The EUMETSAT
Network of
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OSI SAF
Ocean and Sea Ice

Product User Manual for the Atlantic High Latitude Radiative Fluxes

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Version 1.1

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Document Change Record

Version	Date	Change	Description	Responsible
0.1	25 July 2002	Major	First draft describing contents of SSI processing, no information on DLI is given yet.	Øystein Godøy
0.2	6 March 2004	Major	Added description of DLI products and general update of quality flags etc.	Øystein Godøy
0.3	17 February 2005	Minor	General update of the whole document to ensure consistency.	Øystein Godøy
1.0	14 April 2011	Major	Preparation for separate dissemination of High Latitude Fluxes from the OSISAF High Latitude Centre.	Øystein Godøy
1.1	28.11.2011	Minor	Correction of typos, changed name of EUMETCast files	Øystein Godøy, Steinar Eastwood

Table of Contents

1 Introduction

1.1 Scope

This manual presents the High Latitude (HL) Radiative Flux products from the Ocean and Sea Ice Satellite Application Facility (OSISAF) High Latitude (HL) Centre. The intended audience is users of EUMETSAT OSISAF HL Radiative Flux products.

1.2 Overview

The OSISAF HL centre is producing on a operational or pre-operational basis a range of air-sea interface products, namely: sea ice characteristics, Sea Surface Temperatures (SST) and radiative fluxes (Surface Solar Irradiance (SSI) and Downward Longwave Irradiance (DLI)).

Daily SSI and DLI products are available within 2 hours after the last satellite data acquisition on a 5 km Polar Stereographic grid.

Previously the daily High Latitude (HL) Radiative Flux products were input to the daily Merged Atlantic Products maintained by Meteo-France. HL Radiative Flux products are currently derived from NOAA polar orbiter data, but utilisation of EPS/METOP are in progress as part of a major upgrade of the processing chain.

OSISAF HL Radiative Flux products are processed for each satellite passage available, but the deliverable is a daily estimate. For each satellite passage a high resolution product at a nominal horizontal resolution of 1.5km is derived in tiles. This is resampled into a single passage 10km product which is input to the daily product.

OSISAF HL Radiative Flux products are available in NCSA HDF5 and WMO GRIB format through the METNO server (ftp://osisaf.met.no/). See also http://osisaf.met.no/ for real time quick look samples of the products and updated product information.

This document is one of the product manuals dedicated to the OSISAF product users. It describes the High Latitude part of the MAP Radiative Flux products, covering the intermediate single satellite pass products and the daily HL Radiative Flux products.

Section 2 presents a brief description of the algorithms and section 3 gives an overview of the data processing. Section 4 provides detailed information on the file content and format.

1.3 Glossary

Acronym	Description
AVHRR	Adanced Very High Resolution Radiometer
CMS	Centre de Méteorologie Spatiale
DMI	Danish Meteorological Institute
OSISAF	Ocean and Sea Ice SAF
GRIB	Gridded Binary Format
HDF	Hierarchical Data Format
HIRLAM	High Resolution Limited Area Model
HL	High Latitudes
LML	Low and Mid Latitudes

Acronym	Description
NOAA	National Oceanic and Atmospheric Administration
NMI	Norwegian Meteorological Institute
RMDCN	Regional Meteorological Data Communication Network
SAF	Satellite Application Facility
SMHI	Swedish Meteorological and Hydrological Institute
TBC	To Be Confirmed
TBD	To Be Determined
TBW	To Be Written
USGS	US Geological Survey

1.4 Applicable documents

[RD.1] OSI SAF High Latitude SST Product Manual v1.2, October 2002, Norwegian Meteorological, Institute, Oslo, Norway.

[RD.2] EUMETSAT OSISAF Sea Ice Product Manual v3.6, September 2009, Norwegian Meteorological, Institute, Oslo, Norway, http://osisaf.met.no/docs/ss2_pmseaice_v3p6.pdf.

[RD.3] EUMETSAT OSISAF Validation Report for the High Latitude Radiative Fluxes, SAF/OSI/CDOP/met.no/TEC/RP/118, April 2010, Norwegian Meteorological Institute, Oslo, Norway.

2 Algorithms

2.1 Surface Shortwave Irradiance (SSI)

2.1.1 Introduction

The solar irradiance at the surface is a function of the solar irradiance at the top of the atmosphere, the clear sky atmospheric transmittance and the cloud transmittance:

$$
\begin{aligned}
&E = S' \mu_0 T_a T_c \\
&S' = \frac{S_0}{\rho^2} \\
&\mu_0 = \cos\sigma
\end{aligned}
\qquad (1)
$$

where σ is the solar zenith angle, S_0 is the solar constant (1358 W/m^2 when band weighted). ρ^2 is a correction factor for the varying distance between the earth and the Sun and is given in chapter 2.1.3.1 below.

The clear sky transmittance (T_a) is not dependent on the satellite observation, it is merely a function of solar zenith angle and atmospheric load of water vapor, ozone, and aerosol and the surface albedo.

The cloud transmittance is a function of the cloud albedo and requires several processing steps to be determined (see below).

2.1.2 Equations for clear sky transmittance

This clear sky parameterization is described in Darnell et al. (1988) and Darnell et al. (1992). The clear sky atmospheric transmittance (T_a) is estimated as a function of absorption in water vapor, ozone, oxygen, and carbon dioxide, scattering by aerosols and Rayleigh scattering. The atmospheric backscatter is parameterized by the surface pressure and albedo:

$$
\begin{aligned}
&T_a = e^{-\tau}(1 + 0.065\, p_s A_s) \\
&\tau = \tau_0 \left(\frac{1}{\mu_0}\right)^N, \textit{ where } N = 1.1 - 2\tau_0 \\
&\tau_0 = \tau_{O3} + \tau_{H2O} + \tau_{CO2} + \tau_R + \tau_a \\
&\tau_{O3} = 0.038 \mathrm{U}_{O3}^{0.44} \\
&\tau_{H2O} = 0.104 \mathrm{U}_{H2O}^{0.3} \\
&\tau_{O2} = 0.0076 \mathrm{p}_s^{0.29} \\
&\tau_R = 0.038 \mathrm{p}_s \\
&\tau_a = 0.007 + 0.009 \mathrm{U}_{H2O}
\end{aligned}
\qquad (2)
$$

In the equations above, τ represents the optical depth due to various absorbers, μ_0 is as before the cosine of the solar zenith angle, p_s is the nominal surface atmospheric pressure in atmospheres and *U* is the atmospheric load (in cm) of various constituents.

2.1.3 Equations for cloud transmittance

2.1.3.1 Calibration

Adapting the procedure described by NOAA/NOAASIS and described by Rao and Chen at the NOAASIS home page, the digital counts is converted to scaled radiance or often called albedo using a standard linear relationship for the visible channels (NOAA-14 and prior, split-gain for successors). Using the nomenclature of NOAA the "albedo" or better - "reflectance factor" or "scaled radiance" is given as:

$$A = SC_{10} + I \quad (3)$$

where C_{10} is the 10-bit count value, *S* and I are the slope and intercept. The basic processing of AVHRR data at NMI provides *A*.

The equation above gives the reflectance factor for overhead sun. However, the annual cycle in the extraterrestrial solar irradiance is approximately ±3% about the mean due to a variation in the distance between the earth and the Sun. This variation can be defined in different ways, the implementation at NMI follows the specification of Paltridge and Platt (1976).

$$\rho^2 = \frac{1}{1.00011 + 0.034221\cos\theta + 0.001280\sin\theta + 0.000719\cos2\theta + 0.000077\sin2\theta} \quad (4)$$

where

$$\rho^2 = \frac{D^{SE}}{\overline{D^{SE}}} \quad \text{and} \quad \theta = 0.9863\mathrm{d}_n = \frac{2\pi d_n}{365}$$

D^{SE} is the actual distance between the Sun and the Earth and $\overline{D^{SE}}$ is the mean distance (referring to 1*AU*). d_n is the Julian Day of the year starteing at 0 on January 1 and ending at 364 on December 31. In the equation for θ above the last statement produces output in radians and the first in degrees.

Using the information above, the processing of bi-directional reflectances for input the SSI estimation at NMI is performed using the library [libsatimg] and the function *bidirref* which takes the standard scaled radiance (*A*) as input and produces the bi-directional reflectance *r* by applying

$$r = \frac{\rho^2 A}{\cos\theta_0} \quad (5)$$

r in the range 0-100 is input to the SSI computations, but is transformed to the range 0-1 before it is used to estimate the cloud transmissivity.

2.1.3.2 Narrowband to Broadband corrections

The NOAA/AVHRR NTOB correction scheme described by Hucek and Jacobowitz (1995) for Atlantic Ocean (Ocean 2 in Table I below) is used. The regression coefficients are used in a formula of the type:

$$r_b = a + b_1 r_1 + b_2 r_2 \quad (6)$$

Table I Regression coefficients for the surface type and cloud amount dependent model of Hucek and Jacobowitz (1995). Surface types are the same as in Error: Reference source not found.

Coefficient	Surface type						
	snow 1	ocean 2	land 3	desert 4	land 5	ocean 6	coast 7
Clear							
a	3.8995	1.78	2.17	2.60	2.95	2.34	2.77
b_1	0.0520	1.3302	0.3999	0.3896	0.2331	1.2062	0.3779
b_2	0.7423	-0.6250	0.4333	0.3873	0.5025	-0.5504	0.4168
Partly cloudy							
a		4.11	4.24	3.12	3.27	5.38	4.65
b_1		0.9029	0.3166	0.2705	0.2063	0.8909	0.3085
b_2		-0.2441	0.3948	0.4811	0.4926	-0.2876	0.3856
Mostly cloudy							
a		5.08	4.75	5.49	9.53	8.51	5.36
b_1		0.4711	0.3757	0.3255	0.2844	0.3664	0.4362
b_2		0.2983	0.3870	0.3961	0.3149	0.3308	0.3227
Overcast							
a	-0.1174	8.19	6.98	7.50	13.28	13.72	7.79
b_1	-0.0650	0.2301	0.2566	0.7564	0.2998	0.0076	0.2930
b_2	0.8671	0.5032	0.4907	-0.0136	0.3530	0.6310	0.4446

2.1.3.3 Anisotropy correction

The broadband bi-directional reflectance is converted to albedo (planetary) by the method described in Manalo-Smith et al. (1998).

If the surface is not isotropic it is said to be anisotropic and the degree of anisotropy is described by the Bi-Directional Reflectance Function (BRDF) *R* or anisotropic factor[1]:

$$R(\theta, \varphi, \sigma) = \frac{\pi L(\theta, \varphi, \sigma)}{M} \quad (7)$$

where θ is the satellite zenith angle, φ the relative azimuth angle and σ is the solar zenith

1 Not to be confused with the reflectance factor or bi-directional reflectance as *R* is often used for this as well, *r* is used for this in this document.

angle. If *R* is close to unity the assumption of isotropic reflection is not all wrong.

The relationship between the bi-directional reflectivity (*r*) and the albedo (a) is given by:

$$a(\sigma)=\frac{R(\theta,\varphi,\sigma)}{r(\theta,\varphi,\sigma)} \quad (8)$$

2.1.3.4 Cloudy sky parameterization

The cloud transmittance (T_c) is estimated according to the equations specified by Frouin and Chertok (1992). Using the albedo at top of the atmosphere, a combined cloud and surface albedo is estimated. The difference between this combined albedo and the surface albedo can be related to the cloud absorption. Cloud absoroption and the combined surface and cloud albedo are used to estimate the cloud transmittance. The equations used are given below:

$$\begin{aligned} A &= A_{ray}+\frac{T_{dt}A'}{1-S_a A'} \\ a_c &= m\mu_0(A'-A_s) \\ T_c &= \frac{1-A'-a_c}{1-S_a A'} \end{aligned} \quad (9)$$

where A' is the cloud-surface albedo, a_c is the cloud absorption, A_s is the surface albedo. The atmospheric transmittances used above is given below.

$$\begin{aligned} \tau_d &= \tau_{O3}U_{O3}(1/\mu_0+1/\mu)+\tau_{H2O}U_{WV}(1/\mu_0+1/\mu)+\tau_{sc}(1/\mu_0+1/\mu) \\ \tau_{dt} &= \tau_{O3}U_{O3}(1/\mu_0+1/\mu)+\tau_{H2O}0.3\mathrm{U}_{WV}(1/\mu_0+1/\mu)+\tau_{sc}(1/\mu_0+1/\mu) \\ T_d &= e^{-\tau_d} \\ T_{dt} &= e^{-\tau_{dt}} \end{aligned} \quad (10)$$

where *U* represents the atmospheric load of the specified substance in cm. T_d represents the transmittance Sun - Surface -Satellite and T_{dt} the transmittance Sun - Cloud - Satellite. The optical depth (τ) due to atmospheric constituents required above are given by:

$$\begin{aligned} \tau_{H2O} &= 0.102(U_{WV}/\mu_0)^{0.29} \\ \tau_{O3} &= 0.041(U_{O3}/\mu_0)^{0.57} \\ \tau_{sc} &= (a+b/V)\mu_0 \\ &maritime: a=0.059\, b=0.359\, a'=0.089\, b'=0.503 \\ &continental: a=0.066\, b=0.704\, a'=0.088\, b'=0.456 \end{aligned} \quad (11)$$

τ is still the optical depth due to various absorbers. τ_{sc} is scattering due to both Rayleigh and molecules.

2.1.4 Daily integration

Daily integration of the SSI is performed by estimating the mean clear sky insolation of the day. Using the estimated SSI a clearness index is estimated by:

$$K = \frac{SSI^{est}}{SSI^{clear}} \tag{12}$$

The daily estimate is then made by a straightforward arithmetic mean according to:

$$\overline{SSI} = \sum_{i=1}^{N} w_i^{time} K_i SSI_i^{clear} \tag{13}$$

where *w* is a temporal weight to handle to irregularly time spacing of polar orbiting data.

2.1.5 Target accuracy

The target accuracy is defined according to Product requirements Document as a relative bias and standard deviation of respectively 10% and 30% on a monthly basis for daily products.

2.2 Downward Longwave Irradiance (DLI)

2.2.1 Method and equations

The OSISAF HL algorithm for Downward Longwave Irradiance (DLI) is a bulk parametrisation with extensive use of NWP model input. The clear sky DLI is estimated using NWP only, this is corrected for clouds by applying the NWCSAF PPS cloudtype product.

According to experience gained developing algorithms for Low and Mid Latitude within the OSISAF (Brisson et al., 2000) a hybrid method was chosen for estimation of DLI. This is a combination of a bulk parameterization and a satellite derived cloud amount. Basis for the method is briefly described in Godøy (2004) and by the equations below.

DLI is estimated using Stefan-Boltzmann law, a clear sky emissivity (ε_0) and a cloud contribution coefficient (*C*).

$$\begin{aligned} &L = (\epsilon_0 + (1-\epsilon_0)C)\sigma T_a^4 \\ &\epsilon_0 : clear\ sky\ emissivity \\ &C : infrared\ cloud\ amount \\ &\sigma : Stefan-Boltzman\ constant\,(5.6696\times10^{-8}\,\frac{W}{m^2 K^4}) \\ &T_a : Air\ temperature\,(Kelvin) \end{aligned} \tag{14}$$

The cloud contribution is estimated by summarizing individual cloud contribution coefficients and the fractional cloud cover.

$$C=\sum_i (n_i C_i)$$
$$C_i: contribution\ coefficient\ by\ cloud\ type\ i$$
$$n_i: fractional\ cloud\ cover\ by\ cloud\ type\ i \quad (15)$$

Basically the DLI is a sum of the clear sky emitted irradiance (first term), the contribution from cloud (second term) and minus the clear sky contribution obscured by clouds.

The main challenge is to determine the method to use for the clear sky emissivity, how to determine the cloud amount and how to actually implement the method in practise.

To estimate the clear sky emissivity the formulation of Prata (1996) specified in the equations below.

$$\epsilon_0=1-(1+\xi)\exp[-\sqrt{(1.2+3.0\,\xi)}]-0.05\frac{(p_0-p)}{(p_0-710)}$$
$$p_0: 1013.25[hPa] \quad (16)$$

$$\xi=c\left(\frac{e_0}{T_a}\right)$$
$$where\ e_0\ is\ surface\ water\ vapor\ pressure,\ c\ is\ 46.5\left[\frac{cm\,K}{hPa}\right] \quad (17)$$

As the method of Prata needs the surface water vapour pressure (e_0) as input this is estimated using the product of the saturation water vapour pressure *(e_s)* and relative humidity *(R_h)*. e_s is estimated using the Goff- Gratch equation (below) (Goff and Gratch, 1946, List, 1984). The two equations below are for the saturation water vapour pressure over plane surfaces of water and ice.

$$If\ T_a>273.15\ use:$$
$$e_s=10^{(23.8319-2948.964/T_a-5.028\log_{10}T_a-29810.16\exp(-0.0699382T_a)+25.21935\exp(-2999.924/T_a))}$$
$$If\ T_a<273.15\ use:$$
$$e_s=10^{(2.07023-0.00320991T_a-2484.896/T_a+3.56654\log_{10}T_a)} \quad (18)$$

Concerning determination of C_i, at least two different methods can be used. Brisson et al (2000) showed that either a cloud contribution coefficients can be estimated using surface pyrgeometer observations according to the equation below.

$$C_i = \frac{(L_m - \epsilon_0 \sigma T_a^4)}{[(1-\epsilon_0)\sigma T_a^4]} \tag{19}$$

$$L_m : Observed\ downward\ longwave\ irradiance$$

Given a classified satellite image (e.g. Nowcasting SAF PPS products, Dybbroe et al., 2000) a contribution coefficient can be estimated for each cloud type represented in the classified image.

However, Brisson et al (2000) also presented another method that can be used to infer C. This method (see below) is only applicable during day time and is based upon use of the SSI product (e.g. Godøy and Eastwood, 2002a, 2002b).

$$C = 1 - \frac{E}{E_{clr}} \tag{20}$$

$$where\ E\ is\ the\ estimated\ surface\ solar\ irradiance\ (SSI)\ using\ AVHRR\ data,$$
$$E_{clr}\ is\ the\ clear\ sky\ calculated\ SSI$$

In this equation the infrared cloud amount is directly related to the optical thickness of the cloud. The closer the satellite observed SSI is to the clear sky, the less contribution from cloud in the DLI estimate.

The OSISAF HL cloud type generation is performed using the NWCSAF PPS cloud type software (Dybbroe et al., 2000, Godøy, 2002a, Godøy, 2005). Within this study the PPS version 0.20 was used. This software generates the cloud types shown in Table II. However, the DLI estimation does not need all these classes, thus a subset of cloud types are used. The relation between the original cloud types and the subset used in the DLI estimation is shown in Table II.

Table II NWC SAF PPS cloud type products and the categorizing of these used in the DLI calculation.

#	Cloud category SAF NWC PPS	Simplified	DLI Code
0	Unprocessed	NA	0
1	Cloud free land	Clear	1
2	Cloud free sea		
3	Snow contaminated land		
4	Snow or ice contaminated sea		
5	Very low stratiform cloud	Low clouds	2
6	Very low cumuliform cloud		
7	Low stratiform cloud		
8	Low cumuliform cloud		
9	Medium level stratiform cloud	Medium level clouds	3
10	Medium level cumuliform cloud		

#	Cloud category SAF NWC PPS	Simplified	DLI Code
11	High and opaque stratiform cloud	High opaque clouds	4
12	High and opaque cumuliform cloud		
13	Very high and opaque stratiform cloud		
14	Very high and opaque cumuliform cloud		
15	Very thin cirrus cloud	Thin cirrus	5
16	Thin cirrus cloud		
17	Thick cirrus cloud	Thick cirrus	6
18	Cirrus above low or medium level cloud		
19	Fractional or subpixel cloud	Fractional clouds	7
20	Unclassified	NA	0

2.2.2 Daily integration

Daily integration of the DLI product is easier than for the SSI product as there is no diurnal cycle to specifically handle. However, the temporal irregularity of observations throughout the day still has to be handled. The daily integration is implemented by a straightforward arithmetic mean where each individual observation throughout the day is representative for a time period. This way, some time periods might be represented by very few observations while other are well covered.

2.2.3 Target accuracy

The target accuracy is defined as a relative bias and standard deviation of 5% and 10% respectively on a monthly basis for daily products.

3 Processing overview

3.1 SSI

3.1.1 Overview

The High Latitudes SSI product estimated from AVHRR data is not a stand alone product but is used as input to the merged Atlantic product. However, daily products are delivered at the HL grid also.

This section describes the processing scheme used for HL SSI products. AVHRR data are processed whenever they are available, resulting in instantaneous SSI estimates. The instantaneous estimates are combined into a daily product accounting for the irregularly time spaced observations.

Each SSI field have an quality index assigned. This includes a confidence level corresponding to the quality of the estimated SSI. However, in the current specification the quality index do only reflect processing elements of the data, it is not an assessment of the geophysical quality of the product.

3.1.2 Instantaneous estimates

The instantaneous processing of AVHRR data is presented in Figure 1. It uses the algorithms described above. The working grid of this processing is polar stereographic at highest horizontal resolution (1.5km). Each AVHRR passage is divided into several tiles which are processed in sequence (cloud mask and auxiliary data available for each tile).

The auxiliary data used are:

Combined land/sea mask and topography model - GTOPO30 from USGS.

Monthly climatology of surface albedo over land. These are broadband albedo with Sun at zenith developed by Csizar and Gutman (1999).

Monthly climatology of ozone from Total Ozone Mapping Spectrometer. These data are collected from a climatology estimated for the period 1979 – 1992 and is given in cm.

Predicted integrated water vapor content in the atmosphere from the HIRLAM model operated at METNO. Model is run at 00, 06, 12 and 18 UTC. If the required field is not available, the previous model run will be used (results from the last 3 days are available).

Cloud cover[2] from the NOWCASTING SAF Polar Processing Software (Dybbroe et al. 1999, Godøy, 2005) adapted for use over ocean. This is at the same resolution as the input AVHRR data (1.5 km). Cloud cover is given as *clear, contaminated*, and *covered*. These classes are handled as 0, 50 and 100% cloud cover in the anisotropy correction in the processing scheme.

Sea ice cover from the Ocean and Sea Ice SAF project. This is used for the quality flag construction.

When each tile have been processed, the AVHRR passage is remapped to the High Latitude grid following the scheme illustrated in Figure 2.

For both high resolution (1.5 km) and HL grid resolution (5 km) instantaneous products the

2 At present a cloud mask is used for the SSI processing, this should be changed towards use of a cloud type product as for DLI sometime in the future.

output file format is NCSA HDF5. This is post-processed directly to get WMO GRIB and MITIFF files.

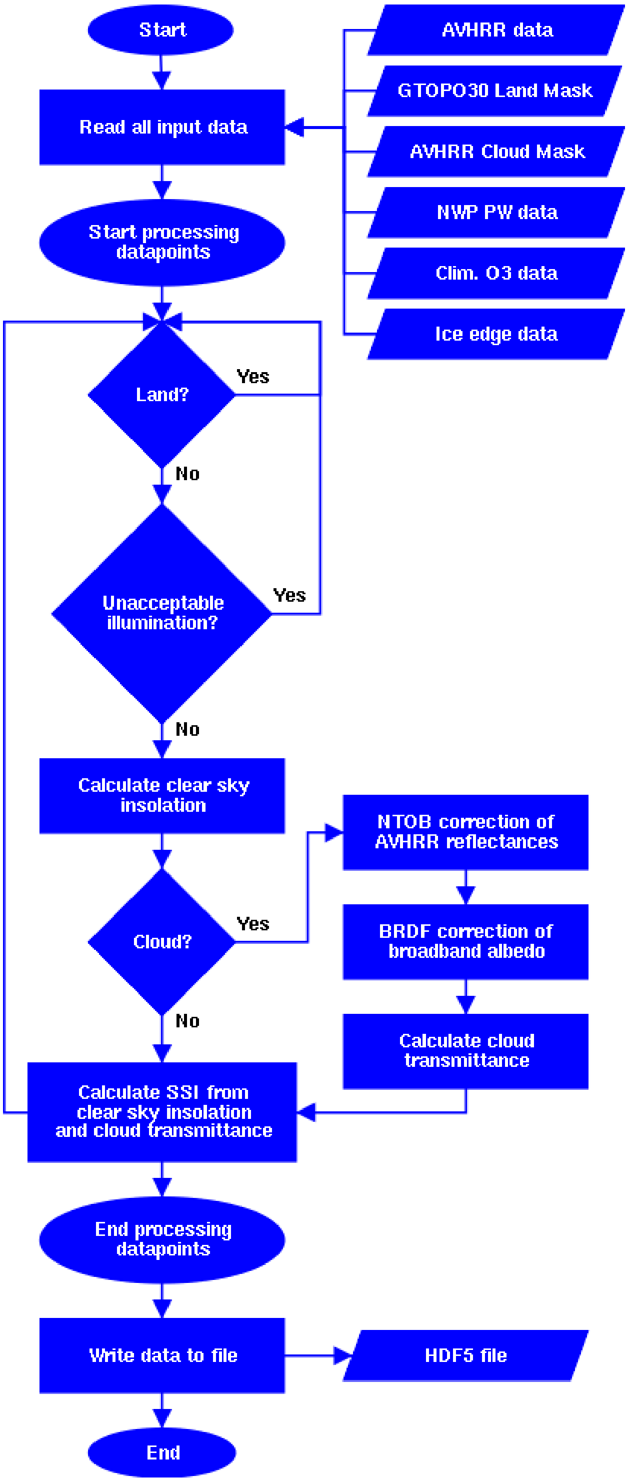

Figure 1 Instantaneous processing of AVHRR data.

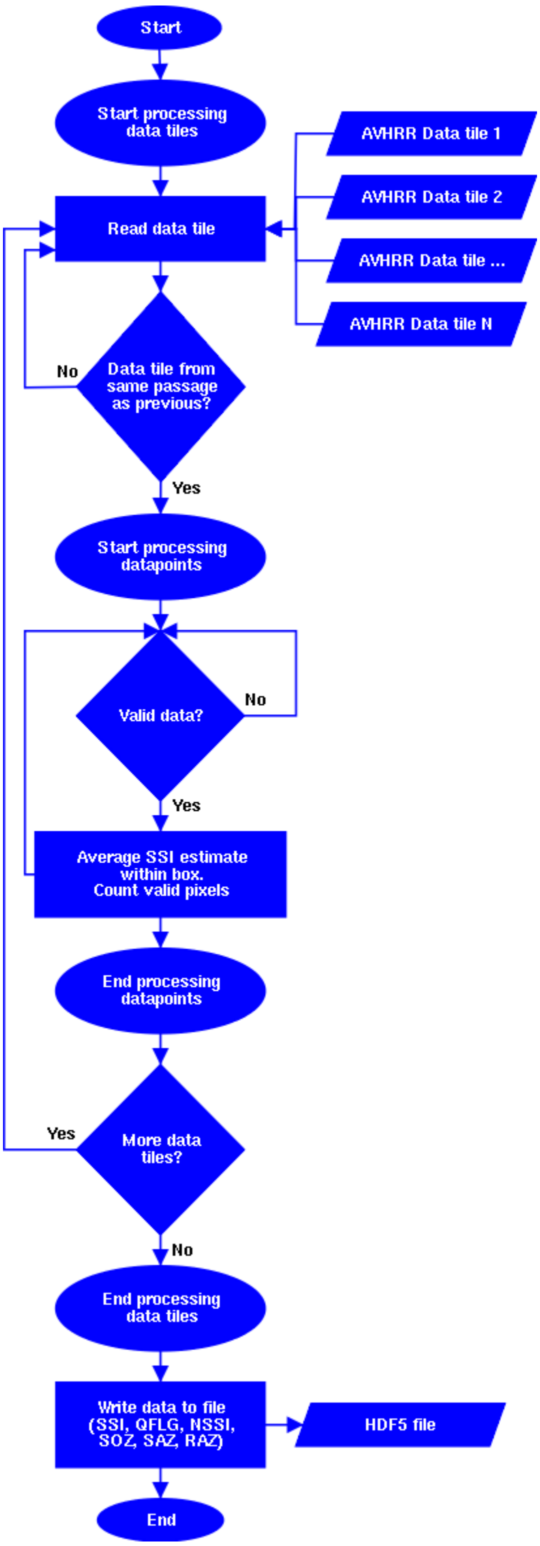

Figure 2 Processing scheme for remapping of tiles to HL grid.

3.1.3 Daily estimates

The estimation of daily SSI values is described in a previous chapter. To account for the in time irregularly spaced observations weights are applied to each observation. The concept of the weighting is illustrated in Figure 3. Basically the weights are similar to clearness indices which are applied to each clear sky estimate during the day.

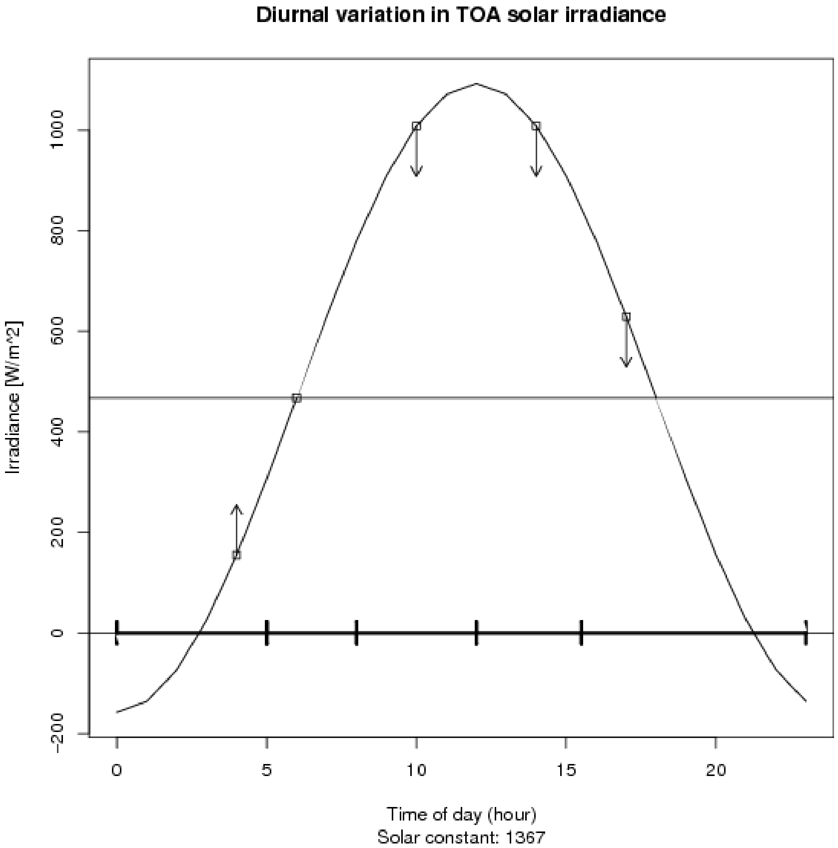

Figure 3 Weighting of observations to estimate daily fluxes are performed according to the daily cycle of insolation.

The processing is illustrated in Figure 4.

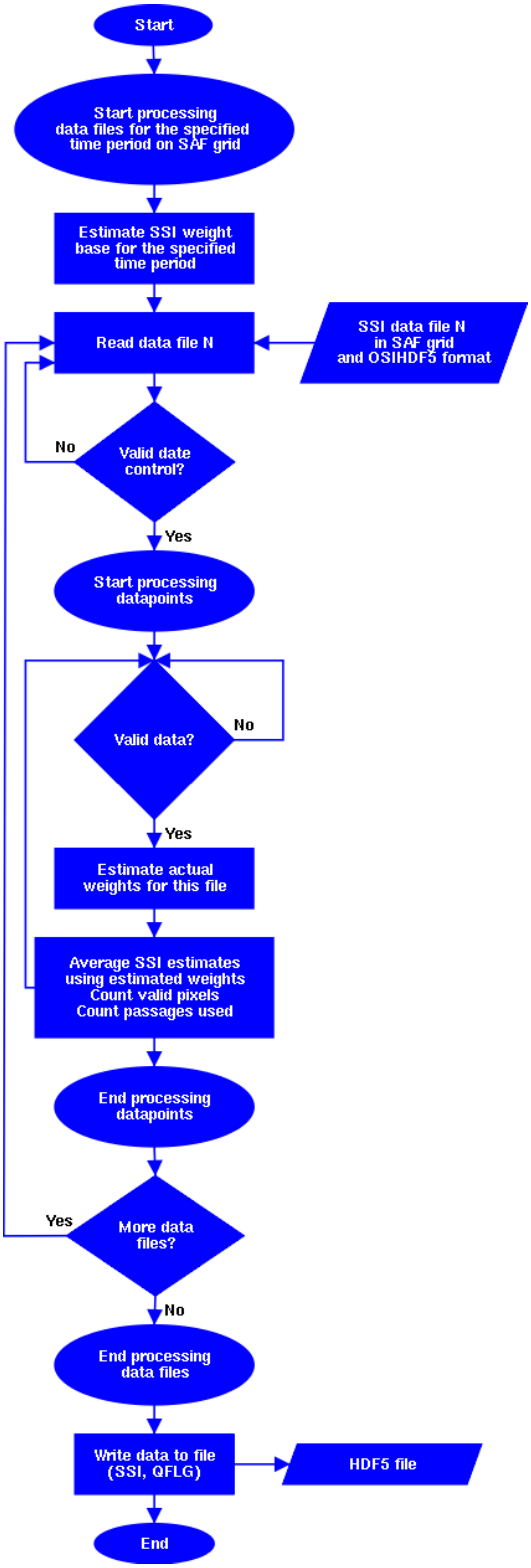

Figure 4 Processing scheme for daily estimates.

3.1.4 Validation and Quality Control

Validation and assessments of product performance is a continuous process and for Surface Shortwave Irradiance the following data sources are important validation data:

- Bioforsk stations (http://www.bioforsk.no/)
    - Agricultural research stations covering Norway are measuring global radiation. Selected stations are used for validation of OSISAF SSI products. In situ measurements are received in real time or near real time at the Norwegian Meteorological Institute.
    - These measurements have been the most important validation resource for OSISAF SSI products as they have been available during the full project. the number of stations measuring global radiation has increased in recent years.
- Norwegian Meteorological Institute
    - During the International Polar Year, the Research Council of Norway funded measurements of the surface radiative fluxes at the meteorological stations operated by the Norwegian Meteorological Institute at Jan Mayen, Bjørnøya and Hopen. Near real time presentation of the time series are available at http://dokipy.met.no/projects/iaoos-norway/radflux.html. Data is received in real time in Oslo.
    - These measurements is being included in the validation setup as of 2010/2011.
- University of Bergen (Norway)
    - Geophysical Institute runs a laboratory for measurement of radiative fluxes in Bergen and at the oil rig Ekofisk in the North Sea.
    - These measurements are received in delayed mode and has primarily been used during algorithm development, but are as of 2011 being included in the updated validation setup.

The output file format of the collocation process is interfaced with analysis tools developed in the statistical software R (R Development Core Team, 2009).

3.2 DLI

3.2.1 Overview

The High Latitude DLI product estimated from AVHRR data is not a stand alone product but is used as input to the merged Atlantic product. However, daily products are delivered at the HL grid also.

This section describes the processing scheme used for HL DL products. AVHRR data are processed whenever they are available, resulting in instantaneous DLI estimates. The instantaneous estimates are combined into a daily product accounting for the irregularly time spaced observations.

Each DLI field have an quality index assigned. This includes a confidence level corresponding to the quality of the estimated SSI. However, in the current specification the quality index do only reflect processing elements of the data, it is not an assessment of the geophysical quality of the product.

3.2.2 Instantaneous estimates

The instantaneous processing of AVHRR data is presented in Figure 5. It uses the algorithms described above. The working grid of this processing is polar stereographic at highest horizontal resolution (1.5km). Each AVHRR passage is divided into several tiles which are processed in sequence (cloud mask and auxiliary data available for each tile).

The auxiliary data used are:

Combined land/sea mask and topography model - GTOPO30 from USGS.

Monthly climatology of surface albedo over land. These are broadband albedo with Sun at zenith developed by Csizar and Gutman (1999).

Monthly climatology of ozone from Total Ozone Mapping Spectrometer. These data are collected from a climatology estimated for the period 1979 – 1992 and is given in cm.

Predicted integrated water vapor content, 2m temperature, and 2m relative humidity in the atmosphere from the HIRLAM model operated at METNO. Model is run at 00, 06, 12 and 18 UTC. If the required field is not available, the previous model run will be used (results from the last 3 days are available).

Cloud cover[3] from the NOWCASTING SAF Polar Processing Software (Dybbroe et al. 1999, Godøy, 2005) adapted for use over ocean. This is at the same resolution as the input AVHRR data (1.5 km). Cloud cover is given as *clear*, *contaminated*, and *covered*. These classes are handled as 0, 50 and 100% cloud cover in the anisotropy correction in the processing scheme.

Sea ice cover from the Ocean and Sea Ice SAF project. This is used for the quality flag construction.

When each tile have been processed, the AVHRR passage is remapped to the High Latitude grid following the scheme illustrated in Figure 6.

For both high resolution (1.5 km) and HL grid resolution (5 km) instantaneous products the output file format is NCSA HDF5. This is post-processed directly to get WMO GRIB and MITIFF files.

3 At present a cloud mask is used for the SSI processing, this should be changed towards use of a cloud type product as for DLI sometime in the future.

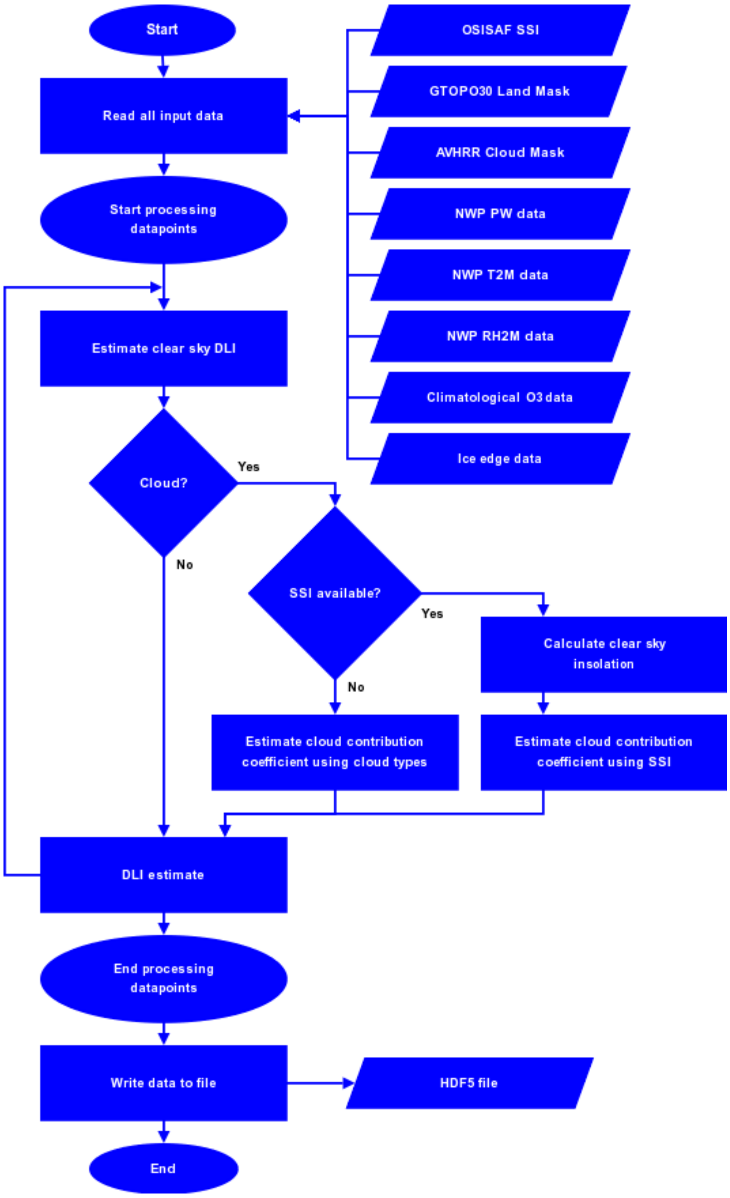

Figure 5 Instantaneous DLI estimation.

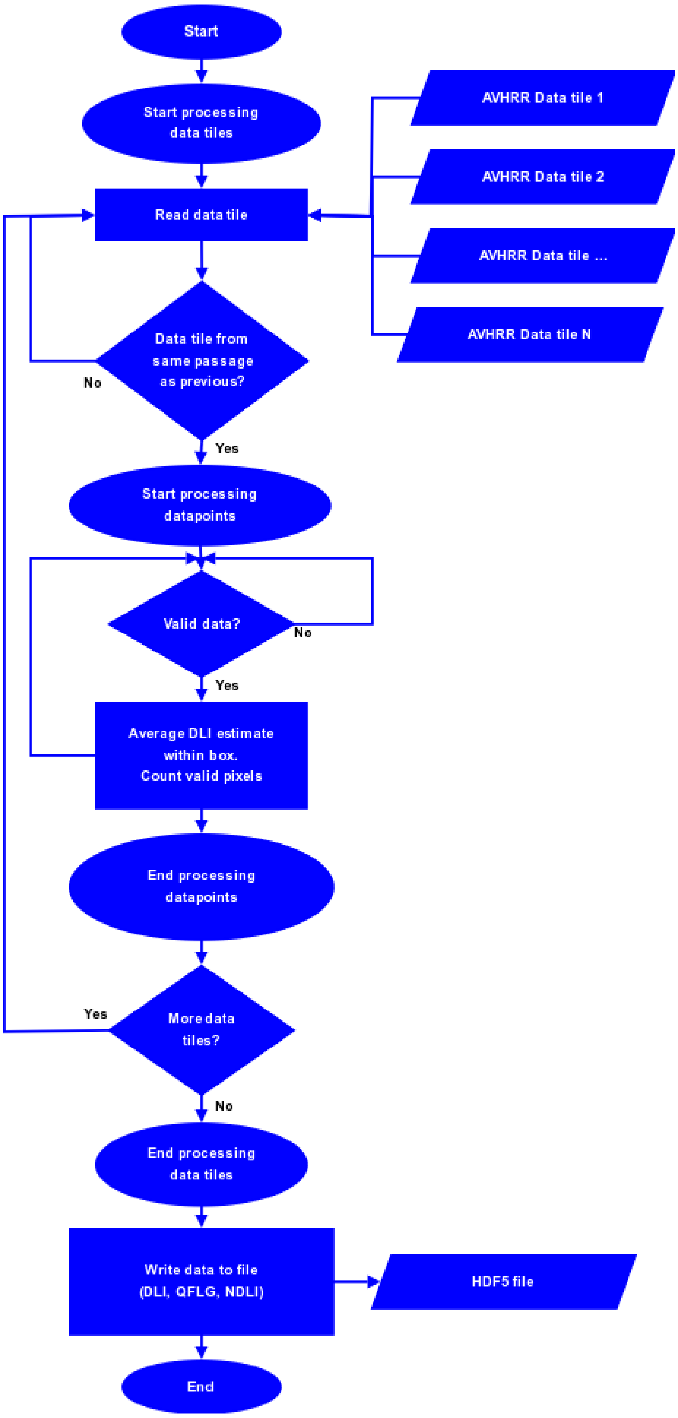

Figure 6 Processing scheme for 5 km instantaneous DLI products.

3.2.3 Daily estimates

The processing of daily DLI estimates is illustrated in Figure 7. The daily DLI is a straightforward average where weights are applied to each observation to reflect the time interval a specific observation is applicable for.

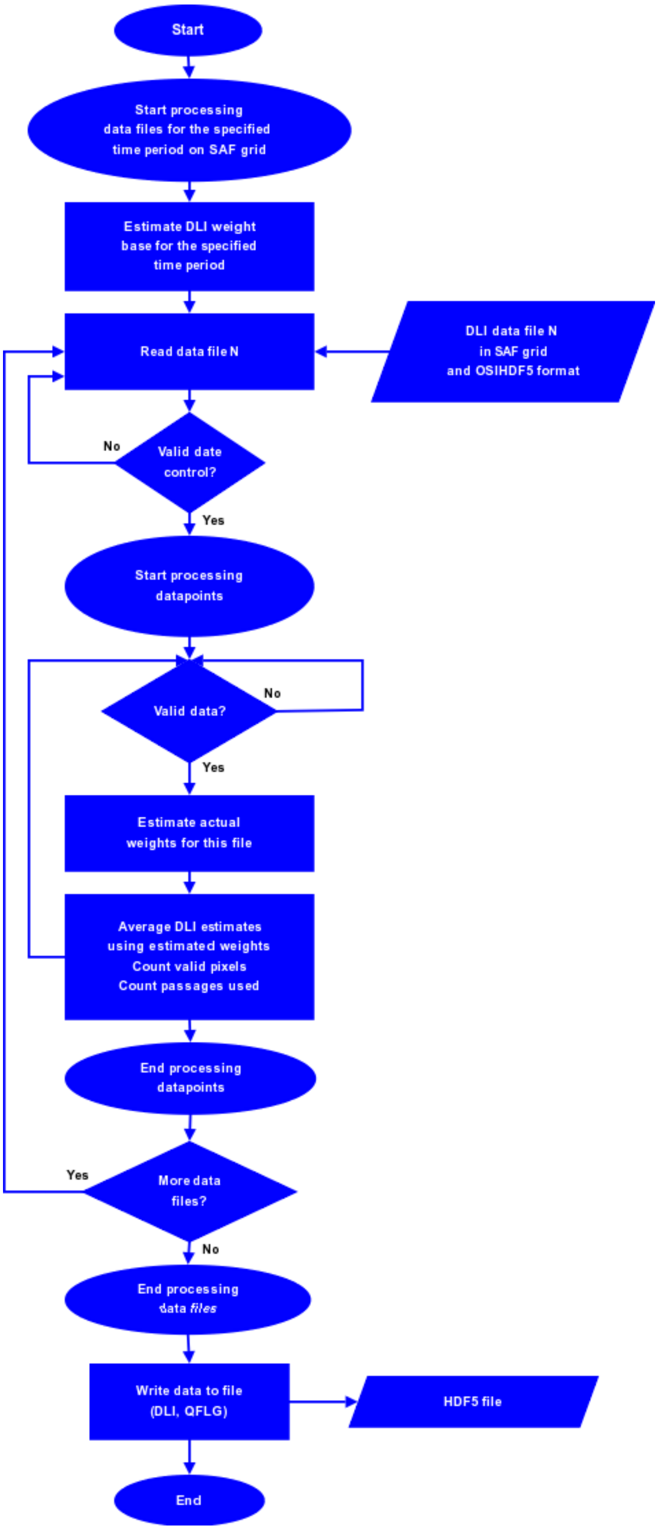

Figure 7 Processing of daily DLI estimates.

3.2.4 Validation and Quality Control

The main difference between validation of the Surface Shortwave Irradiance and the Downward Longwave Irradiance is the amount of validation data and the amount of data available in real or near real time.

Little DLI data are available in real time. Thus DLI estimates are stored in a database for all stations known to, at some time have performed DLI measurements in the area of coverage.

The validation stations are listed below .

- Norwegian Meteorological Institute
  - During the International Polar Year, the Research Council of Norway funded measurements of the surface radiative fluxes at the meteorological stations operated by the Norwegian Meteorological Institute at Jan Mayen, Bjørnøya and Hopen. Near real time presentation of the time series are available at http://dokipy.met.no/projects/iaoos-norway/radflux.html. Data is received in real time in Oslo.
  - These measurements is being included in the validation setup as of 2010/2011.
- University of Bergen (Norway)
  - Geophysical Institute runs a laboratory for measurement of radiative fluxes in Bergen and at the oil rig Ekofisk in the North Sea.
  - These measurements are received in delayed mode and has primarily been used during algorithm development, but are as of 2011 being included in the updated validation setup.

4 Data description

4.1 Overview

The following products are available for both SSI and DLI for each 24 hour integration period:

- a radiative flux field (SSI or DLI)
- a quality index field

Data are created in NCSA HDF5, WMO GRIB and TIFF 6.0 files. A brief description of the formats used are given later.

4.2 Common characteristics

TBW

4.3 Grid specification

The grid specification is given in Table III. The area covered is specified in Figure 8.

Table III Grid specification.

Map projection	Polar Stereographic true at 60°N
Horizontal resolution	5km
Horizontal dimension	1260 columns × 900 lines
Central meridian	0°E
Lower left corner[4]	37.39928°N, 40.16765°W
Upper left corner[5]	-3795.00, 5.00
Radius of Earth	6371.0 km
PROJ4 string	+proj=stere +a=6371000 +b=6371000 +lat_0=90 +lat_ts=60 +lon_0=0

4 In geographical coordinates.
5 In UCS coordinates (Bx, By in km)

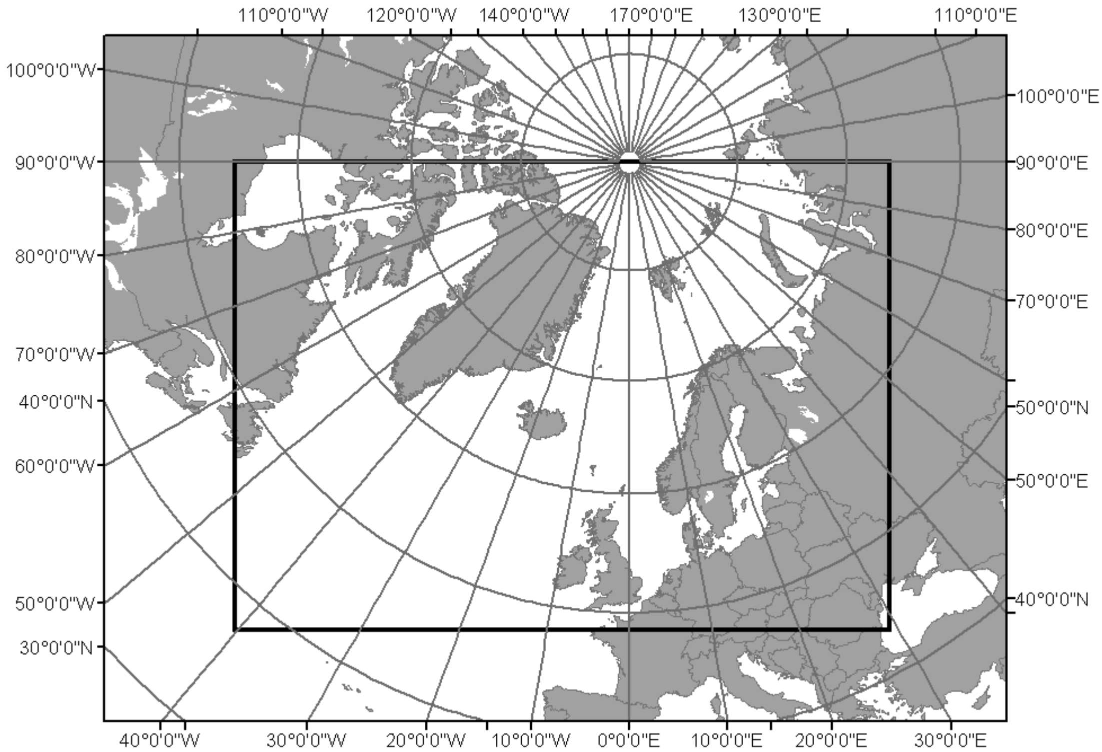

Figure 8 Area coverage of the High Latitude Ocean and sea Ice SAF SSI and DLI products.

4.4 Radiative fluxes

4.4.1 Surface Shortwave Irradiance

The surface downward solar irradiance (global radiation) is presented. Units are W/m^2.

The daily SSI is estimated by estimating the daily mean clear sky solar irradiance. Each hourly estimate is used to compute a clear sky index by dividing the hourly 5 km grid estimate with the clear sky irradiance. The product of the clear sky index and the daily mean clear sky irradiance is averaged to get the daily mean cloud dependent value. Only hourly estimates having a confidence level equal to or above bad (defined later) are used in the averaging processes.

4.4.2 Downward Longwave Irradiance

The surface downward longwave irradiance is presented. Units are W/m^2.

The daily DLI is estimated by a straightforward process averaging the mono-passage products from the highest resolution onto the SAF grid and subsequently averaging all mono-passage products into a daily product. Only estimates having a confidence level equal to or above bad (defined later) are used in the averaging processes.

4.5 Associated fields

4.5.1 Surface Shortwave Irradiance - quality index

The quality index defined below is used both for full resolution (1.5km) SSI products and SAF averaged SSI products at 5 km resolution. When creating the SAF grid product the quality flag within each 5 km square box is created by averaging the full resolution quality flags using the condition that the only SSI values with a confidence level of *bad* or better are used in the end product. All flags described below will have to be recomputed or averaged in the 5 km product, except for the snow or sea ice flag.

Mono-passage SSI quality index		
bit	**signification**	**id**
0-2	Confidence level[6] Excellent (5), Good (4), Acceptable (3), Bad (2), Erroneous (1), Unprocessed (0) *excellent* - clear pixel or cloud factor between 0 and 1 and consistent with cloud cover (rules for consistency given below), this is not used for cloud contaminated pixels *good* - no sunglint and high cloud factor but below 1 and inconsistent with cloud cover *acceptable* - cloud factor equals 0 and is consistent with cloud cover or cloud factor equals 1 (regardless of consistency) *bad* - small cloud factor inconsistent with cloud cover *erroneous* - error in NTOB or BRDF or clear sky insolation *unprocessed* - out of area, or night The confidence level is deduced by averaging the single passage SSI estimates averaged to the HL grid (5 km) after erroneous and unprocessed pixels are removed. The cloud factor is 0 for fully overcast and 1 for clear sky. • If the cloud factor is larger than or equal to 0.8 and the pixel is fully covered by cloud, "the *high cloud factor is inconsistent with cloud"cover* • If the cloud factor is less than or equal to 0.2 and the pixel is cloud contaminated the "*low cloud factor is inconsistent with cloud cover*" • If none of the above is true, then the "*cloud factor is consistent with cloud cover*"	QFPBMCI QFPBMCE QFPBMCA QFPBMCB QFPBMCR QFPBMCU
3	Clear pixel (cloud cover less than 5%)	QFPBMCL
4	Overcast pixel (cloud cover 100%)	QFPBMOC
5	Not used (preferably weak sun glint identification)	(QFPBMSG)
6	Snow or sea ice	QFPBMSI
7	Not used (preferably aerosol occurrence)	
8	Not used (preferably critical sunglint conditions)	
9-14	Depends on status of bit 15	
15	No SSI data[7]	QFPBMND

6 The confidence level should reflect the viewing geometry in the future, but for now it is only based upon consistency of the cloud factor and cloud cover information. At present not all categories are used for all cloud cover classes either.

7 If no data is specified in the quality flag and no other flag given to identify the source of error, the cloud mask have failed to produce the specified classes.

Mono-passage SSI quality index		
If bit 15 is false (i.e. SSI data)		
bit	**signification**	
9-14	Not used	
If bit 15 is true (i.e. no SSI data)		
bit	**signification**	
9	Error in NTOB conversion	QFPBMBB
10	Error in cloud factor estimation	QFPBMCF
11	Error in clear sky insolation	QFPBMGL
12	Night	QFPBMNT
13	Not used	
14	Out of image area	QFPBMOA

The quality index described below is used for daily products. Basically this is an averaging of the mono-passage quality index defined above. The averaging is following the same structure as the averaging process going from highest possible spatial resolution (1.5 km) to the SAF grid (5 km), only using data with a confidence level equal to or better than *bad*.

Daily SSI quality index		
bit	**signification**	**id**
0-2	Confidence level see footnote 6above Excellent (5), Good (4), Acceptable (3), Bad (2), Erroneus (1), Unprocessed (0) The confidence level for daily products is found by averaging the single passage SSI estimates averaged to the HL grid (5 km). Only pixels with confidence level equal to or better than *bad* (2) is used in the average.	QFDBMCI
3-4	Satellite code GOES (0), MTP or MSG (1), NOAA or EPS (2), Unused (3)	QFDBMSC
5	Not used (prefereably sun glint identification)	
6	Snow or sea ice	QFDBMSI
7	Not used (preferably aerosol occurrence)	
8	Not used	
9-14	Depends on status of bit 15	
15	No SSI data	QFDBMND
If bit 15 is false (i.e. SSI data)		
bit	**signification**	

Daily SSI quality index		
9-10	Not used (preferably configuration of solar day)	
11-14	Not used (preferably for daily index???)	
	If bit 15 is true (i.e. no SSI data)	
bit	**signification**	
9-11	Not used	
12	Night for all data	QFDBMNT
13	No SSI estimates	QFDBMNE
14	Out of image area	QFDBMOA

4.5.2 Downward Longwave Irradiance - quality index

The quality index defined below is used both for full resolution (1.5km) DLI products and SAF averaged DLI products at 5 km resolution. When creating the SAF grid product the quality flag within each 5 km square box is created by averaging the full resolution quality flags using the condition that the only DLI values with a confidence level of *bad* or better are used in the end product. All flags described below will have to be recomputed or averaged in the 5 km product, except for the snow or sea ice flag.

Mono-passage DLI quality index		
bit	**signification**	**id**
0-2	Confidence level Excellent (5), Good (4), Acceptable (3), Bad (2), Erroneous (1), Unprocessed (0) *excellent* - using SSI of excellent confidence level or cloud factor formalism during night *good* - using SSI of good confidence level or cloud factor formalism and *reclassification* bit set in cloud type *acceptable* - using cloud factor formalism during day time and cloud type with *low quality* bit set *bad* - using cloud factor formalism and cloud type with *inversion* bit set *erroneous* – no cloud type or failure in DLI computations *unprocessed* - out of area	QFDPBMCI QFDPBMCIE QFDPBMCIG QFDPBMCIA QFDPBMCIB QFDPBMCIR QFDPBMCIU
3	Clear pixel (cloud cover less than 5%)	QFDPBMCL
4	Overcast pixel (cloud cover 100%)	QFDPBMOC
5	Sunglint is likely	QFDPBMSG
6	Snow or sea ice	QFDPBMSI
7	Not used (preferably aerosol occurrence)	
8	Not used	
9	DLI estimated using cloud contribution coefficient from PPS	QFDPBMMC
10	DLI) estimated using SSI to estimate cloud contribution coefficient	QFDPBMMS
11-14	Depends on status of bit 15	
15	No DLI data[8]	QFDPBMND
	If bit 15 is false (i.e. DLI data)	
bit	**signification**	
11-14	Not used	
	If bit 15 is true (i.e. no DLI data)	
bit	**signification**	

8 If no data is specified in the quality flag and no other flag given to identify the source of error, the cloud mask have failed to produce the specified classes.

Mono-passage DLI quality index		
11-13	Not used	
14	Out of image area	QFDPBMOA

The quality index described below is used for daily products. Basically this is an averaging of the mono-passage quality index defined above. The averaging is following the same structure as the averaging process going from highest possible spatial resolution (1.5 km) to the SAF grid (5 km), only using data with a confidence level equal to or better than *bad*.

Daily DLI quality index		
bit	**signification**	**id**
0-2	Confidence level Excellent (5), Good (4), Acceptable (3), Bad (2), Erroneus (1), Unprocessed (0) The confidence level for daily products is found by averaging the single passage SSI estimates averaged to the HL grid (5 km). Only pixels with confidence level equal to or better than *bad* (2) is used in the average.	QFDDBMCI
3-4	Satellite code GOES (0), MTP or MSG (1), NOAA or EPS (2), Unused (3)	QFDDBMST PO is QFDDBMSTP
5	Sunglint is likely in at least one of the input pixels	QFDDBMSG
6	Snow or sea ice in at least one of the input pixels	QFDDBMSI
7	Not used (preferably aerosol occurrence)	
8	Not used	
9	Not used	
10-14	Depends on status of bit 15	
15	No DLI data	QFDDBMND
If bit 15 is false (i.e. DLI data)		
bit	**signification**	
10	Not used	
11-14	Number of hourly values used to compute mean value	QFDDBMNV
If bit 15 is true (i.e. no DLI data)		
bit	**signification**	
10-11	Not used	
12	No hourly estimates	QFDDBMNH
13	Not used	
14	Out of image area	QFDDBMOA

4.6 File formats

4.6.1 WMO GRIB

The header sections used in the GRIB files and specific for the Ocean and Sea Ice SAF High Latitude products are listed in the table below. Parameter names/values tagged with † refers to WMO publication No 306 – Manual on Codes.

Octet	Content	Value
Section 1		
1-3	Length in octets of section 1	
4	Version number	3
5	Center identifier	88 for Norwegian Meteorlogical Institute in Oslo
6	Process identifier	1 for Norwegian Meteorlogical Institute in Oslo
7	Grid definition	255 (grid defined above)
8	Flag section 2 and 3	128† for the QFLG ?? 192† for other fields ??
9	Parameter	117† for SSI 118† for QFLG
10	Type of level	1†
11-12	Level	0†
13-17 and 25	Reference time	
18	Time unit indicator	1†
19	P1†	0
20	P2†	0
21	Time range indicator	0
22-23	Number of products included	Number of hourly/orbit fields actually included
24	Number of products missing	Number of missing hourly/orbit fields
27-28	Decimal scale factor	0†
29	Local use flag	0† (no local use)
Section 2		
1-3	Length in octets of section 2	
4	Number of vertical coordinate parameters	0
5	Location of vertical coordinate parameters list	255†

Octet	Content	Value
6	Data representation type	5 (polar stereographic grid)
7-8	Number of x-points	630
9-10	Number of y-points	450
11-13	Latitude of first grid point	37399
14-16	Longitude of first grid point	-40168
17	Resolution and component flags	00000000†
18-20	Longitudeof the meridian paralell to the y-axis	0
21-23	x-direction grid length	10000
24-26	y-direction grid length	10000
27	Projection centre flag	0† (norht pole on the projection plane)
28	Scanning mode flags	01000000†
Section 3		
1-3	Length in octets of section 3	
4	Number of unused bits at the end of section 3	
5-6	Bitmap flag	1† for the quality index flag 0† for others

4.6.2 NCSA HDF5

More information on the HDF5 format can be found at [http://hdf.ncsa.uiuc.edu/HDF5/]. The top wrapping used is described in Godøy (2002). Some useful parameters are listed in the tables below.

HL OSI SAF daily SSI product in NCSA HDF5 format		
Object	**Element**	**Contents**
Header	source	OSI_SAF_HL
	product	DAILY_SSI
	area	-
data[00]	Description	SSI
	osi_dtype	OSI_FLOAT
data[01]	Description	QFLG
	osi_dtype	OSI_USHORT

HL OSI SAF daily DLI product in NCSA HDF5 format		
Object	**Element**	**Contents**
Header	source	OSI_SAF_HL
	product	DAILY_DLI
	area	-
data[00]	Description	DLI
	osi_dtype	OSI_FLOAT
data[01]	Description	QFLG
	osi_dtype	OSI_USHORT

4.7 Data distribution

There are two main access interfaces to radiative flux products. This is either through FTP or through EUMETCast. In addition the products can be delivered through the Regional Meteorological Data Communication Network (RMDCN) upon request.

FTP access is offered through ftp://osisaf.met.no/prod/flux/ and products are available in GRIB and HDF5. The online archives is available at ftp://osisaf.met.no/archive/flux/.

Products in gzipped GRIB format is available through EUMETCast. More information about EUMETCast is found at http://www.eumetsat.int/.

The file name convention used is provided below.

Filename convention for OSISAF HLC Radiative fluxes	
FTP	
DLI HDF5	dli_24h_hl_polstere-050_multi_<date12>.hdf
DLI GRIB	dli_24h_hl_polstere-050_multi_<date12>.grb
DLIQFLG GRIB	qdli_24h_hl_polstere-050_multi_<date12>.grb
SSI HDF5	ssi_24h_hl_polstere-050_multi_<date12>.hdf
SSI GRIB	ssi_24h_hl_polstere-050_multi_<date12>.grb
SSIQFLG GRIB	qssi_24h_hl_polstere-050_multi_<date12>.grb
EUMETCast	
DLI GRIB	S-OSI_-NOR_-MULT-AHLDLI_FIELD-<date12>Z.grb.gz
DLIQFLG GRIB	S-OSI_-NOR_-MULT-AHLDLI_QUAL_-<date12>Z.grb.gz
SSI GRIB	S-OSI_-NOR_-MULT-AHLSSI_FIELD-<date12>Z.grb.gz
SSIQFLG GRIB	S-OSI_-NOR_-MULT-AHLSSI_QUAL_-<date12>Z.grb.gz

4.8 Validation

The accuracy of the radiative flux products are monitored against in situ measurements using a collocation software generating ASCII files for further processing using dedicated functions in a R-software package.

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6 Appendix A

The basis for bitmask generation used in setting elements of the quality flag is indicated in the table below.

Bit no.	Base 2	Breakdown	Base 10
0	0000000000000001	1×2^{0}	1
1	0000000000000010	1×2^{1}	2
2	0000000000000100	1×2^{2}	4
3	0000000000001000	1×2^{3}	8
4	0000000000010000	1×2^{4}	16
5	0000000000100000	1×2^{5}	32
6	0000000001000000	1×2^{6}	64
7	0000000010000000	1×2^{7}	128
8	0000000100000000	1×2^{8}	256
9	0000001000000000	1×2^{9}	512
10	0000010000000000	1×2^{10}	1024
11	0000100000000000	1×2^{11}	2048
12	0001000000000000	1×2^{12}	4096
13	0010000000000000	1×2^{13}	8192
14	0100000000000000	1×2^{14}	16384
15	1000000000000000	1×2^{15}	32768

The order of bits are indicated in the table below. The least significant bit is the rightmost bit. The number of bits used in a byte and in a 2-byte word (unsigned short int) is also indicated.

Bit #	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Byte									←	—	—	—	—	—	—	→
Word	←	—	—	—	—	—	—	—	—	—	—	—	—	—	—	→