Saharan Dust Early Warning System: Protecting public health in Puerto Rico

NASA Science Mission Directorate
Earth Science Division
Applied Sciences Program

Program Area (Health and Air Quality)

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2022 NASA Annual Meeting

September 2022

(No-cost extension)

NASA Grant Number 80NSSC19K0194

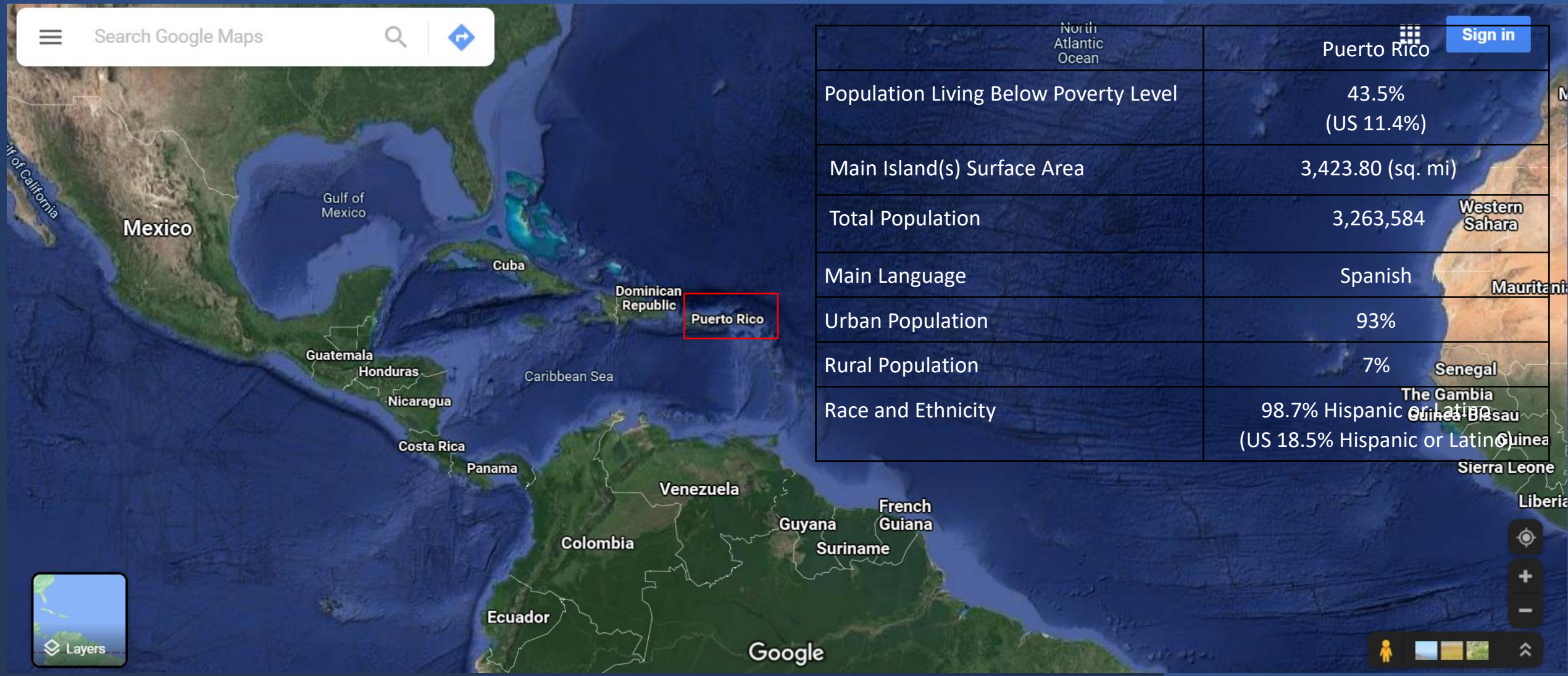
Saharan Dust Early Warning System: Protecting public health in Puerto Rico

- On Nov 2017, we proposed to characterize the distribution pattern and variability of ***Saharan Dust*** using Earth observations data from satellites and ground stations, and quantify the impact on respiratory diseases in Puerto Rico.

- This research is co-designing a **Public Health Early Warning (Monitoring) System** that integrates data from Earth observing satellites, in situ, and modeled weather information, and public health data.

  - **Working Group 1:** Resilience, Public Health and Well Being.
  - **Working Group 2:** Atmospheric Forcing and Air Quality.
  - **Working Group 3:** Decision Support Tool: Computation and Visualization.

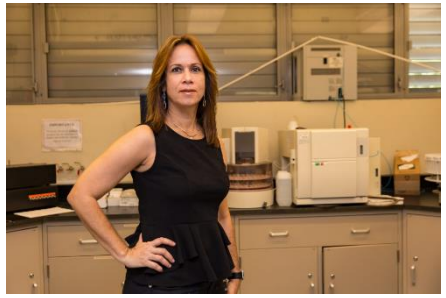
HCD Approach



	Puerto Rico
Population Living Below Poverty Level	43.5% (US 11.4%)
Main Island(s) Surface Area	3,423.80 (sq. mi)
Total Population	3,263,584
Main Language	Spanish
Urban Population	93%
Rural Population	7%
Race and Ethnicity	98.7% Hispanic or Latino (US 18.5% Hispanic or Latino)

Core Team members: Epidemiology, Environmental Health, Remote Sensing, Chemistry, Atmospheric Science, Climatology

Ana Patricia Ortiz, MPH,PhD



Olga L. Mayol-Bracero, Ph.D.

PI: Pablo A. Méndez-Lázaro, Ph.D.

Daniel Otis, PhD

Frank Muller-Karger, Ph.D

Cynthia M. Pérez-Cardona, Ph.D.

Digna Rueda-Roa, Ph.D.

Aluisio Pimenta, PhD, PE

Saharan Dust Early Warning System: Protecting public health in Puerto Rico

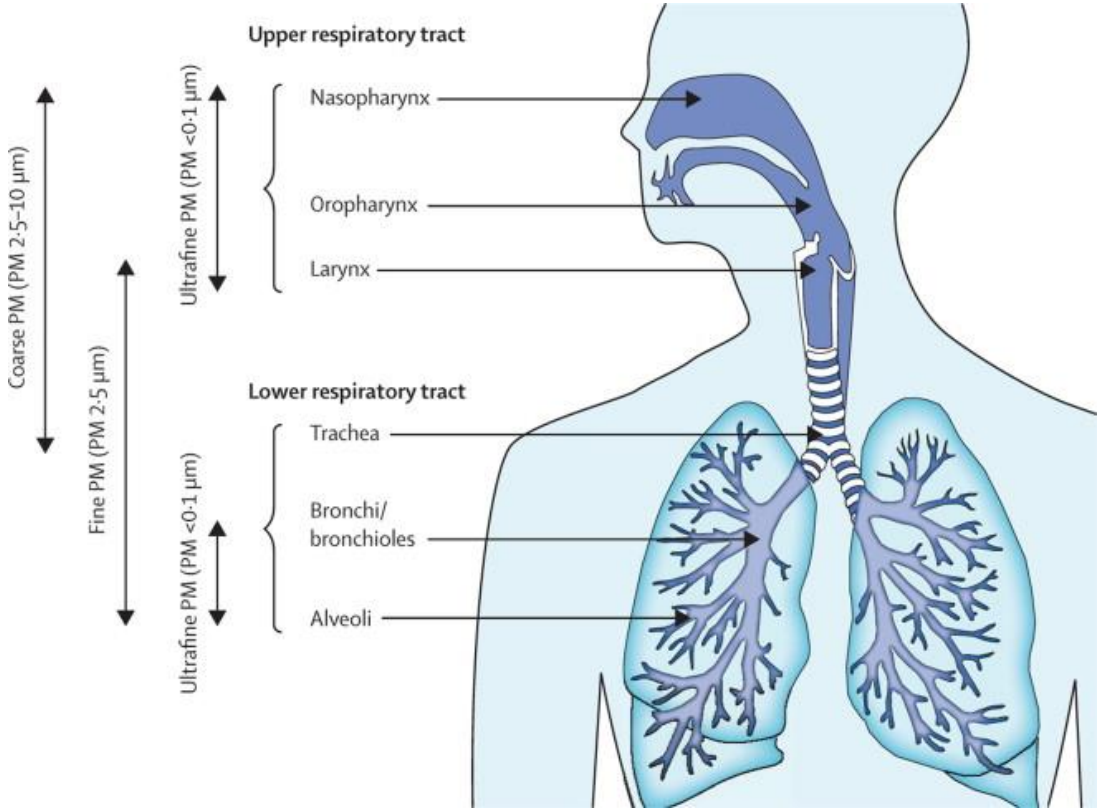
- Over 20 million tons of mineral dust from Africa are transported every year by the Trade Winds over the Atlantic Ocean, reaching South and North America, Caribbean Sea nations, and US territories between May and August every year.

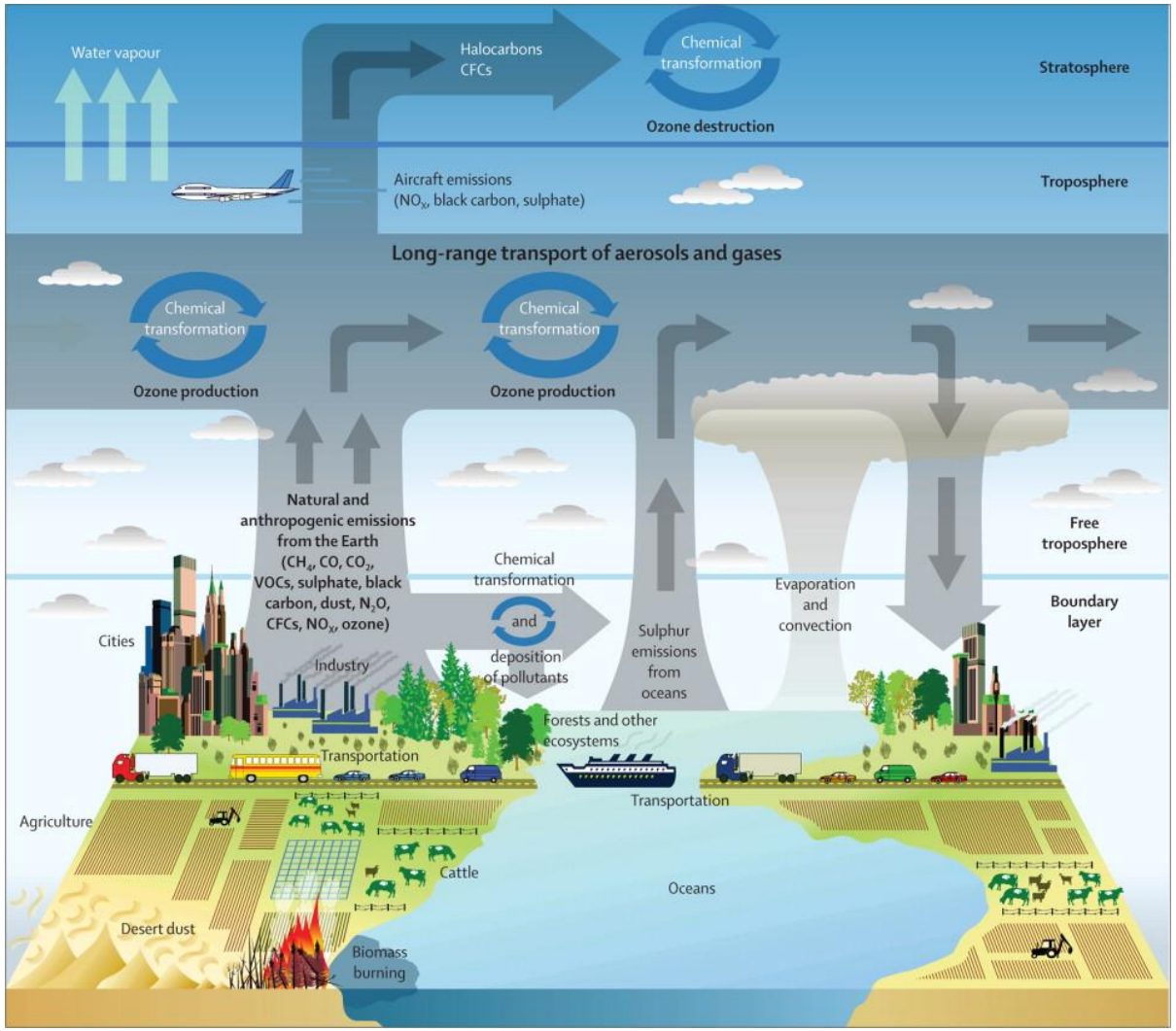
- In the Caribbean islands, dust is associated with increased to excessive risk of emergency room visits and hospitalizations related to respiratory diseases.

- On the other hand, the coronavirus SARS-CoV-2 responsible for the present COVID-19 pandemic increases the risk of mortality due to severe respiratory illness and cardiac injury.

- Our transdisciplinary team proposes to examine these interactions and help understand whether specific African dust transport events lead to higher or lower COVID-19 cases or exacerbate health effects.

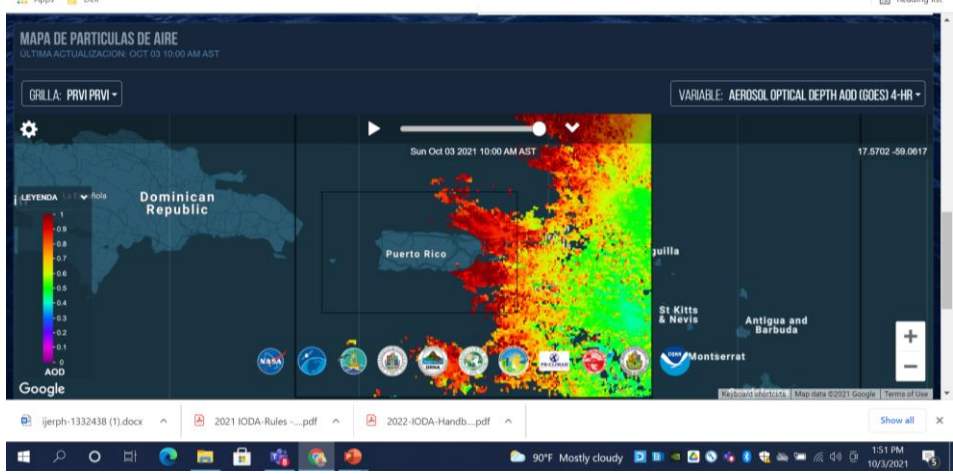
Guarnieri, M., Balmes, J.R. 2014. Outdoor air pollution and asthma. DOI:https://doi.org/10.1016/S0140-6736(14)60617-6. Lancet 2014; 383: 1581–92

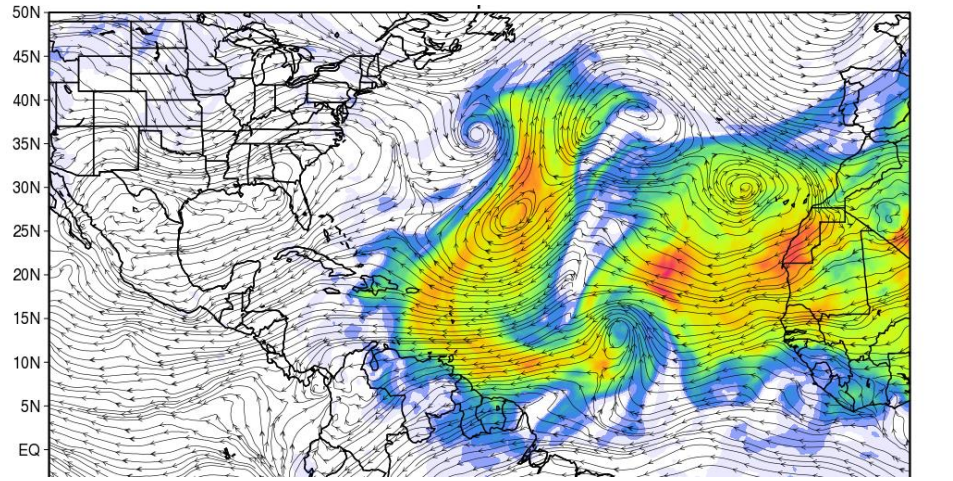


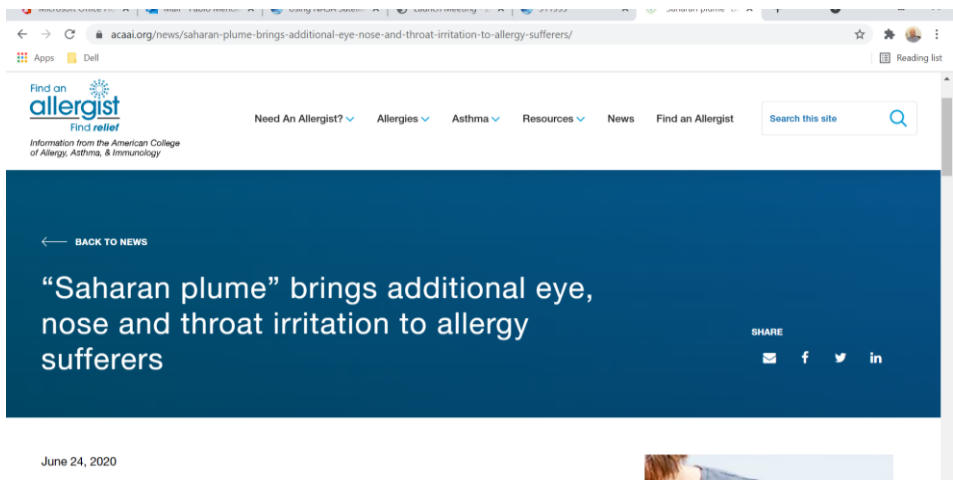


What is Saharan Dust and its seasons in the Caribbean?

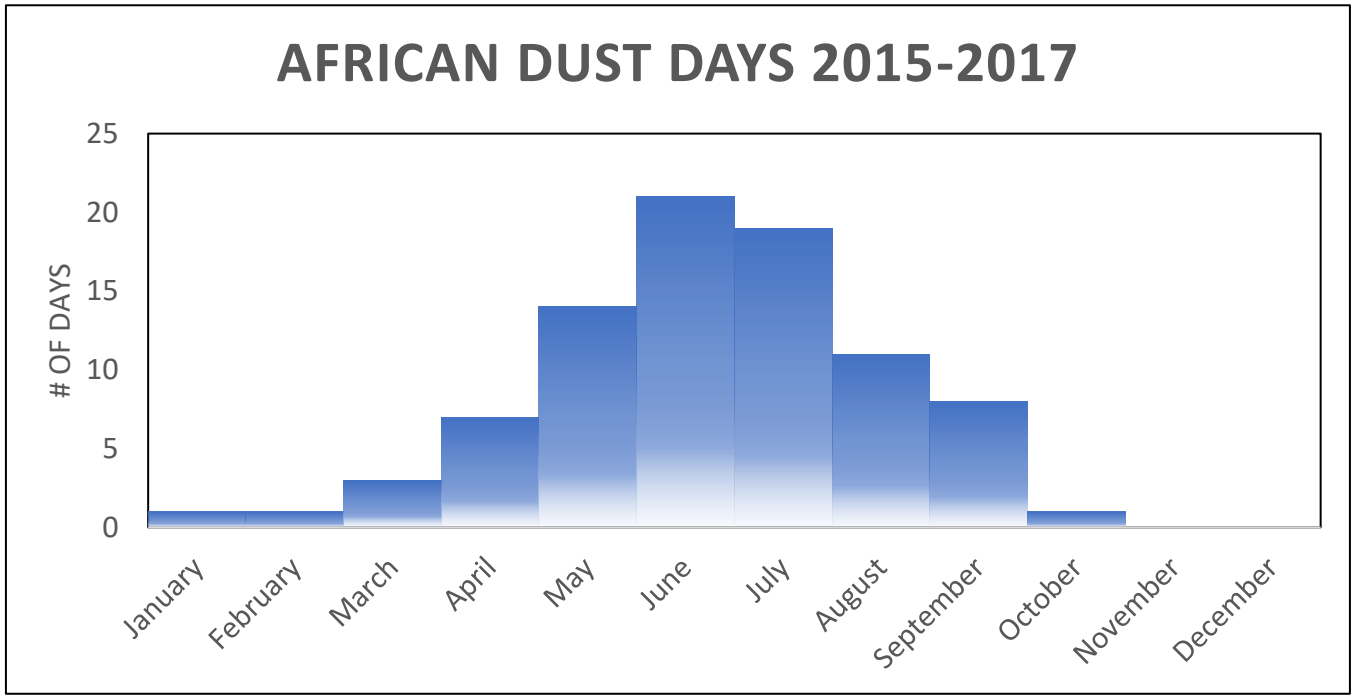
- The mineral dust particles that reach us in the Americas from Africa could contain minerals, organic matter, marine salts, viruses and bacteria.
- Dust Clouds are aerosols, small solid and liquid particles suspended in the atmosphere.
- Examples of aerosols include windblown dust, sea salts, volcanic ash, smoke from fires, and factory pollution.
- These particles are important because they can affect the climate, ecosystems and people's health.







Dust “seasons” in the Caribbean

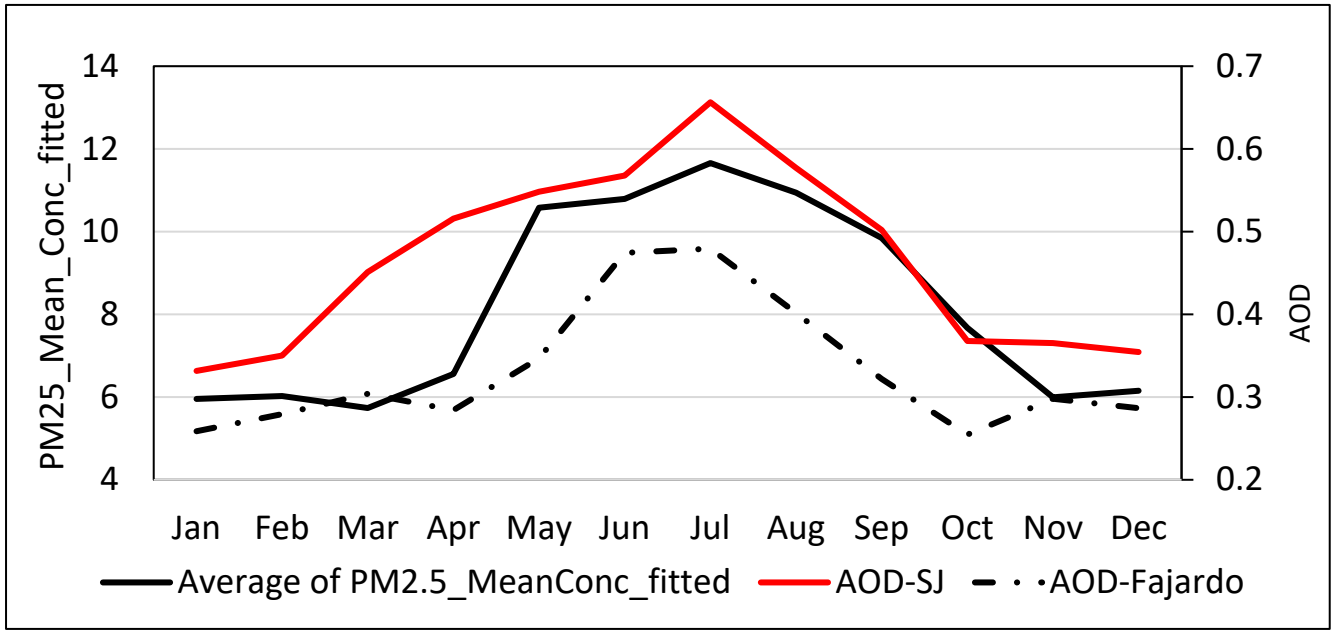


	#’s of African Dust Events	75th Percentile	90thPercentile	95th Percentile	99.9th Percentile
Autumn	1	5	0	0	0
Spring	10	3	1	0	0
Summer	**73**	**72**	**32**	**17**	**1**
Winter	2	1	0	0	0

Dust Season in the Caribbean occurs between May and September. (Summer)

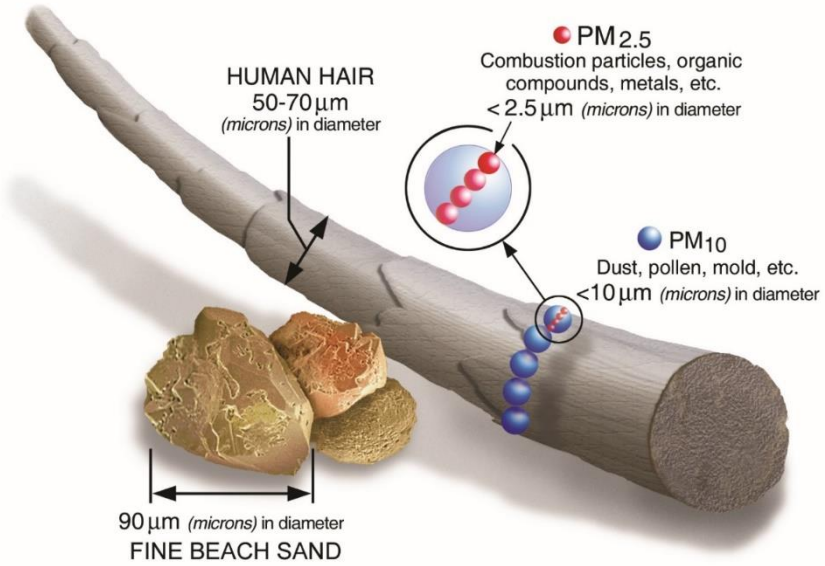
The most intense months in Puerto Rico are between the months of June to August.

Aerosol Optical Depth and PM2.5 seasonal patterns



Dust is positively associated with cardiovascular and respiratory conditions in the Caribbean (Lillianne et al. 2019).

Dust outbreaks have also been associated with increased to excessive risk of emergency room visits and hospitalizations related to asthma in children in Trinidad & Tobago (Gyan et al., 2005), Guadeloupe (Cadelis et al., 2015), and Grenada (Akpinar-Elci et al., 2015).

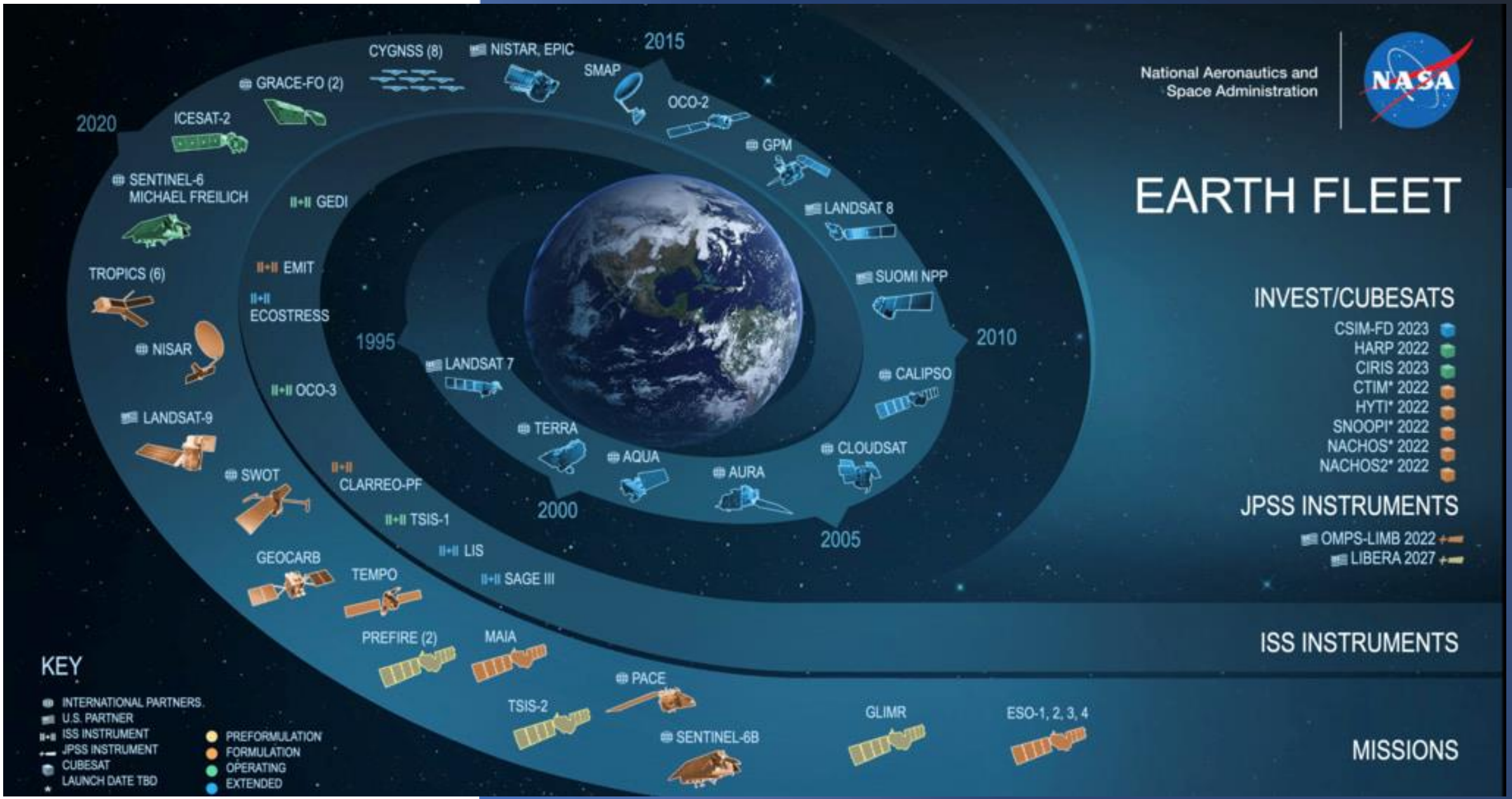


An optical thickness of less than 0.1 indicates a crystal clear sky with maximum visibility, while a value of 1 indicates the presence of aerosols so dense that people would have difficulty seeing the Sun, even at noon.
Journal of the American College of Cardiology Volume 72, Issue 17, October 2018
DOI: 10.1016/j.jacc.2018.07.099

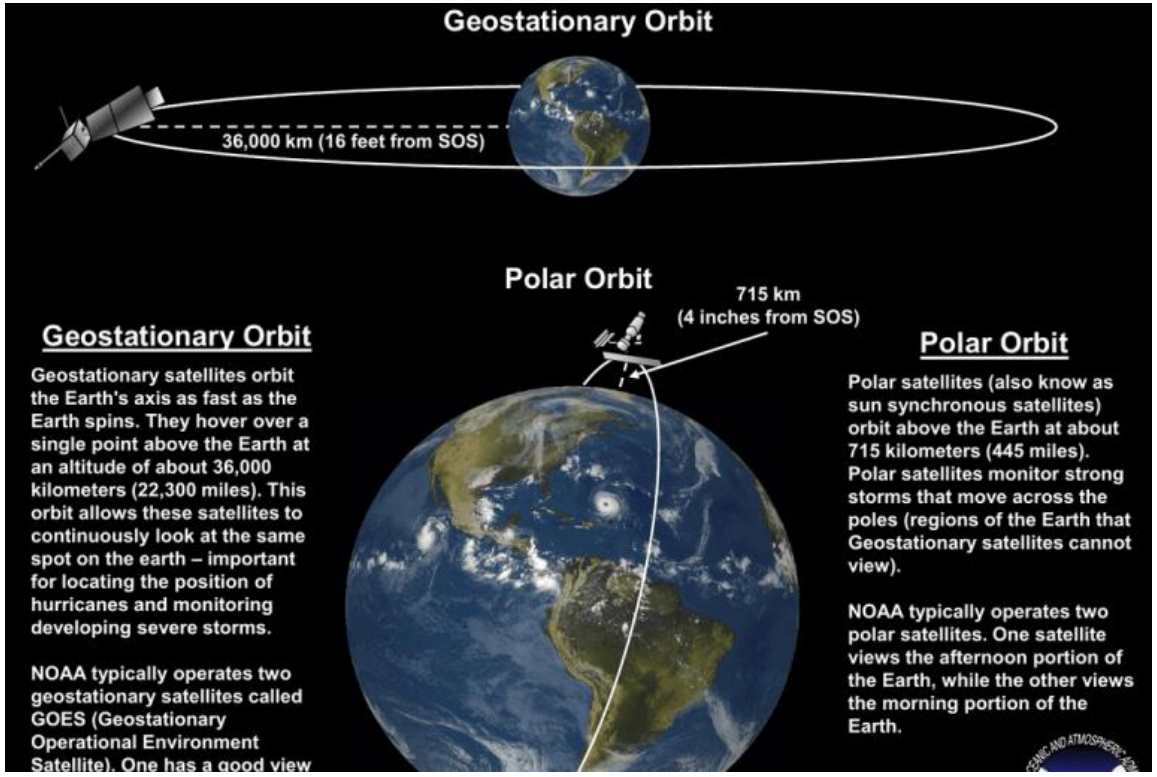
ESO Data

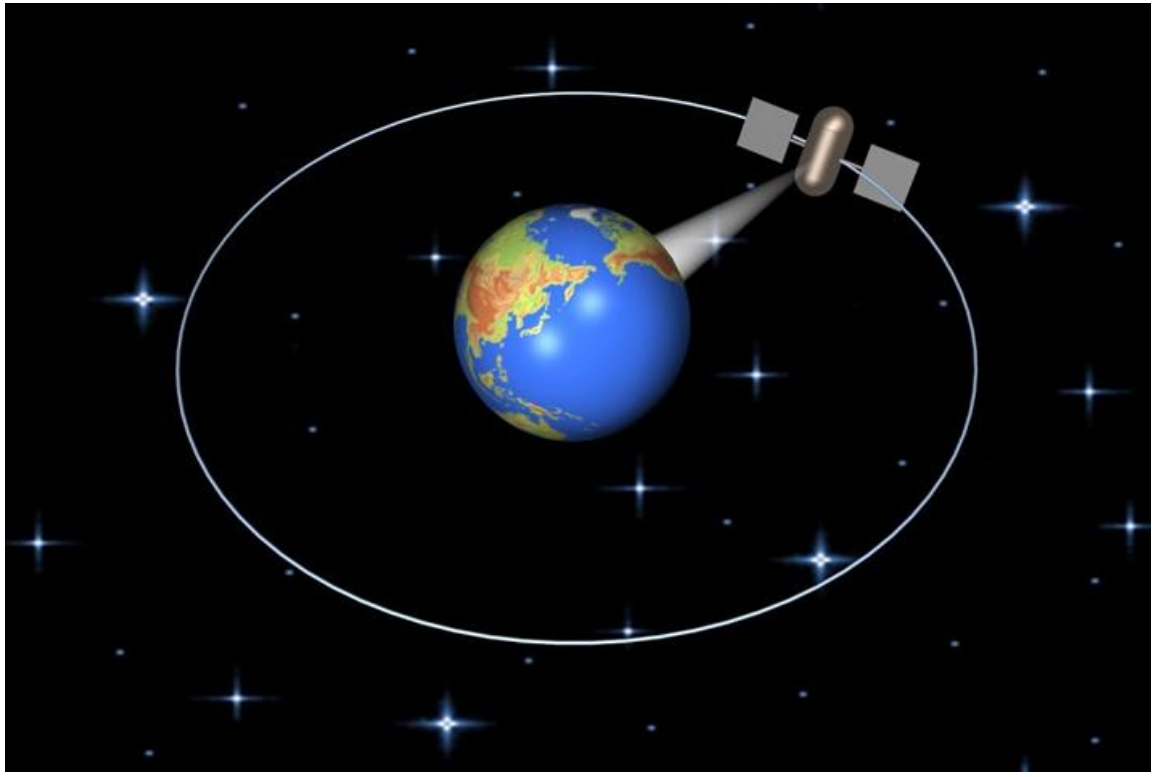
Data Source/Sensor	Variable	Temporal Resolution	Period
Visible Infrared Imaging Radiometer Suite (VIIRS)	AOD (n=1539) SAE (n=1512) MC (n=1368)	Daily	2012-2020
Multi-scale Ultra-high Resolution Sea Surface Temperature	SST (n=1536)	Daily	2012-2020
MODIS-Aqua: Land Surface Temperature	LSTd (n=921) LSTn (n=895)	Daily	2012-2020
ERA5-HEAT (Human thErmAl comforT)	UTCI (n=1539) HI (n=1539) T2M (n=1539)	Daily	2012-2020

PR-CLIMAH
THIS IS PUBLIC HEALTH


National Aeronautics and Space Administration
NASA
EARTH FLEET
2015
2020
1995
2010
2000
2005
CYGNSS (8)
NISTAR, EPIC
SMAP
GRACE-FO (2)
ICESAT-2
OCO-2
GPM
SENTINEL-6 MICHAEL FREILICH
GEDI
LANDSAT 8
TROPICS (6)
EMIT
SUOMI NPP
ECOSTRESS
NISAR
LANDSAT 7
CALIPSO
OCO-3
LANDSAT-9
TERRA
AQUA
AURA
CLOUDSAT
SWOT
CLARREO-PF
TSIS-1
LIS
GEOCARB
TEMPO
SAGE III
PREFIRE (2)
MAIA
PACE
TSIS-2
SENTINEL-6B
GLIMR
ESO-1, 2, 3, 4
INVEST/CUBESATS
CSIM-FD 2023
HARP 2022
CIRIS 2023
CTIM* 2022
HYTI* 2022
SNOOPI* 2022
NACHOS* 2022
NACHOS2* 2022
JPSS INSTRUMENTS
OMPS-LIMB 2022
LIBERA 2027
ISS INSTRUMENTS
MISSIONS
KEY
INTERNATIONAL PARTNERS
U.S. PARTNER
ISS INSTRUMENT
JPSS INSTRUMENT
CUBESAT
LAUNCH DATE TBD
PREFORMULATION
FORMULATION
OPERATING
EXTENDED

Earth Observatory (geostationary vs non geostationary)





Impacting Decision Making Activities:

Co-design strategies and solutions by engaging scientist and public health officials in all project phases.

Communicating Risks and working with end-users

October 07, 2021

Mariane Alvarado López, MPHE, CHES®, CGG

Educadora en Salud del Programa de Manejo y Control del Asma

Departamento de Salud de Puerto Rico

División de Prevención y Control de Enfermedades Crónicas

Secretaría Auxiliar para la Promoción de la Salud

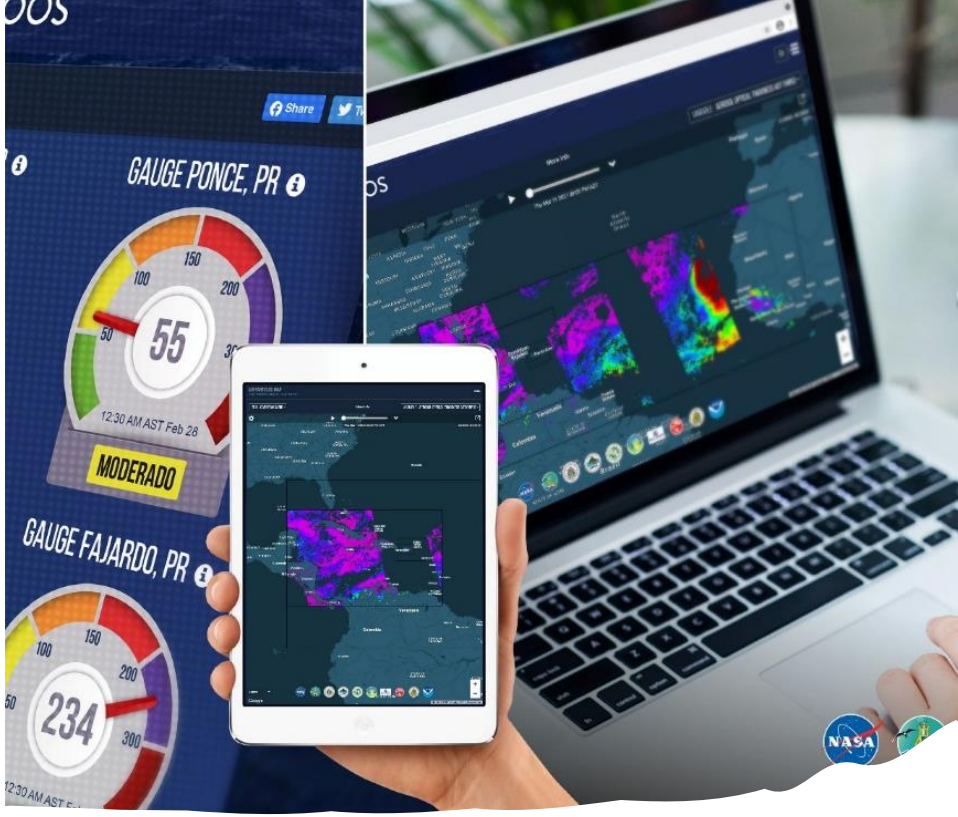
mariane.alvarado@salud.pr.gov

www.salud.gov.pr

http://www.proyectoasmapr.com

Teléfono: (787) 765-2929 Ext. 4157

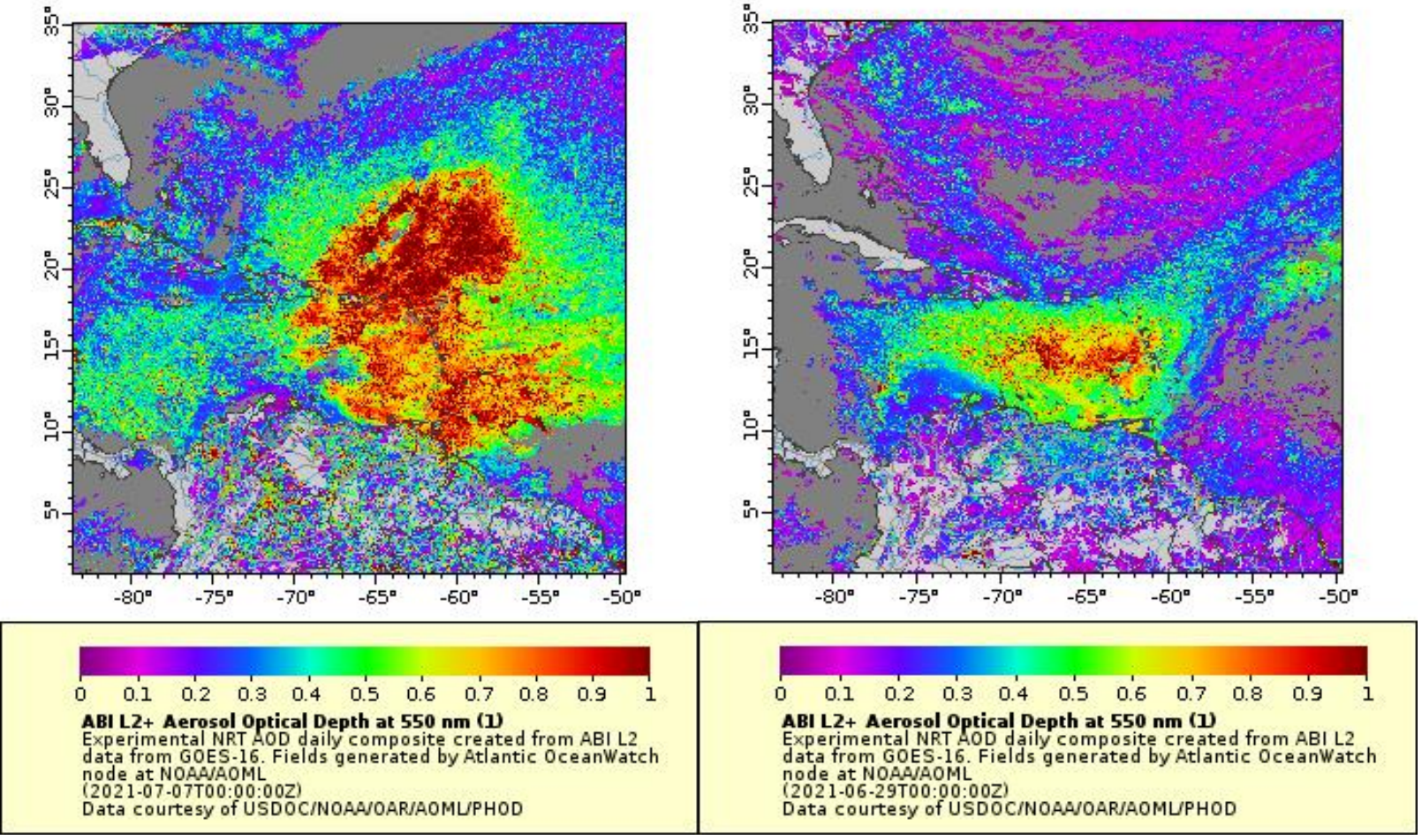
Puerto Rico Department of Hazard and Vulnerability Assessment (every 5 years).



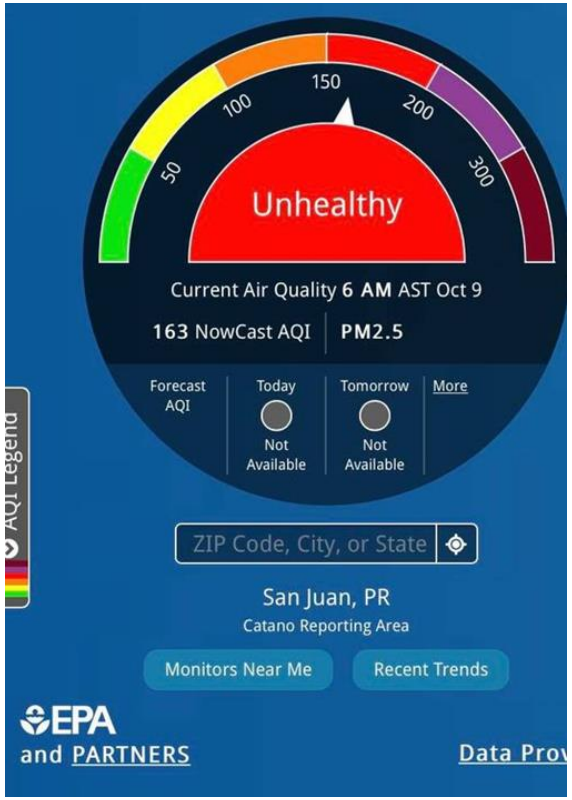
"X-perimental Decision Support Tool "

GOES-16: daily datasets: Experimental NRT AOD daily composite created from ABI L2 data from GOES-16. Fields generated by Atlantic OceanWatch node at NOAA/AOML

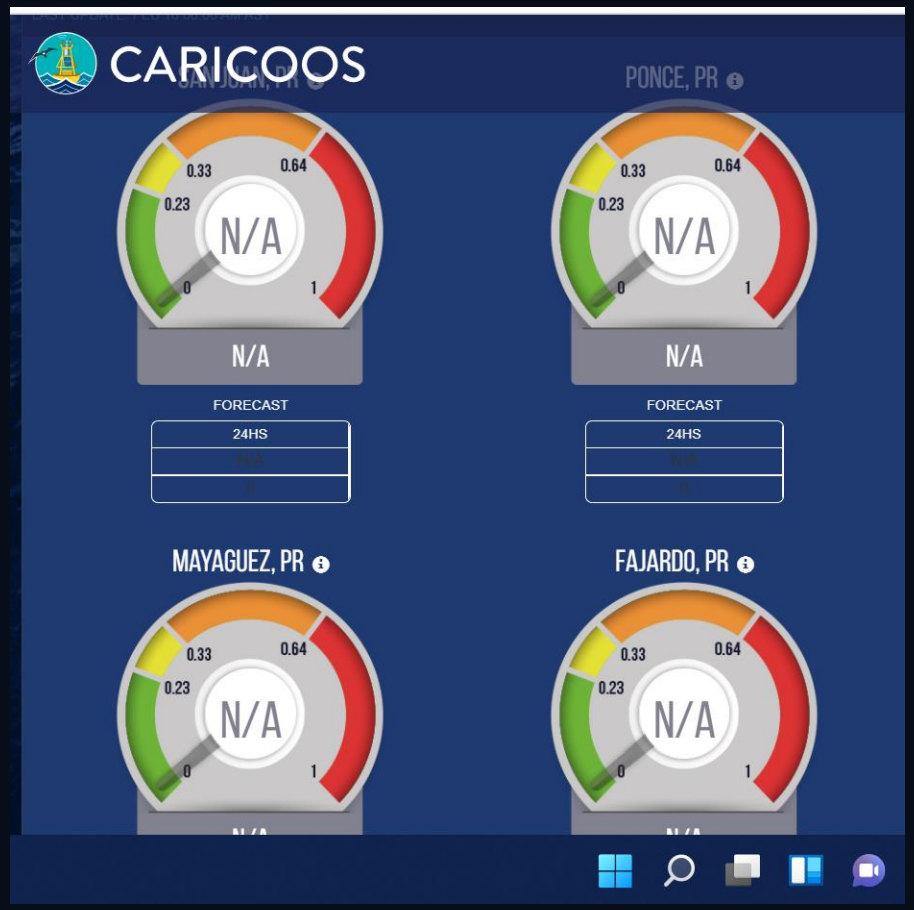
July 07, 2021

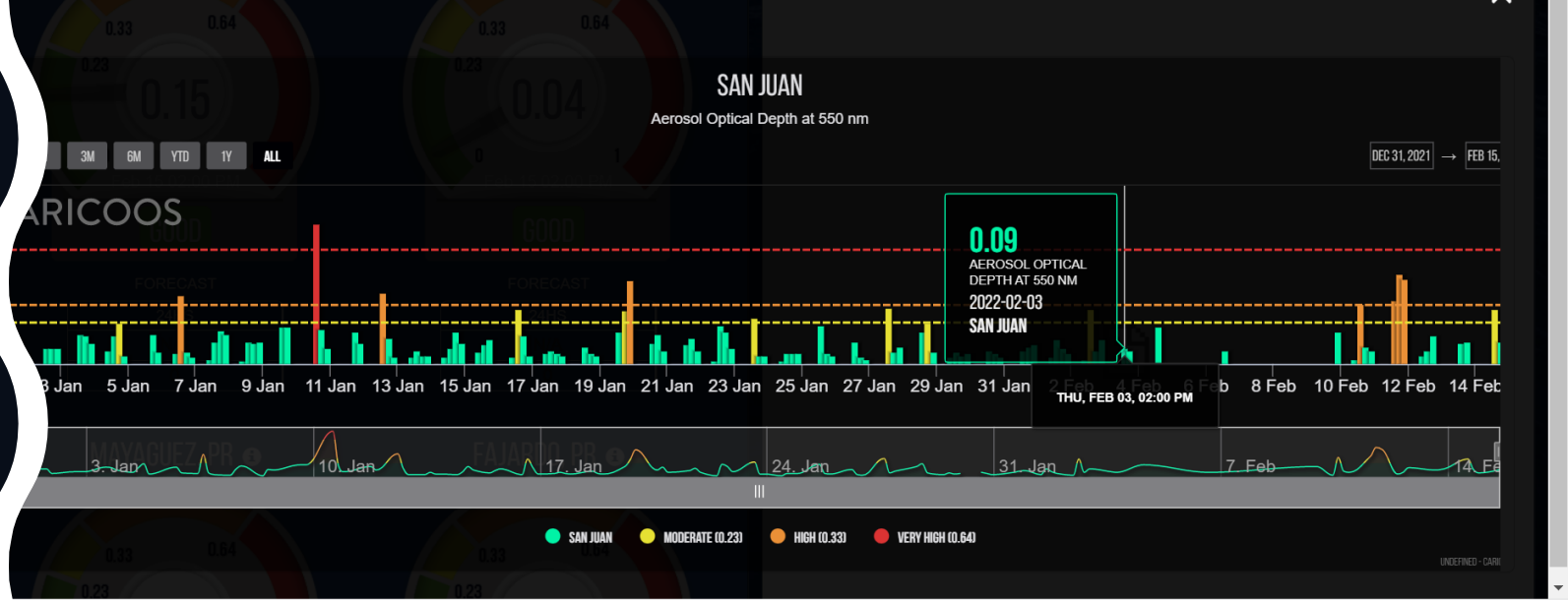


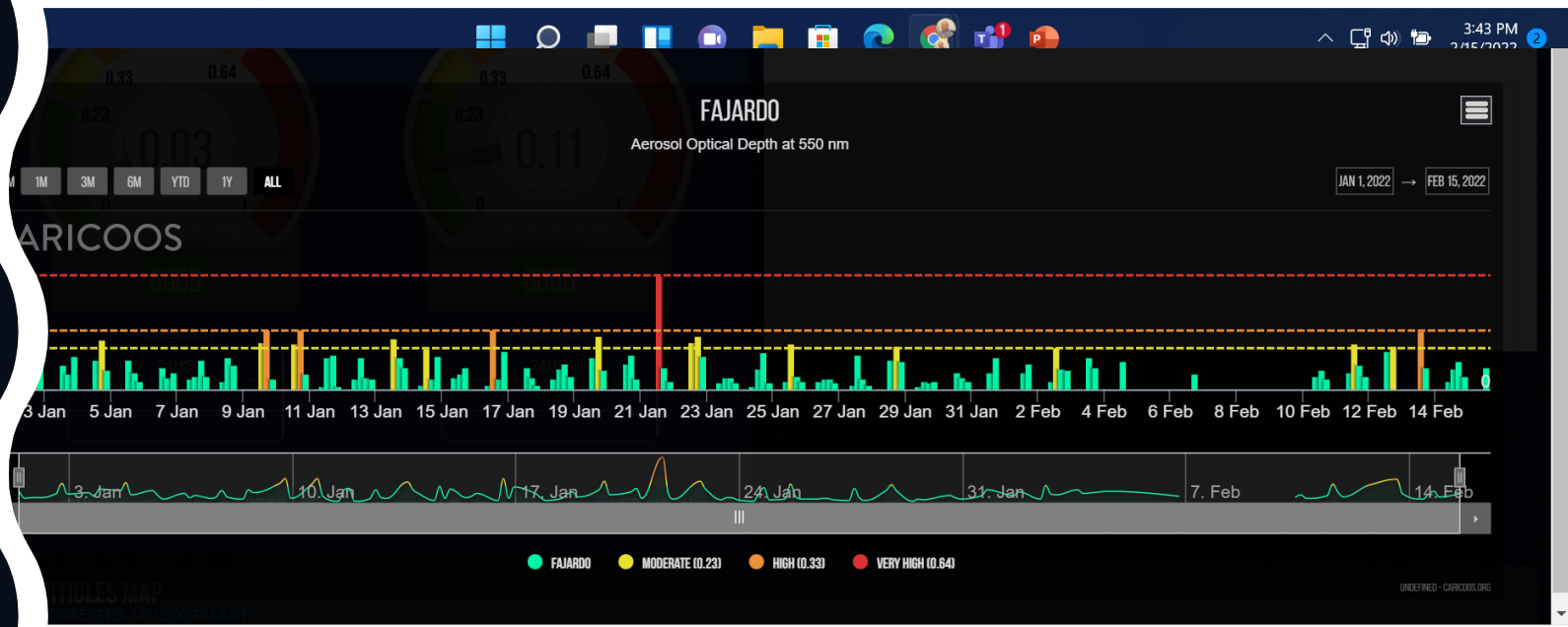
June 29, 2021



October 3rd, 2021







noaa-nos-techrpt0....pdf
IQA_Decision_Tree....pdf
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October 13, 2022

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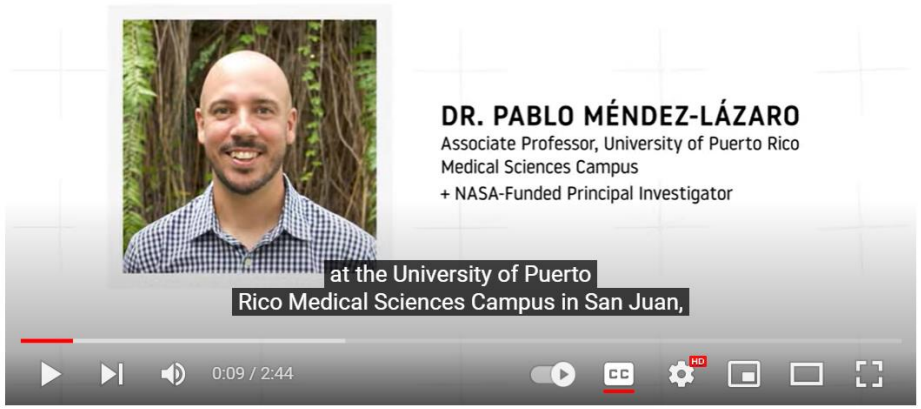

An Early Warning System Helps Puerto Rico Prepare for Saharan Dust

NASA Video
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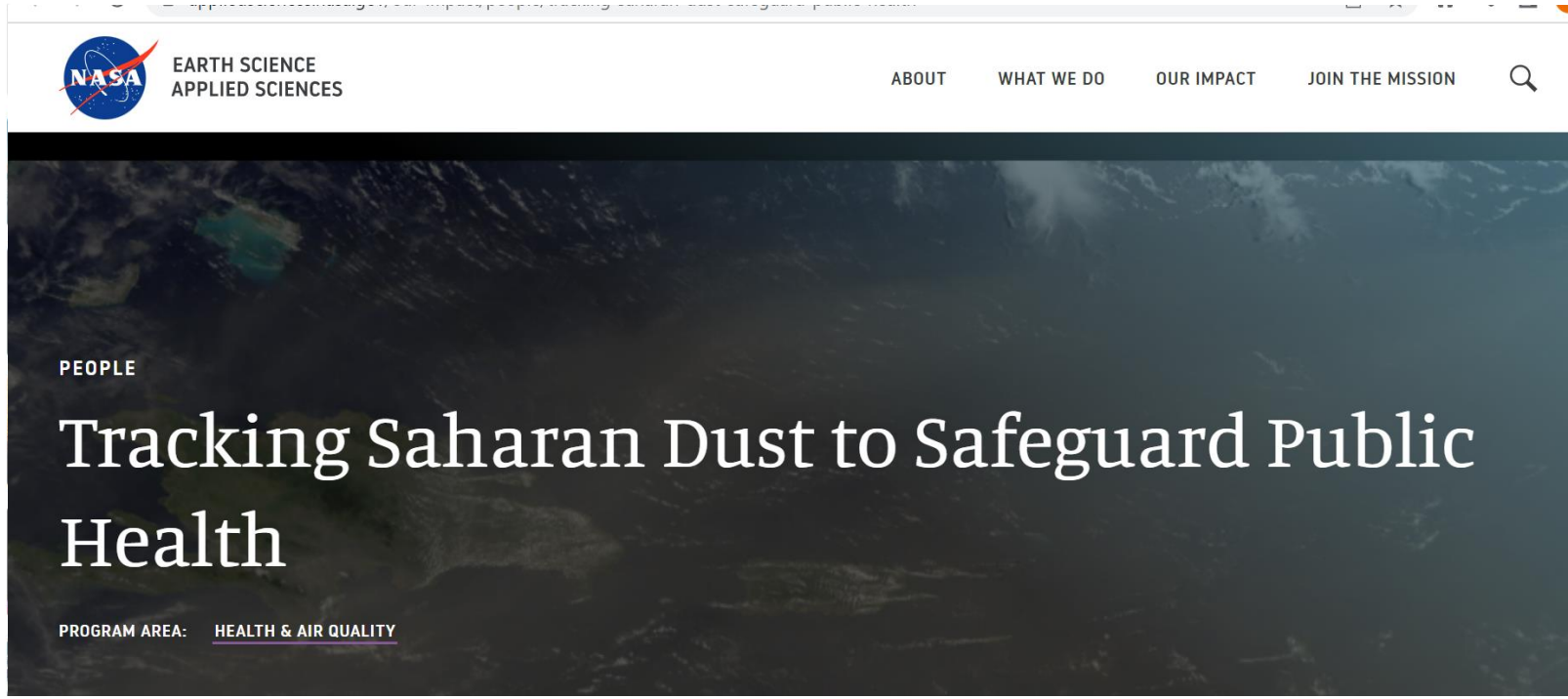
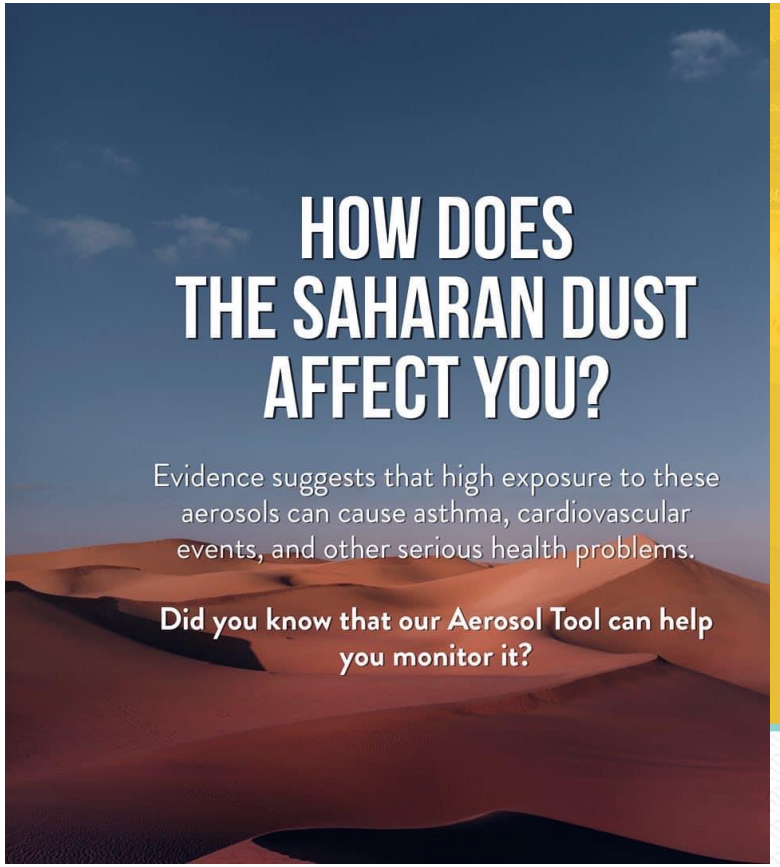
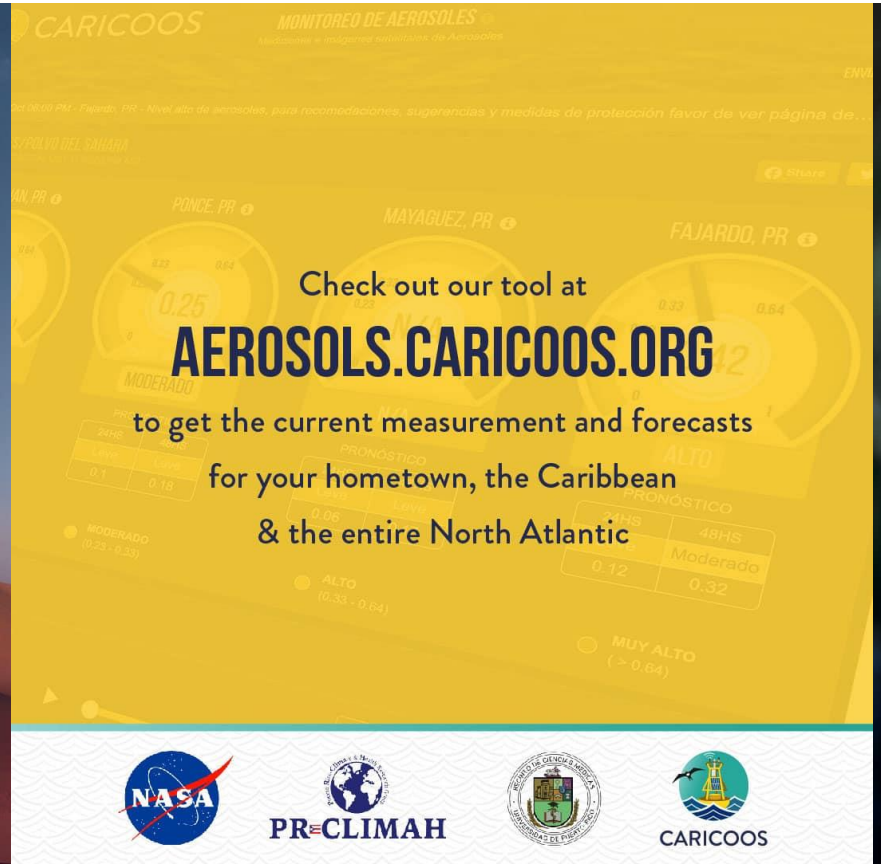
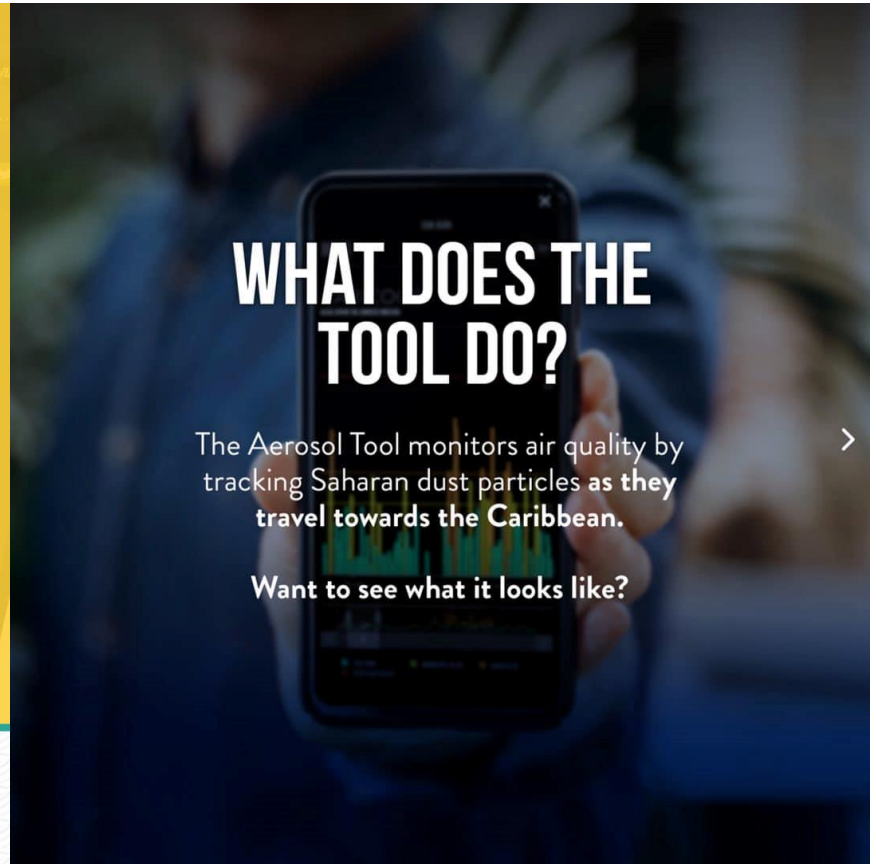
Puerto Ricans can breathe easier thanks to the work of John Haynes, program manager of the NASA Earth Applied Sciences Health and Air Quality program area, and Pablo Méndez-Lázaro, an associate professor at the University of Puerto Rico Medical Sciences Campus in San Juan, and principal investigator for thi ...more

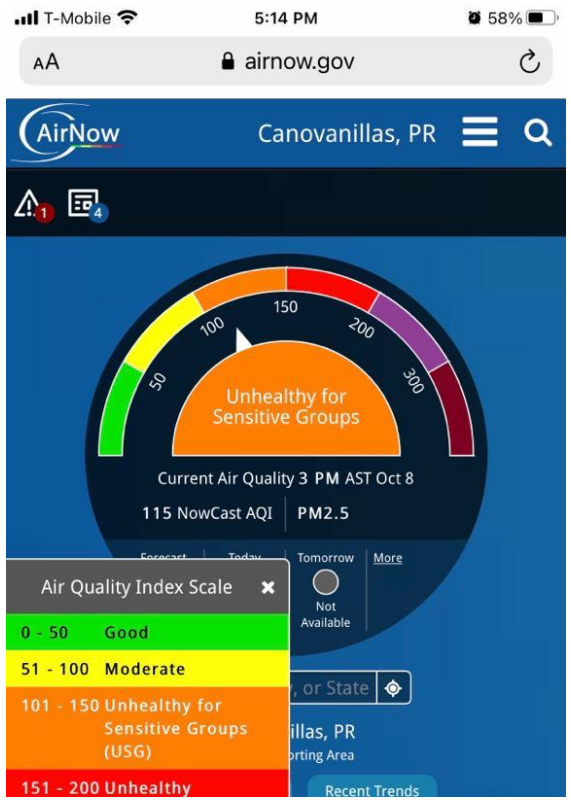


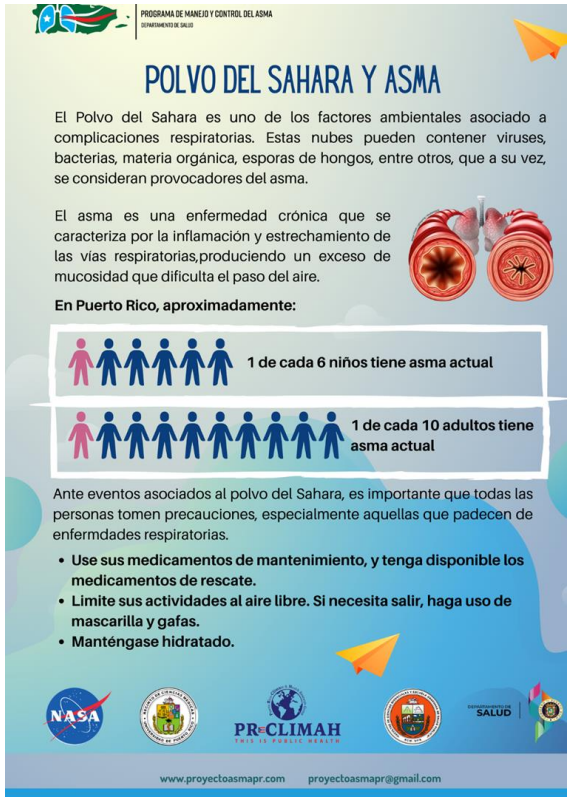
CARICOOS Facebook











Area Forecast Discussion
Issued by NWS San Juan, PR

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Area Forecast Discussion
National Weather Service San Juan PR
412 PM AST Thu Oct 7 2021

.SYNOPSIS...
Saharan dust will result in hazy skies through at least ea
the weekend. However, afternoon activity may still develo
the northwestern quadrant of Puerto Rico. **Unsettled** weath
conditions are expected for the first half of the next wo
Seas are gradually improving, but still remaining a littl

&&

.SHORT TERM...Tonight through Saturday...
A surface high pressure over the central Atlantic will ma
moderate east-southeast wind **flow** through the next severa
At the mid-levels, a **ridge** holds just west of Puerto Rico
at the upper levels, a **trough** lingers north of the island
infrared satellite imagery shows small areas of clouds ad
toward the region. The high resolution models have some o
areas reaching portions of the U.S. Virgin Islands and ea
southeast Puerto Rico, but with **rainfall** accumulation mai
one inch.

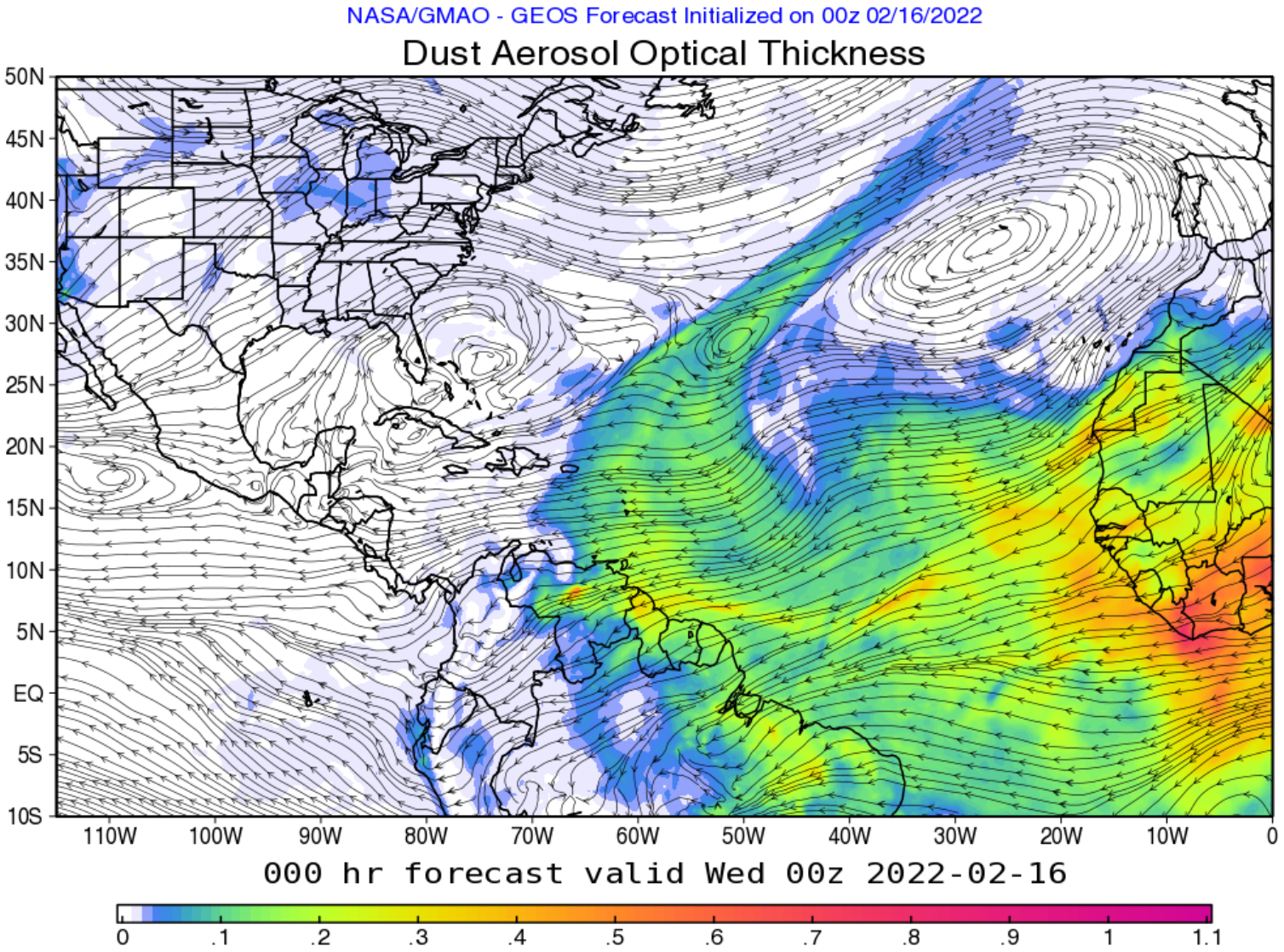
On Friday, a drier **air mass** east of the **Leeward** Islands a
evident in Total **Precipitable Water** from **GOES**-16 will rea
local islands, with values falling to 1.3 to 1.5 inches.
mass also contain Saharan dust, that will linger at least
early in the weekend, hence hazy skies are expected. Each
Friday and Saturday, passing showers may move over portio
eastern Puerto Rico and the U.S. Virgin Islands through t
then in the afternoon showers with **isolated** thunderstorms
develop over the interior and northwestern Puerto Rico.

October 07, 2021

Media Coverage

- https://www.primerahora.com/noticias/puerto-rico/notas/insalubre-la-calidad-del-aire-ante-presencia-de-polvo-del-sahara/
- https://www.noticel.com/el-tiempo/20211009/continua-insalubre-el-indice-de-calidad-del-aire/
- https://www.elnuevodia.com/noticias/el-tiempo/notas/la-calidad-de-aire-amanece-insalubre-en-varias-partes-de-puerto-rico/
- https://www.elnuevodia.com/noticias/locales/notas/densa-bruma-que-afecta-a-puerto-rico-desde-hace-una-semana-deteriora-la-calidad-del-aire/

October 07, 2021



February 15-16, 2022

Programa de Asma de Puerto Rico
131 followers
4h

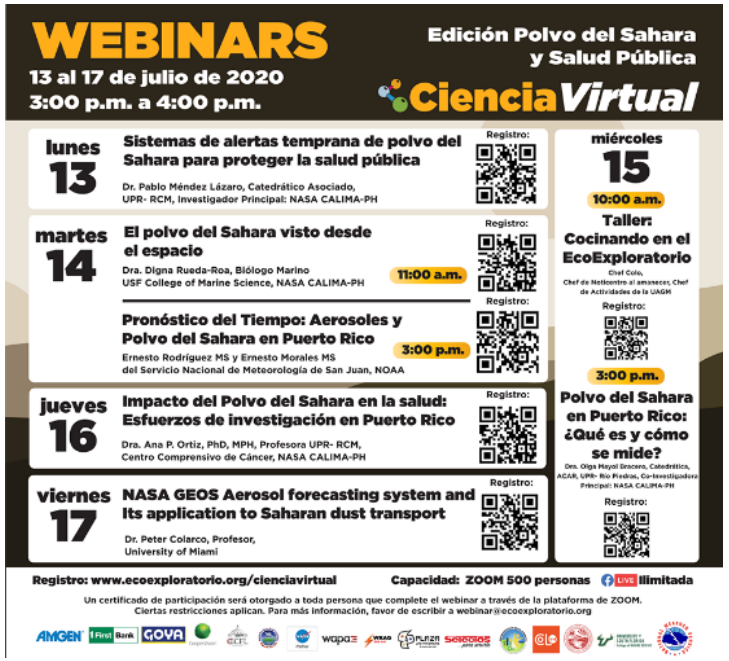
Aquí le compartimos nuevamente información importante sobre el Polvo del Sahara. #AsmaPR #DdepartamentodeSalud #ProgAsma

3:46 23%

Programa de Asma de Puerto Rico
131 followers
8h

El particulado de polvo del Sahara provocará mucho calor y nubosidad toda la semana, y se espera que este patrón se extienda durante el resto de la semana laboral.

Tome medidas de prevención utilizando sus medicamentos de control para evitar crisis asmática y tenga listo su medicamento de rescate. Utilice mascarilla y gafas si planea realizar actividades al aire libre. #AsmaPR #ProgAsma #DepartamentodeSalud



Co-design strategies and solutions by engaging scientist and public health officials in all project phases.

>400,000 people impacted

Project Title (long version): Study of Imminent Interactions between SARS-CoV-2 (COVID-19), Air Quality due to Saharan Dust and Urban Aerosols, and Social-Environmental Factors in Puerto Rico in summer 2020: Proxies of Health Risks in Small Island States in the Caribbean Region.

NASA Grant Number 80NSSC20K1588

- **Funding Opportunity:** Rapid Response and Novel Research in Earth Science NNH20ZDA001N-RRNES

- **Investigators:** Pablo Méndez-Lázaro (PI), Frank Muller-Karger (Co-I), Ana P. Ortiz-Martínez (Co-I), Cynthia Pérez-Cardona (Co-I), Daniel Otis (Co-I), David De Angel Solá (Co-I), Benjamin Bolaños (Co-I).

- **Institutions:** University of Puerto Rico-Medical Sciences Campus, Graduate School of Public Health, San Juan-Puerto Rico (http://sp.rcm.upr.edu/); University of South Florida, College of Marine Science (http://www.marine.usf.edu/), St. Petersburg, Florida

Study of Imminent Interactions between SARS-CoV-2 (COVID-19), Air Quality due to Saharan Dust and Urban Aerosols, and Social-environmental Factors in Puerto Rico in summer 2020: Proxies of Health Risks in Small Island States in the Caribbean Region (80NSSC20K1588)

In the Caribbean islands, Saharan dust is associated with increased to excessive risk of emergency room visits and hospitalizations related to respiratory diseases.

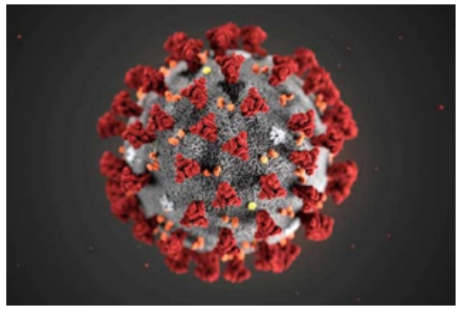
On the other hand, the coronavirus SARS-CoV-2 responsible for the present COVID-19 pandemic increases the risk of mortality due to severe respiratory illness and cardiac injury.

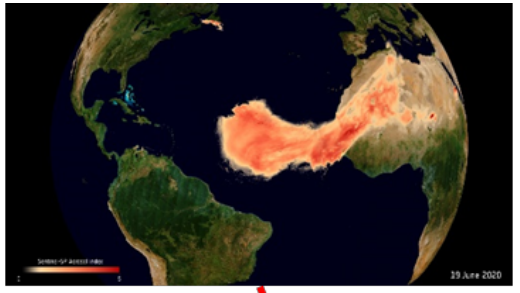
The goal of the proposed work is to expand the scope of a current NASA-sponsored African dust research (80NSSC19K0194) to better understand possible interactions between COVID-19, Saharan dust, and environmental factors (air temperature, sea surface temperature, and precipitation) in Puerto Rico.

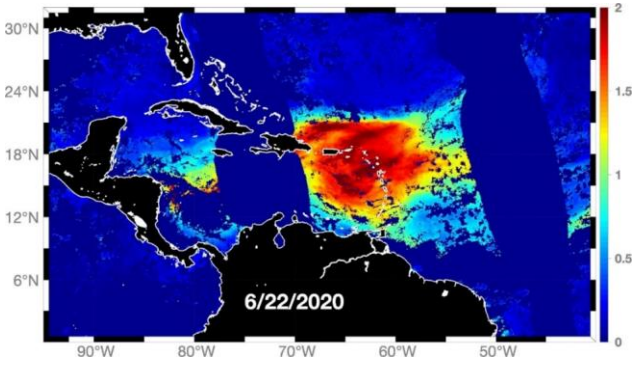
Study of Imminent Interactions between SARS-CoV-2 (COVID-19), Air Quality due to Saharan Dust and Urban Aerosols, and Social-environmental Factors in Puerto Rico in summer 2020: Proxies of Health Risks in Small Island States in the Caribbean Region

- Designed and implemented (Cross sectional study) qualitative instruments aiming to capture **physicians and patients' risks, barriers, and vulnerabilities**.
    - Physicians N=55
    - Patients COVID-19 confirmed cases N=104
    - IRB-Protocol Number B1540520
- **Emergency Room Visits and Hospitalizations-2020-2021**
    - COVID-19 Weekly 2020-2021
    - Weekly in specific diseases of the respiratory system.
- **All Causes Excess Mortality Analysis Islandwide (weekly 2015-2020) Including COVID-19**
    - Weekly average deaths during 2015-2020: overall and by season
    - Weekly average deaths during 2015-2020: overall by year of death for each season
    - Weekly average during 2015-2020 in specific diseases of the respiratory system.
    - COVID-19 Mortality Analysis (weekly 2020)
    - RR adjusted by environmental data (weekly 2015-2020)

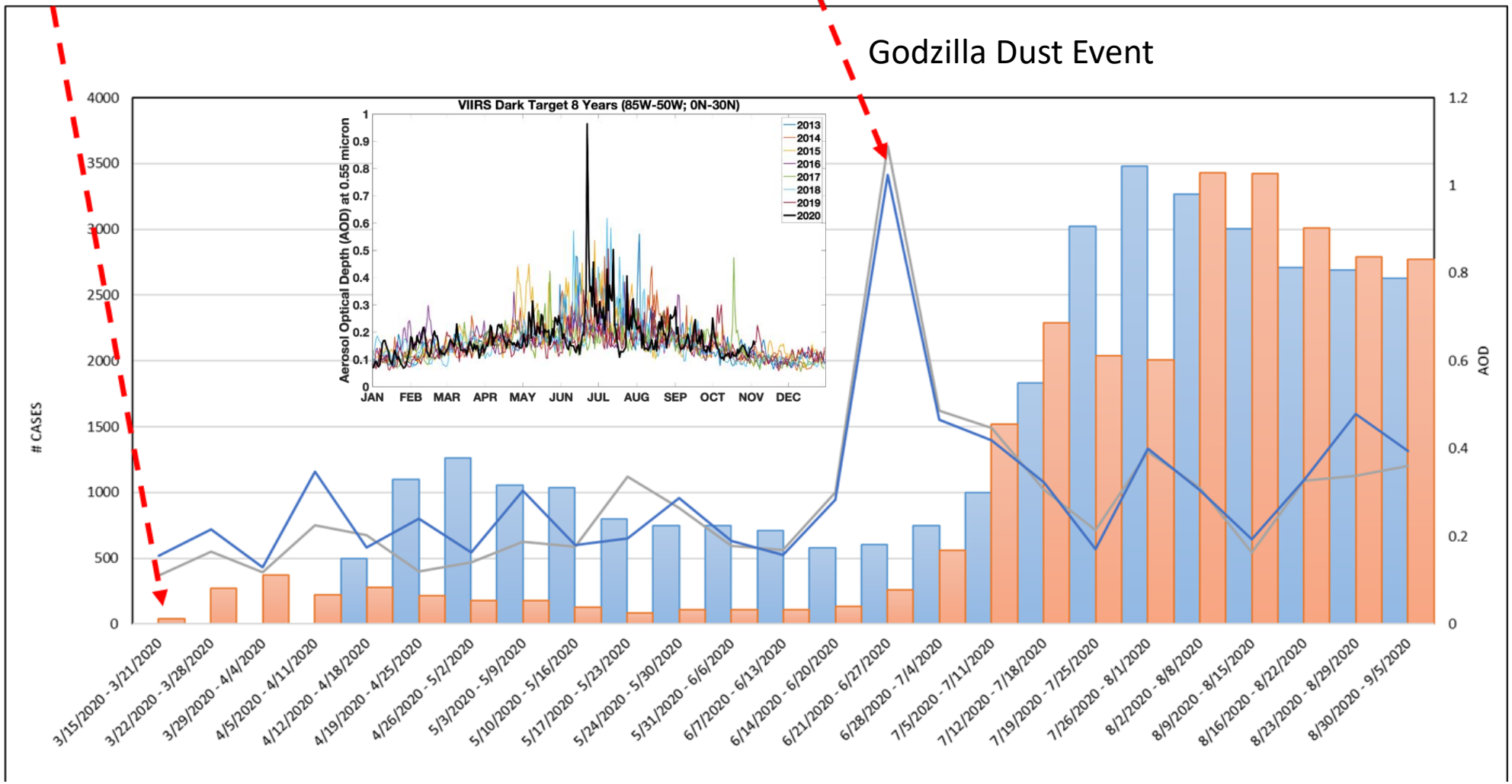
1st COVID-19 Confirmed Case In Puerto Rico



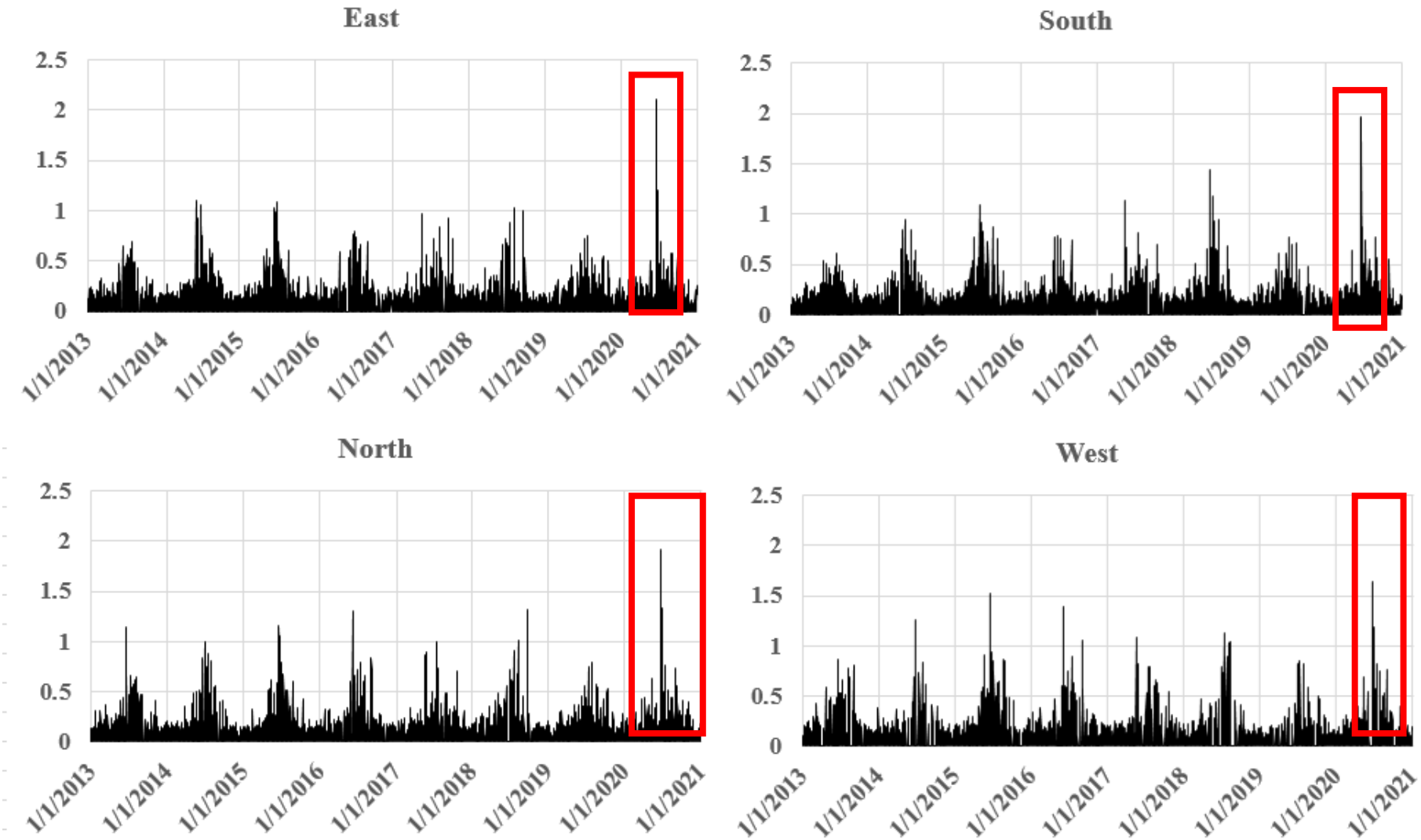




Godzilla Dust Event



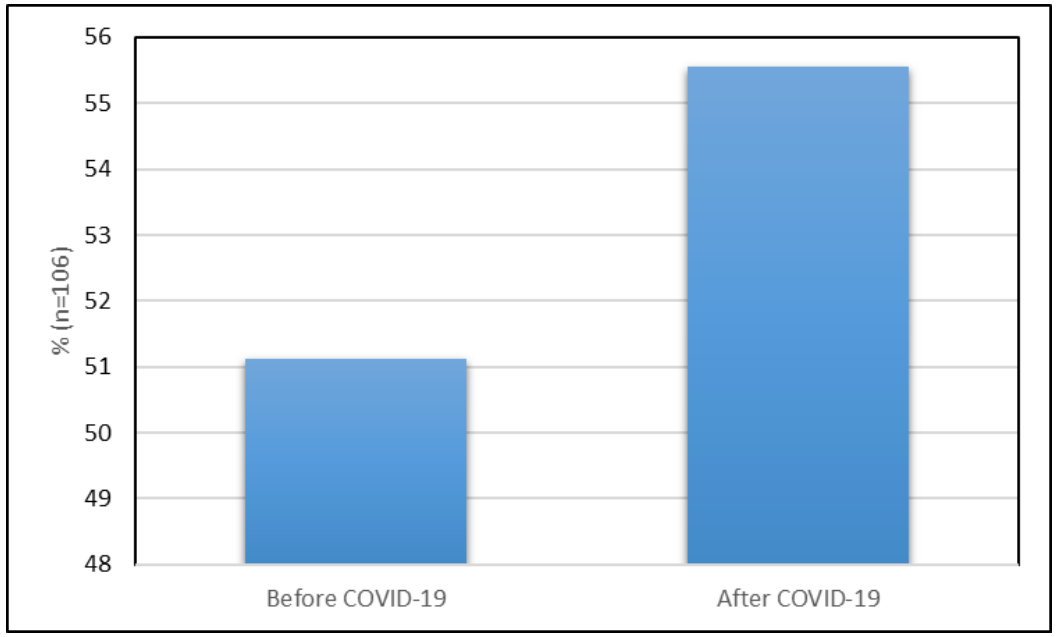
Godzilla Dust Event: Summer 2020

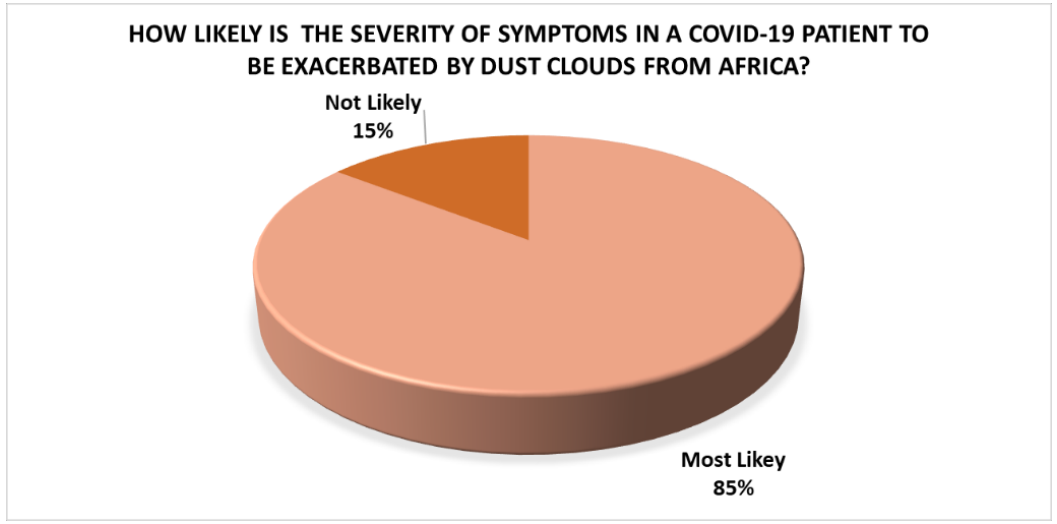


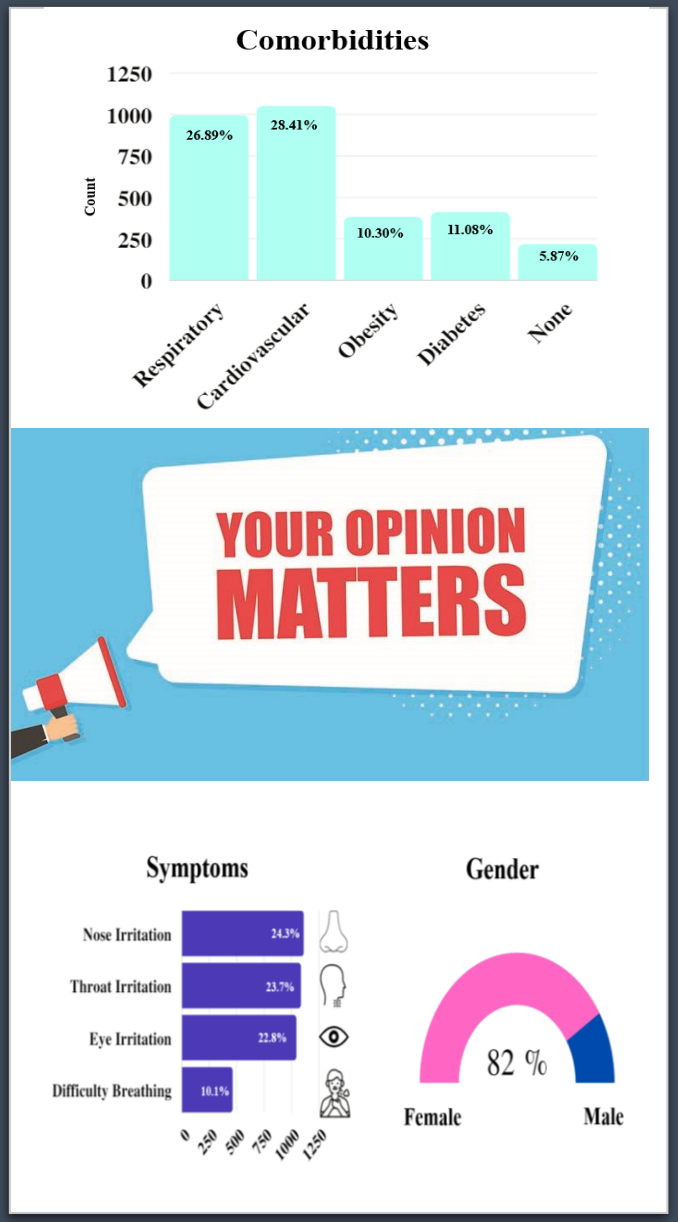
Left: Upper picture June Tuesday June 23dr, 2020 9:30am (AST)
Lower Image Saturday June 20th, 2020 9:30am (AST)

Right: Upper Image: Morning Saturday June 20th, 2020
Lower Image: Morning Tuesday June 22nd, 2020

- Females >55 years of age were more likely to be concern about Saharan Dust
- Females were more susceptible to Saharan Dust after being diagnosed with COVID-19.
- Participants positive to COVID-19 and with at least another pre-existing health condition are more likely to be affected by Saharan Dust







Godzilla Dust Event: Summer 2020 (Survey)

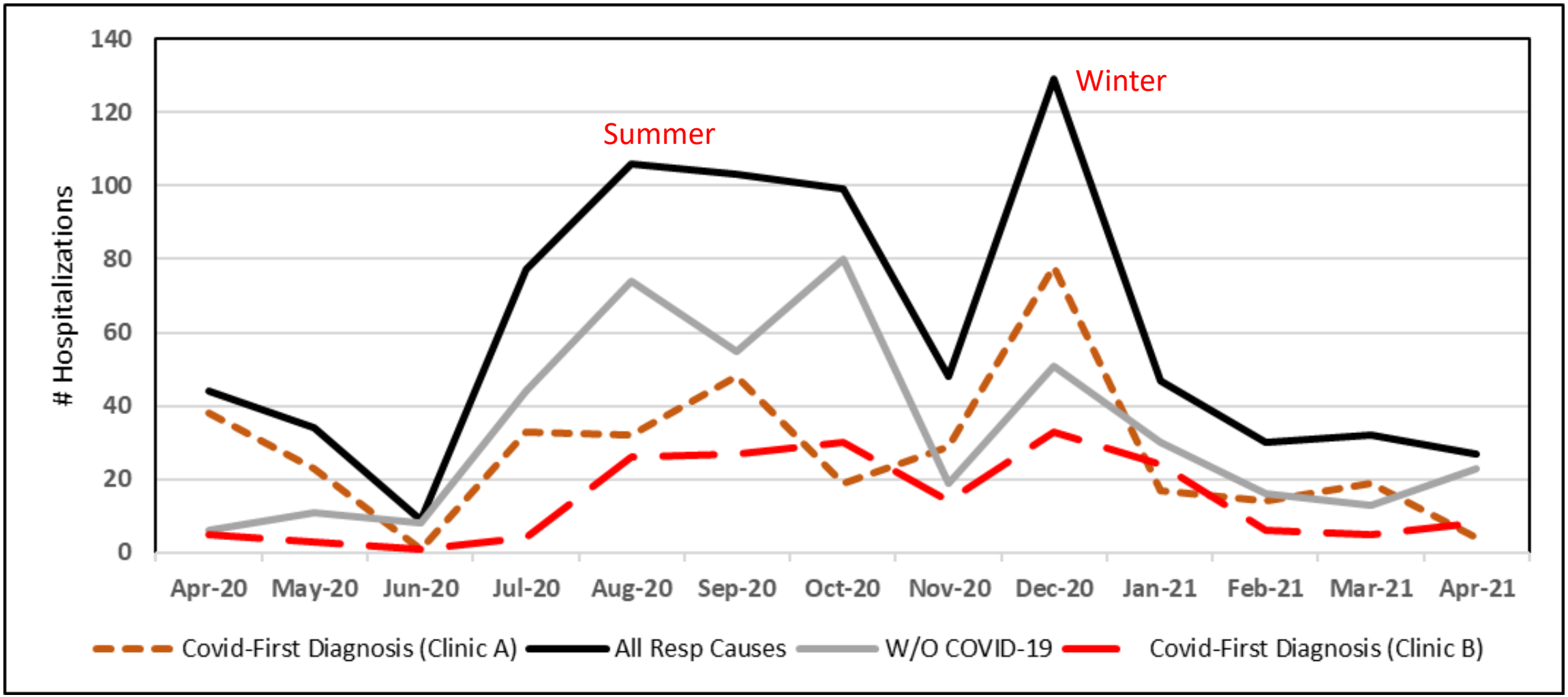
- 1500 participants: most respondents were females (82%), **65% had a history of at least one chronic condition.**
- **Nearly 90%** indicated that Saharan dust affected the health status of both respondents and their family members.
- **Asthma** was the most reported condition (55%).
- However, only 12% reported a physician's visit due to Saharan dust complications. Moreover, nearly two-thirds expressed concern regarding their family's welfare during the Saharan dust events.
- **Individuals with Comorbidities are 14.37% more likely to need medical services in Saharan dust events.**
- Over half (57%) reported that the Saharan dust always or frequently affected their health, causing postnasal drip, cough, red or itchy eyes, shortness of breath, and fatigue.

Public Health Data ER &HA

- **March 2020 to March 2021:**
- U07.1 = confirmed COVID-19
- J12.89 = pneumonia due to other viral pathogen
- J12.82 = pneumonia due to SARS-CoV-2
- J12.81 = pneumonia due to SARS-Associated coronavirus
- M35.81 = MIS-C
- Z86.16 = personal history of COVID-19
- Z20.828 = contact and suspected exposure to viral pathogen
- Z20.822 = contact and suspected exposure to SARS-CoV-2
- B97.2 = Coronavirus as the cause of diseases classified elsewhere
- B97.21 = SARS-associated coronavirus as the cause of diseases classified elsewhere
- B97.29 = Other coronavirus as the cause of diseases classified elsewhere
- We additionally requested the list generated include whether these diagnoses had also been added to each patient's problem list, as a means of expediting record review: I25.1, I50, I21 & I25.2 , I10 & I15, I60-I69, E10, E12, J45, J41-44, E66, G30-32, F33 & N18.

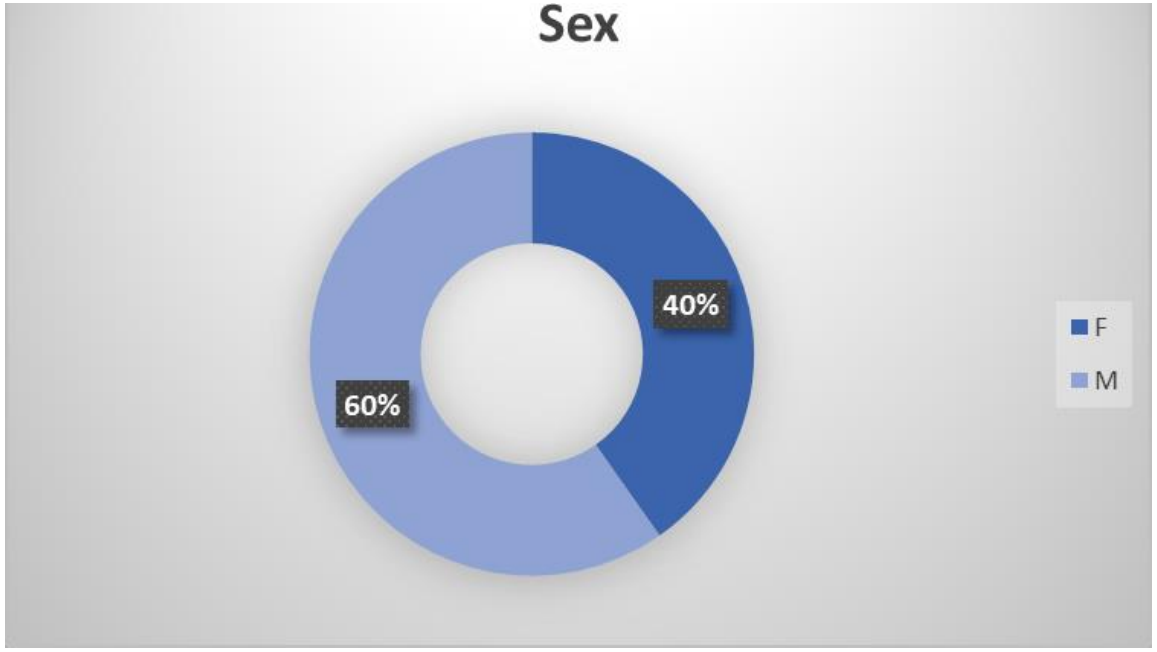
Databases and Sources

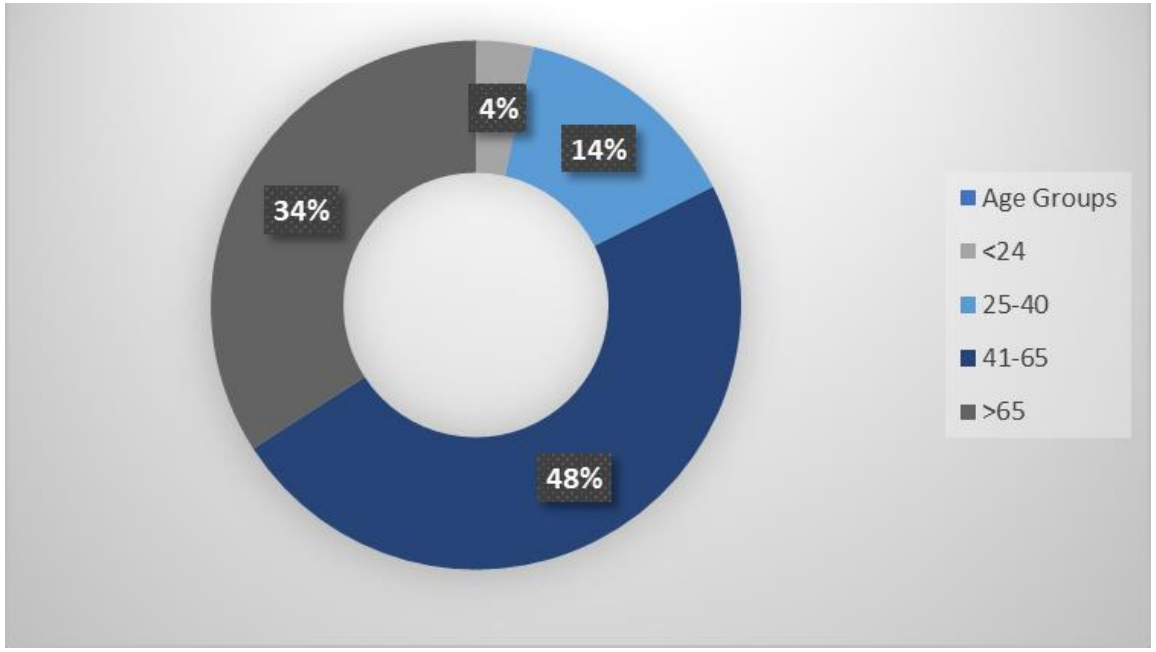
- Non_Acc: Non-Accidental Mortality Accumulated for the day of PM2.5 measurement
- Cardio: Cardiovascular Mortality Accumulated for the day of PM2.5 measurement
- Resp: Respiratory Mortality Accumulated for the day of PM2.5 measurement
- Resp_NoFlu: Respiratory Mortality without Flu cases for the day of PM2.5 measurement
- PM2.5_Mean_Conc_Stations: Mean of the Fajardo, Guaynabo and Bayamon Stations
- Tmax: Associated Maximum Temperature to Date variable
- Sahara: Dichotomous variable that indicates if the corresponding date had a Saharan dust event
- HeatIndex: Associated Maximum Heat Index to Date variable
- Year: Associated year of Date variable
- Population: Population of people 65 years and over in the northeast region of Puerto Rico
- VIIRS data Aerosol Products from Dark Target algorithm, version 1:



Behavioral risk factor

Public Health Data: ER &HA





Study of Imminent Interactions between SARS-CoV-2 (COVID-19), Air Quality due to Saharan Dust and Urban Aerosols, and Social-environmental Factors in Puerto Rico in summer 2020: Proxies of Health Risks in Small Island States in the Caribbean Region

	San Juan City Hospital (n=134)	Trauma Hospital (n=346)	University District Hospital (n=123)	Outpatient Clinics (n=1729)	Total (n=2332)
	n (%)				
Gender					
Female	66 (49.3)	167 (48.3)	60 (48.8)	994 (57.5)	1287 (55.2)
Male	68 (50.7)	179 (51.7)	63 (51.2)	735 (42.5)	1045 (44.8)
Age Group (years)					
0-17	7 (5.2)	2 (0.6)	6 (4.9)	2 (0.1)	17 (0.7)
18-29	26 (19.4)	38 (11)	15 (12.2)	266 (15.4)	345 (14.8)
30-39	19 (14.2)	53 (15.3)	17 (13.8)	340 (19.7)	429 (18.4)
40-49	21 (15.7)	71 (20.5)	19 (15.4)	540 (31.2)	651 (27.9)
50-64	38 (28.4)	106 (30.6)	27 (22)	502 (29)	673 (28.9)
65-74	17 (12.7)	41 (11.8)	15 (12.2)	75 (4.3)	148 (6.3)
75-84	4 (3)	26 (7.5)	17 (13.8)	3 (0.2)	50 (2.1)
85 and over	2 (1.5)	9 (2.6)	7 (5.7)	1 (0.1)	19 (0.8)
Stay of Length (days)	8.7	0.9	16.8	0	1.5

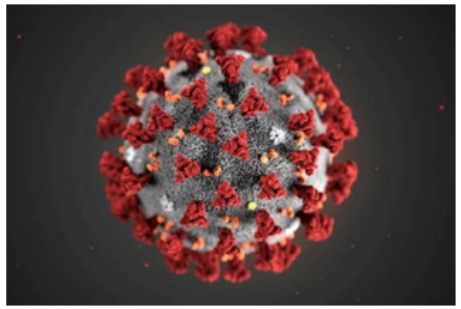
Study of Imminent Interactions between SARS-CoV-2 (COVID-19), Air Quality due to Saharan Dust and Urban Aerosols, and Social-environmental Factors in Puerto Rico in summer 2020: Proxies of Health Risks in Small Island States in the Caribbean Region

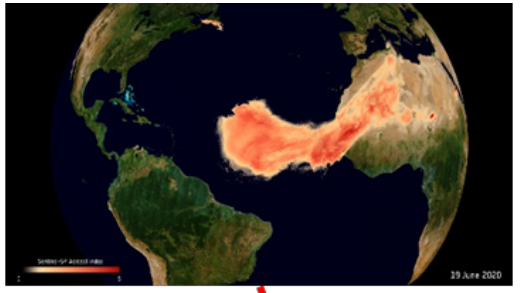
	External Clinics	Trauma Hospital	University District Hospital	S.J. City Hospital	All Hospitals
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	167	4	4	175
Apr	0	20	5	3	28
May	0	14	1	1	16
Jun	0	2	1	4	7
Jul	85	21	17	20	143
Aug	380	22	11	19	432
Sep	353	12	22	27	414
Oct	187	12	11	11	221
Nov	411	24	28	27	490
Dec	313	52	23	18	406

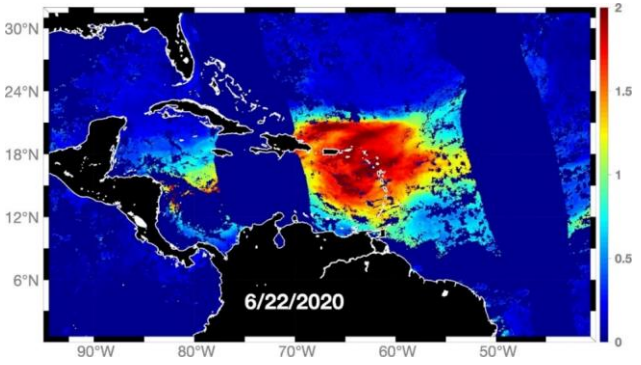
Study of Imminent Interactions between SARS-CoV-2 (COVID-19), Air Quality due to Saharan Dust and Urban Aerosols, and Social-environmental Factors in Puerto Rico in summer 2020: Proxies of Health Risks in Small Island States in the Caribbean Region

ICD-10-CM Group	Description/Category	University District Hospital		Trauma Hospital		Overall	
		n (%)				N (%)	
A00-B99	Certain infections and parasitic diseases	19	(5.4)	150	(9.0)	169	(8.3)
C00-D49	Neoplasms	14	(4.0)	7	(0.4)	21	(1.0)
D50-D89	Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	8	(2.3)	4	(0.2)	12	(0.6)
E00-E89	Endocrine, nutritional and metabolic diseases	17	(4.8)	61	(3.6)	78	(3.8)
F01-F99	Mental, Behavioral and Neurodevelopmental disorders	16	(4.5)	13	(0.8)	29	(1.4)
G00-G99	Diseases of the nervous system	14	(4.0)	11	(0.7)	25	(1.2)
H00-H59	Diseases of the eye and adnexa	5	(1.4)	3	(0.2)	8	(0.4)
H60-H95	Diseases of the ear and mastoid process			1	(0.1)	1	(.05)
I00-I99	Diseases of the circulatory system	27	(7.6)	77	(4.6)	104	(5.1)
J00-J99	Diseases of the respiratory system	25	(7.1)	98	(5.9)	123	(6.1)
K00-K95	Diseases of the digestive system	23	(6.5)	10	(0.6)	33	(1.6)
L00-L99	Diseases of the skin and subcutaneous tissue	6	(1.7)	7	(0.4)	13	(0.6)
M00-M99	Diseases of the musculoskeletal system and connective tissue	13	(3.7)	12	(0.7)	25	(1.2)
N00-N99	Diseases of the genitourinary system	16	(4.5)	14	(0.8)	30	(1.5)
O00- O9A	A Pregnancy, childbirth, and puerperium	44	(12.4)	1	(0.1)	45	(2.2)
P00-P96	Certain conditions originating in the perinatal period	5	(1.4)			5	(0.2)
Q00-Q99	Congenital malformations, deformations and chromosomal abnormalities	3	(0.8)	2	(0.1)	5	(0.2)
R00-R99	Symptoms, signs, and abnormal clinical laboratory findings, not else where classified	17	(4.8)	308	(18.4)	325	(16)
S00-T88	Injury, poisoning, and certain other consequences of external causes	22	(6.2)	73	(4.4)	95	(4.7)
U00-U85	Codes for special purposes	1	(0.3)	248	(14.8)	249	(12.3)
V00-Y99	External causes of morbidity	10	(2.8)	141	(8.4)	151	(7.4)
Z00-Z99	Factors influencing health status and contact with health services	49	(13.8)	434	(25.9)	483	(23.8)

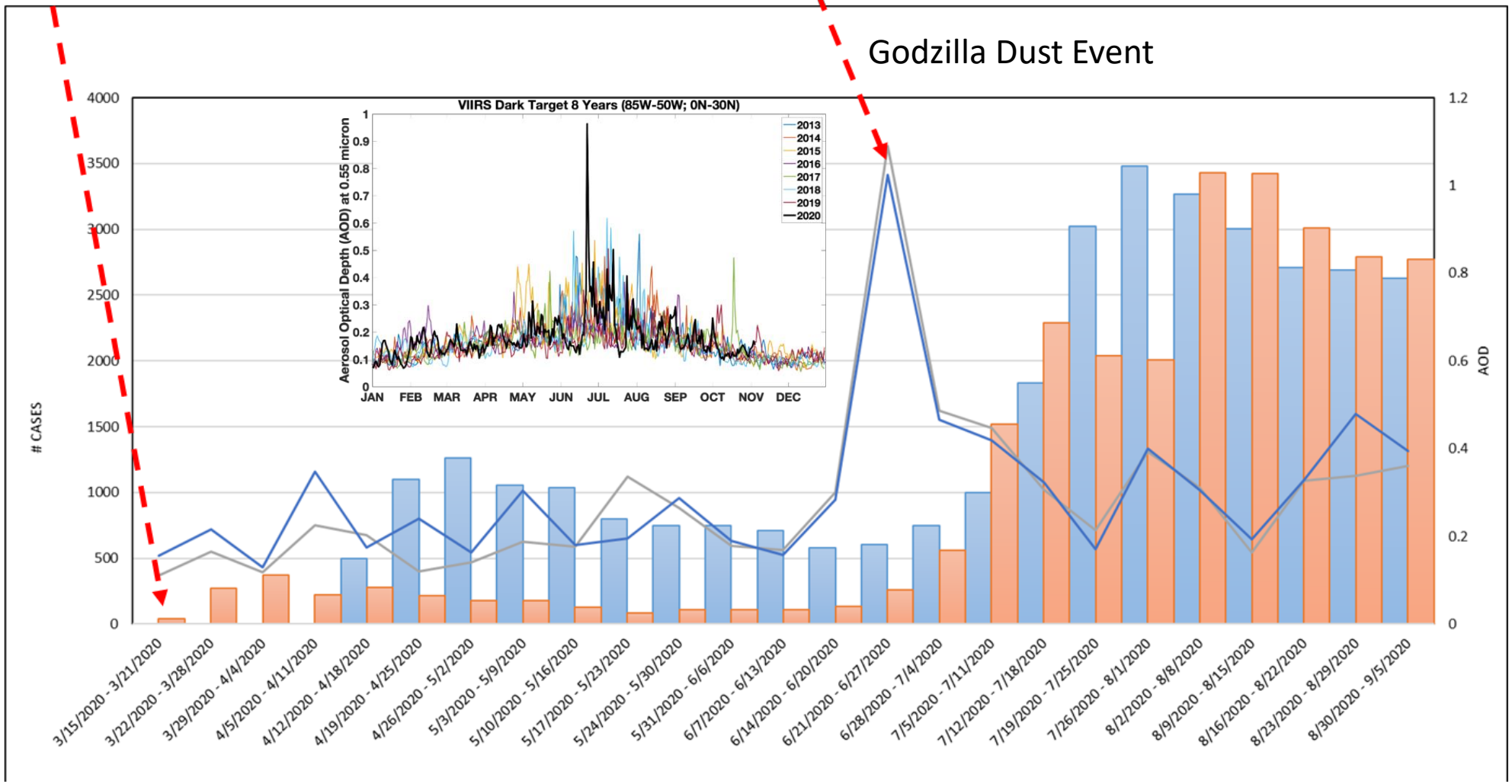
1st COVID-19 Confirmed Case In Puerto Rico







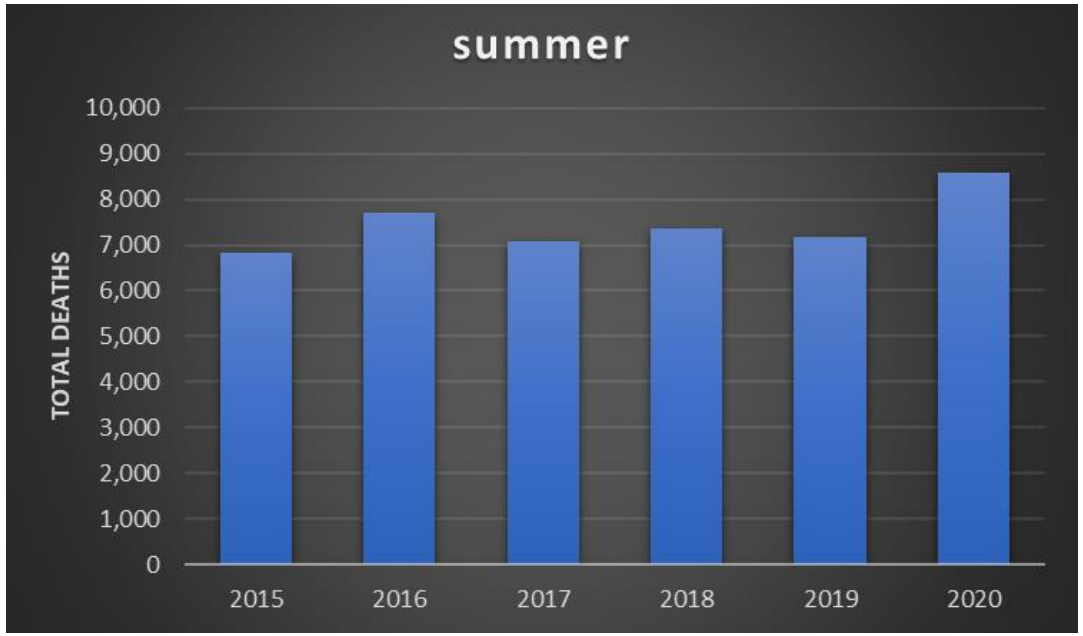
Godzilla Dust Event



- Stata
- 9 environmental variables
- 18 environmental indices
- Retrieved mostly from NASA (MODIS, VIIRS, Sentinel)

	heati~an	heati~in	hi_cli~x	airte~an	airte~in	airtem~x	utci_~in	utci_c~x	utci_~an	angstr~s	mc_viirs	precip~5
heatindex~an	1.0000											
heatindex~in	0.9975	1.0000										
hi_clima_d~x	0.9967	0.9912	1.0000									
airtemp_c~an	0.9901	0.9901	0.9851	1.0000								
airtemp_c~in	0.9871	0.9912	0.9795	0.9946	1.0000							
airtemp_cl~x	0.9788	0.9771	0.9767	0.9929	0.9783	1.0000						
utci_clim~in	0.8614	0.8623	0.8650	0.8390	0.8522	0.8070	1.0000					
utci_clima~x	0.7795	0.7809	0.7844	0.7579	0.7700	0.7282	0.9504	1.0000				
utci_clim~an	0.8665	0.8653	0.8707	0.8416	0.8552	0.8084	0.9896	0.9599	1.0000			
angstrom_v~s	-0.4269	-0.4199	-0.4285	-0.4108	-0.4106	-0.4168	-0.1662	-0.0451	-0.1726	1.0000		
mc_viirs	0.4416	0.4362	0.4396	0.4221	0.4303	0.4173	0.2214	0.1333	0.2435	-0.7891	1.0000	
precip_chr~5	0.2444	0.2386	0.2661	0.2231	0.2051	0.2307	0.3539	0.3163	0.3319	-0.0154	-0.0262	1.0000
precip_chr~3	0.2335	0.2278	0.2552	0.2136	0.1953	0.2223	0.3449	0.3073	0.3215	-0.0112	-0.0315	0.9977
mursst_3x3	0.8788	0.8805	0.8795	0.8947	0.8840	0.8896	0.8772	0.8460	0.8721	-0.1051	0.1146	0.3300
mursst_5x5	0.8790	0.8807	0.8797	0.8949	0.8842	0.8898	0.8773	0.8461	0.8723	-0.1055	0.1151	0.3299
lstn	0.9174	0.9118	0.9199	0.9193	0.9168	0.9053	0.8109	0.7396	0.8163	-0.3662	0.3425	0.2404
lstd	0.4302	0.4125	0.4309	0.3704	0.3846	0.3380	0.3376	0.2841	0.3744	-0.3659	0.3442	-0.0285
aod550_viirs	0.4649	0.4563	0.4654	0.4413	0.4495	0.4314	0.2733	0.1758	0.2928	-0.7417	0.9118	0.0472

Deaths per year of death and season



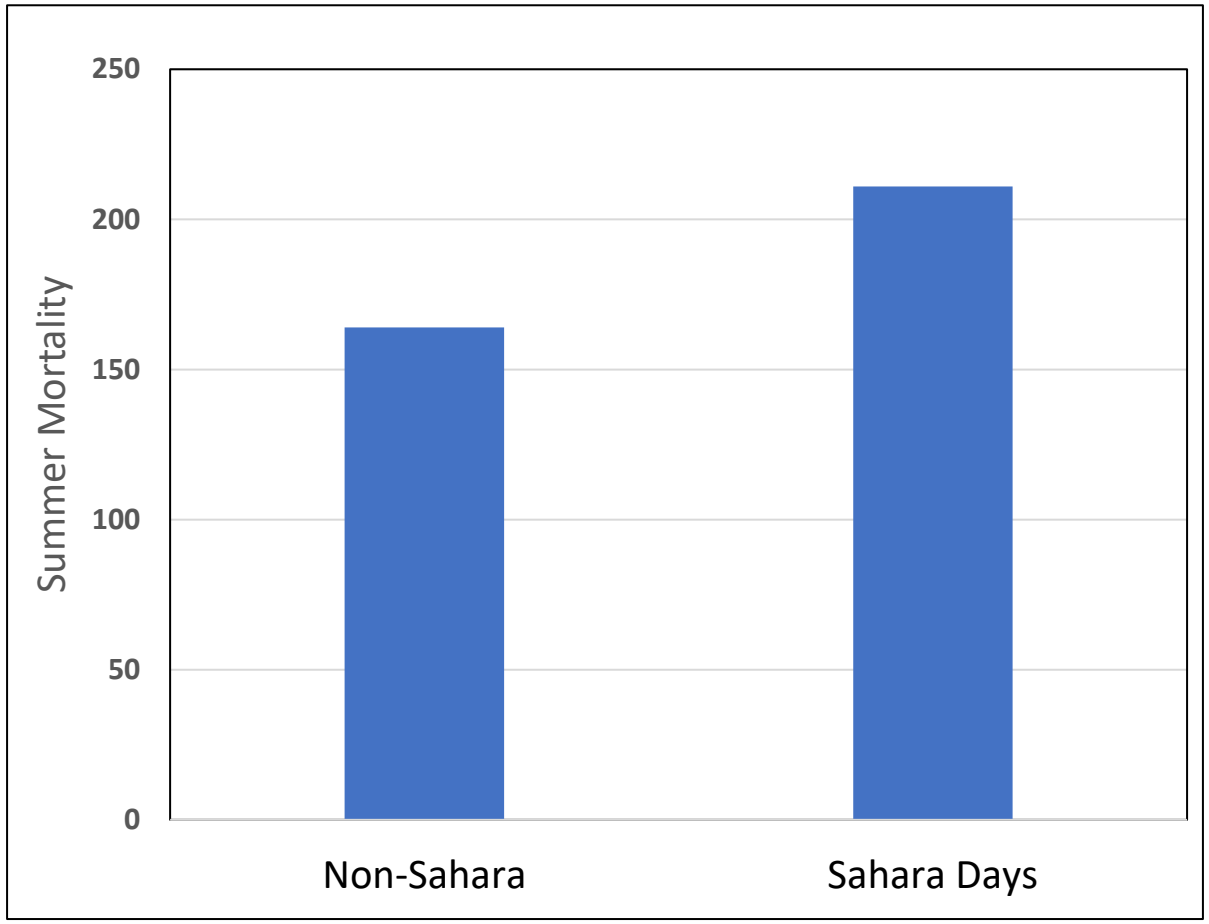
Hurricane Irma & Maria

Deaths per year of death and season

dyr	winter	summer	autumn	spring	Total
2015	6,937	6,828	7,590	6,768	28,123
2016	8,113	7,691	7,478	6,375	29,657
2017	7,410	7,095	9,451	7,164	31,120
2018	8,240	7,356	7,206	6,425	29,227
2019	7,885	7,187	7,236	7,298	29,606
2020	6,463	8,573	8,166	8,077	31,279
Total	45,048	44,730	47,127	42,107	179,012

COVID-19

Respiratory Mortality 2015-2017: Dust Days vs Non Dust Days



- dust concentration increase in the Caribbean between May and September. These plumes are positively associated to respiratory (**without flu causes**) mortality with a relative risk of 1.23 (CI 95%: 1.03, 1.47) when adjusted for PM 2.5 and Air Surface Maximum Temperature.

FINDINGS Poisson model assuming independent observation

- A total of 10,070 deaths occurred in Puerto Rico during the study period. Strong evidence suggests that the heat effect, dust clouds and spores cause an excess risk of non-accidental mortality. Cardiovascular diseases and respiratory conditions were the primary causes of death most associated with elevated temperatures, aerosol optical depth and spores.

- The average number of weekly deaths due **to Covid-19** in decile 5 of **UTCI** is **6 times higher** than the decile 1 of UTCI. This excess was statistically significant ($p<0.05$).

- The average number of weekly deaths due to **Covid-19** in decile 5 of **FUNGAL SPORES** is **6.47 times higher** than the decile 1 of FUNGAL SPORES. This excess was statistically significant ($p<0.05$).

- The average number of weekly deaths due to **Covid-19** for values of **UTCI > 27.93** is 97% higher than for values of UTCI ≤ 27.93, **after adjusting for age**. This excess was statistically significant ($p<0.05$).

FINDINGS Poisson model assuming independent observation

- The average number of weekly deaths due to **ischemic heart disease** in quintile 5 of **AOD550 is 11%** higher than the quintile 1 of **AOD550**. This excess was statistically significant ($p<0.05$).

- The average number of weekly deaths due to ischemic heart disease in quintile 5 of **AOD550 is 9% higher than the quintile 1 of AOD550, after adjusting for age and year of death.** This excess was statistically significant ($p<0.05$).

FINDINGS Poisson model assuming independent observation

- A total of 10,070 deaths occurred in Puerto Rico during the study period. Strong evidence suggests that the heat effect, dust clouds and spores cause an excess risk of non-accidental mortality. Cardiovascular diseases and respiratory conditions were the primary causes of death most associated with elevated temperatures, aerosol optical depth and spores.

- **Pneumonia**

- The average number of weekly deaths due to pneumonia in quintile 5 of **heat index is 10%** (REadjusted: 1.10, 95% CI: 1.03-1.17) higher than the quintile 1 of heat index, after adjusting for age, sex, and year of death. This excess was statistically significant ($p<0.05$).

- The average number of weekly deaths due to pneumonia in quintile 5 of UTCI is 11% (REadjusted: 1.11, 95% CI: 1.05-1.18) higher than the quintile 1 of UTCI, after adjusting for age, sex, and year of death. This excess was statistically significant ($p<0.05$).

- **Heart Failure**

- The average number of weekly deaths due to heart failure in quintile 5 of UTCI is 13% (REadjusted: 1.13, 95% CI: 1.08-1.18) higher than the quintile 1 of UTCI, after adjusting for age, sex, and year of death. This excess was statistically significant ($p<0.05$).

FINDINGS Poisson model assuming independent observation

- **Ischemic Heart Disease**

- The average number of weekly deaths due to ischemic heart disease in quintile **5 of aod550 is 10%** (REadjusted: 1.10, 95% CI: 1.02-1.17) higher than the quintile 1 of aod550, after adjusting for age, sex, and year of death. This excess was statistically significant ($p<0.05$).

- The average number of weekly deaths due to ischemic heart disease in quintile 5 of **UTCI** is 8% (REadjusted: 1.08, 95% CI: 1.01-1.15) higher than the quintile 1 of UTCI, after adjusting for age, sex, and year of death. This excess was statistically significant ($p<0.05$).

- The average number of weekly deaths due to ischemic heart disease in quintile 5 of **heat index** is 9% (REadjusted: 1.09, 95% CI: 1.02-1.16) higher than the quintile 1 of heat index, after adjusting for age, sex, and year of death. This excess was statistically significant ($p<0.05$).

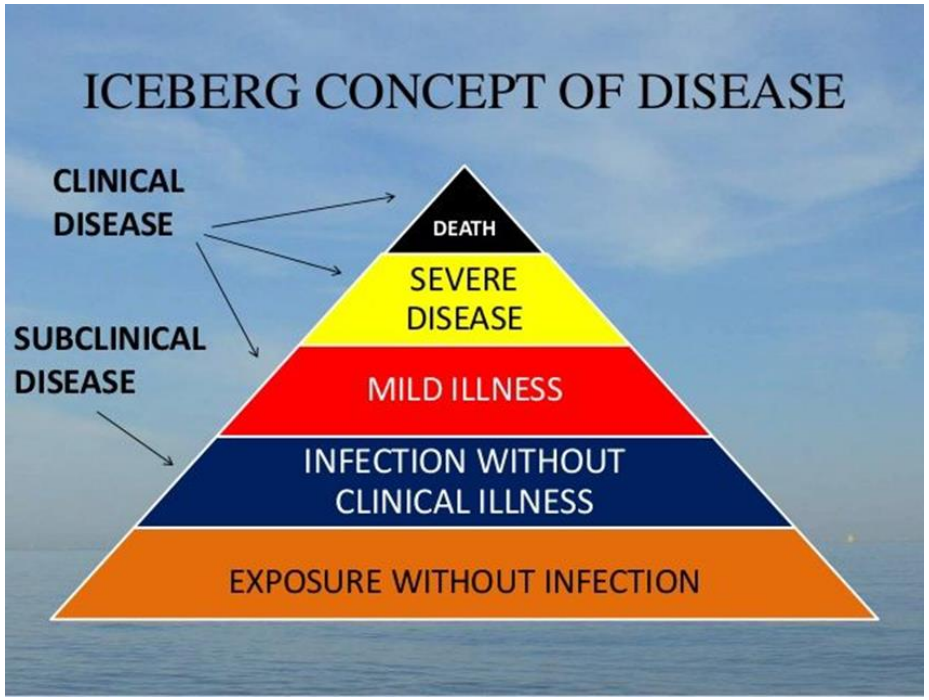
- **Myocardial Infarction**

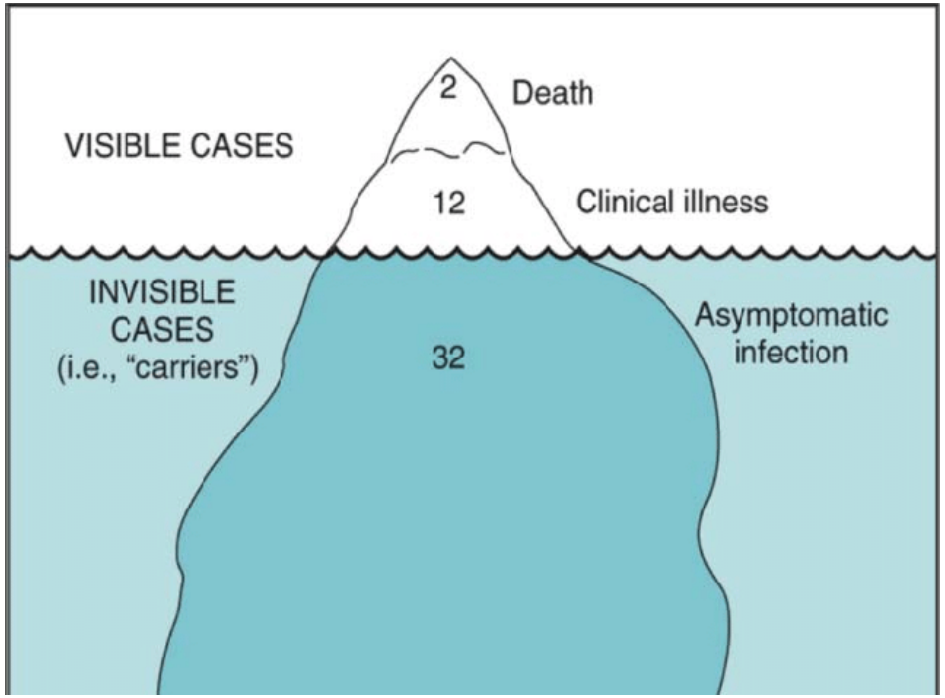
- The average number of weekly deaths due to myocardial infarction in quintile 5 of **aod550** is 9% (REadjusted: 1.09, 95% CI: 1.03-1.15) higher than the quintile 1 of aod550, after adjusting for age, sex, and year of death. This excess was statistically significant ($p<0.05$).

- The average number of weekly deaths due to myocardial infarction in quintile 5 of **UTCI** is 7% (REadjusted: 1.07, 95% CI: 1.02-1.13) higher than the quintile 1 of UTCI, after adjusting for age, sex, and year of death. This excess was statistically significant ($p<0.05$).

- The average number of weekly deaths due to myocardial infarction in quintile 5 of **heat index** is 9% (REadjusted: 1.09, 95% CI: 1.03-1.15) higher than the quintile 1 of heat index, after adjusting for age, sex, and year of death. This excess was statistically significant ($p<0.05$).

Disease/Injury Iceberg Phenomenon





Considerations

- Mortality is always the tip of the iceberg.
- Findings suggest that the arrival from Saharan Dust in Puerto Rico contributes to an increase in cause-specific mortality.
- However, there are remaining questions regarding their effects on vulnerable patient populations, underlying mechanisms of action, and regional variations in both environmental and health effects.
- Better understanding of how these Dust Clouds events affect the health of the population will provide a useful tool for decision makers to address and mitigate the effects on public health.
- The enhanced Dust Early Warning System may be a crucial component in decision making during Watches and Advisories process.

Questions!

Environmental Health Department

Graduate School of Public Health

University of Puerto Rico-Medical Sciences Campus

PR-CLIMAH (**P**uerto **R**ico **Clim**ate and He**a**lth Researc**h** Group)

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Principal Investigator: NASA Grant Number 80NSSC20K1588

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