Pressure Level Selection for IASI Retrievals

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Abstract

Atmospheric profiles of gases or temperature estimated from remote sounding are often presented on overly fine vertical grids that do not realistically represent the observations. Product consumers may be tempted to make overdrawn conclusions without understanding which parts of the profile come from the data and which come from prior knowledge used to constrain the estimates.

This work outlines a method for selecting an optimal coarse vertical grid based on the number and location of the independent pieces of information.

IASI instrument

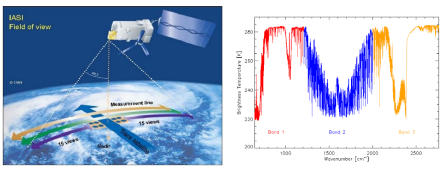

Figure 1: Depiction of the IASI scanning process and an example apodized spectrum. *(Figure credit left: CNES)*

The Infrared Atmospheric Sounding Interferometer (IASI):

- Nadir viewing Fourier transform interferometer
- Polar orbit aboard MetOp-A & B
- $15.5 - 3.6\,\mu\text{m}$ $(645 - 2760\,\text{cm}^{-1})$
- Apodized spectral resolution: $0.5\,\text{cm}^{-1}$

Independent vertical levels?

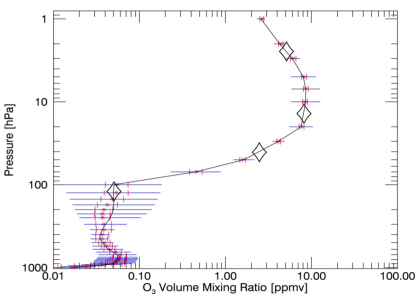

Figure 2: Ozone profile retrieved from an IASI observation (red stars). Prior information is shown by the *a priori* profile (black line) and global variability (blue error bars). The diamonds qualitatively represent the number and location of the actual independent estimates.

Potential pitfall: Imagine a user downloads an IASI ozone retrieval like Fig. 2 (red stars). In this case, are there really 37 independent estimates of the O_3 profile? Surely not! In fact, the actual degrees of freedom that come from the signal may be more like the overlain diamonds in Fig. 2.

Aside from the black diamonds, where did the information come from? In short, *a priori* fills in the gaps [Payne et al., 2009].

Mission statement: Develop a consistent method to select the optimal location and number of vertical retrieval grid levels.

Pressure selection method

The response of the estimate ($\hat{x}$) to true state (x) changes is given by the averaging kernel matrix, AKM,

$$\mathbf{A} = \mathbf{GK} = \frac{\partial \hat{\boldsymbol{x}}}{\partial \boldsymbol{x}}. \qquad (1)$$

$\mathbf{K}$ is the Jacobian matrix and $\mathbf{G}$ is its optimal inverse [Rodgers, 2000]. The degrees of freedom of the signal, DFS, are given by:

$$d_s = \mathrm{Tr}\,(\mathbf{A}). \qquad (2)$$

Selection Method:

1. Single vertical level merged into neighbours. Information content checked.
2. Repeat 1 for all possible levels. Level keeping greatest DFS stays merged.
3. Repeat process ranking levels down to two bulk levels adding the most DFS.

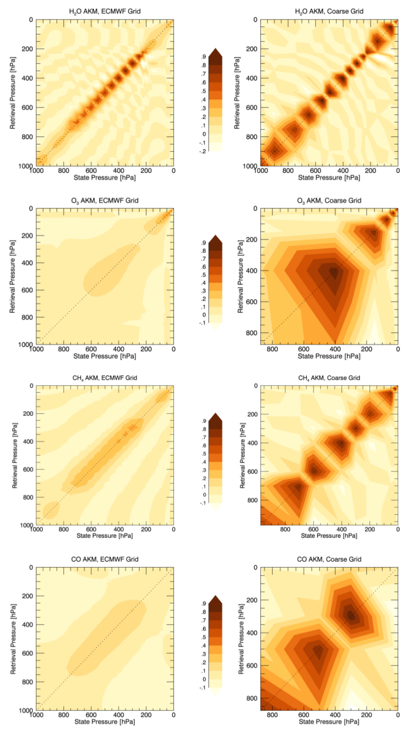

Figure 3: Contours of AKMs for four trace gases in a mid-lat scenario. Left column: True state retrieval sensitivity on the ECMWF 37 level pressure grid. Right column: Sensitivities on coarse grids selected using the above method.

What is the point? For a given atmosphere, observation, and *a priori* the information content is fixed. The designer of a retrieval method has two general choices:

1. Make more profile estimates with less true state sensitivity (left column), or...
2. Make less estimates with more true state sensitivity (right column).

Ranking levels and channels

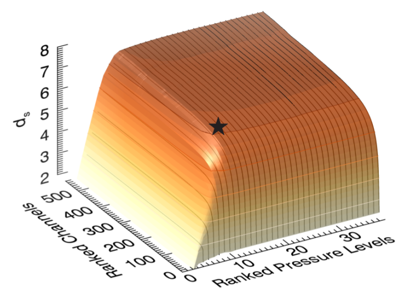

Figure 4: DFS versus both ranked pressure levels and ranked spectral channels for a temperature retrieval with IASI. The black star represents the "best" location to reside.

In Fig. 4 notice that once the number of pressure levels exceeds the DFS, there is a rapid plateau. Thus, adding many more levels adds no new information, only *a priori*.

Applying spectral and pressure level selection is a practical trade-off. Using an optimal subset sacrifices a small amount of DFS, but provides the following:

- **Channel selection**: Reduces sensitivity to unaccounted systematic errors
- **Pressure selection**: Reduces dependence on *a priori* and increases true state sensitivity [von Clarmann and Grabowski, 2007]

Results and conclusions

Many retrieval methods are designed with a coarser grid where the number of estimates is on par with the DFS. Commonly, an equally spaced grid is used. Table 1 shows the % loss in DFS using equally spaced pressure levels versus the proposed selection method. The loss may not be tolerable.

Table 1: Percent loss of DFS from using equally spaced pressure levels versus those selected by the described method. Atmospheric scenarios include mid-latitude (M-L), tropical (trop), arctic summer (A-S), and arctic winter (A-W).

Species	M-L	Trop	A-S	A-W
H_2O	7.4	11.0	11.5	10.3
O_3	32.3	28.6	33.1	36.9
CH_4	9.7	17.2	15.0	9.3
CO	1.6	6.2	6.0	1.3

Bottom line: The vertical retrieval grid should be chosen based on the location of information related to the target species. The proposed method is a robust one that allows for irregular spacing and accounts for strong correlations between different levels.

References

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