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CLARENDON LABORATORY

Atmospheric Physics

The Selective Chopper Radiometer on Nimbus V

Archived Data

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The Nimbus V satellite launched on 11 December 1972 carries a 16 channel infra-red radiometer designed to make remote measurements of the atmosphere. Eight channels are located in the CO_2 15μ m band measuring temperature structure up to about 50 km altitude. The higher levels are achieved by means of a selective chopping technique. The remaining channels make measurements of water-vapour, atmospheric window regions and reflective sunlight. For details see the general references listed.

This paper describes the format of the archive tapes, containing frame by frame radiances and other relevant data, which have been prepared for the National Space Science Data Centre. This document is intended to be read in conjunction with reference 1 which contains details of calibration algorithms together with explanations of all the terms which will be encountered in the following pages.

In general the Nimbus V Selective Chopper Radiometer (SCR) has performed in a very consistent manner, and is still producing excellent data at the time of writing (January 1977). However, there have been a number of problems and anomalies which have occurred from time to time which have a bearing on the use and interpretation of these data. These events have been studied and written up in reference 1, together with a list of relevant dates.

Should any problem arise, would users please contact the Department of Atmospheric Physics, Clarendon Laboratory, University of Oxford.

Tape Format

Introduction

The Nimbus 5 archive tape is a 7 track magnetic tape written at 800 b.p.i. with odd parity and 0.75" interblock gaps. Each tape contains data for approximately 10 'days' where a 'day' refers to the daily transmission of data from NTCC to Oxford. This normally includes data acquired by the ground station between 0000Z and 2400Z the previous day.

Each tape begins with a file summarizing its contents. Subsequent files provide detailed day by day and orbit by orbit information. An orbit is usually a readout orbit from the spacecraft tape recorder but can also represent one or more sections of real time data. The tape ends with a repeat of the summary file.

The structure of an archive tape is summarized in Table I.

TABLE I

Summary header record Summary day records 1 to N where N = number of days on the tape End of summary record End of file (tape mark)		Summary file Volume table of contents
Day header file EOF		repeated for each day
Orbit header record Data records 1 to M where M=No.of major frames/10+1 End of orbit record EOF	repeated for each orbit	
End of day file EOF		
Copy of summary file EOF mark EOF		

Detailed description

In general, for all tables, numbers in the column headed CONTENTS are octal and other numbers decimal. Exceptions are indicated by the subscripts 8 or 10 for octal or decimal.

Each file consists of a series of records and is terminated by a tape mark. Each record is a series of 12-bit integers, each represented by 2 6-bit tape characters with ODD parity, the most significant half of the word appearing first on the tape. The format of a record is as follows:

Word	Contents
0,1	7106, 7106
2	Length L
3	Record Number
4	Identifier
5 to L-3	Data words
L-2	EOR mark
L-1	Checksum

'Length' is the number of 12-bit words in the record from the first 7106_8 up to and including the checksum.

The record number starts at 1 at the beginning of the file and is increased by 1 for each successive record Modulo 4096.

The identifier is a unique code associated with the data content of the record.

The end of record (EOR) mark has one of the following values:

5252	last record of file
5225	file containing one record
6453	last record on the tape
4421	all other records.

The checksum is the 12-bit 1's complement sum of words 0 to L-2 of the record.

Summary Head Record		No.of words	Note
Word	Contents		
0,1	7106, 7106	2	
2	10	1	
3	1	1	
4	5200	1	
5	No. of days on tape	1	
6	EOR (4421)	1	
7	Checksum	1	
Summary Day Record			
0,1	7106, 7106	2	
2	Length	1	
3	Record no.	1	
4	5201	1	
5	'day'	1	
6	'year'	1	
7,8	no. of major frames in day	2	
9	no. of cse's on day's transmission	1	1
10	" " " read from daily tape	1	1
11	no. of cal sequences in day	1	
12	no.of orbits in day	1	
13,14	orbit no.	2	
15	HDRSS	1	2
16	no. of major frames in orbit	1	
17	day of first major frame	1	3
18,19	time of ditto	2	3
20	day of last major frame	1	3
21,22	time of ditto	2	3
23	no. of cse's on orbit's transmission	1	1
24	" " " read from daily tape	1	1
25	no. of cal sequences in orbit	1	
	.		
	.		
	EOR (4421)		
	checksum		

items 13-25 repeated for each orbit in the day.

Day Header File

Word	Contents	No. of words	Note
0,1	7106, 7106	2	
2	11	1	
3	1	1	
4	5202	1	
5-12	same as words 5-12 of the corresponding "Summary Day Record"	8	
13-92	calibration data used for the processing of this day's observations	80	5
93	EOR (5225)	1	
94	checksum	1	

Orbit Header Record

0,1	7106, 7106	2	
2	16	1	
3	Record no.	1	
4	5204	1	
5-17	as orbit summary in this day's summary record (wds 13-25)	13	
18	number of housekeeping functions ($N = 44_{10}$)	1	6
19	N maximum values for this orbit	N	
	N minimum values	N	
	N mean values	N	
	EOR (4421)		
	checksum		

Data Record

Word	Contents	No. of words	Note
0,1	7106, 7106	2	
2	length	1	4
3	record no.	1	
4	5205	1	
5	no. of major frames in this block (10_{10} unless end of orbit)	1	4
6	length of entry for each m.f.(186_{10})	1	4
7	spare and zero	1	
8	checksum word for major frame	1	10
9,10	orbit no.	2	
11	block no.	1	9
12	frame no./HDRSS	1	9
13	day	1	3
14	time	2	3
16	latitude x 8	1	7
17	longitude x 8	1	7
18	altitude	1	7
19	ESMR MAXIMUM	1	8
20	ESMR MINIMUM	1	8
21-25	major frame flags	5	11
26-74	calibrated radiances	49	12
75-79	16 sec ramps	5	13
80-123	4 sec ramps	44	13
124-128	digital A housekeeping	5	6
129-167	analogue housekeeping	39	6
168	FOVC ramp	1	17
169-176	raw ESMR	8	8
177	pitch	1	15
178	roll	1	15
179	yaw	1	15

Continued

Data Record (continued)

Word	Contents	No. of words	Note
180-182	A2, A3, A4 declouded	3	14
183-185	B1-B2, B2-B3, B3-B4 smoothed	3	14
186	sea surface temperature/GEOG	1	16
187-193	B1, B2, B3, B4, B1-B2, B2-B3,B3-B4 corrected radiances	7	14
	.		
	EOR (4421)		
	checksum		

items 8-193 are repeated for each major frame in the block.

End of Summary Record

0,1	7106, 7106	2
2	7	1
3	Record No.	1
4	5202	1
5	EOR (5252)	1
6	Checksum	1

End of Orbit Record

0,1	7106, 7106	2
2	7	1
3	Record No.	1
4	5206	1
5	EOR (5252)	1
6	Checksum	1

End of Day File

0,1	7106, 7106	2
2	7	1
3	1	1
4	5207	1
5	EOR (5225)	1
6	Checksum	1

End of Tape File

Copy of Summary File.

Notes

1. A checksum error (CSE) on transmission implies a block was corrupt when we received it over the link from Nimbus. A CSE on the daily tape implies a block was found to be corrupt on the magnetic tape when it was subsequently processed. A transmission error does not generate a daily tape error.

2. HDRSS refers to the onboard tape recorder used for this orbit.

0 = A data received from tape recorder A

1 = B " " " " " B

2 = R " " as real time pass.

3. 'Day Number' starts at 1 on January 1st and increments through a year. Time is given in seconds since midnight GMT (double length word).

4. Normally each data block will contain 10_{10} major frames of data. Thus the normal block length is

$$186 \times 10 + 10 = 1870_{10} \text{ words.}$$

Short blocks occur at the end of orbits, when the length is not a multiple of 10 major frames. If the number of major frames is a multiple of 10 then there should be no short blocks but it is advisable to cater for the possibility that the last block may be of length 10 words with zero major frames in it.

5. The calibration algorithm is explained in reference 1. The calibration parameters used for each day's data consist of a total of 80 numbers, arranged in 20 groups of 4 numbers each. The 20 groups correspond to the 20 channels of the instrument (D channels on low and high gain have separate calibration parameters). The ordering of these 20 groups is as follows:

B1 to B4

A1 to A4

C1 to C4

D1 to D4 low gain setting

D1 to D4 high " "

The significance of the 4 numbers within each group is:

EZ = electrical zero (counts).

S-EZO = space - electrical zero offset (counts).

r = stray radiation $\sim$ always set to zero in practice.

$$G = g \times \frac{160 \times 2^{11}}{\bar{S}}$$

where g = gain (volts/unit radiance)

$\bar{S}$ = scaling factor used to represent radiances (see table 1).

6. Housekeeping Functions. There are a total of 44 housekeeping functions recorded for each major frame. The first 5 functions are of the 'digital A' type and the remainder are of type 'analogue'. The orbit header record contains a summary of the maximum, minimum and mean values recorded during the orbit for these functions. The ordering is as follows:

Number	Power Supply	Function
DIGITAL A		
1	-	-6V thermistor supply
2	-	Digitizer zero offset
3	1	Black body thermistor 1
4	1	" " " 2
5	1	" " " 3
ANALOG		
6	9	Sensor foot F thermocouple
7	-	Mod PCU stabilized output
8	-	Full time thermistor supply 1
9	-	Switched " "
10	-	Chopper motor current 1
11	-	" " " 2
12-17	8	Sensor housing thermistors 1 to 6
18	29	Black body thermistor 4
19	9	Calib.mirror thermistor
20	8	Chopper motor "
21-23	9	Sensor foot thermistors A, B & C
24	8	Module connector plate thermistor
25	8	Calib. mirror driver "
26	8	Chopper resistor "
27	8	Mod PCU stabilized "
28	9	Mod PCU switched "
29	-	-6V black body thermistor supply

Number	Power Supply	Function
30	-	Signal channel A clamp level
31	9	Sensor foot D thermistor
32	9	Filter wheel A shroud thermistor
33	9	" " A motor "
34	-	Signal channel B clamp level
35	-	Filter wheel B heater power
36	9	" " B shroud thermistor
37	9	" " B motor "
38	-	Signal channel C clamp level
39	9	Filter wheel C shroud thermistor
40	9	" " C motor "
41	-	Clamp level D
42	9	Sensor foot E thermistor
43	9	Filter wheel D shroud thermistor
44	9	" " D motor "

Note the power supplies 8 and 9 are each sampled through a potential divider. Thus to obtain the true power supply multiply functions 8 and 9 by 1.47.

The digital A functions are subject to a digitizer zero offset (function 2) which should be subtracted from each of the other 4 functions to obtain a true value. Function 29 is an analog backup to the digital A, -6 volt supply, i.e. (function 29) = (function 1) - (function 2).

7. Latitude and longitude are in eighths of degrees north and east respectively, e.g. 10°S, 300°E is 4016, 2400. Latitude is a signed integer. Longitude is unsigned. Altitude is taken directly from the header block as received from Nimbus. See reference 2.

8. The eight nadir samples from the electrically scanning microwave radiometer (ESMR) contained within the major frame header block as transmitted can be found in words 169-176. The maximum and minimum of these eight values are also in words 19 and 20 respectively. This data may be used as a land/sea flag.

9. Block number is taken from word 4 of the Header Block as received from Nimbus. Frame # /HDRSS is taken from word 9 of the Header Block as received from Nimbus. See reference 2.

10. Checksum word for major frame. If bit 2^x = 1 then the following checksum error was detected:

x = 0 checksum error on magnetic tape raw data block.
= 1 " " " " " formatted data block.
= 2 " " " transmission to Oxford.

11. Major Frame Flags

5 words.

Bit 2^x is set to 1 when the following conditions are satisfied at any time during the orbit.

Word 1

X = 0 SCR power on
1 Chopper power on
2 Calibration imminent
3 D channels on high gain (else low gain)
4 Calibration enabled
5 FOVC enabled
6 Earth view
7 Black body view
8 Housing view
9 Space view
10 Filter wheel select position 1
11 " " " " 2

Word 2

X = 0 " " " " 3
1 " " " " 4
2 SCR2 format is being used (analog not digital A)
3 Satellite day = 1, night = 0
4 THIR on
5 ESMR on and scanning
6 S-band A on
7 " B on
8 " SCMR on
9 Beacon on
10 Latitude, longitude corrected for pitch bias
11 End of orbit detected

Word 3

X = 0 checksum error in header block
1 " " " "
2 minor frame SYNC error
3 bad filter position detected
4 " chopper sync
5 FOVC motion bad
6 bad end of block marker
11 discontinuity in time code from previous major frame.

Word 4 is spare

Word 5

X = 0 1 = calibrated data slots in format do contain radiances.
0 = " " " contain raw ramps (this occurs where instrument is not viewing earth, i.e. calibration sequences).

12. Calibrated radiances

In order to fit conveniently into one 12 bit word, the radiances for each channel are scaled by some suitable factor (see ref. 1). The contents of the appropriate locations should be divided by the following scale factors in order to obtain a result in radiance units ($mW/m^2/ster/cm^{-1}$).

Table 1

Channel	Scale factor	
A & B	16	
C1	400	
C2	40	
C3 & C4	20	
D1	2.10^4	D channels on low gain
D2	5.10^3	
D3	750	
D4	1000	
D1 & D2	5.10^5	D channels on high gain
D3	6.10^6	
D4	10^4	

The state of the D channels gain is determined from the information given in the flag words.

In the case of the top channels which are not influenced by cloud, the 4 samples for each major frame are averaged to give a single value corresponding to the 16 seconds of the major frame. The calibrated radiances consist of a total of 49 words corresponding to 5 16-second averages for the top channels, plus 4 x 11 samples corresponding to the remaining lower channels.

The ordering is as follows:

16 second radiances

channels B1 to B4, A1

4 second radiances (4 samples/channel)

channels A2 to A4
C1 to C4
D1 to D4

Any slot set to zero implies that the corresponding signal has been rejected for one or other quality criterion. The flag word 5, bit 2^0 should be checked that it contains a one, or else all calibrated radiance slots will contain raw ramps and not radiances. This situation occurs during calibration sequences.

13. The ramps represent the raw signal information. Each observation consists of 5 samples (called S1 to S5) taken on an integration ramp, the samples are 200 mSec apart. The ramp signal is taken as corresponding to an 800 mSec integration period, i.e.

$$\text{Ramp} = S5 - S1.$$

Where the magnitude of the signal is such that the upper sample exceeds the dynamic range of the telemetry, i.e. S5 $>$ 1023, we may make use of the other samples suitably scaled, i.e.

$$\text{Ramp} = \frac{4}{3}(S4-S1) = 2(S3-S1) = 4(S2-S1).$$

The possibility of the lower sample S1 being corrupt is also allowed, i.e.

$$\text{Ramp} = \frac{4}{3}(S5-S2) \quad \text{and so on.}$$

The ordering of the ramps is identical to that of the 49 calibrated radiances (see note 12). Again the top channels B1 to B4 and A1 represent major frame averages, and the remainder 4 second observations.

14. The construction of the B difference channel radiances, together with the smoothing algorithm is described in detail in reference 1. The 'de-clouding' of the A channels involves constructing an envelope radiance indicating the signal one would expect from the A channels in the absence of cloud. This is described in reference 1.

15. Pitch, roll and yaw rate are taken from the Header Block as received at Oxford. See reference 2.

16. Sea surface temperature/geography.

Over land areas, this word represents the mean surface height tabulated for a 1^{o} latitude / longitude grid. Over ocean areas, this word contains the mean climatological sea-surface temperature tabulated for a $2\frac{1}{2}^{o}$ latitude /longitude grid for monthly intervals (see reference 3). The two cases are distinguished as follows:

If this word is positive then we have land - mean height is given in units of 100 feet.

If this word is negative then we have ocean - mean sea-surface temperature is the absolute magnitude in units of tenths of a ^{o}C.

17. The field of view compensator (FOVC) ramp gives a quick indication of FOVC working correctly. FOVC drive is sampled once per second, its motion repeats every 4 seconds.

FOVC ramp = Sample 4 - Sample 1

averaged for the 4 ramps each major frame.

References

1. The Nimbus 5 Selective Chopper Radiometer. Atmospheric Physics Memorandum No. 76.1, University of Oxford.

2. R.A. Stephenson. Formats of Nimbus E Experiment Tape (ET). Stacked Experimental Tape (SET), and DATRAN Tape. General Electric/NASA, 1972.

3. W. Washington (NCAR). Memorandum on Climatological Sea Surface Temperature.

General References

J.J. Barnett, et al. 1973. Stratospheric observations from Nimbus V. Nature, 245, 141.

P. Ellis et al. 1973. Remote sounding of atmospheric temperature from satellites IV. The Selective Chopper Radiometer on Nimbus V. Proc.R.Soc.A 334, 149.