Selection of a subset of IASI Channels for Near Real Time Dissemination

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Abstract

IASI is currently due to be launched on the MetOp-1 satellite in April 2006. Global IASI Level 1C data will be distributed to European users, probably by EUMETCast. Users have requested that it be distributed lossless, i.e. either all 8461 channels, or using PCA data compression plus residuals.

In addition, global IASI Level 1C data will be distributed to many users on the GTS. Here the bandwidth limitations are greater, and so the working assumption is that channel selection will be used, at least on Day 1. Currently AIRS is distributed in near real time to NWP centres in a similar manner with 324 out of 2378 channels being provided (the data volume is further reduced by distributing only one field of view in nine).

A subset of IASI channels that may be distributed should be chosen such that the total loss of information is a minimum. This is achieved through consideration of the loss of information content in the context of retrievals using a short range NWP forecast as prior information. Before the final channel selection, extensive pre-screening is performed to ensure channels are not chosen where there are large forward model errors or interfering species.

Introduction

This document describes a proposed methodology for the selection of a subset of IASI channels that may be distributed such that the total loss of information is a minimum. The final decision on the channels to be used should be made as late as possible as advances in our knowledge of the problem (e.g., forward model errors) or in the exact requirements for this dataset may evolve with time.

The exact content of a selected set of channels will be highly dependent on the precise application to which it is being applied. As techniques and modeling accuracy evolve, the “optimal” set of channels will also change. Therefore, the aim with this study is not to produce an absolutely “optimal” set of channels, as this is almost certainly not possible for all applications, but a conservative but close to optimal set of channels for physical retrievals of the atmospheric state.

The methodology is based on the information content-based channel selection of Rodgers (1996, 2000) but has been modified to account for uncertainties arising from the non-linearity of the temperature Jacobians of the water vapour and ozone channels and also to account for the fact that some channels will not be usable in the daytime but may still contain extra useful information at night. The final channel selections are critically examined to ensure that they are reasonable and so that if there are any obvious gaps in the selection these may be addressed.

Criteria

The information that is required to be preserved in the channel selection is:

Main quantities to be retrieved from the IASI spectra:

Temperature profile, Humidity profile, Ozone profile

Secondary quantities to be retrieved from the IASI spectra (these are additional quantities that are included in the channel selection on the request of users and/or EUMETSAT - the precise choice of these quantities is not considered here) :

Minor gas (e.g., CO_2, CO, CH_4) profiles, cloud properties, surface emissivity

Other restrictions:

Shortwave channels ($\lambda <= 5\mu m$) can be affected by sunlight and should not be chosen in preference to longwave channels that can provide similar information. Water vapour and ozone channels should not be the primary providers of temperature information as their temperature Jacobians can be highly non-linear.

Pre-screening

The channel selection method described should avoid channels with large forward model uncertainty.

This pre-screening can be done through a variety of routes:

1. Consideration of channels that are significantly dominated by trace species (i.e., minor species that one is not able to include in the retrieval vector). This may be achieved through radiative transfer calculations where species' abundances in the radiative transfer model are varied by their climatological range (for various representative test atmospheres) and any channel showing variation by more than the IASI instrument noise level is rejected. However, for some species (e.g., CH_4) this might result in an unacceptably high rejection rate (thousands of channels) and the criterion might need to be relaxed (but with the assumed forward model error adjusted accordingly). Conversely, some species might have a correlated spectral signal that, while below instrument noise level for a single channel, becomes significant when considered for the spectrum as a whole. The information on random noise contributed by trace species for unrejected channels should be included in the estimate for the forward model error covariance matrix.

2. Consideration of intercomparison exercises. Intercomparison exercises such as LIE (Tjemkes *et al.*, 2003) and Rizzi et al. (2002) and the various AIRS validation studies can be used to identify areas in the spectrum where the radiative transfer calculations are particularly problematic. J. Taylor (priv. comm.) has, for example, identified spectral lines in the 6.3μm water vapour band that appear to have erroneous spectroscopy in the line databases.

   The LIE study includes comparisons between different radiative transfer models and between these models and existing observed high spectral resolution infrared observations (plus measurements of the associated atmospheric state), thus highlighting spectral regions where there is disagreement in forward modeling. Although this is useful as an indicator of possible problems, the best possible forward model and spectroscopy should be assumed when doing pre-screening and in determining the forward model error covariance matrix.

3. NWP monitoring statistics. Comparisons between observed radiances and simulated radiances from short-range forecast fields can identify possibly problematic channels which might necessitate late changes to the channel selection. The current experience with AIRS can identify many such channels (e.g., the high-peaking channels around 4.3μm which are highly influenced by non-LTE effects) but AIRS does not cover the same spectral range nor does it have the same spectral resolution as IASI. If post-launch monitoring of IASI does identify bad channels, they may either be substituted for good ones (if such a change is not too late) or advice may be distributed on the use of these channels (as is current practice with satellite measurements).

In summary, channels should be avoided if they are sensitive to elements not in the radiative transfer model; which are sensitive to variable species whose variability is not considered in the background or on retrieval; or which have known radiative transfer weaknesses.

Selection Methodology

After pre-screening, channel selection will be based on the methodology suggested by Rogers (1996, 2000). This method was shown to be the best method for *a priori* determination of an optimal channel set by Rabier et al. (2002) and has been further evaluated in the context of AIRS by Fourrié and Thépaut (2003).

The method relies on evaluating the impact of the addition of single channels on a figure of merit and proceeds as follows:

1. Test which single channel most improves a chosen figure of merit. This figure of merit is normally a quantity reflecting the improvement of the retrieval error covariance matrix, $\mathbf{A}$, over the background error covariance matrix, $\mathbf{B}$. Therefore, starting with $\mathbf{A}_0=\mathbf{B}$ (where $\mathbf{A}_i$ is the retrieval error covariance matrix after i channels have been chosen), the possible values of $\mathbf{A}_1$ for each chosen channel will need to be calculated.

2. After the optimal $\mathbf{A}_i$ has been determined through the choice of the best new channel, find the remaining channel that most improves the figure of merit.

3. Repeat until a sufficient number of channels have been selected.

Rodgers speeds this process up by noting that, if the instrumental noise plus forward model error covariance matrix is diagonal, on adding a new channel, i, to the retrieval, the solution error covariance is changed from $\mathbf{A}_{i\text{-}1}$ to $\mathbf{A}_i$ thus:

$$\mathbf{A_i} = \mathbf{A_{i-1}}\left\{\mathbf{I} - \mathbf{h_i}(\mathbf{A_{i-1}h_i})^T \Big/ \left[1 + (\mathbf{A_{i-1}h_i})^{\mathrm{T}}\mathbf{h_i}\right]\right\}$$

where $\mathbf{h}_i$ is the Jacobian for channel *i* normalised by the standard deviation of the instrument plus forward model noise for that channel. However, provided that a realistic estimate of the full error covariance matrix may be obtained, it will be desirable to properly treat the correct, correlated matrix.

In this scheme, the degrees of freedom for signal (DFS) for the retrievals (defined as $\mathrm{Tr}(\mathbf{I}\text{-}\mathbf{AB}^{-1})$) is used as the figure of merit. An alternative is the entropy reduction ($-\frac{1}{2}\mathrm{Ln}|\mathbf{AB}^{-1}|$) but past experience (e.g., Rabier *et al.*, 2002) has shown that the differences between choosing DFS or entropy reduction are small. Required for this method are an estimate of the background error covariance matrix (the ECMWF NWP background error covariance matrix, modified for use in a 1DVar scenario, for example), an estimate of the observational error covariance matrix (including forward model errors), and a forward model to estimate the Jacobians for the atmospheres being considered which will initially be RTIASI (Matricardi and Saunders, 1999; Matricardi, 2003). Usually, the process is applied to the case of a single atmospheric profile, but it will be extended to consider, simultaneously, multiple profiles.

As the effect of the precise atmospheric profiles used on the final selection may be important (Rabier et al., 2002), the final channel selection will be tested against the optimal selection for a diverse range of atmospheric profiles.

The method is then implemented as follows:

1. Take the IASI channels that remain after pre-screening

2. Choose a range of atmospheric scenarios: the six AFGL standard atmospheres or part of the ECMWF atmospheric database (Chevallier, 1999; Chevallier *et al.* 2000), for example. Consider these different scenarios simultaneously, so that, while the **A** and **B** matrices themselves are calculated independently, the total DFS for all the profiles is used as the figure of merit. The reason for this is to ensure that channels are chosen based on the combined requirements of th range of atmospheres.

3. To ensure that temperature information is primarily coming from the relatively linear CO_2 channels, start by ignoring those channels that are primarily sensitive to water vapour or ozone. Also, ignore those channels that are sensitive to solar irradiance; as it should be ensured that the channel selection does not rely on channels that cannot be used in the daytime.

4. Perform the above analysis for temperature, using the CO_2 channels that remain. The number of channels that are chosen is determined by consideration of the total number that are required and the amount of DFS that is explained as a function of the total for all the channels being considered.

5. With the temperature channels chosen above pre-selected, perform the DFS analysis once more with the water vapour channels included and with both water vapour and temperature retrievals allowed. Further channels are thus chosen which are primarily sensitive to humidity but which will also contribute further temperature information.

5a. Optionally repeat the above for trace gas (O_3, CO_2, CH_4, CO, N_2O etc.) retrievals, if required.

6. Repeat steps 3 and 4, but include the solar-affected channels.

7. The selection of channels useful in the determination of cloud properties and surface emissivity, if this is required, is probably best done through manual selection of channels (if suitable ones are not already in the above dataset) on consideration of the spectral properties being considered. This approach may also be preferable for trace gases (rather than step 5a above) as our knowledge of the B-matrices for these is often poor.

The channel selection process is normally stopped either once a pre-selected number of channels is reached or once the improvement on adding new channels is relatively small. In the above method both criteria will be used and there will necessarily be some subjective choices to be made.

Example Channel Selection

In this section an example of the channel selection method is given where a total of 300 channels are chosen. This is an example with a diagonal observation plus forward model error covariance matrix, where the forward model error is 0.2K plus the effect of trace gases only. The selection of channels for the retrieval of trace gases (i.e., all species except water vapour and ozone) is not performed in this example.

The initially blacklisted channels are shown in Figure 1. Channels are blacklisted if the effect on the brightness temperature due to climatological variability is greater than 1K for any of the six AFGL standard atmospheres. Ten species were examined in this way (CH_4, CO, N_2O, CCl_4, CFC-14, HNO_3, NO_2, OCS, NO, and SO_2) but only the first three had large enough effects for blacklisting. If a species has an impact lower than 1.0K, its effect is added to the forward model error covariance matrix. CO_2 has been assumed to have a constant abundance in this example, although variability in its abundance can cause variations in the observed brightness temperature of up to around 0.5K in the 15μm band, as much of this variability can probably by removed through bias correction or the use of a climatological mean (e.g., Engelen *et al.*, 2001).

In addition channels between 2220cm^{-1} and 2287cm^{-1} are blacklisted as they are affected by non-LTE effects which are greatest in the daytime but are still present at night (based on AIRS experience and calculations by Castelain et al., 1998).

Additionally shown in Figure 1 are those channels which are significantly influenced by the surface, by water vapour, by ozone and by solar irradiance. Some or all of these channels are removed in “pre-selection” runs.

The assumed instrument plus forward model error is shown in Figure 2. The instrument noise is the official level 1c instrument noise; the forward model noise is taken to be a constant 0.2K plus estimates of the error due to the variability of trace gases. In this case the instrument plus forward model error covariance matrix is assumed to be diagonal.

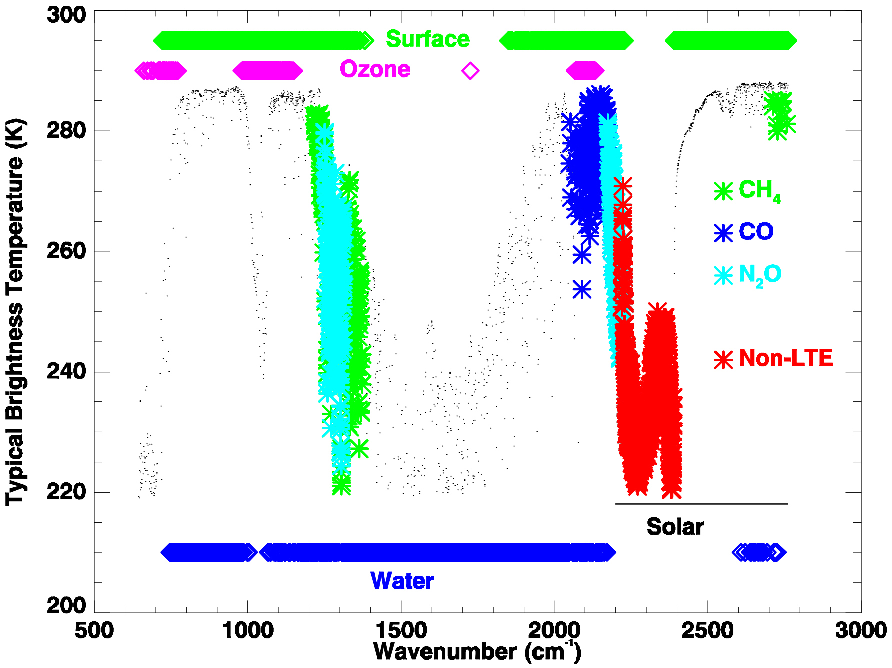

Fig. 1: Blacklisted channels for channel selection. Channels with possible signals from CH_4, CO or N_2O greater than 1K are blacklisted together with those channels in the 4.3µm CO_2 band which are affected by non-LTE effects. Channels with large contributions from H_2O, O_3, the surface and solar irradiance are also indicated above and below the spectrum.

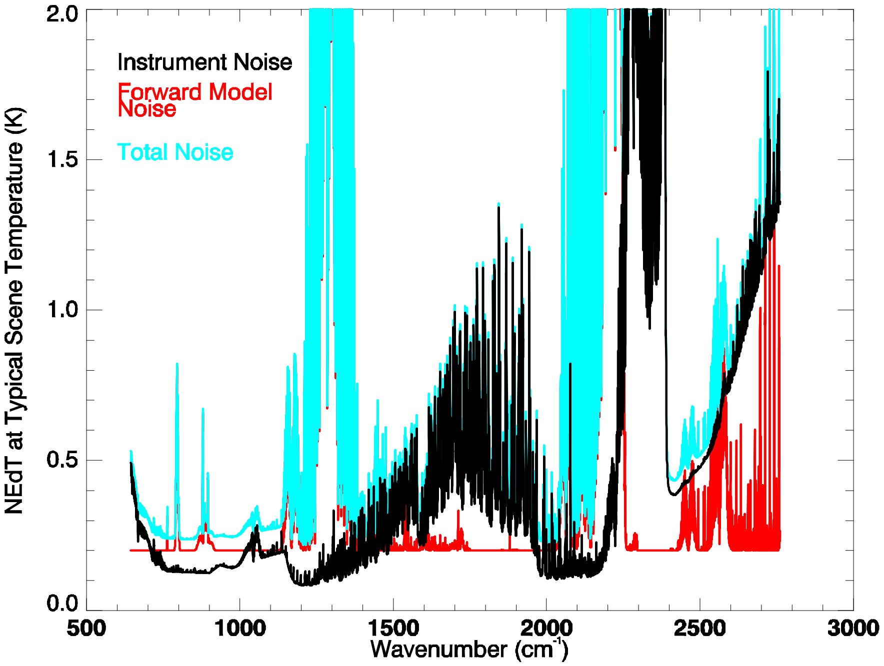

Fig. 2: The assumed observational plus forward model noise for the channel selection.

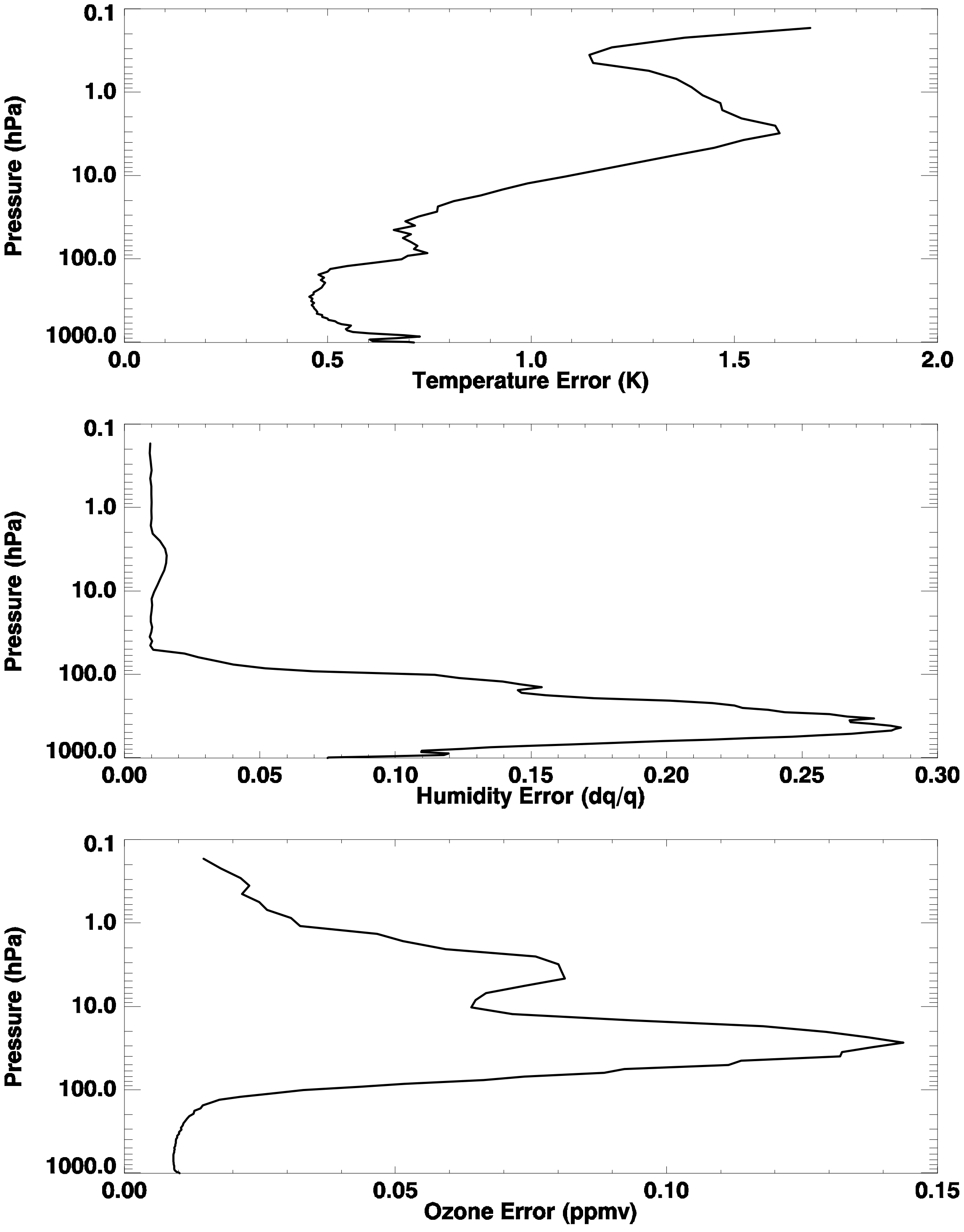

Fig. 3: Standard deviations of temperature, humidity and ozone taken from the operational ECMWF background error covariance interpolated onto the 90 RTIASI levels. A skin temperature error of 0.3K is assumed (based on observed background departures for AIRS).

This channel selection is based on the six AFGL standard atmospheres and degrees of freedom for signal (DFS) is used as the figure of merit. As interchannel error correlations are not accounted for and the IASI level 1c data are apodised and thus have highly correlated errors between adjacent channels, a channel cannot be chosen if one of its immediate neighbours is already chosen.

This channel selection is performed in six stages:

1) An initial run is performed with only the temperature analysis being considered and with the water vapour, ozone and solar channels excluded (in addition to the blacklisted channels, of course). This is to ensure that a minimum amount of temperature information is derived from CO_2 channels rather than H_2O and O_3 channels (as in a linear analysis the dependence of the temperature Jacobians on H_2O and O_3 amount is not accounted for). Solar channels are excluded to ensure that this set is usable in the daytime as well as night. Approximately 50% of the total degrees of freedom for signal are obtained with the first 25 channels.
2) Taking the 25 pre-selected channels from the first stage, the channel selection is now preformed with water vapour being considered in addition to temperature and with the water vapour channels included. 250 channels (including the 25 pre-selected ones) are chosen. The total DFS in this case is 92.4 (i.e., an average of 15.4 per profile) of which 64.7 is obtained with the 250 channels.
3) Allow the solar irradiance-affected channels to be used. The total available DFS increases to 94.0. These selection runs until a channel that is not affected by solar radiation is once more chosen. Only 15 channels are chosen in this way, increasing the total DFS from the selected channels to 65.6.
4) Taking the channels from Stage (2), allow ozone retrievals. For this step the retrieval is for ozone only (i.e., the temperature and water vapour profiles are assumed to be known). The total DFS for ozone is 12.0 with the 15 chosen ozone channels accounting for 7.1.
5) In case these channels might be used at night, select 12 channels that are affected by non-LTE effects (here the non-LTE blacklisting is relaxed). The total available DFS is now 96.2 of which the current channels supply 66.3.
6) Add in 11 additional channels covering the long and shortwave windows that may be used to derive surface emissivity and/or cloud optical properties.

The chosen channels are shown in Figures 4 and 5 and the evolution of the DFS is shown in Figure 6.

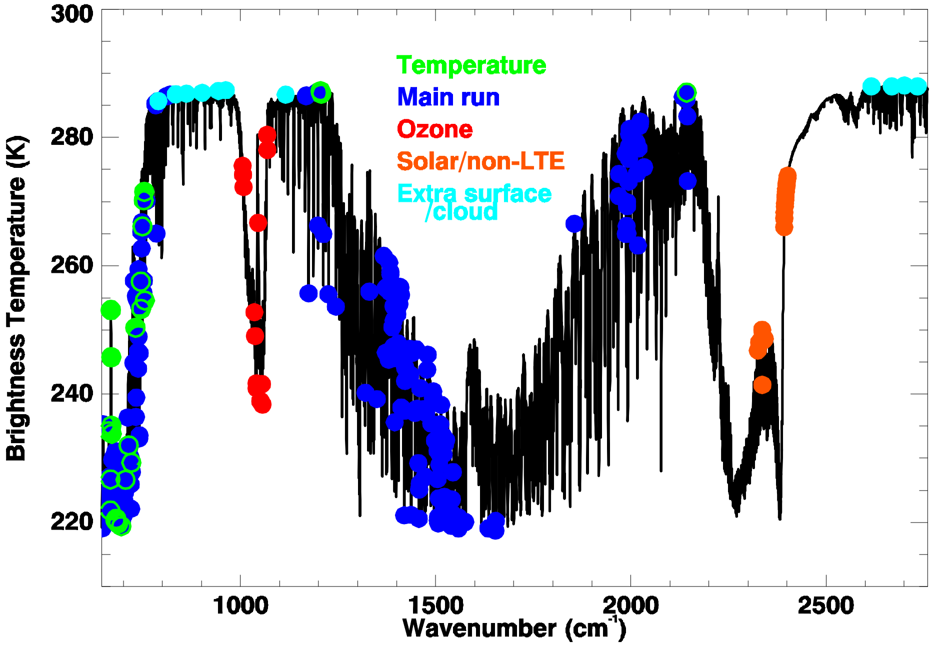

Fig. 4: 300 channels chosen with the methodology described in the text.

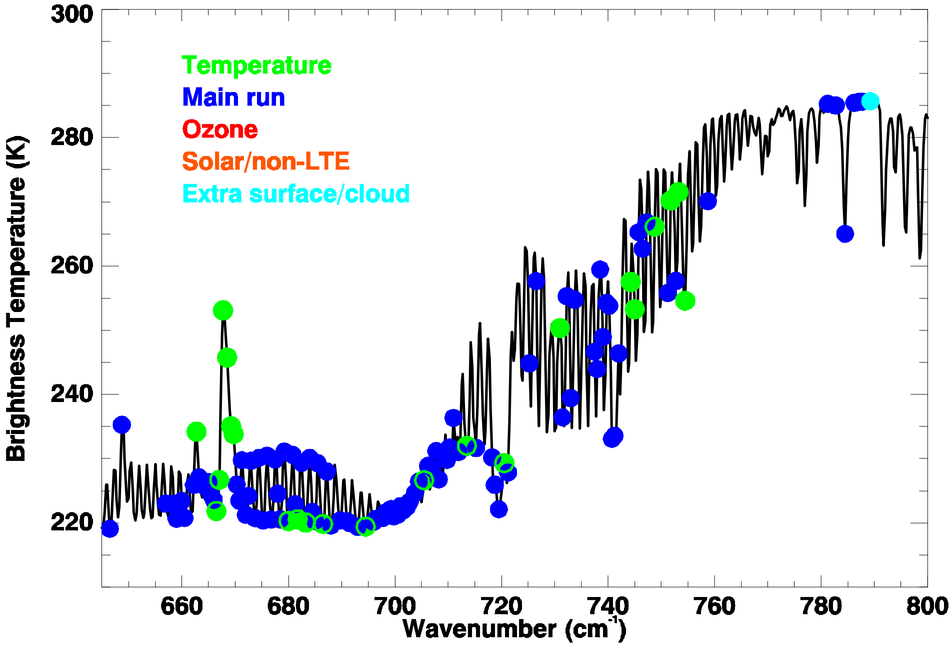

Fig. 5: As Figure 5, except focusing on the 15μm CO_2 band.

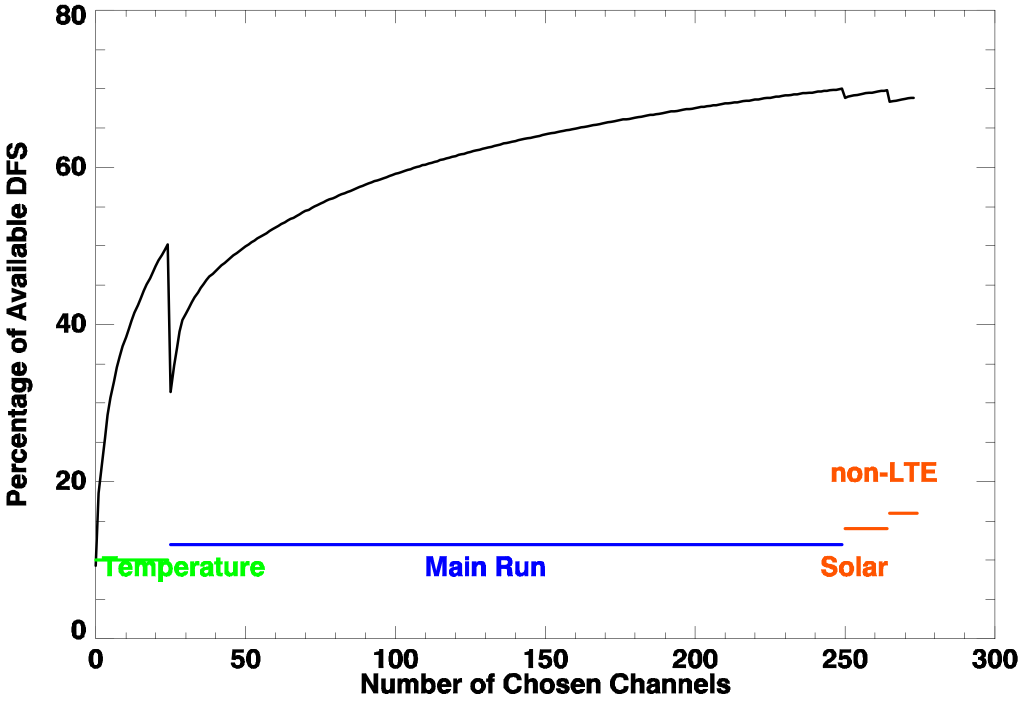

Fig. 6: Evolution of the DFS during the channel selection.

Some notes on the channels chosen:

- Many channels are chosen in the 670-710cm^{-1} region which sounds the upper troposphere and lower stratosphere. This is partially a reflection of the relatively high *a priori* temperature errors in this region, compared to the troposphere, but also reflects the somewhat higher instrument noise levels for these channels.
- Channels are not necessarily chosen that are in the wings of the spectral lines. These channels are, all things being equal, desirable as they have sharper Jacobians. However, this algorithm also considers the sensitivity of the channels in relation to the instrument noise. In the channel selection being performed here channels in the centres of spectral lines are often chosen in preference to channels which sound similar levels in the wings of lines if the former are in regions of relatively low noise.
- While the Jacobians of the channels in the shortwave wing of the 4.3μm CO_2 band in general have sharper Jacobians, only a few add significant information to those in the longwave part of the spectrum. This is a reflection of the relatively high instrument noise in the shortest IASI band. It should be noted that the total *percentage* of the available DFS has fallen from 70.0% before the shortwave was considered to 69.8% on adding the 15 solar channels, although the total DFS still

increases. A similar drop in the percentage explained occurs with the non-LTE channel selection.

- Very few surface sounding channels are chosen as the skin temperature variance is reduced by over an order of magnitude by the very first surface sounding channel chosen. This is a result of the forward model error not including the highly correlated errors resulting from emissivity uncertainty and undetected cloud. This deficiency has been addressed by the manual inclusion of extra window channels in Step 6 above.

Figures 7 and 8 compare this channel selection with the 324 channels chosen for near-real time distribution from AIRS. However, it is hard to make a direct comparison as the AIRS channels do not have exactly the same frequencies as the IASI ones; the instrument spectral response functions differ; the instrument noise characteristics are different; the longwave portion of the 6.3μm water vapour band is missing for AIRS and the criteria for choosing these channels was different.

The robustness of the algorithm is addressed with respect to its dependence on the assumed background error covariance matrix and also on its dependence of the atmospheric profiles being considered. It is tested by performing the channel selection for alternate scenarios (i.e., different B-matrix or different atmospheric profiles) and recomputing the DFS's that would result from the alternate channel sets but for the original scenario. That is, the detailed channel selection may well be different in the alternate scenarios but what is tested is whether the alternate channel selection contains similar information to the original when considered for the same profile and B-matrix.

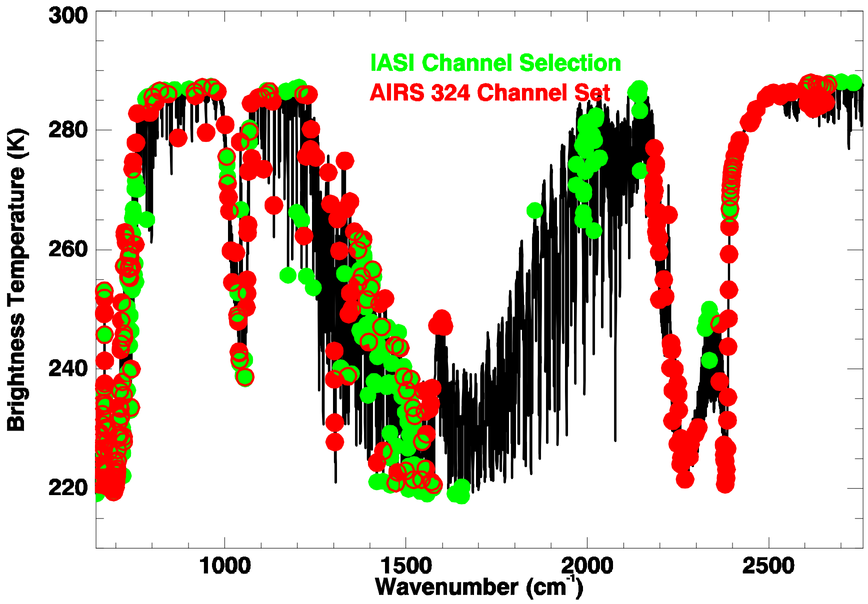

Fig. 7: A comparison of the 324 channels distributed for AIRS and the 300 channels chosen for IASI.

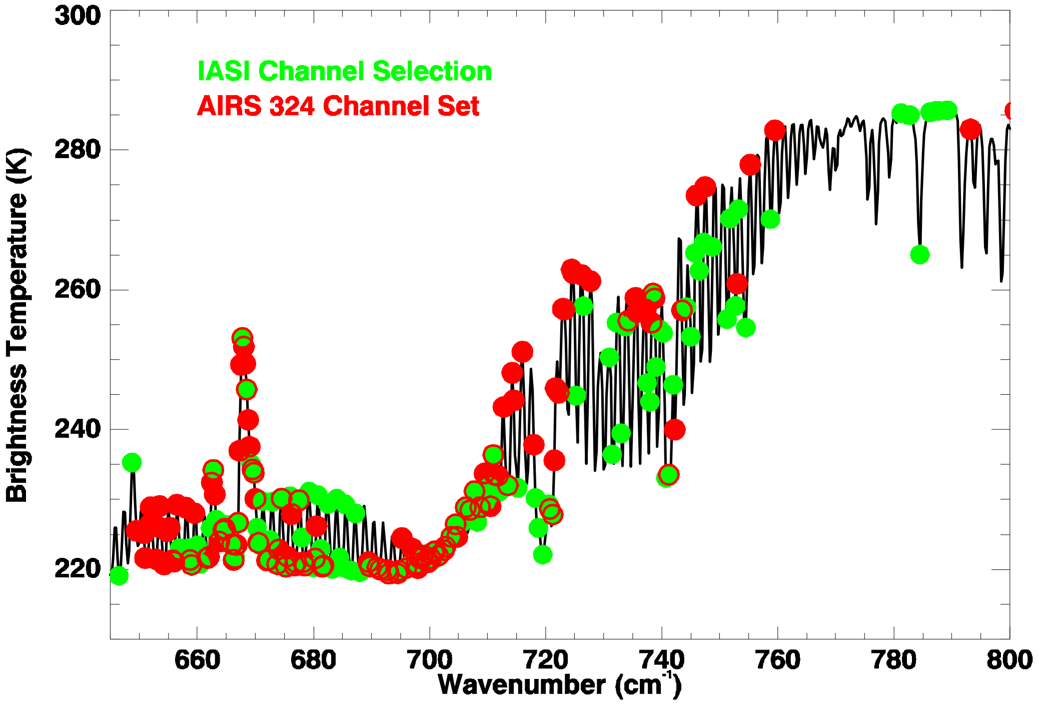

Fig. 8: As Figure 7, except focusing on the 15μm CO_2 band.

The alternate B-matrix used is a diagonal one with constant large standard deviations (100K for temperatures, 1 for dq/Ln(q) and 1 for O_3 mixing ratio). On using this very different B-matrix, the DFS after the temperature channels pre-selection was 18.9 (i.e., 3.2 per profile) rather than 20.1 for the optimal case. After the main run the respective values were 61.8 and 64.7.

Seven alternate atmospheric profiles are taken from the Chevallier dataset and are chosen to cover a representative set of possible atmospheric states. In this case the DFS was identical to three significant figures after the pre-selected temperature channels and 64.5 versus 64.7 after the main run.

The impact of these different selections on the expected retrieval errors for the U.S. Standard atmosphere and the ECMWF B-matrix are shown in Figure 9.

While, as expected, there is some loss of information on changing the selection scenarios, these losses are relatively small and indicate that the channel selection is robust enough to serve as a global channel selection set.

The final set of 300 channels is given in appendix A.

Summary

A selection of IASI channels has been determined based on the ECMWF background error covariance matrix. Channels have been chosen based on their information content (degrees of freedom for signal) derived from a linear analysis, but with the non-linear effects of the change in

Jacobians for variable species being accounted for. The robustness of the selection has been explored with respect to the assumed atmospheric states and the background error covariance matrix.

It is necessary to combine the automatic channel selection algorithm of Rogers (1997, 2002) with manual intervention not only to mitigate the effects of non-linearity but also to ensure that the selection is as close to optimal as possible in various circumstances (e.g., daytime versus nighttime) and to allow for effects that are difficult to explicitly include in the algorithm (correlated error from surface emissivity).

The final choice of channels must also depend on the number of channels that may be communicated. Retrievals with 300 channels explain around 60% of the available DFS, 500 will explain around 80% – at what point is the increased information content not worth the cost of the extra channels? The exact answer to this will depend on the requirements of the final users of the data.

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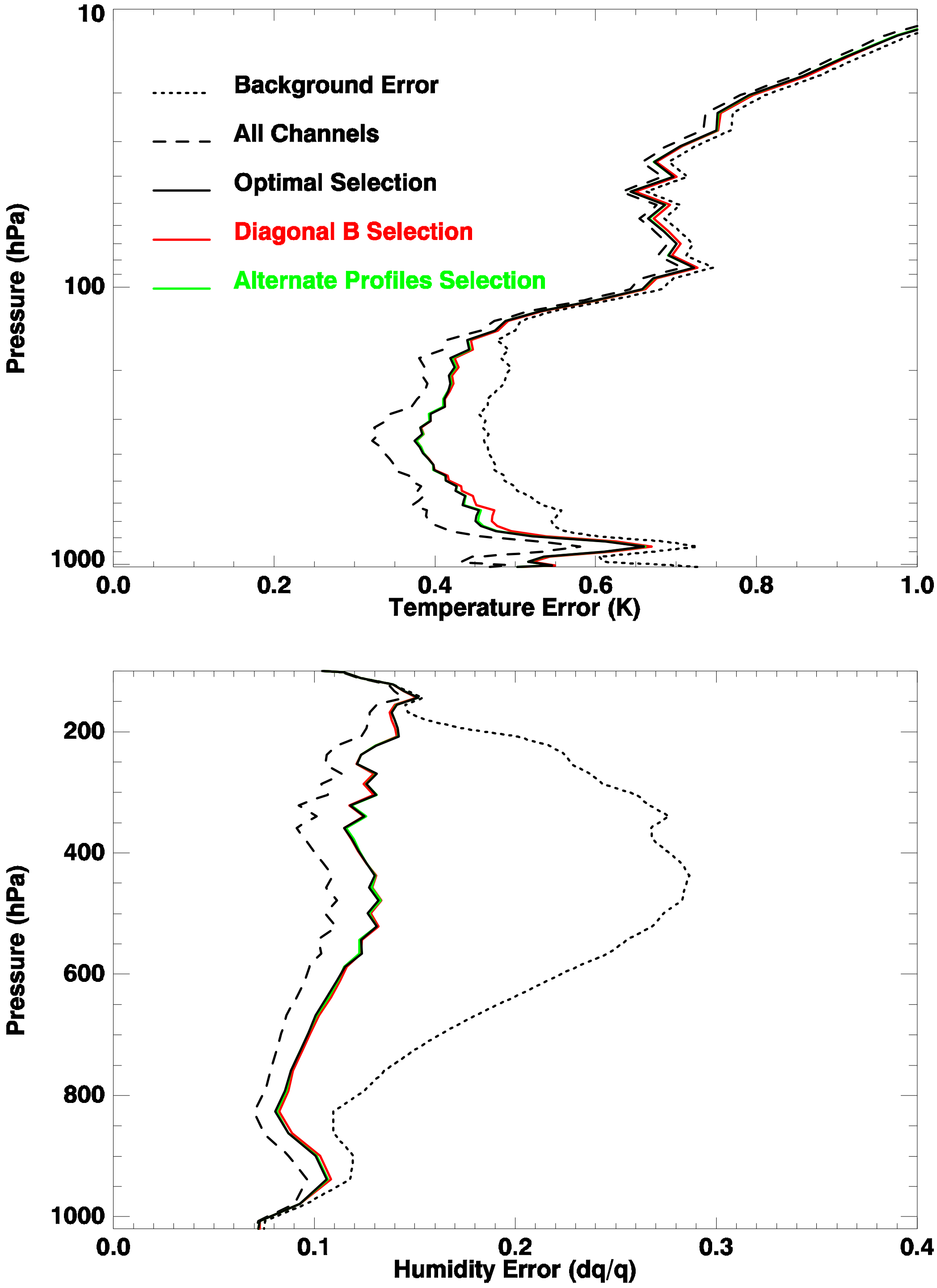

Fig. 9: Retrieval errors for the U.S. Standard atmosphere and the ECMWF B-matrix on using all the channels; the optimal selection of 300 channels for the ECMWF B-matrix and the AFGL profile dataset; the optimal selection for a diagonal B-matrix; and the optimal selection for an alternate set of atmospheric profiles.

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Appendix: A 300 Channel Selection.

The 300 channels chosen by the example selection in this paper. Channels marked “Temp” were derived in the initial temperature pre-selection and “Window” were the additional channels added to ensure cloud and emissivity effects are allowed for.

Channel	Freq. (cm^{-1})	Notes
7	646.50	
16	648.75	
49	657.00	
55	658.50	
57	659.00	
61	660.00	
63	660.50	
70	662.25	
72	662.75	Temp
74	663.25	
79	664.50	
81	665.00	
83	665.50	
85	666.00	
87	666.50	Temp
89	667.00	Temp
92	667.75	Temp
95	668.50	Temp
98	669.25	Temp
100	669.75	Temp
102	670.25	
104	670.75	
106	671.25	
109	672.00	
111	672.50	
113	673.00	
116	673.75	
119	674.50	
122	675.25	
125	676.00	
128	676.75	
131	677.50	
133	678.00	
135	678.50	
138	679.25	
141	680.00	Temp
144	680.75	
146	681.25	
148	681.75	Temp
151	682.50	
154	683.25	Temp
157	684.00	
159	684.50	
161	685.00	
163	685.50	
167	686.50	Temp
170	687.25	
173	688.00	
180	689.75	
185	691.00	
187	691.50	
193	693.00	
199	694.50	Temp
205	696.00	
207	696.50	
212	697.75	
214	698.25	
216	698.75	
218	699.25	
220	699.75	
223	700.50	
225	701.00	
227	701.50	
230	702.25	
232	702.75	
236	703.75	
239	704.50	
243	705.50	Temp
246	706.25	
249	707.00	
252	707.75	
254	708.25	
260	709.75	
262	710.25	
265	711.00	
267	711.50	
269	712.00	
275	713.50	Temp
282	715.25	
294	718.25	
296	718.75	
299	719.50	
303	720.50	Temp
306	721.25	
322	725.25	
327	726.50	
345	731.00	Temp
347	731.50	
350	732.25	
353	733.00	
356	733.75	
371	737.50	
373	738.00	
375	738.50	
377	739.00	
380	739.75	
382	740.25	
384	740.75	
386	741.25	
389	742.00	
398	744.25	Temp
401	745.00	Temp
404	745.75	
407	746.50	
410	747.25	
416	748.75	Temp
426	751.25	
428	751.75	Temp
432	752.75	
434	753.25	Temp
439	754.50	Temp
456	758.75	

546	781.25	
552	782.75	
559	784.50	
566	786.25	
570	787.25	
572	787.75	
578	789.25	Window
662	810.25	
668	811.75	
693	818.00	
699	819.50	
756	833.75	Window
867	861.50	Window
1027	901.50	Window
1194	943.25	Window
1271	962.50	Window
1442	1005.25	Ozone
1446	1006.25	Ozone
1452	1007.75	Ozone
1563	1035.50	Ozone
1570	1037.25	Ozone
1583	1040.50	Ozone
1586	1041.25	Ozone
1600	1044.75	Ozone
1624	1050.75	Ozone
1630	1052.25	Ozone
1635	1053.50	Ozone
1641	1055.00	Ozone
1646	1056.25	Ozone
1694	1068.25	Ozone
1696	1068.75	Ozone
1884	1115.75	Window
2092	1167.75	
2094	1168.25	
2119	1174.50	
2199	1194.50	
2213	1198.00	
2239	1204.50	Temp
2249	1207.00	Temp
2271	1212.50	
2321	1225.00	
2398	1244.25	
2701	1320.00	
2741	1330.00	
2819	1349.50	
2889	1367.00	
2907	1371.50	
2910	1372.25	
2939	1379.50	
2944	1380.75	
2949	1382.00	
2957	1384.00	
2959	1384.50	
2977	1389.00	
2983	1390.50	
2985	1391.00	
2988	1391.75	
2991	1392.50	
3002	1395.25	
3027	1401.50	
3029	1402.00	
3036	1403.75	
3049	1407.00	
3053	1408.00	
3058	1409.25	
3064	1410.75	
3069	1412.00	
3093	1418.00	
3098	1419.25	
3105	1421.00	
3107	1421.50	
3110	1422.25	
3151	1432.50	
3160	1434.75	
3168	1436.75	
3178	1439.25	
3207	1446.50	
3221	1450.00	
3228	1451.75	
3244	1455.75	
3248	1456.75	
3252	1457.75	
3256	1458.75	
3264	1460.75	
3303	1470.50	
3312	1472.75	
3322	1475.25	
3333	1478.00	
3339	1479.50	
3375	1488.50	
3390	1492.25	
3396	1493.75	
3398	1494.25	
3411	1497.50	
3438	1504.25	
3440	1504.75	
3443	1505.50	
3446	1506.25	
3448	1506.75	
3450	1507.25	
3453	1508.00	
3458	1509.25	
3463	1510.50	
3467	1511.50	
3476	1513.75	
3484	1515.75	
3497	1519.00	
3499	1519.50	
3504	1520.75	
3506	1521.25	
3509	1522.00	
3518	1524.25	
3527	1526.50	
3555	1533.50	
3575	1538.50	
3577	1539.00	
3580	1539.75	
3582	1540.25	
3586	1541.25	
3589	1542.00	
3599	1544.50	
3653	1558.00	
3655	1558.50	
3658	1559.25	
3661	1560.00	
3724	1575.75	
3962	1635.25	
4032	1652.75	
4037	1654.00	
4842	1855.25	
5297	1969.00	
5299	1969.50	
5367	1986.50	
5371	1987.50	
5378	1989.25	
5380	1989.75	
5382	1990.25	
5384	1990.75	
5398	1994.25	
5400	1994.75	
5402	1995.25	
5405	1996.00	
5407	1996.50	
5409	1997.00	
5480	2014.75	
5483	2015.50	
5492	2017.75	
5502	2020.25	
5507	2021.50	
5509	2022.00	
5517	2024.00	
5557	2034.00	
5953	2133.00	
5986	2141.25	
5988	2141.75	
5990	2142.25	
5992	2142.75	Temp
5995	2143.50	
6000	2144.75	
6003	2145.50	
6721	2325.00	non-LTE
6736	2328.75	non-LTE
6743	2330.50	non-LTE
6758	2334.25	non-LTE
6765	2336.00	non-LTE
6767	2336.50	non-LTE
6772	2337.75	non-LTE
6785	2341.00	non-LTE
6792	2342.75	non-LTE
6992	2392.75	Solar
6994	2393.25	Solar
6996	2393.75	Solar
6998	2394.25	Solar
7000	2394.75	Solar
7002	2395.25	Solar
7004	2395.75	Solar
7006	2396.25	Solar
7008	2396.75	Solar
7011	2397.50	Solar
7014	2398.25	Solar
7016	2398.75	Solar
7019	2399.50	Solar
7024	2400.75	Solar
7027	2401.50	Solar
7885	2616.00	Window
8094	2668.25	Window
8224	2700.75	Window
8358	2734.25	Window