Land surface response tools

Introduction

As part of the ARSINOE project, we evaluate a modular catalogue of land surface response tools that are currently at a state-of-the-art stage of development. These tools have been applied, adapted or newly developed to assess how climate change affects various land surface processes. Their focus spans hydrological systems, flood risks, surface temperature variability, and related land-based climate hazards. These tools are part of a toolkit which represents a foundational component of ARSINOE's broader strategy to develop cross-sectoral resilience modelling frameworks under climate uncertainty.

🎯 Objectives

The toolkit offers flexible and robust models to stimulate land surface responses to climate impacts, tailored to the highly diverse challenges faced by ARSINOE's highly diverse case studies. It integrates a wide array of simulation approaches, including process-based hydrological models, ensemble techniques, GIS-based spatial analysis, and elements of machine learning. It is designed to address diverse and context-specific risks such as heatwaves in dense urban areas, floods in coastal and riverine zones, droughts impacting agriculture and water supply, and sea-level rise threatening infrastructure. The toolkit is designed to support regionally adapted, cross-sectoral strategies for building resilience under climate change.

💡⚙️ Tools and approaches

The tools reflect a wide spectrum of modelling approaches, each designed to address specific types of climate impacts at the land surface level including:

- Hydrological models (WaSiM, GW-EH-LP, HEC-HMS) simulate flow and water availability;
- Flood models (MIKE21, CAFlood) assess coastal and urban risks;
- GIS tools map temperature-related vulnerability;
- Integrated and sectoral models (IWaMM, DamageCost, Aquacrop, DSSAT) examine crop productivity, economic loss, and ecosystem pressures.

Moreover, some tools include AI-based forecasting, like LSTM-CNNs for water temperature projections.

⚜ Application across Europe

The tools have been designed for and applied in nine ARSINOE case studies, covering diverse geographic and socio-environmental contexts:

Case study #1: In Athens, GIS tools identify urban vulnerability hotspots for targeted resilience measures.

Case study #2: Coastal models in Piraeus and Limassol simulate future wave and storm surge risks.

Case study #3: In Bavaria, hydrological modelling with WaSIM projects more frequent floods and highly amplified water scarcity in the Main River basin.

Case study #4: IWaMM simulations show projected water deficits affecting the environment in the Prespa and Ohrid Lakes.

Case study #5: The Canary Islands benefits from 3D geological and coastal simulations to assess aquifer recharge and shoreline changes.

Case study #6: A HEC-HMS model for the Aliakmonas river's digital twin improves water resource management, flood prevention, and reservoir optimisation.

Case study #7: In Esbjerg, a Damage Cost model evaluates flood protection infrastructure and green multifunctional dikes to optimise future adaptation pathways.

Case study #8: In the UK, CAFlood helps simulate and plan for urban flood scenarios.

Case study #9: In Sardinia, Aquacrop evaluates climate impacts on wheat yields.

Each model is tailored to local conditions and stakeholder needs, supporting targeted climate resilience strategies.

💡 Key findings

Our work in ARSINOE resulted in the creation of a coherent, modular modelling toolkit capable of supporting data-driven decision-making for land-based climate adaptation. Although still in development, the toolkit already demonstrates the ability to provide critical insights into how European landscapes and systems may respond to extreme events such as droughts, floods, storm surges or heatwaves. It offers practical value by supporting spatial prioritisation of adaptation actions, providing early-stage inputs for infrastructure planning, and informing policy discussions at the regional and local level. The tools are well-aligned with ARSINOE's broader objective of integrating multiple sectors and systems to build resilience in the face of climate change. However, the current outputs are provisional, and further updates are expected as new data and stakeholder feedback are incorporated.

Challenges and future directions

Several challenges remain in completing and refining the modelling toolkit. One major area of ongoing work involves updating the tools with generally accessible climate projections, once made available from the CORDEX initiative. The complexity of integrating diverse datasets, land uses, and climate scenarios also requires careful calibration and validation to ensure scientific robustness. In addition, the ARSINOE Living Labs have provided valuable feedback on potential new functionalities, such as the inclusion of groundwater recharge and soil temperature modelling. The project aims to progressively expand the capabilities of the suite to better reflect real-world needs and improve its usability for stakeholders, planners, and policymakers. Integration with digital twins and operational decision support platforms will be key to increasing the impact and accessibility of these tools.

Conclusion

The Modular Toolkit of Land Surface Response Tools developed within ARSINOE is a forward-looking and technically sophisticated resource for analysing and predicting climate change impacts on land systems across Europe. Although the tools are still undergoing validation, they already provide essential building blocks for cross-sectoral climate resilience modelling. Their modularity, adaptability, and scientific foundation make them well-suited for future integration into operational planning processes, supporting a more resilient, informed, and climate-ready Europe.

To find more about the ARSINOE Land Surface Response Tools, read our corresponding deliverable D3.7: **HERE**.

More about the project on our website: **https://arsinoe-project.eu/**
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