C#VID-19 ATLAS

An Illustrated Guide to the Global Impact of the COVID-19 Pandemic

LEONARD LUZ

Appendix 1 Diploma Thesis



COVID-19 Atlas

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> Leonard Luz Copernicus Master in Digital Earth

> > Appendix 1 Diploma Thesis









COVID-19 Atlas

An Illustrated Guide to the Global Impact of the COVID-19 Pandemic

Appendix 1, Diploma Thesis

Thesis Title: Designing a Thematic Atlas on the Geospatial Impact of COVID-19

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About the Atlas

The COVID-19 Atlas presents figures, maps, charts, infographics, and other visualizations that portray the impact of the COVID-19 pandemic in various thematic areas including social, economic, and environmental aspects.

The atlas draws data from various authoritative global data sources for coronavirus reports such as the Johns Hopkins Coronavirus Resource Center and the Oxford COVID-19 Government Response Tracker (OxCGRT). Global statistical datasets for economic topics were obtained from the World Bank (WB), International Monetary Fund (IMF) among others. Copernicus data, specifically from the Sentinel-5 Precursor observation satellite was used to visualize the environmental topics.

Country/territory boundaries are shown according to defacto status. Some disputed areas such as Western Sahara, Somaliland, and Northern Cyprus are shown on the map although the accuracy of the frontiers is not guaranteed. The continent of Antarctica which has no native human population is not displayed in the thematic maps in this atlas.

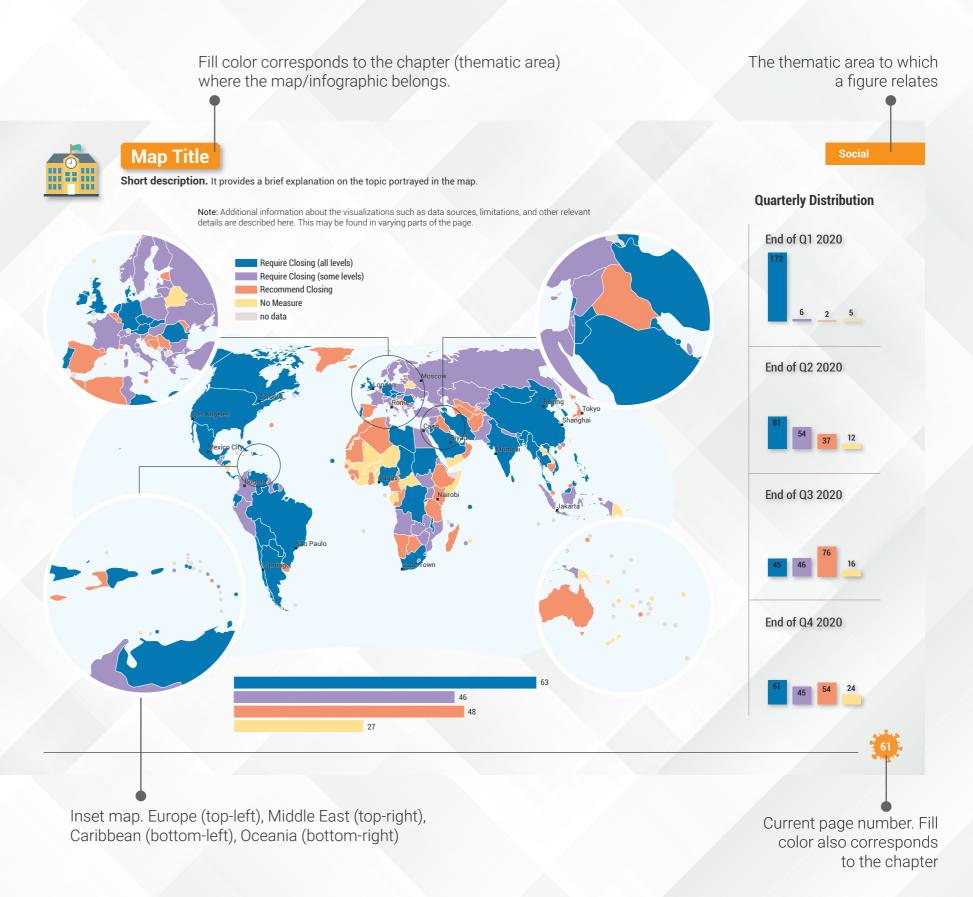
The cut-off date for the data included in this atlas is January 31, 2021 in the interest of visualizing the global status one year after the onset of the pandemic.

This thematic atlas was developed as part of a master's thesis for the Copernicus Master in Digital Earth program under the Geovisualization and Geocommunication Track at the University of Palacký Olomouc.

Disclaimer:

The boundaries and names shown and the designations used on the maps in this atlas do not imply any opinion whatsoever of the author about the legal status of any country, territory, or concerning the delimitation of its boundaries. Due diligence was performed to ensure that each map is free of errors, but there is no warranty of any kind in connection to its accuracy or completeness.

The views and opinions expressed in this atlas are those of the author's and do not necessarily reflect the official position of the Copernicus Digital Earth program, the University of Palacký Olomouc, the University of Salzburg, and the Erasmus+ program.







Projection: World Wagner VII Scale: 1:90,000,000



The thematic maps do not show the country/territory names. Use these reference maps to locate a specific country/territory on the map.



Europe

North and Central America





The thematic maps do not show the country/territory names. Use these reference maps to locate a specific country/territory on the map.

Caribbean





South America



The thematic maps do not show the country/territory names. Use these reference maps to locate a specific country/territory on the map.



Africa

Central, Southern, and Western Asia





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Eastern and Southeastern Asia





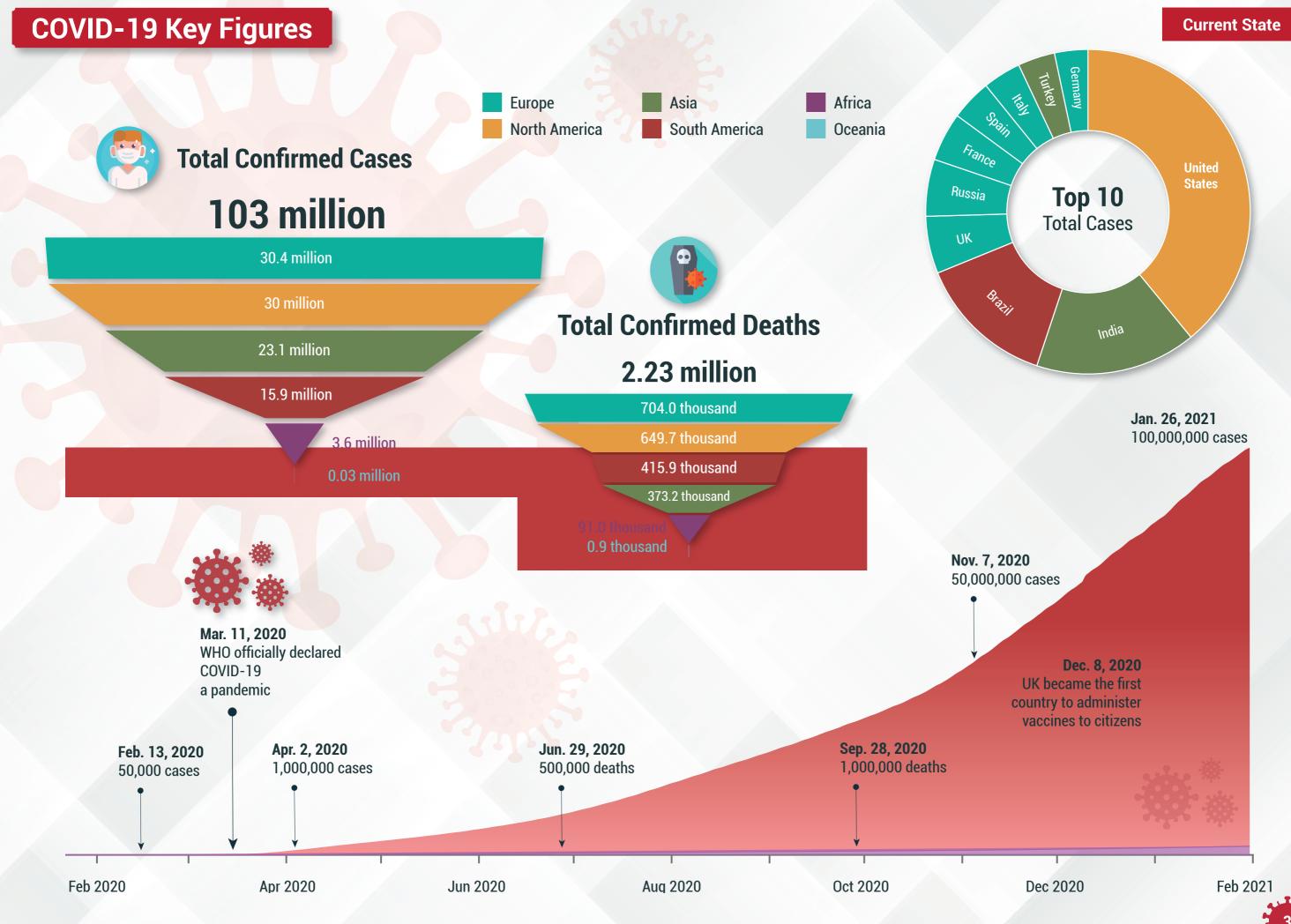
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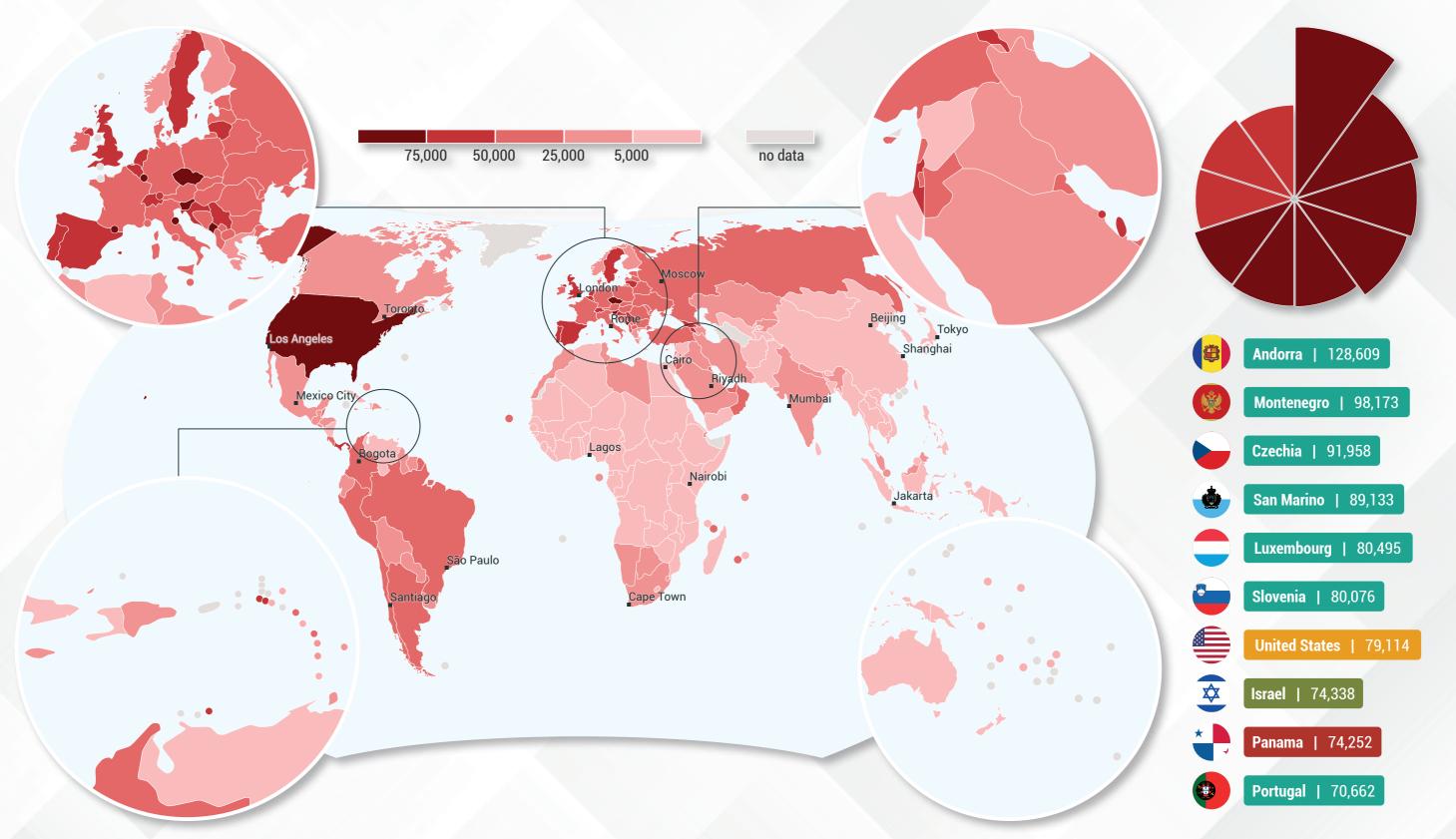




Total Confirmed Cases per Million

Total confirmed cases per million correspond to the cumulative number of those who have contracted the COVID-19 relative to the population. Due to limited testing, the number of confirmed cases may be lower than the actual cases since it only reflects those who have been infected as confirmed from laboratory testing.

Top Ten Countries/Territories



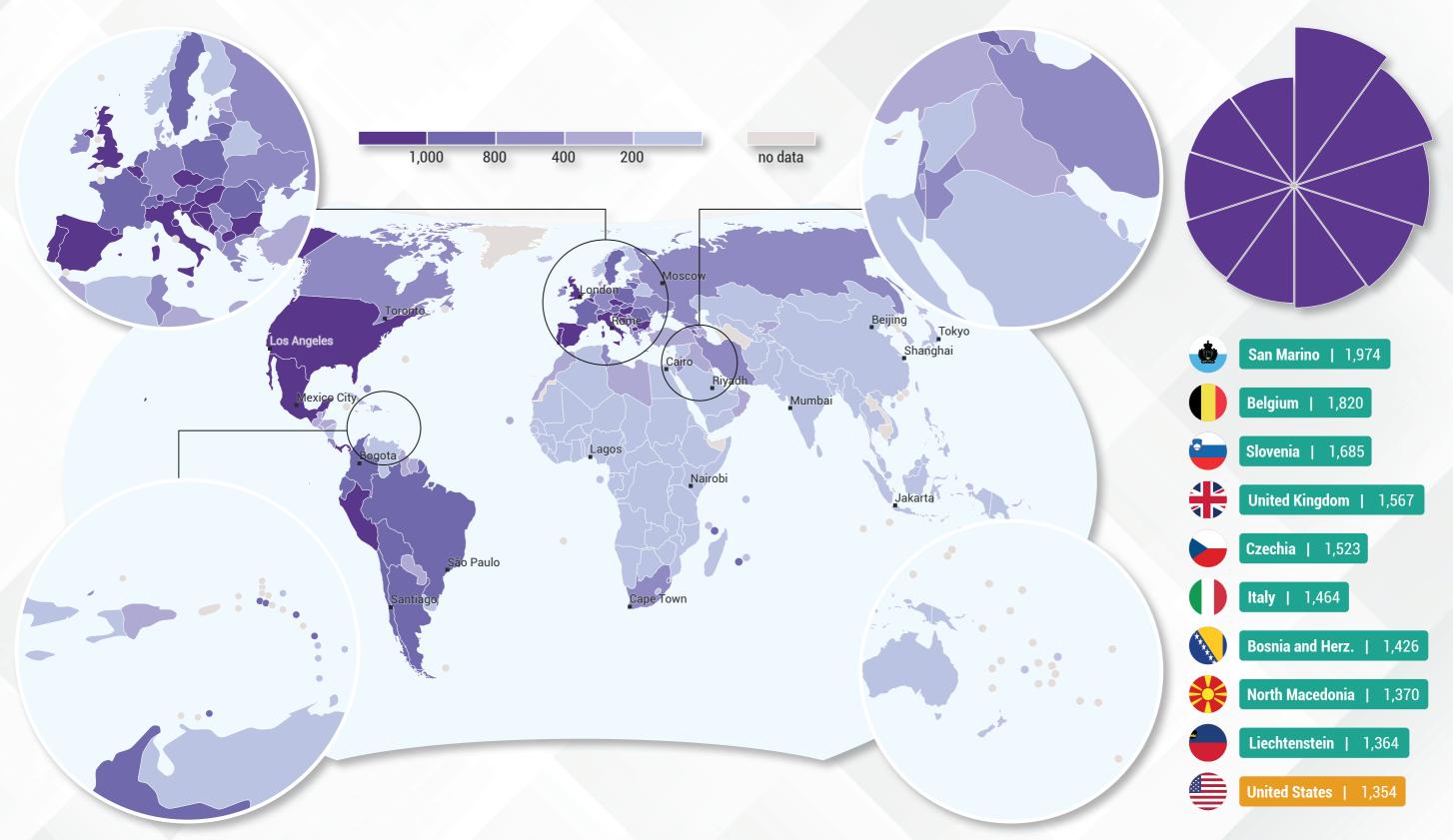
Most countries with high confirmed cases and deaths per million can be found in Europe as the region became the epicenter of COVID-19 after WHO declared that it was a pandemic.



Total Confirmed Deaths per Million

Total confirmed deaths per million correspond to the cumulative number of deaths attributed to COVID-19 relative to the population. Limited testing and problems in the attribution of the cause of death may signify that the actual deaths attributed to COVID-19 are higher than what is being reported.

Top Ten Countries/Territories

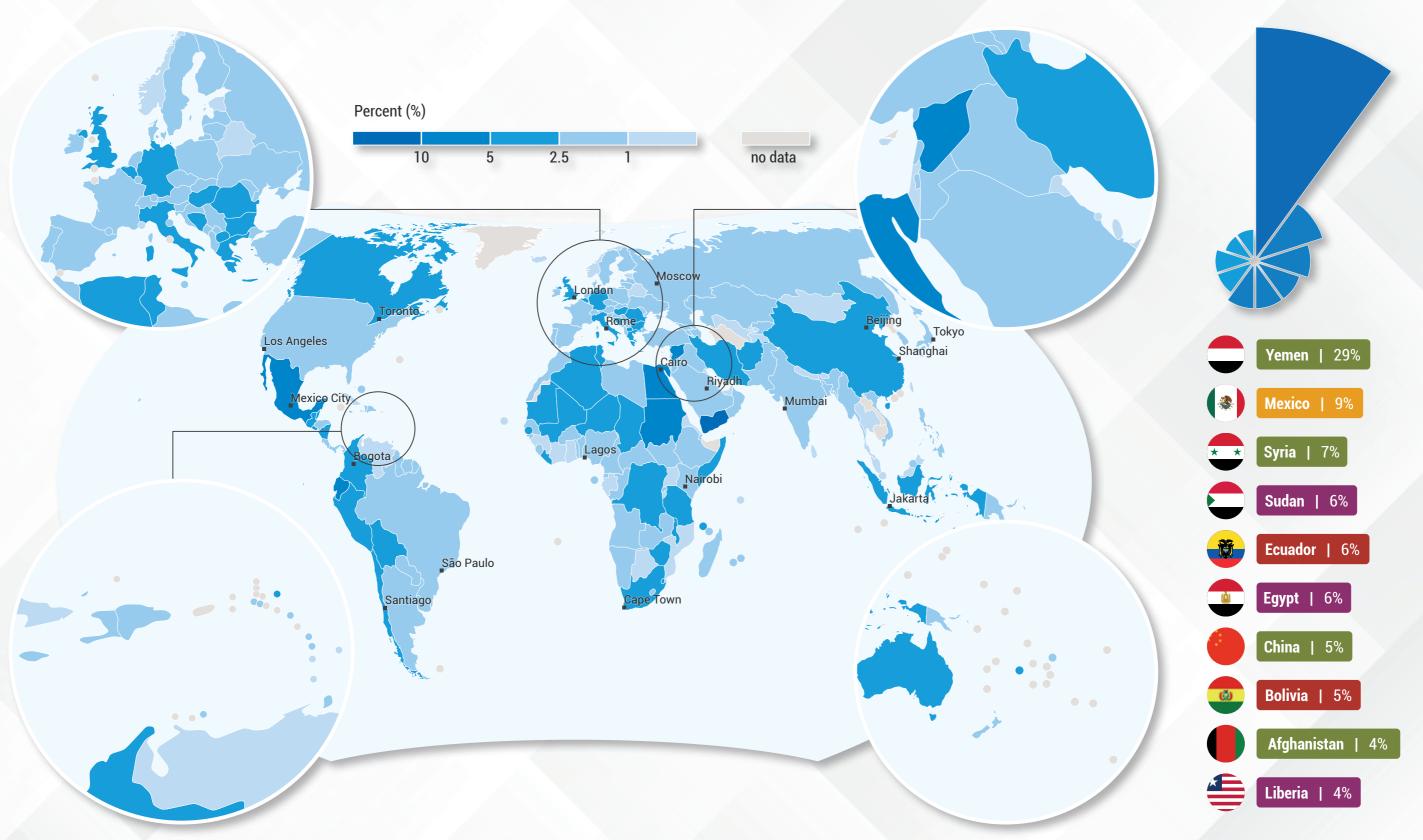




Case Fatality Rate

The Case Fatality Rate (CFR) is the ratio between the confirmed deaths and confirmed cases. During an outbreak, this value should not be used as a measure of mortality risk of the disease since the total number of cases is still not known.

Top Ten Countries/Territories



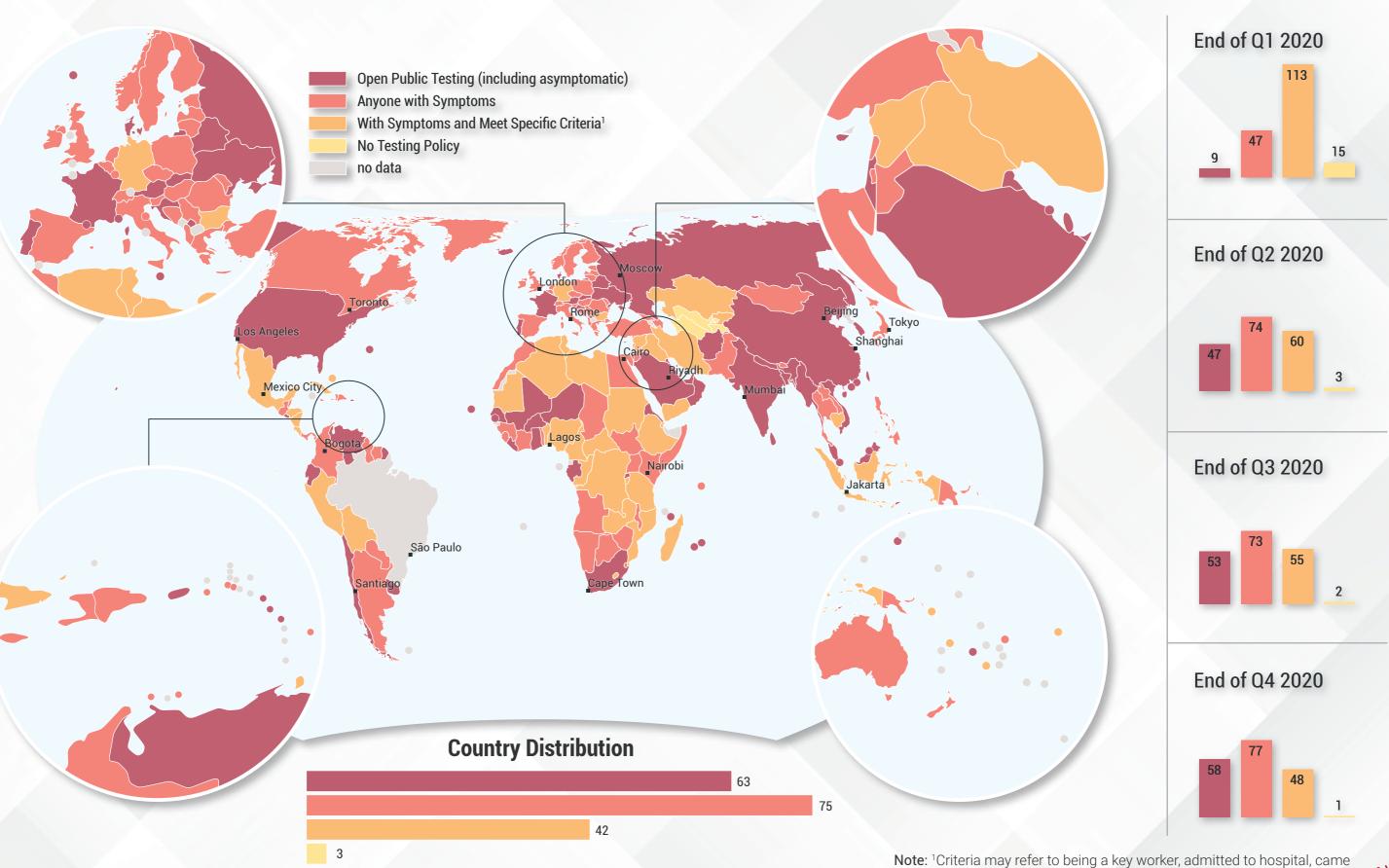
CFR is heavily influenced by the testing capacity which is associated with the availability of resources and manpower. In a war-torn country like **Yemen**, COVID-19 testing is very limited which may extremely skew the CFR. Comparison of CFR should be done only between countries with comparable testing capacities.



Testing Policy

Testing technologies considered only include **PCR** (polymerase chain reaction) test and rapid antigen test. These tests in particular detect whether an individual is currently infected.

Quarterly Distribution



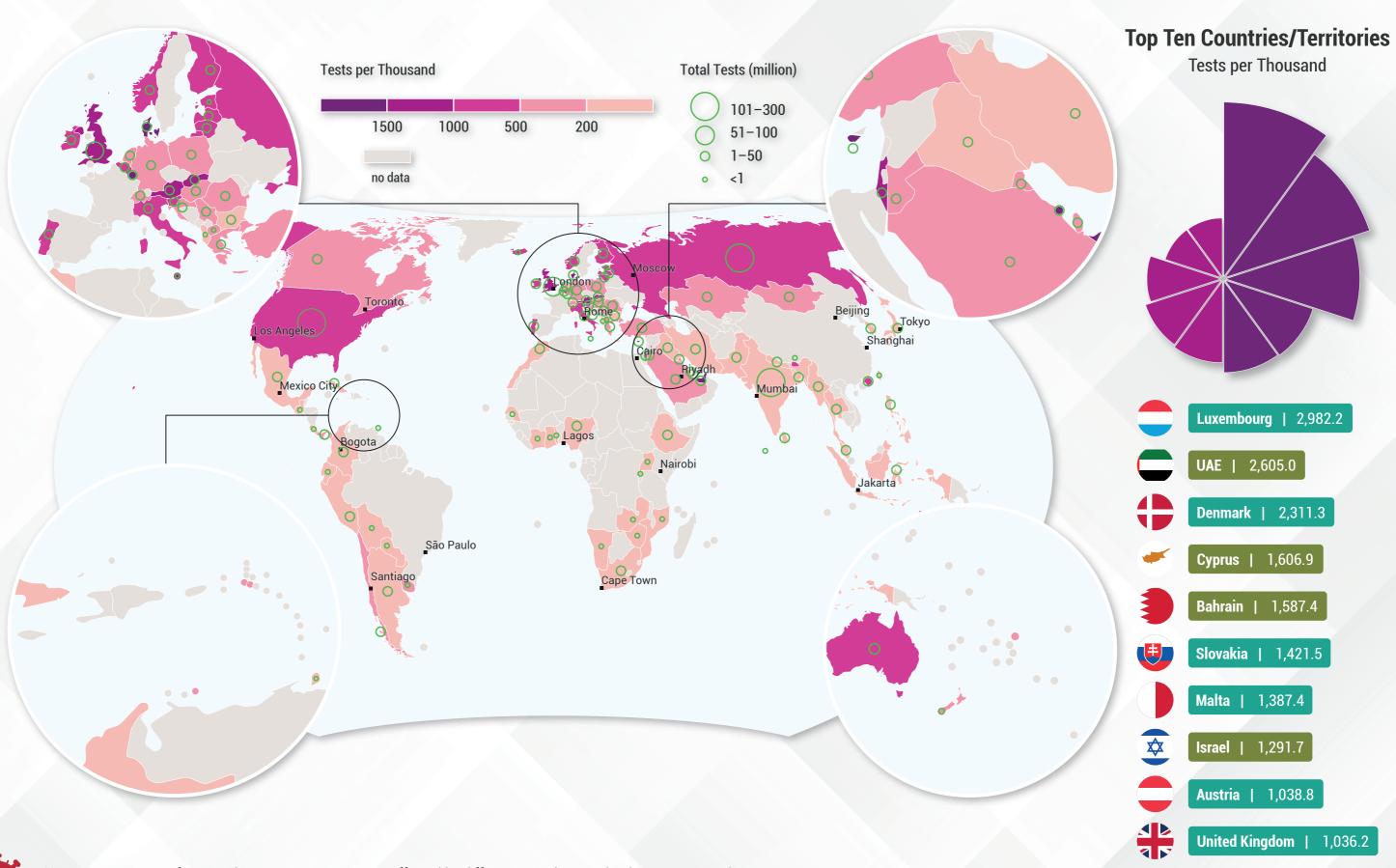


into contact with a known case, returned from overseas.



Tests per Thousand

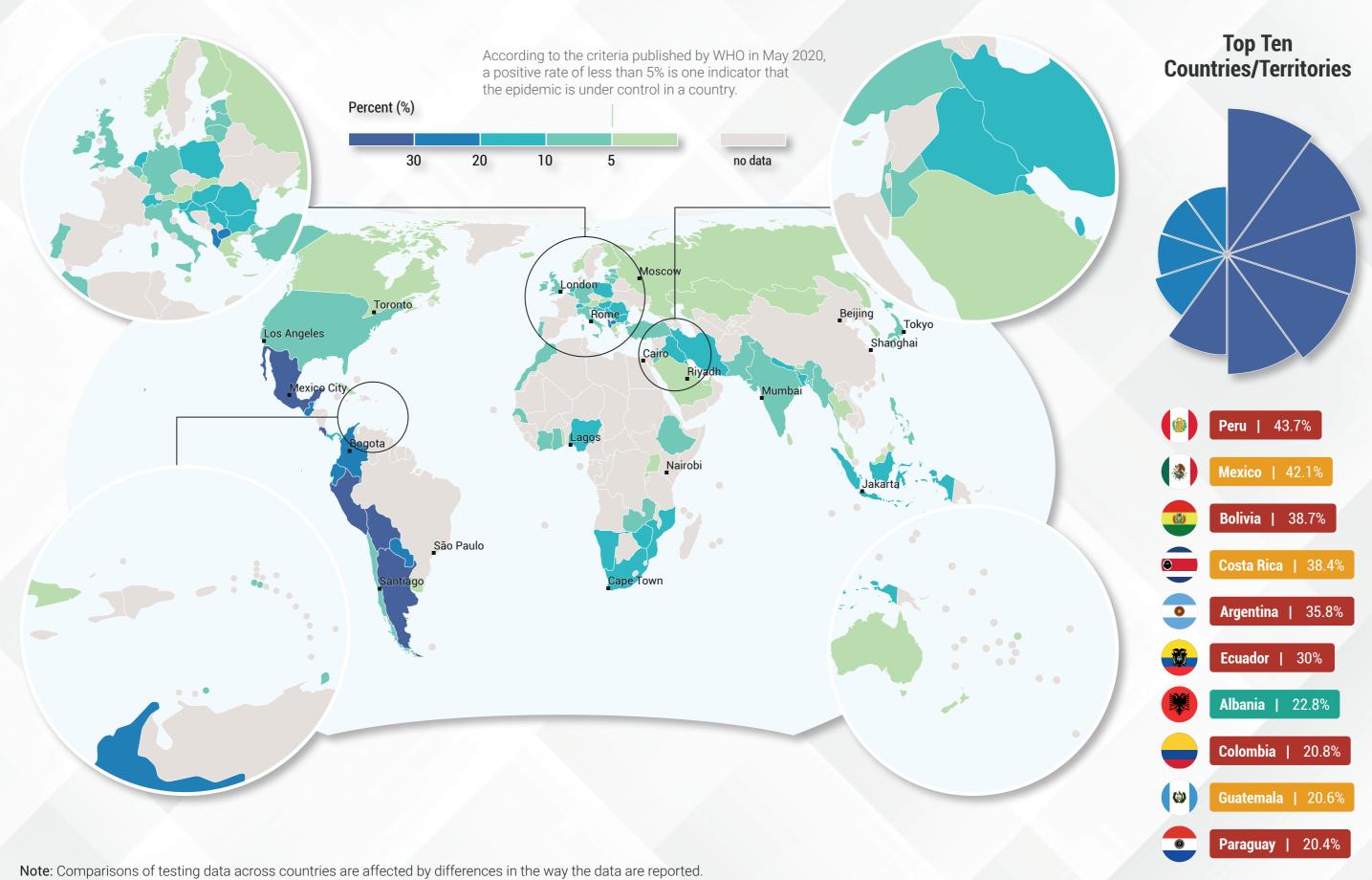
Each country reports testing data differently. Some report the number of people tested while others report the total number of tests which may result in a higher value if a person is tested more than once. While this is the case, the huge disparity between the wealthy and poor nation's responses have been highlighted during this pandemic.





Positive Rate

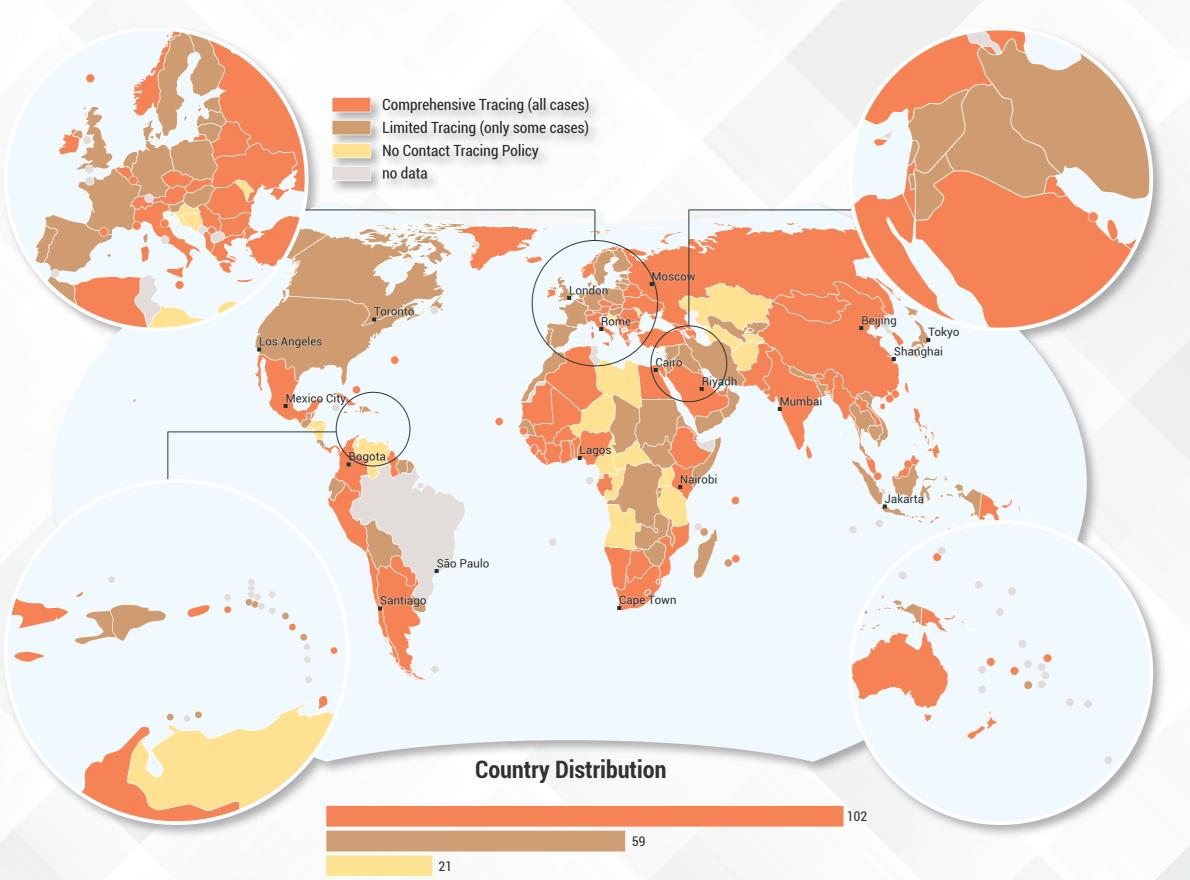
Positive rate shows the share of COVID-19 tests that are positive. This metric not only shows how adequately countries are testing but also helps in understanding how the virus is spreading together with the data on confirmed cases.



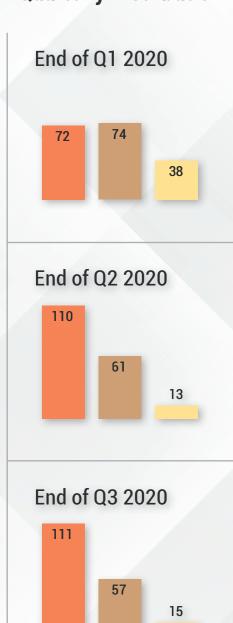


Contact Tracing Policy

This records the government's general contact tracing policy when a positive case is detected. It only includes manual contact tracing procedures that aim to reach all people connected to a newly diagnosed case.



Quarterly Distribution





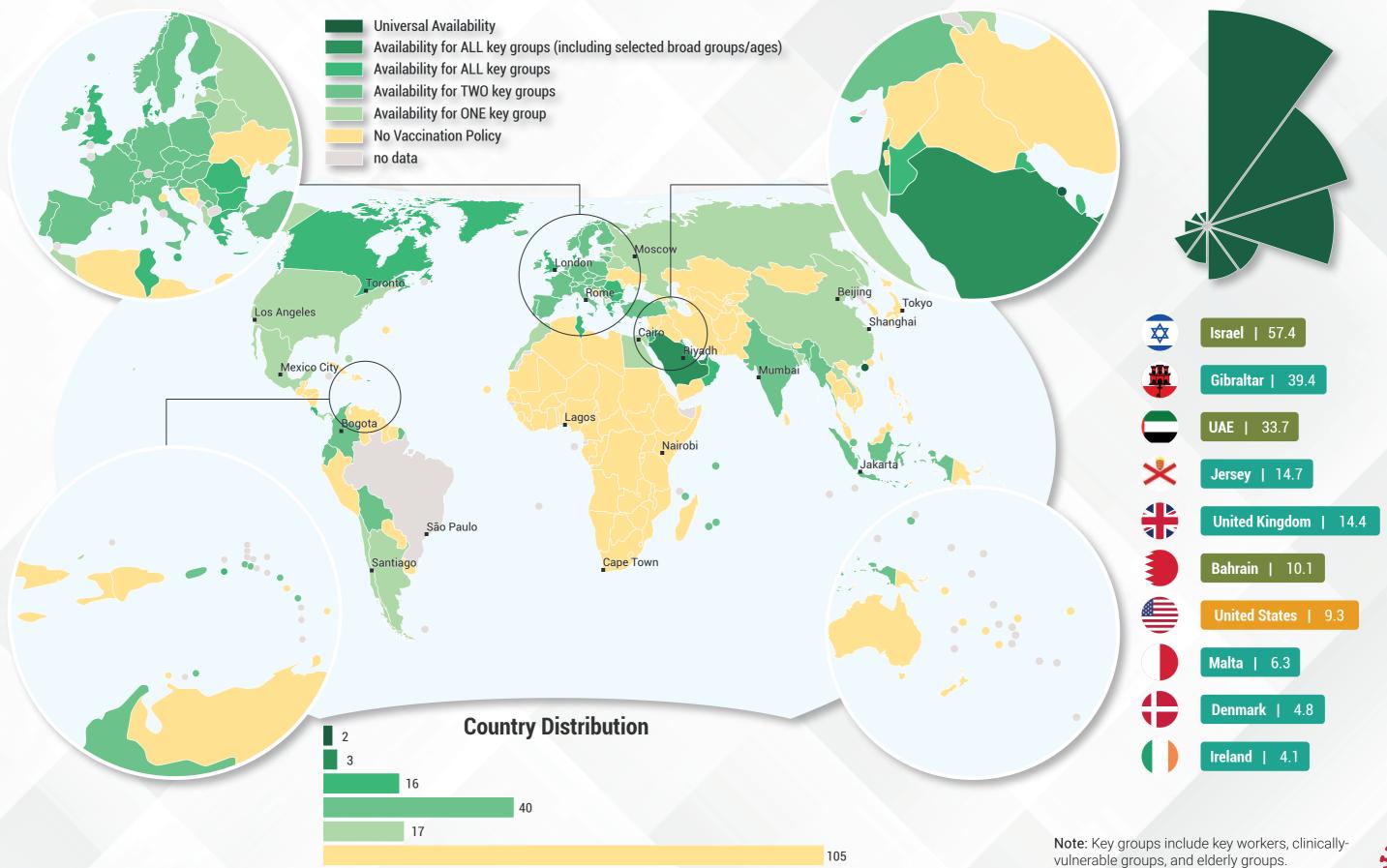


Vaccination Policy

The United Kingdom was the first country to administer COVID-19 vaccines to its citizens in December 2020. Other high-income countries followed immediately with Bahrain offering universal availability to its citizens and Israel having the highest vaccination rate per capita.

Top Ten Countries/Territories

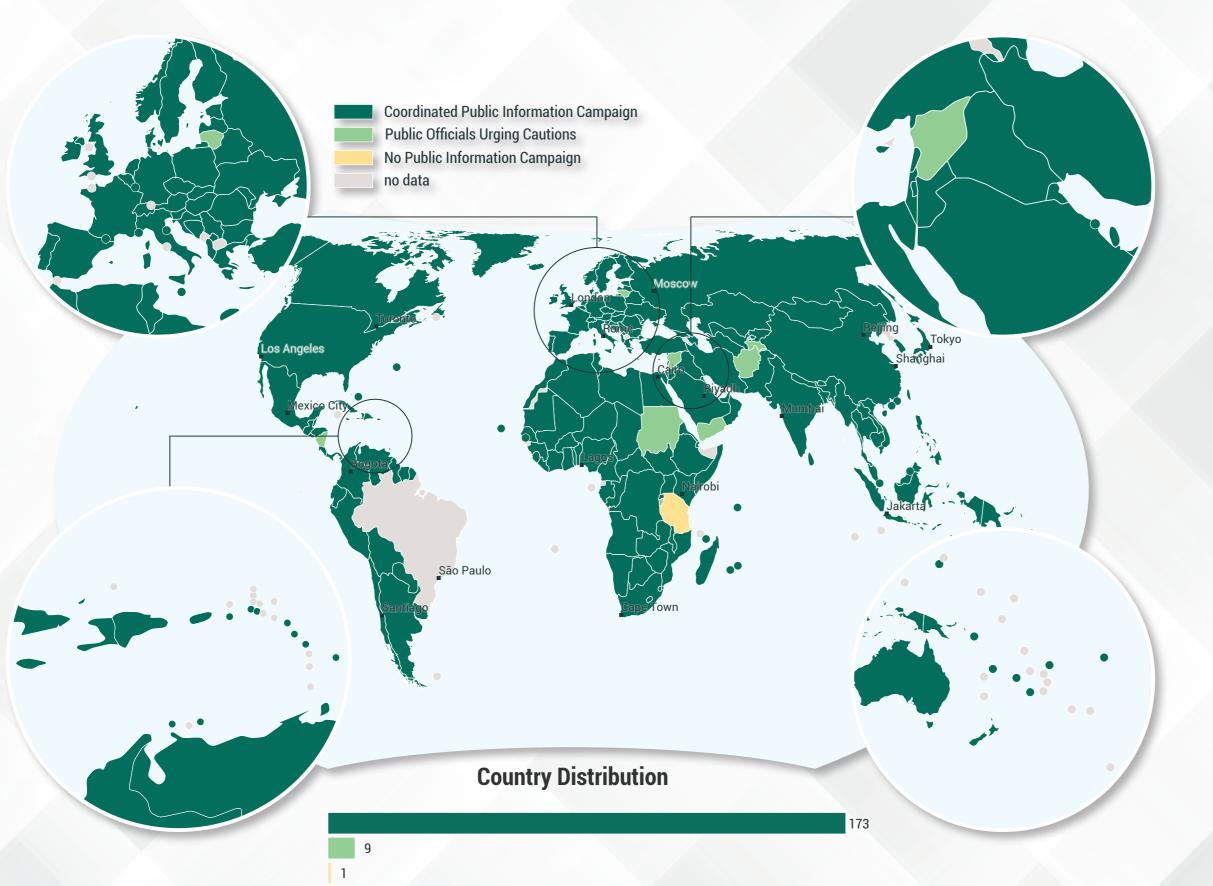
Vaccinations per Hundred



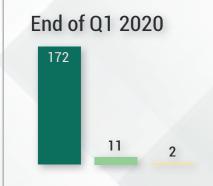


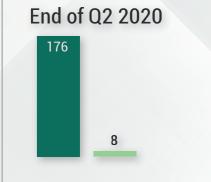
Public Information Campaign

Since the beginning of the pandemic, most countries have implemented coordinated public information campaigns about COVID-19. This campaign includes launching a centralized website dedicated to pandemic response, official press release of health protocols, and social media announcements from the government's health department.

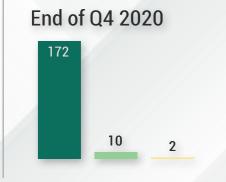


Quarterly Distribution











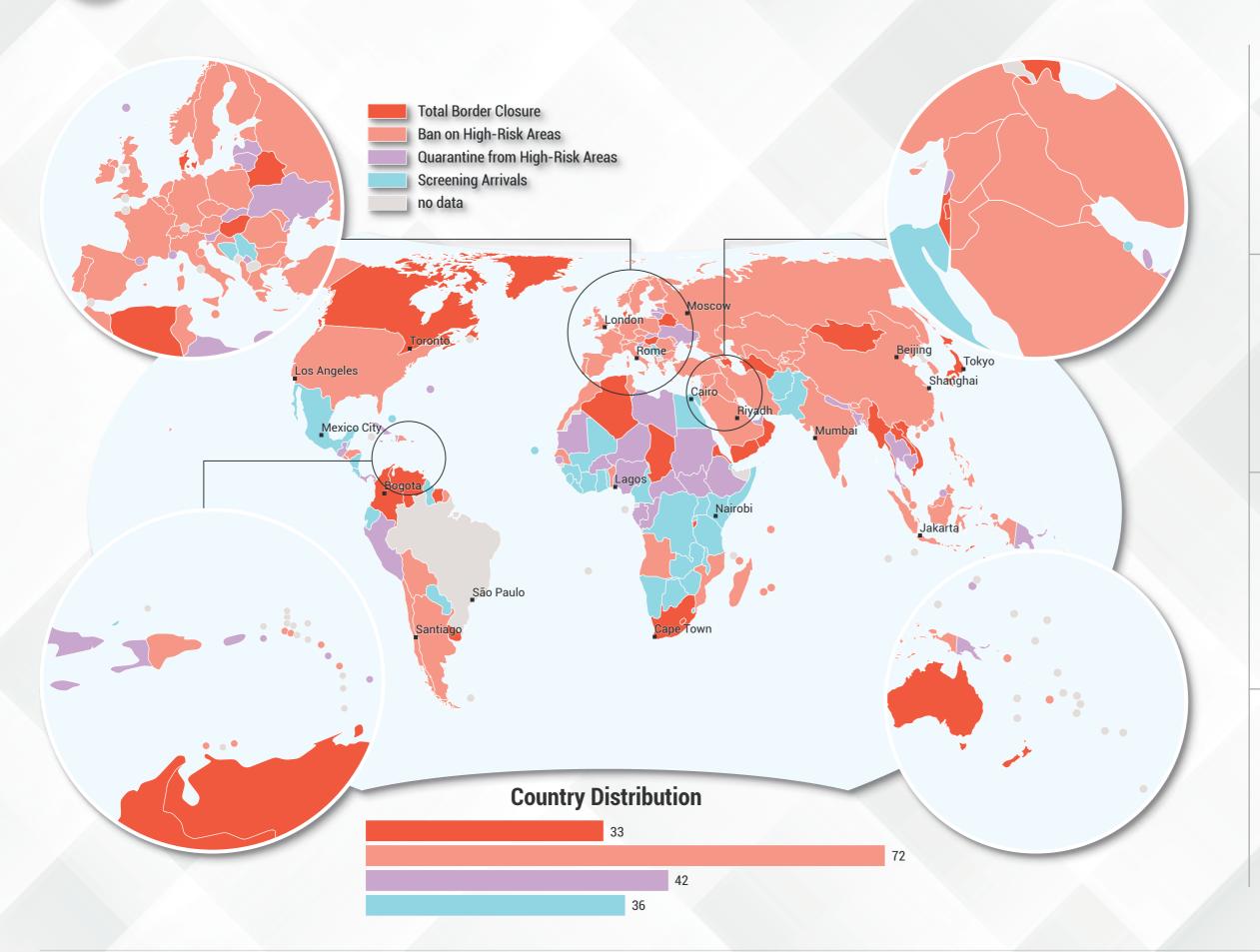
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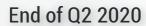
International Travel Controls

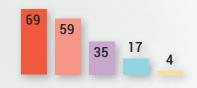
International travel controls refer to the policies implemented for foreign travellers and not for returning citizens of a certain country. Even after a year after the pandemic started, a lot of countries are still implementing border closure for foreign travellers.



Quarterly Distribution







End of Q3 2020



End of Q4 2020





Restrictions on Gatherings

A lot of usual family gatherings such as weddings, outdoor picnics, and funerals were restricted to a limited number of participants. This led to the introduction of 'bubbles' or those (select few) friends or family members with who you can socialize.

Quarterly Distribution Note: The policy categories shown may not apply at all sub-national levels. A country is coded as having these restrictions if at least some sub-national regions have implemented them. End of Q1 2020 <10 people 10-100 people 101-1,000 people >1,000 people No Measure no data End of Q2 2020 End of Q3 2020 End of Q4 2020 **Country Distribution** 23

Quarterly Distribution



School Closure Policy

The UNESCO estimates that over 260 million students have been affected by school closures around the world. Significant learning losses are foreseen if school closure persists and new educations were not adapted especially in the vulnerable and disadvantaged communities.

Note: The policy categories shown may not apply at all sub-national levels. A country is coded as 'required closures' if at least some sub-national regions have required closures. End of Q1 2020 Require Closing (all levels) Require Closing (some levels) **Recommend Closing** No Measure no data End of Q2 2020 End of Q3 2020 End of Q4 2020 **Country Distribution** 63

27

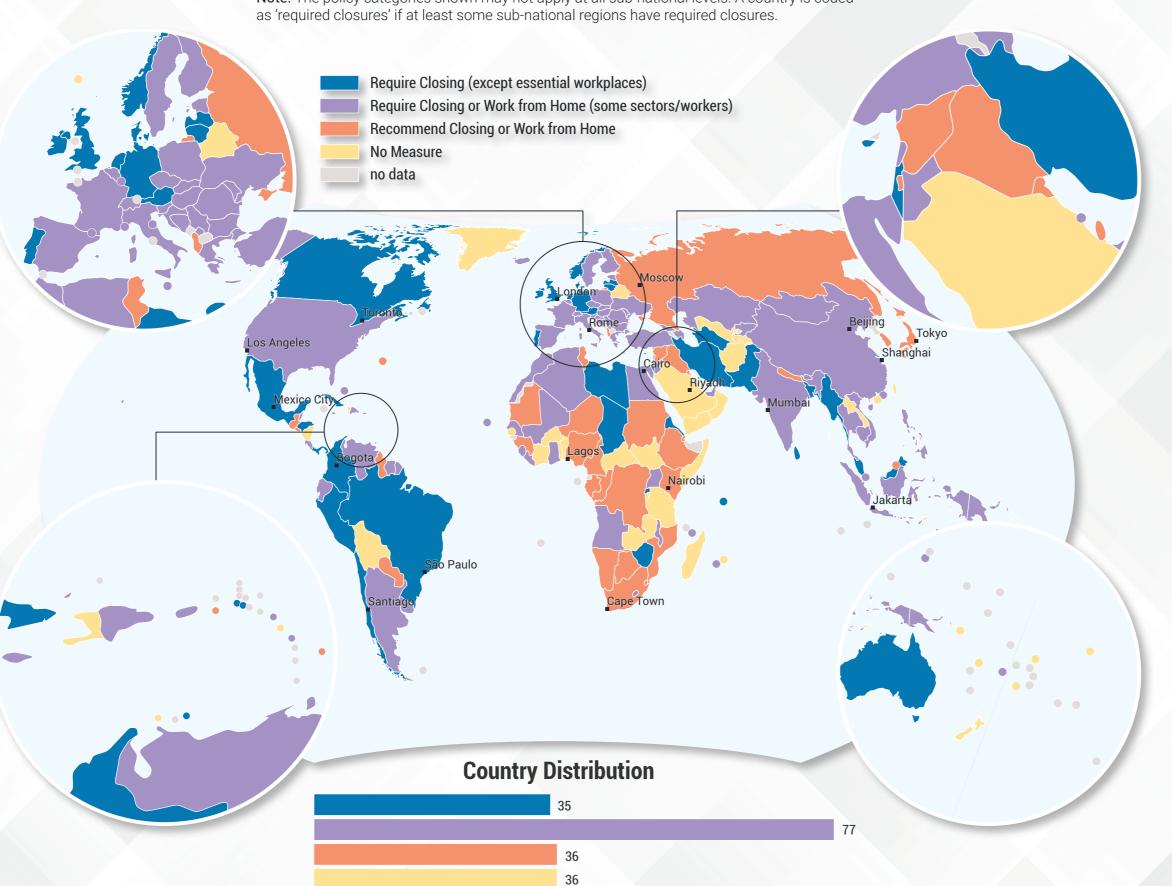




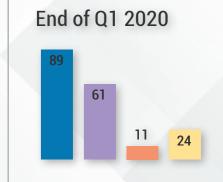
Workplace Closure Policy

Workplace closure has led to an increase in both unemployment and inactivity. Although some companies retained operations through a work-from-home set up for employees, a significant amount of working hours were lost globally as a result of these closures.

Note: The policy categories shown may not apply at all sub-national levels. A country is coded as 'required closures' if at least some sub-national regions have required closures.



Quarterly Distribution









Asia-Pacific

7.9%

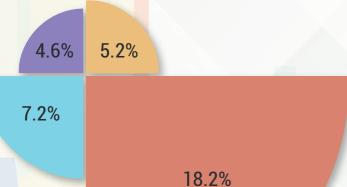
Optimistic

Baseline

Pessimistic

Working Hours Lost

In 2020, **8.8%** of global working hours were lost compared to Q4 of 2019



Working hours lost peaked in Q2 of 2020 when most countries started to enforce tighter containment measures





COVID-19 Pandemic



Latin America and the **Caribbean**

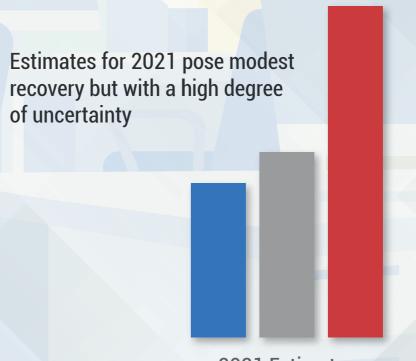
in terms of working hours lost

were among the hardly hit regions

Americas

13.7%

2009 Financial Crisis



Europe and Central Asia

9.2%

7.7%

Arab States

9%





Public Events Cancellation

24

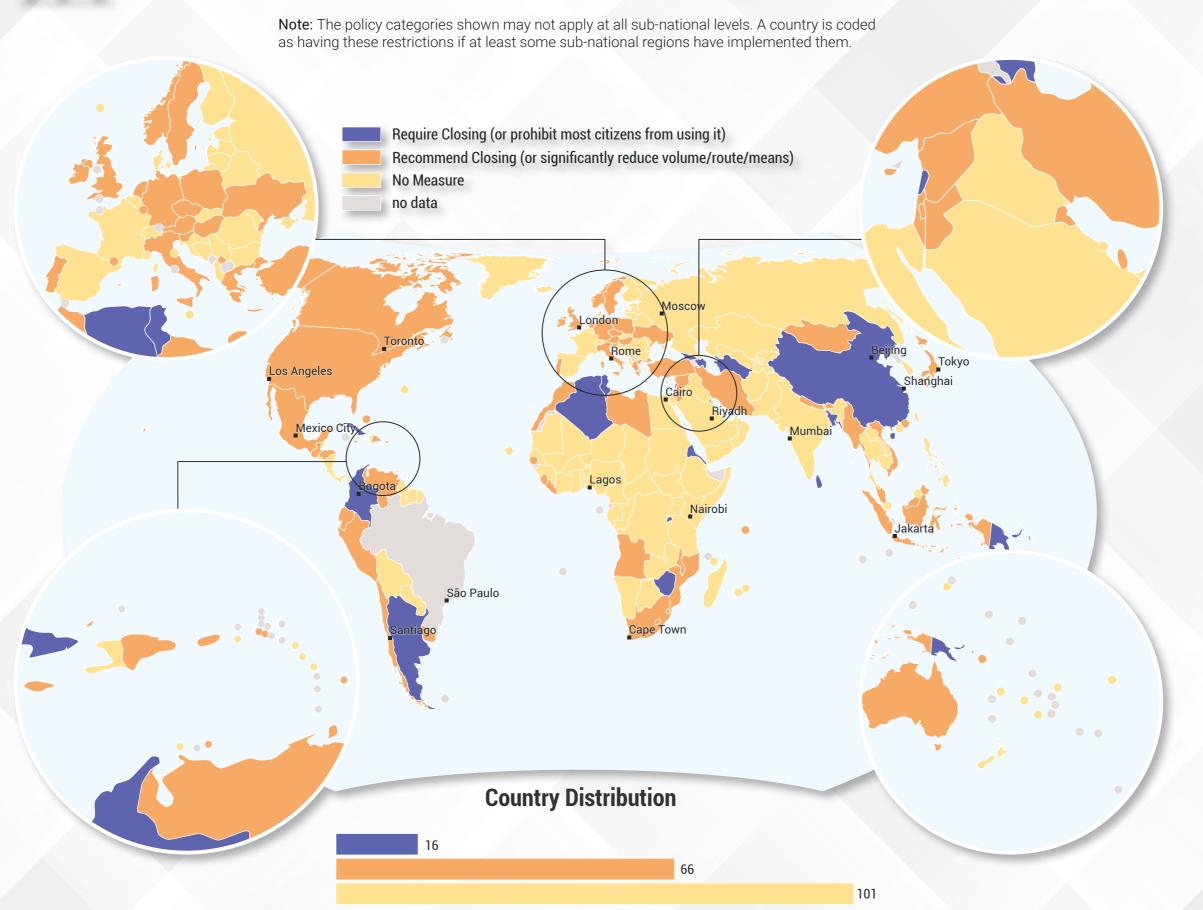
As gatherings are being restricted, public events such as sporting events, music concerts, and award ceremonies are either cancelled or postponed. Some of the significant events affected include the 2020 Summer Olympics, the 93rd Academy Awards, and UEFA Euro 2020.

Quarterly Distribution Note: The policy categories shown may not apply at all sub-national levels. A country is coded as having these restrictions if at least some sub-national regions have implemented them. End of Q1 2020 Require Cancelling **Recommend Cancelling** No Measure no data End of Q2 2020 Los Angeles Mexico City End of Q3 2020 São Paulo End of Q4 2020 **Country Distribution** 44

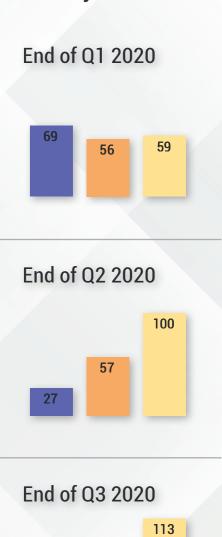


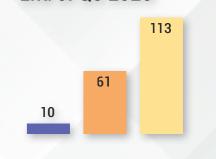
Public Transportation Closure

The use of public transportation has also been restricted especially during the first phase of the pandemic. However, as 'social distancing' protocols are implemented, most countries also started to resume the operation of the public transport system.



Quarterly Distribution





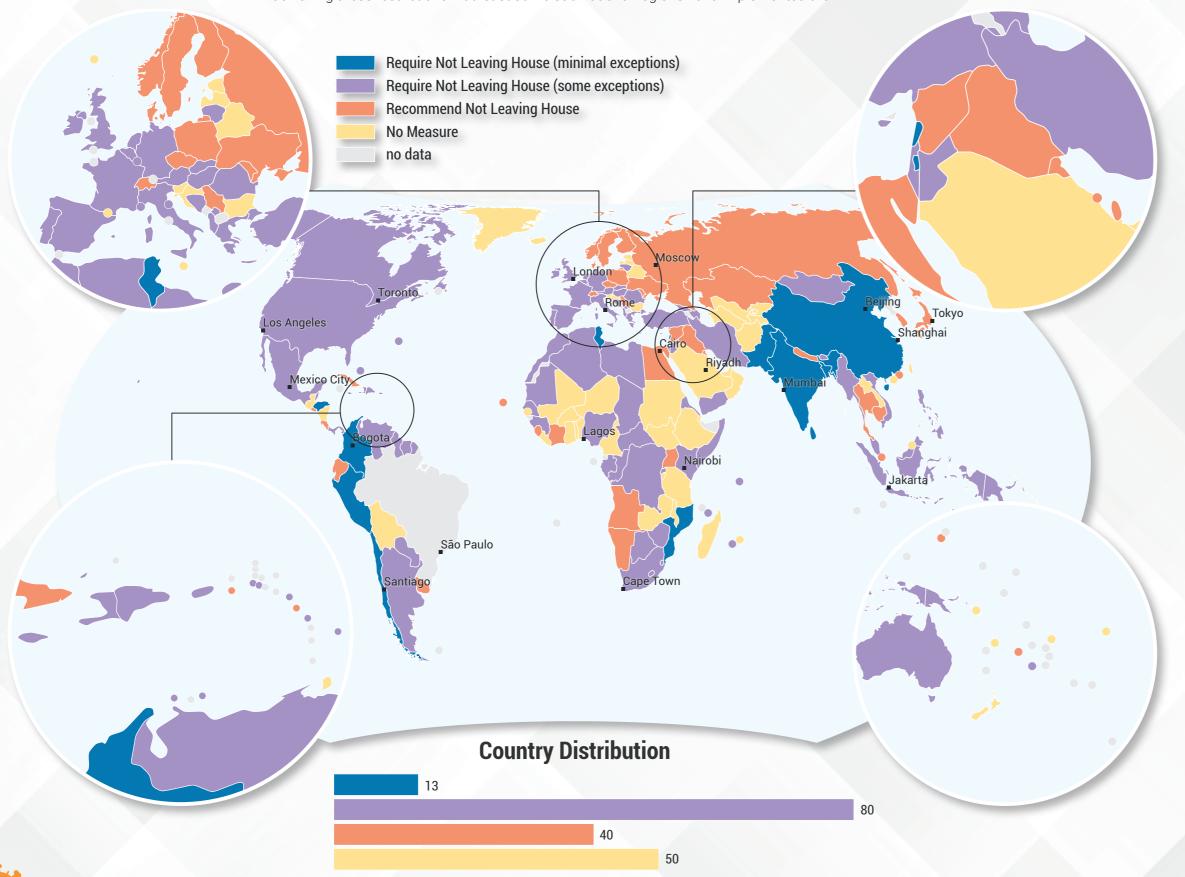




Stay-at-Home Orders

Aside from gathering restrictions, most countries also implement curfews to citizens or even total confinement (e.g. can only go out on a specific day of the week). Curfews are recorded as 'Require Not Leaving House (some exceptions)'.

Note: The policy categories shown may not apply at all sub-national levels. A country is coded as having these restrictions if at least some sub-national regions have implemented them.



Quarterly Distribution



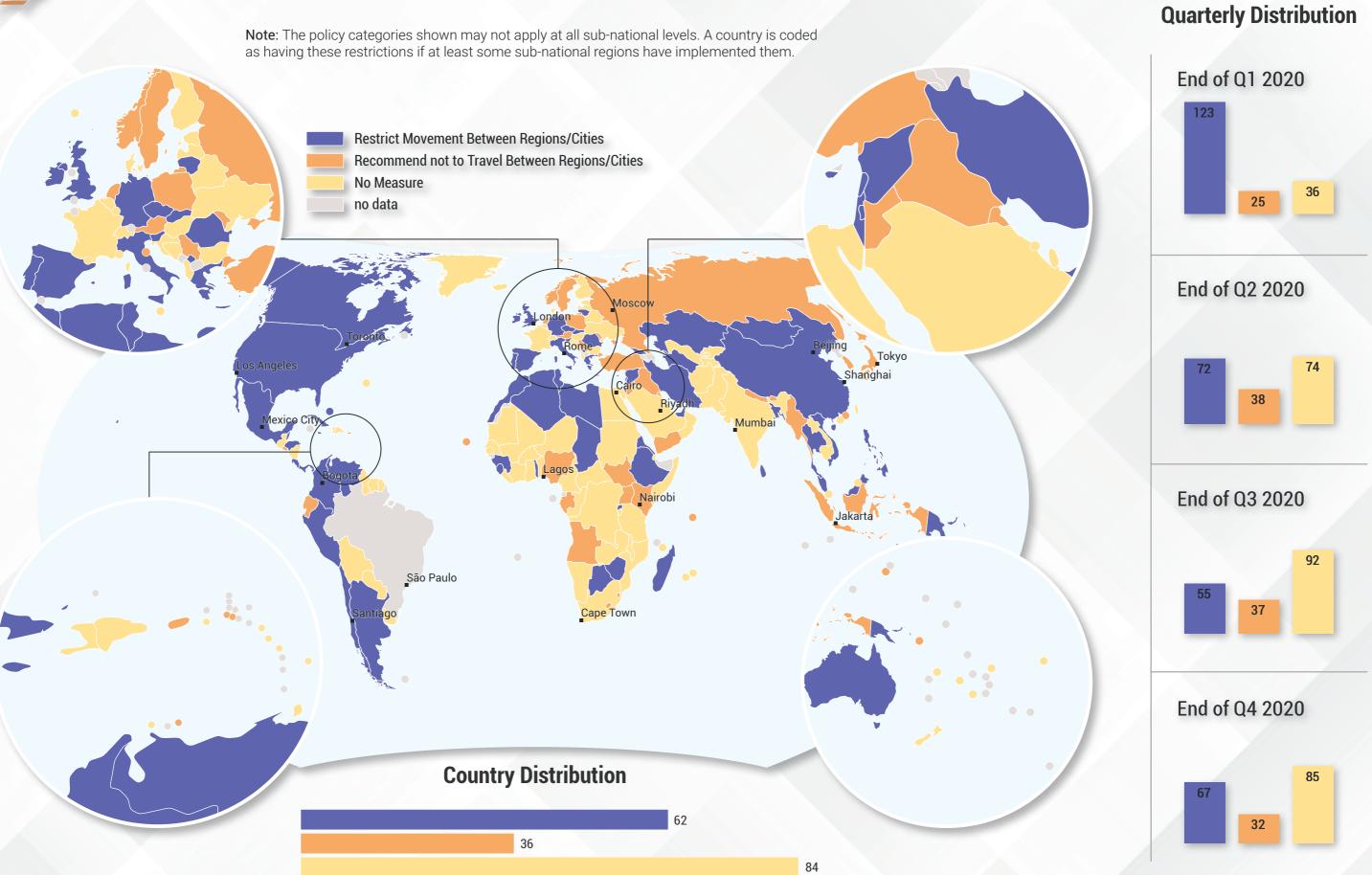






Internal Movement Restrictions

Internal movement restrictions refer to protocols that limit people from travelling to other cities or regions.



Quarterly Distribution



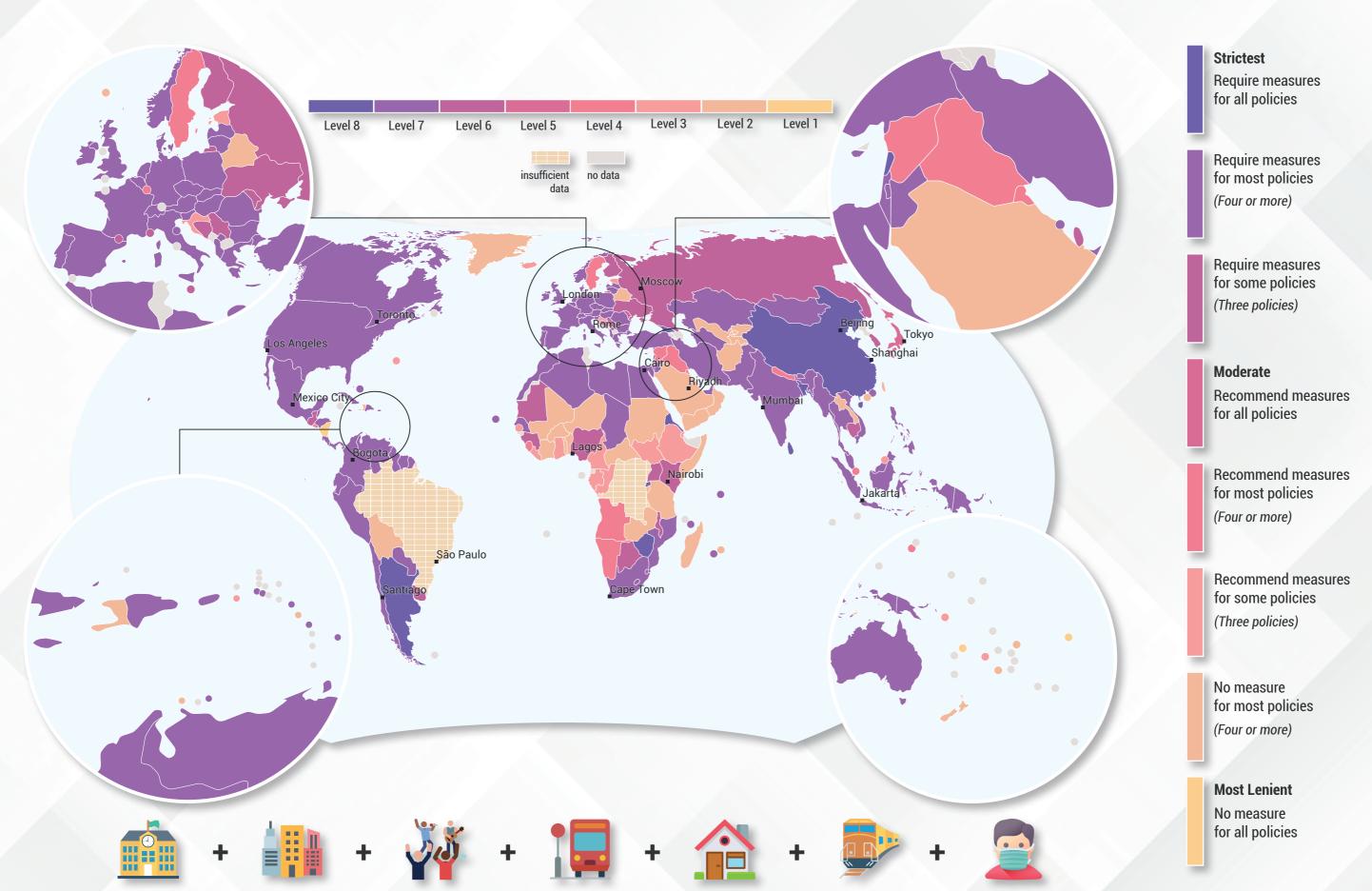
Facial Covering Policy

Wearing face masks became the 'new normal' especially when going outside. While reusable face masks made of fabric are permitted in the beginning, some countries requires citizens to use surgical masks or N95 respirators at the very least due to surge in cases.

End of Q1 2020 Required Outside-the-home at All Times Required in All Public Spaces Required in Some Public Spaces Recommended No Policy no data End of Q2 2020 End of Q3 2020 São Paulo End of Q4 2020 **Country Distribution**

Containment Policies Strictness Level

This synthesis map shows the strictness level in each country using seven response indicators including; school closure, workplace closure, public event cancellation, public transport closure, stay-at-home orders, internal movement restrictions, facial covering policy. Insufficient data means that a country has missing data in at least one of these policies.



Distribution of Countries

According to the Level of Policy Implementations



School Closure Policy

150

100

50

Workplace Closure Policy



Facial Covering Policy



Internal Movement Restrictions



Public Events Cancellation



Required measures in place



Recommend measures only



No measure



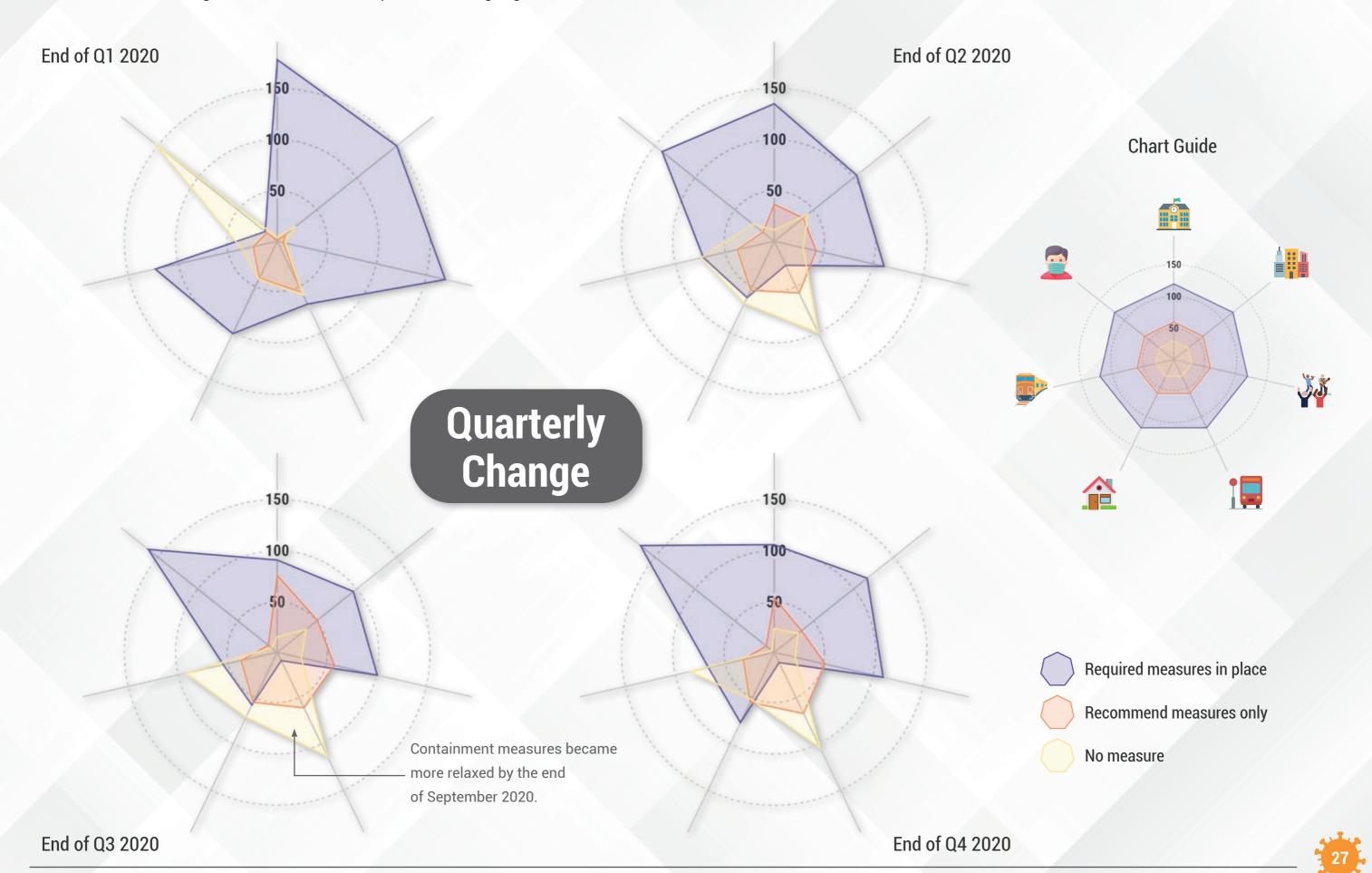
Stay-at-Home Orders



Public Transportation Closure

Distribution of Countries

Stricter containment measures were implemented by most countries during the first quarter of 2020 right after when WHO declared COVID-19 a pandemic. For most countries, wearing a face mask became a requirement when going outside until now.





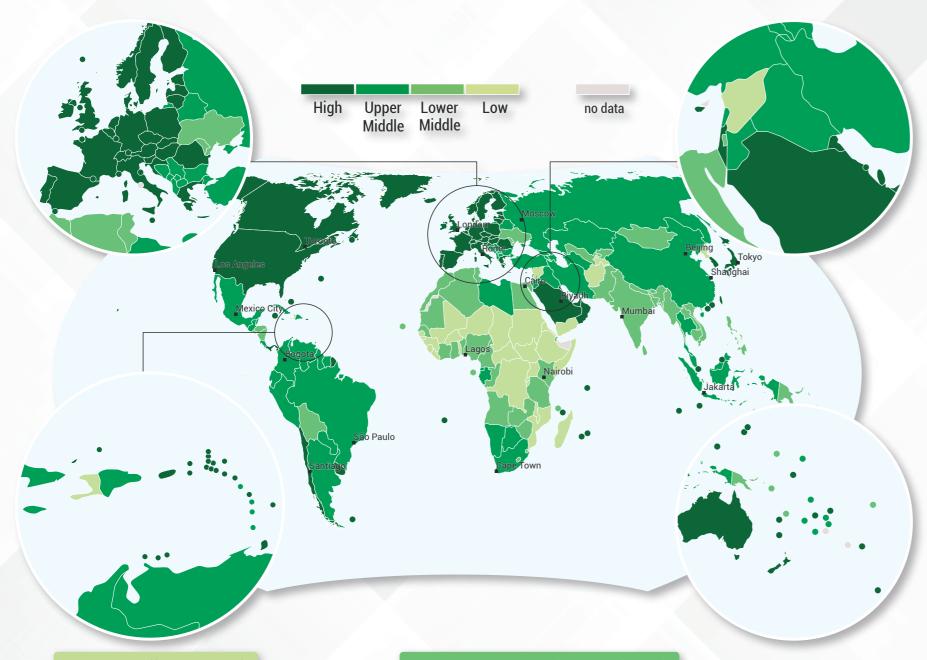
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Income Classification

The World Bank categorizes its member countries/territories into four income groups (high, upper-middle, lower-middle, low) based on their Gross National Income (GNI) per capita. Below is the classification for the fiscal year 2021 that was also used in this atlas.



Low-Income (\$1,035 or less)

Afghanistan	Guinea-Bissau	Sierra Leon
Burkina Faso	Haiti	Somalia
Burundi	South Korea	South Suda
Central African Republic	Liberia	Sudan
Chad	Madagascar	Syria
DR Congo	Malawi	Tajikistan
Eritrea	Mali	Togo
Ethiopia	Mozambique	Uganda
Gambia	Niger	Yemen
Guinea	Rwanda	

Lower-Middle Income (\$1,036 to \$4,045)

Algeria	Congo, Rep.	Kenya	Nepal	Tanzania
Angola	Côte d'Ivoire	Kiribati	Nicaragua	Timor-Leste
Bangladesh	Djibouti	Kyrgyzstan	Nigeria	Tunisia
Benin	Egypt	Lao PDR	Pakistan	Ukraine
Bhutan	El Salvador	Lesotho	Papua New Guinea	Uzbekistan
Bolivia	Eswatini	Mauritania	Philippines	Vanuatu
Cabo Verde	FS Micronesia	Moldova	São Tomé and Principe	Vietnam
Cambodia	Ghana	Mongolia	Senegal	West Bank and Gaz
Cameroon	Honduras	Morocco	Solomon Islands	Zambia
Comoros	India	Myanmar	Sri Lanka	Zimbabwe

High-Income (\$12,536 or more)

Andorra	Cyprus	Ireland	New Caledonia	Slovakia
Antigua and Barbuda	Czech Republic	Isle of Man	New Zealand	Slovenia
Aruba	Denmark	Israel	N. Mariana Is.	South Korea
Australia	Estonia	Italy	Norway	Spain
Austria	Faroe Is.	Japan	Oman	St. Kitts and Nevis
Bahamas	Finland	Jersey	Palau	St. Martin
Bahrain	France	Kuwait	Panama	Sweden
Barbados	French Polynesia	Latvia	Poland	Switzerland
Belgium	Germany	Liechtenstein	Portugal	Taiwan
Bermuda	Gibraltar	Lithuania	Puerto Rico	Trinidad and Tobago
British Virgin Is.	Greece	Luxembourg	Qatar	Turks and Caicos Is
Brunei Darussalam	Greenland	Macao SAR	Romania	United Arab Emirates
Canada	Guam	Malta	San Marino	United Kingdom
Cayman Is.	Guernsey	Mauritius	Saudi Arabia	United States
Chile	Hong Kong SAR	Monaco	Seychelles	Uruguay
Croatia	Hungary	Nauru	Singapore	Virgin Is. (U.S.)
Curação	Iceland	Netherlands	Sint Maarten	

Upper-Middle Income (\$4,046 to \$12,535)

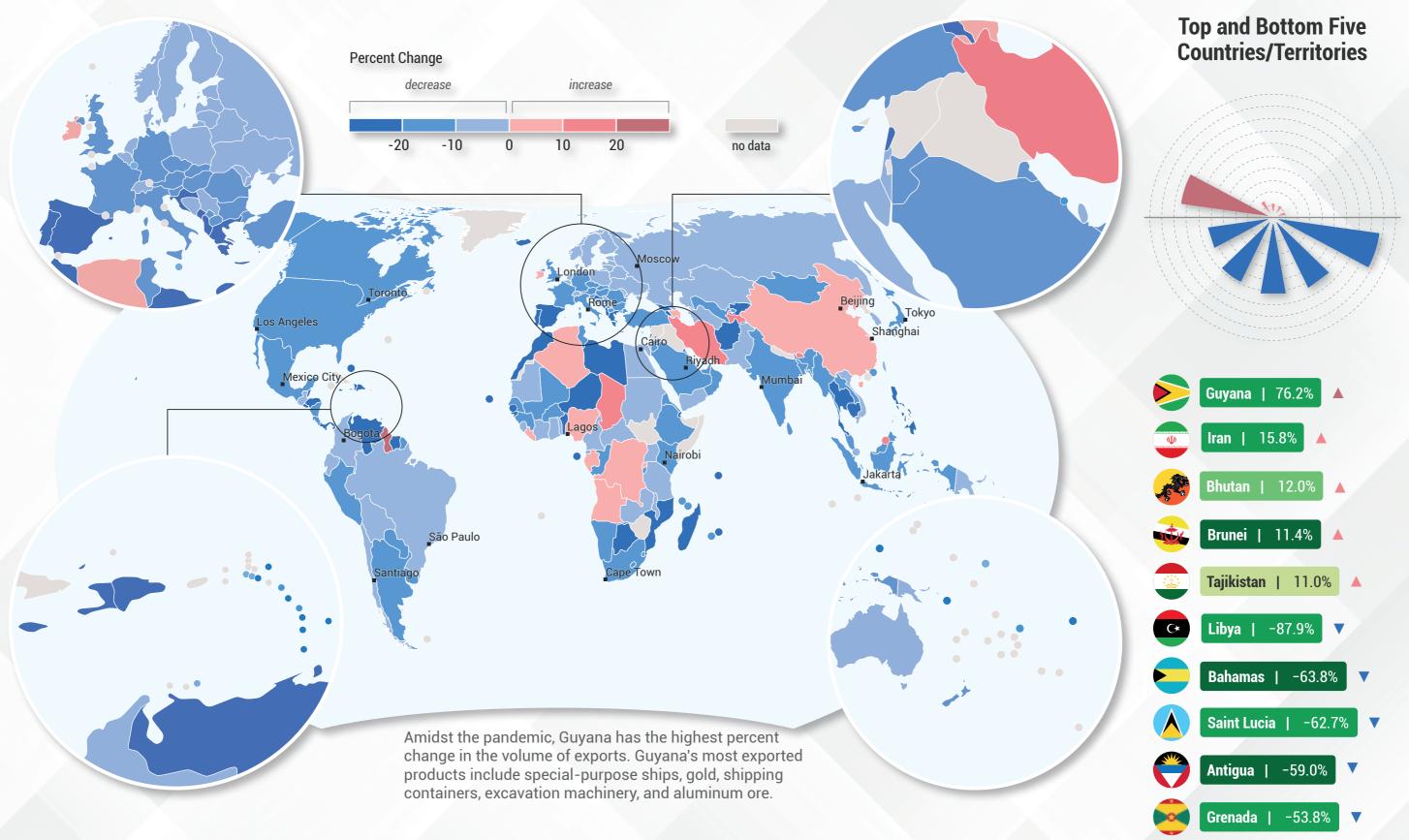
Albania	Colombia	Guyana	Marshall Is.	St. Vincent and the Grenadines
American Samoa	Costa Rica	Indonesia	Mexico	Suriname
Argentina	Cuba	Iran	Montenegro	Thailand
Armenia	Dominica	Iraq	Namibia	Tonga
Azerbaijan	Dominican Republic	Jamaica	North Macedonia	Turkey
Belarus	Equatorial Guinea	Jordan	Paraguay	Turkmenistan
Belize	Ecuador	Kazakhstan	Peru	Tuvalu
Bosnia and Herzegovina	Fiji	Kosovo	Russian Federation	Venezuela
Botswana	Gabon	Lebanon	Samoa	
Brazil	Georgia	Libya	Serbia	
Bulgaria	Grenada	Malaysia	South Africa	
China	Guatemala	Maldives	St. Lucia	

Note: **BOLD** indicates change in classification.



Change in the Volume of Exports

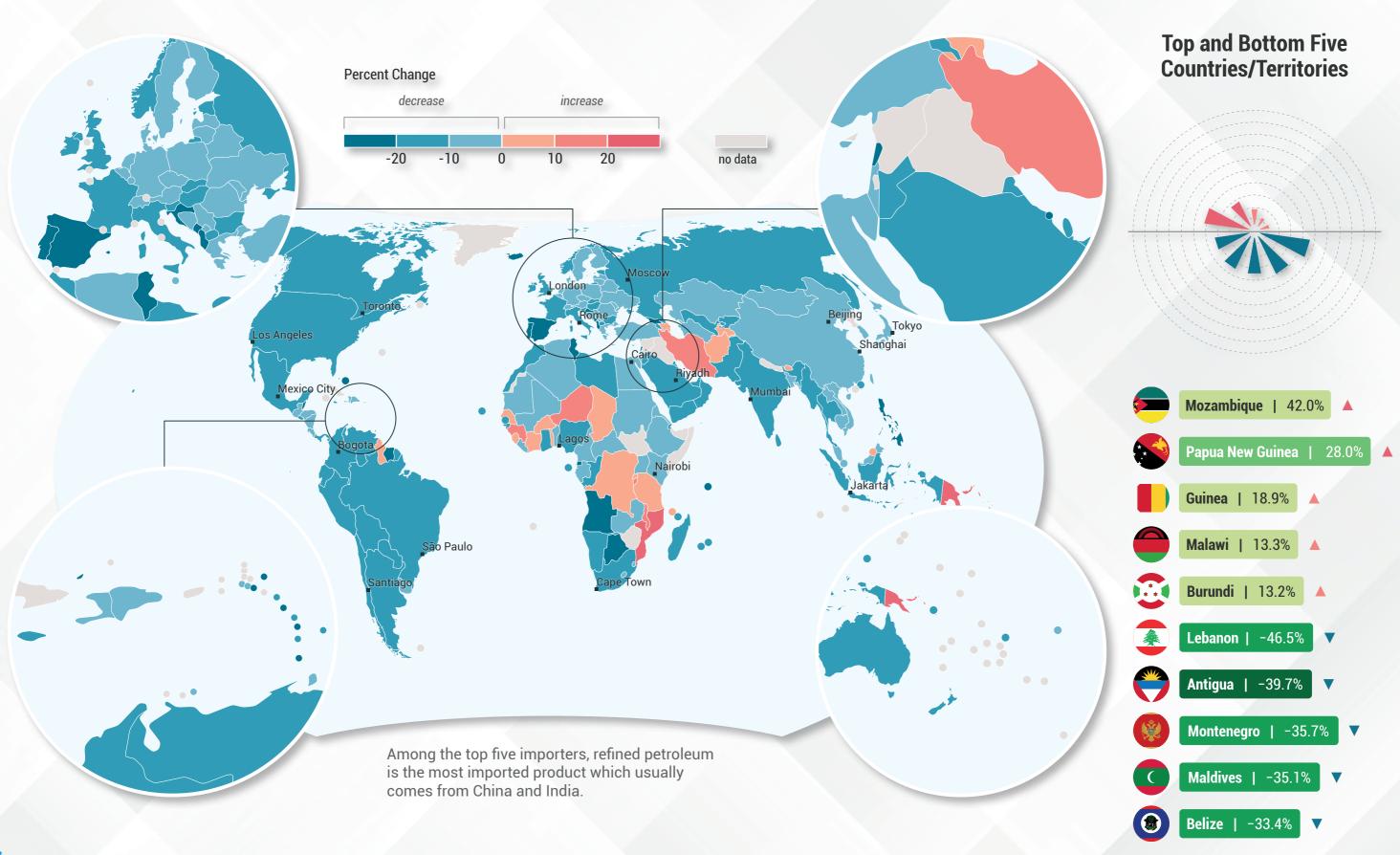
This refers to the aggregate change in total exports wherein the goods and services, and their prices are held constant, so the changes are due to differences in quantities only. The Caribbean region is one of the severely hit regions as tourism activities were halted because of imposed travel restrictions and containment measures.





Change in the Volume of Imports

This refers to the aggregate change in total imports wherein the goods and services, and their prices are held constant, so the changes are due to differences in quantities only. Low-income countries from the African region remain as top importers during the pandemic.

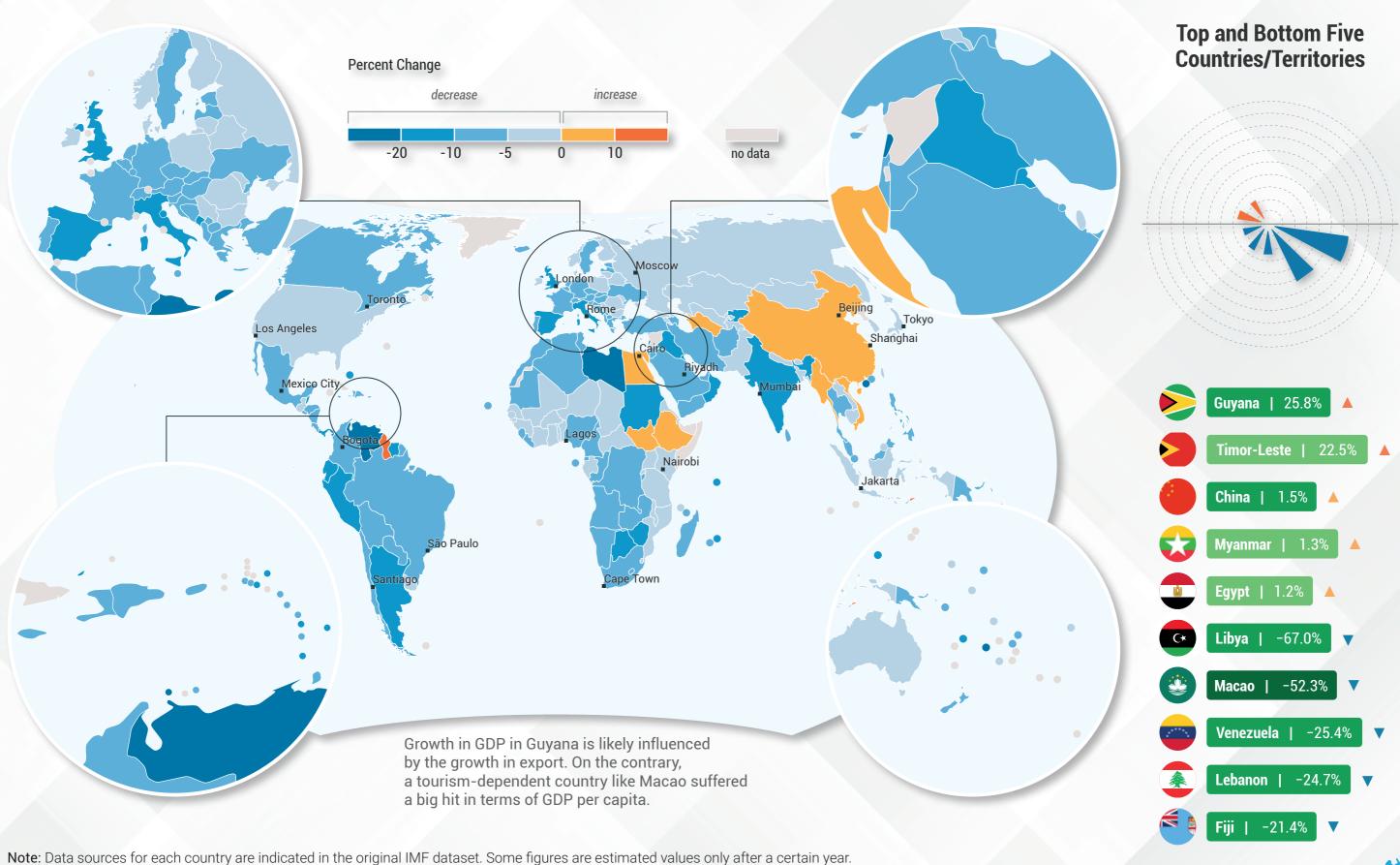




GDP per capita is expressed in constant international dollars (2017) per person.

Change in Gross Domestic Product (GDP) per Capita

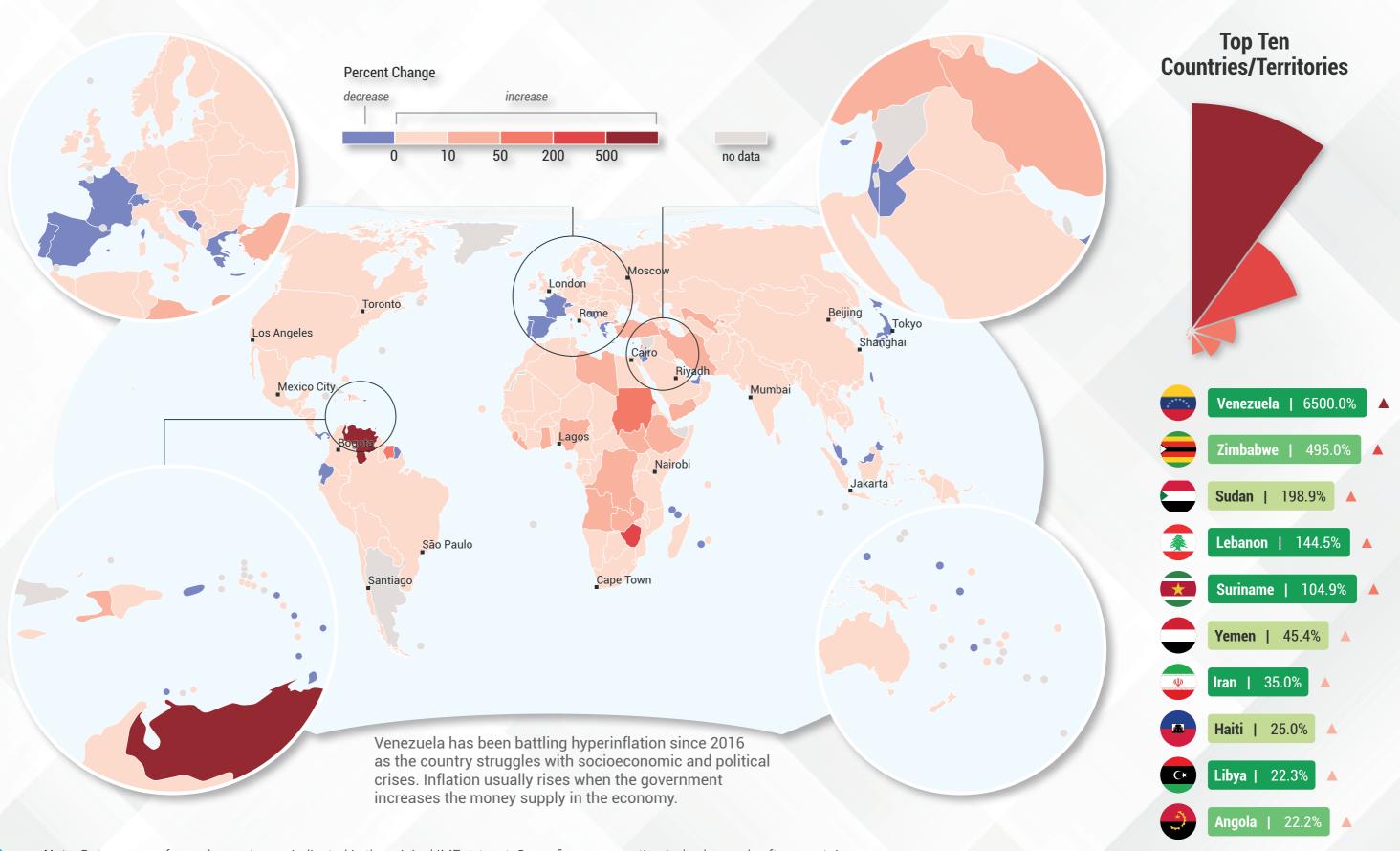
Gross domestic product (GDP) per capita is a monetary measure of the market value of all the final goods and services produced in a specific period divided by the population. Change is expressed as percent change relative to the previous year (2019).





Change in Inflation Rate

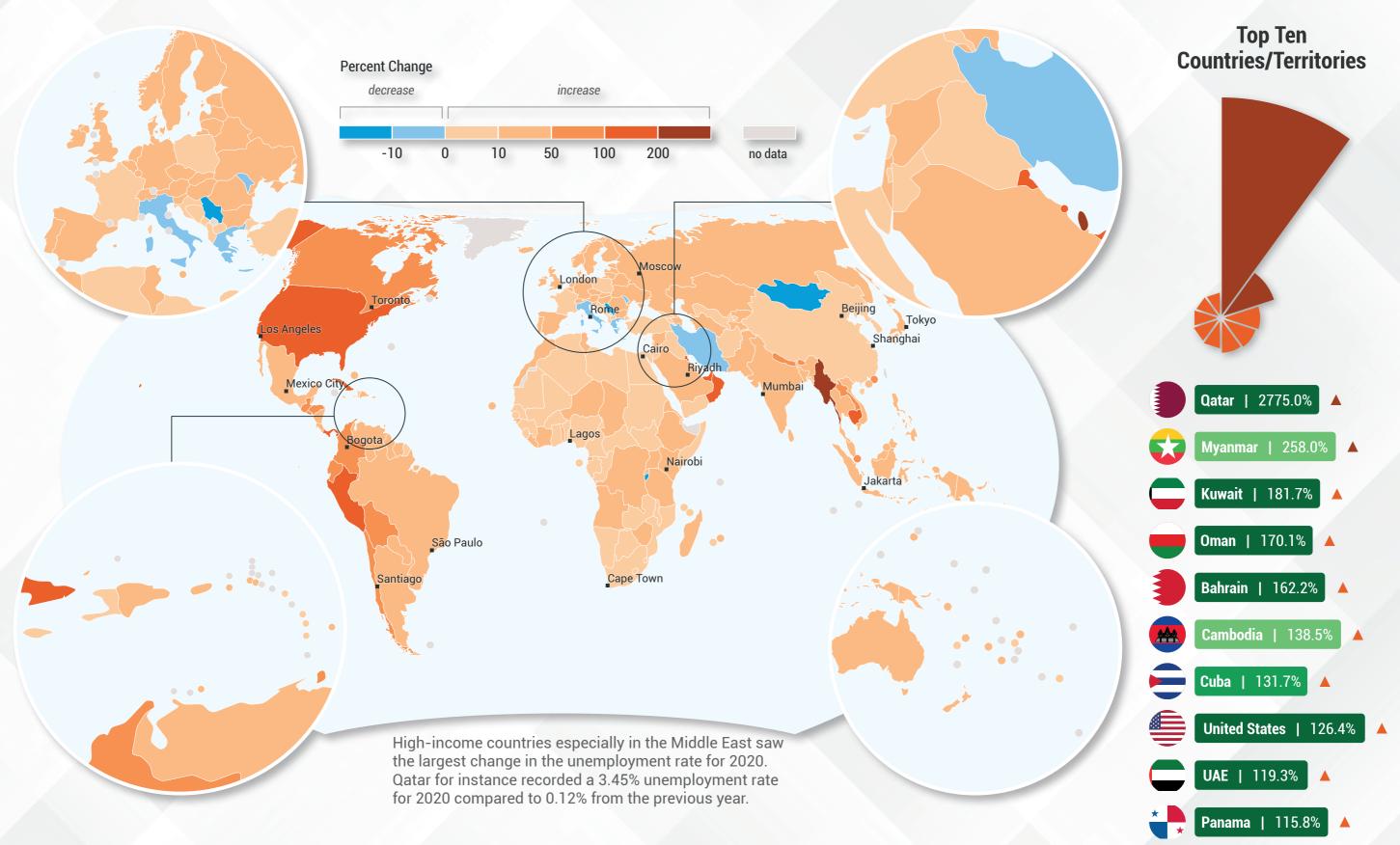
Inflation refers to the rate at which the value of a currency is declining resulting to an increase in the general level of prices for goods and services. The increase in general cost of living for the common public ultimately leads to a deceleration in economic growth.



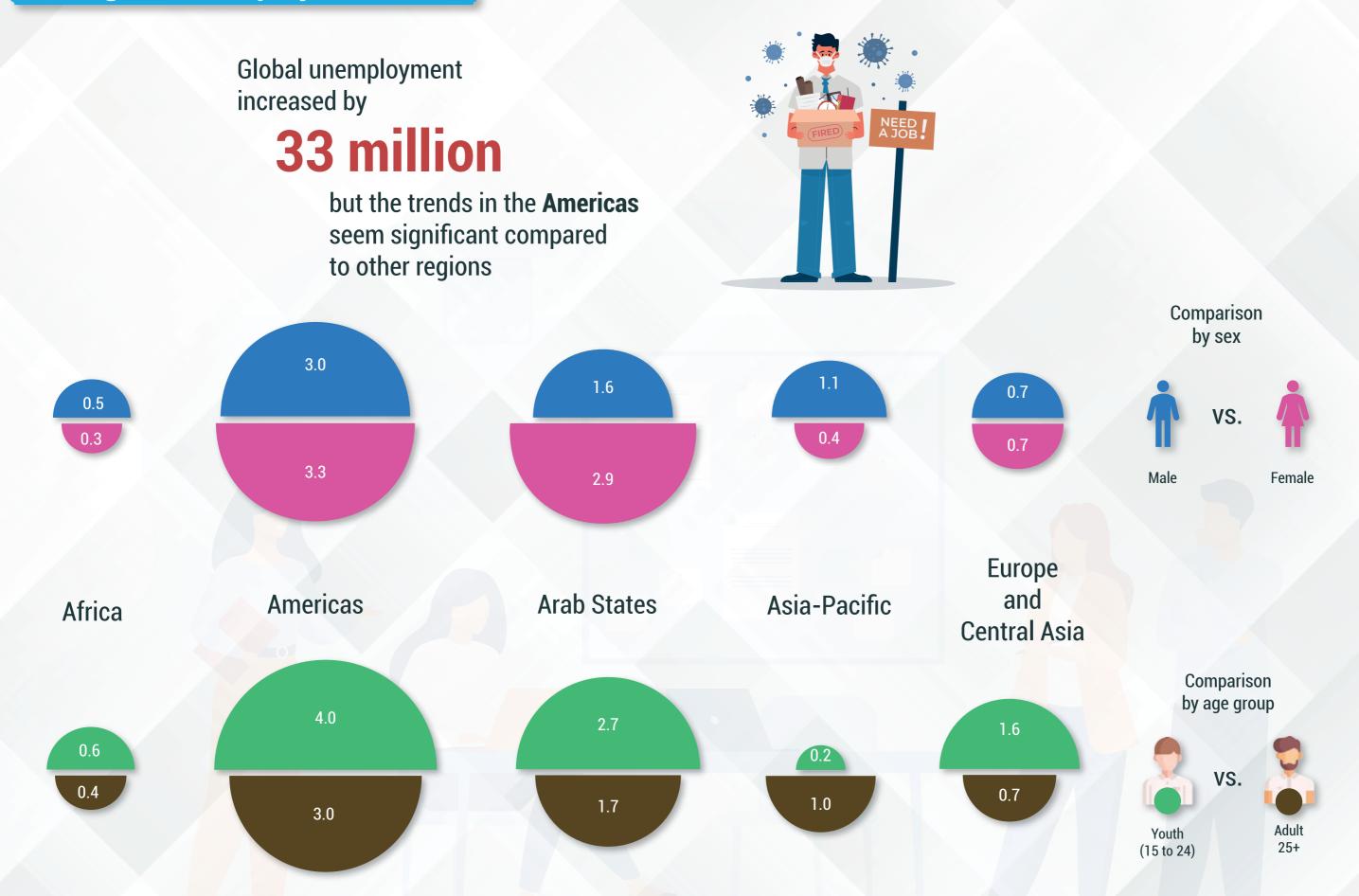


Change in Unemployment Rate

Workplace closures have led to a significant increase in the unemployment rate all over the world. Based on International Labor Organization (ILO) estimates, the global unemployment rate is at 6.5% for 2020 compared to 5.4% from 2019. Change is expressed as percent change relative to the previous year (2019).

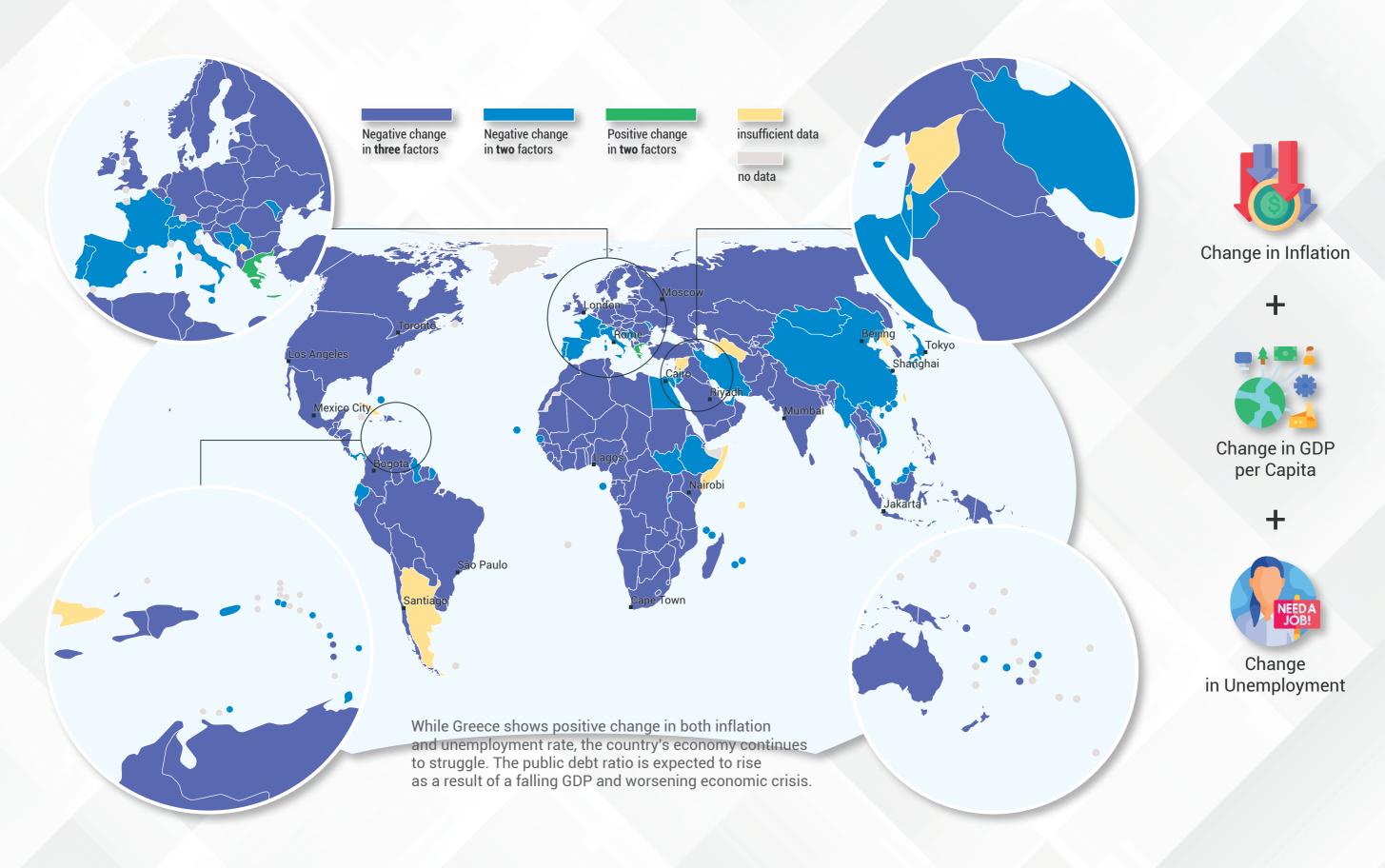


Change in Unemployment Rate



Effects on Major Economic Indicators

This synthesis map shows the general trend of three major economic indicators including; inflation rate, unemployment rate, and GDP per capita. These three are also closely related to each other and are included among the most crucial factors in economic growth. For inflation and unemployment rate, negative change corresponds to an increase in the actual value.

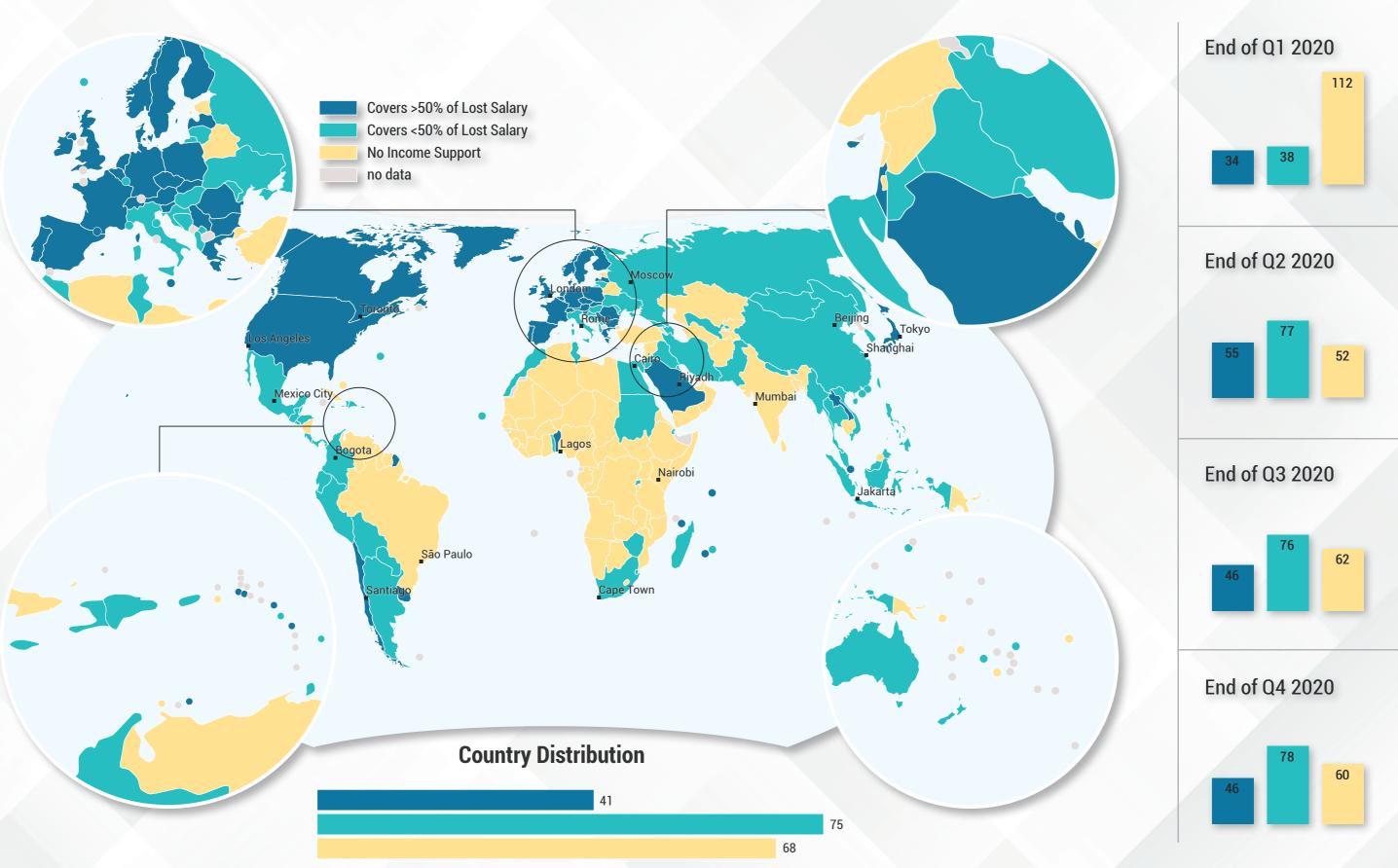




Income Support from Government

As businesses shut down and workers are forced to inactivity, income support from the government is being offered. This map shows if the government is providing direct cash payments, universal basic income, or similar, to people who lose their jobs or cannot work.

Quarterly Distribution





Debt or Contract Relief

Aside from income support, some governments also implement debt or contract relief policy. This shows if the government is freezing financial obligations during the COVID-19 pandemic, such as stopping loan repayments, preventing basic services like water from stopping, or banning eviction.

End of Q1 2020 Broad Debt/Contract Relief Narrow Relief (specific to one kind of contract) No Debt/Contract Relief no data End of Q2 2020 os Angeles End of Q3 2020 São Paulo End of Q4 2020 **Country Distribution** 52

64



Impact on the Aviation Industry

Strict travel restrictions and a decline in the demand among travellers have significantly affected the aviation industry among others. Reduction in passenger numbers means a lot of empty planes flying which resulted in a massive drop in revenues. Most airline companies laid-off workers to avoid significant loss while others even declared bankruptcy.

System-wide global commercial airlines revenue fell by

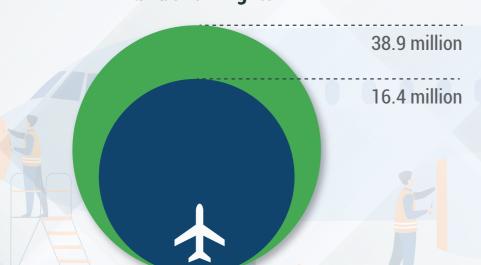
\$510 billion

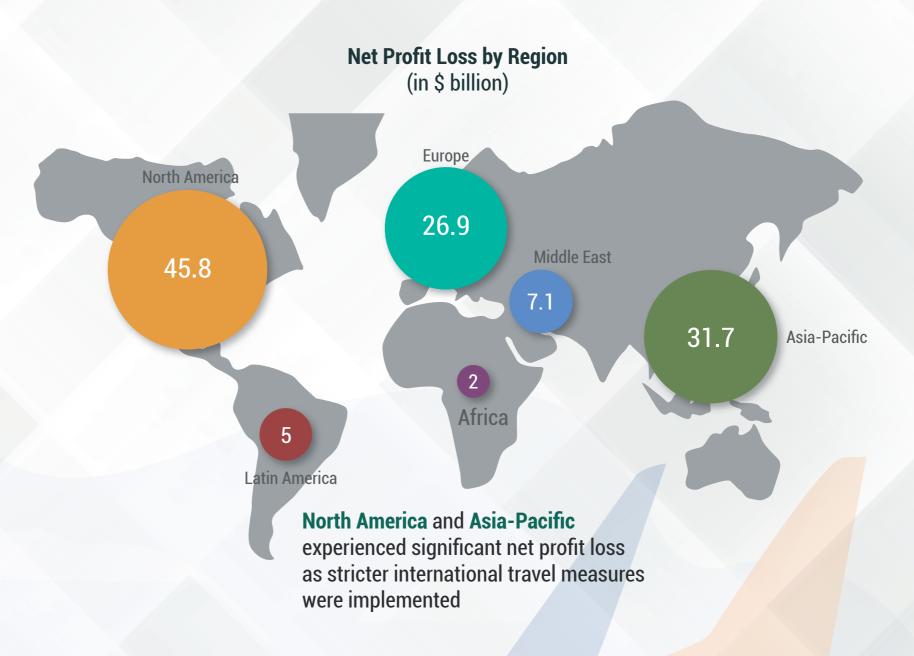


Percent Change in Revenue



Number of Flights





The decline in number of flights also resulted to reduction of CO2 emission by

47%

CO₂ Emission



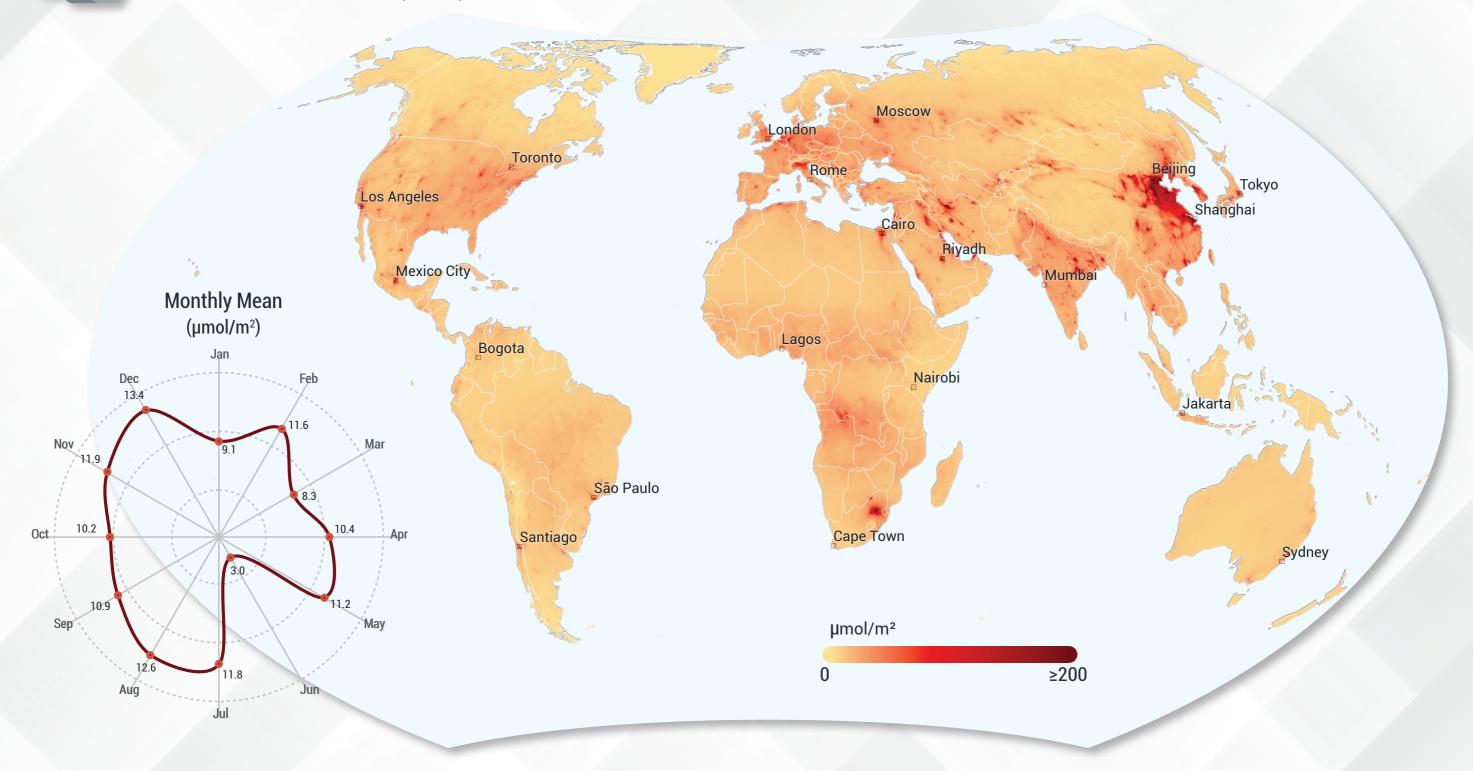
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NO₂

Nitrogen Dioxide Concentration

Global Annual Mean (2020)



Natural sources include:



1,511

Volcanic eruptions Lightnings

Anthropogenic sources include:



Vehicle exhaust fumes



Fossil fuel burning



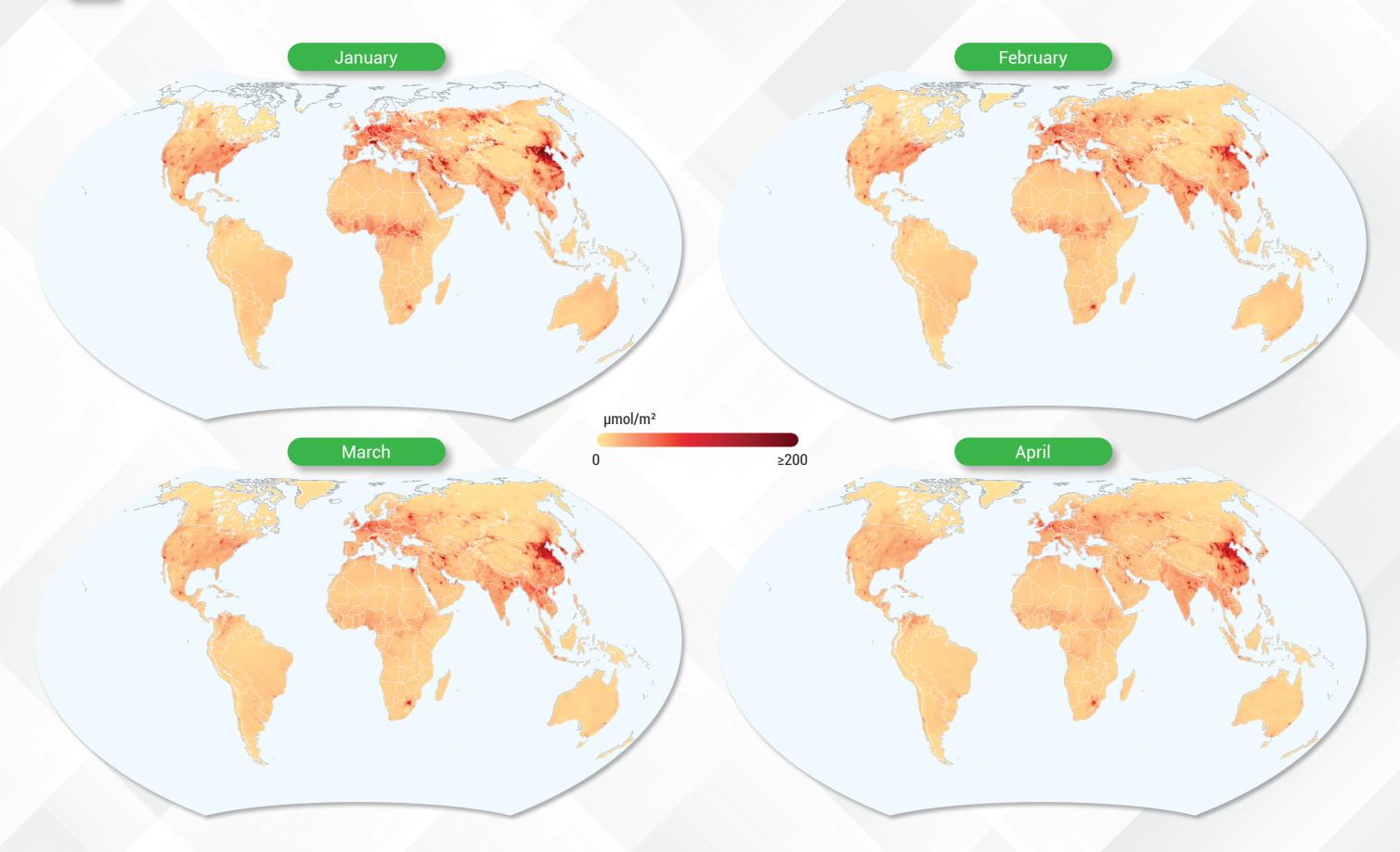
Power plant emissions

Nitrogen Dioxide (NO₂) is one of the widespread air pollutants present in the atmosphere. It gets in the air through burning of fuels and other combustion processes. NO₂ and other nitrogen oxides also contribute to the formation of secondary pollutants such as ozone and particulate matter. NO₂ also plays a huge role in the formation of acid rain.



Nitrogen Dioxide Concentration

Global Monthly Mean (Jan-Apr 2020)



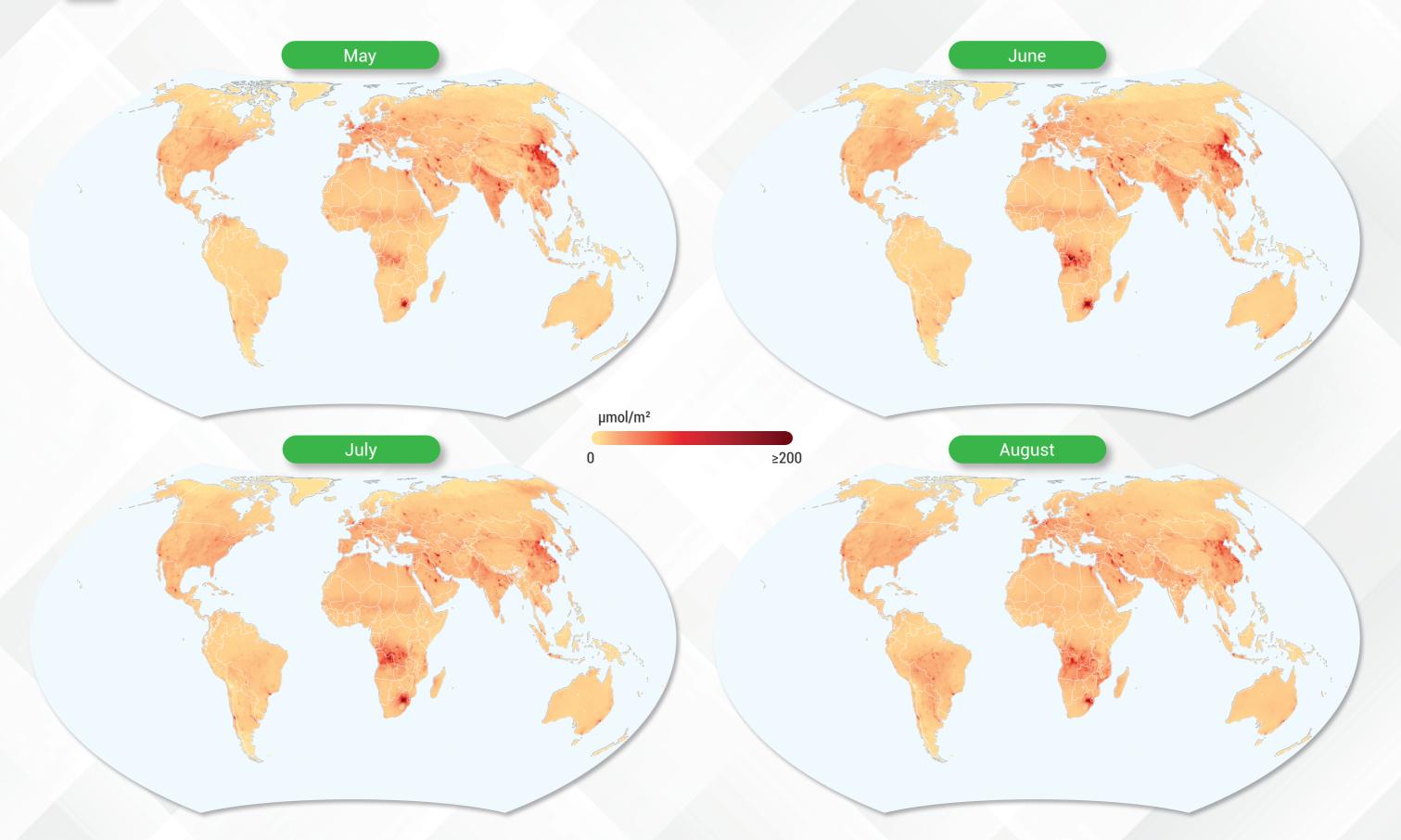


Note: As part of Sentinel-5P's data ingestion procedure to Google Earth Engine, the source data is filtered to remove pixels with QA values less than 75%. Seasonal and inter-annual variations could also affect the monthly distribution of pollutants.



Nitrogen Dioxide Concentration

Global Monthly Mean (May-Aug 2020)

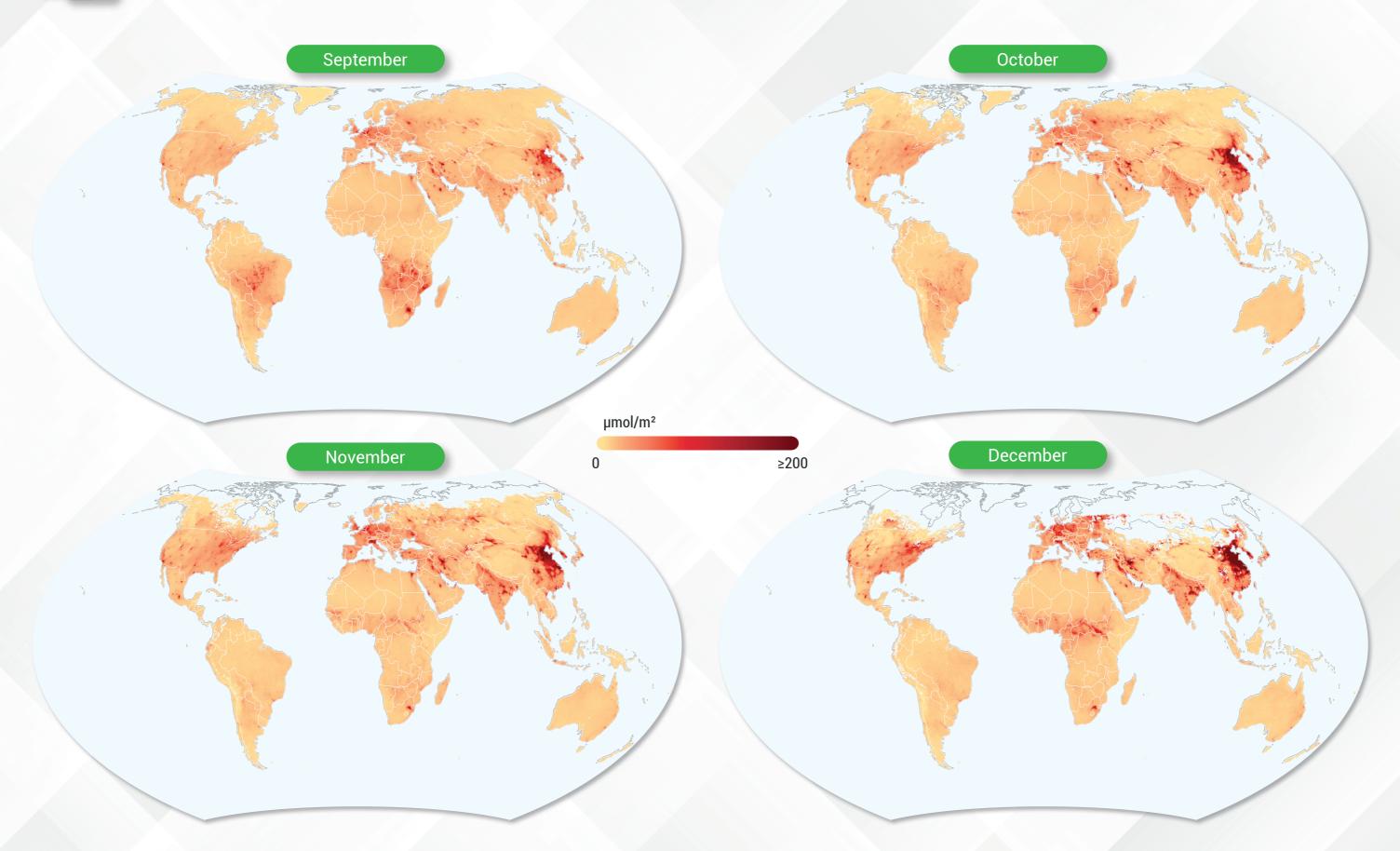


Note: As part of Sentinel-5P's data ingestion procedure to Google Earth Engine, the source data is filtered to remove pixels with QA values less than 75%. Seasonal and inter-annual variations could also affect the monthly distribution of pollutants.



Nitrogen Dioxide Concentration

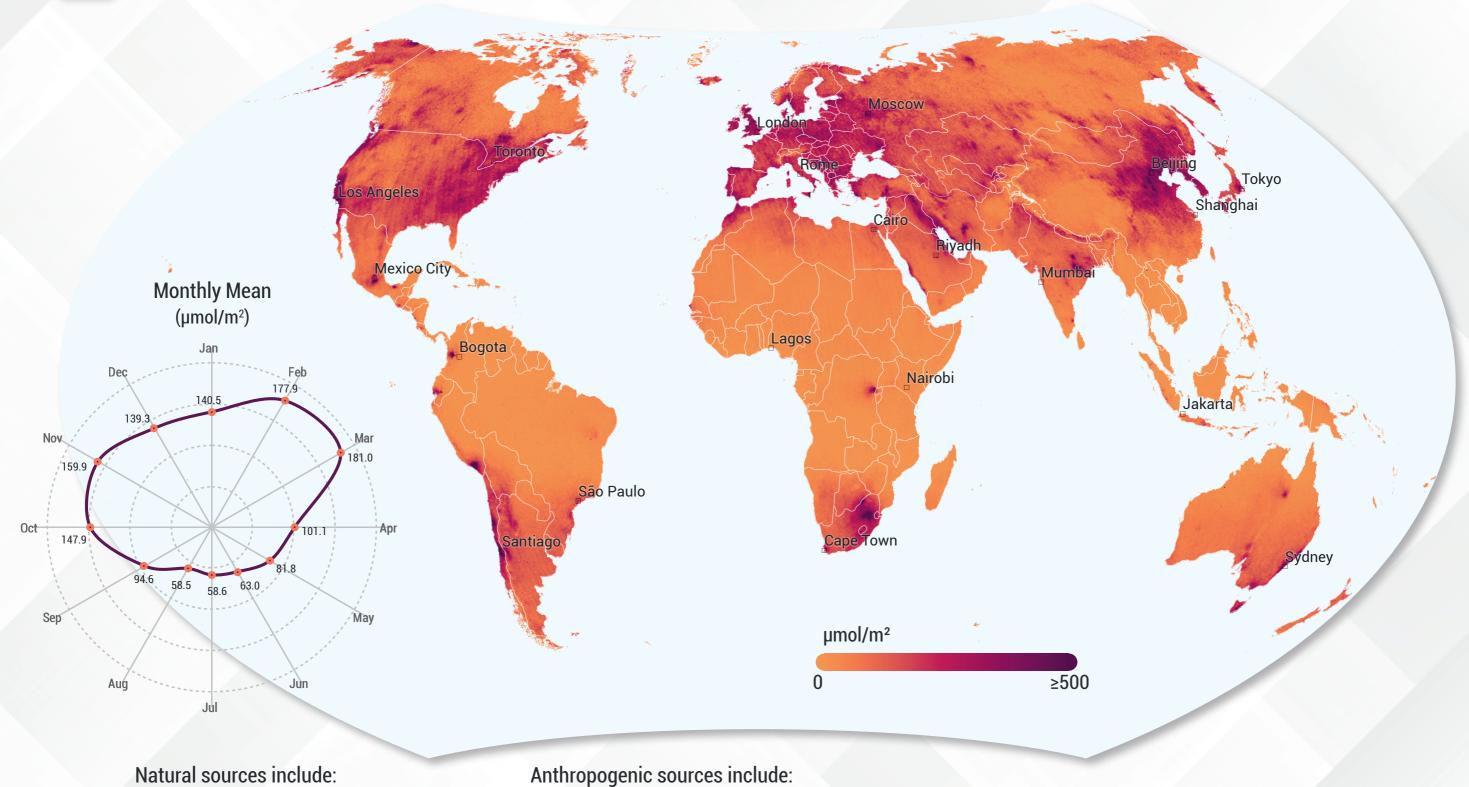
Global Monthly Mean (Sep-Dec 2020)





Sulfur Dioxide Concentration

Global Annual Mean (Jan-Dec 2020)



Natural sources include:



Volcanic eruptions Wildfires

Fossil fuel

burning



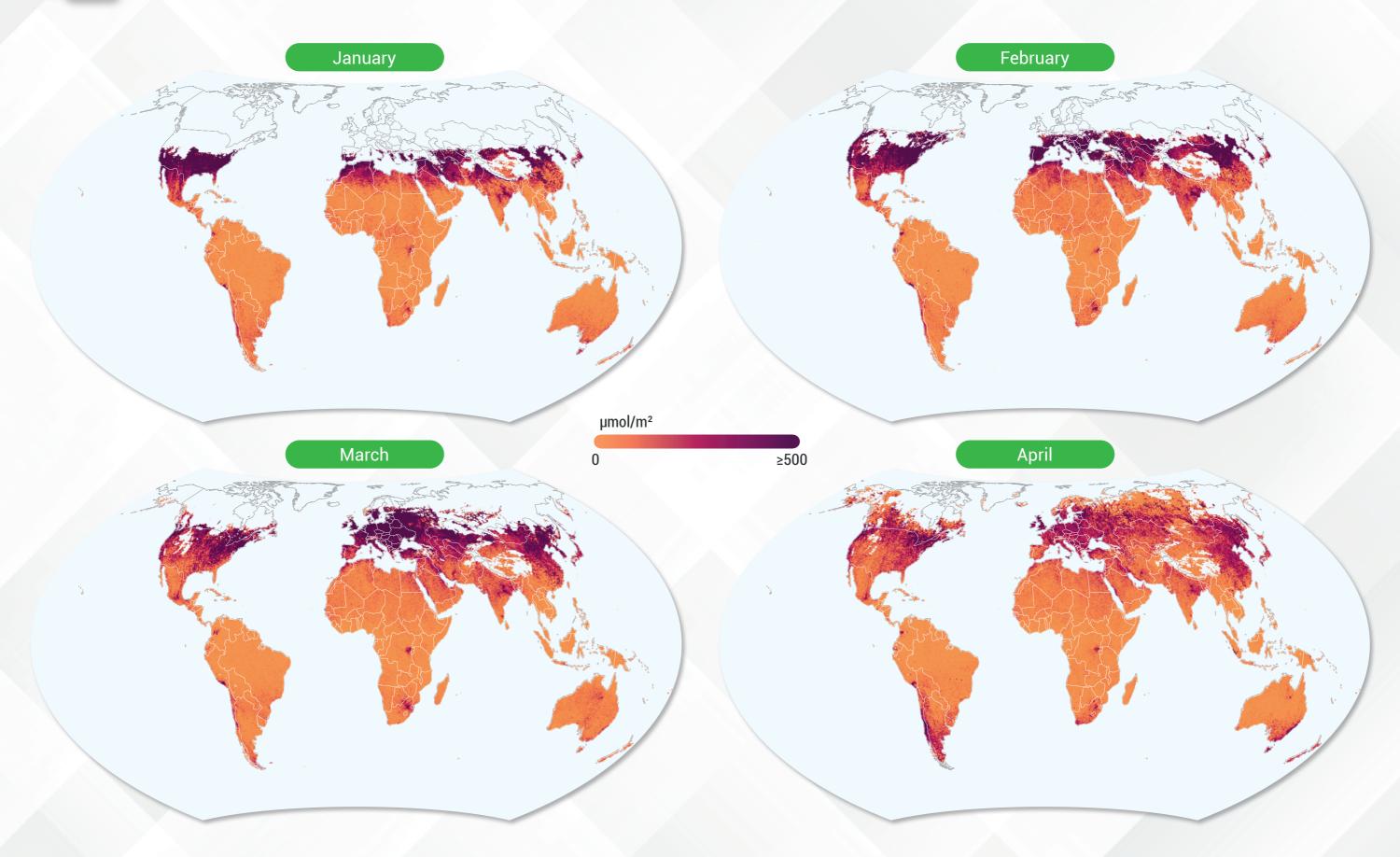
Metal ores smelting

Sulphur dioxide (SO₂) is also another major air pollutant which gets in the air mostly due to anthropogenic activities such as burning of fossil fuels by power plants and industrial facilities. At high concentrations, SO₂ and other sulfur oxides can harm trees and plants by damaging foliage and decreasing growth. SO₂ is also a major contributor to acid rain which can be harmful to sensitive ecosystems.



Sulfur Dioxide Concentration

Global Monthly Mean (2020)

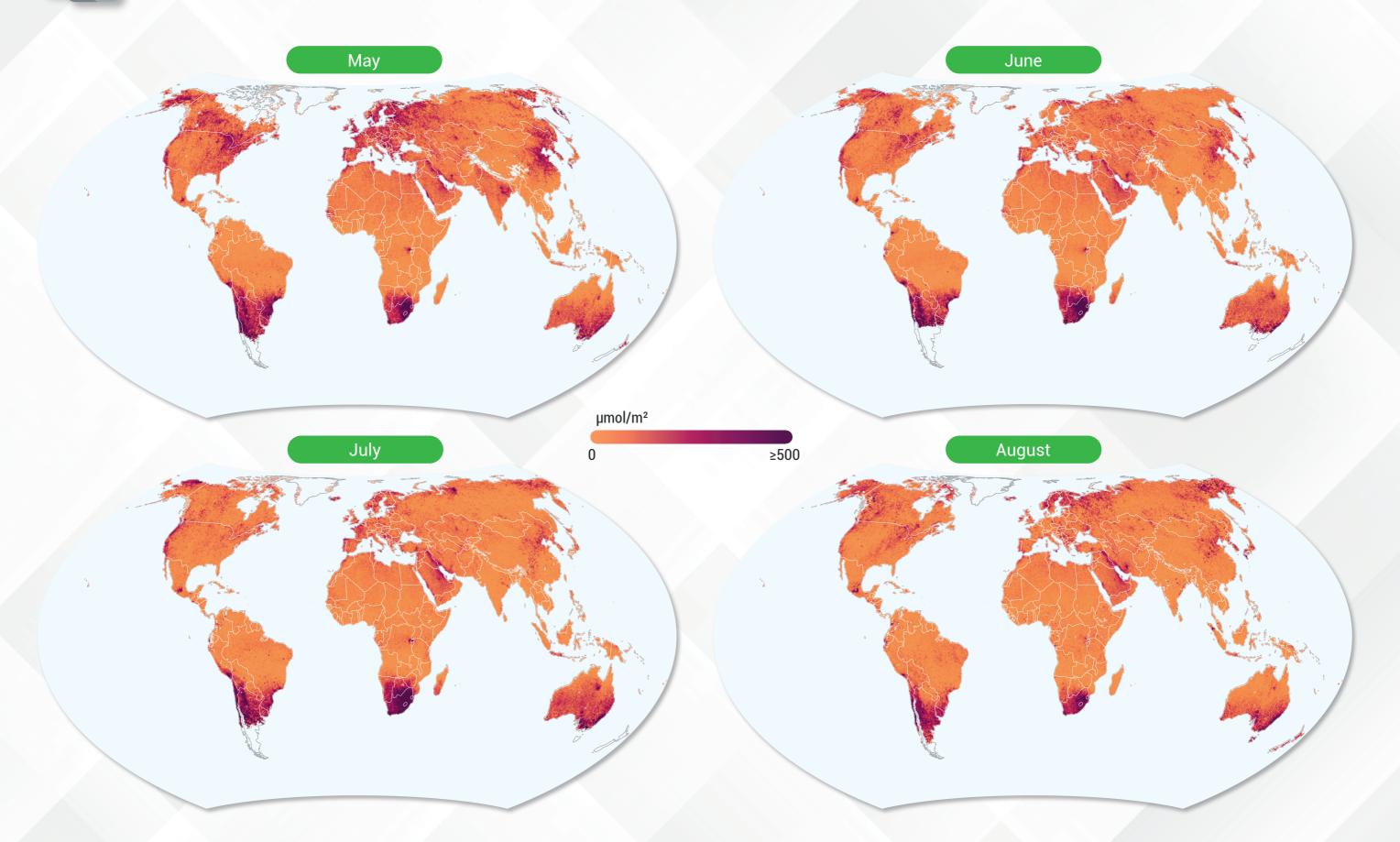




SO₂

Sulfur Dioxide Concentration

Global Monthly Mean (May-Aug 2020)

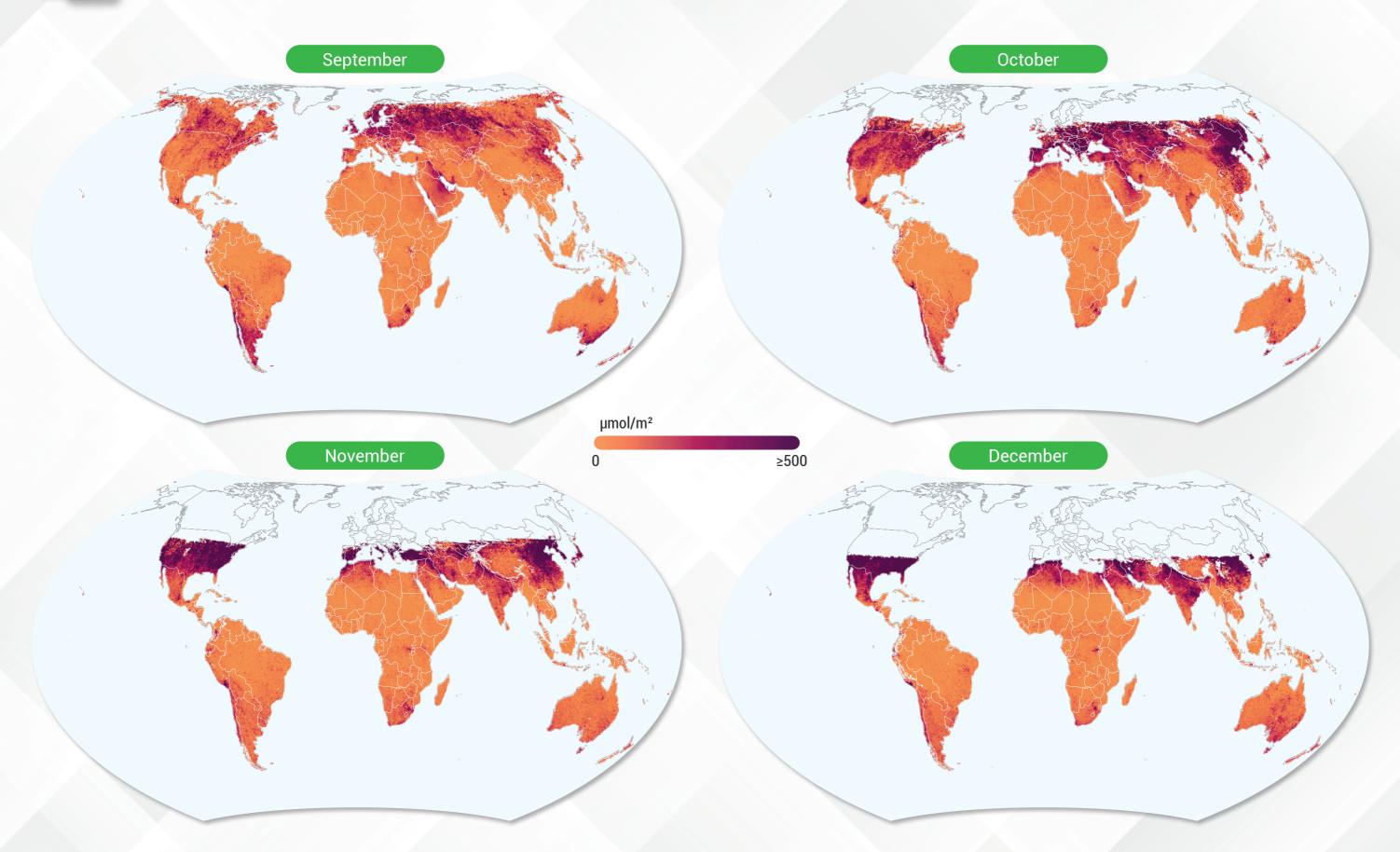


Note: As part of Sentinel-5P's data ingestion procedure to Google Earth Engine, the source data is filtered to remove pixels that do not satisfy the SO₂ QA criteria. Seasonal and inter-annual variations could also affect the monthly distribution of pollutants.



Sulfur Dioxide Concentration

Global Monthly Mean (Sept-Dec 2020)



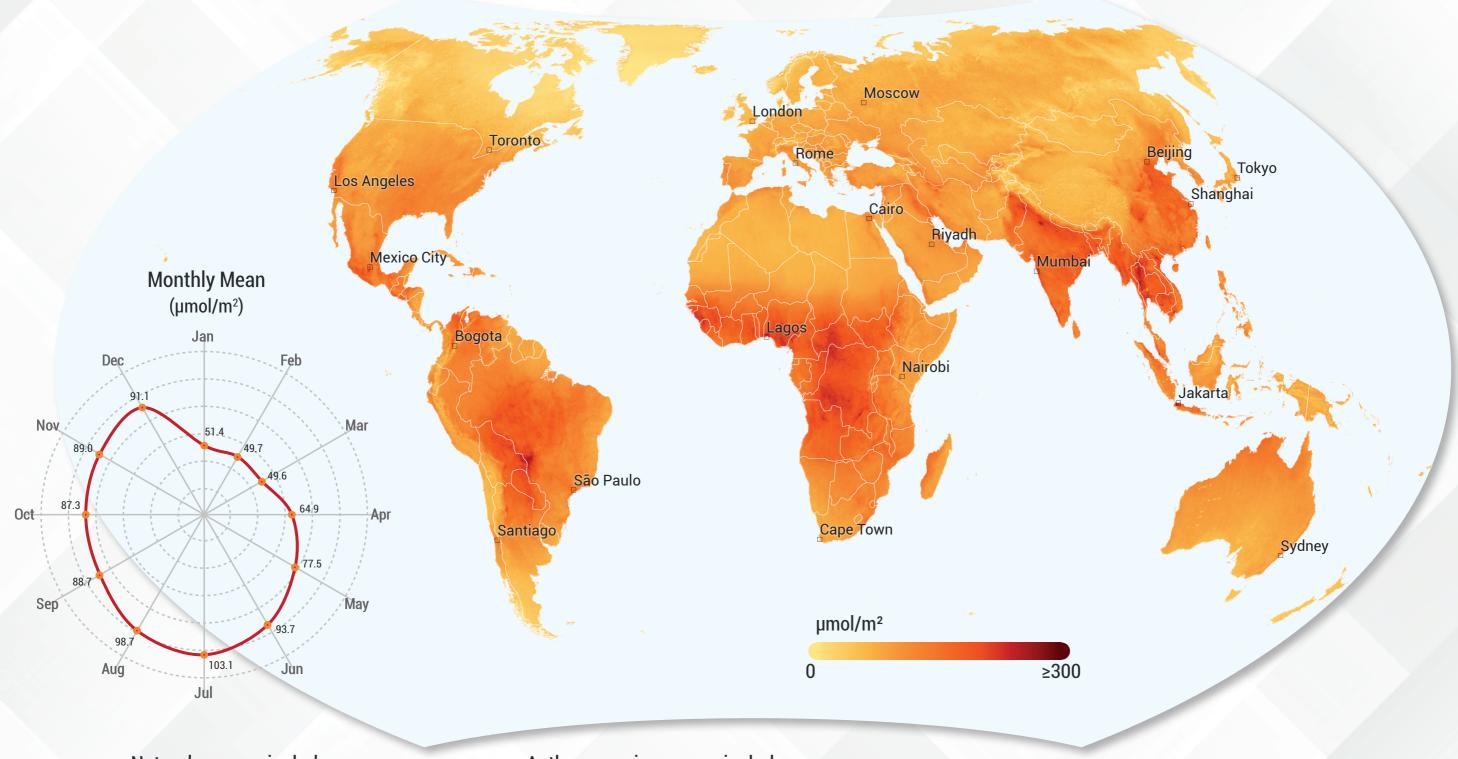


Note: As part of Sentinel-5P's data ingestion procedure to Google Earth Engine, the source data is filtered to remove pixels that do not satisfy the SO₂ QA criteria. Seasonal and inter-annual variations could also affect the monthly distribution of pollutants.



Formaldehyde Concentration

Global Annual Mean (2020)



Natural sources include:



Wildfires

Anthropogenic sources include:



Vehicle exhaust fumes



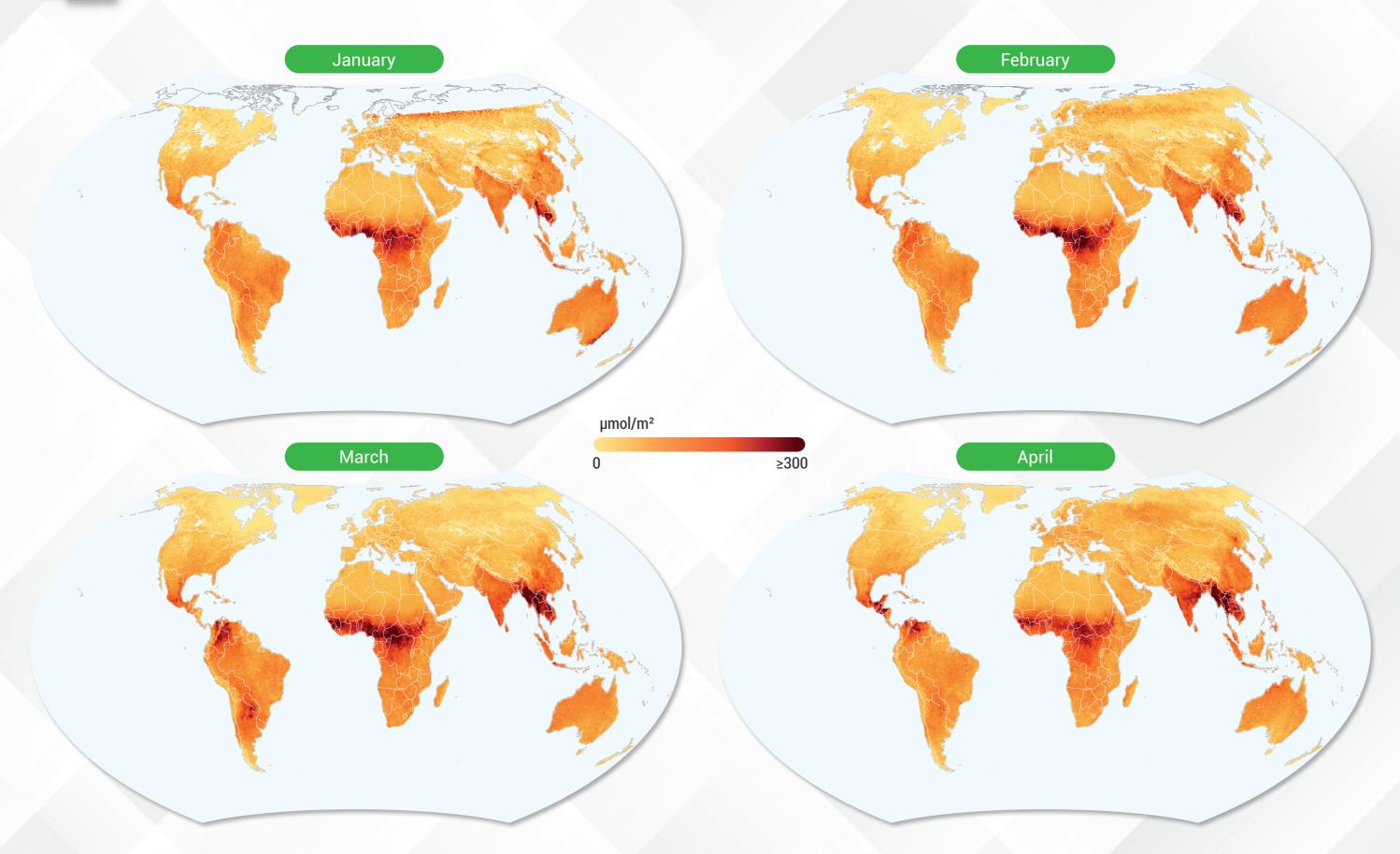
Natural gas burning

Formaldehyde (HCHO) is an intermediate in the oxidation of methane, as well as of other carbon compounds. The oxidation of non-methane volatile organic compounds (NMVOCs) emitted from fires, traffic, and industrial sources enhance localized HCHO levels although, seasonal and inter-annual variations can also affect the distribution of HCHO in the atmosphere.



Formaldehyde Concentration

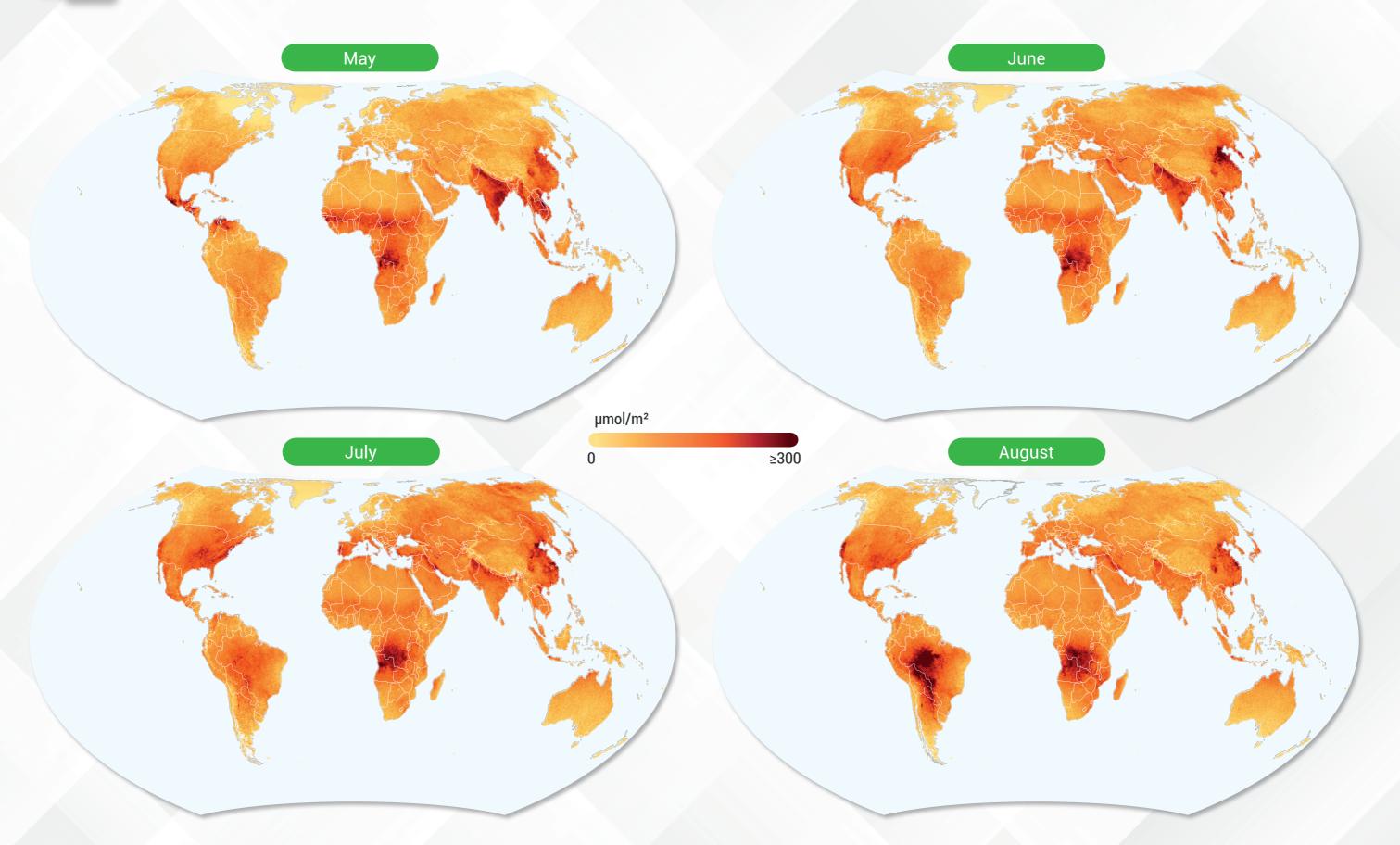
Global Monthly Mean (Jan-Apr 2020)



НСНО

Formaldehyde Concentration

Global Monthly Mean (May-Aug 2020)

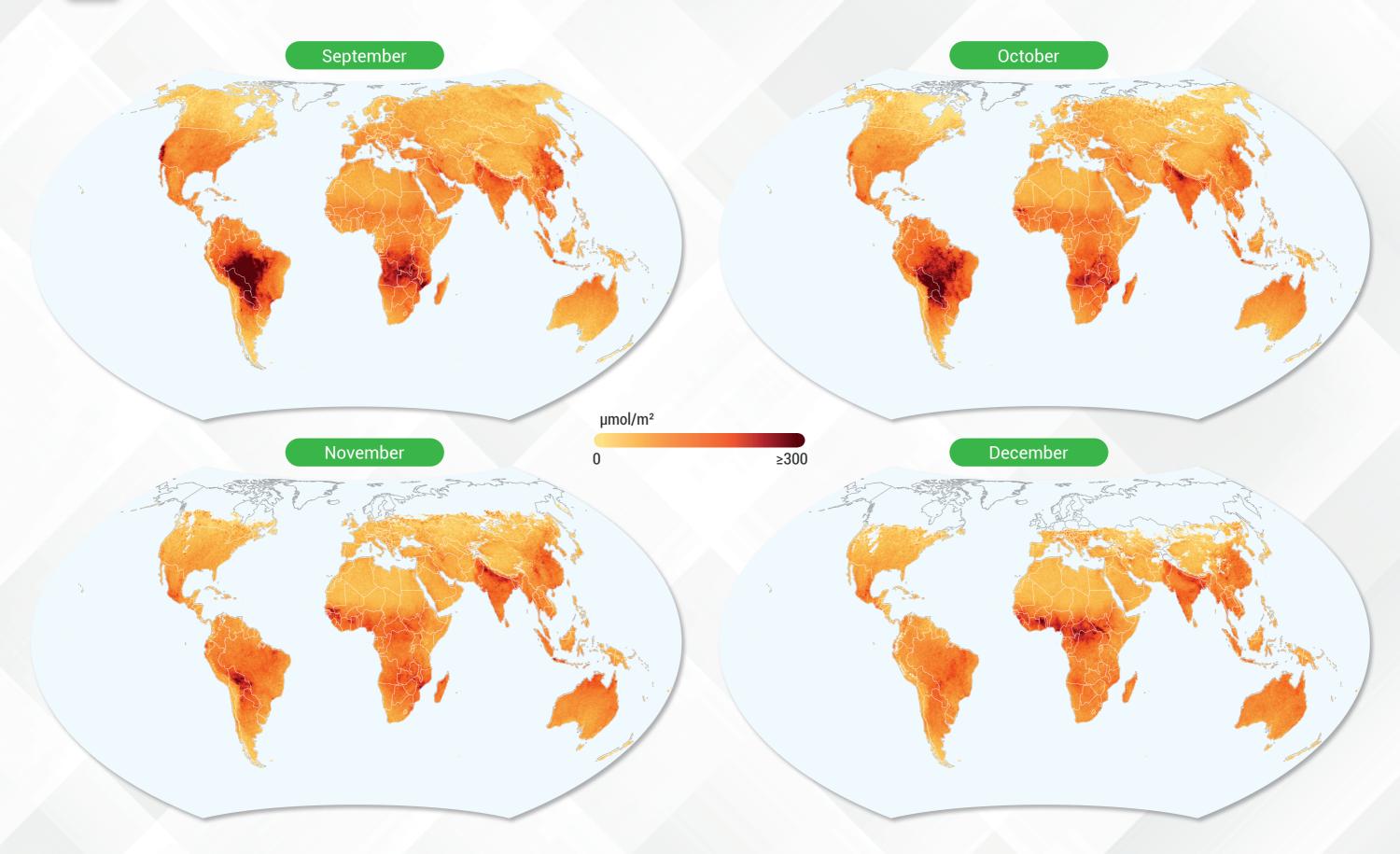


Note: As part of Sentinel5-P's data ingestion procedure to Google Earth Engine, the source data is filtered to remove pixels with QA values less than 50%. Seasonal and inter-annual variations could also affect the monthly distribution of pollutants.



Formaldehyde Concentration

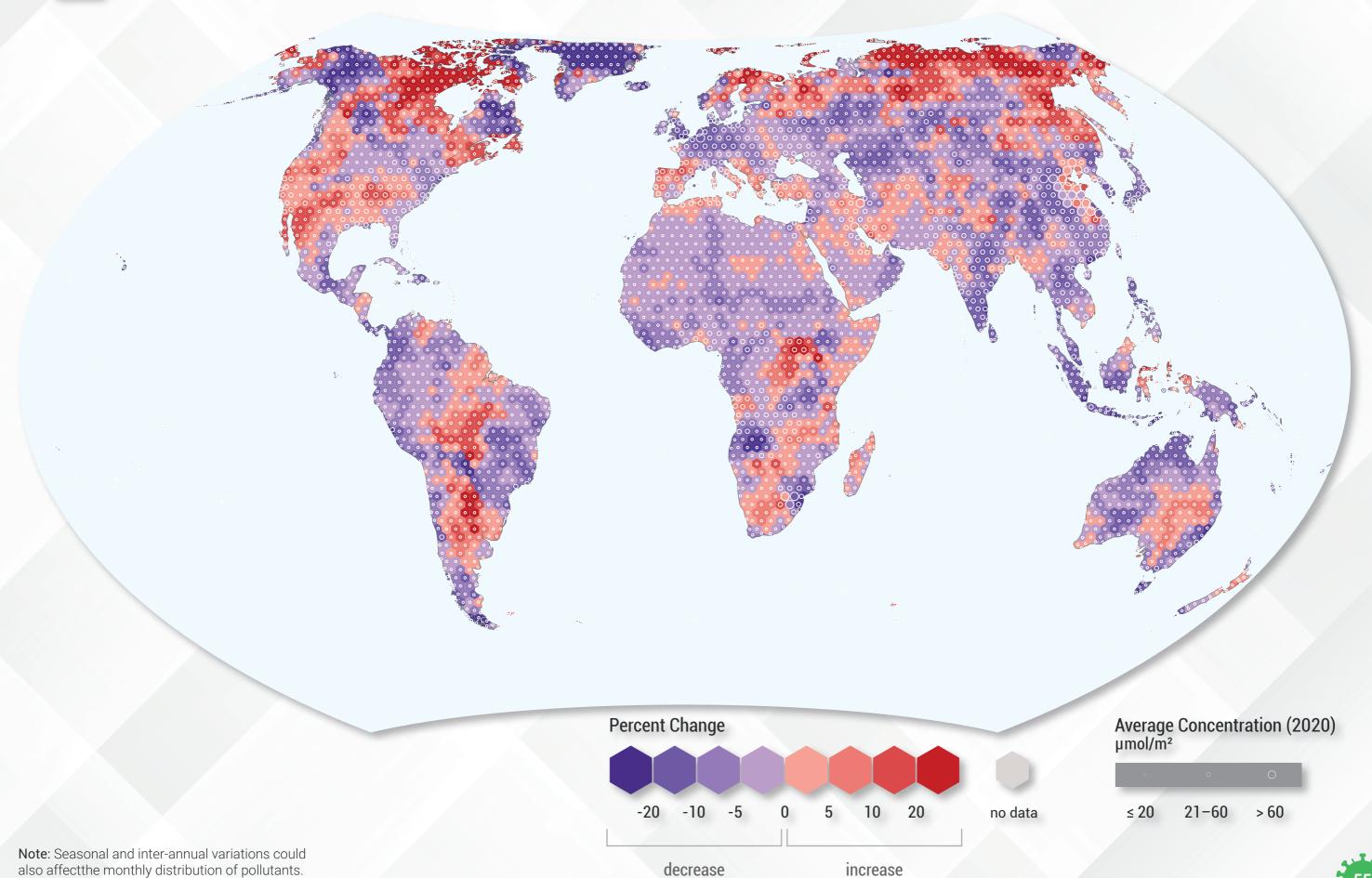
Global Monthly Mean (Sept-Dec 2020)





Change in Nitrogen Dioxide Concentration

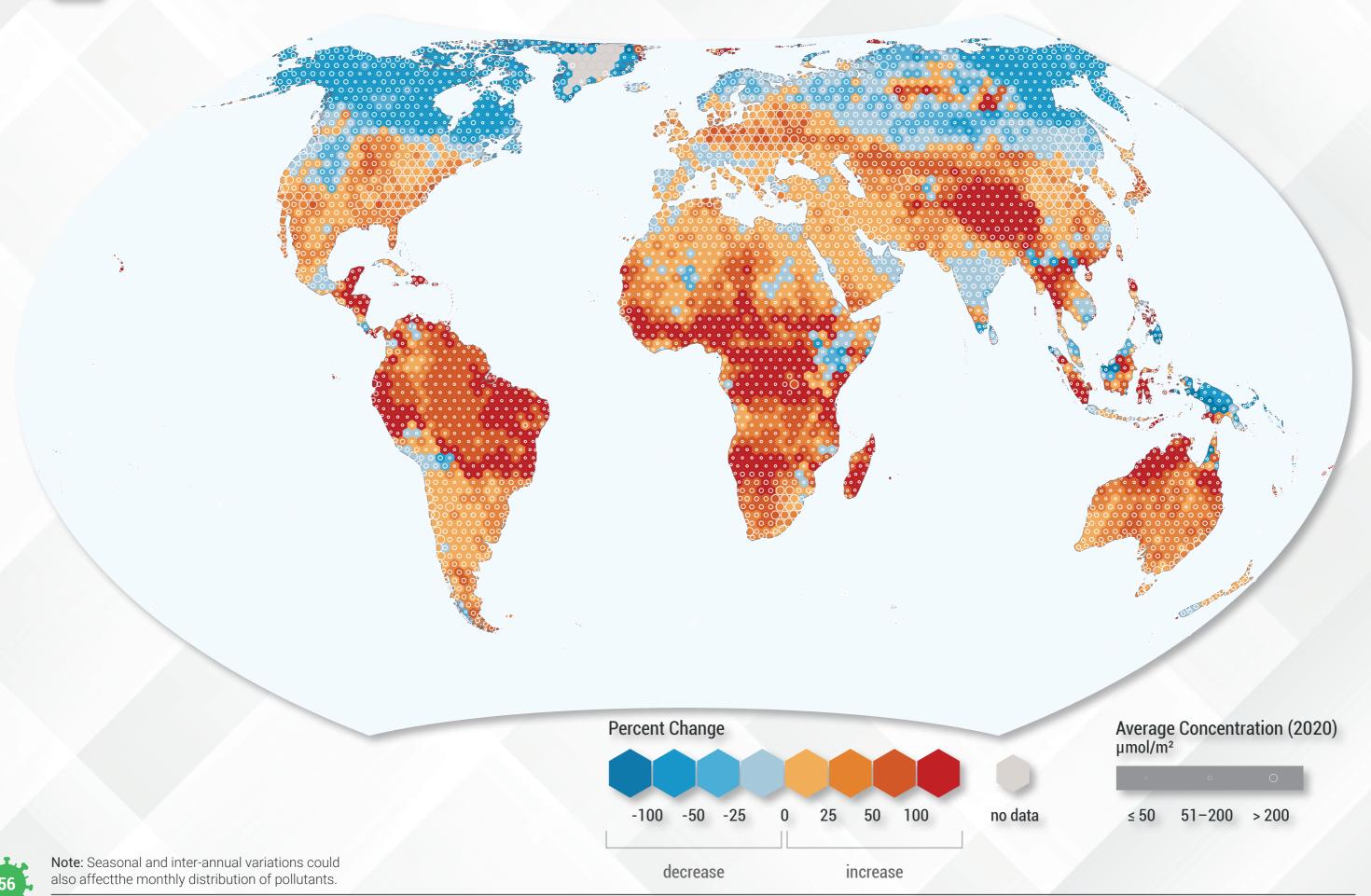
Percent change relative to global annual mean in 2019





Change in Sulfur Dioxide Concentration

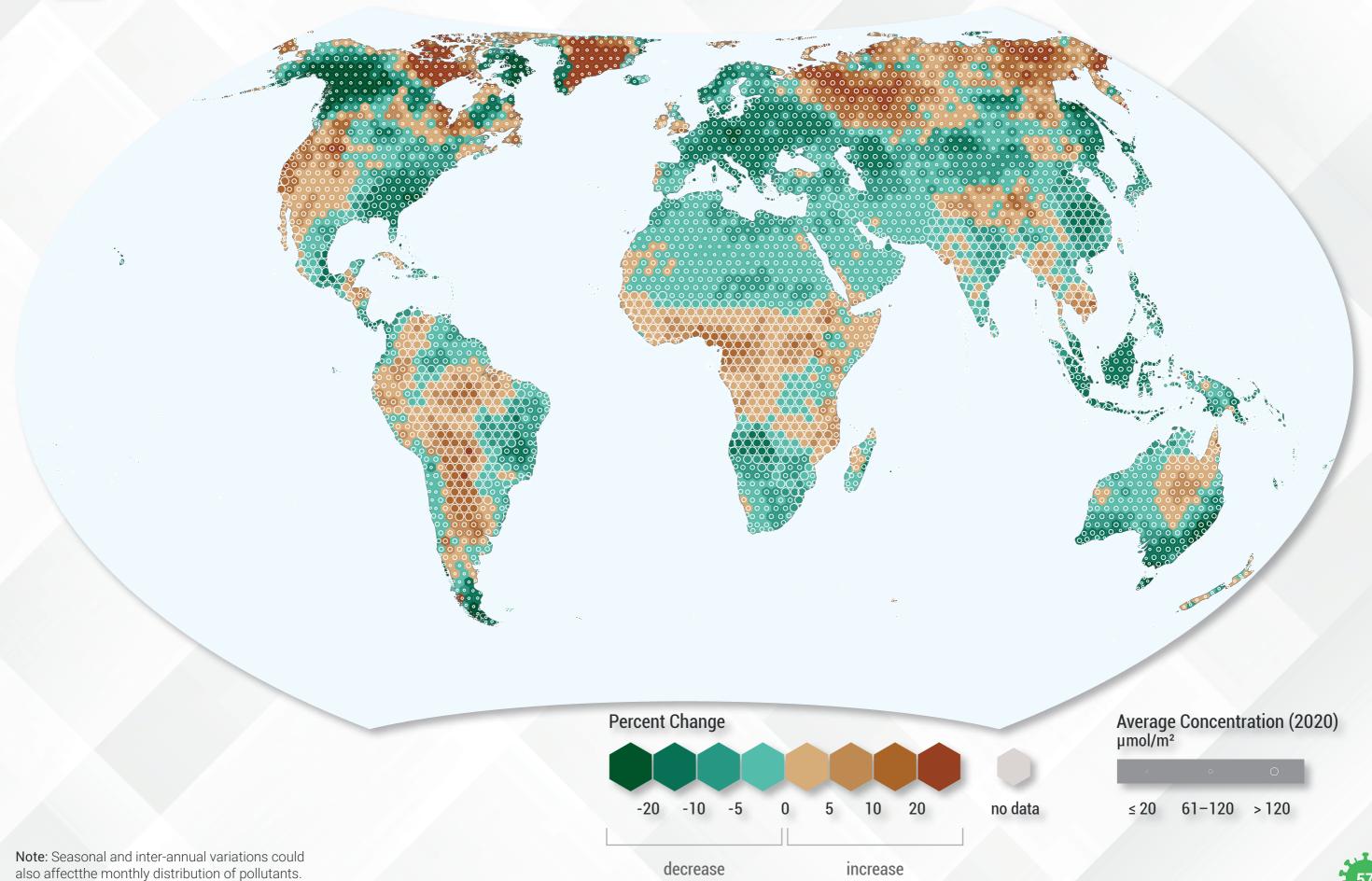
Percent change relative to global annual mean in 2019





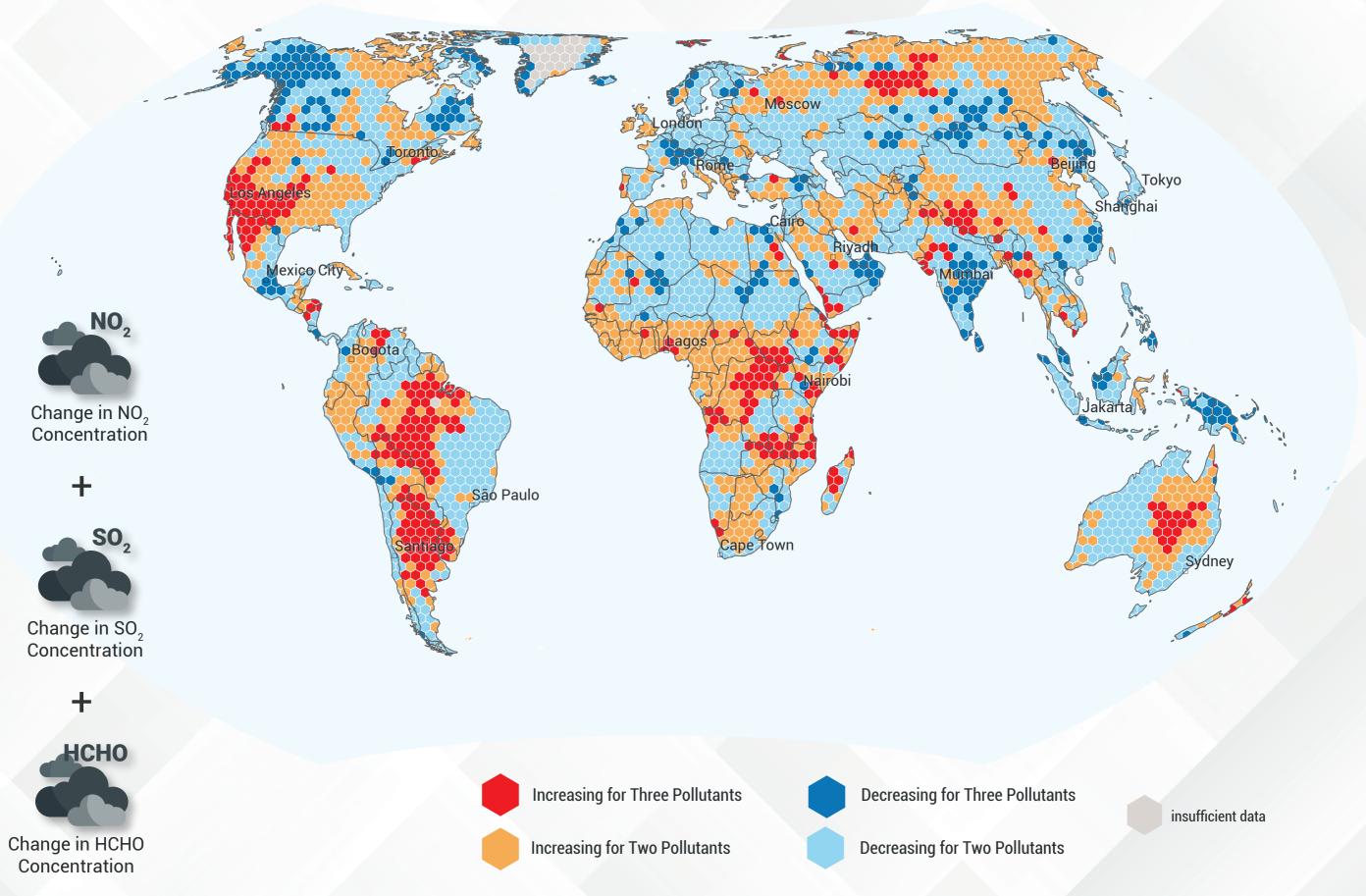
Change in Formaldehyde Concentration

Percent change relative to global annual mean in 2019



Trends in the Concentration of Three Major Pollutants

This synthesis map shows the general trend in the concentration of NO₂, SO₂, and HCHO. It only provides a visualization of how the concentration changes relative to the previous year (2019) and does not indicate any assumptions about the actual air quality in an area.



Resources

Data

Reference Map

Basemap

Country Boundaries, Populated Places

Current State

COVID-19 Statistics

Social

COVID-19 Full National-level Country Data

COVID-19 Data Explorer

Economic

Export, Import, GDP per Capita, Inflation Statistics

Working Hours Lost Statistics

Unemployment Statistics, Income Level Classification

Airline Industry Statistics

Environmental

Nitrogen Dioxide Concentration Sulfur Dioxide Concentration Formaldehyde Concentration

Graphics

Economic Impact Chapter Cover

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Environmental Impact Chapter Cover

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Closing Page

Photo by Taylor Brandon on Unsplash

Social Impact Chapter Cover

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Contents Page

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Esri, Vizzuality, and the Half-Earth Project

https://tiles.arcgis.com/tiles/nGt4QxSblgDfeJn9/arcgis/rest/services/Vibrant/MapServer

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Copernicus Sentinel-5P (processed by ESA), TROPOMI Offline Level 3 product

Copernicus Sentinel-5P (processed by ESA), TROPOMI Offline Level 3 product

Copernicus Sentinel-5P (processed by ESA), TROPOMI Offline Level 3 product

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This pandemic has magnified every existing inequality in our society – like systemic racism, gender inequality, and poverty. And it's impossible to pick one issue as more serious because so many people live at the intersection of all of those challenges.

-Melinda Gates

Co-Chair and Founder, Bill & Melinda Gates Foundation





My name is Leonard Luz, a GIS enthusiast from the Philippines. I earned my bachelor's degree in **Geography** and my master's degree in **Geoinformatics** from the **University of the Philippines.** When I am not making maps, I enjoy traveling around the many islands of my country and taking pictures of busy streets or scenic landscapes of the countryside.

I hope that someday, I will be able to use my skills in geoinformatics to help in solving environmental and humanitarian issues, especially when it comes to poverty and disaster management. The application of GIS and remote sensing in these fields is constantly developing so I would like to focus on improving my expertise in these fields as well.

As GIS remains unpopular in our country, I would also like to **promote this domain** to younger generations and encourage them to pursue future careers related to geoinformatics.

This atlas was created as part of the diploma thesis to fulfill the requirements for the **Copernicus Master in Digital Earth** (Geovisualization and Geocommunication Track), an Erasmus Mundus Joint Master Degree (EMJMD) programme hosted by **Paris Lodron University of Salzburg** and **Palacký University Olomouc.**

