Using ECMWF's Forecasts Event (UEF2026)
1 - 4 June 2026 | ECMWF | Reading, UK

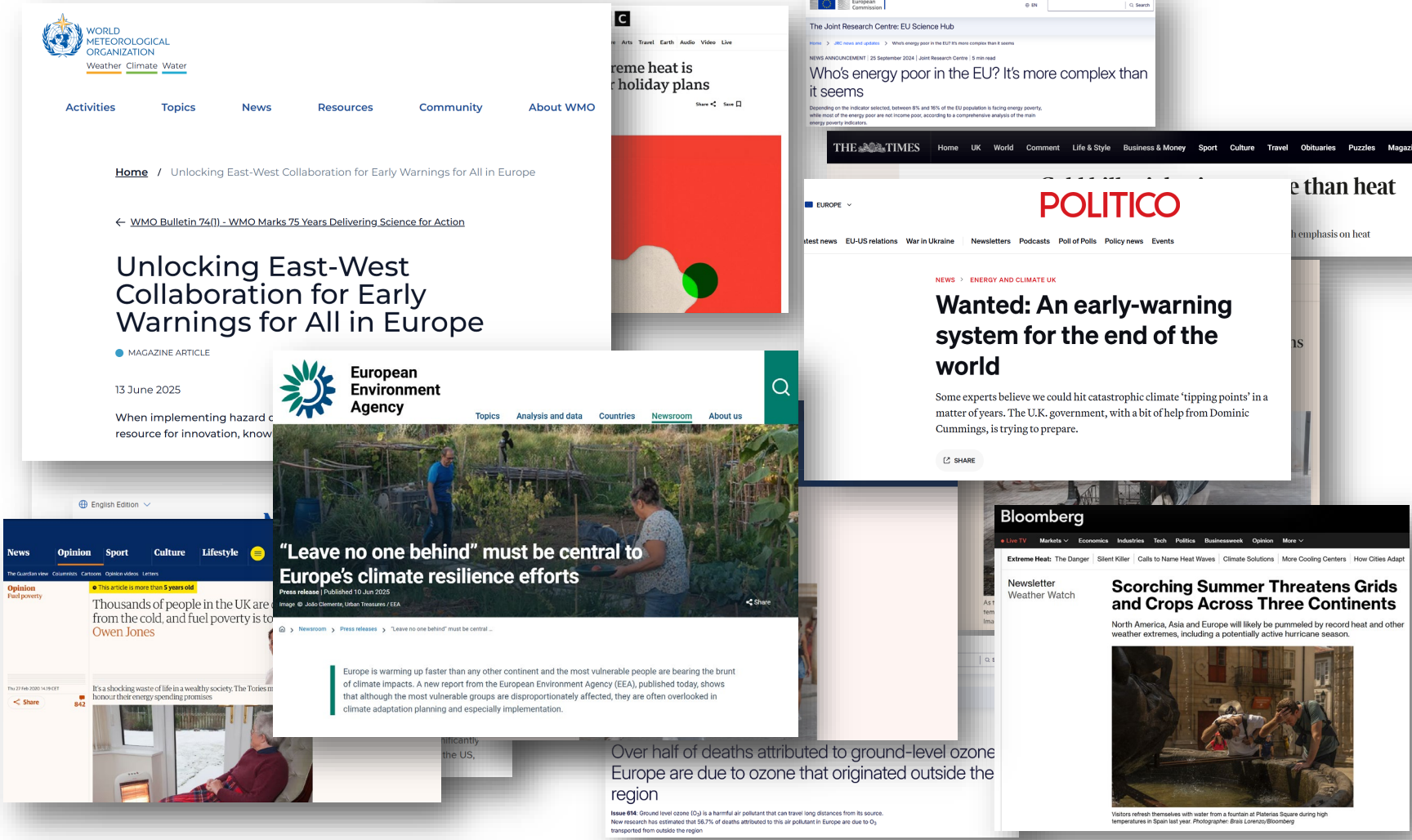
Climate and Environmental Digital Twins for Human Health: Leveraging Earth Observation for Compound Climate and Air Quality Extremes Early Warning

Ana Oliveira, on behalf of the **AIR4health Team**
ana.oliveira@colabatlantic.com, air4health_tech@colabatlantic.com

AIR4health 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.

AIR4health Motivation: **WHY?**

AIR4health 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.


WORLD METEOROLOGICAL ORGANIZATION
Weather Climate Water
Activities Topics News Resources Community About WMO
Home / Unlocking East-West Collaboration for Early Warnings for All in Europe
WMO Bulletin 74(1) - WMO Marks 75 Years Delivering Science for Action
Unlocking East-West Collaboration for Early Warnings for All in Europe
MAGAZINE ARTICLE
13 June 2025
The Joint Research Centre: EU Science Hub
Who's energy poor in the EU? It's more complex than it seems
THE TIMES
Home UK World Comment Life & Style Business & Money Sport Culture Travel Obituaries Puzzles Magazines
POLITICO
EUROPE
Newsletters Podcasts Poll of Polls Policy news Events
NEWS > ENERGY AND CLIMATE UK
Wanted: An early-warning system for the end of the world
Some experts believe we could hit catastrophic climate 'tipping points' in a matter of years. The U.K. government, with a bit of help from Dominic Cummings, is trying to prepare.
SHARE
European Environment Agency
Topics Analysis and data Countries Newsroom About us
"Leave no one behind" must be central to Europe's climate resilience efforts
Press release | Published 10 Jun 2025
Europe is warming up faster than any other continent and the most vulnerable people are bearing the brunt of climate impacts. A new report from the European Environment Agency (EEA), published today, shows that although the most vulnerable groups are disproportionately affected, they are often overlooked in climate adaptation planning and especially implementation.
Bloomberg
Extreme Heat: The Danger | Silent Killer | Calls to Name Heat Waves | Climate Solutions | More Cooling Centers | How Cities Adapt
Newsletter
Weather Watch
Scorching Summer Threatens Grids and Crops Across Three Continents
North America, Asia and Europe will likely be pummeled by record heat and other weather extremes, including a potentially active hurricane season.
Over half of deaths attributed to ground-level ozone in Europe are due to ozone that originated outside the region
News Opinion Sport Culture Lifestyle
Opinion
Fuel poverty
Thousands of people in the UK are dying from the cold, and fuel poverty is to blame
Owen Jones

Motivation

Climate and Environmental Hazards are **LOCAL**

Forecasts and projections **ARE NOT**

✓**OK** regarding **WHEN**

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

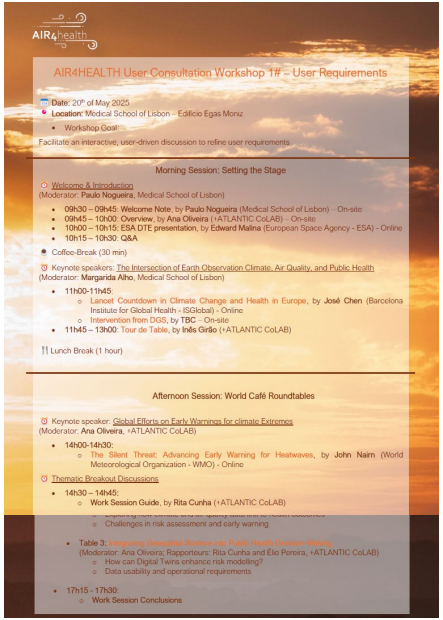
AIR4health Objectives: **TO WHOM?**

AIR4health 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.

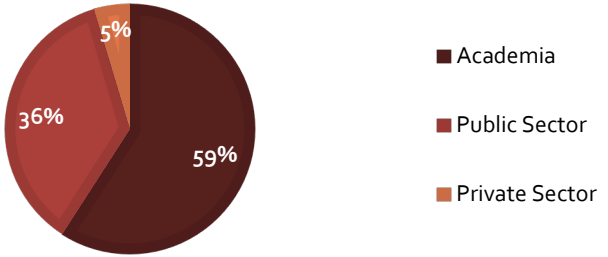
AIR4health Usage Scenarios

2 Workshops were held:

- **In 20th of May of 2025**: User Needs and Requirements.
- **In 13rd of January of 2026**: Demonstration and Validation.

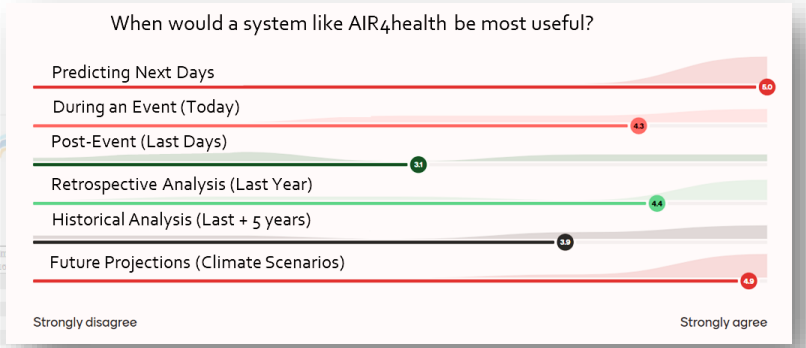


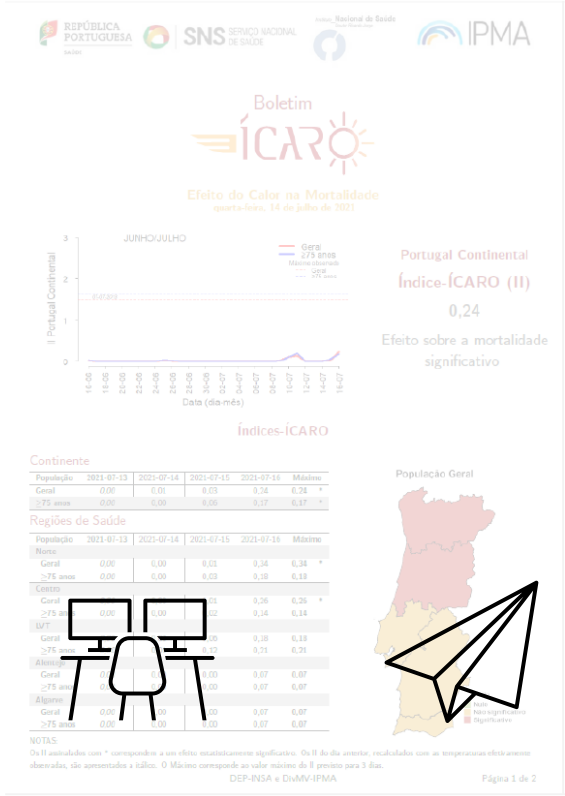
PARTICIPANTS SECTORS

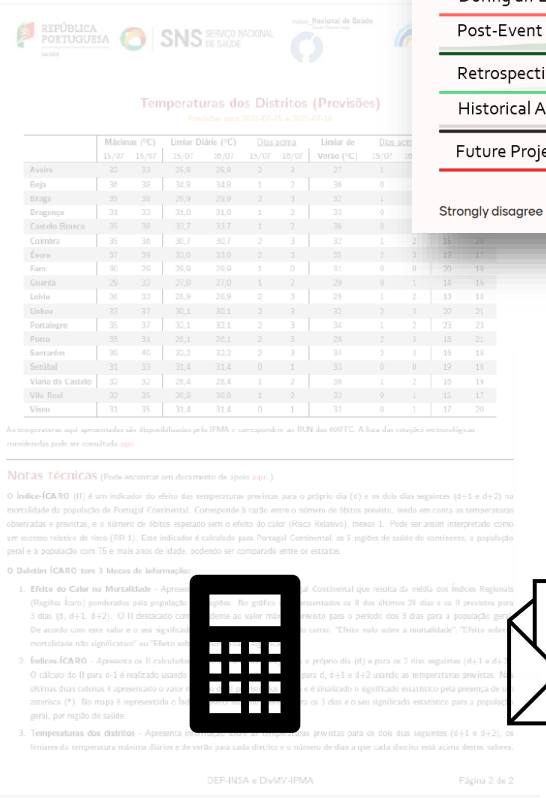


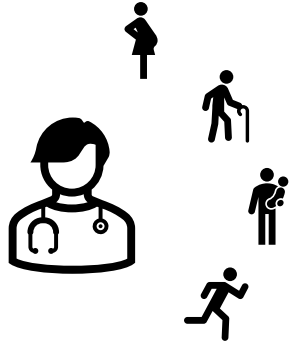
AIR4health is under a programme of, and funded by, the European Space Agency.
Views expressed do not reflect the official opinion of the European Space Agency.

AIR4health Usage Scenarios



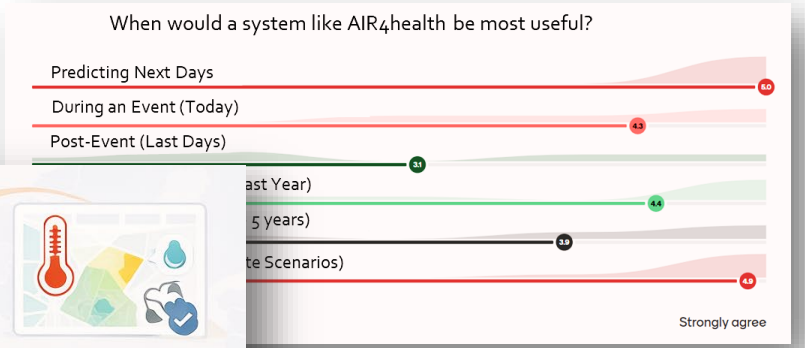






AIR4health is under a programme of, and funded by, the European Space Agency.
Views expressed do not reflect the official opinion of the European Space Agency.

AIR4health Usage Scenarios



Integrated AIR4health Seasonal Surveillance System

AIR4health 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.

AIR4health Approach: **HOW?**

AIR4health 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.

AIR4health Objectives

Local-relevant FITNESS FOR PURPOSE

Empirical Approach to Hazard Mapping

COST-EFFICIENT for All Users

Open-Science Approach and Reproducibility

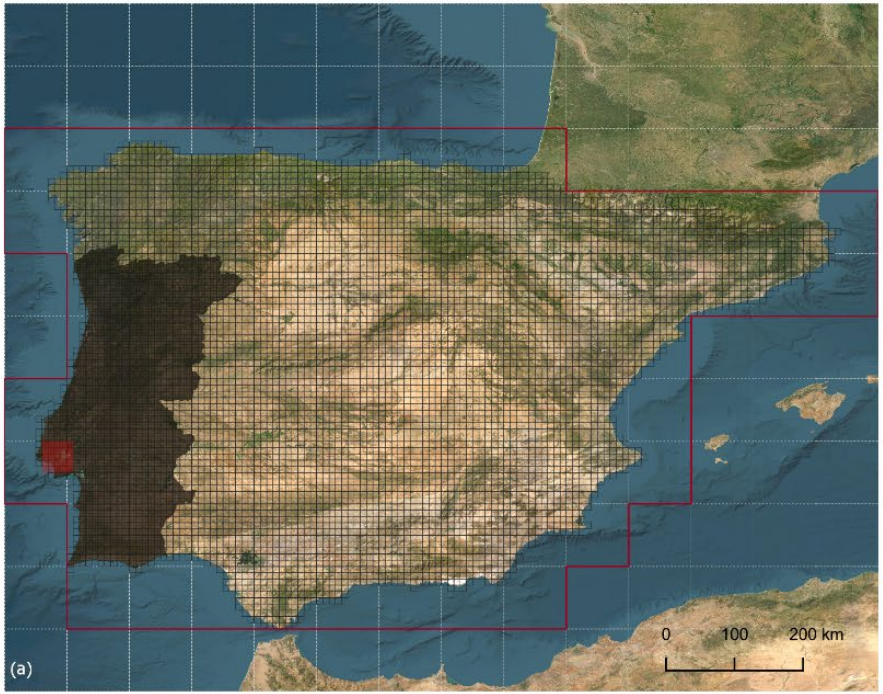
SCALABILITY Across Urban Areas

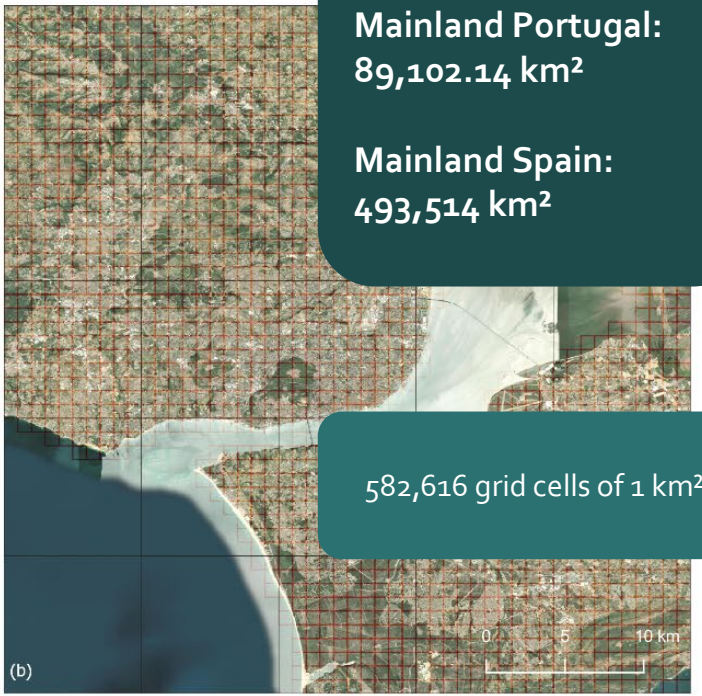
Wide Coverage and Scalability

THE AIM is: A Digital Twin Solution for Compound Climate and Air Quality Monitoring and Forecasting Service for Human Health

AIR4health 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.

AIR4health Approach





Mainland Portugal: 89,102.14 km²

Mainland Spain: 493,514 km²

582,616 grid cells of 1 km²

Outline of the Area of Interest (AoI), corresponding to the mainland Iberian Peninsula

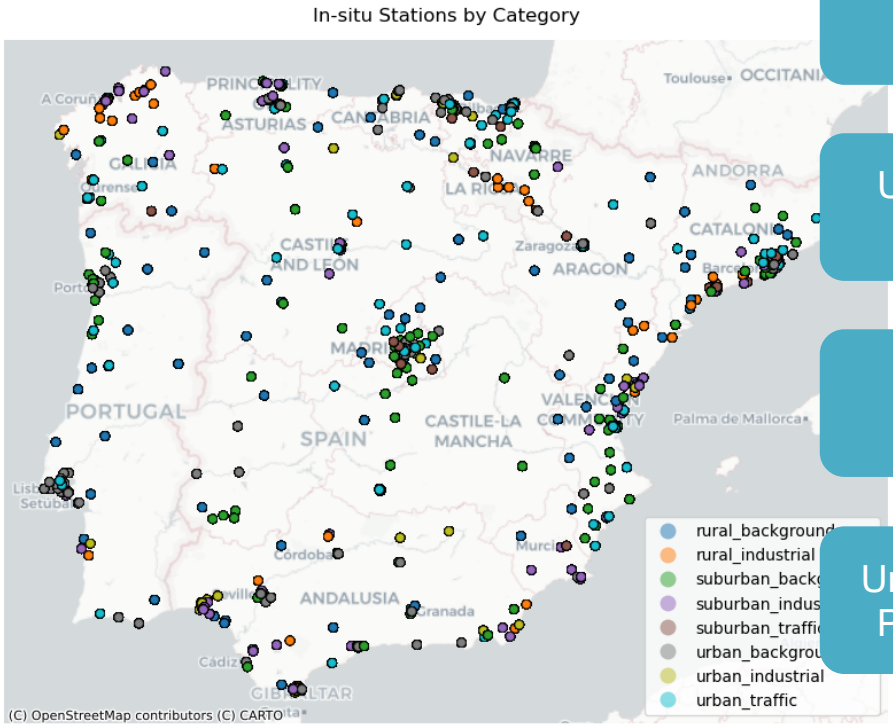
AIR4health Experimental Dataset, low resolution 0.10x0.10° grid (v1.1)

AIR4health Experimental Dataset, high resolution 0.01x0.01° grid (v2.1)

Mainland Portugal AoI

AIR4health 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.

AIR4health Approach



~680 stations

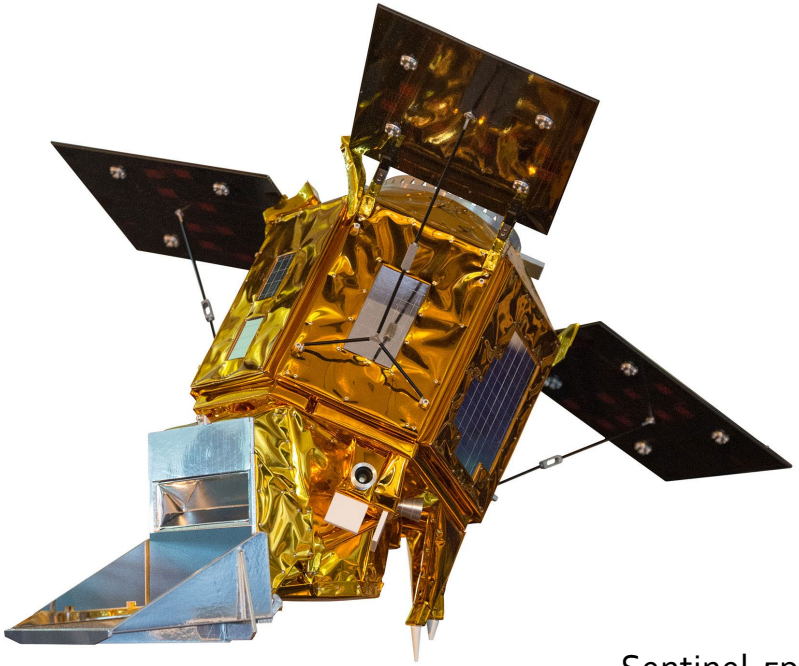
Uneven across site typologies

Inhomogenous in terms of spatial coverage

Unbalanced between Portugal and Spain

AIR4health 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.

AIR4health Approach



Sentinel-5p

2 x daily revisits in adjacent orbits over the AoI

Even across site typologies

Homogenous in terms of spatial coverage

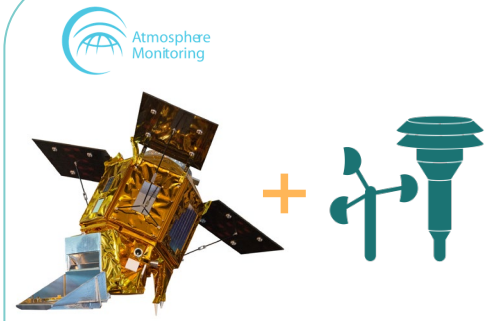
Balanced between Portugal and Spain

AIR4health 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.

AIR4health Approach

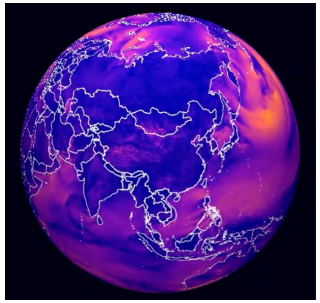
Observations

Sensors, Sentinel-5p, CAMS Reanalysis



Synoptic (Background) Conditions

CAMS Reanalysis (CAMS Forecasts)



Local (Time-Fixed) Predictors

Landscape and Urban Features

Topography

Terrain, Topographic Wind Exposure

Green/Blue Features

Vegetation Density and Type, Phenology

Urban Features

Urban Density, Imperviousness, Sky View Factor

Human Activity

Proximity to traffic lanes per typology

Machine Learning

Domain-Informed Data-driven Downscaling

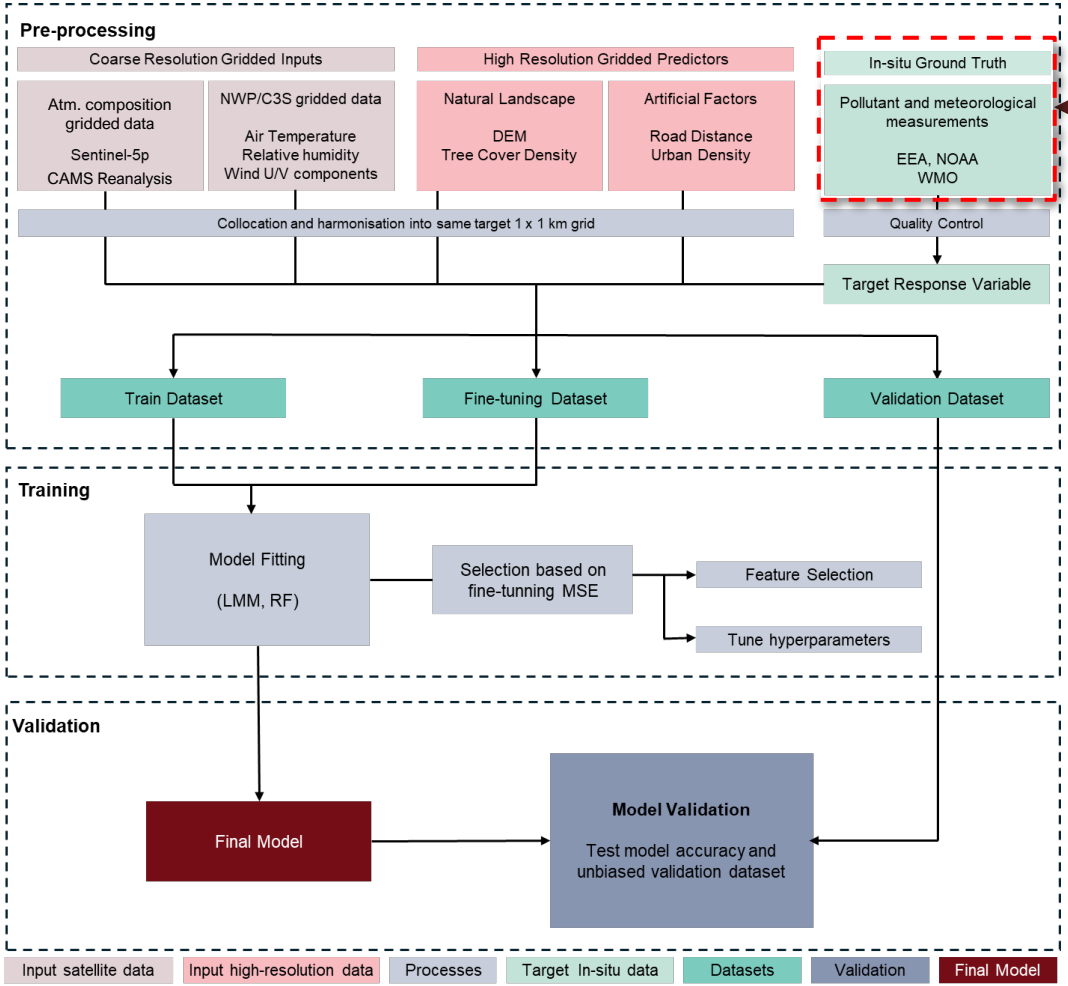
Informed decision-making

- ✓ What?
- ✓ When?
- ✓ **WHERE**?

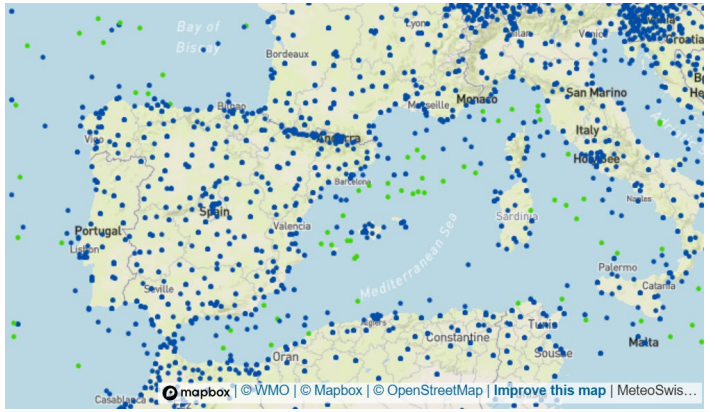
AIR4health is under a programme of, and funded by, the European Space Agency.
Views expressed do not reflect the official opinion of the European Space Agency.

AIR4health Use Case I: Compound CW + NO_2 Events

AIR4health 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.

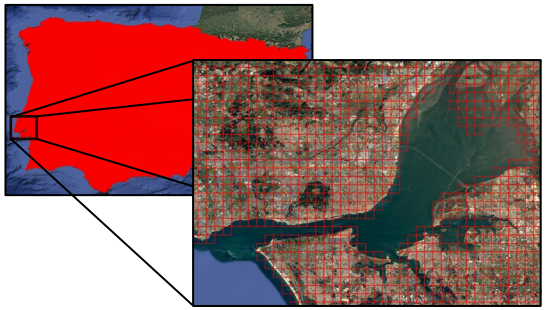


Station of In-situ, European Environment Agency (EEA), Verified hourly data (E1a)

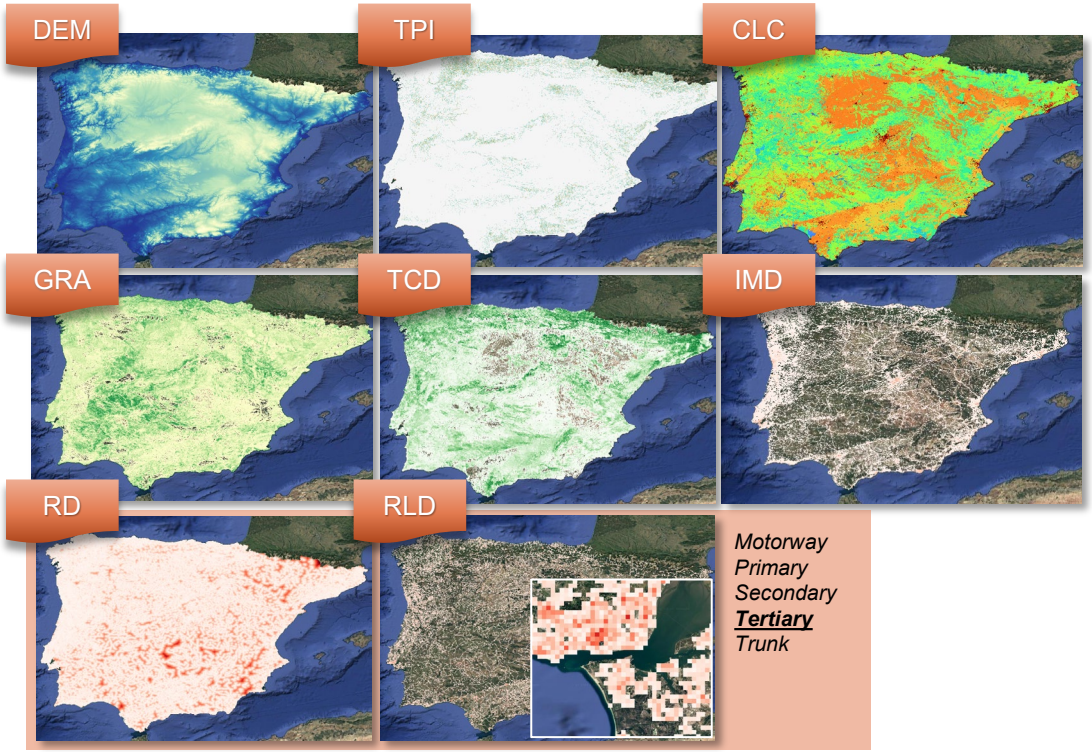


Station of In-situ, OSCAR/Surface, World Meteorological Organization

AIR4health Approach



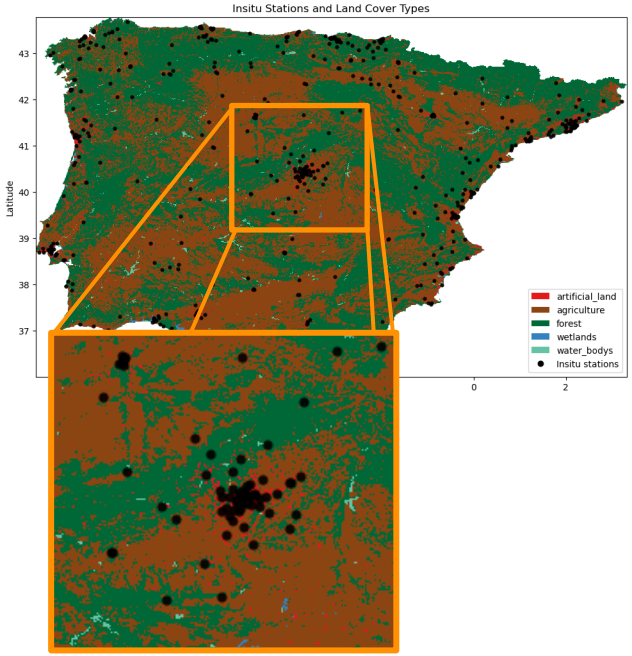
Layer	Source	Method
Elevation (DEM)	Copernicus	Mean
Topographic Position Index (TPI)	DEM-Copernicus	Mean
Corine Land Cover (CLC)	CLMS	Majority
Grasslands (GRA)	CLMS	Mean
Tree Cover Density (TCD)	CLMS	Mean
Imperviousness Density (IMD)	CLMS	Mean
Roads Length Density (RD)	OSM	NA
Roads Distance (RP)	OSM	NA



AIR4health 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.

AIR4health Approach

Input



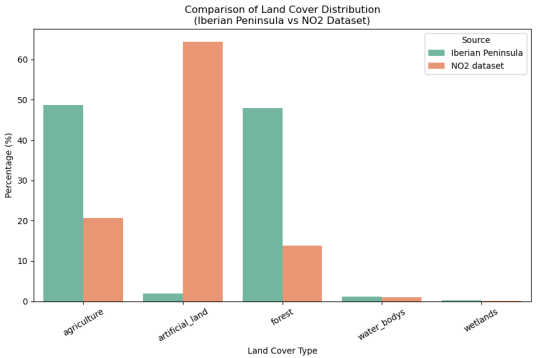
Stratified Weighted Sampling Equation

$$\omega_c = \left(\rho_c^{\beta}\right) \cdot \left(\sigma_c^{\alpha}\right) \cdot \left(\frac{1}{d_c}\right)^{\gamma}$$

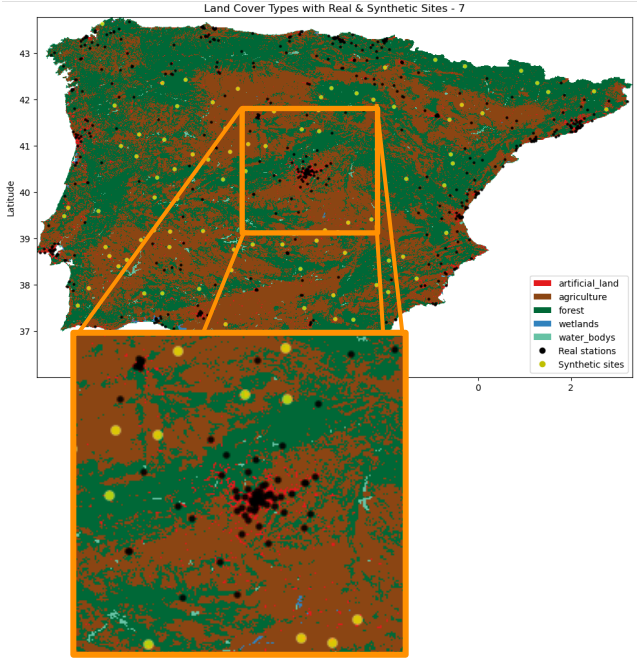
$\left(\rho_c^{\beta}\right)$ = Proportions of each LC type

$\left(\sigma_c^{\alpha}\right)$ = Prioritise classes with higher MAD

$\left(\frac{1}{d_c}\right)^{\gamma}$ = Proportions of stations in each LC type

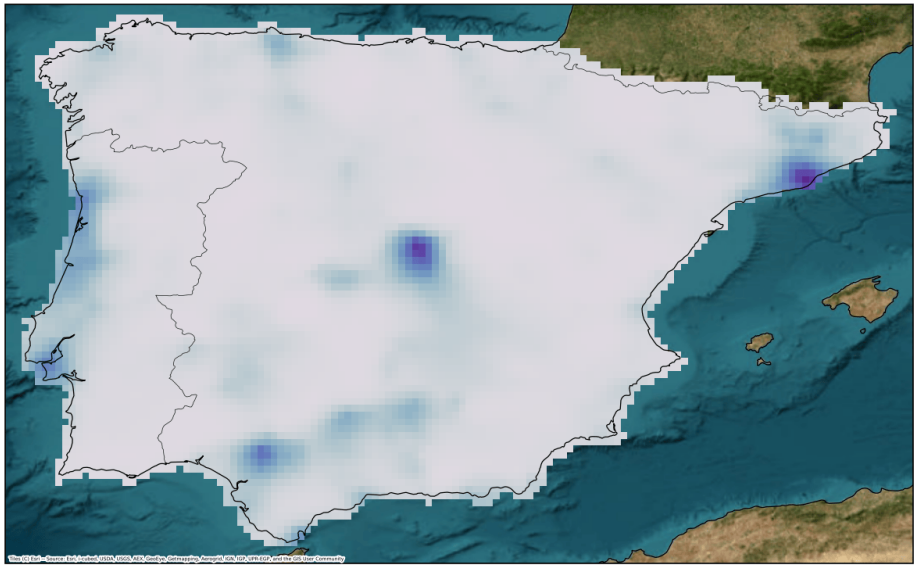


Output

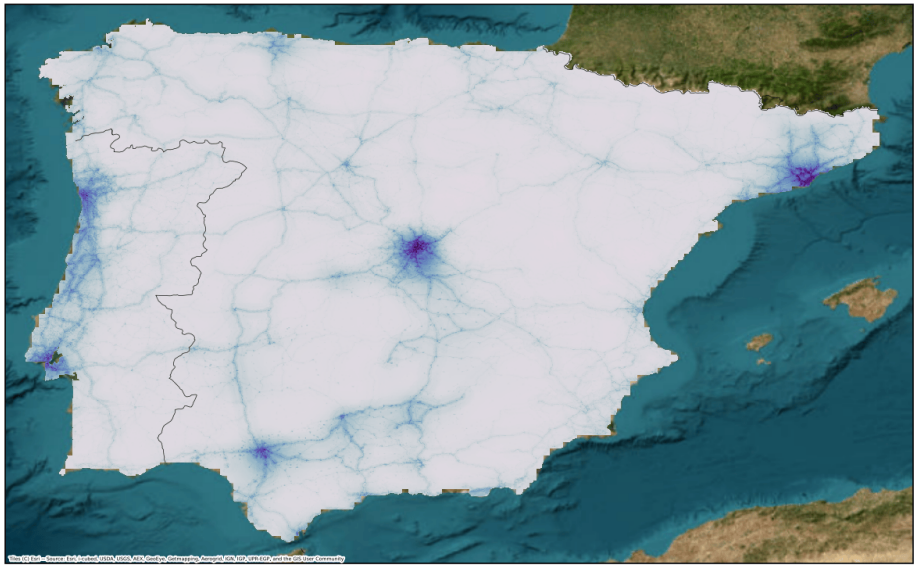


AIR4health Results: Compound CW+NO_2 Events

CAMS NO_2 mass concentration 10km
2017-01-16



Downscaling NO_2 mass concentration
2017-01-16



AIR4health 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.

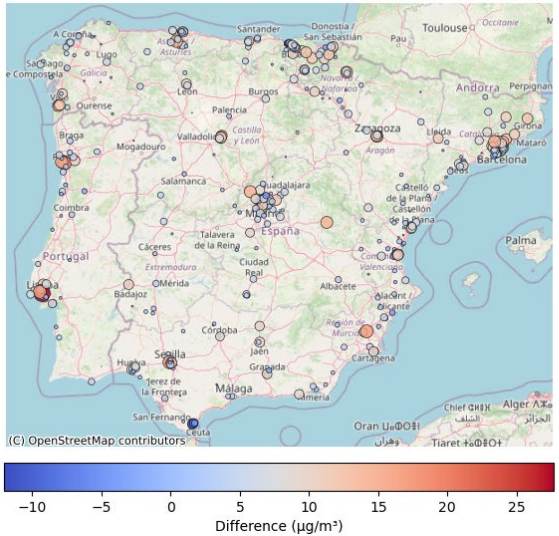
AIR4health Results: Compound CW+NO_2 Events

In-situ versus CAMS: the added-value of SENTINEL-5P for NO2 downscaling

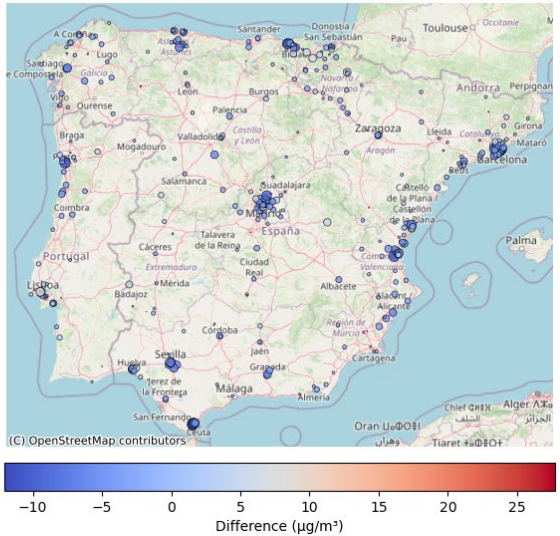
- **CAMS underestimates peak values seen in stations' data**
- **CAMS versus in-situ depend on station types, with urban underestimation**
- **Sentinel-5p shows the "hotspots" in more detail**

(2013-2023)	In-situ	CAMS EU	Downscaling
Nr. Observations	348896	348896	348896
Nr. Exceedances	72416	33036	70983
% Exceedances	20.756	9.469	20.345

Difference between In-situ and CAMS NO_2 in test set



Difference between In-situ and Predicted NO_2 in test set



EU Directive: daily average should not exceed 50 $\mu g/m^3$.

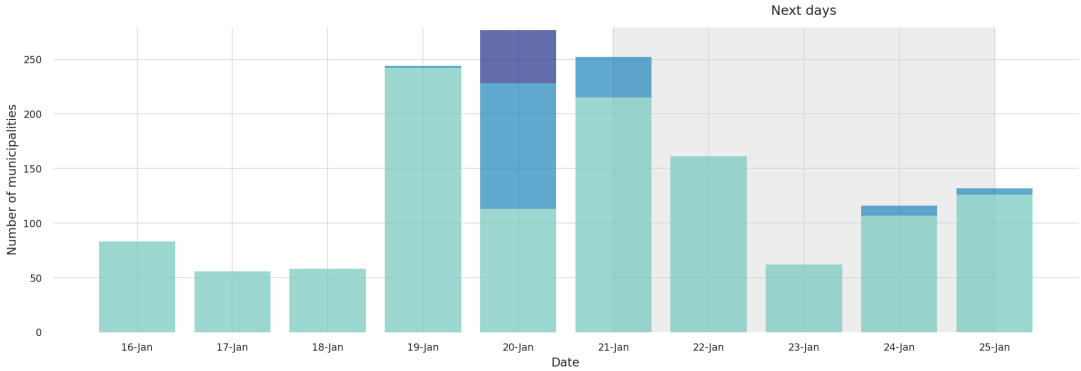
WHO Guideline: daily average should not exceed 25 $\mu g/m^3$.

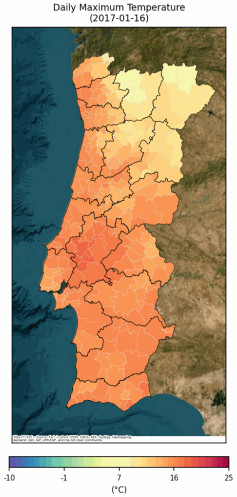
AIR4health is under a programme of, and funded by, the European Space Agency. Views expressed do not reflect the official opinion of the European Space Agency.

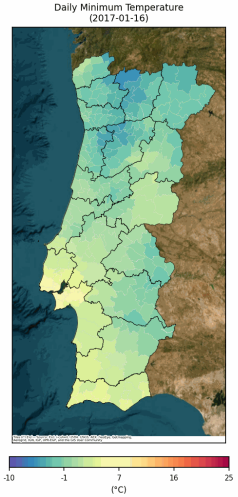
AIR4health Results: Compound CW+NO_2 Events

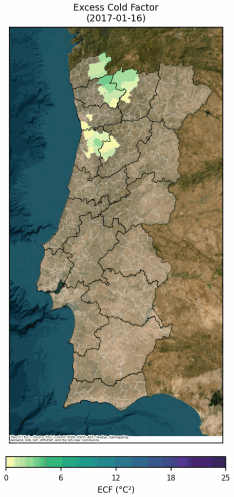
Case in Point: [January 2017 Compound CW+NO_2 Event]

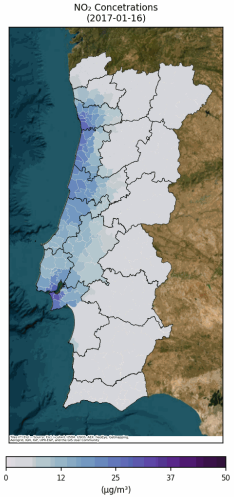
- **Start Date: 19-01-2017**
- **End Date: 25-01-2017**
- **Duration: 7 consecutive days**
- **Max. CW intensity: -8.5°C²**
- **Max. NO2 Exceedance: 11.9µg/m³**

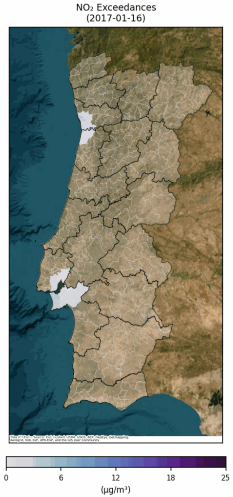


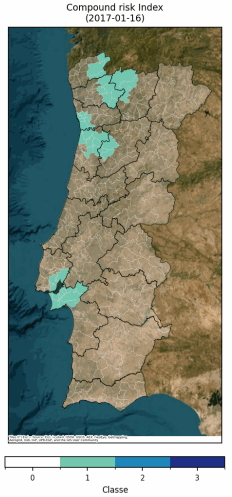












AIR4health

CoLAB +ATLANTIC

gmv INNOVATING SOLUTIONS

FACULDADE DE MEDICINA LISBOA

esa

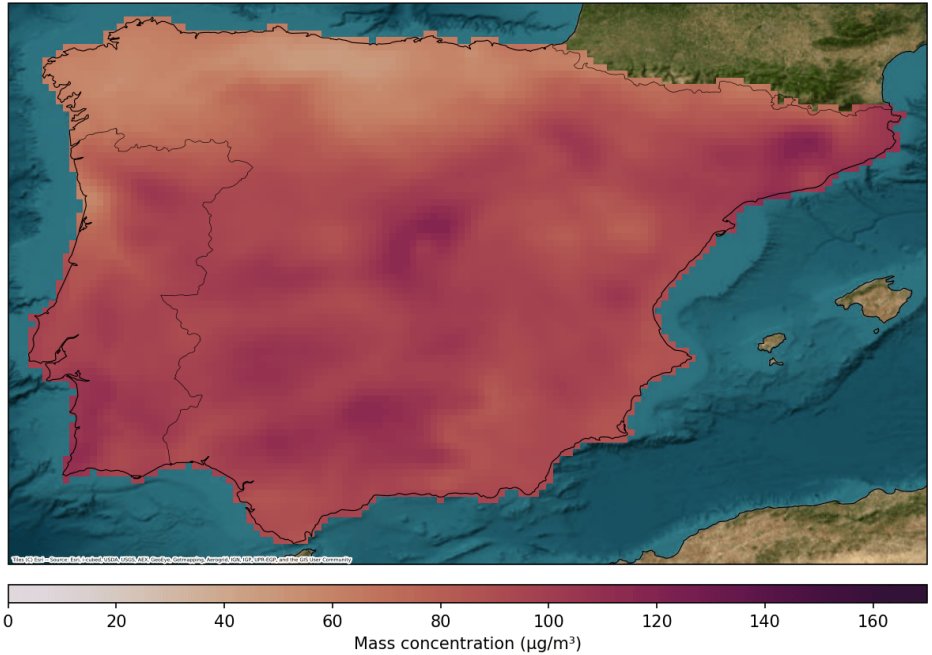
AIR4health is under a programme of, and funded by, the European Space Agency. Views expressed do not reflect the official opinion of the European Space Agency.

AIR4health Use Case II: Compound HW+O3 Events

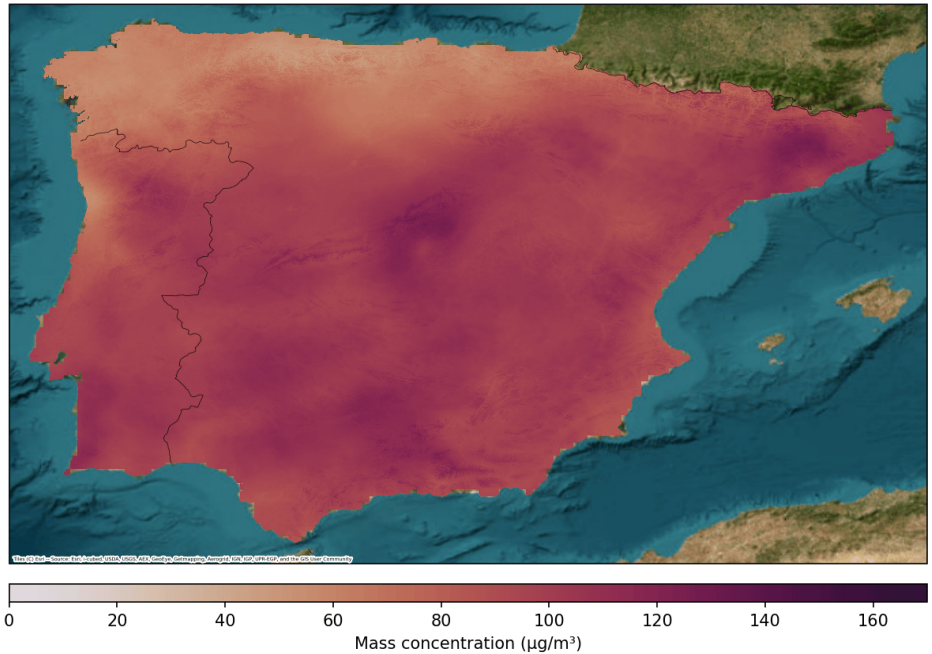
AIR4health is under a programme of, and funded by, the European Space Agency.
Views expressed do not reflect the official opinion of the European Space Agency.

AIR4health Results: Compound HW+O_3 Events

CAMS O_3 mass concentration (10 km)
2013-07-01



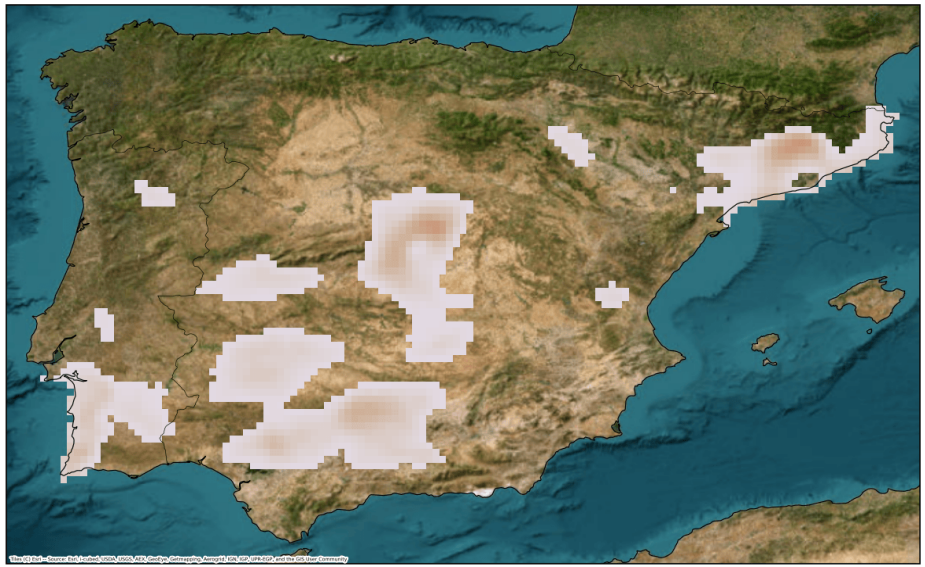
Downscaled O_3 mass concentration
2013-07-01

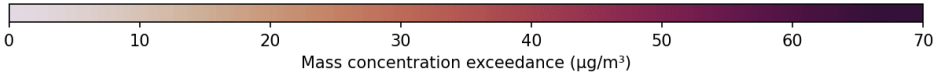


AIR4health is under a programme of, and funded by, the European Space Agency. Views expressed do not reflect the official opinion of the European Space Agency.

AIR4health Results: Compound HW+O_3 Events

CAMS O_3 mass concentration exceedance (10 km)
2013-07-01



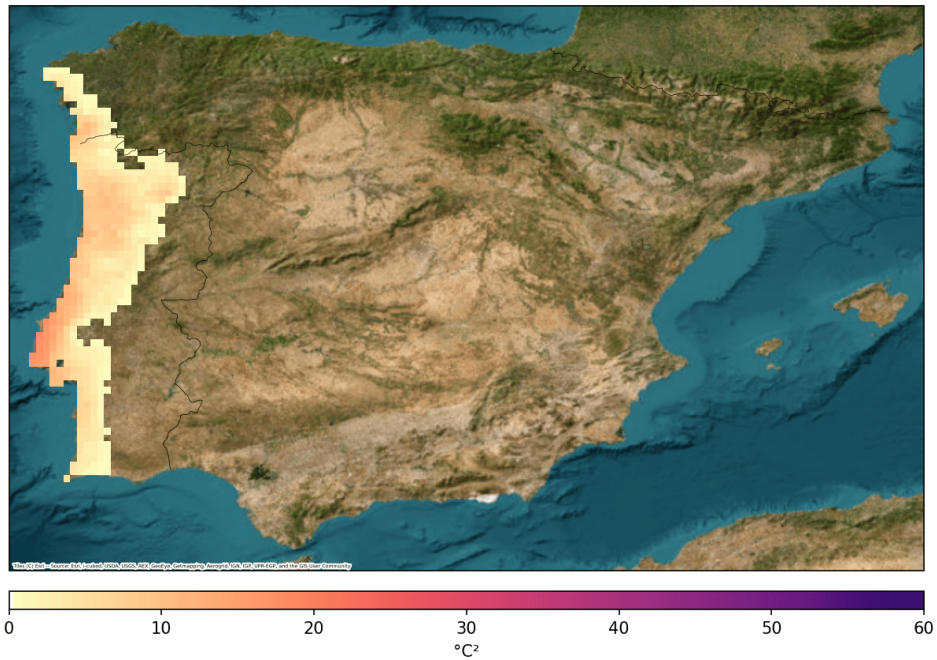


Downscaled O_3 mass concentration exceedance
2013-07-01

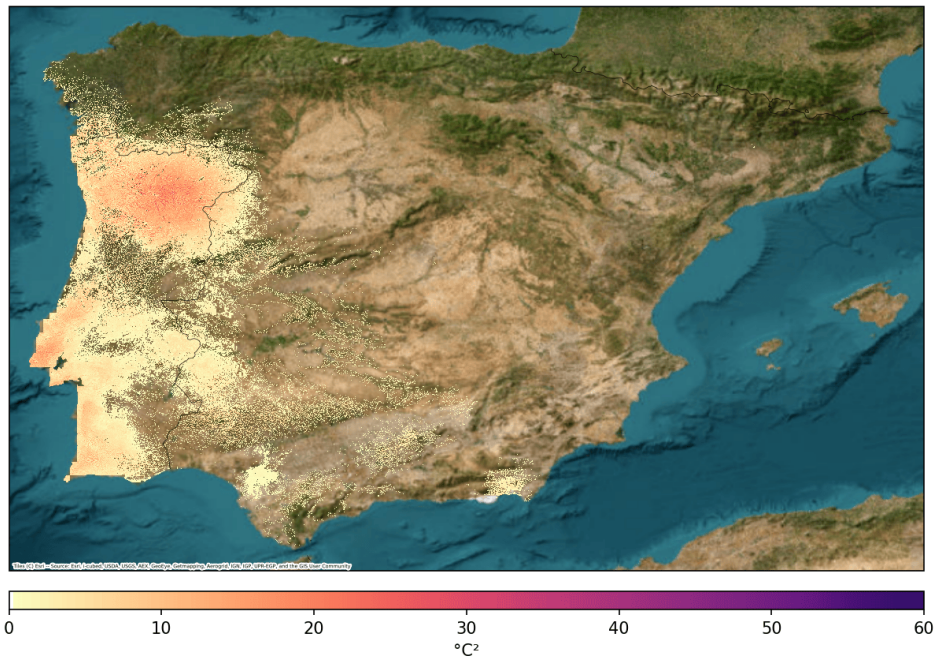
AIR4health is under a programme of, and funded by, the European Space Agency. Views expressed do not reflect the official opinion of the European Space Agency.

AIR4health Results: Compound HW+O_3 Events

EHF (EOBS original grid)
2013-07-01



EHF (Downscaled model)
2013-07-01



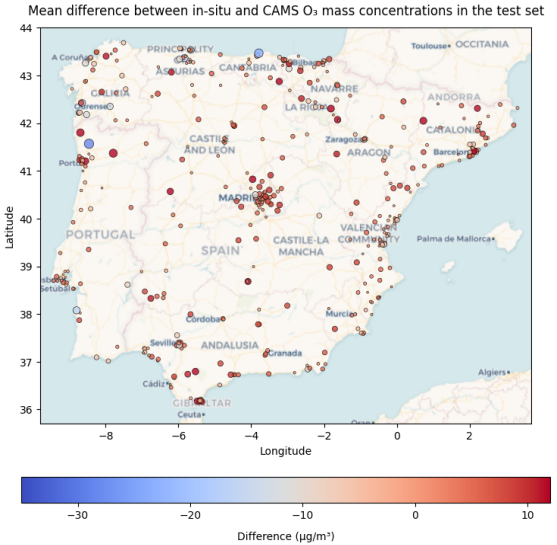
AIR4health is under a programme of, and funded by, the European Space Agency. Views expressed do not reflect the official opinion of the European Space Agency.

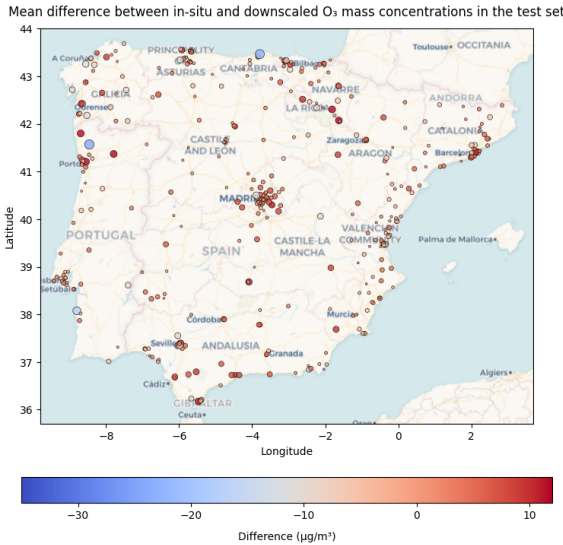
AIR4health Results: Compound HW+O_3 Events

In-situ versus CAMS: the added-value of SENTINEL-5P for O3 downscaling

- CAMS underestimates peak values seen in stations' data
- CAMS versus in-situ depend on station types, with rural underestimation
- Sentinel-5p shows the NO2-to-O3 urban "sinks" in more detail

(2013-2023)	In-situ	CAMS EU	Downscaling
Nr. Observations	337188	337188	337188
Nr. Exceedances	55.469	40.314	45.071
% Exceedances	16.45	11.95	13.36





EU Directive: daily max. of 8-hour moving average should not exceed 120 $\mu g/m^3$.

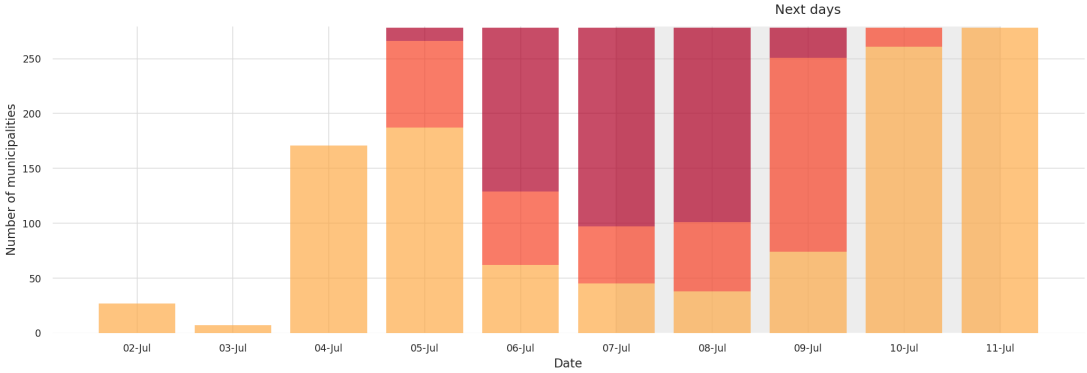
WHO Guideline: daily max. of 8-hour moving average should not exceed 100 $\mu g/m^3$.

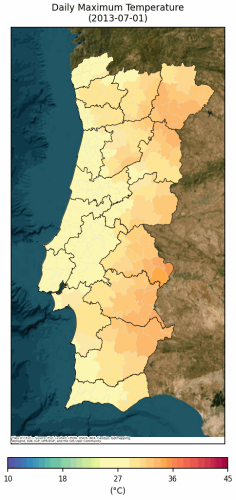
AIR4health is under a programme of, and funded by, the European Space Agency. Views expressed do not reflect the official opinion of the European Space Agency.

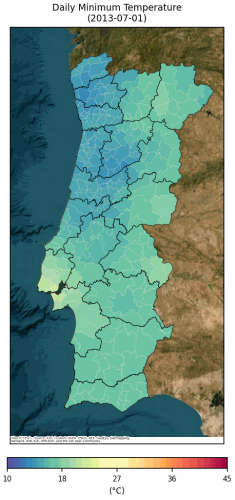
AIR4health Results: Compound HW+O_3 Events

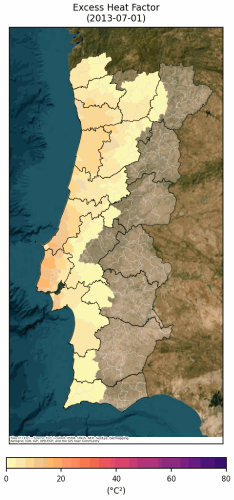
Case in Point: [July 2013 Compound HW+O_3 Event]

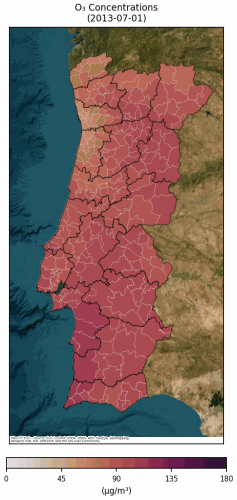
- **Start Date: 05-07-2013**
- **End Date: 10-07-2013**
- **Duration: 6 consecutive days**
- **Max. HW intensity: 49.0°C²**
- **Max. O3 Exceedance: 40.7μg/m³**

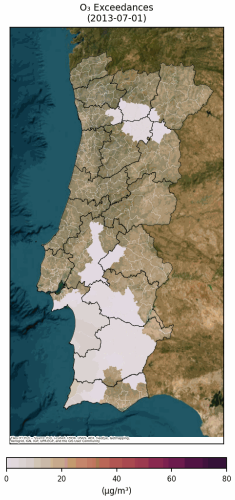


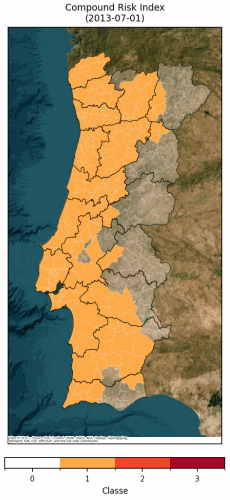










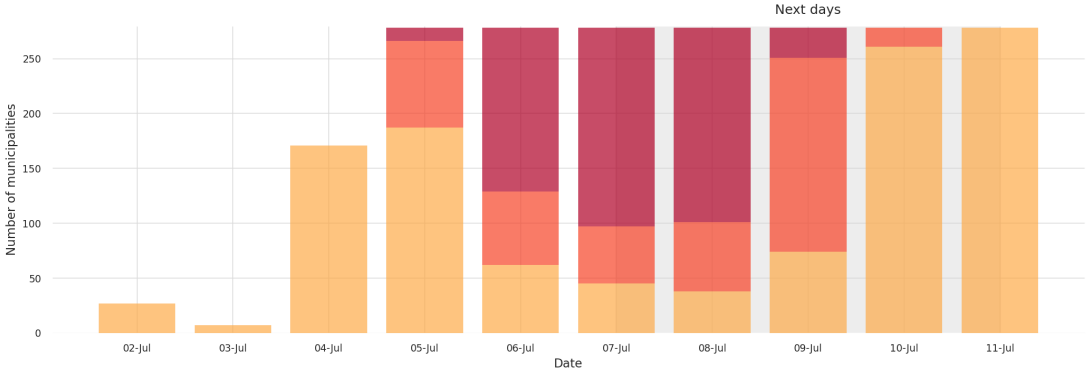


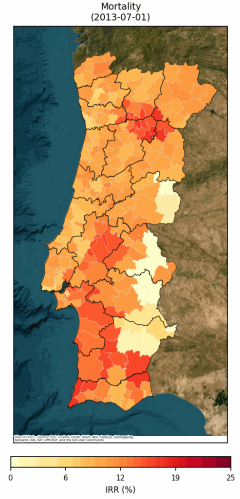
AIR4health is under a programme of, and funded by, the European Space Agency. Views expressed do not reflect the official opinion of the European Space Agency.

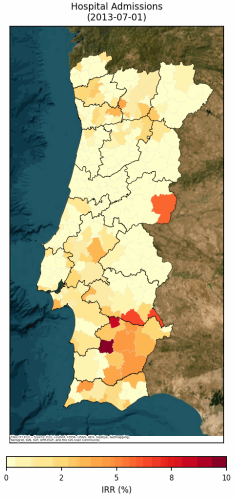
AIR4health Results: Compound HW+O_3 Events

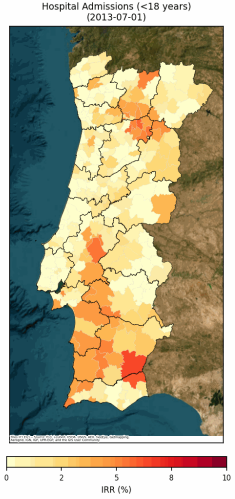
Case in Point: [July 2013 Compound HW+O_3 Event]

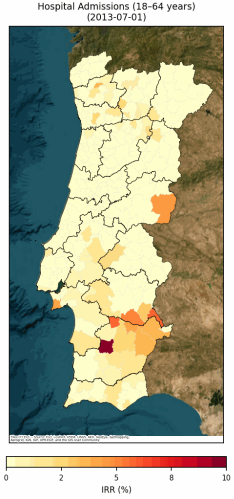
- **Start Date: 05-07-2013**
- **End Date: 10-07-2013**
- **Duration: 6 consecutive days**
- **Max. HW intensity: 49.0°C²**
- **Max. O3 Exceedance: 40.7μg/m³**

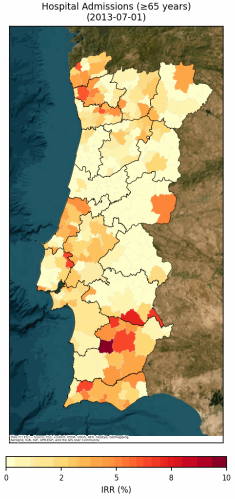


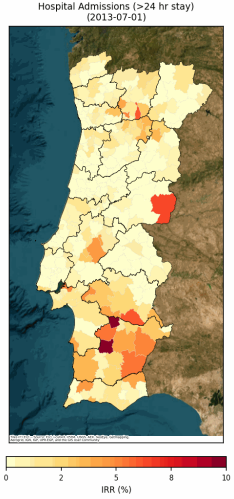










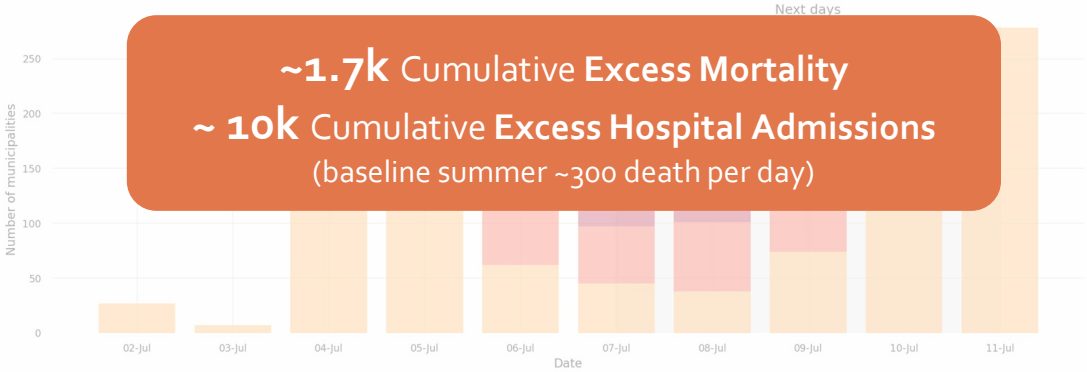


AIR4health is under a programme of, and funded by, the European Space Agency. Views expressed do not reflect the official opinion of the European Space Agency.

AIR4health Results: Compound HW+O_3 Events

Case in Point: [July 2013 Compound HW+O_3 Event]

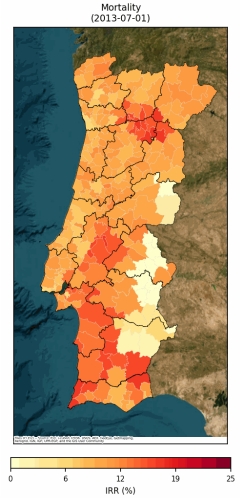
- **Start Date: 05-07-2013**
- **End Date: 10-07-2013**
- **Duration: 6 consecutive days**
- **Max. HW intensity: 49.0°C²**
- **Max. O3 Exceedance: 40.7μg/m³**

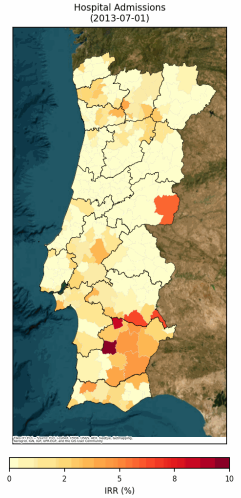


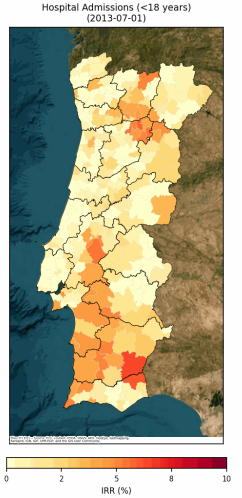
~1.7k Cumulative **Excess Mortality**

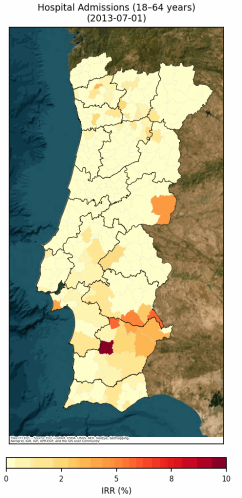
~ 10k Cumulative **Excess Hospital Admissions**

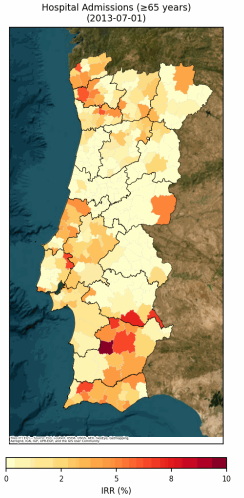
(baseline summer ~300 death per day)

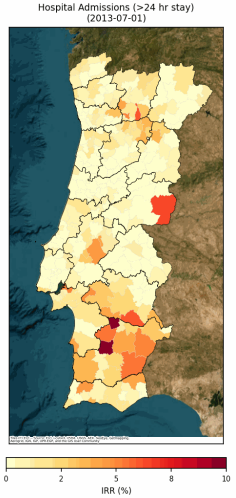








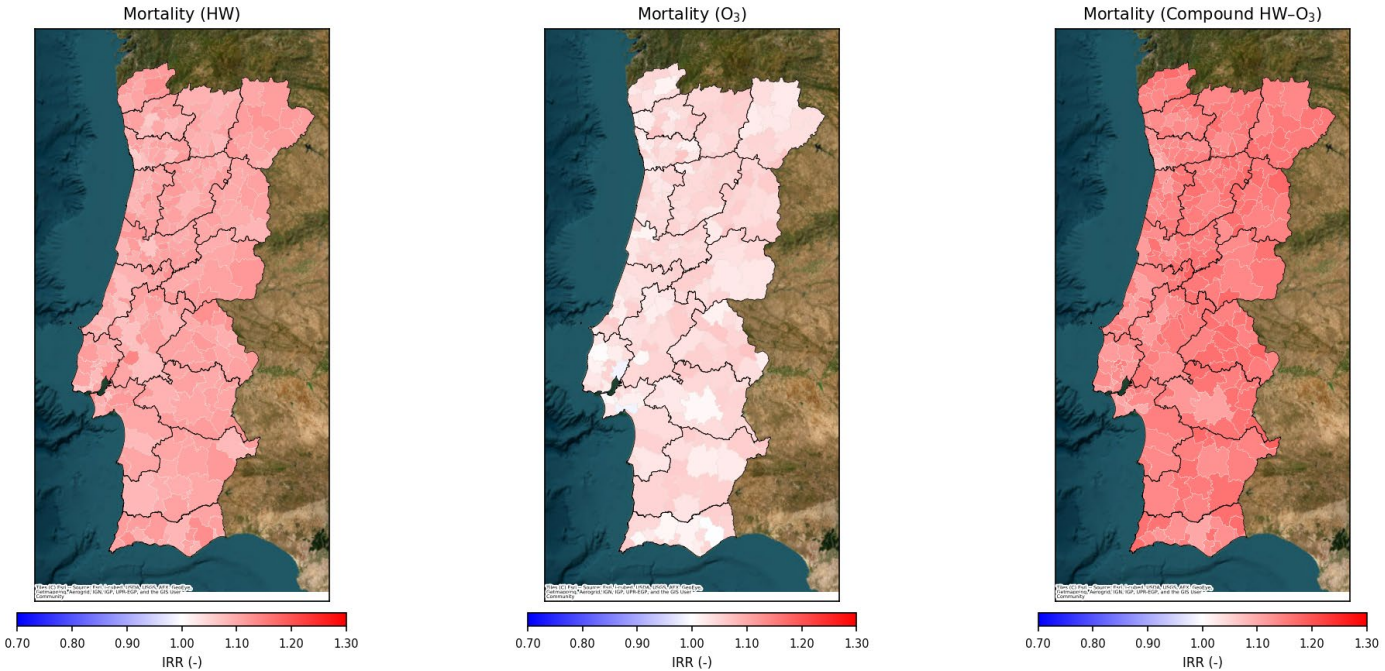




AIR4health is under a programme of, and funded by, the European Space Agency. Views expressed do not reflect the official opinion of the European Space Agency.

AIR4health Results: Compound HW+O_3 Events

Health Outcome	EHF	Excess Ozone
All-cause mortality	1.102 (1.081 – 1.123)	1.042 (1.024 – 1.061)



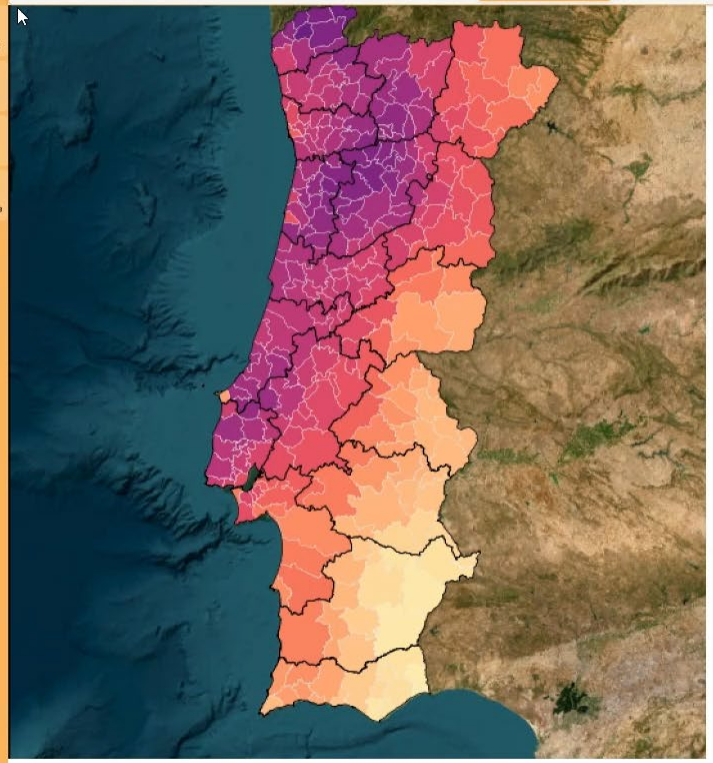
AIR4health Approach: **WHERE TO?**

AIR4health 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.

AIR4health: National System for Seasonal Surveillance and Alerting of the Effect of Extreme Temperatures and Air Quality on Health

Compound Risk Index | Excess Heat Factor | Daily Maximum Temperature | Daily Minimum Temperature | O3 Concentration | O3 Exceedances

Location | Search | About | Language



Subscribe Notifications | Share | Download

Summer

Mainland

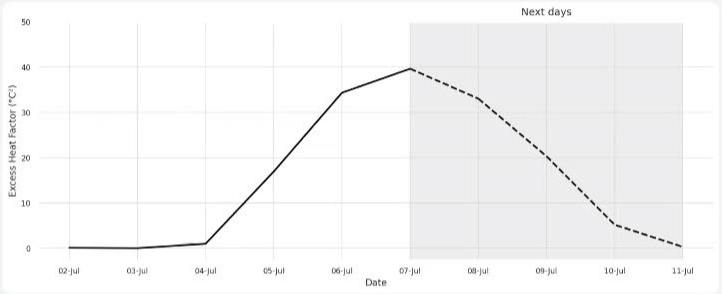
Portugal

Excess Heat Factor: 40°C²

O3 Exceedance: 20 µg/m³

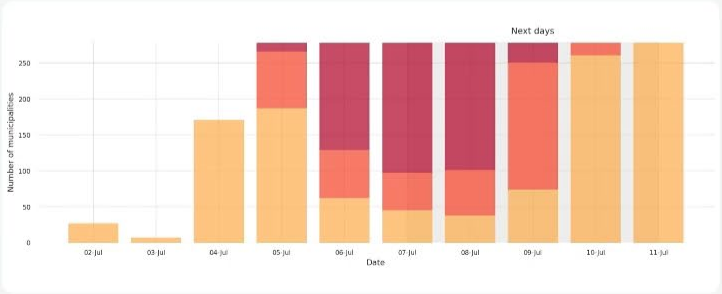
Compound Risk Index: SEVERE

Daily Forecast of Excess Heat Factor



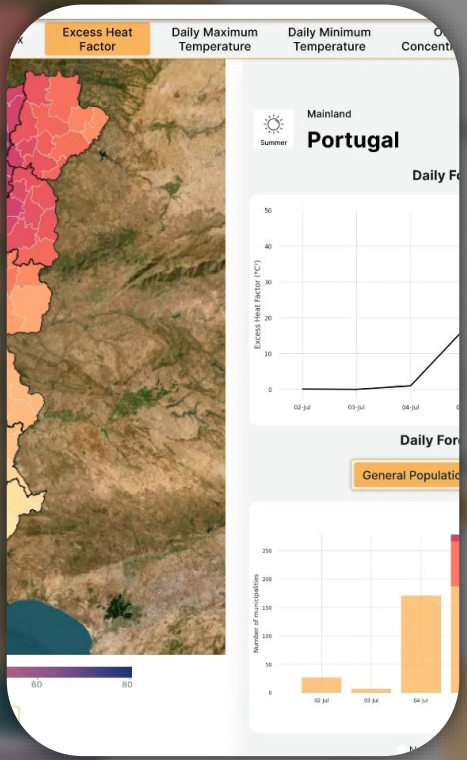
Daily Forecasts of Compound Risk Index

General Population | Age >= 65 Years | Age < 18 Years



No Risk | Low Risk | Moderate | Severe Risk

REPÚBLICA PORTUGUESA SAÚDE | SNS SERVIÇO NACIONAL DE SAÚDE | Instituto_Nacional de Saúde Doutor Ricardo Jorge | IPMA Instituto Português do Mar e da Atmosfera | CoLAB +ATLANTIC | gmv | FACULDADE DE MEDICINA LISBOA

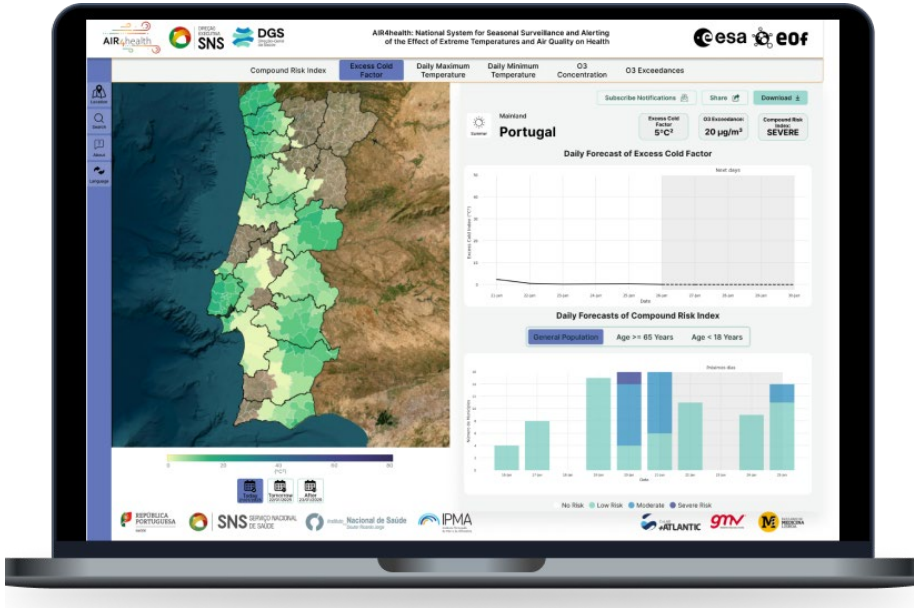

Excess Heat Factor
Daily Maximum Temperature
Daily Minimum Temperature
Mainland
Summer
Portugal
Daily F
Excess Heat Factor (°C)
50
40
30
20
10
0
02-jul
03-jul
04-jul
Daily For
General Populatio
Number of municipalities
250
200
150
100
50
0
02 jul
03 jul
04 jul
60
80

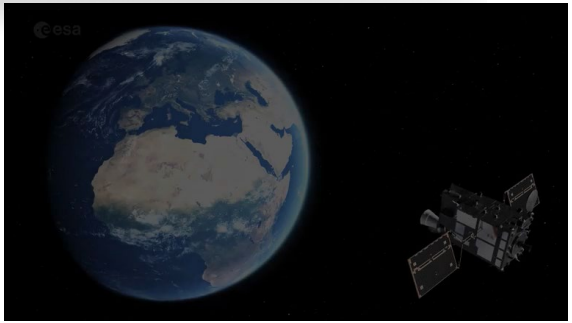
AIR4health Next Steps

- ✓ User Requirements Confirmed
- ✓ User Willingness to Join Confirmed

Design an **Integrated Seasonal Surveillance System Software Development Roadmap**

Evolution and Scalability by **Integrating Multiple Data Sources, including NWP (AROME? IFS? AIFS?), upcoming satellite missions (Sentinel-4, Sentinel-5)**





AIR4health 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.

Thank You! Obrigada!

AIR4health

Ana Oliveira, on behalf of the **AIR4health Team**
ana.oliveira@colabatlantic.com, air4health_tech@colabatlantic.com

AIR4health 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.