



Global warming **decreases** rainfall during heavy precipitation events in the eastern Mediterranean

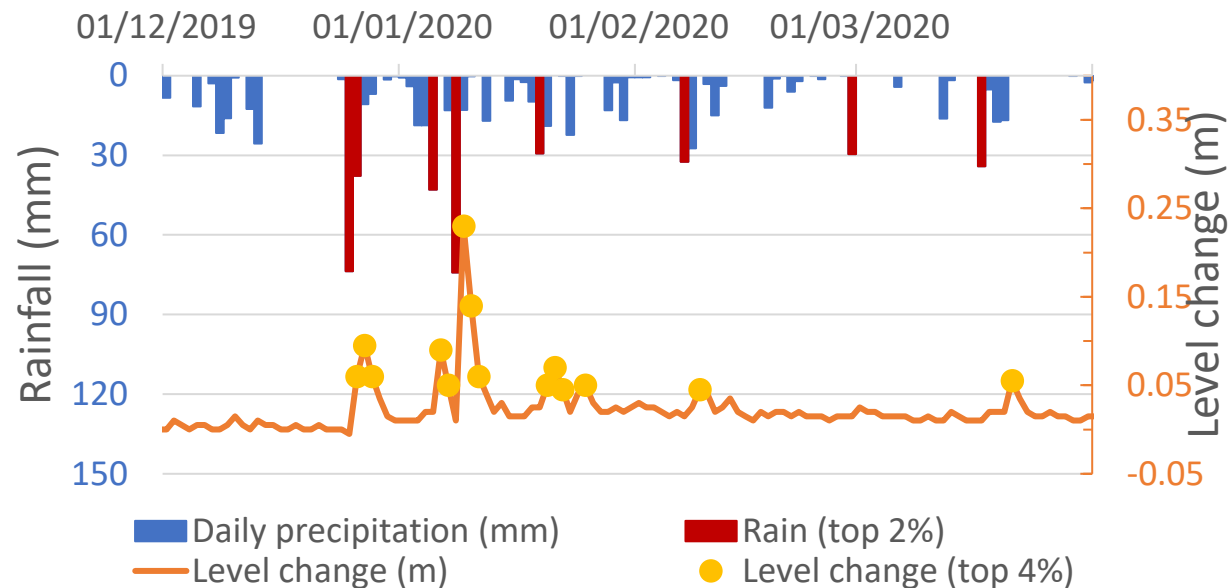
(but increases short-duration rain-rates)

Moshe (Koko) Armon, Francesco Marra, Chaim Garfinkel, Dorita Rostkier-Edelstein, Ori Adam, Uri Dayan, Yehouda Enzel and Efrat Morin



Heavy precipitation events (HPEs)

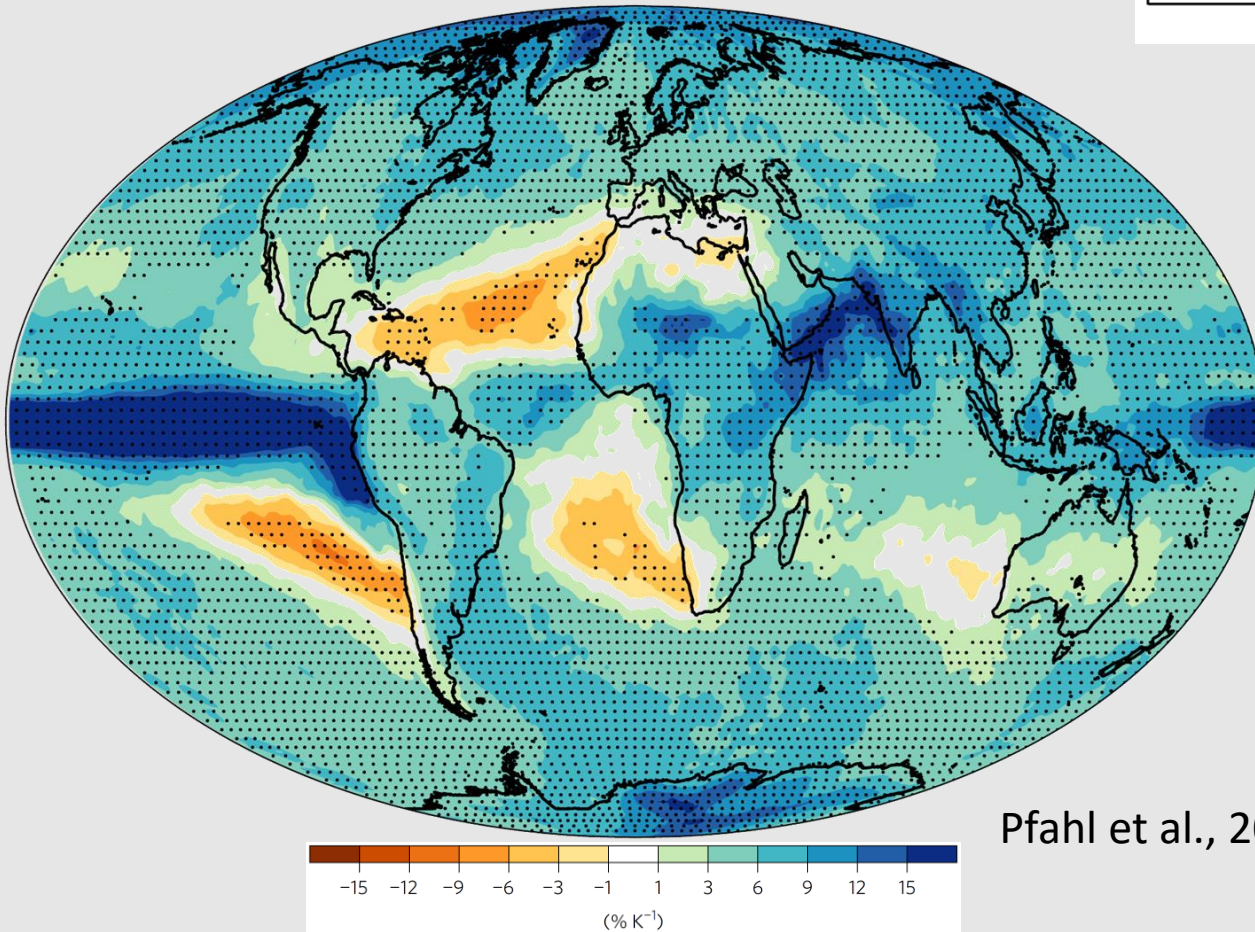
- Water resources
- Flash-floods
- Urban flooding



Paran Stream – Reuters:
18/1/2010

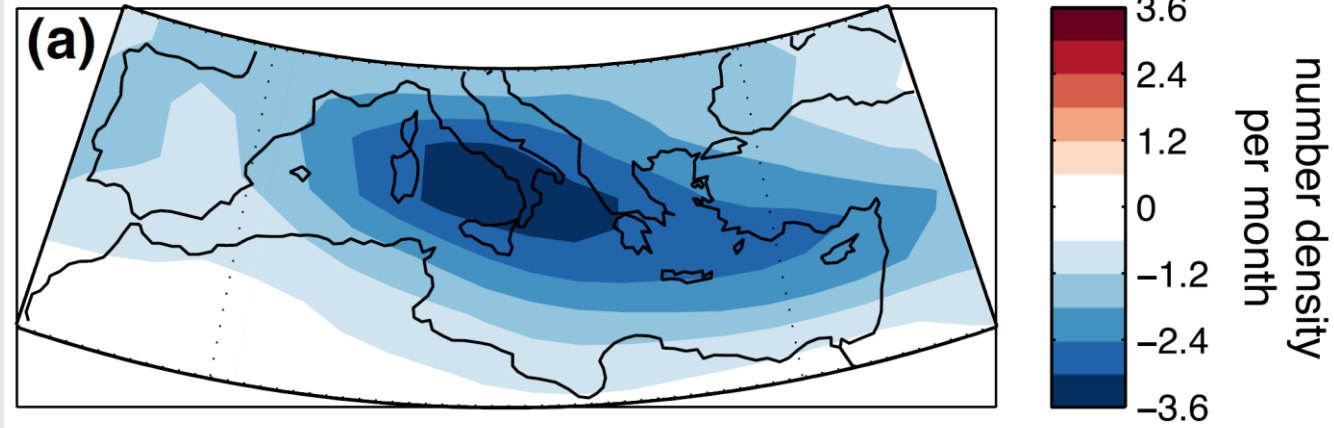
Changes in extreme precipitation

Change in annual maximum precipitation (Rx1day)

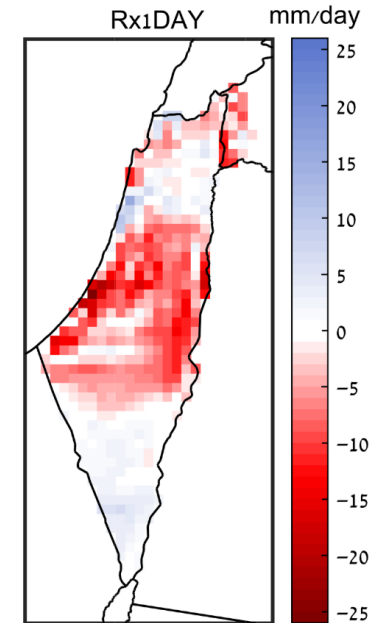


Pfahl et al., 2017

Track density response



Zappa et al., 2015

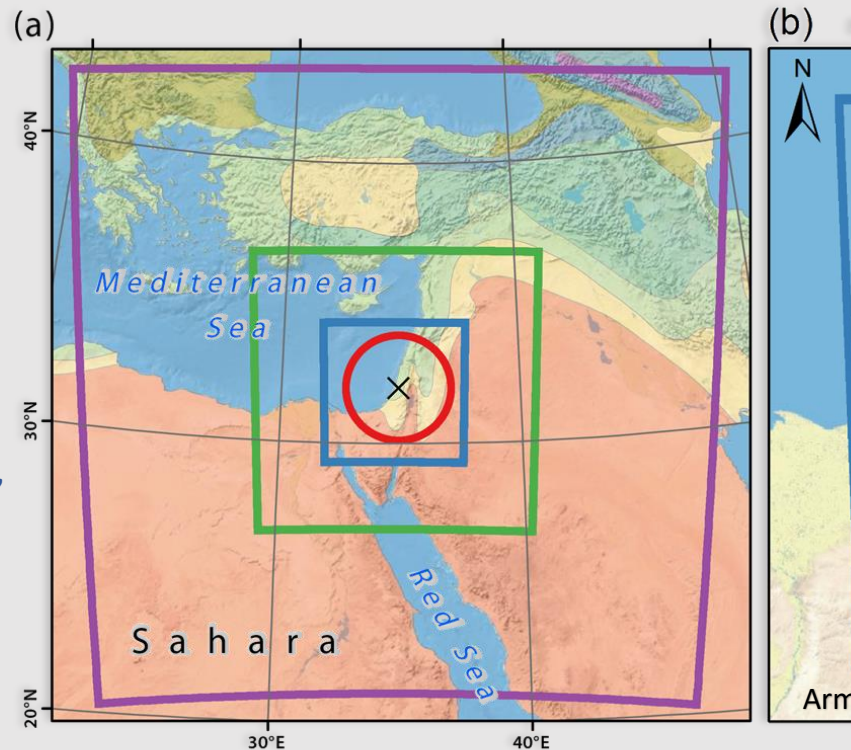


Hochman et al., 2018

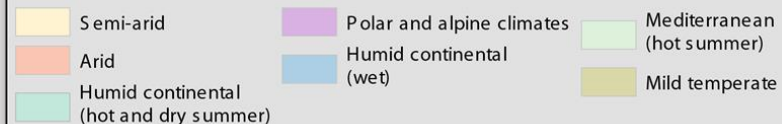
Methodology

Weather research and forecasting model (WRF)

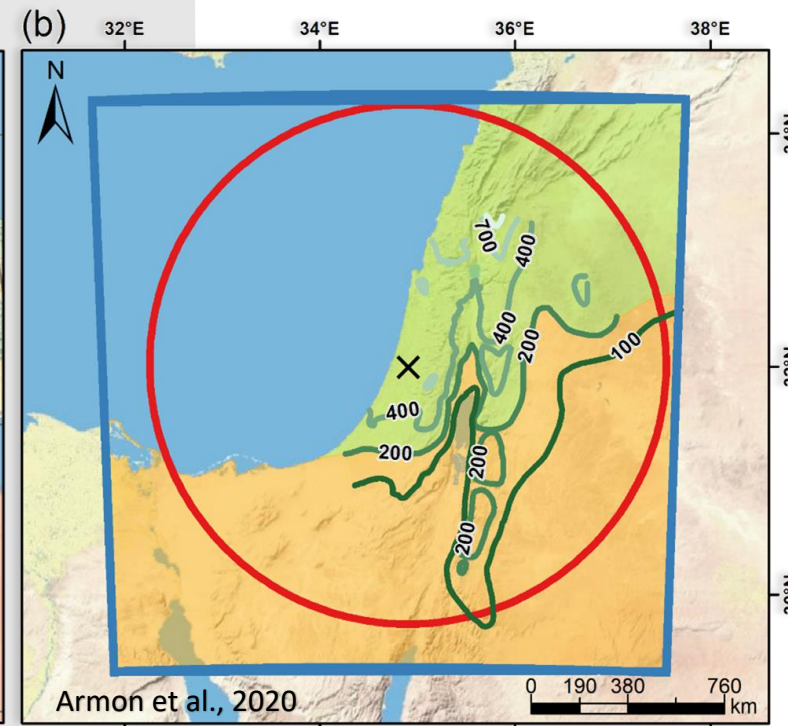
- Input: Era-Interim 6h, ~80 km, 60 horizontal levels
- Three nested domains, 1:5 ratio
- Inner domain – **convection-permitting**, comparable to radar domain



Climate zones

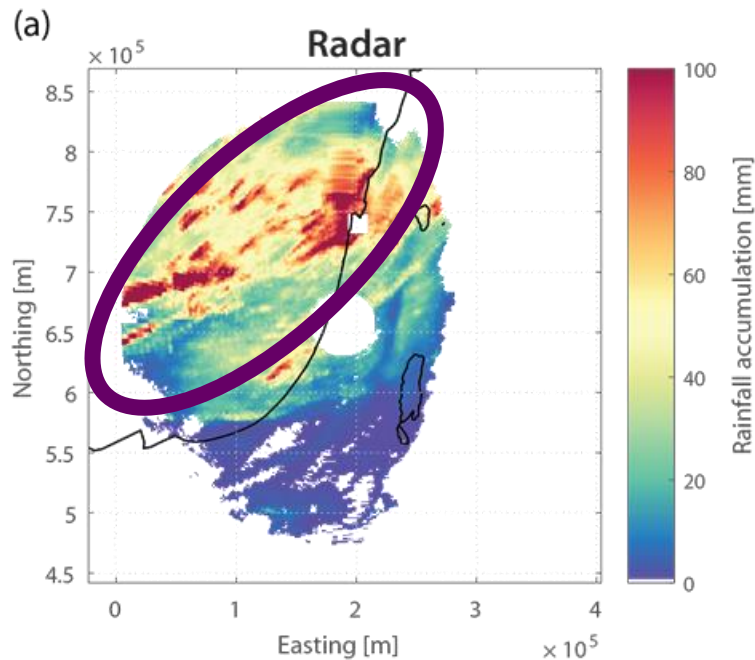
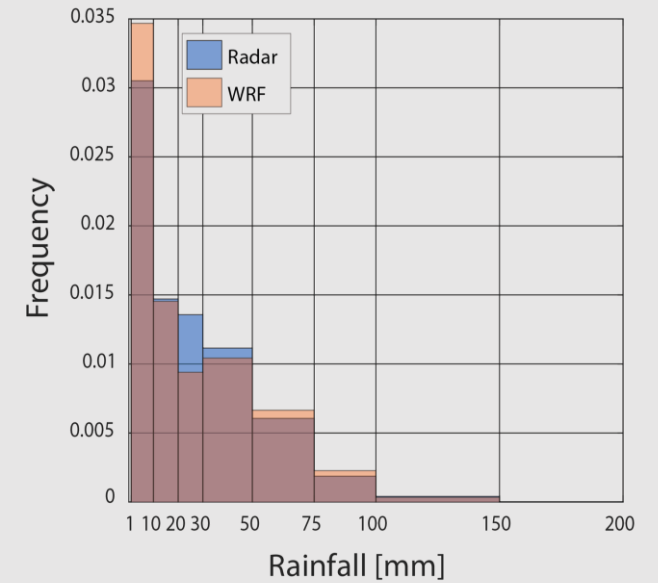


Weather radar

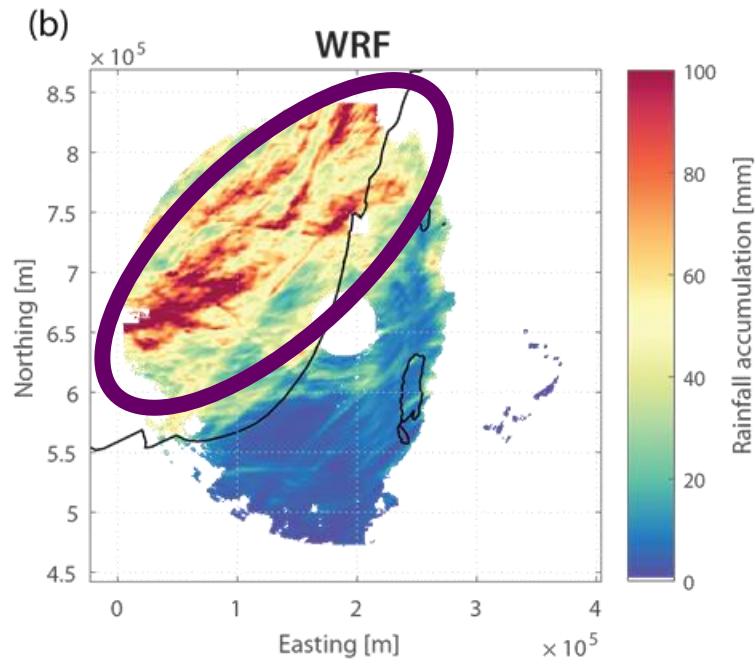


- 24-yr radar data, at 1 km, 5-min resolution
- Quantitative precipitation estimates after Marra & Morin (2015)
- Pixel-based HPE identification

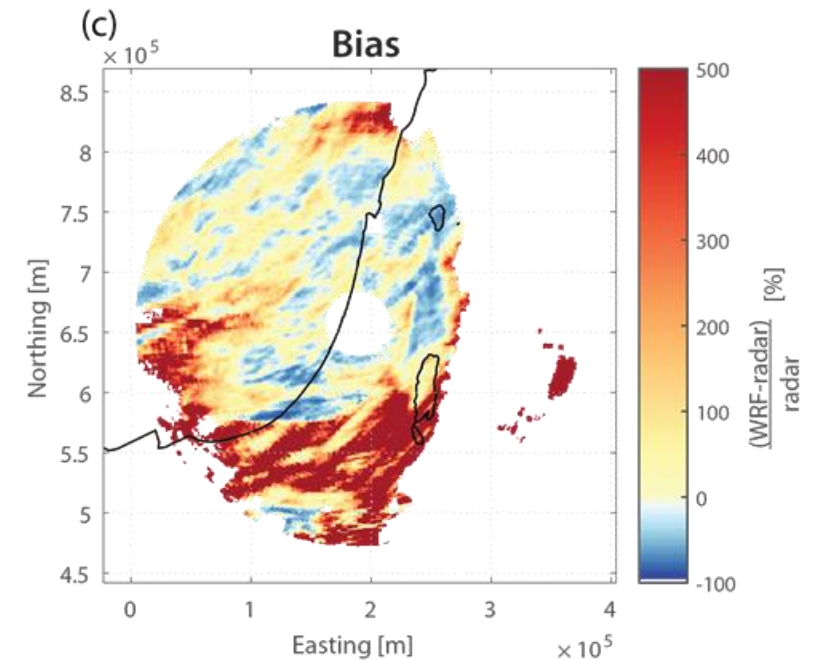
Example case: HPE #1



2-5/11/1991

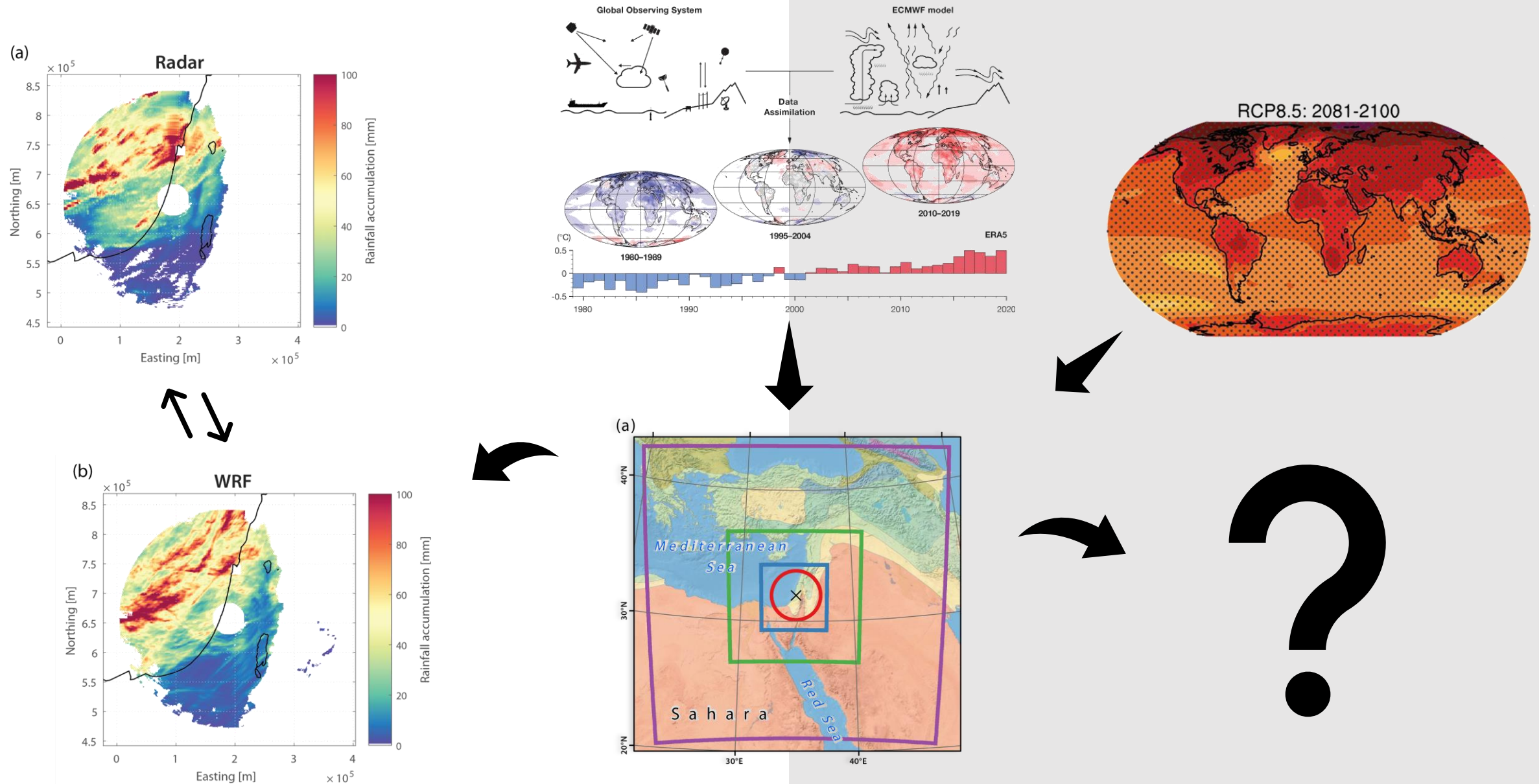


Bias = 120%; CC = 0.76; RMSE = 20 mm

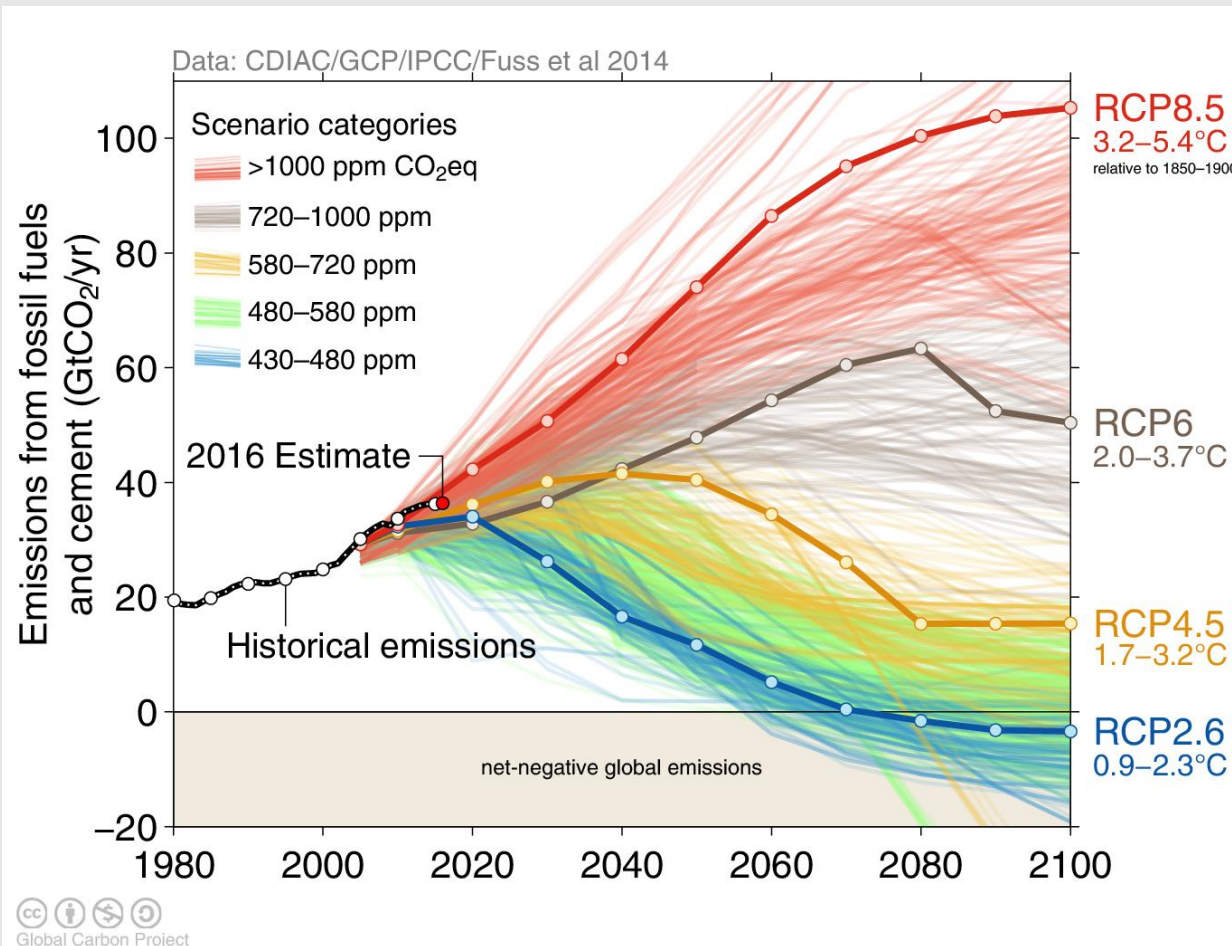


Armon et al., 2020; HESS

HPEs under climate change - Methodology

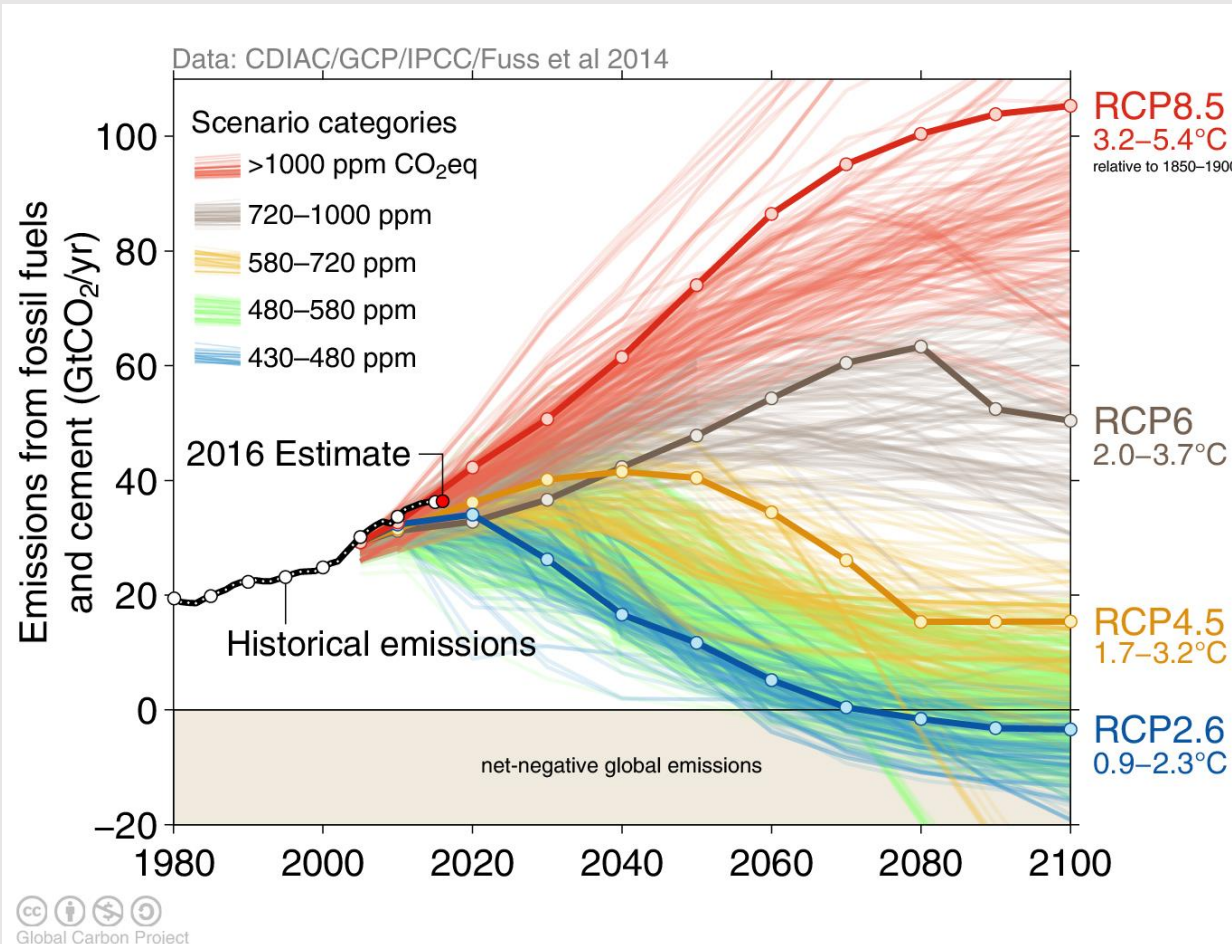


HPEs under climate change – (global) future projections



#	Model name	Lat resolution	Lon resolution	Number of vertical levels	Model top [hPa]
1	ACCESS1-0	1.25	1.88	17	10
2	ACCESS1-3	1.25	1.88	17	10
3	CCSM4	0.94	1.25	17	10
4	CESM1-BGC	0.94	1.25	17	10
5	CESM1-CAM5	0.94	1.25	17	10
6	CMCC-CESM	3.68	3.75	27	1
7	CNRM-CM5	1.39	1.41	17	10
8	CanESM2	2.77	2.81	22	1
9	GFDL-CM3	2.00	2.50	23	1
10	GFDL-ESM2G	1.52	2.50	17	10
11	GFDL-ESM2M	1.52	2.50	17	10
12	GISS-E2-H	2.00	2.50	17	10
13	GISS-E2-R	2.00	2.50	17	10
14	HadGEM2-AO	1.25	1.88	17	10
15	HadGEM2-ES	1.25	1.88	17	10
16	IPSL-CM5A-LR	1.89	3.75	17	10
17	IPSL-CM5A-MR	1.27	2.50	17	10
18	IPSL-CM5B-LR	1.89	3.75	17	10
19	MIROC-ESM	2.77	2.81	29	1
20	MIROC-ESM-CHEM	2.77	2.81	29	1
21	MIROC5	1.39	1.41	17	10
22	MPI-ESM-LR	1.85	1.88	22	1
23	MPI-ESM-MR	1.85	1.88	22	1
24	MRI-CGCM3	1.11	1.13	22	1
25	MRI-ESM1	1.11	1.13	22	1
26	NorESM1-M	1.89	2.50	17	10
27	NorESM1-ME	1.89	2.50	17	10
28	bcc-csm1-1	2.77	2.81	17	10
29	inmcm4	1.50	2.00	17	10

HPEs under climate change – (global) future projections



- End of 21st century minus end of 20th century
- RCP 8.5:

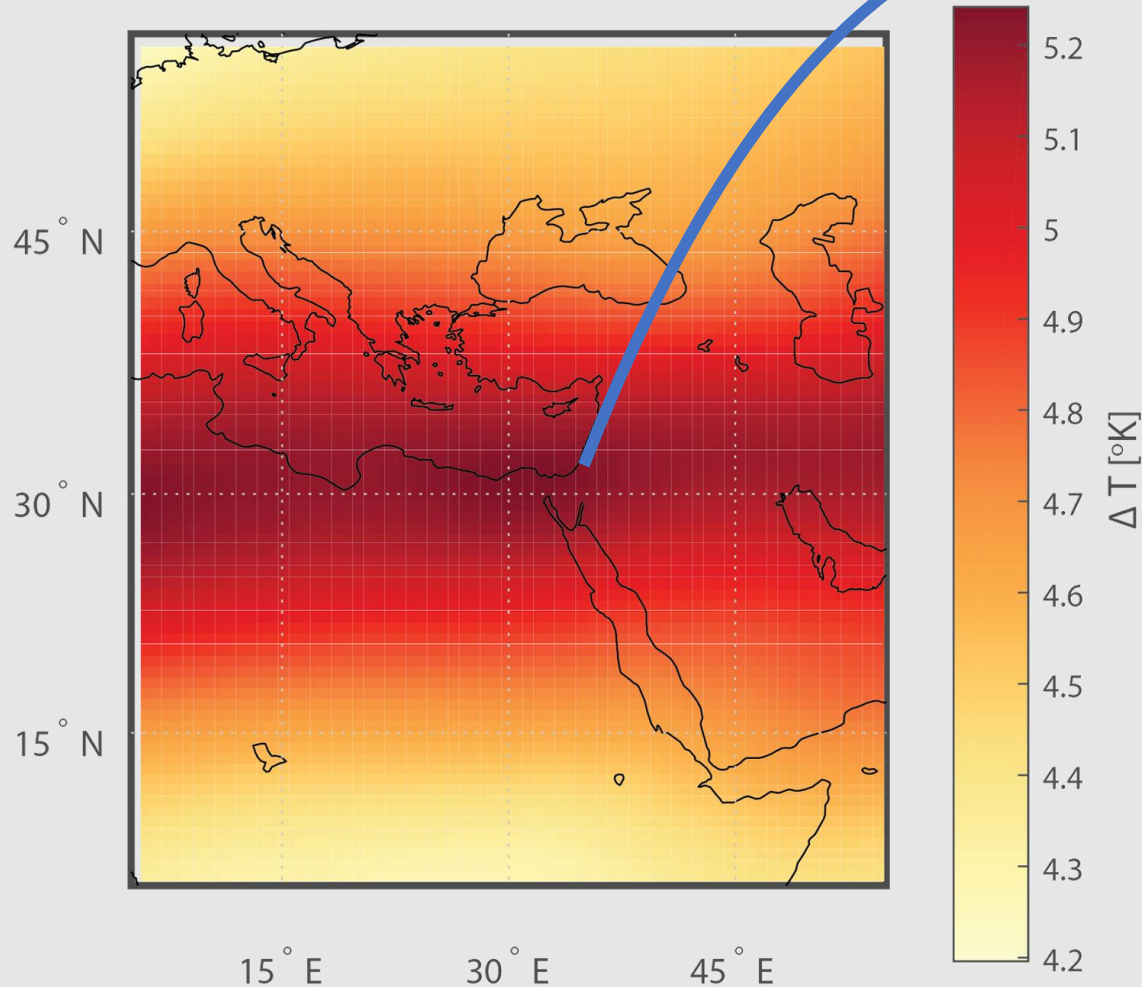
$$\Delta X = \overline{X_{month}} \Big|_{2074-2099}^{29 \text{ models}} - \overline{X_{month}} \Big|_{1979-2004}^{29 \text{ models}}$$

HPEs under climate change

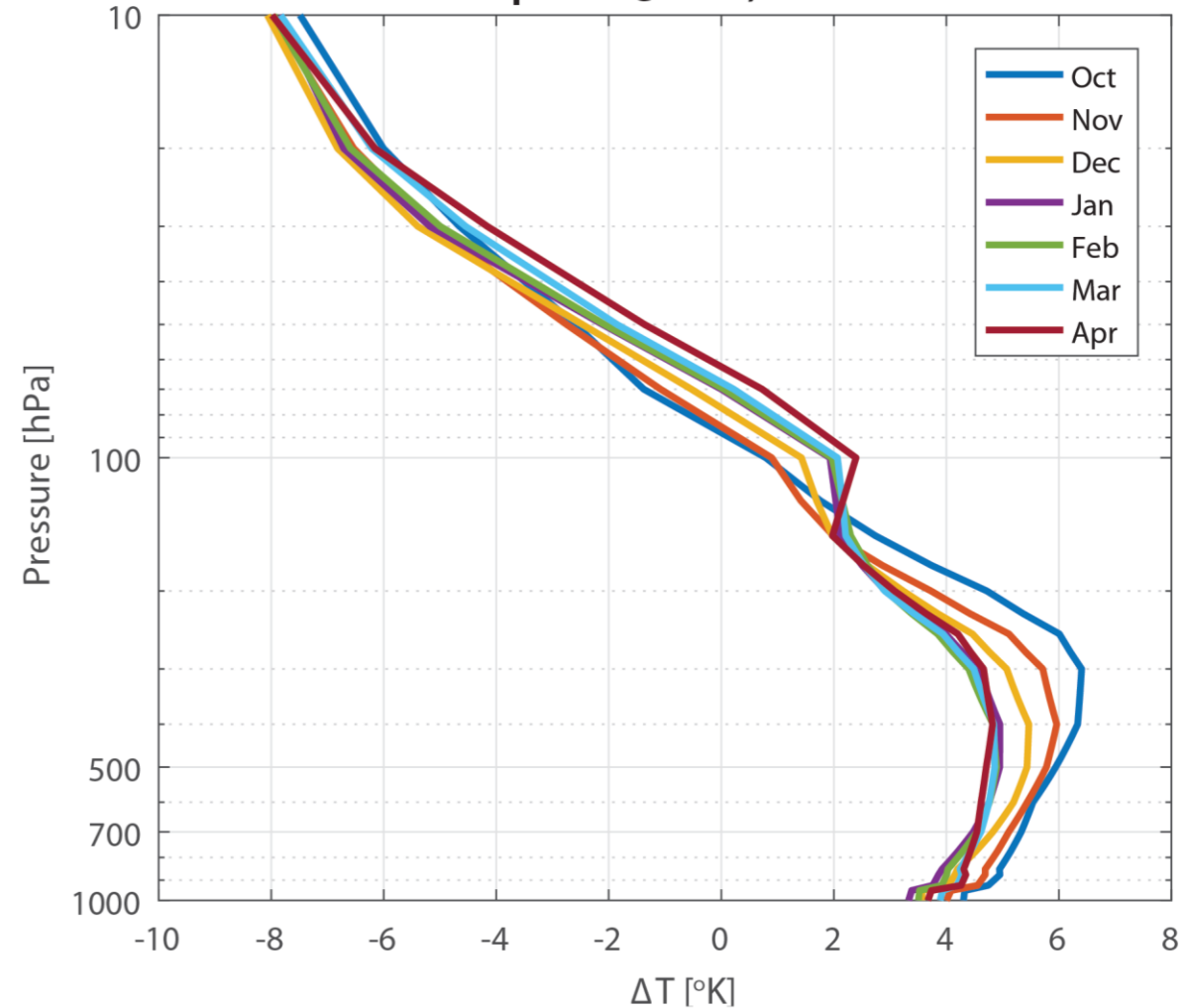
– local projections

Parameters changed: Surface **pressure** and temperature; **wind**, **temperature** and **moisture** profiles

Average ΔT @ 500 hPa [Oct through Apr]

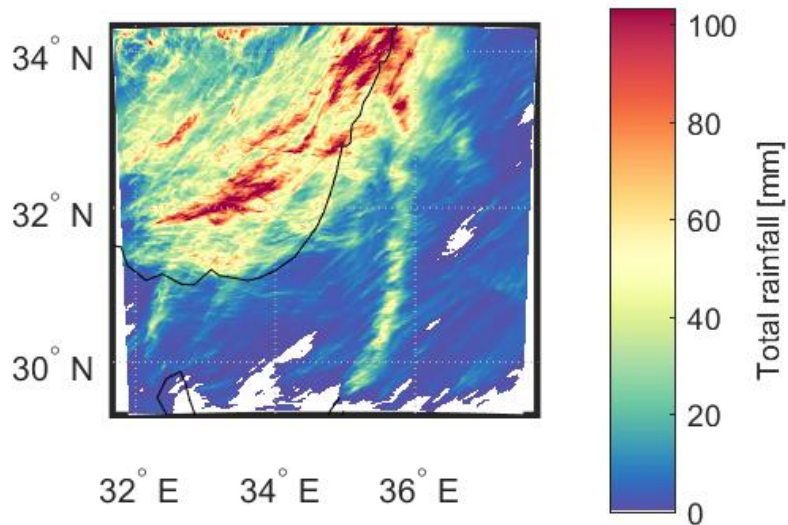


ΔT profile @ 32° N, 35° E

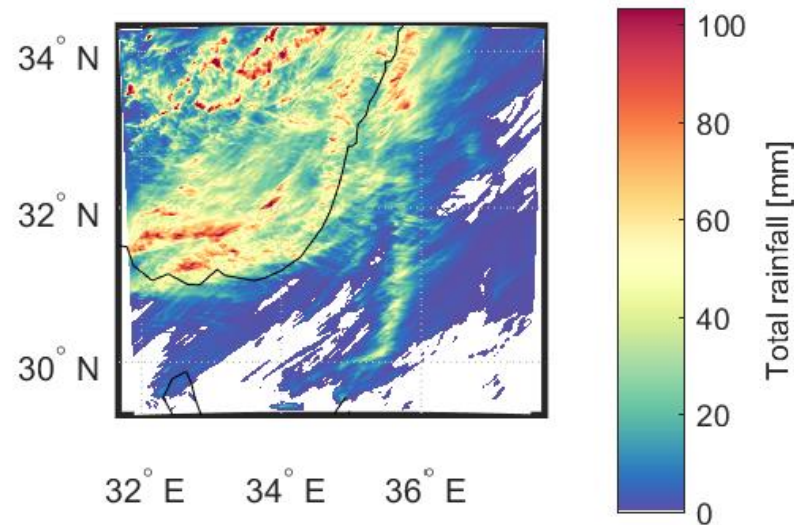


PGW case example: HPE #1

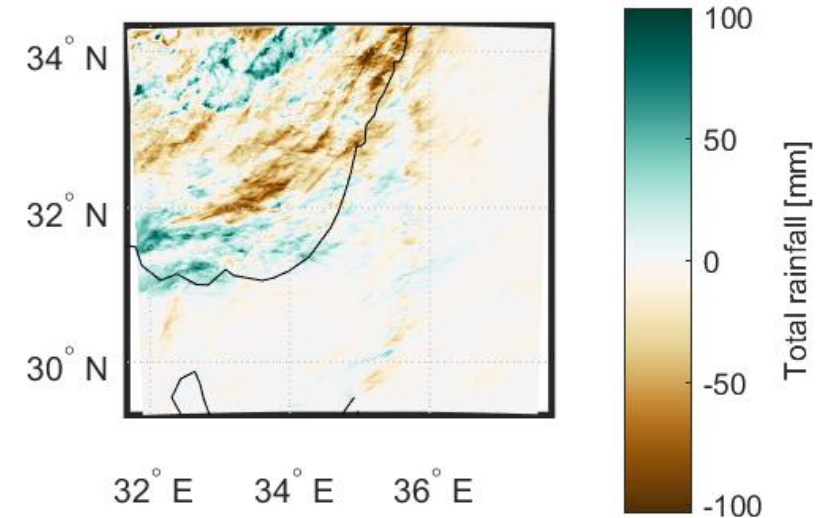
Historic HPE (WRF)
Mean = 21.9 mm



Future HPE (WRF-PGW)
Mean = 17.5 mm



Future – Historic
Mean = -4.4 mm

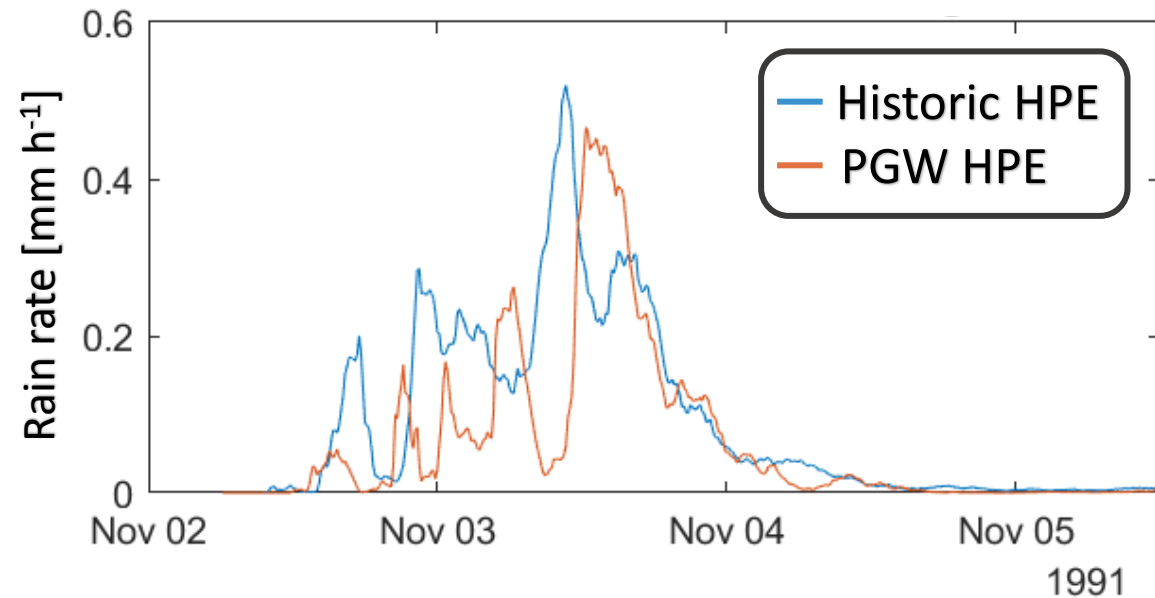


2-5/11/1991

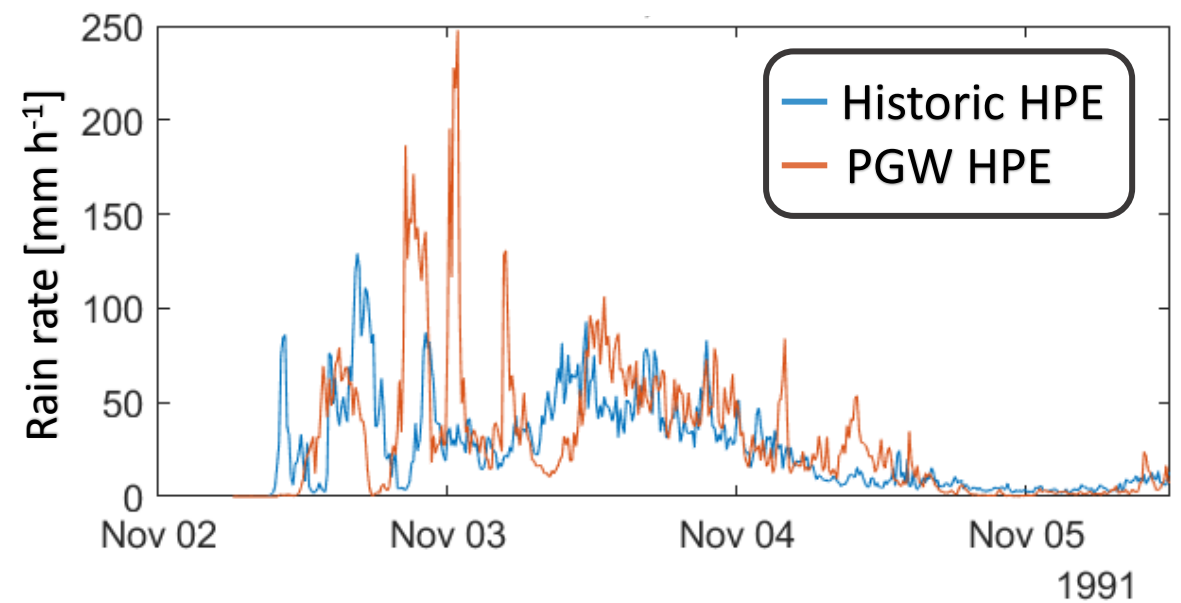
2-5/11/2091?

HPE #1 – temporal evolution

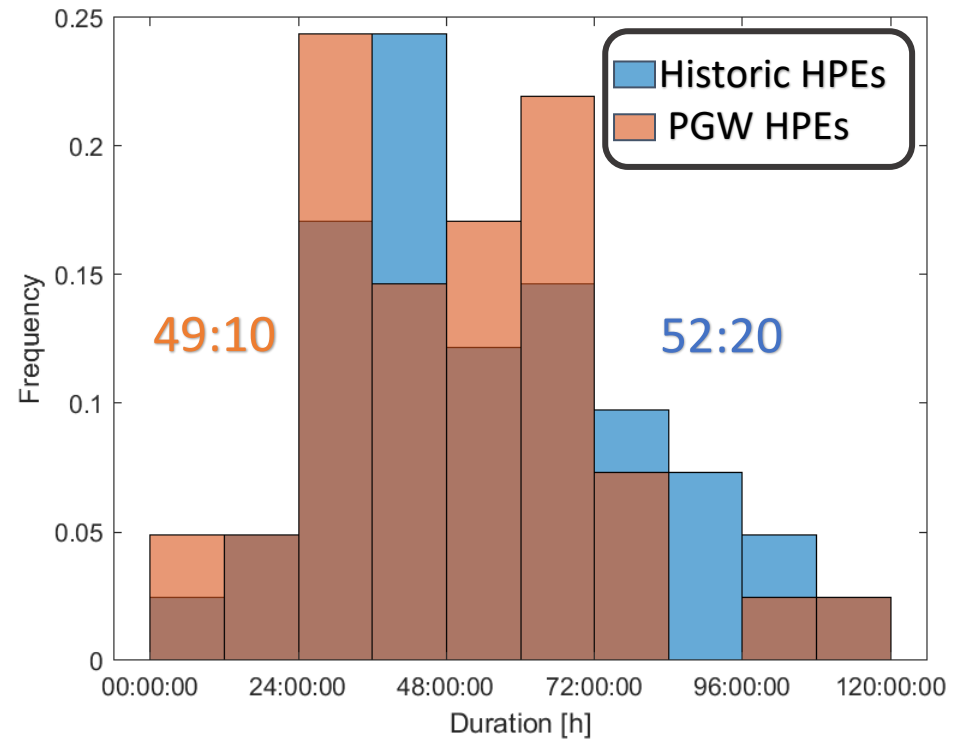
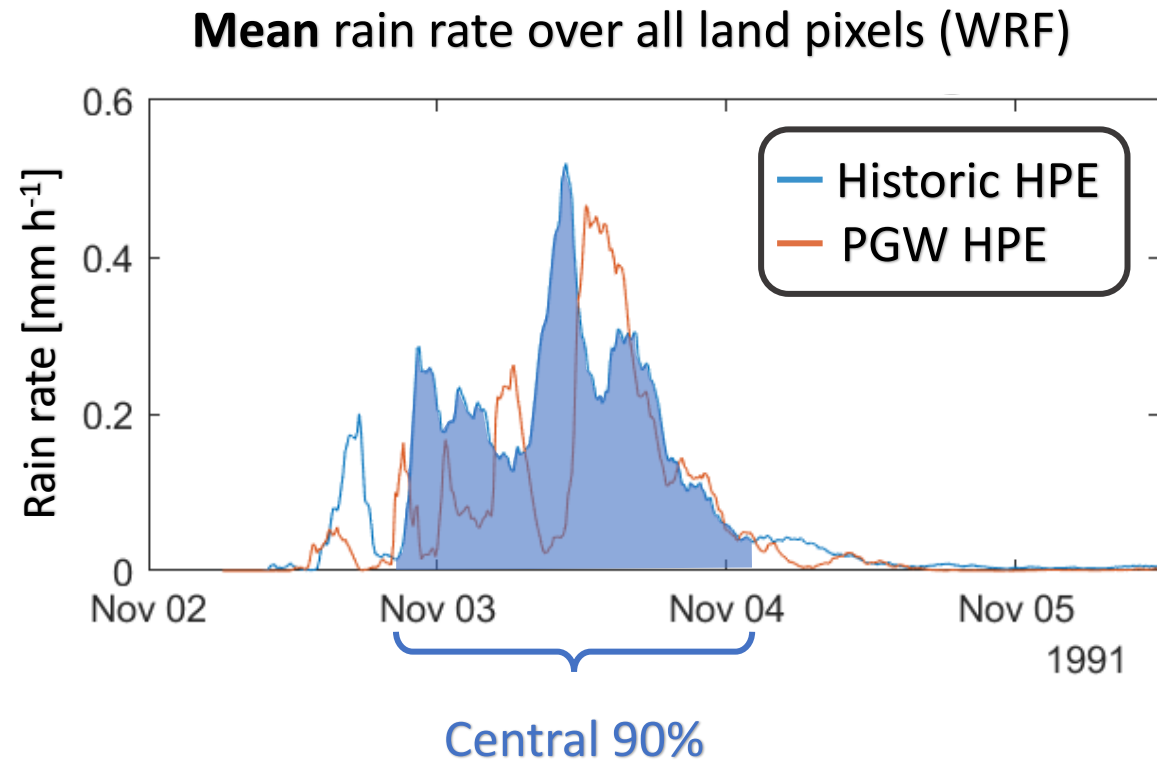
Mean rain rate over all land pixels (WRF)



Pixel-based **max** rain rate over land area (WRF)

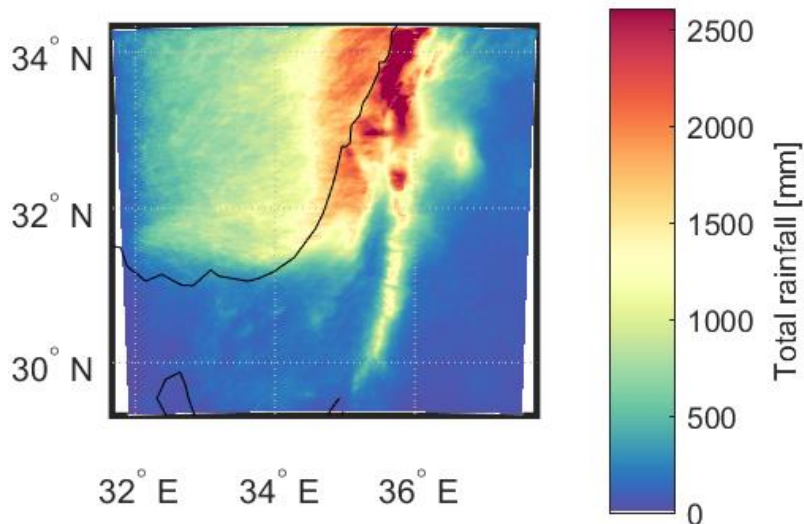


Event durations

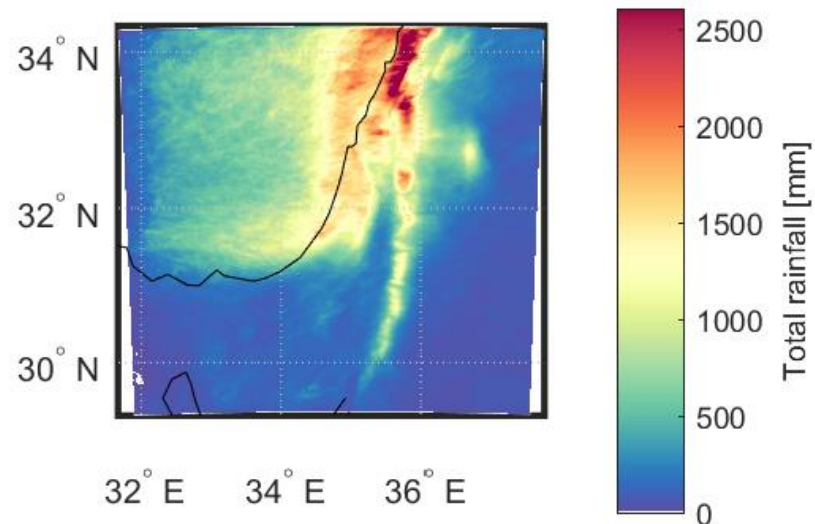


HPEs under climate change – **Total** rainfall

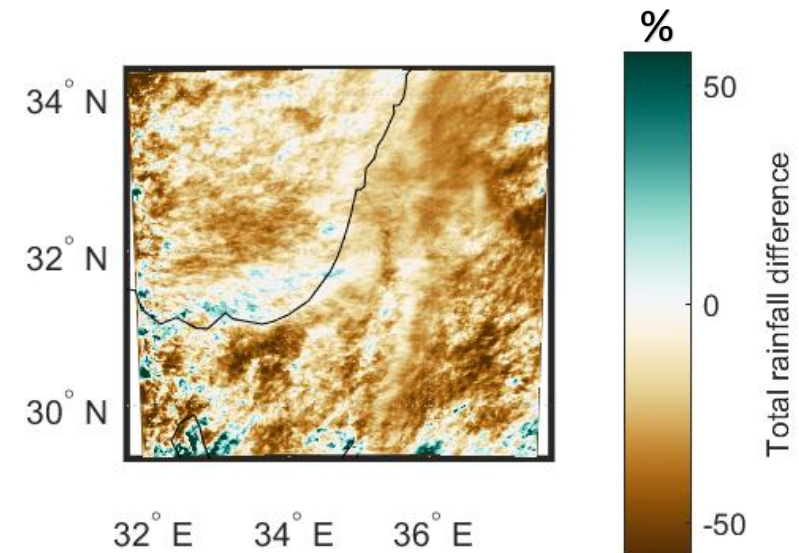
Historic HPE (WRF)
Mean = 600.6 mm



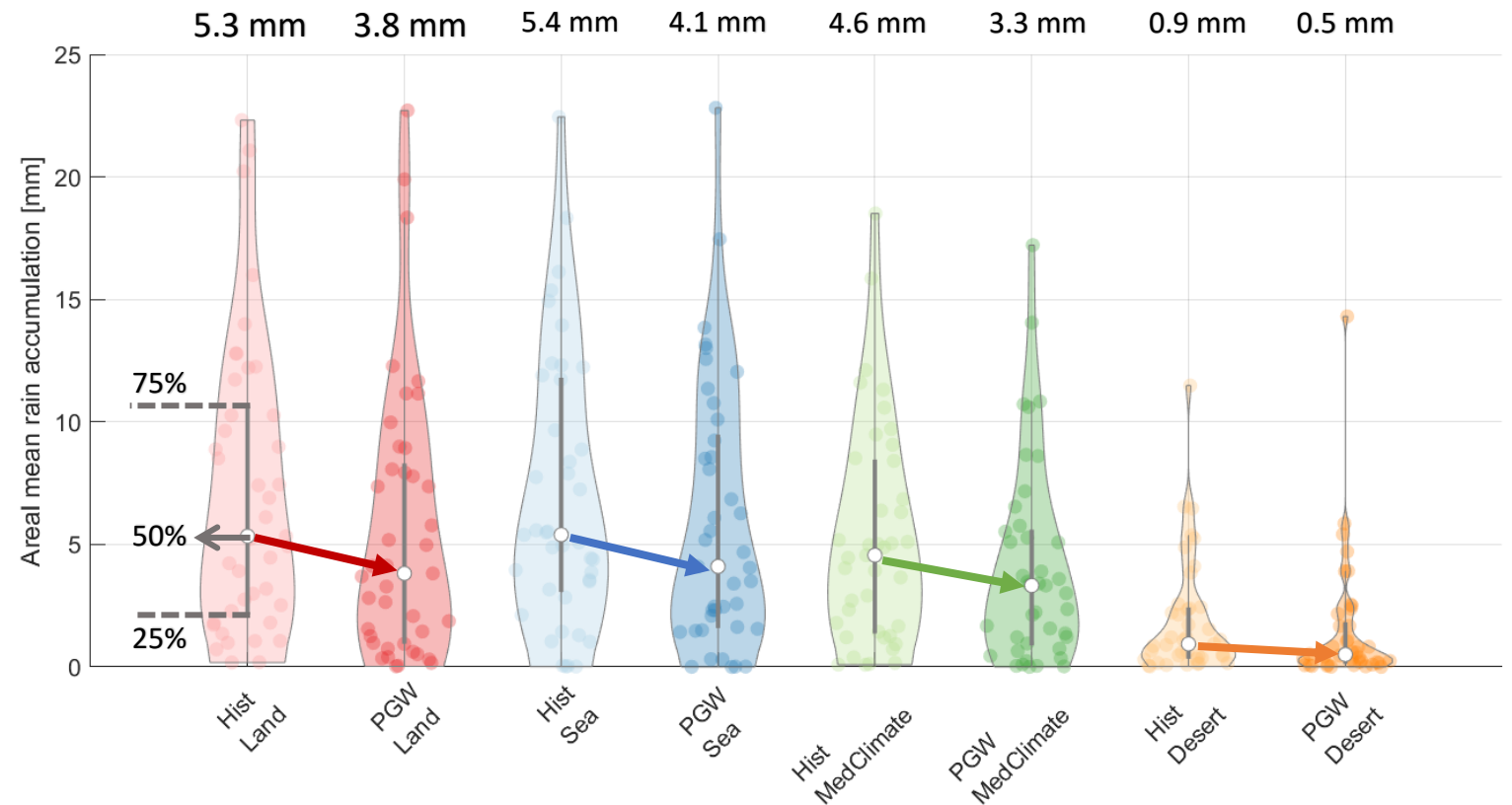
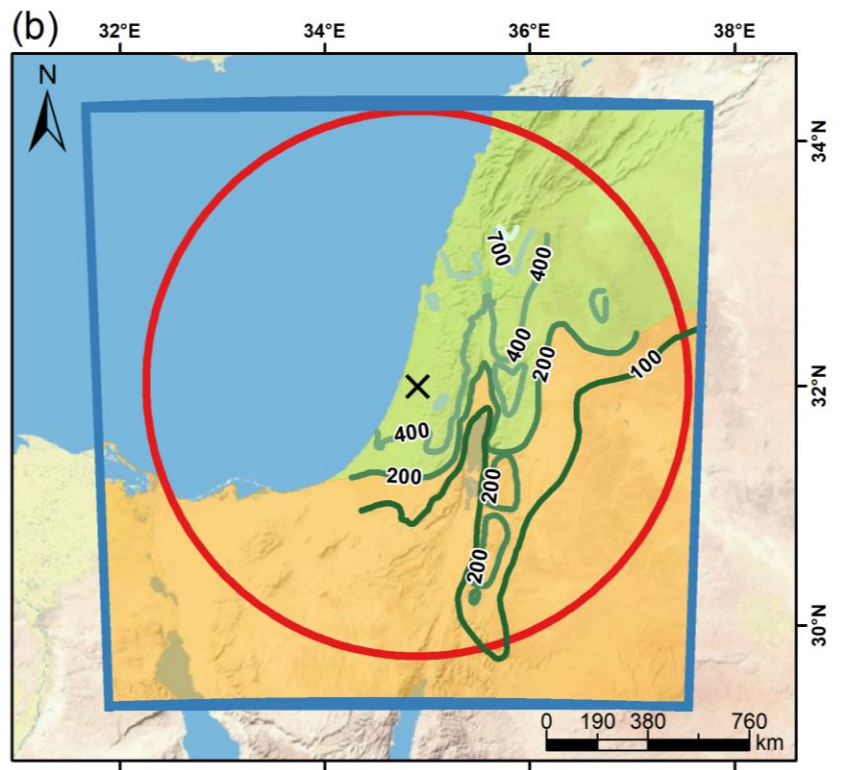
PGW HPE (WRF)
Mean = 484.8 mm



PGW-Historic
Mean = -20.7% mm

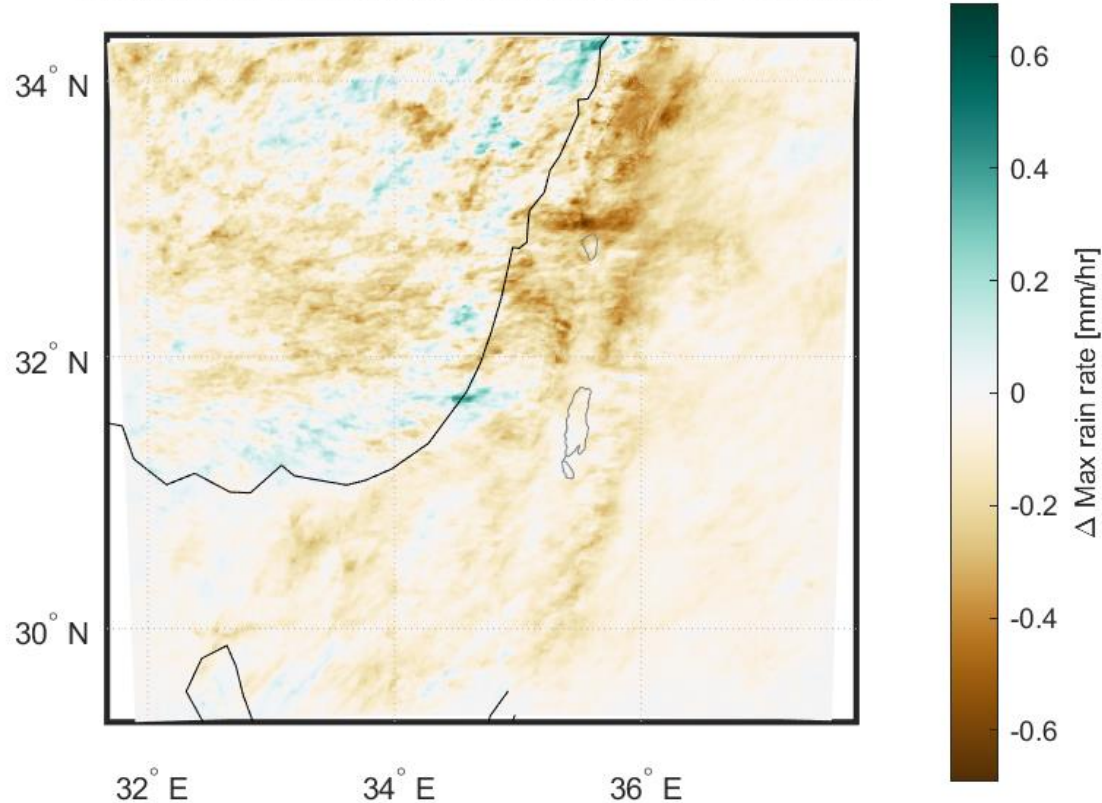


HPEs under climate change – **Total** rainfall

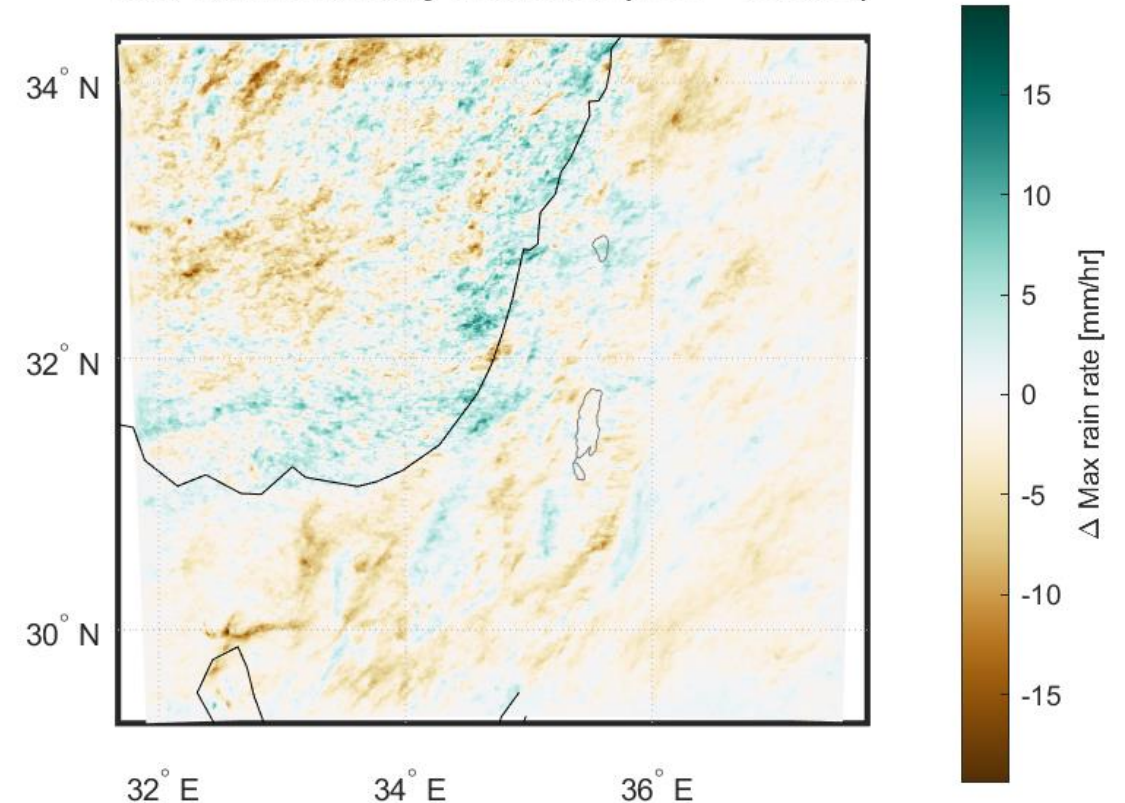


HPEs under climate change – Max rain rates

Max 1440 min intensity difference (PGW - Control)

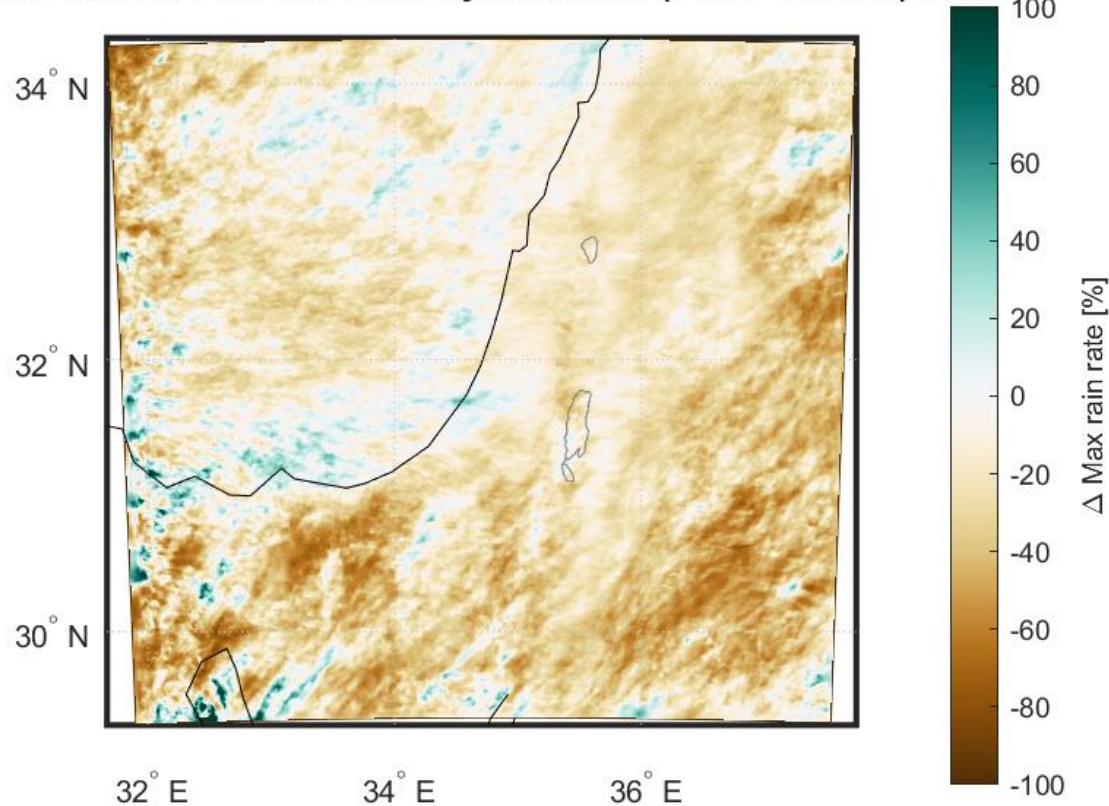


Max 10 min intensity difference (PGW - Control)

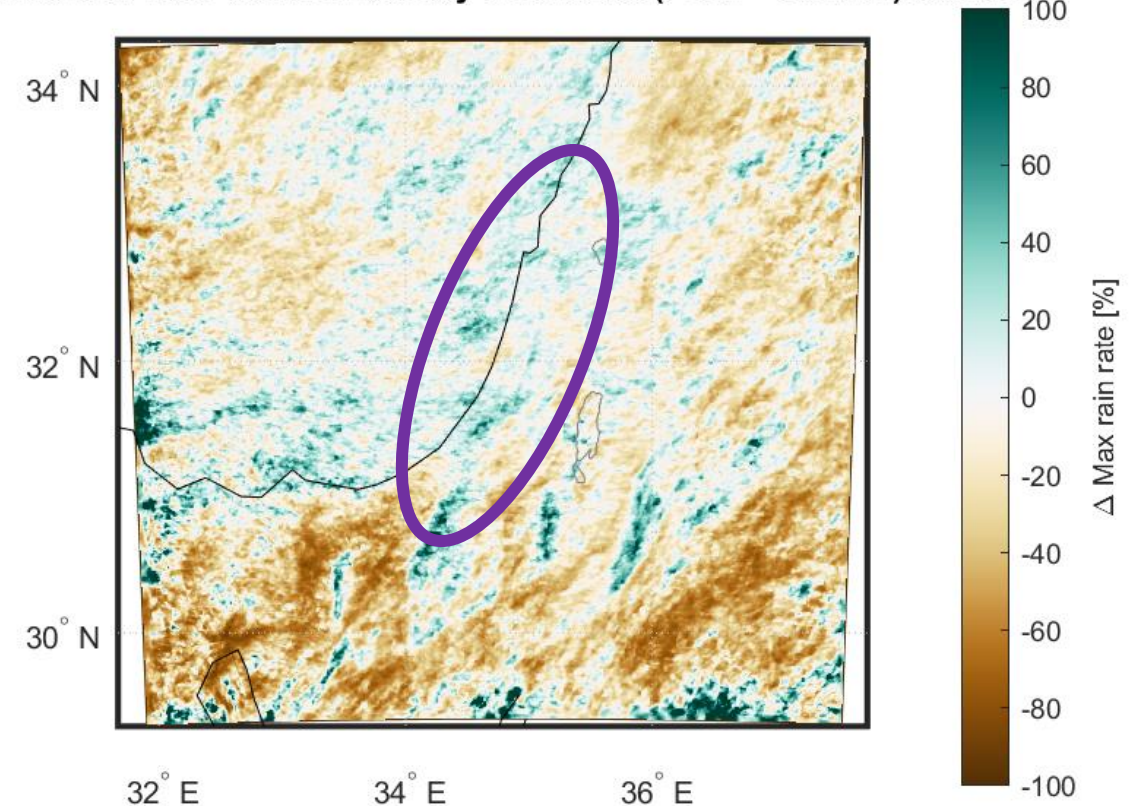


HPEs under climate change – Max rain rates

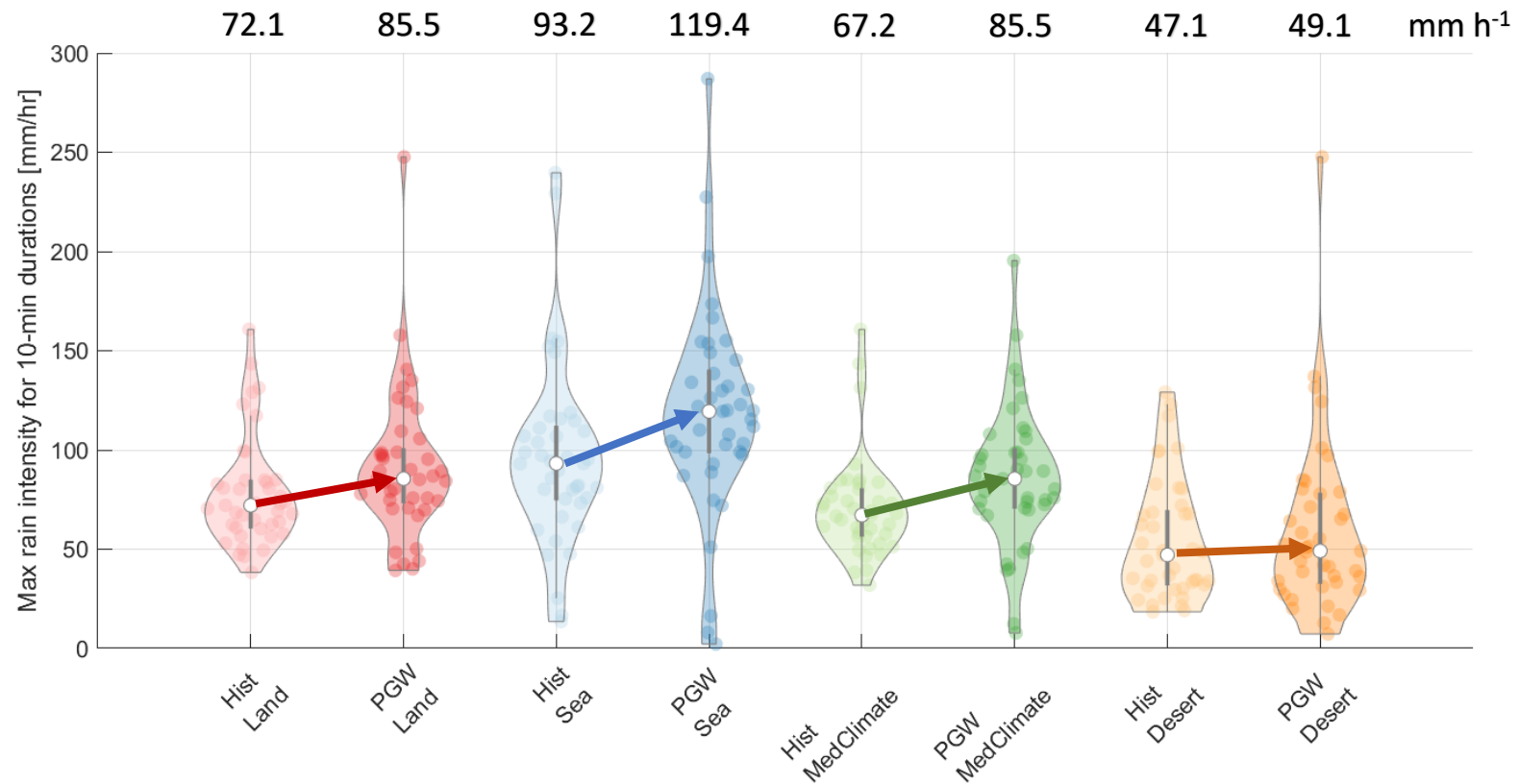
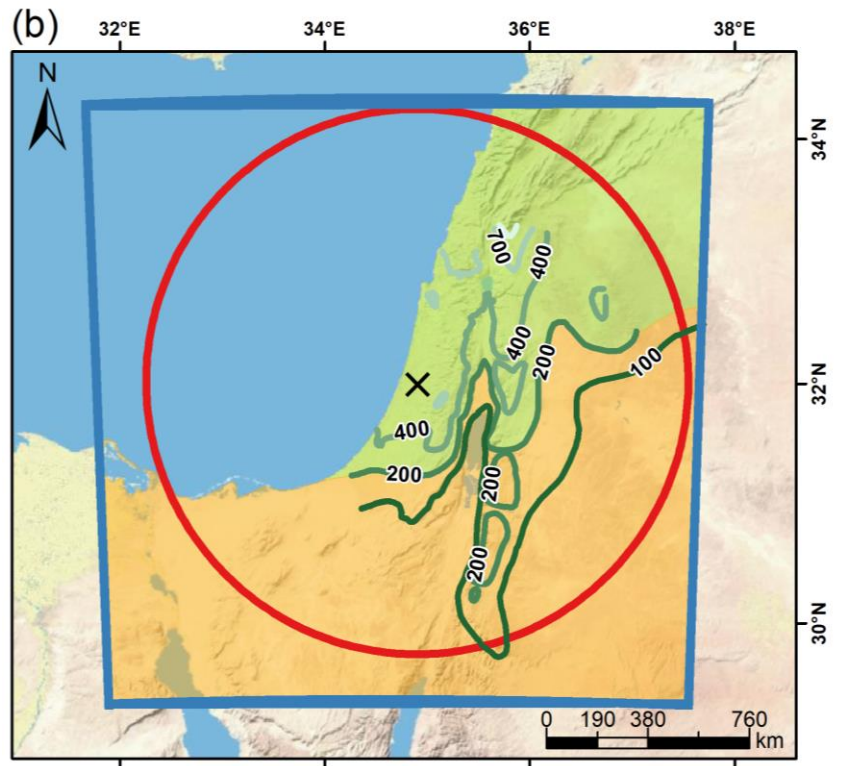
Normalized max 1440 min intensity difference (PGW - Control)/Control



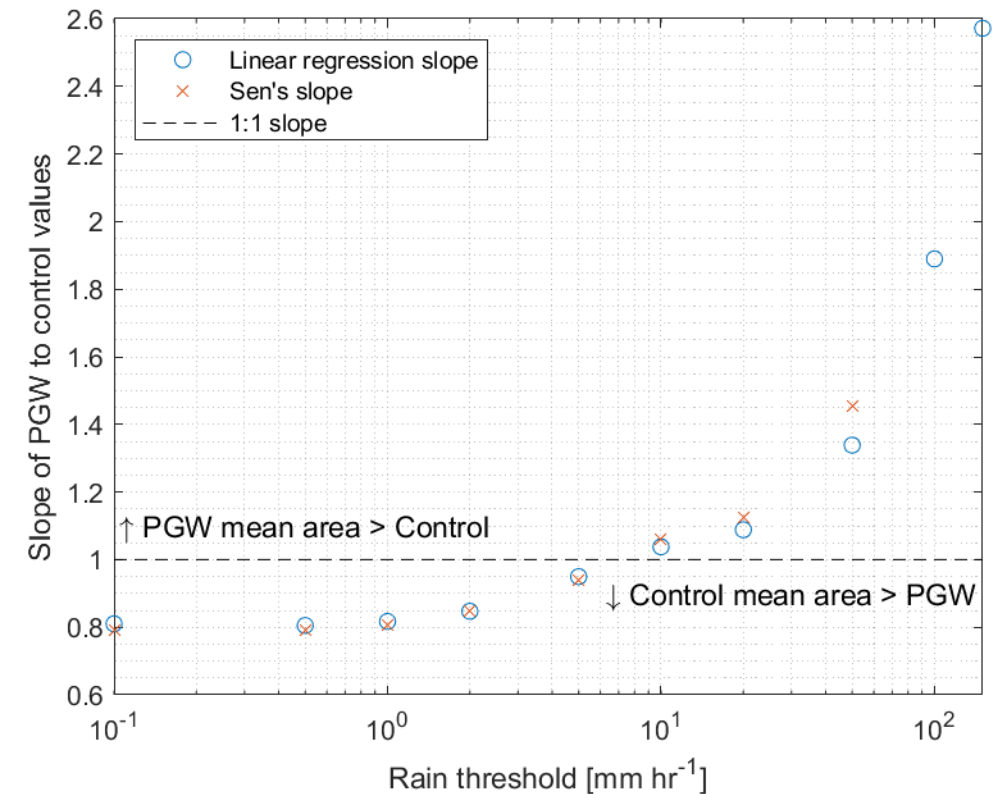
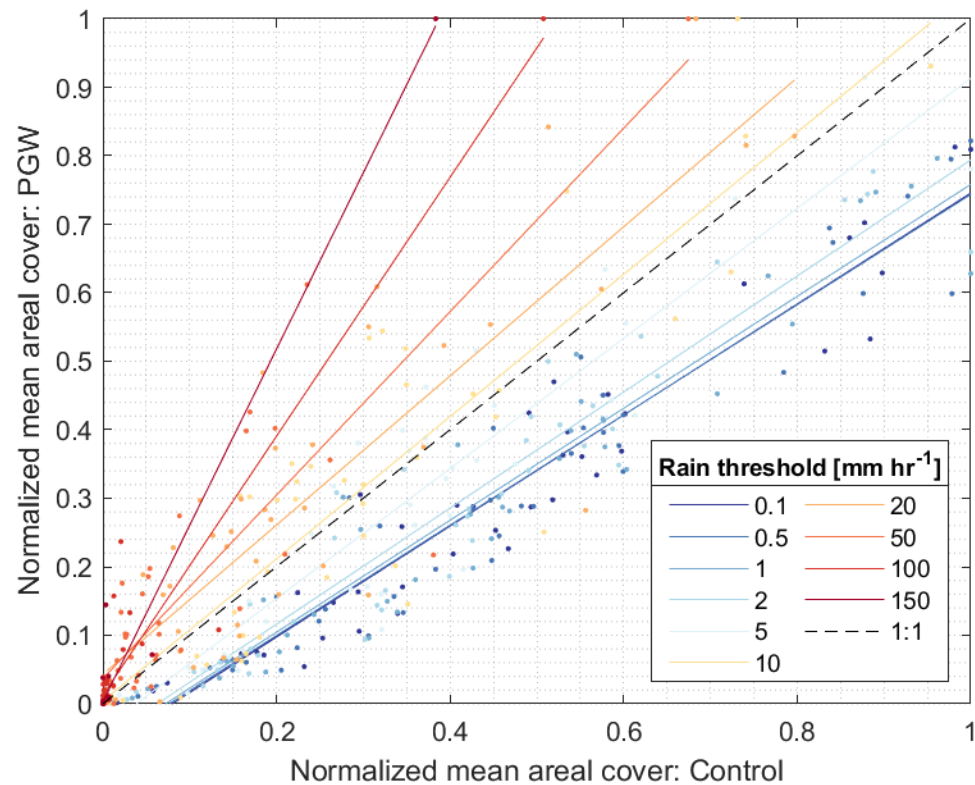
Normalized max 10 min intensity difference (PGW - Control)/Control



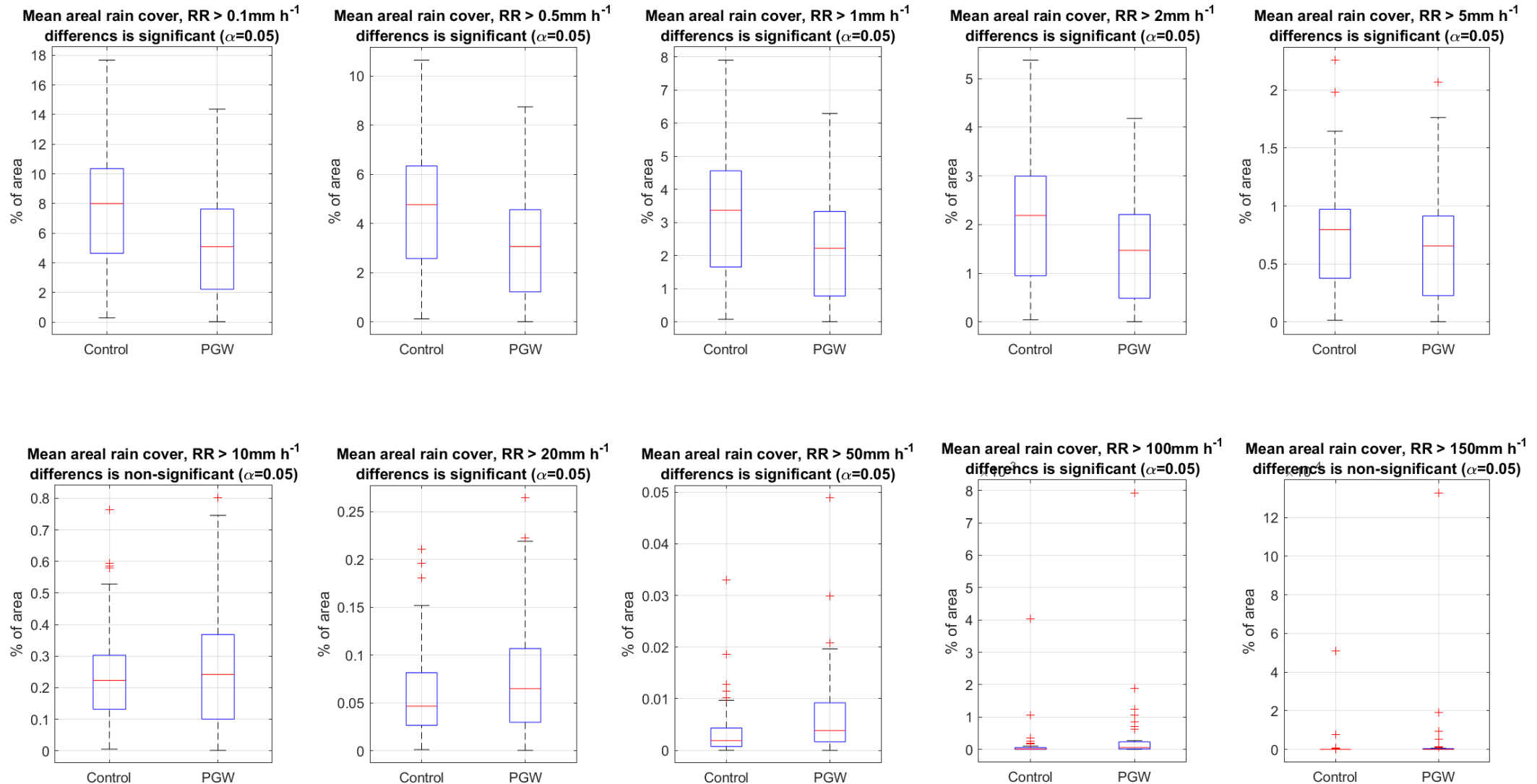
HPEs under climate change – **Max** rain rate



HPEs under climate change – **Areal** coverage

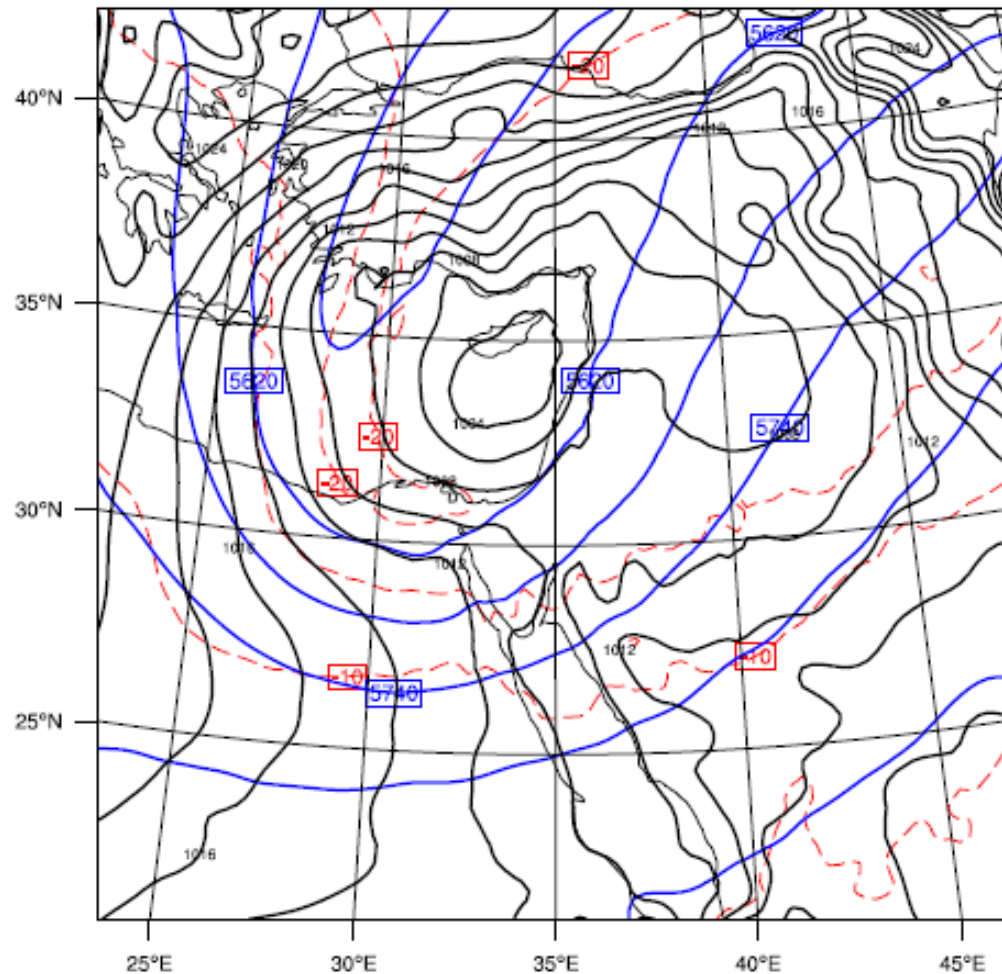


HPEs under climate change – Areal coverage

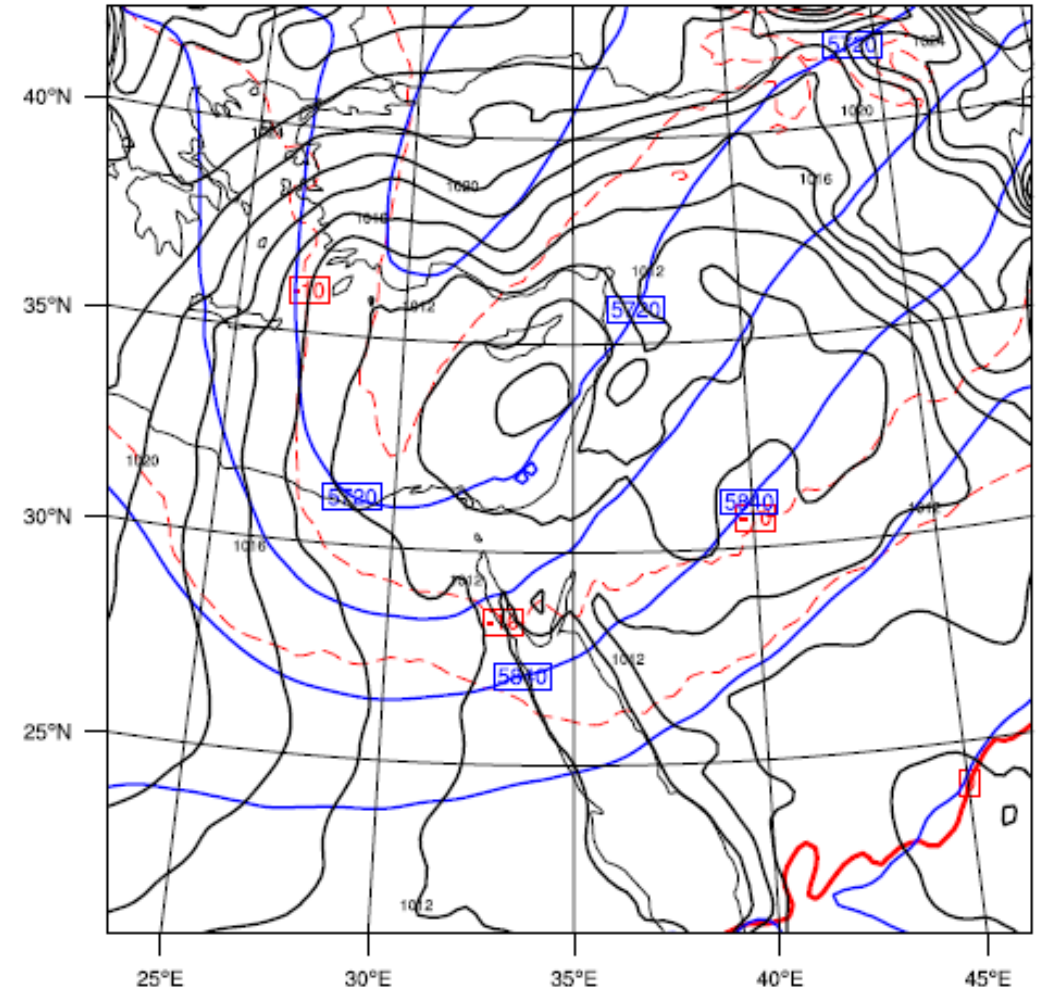


Meteorological causes for changes in rainfall patterns (initial results)

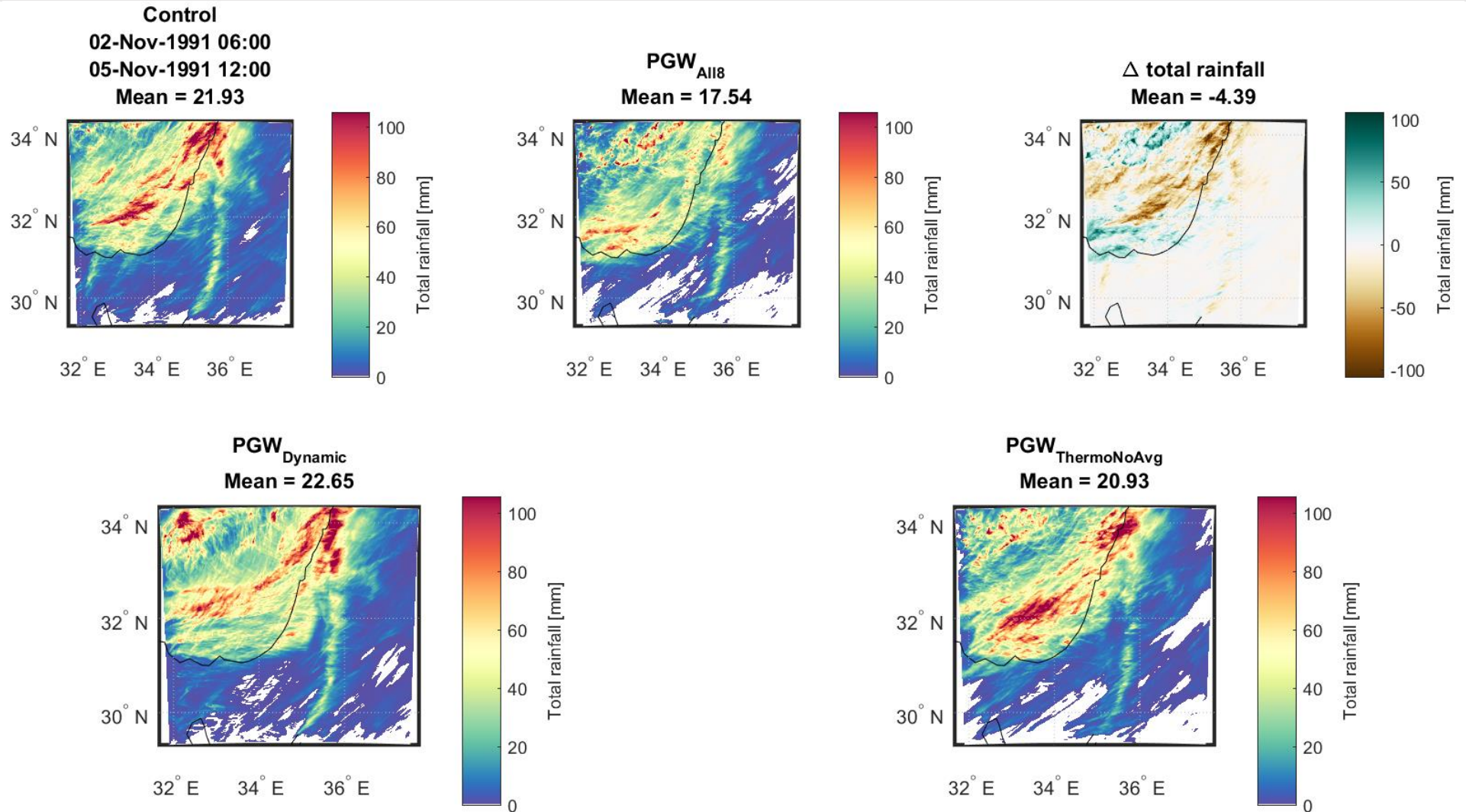
Historic HPE #1



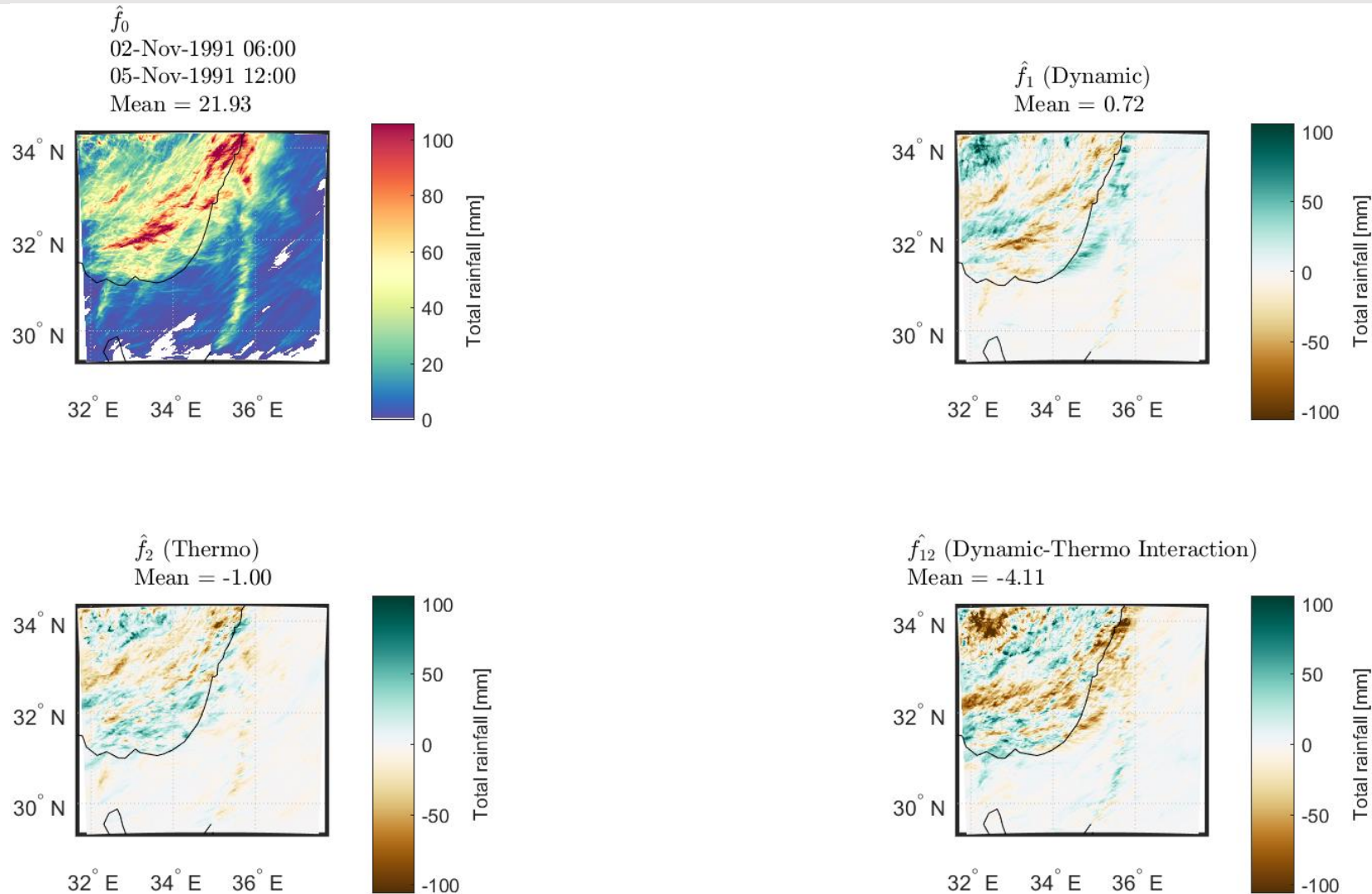
PGW HPE #1



Meteorological causes for changes in rainfall patterns (initial results)



Meteorological causes for changes in rainfall patterns (initial results)



Summary and conclusions

Rainfall during HPEs:

Is **decreased** by 21% on average
(~26% over land)

But its local short-duration **extremes**
gets higher by 19% on average

The events **become shorter** by 9%, and they are
smaller in area (>30% difference for 1 mm threshold)

Meteorological causes for changes in rainfall patterns (initial results):

Cyclones become **shallower**

Substantial **interaction** of dynamic and
thermodynamic parameters

