POLLUTION, URBANIZATION AND PRECARIOUS HABITATS LANDSCAPE IN AMAZONIAN ENVIRONMENT, STANDARDS STUDY OF POLLUTION AND MONITORING OF ANTHROPOGENIC AND NATURAL POLLUTANTS

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BRAZIL PARTICIPANTS : IRD : PLUMMA ANHELO ALBARELO

SURINAM PARTICIPANTS :

UNIVERSITY ANTON DE KOM : P. MAX HUISDEN (PU), KATHLEEN GERSIE (LECTURER)

SUMMARY

- OBJECTIVES
- RESULTS EXPECTED
- I- POLLUTANT ANALYSIS IN FRENCH GUIANA AND ITS FRONTIERS IN BRAZIL AND SURINAM
- II- CHARACTERIZATION OF BIOMASS IN FRENCH GUIANA AND ITS FRONTIERS IN BRAZIL AND SURINAM
- III- LEGAL FRAMEWORK VERIFICATION FOR POLLUTION (AIR, WATER) IN FRENCH GUIANA AND ITS FRONTIERS IN BRAZIL AND SURINAM

- CONCLUSION

OBJECTIVES

- Impact and monitoring of natural pollution (desert dust, marine chlorine, etc…) and of anthropogenic pollution (NOX, benzene, mercury, etc.) linked to the development and change of landscape around the border areas

- Legal framework of safety measures and pollution standards (water, air) in border areas, knowledge and respect of limit values by the population

- Estimate the biomass of different types of vegetation in the transboundary areas of French Guiana/Brazil and French Guiana/Suriname based on field measurements obtained through forest inventories and available data, to check the carbon stock in each vegetation type.

RESULTS EXPECTED

- 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.

- Assessment of the need to harmonize countries' environmental compliance with the implementation of transboundary environmental standards.

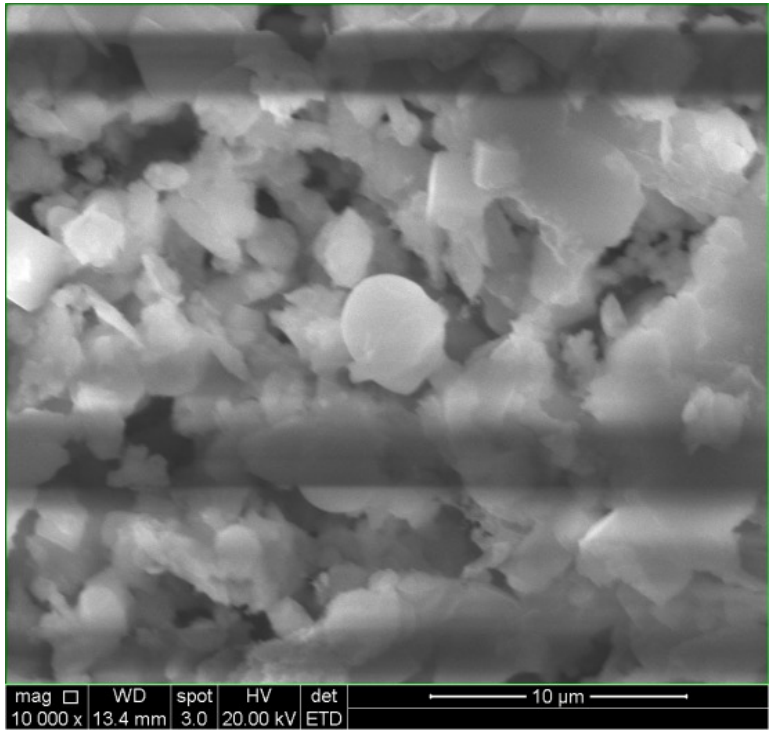
- Characterization and modeling of biomass using satellite

WHAT IS NATURAL POLLUTANT (1/2)

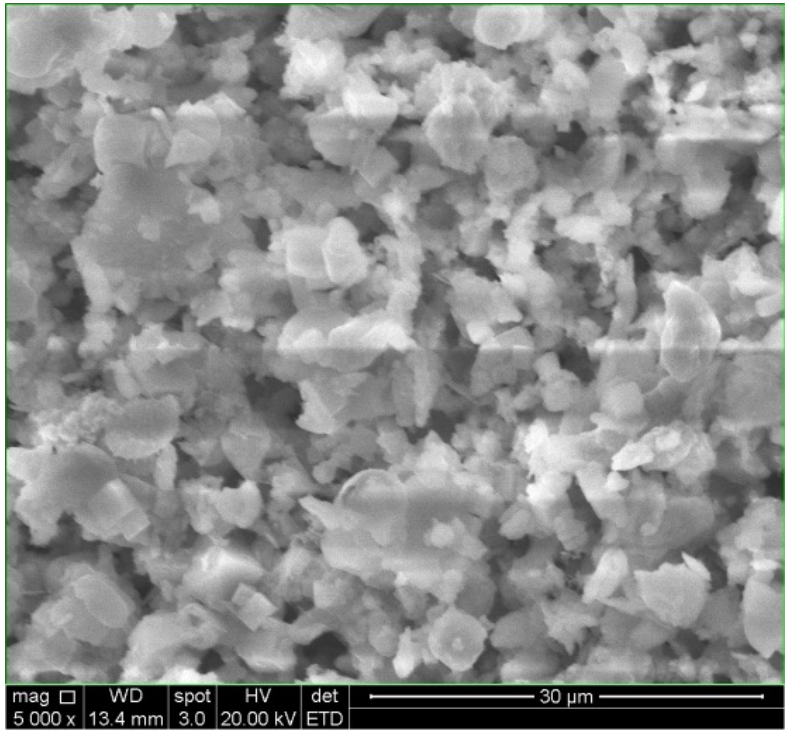
- Natural pollutants are in the form of gases or particles, and are emitted by :

- 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;

WHAT IS NATURAL POLLUTANT (2/2)



Representation of aerosol desert dust AlSi marker of Saharan dust collected in Cayenne and measured by SEM



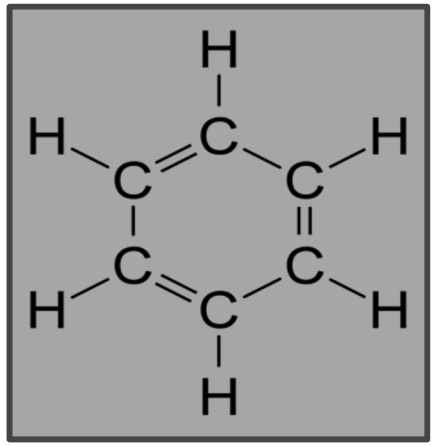
Representation of the sodium chloride NaCl collected in Cayenne and measured by SEM

WHAT IS ANTHROPOGENIC POLLUTANT ? (1/2)

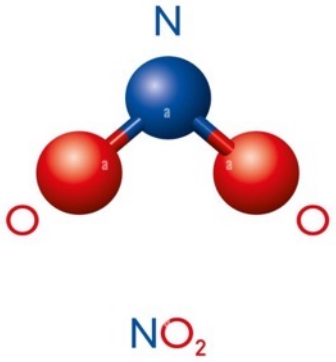
- An anthropogenic pollutant is a pollutant that results from industrial action, hap linked to wood burning, mercury, which is used in the mining industry, the use of fertilisers or pesticides for agricultural purposes, transport and landfill sites.

- Particulate matter, nitrogen oxides, volatile organic compounds (VOCs) and ozone are the most worrying anthropogenic pollutants today.

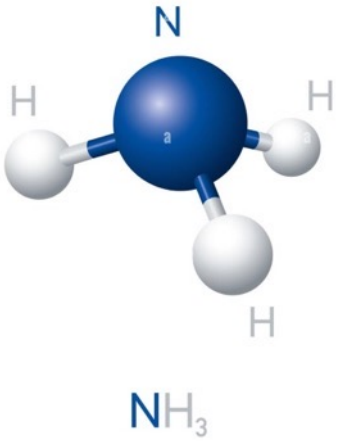
WHAT IS ANTHROPOGENIC POLLUTANT? (2/2)



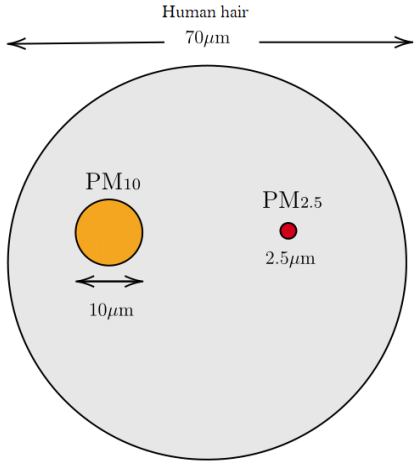
Representation of benzene



Representation of nitrogen Nitrogen Dioxide

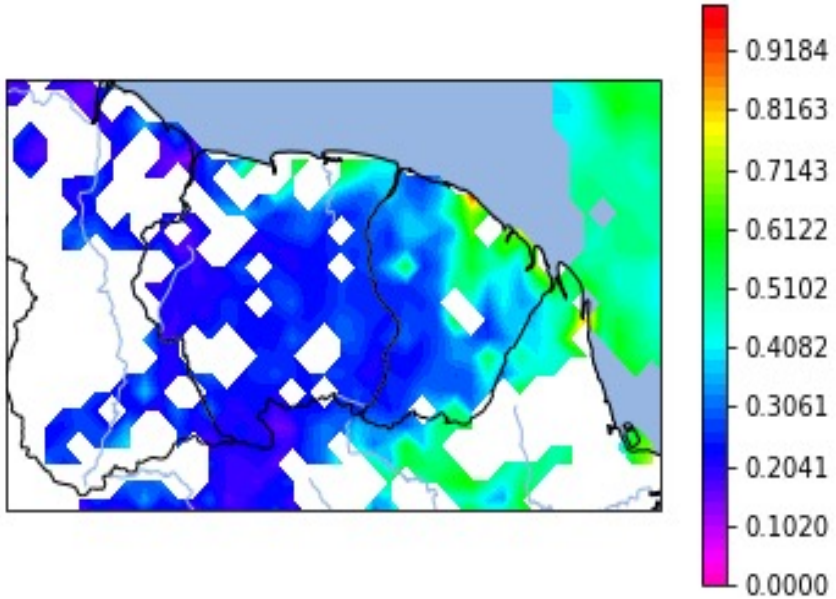


Representation of Ammonia

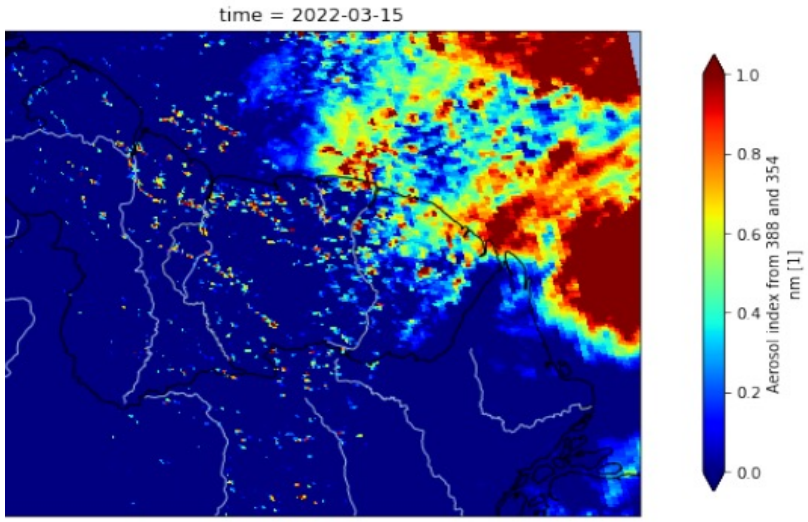


Representation of PM10 and PM2.5 in relation to the diameter of a hair (Pedraza et al. 2020)

WHAT SATELLITE IMAGES CAN BE USED TO STUDY POLLUTION ?



VIIRS satellite image



SENTINEL-5 satellite image

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 ?

ATMO Guyane's TEOM

IRD's Atmo Track

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 : AEROCHAIN (1/3)

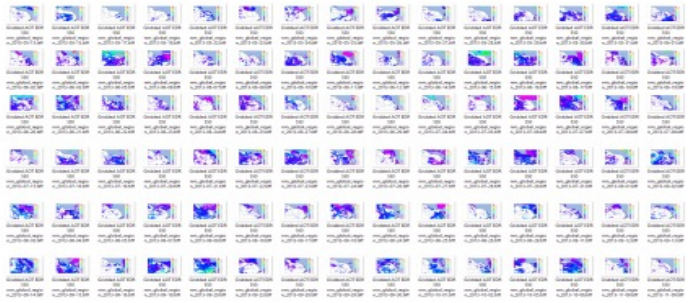
DATA DOWNLOAD

VIIRS
ftp.star.nesdis.noaa.gov
Sentinel-5p
https://s5phub.copernicus.eu/dhus/#/home
Sentinel 3
https://scihub.copernicus.eu/dhus/#/home

DATA PROCESS

Data extraction
Reprojection

MAP TIME SERIES



MATHEMATICAL MODELS

SOFTWARE DEVELOPPED : AEROCHAIN (2/3)

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. **Allyx Fontaine has completed this second block for Sentinel-5 she will present you our work on Thursday.**

Corrections will have to be applied by geographical zone if statistical calculations show that this is necessary.

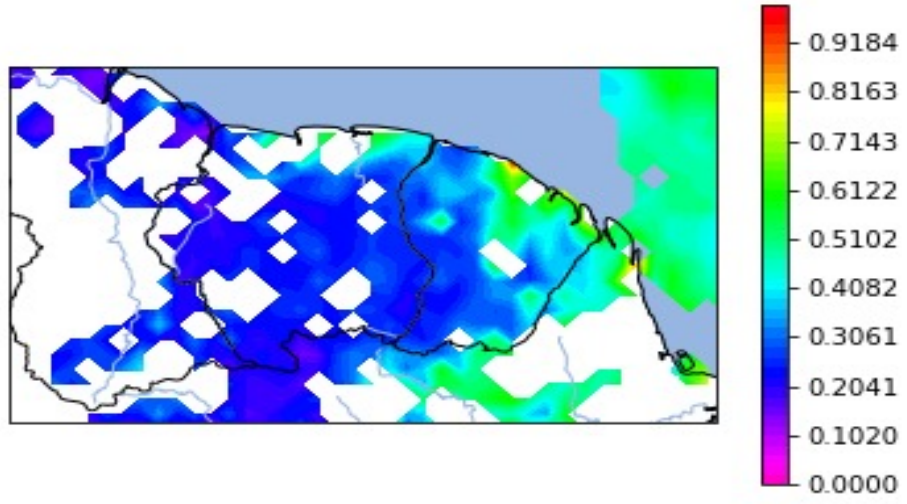
SOFTWARE DEVELOPPED : AEROCHAIN (3/3)

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.

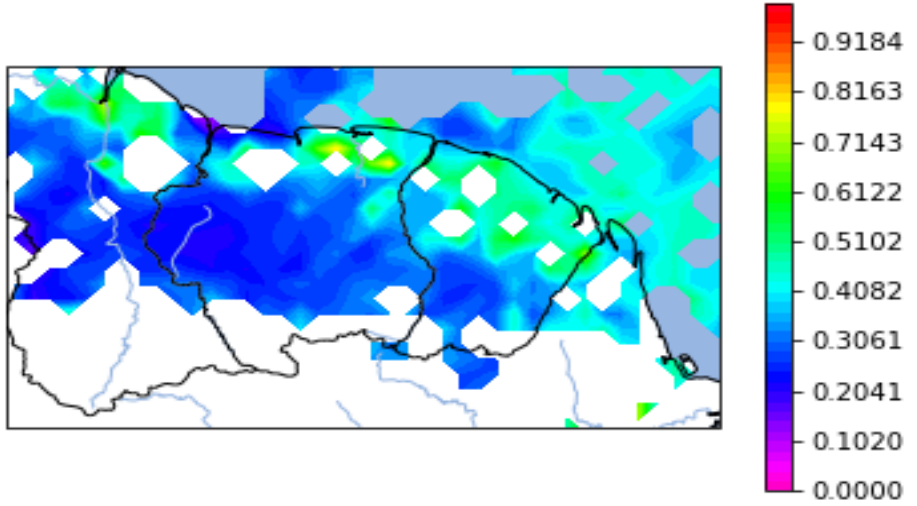
The **Mathematical Model block** enables pollutants to be modeled, taking into account interpolation, smoothing and optimization methods. It is used to compare Sentinel-5 and VIIRS optical thickness values to check data compatibility.

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.

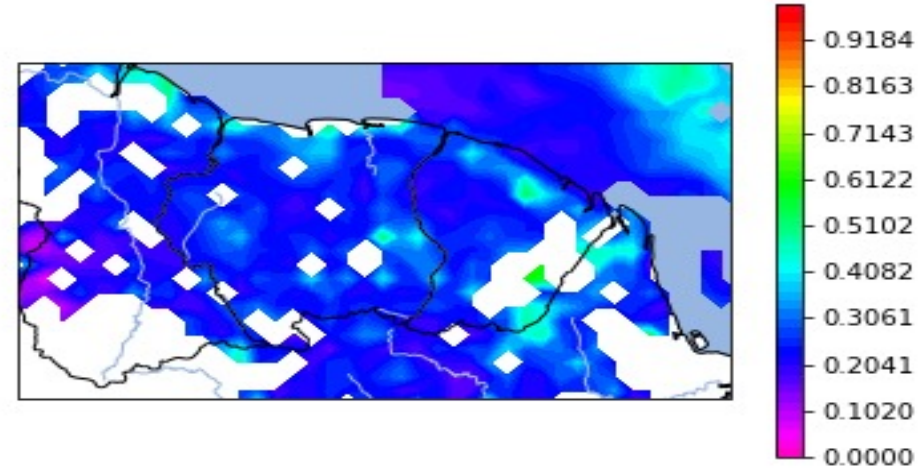
RESULTS : PM10/VIIRS AOT (1/2)



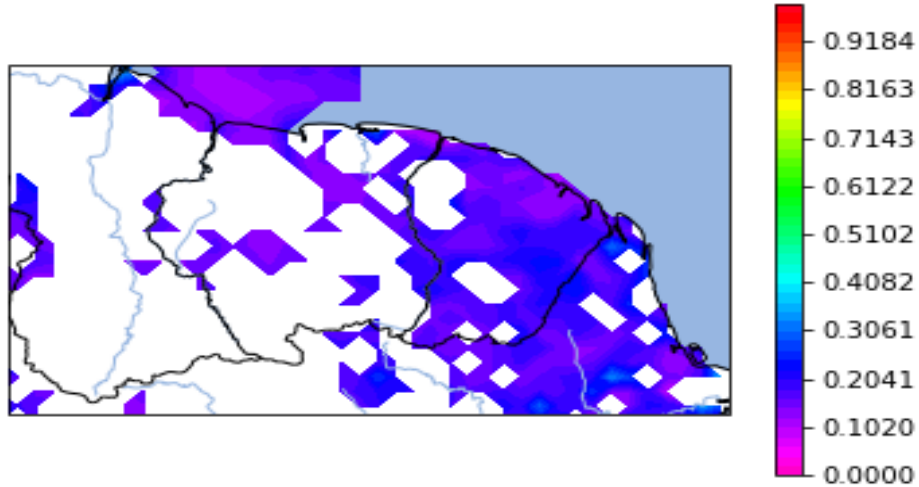
27 Mars 2018 : 100 ug.m-3<PM10<150 ug.m-3



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

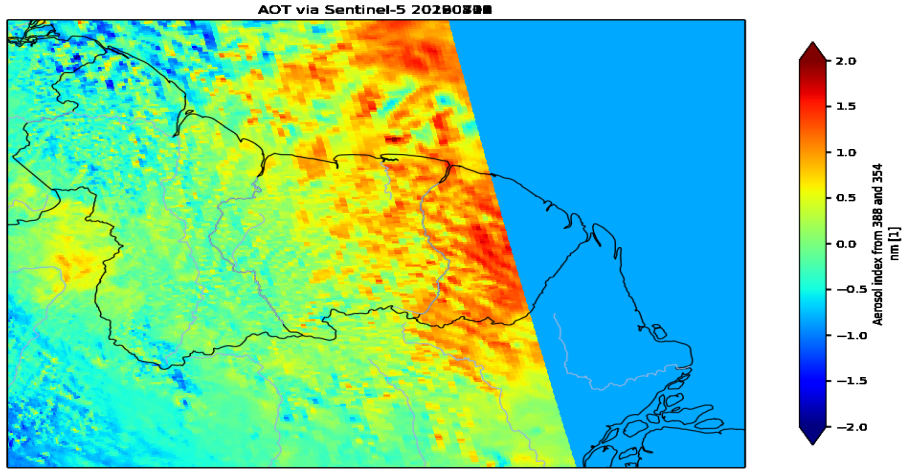


4 Avril 2015 : 20 ug.m-3<PM10<50 ug.m-3

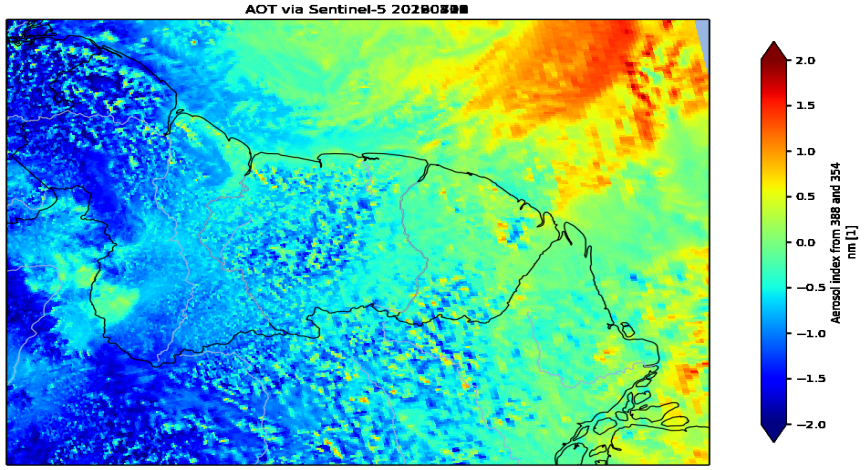


8 Juillet 2017 : PM10<20 ug.m-3

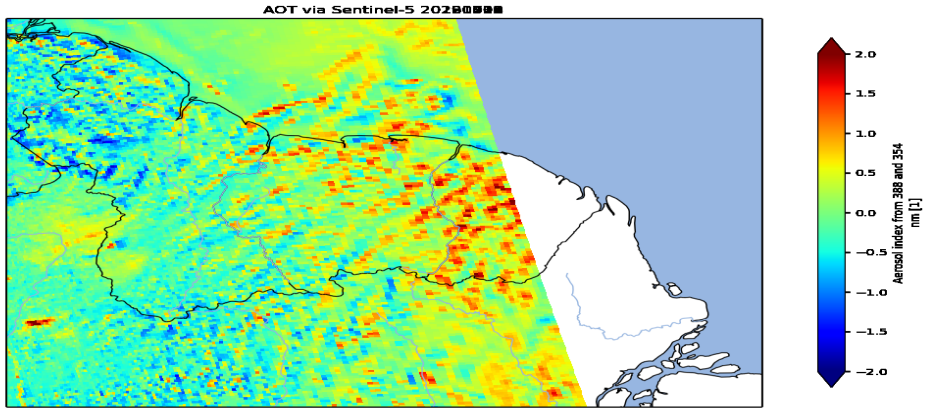
RESULT : PM10/SENTINEL-5 AOD (2/2)



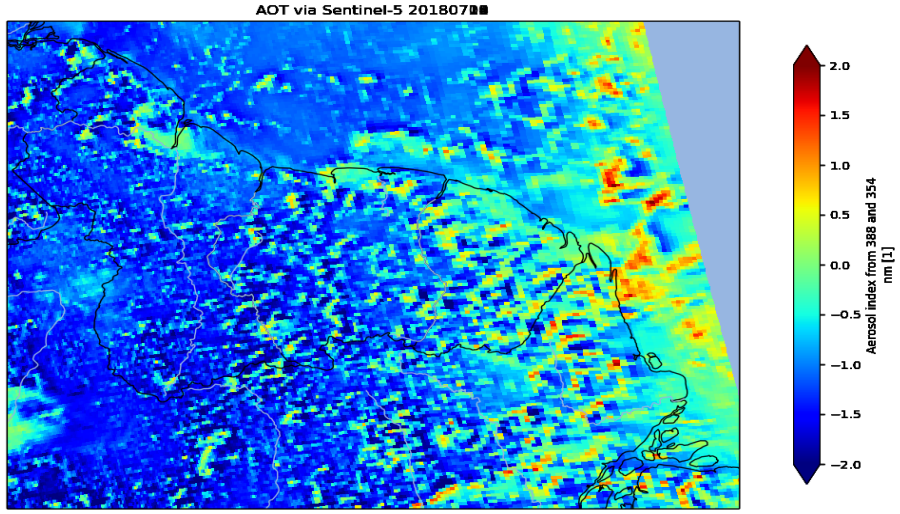
April 1st, 2022 : PM10<50 ug.m-3



April 2, 2022 : PM10<50 ug.m-3



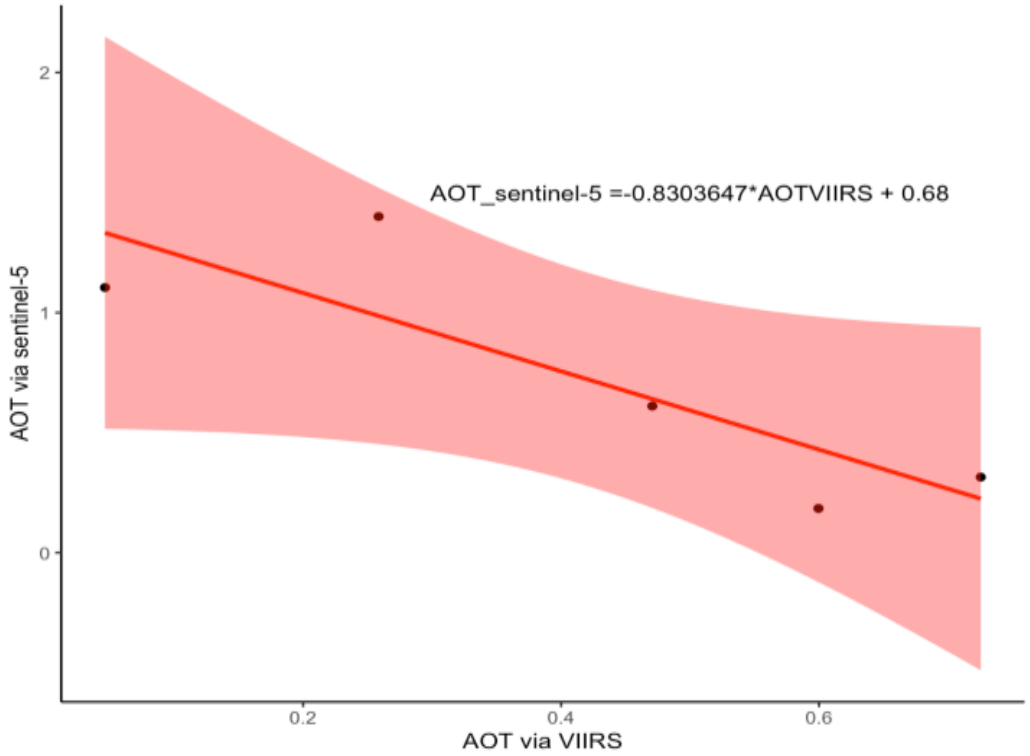
April 3, 2022 : PM10<50 ug.m-3



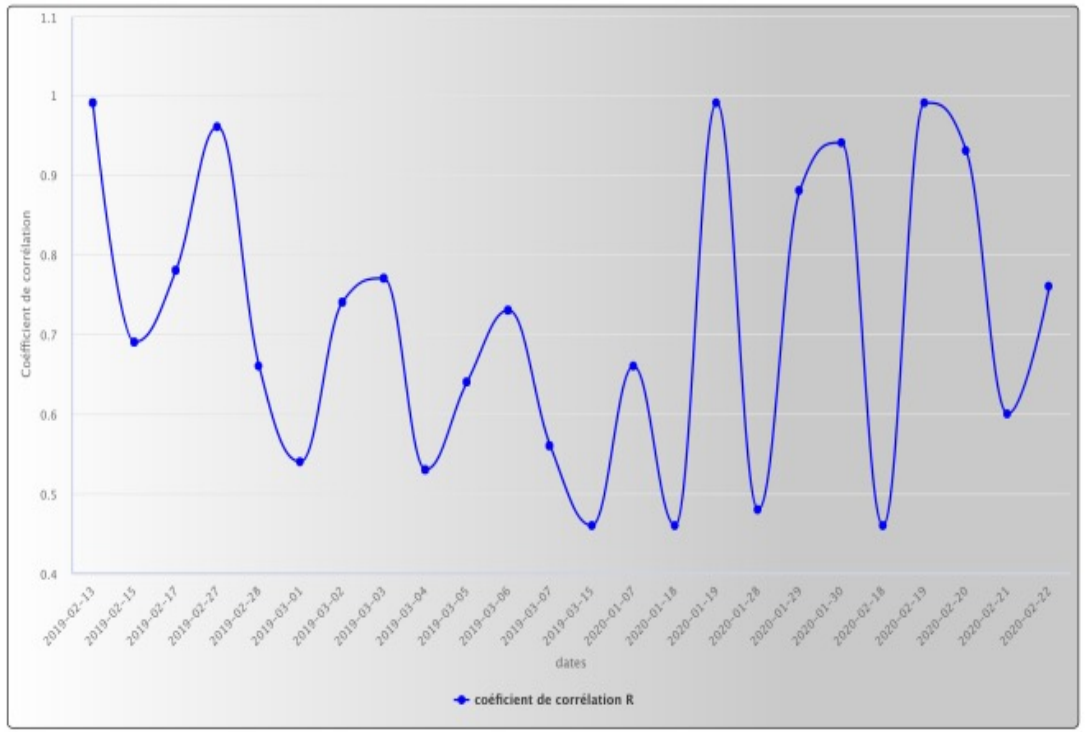
July 21, 2018 : PM10<50 ug.m-3

CORRELATION

During his Master internship, Moustapha Gning who work with Abdennebi Omrane and me was interrested in the comparison between AOD from Sentinel-5 images and AOT from VIIRS



VIIRS and Sentinel-5 correlation for 04/03/2019

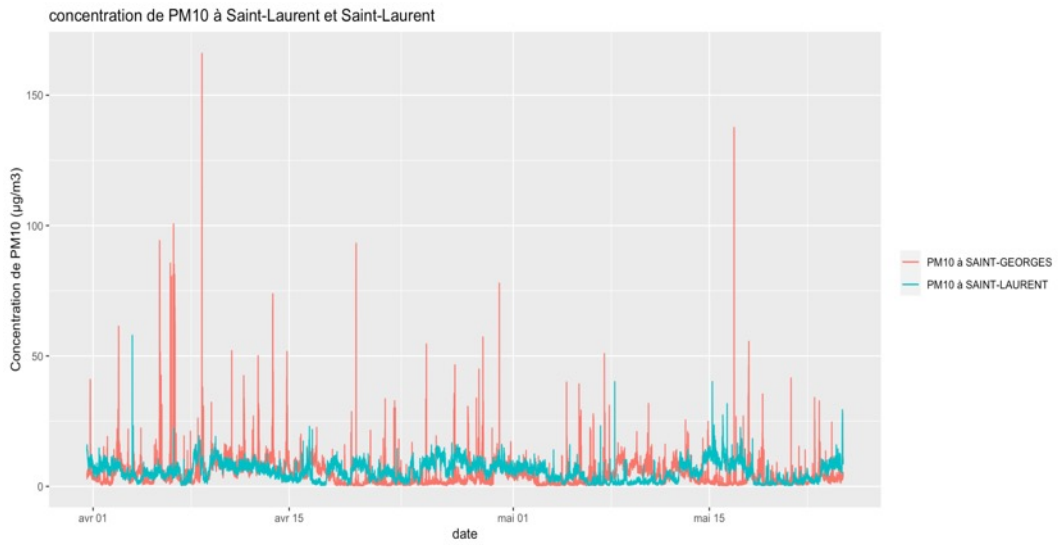


PM10 and AOD correlation over 25 days

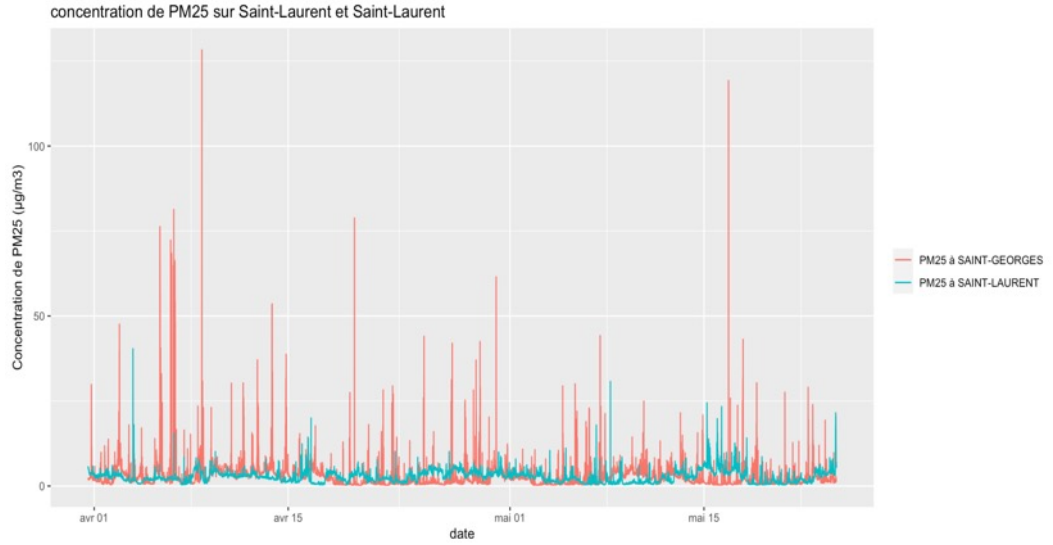
This figure shows the correlations between the PM10 data from the stations of Cayenne, Kourou and Matoury and the AOT values extracted in these areas. We can see that they are generally correlated (most of them higher than 0.5).

ATMO TRACK DATA

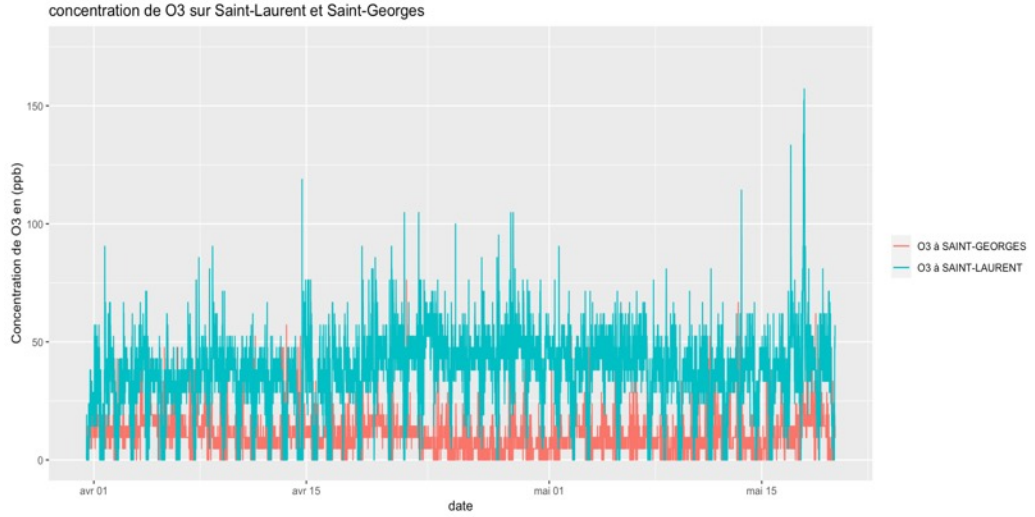
PM10 Concentration



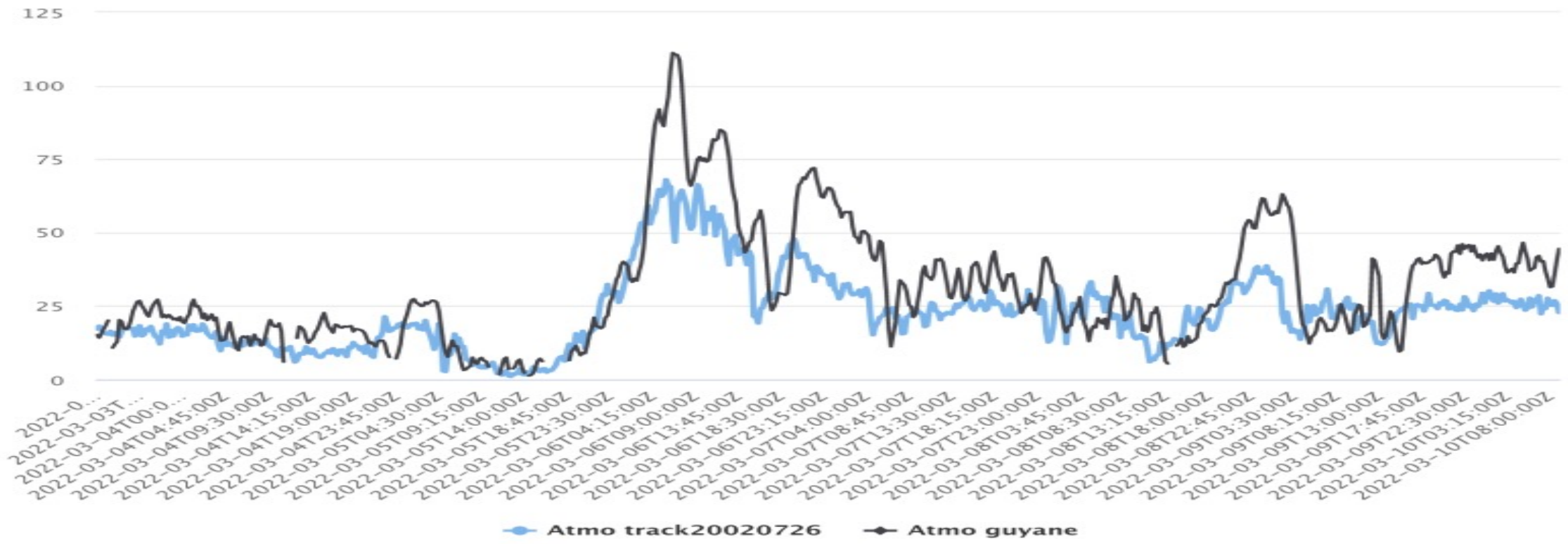
PM2.5 Concentration



Ozone Concentration



PM10 ATMO TRACK DATA COMPARED TO PM10 FROM TEOM

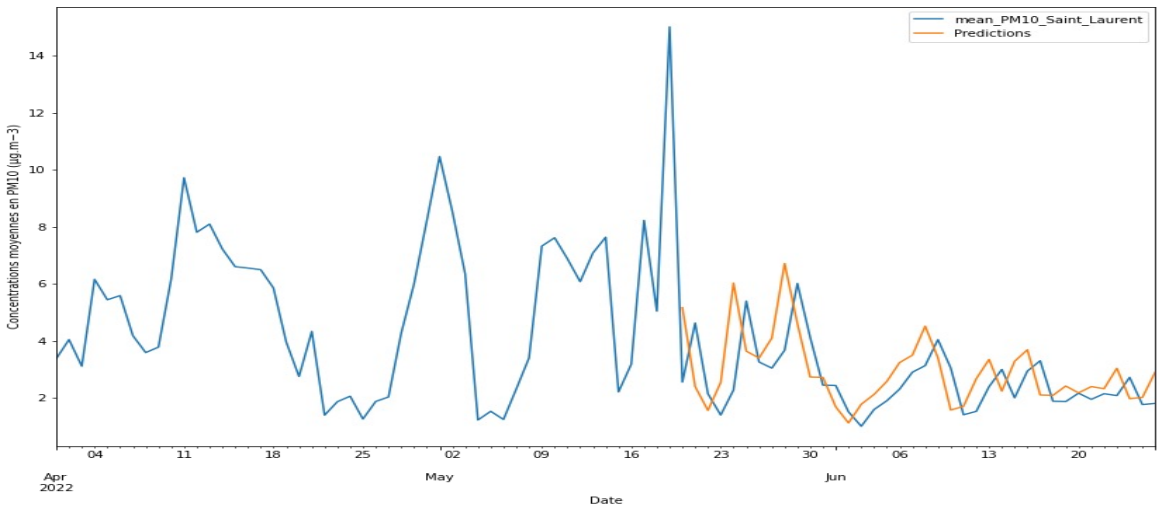


For this example in Cayenne, the proportionality coefficient is equal on average to 0.8440.
The correlation coefficient is equal to 0.8429.

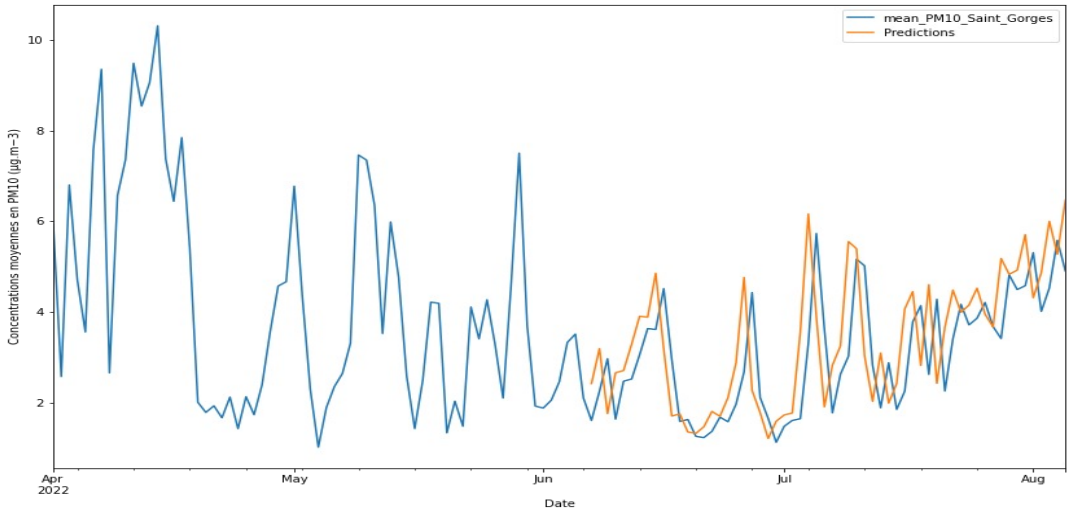
We conclude that the PM10 values of the TEOM and the Atmo Track are relatively well correlated.

ARMA (AUTO REGRESSIVE MOVING AVERAGE) MODEL

ARMA MODEL (1,0) over Saint-Georges



ARMA MODEL (1,0) over Saint-Laurent



For a given ARMA(p,q) model, we may rearrange a_t as

$$a_t = X_t - \phi_1 X_{t-1} - \ldots - \phi_p X_{t-p} - \theta_1 a_{t-1} - \ldots - \theta_q a_{t-q}$$

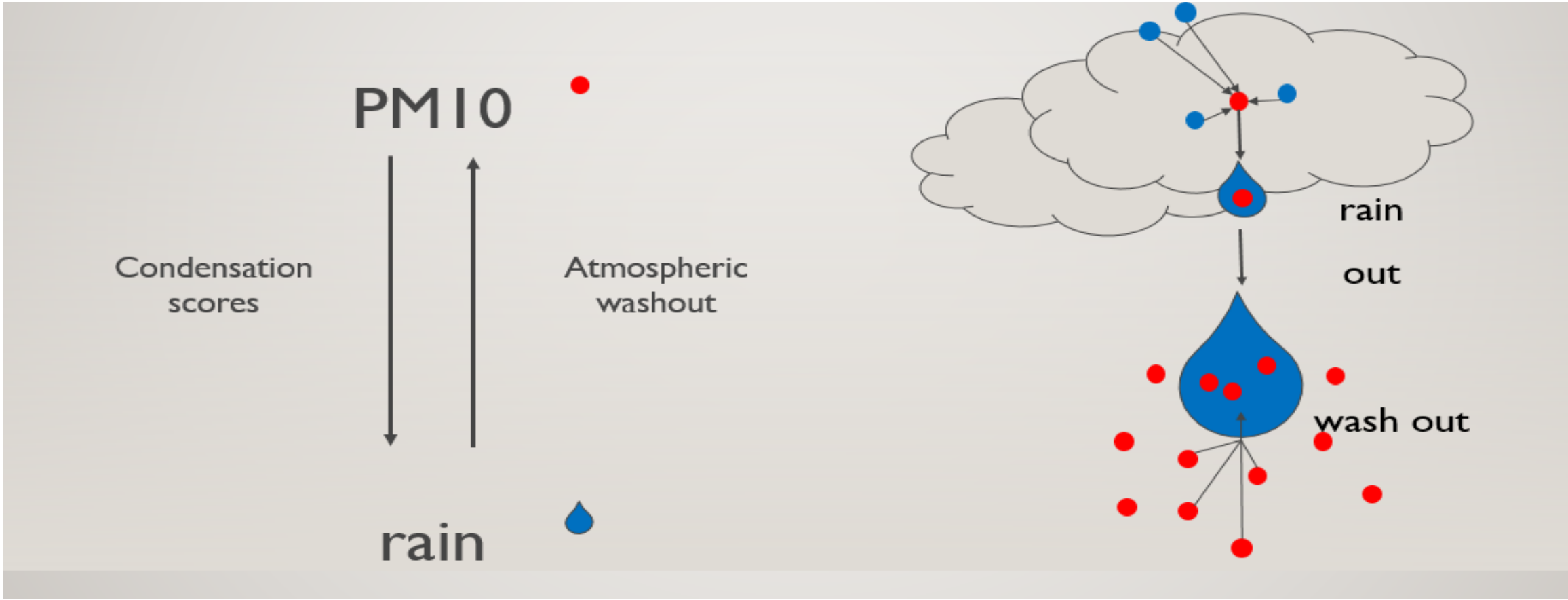
The residuals of a fitted ARMA(p,q) model is

$$\hat{a}_t = X_t - \hat{\phi}_1 X_{t-1} - \cdots - \hat{\phi}_p X_{t-p} - \hat{\theta}_1 a_{t-1} - \cdots - \hat{\theta}_q a_{t-q}$$

where $\hat{\phi}_k, \hat{\theta}_k, \forall k$ are the parameter estimates

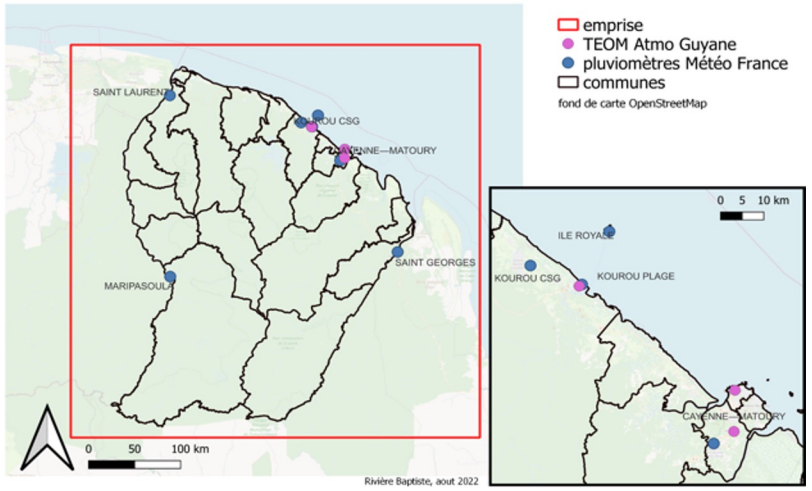
THEORY OF INTERACTIONS BETWEEN RAINFALL AND PM10

We also researched the interaction between rainfall and desert dust aerosols with Baptiste Rivière, an engineering intern from the Ecole Nationale des Sciences Géographiques (ENSG)

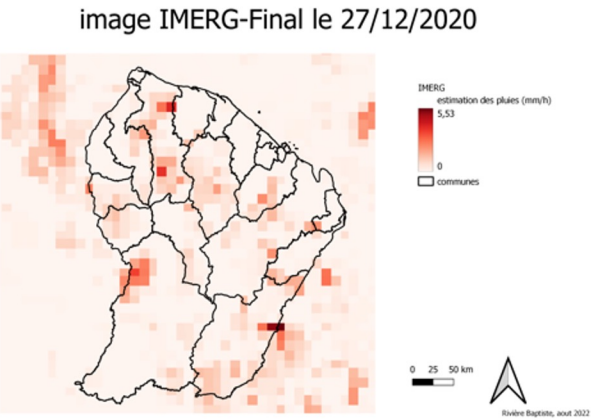


PROGYSAT
Projet régional d'observation des Guyanes par satellite

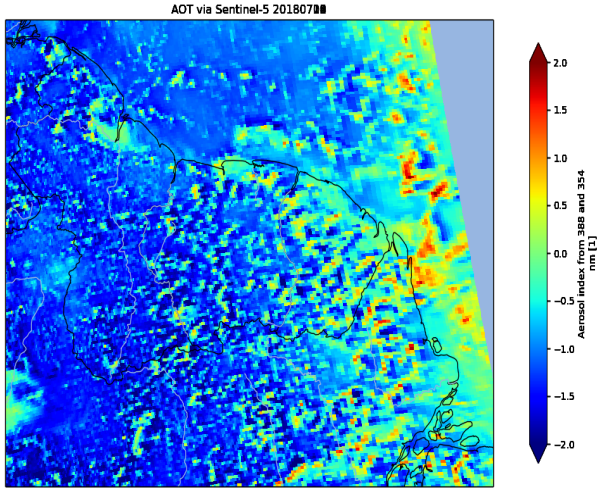
DATA



Distribution of rain gauges and TEOM in French Guiana



	ground measurement	satellite image
rain	Rain gauges	IMERG
PM10	TEOM	AOT, AI (UVAI)



METHOD (1/2)

Search for correlation between rain gauge data and IMERG satellite images

Month	Pearson correlation	RMSE(mm)	BIAS	Rain Mean (mm)
April-May	0.704	24.339	-0.827	16.42
Sept-Oct	0.373	5.202	-0.665	1.52
Dec-Jan	0.665	14.353	-0.799	8.52

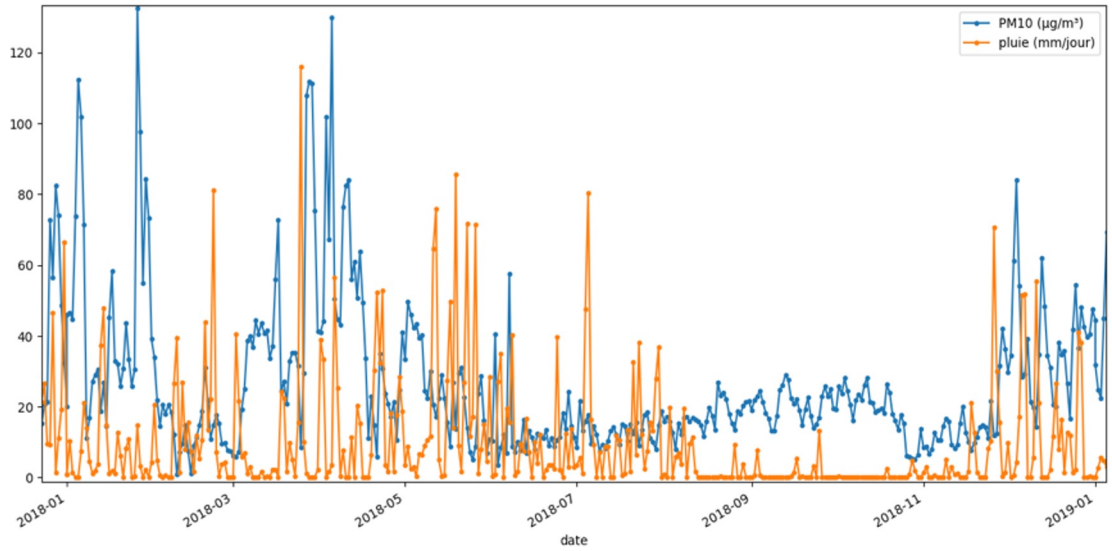
METHOD (2/2)

We looked at :

- relationships between two time series

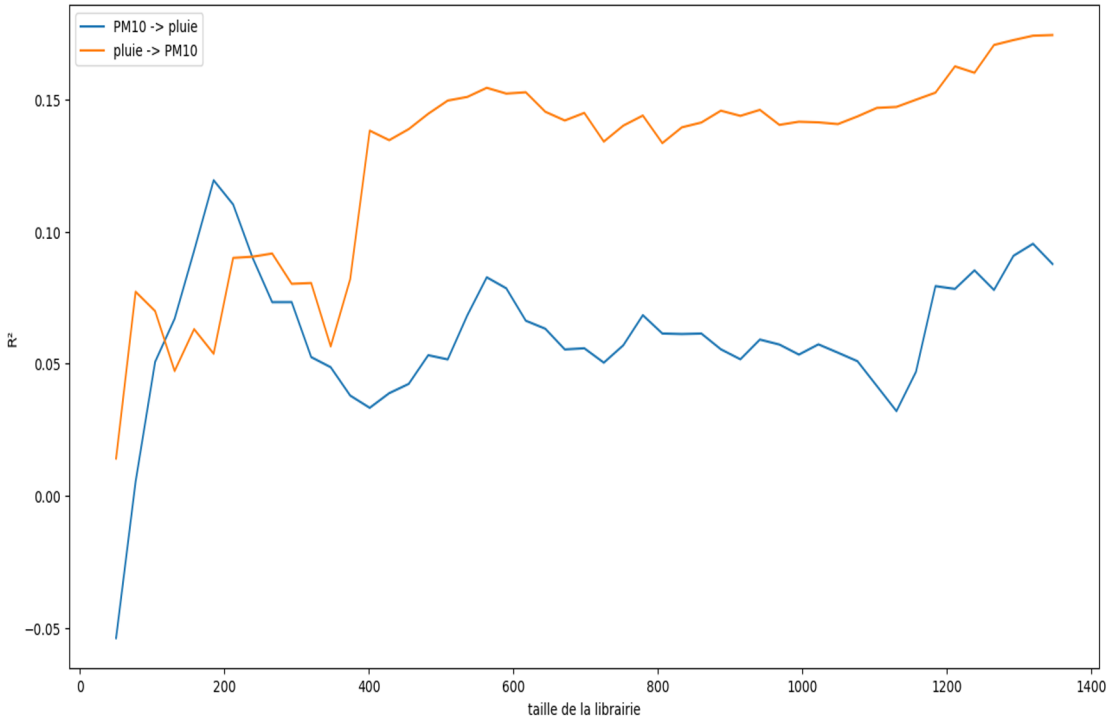
- the coherence function: and in particular the phase shift between two series

- the convergent cross correspondence : and in particular influence of one series on the other

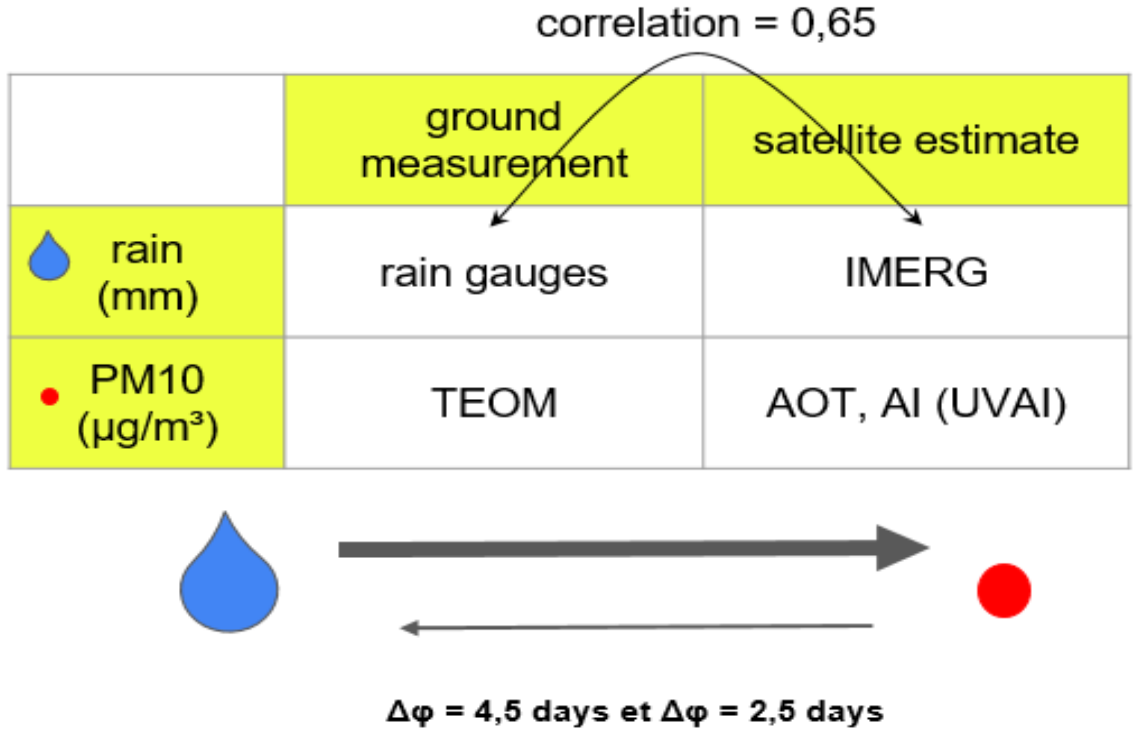


Temporal evolution of PM10 concentration and rainfall series in 2018

RESULTS (1/5)



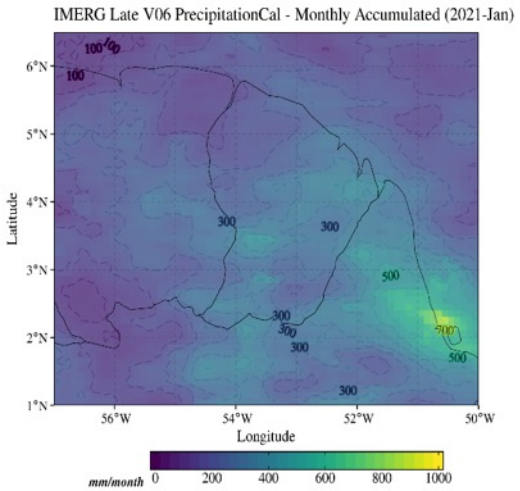
Convergent cross-matching from TEOM measurements and rain gauge measurements

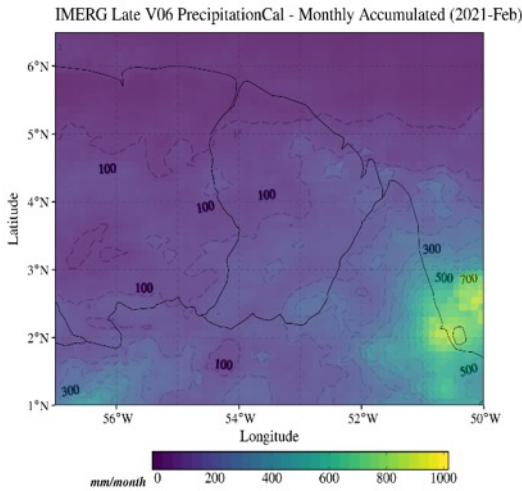


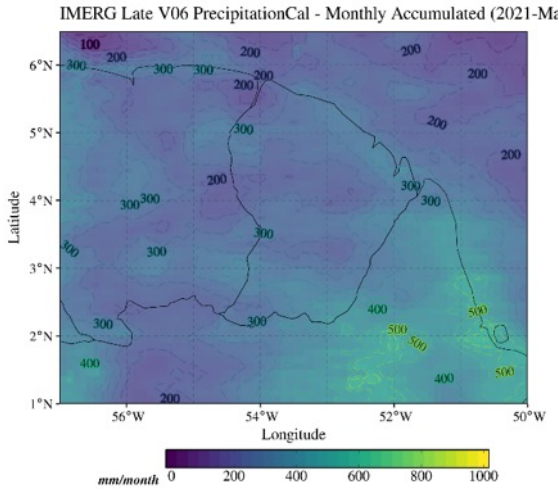
We conclude here that the effect of rain on Saharan dust leaching is greater than an opposite effect. There is a phase shift of 2.5 or 4.5 days between the two.

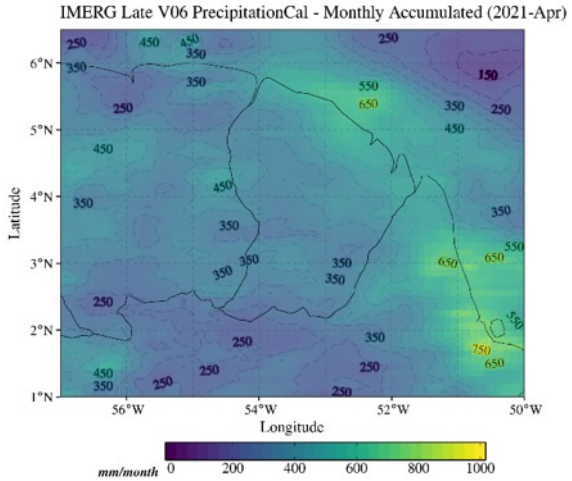
RESULTS (2/5)

With Adrien Paris and Weather Force, I have carried out a new study for the year 2021. This year, which has been the wettest in the last five years, should make it possible to verify the correlation obtained previously.



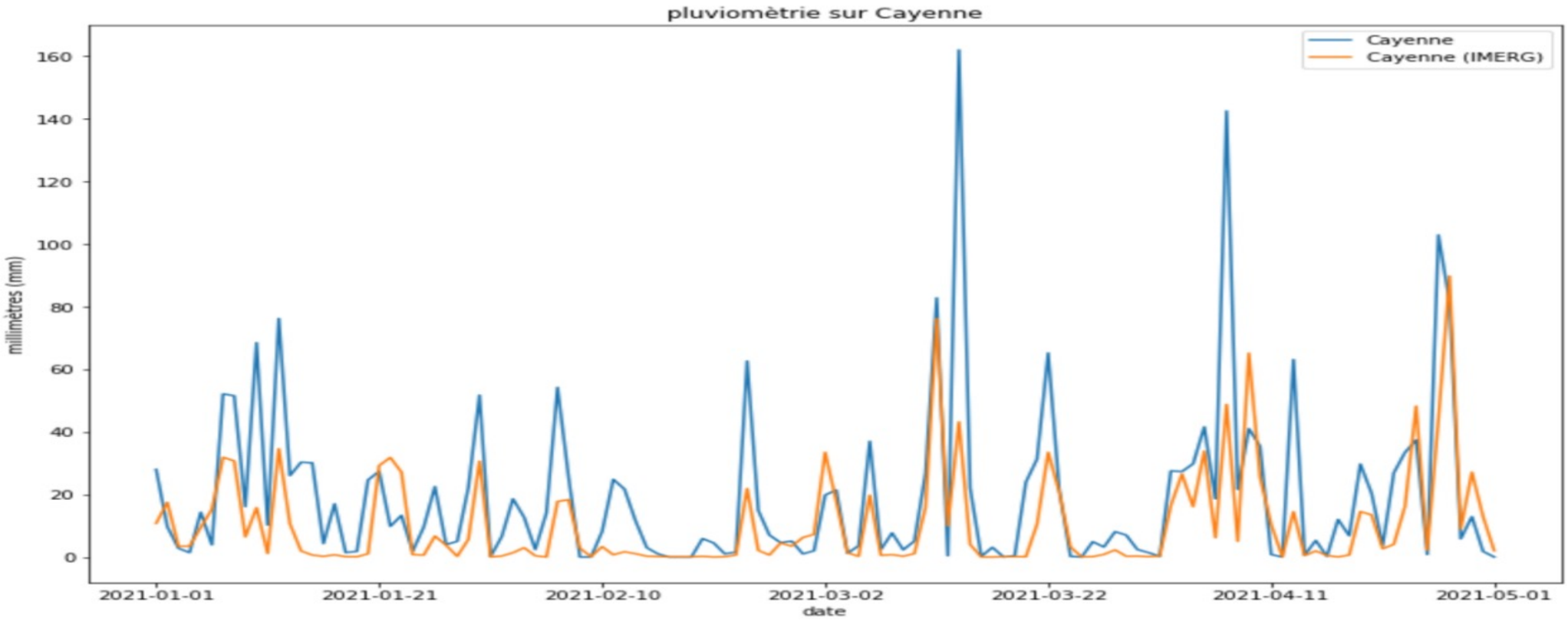






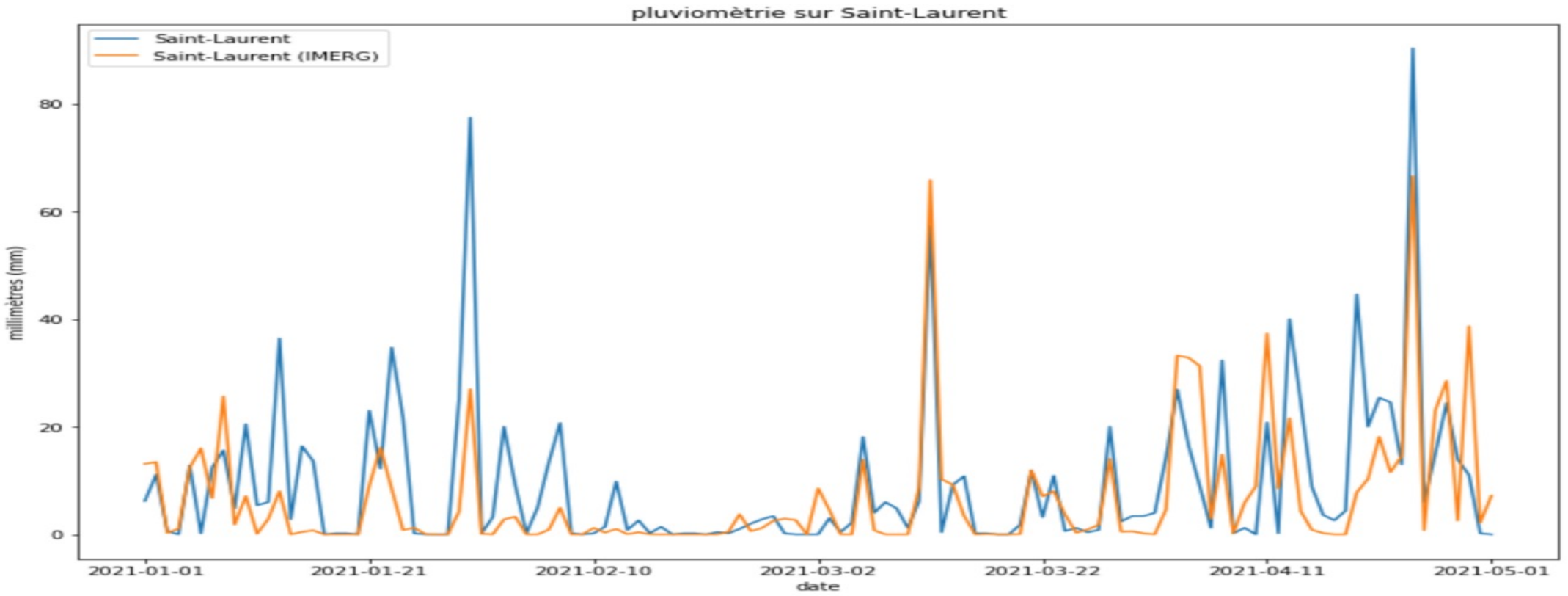
From the IMERG rainfall data for French Guiana, we can see that for the month of January 2021 we had very high rainfall, with a cumulative value of 300 mm for the month of January 2021 over almost all of French Guiana and its closest neighbours.
During April 2021, rainfall continued to intensify along the coast of French Guiana, with cumulative values close to 650 mm. Inland and in the eastern and western cross-border regions, however, rainfall is likely to be between 350 and 400 mm.

RESULTS (3/5)



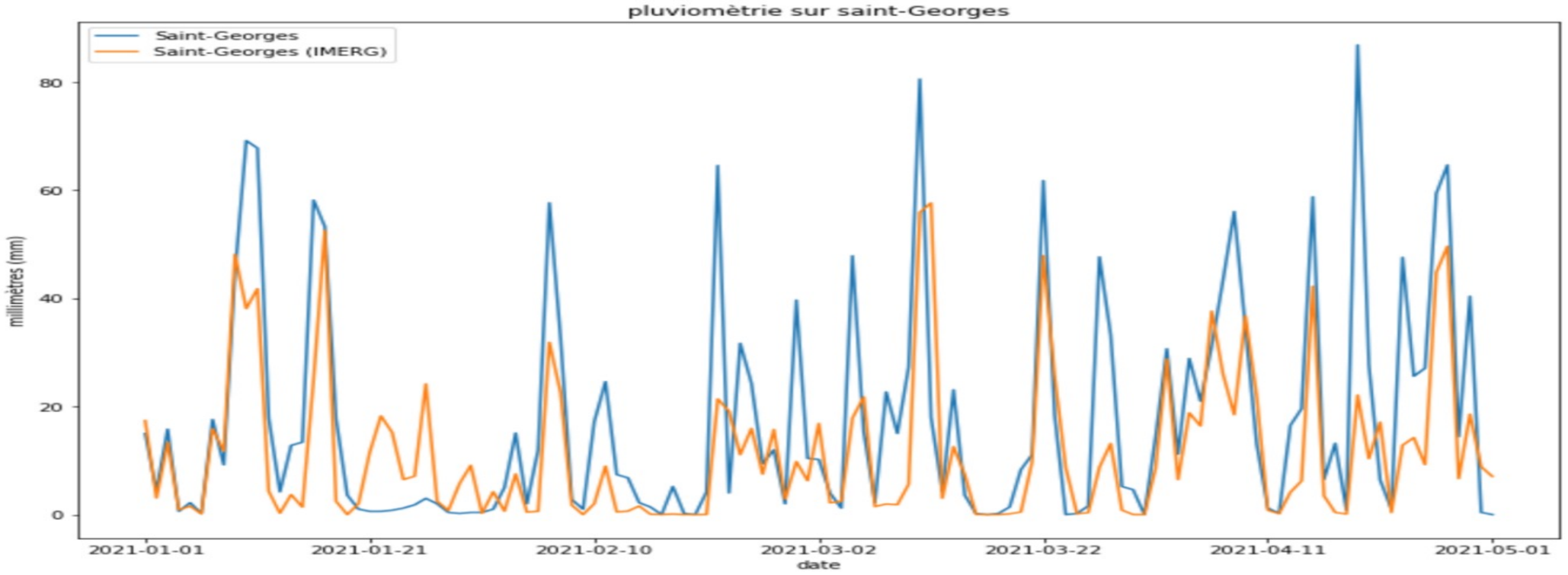
From this figure comparing rainfall data from Météo France and IMERG for the year 2021 in Cayenne, we can see that the cumulative values of rainfall data from IMERG and Météo France are very close during the months of heavy rainfall. The correlation coefficient for these series is 0.73. This means that the results are almost identical.

RESULTS (4/5)



In this figure comparing rainfall data from Météo France and IMERG for the year 2021 in Cayenne, it can be seen that the cumulative values of rainfall data from IMERG and Météo France are very close during months of heavy rainfall. The correlation coefficient for these series is 0.73. This means that the results are almost identical.

RESULTS (5/5)



We observe that the cumulative values of rainfall data from IMERG and Météo-France are very close for most of the periods of heavy rainfall in Saint-Georges-de-l-Oyapock. The correlation coefficient for these series is 0.75. This means that the two series are well correlated.

CHARACTERIZATION OF BIOMASS (FRENCH GUIANA/BRAZIL AND FRENCH GUIANA/ SURINAME) FROM SEAS DATA AND BY REMOTE SENSING AND MODELING TOOLS.

- **Objective :**

Estimate the biomass of different types of vegetation in the transboundary areas of French Guyana/Brazil and French Guiana/Suriname based on field measurements obtained through forest inventories and available data, to check the carbon stock in each type of vegetation.

- **Expected Results :**

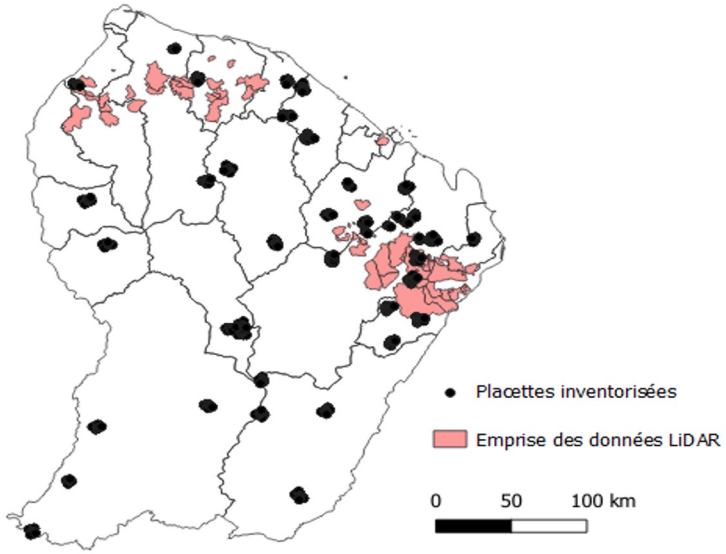
- A database by type of vegetation, biomass and its carbon stock, with the objective of better territorial management.
- Cartography of vegetation and land cover types using the images provided by axis 1.

- **Benefits for French Guiana, Surinam and Brazil :**

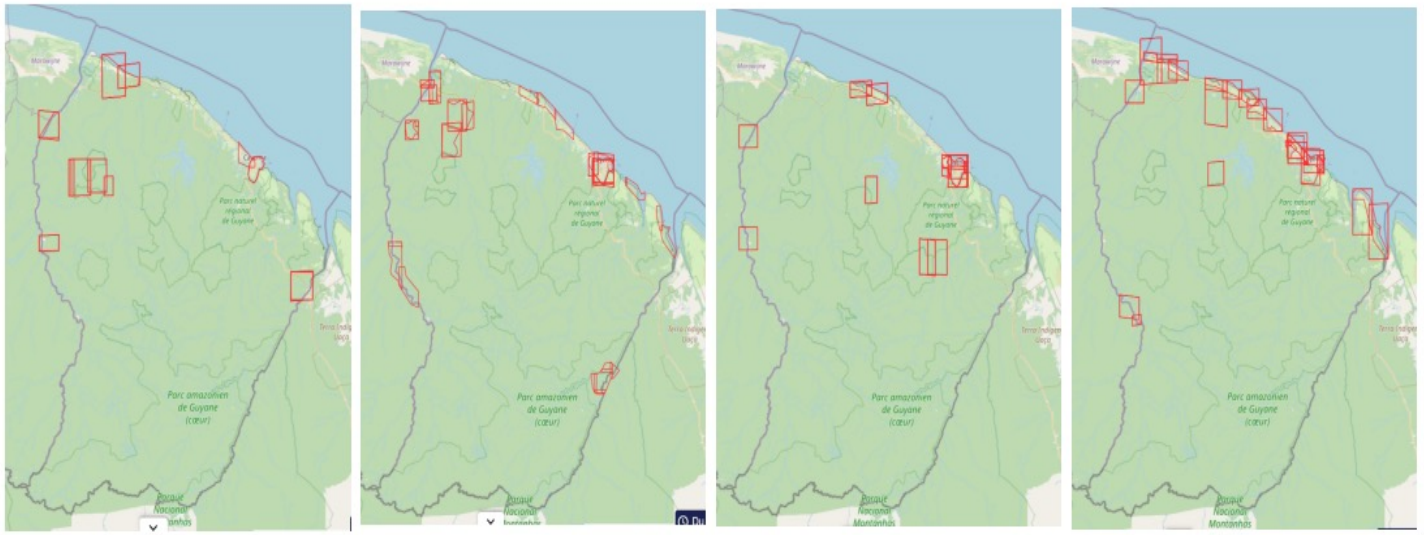
Quantifying the carbon (emitted and / or stored) of forest biomass in transboundary areas French Guiana / Brazil and French Guiana / Surinam: data from time series of NDVI, SAVI and fractional images (shade, vegetation and soil) will be analyzed according the Franca Method (2009).

DATA

This theme was proposed by Mabiane Franca and we worked with Judith Nabec, an engineering intern from the Ecole Nationale des Sciences Géographiques (ENSG). Alexandre Defossez and Yousef Fouazi participated in this study.



Map of LiDAR and forest inventory data available in French Guiana produces by ONF



Range of Pleiades images available between August 1 and October 31 for the years 2016 to 2019

METHOD (1/2)

- 1) Compare the forest inventory data obtained by the ONF which date from 2010 for Saint-Laurent and 2013 for Régina with the LIDAR data obtained by the ONF and which date from 2016 and 2018

- 2) Use of allometric equations:

- Obtained from the work of Dourdain and Hérault in 2015

- Establish differentiated equations for French Guiana, Brazil, Suriname and Guyana

- Differentiated equations for aboveground biomass, bark, trunk, roots

METHOD (2/2)

Implementation of the FOTO method to extract biomass

THRS image

↓ FOTOTEX application

Score on the PCA axis

Plugin « Value Tool » ↓ $\frac{largeur_{image}}{largeur_{vignette}} * \frac{hauteur_{pixel}}{hauteur_{vignette}} + \frac{largeur_{pixel}}{largeur_{vignette}}$

Model for inferring biomass values from scores on the PCA axes by a Random Forest algorithm

↓ Application of the RF model

Biomass mapping of the entire input image

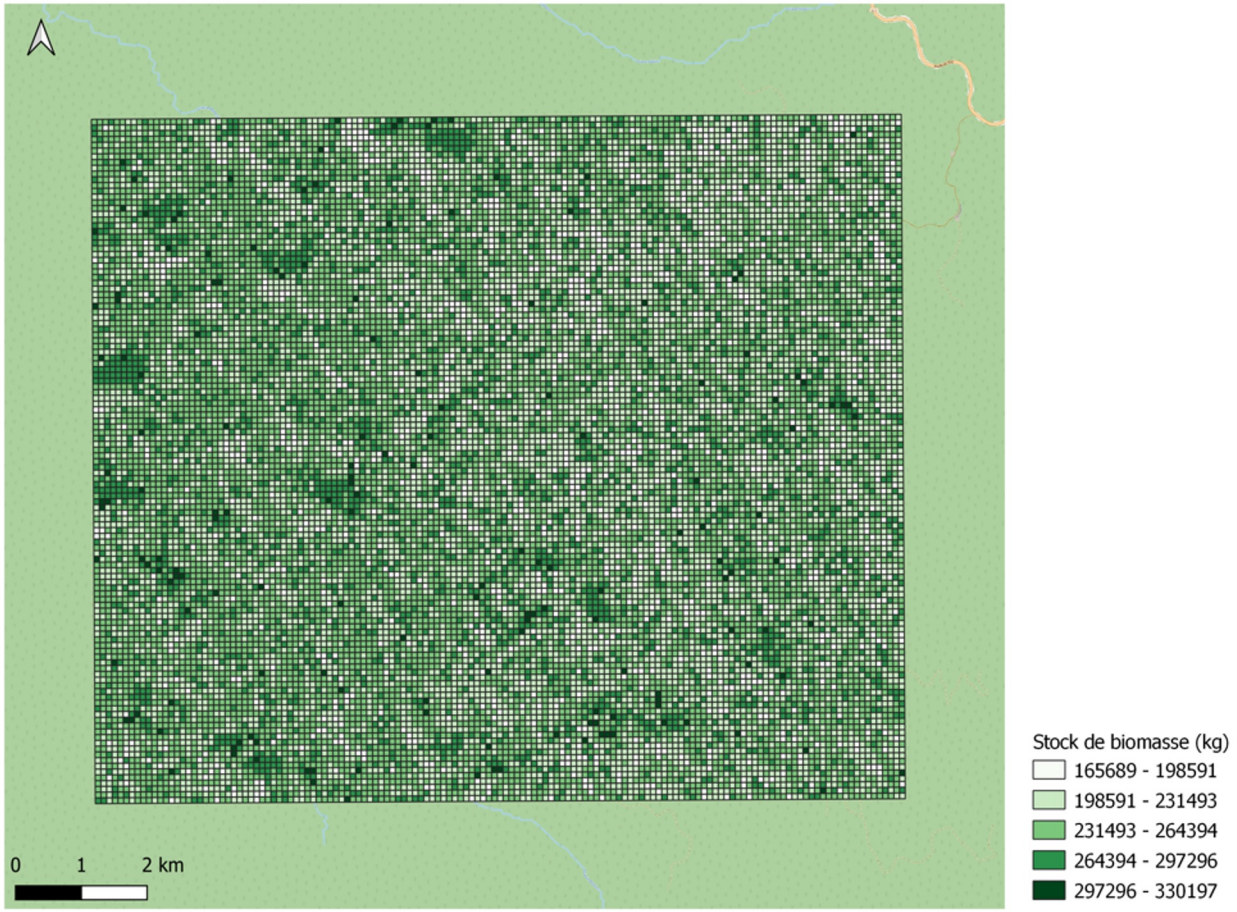
RESULTS (1/2)

	Result 1	Result 2	Result 3
Average biomass per plot in Saint-Laurent	39 442	27 322	27 565
Average biomass per plot in Régina	58 884	64 614	61 864

Comparative table of the results obtained with the 3 methods tested (result 1 corresponds to the method without LiDAR data, result 2 to the method with raw LiDAR and result 3 to the method with modified LiDAR)

Proximity of the results, which suggests that the results obtained are reliable first indicators of the biomass stock in the areas concerned

RESULTS (2/2)



Mapping of the biomass on a part of the Regina municipality

Forest biomass estimates from Lidar data from ONF acquisition campaigns and FOTO output images could constitute a complementary data source for the approach proposed by Jean-Baptiste Féret and Alexandre Defossez to map forest spectral diversity.

Either as validation data and allow discrimination of vegetal communities on biodivMapR cartographic products, or, for Lidar data, as a new metric combined with spectral information to be integrated at the input of the biodivMapR chain to produce a new discrimination axis of forest communities.

LEGAL FRAMEWORK VERIFICATION OF FRANCO-SURINAMESE AND FRANCO-BRAZILIAN SAFETY MEASURES AND STANDARDS OF POLLUTION (WATER, AIR),

Plumma Anhelo Albarelo and Rosuel Lima-Pereira worked on this theme.
Plumma will present you this work now.

Last time, they have explained us that, the ordinances and resolutions that we have on pollutants in Brazil refer mostly only to the handling of the pollutant element and the risks in case of accident with them, however, in contradiction there is no concern in establishing quantitative levels of alert or emergency values, as in the case of pollutants such as **Lead** and **Benzene.**

They have only found compilations of resolutions, decrees and ordinances on the handling of Benzene in gas stations and how to avoid an accident or prevention against prolonged exposure. **Nitrogen dioxide** is one of the rare cases in which its amount values, limits and risks, with Initial Standards (IS) and Final Standards (FS) are described in law.

OBJECTIVES OF THE LEGAL FRAMEWORK VERIFICATION

Goal of this research : **suggest a means to combine the environmental legislation in order to improve the natural and human conditions in French Guiana, Surinam and Brazil.**

➔ It is mandatory to know and understand how these countries prioritize the environmental rights inside their respective legal system.

Environmental legislations in BRA, SUR & FRA :

- **In common :** preservation of the environment is written in the constitutional text of the 3 countries
- **Differences :** the way the environmental right is handled in the subconstitutional legislation of each country.

RESULTS : THE STATE OF THE LEGISLATION IN EACH COUNTRY

- Brazil and Surinam : sparse and fragile legislation through resolutions and legal decrees
- France : **being part of the European Union,** it has a robust legislation because it has a different treatment regarding the importance of the environmental laws.

Right is shaped by the society in which it finds itself.

What can we perceive ?

- Brazil and Surinam « shape » the environmental legislation aiming only economic benefits,
- European Union → France → legislation aims to protect quality of life.

POLITICAL ECOLOGY AND THE PERCEPTION OF NATURE BY SOCIETY

- In this work, we also studied the concept of **political ecology**, and although it has more radical and flexible ramifications, the **prevailing opinion** is that beyond the laws, **it is necessary to change the way of thinking of society with respect to nature**.

- Any international treaty signed between Brazil, Surinam and France has to be permeated with **profound changes in society :** strong laws that do not get trapped in playing into the hands of greedy interests.

CONCLUSION (1/3)

- Regarding Saharan dust, as we had PM10 measurements for many years only on Cayenne with the TEOM, we tried to complete our measurements in other geographical areas from AOT data 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 considering cloud free images.

- Regarding 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 allow us to look at the problems of respiratory. The study could be extended to Brazil and Suriname

CONCLUSION (2/3)

- Based on the comparison between rainfall data from IMERG satellite images and rainfall data from Météo France and CNES sensors, we obtained correlations of around 0.7 in the high rainfall season for the years 2016 to 2020. We can discuss these results with Marie-Paule Bonnet in the future.
- Our new study with Adrien Paris and Weather Forces shows that for a year with heavy rainfall such as 2021 and between the months of January and May, we have correlations greater than 0.7 for all the communes in French Guiana. This correlation even reaches 0.8 for the town of Kourou.
- This allows us to conclude that for episodes of heavy rainfall and in the absence of ground rain gauges, IMERG data can be interesting for studying rainfall in the cross-border regions of French Guiana, but not only. In fact, this is valid for the whole territory and its closest neighbours.

CONCLUSION (3/3)

- Forest biomass estimates from Lidar data from ONF acquisition campaigns and FOTO output images could constitute a complementary data source for the approach proposed by Jean-Baptiste Féret and Alexandre Defossez to map forest spectral diversity, either as validation data and allow discrimination of vegetal communities on biodivMapR cartographic products, or, for Lidar data, as a new metric combined with spectral information to be integrated at the input of the biodivMapR chain to produce a new discrimination axis of forest communities.

- It is necessary to think of a cross-border legislation that privileges the conservation of the environment and the reduction of pollutants to benefit the quality of life for all countries involved and not only for economic profit, which makes it a necessity to awaken awareness of Political Ecology and create public policies aimed towards the preservation of the Amazon.
- Plumma Albarela mentioned that any international treaty signed between Brazil, Surinam and France has to be permeated with **profound changes in society :** strong laws that do not get trapped in playing into the hands of greedy interests.