D3.2 - Experimental protocol for the new CPRCM I4C simulations and lists of the planned runs

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Contents

Abbreviations Used

RCM	Regional Climate Model
GCM	Global Climate Model
GWL	Global Warming Level

1 Summary for Publication

Impetus4Change (I4C) will produce high-resolution regional climate information focussing on our four demonstrator cities (Prague, Paris, Barcelona, Bergen), and technological test-bed cities (Hamburg, Newcastle). This information will be created by statistical emulators trained using convection permitting regional climate models (CP-RCM) dynamically downscaling regional climate simulations. To fit this purpose and to be also able to use the RCM simulations directly, an experimental protocol is established, which ensures a final ensemble of useable and useful simulations.

After long and productive discussions of the modellers within WP3, the I4C CP-RCM experimental protocol establishes the major setup and parameters for the simulations. The major outcome of these discussions is that we will focus on downscaling 20-year–timeslices of different global warming levels (GWLs) for two focus regions covering all demonstrator cities at 3km resolution (Figure 1). The blue domain (NSEA-3) is centered over the North Sea and includes Bergen, Newcastle and Hamburg, while the red domain (ALPX-3, ALP eXtended) extends the CORDEX-FPSCONV Alpine domain (ALP-3) to include Barcelona, Paris and Prague. These are minimal mandatory domains, while those actually used by the different modelling groups are larger and depend on the model projection choice (also depicted in Figure 1). Using these fit-for-purpose domains, modelling groups can afford several time slices or even transient simulations. Our priority list of GWLs is: GWL +3°C (providing an extreme climate training sample for the emulators), reference period (as used in WP4 and IPCC AR6), GWL +1.5°C (likely covered by decadal prediction simulations), and then GWL +2, +1 and +4°C, in this order.

With this protocol and the new model developments, such as improved urban processes representation, the simulations are ready to start. As a first step, before the actual scenario simulations, modelling groups will perform evaluation simulations by downscaling ERA-5.1 reanalysis data, which can be compared to observations in the area of the demonstrator cities.

In addition to analyses performed in T3.2 for the simulation validation, we will provide data to T3.3 for training the Emulators, WP4 for the computation of the risk indicators and WP6 for specific analysis around the demonstrator cities and for the exchanges with the users.

2 Contribution to the top-level objectives of Impetus4Change

This experimental protocol provides the basis for a coordinated and useable ensemble of CP-RCM simulations (with improved urban schemes), which itself serves as training data for the emulators. Both datasets (CP-RCM simulations and climate information from emulators) will be new and unprecedented climate information datasets, which will then be tailored and used in the demonstrator cities.

The experimental protocol serves as framework to establish the CP-RCM ensemble and to assure that it fits the purpose of the other WPs as good as possible. Thereby it provides the necessary constraints to assure usefulness, but also leaving flexibility to the modelling groups to assure that their specific model runs as efficient as possible.
The creation of the experimental protocol finally contributes to the specific project objective "Develop novel methods to downscale predictions to local scales".

2.1.1.1 Objective	2.1.1.2 Contribution from Deliverable
Overall Objective: to improve the quality, accessibility and usability of near-term climate information and services at local to regional scales – where impacts are most keenly felt and on-the ground adaptation is implemented – to strengthen and support end-user adaptation planning and action	The experimental protocol provides the basis for a coordinated and useable ensemble of CP-RCM simulations (with improved urban schemes), which itself serves as training data for the emulators.
1) Improve understanding and flow of climate information through knowledge networks;	
2) Address persistent shortcomings to deliver seasonal to decadal predictions of improved quality;	
3) Develop novel methods to downscale predictions to local scales;	The experimental protocol provides the basis for a coordinated and useable ensemble of CP-RCM simulations (with improved urban schemes), which itself serves as training data for the emulators.
4) Improve assessments of hazards and translate this into usable information for local risk assessments;	
5) Make advances towards the goal of end-to-end seamless climate services;	
6) Through transdisciplinary co-production approaches develop fit-for-purpose "Adaptation support packs" at municipal scales through our so-called urban Demonstrators;	
7) Ensure high impact and visibility through robust and targeted communication and engagement;	

8) Commit to Open Science through development of open access tools and exploitation of data/model outputs via relevant platforms thereby ensuring improved accessibility and usability of climate knowledge.	

3 Detailed Report

3.1 Introduction

The main goal of Task3.2 is to produce very high-resolution (2-4km) climate simulations over Europe (incl. the Demonstrators, Hereon-GERICS, UNESCO-ICTP, CNRS-MF, DMI, NORCE, CSIC) and the Caribbean (Hereon-GERICS, ICTP, NORCE) in order to train and to verify the model emulators developed in Task 3.3. To obtain optimum training data for emulators, CPRCM simulations will be produced for multi-decadal time periods covering very contrasted climates (incl. historical periods, strong GHG emission future scenarios).

CPRCMs will use updated urban schemes to include detailed representation of the cities, to provide urban- specific data to WP6, and to allow the emulators to learn the urban induced phenomena (e.g., UHI effect).

The experimental protocol will provide the boundary conditions and assure the usefulness of the produced simulation ensemble. It will be aligned with the CORDEX CMIP6 downscaling experiment and the CORDEX-FPS URB-RCC and CORDEX-FPS convection experiment protocols. Following this procedure, the project Impetus4Change benefits from the findings, discussions and outcomes of the beforementioned WCRP activities and on the other hand the communities behind the WCRP activities will benefit from the project outcome. They will therefore also have the possibility to contribute to assessments and analysis of the simulation data in various ways.

Within the project, GCM and ensemble member selection as well as other important decisions in the protocol are coordinated with WP2 and WP5.

The resulting ensemble of CPRCM simulations will be used within Task3.3 ("CPRCM statistical emulators") to train the newly developed emulators which will create climate information to be further used mainly in WP4 and WP6. The CPRCM ensemble can optionally be used in those work packages in addition to the information from the emulators.

Project partners who participate in the CPRCM ensemble creation including their planned simulation domains are listed in Table 1.

In order to facilitate the identification of the different model domains, we agreed on new domain names, which include also the target resolution of 3km in their name: EURR-3 (=EUR Reduced), NSEA-3 (=North SEA), ALPX-3 (ALP eXtended).

Partner	**CPRCM**	**EURR-3 (=EUR Reduced) incl.** *Barcelona, Paris, Prague, (Bergen), Hamburg, Newcastle*	**NSEA-3 domain "North"** *(=North SEA) incl. Bergen, Newcastle, Hamburg*	**ALPX-3 (domain "South")** *(=ALP eXtended) incl. Barcelona, Paris, Prague*	**Caribbean domain** *(tropical cyclone season)*
Hereon-GERICS	REMO2020	No	**Yes**	**Yes**	**Yes**
UNESCO-ICTP	RegCM5	**Yes**	No	No	**Yes**
NORCE	WRF451	No	**Yes (*)**	No	**Yes**
CSIC	WRF451	No	No	**Yes** (*)	No
CNRS-MF	AROME46t1	No	No	**Yes**	No
DMI	HCLIMxx-AROME	No	**Yes**	No	No

Table 1: WP3 partner contributions to new CPRCM simulations (CMIP6-driven). Those runs will serve as training and verification datasets for the emulators (WP3) and as inputs for projection needs in WP4 and WP6. (*) The same WRF model configuration will be used by NORCE and CSIC.

The protocol was established by collaboration of the Impetus4Change partners Hereon-GERICS, UNESCO-ICTP, CNRS-MF, DMI, NORCE and CSIC. Within the first year of the project, discussion about the best setup, feasibility and usefulness took place. In the following, the outcome of these discussions is presented as the first version of the experimental protocol v1.2023.10. It might be updated in the course of the project if necessary. Also, more details might be added if in the follow-up discussions and analysis this will be useful. These discussions especially include discussions with stakeholders from the demonstrator cities.

In the following sections, more details and decisions about the common setup will be listed.

3.2 Domains and spatial resolution

An important goal of the project is to provide for each demonstrator city a reasonable set of CPRCM simulations in order to train the emulators (Task3.3). As a secondary goal, the CPRCM ensemble data will also be used directly by the demonstrator cities.

To achieve this, the model domains must be defined in a way that they cover the demonstrator cities sufficiently. Therefore, a 200km x 200km area around each demonstrator city should be covered at least by each of the simulations. On the one hand side, the size of the domains should be large enough to cover as many European regions as possible (especially the demonstrator cities), on the other hand side, the domains should be small enough to allow for multidecadal simulations (different global warming levels, GWL). In addition, the domains should align with previous projects (like EUCP) and ongoing WCRP activities (CORDEX FPS-URBRCC and FPS-convection). In the course of the discussions the following compromise was found.

It was decided to define minimum domains and resolutions based on regular lat-lon. It is then up to the groups to fit them with their projections. This minimum domain can then become the common analysis domain and data sharing domain. Groups with same grid definition can coordinate their grid settings.

A spatial resolution of ~3km (or higher) is highly recommended, while a fixed rotation and grid definition is not requested.

The tentative model domains are depicted in Figure 1

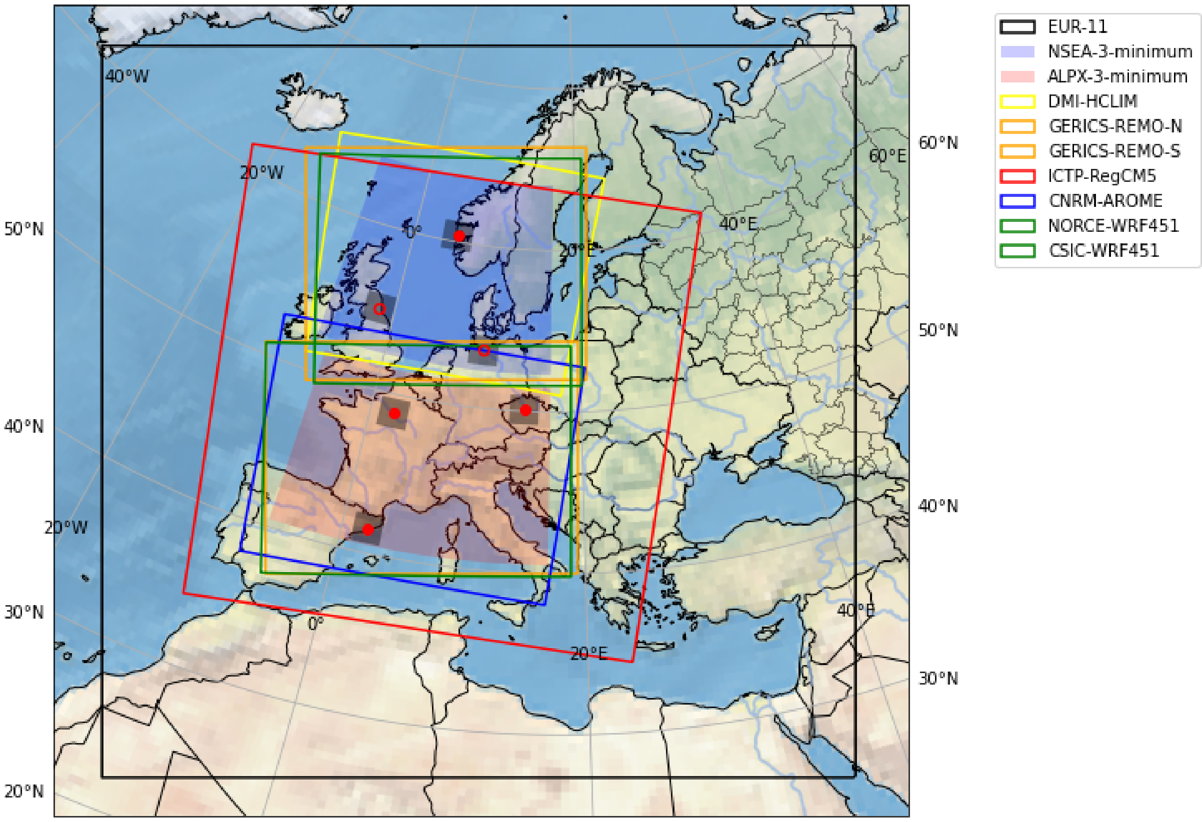

Figure 1: Simulation domains as of October 2023 excluding the boundary. It is decided that the domains should at least cover the minimal areas over northern (NSEA-3-minimum, blue shade) and southern (ALPX-3-minimum, red shade) areas. (Source code for the Plot: https://github.com/jesusff/domains/tree/i4c)

The definitions of the computational model domains are listed in Table 2:

DOMAIN	DOMAIN CORNER POINTS	GRIDPOINTS (~3km)
min North	SW: 52.3 N, -7 E SE: 52.3 N, 17 E NE: 64 N, 17 E NW: 64 N, -7 E	Gridsize = 382309 X: 863 Y: 443 Res: 0.0264°
NORCE-WRF451 North	xfirst = -15.4121° E xlast = 21.5992° E xinc = 3km yfirst = 48.9981° N ylast = 65.9383° N yinc = 3km	Gridsize: 333797 X: 617 Y: 541 Projection: Lambert Conformal Center of the grid: ref_lon=9.7° , ref_lat=49.0° stand_lon=18°, true_lats=30°,60° Res: 3km
DMI-HCLIM43-AROME North	SW: -7.5850° E, 51.0307° N SE: 18.0443° E, 50.9749° N NE: 24.1621° E, 64.3495° N NW: -13.5060° E, 64.4312° N	Gridsize: 307200 X: 600 Y: 512 Projection: Lambert Conformal Center of the grid: Ref_lon=5°, ref_lat=58.5 Stand_lon= 5° Standard parallel 58.5 Res: 3km
Hereon-GERICS-REMO2020 North	xfirst = -16° xinc = 0.0275° yfirst = 1° yinc = 0.0275° grid_north_pole_longitude = -162.0° grid_north_pole_latitude = 39.25°	gridsize = 351109 xsize = 649 ysize = 541 Res: 0.0275°
min South	SW: 40.5 N, -5.8 E SE: 40.5 N, 17 E NE: 51.5 N, 17 E NW: 51.5 N, -5.8 E	Gridsize = 379053 X: 909 Y: 417 Res: 0.0264°
Hereon-GERICS-REMO2020 South	xfirst = -18.5° xinc = 0.0275° yfirst = -11° yinc = 0.0275° grid_north_pole_longitude = -162.0° grid_north_pole_latitude = 39.25°	gridsize = 390061 xsize = 721 ysize = 541 Res: 0.0275°
CNRS-MF-AROME46t1 South	xfirst = -7.6931 yfirst =37.4867	Gridsize = 648000 X: 900 Y: 720

		Res: 2.5km Projection: Lambert Conformal Center of the grid: LON0=4.8°, LAT0=46.2°
CSIC-WRF451 South	xfirst = -5.335605 xlast = 19.5696 xinc = 3km yfirst = 36.80376 ylast = 54.3267 yinc = 3km	Gridsize: 373633 X: 701 Y: 533 Projection: Lambert Conformal Center of the grid: ref_lon=9.7° , ref_lat=49.0° stand_lon=18°, true_lats=30°,60° Res: 3km
UNESCO-ICTP-RegCM5 (North + South)	xfirst = -25.229317 xlast = 38.429317 yfirst = 33.28396 ylast = 64.97	Grid size: 1000x1000 Projection : Rotated Lat-lon Center (lat,lon) in earth coordinates: 50.0, 6.6 Pole (lat,lon) in rotated coordinates: 40.0, 186.6 Res: 0.03

Table 2: Definitions of the model domains for the different CPRCMs (including the boundary zone). The domains highlighted in blue (northern domain) and red (southern domain) are the areas that should be covered by all models that are targeting the respective region. All regions are depicted in Figure 1.

Apart from covering the minimal domains, the computational model domains should leave sufficient distance to the boundaries to accommodate a 200x200 km area around the city (grey boxes in Figure 1). The current domain setups for all models meet this requirement. Figure 2 provides an example of the representation of the demonstrator cities in a CP-RCM (WRF451).

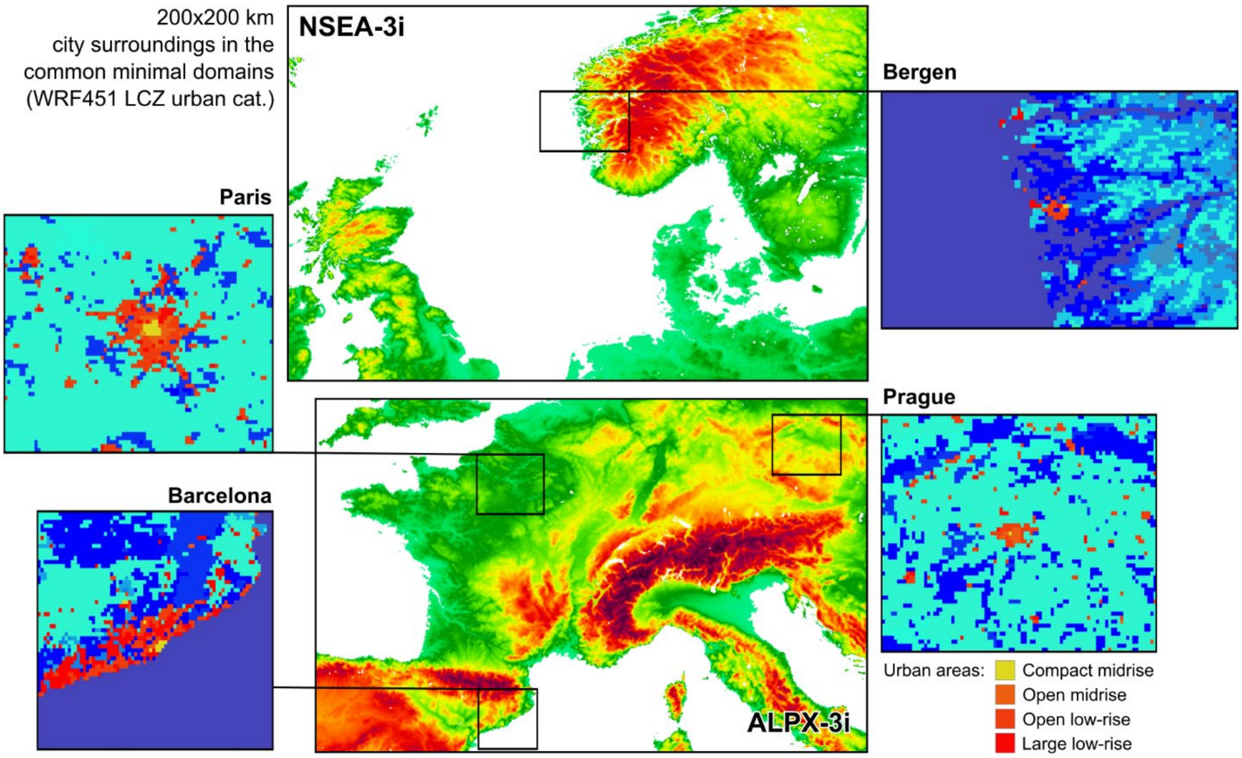

Figure 2: Demonstrator cities representation according to the WRF451 land use including Local Climate Zones (LCZ) urban categories from WUDAPT. Data are interpolated by a nearest neigbour interpolation to a regular longitude latitude grid covering the minimal North and South domains.

The domain setup for the Caribbean domain will share part or the entire domain of the EU-project EUCP in order to benefit from the outcomes of this project too, but it may be different extension. I4C-partners simulating the Caribbean domain (Hereon-GERICS, UNESCO-ICTP and NORCE) are coordinating their simulations.

3.3 Simulation periods

Common simulation periods serve the different purposes of the project, especially Task 3.3 (emulators), WP4 and WP6, but also considering the simulation setups of WP2 and WP5. In this sense, Global Warming Levels (GWLs) will be used as this is a common strategy across I4C.

The priority list for the GWLs to simulate (Table 3) assures that those most needed by Task 3.3 (high global warming signal and reference period with low global warming) are covered by all simulations.

Simulations will cover a 20-year time slice (plus reference) as a minimum, which leaves the possibility of conducting transient simulations to those modelling groups who can afford it.

For each GWL, the simulation period extends 20 years around the central year. The years that correspond to the selected GWLs depend on the selected GCM (see next section). The specific time periods which will be used in I4C for each GWL-GCM combination are taken from the IPCC-AR6-WG1. They can be found here: https://github.com/mathause/cmip_warming_levels/blob/main/warming_levels/cmip6_all_ens/csv/cmip6_warming_levels_all_ens_1850_1900.csv

Priority	Global Warming Level	Comments
1	GWL3	needed by the emulators
2	reference period (1995-2014)	used in WP4 and IPCC, representative of the observed 1.1°C global warming
3	GWL1.5	likely covered by decadal predictions
4	GWL2	
5	GWL1	probably already covered by the ref period
6	GWL4	

Table 3: Priority list of Global Warming Levels

Although not explicitly considered in the description of work of I4C, evaluation simulations will be performed for the improved CPRCMs. They are not required by the emulators, but it is important to evaluate the new, improved CPRCMs. The intention is to coordinate and facilitate intercomparison also for the evaluation simulations, if possible. Modelling groups decided to cover the period 2000-2009 (plus one year of spin-up) for the evaluation simulation driven by ERA5.1, which aligns with other initiatives (e.g. FPS-CONV) that can be used as reference.

Finally, in I4C-WP3, we assume that the model configurations used have been evaluated and validated by the modelling groups with adequate procedures and discussed within the relevant scientific community.

3.4 Forcing data and boundary conditions

The boundary forcing will be taken from CMIP6 GCMs. We will use the SSP3-7.0 scenario to align with CORDEX and EURO-CORDEX protocols. The present state of GCM selection is listed in Table 4.

CPRCM (Group)	**GCM** **CMIP6 scenarioMIP**	**GCM** **WP2/5**
CNRS-MF-AROME46t1	CNRM-ESM2-1, r1i1p1f2	CNRM-ESM2-1 / CNRM-CM6-1
UNESCO-ICTP-RegCM5 DMI-HCLIM43-AROME	EC-Earth3-Veg, r1i1p1f1	EC-Earth3.3
Hereon-GERICS-REMO2020	MPI-ESM1-2-HR, r1i1p1f1	MPI-ESM1.2**re**
CSIC-WRF451 NORCE-WRF451	NorESM2-MM, r1i1p1f1	NorCPM1

Table 4: Current GCM member selection by the different CPRCM modelling groups. As information, the GCMs selected by WP2/WP5 are listed.

The reasoning to align with WP2 and WP5 where possible is that emulators will likely work better if the GCMs driving the CPRCMs used for the training are the same as the GCMs used as inputs of the emulators later (data from WP2 or WP5). We also choose to maximize the future spread of the CPRCM North and South ensembles by choosing the largest diversity possible in the driving GCMs. These GCMs span a wide range of future outcomes according to different metrics and they are a subset of the GCMs selected to be downscaled within EURO-CORDEX (Sobolowski et al. 2023)

3.5 Documentation and output data sharing

For future project internal and external use of the created climate information, it is essential that the process is well documented, and that the data is treated according to the FAIR principles (https://en.wikipedia.org/wiki/FAIR_data): they should be findable, accessible, interoperable and reusable. This is assured by the data management plan, which is part of the project and to which the modelling groups of WP3 contribute. It will contain, among other information, the model setup specifications (urban specific settings and meta data), the final output variable list and the domain setups. Most efficient ways of sharing the produced climate information within and outside the project is also part of the data management plan and not within the scope of this experimental protocol.

3.6 Work Carried Out

The experimental protocol was discussed in several virtual meetings and via the I4C communication platform Mattermost. It was a good and important process, on which the creation of model simulations can now build.

There are no deviations from the Description of Action.

3.7 Discussion and Next Steps

After good and productive discussions, simulations can be conducted on the basis of the experimental protocol. They will be stored and documented according to the I4C data management plan to which WP3 scientists will continue to contribute.

Updates and additions (if necessary) to the experimental protocol will be made available within the project.

4 Impact

The main impact of a good experimental protocol will be a useful ensemble of simulations, which will be produced in the frame of this project.

5 Links Built

The development of the I4C experimental protocol was inspired by the finished EU-H2020 project EUCP as well as by the WCRP CORDEX FPS-URB-RCC and FPS-CONV. In the discussions, the links to the WCRP EURO-CORDEX and Med-CORDEX activities were brought in by members of both communities, which is also important for the later use of the climate information created within I4C.

6 Communication, Dissemination and Exploitation

We wrote an internal newsletter article about the development of the experimental protocol to inform other work packages about the planned simulations of WP3. We didn't consider this relevant for the broader public.

6.1 Peer Reviewed Articles

There are no peer reviewed articles written so far.

7 References

1. Sobolowski, S., Somot, S., Fernandez, J., Evin, G., Maraun, D., Kotlarski, S., Jury, M., Benestad, R. E., Teichmann, C., Christensen, O. B., Katharina, B., Buonomo, E., Katragkou, E., Steger, C., Sørland, S., Nikulin, G., McSweeney, C., Dobler, A., Palmer, T., … Brands, S. (2023). EURO-CORDEX CMIP6 GCM Selection & Ensemble Design: Best Practices and Recommendations. Zenodo. https://doi.org/10.5281/zenodo.7673400

IMPETUS 4CHANGE

IMPETUS4CHANGE (I4C)

IMPROVING NEAR-TERM CLIMATE PREDICTIONS FOR SOCIETAL TRANSFORMATION

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