



From Citizen Science, Machine Learning and Earth Observation towards **Urban Climate Services**

Ana Oliveira, on behalf of the **AIR4health**, **CLIM4cities** and the **CLIM4health** Project Teams

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These projects is under a programme of, and funded by, the European Space Agency. Views expressed do not reflect the official opinion of the European Space Agency.

THE PROBLEM

WHY?



WHY?

THE PROBLEM



Extended Summer Season

→ **25-50 days/year**

Heatwaves

→ **10-20 days/year**

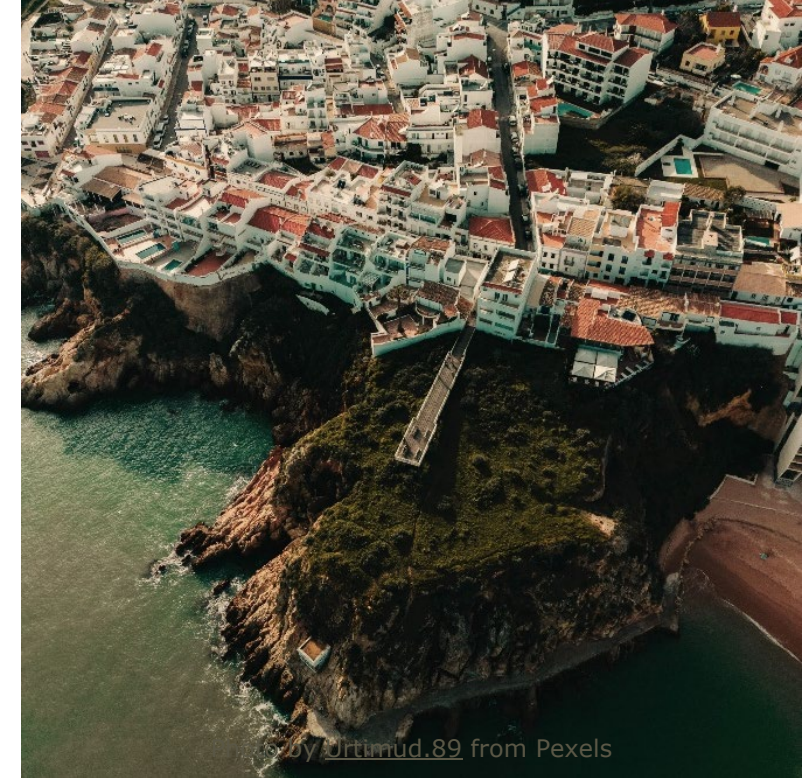


Ageing Population, Ageing Buildings

→ **71% energy poverty rates**

Lack of Adaptation Capacity

→ **88% of houses without AC**



Coastal Setting

→ **60% of the cities**

Compound and Multi-Hazard Extremes

→ **80% of the population**

WHY?

THE PROBLEM

Europe's hottest city battles to keep its cool as tourists arrive for another scorching summer

By Elinde Laferrière, CNN
© 8 minute read - Updated 6:37 AM EDT, Thu May 29, 2025



CNN World

Barcelona, Spain
5:43 PM

EXTREME WEATHER CONNECT THE WORLD

REPORT: 2022 EUROPEAN HEAT WAVES KILLED MORE THAN 61,000 PEOPLE
Joan Ballester | Professor, Barcelona Institute of Global Public Health

Climate report shows 2022 European heatwaves killed more than 61,000

Nearly 62,000 people died heat-related deaths last year during Europe's hottest summer on record, CNN's Eleni Giokos speaks to a professor of global public health about the implications of the findings. 05:50 - Source: CNN

CLIMATE CHANGE | CRISIS - VIABILITY OF LIFE ON EARTH

Extreme Heat Killed Nearly 48,000 People in Europe Last Year: Study

BY MARTINA IGINI | EUROPE | AUG 14TH 2024 | 3 MINS

EARTH.ORG IS POWERED BY OVER 150 CONTRIBUTING WRITERS

europa news Latest Europe World EU Policy Business Travel Next Culture Green Health

Green > Eco-Innovation

Madrid, Frankfurt, Vienna: How are European cities adapting to heatwaves?



Copyright AP Photo/Manu Fernandez

By Lottie Limb
Published on 13/06/2024 - 15:00 GMT+2 - Updated 15:02

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As parts of Greece, Cyprus and Türkiye face searing heatwaves, here's how trees, water and green buildings can help.

Parts of southern Europe are facing scorching heatwaves as summer sets in - while others are suffering record rainfall.

These extreme weather events are becoming fiercer and more frequent as a result of climate change, and for western nations at least, it has been a frightening glimpse into the future.

Record-breaking days have exposed how ill-equipped our cities are to handle 40°C temperatures. Conversely, they've also made us more appreciative of the parts that provide relief: the tree-lined streets, leafy parks, lidos and air conditioned public venues.



Warmest year on record.

Barcelona Institute for Global Health
been 80% higher if it weren't for

Aug 12 (Reuters) - More than 47,000 people died in European countries in the region's south hit the hardest, according to a new study by the International Society for Global Health (ISGlobal) published on Monday.

was the world's hottest on record. As climate change accelerates, more people are expected to live in the world's fastest-warming continent, facing unprecedented heat waves.

europa news Latest Europe World EU Policy Business Travel Next Culture Green Health

Green > Green News

Italy, Spain, Germany: The European countries where the most people died from heat last summer



Climate Action

Europe's Cities Should Prepare for Hotter, More Hazardous Days Ahead

By Michael Doust, Angela Bekkers, Juliana Costa and Saif Shabou | December 2, 2024



Visitors to Trafalgar Square in London attempt to cool down near a fountain during the 2022 heat wave. London faced a record-breaking temperature of 40 degrees C (104 degrees F) in July 2022. Photo: Guy Bell/Alamy Stock Photo

Europe is the world's fastest warming continent, which is severely impacting cities and leading to tens of thousands of deaths, rising hospitalizations, school closures and people adjusting their lives to avoid inhospitable outdoor conditions.

London could see temperatures exceeding 40°C (104°F) in some cities such as Birmingham and Manchester are forecast to challenge all-time July records.

By Zachary Rosenthal, AccuWeather staff writer

Published Jul 15, 2022 5:10 PM WEST | Updated Jul 17, 2022 11:16 PM WEST

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For the first time ever, the United Kingdom Meteorological Office (UK Met Office) has issued a red extreme heat warning for parts of "central, northern, eastern and southeastern England" as unprecedented warmth is set to spread across the U.K. on Monday and Tuesday.

WHY?

THE PROBLEM

Climate and Environmental Hazards are **LOCAL**

Forecasts and projections **ARE NOT**

✓ **OK** regarding **WHEN**

! **NOK** regarding **WHY/WHERE**



THE USER

FOR WHOM?



Photo by [Luis Quintero](#) from Pexels

TO WHOM?

THE USER



PUBLIC HEALTH, CIVIL PROTECTION, URBAN PLANNING

GOALS: I'm an architect, and I'd like to identify which areas are likely to face greater hazard exposure in the future.

FRUSTRATIONS: Uncertainty around designing healthier cities and public spaces while factoring in climate change projections.

SOLUTION: Simulate the climate impacts of future urban scenarios and access reports on recommended adaptation measures.



MUNICIPAL EXECUTIVE BODY, POLICY-MAKER

GOALS: I'm a politician aiming to gain as much public support as possible, avoid controversy, and secure re-election.

FRUSTRATIONS: Constantly facing criticism from the opposition and being vulnerable to shifts in public opinion.

SOLUTION: To champion solutions that are popular and meaningful to the community, and easily presented to the public as innovative.



RESEARCHERS AND PROFESSORS, ACADEMIA

GOALS: I'm a researcher, and I'd like to access free data, select and subset a geospatial time series on demand, and download it.

FRUSTRATIONS: Options to subset or summarise large datasets prior to download are limited, and sharing geospatial outputs visually is challenging.

SOLUTION: To access the most reliable data via a fast platform that supports selection, querying, and merging.



COMMUNITY AND PUBLIC, NGOS AND MEDIA

GOALS: I'm a journalist, and I'd like to easily create engaging plots and infographics from climate and environmental data.

FRUSTRATIONS: Producing eye-catching infographics takes time, so we often struggle to have them ready when extreme events occur.

SOLUTION: To use an intuitive platform for downloading visually compelling infographics, videos, and maps.

Portuguese saying: « 3B's = Bom, Bonito, e Barato »

THE SOLUTION

HOW?



Photo [Reinaldo Simões](#) from
Pexels

HOW?

THE SOLUTION



Local-relevant
FITNESS FOR PURPOSE

**Empirical Approach to
Hazard Mapping**



COST-EFFICIENT
for All Users

**Open-Science Approach
and Reproducibility**



SCALABILITY
Across Urban Areas

**Wide Coverage and
Scalability**

THE AIM is: To Optimise **Early Response Actions for Urban Health** and **Contribute Towards Local Climate Change Adaptation Strategies**

Global temperature change since 1850

Future choices up to 2100

WE

ARE

HERE

WHAT?

The Solution



TODAY

[weather forecasts: predicting impacts]

OUR CHOICES



YESTERDAY

[reanalysis: observing relationships, modelling effects]



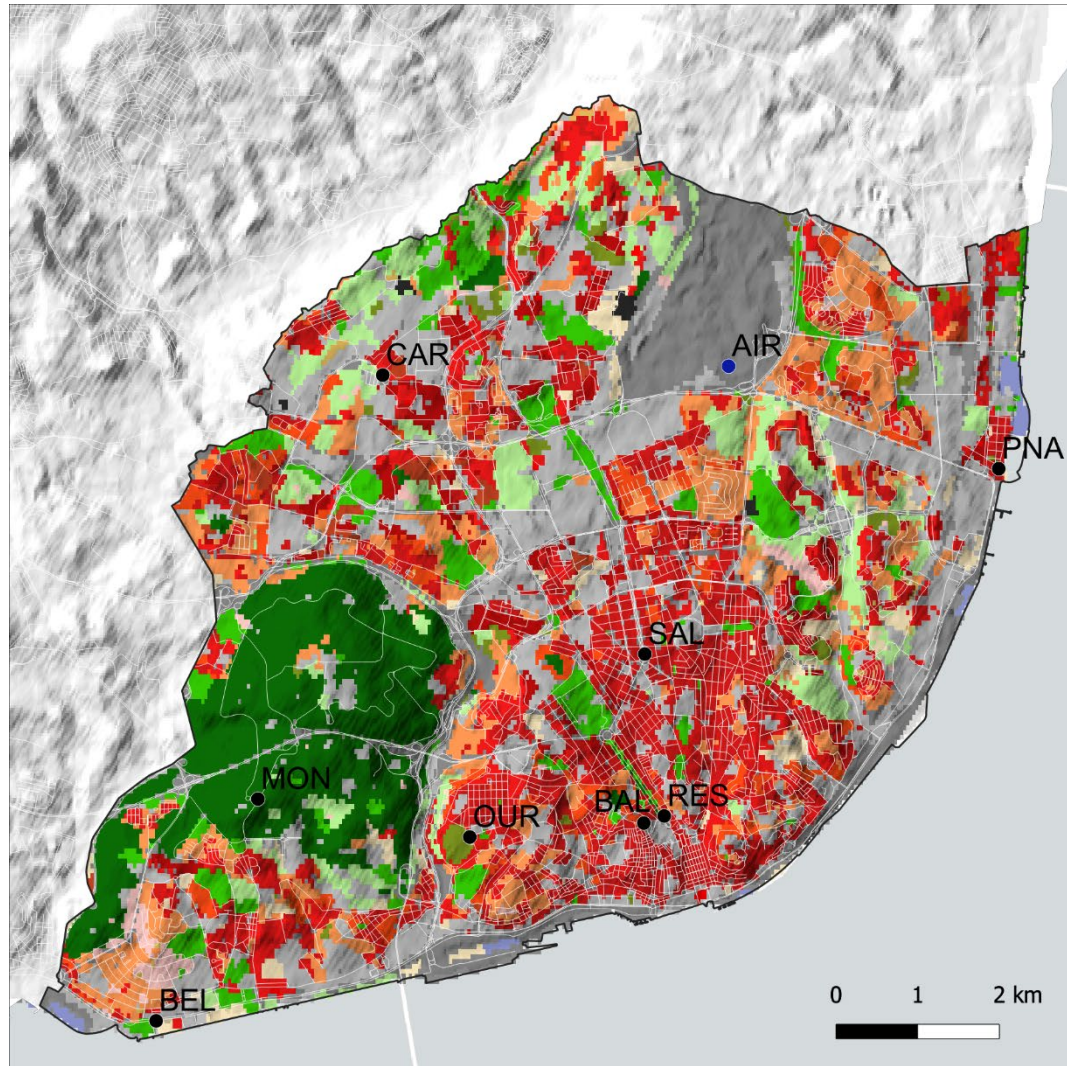
TOMORROW

[climate projections: assess alternative scenarios]



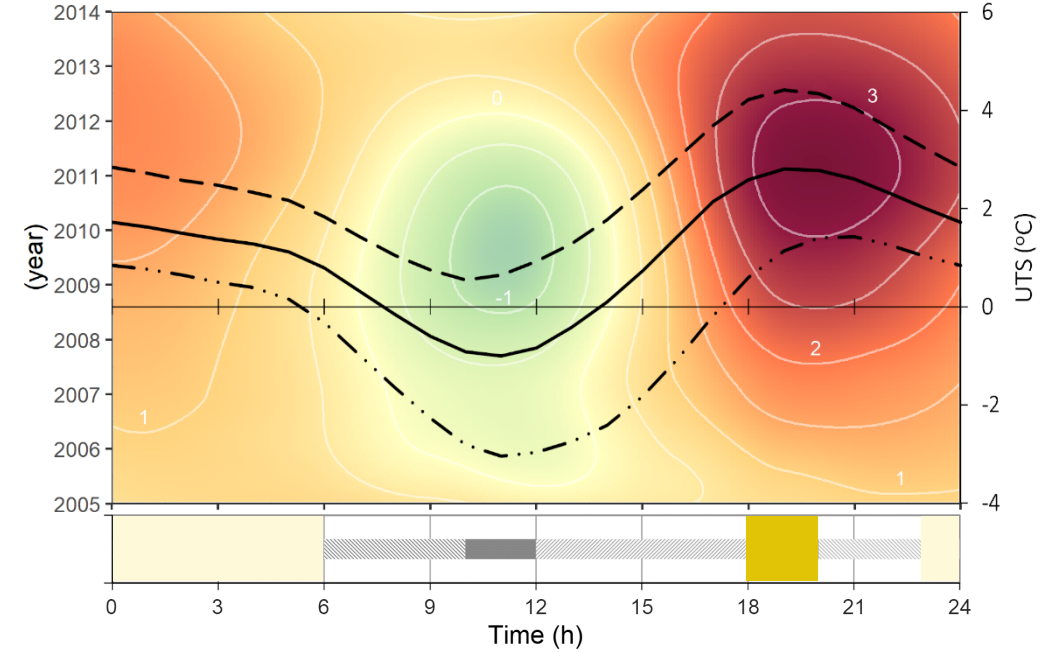
YESTERDAY

[reanalysis: observing relationships, modelling effects]



- City Limits
- Ta Observation Sites
 - IGOT's Network
 - Airport
- LCZ classes
 - 1 - Compact high-rise
 - 2 - Compact midrise
 - 3 - Compact low-rise
 - 123 - Compact mixed-rise
 - 4 - Open high-rise
 - 5 - Open midrise
 - 6 - Open low-rise
 - 456 - Open mixed-rise
 - 8 - Large low-rise
 - 9 - Sparsely built
 - 10 - Heavy industry
 - A - Dense trees
 - B - Scattered trees
 - C - Bush, scrub
 - D - Low plants
 - E - Bare rock or paved
 - F - Bare soil or sand
 - G - Water

UTS (Tu-Tr) daily cycle per month, Summer (JJAS 2005-2014)
(‘N’ and ‘N var’ wind direction)

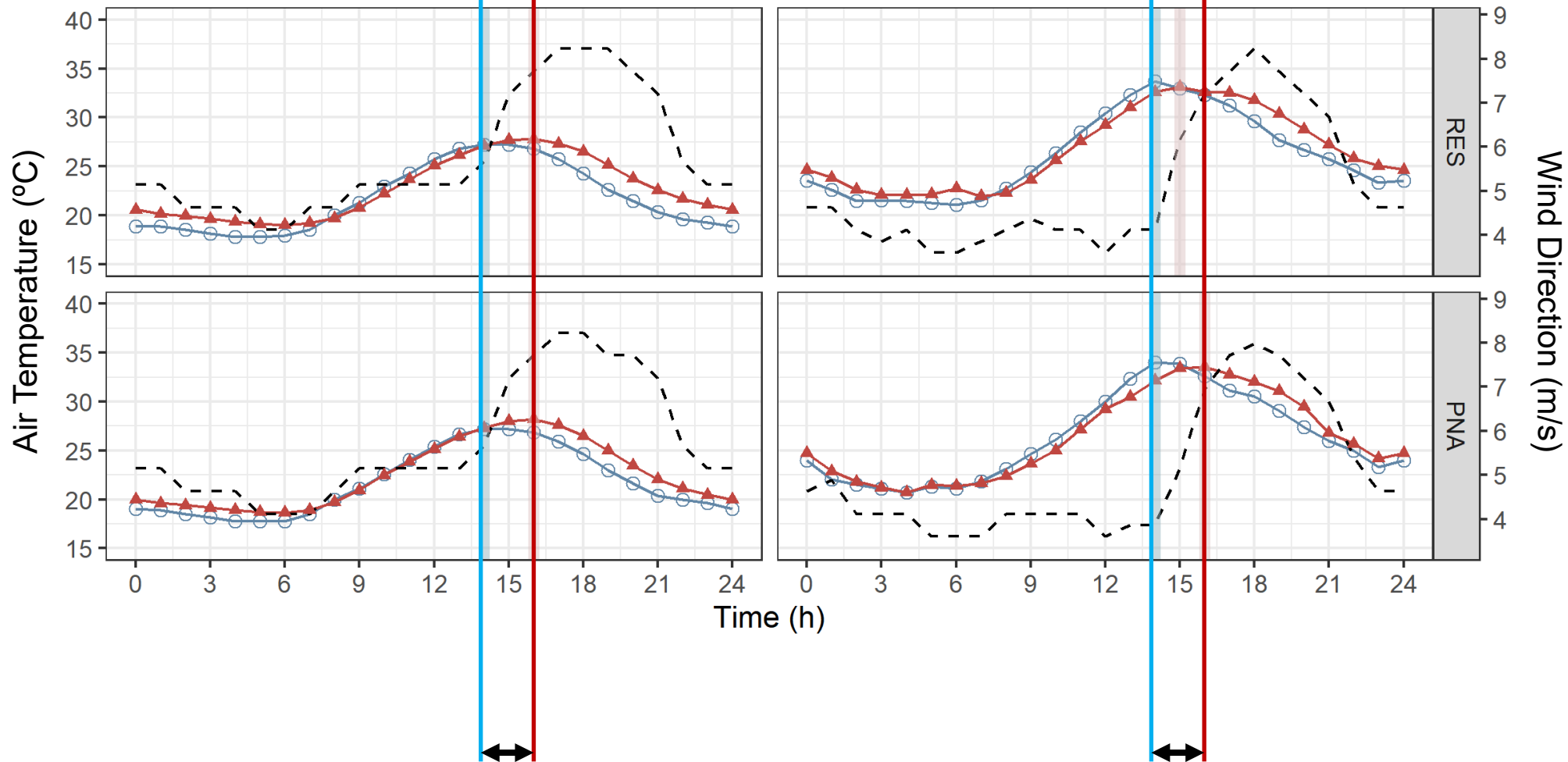


	UTS daily cycle stages	UTS signal
→	1. Nocturnal stable UHI	Positive
	2. Morning transition to UCI	Positive to negative transition
	3. Diurnal Peak UCI	Negative
	4. Afternoon transition to UHI	Negative to positive transition
→	5. Late Afternoon peak UHI	Positive
	6. Evening stabilizing UHI	Positive

Sources:
<https://www.epa.gov/heatislands/learn-about-heat-islands>
 Oliveira A, Lopes A, Correia E, Niza S, Soares A. Heatwaves and Summer Urban Heat Islands: A Daily Cycle Approach to Unveil the Urban Thermal Signal Changes in Lisbon, Portugal. Atmosphere. 2021; 12(3):292. <https://doi.org/10.3390/atmos12030292>

Non-HW Days

HW Days

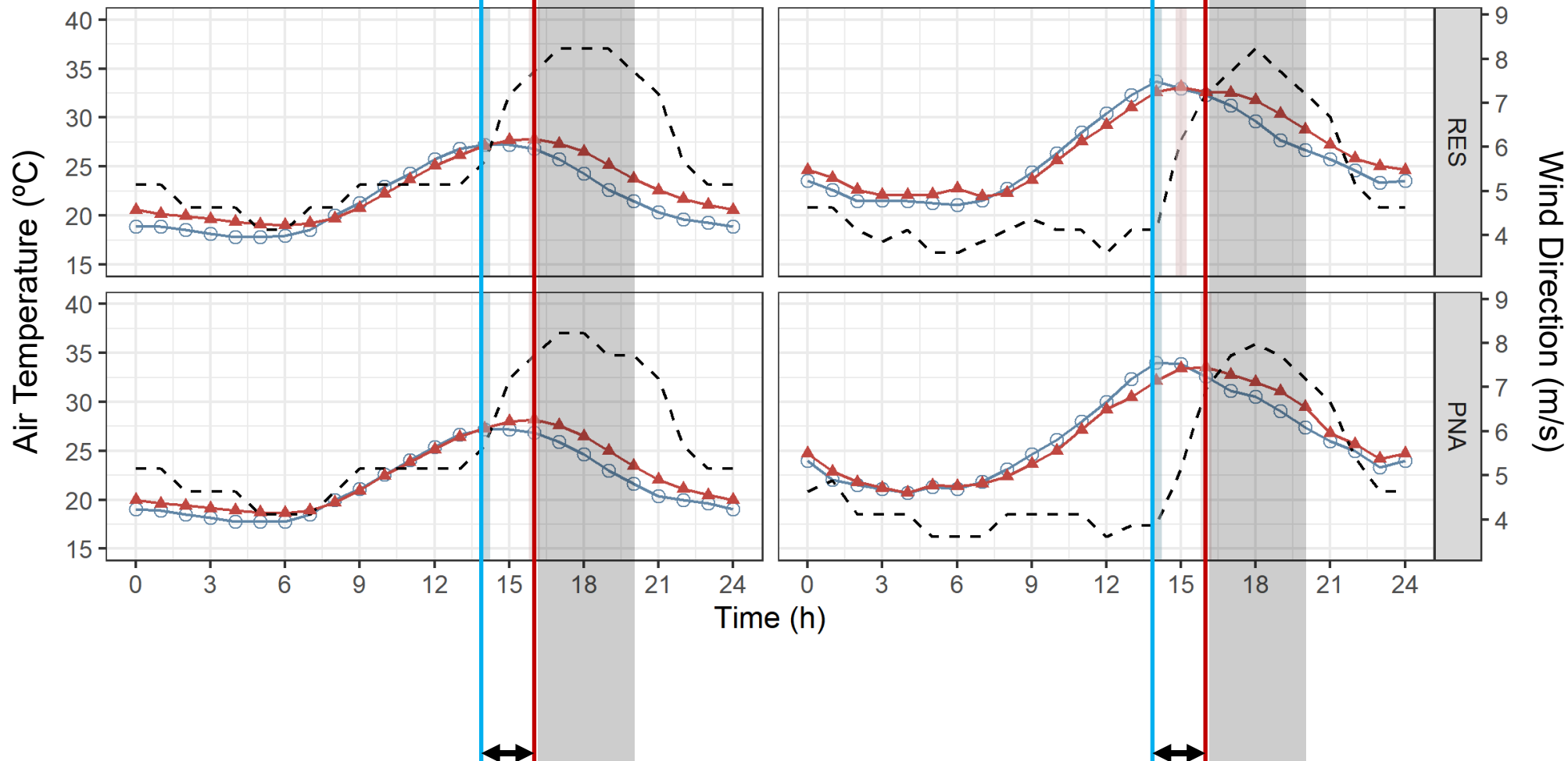


There is a **~2hour lag** between the **Rural** and **Urban Sites**.

- Lisbon Airport Ta (Tr): Median (Tr50p)
- ▲— IGOT's urban sites Ta (Tu): Median (Tu50p)
- - - Lisbon Airport regional wind speed (Ws50p)

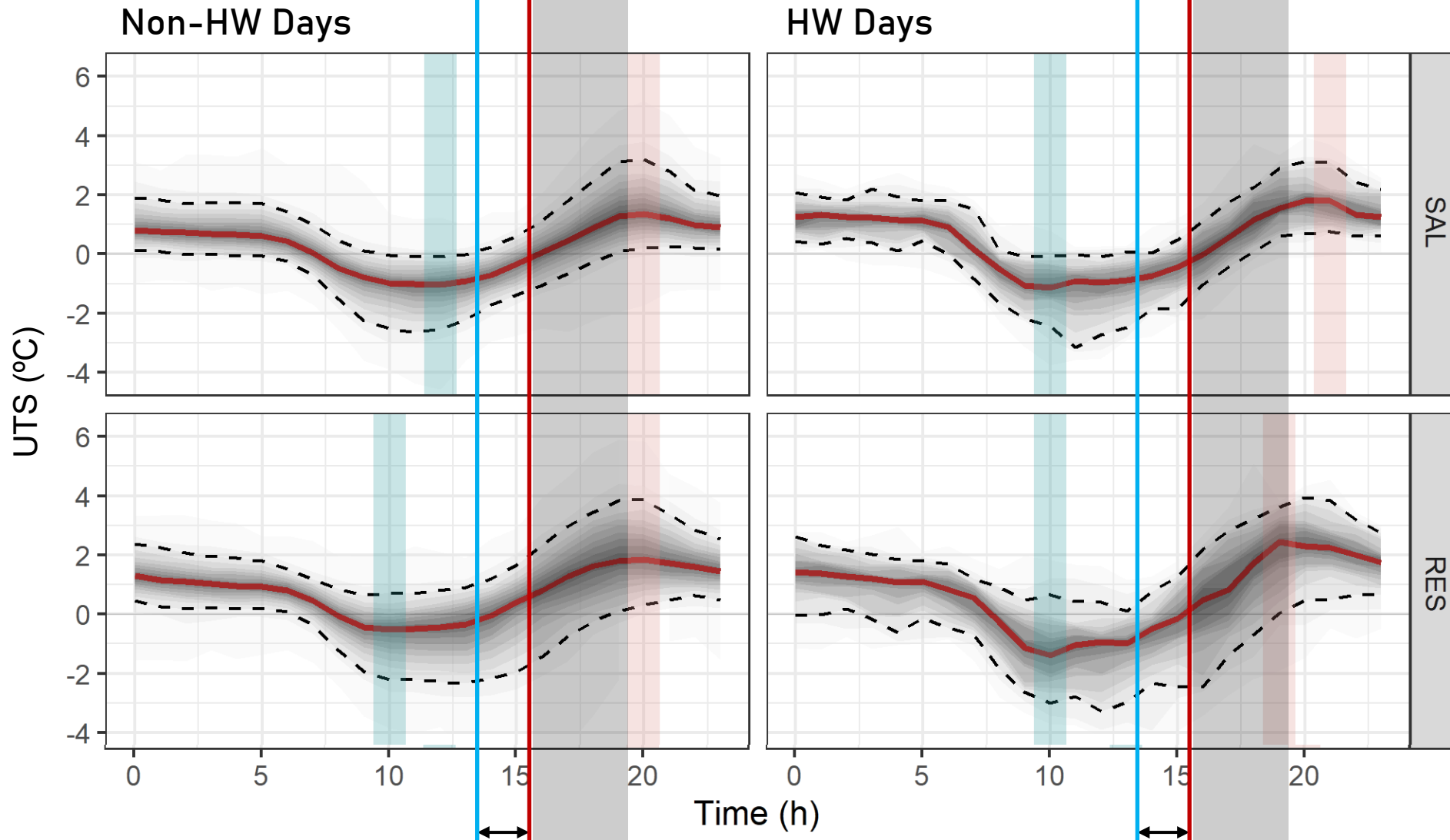
Non-HW Days

HW Days






There is a late afternoon **Wind Speed Peak.**

- Lisbon Airport Ta (Tr): Median (Tr50p)
- ▲— IGOT's urban sites Ta (Tu): Median (Tu50p)
- - - Lisbon Airport regional wind speed (Ws50p)



Both contribute to the **UTS** Late Afternoon **Peak?**

-  UTS upper bound intensity, 90th percentile (UTS90p)
-  UTS median intensity, 50th percentile (UTS50p)
-  UTS lower bound intensity, 10th percentile (UTS10p)

HOW?

THE SOLUTION

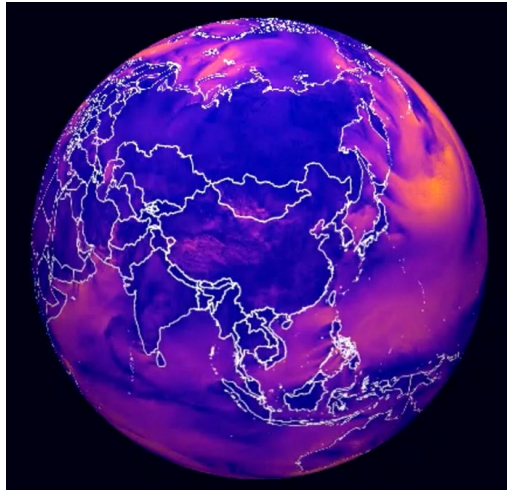
Observations

Sensors, IoT,
Crowdsourcing



Synoptic (Background) Weather

Reanalysis, Forecast and
Climate Projections



Local (Time-Fixed) Predictors

Landscape and Urban
Features

Topography

Terrain,
Topographic Wind
Exposure

Green Features

Vegetation Density
and Type,
Phenology

Urban Features

Urban Density,
Imperviousness,
Sky View Factor

Blue Features

Proximity to the
Coast or Large
Water Bodies

Machine Learning

Domain-Informed Data-
driven Downscaling



Informed decision-making

- ✓ What?
- ✓ When?
- ✓ **WHERE?**

HOW?

THE SOLUTION



Few Observations

Agriculture

Sintra-Cascais
Natural Park

Sea-land breezes

Urban
Sprawl

Urban Parks

Urban Land
Cover

Tagus Estuary

In-situ stations:

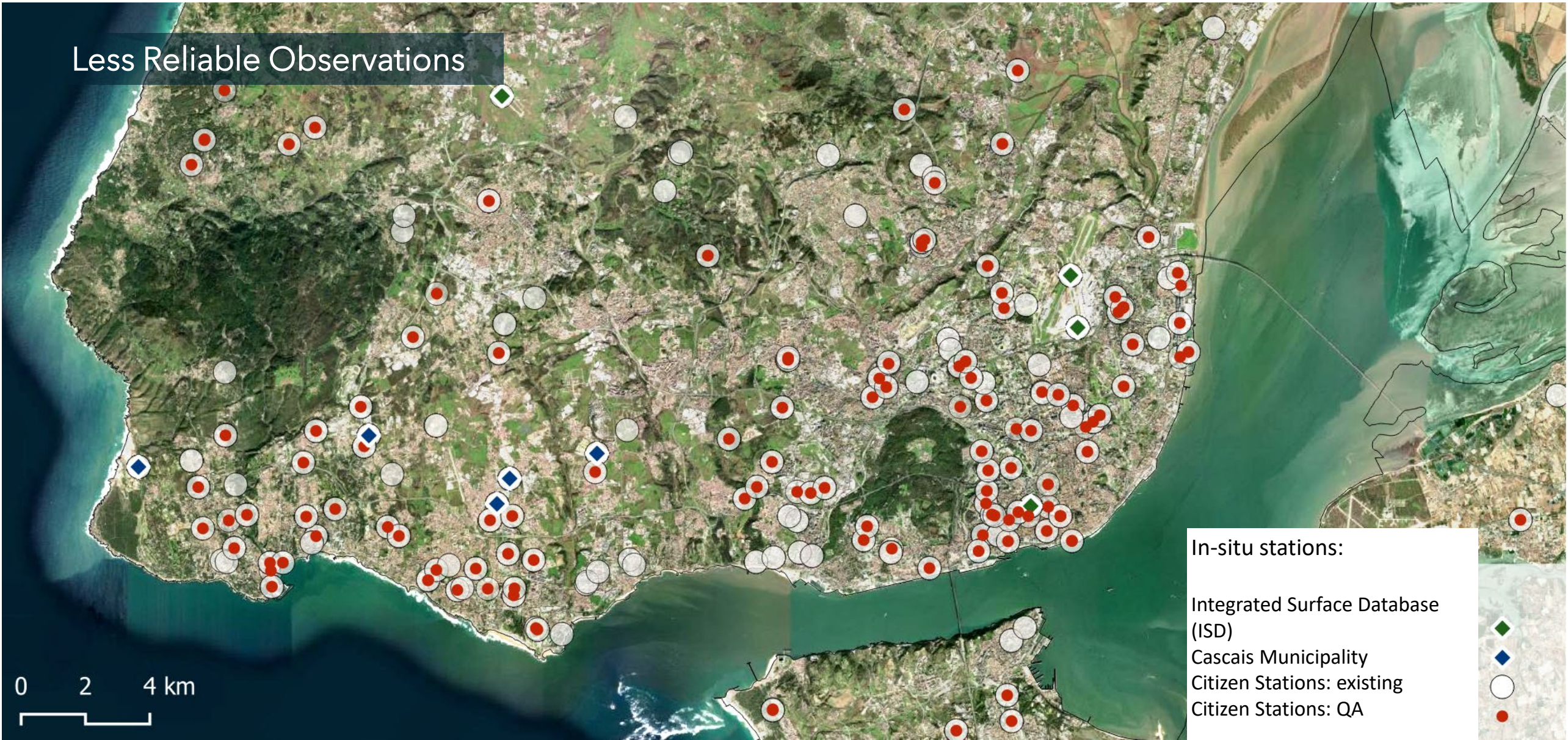
Integrated Surface Database
(ISD)



HOW?

THE SOLUTION

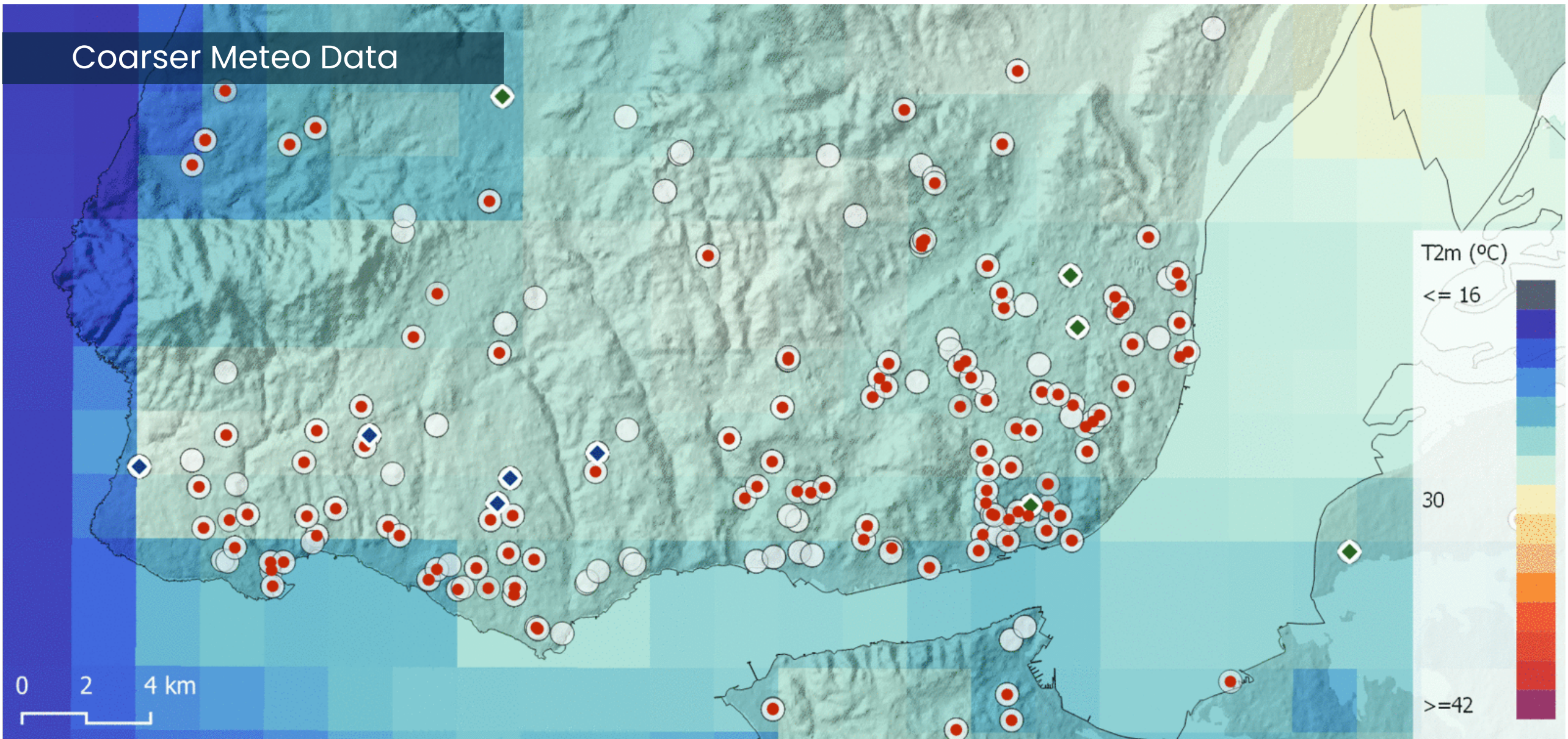
Less Reliable Observations



HOW?

THE SOLUTION

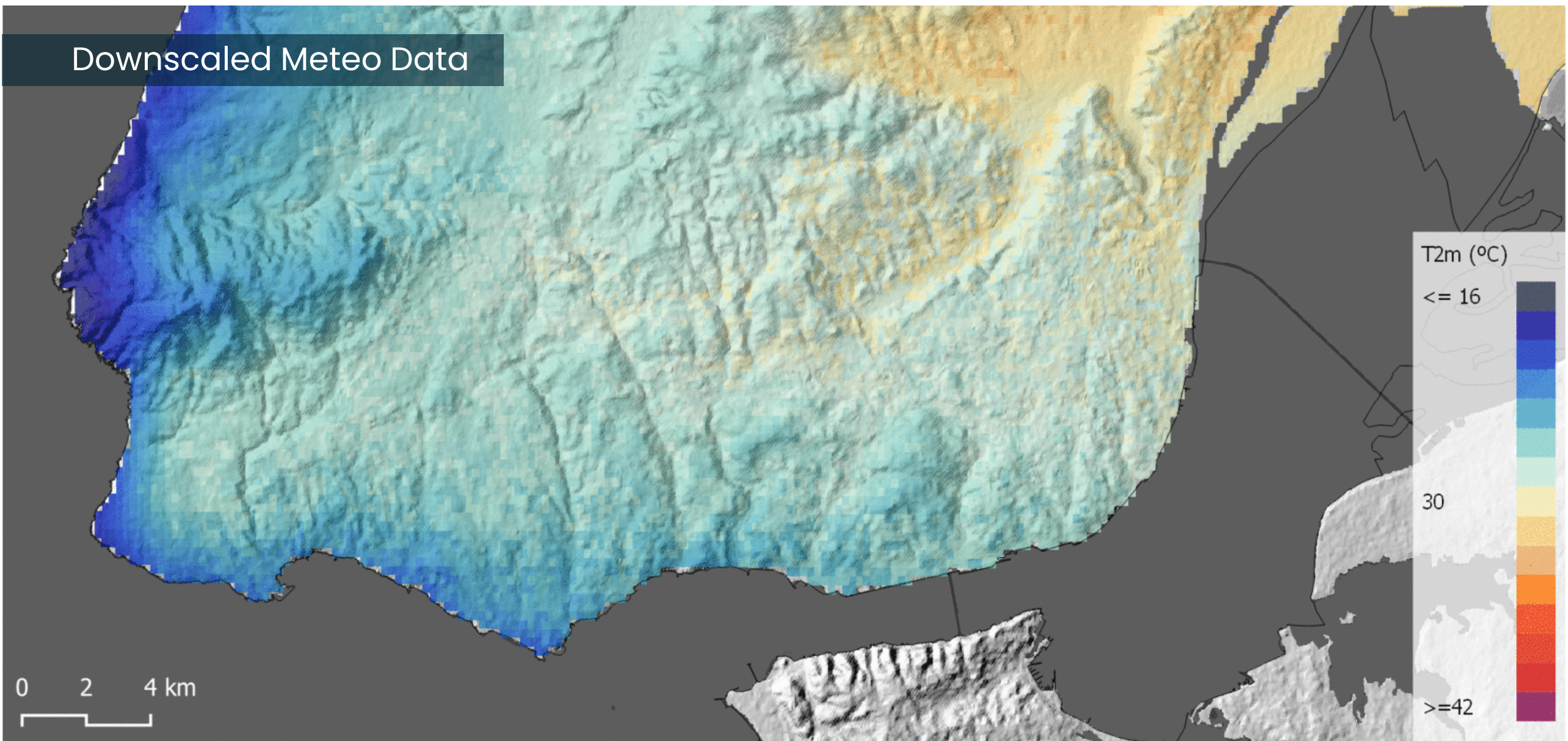
Coarser Meteo Data



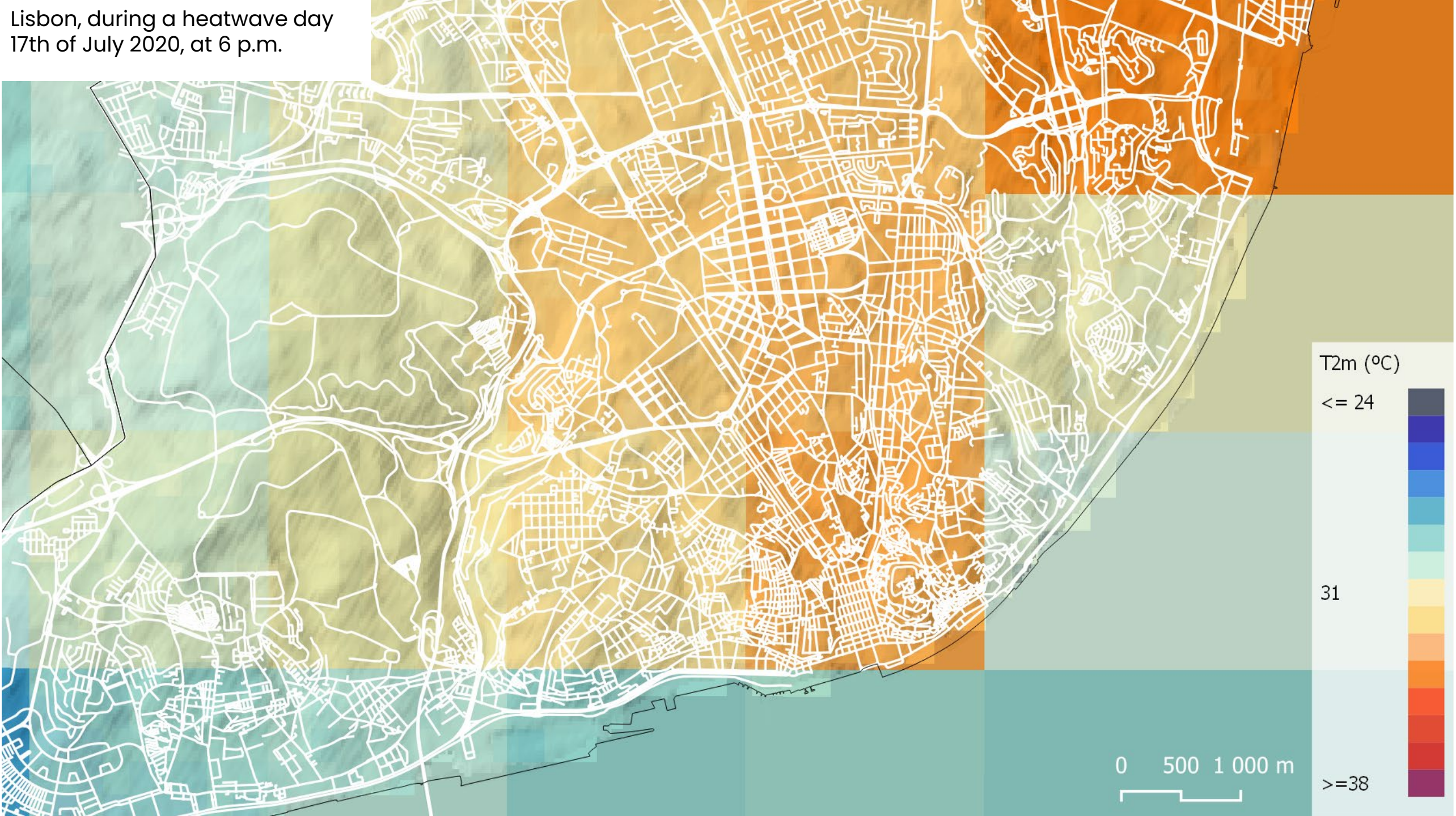
HOW?

THE SOLUTION

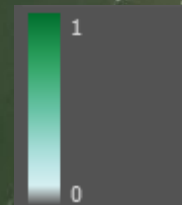
Downscaled Meteo Data



Lisbon, during a heatwave day
17th of July 2020, at 6 p.m.



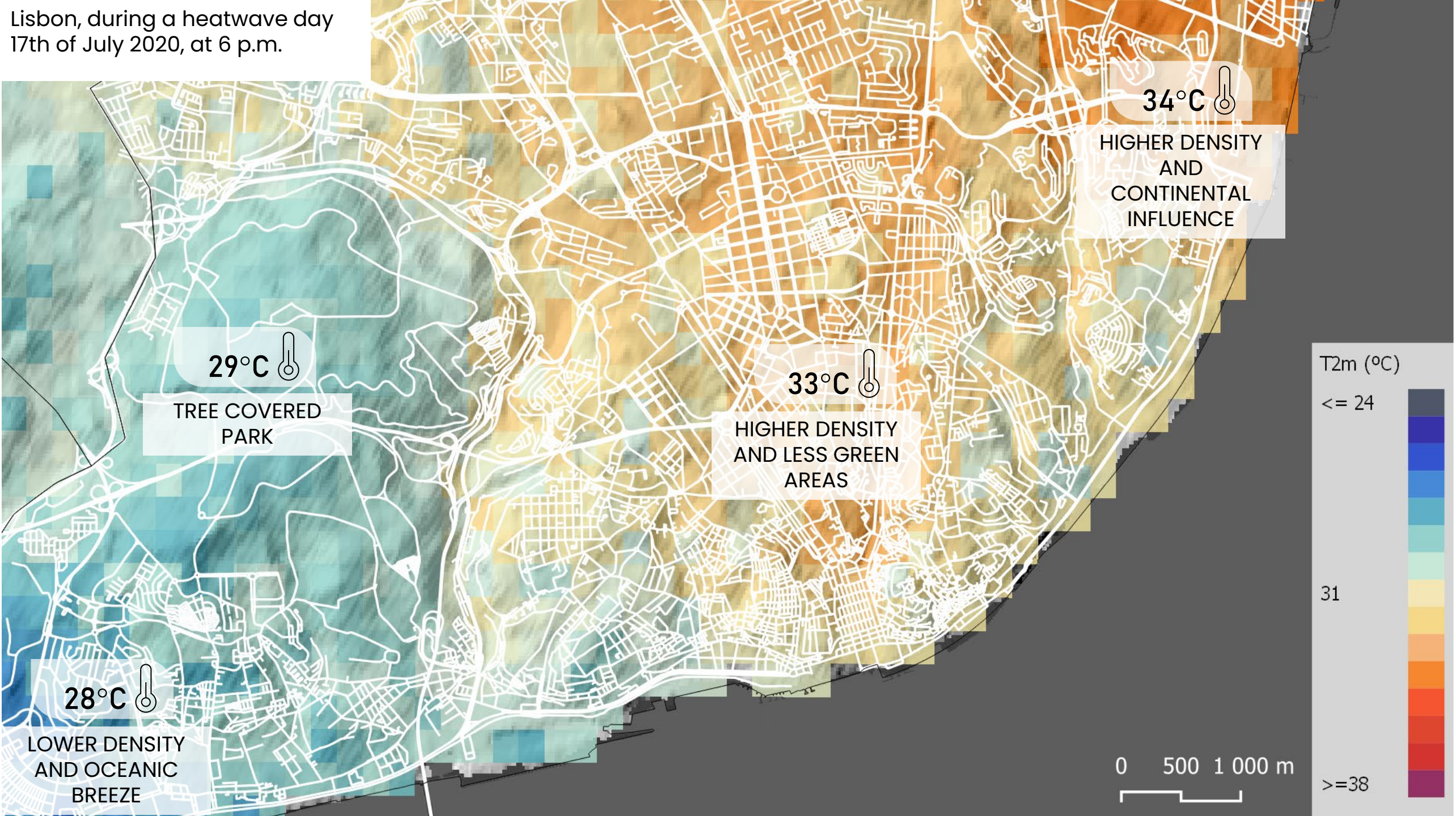
Lisbon, during a heatwave day
17th of July 2020, at 6 p.m.



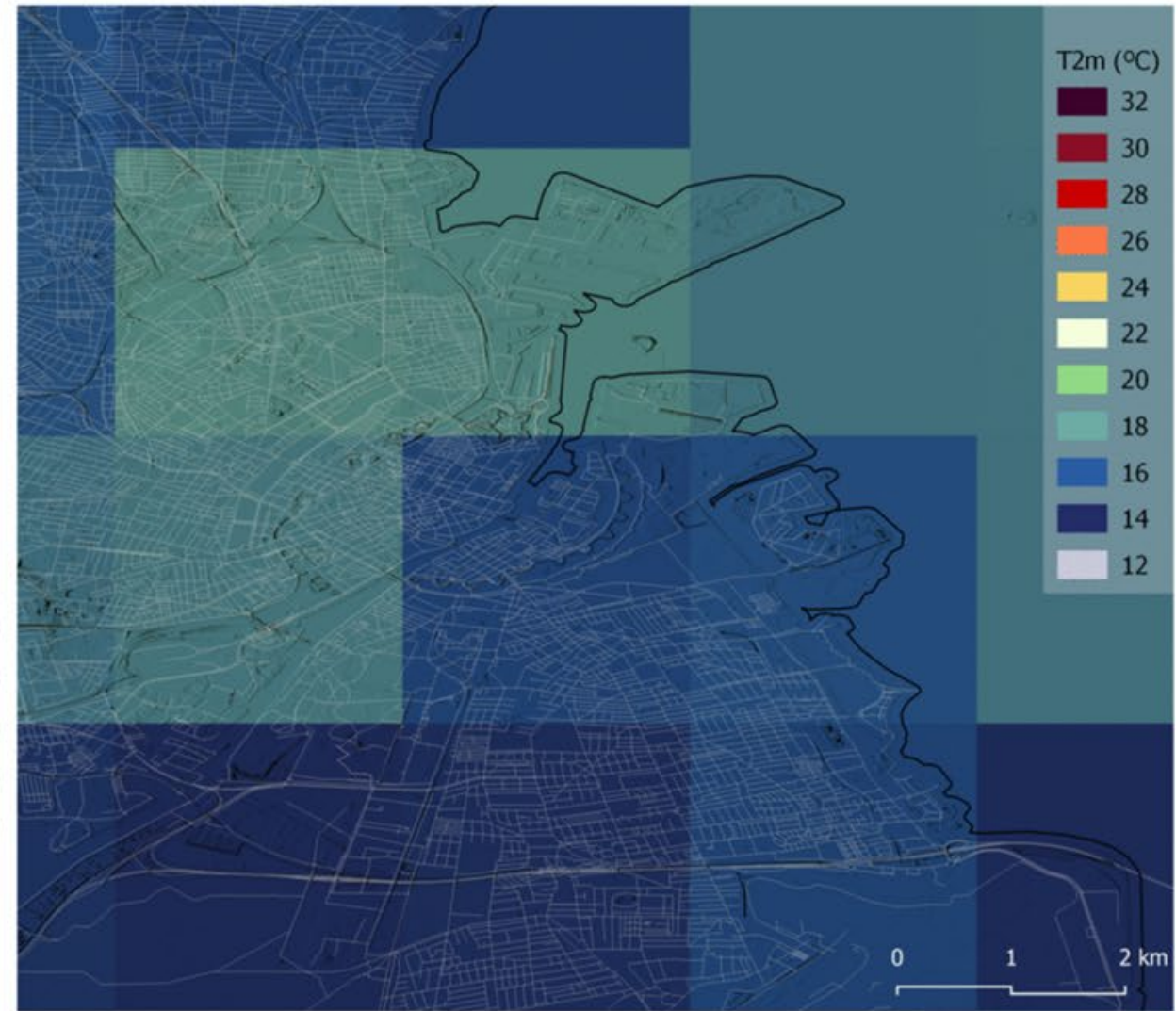
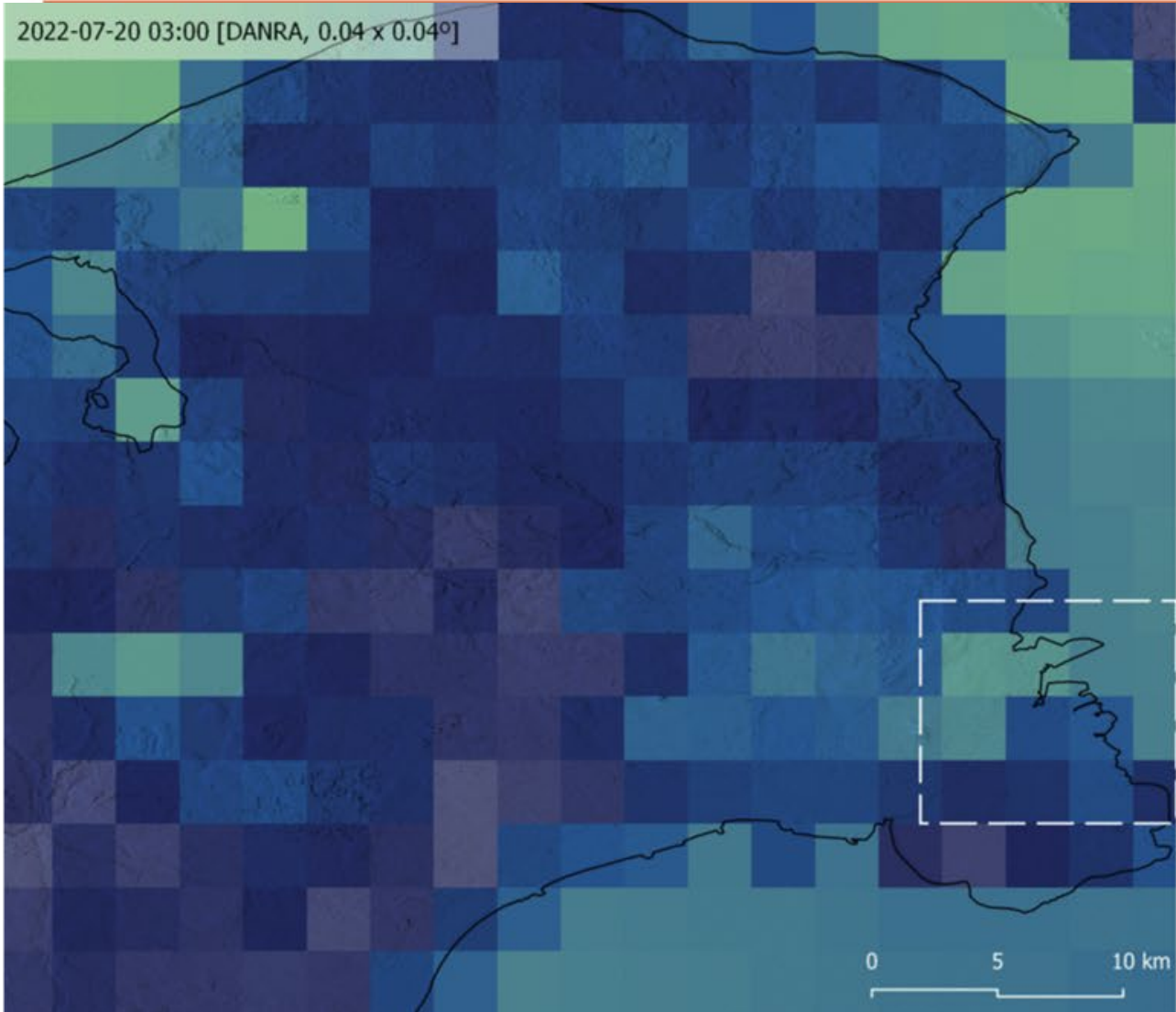
Lisbon, during a heatwave day
17th of July 2020, at 6 p.m.

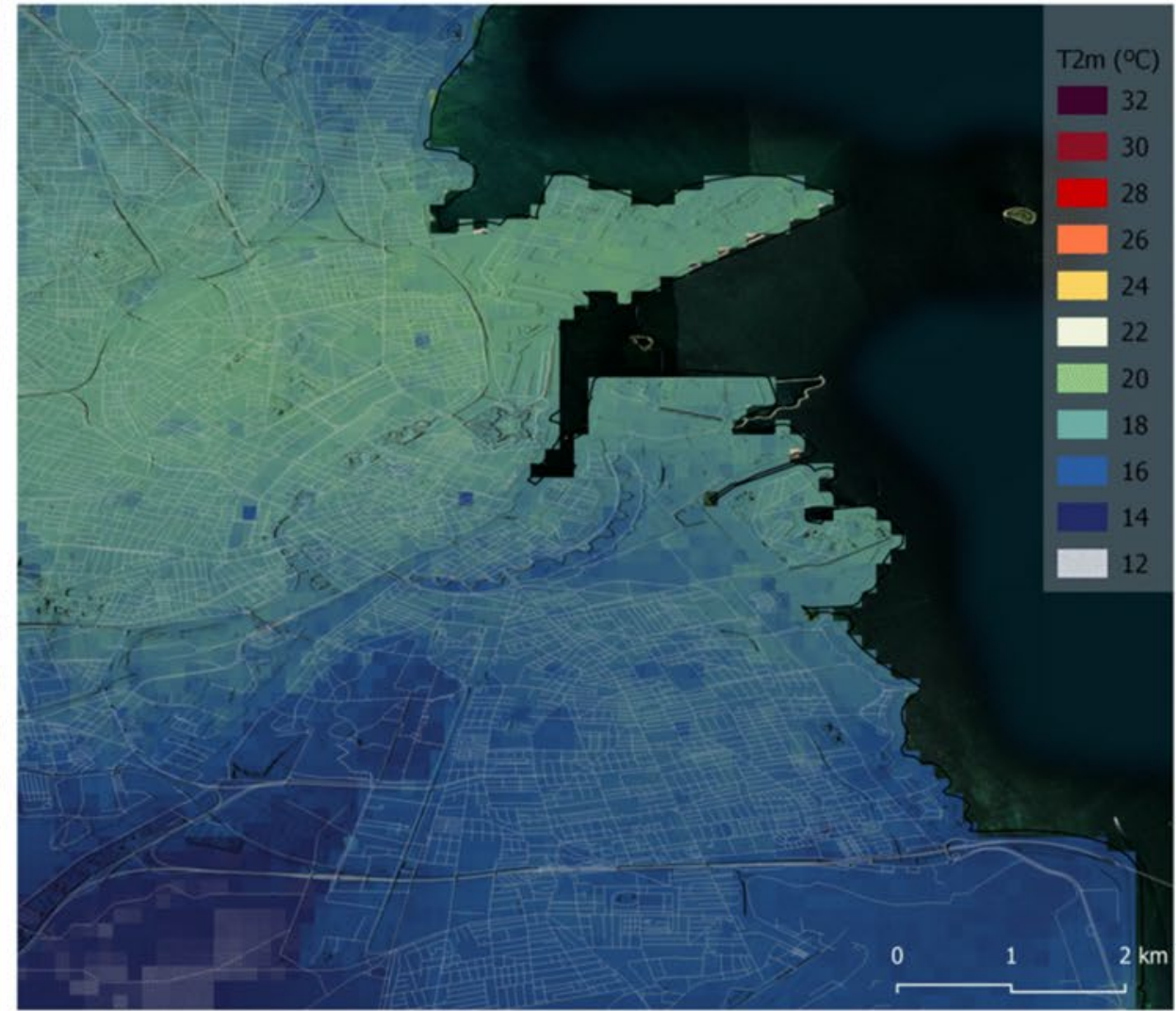
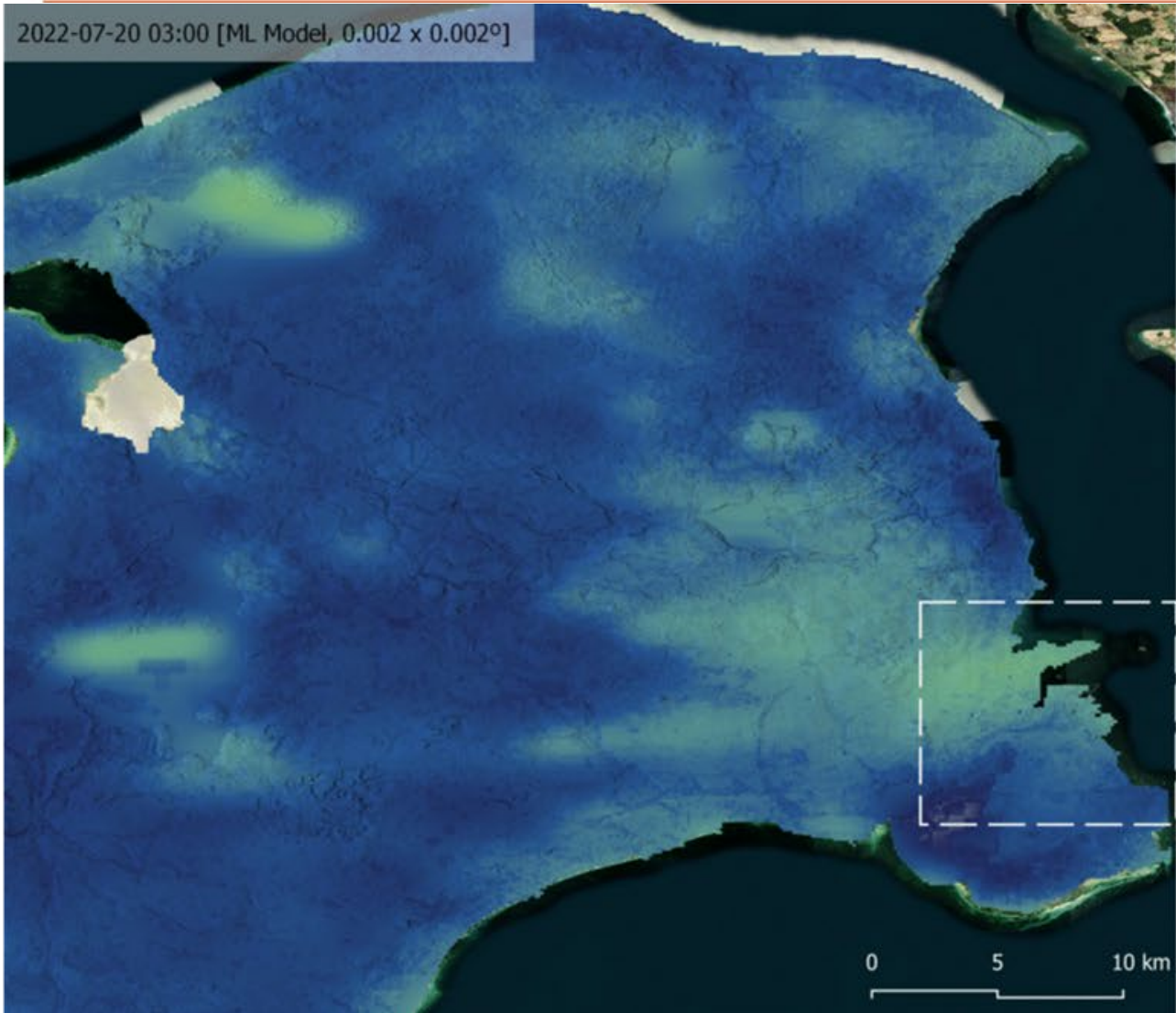


Lisbon, during a heatwave day
17th of July 2020, at 6 p.m.



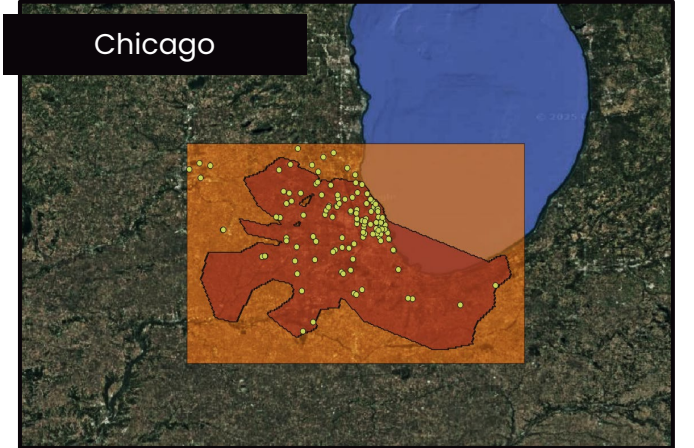
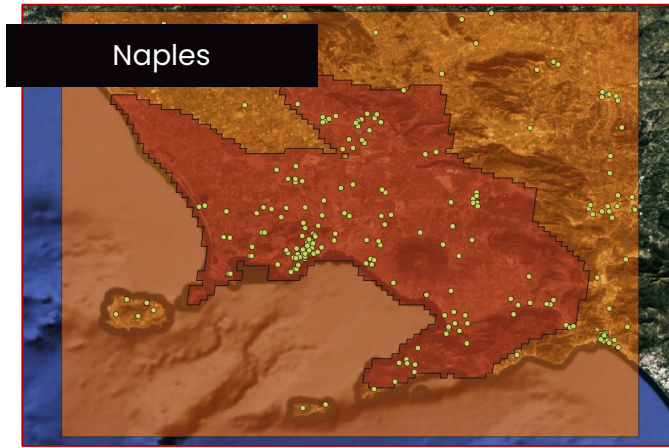




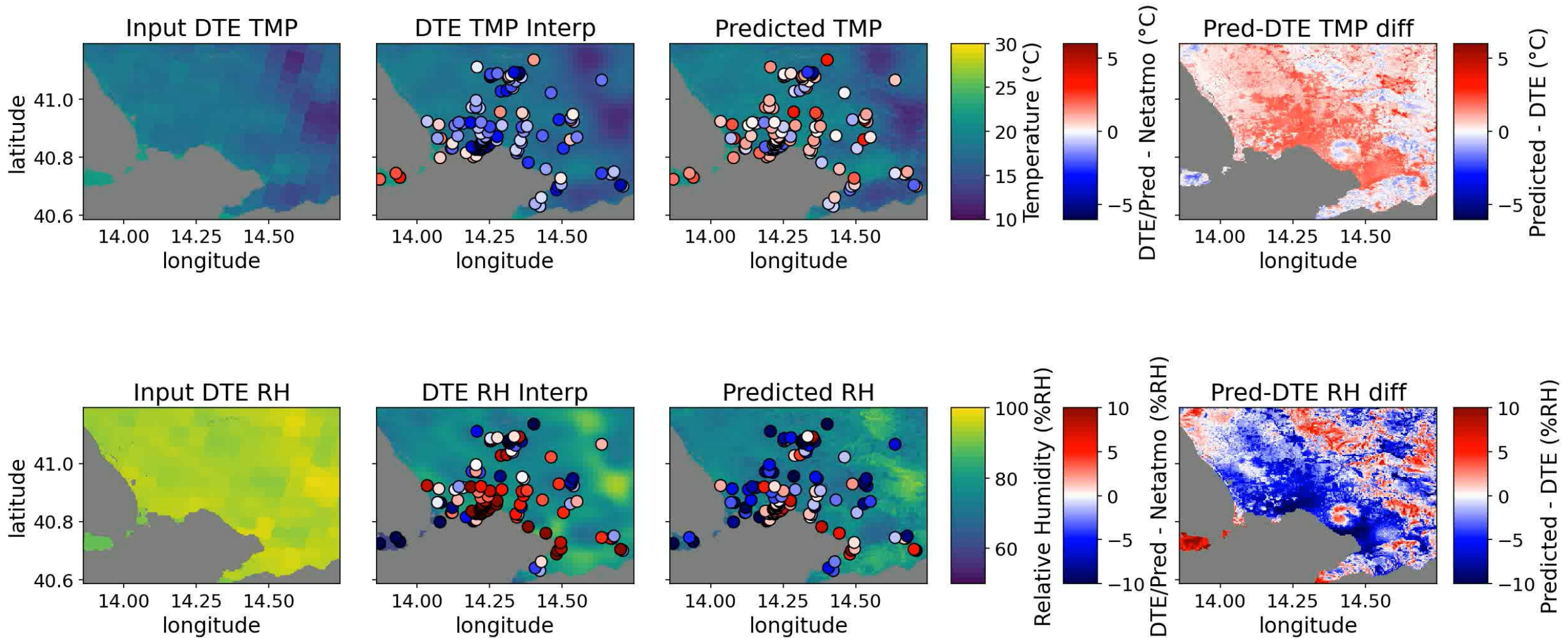


WHAT?

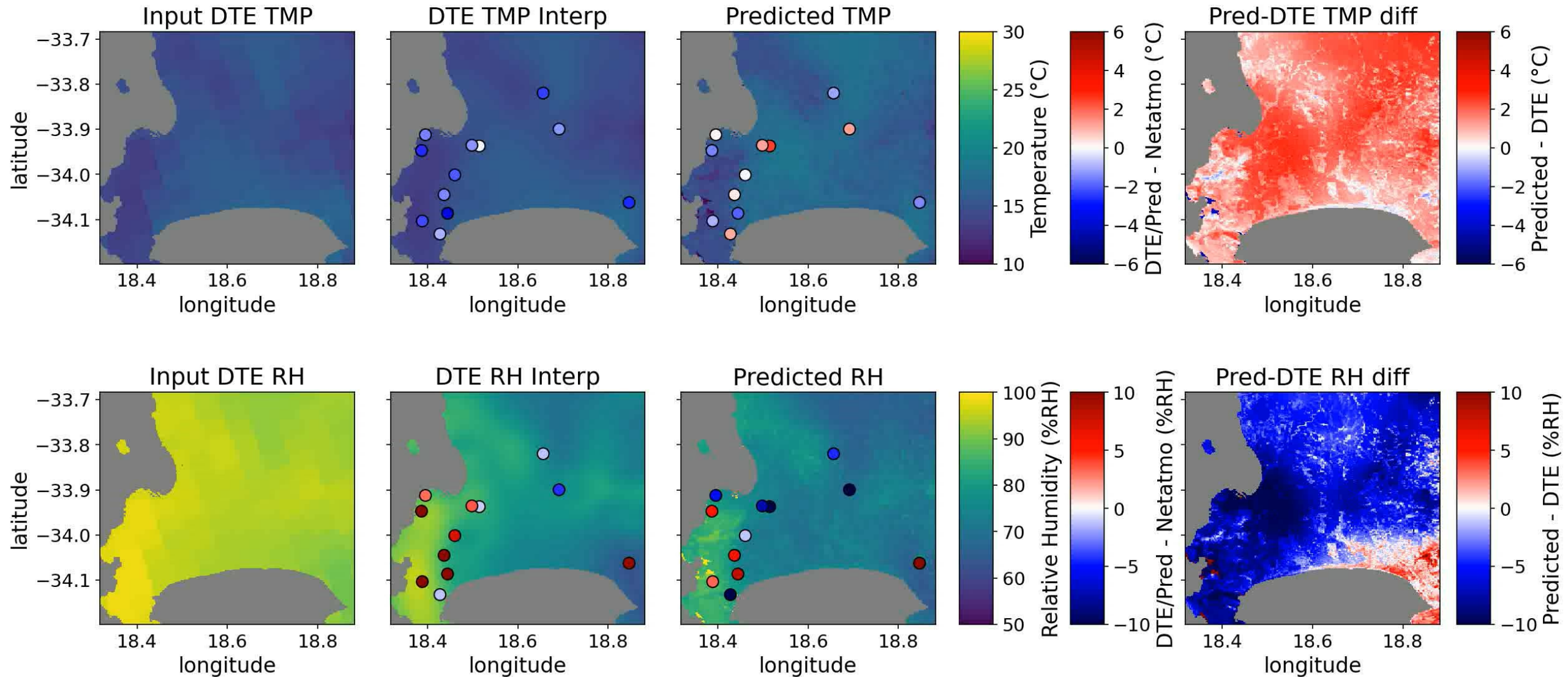
The Solution



NAPLES - Prediction for 2025-10-01 00h



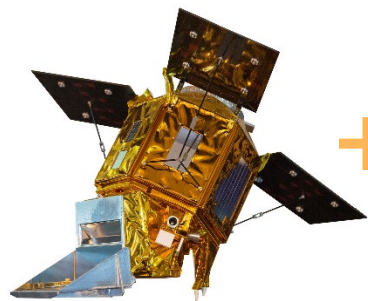
CAPETOWN - Prediction for 2025-10-01 00h



AIR4health Approach

Observations

Sensors, Sentinel-5p,
CAMS Reanalysis



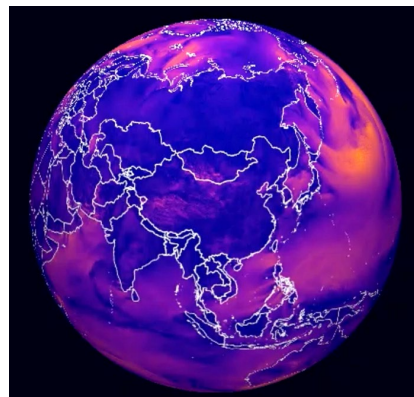
+



=

Synoptic (Background) Conditions

CAMS Reanalysis
(CAMS Forecasts)



+

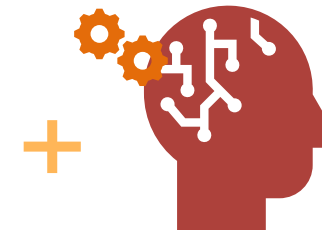
Local (Time-Fixed) Predictors

Landscape and Urban
Features

<p>Topography Terrain, Topographic Wind Exposure</p>	<p>Green/Blue Features Vegetation Density and Type, Phenology</p>
+	
<p>Urban Features Urban Density, Imperviousness, Sky View Factor</p>	<p>Human Activity Proximity to traffic lanes per typology</p>

Machine Learning

Domain-Informed Data-
driven Downscaling

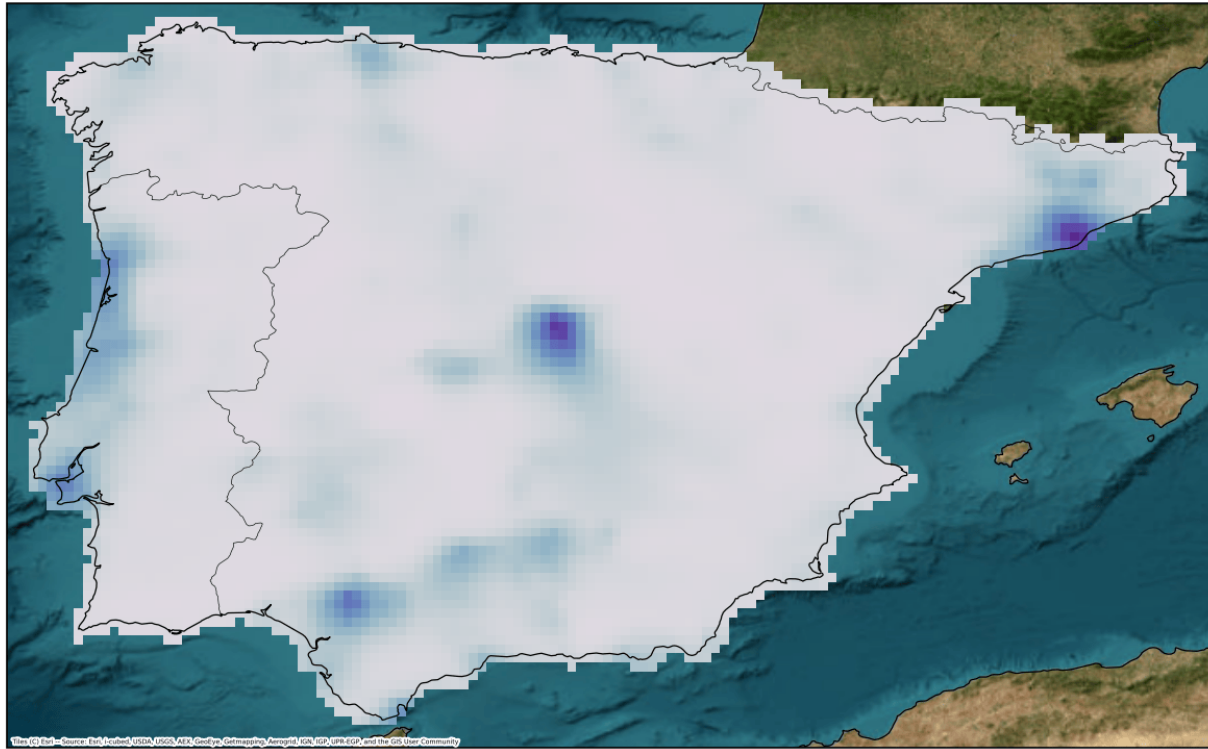


Informed decision-making

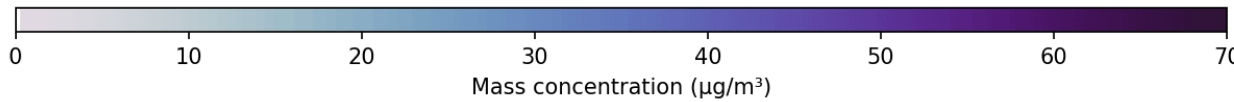
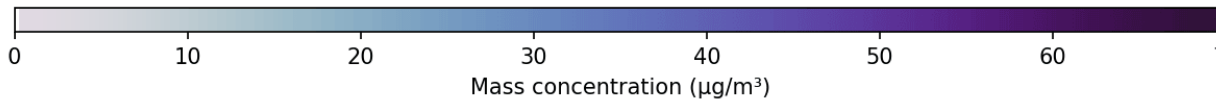
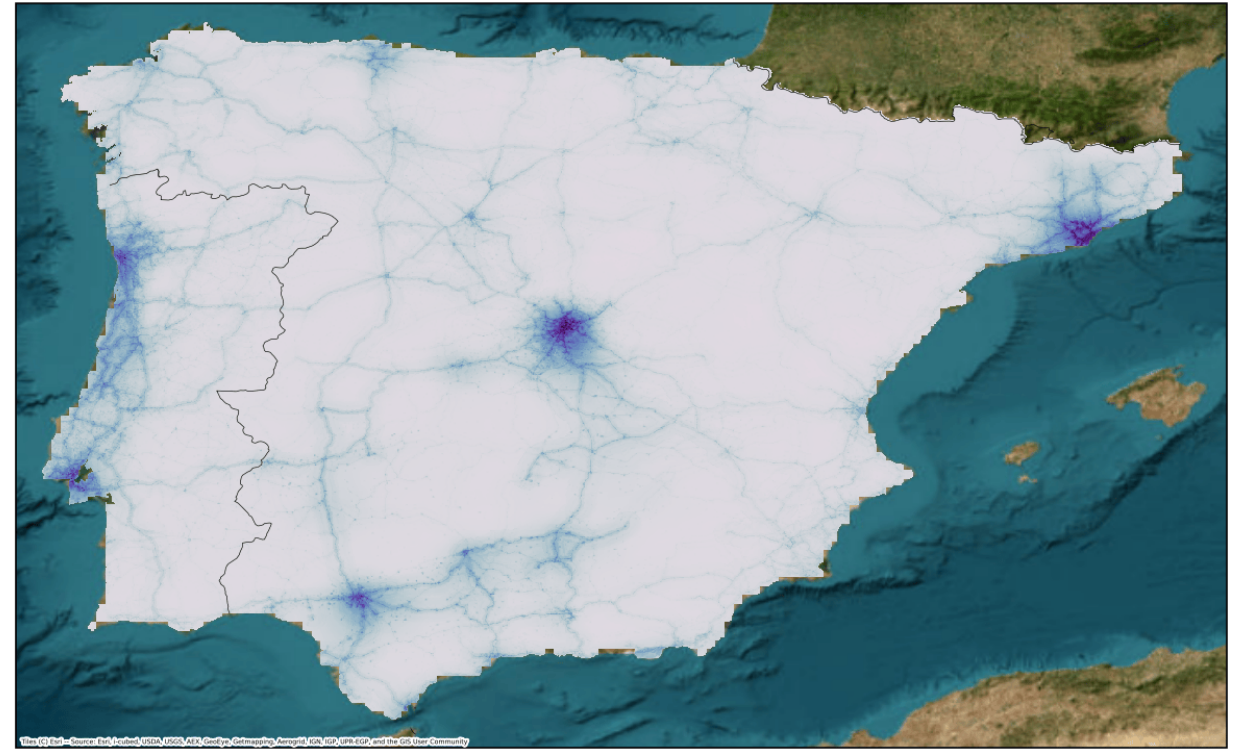
- ✓ What?
- ✓ When?
- ✓ **WHERE?**

AIR4health Results: Compound CW+NO₂ Events

CAMS NO₂ mass concentration 10km
2017-01-16

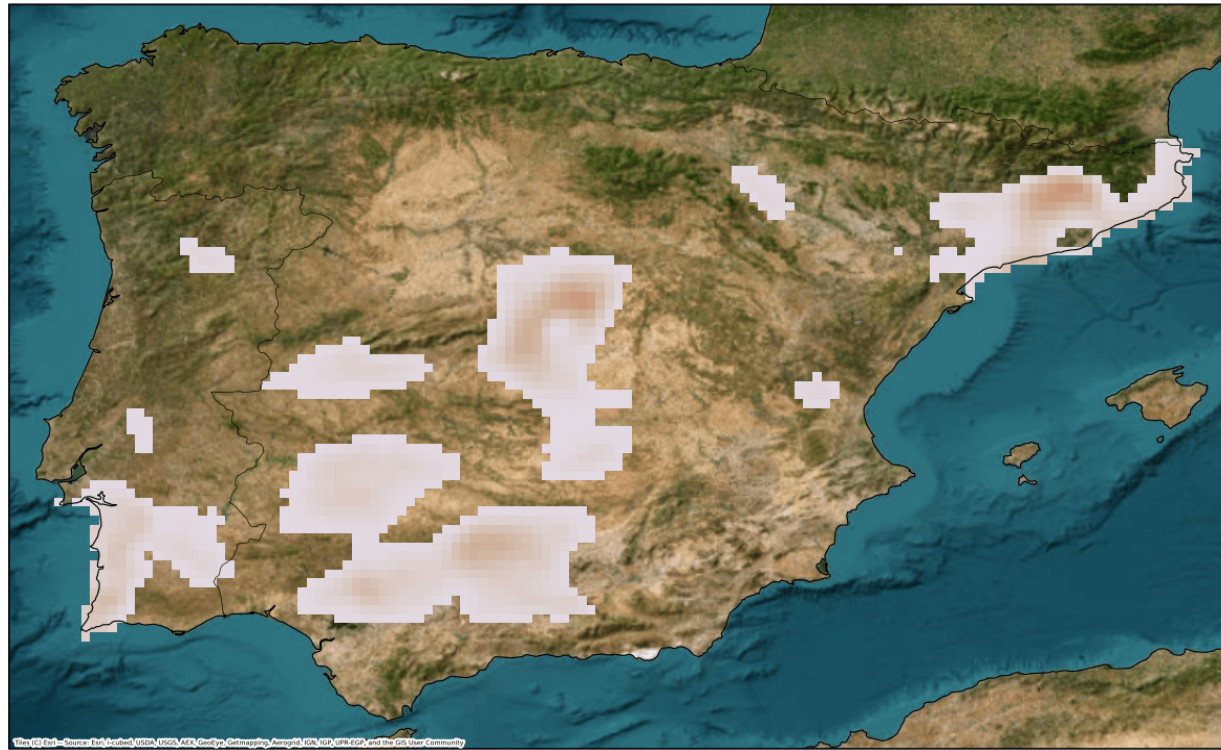


Downscaling NO₂ mass concentration
2017-01-16



AIR4health Results: Compound HW+O₃ Events

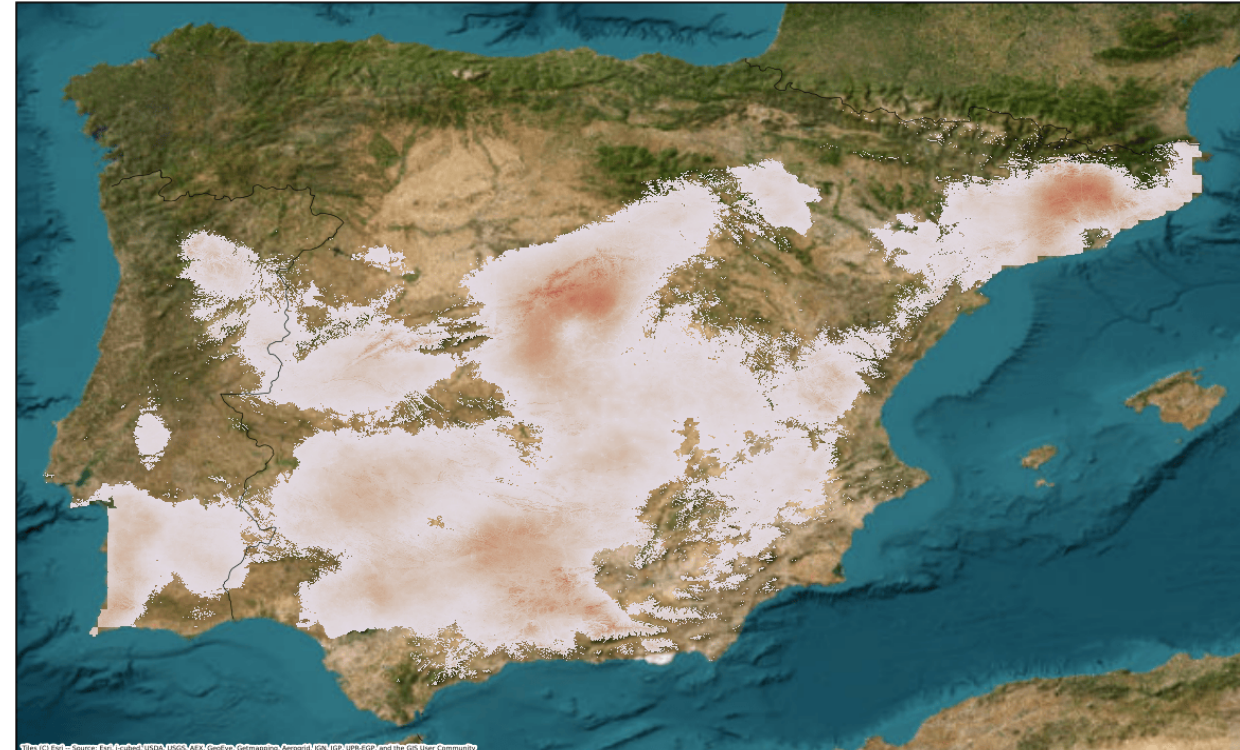
CAMS O₃ mass concentration exceedance (10 km)
2013-07-01



Mass concentration exceedance ($\mu\text{g}/\text{m}^3$)



Downscaled O₃ mass concentration exceedance
2013-07-01



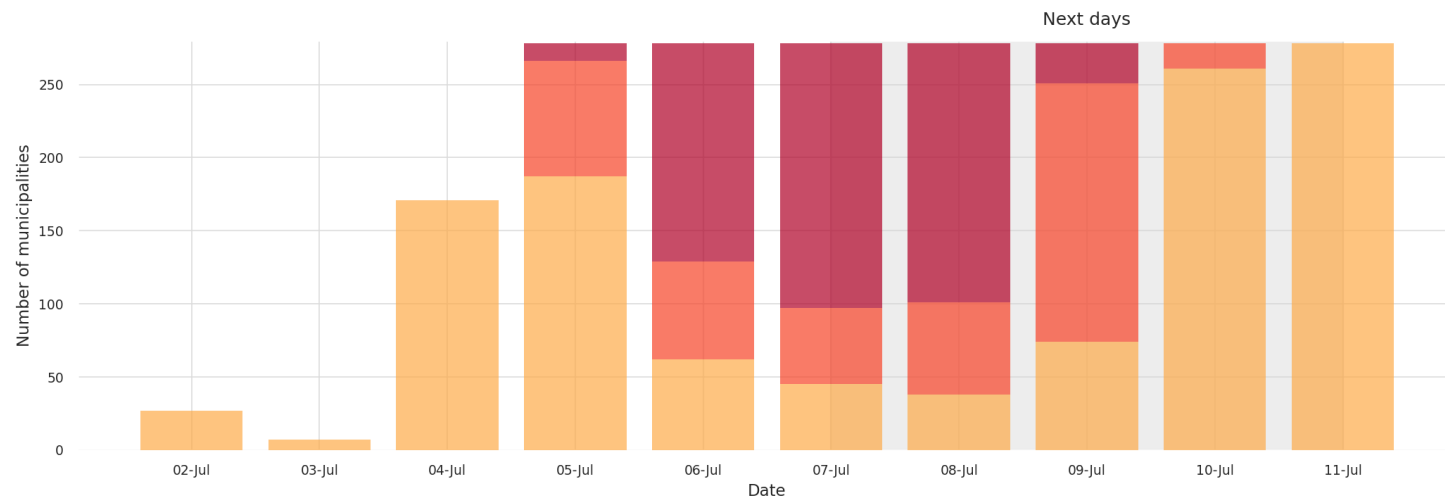
Mass concentration exceedance ($\mu\text{g}/\text{m}^3$)



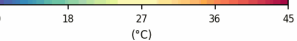
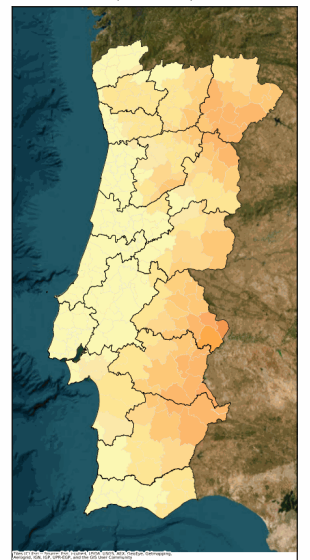
AIR4health Results: Compound HW+O₃ Events

Case in Point: [July 2013 Compound HW+O₃ Event]

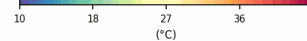
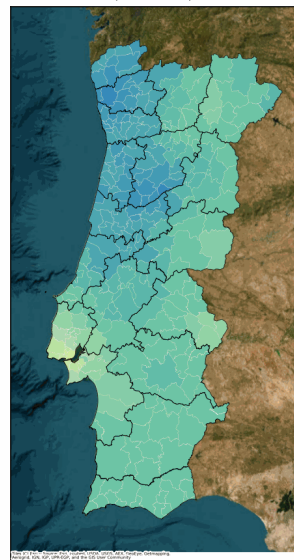
- Start Date: 05-07-2013
- End Date: 10-07-2013
- Duration: 6 consecutive days
- Max. HW intensity: 49.0°C²
- Max. O₃ Exceedance: 40.7µg/m³



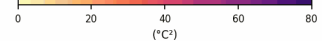
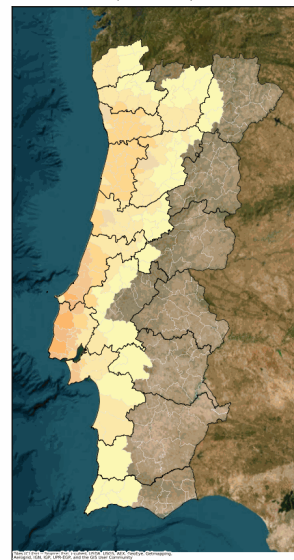
Daily Maximum Temperature (2013-07-01)



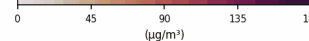
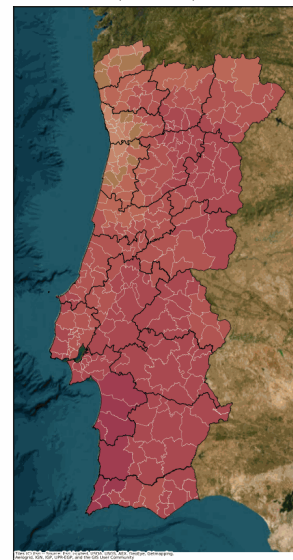
Daily Minimum Temperature (2013-07-01)



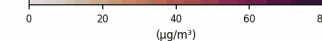
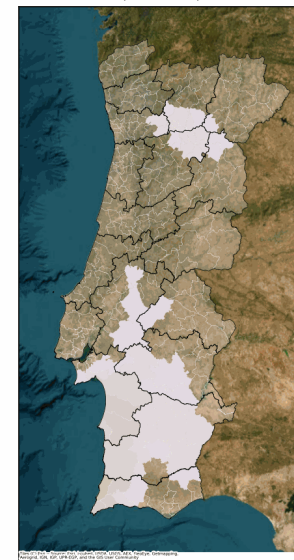
Excess Heat Factor (2013-07-01)



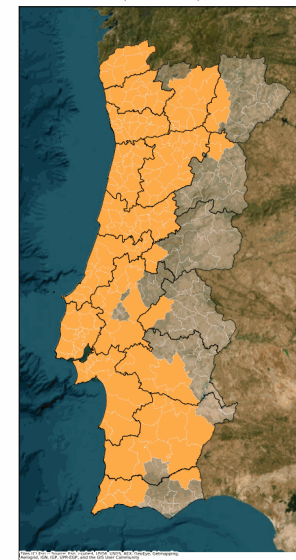
O₃ Concentrations (2013-07-01)



O₃ Exceedances (2013-07-01)



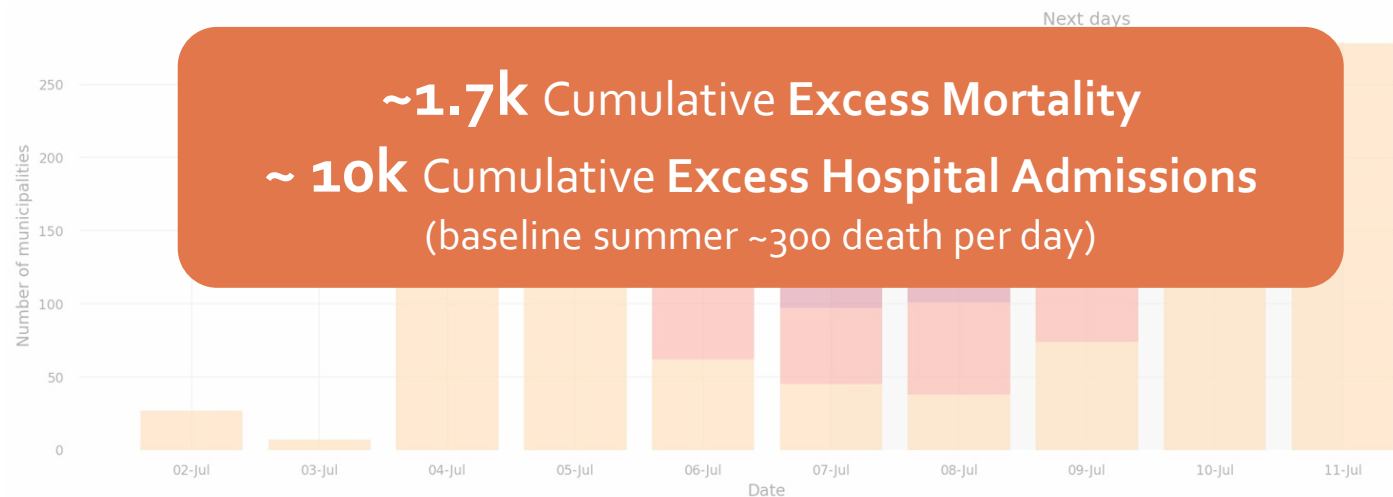
Compound Risk Index (2013-07-01)



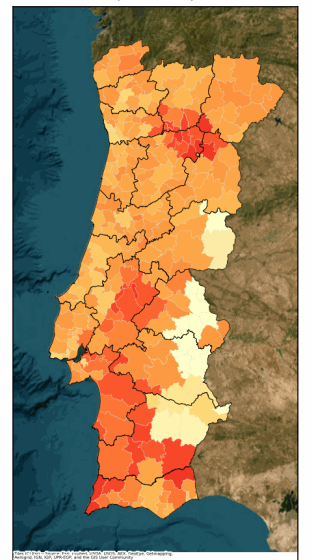
AIR4health Results: Compound HW+O₃ Events

Case in Point: [July 2013 Compound HW+O₃ Event]

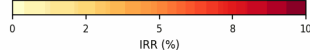
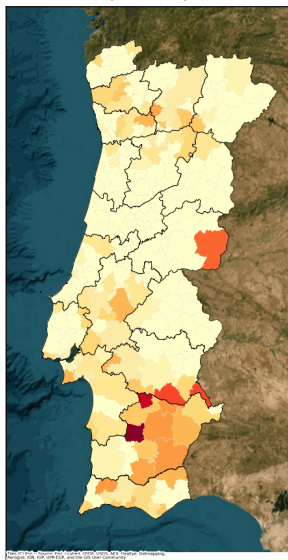
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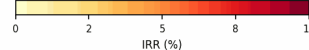
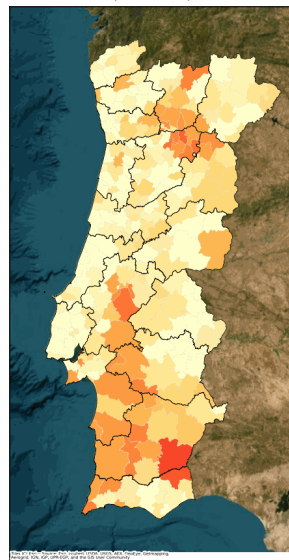
Mortality (2013-07-01)



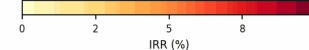
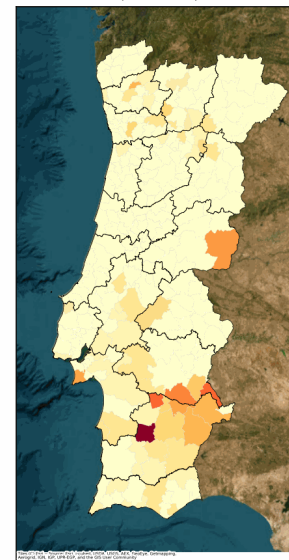
Hospital Admissions (2013-07-01)



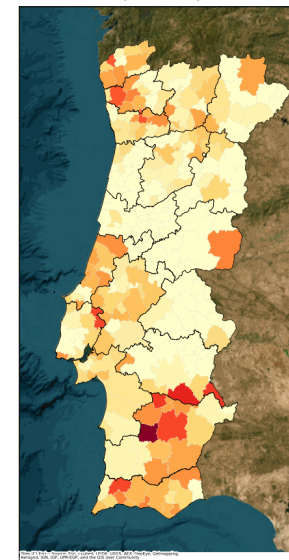
Hospital Admissions (<18 years) (2013-07-01)



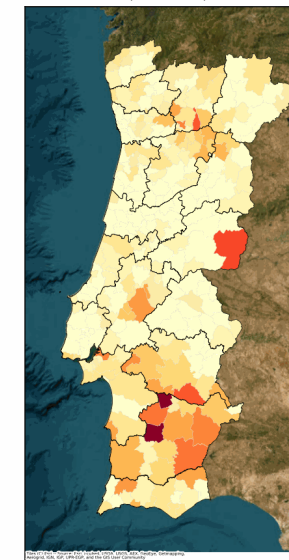
Hospital Admissions (18-64 years) (2013-07-01)



Hospital Admissions (≥65 years) (2013-07-01)



Hospital Admissions (>24 hr stay) (2013-07-01)



Compound Risk Index

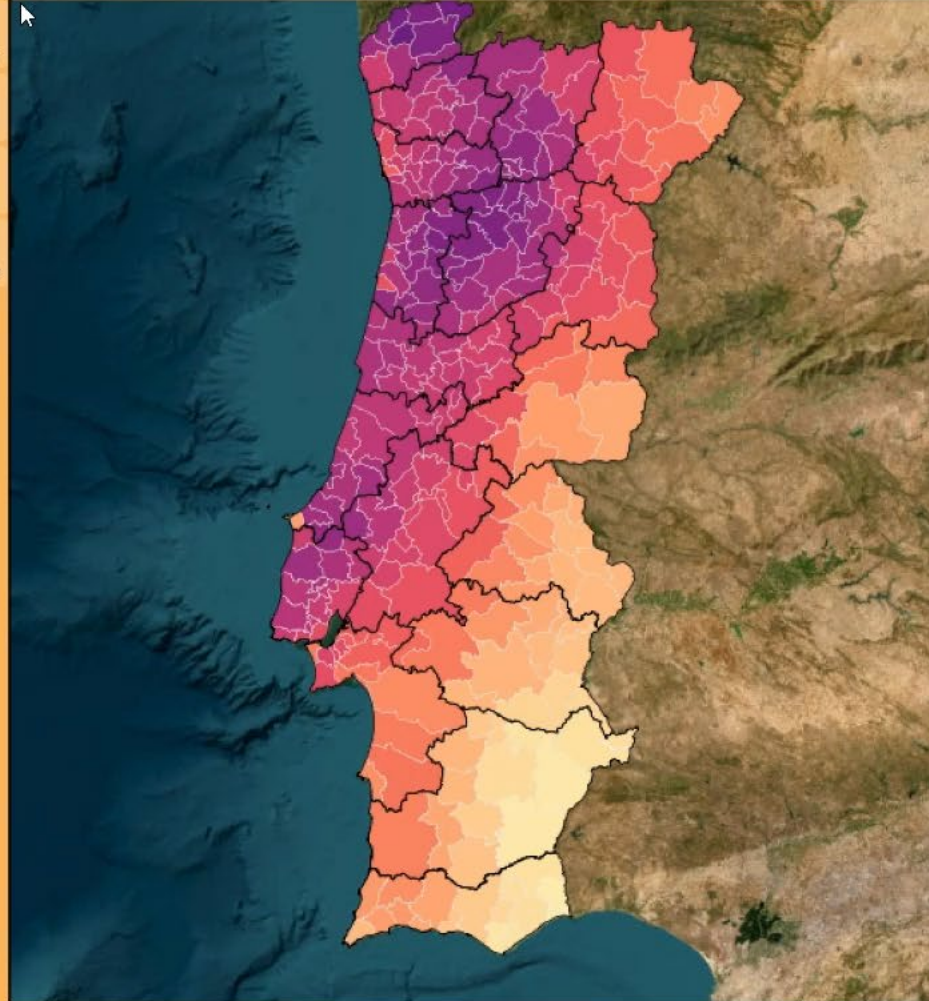
Excess Heat Factor

Daily Maximum Temperature

Daily Minimum Temperature

O3 Concentration

O3 Exceedances



Today 07/07/2025
 Tomorrow 08/07/2025
 After 09/07/2025

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Mainland

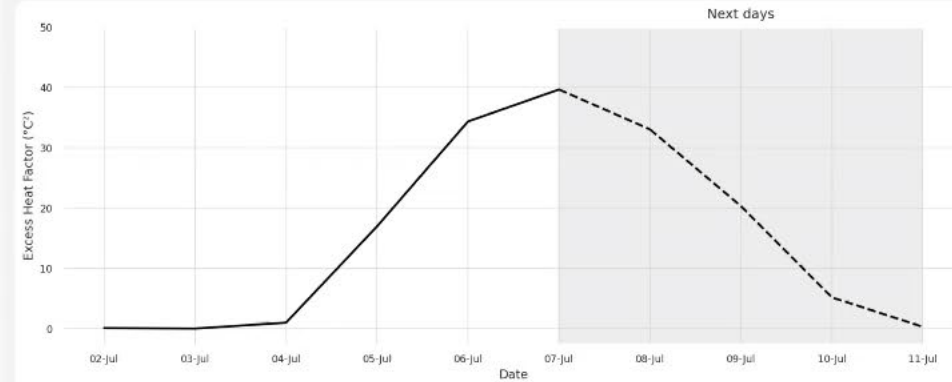
Portugal

Excess Heat Factor
40°C²

O3 Exceedance:
20 µg/m³

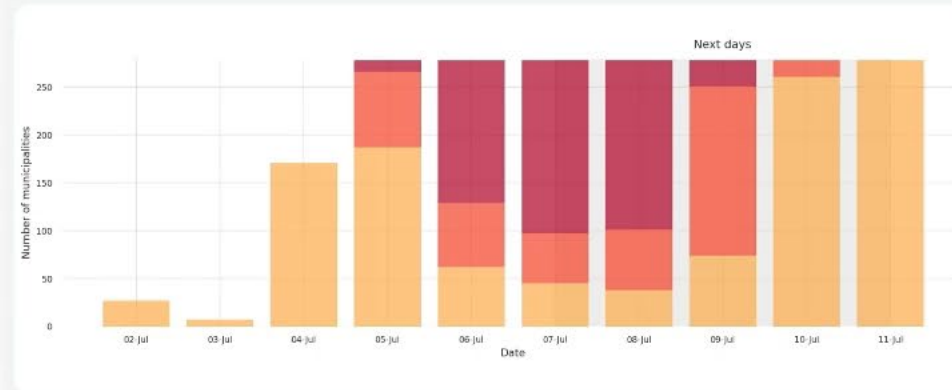
Compound Risk Index:
SEVERE

Daily Forecast of Excess Heat Factor



Daily Forecasts of Compound Risk Index

General Population
 Age >= 65 Years
 Age < 18 Years



No Risk
 Low Risk
 Moderate
 Severe Risk



Results From Previous Projects

- Air Temperature Downscaling Model over 4 Danish Cities (Copenhagen, Aarhus, Aalborg and Odense, 2020-2023, 200x200m grid size)

- Incidence Risk Ratio of Heat and Cold Waves. Impact Model per each of the 258 Municipalities (mainland Portugal, 2000-2018, 1x1km grid size)

- European Mortality Monitoring Project: routine public health mortality monitoring system. (European Countries, weekly, 2009-today)

- Global Heat Resilience Service, aiming to help every city understand the dangers of extreme heat.

Future Work within CLIM4health

- Replicate over four Functional Urban Areas (Copenhagen, Odense, Lisbon and Oporto) by downscaling a multi-decadal historical time series (2000-2018) of near-surface air temperature and heat/cold extremes
- Employ ML downscaling on Climate Projections using the CLIMATE DT scenarios inputs

- Calculate extremes Incidence Risk Ratio using the air temperature ML inputs at the sub-municipal level (200x200m grid size), over a multi-decadal period (200-2018)
- Include socio-economic confounding factors
- Replicate de Incidence Risk Ratio using the CLIMATE DT and the UN Population Prospects Scenarios inputs

- A Benchmark and Methodological Framework for EO -driven support of the Global Heat Resilience Service



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The Global Heat Resilience Service (GHR) will provide every urban area in the world with actionable intelligence on the health and economic risks of exposure to extreme heat.

GHR is currently piloting approaches to delivering heat resilience information to cities in Brazil, India, Sierra Leone, and urban areas in Europe.

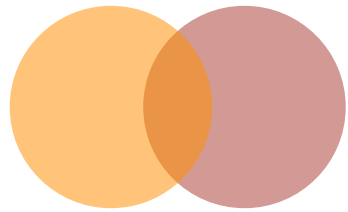


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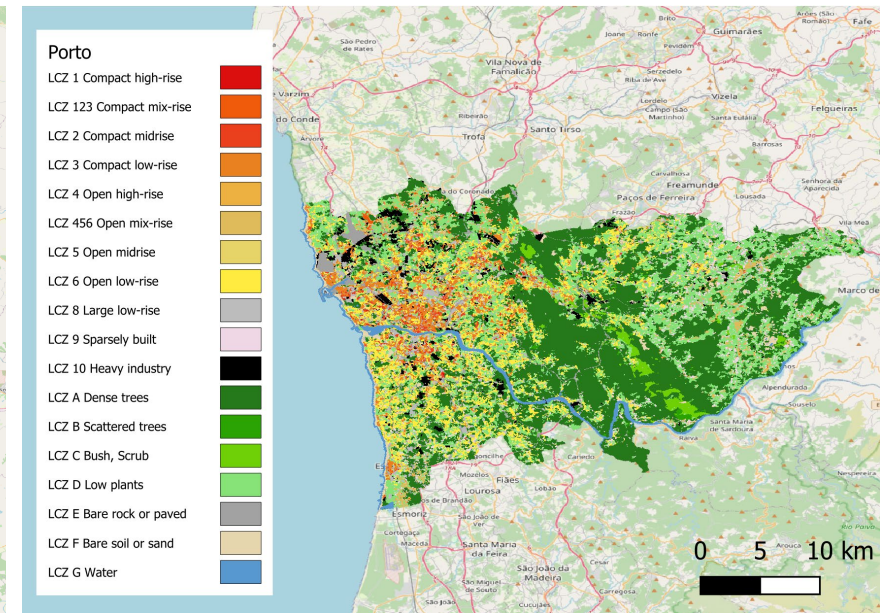
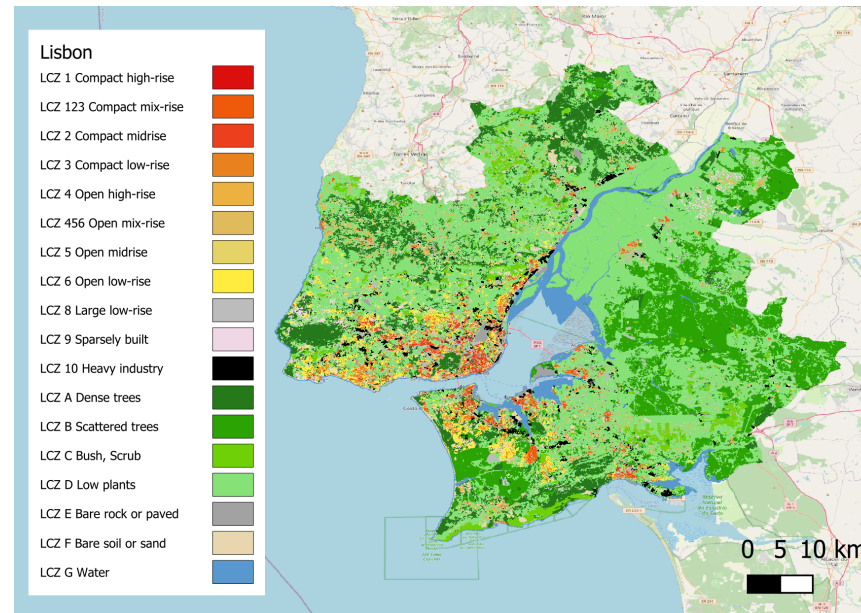
- A Benchmark and Methodological Framework for EO-driven support of the Global Heat Resilience Service

CLIM4health Overview

- The **CLIM4health** overarching goal is thus to develop symmetrical **Extreme Cold and Extreme Heat Climate-Health Risk Indices** (CLIM4health Risk Algorithms) for predicting excess **mortality** and **morbidity** by gender, age group and major diagnostic groups, at the sub-municipal level, over a **total of 4** (four) **metropolitan Functional Urban Areas (FUAs)** in **Portugal** and in **Denmark**, by considering **EO-based land surface indicators** such as vegetation indices, urban density and land cover classes.

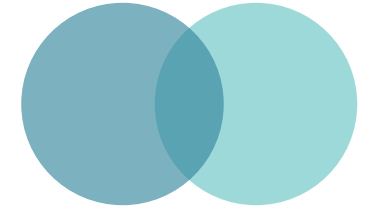
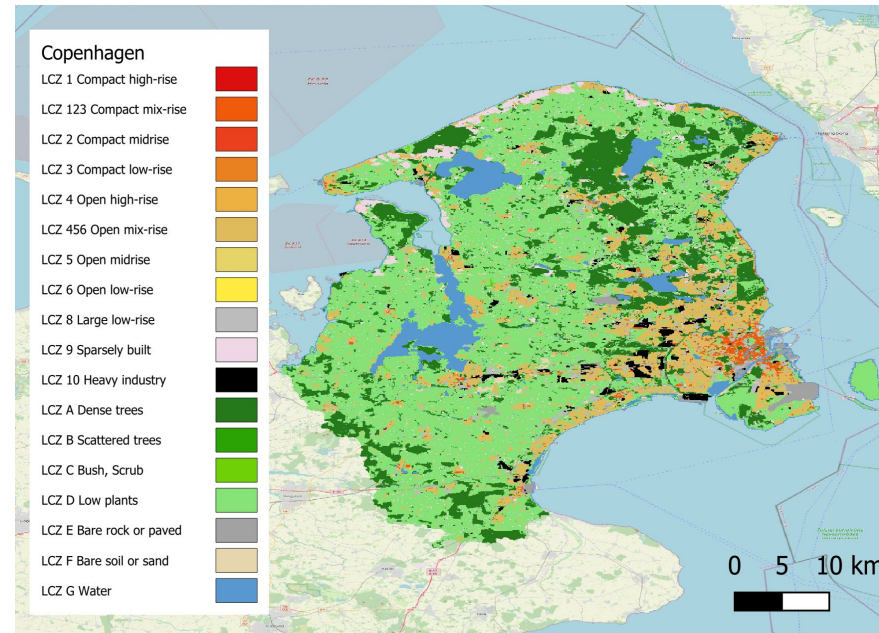
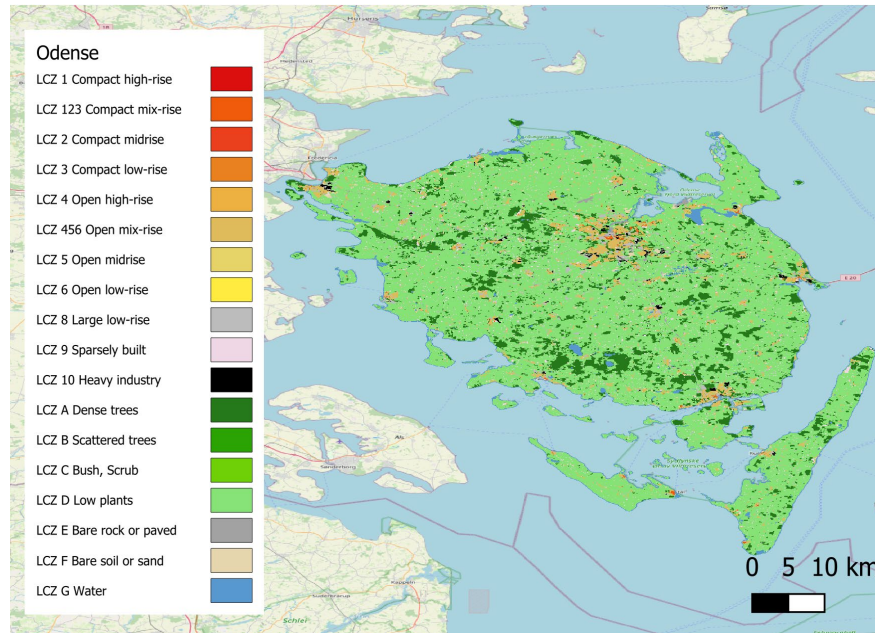


Use Case Group 1, Portugal



CLIM4health Overview

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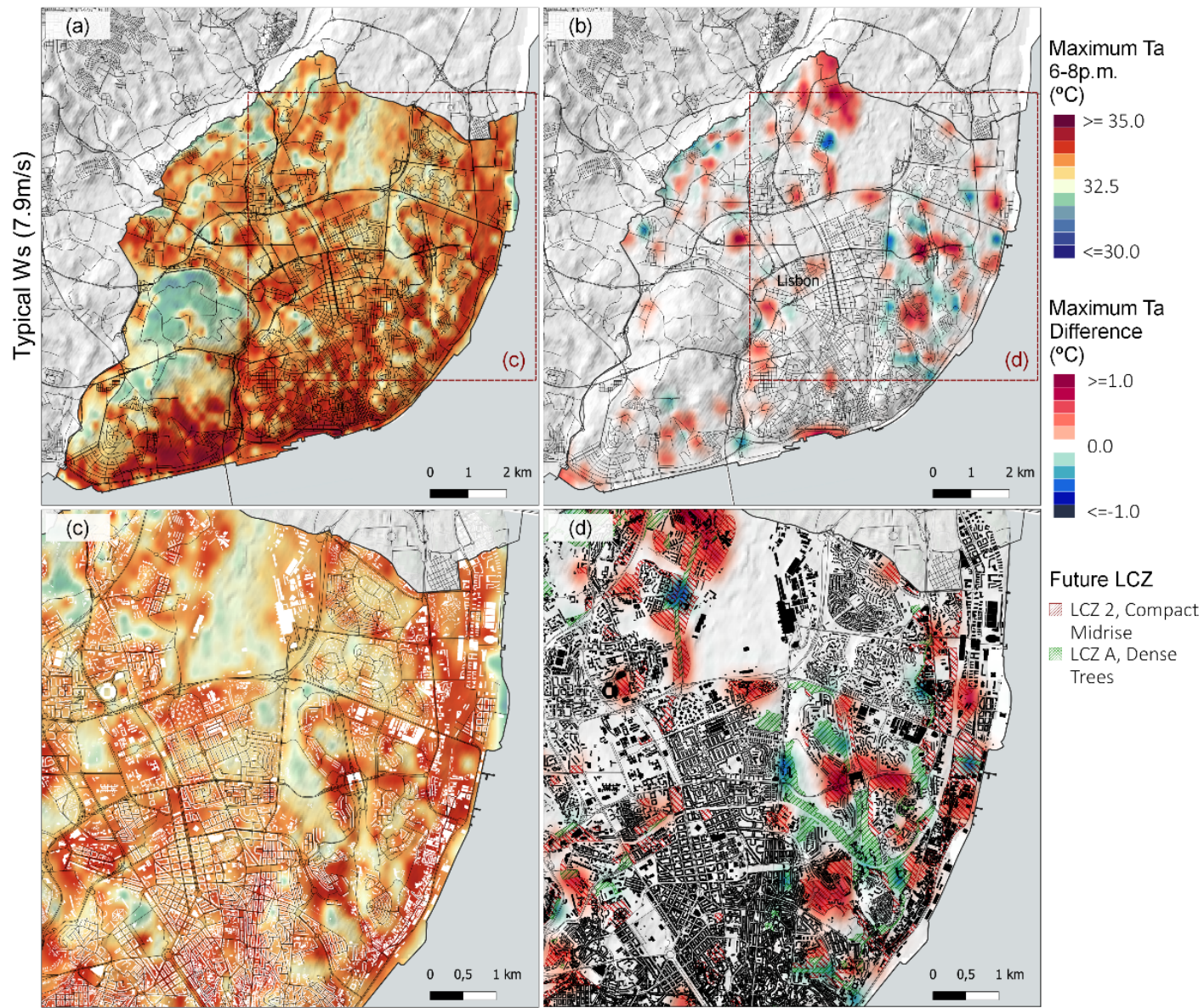
Use Case Group 2, Denmark

CLIM4health Overview



'Future HW day', 'Denser City' scenario
(Tr: 32°C, Tr_d2h: 3.5°C)

Ta Difference between 'Current City' and 'Denser City' scenarios



Intercomparison between 'Current City' and 'Denser City' Scenarios
Source: CoLAB +ATLANTIC

CLIM4health Overview

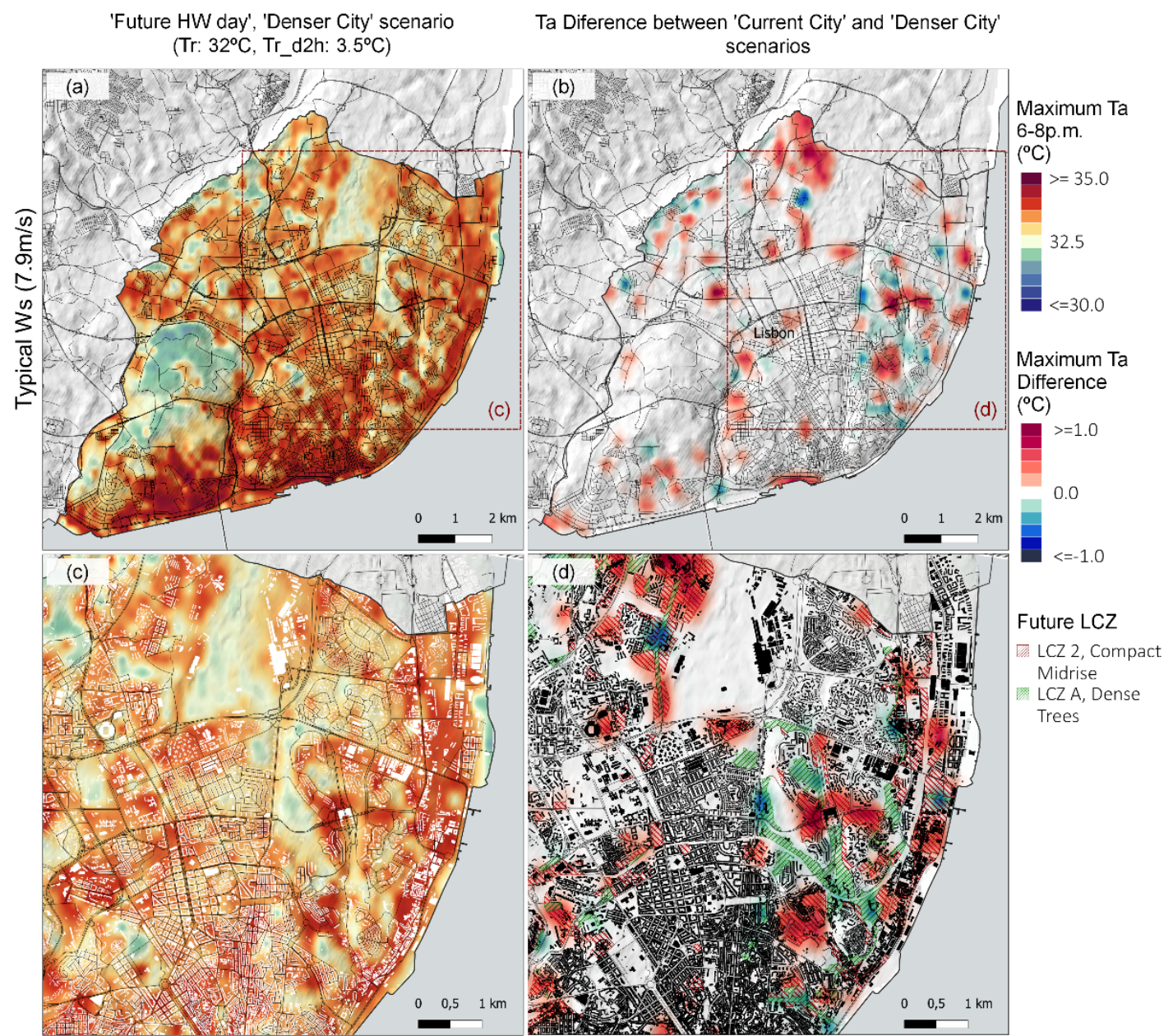
How much cooler/warmer a neighbourhood is, compared to the long-term average climate?



How extreme is the heat (cold) in a given neighbourhood, compared to the local temperature range?



Which are the cooling (heating) acclimatization needs, in each neighbourhood?



Intercomparison between 'Current City' and 'Denser City' Scenarios
Source: CoLAB +ATLANTIC



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Ana Luisa Almeida
COO



Ana Oliveira
CTO Space



Ana Rodrigues



André Brito



André Oliveira



Andreia Silva



Artur Costa



Beatriz Lopes



Bruno Marques



Caio Fonteles



Catarina Cecilio



Cintia Bonanad



Élio Pereira



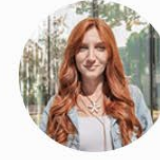
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Inês Girão



Inês de Sousa Magusteiro



Iñigo Aguilera



João Paixão



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Marcelo Lima



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CEO



Paula Salge



Pedro Armada



Rita Cunha



Rui Baeta



Sara Freitas



Soraia Romão



Teresa Costa



Tiago Garcia



Vitor Miranda

THANK YOU!

Ana Oliveira, on behalf of the **AIR4health**, **CLIM4cities** and the **CLIM4health** Project Teams

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