

AIPCN Section française

Journées Méditerranéennes de l'AIPCN

et Assises du port du futur du Cerema
25 au 27 octobre 2023 à Sete France

Détection proactive des épisodes de pollution grâce à l'IA en exploitant les données in situ, les données satellitaires et l'activité portuaire.

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AUTORITÉ PORTUAIRE DES ÎLES BALÉARES



PIANC French Section



PIANC Mediterranean Days

and Conference «Port of the future» by Cerema
25 to 27 october 2023 in Sete France

**Proactive detection of pollution episodes with
AI by exploiting in-situ data, satellite data and
port activity**

Author: Cristina Albuquerque Otero

Balearic Port Authority

Port of the future, ESPO and BPA Environmental Strategy

Port of the future: balances revenues and environmental impact by incorporating the latest technologies.

PIANC Med Days - Sete

27 October 2023

ESPO Environmental Report – EcoPortsInSights 2022

environmental priorities of the port sector over the years

	1996	2009	2013	2018	2019	2020	2021	2022
1	Port development (water)	Noise	Air quality	Air quality	Air quality	Air quality	Air quality	Climate change
2	Water quality	Air quality	Garbage/ Port waste	Energy consumption	Energy consumption	Climate change	Climate change	Air quality
3	Dredging disposal	Garbage/ Port waste	Energy consumption	Noise	Climate change	Energy efficiency	Energy efficiency	Energy efficiency
4	Dredging operations	Dredging operations	Noise	Relationship with the local community	Noise	Noise	Noise	Noise
5	Dust	Dredging disposal	Ship waste	Ship waste	Relationship with the local community	Relationship with the local community	Relationship with the local community	Water quality

BPA air quality network Data from 2019



BPA releases its Environmental Strategy in 2021, aiming to play a leader role in Environment, Sustainability and Corporate responsibility



EIFFEL: “REVEALING THE ROLE OF GEOSS AS THE DEFAULT DIGITAL PORTAL FOR BUILDING CLIMATE CHANGE ADAPTATION AND MITIGATION APPLICATIONS”



European
Commission

Horizon 2020
European Union funding
for Research & Innovation

- **H2020**. Call: Climate action, environment, resource efficiency and raw materials.
- Budget: **5 M €**
- Length **3** years: june 2021 - may 2024
- Consortium: **19** partners
- Pilots : **5**

<https://www.eiffel4climate.eu/>

<https://www.youtube.com/watch?v=8vQDbP7EMaE>



Consortium



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27 October 2023

REVEALING THE ROLE OF GEOS AS THE DEFAULT DIGITAL PORTAL FOR BUILDING CLIMATE CHANGE ADAPTATION & MITIGATION APPLICATIONS



This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101003518

The Project



- Offer the GEOSS community the capability of exploiting the exiting GEOSS datasets
- Foster the co-design of Climate Change adaptation and mitigation applications by bringing onboard the decision makers who are working towards the Paris Agreement goals at local, regional and national scales.
- Develop, using co-creation, a set of Climate Change adaptation and mitigation applications in different and quite diverse GEO Societal Benefit Areas, in order to demonstrate the project innovations



The Pilot

The pilot 3 study area covers the five ports managed by BPA.

Leaded by BPA, Prodevelop and UPV.

Presents a transport management scenario aiming to develop a web app to:

- Monitor and predict the impact of port activity on climate change and air quality at a regional scale, using AI, machine learning (ML), data mining and geospatial techniques.
- Combine real-time in situ measurements with NRT and historical data from GEOS, as well as other external sources.



<https://portsdebalears.com/en/air-quality>



(22261902) K-A10 APB-E 2

Fecha	PM10 (µg/m³)	NO (µg/m³)	CO (mg/m³)	O3 (µg/m³)	SO2 (µg/m³)	NO2 (µg/m³)	TMP (°C)	HR (%)	PRB (hPa)	PM25 (µg/m³)	VV (km/h)	DD (grados)	VVMX (km/h)	PM1 (µg/m³)	R (db(A))
21-10-23 10:00	6.86	0	0.17	55.81	0	0	21.56	50.12	1006.26	3.04	14.3	124.25	29.66	1.66	59.26
21-10-23 9:00	7.27	0	0.18	51.28	0	0	21.3	52.53	1005.87	3.24	12.43	122.92	26.24	1.79	59.39
21-10-23 8:00	7.61	0	0.17	58.79	0	1.11	20.42	54.34	1005.37	3.4	14.38	128.83	28.56	1.7	57.65
21-10-23 7:00	5.3	0	0.13	53.98	0	5.8	18.09	59.37	1004.63	2.24	9.38	145.5	18.8	1.22	55.7
21-10-23 6:00	4.5	0	0.12	55.56	0	3.55	17.7	59.68	1004.02	2.2	8.41	141.42	16.89	1.21	52.11
21-10-23 5:00	5.25	0	0.12	58.62	0	3.5	18.04	59.85	1003.37	2.4	10.74	130.92	22.02	1.24	53
21-10-23 4:00	5.31	0	0.13	59.34	0	3.38	18.17	60.3	1002.59	2.4	10.59	136.92	20.51	1.3	49.34
21-10-23 3:00	4.74	0	0.13	62.69	0	3.31	18.53	59.5	1002.02	2.42	15	113.5	29.76	1.36	54.22
21-10-23 2:00	4.88	0	0.14	65.21	0	1.98	18.92	57.76	1001.7	2.54	15.81	117.25	31.07	1.51	55.42
21-10-23 1:00	4.64	0	0.15	70.1	0	1.13	19.54	53.07	1001.2	2.59	19.08	99.17	37.71	1.58	59.52



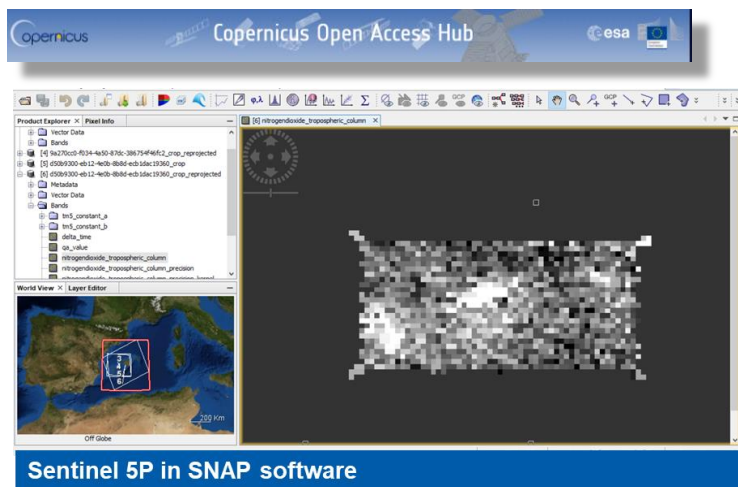
Satellite data



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Sentinel 5P-TROPOMI
Frecuency: NRT (near real time):
 Availability within 3 hours after sensing.
Spatial Resolution: 5,5 x3.5 km
 Parameters:
SO₂, NO₂, O₃

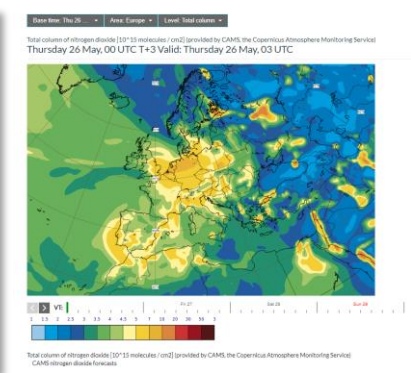


Sentinel 5P in SNAP software

CAMS (Regional Forecasts, Model Esemble)
Frecuency: Every morning the forecast for 4 days
Spatial Resolution: 10x10 km
 Parameters:
SO₂, NO₂, O₃, PM₁₀ and PM_{2.5}

European-scale air quality forecast from model ensemble

Product ID	A.2.1
Status	Operational
Description	This service provides the ensemble median of the European-scale air quality forecasts for every hour up to 4 days in advance. The maps provided are only representative for large scale phenomena, they cannot reproduce local aspects of air pollution.
Product family	Regional forecasts
Species	O ₃ , NO ₂ , CO, SO ₂ , PM ₁₀ , PM _{2.5} , NO, NH ₃ , NMVOCs, PANs, Birch pollen (seasonal)
Geographical area	Europe (-25.0, 45.0, 30.0, 70.0)
Vertical coordinate	Height levels
Vertical coverage	Surface, 30m, 250m, 500m, 1000m, 2000m, 3000m, 5000m
Horizontal resolution	0.1°x0.1°
Time coverage	1 October 2015 - current
Time resolution	Hourly
Update frequency	Daily
Dissemination mechanism	FTP
Data format	NetCDF, GRIB
Dissemination time	06:45UTC for the 00:00UTC 1 st -day and 2 nd -day forecast ; 08:30UTC for the 00:00UTC 3 rd -day and 4 th -day forecast
Key performance indicator	Available on time 95% on an annual basis
Data access	On-line catalogue



REVEALING THE ROLE OF GEOS AS THE DEFAULT DIGITAL PORTAL FOR BUILDING CLIMATE CHANGE ADAPTATION & MITIGATION APPLICATIONS



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CC mitigation objectives

- Monitoring and prediction of pollutions episodes at BPA generated by port activities at the sea-port area and the city of Palma.
- Determination of whether the origin of pollution episodes in port / city is caused by port activity.
- Improvement in the planning and optimization of port activities considering pollution episodes forecasts.
- Improved decision making and minimization of the carbon footprint of the port calls activity and the impact on the city as well as in protected areas in the route
- The app will offer a map-based UI with temporal AQI (following OGC, INSPIRE standards), customised dashboards with pollution KPIs, notifications and data reports for BPA, vessel companies, local authorities and citizens among other stakeholders.



Use Cases

1

Analysis of atmospheric pollution in Palma.

Study of the correlation between port activity and pollution episodes in the city/port, analysing air quality parameters: NO₂, SO₂, O₃ and PM₁₀ and PM_{2.5}, and other external parameters such as wind and traffic in the port/city and nearby areas using the XAI models developed.

2

Atmospheric Emissions study in The Freus.

Monitoring of air quality and emissions from vessels in the Freus area (route between Ibiza and la Savina ports).

3

Berth allocation optimization

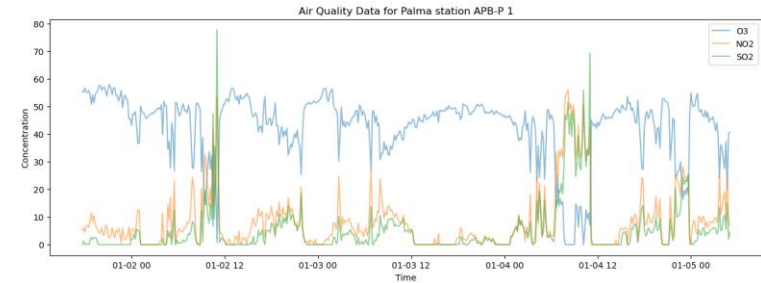
Provide advise on berth allocation based on lessons learned (monitoring and forecasting) supporting BPA in the decision making for the optimization of berth allocations and traffic routes from/to port to affect the least number of people.

Data sets

Private data (PR)	Port Operations Data from the Port Management System: real time and historical port calls with AIS positions since 2016- RT
	Air quality in-situ sensors data from BPA: measures atmospheric pollutant parameters every 10 minutes. Historical data from 2019. RT
Open data (OD)	AEMET: Weather information from the Spanish Meteorological Agency. H OND
	Regional Government Air Quality reference stations (SO ₂ , NO, NO ₂ , PM _x , DD, VV, TMP). H OD
	Traffic Intensity around Palma's port: from Palma city council. H OD
GEOSS data (GEO)	Sentinel 5P data: TROPOMI sensor through the Copernicus Sentinel Access Hub . Available within 3 hours NRT (near real time) Spatial resolution of 5,5 x 3.5 km NO ₂ , SO ₂ , O ₃ air quality parameters in NetCDF format.
	Copernicus Atmosphere Monitoring System (CAMS) data to assess and compare forecasts. The product Regional Forecasts, Model Ensemble is being used for concentration predictions of parameters NO ₂ , SO ₂ , PM _{2.5} , and PM ₁₀ with a spatial resolution of 10x10 km by accessing to https://ads.atmosphere.copernicus.eu/api-how-to

Models applied for data processing

- For the predictions, XAI models are applied.
- In-situ data is received in temporary series, sets of data points collected or recorded at regular time intervals.



- For time series prediction, LSTM is used, a special kind of neural network designed for data sequences.

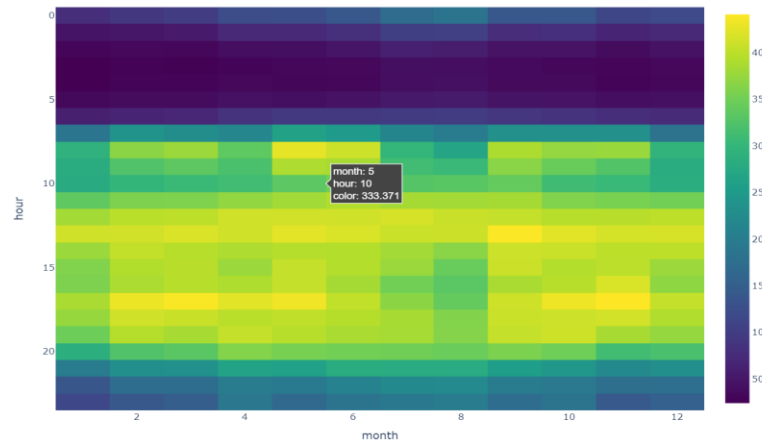
Predictive models performance evaluation:

- **R² (R-squared)**: quantifies how well the model explains the variability in the data.
- **RMSE (Root Mean Square Error)**.
- **RPIQ (Ratio of Prediction to Inter-Quartile Range)**.

Road traffic data analysis

No real time data sources, historical register is provided on demand. Steps:

1. Study traffic data independently to identify traffic profiles.
2. Include the data from the environmental stations and check for correlations between the congestion peaks and increases in the measured values for the pollutants. Current status of the study.
3. Include other additional parameters. Next step.



Heatmap for the whole year 2022.

EUROPEAN AQI EEA CALCULATION

The application offers AQI predictions made using satellite imagery (CAMS), at a number of points of interest (POI) to cover offshore areas with no in-situ data.

POI chosen are in use case 2 area.

Calculation of AQI predictions follow the CAMS training hub notebook <https://ecmwf-projects.github.io/copernicus-training-cams/proc-aq-index.html>



AQI evolution per pollutant and date

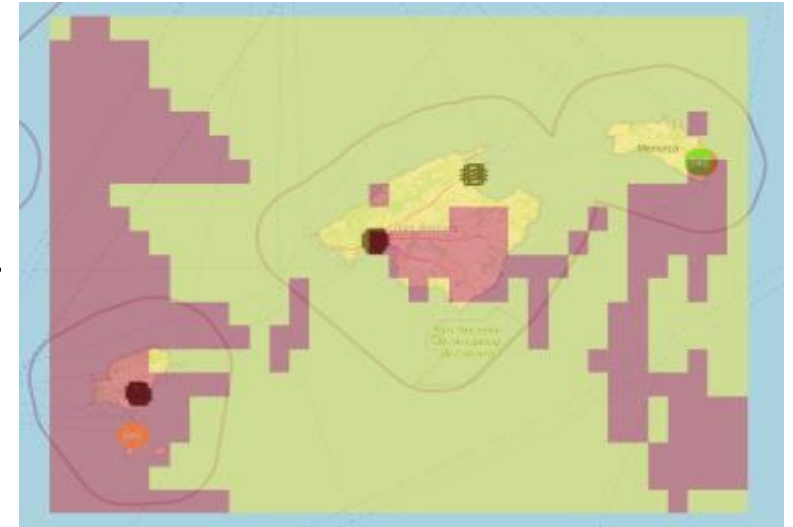


PM_{2.5} concentration by date

Super Resolution tool mechanism I

Satellite imagery has higher resolution than required to implement the use cases.

Sentinel 5p readings are gases concentrations of the whole tropospheric column, while in-situ sensors are measuring ground level concentrations. Both concentrations cannot be compared without further treatment.

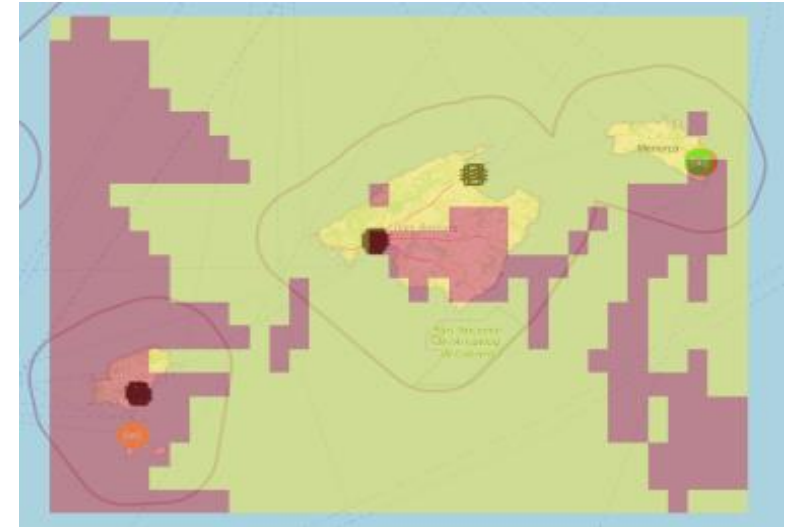


To estimate the ground level concentrations, it's been used Sentinel-5P data, from ERA5 and GTOPO30 elevation data to train the XGBoost model with one year in situ ground measurements from over 3000 stations in Europe provided by the European Environmental Agency (EEA).

Super Resolution tool mechanism II

On the first validation results, the NO₂ and O₃ models perform well.

Validation results for SO₂ and CO ground level concentrations are not so well and with data gaps due to masking - exclusion of pixels with low quality values.



Therefore, the focus is on NO₂ products and results are currently being evaluated in order to assess if they can have value in current or future processes and algorithms.

DL-based algorithms, trained with a large number of in-situ measurements collected from AirBASE can also be applied when in-situ measurements are not available, as required in use case 2.

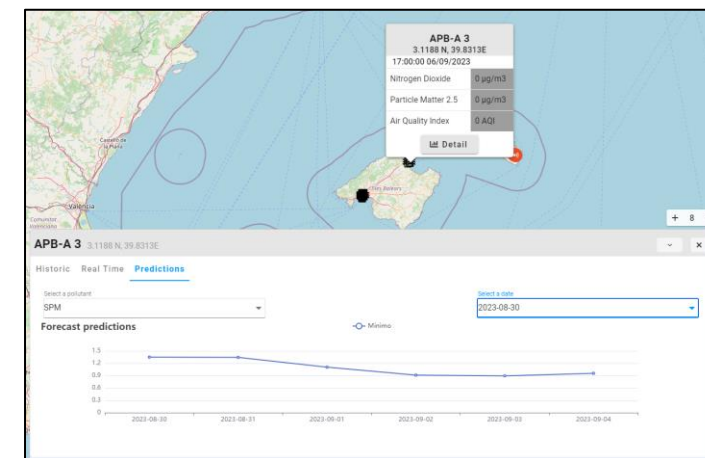
Challenges of ongoing work

- Integration of different data sources, especially port activity and road traffic to establish correlations and design mitigation policies
- Design a mechanism for spatial super-resolution of satellite imagery to support use cases
- Reduce the bias of satellite readings vs. ground data

The App WIP

Using in-situ and satellite data the web application can:

- Gather in-situ data from air quality monitoring (NO₂, SO₂, PM, etc.)
- Predict with ML techniques values for 24 - 48 - 72 upcoming hours.
- Compare predictions with Copernicus Atmosphere Monitoring Service (CAMS), even with lower resolution (10x10 km)
- Integrate Sentinel 5P imagery (5.5x3.5km) for offshore areas
- Provides a map-based user interface (UI) where stakeholders can access and manage data and predictions.



Conclusions and perspectives

- The tool is able to predict pollutants concentration and compare it to CAMS forecasts
- Super Resolution (SR) mechanism produces results with 5 days delay due to the ERA5 tool availability. SR can train the model, useful for use case 2 aims of assessing the pollution in a regional offshore area without available in situ data
- SR accuracy up to 63,6% vs. AQ ground stations, lower this high BIAS could be another project
- New launching of Sentinel 4 and Sentinel 5 are promising in terms of improving the temporal resolution and detection accuracy



Ports de Balears



Autoritat Portuària de Balears



THANK YOU VERY MUCH!!

MERCI BEAUCOUP!!

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