TERRA-MED PhD PROGRAM - Marie Skłodowska-Curie Actions

Context on the program

TERRA-MED is an interregional doctoral program funded under the Marie Skłodowska-Curie COFUND Actions that will recruit and train a new generation of researchers to address the sustainability and resource stress (Water–Land–Energy nexus) in Mediterranean territories.



The Euroregion Pyrenees–Mediterranean, coordinator of the program, brings together the Regions of Occitanie (France), Catalonia and the Balearic Islands (Spain) forming a cross-border research ecosystem. Through this collaboration, TERRA-MED connects world-class universities, research centres and socio-economic actors committed to advancing resilience in the face of climate change. With more than 22,000 scientists across 10 universities and 2 research centers, encompassing 1000 research units, TERRA-MED provides a rich, interdisciplinary environment where doctoral candidates can excel and launch their research careers.

33 PhD positions will be offered to early-stage researchers with a unique interregional, interdisciplinary and intersectoral environment.

Fellows will benefit from having two supervisors (a principal supervisor and a co-supervisor) from two different regions and having a non-academic mentor. The fellows will undertake mandatory cross-border or international stays to the co-institution, as well as a secondment in a non-academic entity.

Moreover, doctoral candidates will receive a specifically designed training program related to their research topics, alongside modules on innovation, entrepreneurship, project management, ethics, open science, etc.

Benefits of TERRA-MED PhD program

- Top-tier PhD education and research training
- Access to world-class laboratories
- Interregional double supervision
- Double PhD degree (France / Spain) where applicable
- Interdisciplinary and cross-sector research experience
- Unique TERRA-MED's excellence training program on resources stress and climate change. See here
- Attractive salary in the frame of MSCA standards
- Extensive network of academic and non-academic partners
- 2 secondments: 1 in the co-supervisor's institution (9 to 12 months); 1 in a non-academic organization to gain extra academic experience and skills (3 to 6 months)

Reference of the thesis project: **URL 3**	**Title of the thesis project** **Leveraging remote sensing data, physical models and machine learning approaches to provide irrigation recommendations in a Mediterranean context.**
Host institution: Universitat Ramon Llull *Ebro Observatory*	**Co-supervision / co-host institution:** *University of Toulouse, CESBIO*
Country Spain	**Country** France
Host Research Unit: The Ebro Observatory Research Unit (Roquetes, Tarragona) is a research institute affiliated with Ramon Llull University (URL) and associated with Spain's National Research Council (CSIC). Its work focuses on understanding Earth and its space environment through long-term monitoring and scientific research. The unit is organized around two main research areas: - Geomagnetism and Aeronomy: studies the Earth's magnetic field and ionosphere, including how they are affected by solar activity and space weather. Researchers develop models of geomagnetic and ionospheric variability and maintain internationally recognized geophysical observation networks. - Hydrology and Climate Change: investigates the impacts of climate change on the continental water cycle, particularly in Mediterranean regions and the Ebro Basin, including water resources, droughts, and hydrological processes. The Observatory is also known for its century-long observational records in meteorology, geomagnetism, seismology, solar physics, and atmospheric sciences, providing valuable data to the international scientific community. Dr. Quintana's group leads the Hydrology and Climate Change Research Line focusing on how climate variability, land surface processes and human activities affect water resources, particularly in Mediterranean environments.	**Co-host Research Unit:** CESBIO (Centre d'Etudes Spatiales de la Biosphère) is a French public research laboratory dedicated to advance our understanding of how land surfaces function and how they interact with the climate and humans. Remote sensing is heavily used by CESBIO scientists to monitor the evolution of the planet at various scales and develop models to tackle societal challenges on biodiversity, climate change, food security, water resources, etc. The laboratory also contributes to the development and promotion of Earth Observation by participating in the definition, implementation and scientific exploitation of space missions. CESBIO is a joint research unit with: National Centre for Space Studies (CNES), National Center for Scientific Research (CNRS), Research Institute for Development (IRD), University Toulouse (UT) and National Institute of Research for agriculture, food and environment (INRAE). Dr. Merlin is leading the Water group at CESBIO, whose goal is to improve our understanding of the hydrological functioning of watersheds -including those with irrigated agriculture in the lowlands and snow in the mountains-and to develop tools that contribute to the sustainable management of water resources. In line with the spatial hydrology approach, we rely heavily on satellite observations, combined with in situ measurements, to map hydrological variables such as soil moisture in the root zone and the water equivalent of the snowpack. Our models enable improved spatial monitoring of certain fluxes (evapotranspiration, irrigation withdrawals, snowmelt, and recharge) which are subject to uncertainty at the levels of individual farm

	plots, irrigated areas, and watersheds, and the assessment of their impacts on streamflow dynamics and groundwater levels. https://www.cesbio.cnrs.fr/v2/
Name of the first co-supervisor Pere Quintana Seguí pquintana@gencat.cat	**Name of the second co-supervisor** Olivier Merlin olivier.merlin@cnrs.fr
Doctoral School: Information Technologies and their Application in Management, Architecture and Geophysics	**Doctoral School:** Geosciences, Astrophysics, Space and Environmental Sciences

Research field(s)

Hydrology and climate change.

Keywords

Irrigation Optimization, Multi-sensor Data Assimilation, Remote Sensing, Machine Learning, Decision Support Systems (DSS), Soil Moisture, Land Surface Temperature, Climate Change Adaptation, Sustainable Agriculture, Traditional Crops, Rainfed Systems

Description of the research project

Context and Rationale:

The Mediterranean region is a primary global climate change hotspot, facing a dual threat of increasing water scarcity and the intensification of extreme weather events, including droughts. This research challenge is positioned at the intersection of technological innovation and resource management.

Pillar: Water (Water Management and Governance)

The project addresses the challenge of "Balancing Human Water Use and Environmental Flows." In Mediterranean regions irrigation often relies on suboptimal estimations. This research proposes a transformative leap by hybridizing classical physical modeling (FAO56) with Machine Learning (ML) in order to obtain accurate estimates of the water balance and thus feed a Decision Support System (DSS). This contributes to the sustainability of water resources, reducing agricultural over-consumption and ensuring that water remains available for environmental flows and other systemic needs.

Secondary Pillar: Food (Agricultural and Food Systems Sustainability)

Irrigation is the backbone of Mediterranean agriculture, yet its long-term viability is threatened by climate uncertainty and growing water scarcity. This challenge moves beyond simple state estimation toward operational decision support that guarantees the sustainability and economic viability of traditional crops, mitigating the risk of agricultural land abandonment. By leveraging Earth Observation and hybrid modeling, the proposed system tailors smart irrigation recommendations to clusters of agricultural plots within irrigation districts, while also providing crucial soil moisture diagnostics for rainfed systems (secà). This approach balances environmental flows with agricultural sustainability, fostering a resilient farming model capable of adapting to projected evapotranspiration increases and precipitation variability.

Objectives:

The primary objective of this doctoral project is to bridge the gap between high-resolution Earth Observation (EO) and operational decision-making across groups of agricultural plots (parcelles) within Mediterranean irrigation districts (e.g., Terra Alta and Alt Penedès in Catalonia, and selected agricultural regions in Occitanie), as well as adjacent rainfed systems. The research will develop an advanced Decision Support System (DSS) to deliver accurate current-state estimations and probabilistic forecasts, aiming to safeguard the viability of traditional crops, improve water efficiency, and support climate adaptation without compromising agricultural livelihoods.

Specific objectives include:

1. Physics-Aware Hybrid Modeling: Develop a robust DSS by hybridizing physical water balance modeling with data-driven approaches. A key innovation will be exploring methodologies that embed physical constraints (e.g., mass conservation) into Machine Learning (ML) architectures (such as Physics-Informed Neural Networks), ensuring predictions remain physically consistent while leveraging the predictive power of AI.
2. Multi-sensor Data Integration & Parameterization: Combine multi-sensor Earth Observation data (e.g., optical, radar, thermal) with existing global datasets to accurately estimate system forcing (irrigation), system states (like Root Zone Soil Moisture) and refine key soil parameterizations—in particular, highly uncertain parameters such as root-zone soil depth, to which physical land surface models exhibit strong sensitivity—across both irrigated and rainfed plot networks.
3. Probabilistic Risk-Based Forecasting: Leverage the physics-aware model's precise estimation of the current land surface state as the initial condition to integrate ensemble weather forecasts (e.g., ECMWF). This will generate robust weekly and bi-weekly probabilistic soil moisture predictions, supporting risk-informed irrigation scheduling and climate adaptation strategies.

Expected Results:

1. Novel Physics-Informed Methodologies: Methodological advances in enforcing physical constraints and mass conservation within machine learning models applied to agro-hydrology.
2. Operational Hybrid DSS Software Pipeline: An open-source, scalable platform coupling physics-aware artificial intelligence with physical hydrology for operational, plot-level irrigation scheduling.
3. Advanced Probabilistic Forecasting Tools: Implementation of weekly and bi-weekly probabilistic irrigation forecasting mechanisms to effectively communicate risk and uncertainty to end-users under climate variability.
4. Multi-Site Cross-Border Validation: Comprehensive evaluation of the hybrid framework across representative study areas in Catalonia (e.g., Terra Alta, Alt Penedès) and Occitanie (France), validating model performance against in situ soil moisture networks, evapotranspiration estimates, and flux towers in both irrigated districts and rainfed agricultural landscapes.
5. High-Impact Publications: Peer-reviewed articles in top-tier international journals and active participation in international scientific conferences.

Work plan:

Work plan:

The 36-month work plan is structured into three main Work Packages (WPs), integrating collaborative research and co-supervision between the Ramon Llull University (Spain) and the Université de Toulouse (France).

- **Year 1 (Months 1–12): Legacy Integration, Data Harmonization & Baseline Modeling**

  - Task 1.1: Legacy Integration & Experimental Setup: Reviewing and taking over the ongoing code, data, and methodologies developed in both host laboratories from previous and ongoing related PhD theses. Harmonizing multi-sensor satellite time series and setting up the in situ validation benchmark.

  - Task 1.2: Baseline Data-Driven Modeling: Consolidating and training the first operational versions of the Machine Learning models to estimate soil states from remote sensing, establishing a robust baseline for the hybrid framework.

  - Co-supervision activity: Regular virtual meetings to align the methodologies transferred from both labs and submission of the PhD Research Plan.

- **Year 2 (Months 13–24): Physics-Aware Coupling & Comprehensive Validation**

- Task 2.1: Physics-Aware Coupling: Formulating and implementing optimal strategies to integrate physical constraints and mass balance into the ML models (e.g., via data assimilation schemes or Physics-Informed Neural Networks).
- Task 2.2: Comprehensive Cross-Validation: Rigorous evaluation of the hybrid system against the in situ networks.
- Co-supervision activity: Joint evaluation of the coupled architectures and ensuring physical robustness across the different modeled regions.

• **Year 3 (Months 25–36): Probabilistic Forecasting, Operational Testing & Dissertation**
- Task 3.1: Probabilistic Forecasting: Utilizing the accurate current-state estimations to ingest ECMWF ensemble weather forecasts, generating weekly and bi-weekly probabilistic irrigation prescriptions.
- Task 3.2: Operational Testing & Synthesis: Evaluating the operational viability of the Decision Support System (DSS) framework, drafting publications, and joint PhD thesis defense (cotutelle double degree framework).

References of both supervisors:

Pere Quintana-Seguí – Ebro Observatory – Ramon Llull University

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- Dari, J., Quintana-Seguí, P., Barella-Ortiz, A., et al. (2024). Quantifying the Hydrological Impacts of Irrigation on a Mediterranean Agricultural Context Through Explicit Satellite-Derived Irrigation Estimates. Water Resources Research.
- Bellvert, J., Pamies-Sans, M., Quintana-Seguí, P., et al. (2024). Analysis and forecast of crop water demand in irrigation districts across the eastern part of the Ebro river basin: estimation of evapotranspiration through copernicus-based inputs. Irrigation Science.
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Olivier Merlin – CESBIO – Toulouse University

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- Amazirh, A., Er-Raki, S., Ojha, N., Bouras, H. E., Rivalland, V., Merlin, O., and Chehbouni, A. (2022). Assimilation of SMAP disaggregated soil moisture and Landsat land surface temperature to improve FAO-56 estimates of ET in semi-arid regions. Agricultural Water Management.

- Paolini, G., Escorihuela, M. J., Merlin, O., Pamies Sans, M., and Bellvert, J. (2022). Classification of different irrigation systems at field scale using time-series of remote sensing data. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing.

Ait Hssaine, B., Chehbouni, A., Er-Raki, S., Khabba, S., Ezzahar, J., Ouaadi, N., Ojha, N., Rivalland, V. and Merlin, O. (2021). On the Utility of High-Resolution Soil Moisture Data for Better Constraining Thermal-Based Energy Balance over Three Semi-Arid Agricultural Areas. Remote Sensing.

Required Skills and Competences:

- **Academic & Quantitative Background:** Solid foundation in Earth sciences, environmental or agricultural engineering, data science, physics, applied mathematics, computer science, or related quantitative fields.
- **Interest in Remote Sensing & Hydrology:** Basic background or strong interest in Earth observation, geospatial data, hydrology, or agricultural water management.
- **Programming & Computational Aptitude:** Programming skills (preferably Python) and a strong willingness to learn scientific computing and geospatial data tools.
- **Motivation for Machine Learning & Modeling:** Curiosity and motivation to learn physics-informed machine learning and physical modeling approaches during the PhD project.
- **Autonomy & Initiative:** Ability to work independently, take initiative, and manage day-to-day research tasks proactively.
- **Teamwork & Collaborative Mindset:** Strong capacity for collaborative work within an interdisciplinary, multi-institutional, and international environment (Spain, France, SME sector), with good English communication skills (minimum B2 level).

Master's degree(s) required or equivalent(s):

Remote Sensing / GIS, Hydrology, Environmental Sciences/Engineering, Agricultural Engineering / Agronomy, Data Science / Computer Science, Physics / Geophysics / Meteorology, or Applied Mathematics.

• *Equivalent fields:* Candidates with a Master's degree in any related scientific, engineering, or quantitative discipline who demonstrate strong motivation and aptitude for Earth observation, environmental modeling, or data analysis are welcome to apply.

Co-supervision partnership framework

Co-supervision (2 supervisors): Yes
Dual degree PhD (France / Spain) where applicable and approved by the relevant institutions : Yes

Indicative mobility arrangements:
Hosting institution: 24 (University Ramon Llull)
Co-hosting institution secondment: 9m to 12mths , University of Toulouse, CESBIO
Non-Academic secondment: 3 months at isardSAT S.L.
isardSAT S.L. is a Barcelona-based research and development company specializing in Earth Observation and satellite remote sensing. Founded in 2006, the company develops scientific and engineering solutions that transform satellite measurements into geophysical products used for environmental monitoring, hydrology, climate studies, agriculture, and water-resource management.
Its core expertise lies in:
- Microwave remote sensing (both passive and active systems)
- Satellite altimetry
- Synthetic Aperture Radar (SAR) imaging
- Development of onboard and ground processing algorithms
- Calibration, validation, and exploitation of Earth observation missions isardSAT works closely with major space agencies, including the European Space Agency (ESA) and EUMETSAT, contributing to satellite missions from instrument design and algorithm development through operational data processing and scientific applications.
A major strength of the company is its application of satellite data to hydrology and water management, including soil moisture retrieval, irrigation monitoring, evapotranspiration estimation, drought assessment, and climate adaptation. Through its climate-services subsidiary Lobelia, isardSAT also provides climate-risk and resilience services based on Earth observation and climate projections.
In summary, isardSAT is one of Europe's leading SMEs in satellite remote sensing, combining advanced engineering, algorithm development, and environmental science to improve monitoring of the Earth's water, land, atmosphere, and climate systems.

Work conditions

Duration: 36 months
Indicative start date : September/ October 2027
Indicative gross salary:
~ €2,450/month + Statutory end-of-contract compensation in accordance with Spanish legislation estimated at ~ €80/months accrued during the contract and paid at the end of the contract. Estimated total annual gross salary: 30.600€
Eligible fellows with one or more dependent children may receive an additional family allowance of €50 per month.

Trainings: -
Mobility required : yes
Non-academic secondment : yes
Dual degree / Cotutelle possible : yes
Doctoral tuition fees and Visa fees: fully covered by TERRA-MED program
Social security: Full employer contributions covered by the recruiting entity.

Host institution	Co-host institution

The **Ebro Observatory** offers an attractive setting for a PhD by combining excellent environmental research, unique observational infrastructure, and a high quality of life. The institute is internationally recognized for its work in Earth Sciences, with strong links to European research projects.

The Observatory is affiliated with Ramon Llull University and the PhD programme in collaboration with LaSalle - Ramon Llull University offers great training activities, including the PhD week.

Research Facilities and Opportunities
- Direct use of the Observatory's observational infrastructure and datasets.
- Opportunities to work with satellite remote sensing data, hydrological models and climate data.
- A small and supportive research environment that allows close interaction with senior scientists and active participation in international projects.

Lifestyle
Located in Roquetes, near Tortosa, the Ebro Observatory offers a lifestyle that is difficult to find in larger research cities:
- Lower cost of living.

CESBIO is one of Europe's leading Earth observation research centers, bringing together experts in remote sensing, hydrology, climate, ecosystems, and agriculture within a highly international scientific environment.

Research facilities and opportunities
- Access to state-of-the-art satellite datasets, including SMOS, Sentinel, and Landsat missions (and TRISHNA mission from 2027).
- Strong expertise in Earth observation, environmental modelling, and AI for large geospatial datasets.
- Excellent computational resources and interdisciplinary teams spanning hydrology, climate science, ecology, and agronomy.

Lifestyle in Toulouse
- A vibrant university city with a large international student and research community.
- Toulouse is the French aerospatial pole offering excellent cultural, social, and professional opportunities.
- Sunny climate and easy access to the Pyrenees, Mediterranean coast, and Atlantic coast.

Eligibility conditions

***Horizon Europe MSCA Mobility Rule*:** Researchers must not have resided or carried out their main activity (work, studies, etc.) in the country of the host organization (France or Spain depending on the employing institution) for more than 12 months in the 36 months immediately before the recruitment date – unless as part of a compulsory national service or a procedure for obtaining refugee status under the Geneva Convention.

***Horizon Europe MSCA Eligibility Criteria*:** Applicants must be eligible for enrolment in a doctoral programme at the employer institution and must not already hold a doctoral degree at the date of recruitment.

Applicants who do not fulfill the Mobility Rule and the Eligibility Criteria WILL NOT be considered for the research position.

***Language requirements*:** Applicants must demonstrate sufficient proficiency (B2) in English to successfully conduct doctoral research and participate in the TERRA-MED training programme.

For more information on this call for candidates see our website here and the guide for applicants here.

APPLY HERE BY Decembre 31st 2026

Administrative Contact

TERRA-MED Programme Office (only for general administrative questions and redress demands. Any research-related question must be addressed to the supervisors by email, see second page)

Email: terramed@euroregio-epm.eu