The benefits of Earth Observation for Public Health applications

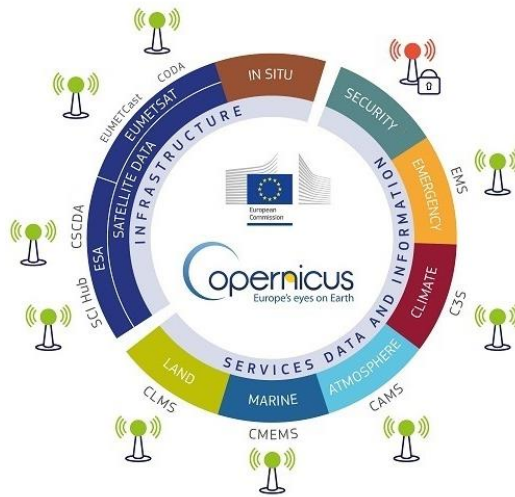**Dr Rochelle Schneider**

Destination Earth **AI Applications Lead** at the **European Space Agency** (ESA)

Visiting Researcher at European Centre for Medium-Range Weather Forecasts (ECMWF)

Member of the Centre on Climate Change and Planetary Health (CCPH – LSHTM)
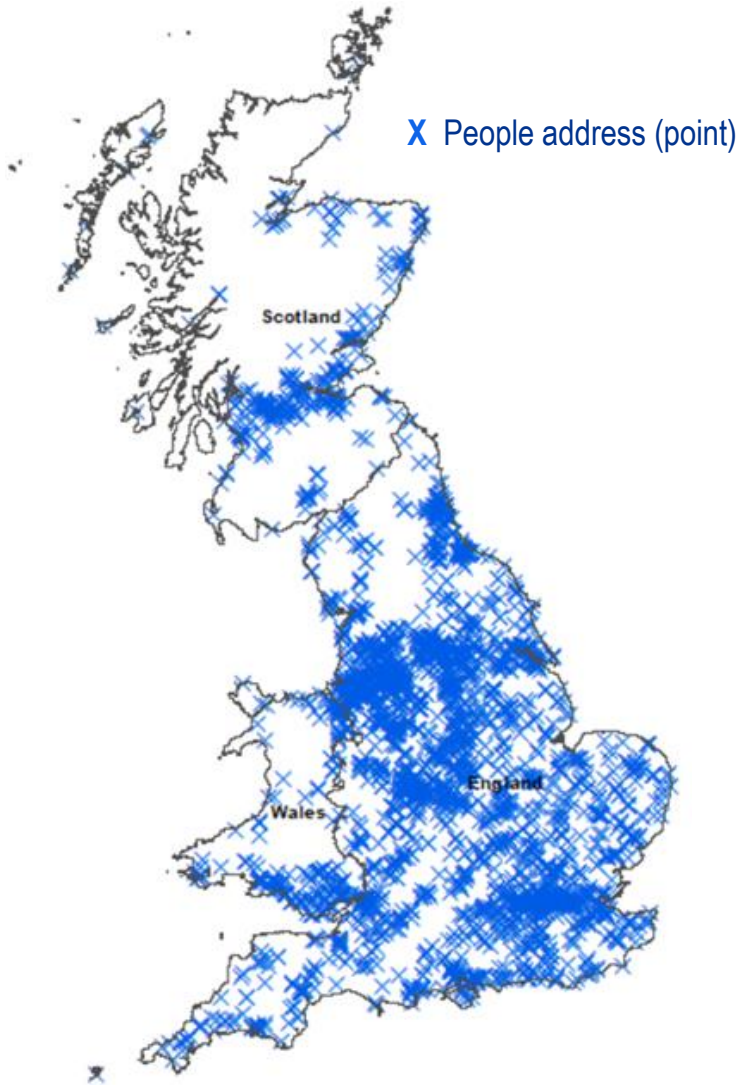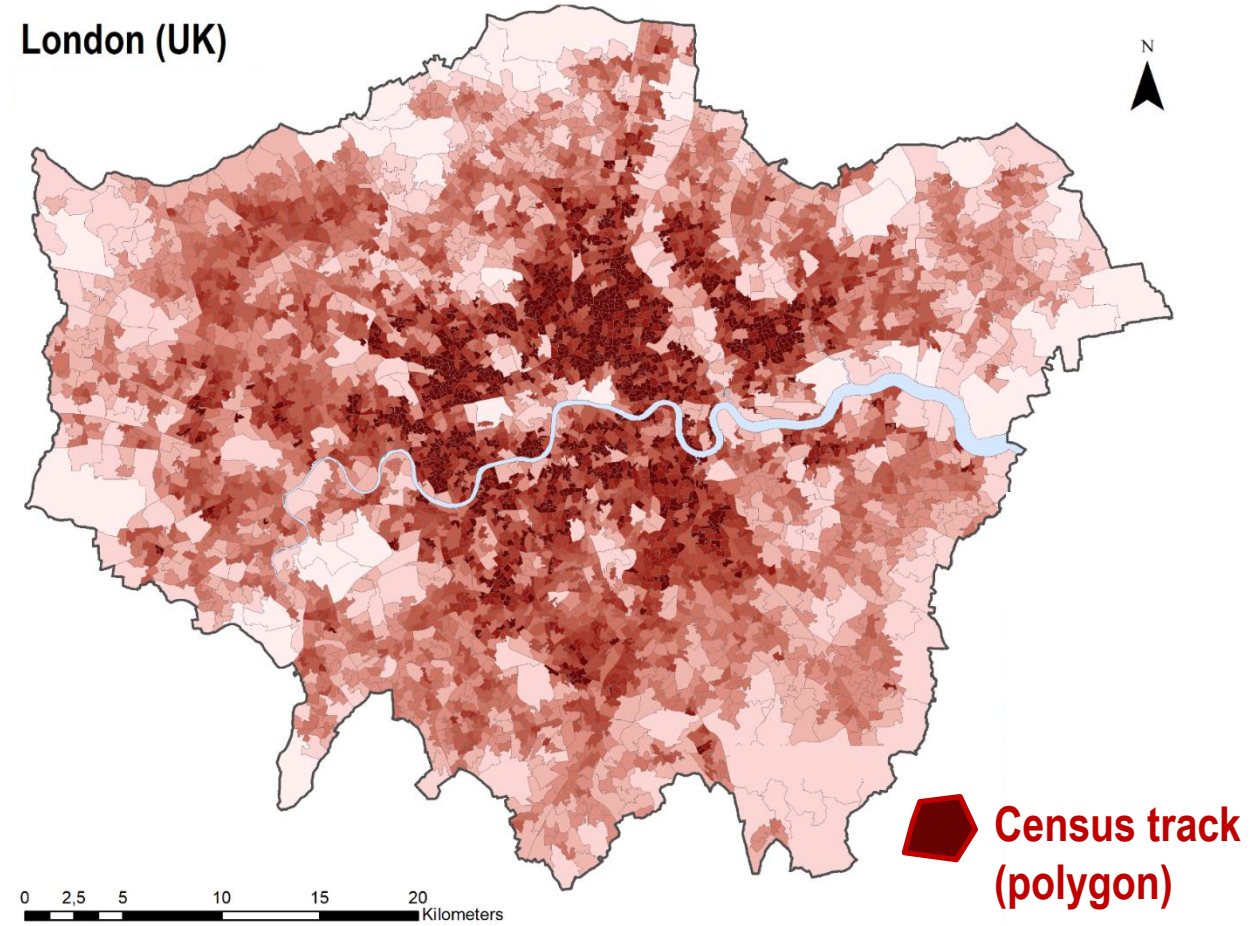
European Space Agency

Artificial Intelligence
AI4EO4Health
Earth Observation

esa
European Space Agency
Φ-lab

Example of collaborations:

Climate-sensitive health risks

Health outcomes

Heat-related illness · Respiratory illness · Water-borne diseases and other water-related health impacts · Zoonoses · Vector-borne diseases · Malnutrition and food-borne diseases · Noncommunicable diseases (NCDs) · Mental and psychosocial health

Health systems & facilities outcomes

Impacts on healthcare facilities · Effects on health systems

SUSTAINABLE DEVELOPMENT GOALS

3 GOOD HEALTH AND WELL-BEING

World Health Organization

Health data format

X People address (point)

London (UK)

Census track
(polygon)
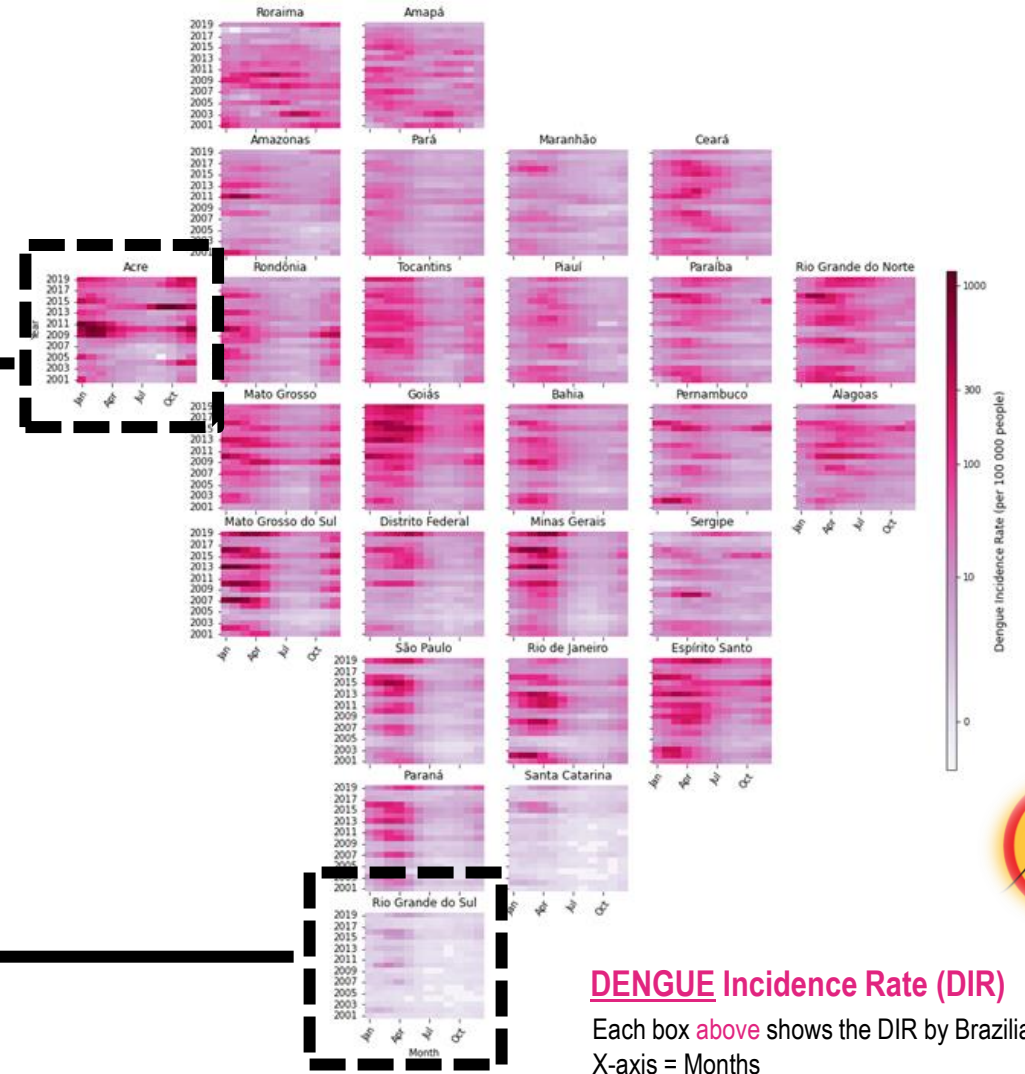
0   2,5   5   10   15   20
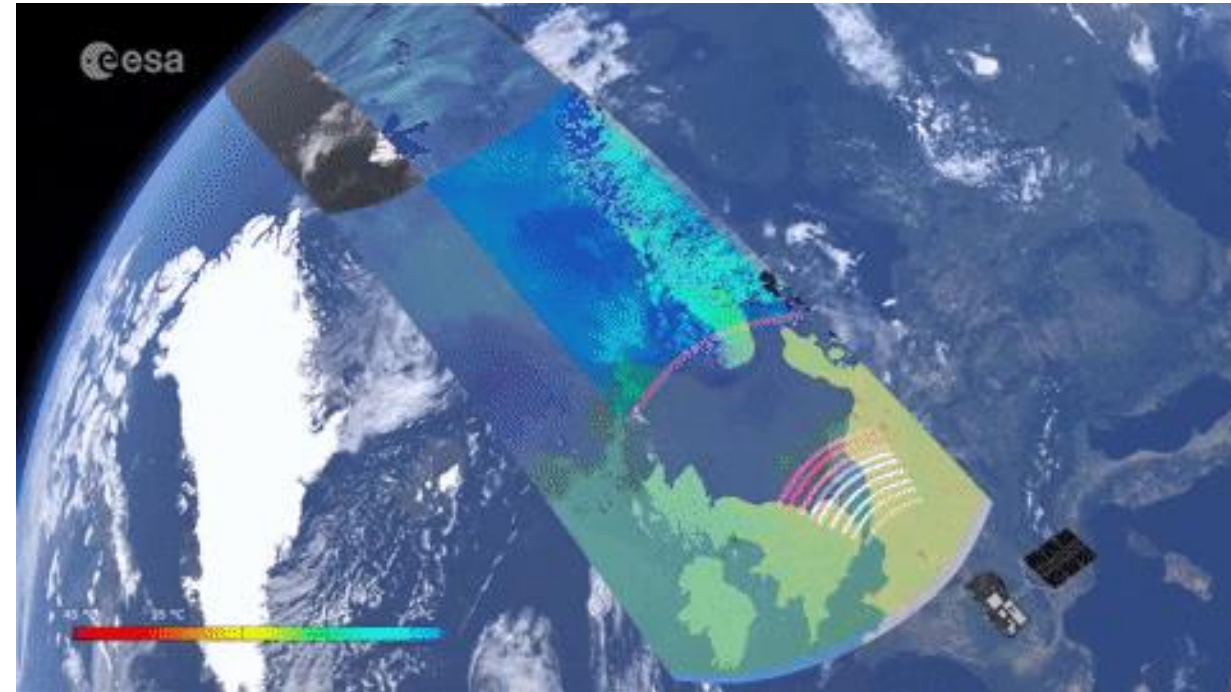Kilometers

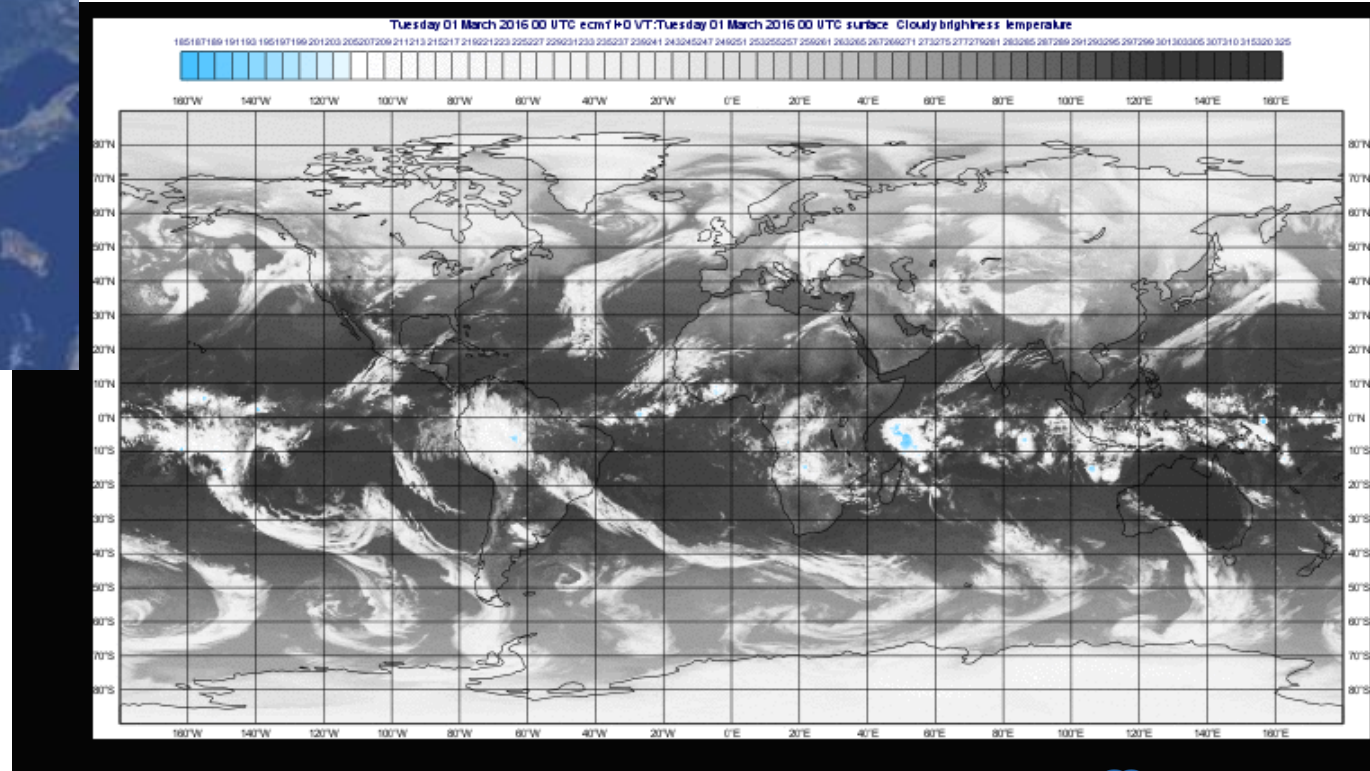# Health data format

27 Brazilian States

Brazil

DENGUE Incidence Rate (DIR)

Each box above shows the DIR by Brazilian State.
X-axis = Months
Y-axis = Years

Satellite and satellite-based data

Source: https://www.esa.int/ESA_Multimedia/Videos/2016/07/Sentinel-3_s_scanning_radiometer
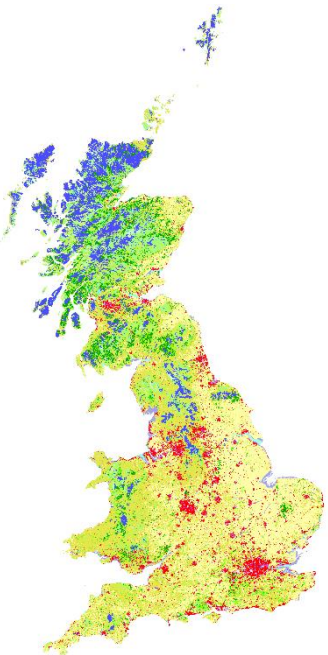

Source: https://confluence.ecmwf.int/display/FCST/Simulated+satellite+data

Satellite data format

Land Cover
Resolution: 100m
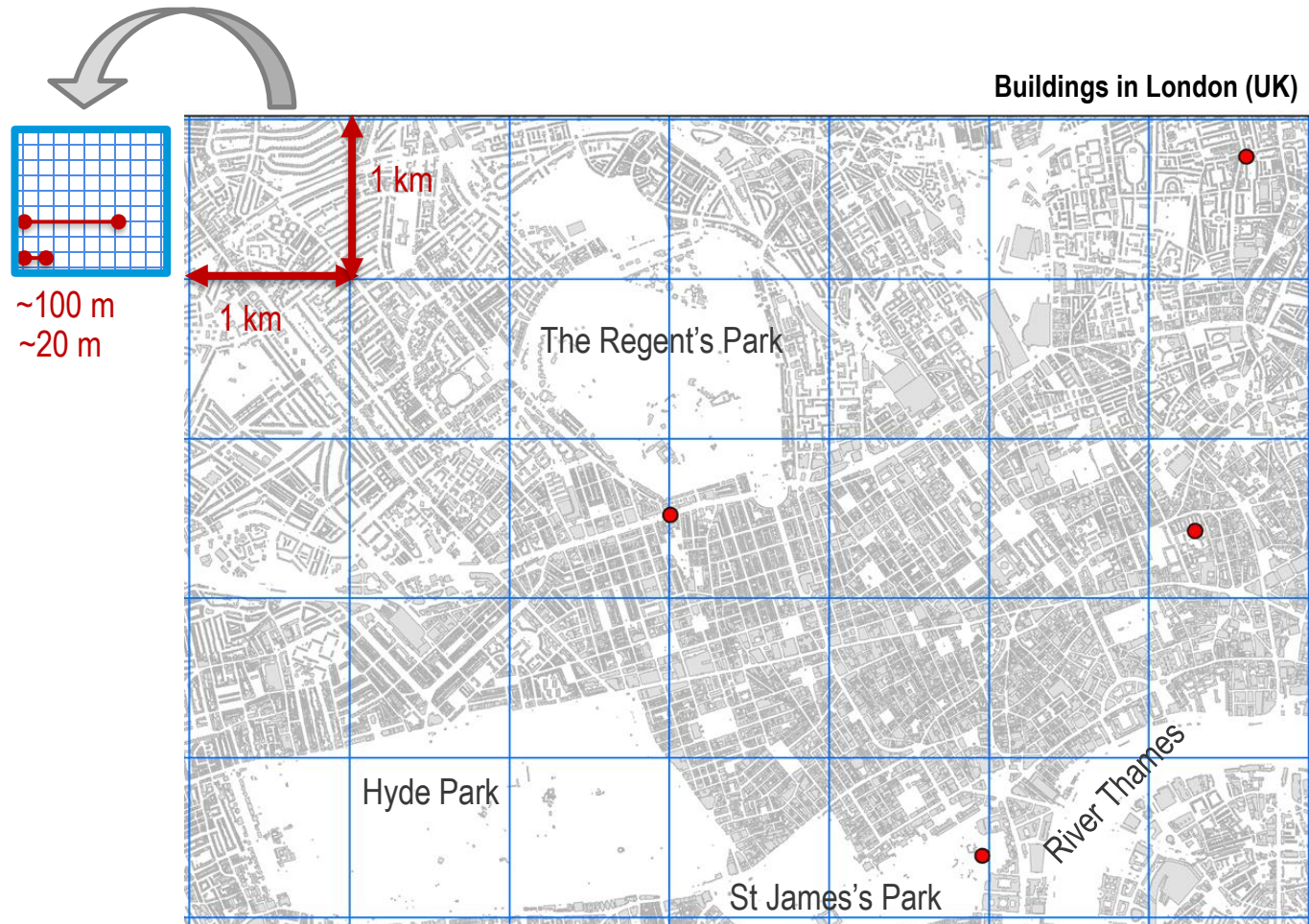**Sources:** Landsat-7 ETM,SPOT-4/5,Sentinel-2, and Landsat-8

Example: Great Britain

Imperviousness density
Resolution: 20/100m.
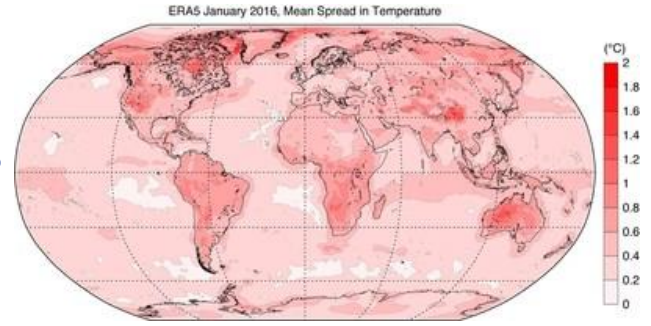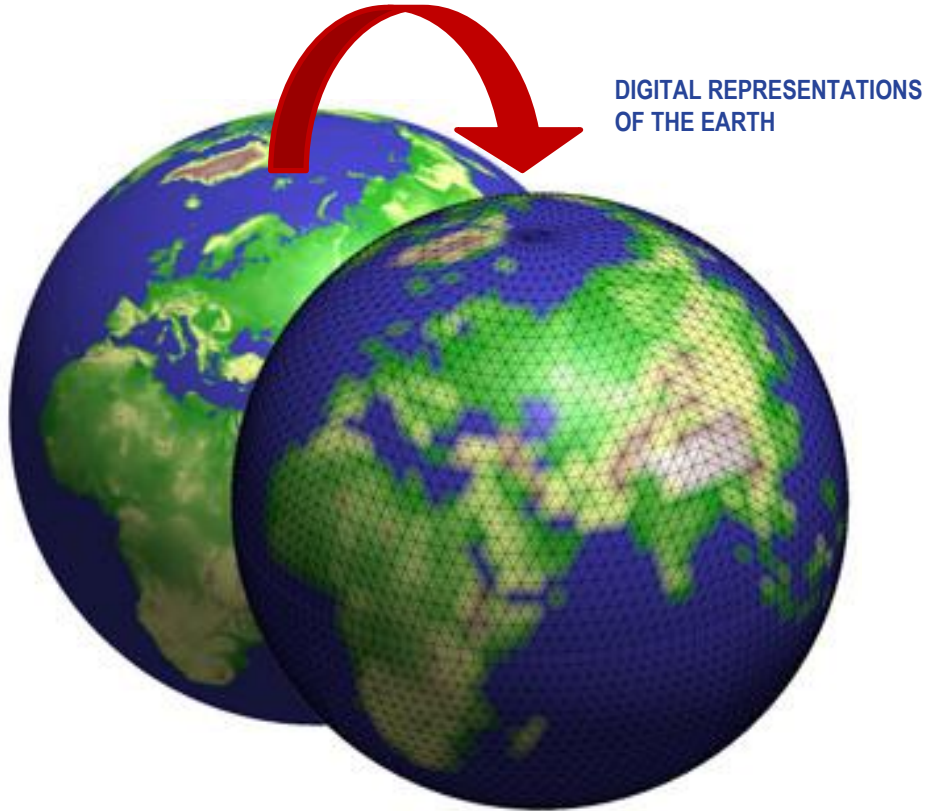**Sources:** SPOT 5 and Landsat 8

Elevation
Resolution: 25m
Ex sources: Aqua ASTER GDEM, Shuttle Radar Topography Mission (SRTM)

~100 m
~20 m

1 km
1 km

Buildings in London (UK)

The Regent's Park

Hyde Park

St James's Park

River Thames

Satellite-based data

DIGITAL REPRESENTATIONS OF THE EARTH

ERA5 January 2016, Mean Spread in Temperature

Model: ERA 5 (~ 25 x 25 km)

Mean 2m temperature for February 2019 from ERA5-Land

Model: ERA 5 Land (~ 9 x 9 km)

CAMS reanalysis of particulate matter d < 2.5 um (PM2.5)
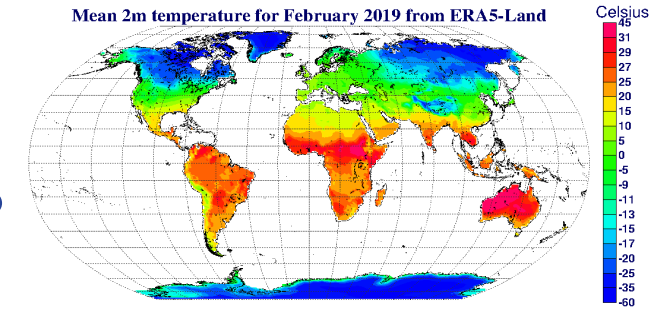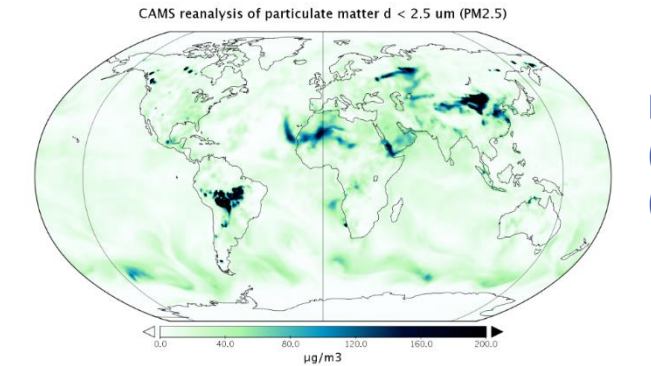
Model: GLOBAL CAMS (~ 40 x 40 km) (~ 80 x 80 km)

Source: ECMWF

Number of satellite data products monitored at ECMWF

Legend: POES, Suomi-NPP, DMSP, Metop, ERS-1/2, ENVISAT, COSMIC, COSMIC-2, CHAMP, GRACE, CNOFS, SAC-C, TERRASAR-X, GCOM-W/C, TRMM, Megha Tropiques, AQUA, AURA, FY3, QuikSCAT, JASON-1/2/3, Oceansat, HY-2A, Meteosat, GOES, MTSAT, FY-2C/D, Terra + Aqua AMVs, Cryosat, SMOS, EarthCARE, ADM Aeolus, GOSAT, Sentinel 1, Sentinel 3, Sentinel 5p

Image source: https://www.ecmwf.int/en/elibrary/9301-impact-satellite-data
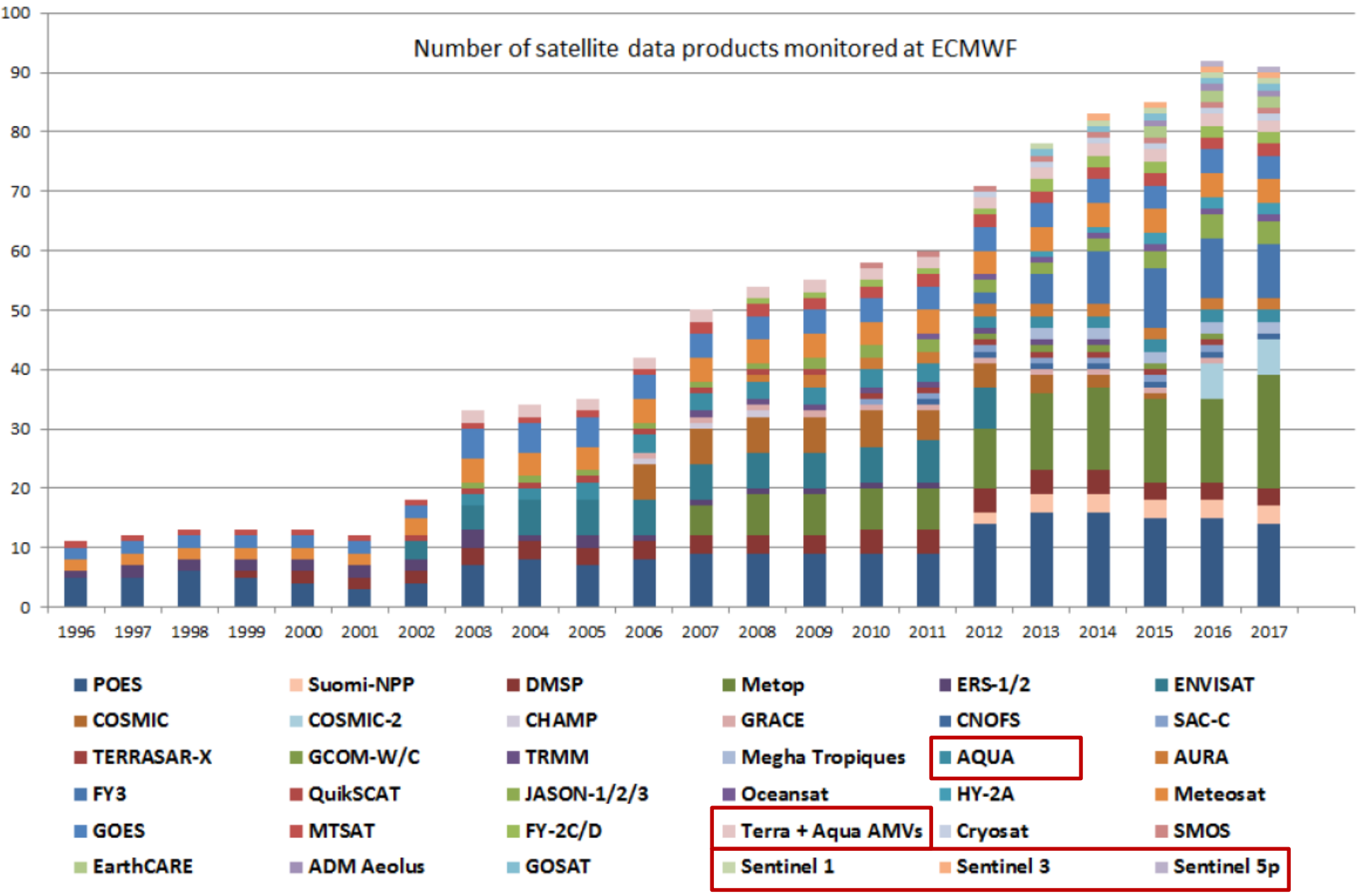
Example:

Satellite-based data

Climate Change

ERA 5 [Global]
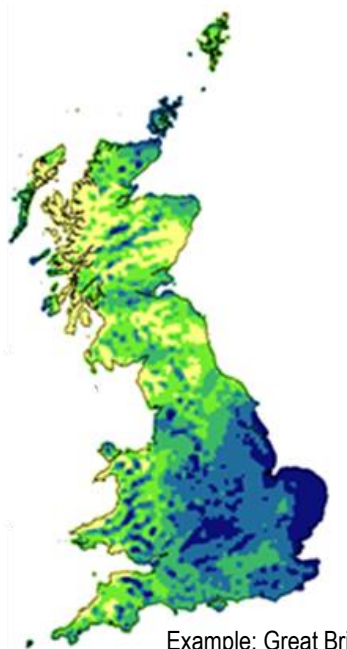Resolution: **~25km**/ Hourly

ERA 5 Land [Global]
Resolution: **~9km**/Hourly

2m Air temperature
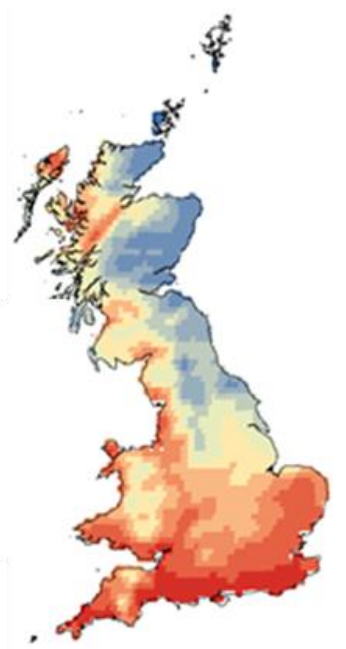
**Precipitation**

Wind Speed/Direction

Example: Great Britain

Average air temperature at 2m height

Minimum air temperature at 2m height

Maximum air temperature at 2m height

Dewpoint temperature at 2m height

Total precipitation

Surface pressure

Mean sea level pressure

London (UK)

25 km
25 km
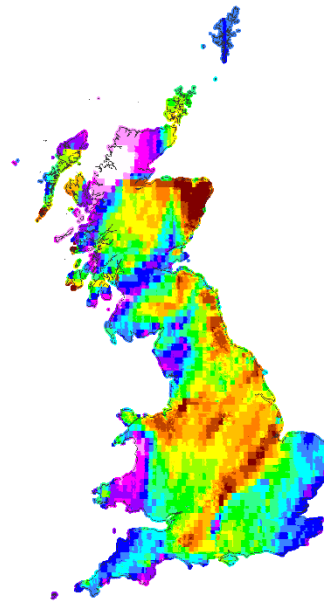**ERA 5**
□ 1 km

9 km
9 km
ERA 5-Land
□ 1 km

Satellite-based data

Atmosphere
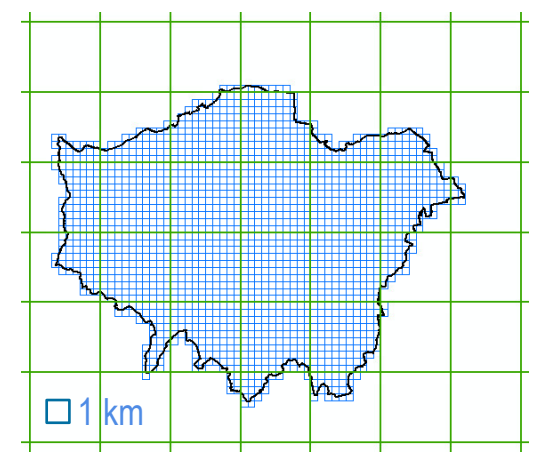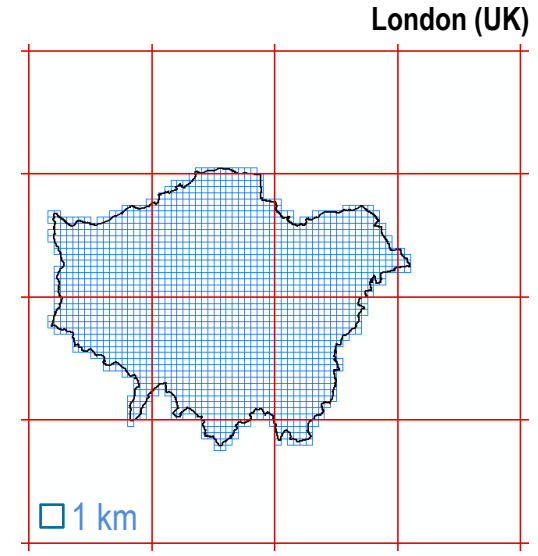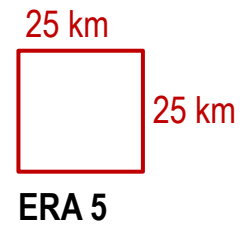
Total Column Aerosol Optical Depth (AOD)
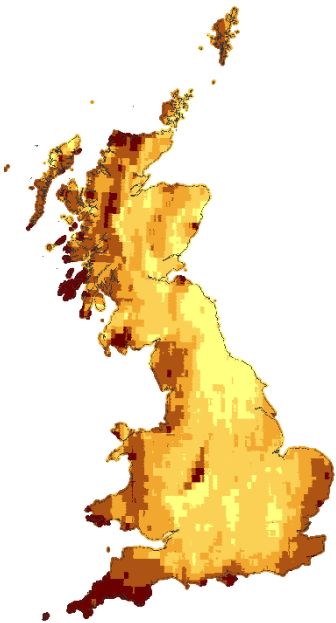
Particule Mater PM$_{25}$ (mg/m^3) [Surface]

Nitrogen Dioxide (NO$_2$) [Surface]

Example: Great Britain

Alder pollen
Birch pollen
Carbon monoxide
Dust
Grass pollen
Mugwort pollen
Nitrogen dioxide
Nitrogen monoxide
Non-methane VOCs
Olive pollen
Ozone
Particulate matter (PM10)
Particulate matter PM10 - wildfires only
Particulate matter PM2.5
Particulate matter PM 2.5 μm - anthropogenic fossil fuel carbon only
Particulate matter PM 2.5 μm - anthropogenic wood burning carbon only
Ragweed pollen
Residential elementary carbon

London (UK)

10 km

10 km

European CAMS

***Global* CAMS
~forecast 40 km
~rean 80km**
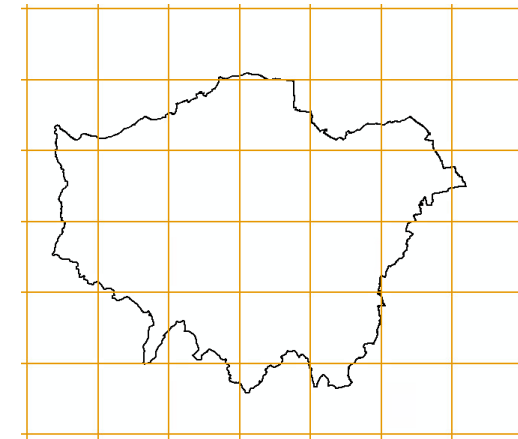
Satellite vs satellite-based data

AEROSOL – Satellite
[Aerosol Optical Depth – AOD*]
Resolution: 1 km
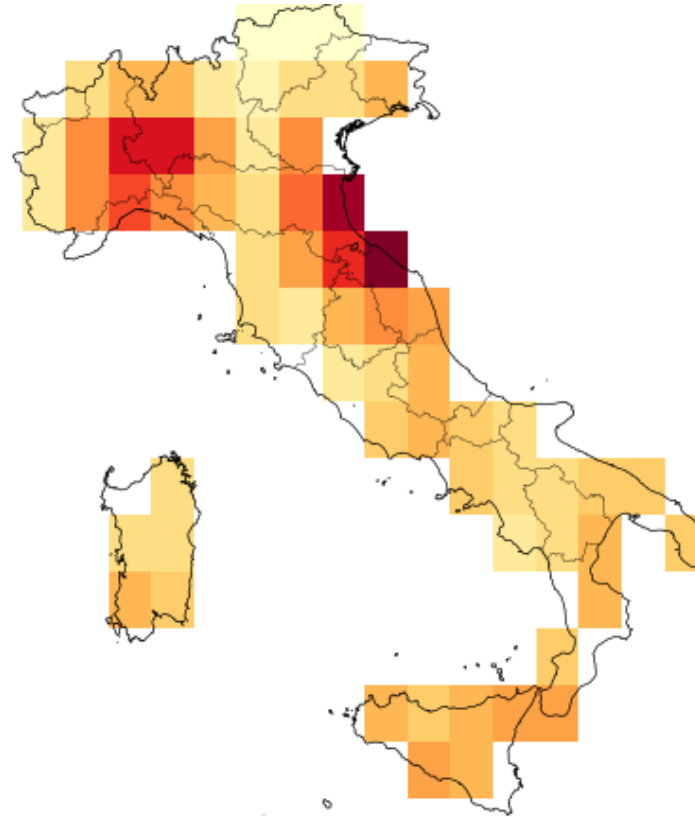**Source:** NASA - MODIS (Terra/Aqua)

Italy

1 January 2020

AEROSOL – Modelled
[Aerosol Optical Depth –AOD*]
Resolution: 10 km
Source: CAMS Europe

1 January 2020

PM$_{2.5}$ – modelled
[Fine Particulate Matter]
Resolution: 10 km
Source: CAMS Europe

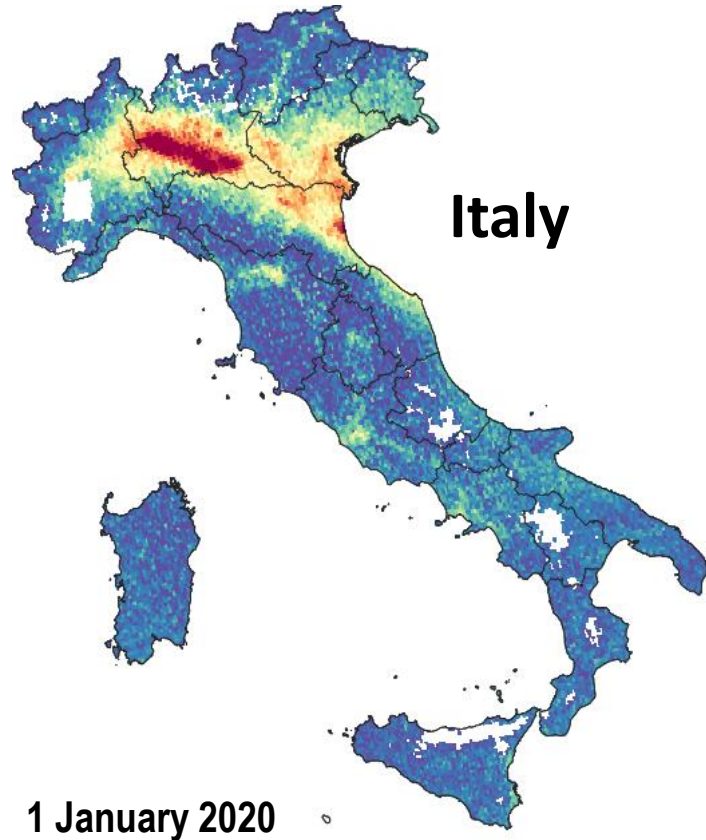**1 January 2020**

European Space Agency
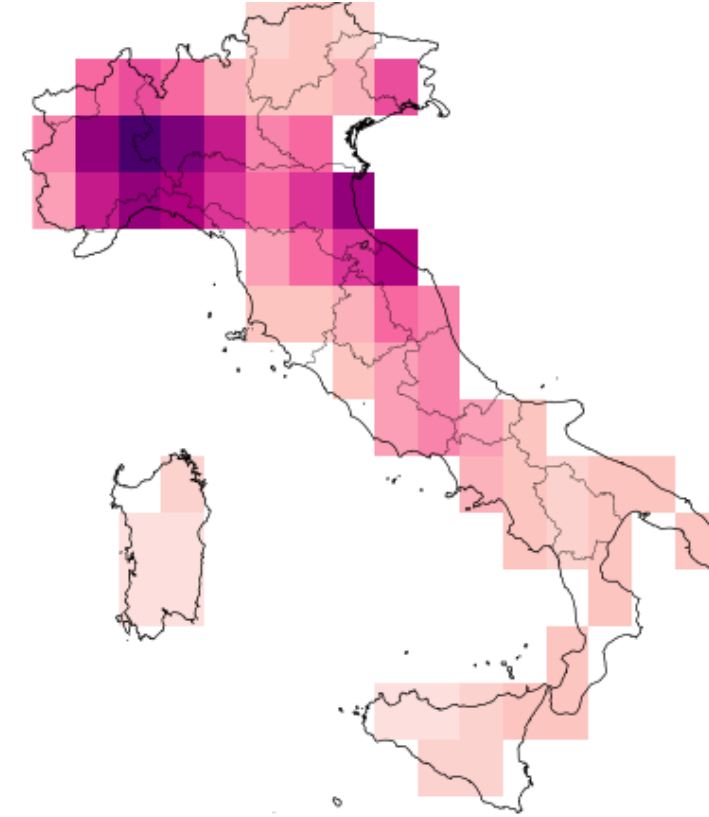
Satellite vs satellite-based data

NITROGEN DIOXIDE – Satellite

[Tropospheric Column, 0-10 km]

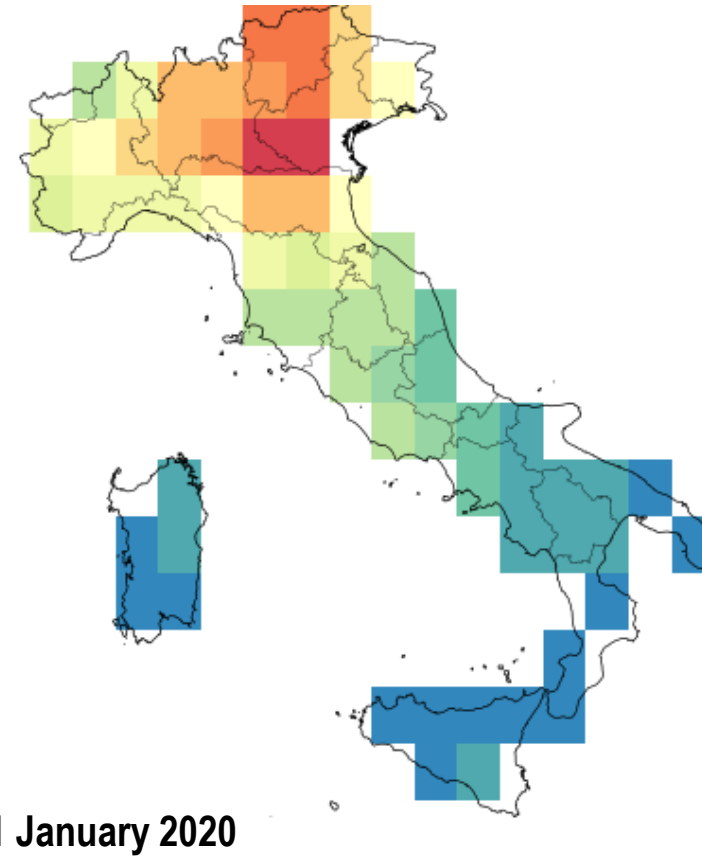**Resolution:** 3.5 x 5.5 Km
Source: ESA Sentinel 5P

NITROGEN DIOXIDE – Modelled

[Tropospheric Column, 0-10 km]

Resolution: 10km
Source: CAMS Europe

Italy

1 January 2020

1 January 2020

Activities

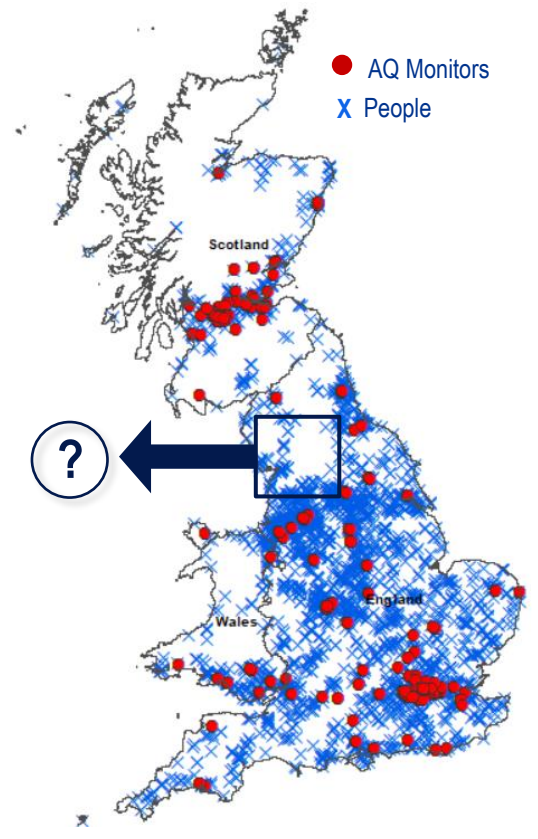Artificial Intelligence
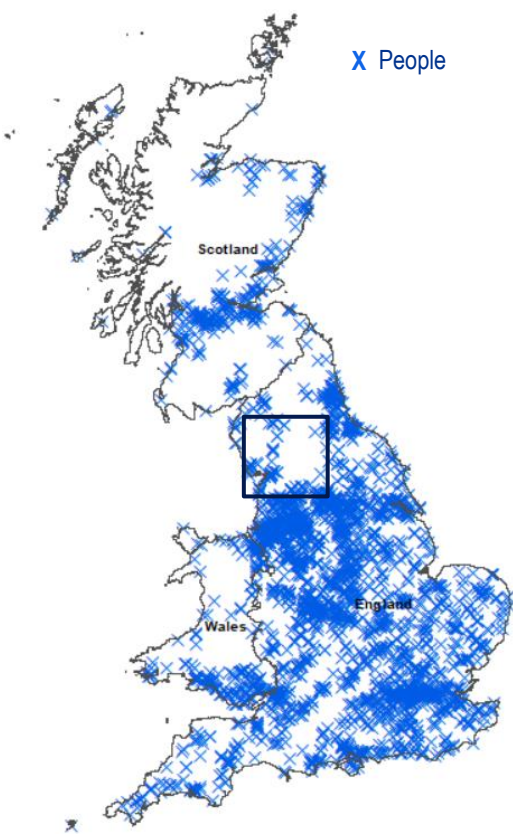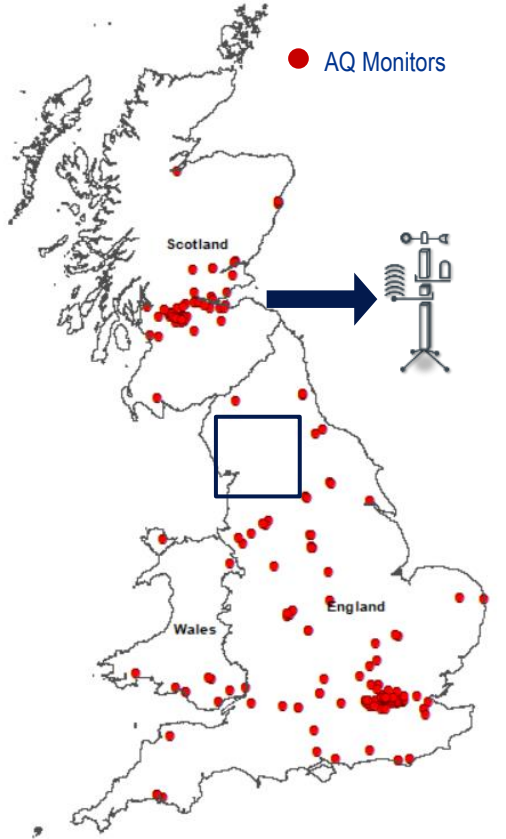**AI4EO4Health**
Earth Observation

Example 1: Reconstruct air pollution to estimate human exposure and risk

- Epidemiological studies on the health effects of air pollution usually rely on observations from ground monitors, which provide discontinuous spatiotemporal records.

- Data from earth observation satellites, climate and atmospheric models offer the spatiotemporal coverage required to reconstruct historical human exposures to air pollution.

Air quality (AQ) monitors	Epidemiological studies (ecologic / cohort)	AQ monitor vs Epidemiological studies locations

Example 1: Reconstruct air pollution to estimate human exposure and risk

Data Sources:

SATELLITES	SATELLITE-BASED LAND MONITORING	CLIMATE AND ATMOSPHERIC REANALYSIS MODELS

Sentinel 3 – AOD   S5P - NO_2 NDVI

Elevation   Land Cover

Temperature   Precipitation   CAMS - NO_2 CAMS - AOD

Example 1: Reconstruct air pollution to estimate human exposure and risk

Measured PM₂.₅

Monitors

Schneider et al. (2020)

Satellite-based products

Vegetation | Elevation | Temperature

Night Light | Aerosol | Precipitation

Artificial Intelligence

Doi.org/10.3390/rs12223803

Reconstructed PM₂.₅
Daily estimations at 1km² | 2008-2018

$PM_{2.5}$ - µg/m³

London

Great Britain

remote sensing

The Telegraph

European Space Agency

Example 1: Reconstruct air pollution to estimate human exposure and risk

2008   2013   2018

London

Great Britain
Daily PM$_{2.5}$ estimations
at 1 x1 km^2 grid cells

PM$_{2.5}$ (µg/m^3)

[0,7]	(9,10)	(12,13)	(15,16)	(18,24)
(7,8]	(10,11)	(13,14)	(16,17)	
(8,9]	(11,12)	(14,15)	(17,18)	

World Health Organization

Pollutant	Averaging Time	2005 AQGs	2021 AQGs
PM$_{2.5}$, µg/m^3	Annual	10	5
	24-hour[a]	25	15
PM$_{10}$, µg/m^3	Annual	20	15
	24-hour[a]	50	45
O$_3$, µg/m^3	Peak season[b]	-	60
	8-hour[a]	100	100
NO$_2$, µg/m^3	Annual	40	10
	24-hour[a]	-	25
SO$_2$, µg/m^3	24-hour[a]	20	40
CO, mg/m^3	24-hour[a]	-	4

Estimate the total excess deaths due to the annual PM$_{2.5}$ above the limits.
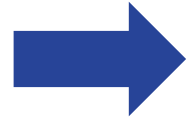
LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

Collaboration:

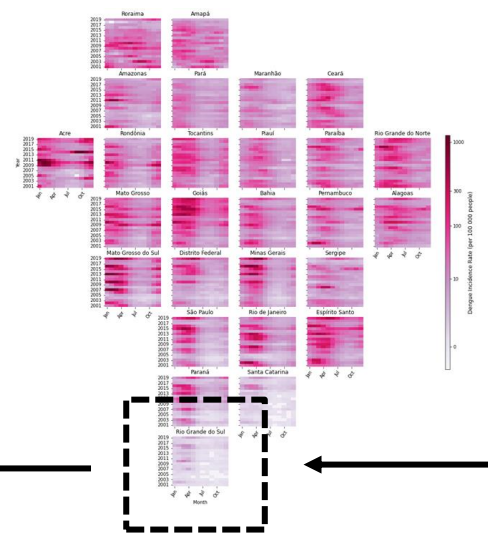European Space Agency

Outside Europe
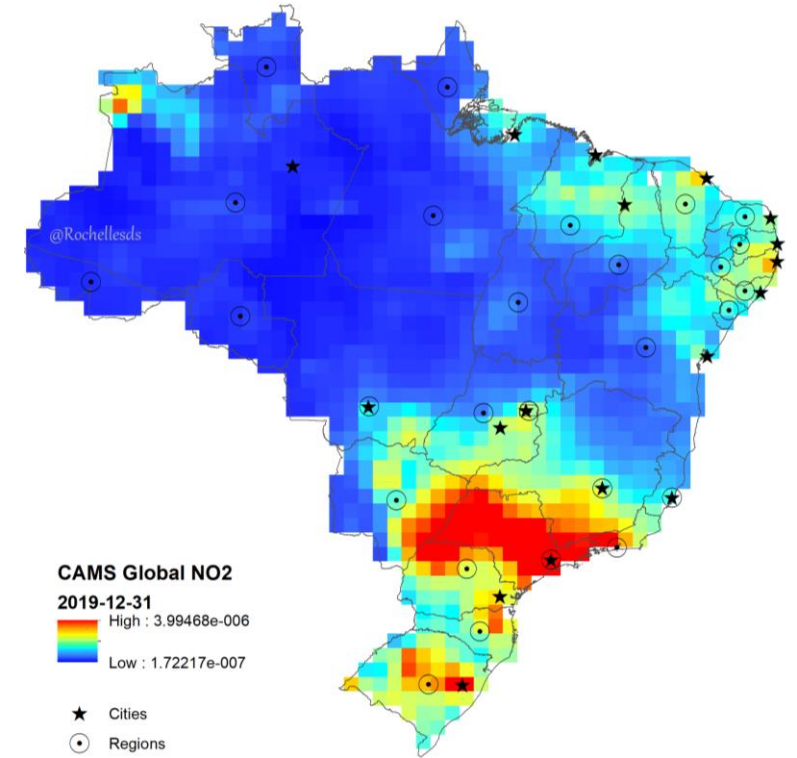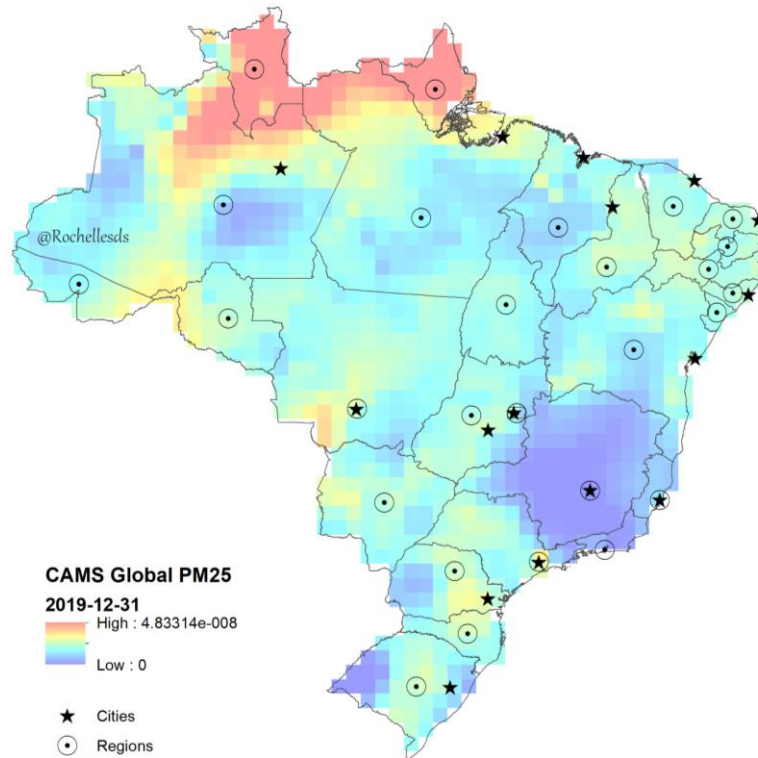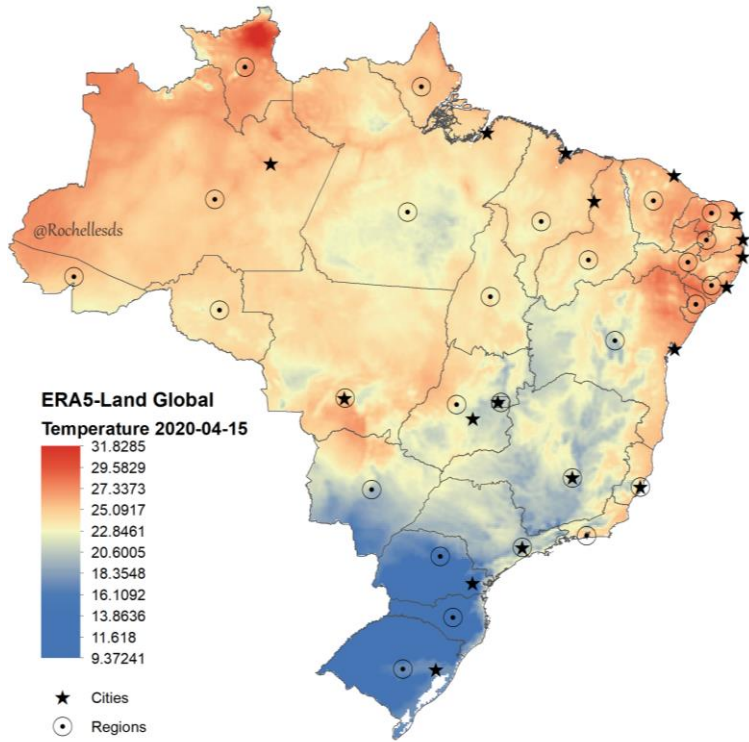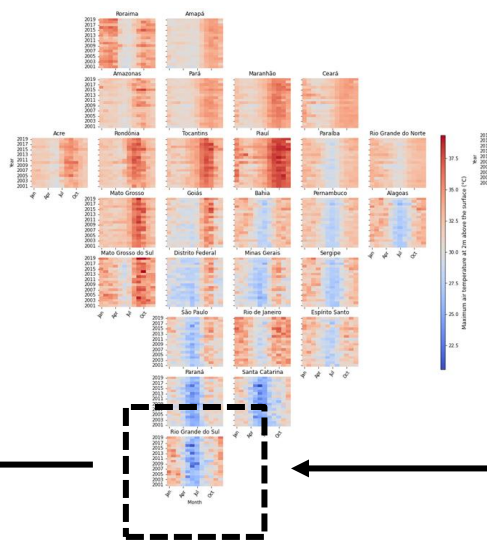
Example 2: Forecasting dengue outbreaks
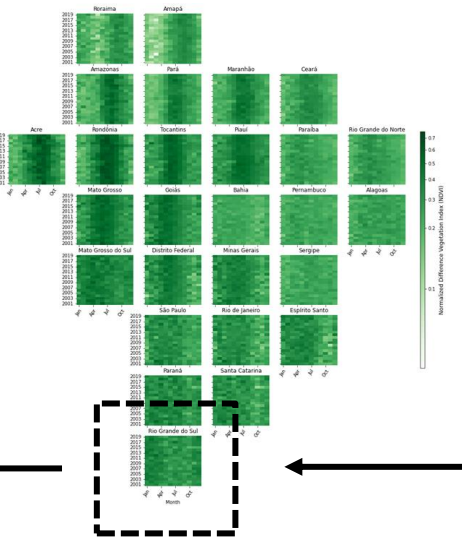

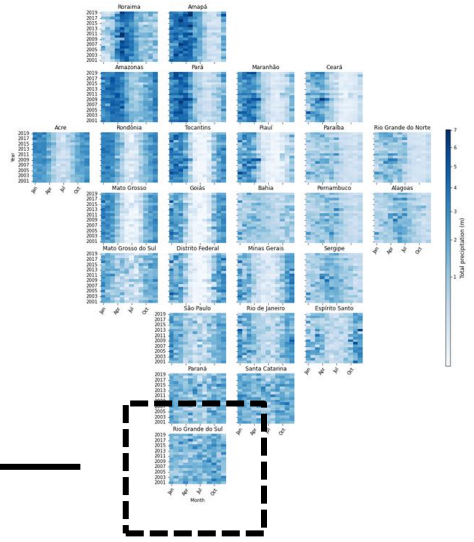**27 Brazilian States**

Dengue Incidence Rate (DIR)

2M MAX AIR TEMPERATURE

NDVI

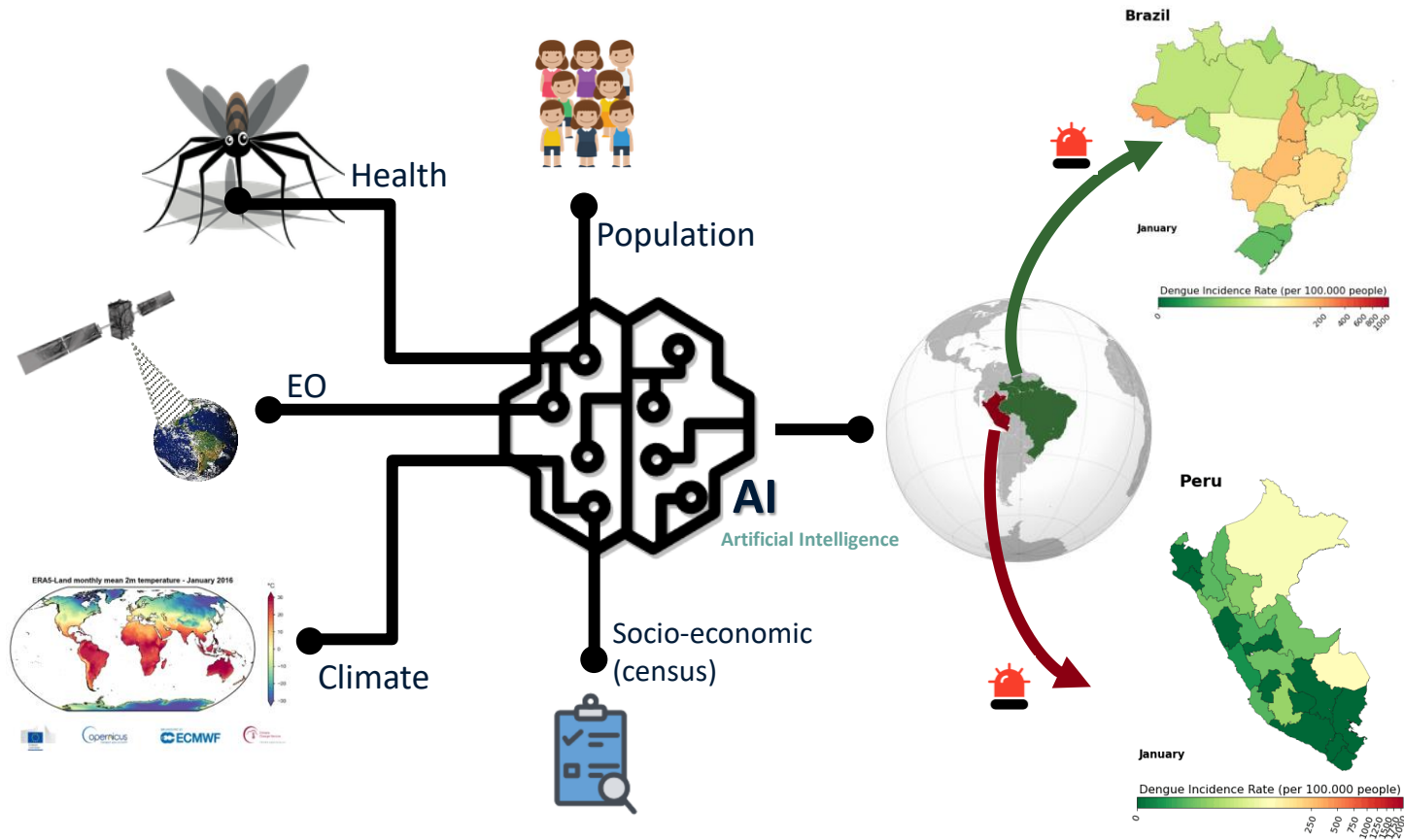**PRECIPITATION**

Each box shows the EO products by Brazilian State.
X-axis = Months
Y-axis = Years

Example 2: Forecasting dengue outbreaks

Health

Population

EO

AI
Artificial Intelligence

Climate

Socio-economic
(census)

Brazil
January
Dengue Incidence Rate (per 100.000 people)

Peru
January
Dengue Incidence Rate (per 100.000 people)

"This project is a perfect example of collaboration between a humanitarian organisation and a research entity to support the UN SDGs."

Dohyung Kim
Lead Data Scientist at the UNICEF Office of Global Innovation.

Multi-Award Winning Project

1 – UNESCO – IRCAI

GLOBAL TOP 100 AI solutions for **SDGs**

2 - Best of UNICEF Research

showcase the most rigorous, innovative and impactful research produced by UNICEF offices worldwide

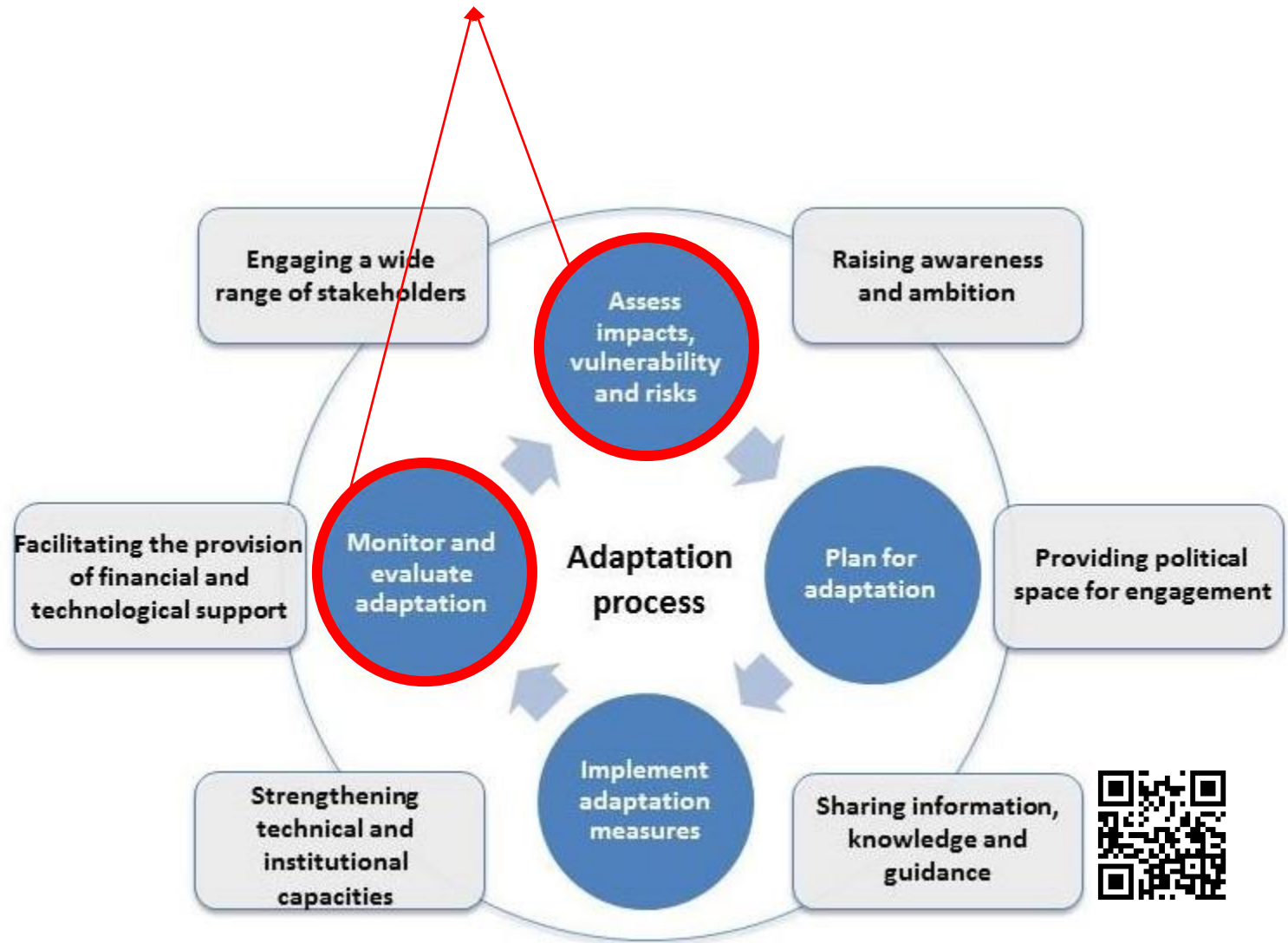### 3 – Wellcome Trust support
Independent charitable foundation

The Wellcome Trust has granted **over €600 000** to UNICEF and partners to develop an end-user web application

How to undertake adaptation?

Further EO4Health applications

ARTICLES — nature climate change
https://doi.org/10.1038/s41558-021-01058-x

The burden of heat-related mortality attributable to recent human-induced climate change

Data: WCRP CMIP6 — nature climate change

nature COMMUNICATIONS

ARTICLE
https://doi.org/10.1038/s41467-021-25914-8 — OPEN

A cross-sectional analysis of meteorological factors and SARS-CoV-2 transmission in 409 cities across 26 countries

Data: Copernicus — nature COMMUNICATIONS

THE LANCET Planetary Health

Small-area assessment of temperature-related mortality risks in England and Wales: a case time series analysis

Data: Copernicus

scientific reports — www.nature.com/scientificreports

OPEN **Differential impact of government lockdown policies on reducing air pollution levels and related mortality in Europe**

Data: Copernicus — nature SCIENTIFIC REPORTS

scientific reports — www.nature.com/scientificreports

OPEN **Comparison of weather station and climate reanalysis data for modelling temperature-related mortality**

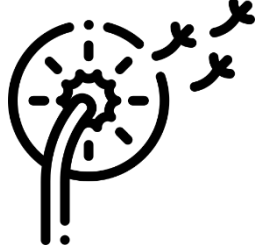Data: Copernicus — nature SCIENTIFIC REPORTS

GeoHealth

Research Article | Open Access

A Comparative Analysis of the Temperature-Mortality Risks Using Different Weather Datasets Across Heterogeneous Regions

Data: Copernicus

Adaptation activities under Climate-Space Initiative: Public Health

Environmental Hazards

Heatwave / Cold wave	Flood	Pollen
Air Pollution	Infectious diseases	Dust storms

Exploitation of **Earth observation** to support **adaptation and resilience-building**, **capacity building**, **loss and damage** aspects to support climate policy needs focused on **health** and **biodiversity**:

Public Health:

❖ Will **focus** initially on **heatwaves and infectious diseases**

❖ Expert meetings to collate requirements ongoing

❖ Complimentary and synergistic to

  ✓ Copernicus Health Hub - Official Launch | Copernicus

  ✓ EU's adaptation mission Mission Projects (europa.eu)

  ✓ GCOS adaptation task team (GCOS_GATT (amazonaws.com))

  ✓ ECCA ECCA2023 JPI Climate led

❖ **Mid 2024: Call for (up to 3) pilot projects**

Stay tuned at ESA Star Publication

THE EN

00:06

European Space Agency