USE OF SYNTHETIC RGB IMAGES IN TRAINING

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Abstract

This paper compares actual and synthetic (calculated) airmass RGB composites, before and after applying different corrections: (a) synthetic airmass RGB calculated with the satellite zenith angle corresponding to the pixel, versus others with fixed zenith angles (0º, 15º, 30º, 45º, 60º and 75º), to observe the blue shift close to the disk boundary due to a longer atmospheric path for the signal in oblique views, (b) Synthetic airmass RGB in areas of sinking tropopause with ozone intrusion for different values in the ozone concentration and humidity. The synthetic RGB for MSG are based on the use of the ECMWF model with RTTOV package and the METEOSAT Second Generation coefficients.

Also synthetic MTG-IRS sounder RGBs have been generated. Based on the use of the RTTOV package with the IASI coefficients for one GRIB file of the ECMWF model, synthetic IASI RTTOV radiances are converted to synthetic MTG-IRS RTTOV brightness temperatures (BT). After one selection of the most adequate MTG-IRS brightness temperatures (BTs), two MTG-sounder synthetic RGBs are created. This is a proving ground experiment for the MTG sounder era.

INTRODUCTION

This study shows how radiative transfer models explain some features of the airmass-RGB product, plus the possibilities opened by the new generation instruments on MTG IRS sounder. A case study 25th May 2009 at 12 UTC, selected by the Convection Working Group is on the basis, when thunderstorms extended over France, Belgium and Germany; more images on (Martinez, 2010).

The SEVIRI synthetic brightness temperatures (BT) have been calculated from the ECMWF analysis GRIB file for this date with the RTTOV-9.3 version. First, brightness temperatures (BT) have been simulated with and without clouds. Then the RTTOV BTs can be used to build RGB images. In the Figure 1 the actual MSG airmass RGB and the two synthetic RGB can be seen (simulated with and without clouds).

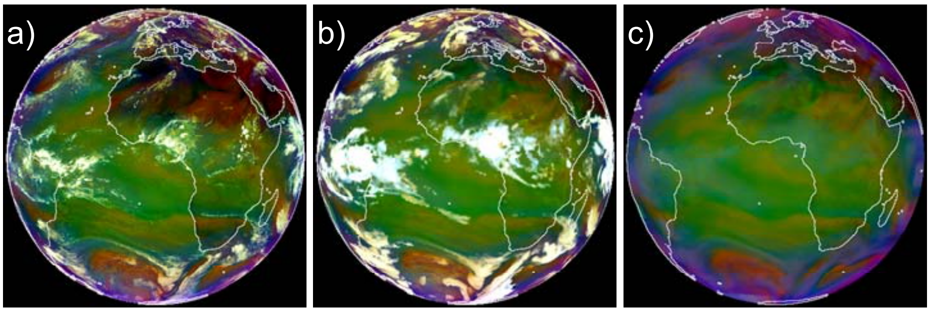

Figure 1: a) Actual MSG-2 airmass RGB, b) Synthetic cloudy RTTOV MSG from ECMWF analysis, c) Synthetic clear air RTTOV MSG from ECMWF analysis. The three images are from 25th May 2009 at 12 UTC

Four SEVIRI simulations have been performed: a) control with clouds; b) control for clear BTs; c) synthetic clear air BTs after changing the ozone profile (West half multiplied by 1.3 and East half multiplied by 0.7 for the ozone profile); d) synthetic clear air BTs datasets after changing the humidity profiles (West half multiplied by 1.3 and East half multiplied by 0.7 for the humidity profile for levels with pressure greater than 200 hPa).

In the second part of the paper, the RTTOV with the coefficients for MSG and IASI has been used to calculate synthetic brightness temperatures and radiances. In the comparison with the actual MSG airmass RGB, several synthetic image datasets are created. The recipe for the airmass RGB composite can be seen in Table 1:

AIR MASS (night & day)					
RGB colour plane	channel (difference)	MIN	MAX	GAMMA	Prominent features
R	6.2 - 7.3	-25 K	0 K	1.0	(Rapid) cyclogenesis, jet streaks PV analysis Mid-level/high clouds
G	9.7 - 10.8	-40 K	+5 K	1.0	
B	6.2 (inverted!)	243 K	208 K	1.0	

Table 1: **MSG airmass RGB construction composite (source best_practices.pdf document)**

CONTROL SIMULATIONS FOR DIFFERENT SEVIRI ZENITH ANGLES

In Fig.1, synthetic RGBs for the cloud and no-cloud cases, using the correct zenith angle for each profile, reproduce the spatial pattern and general look of the actual airmass RGB (Fig1.a). Two experiments were performed to assess the changes in colour and appearance as we move towards the blue boundary. We call them both controls, for the SEVIRI cloudy simulation and for the SEVIRI clear air. All ECMWF analysis profiles are calculated for the same zenith angle, as if SEVIRI were placed over the vertical of each profile on temperature and humidity. To test zenith angle dependence, we repeat the experiment for different fixed zenith angles: 0, 15, 30, 45, 60 and 75 degrees.

We assign clouds as in the total cloud cover and cloud cover profile parameters of the ECMWF analysis. We consider cloudy profiles for total cloud cover fractions above 0.1. The assigned cloud top is the lowest pressure for which the level cloud fraction is 20% of the total cloud cover. The synthetic BT calculation by RTTOV returns a Fortran-90 structure with several fields; *bt* field is used for cloud simulation and *bt_clear* field is used for clear air simulation.

In Fig.2 and Fig.3 one can see the zenith angle dependence, which can be used to train on this effect.

Control SEVIRI cloudy Simulation: MSG RTTOV airmass RGBs with cloud simulations calculated for different fixed zenith angles.

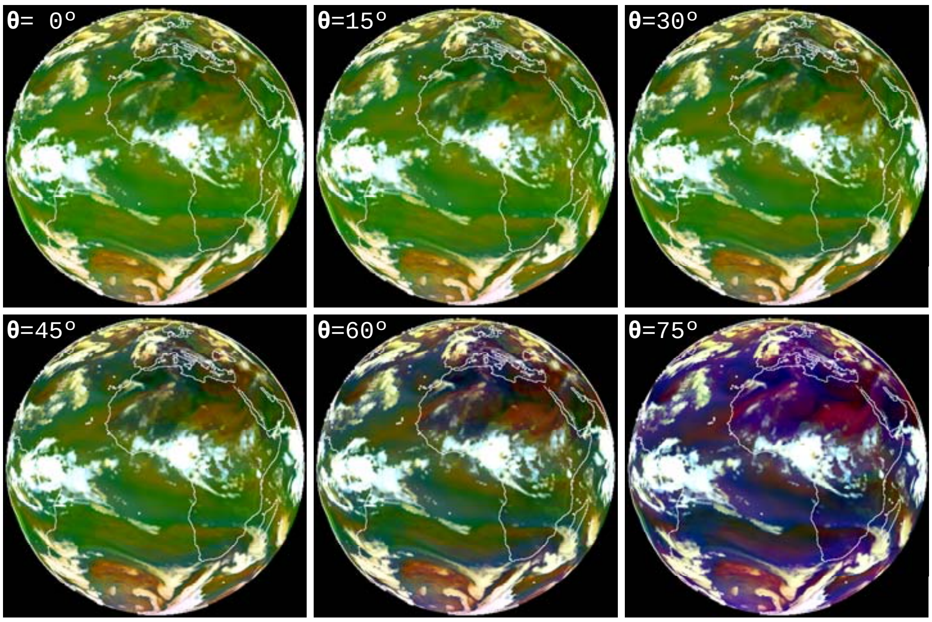

Figure 2: Synthetic cloudy RTTOV MSG airmass RGBs calculated with fixed zenith angles of 0º, 15º, 30º, 45º, 60º and 75º respectively. 25th May 2009 at 12 UTC

Fig.2 shows that the blue appearance increases with the zenith angle, mainly because of the WV6.2 channel cooling. In addition, the reddish colour due to low cloud and the bright white for high cloud change with the zenith angle.

Control SEVIRI clear simulation: MSG RTTOV airmass RGBs without cloud simulation (only clear air RTTOV BT) calculated for different zenith angles.

In Fig.3 we test the zenith angle influence at each pixel for clear air conditions. The bluish look of the images increases with the zenith angle used in the calculation, mainly due to the cooling in the WV6.2 channel (blue component). Fig.3 images will be used for the comparisons with modified O_3/q profiles, to observe the effect of humidity and ozone concentration on the RGB components.

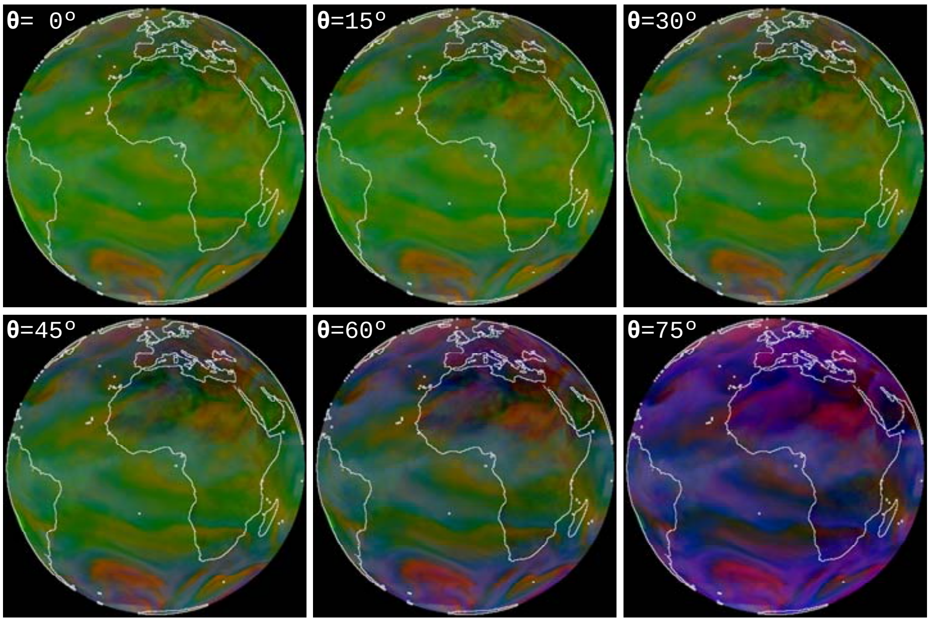

Figure 3: Clear RTTOV MSG airmass RGBs calculated with fixed zenith angles of 0º, 15º, 30º, 45º, 60º and 75º respectively. 25th May 2009 at 12 UTC

SYNTHETIC CLEAR AIR BTs AFTER CHANGING THE OZONE PROFILE

In this experiment the West half of the analysis shows the ozone profile multiplied by 1.3, and the East half multiplied by 0.7. As can be seen in the Fig.4, changes appear in the two halves with respect to the control in Fig 1.c.

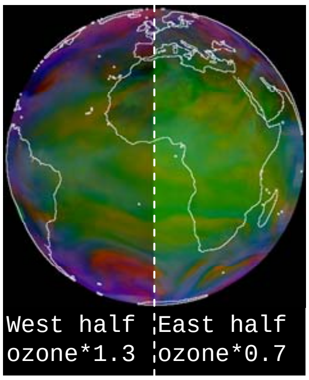

Figure 4: SYNTHETIC CLEAR AIR BTS AFTER CHANGING THE OZONE PROFILE calculated with MSG-2 zenith angles. 25th May 2009 at 12 UTC

The more reddish (greenish) aspect of the images on the West (East) half of the RGBs, is due to the decrease (increase) of the BT in the IR9.7 channel for larger (lower) ozone concentrations. The modification of the IR9.7 BT implies a decrease (increase) in the green component of the RGB. The experiment was performed for several zenith angles to show that all changes are only in the IR9.7 – IR10.8 difference, and not on the red or blue components.

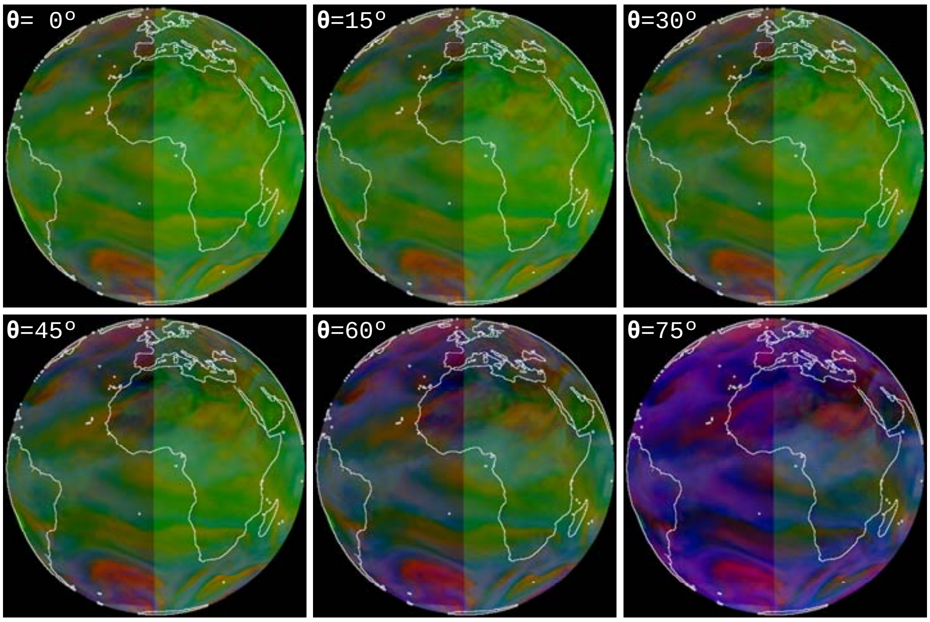

Figure 5: Clear RTTOV MSG airmass RGBs with fixed zenith angles of 0º, 15º, 30º, 45º, 60º and 75º respectively after modifying the ozone profiles (in West half multiplied by 1.3 and in East half multiplied by 0.7 the ozone profile).

SYNTHETIC CLEAR AIR BTs DATASETS AFTER CHANGING THE HUMIDITY PROFILES

In this experiment, for the West half of the analysis the specific humidity profile for pressure levels greater than 200 hPa is multiplied by 1.3 and for the East half it is multiplied by 0.7. As can be seen in Fig.6, changes are visible in both halves with respect to the control in Fig. 1.c.

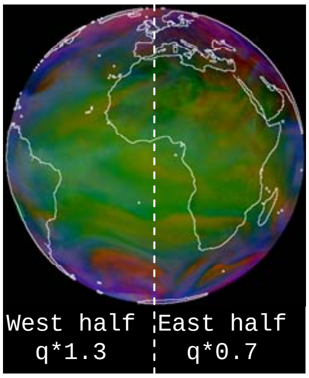

Figure 6: Clear RTTOV MSG RGB calculated with MSG-2 zenith angles

In the West half the increase of the humidity implies a reduction in the WV6.2, WV7.3, IR9.7 and IR10.8 BTs. Thus, the three components of the RGB are affected by humidity changes, but the components more affected are the green and the blue, where a non linear and slight increase in the brightness turns out. The opposite applies to the East half. Changes in the humidity profile affect the four channels reflected in the RGB, and are more difficult to explain.

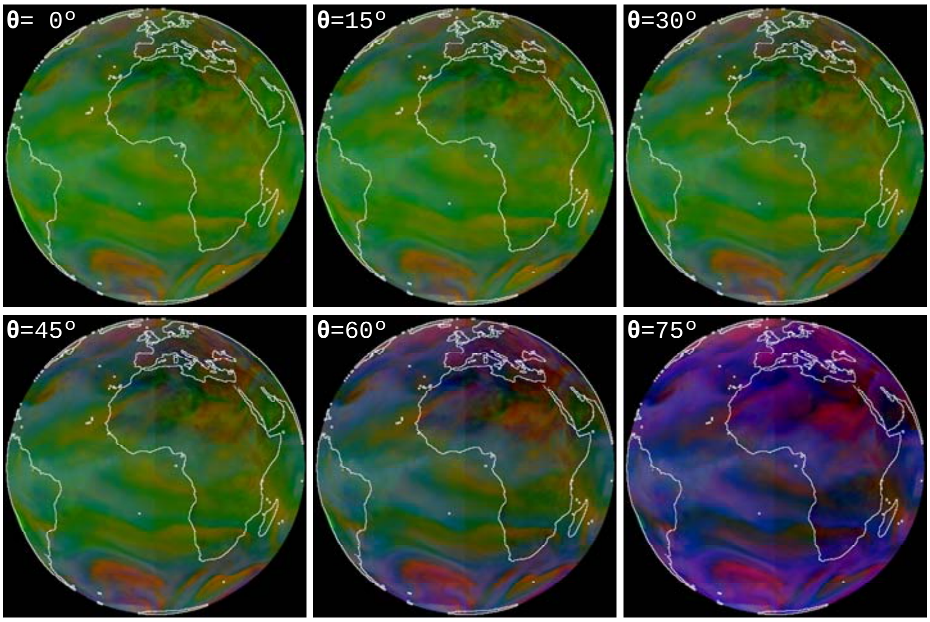

Figure 7: **Clear RTTOV MSG airmass RGBs with zenith angles of 0º, 15º, 30º, 45º, 60º and 75º respectively after modifying the q profiles (in West half q*1.3, in East half q*0.7).**

These two experiments illustrate how profile modifications can affect more than one component. Attempts to trace colour changes to either only humidity or only ozone concentration are bound to fail.

SYNTHETIC MTG-IRS AIRMASS RGB

With the goal of familiarizing the public of the countless applications that the future METEOSAT Third Generation infrared sounder (MTG-IRS) will bring, we have also calculated synthetic BT emulating this instrument. To achieve this, RTTOV-9.3 with IASI coefficients was used to obtain IASI like radiances using as input the same ECMWF fields as the ones used for MSG. These radiances are then converted to MTG-IRS spectral resolution with a radiation converter tool built at EUMETSAT (Tjemkes, 2008), which transforms the 8461 RTTOV IASI channels into the MTG-IRS radiances (1738 channels).

One of the most immediate applications, especially for Nowcasting, is the use of these radiances in RGB composites. They are fast to calculate and can later be analyzed visually. The problem obviously arises as to which selection of channels to use among all the possible endless combinations of the 1738 channels. A possibly good start would be to choose those channels which are more similar to MSG channels and generate similar RGBs composites. These images could then be directly compared to the MSG ones. The airmass MTG-IRS RGB image is shown in Fig. 8.

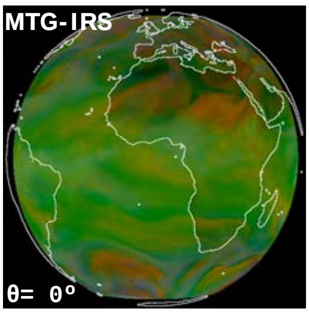

Figure 8: **Clear RTTOV MTG-IRS airmass RGB calculated with zenith angle fixed to 0º using the MTG-IRS channels closest to MSG channels**

To achieve this we need to find the MTG-IRS channels closest to the MSG channels used to generate the MSG RGB air mass image. To do that, we have calculated the correlation and RMSE between each one of the MSG channels and the MTG-IRS ones for all the pixels assuming a zero observation zenith angle. The MTG-IRS channels with highest correlations and lowest RMSE with respect to the MSG air mass ones are selected. To select these channels it has been searched to the MTG-IRS channels with largest value after multiplying the correlation and the normalized inverted RMSE (1 for lowest RMSE and 0 for RMSE greater the mean RMSE value) matrices. With these set of channels we can now build the MTG-IRS air mass RGB composite. When we compare Fig.8 with Fig. 3 we can verify that the contrast in the former is slightly higher.

The list of channels used to build the MTG-IRS RGB is shown in Table 2. We can see that the MSG substitutes for the water vapour channels are two MTG-IRS channels which are spectrally very close. The reason for this is that the high spectral resolution of MTG-IRS separates the individual water vapour lines having a high absorption in the center of the line and a lower one by the side of it, thus having two spectrally nearby channels with very different absorptions. This channel correspondence should be contemplated as an initial first guess, because the atmospheric variability used is very low and there has been no noise introduced in the simulations. It just illustrates the technique.

SEVIRI channel	Closest MTG-IRS channel number (0-based)	Closest MTG-IRS channel λ
WV6.2	1122	5.58464 (μm)
WV7.3	1231	5.37996 (μm)
IR9.7	519	9.76205 (μm)
IR10.8	308	11.2045 (μm)

Table 2: List of MTG-IRS channels used in MTG-IRS airmass RGB

SEARCH OF NEW MTG-IRS RGBS

To take full advantage of the added value of the MTG-IRS spectral resolution with respect to MSG SEVIRI, it is obviously better to follow another strategy than just emulating the MSG RGB behaviour. With this goal in mind we have tried to find other, potentially more interesting, MTG-IRS RGBs. As a first idea, we could find an application for Nowcasting by trying to monitor ozone and the vertical distribution of water vapour. Ozone monitoring could be used as a proxy for the sinking of the tropopause and vorticity maximums. The vertical distribution of water vapour is a critical ingredient to trigger convection.

The content of precipitable water in several layers of the atmosphere is calculated in the Nowcasting SAF Layer Precipitable Water product (PGE07 LPW based on neural networks) as well as in the PGE13 SEVIRI Physical Retrieval product. These two NWC SAF products have been proven to be useful to search and monitor the regions which are susceptible to trigger convection. With this background, we have calculated directly from the profiles corresponding to the ECMWF analysis on 25th May 2009 at 12Z for the following parameters: a) TOZ, total ozone in Dobson units, b) BL precipitable water integrated between the surface pressure layer and 850 hPa and c) ML precipitable water integrated between the 850 hPa and 500 hPa layer.

Having, on one hand, the TOZ, BL and ML values calculated directly from the ECMWF analysis profiles, and on the other hand, the synthetic MTG-IRS BT for every channel, we have proceeded to calculate the correlation and RMSE matrices. These matrices have been obtained by performing a regression between two synthetic MTG-IRS BTs and each one of the parameters. In Figure 9 the correlation matrix for the Total Ozone and each two MTG-IRS channels is shown.

Now the problem is search the optimal regressions which simultaneously satisfies to have the low RMSE and high correlation. Due to the huge size of the matrices and the large variability between near positions on the matrices, one automatic process must be aboard. After that, a “fuzzy-logic” like scheme has been used to search for the regressions with lowest RMSE and highest correlation. The scheme is based on the following process performed with the correlation and RMSE matrices for each nowcasting parameter. First a normalized correlation matrix is calculated by fixing to zero those positions with correlation lower than the mean correlation value and normalize the remaining in the range [0, 1]. Second a normalized RMSE matrix is calculated by fixing to zero those positions with

RMSE greater than the mean RMSE value and normalize the remaining in the range [0, 1] in such way that the lowest RMSE position is assigned the normalized value of 1. Finally, the two normalized matrices are multiplied and the regression for the position with the maximum value in the product matrix is the combination chosen to build the regression. This optimal regression is a combination of MTG-IRS channels having very high correlation and also a very low rmse.

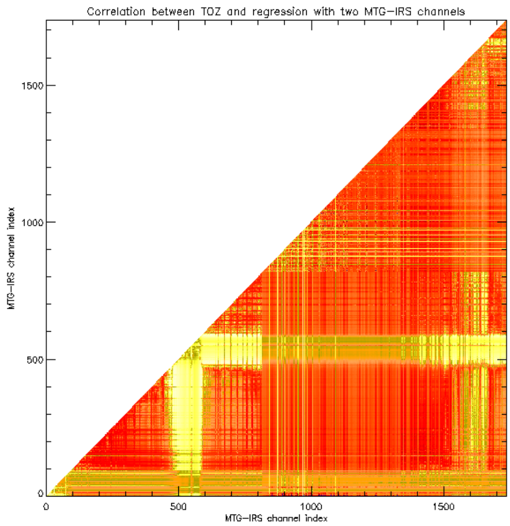

Figure 9: Correlation matrix between total ozone of ECMWF GRIB file and the regression made with each two RTTOV MTG-IRS channels BT

This process has been repeated for the precipitable water in the middle layer ML (precipitable water between 850 and 500 hPa), total ozone and precipitable water at lower levels BL (between surface pressure and 850 hPa). Table 2 shows the optimal selected channels and the regressions that have been chosen to generate the MTG-IRS RGB image on Figure 11. This method could be generalized, for example, to find combinations that fulfil more conditions. For example, if we had a noise distribution or some channels with absorption bands which we would like to avoid, it would be easy to build normalization which would penalize or enhance particular channels and automate the construction of RGBs. This would avoid, for example, the SO_2 absorption band or it would allow to work within a particular spectral range.

Physical parameter	**Number *1st*** **MTG-IRS channel** ***(0-based)***	**λ 1st MTG-IRS *channel***	**Number *2nd*** **MTG-IRS channel** ***(0-based)***	**Λ 2nd MTG-IRS *channel***	***a***	***b***	***c***
ML layer (precipitable water 850 to 500 hPa)	1717	4.6243 (μm)	1539	4.8751 (μm)	-10.34	5.25	-5.13
Toz Total Ozone	465	10.0900 (μm)	457	10.1458 (μm)	971.63	-235.7	232.57
BL layer (precipitable water Psfc to 850 hPa)	1506	4.9246 (μm)	802	8.3247 (μm)	-74.82	-17.07	17.37

Table 3: List of MTG-IRS channels used in the regressions to make the new MTG-IRS RGB

As in the previous case, this channel selection should be seen as a first attempt, because the profile dataset is small and no noise has been introduced in the simulations. It only pretends to illustrate the way to proceed. Further work should consolidate this. In Figure 10 we show the results of using the regressions with the channels of Table 3.

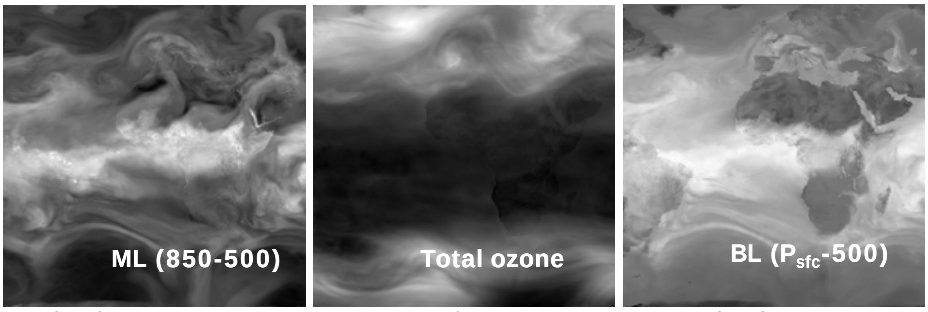

Figure 10: **a) MTG-IRS ML precipitable water regression for red component; b) MTG-IRS Total ozone regression for green component; c) MTG-IRS BL precipitable water regression for blue component. The regressions has been calculated with the MTG-IRS channels and coefficients listed on Table 3 for 25th May 2009 at 12 UTC.**

When all three images from Fig. 10 are combined in a RGB and remapped over SEVIRI projection, we obtain the MTG-IRS RGB image of Figure 11. We can detect the humid regions as purple or pink colors and high ozone concentration regions in green pixels (which is a proxy of vorticity maximum). In Europe we can see the humid region over France and Germany and the green tone of high ozone region over Spain and west part of France. These facts indicate the presence of ingredients needed for convection triggering.

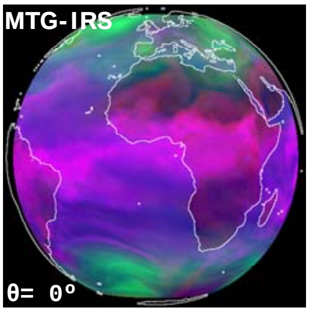

Figure 11: New RTTOV MTG-IRS RGB with 0º zenith angle using the regression between MTG-IRS channels to ML (850-500 hPa), Total Ozone and low layer precipitable water BL (Psurface-850 hPa)

Since the values of *b* and *c* regression coefficients are similar in absolute value, channel differences could be used instead of the regressions in the final design of the MTG-IRS RGBs, (which simplify the MTG-IRS RGBs calculations). This could be done as a follow on work once noise levels and further studies with a greater MTG-IRS dataset will be made.

CONCLUSIONS

The synthetic RGB images could be used in training to explain some features observed in actual RGB images. Also they could be used to show the use of future satellite as MTG-IRS.

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