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Porting the OPS clustering algorithm to VIIRS in CrIS footprint

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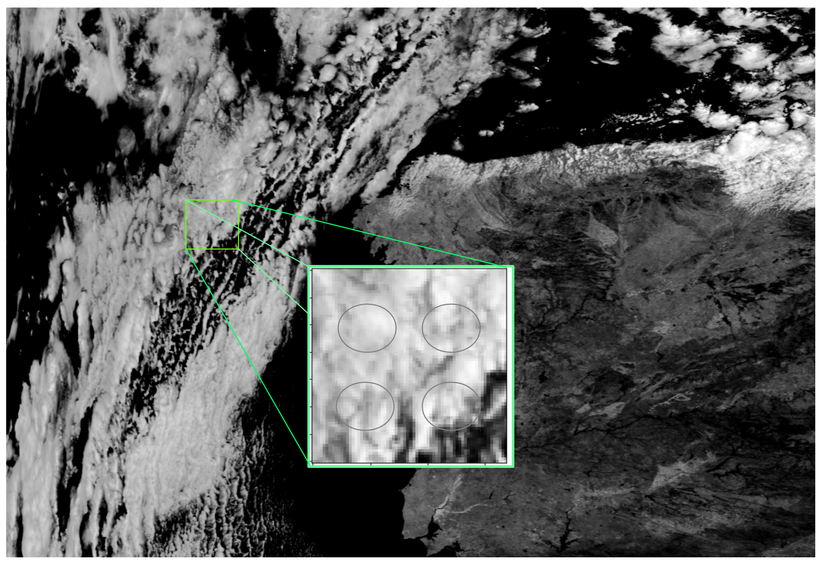
What are clusters ?

At ITSC-XX, was first expressed a recommendation that the AVHRR clustering algorithm available in AAPP should be used for all hyperspectral sounders.
In OPS, the software which processes IASI, a method called "Nuees Dynamiques" groups the AVHRR pixels in each IASI field of regard into clusters of homogeneous scenes.(1)
In the IASI BUFR file, for each IASI FOV, the user can retrieve the number of pixels in clusters as well as the mean and the standard deviation of the AVHRR radiances. This information can be used in order to improve the data assimilation of IASI radiances into numerical weather prediction models.
In AAPP, this method was adapted in 2018 to VIIRS and CrIS for S-NPP and JPSS NOAA20 satellites.

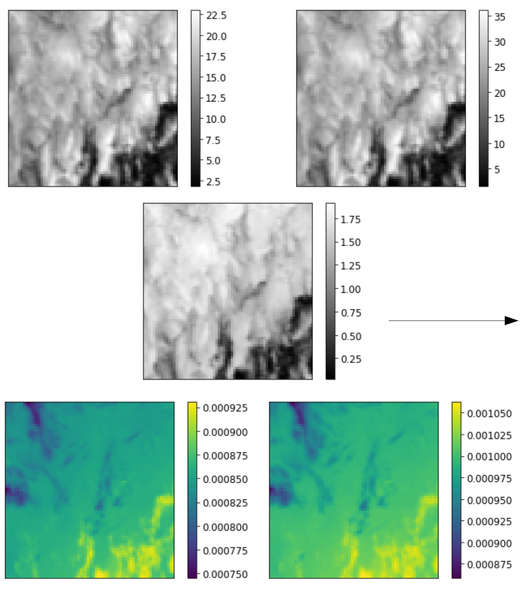
AVHRR over Spain on 2017/07/25 (metopb AAPP Test Case)
Radiances in channel 2



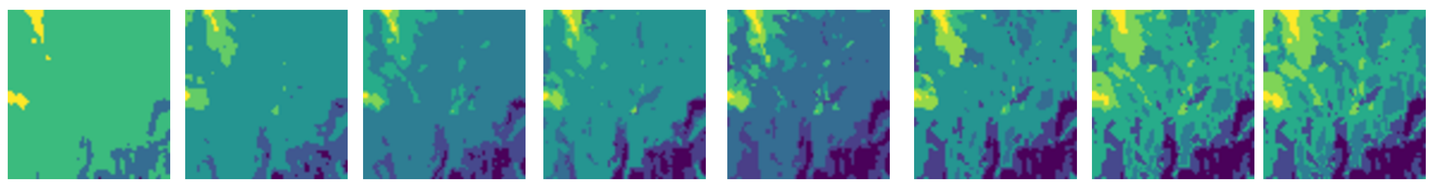
From ITSC-20
« Recommendation DA/NWP-17 to Data providers :
Use the AVHRR cluster algorithm available in AAPP for all hyperspectral sounders. »

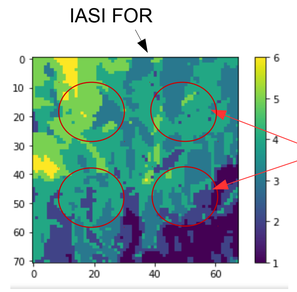
From ITSC-21 :
«The VIIRS cluster analysis in the CrIS footprint was discussed. There are two aspects to this.
The first is the *provision of a cluster analysis similar to that provided for IASI* in which the mean and standard deviation of VIIRS radiances within the CrIS footprint would be computed (for a small number of clusters) and included in BUFR products. This is thought to be reasonably straightforward, pending an AAPP development planned for 2018, and a new BUFR sequence.
The second aspect is that NCEP would like to have VIIRS cloud information associated with each CrIS FOV, using the NOAA enterprise cloud algorithm. If NCEP can clarify what is needed, the CSPP and AAPP teams can look at how it would be provided in DBNet data. »

« Nuées Dynamiques » (can be translated in « dynamic clouds ») was introduced by E. Diday in 1971.(2)
OPS : CNES Software
OPS-LRS : Version of OPS packaged by NWPSAF for DB Users



AVHRR Radiances in 5 channels in a IASI Field of Regard (FOR)
Units: VIS : W m^{-2} sr^{-1}, IR : W m^{-2} sr^{-1} (m^{-1})$^{-1}$





For each IASI FOV :
Numbers of pixels by clusters
Mean and Standard deviation

input :
- Vector of radiances
- Channel noise
- Channel weight
- Sorting channel (clusters are ordered by the values of the radiance in this channel)
- Number of channels
- Max number of clusters
- Max number of iterations
- Max distance
- Thresholds

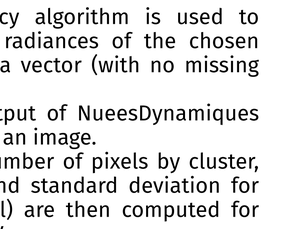
OPS « Nuées Dynamiques » Algorithm Description:
Initialisation :
- Radiances are normalised and weighted
- First centroid = mean
- Second centroid = most distant pixel from first centroid
- Third centroid = most distant pixel from second and first centroid

Iterations :
- If nb clusters > threshold1 : agglomerate 2 clusters
- If nb clusters < threshold2 : create a new cluster → split most scattered cluster
- Associate pixels to clusters
- Recompute centroids (means)

9 iterations, 6 clusters

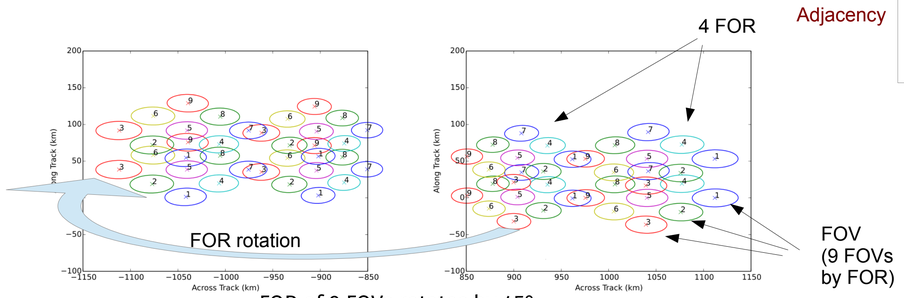
Output:
- mapping AVHRR pixels-> clusters
- statistics (number of pixel by clusters, mean and standard deviation for each channel)

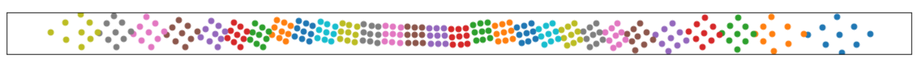
There are many other clustering algorithms. The Kmean algorithm is a popular algorithm which differs by the fact that the number of clusters does not change during the process. However the result obtained by the Kmeans method is very close to the result of the OPS algorithm.



Application to VIIRS and CrIS

The OPS C function « NueesDynamiques » was extracted from the OPS-LRS package and integrated into the AAPP package. For this function, it was necessary to present the VIIRS radiances in a CrIS FOR as a vector with no missing value.
AAPP already had a tool to map VIIRS into CrIS FOV: the nominal footprint contours for a FOV of 16.8mrad were calculated by AAPP with variations from 14x14 km to 48x24 km and the rotation effect of the 9 FOVs. The Fortran generalisation in AAPP of the Common Adjacency algorithm is able to deal with the VIIRS Tie-Bow effect and can find the exact VIIRS pixels that fall into the CrIS FOV.
The mapping tool was added in AAPP 7.10 (2015).(3)(4)

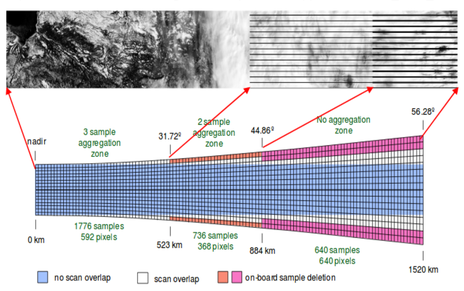


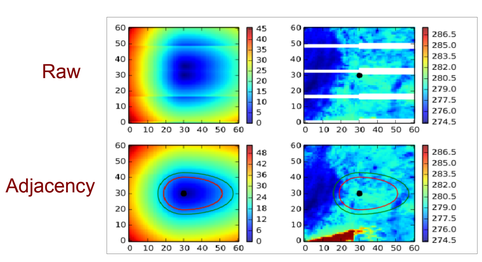


For AAPP 8.3, the VIIRS/CrIS Mapping tools in AAPP (viirs_to_cris) was updated to call the NueesDynamiques fonction.

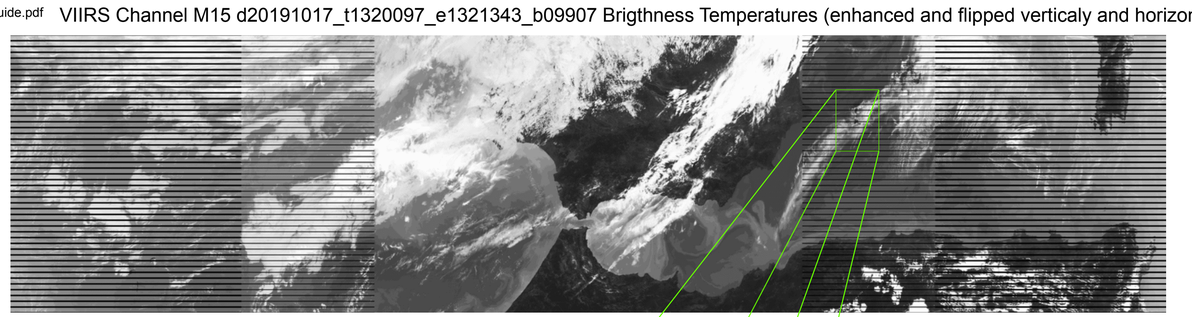
The shell script **VIIRS_CRIS_MAIA4_RUN** processes CrIS with VIIRS cloud mask and cluster analysis (call RUN_MAIA4, viirs_to_cris and BUFR encoding).
Environnement variables :
- **CRIS_SDR_DIR:** directory containing CrIS SDR files.
- **VIIRS_SDR_DIR:** directory containing VIIRS SDR files.
- **VIIRS_BANDS:** bands to include in the cluster analysis. Default: "M5 M7 M12 M15 M16".
- **DIR_FORECAST:** directory containing GFS forecast files (Can be downloaded in advance to save time).

https://www.star.nesdis.noaa.gov/smcd/spb/nsun/snpp/VIIRS/VIIRS_SDR_Users_guide.pdf

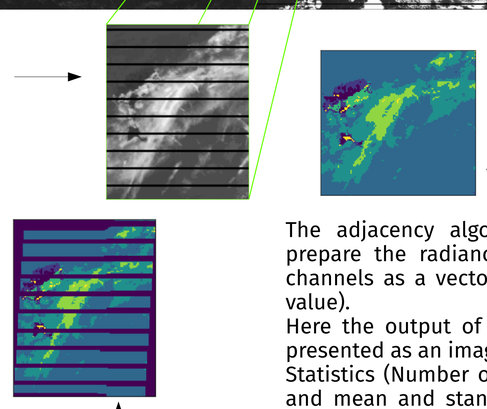




VIIRS Channel M15 d20191017_t1320097_e1321343_b09907 Brigthness Temperatures (enhanced and flipped verticaly and horizontaly)



CrIS FOR in VIIRS granule is computed by viirs_to_cris (AAPP software).

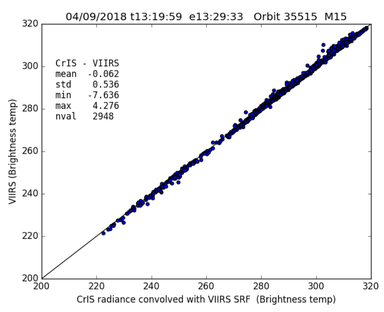


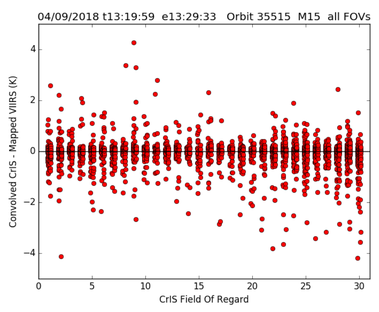
The number of channels can be chosen by the user. Computations with all channels are slower and can lead to many unclassified pixels. The best results are obtained with a small number of channels.

A change of units (W m^{-2} μm^{-1} sr^{-1} to W m^{-2} sr^{-1} (m^{-1})$^{-1}$) is made on VIIRS radiance values for the NueesDynamiques function. The noise is also an input of the algorithm, the performance values in this unit were provided by Changyong Cao (NOAA) on https://ncc.nesdis.noaa.gov/VIIRS/index.php.

Same cluster image mapped on the VIIRS grid.

The adjacency algorithm is used to prepare the radiances of the chosen channels as a vector (with no missing value).
Here the output of NueesDynamiques presented as an image.
Statistics (Number of pixels by cluster, and mean and standard deviation for each channel) are then computed for each CrIS FOV.





The validation of the implementation is carried out by comparing the mean values of the most populated clusters if they contain more than 80 % of the VIIRS pixels with the values of the CriS 1c spectrum convolved with the VIIRS SRFs.
Here are the result for channel M15 for the granule 04/09/2018 t13:19:59 e13:29:33, orbit 355515 (SUOMI-NPP).

Some input parameters for NueesDynamiques are defined in the mapping_viirs_cris.fdf file (Noise and weights for each VIIRS channel).
Other parameters were set for AAPP and defined in NueesParam.h. (ex : algorithm thresholds, number of iterations).

References :
1.Dossier de définition des algorithmes IASI: CNES IA-DF-0000-2006-CNE Fiche 41 Version 3.0 Analyse des radiances dans les FOVs sondeur.
2.Diday, E. Une nouvelle méthode en classification automatique et reconnaissance des formes la méthode des nuées dynamiques. Revue de Statistique Appliquée, Volume 19 (1971) no. 2, pp. 19-33.
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3.NWPSAF-MF-UD-011 VIIRS-CrIS Mapping
https://www.nwpsaf.eu/site/download/documentation/aapp/NWPSAF-MF-UD-011_viirs-cris-mapping.pdf
4.P. Brunel Mapping CrIS field of view onto VIIRS: ITSC-19 (2014)
https://cimss.ssec.wisc.edu/itwg/itsc/itsc19/program/posters/1p_17_brunel.pdf

https://www.nwpsaf.eu/site/software/aapp/