Processing of IASI heterogeneous scenes

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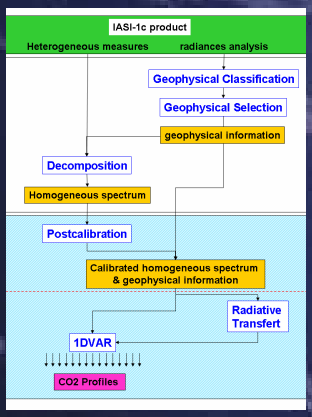
Motivations

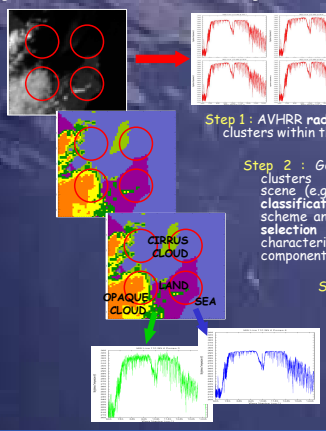
Previous CMS and NOAA studies show that the percentage of uniform clear pixels at the IASI spatial scale is very low, of about 5 %. The derivation of humidity and temperature profiles as well as vertical profiles or integrated columns of atmospheric constituents from partially cloudy or more generally heterogeneous pixels is one of the major challenges for the IASI mission. In general, heterogeneities may come from the cloud coverage or from the variability of surface properties.
The IASI/MetOp mission offers for the first time the ability to provide high quality data to appropriately cope with this heterogeneity problem. An imager (IIS) integrated into the IASI sounder allows to co-register its pixels or FOV (Field Of Regard) with a high level of accuracy with respect to the high spatial resolution data (1km) of the AVHRR imager onboard MetOp. So the analysis of AVHRR radiances allows the identification and the characterization (at the IASI sub-FOV scale) of clouds and surface heterogeneities which contribute to the IASI 1c product distributed by EUMETSAT. This analysis allows:
the spectral post-calibration of the IASI measurements in the case of heterogeneous scenes. Indeed, the off-axis interferometer introduces a residual spectral calibration error for heterogeneous pixels. A correction of this calibration error can be performed using information about the proportion and repartition of various cloud types inside a given IASI pixel or FOV;
the optimal exploitation of the IASI measurements for heterogeneous scenes using the information provided by AVHRR at the sub-FOV scale.

The availability of this high quality data, which can be used at best by a proper synergy between the IASI and AVHRR spectral and spatial information, represents a unique opportunity to make decisive progress in the analysis and processing of cloud and surface heterogeneities in infrared sounding. The goal of this work is to implement and validate the methods and tools necessary for using these data in combination.

Implemented algorithm

The implemented algorithm consists in processing the measurements at level 1c, in order to produce spectra corrected from the AVHRR-imaging detected heterogeneity and corresponding to radiatively homogeneous and geophysically well characterized components. For this purpose, the spectral measurements have to be split into homogeneous spectra by using the weights of the different homogeneous components available in the IASI L1c products. It is supposed that the different components are homogeneous on the whole scene (Field Of Regard or FOR of 50 x 50 km²) consisting of 4 pixels (Field Of View or FOV of 12 km diameter).





Step 1 : AVHRR **radiance analysis** within IASI pixels provide homogeneous clusters within the scene

Step 2 : Geophysical analysis and merging of these radiance clusters provide the homogeneous components of the scene (e.g. : sea, lands, low clouds, Cirrus). The **geophysical classification** algorithm includes the MAIA cloud classification scheme and a soil type identification process. The **geophysical selection** module allows to merge classes according to their characteristics, in order to get at most 4 homogeneous components in the scene;

Step 3 : An inversion scheme (**decomposition** algorithm) is applied to retrieved one or several homogeneous component spectrum from the 4 pixel measurements

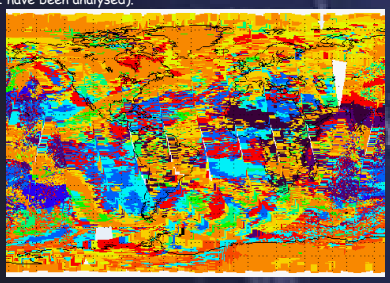
Step 4 : A post calibration is applied on the measured and decomposed spectra to be usable for level 2/3/4 applications; the **post-calibration** function allows the correction of the spectral calibration error linked to heterogeneity.

Quality criteria

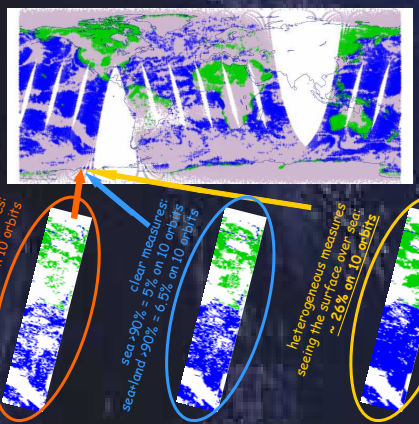
- **quality of the heterogeneous synthetic spectrum** which can be recomposed by a weighted linear combination of the homogeneous spectra and compared to the measured spectrum ; $NEdT_{SN}(SN)$ is expressed in K at 280K.
- **quality of the homogeneous component spectrum:** comparison of the spatially average radiance of the derived components for the AVHRR 4 and 5 channels. This difference is transformed into NEdT at 280 K for each AVHRR channel.
- the theoretical computation of the **noise amplification coefficient**, derived from the values of the spectra decomposition weights for each homogeneous component spectrum. It represents the noise amplification factor due to the decomposition algorithm as compared to the standard level 1 measurement. This is the only prognostic quality criterium.

Validation on IASI measured data

Statistical study on the processing of 10 successive orbits acquired in normal operational mode from January 15th of 2007 starting at 16:27 UTC (7615 lines of IASI have been analysed).



Projection of the cloud type of classes of each pixel determined by MAIA (black & purple = clear / middle & clear dark blue colours = low clouds, green colours = middle & high clouds of type "cumuliform clouds" or "stratiform clouds", yellow, orange & red colours = "cirrus clouds", "fractal clouds" & "non-classified clouds")

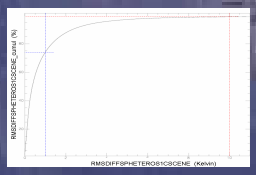


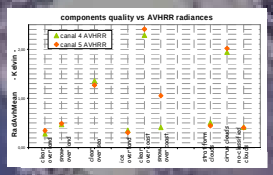
	Completely clear FOV over sea	Clear (90 %) FOV over sea	Clear (90 %) FOV over sea and land
10 orbits	3 %	5 %	6.50 %
65°N-65°S	3.70 %	6.50 %	8 %

Study about the percentage of "clear sky" measurements on 10 orbites, to be compared to the percentage of scenes containing a fraction of clear sky over sea, 26%.

Statistic study

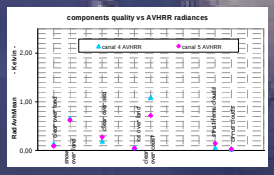
Statistics for the NEdT criterion over the whole set	
NEdT : Mean, K	1,31
NEdT : Standard deviation, K	14,363
Number of components	424626
Number of scenes	201663





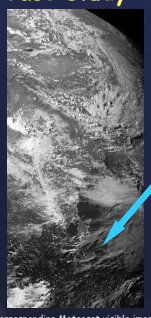
Overall analysis on 10 orbites:
- for ~75% of analysed scenes, $NEdT_{SN}$ criterion is <1K, and for ~1.1% of analysed scenes, $NEdT_{SN}$ criterion is >10K.
- average absolute value of NEdT computed by comparison with the average radiances in AVHRR channels 4 and 5, is ~1.25K for the "clear over sea" component.

Statistics on the 10 selected orbits - scenes containing the "non-classified clouds" component are excluded	
NEdT : Mean, K	0.604
NEdT : Standard deviation, K	3.426
Number of components	84914
Number of scenes	41554

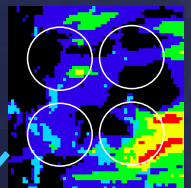


Analysis on 10 orbits without "non-classified clouds" component :
- The "non-classified clouds" component represents about 38 % of the components for the studied orbits, but exists in 80 % of the scenes. Above table presents the average values and standard deviations of the $NEdT_{SN}$ on the 10 selected orbits excluding scenes containing the "non-classified clouds" component. The result is largely improved regarding the analysis of the whole set of 10 selected orbits: the average in $NEdT_{SN}$ goes from 1.3 to 0.6 K and the standard deviation reduces from about 14 to 3.4 K.

Case study: cloud over sea

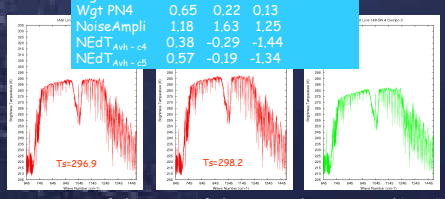


Corresponding Meteosat visible image



Overview of the AVHRR radiance clusters of the FOR « LN 555 SN 4 » - date=2747.638818

CompoType	sea	sea	no-classified
Wgt PN1	0.76	0.04	0.20
Wgt PN2	0.31	0.68	0.01
Wgt PN3	0.11	0.07	0.82
Wgt PN4	0.65	0.22	0.13
NoiseAmpli	1.18	1.63	1.25
$NEdT_{Avh-c4}$	0.38	-0.29	-1.44
$NEdT_{Avh-c5}$	0.57	-0.19	-1.34



Results of the decomposition process in terms of the nature of the retrieved components (CompoType), weights of the components in each pixel (WgtPNx), noise amplification factor (NoiseAmpli) and AVHRR quality criteria ($NEdT_{Avh-c4}$ and $NEdT_{Avh-c5}$ respectively for channels 4 and 5) and IASI retrieved spectra associated to the 3 homogeneous components (surface temperature for the 2 "clear over sea" components are computed by MAIA from the AVHRR radiance analysis)

Conclusions / Perspectives :

The application of the heterogeneous scenes processing algorithm on one day of actual IASI/MetOp measurements allowed us to demonstrate the validity and the interest of the IASI heterogeneous scenes processing. This validation, done on a large number of real spectra corresponding to a great variety of atmospheric and surface conditions, provides preliminary elements to analyse the results and to justify the interest of this processing algorithm. The overall statistic analysis shows that, for 75 % of the 10 selected orbits scenes, one can decompose the measured spectra into homogeneous components reliably (better than 1K in NEdT on average). A first analysis of these overall results allows a preliminary assessment of the performance of this type of processing. The results of the heterogeneous scenes processing algorithm has been illustrated and quantified in a cloud-clearing perspective : the number of 'clear-sky-over-sea' exploitable spectra is multiplied by about 3 in our results.
Now, all the required improvements and optimisation of the processing algorithm should be assessed in the context of a user-oriented validation study. It is proposed to identify some representative applications of the IASI decomposition process, and to involve scientific users both in the demonstration of the interest of the processing and in the improvement/optimisation of the algorithm and of the software. Such applications could be the retrieval of constituents (O3, CO, CH4, CO2) for atmospheric chemistry and climate studies; the retrieval of temperature/humidity fields for meteorology; the retrieval of water vapour profiles in tropical cloudy situation for the assessment of convection and water cycle.

Acknowledgement

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