

## Reprint of the Chapter:

Anna Scolobig, Alexander Garcia-Aristizabal, Nadejda Komendantova, Anthony Patt, Angela Di Ruocco, Paolo Gasparini, Daniel Monfort, Charlotte Vinchon, Mendy Bengoubou-Valerius, Roger Mrzyglocki, and Kevin Fleming (2014), ***From Multi-Risk Assessment To Multi-Risk Governance: Recommendations for Future Directions***. Chapter 3-20 in: “Understanding risk: The Evolution of Disaster Risk Assessment”, International Bank for reconstruction and Development, Washington DC, pp. 163-167.

(Prepared for the Global Assessment Report on Disaster Risk Reduction 2015)

Full text available online at: <https://www.gfdr.org/RAReferenceGuide>

GFDRR



# UR

## **UNDERSTANDING RISK**

The Evolution of Disaster Risk Assessment

GLOBAL FACILITY FOR DISASTER REDUCTION AND RECOVERY

© 2014 International Bank for Reconstruction and  
Development / International Development Association or  
The World Bank  
1818 H Street NW  
Washington DC 20433  
Telephone: 202-473-1000  
Internet: [www.worldbank.org](http://www.worldbank.org)

This work is a product of the staff of The World Bank with external contributions. The findings, interpretations, and conclusions expressed in this work do not necessarily reflect the views of The World Bank, its Board of Executive Directors, or the governments they represent.

The World Bank does not guarantee the accuracy of the data included in this work. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of The World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

#### **Rights and Permissions**

The material in this work is subject to copyright. Because The World Bank encourages dissemination of its knowledge, this work may be reproduced, in whole or in part, for noncommercial purposes as long as full attribution to this work is given.

Any queries on rights and licenses, including subsidiary rights, should be addressed to the Office of the Publisher, The World Bank, 1818 H Street NW, Washington, DC 20433, USA; fax: 202-522-2422; e-mail: [pubrights@worldbank.org](mailto:pubrights@worldbank.org).

## 3-20. From Multi-Risk Assessment to Multi-Risk Governance: Recommendations for Future Directions

*Anna Scolobig (Institute for Environmental Decisions, ETH Zurich; Risk, Policy and Vulnerability Program, International Institute for Applied Systems Analysis); Alexander Garcia-Aristizabal (Analisi e Monitoraggio del Rischio Ambientale); Nadejda Komendantova, Anthony Patt (Institute for Environmental Decisions, ETH Zurich; Risk, Policy and Vulnerability Program, International Institute for Applied Systems Analysis); Angela Di Ruocco, Paolo Gasparini (Analisi e Monitoraggio del Rischio Ambientale); Daniel Monfort, Charlotte Vinchon, Mendy Bengoubou-Valerius (Bureau de Recherches Géologiques et Minières); Roger Mrzyglocki (German Committee for Disaster Reduction [DKKV]); Kevin Fleming (Helmholtz Centre Potsdam, German Research Centre for Geosciences [GFZ], Potsdam)*

Disasters caused by natural hazards can trigger chains of multiple natural and man-made hazardous events over different spatial and temporal scales. Multi-hazard and multi-risk assessments make it possible to take into account interactions between different risks. Classes of interactions include triggered events, cascade effects, and the rapid increase of vulnerability during successive hazards (see Marzocchi et al. 2012; Garcia-Aristizabal, Marzocchi, and Di Ruocco 2013).

Recent research has greatly increased the risk assessment community's understanding of interactions between risks. Several international sets of guidelines and other documents now advocate adopting an all-hazard approach to risk assessments (for example, see UNISDR [2005]; European Commission [2010a, 2010b]; for an overview, see Council of European Union [2009, section 2]).

Nevertheless, barriers to the application of multi-risk assessment remain. The challenges for the development of multi-risk approaches are related not only to the applicability of results, but also to the link between risk assessment and decision

making, the interactions between science and practice in terms of knowledge transfer, and more generally to the development of capacities at the local level. So far, research has focused on the scientific aspects of risk assessment. But the institutional aspects, such as the issues arising when multi-risk assessment results need to be implemented within existing risk management regimes, are also important, though they have received less attention.

The project described here focused on the institutional context of disasters, which includes a variety of elements ranging from sociopolitical to governance components. It looked at how to maximize the benefits arising from, and overcome the barriers to, the implementation of a multi-hazard and multi-risk assessment approach within current risk management regimes. Working at two test sites, one in Naples and one in Guadeloupe, the research team engaged with local authorities and practitioners to better understand how to effectively implement the results of multi-risk assessment. Among the hazards considered were earthquakes,

volcanic eruptions, landslides, floods, tsunamis, wildfires, cyclones, and marine inundation. Beside the practitioners working in the two test sites, risk and emergency managers from 11 countries also provided feedback. In total, more than 70 practitioners took part in the research.

*Research design.* The project, which aimed to encourage interaction between researchers and practitioners/decision makers, began with a policy/institutional analysis—that is, desk studies of legal, regulatory, and policy documents—to provide a description of the institutional and regulatory framework for risk governance within different natural hazard contexts and countries.

To identify the barriers to effective decision making in the case of multiple hazards, we then engaged practitioners in interviews and focus group discussions. In parallel, we performed multi-risk assessments of some specific scenarios at the two test sites. During workshops with practitioners, we presented the results and also discussed the barriers to and benefits of implementing multi-risk assessments. Table 3-9 summarizes the key research phases, the methods employed, and the accompanying aims.

Both test sites face multiple hazards. Naples, the biggest municipality in southern Italy, has a widely recognized high volcanic hazard and is also exposed to interconnected hazards such as earthquakes, floods, landslides, and fires. The French overseas department of Guadeloupe (Département-Région d'Outre Mer), an archipelago in the Lesser Antilles, is exposed to similar hazards (though it is less exposed to fires) and has a high risk of cyclones and tropical storms; its major geological risk is from the active volcano of la Soufrière and the seismic activity along the inner Caribbean arc, both of which can trigger tsunamis and landslides.

Both Naples and Guadeloupe have plans and policies designed to protect their citizens from these risks, and both have deployed scientists,

engineers, and policy makers to reduce risk and vulnerability. Moreover, both sites have performed multi-risk assessments. In Naples, two scenarios of risk interactions were considered for quantitative analysis: the effect (on seismic hazard and risk) of seismic swarms triggered by volcanic activity, and the cumulative effect of volcanic ash and seismic loads. Both cases can be combined into a single scenario of interactions at the hazard and the vulnerability level; the combination highlights the different aspects of risk amplification detected by the multi-risk analysis (Garcia-Aristizabal, Marzocchi, and Di Ruocco 2013). In Guadeloupe, researchers conducted a scenario analysis of cascade effects and systemic risk. Following a deterministic approach, the analysis considered interaction between earthquake and landslide phenomena, along with its consequences on the local road network in Guadeloupe and the transport of injured people to hospitals and clinics (Monfort and Lecacheux 2013).

*Results.* A first (and expected) finding is that risk and emergency managers rarely have the opportunity to deal with multi-risk issues, including triggered events, cascade effects, and the rapid increase of vulnerability during successive hazards. Moreover, multi-risk assessments for different scenarios are at present rarely performed by practitioners at either the national or local level. A second finding is that most participants saw the benefits of including a multi-risk approach in their everyday activities, especially in land-use planning, as well as in emergency management and risk mitigation.

Practitioners identified the following as among the greatest benefits of a multi-risk approach:

*1. Multi-risk assessment improves land-use planning.*

According to practitioners, a multi-risk approach provides a holistic view of the risks affecting a territory and is appropriate in all geographic areas

susceptible to several types of hazards. It would be helpful to have clear criteria to use in determining which scenarios would be most appropriate for a multi-risk assessment. For landslide, for example, hazard and risk mapping may not address the specific effects of different possible triggering events (intense rainfall, earthquakes, etc.). In the case of Naples, a detailed map with the areas susceptible to landslides is available, but it does not include information about the possible short-term effects of volcanic eruptions, even though an eruption could produce unstable ash-fall deposits (including in low-susceptibility areas) that afterward contribute to the generation of lahars (mud flows) triggered by rainfall events.

Urban planners emphasized how a multi-risk assessment could influence decisions about building restrictions, which themselves influence urban and economic planning—for example, by permitting or forbidding construction of new houses and/or economic activities.

### *2. Multi-risk assessment enhances response capacity.*

Practitioners asserted that emergency management would greatly benefit from adopting a multi-hazard and multi-risk approach. Civil protection managers were especially interested in developing multi-hazard and multi-risk scenarios to facilitate management of emergency situations in real time (Monfort and Lecacheux 2013). In Guadeloupe, for example, evidence suggests that failure to consider cascade effects (earthquake-landslide interactions) and to employ a systemic approach may result in gross underestimation of risk. The work undertaken in Guadeloupe considered the interaction between earthquake and landslide phenomena and its consequences for road networks and the removal of injured people to medical facilities. It took into account the possibility that a landslide triggered by an earthquake in the northwest of Basse-Terre might cut off a main east-west road that is critical for moving the injured to hospitals and clinics.

Damage to some lifelines (water, electricity) was also taken into account. The final results of the scenario determined realistic times required for the evacuation of the injured, either considering or not considering the damage to the road network and the connectivity to lifelines of the hospitals (Desramaut 2013; Monfort and Lecacheux 2013).

### *3. Multi-risk assessment identifies priorities for mitigation actions.*

The quantified comparison of risks that would allow a multi-risk approach was also seen as a benefit. Quantified comparison is particularly useful for identifying priorities for actions—a difficult task for policy makers, who generally rely on assessments that do not take cascade and conjoint effects into account. The quantified comparison of risks has policy implications for the planning of mitigation actions. It can show, for example, that prioritizing a particular hazard may mean giving insufficient weight to other hazards, and that mitigation measures against a prioritized hazard could actually increase the area's vulnerability to a different hazard.

### *4. Multi-risk assessment encourages risk awareness and cooperation.*

Multi-risk assessment can help to increase a population's awareness of natural risks, of multi-risk, and of associated cascade effects. Practitioners in Guadeloupe working for municipal authorities noted that while the culture of primary risks (such as cyclones, earthquakes, and volcanoes) is well established in Guadeloupe, the culture of secondary risks (such as tsunamis, landslides, marine and inland floods, and coastal and slope erosion) is less established. Practitioners from other countries indicated that communicating the results of multi-risk assessment to the general population would help to increase awareness of secondary risk.

A multi-risk approach can also enhance cooperation and foster needed partnerships between policy

makers, private sector actors, and scientists. One key to promoting such partnerships is to establish a common understanding of what multi-risk assessment is, what the preferences and needs of practitioners are, and what the implications for regulatory instruments (related to urban planning, for example) may be. Interviewees and workshop participants, especially from the private sector, cited the importance of partnerships between insurers and policy makers in using improved risk information for the development of risk financing schemes that cover large losses after multi-hazard catastrophic events.

*Barriers to multi-risk assessment in the science domain.* Barriers to effectively implementing multi-risk assessment are found in both the science and practice domains. In the science domain, a major barrier involves differences between the geological and meteorological sciences and the research carried out under their auspices. These differences extend to concept definitions, databases, methodologies, classification of the risk levels and uncertainties in the quantification process, and more. Thus each type of risk has its own scale or unit of measure for quantifying risk or damages (e.g., damage states for seismic risk and loss ratios for floods). These differences may make it harder for the various risk communities to share results and may represent a barrier to dialogue on multi-risk assessment.

A barrier that is more worrying for risk managers than for researchers is the lack of open access to risk and hazard databases, the lack of tools for sharing knowledge, and the difficulties associated with accessing new research results. According to a practitioner working for a meteorological service, “The researchers want to keep the data because they want to publish.” Another practitioner stated: “Private companies and research institutions often do not make their data available . . . for the benefit of their competitiveness.” Scientists view the matter differently and maintain that research results are

freely available online. The same is not true for the databases, however, although the reason for this is simple: most practitioners do not know how to use them. The issue, then, is not whether data are available, but who uses and interprets the data and for what purpose—or more fundamentally, who is able to access and present information in a meaningful and useful manner. Scientists maintain that data collected by private actors (such as private consultants or insurers) are often not available to them, or that these data are not collected systematically and thus cannot be used for scientific purposes.

Practitioners and researchers also have different views about the preferred agenda for future research on multi-risk assessment. Researchers working on the technical/scientific aspects want to improve knowledge of the physical processes and models related especially to cascade effects; harmonize terminology and databases; make uncertainty assessment a focus; combine single-risk analyses into integrated multi-risk analyses; integrate the results of multi-risk assessment into existing emergency scenarios and capture cascading effects in probabilistic terms; and conduct multi-vulnerability assessment.

Practitioners on the other hand prioritize collecting evidence about lives and property saved using a multi- versus a single-risk approach, gaining an overview of multi-risk contexts at the town level, and especially learning to use and integrate new research results in existing emergency and urban plans. Depending on the practitioners themselves (risk versus emergency managers, regional officers, insurers, etc.), the needs and expectations vary extensively.

*Barriers to multi-risk assessment in the practice domain.* Differences in the approaches, tools, and methodologies used for single-risk assessment have resulted in a lack of integrated practices for multi-risk governance. Especially where risks are managed by authorities acting at different



governmental levels, cooperation among institutions and personnel is a challenge. The priorities of the various agencies vary extensively, and there may be insufficient financial capacity to cover them all. In some cases a multi-risk approach is perceived as competing with (rather than complementing) single-risk approaches.

Capacities, mainly financial, but sometimes also technical and institutional, are especially lacking at the local level, even though responsibility for DRM often falls to local authorities or private actors. The transfer of responsibility for disaster risk reduction to the local level (to the municipal level in many European countries) has often occurred without sufficient resources for implementing necessary programs (UNISDR 2005b, 2013). Private actors, especially property owners, are being given increasing risk-related responsibilities,

which—depending upon the risk, the country, and the availability of insurance schemes—may differ. Different levels of responsibility are attributed to property owners in geological versus meteorological risk prevention, for example. In the case of earthquakes, the level of individual responsibility is high (given that property owners are usually in charge of household vulnerability reduction measures). In the case of floods, public authorities have responsibility for decisions about risk mitigation measures such as protection works, and the costs are covered collectively. In general, there are few options for public-private responsibility sharing, especially for households exposed to multiple risks (and especially where insurance schemes are not available, as is the case in some European countries).



82 See the Global Flood Working Group portal at <http://portal.gdacs.org/Expert-working-groups/Global-Flood-Working-Group>.

83 EM-DAT: The OFDA/CRED International Disaster Database, [www.emdat.be](http://www.emdat.be), Université catholique de Louvain, Brussels, Belgium.

84 The quotation is from D. Wielinga, senior disaster risk management specialist, World Bank Africa Region; see GFDRR, "GFDRR Connects Science with Policy to Help Address Flood Risk in Nigeria," <https://www.gfdr.org/node/27850>.

85 Geoscience Australia holds a Creative Commons Attribution 3.0 Australia license for the material in this section. All terms of the license apply for reuse of text and graphics.

86 World Bank, "Tonga to Receive US\$1.27 Million Payout for Cyclone Response," press release, <http://www.worldbank.org/en/news/press-release/2014/01/23/tonga-to-receive-payout-for-cyclone-response>.

87 Analysis benefited from funding provided under a grant from the Global Facility for Disaster Reduction and Recovery.

88 The identification and tracking algorithm used was based on the works of Nguyen and Walsh [2001], Walsh and Syktus [2003], and Abbs et al. [2006], and applies eight criteria to identify a tropical cyclone. Further details of the method can be found in Abbs [2012].

89 The five models were ACCESS 1.0, Can ESM, CSIRO Mk3.6.0, IPSL CM5A, and NorESM-1M. More information is available about the PACCSAP program on the Australian Department of the Environment website, <http://www.climatechange.gov.au/climate-change/grants/pacific-australia-climate-change-science-and-adaptation-planning-program>.

90 This case study draws on D. Lallemand, S. Wong, K. Morales, and A. Kiremidjian, "A Framework and Case Study for Dynamic Urban Risk Assessment" [paper presented at the 10th National Conference in Earthquake Engineering, Earthquake Engineering Research Institute, Anchorage, AK, July 2014].

91 Rao's Ph.D. thesis, entitled "Structural Deterioration and Time-Dependent Seismic Risk Analysis," is being completed at the Blume Earthquake Center, Stanford University.

92 OpenQuake 2013 release, Global Earthquake Model, <http://www.globalquakemodel.org/openquake/>.

## References

- Abbs, D. 2012. "The Impact of Climate Change on the Climatology of Tropical Cyclones in the Australian Region." CSIRO Climate Adaptation Flagship Working Paper No. 11, CSIRO, Canberra.
- Abbs, D. J., S. Ayril, E. Campbell, J. L. McGregor, K. C. Nguyen, M. Palmer, A. S. Rafter, I. G. Watterson, and B. C. Bates. 2006. *Projections of Extreme Rainfall and Cyclones: Final Report to the Australian Greenhouse Office*. Canberra: CSIRO.
- ADRC [Asian Disaster Reduction Center]. 2006. "Report on Survey on Tsunami Awareness in Indonesia: Banda Aceh and Aceh Besar Area of Aceh Province." ADRC. [http://www.adrc.asia/publications/Indonesia\\_Survey/Banda%20Aceh/en/index.html](http://www.adrc.asia/publications/Indonesia_Survey/Banda%20Aceh/en/index.html).
- Ahmad Al Waked. 2011. "Evolution of the Impact of an Earthquake on Aqaba and Jordan Economy and Public Finances." In *Disaster Risk Assessment for Aqaba*. UNDP and ASEZA. [http://www.preventionweb.net/files/31205\\_aqabasraeisei1.pdf](http://www.preventionweb.net/files/31205_aqabasraeisei1.pdf).
- Amarasinghe, S. 2007. "Identifying Vulnerability Using Semi-structured Interviews." In *Rapid Vulnerability Assessment in Sri Lanka: Post-Tsunami Study of Two Cities: Galle and Batticaloa*. SOURCE Publication No. 7, 47–53. <http://ihdp.unu.edu/file/get/3992.pdf>.
- Annaka, T., K. Satake, T. Sakakiyama, K. Yanagisawa, and N. Shuto. 2007. "Logic-tree Approach for Probabilistic Tsunami Hazard Analysis and Its Applications to the Japanese Coasts." *Pure and Applied Geophysics* 164: 577–92.
- Aon Benfield. 2012. *Annual Global Climate and Catastrophe Report: Impact Forecasting, 2011*. [http://thoughtleadership.aonbenfield.com/Documents/20120110\\_if\\_annual\\_global\\_climate\\_cat\\_report.pdf](http://thoughtleadership.aonbenfield.com/Documents/20120110_if_annual_global_climate_cat_report.pdf).
- Arkema, K. K., G. Guannel, G. Verutes, S. A. Wood, A. Guerry, M. Ruckelshaus, P. Kareiva, M. Lacayo, and J. M. Silver. 2013. "Coastal Habitats Shield People and Property from Sea-level Rise and Storms." *Nature Climate Change* 3: 913–18. doi:10.1038/nclimate1944.
- Ambraseys, Nicholas. 2009. *Earthquakes in the Mediterranean and Middle East: A Multidisciplinary Study of Seismicity up to 1900*. Cambridge and New York: Cambridge University Press.

- Arnell, N. W., and B. Lloyd-Hughes. 2014. "The Global-scale Impacts of Climate Change on Water Resources and Flooding under New Climate and Socio-economic Scenarios." *Climatic Change* 122: 127–40. doi:10.1007/s10584-013-0948-4.
- Arnold, Margaret, Maxx Dilley, Uwe Deichmann, Robert S. Chen, and Arthur L. Lerner-Lam. 2005. *Natural Disaster Hotspots: A Global Risk Analysis*. Washington, DC: International Bank for Reconstruction and Development/World Bank and Columbia University.
- Arthur, W. C., and H. M. Woolf. 2013. "Assessment of Tropical Cyclone Risk in the Pacific Region: Analysis of Changes in Key Tropical Cyclone Parameters." Record 2013/23, Geoscience Australia, Canberra.
- Arya, A. S. 2000. "Non-engineered Construction in Developing Countries—An Approach toward Earthquake Risk Prediction." *Bulletin of the New Zealand Society for Earthquake Engineering* 33 (3): 187–208.
- ASEP [Association of Structural Engineers of the Philippines]. 2010. *National Structural Code of the Philippines, Volume 1: Buildings, Towers, and Other Vertical Structures*. ASEP: Quezon City, Philippines.
- Atkins. 2012. *Shire Integrated Flood Risk Management Program Final Report: Volume 1*.
- Badilla, R. A., R. M. Barde, G. Davies, A. C. Duran, J. C. Felizardo, E. C. Hernandez, M. G. Ordonez, and R. S. Umali. 2014. "Enhancing Risk Analysis Capacities for Flood, Tropical Cyclone Severe Wind, and Earthquake for the Greater Metro Manila Area. Component 3: Flood Risk Analysis." CSCAND Technical Report for DFAT.
- Barredo, J. I. 2009. "Normalised Flood Losses in Europe: 1970–2006." *Natural Hazards and Earth System Sciences* 9: 97–104. doi:10.5194/nhess-9-97-2009.
- Barthel, F., and E. Neumayer. 2012. "A Trend Analysis of Normalized Insured Damage from Natural Disasters." *Climatic Change* 113: 215–37.
- Batty, M. 2007. *Cities and Complexity: Understanding Cities with Cellular Automata, Agent-Based Models, and Fractals*. Cambridge, MA: MIT Press.
- Bautista, M. L. P., B. Bautista, I. C. Narag, A. D. Aquino, K. Papiona, A. L. Delos Santos, J. Nadua, J. P. Deximo, M. Jakab, and M. A. Dunford. 2014. "Enhancing Risk Analysis Capacities for Flood, Tropical Cyclone Severe Wind, and Earthquake for the Greater Metro Manila Area Component 2—Exposure Information Development." CSCAND Technical Report for DFAT.
- Bautista, M. L. P., B. C. Bautista, I. C. Narag, A. G. Lanuza, J. B. Deocampo, K. L. Papiona, R. A. Atando, R. U. Solidum, T. A. Allen, M. Jakab, H. Ryu, M. Edwards, K. Nadimpalli, M. Leonard, and M. A. Dunford. 2012. "Strengthening Natural Hazard Risk Assessment Capacity in the Philippines: An Earthquake Impact Pilot Study for Iloilo City, Western Visayas." Record 2012/070, Geoscience Australia, Canberra. [http://www.ga.gov.au/metadata-gateway/metadata/record/gcat\\_74132](http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_74132).
- Bear-Crozier, A. N., N. Kartadinata, A. Heriwaseso, and O. Nielsen. 2012. "Development of Python-Fall3D: A Modified Procedure for Modelling Volcanic Ash Dispersal in the Asia-Pacific." *Natural Hazards* 64 (1): 821–38.
- Bear-Crozier, A., and A. Simpson. 2011. "Development and Implementation of Volcanic Ash Modelling in West Java: Completion Report for AusAID." Geoscience Australia Professional Opinion 2011/04, Canberra.
- Beaulieu, A., D. Begin, and D. Genest. 2010. "Community Mapping and Government Mapping: Potential Collaboration?" Symposium of ISPRS Commission I, Calgary, Canada, June 16–18. [http://www.isprs.org/proceedings/xxxviii/part1/10/10\\_01\\_Paper\\_163.pdf](http://www.isprs.org/proceedings/xxxviii/part1/10/10_01_Paper_163.pdf).
- Bilham, R. 2009. "The Seismic Future of Cities." *Bulletin of Earthquake Engineering* 7 (4): 839–87.
- BNPB [National Disaster Management Agency] and Bappenas [National Development Planning Agency], with provincial and district/city governments of West Sumatra and Jambi. 2009. "West Sumatra and Jambi Natural Disasters: Damage, Loss and Preliminary Needs Assessment." [https://www.gfdrr.org/sites/gfdrr.org/files/documents/GFDRR\\_Indonesia\\_DLNA.2009.EN\\_.pdf](https://www.gfdrr.org/sites/gfdrr.org/files/documents/GFDRR_Indonesia_DLNA.2009.EN_.pdf).
- Bouwer, L. M. 2011. "Have Disaster Losses Increased Due to Anthropogenic Climate Change?" *Bulletin of the American Meteorological Society* 92: 39–46. doi:10.1175/2010BAMS3092.1.
- Burbidge, D., P. Cummins, R. Mleczko, and H. Thio. 2008. "A Probabilistic Tsunami Hazard Assessment for Western Australia." *Pure and Applied Geophysics* 165: 2059–88.
- Burbidge, D., P. R. Cummins, R. Mleczko, and H. K. Thio. 2009. "A Probabilistic Tsunami Hazard Assessment for Western Australia." In *Tsunami Science Four Years after the 2004 Indian Ocean Tsunami*, edited by Phil R. Cummins, Laura S. L. Kong, and Kenji Satake, 2059–88. Basel, Switzerland: Birkhäuser.
- Chapman, K. 2012. "Community Mapping for Exposure in Indonesia." Humanitarian OpenStreetMap Team. <http://>

- hot.openstreetmap.org/sites/default/files/CM4E-Indo-en.pdf.
- Chapman, K., A. Wibowo, and Nurwadjadi. 2013. "Filling the Data Gap with Participatory Mapping for Effective Disaster Preparedness." Paper presented at the Disaster Risk Management in East Asia and the Pacific Distance Learning Seminar Series, Jakarta, June 18. [http://www.jointokyo.org/files/cms/news/pdf/\[Final\]\\_Session\\_2\\_Summary.pdf](http://www.jointokyo.org/files/cms/news/pdf/[Final]_Session_2_Summary.pdf).
- CIMNE [Centro Internacional de Métodos Numéricos en Ingeniería] et al. 2013. "Probabilistic Modeling of Natural Risks at the Global Level: Global Risk Model." Background Paper prepared for the 2013 Global Assessment Report on Disaster Risk Reduction, UNISDR, Geneva. [www.preventionweb.net/gar](http://www.preventionweb.net/gar).
- Cornell, C. A. 1968. "Engineering Seismic Risk Analysis." *Bulletin of the Seismological Society of America* 58: 1583–1606.
- Council of European Union. 2009. "Council Conclusions on a Community Framework on Disaster Prevention within the EU." Minutes of the 2979th Justice and Home Affairs Council Meeting, Brussels, November 30.
- Cummins, P., and M. Leonard, M. 2004. "Small Threat but Warning Sounded for Tsunami Research." *AusGeo News* 75: 4–7. September.
- Cummins, P. R., D. R. Burbidge, R. Mleczko, D. H. Natawidjaja, and H. Latief. 2009. *Probabilistic Assessment of Tsunami Hazard in the Indian Ocean*. Canberra: Geoscience Australia.
- Cyranoski, D. 2011. "Japan Faces Up to Failure of Its Earthquake Preparations." *Nature* 471: 556–57.
- Dailey, P., M. Huddleston, S. Brown, and D. Fasking. 2009. "The Financial Risks of Climate Change." ABI Research Paper 19, Association of British Insurers. <http://static.weadapt.org/knowledge-base/files/1040/504a19b1e3d0efinancial-risks-of-climate-change-pdf.pdf>.
- Daniell, J. E., B. Khazai, F. Wenzel, and A. Vervaeck. 2011. "The CATDAT Damaging Earthquakes Database." *Natural Hazards and Earth Systems Sciences* 11: 2235–51. doi:10.5194/nhess-11-2235-2011.
- De Bono, A. 2013. "The Global Exposure Database for GAR 2013." Background paper prepared for the 2013 Global Assessment Report on Disaster Risk Reduction, UNISDR, Geneva. [www.preventionweb.net/gar](http://www.preventionweb.net/gar).
- Desramaut, N. 2013. "Functional Vulnerability: Report on the Functional Vulnerability Assessment of a System Prone to Multiple Hazards." Technical Report D4.3, MATRIX project.
- Dilley, M., R. S. Chen, U. Deichmann, A. Lerner-Lam, M. Arnold, J. Agwe, P. Buys, O. Kjekstad, B. Lyon, and G. Yetman. 2005a. *Natural Disaster Hotspots. A Global Risk Analysis*. Washington, DC: International Bank for Reconstruction and Development/World Bank and Columbia University.
- . 2005b. *Natural Disaster Hotspots: A Global Risk Analysis. Synthesis Report*. Washington, DC: International Bank for Reconstruction and Development/World Bank.
- Erdik, M. 2013. "Earthquake Risk in Turkey." *Science* 341: 724–25.
- Erian, Wadid, Bassem Katlan, Bassem Ouldbedy, Haider Awad, Ebrahim Zaghtity, and Sanaa Ibrahim. 2012. "Agriculture Drought in Africa and Mediterranean." Background paper prepared for the 2013 Global Assessment Report on Disaster Risk Reduction, UNISDR, Geneva. [www.preventionweb.net/gar](http://www.preventionweb.net/gar).
- European Commission. 2010a. "The EU Internal Security Strategy in Action: Five Steps towards a More Secure Europe." Communication from the Commission to the European Parliament and the Council, COM[2010] 673 final, European Commission, Brussels.
- . 2010b. "Risk Assessment and Mapping Guidelines for Disaster Management." Commission Staff Working Paper, SEC[2010] 1626 final, European Commission, Brussels.
- FEMA [Federal Emergency Management Agency]. 2003. *Multi-hazard Loss Estimation Methodology. Earthquake Model. HAZUS-MH 2.1. Technical Manual*. Washington, DC: FEMA.
- Feyen, L., R. Dankers, K. Bódis, P. Salamon, and J. I. Barredo. 2012. "Fluvial Flood Risk in Europe in Present and Future Climates." *Climatic Change* 112: 47–62. doi:10.1007/s10584-011-0339-7.
- Frangopol, D. M., K.-Y. Lin, and A. C. Estes. 1997. "Reliability of Reinforced Concrete Girders under Corrosion Attack." *Journal of Structural Engineering* 123 (3): 286–97.
- Fraser, A., and D. Vincent Lima. 2012. "Survey Results Report: Regional Technical Assistance Initiative on Climate Adaptation Planning in LAC Cities." Latin America and Caribbean Regional Urban, Water,

- and Disaster Risk Management Unit, World Bank, Washington, DC.
- Gadjah Mada University and HOT [Humanitarian OpenStreetMap Team]. 2012. "Evaluation of OpenStreetMap Data in Indonesia: Final Report." [http://openstreetmap.or.id/docs/Final\\_Report-OSM\\_Evaluation\\_in\\_Indonesia\\_2012.pdf](http://openstreetmap.or.id/docs/Final_Report-OSM_Evaluation_in_Indonesia_2012.pdf).
- Gall, M., K. A. Borden, C. T. Emrich, and S. L. Cutter. 2011. "The Unsustainable Trend of Natural Hazard Losses in the United States." *Sustainability* 3: 2157–81. doi:10.3390/su3112157.
- Garcia-Aristizabal, A., W. Marzocchi, and A. Di Ruocco. 2013. "Probabilistic Framework for Multi-hazard Assessment." Technical Report D3.4, MATRIX project.
- Gaume, E., V. Bain, P. Bernardara, O. Newinger, M. Barbuc, A. Bateman, L. Blaškovičová, G. Blöschl, M. Borga, A. Dumitrescu, I. Daliakopoulos, J. Garcia, A. Irimescu, S. Kohnova, A. Koutroulis, L. Marchi, S. Matreata, V. Medina, E. Preciso, D. Sempere-Torres, G. Stancalie, J. Szolgay, I. Tsanis, D. Velasco, and A. Viglione. 2009. "A Compilation of Data on European Flash Floods." *Journal of Hydrology* 367 (1): 70–78. doi:10.1016/j.jhydrol.2008.12.028.
- Geller, R. J. 2011. "Shake Up Time for Japanese Seismology." *Nature* 472: 407–9.
- GFDRR [Global Facility for Disaster Reduction and Recovery]. 2014. *Open Data for Resilience Initiative Field Guide*. Washington, DC: World Bank.
- Ghosh, Jayadipta, Keivan Rokneddin, Jamie E. Padgett, and Leonardo Dueñas-Osorio. 2013. "Seismic Reliability Assessment of Aging Highway Bridge Networks with Field Instrumentation Data and Correlated Failures. I: Methodology." *Earthquake Spectra*. doi:http://dx.doi.org/10.1193/040512eqs155m.
- Goethert, R. 2010. "Incremental Housing." *Monday Developments*. September. [http://monthlydevelopments.org/sites/monthlydevelopments/files/MD\\_Sept\\_10\\_small.pdf](http://monthlydevelopments.org/sites/monthlydevelopments/files/MD_Sept_10_small.pdf).
- Gonzalez, F., E. Geist, B. Jaffe, U. Kanoglu, H. Mofjeld, C. Synolakis, V. Titov, D. Arcas, D. Bellomo, D. Carlton, T. Horning, J. Johnson, J. Newman, T. Parsons, R. Peters, C. Peterson, G. Priest, A. Venturato, J. Weber, F. Wong, and A. Yalciner. 2009. "Probabilistic Tsunami Hazard Assessment at Seaside, Oregon, for Near- and Far-field Seismic Sources." *Journal of Geophysical Research* 114: C11023.
- Government of Malawi. 2010. "National Disaster Risk Reduction Framework 2010–2015."
- . 2011. "National Disaster Risk Management Policy." Department of Disaster Management Affairs.
- Government of Morocco. 2012. "Evaluating Direct and Indirect Economic Impacts of Natural Disasters: The Development of an Input-Output and a CGE Models for Morocco."
- Hallegatte, S., C. Green, R. J. Nicholls, and J. Corfee-Morlot. 2013. "Future Flood Losses in Major Coastal Cities." *Nature Climate Change* 3: 802–6. doi:10.1038/nclimate1979.
- Herold, C., and F. Mouton. 2011. "Global Flood Hazard Mapping Using Statistical Peak Flow Estimates." *Hydrology and Earth System Sciences Discussions* 8: 305–63. doi:10.5194/hessd-8-305-2011.
- Herold, C., and R. Rudari. 2013. "Improvement of the Global Flood Model for the GAR 2013 and 2015." Background paper prepared for the 2013 Global Assessment Report on Disaster Risk Reduction, UNISDR, Geneva. [www.preventionweb.net/gar](http://www.preventionweb.net/gar).
- Hirabayashi, Y., M. Roobavannan, K. Sujan, K. Lisako, Y. Dai, W. Satoshi, K. Hyungjun, and K. Shinjiro. 2013. "Global Flood Risk under Climate Change." *Nature Climate Change* 3: 816–21. doi:10.1038/nclimate1911.
- ICHARM [International Centre for Water Hazard and Risk Management]. 2013. *Technical Assistance for Supporting Investments in Water-related Disaster Management: Main Volume*. Manila: Asian Development Bank. <http://www.adb.org/projects/documents/supporting-investments-water-related-disaster-management-tacr>.
- IPCC [Intergovernmental Panel on Climate Change]. 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. A special report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press.
- . 2013. "Summary for Policymakers." In *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P. M. Midgley. Cambridge: Cambridge University Press.
- Jankaew, K., B. F. Atwater, Y. Sawai, M. Choowong, T. Charoentitirat, M. E. Martin, and A. Prendergast. 2008.

- "Medieval Forewarning of the 2004 Indian Ocean Tsunami in Thailand." *Nature* 455: 1228–31.
- Janssen, G., and D. L. Holden. 2011. *External Independent Evaluation of AIFDR 'Build Back Better' Campaign: Final Evaluation Report*. Jakarta: Australia-Indonesia Facility for Disaster Reduction.
- . 2013. *Rumah Aman Gempa Andalan Masyarakat (RAGAM): Independent Completion Report*. Jakarta: Australia-Indonesia Facility for Disaster Reduction.
- Jayanthi, H., and G. J. Husak. 2012. "A Probabilistic Approach to Assess Agricultural Drought Risk." Background paper prepared for the 2013 Global Assessment Report on Disaster Risk Reduction, UNISDR, Geneva. [www.preventionweb.net/gar](http://www.preventionweb.net/gar).
- Jayasinghem, T., and J. Birkmann. 2007. "Vulnerability Comparison between Galle and Batticaloa based on the Household Survey using Questionnaires." In *Rapid Vulnerability Assessment in Sri Lanka: Post-Tsunami Study of Two Cities: Galle and Batticaloa*. SOURCE Publication No. 7, 39–47.
- Jenkins, S., C. Magill, K. McAneney, and R. Blong. 2012a. "Regional Ash Fall Hazard I: A Probabilistic Assessment Methodology." *Bulletin of Volcanology* 74: 1699–1712.
- Jenkins, S., K. McAneney, C. Magill, and R. Blong. 2012b. "Regional Ash Fall Hazard II: Asia-Pacific Modelling Results and Implications." *Bulletin of Volcanology* 74: 1713–27.
- JICA (Japan International Cooperation Agency). 2011. "The Study on Integrated Water Resources Management for Poverty Alleviation and Economic Development in the Pampanga River Basin." National Water Resources Board, Philippines.
- . 2013. "Project for the Comprehensive Flood Management Plan for the Chao Phraya River Basin." Thailand.
- Jongman B., S. Hochrainer-Stigler, L. Feyen, J. C. J. H. Aerts, R. Mechler, W. J. W. Botzen, L. M. Bouwer, G. Pflug, R. Rojas, and P. J. Ward. 2014. "Increasing Stress on Disaster Risk Finance Due to Large Floods." *Nature Climate Change*. <http://dx.doi.org/10.1038/nclimate2124>.
- Jongman, B., P. J. Ward, and J. C. J. H. Aerts. 2012. "Global Exposure to River and Coastal Flooding—Long Term Trends and Changes." *Global Environmental Change* 22: 823–35. doi:10.1016/j.gloenvcha.2012.07.004.
- Kagan, Y. Y., and D. D. Jackson. 2013. "Tohoku Earthquake: A Surprise?" *Bulletin of the Seismological Society of America* 103 [2B]: 1181–94. doi:10.1785/0120120110.
- Kundzewicz, Z. W., S. Kanae, S. I. Seneviratne, J. Handmer, N. Nicholls, P. Peduzzi, R. Mechler, L. M. Bouwer, N. Arnell, K. Mach, R. Muir-Wood, G. R. Brakenridge, W. Kron, G. Benito, Y. Honda, K. Takahashi, and B. Sherstyukov. 2014. "Flood Risk and Climate Change: Global and Regional Perspectives." *Hydrological Sciences Journal* 59 [1]. doi:10.1080/02626667.2013.857411.
- Kundzewicz, Z. W., I. Pińskwar, and G. R. Brakenridge. 2013. "Large Floods in Europe, 1985–2009." *Hydrological Sciences Journal* 58: 1–7. doi:10.1080/02626667.2012.745082.
- Kwak, Y., K. Takeuchi, K. Fukami, and J. Magome. 2012. "A New Approach to Flood Risk Assessment in Asia-Pacific Region Based on MRI-AGCM Outputs." *Hydrological Research Letters* 6: 70–75.
- Lall, S. V., and U. Deichmann. 2009. "Density and Disasters: Economics of Urban Hazard Risk." Policy Research Working Paper 5161, World Bank, Washington, DC.
- . 2012. "Density and Disasters: Economics of Urban Hazard Risk." *World Bank Research Observer* 27 [1]: 74–105.
- Lallemant, D., S. Wong, K. Morales, and A. Kiremidjian. 2014. "A Framework and Case Study for Dynamic Urban Risk Assessment." Paper presented at the 10th National Conference on Earthquake Engineering, Anchorage, AK, July.
- Lansang, M., and R. Dennis. 2004. "Building Capacity in Health Research in the Developing World." *Bulletin of the World Health Organisation* 82: 764–70.
- Løvholt, F., D. Kühn, H. Bungum, C. B. Harbitz, and S. Glimsdal. 2012. "Historical Tsunamis and Present Tsunami Hazard in Eastern Indonesia and the Philippines." *Journal of Geophysical Research—Solid Earth*. doi:10.1029/2012JB009425.
- Marzocchi, W., A. Garcia-Aristizabal, P. Gasparini, M. L. Mastellone, and A. Di Ruocco. 2012. "Basic Principles of Multi-risk Assessment: A Case Study in Italy." *Natural Hazards* 62 [2]: 551–73.
- McCloskey, J., D. Lange, F. Tilmann, S. S. Nalbant, A. F. Bell, D. H. Natawidjaja, and A. Rietbrock. 2010. "The September 2009 Padang Earthquake." *Nature Geoscience* 3 [2]: 70–71.

- McKee, T. B., N. J. Doesken, and J. Kleist. 1993. "The Relationship of Drought Frequency and Duration of Time Scales." Paper presented at Eighth Conference on Applied Climatology, American Meteorological Society, Anaheim CA, January 17–23.
- MLIT (Ministry of Land, Infrastructure, Transport and Tourism). 2006. *Basic Plan for the Tone River Improvement*. Tokyo: MLIT.
- Monfort, D., and S. Lecacheux. 2013. "West Indies Test Site." Technical Report D7.4, MATRIX project.
- MunichRe. 2013. "Significant Natural Catastrophes 1980–2012, 10 Deadliest Worldwide Events." Geo Risks Research, NatCatSERVICE. [https://www.munichre.com/site/corporate/get/documents\\_E-1233315815/mr/assetpool.shared/Documents/O\\_Corporate%20Website/\\_NatCatService/Focus\\_Analyses/1980-2012-geophysical-events-worldwide-en.pdf](https://www.munichre.com/site/corporate/get/documents_E-1233315815/mr/assetpool.shared/Documents/O_Corporate%20Website/_NatCatService/Focus_Analyses/1980-2012-geophysical-events-worldwide-en.pdf).
- Nadim, F., and T. Glade. 2006. "On Tsunami Risk Assessment for the West Coast of Thailand." ECI Symposium Series 7, Engineering Conferences International, New York. <http://dc.engconfintl.org/cgi/viewcontent.cgi?article=1000&context=geohazards>.
- Neumayer, E., and F. Barthel. 2011. "Normalizing Economic Loss from Natural Disasters: A Global Analysis." *Global Environmental Change* 21 (1): 13–24. doi:10.1016/j.gloenvcha.2010.10.004.
- NGI (Norwegian Technological Institute). 2013. "Landslide Hazard and Risk Assessment in El Salvador." Background paper prepared for the 2013 Global Assessment Report on Disaster Risk Reduction, UNISDR, Geneva. [www.preventionweb.net/gar](http://www.preventionweb.net/gar).
- Nguyen, K. C., and K. J. E. Walsh. 2001. "Interannual, Decadal, and Transient Greenhouse Simulation of Tropical Cyclone-like Vortices in a Regional Climate Model of the South Pacific." *Journal of Climate* 14: 3043–54.
- Nicholls, R. J., S. Hanson, C. Herweijer, N. Patmore, S. Hallegatte, J. Corfee-Morlot, J. Chateau, and R. Muir Wood. 2008. "Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates." OECD Working Paper No. 1, OECD Publishing, Paris.
- OECD (Organisation for Economic Co-operation and Development). 2012. *OECD Environmental Outlook to 2050*. Paris: OECD Publishing. <http://dx.doi.org/10.1787/9789264122246-en>.
- Ordaz, M., F. Martinelli, A. Aguilar, J. Arboleda, C. Meletti, and V. D'Amico. "2012 CRISIS 2012, Program for Computing Seismic Hazard." Instituto de Ingeniería, Universidad Nacional Autónoma de México.
- ORNL (Oak Ridge National Laboratory). 2007. "LandScan™ Global Population Distribution Data [Raster dataset]." Oak Ridge National Laboratory, U.S. Department of Energy. [www.ornl.gov/sci/landscan/index.shtml](http://www.ornl.gov/sci/landscan/index.shtml).
- Pacheco, B. M., J. Y. Hernandez Jr., E. A. J. Tingatinga, P. P. M. Castro, F. J. Germar, U. P. Ignacio, M. C. L. Pascua, L. R. E. Tan, I. B. O. Villalba, D. H. M. Aquino, R. E. U. Longalong, R. N. Macuha, W. L. Mata, R. M. Suiza, and M. A. H. Zarco. 2013. "Development of Vulnerability Curves of Key Building Types in the Greater Metro Manila Area, Philippines." Institute of Civil Engineering, University of the Philippines Diliman, Quezon City, Philippines.
- Pacific Consultants International, OYO Cooperation, JICA, and IMM. 2002. "The Study on a Disaster Prevention / Mitigation Basic Plan in Istanbul including Seismic Microzonation in the Republic of Turkey." [http://www.ibb.gov.tr/tr-TR/SubSites/DepremSite/PublishingImages/JICA\\_ENG.pdf](http://www.ibb.gov.tr/tr-TR/SubSites/DepremSite/PublishingImages/JICA_ENG.pdf).
- Pappenberger, F., E. Dutra, F. Wetterhall, and H. L. Cloke. 2012. "Deriving Global Flood Hazard Maps of Fluvial Floods through a Physical Model Cascade." *Hydrology and Earth System Sciences* 16: 4143–56. doi:10.5194/hess-16-4143-2012.
- Parsons, T., and E. Geist. 2009. "Tsunami Probability in the Caribbean Region." *Pure and Applied Geophysics* 165: 2089–2116.
- Parsons, Tom, Shinji Toda, Ross S. Stein, Aykut Barka, and James H. Dieterich. 2000. "Heightened Odds of Large Earthquakes Near Istanbul: An Interaction Based Probability Calculation." *Science* 288: 661–65.
- Pektas, Mesut, and Polat Gulkan. 2004. "A Metropolitan Municipality Prepares for the Worst: Istanbul Earthquake Master Plan." Paper presented at 13th World Conference on Earthquake Engineering, Vancouver, August 1–6.
- PBL (Netherlands Environmental Assessment Agency). 2014. *Towards a World of Cities in 2050: An Outlook on Water-related Challenges*. PBL background report for UN Habitat Global Report. The Hague: PBL Netherlands Environmental Assessment Agency.
- Peduzzi, P., B. Chatenoux, H. Dao, A. De Bono, U. Deichmann, G. Giuliani, C. Herold, B. Kalsnes, S. Kluser, F. Løvholt, B. Lyon, A. Maskrey, F. Mouton, F. Nadim, and H. Smebye. 2009. "The Global Risk Analysis for the 2009

- Global Assessment Report on Disaster Risk Reduction." Universite de Geneve Publication. [http://www-fourier.ujf-grenoble.fr/~mouton/Publis\\_HDR\\_applis/Peduzzi-The\\_Global\\_Risk\\_Analysis\\_for\\_the\\_2009\\_GAR-149.pdf](http://www-fourier.ujf-grenoble.fr/~mouton/Publis_HDR_applis/Peduzzi-The_Global_Risk_Analysis_for_the_2009_GAR-149.pdf).
- Petiteville, Ivan, Philippe Bally, and Guy Seguin. 2012. "Satellite Earth Observation for Risk Management." In *The Earth Observation Handbook*, edited by S. Ward. European Space Agency. [www.eohandbook.com](http://www.eohandbook.com).
- PHIVOLCS (Philippine Institute of Volcanology and Seismology), JICA (Japan International Cooperation Agency), and MMDA (Metropolitan Manila Development Authority). 2004. "Earthquake Impact Reduction Study for Metropolitan Manila, Republic of the Philippines" (MMEIRS).
- Prochaska, J. O., J. C. Norcross, and C. C. DiClemente. 1994. *Changing for Good: The Revolutionary Program that Explains the Six Stages of Changes and Teaches You How to Free Yourself from Bad Habits*. New York: W. Morrow.
- RMSI. 2011. "Malawi: Economic Vulnerability and Disaster Risk Assessment." [www.masdap.mw/documents/145/download](http://www.masdap.mw/documents/145/download).
- Robinson, D., T. Dhu, and J. Schneider. 2006. "Practical Probabilistic Seismic Risk Analysis: A Demonstration of Capability." *Seismological Research Letters* 77 (4): 453–59.
- Rojas, R., L. Feyen, and P. Watkiss. 2013. "Climate Change and River Floods in the European Union: Socio-Economic Consequences and the Costs and Benefits of Adaptation." *Global Environmental Change* 23: 1737–51. doi:10.1016/j.gloenvcha.2013.08.006.
- Rokneddin, Keivan, Jayadipta Ghosh, Leonardo Dueñas-Osorio, and Jamie E. Padgett. 2013. "Seismic Reliability Assessment of Aging Highway Bridge Networks with Field Instrumentation Data and Correlated Failures. II: Application." *Earthquake Spectra*. doi:<http://dx.doi.org/10.1193/040612EQS160M>.
- Satake, K., and B. F. Atwater. 2007. "Long-Term Perspectives on Giant Earthquakes and Tsunamis at Subduction Zones." *Annual Review of Earth and Planetary Sciences* 35: 349–74.
- Schneider, A., M. A. Friedl, and D. Potere. 2009. "A New Map of Global Urban Extent from MODIS Satellite Data." *Environmental Research Letters* 4 (4): 044003. doi:10.1088/1748-9326/4/4/044003.
- Scolobig, A., C. Vichon, N. Komendantova, M. Bengoubou-Valerius, and A. Patt. 2013. "Social and Institutional Barriers to Effective Multi-hazard and Multi-risk Decision-making Governance." Technical Report D6.3, MATRIX project.
- SCS (Soil Conservation Service). 1986. "Urban Hydrology for Small Watersheds." Technical Release TR-55, USDA, Soil Conservation Service, Hydrology Unit.
- Sengara, W., M. Suarjana, D. Beetham, N. Corby, M. Edwards, M. Griffith, M. Wehner, and R. Weller. 2010. "The 30th September 2009 West Sumatra Earthquake: Padang Region Damage Survey." Record 2010/44, Geoscience Australia, Canberra.
- Sengara, W., M. Suarjana, M. Edwards, H. Ryu, W. Rahmanusyairi, I. Adiputra, I. I. Wahdiny, A. Utami, A. Mariany, M. A. Yulman, and B. Novianto. 2013. *Research on Earthquake Damage Models for Buildings in Indonesia*. Bandung: Research Centre of Disaster Mitigation, Bandung Institute of Technology.
- Setiadi, N. J. 2014. "Assessing People's Early Warning Response Capability to Inform Urban Planning Interventions to Reduce Vulnerability to Tsunamis: Case Study of Padang City, Indonesia." PhD dissertation, Rheinische Friedrich Wilhelms Universität zu Bonn.
- Setiadi, N., H. Taubenböck, S. Raupp, and J. Birkmann. 2010. "Integrating Socio-Economic Data in Spatial Analysis: An Exposure Analysis Method for Planning Urban Risk Mitigation." Paper presented at REAL CORP 2010, Vienna, May 18–20. [http://programm.corp.at/cdrom2010/papers2010/CORP2010\\_80.pdf](http://programm.corp.at/cdrom2010/papers2010/CORP2010_80.pdf).
- Seto, K. C., B. Güneralp, and L. R. Hutyrá. 2012. "Global Forecasts of Urban Expansion to 2030 and Direct Impacts on Biodiversity and Carbon Pools." *Proceedings of the National Academy of Sciences* 109: 16083–16088. doi:10.1073/pnas.1211658109.
- Shela, Osborne, Gaye Thompson, Paul Jere, and George Annandale. 2008. "Analysis of Lower Shire Floods & a Flood Risk Reduction and Recovery Programme Proposal for the Lower Shire Valley." Government of Malawi, Department of Disaster Management Affairs, Office of the President and Cabinet.
- Sieh, K., D. H. Natawidjaja, A. J. Meltzner, C. C. Shen, H. Cheng, K. Li, B. W. Suwargadi, J. Galetzka, B. Philibosian, and R. L. Edwards. 2008. "Earthquake Supercycles Inferred from Sea-Level Changes Recorded in the Corals of West Sumatra." *Science* 322 (5908): 1674–78.

- Simpson, A. L., and T. Dhu. 2009. "Enhancing Natural Hazard Risk Assessment Capacity in the CSCAND Agencies in the Philippines: An Options Paper." Geoscience Australia Professional Opinion 2009/004, Canberra.
- Soden, R., N. Budhathoki, and L. Palen. 2014. "Resilience Building and the Crisis Informatics Agenda: Lessons Learned from Open Cities Kathmandu." *Proceedings of Information Systems for Crisis Response and Management Conference*, State College, PA.
- Sørensen, M., A. Babeyko, S. Wiemer, and G. Grünthal. 2012. "Probabilistic Tsunami Hazard in the Mediterranean Sea." *Journal of Geophysical Research: Solid Earth* 117 [B1]: 2156–2202.
- Stein, S., and E. Okal. 2007. "Ultralong Period Seismic Study of the December 2004 Indian Ocean Earthquake and Implications for Regional Tectonics and the Subduction Process." *Bulletin of the Seismological Society of America* 97 (1A): 279–95.
- Stürck, J., A. Poortinga, and P. H. Verburg. 2014. "Mapping Ecosystem Services: The Supply and Demand of Flood Regulation Services in Europe." *Ecological Indicators* 38: 198a–211. doi:10.1016/j.ecolind.2013.11.010.
- Takeuchi, K., T. Ao, and H. Ishidaira. 1999. "Introduction of Block-wise Use of TOPMODEL and Muskingum-Cunge Method for the Hydro-environmental Simulation of a Large Ungauged Basin." *Hydrological Sciences Journal* 44 (4): 633–46.
- Taubenböck, H., J. Post, A. Roth, G. Strunz, R. Kief, S. Dech, and F. Ismail. 2008. "Multi-scale Assessment of Population Distribution Utilizing Remotely Sensed Data: The Case Study of Padang, West Sumatra, Indonesia." Paper presented at International Conference on Tsunami Warning, Bali, Indonesia, November 12–14.
- Taylor, K. E., R. J. Stouffer, and G. A. Meehl. 2012. "An Overview of CMIP5 and the Experiment Design." *Bulletin of the American Meteorological Society* 93: 485–98.
- Thio, H. K., P. Somerville, and J. Polet. 2010. "Probabilistic Tsunami Hazard in California." PEER Report 2010/108, Pacific Earthquake Engineering Research Center, University of California, Berkeley.
- Thomas, C., and D. Burbidge. 2009. "A Probabilistic Assessment of Tsunami Hazard of Southwest Pacific Nations." Geoscience Australia Professional Opinion 2009/02, Canberra.
- Tsunami Pilot Study Working Group. 2006. "Seaside, Oregon Tsunami Pilot Study—Modernization of FEMA Flood Hazard Maps." NOAA OAR Special Report. NOAA/OAR/PMEL, Seattle.
- UNDP (United Nations Development Programme) and RMSI. 2006. "Developing a Disaster Risk Profile for Maldives." [http://www.preventionweb.net/files/11145\\_MaldivesDisasterRiskProfileFinalRep.pdf](http://www.preventionweb.net/files/11145_MaldivesDisasterRiskProfileFinalRep.pdf).
- UNDP (United Nations Development Programme). 2004. *Reducing Disaster Risk: A Challenge for Development*. New York: United Nations.
- UN-HABITAT. 2010. "Estado de Las Ciudades de America Latina y El Caribe." Regional Office for Latin America and the Caribbean, United Nations Human Settlement Programme, Rio de Janeiro.
- UNISDR (United Nations Office for Disaster Risk Reduction). 2005a. "10 Preliminary Lessons Learned from the Indian Ocean Tsunami of 26 December 2004." [http://www.unisdr.org/files/5605\\_ISDR10lessonslearned.pdf](http://www.unisdr.org/files/5605_ISDR10lessonslearned.pdf).
- . 2005b. *2005 Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters*. Geneva: UNISDR. [www.unisdr.org/wcdr](http://www.unisdr.org/wcdr).
- . 2009. *Global Assessment Report on Disaster Risk Reduction: Risk and Poverty in a Changing Climate*. Geneva: UNISDR. <http://www.preventionweb.net/gar>.
- . 2011. *Global Assessment Report on Disaster Risk Reduction 2011: Revealing Risk, Redefining Development*. Geneva: UNISDR. <http://www.preventionweb.net/gar>.
- . 2013a. *Global Assessment Report 2013 Annex 1*. Geneva: UNISDR. <http://www.preventionweb.net/gar>.
- . 2013b. *Global Assessment Report on Disaster Risk Reduction 2013: From Shared Risk to Shared Value*. Geneva: UNISDR. <http://www.preventionweb.net/gar>.
- United Nations. 2007. *World Urbanization Prospects*. [http://www.un.org/esa/population/publications/wup2007/2007WUP\\_Highlights\\_web.pdf](http://www.un.org/esa/population/publications/wup2007/2007WUP_Highlights_web.pdf).
- Walsh, K. J. E., and J. I. Syktus. 2003. "Simulations of Observed Interannual Variability of Tropical Cyclone Formation East of Australia." *Atmospheric Science Letters* 4: 28–40.
- WAPMERR (World Agency for Planetary Monitoring and Earthquake Risk Reduction). 2013. "Approximate Model for Worldwide Building Stock in Three Size Categories of Settlements." Background paper prepared for the 2013



- Global Assessment Report on Disaster Risk Reduction, UNISDR, Geneva. [www.preventionweb.net/gar](http://www.preventionweb.net/gar).
- Ward, P. J., W. Beets, L. M. Bouwer, J. C. J. H. Aerts, and H. Renssen. 2010. "Sensitivity of River Discharge to ENSO." *Geophysical Research Letters* 37: L12402. doi:10.1029/2010GL043215.
- Ward, P. J., M. Dettinger, B. Jongman, M. Kumm, F. Sperna Weiland, and H. Winsemius. 2013a. "Flood Risk Assessment at the Global Scale—The Role of Climate Variability." Paper presented at EGU General Assembly, Vienna, Austria, April 7–12.
- Ward, P. J., S. Eisner, M. Flörke, M. D. Dettinger, and M. Kumm. 2014. "Annual Flood Sensitivities to El Niño Southern Oscillation at the Global Scale." *Hydrology and Earth System Sciences* 18: 47–66. doi:10.5194/hess-18-47-2014.
- Ward, P. J., B. Jongman, F. Sperna Weiland, A. Bouwman, R. Van Beek, M. Bierkens, W. Ligtvoet, and H. Winsemius. 2013b. "Assessing Flood Risk at the Global Scale: Model Setup, Results, and Sensitivity." *Environmental Research Letters* 8: 044019. doi:10.1088/1748-9326/8/4/044019.
- Winsemius, H. C., R. Van Beek, B. Jongman, P. J. Ward, and A. Bouwman. 2013. "A Framework for Global River Flood Risk Assessments." *Hydrology and Earth System Sciences* 17 [5]: 1871–92. doi:10.5194/hess-17-1871-2013.
- Wisner, B., P. Blaikie, T. Cannon, and I. Davis. 2004. *At Risk: Natural Hazards, People's Vulnerability and Disasters*. 2nd ed. New York: Routledge.
- World Bank. 2010a. *Emerging Stronger from the Crisis*. Vol. 1 of *World Bank East Asia and Pacific Update 2010*. <https://openknowledge.worldbank.org/handle/10986/2455>.
- . 2010b. *Natural Hazards, UnNatural Disasters: The Economics of Effective Prevention*. Washington, DC: World Bank.
- . 2012a. *Bangladesh: Towards Accelerated, Inclusive, and Sustainable Growth—Opportunities and Challenges*. Vol. 2. Washington, DC: Poverty Reduction and Economic Management Sector Unit, South Asia Region, World Bank.
- . 2012b. "Consultancy for Prioritization of High Seismic Risk Provinces and Public Buildings in Turkey, by Proto Engineering."
- . 2013. "Risk Assessment Report, Morocco Natural Hazards Probabilistic Risk Assessment and National Strategy Development, Final Report." Prepared by RMSI Ltd. for the International Bank for Reconstruction and Development, Washington, DC.
- Yamin, Luis Eduardo, Francis Ghesquiere, Omar Darío Cardona, and Mario Gustavo Ordaz. 2013. *Probabilistic Modelling for Disaster Risk Management: The Case of Bogota, Colombia* [in Spanish]. Washington, DC: International Bank for Reconstruction and Development and World Bank.