Improving thermodynamic retrievals using realistic ozone and ozone-sensitive channels

Olivier COOPMANN, Vincent GUIDARD, Nadia FOURRIE, Matthieu PLU
Météo-France & CNRS CNRM, Toulouse, France
olivier.coopmann@meteo.fr vincent.guidard@meteo.fr

Introduction

Hyperspectral infrared sensors like IASI onboard Metop polar-orbiting European satellites cover a wide range of the infrared spectrum. Parts of this spectrum are sensitive to ozone. During the assimilation process, a priori profiles of temperature, humidity, etc. are mandatory, including ozone profiles. In Météo-France operational system, information on ozone within the numerical weather prediction (NWP) process is a climatological profile, constant in space and in time, coming from **RTTOV** learning data base (hereafter named **RTTOV**). Other sources of information on ozone are available:
- a climatology based on measurements, which has a monthly and latitudinal variation (Fortuin and Langematz, 1995, hereafter **FL94**).
- three ozone fields provided by the French Chemistry Transport Model MOCAGE (Sic et al, 2015) such as **MOC47L** with 47 levels up to 5 hPa, **MOC60L** with 60 levels up to 0.01 hPa and **MOC60LTOPC120** with 60 levels and a top convection modification.

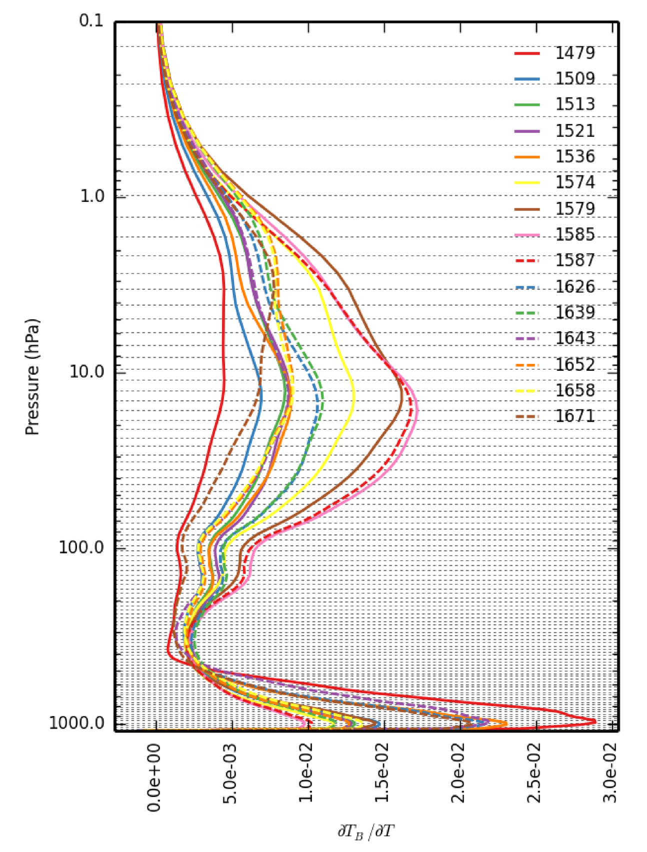

Figure 1. Temperature jacobians with respect to pressure for 15 channels.

The goal of this study is to select the **IASI** ozone sensitive channels that have a positive impact on the retrievals of temperature and humidity profiles, depending on each ozone models.

A set of pixels from the **IASI** instrument have been collocated with **radiosondes** around the Globe between August 2014 and February 2015. Two **1D-Var** methods have been used for the channel selection:
- 1D-Var with a constant and diagonal observation error covariance matrix **R** (**R_{diag}**).
- 1D-Var with observation error covariance matrix **R which is diagnosed (Desroziers method) at each step** (**R_{adapt}**).

Channel list between [**1014,5 - 1062,5 cm^{-1}**]:

1479, 1509, 1513, 1521, 1536, 1574, 1579, 1585, 1587, 1626, 1639, 1643, 1652, 1658, 1671.

1. Evaluation of ozone profiles

Ozonesondes from the US and WouldC network (**32 stations** and **715 profiles** covering the Poles, the Tropics and northern mid-latitudes in Figure 2 Left) have been used to evaluate the five possible sources of information for ozone. Statistics are computed over the whole period and are presented on Figure 3.

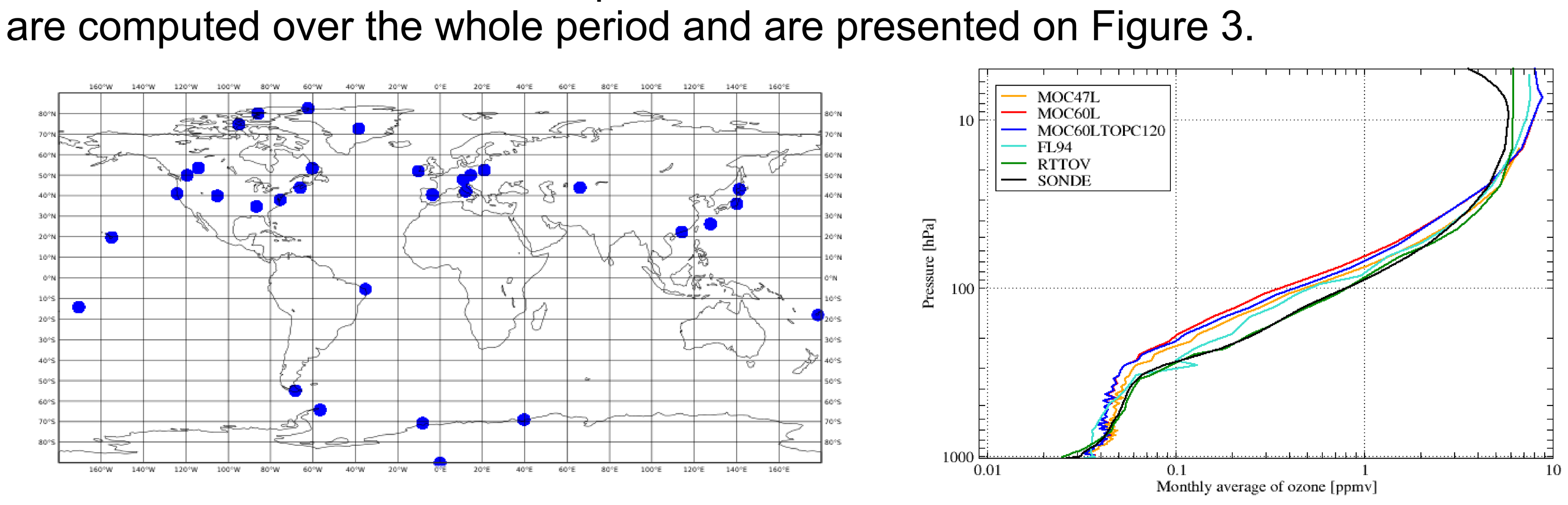

Figure 2. Map of stations (Left) and average of ozone for Models and Sondes (Right) for the study period

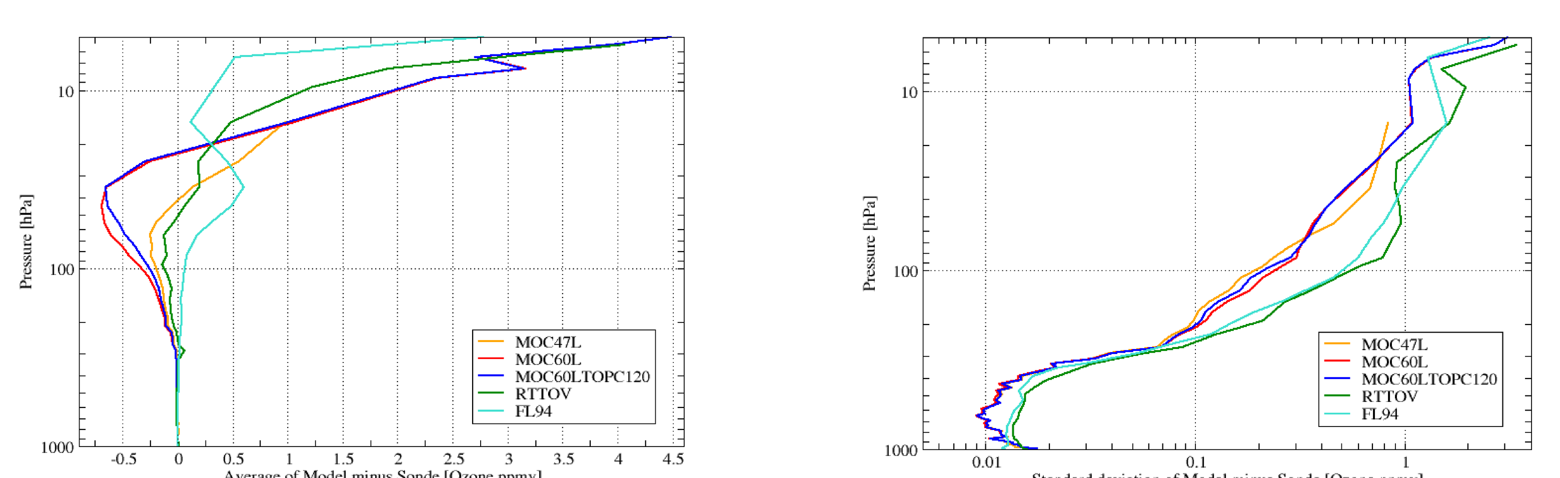

Figure 3. Average (Left) and standard deviation (Right) of differences Models minus Sondes.

2. Impact on the simulations

The five possible sources of information for ozone have been used in the simulator (RTTOV model). In order to evaluate their accuracy, the simulations were compared to real IASI observations (**159 clear observations collocated with sondes**). The ozone band is between **1014.5 cm^{-1}** and **1062.5 cm^{-1}**, in the 314 channel subset used at Météo-France. Figure 4 shows biases which will be subtracted to observations. The low standard deviations for **MOC47L**, **MOC60L** and **MOC60LTOPC120** show that the ozone of MOCAGE is more realistic compared to **FL94** and **RTTOV**.

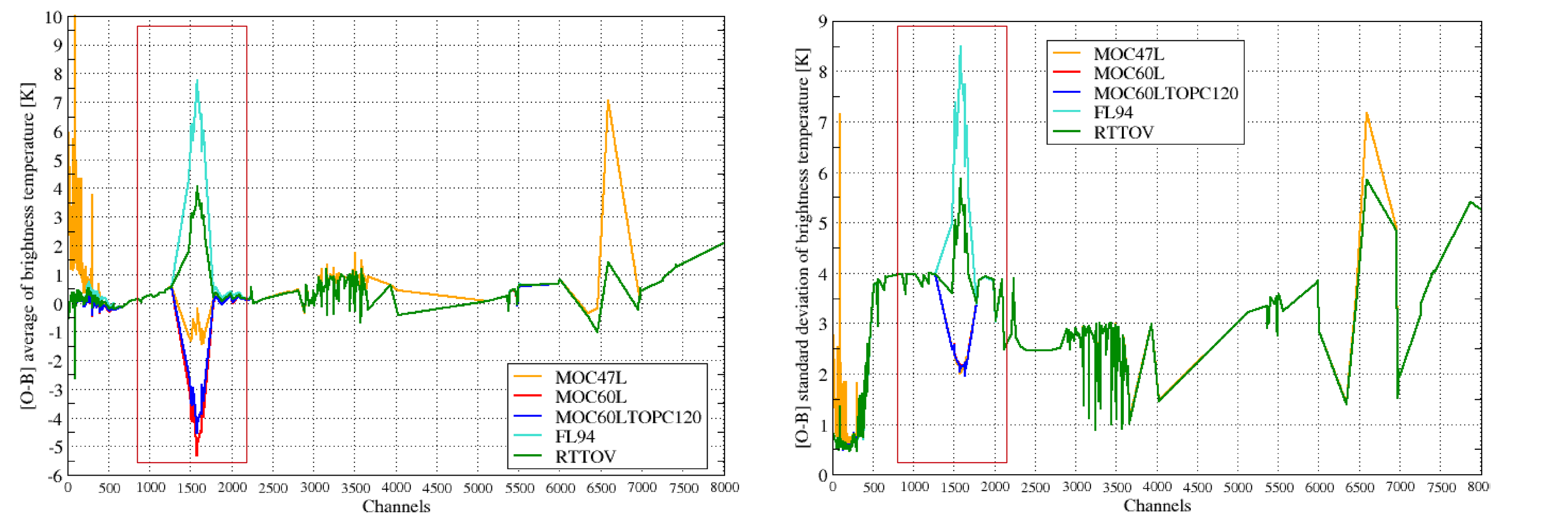

Figure 4. Average (Left) and standard deviation (Right) of differences between real observations and simulations for IASI channels (operationnal 314-subset).

3. 1D-Var and channel selection

A channel selection has been performed with **R_{diag}** (not shown) and **R_{adapt}** shown in Figure 5 (Left). The relative reduction of error is more efficient with **MOC47L**, **FL94** and **RTTOV** models. The channel selection stops when error reduction stops improving (Arrows in Figure 5 Left, channel list and order in Table 1). Figure 5 (Right) details the vertical structure of the relative error reduction for selected channels. **MOC47L** channel selection shows positive impact in mid stratosphere **[15-50 hPa]** and in the whole troposphere. **FL94** shows a reduction between **[20-1000 hPa]**. Reduction is less important for **RTTOV, MOC60L** and **MOC60LTOPC120** models with some degradations. However these models lead to a positive impact in lower troposphere.

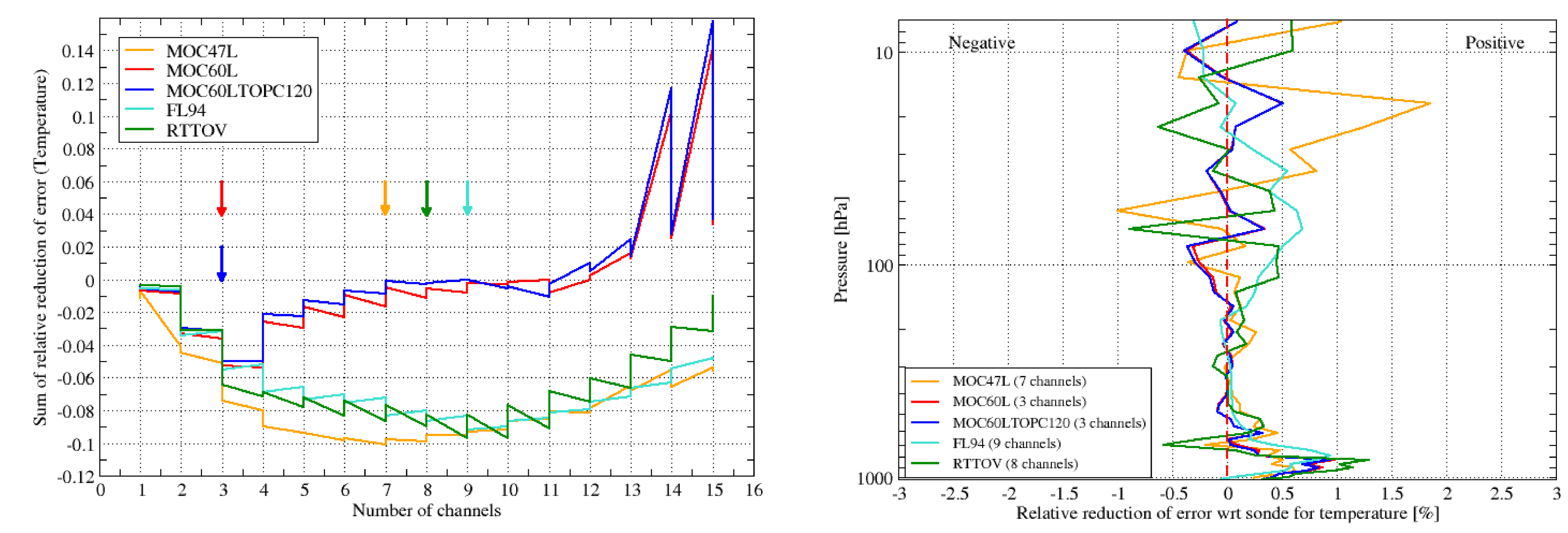

Figure 5. Sum of relative error reduction at each step (Left) and vertical profiles of relative error reduction with respect to sonde for temperature (Right).

Channels / Models	1479	1509	1513	1521	1536	1574	1579	1585	1587	1626	1639	1643	1652	1658	1671
MOC47L	2			7	3			1		6	4	5			
MOC60L	1	2													3
MOC60TOPC120	1	2													3
FL94	1		6	8	9	5	4		2		7				3
RTTOV	1	2	5	4						7	8	3		6	

Table 1. Channel selection for the five ozone models (Numbers indicate the order of channel selection).

4. Observation error correlation between channels

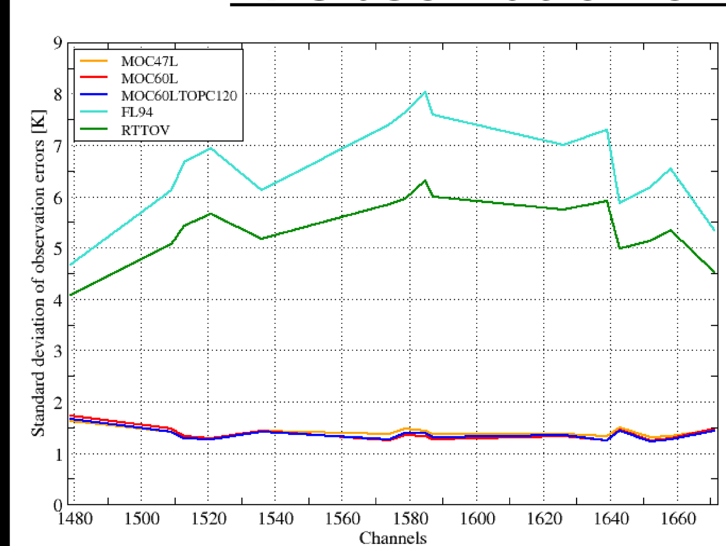

Figure 6. Standard deviation of observation errors for models

The brightness temperature gradient shows a relative sensitivity in lower troposphere and on a large part of stratosphere with a peak around **[25-1000 hPa]** (Figure 1) which is consistent with results of Part 3. A Desroziers diagnostic has been applied to **1D-Var** using the whole **15 channels**. Figure 6 shows diagnosed standard deviation. **FL94** and **RTTOV** exhibit much higher values than MOCAGE models, which is consistent with less realistic ozone profiles for the former than for the latter (cf. Part 1).

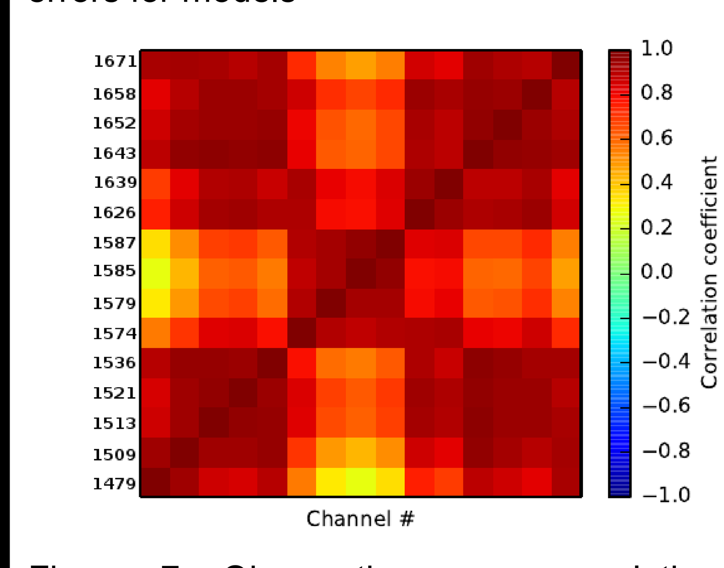

Figure 7. Observation error correlation matrix with 15 channels selection with **Desroziers method** for **MOC47L** model.

The correlation matrix of observation errors for **MOC47L** model in Figure 7 shows a large correlation between channels except for some channels (**1579**, **1585** and **1587**) which have different levels of sensitivity compared to channel **1479** (Figure 1). Whereas the observation errors for **FL94** and **RTTOV** are highly correlated everywhere (not shown) because ozone profiles for these models are less realistic and introduce errors in the simulations (Figure 4).

Conclusion & Future work

Realistic ozone information, such as the one provided by the French Chemistry Transport Model MOCAGE, helps to have much better simulation of ozone-sensitive infrared channels. A channel selection has been carried out for each ozone information. Improvements have been obtained on temperature retrievals.

We are now ready to use the new channel selection in the global model **ARPEGE**. Assimilation experiments will be done with **RTTOV**, **FL94** and **MOC47L** ozone. The impact of assimilation of ozone sensitive channels will be evaluated on analyses and forecasts.

At a longer term, we will evaluate the addition of ozone to the control vector. This paves the way to similar studies with future sensors such as **IASI-NG**.

This study was carried out during a Master 2 stay of Coopmann, funded by CNES in the framework of IASI-NG.

References

Collard (2007). Selection of IASI Channels for Use in Numerical Weather Prediction. Tech. Memo 532, ECMWF (Available from www.ecmwf.int).
Desroziers, G., Berre, L., Chapnik, B. and Poli, P. (2005). Diagnosis of observation, background and analysis-error statistics in observation space. Q.J.R. Meteorol. Soc., 131: 3385–3396. doi: 10.1256/qj.05.108
Fortuin and Langematz (1995). Update on the global ozone climatology and on concurrent ozone and temperature trends. SPIE, 2311 (207).
Guidard et al (2011). Impact of IASI assimilation at global and convective scales and challenges for the assimilation of cloudy scenes. Q.J.R. Meteorol. Soc., 137: 1975–1987. doi: 10.1002/qj.928
Sic et al (2015). Modelling of primary aerosols in the chemical transport model MOCAGE: development and evaluation of aerosol physical parametrizations. Goscientific Model Development, 8(2):381--408