RAMONES
Radioactivity Monitoring in Ocean Ecosystems

Deliverable

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Disclaimer

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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
DB	Database
DL	Deep Learning
EaR	Exposure at Risk
EIC	European Innovation Council
EU	European Union
FSS	Forecasting Support Systems
F2SS	Forecasting & Foresight Support System
GIS	Geographical Information System
GO	Governmental Organization
JA	Judgmental Adjustment
Maastricht	Treaty on the European Union
MAE	Mean Absolute Error
MdAE	Median Absolute Error
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
RelMAE	Relative Mean Absolute Error
RelMdAE	Relative Median Absolute Error
RMIS	**R**isk **M**anagement **I**nformation **S**ystem
SF	Statistical Forecasts
SME	Small and Medium Enterprise
SoA	State of the Art
SRF	Strategic Response Frameworks
VaR	Value At Risk
WP	Work Package

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Abstract

RAMONES is an ambitious, high-risk 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 **inform** key **socio-political and socio-economic stakeholders** at regular intervals at medium frequencies (daily, weekly) of **evolving risks** in sea-areas of interest. To that end, the deliverable 5.6. of Work Package 5, second of four deliverables focusing on **building** and communicating **Risk Indices** via the **RMIS** (Risk Management Information System), a **subsystem of the POIS2ON** (presented in D5.1,D5.2, D5.3. with more to follow in D5.4/[month 37] & D5.8/[month 48]), a subsystem focusing on Risk Assessment for awareness and policy support (with input from POIS2ON). We provide in this second deliverable for RMIS **the first implementation of a Risk Index on 12 simulated timeseries, series informed from real data collected in situ in 2023**.

As per T5.2 intent to Raising Awareness and Supporting policymaking we describe in D5.6 how we **implement** a data-driven risk monitor at high frequency (every 10ms) informing on the probability and likelihood of reaching **instantaneously** maximum annual dosages of radioactivity in areas of interest (the cumulative scenario will be studies in D7.7); we aim via providing this information at raising awareness to interested stakeholders and support enhanced resilience for environmental sustainability, and communities' social, financial and health safety.

Keywords

RAMONES; POIS2ON; Radioactivity; Risk Information System; Forecasting; Risk; Probability distributions.

1. Introduction

1.1 Context

This document belongs to Work Package 5 (WP5, *Citizen Awareness, Communication and Dissemination Activities*), and in particular to Task T5.2 Raising Awareness / Supporting policymaking [M25-M48] - Lead: UDUR with Participants: NKUA, UCA, ENS within which RAMONES [Me22] creates a data-driven risk monitor at high frequency (every 10 ms) **informing on eminent reach of annual limits (within much shorter periods of time than a yea**r), and aiming at raising awareness to interested stakeholders and eventually support enhanced resilience for environmental sustainability, and communities' social, financial and health safety

In this deliverable we illustrate the capabilities of the **RMIS** (Risk Management Information System), a subsystem of POIS2ON (Prototype RAMONES Information System for SocioecONomic stakeholders) **via implementing the first Risk Index**. RMIS aims to **inform** key **socio-political and socio-economic stakeholders** at regular intervals at medium frequencies (daily, weekly) of **evolving risks** in sea-areas of interest. We aim also during the next 12 months to get in discussion with IAEA and ENS, for the later phases of T5.2 as part of the linked deliverables D5.7, D5.8 due in months 42, & 48 respectively.

1.2 Structure of the document

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

Section 2. First Usage Scenario of RMIS

Section 3. First Risk Index implementation

Section 4. Conclusion and the Future

1.3 Objectives and approach

The objectives of the RAMONES D5.6 deliverable is to implement the first **Risk Index** to be implemented with **RMIS**.

2. First Basic usage Scenario

In the **first basic usage scenario** the assumption is that a living organisation (human or not) is **receiving instantaneously a large dosage** of radiation and we examine the chance of receiving (or emitting) in one go the entire annual dosage or more. That will happen by randomly passing from an affected area and it could happen in as fast a 10ms. The **cumulative scenario** where the living organisation lays for a large amount of time in a (less) affected area, e.g. 30 min and gradually received withing that time frame the annual dosage, will be examined in deliverable **D5.7**.

3. First Risk Index implementation of RMIS

The RMIS subsystem is depicted in **figure 1** as the **RED-circled** subsystems within POIS2ON as described and designed in D5.5.

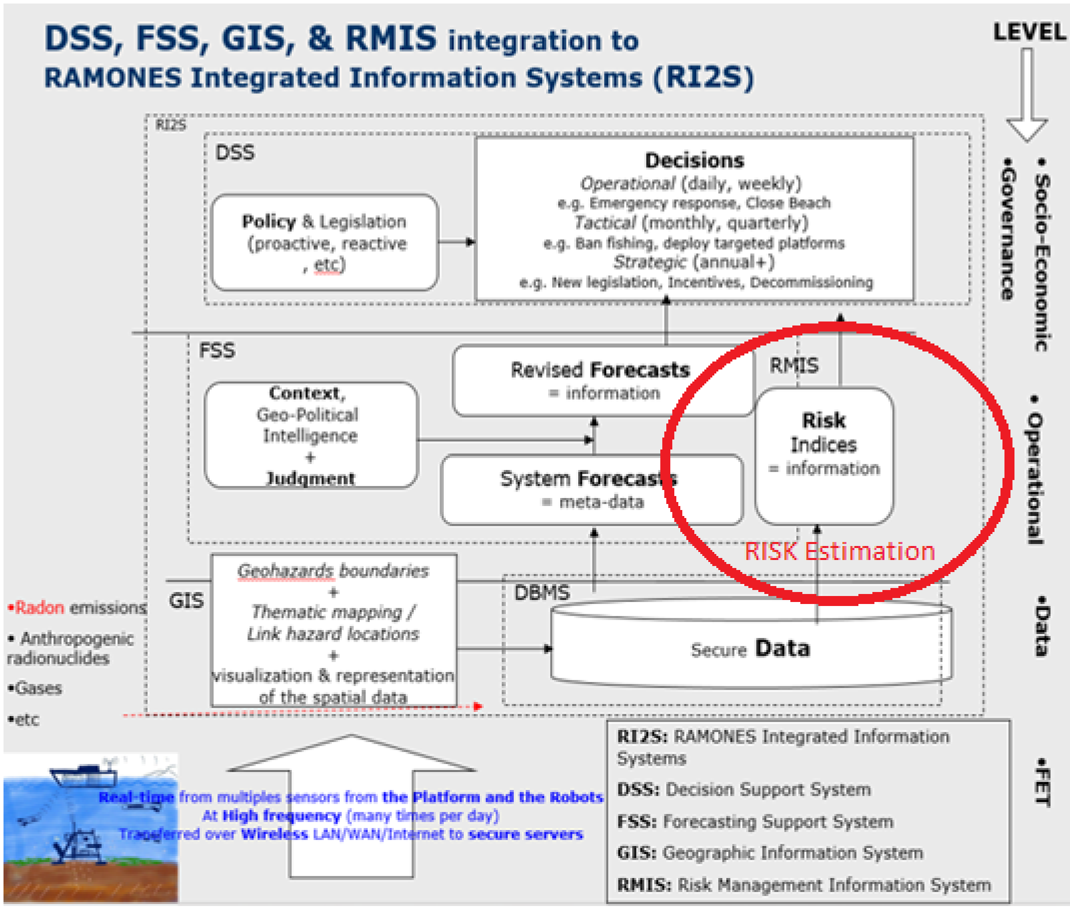

Figure 1 RMIS Subsystem within POIS2ON Prototype RAMONES Information System

The **first Risk index** implementation estimates the probability of hitting the annual dosage in one go, with a single pass over 10ms through the affected radioactive area. The process involves forecasting constantly over the real time measurements at high frequency (10ms) and in real time calculating the forecasting errors that then are fitted to a series of distribution so as to find the best distribution for these errors. Once identified, the probability of reaching at any given time of the maximum dosage is estimated (and respectively communicated)

We simulated the produced code in 15 datasets of the following four elements:

- Cs-137
- Ra-226
- Pb-214
- Pu-240

And the **full spectrum** (figures 2-4) and for three different sub-scenarios: only background noise (figure 2), presence of medium spikes (figure 3), presence of significant spike of radioactive behavior (figure 4).

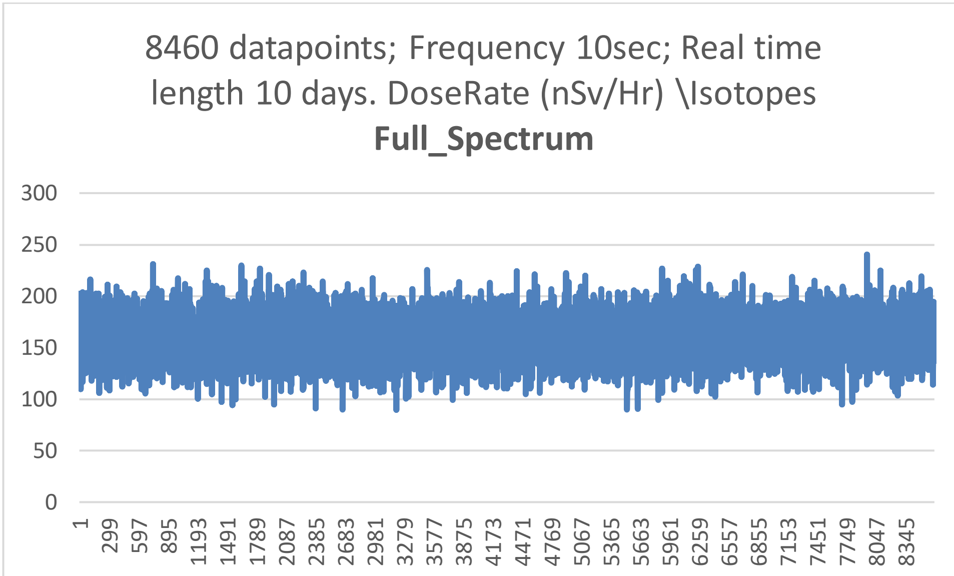

Figure 2 Scenario 1: Background Noise only

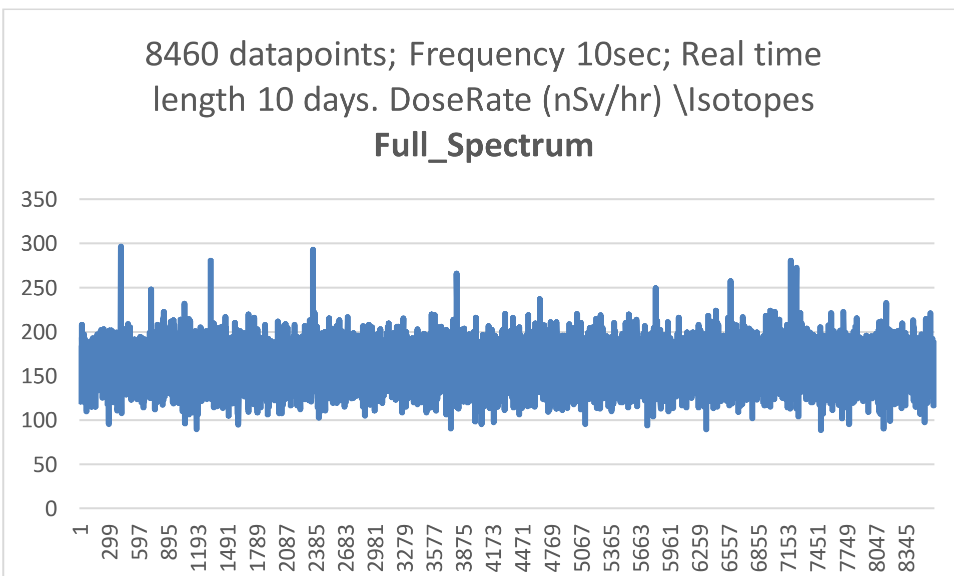

Figure 3 Scenario 2: Background Noise and medium spikes

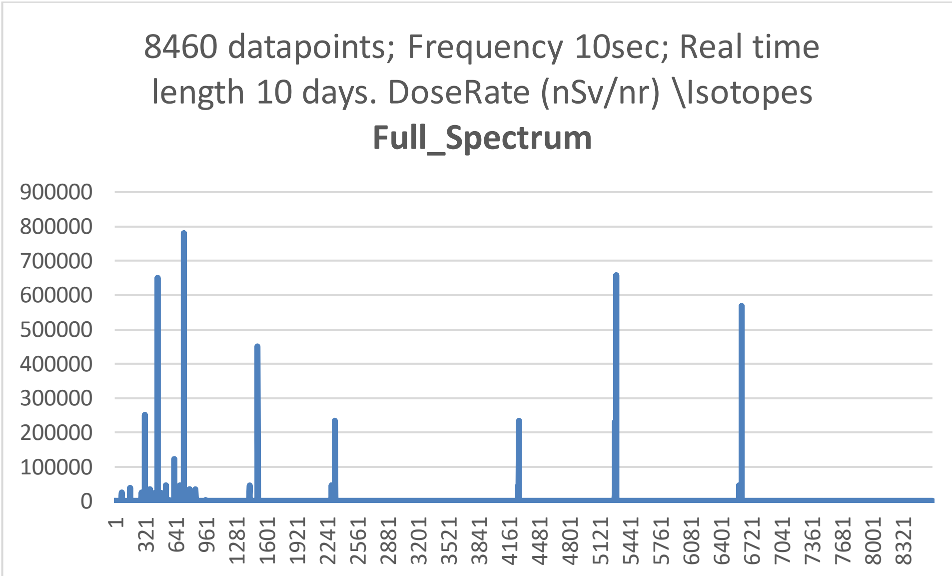

Figure 4 Scenario 3: Background Noise and significant spikes

The produced source code for the respective implementation **hereafter** and the data used in simulation attached with this deliverable:

- **RAMONES Simulated data.xlsx**
- **Ramones_TestData_for_POIS2ON.csv**

Source Code implementation in Python [PYT 2024]

```
# Load packages
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import scipy as sp
import statsmodels.api as sm
from statsmodels.tsa.forecasting.theta import ThetaModel
from statsmodels.tsa.stattools import acf

# Load test data
data = pd.read_csv('Ramones_TestData_for_POIS2ON.csv', header=0, index_col=0)

# Select the series to analyze
name_y = 'Full_Spectrum' # or 'Full_Spectrum'
y = data[name_y]
nobs = y.shape[0]

# Make the index consecutive
y.index = np.arange(0, nobs, 1)

# Set the rolling window to xx% of all observations
set_percent_roll = 0.2
roll = int(set_percent_roll*nobs)

# Set initial gamma for learning
gamma = 0.3
```

```
# Initialize storage of forecast errors
frc_errors = pd.DataFrame(data=None, index=y.index, columns=['eTheta', 'eADL'])
r_adl = pd.DataFrame(data=None, index=y.index, columns=['rho(1)'])
weight = pd.DataFrame(data=None, index=y.index, columns=['weight'])

# Loop over the data to produce forecasts and forecast errors
for i in np.arange(0, nobs-roll, 1):
  # section the data
  yi = y.iloc[i:(roll+i)]
  # Get the actual value for the forecast
  ya = y.iloc[roll+i]
  # Compute the forecast
  ytf = ThetaModel(yi, deseasonalize=False).fit().forecast()
  # Compute the forecast error
  etf = ya - ytf
  # Learn
  if i > 0:
    yaf = ytf + gamma*frc_errors['eADL'].iloc[roll+i-1]
    eaf = ya - yaf
  else:
    yaf = ytf
    eaf = etf
```

```
 # and learn gamma too, if needed
   if i > 9:
       r_adl.iloc[roll+i-1] = acf(frc_errors['eADL'].dropna())[1]
       if r_adl.iloc[roll+i-1][0] > 0:
         if i >= 12:
           weight.iloc[roll+i-1] = np.exp(-r_adl.iloc[roll+i-1].to_numpy()[0])/np.sum(np.exp(-
r_adl.iloc[:(roll+i)].dropna().to_numpy().astype('float')))
           max_weight = (weight.iloc[:(roll+i)]).max()
         else:
           max_weight = r_adl.iloc[roll+i-1]
         gamma_new = (1 - np.sqrt(1 -
4*(max_weight.values[0]**2)))/(2*max_weight.values[0])
         if gamma_new > 0:
           gamma = gamma_new
           print('γ =', gamma_new)
   # Print progress
   print('Now doing', roll+i, 'of', nobs)
   # Store and repeat
   frc_errors.iloc[roll+i] = np.hstack([etf, eaf])

# Post process the results
mse = (frc_errors ** 2).dropna().mean().apply(np.sqrt)
mae = frc_errors.apply(np.abs).dropna().mean()

# and now for the error distribution, normal and Tukey's lambda
e = frc_errors['eTheta'].dropna().to_numpy().astype('float')
```

```
# Fit normal first
params_norm = sp.stats.norm.fit(e)
cdf_norm = sp.stats.norm(loc=params_norm[0], scale=params_norm[1]).cdf
out_norm = sp.stats.ks_1samp(e, cdf_norm)

# Then Tukey's lambda
params_tukl = sp.stats.tukeylambda.fit(e)
cdf_tukl = sp.stats.tukeylambda(lam=params_tukl[0], loc=params_tukl[1], scale=params_tukl[2]).cdf
out_tukl = sp.stats.ks_1samp(e, cdf_tukl)

# Select value to compute a probability (from the estimated cdf), set in multiples of the std
mult = 1.0
set_x_norm = params_norm[1]*mult
set_x_tukl = params_tukl[2]*mult
# Compute the cdf
x_cdf_norm = cdf_norm(set_x_norm)
x_cdf_tukl = cdf_tukl(set_x_tukl)
```

```
# Print everything
print('')
print('---------------------------------------')
print('++ Forecast evaluation and error fit ++')
print('---------------------------------------')
print('')
print('MSE of forecasts: ', mse[0], mse[1])
print('MSE of forecasts: ', mae[0], mae[1])
print('')
print('KS-test (p-value) of Normal distribution      : ', out_norm[1])
print('KS-test (p-value) of Tukey-Lambda distribution: ', out_tukl[1])
print('')
print('Normal distribution probability of error less than:      ', set_x_norm, 'is:', x_cdf_norm)
print('Tukey Lambda distribution probability of error less than:', set_x_tukl, 'is:', x_cdf_tukl)
```

4. 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) frequencies. To that end, the deliverable D5.6 of Work Package 5 provides the first implementation of a Risk Index in this context**.** In parallel in months **42**, we expect to deliver **the next iteration of the RMIS**, and in month **48** the **full version of POIS2ON**. For the immediate next deliverable D5.7 we aim to:

- Analyze the cumulative scenario (as in section 2)
- Introduce a second risk index (as per deliverable D5.5)
- Scanning for more forecasting error distributions (aiming for 10)
- Integrating the Python code for D5.6 in POIS2ON (in R)

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References

[PYT 2024] Welcome to Python.org