Ocean and Sea Ice SAF

Product Users Manual for the OSI SAF 50GHz sea ice emissivity

OSI-404

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Glossary

AMSU - Advanced Microwave Sounding Unit

ATBD - Algorithm Theoretical Basis Document

CDOP – Continuous Development and Operations Phase

DMI – Danish Meteorological Institute

EUMETSAT - European Organisation for the Exploitation of Meteorological Satellites

FOV - Field of View

NWP - Numerical Weather Prediction

OSISAF – Ocean and Sea Ice Satellite Application Facilities

SSMIS - Special Sensor Microwave Imager/Sounder

1.0 Introduction

1.1 The Ocean and Sea Ice Satellite Application Facility

The Ocean and Sea Ice Satellite Application Facility, OSI SAF, is a EUMETSAT project that started in 1997. The OSI SAF is a part of the EUMETSAT distributed ground segment for production of operational near real time value added satellite products. The OSI SAF delivers a range of air-sea interface products, namely: sea ice characteristics, sea surface temperature, radiative fluxes and wind. The sea ice products are sea ice concentration, sea ice edge, sea ice type, sea ice drift and sea ice emissivity and soon sea ice surface temperature.

The OSI SAF project is managed by CMS, Meteo-France. The sea ice products are produced at the OSI SAF High Latitude processing facility under the responsibility of the Norwegian Meteorological Institute, operated jointly by the Norwegian and Danish Meteorological Institutes.

1.2 Reference documents and copyright

This emissivity product fulfils the requirement OSI-PRD-PRO-205 in the OSI SAF Product Requirement Document [RD.1]. No validation results are presented in this document. The validation results are presented in a separate validation report [RD.2]. The algorithm is presented in the Algorithm Theoretical Basis Document [RD.3].

The OSI SAF emissivity data is produced under responsibility of Norwegian Meteorological Institute and Danish Meteorological Institute. The ownership and copyrights of the data set belongs to EUMETSAT. The data is distributed freely, but EUMETSAT must be acknowledged when using the data. EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used. User feed-back to the OSI SAF project team is highly valued. The comments we get from our users is important argumentation when defining development activities and updates. We urge anyone to use the data and provide feed-back.

1.3 The 50GHz emissivity model

The microwave sea ice surface emissivity is relevant when solving the radiative transfer equation for top of the atmosphere up-welling Earth emission measured by satellite radiometers such as SSMIS and AMSU. The sea ice surface emissivity estimate presented here is representative for the near 50 GHz channels used for temperature sounding of the atmosphere. The emissivity is combined with the surface effective temperature, sometimes called the skin temperature, in the radiative transfer equation. Model simulations indicate that the snow-ice interface temperature or alternatively the 6 GHz brightness temperature is a closer proxy for the 50 GHz effective temperature than the snow surface or air temperature (Tonboe et al., 2011). We do not provide the effective temperature as part of this product. The emissivity estimate is given for both sea ice and ice shelves in the Arctic and around Antarctica.

The microwave emissivity near 50 GHz is characterised here using a model where the emissivity at 50º is a function of the spectral gradient and the polarisation ratio measured at the neighbouring atmospheric window frequencies at 18 and 36 GHz. The PR and GR can be measured with SSM/I, AMSR and SSMIS sensors currently in orbit. Output from a combined 1D thermodynamic and a microwave emission model is used for generating the relationships between the emission at 50 GHz at 50º of incidence and the 19 GHz and 37 GHz simulated brightness temperatures. The approaches of both the community model (Drusch et al., 2009) and Mätzler's model (Mätzler, 2005) find solutions between two extreme cases. Similarly this model can attain solutions in between: 1) perfectly diffuse emission where there is no angular dependence and no polarisation difference similar to the model used in Heygster et al. (2009), and 2) the specular reflection with the angular dependence and the polarisation determined by the Fresnel reflection coefficients and a surface permittivity of 3.5 which is typical for sea ice. The model is expected to be valid for incidence angles between 0º and 60º and cases in between the two specular and diffuse extremes.

Brightness temperatures are measured at window frequencies where the sensitivity to the atmosphere is minimized e.g. at 19 and 37 GHz. The spectral gradient (GR1937) is given by the following equation:

$$GR1937 = \frac{T_{v37} - T_{v19}}{T_{v37} + T_{v19}} \quad (1).$$

The normalisation reduces the GR sensitivity to effective temperature, and ice concentration algorithms use it to correct for first- and multiyear ice types with different volume scattering magnitudes (Comiso et al., 1997). Though the sensitivity to temperature (Teff) is reduced in GR there is still a reminiscent due to different microwave penetration at 19 and 37 GHz across the temperature gradient in snow and ice.

The polarisation ratio at 37 GHz, PR37, is given by the difference over the sum of the Tv37 and Th37 brightness temperatures at 37GHz, i.e.

$$PR37 = \frac{T_{v37} - T_{h37}}{T_{v37} + T_{h37}} \quad (2).$$

Also for the polarisation ratio the temperature dependence is minimized by the normalisation.

1.4 Product overview

Because of the relationship between the PR37 and PR50, R is given as a function of PR36. For R = 0 the scattering at the surface is totally diffuse and for R = 1 the scattering is specular. R equals 1 when PR36 = 0.11 and the sea ice permittivity is 3.5. A 3rd degree polynomial is fitted to the simulated data (Tonboe, 2010) using least squares for the northern and southern hemisphere, i.e.

North $R(PR36) = 0.000215 + 10.238PR36 - 11.492PR36^2 + 9.286PR36^3$ (3a)

South $R(PR36) = 0.000471 + 10.22PR36 - 11.02PR36^2 + 5.93PR36^3$ (3b).

and S as a function of GR1836 using least squares and a linear fit:

North $S(GR1836) = 3.185GR1836 + 0.978$ (4a)

South $S(GR1836) = 3.13GR936 + 0.96$ (4b).

The daily grid files contain the R and S coefficient which are input to the model for the emissivity (See the RD.3):

$ev(\theta) = S(1 - Rrv(\theta))$ (5),

$eh(\theta) = S(1 - Rrh(\theta))$ (6),

where rv, rh are the Fresnel reflection coefficients (permittivity = 3.5+0.0i) and theta is the incidence angle.

In addition there is the nadir emissivity, and ev at 50º incidence angle for channels 1-5 on SSMIS (1: 50.3 GHz, 2: 52.8 GHz, 3: 53.596 GHz, 4: 54.40 GHz, 5: 55.50 GHz). If it is sea ice we provide the coefficients and the emissivity estimates if the data point is within the valid range of the model. Each of these two options for sea ice is flagged. The flag indicates the surface type when it is not sea ice. The input to the model is Tb19v, Tb37v, and Tb37h SSM/I or SSMIS brightness temperatures and we use no auxiliary data in the processing except the flags in the swath files.

Summary of the 11 processing steps:

1. The NetCDF format swath data are read.
2. The 37 GHz channels are re-sampled to 19 GHz resolution using a Gaussian weighting function and a circular 'field of view' of 56.5 km.
3. Realistic brightness temperatures for sea ice are selected for further processing:
   160.0 K < Tb19v < 273.15 K
   130.0 K < Tb37v < 273.15 K
   100.0 K < Tb37h < 273.15 K
   (Tb37v - Tb19v) / (Tb37v + Tb19v) < 0.05
   (Tb37v - Tb37h) / (Tb37v + Tb37h) < 0.15
4. Each of the two hemispheres is selected using each of the data point latitudes.
5. The R, S, ev and nadir e are estimated using the model.
6. Data-points where the model yields false emissivities at any angle exceeding 1 or below 0 are excluded and flagged.
7. Each of the new data fields (R, S, ev, nadir e and flags) are appended to the swath file as super-files and written in NetCDF format.
8. The parameters in the swath file are re-sampled using a nearest neighbour re-sampler.
9. The data are plotted as png-quick looks.
10. The re-sampled data are written as NetCDF format files.
11. The product ev is validated against emissivities derived indepently using SSMIS data, NWP data and and a radiative transfer model for the atmosphere.

The data can be retrieved at osisaf.met.no and via EUMETCast.

1.4.1 The effective temperature

The up-welling brightness temperature from the ice surface is the multiplication of the emissivity and the effective temperature. Because of significant penetration through the snow and to some extent the ice the surface temperature which is retrievable in NWP models can be different from the effective temperature. Model simulations indicate that the effective temperature is closer to the snow ice interface temperature than the snow surface temperature (Tonboe et al., 2011). Assuming a simple two-layer model with a homogeneous snow layer on top of homogeneous level ice in thermal equilibrium the snow ice interface temperature can be estimated by:

$$Tsi = \frac{Tw + fTs}{f + 1}, \quad f = \frac{ks * di}{ki * ds} \qquad (7)$$

where Tw is the water temperature (271.35K), Ts is the snow surface temperature, ks is the snow thermal conductivity (0.3W/mK), ki is the ice thermal conductivity (2.1W/mK), ds and di are the thickness of snow and ice respectively.

The importance of the effective temperature is described in English (2008).

2.0 Processing of the emissivity product

2.1 Input data and pre-processing

The input data to the algorithm is an internal conversion of the SSMIS SDR BUFR format to NetCDF. The BUFR format files are described in Patterson (2010). The NetCDF format swath files contain the parameters included in the Table 1. The brightness temperatures are from the "environmental" channels on SSMIS i.e. channel 12 (Tb19h), 13 (Tb19v), 14 (Tb22v), 15 (Tb37h), and 16 (Tb37v). We use channel 13, 15, and 16.

Parameter name	Parameter description
lat_l	latitude 1/100 deg.
lon_l	longitude 1/100 deg.
surf_l	surface flag: 0=no ice, 3=ice, 5=ocean, 6=coast.
tb19v	the brightness temperature at 19GHz vertical polarisation 1/100K
tb37v	the brightness temperature at 37GHz vertical polarisation 1/100K
tb37h	the brightness temperature at 37GHz horizontal polarisation 1/100K

Table 1. The parameter name and parameter description in the input NetCDF format SSMIS swath file.

2.2 Resolution matching

The resolution (integrated field of view) of the 19GHz channels is an ellipse about 45 x 68 km and the 37 GHz channels have a resolution about 3.5 times higher i.e. 24 x 36 km. The 19 and 37 GHz channels are combined in the emissivity model and in order to reduce noise near emissivity gradients the 37 GHz channels are re-sampled to the coarser 19 GHz resolution. The re-sampling is done using a Gaussian weighting function with a standard deviation of 56.5 km which is the 45 km and 68 km ellipse axis mean. The re-sampling is done using pyresample (http://code.google.com/p/pyresample/).

2.3 Processing methodology

First the brightness temperatures are filtered, roughly, selecting those realistic for sea ice. Then the algorithm coefficients and the emissivity are computed and filtered for values outside of model range.

Realistic ranges for sea ice brightness temperatures are selected using:

$$160.0\ K < Tb19v < 273.15\ K$$
$$130.0\ K < Tb37v < 273.15\ K$$
$$100.0\ K < Tb37h < 273.15\ K$$
$$(Tb37v - Tb19v) / (Tb37v + Tb19v) < 0.05$$
$$(Tb37v - Tb37h) / (Tb37v + Tb37h) < 0.15$$

If any of these conditions are not satisfied the data point is not processed and the data point is flagged (flag=1).

The algorithm coefficients for the southern and northern hemisphere are different. Therefore each of the two hemispheres is selected using the data point latitude. Then the R, S, ev at 50º incidence angle and the nadir emissivity are estimated using the model. The R and S coefficients are input to the model for estimating the emissivity at angles between 0 and 60º and at both vertical and horizontal polarisation using equation 1 and 2. The derivation of R and S is described in the ATBD [RD.3].

Data points where the model yields false emissivities for both ev and eh at any angle between 0 and 90º exceeding 1 or below 0 violates model validity and they are excluded from the processing and flagged (flag=1).

The emissivity at vertical polarisation and at 50º incidence angle given as a parameter in the output file is compatible with the configuration of SSMIS. The nadir emissivity estimate given in the output file is compatible with the AMSU configuration in the central part of the swath. The AMSU emissivity near the edges of the swath will be lower than the nadir emissivity.

2.4 Validation

The emissivity product parameter ev is compared to independent estimates of the emissivity derived using SSMIS and ECMWF data as input to a radiative transfer model. The validation procedure together with the validation results is described in the validation report.

3.0 Output data

The output daily mean is provided on the 25 km grid point spacing EASE grid in NetCDF format CF 1.4. The re-sampling is done using pyresample with nearest neighbour. In addition there are quick-looks in PNG format for each of the parameters except latitude, longitude and flags. The grid point spacing is not indicating the real spatial resolution of the product which is about 50 km.

Parameter name	Parameter description
Lat	float, latitude of grid point in 1/100 deg. [-90; 90]
Lon	float, longitude of grid point in 1/100 deg. [-180; 180]
R	float, the R coefficient describing the polarisation [0; 1]
S	float, the S coefficient describing the nadir emissivity [0; 1]
Ev	float, the 50GHz vertically polarised emissivity at 50 deg incidence angle
E	float, the 50GHz nadir emissivity [0; 1]
Flag	int, 0 = no ice, 1=model not valid, 2=valid parameter, 3=sea ice and ice shelves, 5=ocean, 6=coast.

Table 2 The parameters in the NetCDF output file

Figures 1-4 show examples of the emissivity coefficents and the emissivity for three swaths on 09. Nov. 2011.

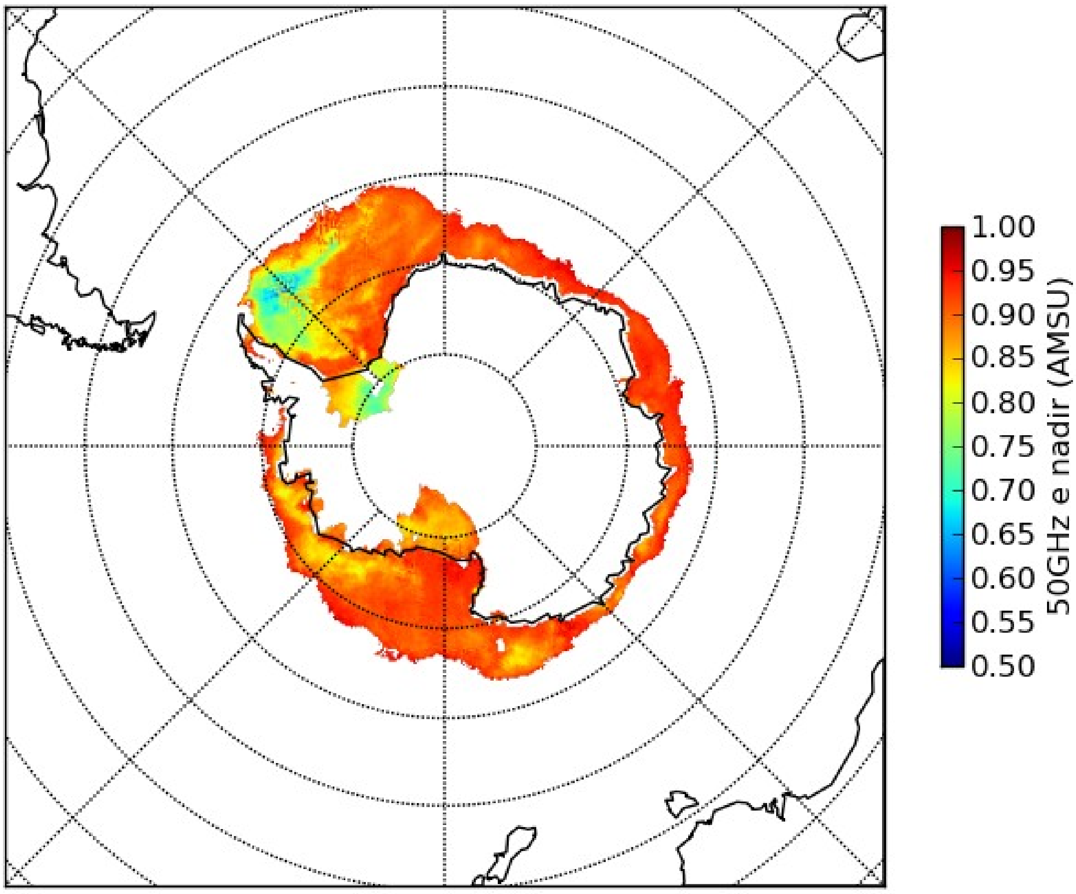

Figure 1. The nadir 50GHz emissivity of ice shelves and sea ice on 21. May 2012.

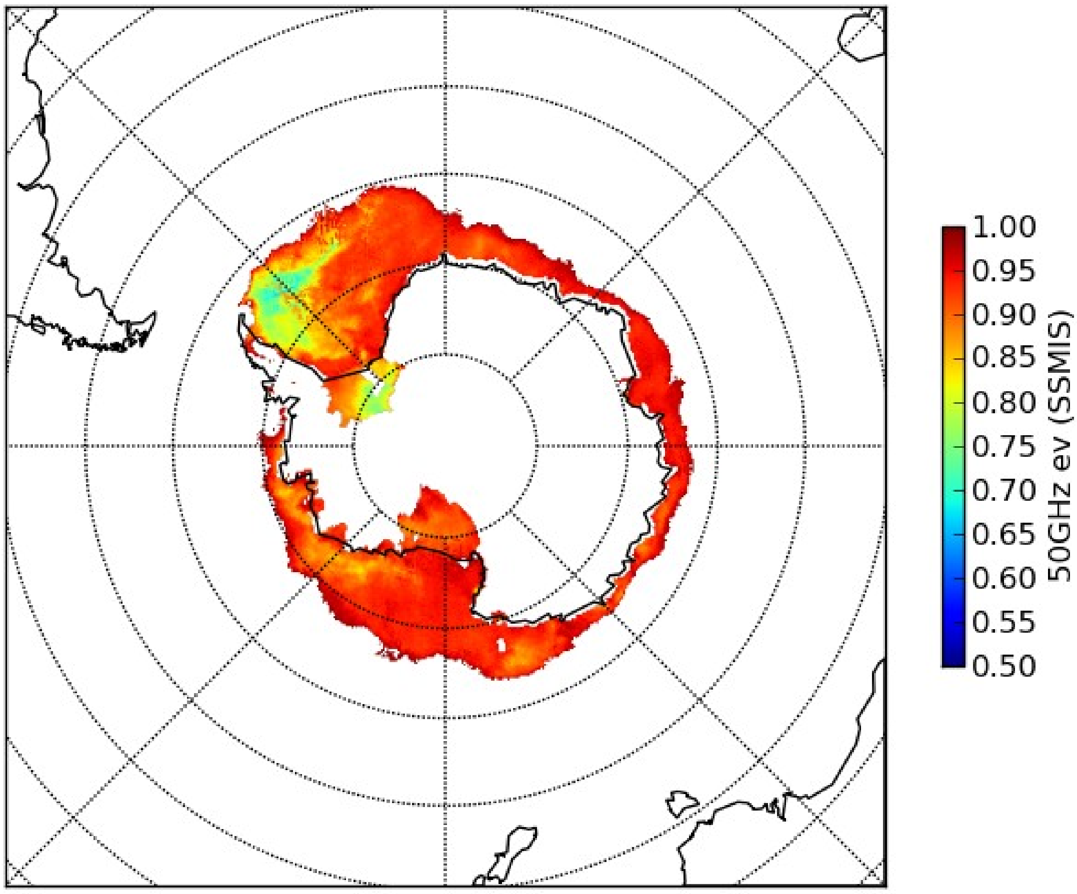

Figure 2. The 50GHz ev at 50º incidence angle 21. May 2012.

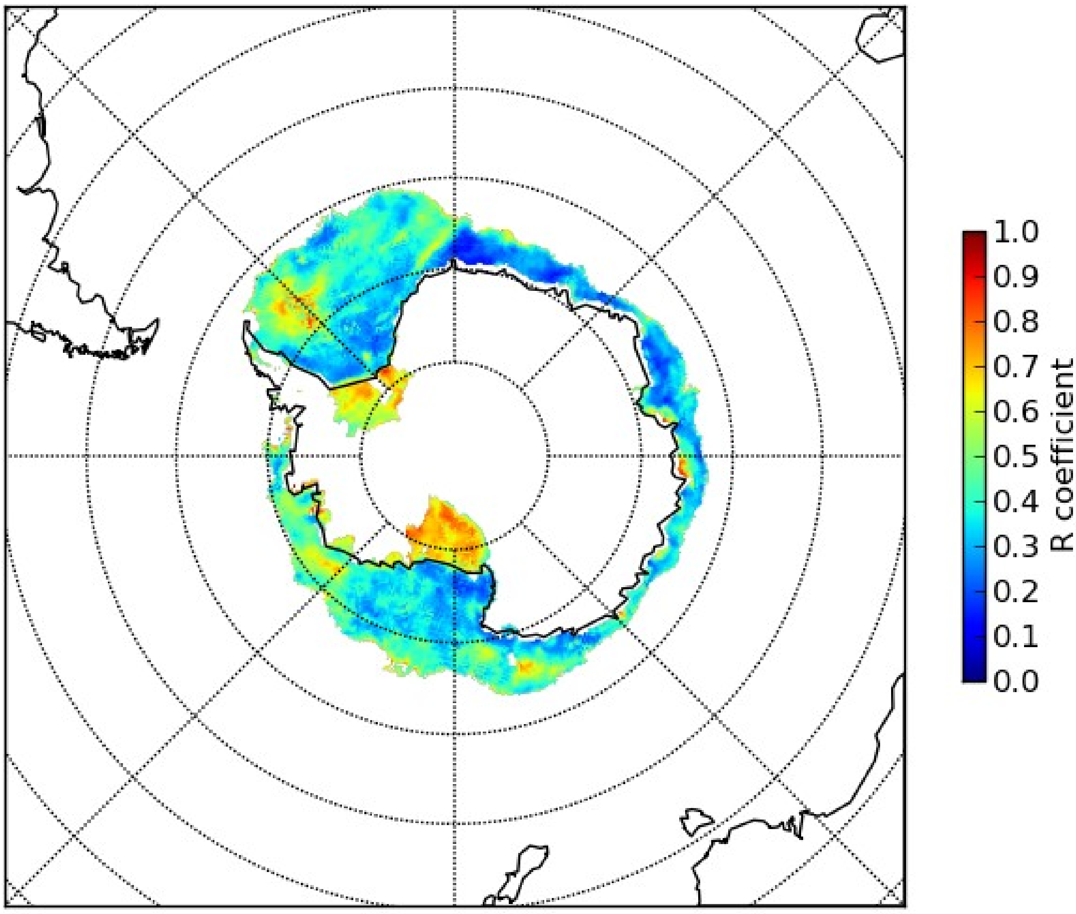

Figure 3. The S coefficient 21. May 2012.

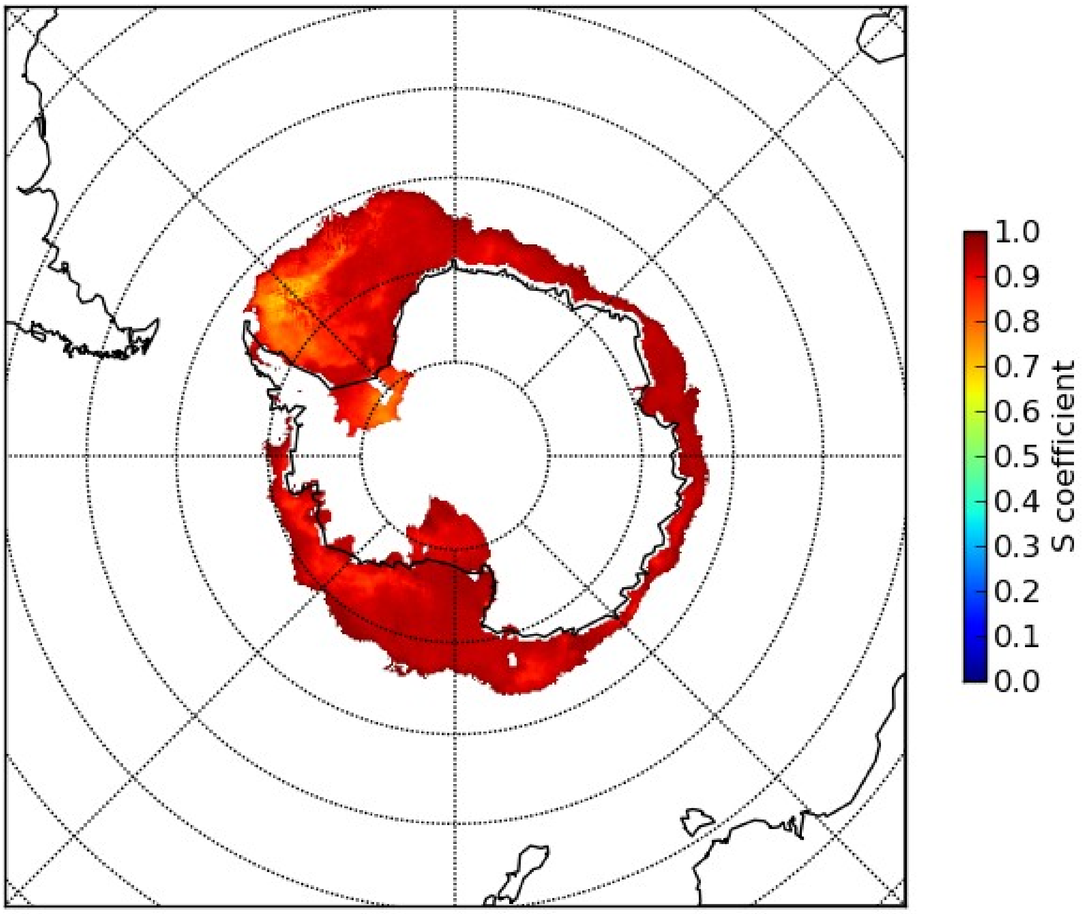

Figure 4. The R coefficient 21. May 2012.

3.1 Grid specification

The emissivity product is available on one projection with one product for each hemisphere. The projection used is a Lambert Azimuthal Equal Area projection with grid a resolution of about 25 km. The Lambert grid is also called the EASE grid, and it is used by NSIDC for several of their sea ice products. More documentation about the EASE grid can be found on their web site: http://nsidc.org/data/ease/.
The details of the grid definition is given below. Projection definitions in the form of PROJ-4 initialization strings are also given (see [http://www.remotesensing.org/proj] for details).

Geographical definition for the EASE 25km km grid, Northern and Southern Hemisphere

Projection:	Lambert Azimuthal Equal Area
Size:	425 columns, 425 lines
Central Meridian:	0°
Radius of Earth:	Spherical: 6371228.0 m
PROJ-4 string:	NH: +proj=laea +R=6371228.0 +lat_0=90 +lon_0=0
	SH: +proj=laea +R=6371228.0 +lat_0=-90 +lon_0=0

3.2 File name convention and availability

The daily re-sampled NetCDF files ate named according to the following convention:
ice_emis_nh_ease-250_ssmis_<date12>.nc
ice_emis_sh_ease-250_ssmis_<date12>.nc
where <date12> is the date: YYYYMMDDHHMM, e.g. 201112091200.

The products are available by FTP and will be through EUMETCast in spring 2012. Products from the last month can be collected at the OSI SAF Sea Ice FTP server [ftp://osisaf.met.no/prod/ice/emis], and archived products can be found at [ftp://osisaf.met.no/archive/ice/emis].

References

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Appendix A

Example of the NetCDF header:

```
netcdf ssmi_f17_201204241200_ease_north {
dimensions:
        xc = 425 ;
        yc = 425 ;
variables:
        int lambert_azimuthal_equal_area ;
                lambert_azimuthal_equal_area:grid_mapping_name =
"lambert_azimuthal_equal_area" ;

        lambert_azimuthal_equal_area:longitude_of_projection_origin = 0 ;

        lambert_azimuthal_equal_area:latitude_of_projection_origin = 90 ;
                lambert_azimuthal_equal_area:semi_major_axis = 6371228. ;
                lambert_azimuthal_equal_area:inverse_flattening = 0 ;
        double xc(xc) ;
                xc:long_name = "x-coordinate in Cartesian system" ;
                xc:standard_name = "projection_x_coordinate" ;
                xc:units = "m" ;
        double yc(yc) ;
                yc:long_name = "y-coordinate in Cartesian system" ;
                yc:standard_name = "projection_y_coordinate" ;
                yc:units = "m" ;
```

```
        float lon(yc, xc) ;
                lon:long_name = "longitude coordinate" ;
                lon:standard_name = "longitude" ;
                lon:units = "degrees_east" ;
        float lat(yc, xc) ;
                lat:long_name = "latitude coordinate" ;
                lat:standard_name = "latitude" ;
                lat:units = "degrees_north" ;
        float R(yc, xc) ;
                R:_FillValue = -1.e+10f ;
                R:units = "1" ;
                R:long_name = "R coefficient" ;
                R:coordinates = "lat lon" ;
                R:grid_mapping = "lambert_azimuthal_equal_area" ;
        float S(yc, xc) ;
                S:_FillValue = -1.e+10f ;
                S:units = "1" ;
                S:long_name = "S coefficient" ;
                S:coordinates = "lat lon" ;
                S:grid_mapping = "lambert_azimuthal_equal_area" ;
        float ev(yc, xc) ;
                ev:_FillValue = -1.e+10f ;
                ev:units = "1" ;
                ev:long_name = "surface emissivity at 50GHz ev (SSMIS)" ;
                ev:standard_name = "surface_microwave_emissivity" ;
                ev:coordinates = "lat lon" ;
                ev:grid_mapping = "lambert_azimuthal_equal_area" ;
        float e(yc, xc) ;
                e:_FillValue = -1.e+10f ;
                e:units = "1" ;
                e:long_name = "surface emissivity at 50GHz e (AMSU)" ;
                e:standard_name = "surface_microwave_emissivity" ;
                e:coordinates = "lat lon" ;
                e:grid_mapping = "lambert_azimuthal_equal_area" ;
        short flag(yc, xc) ;
                flag:_FillValue = -32767s ;
                flag:units = "1" ;
                flag:long_name = "surface emissivity quality flag" ;
                flag:coordinates = "lat lon" ;
                flag:grid_mapping = "lambert_azimuthal_equal_area" ;

// global attributes:
                :Conventions = "CF-1.5" ;
                :title = "The near 50GHz sea ice emissivity" ;
                :institution = "The EUMETSAT Ocean and Sea Ice Satellite
Application Facility" ;
```