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ESMA TRV Risk Analysis

Sustainable Finance

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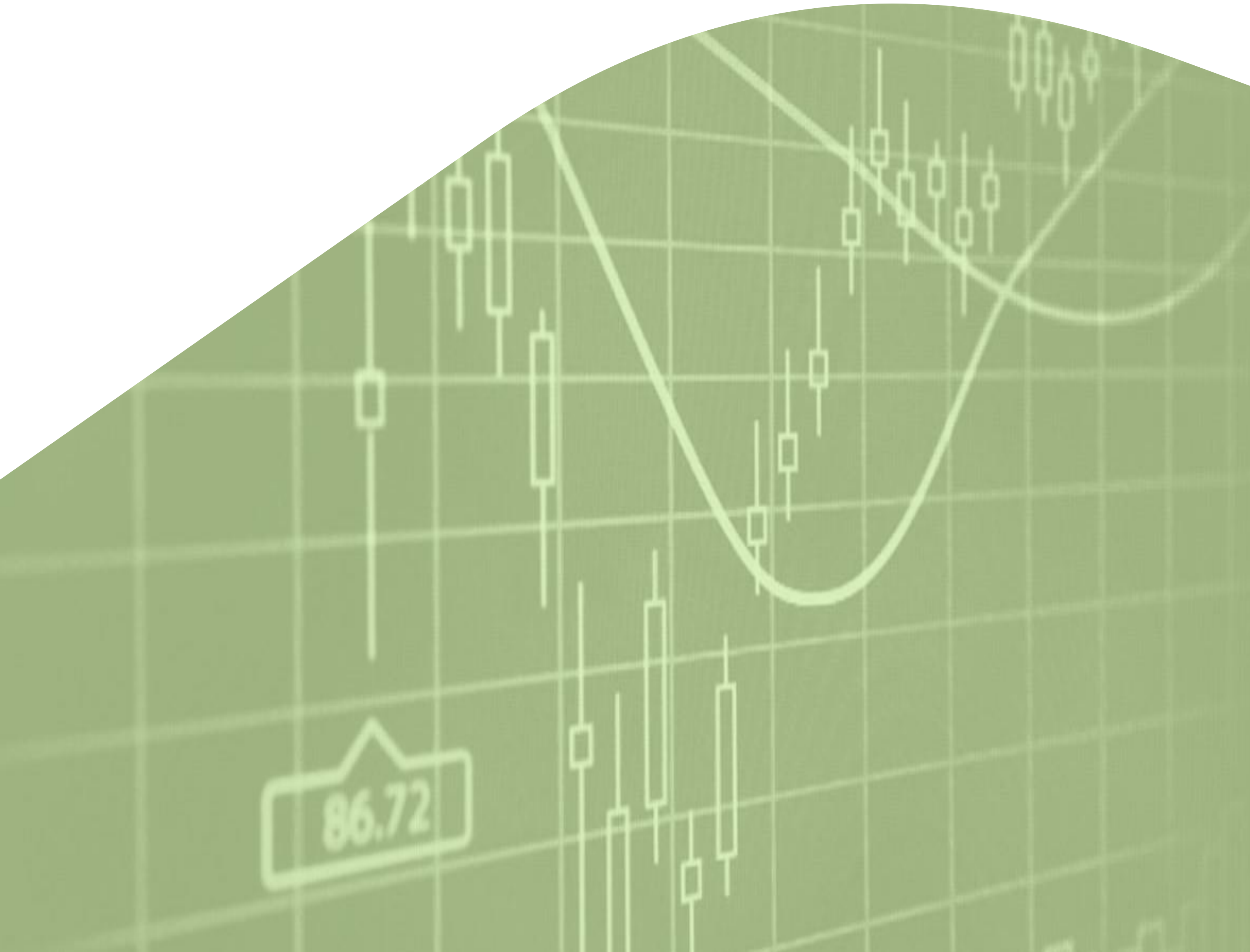

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Sustainable Finance

Assessing portfolio exposures to climate physical risks

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Summary

Understanding the physical impacts of climate change (i.e. climate physical risks) is important for fund managers to identify and manage in advance the potential risks stemming from climate change, and for financial sector authorities to monitor climate-related risks to entities and products within their supervisory remit.

The economic impact of physical climate change could vary between 4% and 18% of global gross domestic product by 2050, according to estimates. The nature and size of the impact are highly dependent on the business sector considered. Within the financial sector, a key challenge is the management of the indirect exposure to climate physical risks through financial assets.

While investment funds' portfolio vulnerabilities to physical risks appear limited given their ability to rebalance portfolios quickly and the short-term nature of their liabilities, some funds may still be exposed to climate physical risks. However, the assessment of portfolio exposures to the physical impacts of climate change is fraught with challenges. The accuracy of these assessments is subject to various limitations, while their interpretation requires context. Such context is key to understanding the implications of choices made with respect to measurements, aggregation methodology and time horizon.

This article illustrates how two different assessment methodologies and data sources can nonetheless yield some insights on climate physical risk exposures, based on an analysis of EU investment fund portfolio holdings. As expected, funds domiciled in northern Europe tend to be more exposed to companies subject to flood risks, while those domiciled in southern Europe are relatively more exposed to the consequences of water supply-and-demand imbalances.

1 This article was written by Julien Mazzacurati and Natacha Mosson. The authors would like to thank Malgorzata Osiewicz from the European Central Bank for her help.

Climate change economic and financial impacts

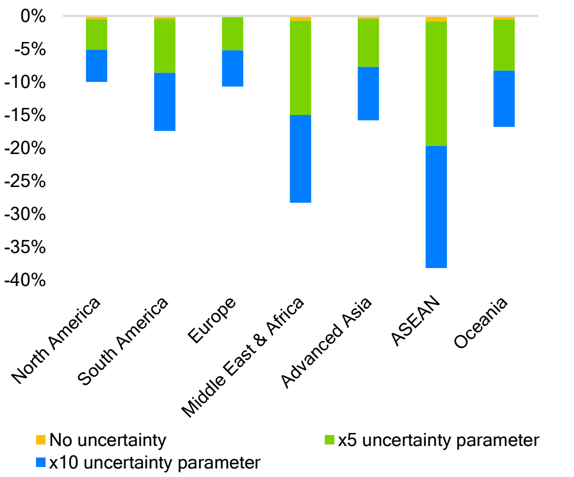
Climate change has led to an increase in the frequency and the intensity of some weather and climate extremes since pre-industrial times (IPCC, 2021). Global warming is associated with increases in temperature extremes, heavy precipitation and droughts.

Estimates of the economic impact of physical climate change risks vary between 4% and 18% of global gross domestic product (GDP) by 2050, depending on the mitigating actions undertaken to limit greenhouse gas emissions (Swiss Re Institute, 2021). Emerging economies in warmer regions would be hit the hardest given their limited adaptive capacity, with a potential output loss of up to 45% of GDP in some countries under the most severe scenario (Chart 1).

Chart 1

Regional GDP losses under 3.2C scenario by 2050

Southeast Asia most impacted



Note: Real GDP impact (in % of baseline GDP) under the most severe IPCC climate change scenario of 3.2 degrees Celsius by 2050 from pre-industrial times by region. The uncertainty parameter represents potential tail risk from the non-linear relationships between temperature increases and economic activity.
Sources: Swiss RE Institute, ESMA.

However, such estimates should be treated with caution given the uncertainties associated with climate change projections, the climate-biodiversity nexus (Finance For Biodiversity Foundation, 2023), and the non-linear relationship between temperature increases and economic activity (Nath et al., 2024).

The potential scale of climate change impacts has brought climate risks to the top of business leaders' risks over the next 10 years (World Economic Forum, 2024). However, the financial impact of climate risks varies significantly between sectors. For example, data centres are highly sensitive to extreme temperatures due to their dependency on heating, ventilating and air conditioning, making telecommunication firms, media companies and data providers particularly vulnerable to climate physical risks (S&P Global, 2023). The expression 'physical risks' further captures multiple types of hazards to which companies may be more or less exposed, depending on the nature of their activities, location and supply-chain dependencies (see Textbox 1).

Textbox 1

Defining climate physical risks

Climate physical risks can be broadly defined as the physical impacts from climate change. This encompasses the effects of climate change on physical capital, human health and productivity and agriculture (Network for Greening the Financial System, 2020).

Climate physical risks typically include acute physical risks, which arise from particular hazards – including weather-related events such as storms, floods, fires or heatwaves – and chronic physical risks, which arise from longer-term changes in the climate – such as temperature changes, rising sea levels, reduced water availability, biodiversity loss and changes in land and soil productivity (European Financial Reporting Advisory Group, 2022).

From a financial risk management perspective, the distinction between acute and chronic physical risks is an important one. The more predictable nature of chronic risks implies that the exposure to these can be reduced through diversification, or that this exposure can be hedged. In contrast, the unpredictable nature of acute impacts highlights the role of insurance coverage to reduce financial losses at the firm level.

Although financial sector firms may also be exposed through their physical assets, a key question for them is how to manage their indirect exposure to climate physical risks through financial assets. This has also become an important aspect of EU financial regulation, with the European Supervisory Authorities recently opining on the need to adjust the prudential framework for banks and insurers (EBA, 2023 and EIOPA, 2023).

Climate physical risks discussions have remained largely absent from the investment management sector for several reasons. First, many funds invest in liquid assets, allowing them to quickly rebalance their portfolio in reaction to (or anticipation of) climate-related shocks. Second, the short-term nature of open-ended funds' liabilities makes them less vulnerable to long-term developments compared with insurers, for example. The development of liquidity management tools may further strengthen the ability of the sector to withstand future redemption shocks.

Nonetheless, some investment funds may be exposed to climate physical risks due to the nature of their investments (e.g. real-estate assets), the sectorial composition of their portfolio or the geographical focus of their investment policy. Moreover, both UCITS and AIFs are required to disclose whether and how they integrate sustainability risks into their investment decisions[2], while fund managers have to consider sustainability risks in their internal processes, systems and controls policies[3].

This article provides an overview of the main challenges and trade-offs involved in the assessment of portfolio exposures to climate physical risks. It also provides an illustration for the asset management sector of insights that may be drawn from such assessments using two different methodologies and data sources. This article is part of ESMA's broader efforts to develop a monitoring framework for environmental risks in EU financial markets, which identified climate physical risks as one of the three core environmental risks to ESMA's remit (ESMA, 2022a), and in line with the objectives of ESMA's *Sustainable Finance Roadmap 2022-2024* of monitoring, assessing and analysing markets and risks related to environmental, social and governance (ESG) issues (ESMA, 2022b)

Assessing climate physical risk exposures

One of the main obstacles to climate physical risk assessments is data. The mapping of climate risk exposures requires three main components:

— Information on the *financial dependency* of portfolio investments (firms, countries) to the physical assets they own or to their suppliers.

— *Geospatial information* on these physical assets and suppliers (e.g. address, postal code).

— Information on the *physical risk drivers* that can impact these physical assets and suppliers.

Beyond general data availability and quality issues – in and of themselves already highly problematic – the different granularity of the information creates several challenges (ECB-ESRB, 2021). First, the resolution level of data on physical risk drivers can vary substantially based on the observation method (e.g. station measurements vs. satellite data) and type of physical hazard, which may affect the accuracy of the information. These data then need to be aggregated at higher levels of territorial units for merging with geospatial information, which tends to be less granular (e.g. at the postal-code or regional level). However, crucial information can get lost in the process, for example on the probability and depth of flood events which tend to be very localised. There are thus some trade-offs between the reliability of physical risk assessments and the complexity (and costs) of the exercise.

One way to perform a full bottom-up assessment of exposures is to outsource it. Several ESG data providers offer corporate or country-specific climate physical risk ratings and scores, allowing subscribers to download (for a fee) and merge these with portfolio data. However, these data products suffer from the same inconsistency issues as broader ESG ratings: a comparison of six physical risk scores using model-based or language-based methodologies reveals substantial divergence between the scores (Hain et al., 2022). Meanwhile, users may not have a full understanding of the underlying assumptions used to fill in data gaps and measurement limitations. The forthcoming EU regulation on ESG rating activities, which requires rating providers to be authorised and supervised by ESMA, will lead to greater transparency with regard to methodologies and data sources.

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2 See Article 6, Regulation (…) on sustainability-related disclosures in the financial services sector (SFDR), *Official Journal of the European Union*, OJ L 317, 9 December 2019, p. 1,.

3 See relevant Delegated Acts for UCITS and for AIFMs.

An in-house alternative to bottom-up exposure mapping is to rely on a top-down assessment using aggregate physical risk measures (e.g. at country or industry-level) applied to individual financial exposures (Bank for International Settlements, 2021). While this type of approach is less resource intensive, it involves important simplifying assumptions.

The next section provides examples of top-down and bottom-up assessments, to illustrate their merits and limitations.

Examples of application to fund portfolio exposures

ND GAIN Index

The University of Notre Dame Global Adaptation Initiative (ND GAIN) Country Index[4] is an open-source index assessing the vulnerability and readiness of 193 countries to climate disruptions. It is based on 45 indicators from 74 data sources from 1995 and updated annually. Vulnerability is decomposed between the exposure, sensitivity and adaptive capacity of each country. We focus here on exposure, defined as '*the extent to which human society and its supporting sectors are stressed by future changing climate conditions*.'

The vulnerability indicators cover six life-supporting sectors: food, water, health, ecosystem services, human habitat and infrastructure. Each sector includes two exposure indicators (Table 1) standardised between 0 and 1 to facilitate aggregation, using baseline minimum and maximum values and a best-performance reference point. All indicators are projection-based as they aim to assess exposure to future climate conditions.

Table 1
ND GAIN vulnerability exposure indicators by sector
Exposure indicators are forward-looking

Sector	Indicator	Description
Food	Projected change in cereal yield	Projected amount that climate change is predicted to change food supply by mid-century for three staples: rice, wheat and maize.
	Projected population change	An indication of food demand by the mid-century.
Water	Projected change in annual runoff	An indication of how climate change will bring changes to annual surface water resources by the mid of the century.
	Projected change in annual groundwater recharge	An indication of how climate change will bring changes to annual groundwater resource by mid-century.
Health	Projected change in deaths from climate change induced diseases	An indication of the climate change impacts on several types of diseases. The indicator is a model-based estimate of the quality-adjusted loss of life years under several different climate scenarios.
	Projected change in vector-borne diseases	This indicator takes the projection of malaria length-of-transmission season as an indication of the climate change impacts on vector-borne diseases.
Eco-systems	Projected change in biome distribution	An indication of how climate change will impact the change in terrestrial biome biodiversity within a country by the end of the century.
	Projected change in marine biodiversity	An indication of how climate change will impact the change in marine biodiversity in a country's exclusive economic zones by mid-century.
Habitat	Projected change in warm periods	An indication of the probability of extreme heat under climate change by mid-century.
	Projected change of flood hazards	Flood hazard is measured by the predicted, monthly maximum precipitation in 5 consecutive days.
Infra-structure	Projected change in hydropower generation capacity	An indication of the potential risk of hydropower generation capacity weighted by the importance of hydropower to one country, i.e. the proportion of the electricity production from hydroelectric sources.
	Projected change in sea level rise impacts	An indication of how coastal infrastructure will be impacted by the combined effect of sea level rise and potential storm surge by the end of the century.

Source: University of Notre Dame Global Adaptation Initiative (ND GAIN)

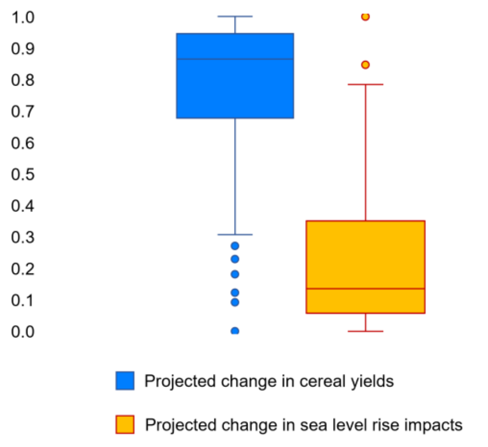
There are three important observations to make at this stage. First, physical risk assessments are highly dependent on the selection of metrics, which reflects not only the nature of underlying data but also the time dimension and horizon (e.g. backward- or forward-looking; see next section).

[4] https://gain.nd.edu/our-work/country-index/

Second, country-level aggregates have clear limitations to the extent that large geographical areas tend to have different climates and are thus exposed to diverse hazard types – one prominent example being the United States.

Third, understanding the methodology used to calculate aggregates is crucial since this has direct implications on the overall scores. Even once standardised, the distributions of the different indicators look very different, which makes them hardly comparable. For example, a large number of countries have high exposure to climate physical risks through their food production. In comparison, fewer countries are highly exposed to sea level rise, but the impact of this particular hazard on these countries could be very significant (Chart 2). These differences in interpretation tend to be lost when looking at sector- or country-level averages and indices.

Chart 2
Distribution of selected hazards across countries
Hazard distributions are differently shaped



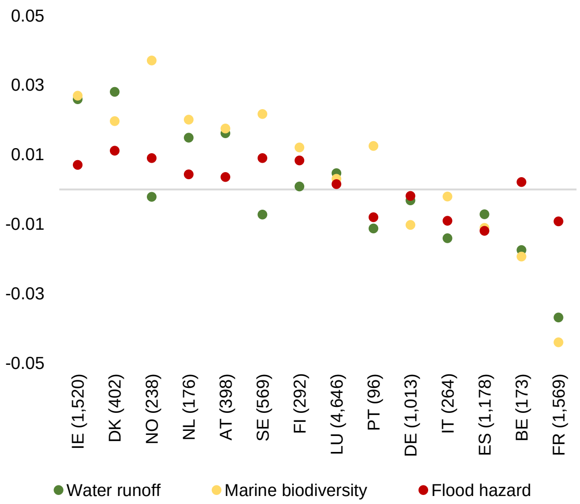
Note: Distribution of selected ND GAIN exposure scores across countries (1=highest exposure score).
Sources: ND GAIN, ESMA.

To assess fund portfolio exposures to climate physical risks, we match ND GAIN's country-level exposure scores and underlying indicators with Morningstar's fund-level data on country exposures [5], based on country names. The dataset includes 12,318 EU funds with EUR 4.5 trillion in assets under management as of the end of 2023. Funds' country exposures are highly concentrated, with 38% to the United States, 22% to the EU and United Kingdom, and 14% to China. The results allow us to calculate fund portfolio exposure indicators.

The aggregation of physical hazards at the country level and of financial exposures at the portfolio level result in a high concentration of physical risk exposure scores within a narrow range. While the outcome may be useful to rank different portfolios, the focus on specific climate risk indicators or metrics yields more insights.

We find that EU funds are mainly exposed to marine biodiversity risks and flood hazards. This exposure is primarily driven by funds domiciled in northern Europe (Chart 3). This outcome is mainly driven by financial exposures to firms domiciled in the United States and in Nordic countries, where water-related risks are relatively high compared with most other countries in the ND GAIN database.

Chart 3
EU fund exposures to water-related physical hazards
Funds in northern Europe are more exposed



Note: EU fund portfolio exposures to selected climate physical risk hazards by fund domicile, displayed as deviation from the average score across all EU funds. Fund sample size for each country in brackets.
Sources: ND GAIN, Morningstar, ESMA.

ESCB climate risk indicators

The European System of Central Banks (ESCB) has developed a number of climate risk indicators

5 Morningstar collects geographic segment revenues for each company and maps them to different countries. Revenue exposures are calculated for each fund in % using equity holdings only, provided that the sum of these holdings represents at least 20% of the portfolio (which is rescaled to 100%).

in recent years. Following a first publication in early 2023 (ESCB, 2023), the indicators have been refined and expanded in 2024 (ESCB, 2024a; ESCB, 2024b). These indicators measure the exposure of euro-area financial institutions (through their loans, debt securities and equity portfolios) to the risks stemming from climate change-related hazards (ESCB, 2024a).[6]

In contrast to the ND GAIN index, the ESCB methodology assesses the exposures to physical risks at the company level. It uses a bottom-up approach based on three layers:

— A hazard layer which describes for each location the intensity and probability of the hazard.

— An exposure layer which maps the company's exposures through their physical assets and financial investments.

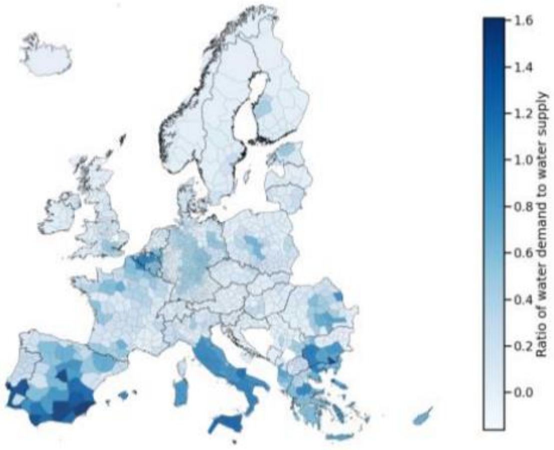
— A vulnerability layer which translates hazard data into expected losses based on damage functions.

The ESCB methodology thus provides more granular information that goes beyond country-level indicators from the ND GAIN dataset. As illustrated by Chart 4, country-level indicators are not always representative of the diversity of exposure within a country. Significant differences in the exposure to water stress can be observed depending on the area considered (for instance, the south of Spain and Portugal compared to the north).

However, more granular information also has limitations. Here, geospatial information is based on the company headquarters' location which may only give a partial view of the company's physical assets and related exposures (i.e. headquarters located in one area and production sites located in other areas). This is especially relevant for large companies that can have multiple production sites located all over the world.

The ESCB methodology provides information on EU non-financial corporations. This implies a limited portfolio coverage for funds investing mostly outside the EU or in financial sector firms.

Chart 4
Exposure to water stress in Europe
High disparities within countries



Note: Ratio of water demand to supply (1960 - 2014 average).
Sources: World Resources Institute (WRI) Aqueduct dataset, ESCB (2024), Climate change-related statistical indicators.

To exploit the ESCB data available at the company level, we rely on investment funds portfolio holdings at ISIN level, also from Morningstar. This second fund sample includes 18,413 EU funds with EUR 10.2 trillion in assets under management[7]. As an illustration of the portfolio coverage limitation, only 12% of the investment funds in our sample have more than half of their portfolio holdings mapped with the ESCB data.

Nine types of hazards are considered in the 2024 dataset: coastal flooding, river flooding, windstorms, landslides, subsidence, wildfires, water stress, consecutive dry days and the standardised precipitation index (Table 2). Although they cover similar topics, a first observation is that the metrics used in the ND GAIN and ESCB datasets differ. For example, the ESCB measures of river and coastal flooding are based on expected water level rise across different periods, while ND GAIN measures flood hazard as the predicted, monthly maximum precipitation in five consecutive days. While the two measures possibly correlate, they are likely to result in different flood risk assessment outcomes.

[6] Aggregated data are accessible through the ECB website.

[7] We consider the latest available assets under management. For more than 90% of the funds in our sample, the assets under management's date ranges between end-December 2023 and end-January 2024. The sample only includes funds with portfolio holdings information reported at least once since December 2022.

Table 2
ESCB physical hazards
Combination of forward and backward-looking indicators

Hazard	Indicator	Source	Climate scenario
Coastal / river flooding	Water level rise (m)	Delft University of Technology	RCP 4.5 RCP 8.5
Windstorms	Wind gust speed (m/s)	Based on Copernicus	
Landslides	Score based on characteristics of the terrain combined with daily maximum precipitation	Disaster Risk Management Knowledge Centre Risk Data Hub	
Subsidence	Score based on soils' clay content	Disaster Risk Management Knowledge Centre Risk Data Hub	
Wildfires	Probability of a fire event	Based on Copernicus	RCP 4.5 RCP 8.5
Water stress	Ratio of water demand and water supply	Aqueduct WRI	SSP2 RCP 4.5 SSP2 RCP 8.5
Consecutive dry days	Maximum number of consecutive dry days	IPCC	RCP 4.5 RCP 8.5
Standardised precipitation index	Index comparing cumulated precipitation for 6 months with the long-term precipitation distribution	IPCC	RCP 4.5 RCP 8.5

Source: ESCB (2024a)

A comparison of the assessment outcomes highlights the relevance of using datasets with different levels of granularity and coverage for the purpose of understanding physical risk exposures.

By combining the ESCB scores and Morningstar portfolio holdings, we obtain for each fund in our sample a risk score for the nine types of hazards considered.[8] Similar to ND GAIN data, the risk scores are not immediately comparable (even after standardisation) given the diversity of methodologies, measurements and data sources.[9] The hazard-by-hazard assessment based on ESCB data shows that the exposure of EU funds[10] varies greatly depending on their domicile. Thus, the exposure to consecutive dry days, wildfires and water stress tends to be more prominent for funds domiciled in southern European countries, while funds domiciled in northern and central European countries tend to be more exposed to floods.

Compared with the ND GAIN exposure scores – which rely exclusively on projected data, ESCB risk scores are based on historical data. However, forward-looking risk scores derived from projected data under different scenarios[11] are also available in the ESCB data for a subset of hazards.

Beyond the different methodologies and data sources, the use of scores derived from historical data compared with those derived from projections provides additional information, leading in some cases to different assessment outcomes. For example, based on historical data, almost all EU funds have limited portfolio exposure to water stress (i.e. a risk score below 1), measured as the ratio of water demand to water supply. However, based on projections, the majority of EU funds will see their exposure to

8 In total, the ESCB database makes available four types of indicators for each hazard and each ISIN within its perimeter. Two of these indicators are based on the physical risk level categories: the risk scores and the potential exposure at risk. Risk scores are measures splitting the potential exposure risk into four categories (i.e. from 0 to 3). The other two are based on expected losses that take into consideration the probability and the intensity of the hazard: the normalised exposure at risk and the collateral-adjusted exposure at risk (ESCB, 2024b).

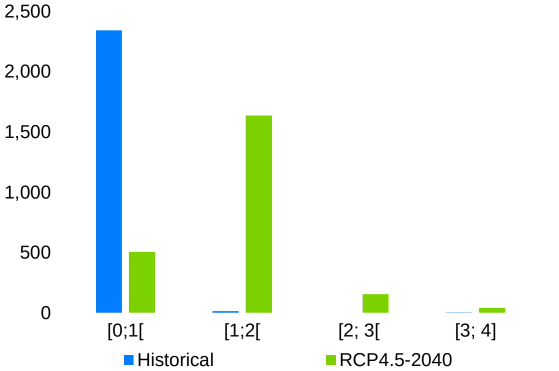
9 However, the indicators in monetary terms allow for a comparison across hazards.

10 To assess fund exposures to climate physical risks, we aggregate the instrument-level ESCB data at the portfolio level.

11 The scenarios considered are the Representative Concentration Pathways (RCPs) which describe future greenhouse gas concentrations. The ESCB selected two scenarios: an intermediate one and a pessimistic one.

water stress increase by 2040 (i.e. a risk score between 1 and 3; Chart 5). This again highlights the importance of relying on complementary information given the time-sensitive nature of climate change events, despite the high degree of uncertainty.

Chart 5
Portfolio-level water stress risk scores
Exposure to water stress expected to rise



Note: Number of funds depending on their aggegated water stress risk scores with historical or projected data. RCP4.5-2040 are projections for 2040 under a moderate mitigation scenario. Risk scores at the instrument level are aggregated at the fund level using portfolio holdings. Only funds with a portfolio coverage equal to or higher than 50% are kept.
Sources: ESCB, Morningstar, ESMA.

Conclusion

Developing an understanding of climate physical risk exposures is important for fund managers to identify and proactively manage the potential risks stemming from climate change, and for authorities to monitor climate-related risks to their supervisory remit. However, the assessment of portfolio exposures to physical risks is fraught with challenges.

This article highlights some of the key issues raised by physical risk exposures assessments. The accuracy of these assessments is subject to various limitations, while their interpretation requires context to understand the implications of choices made with respect to measurements, aggregation methodology and time horizon. The use of different methodologies, metrics and datasets can provide different insights and helps limit the risk of potential blind spots.

With these caveats in mind, this article illustrates how two methodologies and data sources can yield some insights. To assess EU fund portfolio exposures to climate physical risks, we first match ND GAIN's country-level exposure scores and underlying indicators with Morningstar's data on funds' country exposures based on country names. We then combine the portfolio holdings data with the ESCB climate physical risk indicators at the ISIN level.

The results from these two approaches highlight the importance of assessing climate risks at the individual hazard level given the varying nature, interpretation and distribution of these risks. Even though the two methodologies and definitions differ between the two approaches, they both tend to show that the most prominent risks for EU funds relate to water. As expected, funds domiciled in northern Europe tend to be more exposed to companies potentially subject to flood risks. The ESCB data also reveals that funds domiciled in southern Europe are relatively more exposed to the consequences of water supply-and-demand imbalances.

Going forward, ESMA will continue to monitor EU fund exposures to climate physical risks by including some of these indicators into its regular risk assessments.

References

Bank for International Settlements (2021). Climate-related financial risks – measurement methodologies, Basel Committee on Banking Supervision, April 2021.

EBA (2023), Report on the role of environmental and social risks in the prudential framework, October.

ESCB (2023), Towards climate-related statistical indicators, January.

ESCB (2024a). Climate change-related statistical indicators, April.

ESCB (2024b). Climate change-related statistical indicators, Technical annex, April.

ECB-ESRB (2021). Climate-related risk and financial stability – Data supplement, July 2021.

EIOPA (2022), Discussion paper on physical climate change risks, 20 May 2022.

EIOPA (2023), Consultation paper on the prudential treatment of sustainability risks, 13 December.

ESMA (2022a), Monitoring environmental risks in EU financial markets, 15 February.

ESMA (2022b), Sustainable Finance Roadmap 2022-2024, 10 February.

European Financial Reporting Advisory Group (2022), Draft European Sustainability Reporting Standards, November.

Finance For Biodiversity (2023), Unlocking the biodiversity-climate nexus, 10 October.

Intergovernmental Panel on Climate Change (2021), Sixth Assessment Report – Climate Change 2021: The Physical Science Basis, Chapter 11, 9 August.

JRC Disaster Risk Management Knowledge Centre, Risk Data Hub.

Hain, L. Koelbel J. and Leippold M. (2022). Let's get physical: Comparing metrics of physical climate risk. *Finance Research Letters*, vol 46(B), May 2022.

Nath, I. Ramey, L. and Klenow P. (2024), How much will global warming cool global growth? NBER Working Paper 32761, July.

Network for Greening the Financial System (2020), Guide to climate scenario analysis for central banks and supervisors.

S&P Global (2023), Quantifying the financial costs of climate change physical risks for companies, 23 November.

Swiss Re Institute (2021), The economics of climate change: no action not an option, April.

World Economic Forum (2024), Global Risks Report, 10 January.

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