Sensitivity of global river flood simulations to the choice of climate forcing and hydrological model

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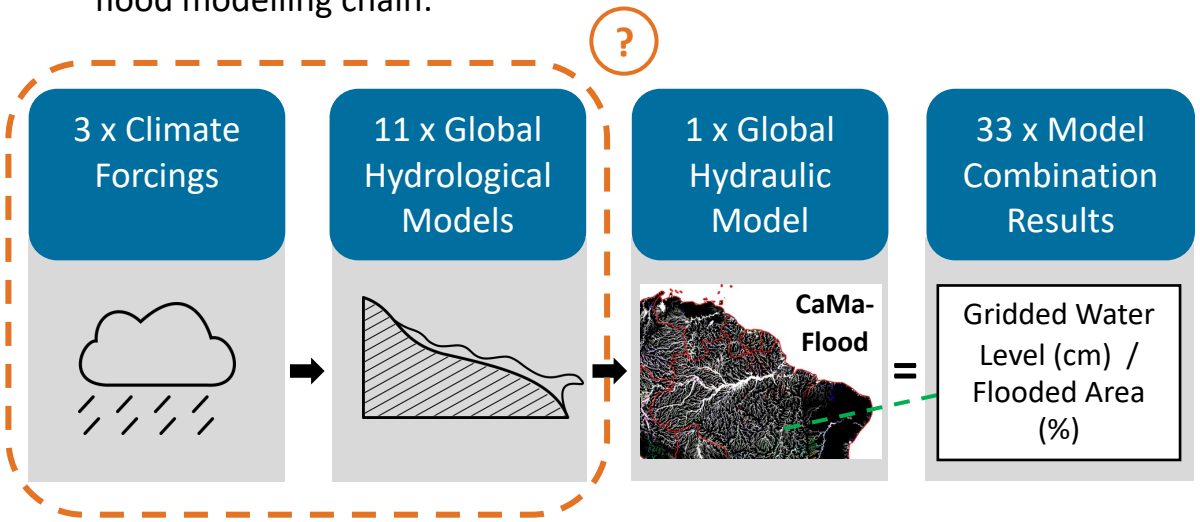
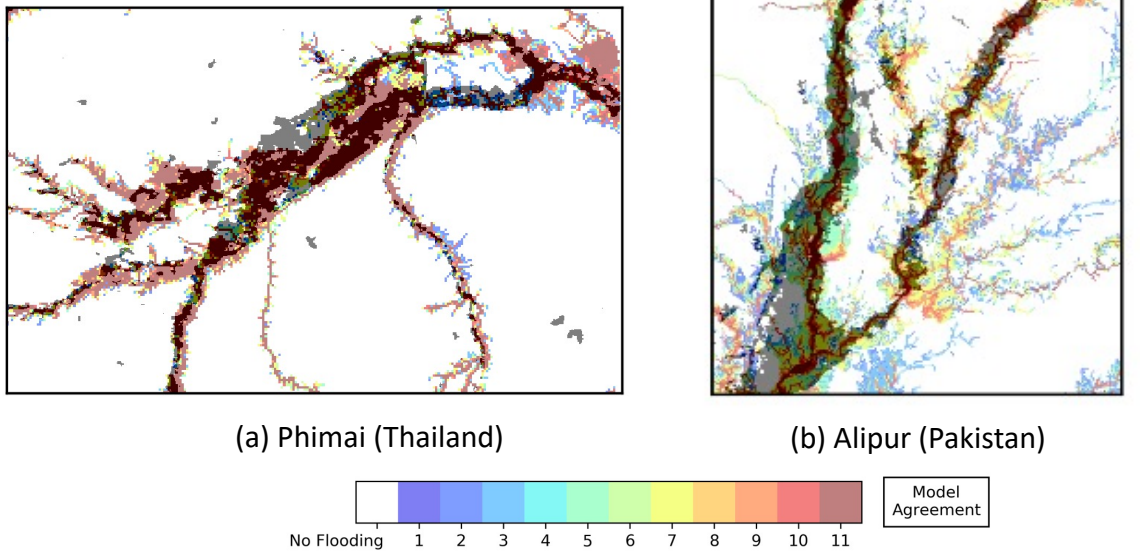
1. **Background:** Uncertainties regarding the input products of the global flood modelling chain:



2. **Case Study:** Eight historical flood events spread over four continents and various climate zones
3. **Method:** Evaluate input sensitivity by comparing simulated flood extent to satellite imagery using model agreement maps and spatial performance metrics

4. **Results (extract):**



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5. **Conclusion:** (a) **For most events**, the simulated inundation extent is **relatively insensitive** to the choice of climate forcing and global hydrological model (b) **For some events**, however, individual combinations lead to **much lower agreement with observations** than the others, mostly resulting from an overestimation of inundated areas.

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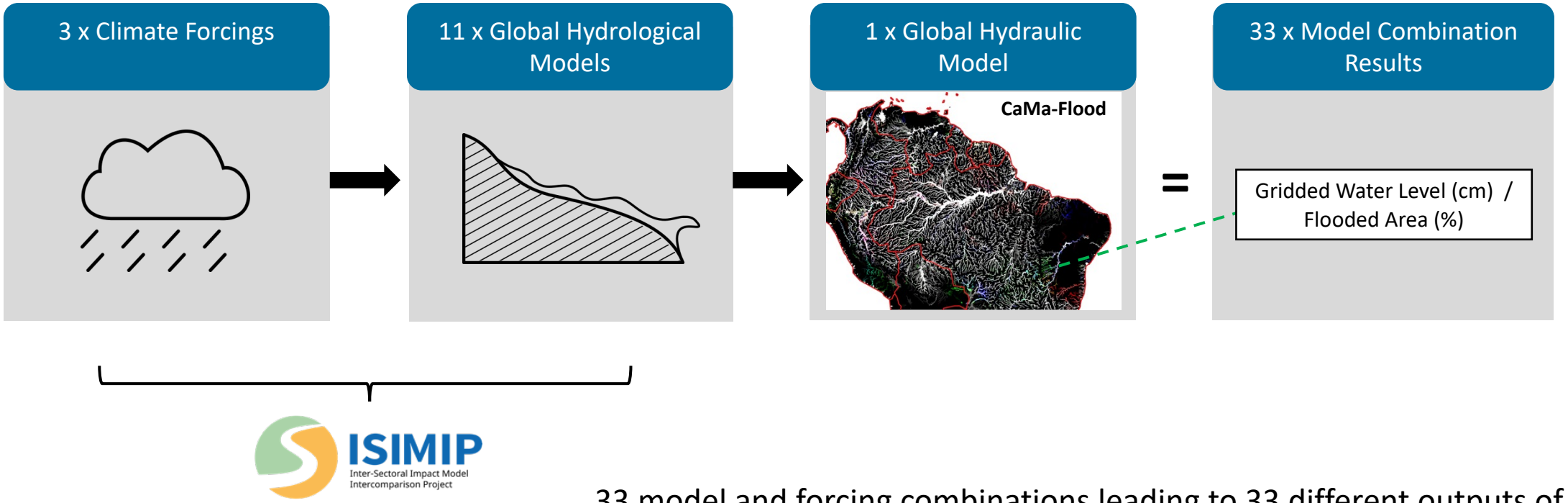
vEGU21 – Session NH9.1 - 'Natural hazards and vulnerable societies – perspectives on natural hazard risk methods, data, interactions, and practice from global to local scales'

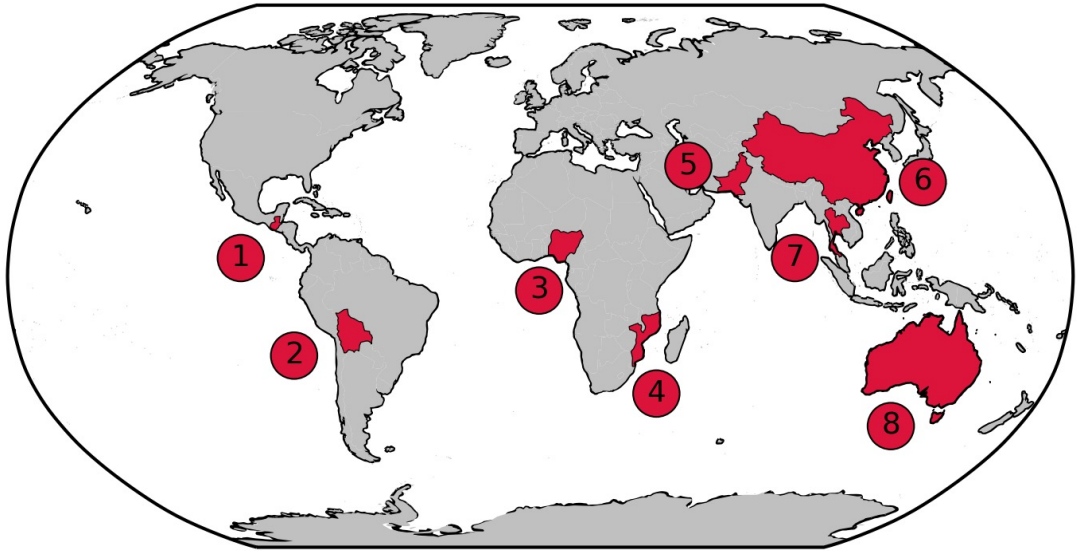
1. Global Flood-Modelling Chain



33 model and forcing combinations leading to 33 different outputs of the global flood model CaMa-Flood (Yamazaki et al., 2011). Are the input products interchangeable or are some combinations to be favored?

2. Case Study - Overview

- 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 gadm.org

3. Case Study - Validation with MODIS satellite imagery

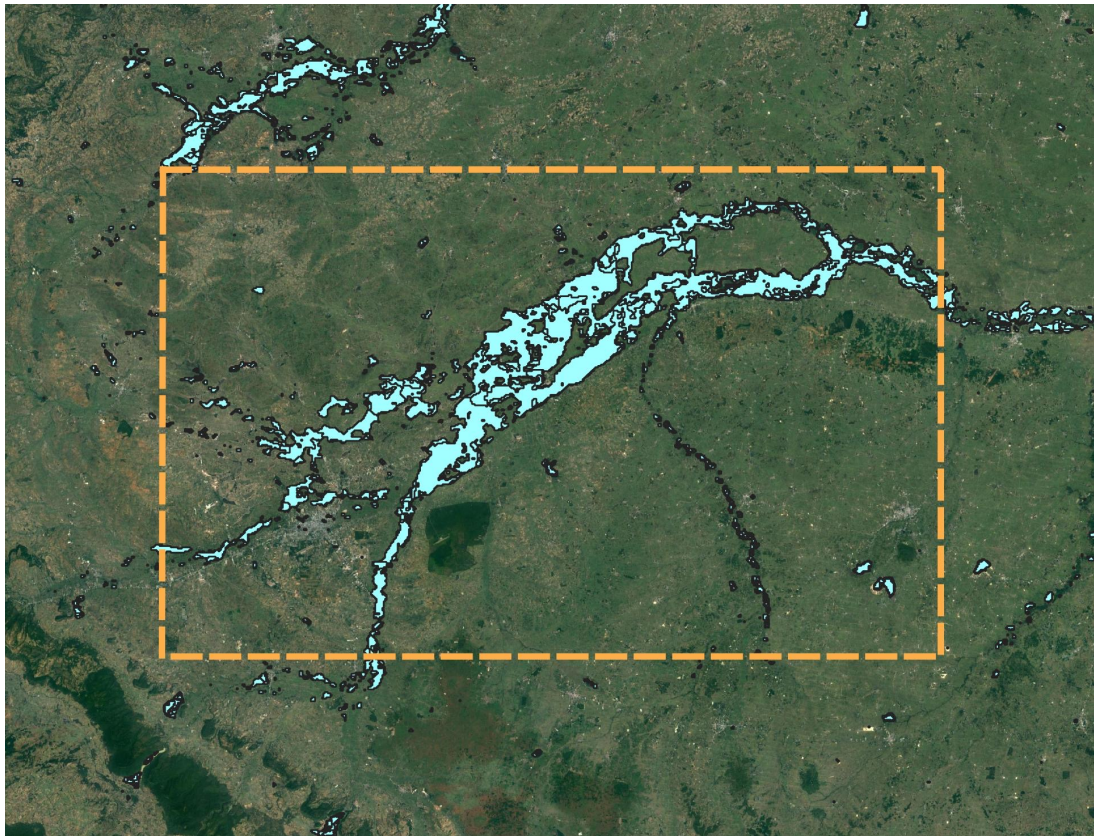
Example:

Flooding in the Mun River Basin

Phimai in Thailand (2010)

turquoise = flooded area

yellow = area of interest

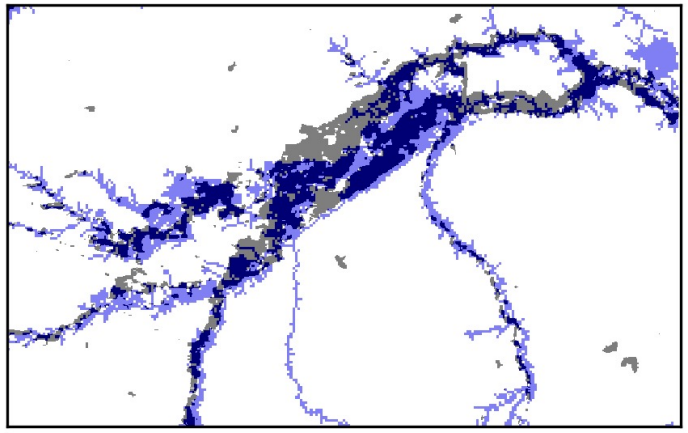


Satellite Data:
Dartmouth Flood Observatory (DFO) (https://floodobservatory.colorado.edu/) (Brakenridge 2006)
UNOSAT Flood Portal (UFP) (http://floods.unosat.org/geoportal/catalog/main/home.page

4. Results – Model Agreement Maps

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

PGFv2



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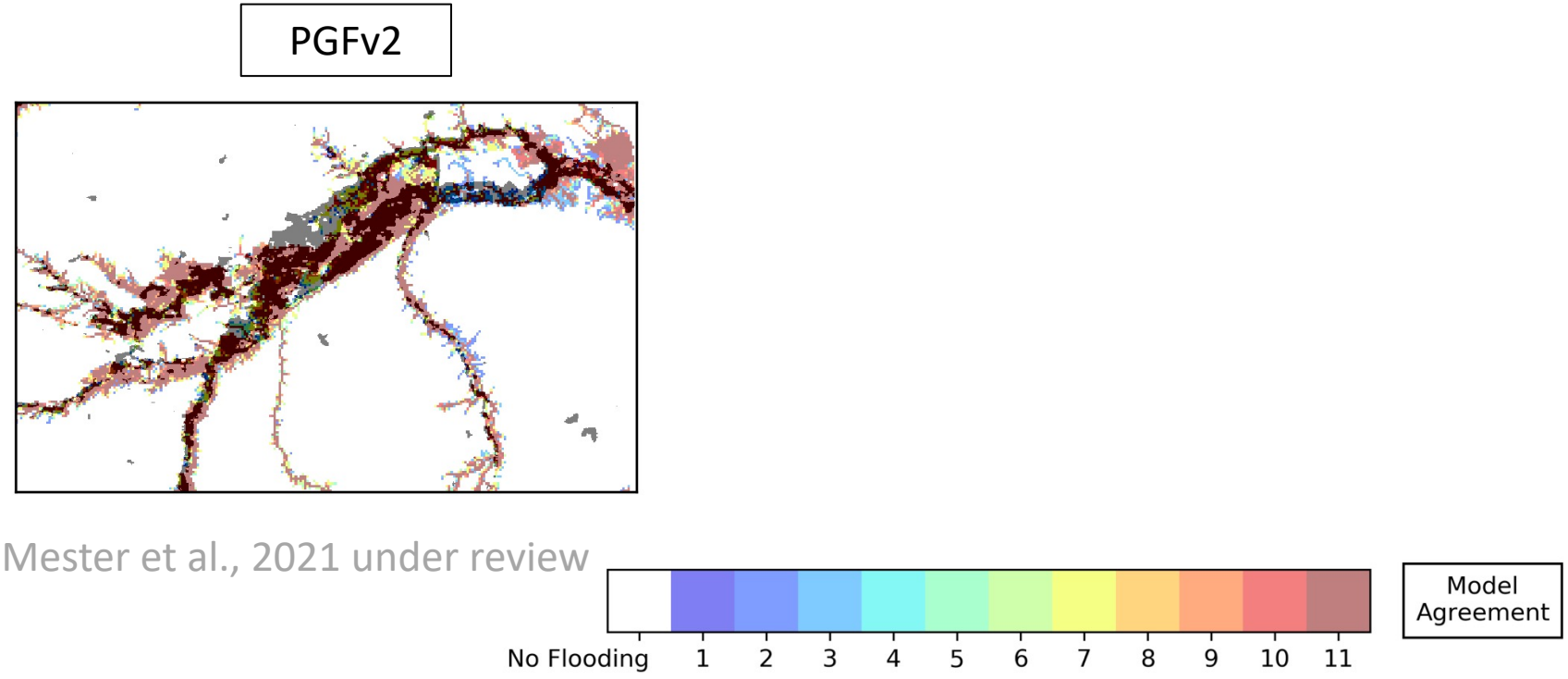
4. Results – Model Agreement Maps

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



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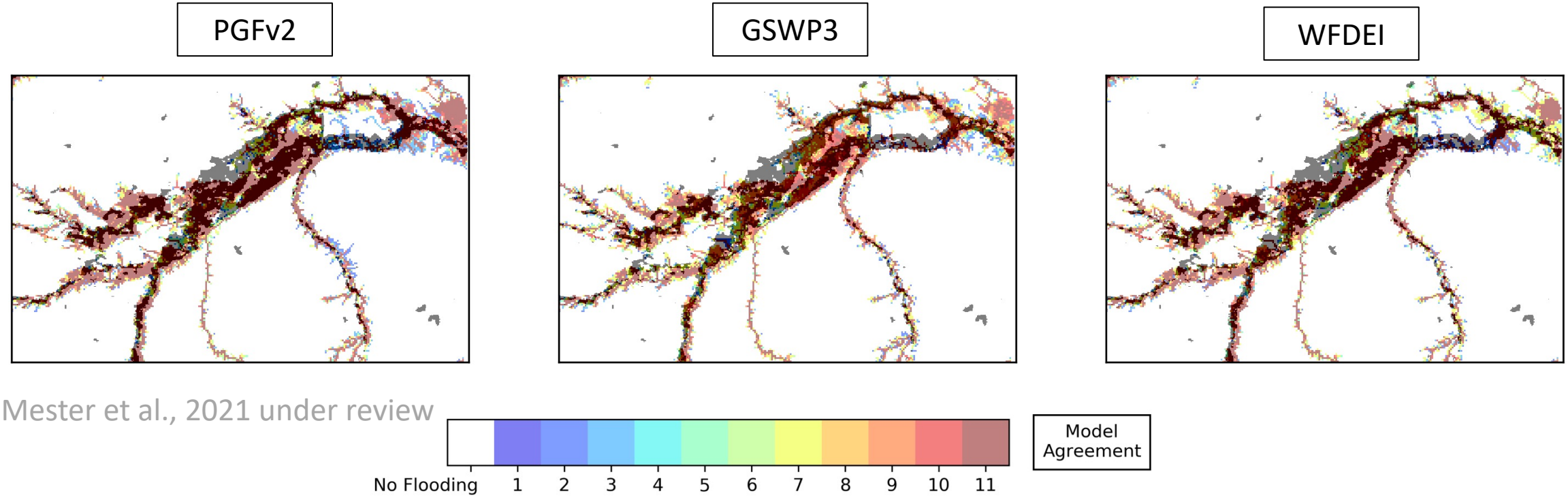
4. Results – Model Agreement Maps

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



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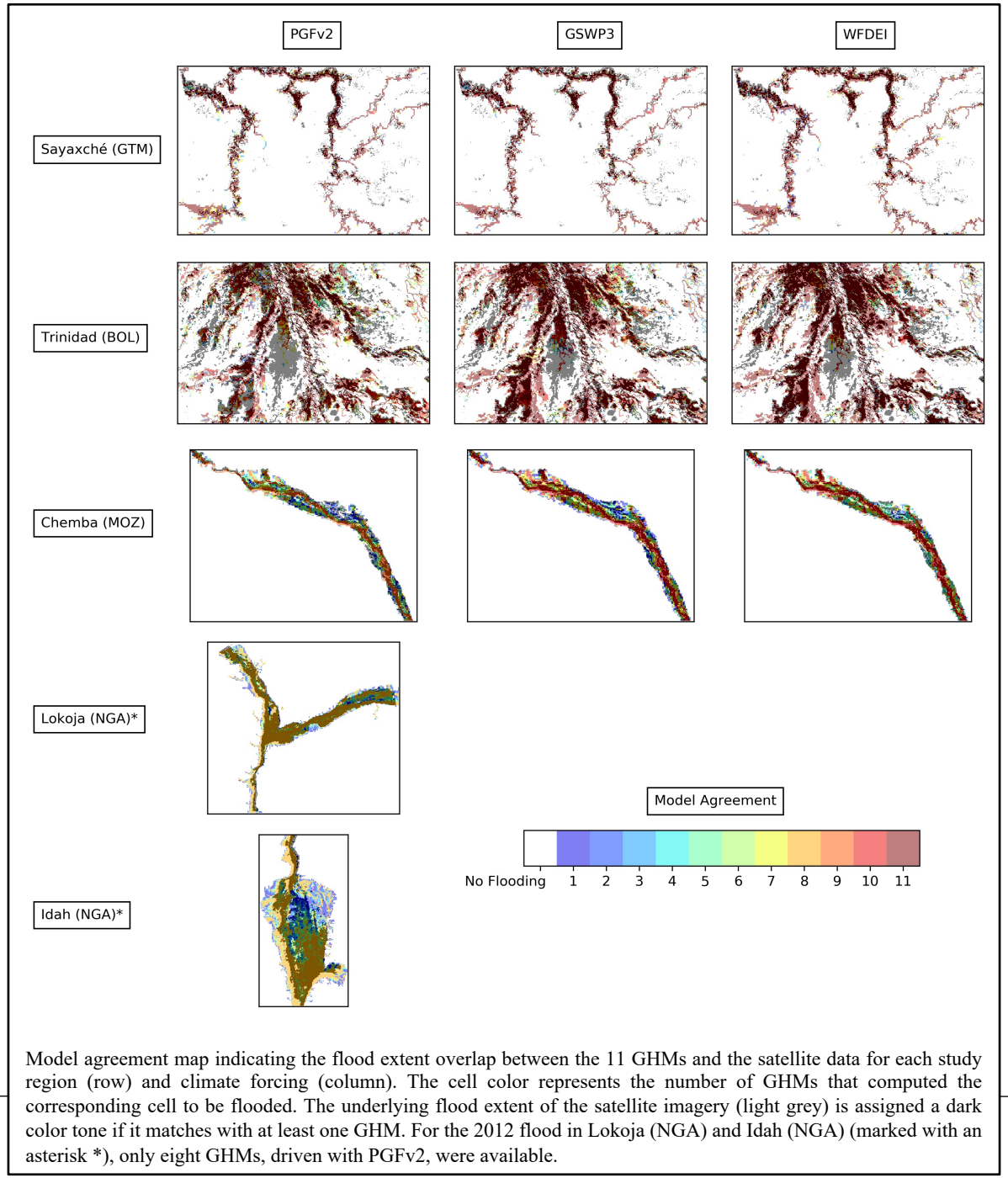
4. Results



Model agreement map indicating the flood extent overlap between the 11 GHMs and the satellite data for each study region (row) and climate forcing (column). The cell color represents the number of GHMs that computed the corresponding cell to be flooded. The underlying flood extent of the satellite imagery (light grey) is assigned a dark color tone if it matches with at least one GHM. For the 2012 flood in Lokoja (NGA) and Idah (NGA) (marked with an asterisk *), only eight GHMs, driven with PGFv2, were available.

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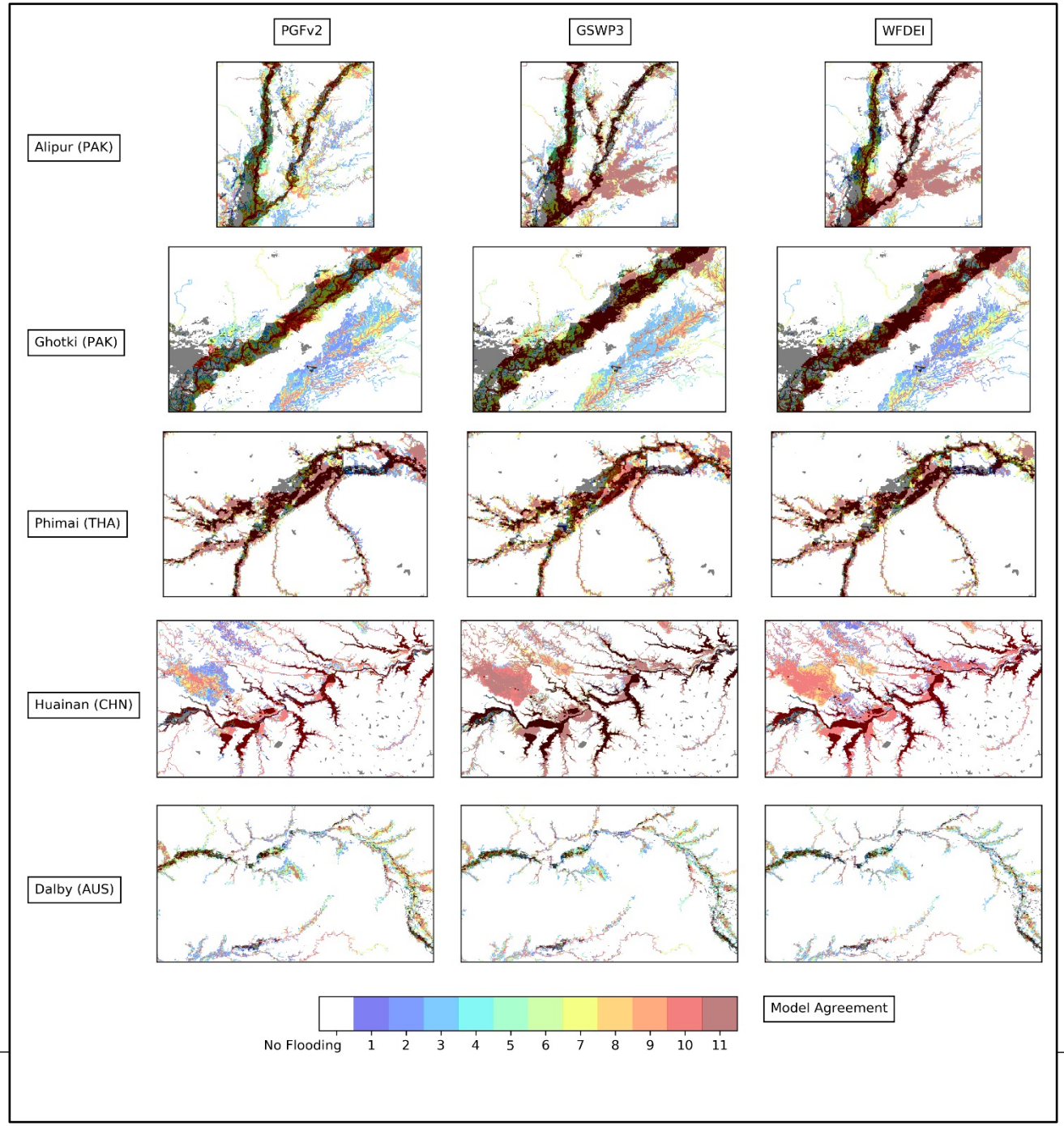
4. Results



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4. Results

PGFv2	CLM	DBH	H08	JULES-W1	LPJmL	MATSIRO	MPI-HM	ORCHIDEE	PCR-GLOBWB	VIC	WaterGAP2	Median GHMs	Min. GHMs	Max. GHMs	Spread GHMs
Sayaxché (GTM)	0.52	0.55	0.52	0.53	0.53	0.56	0.52	0.52	0.54	0.53	0.56	0.53	0.52	0.56	0.04
Trinidad (BOL)	0.47	0.51	0.52	0.50	0.51	0.34	0.52	0.51	0.48	0.43	0.51	0.51	0.34	0.52	0.18
Chemba (MOZ)	0.43	0.71	0.68	0.67	0.67	0.00	0.40	0.71	0.53	0.00	0.56	0.56	0.00	0.71	0.71
Alipur (PAK)	0.23	0.37	0.39	0.35	0.40	0.11	0.34	0.36	0.44	0.39	0.38	0.37	0.11	0.44	0.33
Ghotki (PAK)	0.20	0.34	0.42	0.34	0.35	0.11	0.34	0.32	0.43	0.38	0.41	0.34	0.11	0.43	0.32
Phimai (THA)	0.44	0.46	0.41	0.50	0.47	0.49	0.45	0.45	0.44	0.43	0.50	0.45	0.41	0.50	0.09
Huainan (CHN)	0.38	0.34	0.39	0.38	0.39	0.46	0.43	0.42	0.32	0.39	0.40	0.39	0.32	0.46	0.14
Dalby (AUS)	0.24	0.17	0.22	0.16	0.19	0.24	0.24	0.20	0.21	0.26	0.26	0.22	0.16	0.26	0.10
Lokoja (NGA)*	-	-	0.73	0.74	0.74	0.74	0.76	0.68	0.72	-	0.75	0.74	0.68	0.76	0.08
Idah (NGA)*	-	-	0.66	0.69	0.69	0.60	0.70	0.60	0.60	-	0.69	0.68	0.60	0.70	0.10
Median Region	0.40	0.42	0.42	0.44	0.44	0.29	0.42	0.44	0.44	0.39	0.45	0.42	0.24	0.48	0.16

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

WFDEI	CLM	DBH	H08	JULES-W1	LPJmL	MATSIRO	MPI-HM	ORCHIDEE	PCR-GLOBWB	VIC	WaterGAP2	Median GHMs	Min. GHMs	Max. GHMs	Spread GHMs
Sayaxché (GTM)	0.52	0.53	0.50	0.51	0.51	0.53	0.50	0.51	0.53	0.51	0.52	0.51	0.50	0.53	0.03
Trinidad (BOL)	0.53	0.53	0.54	0.54	0.54	0.53	0.54	0.54	0.54	0.51	0.53	0.54	0.51	0.54	0.03
Chemba (MOZ)	0.65	0.71	0.70	0.61	0.71	0.55	0.66	0.71	0.71	0.00	0.49	0.66	0.00	0.71	0.71
Alipur (PAK)	0.27	0.36	0.37	0.38	0.36	0.30	0.36	0.34	0.37	0.31	0.38	0.36	0.27	0.38	0.11
Ghotki (PAK)	0.37	0.34	0.48	0.40	0.35	0.47	0.47	0.37	0.44	0.42	0.41	0.41	0.34	0.48	0.14
Phimai (THA)	0.47	0.46	0.41	0.50	0.47	0.49	0.47	0.47	0.46	0.45	0.49	0.47	0.41	0.50	0.09
Huainan (CHN)	0.29	0.28	0.30	0.32	0.31	0.37	0.33	0.32	0.27	0.31	0.31	0.31	0.27	0.37	0.10
Dalby (AUS)	0.25	0.18	0.24	0.20	0.20	0.27	0.25	0.25	0.22	0.26	0.27	0.25	0.18	0.27	0.09
Median Region	0.42	0.41	0.44	0.45	0.42	0.48	0.47	0.42	0.45	0.36	0.45	0.44	0.31	0.49	0.10

CSI

Critical successs index (CSI) scores for all combinations of GHMs and PGFv2 (top), GSWP3 (middle), and WFDEI (bottom) forcing. The "Median Region" across the even number of regions is calculated as the mean of the two middle values. Lokoja (NGA) and Idah (NGA) (marked with *) were excluded from the computation of the "Median Region". "-" means no input data was available and a black box indicates the best-performing GHM(s) for a given region.

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4. Results

PGFv2	CLM	DBH	H08	JULES-W1	LPJmL	MATSIRO	MPI-HM	ORCHIDEE	PCR-GLOBWB	VIC	WaterGAP2	Median GHMs	Min. GHMs	Max. GHMs	Spread GHMs
Sayaxché (GTM)	0.28	0.18	0.29	0.23	0.25	0.17	0.29	0.28	0.22	0.25	0.17	0.25	0.17	0.29	0.12
Trinidad (BOL)	-0.15	-0.04	0.03	-0.08	-0.01	-0.38	0.01	-0.02	-0.12	-0.22	-0.04	-0.04	-0.38	0.03	0.41
Chemba (MOZ)	-0.38	0.03	-0.04	-0.06	-0.06	-1.00	-0.41	0.07	-0.26	-1.00	-0.23	-0.23	-1.00	0.07	1.07
Alipur (PAK)	-0.44	0.59	0.21	0.67	0.40	-0.76	-0.25	0.01	0.27	0.13	0.56	0.21	-0.76	0.67	1.43
Ghotki (PAK)	-0.38	0.48	-0.09	0.50	0.26	-0.80	-0.32	-0.24	0.09	-0.02	0.26	-0.02	-0.80	0.50	1.30
Phimai (THA)	0.46	0.38	0.58	0.17	0.33	0.30	0.42	0.45	0.42	0.50	0.21	0.42	0.17	0.58	0.41
Huainan (CHN)	0.46	0.70	0.44	0.50	0.43	0.13	0.30	0.34	0.72	0.44	0.36	0.44	0.13	0.72	0.59
Dalby (AUS)	0.41	2.25	1.32	2.30	1.70	0.17	0.84	1.71	1.50	0.63	0.61	1.32	0.17	2.30	2.13
Lokoja (NGA)*	-	-	0.16	0.06	0.13	-0.02	0.10	0.22	-0.04	-	0.07	0.09	-0.04	0.22	0.26
Idah (NGA)*	-	-	0.24	0.06	0.18	-0.08	0.12	0.32	-0.09	-	0.08	0.10	-0.09	0.32	0.41
Median Region	0.07	0.43	0.25	0.36	0.30	-0.12	0.15	0.18	0.24	0.19	0.24	0.23	-0.12	0.54	0.83

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)	0.27	0.17	0.24	0.17	0.20	0.10	0.23	0.23	0.16	0.21	0.16	0.20	0.10	0.27	0.17
Trinidad (BOL)	0.05	0.05	0.11	0.02	0.08	-0.09	0.10	0.09	0.02	-0.15	0.02	0.05	-0.15	0.11	0.26
Chemba (MOZ)	-0.02	0.09	0.12	-0.17	0.07	-0.27	0.00	0.22	0.06	-1.00	-0.26	0.00	-1.00	0.22	1.22
Alipur (PAK)	0.29	0.77	0.51	0.81	0.71	0.30	0.34	0.38	0.61	0.52	0.54	0.52	0.29	0.81	0.52
Ghotki (PAK)	-0.04	0.38	0.02	0.52	0.49	-0.14	-0.12	0.00	0.26	0.25	0.49	0.25	-0.14	0.52	0.66
Phimai (THA)	0.38	0.41	0.53	0.19	0.33	-0.19	0.37	0.39	0.41	0.47	-0.07	0.38	-0.19	0.53	0.72
Huainan (CHN)	1.14	1.06	1.02	0.74	0.94	0.60	0.95	0.90	1.09	0.85	0.84	0.94	0.60	1.14	0.54
Dalby (AUS)	0.38	2.06	0.88	1.98	1.62	0.87	0.02	1.33	1.40	0.39	0.50	0.88	0.02	2.06	2.04
Median Region	0.28	0.40	0.38	0.36	0.41	0.01	0.16	0.30	0.34	0.32	0.32	0.32	-0.06	0.52	0.60

WFDEI	CLM	DBH	H08	JULES-W1	LPJmL	MATSIRO	MPI-HM	ORCHIDEE	PCR-GLOBWB	VIC	WaterGAP2	Median GHMs	Min. GHMs	Max. GHMs	Spread GHMs
Sayaxché (GTM)	0.30	0.24	0.37	0.31	0.33	0.27	0.36	0.34	0.27	0.33	0.28	0.31	0.24	0.37	0.13
Trinidad (BOL)	0.01	0.05	0.09	0.04	0.07	0.00	0.07	0.07	0.04	-0.06	-0.01	0.04	-0.06	0.09	0.15
Chemba (MOZ)	-0.09	0.10	0.12	-0.17	0.07	-0.24	-0.07	0.09	0.05	-1.00	-0.31	-0.07	-1.00	0.12	1.12
Alipur (PAK)	0.27	0.59	0.50	0.50	0.66	0.27	0.37	0.24	0.49	0.33	0.52	0.49	0.24	0.66	0.42
Ghotki (PAK)	-0.03	0.47	0.10	0.19	0.42	-0.15	-0.08	-0.24	0.15	0.07	0.26	0.10	-0.24	0.47	0.71
Phimai (THA)	0.35	0.39	0.54	0.11	0.36	0.16	0.35	0.36	0.39	0.42	0.01	0.36	0.01	0.54	0.53
Huainan (CHN)	1.06	1.11	0.97	0.81	0.90	0.64	0.84	0.86	1.12	0.87	0.87	0.87	0.64	1.12	0.48
Dalby (AUS)	0.19	1.89	0.97	1.68	1.61	0.16	0.29	1.02	1.32	0.37	0.48	0.97	0.16	1.89	1.73
Median Region	0.23	0.43	0.44	0.25	0.39	0.16	0.32	0.29	0.33	0.33	0.27	0.34	0.08	0.50	0.51

Bias

Bias scores for all combinations of GHMs and PGFv2 (top), GSWP3 (middle), and WFDEI (bottom) forcing. Positive (negative) scores reflect an overprediction (underprediction) in simulated flood extent in comparison with satellite imagery. The “Median Region” across the even number of regions is calculated as the mean of the two middle values. Lokoja (NGA) and Idah (NGA) (marked with *) were excluded from the computation of the “Median Region”. “-“ means no input data was available and a black box indicates the best-performing GHM(s) for a given region.

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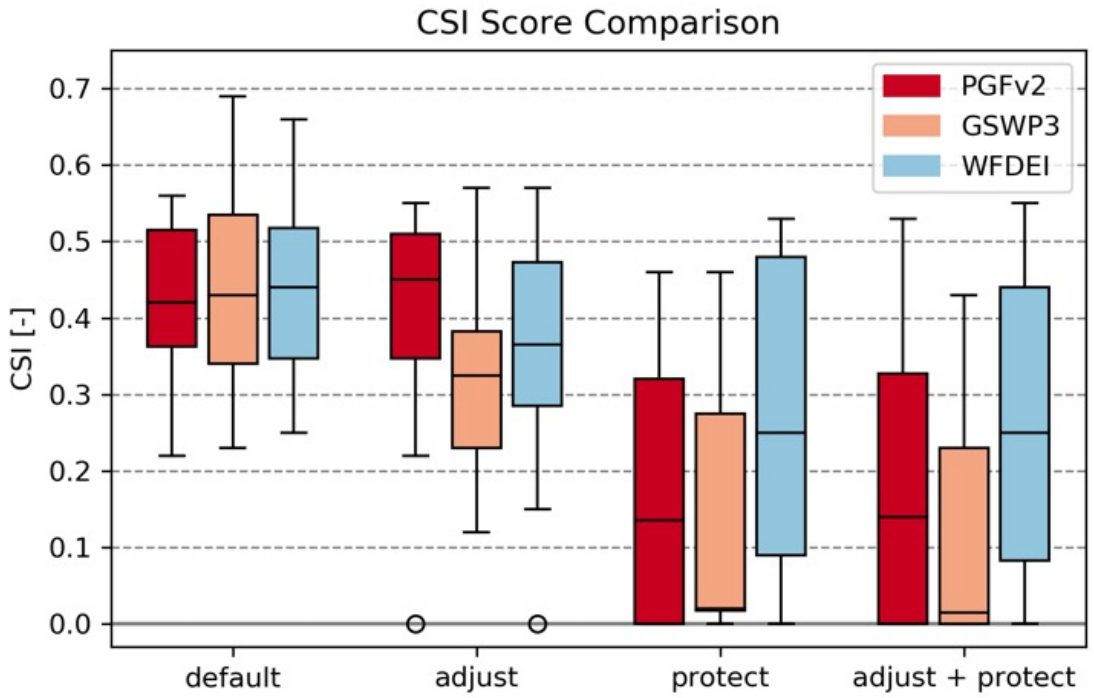
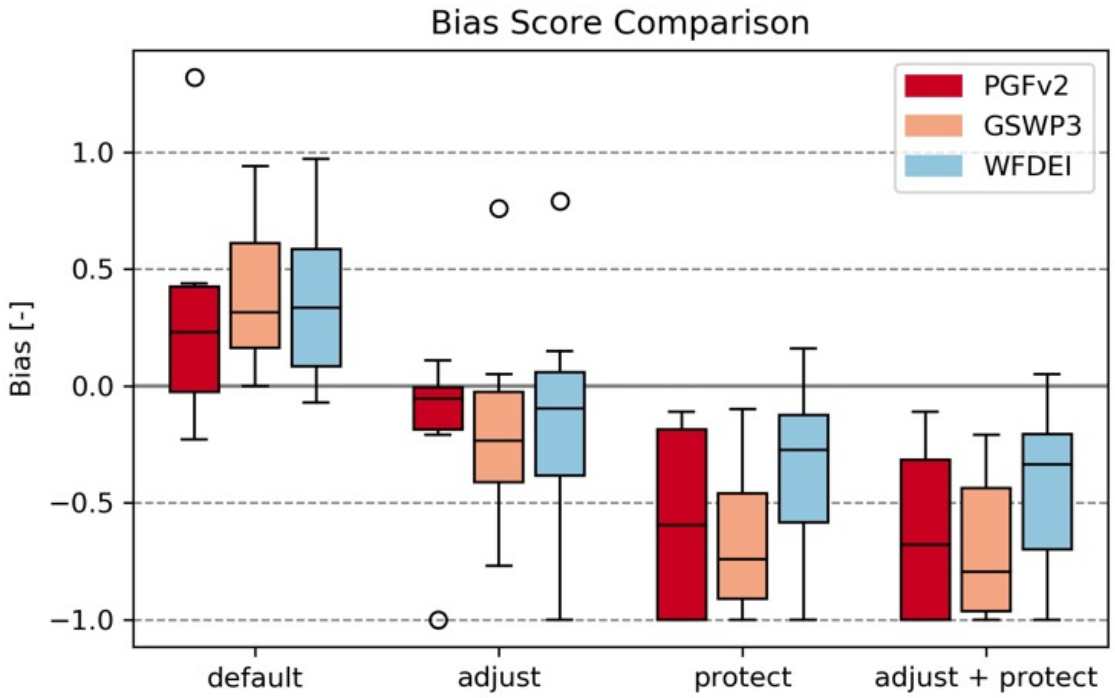
4. Results – Spatial Performance Metrics





Comparison of CSI and Bias scores between the default setting ("default"), flood-volume adjustment procedure ("adjust"), inclusion of spatially explicit flood protection levels of FLOPROS ("protect") and a combination of the latter two ("adjust + protect") for the climate forcings PGFv2, GSWP3 and WFDEI. The regions Lokoja (NGA) and Idah (NGA) were excluded from the computation.

Mester et al., 2021 under review

5. Conclusion

- For most events, the simulated inundation extent is relatively insensitive to the choice of climate forcing and global hydrological model. For some events, however, individual combinations lead to much lower agreement with observations than the others, mostly resulting from an overestimation of inundated areas
- Neither a flood volume adjustment procedure, nor accounting for flood protection, lead to clear improvements
- Bias Scores: Overestimation („default“) and underestimation („adjust“ and/or „protect“) of flood extent translate into high differences of simulated affected people

→ 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

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Questions & Answers

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