PRECONVECTIVE SOUNDING ANALYSIS USING IASI AND MSG-SEVIRI

Marianne König, Dieter Klaes
EUMETSAT, Eumetsat-Allee 1, 64295 Darmstadt, Germany

Abstract

EUMETSAT operationally generates the Global Instability Index (GII) product, based on MSG SEVIRI observations. The GII is an airmass parameter indicating the stability of the clear atmosphere. The usefulness of this product has been demonstrated in many nowcasting applications, in particular to identify regions of potentially severe convective storms and related hazardous weather.

The MSG based GII retrieval currently uses forecast profiles from the European Centre of Medium Range Weather Forecast (ECMWF) as first guess or background profiles. EUMETSAT is currently investigating the possibility to obtain initial temperature and humidity information from collocated measurements from the hyperspectral Infrared Atmospheric Sounding Interferometer (IASI) instrument on EUMETSAT’s polar orbiting Metop-A satellite. Temperature and moisture profiles are derived from IASI on an orbital basis.

These derived profiles are used as initial input to the GII retrieval, where the temporal evolution of the air mass properties can then be recorded by the geostationary MSG observations. This paper presents first results on the feasibility and limitations of this combined MSG/IASI approach.

INTRODUCTION

Since 2004, a number of instability indices (e.g. Lifted Index, K-Index, Total Precipitable Water as a further airmass parameter) are routinely extracted from the MSG-SEVIRI image data and disseminated to the user community as the so-called GII product (GII = Global Instability Indices). Such indices are useful in identifying regions of potential onset of convection and evolution of possibly severe convective storms. The underlying retrieval algorithm, as described in the next section, needs a "first guess" field of temperature and humidity information, which, for the operational GII product, is taken from the global ECMWF forecast fields. The quality of the first guess field is highly relevant for the final product: The MSG derived instability information can differ from the first guess – e.g. differences in local gradients and extremes are often encountered. However, the overall impact of the forecast fields on the final products is high and may lead to erroneous results in the case of a wrong forecast.

This paper investigates the possibility to use the IASI profile retrievals (IASI = Infrared Atmospheric Sounding Interferometer, onboard Metop-A) as an independent first guess. Although this approach does not have the potential to be used operationally (due to the time / space limitations of IASI in its polar orbit), IASI data can serve as a proxy for the future hyperspectral infrared sounder onboard Meteosat Third Generation (MTG), which will provide global (i.e. Meteosat field of view) and hourly coverage.

THE MSG-SEVIRI GII PRODUCT

The GII product comprises a number of instability indices, which – originally defined from radio soundings – describe the potential for the onset of convection during till cloud free conditions. The usage of such indices is such that empirical thresholds exist, depending on the individual index, but
also depending on regional and other influences, beyond which convection can start or can even
develop into severe convective storms.

Figure 1 gives an example of the MSG full-disk products Lifted Index, K-Index, and Total Precipitable Water.

![Figure 1: Example of the GII product over the entire MSG disk: Lifted Index (left), K-Index (centre), Total Precipitable Water TPW (right). GII retrievals are confined to clear sky, so cloudy areas are shown in different shades of grey.](image)

The index definitions imply that we need information on temperature and moisture conditions near the surface and at mid-levels, e.g.

\[
\text{Lifted Index} = T(500 \text{ hPa}) - T(\text{near surface, lifted to 500 hPa})
\]

\[
\text{K-Index} = [T(850 \text{ hPa}) - T(500 \text{ hPa})] + TD(850 \text{ hPa}) - [T(700 \text{ hPa}) - TD(700 \text{ hPa})]
\]

\[
\text{TPW} = \text{Vertically integrated water vapour concentration}
\]

(T being air temperature, TD dewpoint temperature, pressure levels refer to temperature / dew point at that respective level).

Looking at the available infrared channels on MSG-SEVIRI we see that such information is provided by the channels centred at 6.2 μm and 7.3 μm (the two water vapour channels, providing information on high and midlevel moisture), channels centred at 8.7 μm, 10.8 μm and 12 μm are sensitive to low level moisture and to surface temperature, and the channel centred at 13.4 μm is affected by midlevel air temperature.

The GII retrieval uses these six MSG channels (WV6.2, WV7.3, IR8.7, IR10.8, IR12.0, IR13.4) in a so-called physical retrieval scheme: Radiative transfer calculations are used to find a combination of surface skin temperature, air temperature and moisture profile that best matches the observations in these six channels. Calculations start from a first guess profile, which – for the operational GII – is the global ECMWF forecast. Local installations of the GII retrieval software, as e.g. exist in South Africa, Slovakia, Poland or the UK, use forecasts from a regional model.

A detailed description of the retrieval scheme can be found in Koenig and de Coning (2009).

**CASE STUDY**

As already mentioned in the previous paragraph, the GII physical retrieval needs a first guess field of temperature and humidity information to initialise the retrieval process. A case study will be described in this section, where this forecast information was replaced by temperature and humidity profiles retrieved from the IASI instrument onboard the polar orbiting satellite Metop-A, which are one of the IASI Level-2 products.
The scope of this case study is two-fold:
(a) assess the potential of the initial IASI retrievals to be used in the instability analysis by comparing the IASI derived information to the forecast based MSG GII product,
(b) assess the suitability of using these IASI retrievals within the MSG GII retrieval as a first guess field and study the respective time scales (i.e. for how many hours of subsequent MSG observations can the IASI data serve as a first guess?)

A case on 23 December 2008 was chosen over the southern part of Africa: The day started with clear sky conditions, where convection developed at around 1200 UTC. Figure 2 shows the morning IR10.8 image together with the Convection RGB for 1500 UTC, which shows a NW – SE line of strong convection over the northern part of South Africa and neighbouring countries.

The morning IASI overpass around 0740 UTC nicely covered the central part of the South African landmass (Figure 3).

IASI Level 2 data were obtained from the NOAA Class Archive [http://class.noaa.gov](http://class.noaa.gov), where one retrieval is available for each group of 4 IASI individual fields of view.
As a first step, the instability parameters K-Index and TPW were derived from the IASI profiles and compared to the respective MSG product, which uses the operational setup of the ECMWF forecast fields as first guess (Figures 4 and 5). Ignoring the missing coverage to the east and west of the IASI swath, the overall agreement of the two products is rather good: For the K-Index, we see in both products a strong gradient from stable conditions over the Cape area (dark brown) to rather unstable air in the northeast (yellow and red), while for TPW this gradient is between dry conditions over the Cape (dark brown and blue) to much moister air in the northeast, especially over the adjacent Indian Ocean (green to light yellow and red). Similar conditions were for this particular day also captured by the ECMWF forecast (also shown in Figures 4 and 5).

![Figure 4: K-index for 23 December 2008, 0745 UTC: ECMWF forecast (top left, for 1 x 1 deg latitude/longitude grid), as derived from the corresponding IASI Level 2 data (top right) and as provided by the MSG GII product (left). Basically all three products show the same SW to NE gradient of air stability.](image)

In summary, this initial analysis, where MSG and IASI information are still kept separate, shows the general agreement between the two products. As a next step we investigate in how far – and especially for how long during the following hours – the IASI retrievals can be used as a first guess for the MSG GII retrieval, starting at 0745 UTC on that particular day.

Figures 5 and 6 show the K-Index and TPW for 1 and 2 hours after the IASI overpass, as retrieved from MSG, using the 0745 UTC IASI data as first guess, together with the conventional GII product, using ECMWF forecasts as first guess. One striking feature is the loss of coverage as time progresses due to the movement of clouds, as indicated in the figures: An originally cloud covered IASI field of view does not provide any first guess information, so that this area will remain void even if it becomes cloud free in the subsequent in the subsequent hours. Another striking feature is that the strong increase of instability (increase in K-Index) observed at 1000 UTC is not reflected in the IASI based
product, indicating that a 2 hours time difference to the IASI overpass is too long to capture such development. For reference, the Johannesburg radiosonde reported a K-Index of 37.1 C for 0000 UTC and of 41.3 C at 1200 UTC, which is in line with the developments shown by the conventional MSG GII product.

Figure 5: As Figure 4, but now for the total precipitable water (TPW). Again, all three products agree well. It is interesting to note, however, that both the IASI and the MSG product show slightly moister conditions, i.e. a different position of the strong moisture gradient, in the area marked by the circle.

Figure 6a: K-Index for 0900 UTC (~1 hour past the IASI overpass), as provided by the conventional MSG GII product (left) and by the IASI based product (right). Note that areas to the east and west of the original IASI overpass are not processed, hence the missing coverage over the Atlantic and the Indian Ocean.
Figure 6b: As Figure 6a, but now for 1000 UTC, i.e. ~ 2 hour time difference to the IASI overpass. Note the increased loss of coverage (white circles) due to cloud motion and the missed K-index development in the IASI product (green circle).

Figure 7a: As Figure 6a, but now for the total precipitable water TPW.

Figure 7b: As Figure 6b, but now for the total precipitable water TPW. Again, the loss of coverage due to cloud motion is shown by the white circles.
A somewhat special case is the Lifted Index: From its definition, it strongly depends on the near surface atmospheric properties, which are difficult to correctly retrieve from satellite sounding measurements. In this particular case, the Lifted Index derived from the IASI profiles at 0745 UTC shows the same structure as the MSG product – stable air over the Cape region, unstable air in the northeast, but the IASI Lifted Index largely overestimates the instability and produces Lifted Index values of -15°C and less, which is highly unrealistic. Figure 8 shows the results. For comparison, the Johannesburg radiosonde reported -1 °C at 0000 UTC and -6.5 °C at 1200 UTC, which is in line with the MSG product, but much less negative than the IASI values.

![Figure 8: Lifted Index, as provided by the ECMWF forecast based MSG product (left) and by the IASI retrieval (right), for 0745 UTC. The white circles denote the area of disagreement between the two products.](image)

**CONCLUSIONS**

This paper provided a first attempt to link the MSG GII retrievals to the forecast independent IASI Level 2 product. From the one presented test case we can conclude:

(a) Hyperspectral soundings reasonably well compare to instability parameters derived from an MSG-SEVIRI like imager. Best results are obtained for indices which do not need near surface information, as e.g. the K-Index. Results are also good for TPW.

(b) The hyperspectral soundings can be used as first guess fields for an imager based retrieval, as long as the time difference between the two observations is not too large. This particular study suggests that a time difference of ~ 1 hour is still acceptable. A major problem in longer time differences is the movement of clouds - originally cloud filled areas do not provide the necessary first guess information, so the GII retrieval is impossible even if the area becomes clear.

These very first and preliminary results suggest that a combined usage of the planned MTG Infrared Sounder – a hyperspectral instrument – together with the MTG Flexible Combined Imager – an MSG-SEVIRI like instrument – will enable nowcasting the pre-convective environment. Such a combination will ensure that the instability information will be less dependent on NWP forecasts as is currently the case for the MSG GII.

**REFERENCES**