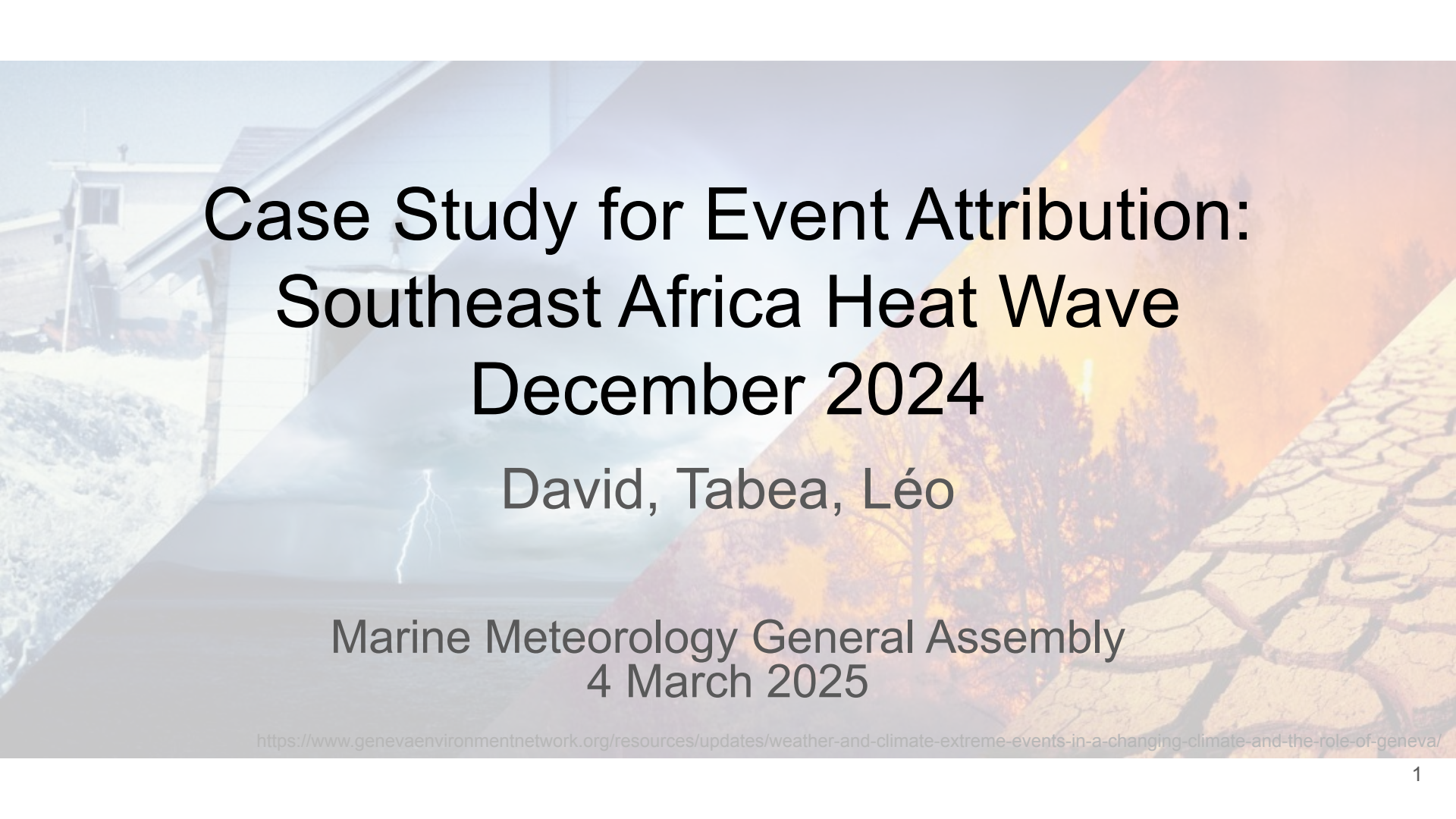




Case Study for Event Attribution: Southeast Africa Heat Wave December 2024

David, Tabea, Léo

Marine Meteorology General Assembly
4 March 2025

<https://www.genevaenvironmentnetwork.org/resources/updates/weather-and-climate-extreme-events-in-a-changing-climate-and-the-role-of-geneva/>

Outline

- Summary of the course week
- Why & How do we do extreme event attribution?
- Case Study: Southern African heatwave Dec 2024
- Conclusion
- Discussion & Questions

Course outline experience

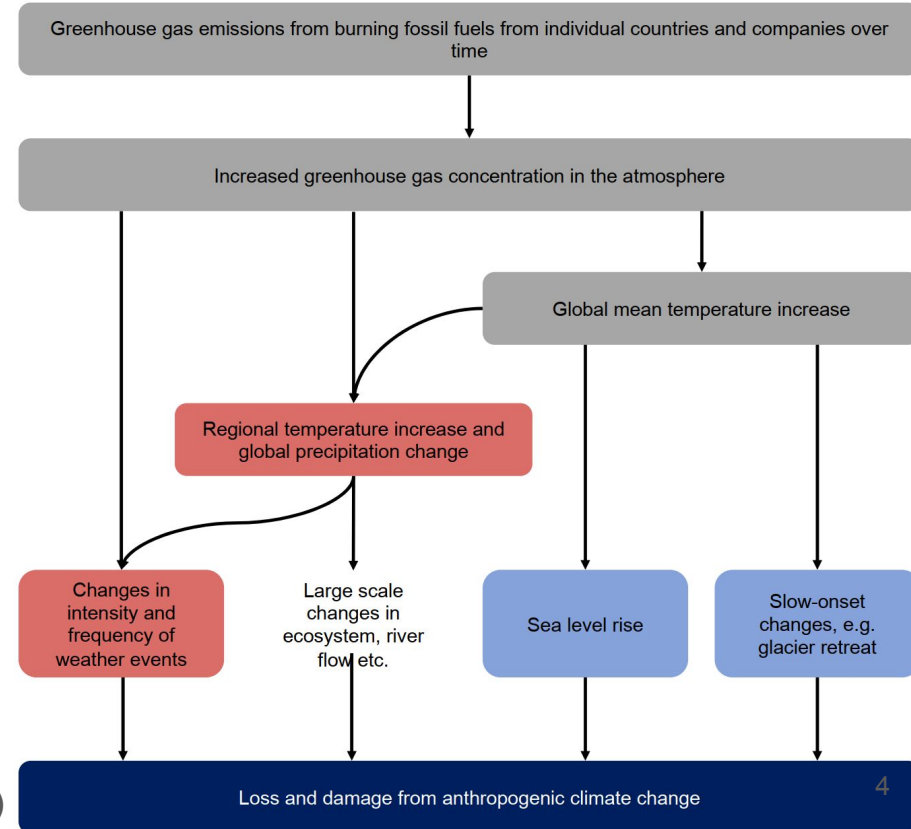
- 10-14 Feb in GEOMAR conference rooms
- Friederike Otto & Clair Barnes ([World Weather Attribution](#), Imperial College London)
- [Example Video](#)
- prepared notebooks (python, R) on jupyter hub
- 30 participants (90% MSc)
- What we liked:
 - hands on
 - worked with real, recent events
 - everything is political
 - science communication encouragement
- What we would have liked to hear more about:
 - announcements before the week
 - statistical model



Monday morning	Introduction + background general attribution; Trigger methodology & event definition	Lectures
Monday afternoon	Get everyone set up on JupyterHub Intro to what we want to do, event list; Play with obs	Guided practical
Tuesday morning	Practical, do the attribution	Guided practical
Tuesday afternoon	Do more of the attribution (models if things go well)	Independent practical
Wednesday morning	Models and troubleshooting	Independent practical
Wednesday afternoon	Climate justice, L&D V&E; interpreting the synthesis	Lectures
Thursday morning	Students present results	Students present
Thursday afternoon	Targeted literature review, incorporating IPCC findings	Guided practical
Friday morning	Lecture on comms & policy	Lecture + independent practical
Friday afternoon	Wrap up & other attribution approaches	Guided practical/ lecture 3

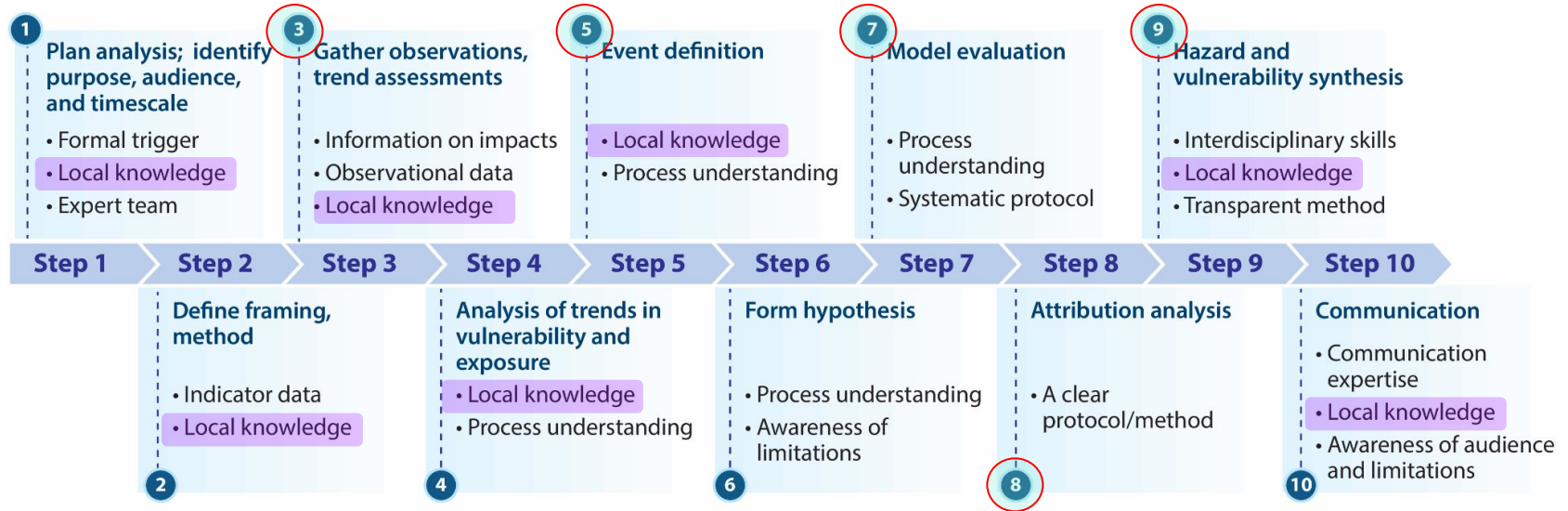
Why Attribution

- create **causal** connection between GHG emissions and climate change impacts/damages
- motivate mitigation, adaptation
- claim loss & damages (maybe?)



How Attribution

1. probabilistic



2. storyline

List of candidate events

1	Trigger date	Time period	Hazard	County/-ies affected	Threshold	Decision	Studies	Comment	Trigger document
201	08-11-2024	5 November - present	Storm	Cuba, Jamaica	2/3 criteria (2, 3)	No			Storm: Caribbean - Google Docs
202	08-11-2024	6 November - present	Storm	The Philippines	1/3 criteria (2)	Yes			Storm: The Philippines - Google Docs
203	08-11-2024	Different between regions, some starting around 3 November - present (ongoing since March of 2023 in Southeast Asia)	Heatwave	Most Asian countries, from West Asia (e.g. UAE, Oman) to East (e.g. Japan, the Koreas) and Southeast Asia (e.g. Thailand)	3/5 criteria (1, 4, 5)	No			Heatwave: Asia - Google Docs
204	08-11-2024	Approx. 5 November - present	Heatwave	All Caribbean countries, Mexico, USA, Canada	3/5 criteria (1, 4, 5)	No			Heatwave: Caribbean - Google Docs
205	08-11-2024	Approx. 1 November - present	Heatwave	Nearly every country from Iceland and Fennoscandia to North Africa (Morocco, Algeria)	2/5 criteria (1, 4)	No			Heatwave: North Africa & Europe - Google Docs
206	15-11-2024	09 - 14 November	Storm	The Philippines and China	1/3 criteria (2)	No			Storm: Asia - Google Docs
207	15-11-2024	07 November - present	Floods	Colombia	1/4 criteria (4)	No			Floods: Colombia - Google Docs
208	22-11-2024	15 - 17 November	Storm	Philippines	1/3 criteria (2)	Yes			Storm: Philippines - Google Docs
209	22-11-2024	14 - 16 November	Storm	Philippines, Taiwan	1/3 criteria (2)	Yes			Storm: Asia - Google Docs
210	22-11-2024	14 - 18 November	Storm	Honduras, Costa Rica, Panama, Belize, Nicaragua, Guatemala, El Salvador, Mexico	1/3 criteria (2)	No			Storm: Central America - Google Docs
211	22-11-2024	19 - 21 November	Storm	Most of Northern, Western, Eastern and Central Europe	1/3 criteria (2)	No			Storm: Europe - Google Docs
212	22-11-2024	20 November - present	Storm	USA, Canada	1/3 criteria (2)	No			Storm: USA, Canada - Google Docs
213	22-11-2024	Approx. 15 November - present	Heatwave	Australia	3/5 criteria (1, 3, 4)	No			Heatwave: Australia - Google Docs
214	29-11-2024	23 November - 27 November	Heatwave	Australia	3/5 criteria (1, 3, 4)	No			Heatwave: Australia - Google Docs
215	29-11-2024	23 - 25 November	Storm	England, Wales, Ireland	1/3 criteria (2)	No			Storm: England, Wales, Ireland, Scotland - Google Docs
216	29-11-2024	26 - 27 November	Storm	Southeast England, northern Netherlands	1/3 criteria (2)	No			Storm: England, Netherlands - Google Docs
217	06-12-2024	30 November - present	Storm	Canada, USA	1/3 criteria (2)	No			Storm: Canada, USA - Google Docs
218	06-12-2024	26 November - 3 December	Floods	Thailand, Malaysia	1/4 criteria (2)	No			Floods: Thailand & Malaysia - Google Docs
219	13-12-2024	5-9 December	Storm	UK	1/3 criteria (2)	No			Storm: UK - Google Docs
220	13-12-2024	Approx. 8 December - present	Heatwave	South Africa, Eswatini, Zimbabwe, Mozambique, Malawi, Botswana, Namibia	4/5 criteria (1, 3, 4, 5)	No			Heatwave: Southern Africa - Google Docs



Event document

Southern Africa heatwave

Hazard: Heatwave

- Monthly Tmax and Tmin records [xx, xx, xx, xx, xx]
- Hottest day in Botswana's recorded history [xx]

Countries affected: South Africa, Eswatini, Zimbabwe, Mozambique, Malawi, Botswana, Namibia

Time period: Approx. 8 December - present

Impacts:

- *No reported impacts found*

Using the heatwave criteria, our threshold is 4/5 met:

- Criteria 1: Forecast or observation of record-breaking or unseasonably high temperatures over a large geographic area, for a prolonged period (3+ days)
- Criteria 3: Occurrence during the first 3-6 weeks of the hot season (when the most temperature-related deaths tend to occur)
- Criteria 4: Event occurrence in a densely populated area (≥ 200 people/km²)
- Criteria 5: Event occurrence in a highly vulnerable area (≥ 4.8 [INFORM](#)) and/or high lack of coping capacity (≥ 6.0 [INFORM](#))

Heat wave/ Cold wave	•Google alert ("extreme heat", "extreme cold", "heatwave", "cold wave", "polar vortex") •Reliefweb: Alert and Ongoing Disaster •GLIDENumber •Metblue: Apparent Temperature Map •Metblue: Severe Weather Warning •WMO World Weather Information Service: Present Temperature Map •Twitter accounts ("Extreme Temperatures Around The World", "World Meteorological Organization")	1.Forecast of potential record-breaking temperatures 2.Newspaper reports of ≥ 10 heat/cold-related deaths or major disruptions to critical sectors (notably transportation, energy, and manufacturing) 3.Occurrence during the first 3-6 weeks of the hot/cold season (when the most temperature-related deaths tend to occur) 4.Event occurrence in a densely populated area (≥ 200 people/km²) 5.Event occurrence in a highly vulnerable area (≥ 4.8 INFORM) and/or high lack of coping capacity (≥ 6.0 INFORM)
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8

Data

Observational/Reanalysis data

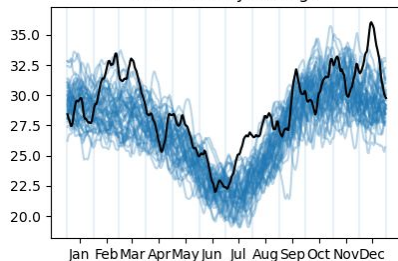
- ERA5 (ECMWF) for 1950 to 2025
- CPC (Climate Prediction Centre, NOAA) for 1979 to 2025
- low-pass (4-year) filtered GMST data (GISTEMP) for 1879 to 2025
- time series for 9 meteorological stations in Zimbabwe & Mozambique

Model data

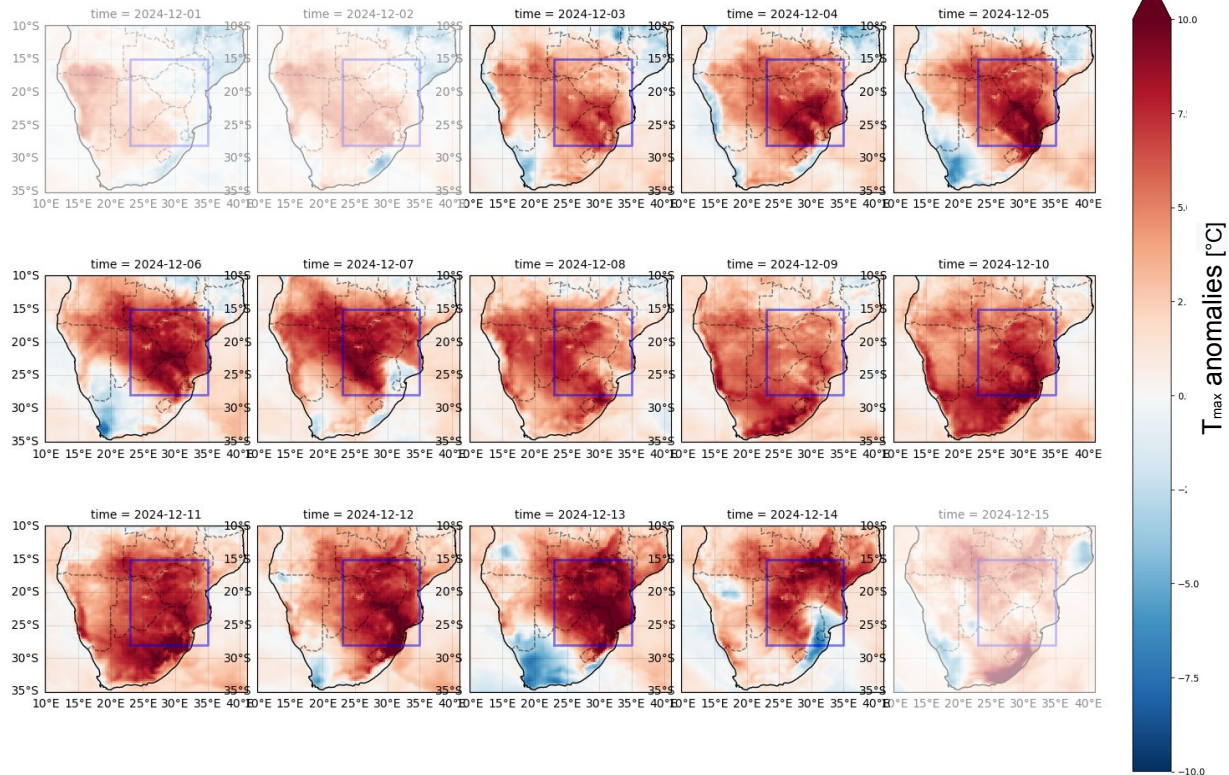
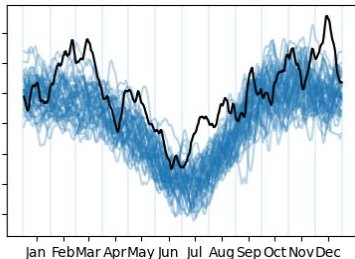
- regionally downscaled CORDEX model output for AFR-22 domain
 - historical run
 - RCP8.5 scenario

Event Definition

ERA5: 12-day average



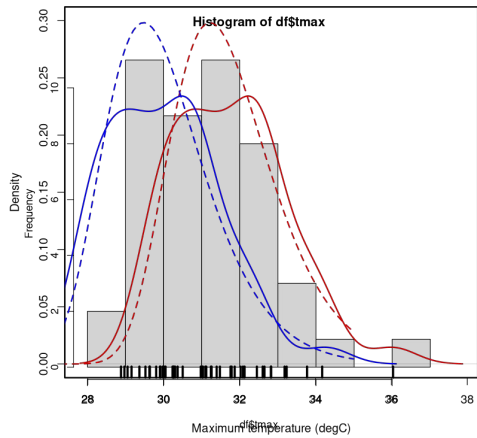
CPC: 12-day average



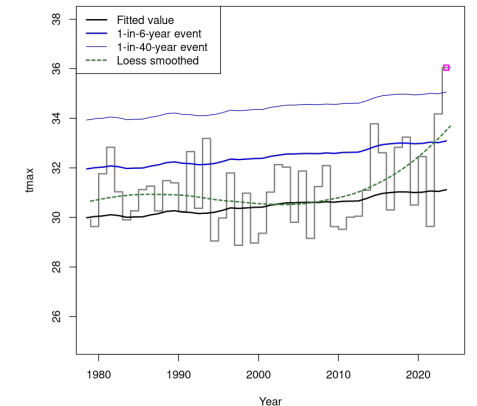
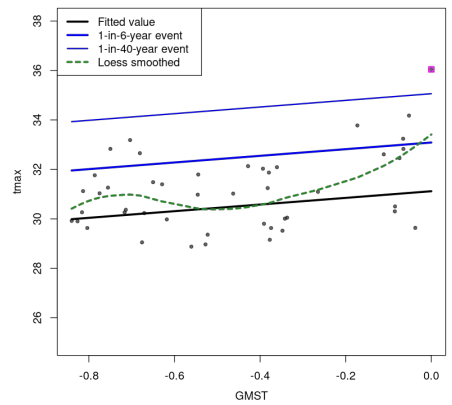
- Maximum ever recorded 12-day averaged $T_{\max}$ in December in the box ([23E,35E], [-15S,-28S])
- Also observed in 12-day averaged $T_{\min}$ and T_{2m} (ERA5; CPC: only $T_{\max}$)

Statistical Model

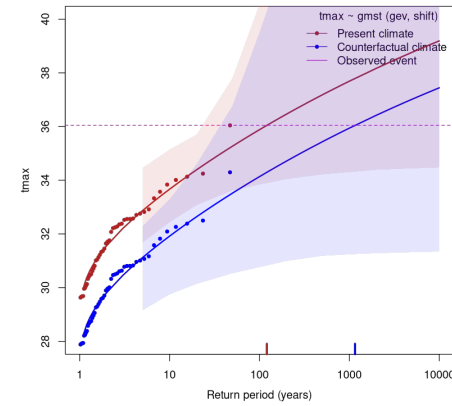
- Fit a generalised extreme value distribution function (params location, scale, shape) with Maximum Likelihood Estimation



fit PDF with location increasing linearly with GMST



make frequency histogram

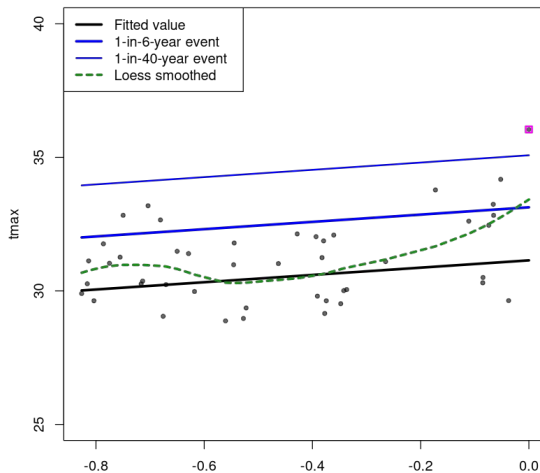


cumulative DF

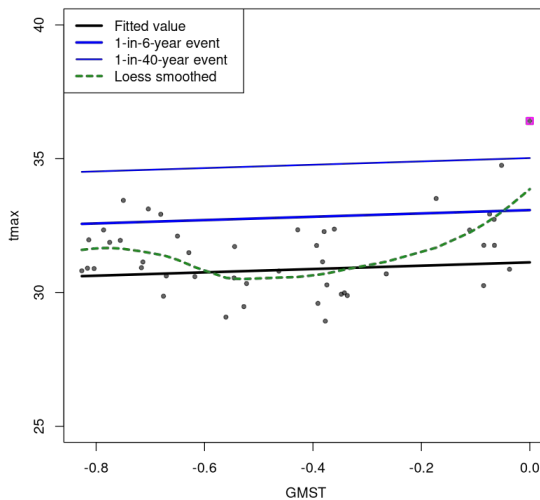
Trend fitting

- ERA5, CPC: 1979-2024;
- Event slightly stronger in CPC;
- Return period: approx. 120 (ERA5) and 200 (CPC) years;

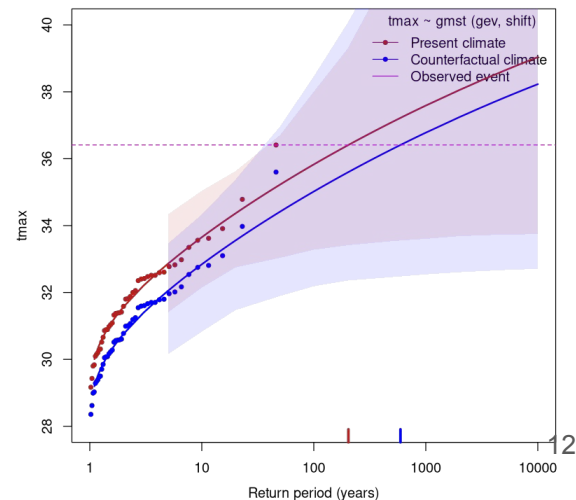
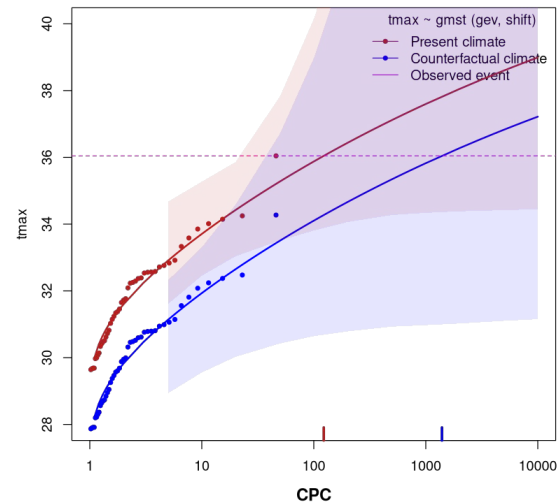
ERA5: GEV distribution



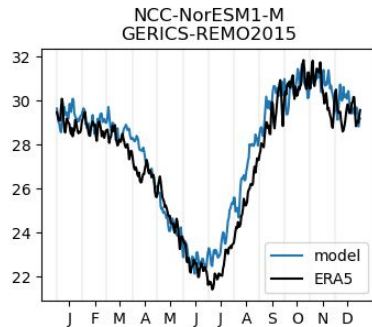
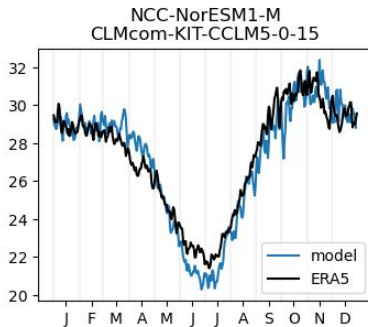
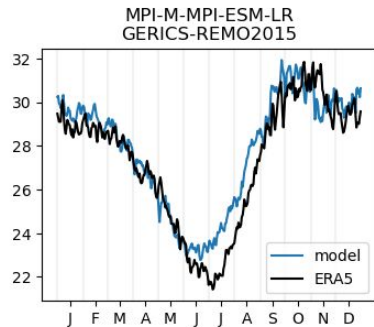
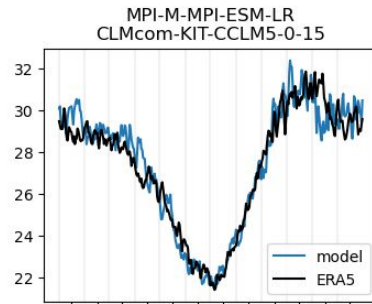
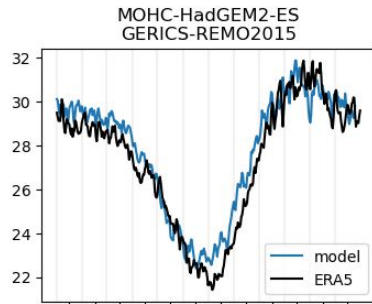
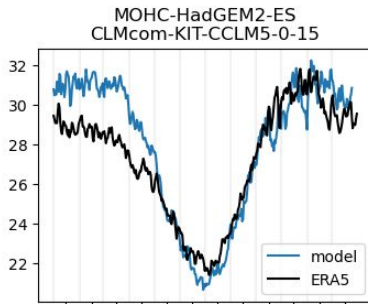
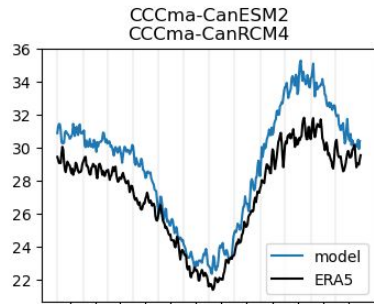
CPC: GEV distribution



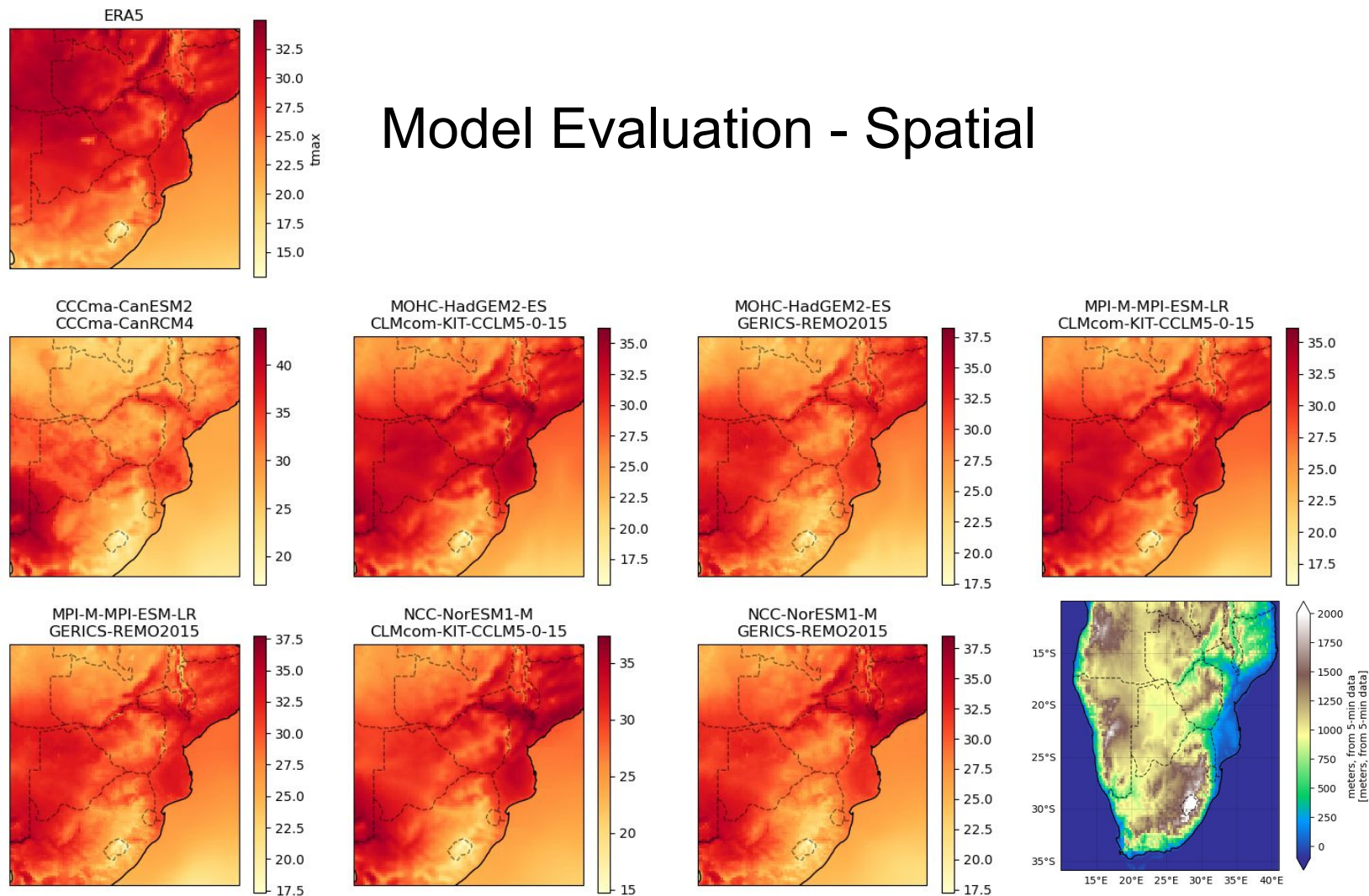
ERA5



Model Evaluation - Seasonality

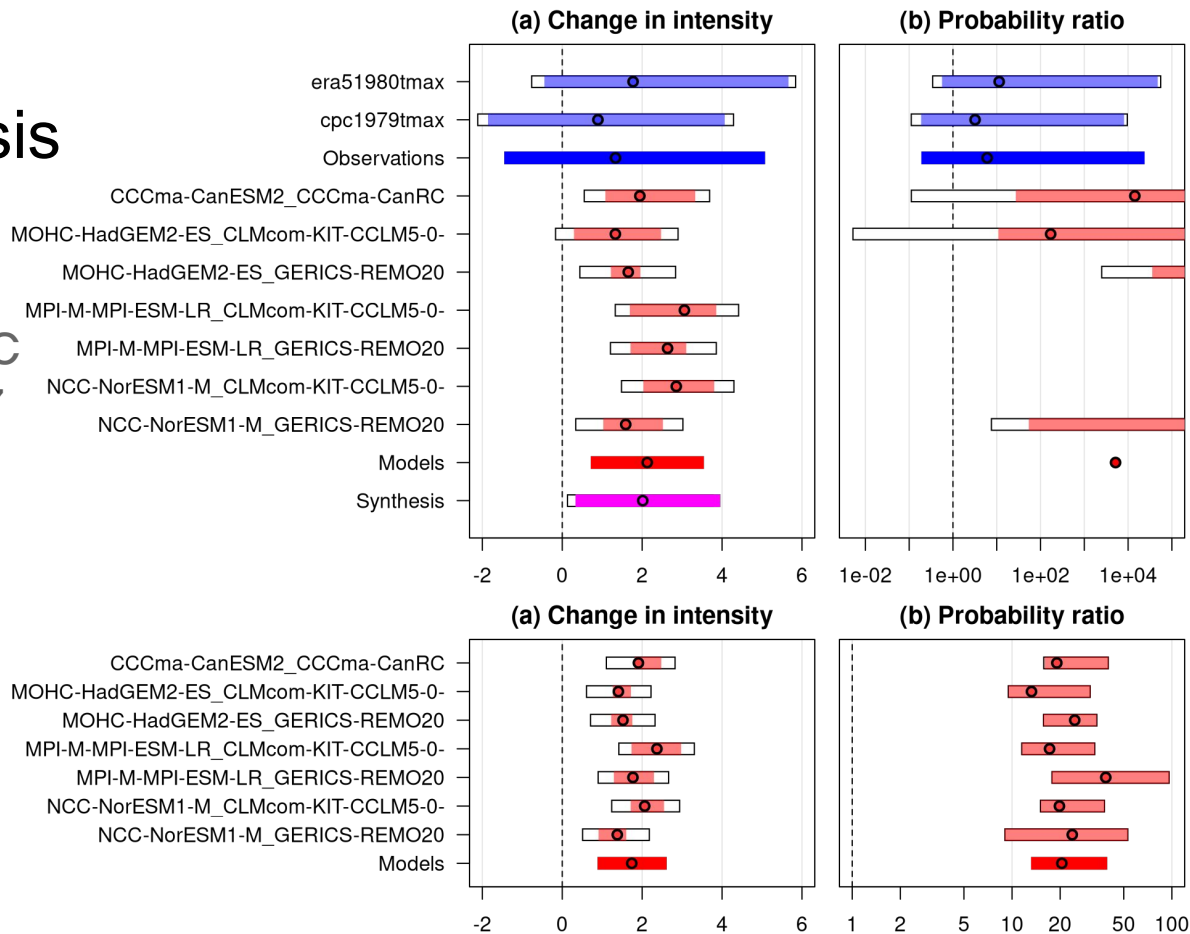


Model Evaluation - Spatial



Model/Obs Synthesis

- intensity change compatible between observations/models: 1-2°C
- observed PR: best est. 3-7
- model PR undefined

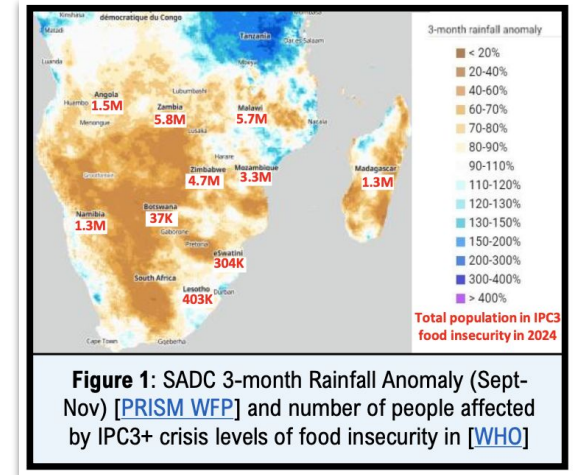
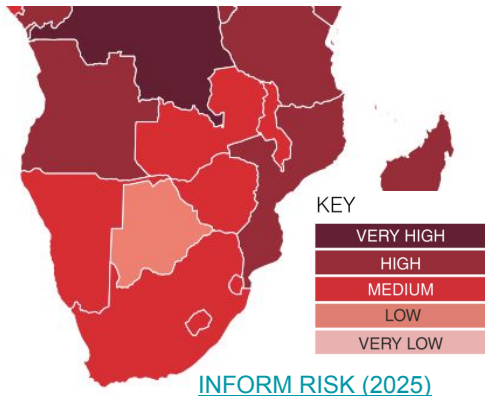


Hazard Synthesis

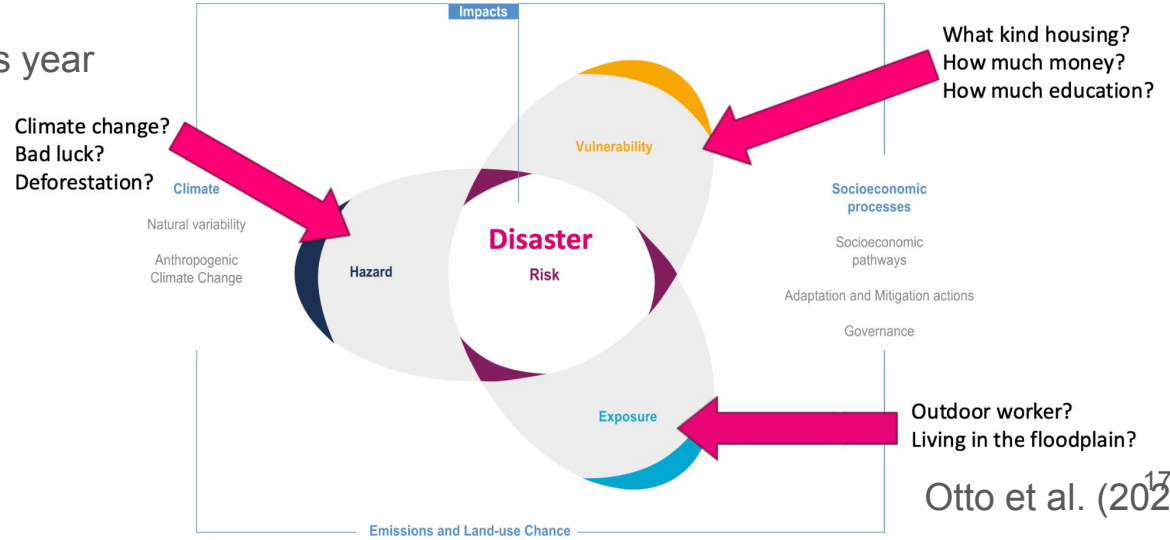
Data	Changes due to GMST		
		Probability ratio (95 % CI)	Intensity change (°C) (95% CI)
Observations	Past - Present	6.0 (0.27 - 17000)	1.3 (-1.29 - 4.92)
Models		5170 (NA - NA)	2.1 (0.87 - 3.39)
Synthesis		NA	2.0 (0.49 - 3.80)
Models only	Present - Future	20.5 (14.4 - 36.0)	1.7 (1.04 - 2.46)

Impacts, vulnerability & exposure

- What makes a heatwave dangerous?
- Who's vulnerable and exposed?
- coping strategies, heat plans
- aggravating circumstances
 - '23/'24 El Nino
 - drought/famine in previous year



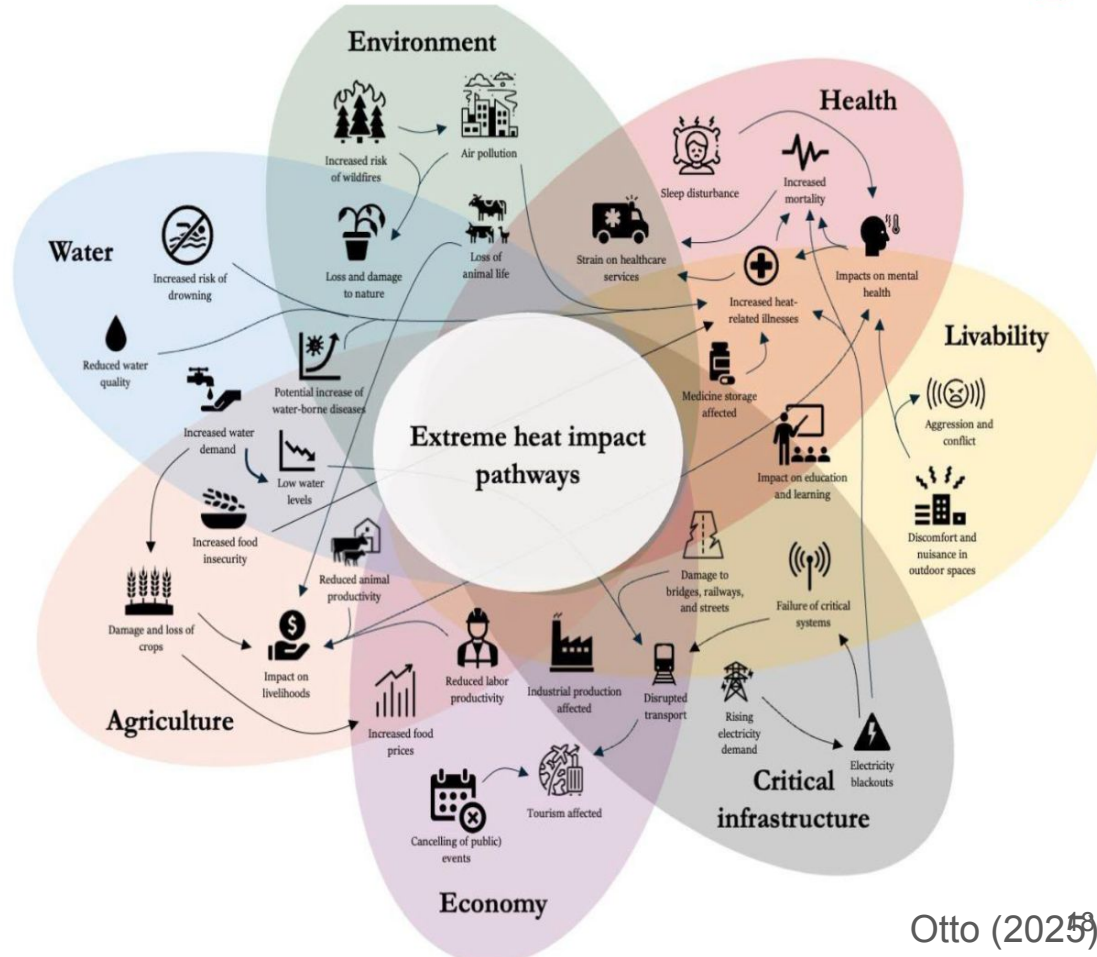
SEASONAL OUTLOOK SOUTHERN AFRICA, MSF (2024)



What caused the damage?

Factors determining the impacts of extreme weather on individuals

- **Institutional:** was there early warning? Are there emergency plans? Drills? Shelters?
- **Physical:** Informal housing? Sanitary facilities? Potable water? Standing water? Distance to health facilities?
- **Attitudinal:** Unafraid of heat/floods...? Distrusting governments/institutions? Disregarding zoning laws, water usage plans...
- **Social:** Low level of education? Little experience with extreme events? Access to social security?
- **Economic:** Low income? Few livelihood options? Many dependants?





“Wield your Academic Freedom like Gandalf’s staff”

- Lead with your good takes, not responses to others’ bad ones.
- When asked by journalists to comment on an upcoming study, do comment on the value & importance, don’t nitpick on details you might have done better
- Contribute to Wikipedia
- Join Bluesky
- Publish Open Access
- Don’t hide behind uncertainty
- Also, of course do what you can as a citizen

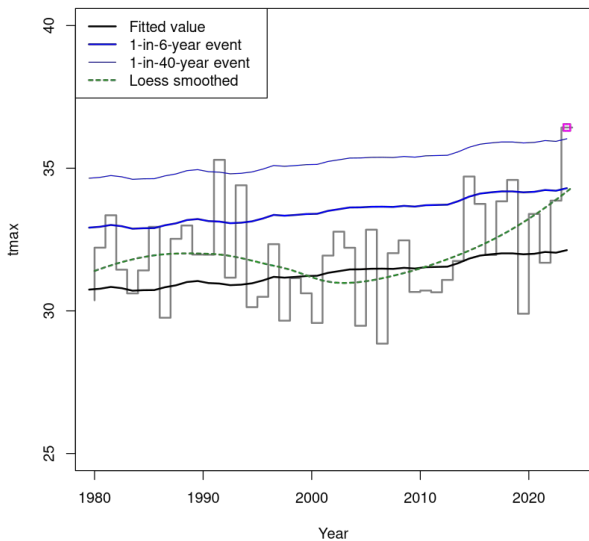


Be like Gandalf

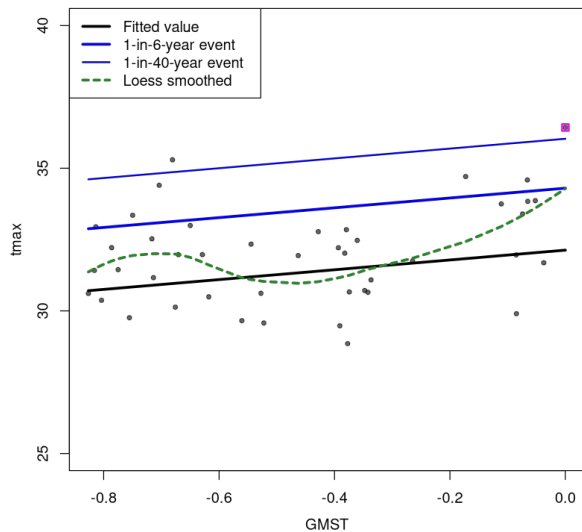
Bonus

5-days rolling mean (1979-2024)

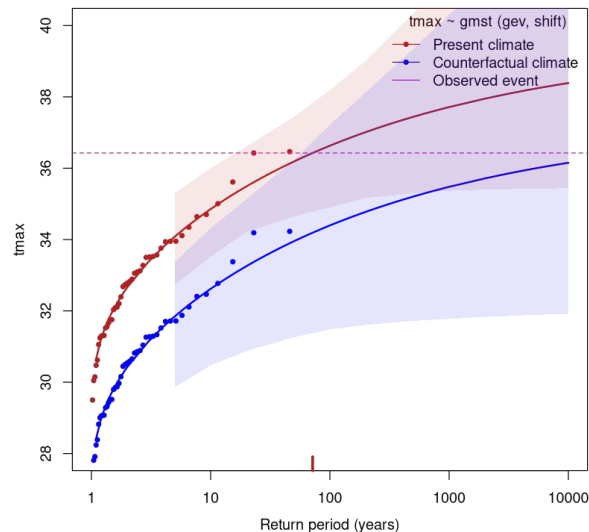
ERA5: GEV distribution



ERA5: GEV distribution

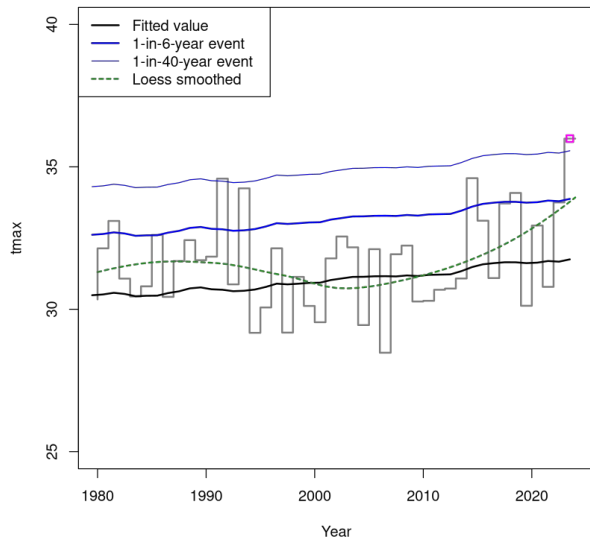


ERA5

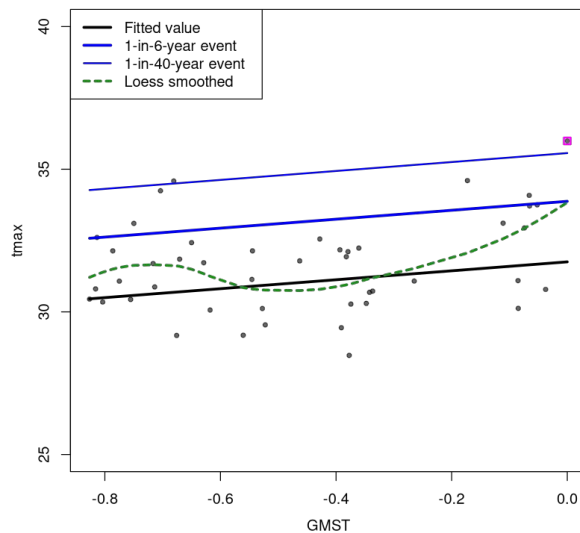


7-days rolling mean (1979-2024)

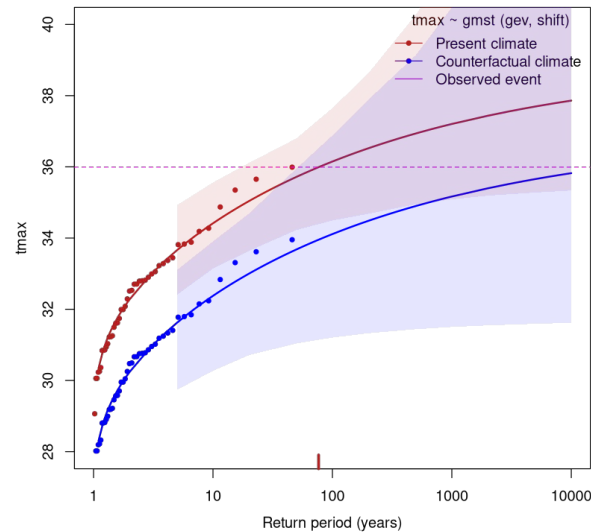
ERA5: GEV distribution



ERA5: GEV distribution

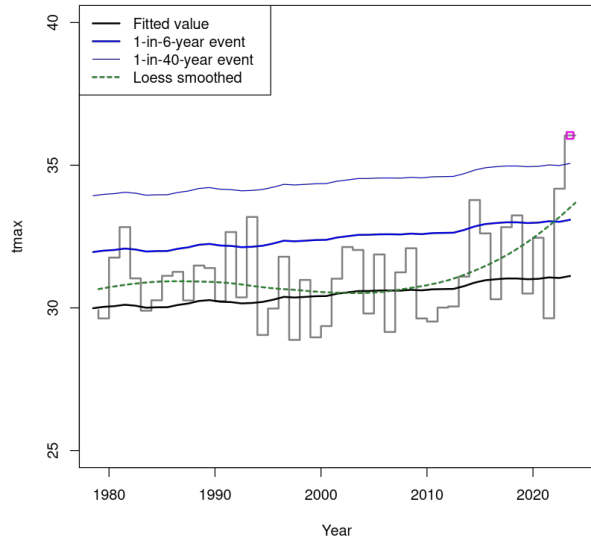


ERA5

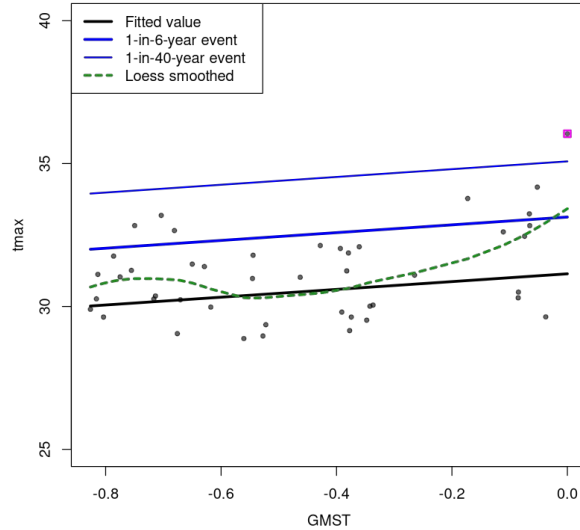


12-days rolling mean (1979-2024)

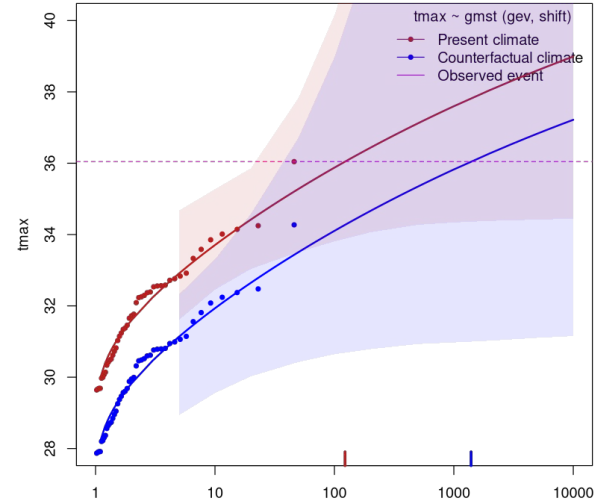
ERA5: GEV distribution



ERA5: GEV distribution

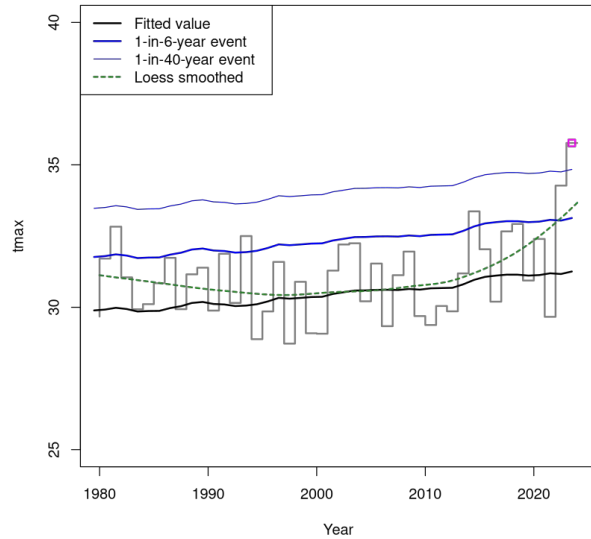


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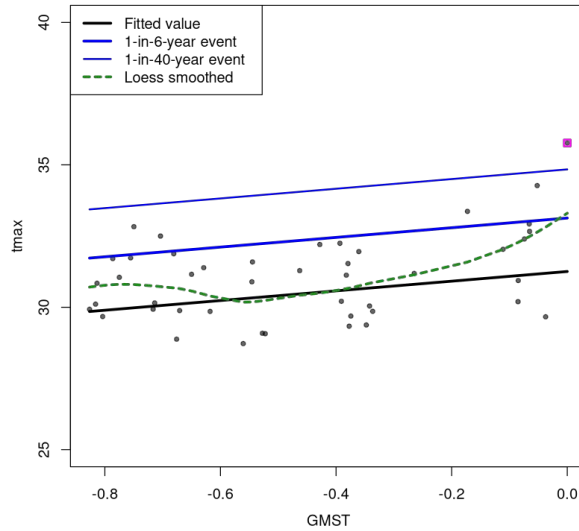


14-days rolling mean (1979-2024)

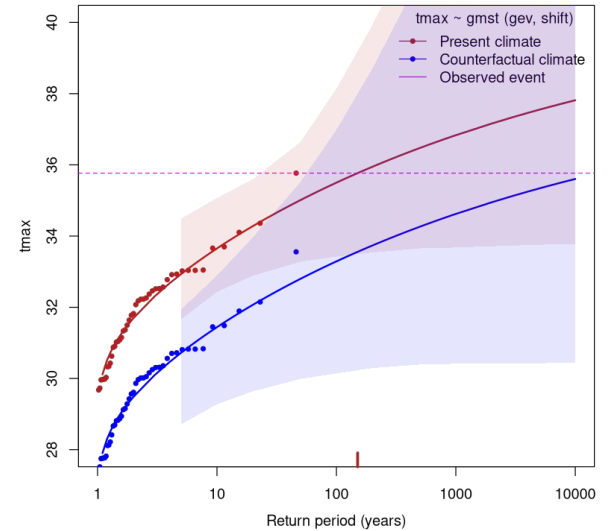
ERA5: GEV distribution



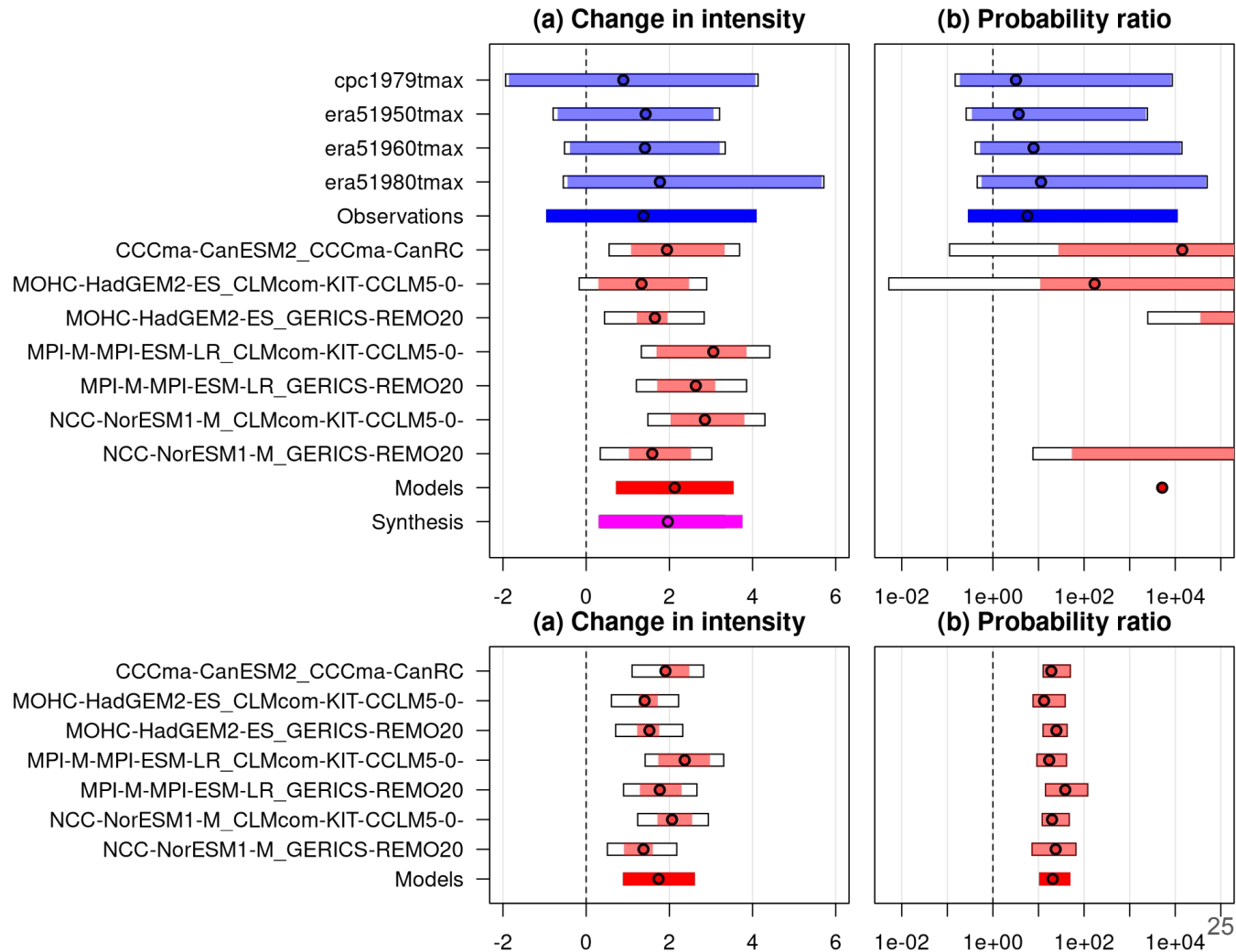
ERA5: GEV distribution



ERA5



Synthesis

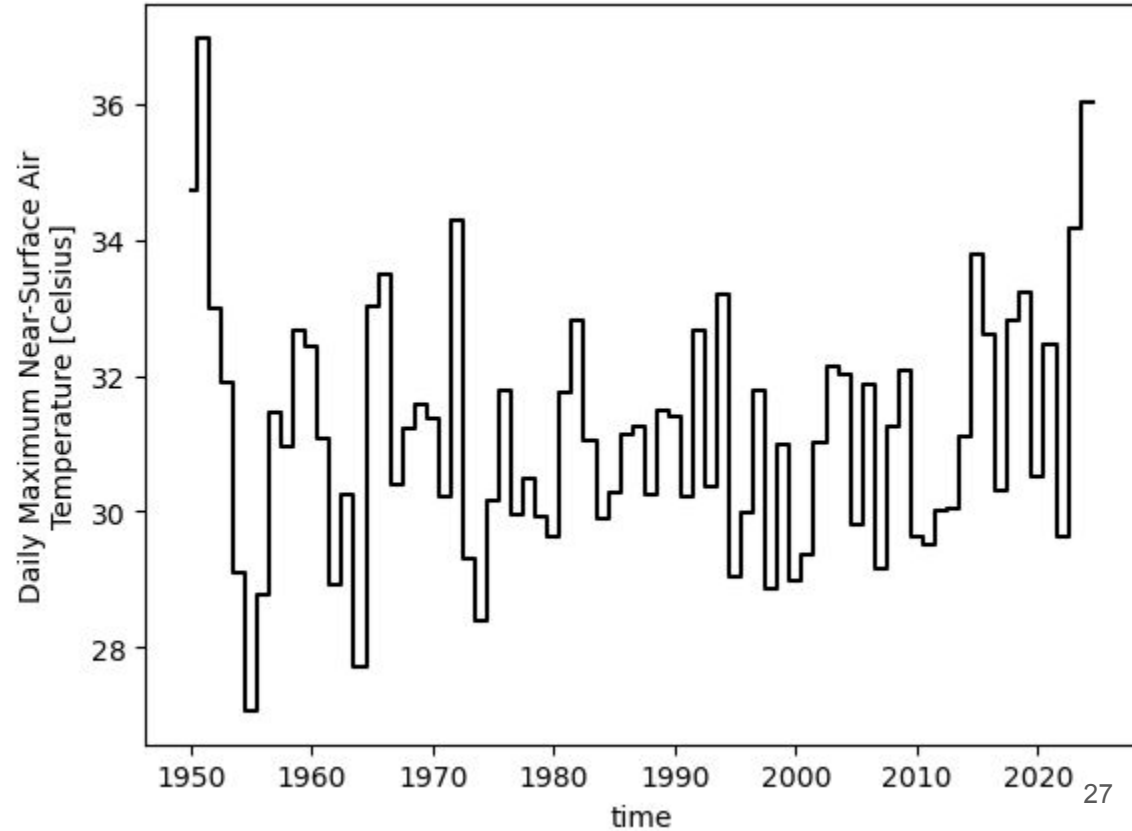


Triggers

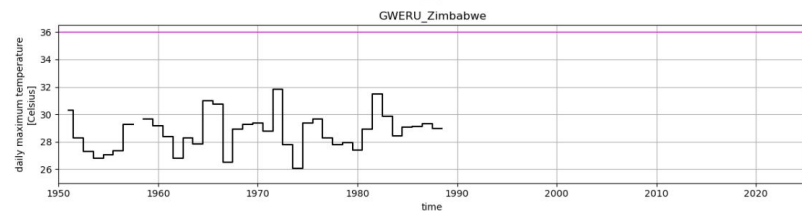
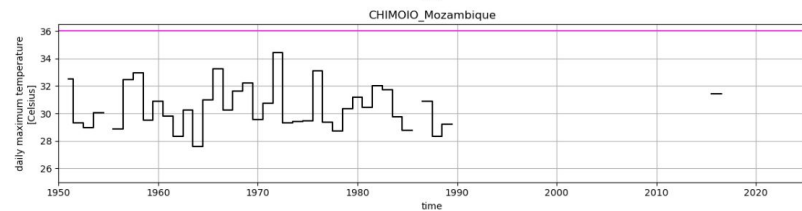
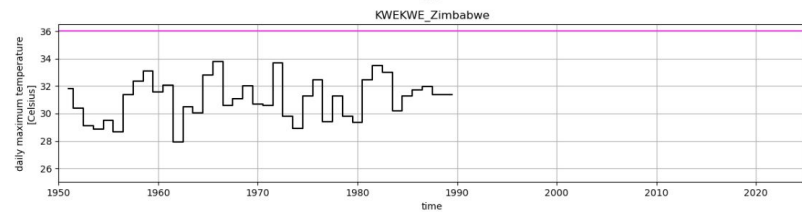
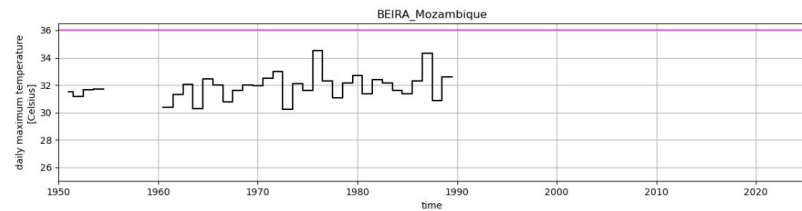
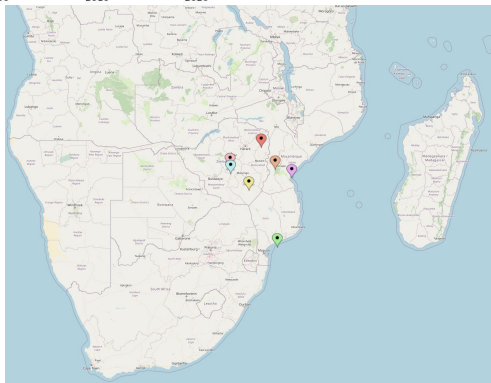
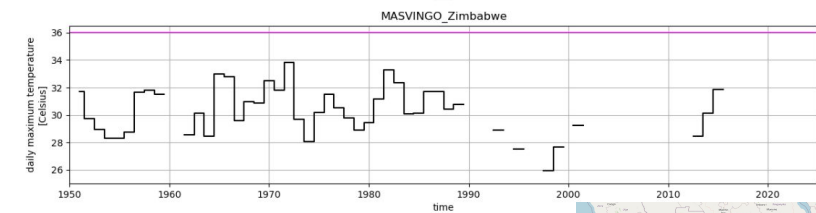
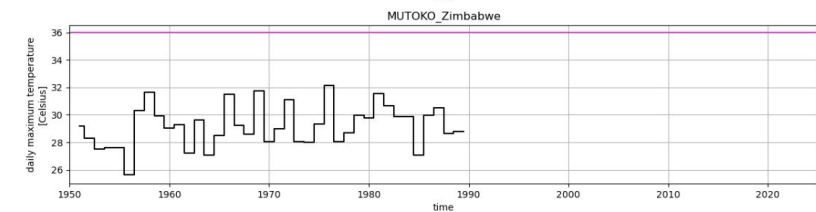
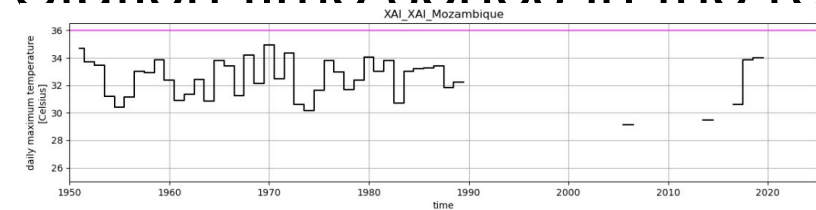
Hazard	Monitoring	Threshold
Flood	•Google alert ("flood") •Reliefweb: Alert and Ongoing Disasters •ECHO Daily Flash •FloodList •IFRC DREF •GLIDE number	•≥100 deaths OR •≥1,000,000 people affected OR •≥50% of total population affected OR •Declaration of State of Emergency/Disaster
Storm	•GDACS Alert •Google alert ("storm", "hurricane", "cyclone", "typhoon") •Reliefweb: Alert and Ongoing Disasters •ECHO Daily Flash •IFRC DREF •GLIDE number	•≥100 deaths OR •≥1,000,000 people affected OR •≥50% of total population affected
Drought	•GDO •FEWS Net •EM-DAT •IFRC DREF •Google alert ("drought", "state of emergency", "state of disaster") •Reliefweb: Alert and Ongoing Disasters •ECHO Daily Flash •IFRC DREF •GLIDE number	•≥2 million people affected OR •≥50% of total population affected OR •Declaration of State of Emergency/Disaster OR •Orange or red GDACS Alert •Missing – economic impacts
Heat wave/ Cold wave	•Google alert ("extreme heat", "extreme cold", "heatwave", "cold wave", "polar vortex") •Reliefweb: Alert and Ongoing Disaster •GLIDE number •Metblue: Apparent Temperature Map •Metblue: Severe Weather Warning •WMO World Weather Information Service: Present Temperature Map •Twitter accounts ("Extreme Temperatures Around The World", "World Meteorological Organization")	1.Forecast of potential record-breaking temperatures 2.Newspaper reports of ≥10 heat/cold-related deaths or major disruptions to critical sectors (notably transportation, energy, and manufacturing) 3.Occurrence during the first 3-6 weeks of the hot/cold season (when the most temperature-related deaths tend to occur) 4.Event occurrence in a densely populated area (≥200 people/km²) 5.Event occurrence in a highly vulnerable area (≥4.8 INFORM) and/or high lack of coping capacity (≥6.0 INFORM)
Fires	•GDACS Alert •Reliefweb: Alert and Ongoing Disaster •Google alert ("forest fire", "bushfire", "wildfire") •ECHO Daily Flash •EM-DAT	We will trigger if criteria 1 is met, along with at least one of criteria 2-4: 1.Concurrent heatwave and/or drought 2.≥400.000 acres / 160.000 hectares / 1.600 km² burnt area 3.≥10.000 people affected 4.≥10 deaths

1951?

- outlier in 1951?
- need local experts



Station time series in the region



Different questions answered



Probabilistic attribution (based on results from Otto et al., 2012)	Averaged over the Russian domain and over the month of July, temperatures in 2010 were 5 °C above the 1960s climatology, of which 4 °C was due to internal variability, and 1 °C was due to anthropogenic climate change. The heatwave represented a 1-in-33-year event, which was 3 times more likely than it would have been in the 1960s.
Storyline attribution (based on present results)	Averaged over the Russian domain, temperatures in 2010 steadily increased from the 1985–2015 climatology through the month of July until about 10 August, then rapidly returned to climatology. The domain-averaged heatwave reached 10 °C above the 1985–2015 climatology in early August, of which 8 °C was due to internal variability, and 2 °C was due to anthropogenic climate change. The anthropogenic component of the warming reached 4 °C in the region to the south of Moscow during the first half of August, where it exacerbated the already warm temperatures there.