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How could climate services support disaster risk reduction in the 21st century

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A R T I C L E I N F O

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A B S T R A C T

In January 2018, three leading European initiatives on climate services (CS) and disaster risk reduction (DRR) initiated a discussion on how the DRR community could be best served by new and emerging CS. The aim was to identify challenges and opportunities for delivery of effective operational disaster risk management and communication informed by an understanding of future climate risks.

The resulting discussion engaged experts from civil protection, health, insurance, engineering and the climate service community. Discussions and subsequent reflections recognised that CS can strengthen all phases of the DRR cycle and that there are lessons to learn from experience that could enhance and demonstrate the value of CS supporting the DRR community. For this to happen, however, the supporting information should be relevant, accessible, legitimate and credible and engage both service supply and demand sides. It was also agreed that there was need for identifiable and credible champions recognised as providing leadership and focal points for the development, delivery and evaluation of CS supporting DRR.

This paper summarises the identified key challenges (e.g. disconnection between CS and DRR; accessibility of relevant and quality-controlled information; understanding of information needs; and understanding the role of CS and its link to the DRR planning cycle). It also suggests taking advantage of the unique opportunities as a result of the increased coherence and mutual reinforcement across the post-2015 international agendas and the increasing recognition that links between public health and DRR can provide impetus and a focus for developing CS that support DRR.

1. Setting the scene

The adoption of landmark UN agreements, notably the Sendai Framework for Disaster Risk Reduction 2015–2030,[1] the 2030 Agenda for Sustainable Development,[2] the UNFCCC Paris Agreement,[3] the Agenda for Humanity[4] and the New Urban Agenda[5] have created an exciting opportunity to build coherence across different but strongly overlapping policy areas. Taken together, these frameworks and agreements provide a comprehensive resilience agenda, one that recognises that building resilience requires action spanning development, humanitarian aims, climate change response and disaster risk reduction. Moving forward, this coherence will facilitate the reduction of existing fragmentation and conflicts within the existing DRR and climate change adaptation (CCA) agendas by strengthening resilience

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[1] https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf.
[2] https://sustainabledevelopment.un.org/post2015/transformingourworld/publication.
[3] https://unfccc.int/sites/default/files/english_paris_agreement.pdf.
[4] https://agendaforhumanity.org/sites/default/files/asr/2017/Nov/Annex_Agenda%20for%20Humanity_web.pdf.
[5] http://habitat3.org/the-new-urban-agenda/.

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frameworks for multi-hazard assessments and actions, with the aim of developing a dynamic, targeted, preventive and adaptive governance system at global, national and local levels. Targeting knowledge and evidence through climate services (CS) to support actions consistent with this coherence will be critical.

Despite the obvious links, CCA and DRR have been developed largely as separate policy domains. This has resulted from a range of reasons, including the different temporal and spatial scales considered by the two domains, the diversity of actors involved in them and the policies and institutional frameworks of relevance, as well as the differences in the terminology and methodological approaches used in research activities related to the two domains (e.g. [2,3,1]). As a result, the CCA and DRR communities are not always well connected and both generally regard the other community as covering only a subset of their work. This limited connectivity also holds true with respect to the knowledge and evidence being generated within the two communities to support decision-making processes related to extremes.

Extreme weather and climate-related events are the most impactful type of natural disasters and are identified by some as being the highest risk[6] to society in the last 10 years.[7] The hazards[8] and vulnerabilities associated with these events are projected to alter due to climate change directly, as well as a result of changes to determinants of vulnerability such as land use and demographics. Thus, access to relevant and quality-controlled climate information is crucial to enable better informed decisions aimed at addressing existing and emerging weather and climate-related risks. This includes characterising present-day risk and understanding past and future trends of extreme events, including those related to slow onset events (e.g. sea level rise and increasing temperatures that can enhance the likelihood of exceeding thresholds). Such climate information can and should support both CCA and DRR policy and practice. This also suggests that to be effective, this climate information should also be integrated with social, economic and environmental objectives reflecting the comprehensive resilience agenda which necessarily requires complementary information such as land use change, demographics and insurance penetration. The challenge is to understand what information is needed and can be credibly provided (decision-driven and science-informed), and then to work with the respective user communities to deliver it.

From the perspective of CS, DRR can be regarded as a separate application area. From a broader perspective, however, the link between DRR, CCA and sustainable development suggests that the climate services required should also support DRR as an integral part of sectoral and system management and development (i.e., water, infrastructure or health sectors, as well as community, urban and catchment levels). For example, provision of information to support disaster risk management in relation to water resources should consider that those decisions - whilst targeting DRR (e.g. supporting drought and flood management) - are part of a broader water resource management and development system.

In the context of a changing climate, there is emerging recognition that climate services are important for DRR and, as such, there is a need for the CS and DRR communities to engage in addressing the emerging potential. Towards addressing this emerging potential, this paper reflects on this engagement in the context of mutually beneficial collaboration and partnerships that are increasingly key to the joined-up thinking on design and delivery of knowledge and evidence. This includes that knowledge and evidence required to support the Sendai Framework Global Target (e.g. substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030). In doing so this paper recognises that there are barriers to achieving the required engagement, most of which can be framed around barriers to joined-up thinking and innovation.

A particular focus for understanding and developing the role of CS is to link those services to the DRR planning cycle: prevention, preparedness, response and recovery (based on the 'Build Back Better' principle[9]). In engaging with the relevant user communities, the intention should be to ensure that the services and information provided are useful, relevant, accessible, credible and legitimate. In the context of the European research and innovation Roadmap for Climate Services, CS are defined as: "the *transformation of climate-related data and other information into customised products such as projections, trends, economic analysis, advice on best practices, development and evaluation of solutions, and any other service in relation to climate that may be of use for the society at large*".[10] This stresses the importance of a user-driven approach which goes beyond the mainly supply-driven Global Framework for Climate Services (GFCS) definition according to which CS merely "*strengthen the production, availability, delivery and application of science-based climate prediction and service*".

In responding to the challenges of delivering CS for DRR, future efforts targeting the development of CS for DRR should take advantage of the unique opportunities that now exist as a result of the shift in focus of the Sendai Framework from managing 'disasters' to managing 'risks' and the potential offered by addressing health as a driver for action on DRR. The shift in focus to managing risks provides a basis and opportunities for increased coherence and mutual reinforcement across the post-2015 agendas reflected in policies, institutions, goals, indicators and measurement systems for implementation. The strategies for promoting coherence and mutual reinforcement include establishing political recognition of the need for such; linking mechanisms for monitoring and reporting of linked goals and indicators; and promoting cooperation in implementation.

The need for health to be a major focus of DRR and management is now recognised within the Sendai Framework as playing a critical role; strongly promoting health resilience. In this context, health is identified as a major driver and the Sendai Framework calls for resilience of national health systems, including by integrating DRR into primary, secondary and tertiary health care, especially at the local level; developing the capacity of health workers in understanding disaster risk and applying and implementing DRR approaches in health work; promoting and enhancing the training capacities in the field of disaster medicine; and supporting and training community health groups in DRR approaches in health programmes, in collaboration with other sectors, as well as in the implementation of the International Health Regulations (2005) of the World Health Organization. We recognise that currently at the local and regional level health care is not necessarily well connected to civil protection agencies dealing with DRR and environmental/spatial planning agencies dealing with CCA. Our vision includes recognition of the advantages of enhancing these connections consistent with the Sendai Framework.

It is evident that while CS are critical for supporting CCA, their full potential in supporting DRR has not yet been exploited. Opportunities for focusing future climate service efforts exist across the DRR cycle, both internationally and nationally. This is also reflected in the number of relevant references within the Sendai Framework including: promoting scientific research of disaster risk patterns, causes and effects; disseminating risk information with the best use of geospatial information technology; providing guidance on methodologies and standards for risk assessments, disaster risk modelling and the use of data;

[6] For terms such as hazard, risk, vulnerability and exposure, definitions unless otherwise stated are as used within the IPCC AR5 Glossary: https://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-AnnexII_FINAL.pdf.

[7] http://www3.weforum.org/docs/WEF_GRR18_Report.pdf.

[8] The term hazard is used here as a description of the combination of the probability of occurrence of an event with a certain level of intensity.

[9] https://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf.

[10] https://ec.europa.eu/research/environment/index.cfm?pg = climate_services.

and promoting and supporting the availability and application of science and technology to decision-making. Furthermore, CS are explicitly mentioned in the Sendai Framework under Priority 4: Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction. In addition, the Sendai Framework defines an early warning system as "*an integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events*". It has been suggested that such a system would be better informed through the effective use of targeted climate services.

Of particular importance in this context is the UNFCCC report on "Opportunities and options for integrating CCA with the Sustainable Development Goals (SDG) and the Sendai Framework for Disaster Risk Reduction 2015–2030".[11] This 2017 report specifically refers to the importance of the availability of climate data, climate services, and associated capacity building in delivering the integration across these agreements and frameworks.

It is worth noting that in high-level documents related to DRR at the national level, the importance of taking into account longer-term climate change for prevention is often mentioned. The fact that CS are already providing fundamental data to better characterise present day and evolving risks suggests that these services could be further developed to benefit the preparedness and response aspects of the DRR cycle. Furthermore, experiences within CCA at the national and transnational levels are further promoting the significant role CS should be playing within a 'Build Back Better' approach.

The CS community is responding. For example, DRR is one of the five priorities of the GFCS, and the Copernicus Climate Change Service (C3S) has identified DRR as a key sector for the C3S Sectoral Information System.

2. Further exploring the potential

Three leading European initiatives (PLACARD,[12] C3S[13] and ERA4CS[14]) on CS and DRR initiated a discussion on how the DRR community could be best served by new and emerging climate services as well as on the relevant challenges and opportunities (Climate Services for Disaster Risk Reduction workshop,[15] 29–30 January 2018, Bologna). The discussion engaged experts from sectors as different as civil protection, health, insurance, civil engineers and representatives from CS providers and purveyors, including national meteorological services. As a result of the deliberations during the Climate Services for DRR workshop, a number of relevant points were raised, the highlights of which are summarised in the rest of this brief paper.

2.1. Climate services are important for planning in climate change adaptation and disaster risk reduction

CS can strengthen all phases of the DRR cycle, including through better informed climate risk and action assessments, early warning systems and response planning (Fig. 1 and Table 1). The relevance of longer-term climate risks may be obvious for prevention (building-in resilience) and recovery (e.g. 'Building Back Better'). Yet CS that draw on high-resolution exposure and vulnerability information can also support strategic planning for better preparedness and response. CS are providing essential inputs for national adaptation strategies. But persistent low familiarity of DRR practitioners with CS and climate knowledge in general make their application for operational and strategic DRR purposes less likely. This deficiency is particularly acute considering that adaptation and resilience in relation to extreme events in the context of a changing climate will depend on the extent to which the goals within the Paris Agreement (mitigation and adaptation) are being achieved. Of all hazards, flooding is probably the one - at least in Europe - for which climate change drivers have mostly been taken into account. Learning from this experience and extending the approach to other hazards could be a way of facilitating the interaction between DRR and the CS communities and for enhancing and demonstrating the value of CS for DRR.

There are a number of options for providing CS that can support risk assessment. Longer-term climate projections are for the most part probabilistic (based on frequency distributions of many model runs, not likelihood which depends on human choices yet to be made) and ensembles, including those provided by a number of CS providers, are amendable to risk assessment. Furthermore, the recent development of a storyline approach [5] suggests that there may be other ways of estimating the likelihood of future events beyond the probabilistic approach.

2.2. To be effective for DRR, information about future climate risks should be easily accessible, based on harmonized datasets as much as possible and should include vulnerability and exposure information and be supported by capacity development

Data availability, whilst improving, is still a critical issue. Information related to damage and losses caused by extreme weather events represents one of the most tangible gaps. Standardisation of climate data and their harmonisation with other datasets such as damage and losses, including the way they are collected, are critical to building an effective interface between CS and DRR. These will require targeted efforts (co-design and co-delivery) to ensure the compatibility of information sources in the context of supporting decision-making processes, but also co-evaluation to promote future refinement and development. To achieve effective climate services, there is a need to ensure that these services are decision-driven (as well as science-informed). For example, there is a need for information on vulnerability and exposure (including resilience and adaptive capacity) that could be included in or linked to CS.

Capacity development is required to support informed engagement with the intended and potential users within the DRR community to support co-design, co-delivery and co-evaluation, and to provide a better understanding of what is available and how it can be used. The focus should be on where CS providers can add value - knowledge and evidence to support prevention and recovery - building on strengths from supporting CCA. There are additional added-value areas being developed that can provide opportunities that bridge the gap between short-term weather predictions and climate services. These include improved seasonal to decadal forecasts, and the development of near-present climatologies (and associated probabilities of extreme events).

Equally important is the need for developing the understanding of the CS providers (and/or the intermediaries) on the needs and capacities of the users within the DRR community. International guidelines and good practice examples would be useful for informing and complementing capacity development at national and subnational level.

Participants at the above-mentioned workshop recognised that the lack of availability or accessibility of meteorological and impact data in an event catalogue (or library) that could be shared was a particular barrier. Progress in this regard is being made with increased availability of traceable and transparent datasets describing the impacts of past events becoming more common. Efforts include Sendai Monitor, Desinventar and the European Commission's Disaster Risk Management Knowledge Centre (DRMKC) that are open access repositories of disaster loss and impacts data. As such, future efforts in delivering CS for

[11] http://unfccc.int/resource/docs/2017/tp/03.pdf.
[12] https://www.placard-network.eu/.
[13] https://climate.copernicus.eu/.
[14] http://www.jpi-climate.eu/ERA4CS.
[15] https://www.placard-network.eu/climate-services-for-disaster-risk-reduction/.

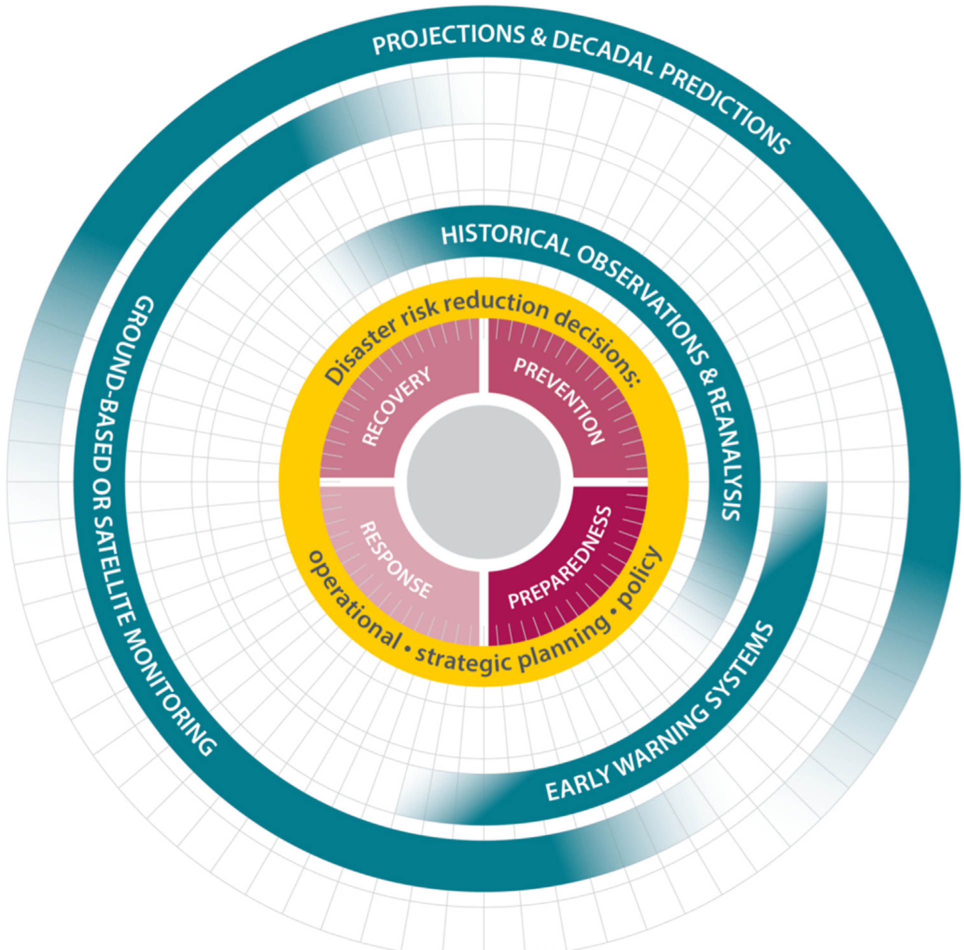

Fig. 1. Examples of CS that can support DRR policy, decision-making, planning and operations within the DRR cycle.

DRR will need to be linked to advancements in collecting and making available disaster damage and loss data. These data catalogues along with engaging with national DRR communities when developing CS for DRR (decision-driven and science-informed) have the potential to improve the quality, relevance and legitimacy of the intended services.

2.3. *The supply and demand sides of climate services for DRR should be well connected, involving all users for developing a viable market for climate services*

The development of markets for public and private CS for DRR depends on the enhancement of both the supply side (decision-driven, outreach with showcases, capacity development, quality control) and demand side (legal requirements, integration of climate risk assessment in standardised practices, climate-related risk disclosures, reputational issues). For continuity and legitimacy reasons, relationships across the DRR and CS communities should be sustained over time based on a sound understanding of the targeted decision-making processes and the robustness of the services available. DRR involves a varied and diverse community composed of many sub-communities, including, but not limited, to civil protection and public health, as well as other sectors such as water, agriculture and forestry, infrastructure, tourism, and finance. Different actors involved in DRR have different capacities and needs for climate information, which should be recognised. Moreover, different actors often have very different mindsets, perspectives and roles on reducing and managing risk within the DRR cycle. Effective management and communication of risks remain a critical challenge for DRR, requiring a tailored approach for the supportive CS, which accounts for specific regional, cultural, political and sectoral characteristics of the target audience at national and sub-national level.

2.4. *A clear and credible champion supporting climate services for DRR*

Such a champion could be positioned within existing institutions. It could provide leadership and serve as a focal point for the development and delivery of services engaging the DRR community and other providers and purveyors. In Europe, the significant investment the European Commission has put into the Copernicus Climate Change Service (C3S) represents an important step in this direction as standardised, high-quality data will be made available operationally and free of charge. While in principle CS for DRR should ideally be free to promote effective decision-making, raise awareness and demonstrate their value, it is recognised that tailoring of information for specific questions related to risk assessment and management would come at a significant price. For these latter cases, private consultants and other intermediaries become important. Finding an appropriate balance between the private and public dimensions of a growing market for CS is fraught with questions related to ethics and social responsibility. This includes dilemmas associated with those countries and actors who need the information the most but may also be those who are less likely to be able to pay for it.

3. Concluding remarks

In responding to the challenges of delivering CS for DRR, efforts are needed by funders, providers and users of the intended climate services

Table 1
Climate information supporting DRR policy and decision-making (Adapted from [4]).

Example DRR decision-making	Example Climate Service	Time Scale	Status of development of climate services
Estimating extreme event trends and informing regression analysis to understand associations of climate and disasters Forecasting and mapping disaster risk Supporting post-event analyses and assessments Identifying disaster risk based on extreme event return period	Historic time series data, summary statistics and reanalysis products, satellite data	Historic and contemporary past records and observations	Operational
Informing short-term operational decisions on supplies procurement, workforce deployment, DRR education and training, surveillance strengthening (e.g. early-warning systems) and prevention activities	Long-range forecasts of averages associated with disasters: maximum and minimum temperatures, and precipitation (e.g., seasonal forecasts)	Short-term climate forecasts (monthly to seasonal)	Operational
	User effective forecasts (e.g., above normal, normal, below normal) probabilistic prediction of rainfall and temperature		Operational
	Seasonal forecasts of storms, floods, wind storms, extreme temperature, flood (coastal, fluvial and pluvial), fire, and drought		Experimental
Supporting 1–5 year policy decisions for DRR, research, DRR services and workforce and supply planning	Annual to interannual forecasts (relative severity of the year ahead) describing large scale state of the climate	Mid-term climate forecasts / projections	Experimental
	Status of natural climate oscillations (Atlantic Multi-decadal Oscillation and Pacific Decadal Oscillation) conditions		Experimental
	Dynamic (modelled) and statistical climate outputs (decadal)		Experimental
Planning long-term DRR infrastructure investments and research efforts Projecting demographic and population trends - exposure and vulnerability Anticipating changes in disaster trends and risk dynamics on local, regional and national and temporal scales Informing DRR policy evaluation and planning Estimating impacts on key disaster risk determinants (heat stress, flooding, water resources, etc.)	Global and regional circulation model outputs, including decadal to multi-decadal projections and scenarios of surface temperature precipitation, sea surface temperature, sea-level, wind, synoptic scale features, etc.	Long-term climate projections (decades to centuries)	Experimental

(public and private, and intermediaries and societal end-users) with the support of those UN Member States that have agreed to the adoption of the Sendai Framework and its global targets. The adoption of a comprehensive resilience agenda and the shift in focus within the DRR community from 'managing disasters' to 'managing risks' provides unique opportunities for better integrating CS into DRR decision making at the strategic and tactical levels. The results of our discussions also suggest that these opportunities are enhanced by addressing public health as a driver for action on DRR. Doing so will not be without challenges but the advantages to society offered by providing CS that supports decisions and actions taking advantage of these opportunities is critical (as indicated in the Sendai Framework). We suggest that sustained and informed engagement of the DRR and CS communities in the co-design, co-development and co-evaluation of CS for DRR can be effective in addressing these challenges.

In terms of further developing CS, the shift in focus of the Sendai Framework has resulted in a more prominent role of science and technology in providing the evidence and knowledge on risks in all its dimensions of hazards, exposure and vulnerability. This shift and the prominence of science and technology includes expected outcomes, actions and deliverables under each of the four priority of actions of the Sendai Framework.

Recognising health as a significant driver can provide impetus and a focus for developing CS that support DRR. The link between public health and DRR, especially in terms of the knowledge and information to inform policy and decisions, should be exploited and further developed to engage stakeholders at all levels towards implementing the UN Landmark agreements of 2015 more effectively by 2030.

We suggest seizing these opportunities quickly to focus the collaboration between the DRR and the CS communities in both research and application of knowledge to create and deliver relevant, credible and legitimate useful, usable and used information and CS. Seizing these opportunities will require continued efforts within both the DRR and CS communities. First and foremost, these efforts will need to be reflected in the implementation of the Sendai Framework, the SDGs and the Paris Agreement and by the UN Member States who will be reporting on their respective implementation activities. Funders of research and CS should broaden their perspectives of the role of CS to include those supporting DRR as reflected in the post-2015 agenda, including the S&T Roadmap to support implementation of the Sendai Framework for DRR 2015–2030. One particular challenge that also needs addressing relates to identifying and understanding the value chain for CS in the context of DRR. The European research and innovation Roadmap for Climate Services recognises that this is a major gap for CS in general and efforts have been underway to address this gap under Horizon 2020 (e.g., EU-MACS, MARCO and CLARA). As for all climate services, the CS value chain for DRR is more than likely a web with providers, intermediaries and users all extracting and adding value for their targeted and subsequent users. The Roadmap also recognises that capacity building for all operating in the value chain is critical to realise the benefits that CS is and could be offering.

The DRR and CS communities will need to enhance efforts towards working together. These efforts should include effective engagement at the international (e.g., UNISDR and GFCS) and national (DRR agencies and CS providers) levels directed at realising and demonstrating potential benefits. There is also a need to recognise these challenges and opportunities within research and innovation efforts nationally and multi-nationally in terms of identifying related research questions and enabling innovations. A useful step forward would be working together within science and operational fora of the respective communities.

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References

[1] EFDRR. How does Europe Link DRR and CCA? Working Paper. ⟨https://www.unisdr.org/we/inform/publications/35277⟩.

[2] L. Schipper, M. Pelling, Disaster risk, climate change and international development: scope for, and challenges to integration, Disasters 30 (1) (2006) 19–38.

[3] F. Thomalla, T. Downing, Spanger-Siegfried, G. Han, J. Rockström, Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation, Disasters 30 (1) (2006) 39–48.

[4] WHO/WMO, 2016. Climate Services for Health: Improving public health decision-making in a new climate. Eds J. Shumake-Guillemot and L. Fernandez-Montoya. Geneva (Table 1.2).

[5] G. Zappa, T.G. Shepherd, Storylines of atmospheric circulation change for European regional climate impact assessment, J. Clim. 30 (16) (2017) 6561–6577, https://doi.org/10.1175/JCLI-D-16-0807.1.