CURSO RESPUESTA AL CAMBIO CLIMÁTICO PARA LA SALUD EN LATINOAMÉRICA

Recolección de datos y vigilancia de enfermedades sensibles al clima
12 de mayo, 2022

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Agradecimientos

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- Sophie Lee (LSHTM)
- Dr Rory Gibb (LSHTM)
- Dr Felipe González-Colón (Wellcome Trust/LSHTM)
- Dr Isabel Fletcher (Wellcome Trust/LSHTM)

Objetivos de aprendizaje

- Discutir el riesgo de las enfermedades infecciosas sensibles al clima en el contexto de eventos extremos y el cambio climático
- Describir el flujo de datos (climáticos y epidemiológicos) y los métodos generalmente utilizados para:
  - Monitorear las condiciones climáticas adecuadas para la transmisión de enfermedades sensibles al clima.
  - Transformar información climática para su uso local en sistemas de alerta temprana.
  - Identificar indicadores hidrometeorológicos útiles para predecir el riesgo de epidemias de enfermedades sensibles al clima.


Viajes internacionales

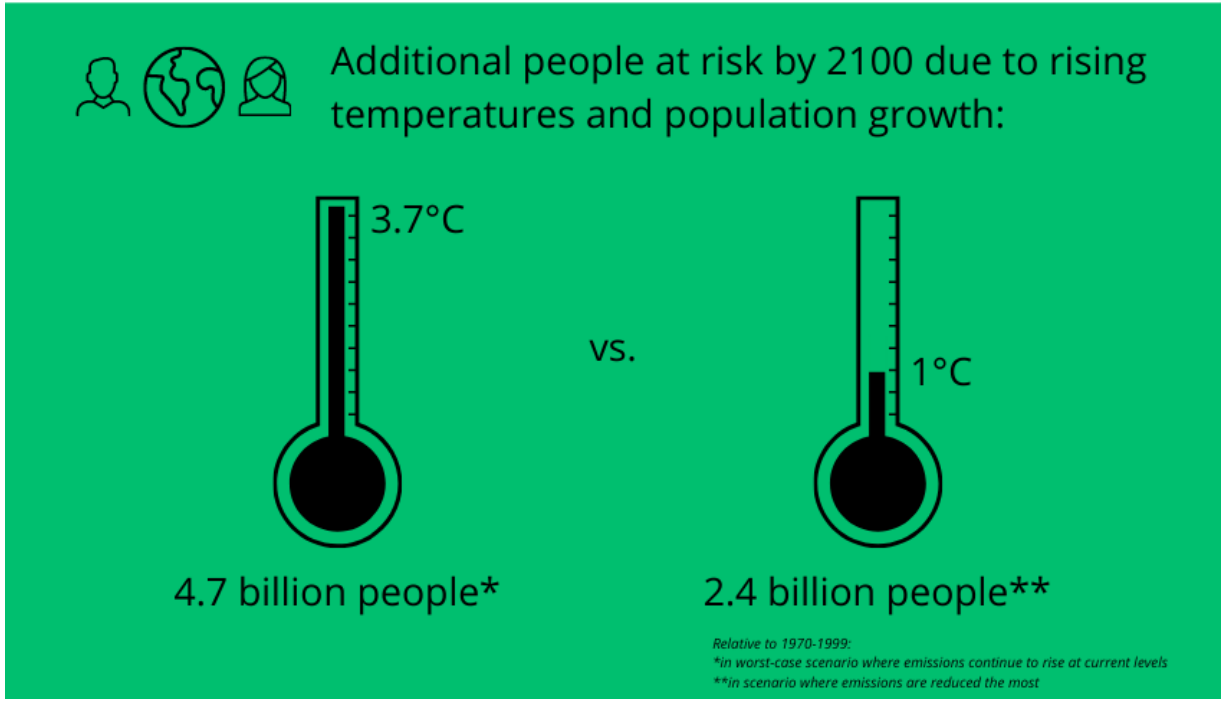

Comercio internacional


Cambio climático


Eventos extremos

La mitad de la población mundial está en riesgo de enfermedades transmitidas por mosquitos

Riesgo de dengue y malaria en un mundo más cálido



Felipe J Colón-González *et al.*, *The Lancet Planet Health* 2021

Votación en Zoom

¿Cuál cree que es la enfermedad más estudiada en relación con eventos climáticos extremos?

a) Malaria
b) Cólera
c) Enfermedades diarreicas
d) Dengue

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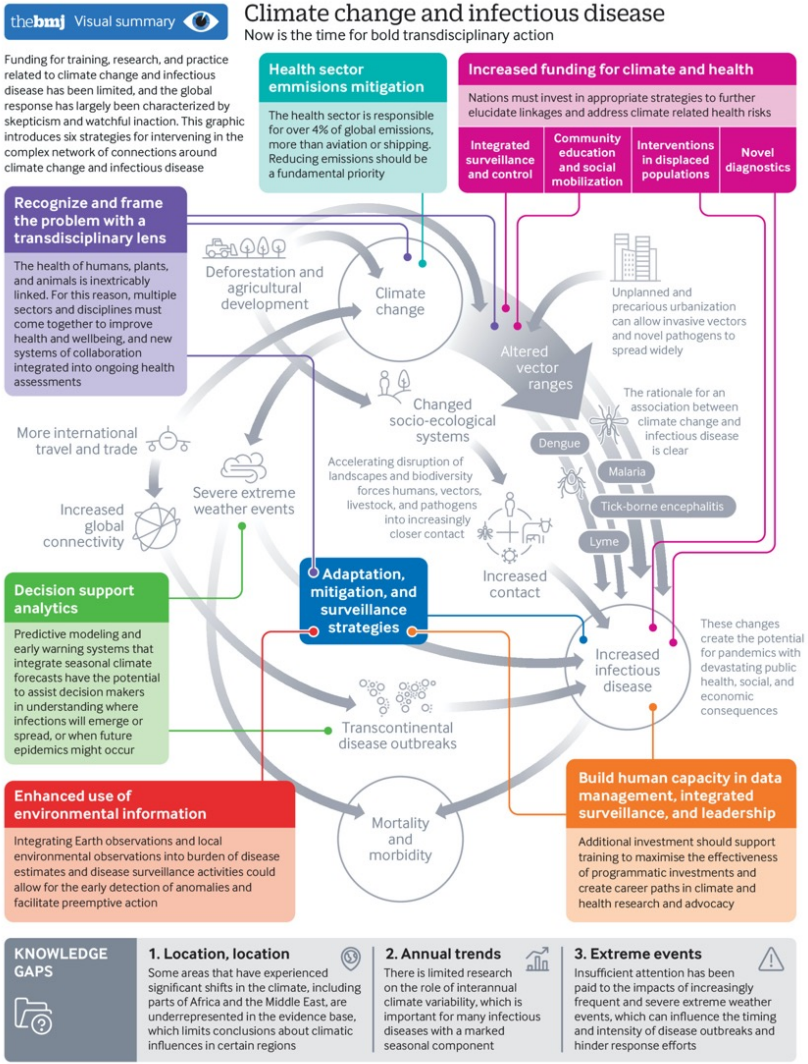
Brotes de enfermedades infecciosas después de eventos climáticos extremos

Tilly Alcayna *et al.*, One Earth 2022

Disease	Heavy Rainfall	Tropical Cyclones	Drought	Flooding	Heatwaves	Multiple Events	Total
Cholera	**Low evidence** (N=1) Outbreak [53]	**High agreement, high evidence** (N=7) Outbreak [51, 54–59]	**High agreement, low evidence** (N=2) Outbreak [46,52]	**Medium agreement, medium evidence** (N=4) Outbreak [41,60] [50] noted the floods did not seed the outbreak; outbreaks began during only one out of every 14 floods [46]	**Low evidence** (N=1) Outbreak [30]	**High agreement, medium evidence** (N=3) Including drought followed by heavy rains [49] and two systematic reviews investigating water-related disasters[48, 61]	N=18
Diarrheal Diseases (Non-cholera)	**High agreement, high evidence** (N=5) Outbreak:[32,34,35] But dynamics of dry period followed by rainfall vs wet period followed by rainfall are important[33] and on type of rainfall event[62]	**High agreement, high evidence** (N=10) Outbreak:[44,68,69,71,73-75,80,84,,85]	**High agreement, low evidence** (N=2) Outbreak [63,64]	High agreement, high evidence (N=20) Outbreak [36-39, 62, 66, 70, 71, 76-79, 81-83, 86, 87, 94, 104, 105 [62] found that the relationship between flooding and diarrhea risk appeared to vary by pathogen	**Low evidence** (N=1) Increasing heatwaves days were linked with increased emergency department visits for childhood diarrhea[79]	**High agreement, high evidence** (N=5) [106]looked at EM-DAT data in general for a 'disaster' period [47,87,72,88]were all reviews which covered multiple hazards	N= 43
Malaria	**Low evidence** (N=1) Outbreak[91]	**Low evidence** (N=1) No outbreak[90]	**Low agreement, low evidence** (N=1) [64] found that evidence of associations was mixed	**Medium agreement, medium evidence** (N=8) Outbreaks [38,92, 93, 95] A scoping review reports overall positive linkages between floods and outbreaks [94] No outbreak [76,89]	*No papers retrieved*	*No papers retrieved*	N = 11
Dengue	**High agreement, medium evidence** (N=3) Increased outbreak risk[31,42,43]	**Low agreement, high evidence** (N=5) Outbreak[96,73, 103] No outbreak[90,100]	**High agreement, medium evidence** (N=4) Increased outbreak risk[42,43,64,99]	**Medium agreement, low evidence** (N=2) Unclear impacts of flooding on outbreaks Mixed findings, including decreases and increases[65] Decreased risk (possibly due to vector control activities)[78]	**Medium agreement, medium evidence** (N=3) Outbreak [31,97] No outbreak[29]	**Low evidence** (N = 1) [98]investigate heavy rainfall, but defined 'flood' periods caveating that this did not necessarily correspond with actual flood waters	N = 18
Total	N=10	N=23	N= 9	N= 34	N=5	N= 9	90

Fortaleciendo la respuesta global al cambio climático y a la amenaza de las enfermedades infecciosas

Hess J, Boodram LG, Paz S, Stewart-Ibarra AM, Wasserheit JN, Lowe R, BMJ 2020



De observaciones globales a intervenciones locales

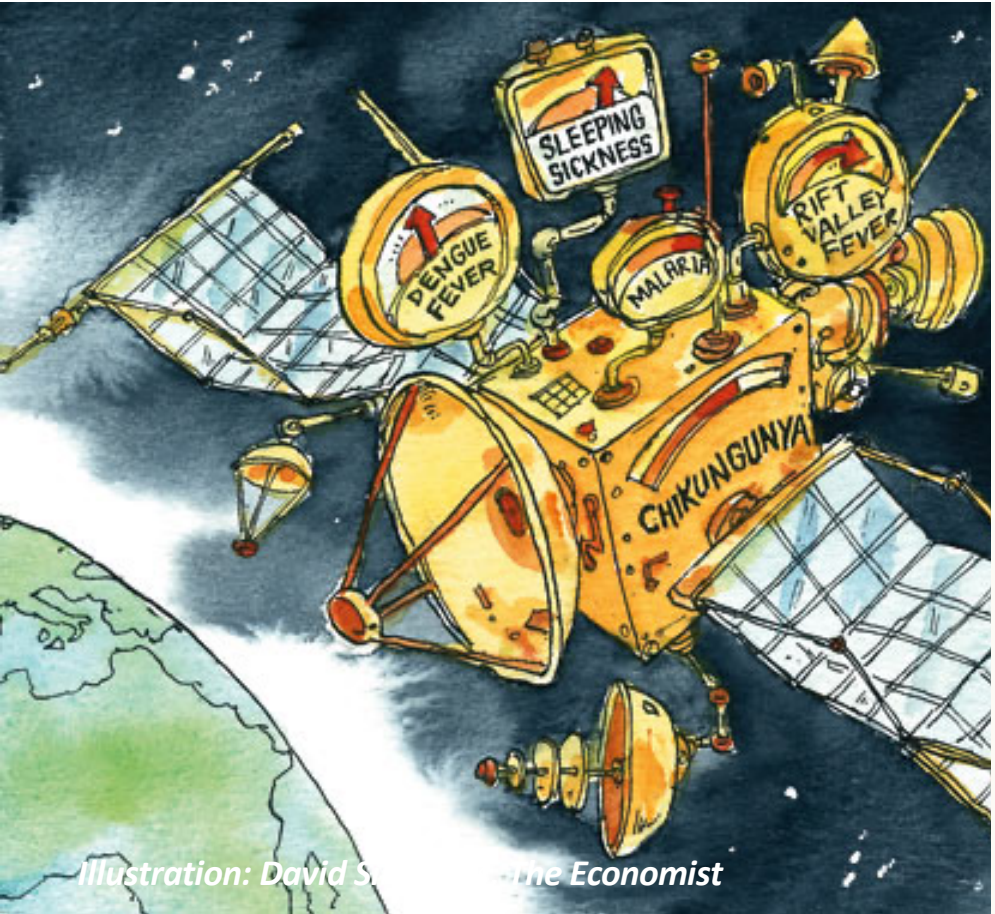
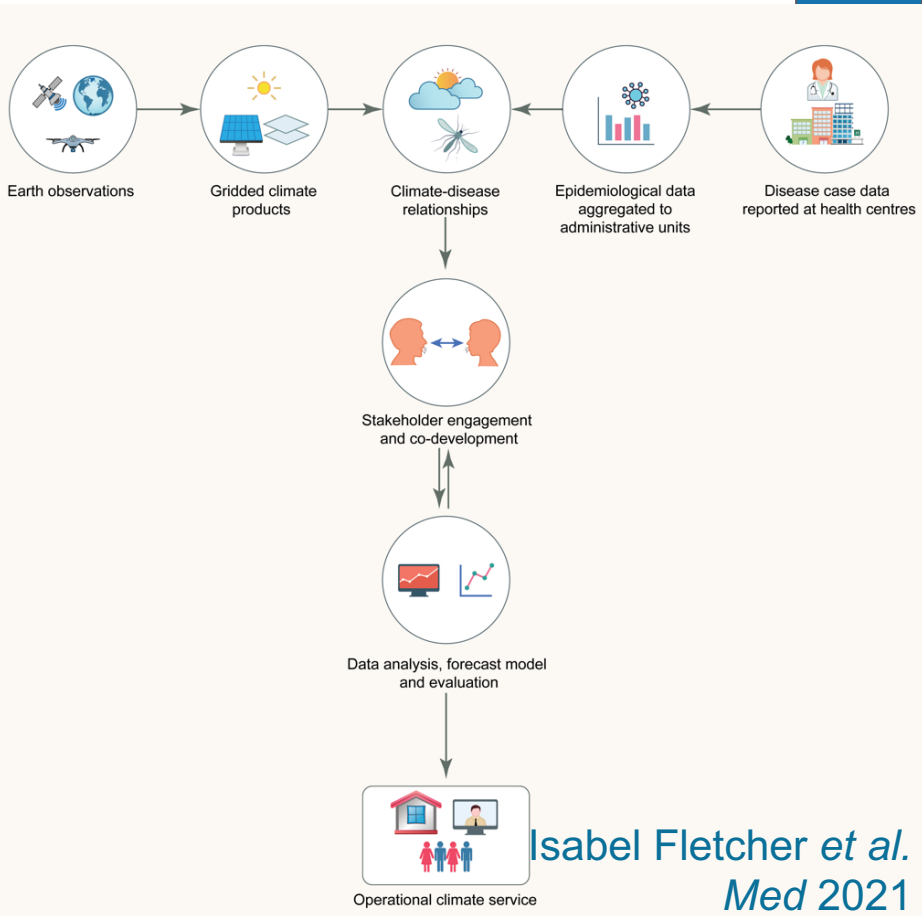


Illustration: David S… …he Economist



Isabel Fletcher *et al.* *Med* 2021

Monitoreo de las condiciones climáticas adecuadas para la transmisión de enfermedades sensibles al clima

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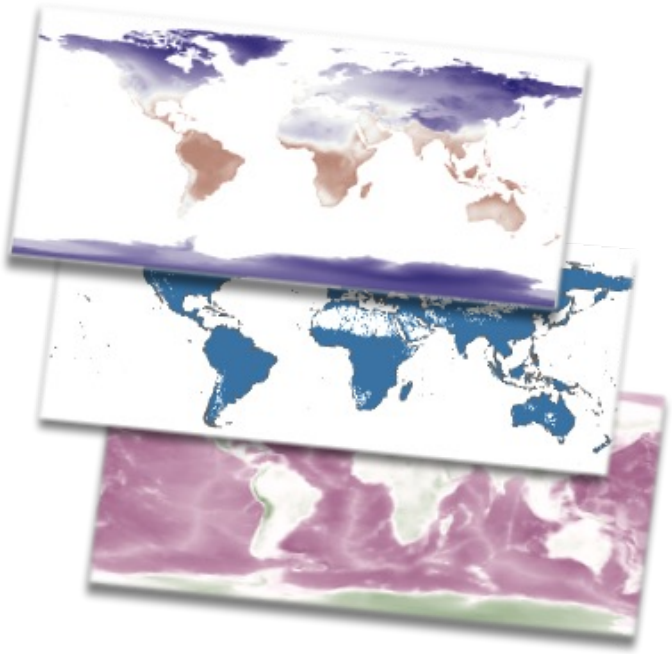
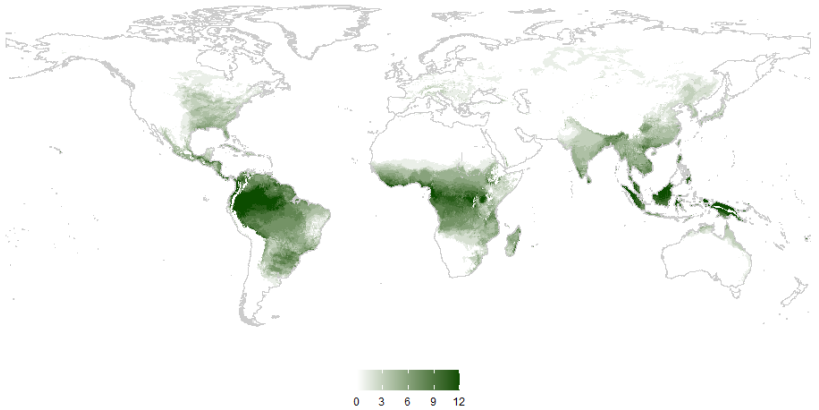
Combinación de capas para determinar condiciones favorables





Número de meses favorables para la transmission de malarria (enero, 2019)

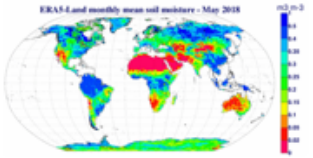
Datos climáticos: ERA5-Land

- Datos globales que contienen variables climáticas (p.ej., temperatura, precipitación y viento)
- Escala espacial: 0,1° x 0,1° (~ 9 km)
- Disponible por hora o mensual desde 1950 hasta el presente
- Acceso a través de Copernicus (el acceso es gratuito pero requiere registro)

ERA5-Land monthly averaged data from 1950 to present

Overview | Download data | Quality assessment | Documentation

ERA5-Land is a reanalysis dataset providing a consistent view of the evolution of land variables over several decades at an enhanced resolution compared to ERA5. ERA5-Land has been produced by replaying the land component of the ECMWF ERA5 climate reanalysis. Reanalysis combines model data with observations from across the world into a globally complete and consistent dataset using the laws of physics. Reanalysis produces data that goes several decades back in time, providing an accurate description of the climate of the past.



ERA5-Land provides a consistent view of the water and energy cycles at surface level during several decades. It contains a detailed record from 1950 onwards, with a temporal resolution of 1 hour. The native spatial resolution of the ERA5-Land reanalysis dataset is 9km on a reduced Gaussian grid (TCo1279). The data in the CDS has been regridded to a regular lat-lon grid of 0.1x0.1 degrees.

The data presented here is a post-processed subset of the full ERA5-Land dataset. Monthly-mean averages have been pre-calculated to facilitate many applications requiring easy and fast access to the data, when sub-monthly fields are not required.

Hourly fields can be found in the ERA5-Land hourly fields CDS page. Documentation can be found in the online ERA5-Land documentation.

Earth Syst. Sci. Data, 13, 4349–4383, 2021
https://doi.org/10.5194/essd-13-4349-2021

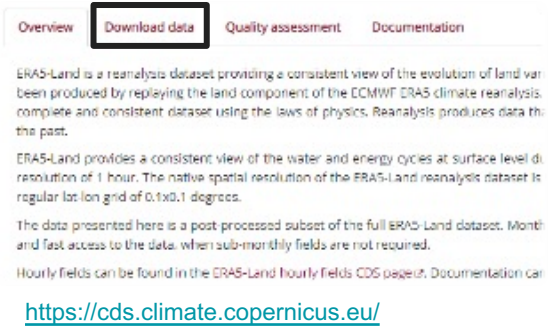
Open Access Earth System Science Data

ERA5-Land: a state-of-the-art global reanalysis dataset for land applications

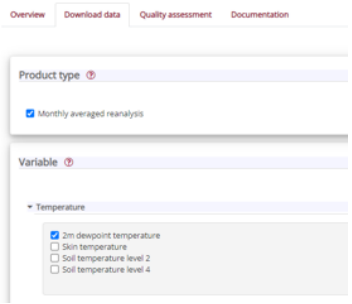
Joaquín Muñoz-Sabater[1], Emanuel Dutra[2,3], Anna Agustí-Panareda[1], Clément Albergel[4,5], Gabriele Arduini[1], Gianpaolo Balsamo[1], Souhail Boussetta[1], Margarita Choulga[1], Shaun Harrigan[1], Hans Hersbach[1], Brecht Martens[6], Diego G. Miralles[6], María Piles[7], Nemesio J. Rodríguez-Fernández[8], Ervin Zsoter[1], Carlo Buontempo[1], and Jean-Noël Thépaut[1]

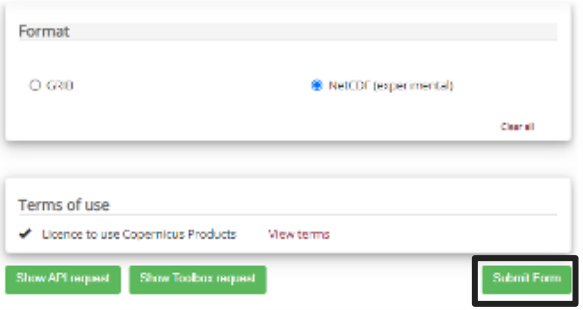
Datos climáticos: ERA5-Land

Data request



https://cds.climate.copernicus.eu/





Datos climáticos: ERA5-Land

Data processing

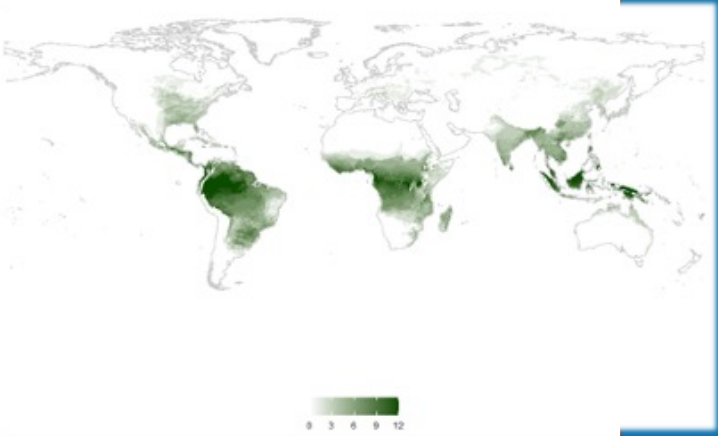
Temperatura en enero 2019

Precipitación total en enero 2019

Temperatura de rocío en enero 2019

CDO

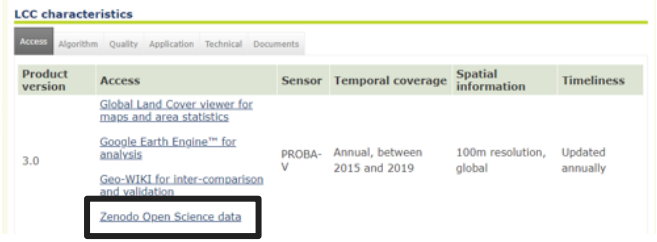
- *Transformar unidades,*
- *Calcular condiciones climáticas*
- *Calcular de media anual*



Número de meses con condiciones climáticas apropiadas para transmission de malaria (enero 2019)

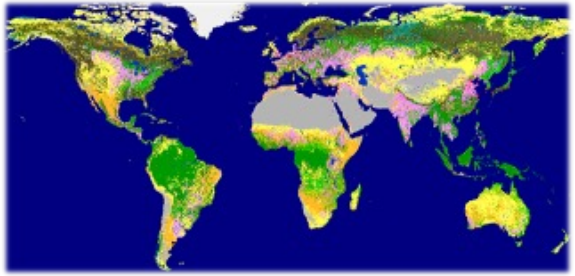
Datos del medio ambiente: Copernicus Global Land Service

Data request



Datos del medio ambiente: Copernicus Global Land Service

Data processing



Copernicus Global Land Service (2019)

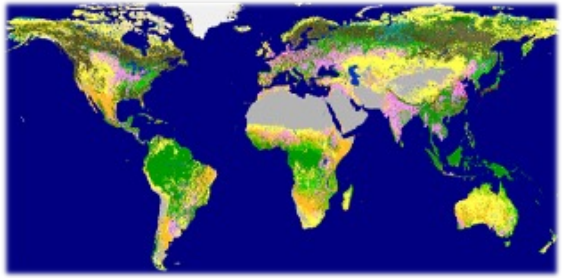
Reclasificación

Lancet Countdown: seguimiento de las condiciones climáticas favorables para las transmisión de malaria

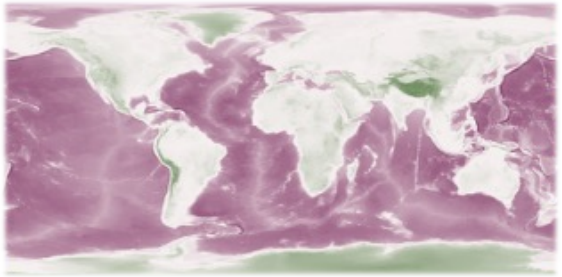
Martin Lotto Batista & Lowe (in prep)

ERA5-Land (Temperatura en enero 2019)

Copernicus Global Land Service (2019)



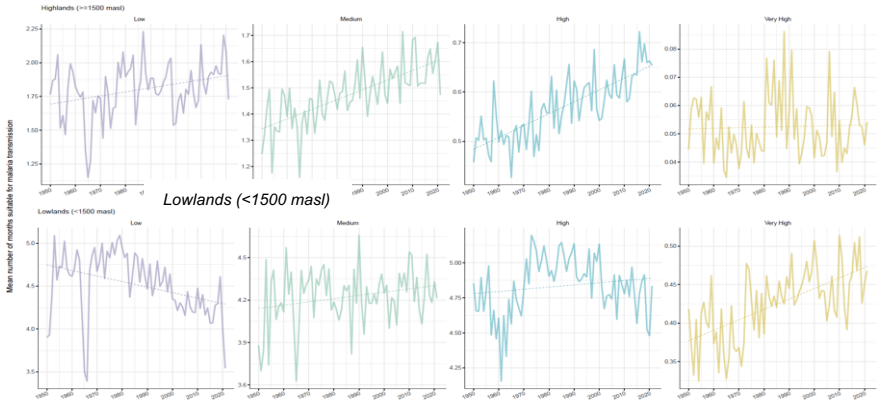
Elevación JISAO



Percentage change between 1950 and 2019

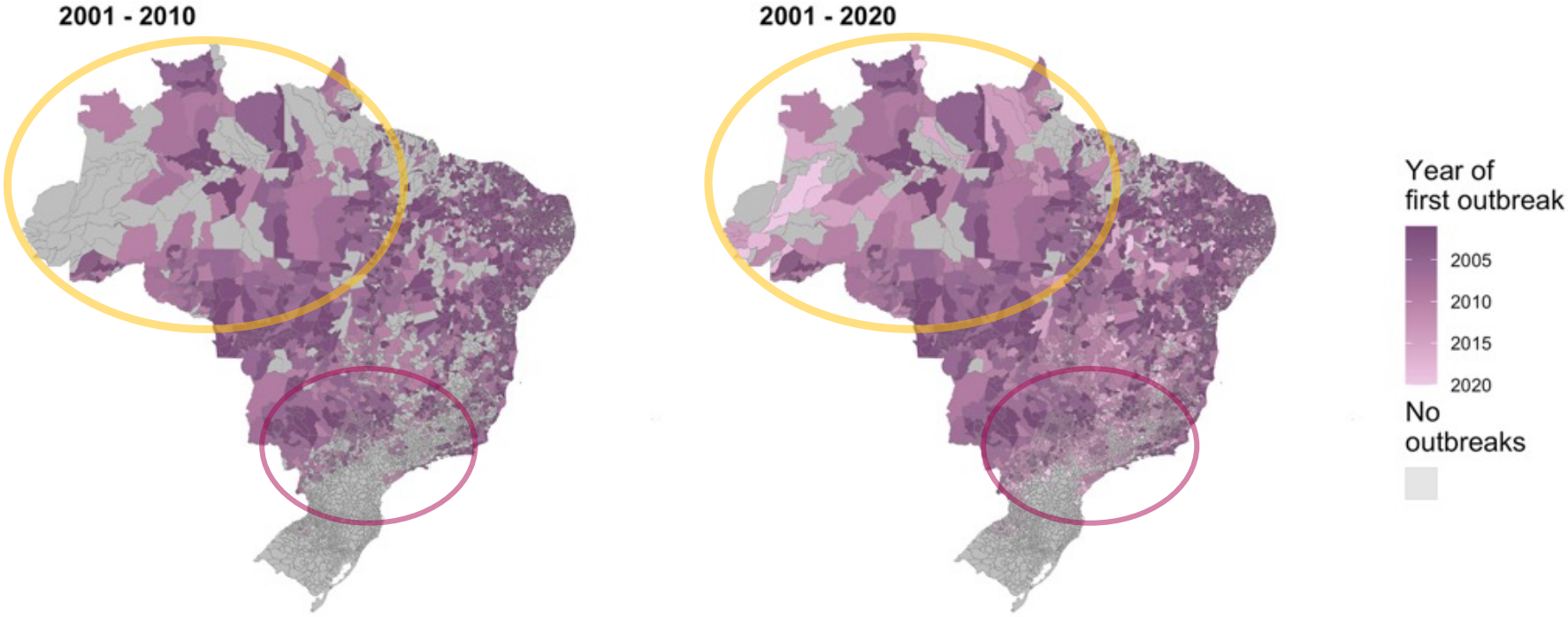
Highlands (≥1500 masl)

Lowlands (<1500 masl)



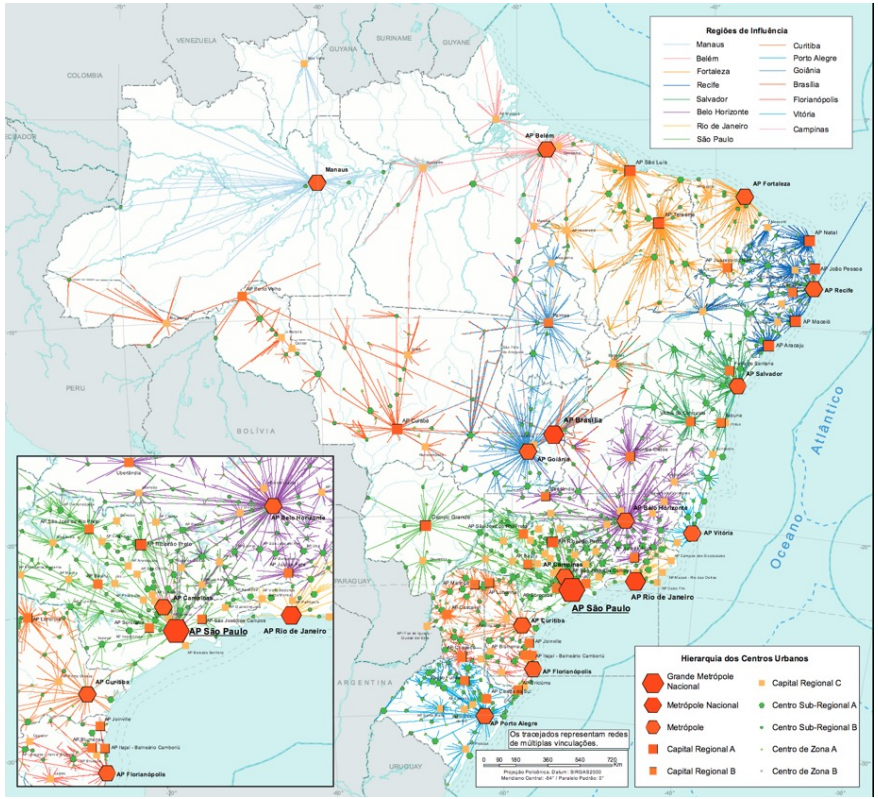
Trend by Human Development Index (HDI)

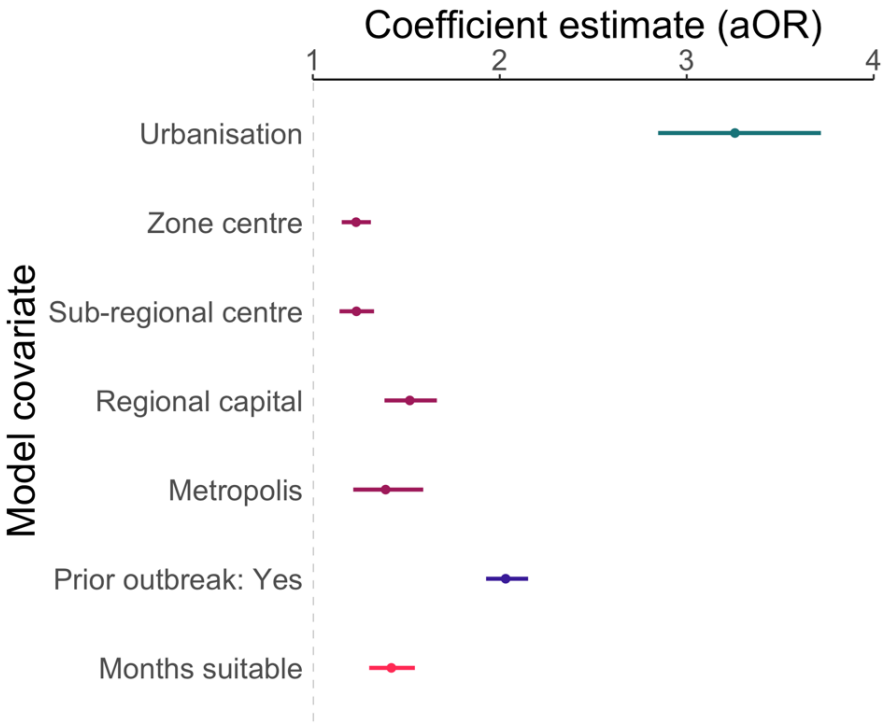
Expansión del dengue en el Brasil del siglo XXI



Sophie Lee *et al.*, *PLOS Neglected Tropical Diseases* 2021

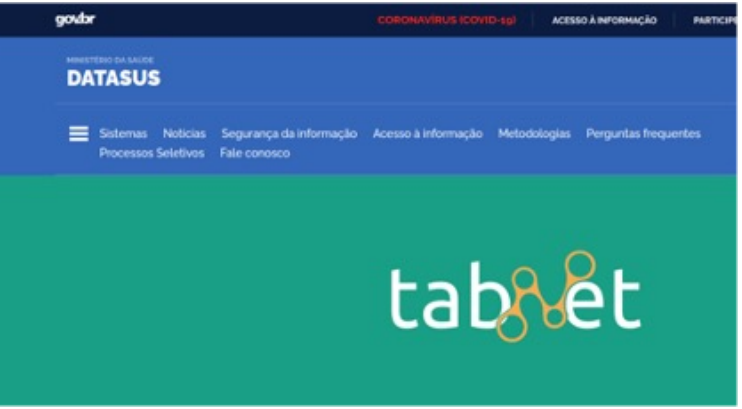
Clima, urbanización y conectividad

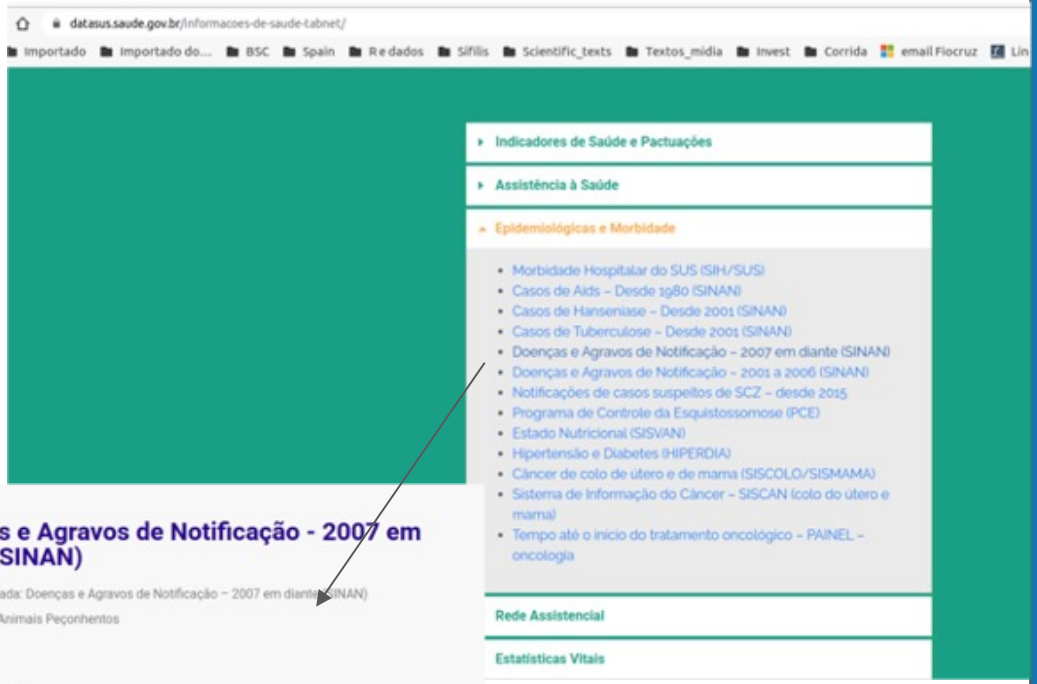




Sophie Lee *et al.*, *PLOS Neglected Tropical Diseases* 2021

¿Qué datos necesitamos para comprender el impacto del clima en las enfermedades infecciosas?





Doenças e Agravos de Notificação - 2007 em diante (SINAN)

Opção selecionada: Doenças e Agravos de Notificação – 2007 em diante (SINAN)

- ○Acidente por Animais Peçonhentos
- ○Botulismo
- ○Cólera
- ○Coqueluche
- ○Dengue até 2013
- ○Dengue de 2014 em diante
- ○Difteria
- ○Doença de Chagas Aguda
- ○Doenças Exantemáticas
- ○Esquistossomose
- ○Febre Amarela
- ○Febre de Chikungunya
- ○Febre Maculosa
- ○Febre Tifóide
- ○Hantavirose
- ○Hepatite
- ○Influenza Pandêmica

- ○Dengue até 2013
- ◉Dengue de 2014 em diante
- ○Difteria
- ○Doença de Chagas Aguda
- ○Doenças Exantemáticas
- ○Esquistossomose
- ○Febre Amarela
- ○Febre de Chikungunya
- ○Febre Maculosa
- ○Febre Tifóide
- ○Hantavirose
- ○Hepatite
- ○Influenza Pandêmica
- ○Intoxicação Exógena
- ○Leishmaniose Visceral
- ○Leishmaniose Tegumentar Americana

Selecione a opção ou clique no mapa

- Brasil por Região, UF e Município
- Acre
- Alagoas
- Amazonas
- Amapá
- Bahia
- Ceará
- Distrito Federal
- Espirito Santo
- Goiás
- Maranhão
- Mato Grosso
- Mato Grosso do Sul
- Minas Gerais
- Pará
- Paraíba
- Paraná
- Pernambuco
- Piauí

Selecione a opção ou clique no mapa

DENGUE - NOTIFICAÇÕES REGISTRADAS NO SISTEMA DE INFORMAÇÃO DE AGRAVOS DE NOTIFICAÇÃO - BRASIL

Linha	Coluna	Conteúdo
Ano 1° Sintoma(s)	Capital de notificação	Casos Prováveis
Mês 1° Sintoma(s)	Região de residência	
Semana epidem. 1° Sintomas(s)	UF de residência	
Ano notificação	Capital de residência	

PERÍODOS DISPONÍVEIS

- 2021
- 2020
- 2019
- 2018
- 2017

SELEÇÕES DISPONÍVEIS

- ⊞ Ano 1° Sintoma(s)
- ⊞ Mês 1° Sintoma(s)
- ⊞ Semana epidem. 1° Sintomas(s)
- ⊞ Ano notificação
- ⊞ Mês notificação
- ⊞ Semana epidem. notificação
- ⊞ Ano epidem. notificação
- ⊞ Ano epidem. 1° Sintomas(s)
- ⊞ Região de notificação

- ⊞ Caso autóctone munic resid
- ⊞ Faixa Etária
- ⊞ Raça
- ⊞ Sexo
- ⊞ Class. Final
- ⊞ Criterio conf.
- ⊞ Evolução
- ⊞ Exame sorológico (IgM) Dengue
- ⊞ Exame sorologia Elisa
- ⊞ Exame isolamento viral
- ⊞ Exame de RT-PCR
- ⊞ Sorotipo
- ⊞ Exame de Histopatologia
- ⊞ Exame de Imunohistoquímica
- ⊞ Ocorreu hospitalização

☐Ordenar pelos valores da coluna ☐Exibir linhas zeradas

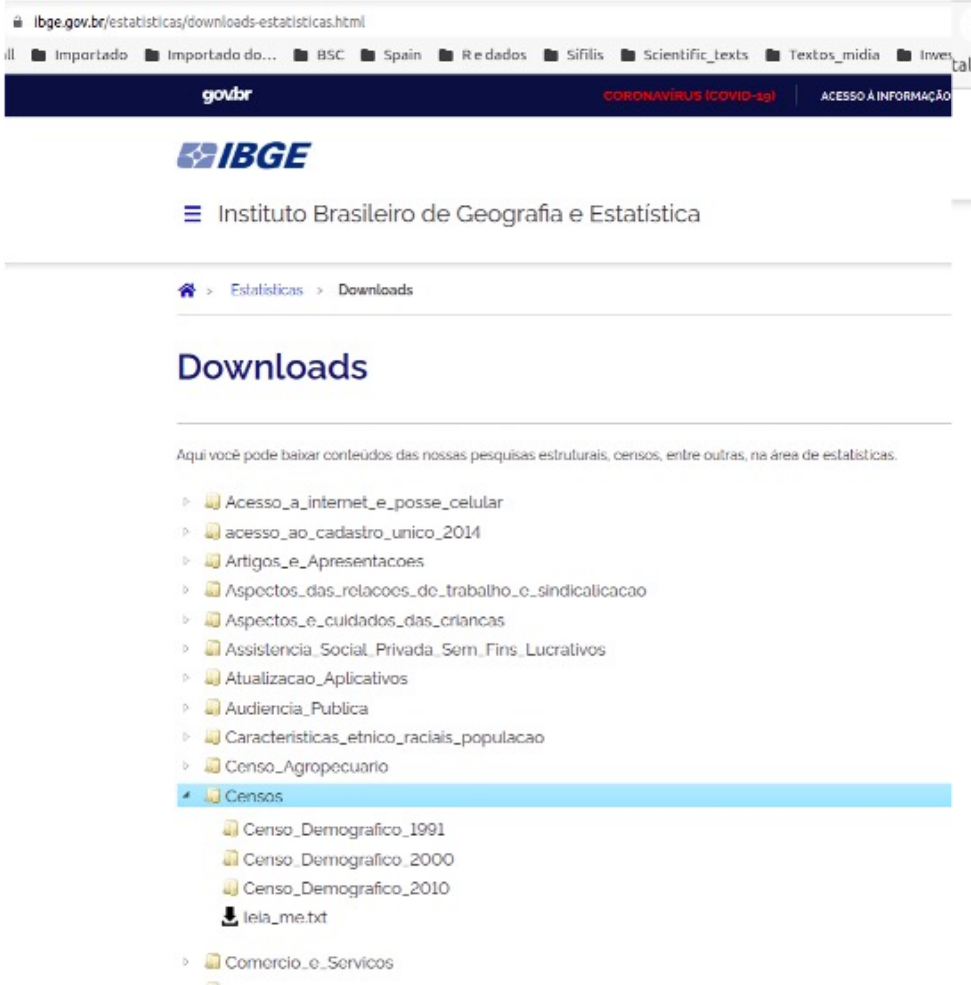
Formato ◉Tabela com bordas ○Texto pré formatado ○Colunas separadas por ";"

Mostra | Limpa

Fonte: Ministério da Saúde/SVS - Sistema de Informação de Agravos de Notificação - Sinan Net

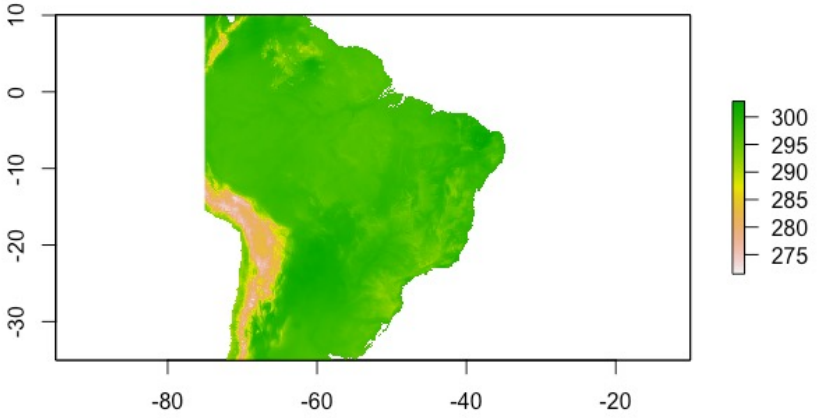
Notas:

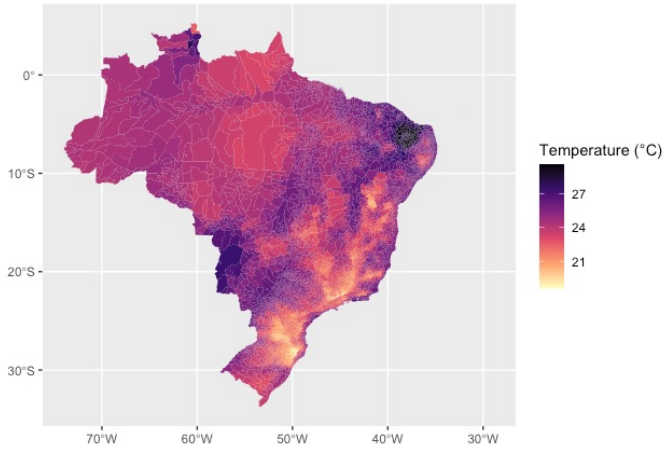
Datos del censo: población e indicadores socioeconómicos



Postprocesamiento de datos climáticos

- Los archivos en formato NetCDF pueden ser manipulados en R como archivos raster (en grillas) y con el paquete `raster`
- Antes del análsis, el raster debe ser convertido en un mapa de polígonos (áreas) usando un mapa de referencia importado con `sf`
- Para reducir los valores de las celdas a uno por polígono, usamos el paquete `exactextractr` para extraer distintas medidas de resumen
- Por ejemplo, este mapa fue convertido de Kelvin a °Celsius y luego se extrajo la media de temperatura por polígono usando el código `exact_extract(raster_temp, sf_brazil, 'mean')`





Transformación de la información climática para el uso en sistemas de alerta temprana

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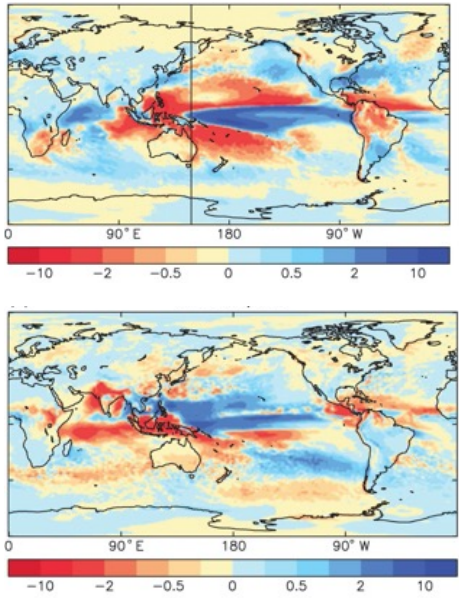
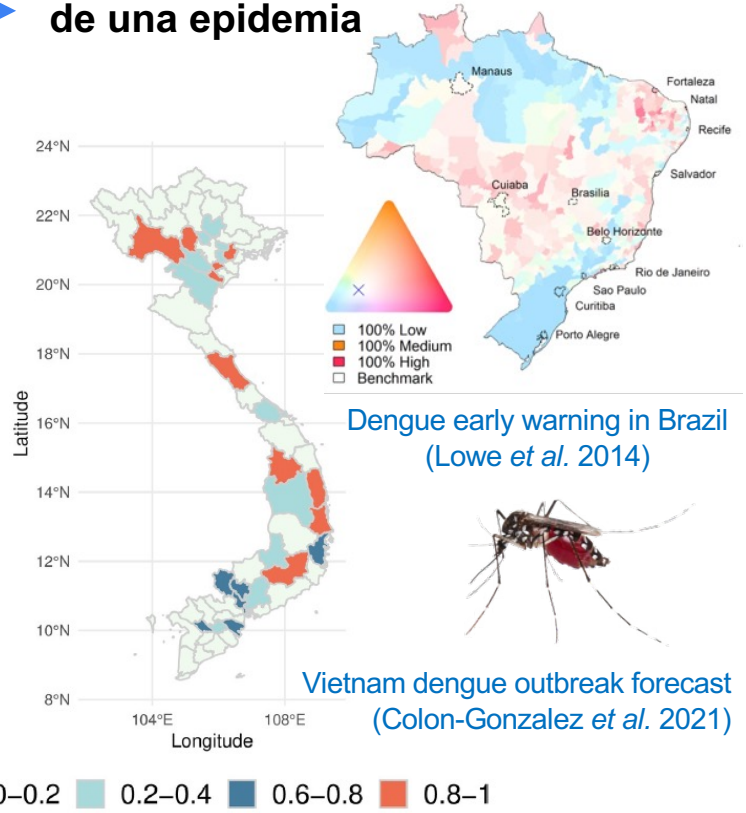
Sistemas de alerta para el dengue

Pronótico estacional del clima → **Modelo estadistico** → **Pronóstico de la probabilidad de una epidemia**



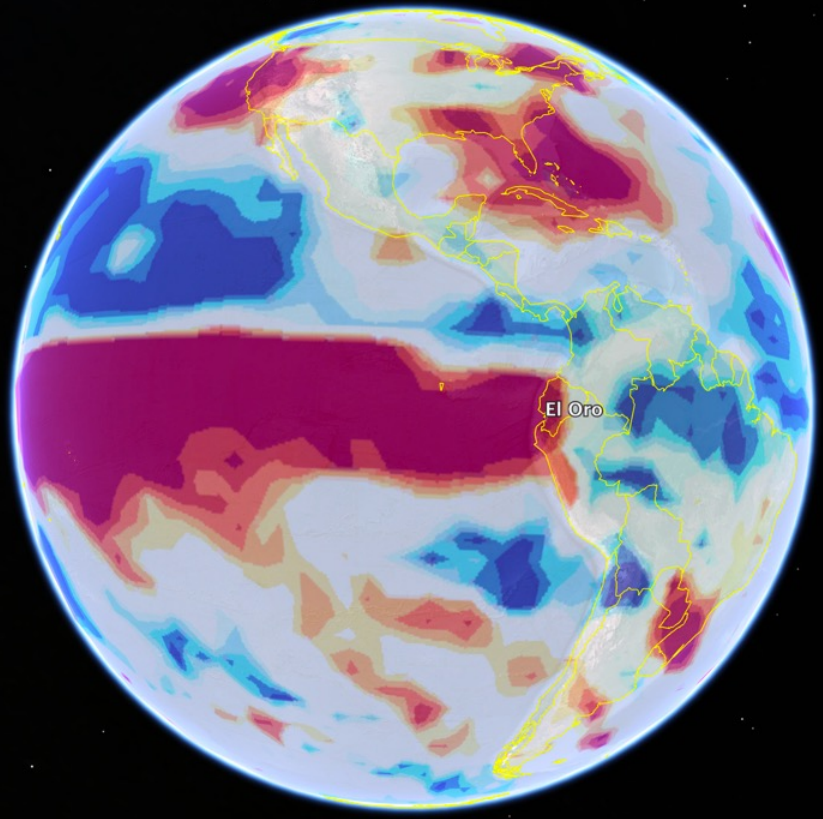
Met Office GloSea5
(MacLachlan *et al.* 2014)

usa asociaciones aprendidas de datos climático históricos para predecir el riesgo de una epidemia



Dengue early warning in Brazil
(Lowe *et al.* 2014)

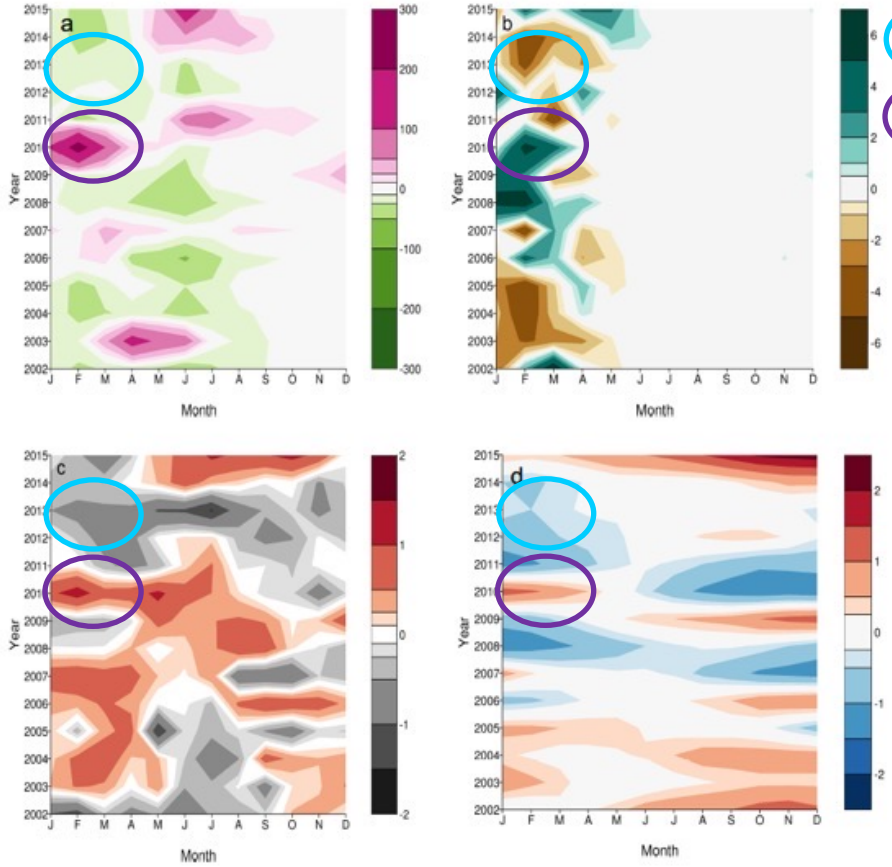
Vietnam dengue outbreak forecast
(Colon-Gonzalez *et al.* 2021)


El Oro

En 2016, la peor inundación desde 1998 ocurrió en Machala, Ecuador

Photo: Danny Krom

Dengue y clima: datos y modelos



más frío/seco que lo usual → menos dengue

más cálido/húmedo que lo usual → más dengue

$$y_t \sim \text{NegBin}(\mu_t, \kappa)$$

$$\log(\mu_t) = \log(p) + \log(r_t)$$

$$\log(r_t) = \alpha + f(\beta_{t'(t)}) + \Sigma\gamma_j x_{jt} + \delta_{T'(t)}$$

Dengue incidence rate

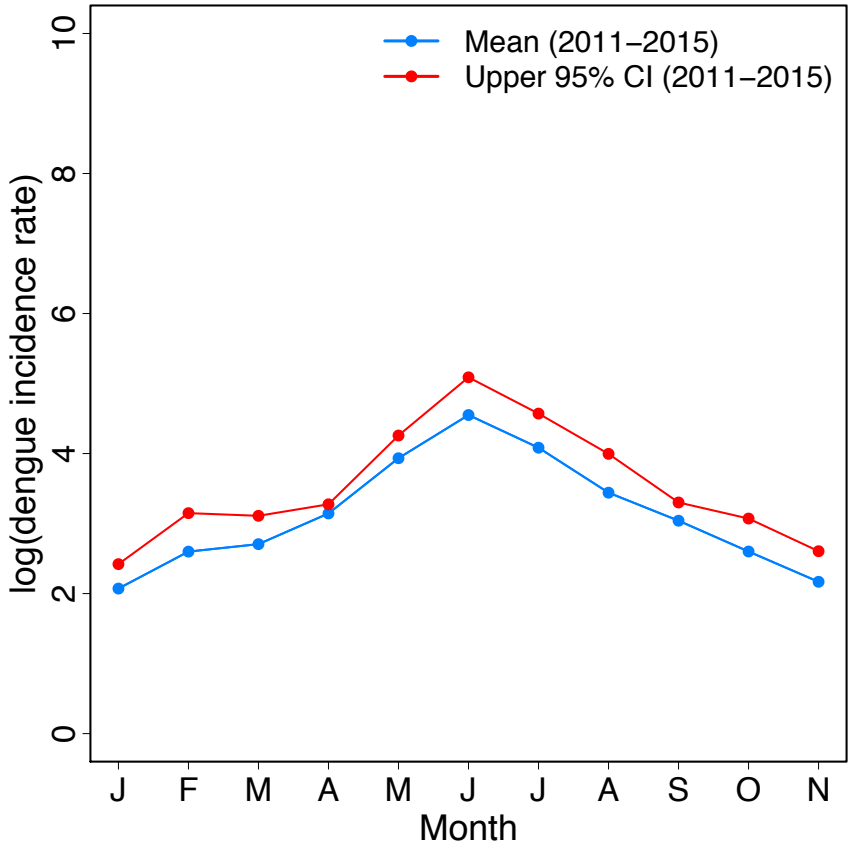
Annual cycle

Climate variables

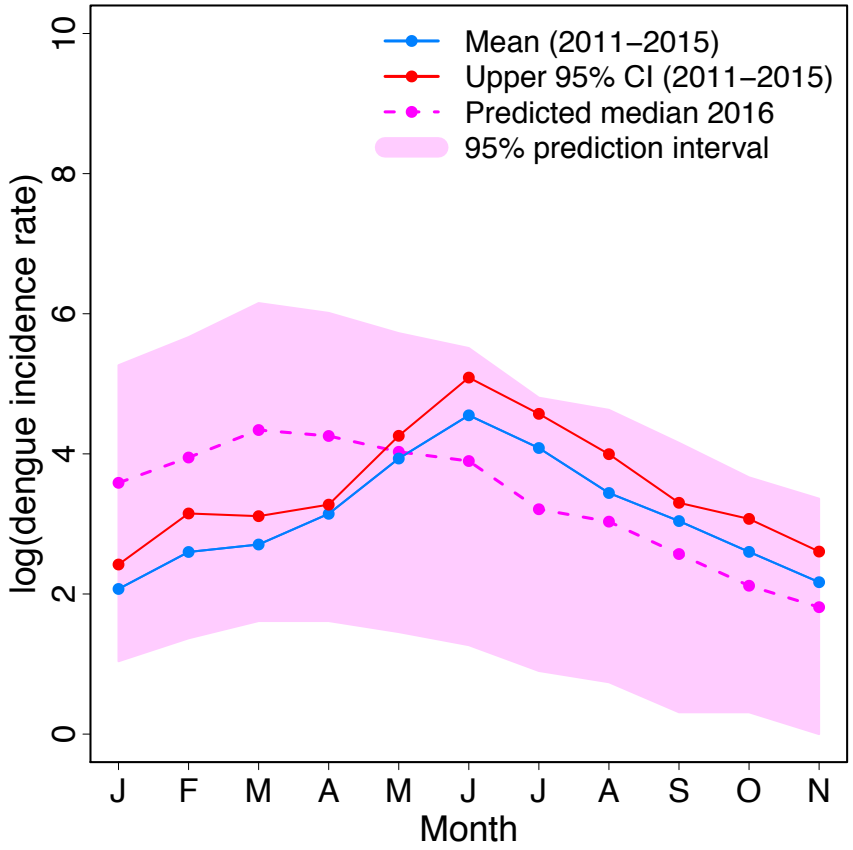
Inter-annual variation

Lowe *et al.*, 2017 *Lancet Planet Health*

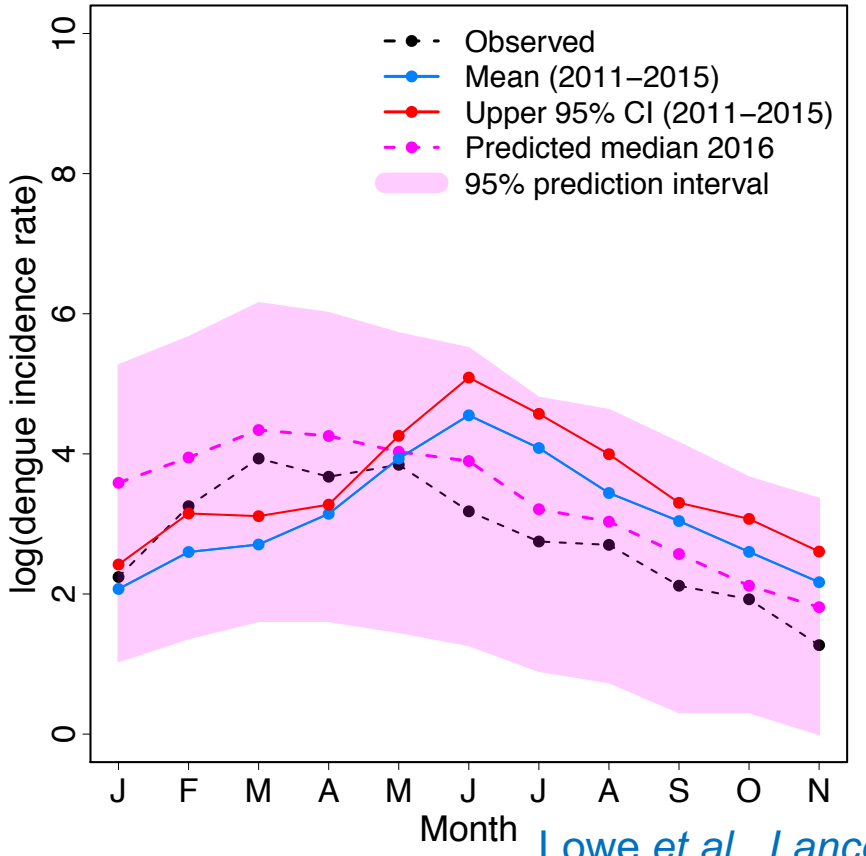
Práctica habitual de vigilancia: canal endémico



Predicción del dengue usando pronósticos climáticos



Pico temprano detectado usando pronóstico del clima

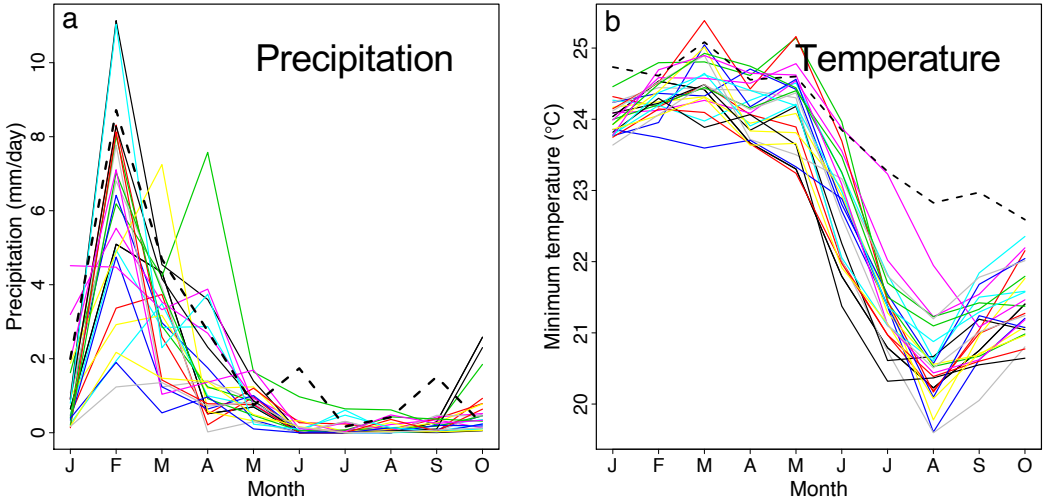


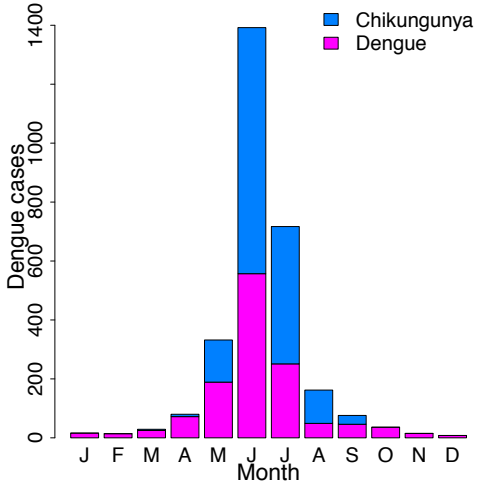
Lowe *et al.*, *Lancet Planet Health 2017*

Fuentes de previsibilidad

Sincronización

Magnitud





Pronóstico climático estacional

Vigilancia activa

Alineación de la estación meteorológica y los datos cuadriculados

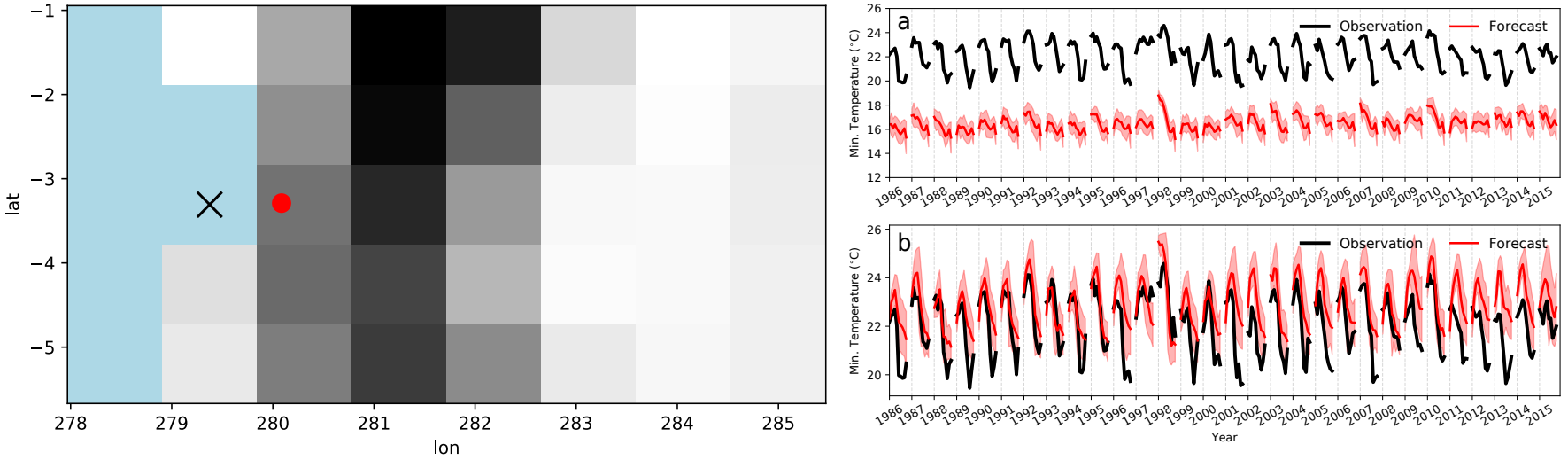


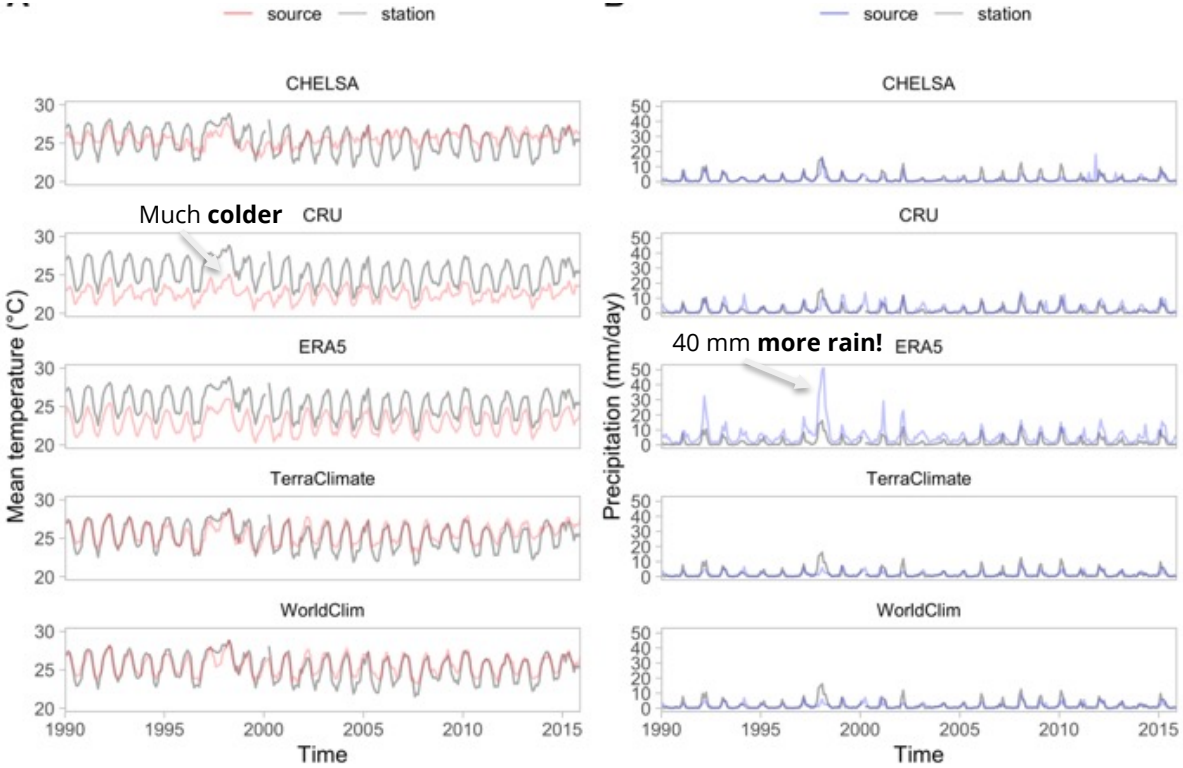
Figure S5: Topography in the Ecuador area as seen by the Climate Forecast System version 2 (CFSv2) model with 1 degree resolution (111 km at the Equator). Points marked as sea by the model land-sea mask are shaded in blue. The weather station is Machala is indicated with a red dot. The grid point chosen as being representative of the climate in Machala is marked with a black cross.

Varios productos de datos climáticos

Source	Description	Temporal resolution	Spatial resolution	Historical coverage	File format
CHELSA	Based on mechanistical statistical downscaling of global reanalysis data (ERA-Interim) to a high resolution	Monthly	1 km/0.008°	1980-2019	GeoTiff
CRU TS	Estimates are produced using angular-distance weighting interpolation of climate anomalies from extensive global weather station observations	Monthly	55 km/0.5°	1901-2020	ASCII, NetCDF
ERA5-Land	A reanalysis dataset based on climate models of land surfaces	Up to hourly	9 km/0.08°	1950-present	GRIB, NetCDF
TerraClimate	Uses climatically aided interpolation and combines climatological normals from WorldClim with time-varying anomalies from CRU TS v.4.0 and Japanese 55-year Reanalysis (JRA55)	Monthly	4 km/0.04°	1958-2019	NetCDF
WorldClim	Historical estimates of climate variables downscaled from CRU TS v.4.03 and using WorldClim 2.1 for bias correction	Monthly	21 km/0.2°	1960-2018	GeoTiff

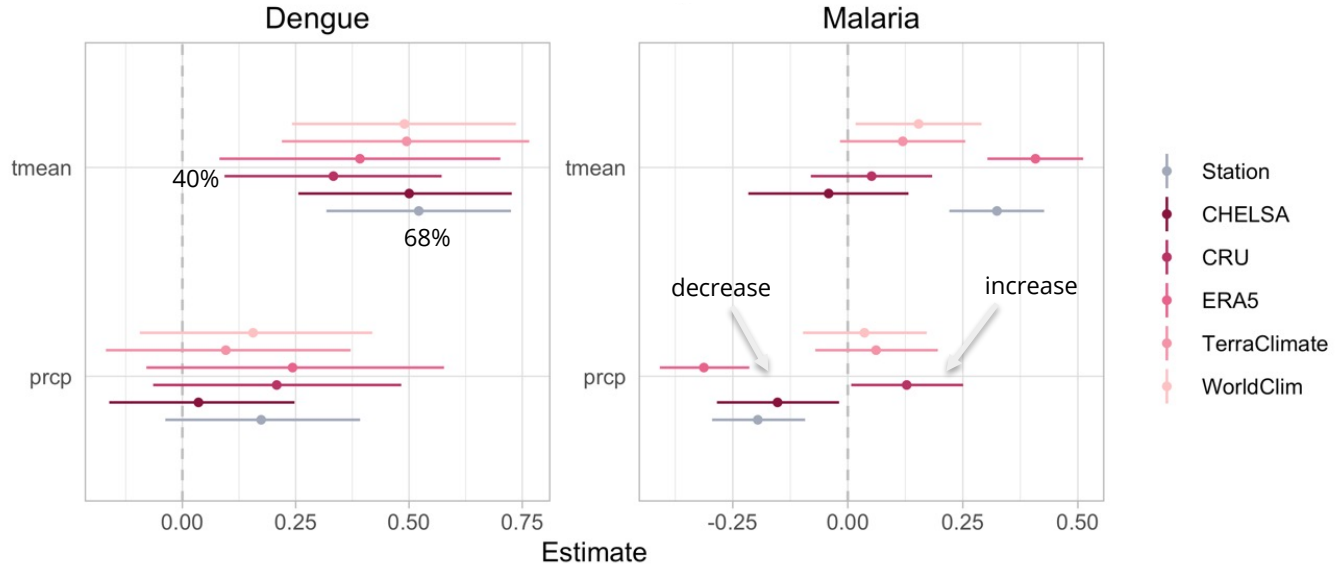
Isabel Fletcher *et al.*, *Med 2021*

Los datos climáticos para una misma ubicación varían según el producto



Monthly mean (A) temperature (°C) and (B) precipitation (mm/day) from the Granja Santa Ines meteorological station in Machala, Ecuador, and corresponding estimates from five global climate datasets

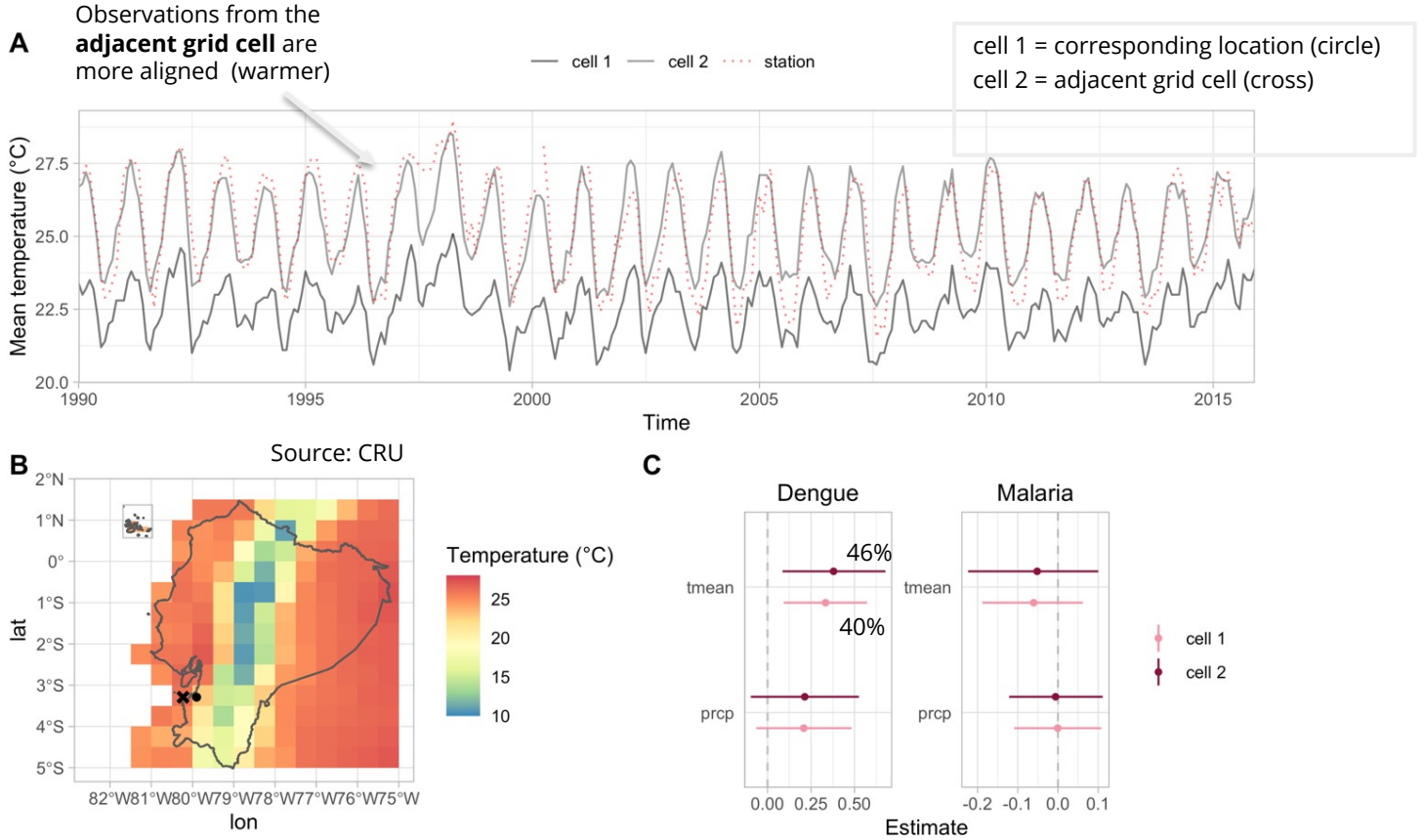
La elección del producto afecta la relación clima-enfermedad



Posterior mean and 95% credible intervals of mean temperature (tmean) and precipitation (prcp) variables, in temporal models of monthly (C) dengue cases 2002–2014 and (D) malaria cases 1990–2015 in Machala.

Isabel Fletcher *et al.*, *Med 2021*

La elección de la celda adecuada es importante para capturar las condiciones reales del terreno



Identificación de indicadores hidrometeorológicas para predecir el riesgo de brotes de enfermedades sensibles al clima

COLUMBIA
MAILMAN SCHOOL OF PUBLIC HEALTH
GLOBAL CONSORTIUM ON CLIMATE AND HEALTH EDUCATION

INSTITUTO INTERAMERICANO PARA LA INVESTIGACIÓN DEL CAMBIO GLOBAL
IAI

OPS
Organización Panamericana de la Salud
Organización Mundial de la Salud
Américas

Votación en Zoom

¿Cuál es el hábitat favorito de las larvas del mosquito *Aedes aegypti*?

a) Contenedores de agua artificiales
b) Huecos en el tronco de árbol
c) Piscinas

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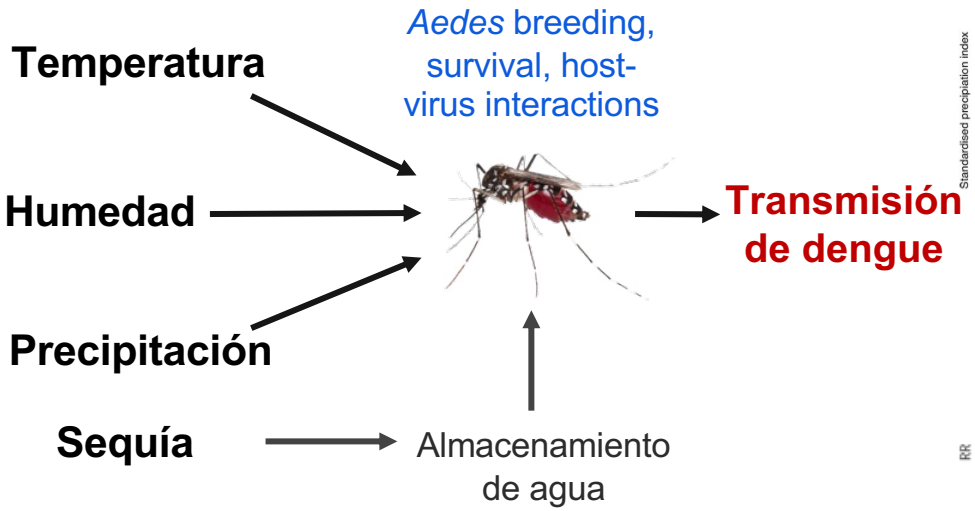
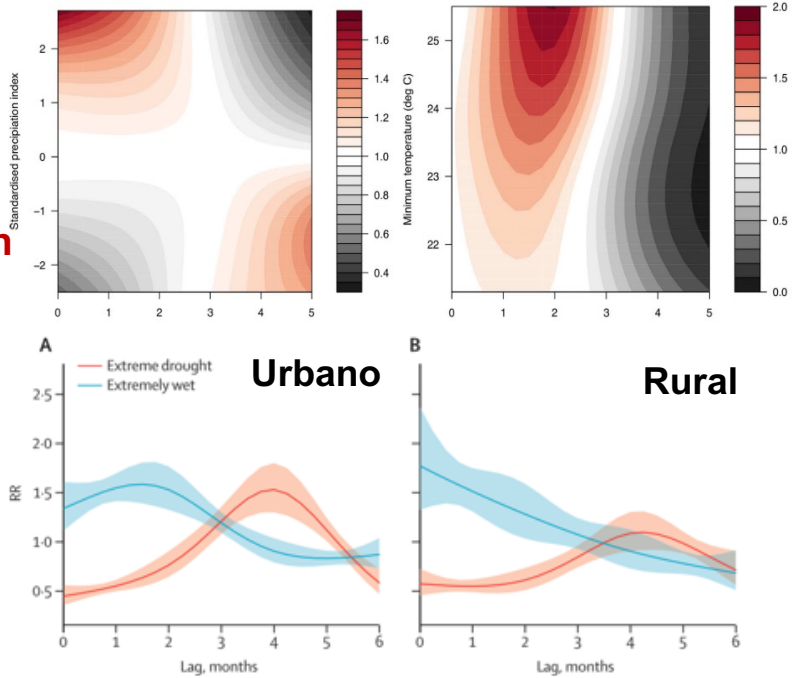
Américas

Los factores climáticos son importantes predictores del riesgo de dengue



Nonlinear and delayed impacts of temperature and precipitation on dengue risk in Barbados (Lowe *et al.* 2018)



Dengue risk at different time lags under extreme wet and drought in Brazil (Lowe *et al.* 2021)

Urbanización no planificada e infraestructura inadecuada

Los contenedores temporales de almacenamiento de agua se convierten en criaderos de mosquitos

Photo Credit: Christovam Barcellos, Fiocruz

Modelado de asociaciones retrasadas y no lineares

Incidencia anual de dengue por cada 100,000 habitantes

$$y_t \mid \mu_t \sim \text{NegBin}(\mu_t = p_{T'(t)}\,\rho_t,\ \kappa)$$

$$\log(\mu_t) = \log(p_{T'(t)}) + \log(\rho_t)$$

$$\log(\rho_t) = \alpha + \beta_{t'(t)} + \gamma_{T'(t)} + f.w(x_{1t}, l) + f.w(x_{2t}, l).$$

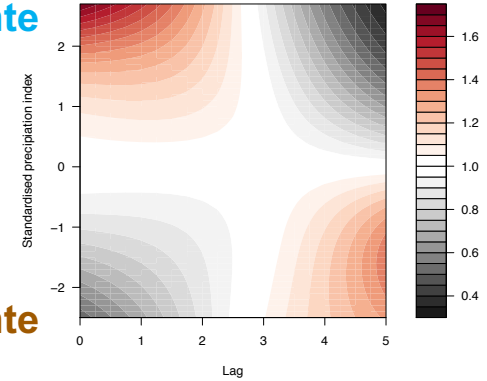
Ciclo annual

variación inter-anual

funciones de exposición-respuesta-tardía para SPI-6 y Tmín

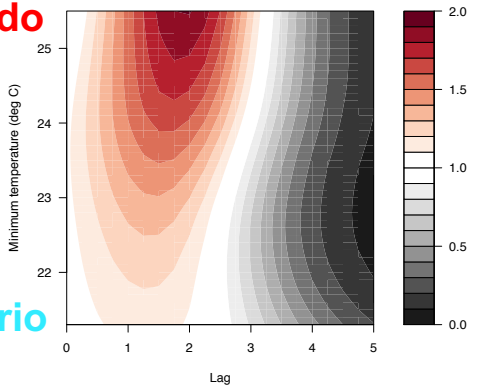
Excepcionalmente húmedo

Excepcionalmente seco



Mas calido

Mas frio

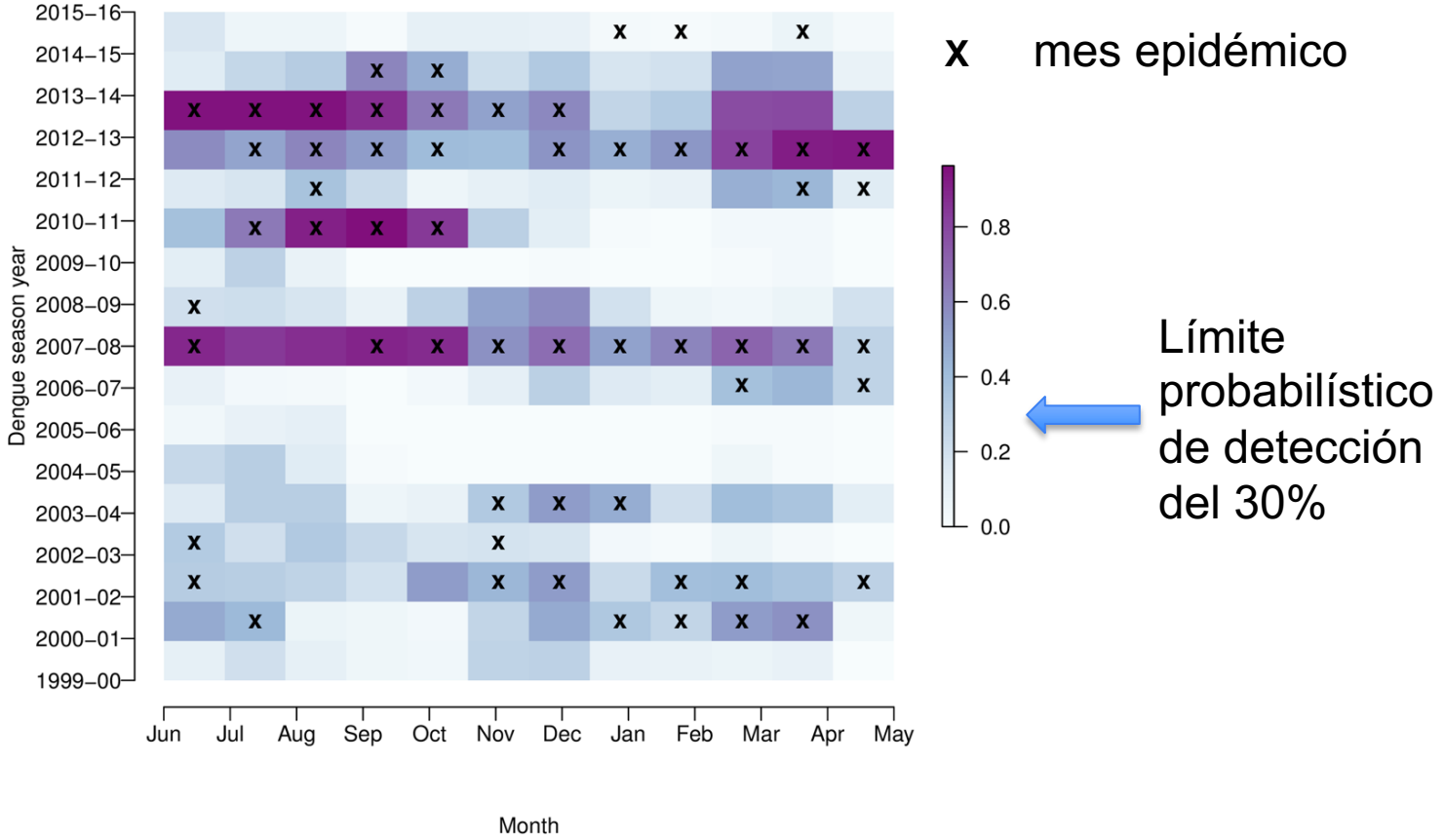


Short lag

Long lag

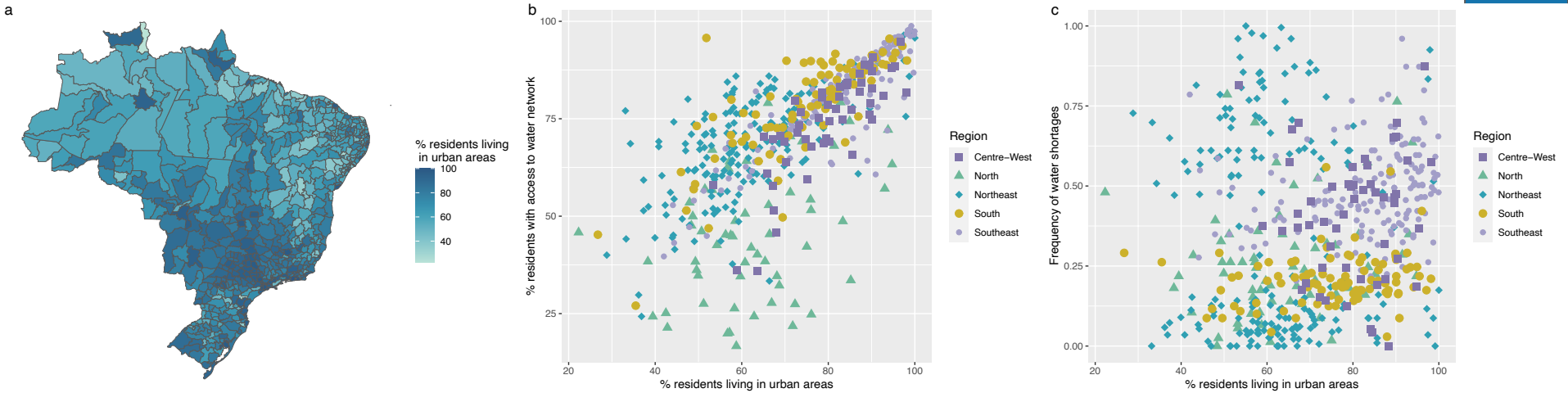
Lowe *et al.*, 2018, *PLOS Medicine*

Probabilidad de exceder el límite de epidemia

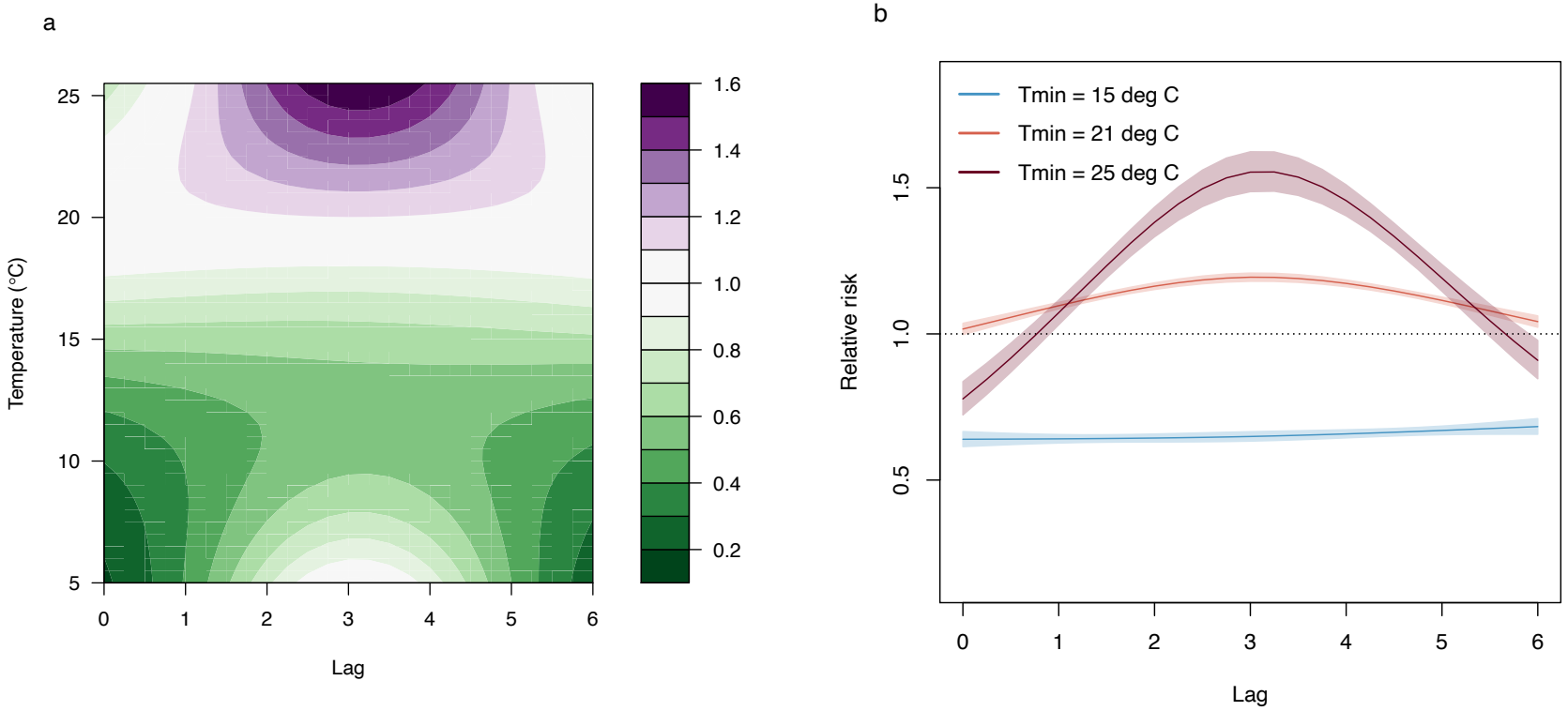


Dengue y sequías 2001–2019

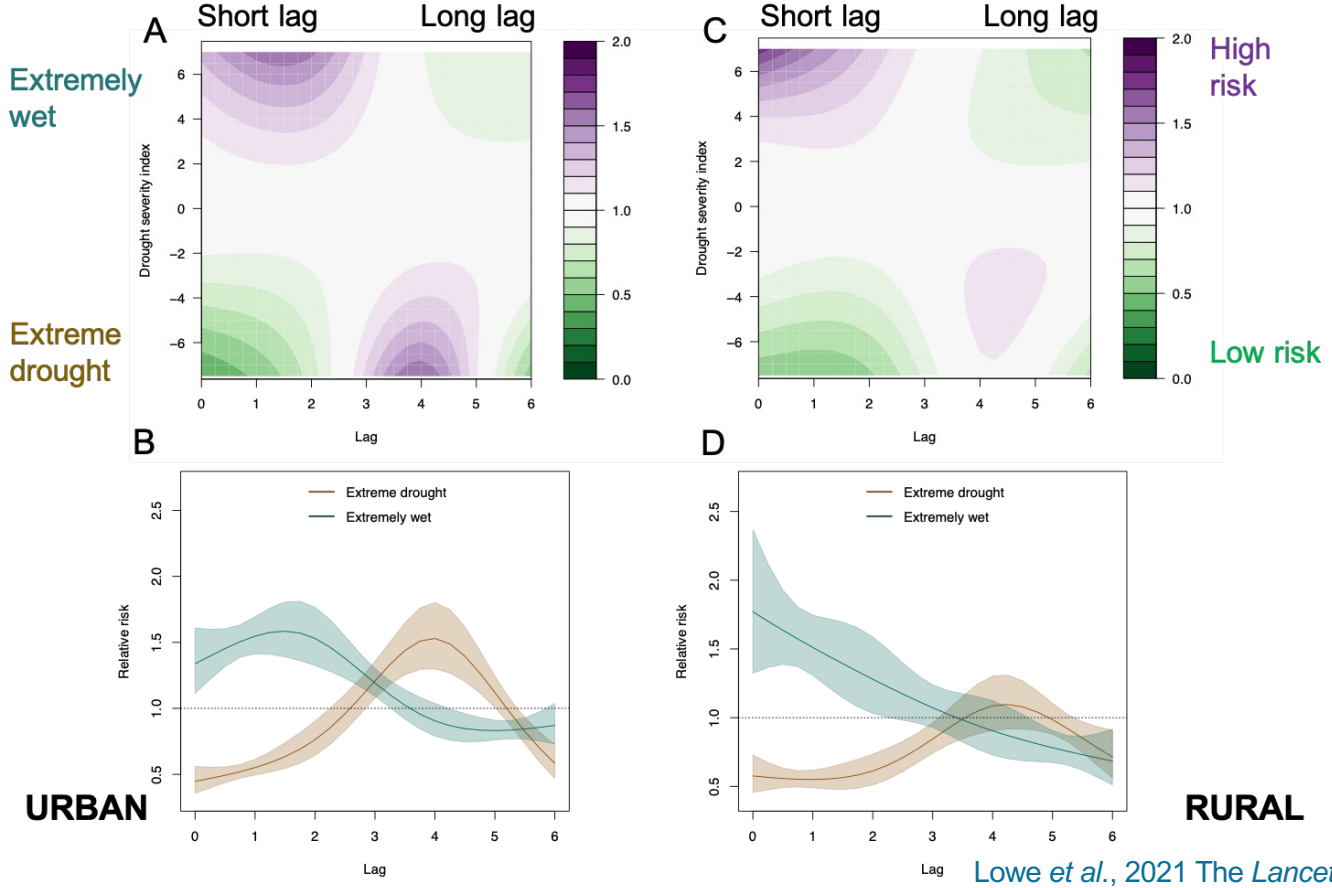
Nivel de urbanización, acceso a agua corriente y frecuencia de escasez de agua



Temperaturas más cálidas y riesgo de dengue

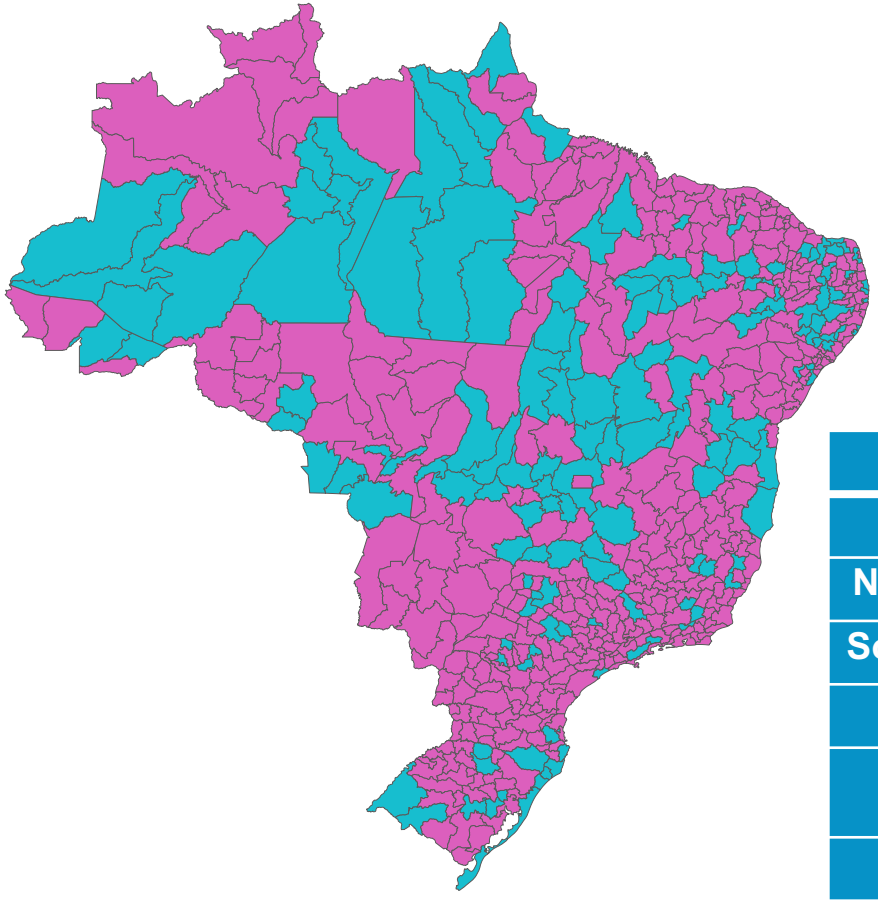


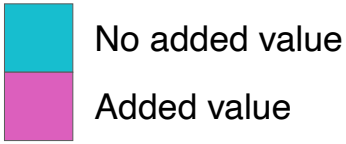
Extremos hidrometeorológicos a lo largo de un gradiente urbano



Lowe *et al.*, 2021 The *Lancet Planet Health*

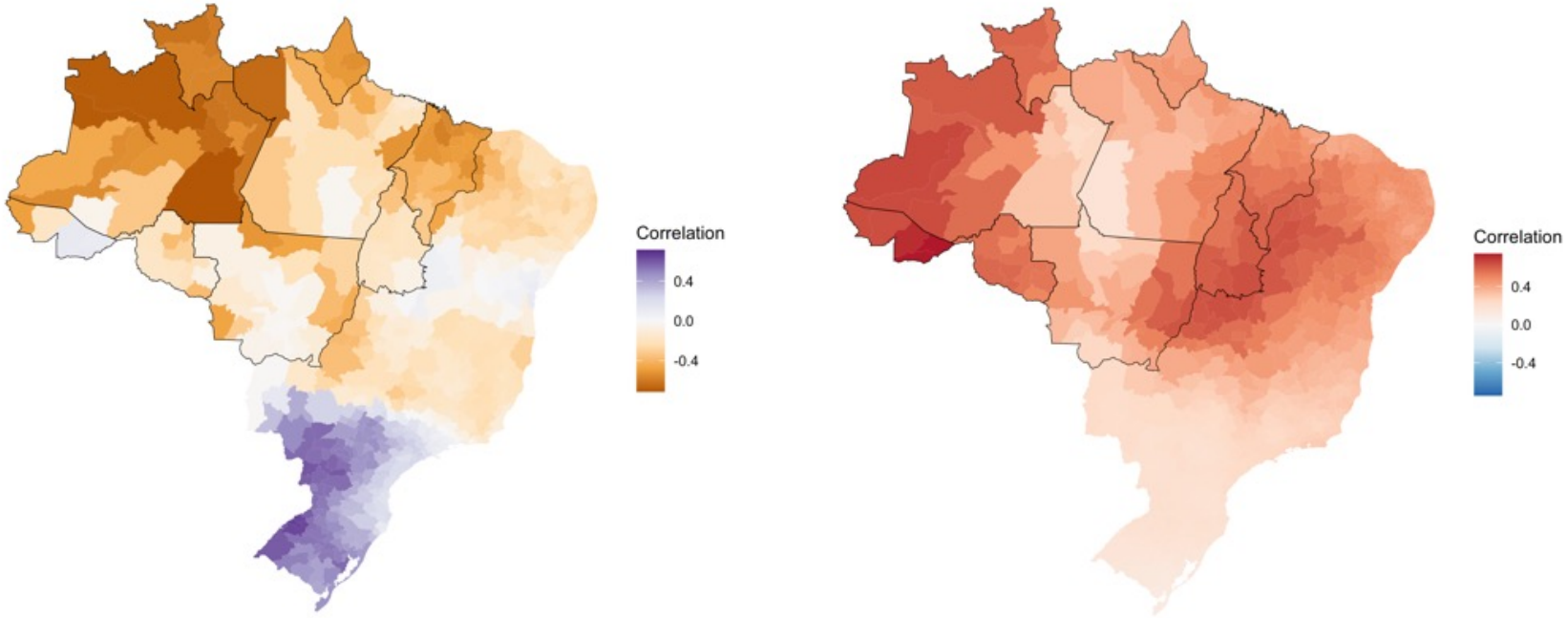
Valor añadido de los predictores hidrometeorológicos





Region	Added value	Total	Proportion
North	37	64	58%
Northeast	130	188	69%
Southeast	135	160	84%
South	75	94	80%
Centre-West	32	52	62%
Brazil	409	558	73%

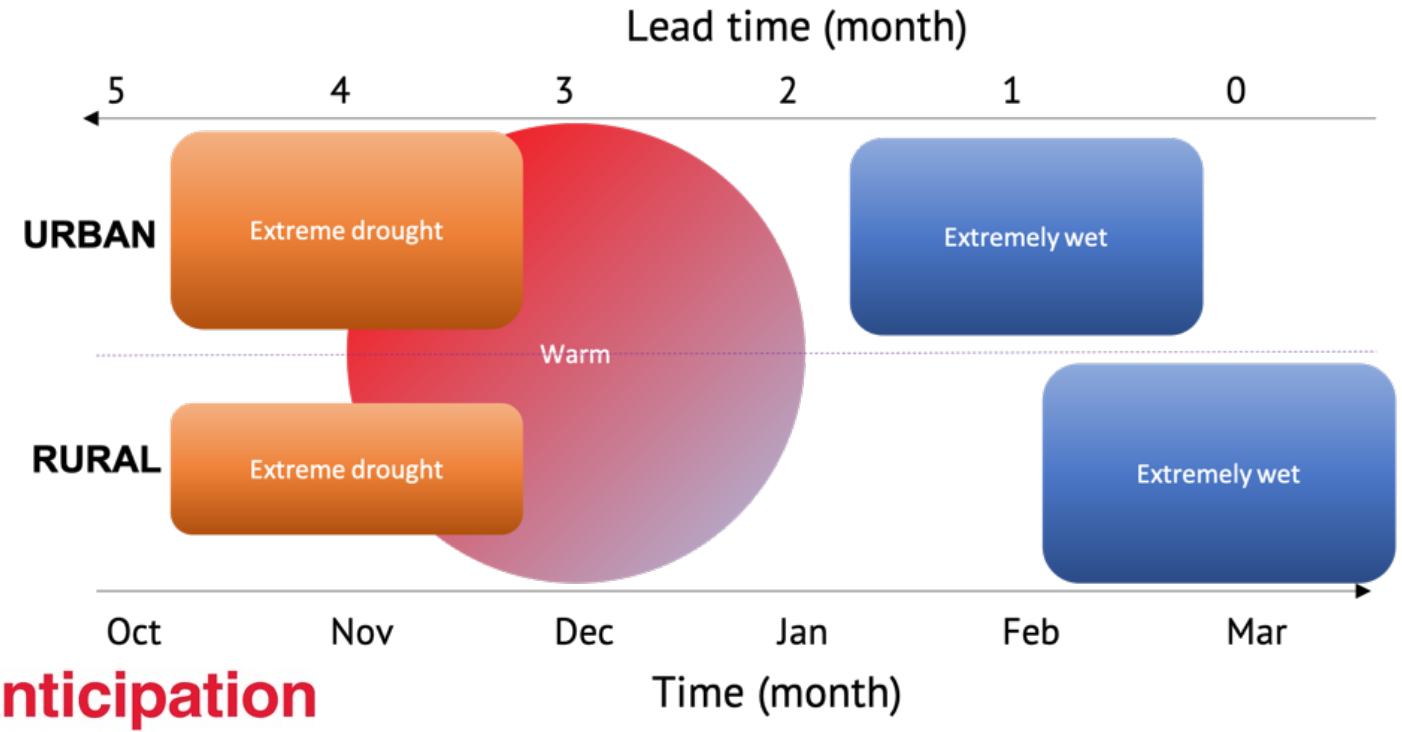
Donde funcionaría mejor un sistema de alerta?



Teleconexión entre El Niño-Oscilación del Sur (Nov-Dic-Ene), precipitaciones extremas y temperatura en Brasil (Feb-Mar-Abr)

Lowe *et al.*, *BMJ 2020*

Adaptar el pronóstico dependiendo del paisaje



Anticipation Hub


Barcelona
Supercomputing
Center

Earth System Services

Air Quality Services

Developing air quality products and services tailored to user's needs, from global/regional to local urban scale.

Climate Services

Applying state-of-the-art climate knowledge for the co-development of climate information and solutions for key societal sectors to adapt to climate change.

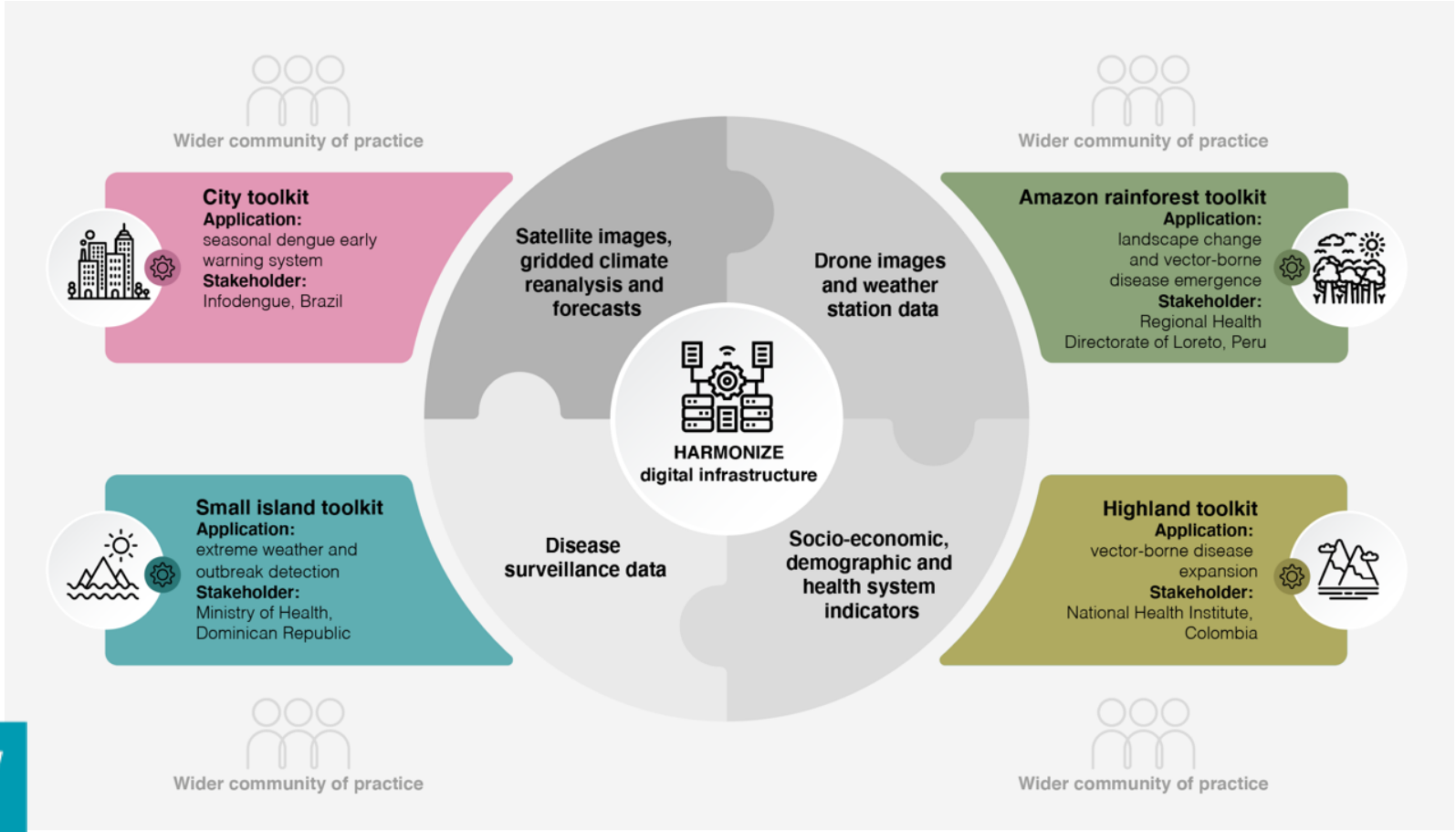
Global Health Resilience

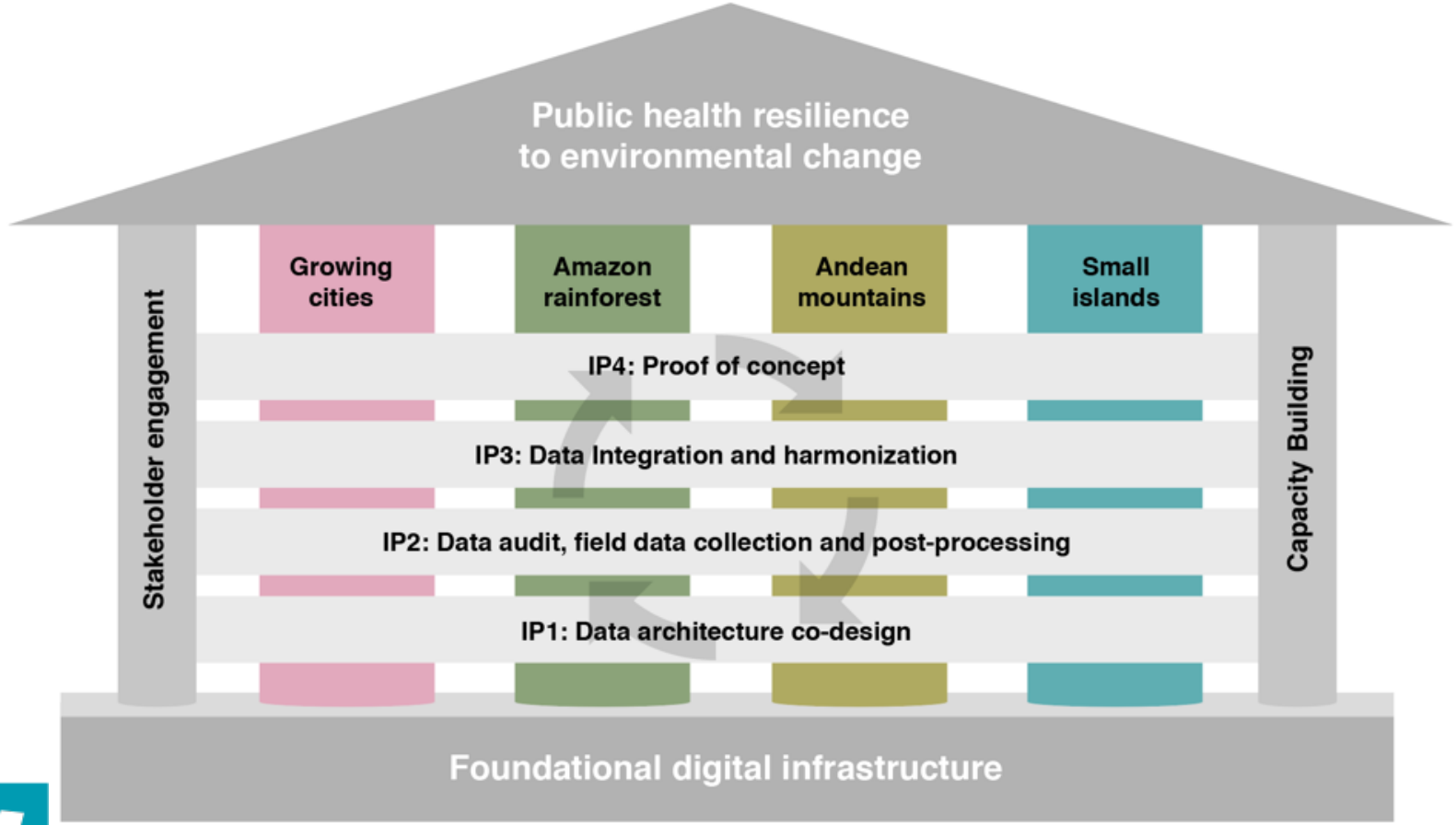
Applying a transdisciplinary approach to co-designing policy-relevant solutions to enhance response to climate-sensitive disease outbreaks and emergence.

Knowledge Integration

Coproducing knowledge regarding environmental topics, as well as technology transfer, communication and dissemination, visualisation, education, and outreach.

HARMONIZE


Wider community of practice
Wider community of practice
City toolkit
Application:
seasonal dengue early warning system
Stakeholder:
Infodengue, Brazil
Satellite images, gridded climate reanalysis and forecasts
Drone images and weather station data
Amazon rainforest toolkit
Application:
landscape change and vector-borne disease emergence
Stakeholder:
Regional Health Directorate of Loreto, Peru
HARMONIZE
digital infrastructure
Small island toolkit
Application:
extreme weather and outbreak detection
Stakeholder:
Ministry of Health, Dominican Republic
Disease surveillance data
Socio-economic, demographic and health system indicators
Highland toolkit
Application:
vector-borne disease expansion
Stakeholder:
National Health Institute, Colombia
Wider community of practice
Wider community of practice


Public health resilience
to environmental change
Stakeholder engagement
Growing cities
Amazon rainforest
Andean mountains
Small islands
Capacity Building
IP4: Proof of concept
IP3: Data Integration and harmonization
IP2: Data audit, field data collection and post-processing
IP1: Data architecture co-design
Foundational digital infrastructure

Referencias

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Climate-sensitive disease outbreaks in the aftermath of extreme climatic events: A scoping review https://www.cell.com/one-earth/pdf/S2590-3322(22)00144-0.pdf

Climate services for health: predicting the evolution of the 2016 dengue season in Machala, Ecuador https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(17)30064-5/fulltext

Combined effects of hydrometeorological hazards and urbanisation on dengue risk in Brazil: a spatiotemporal modelling study https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(20)30292-8/fulltext

¡Muchísimas gracias!

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European Environment Agency

LANCET COUNTDOWN: TRACKING PROGRESS ON HEALTH AND CLIMATE CHANGE

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