EO-WIMEX

Wave Interaction Models EXploitation

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Introduction

Forward and inverse models developed by the Earth Observation (EO) scientific community describe, respectively, the relation between electromagnetic waves interacting with natural surfaces and the methodologies for retrieving bio-geophysical variables from remotely sensed data.

Yet the current landscape - marked by the development of an extensive and heterogeneous suite of models - reveals some limitations:

- models not systematically implemented;
- models tested and validated only on small amounts of data and
- limited integration of the models with the emerging Artificial Intelligence (AI)-based inversion techniques.

To overcome these challenges, this poster introduces the Wave Interaction Models EXploitation (WIMEX) framework.

1. What is EO-WIMEX

WIMEX, leveraging the unprecedented amount of EO data today available, promotes a **systematic approach to the development, validation, and use of existing and future forward and inverse models** for increased efficiency and flexibility, resorting where needed to GPU and parallel computing. Unlike existing solutions:

WIMEX is designed to be model-independent

It accommodates, manages, and operates any forward and inverse model independently of sensor and model objectives, supporting the use of cloud infrastructure, including **GPU and parallel computing**, for improving performance. This versatility reinforces the framework role in supporting existing and next-generation EO missions.

WIMEX interfaces with different EO data sources

Such as EO data, in situ data, ad-hoc datasets, etc. It supports the design, development and validation of forward models and the generation and storing of **Lookup tables and Datacubes** in a flexible way.

WIMEX supports AI techniques

It assists with the use of the forward models outputs the testing and calibration of inverse models, through processes like neural networks training. It also fosters the design of new and/or more accurate inverse models combining their implementation with **AI-based inversion techniques.**

This new systematic approach is expected to improve the overall performance of the models and to align with the evolving needs of the research community.

2. Main advantages of EO-WIMEX

The WIMEX prototype architecture depicted in Figure 1 is thought to be scientific user oriented, flexible and at the same time efficient. It implements various advantages, the main of which are:

- **Model independence, guided development and version control**
  Within the Model Development Environment users are guided through a dockerization process to smoothly integrate their forward and/or inverse models into the framework. The dockerization of the models, combined with the definition of the related descriptor file containing the information necessary to deploy and invoke the containerized model, ensures the Framework independence of the models which are therefore managed as "black boxes". Furthermore, a versioning service is provided by the Framework Model Repository, thus allowing users to handle multiple versions of a certain model together with its documentation.

- **Flexible data access, preparation and management**
  Regarding input/output data handling, through standardized interfaces, the Framework Data Manager module manages the interconnection of the models with local and remote/distributed input data sources and databases (EO data, in situ data, ad-hoc datasets, etc.) and the generation of Lookup Tables (LUTs) and Datacubes from the forward models' outputs. Moreover, such generated LUTs and Datacubes are available for the testing and calibration of the inverse models integrated in the framework through the exploitation of AI techniques.

- **Infrastructure flexibility and independence**
  The Framework is infrastructure independent, in fact its Computational Resource Manager allows the execution of models on both ESA internal and external (cloud) computational resources. Moreover, the configuration of such resources as Kubernetes clusters makes the Framework agnostic to the underlying hosting infrastructure.

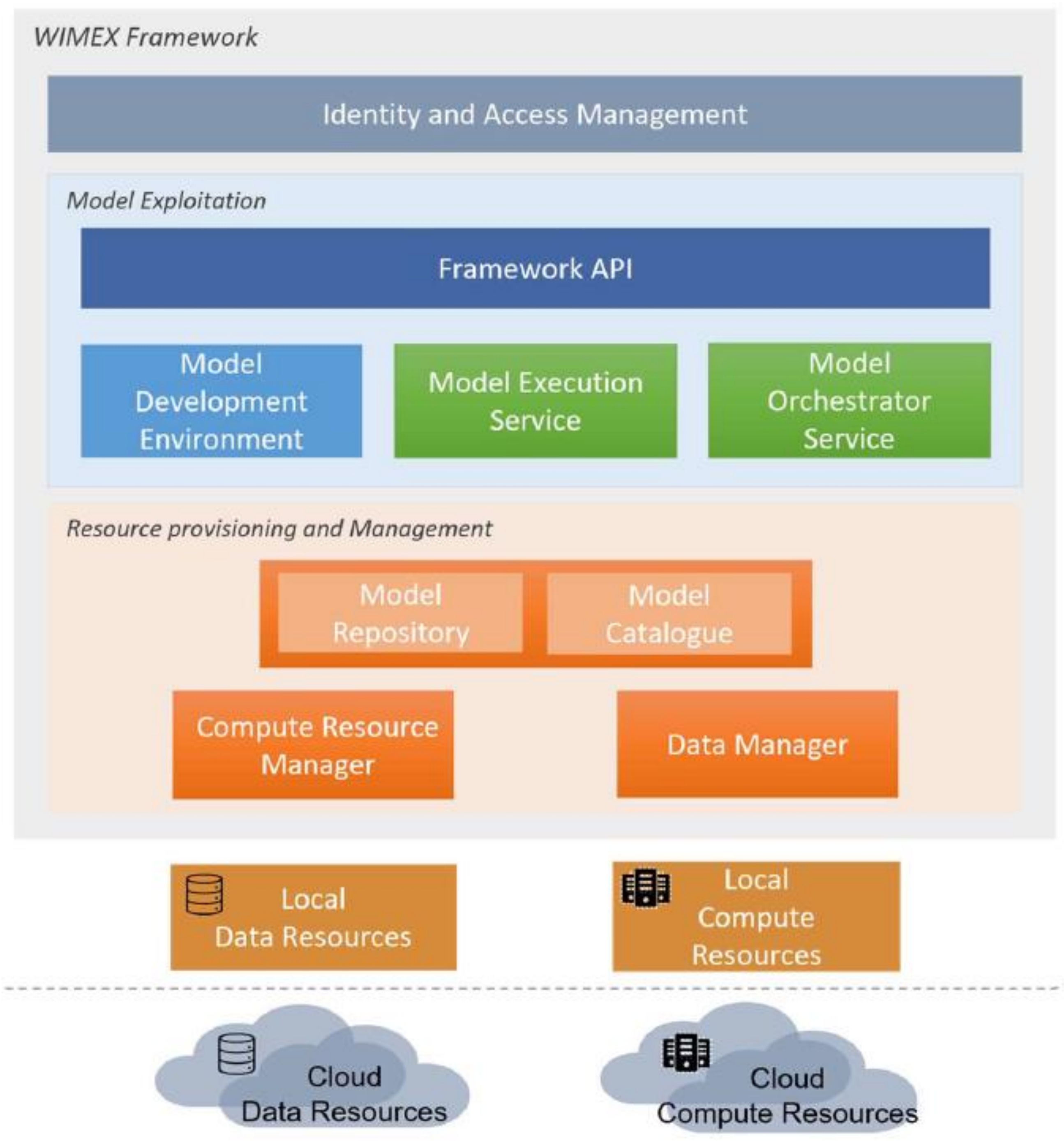

Figure 1 - WIMEX Framework architecture

3. EO-WIMEX Prototype

The prototype version of WIMEX, set to be released in the second half of 2024, demonstrates its efficacy and flexibility for remote sensing over land applications, specifically through the management and execution of the following forward and inverse models for the estimation of **soil moisture** and **snow water equivalent** by means of Synthetic Aperture Radar (SAR) acquisitions.

Forward models

Owner	Model Type	Main Features
Sapienza	First order Small Slope Approximation (SSA1/2)	It provides Normalised Radar Cross Section (NRCS) of bare soils as a function of the acquisition geometry.
INRAE	First order semi-empirical Integral equation model (IEM)	It provides NRCS of bare soils for monostatic acquisitions. It consists in a semi-empirical calibration of the Integral Equation Model (IEM).
INRAE	Empirical Model	It simulates the backscatter coefficients in HH and VV polarizations as a function of the soil dielectric constant and surface roughness.
INRAE	Water Cloud Model	It describes the effect of vegetation cover over soils (calibrated using mainly wheat plots and grassland).
FMI	Snow Layer Phase Signature	It calculates radar signal path length in a multilayer snowpack, leading to capability to estimate InSAR phase difference in natural snow due to snow accumulation.

Inverse models

Owner	Model Type	Main Feature
INRAE	Inverse model for soil moisture estimation	It maps soil moisture at plot scale over agricultural areas based on coupling Sentinel-1 SAR data and Sentinel-2 optical data using the neural network technique.
UT3	Inverse model for soil moisture estimation	Algorithm based on change detection for the estimation soil moisture based on Sentinel-1 SAR and Sentinel-2 optical data time series.
FMI	InSAR Snow Water Equivalent (SWE)	It describes the relation between interferometric phase and changes in dry snow.

4. Conclusions and future developments

The WIMEX framework prototype here presented aims at promoting a new systematic approach expected to improve the overall performance of the wave interaction models and to progressively align with the evolving needs of the research community.

In the near future, upcoming versions of WIMEX will incorporate support to additional sensors and further geophysical variables retrieval techniques, as well as diverse missions, to enhance user experience and address a wider spectrum of requirements.

5. Acknowledgments

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