Potsdam Institute for Climate Impact Research

PIK

RECEIPT

Evaluation of a global modeling chain for flood-induced displacement risk

WP5 International cooperation, development and resilience
RECEIPT webinar – 30.04.2021

Benedikt Mester

Leibniz Association

Agenda

1. Setting the Scene: Intro on Disaster-Induced Displacement
2. Roadmap: Storyline Approach and Research Questions
3. The Uncertainties of Modeling: Evaluation of the Global Flood Modeling Chain
4. Outlook: Displacement Vulnerability

Setting the scene

1. Intro on Disaster-Induced Displacement

1. Intro on Disaster-Induced Displacement

Natural Hazards

Disruption of Communities
Unemployment
Costs of Response and Relief
Insurance Losses
Interruption of Business
Pollution
Displacement
Diseases
Political Unrest
Loss of Assets
Damage to Infrastructure
Injuries
Less Investment
Loss of Cultural Heritage
Fatalities
Loss of Productivity
Loss of Biodiversity
Sedimentation
Psychological Impacts
Loss of Ecosystems
Reduction of Tourism

1. Intro on Disaster-Induced Displacement

Disruption of Communities
Unemployment
Costs of Response and Relief
Insurance Losses
Interruption of Business
Pollution
Displacement
Diseases
Natural Hazards
Political Unrest
Injuries
Loss of Assets
Damage to Infrastructure
Less Investment
Loss of Cultural Heritage
Fatalities
Loss of Productivity
Loss of Biodiversity
Sedimentation
Psychological Impacts
Reduction of Tourism
Loss of Ecosystems

Jongman *et al.* 2015
Tanoue *et al.* 2016
Dottori *et al.* 2018
Willner *et al.* 2018
…

1. Intro on Disaster-Induced Displacement

RECEIPT

Kakinuma et *al.*, 2020
Kam et *al.*, 2021

Displacement

Disruption of Communities
Unemployment
Costs of Response and Relief
Interruption of Business
Pollution
Insurance Losses
Diseases
Political Unrest
Damage to Infrastructure
Injuries
Natural Hazards
Less Investment
Loss of Assets
Loss of Cultural Heritage
Fatalities
Loss of Productivity
Loss of Biodiversity
Sedimentation
Psychological Impacts
Loss of Ecosystems
Reduction of Tourism

Jongman *et al.* 2015
Tanoue *et al.* 2016
Dottori *et al.* 2018
Willner *et al.* 2018
…

1. Intro on Disaster-Induced Displacement

Definition of Displacement

Internally displaced person (IDP):

- Evacuated or left homeless after a natural disaster
- Fails to return to their home and is neither integrated locally nor into another settlement
- Stays within national borders (↔ refugee, migrant and asylum seeker)

1. Intro on Disaster-Induced Displacement

Diversity of Displacement

Photo by Gideon Mendel

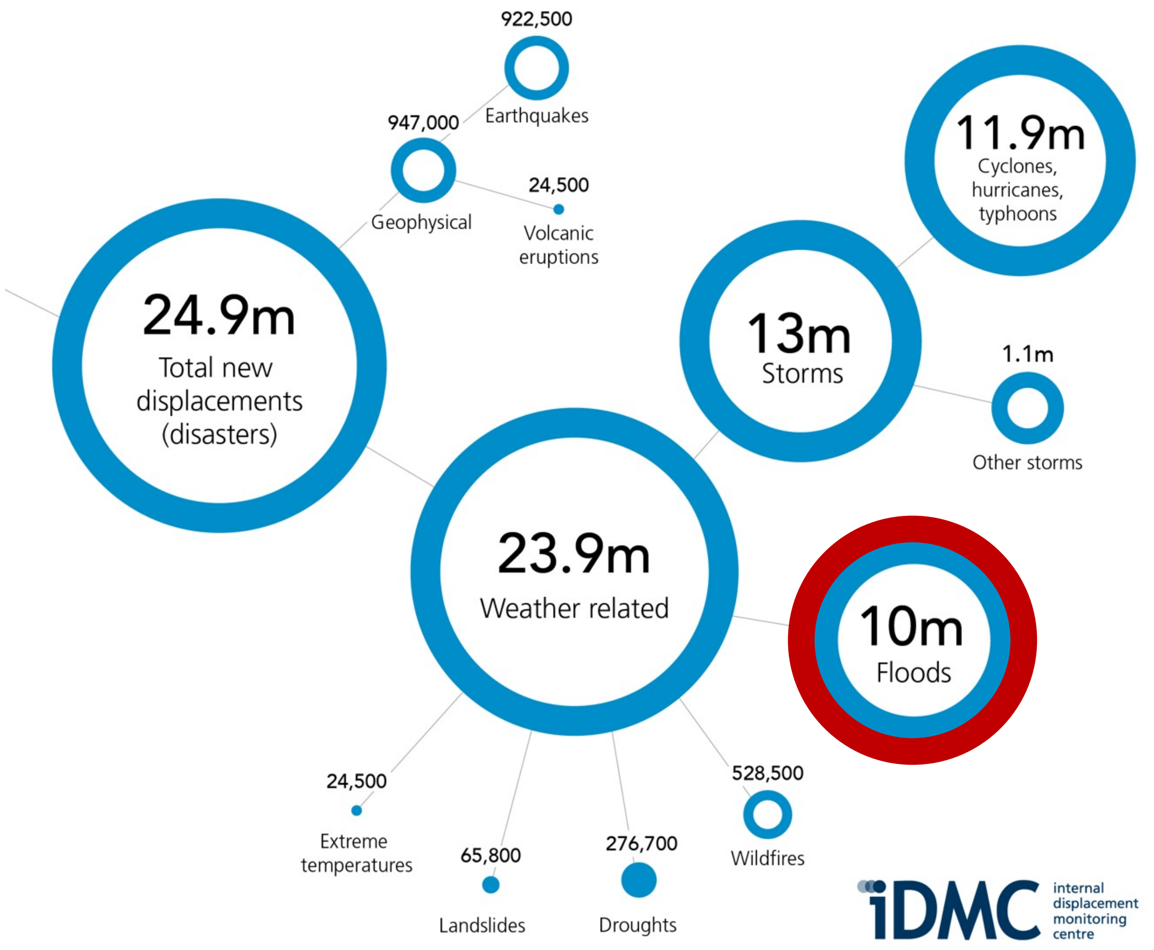
Flooding in Bangkok, Thailand
November 2011

Photo by Justin McManus

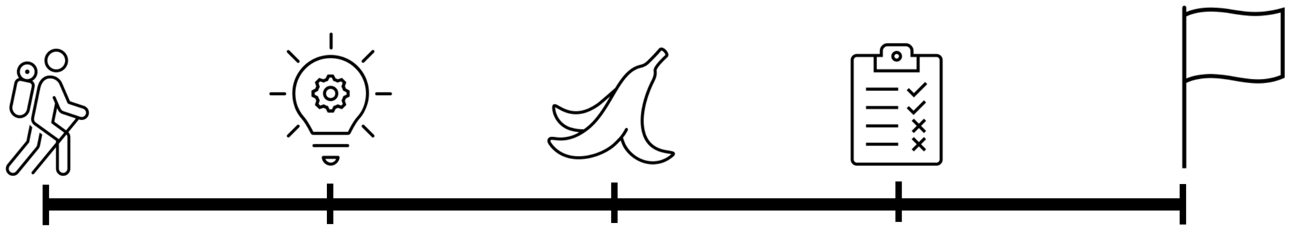
Bushfires in Mallacoota, Australia
December 2019

1. Intro on Disaster-Induced Displacement

Displacement in Numbers



IDMC, 2020



Roadmap

2. Storyline Approach and Research Questions

2. Storyline Approach and Research Questions

Displacement Storylines

Four hotspot regions:

Country shapes by www.gadm.org

Storylines on the Past:

- Simulate past extreme floods with today's exposure
- Simulate historic exposure with recent events (e.g., Mozambique 2007, Nigeria 2012)
- Compare observed events with **counterfactual impact** events (Mengel et al., 2020 in review)

Storylines on the Future:

- Simulate displacement risk under different **RCP and SSP** projections
- Include **vulnerability** scenarios

Link to EU:

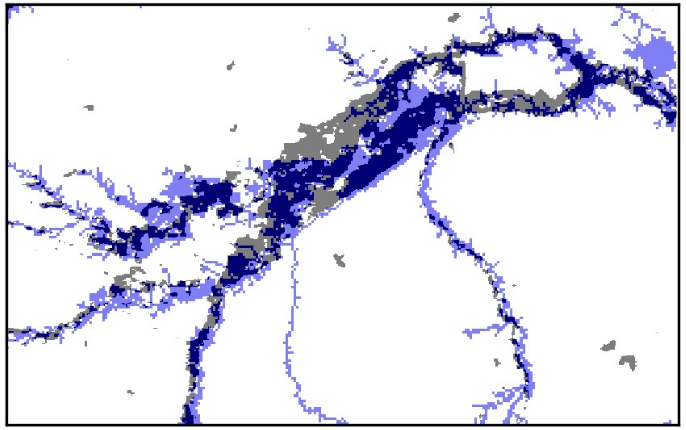
- Identify future policy needs for humanitarian and development aid
- Highlighting potential sources of social and political instability

2. Storyline Approach and Research Questions

Research Questions

1. Is our flood model capable of capturing past displacement events? ➡ Evaluation of the global flood modeling chain

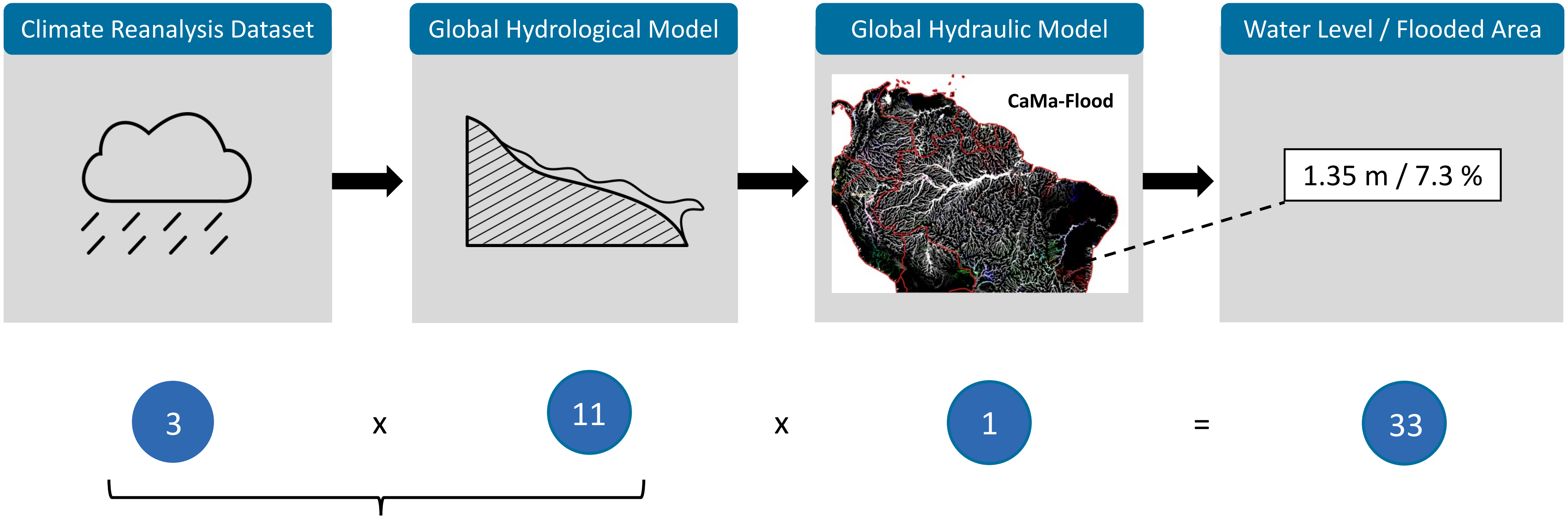
2. How does the vulnerability to flood-induced displacement depend on socio-economic factors? ➡ Past displacement vulnerability



The Uncertainties of Modeling

3. Evaluation of the Global Flood Modeling Chain

3. Evaluation of the Global Flood Modeling Chain

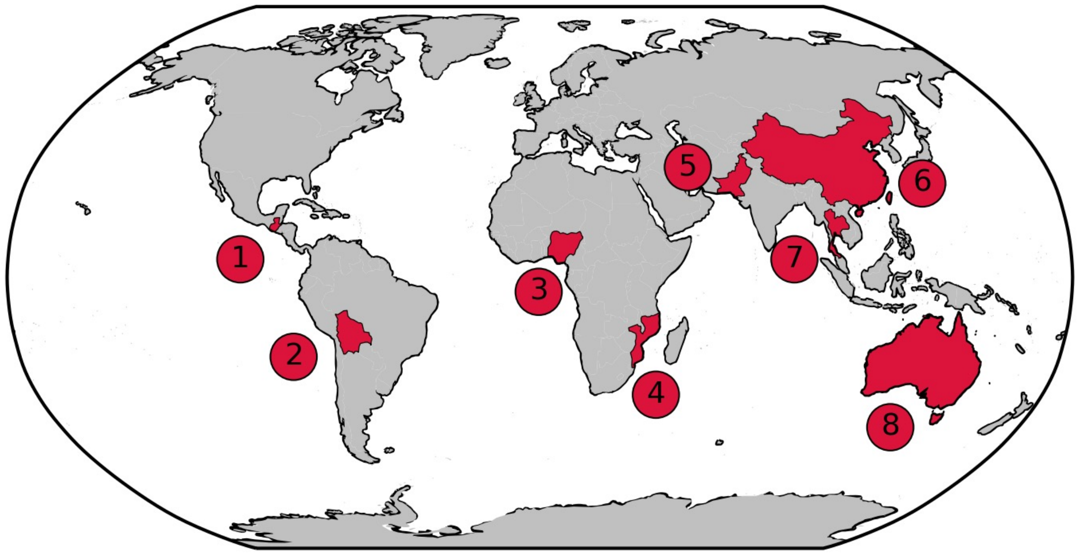


ISIMIP
Inter-Sectoral Impact Model
Intercomparison Project

3. Evaluation of the Global Flood Modeling Chain

Case Study

- Eight major floods on four continents, covering a variety of climates and hydraulic characteristics
- Evaluation using model agreement maps and spatial performance metrics
- Testing the effect of a flood-volume adjustment procedure („adjust“) (Kim et., 2009; Hirabayashi et al., 2013) and the inclusion of spatially explicit flood protection levels („protect“) (Scussolini et al., 2016)



Country shapes by www.gadm.org

3. Evaluation of the Global Flood Modeling Chain

Validation with MODIS satellite imagery

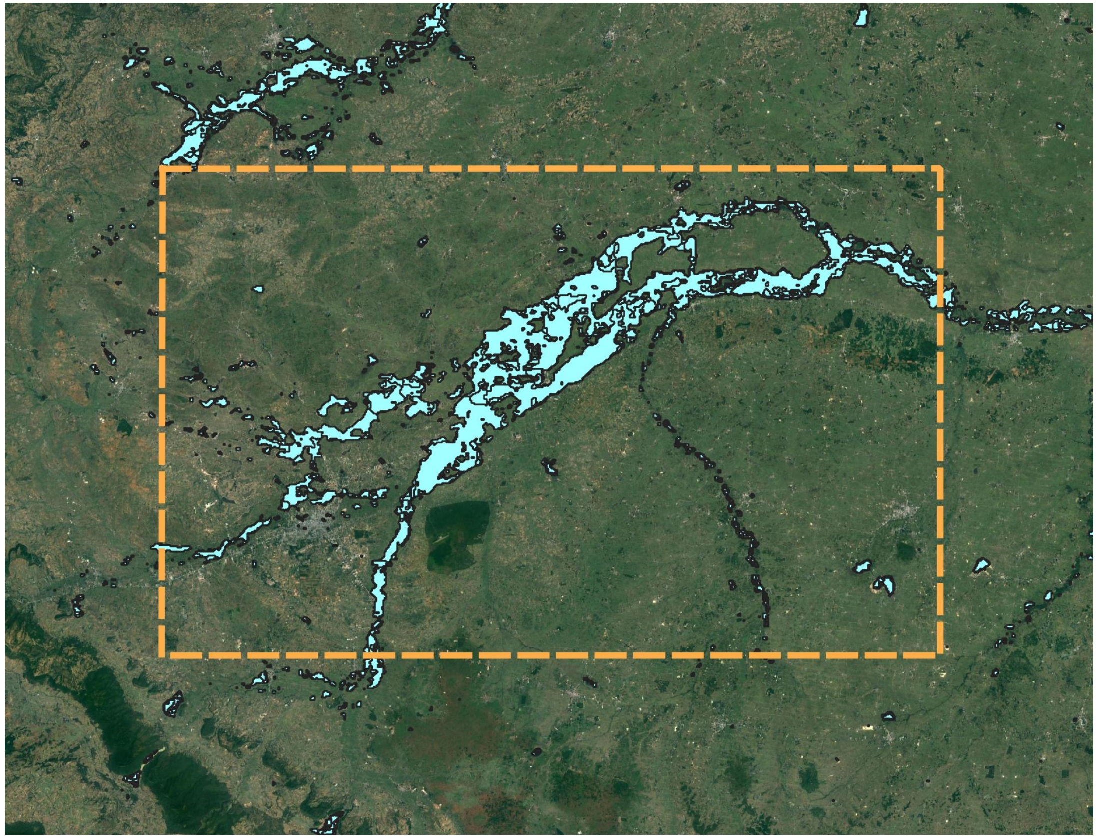
Example:

Flooding in the Mun River Basin

Phimai in Thailand (2010)

turquoise = flooded area

yellow = area of interest



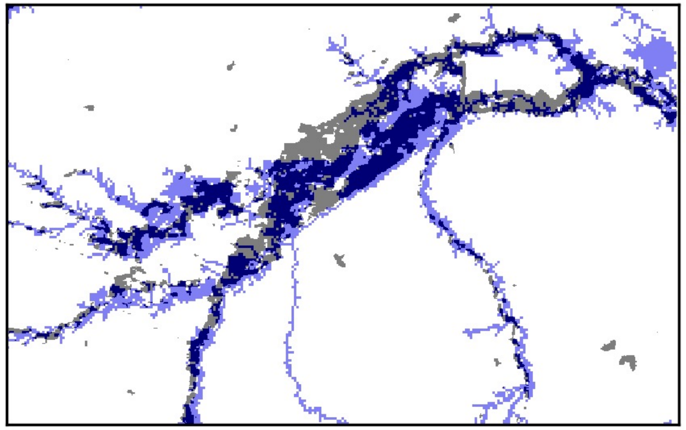
Satellite Data:
Dartmouth Flood Observatory (DFO) (https://floodobservatory.colorado.edu/) (Brakenridge 2006)
UNOSAT Flood Portal (UFP) (http://floods.unosat.org/geoportal/catalog/main/home.page

3. Evaluation of the Global Flood Modeling Chain

Results – Model Agreement Maps

Thailand (Mun River, 2010) – Model agreement of 1 x hydrological model with „PGFv2“ forcing:

PGFv2

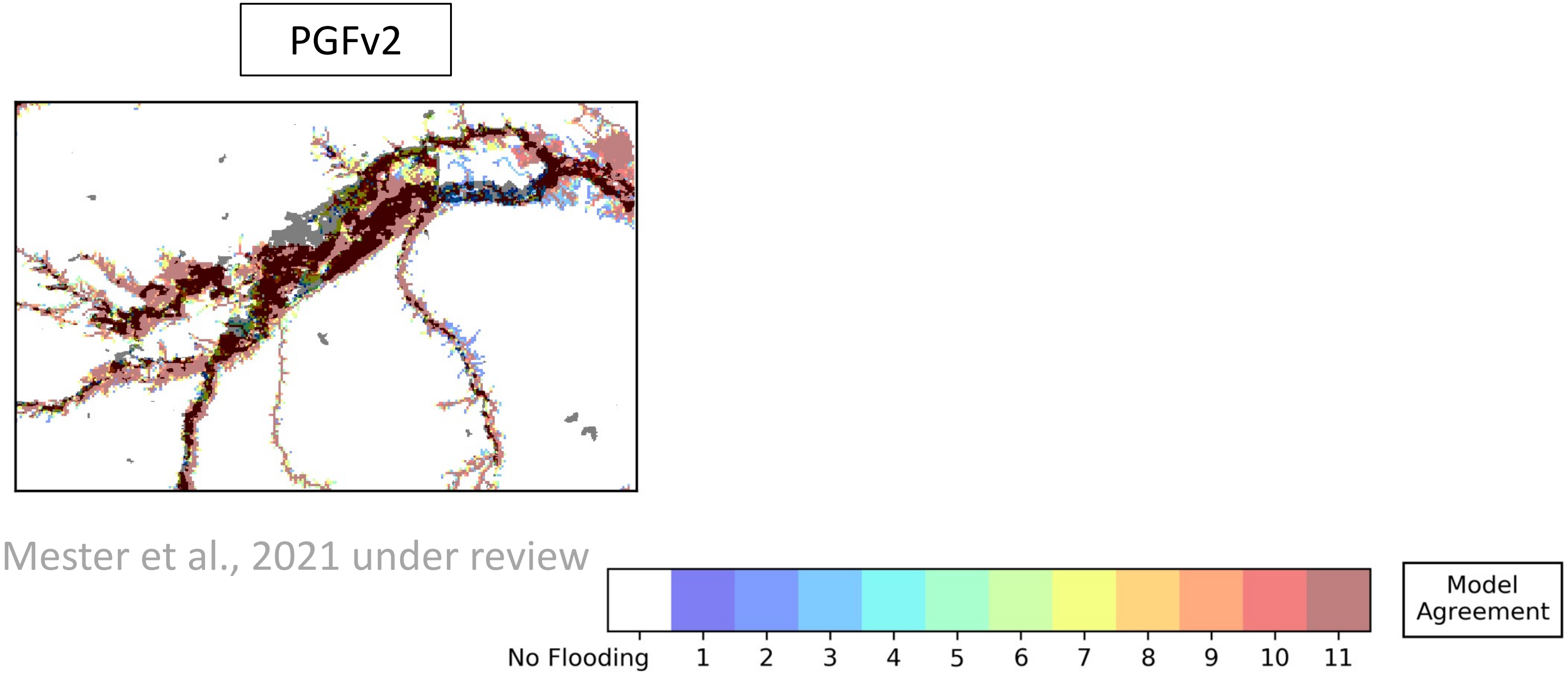


Mester et al., 2021 under review

3. Evaluation of the Global Flood Modeling Chain

Results – Model Agreement Maps

Thailand (Mun River, 2010) – Model agreement of 11 x hydrological models with „PGFv2“ forcing :

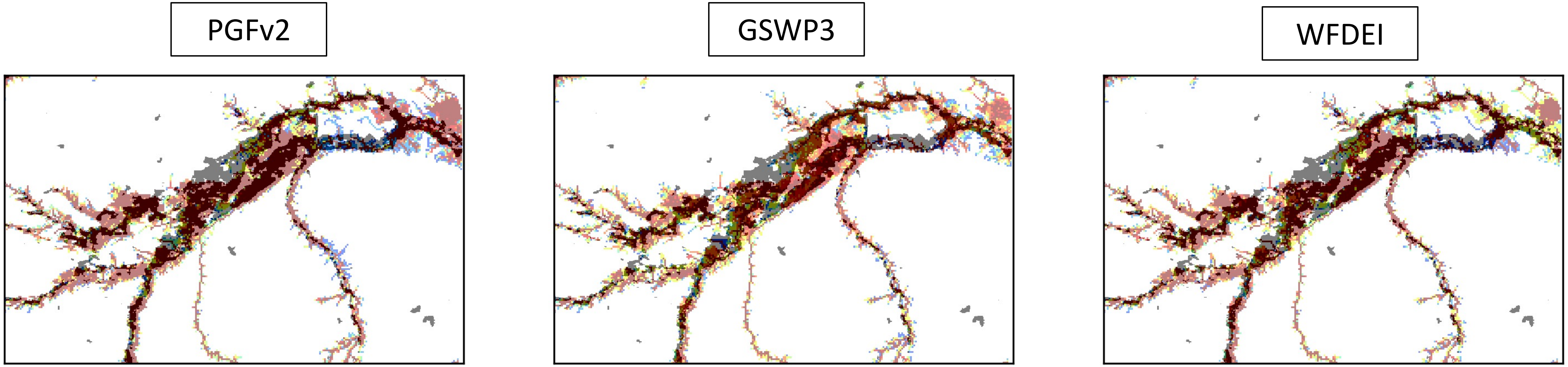


Mester et al., 2021 under review

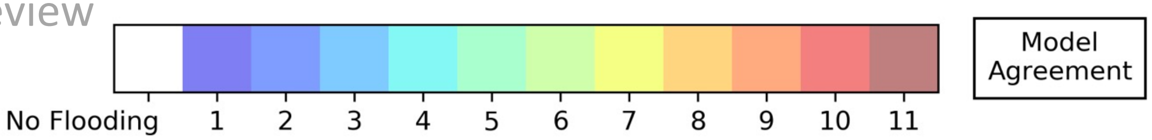
3. Evaluation of the Global Flood Modeling Chain

Results – Model Agreement Maps

Thailand (Mun River, 2010) – Model agreement of 11 x hydrological models with three forcings:



Mester et al., 2021 under review



3. Evaluation of the Global Flood Modeling Chain

Results – Spatial Performance Metrics

Critical Success Index (CSI)

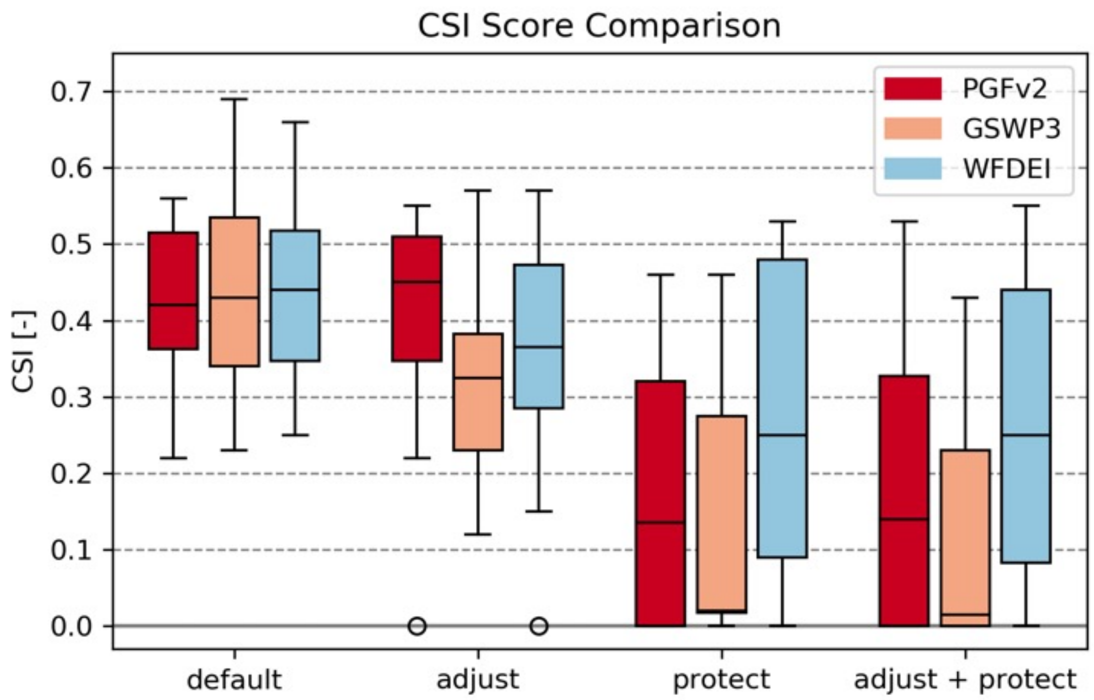
$$CSI = \frac{F_m \cap F_o}{F_m \cup F_o}$$

F_m = modelled flooded area
F_o = observed flooded area (MODIS)

GSWP3	CLM	DBH	H08	JULES-W1	LPJmL	MATSIRO	MPI-HM	ORCHIDEE	PCR-GLOBWB	VIC	WaterGAP2	Median GHMs	Min. GHMs	Max. GHMs	Spread GHMs
Sayaxché (GTM)	0.53	0.56	0.54	0.56	0.55	0.58	0.54	0.54	0.56	0.55	0.56	0.55	0.53	0.58	0.05
Trinidad (BOL)	0.53	0.54	0.54	0.53	0.54	0.49	0.53	0.54	0.53	0.46	0.53	0.53	0.46	0.54	0.08
Chemba (MOZ)	0.69	0.71	0.70	0.60	0.71	0.53	0.70	0.62	0.71	0.00	0.53	0.69	0.00	0.71	0.71
Alipur (PAK)	0.32	0.33	0.36	0.33	0.35	0.33	0.35	0.35	0.36	0.35	0.37	0.35	0.32	0.37	0.05
Ghotki (PAK)	0.34	0.40	0.44	0.35	0.35	0.42	0.43	0.34	0.42	0.40	0.34	0.40	0.34	0.44	0.10
Phimai (THA)	0.46	0.45	0.42	0.50	0.47	0.41	0.47	0.46	0.45	0.43	0.46	0.46	0.41	0.50	0.09
Huainan (CHN)	0.28	0.28	0.29	0.33	0.30	0.38	0.31	0.31	0.28	0.31	0.32	0.31	0.28	0.38	0.10
Dalby (AUS)	0.23	0.18	0.24	0.18	0.20	0.23	0.25	0.22	0.22	0.26	0.25	0.23	0.18	0.26	0.08
Median Region	0.40	0.43	0.43	0.42	0.41	0.42	0.45	0.40	0.44	0.38	0.42	0.43	0.33	0.47	0.09

Mester et al., 2021 under review

3. Results – Spatial Performance Metrics



➡ **A multi-model, multi-forcing ensemble approach** (such as ours) is recommended when there is no prior knowledge about a certain combination's performance for the specific type of region

Mester et al., 2021 under review

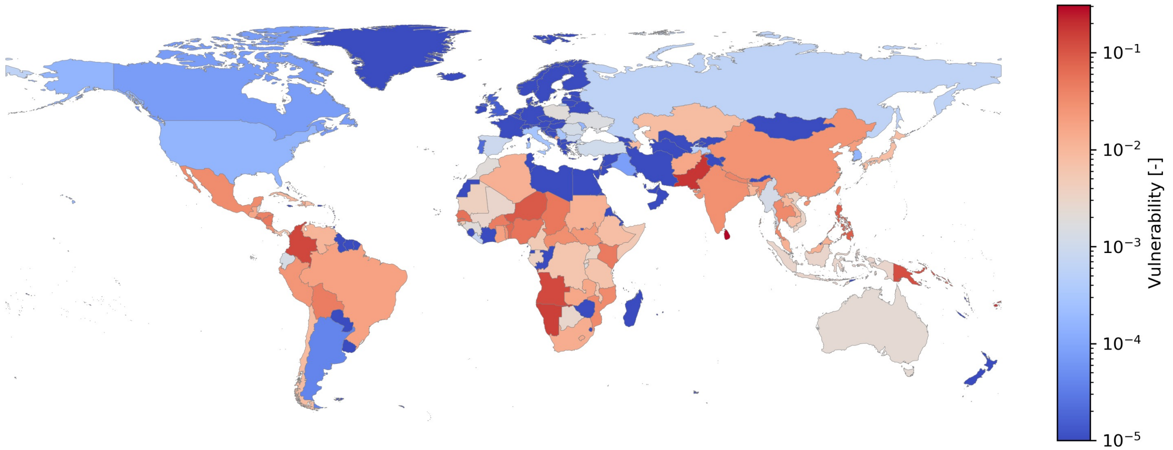
Outlook

4. Displacement Vulnerability

4. Displacement Vulnerability

- Determine global flood displacement vulnerability
- Establish a vulnerability function and find patterns in data using (non-)linear multivariate analysis and Machine Learning algorithms
- Using on a set of predictors of different categories:

  - **Economy**: GDP, government debt, ..
  - **Politics and Legislation**: democracy index, ..
  - **Demography**: age cohorts, population growth, ..
  - **Society**: social equality, poverty, education, ..
  - ..



References

Photo by Gideon Mendel http://gideonmendel.com/submerged-portraits/

Photo by Justin McManus/The Age/Fairfax Media via Getty Images https://medias.liberation.fr/photo/1283544-australian-bushfire-coverage.jpg?modified_at=1578335061&width=960

https://www.internal-displacement.org/global-report/grid2020/img/2020/versions/displacements-worldwide-bar-countries-disasters-top-5-dl.png

https://www.internal-displacement.org/global-report/grid2020/

Ghimire, R., Ferreira, S., & Dorfman, J. H. 2015 Flood-induced displacement and civil conflict. *World Development*, *66*, 614–628. https://doi.org/10.1016/j.worlddev.2014.09.021

Dottori F, Szewczyk W, Ciscar J C, Zhao F, Alfieri L, Hirabayashi Y, Bianchi A, Mongelli I, Frieler K, Betts R A and Feyen L 2018 Increased human and economic losses from river flooding with anthropogenic warming Nat. Clim. Chang. 8 781–6

Jongman B, Winsemius H C, Aerts J C J H, Coughlan De Perez E, Van Aalst M K, Kron W and Ward P J 2015 Declining vulnerability to river floods and the global benefits of adaptation Proc. Natl. Acad. Sci. U. S. A. 112 E2271–80

Tanoue M, Hirabayashi Y and Ikeuchi H 2016 Global-scale river flood vulnerability in the last 50 years Sci. Rep. 6 1–8

Willner S N, Otto C and Levermann A 2018 Global economic response to river floods Nat. Clim. Chang. 8 594–8

IPCC 2013 IPCC CLIMATE CHANGE 2013 Climate Change 2013 Online: https://www.researchgate.net/profile/Abha_Chhabra2/publication/271702872_Carbon_and_Other_Biogeochemical_Cycles/links/54cf9ce80cf24601c094a45e/Carbon-and-Other-Biogeochemical-Cycles.pdf

IPCC 2012 Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change vol 9781107025 ((eds. Field, C. B. et al.) Cambridge Univ. Press)

References

McNamara, K. E. and H. J. Des Combes, 2015: Planning for Community Relocations Due to Climate Change in Fiji. International Journal of Disaster Risk Science, 6 (3), 315-319, doi:10.1007/s13753-015-0065-2.

Wadey, M., S. Brown, R. J. Nicholls and I. Haigh, 2017: Coastal flooding in the Maldives: an assessment of historic events and their implications. Natural Hazards, 89 (1), 131-159, doi:10.1007/s11069-017-2957-5.

Albert, S. et al., 2016: Interactions between sea-level rise and wave exposure on reef island dynamics in the Solomon Islands. Environmental Research Letters, 11 (5), doi:10.1088/1748-9326/11/5/054011.

Heslin, A., & Thalheimer, L. 2020 The picture from above: Using satellite imagery to overcome methodological challenges in studying environmental displacement. Oxford Monitor of Forced Migration, 8(2), 75–87.

Mengel, M., Treu, S., Lange, S., and Frieler, K.: ATTRICI 1.0 – counterfactual climate for impact attribution, Geosci. Model Dev. Discuss. [preprint], https://doi.org/10.5194/gmd-2020-145, in review, 2020.

Yamazaki D, Kanae S, Kim H and Oki T 2011 A physically based description of floodplain inundation dynamics in a global river routing model Water Resour. Res. 47 1–21

Brakenridge G R 2006 “Global Active Archive of Large Flood Events”, Dartmouth Flood Observatory, University of Colorado Online: http://floodobservatory.colorado.edu/Archives/index.html

Kim H, Yeh P J-F, Oki T and Kanae S 2009 Role of rivers in the seasonal variations of terrestrial water storage over global basins Geophys. Res. Lett. 36 Online: https://doi.org/10.1029/2009GL039006

Hirabayashi Y, Mahendran R, Koirala S, Konoshima L, Yamazaki D, Watanabe S, Kim H and Kanae S 2013 Global flood risk under climate change Nat. Clim. Chang. 3 816–21

Scussolini P, Aerts J C J H, Jongman B, Bouwer L M, Winsemius H C, De Moel H and Ward P J 2016 FLOPROS: an evolving global database of flood protection standards Nat. Hazards Earth Syst. Sci. 16 1049–61

Mester B, Willner S N, Frieler K, Schewe J 2021 Evaluation of river flood extent simulated with multiple global hydrological models and climate forcings Submitted and under review in Environmental Research Letters

Questions & Answers

Email: benedikt.mester@pik-potsdam.de