SENSITIVITY ANALYSIS OF MTG-IRS L2 PROTOTYPE CONCEPT

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Abstract

EUMETSAT prepares for the next generation of geostationary satellites. Among the four missions foreseen is an infrared sounder.
An important mission objective is to frequently monitor vertical distributions of temperature and moisture. A prototype concept is being prepared which extracts these products from the MTG-IRS observations. An important objective of this so called Level 2 prototype concept is a feasibility demonstration for an operational processor. The consolidation of a L2 prototype concept is subject of analysis by the MTG-IRS Science Team (MIST), a small team of European scientists looking at different aspects of the L2 processor.
Within this environment and to document the performance and understand the critical components of a prototype concept, a sensitivity analysis has been performed. The sensitivity analysis is based upon retrievals made from synthetic radiances generated from a particular pre-convective ECMWF analysis plus the OSS fast radiative transfer model. Radiances with different conditions have been generated, namely with sea surface emissivity only versus land and sea surface emissivity, no instrument noise versus MTG-IRS specified instrument noise and moisture only retrievals assuming all other parameters are known.

MTG-IRS

EUMETSAT is preparing the next generation of meteorological geostationary satellites known as Meteosat Third Generation (MTG). In particular, the MTG project is currently in its phase B, where a preliminary design of the system is made both for the space and ground segment.
One of the instruments considered in Phase B is the Infrared Sounder (MTG-IRS) with which we are concerned here. It is a hyperspectral instrument that is planned to fly on board one of the Meteosat Third Generation satellites, the so called MTG-S (MTG-Sounder). This instrument will measure the whole Earth disc every 60 minutes with a spatial resolution of 4 km at nadir providing about 3500x3500 pixels on the globe of the so called hyperspectral soundings. These constitute spectra at a moderately high spectral resolution of 0.754 cm-1 with a spectral sampling of 0.625 cm-1 in two bands. One of the bands is in the long wave infrared region (700 to 1210 cm-1) and the other one is in the mid wave infrared (1600 to 2175 cm-1) providing a total of 1738 channels.
The main mission of the MTG-IRS is to provide frequent information of the atmospheric state, in particular moisture and temperature. Furthermore, observations by MTG-IRS can be used to support operational atmospheric chemistry applications through the provision of Ozone and CO information. From the hyperspectral measu
rements, high resolution vertical profiles of atmospheric temperature and humidity can be obtained. The accuracies that should be achieved for these profiles are in the order of about 1 degree Centigrade in temperature and
about ± 10% in relative humidity in vertical layers between 1 and 2 km deep.

MTG-IRS PC

The ground segment processing facility will need to convert in near real time the measured spectra into temperature and moisture atmospheric profiles. To achieve this goal, it follows from the described specifications that this facility will need to process about 3400 spectra per second, each one of them having 1738 channels.

The current MTG-IRS Level 2 Prototype Concept (MTG-IRS L2 PC) will be the test bed for the final Processor. The current MTG-IRS L2 PC is the heritage of the actual IASI Level 2 PPF.
The IRS L2 PC is, very succinctly, composed of three steps which are run sequentially:
Scene analysis. In this step each field of view is classified as being clear or cloudy. Due to the expected large volume of data coming from the IRS, the current plan is to only process the clear cases. In this poster all simulations have been performed with no clouds.
Spectra are reduced in dimensionality by means of principal components or Empirical Orthogonal Functions (EOF). A linear regression is then made between these EOFs and the atmospheric profiles or state vectors. From this linear relationship the atmospheric state vectors can be calculated from the spectra EOFs. This process is known as EOF retrieval. The EOF retrievals used to generate this poster have been trained with sea surface emissivity only. A more elaborate EOF retrieval that will also work over land is currently under development.
The EOF retrieval is then fed as a first guess into an iterative non-linear retrieval known as Optimal Estimation (OE). This method seeks the atmospheric profile that minimizes the difference between the observed spectra and a calculated one using this same atmospheric profile which is input into a radiative transfer model of the atmosphere. Background state and covariance matrix are obtained from the ECMWF climatology analysis from the Chevallier dataset (Document No. NWPSAF-EC-TR-004, January 2002). All MTG-IRS channels have been used for all the retrievals presented here.

SCENE

The scene is based on an ECMWF analysis field from 16.05.2009 at 06 UTC around the Italian peninsula. This was a pre-convective situation as evidenced by the output of the COSMO regional scale model precipitation output at 15 UTC shown in Fig. 1.

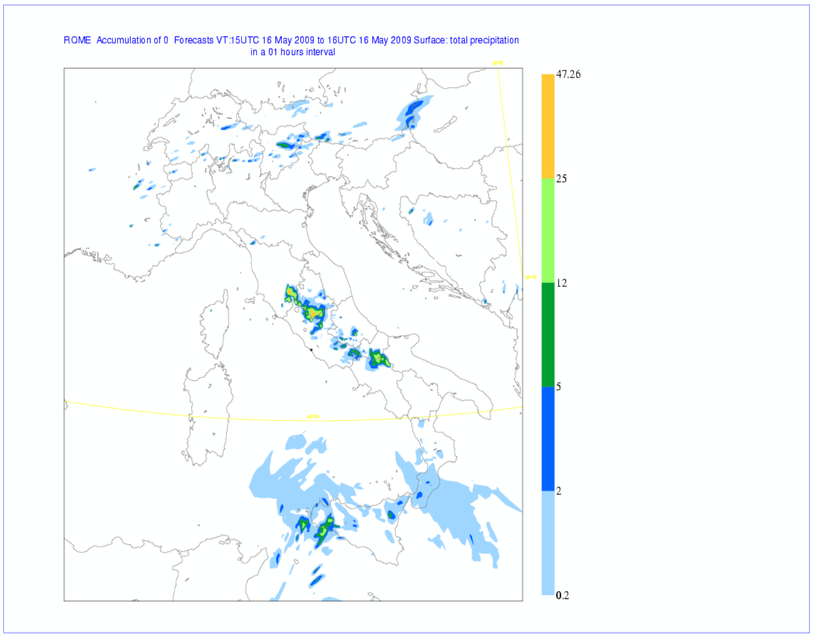

Figure 1: **COSMO regional NWP model output at 15 UTC.**

To get a grasp of the ECMWF analysis used in this study, the surface pressure at 06 UTC from the ECMWF analysis is shown in Fig. 2. The analysis has a spatial resolution of 0.5° and 90 levels in the vertical.

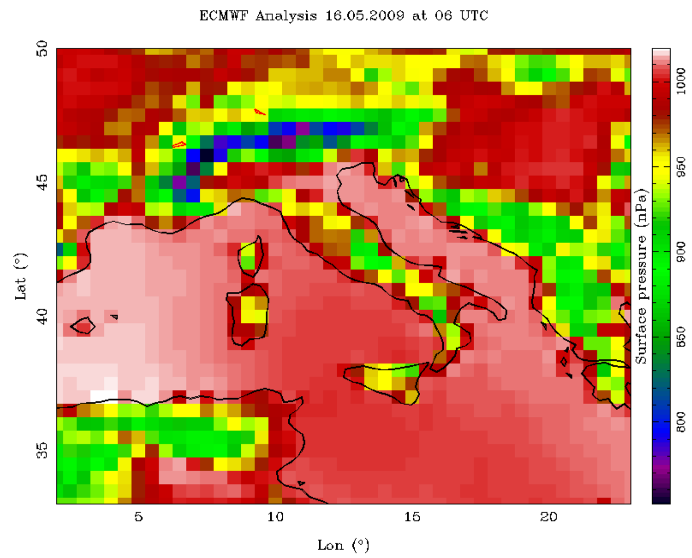

Figure 2: **ECMWF analysis surface pressure at 06 UTC used in this study.**

EXPERIMENT 1. NO NOISE AND SEA SURFACE EMISSIVITY

The first experiment to perform is the most simple simulation to verify the validity of the MTG-IRS PC code. We generate synthetic radiances using the OSS (http://rtweb.aer.com) model with no clouds, over the ocean and with no instrument noise. Sea surface emissivity is simulated using the Masuda et al. model (Remote Sensing of Environment, 24, 313, 1988). The straight statistics of the retrievals (no averaging kernels used) are shown in Fig.3.

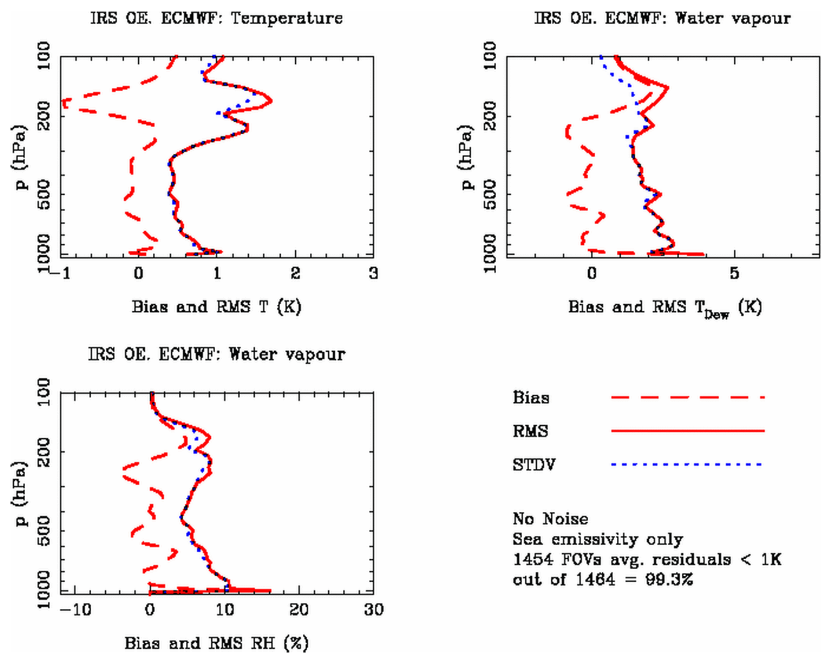

Figure 3: **Retrieval statistics for Experiment 1.**

Pressure levels used in the retrievals versus their approximate height are shown in Fig. 4. Height differences between lower levels is of about 300-400m. Only fields of view with a per channel average residual of less than 1 K have been selected to generate the statistics.

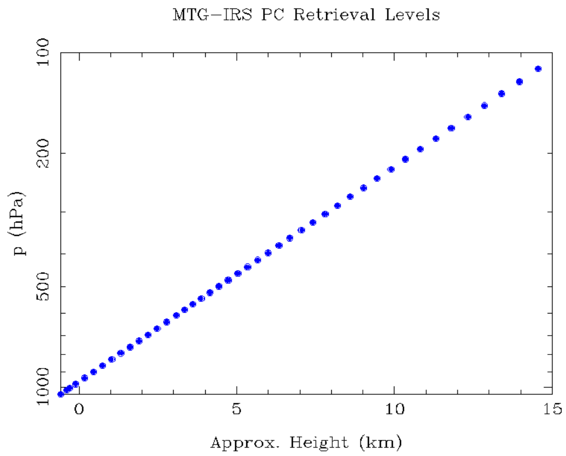

Figure 4: **Pressure level grid used in the retrievals shown in pressure and height units.**

EXPERIMENT 2. INSTRUMENT SPECIFIED NOISE, SEA SURFACE EMISSIVITY

To have more realistic simulations, we include the MTG-IRS specified instrument noise (Fig. 5) to the radiances. The retrieval results are shown in Fig. 6. As expected, retrieval performance is degraded significantly when adding instrument noise.

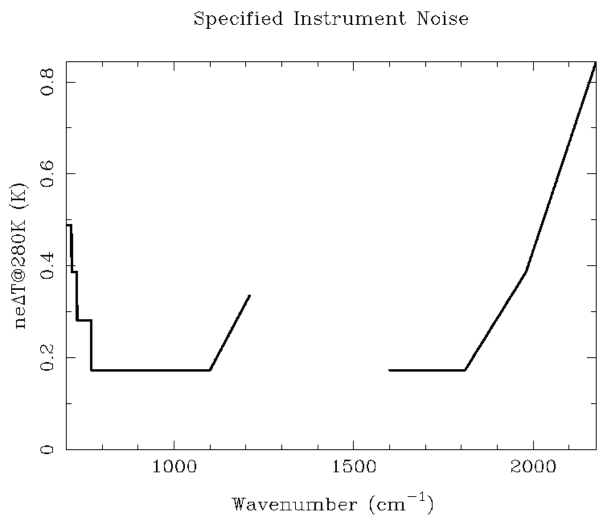

Figure 5: **MTG-IRS specified instrument noie.**

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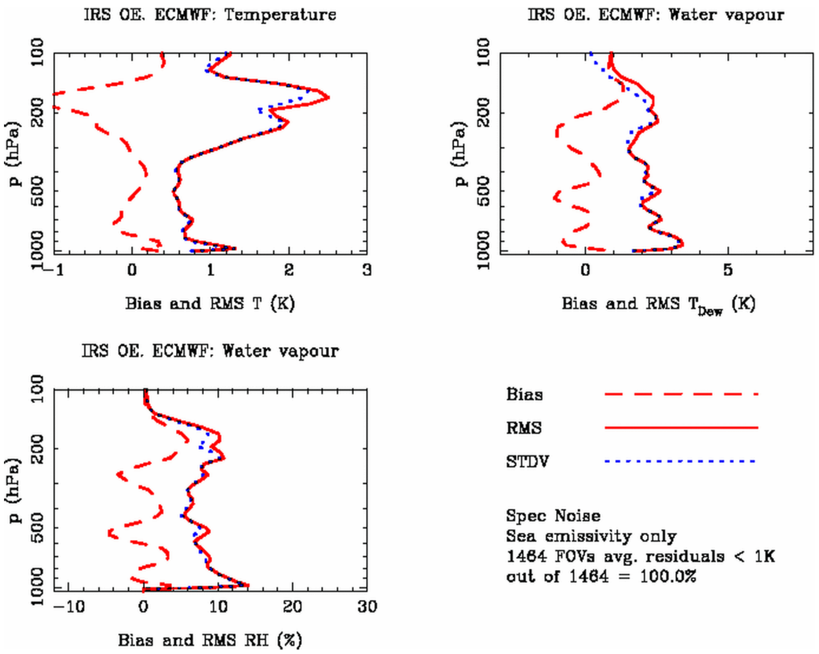

Figure 6: **Retrieval statistics for Experiment 2.**

EXPERIMENT 3. INSTRUMENT SPECIFIED NOISE, SEA SURFACE EMISSIVITY. WATER VAPOUR ONLY RETRIEVALS

Can we make some type of "clever" retrieval to improve the moisture profiles? This is a first attempt, by assuming that we know all parameters from the atmospheric state vector except the moisture profile. The moisture profile statistics does improve as is shown in Fig. 7.

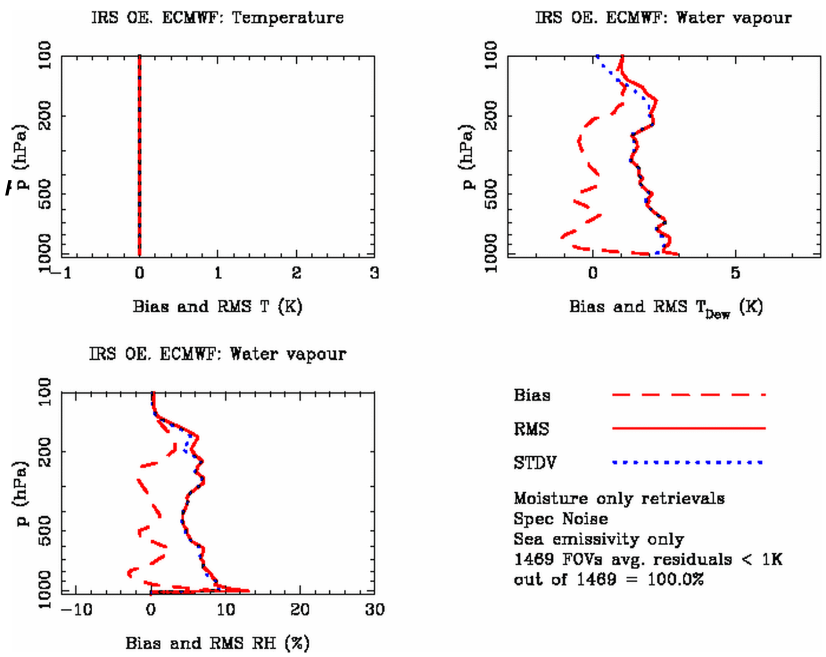

Figure 7: **Retrieval statistics for Experiment 3.**

EXPERIMENT 4. NO NOISE, LAND AND SEA SURFACE EMISSIVITY

Next step is to elaborate further the synthetic radiances by including land surface emissivities. These emissivities have been obtained from Borbas et al. (http://cimss.ssec.wisc.edu/iremis). First guess EOF retrieval have been trained with sea surface emissivities only. Emissivities are not retrieved in the OE but are assumed already known. Improvements on land retrieval schemes are under development. Results of retrievals are shown in Fig. 8.

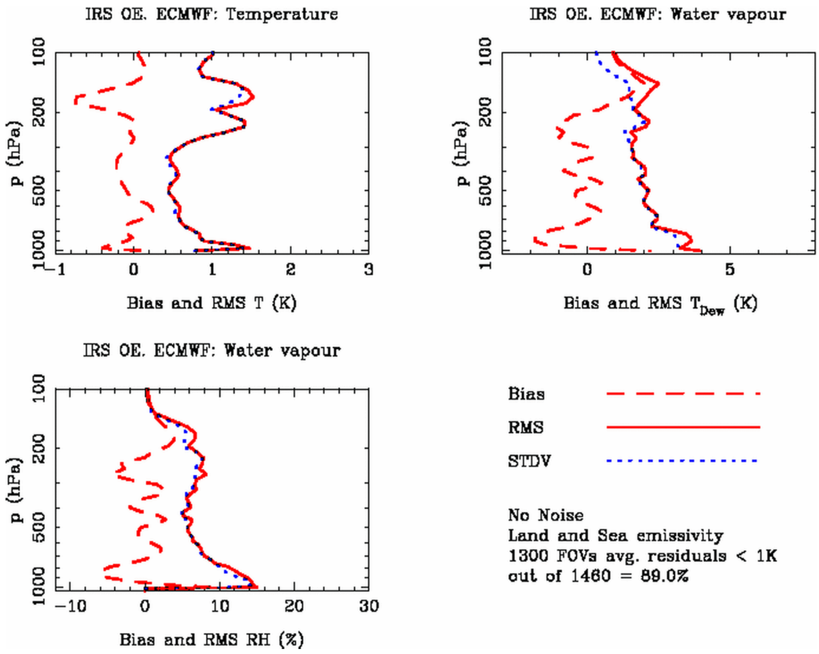

Figure 8: **Retrieval statistics for Experiment 4.**

SUMMARY

Some sensitivity analysis have been explored going from less to more realistic synthetic datasets. Retrieval capabilities, with similar techniques to the ones used for polar orbiting satellites (IASI), i.e. individual single field of view retrievals, and specified instrument noise have been demonstrated. Other innovative techniques applicable to geostationary satellites, which have the possibility of measuring the same scenes frequently in time, should be explored to exploit the full potential of MTG-IRS.

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