Finanziato dall'Unione europea NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

ICSC
Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

ICSC
Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

Spoke 4 Earth & Climate

Silvio Gualdi

Kick off meeting 25/26 novembre 2022, Bologna

ICSC-Spoke4 Earth & Climate

Objectives

Kick off meeting

- Raise to the challenge by setting up an **interdisciplinary modelling framework** that integrates state-of-the-art Earth system modelling components, providing a flexible, reliable and powerful tool to the scientific and operational community

- Implement a digital infrastructure integrated in the HPC facilities made available through the HPC National Centre that will:
  - **assess and store high–quality climate related data**,
  - facilitate the **development and sharing of ESM components** (e.g., models of the atmosphere, oceans, biogeochemistry, sea-ice, land-surface, vegetation, etc.);
  - facilitate the production and **management of numerical simulations**;
  - be a **national asset** available to the entire Italian community engaged in research, education and operational activities in the field of climate predictions and climate change, positioning our country at the forefront of climate research.

- Establish technologies that will make it possible to **fulfil the climate objectives identified by the PNRR** for the digital and green transition.

ICSC-Spoke4
Earth & Climate

Partners

Kick off meeting

Spoke leader

cmcc

Spoke co–leader

imati

ISAC

CNR ISMAR ISTITUTO DI SCIENZE MARINE

Istituzioni affiliate

ENEA Agenzia Nazionale per le Nuove tecnologie, l'Energia e lo Sviluppo economico sostenibile

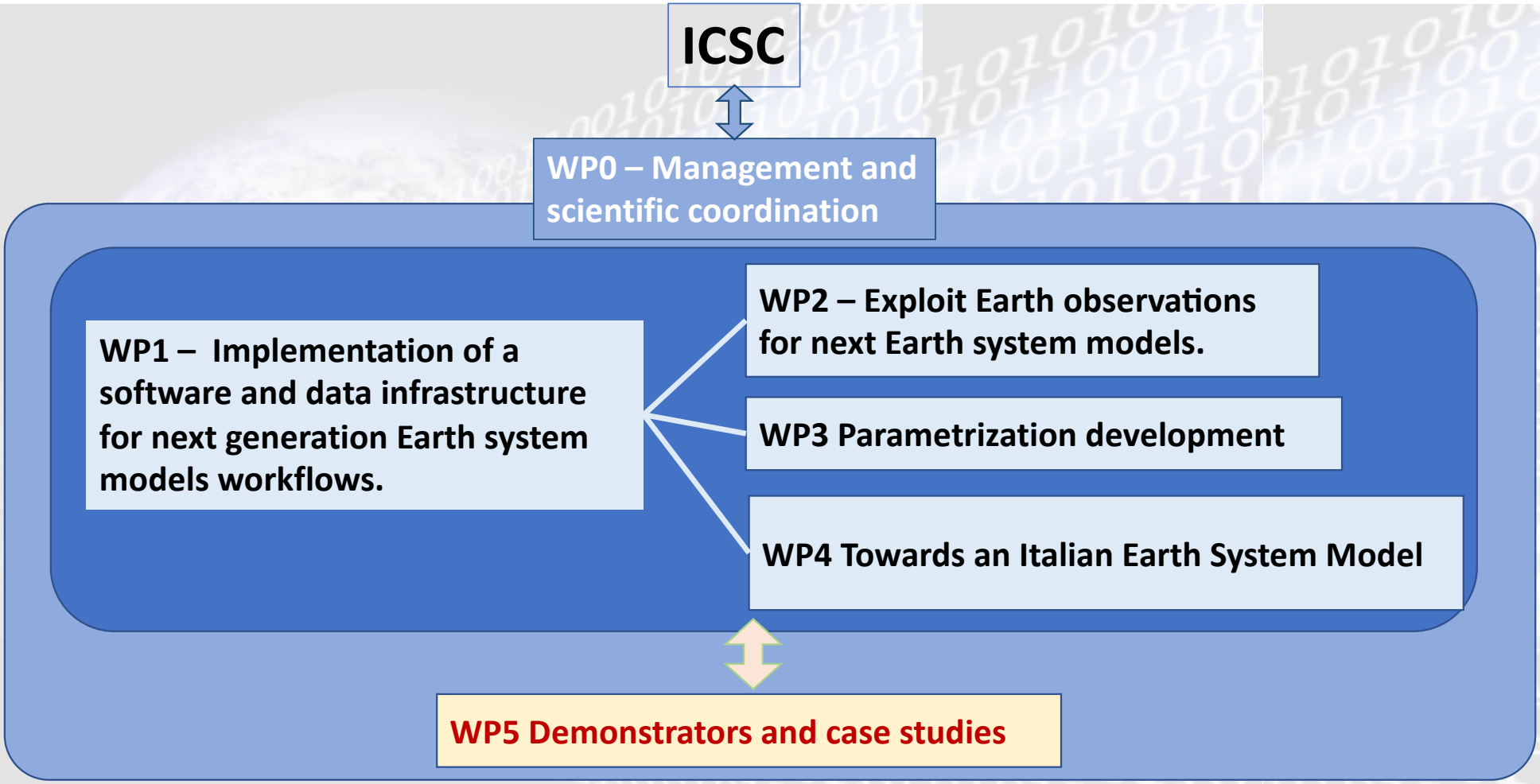
FONDAZIONE BRUNO KESSLER

OGS

UNIVERSITÀ DEL SALENTO

UNIVERSITÀ DI TRENTO

Spoke structure



ICSC-Spoke4 Earth & Climate

WP0 Management and scientific coordination

Bologna, 25/26 novembre 2022

Kick off meeting

Leader CMCC, Co-Leader: CNR; Participants: ENEA, FBK, OGS, UniSalento, UniTrento.

Objectives: ensure sound, effective and efficient management and coordination of the Spoke towards achieving its objectives, in compliance with best management practices.
WP0 will assure:

- Intensive, flexible, and open dialogue among partners
- Effective decision-making on technical and organizational issues
- Coordination of the management structures and effective risk management
- Compliance with the PNRR and CN–HPC administrative and reporting requirements

Task 0.1: **Administrative, data and financial management**.

- implement **efficient exchange of administrative information**, financial documents and reports among **partners and with the ICSC National Centre board**;
- **Preparation of the open calls**;
- Preparation of the implementation **plans for the innovation funds**;
- Monitor the effective and timely issuing of the PhD bursaries and calls for staff recruiting;
- Definition and implementation of a **Spoke's Data Management Plan**.

WP0 Management and scientific coordination

Task 0.2: **General management and risk management.**

- Control and coordination of the activities through a **Spoke's Steering Committee** (SSC), which will monitor the activity progress to ensure the achievements of goals and milestones ;
- Organize (frequent) **review meetings of the SSC** to monitor the activity progress, ensuring the achievements of goals and milestones;
- **Ensure the timing release of all milestones and deliverables**;
- **Risk Management**: (i) identify emerging issues that will be collected in a risk register; (ii) Identification of corrective actions, also recorded in the risk register; (iii) Internal audits to monitor if the management system matches its processes and weather new and improved techniques become normal practice.

Task 0.3: **Dissemination and Communication Activities.**

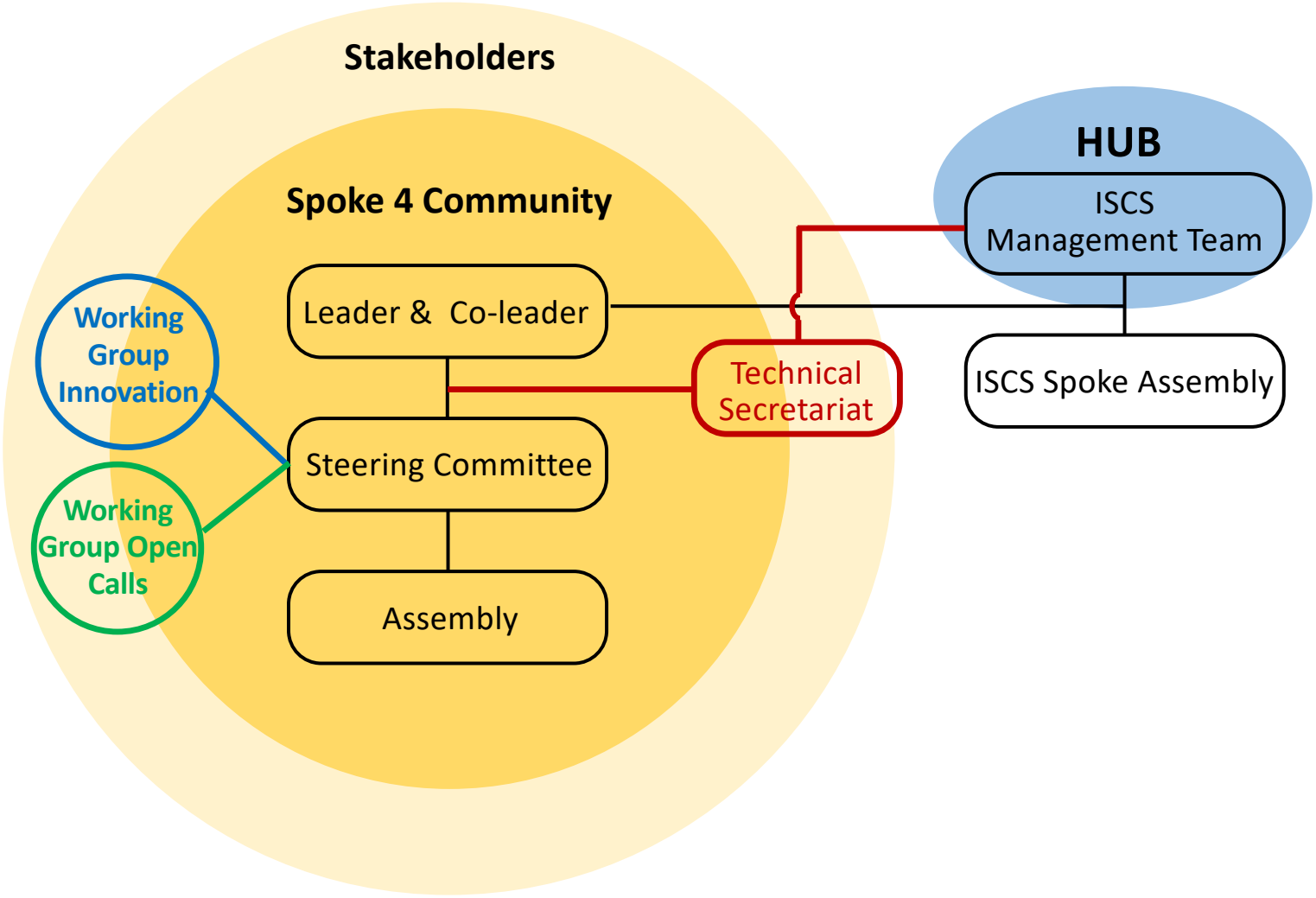
- **Internal communication:** interactive **wiki web-tool** that will provide areas to discuss issues, exchange information and documents ;
- **External communication**: conducted through a **public website** that will communicate and disseminate project results;
- Guarantee the **Industrial partners engagement** in the project activities by means of dedicated meetings.

ICSC-Spoke4
Earth & Climate

Spoke Governance

Bologna, 25/26
novembre 2022

Kick off
meeting



ICSC-Spoke4 Earth & Climate

WP1: Implementation of a software and data infrastructure for next generation Earth system models (ESMs) workflows

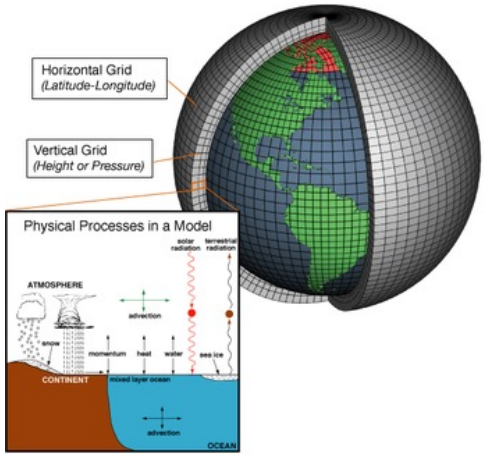
Bologna, 25/26 novembre 2022

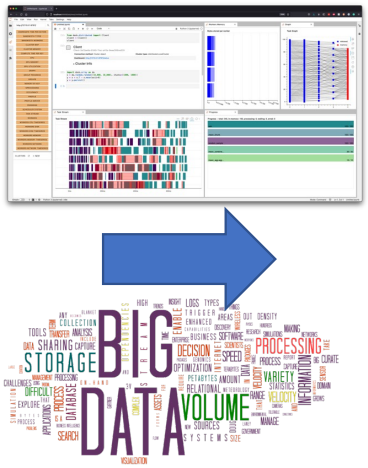
Kick off meeting

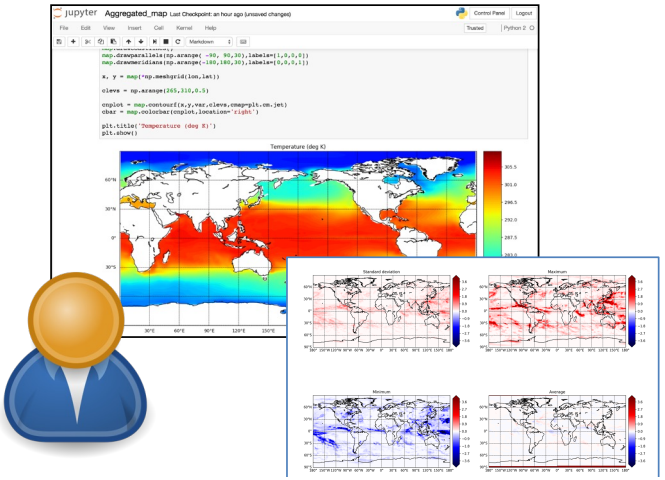
Leader UniTrento; Participants: CMCC, CNR-IMATI, CNR–ISAC, CNR–ISMAR, ENEA, FBK, OGS, UniSalento

Objectives:

- Development of an integrated **HPC-based and FAIR-enabled digital infrastructure** to manage a **wide spectrum of tools**, **ESM components**, applications, **workflows** to support climate scientists.
- Address data and computational challenges: **code optimization, large volume data management**, **provenance management (data traceability)**.
- **Exploit the resources and software platform made available by the Centro Nazionale ICSC**.







ICSC-Spoke4 Earth & Climate

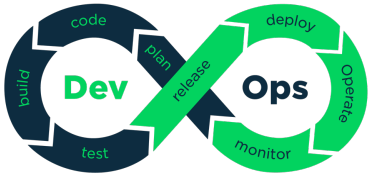
WP1: Implementation of a software and data infrastructure for next generation Earth system models (ESMs) workflows

Bologna, 25/26 novembre 2022

Kick off meeting

Task 1.1 – Design and setup of the software and data infrastructure:

- **design a software and data infrastructure** to merge/integrate the most appealing and promising software tools.
- close synergy with the architecture design defined by the ICSC and will **leverage a close collaboration with the system admin staff of the Tier0 resources**.



Task 1.2 – Code harmonization and release management

- **integrate existing packages for the coupling**, *set up tools for collaboration and versioning of the codes*.
- This task will also be devoted **to software release management**. It will leverage on services provided by the *Tier0 to ensure the proper* ***software lifecycle management***.

ICSC-Spoke4 Earth & Climate

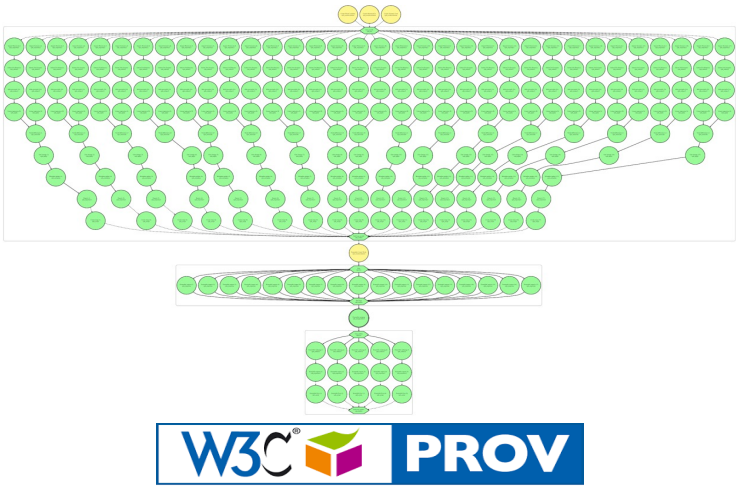
WP1: Implementation of a software and data infrastructure for next generation Earth system models (ESMs) workflows

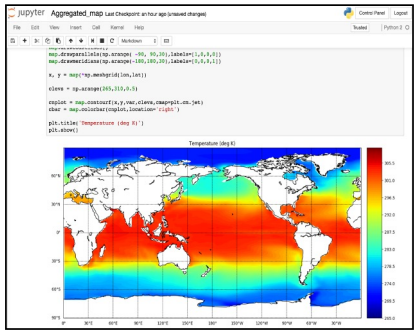
Bologna, 25/26 novembre 2022

Kick off meeting

Task 1.3 – End-to-End workflow and provenance management:

- develop an end-to-end support to **automate the execution of the ESM workflow** on the resources made available by the Centro Nazionale ICSC.
- Efficient **management of the ESM workflows**.
- **Manage provenance** to keep track of all the activities performed in the workflows.





Keras DASK SciPy jupyter TensorFlow NumPy matplotlib xarray

Task 1.4 – Data Science and learning software infrastructure:

- **develop a data science and learning software infrastructure**, providing solutions at the intersection of HPC, big data and data science to support the analysis of large-scale datasets (both data-driven and data-intensive workloads).

ICSC-Spoke4 Earth & Climate

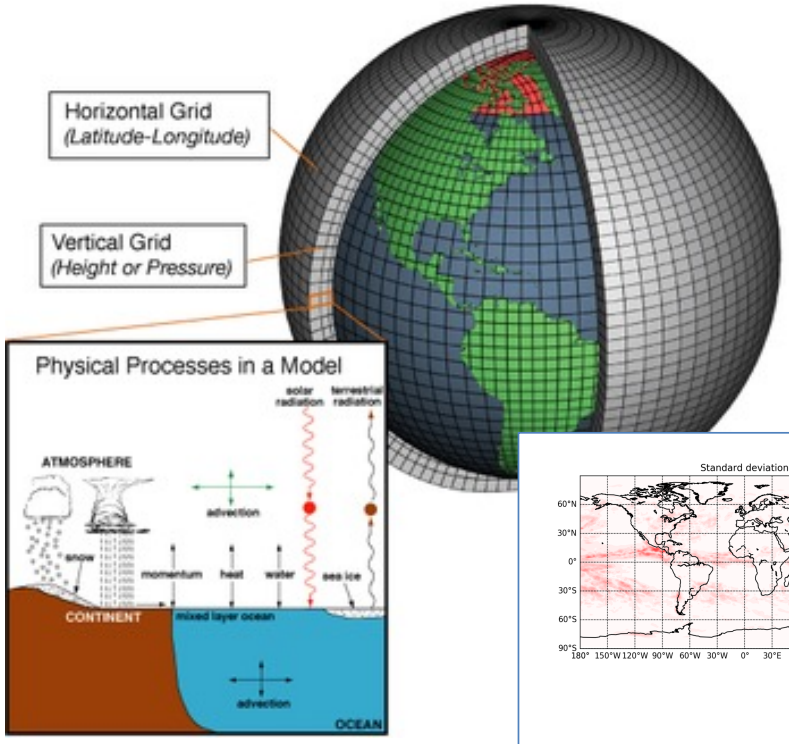
WP1: Implementation of a software and data infrastructure for next generation Earth system models (ESMs) workflows

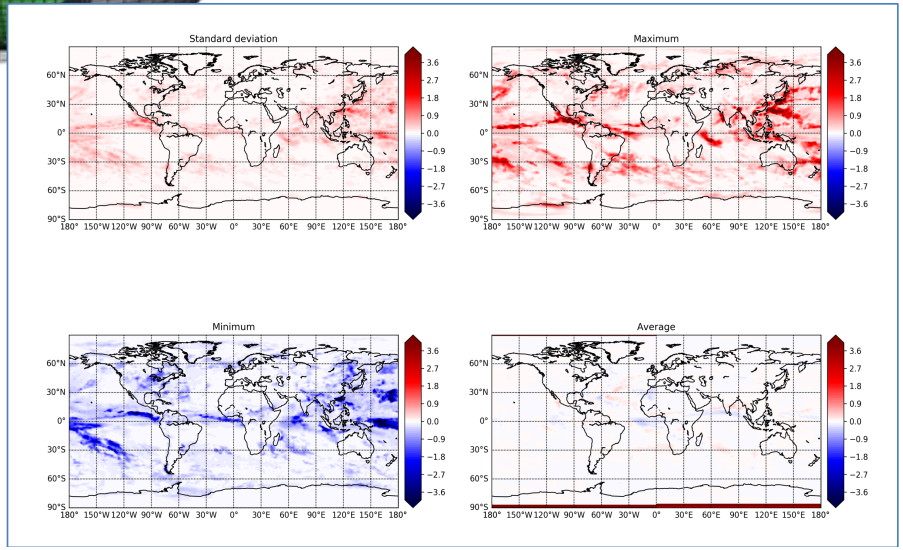
Bologna, 25/26 novembre 2022

Kick off meeting

Task 1.5 – Optimization of code:

- **optimization of codes** and computational demanding data streaming and diagnostics to **fully exploit hybrid pre–exascale HPC machines**.
- Develop software interfaces to address (ESM agnostic) data analytics features and quick look capabilities to support scientists for fast and real-time evaluations.





ICSC-Spoke4 Earth & Climate

WP2 Exploit Earth observations for next generation ESMs

Bologna, 25/26 novembre 2022

Kick off meeting

Leader CNR (ISMAR); Participants: CMCC, CNR–IMATI, CNR–ISAC, ENEA, FBK, OGS, UniSalento, UniTrento

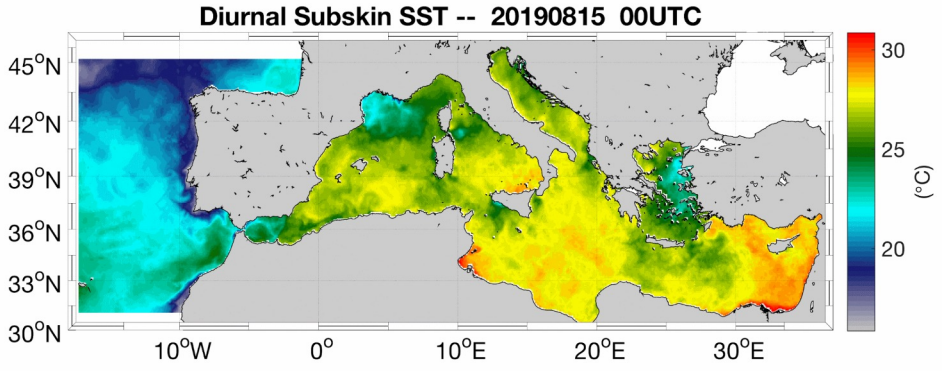
Objectives: Improve the exploitation of large observational datasets for:

i) **identifying weaknesses in ESMs through comparison with observations;**

ii) **improve data assimilation for climate applications.**

Task 2.1 – Observational data collection:

- collection, quality control, organization and sharing of the observations required for project activities.
- Data stored, made accessible and managed following principles and recommendations of the ICSC Data Management policy.



Task 2.2 – Development of novel algorithms to optimize exploitation of observations:

- statistical, physical-based and AI techniques and tools to exploit observations for climate analyses, data assimilation and predictions.

ICSC-Spoke4 Earth & Climate

WP2 Exploit Earth observations for next generation ESMs

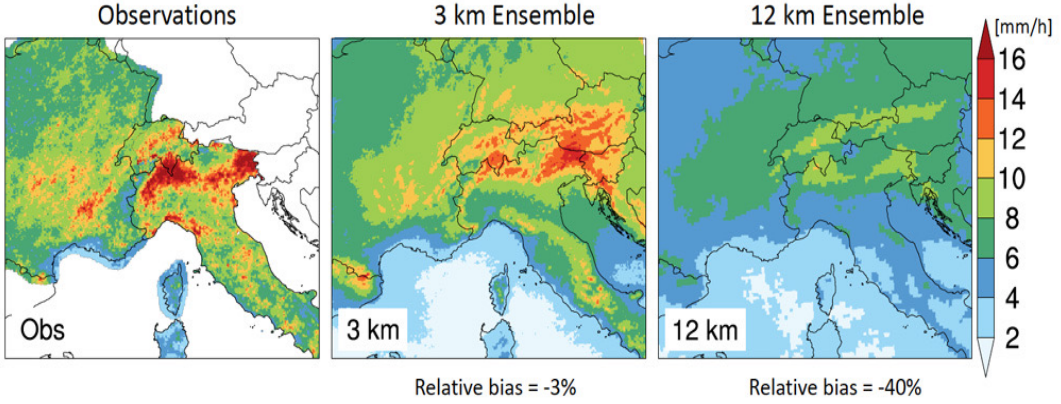
Bologna, 25/26 novembre 2022

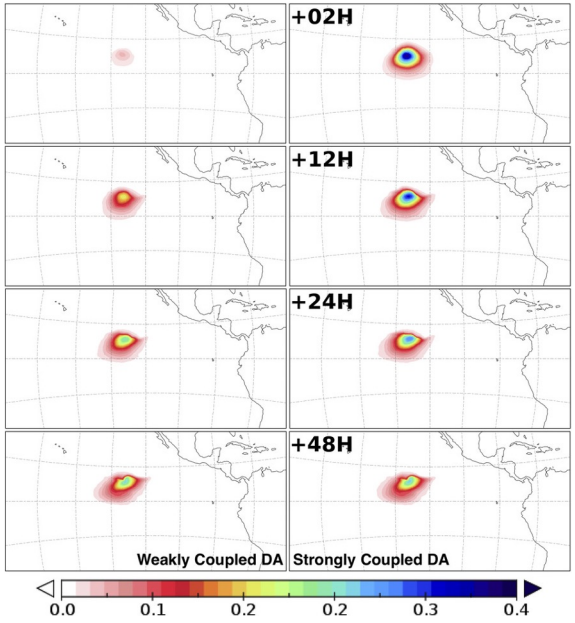
Kick off meeting

Task 2.3 – Observations to identify gaps in ESMs:

- combine **observations and diagnostic tools to identify and analyze weaknesses in ESMs** at different spatial and temporal scales.
- Identify **processes that are poorly modelled** with the aim to improve their simulation in ESMs.

EU-Project EUCP high – resolution simulations. Credit: Nikolina Ban





Formulation and assessment of a coupled air-sea data assimilation system for seamless predictions. T2m anomaly (C)

Task 2.4 – Enhanced data assimilation for climate applications:

- **advance data assimilation scheme** towards coupled data assimilation algorithms (land-atmosphere, ocean-atmosphere, in both global and regional systems).
- full and efficient exploitation of the HPC infrastructure through a revision and **optimization of the current data assimilation codes**.

ICSC-Spoke4 Earth & Climate

WP3 Parametrization Development

Bologna, 25/26 novembre 2022

Kick off meeting

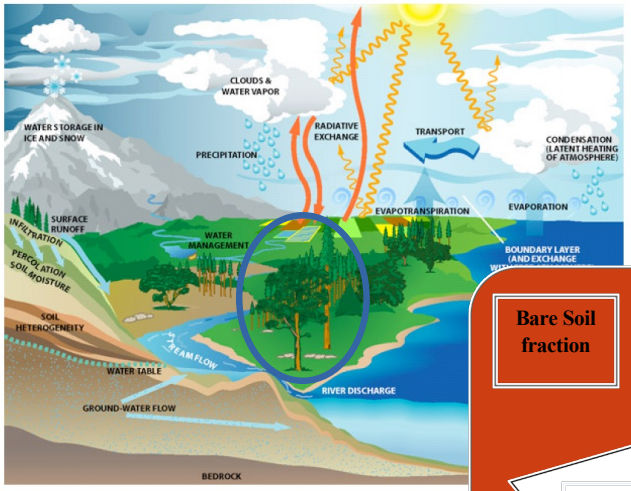
Leader CNR; Participants: CMCC, ENEA, FBK, OGS, UniSalento, UniTrento

Objectives: develop a novel set of physical parametrizations, to be implemented in climate models (WP4)

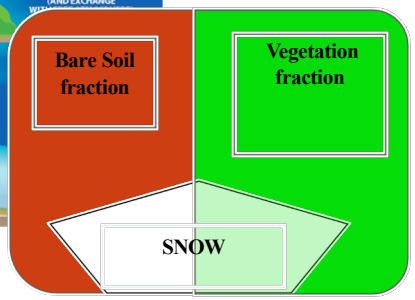
- **Physical parametrizations are key to climate model development**: they represent all physical processes (e.g. microphysics, radiative transfer, ..) and dynamical processes happening at scales too small to be resolved (e.g. convection and turbulence)
- **Observational datasets from WP2** will be used to constrain parametrization performance.

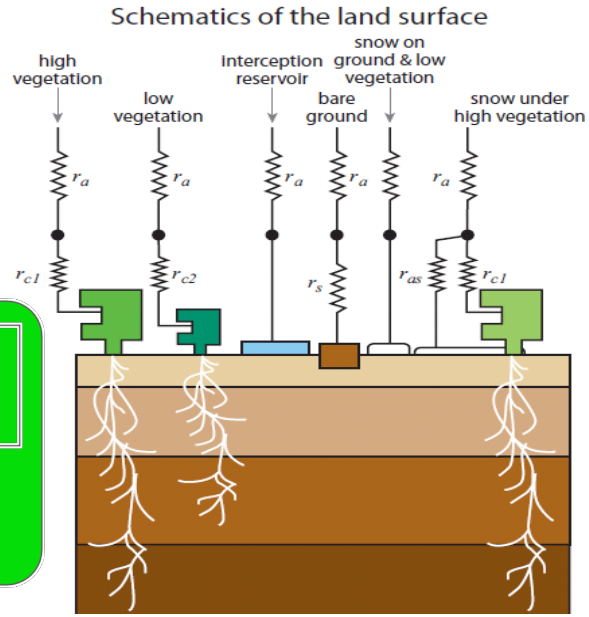
Task 3.1 – Design and development of novel Land-Surface parametrizations, including:

- better representation of hydrological and biophysical processes
- more realistic vegetation effective cover, emissivity and albedo



Courtesy of NASA Land Surface Hydrology Program

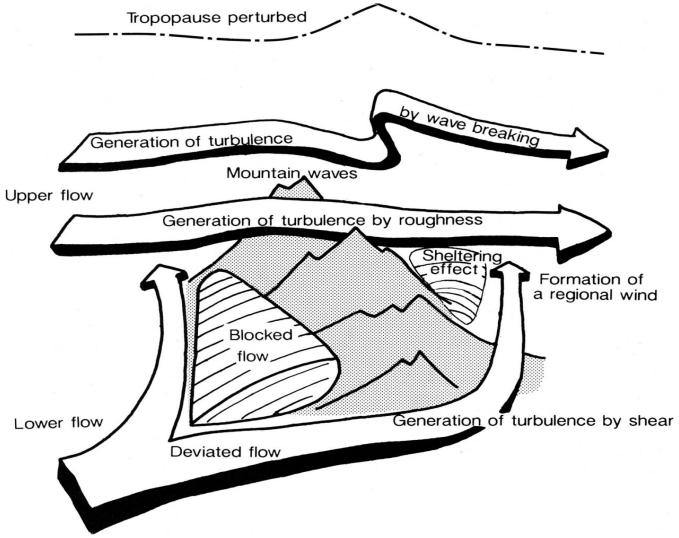




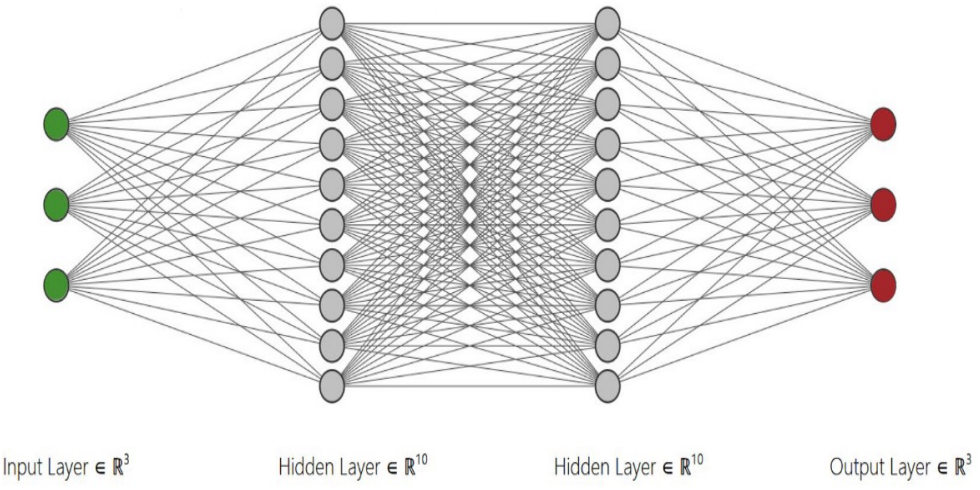
WP3 Parametrization Development

Task 3.2 – Design and implementation of new parametrizations of atmospheric and oceanic drag:

- orographic drag with non-elliptical mountain shape and flow directional effects;
- over-water drag mediated by sea- spray aerosols.



Task 3.3 – Design of **machine learning approaches for the parametrization of physical processes**, including data understanding through explainable AI and physics-informed machine learning. For example, **speed-up computation of expensive parametrizations through machine learning** acceleration.



ICSC-Spoke4 Earth & Climate

WP4 Towards an Italian Earth System Model

Bologna, 25/26 novembre 2022

Kick off meeting

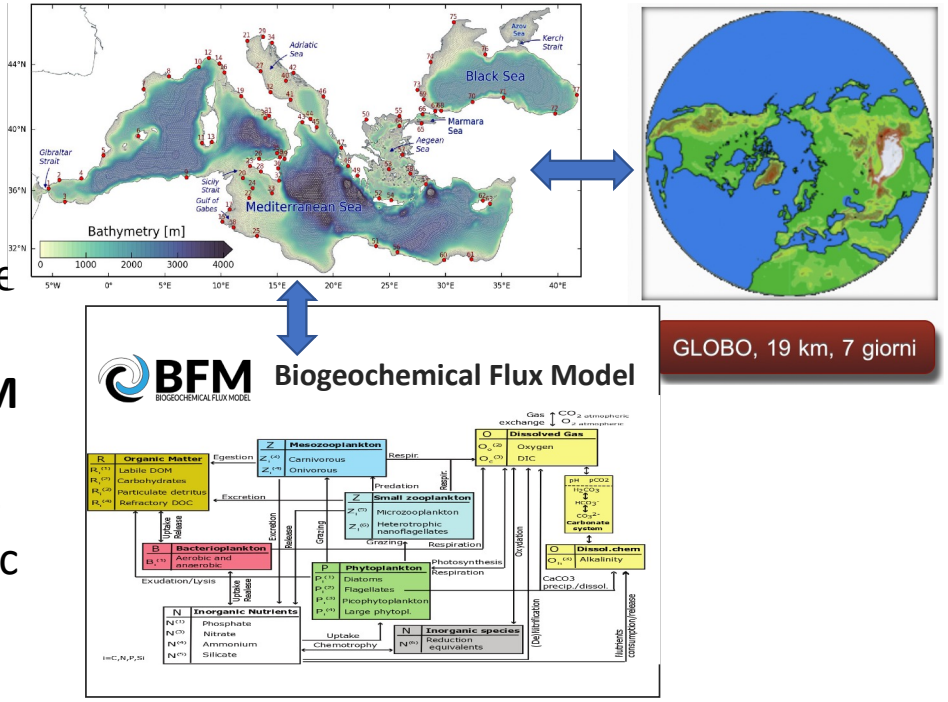
Leader CMCC; Participants: CNR-ISMAR, CNR–ISAC, CNR-IMATI, ENEA, OGS, UniSalento, UniTrento

Objectives:

- development of **community global and regional ESM components**;
- **multi-scale, structured and unstructured, ocean modelling** from the open ocean to the coast;
- development and implementation of **modular regional ESMs interchangeable in their components** and coupling with global ESMs.

Task 4.1 – Towards an Italian ESM: development of community Earth system components:

- **Development and optimization of existing ESMs and their components** (e.g., SHYFEM ocean model, GLOBO atmosphere model, BFM biogeochemical model, etc.)
- Development of **coupling interfaces between available ESM components**, e.g. atmosphere (GLOBO, OpenIFS), ocean (SHYFEM, NEMO), biogeochemical (BFM), waves (e.g. WW3).
- Contribute in **evaluation of developed ESMs** with diagnostic tools from WP2.



ICSC-Spoke4
Earth & Climate

WP4 Towards an Italian Earth System Model

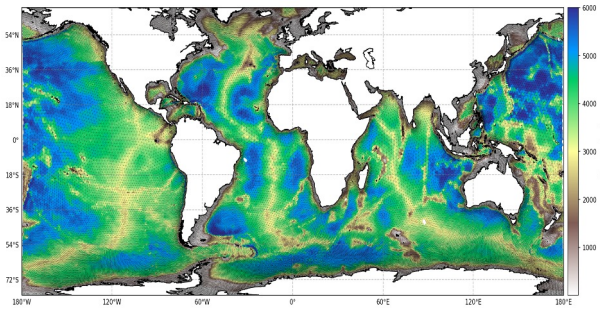
Bologna, 25/26 novembre 2022

Kick off meeting

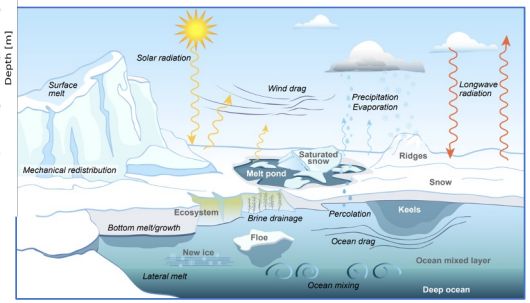
Task 4.2 – Development of a global version of a community ocean model, including the coupling with a sea-ice model

- Develop a **new global ocean and sea ice system**, on **unstructured meshes** that will be able to represent and resolve **global and coastal scales in continuity**.
- Develop a **thermodynamic-dynamic sea-ice model** as component of the ocean model on unstructured grid

Example of unstructured mesh on global scales

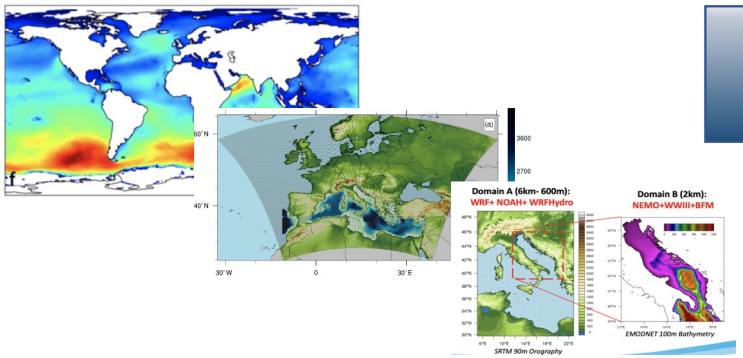


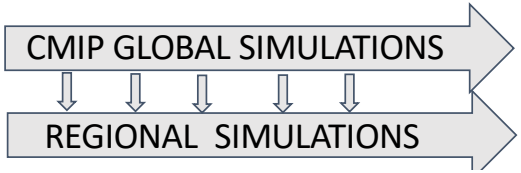
Schematic of the complex sea-ice physics and breadth of variables at play



Task 4.3 – Design, development and implementation of modular regional ESMs interchangeable in their components and in their coupling with global ESMs

- Downscaling of CMIP simulations (Mediterranean region, Italian peninsula) → CORDEX and MedCORDEX.
- Limited Area Climate Downscaling over the **Mediterranean sub-basins,** e.g Adriatic and North Adriatic Sea.



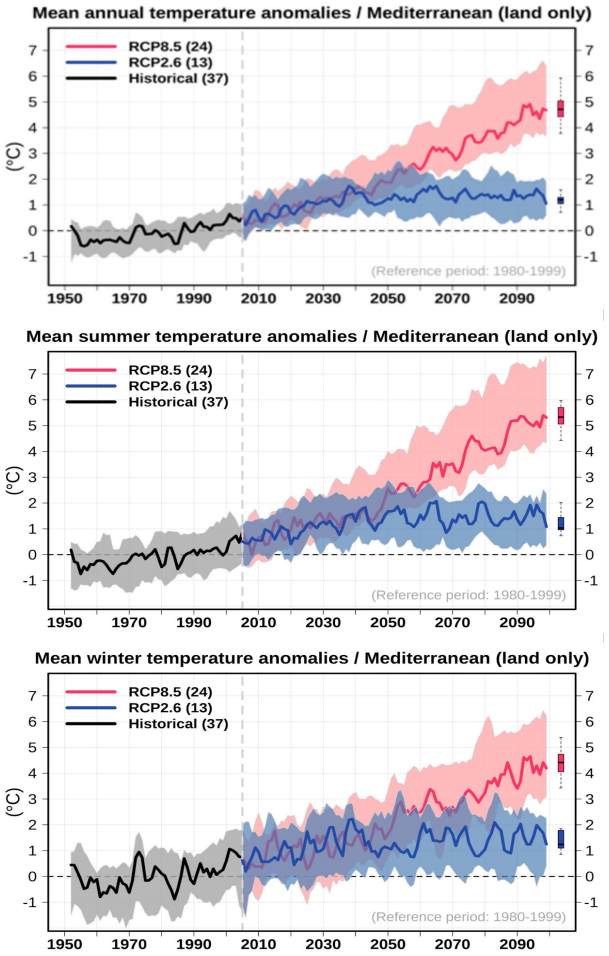


WP5 Demonstrators and case studies

Leader UniSalento; Participants: CMCC, CNR-ISMAR, CNR–ISAC, CNR-IMATI, ENEA, OGS, UniTrento

Objectives:

- To use the tools developed in WP1-4 to provide **new knowledge on the expected evolution of the relevant climate impact drivers** with a **focus on the Mediterranean** region considering multiple time scales ranging **from sub-seasonal predictions to long term projections**.
- Provide information on the **predictability of droughts, heat waves, extreme precipitation, storms** and on their future frequency depending on time and projected socioeconomic global changes (Shared Socioeconomic Pathways)
- Explore the regional characteristics of **sea level rise and coastal floods** in climate projections.
- **Co-definition** od the case studies with the **industrial partners** involved in the Spoke.



ICSC-Spoke4 Earth & Climate

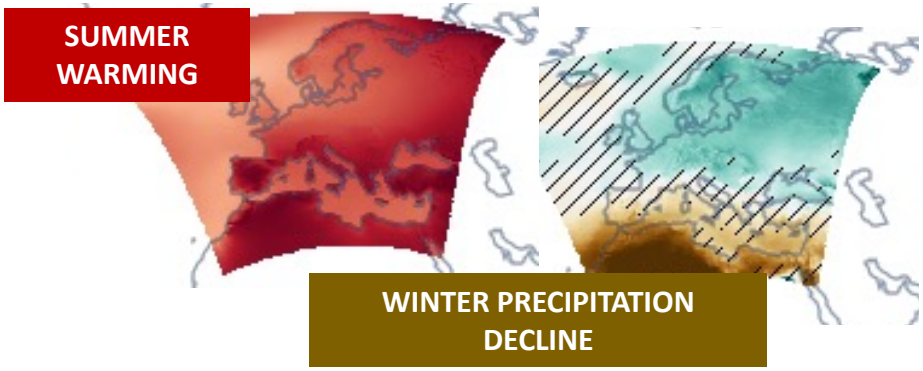
WP5 Demonstrators and case studies

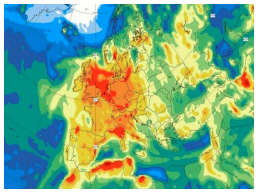
Bologna, 25/26 novembre 2022

Kick off meeting

Task 5.1 – Simulations and predictions of the Italian and Mediterranean climate:

- a new set of high-quality climate change projections for the Mediterranean region and the Italian Peninsula, allowing to explore the possible changes in the Mediterranean climate.
- **Explore the predictability of the Mediterranean climate** at different time and spatial scales.





Task 5.2 – Evolution and shifts of extreme events:

- analysis of the changes in occurrence (frequency and intensity) of **extreme events in the Italian Peninsula and in the Mediterranean basin,** including **droughts and terrestrial and marine heat waves**.
- Use of a set of **convection permitting models** over the Italian Peninsula, to **demonstrate their added value for climate simulations.**
- **Machine Learning approaches for automating the detection of extreme events** (e.g., cold and heat waves) in the Mediterranean region.

Attività in corso

- ✓ **Kick-off meeting dello Spoke (19/10/2022).**
- ✓ **Definizione della struttura di Governance → working groups per Open calls e Innovation funds (industrial partners involvement).**
- ✓ **Avviate attività di quasi tutti i WPs (entro primi di dicembre tutti partiti).**
- ✓ **Avviate attività di reclutamento (borse di PhD e contratti a TD) da parte di tutte le istituzioni affiliate.**

Kick off meeting

ICSC-Spoke4

Earth & Climate

Grazie!