Earth Observation Big Data exploitation for water reservoirs continuous monitoring: feasibility of a prototypal service based on Sentinel data and HPC

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Summary

- Introduction
- HPC4RM project
- Methodology
- Case studies
- First results
- Conclusions and outlook

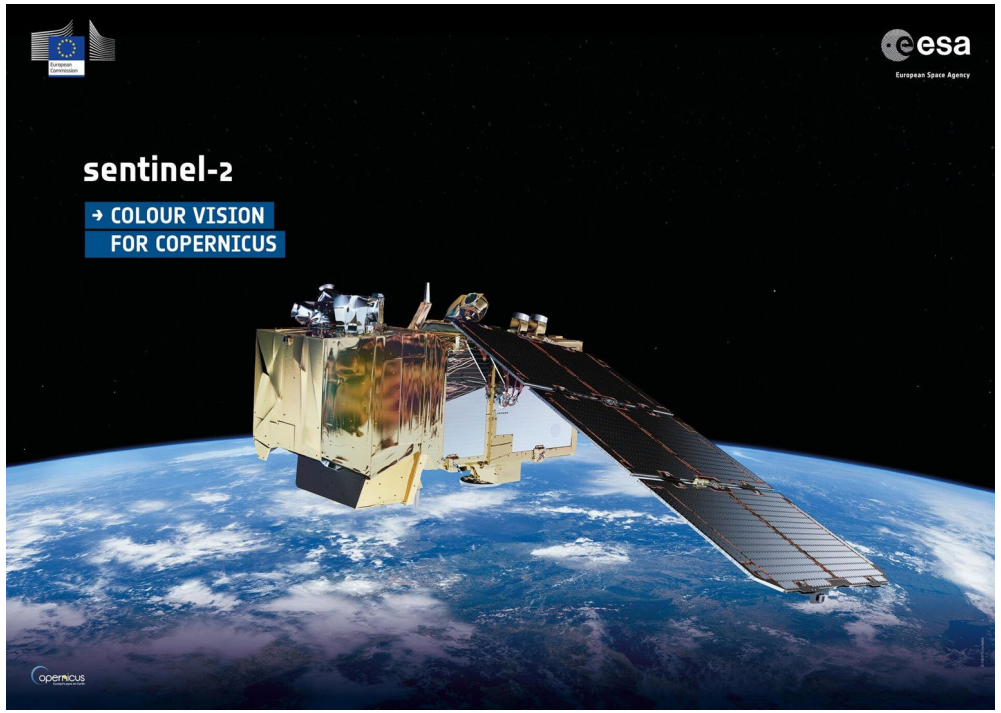
Introduction

- **Water reservoirs** are essential for **freshwater supply** and **hydroelectric power production**
- **Sustainable management** of water reservoirs is crucial to monitor hydrological stresses and **predict water availability**
- Water levels are usually monitored **locally** through traditional ground methods (e.g. **gauge stations**) by a variety of administrations or companies
- The water level measurements collected by gauge stations are generally used together with morphological information (contour lines) to compute the water volume variation of the reservoir under investigation
- Data from gauge stations are **not** always **easily available** and require direct access to the reservoir

Introduction

- **Remote Sensing** technologies can limit the monitoring costs and provide frequently **updated spatially continuous** data that facilitate mapping and analysis of water bodies

- Remote Sensing can represent a **viable** and **low-cost** solution for a **continuous** and **long-term monitoring** of fundamental reservoir parameters such as **water volume/area/level**



HPC4RM project - HPC for Reservoir Management

Identifier: **FF4EuroHPC Call-2**
Call title: First call for FF4EuroHPC application experiments
Project full name: FF4EuroHPC: HPC Innovation for European SMEs
Acronym: FF4EuroHPC

Identifier: 1113
Acronym: HPC4RM
Project full name: HPC for Reservoir Management

Project Organizations

Service Provider
will take advantage of its experience in the creation of specialized software and services for satellite data processing to define and develop the foreseen application to provide new service by using HPC assets

Domain Expert
will provide insights and expertise in optical image processing and advanced geomatic methodologies and techniques to help the design of the overall application and to tailor the processing step in the workflow

HPC Expert / Centre
will support the definition of the best strategies for efficient exploitation of HPC capabilities and support the development of the proposed solution

End User
will provide access to all the needed information of their reservoirs, targeted by the experiment; they will drive the definition of the real needs of end-users and assess the result of the experiment

HPC4RM project - HPC for Reservoir Management

- Satellite data will play a key-role in enabling a continuous monitoring service over time at a **negligible cost**, as **continuous** (i.e., every few days) monitoring is in place, giving new insights to water resource managers on their assets

- **HPC4RM experiment** will allow designing a **new service** that takes advantage of **HPC** to build an evolving **3D model of the reservoir** through the **integration** of the **planimetric water extent, estimated** from **AI super-resolved Sentinel-2** imagery, with **local information** on **water level**

HPC4RM project - HPC for Reservoir Management

The goal the project is strictly related to United Nations Sustainable Development Goals (**SDGs**) related to **water availability** (SDG 6) and **climate change effect** monitoring (SDG 13) and with the Recovery Plan Next Generation EU

Methodology

The proposed **methodology** implements the following main steps:

- Artificial Intelligence (AI) powered **super resolution** of **Sentinel-2 imagery**
- Detection of the (**2D**) **extent** of the reservoirs from the super resolved **Sentinel-2 imagery**
- Computation of **3D volumetric changes** by **integrating** the computed **water surface extent** with **local information** on the **water level**

AI powered super resolution

- The goal of **super-resolution** is to take a **low resolution** image I0 and **upsampling factor t**, and generate a corresponding **high resolution** version I
- We follow the **deep image prior** approach to provide a **super-resolution** algorithm that does **NOT depend on the availability of training datasets**
- The main **disadvantage** of the proposed approach is that, while avoiding any training phase, the actual **super resolution step** can be regarded as a training phase itself, with a similar (**high**) **computational cost**
- The availability of **HPC premises** (in particular, GPU HW), is mandatory to allow any **practical implementation** of the deep image prior super resolution approach on the **Sentinel-2 imagery**

Detection of the extent of the reservoirs

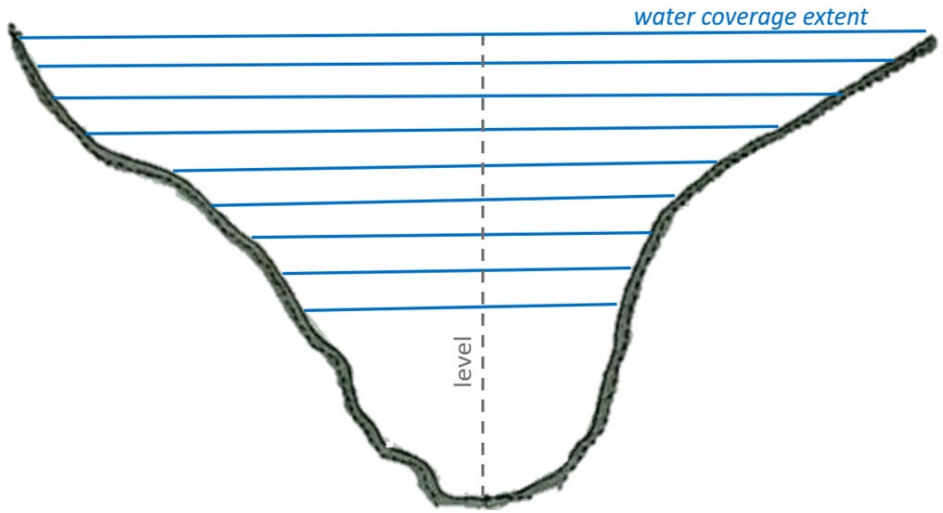
Two different **methods** to detect the **horizontal extent of the reservoirs**, originally developed for Landsat imagery, were investigated to **segment** the **pixels** that belong to **water** areas:

- **Method 1** relies on the use of the **Automatic Water Extraction Index** (applied on the atmospherically corrected surface reflectance values) and on a non-parametric unsupervised method based on the Canny edge filter and Otsu thresholding (Donchyts et al 2016), (Sengupta et al 2020)

- **Method 2** generates **false color composites** starting from the Short-wave infrared (SWIR1)/NIR/Red bands of Landsat images and then applies a **HSV transformation** (Valadão et al, 2021)

Computation of 3D volumetric changes

- The **3D volumetric changes** will be computed by **integrating** the information of **in-situ measured water level** with the corresponding **estimated water surface extent**
- The **seasonal variations** of the reservoir water storage allow **defining a volumetric 3D** model of the reservoir: the varying water level acts as a layer stripping procedure
- The ability to map the time variations of the shallower areas of the reservoir plays a key role in reservoir and water resources management



Relation between estimated water coverage exent and reservoir filling level (shown for a selected reservoir cross-section)

Case studies

Two different **reservoirs** in the south of Italy (Calabria region) providing the freshwater supply for nearly two million people:

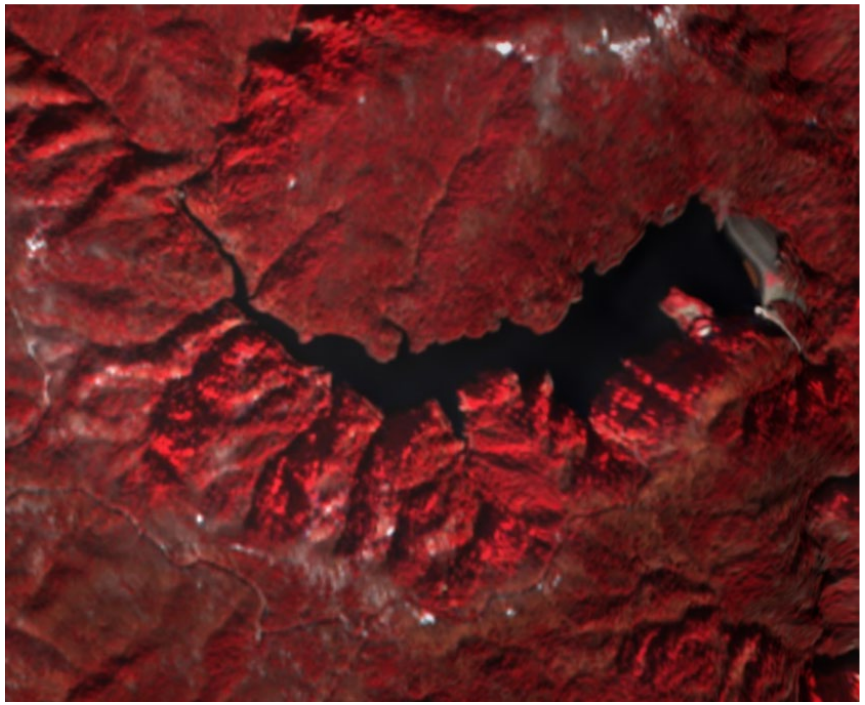
- **Menta dam lake** with a total volume of 17.9 hm^3
- **Alaco dam lake** with a total volume of 32 hm^3

characterized by quite different environments and average shore steepness

Local water level data are provided by Società Risorse Idriche Calabresi S.p.a. (So.Ri.Cal.)

HPC4RM: S2A image examples

Bands: 4,3,2 (red, green, blue)

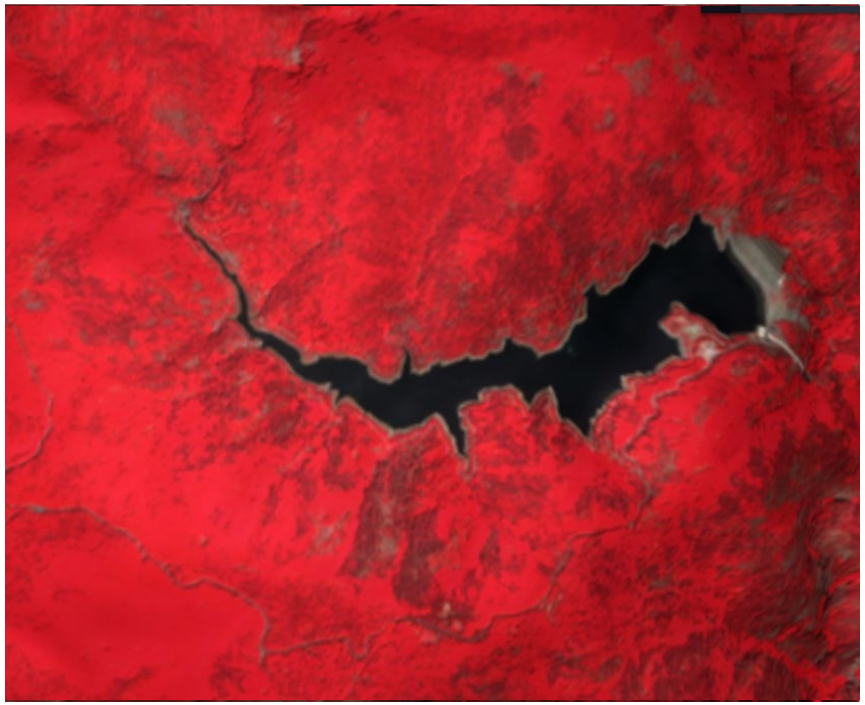


Bands: 8,4,3 (near infrared, red, green)

Diga del Menta: Jan 4th, 2022

HPC4RM: S2A image examples

Bands: 4,3,2 (red, green, blue)

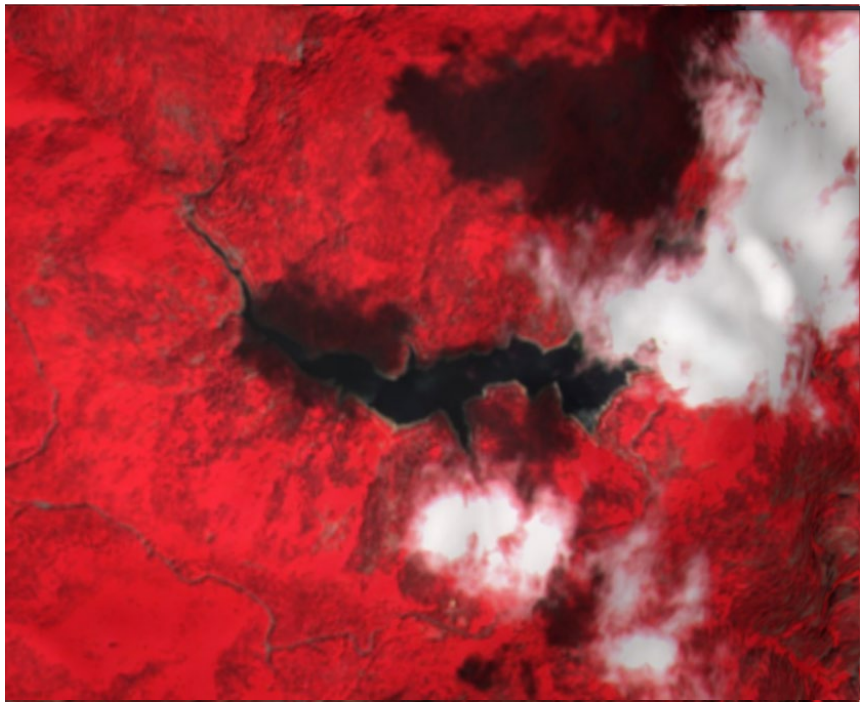


Bands: 8,4,3 (near infrared, red, green)

Diga del Menta: Aug 17th, 2020

HPC4RM: S2A image examples

Bands: 4,3,2 (red, green, blue)



Bands: 8,4,3 (near infrared, red, green)

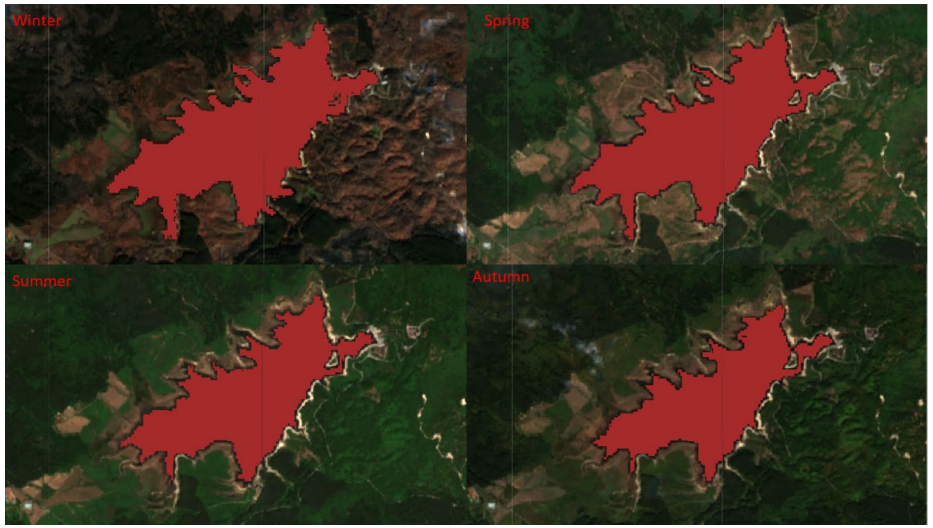
Diga del Menta: Aug 20th, 2020

Results - Alaco dam lake

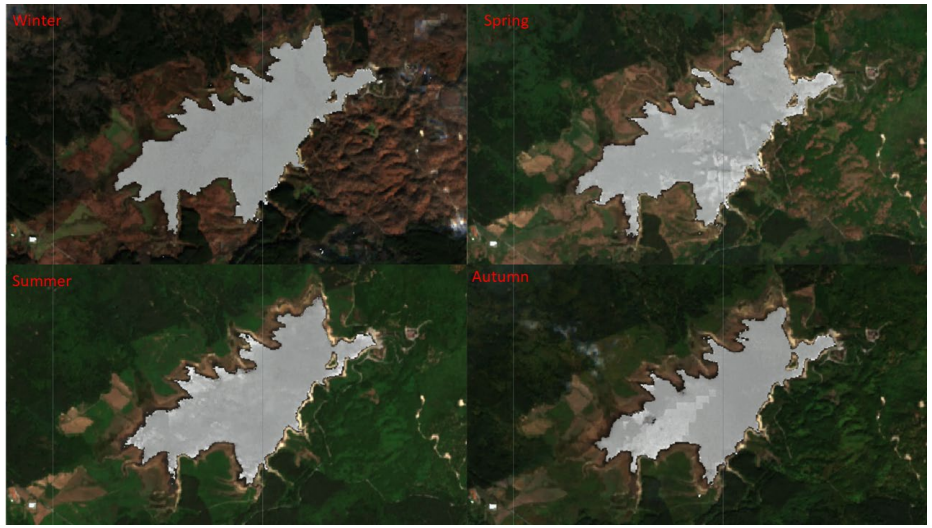
- **All the images of Sentinel-2** available for for the **year 2021** were filtered by selecting the ones with the **lowest cloud coverage** and **masking out** the remaining **cloudy pixels**

- A total of **4 images**, one for every three months of the considered period, were obtained by computing the **median values** of the **pixels** from the **filtered set of images**

- The **two methods** for the **water extent detection** were applied to each of the four images



Results of the detection of the water extent (spectral index based) for the 2021 year - method 1



Results of the detection of the water extent for the second (HSV based) method for the 2021 year - method 2

Conclusions

- Water shortage and long periods of droughts interspersed with extreme weather events make the **correct management** of **water resources** a critical issue
- The **continuous monitoring** of water reservoirs can be performed **by satellite data** without the need for direct access to reservoir sites and with an overall cost that is independent of the actual extent of the reservoir
- A **complete data processing chain** is currently **under development**, starting from satellite raw data up to water body detection and surface extent estimation
- The use of **AI-powered super-resolution** techniques will allow achieving the required resolution starting from the ESA Sentinel-2 constellation

Thank you for your attention

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www.ff4eurohpc.eu/en/experiments/2022031511555138/hpc_for_reservoir_monitoring