Climate module for Railway infrastructures risk management

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THE PROJECT

IU-RESCAT/C3 and ETS SrI are collaborating on an innovative project to adapt risk management in railway infrastructure to the effects of climate change. As climate change poses various challenges to the transportation sector, particularly to railways, this joint effort aims to enhance the resilience of railway systems in the face of changing environmental conditions.

AN UNIVERSITY – INDUSTRY CONSORTIUM to boost climate change adaptation measures

IU-RESCAT/C3 (URV), known for their expertise in climate science, climate services, and climate change adaptation, brings their knowledge and experience to the table. They provide valuable insights on identifying vulnerabilities and potential impacts of climate change on railway operations.

On the other hand, ETS SrI specializes in engineering and technology solutions for railway systems. Leveraging their technical capabilities, they contribute to the project by developing innovative methodologies and technologies to adapt existing railway infrastructure to climate changeinduced risks.

THE BACKGROUND

IURESCAT/C3 has led projects in both climate database management and the development of a methodological process to transform these databases into services (from data to service). In the INDECIS project, a co-creation methodology for tourism services (Font et al 2021) was developed. By engaging stakeholders in the process, IURESCAT/C3 ensured that the resulting services would be relevant and aligned with the demands of the target audience.

Since 2005 ETS SrI has improved its engineering services and has offered high-quality innovative solutions. They are related to railway and road design, environmental and territorial design. Multidisciplinary team talent is supported by cutting-edge solutions, technologies and Project Management processes. This association makes it possible to manage every single phase of the project in a linear and meticulous way: analysis, planning, design and delivery. Thanks to this accurate process, it is possible to reach new standards in terms of quality, value, respect of deadlines and cost savings.

PROJECT OBJECTIVES

- Co-Creation of risk indices.
- 2. Enhancement of Risk Management Services: Improve ETS' existing risk management services, specifically MIRET (Management and Identification of the Risk for Existing Tunnels) and MIRETS (Management and Identification of the Risk – ETS).
- 3. Future Scenario Consideration: Enable consideration of Representative future scenarios different based Concentration Pathways (RCPs) to assess infrastructure vulnerability and give information to plan adaptation and mitigation actions.
- User-Centric Approach: Gather feedback User engagement to meet their specific needs and address their concerns.
- Value Addition to ETS Management Systems: Provide added value to ETS' management systems.





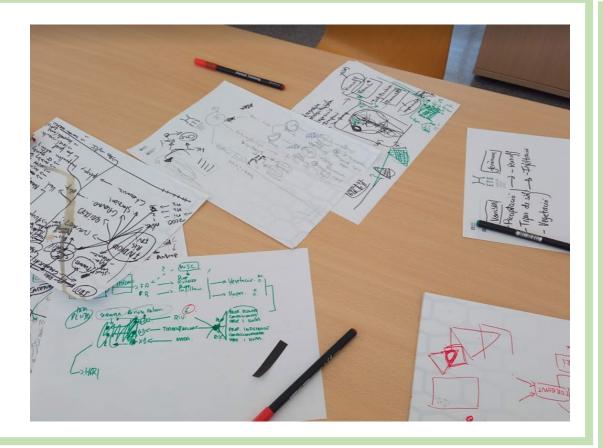
. Stakeholder Engagement

people, Technical managers, and other type stakeholders were engaged to participate in workshops



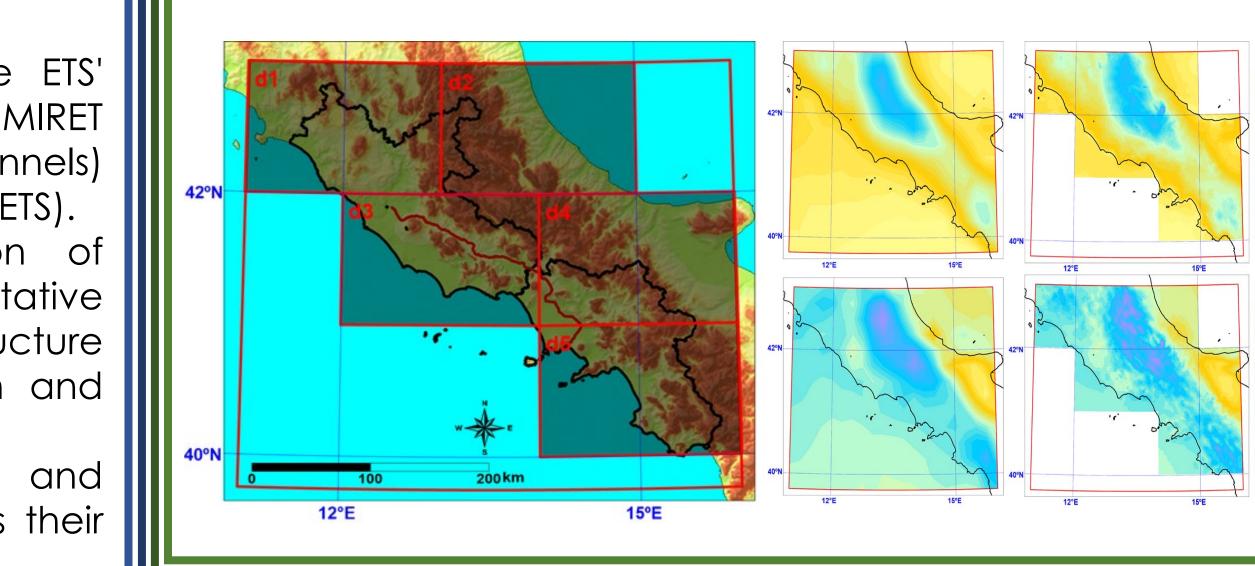
3, Indices Theoretical definition

The information obtained in the workshops is operationalized for computation with climatic data. Operationalizing the information involves converting the data and knowledge acquired during the workshops for decision-making and planning adaptation measures.



5. Downscaling

The initial data used are from the ERA5 global reanalysis with hourly time resolution and 0.25 degrees by 0.25 degrees spatial resolution, but downscaling is necessary for improved accuracy. The MISH interpolation software is employed, combining deterministic algorithms and geospatial stochastic modeling. It utilizes various deterministic predictors, such as terrain elevation, AURELHY principal components, distance to the coastline, and surface roughness, to establish statistical dependencies between climate parameters and supplementary predictors. The downscaling is conducted on 0.02 degrees by 0.02 degrees 📗 🚛 (~2km by 2km) grid. The MISH modeling part is performed for the entire domain, while the interpolation is executed for five nonoverlapping subdomains. This downscaling procedure generates high-resolution climate modeling for the study area.



The final part of the project involves integrating the Climatic Module into the MIRET and MIRETS frameworks. The MIRET and MIRETS frameworks gain enhanced capabilities for considering climate-related factors and their impact on infrastructure performance and resilience. This integration allows for a more comprehensive evaluation of infrastructure risk, enabling stakeholders to make informed decisions and implement appropriate adaptation measures to mitigate the potential effects of climatic conditions on the train line

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• Benichou P., Le Breton O. (1987) AURELHY: une methode d'analyse utilisant le relief pour les besoins de l'hydrometeorologie. In Deuxiumes Journues Hydrologiques de l'ORSTOM a Montpellier (Colloques et Seminaires). ORSTOM: Paris; 299–304. ISBN: 2-7099-0865-4 • Copernicus Climate Change Service (C3S) (2017): ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate Change Service Climate Data Store (CDS), date of access. https://cds.climate.copernicus.eu/cdsapp#!/home • Font Barnet, A., Boqué Ciurana, A., Olano Pozo, J. X., Russo, A., Coscarelli, R., Antronico, L., De Pascale, F., Saladié, O., Anton-Clavé, S., & Aguilar, E. (2021). Climate services for tourism: An applied methodology for user engagement and co-creation in European destinations. Climate Services, 23, 100249. https://doi.org/10.1016/j.cliser.2021.100249 Schulzweida, Uwe. (2021). CDO User Guide (Version 2.0.0). Zenodo. http://doi.org/10.5281/zenodo.5614769 Szentimrey T., Bihari Z., Manual of interpolation software MISHv1.03, Hungarian Meteorological Service, Budapest, Hungary, 2014.

METHODOLOGY AND OUTCOMES

2. Co-Creation Workshops These workshops are collaborative sessions designed to bring together stakeholders to generate ideas, solve problems, and make decisions collectively. Following the methodology defined by Font et al. 2021, three steps were developed:

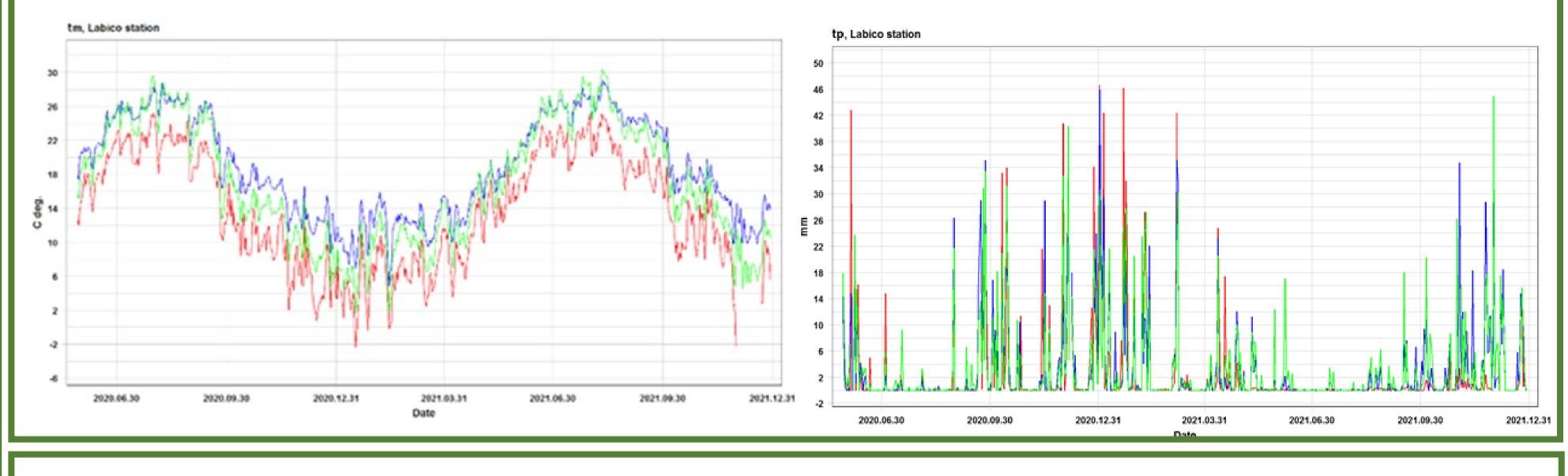
- Definition of topic and diagnoses: In this step, participants identify and define the topic or problem that will be the focus of the co-creation workshop.
- 2. Climate and meteorological impacts on railway infrastructure elements: Once the topic is defined, participants delve into understanding the specific climate and meteorological impacts on railway infrastructure elements
- 3. Solutions and decisions: With the information gathered in the previous steps, ot or REDMING participants move on to generating potential solutions and making decisions

4. Data compilation

To gather the required data for the analysis, ERA5 and ERA5 Land reanalysis models utilized. These models provide comprehens and high-quality climate data on a glo scale. In addition to the reanalysis models, do from ETS's own stations are sought of identified. These stations likely comprise network of weather monitoring stations sensors maintained by ETS

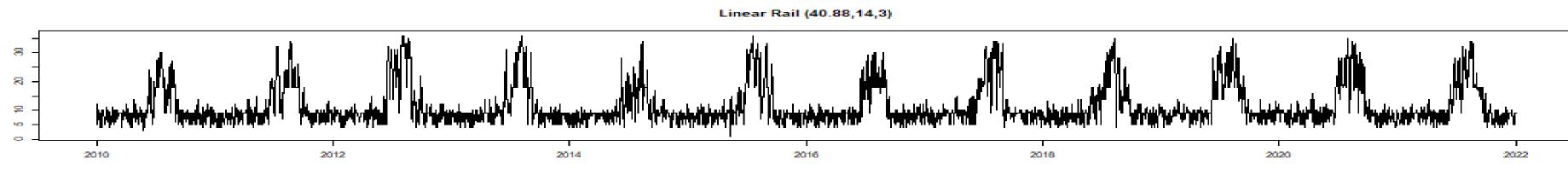
6. Validation

The downscaled data is validated, and shows improved accuracy compared to the original ERA5 data. This downscaled climate model enhances the assessment of infrastructure risk in the study area, considering various factors and climatic conditions.



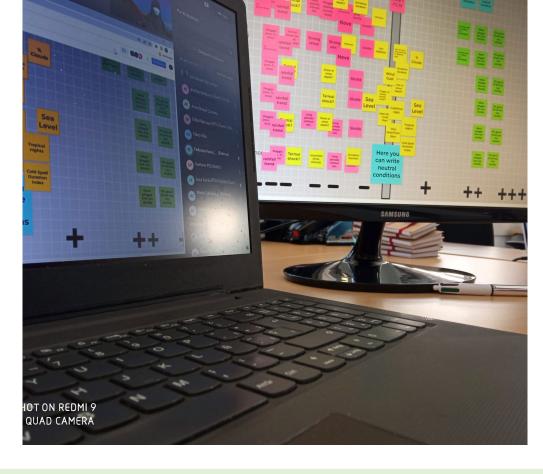
7. Indices Compilation and visualization

A specific code is developed using the R software. Additionally, a Shiny application, programmed by the IURESCAT/C3 researchers, is utilized for visualizing the results. This integrated approach allows for comprehensive analysis and informed decision-making and risk management.



8. Integration in MIRETS Module

REFERENCES



ERA5 hourly data on single levels from 1940 to present
Overview Download data Quality assessment Documentation
ERAS is the fifth generation ECMWF reanalysis for the global climate and weather for the past 8 decades. Data is available form 1940 onwards. ERA5 replaces the ERA-Interim reanalysis. Reanalysis combines model data with observations from across the world into a globally complete and consistent dataset using the laws of physics. This principle, called data assimilation, is based on the method used by numerical weather prediction centres, where every so many hours (12 hours at ECMWF) a previous forecast is combined with newly available observations in an optimal way to produce a new best estimate of the state of the atmosphere, called analysis, from which an updated, improved forecast is issued. Reanalysis works in the same way, but at reduced resolution to allow for the provision of a dataset spanning back several decades. Reanalysis does not have the constraint of issuing timely forecasts, so there is more time to collect observations, and when going further back in time, to allow for the ingestion of improved versions of the original observations, which all benefit the quality of the reanalysis product.
ERA5 provides hourly estimates for a large number of atmospheric, ocean-wave and land-surface quantities. An uncertainty estimate is sampled by an underlying 10-member ensemble at three-hourly intervals. Ensemble mean and spread have been pre-computed for convenience. Such uncertainty estimates are closely related to the information content of the available observing system which has evolved considerably over time. They also indicate flow-dependent sensitive areas. To facilitate many climate applications, monthly-mean averages have been pre-calculated too, though monthly means are not available for the ensemble mean and spread.
ERA5 is updated daily with a latency of about 5 days. In case that serious flaws are detected in this early release (called ERA5T), this data could be different from the final release 2 to 3 months later. In case that this occurs users are notified.
The data set presented here is a regridded subset of the full ERA5 data set on native resolution. It is online on spinning disk, which should ensure fast and easy access. It should satisfy the requirements for most common applications.
An overview of all ERA5 datasets can be found in this article 🗷. Information on access to ERA5 data on native resolution is provided in these guidelines 🖉.
Data has been regridded to a regular lat-lon grid of 0.25 degrees for the reanalysis and 0.5 degrees for the uncertainty estimate (0.5 and 1 degree respectively for ocean waves). There are four main sub sets: hourly and monthly products, both on pressure levels (upper air fields) and single levels (atmospheric, ocean-wave and land surface quantities).