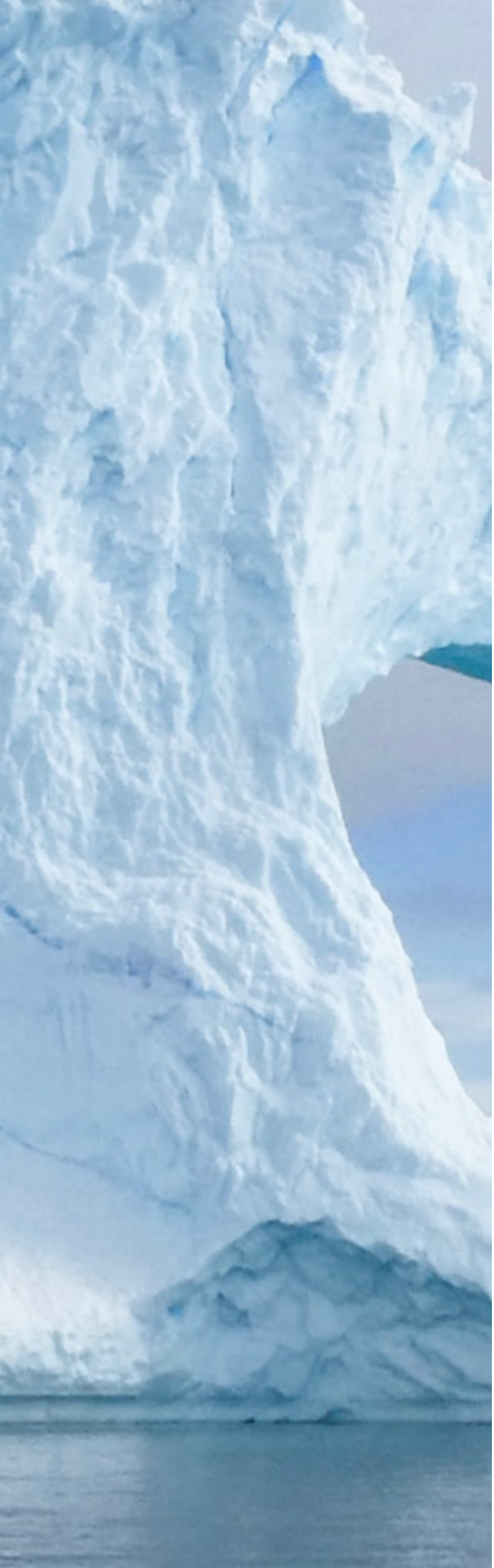
IMPAX Asset Management

Physical Climate Risks

Designing a resilient response to the inevitable impact of climate change



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Executive summary

The physical risks of climate change can no longer be viewed as a distant problem. Extreme weather and record temperatures are now understood to be events that can be anticipated and incorporated into investment decisions.

Physical climate risks are either acute or chronic. Acute risks include droughts, floods, extreme precipitation and wildfires. Chronic risks include rising temperatures, the expansion of tropical pests and diseases into temperate zones, and an accelerating loss of biodiversity. These threats pose both idiosyncratic and systemic risks to investors. The physical impacts of climate change are increasingly obvious and expensive.

One study estimated that the 'climate value at risk' of global financial assets could reach up to US$24.2tr by 2100.[1] CDP recently reported that 215 of the world's largest companies expected to see almost US$1tr in value at risk from climate change within the next five years.[2] Losses could be significantly higher over the long term across all asset classes.

Alarming as they are, these estimates are all likely to be underestimates. Recent reports suggesting that existing economic forecasts of climate value at risk are too low because they fail to incorporate tipping points and risks of conflict and mass migration.[3]

We do not have climate models that can pinpoint specific future events in time or place. However, it is possible for investors to use what is known about the *likelihood* of future climate hazards, to forecast the potential impacts of physical climate risk on their portfolios. Failing to do so will subject investors to a series of increasingly frequent and severe surprises. Using existing knowledge from climate modeling can help investors avoid or price in these physical climate risks.

The toolsets available to help investors understand and assess the value at risk from climate change's physical impacts are developing rapidly. Continued progress will be informed by investor views on what constitutes decision-useful information, and will lead to new, better tools which can more accurately price the physical risks of climate change.

Concluding Impax View

Physical climate risks are complex, but tools to assess and analyse these risks are improving. In the meantime, investors should make the best use of what is available and incorporate pricing of risks into investment decisions where analysis is sufficiently robust.

We encourage others to join the conversation and support initiatives like The Task Force on Climate-related Financial Disclosures (TCFD) that will ultimately integrate this key risk into standard investment practice, creating a more resilient financial system ahead of the inevitable turmoil of the next several decades.

[1]Nature Climate Change https://www.nature.com/articles/nclimate2972 [2]CDP is a not for profit charity that runs carbon disclosure systems. https://www.cdp.net/en/articles/media/worlds-biggest-companies-face-1-trillion-in-climate-change-risks [3]https://www.lse.ac.uk/granthaminstitute/news/economic-models-significantly-underestimate-climate-change-risks/

Introduction

The global climate is changing as a result of greenhouse gas emissions from human activities. This brings with it events that pose risks to the global economy, financial markets, civil society and investors.

Increases in GHG emissions have driven a global increase in temperature of more than 1°C above pre-industrial levels.[4] A range of scenarios relating to different future emissions trajectories to the end of the century predict possible global increases of between 1.5°C and 5°C, dependent on the effectiveness of national policies. Based on recent pledges for emissions mitigation from the global community, we are currently heading for a warming of around 3°C by 2100.[5] The Paris agreement of 2015 created ambitions to limit global warming to 'well below 2°C' from pre-industrial levels, but even those changes will be significant on a global scale.[6] For example, freshwater availability in the Mediterranean is expected to decline by 9% this century if the average global temperature rises by 1.5°C and by 17% if the rise is 2°C. Further, global exposure to severe heatwaves on a five-year basis increases from 14% to 37%.[7,8]

A warming world has already led to the increased severity and frequency of many climate hazards – including flooding, wildfires, extreme precipitation, coastal storms, sea level rise, and expanding ranges of tropical diseases and pests. Hazard severity depends on the environment exposed, with coastal systems facing different risks than inland areas; for example, sea level rise and coastal flooding versus inland drought events.

Our ability to predict each hazard with reasonable certainty is limited, and forecasting becomes less precise as the forecast horizon lengthens. However, we can foresee changes in vulnerability to climate-related hazards. The science of climate modeling is improving quickly, but some hazards are likely to remain more difficult to predict than others. For example, projections for sea level rise due to rising sea temperature and melting glaciers predict large increases across the globe by the end of century, with good confidence. However, it is only possible to make seasonal predictions of hurricane occurrence, with little detail on specifics such as area of landfall.

These evolving hazards are becoming increasingly associated with financial impacts, posing financial risk to investors. The climate value at risk of global financial assets in a scenario with negligible reductions in emission likely equals US$2.5tr but tail risks could reach US$24.2tr (in 2016), according to current forecasts. It is therefore incumbent on financial analysts and portfolio managers to understand and price these risks correctly. Table 1 (overleaf) details recent studies on potential aggregated impacts of climate change. While different studies use different metrics—changes in GDP, change in income, annual losses, value at risk—it is clear from all of them that the impacts of climate change will be profound, and likely to be catastrophic if we are unsuccessful in quickly curbing emissions.

These risks are referred to as physical climate risks and describe the effects that current and future changes in climate variables may have on business operations.

[4]NOAA National Centers for Environmental information, Climate at a Glance: Global Time Series, published March 2020, retrieved on April 13, 2020 from https://www.ncdc.noaa.gov/cag/ [5]"2100 Warming Projections", ClimateActionTracker, https://climateactiontracker.org/global/temperatures/ [6]IPCC Assessment Report 5, https://ar5-syr.ipcc.ch/topic_summary.php Roz Pidcock, "Scientists compare climate change impacts at 1.5C and 2C," CarbonBrief, 21 April 2016. [7]Roz Pidcock, "Scientists compare climate change impacts at 1.5C and 2C," CarbonBrief, 21 April 2016. [8]"The Impacts of Climate Change at 1.5C, 2C and beyond", CarbonBrief https://interactive.carbonbrief.org/impacts-climate-change-one-point-five-degrees-two-degrees/?utm_source=web&utm_campaign=Redirect

Figure 1: Global Warming Pathways[5]

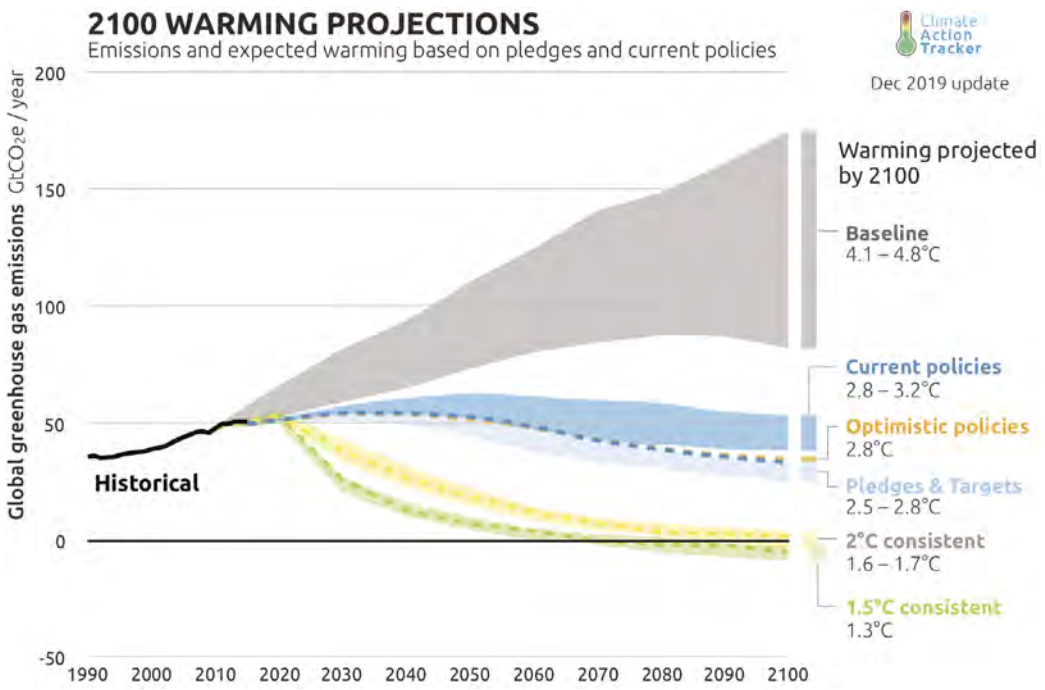


Table 1:

Report and Date	Estimated Impact
Stern Review, The Economics of Climate Change, 2007	• Equivalent to losing at least 5% of global GDP in perpetuity • With a wider range of risks and impacts, estimates of damage could rise to 20% of GDP or more
Risky Business, The Economic Risks of Climate Change in the United States, 2014	• US$238bn - US$507bn worth of U.S. coastal property below sea level by 2100 • Average annual losses from hurricanes and other coastal storms along the Eastern Seaboard and the Gulf of Mexico will rise by US$42bn to US$108bn
Nature Climate Change, Global non-linear effect of temperature on economic production, 2015	• Unmitigated warming is expected to reduce global incomes by ~23% by 2100
The Economist Intelligence Unit, The cost of inaction: Recognising the value at risk from climate change, 2015	• Average expected loss to the total global stock of manageable assets of US$143tr is expected to be US$4.2tr by 2100 (present value)
OECD, The Economic Consequences of Climate Change, 2015	• 1.0 – 3.3% reduction in global annual GDP by 2060 • 2.0 – 10% reduction in global GDP by 2100
Nature Climate Change, 'Climate value at risk' of global financial assets, 2016	• Mean estimate of present value at risk from climate change, 2015 – 2100, is 1.77% of the value of global assets, and possibly as much as 16.86%
Federal Reserve Bank of Richmond, Temperature and Growth: A Panel Analysis of the United States, 2018	• Rising temperatures could reduce U.S. economic growth by up to one-third over the next century.

Risk assessment

Physical climate risk poses material and immediate risks to investors. Early action will be necessary in order to assess, manage and price the risk transparently and comprehensively, and to ensure that investments remain strong and compelling in the short– and long-term future.

Physical risks are complex and multidimensional risks that are functions of hazard, exposure and vulnerability.

Hazard refers to the probability of dangerous climate change events. These events may be acute – such as cyclones or droughts or wildfires – or chronic – such as increasing temperature-driven heat stress and sea level rise. Exposure refers to the risk each facility faces in situ. Finally, vulnerability is the sensitivity to the hazard in terms of physical, societal and economic factors which includes actions taken to reduce or adapt to the hazard; this could be referred to as a net risk value. Physical climate risk assessment requires information on each of these factors for each company or security issuer. (See Figure 2)

Figure 2: The Physical Climate Risk function[9]

Each company faces its own unique set of risks. These can depend on the the nature of its business, location of its significant assets, its supply chain, and the dependence of its value chain on conditions affected by climate change.

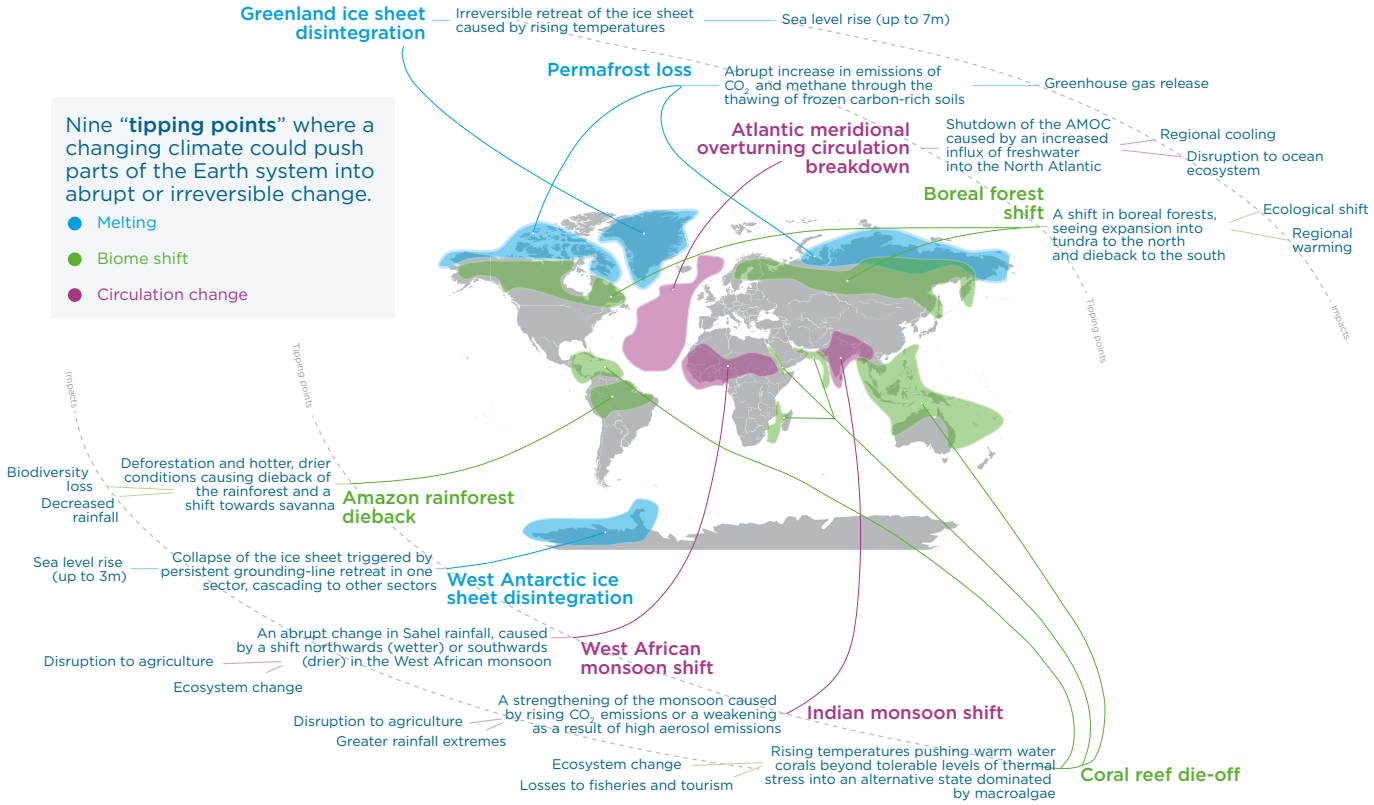
Equally, each hazard comes with its own data-related and forecasting difficulties (discussed in the section on further information). The non-linear nature of the hazards themselves makes predictions less certain. Forecasting the probabilities of certain hazards on a geographic scale relevant to the risks they pose to key assets is therefore complicated. Moreover, there are tipping points – abrupt and irreversible changes to the climate system – where, above some level, hazards are likely to be amplified. At the moment these are not forecastable with any assurance.[10]

Figure 3 details a number of these tipping points. It is clear investors must consider immediate, notable hazards that may affect facilities, and the potential future impacts of other hazards that will develop over the lifetime of an asset. Although gradual changes are often thought to pose long term risks, the fact is that associated hazards are already occurring with increasing frequency and may continue or occur over any time

[9]United Nations International Strategy for Disaster Reduction. "UNISDR terminology on disaster risk reduction." (2009).
[10]"Climate tipping points — too risky to bet against", Nature, https://www.nature.com/articles/d41586-019-03595-0

scale. For investors, each portfolio may present a different aggregate set of risks, based on the specific mix and weight of assets in the portfolio.

Figure 3: Details of several potential tipping points[11]



All sectors of the economy face risk from both short- and long-term physical effects of climate change. The World Economic Forum's 2020 Global Risk Report reports that worldwide economic stress and damages from natural disasters in 2018 reached US$165bn, with 50% of that total uninsured.[12] Companies with physical assets, companies in industries such as infrastructure, and industries with high dependency on natural resources and financials are particularly exposed. However, since every company depends, to some degree, on infrastructure—electricity, water, internet, transportation, and other common services—all companies will likely face some vulnerability to climate hazards.

The future climate will be unlike any other in human memory, which means that we have little in our historical experience to serve as a guide. The risks posed to companies are increasing as global temperatures increase, often presenting situations that companies have never confronted before. A recent example is the case of a Californian utility whose generation and transmission assets are spread across an increasingly dry, hot, fire-prone landscape. That vulnerability was highlighted with several recent bad fire seasons in California, which resulted in the company being assessed as liable for tens of billions of dollars' worth of damage, and resulted in the company declaring Chapter 11 bankruptcy.[13] This is just one example of the importance of emergent, unfamiliar challenges. For investors, this should emphasise that physical climate risks will not be comprehensively managed if only historical norms are used as the basis for the risk management and future mitigation strategies.

[11]"Explainer: Nine 'tipping points' that could be triggered by climate change", CarbonBrief, https://www.carbonbrief.org/explainer-nine-tipping-points-that-could-be-triggered-by-climate-change [12]"The Global Risk Report 2020, World Economic Forum, http://www3.weforum.org/docs/WEF_Global_Risk_Report_2020.pdf [13]"California Utility Firm Files for Bankruptcy After Deadly 2018 Wildfires", The Guardian, https://www.theguardian.com/us-news/2019/jan/29/pge-bankruptcy-california-wildfires-utilities

Risk analysis

Methods to quantify physical climate risk are limited today. However, models and data sources will continue to improve in quality if investors proactively shape the conversation towards actionable decisions.

For physical climate risk to be assessed and quantified using financial metrics, investors need to understand the degree of uncertainty of model projections and be prepared to alter investment choices as our understanding of future risks improves. Incorporating an assessment of climate hazards into financial analysis is possible, though only at an indicative level at present. Investors should be mindful of the uncertainty associated with these risk metrics. However, letting climate risks remain unrecognised and unpriced on financial markets is not a viable alternative. Financial decision making always involves forecasting future events and trends to some degree, and while climate risk presents some additional forecasting difficulty, we do know enough to start using the best forecasts we have to assess physical risk.

Where possible, scenario analysis should be used to illuminate the probabilities of various outcomes in different emissions pathways. Climate science suggests that there is a range of hazard outcomes possible over the foreseeable future. Many different scenarios exist already, but it is important to enhance these common scenarios with other factors that may be uniquely relevant to each investor. The scenarios developed should be simple and exploratory in nature, using both hazard data from climate models as well as various expectations of socioeconomic developments in terms of policy response and increased conflict into the future.[14]

There are many scenarios in existence for an investor to base their scenario analysis on. The main examples are the IPCC Representative Concentration Pathway (RCP) Scenarios and the IEA World Energy Outlook scenarios, which describe carbon dioxide concentration in the atmosphere and the future global energy mix respectively. There will be annual updates on energy outlook projections, and the IPCC will refresh its scenarios in 2021/2022, building in demographic and other societal forecasts, too.

Several barriers still exist in the assessment of physical climate risk. Major difficulties include:

- differences between the geographic scale relevant to investors and those available in climate models;
- communicating the uncertainty over the mechanisms behind major hazards[15];
- availability of asset location data[16]; and
- the ability of the models to predict the timing of hazard incidence. Models allow us to understand changes in the probabilities of hazard incidences, but not the exact timing and location of each future hazard.

We expect that these barriers will be diminished, though the timing and efficacy of the solutions are still to be determined. We believe that investors should be proactive and drive the development and disclosure of the necessary information, as well as the conversation on which indicators they may require from the climate models to inform climate-related risks and opportunities.

[14]"The Use of Scenario Analysis in Disclosure of Climate-related Risks and Opportunities", https://www.tcfdhub.org/scenario-analysis/ [15]"Communicating Model Uncertainty for Natural Hazards: A Qualitative Systematic Thematic Review", International Journal of Disaster Risk Reduction, https://www.sciencedirect.com/science/article/pii/S2212420918306630
[16]"ASSET-LEVEL DATA AND CLIMATERELATED FINANCIAL ANALYSIS: A MARKET SURVEY", Transition Monitor", http://www.transitionmonitor.com/wp-content/uploads/2017/04/assetdata_v0.pdf

Risk management

Where an investor believes that the physical climate risk analysis is sufficiently robust, portfolio investment decisions should be informed by analysis that incorporates appropriate pricing of physical risks.

Investors should seek to understand the actual risk of their investments, which involves incorporating resilience and adaptation strategies. The actual 'net' risk is the final piece of the puzzle. As well as understanding the vulnerability of an asset to climate hazard exposure, net risk incorporates any risk mitigation applied to that asset through adaptation mechanisms. For example, a coastal factory with a flood wall is less vulnerable and will therefore have a lower net risk value compared to an identical asset without the flood defenses, assuming the location is exposed to sea level rise.

For portfolio managers, effective management of physical risk will inform investment decisions, through company valuations and portfolio shifts. For investors to understand what physical climate risks might do to their portfolios, it is always useful to begin with the analyses conducted by companies (or other issuers) themselves. Companies doing more to mitigate their physical risks should command a premium, and companies that aren't should be considered for discounting. Relative weightings could be applied to those sectors or thematic areas where climate resiliency is higher or lower, to inform a physical climate risk-mindful strategy. Independent of the strategy chosen, the onus is on investors to incorporate physical climate risk into their core risk management strategy, to ensure increased resilience across the wider financial system. That, in turn, creates a responsibility for companies to inform investors of what their own assessments of their risks are, and to disclose any efforts to mitigate or adapt to those risks.

Investment decisions based on physical climate risk analysis should inform engagement strategies to illuminate to what extent a company understands and plans to adapt to physical risk on its own operations. Engagement can also be used to influence companies' mitigation and adaptation strategies and may serve to highlight resilient companies and adaptation solution providers as significant opportunities. Engagement with public policy bodies can also be helpful in leveling the playing field in terms of strategic approaches to mitigation, adaptation, and company/issuer disclosures of information relevant to assessing their vulnerability to climate hazards.

What investors can expect over the next few years

Investors should expect better analytical tools in order to gain actionable insight into the resilience of their investments. Pressure will increase from the wider stakeholder community to disclose and manage their physical climate risk.

There are ongoing efforts within climate science and the broader scientific community to improve our understanding of the key drivers of climate change at all geographic scales. This includes the relationships that govern them and the feedback loops which will exacerbate change at thresholds called tipping points. It is reasonable to expect that these efforts will lead to improved climate models, with stronger predictive capabilities over any time span. This should decrease uncertainty and increase resolution, and enable more granular assessment.

Improved assessments with lower uncertainty levels will allow for the development of better analytical tools, and increased consensus on best practice approaches to physical climate risk assessment. As more investors use these assessments, disclosure of these key data points by issuers should improve. However,

without disclosure requirements, they will remain patchy and inconsistent. As more investors become aware of the potential impacts of physical risks, there is likely to be greater pressure on companies to disclose these risks and their own policies for managing them, as well as greater pressure on regulators to establish standardised disclosures related to physical risk.

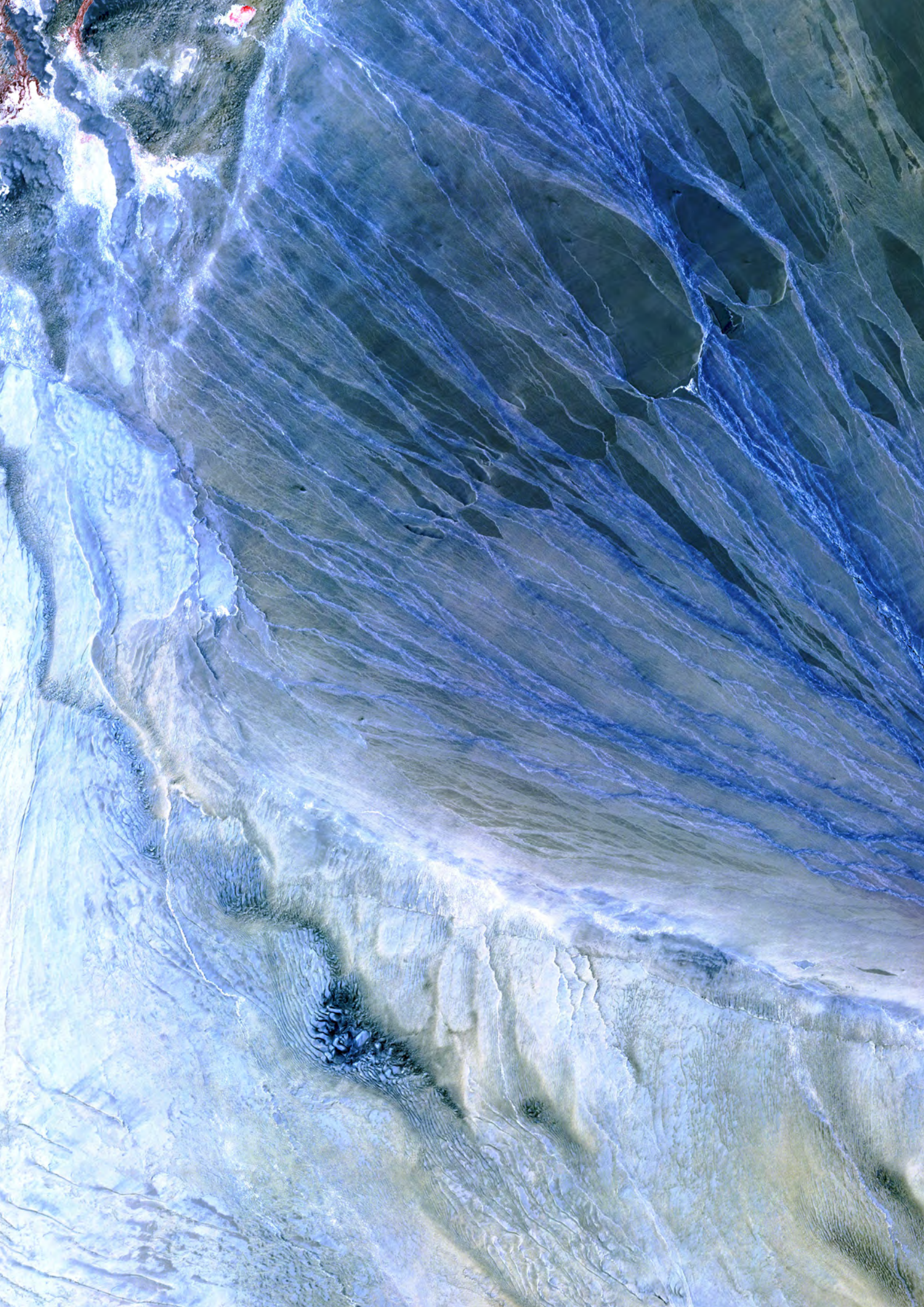
Action in three areas

Investors' tools for understanding climate change's physical risks are limited and imperfect, but improvements in quality and accuracy are likely to continue. It behoves investors to make best use of the information and tools that are available; the only alternative is to be resigned to a future marked by increasingly severe and frequent surprises. There are three things prudent investors can do now:

1. **Identify key risk hotspots by sector, asset type or location using basic climate information.** Understanding the broad geographic outlines of various types of physical risk can be done even without the help of climate science. The Intergovernmental Panel on Climate Change (IPCC) publishes a series of reports addressing the consequences of climate change, with a great deal of information about what changes are expected and the geographic scope of such changes. Together with geographic information on the location of the principal facilities and supply chains of the companies or other issuers in a portfolio, this can be a useful first step in understanding where further refinement is most useful in calculating the probabilities of damage to portfolio assets from climate change.
2. **Develop the expertise necessary to identify specific hazards to assets within investment portfolios.** Understanding physical risk to specific facilities and assets in an investment portfolio does require access to expertise in climate science. This includes the ability to either downscale the output of climate models or access downscaled data to assess future probabilities of damaging events or conditions. It also means selecting the scenarios to be tested. This ranges from a lower-emissions scenario, such as conformity with the target of the Paris Agreement, to business as usual, and possibly options between the two. The TCFD provides useful advice in selecting and testing scenarios, as does the United Nations Environment Programme,[17] the Principles for Responsible Investment, and various private sector consultants and nonprofits.
3. **Monitor developments in climate science and the tools available to price physical climate risk.** There are very few risks that can be thoroughly understood on a one-and-done basis. Climate risk assessment or modeling is particularly important to conduct on an ongoing basis, as both climate science and the climate itself are continually changing.

Risk assessment in investment is about forecasting, and that is an inherently imprecise activity. Forecasting climate risks for portfolio construction is even more imprecise because the future we face is one we have never experienced in human history. However, our current understanding of climate risks is sufficient enough to give us a good starting point for the development of better tools and techniques, and the time to begin understanding those risks is now.

[17]UNEP Finance Initiative, "Changing Course: A comprehensive investor guide to scenario-based methods for climate risk assessment, in response to TCFD," UNEP FI, Vivid Economics and Carbon Delta, 2019.



Further information

Climate literature

The body of literature studying the financial impact of climate change on global and national economies, plus various industries, is rapidly expanding. Here we highlight a few examples, with their key findings.

As referenced previously, Nature published an article analysing the 'Climate Value at Risk' of global financial assets, finding high probability that it equals US$2.5tr, and US$24.2tr in the 99th percentile of the analysis. The article also analyses the positive impact on this value from limiting warming to 2°C, which makes financial sense to both risk neutral and risk averse investors.[18]

The Economist Intelligence Unit estimates that climate change will reduce GDP to 3% by 2050, incorporating resilience by region. For example, the impacts in Western Europe are less (1.7%) versus Africa (4.7%), but not negligible. The same source estimated that the climate value at risk of global public assets could reach US$43tr by 2100.[19]

Other sources have emphasised that larger, high income countries are not automatically resilient to climate hazards. A paper by Colacito suggests that state level output growth in the US could be affected by increasing temperatures, falling by up to one third by 2100.[20]

Broader national studies show reduced annual economic growth of 1.3% in lower income countries[21] due to marginal temperature increases. Productivity losses in Chinese manufacturing plants could reach 12% - equivalent to US$39.5bn (base 2007).[22]

The 2019 World Economic Forum's risk report demonstrated just how important environmental issues have become within conversations regarding the global economy. The same report states that worldwide economic stress and damage reached a value of US$165bn directly from natural disasters in 2018.[23]

AON, an insurance company, states the economic cost of weather-related disasters globally reached US$232bn in 2019, making the last decade the costliest for weather disasters on record. Only US$71bn were insured losses. The total insured loss from cyclones, flooding, severe weather, drought, winter weather, wildfire and windstorms reached US$3.5tr since 2000.[24]

[18]See source 1 [19]Unit, Economist Intelligence. "The cost of inaction: Recognising the value at risk from climate change." London: Economist Intelligence Unit (2015). [20]Colacito, Riccardo, Bridget Hoffmann, and Toan Phan. Temperature and growth: a panel analysis of the United States. No. IDB-WP-676. IDB Working Paper Series, 2016. [21]Dell, Melissa, Benjamin F. Jones, and Benjamin A. Olken. "Temperature shocks and economic growth: Evidence from the last half century." American Economic Journal: Macroeconomics 4, no. 3 (2012): 66-95. [22]Zhang, Peng, Olivier Deschenes, Kyle Meng, and Junjie Zhang. "Temperature effects on productivity and factor reallocation: Evidence from a half million Chinese manufacturing plants." Journal of Environmental Economics and Management 88 (2018): 1-17. [23]Refer to source 12. [24]"Weather, Climate & Catastrophe Insight: 2019 Annual Report", AON, http://thoughtleadership.aon.com/Documents/20200122-if-natcat2020.pdf?utm_source=ceros&utm_medium=storypage&utm_campaign=natcat20

Company examples

Recent instances of the impact of climate change on individual companies.

- A Japanese manufacturer of broad-use electric motors suffered a significant productivity loss as a result of the major Thai floods of 2011, which directly impacted top-line values and operating income.
- An electric utility in California, USA, faced a share price collapse on the back of wildfire events in 2015 and 2018, along with significant legal repercussions regarding its liabilities for causing the wildfires through inadequate management and infrastructure. These proceedings are ongoing but demonstrate the potential impacts on an otherwise strong entity with great resiliency deficits to a changing world with new hazards.
- A London insurer blamed extreme weather events for consecutive year losses in 2018/2019. They resulted in claims of £19.7bn through events such as Hurricane Florence, Michael and Typhoon Gebi.

Hazards

Predicting hazards is a difficult process and it may remain impossible to pinpoint events in space and time beyond seasonal forecasts. However, our ability to predict changing probabilities is improving.

The key hazards that are being assessed include:

Sea level rise

Rising sea levels are being driven by the thermal expansion of the oceans and the melting of ice sheets and glaciers worldwide.

This hazard is increasingly well understood but likely underestimated by global climate models. As an example of a first-order impact, recent improvements to elevation models show the number of people living below high tide lines in a low-emissions scenario will increase by 36-127% by 2100.[25] Sea level rise can also have significant impacts through heightened erosion, salinising groundwater and enhanced storm surges.

An example of the impact is the current Indonesian capital and megacity, Jakarta.[26] The capital is being relocated from Java to Kalimantan province due to the rising risks associated with sea level rise and coastal flooding. According to C40 cities, over 570 low lying cities face projected sea level rises of at least 0.5m, placing 800 million people at risk.[27]

[25]Kulp, S.A., Strauss, B.H. New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding. Nat Commun 10, 4844 (2019). https://doi.org/10.1038/s41467-019-12808-z [26]"Indonesia is planning to move its capital from a sinking city to an island where forests have been burning", https://www.businessinsider.com/indonesia-capital-move-jakarta-borneo-environmental-concerns-2019-8?r=US&IR=T [27]https://www.c40.org/other/the-future-we-don-t-want-staying-afloat-the-urban-response-to-sea-level-rise

Cyclones

Cyclones are tropical storms that bring extremely high wind speeds and extreme rainfall. They are often referred to as hurricanes when formed over the North Atlantic or Northeast Pacific oceans, and referred to as cyclones when formed over the South Pacific and Indian ocean and typhoons over the Northwest Pacific ocean.

They are notoriously difficult to predict accurately beyond the short term, but there is enough evidence to suggest that cyclones are following three key trends due to climate change: Poleward shift: the movement of average landfall area away from the equator in both hemispheres[28,29]; Intensification: the increase in the overall power and associated damage caused by the storm[30,31]; and an absolute reduction in numbers[32].

Cyclones can have a huge impact on a national economy. An example of the financial significance of these trends is in Japan. Japan's top three property and casualty insurers reported in late 2019 that insurance payments for damages from two recent typhoons would exceed US$8bn. That followed payouts of nearly US$14bn the year before resulting from severe flooding and landslides in the western part of Japan, the country's deadliest weather disaster in 36 years.[33]

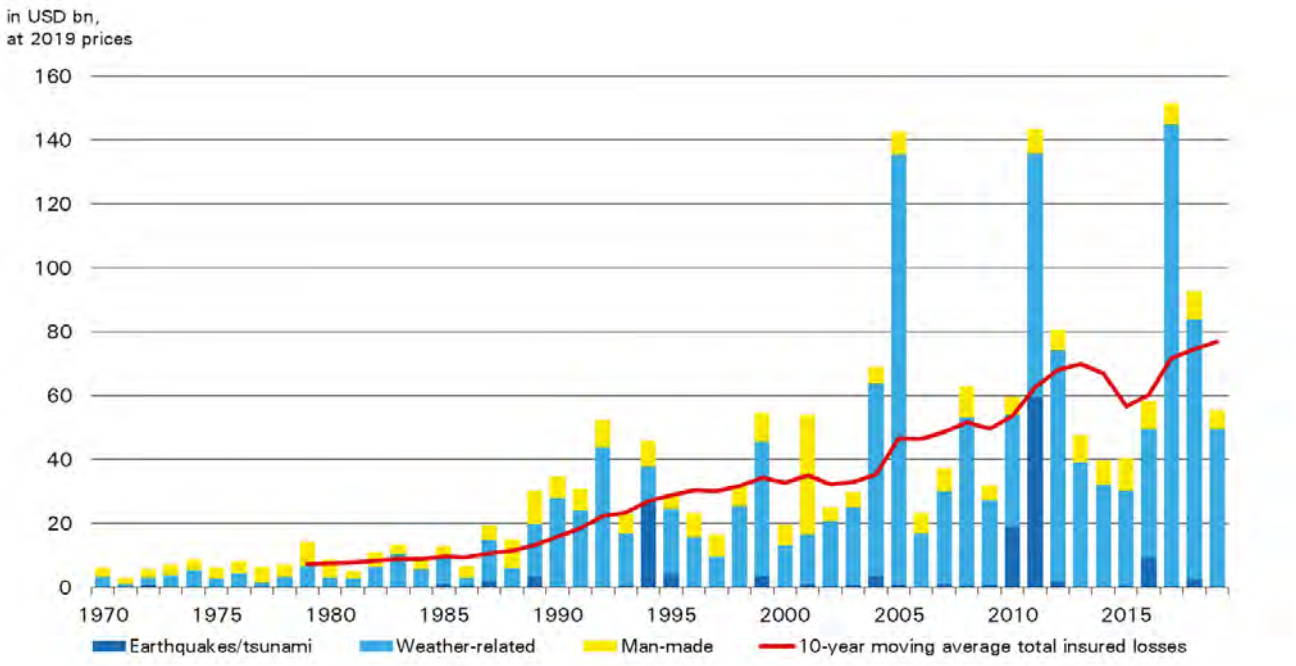
Flood events

Flood events may refer to fluvial or riverine floods or coastal flooding. The latter refers to storm surge events, which will worsen over time as sea levels rise. The former are times of extremely high water flows in existing river systems due to heightened levels of precipitation. At a critical point, the increased flow will inundate its surroundings with surface water, often damaging property and local infrastructure. These events are difficult to predict, but probabilistic forecasts based on historical evidence can give an indication of where the impacts will be greatest for a range of different events. Projections are available for extreme precipitation within the major climate models.

There is mixed evidence on the impact of climate change on fluvial flooding, as it is unclear if the projections surrounding extreme precipitation increases regionally have materialised. However, we can say that impacts have increased due to urbanisation and general mismanagement of risk in construction on high risk floodplain areas across the world. Figure 4 demonstrates the increasing trend in insured losses due to weather related events. The cost of extreme weather in the US from 2010-2018 was estimated at US$763bn by the NOAA (Emission Impossible), of which 77% was attributed to tropical cyclones and severe storms, 10% to drought events, 7% to wildfires and 5% to flooding, for context.[34]

[28]Altman, Jan, Olga N. Ukhvatkina, Alexander M. Omelko, Martin Macek, Tomas Plener, Vit Pejcha, Tomas Cerny et al. "Poleward migration of the destructive effects of tropical cyclones during the 20th century." Proceedings of the National Academy of Sciences 115, no. 45 (2018):11543-11548. [29]Tamarin, T., and Y. Kaspi. "The poleward shift of storm tracks under global warming: A Lagrangian perspective." Geophysical Research Letters 44, no. 20 (2017): 10-666. [30]Bhatia, K.T., Vecchi, G.A., Knutson, T.R. et al. Recent increases in tropical cyclone intensification rates. Nat Commun 10, 635 (2019). https://doi.org/10.1038/s41467-019-08471-z [31]Peduzzi, P., Chatenoux, B., Dao, H. et al. Global trends in tropical cyclone risk. Nature Clim Change 2, 289–294 (2012). https://doi.org/10.1038/nclimate1410 [32]Global Warming and Hurricanes, Geophysical Fluid Dynamics Laboratory, https://www.gfdl.noaa.gov/global-warming-and-hurricanes/ [33]Thomson Reuters, "Powerful typhoons scar Japanese insurers' earnings," November 19, 2019. [34]https://www.bofaml.com/content/dam/boamlimages/documents/articles/ID20_0127/Climate_Change.pdf

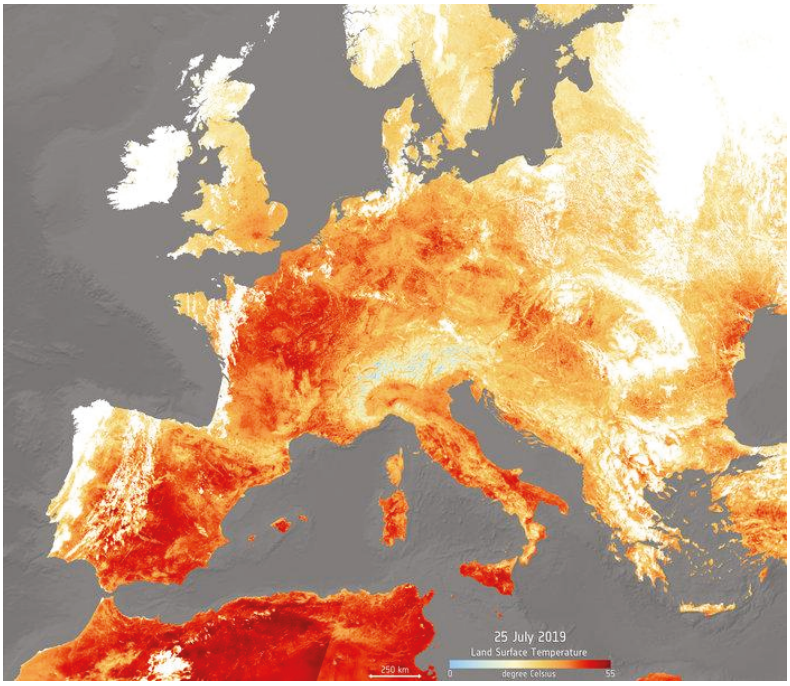
Figure 4: Catastrophe-related insured losses (1970-2019)[35]



Chronic changes

Chronic changes refer to gradual changes in key climate variables such as temperature, humidity and precipitation. The spatial resolution of future projections for these variables are low globally but higher regionally. In the summer of 2019, temperature records were consistently broken across Europe and the East coast of America. Figure 5 shows temperatures across Europe at the height of this heatwave. Further, four out of the last five years have been the hottest on record. Reports such as that written by the international labour organisation predicts the impact of changing temperate and heat stress on human productivity to be equivalent to a loss of up to 80 million jobs. As these changes are gradual and don't impact economies in the same immediate and devastating way that a hurricane might, these impacts are understated and misunderstood. The risks associated with economies becoming increasingly exposed to climate conditions they are not prepared for is underappreciated.

Figure 5: Extreme heatwave[36]



[35]https://www.swissre.com/media/news-releases/nr-20191219-global-catastrophes-estimate.html [36]https://www.copernicus.eu/en/media/images/extreme-heatwave

Water stress and drought

The water balance is delicate and often the demand on a hydrological system is greater than it is able to supply. This overuse means that the groundwater cannot replenish at a renewable rate and is referred to as water stress. It is largely under-priced as a risk in agriculturally reliant stocks,[37] and the effects are worsening. Water stress can exacerbate the problems associated with a drought, too, where there is significantly less rainfall than average for a region, further reducing the available supply of water. Tools to understand current and future risk are comprehensive and actionable on a basin level, through the WRI Aqueduct tool. The Aqueduct Water Risk Atlas is a powerful tool provided by the Water Resources Institute to visualise and pinpoint water-related risks and to assess exposure to various water risks across different asset locations.

As a fundamental resource necessary for survival, limited supply can cause geopolitical tension as it did in Syria. This is an immense and significant risk.

Wildfires

Wildfire events are aided by our understanding of drought risk and seasonal forecasts of extreme heat, together with the geographic mapping of fuel distribution (e.g. vegetative cover, the built environment), and the presence of human activity (sources of ignition). Firestorms within increasingly intense wildfires are decreasing in rarity as the world warms. This hazard is highly geographical and has the potential to devastate entire forests. A clear example of a financially-impactful wildfire was the recent occurrence in Australia. The government of Australia has recently set up a recovery fund to help the victims of the recent bushfires. That fund already contains AU$2bn and that is likely to fall far short of what is needed. 10 years ago the recovery fund to help victims of the Black Saturday bushfires cost at least AU$4bn.[38] Further, on prediction, while at least one Australian government official denied that there was a link between climate change and those bushfires, the risk had actually been predicted in 2007 by an IPCC report, and in 2008 by the Australian government itself.

[37]Hong, Harrison, Frank Weikai Li, and Jiangmin Xu. "Climate risks and market efficiency." Journal of Econometrics 208, no. 1 (2019): 265-281. [38]Chloé Farand, "Australia's Bushfires to cost billions as climate risks rise," climate change news, July 1st 2020.

Initiatives

Initiatives such as the TCFD and policy drives through the EU Green Taxonomy will enable and push investors to integrate physical climate risk into their investment processes.

The TCFD is a major private sector-led initiative seeking to encourage listed entities and asset managers to disclose their climate-related financial risks (physical and transition risks) through a framework of recommendations on governance, strategy, risk management and metrics & targets. The rationale is that strong, standardised disclosure across industries will provide the transparency that investors require to effectively price physical climate risk and reposition strategies against it. Further progress is needed for the initiative to be successful but will require better guidance on the unfamiliar methodologies referred to above.

Other notable initiatives include the Carbon Disclosure Project, the Institutional Investors Group on Climate Change (IIGCC), the Coalition for Climate Resilient Investment and others such as the Spatial Finance Institute and the Global Innovation Lab for Climate Impact.

The Carbon Disclosure Project creates a climate-related questionnaire to be sent out to listed companies annually, and its completion signals that the company is aligned with the TCFD to some degree. The questionnaire is increasingly utilised each year and will become integral in the full disclosure of climate related risks for investors.

The IIGCC is a membership body which facilitates collaboration between large European investors, creating groups and programs on policy, property, corporates and investor practices to ensure comprehensive and actionable coverage for the 190 investors it serves, with a combined AUM of €28tr.

Policy shifts for the integration of risk management relating to physical and transition climate risks are becoming widespread globally, but the main initiatives are borne out of the EU and the UK. The UK published a paper on their green finance strategy in 2019, suggesting that they will make climate risk disclosure mandatory for listed companies by 2022, while the Bank of England put forward its scenario-based methodology for new climate-related stress tests for insurers and lenders in 2021. This could signal the isolation of both best and worst in class companies associated with the UK, who could be penalised officially or affected reputationally in the short to medium term. It could also pave the way for other central banks to create their own stress-test methodologies.

The Technical Expert Group on Sustainable Finance published a report detailing EU proposals to create a taxonomy along which green activities can be defined. It aligns with the TCFD recommendations and mentions physical climate risk in the context of adaptation revenue and climate-related resiliency. The SEC published guidance on climate risk and opportunity reporting, with the Federal Reserve starting to examine the possibilities of using macroeconomic and monetary policy to address the systemic risks posed by climate change. This could signal a change and progression in the US markets towards recognition of material business impacts of a changing climate.

At a global level, the Network for Greening the Financial System, formed at COP21 in Paris, has developed a scenario analysis framework for central banks to facilitate work on climate-related financial stability risks, also spinning off to create the Global Adaptation and Resilience Initiative, which provides key insights on adaptation opportunities for investors.

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