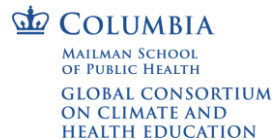


Caribbean Climate and Health Responders Course

Degraded Air Quality- May 4, 2022

Andrea M. Sealy, Ph.D.

Meteorologist, Caribbean Institute for Meteorology and Hydrology



Learning Objectives

- Describe the pathways through which climate change affects ozone, PM2.5, and other ambient respiratory irritants and how these pollutants impact climate-sensitive respiratory diseases
- Describe how climate change might impact indoor air quality
- Describe how climate change makes air quality regulation more complex and difficult
- Identify populations that are vulnerable to degraded air quality. Describe how health professionals can protect these vulnerable patients

Learning Objectives

- Explain how wildfires/bushfires are impacted by climate change and the direct and indirect health implications
- Describe how climate change increases the risk of complex disasters due to combined and cascading events (heatwaves followed by wildfires)
- Identify particularly vulnerable patients and families and teach about risk mitigation, such as limiting outside work and recreation during poor air quality days

Introduction

- In 2019, 99% of the world population was living in places where the WHO air quality guidelines levels were not met



**Nine out of ten people
breathe polluted air.**

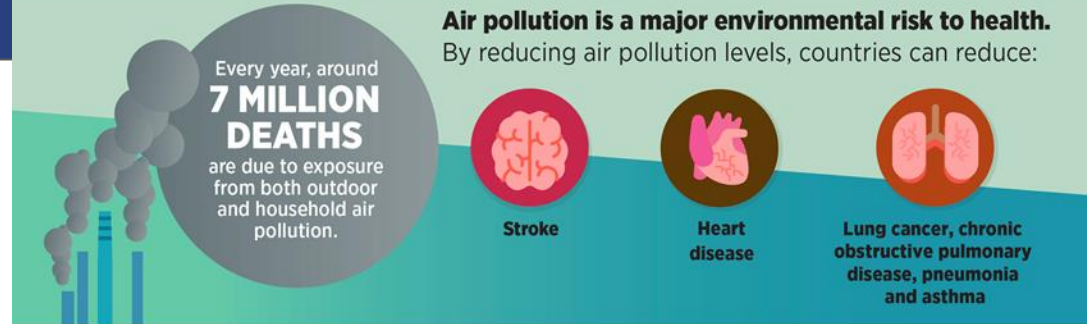


#HealthierTomorrow

Introduction

- Ambient (outdoor) air pollution and indoor (household, in particular) air pollution combined cause approximately 7 million premature deaths every year
 - Result of increased mortality from stroke, ischemic heart disease (IHD), chronic obstructive pulmonary disease (COPD), lung cancer and acute respiratory infections

AIR POLLUTION – THE SILENT KILLER



REGIONAL ESTIMATES ACCORDING TO WHO REGIONAL GROUPINGS:



WHO Air Quality Guidelines set goals to protect millions of lives from air pollution.

CLEAN AIR FOR HEALTH

#AirPollution



Air pollution kills 13 people every minute



World Health
Organization

due to lung cancer, heart disease
and strokes.

Stop burning fossil
fuels like oil, coal
and natural gas.

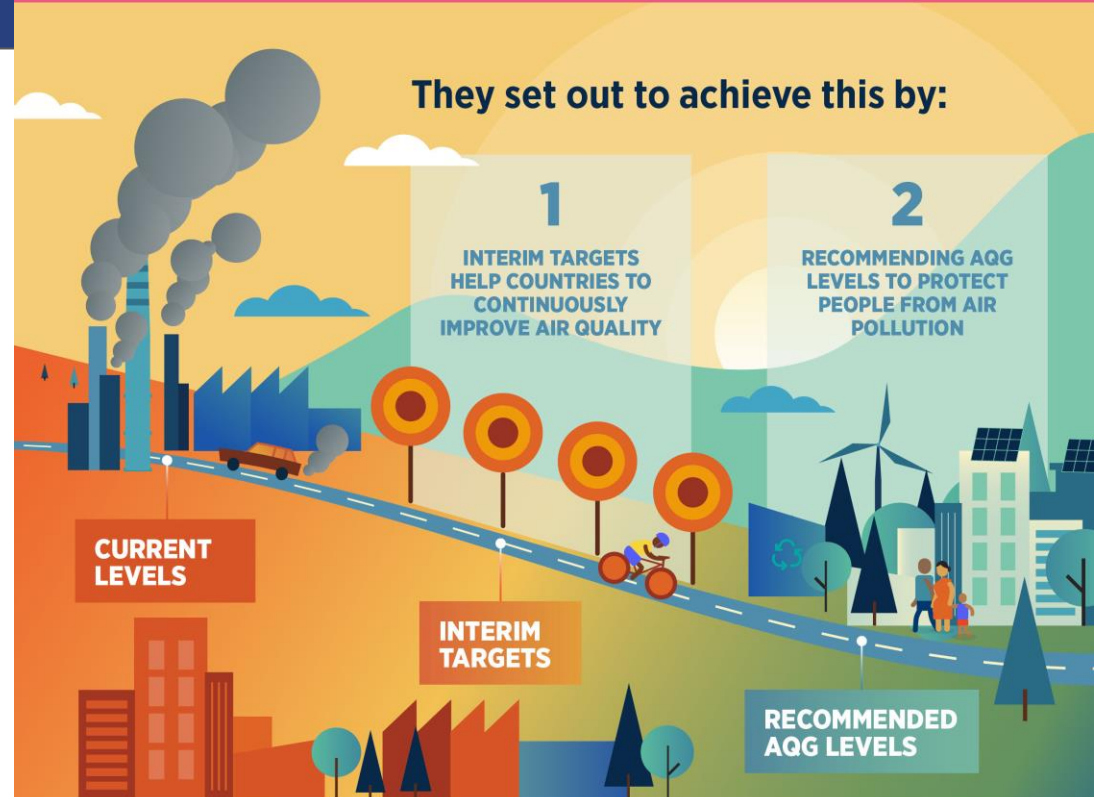


[#HealthierTomorrow](#)

Key air pollutants

- Ozone
- Particulate matter (PM_{2.5} and PM₁₀)
- Nitrogen Dioxide
- Sulfur Dioxide
- Carbon Monoxide

THE WHO AIR QUALITY GUIDELINES (AQGs) SET GOALS TO REDUCE AIR POLLUTION



Recommended AQG levels and interim targets (WHO global air quality guidelines, 2021)

- Evidenced, health-based standards for specific air pollutants that should be adopted
- Initially set in 2005, updated in 2021
- Most new recommended limits for concentrations and exposures are lower
- 2021 update shows how air pollution affects many aspects of health, even at low levels

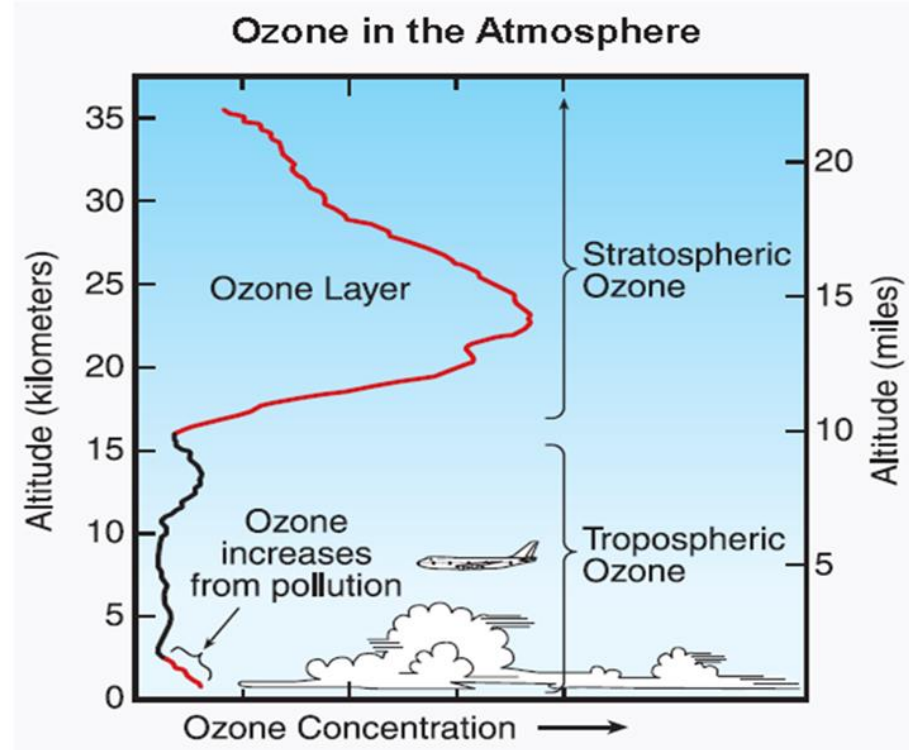
Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
PM _{2.5} , µg/m ³	Annual	35	25	15	10	5
	24-hour ^a	75	50	37.5	25	15
PM ₁₀ , µg/m ³	Annual	70	50	30	20	15
	24-hour ^a	150	100	75	50	45
O ₃ , µg/m ³	Peak season ^b	100	70	-	-	60
	8-hour ^a	160	120	-	-	100
NO ₂ , µg/m ³	Annual	40	30	20	-	10
	24-hour ^a	120	50	-	-	25
SO ₂ , µg/m ³	24-hour ^a	125	50	-	-	40
CO, mg/m ³	24-hour ^a	7	-	-	-	4

^a 99th percentile (i.e. 3–4 exceedance days per year).

^b Average of daily maximum 8-hour mean O₃ concentration in the six consecutive months with the highest six-month running-average O₃ concentration.

Ozone (O₃)

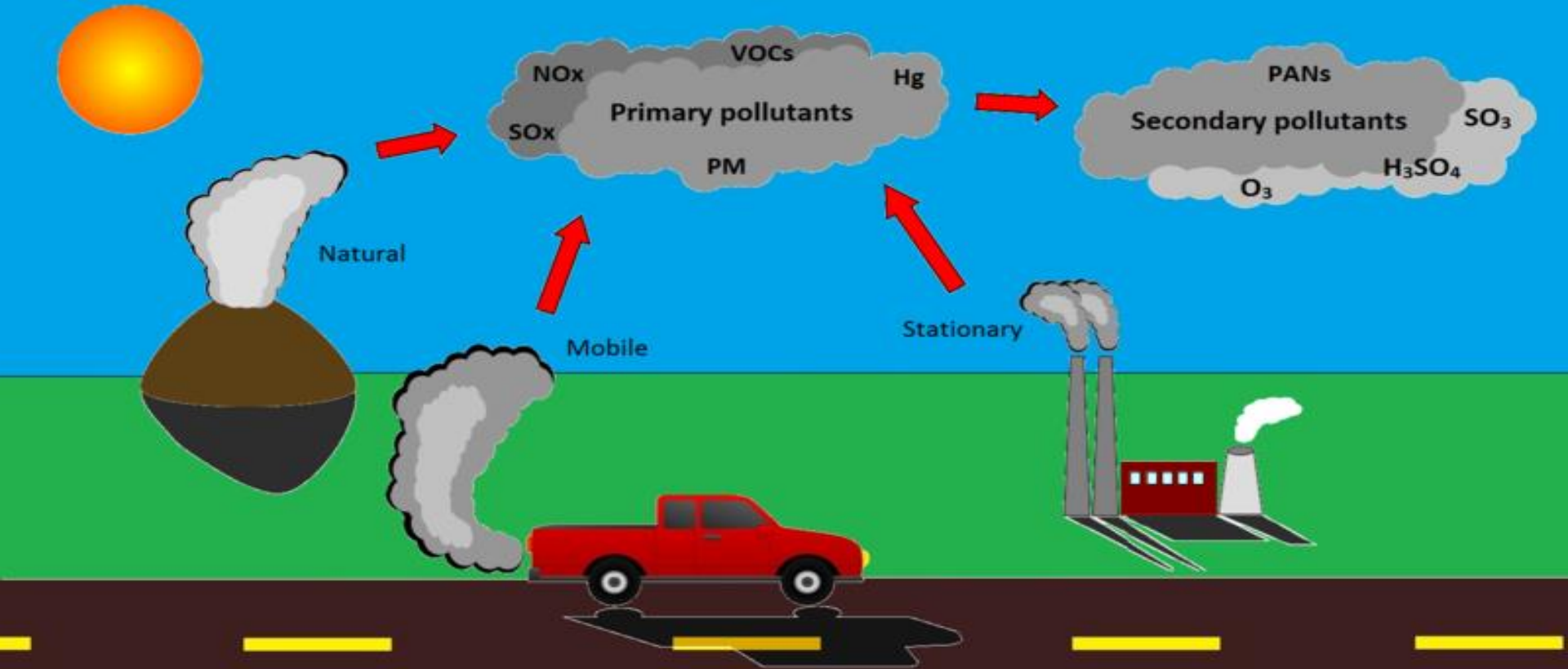
- Primarily in troposphere (10%) and stratosphere (90%; “ozone layer”)
- Tropospheric ozone- mostly created as a byproduct of human activities creating photochemical smog
 - Secondary pollutant
 - Sunlight is required for production- concentrations of tropospheric ozone higher during afternoons and summer months



Ozone (O₃)

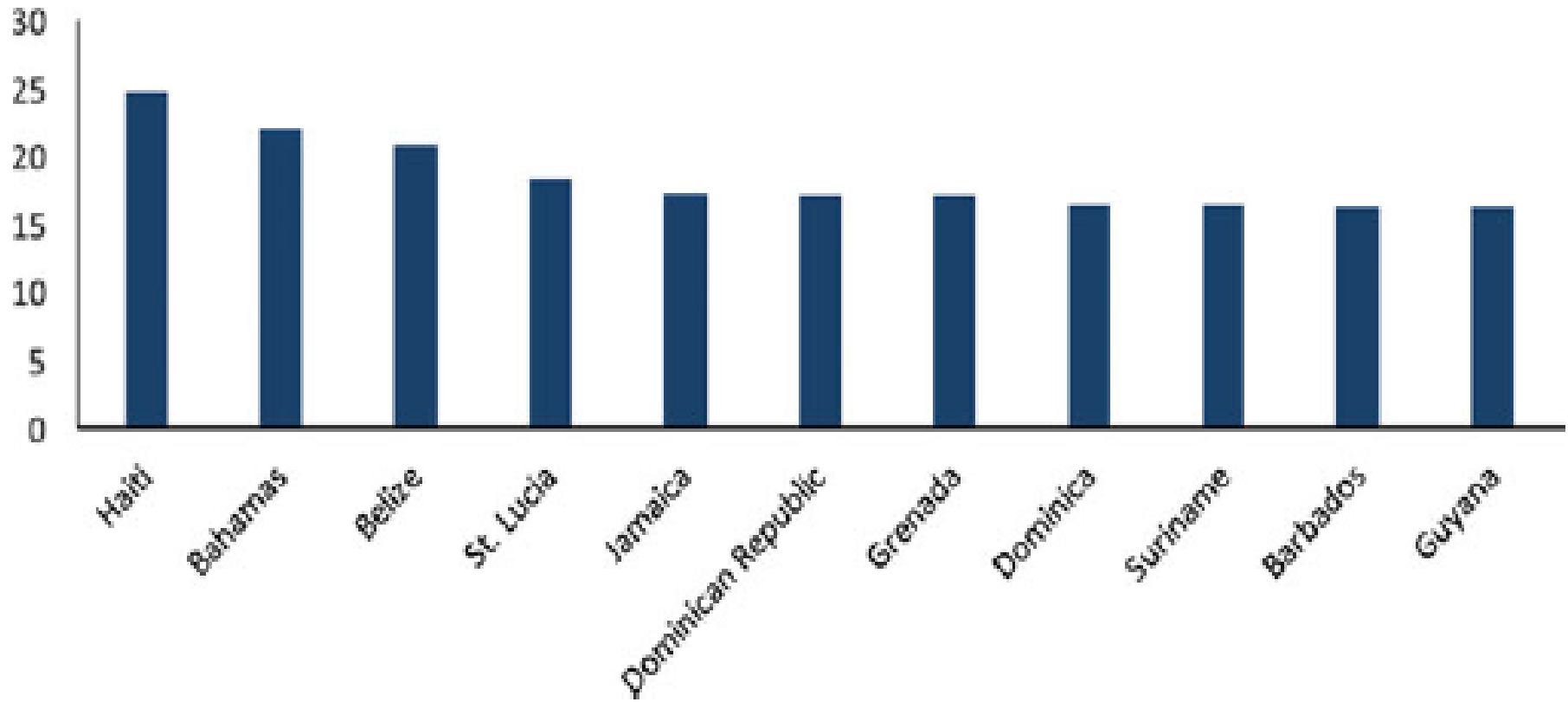
- Pungent smell
 - Irritates eyes and the mucous membranes of the respiratory system, aggravating chronic diseases, such as asthma
- In healthy people, exposure to relatively low concentrations of ozone during periods of moderate exercise can significantly reduce lung function
 - Symptoms may include chest pain, nausea, coughing, and pulmonary congestion
- Damages vegetation causing significant reduction in crop yield and crop quality

Various pollutants are involved in the production of photochemical smog, which consists of both primary and secondary pollutants.



Particulate matter (PM_{2.5} and PM₁₀)

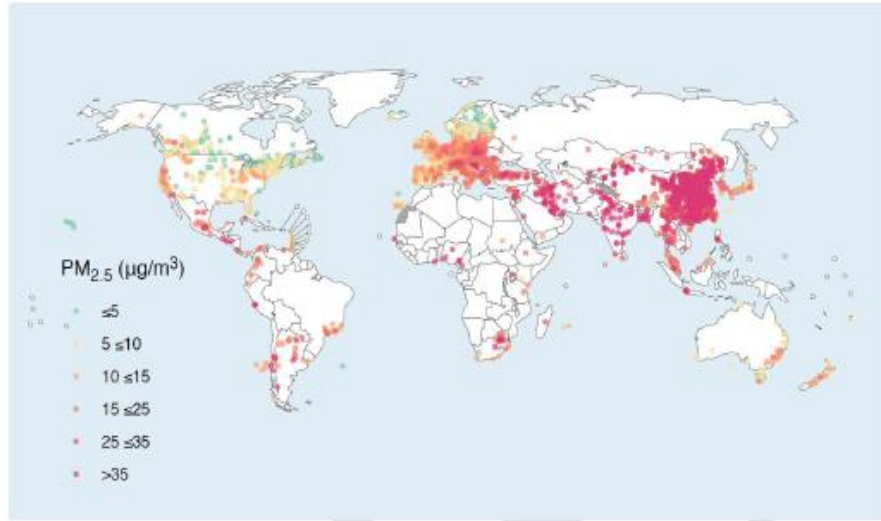
- Particulate matter- mixture of solid particles and liquid droplets found in the air
 - PM₁₀ : inhalable particles, with diameters 10 micrometers and smaller
 - PM_{2.5} : fine inhalable particles, with diameters 2.5 micrometers and smaller
- Sources of PM
 - Construction sites, unpaved roads, fields, smokestacks, fires
- Harmful effects
 - Contains microscopic solids or liquid droplets that are easily inhaled
 - PM₁₀ particles can get deep into the lungs or even the bloodstream
 - PM_{2.5} (fine particles) pose the greatest risk to health
 - Reduced visibility



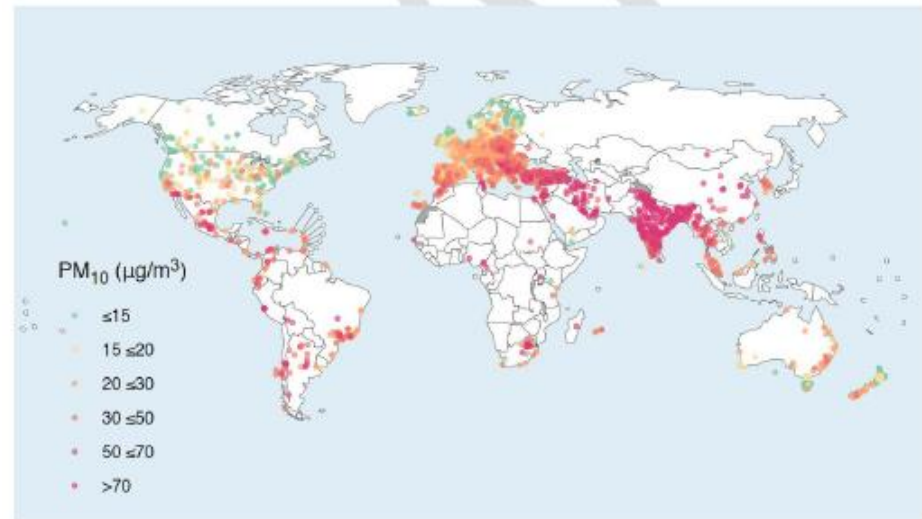
Caribbean countries with annual mean concentrations of PM_{2.5} in urban areas exceeding the WHO recommendation of 10 µg/m³ Source of data: WHO http://gamapserver.who.int/gho/interactive_charts/phe/oap_exposure/atlas.html

Locations of settlements with data on (A) $PM_{2.5}$ and (B) PM_{10} concentrations, 2010–2019

A. $PM_{2.5}$



B. PM_{10}

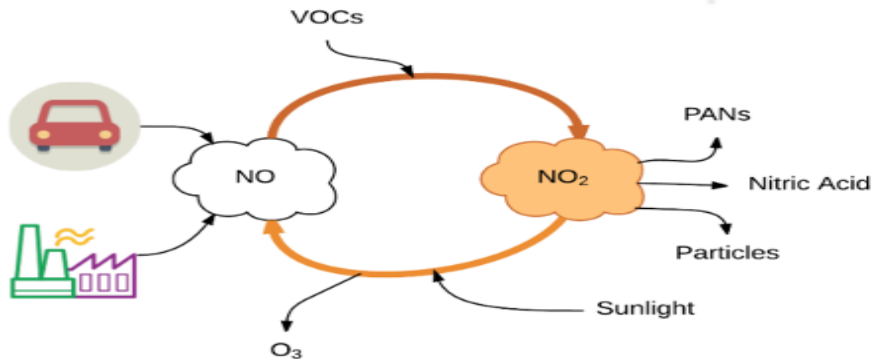


Nitrogen Dioxide (NO₂)

- Nitrogen Dioxide (NO₂) is part of the highly reactive NO_x gases family (oxides of nitrogen or nitrogen oxides)
 - Used as the indicator for the larger group of NO_x
- Primary source- burning of fuel
 - Emissions from cars, trucks and buses, power plants, and off-road equipment
- Exposure irritates airways in the human respiratory system
 - Short periods- aggravate respiratory diseases, particularly asthma (coughing, wheezing or difficulty breathing)
 - Longer periods- contribute to the development of asthma and potentially increase susceptibility to respiratory infections

Nitrogen Dioxide (NO₂)

- NO_x starts as mostly NO
- VOCs in atmosphere convert to NO₂
- NO₂ reacts with others to form nitric acid and PANs (peroxyacyl nitrates)
- Sunlight- NO₂ convert back to NO and produce O₃



Nitrogen dioxide pollution from traffic, power plants, industry or agriculture

can aggravate respiratory diseases, particularly asthma



Well planned public transport, along with safe walking and cycling can:

- improve air quality
- mitigate climate change
- improve physical activity



Sulfur Dioxide (SO₂)

- SO₂ is used as the indicator for the larger group of gaseous sulfur oxides (SO_x)
- Largest atmospheric source- burning of fossil fuels by power plants and other industrial facilities
- Smaller sources- industrial processes; natural sources (volcanoes); and locomotives, ships and other vehicles and heavy equipment that burn fuel with a high sulfur content

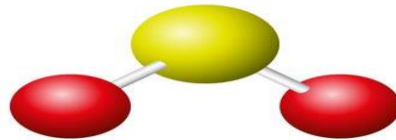


Sulfur Dioxide (SO₂)

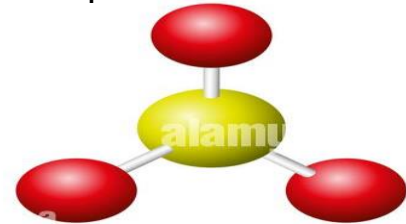
- Short-term exposure- irritates respiratory system and makes breathing difficult
- SO₂ emissions that lead to high concentrations in the air generally also lead to the formation of other sulfur oxides (SO_x)
- SO_x can react with other compounds in the atmosphere to form small particles (contribute to PM)



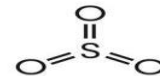
Sulfur monoxide



Sulfur dioxide



Sulfur trioxide



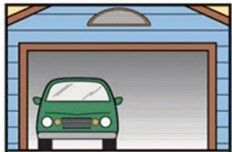
Carbon Monoxide (CO)

- CO is a colorless, odorless gas that can be harmful when inhaled in large amounts
 - Released by combustion
- Exposure to high concentrations- reduces the oxygen that can be transported in the blood stream to critical organs
- Indoor air quality- high concentrations can cause dizziness, confusion, unconsciousness and death
- Outdoor air quality (rarely compromised by CO)- elevated levels affect persons with some types of heart disease.

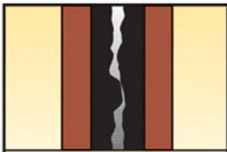
Carbon Monoxide (CO)

- Outdoor sources- vehicles or machinery that burn fossil fuels
- Indoor sources- unvented kerosene and gas space heaters, leaking chimneys and furnaces, and gas stoves

SOURCES OF CARBON MONOXIDE IN A HOME



Car Left Running in Attached Garage



Clogged Chimney



Corroded or Disconnected Water Heater Vent Pipe



Gas or Wood-Burning Fireplace



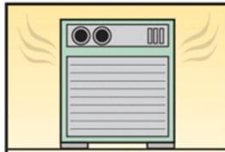
Cracked or Loose Furnace Exchanger



Improperly Installed Kitchen Range or Vent



Operating a Grill Indoors or in Garage

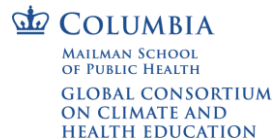


Portable Kerosene or Gas Heaters



Source: Jamaica Gleaner

Zoom Poll Question 1



How do you think Caribbean air quality levels and the associated impacts compare to those in the US?

- Lower
- Higher
- The same

Air Quality in the Caribbean

- Exposure to particulate matter in 26 cities across the Caribbean and Latin America is “more than twice the US standard” (Cifuentes et al, 2005)
 - Uncertainty about ground-level ozone due to lack of data
- Air pollution a major contributor to morbidity and mortality, especially in developing countries (including Caribbean countries)
 - Lack of air quality regulations and enforcement
 - Socioeconomic, geographic, and climatological factors



Air Quality in the Caribbean

Attributable mortality and disability adjusted life years (DALYs) due to outdoor air pollution

30 deaths and 307 DALYS per 1000

Americas subregion B (includes the Caribbean)

>

28 deaths and 200 DALYs per 1000

Americas subregion A (includes Canada and the US)

Air Quality in the Caribbean

- Sources include:
 - Burning fossil and biomass fuels to generate electricity, for heating, cooking, and transportation (PM_{2.5}, PM₁₀, CO, NO₂, Pb, SO₂, ground-level O₃, CO₂)
 - Windblown dust
 - Wildfires
 - Gases and PM emitted from volcanic eruptions
- Origins
 - Local/regional sources
 - Distant/global sources
- Transportation of volcanic ash and dust across long distances, has been shown to contribute to air pollution and respiratory diseases in some Caribbean countries

Air Quality in the Caribbean

- Study of air pollution and respiratory health among elementary school children in Guadeloupe (Amadeo et al. 2015)
 - Mean PM_{10} levels in over 70% of the schools exceeded the WHO AQG
 - Saharan dust strongly suspected



2020 Godzilla dust event

Photo credit: Alexander James

Air Quality in the Caribbean

- Humidity interacting with dust from the Sahara has been shown to produce PM in Barbados, Grenada, Trinidad and Tobago, and USVI
 - Increased visits to the emergency department due to exacerbated asthma in the Caribbean (Akpinar-Elci et al. 2015; Garrison et al. 2014; Gyan et al. 2005; Monteil 2008)
 - Note that particle size of Saharan dust varies from $< 5 \mu\text{m}$ (as reported in studies from Barbados and Bermuda) to between 5 and $30 \mu\text{m}$ (Goudie and Middleton 2001)

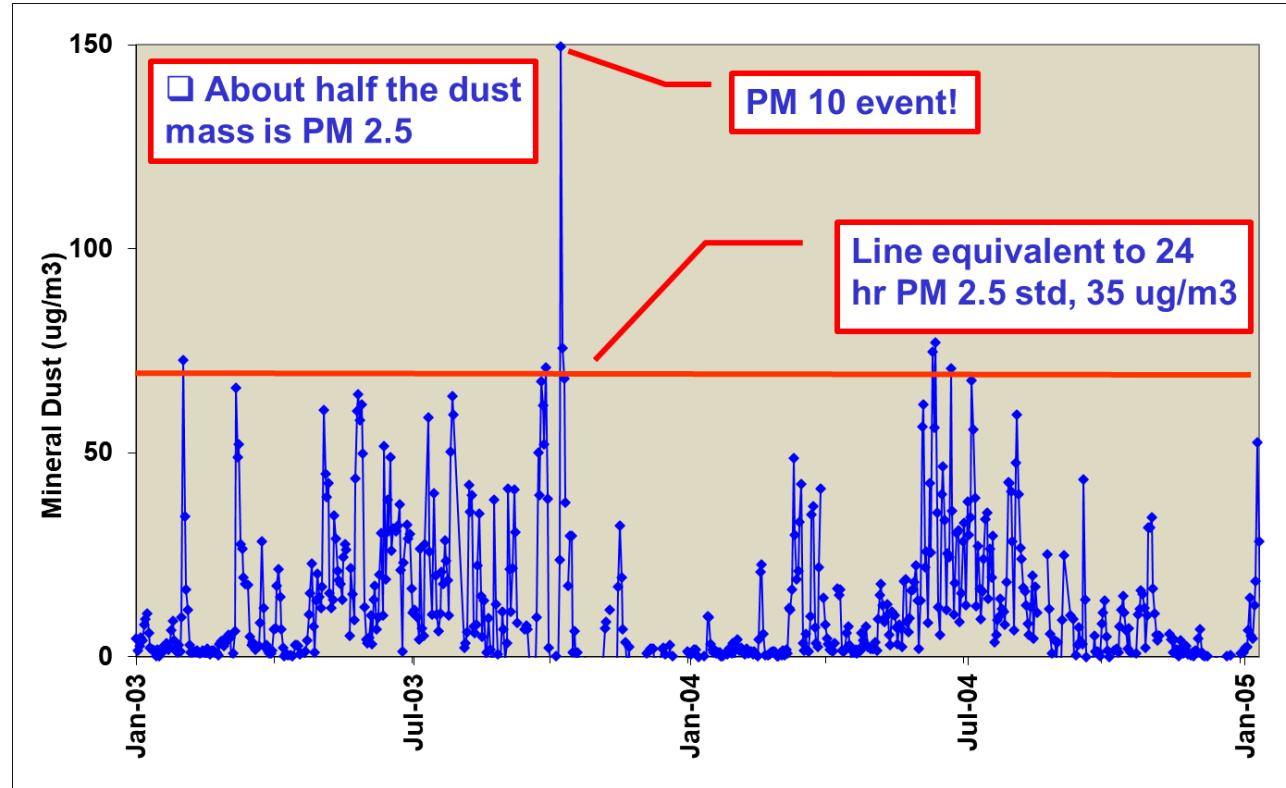


Ragged/Deebles Points, Barbados

Photo credit: CIMH

Air Quality in the Caribbean

**Barbados Daily Dust
Concentrations: 2003-2004**
Air Quality Issues
(Prof. Joseph Prospero,
University of Miami)



Air Quality in the Caribbean

- Ash from the Soufriere volcano in Montserrat was linked to an increase in asthma admissions in Guadeloupe after it erupted in 2010 (Cadelis et al. 2013)
- Fine volcanic ash/dust (combination of PM, SO₂ & other toxic gases, H₂Ov) < 60 μm



Ash in Barbados after La Soufriere, St Vincent 2021 eruption



Photo credit: Andrea Sealy

Indoor Air Quality

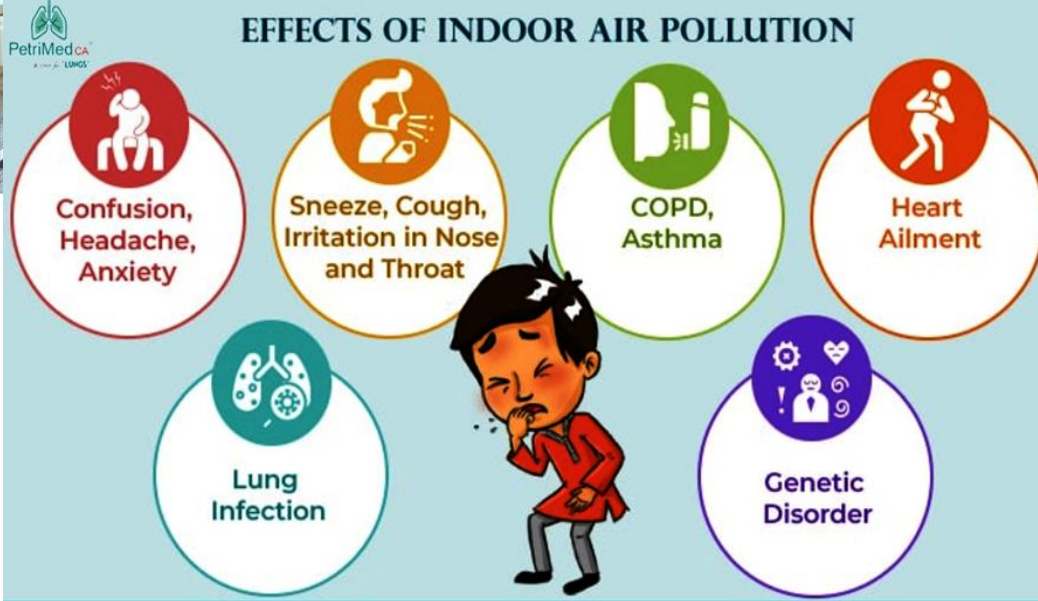
- Around 2.6 billion people cook using polluting open fires or simple stoves fueled by kerosene, biomass (wood, animal dung and crop waste) and coal.
- Each year, close to 4 million people die prematurely from illness attributable to household air pollution from inefficient cooking practices using polluting stoves paired with solid fuels and kerosene.
 - 27% are due to pneumonia
 - 18% from stroke
 - 27% from IHD
 - 20% from COPD
 - 8% from lung cancer

Indoor Air Quality

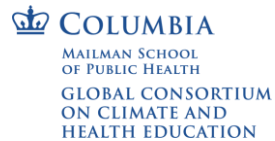


Source: <https://m.facebook.com/caribbeanindustrialresearchinstitute/>

Almost 50% of deaths due to pneumonia among children under 5 years of age are caused by particulate matter (soot) inhaled from household air pollution



Zoom Poll Question 2



Wildfires are predicted to increase under all future climate scenarios.

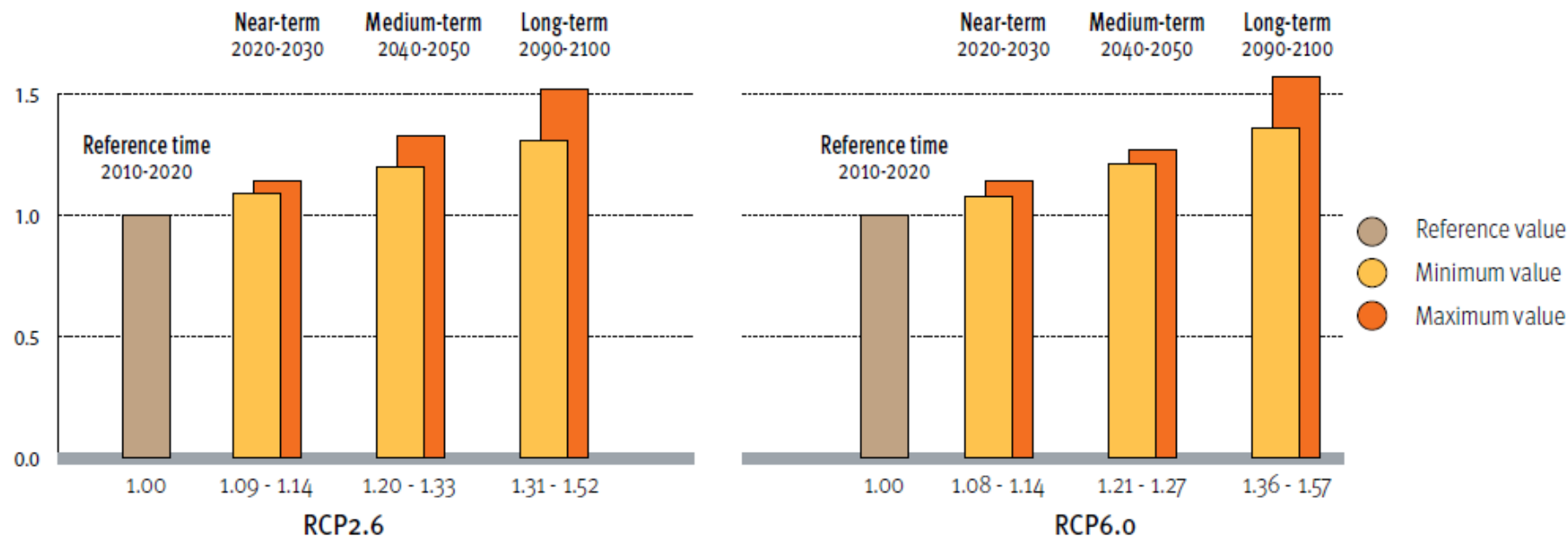
- TRUE
- FALSE

Climate Change and Wildfires

- Wildfires significantly affect the global carbon cycle
 - Occurrence in ecosystems which store large amounts of terrestrial carbon releases vast quantities of CO₂
 - May accelerate the positive feedback loop in the carbon cycle - rising temperatures
- Wildfire smoke contains particulates and toxic combustion
 - Respiratory harm
 - Cardiovascular impacts
 - Increased risk of neurological disorders
- Sustained exposure to smoke PM can be fatal (esp. persons with impaired lung function or other pre-existing health problems)
- Exposure to smoke particulates above safe levels can cause chronic impacts that reduce life expectancy and increase pressure on public health systems

Climate Change and Wildfires

Global change in wildfire events



Source: Douglas I. Kelley, UK Centre for Ecology and Hydrology

Kristina Thygesen, GRID-Arendal, 2022

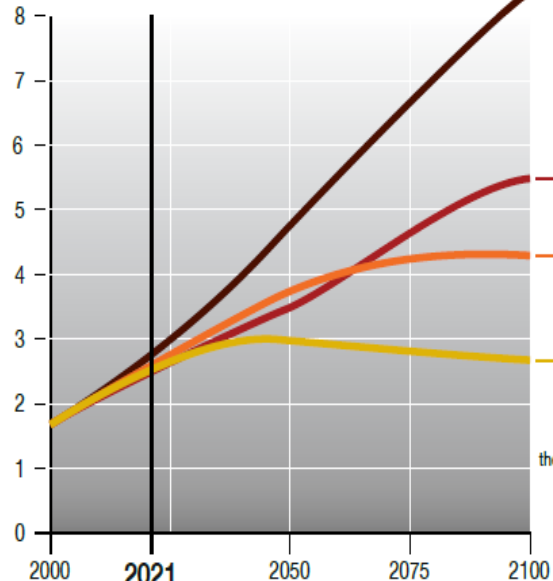
Figure s2. By the end of the century, the likelihood of catastrophic wildfires events will increase by a factor of 1.31 to 1.57. Even under the lowest emissions scenario, we will likely see a significant increase in wildfire events. See appendix for construction.

Climate Change and Wildfires

Representative Concentration Pathway (RCP)

Scientists use the RCPs to model climate change and build scenarios about the impacts

Radiative forcing
W/m²



If we follow the RCP8.5 pathway, more wildfires will occur.

RCP8.5

Temperature 2081-2100

3.7°C

Extreme weather 2081-2100



Large

RCP6.0

2.2°C



Moderate

RCP4.5

1.8°C



Moderate

RCP2.6

1.0°C



Small

If we follow the RCP2.6 pathway, fewer wildfires will occur.

Average increase relative to 1986-2005

Increase

- The numerical values of the RCPs refer to the possible range of radiative forcing values in the year 2100.
- RCPs are used to build future climate scenarios based on greenhouse gas emissions from human activities, depending on the efforts taken to limit greenhouse gas emissions (high efforts taken under RCP2.6, low efforts under RCP8.5)
- RCP2.6 is the scenario that will likely keep global warming below 2°C by 2100 – significant impact on reducing wildfire occurrence

Potential reinforcing feedback loop of climate change on wildfires



Illustration by Andrew Sullivan/CSIRO, 2021.

GRD-Aerial/Studio Aleria, 2021

Climate change will directly affect the frequency and magnitude of extreme weather conducive to the outbreak and spread of wildfires. It will also lead to longer wildfire seasons where the fire season may begin earlier and end later.

Increased wildfire activity can positively impact greenhouse gas emissions that reinforce climate change drivers. (UNEP, 2022)

(Illustration by Andrew Sullivan/CSIRO, 2021)

Climate Change and Air Quality

Climate change favoring atmospheric temperature increase
(natural or anthropogenic)



Increased demand for air conditioning
(mean daily minimum temperature > 18 °C, Trewin 2014)



Increased energy consumption



Increased air pollutant concentration
(e.g., PM such as black carbon) and GHG

Climate Change and Air Quality

- The long-term cumulative effects of GHG
 - Global warming, an important indicator of climate change
- Climate change expected to alter the concentration of airborne respiratory allergens because of CO₂ and temperature impact on plant growth
 - Impacts health burden of meteorological events such as windblown dust and mold



Climate Change and Air Quality

SIXTH ASSESSMENT REPORT

Working Group I – The Physical Science Basis







ipcc

INTERGOVERNMENTAL PANEL ON climate change



Regional fact sheet - Small Islands

Common regional changes

-  Observed warming (*high confidence*) in the Small Islands¹ has been attributed to human influence (*medium confidence*). Warming will continue in the 21st century for all global warming levels and future emissions scenarios, further increasing heat extremes and heat stress (*high confidence*).
-  Ocean acidification has increased globally as have the frequency and intensity of marine heatwaves in some areas of the Indian, Atlantic and Pacific Oceans except for a decrease over the eastern Pacific Ocean. Marine heatwaves and ocean acidification will increase further with 1.5°C of global warming (*high confidence*) and with larger increases at 2°C and higher.
-  Sea levels will very likely continue to rise around Small Islands, more so with higher emissions and over longer time periods (*high confidence*).
-  Sea level rise coupled with storm surges and waves will exacerbate coastal inundation and the potential for increased saltwater intrusion into aquifers (*high confidence*).
-  Sea level rise will cause shorelines to retreat along sandy coasts of most Small Islands.
-  Small Islands will face more intense but generally fewer tropical cyclones, except in the central north Pacific where frequency will increase (*medium confidence* at a global warming level of 2°C and above).

Climate Change and Air Quality

SIXTH ASSESSMENT REPORT

Working Group I – The Physical Science Basis

ipcc

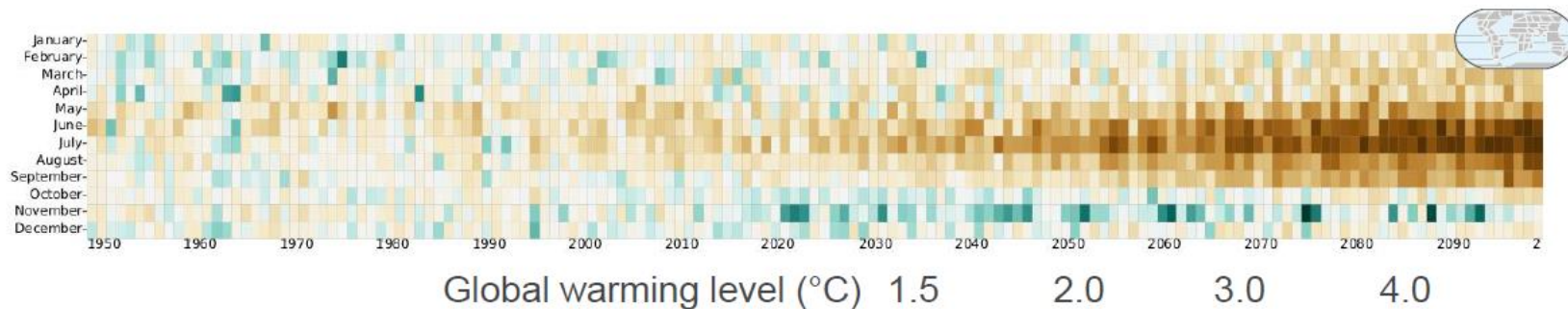
INTERGOVERNMENTAL PANEL ON climate change



Caribbean (CAR)

- Declining trend in rainfall during June–July–August in CAR will continue in coming decades (*high confidence* at 2°C global warming and above).
- Higher evapotranspiration under a warming climate will result in increased aridity and more severe agricultural and ecological droughts in CAR (*medium confidence* at global warming level of 2°C and above).

Change in monthly average precipitation relative to 1995–2014 for the Caribbean under increasing warming levels



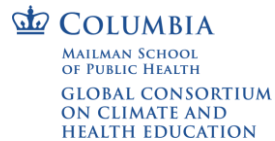
Climate Change and Air Quality

- Predicted to impact air quality by altering the concentration and distribution of major air pollutants particularly CO₂, O₃, fine PM , and aeroallergens
- Extreme weather (hurricanes, heavy precipitation, and flooding) create environments conducive for mold, mildew, and other bioaerosols (Ivey et al. 2003; Milia´n and Di´az 2004)
- Climate change will have a major impact on terrestrial ecosystems of small islands, hence increasing atmospheric carbon concentration via a reduction in natural carbon sinks
- Aggravated by poor land use management, indiscriminate forest and bush burning practices, urbanization and industrialization, rapid population growth, and an increase in energy demand by citizens and tourists

Climate Change and Air Quality

- Expected increases in environmental exposure to PM (e.g., black carbon, soot, and Saharan dust), pollens, mold, other bioaerosols, and ground-level ozone
- Increased atmospheric CO₂ levels associated with increase in ragweed (flourishes in tropical and subtropical climates and native to Guadeloupe, Jamaica, and Martinique; CABI 2016, Ziska et al. 2011)
- Aeroallergens from pollen producing plants are expected to increase (Richter et al. 2013).

Zoom Poll Question 3

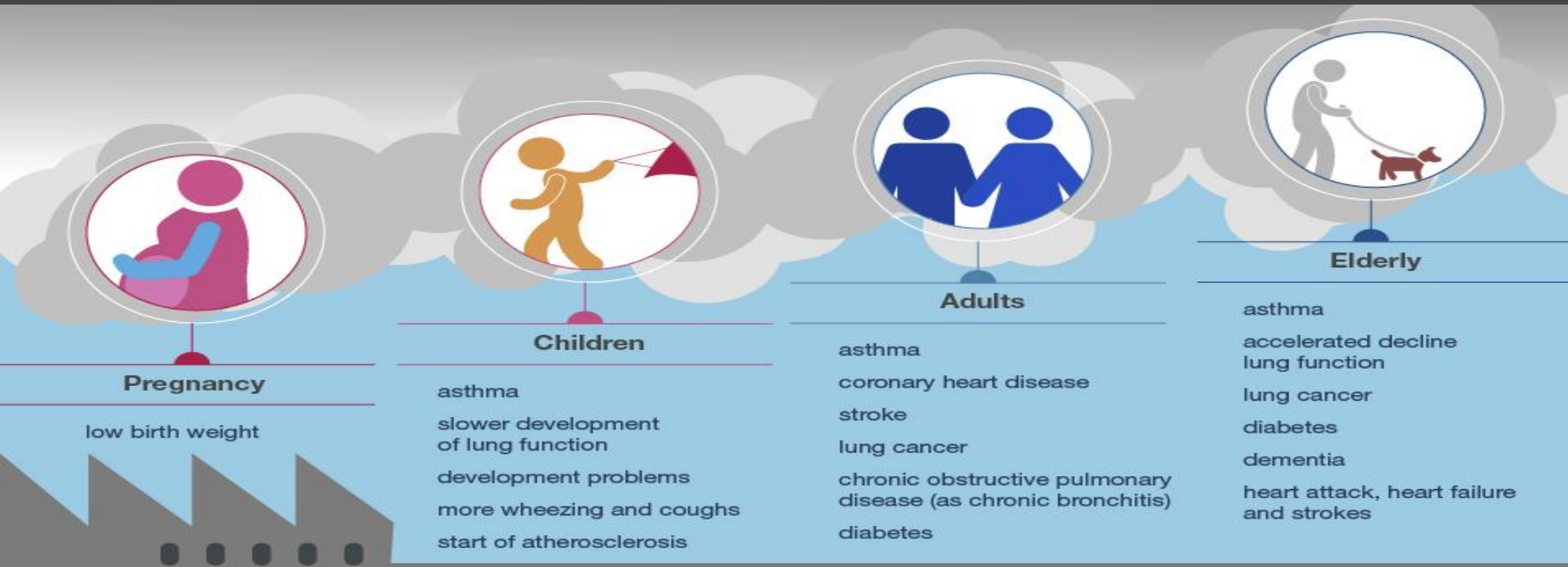


Which of these do you think is useful in preparing for an air pollution event and protecting those most vulnerable?

- Observations
- Predictions
- Advisories
- All of the above

Who is vulnerable?

Air pollution affects people throughout their lifetime



Who is vulnerable?

Air pollution affects everyone but there are **inequalities in exposure** and **the greatest impact on the most vulnerable**

older people
(65 and older)



pregnant women



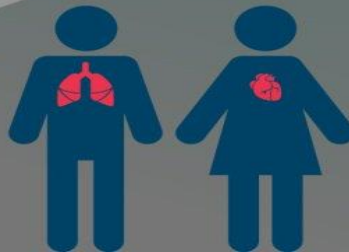
communities with poorer air quality
(eg. those situated closer to main roads)



children



those with cardiovascular disease and/or respiratory disease



Who is vulnerable?

WHO IS MOST IMPACTED BY AIR POLLUTION?

Children

Pneumonia is the leading cause of death in children under five years of age. Air pollution is a major risk factor.

Women

Women working in smoky kitchens are exposed to high levels of household air pollution.

Outdoor workers

People who work outdoors, such as street vendors and traffic officers, are affected by air pollution.

IMPACT OF AIR POLLUTION ON CHILDREN'S HEALTH

A child who is exposed to unsafe levels of pollution can face a lifetime of health impacts. Exposure in the womb or in early childhood can lead to:



Stunted lung growth
Reduced lung function
Increased risk of developing asthma
Acute lower respiratory infections



Impaired mental and motor development
Behavioral disorders



Low birth weight
Premature birth
Infant mortality



Childhood cancers



Increased risk of heart disease, diabetes and stroke in adulthood

IN 2016, AMBIENT AND HOUSEHOLD AIR POLLUTION CAUSED

543,000 deaths
in children under 5 years

52,000 deaths
in children aged 5 - 15 years

Household and ambient air pollution cause more than 50% of acute lower respiratory infection in children under 5 years in lower- and middle-income countries.



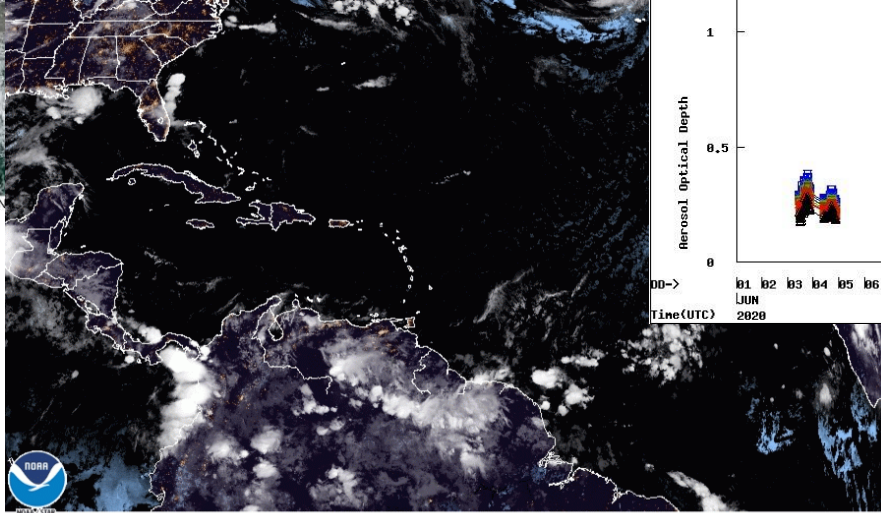
How can we prepare and protect?

- Observations
- Predictions
- Advisories (short term and seasonal)
- WMO Caribbean Regional Climate Center
<https://rcc.cimh.edu.bb/>
- CIMH Dust and Air Quality Forecasting Centre
<http://dafc.cimh.edu.bb/>
- Other mitigation strategies

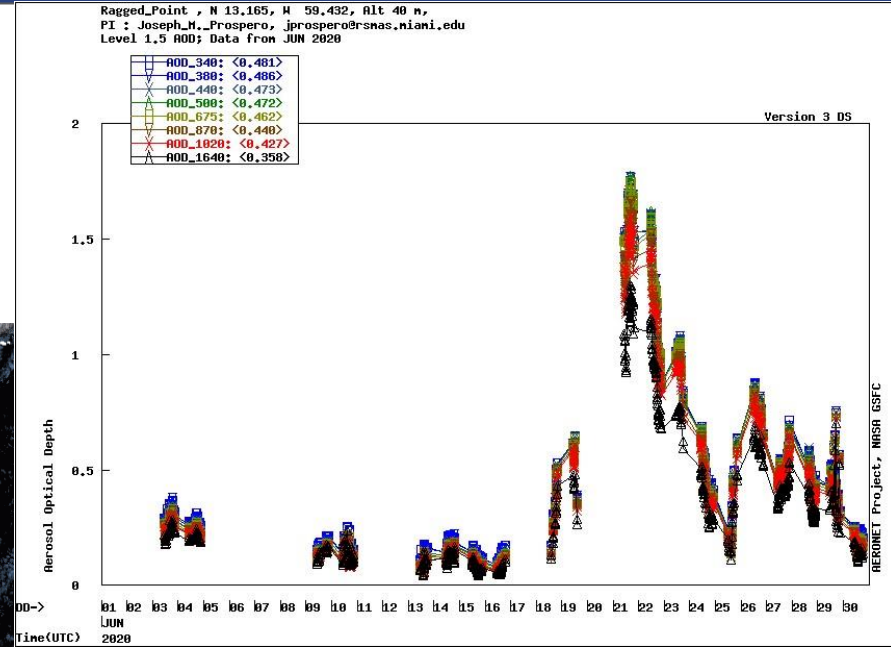
How can we prepare and protect?



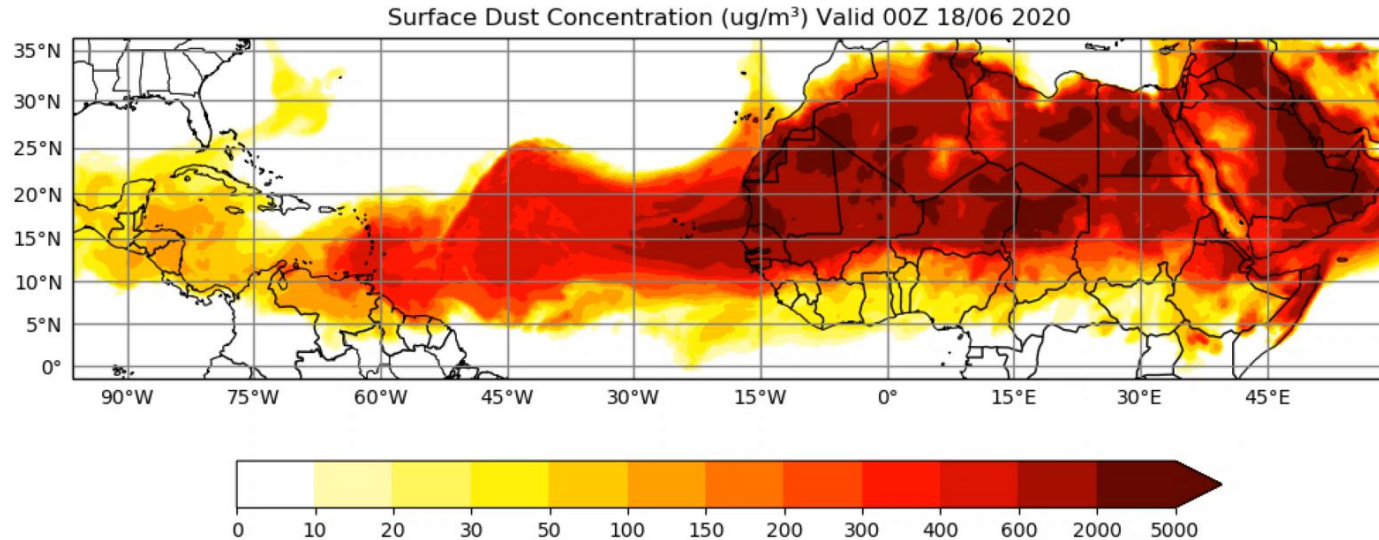
23 Jun 2020 12:00Z



23 Jun 2020 05:30Z NESDIS/STAR GOES-East GEOCOLOR



How can we prepare and protect?



How can we prepare and protect?



Caribbean Health Climatic Bulletin Vol 6 | Issue 1 March 2022



CARPHA, PAHO and CIMH celebrate the 5th anniversary of the publication of the Caribbean Health Climatic Bulletin!

This Bulletin is a joint effort between the Caribbean Public Health Agency (CARPHA), the Pan American/World Health Organization (PAHO/WHO) and the Caribbean Institute for Meteorology and Hydrology (CIMH). It aims to help health professionals identify and prepare health interventions for favourable or inclement climate conditions in the Caribbean. The period covered is March-May 2022. It is recommended that health stakeholders should use the combination of monitoring (November 2021-January 2022) and forecast (March-May 2022) climate information presented in this Bulletin in tandem with weather forecasts (1-7 days). This suite of information is intended to guide strategic and operational decisions related to health interventions and the management of health care systems.

What are the Key Climate Messages for March - May 2022?

- Climatically, March to May forms the second half of the Caribbean Dry Season in Belize and the Caribbean Islands, characterised by relatively few wet days and a small number of wet spells, but many dry days and quite a few dry spells. There is typically an increase in wildfire potential during this part of the dry season. In the Guianas, the first part of this period ends one of their two climatological dry seasons.
- Regionally, forecasts of rainfall totals are not typically very confident for the period March to May (MAM). For the forecast period March to May (MAM) 2022, a persistent weak La Nina pattern is expected to transition to near neutral conditions during the upcoming season, which may drive increasing uncertainty into the seasonal rainfall forecast. This uncertainty points the MAM rainfall and wet day forecast towards climatology across most of the region (equal chances for above normal, normal, and below normal probabilities, so prepare for what is typical at this time of the year).



Saharan Dust Update for Monday June 7, 2021

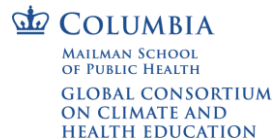
This update is being provided by the Caribbean Institute for Meteorology and Hydrology (CIMH) in its role as the Pan American Centre for the World Meteorological Organization (WMO) Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS).

CONDITIONS AS OF JUNE 7, 2021

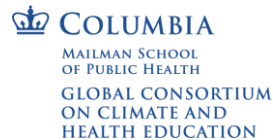


Figure 1: GOES-East Geocolor imagery valid 1500 UTC/1100 AST June 7, 2021

Open-ended question



How can health professionals protect the vulnerable persons in our communities ?



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Thank You
For Your Attention!

Any Questions

