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An Approximation to the Relationship Between Climatic Variables Obtained Through Remote Satellite Sensors and Hospital Admissions: A Case Study on Gran Canaria Island

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Abstract: The risk to human health is among the possible consequences of climate change or global warming. In this sense, it is necessary to deepen between climate and health interactions, in order to establish scenarios and policies to mitigate their consequences. The Sahara dust is well known to have an adverse impact on human health. The Canary Islands, due to their vicinity to the Sahara Desert, are frequently affected by the Sahara aerosols carried by the winds. This study analyses the correlation between climatic (Sea Surface Temperature, Aerosol Optical Thickness, Wind Intensity and Wind Direction) and clinical (emergency admissions due to respiratory pathologies) variables in the island of Gran Canaria and for a period of 14 years. The bivariate lineal correlation (Pearson) shows statistical significance between accumulated monthly averaged values of Sea Surface Temperature and the emergency admissions. There is also a significant correlation between the climatic variables Wind Intensity and Aerosol Optical Thickness.

Keywords: Remote sensing, Health risks, Climate Change, Global warming, SST, AOT, Wind intensity, Wind direction.

1. Introduction

Climate change or global warming is one of the scientific challenges with the greatest social impact today. The number of papers published as well as the impacts in all types of media confirm this statement [1-2].

The main consequence of warming the Earth's surface is a change in the climate associated with adverse meteorological events that will occur progressively more frequently; extreme heat waves, natural disasters and rainfall variation [3-4]. Consequently, climate change influences the social and environmental determinants of health, namely clean air, clean water, enough food and safe housing [5].

Thus, to help establish policies to mitigate the effects associated with global warming, it is necessary to study the relationship between health and climate [6-8]; especially in those particularly vulnerable territories: islands and archipelagoes, and less developed regions [9].

On the other hand, the availability of data captured with satellite edge remote sensing sensors has increased significantly in recent years [10]. Likewise, the spatial, spectral and temporal resolution of the products they provide [11]. As a result, these technologies are used for the monitoring of the terrestrial surface in order, among others, to analyze climate change, as well as for the generation of time series of climate variables that allow to analyze their evolution and help in predicting future scenarios.

In this context, the main contribution of this work is to try to analyze the relationship between the evolution of climate variables obtained by remote satellite remote sensing and health, through hospital admission data in the environment of Canary archipelago. This work is a review of the one presented at Fifth International Conference on Sensors and Electronic Instrumentation Advances (SEIA' 2019) [12].

Canary Islands are frequently influenced by the Sahara dust that crosses the Atlantic Ocean sweeping the Spanish archipelago. This meteorological event is commonly known as "CALIMA" (Cloud, Aerosols and Ice Measurements in the Sahara Air Layer). This paper is part of a wider research project which studies the relationship between the CALIMA and the weather conditions and their influence on respiratory, psychic and allergic conditions.

The influence of Sahara dust in human health is well studied not only in several European countries [13-18] but also across the Atlantic Ocean, all the way in USA [19]. The emergency services of the Canary Islands are very familiar with the effect that this event has in the population´s health, noticing an increase in the attendance of patients during the days when the event is present (Doctor Negrín University Hospital, admissions team personal comment).

Sahara dust is transported along several paths around the globe; over the North Atlantic Ocean to North America and South America, across the Mediterranean to Southern Europe and sometimes as far north as Scandinavia or east as Middle East [20]. Considering the proximity of the Macaronesian Region to the desert´s coast and that the dust sweeps along the Canary Island when the wind blows towards the Atlantic, the relevance of studding the impact of these aerosols in the canarian population seems evident. Furthermore, there are studies looking into the possibility of the Trend Winds rotation to the east [21] which would increase the periods of time in which the canarian archipelago is exposed to the Sahara dust. Therefore, it is crucial for the medical services of the Canary Islands to understand what the consequences of such change in the wind climate could mean in the health of their residents in order to plan the adaptation of their services.

The project counts with the Admission Department of one of the main hospital in the island of Gran Canaria (Doctor Negrín University Hospital). They provide not only the clinical data but also their medical expertise to the study.

The section of the study presented in this paper shows results of the early stages of the project and focuses on the analysis of climatic and clinical parameters, their correlation and the influence on respiratory conditions in the gran canarian population.

The rest of the paper is organized as follows: in the next section the data as well as the methodology applied to analyze them are described; in Section 3 the results are presented and discussed; finally, in Section 4, the conclusions are detailed.

2. Data and Methodology

2.1. Study Area

The Canary Islands are in the west coast of the African Continent and are part of the Macaronesian Region. Its climate is characterized by the predominance of the Trade Winds, which reach the islands with a north-northeasterly direction [14], [22]. The wind climate of the islands is driven by the Azores high pressure system which dominate below approx. 1500 m a.s.l. [23]. When the dominant wind direction changes to easterly and southerly the islands receive Sahara air, which is characterized by warm temperatures, high relative humidity and the presence of suspended Sahara dust (CALIMA) [13]. This happens most frequently during the months of summer, July to August [15].

Although this phenomenon affects all the islands that constitute the archipelago, in this work we focus on the island of Gran Canaria. Gran Canaria offers a unique orography with an area of 1560.1 km^2 and a maximum altitude of 1956 meters [24]. Its population is 846,717 inhabitants, residing in the capital, Las Palmas de Gran Canaria, 383,343 people, making it the most populous city in the Canary Islands [25]. Specifically, as it will be seen in the section describing the clinical data, the study area will comprise the northern area of the island and the city of Las Palmas.

2.2. Data

The following subsections describe the medical and climate data that have been used in this work. According to its availability, the data cover the period from January 2003 to December 2017, 14 years in total.

2.2.1. Climatic Data

The following climate variables were selected for this study: Wind Direction (WD), Wind Intensity (WI), Sea Surface Temperature (SST) and Optical Aerosol Thickness (AOT), all expressed in monthly averages. The selection criterion has been its known influence on human health [26]. Indeed, the sea acts as a modeler of global temperature in an island environment of small dimensions, such as the island of Gran Canaria. Similarly, AOT, WD and WI act as elements that may condition the quality of the breathed air.

Wind data was obtained from the National Centre of Atmospheric Prediction and the National Centre for Atmospheric Research of the United States of America (NCEP/NCAR). They consist on a re-analysis of monthly averages of the u and v components of the wind measured at 10 meters above sea surface, both near shore and offshore. The data is provided in a matrix of 192 pixels of longitude and 94 pixels of latitude (Gaussian grid), with a processing level 4, and a geographical resolution of 0.25º × 0.25º (approx. 25 km × 25 km). It is provided in HDF5 format [27]. From the Gaussian grid, 8 time series were extracted around the archipelago. After comparison of WD and WI for all points and corroboration that there was no significant spatial variation of the wind data in the study area, an average was performed and so one single (averaged) time series was used for the analysis performed in the present study. Fig. 1 shows the location of the 8 NCEP extracted data points.

Fig. 1. NCEP data points locations. P1 to P8. (Google earth Pro. Image Landsat/Copernicus).

AOT [28] and SST [29] are a product of MODIS (Moderate Resolution Imaging Spectroradiometer), aboard the NASA satellite Aqua and presented in monthly averages. The data is provided in maps, the 4km resolution was selected for the tasks performed in this study. Six data points (time series) were extracted from the mentioned map. An average of the 6 data points was performed and so single averaged time series of AOT and SST are presented in this work. The AOT used is AOT_869. Fig. 2 shows the location of the 6 AOT and SST extracted data points.

Fig. 3 to Fig. 5 display the monthly time series of climate data for the entire study-period. Fig. 1 shows some cyclic pattern in the wind direction and wind intensity components. This responds to the predominant presence of trade winds blowing over the archipelago. Similarly, Fig. 3 shows the cyclicity of SST between cold and warm seasons. On the contrary, Fig. 2 shows the random pattern of the presence of aerosols on the atmosphere.

Fig. 2. MODIS-Aqua data points location. P1-P6. (Google Earth Pro. Image Landsat/Copernicus).

2.2.2. Clinical Data

The clinical data was provided by the admissions team of the Gran Canarian Doctor Negrín University Hospital. This center is one of the largest hospital facilities in the Canary Islands. Specifically, its area of influence encompasses the entire north of the island and the northern half of the city of Las Palmas de Gran Canaria. These facts were key criteria to the selection as reference center for this study.

The data consists on the number of daily emergency admissions due to breathing pathologies (IUPR). Since the climatic data was obtained in monthly averages, the daily clinical data was accumulated into the same time step.

The data was converted to 1000 %, for a population of 350000 citizens that were assigned to the Hospital when the study took place [30].

Fig. 6 displays the monthly clinical data in rates per thousand and for the entire study-period.

3. Results

The data analysis presented in this article consists on bivariate linear correlations and were applied to all pairs of variables. The Pearson coefficient was calculated for all pairs of climatic variables as well as between the climatic and clinical variables. Other than correlation analysis applied to the whole data series as one, seasonal analysis was also performed, as well as annual trends.

The following figures show some of the results obtained.

Fig. 7 shows the accumulated monthly averaged values of SST vs IUPR for the 14-year period, that is, the annual trends. The trend lines show an inverse relationship between these two variables. For the first trimester of the year, both variables see a progressive decrease, but while IUPR keeps dropping until the end of the year (with excuse of small raises in June and

September), the Sea Surface Temperature increases from March to September, to drop again from then to December. The temperature ranges between a maximum of 25º seen in September and 20º in March.

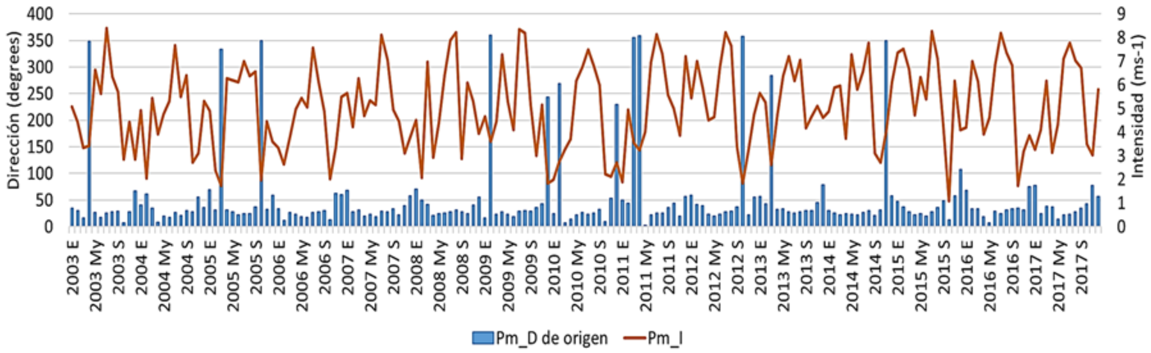

Fig. 3. Wind Intensity (Pm_I, orange line) and Wind Direction (Pm_D de origen, orange line) averaged time series of 8 data points. Monthly average. Period 2003-2017.

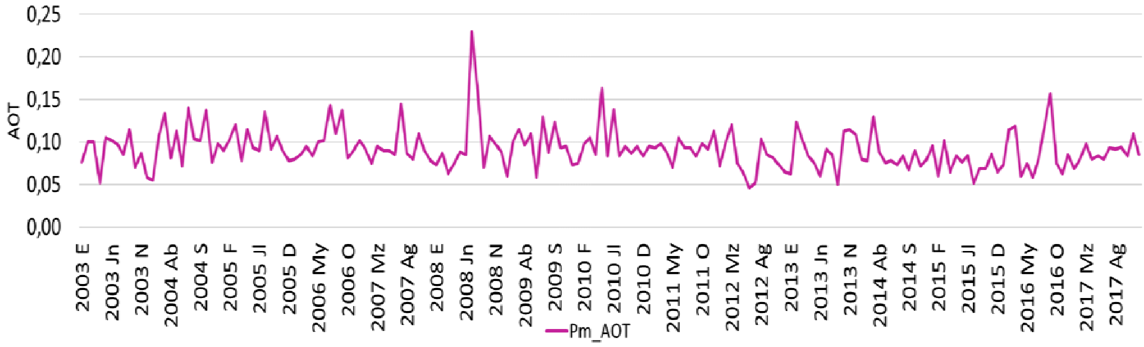

Fig. 4. Aerosol Optical Tickness (Pm_AOT) averaged time series of 6 data points. Monthly average. Period 2003-2017.

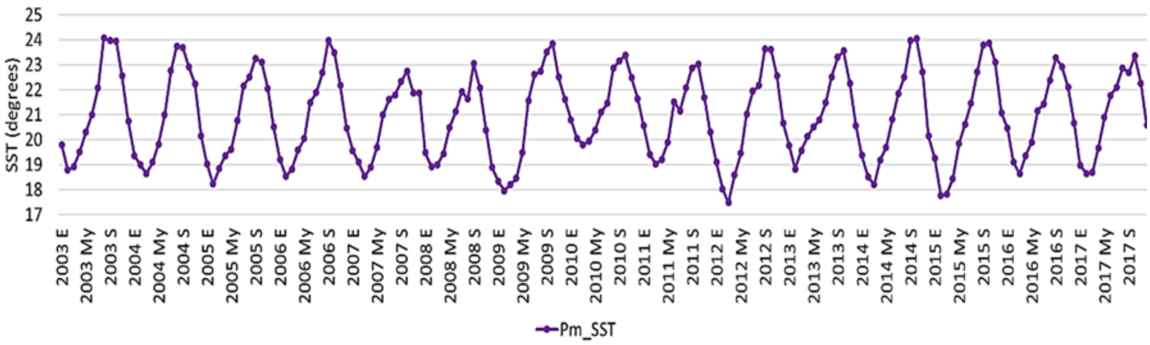

Fig. 5. Sea Surface Temperature (Pm_SST) averaged time series of 6 data points. Monthly average. Period 2003-2017.

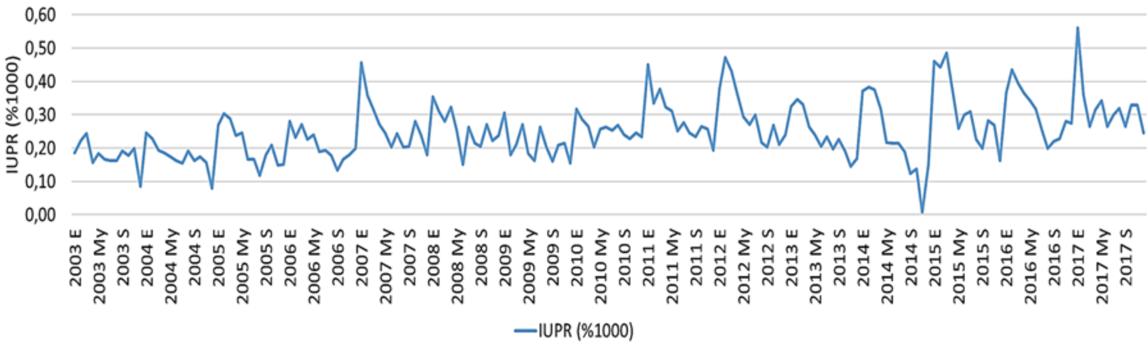

Fig. 6. Emergency admissions due to breathing pathologies (IUPR). Monthly accumulations. Period 2003-2017.

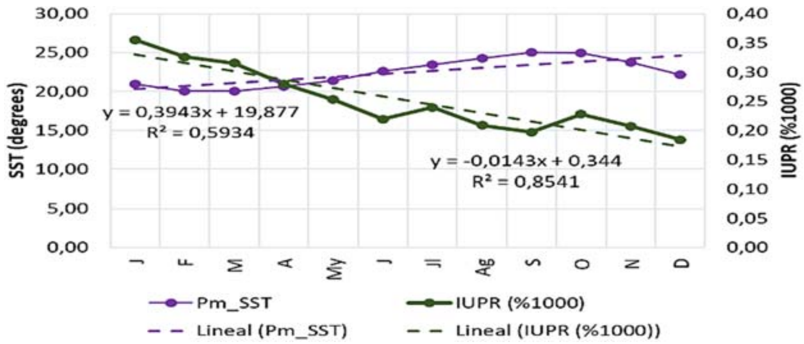

Fig. 7. Accumulated monthly averages of SST (·C, purple line) vs IUPR (% 1000, green line) and corresponding trendlines. Period 2003-2017.

As for the IUPR, data varies between 0.36 ‰ cases in January and a minimum of 0.18 ‰ in December.

The Pearson correlation coefficient between the monthly accumulated values of SST and IUPR (% 1000) for the 2003-2017 period is -0.661 (p<0.001).

Fig. 8 shows two of the climatic variables plot against each other, Wind Intensity (WI) vs the Aerosol Optical Thickness (AOT) both in monthly averages and for the full study-period. The correlation coefficient of this pair is the only one that, analyzed in (non-accumulated) monthly averages gives a significant statistical correlation, with Pearson's coefficient being 0.256 (p<0.001).

Fig. 9 shows the time series of AOT vs IUPR for monthly averages of the trimester March-April-May, for every year from 2003 to 2017. Visually, it is easy to identify that for most years, the AOT and IUPR present the same trends, in some cases (2006 and 2013) it is almost parallel. It is noticeable the year 2009 for the opposite event; the graphs are mirrored.

However, even though there is visually a clear relationship between the amount of aerosol in the atmosphere and the number of recorded respiratory medical admissions, the correlation coefficient is not statistically significant (0.083 (sig. (bilateral)=0.262)). Ongoing investigations are taking place in this respect.

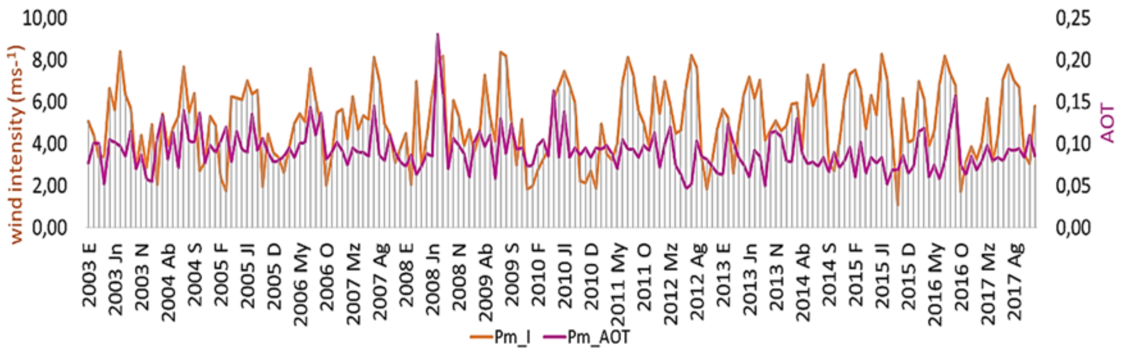

Fig. 8. Wind Intensity (ms-[1], orange line) vs AOT (pink line). Monthly average. Period 2003-2017.

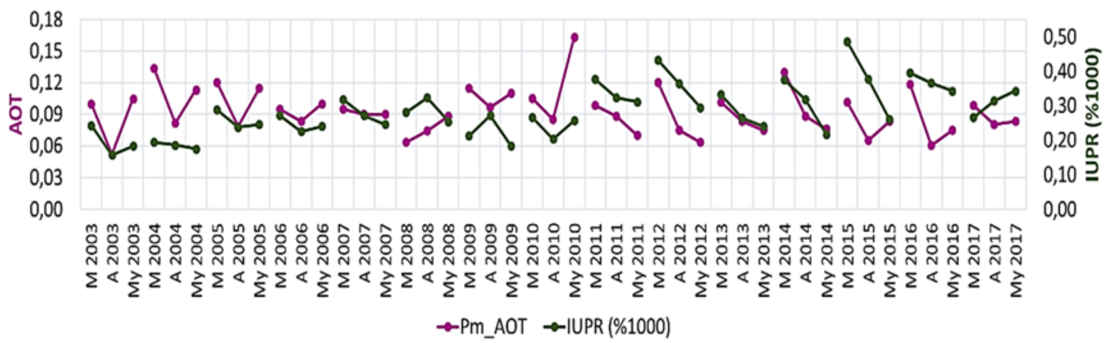

Fig. 9. AOT (adimentional, pink line) vs IUPR (% 1000, green line). Monthly averages for March, April and May. Period.

4. Conclusions

The results presented in this study show significant correlations between some climatic variables and the respiratory health status of the grancanarians. When looking into the correlation among the predicting variables (climatic variables), there is significant correlation between Wind Intensity and the Aerosol thickness. This coupled meteorological phenomena may be expected considering that the stronger the wind blows over the Sahara, the concentration of dust resuspended into the atmosphere increases as well as the stronger the wind, the further it is transported across the ocean and through the archipelago.

Analyzing the data in monthly averages for the 14 years period, the aerosols do no show significant correlation with any other climatic variable. In future studies the plan is to use wind data in a shorter temporal resolution (daily). Considering that the CALIMA events lasts in average 3 days at the time, using monthly averages might mask the data preventing, for instance, the expected correlation between wind direction and aerosol concentrations, to be significant.

Same applies to the correlation between Wind Direction and clinical data. It was expected to find a clear correlation between these two; aerosols reach the archipelago when the wind blows westwards or northwards over the Sahara. No correlation is shown in our study, so the idea is to repeat the correlation analysis using daily data.

On the other hand, it is also important to consider that the AOT data provided by MODIS-Aqua represents all solid and liquid particle in the full atmospheric column. Another option to depurate the data for correlation analysis would be to apply an algorithm to calculate the particles of a size between 2.5 μm and 10 μm, being this range the usually analyzed in human health related studies.

However, even though correlation analysis applied to the full length of the period do not show significance, when looking into the plot for shorter periods (i.e. trimester March-April-May) there seems to be a visual relationship between AOT and IUPR, showing a possible seasonal influence in the relationship of climatic and clinical variables. Further studies are carried out at the time this article is released.

When accumulating the data sets monthly for the full 14-year period, the variables SST and IUPR present significant correlation, however, it is important to note that this correlation does not necessary imply causality. The correlation between these two variables is slightly negative, which is expected considering that respiratory conditions tend to increase during winter, when the temperature drops, and decrease during the summertime.

For future studies, in order to get a better understanding of the influence of climatic factors like Wind Direction, it is advisable to use shorter temporal resolution, preferably daily time steps. In the case of Aerosols, considering working with specific particle sizes in advisable.

The final aim of this project is to help the Canary Islands health system be prepared for the changes that climate change might force in the number and nature of emergency admissions in the island of Gran Canaria. Considering the correlations found in this study, the well-known adverse impact of CALIMA in human health and the potential increase of CALIMA episodes due to climate change in the Macaronesian Region, it is essential to keep investigating the relationship between climatic and clinical parameters in the Canary Islands.

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