Photo: Annika Schlemm

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Possible role of climate change in the record-breaking 2020 Lake Victoria levels and floods

Rosa Pietroiusti, Inne Vanderkelen, Friederike E. L. Otto, Mary Akurut, Philippe Bally, Nicole P. M. van Lipzig, and Wim Thiery

Attributing the 2020 Lake Victoria floods in East Africa

Kenya floods kill 194, people evacuated from risk areas near dams

by Reuters
Wednesday, 6 May 2020 11:25 GMT

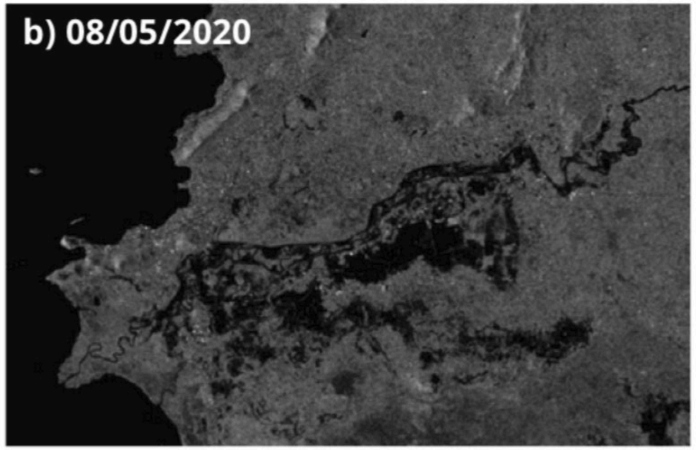
Lake Victoria now at record high 13.42 metres

The Independent · May 8, 2020 · The News Today · Leave a comment

→ Did climate change play a role?

Did anthropogenic climate change increase the **probability or intensity** of the flooding in the Lake Victoria area in mid-2020?

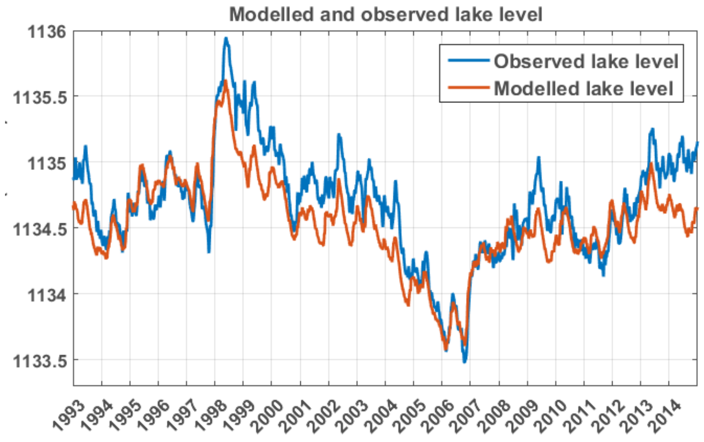
HASARD



1. Remote sensing

Modelling the water balance of Lake Victoria (East Africa) – Part 1: Observational analysis

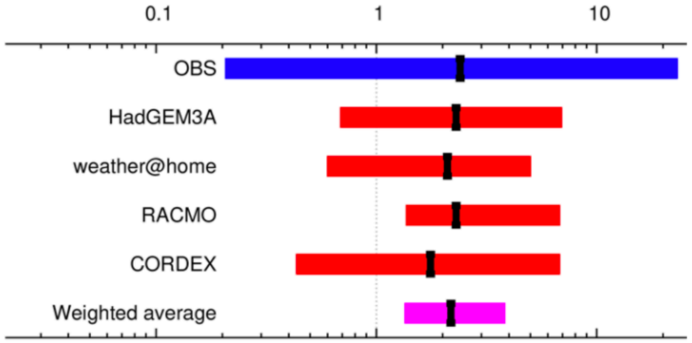
Inne Vanderkelen[1], Nicole P. M. van Lipzig[2], and Wim Thiery[1,3]



2. Water balance model

A protocol for probabilistic extreme event attribution analyses

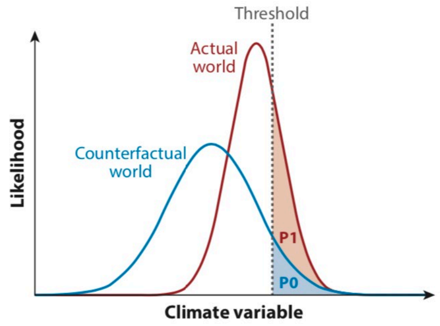
Sjoukje Philip[1], Sarah Kew[1], Geert Jan van Oldenborgh[1], Friederike Otto[2], Robert Vautard[3], Karin van der Wiel[1], Andrew King[4], Fraser Lott[5], Julie Arrighi[6], Roop Singh[6], and Maarten van Aalst[6]



3. EEA protocol

WWA-style extreme event attribution

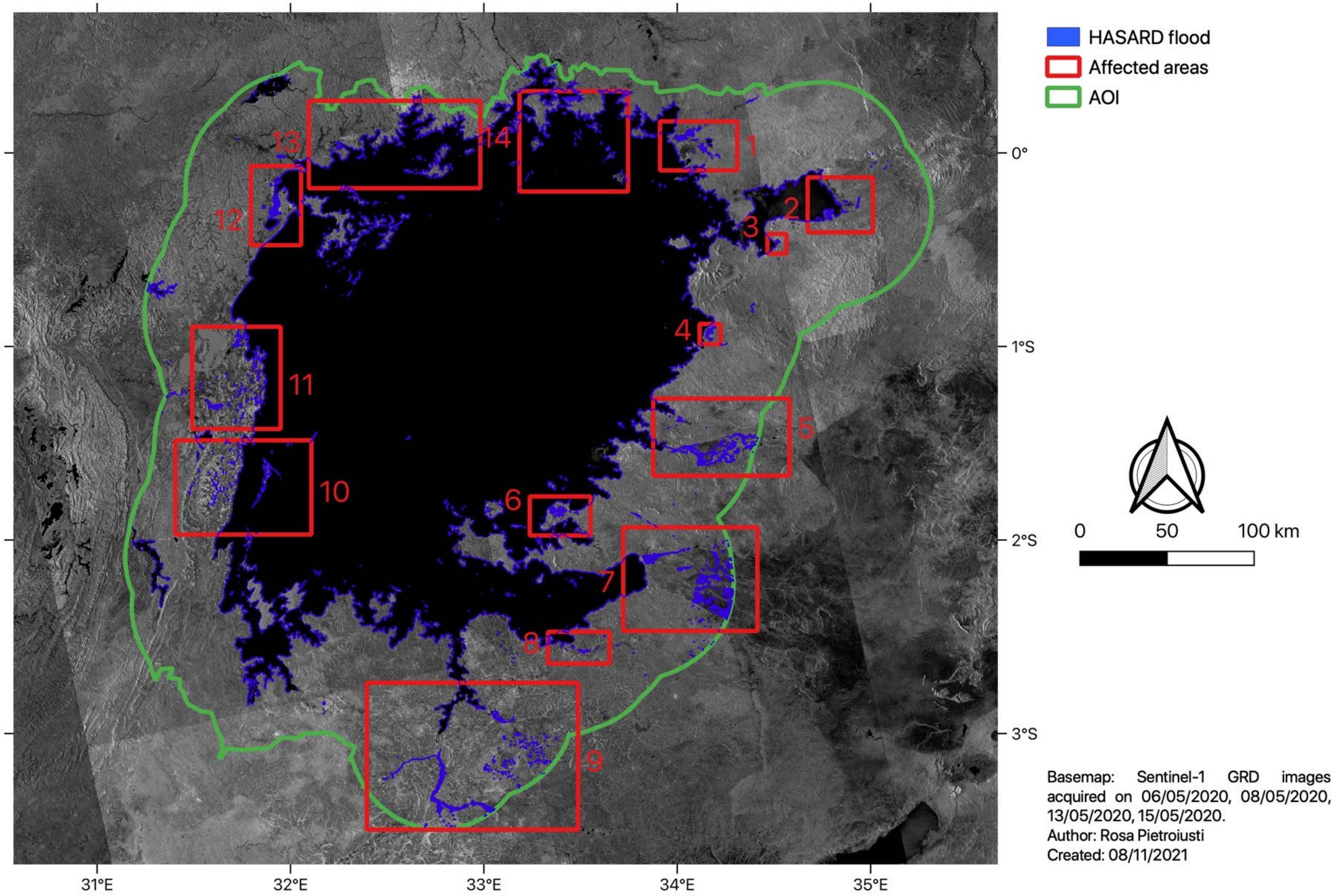
Step 1 : Analysis trigger	High impact, public interest, extremity
Step 2 : Event definition	Univariate
Step 3 : Observed probability and trend	Is there a change in probability in observations?
Step 4 : Model evaluation	Can the climate models be trusted?
Step 5: Multi-model attribution	Is there a change in probability in models?
Step 6: Synthesis	Combine observation and model results



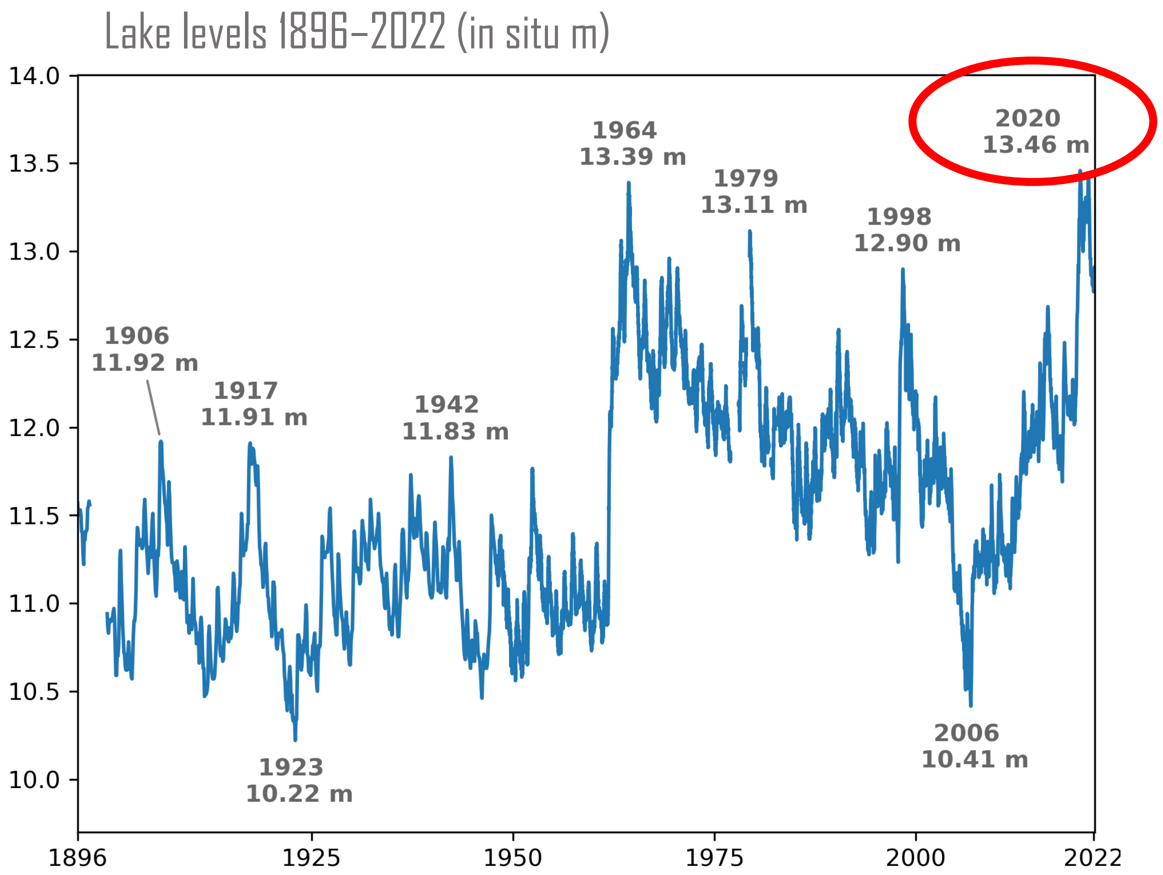
Philip et al. (2020), Adv. Stat. Clim. Meteorol. Oceanogr.
Otto (2017) Annu. Rev. Environ. Resour.

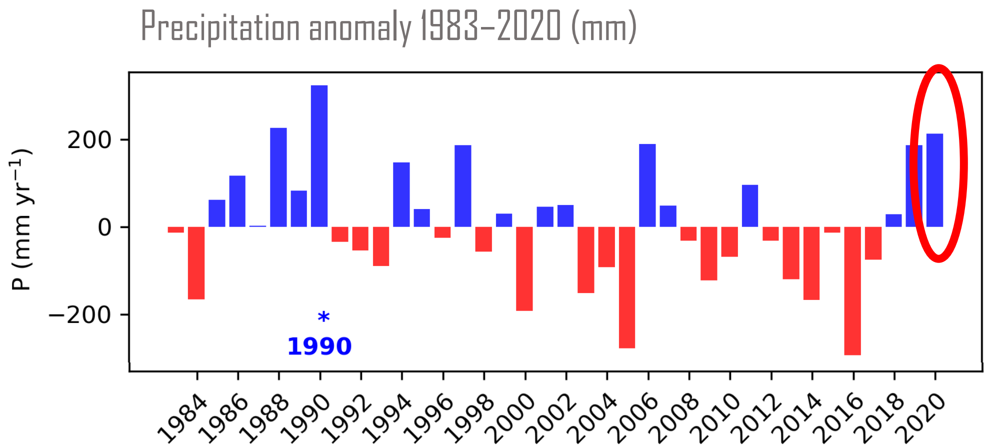
A high impact event

- Lake Victoria basin within 50 km of shores April - June 2020
- **650 km^2**
- **30k people**

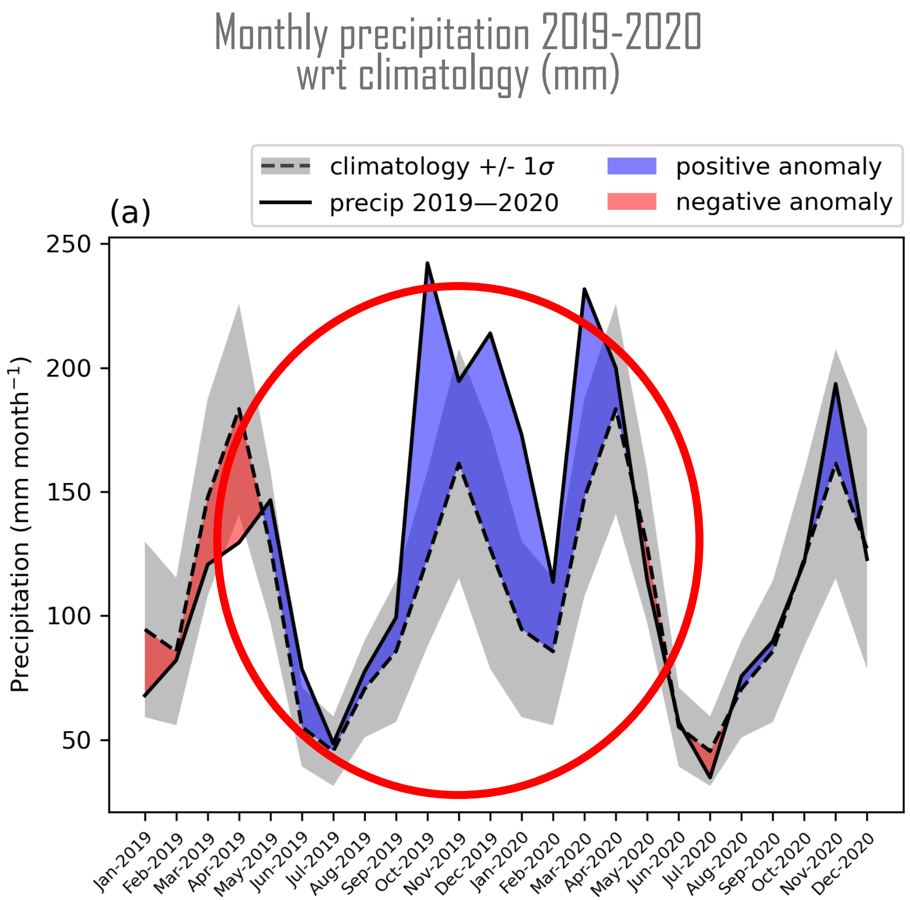


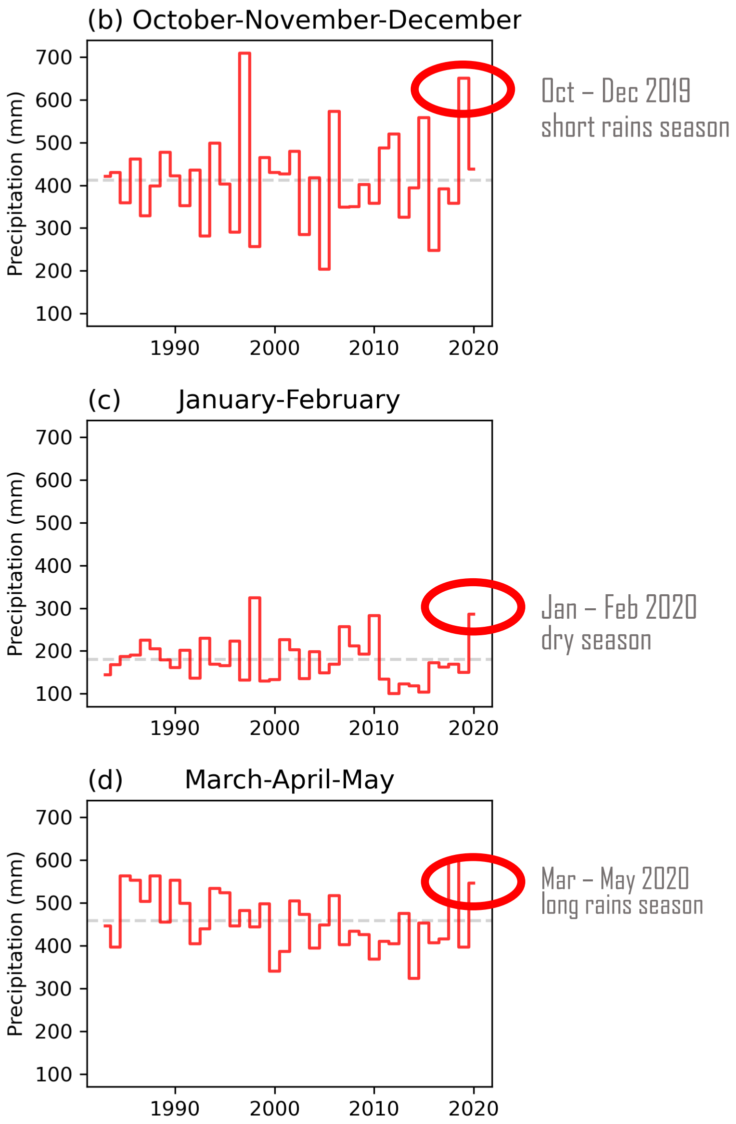
Lake levels and precipitation were record-breaking in 2020





Above-average precipitation from May 2019 – May 2020



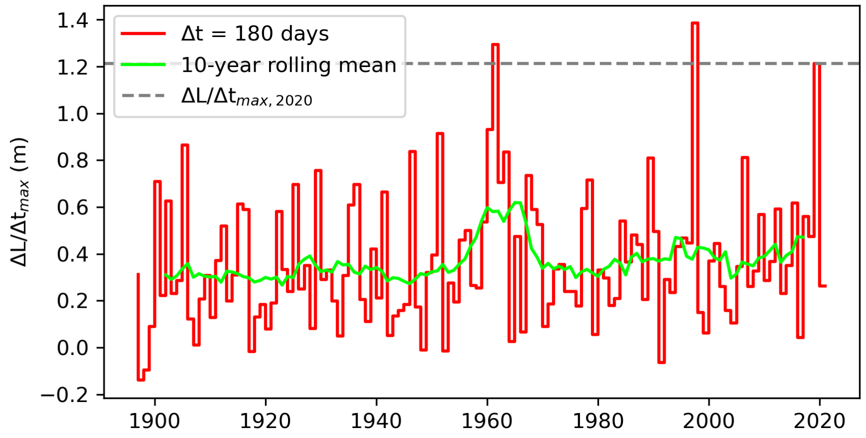


Flood event **defined** as a **180-day rate of change in lake levels**

$\Delta L/\Delta t$ for Δt = previous 180 days (m)

November–May 2020 levels rose by
1.2 m

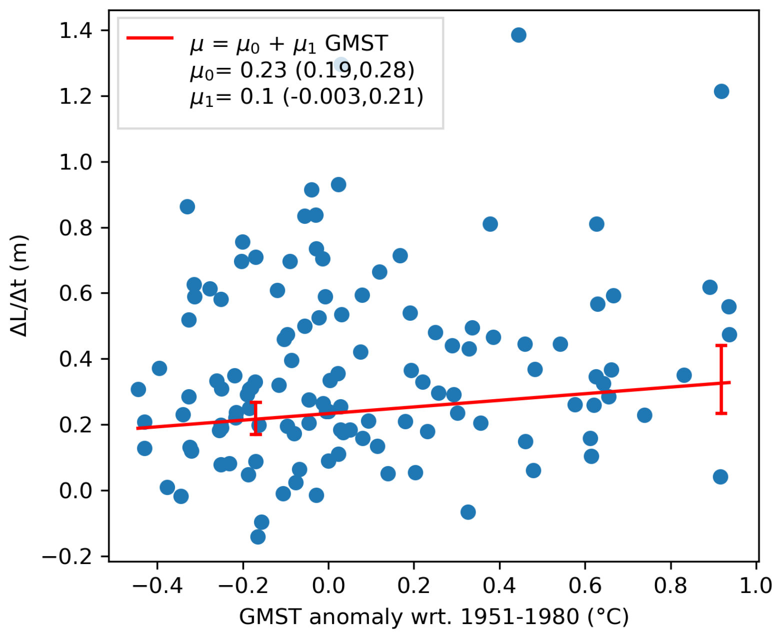
6-month lake level change
annual block maxima 1897-2020
$\Delta L/\Delta t$ (m)



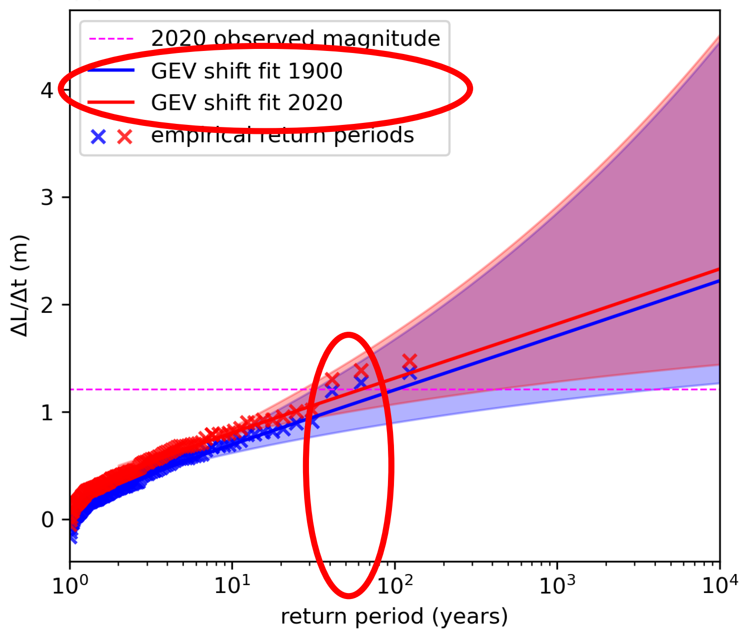
Change in likelihood from observations

GEV shift fit method

Shift fit (μ ~ GMST)



Return time plot (GEV)

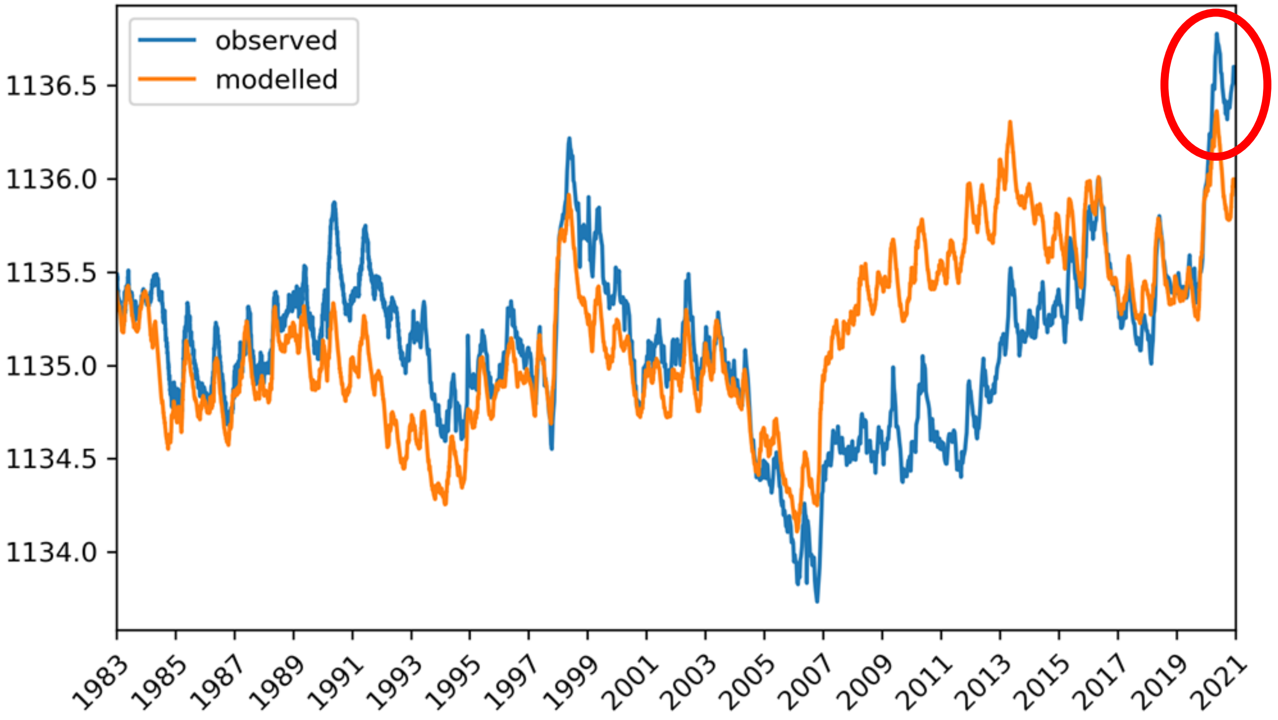


In today's climate the flood is a **63-year event** (27 - 395 years)

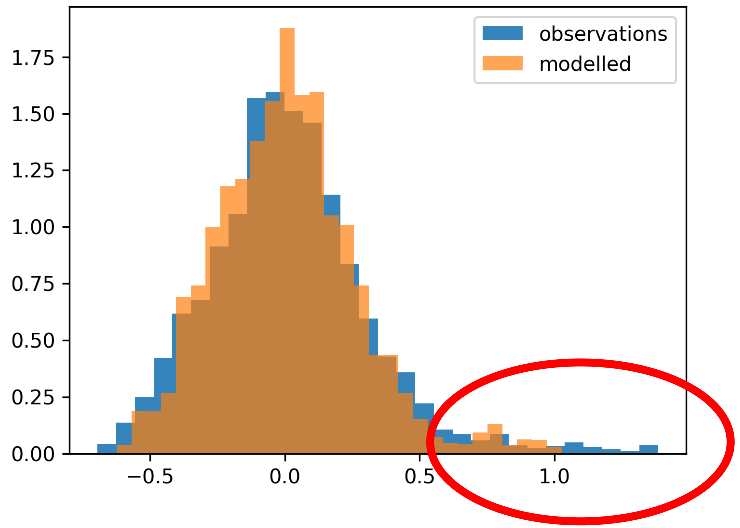
The event is modelled **1.7 times more likely in the present-day climate** but the CI includes **no change** (0.3 - 3.9)

Water balance model reproduces lake level variations well but with some muting of the tails

Lake levels: observed and modelled
with observational precipitation (m a.s.l.)

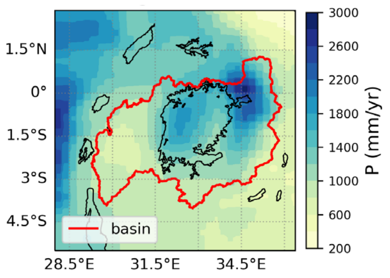


Distribution of 6-monthly
lake level variations
ΔL/Δt (m)

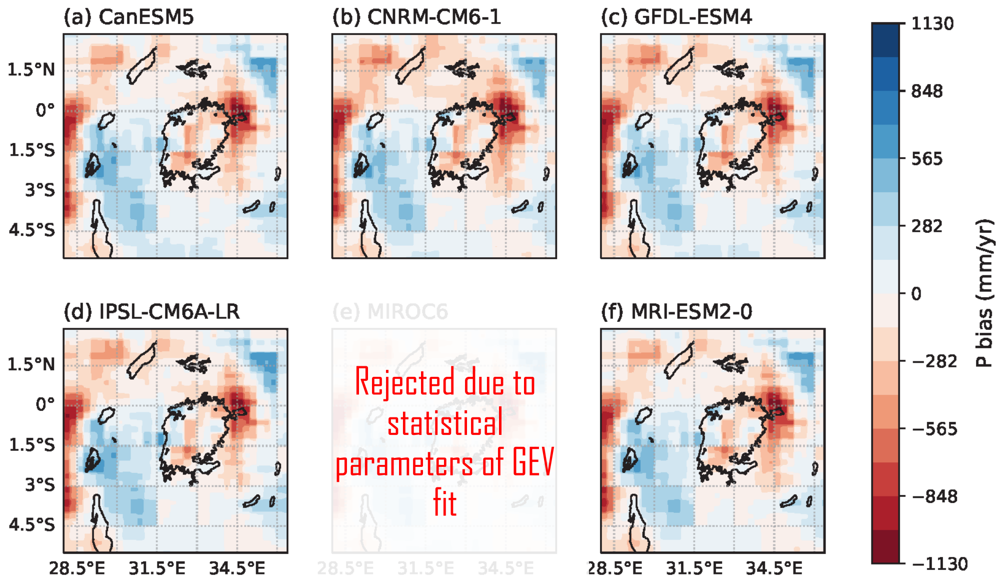


Ensemble of CMIP6 models bias corrected within ISIMIP3b represent spatial and seasonal pattern of precipitation well

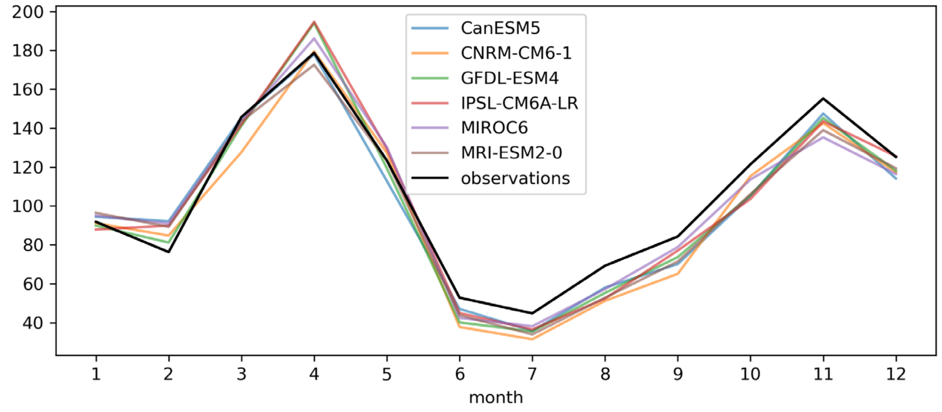
Observations (PERSIANN-CDR)



CMIP6 models



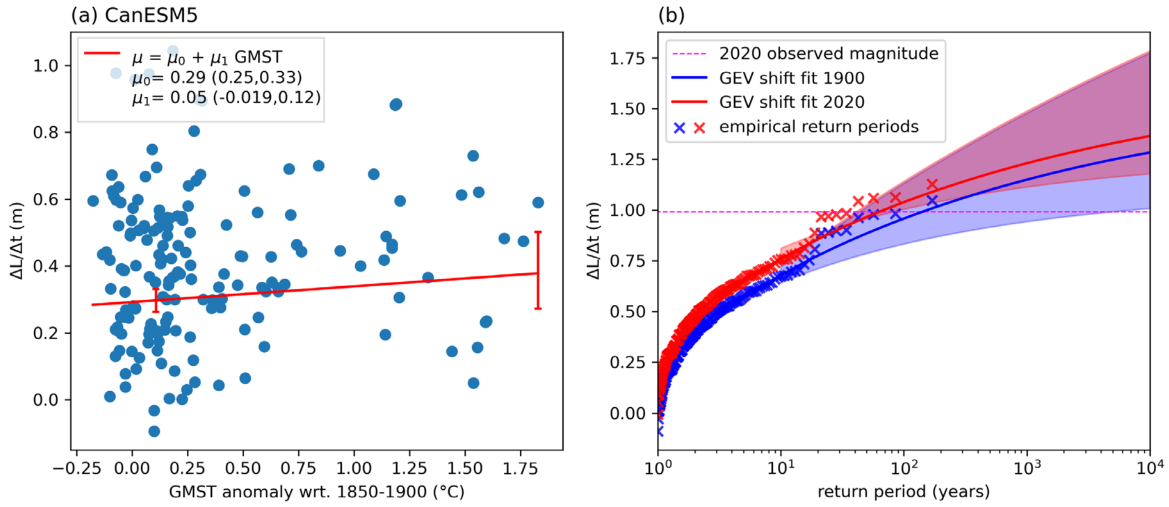
Seasonal cycle of precipitation (mm/month)



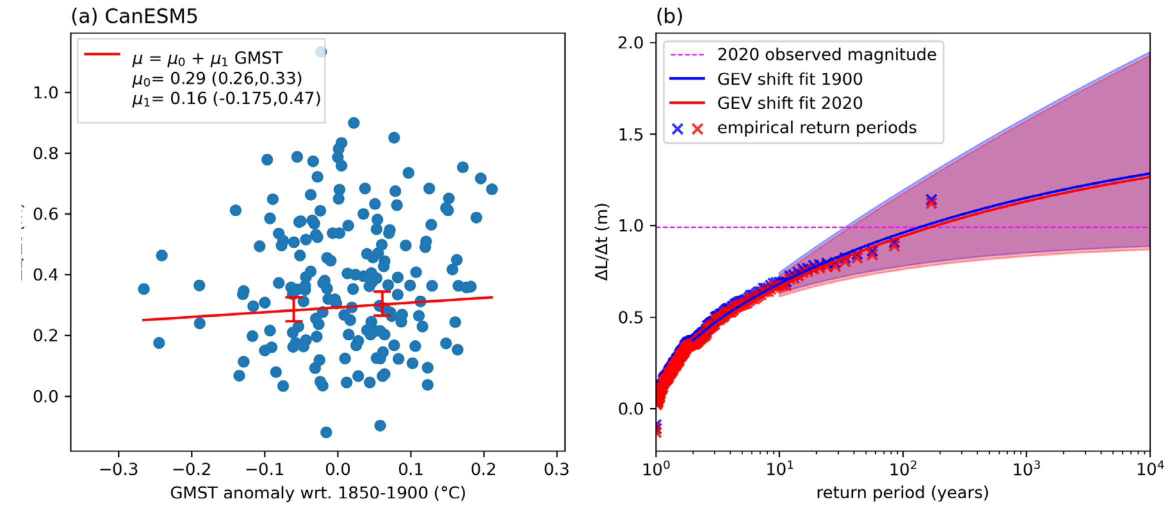
Change in probability and intensity from hist and hist-nat models

- Model-specific magnitude threshold
- GEV shift fit on historical and hist-nat simulations
- Change in likelihood and intensity of event in a
  ‘factual’ 2020 climate vs. a
  ‘counterfactual’ 2020 climate

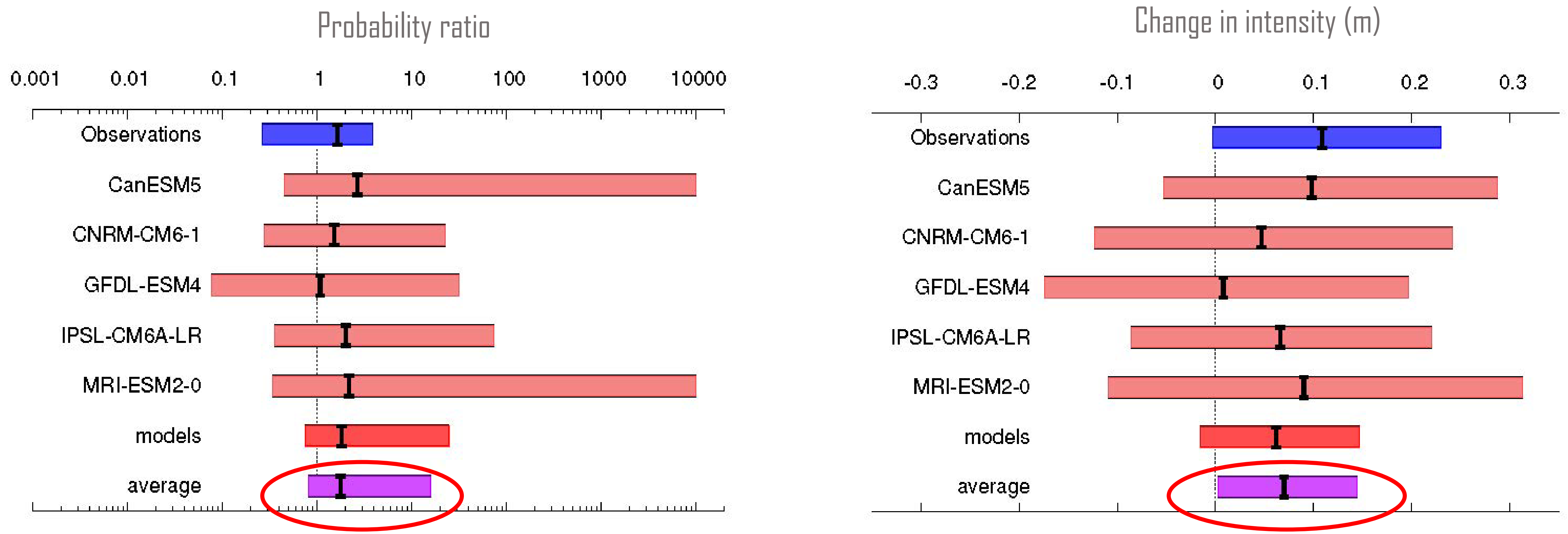
CanESM5
hist



CanESM5
hist-nat



Synthesis models and observations



Best estimate **1.8 times more likely** in present climate

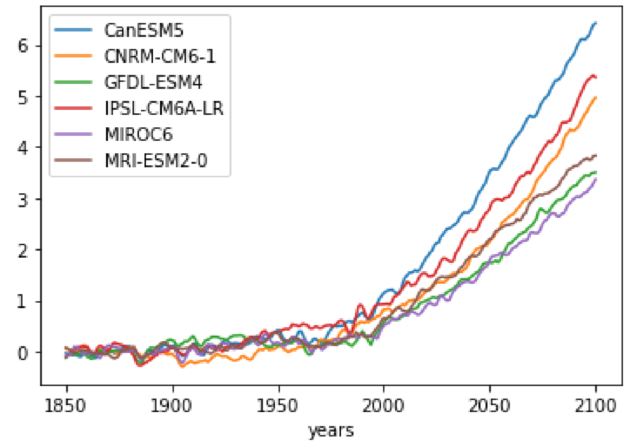
CI includes **no change (0.8 - 15.8)**

Reflections on ISIMIP3b-based event attribution

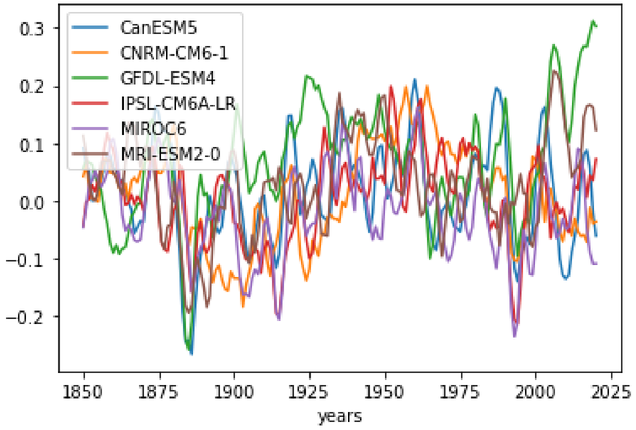
- **Small** model ensemble
- Spread of model representation of **GMST** for shift fit-based event attribution
- **Bias correction** → intra vs. inter-model disagreement
- Comparison with **ISIMIP3a** attribution

CMIP6 ISIMIP3BASD

hist



hist-nat



Conclusions

High-impact event

Lake levels were **record-breaking**

Driven by above-average **precipitation and inflow**

Today approximately a **63-year event**

Possible role of climate change increasing likelihood of event by **1.8 times (0.8 – 15.8)** , intensity by **7 cm (0 – 14 cm)**

High natural variability → uncertainty

Other drivers:

- human land and water management
- exposure changes
- modes of climate variability (e.g., IOD)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Sharing is encouraged

References

Chini, Marco, Renaud Hostache, Laura Giustarini, and Patrick Matgen. 2017. "A Hierarchical Split-Based Approach for Parametric Thresholding of SAR Images: Flood Inundation as a Test Case." *IEEE Transactions on Geoscience and Remote Sensing* 55 (12): 6975–88. https://doi.org/10.1109/TGRS.2017.2737664.

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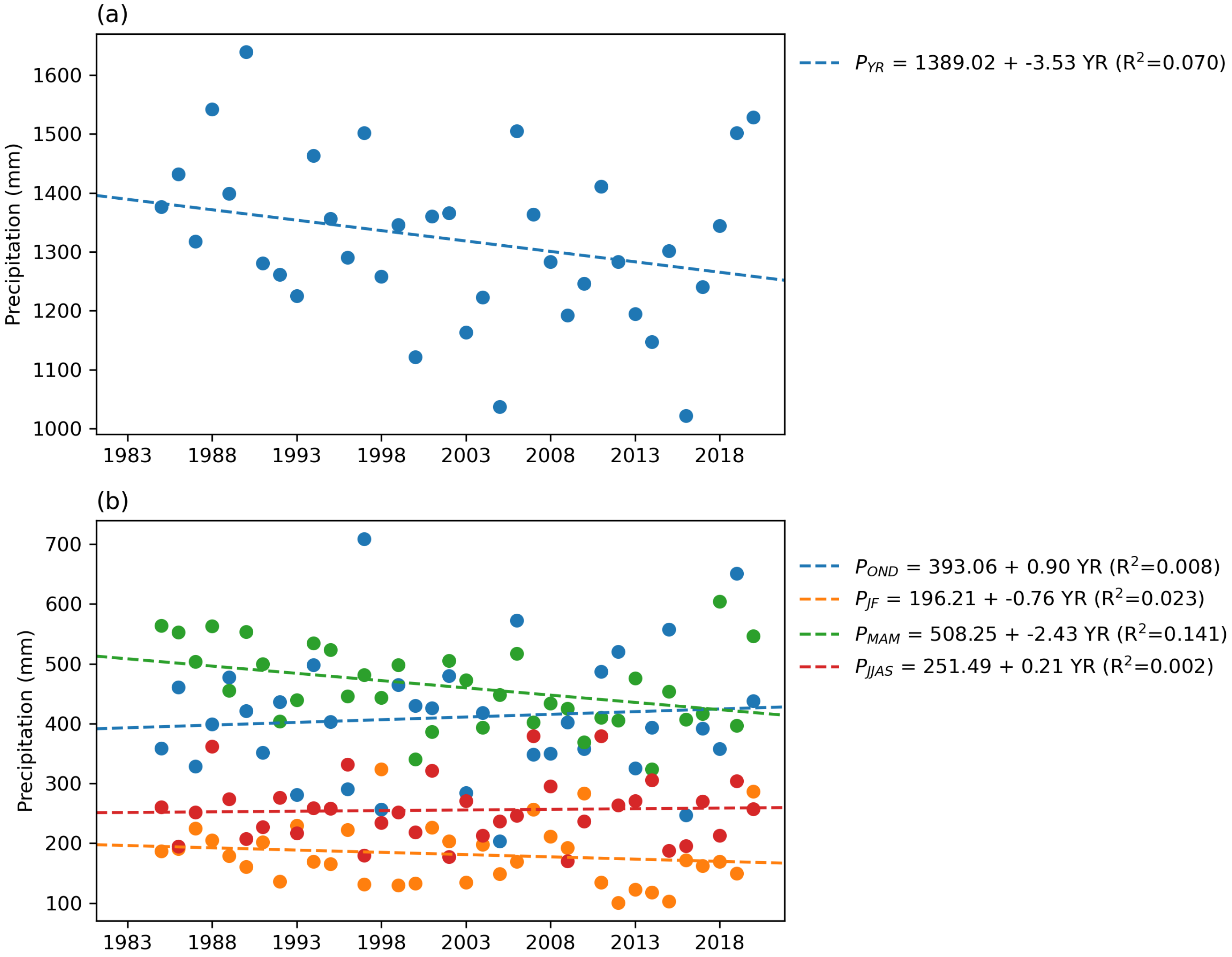
Vanderkelen, Inne, Nicole P.M. Van Lipzig, and Wim Thiery. 2018. "Modelling the Water Balance of Lake Victoria (East Africa)-Part 2: Future Projections." Hydrology and Earth System Sciences 22 (10): 5527–49. https://doi.org/10.5194/hess-22-5527-2018.

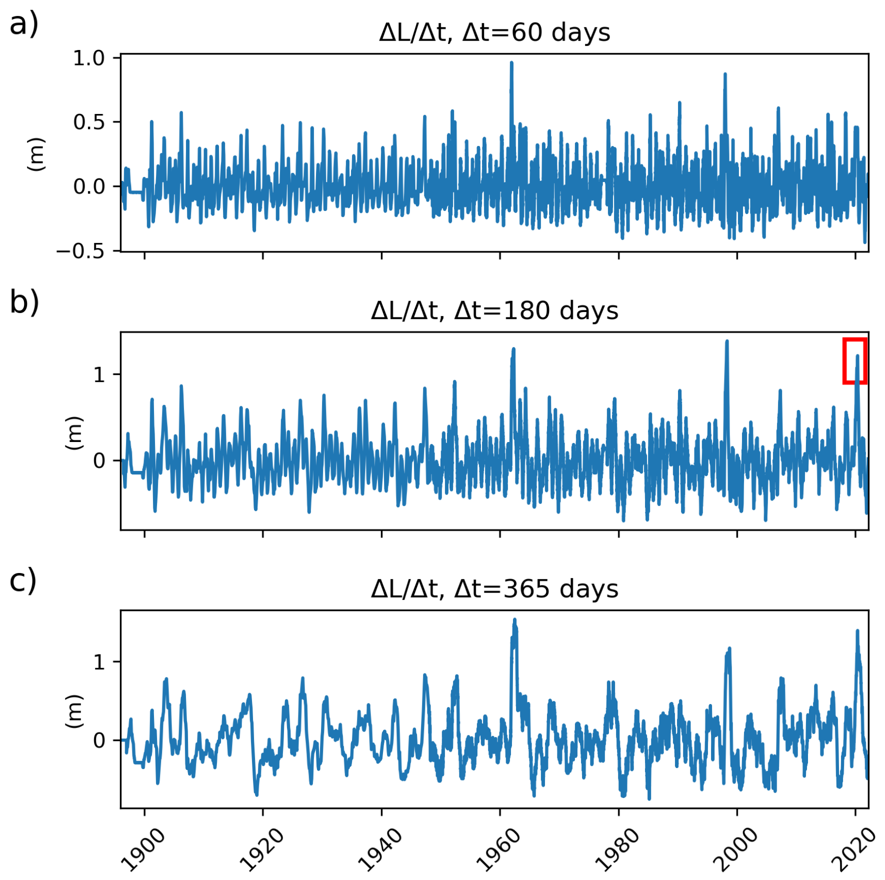
Future work

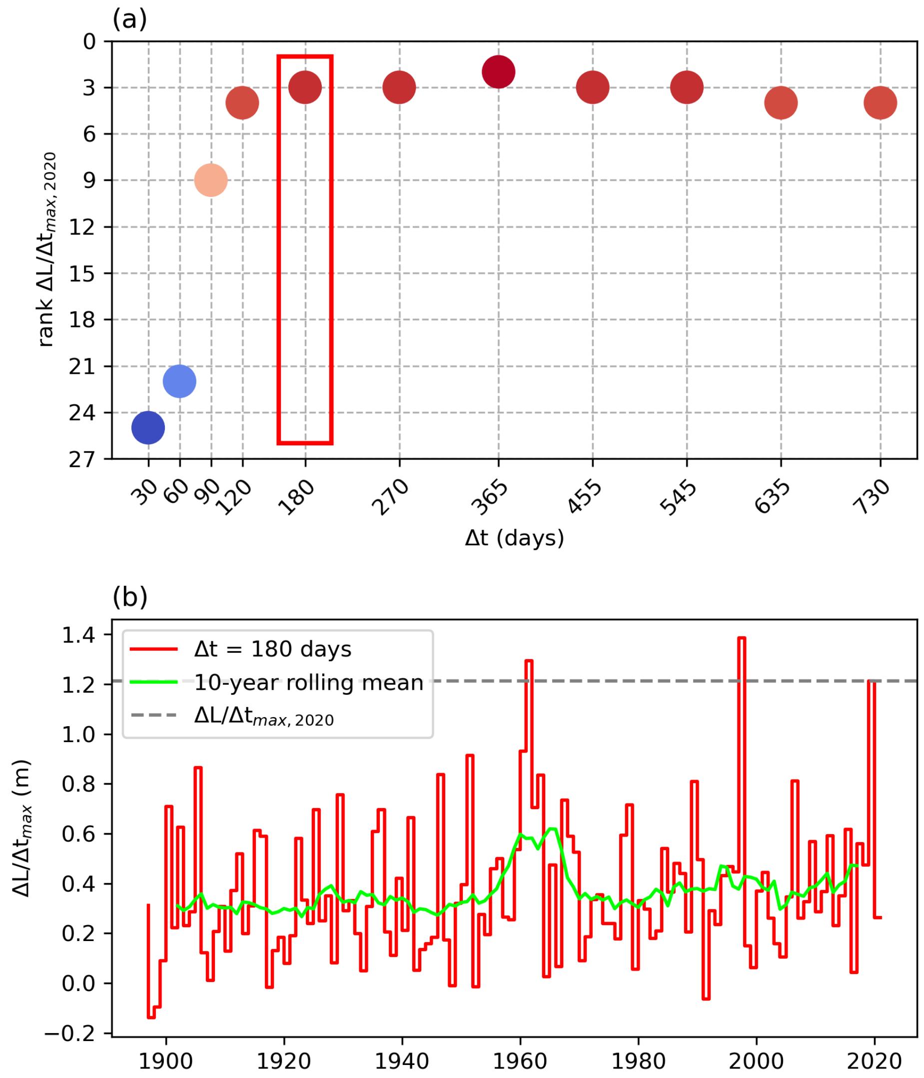
- Scientific evidence used in **youth-led climate litigation**
- Work with stakeholders in climate litigation
- Attributable harms to youth and children today & accumulated risks projected in the future

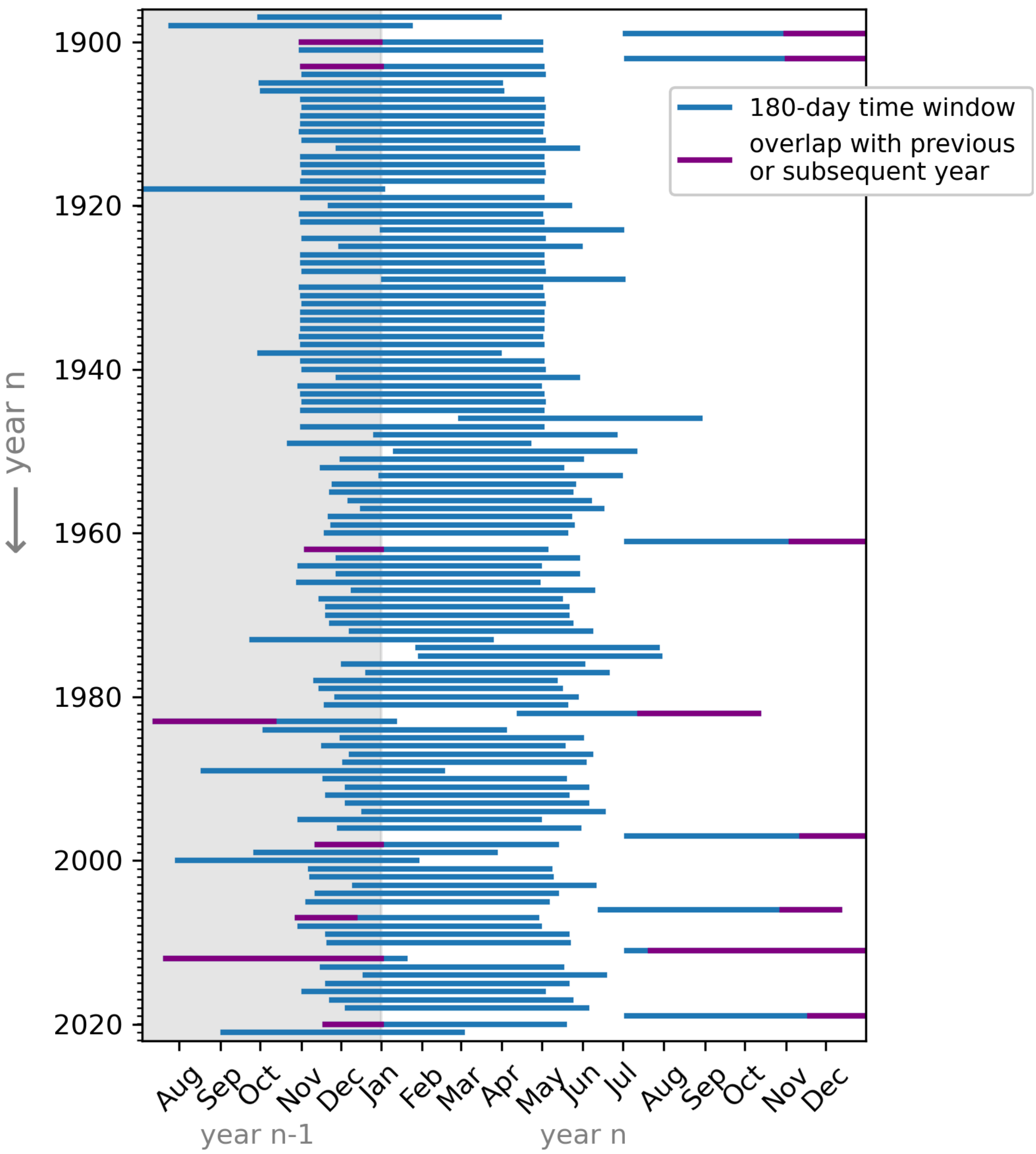
Temporal trends in annual and seasonal precipitation totals in the Lake Victoria basin, (PERSIANN-CDR,1983 – 2020)

Missing data filled with climatology

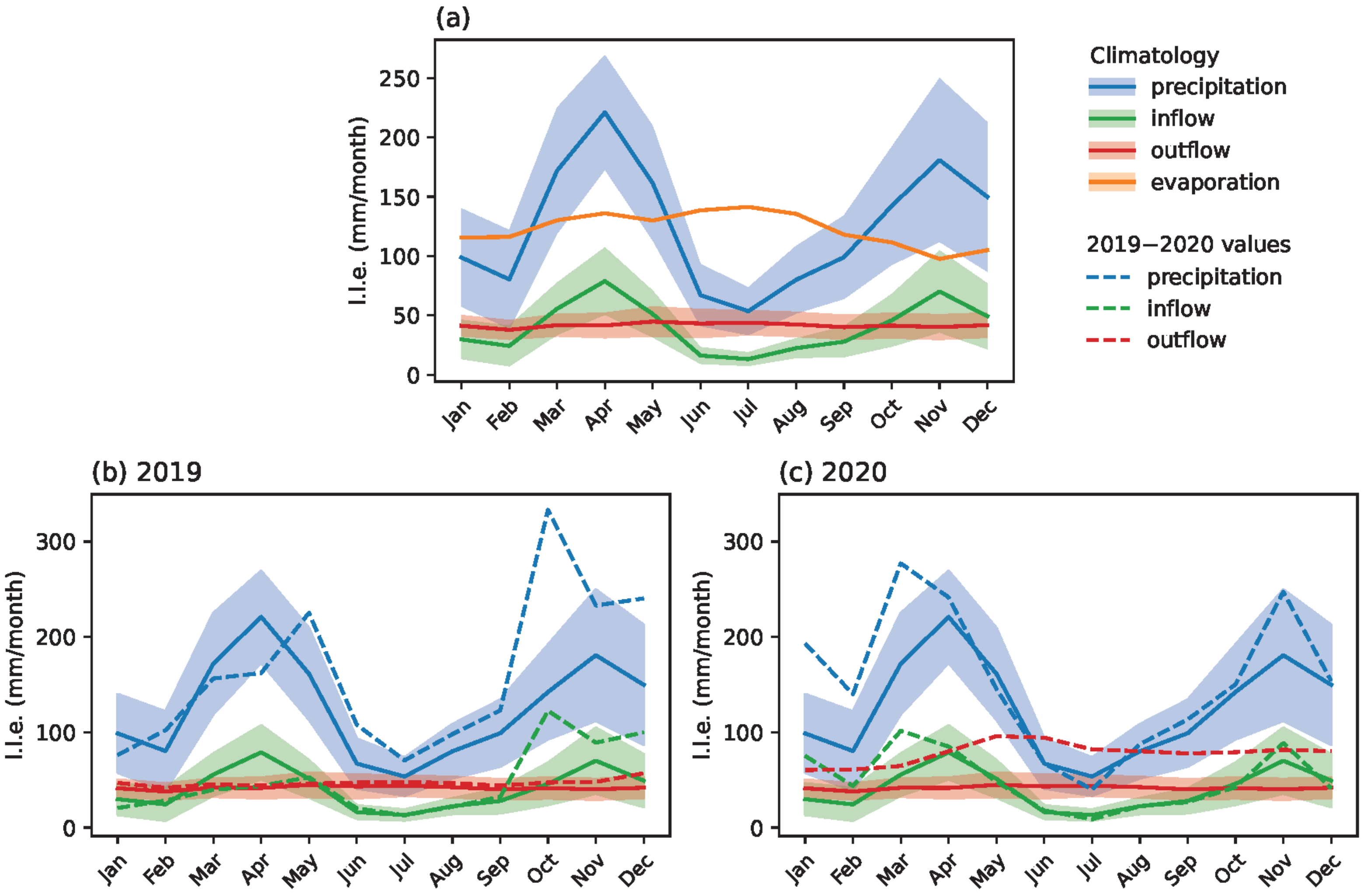



a)
ΔL/Δt, Δt=60 days
b)
ΔL/Δt, Δt=180 days
c)
ΔL/Δt, Δt=365 days
(m)
1900
1920
1940
1960
1980
2000
2020

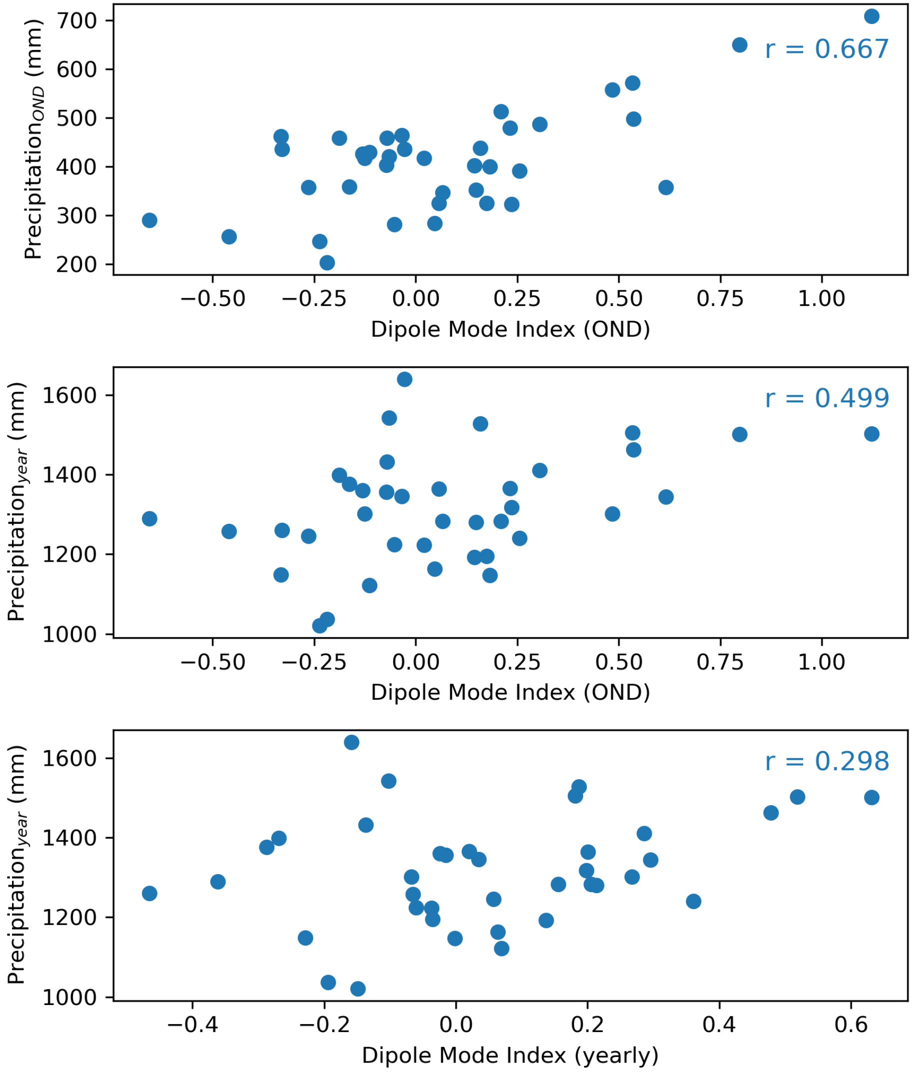

(a)
rank ΔL/Δt$_{max, 2020}$
Δt (days)
30
60
90
120
180
270
365
455
545
635
730
(b)
Δt = 180 days
10-year rolling mean
ΔL/Δt$_{max, 2020}$
ΔL/Δt$_{max}$ (m)
1900
1920
1940
1960
1980
2000
2020

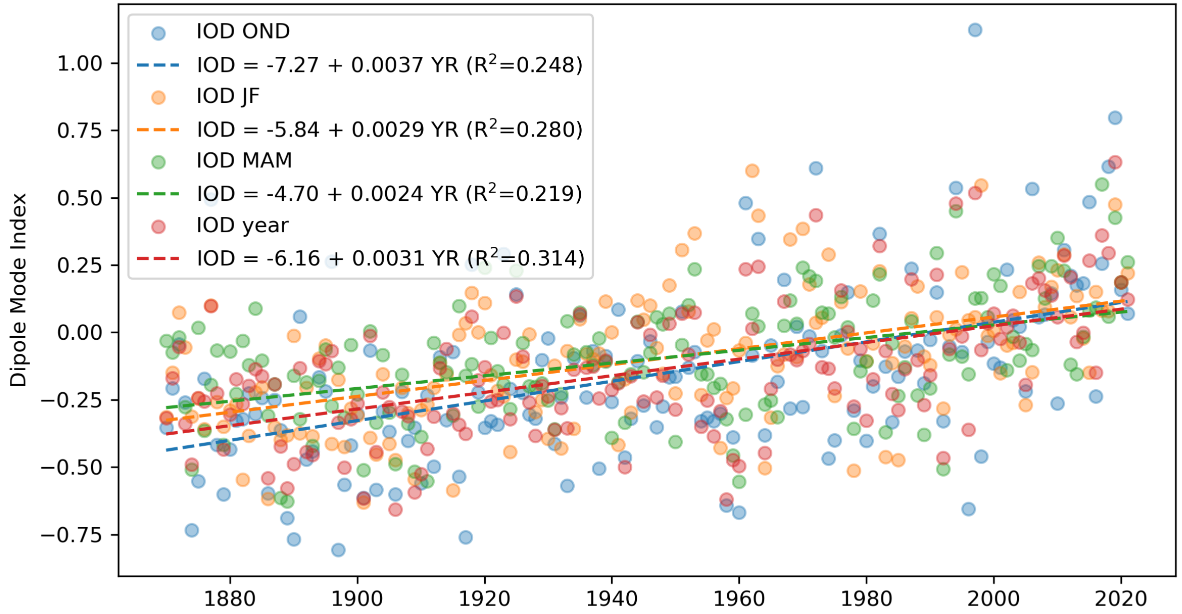


180-day time window
overlap with previous or subsequent year
1900
1920
1940
1960
1980
2000
2020
year n
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
year n-1
year n



(a)
l.l.e. (mm/month)
0
50
100
150
200
250
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Climatology
precipitation
inflow
outflow
evaporation
2019–2020 values
precipitation
inflow
outflow
(b) 2019
l.l.e. (mm/month)
0
100
200
300
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
(c) 2020
l.l.e. (mm/month)
0
100
200
300
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


r = 0.667
Precipitation$_{OND}$ (mm)
Dipole Mode Index (OND)
r = 0.499
Precipitation$_{year}$ (mm)
Dipole Mode Index (OND)
r = 0.298
Precipitation$_{year}$ (mm)
Dipole Mode Index (yearly)


IOD OND
IOD = -7.27 + 0.0037 YR (R^2=0.248)
IOD JF
IOD = -5.84 + 0.0029 YR (R^2=0.280)
IOD MAM
IOD = -4.70 + 0.0024 YR (R^2=0.219)
IOD year
IOD = -6.16 + 0.0031 YR (R^2=0.314)
Dipole Mode Index

Supplementary slide:

Results of non-stationary GEV fits
to estimate change in the return period of the 2020 flood event in observations, historical and hist-nat GCM simulations

Data	return period in 2020 climate (years)	return period in 1900 climate (years)	probability ratio (PR)	Intensity change (m)
Observations and observational precipitation				
Observations (1897–2020)	63 (27, 395)	104 (43, 1100)	1.7 (0.3, 3.9)	0.11 (0, 0.23)
Observational WBM (1983–2020)	34 (12, ∞)	79 (16, ∞)	2.3 (0, 6.6)	0.14 (-0.18, 0.53)
GCM historical-ssp370 (ISIMIP3BASD)				
CanESM5	63 (21, 335)	142 (57, 1160)	2.2 (0.4, 6.6)	0.08 (-0.03, 0.21)
CNRM-CM6-1	63 (23, 307)	66 (34, 253)	1.1 (0.2, 2.9)	0.01 (-0.13, 0.16)
GFDL-ESM4	63 (16, 711)	88 (43, 464)	1.4 (0.1, 5.4)	0.03 (-0.08, 0.15)
IPSL-CM6A-LR	63 (28, 300)	85 (42, 813)	1.3 (0.3, 3)	0.04 (-0.07, 0.15)
MRI-ESM2-0	63 (26, 358)	86 (43, 383)	1.4 (0.2, 3.3)	0.05 (-0.09, 0.19)
GCM hist-nat (ISIMIP3BASD)				
CanESM5	170 (58, ∞)	139 (53, 65000)	0.8 (0, 2.4)	-0.02 (-0.06, 0.02)
CNRM-CM6-1	97 (46, 1634)	85 (37, 1340)	0.9 (0.1, 1.8)	-0.01 (-0.06, 0.03)
GFDL-ESM4	69 (28, 1580)	55 (30, 323)	0.8 (0, 2)	-0.02 (-0.09, 0.04)
IPSL-CM6A-LR	129 (50, 4910)	132 (55, 2440)	1 (0, 2.7)	0 (-0.05, 0.05)
MRI-ESM2-0	139 (54, ∞)	136 (56, 61900000)	1 (0, 2.5)	0 (-0.02, 0.01)

Table 2. Validation results based on seasonal cycle, spatial pattern and fitted scale σ and shape ξ parameters, with 95% confidence intervals in brackets. For observations, the magnitude of the 2020 event is shown and for GCMs the estimated magnitude of a 63-year event in the current climate based on a non-stationary GEV fit. The location parameter μ_{new} represents the current climate. Rejected models are shown in italics.

Data	**Seasonal cycle**	**Spatial pattern**	**Magnitude** (m)	μ_{new} (m)	σ (m)	ξ	**Conclusion**
Observations and observational precipitation							
Observations (1897–2020)			1.21	0.33 (0.23, 0.44)	0.21 (0.18, 0.24)	0.01 (-0.12, 0.13)	
Observational WBM (1983–2020)			0.94	0.32 (0.2, 0.5)	0.18 (0.14, 0.22)	-0.03 (-0.69, 0.28)	
GCM historical-ssp370 (ISIMIP3BASD)							
CanESM5	good	reasonable	0.99	0.38 (0.27, 0.5)	0.2 (0.18, 0.22)	-0.15 (-0.23, -0.07)	good
CNRM-CM6-1	good	reasonable	1.08	0.31 (0.18, 0.46)	0.25 (0.22, 0.28)	-0.15 (-0.23, -0.06)	good
GFDL-ESM4	good	reasonable	0.9	0.34 (0.22, 0.48)	0.2 (0.17, 0.22)	-0.19 (-0.29, -0.1)	good
IPSL-CM6A-LR	good	reasonable	0.95	0.3 (0.20, 0.41)	0.19 (0.17, 0.21)	-0.10 (-0.22, -0.01)	good
MIROC6	good	reasonable	*0.64*	*0.31 (0.25, 0.39)*	*0.17 (0.16, 0.19)*	*-0.45 (-0.54, -0.36)*	rejected due to statistical parameters
MRI-ESM2-0	good	reasonable	1.16	0.36 (0.25, 0.49)	0.24 (0.21, 0.26)	-0.11 (-0.2, -0.01)	good