Godzilla dust event sheds light on desert aerosols in the Caribbean

The Godzilla dust event of June 2020 was the largest dust storm in half a century. In light of this extreme event, Dr Thomas Plocoste of KaruSphère SASU, Guadeloupe, and colleagues, used ground-based, satellite, soundings and model data to better characterise the desert mineral dust that is transported to the Caribbean basin from Africa. Through greater understanding of the behaviour of this particulate matter, the impacts on the environment and human health can be more effectively mitigated by the local population.

Mineral dust deposited in the Caribbean basin is mainly derived from African deserts, where dry soil, sparse vegetation, saltating (bouncing) particles and strong winds create an atmosphere laden with dust particles year-round. Millions of tonnes of this mineral dust are transported across the Atlantic Ocean every year within the Saharan Air Layer, where they are deposited in the atmospheric boundary layer by gravitational settling (dry deposition) and wet scavenging process (wet deposition).

There are two dust seasons in the Caribbean basin: low dust season from October to April and high dust season from May to September. This latter period sees a continuous alternation between African Easterly Waves (areas of low air pressure) and dust plumes, bringing concentrations of particulate matter of less than 10µm diameter (known as PM10) 1.5 times higher than during the low season, every three to five days. Significantly, June is the peak of the high dust season.

The dust provides micronutrients to both land and ocean environments. But while some effects can be positive, epidemiological studies have revealed dust-laden air can have severe effects on human health, potentially increasing the risk of death from cardiovascular diseases by 2%, while chronic exposure to PM10 is associated with respiratory diseases. The Caribbean is known to have some of the highest incidences of asthma on the planet.

Photo credit: https://guadeloupe-actu.com/guadeloupe-un-episode-exceptionnel-de-brume-de-sable-jamais-vu-en-10-ans/

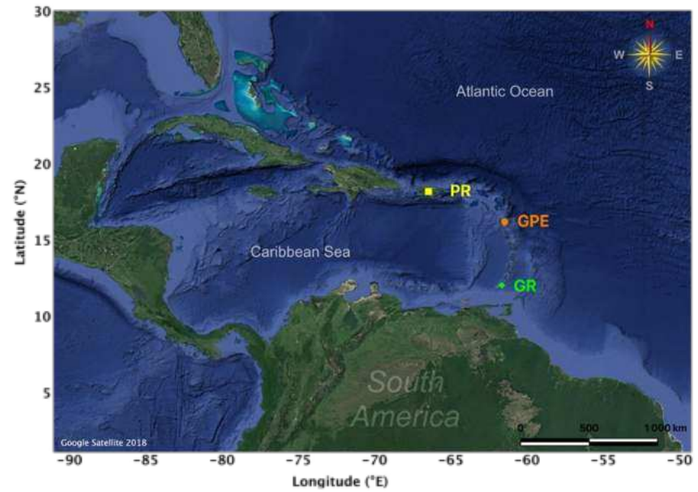
Photo credit : A record-setting dust storm stretched from the Sahara Desert to the Caribbean in late June.NASA/NOAA/ Colin Seftor

Above: Godzilla event dust movement from Africa to the Caribbean.
Left: Godzilla event over Guadeloupe Archipelago.

GODZILLA DUST EVENT

Between 19 and 23 June 2020, the largest dust storm in 50 years crossed the Atlantic Ocean, covering the Caribbean Sea in particulate matter and darkening the skies in several US states. In order to determine the characteristics of this extreme event, Dr Thomas Plocoste, founder and President of KaruSphère SASU, and his research team, studied the last 20 years of dust storms to impact the Caribbean islands of Puerto Rico, Guadeloupe, and Barbados using ground-based, satellite, model, and soundings data.

With dust particles known to play a significant role in both air quality and the climate system, the Godzilla event was an ideal opportunity for the team to build on their previous work, to better understand the impacts of the event on people and the environment.



Overview of Caribbean area: PR – Puerto Rico, GPE – Guadeloupe, GR – Grenada.

A GLOBAL PERSPECTIVE

Satellite images of the Godzilla dust storm using MODIS observations of land, ocean, and atmospheric characteristics, reveal the magnitude of the event. Applying a 550nm spectral band to the satellite images revealed the aerosol optical density in June 2020 to be extraordinary, covering an area extending from Cape Verde to the middle of the Atlantic Ocean. At the peak of the event, PM10 concentrations were nine times greater than the safety threshold recommended by the World Health Organization during a single day.

The researchers used the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) to determine the origin of dusty air masses at San Juan (Puerto Rico) and Grantley Adams (Barbados) – areas representative of air structure within the Caribbean. The HYSPLIT modelling produced back trajectories that reveal three main circulation pathways for dust-laden air: directly from west Africa to the Caribbean; from the US, across the Atlantic and back to the Caribbean; or from South America to the Caribbean.

For the Godzilla dust event, Plocoste's back trajectories showed that the dusty air masses come directly from the dust belt in Africa. A significant period of dust uplift occurred nine days before the storm hit the Caribbean, with aerosols reaching a maximum of 6km into the atmosphere. The dust was then continuously driven westwards from the African coasts in the Saharan Air Layer, with average wind speeds of 15m.s^{-1} between 14 and 19 June.

PARTICLE SIZE MATTERS

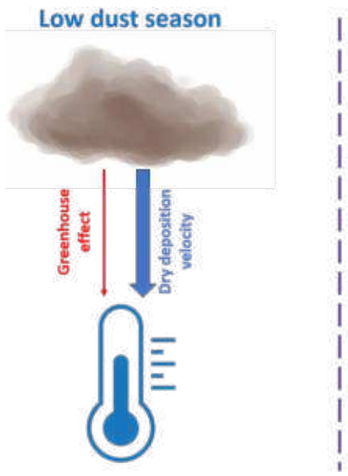
The size of the particles that make their way across the Atlantic influences the impacts experienced in the Caribbean. To understand the particle size distribution, the NASA AERONET programme provided optical data which reflects the state of the atmospheric column during dusty events (ie, the amount of solar-beam extinction by particles, depending upon their size, in both Africa and the Caribbean). The particle size distribution leads to the characterisation of their composition and their properties, enabling researchers to distinguish desert dust aerosols (signature radius 2.24µm) from sea salt aerosols (signature radius 3.86µm). In the Caribbean sites, desert dust aerosols predominate in the high dust season, while they are present in the African sites throughout the year.

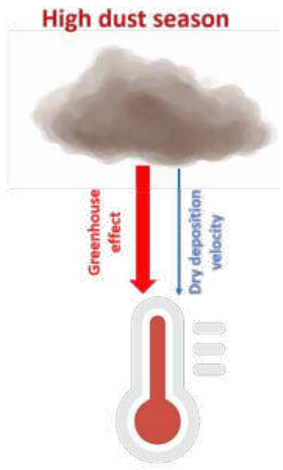
Plocoste used data from Guadeloupe and Puerto Rico air quality networks to extrapolate daily PM10 and PM2.5 (particles of less than 2.5µm diameter) concentrations over spatial and temporal scales. The concentrations could then be attributed to natural or anthropogenic pollution activities. Anthropogenic pollution is low in the Caribbean basin, hence PM10 concentrations equal to or greater than 35µg.m-3 are considered to result from desert dust. As such, the data show that dust storms in the Caribbean have been primarily driven by African mineral dust in the atmosphere.

Millions of tonnes of mineral dust are transported every year across the Atlantic to the Caribbean.

DUST ON THE HORIZON

While dust storms can be recognised from remote sensing technology, they have a significant impact on land for the local population as high particulate matter concentrations impact visibility. For the Godzilla dust event, daily visibility data measured in Guadeloupe, revealed ground visibility was reduced to just 9km. Thankfully, permanent trade winds act to disperse the dust aerosols, ensuring that individual dust events are not long lived, even if they are numerous during high dust season. Conversely, during the low dust season, PM10 sea salt dominates over mineral





Causality between PM10 and air temperature.

dust, hence the impact upon visibility is minimal during these months.

CLIMATIC AND METEOROLOGICAL INFLUENCES

Dust-laden air influences a variety of meteorological and climatic factors. Daily atmospheric sounding data and Guadeloupe weather station measurements helped Plocoste to describe the structure of the air with regards to temperature, wind speed and direction. Notably, PM10 concentration data shows a tendency to stabilise air temperature. This phenomenon results as dust particles scatter, absorb and re-emit solar radiation, creating a warming effect.

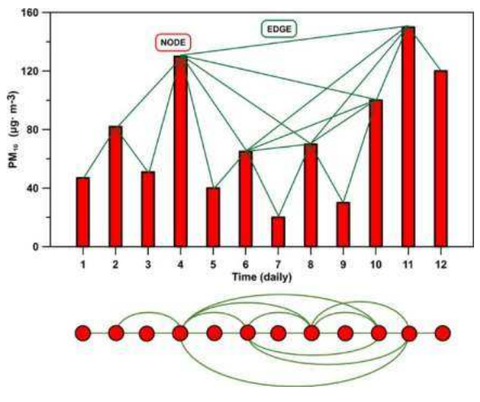
Conversely, wind speed and direction influence dust storms by causing both accumulation and dispersal of atmospheric particulate matter. An atmosphere laden with dust increases air density, thus reducing wind speed and allowing dust to persist in the atmosphere over Caribbean islands. As such, aerosols influence Caribbean climate by acting as nuclei for clouds and ice. However, due to their low solubility, dust particles are known to reduce precipitation once they are moved away from African coasts. This is the reason why the high dust season is juxtaposed with the hurricane season. Thus, a dusty episode is always followed by a rainy event from synoptic scale origin to purify the air.

At the peak of the event, PM10 concentrations were nine times greater than the safety threshold recommended by the World Health Organization.

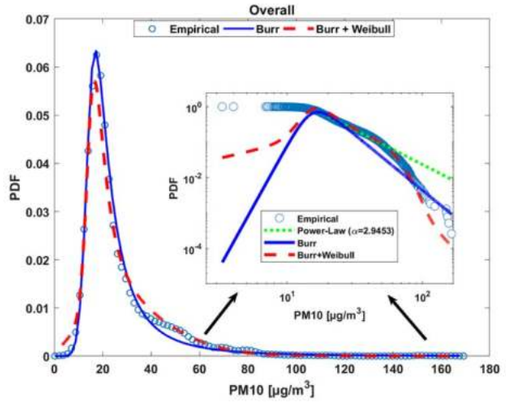
PROTECTING THE CARIBBEAN PEOPLE

Besides respiratory diseases, recent studies have found that Saharan dust events reduced the weight of babies born small for gestational age, while raising PM10 concentrations by just 10µg/m^3 increased the risk of hospitalisation for heart attacks. Better understanding of these desert dusts and their health impacts is crucial, to better prepare healthcare services to treat local populations.

Plocoste and colleagues have produced a library of work characterising the behaviour and impact of desert aerosols in the Caribbean basin. Contrary to megacities in Europe, China or the US, a mixture model has been found for PM10 distribution, providing scientists with a greater understanding of the environmental and human impacts experienced in the Caribbean.



PM10 time series transformed into a complex network.



PM10 distribution fit with bimodal model.

Behind the Research

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Research Objectives

Understanding the origins and impact of dust-laden air on climate and the wellbeing of Caribbean communities.

Detail

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Bio
Dr Thomas Plocoste (PhD, Université des Antilles) is the founder and President of KaruSphère SASU, and Research Director of the Department of Research in Geoscience at the KS Laboratory. He is a specialist in air pollution and climate change in the Caribbean area.

Funding
KaruSphère SASU

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Personal Response

With the knowledge gained about particle size, distribution patterns and meteorological interactions, what mitigating actions should now be implemented to help protect the health of local populations?

The impact of the African dust storm is difficult to mitigate because it is of natural origin. Nevertheless, it is important to have an adequate lifestyle depending on the presence of dust or not. As an example, when PM10 concentrations exceed the 50µg/m3 alert threshold recommended by the World Health Organization and the European directives, outdoor sports activities should be prohibited, especially for vulnerable people.

What are the benefits of Karusphère nurturing new young talent in this field?

Air pollution is a global concern. However, climate change in recent years has increased desertification in Africa causing an increase and intensification of dust storms. As desert aerosols are an integral part of the atmospheric equilibrium, it is important to be able to estimate and predict the evolution of the latter – so it's crucial for the KaruSphère laboratory to train new young talents, to deepen our knowledge and bring new skills in this field.

Your postdoctoral fellow, Lovely Euphrasie-Clotilde, won the L'Oréal-UNESCO Young Talent Award France for Women in Science in October 2021 – what does that success mean for your laboratory?

For me this award highlights several aspects. Firstly, the importance of women in science. Indeed, skills have neither gender nor skin colour. Secondly, it also highlights the quality and relevance of our research. The aim of our laboratory is to produce and improve scientific knowledge while making it available to the Caribbean population.

What are your future prospects in this area of work?

With the knowledge we have acquired, our goal now is to develop a multidisciplinary approach, to integrate our existing approach with, for example, epidemiological or agricultural aspects of the impact of desert aerosols and dust storms.