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Brief communication: Strengthening coherence between climate change adaptation and disaster risk reduction

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Abstract. Reducing disaster risks and adapting to climate change are ever more important policy goals in Europe and worldwide. The commitment to the 2030 Agenda for Sustainable Development and complementary multilateral frameworks, including the Sendai Framework for Disaster Risk Reduction 2015–2030 and the Paris Agreement on Climate Change, has galvanized pursuits for policy coherence. The report "Climate change adaptation and disaster risk reduction in Europe: enhancing coherence of the knowledge base, policies and practices" of the European Environment Agency identified several ways for how coherence and resilience can be built through knowledge sharing, collaboration and investments.

1 Introduction

The reported economic impacts from extreme weather and climate-related events (hereafter, climate extremes) in the member countries of the European Environment Agency (EEA) over 1980–2017 come to cost more than EUR 452 billion (EEA, 2018b). These are conservative estimates of the actual economic impacts since many intangible and non-monetary impacts are difficult to quantify (OECD, 2018). Climate variability and change have noticeable effects on human health, the spread of climate-sensitive diseases, environmental quality, and social well-being, and these impacts are either not or only partially accounted for. Climate extremes can affect and shape ecosystems and thus have an impact on the services they provide (e.g. water retention, food production, cooling, energy production, recreation, and carbon sequestration). In some cases the loss of such services can increase the probability of further hazards. For example, forest fires exacerbated by drought can lead to slope destabilization and increase the risk of landslides during extreme rainfall events.

The already high tolls of climate extremes are expected to further increase as a result of human-induced climate change. Under future climate change, nearly all climate extremes are projected to increase in severity, duration, and/or extent, and some also in frequency (EEA, 2016). Heat waves are projected to become more intense and to persist longer in all regions in Europe (Russo et al., 2014). However, projected changes in frequency and intensity of extreme precipitation show regional differences, with the largest increases in central and eastern Europe in winter months (Jacob et al., 2014). Similarly, changes in river floods show strong regional differences, with the greatest increases for the British Isles,

northwestern and southeastern France, northern Italy, parts of Spain, the Balkans, and the Carpathians (Alfieri et al., 2015; Russo et al., 2014). Changes in population and wealth, driven by developments in hazard-prone areas (Winsemius et al., 2015), and the deteriorated status of natural ecosystems drive the impacts upwards.

Sound climate risk management (Mechler and Schinko, 2016) can lessen the impacts of disaster risks and contribute to boosting resilience. Climate change adaptation (CCA) and disaster risk reduction (DRR) (see Supplement for the definition of main terms) have been, to some extent, mainstreamed into European and national policies, but it is important to make the resulting efforts internally consistent and mutually supportive. Policy coherence is an objective of the European Commission's regulation agenda (EC, 2017a) and external actions. But there is a notable paucity about how policy coherence between CCA and DRR can be actively promoted. Evidence of good practices does exist (EFDRR, 2013) but the opportunities for building up resilience by better integrating CCA and DRR are yet to be fully exploited. The EEA report "Climate change adaptation and disaster risk reduction in Europe: enhancing coherence of the knowledge base, policies and practices" (EEA, 2017) tries to fill the above gap. The report builds upon an extensive expert review and consultations with the European Environment Information and Observation Network (EIONET) countries. The release of the report was aligned in a timely way with complementary reports of the Disaster Risk Management Knowledge Centre and the UN Office for Disaster Risk reduction (Poljanšek et al., 2017; UNISDR, 2017). It sets out to feed information for an ongoing review of the EU's Adaptation Strategy (EC, 2018) and the implementation of the Sendai Framework for DRR 2015–2030 in the EU (EC, 2016a).

2 Defining good examples of policies, methods, and practices

2.1 Policies driving cohesion between CCA and DRR in Europe

Building state and societal resilience to climate variability and change is a shared, progressively more coordinated and goal-oriented concern of EU internal and external actions. The EU and member states' commitment to the 2030 Agenda for Sustainable Development (UN, 2015a) and complementary multilateral frameworks, including the Sendai Framework for Disaster Risk Reduction 2015–2030 (UN, 2015b) (SFDRR) and the Paris Agreement on Climate Change (UNFCCC, 2015), has sponsored greater policy coherence and resilience building. The SFDRR advocates multi-hazard, inclusive, science-based, and risk-informed decision-making and lays down priorities for action and policy targets. Progress in achieving these targets is monitored and assessed by means of 38 indicators, some of which are also used to report on the UN Sustainable Development Goals (SDGs). The Sendai Framework Monitor was launched in March 2018 to facilitate the reporting. The Paris Agreement specifies, among other things, a global adaptation goal focussed on the ability to adapt to the adverse impacts of climate change and on climate resilience, both among the essential prerequisites for sustainable development.

Coherence on sustainable development, DRR, and CCA is backed by interrelated and consistent European action plans (EC, 2016a, b), aiming to reinforce resilience to shocks and stresses, while boosting innovation, growth, and job creation. The EU Strategy on Adaptation to Climate Change (EC, 2013a) has fostered development of national adaptation strategies and national adaptation plans and boosted knowledge sharing and mainstreaming of climate adaptation in other policy areas. These policy domains include environment and critical infrastructure protection, agriculture, food and nutrition security, integrated coastal management, cohesion policy, and EU Structural and Investment Funds. While the EU Adaptation Strategy only addressed impacts that may occur within EU borders, the 2017–2018 review (EC, 2018) recommended more emphasis on (i) risks from climate impacts that (may) materialize elsewhere and the (ii) relations between adaptation within and beyond the EU. The EU's Civil Protection Mechanism (EC, 2013b) emphasizes multi-hazard risk assessments and (short- to long-term) prevention as bases for effective disaster preparedness and response. In 2017 the European Commission (EC) proposed a reform of the mechanism (EC, 2017b) which accentuates coherence among CCA, disaster prevention, and disaster response.

A systemic approach on policy coherence and resilience also informs the EU's external action. The 2016 Global Strategy for the EU's foreign and security policy (EC, 2016c) included "state and societal resilience" among its five priorities. The strategy recognized that climate change exacerbates potential conflicts and laid down shared vision and common principles that foster coherence of external EU actions. The 2017 "Joint Communication on Resilience" by the Representative for Foreign Affairs and Security Policy and the EC further specifies how a strategic approach to resilience can support the EU's development and humanitarian commitments, while better protecting it from external threats (EC, 2017c). The communication identified four "building blocks" for incorporating resilience in the EU's external actions: (i) improving risk analysis at the country and regional level; (ii) a more dynamic monitoring of external pressures; (iii) integrating resilience in programming and financing external action; and (iv) developing international policy and practice on resilience.

2.2 Common methods and concerns

Assessment of climate-related hazards and risks is an area that has long stimulated the building of common grounds between CCA and DRR. Climate-related hazards are outcomes

of multiple stochastic processes. On a temporal scale, the probability distributions span years, decades, and centuries. In some cases, even lower probabilities are still relevant for today's decision-making. These stochastic processes are often not stationary but respond to environmental changes, including climate change. This is why CCA and DRR communities have successfully sought to reconcile key terms and definitions (Jurgilevich et al., 2017). The levels of vulnerability are changing as our societies are transformed in terms of demography, wealth, cohesion, and use of technology (Ward et al., 2017). Notwithstanding the importance of the quality-assured, systematically collected, and thorough records on impacts of natural hazards, the loss data systems in Europe are fragmented and inconsistent. Empirical and evidence-based risk analysis and assessment are a vital part of CCA and DRR efforts.

2.3 Characteristics identified in good practice examples

The desk review and consultations have revealed a lack of explicit criteria that define "good" practice examples in terms of policy coherence. Cases were identified which were characterized by a higher level of coherence, as well as examples that hold greater potential for transferable lessons learned. However, throughout our extensive search we did not find many cases in which (i) improved coherence was a planned outcome, with clearly demonstrated added value for both policy areas; (ii) uncertainty was given due regard from a long-term perspective; and (iii) the existing practices were thoroughly embedded within the risk management and climate adaptation planning cycles.

Good examples of governance exhibit a robust legislative mandate, well-defined organizational and institutional tiers, and clearly assigned roles and responsibilities. In terms of risk and adaptation financing, good practices include proper budgetary endowments and sound use of financial or economic instruments and incentives. From a policy perspective, the proposed measures should not only be efficient and effective, but also compatible with and complementary to measures implemented for other similar purposes. On a more practical level, good practice examples imply use of combined knowledge and data on short- and long-term hazards, exposure, vulnerability, and performance of past climate risk reduction efforts, including the underlying assumptions and uncertainties.

Six good examples were eventually chosen for the report and include (1) development of a long-term planning vision in the Netherlands; (2) insurance and risk financing based on public–private partnerships in Spain, France, and the United Kingdom; (3) local risk governance in Switzerland; (4) national risk assessments serving both CCA and DRR purposes; (5) city networking for improved urban resilience; and (6) financing nature-based solutions for CCA and DRR (Table 1).

3 Opportunities to enhance coherence between climate change adaptation and disaster risk reduction in policy and practice

Even though CCA and DRR pursue complementary goals, they are two distinct areas of policy and practice, each characterized by its own institutional organization and legal frameworks, which differ across countries as a result of multiple factors. The coherence between them can be promoted through knowledge sharing and a closer collaboration across existing science and policy platforms and networks.

Resilience to climate variability and change provides common ground for CCA and DRR, upon which more coherent actions can be built. Building the culture and practice of resilience (NRC, 2012) means more than just reducing the consequences of foreseeable events and builds resilience into systems to recover and adapt when adverse events occur. Climate change mitigation and adaptation contribute to closing the "resilience gap" by helping to avoid unmanageable changes and managing them when they become unavoidable (Scientific Expert Group on Climate Change, 2007). DRR does the same by improving the capacity to cope with climate extremes. For DRR, taking into account long-term climate change will enhance preventive responses to risks.

Improved climate risk assessment (EEA, 2018a) presents opportunities for enhancing coherence between the two policy areas. National risk assessments and national adaptation strategies have been completed by most of the EEA member countries, sometimes in a coordinated manner. Hazard mapping and risk assessment are areas where integration of CCA and DRR is more advanced and recognized as a priority. High-performance computing has enabled a new generation of climate models that are better able to simulate climate extremes. Progress in climate risk assessment and modelling of cascade and spillover effects (Pérez-Blanco et al., 2016) and their propagation through networks has resulted in improved methodologies for estimating damage and losses. These advances should be harnessed for a better understanding of implicit and explicit government liabilities and designing comprehensive risk financing strategies (OECD, 2015).

Web-based knowledge portals and multi-stakeholder coordination platforms can be designed to help communicate and share a more consistent and complementary knowledge for CCA and DRR. To make the multiple strategies responsive and sensitive to the needs of vulnerable communities, social strata, and businesses, national and local multi-stakeholder platforms have been established in many countries across Europe, driving horizontal cooperation and partnerships across public and private spheres. In order to be effective, the stakeholders' engagement and partnerships are to be complemented by effective means of sharing and reusing information and knowledge conducive to a common understanding of vulnerabilities, risks, and solutions.

A well-functioning system of public and private user-driven climate services that connect short- and long-term

Table 1. Selected examples of good practice that fosters coherence between DRR and CCA.

Good practice examples	and their features
Multi-level and long-term governance (e.g. Delta Programme in Netherlands)	– Multi-actor partnership for co-designing climate-proof water management across otherwise separate policy domains – Multi-layer safety policies and measures in which an optimal mix is proposed among prevention, sustainable spatial planning, and crisis management – Adaptive Delta management employing short-term interventions within long-term planning perspectives, while taking into account uncertain impacts of climate change through a range of scenarios
Public–private partnerships (PPPs) for hazard risk transfer (e.g. insurance and reinsurance schemes in Spain, France, the UK)	– Examples of longstanding insurance-related PPPs include the Spanish Consorcio de Compensación de Seguros (CCS), the French Catastrophes Naturelles (CatNat), and the Flood Reinsurance Scheme (Flood Re) in the UK – Vehicles of joint bearing of responsibilities and efficient risk sharing enabling insurability and financial backing for low-probability–high-impact risks – Incentivizing risk prevention, helping to improve risk understanding and knowledge, and stimulating active engagement and investment
Multi-level risk governance (e.g. Switzerland)	– Decentralized system with cantons and municipalities investing operational responsibility for DRR and civil protection and federal authorities engaged in strategic planning, financial and technical support, and overall control – Formal arrangements secure cooperation among these actors, horizontally and vertically, and among federal organizations, the private sector, and academic organizations
National risk assessments (NRAs)	– NRAs are instrumental for identifying, assessing, and prioritizing security threats, including those arising from climate variability and change, in a close collaboration with and building upon the local knowledge of the locally affected communities – Experiences of some countries, such as France, the Netherlands, and the United Kingdom, show that climate vulnerability and risk assessments need to build on strong institutional frameworks, clearly assigned responsibilities and authority, and close stakeholder engagement
City networks	– Covenant of Mayors for Climate and Energy, C40 Cities, UNISDR Making Cities Resilient campaign and Rockefeller Foundation 100 Resilient Cities, and others – Collaboration in absence of hierarchical authority, building upon information and communication, project funding, capacity building, good practice benchmarking, and certification
Financing nature-based solutions (NBSs) (e.g. European Investment Bank)	– Ecosystems may mitigate natural hazard risks by mediation of flows and nuisances or through maintenance of physical, chemical, and biological conditions in the face of pressures – European Investment Bank's Natural Capital Finance Facility (NCFF) is a new finance instrument which aims specifically at financing projects which apply NBSs to adaptation measures – NCFF sets out to generate a revenue stream or achieve cost savings in order to pay back the investment; the instrument typically includes an equity-type component to reduce risk and a technical assistance component

climatic changes can help catalyse an economic and societal transformation that reduces risks and improves societal resilience. Climate services support mitigation and adaptation to climate change and encourage science-based and climate-informed policy development. Moreover, climate services may unlock Europe's innovation potential, competitiveness, and economic growth. Over the past decades, the climate services have grown in number, quality, and sophistication. The EU has made large investments in front-line systems enabling modern meteorological services under the Copernicus Earth observation programme. But the uptake of climate services for policymaking and decision-making is relatively modest (Brasseur and Gallardo, 2016). Improved alignment of demand-led CCA and DRR climate service

products requires decision-makers from both communities to have stronger linkages with each other, as well as with the providers of climate information and knowledge and intermediate providers of climate services. The DRR community has a long history of making use of hydro-meteorological services, but there are opportunities to better integrate uncertainty associated with future climate variability and change (Street et al., 2018).

Nature-based solutions (NBSs) are a prime example of means for simultaneously reducing natural hazard risks and boosting societal resilience that address both CCA and DRR. Ecosystems can provide means for mitigating natural hazard risks and boosting societal resilience, locally or regionally. Compared to engineered or built solutions, ecosystem-based approaches can be cost-effective and have co-benefits, thus becoming increasingly valuable in the face of more frequent and/or severe extreme events. They have an economic value in the context of DRR, even if no price is actually paid for their provision and/or maintenance. Many ecosystem-based initiatives have been developed for DRR and CCA to respond to societal challenges through innovative actions inspired or supported by nature. However, a more systematic learning about impacts and effectiveness of ecosystem-based approaches is needed, by taking account of local perceptions and knowledge and sustained political support, monitoring, and funding.

Connecting available funding and financing options for CCA and DRR at the EU and other levels can identify new opportunities for projects and programmes enhancing resilience. To mainstream climate change concerns in its broader development strategy, the EU has agreed to spend 20 % of its resources under the Multiannual Financial Framework 2014–2020 on climate-change-related action. Under the European Structural and Investment Funds (ESIF), EUR 29 billion has been allocated to the thematic objective "Climate change adaptation and risk management" (EC, 2016a), but disaster resilience and climate risk management are also promoted under other priorities. Additional funds available for fostering climate adaptation and DRR include Horizon 2020, LIFE, and the European Union Solidarity Fund. Policy instruments that incentivize a more efficient use of natural resources contribute to reducing the impacts of climate change. Economic incentives and/or disincentives drive individual and business behaviour toward achieving sustainable development objectives, including an efficient use of natural resources and DRR. Pricing instruments such as land taxes, tax reliefs, or subsidies are commonly applied to correct market failures and decouple environmental pressures from economic growth. Incentive and transparent pricing (e.g. of insurance policies or water) can contribute to reducing the economic effects of extreme events (such as droughts and floods).

Setting up an interaction and learning mechanism among emerging monitoring, reporting, and evaluation (MRE) schemes can improve coherence, quality, and relevance for CCA and DRR. MRE can help learning campaigns across cities, regions, and countries. CCA and DRR share a number of characteristics that can make MRE challenging, such as long timescales, uncertainty, and common baselines. Improving the connectivity and coordination of national-level indicators among DRR, CCA, and other policy frameworks such as the SDGs can improve the efficiency of data collection and build up a more complete picture of CCA and DRR progress and priorities. It can also support improved learning regarding the integration of CCA and DRR and how this can lead to more efficient and effective implementation on the ground.

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References

Alfieri, L., Feyen, L., Dottori, F., and Bianchi, A.: Ensemble flood risk assessment in Europe under high end climate scenarios, Global Environ. Chang., 35, 199–212, https://doi.org/10.1016/j.gloenvcha.2015.09.004, 2015.

Brasseur, G. P. and Gallardo, L.: Climate services: Lessons learned and future prospects, Earth's Future, 4, 79–89, https://doi.org/10.1002/2015EF000338, 2016.

EEA: Climate change, impacts and vulnerability in Europe 2016 – An indicator-based report, available at: http://www.eea.europa.eu/publications/climate-change-impacts-and-vulnerability-2016 (last access: 1 October 2018), 2016.

EEA: Climate change adaptation and disaster risk reduction in Europe – Enhancing coherence of the knowledge base, poli-

cies and practices, 15/2017, European Environment Agency, Copenhagen (Denmark), available at: https://www.eea.europa.eu/publications/climate-change-adaptation-and-disaster (last access: 1 October 2018), 2017.

EEA: National climate change vulnerability and risk assessments in Europe, https://doi.org/10.2800/348489, 2018a.

EEA: Economic losses from climate-related extremes, available at https://www.eea.europa.eu/data-and-maps/indicators/direct-losses-from-weather-disasters-3/assessment-1, last access: 1 October 2018b.

EC: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions An EU Strategy on Adaptation to climate COM(2013) 216 final, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0216&from=EN (last access: 1 October 2018), 2013a.

EC: Decision No 1313/2013/EU of the European Parliament and of the Council of 17 December 2013 on a Union Civil Protection Mechanism, Off. J. Eur. Union, L 347, 924–947, ELI, available at: http://data.europa.eu/eli/dec/2013/1313/oj (last access: 1 October 2018), 2013b.

EC: Commission staff working document – Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030, A disaster risk-informed approach for all EU policies. Brussels, 16.6.2016 SWD(2016) 205 final, available at: http://ec.europa.eu/echo/sites/echo-site/files/1_en_document_travail_service_part1_v2.pdf (last access: 1 October 2018), 2016a.

EC: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Next steps for a sustainable European future European action for sustainability, COM(2016) 739 final, available at: https://ec.europa.eu/europeaid/sites/devco/files/communication-next-steps-sustainable-europe-20161122_en.pdf (last access: 1 October 2018), 2016b.

EC: A Global Strategy for the European Union's Foreign and Security Policy. Shared Vision, Common Action: A Stronger Europe. Report by the European External Action Service (2016), available at: https://europa.eu/globalstrategy/sites/globalstrategy/files/regions/files/eugs_review_web_0.pdf (last access: 1 October 2018), 2016c.

EC: Better Regulation Guidelines – Commission staff working document SWD (2017) 350, available at: https://ec.europa.eu/info/sites/info/files/better-regulation-guidelines.pdf (last access: 1 October 2018), 2017a.

EC: Communication from the Commission to the European Parliament, the Council and the Committee of the Regions Strengthening EU Disaster Management: rescEU Solidarity with Responsibility. Brussels, 23 November 2017 COM(2017) 773 final, available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52017DC0773&from=EN (last access: 1 October 2018), 2017b.

EC: Joint Communication to the European Parliament and the Council, A Strategic Approach to Resilience in the EU's external action, Brussels, 7.6.2017 JOIN(2017) 21 final, available at: https://ec.europa.eu/europeaid/sites/devco/files/joint_communication_-a_strategic_approach_to_resilience_in_the_eus_external_action-2017.pdf (last access: 1 October 2018), 2017c.

EC: Evaluation of the EU Strategy on Adapting to Climate Change – public consultation meeting report, Brussels 23 January 2018, available at: https://ec.europa.eu/clima/sites/clima/files/events/docs/0119/2018_01_23_report_en.pdf, last access: 1 October 2018.

EFDRR: How does Europe link DRR and CCA?, available at: https://www.preventionweb.net/files/35277_ddrccafinal.pdf (last access: 1 October 2018), 2013.

Jacob, D., Petersen, J., Eggert, B., Alias, A., Christensen, O. B., Bouwer, L. M., Braun, A., Colette, A., Déqué, M., Georgievski, G., Georgopoulou, E., Gobiet, A., Menut, L., Nikulin, G., Haensler, A., Hempelmann, N., Jones, C., Keuler, K., Kovats, S., Kröner, N., Kotlarski, S., Kriegsmann, A., Martin, E., van Meijgaard, E., Moseley, C., Pfeifer, S., Preuschmann, S., Radermacher, C., Radtke, K., Rechid, D., Rounsevell, M., Samuelsson, P., Somot, S., Soussana, J.-F., Teichmann, C., Valentini, R., Vautard, R., Weber, B., and Yiou, P.: EURO-CORDEX: new high-resolution climate change projections for European impact research, Reg. Environ. Change, 14, 563–578, https://doi.org/10.1007/s10113-013-0499-2, 2014.

Jurgilevich, A., Räsänen, A., Groundstroem, F., and Juhola, S.: A systematic review of dynamics in climate risk and vulnerability assessments, Environ. Res. Lett., 12, 13002, https://doi.org/10.1088/1748-9326/aa5508, 2017.

Mechler, R. and Schinko, T.: Identifying the policy space for climate loss and damage, Science, 354, 290–292, https://doi.org/10.1126/science.aag2514, 2016.

NRC: Disaster Resilience?: A National Imperative, The National Academies Press, Washington DC, USA, aailable at: https://www.nap.edu/catalog/13457/disaster-resilience-a-national-imperative (last access: 1 October 2018), 2012.

OECD: Disaster Risk Financing. A global survey of practices and challenges, OECD Publishing, Paris, 2015.

OECD: Assessing the Real Cost of Disasters: The Need for Better Evidence, OECD Reviews of Risk Management Policies, OECD Publishing, Paris, https://doi.org/10.1787/9789264298798-en, 2018.

Pérez-Blanco, C. D. D., Standardi, G., Mysiak, J., Parrado, R., Gutiérrez-Martín, C., Perez-Blanco, C. D., Standardi, G., Mysiak, J., Parrado, R., Gutierrez-Martin, C., Gutiérrez-Martín, C., Pérez-Blanco, C. D. D., Standardi, G., Mysiak, J., Parrado, R., and Gutiérrez-Martín, C.: Incremental water charging in agriculture. A case study of the Regione Emilia Romagna in Italy, Environ. Modell. Softw., 78, 202–215, https://doi.org/10.1016/j.envsoft.2015.12.016, 2016.

Poljanšek, K., Marin Ferrer, M., De Groeve, T., and Clark, I.: Science for disaster risk management 2017: knowing better and losing less, EUR 28034 EN, Publ. Off. Eur. Union, https://doi.org/10.2788/688605, JRC102482, 2017.

Russo, S., Dosio, A., Graversen, R. G., Sillmann, J., Carrao, H., Dunbar, M. B., Singleton, A., Montagna, P., Barbola, P., and Vogt, J. V.: Magnitude of extreme heat waves in present climate and their projection in a warming world, J. Geophys. Res.-Atmos., 119, 12500–12512, https://doi.org/10.1002/2014JD022098, 2014.

Scientific Expert Group on Climate Change (SEG): Confronting Climate Change: Avoiding the Unmanageable and Managing the Unavoidable, edited by: Bierbaum, R. M., Holdren, J. P., MacCracken, M. C., Moss, R. H., and Raven, P. H., Report prepared for the United Nations Commission on Sustainable Development. Sigma Xi, Research Triangle Park, NC, and the United Nations Foundation, Washington, DC, 144 pp., 2007.

Street, R., Buontempo, C., Mysiak, J., Karali, E., Pulquério, M., Murray, V., and Swart, R.: How could climate services support Disaster Risk Reduction in the 21st century, Int. J. Disast. Risk Re., in review, 2018.

UN: Transforming our world: the 2030 Agenda for Sustainable Development. Resolution adopted by the UN General Assembly on 25 September 2015, available at: http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E (last access: 1 October 2018), 2015a.

UN: Sendai Framework for Disaster Risk Reduction 2015–2030, A/CONF.224/CRP.1, 18 March 2015, available at: https://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf (last access: 1 October 2018), 2015b.

UNFCCC: Adoption of the Paris Agreement. Decision 1/CP.21 UN Framework Convention on Climate Change, 2015, available at: https://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf (last access: 1 October 2018), 2015.

UNISDR: Words into Action Guidelines – National Disaster Risk Assessment: Governance System, Methodologies, and Use of Results, 2017.

Ward, P. J., Jongman, B., Aerts, J. C. J. H., Bates, P. D., Botzen, W. J. W., Diaz Loaiza, A., Hallegatte, S., Kind, J. M., Kwadijk, J., Scussolini, P., and Winsemius, H. C.: A global framework for future costs and benefits of river-flood protection in urban areas, Nat. Clim. Change, 7, 642–646, https://doi.org/10.1038/nclimate3350, 2017.

Winsemius, H. C., Aerts, J. C. J. H., van Beek, L. P. H., Bierkens, M. F. P., Bouwman, A., Jongman, B., Kwadijk, J. C. J., Ligtvoet, W., Lucas, P. L., van Vuuren, D. P., and Ward, P. J.: Global drivers of future river flood risk, Nat. Clim. Change, 6, 381–385, https://doi.org/10.1038/nclimate2893, 2015.