Inteligência artificial para a saúde planetária

Desafios, oportunidades e escolha humana

Escola de verão Climate Change AI 2026: série Clima e saúde

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sara.khalid@ndorms.ox.ac.uk

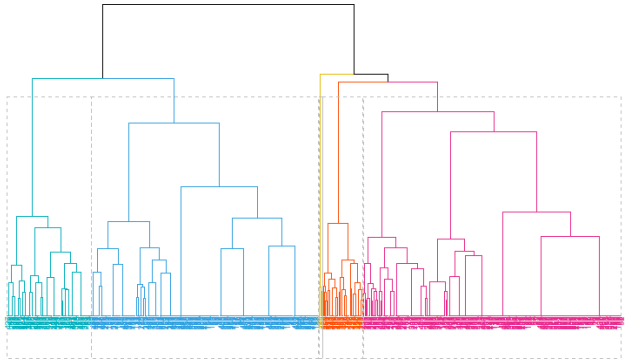
www.csm.ox.ac.uk |

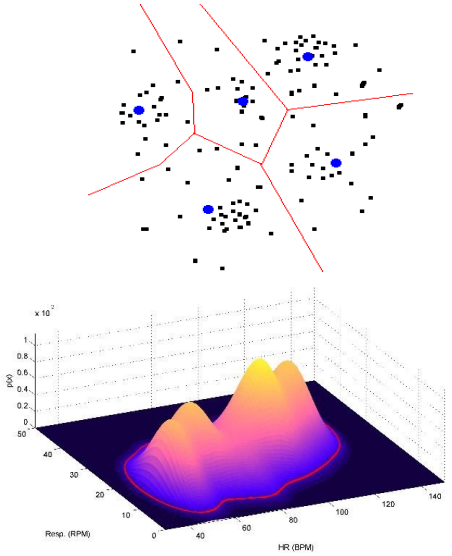
@PHI_Oxford

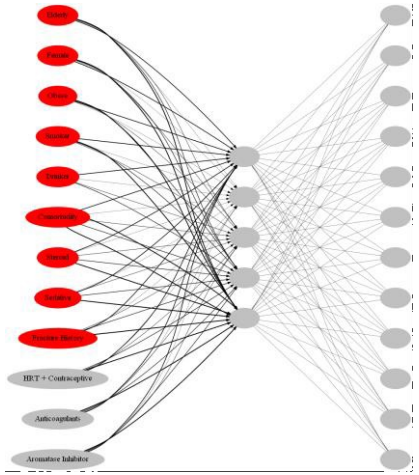
www.ndorms.ox.ac.uk/planetary-health-informatics

Roteiro

1. Mudança climática e saúde planetária
2. O papel da informática em saúde
3. Desafios e oportunidades da análise em saúde planetária





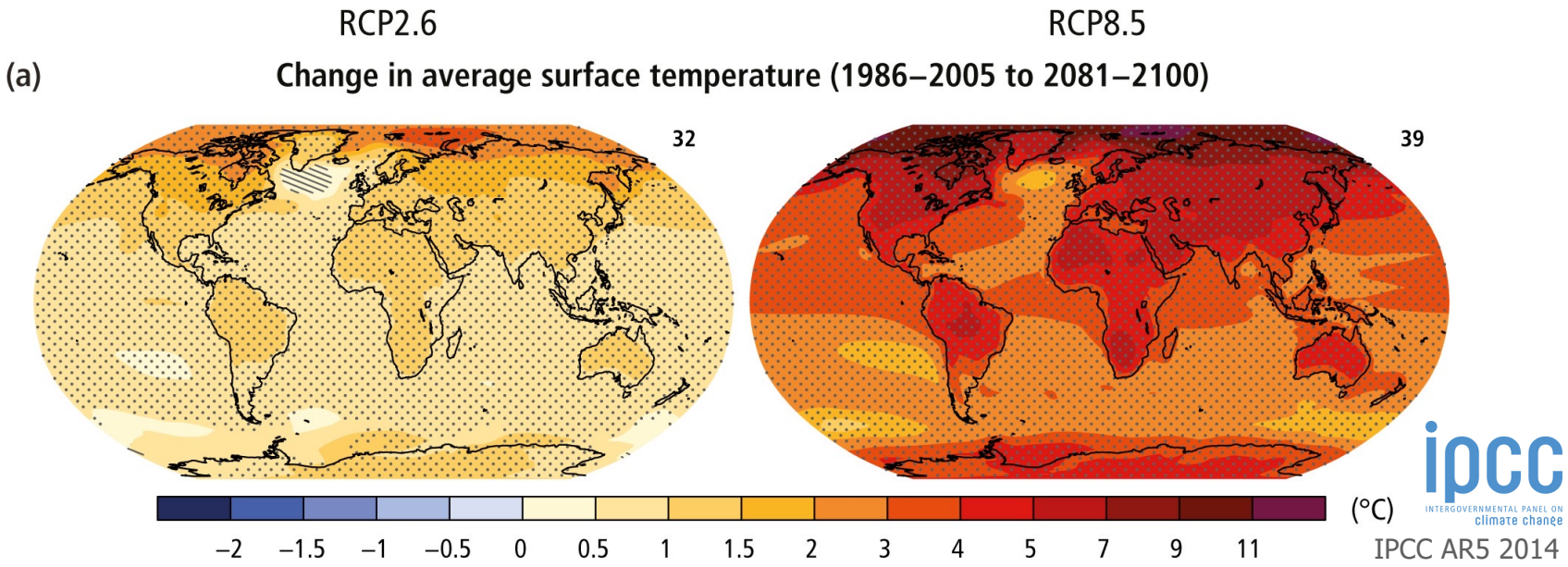


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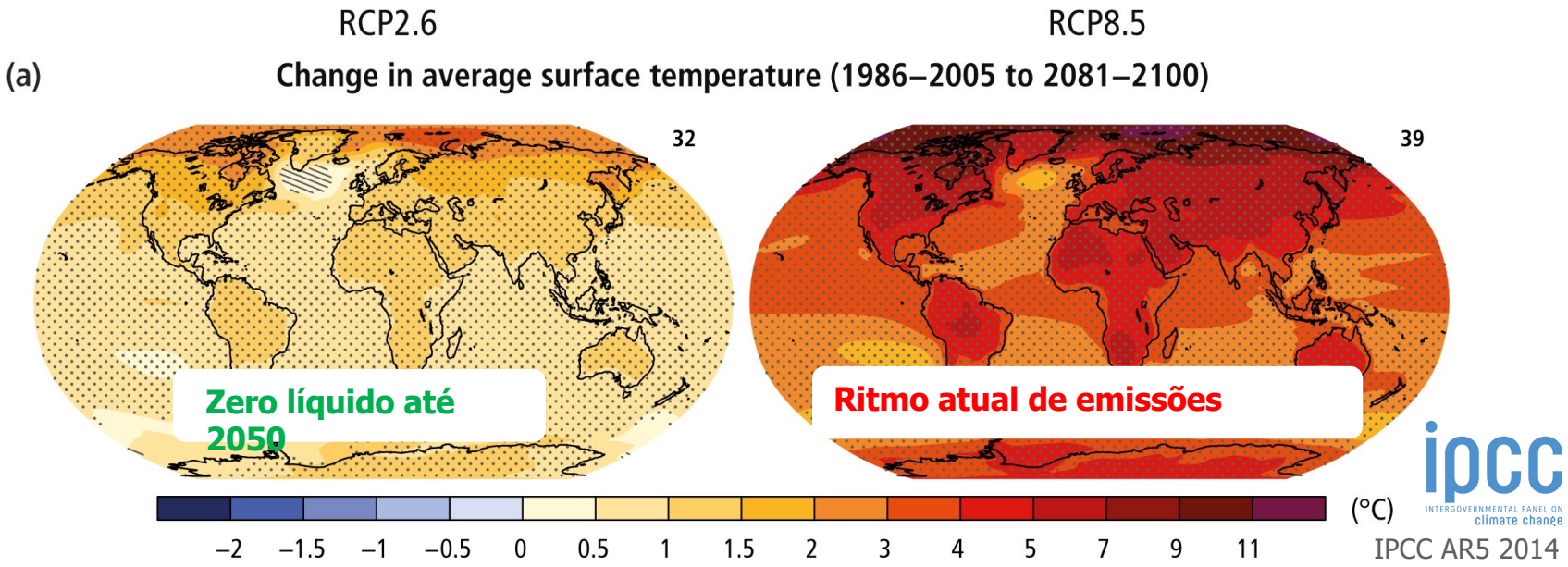
Mudança climática e saúde planetária

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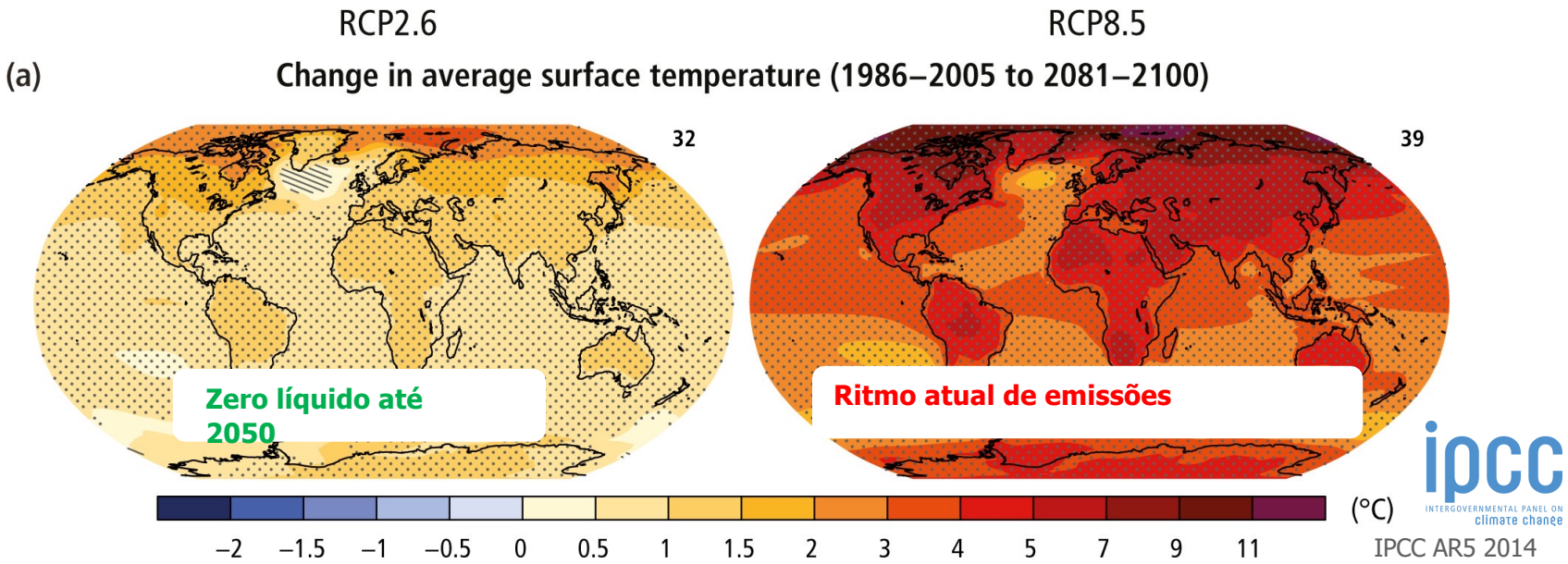
Um aquecimento rápido



Um aquecimento rápido



Um aquecimento rápido



IPCC AR5 2014

"A mudança climática é a maior ameaça à saúde global do século XXI"

Lancet Commission 2009

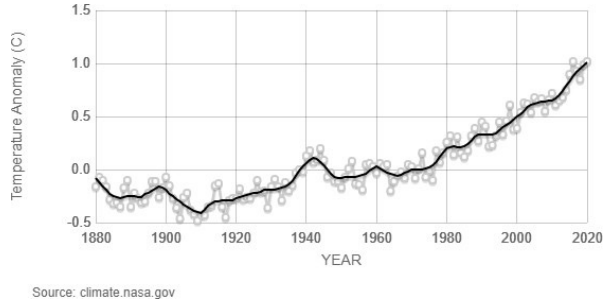
"A mudança climática ameaça os próprios fundamentos da saúde e do bem-estar humanos"

Relatório Lancet Countdown 2020

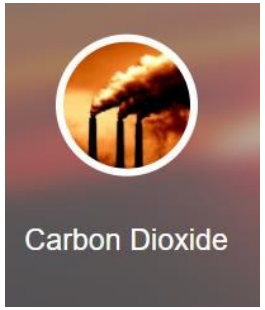
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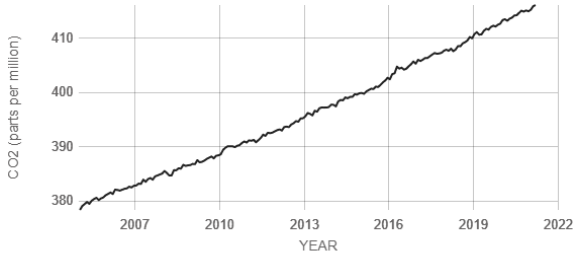
Os sinais vitais da Terra





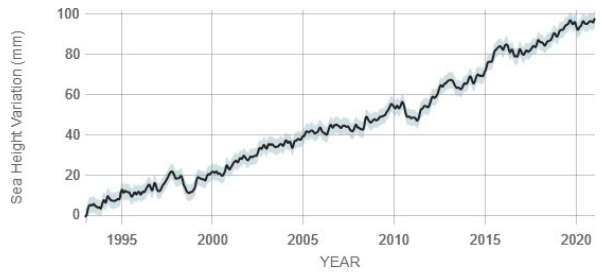
Source: climate.nasa.gov





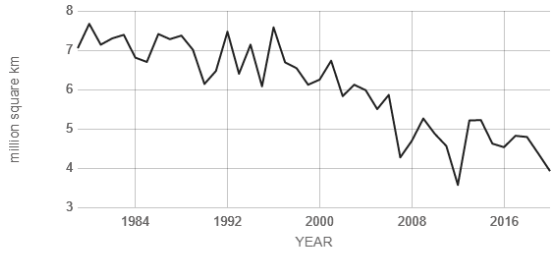
Source: climate.nasa.gov





Source: climate.nasa.gov



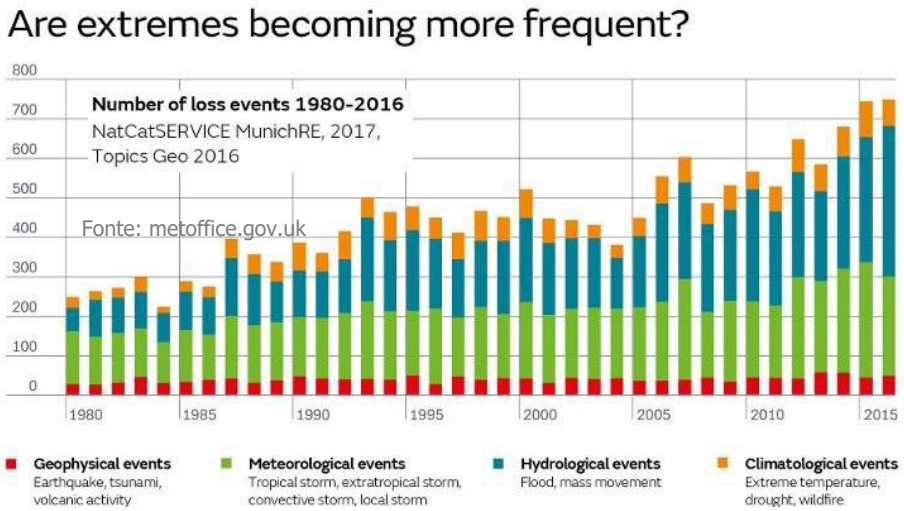


Source: climate.nasa.gov

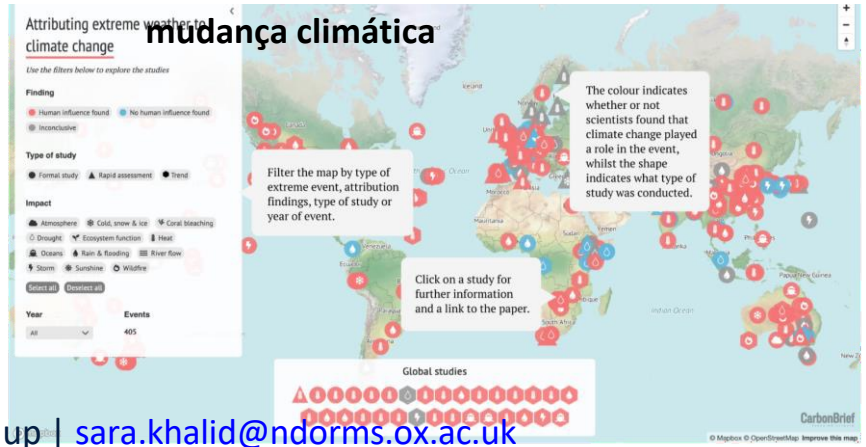


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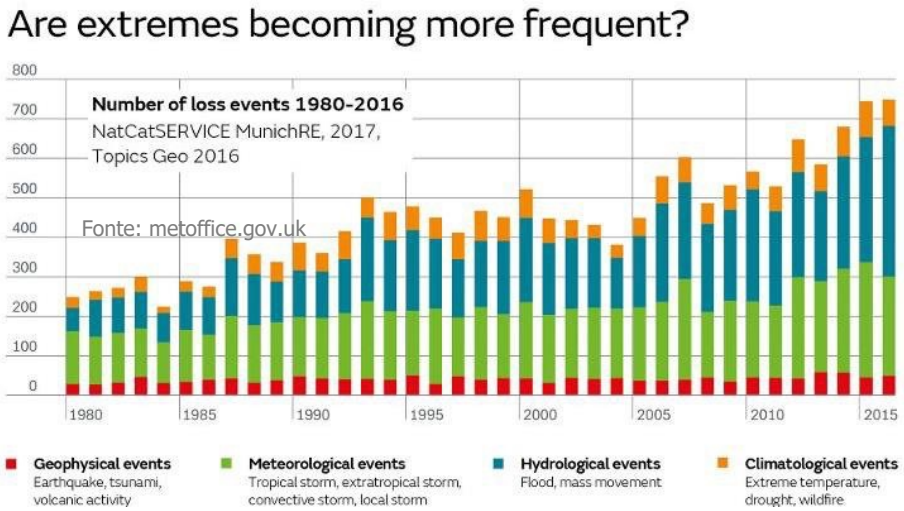
Mudança, variabilidade, tempo

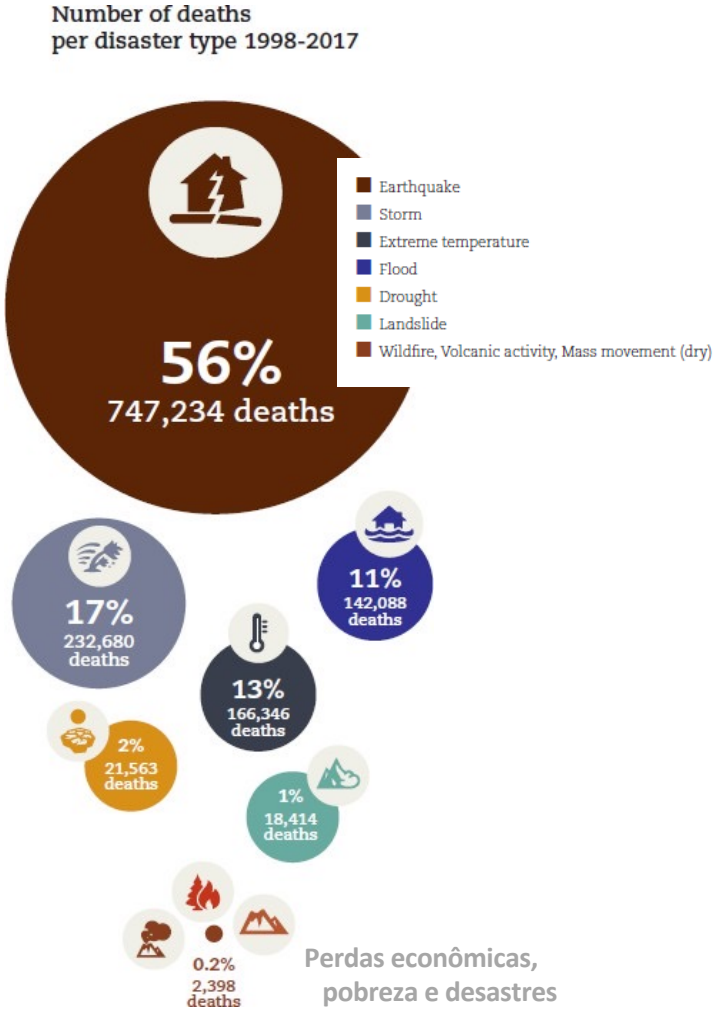


Mais de 350 estudos revisados por pares sobre 450 eventos climáticos extremos atribuídos à mudança climática



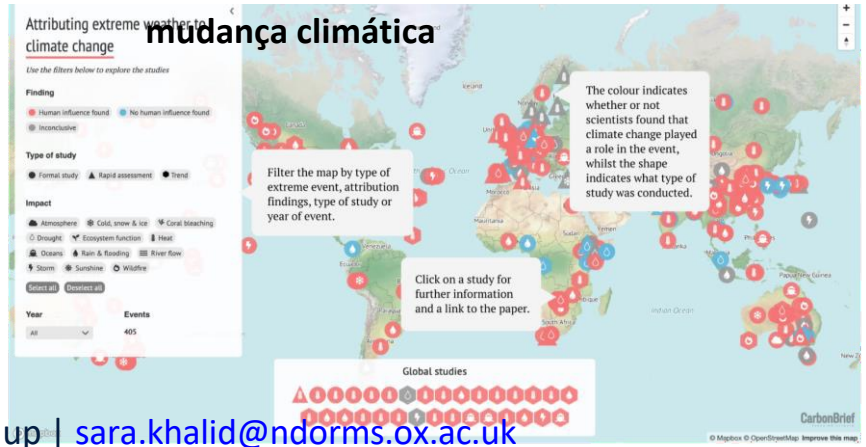
Mudança, variabilidade, tempo





Perdas econômicas, pobreza e desastres 1998-2017
Relatório CRED, UNISDR 2018

Mais de 350 estudos revisados por pares sobre 450 eventos climáticos extremos atribuídos à mudança climática



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Perda de biodiversidade

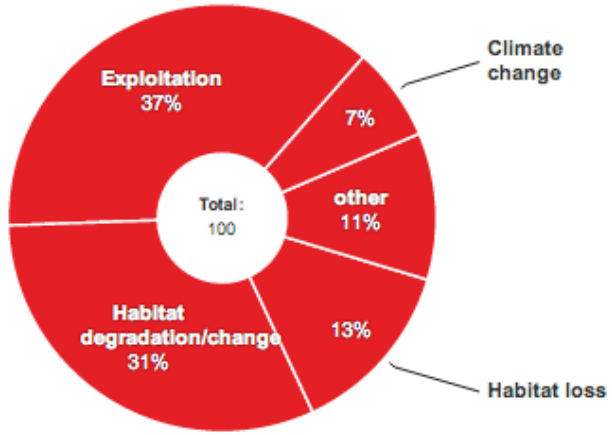
The Guardian

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



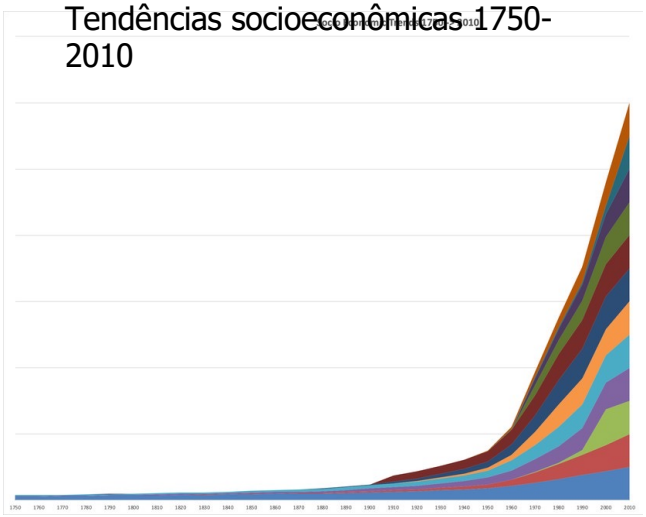
SOURCE: WWF

theguardian

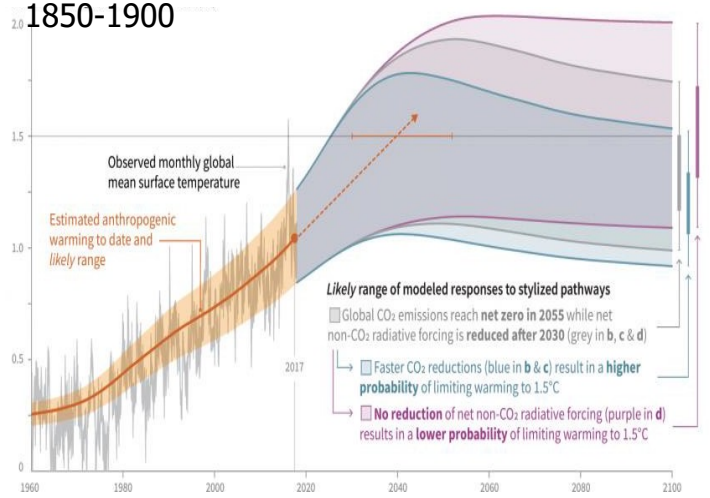
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Aceleração e ponto de virada

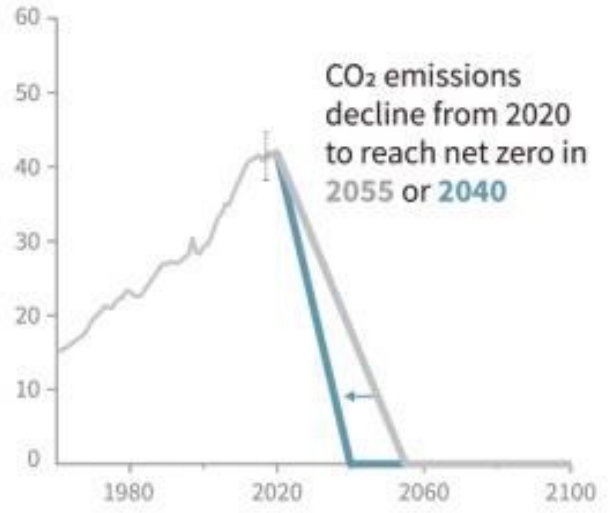
Tendências socioeconômicas 1750-2010



Aquecimento global em relação a 1850-1900



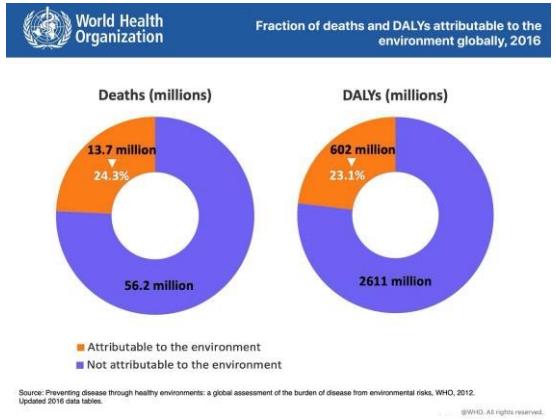
ipcc
INTERGOVERNMENTAL PANEL ON climate change



Relações com a saúde

- “85 das 102 doenças investigadas estão relacionadas
ao meio ambiente.”
  - OMS, Preventing Disease Through Healthy Environment 2006

- ¼ das mortes no mundo ligadas ao meio ambiente
  - OMS, Preventing Disease Through Healthy Environment 2012





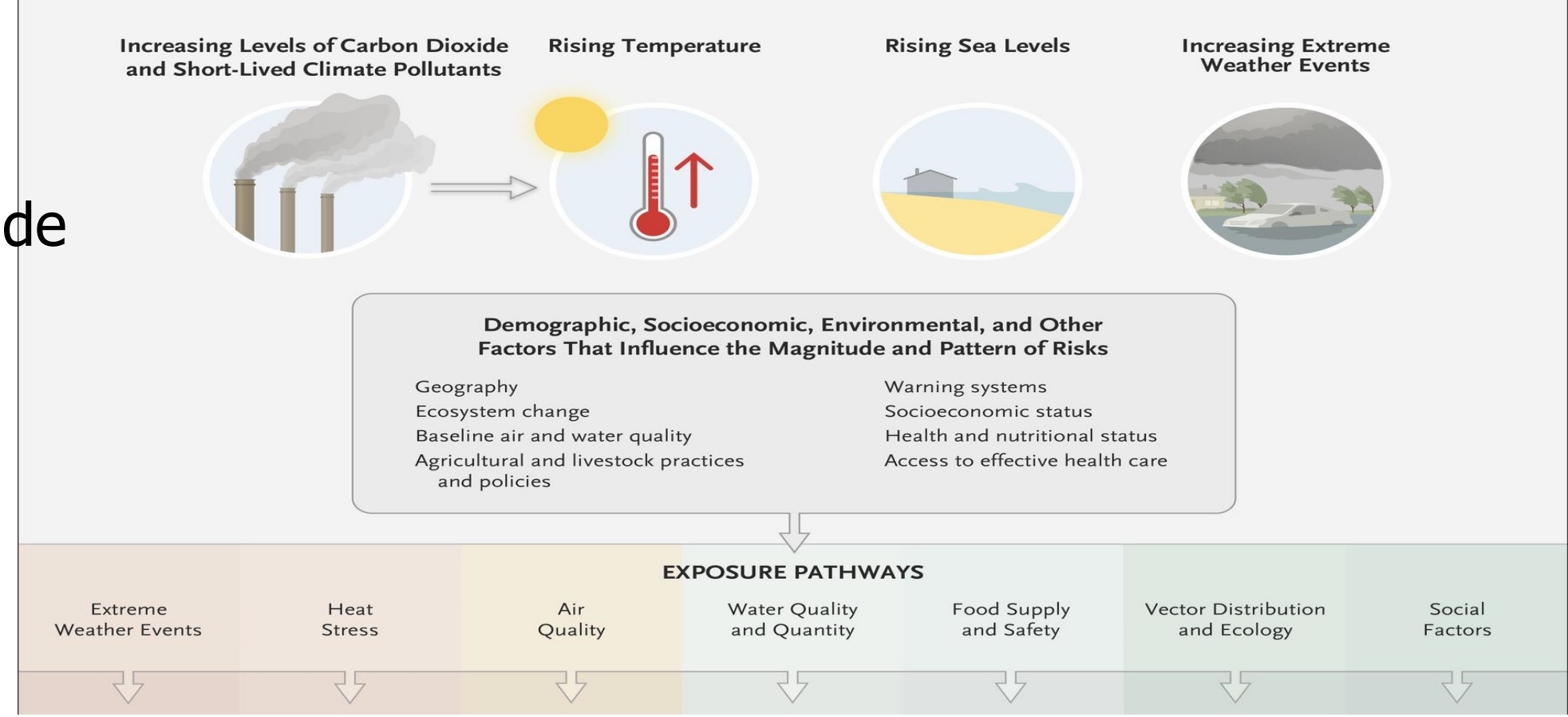




CNN
Deadly flooding. 'Zombie fires.' A massive iceberg. It's been a wild week in weather and climate change
By Faith Karimi, CNN

Impactos na saúde

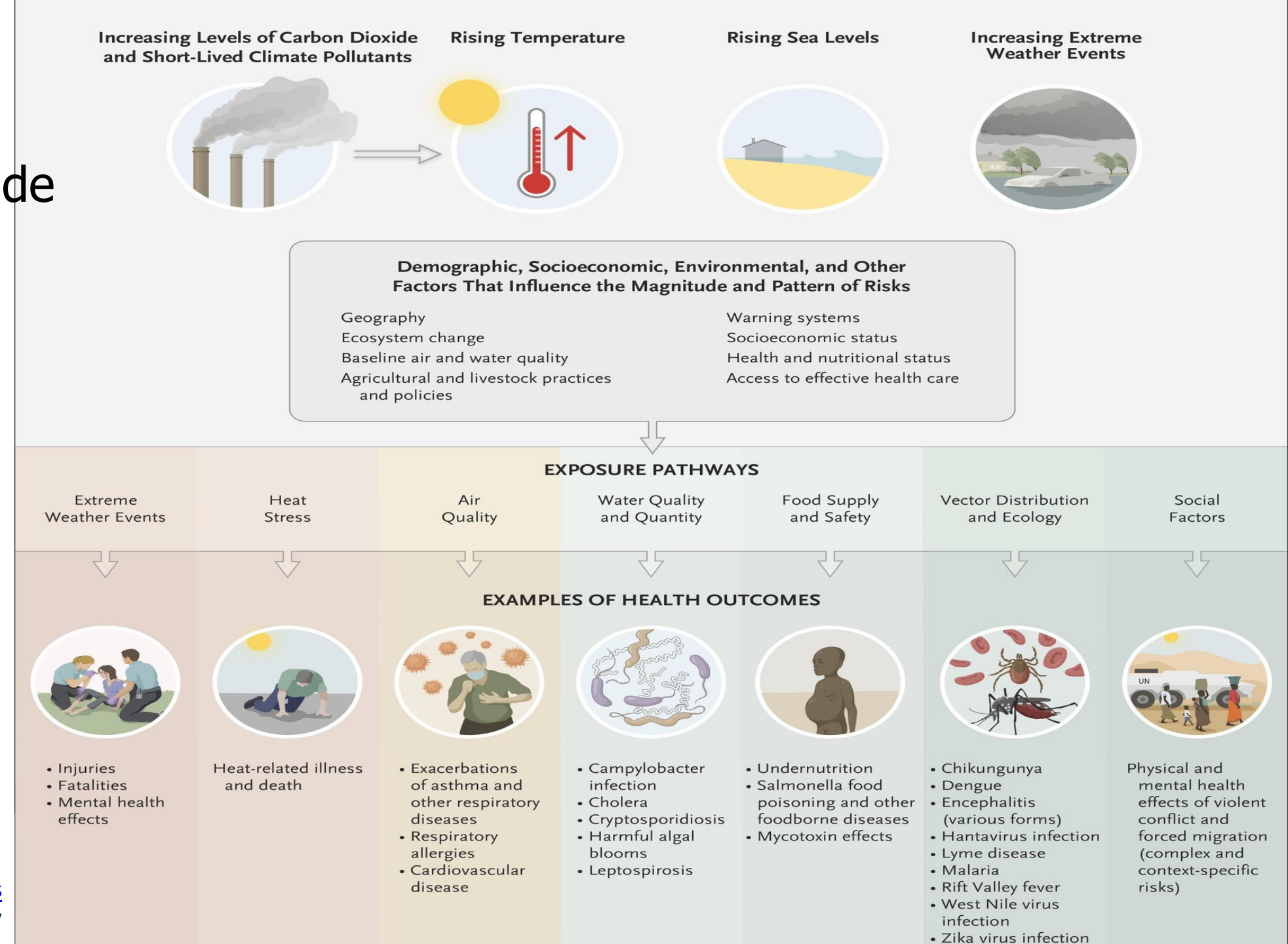
- Diretos
- Indiretos
- De longo prazo



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

Impactos na saúde

- Diretos
- Indiretos
- De longo prazo

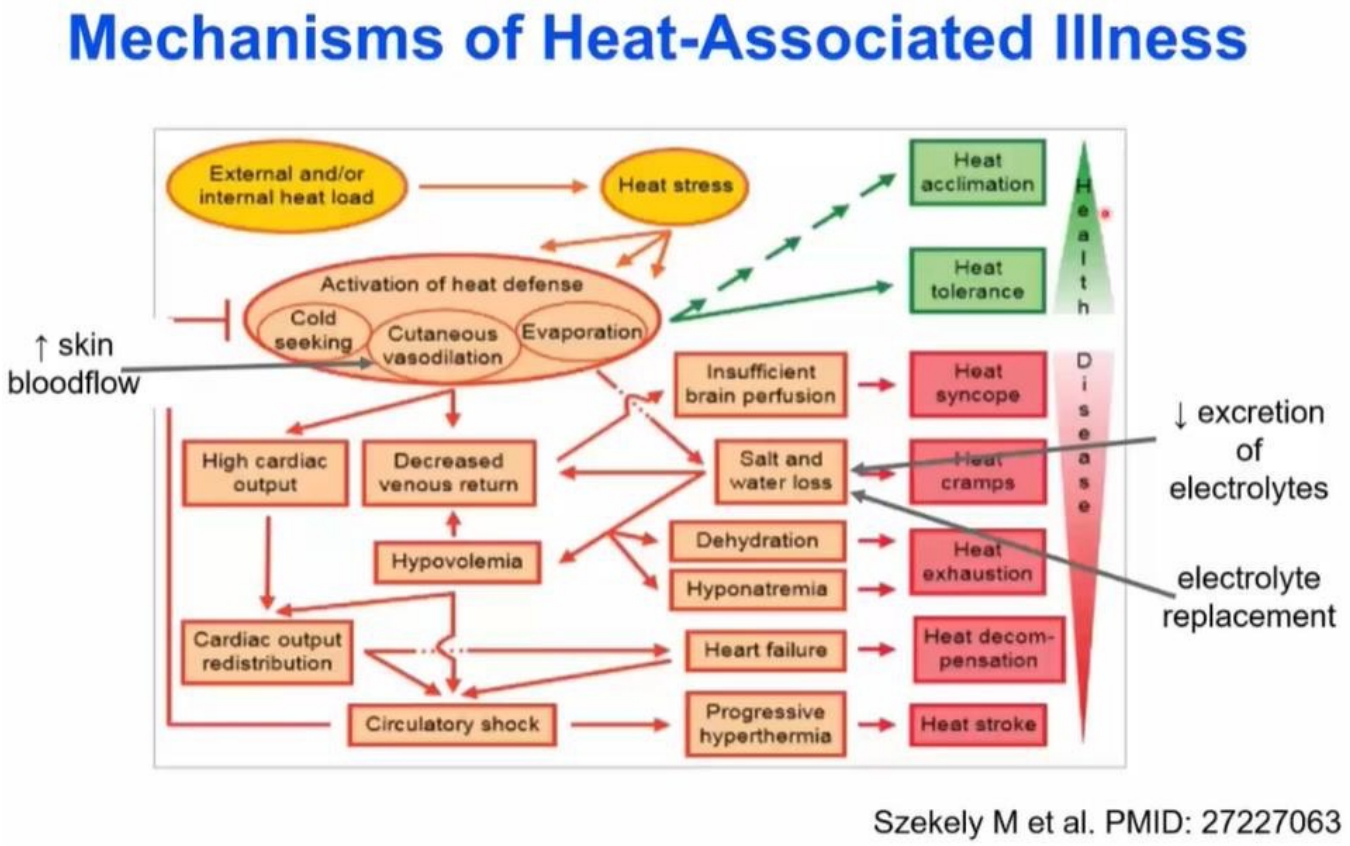


Haines et al. Engl J Med 2019

DOI: 10.1056/NEJMra1807873

Calor e saúde

- Diretos
  - Insolação
  - Cãibras
  - Exaustão
  - Hiper/hipotermia
- Doenças crônicas
  - Doença cardiovascular
  - Diabetes
  - Doença respiratória
  - Doença cerebrovascular
- Hospitalizações
  - Distúrbios cardiovasculares
  - renais
  - respiratórios



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Calor e saúde

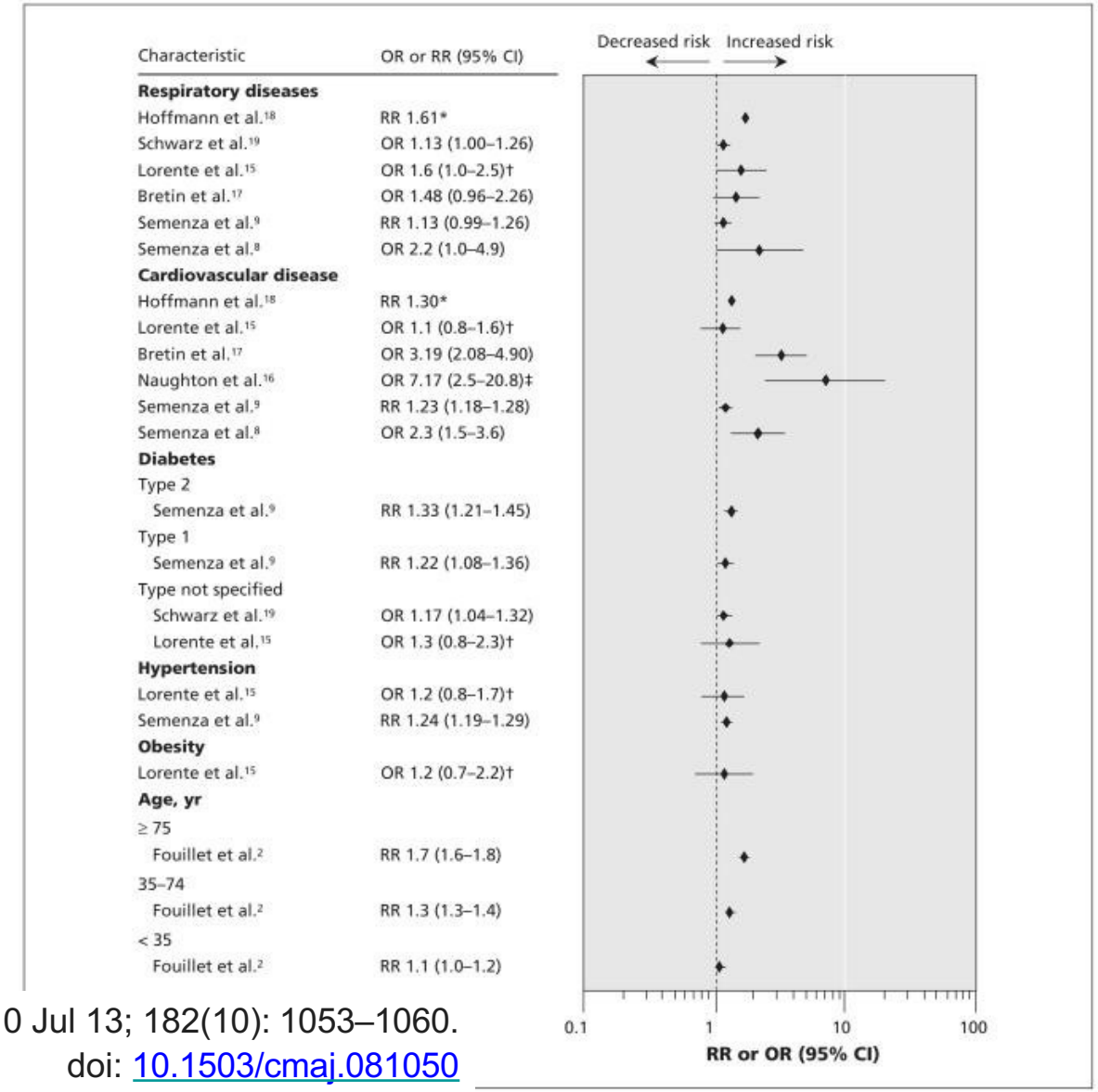
- **Quem é mais vulnerável?**

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

Calor e saúde

- **Quem é mais vulnerável?**
  - **Multimorbidade, polifarmácia**
  - Idosos
  - Crianças pequenas
  - Gravidez, menopausa nas mulheres
  - Ocupações ao ar livre ou sem ventilação

- Determinantes sociais e disparidades
  - Nível socioeconômico
  - Fatores de estilo de vida
  - Etnia/genética



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

Calor e saúde

- Os mais vulneráveis
  - Multimorbidade, polifarmácia
  - **Idosos**
  - Crianças pequenas
  - Gravidez, menopausa nas mulheres
  - Ocupações ao ar livre ou sem ventilação
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  - Etnia/genética

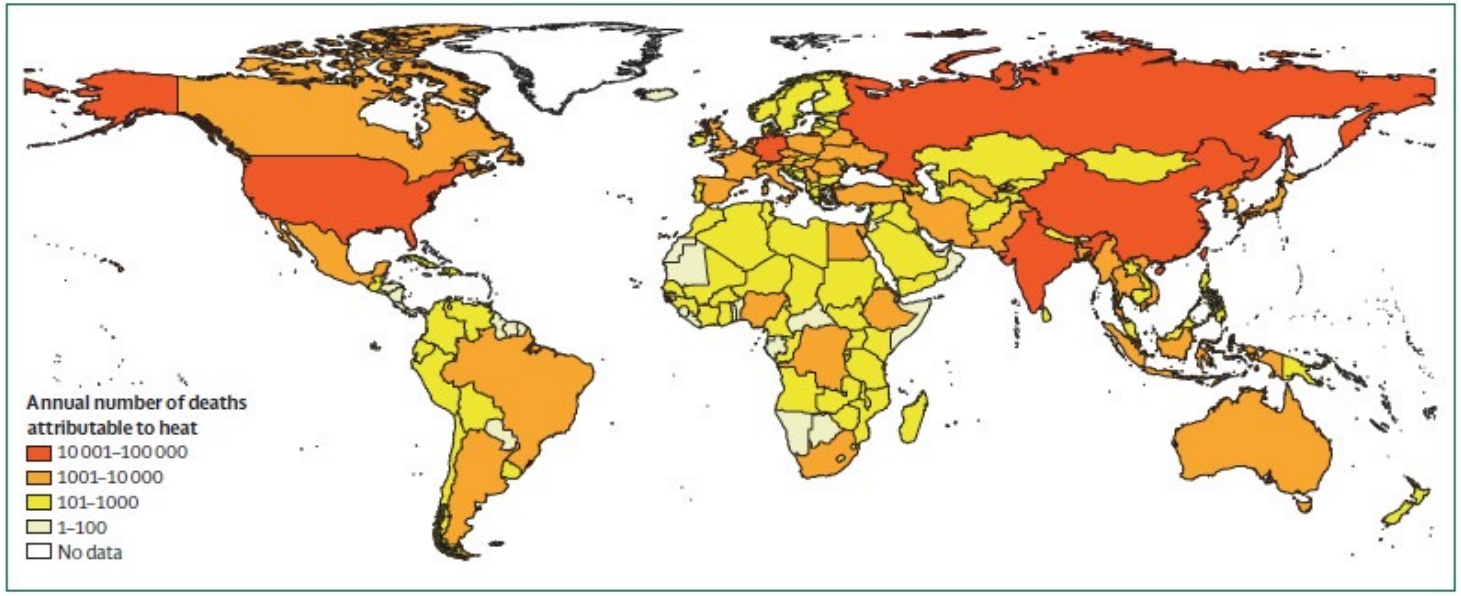


Figure 3: Annual heat-related mortality in the population older than 65 years averaged from 2014 to 2018

"Aumento de mais de 50% na mortalidade relacionada ao calor em pessoas com mais de 65 anos, totalizando 296 mil mortes em 2018."

Lancet Countdown 2015

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

Poluição do ar e mortalidade

World Health Organization

Household air pollution

3.8 million

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

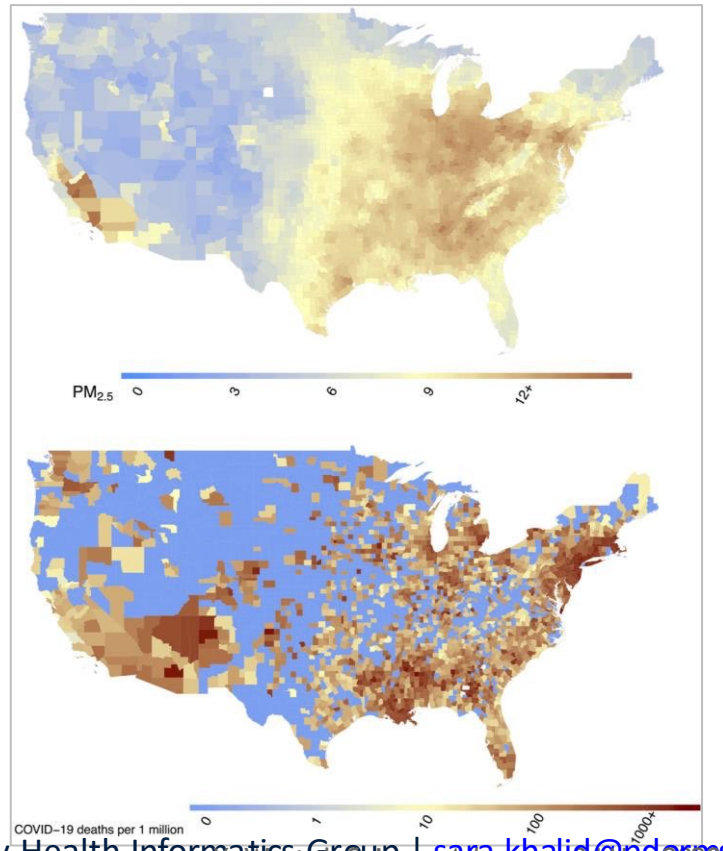
4.2 million

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

www.who.int/data

Poluição do ar e mortalidade

Concentrações históricas de PM2,5 (acima) e mortes por COVID-19 (abaixo) nos EUA.



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

Household air pollution

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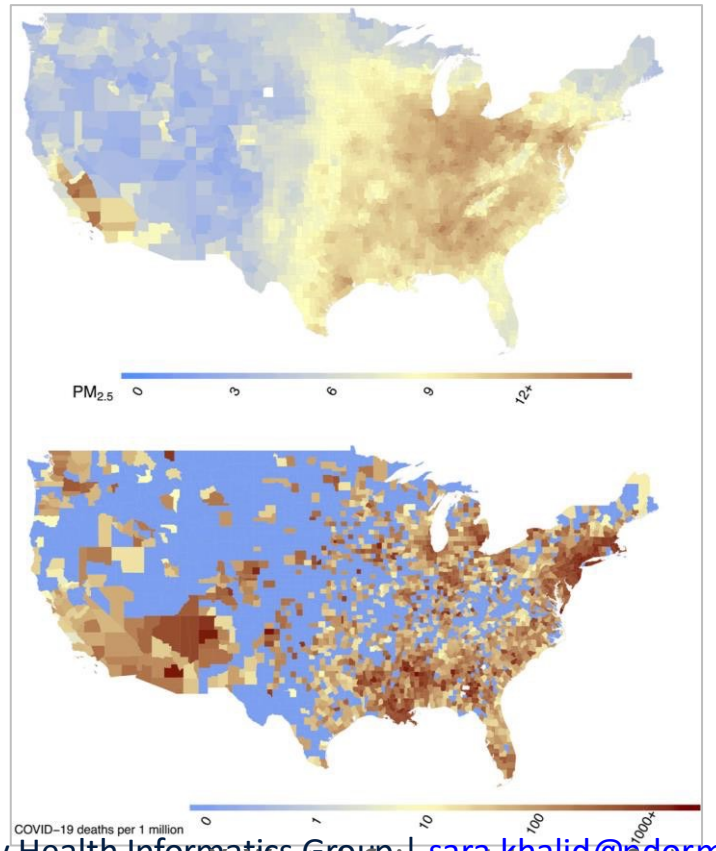
4.2 million

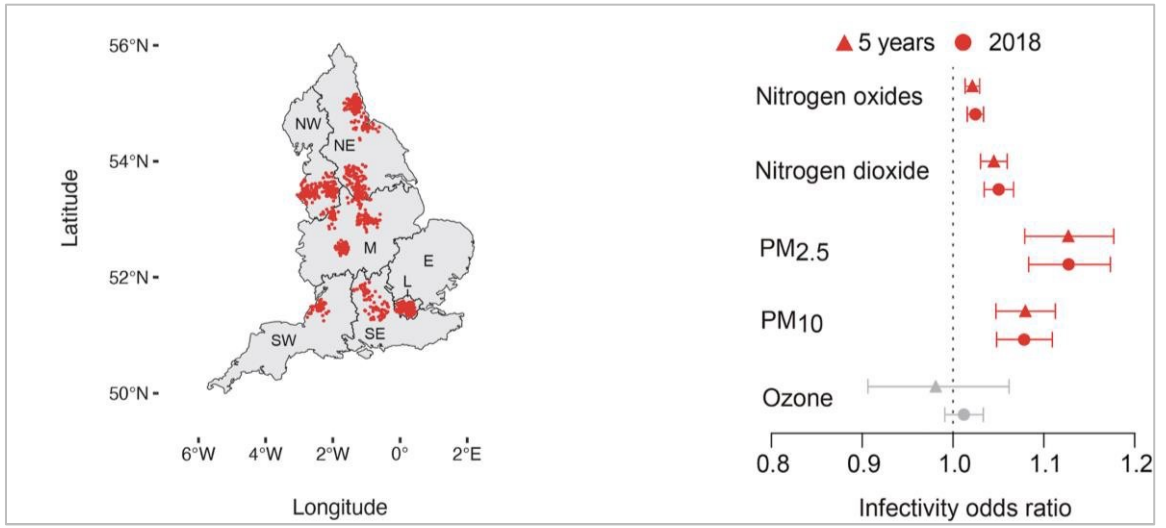
deaths every year as a result of exposure to fine particulate matter

www.who.int/data

Poluição do ar e mortalidade

Concentrações históricas de PM2,5 (acima) e mortes por COVID-19 (abaixo) nos EUA.





Associação entre a exposição a poluentes do ar e o número de casos de COVID-19 confirmados em laboratório no UK Biobank.

X. Wu et al. *Science Advances* 04 Nov 2020:
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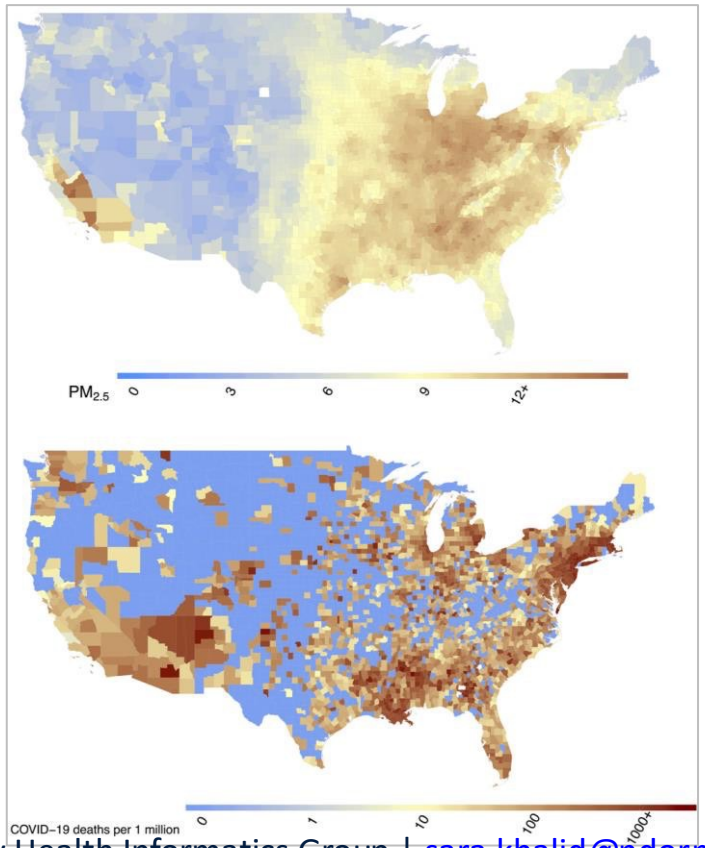
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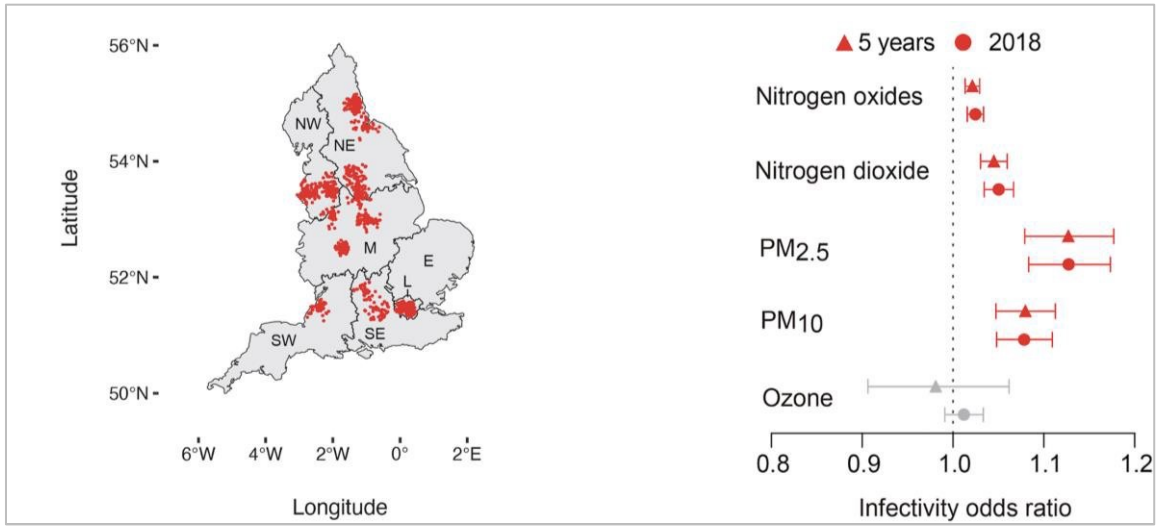
www.who.int/data

Poluição do ar e mortalidade

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



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Household air pollution

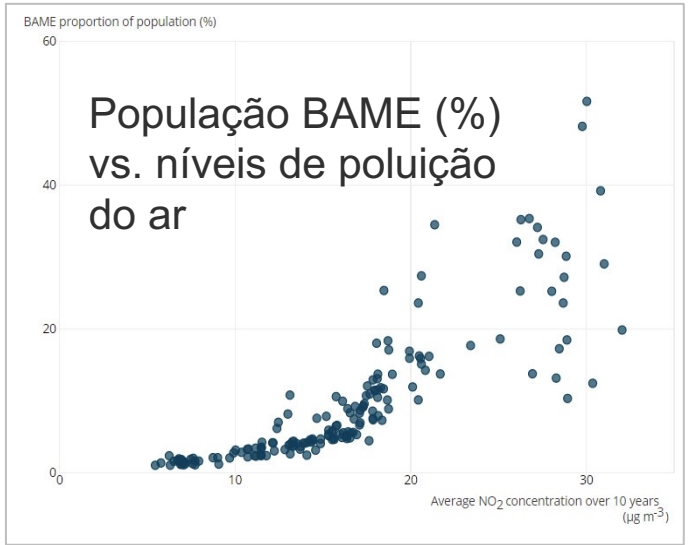
3.8 million

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



...e mais

Efeitos do ambiente na saúde mental

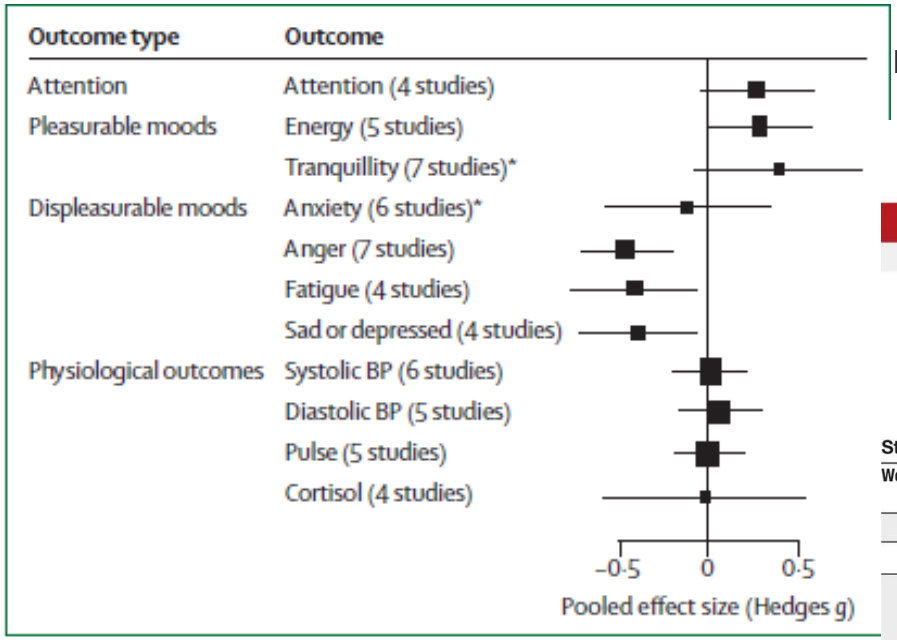


Figure 18: Psychological and emotional outcomes from exposure to natural versus synthetic environments

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

Efeito do tempo sobre a dor

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

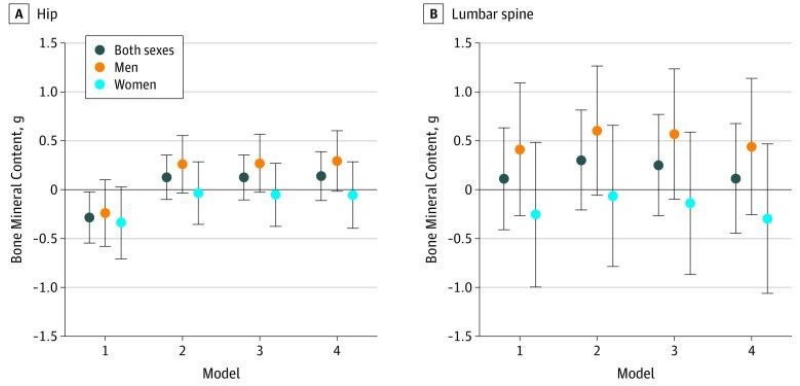
Beukenhorst, Anna L.[a,*]; Schultz, David M.[b,c]; McBeth, John[a,d]; Sergeant, Jamie C.[a,e]; Dixon, William G.[a,d]

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)

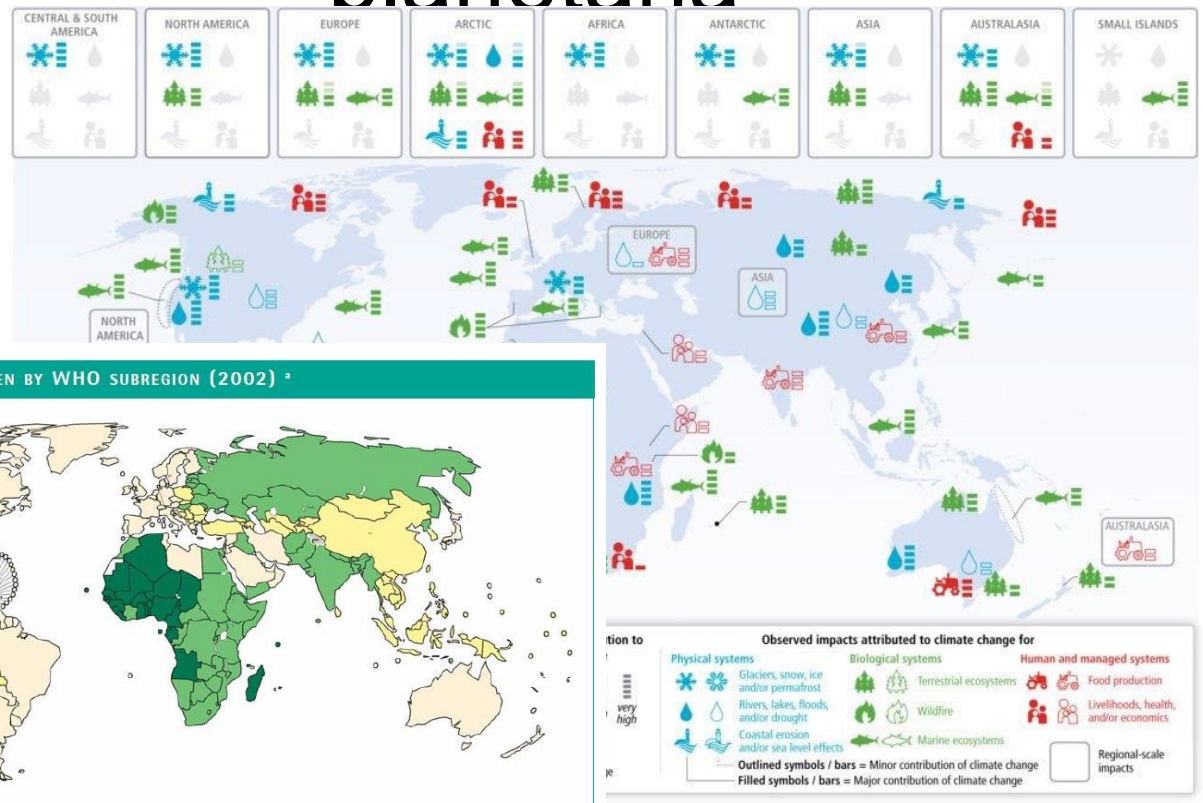
PAIN 161(4):668-683, April 2020.

Efeitos da poluição do ar na saúde musculoesquelética



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

Um problema de escala planetária



Prüss-Üstün et al. Relatório OMS Preventing Disease 2006

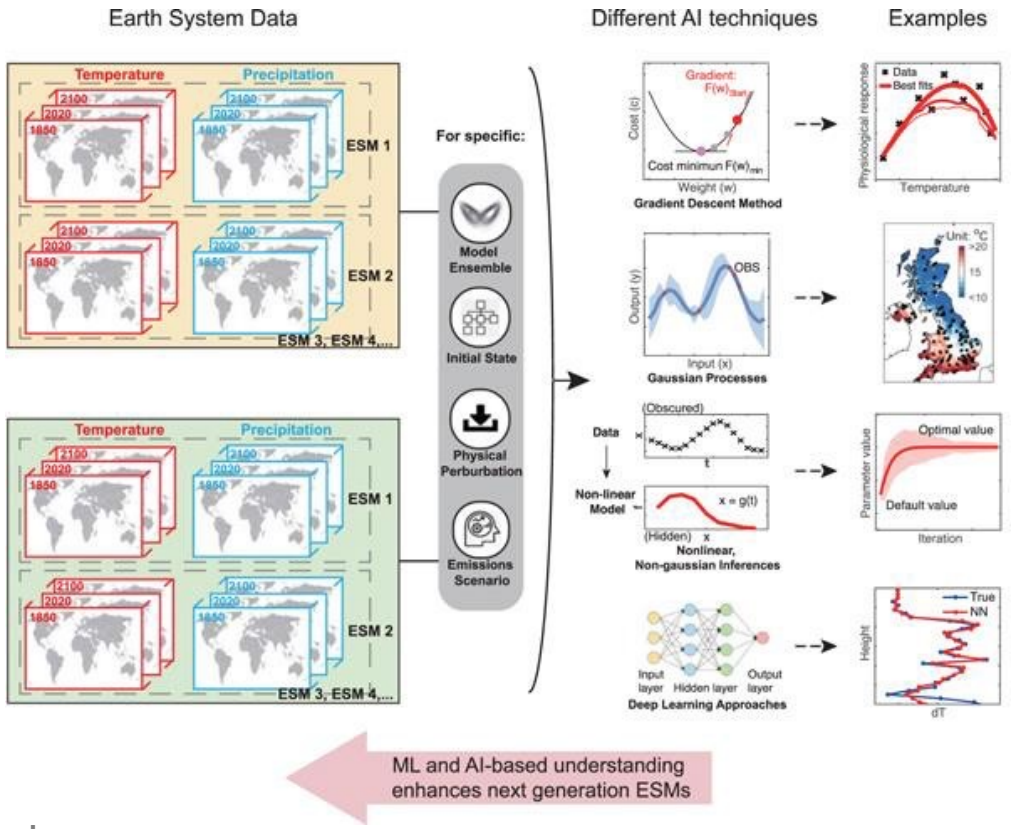
Cramer et al. Detection and attribution of observed impacts. Climate Change 2014: IPCC 5th AR

"É a primeira vez que uma geração inteira de crianças vai crescer em um mundo muito mais perigoso e incerto por causa da mudança climática e da degradação ambiental." UNICEF

Informática em saúde e saúde planetária

Ciência de dados climáticos

- Modelagem do sistema terrestre
  - p. ex. classificação da cobertura do solo
- Cenários climáticos futuros
- Previsão do tempo
- Previsão de eventos extremos
  - p. ex. previsão de inundações
- Impactos climáticos
  - p. ex. na agricultura, saúde, economia
- Curadoria e qualidade dos dados
  - p. ex. dados pontuais, em grade e de satélite de precipitação,
    temperatura, vegetação e ambiente construído

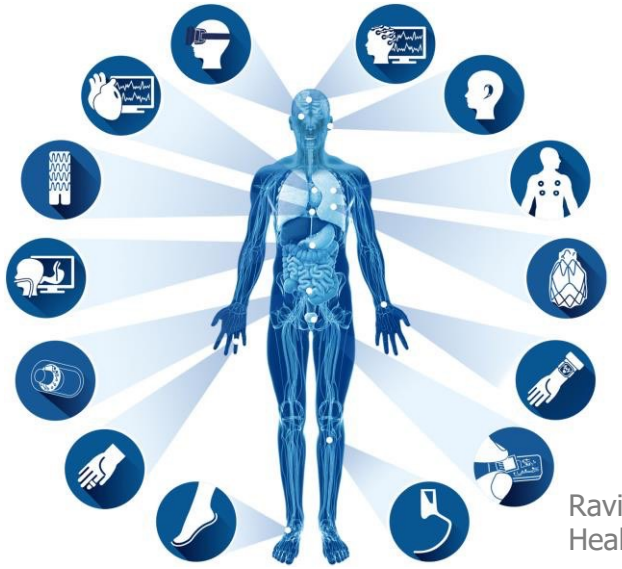


Huntingford C *et al* 2019 *Environ. Res. Lett.* **14** 124007

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Ciência de dados em saúde

- Fornecer dados em tempo real e do mundo real

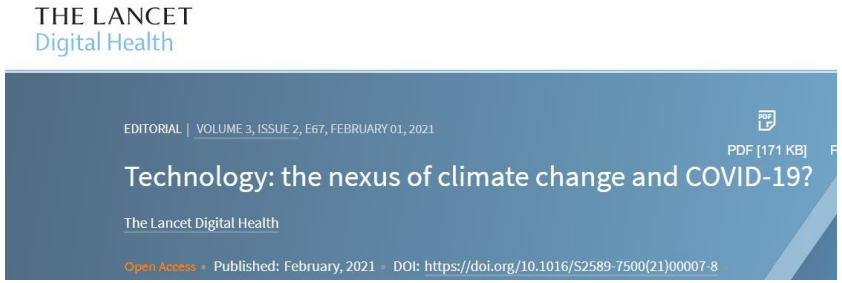


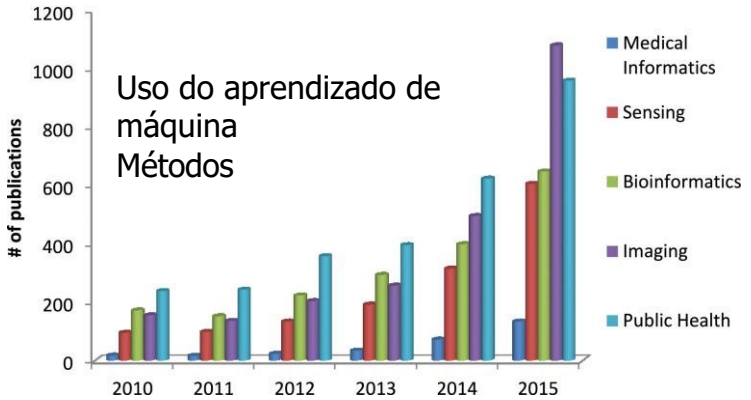
Ravi et al., IEEE Biomed & Health Informatics 2017

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Ciência de dados em saúde

- Fornecer dados em tempo real e do mundo real
- Melhorar **o conhecimento sobre** clima e saúde



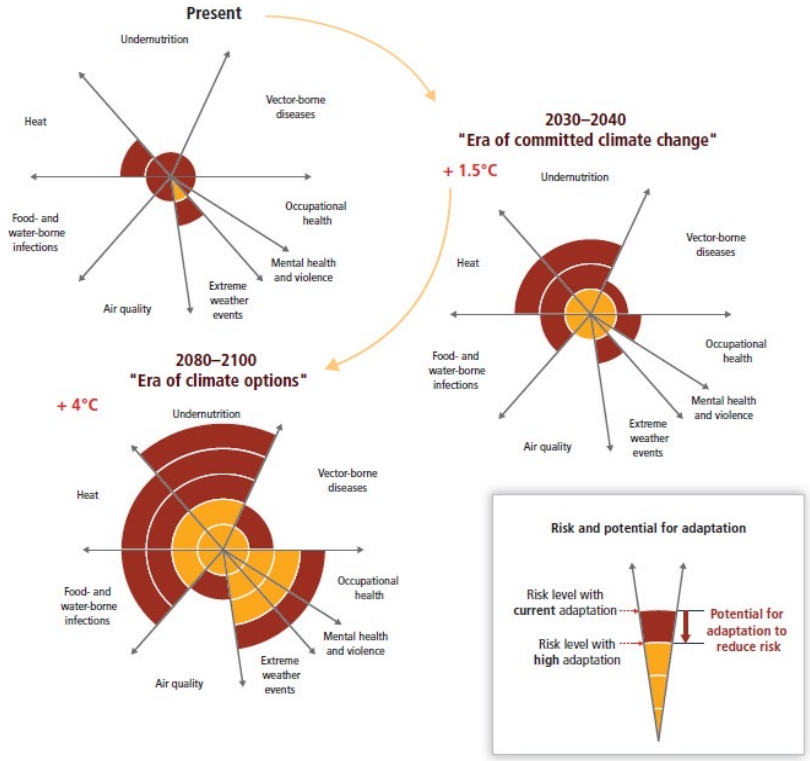


Ravi et al. IEEE Biomed & Health Informatics 2017

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Ciência de dados em saúde

- Fornecer dados em tempo real e do mundo real
- Melhorar o conhecimento sobre clima e saúde
- **Adaptação dos sistemas de saúde à mudança** climática



Impacto do clima em 8 setores da saúde e potencial de mitigação por meio da adaptação.

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

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Sistemas de alerta precoce

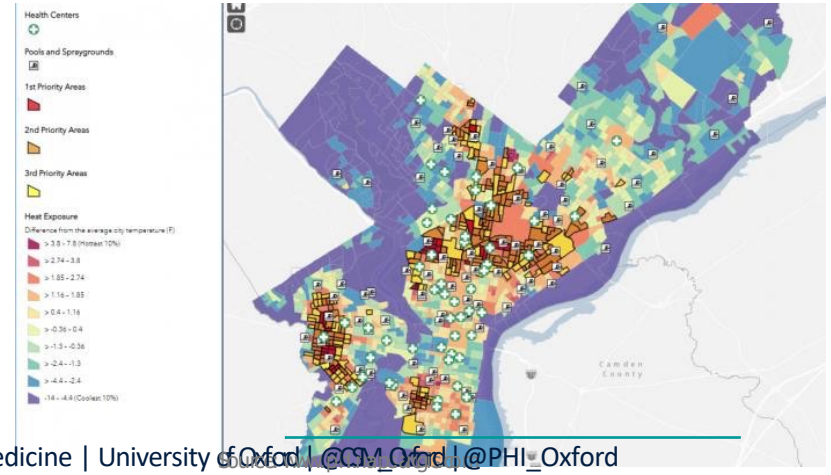
- Tradicionalmente baseados no conhecimento local
- SAP inteligentes baseados em
  - Conhecimento especializado
  - Big data em tempo real
  - Análises avançadas

Avaliação de sistemas de alerta calor-saúde em Xangai, China

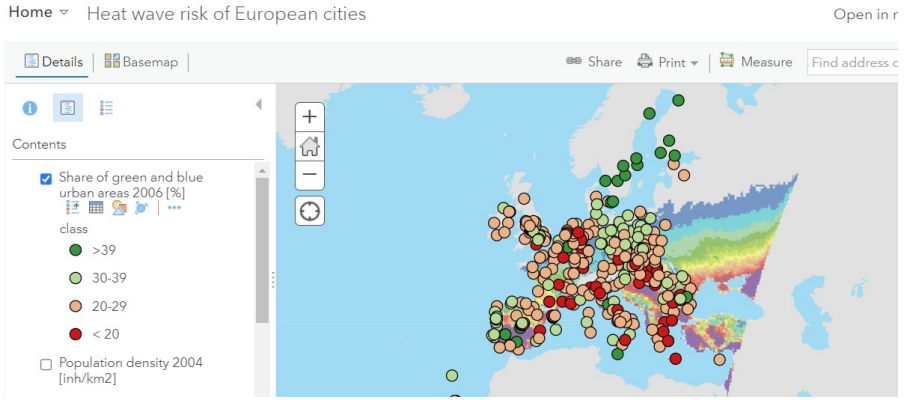


Yaqiao et al. Science of The Total Env. https://doi.org/10.1016/j.scitotenv.2020.136883

Índice de risco de calor, Filadélfia, EUA.

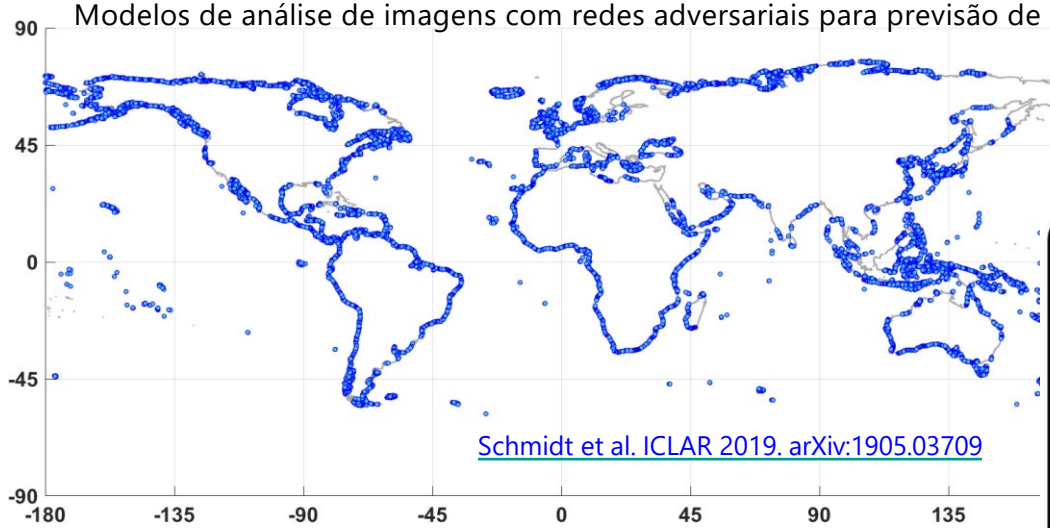


Mapa de risco de calor. Agência Europeia do Ambiente

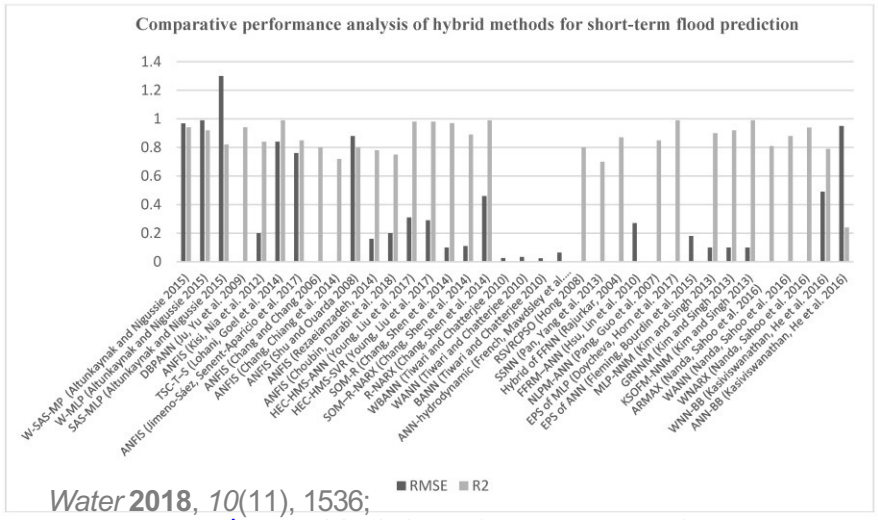


Modelos de previsão de inundações

Modelos de análise de imagens com redes adversariais para previsão de inundações

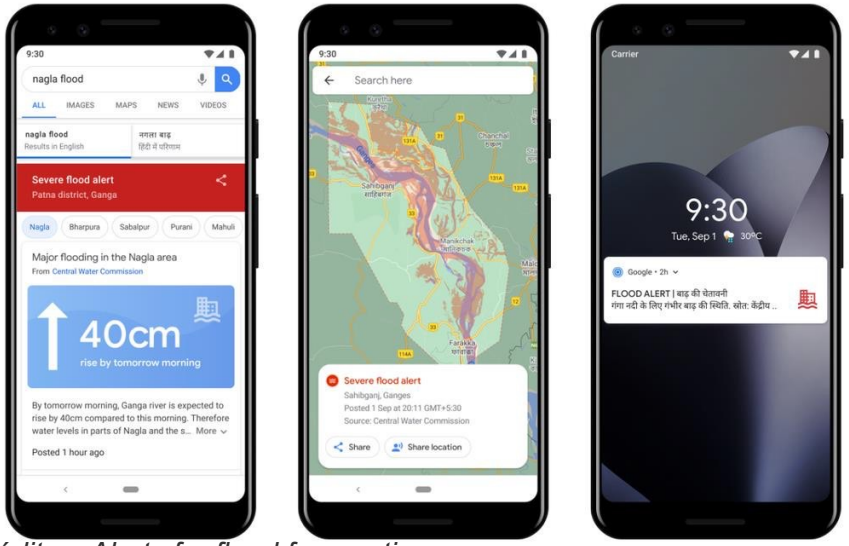


Schmidt et al. ICLAR 2019. arXiv:1905.03709



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

Iniciativa de previsão de inundações do Google em uso na Índia e em Bangladesh



Créditos: Alerts for flood forecasting, Google

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Prever surtos de doenças



Dados de satélite Landsat combinados com dados de solo sobre precipitação, temperatura, umidade do solo e vegetação



Modelos computacionais que acompanham eventos humanos e ambientais

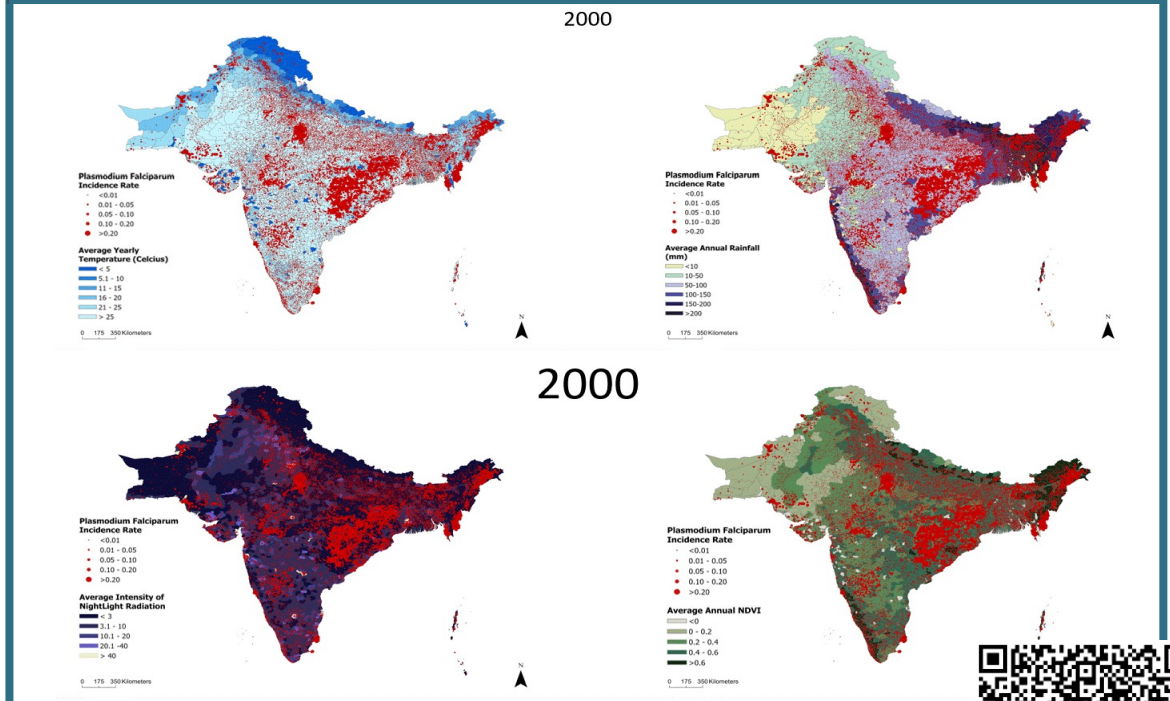
Prever surtos de malária no Peru no nível domiciliar

Schmidt et al. ICLAR 2019. arXiv:19



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

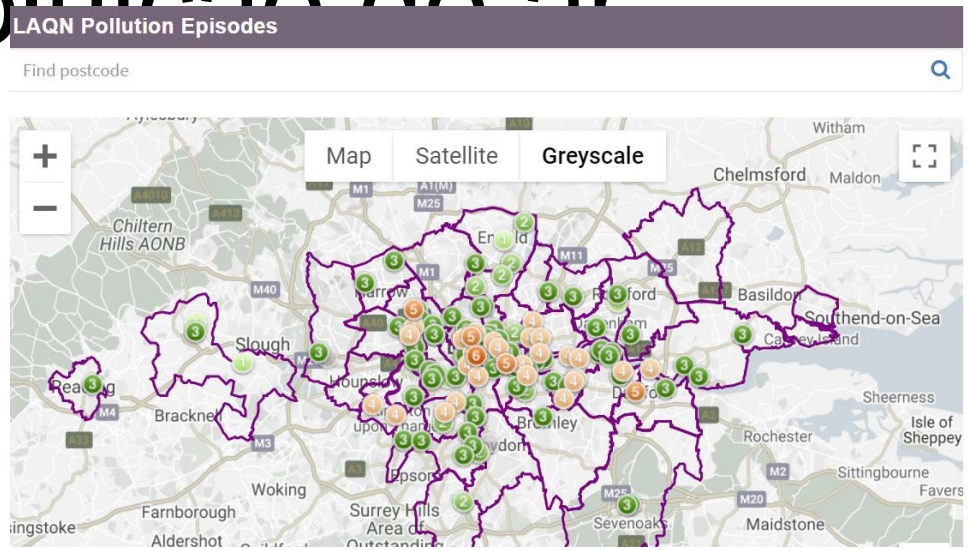
Usman Nazir[1], Muhammad Talha Quddoos[1], Momin Uppal[1], Sara Khalid[2]
[1]Lahore University of Management Sciences, [2]Centre for Statistics in Medicine, University of Oxford
sara.khalid@ndorms.ox.ac.uk



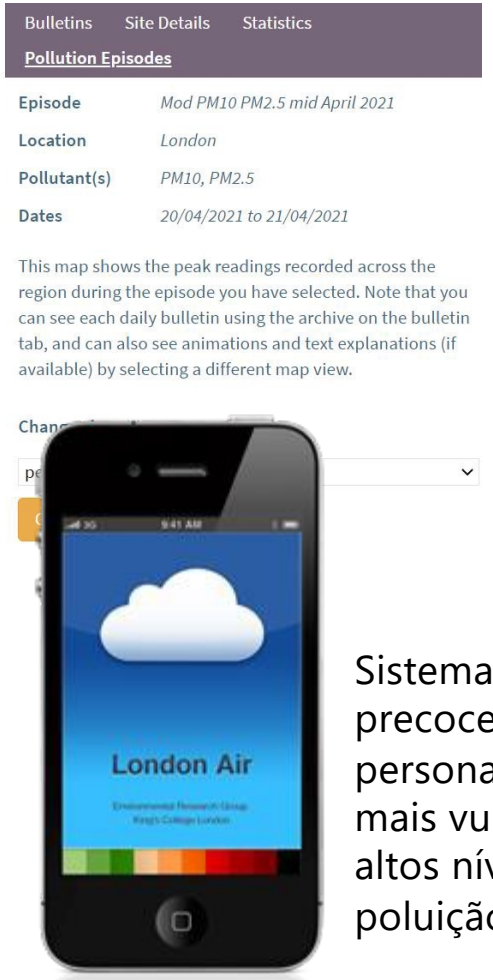
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Acompanhamento e monitoramento da poluição do ar



A London Air Quality Network monitora e prevê os níveis de ozônio, óxido de nitrogênio, PM2,5 e PM10



Sistema de alerta precoce personalizado para os mais vulneráveis a altos níveis de poluição

Crédito: londonair.org.uk

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IA e biodiversidade

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

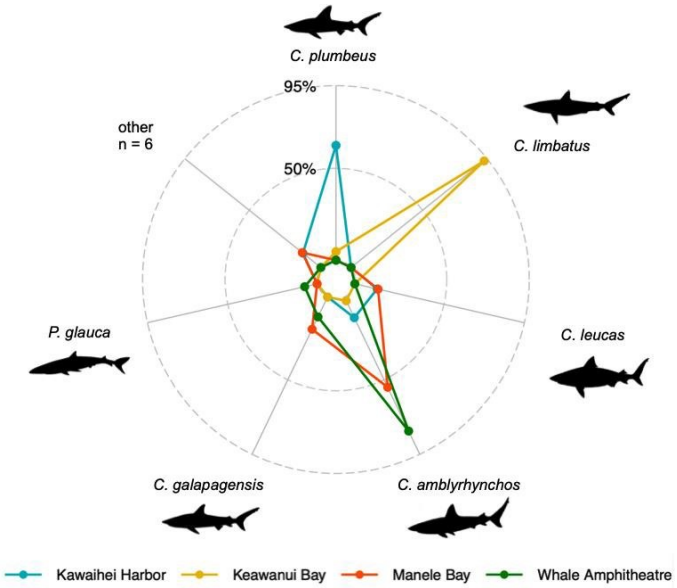
Select Video

20220924_KeawanuiBay_S3_GX110006.mp4

PROCESS DETECT VIDEO PLAY VIDEO RESET

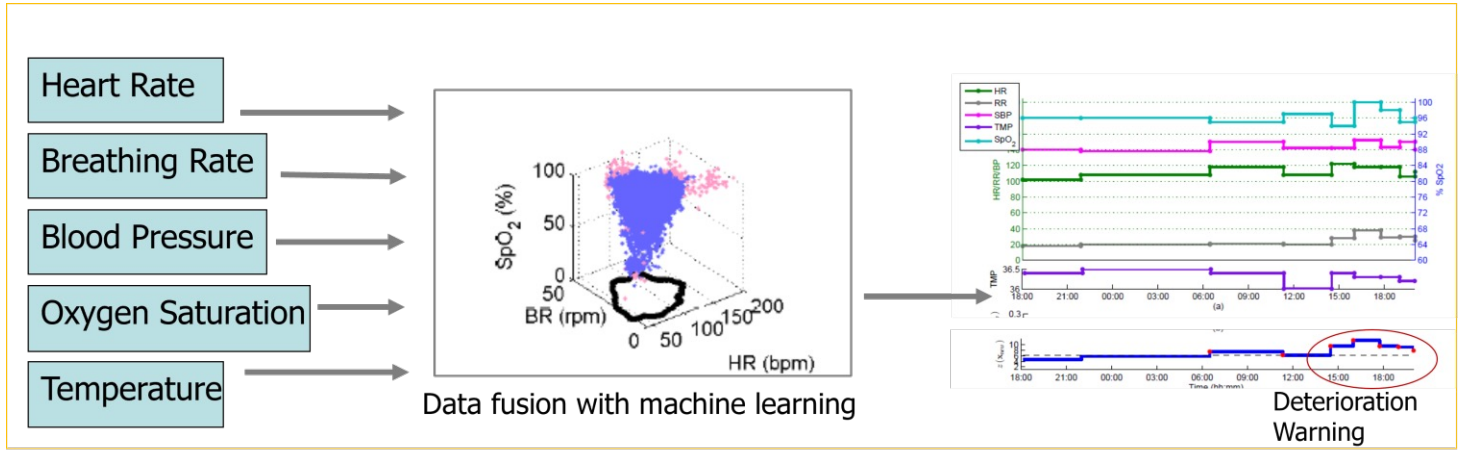
Shark	Prediction
Carcharhinus limbatus	94.15 %
Carcharhinus plumbeus	4.13 %
Carcharhinus amblyrhynchos	0.47 %
Galeocerdo cuvier	0.44 %
Carcharodon carcharias	0.39 %





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Monitoramento remoto de pacientes em zonas de desastre/conflito





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

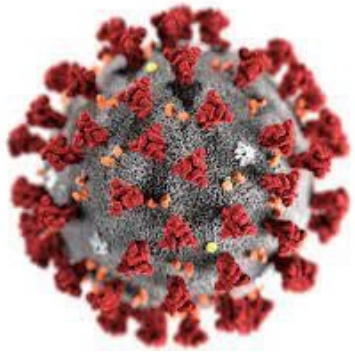
Home monitoring kit for remote management of Covid-19 infection



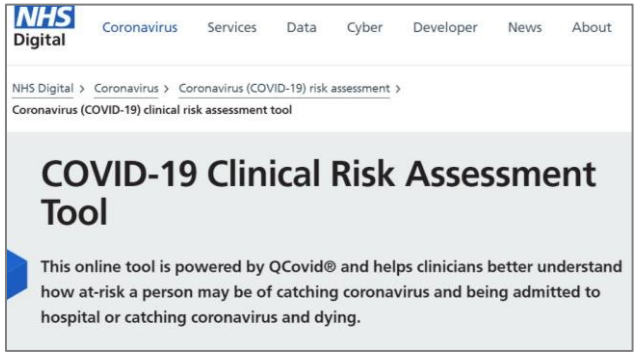
Santos et al. Front. Digit. Health
https://doi.org/10.3389/fdgth.2021.630273

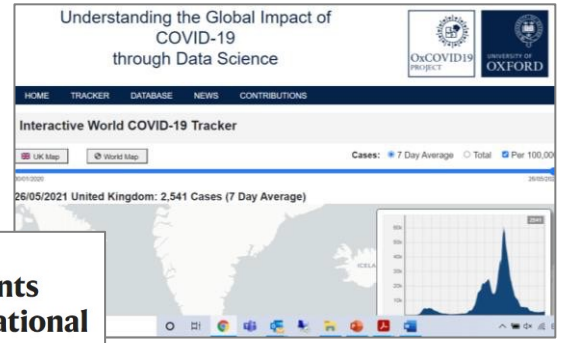
Resposta a pandemias

- Diagnóstico
- Previsão de risco clínico
- Estratégia de vacinação
- Fenotipagem profunda

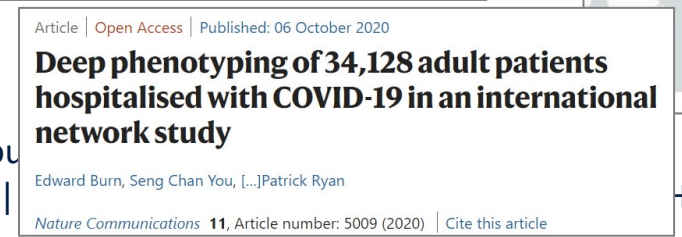








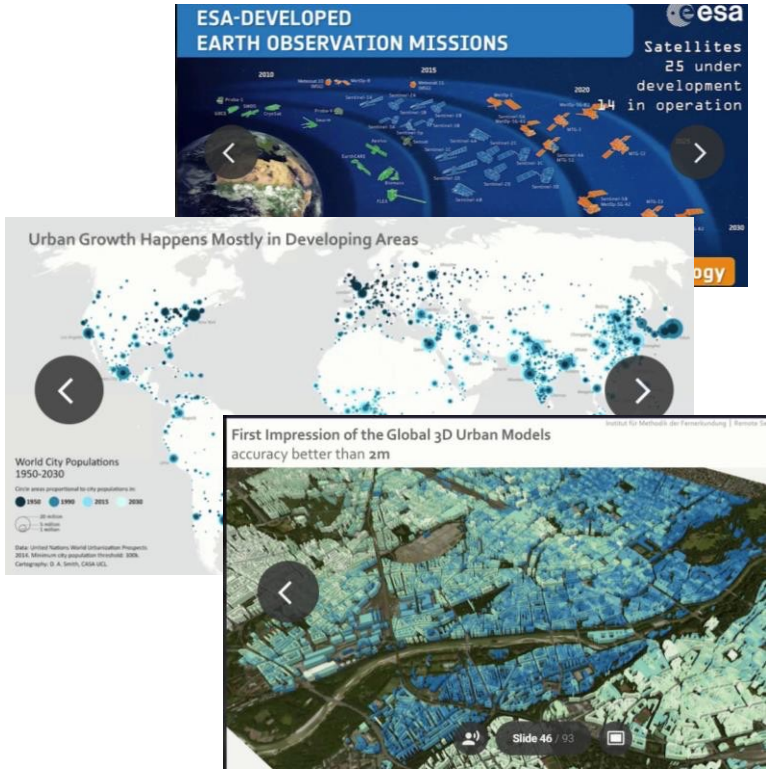




Modelos computacionais

- Cidades do futuro
  - Conforto térmico urbano
  - Otimização do uso do solo
  - Maior cobertura vegetal
- Modelagem de transportes
  - Mais atividade física
  - Menor pegada de carbono
- IA para energias renováveis
- Pegada de carbono da IA

Construir uma planta 3D das ilhas de calor urbanas com dados de observação da Terra e aprendizado profundo



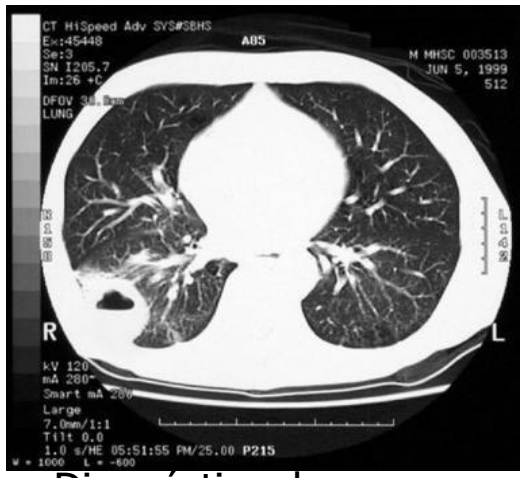
XX Zhu et al. IEEE Trans. Geoscience & Remote Sens 2017

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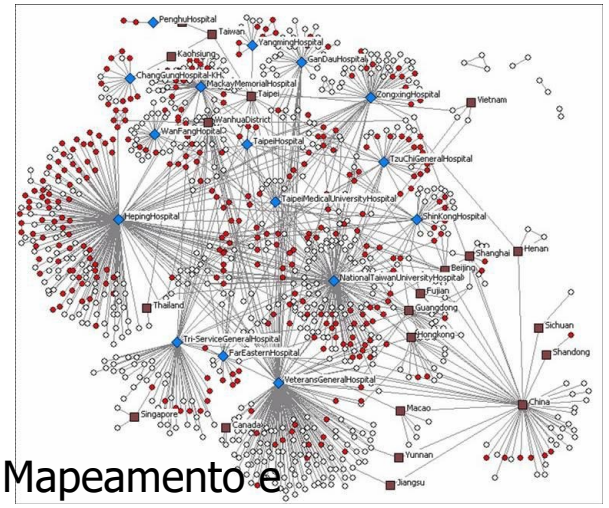
Aplicações reais



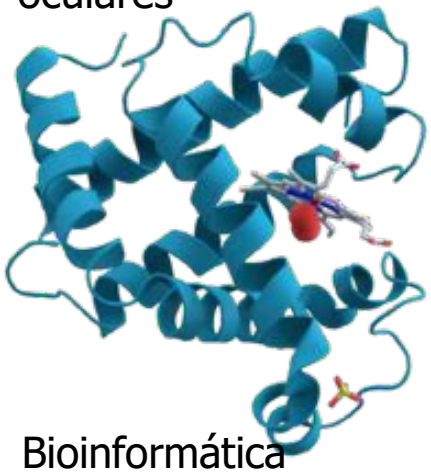
Detecção de doenças oculares



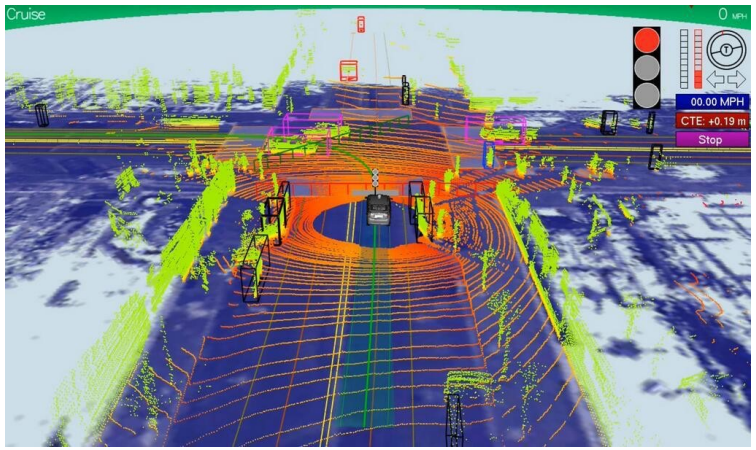
Diagnóstico de tumores



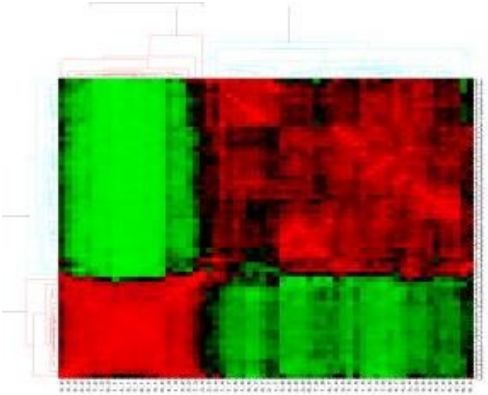
Mapeamento e rastreamento de doenças



Bioinformática



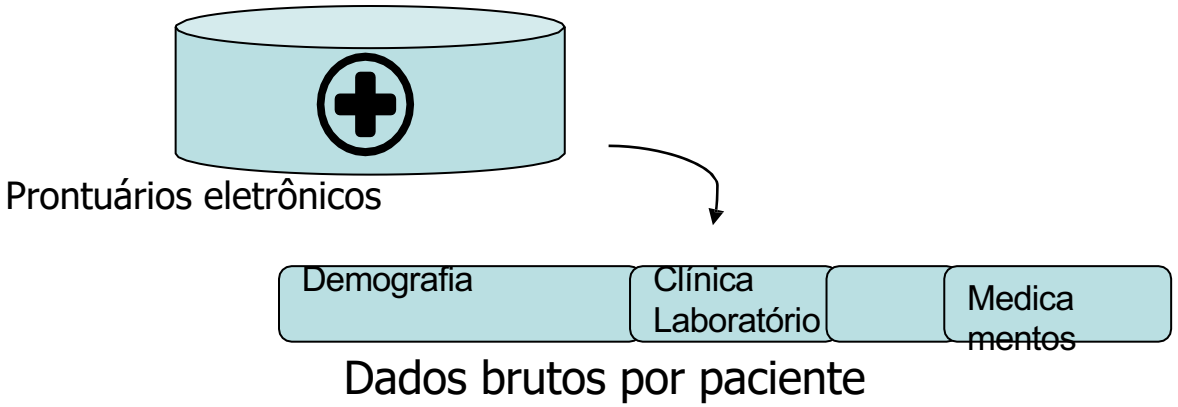
Autonomous vehicle navigation



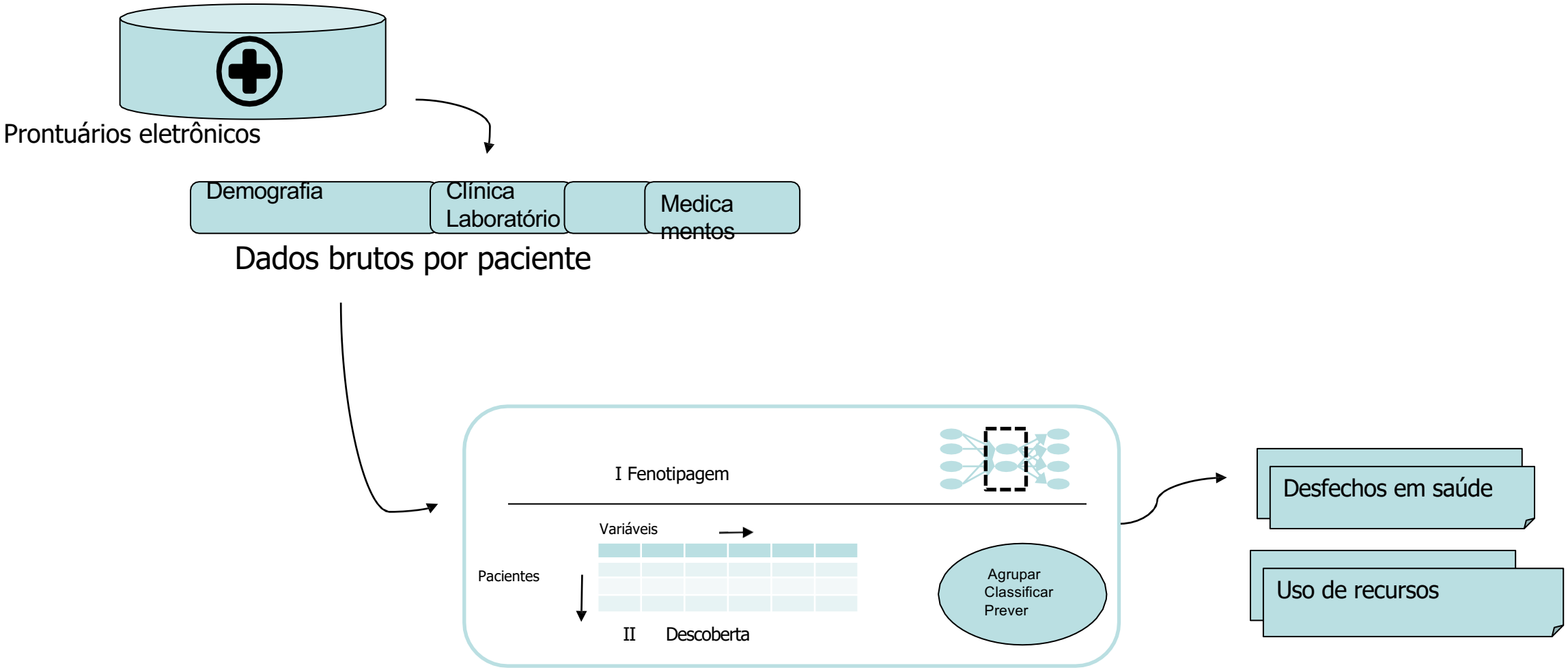
Agrupamento da expressão gênica

Desafios e oportunidades

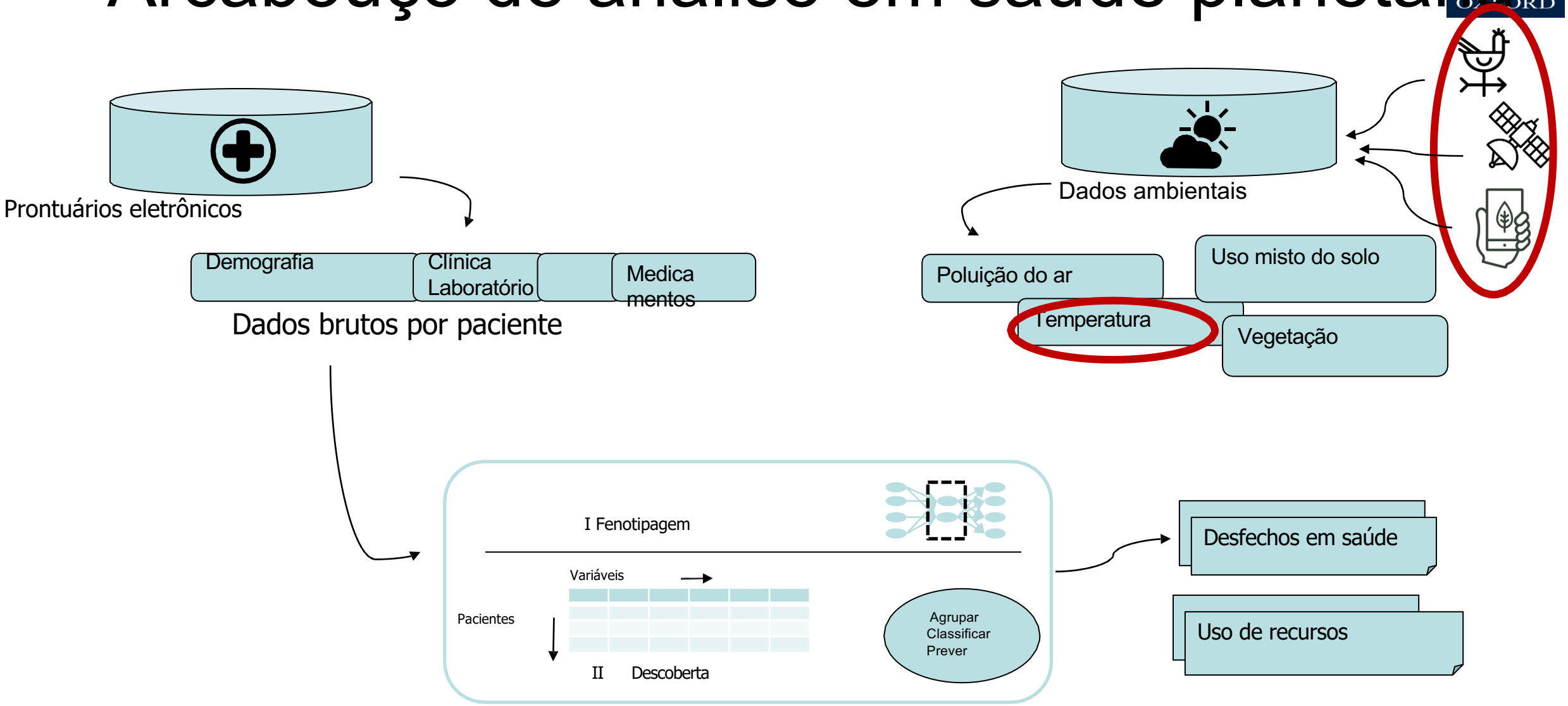
Arcabouço de análise em saúde planetária



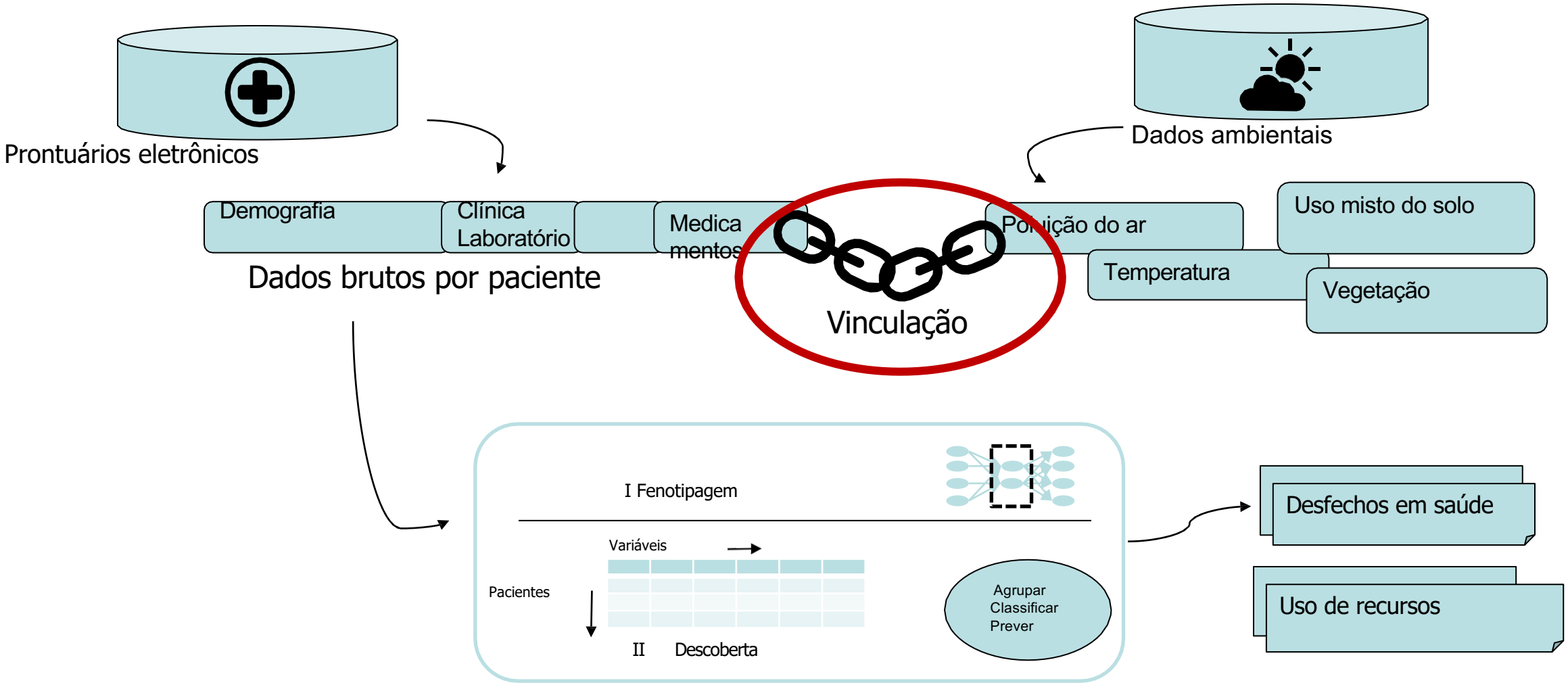
Arcabouço de análise em saúde planetária



Arcabouço de análise em saúde planetária

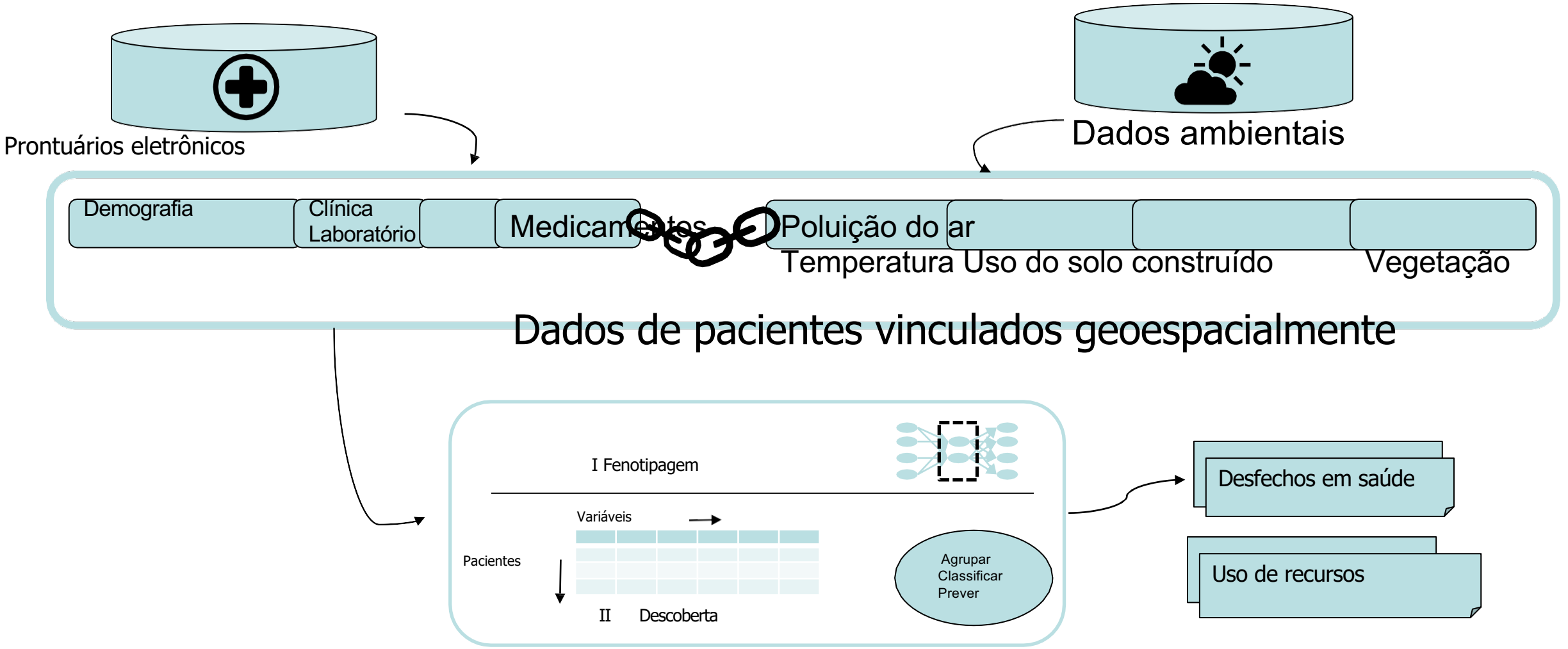


Arcabouço de análise em saúde planetária



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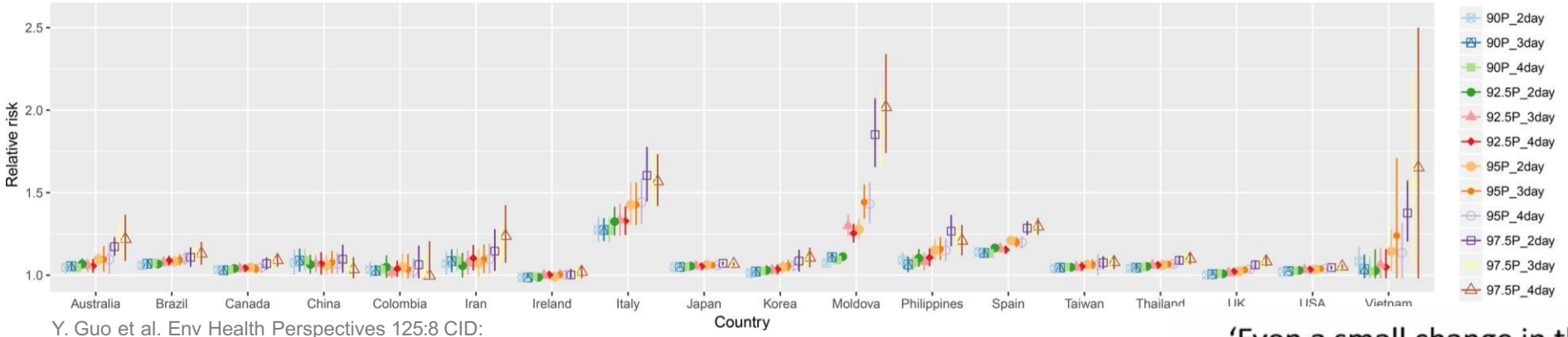
Arcabouço de análise em saúde planetária



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Definição, codificação e registro do calor

Efeito das ondas de calor na mortalidade em 18 países com 12 definições diferentes de onda de calor



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

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Dados do mundo real, IA e equidade em saúde

Viés dos dados

+

Viés algorítmico

→

Avaliação de saúde incorreta



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

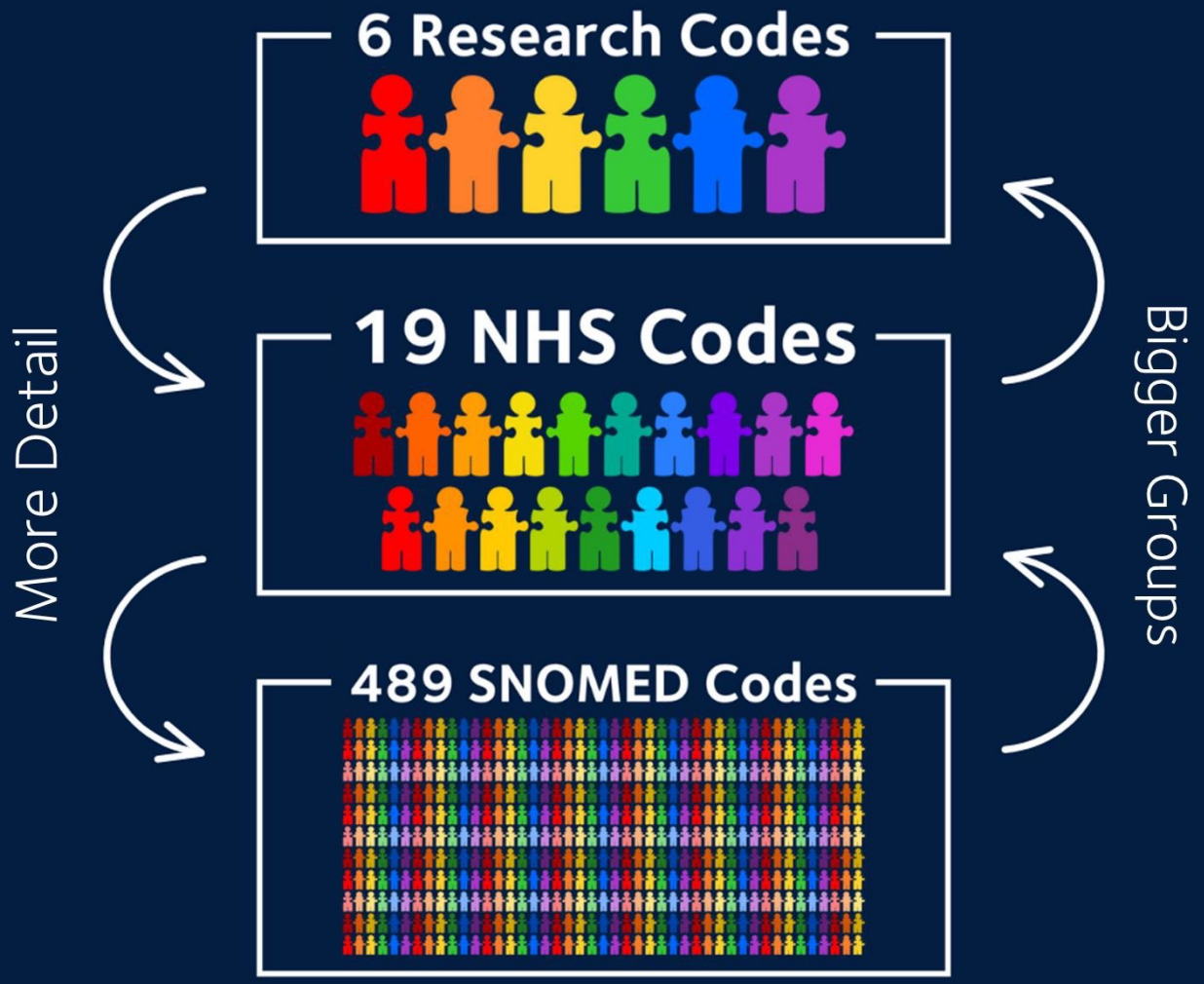
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Dados do mundo real, IA e equidade em saúde

60 milhões

de registros de pacientes anonimizados

Que dados de etnia estão disponíveis?



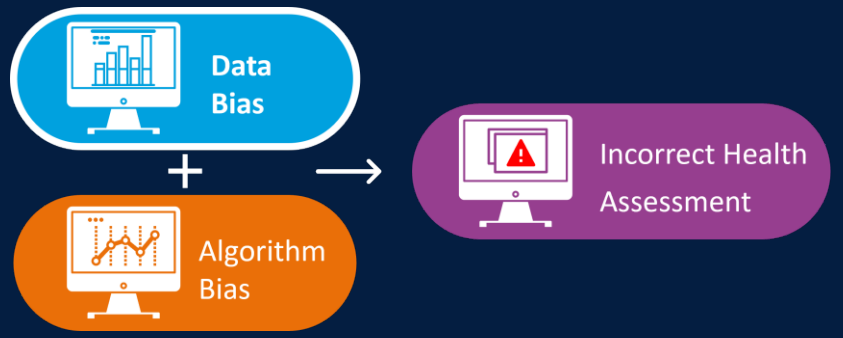
The Planetary Health Informatics Lab | NDORMS | @PHI_Oxford | sara.khalid@ndorms.ox.ac.uk

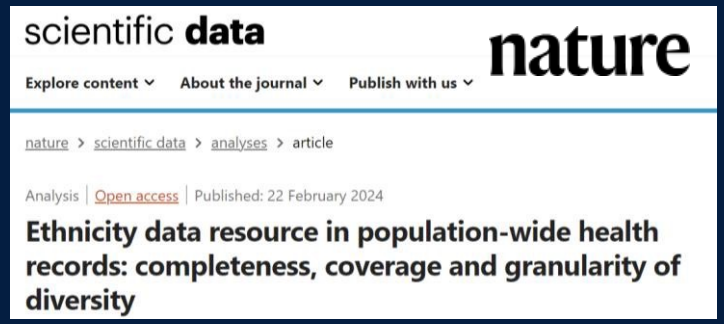
Projeto Etnia, equidade em saúde e IA

[Página do projeto]

[Link para a publicação completa]

Um estudo central sobre COVID-19 do governo britânico para corrigir vieses nos dados que se traduziam em desigualdades em saúde.
A análise de dados do NHS England revelou dados ricos e antes não utilizados sobre etnia.




scientific data

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Analysis | Open access | Published: 22 February 2024

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

60 mi

de pacientes,

94% da

população britânica

255

Autodeclarada pelo paciente, no sistema SNOMED

1/10

dos pacientes não têm dados de etnia em seus registros de atenção primária e secundária

17%

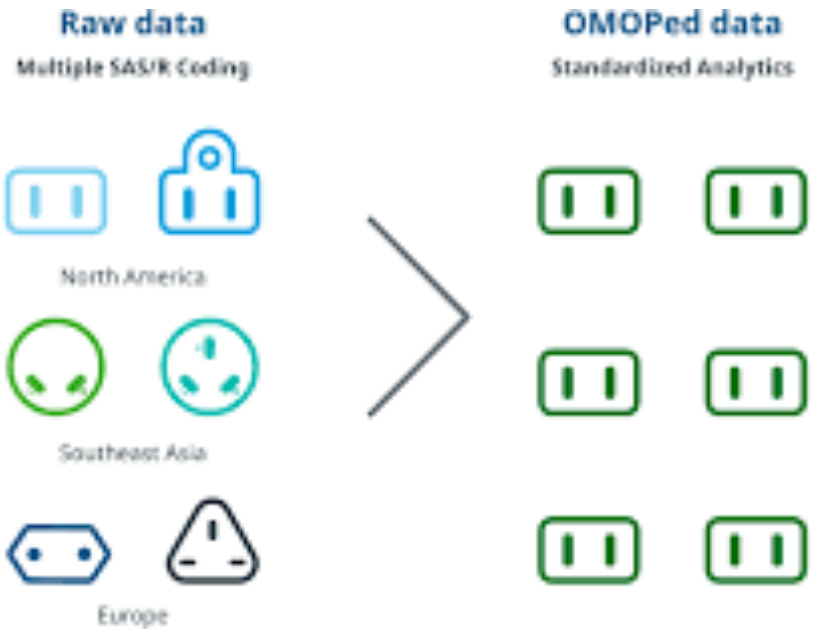
dos pacientes têm códigos de etnia conflitantes em seus registros

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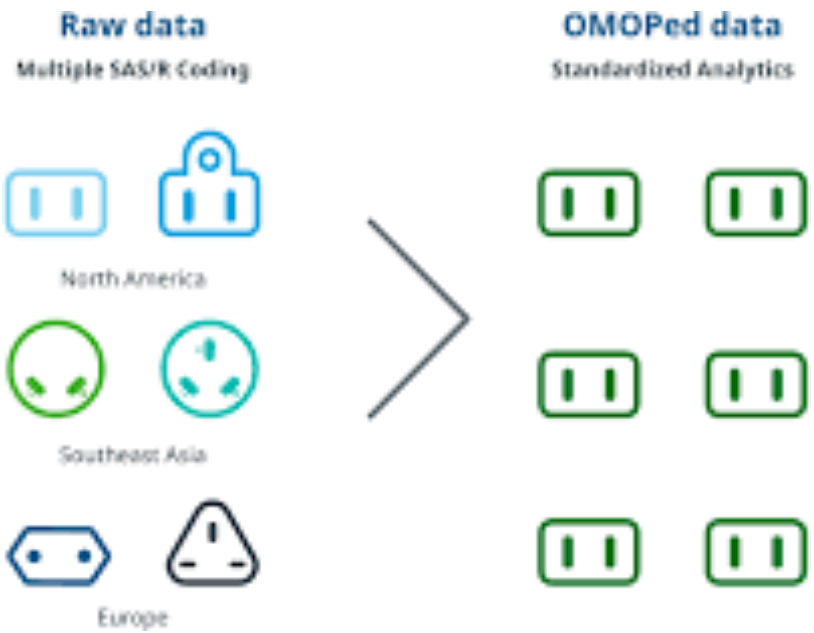
Modelos de dados comuns e análises padronizadas

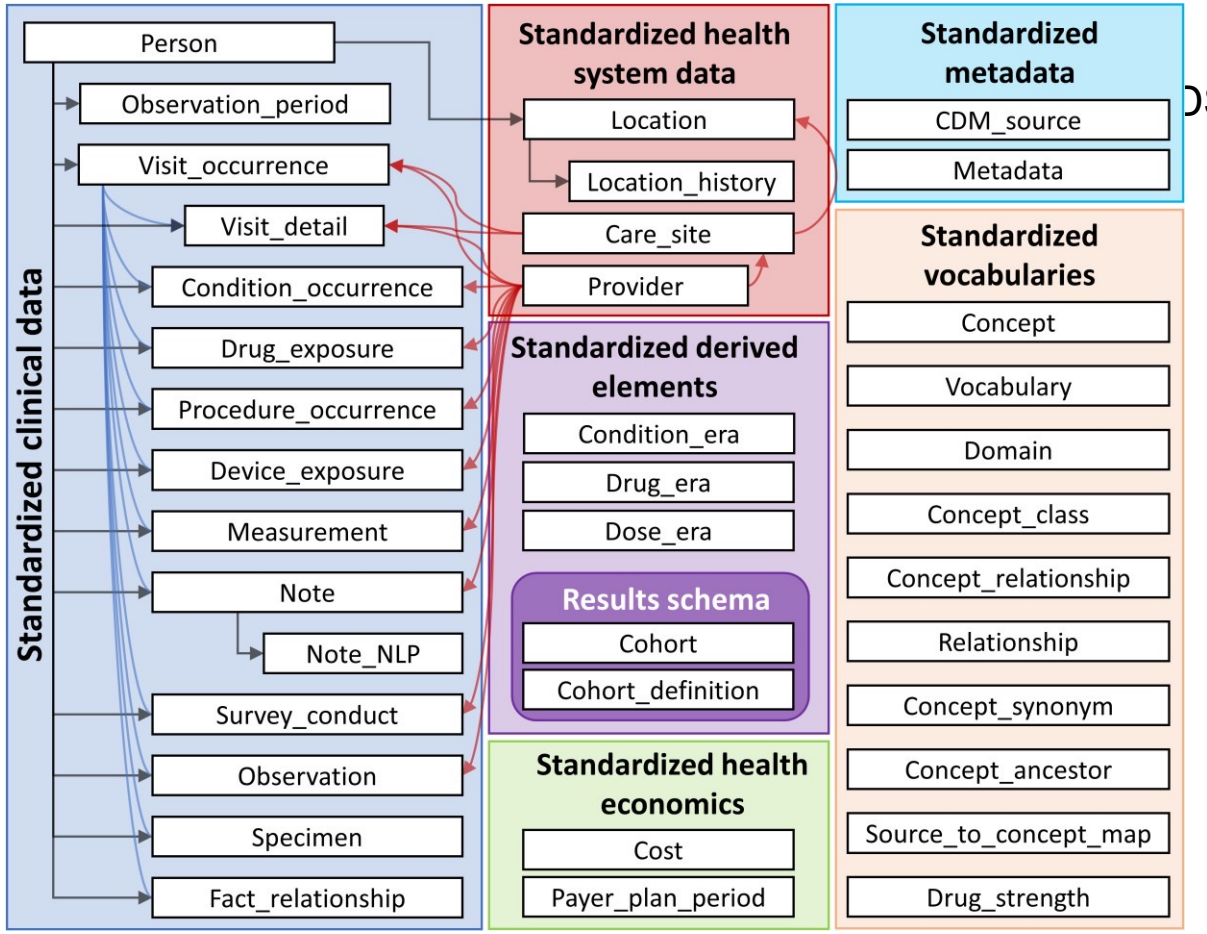


Modelos de dados comuns e análises padronizadas



Modelos de dados comuns e análises padronizadas





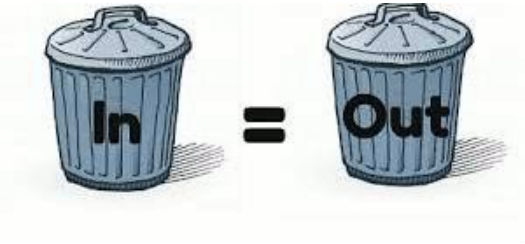
OHDSI
OBSERVATIONAL HEALTH DATA SCIENCES AND INFORMATICS

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Considerações

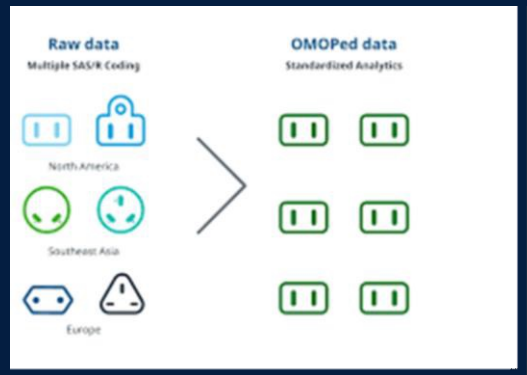
- Fontes de dados
  - Globais, éticas, representativas
- Vinculação
  - Dados anonimizados
- Padronização
  - Definições universais
  - Sincronização temporal
  - Modelo de dados comum

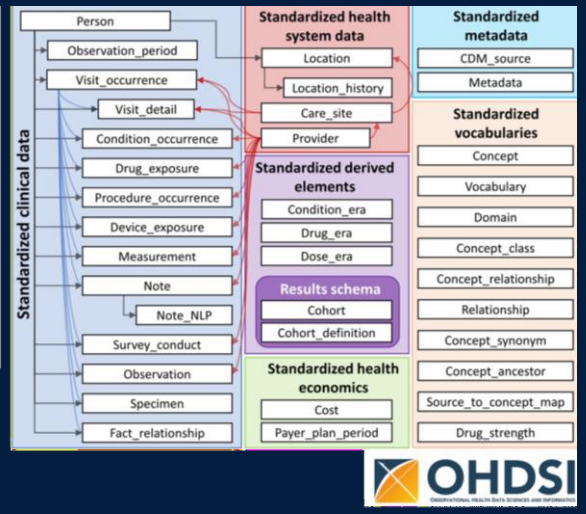
- Qualidade dos dados
  - Completude e precisão do registro (p. ex. calor)
- Análise de dados
  - Muitas incógnitas
  - Fatores de confusão
    - Interações entre múltiplos estressores



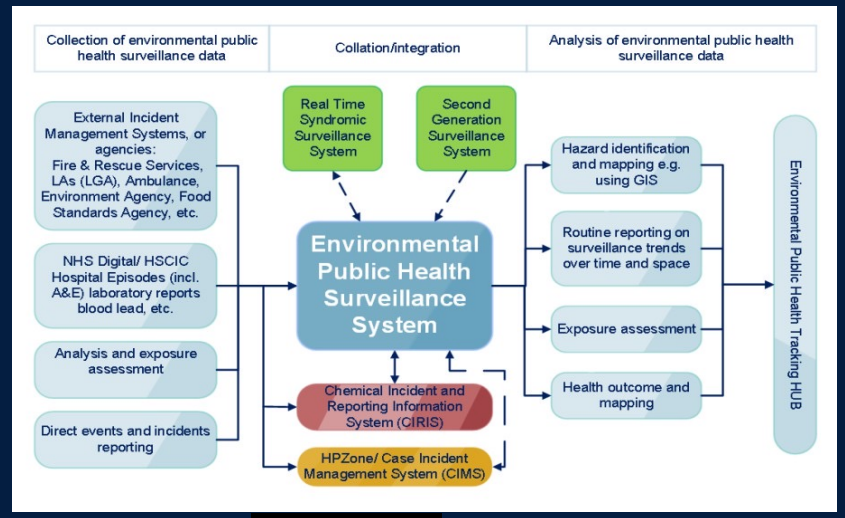
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Infraestrutura para análises em larga escala em saúde planetária



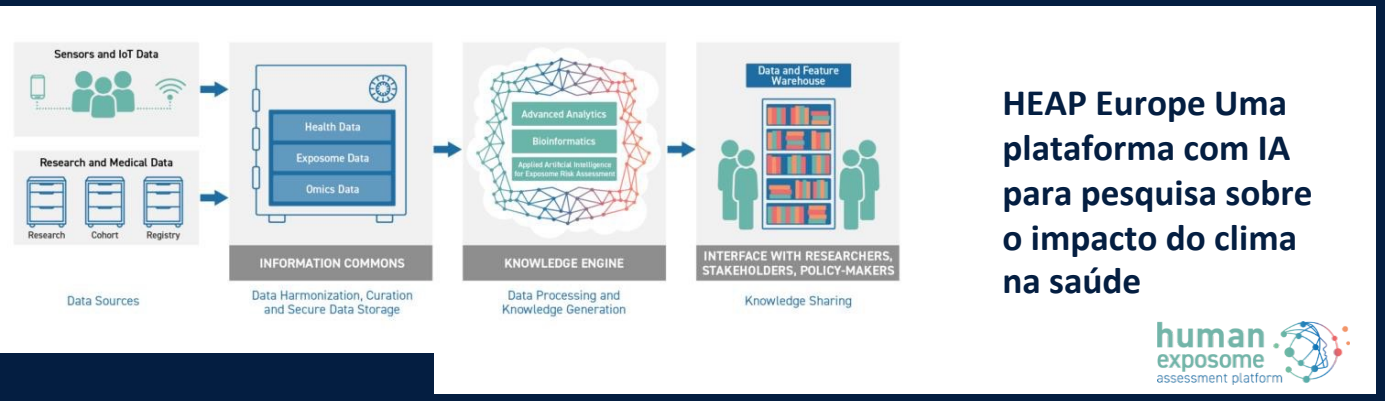


Modelos de dados comuns e análises padronizadas



Public Health England

EPHSS Sistema de vigilância em saúde pública ambiental, Reino Unido



HEAP Europe Uma plataforma com IA para pesquisa sobre o impacto do clima na saúde

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

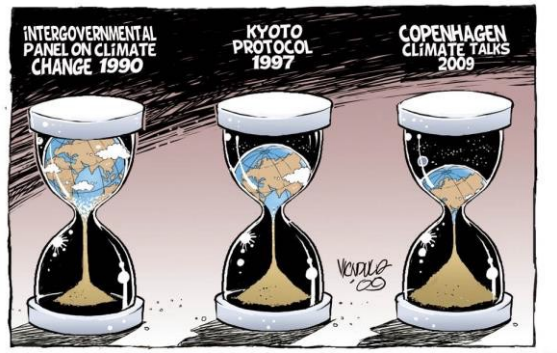
EXTREME EARTH

Deep Cube IA para analisar dados de satélite Copernicus e prever impactos climáticos

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Cobenefícios clima-saúde

- Gastos globais com adaptação em saúde US$ 18 bi, ↑ 5,3%
- Planejamento da adaptação dos sistemas de saúde em 86 países
- Planos ambiciosos de saúde com emissão zero líquida, p. ex. NHS britânico: emissões da assistência ↓ 57%
- Desinvestimento dos prestadores de saúde: US$ 42 bi
- **A pesquisa sobre saúde e clima cresceu 8 vezes**
- Benefício econômico de 1,5 °C: US$ 600 trilhões
  - força de trabalho mais saudável, menores custos de saúde



Créditos: Victor Ndula 2009

Relatório Lancet Countdown 2020

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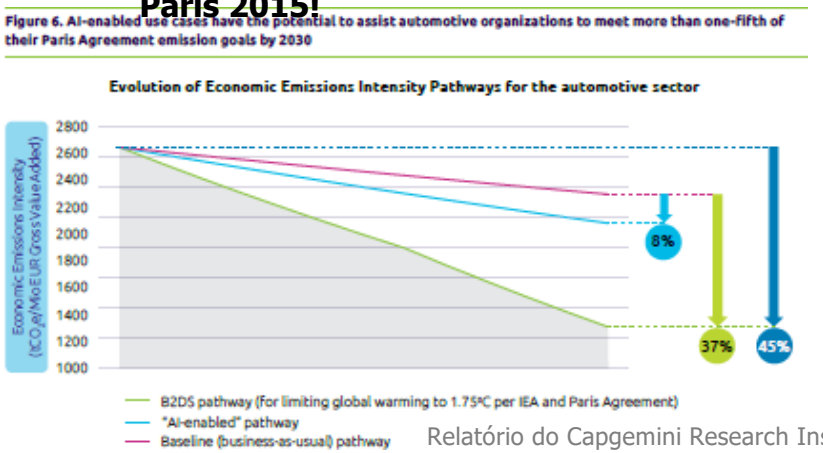
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Créditos: Victor Ndula 2009

Relatório Lancet Countdown 2020

Forbes **A IA pode ajudar a cumprir 45% das metas de Paris 2015!**



Relatório do Capgemini Research Institute 2020

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Manuseie com cuidado

Top scientists call for caution over artificial intelligence

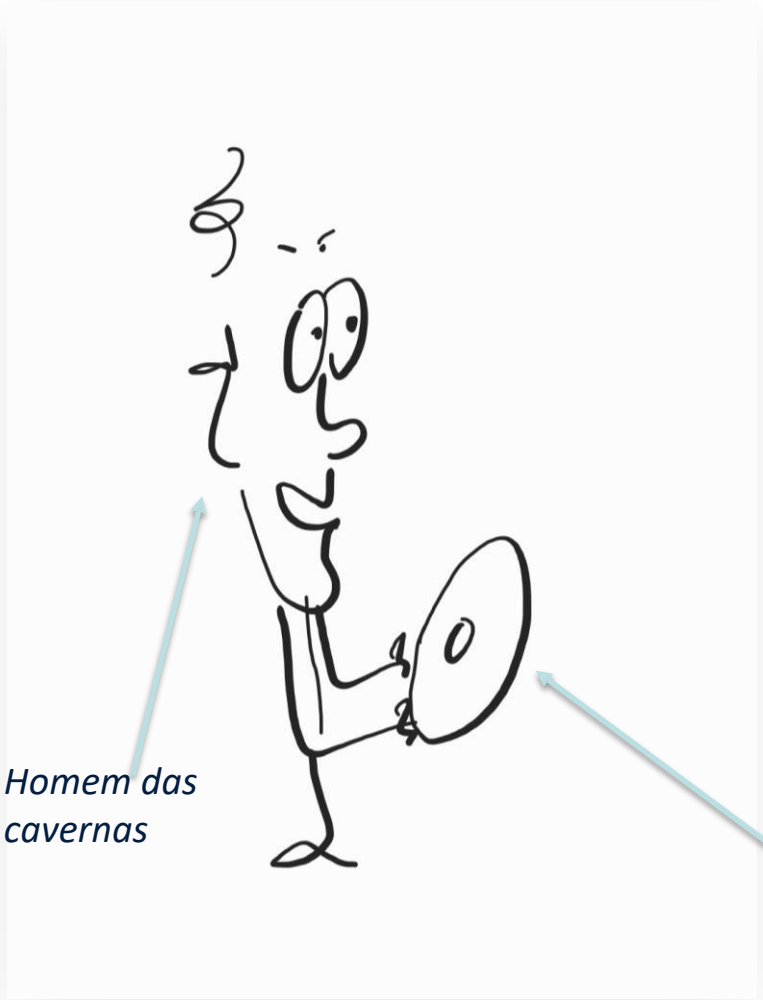
Artificial intelligence has the potential to eradicate disease and poverty, say world's top scientists, but researchers must not create something which cannot be controlled



The Telegraph (2015)

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

Há uma escolha

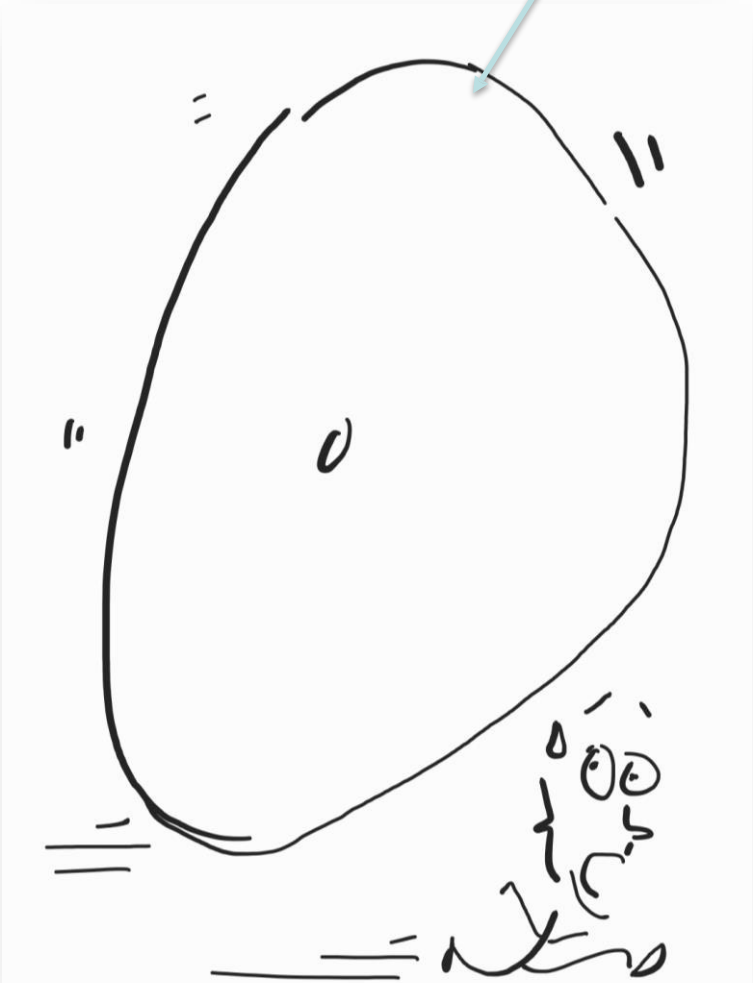


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A escolha é nossa

A primeira roda (não é uma rosquinha!)



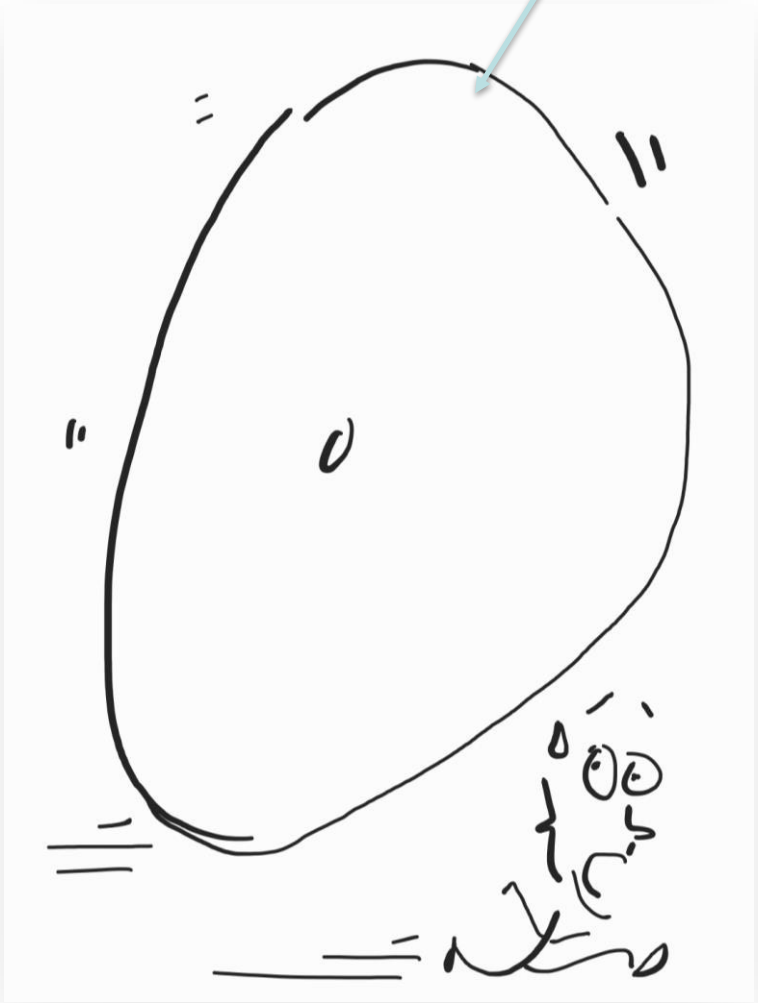


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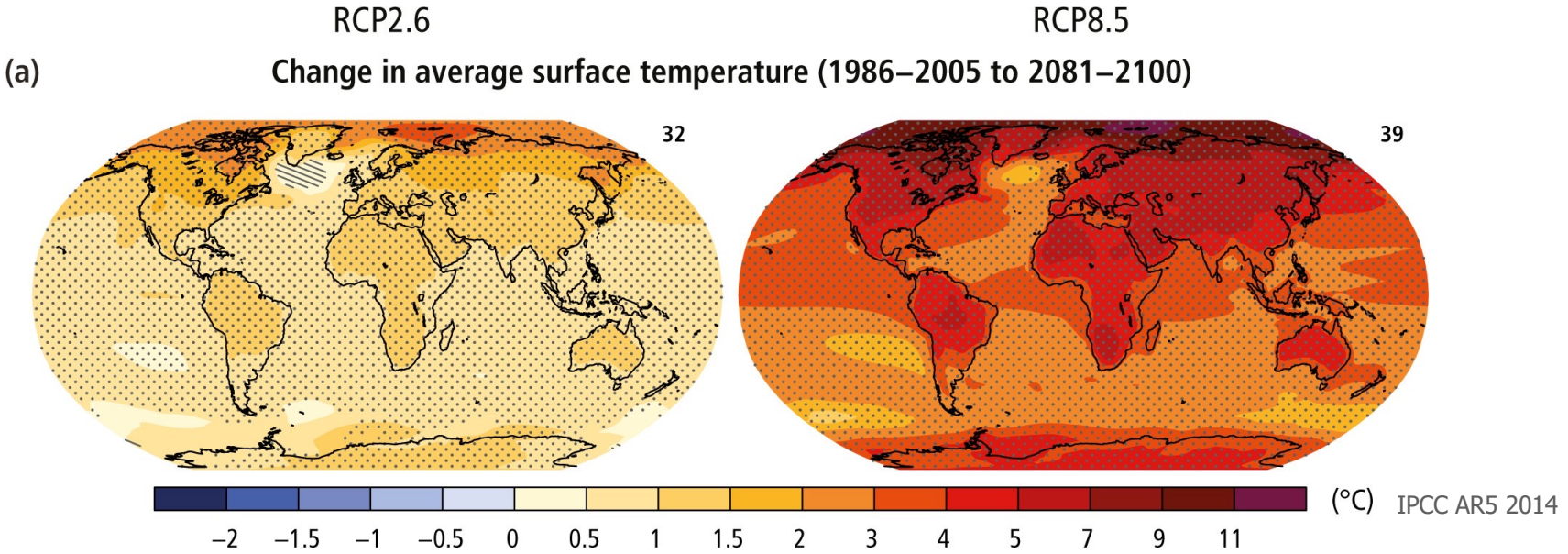
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Nosso mundo em rápido aquecimento



IPCC AR5 2014

"A mudança climática é a maior ameaça à saúde global do século XXI"

Relatório da Lancet Commission 2009

"Enfrentar a mudança climática pode ser a maior oportunidade para a saúde global do século XXI"

Relatório da Lancet Commission 2015























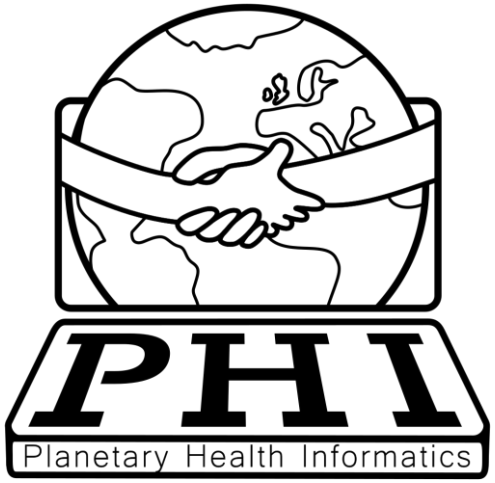










































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Inteligência artificial para a saúde planetária

Desafios, oportunidades e escolha humana

Escola de verão Climate Change AI 2024: série Clima e saúde

Sara Khalid *BE MSc DPhil Oxon*

Professora associada | Centre for Statistics in Medicine Chefe | Planetary Health Informatics Lab

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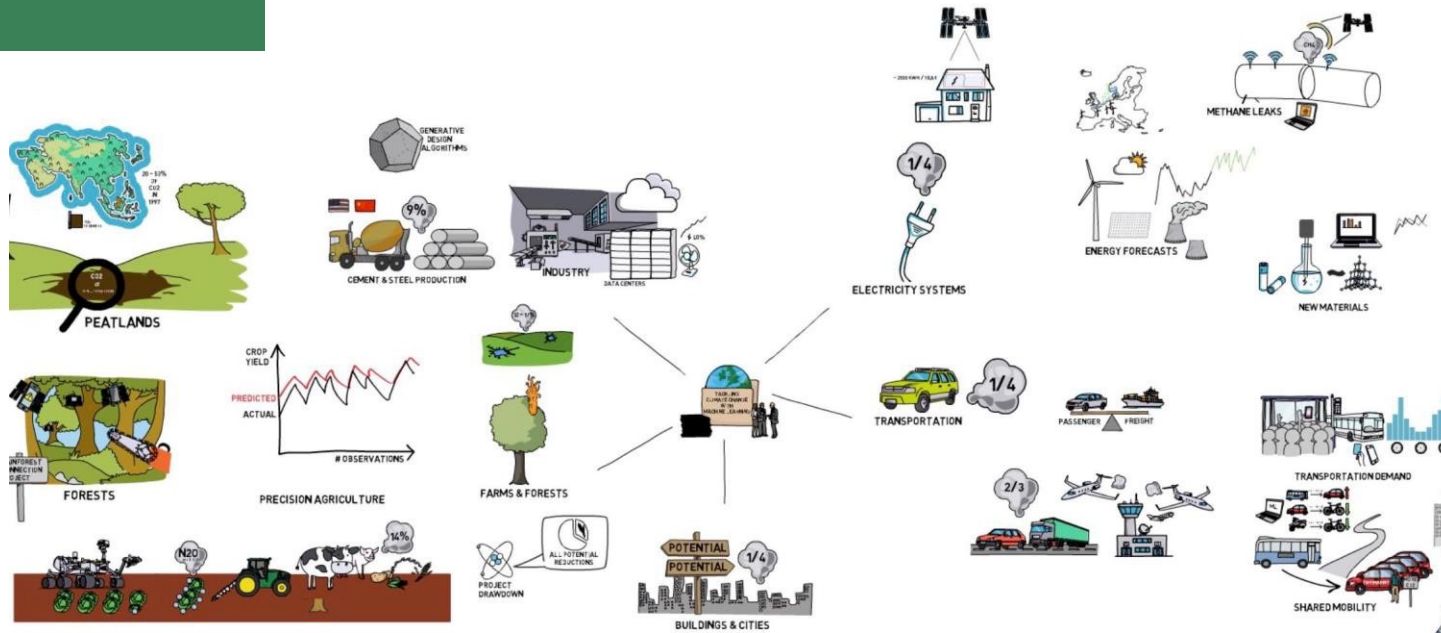
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Um chamado à ação

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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