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Impact of an updated observation error covariance matrix on the ozone analysis

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1 Abstract

In atmospheric chemistry retrievals and data assimilation systems, observation errors associated with satellite radiances are chosen empirically and generally treated as uncorrelated. In this work, we estimate inter-channel error covariances for the Infrared Atmospheric Sounding Interferometer (IASI) and evaluate their impact on ozone assimilation with the chemical transport model MOCAGE.
The results show significant differences between using the estimated error covariance matrix with respect to the empirical diagonal matrix employed in previous studies. The validation of the analyses against independent data reports a significant improvement, especially in the tropical stratosphere. The computational cost has also been reduced when the estimated covariance is employed in the assimilation system.

2 Context and objectives

2.1 Why do we monitor ozone ?

- Tropospheric ozone behaves as a **pollutant** with negative effects on vegetation and human health.
- Tropospheric ozone contributes to **global warming** with a net positive effect.
- The stratospheric ozone is a vital component of life on the Earth since it protects the **biosphere** from harmful ultraviolet.
- Ozone is used recently to improve temperature in **NWP**.

2.2 Assimilation: context and assumptions

- Level 2 products have been assimilated for several years.
- Recently, direct assimilation of IASI radiances has been introduced (Emili 2019).
- **Assumption: Uncorrelated observation errors and constant variance.**

2.3 Objectives

- **Is the observation error correlated ? Variance constant?**
- **If yes ? What might be the impact on the analyses ?**

3 Methodology

3.1 Model: MOCAGE

- Developed at CNRM (Météo France). (Josse et al., 2004)
- Modelled processes: Sources, Sinks, Transport and Chemistry.
- Multiscale: regional and global.

3.2 Observations: IASI

IASI : Infrared Atmospheric sounding Interferometer(Metop-A)

- Measures between 3 and 15 µm (645 and 2760 cm^{-1}), Spectral resolution 0.5 cm^{-1}.
- Spectral range used: between 980 and 1100 cm^{-1} (ozone and surface skin temperature).

3.3 Assimilation method : **3D-Var**

$$\mathcal{J}(\mathbf{x}) = \frac{1}{2}(\mathbf{x}_b - \mathbf{x})^T\mathbf{B}^{-1}(\mathbf{x}_b - \mathbf{x}) + \frac{1}{2}(\mathbf{y} - \mathcal{H}(\mathbf{x}))^T\mathbf{R}^{-1}(\mathbf{y} - \mathcal{H}(\mathbf{x}))$$

- x_b : Background . y: Observations. $\mathcal{H}$: Observation operator.
- **B** : Background error covariances matrix.
- **R** : Observation error covariances matrix.

3.4 Radiative transfer model

RTTOV (Radiative Transfer for TOVS) (R. Saunders and Brunel, 1999)

- Simulates radiances in the infrared and microwave spectrum.
- Takes as inputs an atmospheric profile of temperature, water vapor and, optionally, trace gases, aerosols and hydrometeors, together with surface parameters and a viewing geometry.

3.5 Data

✓ Assimilated : IASI. Validation : Radiosoundings and OMI

4 Estimation: Method

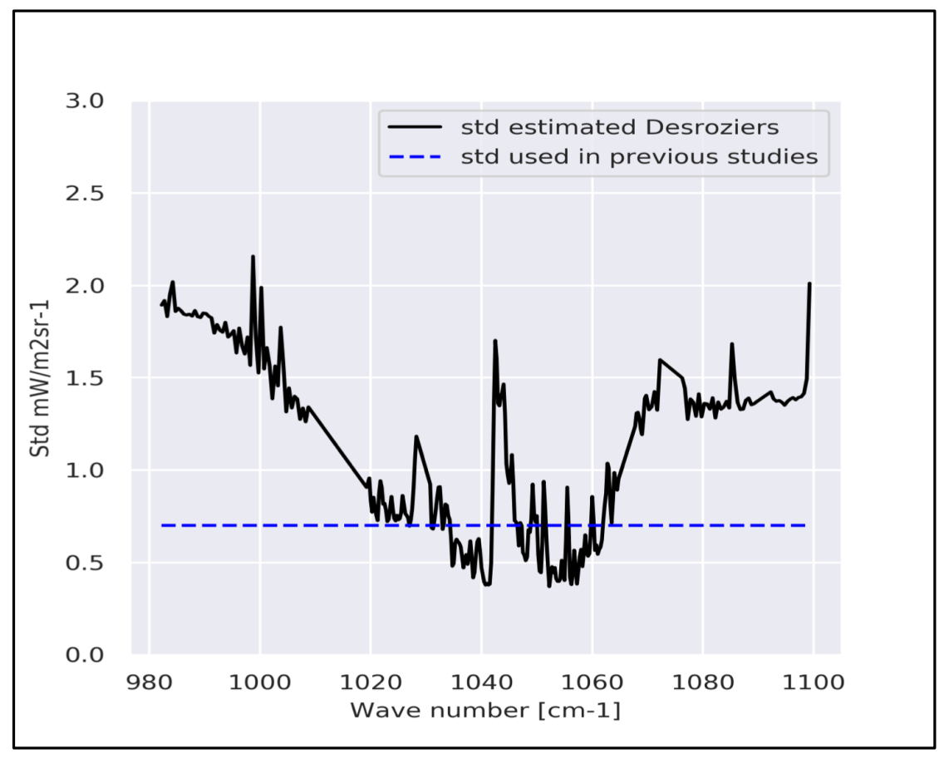
Desroziers method (Desroziers et al. 2005)

- $d_a^o = Y - H(X_a)$
- $d_b^o = Y - H(X_b)$
- Y : Observation.
- X_a: analysis from previous assimilation (using a diagonal matrix as in Emili et al 2019).
- X_b: Background state.
- **E**: The mathematical expectation

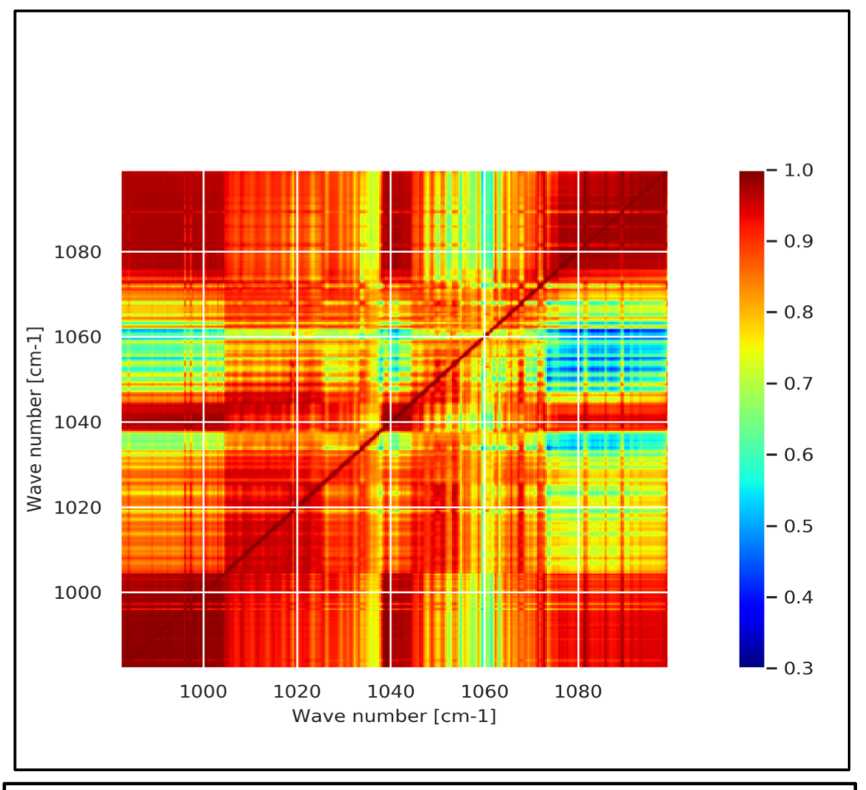
$$\boxed{\mathbf{R} = \mathrm{E}[(d_a^o(d_b^o)^T]}$$

5 Estimation: Results

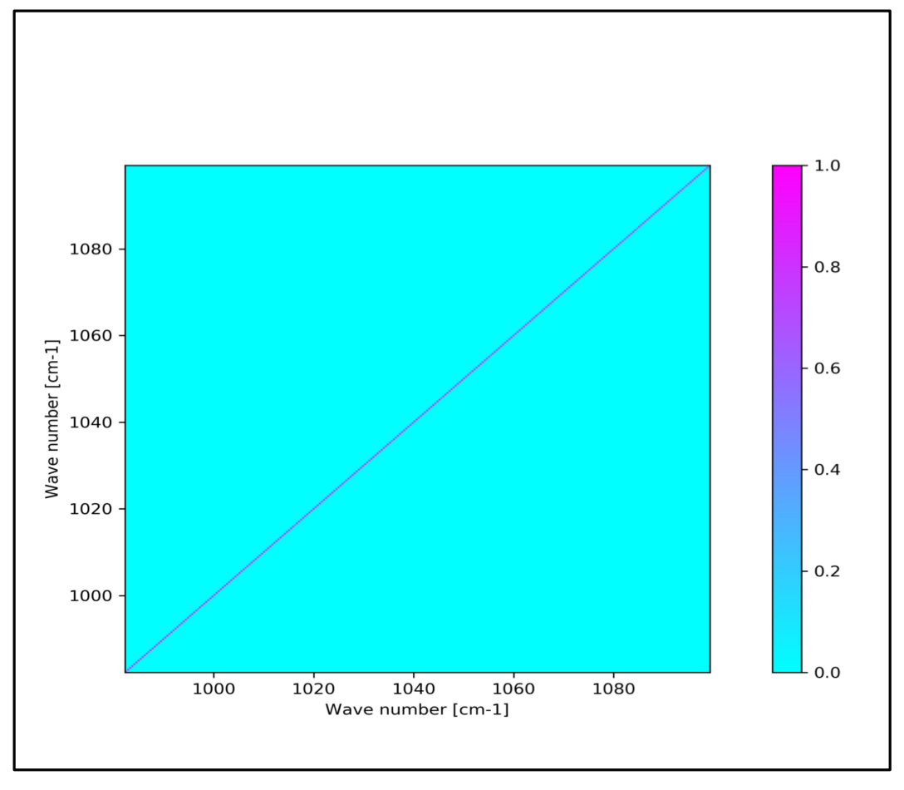
Standard deviation and correlation matrix



Standard deviation

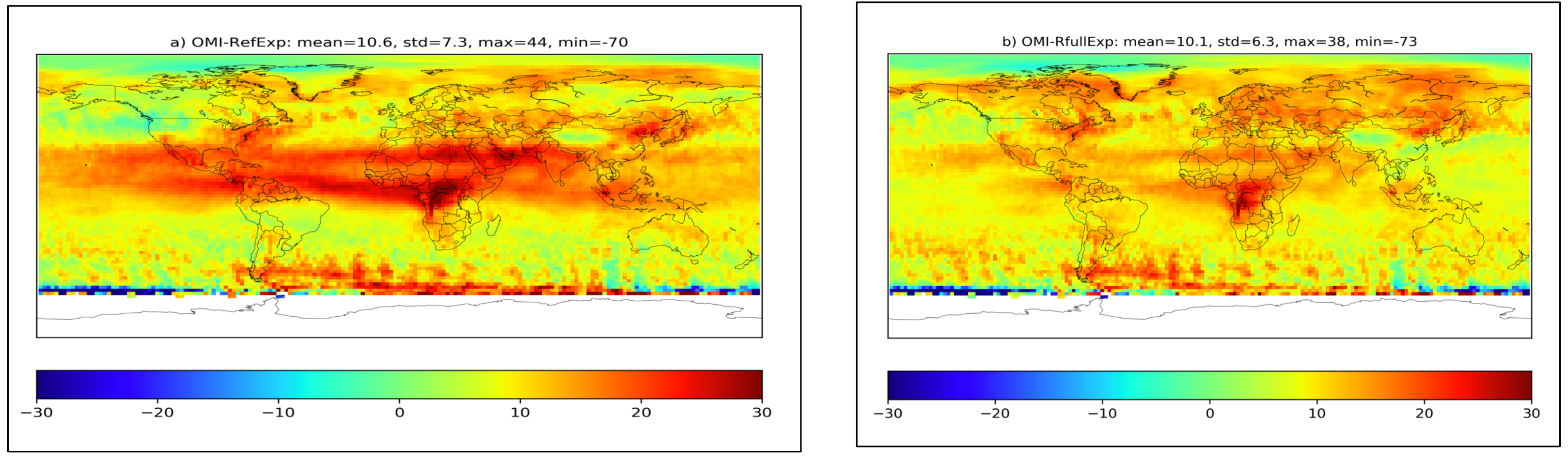


Correlation matrix estimated



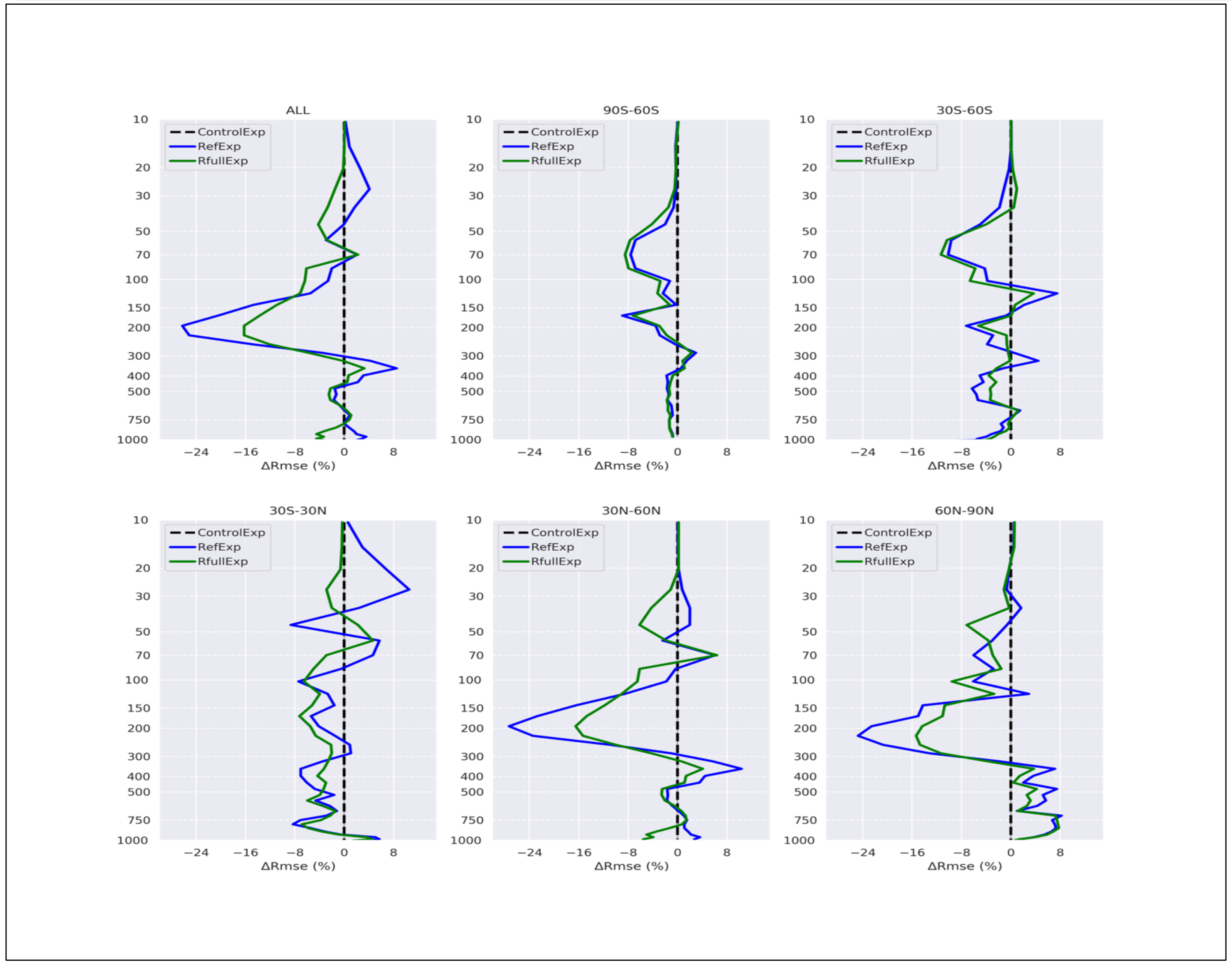
Correlation matrix used in previous studies

Impact on ozone analysis: Total column



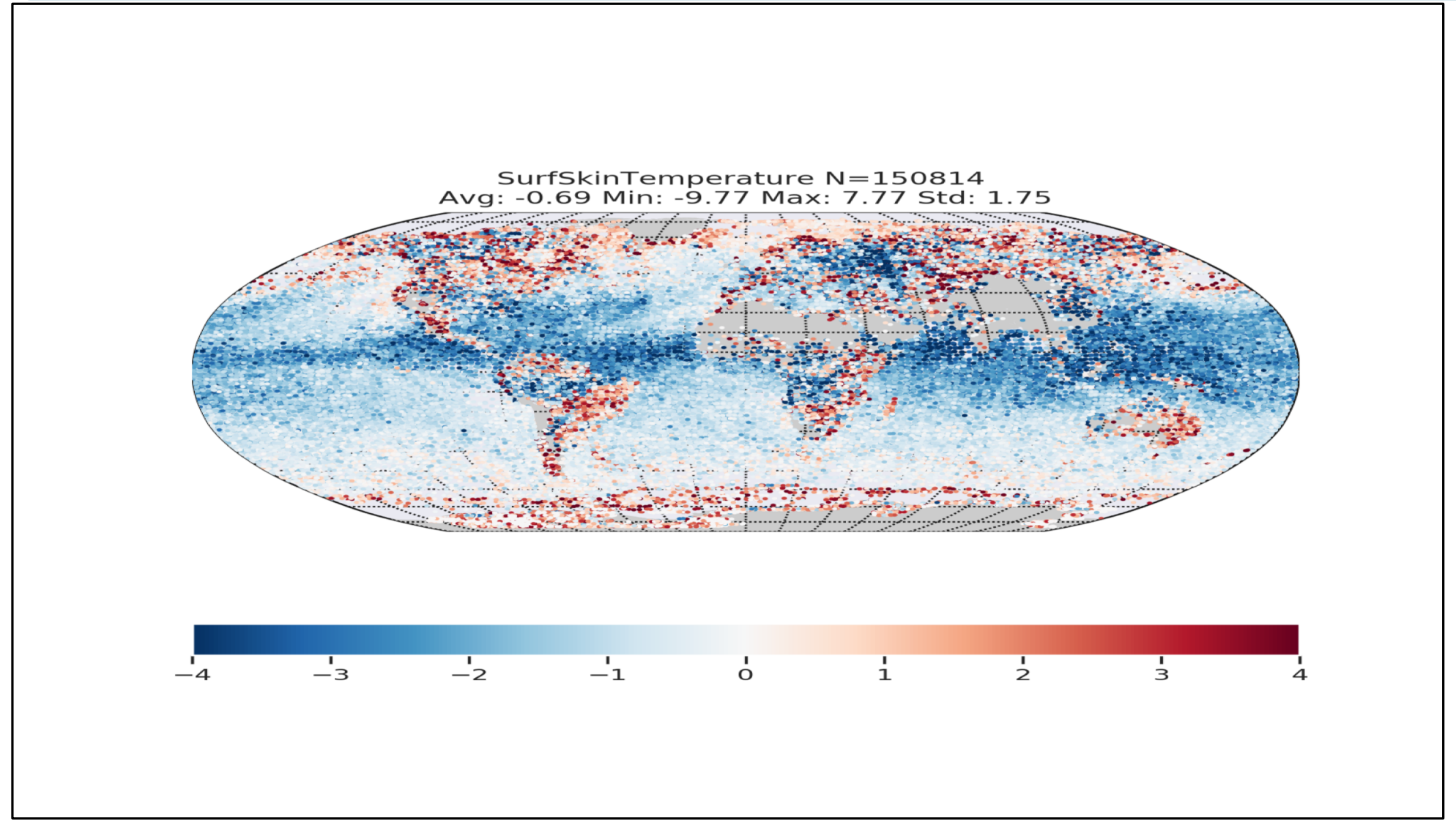
← Difference of the ozone total column (DU) provided by OMI and that of the assimilation experiment using the diagonal matrix (a) , and that of using the estimated matrix (b), averaged over the month of the study.

Impact on ozone analysis: Validation of vertical profile against ozonesondes.

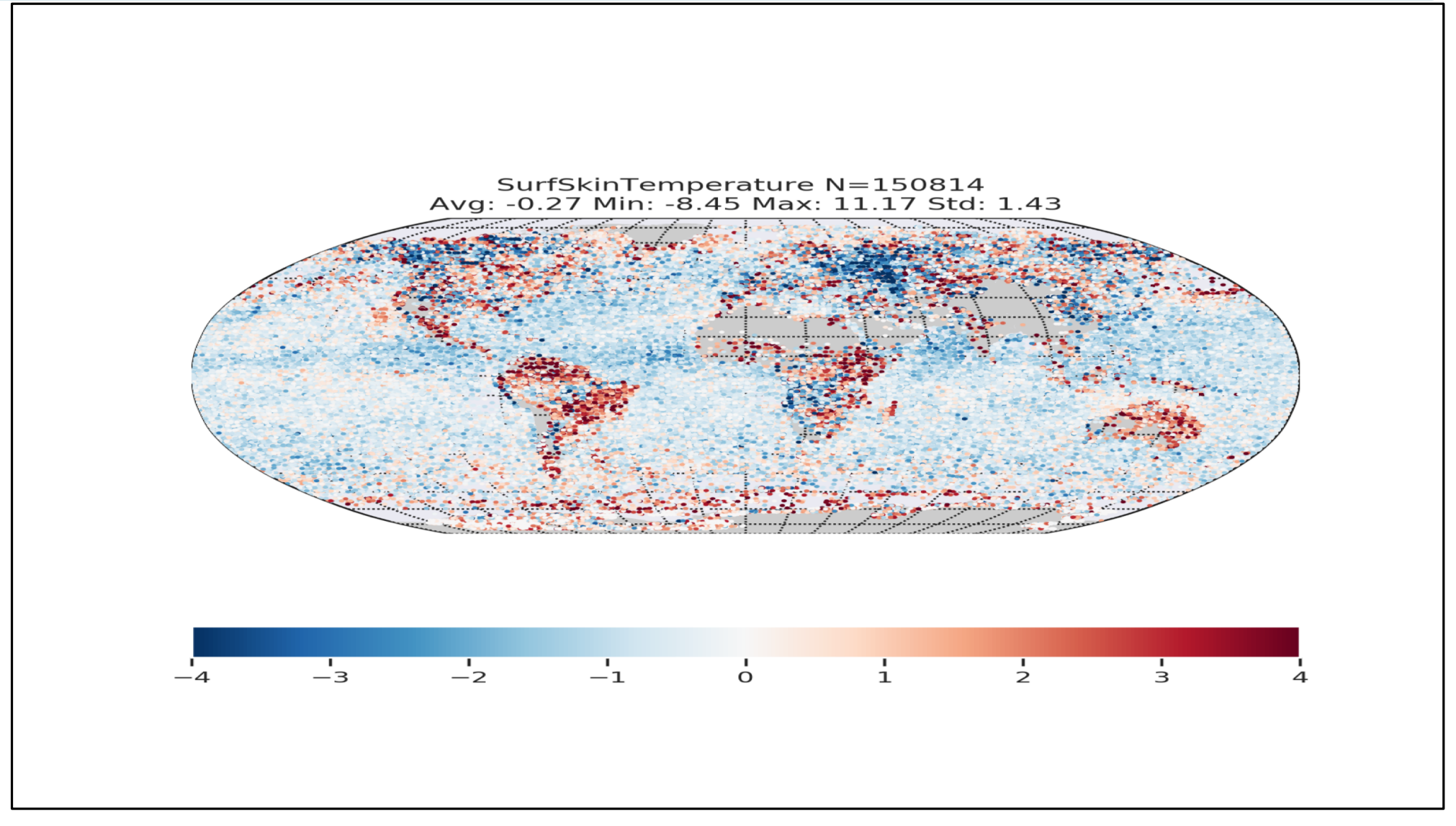


← Relative difference of the RMSE with respect to radiosoundings for the R estimated (green) and R diagonal (blue). The relative difference of the RMSE was computed by subtracting the RMSE of the control from the RMSE of the analysis of each experiment, divided by the average profile of radiosoundings. Negative values show an improvement.

Impact on the surface skin temperature: Validation against IFS data.



SST analysis where R diagonal – IFS background



SST analysis where R estimated by Desroziers stat – IFS background

Impact on the computational cost:

✓ the computational cost of the minimization is reduced by almost 2/3 (from 150 iterations to 90 iterations in average each window).

6 Conclusions

The correct specification of the observation error becomes a critical issue to assimilate efficiently the increasing amount of satellite data available in the recent years. We have estimated the observation errors and their inter-channel correlations for clear sky radiances from IASI ozone sensitive channels. We have evaluated, then, the impact of this estimation on the SST and ozone analysis within our 3D-Var assimilation system. The results of the experiments were, then, validated against independent data: ozonesondes.
The validation reports a significant improvement, especially in the tropical stratosphere. The computational cost has also been reduced by 150% when the estimated covariance is employed in the assimilation system.

7 References

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8 Acknowledgements

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