PROGYSAT
Projet de coopération Régionale d'Observation des GuYanes par SATellite

Protecting the Amazon landscape by studying compliance with pollution standards and monitoring anthropogenic and natural pollutants

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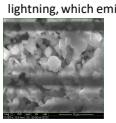
Introduction

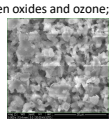
Reducing environmental pollution requires knowledge and control of the pollutants in our environment. In 2000, Santé Publique France estimated the number of pollution-related deaths in France at 40,000.There are 2 main types of natural pollutant in French Guiana:- Chlorine from marine aerosols (Gobinddass et al., 2020) and,- Desert dust characterised by Atmo Guyane during measurements of PM10, PM2.5 and by satellite images with extraction of optical thickness (AOT). During the PROGYSAT project, we acquired Atmo-Track in order to measure anthropogenic and natural pollutants in the cross-border region of French Guyana, with the aim of completing the ATMO GUYANE dataset.
Our main objectives were to study :
-the legal framework for safety measures and pollution standards (water, air) in border areas, knowledge of and compliance with limit values by the population.
-the impact and monitoring of natural pollution (desert dust, marine chlorine, etc.) and anthropogenic pollution (NOX, benzene, mercury, etc.) linked to the development and modification of the landscape around border areas.
And our expected results were :
-Assessment of the need to harmonize countries' environmental compliance with the implementation of transboundary environmental standards.
-Modelling, mapping and monitoring of natural and anthropogenic pollutants (mathematical models: dynamics atmospheric dispersion of pollutants, air quality models will be used) and sensitivity of remote sensing observations to the state of aerosol mixing.

What is a natural pollutant?

Natural pollutants are in the form of gases or particles, and are emitted by :
- erosion, which produces dust. Saharan dust is carried by the wind and can travel very long distances.
- Volcanoes, which send huge quantities of gas and particles into the atmosphere;
- Plants that produce pollen, some of which can cause allergies;
- lightning, which emits nitrogen oxides and ozone;



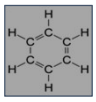
Representation of the sodium chloride NaCl marker of Saharan dust collected in Cayenne and measured by SEM



Representation of marine chlorine collected in Cayenne and measured by SEM

What is an anthropogenic pollutant?

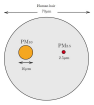
An anthropogenic pollutant is a pollutant that results from industrial action, the use of fertilisers or pesticides for agricultural purposes, transport and landfill sites.
Particulate matter, nitrogen oxides, volatile organic compounds (VOCs) and ozone are the most worrying anthropogenic pollutants today.



Representation of benzene

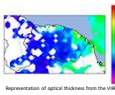
Representation of nitrogen Nitrogen Dioxide

Representation of Ammonia

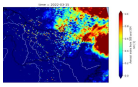


Representation of PM10 and PM2.5 in relation to the diameter of a hair (Pedraza et al. 2020)

What satellite images can be used to study pollution?



Representation of optical thickness from the VIIR sensor



Representation of the optical thickness from the Sentinel-5 sensor

The optical thickness of an atmospheric layer measures the degree of transparency of the medium. It is defined by the fraction of electromagnetic radiation (or light) scattered or absorbed by the components of the layer through which it passes. Sensors on the VIIRS and Sentinel-5 satellites measure this parameter, giving us an indication of the PM10 content present during Saharan dust peaks.

What are the most accurate ground-based measuring instruments?

TEOM measuring instrument (source ATMO GUYANE)

Atmo-Track sensor acquired by the PROGYSAT project

The TEOM (Tapered Element Oscillating Microbalance) microbalance can measure two types of particle with high accuracy:- particles with an aerodynamic diameter of less than 10 microns (PM10-Particulate Matter)- particles with an aerodynamic diameter of less than 2.5 microns (PM2.5). Volumetric flow measurement is used to determine the concentration in micrograms of particulate matter per cubic meter of air. The Atmo Track is a field instrument acquired by PROGYSAT to measure PM10 and PM2.5, as well as other pollutants.

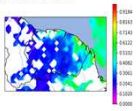
Methodology

- 1) AOT parameters of images from the VIIRS (Visible-Infrared Imager/Radiometer Suite Sensors) sensor are compared with PM10 ground data from the Thermo Scientific Tapered Element Oscillating Microbalance (TEOM) sensor.
- 2) AOD parameters from Sentinel-5 images are compared with ground-based PM10 data from the Thermo Scientific Tapered Element Oscillating Microbalance (TEOM) sensor.
- 3) Statistical calculations and correlation coefficients have been calculated for 1) and 2).
- 4) The new ATMO-TRACK sensors obtained by PROGYSAT were installed in Saint-Laurent du Maroni and Saint-Georges de l'Oyapock. One of the parameters obtained is PM10. PM10 from ATMO-TRACK was compared with PM10 from the TEOM

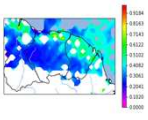
Software developped

The first block, called **Data Download**, enables the acquisition of VIIRS, Sentinel-5 and Sentinel-3 satellite images. From the second **Data Process block**, we can extract optical thicknesses from Sentinel-5 and VIIRS images, enabling us to map AOT values that do not contain anomalies. Corrections will have to be applied by geographical zone if statistical calculations show that this is necessary. Then, using other input data from Atmo Guyane's TEOM ground measurements or from Atmo Track sensors, such as PM10, we can search for correlations between satellite and ground data before moving on to modeling. The **Mathematical Model block** enables pollutants to be modeled, taking into account interpolation, smoothing and optimization methods. It is used to compare Sentinel-5 and VIIRS optical thickness values to check data compatibility. The model studied here provides promising results for French Guiana. Brazil and Suriname will have to provide us with PM10 values from sensors located on their territory in order to validate this method for these areas.

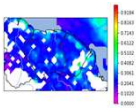
Results (1/2)



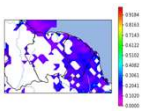
27 Mars 2018 : 100 ug.m-3<PM10<150 ug.m-3



11 Avril 2018 : 50 ug.m-3<PM10<100 ug.m-3



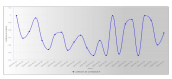
4 Avril 2015 : 20 ug.m-3<PM10<50 ug.m-3



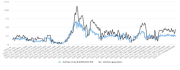
8 Juillet 2017 : PM10<20 ug.m-3

Both VIIRS and Sentinel-5 optical thickness results correlate relatively well with Atmo Guyane's TEOM PM10 data on Saharan dust days, particularly for cloud-free images.

Results(2/2)



PM10 and AOD correlation over 25 days
This figure shows the correlations between the PM10 data from the stations of Cayenne, Kourou and Matoury and the AOT values extracted in these areas. We can see that they are generally correlated (most of them higher than 0.5).



For this example in Cayenne, the proportionality coefficient is equal on average to 0.8440. The correlation coefficient is equal to 0.8429. We conclude that the PM10 values of the TEOM and the Atmo track are relatively well correlated.

Law

With regard to the three legislations compared, the way in which each country deals with environmental law and the effective protection of the environment through the reduction of pollutants clearly shows that they are constructed according to the historical and social maturity of each region. Whereas Brazil and Suriname are in a purely preventive context, the French legislation is comprehensive, so that in addition to reducing the quantity of pollutants, its parameters are established and effective penalties are provided for in the event of non-compliance, in addition to establishing the figures to be considered an environmental emergency, which is not the case in the Brazilian legislation.

Conclusion

As far as Saharan dust is concerned, since for many years we had only measured PM10 in Cayenne using the TEOM, we tried to supplement our measurements in other geographical areas using AOT or AOD data from Sentinel-5 or VIIRS images. The correlation between Sentinel-5 or VIIRS data and TEOM ground measurements gives a correlation of 0.75. This is an interesting result for studying cross-border regions. However, too many satellite images are still heavily clouded during Saharan dust episodes.
As for the ARMA predictive model, it gives very good results for PM10 values in Saint-Laurent, Saint-Georges and Cayenne. A good determination of PM10 over several years and with several cities will enable us to look at respiratory health problems with Allyx Fontaine, Emmanuel Roux, Aude Ansel-Wallois and doctors at André Rosemon Hospital. The study could be extended to Brazil and Suriname.
Whereas Brazil and Suriname are in a purely preventive context, the French legislation is comprehensive, so that in addition to reducing the quantity of pollutants, its parameters are established and effective penalties are provided for in the event of non-compliance, in addition to establishing the figures to be considered an environmental emergency, which is not the case in the Brazilian legislation.