Impact of the assimilation of MSG/SEVIRI geostationary radiances in a mesoscale NWP model : preliminary 1d-var studies

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1. Introduction

In the context of high-resolution weather forecasting, the high horizontal and temporal resolutions of measurements performed by geostationary satellites are an asset compared to polar satellites, despite their weaker spectral and vertical resolutions. At the beginning of summer 2003, the SEVIRI radiometer onboard MSG (Meteosat Second Generation) will provide a complete set of radiance observations in the visible and infrared spectrum every 15 mn with an approximate spatial resolution of 3 km over Europe. Those measurements therefore seem to be particularly well adapted for weather prediction at convective scales, since they allow continuous access to information about the variation rates of temperature and humidity fields in space and time.

In order to quantify the impact of the assimilation of SEVIRI radiances in the analysis of the vertical distribution of those meteorological quantities, a 1d-var method has been adapted from Rabier et al. (2001) and applied on two different datasets. The first one is made of radiances which have been simulated using the radiative transfer model RTTOV-7 (Saunders et al., 1999) from an ALADIN analysis, and the second one is composed of real radiances observed by the 5 channels of the MODIS radiometer whose spectral responses are comparable to SEVIRI ones. After a presentation of the experimental framework in section 2, the results of these two different studies are exposed respectively in sections 3 and 4.

2. Experimental framework

The analysis $\mathbf{x^a}$ represents the atmospheric state which is the best fit between the background $\mathbf{x^b}$ and the available observed radiances stored in the $\mathbf{y}$ vector. In this nonlinear 1d-var method, $\mathbf{x^a}$ and $\mathbf{x^b}$ are made of vertical profiles of temperature, specific humidity and ozone. $\mathbf{x^a}$ minimizes the following cost-function :

$$J(\mathrm{x}) = (\mathbf{x} - \mathbf{x^b})^{\mathrm{T}}\, \mathbf{B}^{-1}\, (\mathbf{x} - \mathbf{x^b}) + (\mathbf{y} - H(\mathbf{x}))^{\mathrm{T}}\, \mathbf{R}^{-1}\, (\mathbf{y} - H(\mathbf{x}))$$

where $\mathbf{B}$ is the background covariance error matrix used by the ECMWF global model, $\mathbf{R}$ the observation covariance error matrix and H the observation operator which makes the link between the model and observation spaces. In this study, H is composed of the radiative transfer model RTTOV-7 and of a vertical interpolation operator allowing to interpolate fields from the model to RTTOV-7 vertical levels.

$\mathbf{x^a}$ is the optimal unbiased estimate of the true state $\mathbf{x^t}$: $\mathbf{x^t}$: $\mathbf{x^a} = \mathbf{x^t} + \alpha$, where α denotes the analysis error that follows a probability distribution with a covariance matrix $\mathbf{A}$ given by :

$$\mathbf{A}^{-1} = \mathbf{B}^{-1} + \mathbf{H}^{\mathrm{T}}\, \mathbf{R}^{-1}\, \mathbf{H}$$

where $\mathbf{H}$ is the matrix associated with the tangent linear of the observation operator H.

3. Simulated SEVIRI radiances

This 1d-var analysis has been used to infer the information content of simulated infrared radiances coming from 8 SEVIRI channels. These 8 channels cover the 3.9 - 13.4 µm spectrum and include two channels in the water vapour absorption spectrum that allow to sense a broad layer in the middle troposphere (Fig. 1). Since real SEVIRI observations are not yet available, the radiances stored in $\mathbf{y}$ have been simulated from a vertical profile located in a cloud-free area of an ALADIN analysis, which represents the true state $\mathbf{x^t}$, and a Gaussian centred random noise ε : $\mathbf{y} = H(\mathbf{x^t}) + \varepsilon$. The background $\mathbf{x^b}$ is the sum of the true state $\mathbf{x^t}$ and a centred random noise β with $\mathbf{B}$ covariance : $\mathbf{x^b}=\mathbf{x^t}+\beta$

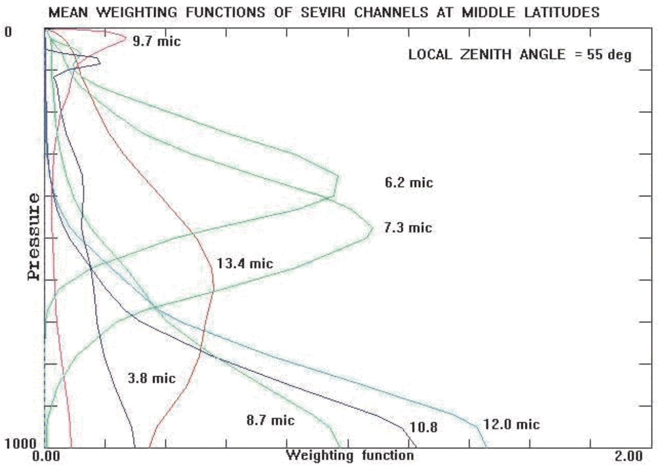

Figure 1: *SEVIRI normalized weighting functions*

The mean results of the nonlinear 1d-var analysis applied on 895 vertical profiles extracted from the ALADIN analysis of the 13th of May 2002 at 12 h UTC are presented in Fig. 2. This figure shows a positive impact on specific humidity above 800 hPa, characterized by a notable reduction (up to 50 %) of the error between analysis and background. However, the poor vertical resolution of SEVIRI for the channels that are sensible to temperature variations implies a very weak improvement of the analysed temperature compared to the background one. This improvement is only noticeable in the boundary layer. These results are more pronounced for the theoretical variances, which are the diagonal terms of **A** and **B** matrices (Fig. 3).

4. Real MODIS radiances

The impact of real data was studied using measurements coming from 5 channels of the MODIS radiometer (onboard the TERRA polar satellite), the spectral responses of which are comparable with SEVIRI ones. The band-width of the selected channels are stored in Table 1.

MSG/SEVIRI		TERRA/MODIS	
IR.1 :	3.5- 4.4	IR.23 :	4.02- 4.08
WV.3 :	6.8- 7.8	WV.28 :	7.17- 7.50
IR.4 :	8.3- 9.1	IR.29 :	8.4 - 8.7
IR.6 :	9.8-11.8	IR.31 :	10.8 -11.3
IR.7 :	11.0-13.0	IR.32 :	11.8 -12.8

Table 1 : *Band width (in m) of the different channels that are comparable between MODIS and SEVIRI.*

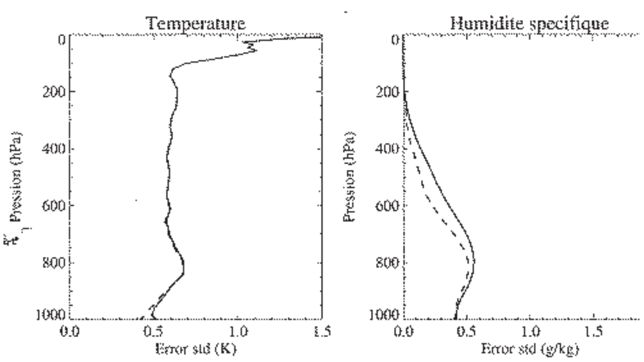

Figure 2: *Mean background (solid line) and analysis (dashed) errors standard deviations for 895 clear air profiles after the assimilation of simulated SEVIRI radiances.*

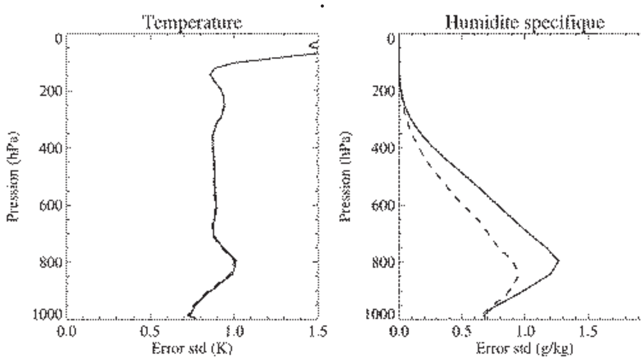

Figure 3: *Mean theoretical background (solid line) and analysis (dashed) errors standard deviations for 895 clear air profiles after the assimilation of simulated SEVIRI radiances*