Climate Impact Explorer

ESA's Digital Twin Earth (DTE) Precursor project

Louise Mercy, Mohamad Nobakht

Telespazio UK, 350 Capability Green, Luton, LU1 3LU, UK. E-mail: louise.mercy@telespazio.com

Project Overview

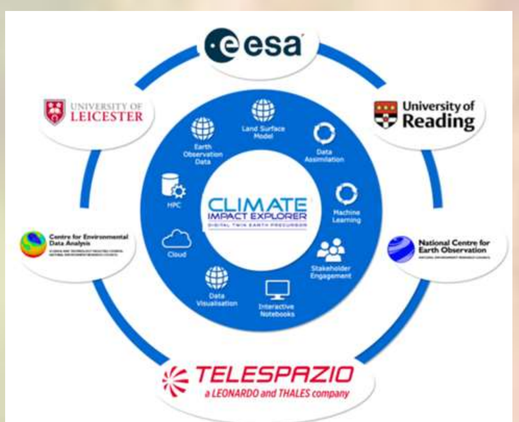
Achieving the European Commission's vision of achieving a sustainable and green EU and approaching a realisation of the Destination Earth (DestinE) initiative – to produce a comprehensive Digital Twin of the Earth (DTE) - will require considerable advancement in a number of capabilities.

A number of evolutions in technology and science will be necessary, in order to achieve a system level (horizontal) and scenario-specific (vertical) implementation of a scientifically sound, leading-edge solution capable of supporting policy-making and environmental management.

The European Space Agency (ESA) proposed a number of precursor Themes to take forward via investigative projects, ahead of the implementation of a real DTE, as envisaged by the DestinE initiative. This project targeted Theme 7 – "The local impacts of global climate change (Hot Spots)".

Tasks of the Project

A Telespazio UK led Consortium, working with the University of Leicester (UoL), University of Reading (UoR) and the Centre for Environmental Data Analysis (CEDA).



Together, the main tasks for this project were undertaken, including selection of the final DTE project theme, definition of User Requirements, creation of a preliminary DTE definition, development of the DTE precursor demonstrator and subsequent Performance review of this prototype. The project culminated in the specification of the DTE Architecture and proposal of a product roadmap.

Creating a preliminary DTE Definition

During the Preliminary DTE Definition task, a group of User and Supply-stakeholders were engaged, which allowed a vast number of different user requirements to be captured.

Workshops were held and follow-up questionnaires were used, in order to define the requirements for both the demonstrator system (Climate Impact Explorer), to enable the production of projected drought metrics over Africa and UK, but also to collate requirements for the future DestinE.

The stakeholder-driven "Climate Impact Explorer" Prototype

The Consortium proposed an innovative combination of Earth Observation EO) Data, a physical Process-Based Model, Climate Change Scenarios, Data Assimilation and Machine Learning.

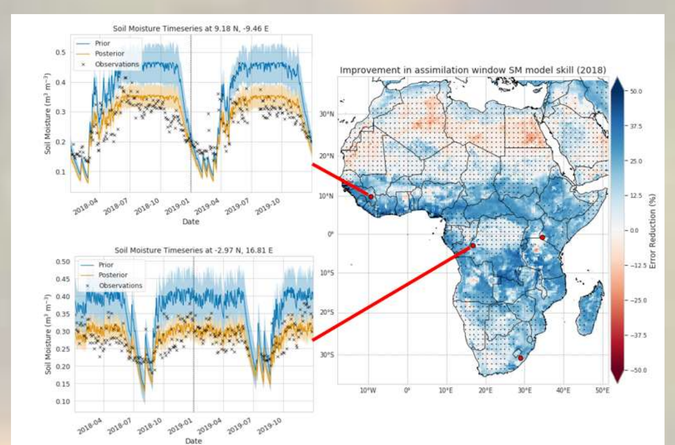
Input and Output Datasets

The Climate Impact Explorer made use of a wide variety of datasets and generated a number of different outputs, used for different parts of the end to end process.

Input / Output	Name	Data Source	Purpose
Input	Surface Air Temperature	CRU-NCEP	Drive land surface model
	Precipitation	TAMSAT	
	SIF	TROPOMI CalTech	Optimise land surface model
	Soil Moisture	SMAP	
Output	Historical Soil Moisture	JULES	Train the ML emulator
	ISIMIP-based Soil Moisture		
	Historical Soil Moisture	Emulator	Use in Interactive Data Portal for calculation of drought metrics
	ISIMIP-based Soil Moisture		
	Training Data	Multiple	All features used to train emulator
	Drought Metric "Dry Days"	JULES	Final Output
	Drought Metric "Wet Season Length"		

Data Assimilation

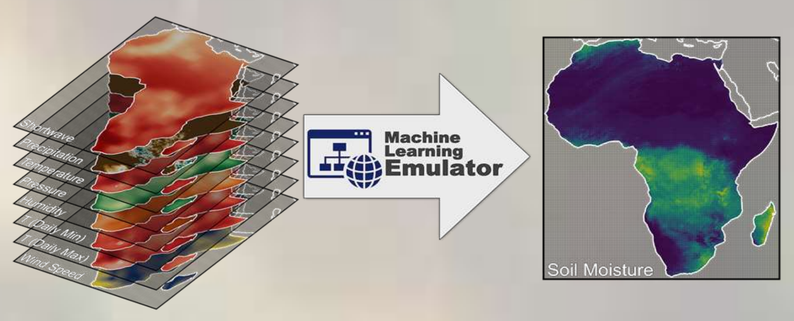
LAVENDAR was used to perform joint data assimilation of soil moisture and TROPOMI Solar Induced Fluorescence EO data with the JULES land surface model, and the modelled soil parameters were optimised to improve physical representation of water budget variables.



Machine Learning Emulation

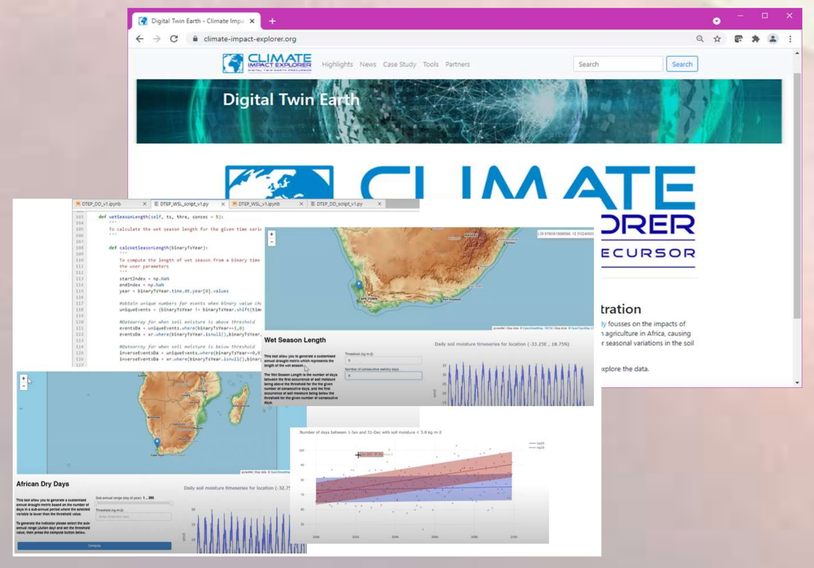
A Machine Learning emulator was constructed using the Extreme Gradient Boosting (XGBoost) algorithm, where the output value of a single tree is determined through succession of specific value tests applied to input variables. Gradient descent is used to determine which set of possible trees would minimise the prediction error.

The final model was portable and easy to host on a Jupyter notebook and the emulator was found to be extremely fast/scalable - emulating 1 year for 1 pixel takes 4-5 ms



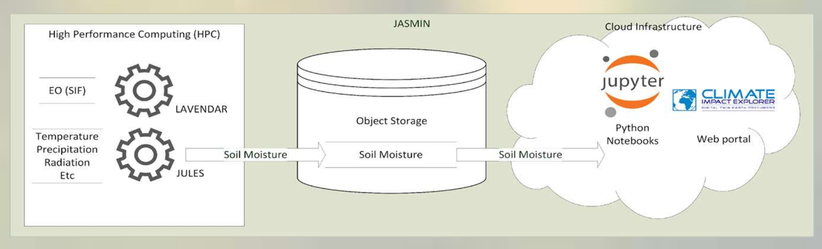
Interactive Web Portal

An interactive web portal was created, which was able to produce drought metrics, support user configuration and provide pre-set simulations.



Final Demonstration Architecture

1. HPC is needed to run the land surface simulator (JULES) and to optimise it using LAVENDAR with EO data. Soil moisture projections are computed from climate model data.
2. Datasets are very large, so it is not realistic to download the files. Rather they are published on the object store (S3 buckets), structured using zarr for optimal performance according to the expected Access patterns (e.g. time series).
3. Users develop and run interactive applications in the cloud, processing close to the data for optimal performance. Workspace and other resources are provided to registered users of the platform.



Future potential for the Climate Impact Explorer and further precursor studies

The Climate Impact Explorer, even as a demonstrator system, inherently highlights the importance of EO as an invaluable tool for climate action. It specifically endeavours to allow decision-relevant information to be made available to key stakeholders – in particular, this is relevant to those potentially non-scientific policy makers responsible for mobilisation of finances.

The demonstrator DTE system gives the opportunity for state-of-the-art 'what if' simulation, at a regional level with dramatically increased accuracy and efficiency, in turn supporting improved reporting, tracking and measurement.

The project has been developed in strong collaboration with a large number of international stakeholders, including EARSC, WFP, the AATF and more, and the EO metrics provided by the demonstrator system allowing risk mitigation decisions to be supported and the 'what-if' simulations to highlight the impact of any chosen or simulated adaptation.

Now, there is considerable scope for further study, having proven the concept for DestinE, via a thin vertical slice through an envisaged system. Telespazio UK anticipate more precursor studies, with the objective of more fully understanding the real world Use Cases for DestinE and the most promising technologies with which to achieve it.