Supplement

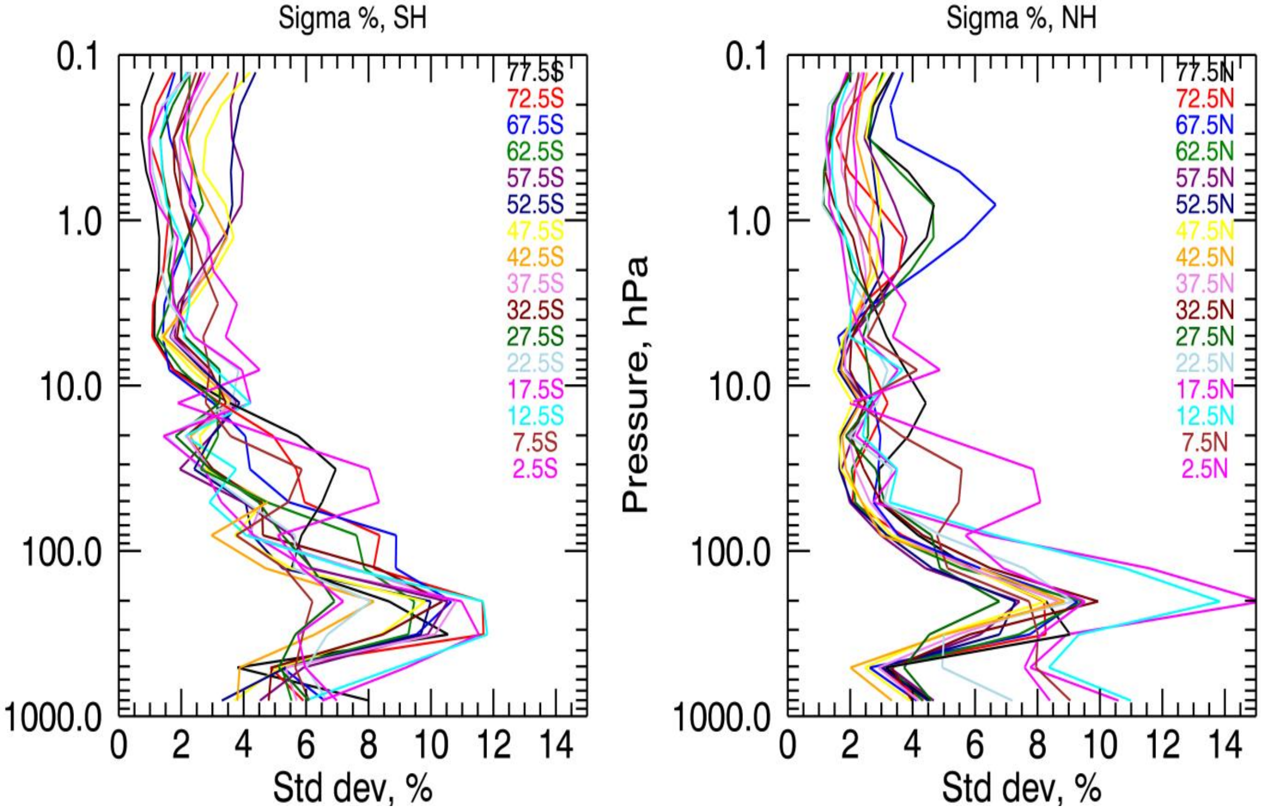
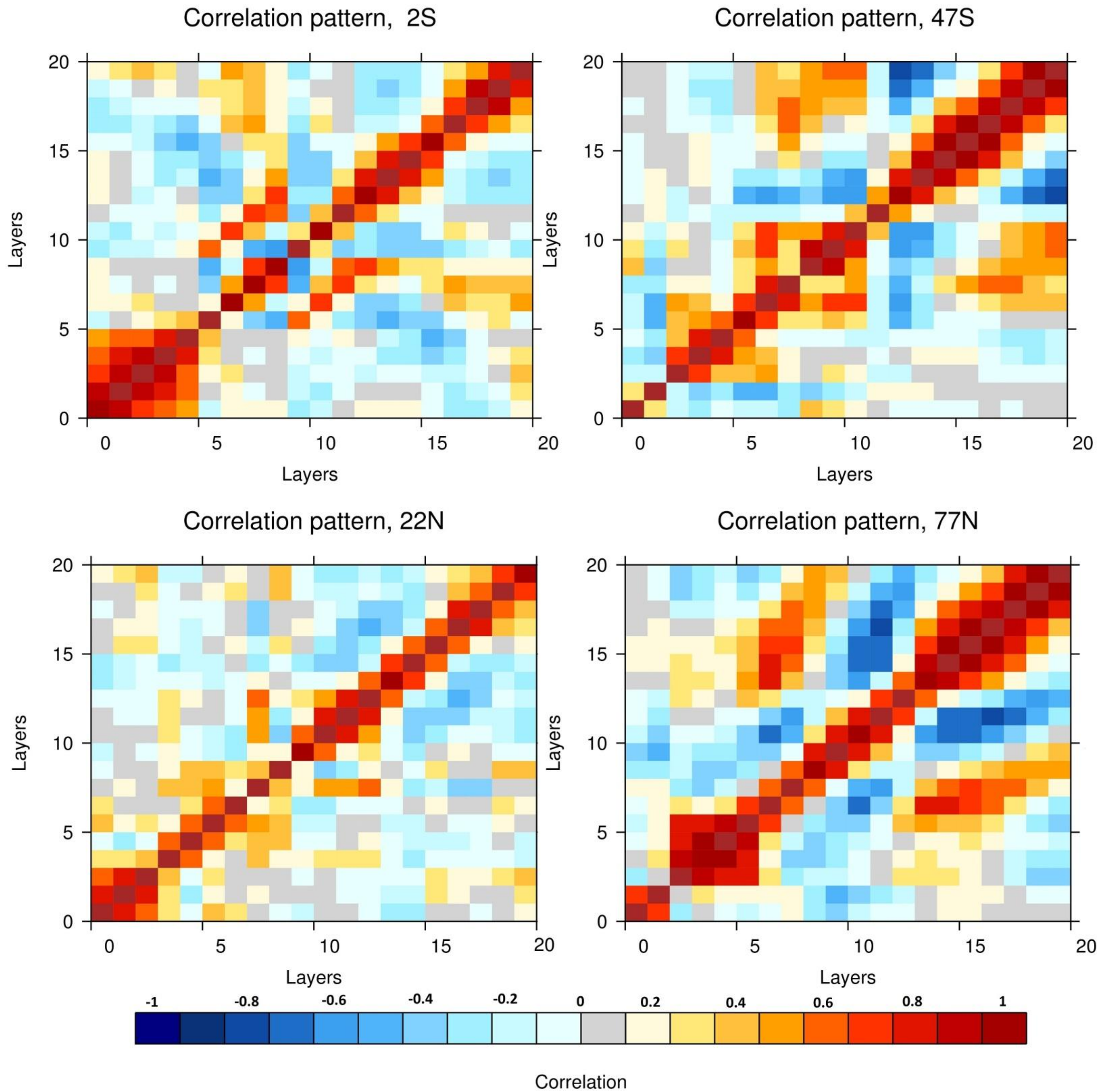
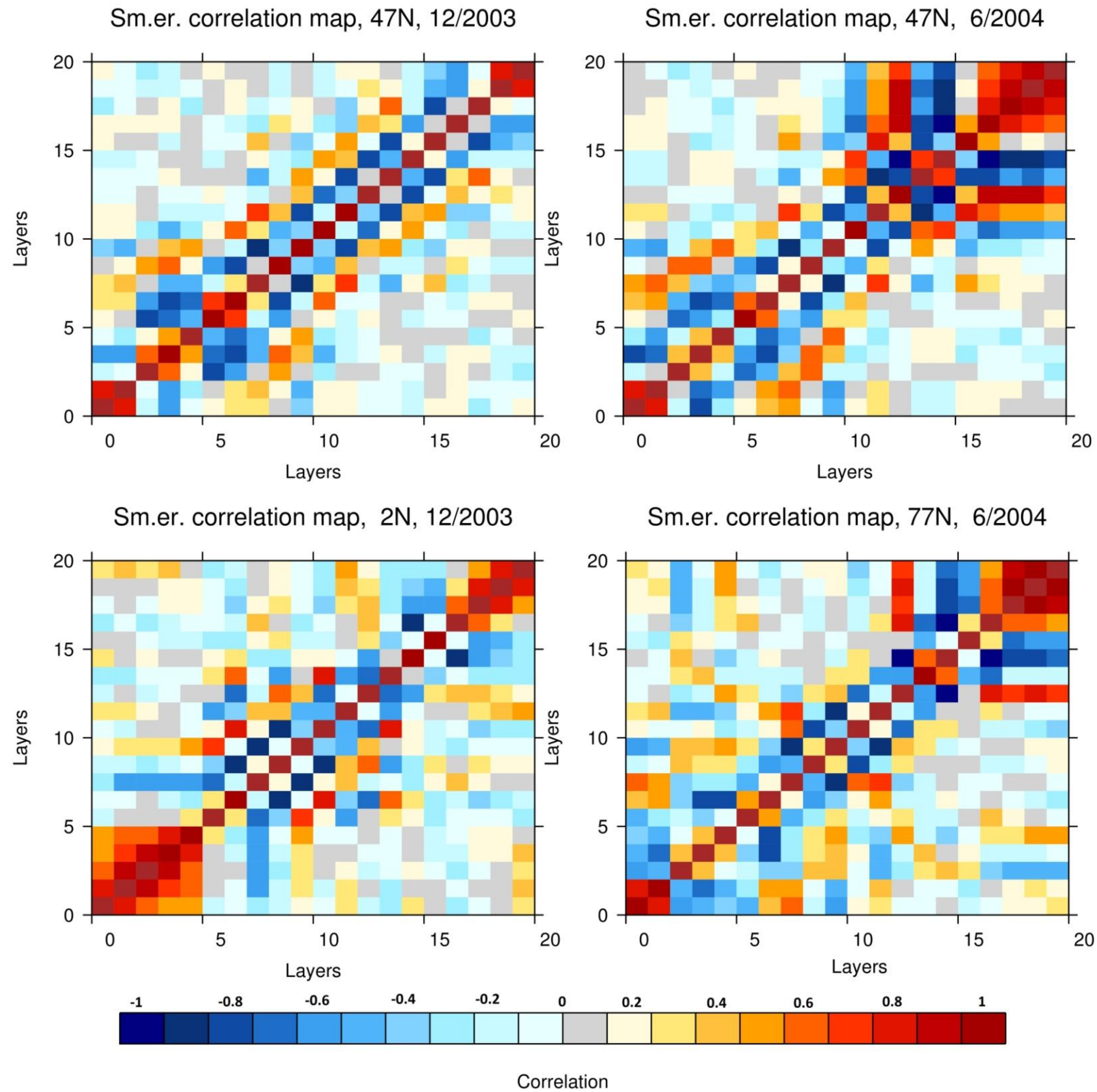


Figure S1. Vertical profiles of the square roots of the diagonal elements of the covariance matrices **C** for different latitude bins in the southern (left) and northern (right) hemispheres. These quantities are equal to the standard deviations of the mzm merged MLS/sonde profiles. Different colors correspond to 5° latitude bins with the middle points from 77.5° S to 77.5° N. Standard deviations for each latitude bin are expressed as percent from the annual mean a priori in the corresponding latitude bin. Standard deviations are notably larger in the troposphere in latitude bins 10°N and 20°N. This is due to the limited number of ozone sonde observations in this region.



<u>Figure S2.</u> Correlation patterns derived from the 6-year time series of mzm merged Aura MLS and sonde data for four selected latitude bins: (a) 0-5° S; (b) 45-50° S; (c) 20-25° N; (d) 75-80° N. Correlation was calculated from the covariance matrix **C** by normalizing each element of **C** by the product of square roots of the corresponding diagonal elements $\frac{\mathbf{C(i,j)}}{\sqrt{\mathbf{C(i,i)}}\sqrt{\mathbf{C(j,j)}}}$.



<u>Figure S3.</u> Correlation patterns obtained from the smoothing error covariance matrix $\mathbf{S_{serr}}$ that demonstrate inter-level correlation of the smoothing errors for: (a) latitude bin 45-50° N in December; (b) latitude bin 45-50° N in June; (c) latitude bin 0-5° N in December; (d) latitude bin 75-80° N in June. To obtain the correlation pattern, each element of the $\mathbf{S_{serr}}$ was normalized by the product of square roots of the corresponding diagonal elements $\frac{\mathbf{S_{serr}}(\mathrm{i,j})}{\sqrt{\mathbf{S_{serr}}(\mathrm{i,i})}\sqrt{\mathbf{S_{serr}}(\mathrm{j,j})}}$. When the off-diagonal elements of $\mathbf{S_{serr}}$ indicate that the errors are highly correlated, then we have more information about the measured state $\boldsymbol{x}$ (Rodgers, 1990)**.** We can see that the correlation length (number of layers with the correlation > |0.5|) increases in the upper layers (above 1 hPa) and in the troposphere/lower stratosphere. This explains why the smoothing error decreases for the thick, merged layer.

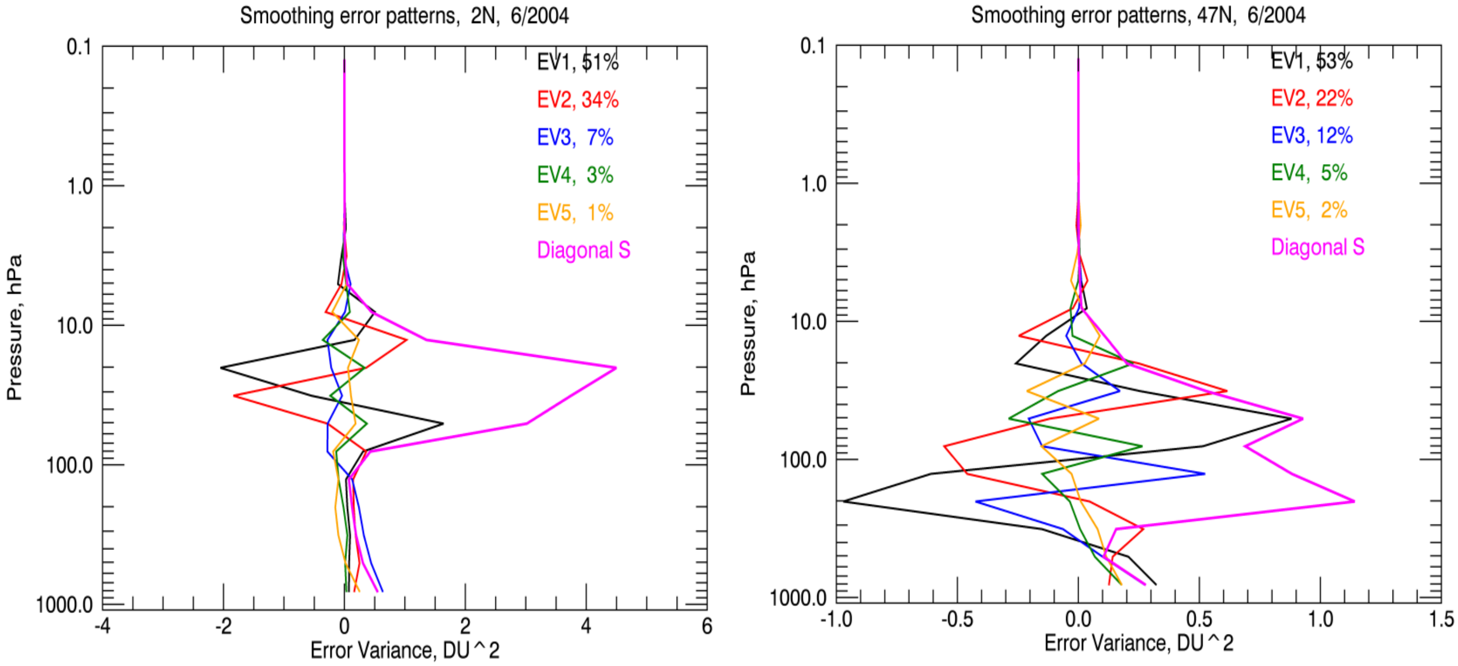
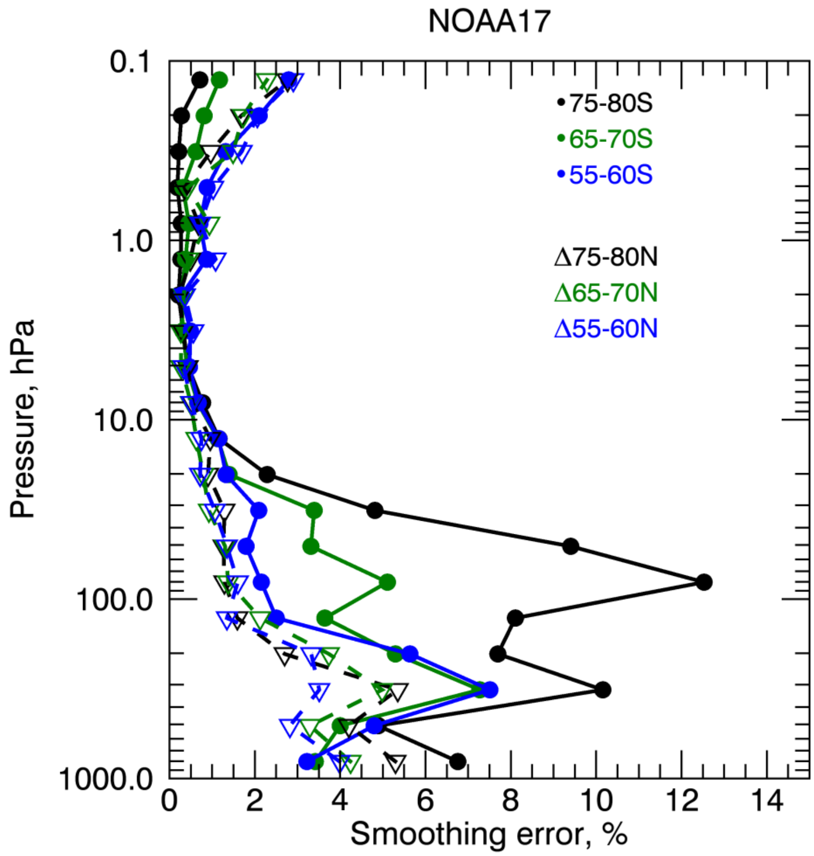


Figure S4. Five first eigenvectors $\boldsymbol{e_v}$ (or "error patterns") of the smoothing covariance matrix $\mathbf{S_{serr}}$, scaled by the square roots of their eigenvalues, along with the diagonal elements of the $\mathbf{S_{serr}}$ (magenta lines) for: (a) latitude bin 0-5° N in June; (b) latitude bin 45-50° N in June. The first five eigenvectors capture about 90% - 99% of the $\mathbf{S_{serr}}$ variance. According to Rodgers, (1990) the error in the retrieved profiles $\hat{\boldsymbol{x}}$ is the sum of these patterns multiplied by a random factor a_i having unit variance: $\boldsymbol{\epsilon_x} = \sum_{i=1}^{n} a_i\, \boldsymbol{e_v}(\boldsymbol{i})$**.** The sum of different combinations of $\boldsymbol{e_v}$ will be smaller or equal to the diagonal elements. This figure demonstrates that our approach using only diagonal elements of the $\mathbf{S_{serr}}$ provides a simple, reasonable estimation of the layer smoothing errors. However, in some cases the "diagonal" approach overestimates errors, particularly for layers 6 (100-63 hPa) and 10 (16-10 hPa) in the tropics 10°S-10°N.



<u>Figure S5.</u> Vertical profiles of the smoothing error for the high latitudes of both hemispheres in boreal spring. Smoothing errors are expressed as a percentage from the retrieved profiles. Profiles are for NOAA17, April (NH) and October (NH) of 2007. Smoothing errors are larger in the southern hemisphere due to the Antarctic Ozone Hole. The SBUV a priori provides inaccurate constraints in Antarctic Ozone Hole conditions, and as a result the smoothing errors increase.

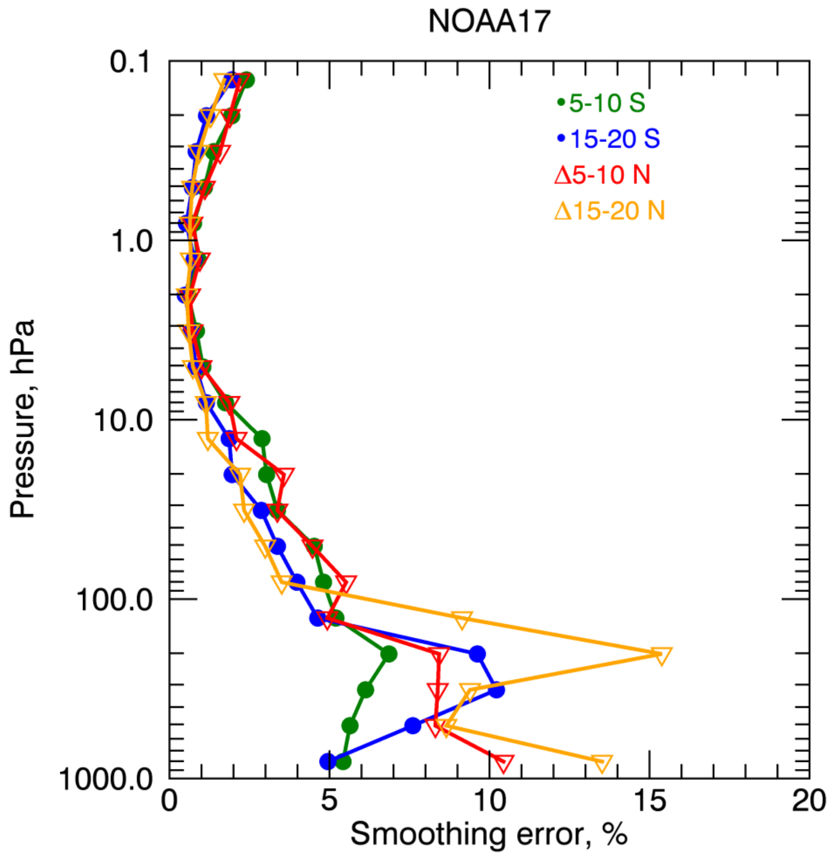


Figure S6. Vertical profiles of the smoothing error for the tropical latitudes of both hemispheres in July 2007 (NOAA 17). Smoothing errors are expressed as a percentage of the retrieved profiles. Smoothing errors are larger in the 15-20° N latitude bin due to larger ozone variability determined from the mzm merged MLS/sonde profiles in 10-20° N latitude bins (See Fig. S1).

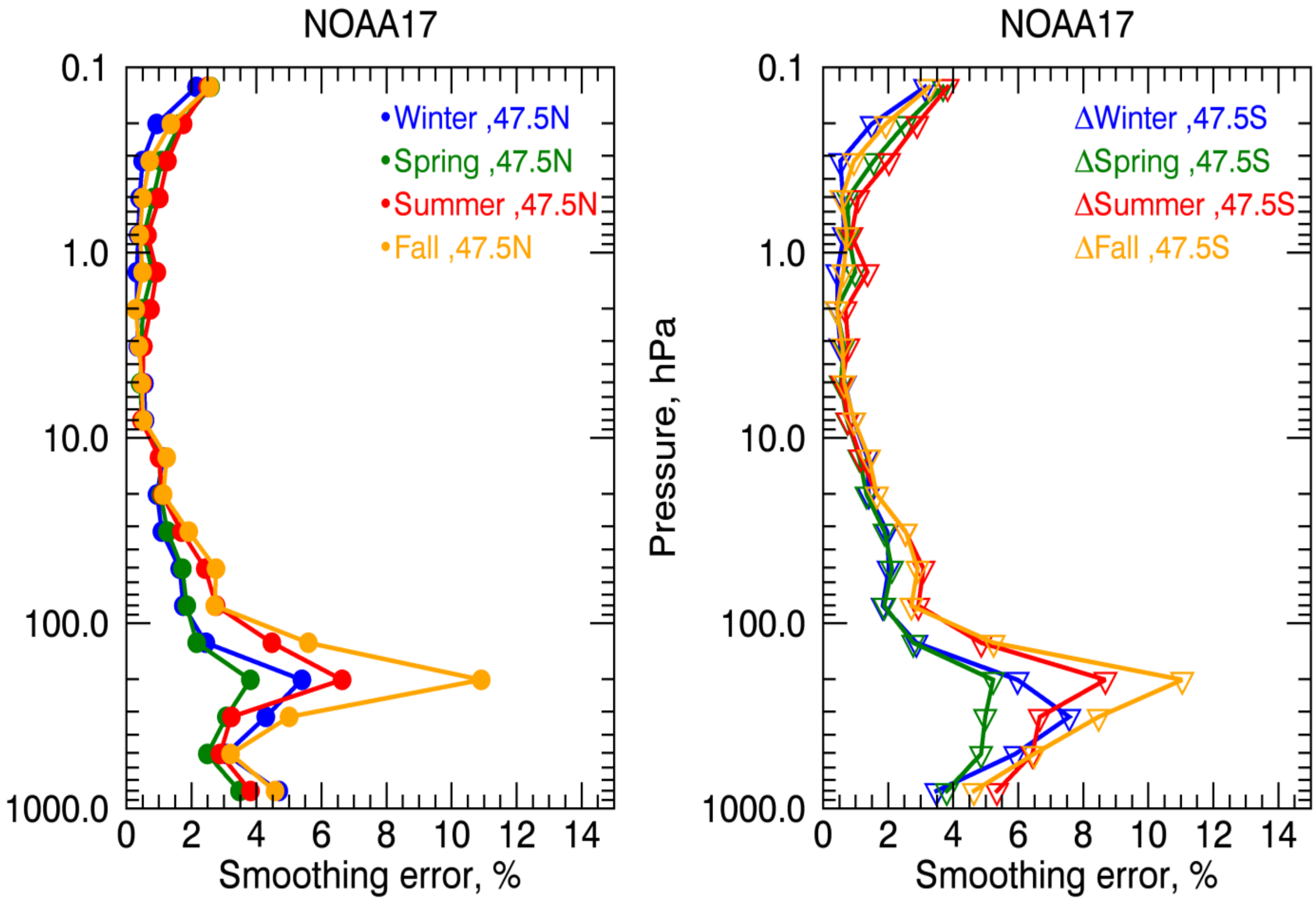


Figure S7. Vertical profiles of the smoothing error in the northern (left) and southern (right) midlatitudes for 4 seasons. Smoothing errors are expressed as a percentage of the retrieved profiles. Profiles are for NOAA17, 2007 (January, April, July and October). Smoothing errors show a similar seasonal behavior in both hemispheres with larger errors at about 200 hPa in boreal fall.

Derivation of equation 5.

To calculate the smoothing error for the thick, combined layer we use the following equations:

$$\mathrm{S}_{\mathrm{merged}} = \boldsymbol{L}^{\boldsymbol{T}}\mathbf{S}_{\mathbf{serr}}\boldsymbol{L} \tag{S1}$$

Where $\boldsymbol{L}$ is a state vector with 1 for the layers to be merged and 0 elsewhere.

If, for example, we want to merge layers 2 and 3 then the state vector $\boldsymbol{L}$ will be $\boldsymbol{L} = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$

$$S_{2+3} = [0 \quad 1 \quad 1] * \begin{bmatrix} \mathrm{S}_{11} & \mathrm{S}_{21} & \mathrm{S}_{31} \\ \mathrm{S}_{12} & \mathrm{S}_{22} & \mathrm{S}_{32} \\ \mathrm{S}_{13} & \mathrm{S}_{23} & \mathrm{S}_{33} \end{bmatrix} * \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix} =$$

$$[\mathrm{S}_{12} + \mathrm{S}_{13} \quad \mathrm{S}_{22} + \mathrm{S}_{23} \quad \mathrm{S}_{32} + \mathrm{S}_{33}] * \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix} = \mathrm{S}_{22} + \mathrm{S}_{23} + \mathrm{S}_{32} + \mathrm{S}_{33} = \sum_{i=2}^{3}\sum_{j=2}^{3}\mathbf{S}(i,j) \tag{S2}$$

Thus the smoothing error for the thick merged layer can be calculated using the expression:

$$S_{serr}^{k_o,k_n} = \sqrt{\sum_{i=k_0}^{i=k_n}\sum_{j=k_0}^{j=k_n}\mathbf{S}_{\mathbf{serr}}(\mathbf{i},\mathbf{j})} \tag{S3}$$