SHARP LEVEL-2

USER GUIDE

Release 1.0

Eathnet Programme Office

30 April 1992

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INDEX

Overview

Overview

The purpose of this document is to provide the user with :

- Detailed description of data treatment performed during SHARP level-2 generation.

- Explanation and examples of how to read SHARP level-2 data and to extract physical information.

The content of this document refers to the SHARP-2 products distributed at present, any future change in algorithms or coefficients will be documented with a new release of this guide .

SHARP LEVEL 2

INTRODUCTION

SHARP is the ESA Earthnet format for AVHRR and TOVS data generated to provide an easy data access for the international remote sensing user community.
At present SHARP-1 consists of two volumes: AVHRR volume and TOVS volume.
The first one contains AVHRR digital raw data and the second one calibrated TOVS data. Both the products have supplementary informations helpful to the user.
In order to save user time of extracting from the raw data the useful quantities needed for the problem in hand, a family of higher level products has been proposed by Earthnet : this is the SHARP level-2 .
The SHARP level-2 is available in 2 versions for daytime NOAA AVHRR images:

SHARP-2A containing calibrated data of the AVHRR channels and classification .

SHARP-2B containing geophysical parameters extracted from AVHRR raw data with processing algorithms selected according to the state-of-the-art and classification .

The TOVS volume distributed together with the SHARP Level-2 AVHRR volume (under user request.) is unchanged compared to the one generated for SHARP -1

1 SHARP-2 INPUT DATA

The SHARP-1 format (AVHRR volume) is the logical start point of the processing chain. According to the specification of level 1 everything necessary for the elaboration of the level-2 should be present on the level-1 output.
SHARP-1 Image records consisting of raw data plus ancillary informations are used as input for SHARP-2A and SHARP-2B generation.

1.1 Satellites Processed

The data converted into SHARP level-2 are derived from the following satellites:

<u>For SHARP-2A</u>

At present :

NOAA-9
NOAA-10
NOAA-11
NOAA-12

For SHARP-2B

At present :

NOAA-9
NOAA-11
(NOAA-12 available in level-2B when SST algorithms will be defined)

1.2 Passages Processed

All day-time passages acquired by the following Earthnet coordinated stations can be processed to generate SHARP Level-2 products:

Acquisition site	Processing site
Maspalomas	Maspalomas
Niamey	Frascati
La Reunion	Frascati
DLR	Frascati

A passage is considered to be day-time if the AVHRR band-1 histogram read from the SHARP-1 Trailer File has a mean value greater than a given limit.

1.3 Product Archiving

Because of the possibility of making changes in the data calibrations or in the geophysical algorithms, the SHARP Level-2 will be not archived.

2 SHARP-2 LOGICAL VOLUME CONTENT

Following the structure of the SHARP-1 format, the SHARP Level-2 logical Volume will contain the following files:

Volume Directory File	5 records	360 bytes each
Leader File	6 records	1800 bytes each
Imagery File	up to 1441 records	22680 bytes each
Trailer File	6 records	4140 bytes each
Null Volume Directory File	1 record	360 bytes each

2.1 - Imagery File

The Imagery File contains the File Descriptor Record and Image Records.
The Image frame size is 2048 pixels by 1440 lines.

Following the same structure of SHARP-1, SHARP Level-2 is a 5-bands image in LINN format . Together with the image data in SHARP Level-2 imagery records there are other information as Prefix data and Suffix data.
They have the same organization and information found in the correspondent SHARP-1 product.

2.1.1 SHARP-2A

The SHARP-2A product contains the SHARP-1 raw data calibrated and classified according to the procedures specified in 4.1, 4.2. 4.3 and 8. The calibration for visible channels consists in the conversion from raw data to equivalent Reflectance, while for infrared channels 4 and 5 the conversion is from raw data to Brightness Temperature, corrected by non-linear effects. The infrared channel 3 is converted to spectral Radiance.
If data are derived from 4-channels AVHRR (even-numbered Satellites, except NOAA-12 that has 5-channels) the SHARP Level 2 band 5 is empty.

Band 1 : Channel 1 equivalent Reflectance
Band 2 : Channel 2 equivalent Reflectance
Band 3 : Channel 3 spectral Radiance
Band 4 : Channel 4 Brightness Temperature
Band 5 : Channel 5 Brightness Temperature

2.1.2 SHARP-2B

The SHARP-2B product is consisting of :
2 bands (1 and 5) containing class depending geophysical parameters .
3 bands (2,3 and 4) containing calibrated data converted in: equivalent rRflectance (band 2), AVHRR channel 3 spectral Radiance (band 3) and AVHRR channel 4 Brightness Temperature (band ,4).

Band 1 : Class Dependent parameter:

Land	- NDVI (Normalized Difference Vegetations Index)
Sea	- Channel 1 equivalent Reflectance
cloud	- Channel 1 equivalent Reflectance
snow/ice	- Channel 1 equivalent Reflectance
glint	- Channel 1 equivalent Reflectance
unclass.	- Channel 1 equivalent Reflectance

Band 2 : Channel 2 equivalent Reflectance
Band 3 : Channel 3 spectral Radiance
Band 4 : Channel 4 Brightness Temperature

Band 5 : Class Dependent parameters

Land	- Channel 5 Brightness Temperature
Sea	- Sea Surface Temperature
cloud	- Channel 5 Brightness Temperature
snow/ice	- Channel 5 Brightness Temperature
glint	- Sea Surface Temperature
unclass.	- Channel 5 Brightness Temperature

2.4.1 -SHARP Level-2 Pixel Organization

SHARP Level-2 Pixel is organized in 2 bytes (see SHARP-2 Technical Specification of Format). Starting from the Less Significant Bit there are:

10 Bits used for image data
3 Bits used for state boundary, coastlines and Lat/Long grids flags
3 Bits used for classification flags for the following classes:
land, cloud, sea, snow/ice, unclassified, not processed

The Classification code is:

bit:	1	2	3	code n.
Land	0	0	1	1
Sea	0	1	0	2
cloud	0	1	1	3
snow/ice	1	0	0	4
unclass.	1	1	1	7
unprocess.	0	0	0	0

NOTE: At present the code n.5, 6 are not used

3 GEOMETRIC CORRECTIONS

3.1 Image Navigation

The image is navigated during the SHARP Level-1 generation.

At this stage the navigation is performed using the orbital model for satellite location and tested by the operator who also performs, if it is necessary , further corrections to improve image navigation accuracy.

3.2 Image Remapping

SHARP Level-2 are in the original spacecraft projection without remapping .
A location grid of tie points (Latitude and Longitude) is included into the Suffix data of the IMAGE file (as for SHARP-1). The tie point grid is each 32 pixels and each 16 lines.

4 - CALIBRATION

The calibrations are performed for all the AVHRR channels in the following way:

4.1 VISIBLE bands, AVHRR channels 1 and 2

4.1.1 - Odd-numbered Satellites (NOAA-9 , NOAA-11) : Computation of equivalent Reflectance

Because there are no on-board calibrated sources of visible radiation within the AVHRR instrument, the calibration of these bands for odd-numbered NOAA satellites is derived using the coefficients suggested by Holben et Al. (see ref.(7)).
The procedure is based on radiance measurements over desert areas and it leads, for each satellite, to an absolute and time depending calibration accounting for the degradation of sensivity in AVHRR Channels 1 and 2.
Raw counts are then converted to equivalent Reflectance using the formula (ref.(2), (15)):

$$r_i(l,c) = 100 * \pi * (d_S)^2 * \alpha_i * (CN_i (l,c) - CN_{0i}) \; / \; E_{Si} * \cos \vartheta_{l,c}$$

for $i=1,2$

And d_S is defined as:

$$d_S \cong 1 - 0.01672 * \cos(0.9856 * (Dy - 4)) \qquad \text{(cos argument in decimal degrees)}$$

Where,

d_S = rate between actual Sun-Earth distance and Sun-Earth mean distance
Dy = day of the year (from 1 to 365)
α_i = calibration coefficient band i ($W\ m^{-2}\ sr^{-1}\ \mu m^{-1}\ count^{-1}$)
$CN_i(l,c)$ = digital counts band i for pixel of coordinates l,c (l = line, c = column)
CN_{0i} = deep space digital count for band i
E_{si} = equivalent solar irradiance ($W\ m^{-2}\ \mu m^{-1}$)
$\vartheta_{l,c}$ = Solar zenith angle for pixel of coordinates l,c (decimal degrees)
$r_i(l,c)$ = equivalent Reflectance band i for pixel of coordinates l,c (%)

The calibration coefficients α_i and deep space counts CN_{0i} are given for each odd-numbered satellite in APPENDIX-B.
The day of the year Dy is retrieved from SHARP-1 Image File
The equivalent solar irradiance E_{si} (see APPENDIX-B) is calculated from the solar irradiance weighted by instrument response function . The values of the solar irradiance are derived for channels 1,2 from Holben et Al. they are given in APPENDIX-B.
The Solar zenith angles $\vartheta_{l,c}$ are extracted from the tie point grid.

4.1.2 -<u>Even-numbered Satellites</u> (NOAA-10, NOAA-12): **Computation of effective Albedo**

For even-numbered satellites the visible band calibration is deduced from the pre-launch calibration data published by NOAA, Technical Memorandum NESS 107 (ref. (3)). Using these data raw counts are initially converted to effective Albedo.
Calibration data are given in terms of slope and intercept to be used in the linear formula (ref.(8), (12), (13)):

$$C_i(l,c) = A_i * CN_i(l,c) + B_i \qquad \text{for } i=1,2 \qquad (\%)$$

Where,

$CN_i(l,c)$ = digital counts band i for pixel of coordinates l,c (l = line, c = column)
A_i = slope values band i
B_i = intercept value band i
$C_i(l,c)$ = effective Albedo band i for pixel of coordinates l,c

The calibration coefficients values A_i and B_i are given in APPENDIX-B.
Effective Albedo C_i expresses the target albedo as a percentage .
100% of Albedo corresponds to the channel radiance of a perfectly reflecting Lambertian surface, illuminated at normal incidence by a solar irradiance at the mean Sun-Earth distance, integrated on the instrument bandwidth for the channel i and weighted by instrument response function.

4.1.3 -<u>Even-numbered Satellites</u> (NOAA-10, NOAA-12)**: Computation of equivalent Reflectance**

To compute the equivalent Reflectance at the sensor for the band i the values C_i must be normalized by a term depending from the solar zenith angle that takes into account the oblique solar illumination and by a term that takes into account the actual Sun-Earth distance.
The formula is:

$$r_i(l,c) = (d_S)^2 * C_i(l,c) / \cos \vartheta_{l,c} \qquad i = 1,2$$

where,

d_S = defined in 4.1.1
$C_i(l,c)$ = effective Albedo band i for pixel of coordinates l,c
$\vartheta_{l,c}$ = Solar zenith angle for pixel of coordinates l,c (see 4.1.1) (decimal degrees)
$r_i(l,c)$ = equivalent Reflectance band i for pixel of coordinates l,c (%)

4.2 <u>Infrared bands, AVHRR channels 3,4,5</u>

4.2.1 - Computation of spectral Radiance

In order to calculate the Brightness temperature for the infrared bands, raw counts have first to be converted in at-sensor spectral radiances L_i, using the formula (see ref.(3),(8))):

$$L_i(l,c) = A_i(l) * CN_i(l,c) + B_i(l) \qquad i = 3,5$$

where,

CNi(l,c) = digital counts band i for pixel of coordinates l,c
$A_i(l)$ = Slope value band i for line l ($mW\ m^{-2}\ sr^{-1}\ cm\ count^{-1}$)
$B_i(l)$ = Intercept value band i for line l ($mW\ m^{-2}\ sr^{-1}\ cm$)
$L_i(l,c)$ = Spectral Radiance in band i for pixel of coordinates l,c ($mW\ m^{-2}\ sr^{-1}\ cm$)

$A_i(l)$ and $B_i(l)$ are derived from radiometric in flight calibration according to NOAA -NESDIS procedure, based on regular measurements of the deep space and AVHRR internal blackbody.

The values $A_i(l)$ and $B_i(l)$ are given at each scanline and they are retrieved from suffix data of SHARP1 imagery file records .

4.2.2 - Conversion from radiance to Brightness Temperature

Under the assumption that the Earth viewed by the sensor in the infrared spectral regions emits as a blackbody, the Radiance L_i derived above can be considered as the radiance, sensed in the channel i, from a blackbody at temperature T_i . Thus L_i corresponds to the weighted mean of the Plank's function over the spectral response function of the channel i (ref.(8), (4)).
In terms of discrete steps for the spectral response function:

$$L_i(T_i) = \Sigma_n \; B(v_{i,n}, T_i) * \Phi(v_{i,n}) \; / \; \Sigma_n \; \Phi(v_{i,n}) \qquad i=4,5 \quad n=0,59$$

where $B(v_{i,n},T_i)$ is the Plank's function for a blackbody,

$$B(v_{i,n},T_i) = C1 * v^3_{i,n} / [\exp(C2*v_{i,n}/T_i) - 1] \qquad (mW\ m^{-2}\ sr^{-1}\ cm)$$

and $v_{i,n}$ is defined as:

$$v_{i,n} = v1_i + n* \Delta v_i \qquad (cm^{-1})$$

$v_{i,n}$	=	wave number in the spectral bandwidth of channel i	(cm^{-1})
$v1_i$	=	starting wave number of channel i	(cm^{-1})
Δv_i	=	wave number increment for channel i	(cm^{-1})
$\Phi(v_{i,n})$	=	band i spectral response function at the wave number $v_{i,n}$	
T_i	=	band i Brightness temperature	(K)
C1	=	$1.1910659*10^{-5}$	$(mW\ m^{-2}\ sr^{-1}\ cm^4)$
C2	=	1.438833	(K cm)

The values $v1_i$,Δv_i and band spectral response Φ for 60 values of $v_{i,n}$ are supplied by NOAA and their respective values are published in NESS 107 (see APPENDIX-C) .
For the SHARP level-2 processing, a set of look-up tables of Radiance Vs Temperature are created for each satellite using the formula $L_i(T_i)$.
The look-up tables are calculated for infrared channel 4 and 5 every tenth degree of Brightness temperature starting from T_i = 223.0 K
Thereafter these look-up tables are inverted in order to have for a given input radiance the brightness temperature at 1/10 of Kelvin degree .
A sample of look-up tables Radiance Vs Temperature is shown in appendix A .

4.2.3 Non-linearity correction to the scene Brightness Temperature

The Calibration of the channels 4 and 5 are slightly non-linear and it has been demonstrated by Weinreb et Al. that the nonlinearity is large enough to warrant a correction. NESDIS has provided the corrections that have to be added to the scene Brightness Temperature computed from linear calibrations (see ref.(16)).

$$T_i = T_{i\ linear} + \Delta T_i \qquad i = 4,5$$

where,

T_i	= True brightness Temperature in channel i	(K)
$T_{i\ linear}$	= Brightness temperature in channel i derived as in 4.2.1	(K)
ΔT_i	= Correction term for channel i	(K)

The correction terms ΔTi for the NOAA satellites are published in the article of Weinreb et Al. and they are given in APPENDIX-C . For each channel the corrections for three different values of the internal target temperature, are tabulated against scene Temperature in steps of 10 or 5 degrees . For SHARP Level-2 processing a table containing correction terms ΔTi is computed for each satellite performing a bi-linear interpolation using the data in APPENDIX-C . The interpolation is done for each degree of the scene brightness temperature and for each tenth of degree of the internal blackbody temperature. The mean value of the internal blackbody temperature is computed for the scene using the PRT counts retrieved from SHARP-1 Image File records (bytes 20663-20672) (see for PRT calibrations ref(3) and ref(8)) .

5 GEOPHYSICAL PARAMETERS

5.1 Computation of NDVI

The Normalized Difference Vegetation Index is a parameter derived from reflectance measurements in AVHRR channel 1 and 2.
NDVI is used for exploiting the contrast in optical properties of green vegetation between visible and near-infrared. Therefore, NDVI is very sensitive to the presence of vegetation on the surface of the Earth.
The formula for computing NDVI is:

$$NDVI = [r_2 - r_1] / [r_2 + r_1]$$

that is, simplifying in the above ratio the term cos $\vartheta_{l,c}$ from which depends the reflectance:

$$NDVI = [C_2 - C_1] / [C_2 + C_1]$$

where:

r_1 , r_2 = equivalent Reflectance in channels 1 and 2 derived as in 4.1.1 and 4.1.3
C_1 , C_2 = effective Albedo in channels 1 and 2 derived as in 4.1.2
NDVI = Normalized Difference Vegetation Index

5.2 Computation of SST

NOAA-11

The Sea Surface Temperature is derived using the Split-Window algorithm developed by McClain et Al (ref. (10)) . This algorithm is in operational use at NOAA/NESDIS for daytime images and consists of a non-linear combination of Brightness Temperatures obtained from infrared channels 4 and 5 (corrected by non linearity effects) plus a term that accounts for the satellite zenith angle .

$$SST = a_0 + a_1(T_4 - T_5) * (\sec \phi_{l,c} - 1) + a_2 * T_5 + \frac{a_{31} * T_5 + a_{32}}{a_{33} * T_5 + a_{34} * T_4 + a_{35}} (T_4 - T_5 + a_{30})$$

T_4 , T_5	= Brightness Temperatures calculated as in 4.2.3	(K)
a_0, a_1, ... a_{30}	= constant coefficients given in APPENDIX -D	
$\phi_{l,c}$	= satellite zenith angle for pixel of coordinates l,c	(decimal degrees)
SST	= Sea Surface Temperature	(C)

The coefficients a_0, ... a_{30} were derived from a large global set of buoy matchups in 1990. The satellite zenith angles $\phi_{l,c}$ are extracted from SHARP-1 Image record suffix data.

NOAA-9

The Sea Surface Temperature is derived using the split window algorithm used by NESDIS for this satellite:

$$SST = b_0 + b_1 * T_4 + b_2 * T_5$$

T_4 , T_5	= Brightness Temperatures calculated as in 4.2.3	(K)
b_0, b_1, b_2	= constant coefficients given in APPENDIX -D	
SST	= Sea Surface Temperature	(C)

6 ATMOSPHERIC CORRECTIONS

At present Atmospheric Corrections are not performed for SHARP Level-2

7 DATA CODING

Calibrated data are coded in 10 bits. This means that the digital data range is between 0 and 1023 .
The following look-up tables are set to code each geophysical parameter .

7.1 Equivalent Reflectance coding

The equivalent Reflectance $\mathbf{r_i}$, like the effective Albedo, is expressed as percentage.
In SHARP Level-2 $\mathbf{r_i}$ is coded in 1000 different digital levels:

$$r_{coded} = \text{int}\,[\, r_i * 10 \,]$$

Values less then	$r_i = 0$	are set to:	$r_{i\ coded} = 0$
Values greater then	$r_i = 100$	are set to:	$r_{i\ coded} = 1000$

The expression 'int [.] ' stands for the nearest integer to the value calculated

NOTE:
If it appens that the sun zenith angle is negative (that is when the sun is below the local horizon) for some pixels of the image considered 'daytime' as whole (case of higher latitude during winter, early morning passage, .. etc.) the relevant reflectances $\mathbf{r_i}$ are set to 0 and the classification is not performed (the classification flag set is : "unprocessed", code n. 0 , see 2.4.1) for the pixels .

7.3 Spectral Radiance Coding

The spectral radiance values obtained calibrating AVHRR channel 3, are coded for the band 3 of SHARP Level-2 as follows:

$$L_{3\ coded} = \text{int}\,[\, L_3 * 100 \,]$$

7.4 Brightness Temperature Coding

The Brightness Temperature is calculated at the tenth of degree.
Therefore the value is coded as :

$$T_{i\ coded} = \text{int}\,[\, (T_i - 223.0)*10.0 \,]$$

The minimum value of T_i coded corresponds to:

T_i min = 223.0 K (-50.2 C degrees) $T_{i\ coded} = 0$

The maximum value of T_i coded corresponds to:

$T_i$max = 325.3 K (+52.1 C degrees) $T_{i\ coded} = 1023$

Values less then	T_i min = 223.0 K	are set to:	$T_{i\ coded} = 0$
Values greater then	T_i max = 325.3 K	are set to:	$T_{i\ coded} = 1023$

7.5 SST coding

The SST accuracy obtained from the algorithm proposed by McClain et Al. is in the range of : 0.1 - 0.3 C degrees.
Thereafter the SST has been coded as follow:

$$SST_{coded} = \text{int}\,[SST * 10.0]$$

The minimum value of SST coded corresponds to:

SST_{min} = 0.0 C $SST_{coded} = 0$

The maximum value of SST coded corresponds to:

SST_{max} = 50.0 C $SST_{coded} = 500$

Values less then SST_{min} = 0.0 C are set to: $SST_{coded} = 0$

7.6 NDVI coding

As the NDVI is calculated only for pixel classified 'land ' (both vegetated and nearly desert) the values obtained for NDVI are positive and less than 1.
The coded number is up the thousandth of the NDVI value.
that is in terms of digital levels:

$$NDVI_{coded} = \text{int}[\ NDVI * 1000\ ]$$

Negative NDVI values are set to 0

8 CLASSIFICATION

The image pixels are classified in LAND, CLOUD, SEA, SNOW/ICE according the following algorithm (ref.(11)), the pixels which do not belong to any of these classes are defined UNCLASSIFIED .

The classification algorithm comprises a series of threshold tests performed for each pixel and it is completely automatic.

Tests are performed in the following order:

1) <u>LAND</u> (vegetated)

(ALBEDO2-ALBEDO1)/(ALBEDO2+ALBEDO1) > 0.04

BTEM4-ALBEDO2 > 262

2) <u>CLOUD</u>

BTEM4-ALBEDO2 < 274

BTEM4 <290 K

4) <u>SEA</u>

BTEM4 > 273 K

0.35 < ALBEDO2/ALBEDO1 < 0.89

ALBEDO2 < 9.2%

6) <u>SNOW/ICE</u>

BTEM4 < 275 K

0.6 < ALBEDO2/ALBEDO1 < 0.9

ALBEDO2 > 15%

7) <u>UNCLASSIFIED</u>

If the pixel does not belong to any of the previous tested classes.

APPENDIX-A

Radiance Vs Temperature Look-up table

NOAA-09		NOAA-10	NOAA-11		NOAA-12		Temp.
band 4 Radiance $mW\ m^{-2}\ sr^{-1}\ cm$	band 5 Radiance $mW\ m^{-2}\ sr^{-1}\ cm$	band 4 Radiance $mW\ m^{-2}\ sr^{-1}\ cm$	band 4 Radiance $mW\ m^{-2}\ sr^{-1}\ cm$	band 5 Radiance $mW\ m^{-2}\ sr^{-1}\ cm$	band 4 Radiance $mW\ m^{-2}\ sr^{-1}\ cm$	band 5 Radiance $mW\ m^{-2}\ sr^{-1}\ cm$	K
23.89	30.98	25.45	24.02	31.25	24.55	31.69	**223.0**
24.54	31.75	26.13	24.67	32.02	25.21	32.46	**224.0**
25.20	32.52	26.82	25.33	32.80	25.88	33.25	**225.0**
25.87	33.31	27.52	26.01	33.59	26.57	34.05	**226.0**
26.55	34.11	28.23	26.70	34.40	27.26	34.86	**227.0**
27.25	34.93	28.95	27.39	35.22	27.97	35.69	**228.0**
27.96	35.75	29.69	28.10	36.05	28.69	36.52	**229.0**
28.68	36.59	30.44	28.83	36.89	29.42	37.37	**230.0**
29.41	37.44	31.20	29.56	37.74	30.16	38.23	**231.0**
30.15	38.31	31.97	30.31	38.61	30.92	39.11	**232.0**
30.91	39.18	32.76	31.06	39.49	31.69	39.99	**233.0**
31.68	40.07	33.55	31.84	40.38	32.47	40.89	**234.0**
32.46	40.97	34.36	32.62	41.28	33.26	41.80	**235.0**
33.25	41.88	35.19	33.42	42.20	34.07	42.72	**236.0**
34.06	42.80	36.02	34.22	43.13	34.89	43.65	**237.0**
34.88	43.74	36.87	35.04	44.07	35.72	44.60	**238.0**
35.71	44.69	37.73	35.88	45.02	36.56	45.56	**239.0**
36.55	45.65	38.60	36.72	45.99	37.42	46.53	**240.0**
37.41	46.63	39.49	37.58	46.97	38.29	47.52	**241.0**
38.28	47.61	40.39	38.46	47.96	39.17	48.52	**242.0**
39.16	48.62	41.30	39.34	48.96	40.06	49.53	**243.0**
40.06	49.63	42.22	40.24	49.98	40.97	50.55	**244.0**
40.96	50.65	43.16	41.15	51.01	41.89	51.58	**245.0**
41.89	51.69	44.11	42.07	52.05	42.82	52.63	**246.0**
42.82	52.74	45.08	43.01	53.10	43.77	53.69	**247.0**
43.77	53.81	46.05	43.96	54.17	44.73	54.77	**248.0**
44.73	54.88	47.04	44.93	55.25	45.70	55.85	**249.0**
45.70	55.97	48.05	45.90	56.34	46.69	56.95	**250.0**

APPENDIX-A

Radiance Vs Temperature Look-up table

NOAA-09		NOAA-10	NOAA-11		NOAA-12		Temp.
band 4 Radiance $mW\,m^{-2}\,sr^{-1}\,cm$	band 5 Radiance $mW\,m^{-2}\,sr^{-1}\,cm$	band 4 Radiance $mW\,m^{-2}\,sr^{-1}\,cm$	band 4 Radiance $mW\,m^{-2}\,sr^{-1}\,cm$	band 5 Radiance $mW\,m^{-2}\,sr^{-1}\,cm$	band 4 Radiance $mW\,m^{-2}\,sr^{-1}\,cm$	band 5 Radiance $mW\,m^{-2}\,sr^{-1}\,cm$	K
46.69	57.08	49.06	46.89	57.45	47.69	58.06	**251.0**
47.69	58.19	50.09	47.90	58.57	48.70	59.19	**252.0**
48.71	59.32	51.14	48.91	59.70	49.73	60.32	**253.0**
49.73	60.46	52.19	49.94	60.85	50.77	61.47	**254.0**
50.78	61.62	53.26	50.99	62.00	51.82	62.64	**255.0**
51.83	62.78	54.35	52.04	63.17	52.89	63.81	**256.0**
52.90	63.96	55.44	53.12	64.36	53.97	65.00	**257.0**
53.98	65.16	56.55	54.20	65.55	55.06	66.20	**258.0**
55.08	66.36	57.68	55.30	66.76	56.17	67.42	**259.0**
56.19	67.58	58.82	56.41	67.98	57.29	68.65	**260.0**
57.31	68.81	59.97	57.54	69.22	58.43	69.89	**261.0**
58.45	70.06	61.13	58.68	70.47	59.58	71.14	**262.0**
59.60	71.32	62.31	59.83	71.73	60.74	72.41	**263.0**
60.76	72.59	63.50	61.00	73.00	61.92	73.69	**264.0**
61.94	73.87	64.71	62.18	74.29	63.11	74.98	**265.0**
63.13	75.17	65.93	63.37	75.59	64.31	76.28	**266.0**
64.34	76.48	67.17	64.58	76.91	65.53	77.60	**267.0**
65.56	77.80	68.41	65.80	78.23	66.76	78.93	**268.0**
66.80	79.14	69.67	67.04	79.57	68.01	80.28	**269.0**
68.04	80.49	70.95	68.29	80.92	69.26	81.63	**270.0**
69.31	81.85	72.24	69.56	82.29	70.54	83.00	**271.0**
70.58	83.23	73.54	70.83	83.67	71.83	84.39	**272.0**
71.87	84.62	74.86	72.13	85.06	73.13	85.78	**273.0**
73.18	86.02	76.19	73.43	86.46	74.44	87.19	**274.0**
74.50	87.43	77.53	74.76	87.88	75.77	88.61	**275.0**
75.83	88.86	78.89	76.09	89.31	77.12	90.05	**276.0**
77.18	90.30	80.27	77.44	90.75	78.47	91.50	**277.0**
78.54	91.76	81.65	78.80	92.21	79.85	92.96	**278.0**
79.92	93.23	83.05	80.18	93.68	81.23	94.43	**279.0**
81.31	94.71	84.47	81.57	95.16	82.63	95.92	**280.0**
82.71	96.20	85.90	82.98	96.66	84.05	97.41	**281.0**
84.13	97.71	87.34	84.40	98.17	85.47	98.93	**282.0**
85.56	99.22	88.80	85.84	99.69	86.92	100.45	**283.0**
87.01	100.76	90.27	87.28	101.22	88.37	101.99	**284.0**
88.47	102.30	91.75	88.75	102.77	89.85	103.54	**285.0**
89.94	103.86	93.25	90.22	104.33	91.33	105.10	**286.0**
91.43	105.43	94.77	91.72	105.90	92.83	106.68	**287.0**
92.94	107.02	96.29	93.22	107.49	94.34	108.27	**288.0**
94.46	108.61	97.83	94.74	109.09	95.87	109.87	**289.0**
95.99	110.22	99.39	96.28	110.70	97.41	111.49	**290.0**

APPENDIX-A
Radiance Vs Temperature Look-up table

NOAA-09		NOAA-10	NOAA-11		NOAA-12		Temp.
band 4 Radiance $mW\ m^{-2}\ sr^{-1}\ cm$	band 5 Radiance $mW\ m^{-2}\ sr^{-1}\ cm$	band 4 Radiance $mW\ m^{-2}\ sr^{-1}\ cm$	band 4 Radiance $mW\ m^{-2}\ sr^{-1}\ cm$	band 5 Radiance $mW\ m^{-2}\ sr^{-1}\ cm$	band 4 Radiance $mW\ m^{-2}\ sr^{-1}\ cm$	band 5 Radiance $mW\ m^{-2}\ sr^{-1}\ cm$	K
97.54	111.85	100.96	97.83	112.33	98.97	113.11	**291.0**
99.10	113.48	102.54	99.39	113.96	100.54	114.75	**292.0**
100.67	115.13	104.14	100.97	115.61	102.13	116.41	**293.0**
102.26	116.79	105.75	102.56	117.28	103.72	118.07	**294.0**
103.87	118.47	107.38	104.17	118.95	105.34	119.75	**295.0**
105.49	120.16	109.02	105.79	120.64	106.96	121.44	**296.0**
107.12	121.86	110.67	107.42	122.34	108.61	123.15	**297.0**
108.77	123.57	112.34	109.07	124.06	110.26	124.86	**298.0**
110.43	125.30	114.02	110.74	125.79	111.93	126.59	**299.0**
112.11	127.04	115.72	112.41	127.53	113.62	128.33	**300.0**
113.80	128.79	117.42	114.11	129.28	115.32	130.09	**301.0**
115.50	130.55	119.15	115.81	131.04	117.03	131.86	**302.0**
117.22	132.33	120.89	117.54	132.82	118.76	133.64	**303.0**
118.96	134.12	122.64	119.27	134.61	120.50	135.43	**304.0**
120.71	135.92	124.40	121.02	136.42	122.25	137.23	**305.0**
122.47	137.74	126.18	122.79	138.23	124.02	139.05	**306.0**
124.25	139.56	127.98	124.56	140.06	125.81	140.88	**307.0**
126.04	141.41	129.79	126.36	141.90	127.60	142.72	**308.0**
127.84	143.26	131.61	128.16	143.75	129.42	144.58	**309.0**
129.66	145.12	133.44	129.99	145.62	131.24	146.44	**310.0**
131.50	147.00	135.29	131.82	147.50	133.08	148.32	**311.0**
133.35	148.89	137.16	133.67	149.39	134.94	150.21	**312.0**
135.21	150.80	139.04	135.54	151.29	136.81	152.12	**313.0**
137.09	152.71	140.93	137.41	153.21	138.69	154.03	**314.0**
138.98	154.64	142.83	139.31	155.14	140.59	155.96	**315.0**
140.88	156.58	144.75	141.21	157.08	142.50	157.90	**316.0**
142.80	158.54	146.69	143.14	159.03	144.42	159.86	**317.0**
144.74	160.50	148.63	145.07	161.00	146.36	161.82	**318.0**
146.69	162.48	150.59	147.02	162.97	148.32	163.80	**319.0**
148.65	164.47	152.57	148.98	164.96	150.29	165.79	**320.0**
150.63	166.47	154.56	150.96	166.97	152.27	167.79	**321.0**
152.62	168.49	156.56	152.96	168.98	154.26	169.80	**322.0**
154.62	170.51	158.58	154.96	171.01	156.27	171.83	**323.0**
156.64	172.55	160.61	156.98	173.05	158.30	173.87	**324.0**
158.68	174.60	162.65	159.02	175.10	160.33	175.92	**325.0**

APPENDIX-B

Odd numbered satellites: **NOAA-9, NOAA-11**

AVHRR visible channels calibration coefficients from Holben et Al.:

Satellite	Year	α_1	CN_{o1}	α_2	CN_{o2}
NOAA - 9	1985 (Aug)	0.60	38.0	0.42	39.9
	1986 (Aug)	0.63	37.9	0.43	39.3
	1987 (Aug)	0.68	37.8	0.45	39.1
	1988 (Aug)	0.71	37.8	0.46	39.0
NOAA-11	1989 (Feb/Mar)	0.60	40.0	0.41	40.0

α_1, α_2 unit are (W m^{-2} sr^{-1} μm^{-1} count $^{-1}$)

NOTE: The calibration coefficients to be used for each SHARP-2 processing have to be linearly interpolated between the nearest 2 available.
For NOAA-9 data acquired after 1988 the calibration coefficients of 1988 have to be used.
For NOAA-11 data acquired before 1989 the coefficients will be obtained with a linear interpolation with the NOAA preflight and Holben's ones.
For NOAA-11 data acquired after 1989 the calibration coefficients of 1989 have to be used.

Equivalent solar Irradiance:

E_{si} values from Holben et Al.

Satellite	E_{s1}	E_{s2}
NOAA-9	1629	1043
NOAA-11	1629	1053

E_{s1},E_{s2} unit are (W m^{-2} μm^{-1})

APPENDIX-B: Visible Channels coefficients

Even numbered satellites: **NOAA-10, NOAA-12**

Calibration coefficients from NOAA NESS 107

Satellite	A_1	B_1	A_2	B_2
NOAA - 10	0.10588	-3.52793	0.10607	-3.47665
NOAA - 12	0.1042235	-4.4490805	0.1014400	-3.9925614

APPENDIX-C: Infrared Channels coefficients

Non linearity correction Terms for NOAA-9:

Scene Temperature (K)	Internal Target Temperature (C)					
	channel 4			channel 5		
	10.0	15.0	19.3	10.0	15.0	19.3
320	2.35	2.53	2.28	0.82	1.14	1.16
315	1.89	1.97	1.81	0.64	0.83	0.91
310		1.55	1.31		0.71	0.68
305	1.45	1.02	0.88	0.66	0.35	0.47
295	0.82	0.46	0.17	0.45	0.20	0.09
285	0.11	-0.22	-0.48	0.05	-0.09	-0.24
275	-0.48	-0.61	-0.90	-0.25	-0.31	-0.47
265	-0.71	-0.84	-1.26	-0.42	-0.46	-0.75
255	-0.96	-1.25	-1.50	-0.63	-0.81	-0.91
245	-1.09	-1.36	-1.66	-0.76	-0.92	-1.12
235	-1.15	-1.38	-1.60	-1.03	-1.19	-1.31
225	-1.32	-1.39	-1.53	-1.14	-1.11	-1.14
215	-1.22	-1.34	-1.42	-1.24	-1.28	-1.41
205	-1.21	-1.48	-0.90	-1.43	-1.62	-1.23

APPENDIX-C: Infrared Channels coefficients

Non linearity correction Terms for NOAA-10:

Scene Temperature (K)	Internal Target Temperature (C)		
	channel 4		
	8.7	13.8	19.1
320	3.50	2.83	2.54
315	2.93	2.19	1.97
305	1.88	1.34	1.11
295	1.12	0.57	0.12
285	0.20	-0.15	-0.38
275	-0.46	-0.53	-1.08
265	-0.76	-0.93	-1.37
255	-1.33	-1.49	-1.77
245	-1.74	-2.09	-2.26
235	-1.79	-2.20	-2.53
225	-2.22	-2.51	-2.53
215	-2.58	-2.65	-2.80
205	-2.47	-2.88	-3.27

APPENDIX-C: Infrared Channels coefficients

Non linearity correction Terms for NOAA-11:

Scene Temperature (K)	Internal Target Temperature (C) channel 4			channel 5		
	9.2	14.2	19.0	9.2	13.9	19.0
320	4.29	3.71	3.25	1.43	1.26	1.12
315	3.50	2.98	2.55	1.23	1.03	0.89
310	2.85	2.33	1.91	1.05	0.84	0.70
305	2.23	1.73	1.32	0.85	0.64	0.47
295	1.05	0.68	0.22	0.43	0.28	0.09
285	0.24	-0.21	-0.67	0.07	-0.07	-0.23
275	-0.45	-0.79	-1.15	-0.19	-0.34	-0.47
265	-1.06	-1.37	-1.66	-0.37	-0.51	-0.60
255	-1.41	-1.72	-2.03	-0.60	-0.77	-0.78
245	-1.70	-1.96	-2.22	-0.72	-0.90	-1.92
235	-1.87	-2.10	-2.28	-0.84	-1.02	-1.00
225	-1.90	-2.14	-2.36	-0.94	-1.06	-1.16
215	-1.82	-2.02	-2.20	-1.12	-1.24	-1.16
205	-1.54	-1.76	-1.98	-1.15	-1.27	-1.23

APPENDIX-C: Infrared Channels coefficients

Non linearity correction Terms for NOAA-12:

Channel 4 Non-Linearity Table

Measured Scene Temperature (deg K)	Internal Target Temperature (deg C) 10	15	20	25
205	-1.58	-1.8	-1.31	-1.33
215	-1.24	-1.65	-1.49	-1.53
225	-1.33	-1.65	-1.58	-1.67
235	-1.05	-1.59	-1.51	-1.63
245	-1.18	-1.4	-1.58	-1.62
255	-1.04	-1.2	-1.53	-1.59
265	-0.71	-0.97	-1.19	-1.32
275	-0.41	-0.84	-1.05	-1.19
285	0.16	-0.23	-0.52	-0.7
295	0.8	0.53	0.13	-0.16
305	1.6	1.42	0.8	0.52
310	2.04	1.94	1.28	0.98
315	2.58	2.39	1.72	1.43
320	3.21	2.88	2.27	1.91

Channel 5 Non-Linearity Table

Measured Scene Temperature (deg K)	Internal Target Temperature (deg C) 10	15	20	25
205	-1.17	-1.16	-1.19	-1.23
215	-1.15	-1.19	-1.17	-1.16
225	-1.01	-1.1	-1.15	-1.19
235	-0.88	-0.94	-1.01	-1.1
245	-0.63	-0.76	-0.88	-0.94
255	-0.47	-0.53	-0.63	-0.76
265	-0.37	-0.41	-0.47	-0.53
275	-0.21	-0.31	-0.37	-0.41
285	0.08	-0.08	-0.21	-0.31
295	0.37	0.18	0.08	-0.08
305	0.73	0.61	0.37	0.18
310	0.8	0.73	0.61	0.37
315	0.8	0.8	0.73	0.61
320	0.8	0.8	0.8	0.73

APPENDIX-C: Infrared Channels Normalized Sensor Response Functions

NOAA - F/9 FM 202

Channel 3:

Starting Wave Number: 2469.1355
Delta Wave Number: 7.76849
Response at Starting Wave Number + N * Delta Wave Number
N = 0 through 59

0.0	0.75765E-05	0.14659E-04	0.23167E-04
0.43949E-04	0.91160E-04	0.18353E-03	0.35407E-03
0.68830E-03	0.12443E-02	0.18939E-02	0.24721E-02
0.29108E-02	0.31837E-02	0.33195E-02	0.33728E-02
0.33888E-02	0.34053E-02	0.34316E-02	0.34478E-02
0.34401E-02	0.34075E-02	0.33552E-02	0.33039E-02
0.32757E-02	0.32835E-02	0.33344E-02	0.34060E-02
0.34511E-02	0.34509E-02	0.34395E-02	0.34470E-02
0.34542E-02	0.34294E-02	0.33826E-02	0.33584E-02
0.33815E-02	0.34250E-02	0.34563E-02	0.34623E-02
0.34406E-02	0.33943E-02	0.33365E-02	0.32740E-02
0.31516E-02	0.28842E-02	0.24409E-02	0.19012E-02
0.13559E-02	0.87464E-03	0.51259E-03	0.30171E-03
0.19524E-03	0.13052E-03	0.74406E-04	0.31412E-04
0.75269E-05	0.0	0.0	0.0

Channel 4

Starting Wave Number: 862.0688
Delta Wave Number: 2.37812
Response at Starting Wave Number + N * Delta Wave Number
N = 0 through 59

0.0	0.30603E-04	0.64563E-04	0.10523E-03
0.17057E-03	0.37139E-03	0.85488E-03	0.17526E-02
0.29947E-02	0.43718E-02	0.56739E-02	0.67844E-02
0.77153E-02	0.84881E-02	0.91222E-02	0.96298E-02
0.10022E-01	0.10310E-01	0.10525E-01	0.10708E-01
0.10903E-01	0.11130E-01	0.11370E-01	0.11596E-01
0.11786E-01	0.11949E-01	0.12111E-01	0.12299E-01
0.12523E-01	0.12746E-01	0.12926E-01	0.13022E-01
0.13039E-01	0.13030E-01	0.13047E-01	0.13135E-01
0.13274E-01	0.13419E-01	0.13522E-01	0.13518E-01
0.13274E-01	0.12640E-01	0.11466E-01	0.97239E-02
0.76698E-02	0.56031E-02	0.38225E-02	0.25039E-02
0.15835E-02	0.97002E-03	0.57192E-03	0.31626E-03
0.16604E-03	0.88422E-04	0.50625E-04	0.27594E-04
0.13455E-04	0.52455E-05	0.53119E-09	0.0 /

Channel 5

Starting Wave Number: 793.6506

Delta Wave Number: 1.71045

Response at Starting Wave Number + N * Delta Wave number

N = 0 through 59

0.0	0.0	0.0	0.15207E-04
0.49409E-03	0.13229E-02	0.24498E-02	0.38133E-02
0.53498E-02	0.69507E-02	0.84644E-02	0.97377E-02
0.10632E-01	0.11173E-01	0.11486E-01	0.11700E-01
0.11932E-01	0.12210E-01	0.12526E-01	0.12868E-01
0.13226E-01	0.13583E-01	0.13923E-01	0.14227E-01
0.14479E-01	0.14678E-01	0.14826E-01	0.14928E-01
0.14989E-01	0.15030E-01	0.15082E-01	0.15175E-01
0.15339E-01	0.15557E-01	0.15773E-01	0.15930E-01
0.15971E-01	0.15888E-01	0.15756E-01	0.15658E-01
0.15675E-01	0.15847E-01	0.16041E-01	0.16079E-01
0.15785E-01	0.14993E-01	0.13702E-01	0.12032E-01
0.10104E-01	0.80408E-02	0.59652E-02	0.40025E-02
0.22783E-02	0.91823E-03	0.38213E-04	0.0
0.0	0.0	0.0	0.0

Channel 3:

Starting Wave Number: 2424.24219
Wave Number Increment: 8.17773
Response at Wave Number + N * Wave Number Increment,
N = 0 through 59

0.0	0.13751E-05	0.39496E-05	0.79338E-05
0.11357E-04	0.15556E-04	0.26964E-04	0.50379E-04
0.90236E-04	0.17211E-03	0.33730E-03	0.63486E-03
0.11045E-02	0.16912E-02	0.22951E-02	0.27927E-02
0.30806E-02	0.32169E-02	0.33036E-02	0.33819E-02
0.34655E-02	0.35293E-02	0.35407E-02	0.35122E-02
0.34747E-02	0.34587E-02	0.34906E-02	0.35512E-02
0.35920E-02	0.36036E-02	0.36146E-02	0.36384E-02
0.36644E-02	0.36805E-02	0.36761E-02	0.34652E-02
0.36451E-02	0.36007E-02	0.35607E-02	0.35293E-02
0.35021E-02	0.34652E-02	0.33925E-02	0.32785E-02
0.31784E-02	0.31404E-02	0.30626E-02	0.27733E-02
0.16517E-02	0.11382E-02	0.72913E-03	0.41352E-03
0.18744E-03	0.53037E-04	0.36903E-05	0.30597E-05
0.99799E-05	0.75164E-05	0.85569E-12	0.0

Channel 4:

Starting Wave Number: 840.33594
Wave Number Increment: 2.41476
Response at Wave Number + N * Wave Number Increment,
N = 0 through 59

0.0	0.95537E-06	0.93891E-05	0.32781E-04
0.85461E-04	0.20529E-03	0.43520E-03	0.82424E-03
0.14425E-02	0.23647E-02	0.36140E-02	0.50077E-02
0.63116E-02	0.73295E-02	0.80726E-02	0.86233E-02
0.90618E-02	0.94490E-02	0.98355E-02	0.10270E-01
0.10765E-01	0.11299E-01	0.11848E-01	0.12379E-01
0.12847E-01	0.13202E-01	0.13409E-01	0.13505E-01
0.13552E-01	0.13609E-01	0.13713E-01	0.13882E-01
0.14132E-01	0.14472E-01	0.14884E-01	0.15344E-01
0.15822E-01	0.16164E-01	0.16103E-01	0.15373E-01
0.13800E-01	0.11625E-01	0.92035E-02	0.68878E-02
0.49065E-02	0.32916E-02	0.20569E-02	0.12120E-02
0.70445E-03	0.43396E-03	0.29898E-03	0.20697E-03
0.13060E-03	0.71096E-04	0.29818E-04	0.72388E-05
0.0	0.19847E-05	0.93339E-05	0.0

Channel 5: Repeat of Channel 4

APPENDIX-C: Infrared Channels Normalized Sensor Response Functions

AVHRR FM-203 NOAA-H/11

AVHRR Channel 3

Starting Wave Number: 2484.47217
Wave Number Increment: 7.13929
n = 0 through 59

0.00000E+00	0.10945E-04	0.28150E-04	0.60983E-04	0.14006E-03
0.30581E-03	0.61175E-03	0.11183E-02	0.17813E-02	0.24182E-02
0.28923E-02	0.32167E-02	0.34267E-02	0.35421E-02	0.35775E-02
0.35651E-02	0.35534E-02	0.35689E-02	0.35852E-02	0.35727E-02
0.35346E-02	0.34888E-02	0.34493E-02	0.34248E-02	0.34216E-02
0.34349E-02	0.34568E-02	0.34775E-02	0.34852E-02	0.34733E-02
0.34581E-02	0.34613E-02	0.34858E-02	0.35114E-02	0.35197E-02
0.35126E-02	0.34999E-02	0.34871E-02	0.34715E-02	0.34493E-02
0.34129E-02	0.33519E-02	0.32592E-02	0.31470E-02	0.30333E-02
0.29110E-02	0.27154E-02	0.23767E-02	0.19012E-02	0.13852E-02
0.92617E-03	0.56593E-03	0.30800E-03	0.15192E-03	0.74249E-04
0.41157E-04	0.22843E-04	0.10043E-04	0.34684E-09	0.00000E+00

AVHRR Channel 4

Starting Wave Number: 854.70068
Wave Number Increment: 2.50516
n = 0 through 59

0.12838E-04	0.00000E+00	0.00000E+00	0.56581E-04	0.17545E-03
0.31639E-03	0.42930E-03	0.52284E-03	0.79863E-03	0.14977E-02
0.27592E-02	0.43408E-02	0.59102E-02	0.71887E-02	0.81658E-02
0.89152E-02	0.95077E-02	0.99887E-02	0.10391E-01	0.10748E-01
0.11065E-01	0.11329E-01	0.11527E-01	0.11658E-01	0.11748E-01
0.11821E-01	0.11901E-01	0.11991E-01	0.12088E-01	0.12191E-01
0.12297E-01	0.12406E-01	0.12517E-01	0.12627E-01	0.12724E-01
0.12794E-01	0.12827E-01	0.12830E-01	0.12826E-01	0.12838E-01
0.12845E-01	0.12645E-01	0.11996E-01	0.10657E-01	0.86431E-02
0.63424E-02	0.41718E-02	0.25247E-02	0.14741E-02	0.86297E-03
0.52935E-03	0.32464E-03	0.19180E-03	0.11184E-03	0.65860E-04
0.37159E-04	0.19221E-04	0.84591E-05	0.12845E-05	0.00000E+00

APPENDIX-C: Infrared Channels Normalized Sensor Response Functions

AVHRR FM-203 NOAA-H/11

AVHRR Channel 5

Starting Wave Number: 781.24976
Wave Number Increment: 2.06295
n = 0 through 59

0.13817E-03	0.13106E-03	0.13327E-03	0.15412E-03	0.19677E-03
0.24099E-03	0.26101E-03	0.27834E-03	0.51016E-03	0.12242E-02
0.26155E-02	0.44979E-02	0.65607E-02	0.85105E-02	0.10182E-01
0.11472E-01	0.12285E-01	0.12691E-01	0.12880E-01	0.13042E-01
0.13290E-01	0.13626E-01	0.14043E-01	0.14516E-01	0.14965E-01
0.15298E-01	0.15437E-01	0.15392E-01	0.15223E-01	0.14989E-01
0.14741E-01	0.14516E-01	0.14351E-01	0.14271E-01	0.14252E-01
0.14254E-01	0.14235E-01	0.14171E-01	0.14062E-01	0.13910E-01
0.13708E-01	0.13402E-01	0.12918E-01	0.12181E-01	0.11144E-01
0.98207E-02	0.82362E-02	0.64174E-02	0.44925E-02	0.26917E-02
0.12499E-02	0.37444E-03	0.15195E-04	0.00000E+00	0.82010E-04
0.15007E-03	0.15868E-03	0.12764E-03	0.76770E-04	0.00000E+00

APPENDIX-C: Infrared Channels Normalized Sensor Response Functions

AVHRR FM-205 NOAA-D/12

AVHRR CHANNEL 3
STARTING WAVE # 2439.02393
INCREMENT 9.41466
NUMBER OF POINTS 60

0.44399E-04	0.43179E-04	0.55936E-04	0.97795E-04	0.18920E-03
0.37930E-03	0.75692E-03	0.14601E-02	0.23085E-02	0.28790E-02
0.31477E-02	0.32420E-02	0.32708E-02	0.33021E-02	0.33566E-02
0.34098E-02	0.34272E-02	0.34366E-02	0.34663E-02	0.35015E-02
0.35179E-02	0.34885E-02	0.34301E-02	0.33948E-02	0.33967E-02
0.34267E-02	0.34769E-02	0.35333E-02	0.35484E-02	0.34981E-02
0.34954E-02	0.36188E-02	0.36995E-02	0.35961E-02	0.34420E-02
0.33216E-02	0.29562E-02	0.21401E-02	0.12370E-02	0.65119E-03
0.35555E-03	0.21053E-03	0.14129E-03	0.10082E-03	0.73649E-04
0.60597E-04	0.56961E-04	0.53706E-04	0.47812E-04	0.44102E-04
0.45278E-04	0.47985E-04	0.48839E-04	0.48308E-04	0.47904E-04
0.47980E-04	0.48140E-04	0.48160E-04	0.48099E-04	0.00000E+00

AVHRR CHANNEL 4
STARTING WAVE # 847.45752
INCREMENT 2.80419
NUMBER OF POINTS 60

0.23528E-03	0.24989E-03	0.24905E-03	0.21907E-03	0.20944E-03
0.34807E-03	0.75972E-03	0.15077E-02	0.26267E-02	0.40744E-02
0.55908E-02	0.68815E-02	0.78196E-02	0.84976E-02	0.90207E-02
0.94608E-02	0.98665E-02	0.10275E-01	0.10653E-01	0.10935E-01
0.11072E-01	0.11104E-01	0.11095E-01	0.11102E-01	0.11148E-01
0.11250E-01	0.11415E-01	0.11628E-01	0.11867E-01	0.12104E-01
0.12293E-01	0.12382E-01	0.12336E-01	0.12206E-01	0.12071E-01
0.11983E-01	0.11819E-01	0.11368E-01	0.10435E-01	0.90487E-02
0.74144E-02	0.57432E-02	0.41985E-02	0.28674E-02	0.18300E-02
0.11384E-02	0.73017E-03	0.51293E-03	0.39701E-03	0.33244E-03
0.30034E-03	0.28265E-03	0.26617E-03	0.25081E-03	0.23872E-03
0.23185E-03	0.23012E-03	0.23183E-03	0.23528E-03	0.00000E+00

AVHRR CHANNEL 5
STARTING WAVE # 787.40137
INCREMENT 2.09809
NUMBER OF POINTS 60

0.34277E-03	0.81468E-04	0.75120E-04	0.57879E-03	0.17627E-02
0.34788E-02	0.55052E-02	0.76087E-02	0.95132E-02	0.10932E-01
0.11658E-01	0.11897E-01	0.11984E-01	0.12216E-01	0.12624E-01
0.13116E-01	0.13603E-01	0.14051E-01	0.14467E-01	0.14858E-01
0.15207E-01	0.15466E-01	0.15585E-01	0.15547E-01	0.15433E-01
0.15340E-01	0.15351E-01	0.15442E-01	0.15531E-01	0.15538E-01
0.15451E-01	0.15348E-01	0.15313E-01	0.15387E-01	0.15383E-01
0.15044E-01	0.14117E-01	0.12541E-01	0.10500E-01	0.81903E-02
0.58119E-02	0.35862E-02	0.17429E-02	0.51081E-03	0.00000E+00
0.00000E+00	0.12053E-03	0.28451E-03	0.32615E-03	0.29113E-03
0.23141E-03	0.19459E-03	0.18866E-03	0.20050E-03	0.21681E-03
0.22623E-03	0.22785E-03	0.22429E-03	0.21813E-03	0.00000E+00

APPENDIX-D

In the following table there are the coefficients used for the split window algorithm derived by McClain et Al. .

Split Window Coefficients

NOAA-11

a_0 = - 254.18

a_1 = 0.81

a_2 = 0.9291

a_{30} = 0.789

a_{31} = 0.1907

a_{32} = - 49.16

a_{33} = 0.2052

a_{34} = - 0.1733

a_{35} = - 6.78

NOAA-9

b_0 = -265.4789

b_1 = 3.6084

b_2 = -2.6353

APPENDIX - E

In the following pages it is shown a Fortran program which gives example of how extract geophysical parameters and flags from the digital data.

```
**********************************************************************
  variable declarations

  Buffers containing record
  character*1800  learec
  character*22680 imarec

  band() is the buffer containing image counts
  integer*2       band(2048,5)

  flaggeo and flagcla contain the flag values extracted from the
  pixel relevant to grid/coastline/st.bound. and  to
  the classification
  integer*2       flaggeo, flagcla

  The following variables are used to store the whole set of
  classification flags.
  integer*2      fland, fsea, fcloud, fice, funcl, funpr

  realbuf() contains the physical values extracted from the counts
  real*8          realbuf(5)

  slp() and int() contain the slope and intercept values
  used  to convert digital counts into phys. value.
  real*8          slp(7), int(7)

  dcmax(), dcmin() contain the maximum and the minimum digital
  value written for a physical parameter.
  integer*4       dcmax(7), dcmin(7)

  nrig is the n. of image lines  for this image (up to 1440)
  The value of nrig has to be read from IMAGE file descriptor rec.
  integer*4       nrig
  character*6     ncha

  bnd is the no. of bands for the satellite and can be 4 (NOAA-10)
  or 5 (NOAA-12,-11,-9,..)


  equivalence (imarec(37:20516), band(1,1))
  equivalence (imarec(181), ncha)

  data fland      /  8192   /
  data fsea       /  16384  /
  data fcloud     /  24576  /
  data fice       /  -32768 /
  data funcl      /  -8192  /
  data funpr      /  0      /
**********************************************************************

  open Level-2 LEADER file

  open(unit = 8, file='LEADER2B', access = 'direct',
+      form='unformatted', recl= 1800)
  For unformatted open:
  in Sun Fortran the recl is expressed in n.of bytes per record
  in VMS Fortran the recl is expressed in n.of longwords per record


  open Level-2 IMAGE file
  open(unit = 9, file='IMAGE2B', access = 'direct',
+      form='unformatted', recl= 22680)
```

APPENDIX - E

```
c       read the Level-2 LEADER file record n. 6
        read(unit=8, rec=6)learec

c       get slope & intercept to extract phys. value from data
        iys=77
        iye=749
        iyg=112
        id=0
        do iy=iys,iye,iyg
        id = id + 1
        read(learec(iy:iy+47),222)dcmin(id), dcmax(id), slp(id), int(id)
        end do
222     format(2i8,2f16.4)


c       read Level-2 IMAGE record

c       Reading the file descr. rec.
        read(unit=9, rec=1)imarec
c       get nrig
        read(unit=ncha(:6), fmt=300) nrig
300     format(i6)
        bnd=5
c       (or bnd=4)

c       starting from the IMAGE rec n. 2 to skip the file descr. rec.

        do i=2, nrig
        read(unit=9, rec=i)imarec

        do j=1,2048

        flaggeo = 0
        flagcla = 0

c       extract grid/coastline/state boundary flag
        flaggeo = and(band(j,1),7168)

c       extract classification flag
        flagcla = and(band(j,1),57344)

c       clean up the pixel from the flagged bits
        do k = 1, bnd
        realbuf(k) = 0
        band(j,k) = and(band(j,k), 1023)
c       Level 2A case :  converts count to phys. value
        realbuf(k) = dble(band(j,k))*slp(k) + int(k)
        end do



c       Level 2B case :  converts count to phys. value


        if(flagcla .eq. fland)then
        realbuf(1) = dble(band(j,1))*slp(6) + int(6)
        do l=2,5
        realbuf(l) = dble(band(j,1))*slp(l) + int(l)
```

```
end do

else if(flagcla .eq. fcloud)then
do l=1,5
realbuf(l) = dble(band(j,l))*slp(l) + int(l)
end do

else if (flagcla .eq. fsea)then
do l=1,4
realbuf(l) = dble(band(j,l))*slp(l) + int(l)
end do
realbuf(5) = dble(band(j,5))*slp(7) + int(7)

else if(flagcla .eq. fice)then
do l=1,5
realbuf(l) = dble(band(j,l))*slp(l) + int(l)
end do

else if(flagcla .eq. funcl)then
do l=1,5
realbuf(l) = dble(band(j,l))*slp(l) + int(l)
end do

else if(flagcla .eq. funpr)then
do l=3,5
realbuf(l) = dble(band(j,l))*slp(l) + int(l)
end do

End of level 2B case
endif


end do

end do


close(8)
close(9)

stop
end
```

REFERENCES

Ref. (1)
P. Abel Prelaunch Calibration of NOAA 11 AVHRR visible and near IR channels.
Remote Sensing of Environment 1990 31:227-229

Ref. (2)
O. Arino Etude de la variabilite spatiale et temporelle d'indices de vegetation sur l'Afrique.
Contrat LERTS-IATD 30 Avril 1991

Ref. (3)
" Data Extraction and Calibration of Tiros-N/NOAA Radiometers". NOAA Technical Memorandum NESS-107 Rev.1, Nov. 1979 (Revised Oct. 1988)

Ref. (4)
P. Y. Deschamps, Y. H. Kerr Definition study of AVHRR derived products.
Prepared for ESA-Earthnet, final report November 1990

Ref. (5)
P. Y. Deschamps, T. Phulpin Atmospheric correction of infrared measurements of sea surface using channels at 3.7, 11 and 12 micron. Boundary Layer Meteorological, 1980

Ref. (6)
O. Hagolle Chaine de traitement CNES des images AVHRR-NOAA
Campagne 1988-89-90 manuel de l'utilisateur. 9 Jan. 1991 note n.006 Edition 1 rev. 0

Ref. (7)
B.N. Holben, Y.J. Kaufman, J.D. Kendall NOAA-11 AVHRR visible and near-ir inflight calibration.
International Journal of Remote Sensing 1990 11, 1511-1519

Ref. (8)
K. B. Kidwell Noaa Polar Orbiter Data User Guide. July 1991

Ref. (9)
D.T. Llewellyn-Jones, P.J. Minnet, R.W. Saunders, A.M. Zavody
Satellite multichannel infrared measurements of sea surface temperature of the N.E. Atlantic Ocean using AVHRR/2 .
Quarterly Journal of the Royal Meteorological Society, 1984 110 p. 613-631

Ref. (10)
E.P. McClain, C.C. Walton, L.L. Stowe CLAVR, cloud/clear algorithms and non linear atmospheric corrections for multichannel sea surface temperatures.
Fifth conference on satellite meteorology and oceanography, 3-7 September 1990

Ref. (11)
K. Muirhead Automatic classification of AVHRR images 4th AVHRR Data User Meeting, 1989

Ref. (12)
J.C. Price Calibration of satellite radiometers and comparison of vegetation indices. Remote Sensing of Environment 1987 21:15-27

Ref. (13)
J.C. Price An update on visible and near infrared calibration of satellite instruments . Remote Sensing of Environment 1988 24:419-422

Ref. (14)
H.Neckel, D.Labs The solar radiation between 3300 and 12500 A, Solar Physics 1984 90:205-208

Ref. (15)
P. M. Teillet
Report on a special meeting on AVHRR Data preprocessing and compositing Methods. 12 -14 March 1990

Ref. (16)
P.M. Weireb, G. Hamilton, S.Brown, R.J. Koczor Nonlinearity Corrections in Calibration of Advanced Very High Resolution Radiometer Infrared Channels. Journal of Geophysical research 1990 Vol.95 p. 7381-7388