L’intelligenza artificiale per la salute planetaria

Sfide, opportunità e scelta umana

Scuola estiva Climate Change AI 2026: serie Clima e salute

Sara Khalid *BE MSc DPhil Oxon*

Professoressa associata | Centre for Statistics in Medicine Responsabile | Planetary Health Informatics Lab

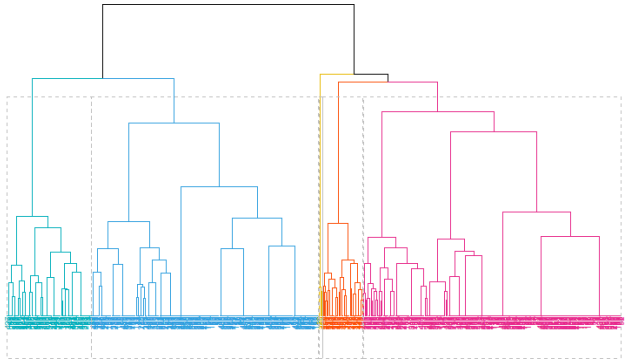
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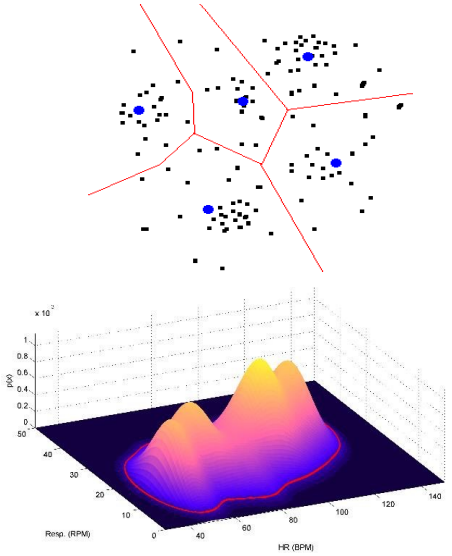
sara.khalid@ndorms.ox.ac.uk

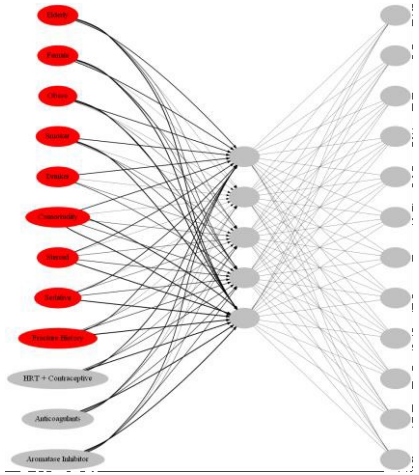
www.csm.ox.ac.uk | @PHI_Oxford

Indice

1. Cambiamenti climatici e salute planetaria
2. Il ruolo dell'informatica sanitaria
3. Sfide e opportunità dell'analisi in salute planetaria





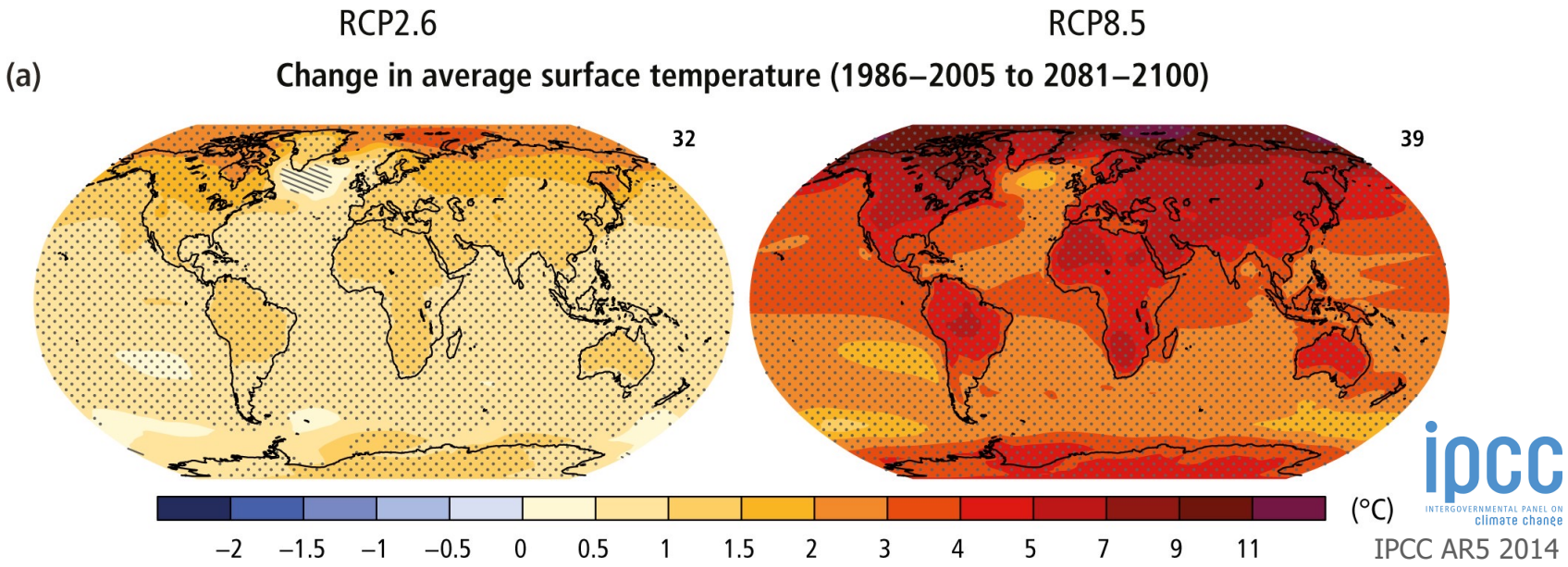


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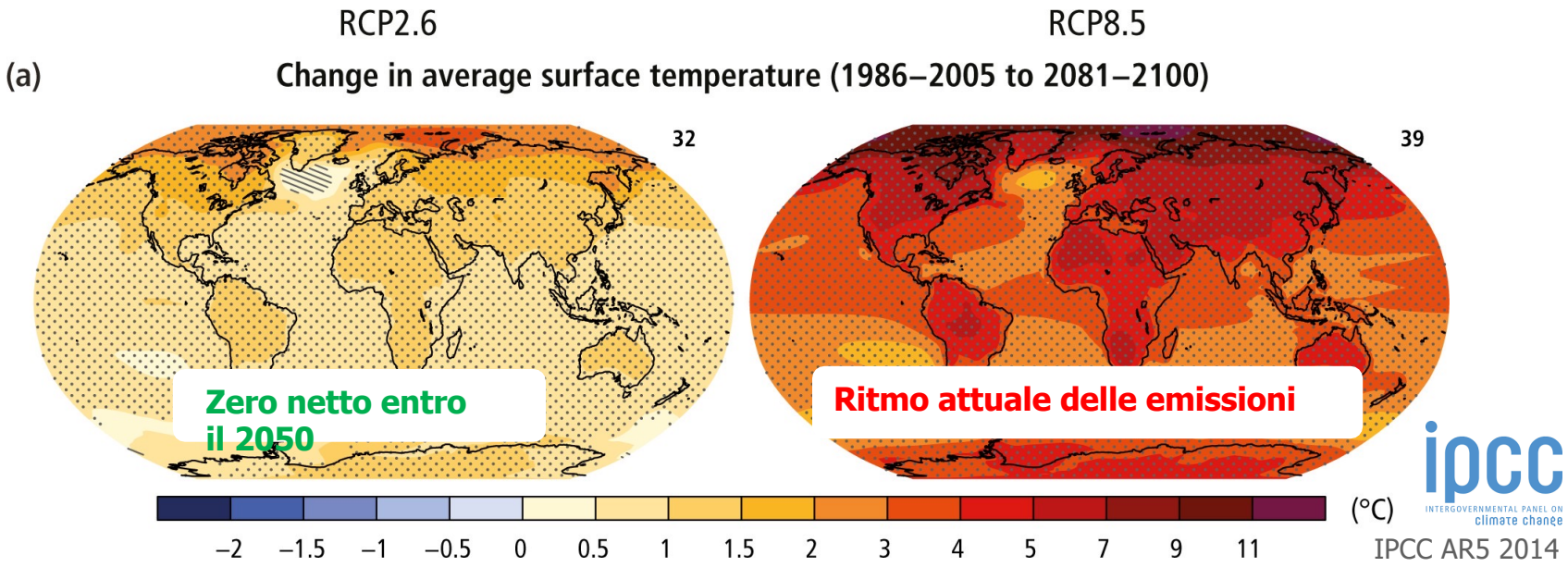
Cambiamenti climatici e salute planetaria

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Centre for Statistics in Medicine | University of Oxford | @CSM_Oxford | @PHI_Oxford

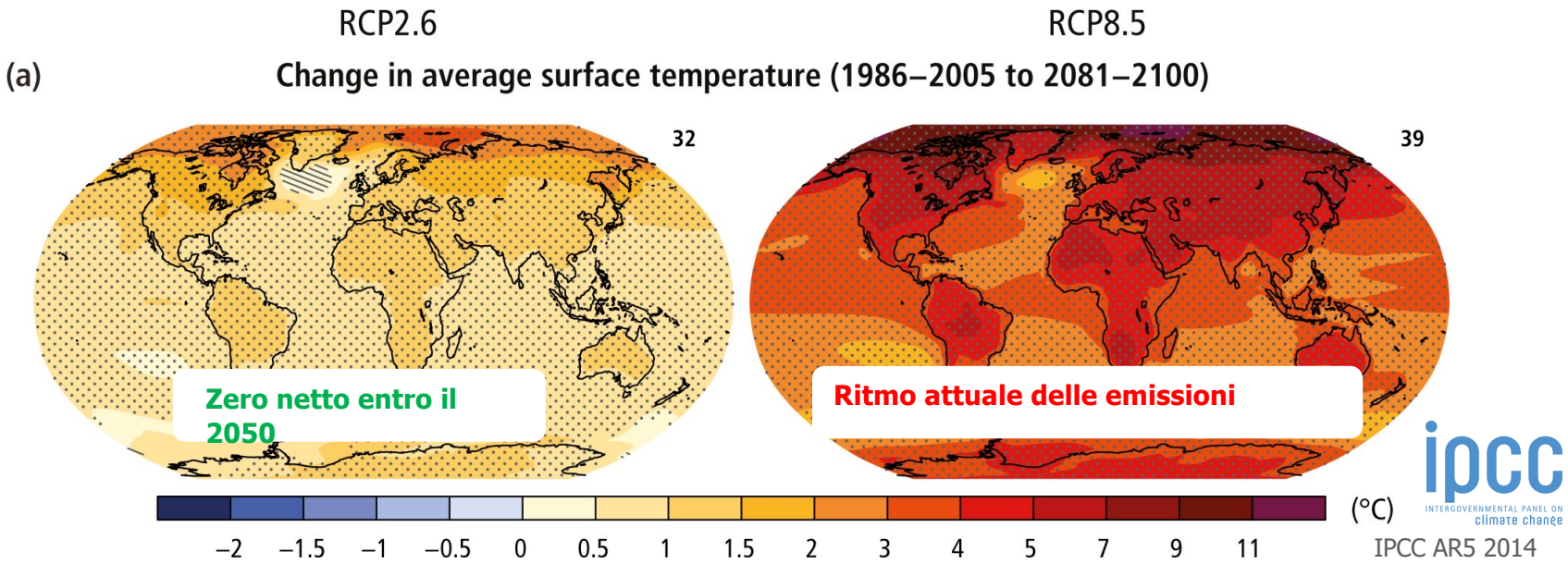
Un riscaldamento rapido



Un riscaldamento rapido



Un riscaldamento rapido



«I cambiamenti climatici sono la più grande minaccia sanitaria globale del XXI secolo»

Lancet Commission 2009

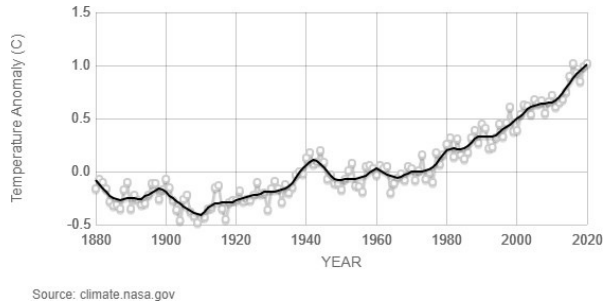
«I cambiamenti climatici minacciano le basi stesse della salute e del benessere umani»

Rapporto Lancet Countdown 2020

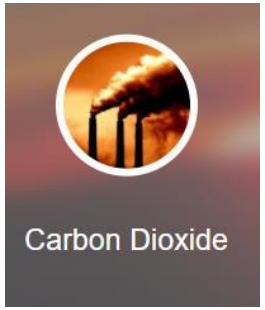
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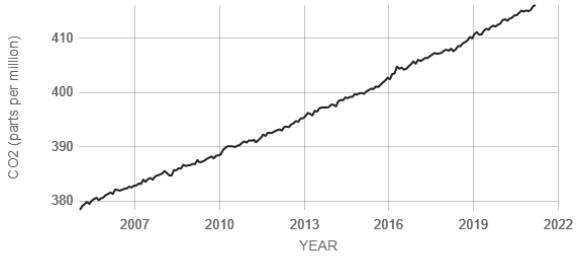
I parametri vitali della Terra





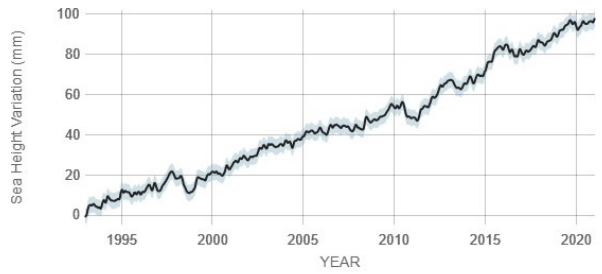
Source: climate.nasa.gov





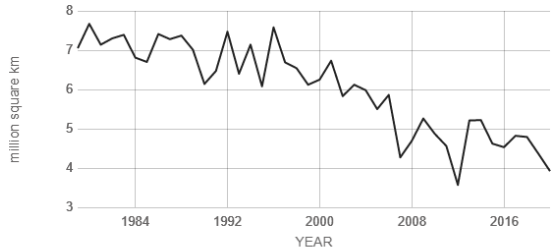
Source: climate.nasa.gov





Source: climate.nasa.gov



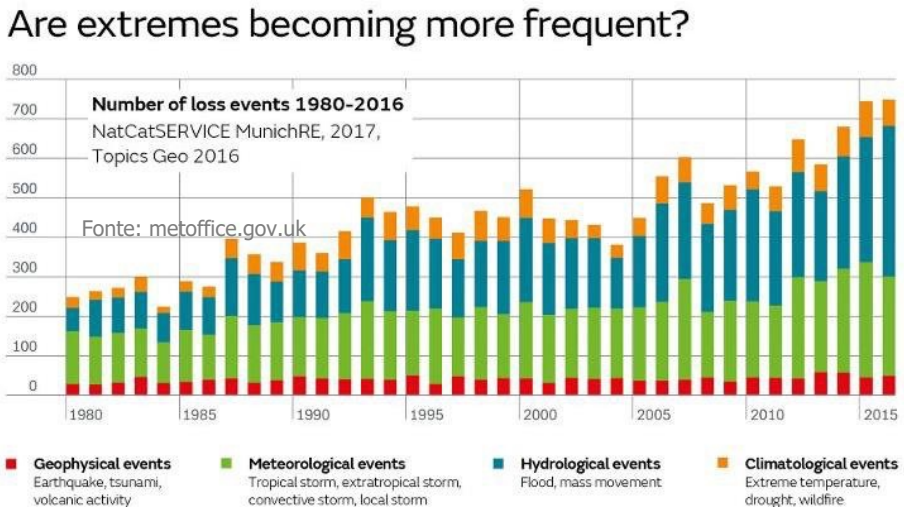


Source: climate.nasa.gov

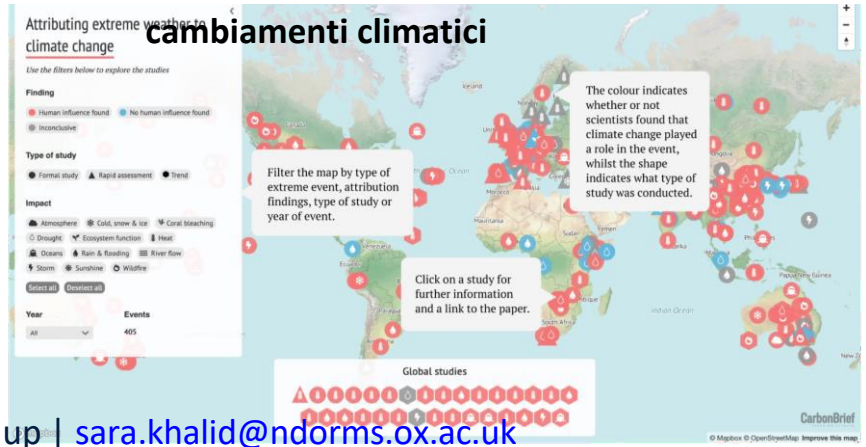


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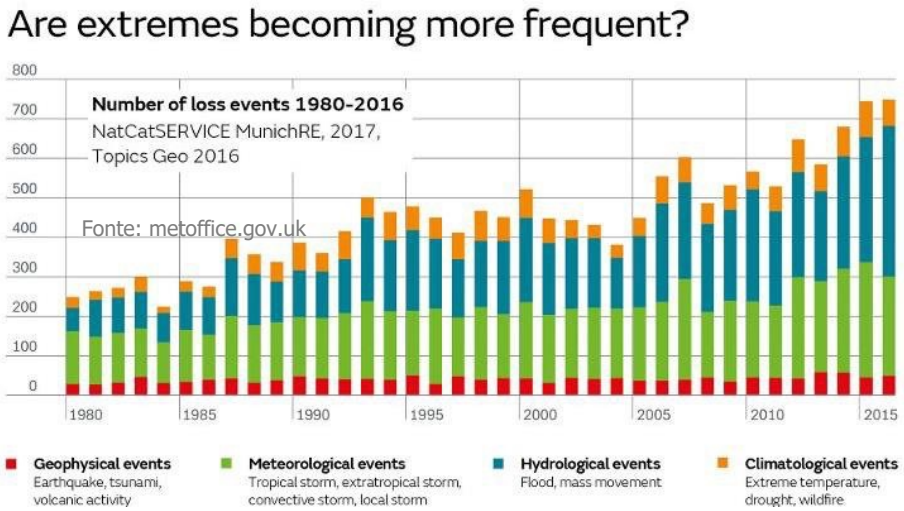
Cambiamento, variabilità, meteo

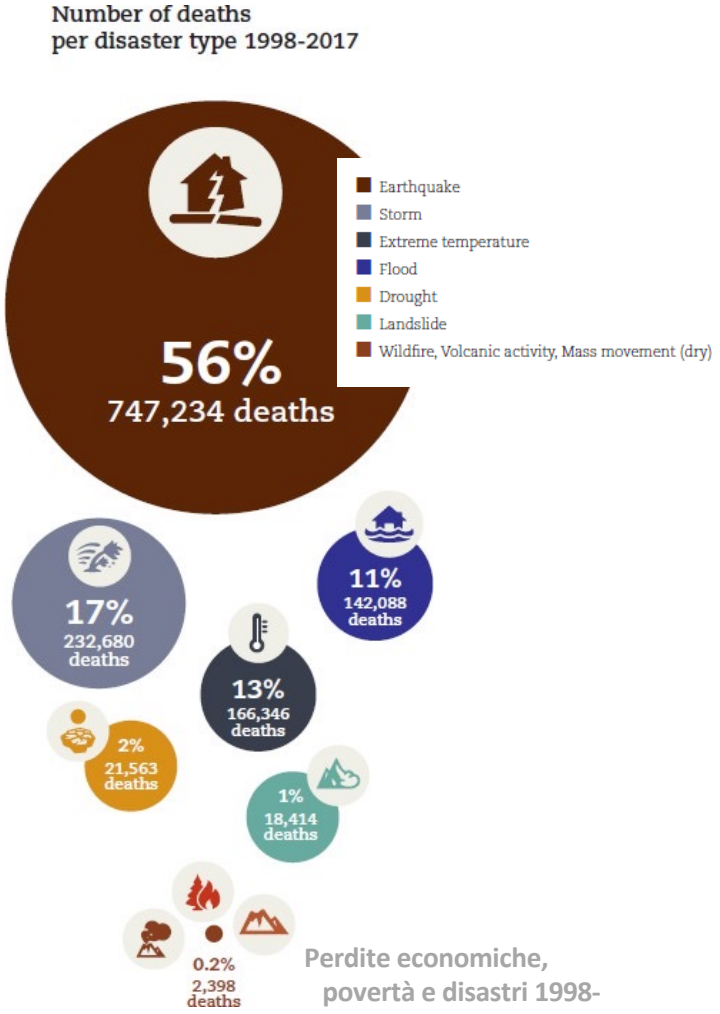


Oltre 350 studi sottoposti a revisione paritaria su 450 eventi meteo estremi attribuiti ai cambiamenti climatici



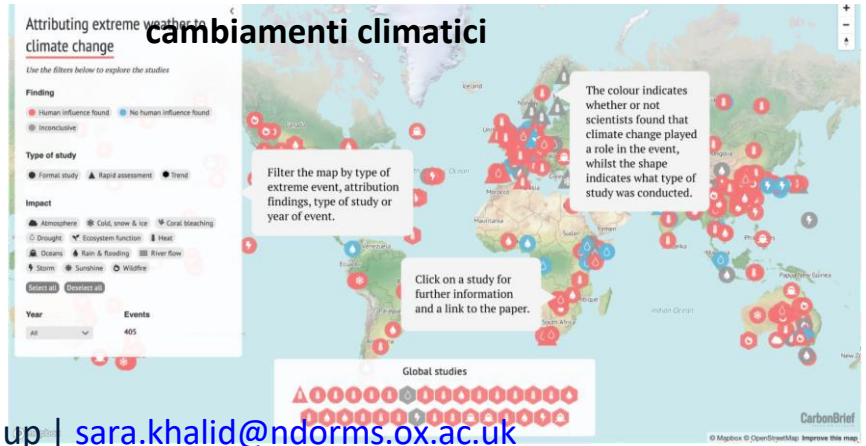
Cambiamento, variabilità, meteo





Perdite economiche, povertà e disastri 1998-2017. Rapporto CRED, UNISDR 2018

Oltre 350 studi sottoposti a revisione paritaria su 450 eventi meteo estremi attribuiti ai cambiamenti climatici



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Perdita di biodiversità

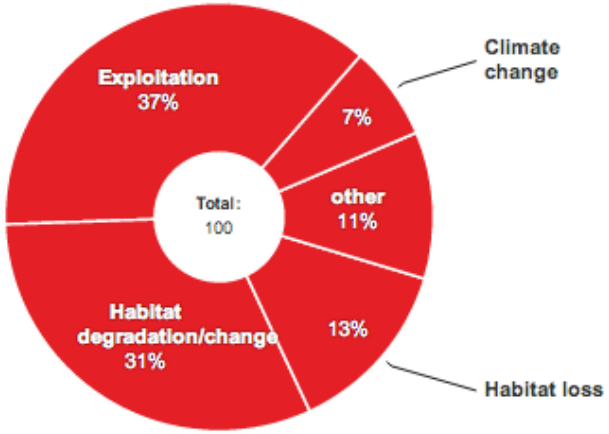
The Guardian

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



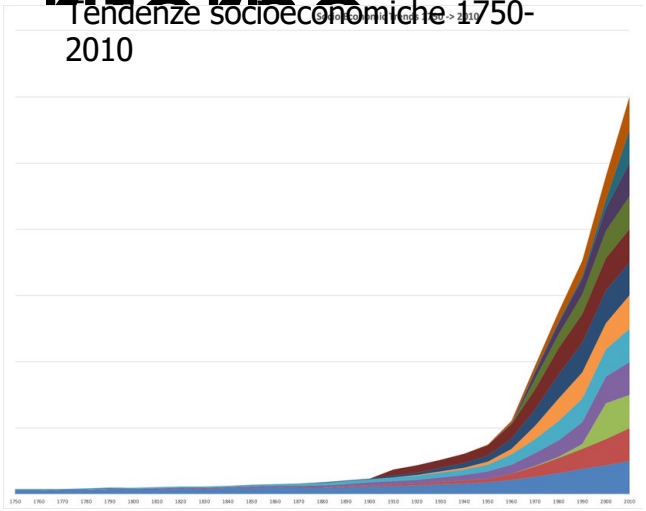
SOURCE: WWF

theguardian

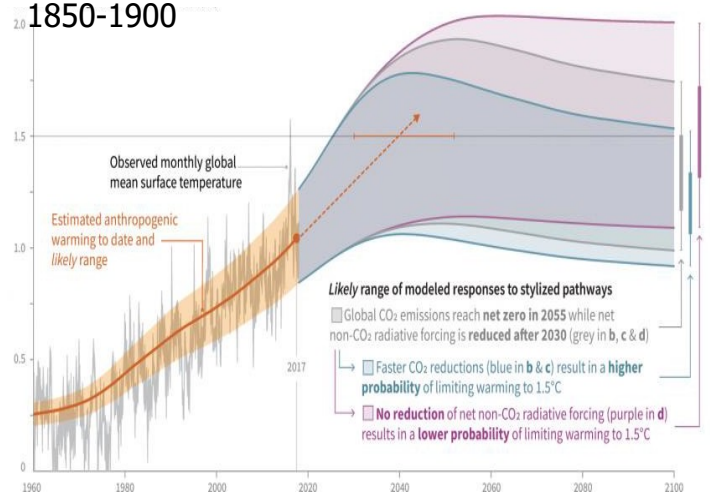
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Accelerazione e punto di non ritorno

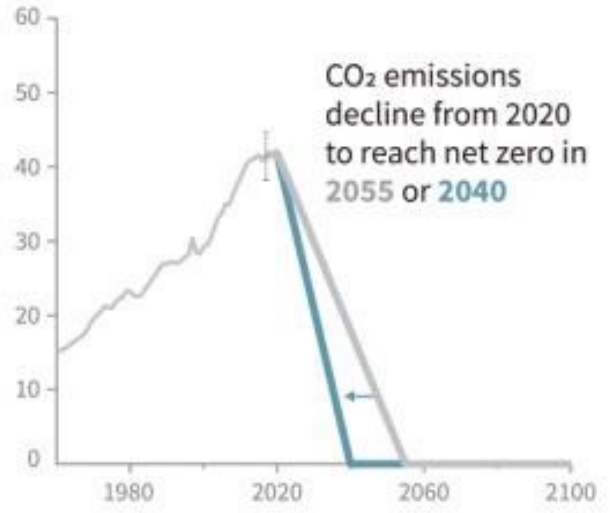
Tendenze socioeconomiche 1750-2010



Riscaldamento globale rispetto al 1850-1900

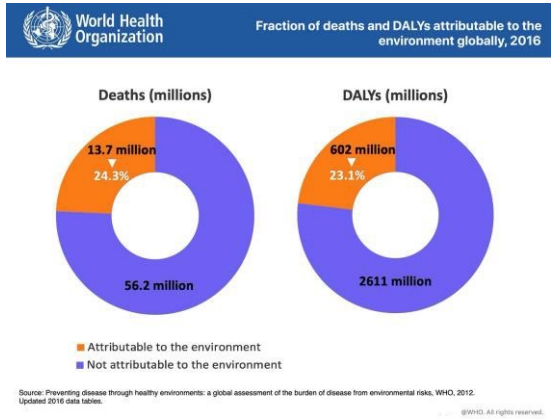


ipcc
INTERGOVERNMENTAL PANEL ON climate change



Legami con la salute

- «85 delle 102 malattie studiate sono legate all'ambiente.»
  - OMS, Preventing Disease Through Healthy Environment 2006
- ¼ dei decessi nel mondo legati all'ambiente
  - OMS, Preventing Disease Through Healthy Environment 2012







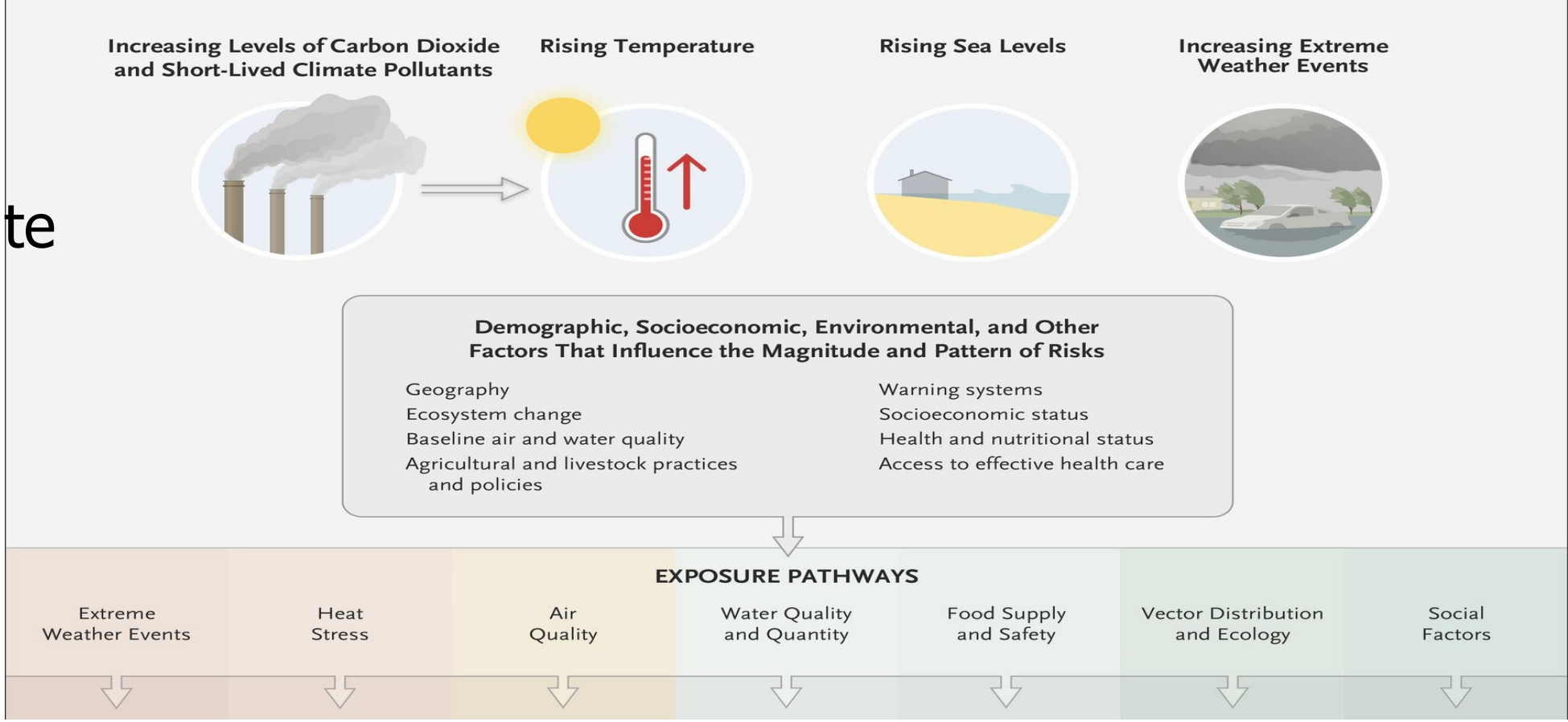


CNN
Deadly flooding. 'Zombie fires.' A massive iceberg. It's been a wild week in weather and climate change

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Impatti sulla salute

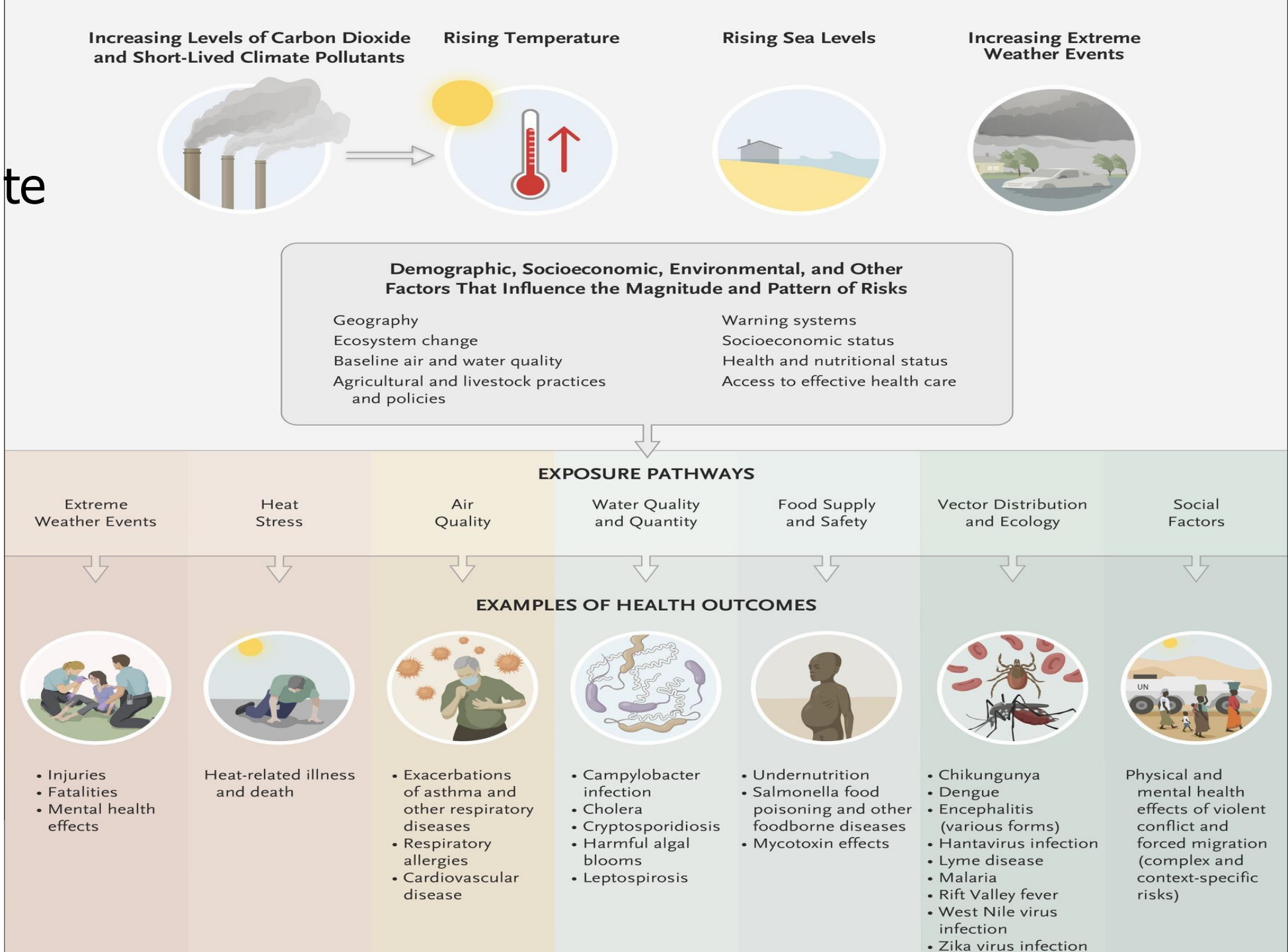
- Diretti
- Indiretti
- A lungo termine



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

Impatti sulla salute

- Diretti
- Indiretti
- A lungo termine

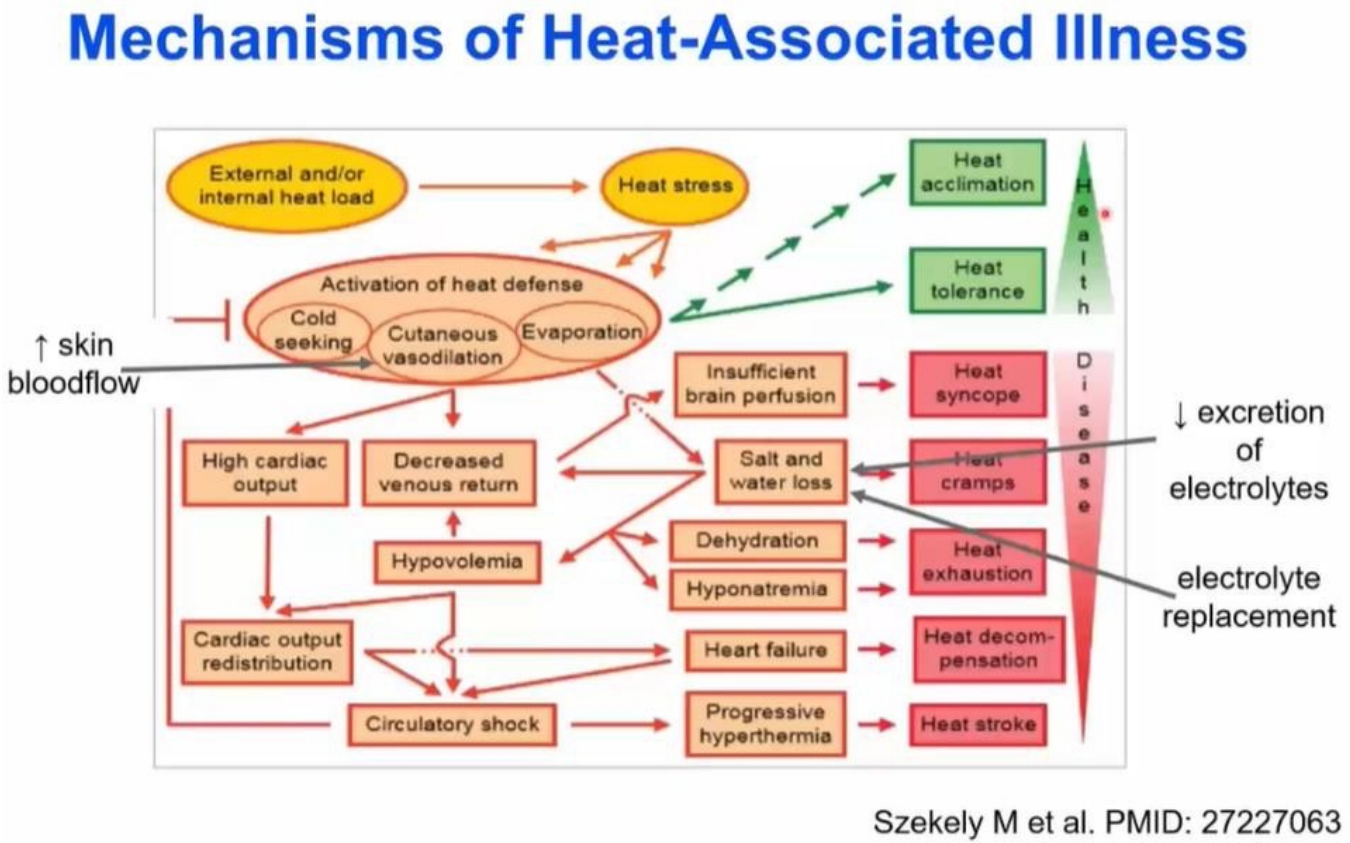


Haines et al. Engl J Med 2019

DOI: 10.1056/NEJMra1807873

Caldo e salute

- Diretti
  - Colpo di calore
  - Crampi
  - Esaurimento
  - Iper/ipotermia
- Malattie croniche
  - Malattie cardiovascolari
  - Diabete
  - Malattie respiratorie
  - Malattie cerebrovascolari
- Ricoveri
  - Disturbi cardiovascolari
  - renali
  - respiratori



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Caldo e salute

- **Chi è più vulnerabile?**

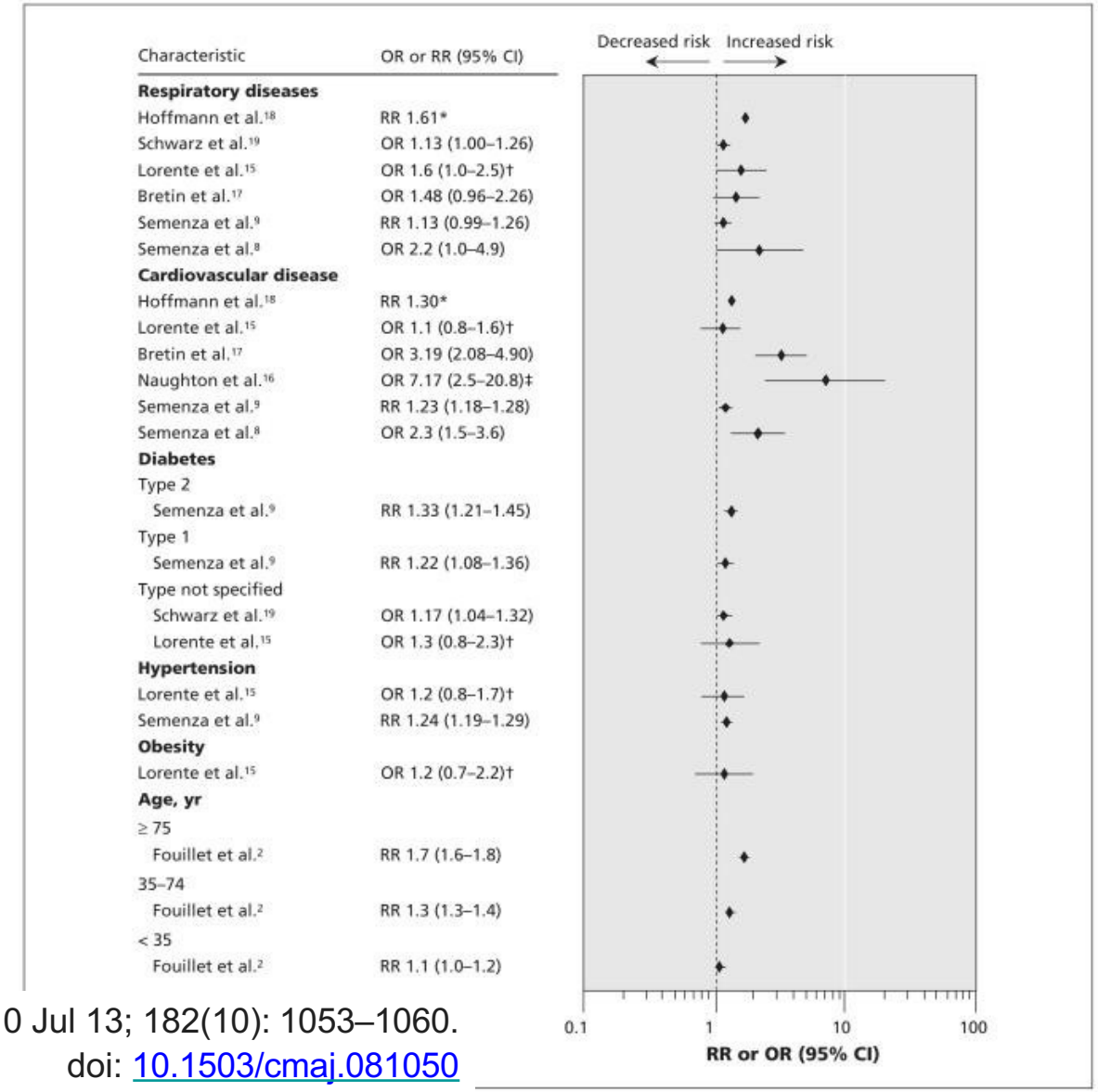
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Centre for Statistics in Medicine | University of Oxford | @CSM_Oxford | @PHI_Oxford

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

Caldo e salute

- **Chi è più vulnerabile?**
  - **Multimorbilità, politerapia**
  - Anziani
  - Bambini piccoli
  - Gravidanza, menopausa nelle donne
  - Lavori all'aperto o in ambienti non ventilati

- Determinanti sociali e disparità
  - Status socioeconomico
  - Fattori legati allo stile di vita
  - Etnia/genetica



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

Caldo e salute

- I più vulnerabili
  - Multimorbilità, politerapia
  - **Anziani**
  - Bambini piccoli
  - Gravidanza, menopausa nelle donne
  - Lavori all'aperto o in ambienti non ventilati

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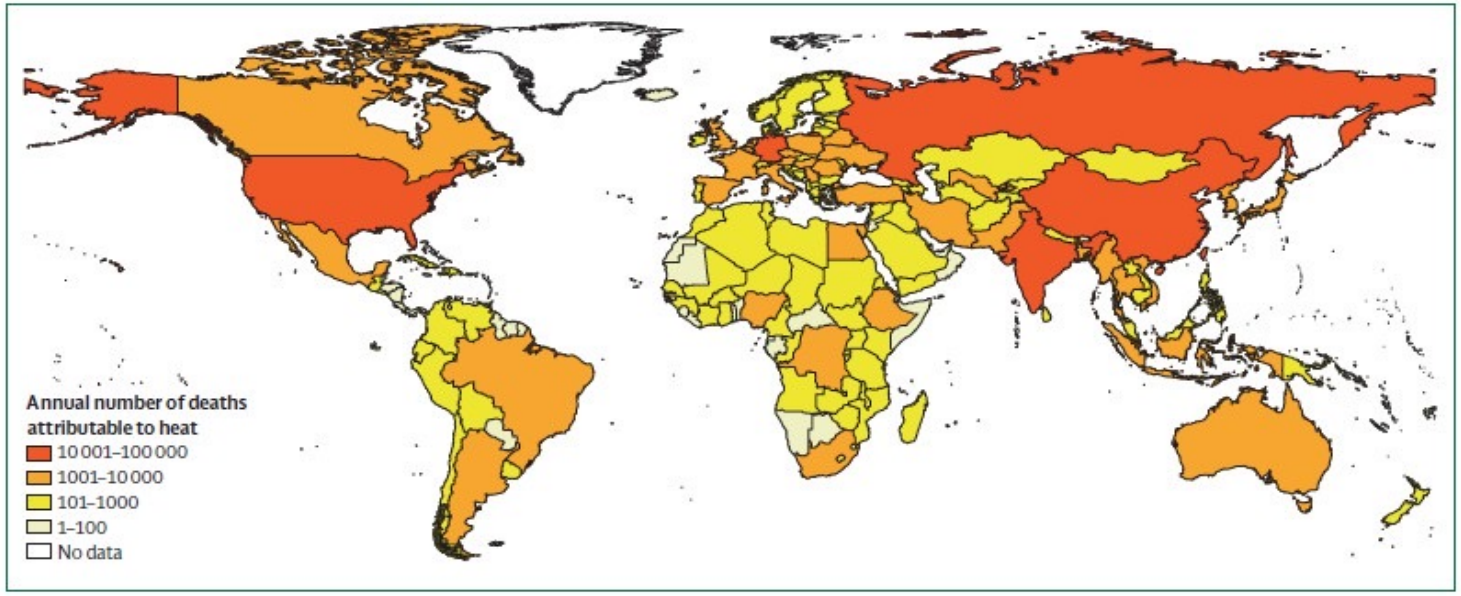


Figure 3: Annual heat-related mortality in the population older than 65 years averaged from 2014 to 2018

«Aumento di oltre il 50% della mortalità legata al caldo nelle persone con più di 65 anni, per un totale di 296.000 decessi nel 2018.»

Lancet Countdown 2015

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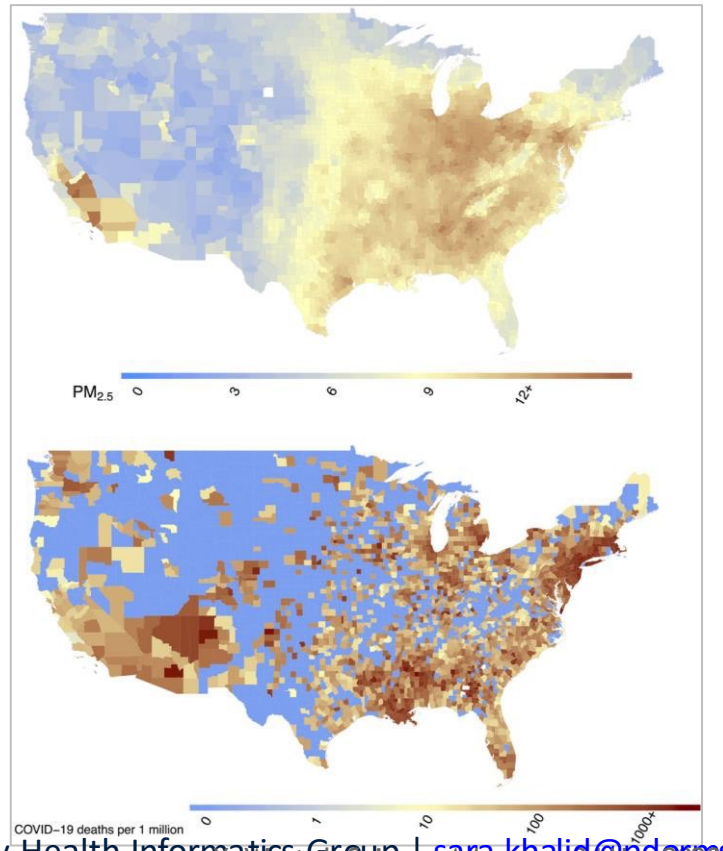
Kenny et al. CMAJ. 2010 Jul 13; 182(10): 1053–1060.
doi: 10.1503/cmaj.081050

Inquinamento atmosferico e mortalità



Inquinamento atmosferico e mortalità

Concentrazioni storiche di PM2,5 (in alto) e decessi per COVID-19 (in basso) negli Stati Uniti.



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

Household air pollution

3.8 million

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

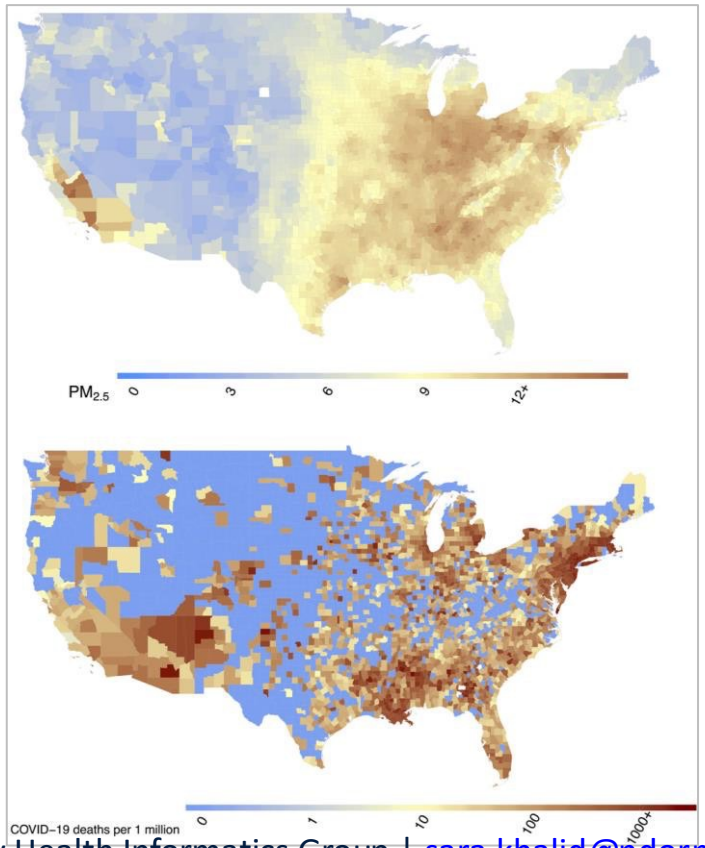
4.2 million

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

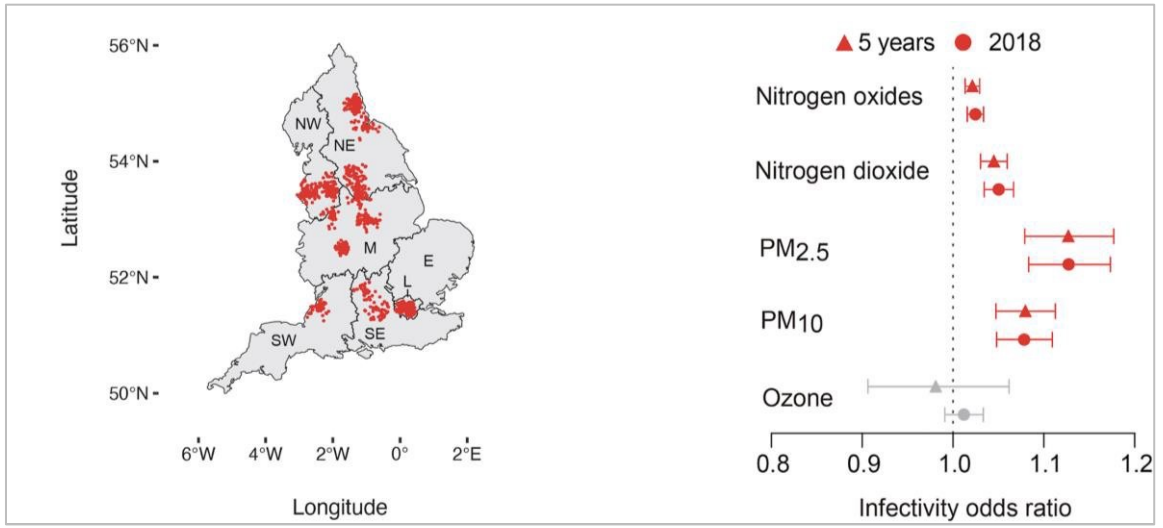
www.who.int/data

Inquinamento atmosferico e mortalità

Concentrazioni storiche di PM2,5 (in alto) e decessi per COVID-19 (in basso) negli Stati Uniti.



X. Wu et al. *Science Advances* 06 Nov 2020:
Vol. 6, no. 45, DOI: 10.1126/sciadv.abd4049



Associazione tra esposizione agli inquinanti atmosferici e numero di casi di COVID-19 confermati in laboratorio nella UK Biobank.

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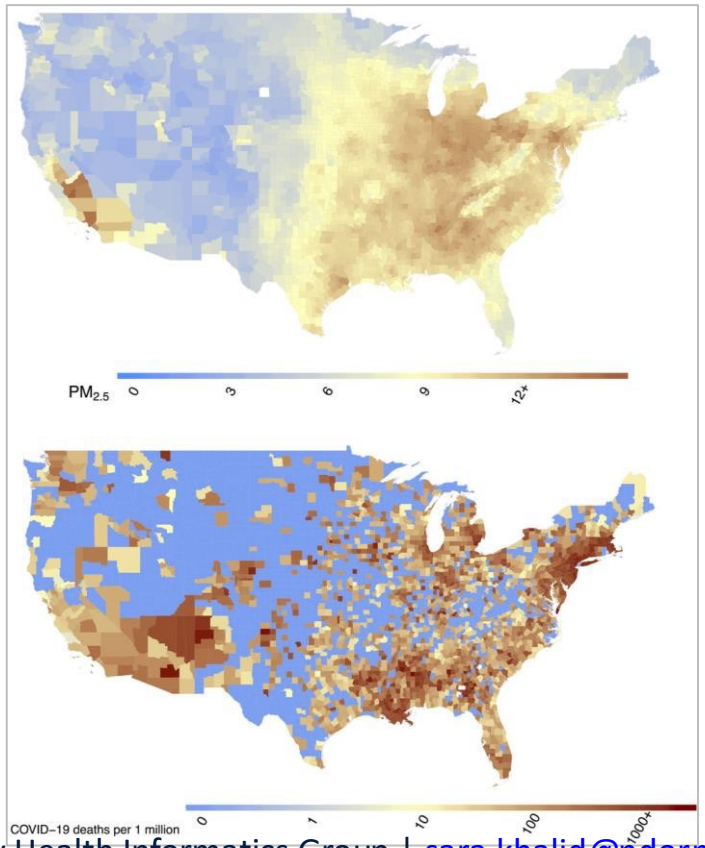
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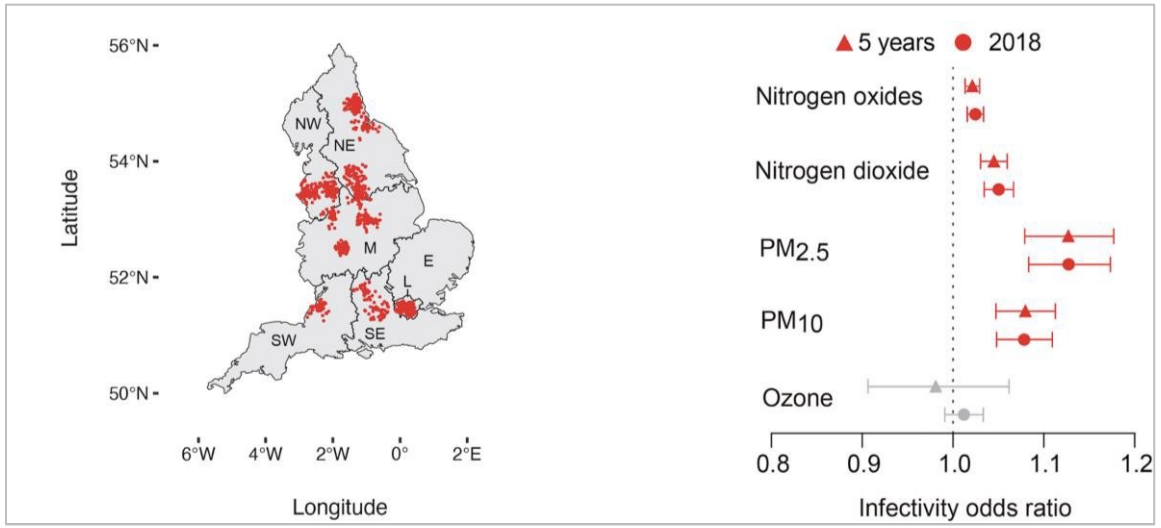
www.who.int/data

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Household air pollution

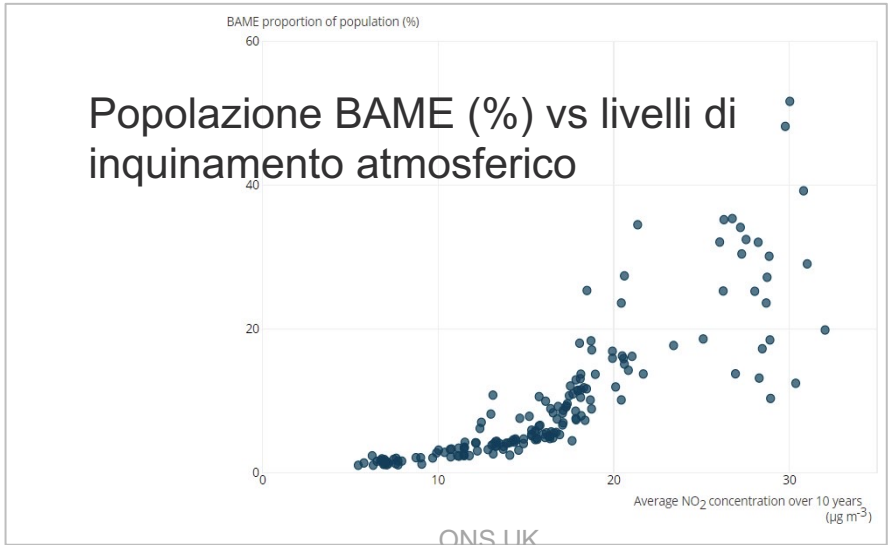
3.8 million

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



Popolazione BAME (%) vs livelli di inquinamento atmosferico

…e altro

Effetti dell'ambiente sulla salute mentale

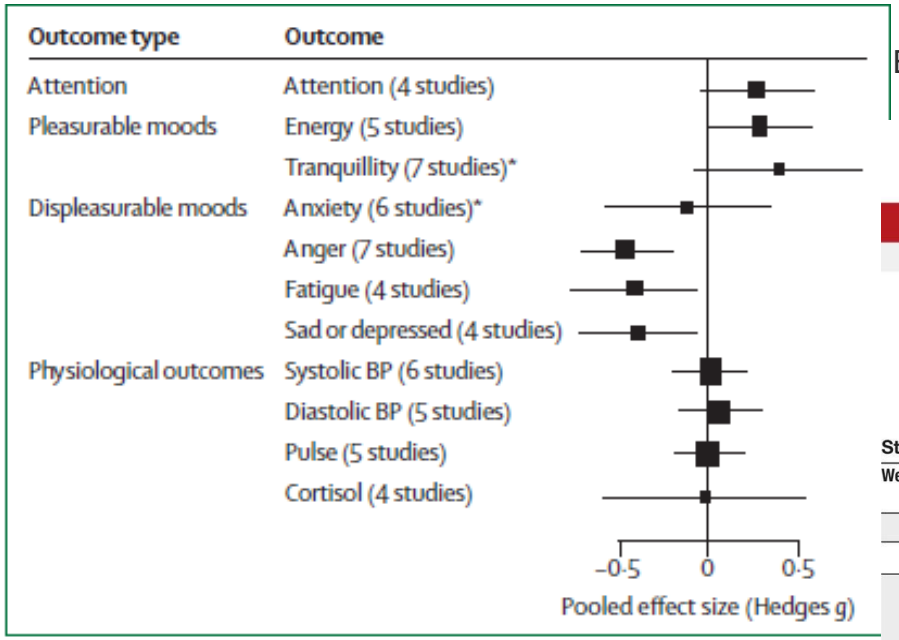


Figure 18: Psychological and emotional outcomes from exposure to natural versus synthetic environments

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

Effetto del meteo sul dolore

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

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

NARRATIVE REVIEW

Outline
Images

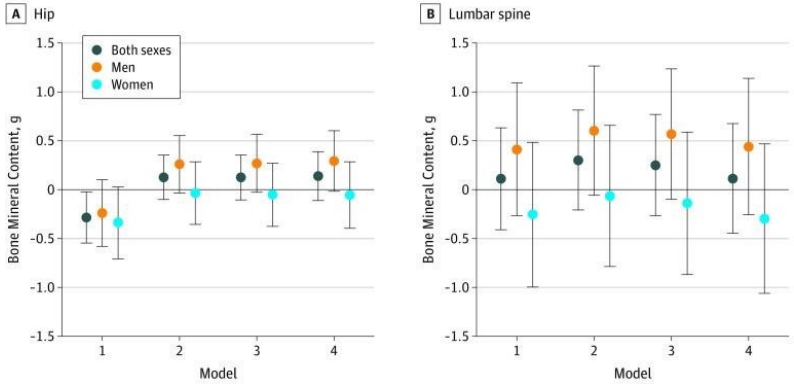
Are weather conditions associated with chronic musculoskeletal pain? Review of results and methodologies

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.

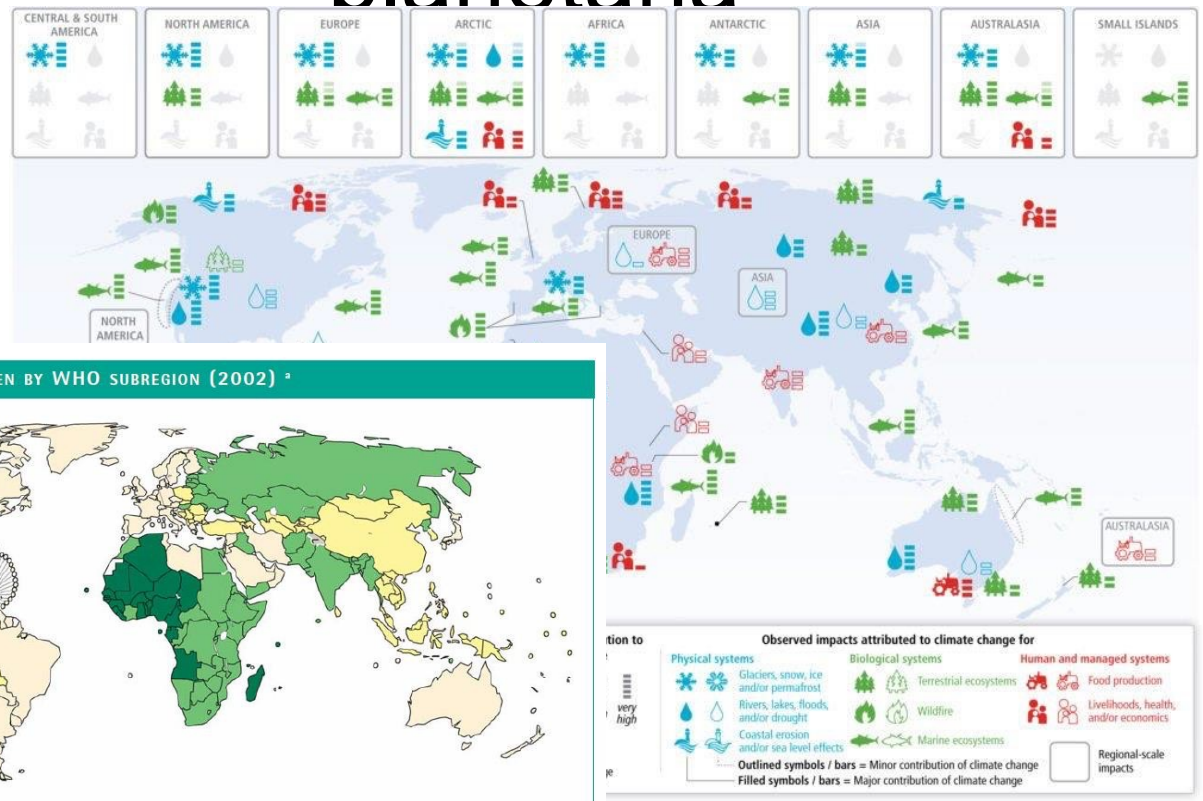
Weather variable	No. of studies investigating this variable	No. of studies finding no association with pain (%)	No. of studies finding an association with pain (%)
Temperature	41	21 (51)	20 (49)
Atmospheric pressure	41	20 (49)	21 (51)
Humidity			
Relative humidity	35	16 (46)	19 (54)
Vapor pressure	6	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)

Effetti dell'inquinamento atmosferico sulla salute muscolo-scheletrica



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

Un problema su scala planetaria



Prüss-Üstün et al. Rapporto OMS Preventing Disease 2006

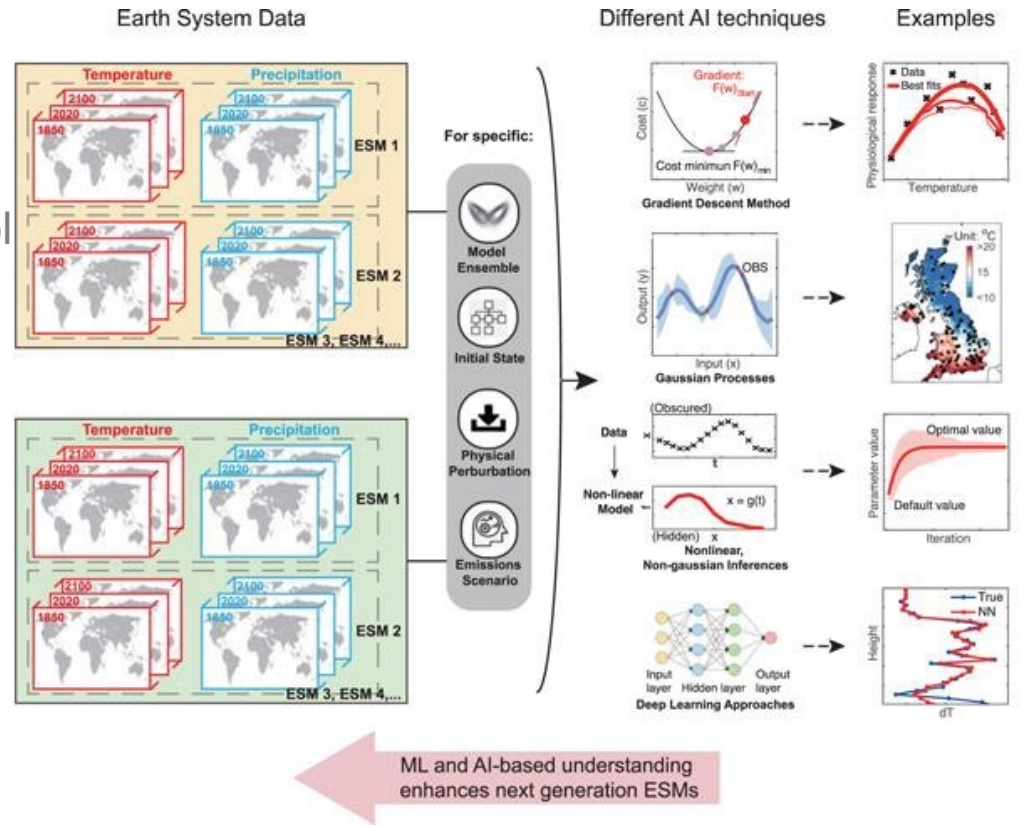
Cramer et al. Detection and attribution of observed impacts. Climate Change 2014: IPCC 5th AR

«È la prima volta che un'intera generazione di bambini crescerà in un mondo reso molto più pericoloso e incerto dai cambiamenti climatici e dal degrado ambientale.» UNICEF

Informatica sanitaria e salute planetaria

Scienza dei dati climatici

- Modellazione del sistema Terra
  - ad es. classificazione della copertura del suol
- Scenari climatici futuri
- Previsioni meteo
- Previsione degli eventi estremi
  - ad es. previsione delle alluvioni
- Impatti climatici
  - ad es. su agricoltura, salute, economia
- Cura e qualità dei dati
  - ad es. dati puntuali, su griglia e satellitari di precipitazione,
    temperatura, vegetazione e ambiente costruito

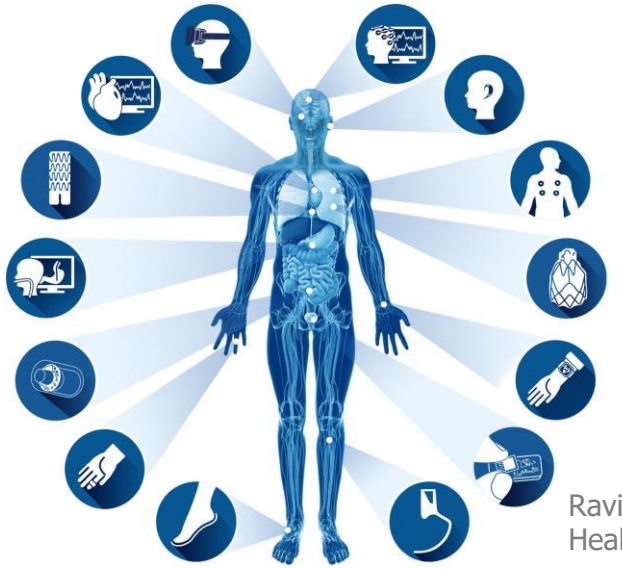


Huntingford C *et al* 2019 *Environ. Res. Lett.* **14** 124007

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Scienza dei dati sanitari

- Fornire dati in tempo reale e del mondo reale

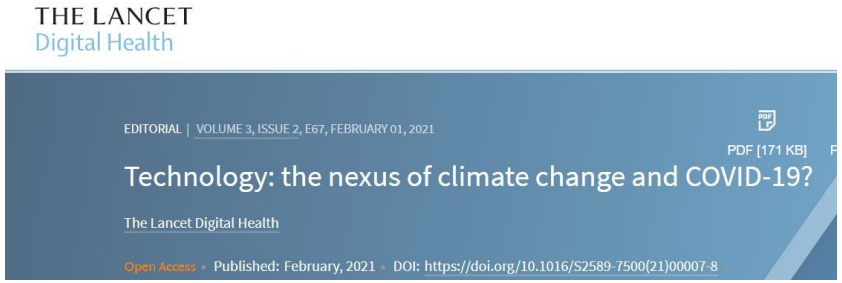


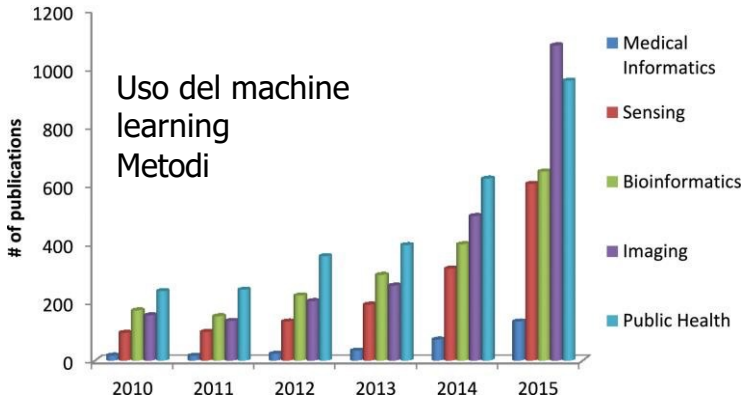
Ravi et al., IEEE Biomed & Health Informatics 2017

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Scienza dei dati sanitari

- Fornire dati in tempo reale e del mondo reale
- Migliorare **le conoscenze su** clima e salute



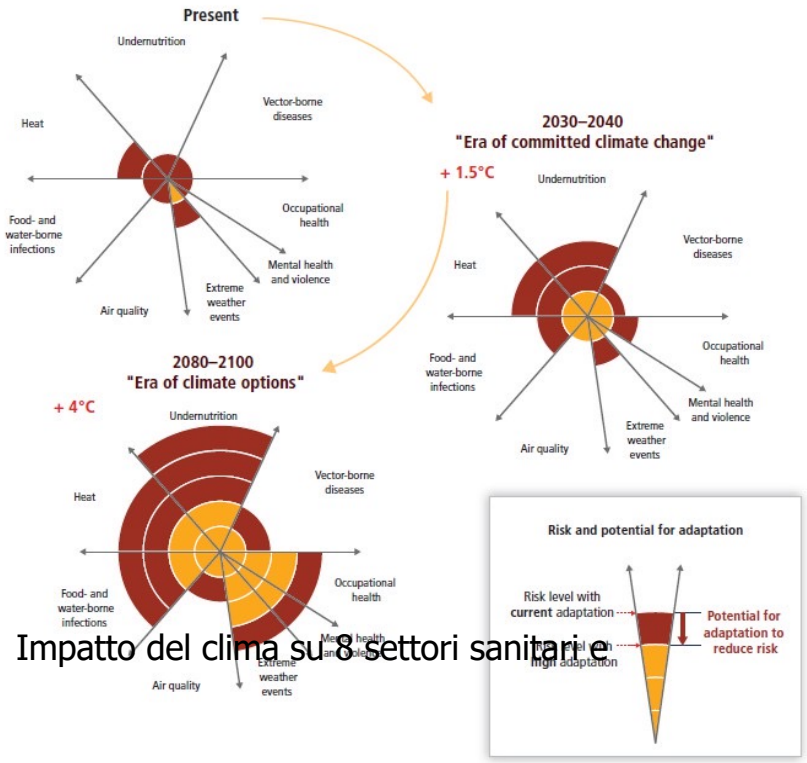


Ravi et al. IEEE Biomed & Health Informatics 2017

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Scienza dei dati sanitari

- Fornire dati in tempo reale e del mondo reale
- Migliorare le conoscenze su clima e salute
- **Adattamento dei sistemi sanitari al cambiamento**



Impatto del clima su 8 settori sanitari e

climatico

potenziale di mitigazione tramite l'adattamento.

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

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Sistemi di allerta precoce

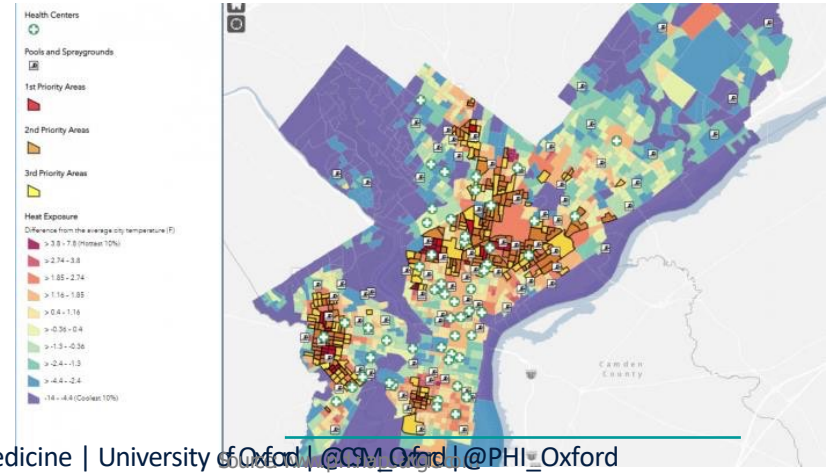
- Tradizionalmente basati sulle conoscenze locali
- Sistemi di allerta intelligenti basati su
  - Conoscenze esperte
  - Big data in tempo reale
  - Analisi avanzate

Valutazione dei sistemi di allerta caldo-salute a Shanghai, Cina

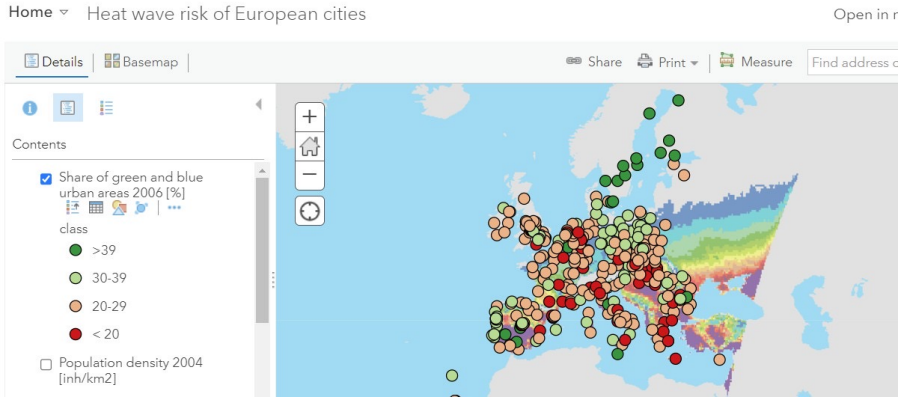


Yaqiao et al. Science of The Total Env. https://doi.org/10.1016/j.scitotenv.2020.136883

Indice di rischio di calore, Filadelfia, USA.

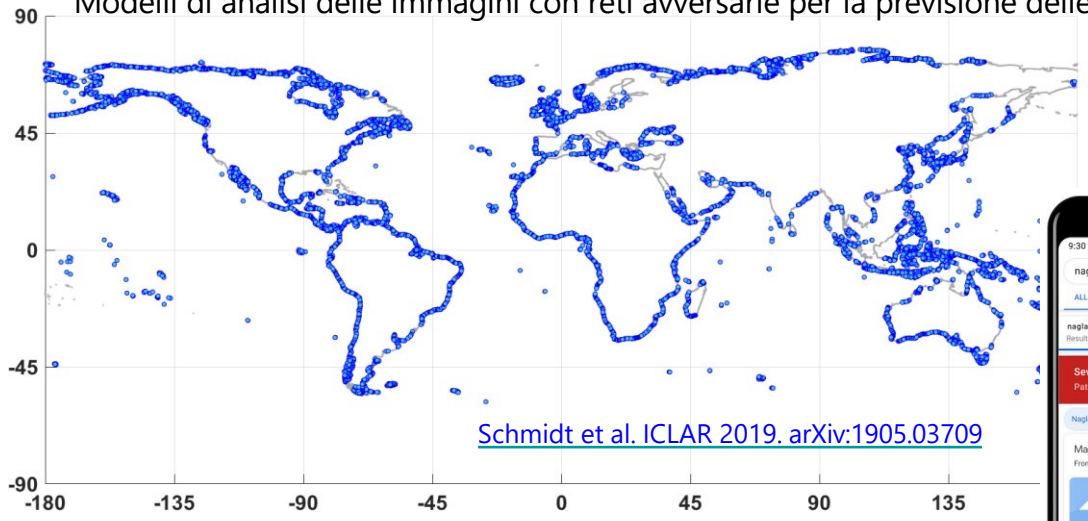


Mappa del rischio di calore. Agenzia europea dell'ambiente

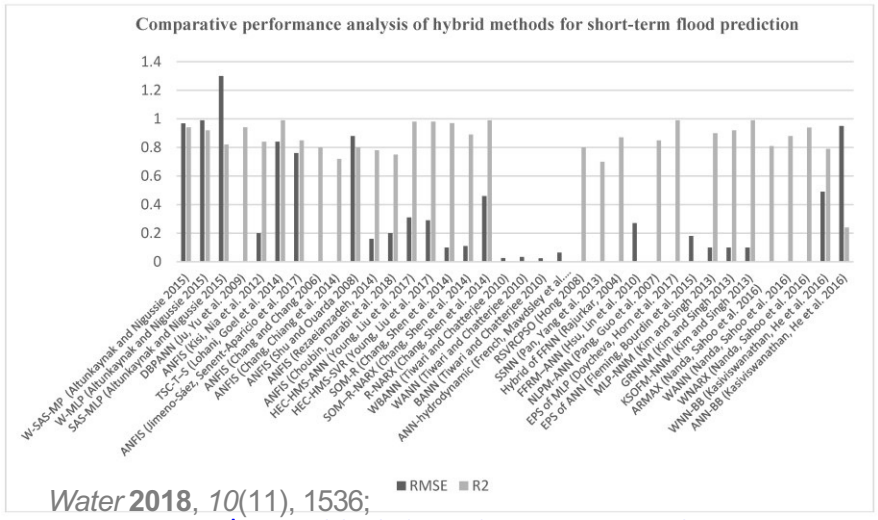


Modelli di previsione delle alluvioni

Modelli di analisi delle immagini con reti avversarie per la previsione delle alluvioni

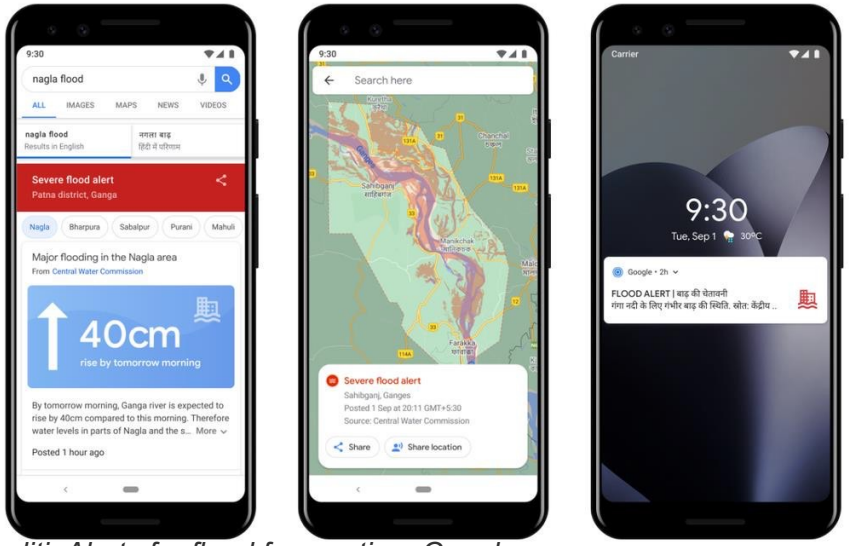


Schmidt et al. ICLAR 2019. arXiv:1905.03709



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

Iniziativa di previsione delle alluvioni di Google in uso in India e Bangladesh



Crediti: Alerts for flood forecasting, Google

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Prevedere i focolai epidemici



Dati satellitari Landsat combinati con dati a terra su precipitazioni, temperatura, umidità del suolo e vegetazione

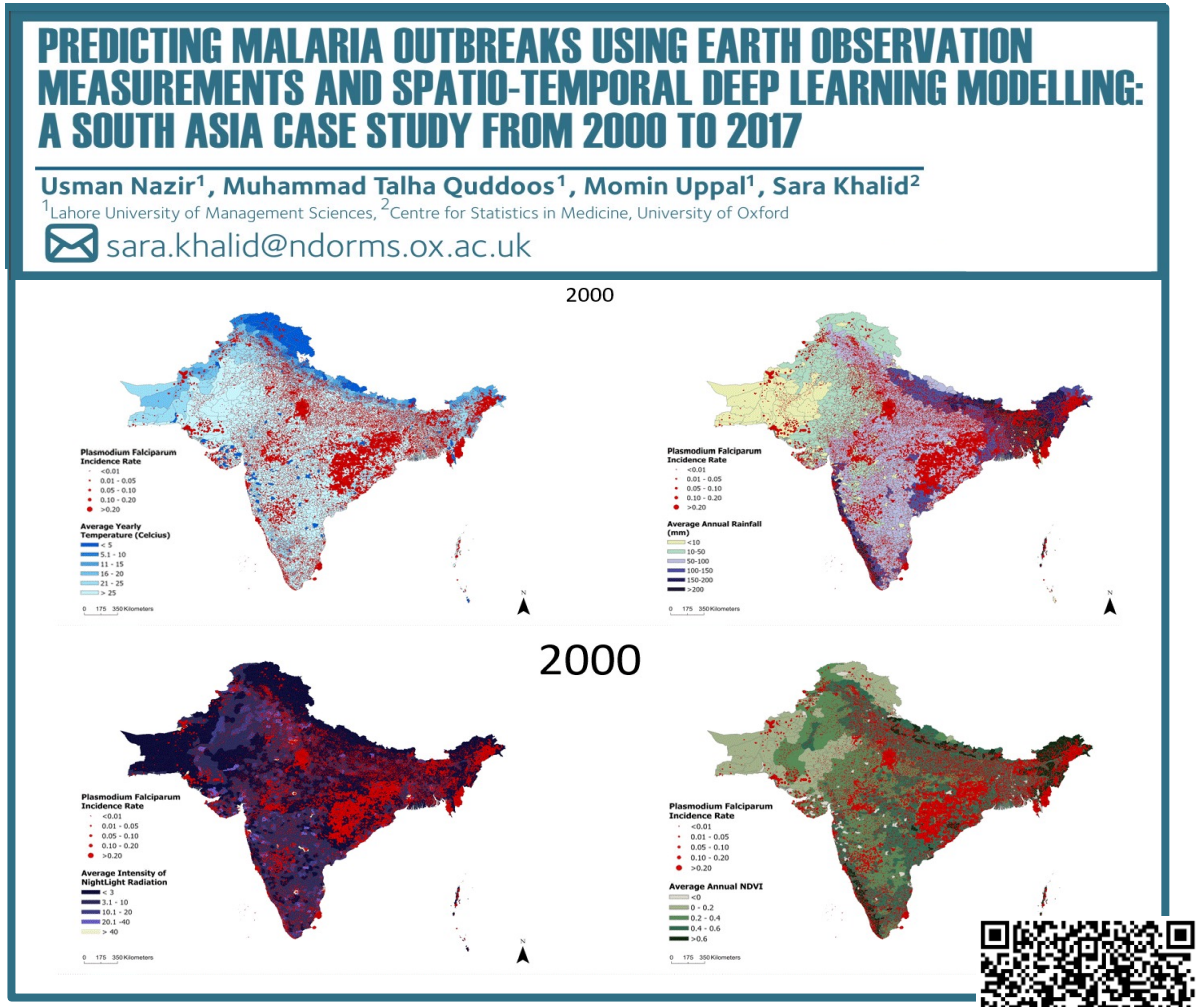


Modelli computazionali che seguono eventi umani e ambientali



Prevedere i focolai di malaria in Perù a livello di nucleo familiare

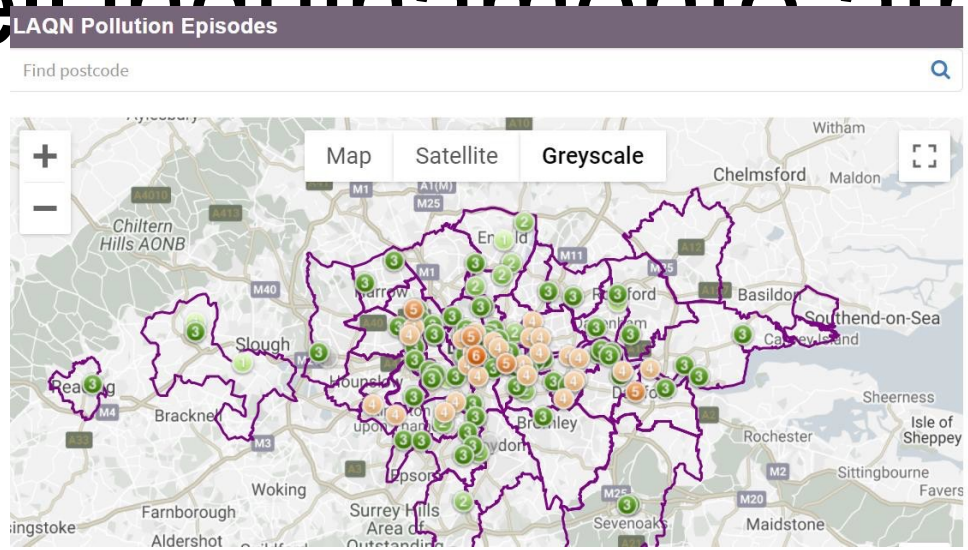
Schmidt et al. ICLAR 2019. arXiv:19



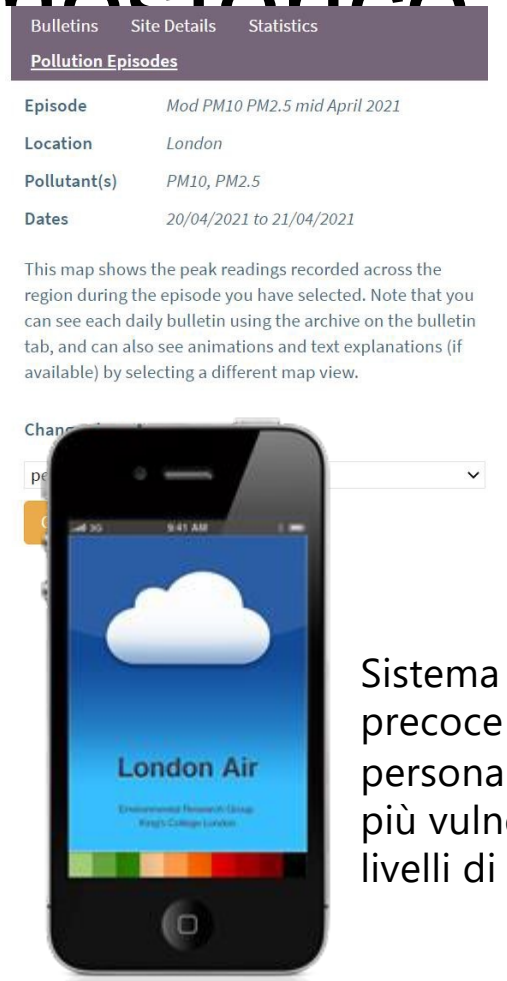
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Tracciamento e monitoraggio dell'inquinamento atmosferico



Il London Air Quality Network monitora e prevede i livelli di ozono, ossido di azoto, PM2,5 e PM10



Credito: londonair.org.uk

Sistema di allerta precoce personalizzato per i più vulnerabili ad alti livelli di inquinamento

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IA e biodiversità

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

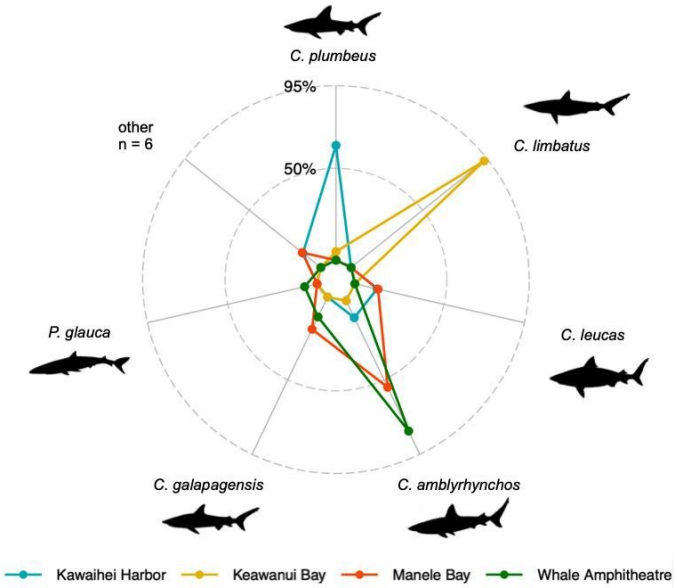
Select Video

20220924_KeawanuiBay_S3_GX110006.mp4

PROCESS DETECT VIDEO PLAY VIDEO RESET

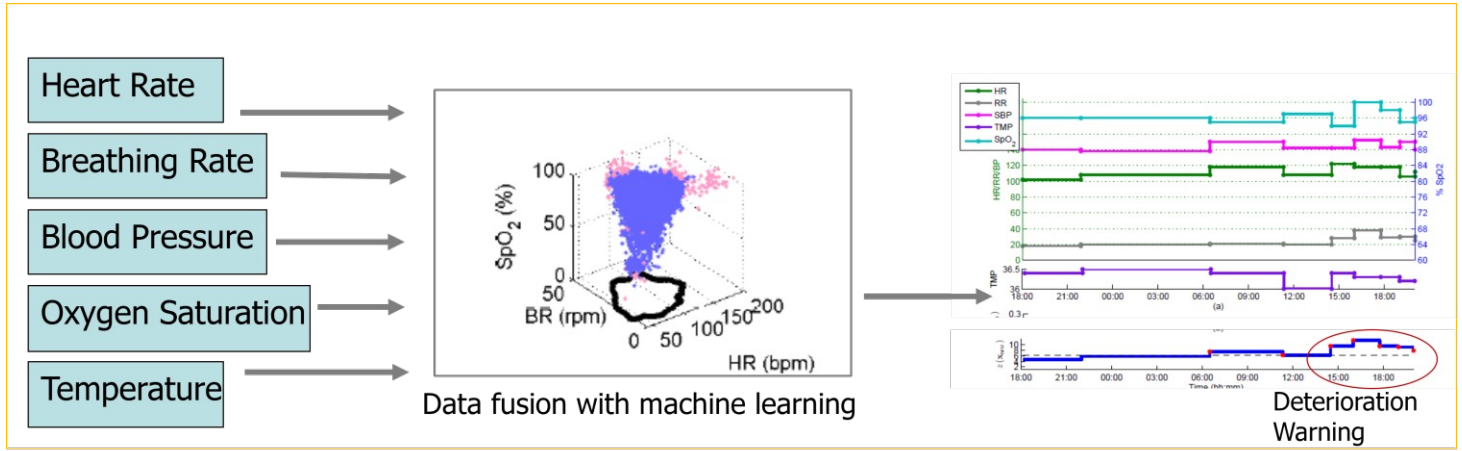
Shark	Prediction
Carcharhinus limbatus	94.15 %
Carcharhinus plumbeus	4.13 %
Carcharhinus amblyrhynchos	0.47 %
Galeocerdo cuvier	0.44 %
Carcharodon carcharias	0.39 %





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Monitoraggio a distanza dei pazienti in zone di disastro/conflitto





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

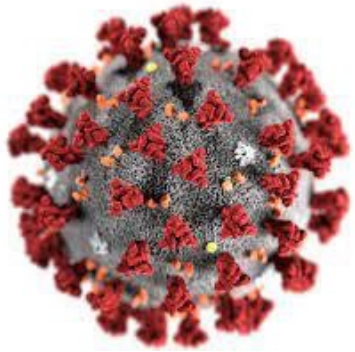
Home monitoring kit for remote management of Covid-19 infection



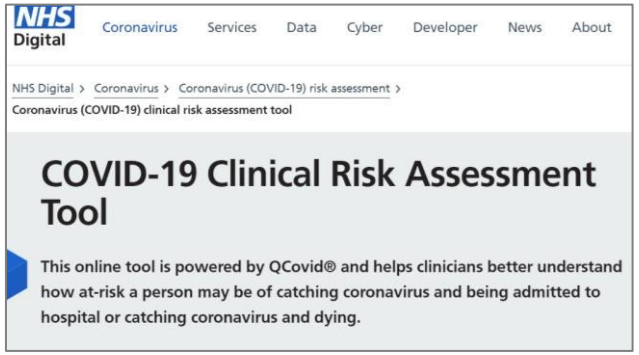
Santos et al. Front. Digit. Health
https://doi.org/10.3389/fdgth.2021.630273

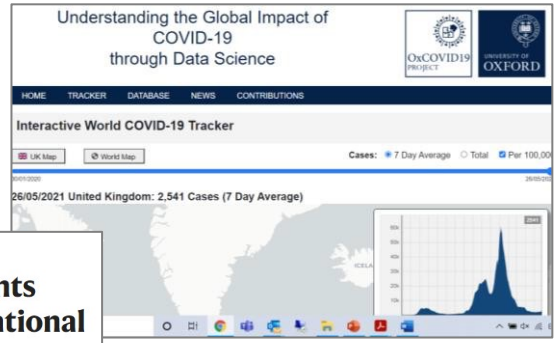
Risposta alle pandemie

- Diagnostica
- Previsione del rischio clinico
- Strategia vaccinale
- Fenotipizzazione approfondita

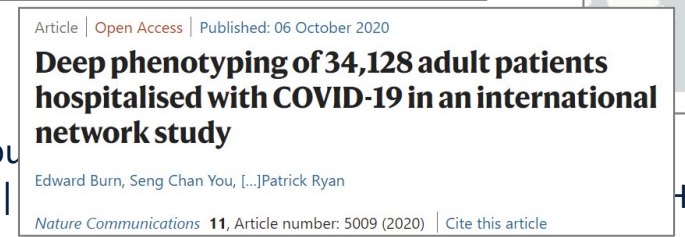








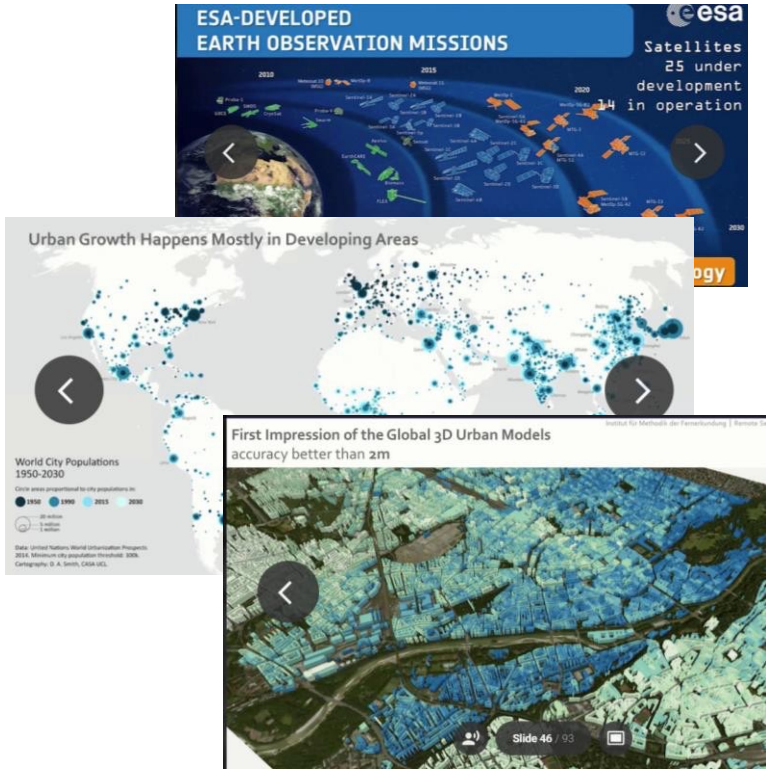




Modelli computazionali

- Città del futuro
  - Comfort termico urbano
  - Ottimizzazione dell'uso del suolo
  - Maggiore copertura vegetale
- Modellazione dei trasporti
  - Più attività fisica
  - Minore impronta di carbonio
- IA per le energie rinnovabili
- Impronta di carbonio dell'IA

Costruire una mappa 3D delle isole di calore urbane con dati di osservazione della Terra e deep learning



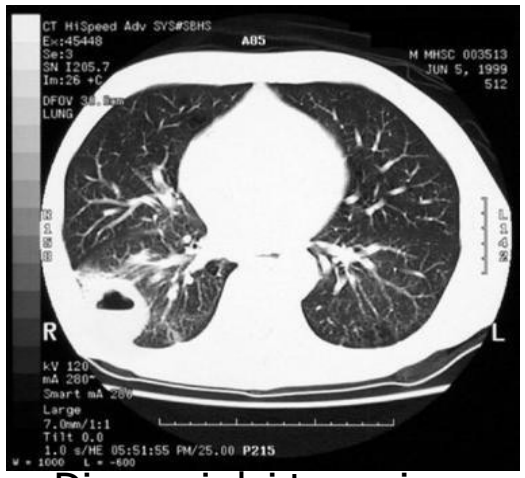
XX Zhu et al. IEEE Trans. Geoscience & Remote Sens 2017

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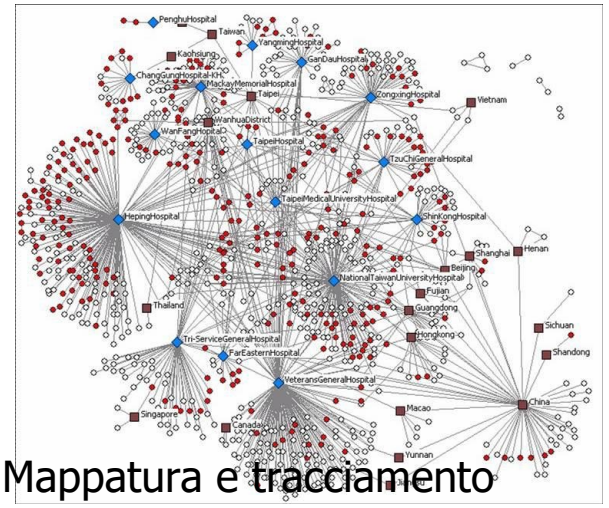
Applicazioni reali



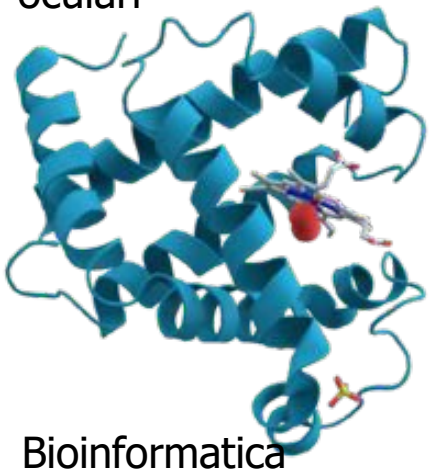
Rilevamento delle malattie oculari



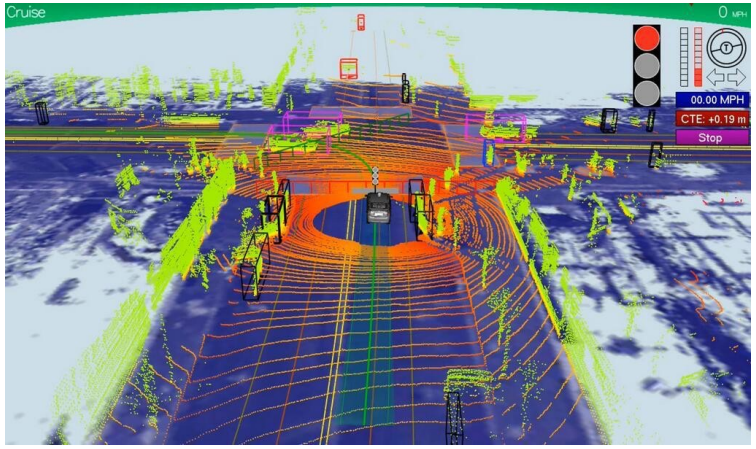
Diagnosi dei tumori



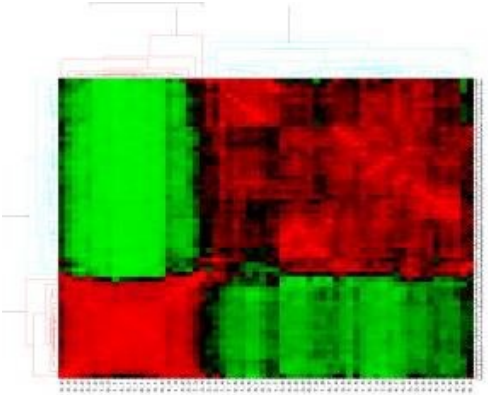
Mappatura e tracciamento delle malattie



Bioinformatica



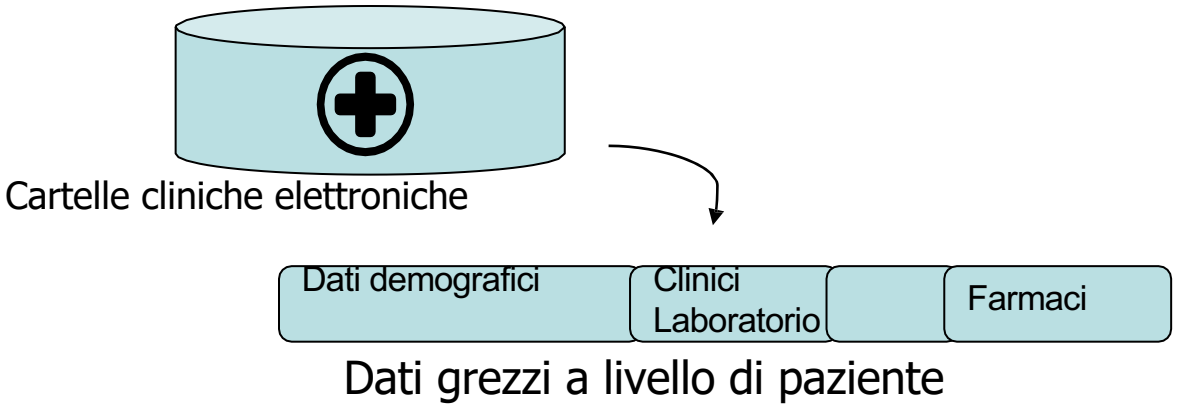
Autonomous vehicle navigation



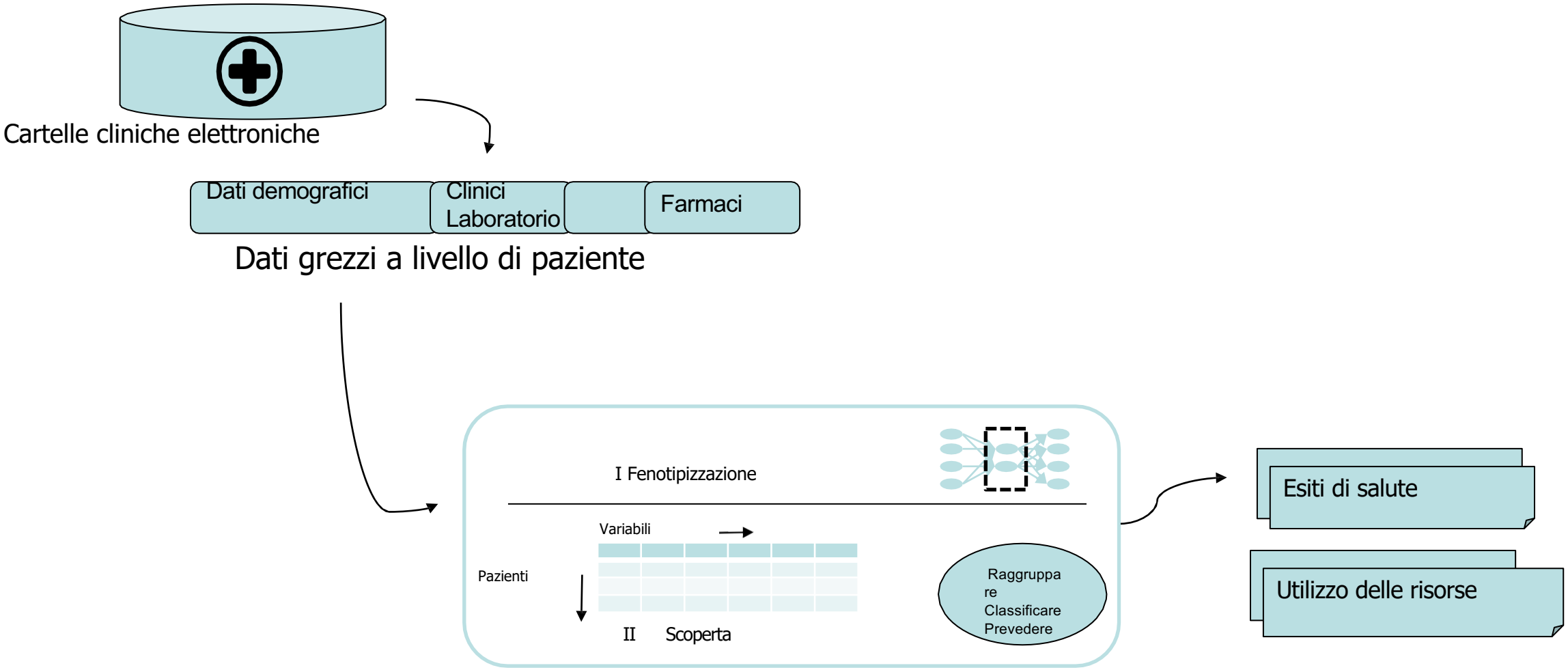
Clustering dell'espressione genica

Sfide e opportunità

Quadro di analisi della salute planetaria

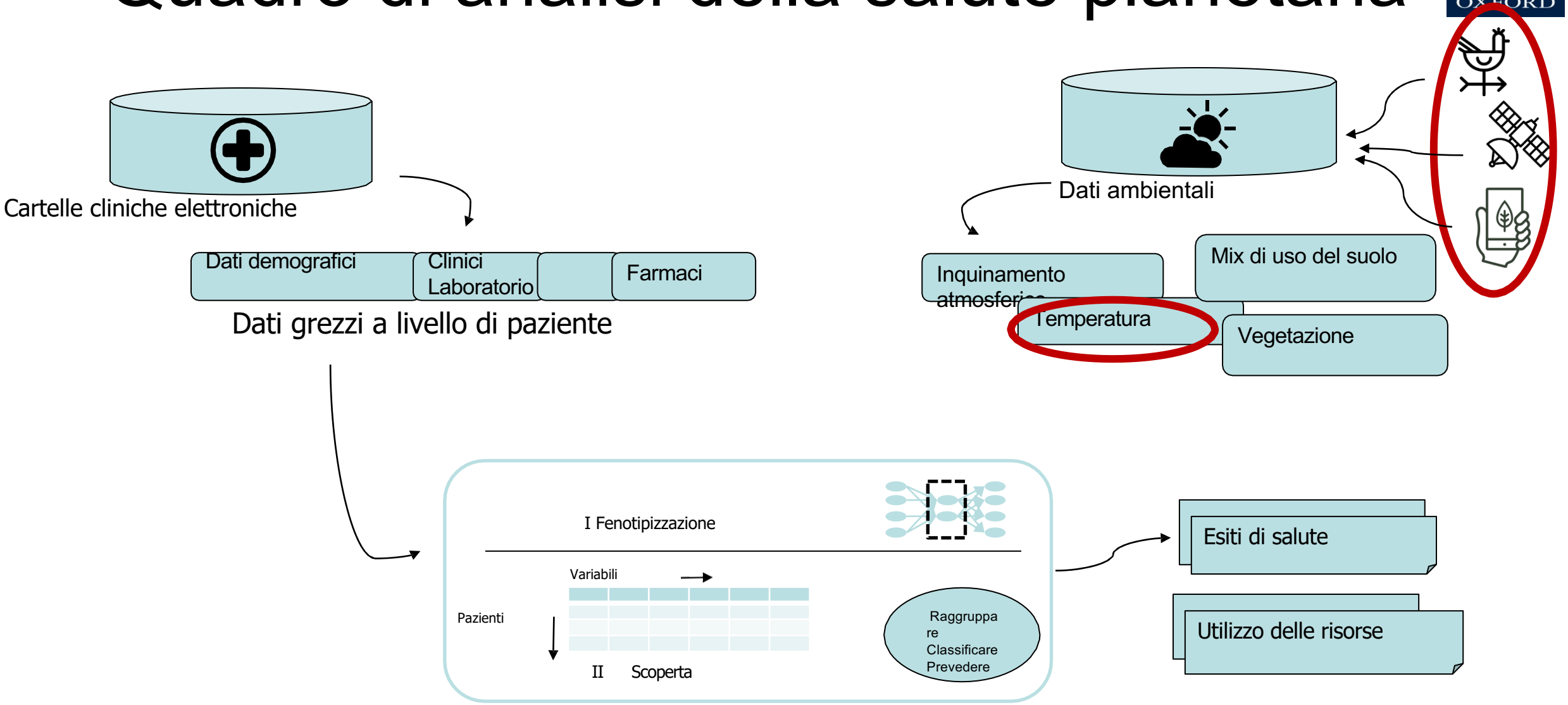


Quadro di analisi della salute planetaria



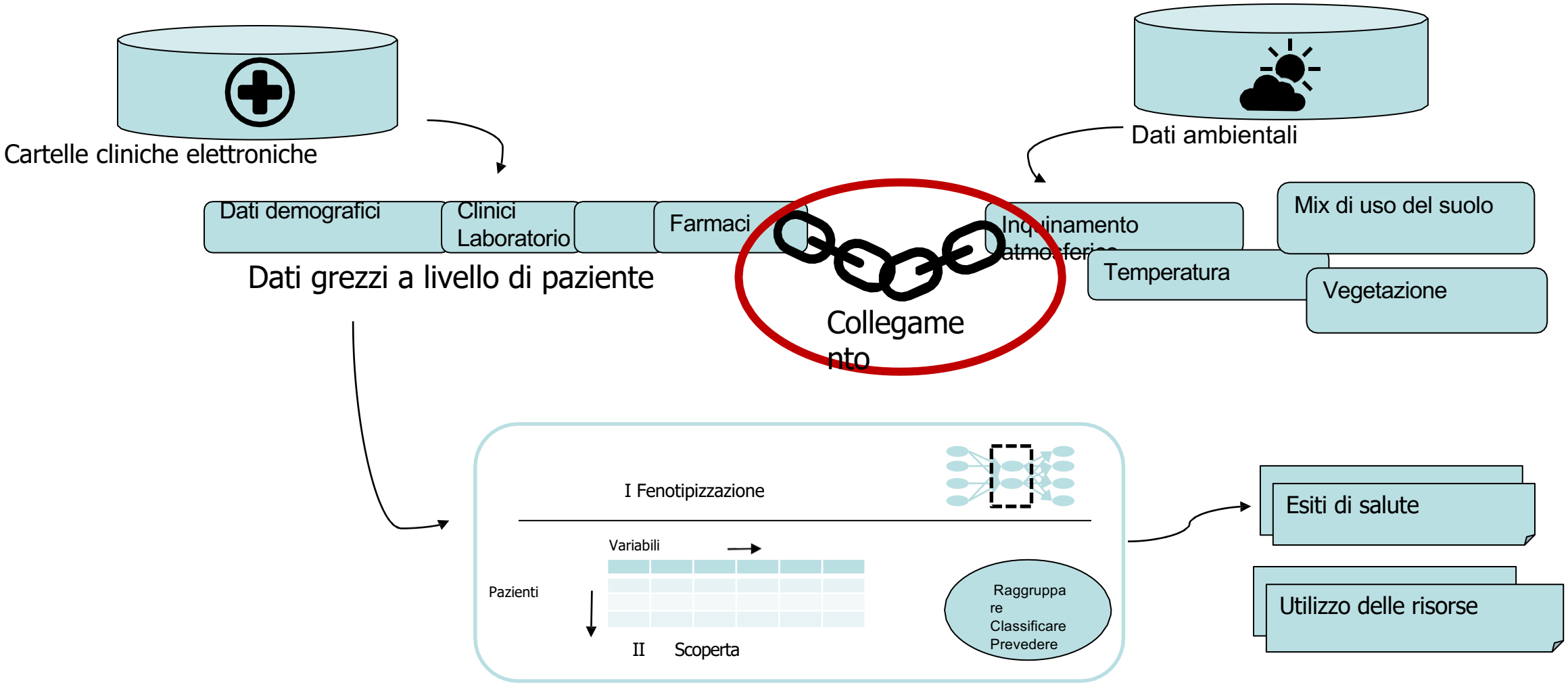
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Quadro di analisi della salute planetaria



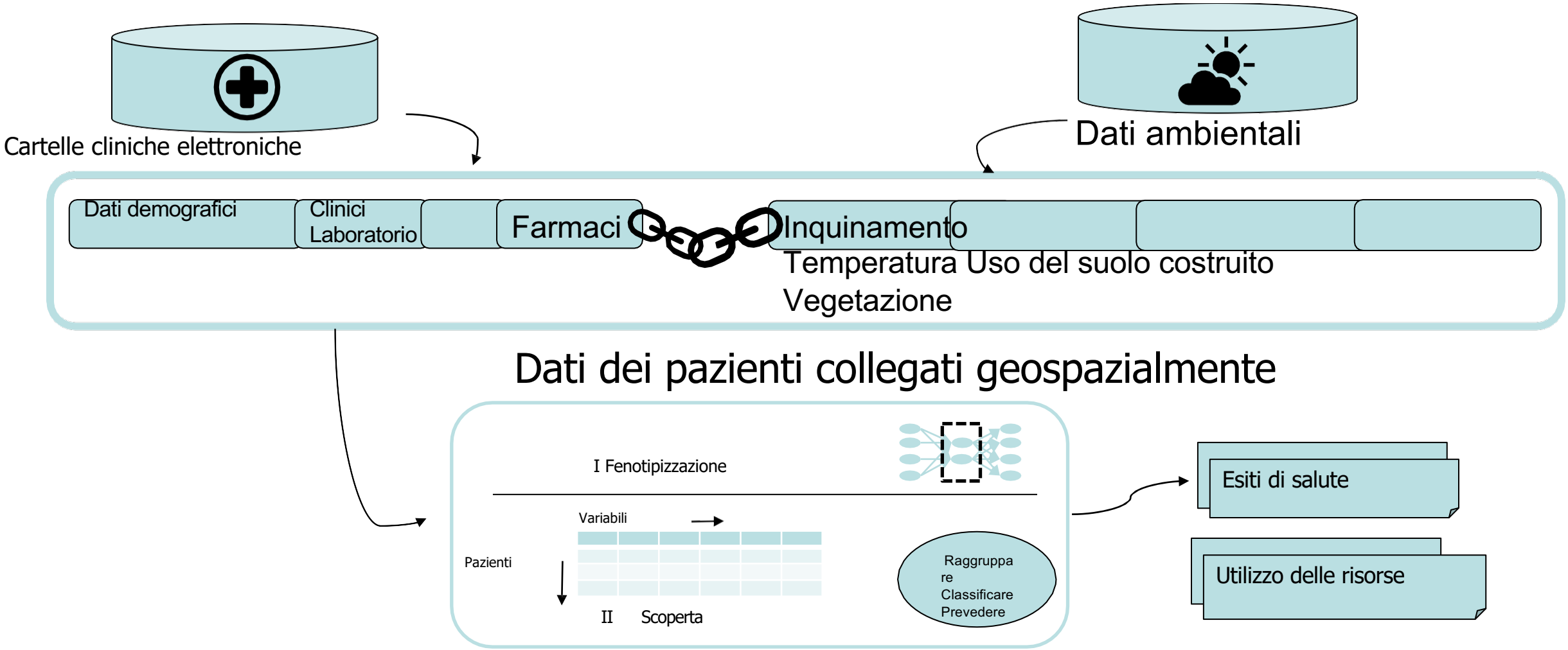
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Quadro di analisi della salute planetaria



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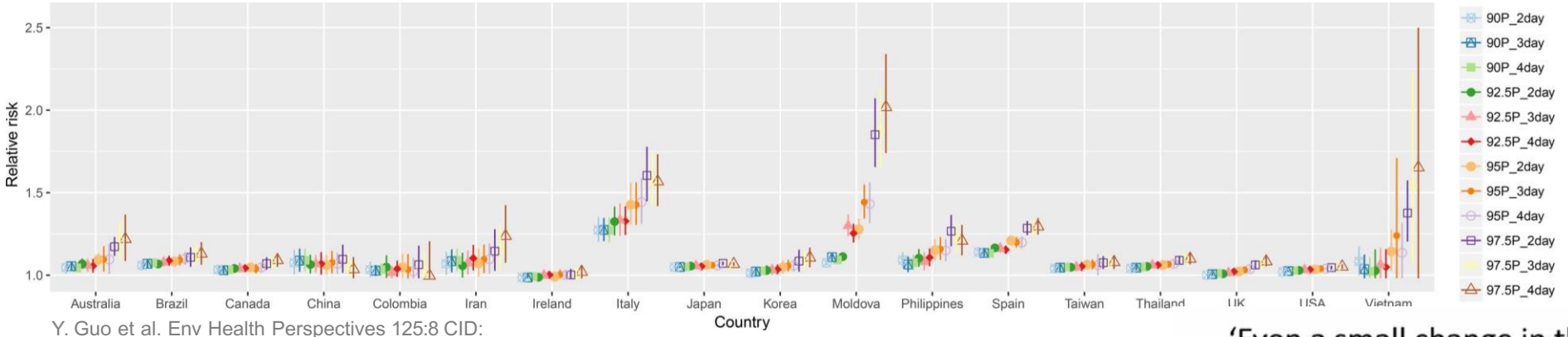
Quadro di analisi della salute planetaria



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Definizione, codifica e rilevazione del caldo

Effetto delle ondate di calore sulla mortalità in 18 paesi con 12 diverse definizioni di ondata di calore



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

Dati del mondo reale, IA ed equità sanitaria

Bias dei dati

+

Bias algoritmico

→

Valutazione sanitaria errata



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

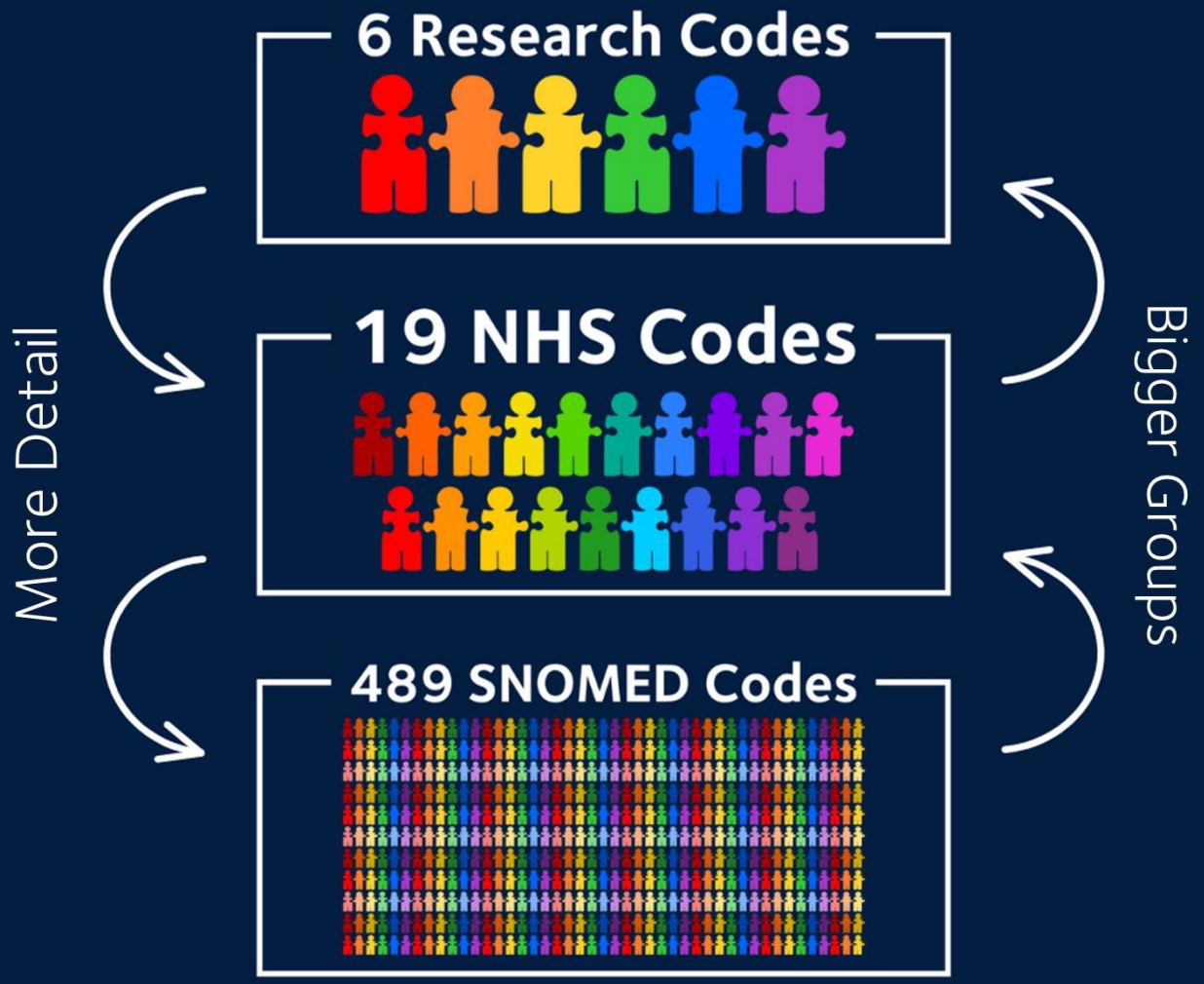
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Dati del mondo reale, IA ed equità sanitaria

60 milioni

di cartelle cliniche anonimizzate

Quali dati sull'etnia sono disponibili?

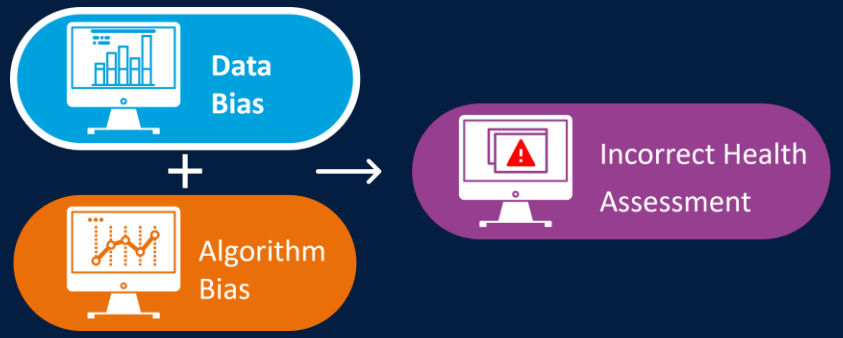


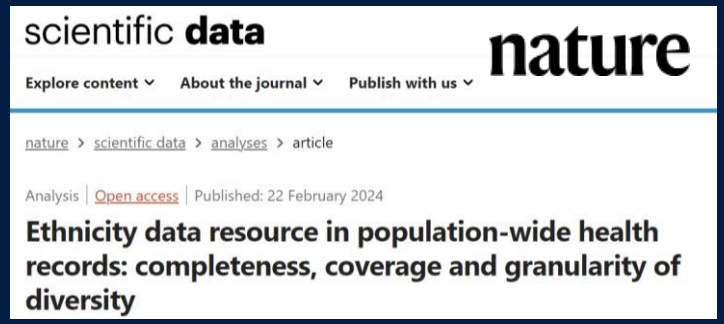
Progetto Etnia, equità sanitaria e IA

[Pagina del progetto]

[Link alla pubblicazione completa]

Uno studio centrale sulla COVID-19 del governo britannico per correggere i bias nei dati che si traducevano in disuguaglianze sanitarie.
L'analisi dei dati del NHS England ha rivelato dati ricchi e finora inutilizzati sull'etnia.




scientific data

nature

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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 mln

di pazienti, pari al 94% della **popolazione britannica**

255

Autodichiarata dal paziente, con il sistema SNOMED

1/10

dei pazienti non hanno dati sull'etnia nelle cartelle di assistenza primaria e secondaria

17%

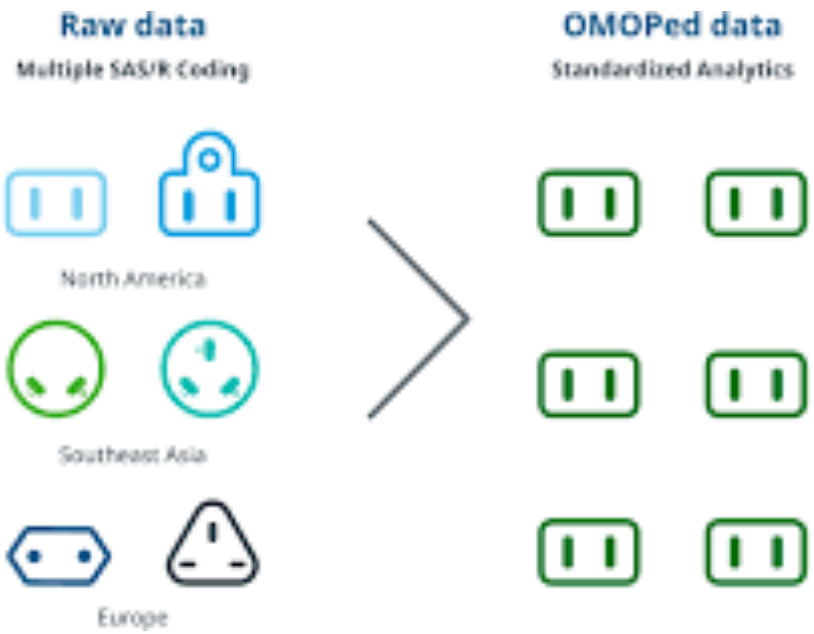
dei pazienti hanno codici etnici contrastanti nelle cartelle

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

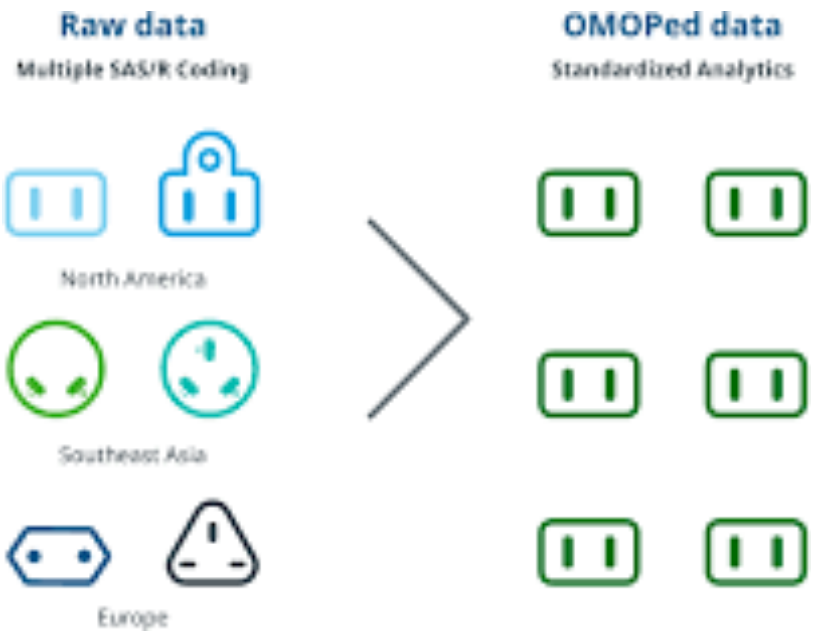
Modelli di dati comuni e analisi standardizzate



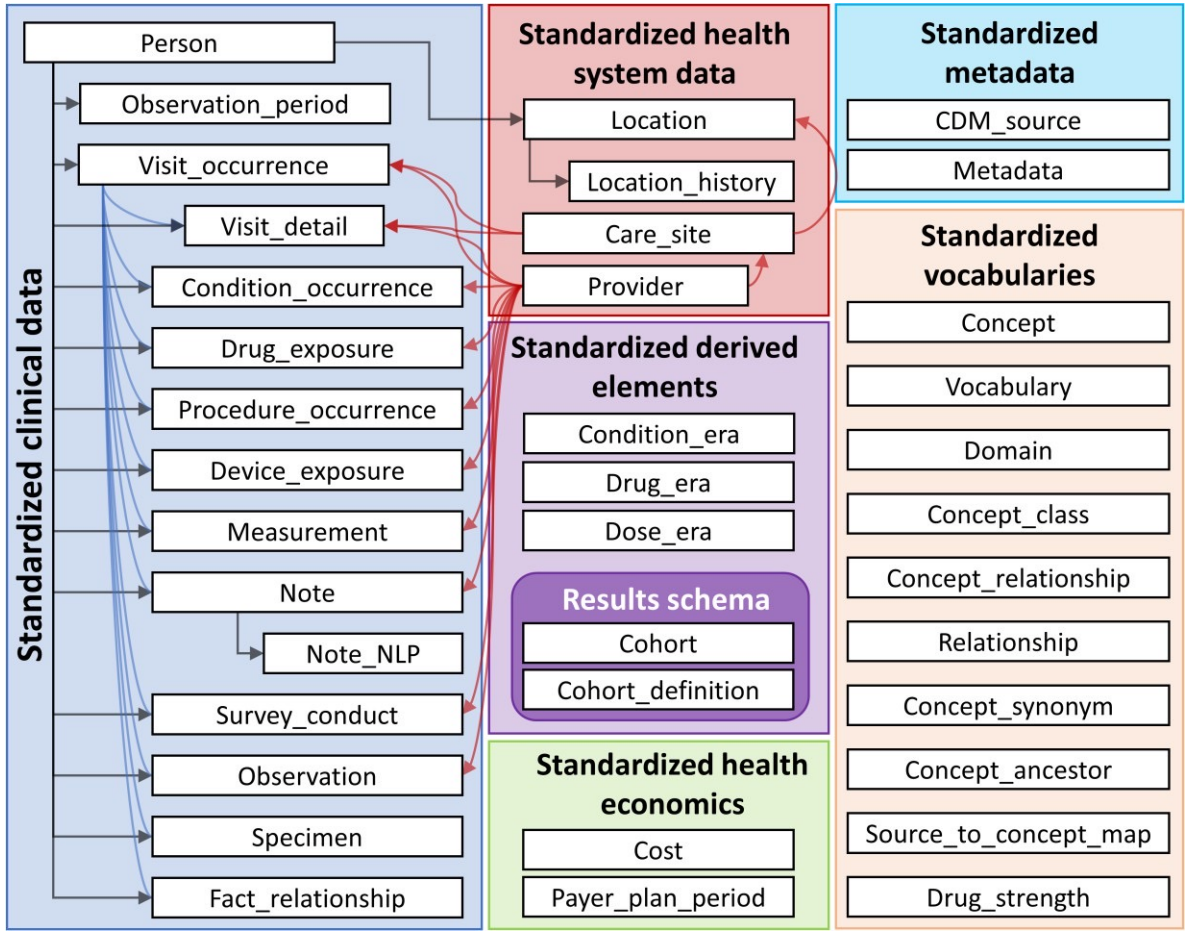
Modelli di dati comuni e analisi standardizzate



Modelli di dati comuni e analisi standardizzate



Esempio di modello di dati comune sviluppato da OHDSI

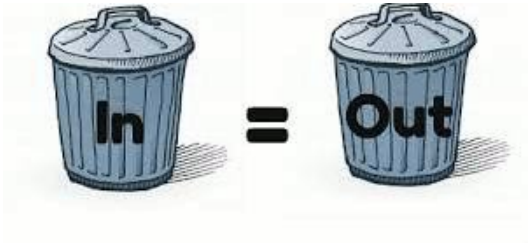


OHDSI
OBSERVATIONAL HEALTH DATA SCIENCES AND INFORMATICS

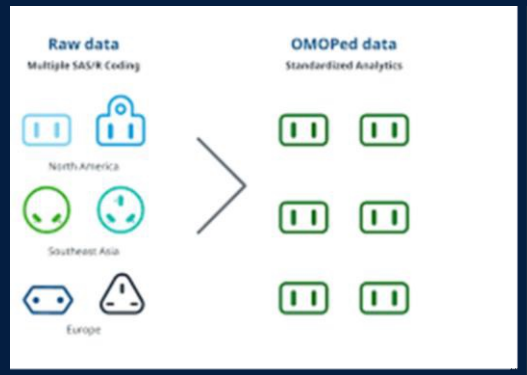
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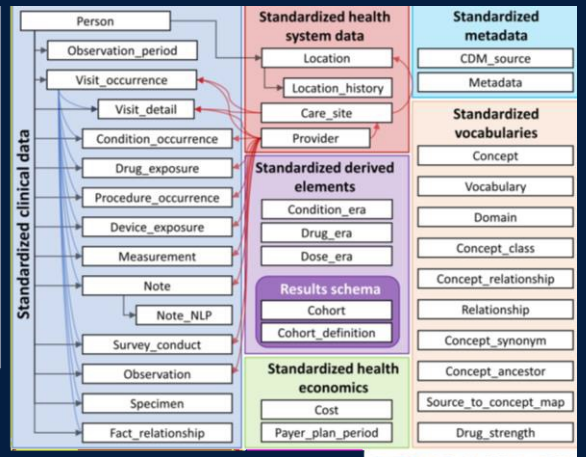
Aspetti da considerare

- Fonti di dati
  - Globali, etiche, rappresentative
- Collegamento
  - Dati anonimizzati
- Standardizzazione
  - Definizioni universali
  - Sincronizzazione temporale
  - Modello di dati comune
- Qualità dei dati
  - Completezza e accuratezza della registrazione (ad es. caldo)
- Analisi dei dati
  - Molte incognite
  - Fattori di confondimento
    - Interazioni tra più fattori di stress

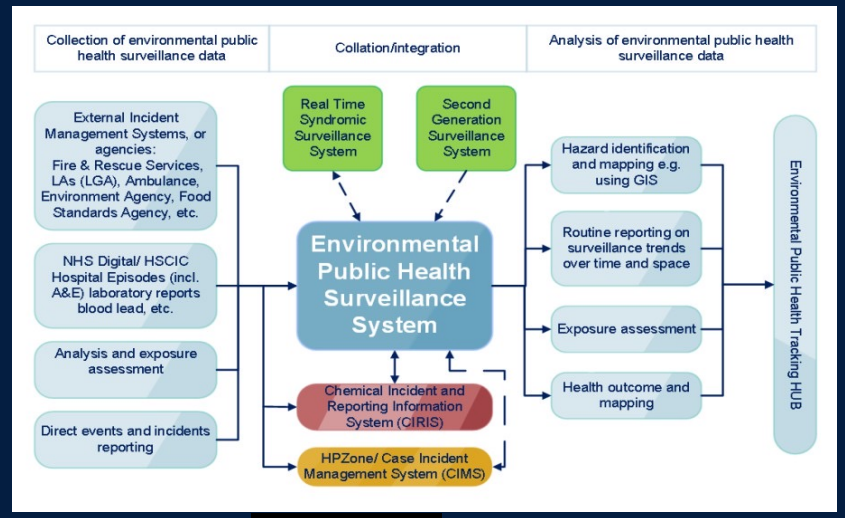


Infrastrutture per l'analisi su larga scala della salute planetaria



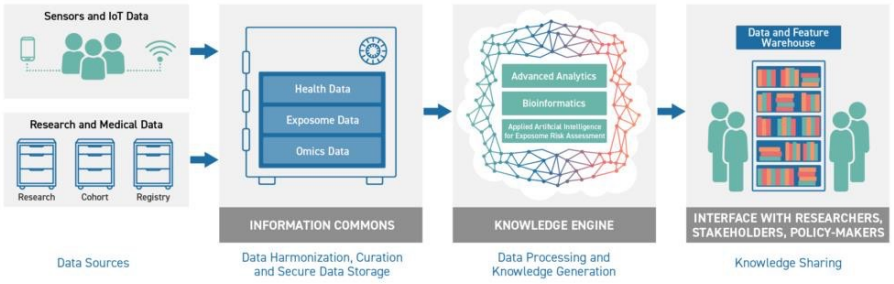


Modelli di dati comuni e analisi standardizzate



Public Health England

EPHSS Sistema di sorveglianza di sanità pubblica ambientale, Regno Unito



HEAP Europe Una piattaforma basata sull'IA per la ricerca sull'impatto del clima sulla salute

human exposome assessment platform



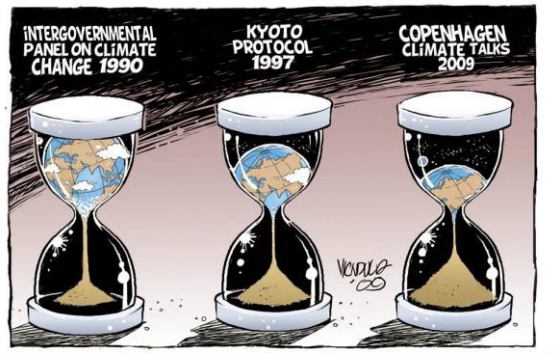
EXTREME EARTH

Deep Cube IA per analizzare i dati satellitari Copernicus e prevedere gli impatti climatici

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Co-benefici clima-salute

- Spesa globale per l'adattamento sanitario 18 mld $, ↑ 5,3%
- Pianificazione dell'adattamento dei sistemi sanitari in 86 paesi
- Piani ambiziosi di sanità a zero netto, ad es. NHS britannico: emissioni dell'assistenza ↓ 57%
- Disinvestimento dei fornitori sanitari: 42 mld $
- **La ricerca su salute e clima è aumentata di 8 volte**
- Beneficio economico di 1,5 °C: 600.000 mld $
  - forza lavoro più sana, costi sanitari ridotti



Crediti: Victor Ndula 2009

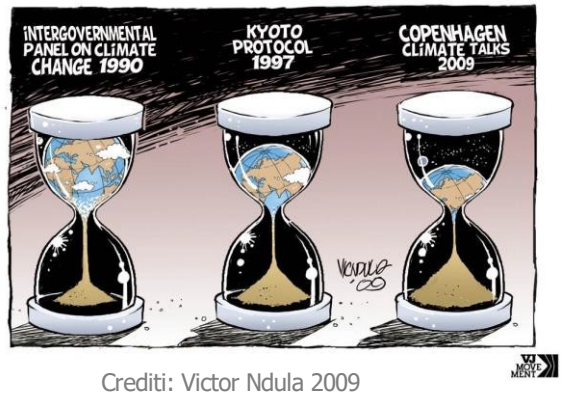
Rapporto Lancet Countdown 2020

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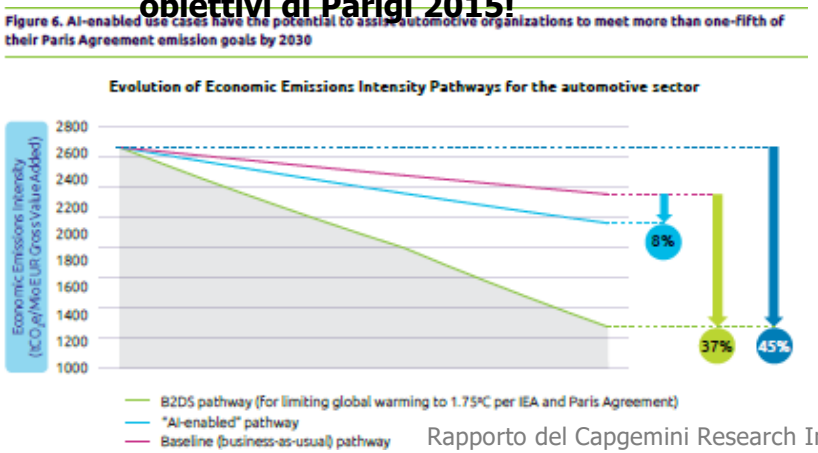
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Rapporto Lancet Countdown 2020



Crediti: Victor Ndula 2009

Forbes **L'IA può aiutare a raggiungere il 45% degli obiettivi di Parigi 2015!**



Rapporto del Capgemini Research Institute 2020

Maneggiare con cura

Top scientists call for caution over artificial intelligence

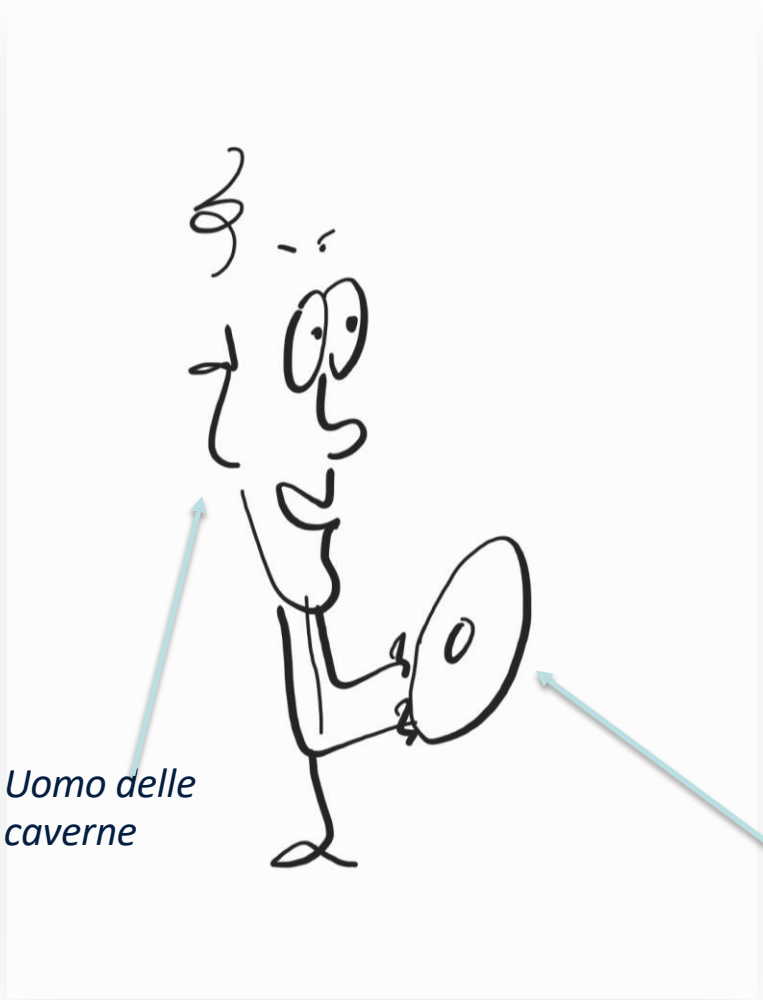
Artificial intelligence has the potential to eradicate disease and poverty, say world's top scientists, but researchers must not create something which cannot be controlled



The Telegraph (2015)

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

C’è una scelta

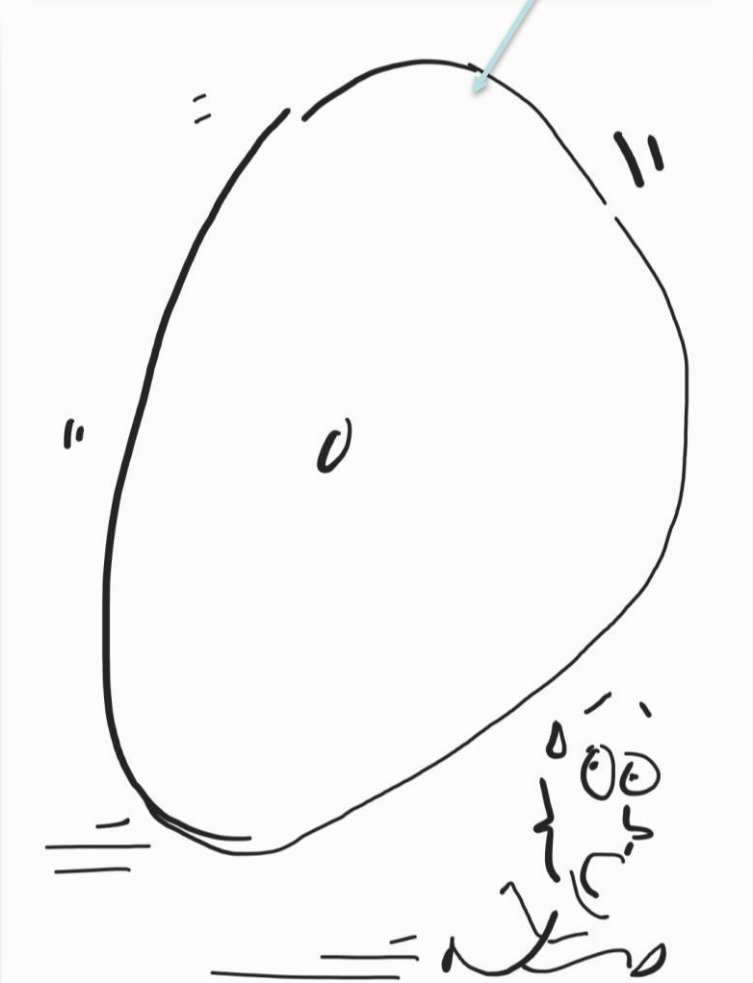


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La scelta è nostra



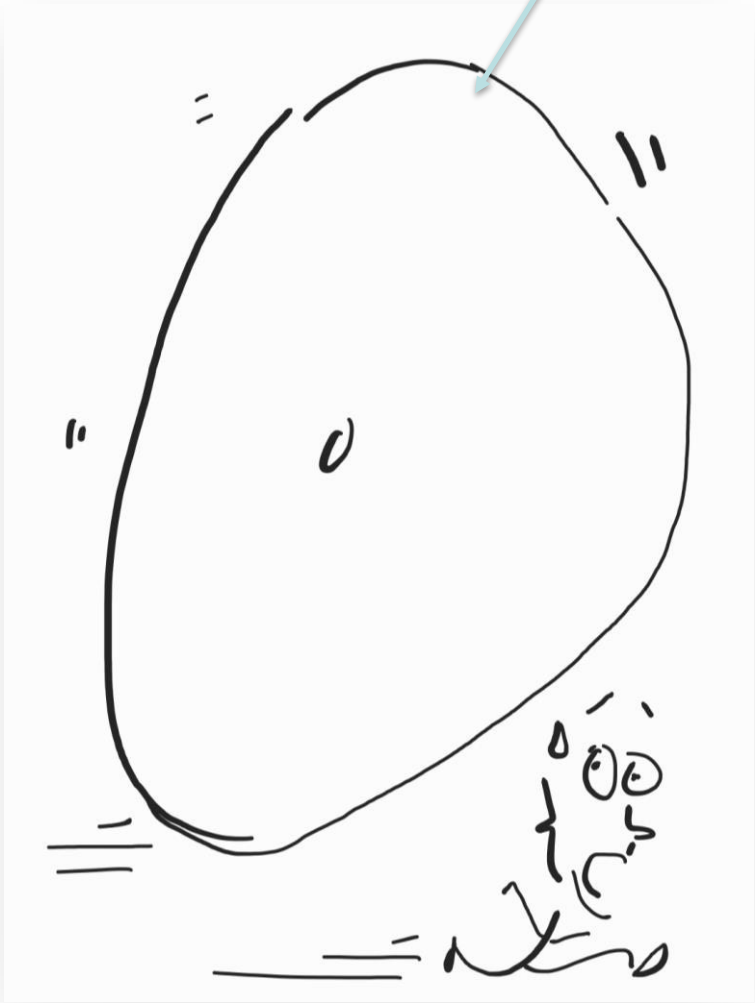
La prima ruota (non una ciambella!)

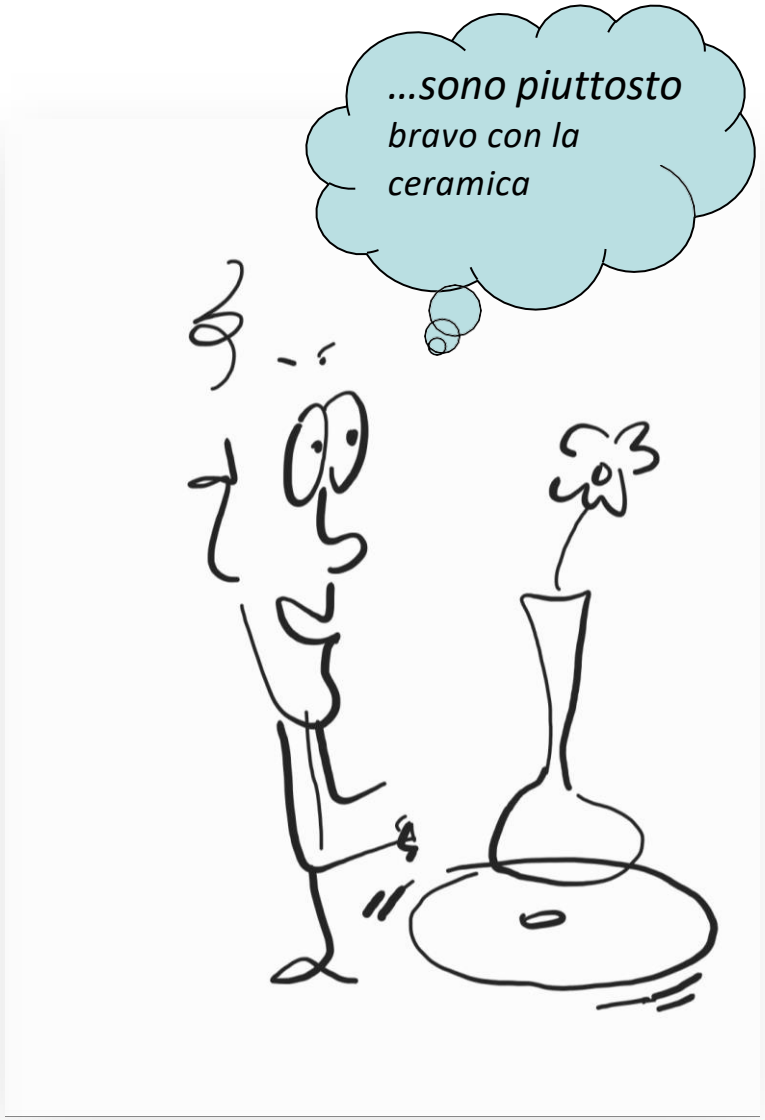


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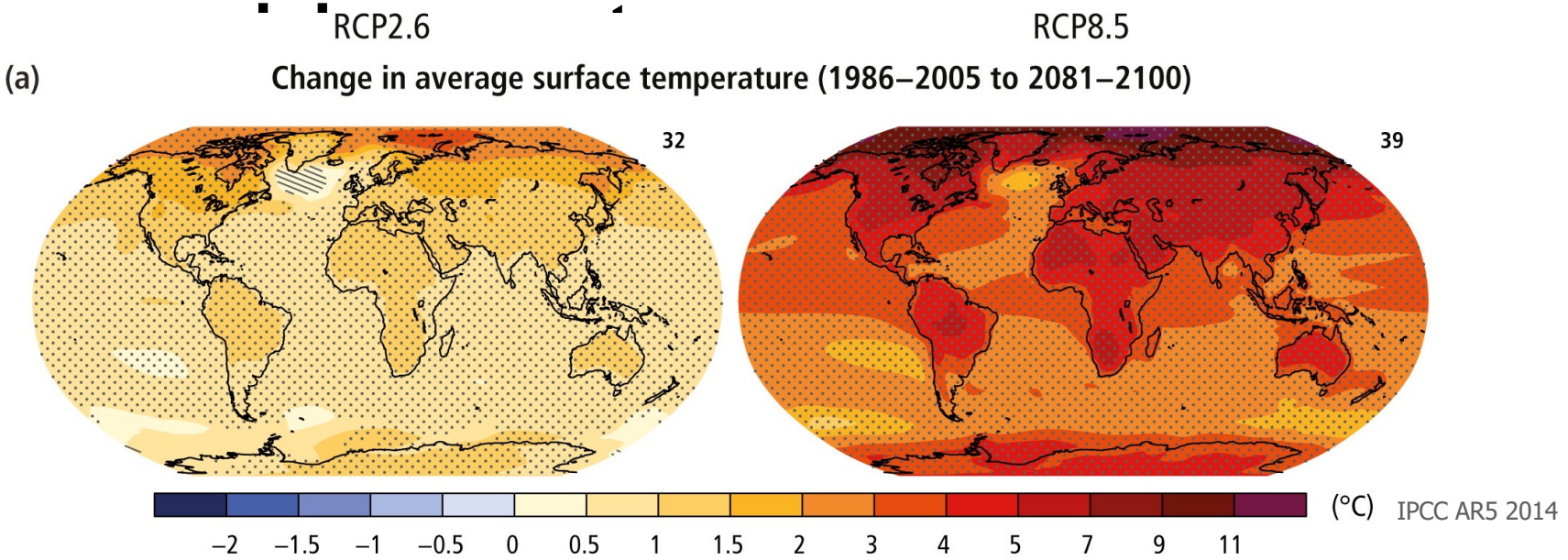






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Il nostro mondo si riscalda



IPCC AR5 2014

«I cambiamenti climatici sono la più grande minaccia sanitaria globale del XXI secolo»

Rapporto della Lancet Commission 2009

«Affrontare i cambiamenti climatici potrebbe essere la più grande opportunità per la salute globale del XXI secolo»

Rapporto della Lancet Commission 2015























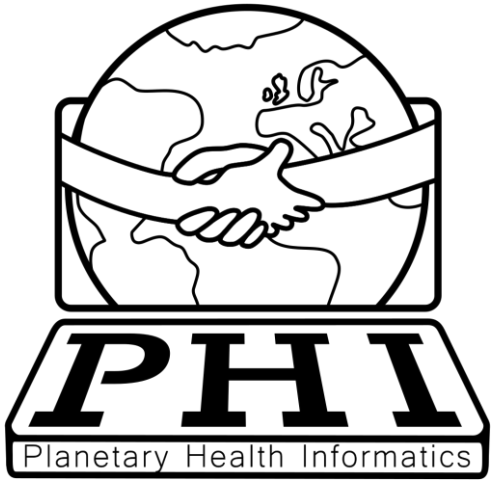










































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L’intelligenza artificiale per la salute planetaria

Sfide, opportunità e scelta umana

Scuola estiva Climate Change AI 2024: serie Clima e salute

Sara Khalid *BE MSc DPhil Oxon*

Professoressa associata | Centre for Statistics in Medicine Responsabile | Planetary Health Informatics Lab

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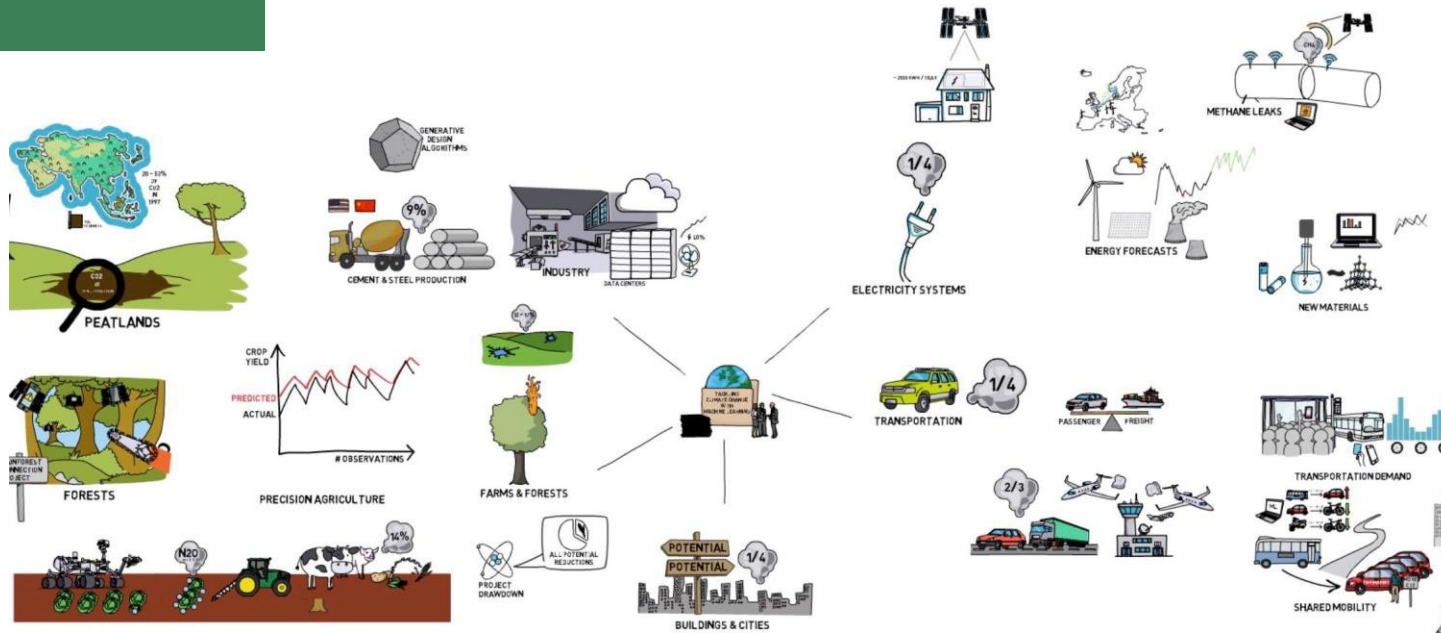
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Home page di Planetary Health Informatics

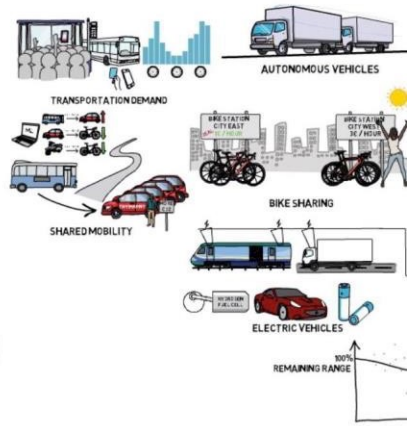
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Una chiamata all'azione

Climate Change AI









CompSustNet
Computational Sustainability Network

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