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

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SUMMARY

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

I -POLLUTANT ANALYSIS IN FRENCH GUIANA AND ITS FRONTIERS IN BRAZIL AND SURINAM

- **Main Objective :**

Complete the measurement campaigns carried out by the French Guiana Regional Air Observatory (ATMO Guyane) in transboundary areas.

It will help to have a better knowledge of pollution rates (natural and anthropic) and also to estimate health risks. A prediction scenario based on the rate of urbanization will be

- **Expected results :**

- cartography and prediction of their evolution according to the territory planning considered by the political authorities.
- New pollutants models (spatiotemporal evolution)
- Statistical analysis of pollutants

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

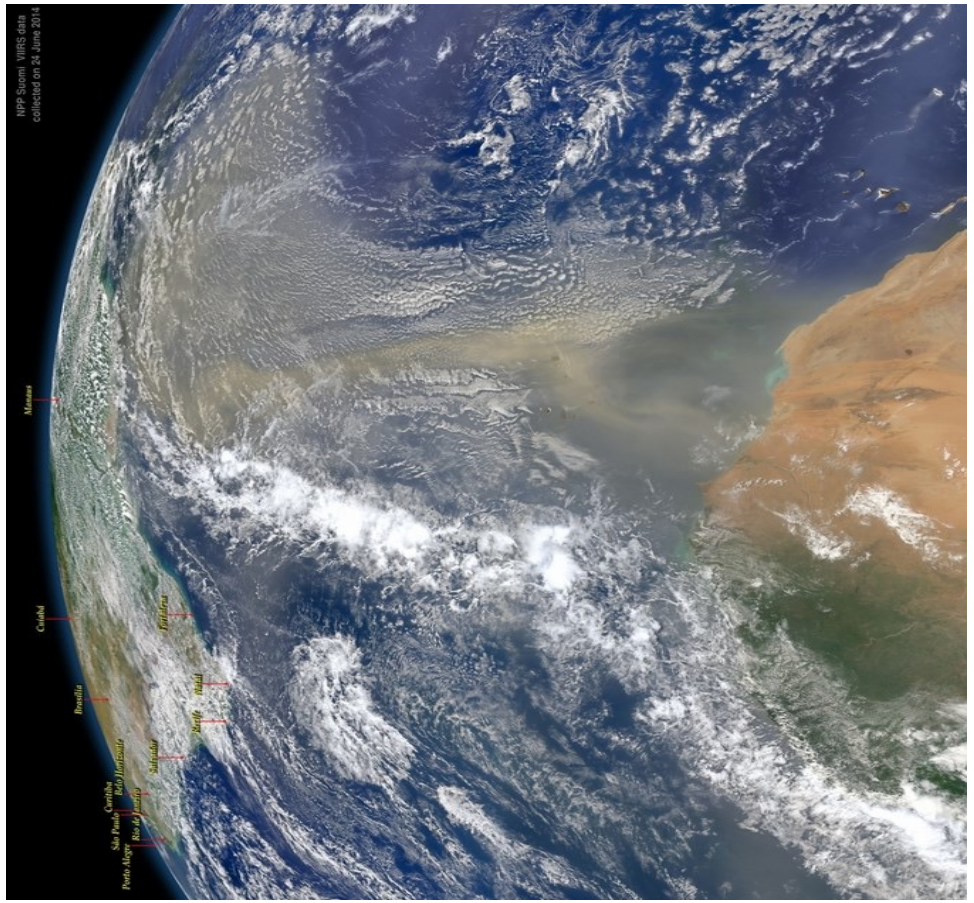
- Establishment of transboundary environmental monitoring of pollution (Suriname / French Guiana/ Brazil)
- Set up prevention plans in agreement with local public structures.
- Creation of an e-learning support dedicated to the monitoring of the evolution of pollutants (anthropic or not) in the Amazonian environment by satellites and through ground sensors.

NATURAL POLLUTANTS (1/2)

- Among the 2 major types of natural pollutants in French Guiana there are :

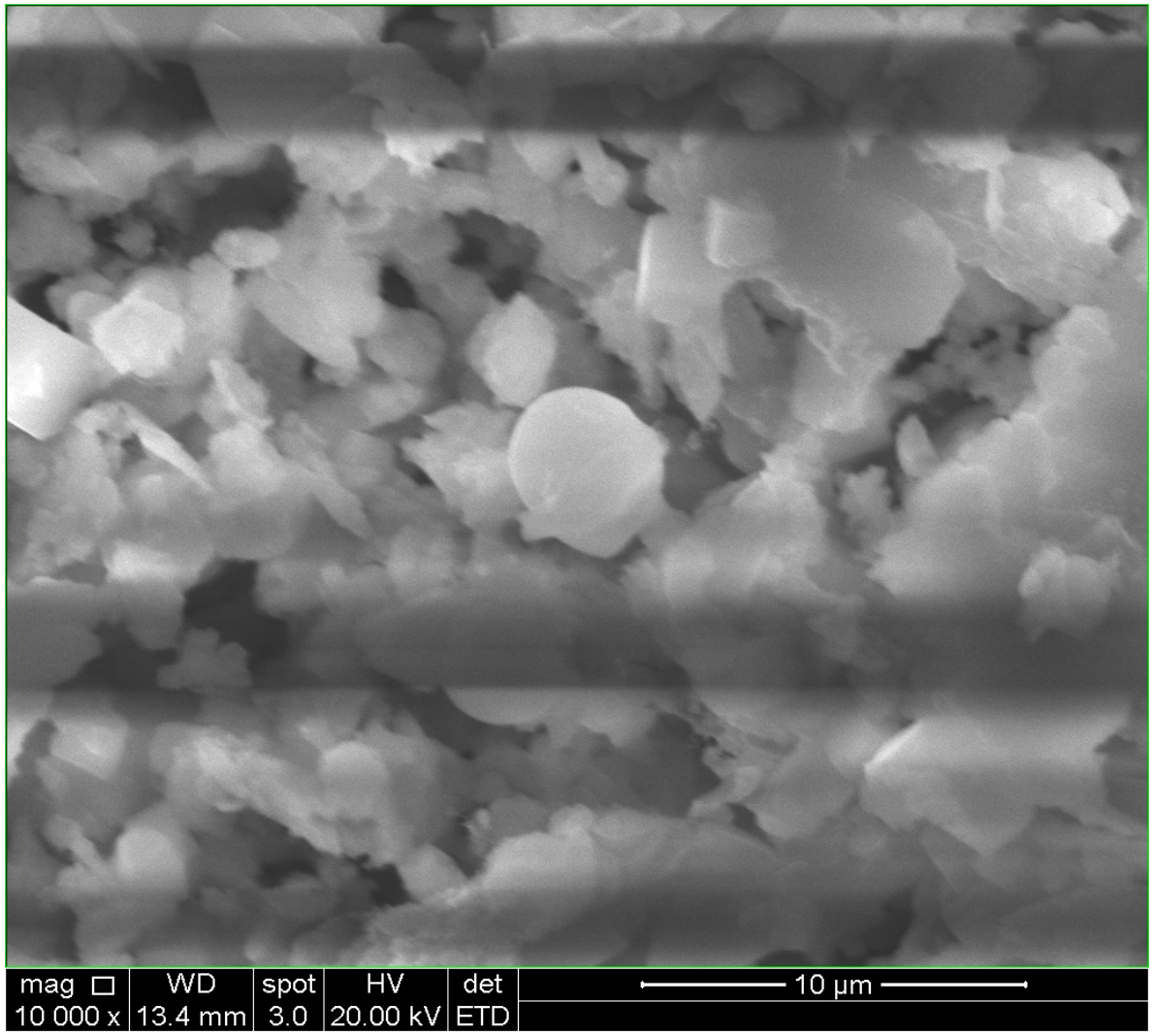
- Marine aerosol chlorine **(Gobinddass et *al.*, 2020)** et,

- Desert dust characterized by Atmo Guyane during measurements of PM10, PM2.5 and by satellite images with optical thickness extraction (AOT)

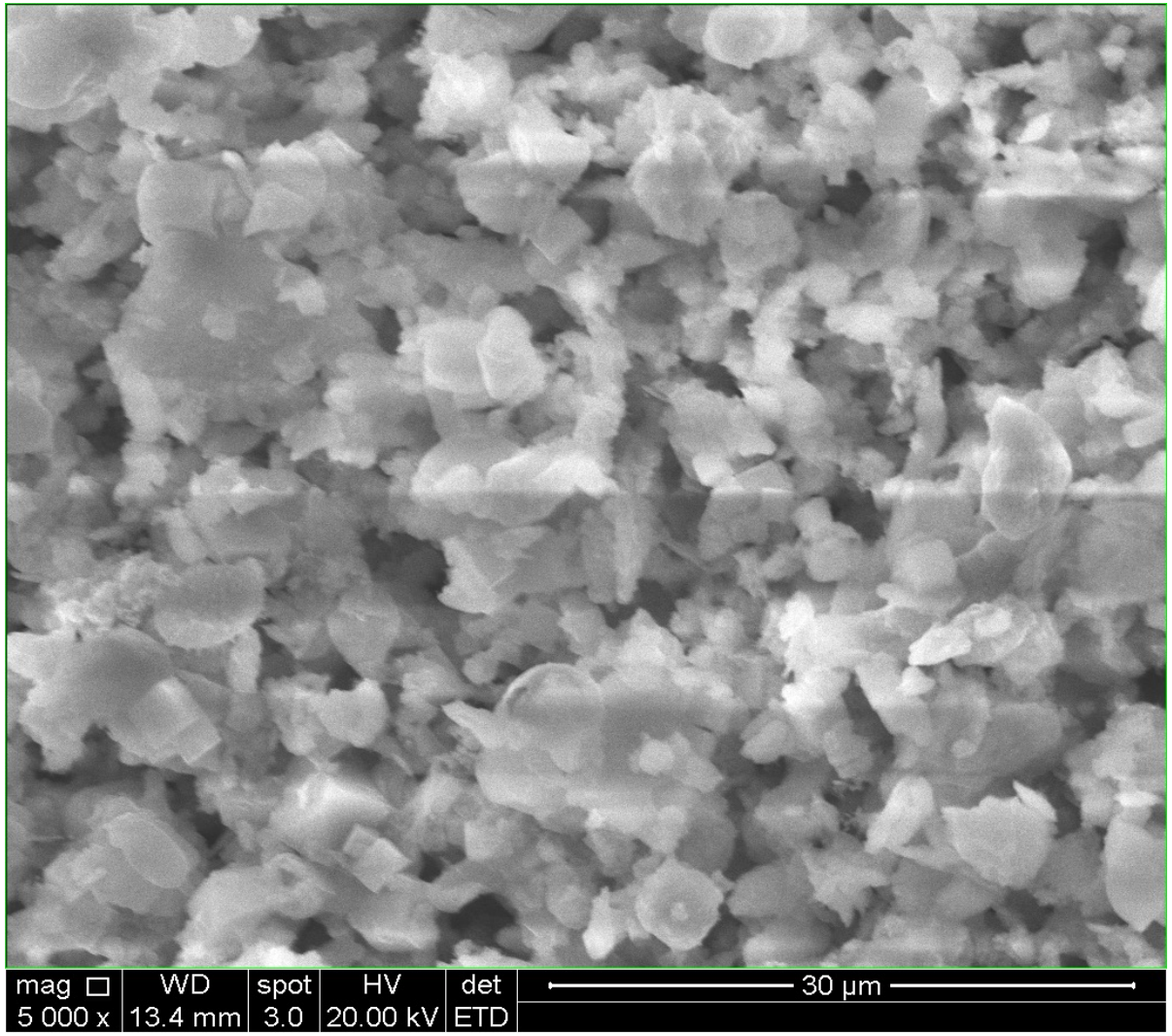


Desert dust transport from Africa to Franch Guiana (NASA)

NATURAL POLLUTANTS (2/2)



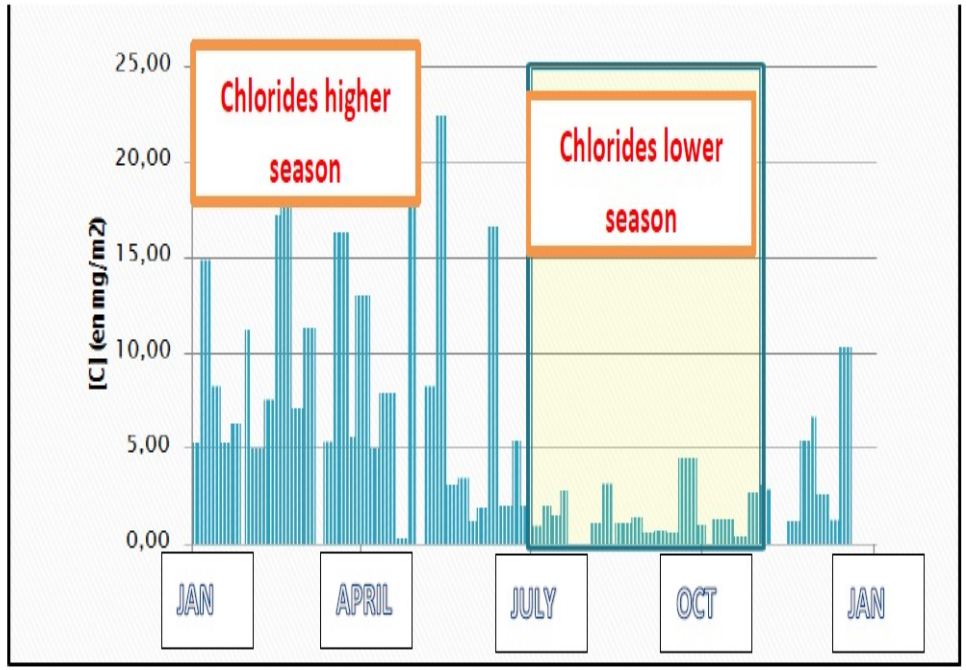
Aerosol dust Al Si by scanning electron microscope

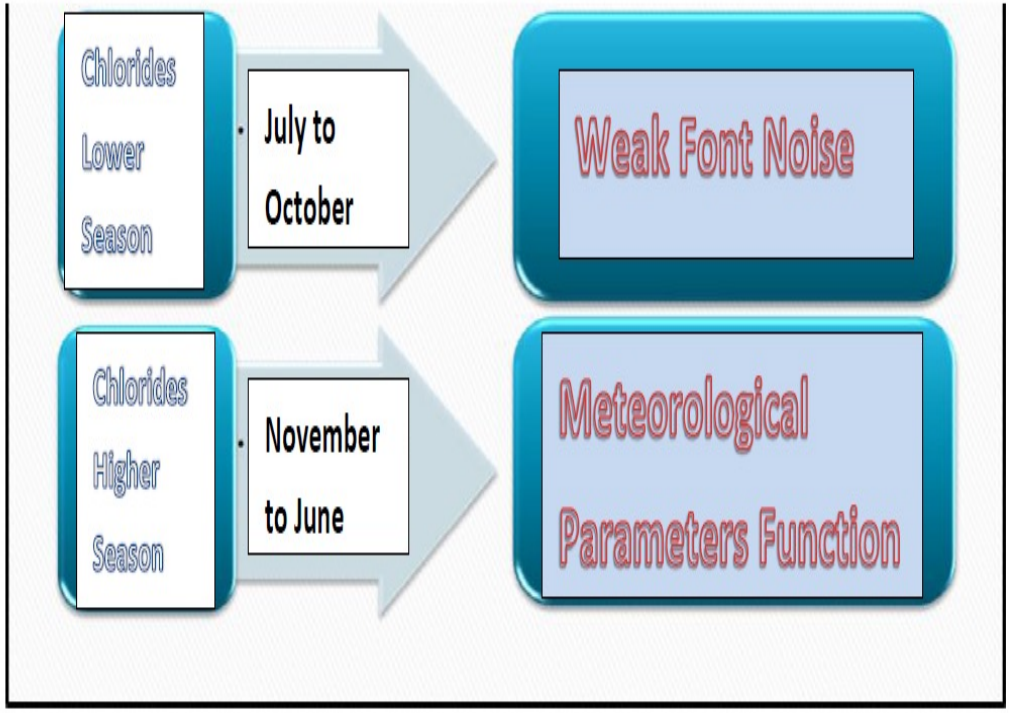


Marine aerosol Cl by scanning electron microscope

CHLORINE SEASON

Two differents seasons has been observed for a period of four years during deposition datas has been collected in French Guiana (Gobinddass et al. 2020).

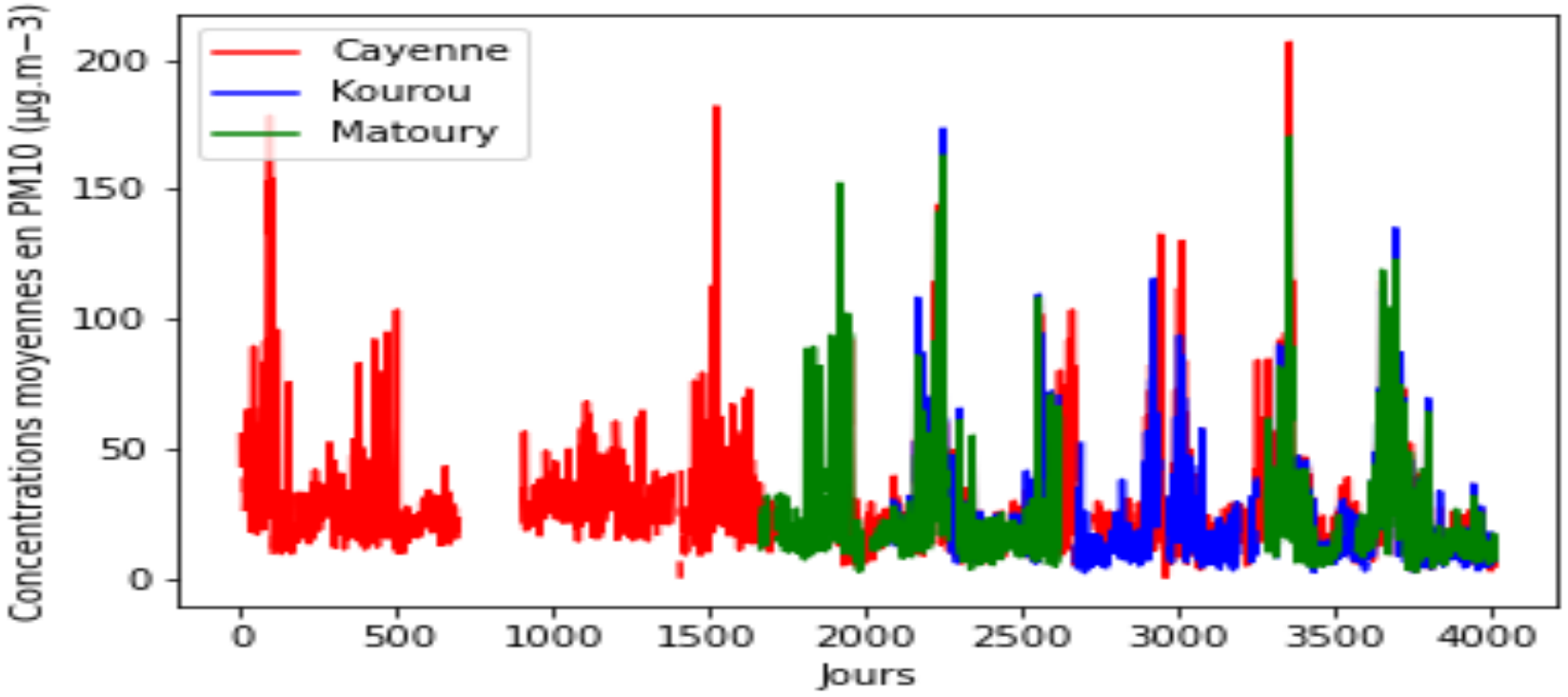




Higher and lower natural chlorides seasons

AEROSOL DESERT DUST PERIOD

In French Guiana (Sahara et Sahel, Gobinddass, 2021) every year desert dust particles coming from Africa is transported over the Atlantic Ocean in a westward flux.



Daily mean concentration of PM_{10} in Cayenne, Kourou et Matoury from 01-2010-01 to 21-2020-12

Every year, the high period of desert dust concentration is between December to April

METHOD (1/2)

1) The AOT parameters of images from Visible-Infrared Imager/Radiometer Suite Sensors (VIIRS) are compared to the PM10 sensor ground data from Thermo Scientific Tapered Element Oscillating Microbalance (TEOM)

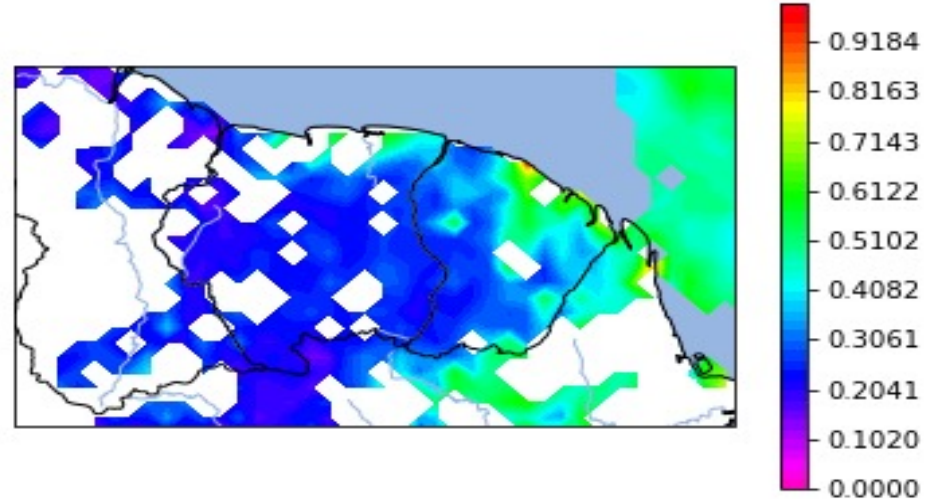
2) The AOD parameters of images from Sentinel-5 are compared to the PM10 sensor ground data from Thermo Scientific Tapered Element Oscillating Microbalance (TEOM)

3) Statistics computation and correlation's coefficient has been computed for 1) and 2)

4) The new sensors ATMO-TRACK obtained by PROGYSAT has been installed in Saint-Laurent du Maroni and Saint-Georges de l'Oyapock. One of the parameter obtained is PM10.
The PM10 of ATMO-TRACK has been compared to the PM10 of the TEOM

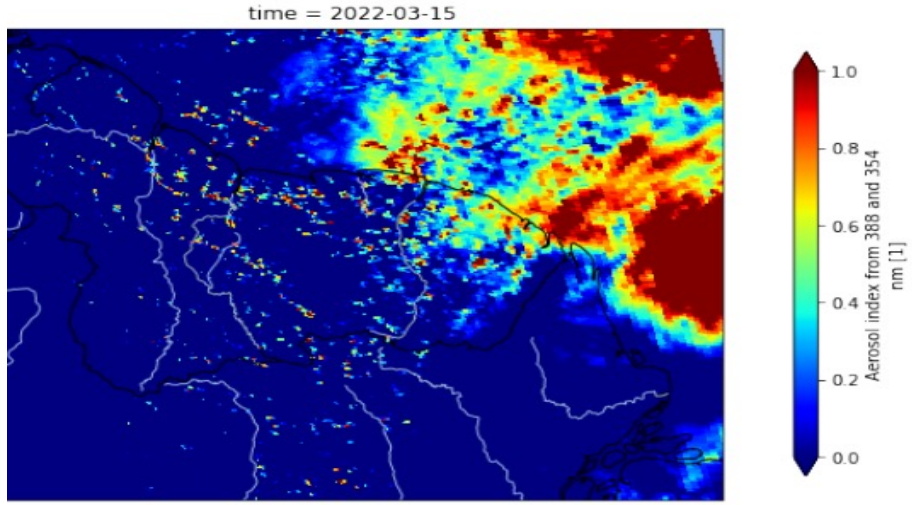
METHOD (2/2)

PROGYSAT's ATMO-TRACK



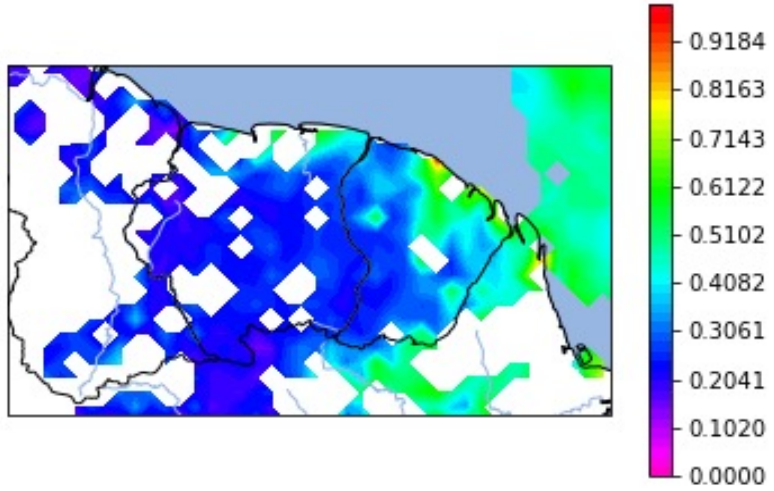
EXEMPLE OF VIIRS AOT

ATMO-GUYANE's TEOM

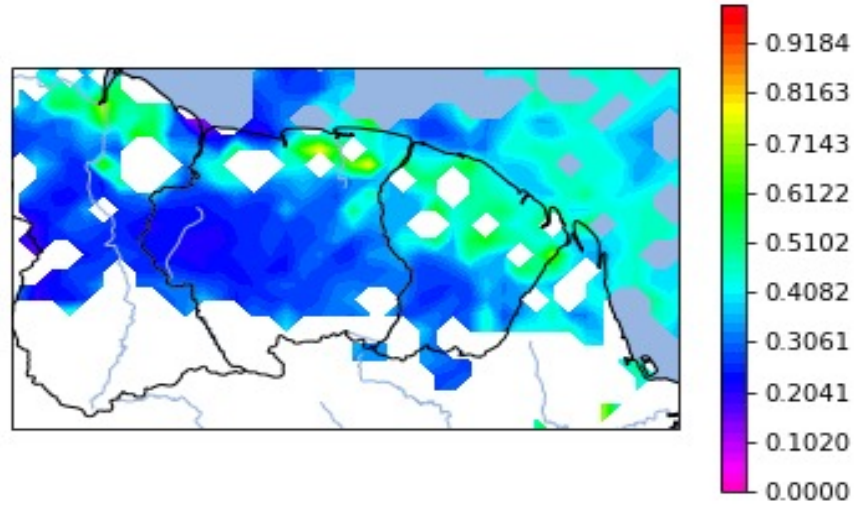


EXEMPLE OF SENTINEL-5 AOD

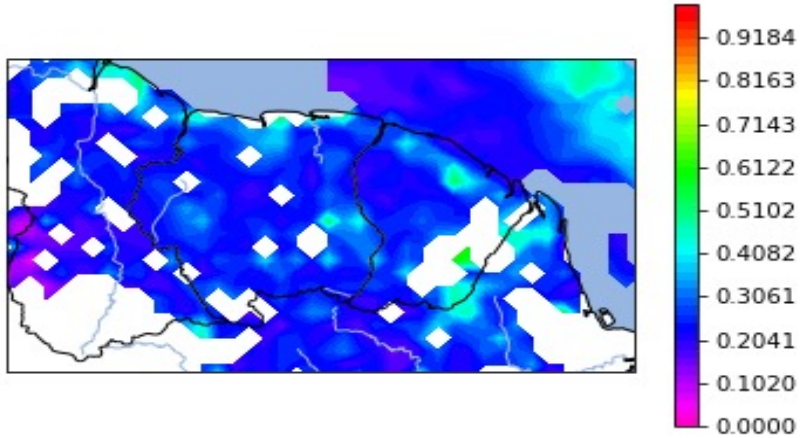
RESULTS : PM10/AOT IN FRENCH GUIANA AND CROSS-BORDER REGION SURINAM AND BRAZIL (1/2) :



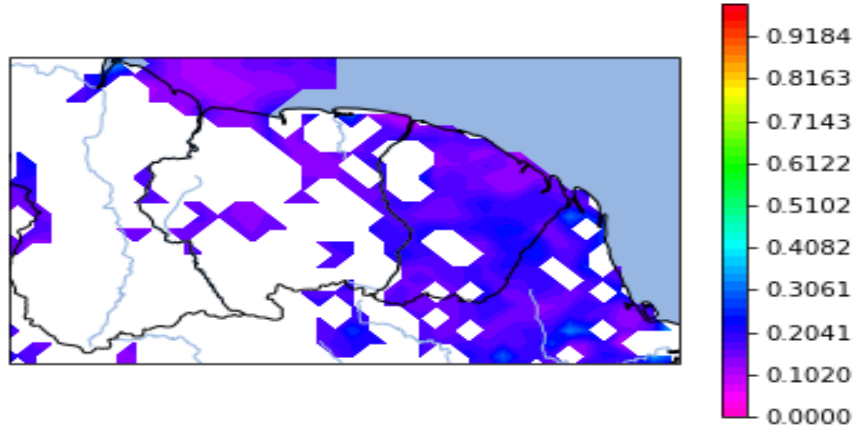
March 27 2018 : 100 ug.m-3<PM10<150 ug.m-3



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



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



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

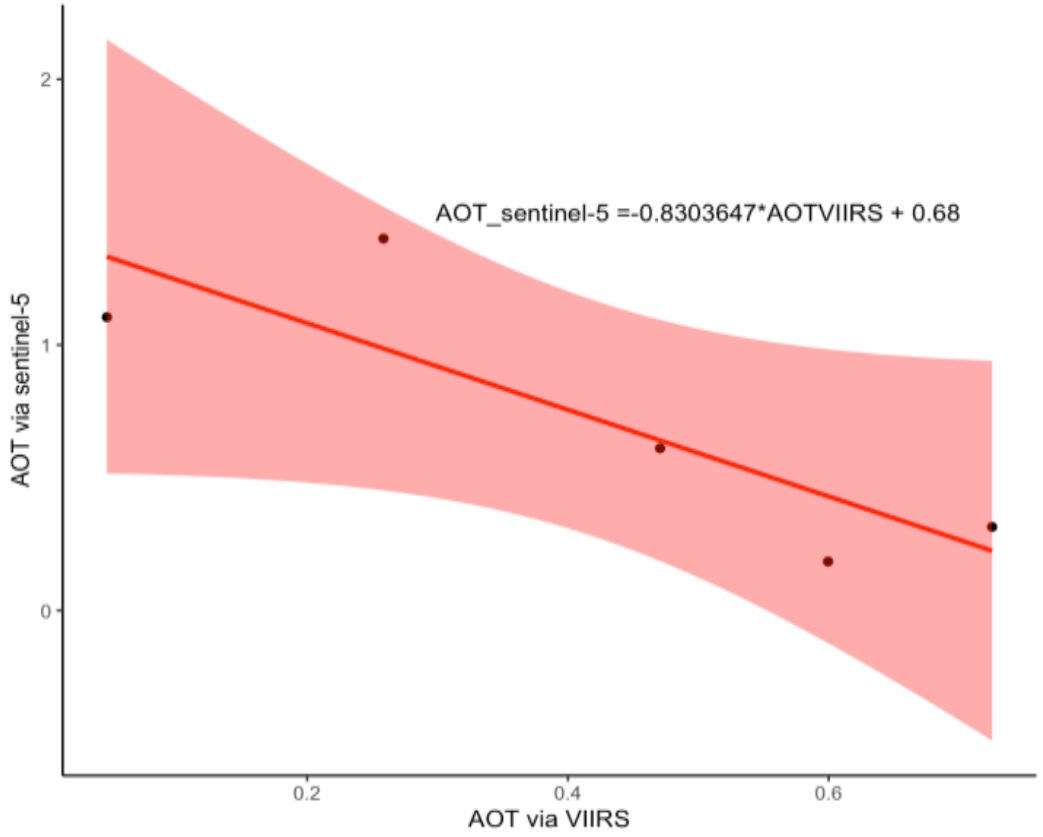
RESULTS : PM10/AOD IN FRENCH GUIANA (2/2)

During his Master internship, Moustapha Gning was interrested in the comparison between AOD from Sentinel-5 images and AOT from PM10

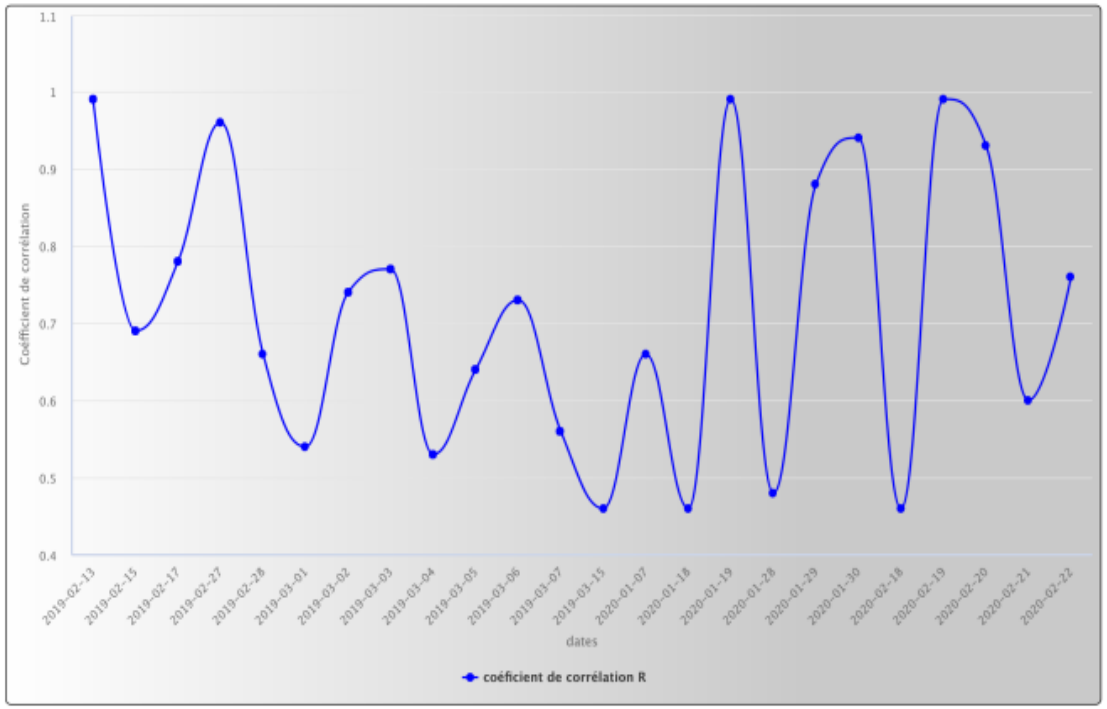
	Date	AOT 354_388 nm Cayenne	AOT 354_388 nm Kourou	AOT 354_388 nm Mana	AOT 354_388 nm Matoury	AOT 354_388 nm Montjoly	AOT 354_388 nm Régina	AOT 354_388 nm Saint-Georges	AOT 354_388 nm Saint-Laurent	AOT 354_388 nm Sinnamry
0	2019-02-25	0.277516	0.421940	0.504831	0.010525	0.277516	0.412895	0.433576	0.533503	1.081314
1	2022-04-07	0.107955	0.798478	0.861825	0.052509	0.069770	0.322220	0.775600	0.823579	1.088519
2	2022-03-27	1.049429	0.821781	0.421370	1.154795	1.178305	1.440945	1.065724	0.872969	0.609815
3	2022-04-25	1.574278	1.673754	1.686660	1.389477	1.446160	1.551793	1.334697	0.641804	1.661746
4	2022-03-24	1.486846	1.408156	1.771407	1.452869	1.452535	1.218181	1.429235	0.901076	1.344670
...	...	...	...	...	...	...	...	...	...	...
64	2022-04-11	1.475709	1.653604	1.227543	1.499489	1.476457	1.277865	1.284412	0.666871	1.603005
65	2019-02-26	0.480171	0.302655	0.281794	0.469864	0.480171	0.342895	0.297776	0.003066	0.107931
66	2022-04-12	0.810081	0.722625	2.007165	0.980442	0.872500	1.609937	1.911727	0.473086	2.023658
67	2022-03-16	1.519250	1.316338	1.161585	1.552606	1.495441	1.239453	1.163457	0.430485	1.174833

This table shows the AOD value from Sentinel-5 images.
During intense Saharan dust episodes like April 12, 2022 the values of AOD are 0.81 for Cayenne, 0.72 for Kourou, 0.98 for Matoury, 0,87 for Montjoly, 1,6 for Regina. The Saharan dust event was important for this date.

CORRELATION



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

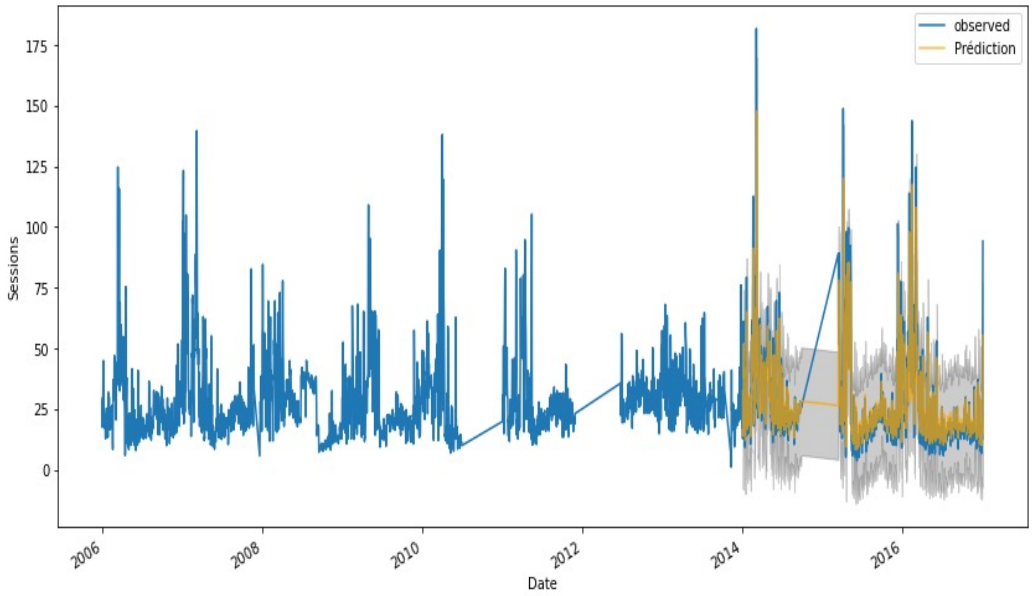


PM10 and AOD correlation over 25 days
This figure shows the correlations between the PM10 data from the stations of Cayenne, Kourou and Matoury and the AOT values extracted in these areas. We can see that they are generally correlated (most of them higher than 0.5).

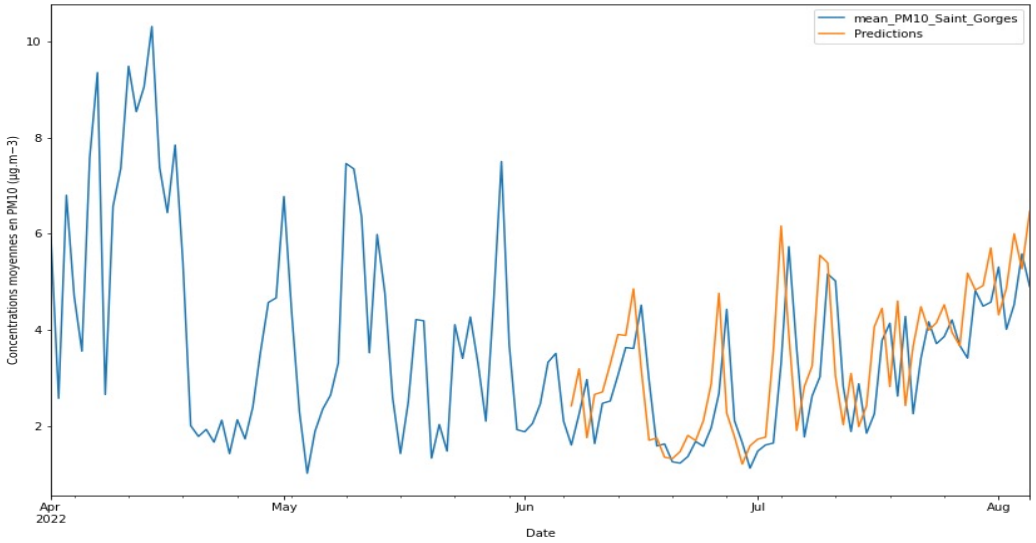
The processing chain developed here will be improved by Jérôme Fozzani in Aerochain

ARMA (AUTO REGRESSIVE MOVING AVERAGE) MODEL

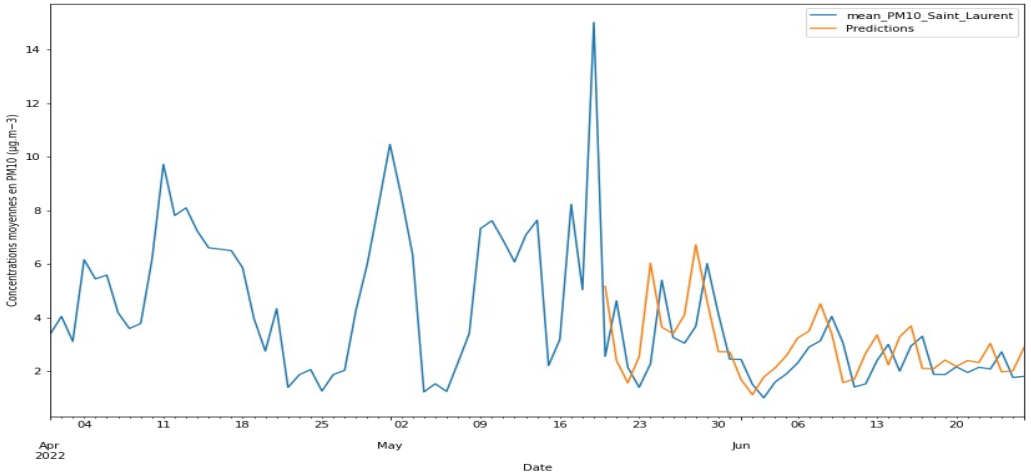
ARMA MODEL (3,1) over Cayenne



ARMA MODEL (1,0) over Saint-Laurent



ARMA MODEL (1,0) over Saint-Georges



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

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

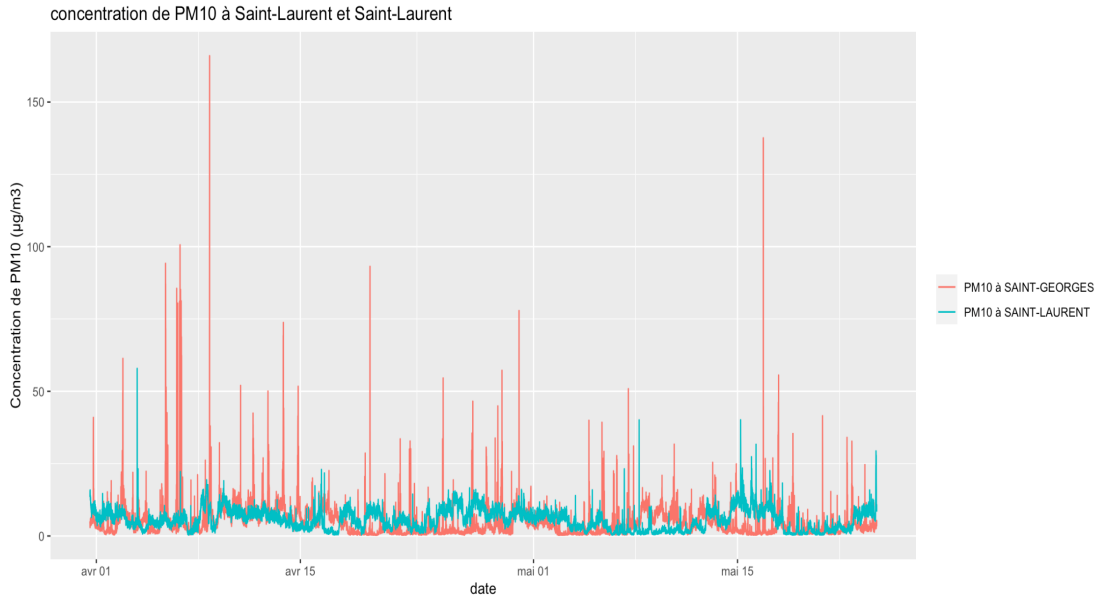
The residuals of a fitted ARMA(p,q) model is

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

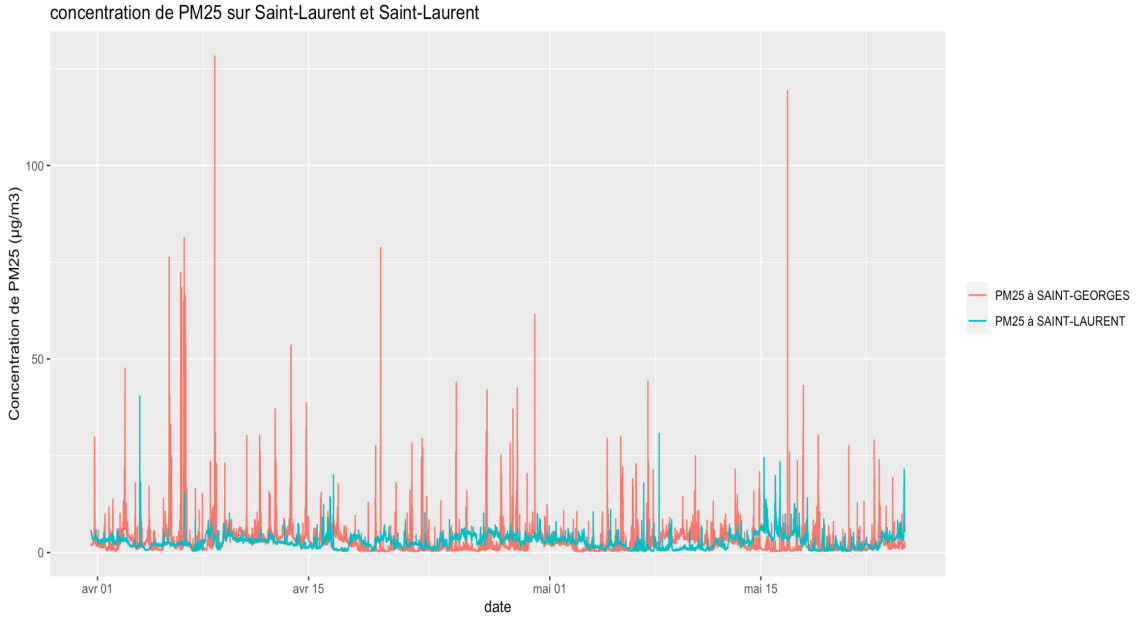
where $\hat{\phi}_k, \hat{\theta}_k, \forall k$ are the parameter estimates

ATMO TRACK DATA

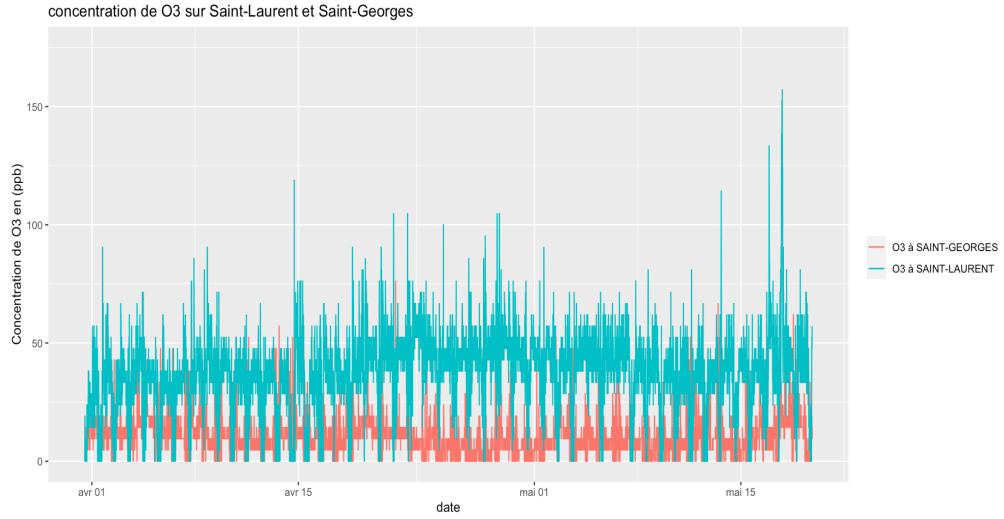
PM10 Concentration



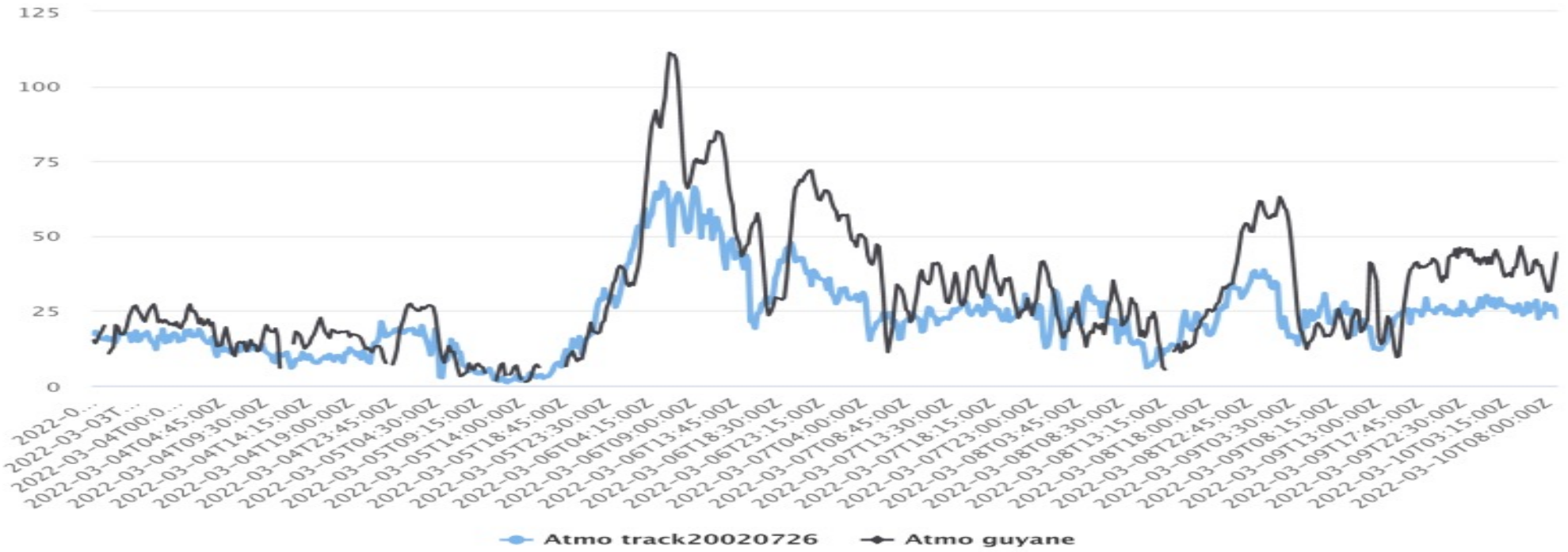
PM2.5 Concentration



Ozone Concentration



PM10 ATMO TRACK DATA COMPARED TO PM10 FROM TEOM

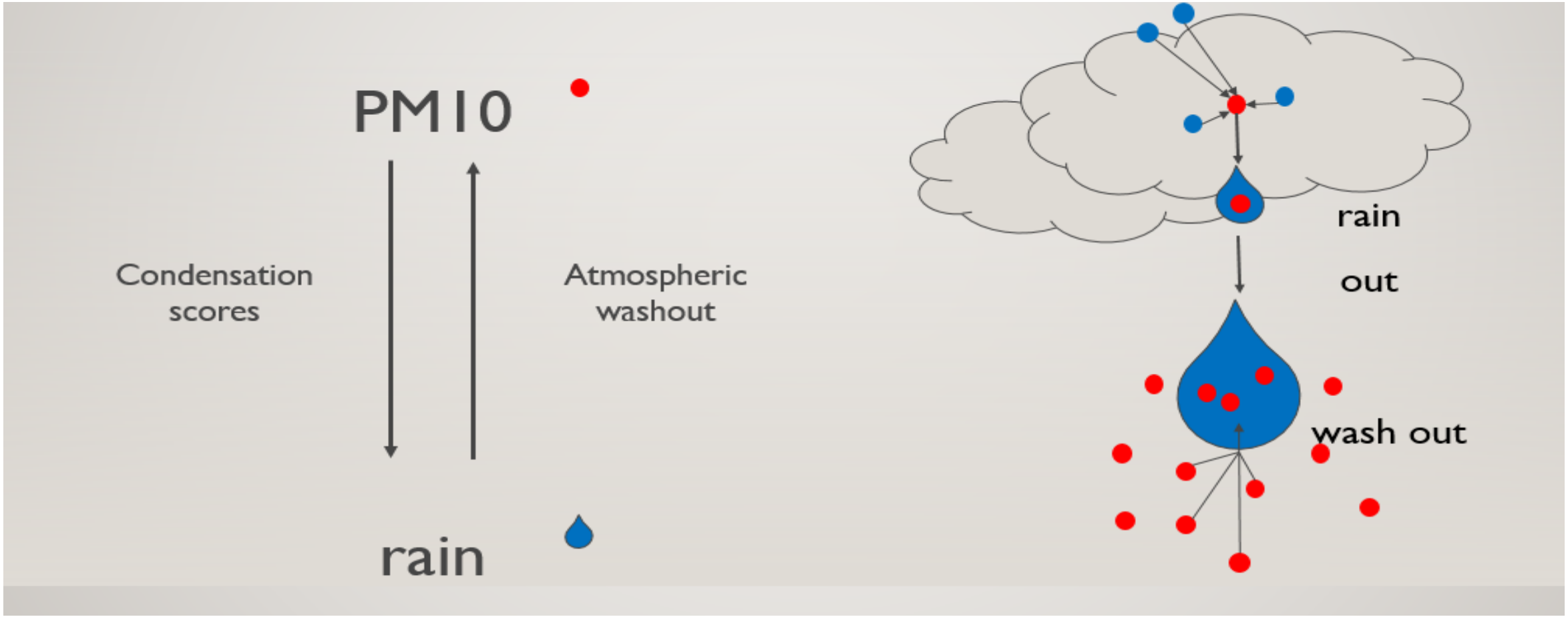


For this example in Cayenne, the proportionality coefficient is equal on average to 0.8440. The correlation coefficient is equal to 0.8429. We conclude that the PM10 values of the TEOM and the atmotrack are relatively well correlated.

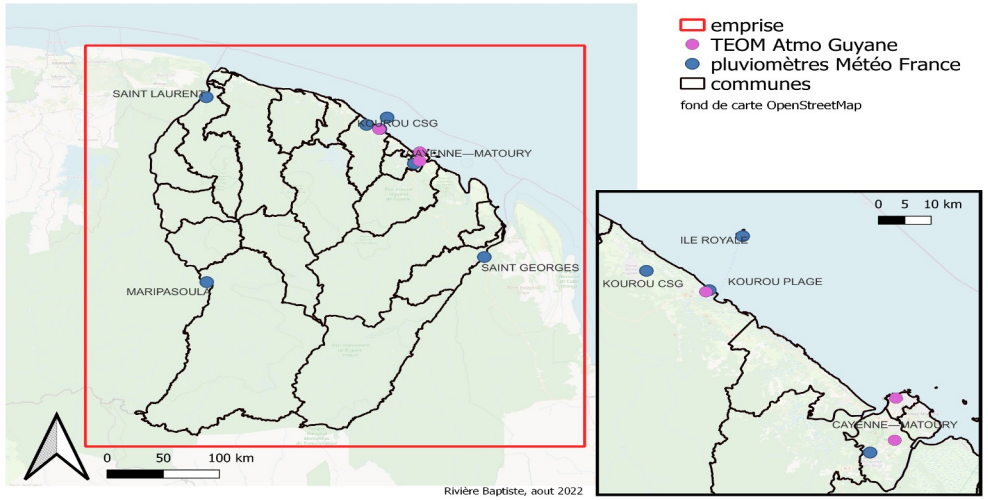
A good determination of PM10 over several years and with several cities will allow us to look at the problems of respiratory health with Allyx Fontaine, Emmanuel Roux and doctors from the André Rosemon Hospital. This study could be extended to Brazil and Suriname

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)



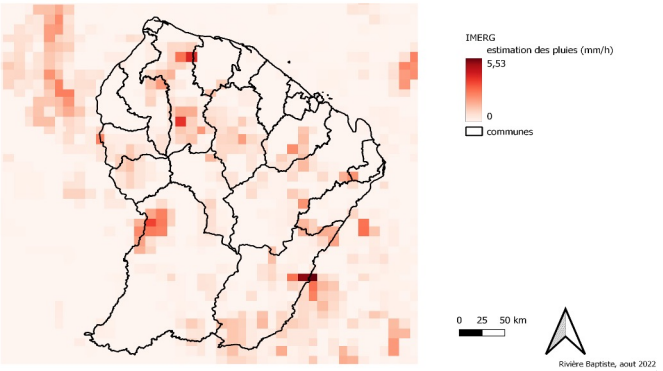
DATA



Distribution of rain gauges and TEOM in French Guiana

Rain gauges
(source Meteo France)

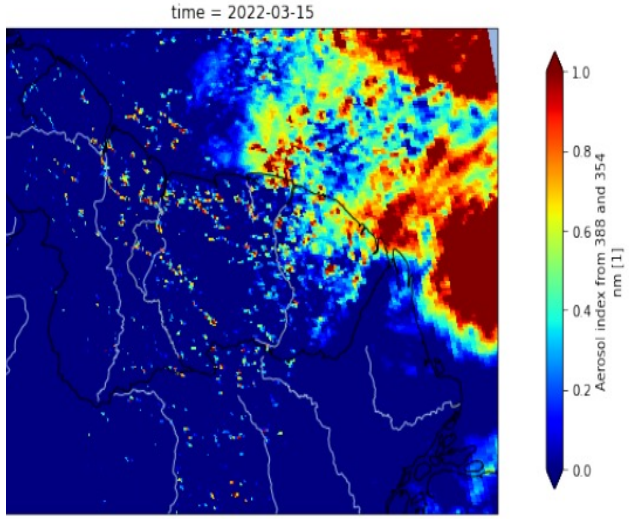
image IMERG-Final le 27/12/2020



IMERG satellite image
(source Meteo France)

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

TEOM



Sentinel-5 satellite image

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
Sep-Oct	0,373	5,202	-0,665	1,52
Dec-Jan	0,665	14,353	-0,799	8,52

METHOD (2/2)

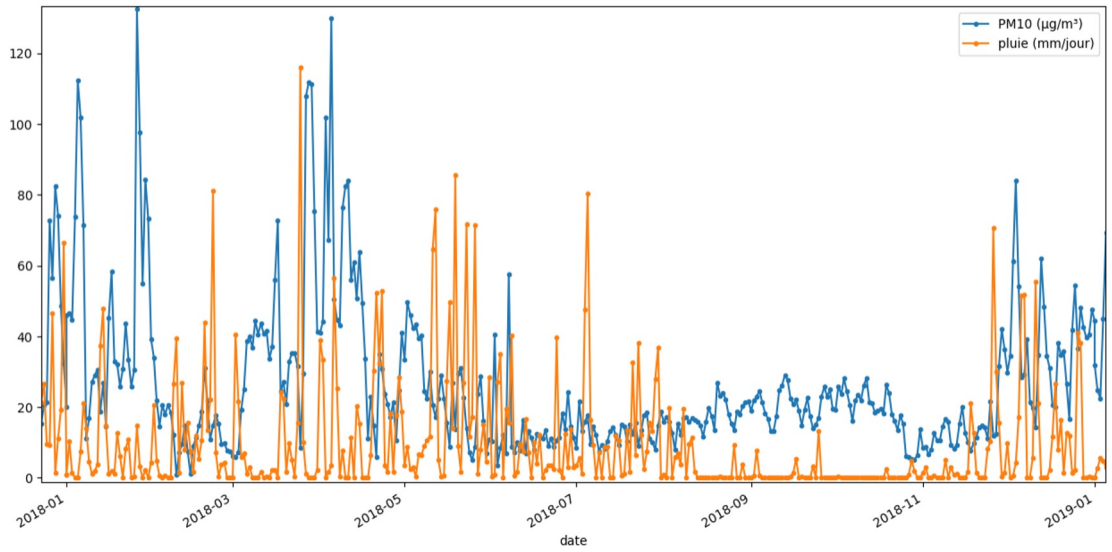
We looked at :

- relationships between two time series

- the coherence function: and in particular the

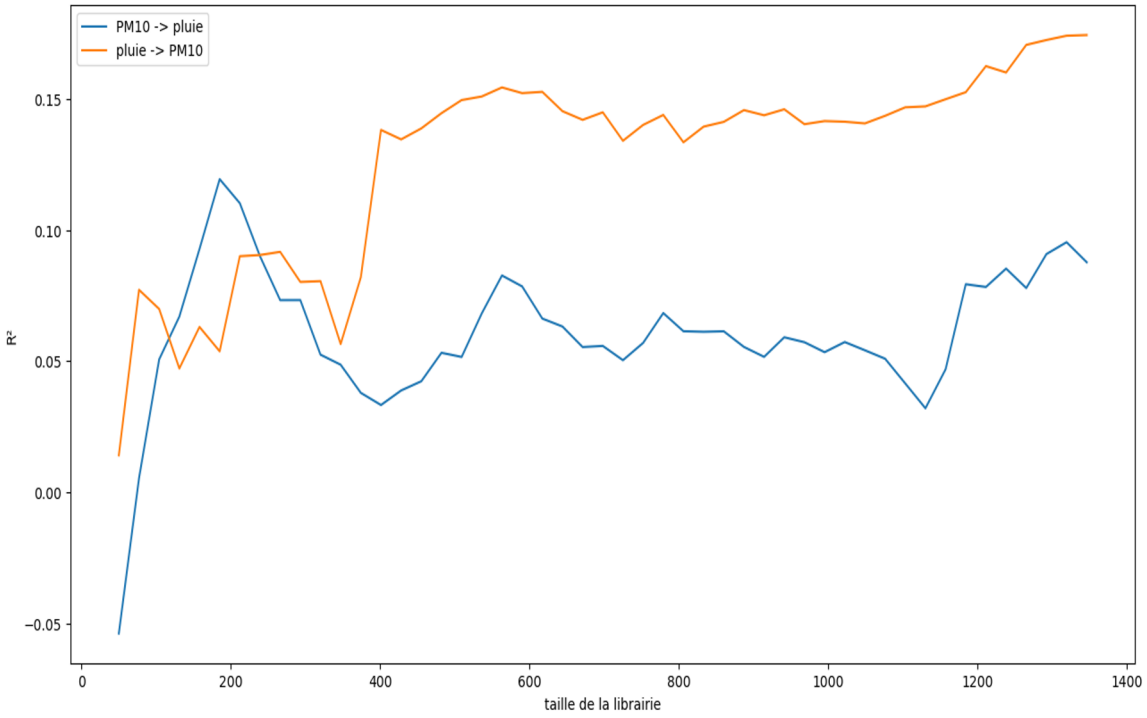
phase shift between two series

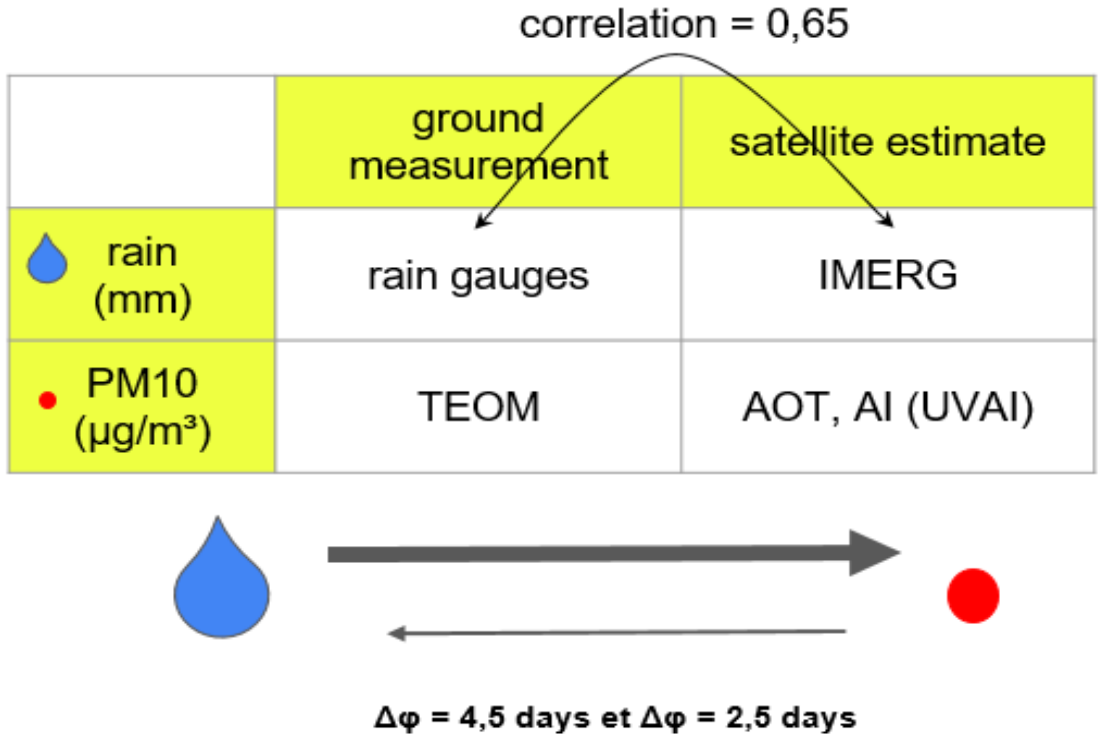
- the convergent cross correspondence : and in particular influence of one series on the other



Temporal evolution of PM10 concentration and rainfall series in 2018

RESULTS





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.

Exchanges will have to be carried out with the team of Marie-Paule Bonnet as well as Marielle Gosset and Adrien Paris in order to check more finely the function of coherence between the rains and the Saharan dust particles

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

- **Objectives :**

- Analytical and comparative study of the legal norms (environment, safety..) in France, Brazil and Suriname.
- Knowledge of the legal norms of cross-border areas (Saint Georges de l'Oyapock and Saint Laurent du Maroni).
- Detection of homes, neighborhoods, schools, communities to help of reducing the production of waste and pollutants.

- **Expected Results :**

The main results of this work will enable policy makers to make recommendations :

- For land management
- For public health

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

Our analytical and comparative study on the environment, security and pollution may also allow, in addition recommendations, a pedagogy component contextualized to the reality of the Guiana shield and its environment.

LEGAL ANALYSIS OF STANDARDS IN BRAZIL (1/2)

Plumma Anhelo Albarelo and Rosuel Lima-Pereira worked on this theme

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.**

Lead amount values symbolizing risk have been repealed from the current legislation. As for Benzene, despite being an abundant pollutant in the Brazilian atmosphere (because it is contained in fossil fuels), there is no text in the Brazilian legal system, with force of law, delimiting its parameters of alert or normality.

We only find 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.

LEGAL ANALYSIS OF STANDARDS IN BRAZIL (2/2)

The examples of Lead, Benzene and Nitrogen Dioxide are a sample of why the Brazilian environmental legislation alone is a major challenge when thinking about the creation of cross-border environmental standards.

Regulations only have strength when they demonstrate stability and consonance.

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.

SOME EXAMPLES (1/3)

Pollutant Polluant	Equivalent Values in Brazil. Standard Values. Valeurs équivalentes au Brésil. Valeur standard.	Values of Attention/ Alert/ Emergency Valeurs d'attention/Alerte/ Urgence	Legislation Législation	Observations Observations
NO_2 (Nitrogen Dioxide) (Dioxyde d'Azote)	1 hour Initial Standards1: 260µg/m³ Initial Standards2: 240µg/m³ Initial Standards3: 220µg/m³ Initial Standards: 200µg/m³ Annual Initial Standards1: 60µg/m³ Initial Standards2: 50µg/m³ Initial Standards3: 45µg/m³ final standard.: 40µg/m³	200 µg/m³ (mean of 1h)** 400-600µg/m³ (mean of 1h)**	Resolution 491, November 19, 2018 - Provides for Air Quality Standards. Résolution 491, 19 novembre 2018 - Prévoit des normes de qualité de l'air.	

SOME EXAMPLES (2/3)

Pollutant Polluant	Equivalent Values in Brazil. Standard Values. Valeurs équivalentes au Brésil. Valeur standard.	Values of Attention/ Alert/ Emergency Valeurs d'attention/Alerte/ Urgence	Legislation Législation	Observations Observations
Lead **Plomb**	The final air quality standard will be adopted: 0.5 µg/m³ Annually La norme finale de qualité de l'air sera adoptée : 0,5 µg/m³ par an	Art. 3° The maximum limits for arsenic, cadmium, lead tin and mercury set out in the Annex to Ordinance SVS No 685 of 27 August 1998 are hereby repealed. Art. 3° Les limites maximales pour l'arsenic, le cadmium, le plomb, l'étain et le mercure figurant à l'annexe de l'ordonnance SVS n° 685 du 27 août 1998 sont abrogées.	Resolution 491, Of 19 November 2018. Résolution 491, du 19 novembre 2018. Resolution - Rdc Nº 42, Of 29 August 2013 - Provides For The Mercosur Technical Regulation On Maximum Limits Of Inorganic Contaminants In Food. Résolution - Rdc Nº 42, du 29 août 2013 - Prévoit le règlement technique du Mercosur sur les limites maximales des contaminants inorganiques dans les aliments.	The Brazilian legislation only quantified the standard levels of Lead, but excluded any count of danger indexes (attention, alert or emergency) to the environment. La législation brésilienne ne quantifie que les niveaux standard de plomb, mais exclut tout décompte des indices de danger (attention, alerte ou urgence) pour l'environnement.

SOME EXAMPLES (3/3)

Pollutant Polluant	Equivalent Values in Brazil. Standard Values. Valeurs équivalentes au Brésil. Valeur standard.	Values of Attention/ Alert/ Emergency Valeurs d'attention/Alerte/ Urgence	Legislation Législation	Observations Observations
Benzene **Benzène**	Benzene, due to its high level of toxicity and varied risks to human health, does not have in Brazilian legislation safe values/ quantity standards in the environment. Le benzène, en raison de son haut niveau de toxicité et des risques variés qu'il présente pour la santé humaine, ne dispose pas, dans la législation brésilienne, de valeurs sûres/de normes quantitatives dans l'environnement.		National Confederation of Industry. Consolidation of legislation on benzene. - Brasília: CNI/SESI, 2012. Confédération nationale de l'industrie. Consolidation de la législation sur le benzène. - Brasília : CNI/SESI, 2012.	As there are no safe limits for the protection of environmental health, the Brazilian legislation has a series of resolutions, ordinances, technical standards that regulate its use with less possible risk to human life and its safe handling to prevent accidents caused by direct contact with the substance, their presence in fuels and the care that gas stations must take with their storage and levels that can interfere with the quality of the products that contain the substance. Étant donné qu'il n'existe pas de limites de sécurité pour la protection de la santé de l'environnement, la législation brésilienne prévoit une série de résolutions, d'ordonnances et de normes techniques qui réglementent l'utilisation de cette substance en limitant les risques pour la vie humaine et sa manipulation en toute sécurité afin de prévenir les accidents causés par le contact direct avec la substance, sa présence dans les carburants et le soin que les stations-service doivent apporter à son stockage et aux niveaux qui peuvent interférer avec la qualité des produits qui la contiennent.

III - 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 :**

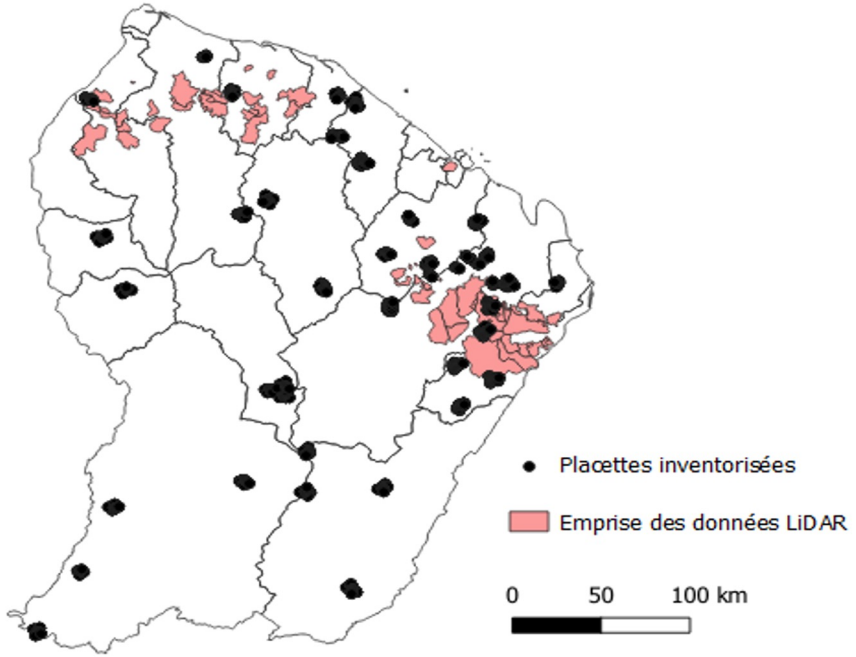
- A database by type of vegetation, biomass and its carbon stock, with the objective of better territorial management.
- Cartography of vegetation and land cover types using the images provided by axis 1.

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

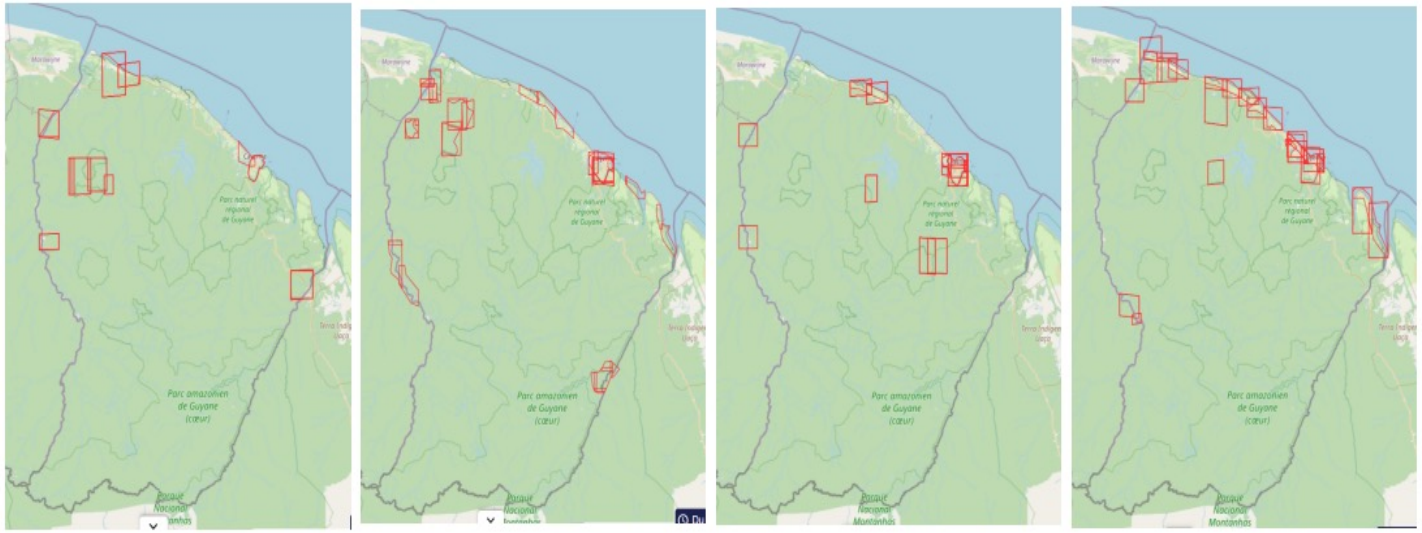
Quantifying the carbon (emitted and / or stored) of forest biomass in transboundary areas French Guiana / Brazil and French Guiana / Surinam: data from time series of NDVI, SAVI and fractional images (shade, vegetation and soil) will be analyzed according the Franca Method (2009).

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



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:

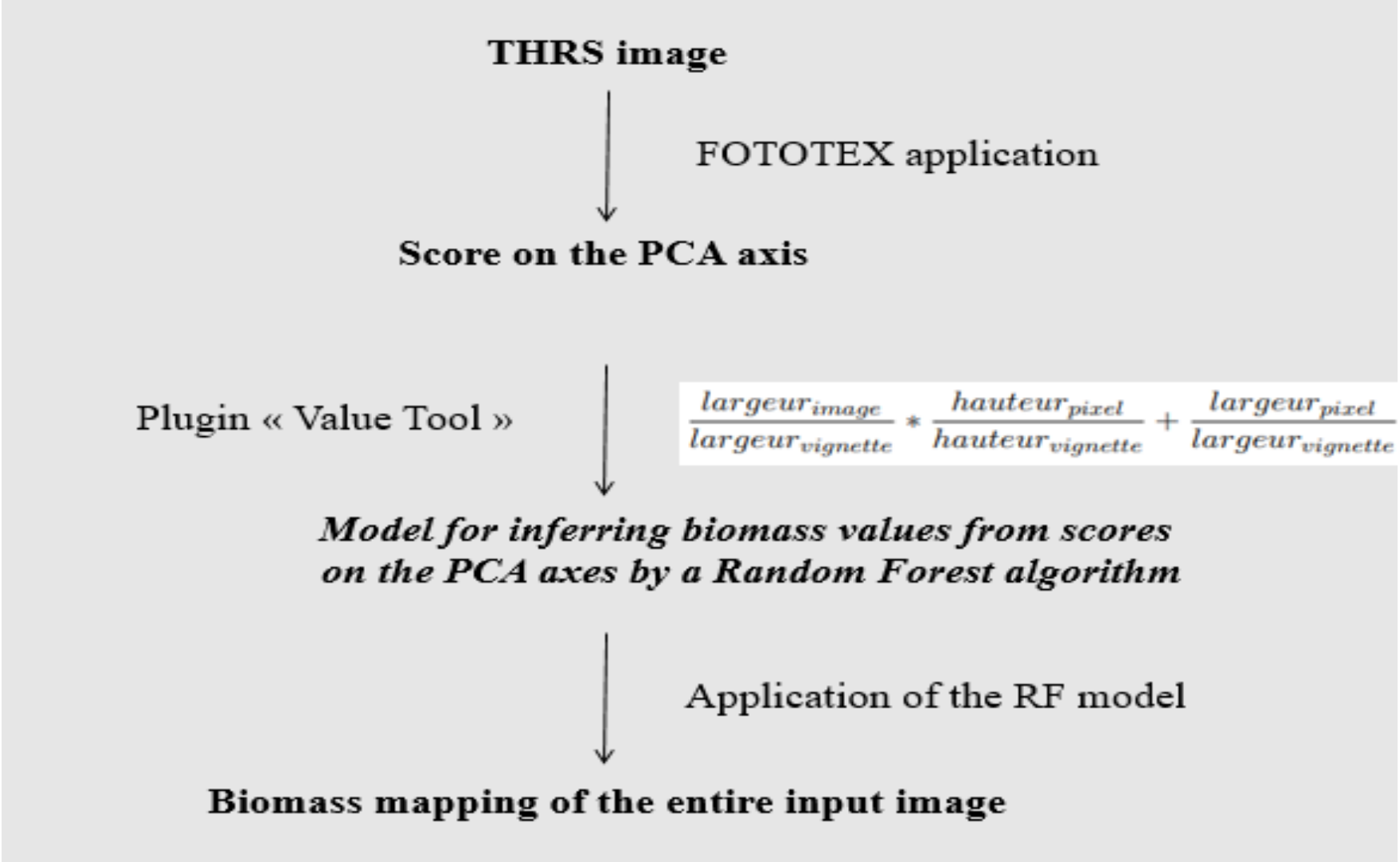
- Obtained from the work of Dourdain and Hérault in 2015

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

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

METHOD (2/2)

Implementation of the FOTO method to extract biomass



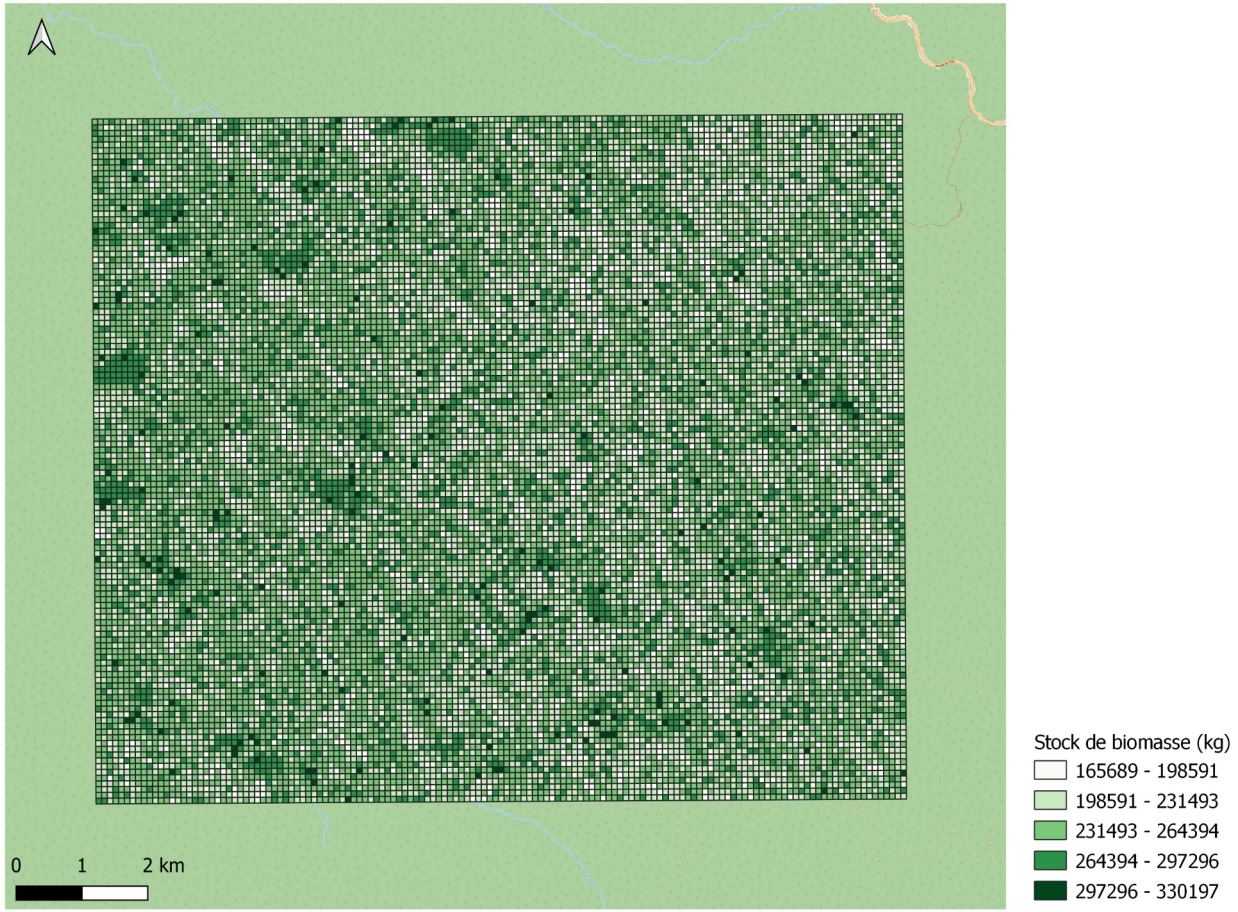
RESULT (1/2)

	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

RESULT (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

CONCLUSION (1/2)

- 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

The method and processing chains must be improved.

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 health with Allyx Fontaine, Emmanuel Roux and doctors from the André Rosemon Hospital. The study could be extended to Brazil and Suriname

- Exchanges will have to be carried out with the team of Marie-Paule Bonnet as well as Marielle Gosset and Adrien Paris in order to check more finely the function of coherence between the rains and the Saharan dust particles

CONCLUSION (2/2)

- 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.

- 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