HIRDLS

TC-OXF-89A

HIGH RESOLUTION DYNAMICS LIMB SOUNDER

Originator: J. J. Barnett

Date: 19 Dec 97

Subject/Title: **SIGNAL-TO-NOISE RATIOS FOR ATMOSPHERIC VIEWS**

Description/Summary/Contents:

Changes from previous version:

1) Height ranges updated to new value in SC-HIR-18L (channel 3 lower limit needed changing).

2) NEN figures revised to those of SC-HIR-18L (channel 8 needed changing).

3) Atmospheric radiance profiles changed by revision of TC-HIR-90A (to reflect passband changes in channels 10 and 11).

4) Jitter angle of 3.4 micro radian used instead of 0.7 arc sec (which is almost identical); this has caused slight changes in some of the quantities, notably the signal to noise ratios.

5) Noise equivalent angles are now given in microradian (arc sec previously).

Keywords: Signal_to_noise; stability; pointing; noise; radiance; NEN

Purpose of this Document:
(20 char max.)

Reviewed/Approved by: Date (yy-mm-dd):			

Oxford University
Atmospheric, Oceanic & Planetary Physics
Parks Road
OXFORD OXI 3PU
United Kingdom

EOS

Tables of radiance as a function of tangent height measured by each channel of the HIRDLS instrument have been used to calculate maximum signal-to-noise ratios. The tables are given in TC-HIR-90A (Halvorson 1994), and Appendix A for tropical conditions has been used. The spectral bandpasses are those specified in the IRD version SC-HIR-18L. TC-HIR-90A lists radiances at every one kilometre of apparent tangent height between 0 and 80 km altitude. It also gives the actual tangent heights (different from apparent because of refraction); these differ by 0.9 km at about 8 km, (decreasing to smaller values higher up) but the distinction between the two heights is not sufficient to be of concern for this application, and apparent tangent heights have been used here.

The sources of short term random error may be divided into two categories for the present purposes:

i) Radiometric noise (arising from detectors, preamplifiers, digitisation error, chopper imperfections, etc); this error is contained in the NEN and is given in the IRD separately for each channel and is assumed to be independent of signal.

ii) Error due to incorrect knowledge of the tangent height; if there exists a non-zero vertical gradient of radiance, this will lead to a radiance error. An rms (i.e. 1 sigma) value of 3.4 micro radian (0.7013 arc sec) elevation angle is specified in SC-HIR-18L section 2.7.5, which corresponds to 0.010 km altitude increment at the limb.

The total error will arise from a combination of these errors; at some heights one will dominate, and at others the other may dominate. Given enough resources either could be made smaller; for example as shown later the pointing error contribution could be made negligible compared with the current NENs in all channels if the pointing error could be made 1-2 orders of magnitude smaller, but this is not considered to be a realistic objective.

Table 1 gives several quantities for each channel for the altitude of maximum radiance within the altitude range when the IRD states that good quality radiance data are required for retrieval purposes. (Note that lower quality radiance data may also be required at lower latitudes for correcting for out of field responses). This maximum radiance divided by the required one sigma NEN is given (S:NEN), and this represents the maximum atmospheric signal to noise ratio, in the absence of noise due to uncertainty in the tangent height. Subsequent columns give the vertical radiance gradient at this height, the elevation angle increment in micro radians that will produce a radiance error equal to the NEN (called NEA or noise equivalent angle), and the signal-to-noise ratio (S:AN) that would arise if the angular error of 3.4 micro radian rms were the only source of error. Then the total signal-to-noise ratio is given (based on the RSS of angular and radiometric noise), followed by the tangent height for which all of this information has been given. It may be noted that in all cases except channel 4 the maximum radiance occurs at the bottom of the wanted atmospheric range, primarily because the limb path opacity increases with decreasing height. In the case of channel 4 (mid altitude carbon dioxide) the atmosphere is nearly opaque in the bottom part of this range, and with the temperature falling with decreasing height, the radiances peak within the range at 21 km. This produces an extremely small vertical gradient at this point, hence negligible radiance errors due to pointing uncertainties (the NEA is 400 micro radian), and large signal-to-noise ratios from this cause. For many of the channels the total signal-to-noise ratio is limited by pointing knowledge. Channel 5 provides the highest total signal-to-noise ratio (3657), which arises from the highest radiometric ratio (4009) coupled with relative insensitivity to pointing errors (7.6 micro radian NEA).

Table 2 provides the same information as table 1, but for the height of maximum vertical radiance gradient. Hence these are the levels most sensitive to pointing errors. In some cases this height is again at the bottom of the required height range. This table shows that channel 12 has the greatest sensitivity (smallest NEA), with a NEN equivalent angle of 0.38 micro radian.

Table 3 provides the same information as tables 1 and 2 but for the altitude of maximum total signal-to-noise ratio. Hence this table can be used to obtain the best total signal-to-noise ratio. Again several of the channels have the best performance at the bottom of their height range. The best ratio of 3657 is obtained from channel 5 at 30 km, and channel 6 provides the worst ratio (237), being limited by the pointing knowledge. This should not be taken to indicate that the channel 6 NEN could be increased without penalty, because the NEN limits the higher altitude performance of this channel (i.e. the maximum height to which aerosol can be measured).

These results have a bearing on the apportionment of the NEN to different sources. If we assume that for the channel for which the highest signal-to-noise ratio is required, half of the variance (71% of the standard deviation) is assumed to apply to a fixed (signal-independent) component, and half to a component proportional to the chopped signal, then for a chopper with a cold reference, channel 5 is the driver. It requires that the proportional component be stable to 1 part in 1.414 x 4009 = 5669 (1 sigma). Such a stability would provide adequate accuracy for viewing the IFC black body, since the signal-to-noise ratio obtained (which would be between 4009 and 5669) would be further improved since that view would be obtained for several samples.

The corresponding figure for a chopper with a reference at the instrument ambient temperature can be found from table 3 of the IRD (SC-HIR-18L). We assume that the chopper is at approximately 300 K, and find the largest ratio of black body radiance to NEN. This occurs for channel 20 and has a value of 24381. The black body radiance corresponds to the maximum chopped signal because channel 20 (H_2O) is required to take good atmosphere view data to well above the height at which the radiance becomes negligible compared with that emitted by the black body. Assuming a similar apportionment of error terms to the above the component proportional to chopped signal would need to be stable to one part in 24381 x 1.414 = 34475 (1 sigma).

Summary of column headings of tables:

Height range:	these are extremes of height range of useful atmospheric measurement taken from table 2 of the IRD (SC-HIR-18L);
NEN:	this is noise equivalent radiance (1 standard deviation) taken from table 3 of SC-HIR-18L;
Radiance:	the radiance at the selected height;
S:NEN	this is the signal to radiometric noise ratio at this height
Radiance gradient:	the vertical radiance gradient derived from the difference between levels 1 km above and below;
NEA:	noise equivalent angle, i.e. the angular LOS error that is equivalent to the NEN (micro radian)
S:AN:	signal to angular noise ratio, i.e. the radiance divided by noise due to LOS uncertainty
Total S:N	1/RSS of 1/S:AN and 1/S:NEN, i.e. net signal-to-noise ratio
Height:	height for which values are given

Values are taken from SC-HIR-18L, assuming a LOS 1 sigma knowledge of 3.4 micro radian. Limb radiance data taken from TC-HIR-90A.

Table 1 - Height selected is that of maximum radiance

Channel	Ht range min	max	NEN	Radiance	S:nen	Radiance gradient	NEA	S:AN	Total S:N	Height of max
	km	km	W/m**2/st	W/m**2/st	-	W/m**2/st/km	micro radian	-	-	km
1 N2O, aer	8	70	1.2E-03	1.6E+00	1371	1.4E-01	2.9E+00	1164	887	8
2 CO2	8	40	6.3E-04	7.8E-01	1241	1.0E-02	2.0E+01	7394	1224	8
3 CO2	8	60	5.9E-04	1.5E+00	2625	6.0E-03	3.3E+01	25388	2611	8
4 CO2	15	60	6.0E-04	1.9E+00	3247	-5.0E-04	4.0E+02	383113	3247	21
5 CO2	30	105	4.3E-04	1.7E+00	4009	1.9E-02	7.6E+00	8923	3657	30
6 aerosol	8	55	1.9E-04	2.8E-01	1495	1.2E-01	5.4E-01	240	237	8
7 CFCl3	8	50	2.0E-04	3.9E-01	1963	1.4E-01	4.8E-01	275	273	8
8 HNO3	8	70	4.2E-04	8.7E-01	2081	3.0E-01	4.7E-01	290	287	8
9 CF2Cl2	8	50	2.0E-04	3.9E-01	1947	1.3E-01	5.1E-01	292	288	8
10 O3	8	55	1.5E-04	4.7E-01	3119	5.3E-02	9.5E-01	874	841	8
11 O3	30	85	2.4E-04	9.2E-01	3842	1.5E-02	5.5E+00	6210	3267	30
12 O3	8	55	9.6E-05	3.3E-01	3445	8.4E-02	3.8E-01	385	383	8
13 aerosol	8	55	1.1E-04	3.0E-01	2752	7.7E-02	4.8E-01	388	385	8
14 N2O5	8	60	1.1E-04	3.5E-01	3226	5.6E-02	6.6E-01	622	611	8
15 N2O	8	70	1.1E-04	2.0E-01	1797	1.4E-02	2.6E+00	1399	1104	8
16 ClONO2	8	70	1.1E-04	1.3E-01	1171	6.2E-03	5.9E+00	2043	1016	8
17 CH4	8	80	1.2E-04	2.9E-01	2443	2.1E-02	1.9E+00	1360	1188	8
18 H2O	8	40	1.2E-04	2.9E-01	2433	2.3E-02	1.7E+00	1245	1109	8
19 aerosol	8	55	1.3E-04	9.4E-02	725	1.2E-02	3.7E+00	785	533	8
20 H2O	15	85	1.6E-04	9.3E-02	579	2.2E-02	2.4E+00	411	335	15
21 NO2	8	70	1.1E-04	9.8E-02	892	6.4E-03	5.7E+00	1505	767	8

Table 2 - Height selected is that of maximum radiance gradient

Channel	Ht range min	max	NEN	Radiance	S:nen	Radiance gradient	NEA	S:AN	Total S:N	Height of max
	km	km	W/m**2/st	W/m**2/st	-	W/m**2/st/km	micro radian	-	-	km
1 N2O, aer	8	70	1.2E-03	1.3E+00	1056	2.2E-01	1.8E+00	564	497	10
2 CO2	8	40	6.3E-04	6.2E-01	986	4.8E-02	4.3E+00	1261	777	14
3 CO2	8	60	5.9E-04	9.4E-01	1590	5.5E-02	3.6E+00	1679	1154	30
4 CO2	15	60	6.0E-04	1.2E+00	2033	8.3E-02	2.4E+00	1445	1178	36
5 CO2	30	105	4.3E-04	1.2E+00	2774	7.7E-02	1.9E+00	1524	1335	39
6 aerosol	8	55	1.9E-04	2.8E-01	1495	1.2E-01	5.4E-01	240	237	8
7 CFCl3	8	50	2.0E-04	3.9E-01	1963	1.4E-01	4.8E-01	275	273	8
8 HNO3	8	70	4.2E-04	8.7E-01	2081	3.0E-01	4.7E-01	290	287	8
9 CF2Cl2	8	50	2.0E-04	3.9E-01	1947	1.3E-01	5.1E-01	292	288	8
10 O3	8	55	1.5E-04	4.7E-01	3119	5.3E-02	9.5E-01	874	841	8
11 O3	30	85	2.4E-04	5.7E-01	2390	5.2E-02	1.6E+00	1092	993	39
12 O3	8	55	9.6E-05	3.3E-01	3445	8.4E-02	3.8E-01	385	383	8
13 aerosol	8	55	1.1E-04	2.2E-01	1985	8.3E-02	4.4E-01	259	257	9
14 N2O5	8	60	1.1E-04	2.9E-01	2655	6.6E-02	5.6E-01	438	432	9
15 N2O	8	70	1.1E-04	1.4E-01	1274	2.1E-02	1.7E+00	644	575	11
16 ClONO2	8	70	1.1E-04	1.0E-01	930	1.1E-02	3.4E+00	938	661	11
17 CH4	8	80	1.2E-04	1.9E-01	1542	4.5E-02	8.9E-01	405	392	11
18 H2O	8	40	1.2E-04	1.7E-01	1402	5.6E-02	7.1E-01	293	287	11
19 aerosol	8	55	1.3E-04	6.1E-02	468	2.0E-02	2.2E+00	298	251	10
20 H2O	15	85	1.6E-04	9.3E-02	579	2.2E-02	2.4E+00	411	335	15
21 NO2	8	70	1.1E-04	5.9E-02	537	1.3E-02	2.9E+00	461	350	12

Table 3 Height selected is that of maximum total signal-to-noise ratio

	Channel	Ht range min	max	NEN	Radiance	S:nen	Radiance gradient	NEA	S:AN	Total S:N	Height of max
		km	km	W/m**2/st	W/m**2/st	-	W/m**2/st/km	micro radian	-	-	km
1	N2O, aer	8	70	1.2E-03	1.6E+00	1371	1.4E-01	2.9E+00	1164	887	8
2	CO2	8	40	6.3E-04	7.8E-01	1241	1.0E-02	2.0E+01	7394	1224	8
3	CO2	8	60	5.9E-04	1.5E+00	2625	6.0E-03	3.3E+01	25388	2611	8
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5	CO2	30	105	4.3E-04	1.7E+00	4009	1.9E-02	7.6E+00	8923	3657	30
6	aerosol	8	55	1.9E-04	2.8E-01	1495	1.2E-01	5.4E-01	240	237	8
7	CFCl3	8	50	2.0E-04	3.9E-01	1963	1.4E-01	4.8E-01	275	273	8
8	HNO3	8	70	4.2E-04	1.8E-01	433	-2.4E-03	5.7E+01	7305	433	19
9	CF2Cl2	8	50	2.0E-04	3.9E-01	1947	1.3E-01	5.1E-01	292	288	8
10	O3	8	55	1.5E-04	3.7E-01	2445	-9.5E-04	5.3E+01	37969	2440	24
11	O3	30	85	2.4E-04	9.2E-01	3842	1.5E-02	5.5E+00	6210	3267	30
12	O3	8	55	9.6E-05	9.0E-02	939	2.3E-04	1.4E+02	37737	939	22
13	aerosol	8	55	1.1E-04	3.0E-01	2752	7.7E-02	4.8E-01	388	385	8
14	N2O5	8	60	1.1E-04	3.5E-01	3226	5.6E-02	6.6E-01	622	611	8
15	N2O	8	70	1.1E-04	2.0E-01	1797	1.4E-02	2.6E+00	1399	1104	8
16	ClONO2	8	70	1.1E-04	1.3E-01	1171	6.2E-03	5.9E+00	2043	1016	8
17	CH4	8	80	1.2E-04	2.9E-01	2443	2.1E-02	1.9E+00	1360	1188	8
18	H2O	8	40	1.2E-04	2.9E-01	2433	2.3E-02	1.7E+00	1245	1109	8
19	aerosol	8	55	1.3E-04	9.4E-02	725	1.2E-02	3.7E+00	785	533	8
20	H2O	15	85	1.6E-04	7.1E-02	446	3.8E-03	1.4E+01	1850	433	17
21	NO2	8	70	1.1E-04	9.8E-02	892	6.4E-03	5.7E+00	1505	767	8