RAMONES
Radioactivity Monitoring in Ocean Ecosystems

Deliverable

Document ID: D5.2 Repository, Information System and Risk no2

03/02/2023

RAMONES funded by European Union under Horizon 2020 FET Proactive programme via grant agreement No.101017808

Document Info

Project Information			
Acronym	RAMONES		
Name	Radioactivity Monitoring in Ocean Ecosystems		
Start Date	1 Jan 2021	End Date	31 Dec 2024
Program	H2020-EU.1.2.2. - FET Proactive		
Call ID	H2020-FETPROACT-2020-2	Topic	FETPROACT-EIC-08-2020 - Environmental Intelligence
Grant No	101017808	Instrument	RIA
Document Information			
Document Id	D5.2		
Document Title	D5.2 Repository, Information System and Risk no2		
Due Date	31-Dec-2022	Delivery Date	03-Feb-2023
Lead Beneficiary	UDUR(1)		
Beneficiaries (part.)	UDUR(1), ENS(2), UCA(3)		
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Workpackages	WP5 - Citizen Awareness, Dissemination and Communication Activities		
Version	V1.0	Stage	Submitted
Distribution	Public		
Keywords	Pathfinder, EIC, FET, Radioactivity, Environmental Intelligence, Underwater Research	Type	R

Document Change Record

Version	Date	Change Description	Editor	Change Location (page/section)
1.0	09/11/2022	Presentation made in GoodIT22	UDUR	
	29/01/2023	Document delivered to main authors	UDUR	
	02/02/2023	Document delivered to all authors	UDUR	
	03/02/2023	Feedback implemented and document/deliverable submitted to funder	UDUR	

Disclaimer

RAMONES is a European Innovation Council (EIC) FET Proactive project in the Environmental Intelligence Scope B, related to radically novel approaches to resilient, reliable, and environmentally responsible in-situ monitoring. It is funded by the European Union under the Horizon 2020 FET proactive programme, via grant agreement No. 101017808.

RAMONES project's main objective is to close the current marine radioactivity gap in sampling and foster new interdisciplinary research in ocean ecosystems. RAMONES will invest a significant effort to provide tools to enable long-term data acquisition missions, rapid deployments, low cost per information byte, and propose new AI and Robotics-driven and supported methodologies, being ambitious to eventually offer scaled-up solutions to researchers, policy makers and communities. These goals will be achieved by combining state-of-the-art (SoA) methodologies and equipment from various disciplines in a well-balanced synergy. It will also design new and effective methodologies targeting the marine environment, which will provide efficient response to existing natural and man-made hazards, and shape future policies for the global population. RAMONES will additionally contribute to shaping a blueprint on Environmental Intelligence in the EU and worldwide.

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List of acronyms

Acronym	Description
AI	Artificial Intelligence
ASV	Autonomous Surface Vehicle
AUV	Autonomous Underwater Vehicle
DB	Database
DL	Deep Learning
EIC	European Innovation Council
EU	European Union
F2SS	Forecasting & Foresight Support System
FGDB	File Geodatabase
FSS	Forecasting Support Systems
GIS	Geographical Information System
GO	Governmental Organization
JA	Judgmental Adjustment
Maastricht	Treaty on the European Union
ML	Machine Learning
NGO	Non-Governmental Organization
pF2SS	Prototype Forecasting & Foresight Support System
POIS2ON	**P**rototype RAM**O**NES **I**nformation **S**ystem for **S**ocioec**ON**omic stakeholders
SF	Statistical Forecasts
SME	Small and Medium Enterprise
SoA	State of the Art
SRF	Strategic Response Frameworks
WP	Work Package

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Abstract

RAMONES is an ambitious, high-risk EU FET H2020 project, which aims to achieve high-resolution temporal and spatial underwater AI-driven radioactivity measurements, *in situ* and in near-real-time, forming a game changer in deep-water environmental monitoring. RAMONES proposes a new generation of submarine radiation-sensing instruments, assisted by State of the Art robotic and artificial intelligence solutions towards understanding radiation related risks near and far from coastal areas, while providing data for the international community towards shaping new policies and governance guidelines for environmental sustainability, economic growth, and human health.

One of the main goals also of RAMONES is to introduce novel monitoring and response channels to **inform key socio-political and socio-economic stakeholders** at regular intervals at medium (hourly, daily, weekly) to low (monthly to inter-annually) frequencies. To that end, the deliverable **5.2. of Work Package 5 provides the Functional Design** for the prototype information system, **POIS2ON** (Prototype RAMONES Information System for SocioecONomic stakeholders), an amalgamation of the French words 'fish' and 'poison' to indicate the risk of deep sea anthropogenic and natural emitted radioactivity to our ecosystem and respective food chain.

POIS2ON will provide statistical forecasts and respective judgmental adjustments primarily for cumulative radionuclide concentrations as well as other time series monitoring hazardous activities and respective risks. At a second stage and once Risk Indices have been developed (deliverables D5.5 – D5.8), foresight capabilities will be added to the system (functional requirements provided in D5.5) leading to a complete Forecasting & Foresight Support System (F2SS) given the long-term nature of such activities. Finally, provision for spatio-temporal representation and visualization will be prescribed via connections to off-the-shelf GIS systems (Geographical Information Systems).

Keywords

RAMONES; POIS2ON; Radioactivity; Deep Water; Information System; Forecasting; Risk.

1. Introduction

1.1 Context

This document belongs to Work Package 5 (WP5, *Citizen Awareness, Communication and Dissemination Activities*), and in particular to Task T5.1 *Forecasting and risk management* led by UDUR that is aiming to transliterate the in-situ, high frequency (e.g. hourly, multiple times per day) measurements of radioactivity in deep ocean waters to actual time series that can be forecasted, estimating when general acceptable daily/weekly/monthly/annually limits are reached/exceeded, and as such quantify the risk and potential impact to the environment and human populations. Moreover, the present deliverable builds upon and consolidates the work reported earlier in Deliverable D5.1 where the initial design of the Risk Information System was reported.

POIS2ON (Prototype RAMONES Information System for SocioecONomic stakeholders), a forecasting & foresight support system (F2SS) system is developed [Me22], which will include a decentralized Repository for recorded time series, to offer forecasted cumulative radionuclide concentrations, as well as other potentially dangerous elements concentrations at medium frequencies (hourly, daily & weekly) and the associated impact to relevant stakeholders: policy makers, regulatory agencies, governments, etc.

This process will be fully automated and be able to run unsupervised at prescribed frequencies. Initially standard statistical techniques will be employed but given enough datapoints collected per time series, machine learning (ML) and (if possible) deep learning (DL) methods will be used.

After consultation with IAEA and EU, and in the later phases of T5.1 as part of the linked deliverables due in month 27 & 33, D5.5 & D5.6 (Forecasting and Risk Assessment for awareness policy support no1 & no2), we will report on the functional requirements and design of a data-driven **risk monitor** at medium frequency for the awareness of interested stakeholders and communities. Health safety novel risk indices will be proposed: i) based on [Ni21] and cumulative Points-Over-Threshold that would give medium- to long-term forecasts for radioactivity - and other dangerous elements- levels, ii) based on [Be17] and real-time monitoring of radon emissions, and using value-at-risk measure and control charting, for short-term local policy response, and/or iii) based on [Ma13] and the use of a real options approach to examine the impact of abrupt increases in radioisotopes- related socio-economic costs for longer-term policy recommendation, legislation and adoption.

1.2 Structure of the document

From this point, the current document is organized according to the following structure and contents:

Section 2. Basic Usage Scenarios of POIS2ON

Section 3. Functional Design of POIS2ON

Section 4. Updated Functional Requirements of POIS2ON

Section 5. Conclusion and the Future

1.3 Objectives and approach

The objectives of the RAMONES D5.2 deliverable is to set the design for the prototype information system **POIS2ON** that provides statistical forecasts and respective judgmental adjustments primarily for cumulative radionuclide concentrations, as well as other time series monitoring hazardous activities and respective risks.

At a second stage and once Risk Indices have been developed too (deliverables D5.5 – D5.8), and from as early as when D5.5 & D5.6 are submitted by month 33 of the project, foresight capabilities will be added to the system (functional requirements provided in D5.5) leading to a complete Forecasting & Foresight Support System (F2SS) given the long-term nature of such activities.

Finally, provision for spatial-temporal representation and visualization is prescribed via connections to GIS (Geographical Information Systems).

2. Basic usage Scenarios

As elaborated in deliverable D5.1 in our basic usage scenarios of POIS2ON, socioeconomic stakeholders depict **an area of interest** in the sea where **natural activity** takes place (like an underwater **Volcano)** or **anthropogenic activity** takes place (like an underwater **Drilling for Oil**) and respective risks are realised and thus need to be forecasted and measured. The area of interest is depicted in the sea in a map, by either indicating a polygon of (latitude, longitude) for each corner of the polygon.

Then the RAMONES deployment team will break the 3D polygonal object into thousands of datapoints of (latitude, longitude, depth from surface) on which measurement will be made for the element(s) of interest (e.g. ^{222}Rn), for the period of time of interest, at high frequencies per datapoints.

These measurements will then be converted into hourly measurements (and bi-daily, daily, weekly) via using the maximum or average (there is an option in the system of what to be used) measurement per area of interest for the time block of interest.

These hourly/bi-daily/daily/weekly series can then be forecasting with time series models (statistical benchmarks, ML and, if possible, DL more advanced models) and estimates of how soon annual limits might be reached/exceeded and respective alarms can be raised and communicated to the respective socioeconomic stakeholders, and respective Strategic Response Frameworks (SRF) initiated.

These are the basic capabilities of POIS**2ON** which will also be available via **GIS** system in the form of **Heat maps**. The series will be reported in the dosimetric units nanosievert-per-hour (nSv/h) and alerts will be raised, given when annual limits are expected to be reached, and the area of interest will be characterised longitudinally by a five-colour code via the Heat map (no risk, normal, low risk, high risk, eminent risk), and informing respective the interested stakeholders.

3 Functional Design of POIS2ON

3.1 The prototype POIS2ON system

The system is depicted in **Figure 1** (as reported in D5.1 too); at the current implementation there are two gliders, but in the future this technology is fully scalable and there is provision in POIS2ON for receiving measurements from more than four devices (currently the Benthic lab, the Autonomous Surface Vehicle (ASV), and the two Gliders)

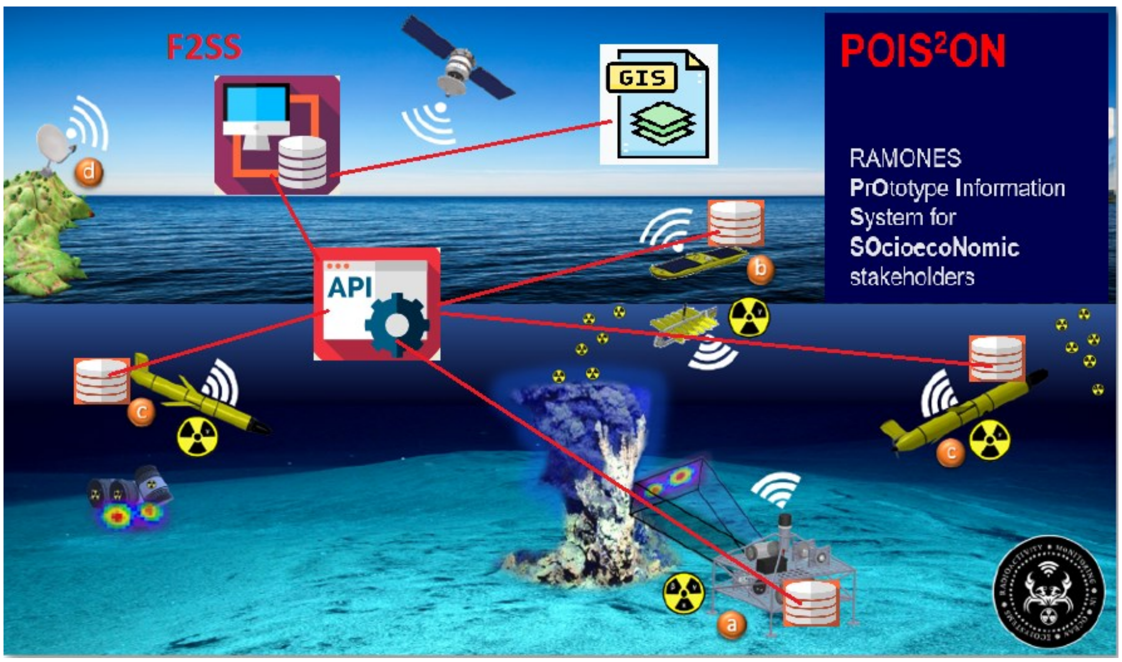


Figure 1 - POIS2ON Prototype RAMONES Information System (adopted from D5.1)

3.2 Architecture of the prototype POIS2ON system

In Figure 2, the architecture of the software information system is provided; the initial breakdown of POIS2ON (the R2IS in Figure 2) in subsystems is depicted respectively where:

- a DSS (Decision Support System) to inform stakeholders and help make decisions once an alert is issued, that an annual dosage of an element in the area of interest is about to be reached in the immediate future;
- an FSS (Forecasting Support system), to create forecasts with
  - statistical methods,
  - machine learning methods,
  - (if possible given the computation time constraints and need to have forecasts in less than an hour in a mobile device) deep learning methods,
  - Judgmental methods;
- a GIS, (Geographical Information System) to visualize data and forecasts in heat maps in the areas of interests with a color code indicating levels of respective risk (per element of interest);
- an RMIS, (Risk Management Information System) to be implemented in parallel and integrated to POIS2ON, during the deliverables D5.5-D5.8;
- A Repository of low frequency time series measurements (hourly, bi-daily, daily, weekly) for all elements of interest, coming from the RAMONES devices, whenever they are deployed and in operation;
- The integration of all these subsystems, resulting in the RAMONES Integrated Information System, is the **POIS2ON** system.

The logic of modular system is derived from several similar successful implementations of FSS and F2SS as in [Me03,Ni03a,Ni03b,Pa03a,Pa03b,Pe03].

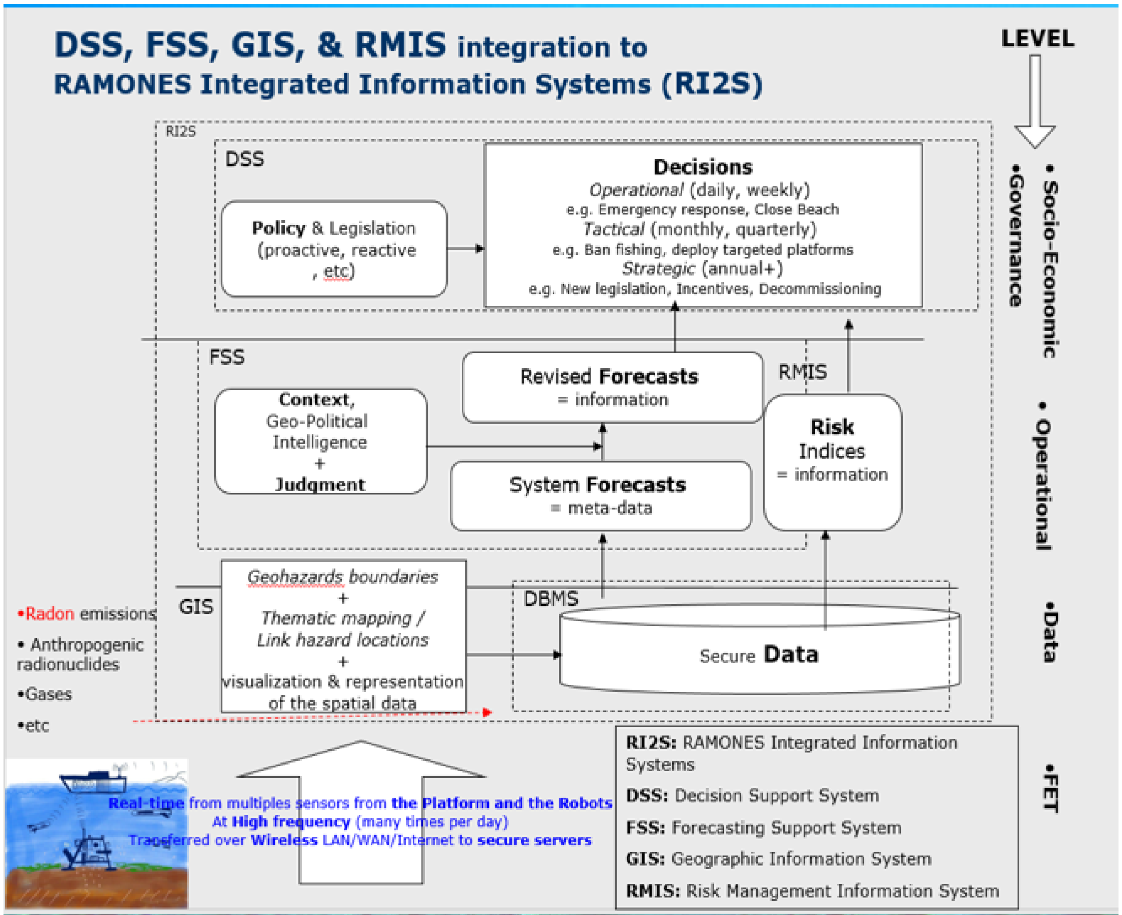


Figure 2 - Architecture of POIS2ON

3.3 The Business Logic of POIS2ON

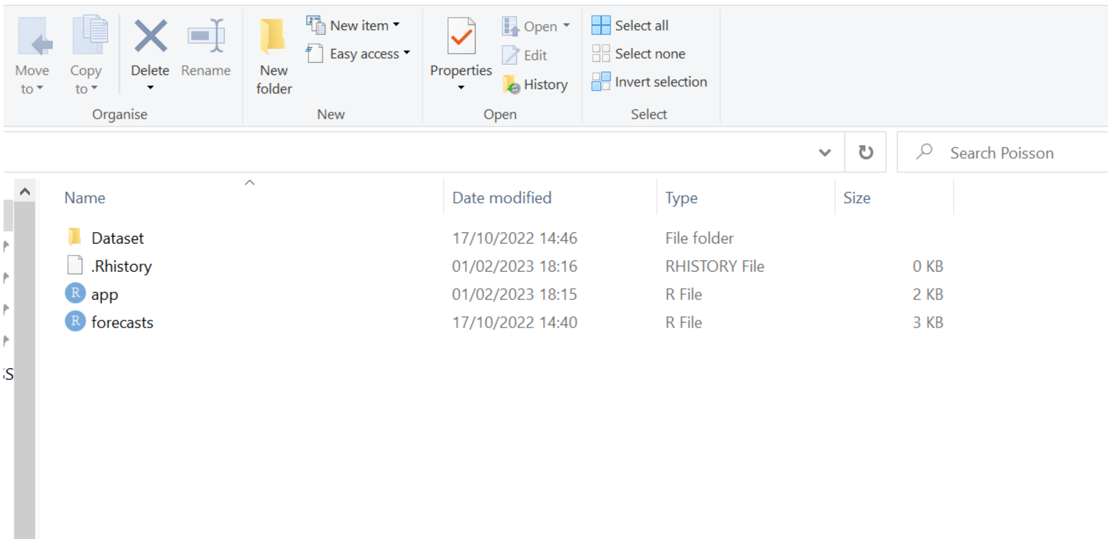


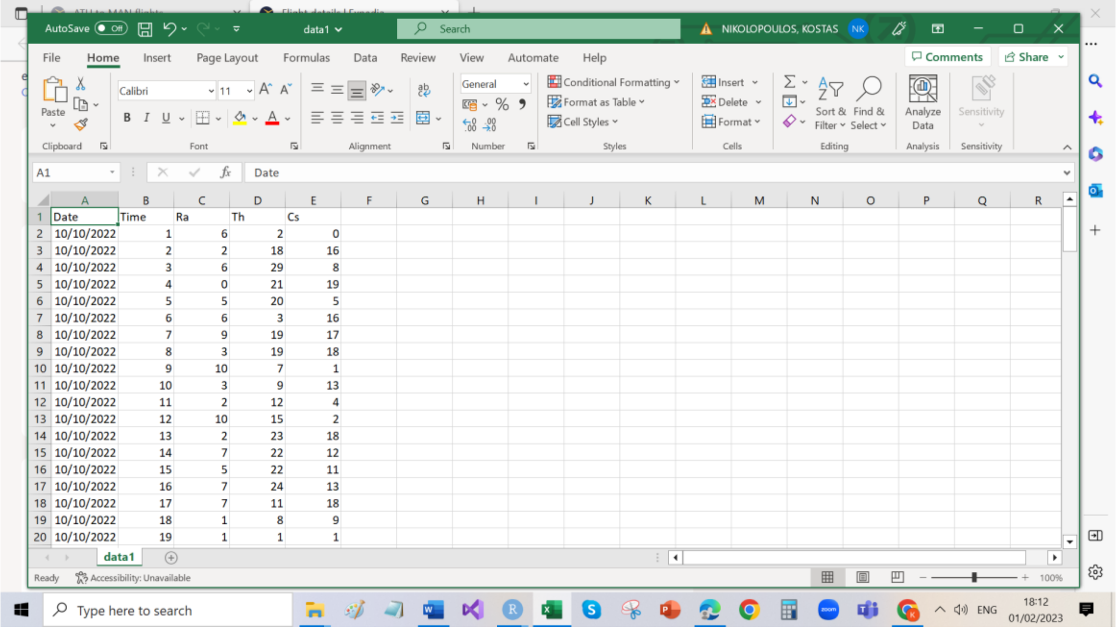
Figure 3 - Business Logic of POIS2ON

At the current stage (Figure 3) two separate apps are running, one taking care of the main interface, and one taking care of all the forecasting capabilities. From month 27 onwards a third one will be added taking care all the risk indices capabilities. This distributed business logic ensures the scalability and smooth maintenance of the information system as well as the potential reuse of some subsystems in future information systems.

3.4 The Database of POIS2ON

In its current version the system runs with MS **Excel** as its database (Figure 4) and there is provision for working with **mysql** (via the RMySQL package).

At the moment, POIS2ON includes hourly data and measurements (simulated) from three isotopes, namely ^{226}Ra (natural U-series), ^{208}Tl (natural Th-series), and ^{137}Cs (anthropogenic).



Date	Time	Ra	Th	Cs
10/10/2022	1	6	2	0
10/10/2022	2	2	18	16
10/10/2022	3	6	29	8
10/10/2022	4	0	21	19
10/10/2022	5	5	20	5
10/10/2022	6	6	3	16
10/10/2022	7	9	19	17
10/10/2022	8	3	19	18
10/10/2022	9	10	7	1
10/10/2022	10	3	9	13
10/10/2022	11	2	12	4
10/10/2022	12	10	15	2
10/10/2022	13	2	23	18
10/10/2022	14	7	22	12
10/10/2022	15	5	22	11
10/10/2022	16	7	24	13
10/10/2022	17	7	11	18
10/10/2022	18	1	8	9
10/10/2022	19	1	1	1

Figure 4 - Database of POIS2ON

The upgraded version of the database (to be reported in the follow-up deliverable D5.3) will extend the system to operating in four frequencies (hourly, bi-daily, daily, weekly). Also, in the deliverable D5.3 (simulated) measurements will include the following isotopes:

- ^{137}Cs
- ^{222}Rn
- ^{226}Ra
- ^{214}Pb
- ^{210}Pb
- ^{214}Bi
- ^{208m}Tl
- ^{239,240}Pu

For sensors offering vision capabilities in RAMONES, a separate database of images will be developed to store and make available all information recorded. This database will serve a complementary role to the POIS2ON system for comparison and validation purposes.

In the present deliverable, the forecasts have been calculated with three statistical methods (Simple Exponential Smoothing, Theta method, ARIMA) and one machine learning method (a MLP Neural Network), but there is provision for inclusion of ten statistical methods via the R package FORECAST https://cran.r-project.org/web/packages/forecast/index.html and five machine learning methods via the packages CARAT, E1071, and Random Forest https://cran.r-project.org/web/packages/forecast/index.html

For the complete implementation of POIS2ON (D5.4, M36), there will be additionally an attempt to include one Deep Learning method via the TensorFlow https://tensorflow.rstudio.com/, however this needs to be able to run in less than an hour in the prescribed mobile device.

Judgmental forecasts and judgmental adjustments to statistical and machine learning forecasts will also be provided.

3.5 The Interface of POIS2ON

The current preliminary implementation of POIS2ON (and we decided to be the one for the duration of the RAMONEs projects) is in R https://www.r-project.org/ and Rshiny https://shiny.rstudio.com/ and the interface implemented and tested in month 24 of the RAMONEs project is depicted in Figures 5, 6 and 7 where respectively we can see **hourly forecasts** for **Radium** with **SES**, Simple Exponential Smoothing

https://www.statsmodels.org/dev/examples/notebooks/generated/ets.html#Simple-exponential-smoothing

in Figure 5,

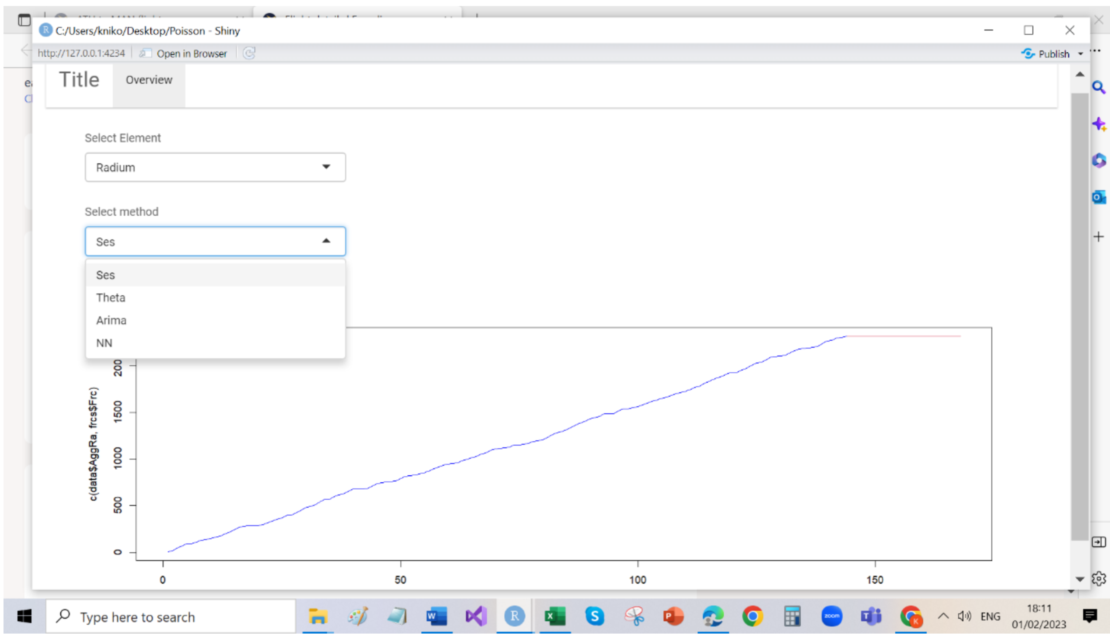


Figure 5 - Interface 1.0 of POIS2ON, Forecasting Radium with SES

Theta, the Theta method

https://www.statsmodels.org/dev/examples/notebooks/generated/theta-model.html

in Figure 6,

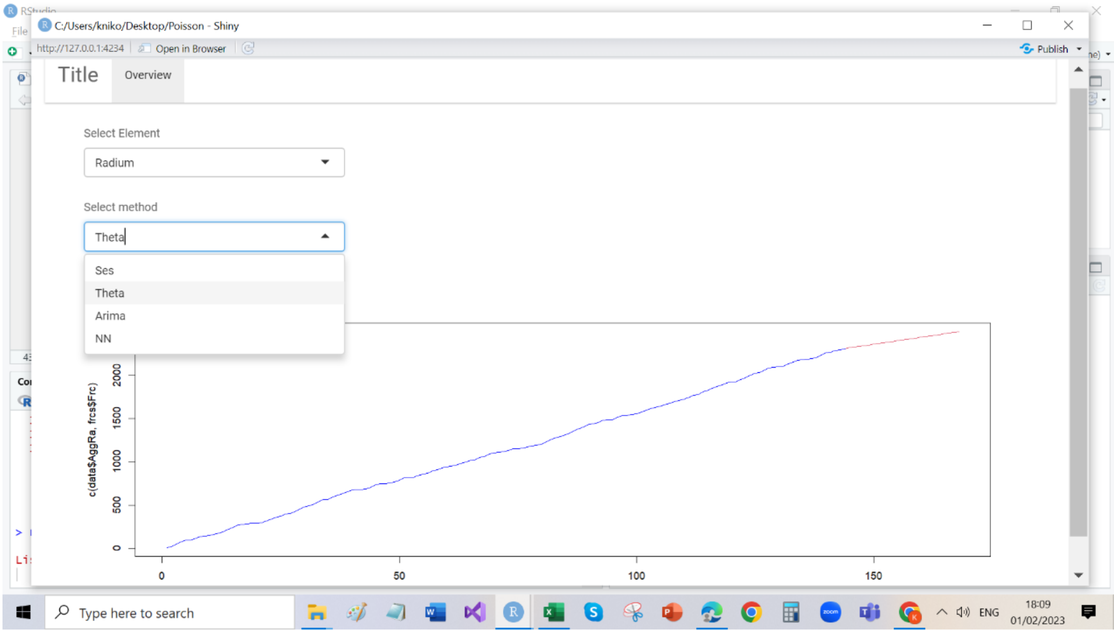


Figure 6 - Interface 1.0 of POIS2ON, Forecasting Radium with Theta

and **ARIMA**

https://www.statsmodels.org/dev/examples/notebooks/generated/statespace_sarimax_faq.html#ARIMA

in Figure 7,

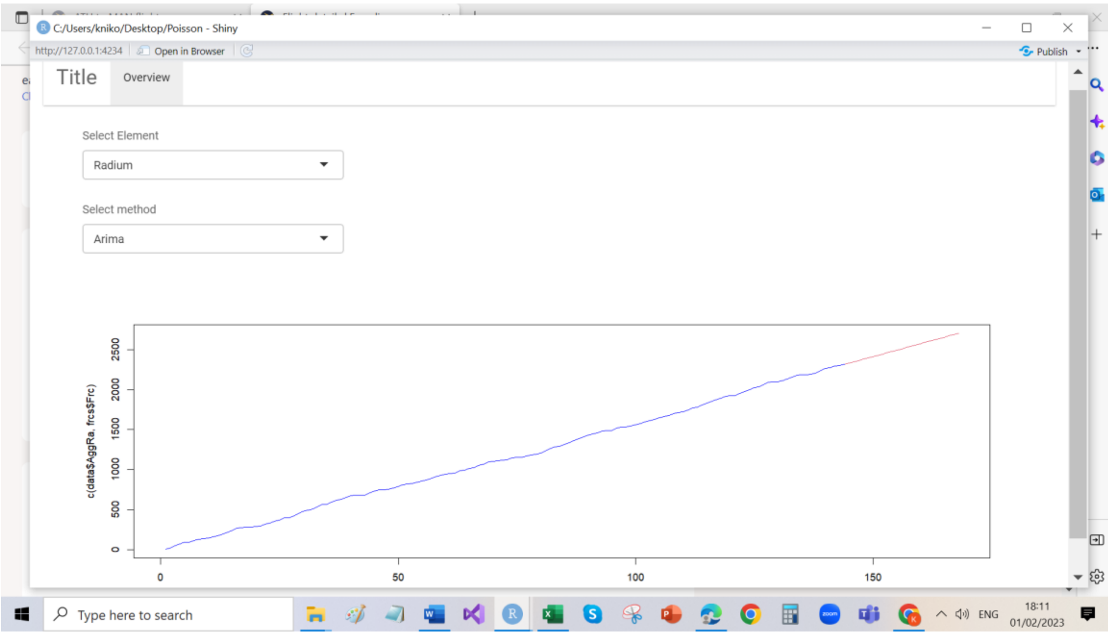


Figure 7 - Interface 1.0 of POIS2ON, Forecasting Radium with ARIMA

Selection of element (one option in Jan 2023) and selection of method (four methods in Jan 2023) and one frequency (hourly) are possible at this current stage.

3.6 Source Code Excerpts from POIS2ON

This is from the core APP where according to the Business Logic there will is a separate Library for the forecasting tasks and there will be a separate one for the Risk Indices, fully independent and coordinated and called by the main app for the basic implementation of POIS2ON

```
# Libraries ----

library(shiny)

library(shinydashboard)

library(shinythemes)

library(lubridate)


# Path ----

setwd("C:/Users/kniko/Desktop/Poisson")


# App ----

## UI ----

ui <- fluidPage(

  title = "Title",

  tags$head(

    tags$link(rel="shortcut icon",href="")),

  theme = shinytheme("paper"),

  navbarPage(

    id = "navbar",

    title="Title",

    header = tagList(
```

```
  ),
  # Overview tab ----
  tabPanel("Overview",
           mainPanel(width=12,
                     column(width=12,
                            selectInput("slct0","Select
Element",choices=c("Radium","Thorium","Caesium"), selected = "Radium"),
                            selectInput("slct","Select method",choices=c("Ses","Theta","Arima","NN"),
selected = "Ses"),
                            plotOutput("plot")
                     )
           )
  )
 )
)

## Server ----
server <- function(input, output, session) {
 # Read data ----
 data<-read.csv("Dataset/data1.csv")
 data$Date<-as.Date(data$Date, format = "%d/%m/%Y")
 data$AggRa<-cumsum(data$Th)



 ses<-read.csv("Dataset/forecasts/ses_forecasts.csv")
```

```
theta<-read.csv("Dataset/forecasts/theta_forecasts.csv")

arima<-read.csv("Dataset/forecasts/arima_forecasts.csv")

nn<-read.csv("Dataset/forecasts/nn_forecasts.csv")


# Overview ----

forecasts_final<-reactive({

 input$slct

 #input$slct

 if (input$slct == "Ses"){

  frcs<-ses

 }else if (input$slct == "Theta"){

  frcs<-theta

 }else if (input$slct == "Arima"){

  frcs<-arima

 }else if (input$slct == "NN"){

  frcs<-nn

 }

 frcs

})




 output$plot<-renderPlot({
```

```
    frcs<-forecasts_final()
    plot(c(data$AggRa,frcs$Frc),type="l",col=2)
    lines(data$AggRa,col="blue")
  })
}

# Start App ----
shinyApp(ui, server)
```

3.7 GIS Connectivity

GIS is a framework and software used to collect, store, manage, analyze, and visualize spatially distributed data. The GIS approach is particularly advantageous when the analysis utilizes spatial data collected from multiple sources, requires an understanding of the spatial relationship between the data points (distance, travel time, etc.), deals with spatial patterns (e.g., hot spot analysis), and largely involves mapping, among other similar applications [Kr22].

Regarding the geospatial data, the selected marine areas will be collected and homogenized in order to process them as input for the relational File Geodatabase (FGDB) integration. All data could be displayed as either vector data depicted as points, lines, or polygons or raster data, which represent geospatial information as a matrix of cells. The imported geospatial content may be georeferenced in a particular coordinate reference system, such as ETRS89 - European Terrestrial Reference System, which is recommended by the WFD GIS Working Group / INSPIRE directive for pan-European spatial data collection, storage, and analysis. FGDB data could produce spatial-temporal representation and visualization in order to generate thematic maps 2d and/or 3d scenes illustrated in a specific color code related to the measured units/concentrations, concerning the level of interaction including such zoom level, initial scale of a map/scene.

4. Updated Functional Requirements

In this section we only provide those requirements (versus D5.1) where minor amendments have been made

Background and Dependent Deliverables

The deliverable 5.2 is the second of a series of eight deliverables D5.1 to D5.8, following every 6 months respectively (D5.5 starting in month 27), being the main outputs of T5.1 and T5.2 as stated in the GA. D5.2 is focusing on the design of POIS2ON

D5.2 is following and abiding to:

D6.6 : *Data Management Plan* [month 6]

D5.1 : *Repository, Information System and Risk no1* [month 24], Repository, Information System and Risk, report (first - intermediate) on the functional requirements of the Information System

and is linked and creates a predicament for:

D5.3 : *Repository, Information System and Risk no2* [month 30], Repository, Information System and Risk, report (first - intermediate) on the Prototype version of POIS2ON information System

D5.4 : *Repository, Information System and Risk no2* [month 36], Repository, Information System and Risk, final implementation and report.

And more importantly to

D5.5 : *Forecasting and Risk Assessment for awareness policy support no1* [month 27], Forecasting and Risk Assessment for awareness policy support, report on the functional requirements of the data driven risk monitor at medium frequency for the awareness of interested stakeholders and communities health safety

Assumptions and Constraints

D5.2 and POIS2ON is developed under the assumption that the necessary measurements of respective radioactivity levels in the sea will be achievable thought the technology developed by RAMONES at the prescribed high frequencies.

Interfaces to External Systems

POIS2ON will interface via APIs with all the decentralized and distributed repositories of each of the devices (mobile and static) of the RAMONES system, as well as governmental information systems of respective interested socioeconomic stakeholders. Owner of POIS2ON will be the RAMONES consortium.

POIS2ON will operate **only** with a safe and secure intranet provided by the respective interested stakeholder or within an intranet of one of the RAMONES partners to guarantee the security and safety of the system and the respective data.

Functional Process Requirements

POIS2ON will process the respective measurement in time series of lower frequency (hourly, bi-daily, daily, weekly) and provide forecasts of these and respective alerts of when annual acceptable limits will be achieved, binding to the status of deployment and operation of the sensors in the marine environment.

Security

Clearance: "*No user may access any part of this application who does not have at least a (specified) clearance*." There is a need to grant one type of user access to certain system functions but not to others, for example, administrator access

POIS2ON will operate **only** with a safe and secure intranet provided by the respective interested stakeholder or within an intranet of one of the RAMONES partners to guarantee the security, and safety of the system and the respective data.

System Availability

POIS2ON will be fully and constantly available through the time of the deployment of the RAMONES team in-situ but running within a secure intranet.

Performance

Real-time response and provision of forecasts within less than one hour with a combination of statistical, ML, and if possible, DL methods too.

Capacity

System should run in an off-the-shelf laptop of no more than (current cost in January 2023) of 1000 EUR – typically an i7 device (penultimate generation) with 16GB RAM and 128GB SSD.

(This is the device: Lenovo T470 - that is currently used for the development of the software with these exact specifications).

Data Retention

Data retained for each deployment of RAMONES and then passed and stored by the respective socioeconomic stakeholders that required, authorized and reimbursed the deployment.

5. Conclusion and the Future

RAMONES aspires to introduce novel monitoring and response channels to inform key socio-political and socio-economics stakeholders at regular intervals at medium (daily, weekly) to low (monthly to inter-annually) frequencies. To that end, the deliverable D5.2 of Work Package 5 provides the Functional Design for the prototype information system **POIS2ON.** POIS2ON will provide statistical forecasts and respective judgmental adjustments primarily for cumulative radionuclide concentrations as well as other time series monitoring hazardous activities and respective risks, and visualize them in GIS as well via Heat maps.

Next respective deliverables linked are D5.3 presenting the first **fully working version** of POIS2ON in month **30** (with simulated data) and D5.4 in month 36 the final version working with simulated and **real data**.

In parallel, in months 27, 33, 39, and 45 **capabilities for calculating and visualizing Risk indices** will be added to POIS2ON via the deliverables **D5.5-D5.8.**

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