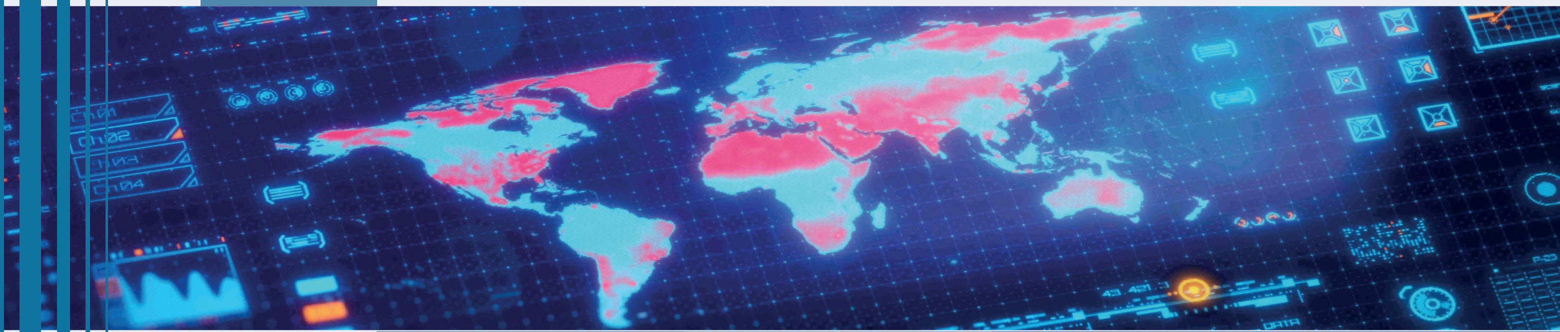

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# EDHEC-CLIRMAP: EDHEC-CLimate-Induced Regional MAcroimpacts Projector— A High-Level View

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## Abstract
The EDHEC-CLIRMAP (EDHEC-CLimate-Induced Regional MAcroimpacts Projector) is a web-hosted tool developed by the EDHEC Climate Institute. It provides a user-friendly platform for scientists, experts, professional investors and policymakers to visualise how climate change-induced shifts in average temperature are projected to affect gross regional economic product (GRP) over time and space, and under various warming scenarios. This note provides a high-level view of the scientific background underpinning EDHEC-CLIRMAP. A full-length companion technical document *EDHEC-CLIRMAP– The Macroeconomic and Econometric Background* is also available.


## 1. Introduction
The EDHEC-CLIRMAP (EDHEC-CLimate-Induced Regional MAcroimpacts Projector) is a web-hosted tool developed by the EDHEC Climate Institute. It offers an intuitive platform for scientists, experts, professional investors and policymakers to explore how climate change-induced temperature variations impact gross regional product (GRP) across a range of reference temperature models and scenarios.

The geographic coverage of this product is global, but it contains highly-spatially disaggregated information on 3,672 sub-national administrative provinces. The user can configure a choice of:

(i) future epoch (e.g., 2050);
(ii) benchmark climate scenario (e.g., such as the SSP-RCP climate scenarios from IPCC IPCC (2021)); and
(iii) global climate model (e.g., ACCESS-ESM1-5).

EDHEC-CLIRMAP will then offer a spatial visualisation of what the climatically induced change in GRP is expected to be. By zooming in on the map, the user can point to specific areas of the world (e.g., the Alpes-Maritimes district or the West Midlands) and view summary statistics of expected climate change impacts on regional economic output.

This document provides a high-level description of EDHEC-CLIRMAP. A companion technical document (*EDHEC-CLIRMAP: EDHEC-CLimate-Induced Regional MAcroimpacts Projector – The Macroeconomic and Econometric Back- ground* )[1] is also available[2].

## 2. The Structure of EDHEC-CLIRMAP
CLIRMAP is made up of four distinct building blocks:

1. a temperature-GRP matching component, to geographically coincide economic and climate data over the last 50 years;
2. an econometric component, estimated based on *historical* data, that establishes the functional relationship between climate variables and GRP;
3. a processing component, that extracts and concatenates localised simulations of future temperatures from NASA to the spatial extent of sub-national regions; and
4. a projection component, that computes and maps the regional future temperature change under a given scenario and global climate model (GCM) to a regional future change induced in GRP.

Together, these components constitute the supply chain that leads to sub-national projections of climate change impacts on economic production. While all steps are important, a critical segment of the approach resides in the econometric component. The reason is that it structures a so-called *transfer function*. Mathematically, we assume (as did Kotz et al. (2024), Kalkuhl and Wenz (2020), and Burke et al. (2015) before them) that this

1 - For brevity we refer to this document as *CLIRMAP Ref.*
2 - https://climateinstitute.edhec.edu/data-visualizations#edhec-clirmap

transfer function is a stable manifold representing the climate-GRP relationship. Without this crucial step, one cannot credibly predict how regional economic production will structurally respond to future climate-change-driven shifts in average temperature.

The rest of the document provides a high-level description of how the different components work, and how they are combined. Again, the companion document referenced above provides the underlying technical details.

### 2.1 The Temperature-GRP Matching Component

Our starting point are several sets of historical data, that fall into two broad categories:

1. high-resolution **weather** data (collected and curated by institutions such as NASA, the Goddard Space Flight Center or the National Center for Environmental Prediction) (Rodell et al., 2004); and
2. high-resolution **macro-financial** data, taken from sources such as the MCC-PIK Database of Subnational Economic Output (Wenz et al., 2023).

These data sources provide climate and macro-financial information with different geographical and temporal resolution. The next step is to geographically coincide these data over the last 50 years. We thus harmonise and curate these data so as to obtain a single 'master source' that contains reliable yearly synchronised historical information about weather quantities, on the one hand, and GRP on the other.

While conceptually straightforward, this part of the project is labour-intensive and far from straightforward. Details of how the data matching is achieved via a population density-weighting method are provided in Section §4.1 of *CLIRMAP Ref*.

### 2.2 The Econometric Component

The 'master source' obtained as described in Section 2.1 lends itself perfectly to the econometric analysis carried out in the second phase of the project.

What one would like to establish is a universal link (a functional relationship that does not depend on time or location – meaning our estimated coefficients have been stripped of any time- or spatially-varying influences, and instead reflect stable, underlying sensitivities) between temperature and GRP. In econometric analysis, relationships of this type are typically established via linear regressions. In our case, the relationship we are trying to establish is between GRP (the so-called left-hand variable *y*), and various powers of average temperature[3] (the so-called right-hand variables *x*). The estimated function itself is often referred to as the 'transfer function'.

Conceptually, the approach is straightforward. However, the GRP varies across time and across locations for a number of reasons, and the temperature effect has so far been rather limited – considering the 50 years of data we are working with. Therefore, special techniques to deal with what are called 'region- specific trends' must be employed in a panel Ordinary Least Squares Fixed-Effects framework. This type of model controls for unobserved time-invariant heterogeneity by allowing entity-specific intercepts, isolating the impact of time-varying regressors. Put differently, it accounts for all time-invariant differences between entities, so that the effect of x on y is not biased by these omitted variables. These are detailed in Section §4.2 of *CLIRMAP Ref*.

A few comments are in order:

First, *global* temperature increases have so far been modest. When the EDHEC-CLIRMAP tool is used for projections, higher temperatures (both locally and globally) will have to be fed into the transfer function. That is why it

3 - Powers of the temperature higher than one are used to capture non-linearities in the GRP-temperature relationship. See McIntosh and Schlenker (2006).

is important to have a temperature-GRP relationship calibrated with highly granular historical information: even if global temperature increases so far have been of only about 1.25°C, much higher temperatures have been recorded locally (together with the corresponding changes in GRP). Since the regression above takes as inputs the highly variable data available at the local level, one can estimate a transfer function that will work over a wide range of temperatures. Regressions, after all, perform better the wider the statistical variability of input variables, and this greater variability is what we achieve with a high geographical resolution. We will need this because, when we do projections, we want to use with confidence our GRP-temperature relationship even when the input temperature is well above 1.25°C; as in all econometric analyses, we want to extrapolate as little as possible, and to *inter*polate as much as we can.

The second important observation is that our transfer function is estimated using temperature and GRP couples collected at different times and in different locations. Yet, we extract a single, universal, transfer function. Therefore, we must make the assumption that the same change in temperature will produce the same (percentage) change in GRP wherever and whenever it happens.

The analysis in EDHEC-CLIRMAP uses a finer geographic resolution than any similar study conducted to date. It is reassuring to note that, when our data are consolidated at the next coarser geographical, as in the seminal study by Kotz et al. (2024), we recover their results. This is important, because the work by Kotz et al. (2024) has become a literature benchmark, and has been promptly adopted by the Network for Greening the Financial System for its last generation of climate scenarios. So, our work is in line with the state- of-art damage-function literature and goes a step beyond it in geographical resolution.

To compute projections of GRP changes, EDHEC-CLIRMAP uses directly the regression coefficients obtained as described above (i.e., the 'temperature semi-elasticities of GRP'). This is defined as the percentage change in GRP for a unit change in temperature. How it is calculated is described in Section §4.2 of *CLIRMAP Ref*.

### 2.3 The Processing Component

The next step of the procedure extracts and concatenates localised simulations of future temperatures from NASA to the spatial extent of sub-national regions. IPCC-sponsored scenarios have produced projections of future global temperatures which NASA's NEX-GDDP-CMIP6[4] (Eyring et al., 2016) downscales over time (days) and space (0.25 deg. grid). Future temperatures are, of course, unknown, and depend on the future course of emissions. Ultimately, a number of emission patterns give rise, for a given horizon, to the same concentration, and, to a good approximation, to the same 'forcing' – where forcing (measured in W/m$^2$) means different from energy in and energy out for the Earth system. Climate physics then establishes a link between forcing and temperature, as explored in the EDHEC web tool EXCITE[5], and described in the documents *EXCITE: The Physics and Modelling Background* and *EXCITE: The How-To Guide*. The IPCC scenarios specify a number of Representative Carbon Pathways (RCPs), each one denoted by a symbol such as RCPX.Y, which signifies a forcing of X.Y (in W/m$^2$) at the end of the century. So, for instance, the RCP8.5 corresponds to all the emission paths that give rise by 2100 to a forcing of 8.5 W/m$^2$. The important thing is that, once the RCP is known, the (distribution of) temperature is (assumed to be) perfectly known.

CLIRMAP is based on scenarios RCP4.5 and RCP8.5, supported by outputs from 29 GCMs, along with an additional intermediate scenario[6]. These, according to EDHEC studies (see Rebonato et al. (2025)), are the emission pathways most likely to occur.

4 - The most recent NEX-GDDP-CMIP6 data product is available here: https://www.nccs.nasa.gov/services/data-collections/land-based-products/nex-gddp-cmip6
5 - EXCITE Emulator is available here: https://climateinstitute.edhec.edu/data-visualizations#edhec-clirmap
6 - Note that the intermediate scenario is computed directly at the source as the midpoint average between the SSP5-8.5 and SSP2-4.5 future temperature trajectories.

For a given RCP scenario, we now have processed from NASA (via a high-performance computing system) the gridded future temperatures at every point in time between today and 2100. We collapse these values over the time frequency of our GRP realisations (i.e., years), prior to concatenating them to the geographic extent of subnational administrative regions, following the same parametrisation as for the historical dataset in §2.1. This enables to calculate in a vectorised fashion: local climate deltas (called climate 'shifters'). These capture the temperature difference (i.e., the climate-change-driven shifts in average temperature) occurring between future and historical periods by scenario and GCM, and are central to our projection modelling.

The next step is to use these climate deltas to compute projected GRP changes down to the highly granular regional level of the EDHEC-CLIRMAP analysis. The details of how this is done are presented in Section §5.1 of *CLIRMAP Ref*, but, for the present purposes, the important thing is that we now have the necessary inputs for the last stage of the process.

### 2.4 The Projection Component

Recall that the econometric component of the project allowed us to establish a universal relationship between temperature changes and percentage GRP changes. The processing part of the project then allowed us to map future (scenario-dependent) local temperature changes (our regional climate 'deltas' or 'shifters') over 2025-2100. We can now combine these two components to obtain what we promised in the introduction: an estimate of the change in GRP due to physical climate risk in any of the regions in our database, at any point in time, for a given RCP scenario and GCM. So, for instance, if we find that, under RCP8.5, the temperature increase in the West Midlands in 2065 will be 0.7°C, and in the econometric part of the analysis we have estimated a semi-elasticity of, say, 0.8, then we can say that the percentage change in RCP at that location at that time will be $0.7 \times 0.8 = 0.56\%$[7]. As the tool shows, the geographic variations are substantial, and heterogeneity matters. Any serious policy or economic analysis would greatly benefit from this type of information.

## 3. Integration with Other EDHEC Initiatives

Even the thumbnail description of the EDHEC-CLIRMAP tool that we have provided brings some important considerations to mind:

First, a carbon pathway (an RCP) uniquely specifies a level of forcing. However, we know that, even if the RCP were known with certainty, there would still remain a wide uncertainty in the temperature outcomes (because the climate physics is still imperfectly understood). With EDHEC-CLIRMAP, we capture this important feature, which is analysed in detail with the EXCITE web-based tool – a tool that produces the *distribution* of global temperatures associated with a given emissions (RCP) pattern.

Second, the RCP scenarios that we use in the EDHEC-CLIRMAP analysis are chosen in a sensible, but ultimately arbitrary, manner. A vibrant parallel research stream at ECI is under way[8] to associate probabilities to the various RCP pathways. By combining this aspect of research with the present project, one could have a full unconditional distribution of future GRC damages, while maintaining the temporal and geographical resolution of EDHEC-CLIRMAP.

7 -These numbers are provided for illustration only. For communication purpose, we actually reduced the temperature functional form $f_T(T_{r,t})$ from §4.2 to one simple semi-elasticity ($\beta^T$) of a linear temperature variable. In practice, our temperature functional form $f_T(T_{r,t})$ is characterised by a polynomial function. See §5.2 of *CLIRMAP Ref* and refer to the outputs from the web-tool.

8 - A first block is available here: http://dx.doi.org/10.2139/ssrn.5128228

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# About EDHEC Climate Institute

## Institutional Context

Operating from campuses in Lille, Nice, Paris, London and Singapore, EDHEC Business School is ranked in the top ten European business schools. With more than 110 nationalities represented in its student body, some 50,000 alumni in 130 countries, and learning partnerships with 290 institutions worldwide, it is truly international.

EDHEC Business School has been recognised for over 20 years for its expertise in finance. Its approach to climate finance is founded on a commitment to equipping finance professionals and decision-makers with the insights, tools, and solutions necessary to navigate the challenges and opportunities presented by climate change. EDHEC has developed a significant research capacity on the financial measurement of climate risk, which relies on the best researchers in climate finance, and brings together experts in climate risks as well as in quantitative analysis.

The DNA of EDHEC's work has also resided, since its origin, in the ability to generate business ventures, by encouraging spin-offs based on the research work of its teams. EDHEC is currently involved in three ventures: Scientific Portfolio, Scientific Infra and Private Assets, and the soon-to-launch Scientific Climate Ratings.

## Mission and Ambitions

The EDHEC Climate Institute (ECI) focuses on helping private and public decision-makers manage climate-related financial risks and make the most of financial tools to support the transition to a low-emission economy that is more resilient to climate change.

It has a long track record as an independent and critical reference centre in helping long-term investors to understand and manage the financial implications of climate change on asset prices and the management of investments and climate action policies.

The institute has also developed an expertise in physical risks, developing proprietary research frameworks and innovative approaches. ECI is also conducting advanced research on climate transition risks, with a focus on supply chain emissions (Scope 3), consumer choices, and emerging technologies.

As part of its mission, ECI collaborates with academic partners, businesses, and financial players to establish targeted research partnerships. This includes making research outputs, publications, and data available in open source to maximise impact and accessibility.

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