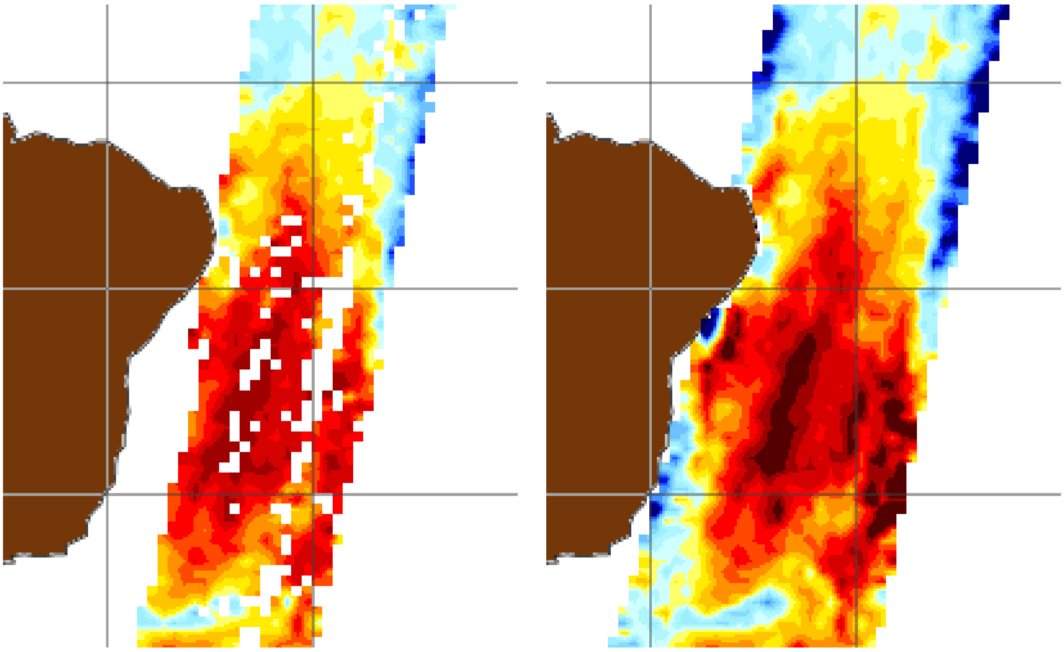
(a) Case with `-land=5`. Note the hole produced by the small island of Bingaram

(b) Case with `-land=95`

Figure 2: Differences in the coast definition

Quality Flags

SMOS products contain quality flags that allows to the user to discard points in which the measures or the computational processing have failed or not provide acceptable values. *remapISEA* is capable to generate remapped products applying these quality flags (figure 3). By default no quality flags are applied and all points included in the original product are used to recalculate the desired fields in the new regular grid. In order to include only the points flagged as acceptable the flag `-qualityFlags` must be included. The name of the original quality flags applied are stored as a global attribute in the resulting netCDF file.



(a) Case with `-qualityFlags`.
Points with no quality are discarded

(b) No quality flags applied.
All points present in the original product are included

Figure 3: Effect of qualityFlag tag

The presence of `-qualityFlags` flag imposes that a given grid point is only taken in consideration if its `failedFlag` value is false. This flag depends on the original SMOS product and it is defined as follows (see [IND10], [IND11] and [GMV11] for additional information):

Browse Brightness Temperature L1 product (BWLF1C/BWSF1C/BWSD1C/BWLD1C)

- `failedFlag` is true if `RFI_strong` or `RFI_point` are true

Sea Surface Salinity Level 2 User Data Product (OSUDP2)

- `failedFlag` is true if `Fg_ctrl_poor_geophysical` or `Fg_ctrl_poor_retrieval` are true

If the product was generated with a version of the L2 processor prior to 3.17 these flags are not available. In this case, the previous definition is also applied but *remapISEA* calculates

Fg_ctrl_poor_geophysical and Fg_ctrl_poor_retrieval following these expressions:

$$\texttt{Fg\_ctrl\_poor\_retrieval} = \texttt{Fg\_ctrl\_range} + \texttt{Fg\_ctrl\_sigma} + \texttt{Fg\_ctrl\_chi2} + \texttt{Fg\_ctrl\_chi2\_P} + \texttt{Fg\_ctrl\_reach\_maxiter} + \texttt{Fg\_ctrl\_marq}$$

$$\texttt{Fg\_ctrl\_poor\_geophysical} = \texttt{Fg\_sc\_TEC\_gradient} + \texttt{Fg\_sc\_suspect\_ice} + \texttt{Fg\_sc\_rain} + \texttt{Fg\_ctrl\_many\_outliers} + \texttt{Fg\_ctrl\_sunglint} + \texttt{Fg\_ctrl\_moonglint} + \texttt{Fg\_ctrl\_gal\_noise} + \texttt{Fg\_ctrl\_gal\_noise\_pol} + \texttt{Fg\_ctrl\_num\_meas\_low}$$

Soil Moisture Level 2 User Data Product (SMUDP2)

- `failedFlag` is true if at least one of the following flags is true: `FL_NO_PROD`, `FL_RANGE` or `FL_Chi2_P`

Sea Surface Salinity Level 3 User Data Product (M___Oxxxxn $n = \{1, 3, 4, 5\}$)

- `failedFlag` is true if `Fg_Failed` is true

Soil Moisture Level 3 User Data Product (M___Lxxxxn $n = \{1, 3, 4, 5\}$)

- `failedFlag` is true if `FL_Failed` is true

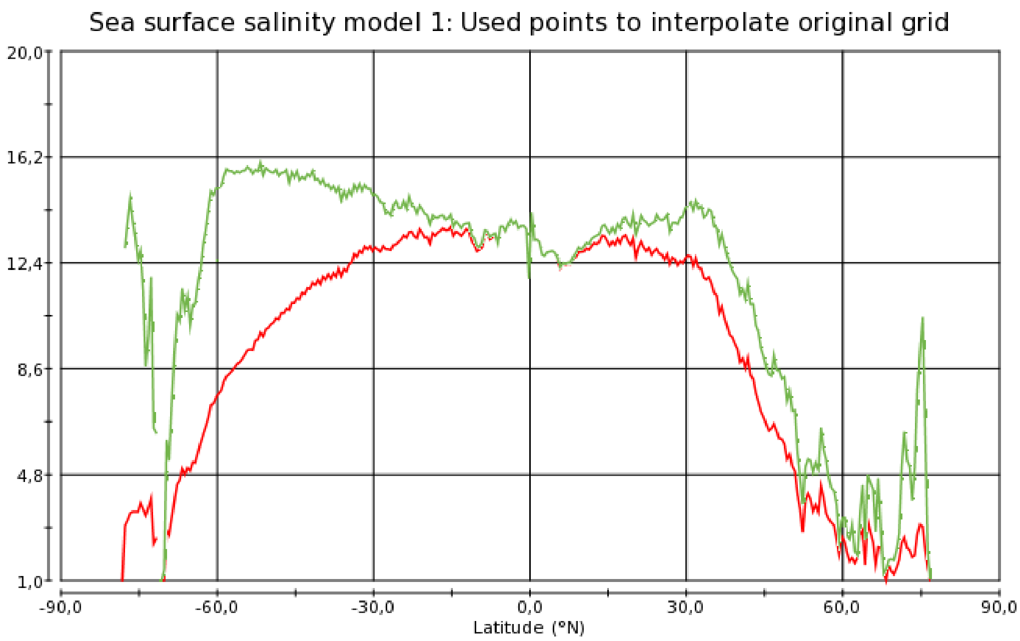


Figure 4: Zonal averages of number of points used to interpolate each cell in a SMOS salinity map (Sea Surface Salinity Level 3 User Data Product remapped with a mesh size of 0.5°). Green line stands for `remapISEA` enhanced usual method whereas red line corresponds to `-nocos` flag activated case.

Statistics

To have statistical information stored in the resulting netCDF file it is necessary to execute *remapISEA* with `-stat` option. This option will include two additional fields for each desired variable: One of them stands for the number of points used in each cell to compute the average whereas the second one stores the value of the variance of grid interpolation for the computed variable. *remapISEA* computes an unbiased estimator of the population variance for interpolation of variable X following the expression:

$$S_X^2 = \frac{\sum_{i=1}^{N} \left(X_i - \overline{X}\right)^2}{N-1}$$

Equal-populated grid

As has been mentioned before, *remapISEA* uses an equal-populated grid method to calculate the average in each cell. This method assumes that the grid points contribute to cells located at a distance which increases with the inverse of the cosinus of the latitude (see [MB11] for additional information). This method allows an equal-populated grid even in zones close to the poles maintaining the statistical significance of the average far from the equatorial zones. Nevertheless this method can be avoided activating the flag `-nocos`. In this case, the grid points that contribute to the value assigned to a cell are only those that are included in the cell itself (see figure 4 to compare both cases in a real interpolation).

4 Command line execution

The program can be executed from the command line or as a part of script. An example of use in Linux (64 and 32 bits) and Mac Intel operating systems is:

```
bin/remapISEA -input=data/SM_OPER_MIR_OSUDP2_20101121T192742_20101121T202143_316_001_1/
SM_OPER_MIR_OSUDP2_20101121T192742_20101121T202143_316_001_1.DBL
-output=salinity.nc -incLon=0.5 -extract=SSS3,WS -land=5 -stat -qualityFlags
```

remapISEA also runs in 32 bit Windows operating systems. In this case, an example of use could be:

```
C:\remapISEA\bin\remapISEA\.exe
-input=C:\data\SM_OPER_MIR_OSUDP2_20101121T192742_20101121T202143_316_001_1\
SM_OPER_MIR_OSUDP2_20101121T192742_20101121T202143_316_001_1.DBL
-output=salinity.nc -incLon=0.5 -extract=SSS3,WS -land=5 -stat -qualityFlags
```

The binary file to be executed is stored in the *bin* folder. The folder structure (*bin* and *seasmask*) must remain unchanged to ensure a correct execution of the program.

Some mandatory parameters are needed to get a correct execution of *remapISEA*: .

MANDATORY PARAMETERS

-input= `Product DBL file`
Data Block file of the product to be remapped.

-output= `netCDF file`
Location and name of the resulting netCDF file

-extract= `comma separated fields`
List of fields to be extracted from the product file (see tables of section 2)

and the command line must include at least one of the following:

-incLon= `degrees`
: Mesh size for longitude in the resulting grid. Minimum allowable value depends on the original grid resolution (0.1 for ISEA 4H9, 0.2 for ISEA 4H8, 1 for 100x100 km and 2 for 200x200 km). Default value: The value indicated by `-incLat` parameter.

-incLat= `degrees`
: Mesh size for latitude in the resulting grid. Minimum allowable values have been indicated above. Default value: The value indicated by `-incLon` parameter

OPTIONAL PARAMETERS

-lat= `degrees,degrees`
: Comma separated values limiting the desired region latitude. If the first one is omitted -90 is assumed as default value. If the second one is omitted 90 is assumed. If this parameter is not included the latitude range coincides with the given by the original product.

-lon= `degrees,degrees`
: Comma separated values limiting the desired region longitude. If the first one is omitted -180 is assumed as default value. If the second one is omitted 180 is assumed. If this parameter is not included the longitude range coincides with the given by the original product.

-land= `percent`
: Maximum land percentage in a sea cell.Cells with a land percentage higher than the by this parameter are treated as land. Its default value is 10

OPTIONAL FLAGS

-stat
: Computes the variance and the number of points used to interpolate each extracted field

-qualityFlags
: Quality flags for the corresponding product are applied and only measures that pass the quality test are considered

-nocos
: A grid point only contributes to one cell, independently from its latitude.

-q
: Quiet mode. remapISEA does not send any information to the standard output

-h
: Shows quick help

-v
: Shows version information

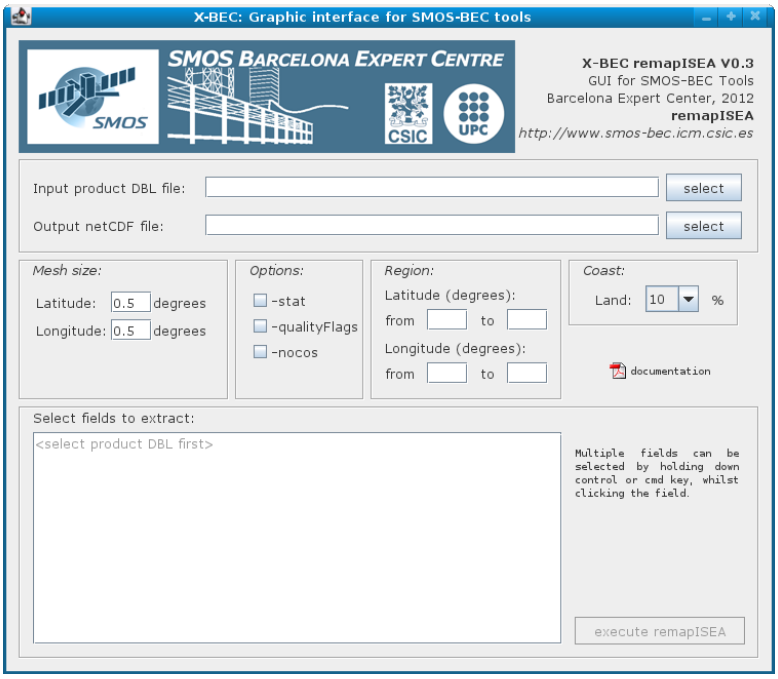


Figure 5: XBEC interface for remapISEA

5 XBEC GUI

In order to provide a friendly execution environment, *remapISEA* is accompanied by a GUI (Graphical User Interface). This GUI is known as *XBEC* and it has been written in java allowing to be executed from a wide variety of operating systems.

The *XBEC* GUI can be started in Linux systems by executing the shell script named `remapISEA` that is located in the main folder of the application. In 32 bit Windows systems and Mac Intel systems the graphical interface can be initiated by double clicking on the XBEC java application. The apperance of *XBEC* is shown in figure 5.

The list of allowed fields that can be extracted is filled once the input product DBL file is provided. This list is shown in the text area located at the bottom of the panel. In some operating systems the DBL file can be dragged into the corresponding text field or selected from conventional files browsing. To activate the `execute remapISEA` button it is necessary to give an output netCDF file name and to select at least one field to extract. Once the `execute remapISEA` button is pressed the conversion starts, the button is deactivated and the message `Processing data...` appears behind the button. This message disappears when the resulting file is created.

The mesh size in the resulting grid is assumed as 0.5° but it can be changed to any value within the allowable interval $[\alpha_{min}, 90.0)$ where $\alpha_{min} = 0.1°$ for ISEA 4H9, $\alpha_{min} = 0.2°$ for ISEA 4H8, $\alpha_{min} = 1.0°$ for 100x100 km and $\alpha_{min} = 2.0°$ for 200x200 km). Also the maximum percentage in a sea cell is assumed with its default value (10%) but it can be changed from 0% to 100% in intervals of 5%

The optional flags `-stat`, `-qualityFlags` and `-nocos` described in the previous section can be activated by means of *XBEC* panel. Note that if the GUI is used, *remapISEA* will show error messages but not information messages.

References

[DEI04] DEIMOS. *SMOS L1 Processor Discrete Global Grids Document SMOS-DMS-TN-5200*, June 2004. version 1.4.

[GMV11] GMV. *SMOS CP34 Product Output Format Definition CP34-PS-0001*, Sep 2011. version 2.9d.

[IND10] INDRA. *SMOS Level 1 and Auxiliary Data Products Specifications SO-TN-IDR-GS-0005*, Dec 2010. version 5.18.

[IND11] INDRA. *SMOS Level 2 and Auxiliary Data Products Specifications SO-TN-IDR-GS-0006*, May 2011. version 6.0.

[MB11] J. Martínez and J. Ballabrera. Remapping isea grid to lat-lon grid in smos context. Technical report, BEC-TN.2011.02.10 SMOS Barcelona Expert Centre, 2011.