**Borsa di studio attivata ai sensi di quanto disposto dal D.M. n. 1061 del 10/08/2021**

Titolo del progetto: CIMR4Earth - Telerilevamento dell'idro-criosfera terrestre: modellistica avanzata fisico-elettromagnetica e stime basate su apprendimento automatico per la futura missione Copernicus Imaging Microwave Radiometer

La borsa sarà attivata sul seguente corso di dottorato accreditato per il XXXVII ciclo:
TECNOLOGIE DELL'INFORMAZIONE E DELLE COMUNICAZIONI (ICT)

Responsabile scientifico: Prof. FRANK S. MARZANO
Area per la quale si presenta la richiesta: GREEN
Numero di mensilità da svolgere in azienda: 6
Numero di mensilità da svolgere all'estero: 6 presso Paris Observatory, Centre National de la Recherche Scientifique (CNRS) https://cimr.eu/node/54, 61 avenue de l'Observatoire, 75014 Parigi, FR Referente: Dr. Catherine Prigent, catherine.prigent@obspm.fr
Azienda: SERCO Italia SpA https://www.serco.com/eu, RED Lab, Via Sciadonna, 24/26 – 00044 Frascati (RM) Referente: Dr. Raffaele Crapolicchio, raffaele.crapolicchio@esa.int
Il Dipartimento è disponibile a cofinanziare per un importo pari a euro: Euro 10.000,00
Dipartimento finanziatore: DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE, ELETTRONICA E TELECOMUNICAZIONI con delibera del 21/09/2021

Progetto di ricerca:
In recent years, the cryosphere role in climate change has become much more prominent, the Arctic is warming at almost twice the global average rate and the snow coverage in the mountains decreasing its extent year after year. Whereas in the past attention focused almost solely on the effects of climate change in the Arctic and mountain snow, there is a growing awareness that feedback loops are turning the Arctic and mountain snow into a contributor to climate change. Understanding these dynamics and helping to develop specific strategies to mitigate and adapt to climate change in the Arctic and mountain snow mantle form part of the EU's wider efforts to combat climate change. Adaptation strategies are needed to help, in particular, Arctic inhabitants respond to the serious challenges they face because of climate change. In view of increasing vessel traffic in the Arctic, the EU will contribute to enhance the safety of navigation in the Arctic by monitoring of spatial and temporal development of maritime activities in the Arctic; such knowledge is essential to assess the consequent risks and make better decisions on possible mitigating measures. Given the important role of Arctic as a regulator for the climate of the planet and acting as a sink for long-range pollution, the EU has a duty to protect the Arctic environment and strengthen ecosystem resilience.

Since 1978 satellite microwave radiometers have provided a long-term, consistent, and reproducible climate data record of floating sea ice parameters and mountain snow coverage. Poor spatial resolution and uncertainty regarding the continuity of low-frequency (i.e. < 18GHz) capability are concerns. To address the Integrated European Arctic Policy, a sustainable European operational provision of medium-resolution (5-10 km) multi-frequency and multi-polarization microwave radiometer observations delivering all-weather Sea Ice Concentration (SIC), Sea Surface Temperature (SST) with AMSR-2-like (or better) capability is required. Following extensive study of different concepts since 2010 (scanner, interferometer, push-broom, focal-plane array), ESA together with European Industry has converged on a preferred solution based on performance requirements and technical constraints. The CIMR mission will embark a multi-frequency imaging microwave radiometer payload to measure the brightness temperature of the upwelling microwave radiation at different frequencies. Given that MetOp-SG(B) MWI has a wide-swath capability with channels of 18.7 GHz and above, CIMR is focused on the low frequency domain (1.4-36.5GHz) and is complementary to MWI. Accordingly, CIMR is designed to fly in loose convoy with MetOp-SG(B) that provides a unique capability including MWI and ICI radiometer and SCA scatterometry.

The aim of the Copernicus Imaging Microwave Radiometry (CIMR) mission, to be launched by EU within 2025, is to provide high-spatial resolution microwave imaging radiometry measurements and derived products with global coverage and sub-daily revisit in the Polar regions to address Copernicus user needs and the EU Integrates Policy for the Arctic. The Primary objectives of the CIMR mission are to: i) Measure all-weather Sea Ice Concentration (SIC) and Sea Ice Extent (SIE) at a spatial resolution of <5 km, with a standard uncertainty of <5%, and sub-daily coverage of the Polar Regions and daily coverage of Adjacent Seas. ii) measure all-weather Sea Surface Temperature (SST) at an effective spatial resolution of <15 km, with a standard uncertainty of <0.2 K and focusing on sub-daily coverage of Polar Regions and daily coverage of Adjacent Seas Ensure improved continuity of AMSR-type capability in synergy with other missions (eg. MetOp-SG(B)). iii) Ensure improved continuity of AMSR-type capability in synergy with other missions. Iv) Secondary Measurement objectives include: Sea Ice Drift (25 km, 3 cm/s), Thin Sea Ice Thickness (~40 km, 10%), Snow on Sea Ice, Snow Water Equivalent, Sea Surface Salinity (~40 km), Ice Type (5 km), Extreme Wind. iv) Additional tertiary products, such as global soil moisture, water vapor, and precipitation rate.

The objectives of the PhD project are manifold: i) to develop advanced physical-electromagnetic modeling to simulate CIMR response in presence of sea surface, polar ice and mountain snow; ii) to study new machine-learning based retrieval approaches to extract quantitative information on the sea surface temperature and salinity, polar ice extent and depth and mountain snow water equivalent; iii) to apply the estimates from CIMR to characterize the Artic polar ice region dynamical evolution in the context of climate change, the Alpine and Apennines snow mantle extent and depth as well as to couple these estimates for the Mediterranean sea temperature and salinity. The need to couple physical theories with artificial intelligence (AI) methods is considered to be the virtuous approach to remote sensing where the wave-matter interaction modeling should orient the design of AI techniques to better exploit the information content embedded in the radiometric measurements of Earth satellite instruments.

The PhD project time plan is as follows:
Year 1. Development of microwave model to simulate CIMR radiometric response
-1.a Characterization of sea surfaces
-1.b Characterization of polar ice sheets
-1.c Characterization of mountain snow areas
Year 2. Development of CIMR-based retrieval of hydro-cryosphere
-2.a Statistical methods and machine learning techniques
-2.b Tuning to sea surface, polar ice and mountain snow and collection of SMOS/AMSR-2 satellite data
-2.c Validation for applications to Artic, Alpine/Apennines and Mediterranean Sea
Stage of 3 months at the selected company (Serco, Italy)
Year 3. Development of CIMR-based retrieval of hydro-cryosphere
-3.a Statistical methods and machine learning techniques
-3.b Tuning to sea surface, polar ice and mountain snow
-3.c Validation for applications to Artic, Alpine/Apennines and Mediterranean Sea
Stage of 6 months at the selected foreign institute (CNRS, France)

These PhD goals are strictly related to the Sustainable Development Goals (SDG) and, in particular, to SDG13 (Climate action), SDG14 (Life below water) and SDG15 (Life on land). The PhD objectives are also coherent with the aims of the Italian plan PNRR (Piano Nazionale Ripresa e Resilienza) and, in particular, with the mission component M2C4 (Tutela del territorio e della risorsa idrica) and its Topic 1 (Rafforzamento della capacità previsionale degli effetti del cambiamento climatico tramite sistemi avanzati ed integrati di monitoraggio e analisi) and its Topic 2 (Prevenzione e contrasto delle conseguenze del cambiamento climatico sui fenomeni di dissesto idrogeologico e sulla vulnerabilità del territorio) as well as with mission component M1C2 (Digitalizzazione, Innovazione e Competitività nel sistema produttivo) and its Topic 3 (Rafforzare la partecipazione allo sviluppo dell’economia dello spazio e i sistemi di osservazione della Terra).

Titolo del progetto (inglese): CIMR4Earth - Remote sensing of Earth hydro-cryosphere: advanced physical-electromagnetic modeling and machine-learning based retrieval for the forthcoming Copernicus Imaging Microwave Radiometer mission

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In recent years, the cryosphere role in climate change has become much more prominent, the Arctic is warming at almost twice the global average rate and the snow coverage in the mountains decreasing its extent year after year. Whereas in the past attention focused almost solely on the effects of climate change in the Arctic and mountain snow, there is a growing awareness that feedback loops are turning the Arctic and mountain snow into a contributor to climate change. Understanding these dynamics and helping to develop specific strategies to mitigate and adapt to climate change in the Arctic and mountain snow mantle form part of the EU’s wider efforts to combat climate change. Adaptation strategies are needed to help, in particular, Arctic inhabitants respond to the serious challenges they face because of climate change. In view of increasing vessel traffic in the Arctic, the EU will contribute to enhance the safety of navigation in the Arctic by monitoring of spatial and temporal development of maritime activities in the Arctic; such knowledge is essential to assess the consequent risks and make better decisions on possible mitigating measures. Given the important role of Arctic as a regulator for the climate of the planet and acting as a sink for long-range pollution, the EU has a duty to protect the Arctic environment and strengthen ecosystem resilience.

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