MIPAS Ultimate Retrieval Accuracy
Appendix
PO-TN-OXF-GS-0014
Task 4.3, CCN5 11886/96/NL/GS

Anu Dudhia [*]

7th December, 2000

Revised Figures

This appendix presents revised figures and tables for a microwindow selection based on the separation of the temperature errors into a 1 K retrieval error plus a 1 K/100 km horizontal gradient, shown as 'gra' where significant in the tables (previously these were both combined as a 3 K equivalent retrieval error which dominated the systematic errors).

Other (minor) changes are

- The continuum is considered to be retrieved over the whole tangent altitude range of each microwindow (previously limited to 29 km upper level)

- All microwindows are limited to a minimum of two wavenumber grid-points (previously single grid point microwindows were allowed).

- Instrument line-shape uncertainty added, shown as 'ils' in the tables of significant errors.

Revised results for each of the 7 retrievals are shown in Figs. 1–7 and Tables 1–8, with a summary plot in Fig. 8. The pT retrieval errors are split into the single pressure component (Table 1) and the temperature profile (Table 2).

Table 1: pT Pressure error contributions.

Rnd	0.2
Sys	3.8
Tot	3.8
h2o	0.6
o3	2.5
n2o	0.4
ch4	1.1
hitran	0.8
gain	0.2
ils	0.3
shift	0.1
co2mix	0.3
ctmerr	0.2
gra	2.3

[*] Atmospheric, Oceanic and Planetary Physics, Oxford University, UK

PT Information

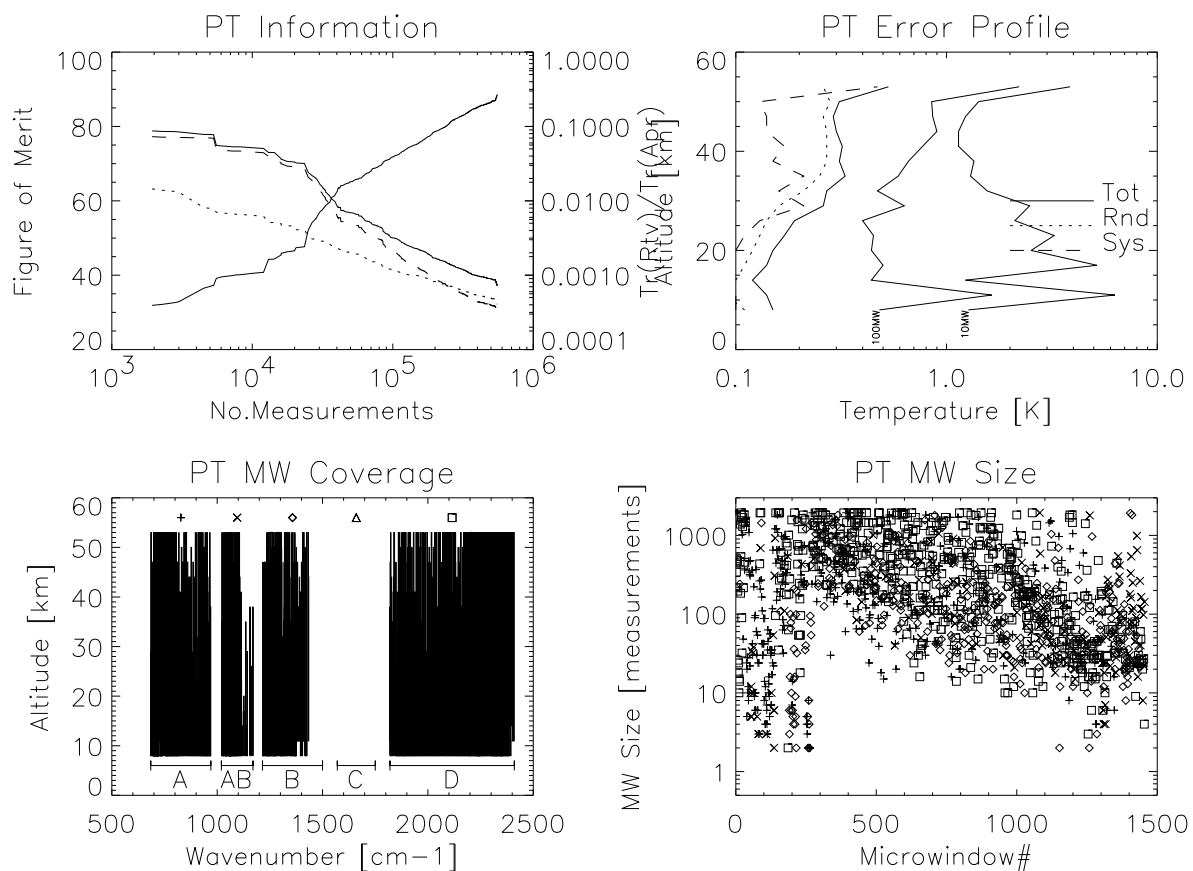**PT Error Profile**

PT MW Coverage

PT MW Size

Figure 1: *pT* Results. Top left panel shows increase in information with number of measurements, along with reduction in trace of the error covariances (key as in top right). Top right shows final total error profile, together with profiles of the random and systematic error components. Also shown are the total error profiles after 10 and 100 microwindows have been selected. Bottom left plot shows wavenumber and altitude coverage of the microwindows. Bottom right plot shows band and size of microwindows as a function of selection number (see bottom left plot for key).

Table 2: *pT* Temperature error contributions.

Microwindows = 1455				Average size = 381 meas./MW				Used/Total meas. = 212820/554580 (38%)								
Alt	8km	11km	14km	17km	20km	23km	26km	29km	32km	35km	38km	41km	44km	47km	50km	53km
Rnd	.11	.09	.10	.11	.12	.13	.14	.16	.21	.25	.27	.27	.27	.26	.28	.26
Sys	.10	.10	.07	.08	.10	.11	.13	.21	.16	.21	.15	.17	.14	.14	.13	.47
Tot	.15	.14	.12	.14	.15	.17	.19	.26	.27	.33	.31	.32	.30	.29	.31	.53

Significant systematic error sources (largest error source at each altitude in bold).

	8km	11km	14km	17km	20km	23km	26km	29km	32km	35km	38km	41km	44km	47km	50km	53km
h2o	.00	.00	.01	.01	.01	.01	.01	.02	.02	.02	.01	.02	.02	.01	.02	.05
o3	.00	.00	.00	.00	.00	.01	.00	.01	.01	.05	.02	.02	.01	.03	.04	.08
n2o	.01	.00	.00	.00	.00	.01	.01	.02	.01	.02	.01	.02	.01	.01	.00	.06
ch4	.01	.01	.00	.00	.01	.01	.00	.01	.02	.03	.01	.02	.01	.01	.02	.04
hitran	.05	**.06**	**.05**	.05	**.06**	.05	.07	.10	.08	.10	.08	**.10**	.07	**.08**	.06	.19
gain	**.06**	.04	.03	**.06**	.05	**.07**	**.08**	.06	.08	.11	**.09**	.09	.07	.07	.06	.20
ils	.02	.03	.03	.03	.05	.06	.06	**.16**	**.10**	**.13**	.08	.09	**.08**	.07	**.08**	**.35**
shift	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.02	.05	.03	.01	.01	.02
co2mix	.05	**.06**	.02	.01	.01	.01	.00	.00	.01	.01	.01	.01	.00	.01	.00	.04
ctmerr	.02	.03	.00	.00	.00	.01	.02	.02	.02	.03	.00	.01	.02	.03	.01	.01
gra	.01	.01	.00	.00	.00	.01	.01	.02	.03	.02	.00	.02	.01	.01	.00	.05

CH4 Information

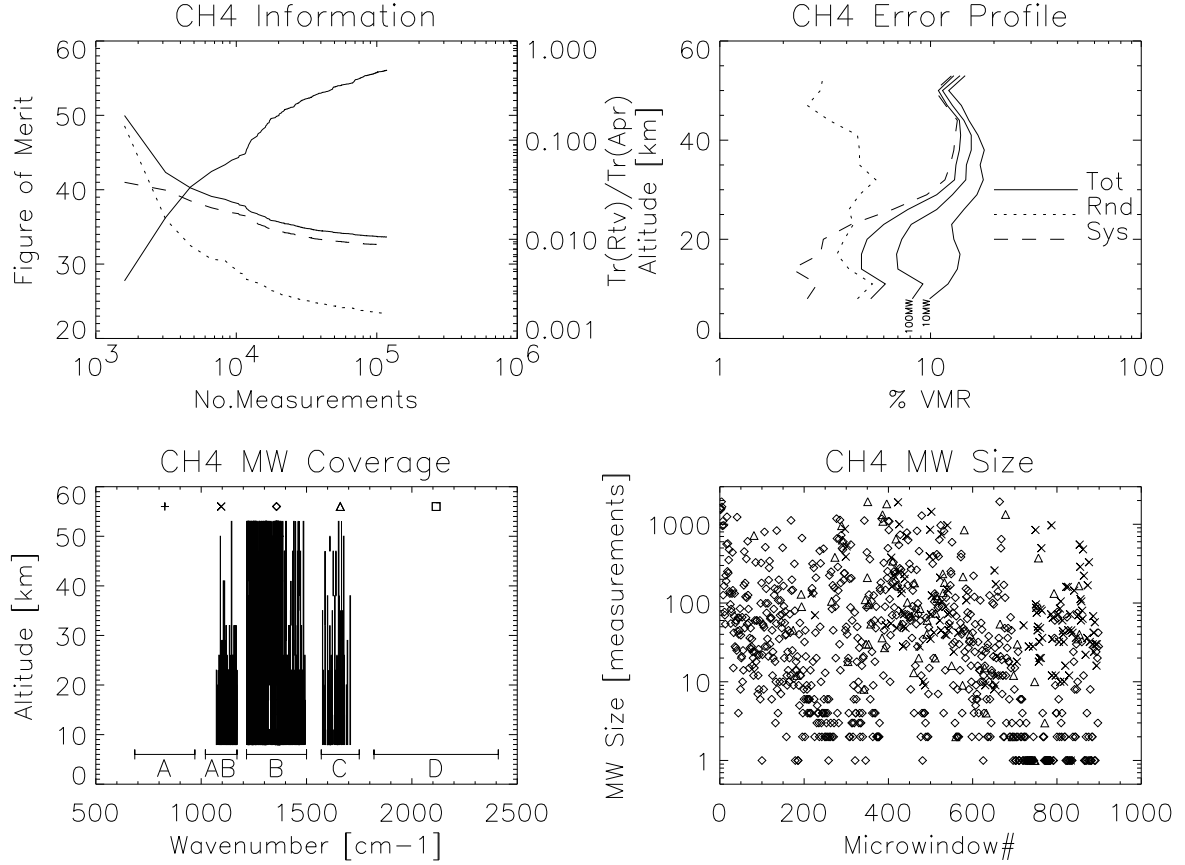## CH4 Error Profile

CH4 MW Coverage

CH4 MW Size

Figure 2: CH$_4$ Results. Top left panel shows increase in information with number of measurements, along with reduction in trace of the error covariances (key as in top right). Top right shows final total error profile, together with profiles of the random and systematic error components. Also shown are the total error profiles after 10 and 100 microwindows have been selected. Bottom left plot shows wavenumber and altitude coverage of the microwindows. Bottom right plot shows band and size of microwindows as a function of selection number (see bottom left plot for key).

Table 3: CH$_4$ Error contributions.

Microwindows = 459				Average size = 352 meas./MW				Used/Total meas. = 63858/161557 (40%)							
Alt	8km	11km	14km	17km	20km	23km	26km	29km	32km	35km	38km	41km	44km	47km	50km	53km
Rnd	1.7	1.8	1.9	2.2	2.4	2.6	3.2	3.9	4.7	5.2	5.3	4.9	4.6	4.2	4.0	3.9
Sys	3.6	5.2	4.8	3.1	3.9	4.8	5.4	5.3	5.6	5.1	5.8	6.6	5.6	4.8	4.5	10.6
Tot	4.0	5.5	5.2	3.8	4.6	5.5	6.3	6.6	7.3	7.3	7.8	8.3	7.3	6.3	6.0	11.3

Significant systematic error sources (largest error source at each altitude in bold):

	8km	11km	14km	17km	20km	23km	26km	29km	32km	35km	38km	41km	44km	47km	50km	53km
nonlte	0.1	0.1	0.1	0.0	0.1	0.1	0.2	0.1	0.9	0.7	0.9	1.7	2.1	1.2	1.2	**9.3**
hitran	1.6	2.0	1.1	1.0	1.4	1.7	2.1	1.5	2.0	1.6	1.7	2.6	1.4	1.6	1.0	2.0
gain	1.2	1.0	0.4	0.4	0.3	0.3	0.4	0.3	0.4	0.5	0.9	1.8	1.4	1.3	1.2	2.7
tem	**2.4**	**3.8**	**3.9**	**2.4**	**3.0**	**3.7**	**4.2**	**4.4**	**4.4**	**4.2**	**4.8**	**5.1**	**4.4**	**3.6**	**3.5**	3.4
los	1.6	2.4	1.9	1.6	1.9	2.2	2.4	2.2	2.3	2.1	2.1	1.9	2.0	1.9	2.0	2.0

H2O Information

Figure of Merit

70
60
50
40
30

10^3 10^4 10^5 10^6

No.Measurements

Tr(Rtv)/Tf(Apf)

1.0000
0.1000
0.0100
0.0010
0.0001

H2O Error Profile

Altitude [km]

60
40
20
0

1 10 100

% VMR

Tot
Rnd
Sys

100MW 10MW

H2O MW Coverage

Altitude [km]

60
50
40
30
20
10
0

500 1000 1500 2000 2500

Wavenumber [cm−1]

A AB B C D

+ × ◇ △ □

H2O MW Size

MW Size [measurements]

1000
100
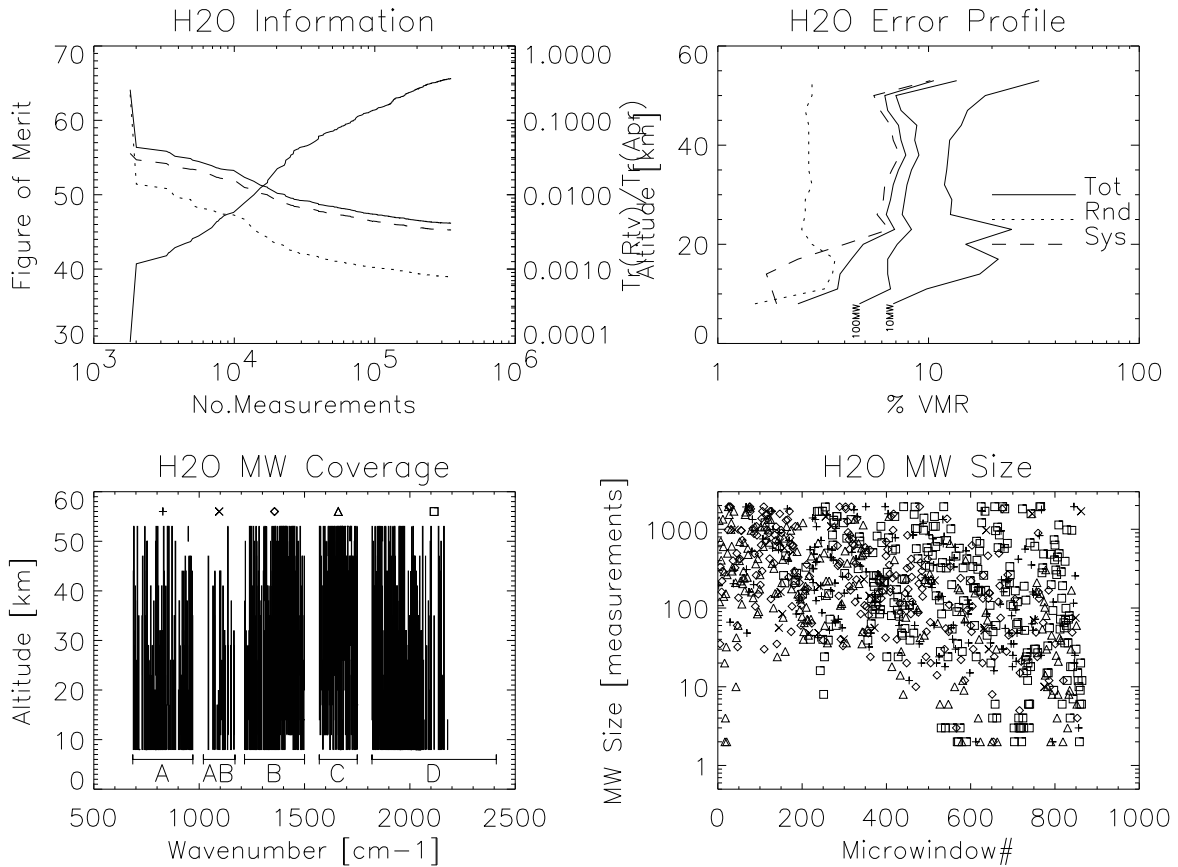10
1

0 200 400 600 800 1000

Microwindow#

Figure 3: H_2O Results. Top left panel shows increase in information with number of measurements, along with reduction in trace of the error covariances (key as in top right). Top right shows final total error profile, together with profiles of the random and systematic error components. Also shown are the total error profiles after 10 and 100 microwindows have been selected. Bottom left plot shows wavenumber and altitude coverage of the microwindows. Bottom right plot shows band and size of microwindows as a function of selection number (see bottom left plot for key).

Table 4: H_2O Error contributions.

	Microwindows = 864			Average size = 404 meas./MW					Used/Total meas. = 140276/349430 (40%)							
Alt	8km	11km	14km	17km	20km	23km	26km	29km	32km	35km	38km	41km	44km	47km	50km	53km
Rnd	1.5	3.2	3.5	3.6	2.8	2.5	2.6	2.6	2.8	2.7	2.7	2.7	2.7	2.6	2.8	2.8
Sys	1.9	1.8	1.7	2.4	4.0	6.5	5.7	6.1	6.2	6.7	7.3	6.8	6.6	5.9	5.5	10.2
Tot	2.4	3.7	3.8	4.3	4.9	6.9	6.3	6.6	6.8	7.2	7.8	7.4	7.2	6.4	6.2	10.6
Significant systematic error sources (largest error source at each altitude in bold):																
co2	0.4	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ch4	0.1	0.0	0.0	0.1	0.7	1.9	1.1	0.9	0.7	0.7	0.6	0.2	0.5	0.6	0.1	0.5
nonlte	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.4	1.0	1.7	2.3	2.0	1.7	1.6	**8.2**
hitran	0.5	0.8	**1.2**	**1.4**	1.5	2.1	1.4	1.5	1.8	1.6	3.9	2.1	3.0	1.5	1.6	1.7
gain	**1.3**	1.0	0.6	0.6	0.3	0.4	0.3	0.4	0.4	0.4	1.1	0.8	0.9	0.6	0.6	1.6
ils	0.5	0.6	0.4	0.6	0.5	0.5	0.6	0.7	0.4	0.6	0.5	0.4	0.6	0.4	0.3	0.8
tem	0.7	0.7	0.7	1.2	**2.9**	**4.8**	**4.4**	**4.7**	**4.6**	**5.1**	**4.4**	**4.9**	**4.5**	**4.6**	**4.4**	5.0
los	0.6	0.9	0.7	1.2	2.1	2.8	3.0	3.1	3.4	3.4	3.4	3.1	2.9	2.5	2.2	2.0

HNO3 Information

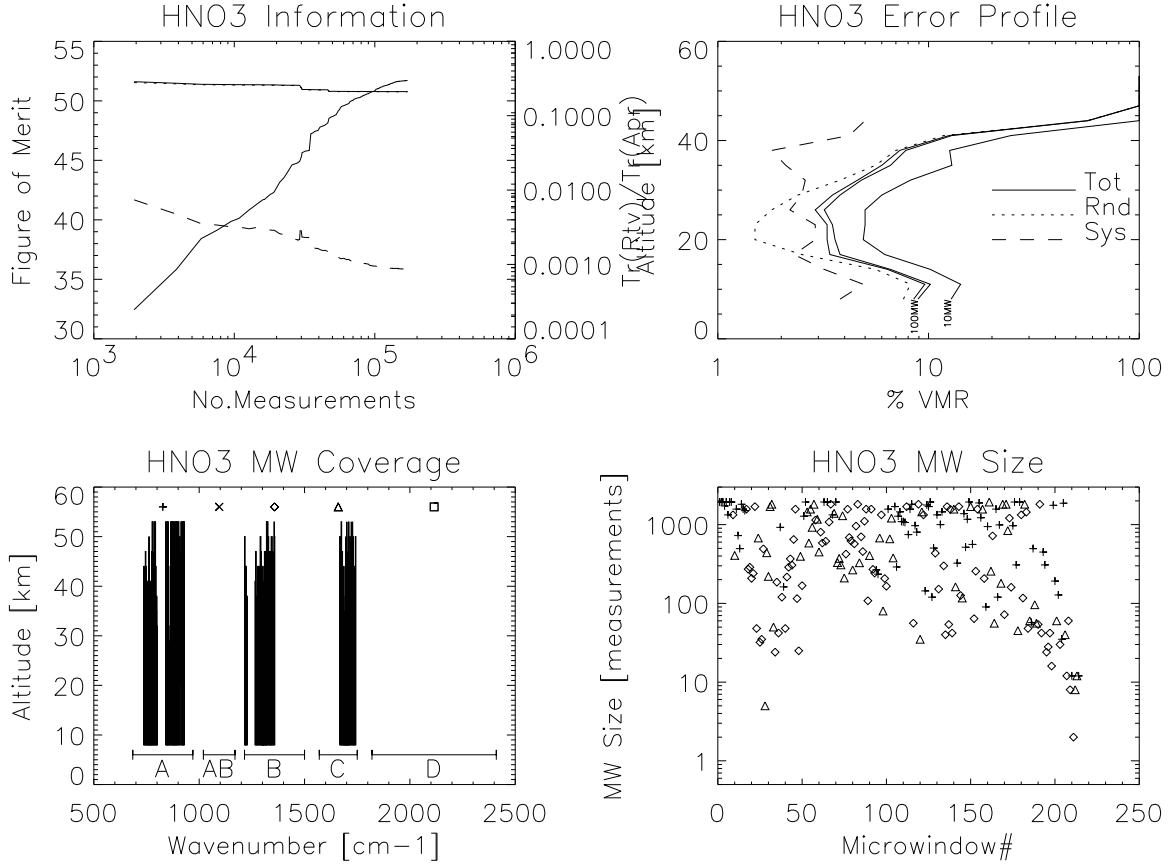## HNO3 Error Profile

HNO3 MW Coverage

HNO3 MW Size

Figure 4: HNO₃ Results. Top left panel shows increase in information with number of measurements, along with reduction in trace of the error covariances (key as in top right). Top right shows final total error profile, together with profiles of the random and systematic error components. Also shown are the total error profiles after 10 and 100 microwindows have been selected. Bottom left plot shows wavenumber and altitude coverage of the microwindows. Bottom right plot shows band and size of microwindows as a function of selection number (see bottom left plot for key).

Table 5: HNO₃ Error contributions.

	Microwindows = 214			Average size = 800 meas./MW			Used/Total meas. = 72966/171253 (43%)									
Alt	8km	11km	14km	17km	20km	23km	26km	29km	32km	35km	38km	41km	44km	47km	50km	53km
Rnd	7.6	8.2	5.6	2.5	1.5	1.5	1.8	2.4	3.8	5.6	7.0	11.8	56.7	100	100	100
Sys	3.8	4.9	3.2	2.3	2.9	2.9	2.2	2.5	2.6	2.1	1.8	4.2	5.0	0.0	0.0	0.0
Tot	8.5	9.6	6.4	3.4	3.3	3.3	2.9	3.5	4.6	6.0	7.3	12.5	56.9	100	100	100

Significant systematic error sources (largest error source at each altitude in bold):

|	8km	11km	14km	17km	20km	23km	26km	29km	32km	35km	38km	41km	44km	47km	50km	53km
o3	0.0	0.2	0.1	0.2	0.5	0.6	0.3	0.3	0.3	0.3	0.4	0.2	0.4	0.0	0.0	0.0
ch4	0.1	0.2	0.0	0.1	0.2	0.5	0.3	0.4	0.4	0.3	0.3	1.0	0.9	0.0	0.0	0.0
nonlte	0.7	1.4	0.7	0.3	0.4	0.3	0.1	0.1	0.2	0.4	0.3	0.3	1.0	0.0	0.0	0.0
hitran	**2.8**	**2.6**	**1.9**	1.3	1.0	1.4	**1.3**	**1.7**	**1.7**	**1.1**	**1.1**	2.3	**3.0**	0.0	0.0	0.0
gain	1.4	1.5	1.1	0.7	0.7	0.7	0.7	0.7	0.7	0.4	0.4	1.0	0.9	0.0	0.0	0.0
ils	1.0	1.8	1.1	0.6	0.5	0.6	0.6	0.8	0.9	0.9	0.9	**2.9**	2.9	0.0	0.0	0.0
shift	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.9	0.0	0.0	0.0
gra	1.3	1.9	0.6	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
tem	1.1	2.2	1.6	**1.4**	**2.2**	**1.8**	1.0	0.9	0.9	0.9	0.6	1.0	1.6	0.0	0.0	0.0
los	0.5	0.9	0.8	0.9	1.3	1.3	1.0	1.1	1.1	0.8	0.4	0.5	0.5	0.0	0.0	0.0
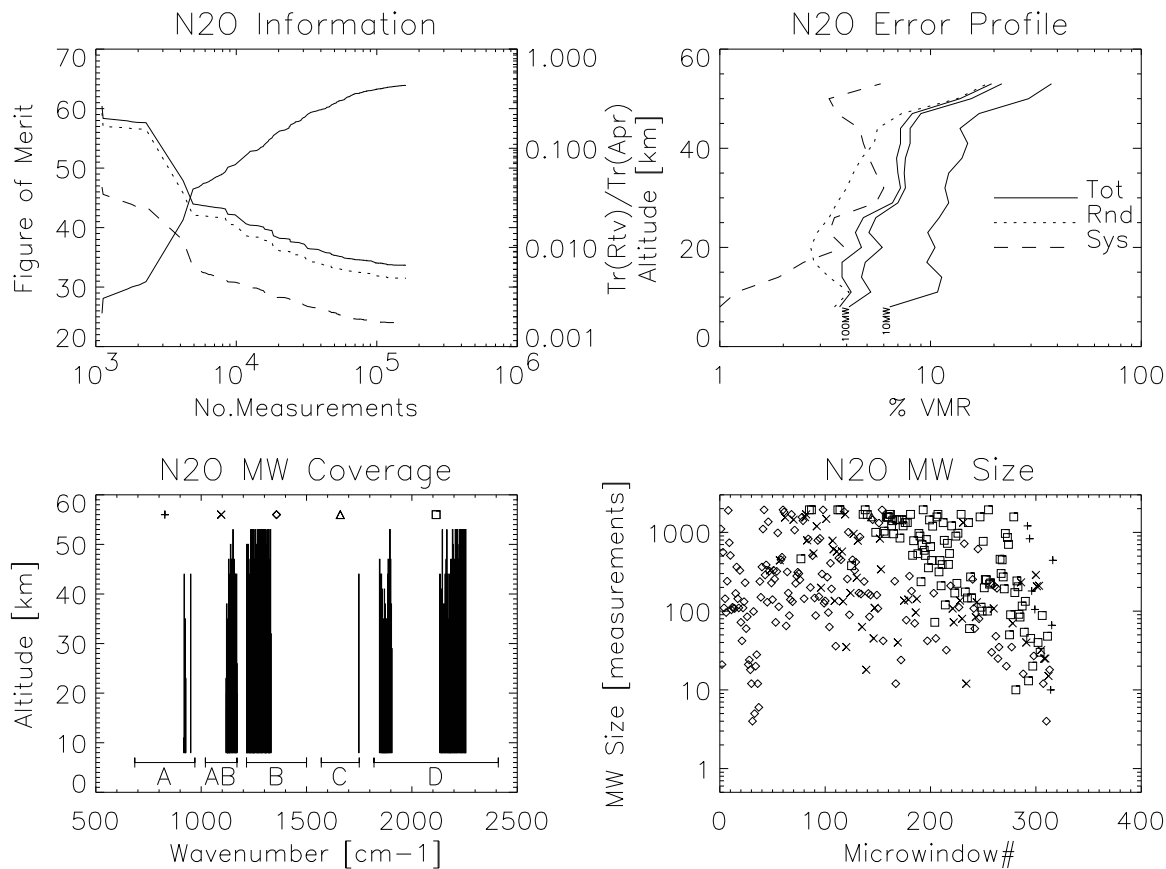
Figure 5: N$_2$O Results. Top left panel shows increase in information with number of measurements, along with reduction in trace of the error covariances (key as in top right). Top right shows final total error profile, together with profiles of the random and systematic error components. Also shown are the total error profiles after 10 and 100 microwindows have been selected. Bottom left plot shows wavenumber and altitude coverage of the microwindows. Bottom right plot shows band and size of microwindows as a function of selection number (see bottom left plot for key).

Table 6: N$_2$O Error contributions.

	Microwindows = 316			Average size = 511 meas./MW			Used/Total meas. = 60547/161425 (38%)								
Alt	8km	11km	14km	17km	20km	23km	26km	29km	32km	35km	38km	41km	44km	47km	50km	53km
Rnd	3.5	4.1	3.3	2.8	2.7	2.9	3.3	3.6	4.0	4.3	4.7	5.4	5.6	7.3	13.4	18.6
Sys	1.0	1.2	1.9	2.5	3.9	3.3	3.5	5.5	6.0	5.5	5.1	4.8	4.6	3.6	3.3	5.8
Tot	3.7	4.2	3.8	3.8	4.7	4.4	4.8	6.6	7.2	7.0	6.9	7.2	7.2	8.2	13.8	19.5

Significant systematic error sources (largest error source at each altitude in bold).

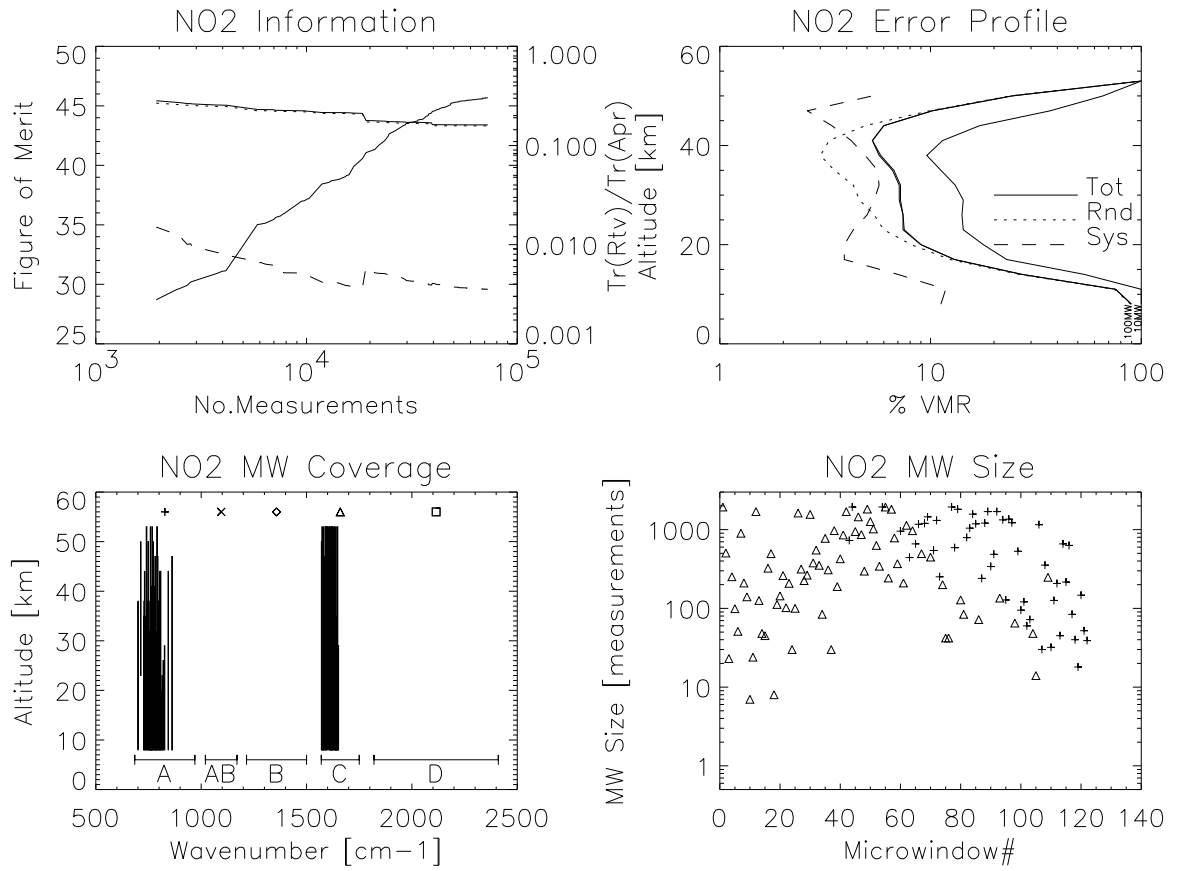|	8km	11km	14km	17km	20km	23km	26km	29km	32km	35km	38km	41km	44km	47km	50km	53km
o3	0.0	0.1	0.1	0.4	1.3	1.1	1.2	2.3	2.0	1.4	0.5	0.2	0.0	0.3	0.3	0.0
ch4	0.0	0.1	0.3	0.9	1.9	1.2	1.1	1.6	1.6	1.5	1.5	0.9	1.1	0.6	0.4	1.0
hitran	**0.8**	**0.9**	0.9	1.0	1.3	0.8	1.0	1.0	1.1	1.6	1.2	1.1	1.7	1.6	**1.9**	**4.2**
gain	0.4	0.3	0.4	0.4	0.5	0.2	0.4	0.3	0.6	0.7	0.8	0.7	1.5	0.9	1.1	2.2
tem	0.2	0.4	**1.3**	**1.8**	**2.3**	**2.3**	**2.4**	**4.0**	**4.5**	**4.2**	**4.1**	**4.0**	**3.3**	**2.4**	1.9	2.6
los	0.2	0.5	0.7	1.0	1.4	1.4	1.5	2.1	2.4	2.3	2.1	1.9	1.9	1.7	1.4	1.5

Figure 6: NO$_2$ Results. Top left panel shows increase in information with number of measurements, along with reduction in trace of the error covariances (key as in top right). Top right shows final total error profile, together with profiles of the random and systematic error components. Also shown are the total error profiles after 10 and 100 microwindows have been selected. Bottom left plot shows wavenumber and altitude coverage of the microwindows. Bottom right plot shows band and size of microwindows as a function of selection number (see bottom left plot for key).

Table 7: NO$_2$ Error contributions.

Microwindows = 122				Average size = 594 meas./MW					Used/Total meas. = 28243/72498 (39%)						
Alt	8km	11km	14km	17km	20km	23km	26km	29km	32km	35km	38km	41km	44km	47km	50km	53km
Rnd	89.1	74.6	26.3	12.4	8.1	6.0	5.4	4.6	4.3	3.5	3.0	3.3	4.9	9.9	23.8	100
Sys	11.2	11.8	7.0	3.9	3.9	4.3	5.0	5.4	5.7	5.6	4.9	4.2	3.4	2.6	5.3	0.0
Tot	89.8	75.5	27.2	13.0	9.0	7.4	7.4	7.1	7.1	6.6	5.7	5.3	6.0	10.2	24.4	100
Significant systematic error sources (largest error source at each altitude in bold).															
h2o	**8.1**	**7.0**	0.5	0.2	0.2	0.3	0.8	0.9	0.8	0.9	0.7	0.8	0.7	0.4	0.1	0.0
o3	4.0	0.4	0.5	0.2	0.2	0.1	0.2	0.3	0.1	0.1	0.2	0.1	0.0	0.0	0.2	0.0
ch4	0.3	0.4	0.3	0.3	1.5	1.3	1.1	0.9	0.8	0.6	0.2	0.2	0.1	0.3	0.7	0.0
c2h6	1.8	6.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
hitran	1.9	2.6	3.7	**2.2**	1.5	1.6	1.4	1.3	1.1	0.9	1.0	1.0	1.3	**1.4**	**2.9**	0.0
gain	0.4	0.7	1.6	1.0	0.7	0.3	0.5	0.4	0.6	0.5	0.7	0.8	0.8	0.8	1.9	0.0
ils	2.4	4.4	**3.8**	1.6	1.2	1.4	1.2	0.9	0.9	0.8	0.6	0.7	0.6	1.2	2.8	0.0
ctmerr	0.1	0.2	1.3	0.7	1.0	1.6	1.1	1.1	0.1	0.6	0.1	0.3	0.1	0.2	0.2	0.0
gra	0.8	0.7	0.0	0.2	0.1	0.1	0.4	0.2	0.1	0.2	0.3	0.0	0.1	0.2	1.4	0.0
tem	2.0	2.7	3.2	**2.2**	**2.5**	**3.0**	**4.2**	**4.7**	**5.2**	**5.0**	**4.2**	**3.4**	**2.4**	1.2	1.9	0.0
los	1.2	1.3	1.6	1.1	0.7	0.3	0.7	1.1	1.5	1.8	1.9	1.8	1.6	1.0	1.2	0.0

O3 Information

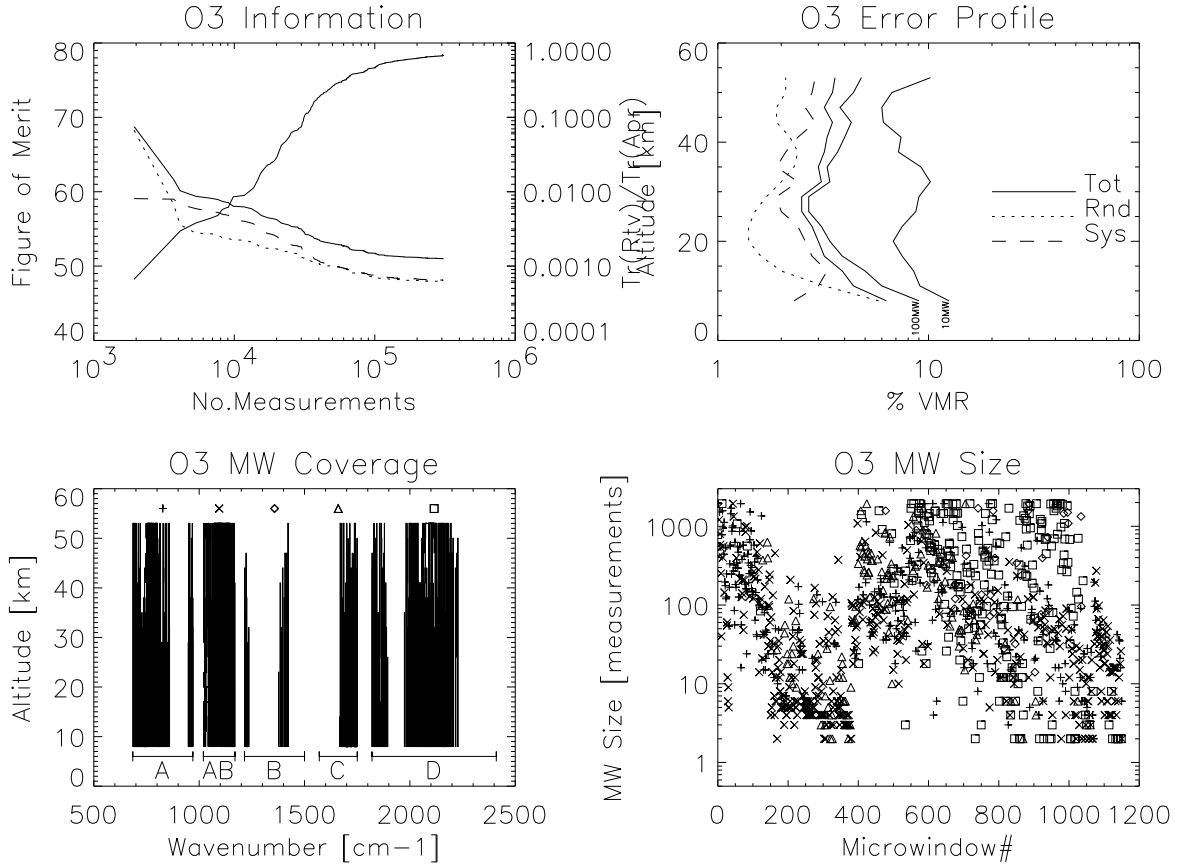## O3 Error Profile

O3 MW Coverage

O3 MW Size

Figure 7: O_3 Results. Top left panel shows increase in information with number of measurements, along with reduction in trace of the error covariances (key as in top right). Top right shows final total error profile, together with profiles of the random and systematic error components. Also shown are the total error profiles after 10 and 100 microwindows have been selected. Bottom left plot shows wavenumber and altitude coverage of the microwindows. Bottom right plot shows band and size of microwindows as a function of selection number (see bottom left plot for key).

Table 8: O_3 Error contributions.

Microwindows = 1151				Average size = 267 meas./MW					Used/Total meas. = 111955/306861 (36%)						
Alt	8km	11km	14km	17km	20km	23km	26km	29km	32km	35km	38km	41km	44km	47km	50km	53km
Rnd	5.8	3.2	2.0	1.6	1.4	1.4	1.5	1.7	2.0	2.3	2.4	2.2	1.9	1.9	2.1	2.1
Sys	2.3	3.0	3.3	2.8	2.6	2.4	2.0	1.9	2.4	1.9	2.1	2.4	2.9	2.6	2.8	2.9
Tot	6.3	4.4	3.9	3.2	3.0	2.8	2.5	2.5	3.1	3.0	3.2	3.3	3.5	3.2	3.5	3.6

Significant systematic error sources (largest error source at each altitude in bold).

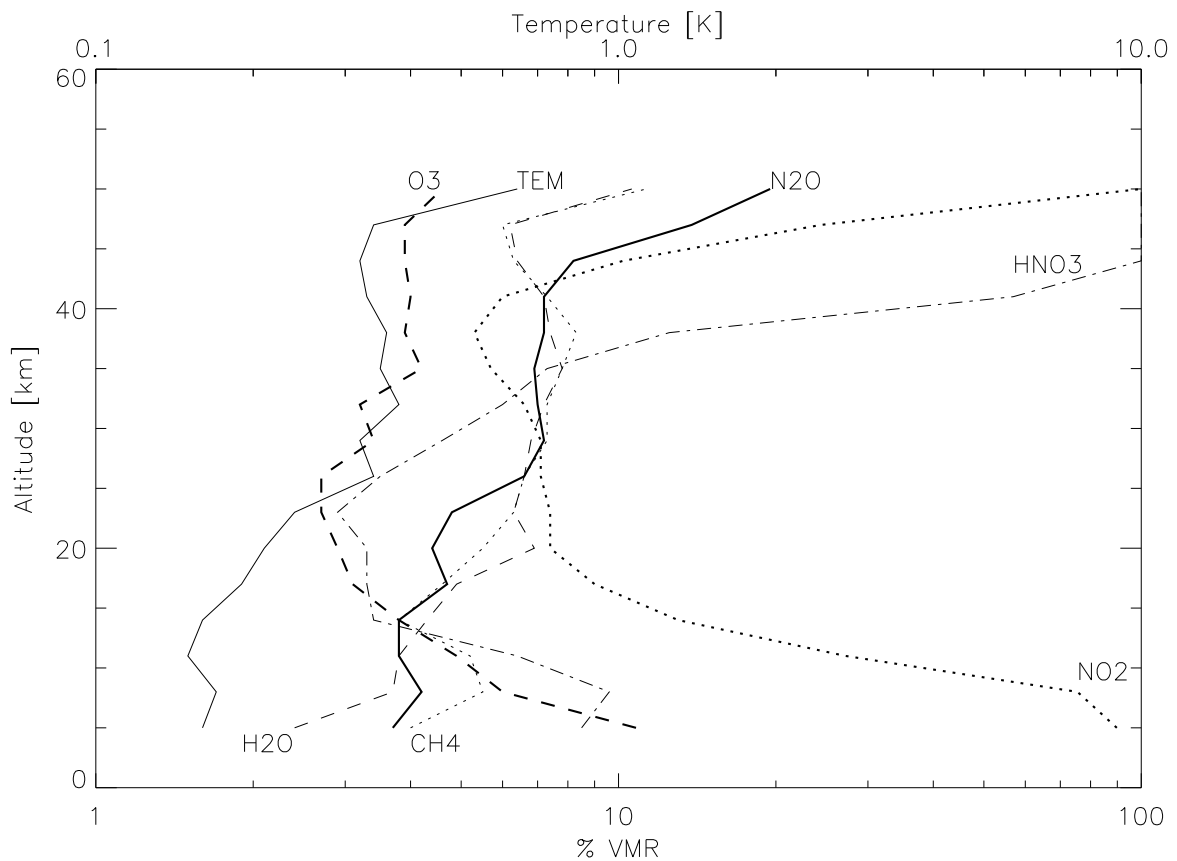|	8km	11km	14km	17km	20km	23km	26km	29km	32km	35km	38km	41km	44km	47km	50km	53km
hitran	**1.2**	1.0	1.1	1.0	1.0	1.2	1.1	1.0	1.4	1.0	**1.1**	1.0	0.9	0.9	1.0	0.9
gain	0.8	0.5	0.4	0.4	0.3	0.4	0.3	0.2	0.4	0.3	0.4	0.6	0.7	0.5	0.7	0.4
ils	1.1	1.4	**2.0**	1.3	0.9	0.9	0.7	0.6	1.2	0.9	1.0	0.9	1.6	1.0	1.2	0.9
tem	1.1	**1.9**	1.8	**1.5**	**1.6**	1.2	0.8	0.8	0.9	0.8	1.0	**1.6**	**1.7**	1.5	1.6	**1.9**
los	0.6	1.4	1.4	**1.5**	**1.6**	**1.5**	**1.2**	**1.2**	**1.3**	**1.1**	1.0	1.1	1.4	1.4	**1.6**	1.7

Figure 8: Summary of Ultimate Accuracy Results.

Table 9: Summary. The number of measurements used excludes those which are masked out, and the percentage used is based on a total of 59 605 points per spectrum × 16 scans = 953 680 measurements available.

	pT	CH_4	H_2O	HNO_3	N_2O	NO_2	O_3
Information content [bits]	92.4	65.0	66.4	53.0	65.6	46.6	79.212
No. measurements used	212 820	63 858	140 276	72 966	60 547	28 243	111 955
% spectrum used	22.3	6.7	14.7	7.7	6.3	3.0	11.7