Artificial Intelligence for Planetary Health

Challenges, Opportunities, and Human Choice

The Climate Change AI Summer School 2026: Climate & Health Series

Sara Khalid *BE MSc DPhil Oxon*

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Head | Planetary Health Informatics Lab

University of Oxford

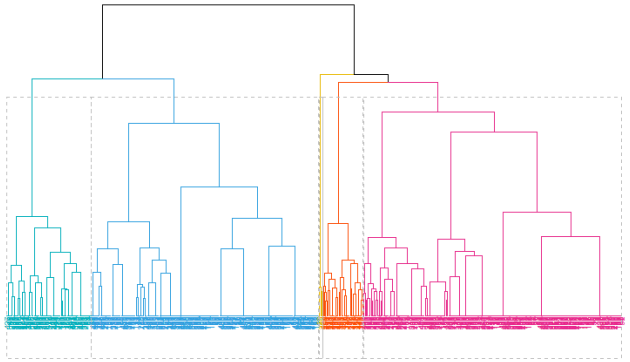
sara.khalid@ndorms.ox.ac.uk

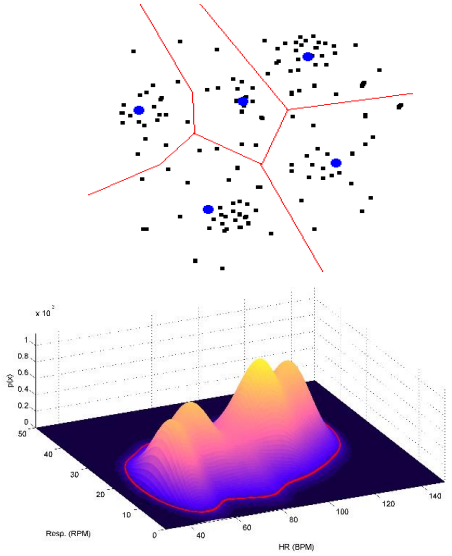
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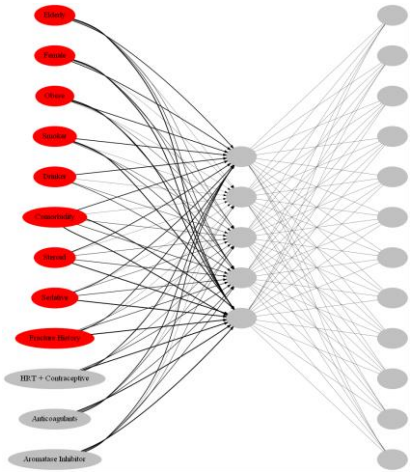
www.ndorms.ox.ac.uk/planetary-health-informatics

Outline

1. Climate Change and Planetary Health
2. The Role of Health Informatics
3. Challenges and Opportunities in Planetary Health Analytics





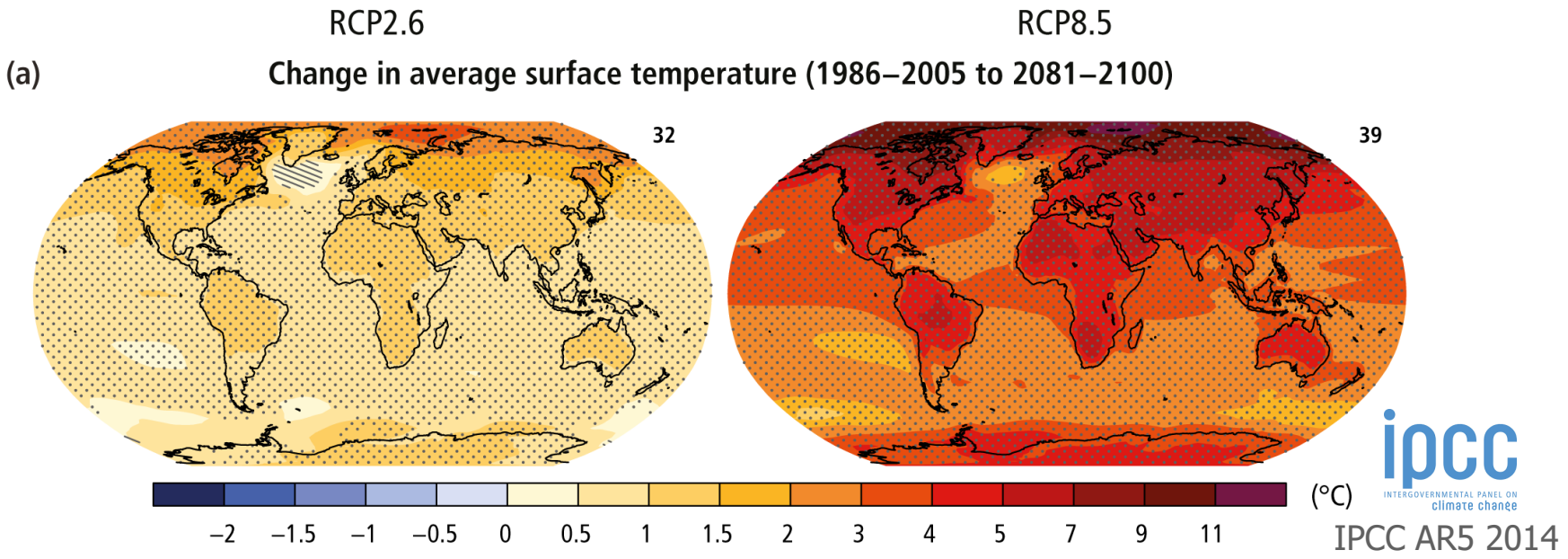


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Climate Change & Planetary Health

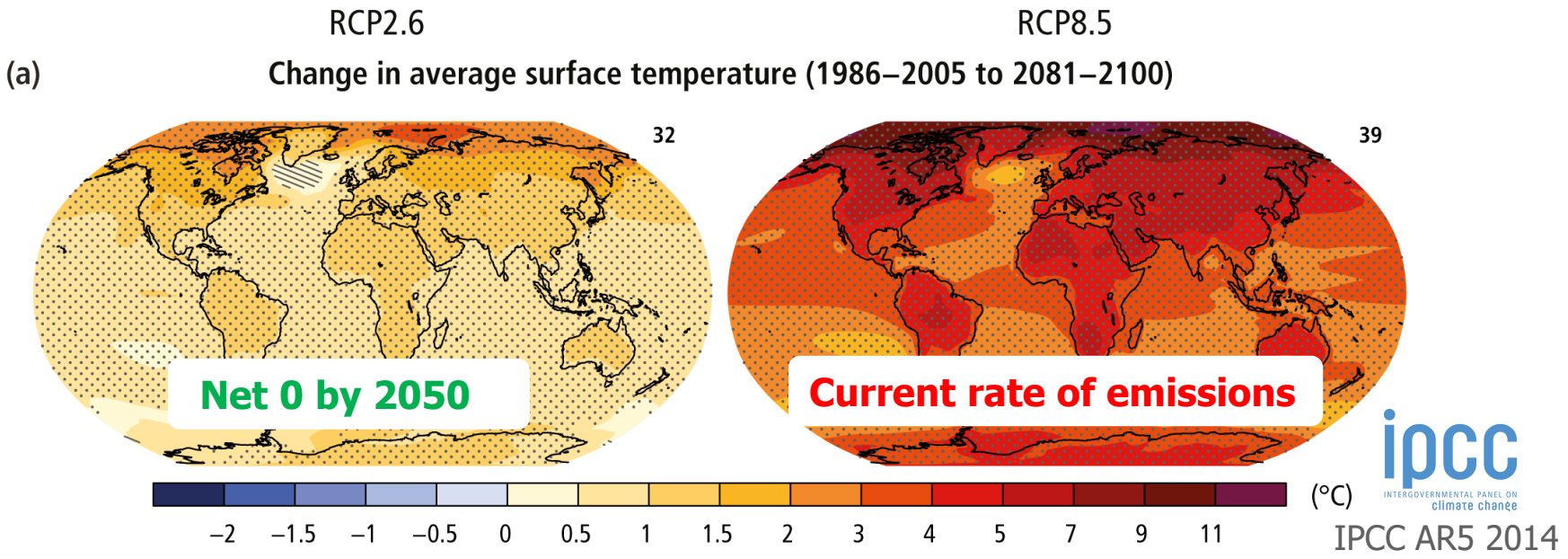
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A Rapidly Warming World



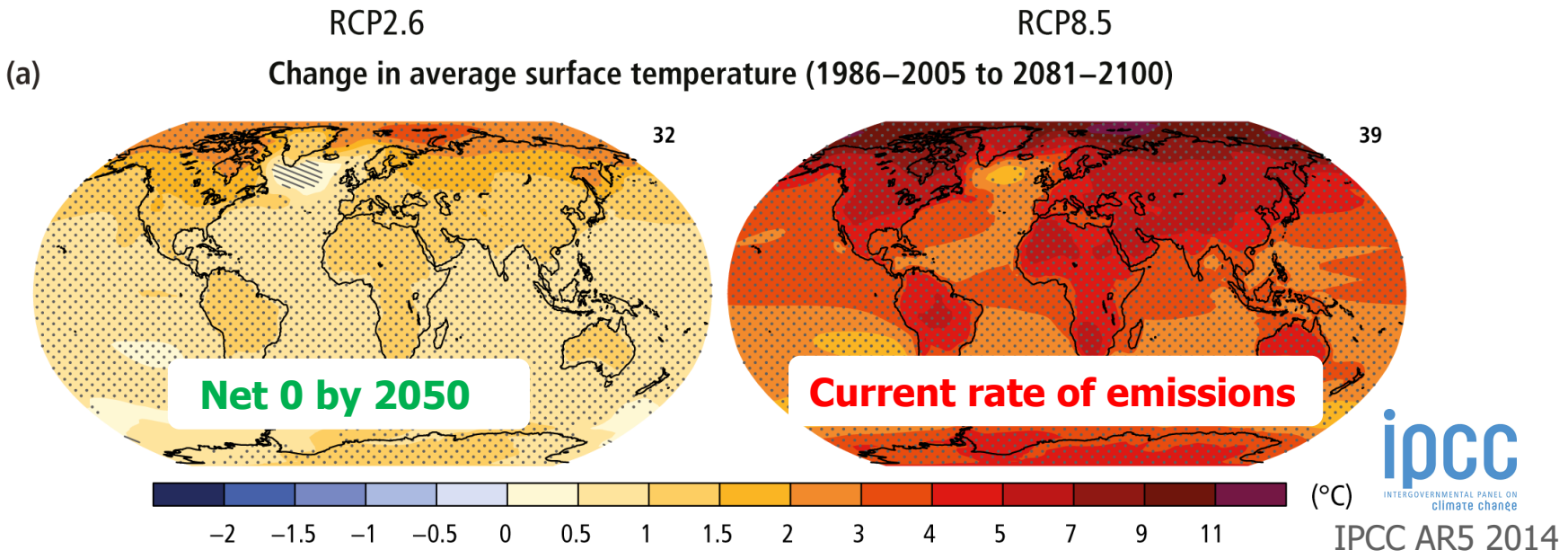
IPCC AR5 2014

A Rapidly Warming World



IPCC AR5 2014

A Rapidly Warming World



IPCC AR5 2014

"Climate change is the biggest global health threat of the 21s century"

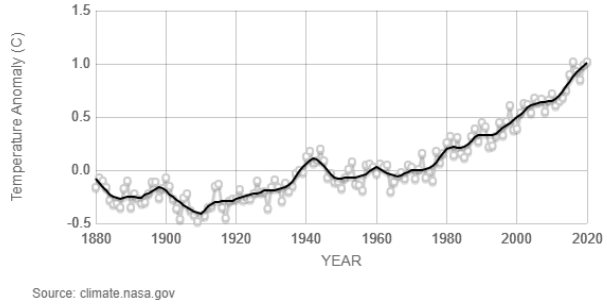
Lancet Commission 2009

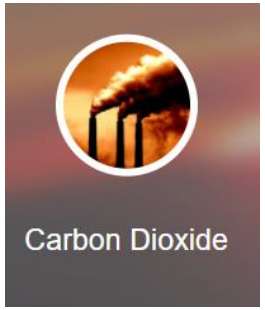
"Climate change threatens the very foundations of human health and wellbeing"

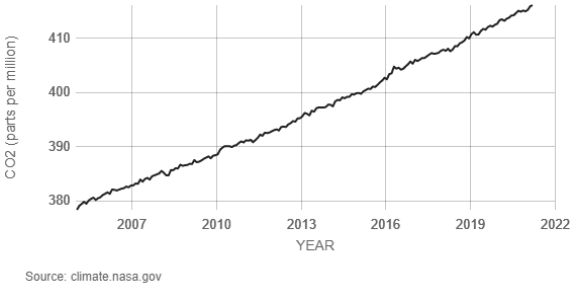
Lancet Countdown Report 2020

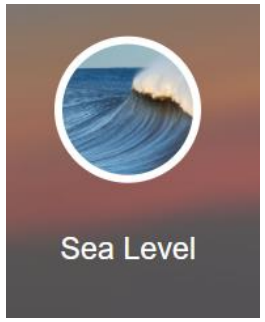
The Earth's Vital Signs

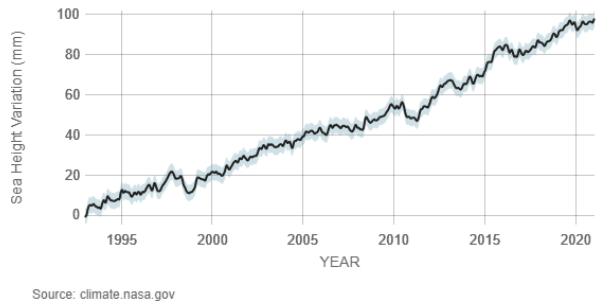




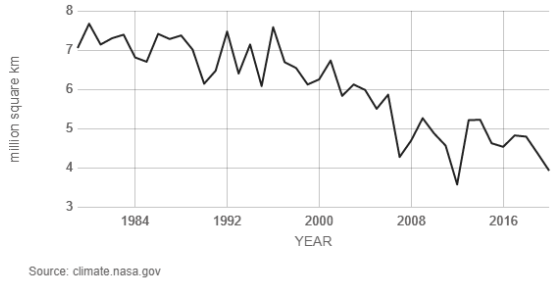








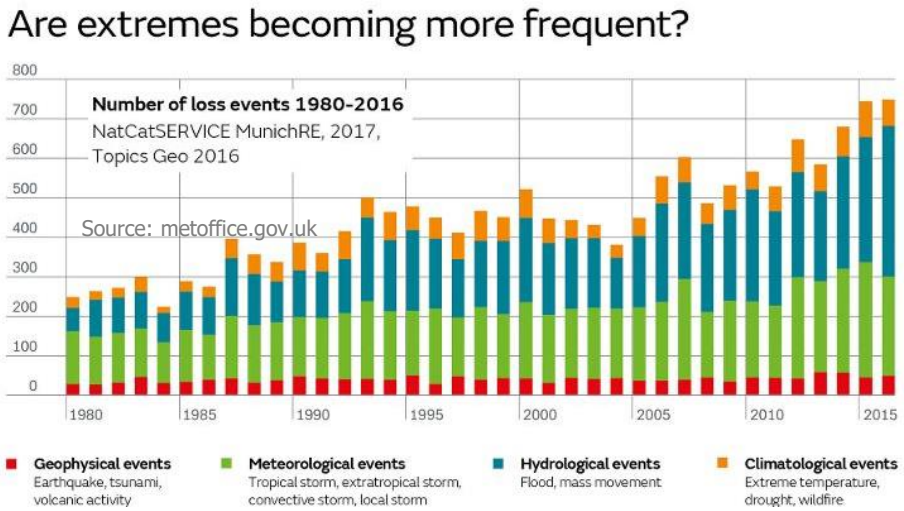




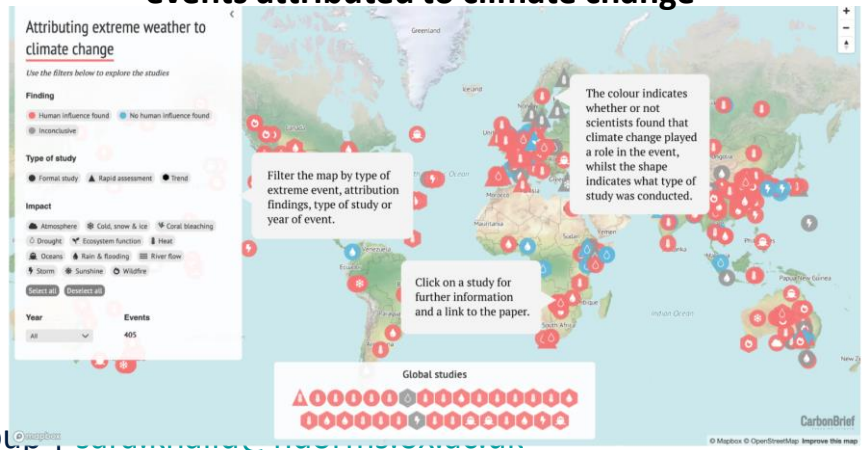


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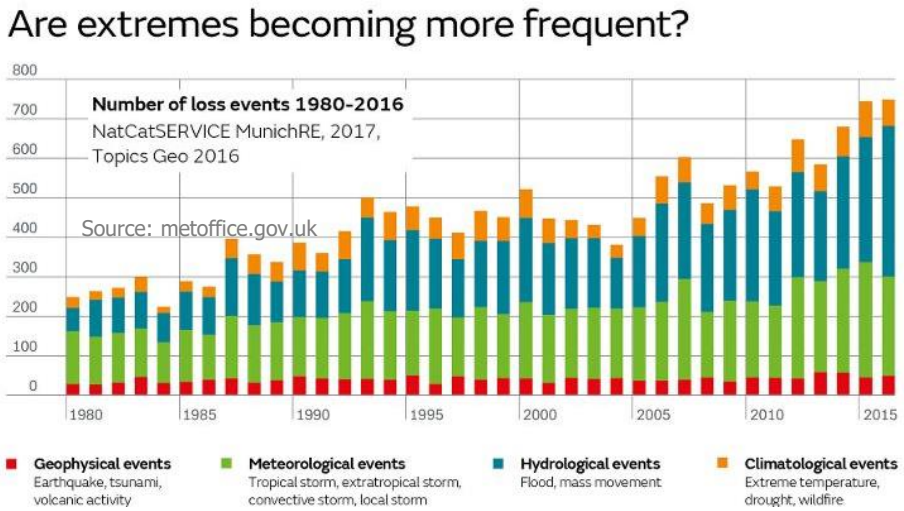
Change, Variability, Weather



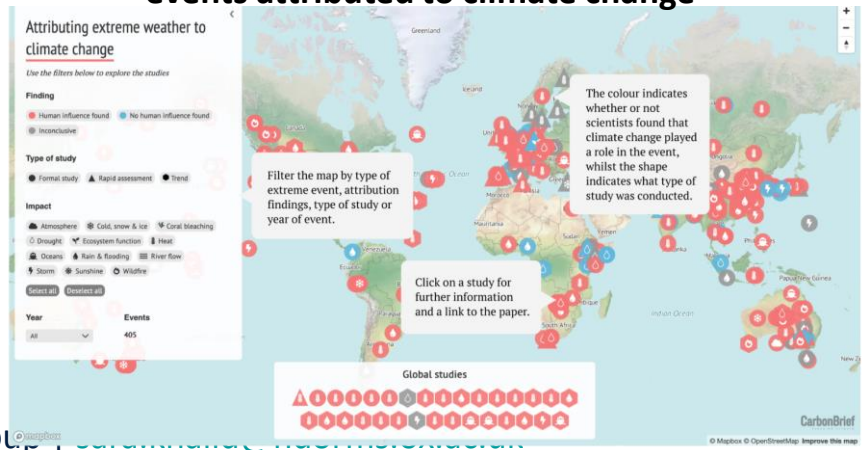
350+ peer-reviewed studies on 450 extreme weather events attributed to climate change

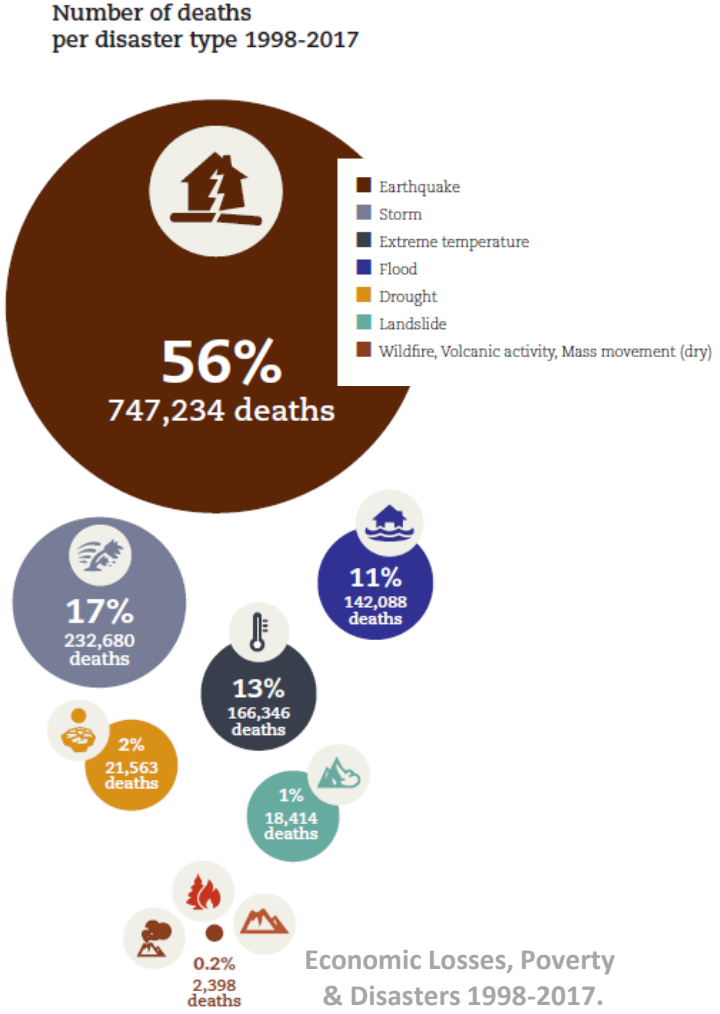


Change, Variability, Weather



350+ peer-reviewed studies on 450 extreme weather events attributed to climate change





Economic Losses, Poverty & Disasters 1998-2017. CRED, UNISDR Report 2018

Biodiversity Loss

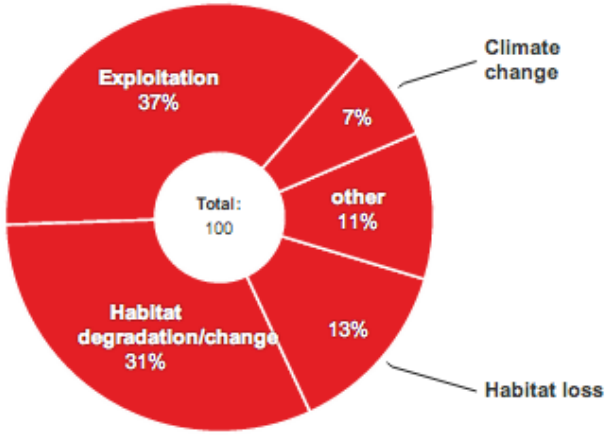
The Guardian

Earth has lost half of its wildlife in the past 40 years, says WWF



Causes of wildlife declines globally

WWF's 'Living Planet Index' categorises the causes of wildlife declines based on analysis of 3,430 species' populations

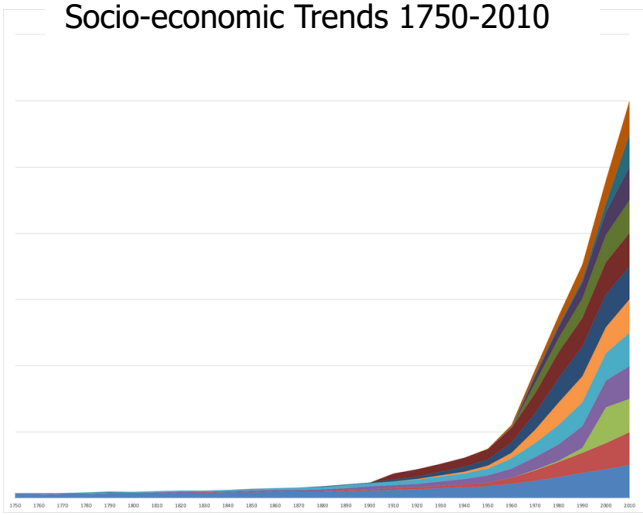


SOURCE: WWF

theguardian

Acceleration and Tipping Point

Socio-economic Trends 1750-2010

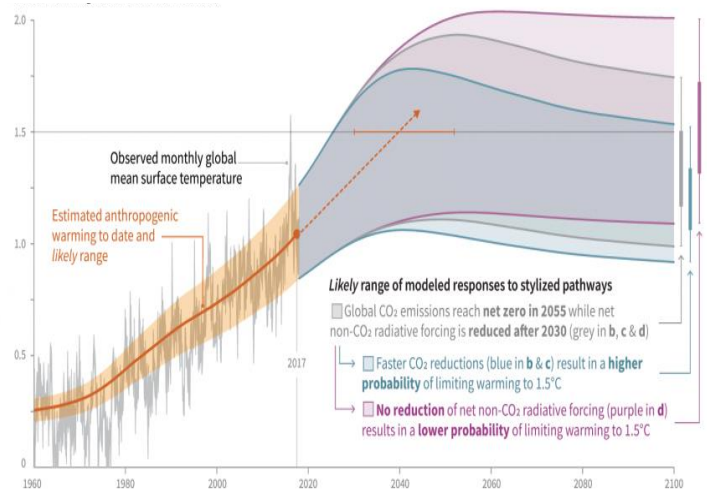


Bryan MacKinnon

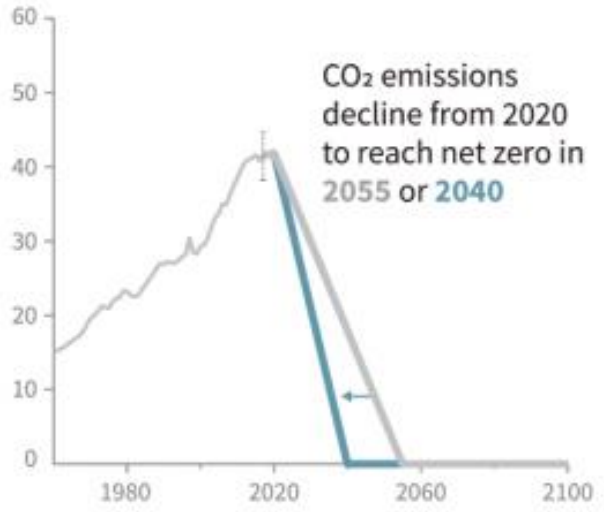
GLOBAL IGBP International Geosphere-Biosphere Programme CHANGE

- International Tourism: 0->939.9 millions of arrivals
- Telecommunications: 0->6.48 billion landlines & subscriptions
- Transportation: 0->1281.35 mega vechicles
- Paper Production: 0->398.77 megatons
- Water Use: 0->3.87 1000km3
- Large Dams: 0.06->31.63 >15 meter height
- Fertilizer consumption: 171.46 megatons
- Primary engergy use: 16->533.37 exajoule
- Urban Population: 0.05->3.5 billions
- Foreign Direct Investment: 0->1.3 trillion (2013 USD)
- Real GDP: 0.35->50.15 trillion (2005 USD)
- World Population: 0.73->6.9 billions

Global Warming Relative to 1850 -1900

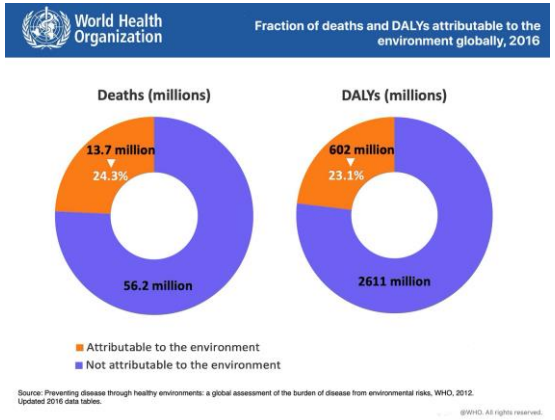


ipcc INTERGOVERNMENTAL PANEL ON climate change



Links with Health

- “85 of 102 investigated diseases are related to the environment.”
  - WHO Preventing Disease Through Healthy Environment 2006
- ¼ deaths worldwide linked to environment
  - WHO Preventing Disease Through Healthy Environment 2012





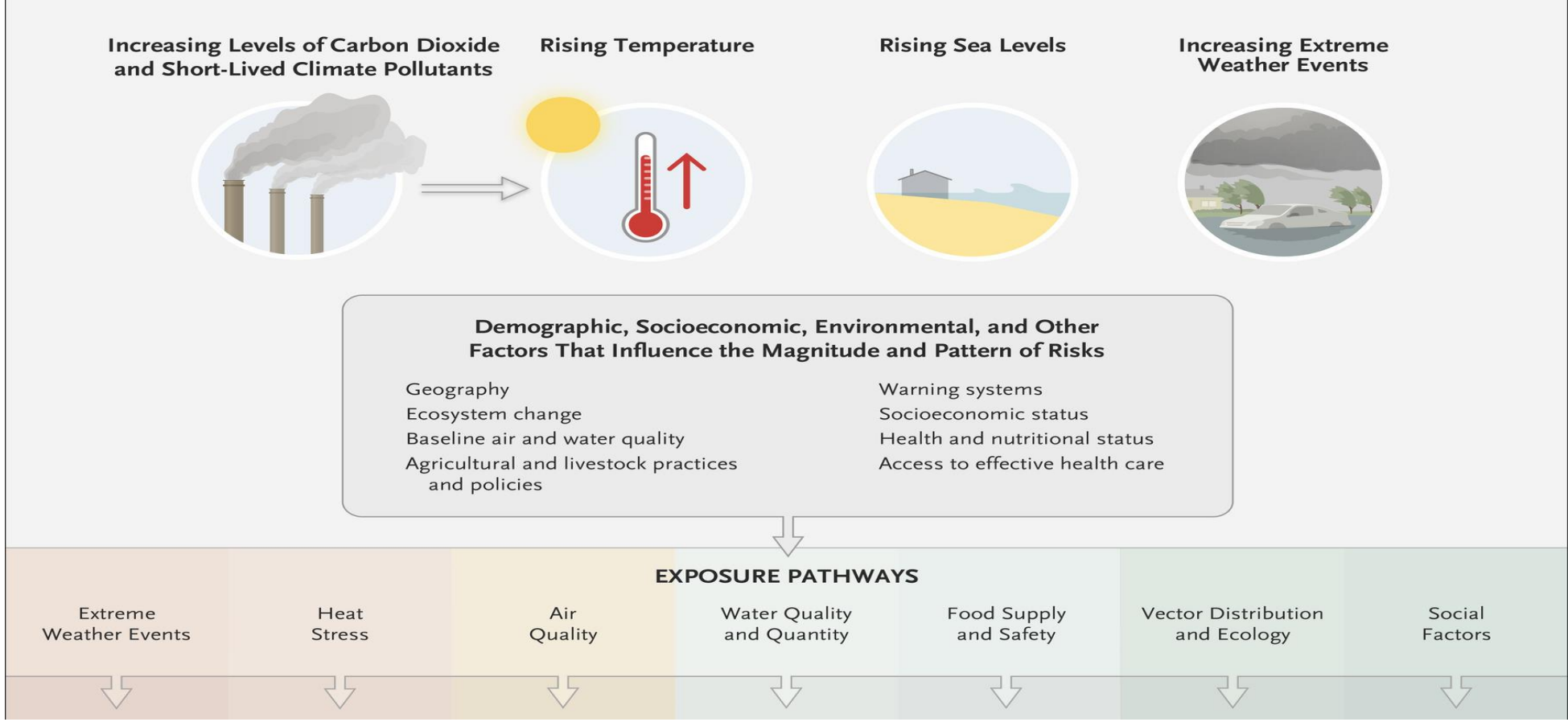






Health Impacts

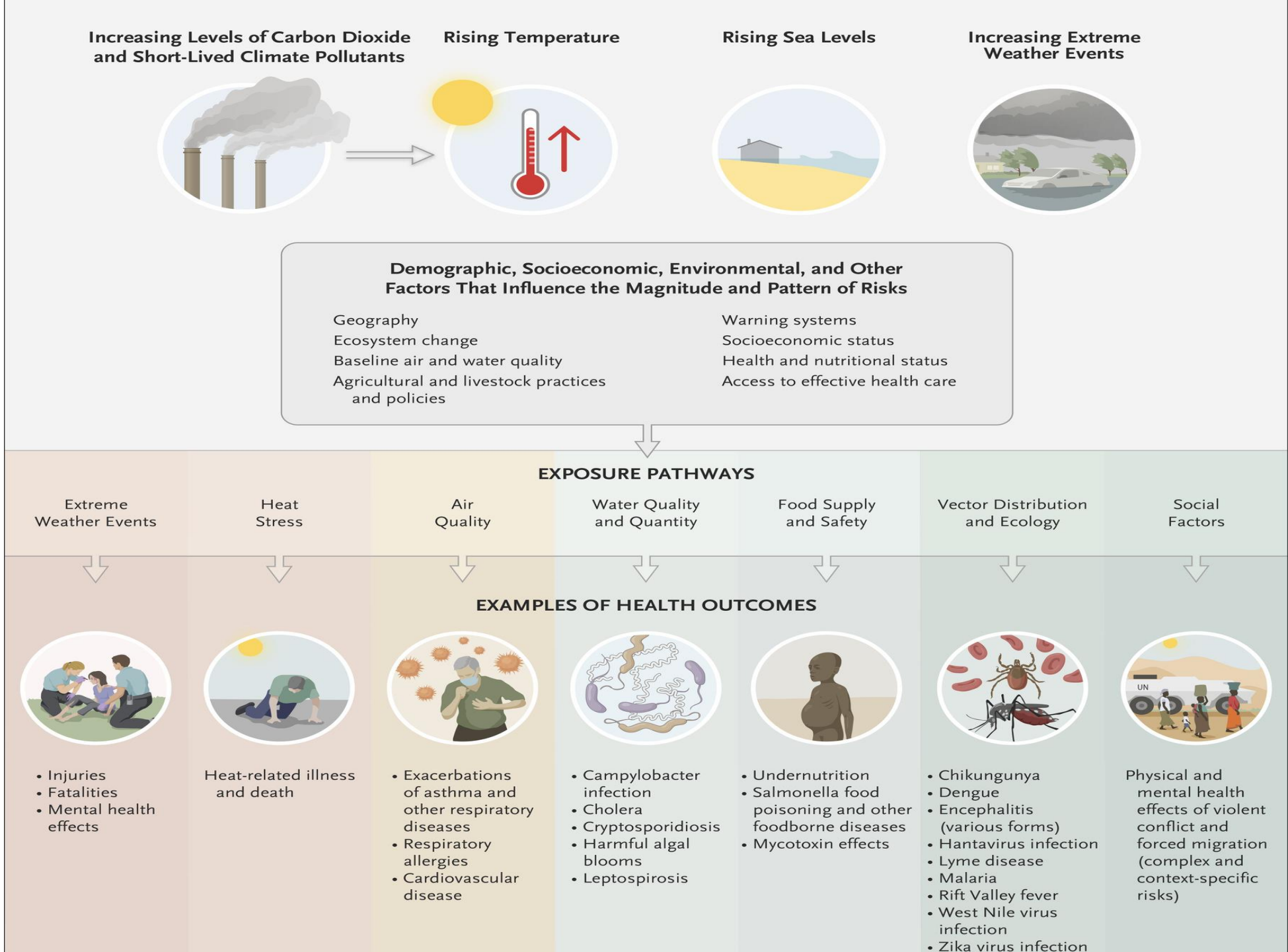
- Direct
- Indirect
- Long-term



Haines et al. Engl J Med 2019
DOI:
10.1056/NEJMra1807873

Health Impacts

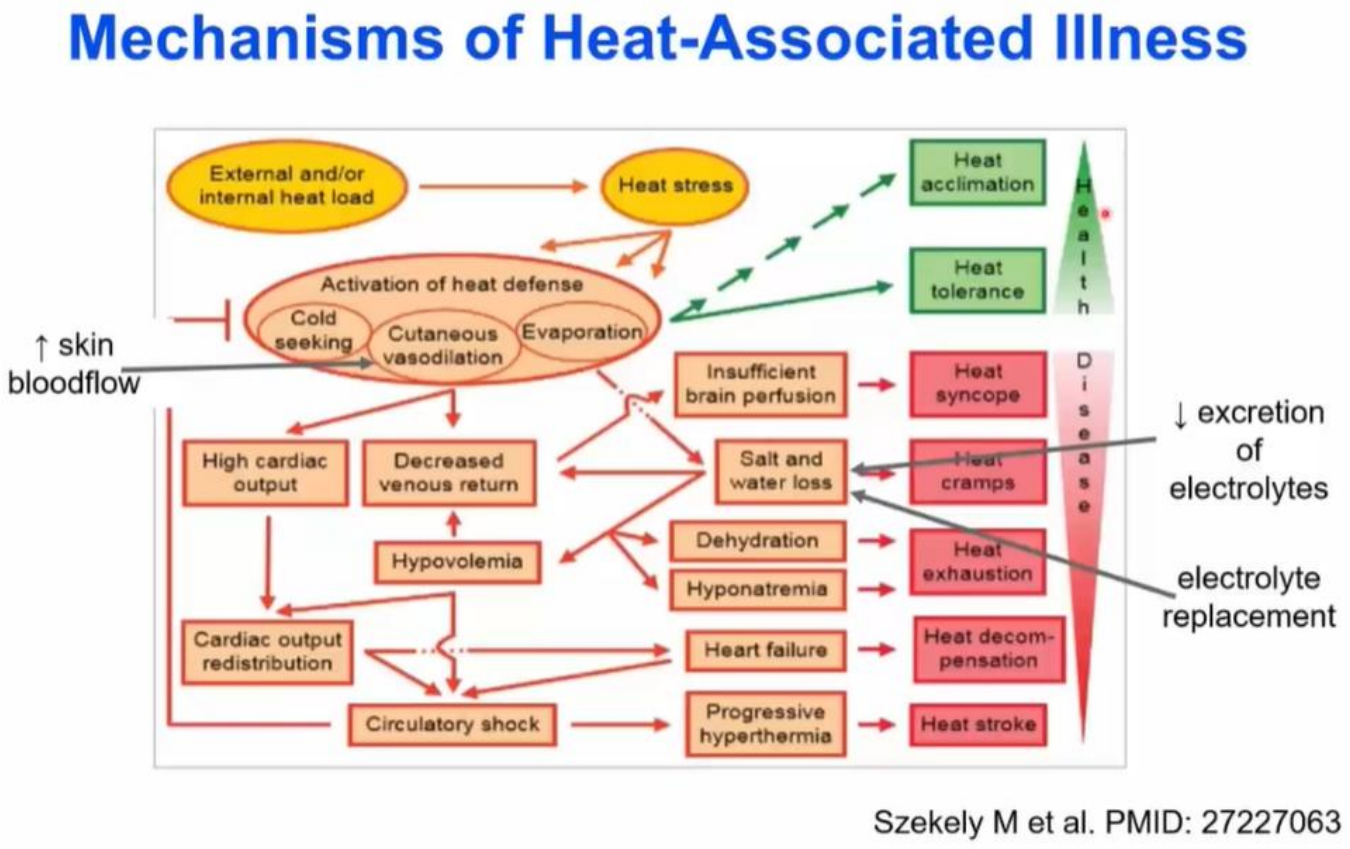
- Direct
- Indirect
- Long-term



Haines et al. Engl J Med 2019
DOI:
10.1056/NEJMra1807873

Heat and Health

- Direct
  - Heat stroke
  - Cramps
  - Exhaustion
  - Hyper/hypo-thermia
- Chronic Conditions
  - Cardiovascular disease
  - Diabetes
  - Respiratory disease
  - Cerebrovascular disease
- Hospitalisations
  - Cardiovascular
  - renal
  - respiratory disorders



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Heat and Health

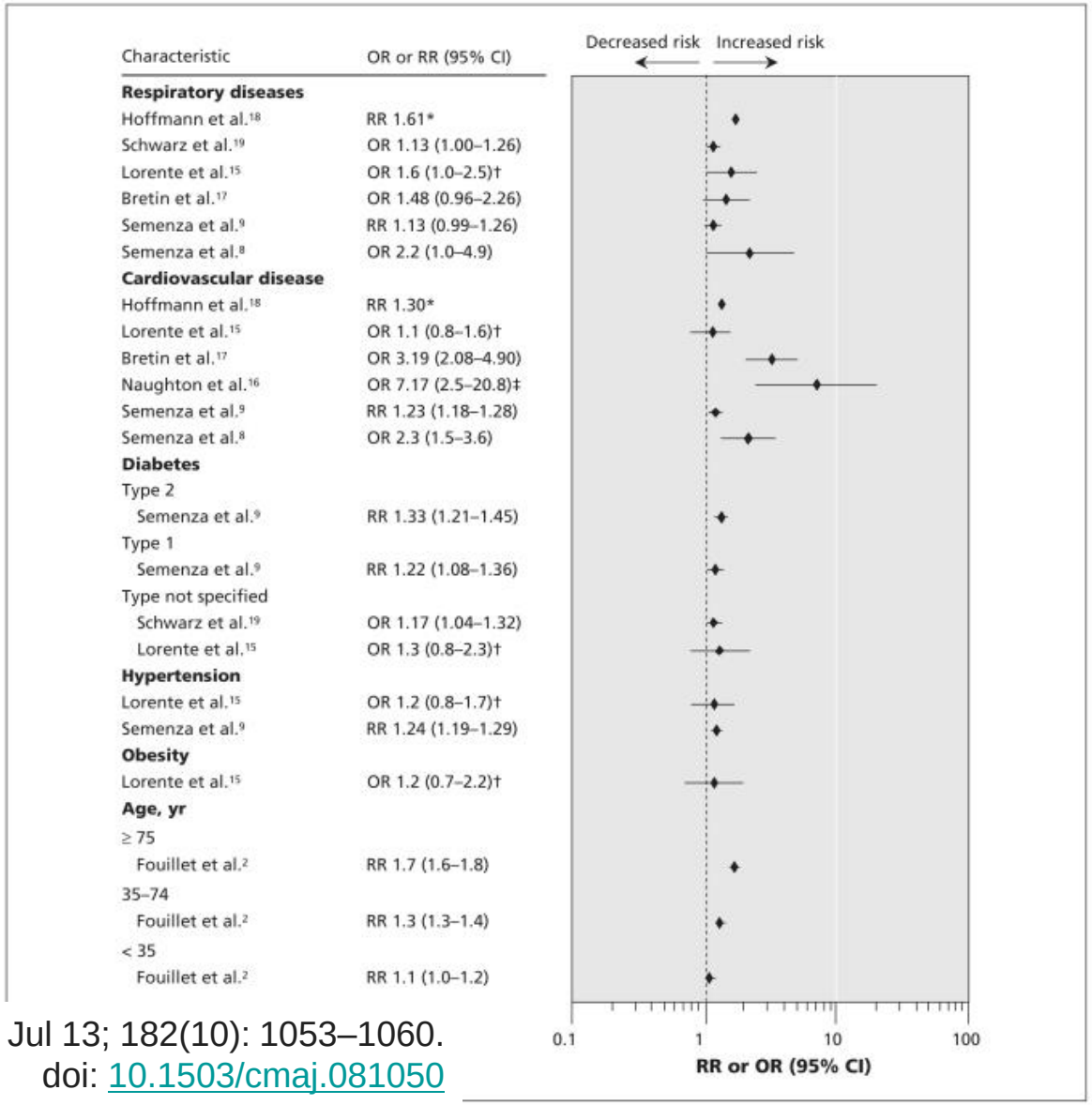
- **Who is most vulnerable?**

Kenny et al. CMAJ. 2010 Jul 13; 182(10): 1053–1060.
doi: 10.1503/cmaj.081050

Heat and Health

- **Who is most vulnerable?**
  - **Multi-morbidity**, poly-pharmacy
  - Older adults
  - Young children
  - Pregnancy, menopause in women
  - Outdoor, unventilated occupations

- Social determinants and Disparities
  - Socioeconomic status
  - Lifestyle factors
  - Ethnicity/Genetics



Kenny et al. CMAJ. 2010 Jul 13; 182(10): 1053–1060.
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Heat and Health

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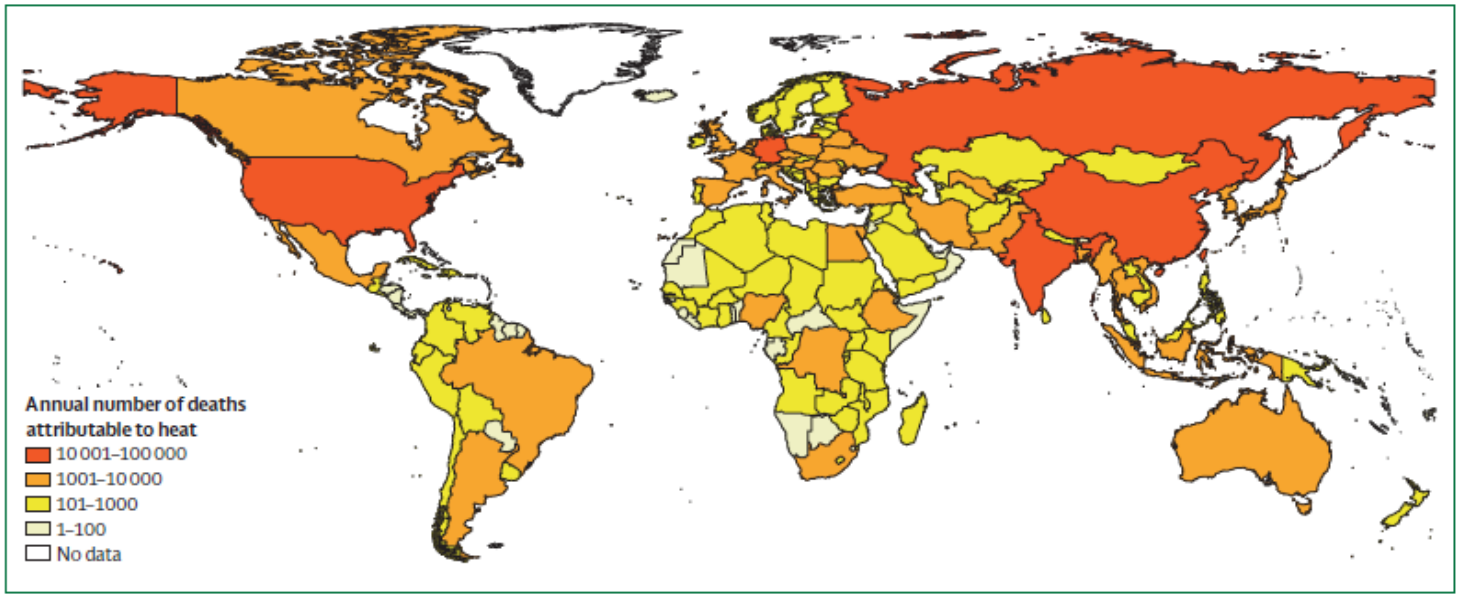


Figure 3: Annual heat-related mortality in the population older than 65 years averaged from 2014 to 2018

"Over 50% increase in heat-related mortality in people older than 65 years, resulting in a total of 296 000 deaths in 2018."

Lancet Countdown 2015

Kenny et al. CMAJ. 2010 Jul 13; 182(10): 1053–1060.
doi: 10.1503/cmaj.081050

Air Pollution and Mortality

World Health Organization

Household air pollution

3.8 million

deaths every year as a result of exposure to indoor smoke from cooking fuels

4.2 million

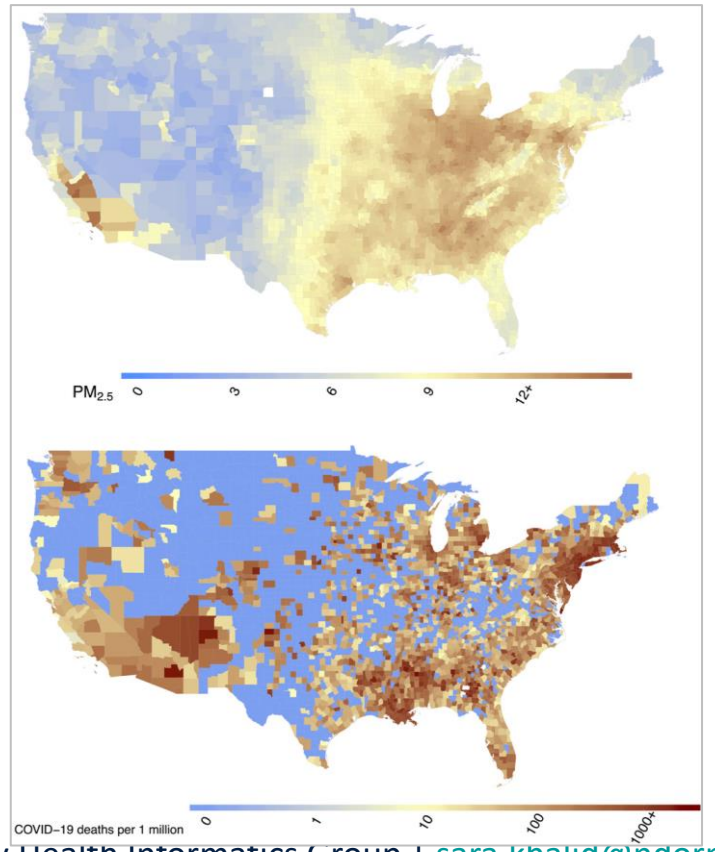
deaths every year as a result of exposure to fine particulate matter

www.who.int/data

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Air Pollution and Mortality

Historical $PM_{2.5}$ concentrations (top) and COVID-19 deaths (bottom) in the US.



X. Wu et al. Science Advances 04 Nov 2020:
Vol. 6, no. 45, DOI: 10.1126/sciadv.abd4049

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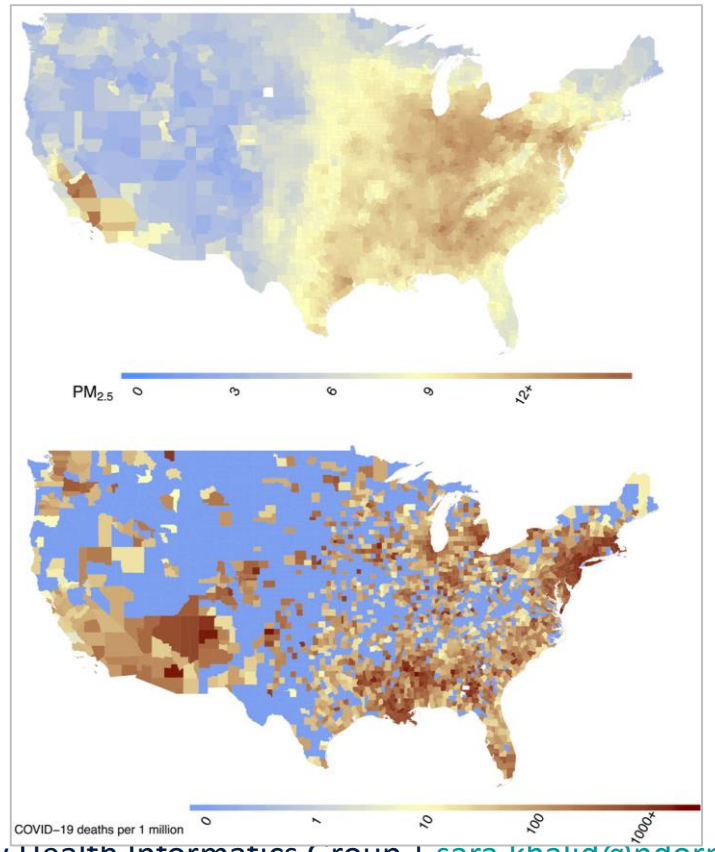
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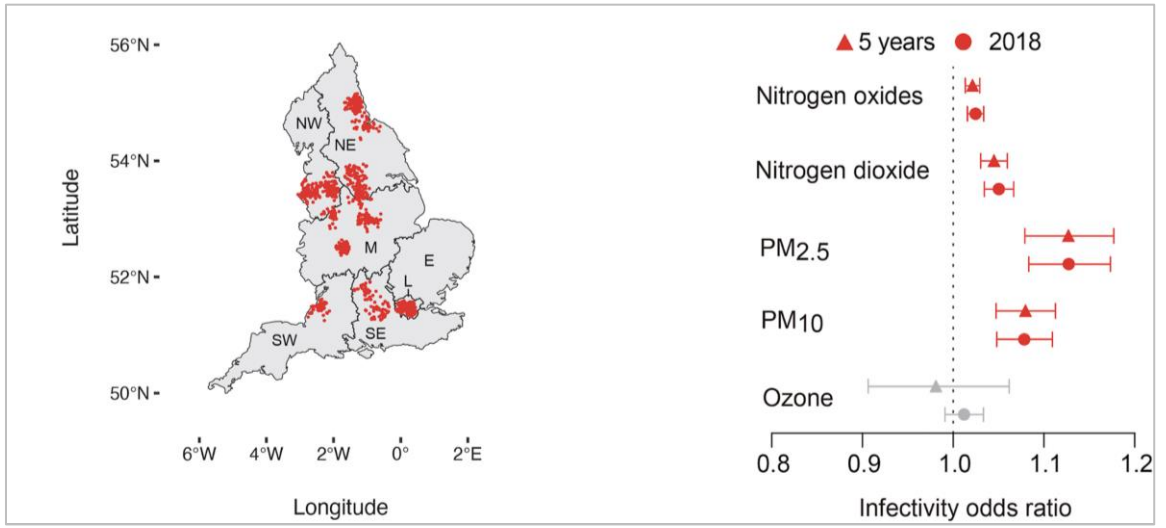
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Historical $PM_{2.5}$ concentrations (top) and COVID-19 deaths (bottom) in the US.





Association between exposure to air pollutants and the number of lab-confirmed COVID-19 cases in the UKBiobank.

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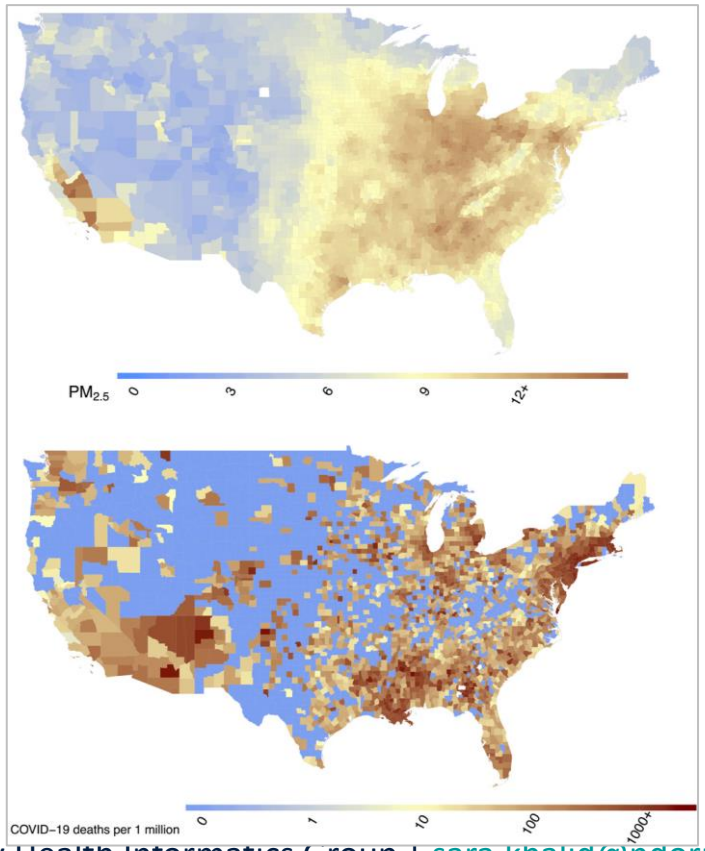
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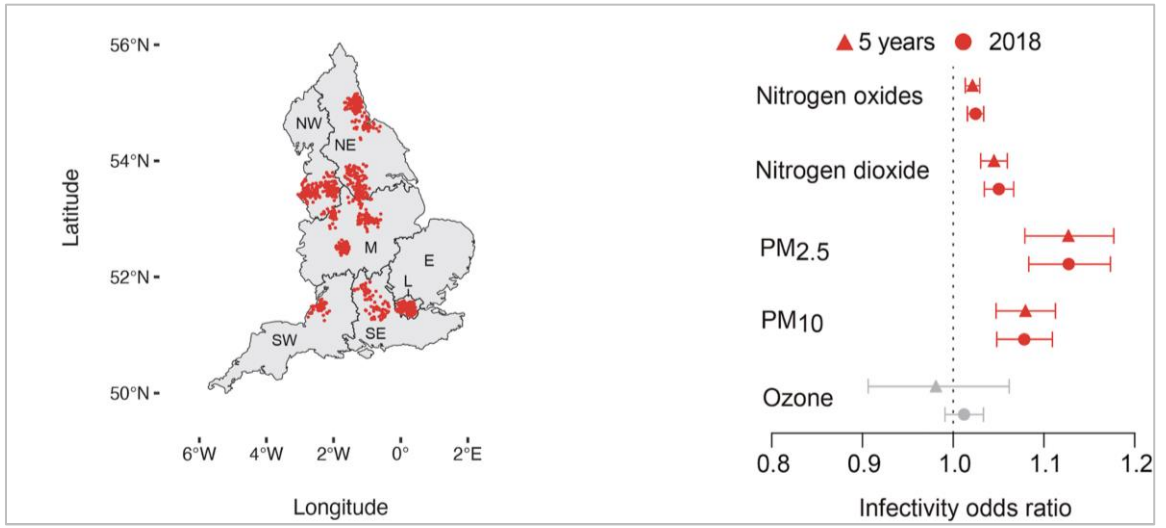
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X. Wu et al. *Science Advances* 04 Nov 2020:
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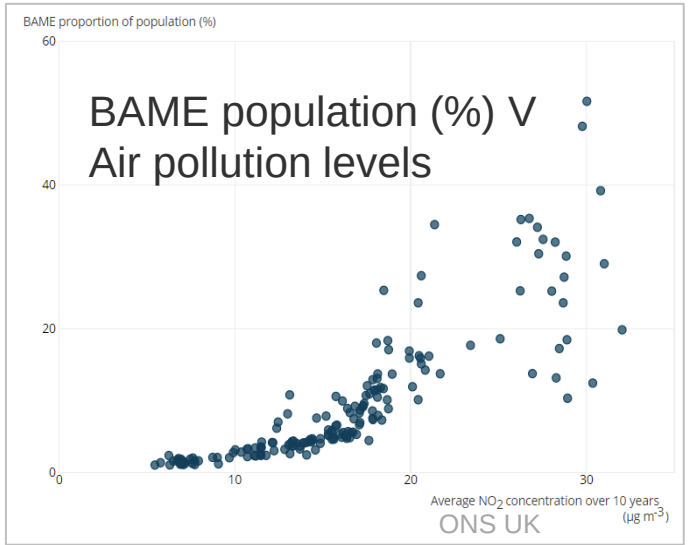
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…and More

Effects of environment on mental health

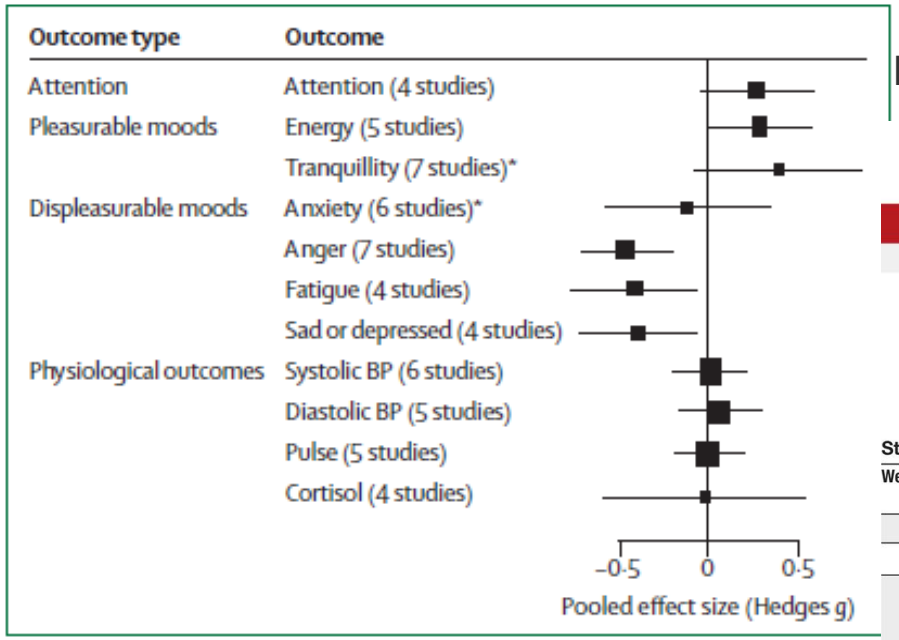


Figure 18: **Psychological and emotional outcomes from exposure to natural versus synthetic environments**

Bowler, D et al. BMC Public Health,2010. https://doi.org/10.1186/1471-2458-10-456

Effect of weather on pain

PAIN®
The Journal of the International Association for the Study of Pain

Articles & Issues | Collections | Videos | For Authors | Journal Info

NARRATIVE REVIEW

Outline

Images

Are weather conditions associated with chronic musculoskeletal pain? Review of results and methodologies

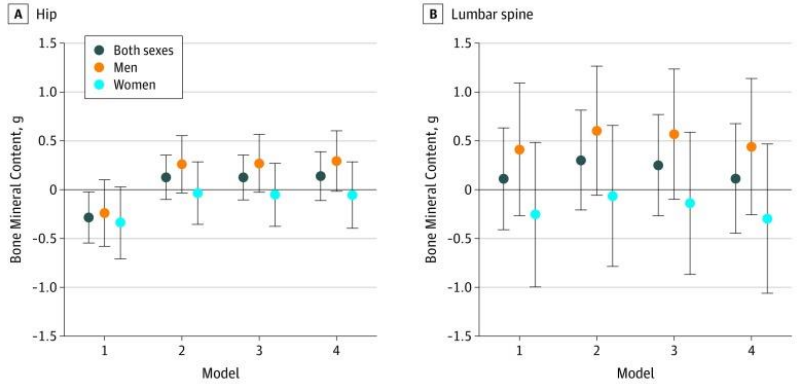
Beukenhorst, Anna L.[a,*]; Schultz, David M.[b,c]; McBeth, John[a,d]; Sergeant, Jamie C.[a,e]; Dixon, William G.[a,d]

Study results by weather variable, ordered by number of studies that investigated the weather variable.

Weather variable	No. of studies investigating this variable	No. of studies finding no association with pain (%)	No. of studies finding an association with pain (%)
Temperature	41	21 (51)	20 (49)
Atmospheric pressure	41	20 (49)	21 (51)
Humidity			
Relative humidity	35	16 (46)	19 (54)
Vapor pressure	6	3 (50)	3 (50)
Dew-point temperature	3	2 (67)	1 (33)
Precipitation	30	8 (27)	22 (73)
Wind speed	20	9 (45)	11 (55)
Sunshine	16	5 (31)	11 (69)
Cloud cover	7	3 (43)	4 (57)
Wind direction	3	0 (0)	3 (100)
Wind gust	2	1 (50)	1 (50)
Leuven weather index	2	1 (50)	1 (50)

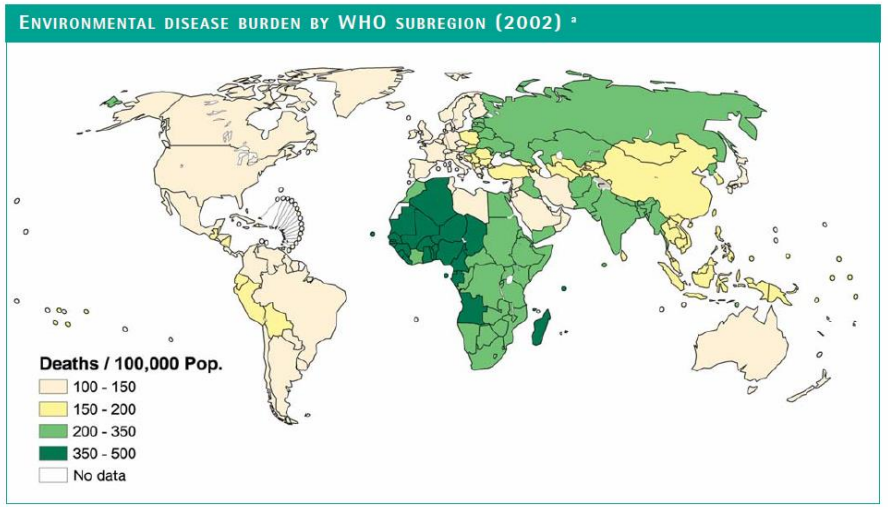
PAIN 161(4):668-683, April 2020.

Effects of air pollution on musculosketal health



Ranzani, O et al. JAMA Open 2020. doi: 10.1001/jamanetworkopen.2019.18504

A Planet-wide Problem



Prüss-Üstün et al. WHO Preventing Disease Report 2006

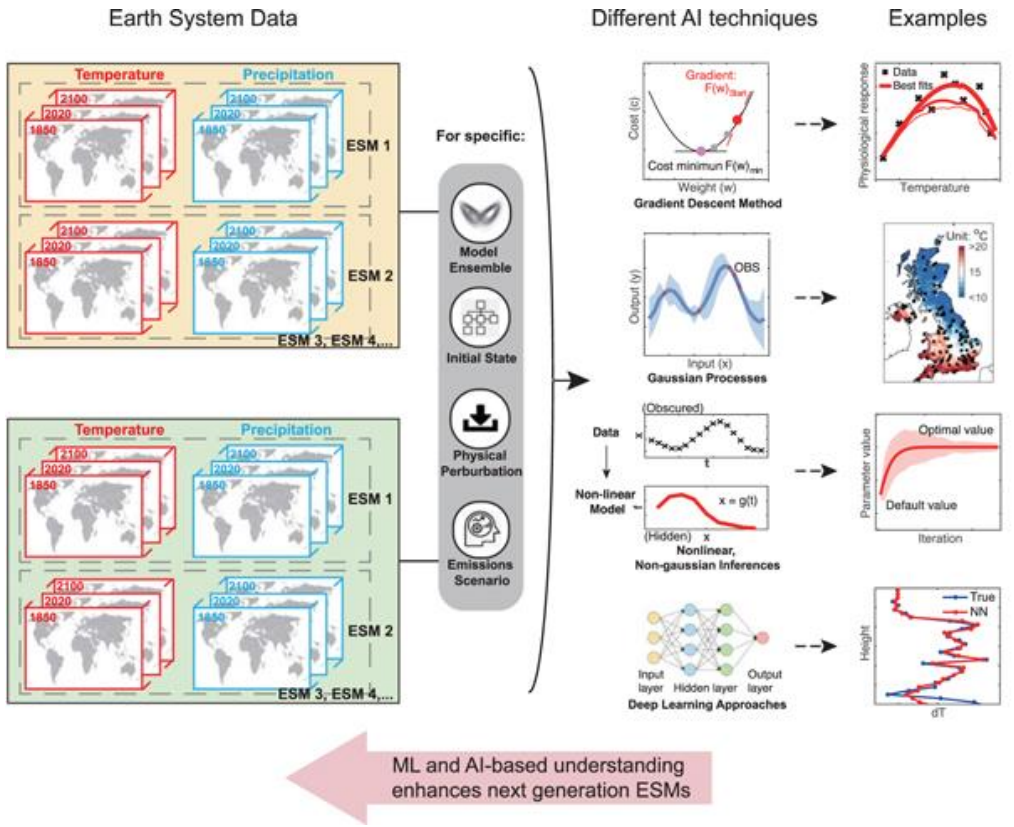
Cramer et al. Detection and attribution of observed impacts. Climate Change 2014, IPCC 5th AR

"This is the first time a global generation of children will grow up in a world made far more dangerous and uncertain as a result of a changing climate and degraded environment."
UNICEF

Health Informatics & Planetary Health

Climate Data Science

- Earth systems modelling
  - e.g. classification of land cover
- Future climate scenarios
- Weather forecasting
- Extreme event prediction
  - e.g. flood prediction
- Climate impacts
  - e.g. on agriculture, health, economics
- Data curation and data quality
  - e.g. point-, grid-, satellite-based precipitation, temperature, vegetation, built environment data

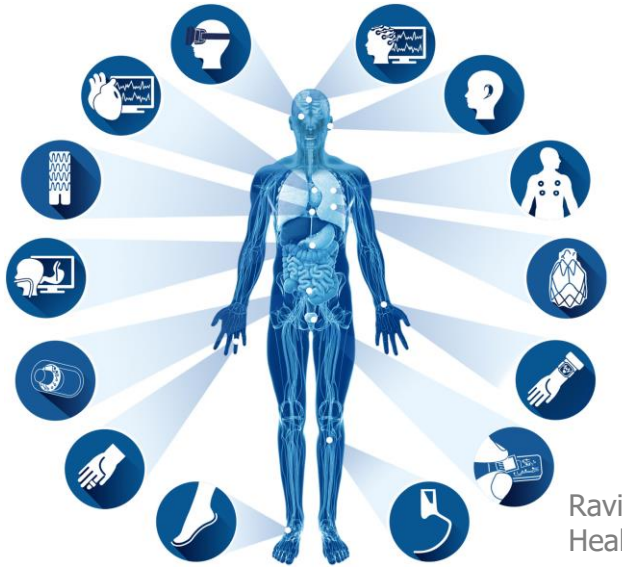


Huntingford C *et al* 2019 *Environ. Res. Lett.* **14** 124007

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Health Data Science

- Providing real-time, real-world **data**

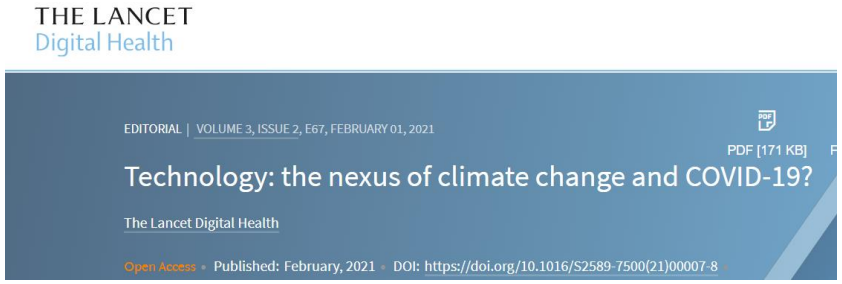


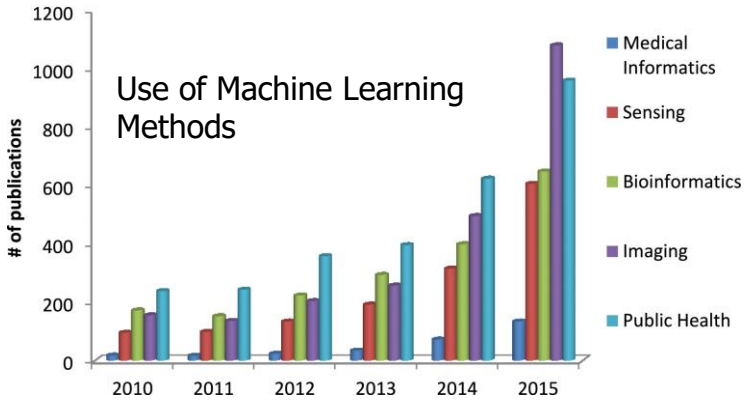
Ravi et al., IEEE Biomed & Health Informatics 2017

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Health Data Science

- Providing real-time, real-world **data**
- Improving **knowledge** on climate and health



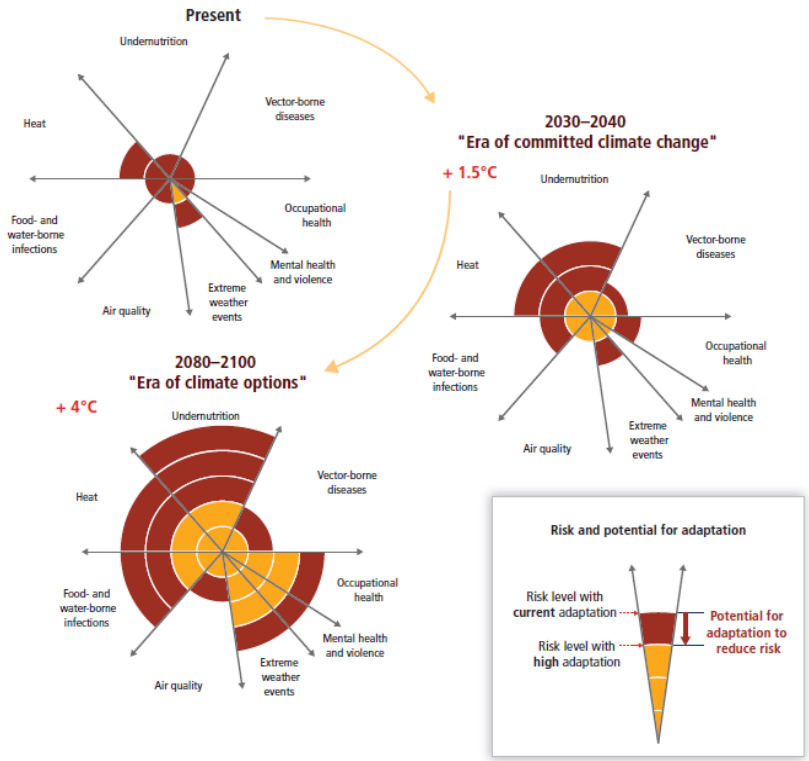


Ravi et al. IEEE Biomed & Health Informatics 2017

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Health Data Science

- Providing real-time, real-world **data**
- Improving **knowledge** on climate and health
- **Adaptation** of health systems to changing climate



Climate impact on 8 health sectors and potential for mitigation through adaptation.

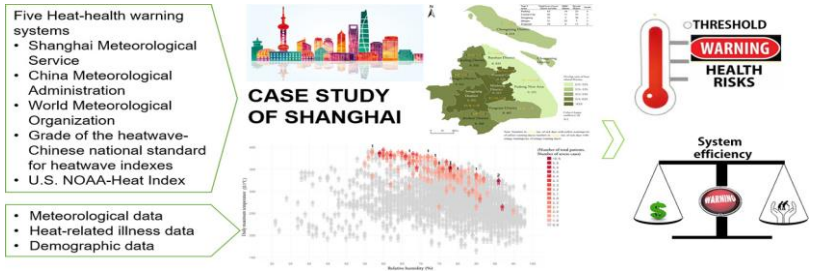
Smith et al. Human health: impacts, adaptation, and co-benefits.
Climate Change IPCC 5th AR 2014

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Early Warning Systems

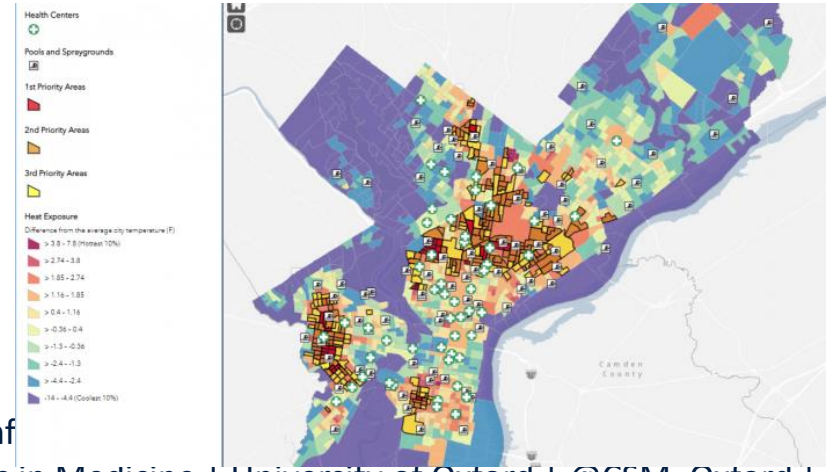
- Traditionally based on local knowledge
- Intelligent EWS based on
  - Expert knowledge
  - Real-time big data
  - Advanced analytics

Evaluation of heat-health warning systems in Shanghai, China

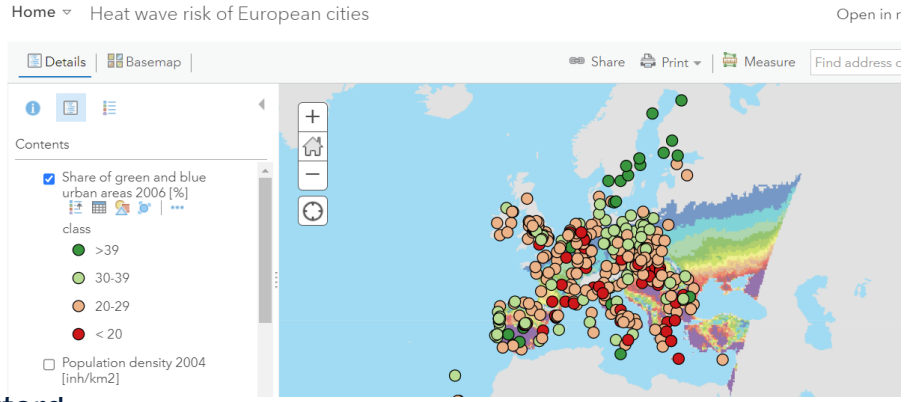


Yaqiao et al. Science of The Total Env. https://doi.org/10.1016/j.scitotenv.2020.136883

Heat risk index Philadelphia, USA.



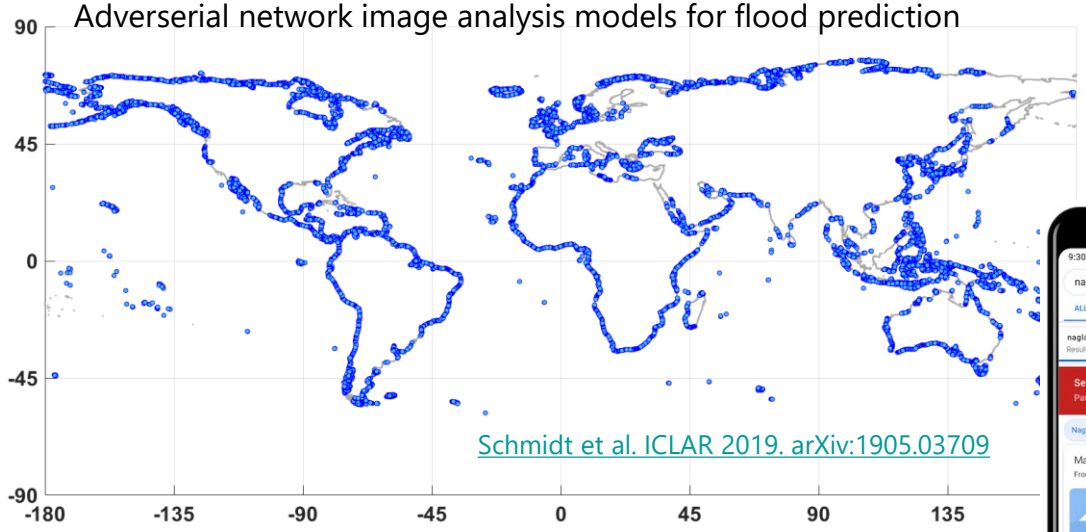
Heat risk map. European Environment Agency



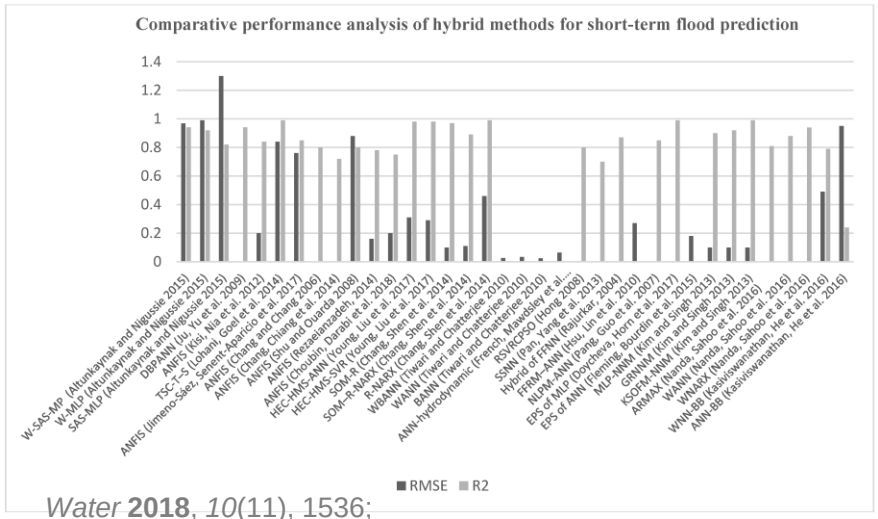
Source: www.phi.maps.arcgis.com

Flood Prediction Models

Adverserial network image analysis models for flood prediction

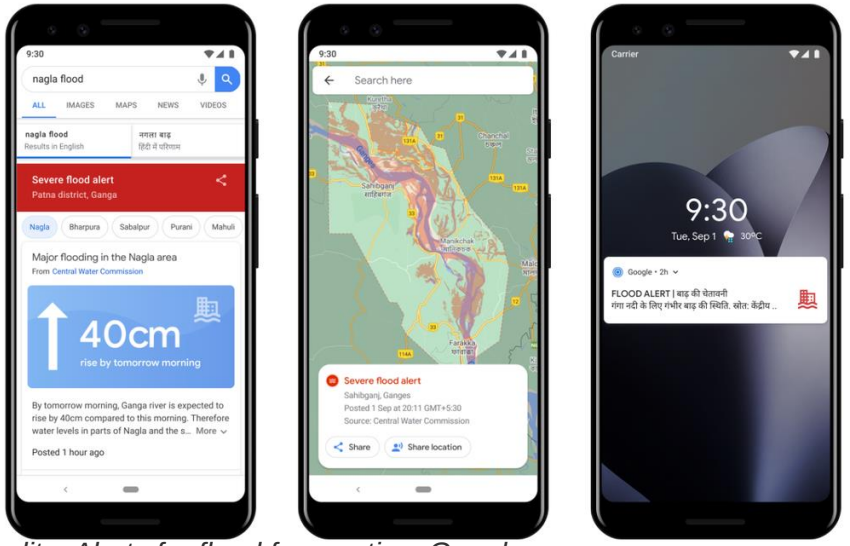


Schmidt et al. ICLAR 2019. arXiv:1905.03709



Water **2018**, *10*(11), 1536; https://doi.org/10.3390/w10111536

Google Flood Forecasting Initiative in use in India and Bangladesh



Credits: Alerts for flood forecasting, Google

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Predicting Disease Outbreaks



Satellite data from Landsat series combined with ground data on precipitation, temperature, soil moisture, vegetation



Computational models tracking human and environmental events

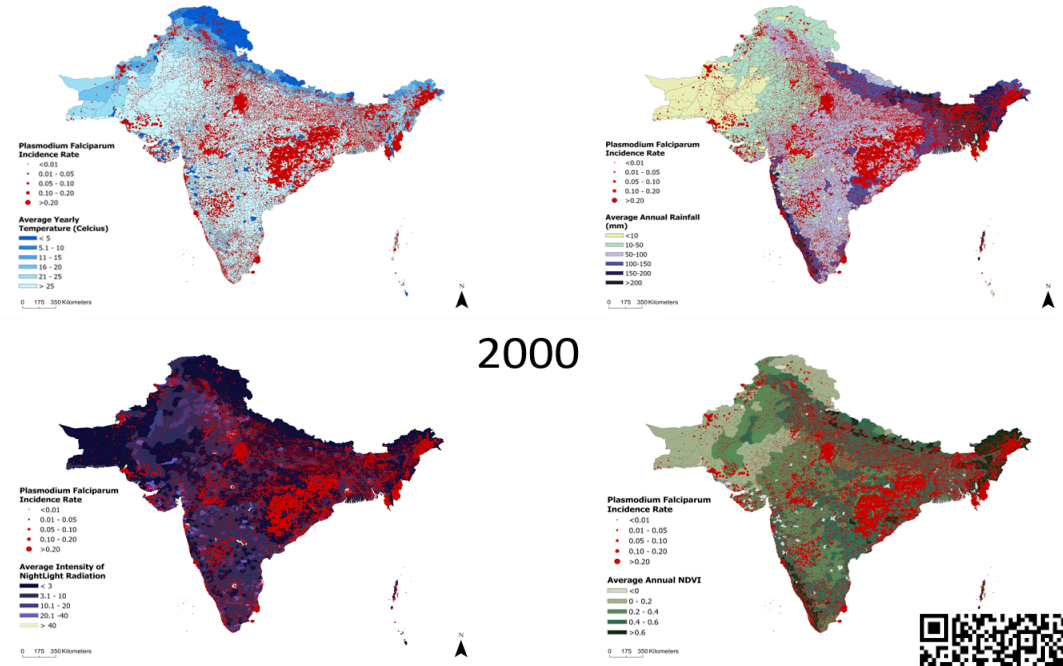


Predicting malaria outbreaks in Peru at household level

Schmidt et al. ICLAR 2019. arXiv:190

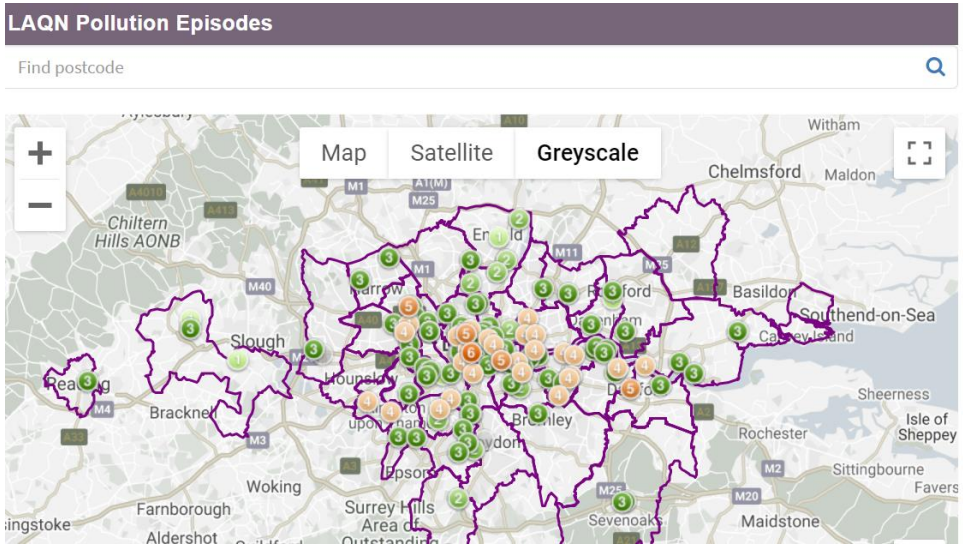
PREDICTING MALARIA OUTBREAKS USING EARTH OBSERVATION MEASUREMENTS AND SPATIO-TEMPORAL DEEP LEARNING MODELLING: A SOUTH ASIA CASE STUDY FROM 2000 TO 2017

Usman Nazir[1], Muhammad Talha Quddoos[1], Momin Uppal[1], Sara Khalid[2]
[1]Lahore University of Management Sciences, [2]Centre for Statistics in Medicine, University of Oxford
sara.khalid@ndorms.ox.ac.uk

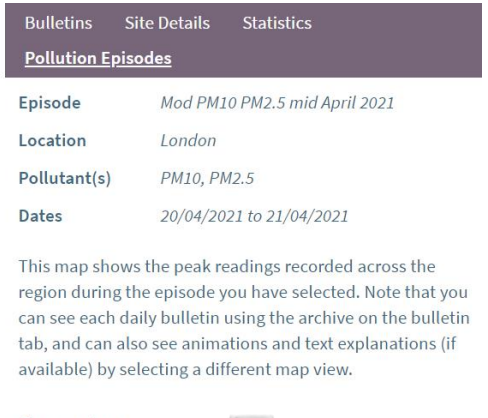


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Tracking and Monitoring Air Pollution



The London Air Quality Network monitors and predicts level of ozone, nitrogen oxide, PM2.5 and PM10





Personalised early warning system for those most vulnerable to high levels of pollution

Credit: londonair.org.uk

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AI and Biodiversity

IMAGE

BROWSE... No file selected

Detection threshold:

0 0.68 1

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

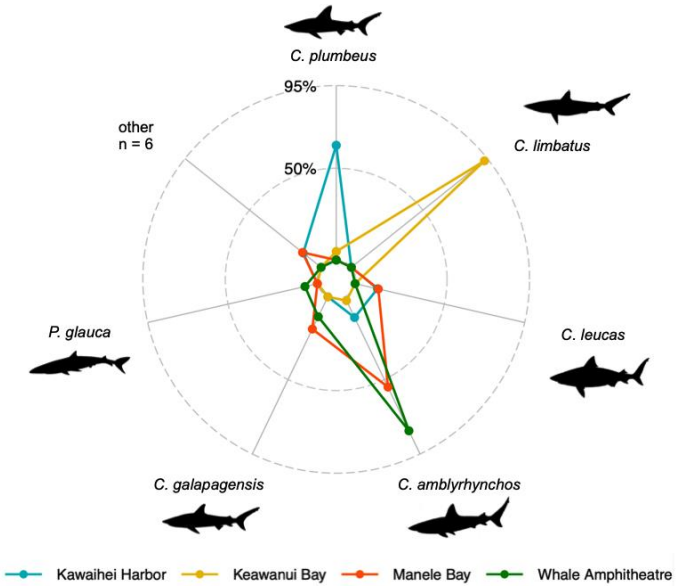
Select Video

20220924_KeawanuiBay_S3_GX110006.mp4

PROCESS DETECT VIDEO PLAY VIDEO RESET

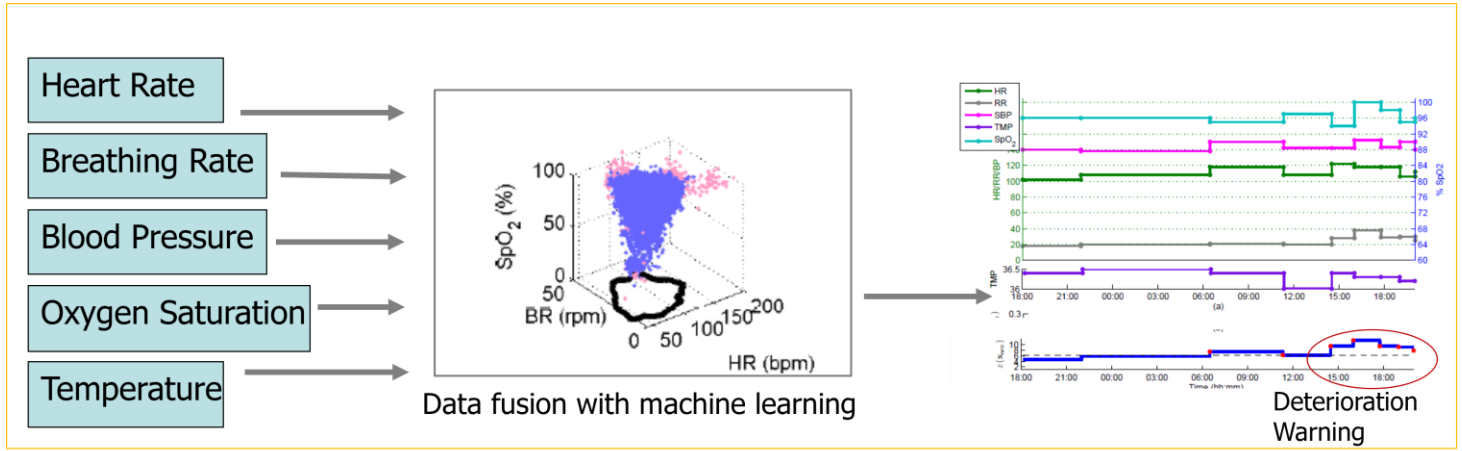
Shark	Prediction
Carcharhinus limbatus	94.15 %
Carcharhinus plumbeus	4.13 %
Carcharhinus amblyrhynchos	0.47 %
Galeocerdo cuvier	0.44 %
Carcharodon carcharias	0.39 %





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Remote Monitoring of Patients in Disaster/Conflict Zones





Khalid et al. IEEE Trans Biomed Eng 2012
DOI: 10.1109/TITB.2012.2212202

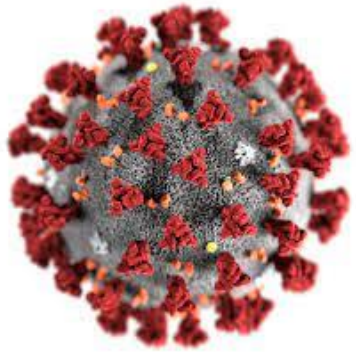
Home monitoring kit for remote management of Covid-19 infection



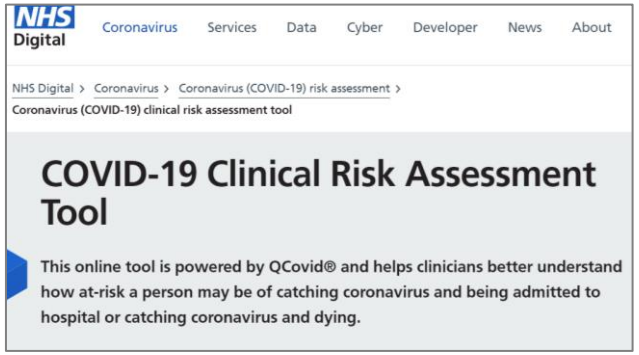
Santos et al. Front. Digit. Health
https://doi.org/10.3389/fdgth.2021.630273

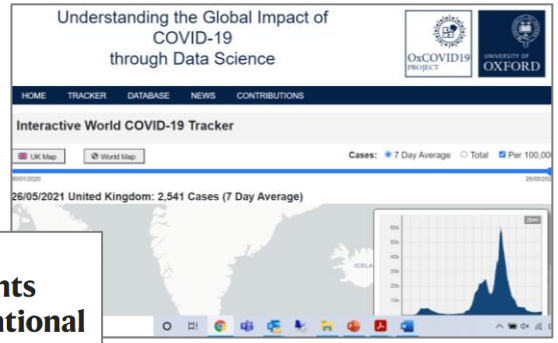
Pandemic Response

- Diagnostics
- Clinical Risk Prediction
- Vaccine Strategy
- Deep Phenotyping

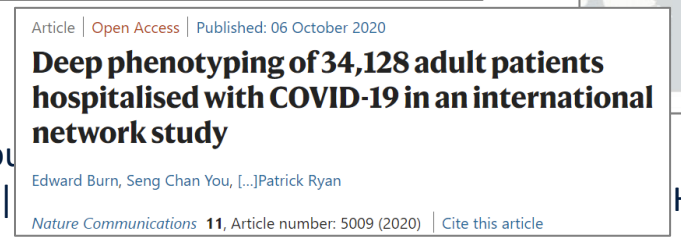








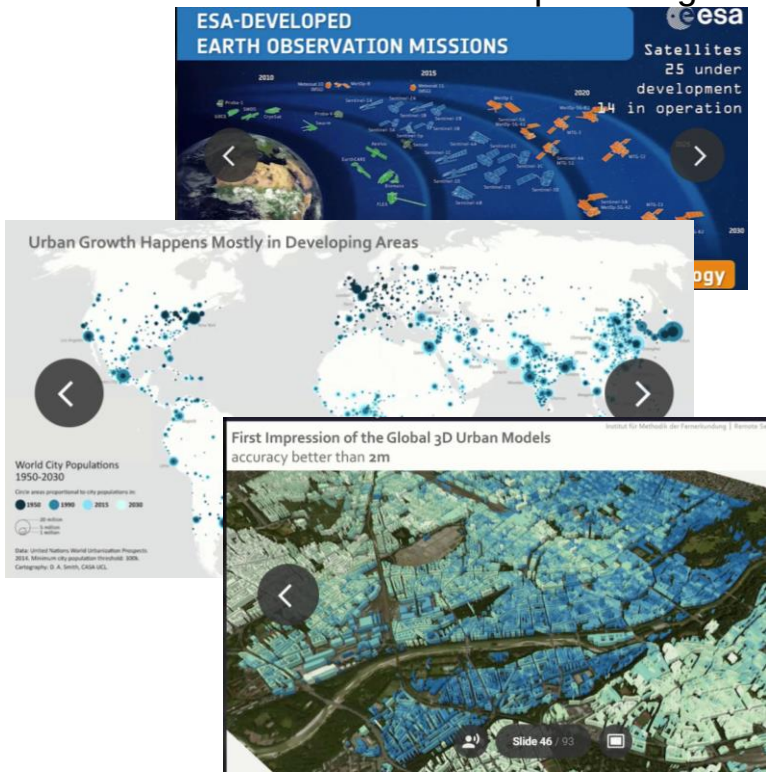




Computational Models

- Future cities
  - Urban thermal comfort
  - Land use optimisation
  - Increased vegetation cover
- Transport modelling
  - More physical activity
  - Less carbon footprint
- AI for renewable energy
- Carbon footprint of AI

Building a 3D blueprint of urban hot spots using earth observation data and deep learning



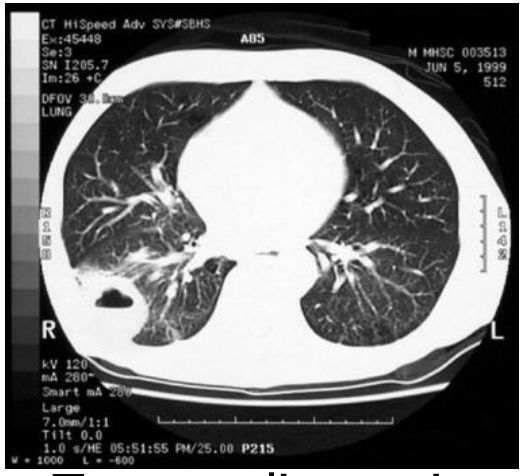
XX Zhu et al. IEEE Trans. Geoscience & Remote Sens 2017

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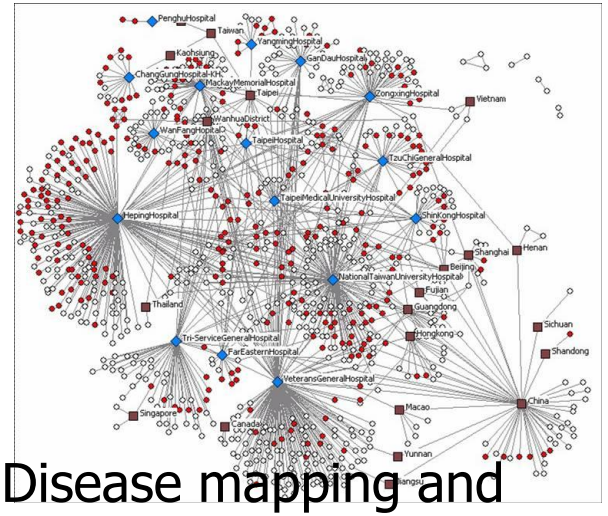
Real-world Applications



Eye disease detection



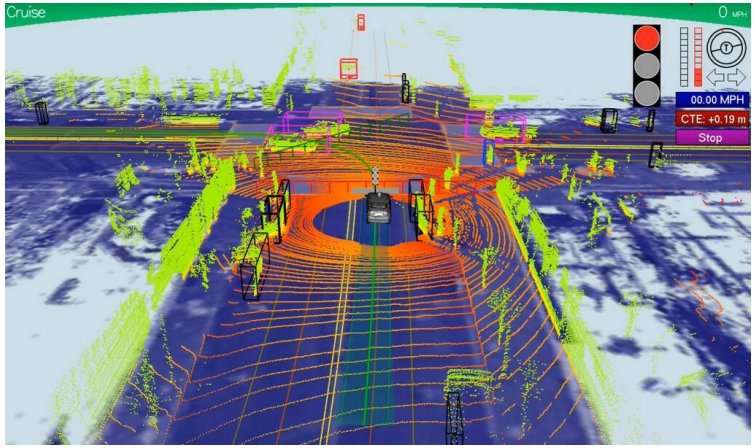
Tumour diagnosis



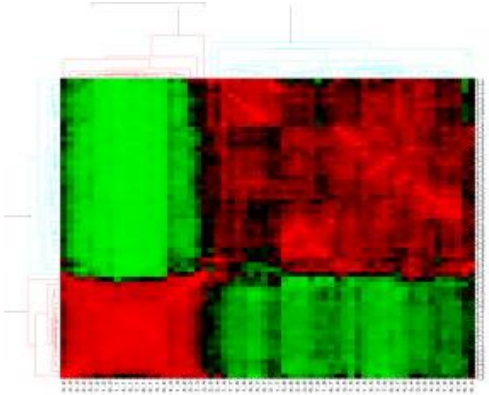
Disease mapping and tracking



Bioinformatics



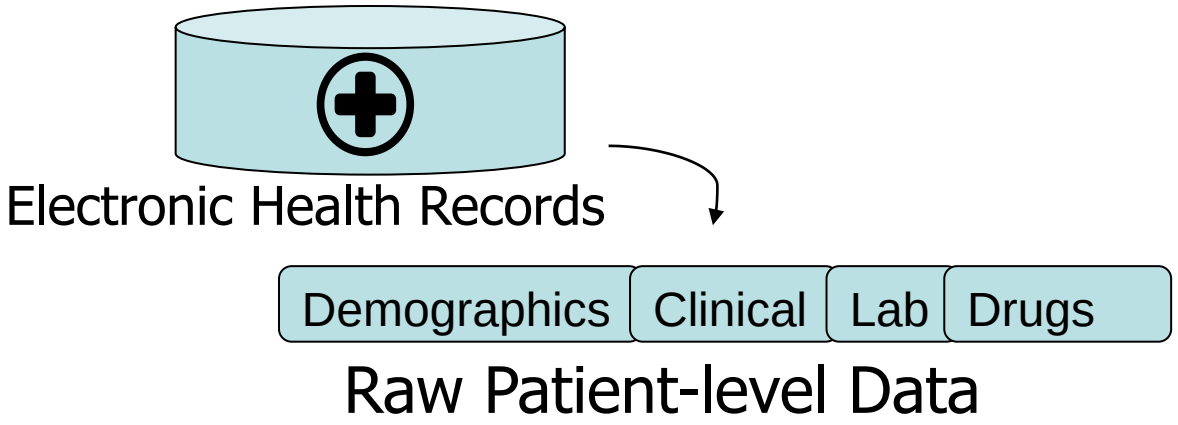
Autonomous vehicle navigation



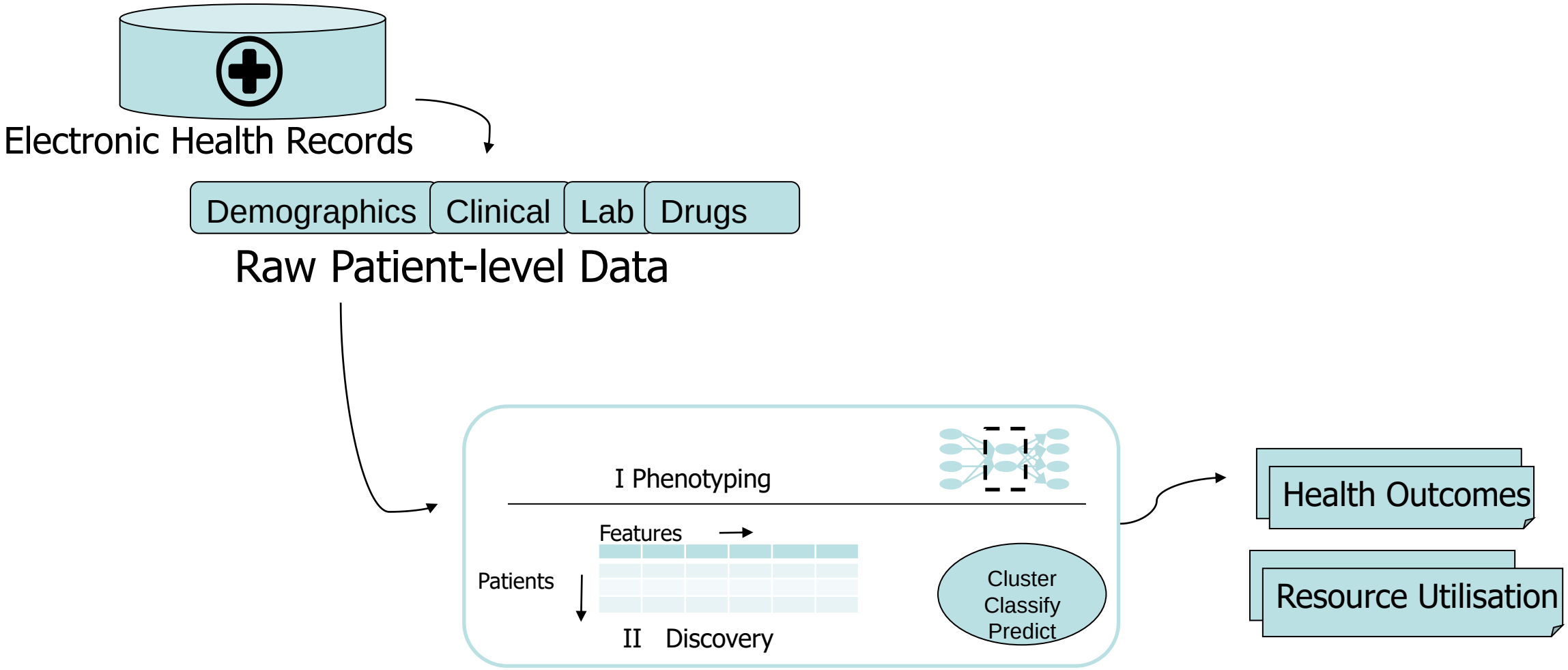
Gene expression clustering

Challenges and Opportunities

Planetary Health Analytics Framework

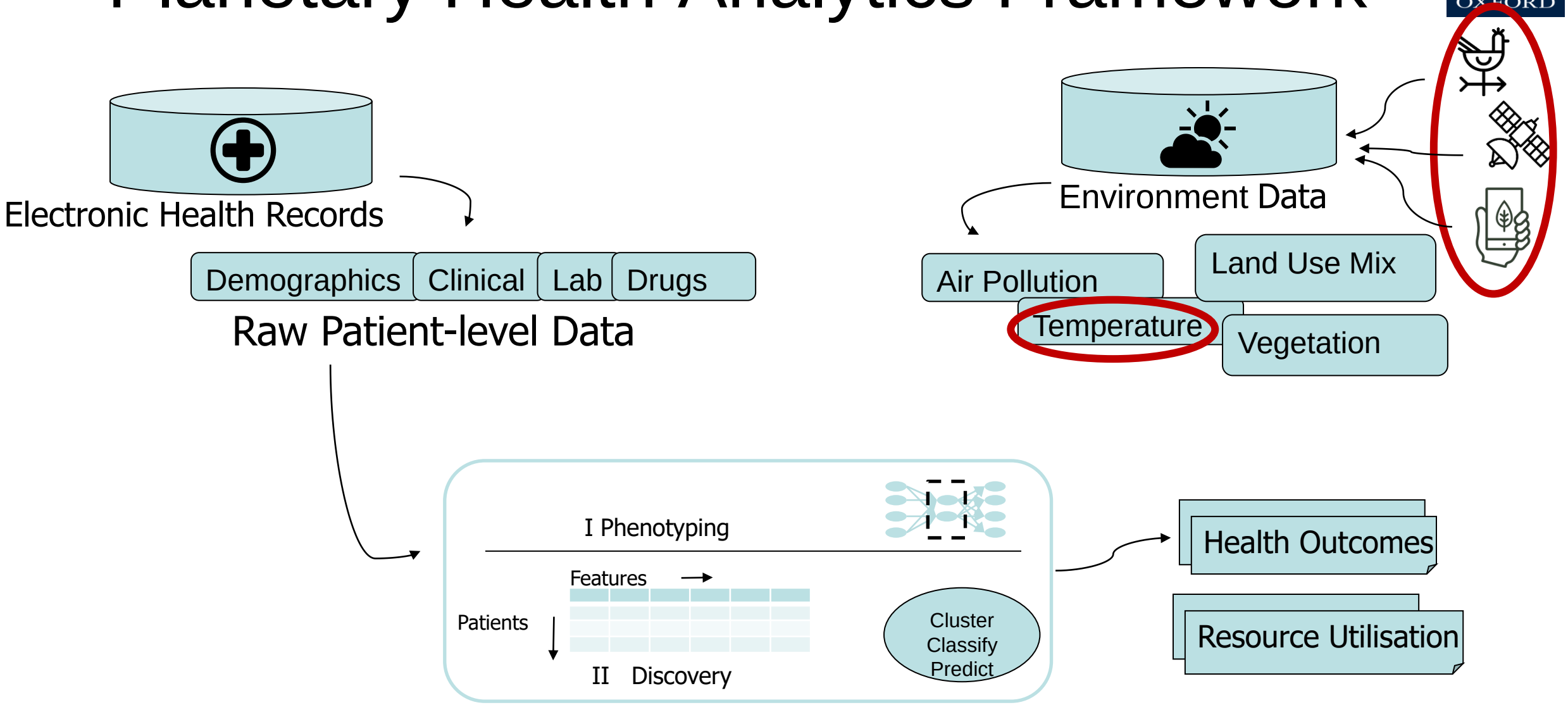


Planetary Health Analytics Framework



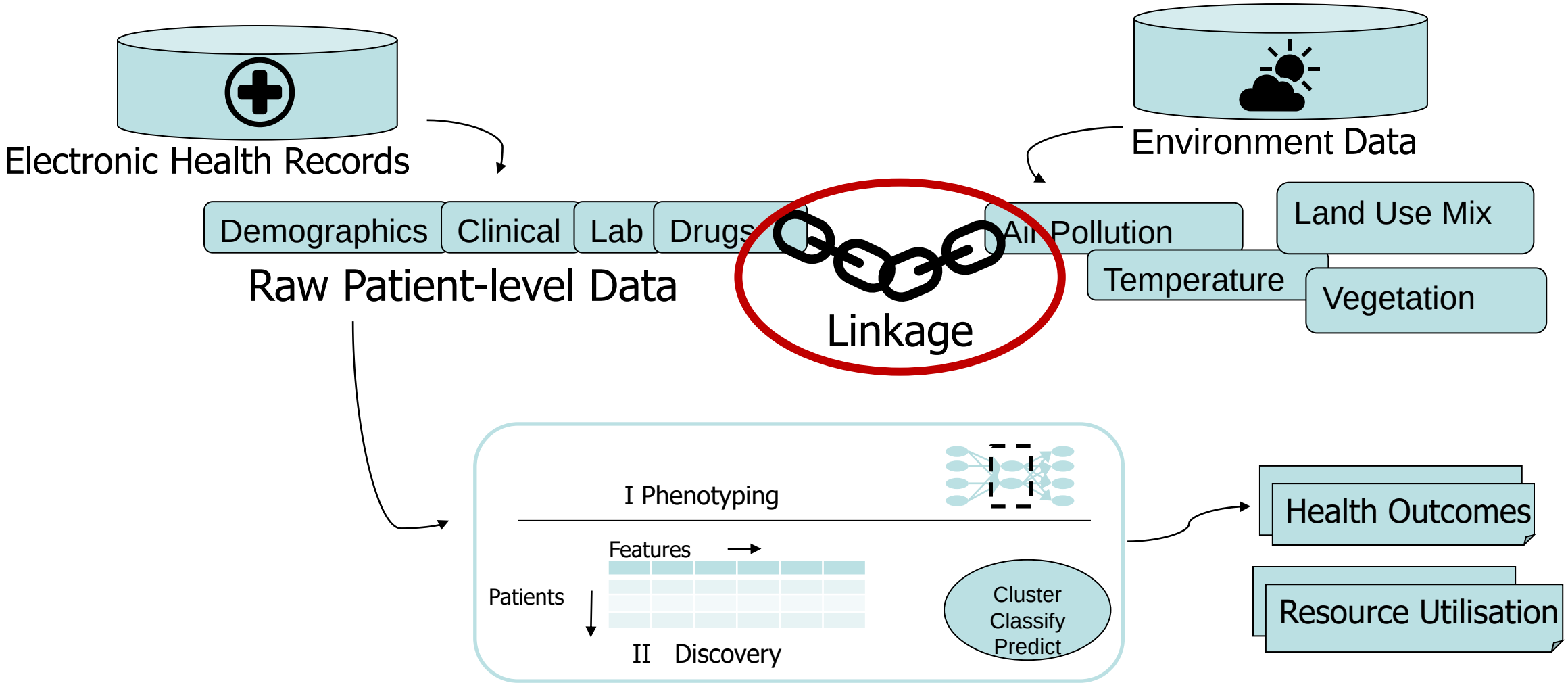
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Planetary Health Analytics Framework



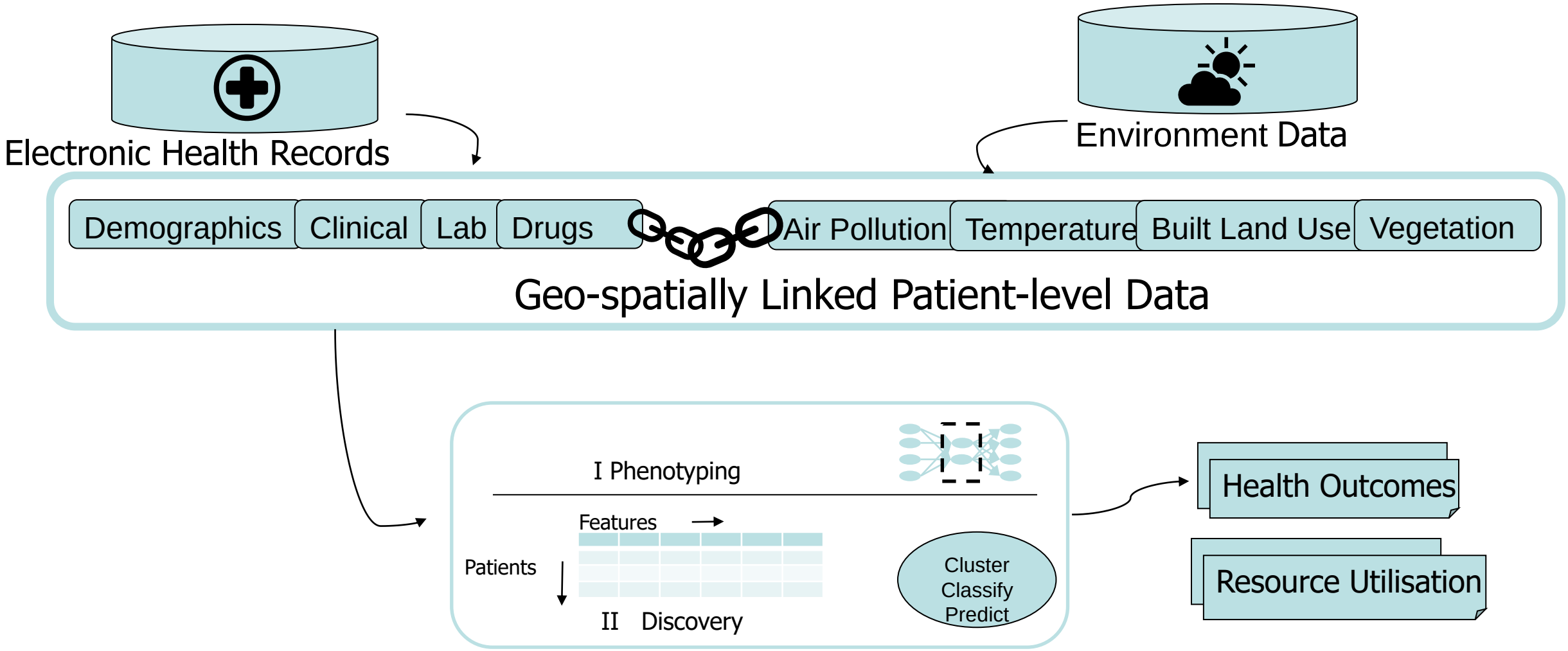
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Planetary Health Analytics Framework



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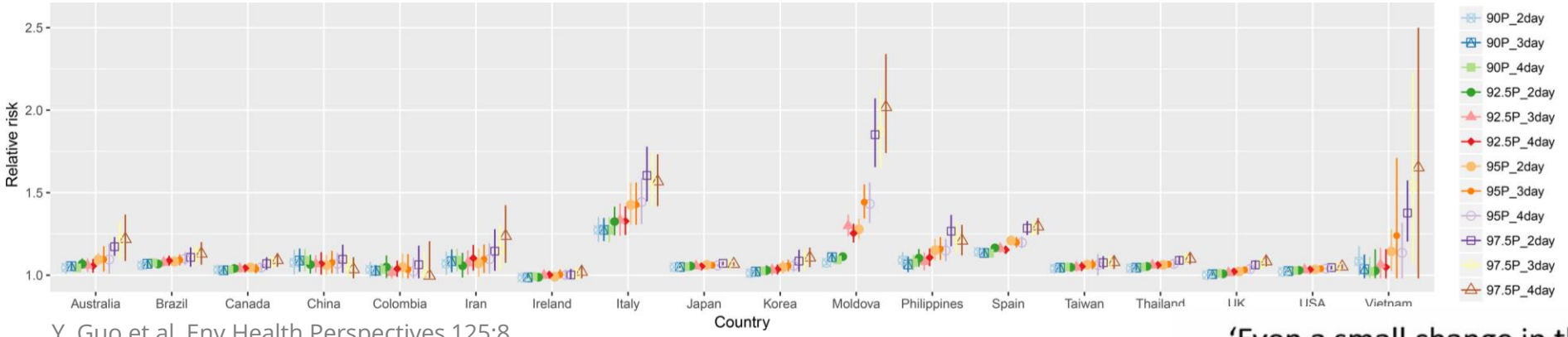
Planetary Health Analytics Framework



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Heat Definition, Coding, and Capture

Effect of heat wave on mortality in 18 countries with 12 different definitions of heat wave



Y. Guo et al. Env Health Perspectives 125:8
CID: 087006 https://doi.org/10.1289/EHP1026

'Even a small change in the heatwave definition had an appreciable effect on the estimated health impact' in Brisbane, Australia - Case Cross Over Design

HWD	Definition
1	The daily maximum temperature ≥35°C (about top 1%) for 3 or more consecutive days
2	The daily maximum temperature of more than 5 consecutive days exceeds the average maximum temperature by 5°C, the normal period being 1961–1990
3	The heat index (maximum temperature + relative humidity) is expected to reach 40.6°C with a minimum temperature not below 26.7°C as a period of at least 48 h
4	The daily maximum temperature would be equal to or greater than 35°C (about top 1%) for at least consecutive 2 days
5	The daily maximum temperature would be equal to or greater than 37°C (about top 0.5%) for at least consecutive 2 days
6	The top 2.5% (≥33.59°C) of daily maximum temperatures for a continuous 2 days period
7	The top 2.5% (≥33.59°C) of daily maximum temperatures for a continuous 3 days period
8	The top 5% (≥32.65°C) of daily maximum temperatures for a continuous 3 days period
9	The top 5% (≥32.65°C) of daily maximum temperatures for a continuous 4 days period
10	The top 5% (≥32.65°C) of daily maximum temperatures for a continuous 5 days period

Mortality	OR with 95% CI	
HWD1	0.87	0.68, 1.10
HWD2	0.99	0.83, 1.18
HWD3	1.73	1.32, 2.28
HWD4	1.26	1.10, 1.43
HWD5	1.53	1.27, 1.84
HWD6	1.16	1.06, 1.27
HWD 7	1.21	1.08, 1.35
HWD8	1.10	1.03, 1.18
HWD9	1.14	1.05, 1.24
HWD10	1.24	1.13, 1.36

Tong et al. 2010

Real-world Data, AI & Health Equity

Data Bias

+

Algorithm Bias

→

Incorrect Health Assessment



Khalid et al. *Nature Sci Data (2024)*

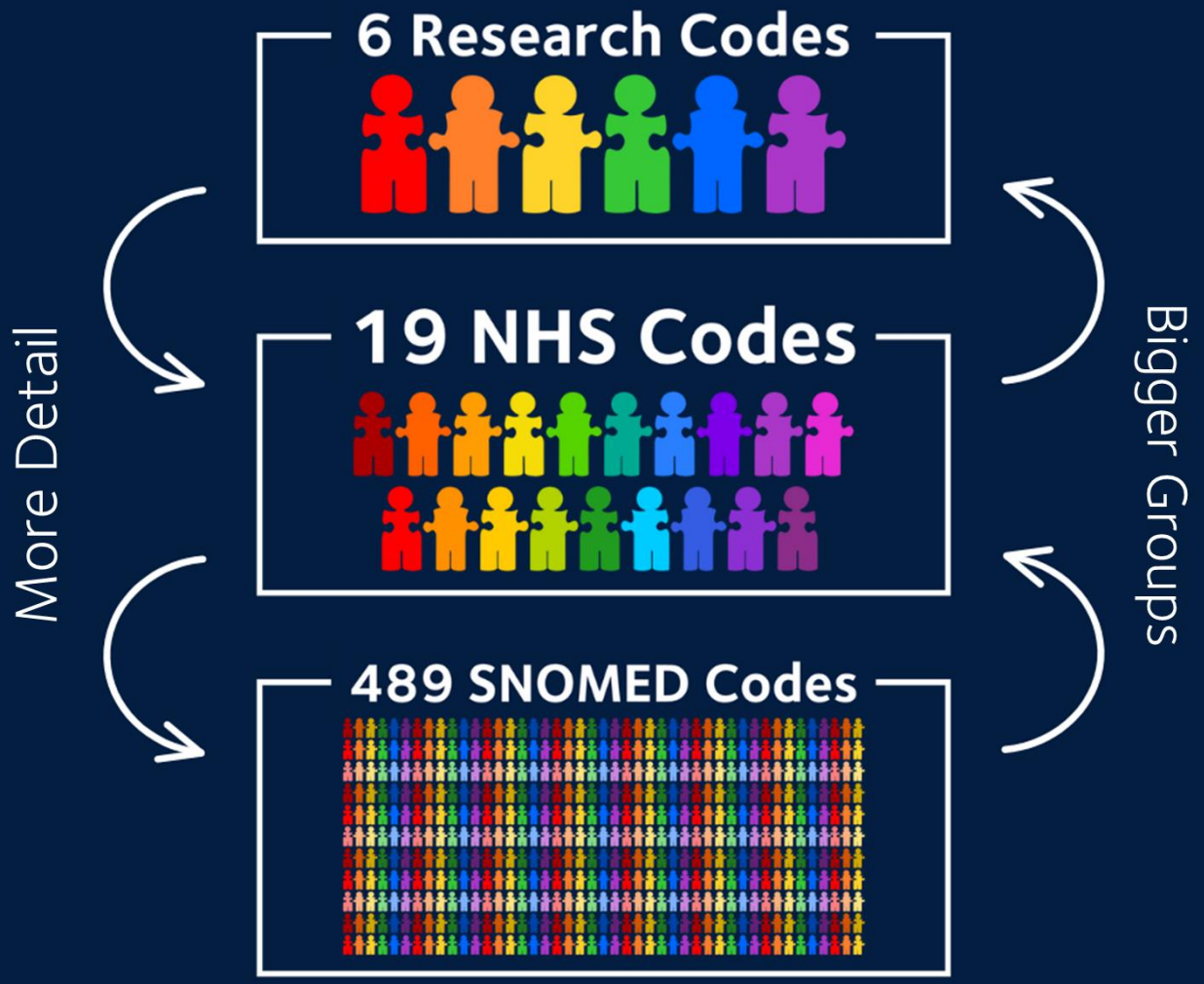
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Real-World Data, AI & Health Equity

60 Million

de-identified patient records

What Ethnicity Data is available?



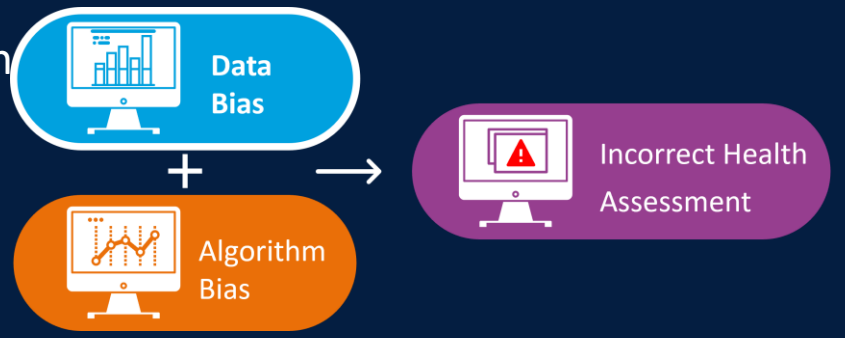
The Planetary Health Informatics Lab | NDORMS | @PHI_Oxford | sara.khalid@ndorms.ox.ac.uk

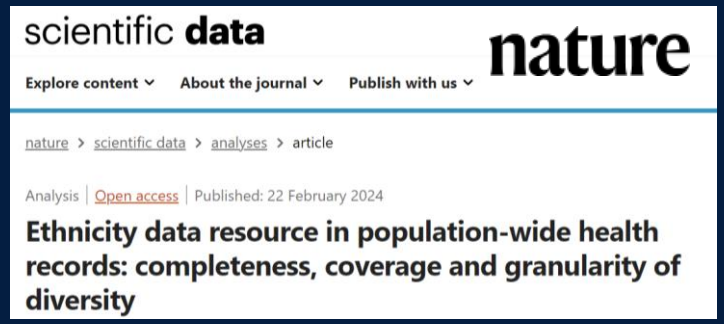
Ethnicity, Health Equity and AI Project

Project Webpage

Full Publication Link

A UK Government COVID-19 Core Study aimed at addressing biases in data which translated to health inequalities. Analysing data from NHS England revealed previously unused, rich ethnicity data.




scientific data

nature

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nature > scientific data > analyses > article

Analysis | Open access | Published: 22 February 2024

Ethnicity data resource in population-wide health records: completeness, coverage and granularity of diversity

60m

Patients, representing **94% of UK population**

255

Patient self-identified, using the SNOMED system

1/10

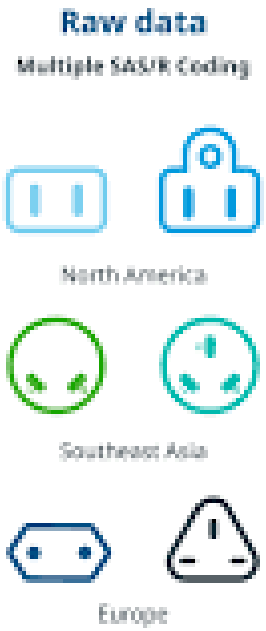
Patients have missing ethnicity data across their primary and secondary care records

17%

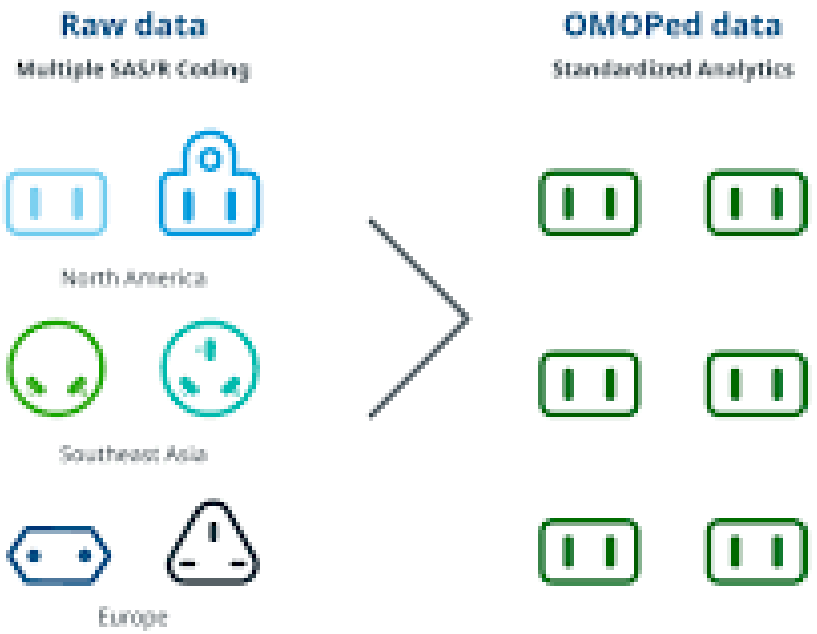
Of patients have conflicting ethnicity codes in their health records

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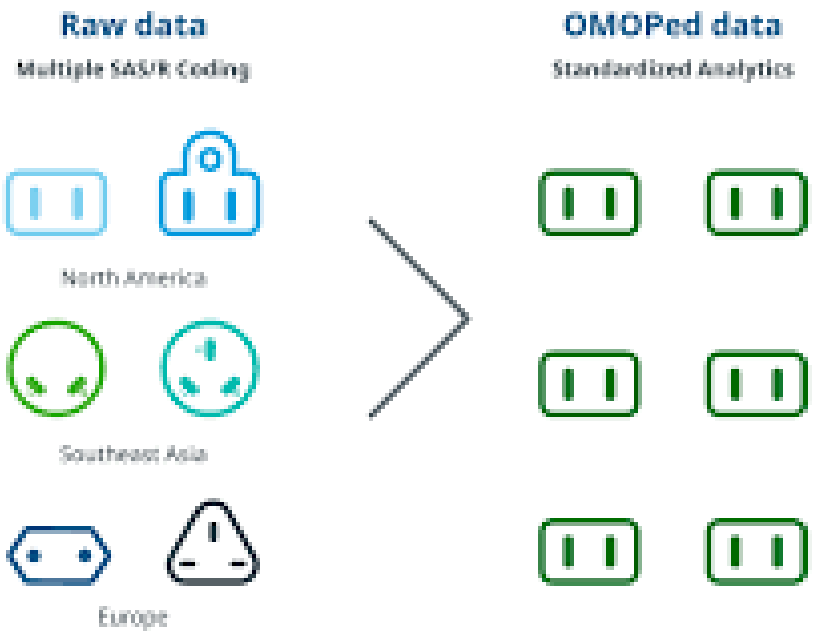
Common Data Models & Standardised Analytics



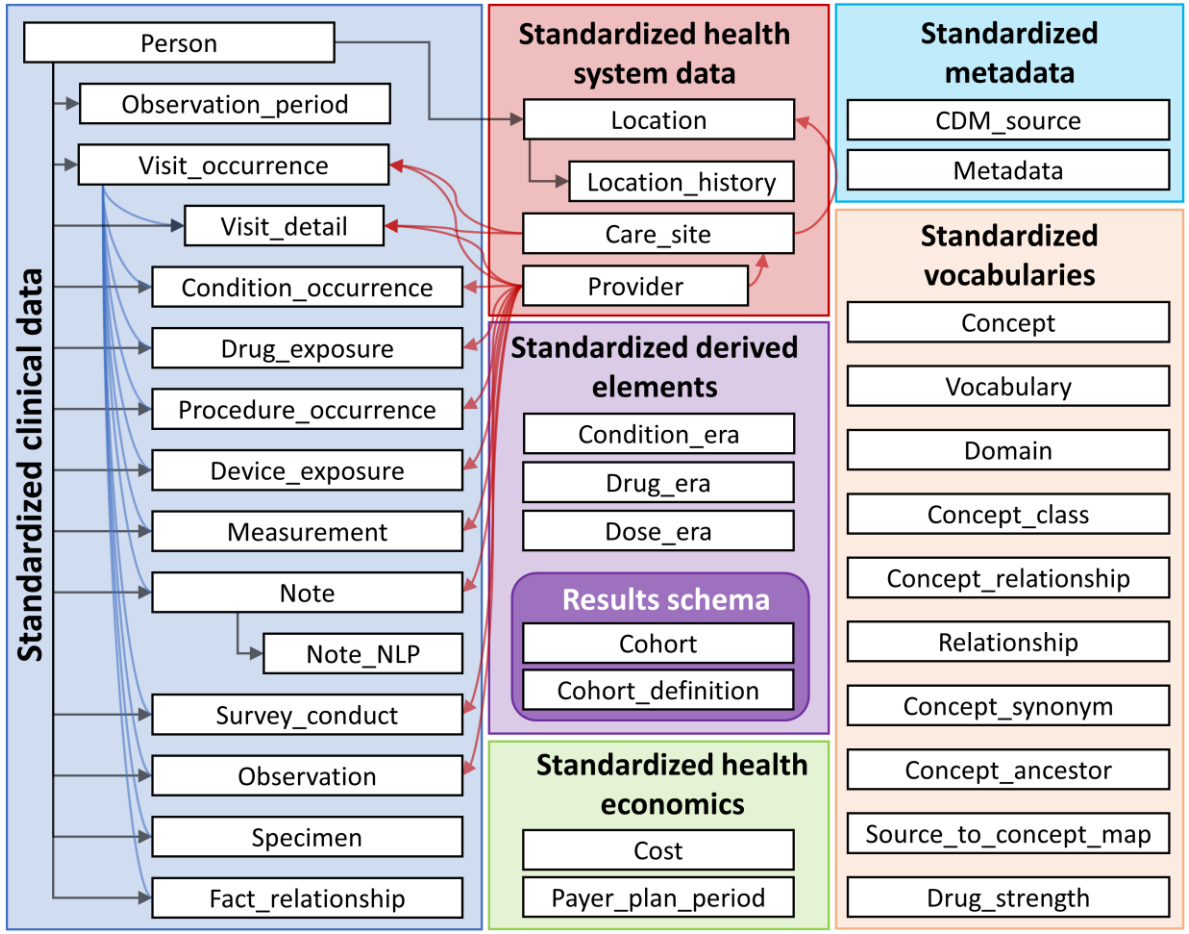
Common Data Models & Standardised Analytics



Common Data Models & Standardised Analytics



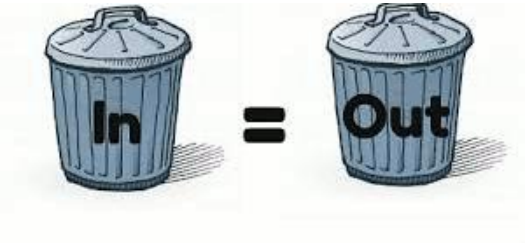
Example of a common data model developed by OHDSI



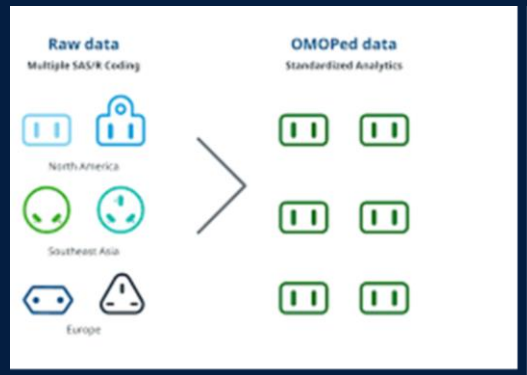
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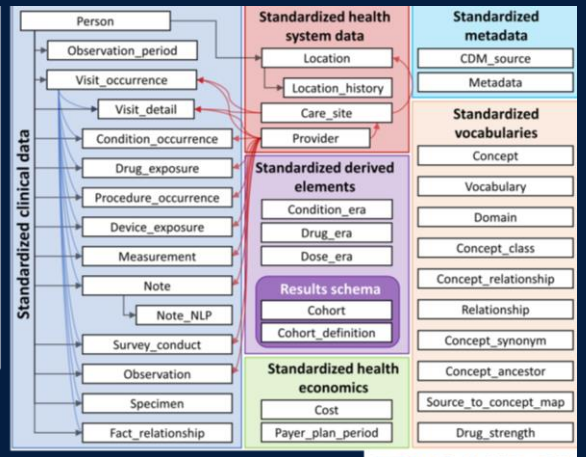
Considerations

- Data Sources
  - Global, ethical, representative
- Linkage
  - De-identified data
- Standardisation
  - Universal definitions
  - Temporal synchronization
  - Common data model
- Data Quality
  - Completeness and accuracy of recording (e.g. heat)
- Data Analysis
  - Many unknowns
  - Confounding
  - Multi-stressor interactions

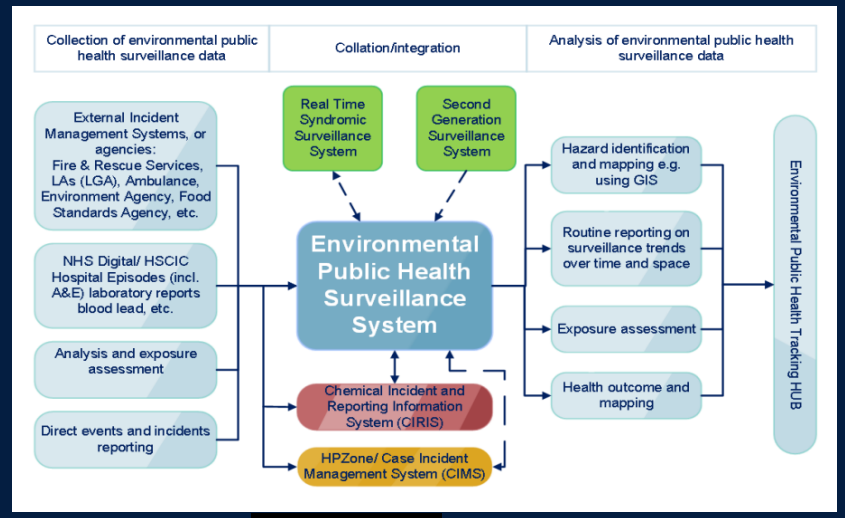


Infrastructure for Large-scale Planetary Health Analytics



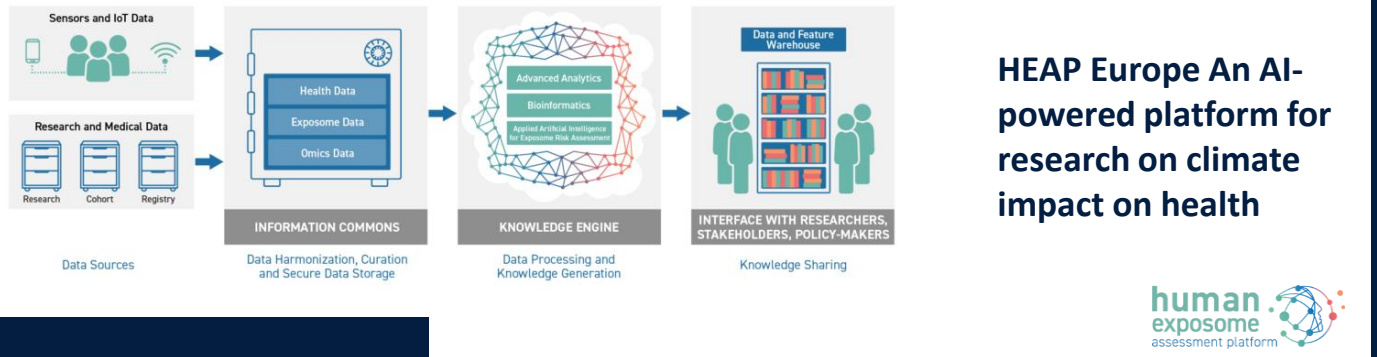


Common data models and standardised analytics



Public Health England

EPHSS Environmental public health surveillance system UK



HEAP Europe An AI-powered platform for research on climate impact on health

human exposome assessment platform

A project receiving funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement N. 101004188

DEEP CUBE

DeepCube Explainable AI pipelines for big Copernicus data

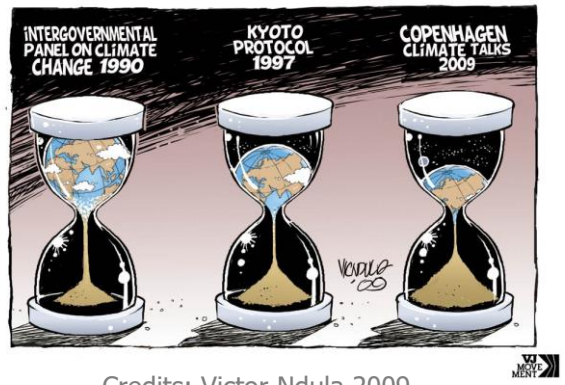
EXTREME EARTH

Deep Cube Using AI to analyse Copernicus satellite data and predict climate impacts

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Climate-health Co-benefits

- Global health adaptation **spending** $18Bn, ↑ 5.3%
- Health systems adaptation **planning** in 86 countries
- Ambitious **net-zero** healthcare plans, e.g. UK NHS care delivery emissions ↓ 57%
- Health providers **divestment:** $42Bn
- **Research** on health and climate is up 8 times
- Economic **benefit** of 1.5C: $600 trillion
  - healthier workforce, reduced healthcare costs



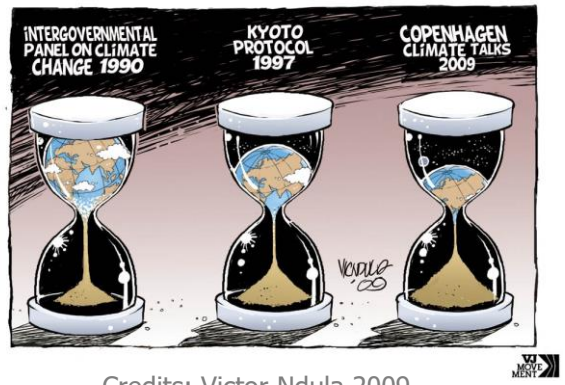
Credits: Victor Ndula 2009

Lancet Countdown Report 2020

Climate-health Co-benefits

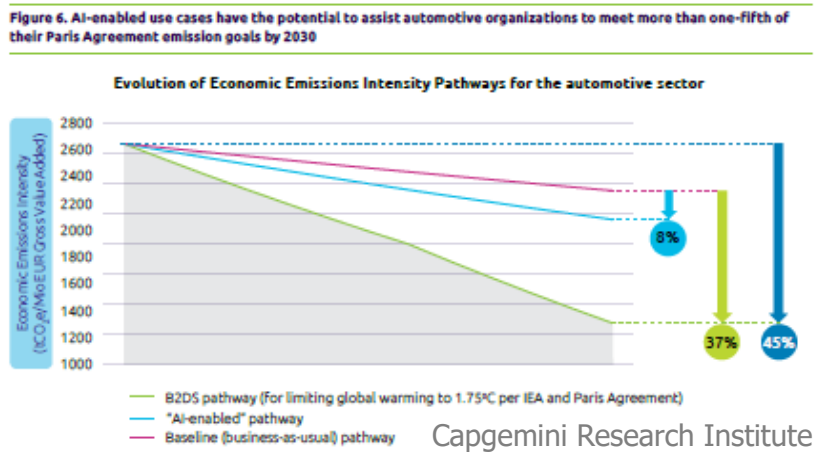
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Forbes **AI to help meet 45% Paris 2015 targets!**



Capgemini Research Institute Report 2020

Handle with Care

Top scientists call for caution over artificial intelligence

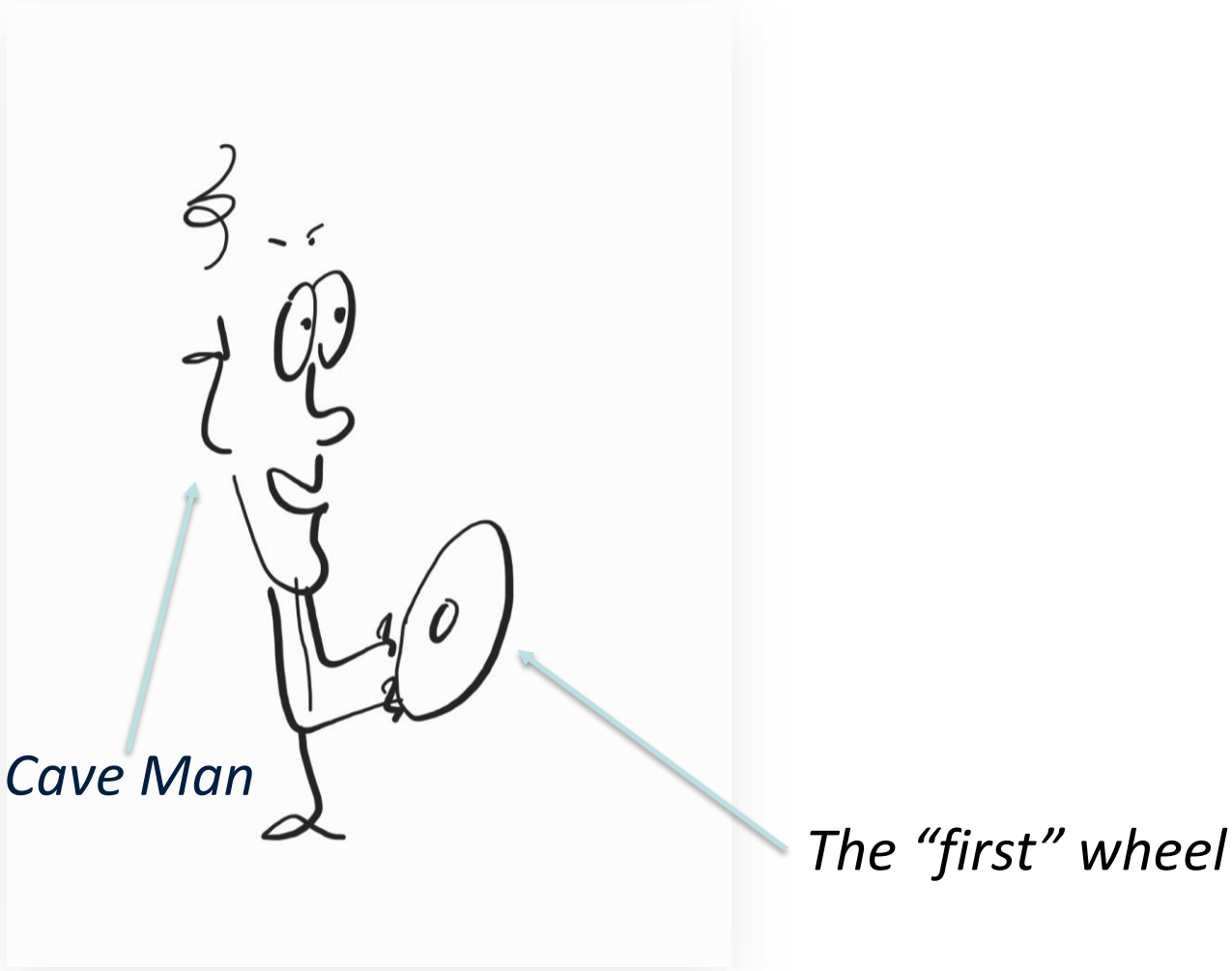
Artificial intelligence has the potential to eradicate disease and poverty, say world's top scientists, but researchers must not create something which cannot be controlled



The Telegraph (2015)

Artificial intelligence must be carefully considered, say scientists Photo: REX

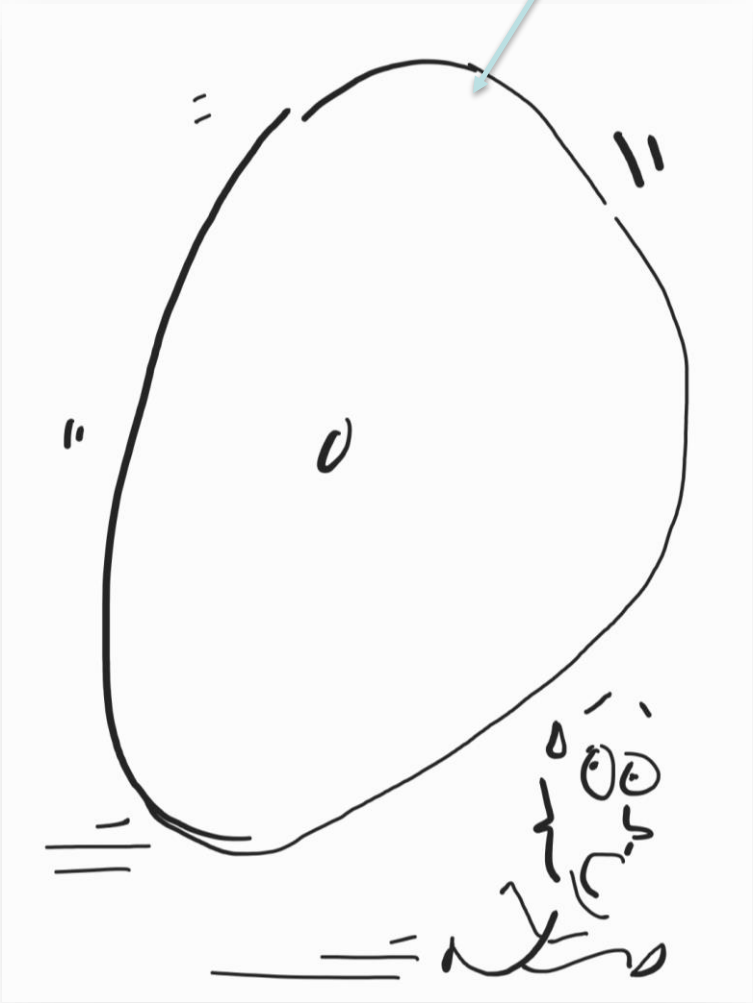
There is a choice



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The choice is ours

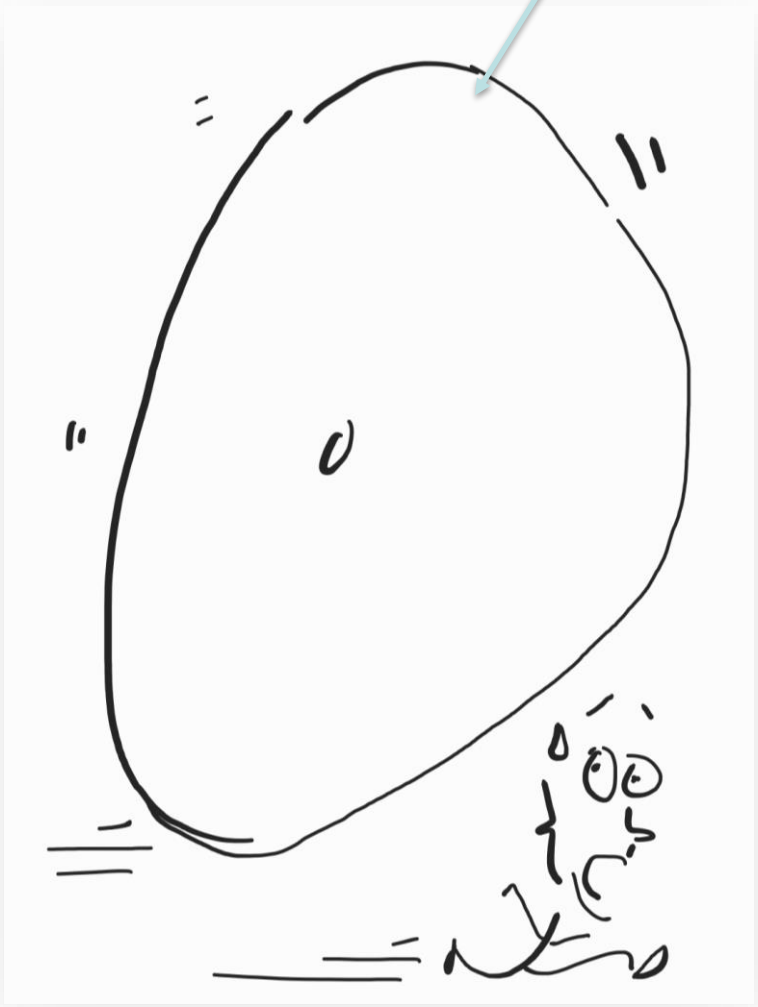




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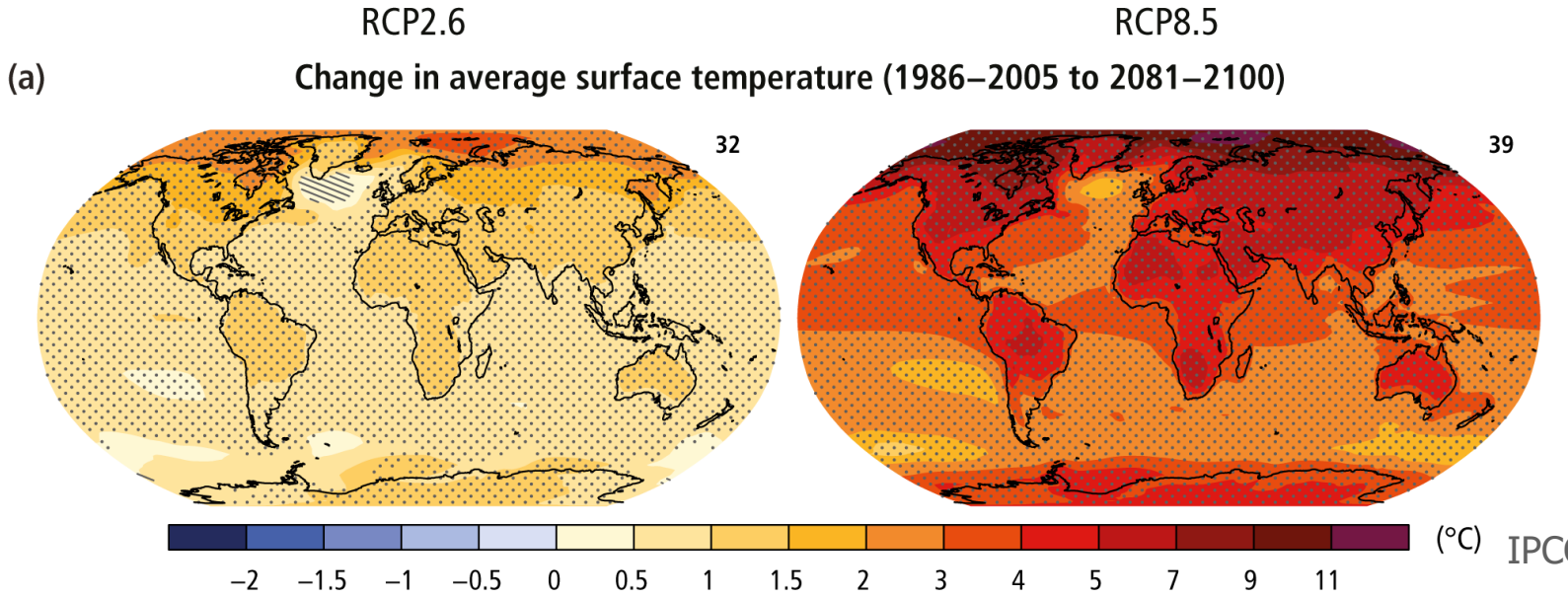






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Our Rapidly Warming World



IPCC AR5 2014

"Climate change is the biggest global health threat of the 21s century"

Lancet Commission Report 2009

"Addressing climate change could be the biggest global health opportunity of the 21st century"

Lancet Commission Report 2015

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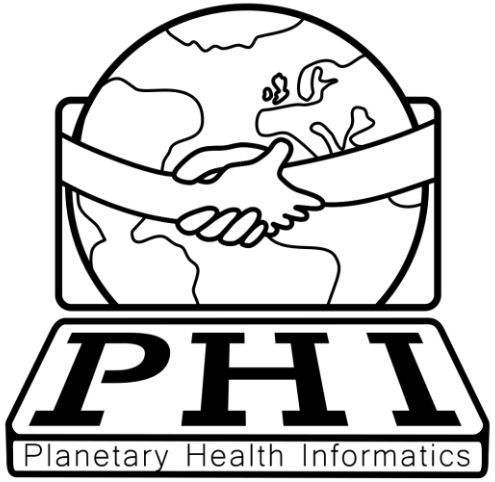








































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Artificial Intelligence for Planetary Health

Challenges, Opportunities, and Human Choice

The Climate Change AI Summer School 2024: Climate & Health Series

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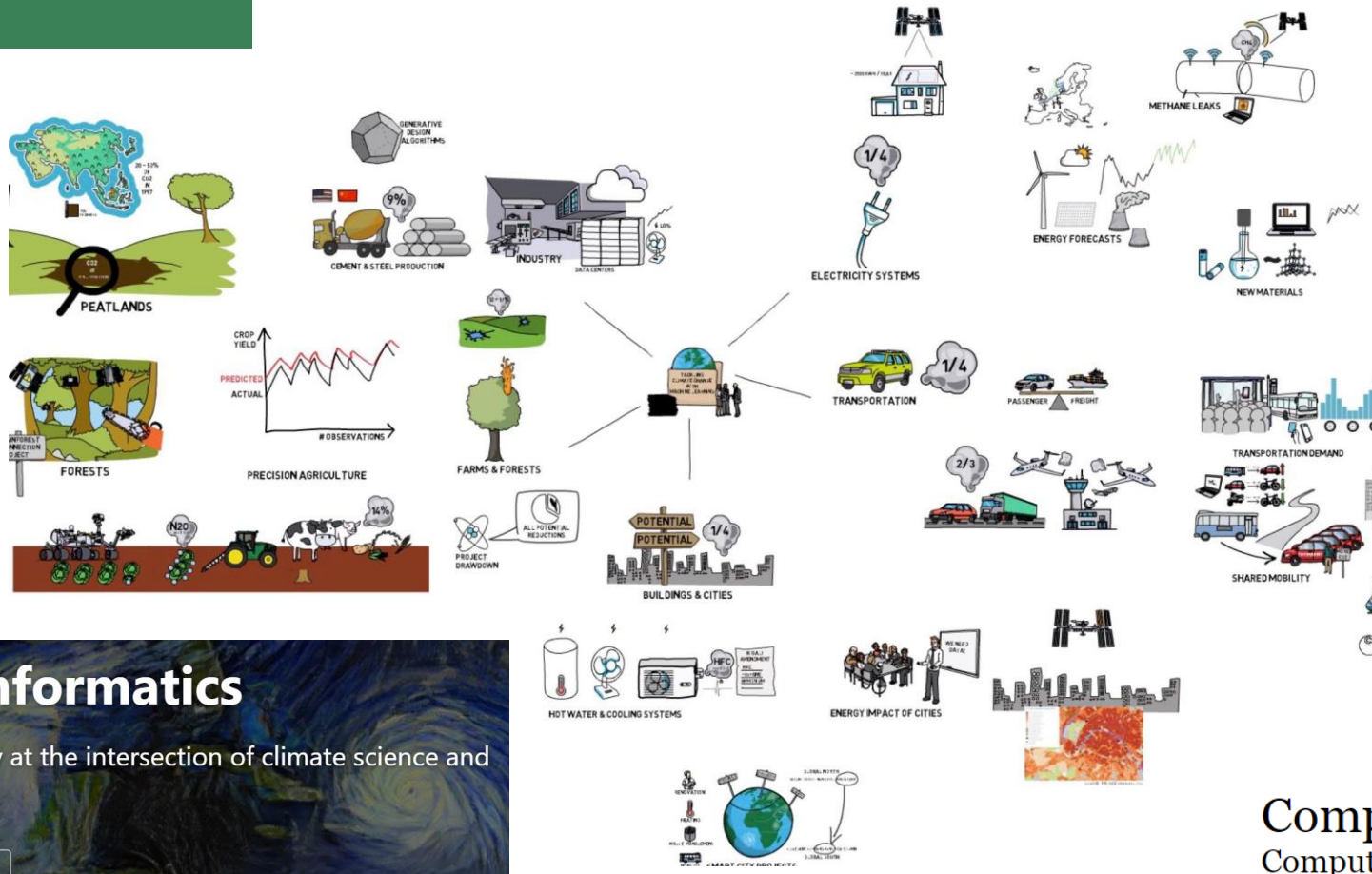
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A Call to Arms

Climate Change AI



A JOINT INITIATIVE OF THE STOCKHOLM RESILIENCE CENTRE AT STOCKHOLM UNIVERSITY, THE BEIJER INSTITUTE OF ECOLOGICAL ECONOMICS AT THE ROYAL SWEDISH ACADEMY OF SCIENCES, THE PRINCETON INSTITUTE FOR INTERNATIONAL AND REGIONAL STUDIES AND, THE URBAN SYSTEMS LAB AT THE NEW SCHOOL

AI, People & Planet

Climate Informatics

An open community at the intersection of climate science and data science.

Join the Community

CompSustNet
Computational Sustainability Network

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