The impact of climate change on heavy precipitation events in the eastern Mediterranean: Insights from event-based storylines.

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Introduction

- Heavy precipitation events (HPEs) cause natural hazards such as: flash and urban floods, landslides and debris flows.
- They also serve as a resource for recharging groundwater and surface water reservoirs.
- Diverse rainfall patterns during HPEs cause different hydrological responses.
- Accurate representation of rainfall patterns during these events is crucial for detecting and predicting climate-change-induced precipitation changes
- Understanding the specific interactions between rainstorms and catchments is critical in small watersheds, where accurate, high spatiotemporal resolution observations and forecasts are required.

Study objectives

- Characterization of rainfall patterns during HPEs (41 cases) based on high-resolution weather radar data
- Evaluation of the performance of a high-resolution, convection-permitting Weather Research and Forecasting (WRF) model in simulating these patterns
- Identification and quantification of changes in rainfall patterns during HPEs induced by climate change
- Examination whether a common change emerges over a variety of HPEs

Methodology and data: Radar

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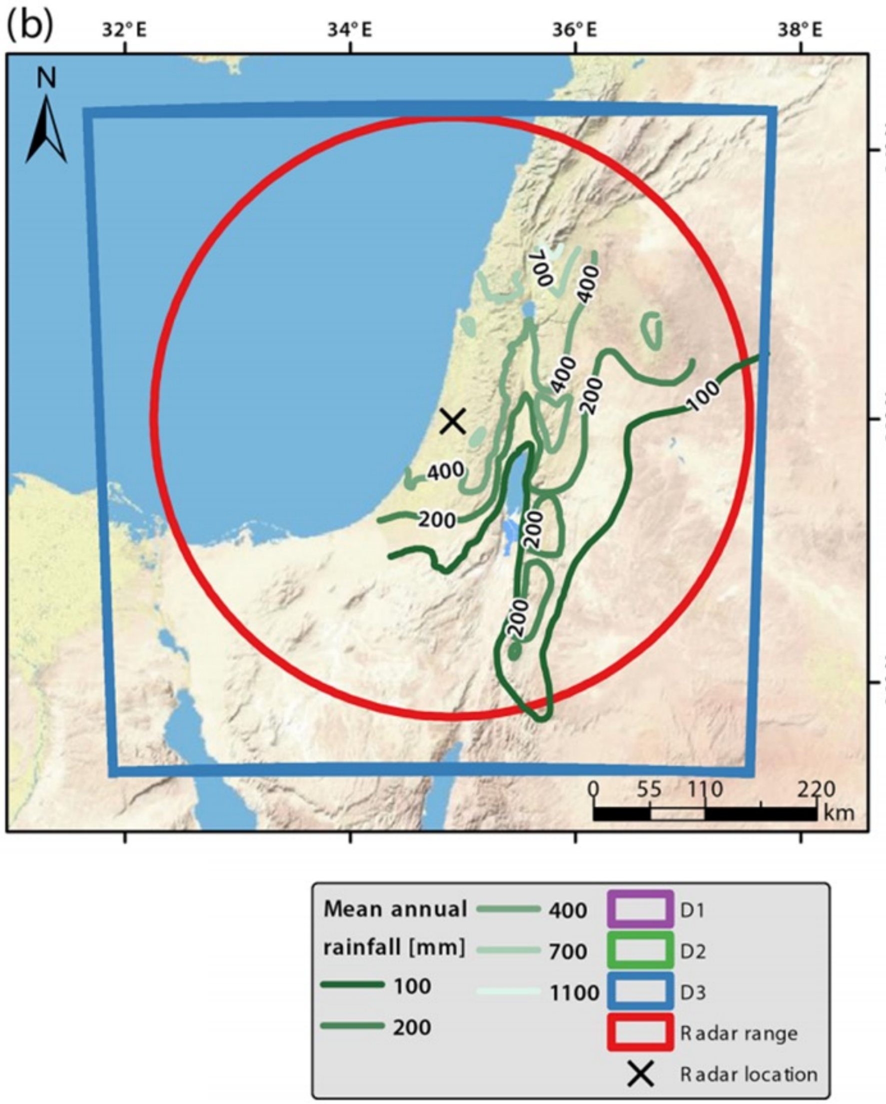
- 24 hydrological years (September–August), between 1990–1991 and 2013–2014
- Observed by non-Doppler C-band weather radar (5.35 cm wavelength), effective range - 185 km
- Raw radar reflectivity data were translated to quantitative precipitation estimates (QPEs) using a fixed Z–R relationship ($Z = 316 \cdot R^{1.5}$) and applying physically based corrections and gauge-based adjustment procedures
- This produced QPEs at 1 km^2 and roughly 5 min resolutions



Methodology and data: WRF model

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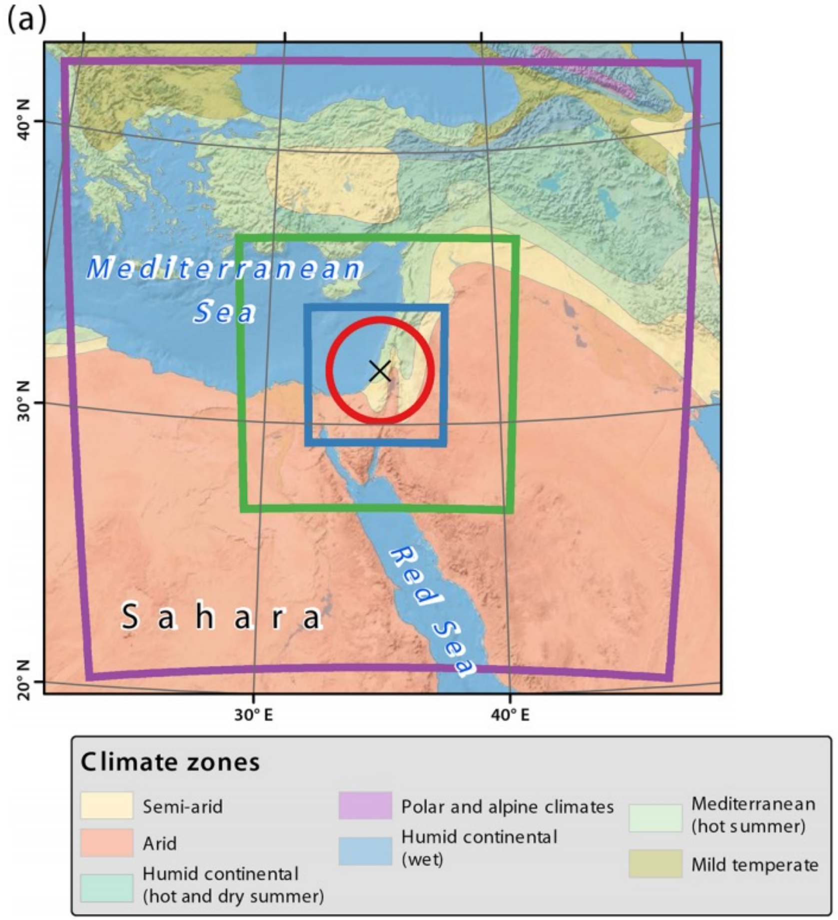
- Three two-way nested domains (25, 5 and 1 km grid sizes)
- 68 vertical levels (model top is at 25 hPa)
- Inner domain – 1-km horizontal resolution
- Historical IC/BC: 6-hourly ERA-Interim reanalyses, at ~80 km horizontal resolution, and 60 vertical levels
- Spin-up of at least 24h
- The model was used to simulate the HPEs identified in the radar archive



Physics	
Cumulus scheme (outer and middle nests only)	Tiedtke (Tiedtke, 1989; C. Zhang et al., 2011)
Microphysical scheme	Thompson (Thompson et al., 2008)
Radiative transfer scheme	RRTMG short wave and long wave (Iacono et al., 2008)
Planetary boundary layer scheme	Mellor–Yamada–Janjić (Janjić, 1994)
Surface layer scheme	Eta similarity scheme (Janjić, 1994)
Land surface model	Unified Noah land surface (Tewari et al., 2004)

HPEs under climate change - Methodology

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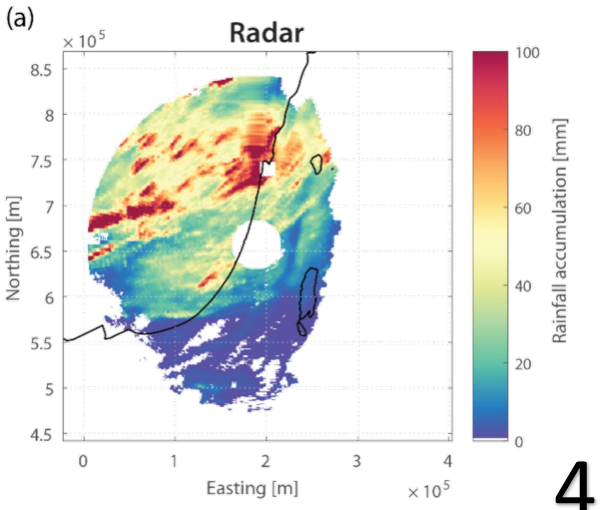
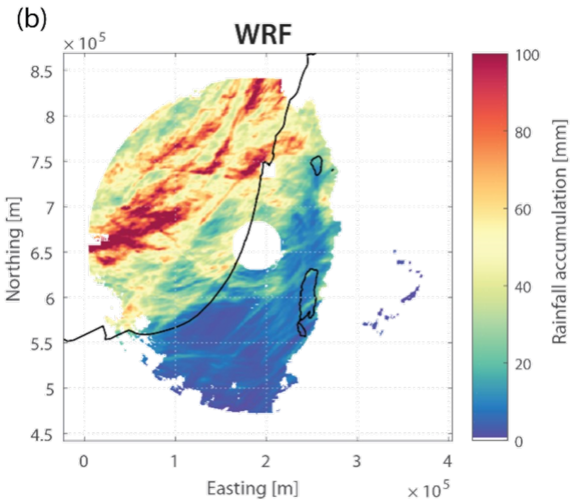
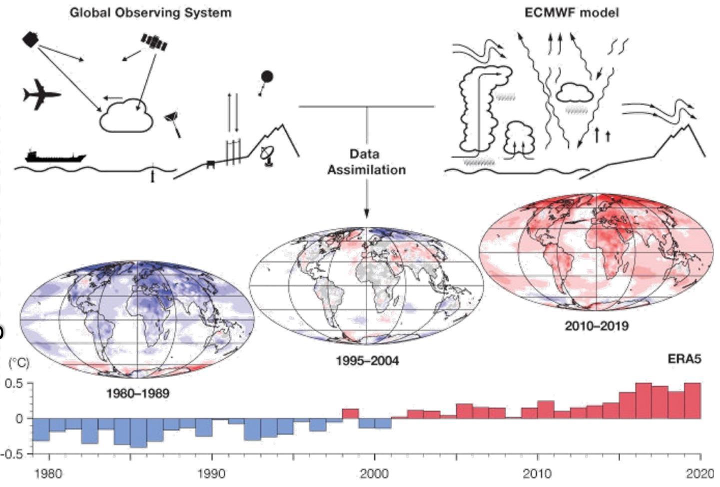
Armon et al., 2020: HESS

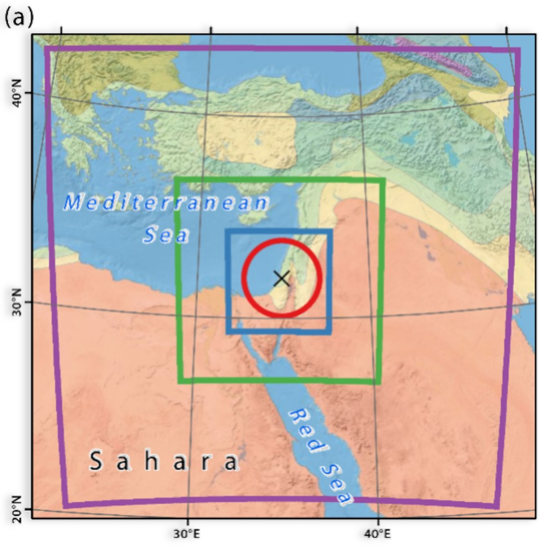




41 HPEs

Image source: ECMWF

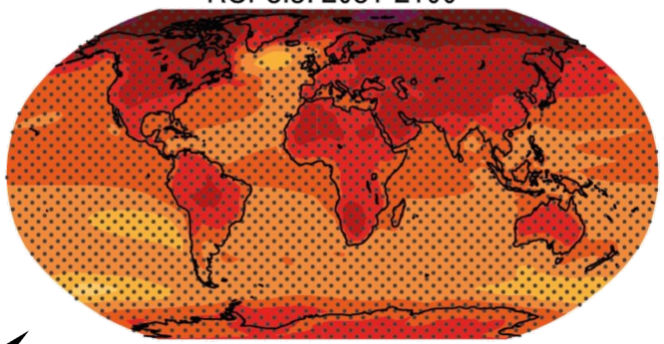




29 CMIP5 models:

SLP, T, wind, moisture

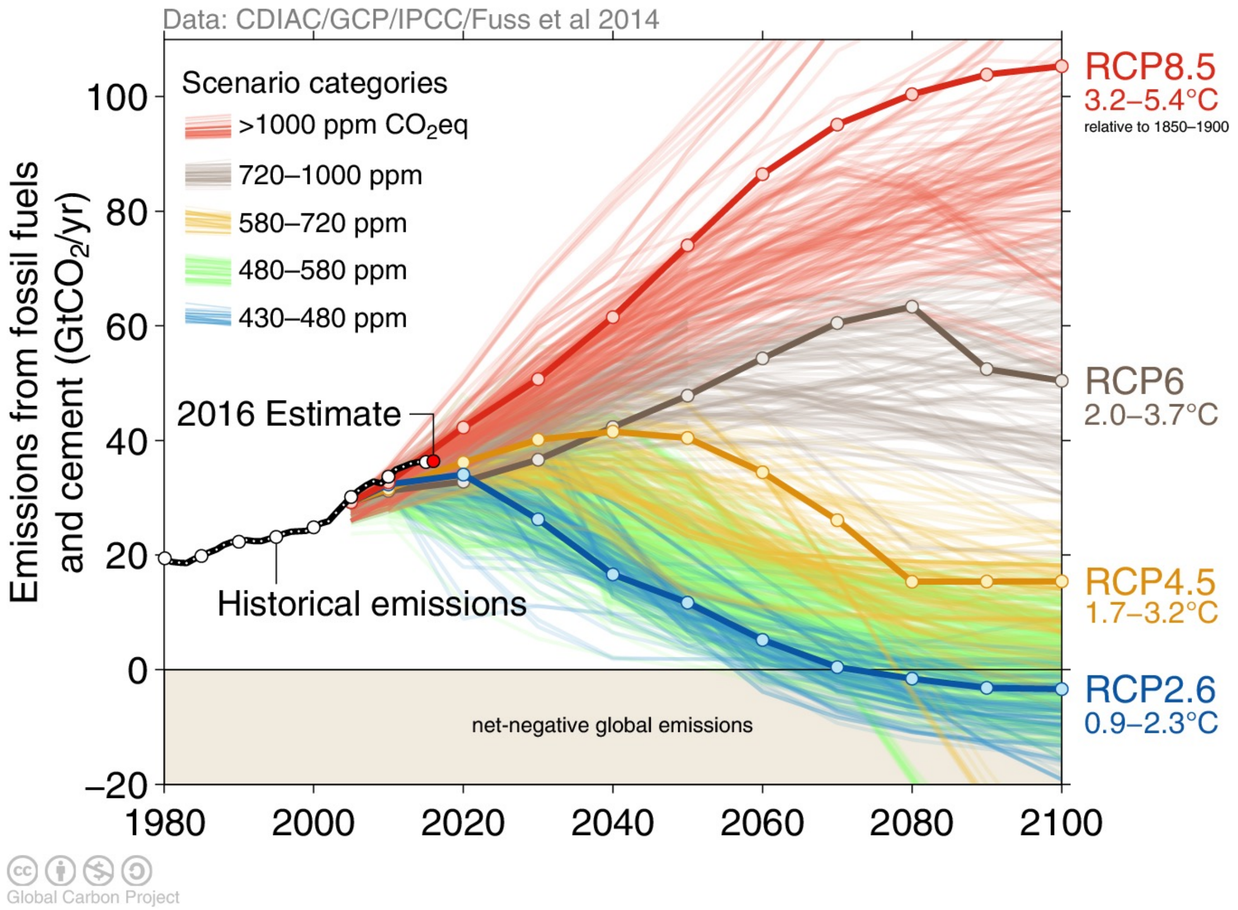
RCP8.5: 2081-2100



Pseudo Global Warming (PGW) Schär et al., 1996

?

HPEs under climate change – (global) future projections

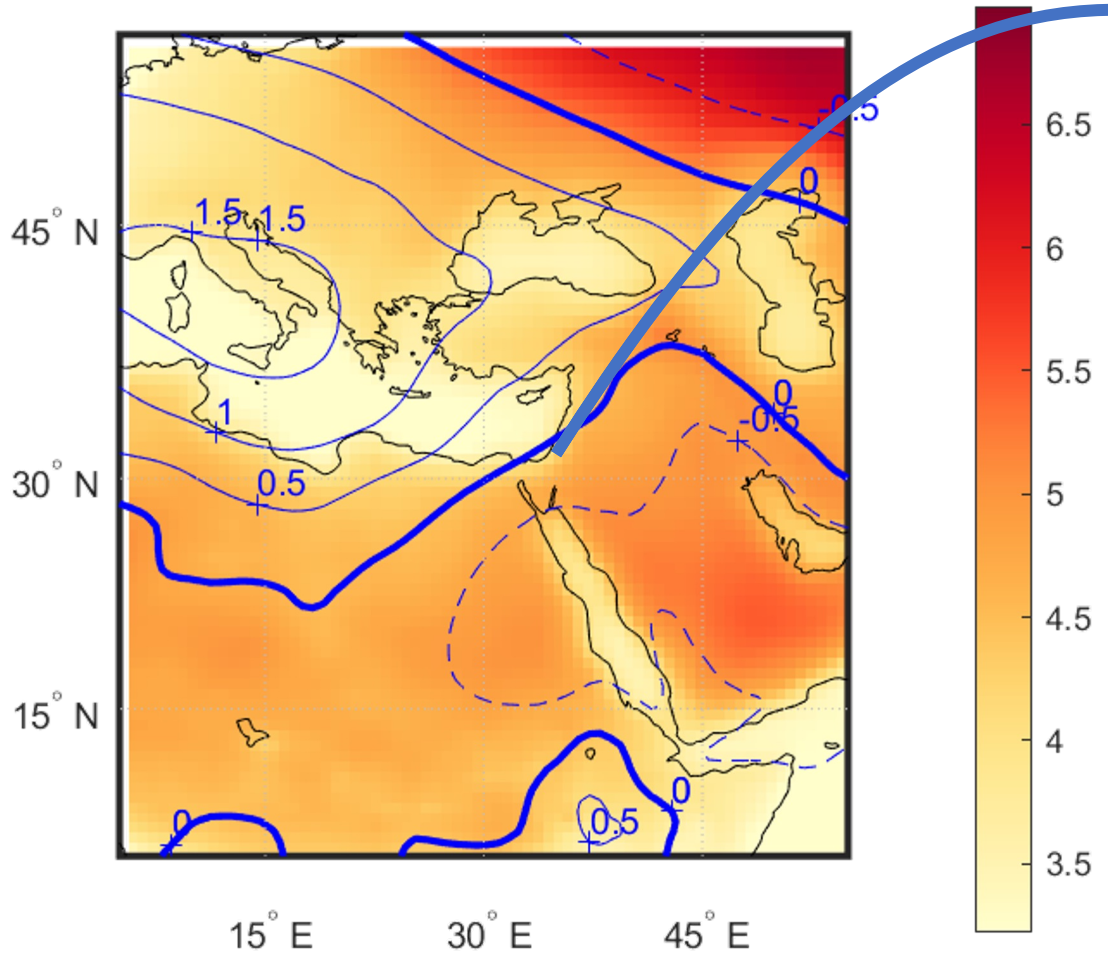


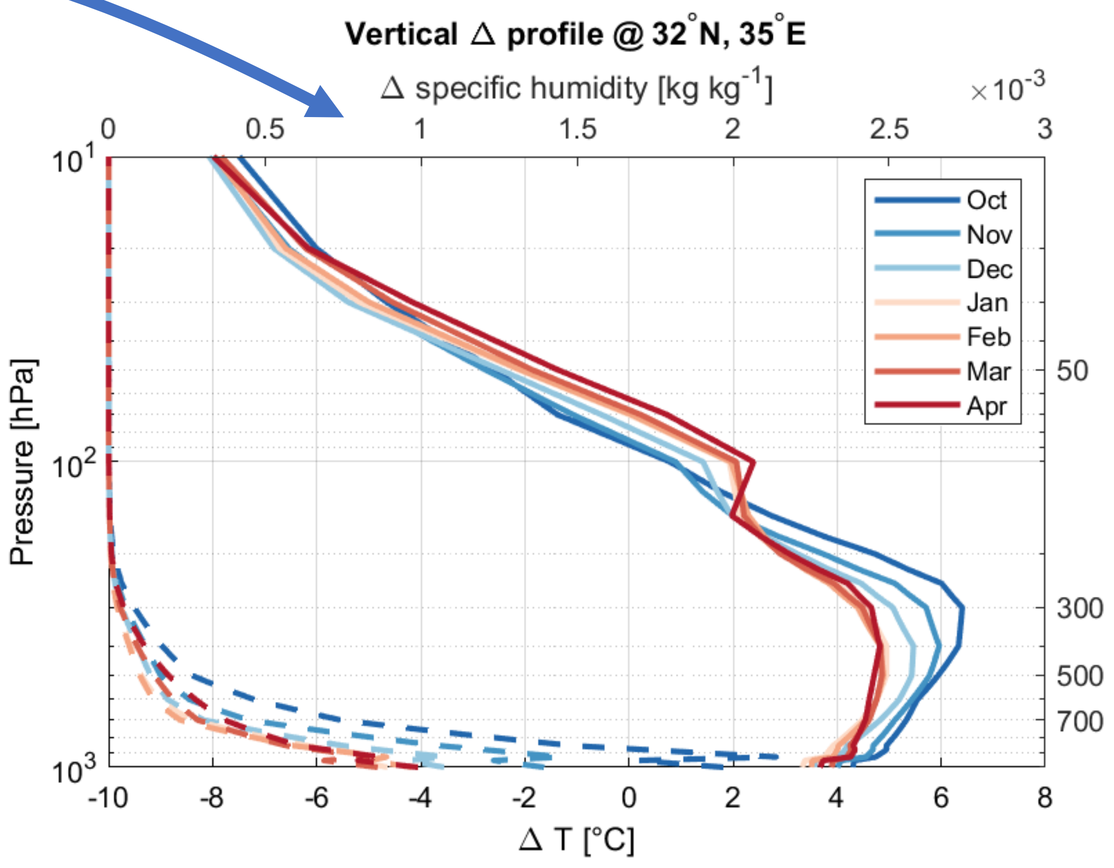
- End of 21st century minus end of 20th century
- CMIP5, RCP 8.5:

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

HPEs under climate change – local projections

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





Future changes

Decreased rainfall accumulation throughout events

- 41 events
- Decrease in rainfall accumulation of 19%: spatial average of 485 mm (PGW) and 601 mm (historic).
- Contraction of the rainfall area
- The decrease is most severe in the wetter part of the region (the northern area and the mountains)

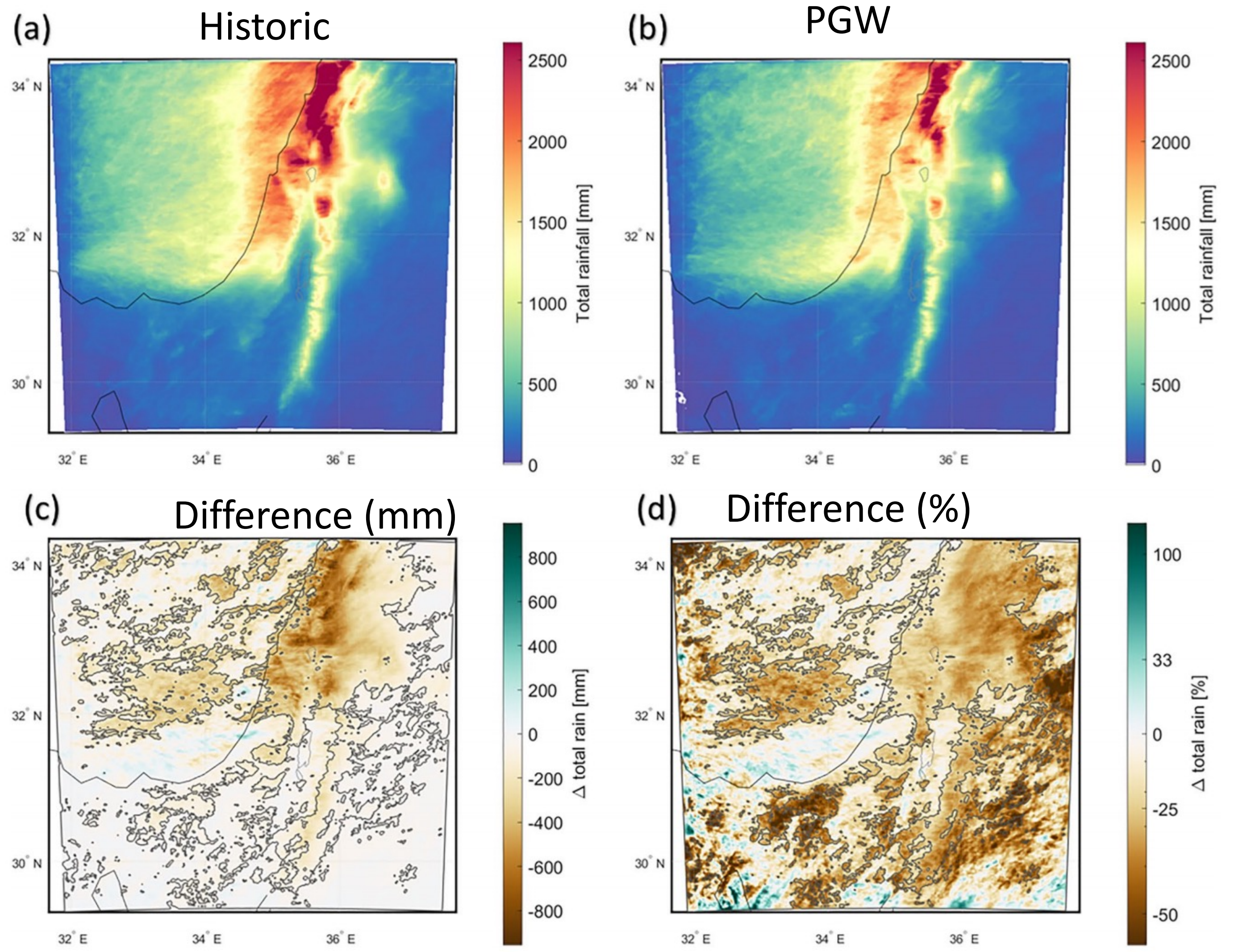
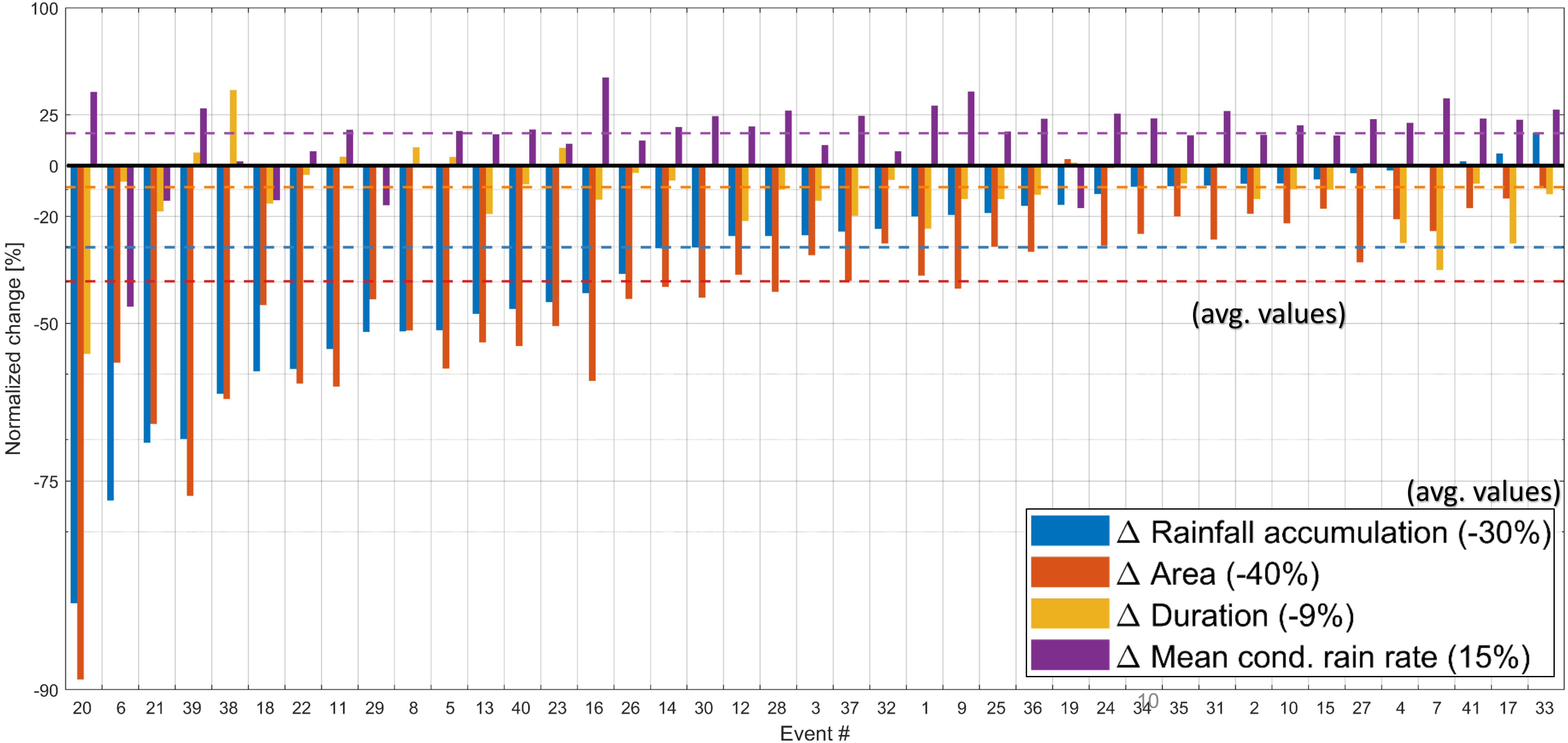


Figure 3. Total rainfall summed over the 41 HPEs historic (a) and future (PGW; (b) simulations. (c) Difference between historic and future simulations (future–historic). Statistically significant differences are demarcated by gray lines. (d) Same as (c) but in relative terms: $\left(100 \times \frac{future-historic}{historic}\right)$.

Change in rainfall properties under PGW conditions



Summary and conclusions

Rainfall during HPEs in future climate:

Decrease by 30% on average (-36% over land)

But rain rates **get higher** by 15% on average (22% for local, short duration rain rates)

Events **become shorter** by 9%

The rainy area is **much smaller** (-40% for 0.1 mm threshold)

WRF model:

A convection-permitting high-resolution WRF model can simulate most HPEs, except for some of the shortest, most localized storms

WRF, a **weather forecasting model**, resulted useful in **climate applications**.

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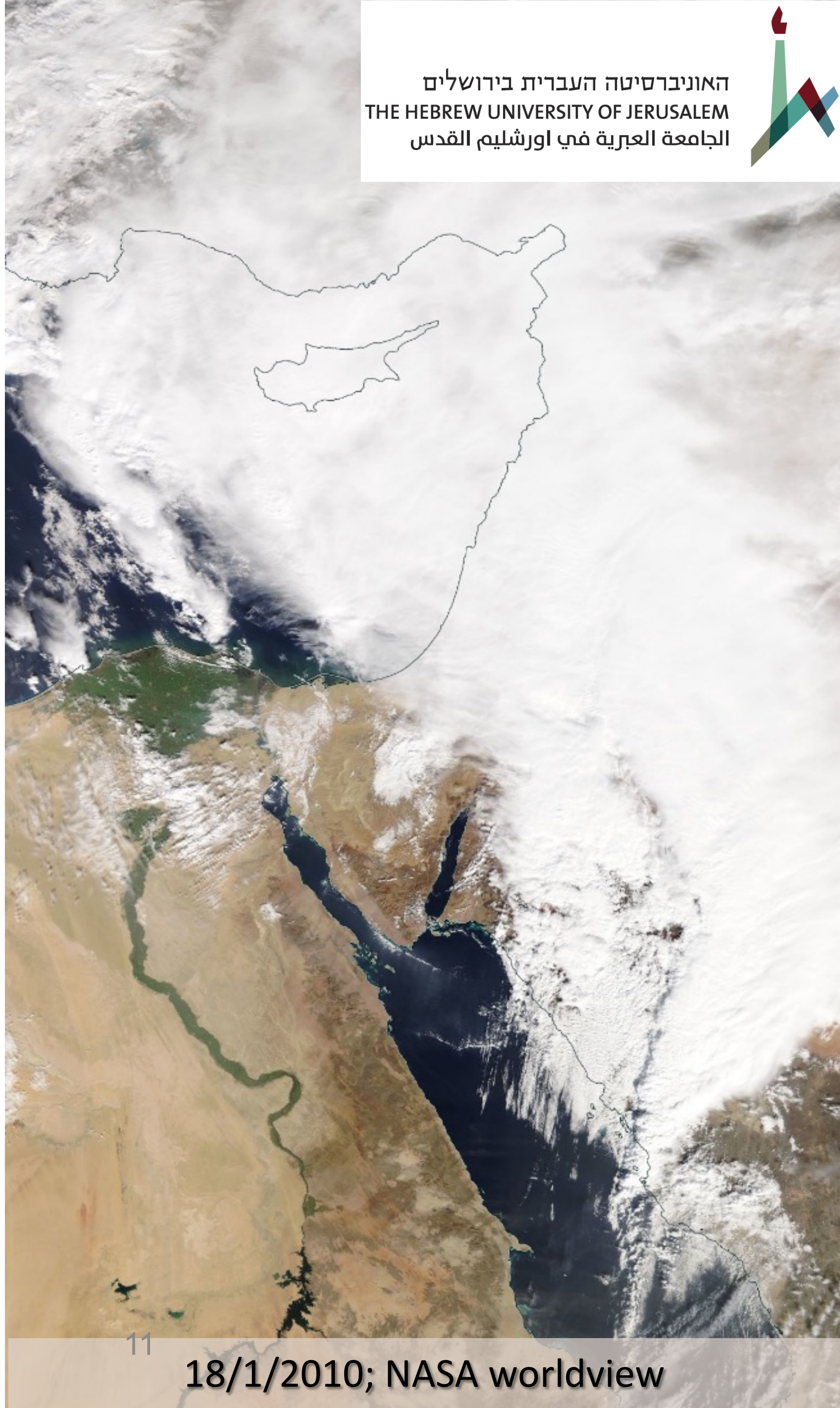
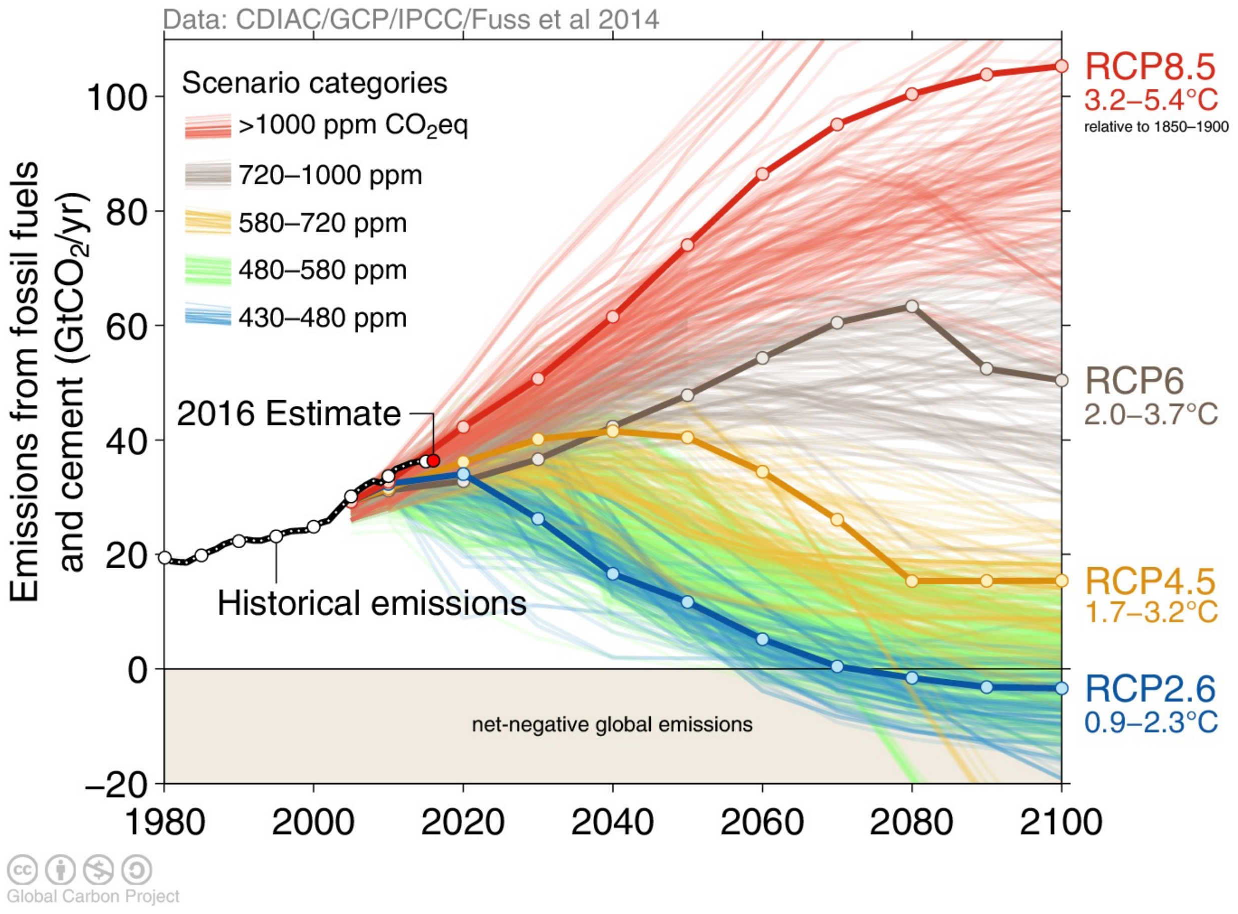


18/1/2010; NASA worldview

- M. Armon, F. Marra, Y. Enzel, D. Rostkier-Edelstein, E. Morin (2020) Radar-based characterisation of heavy precipitation in the eastern Mediterranean and its representation in a convection-permitting model. Hydrology and Earth System Sciences. 24, 1227–1249.
- M. Armon, F. Marra, Y. Enzel, D. Rostkier-Edelstein, C. I Garfinkel, O. Adam, U. Dayan, E. Morin (2021). Reduced Rainfall in Future Heavy Precipitation Events Related to Contracted Rain Area Despite Increased Rain Rate. Earth's Future, 10, e2021EF002397. https://doi.org/10.1029/2021EF002397

Thank you

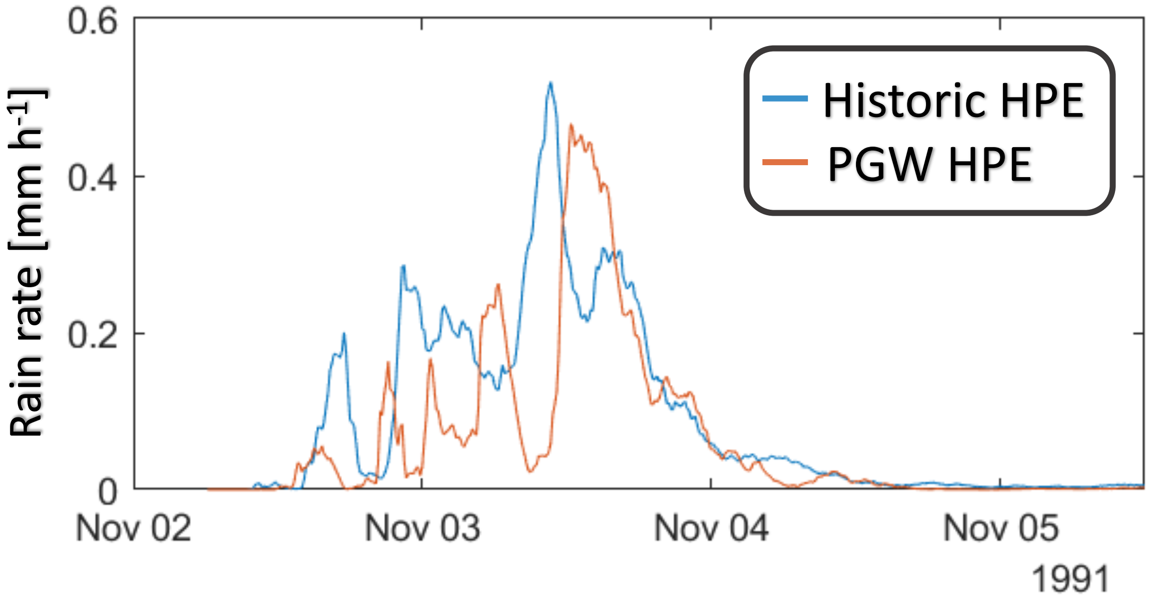
HPEs under climate change – (global) future projections



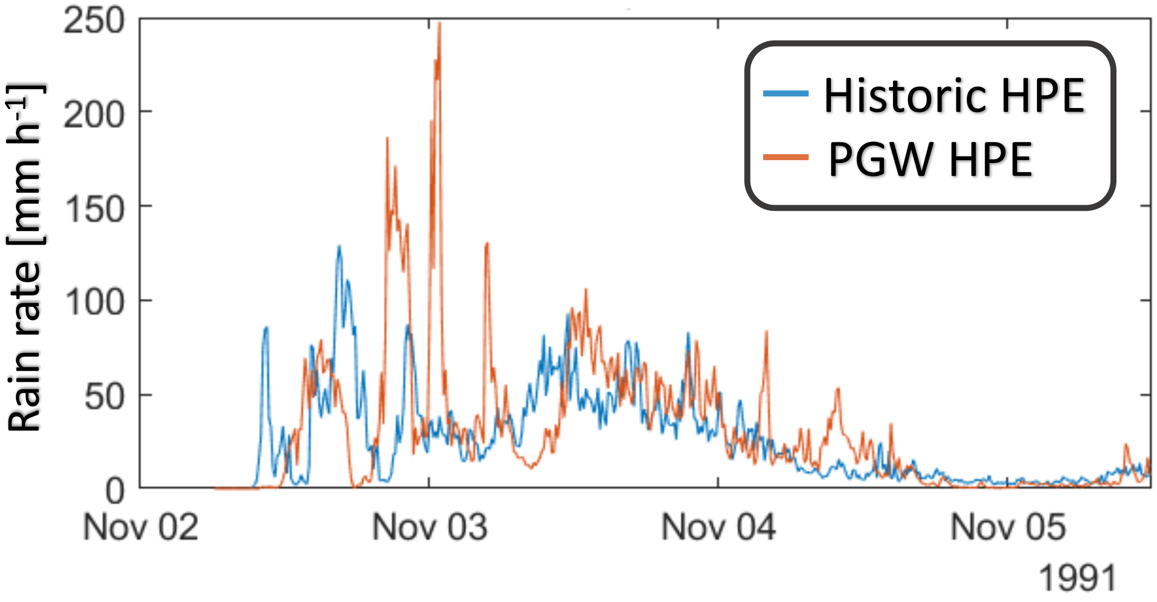
#	Model name	Lat resolution	Lon resolution	Number of vertical levels	Model top [hPa]
1	ACCESS1-0	1.25	1.88	17	10
2	ACCESS1-3	1.25	1.88	17	10
3	CCSM4	0.94	1.25	17	10
4	CESM1-BGC	0.94	1.25	17	10
5	CESM1-CAM5	0.94	1.25	17	10
6	CMCC-CESM	3.68	3.75	27	1
7	CNRM-CM5	1.39	1.41	17	10
8	CanESM2	2.77	2.81	22	1
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

HPE #1 – temporal evolution

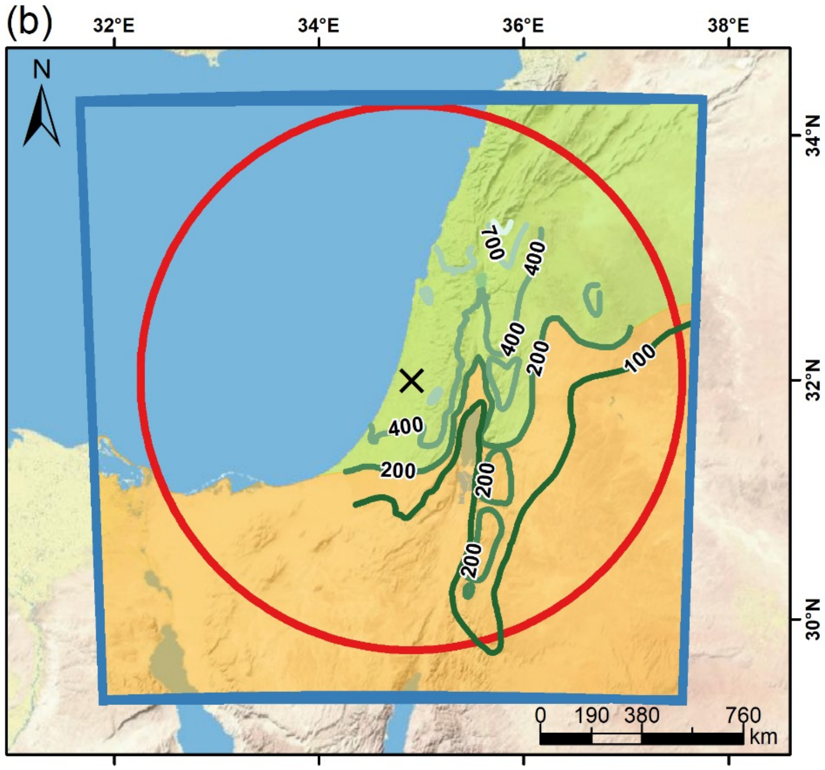
Mean rain rate over all land pixels (WRF)



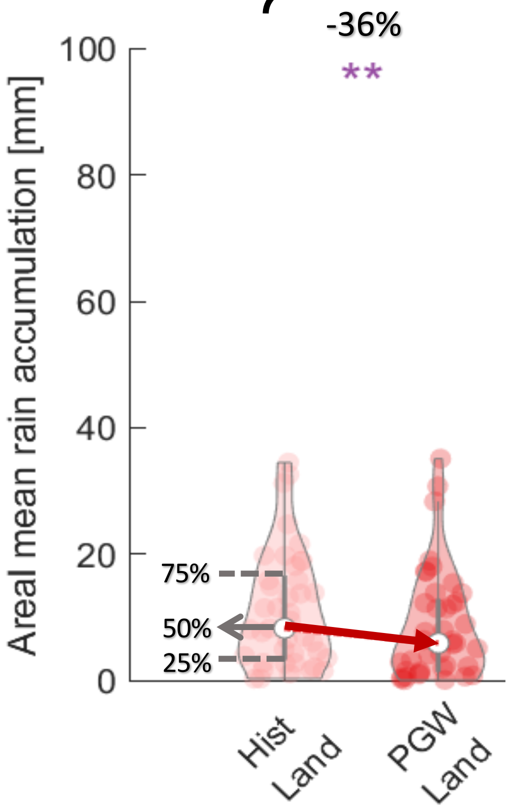
Pixel-based **max** rain rate over land area (WRF)



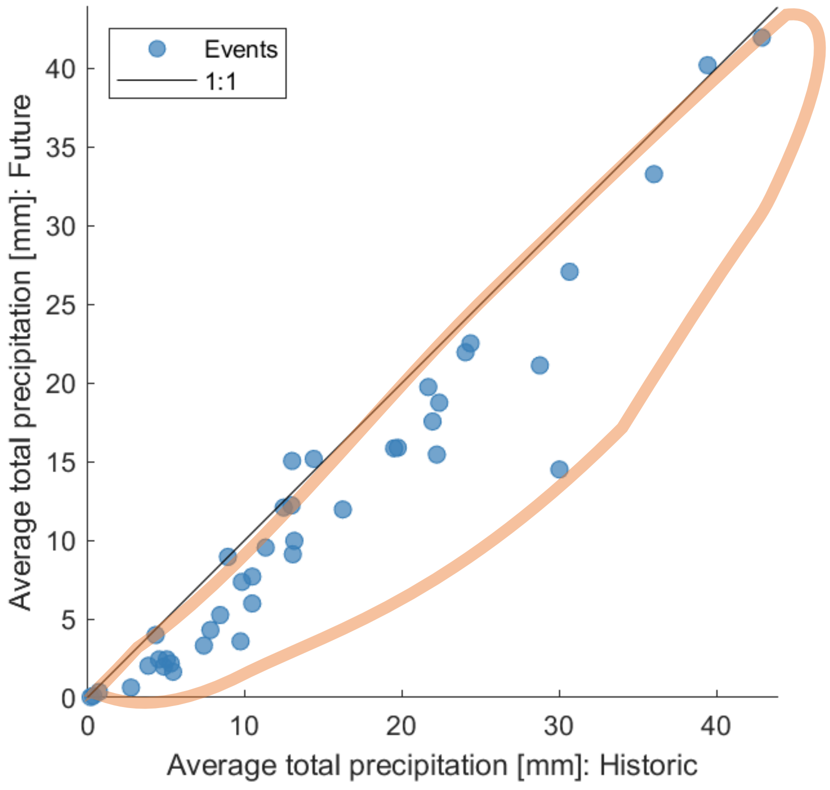
HPEs under climate change – **Total** rainfall

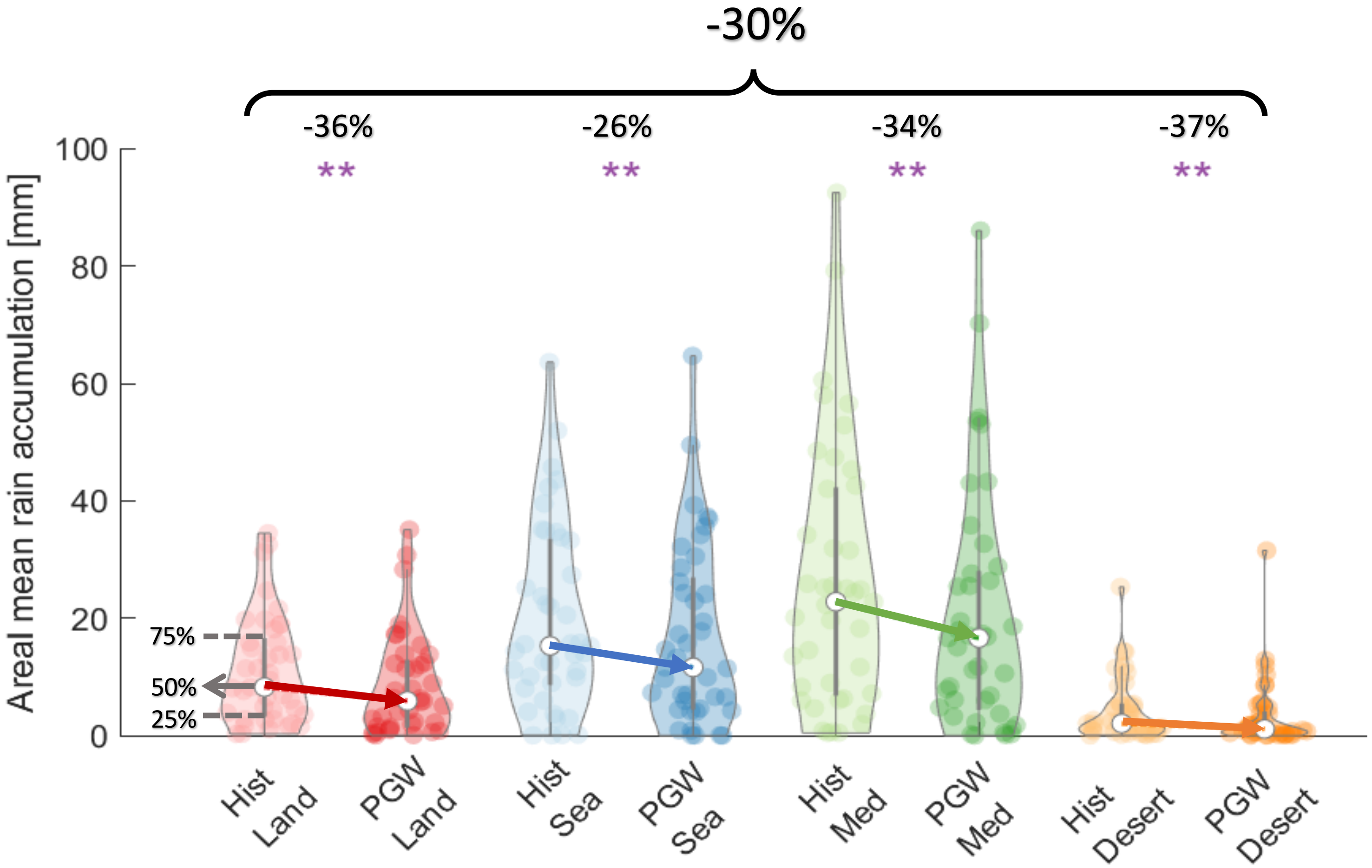


-30%

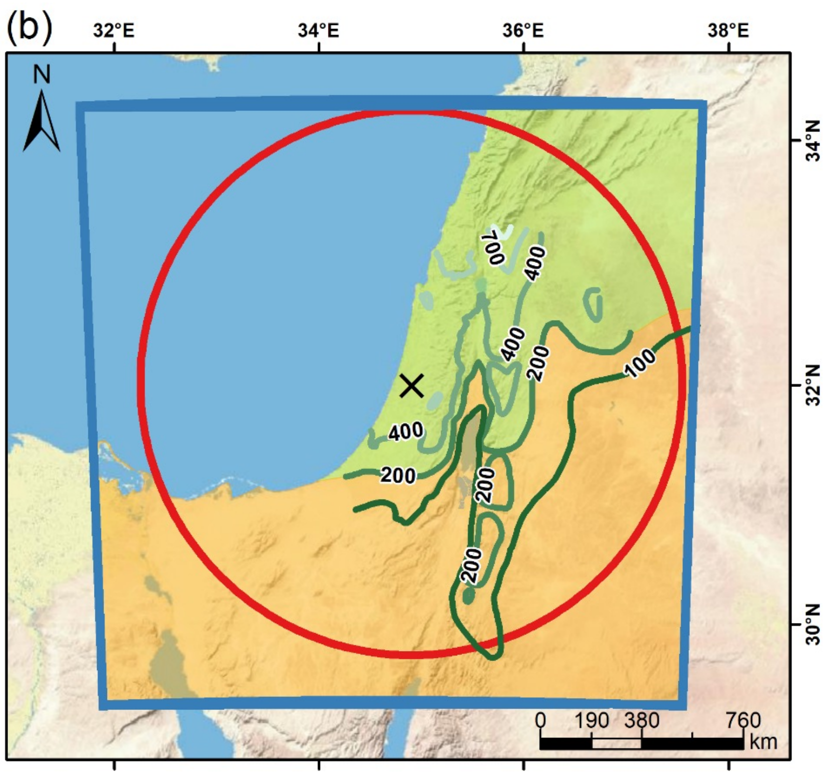


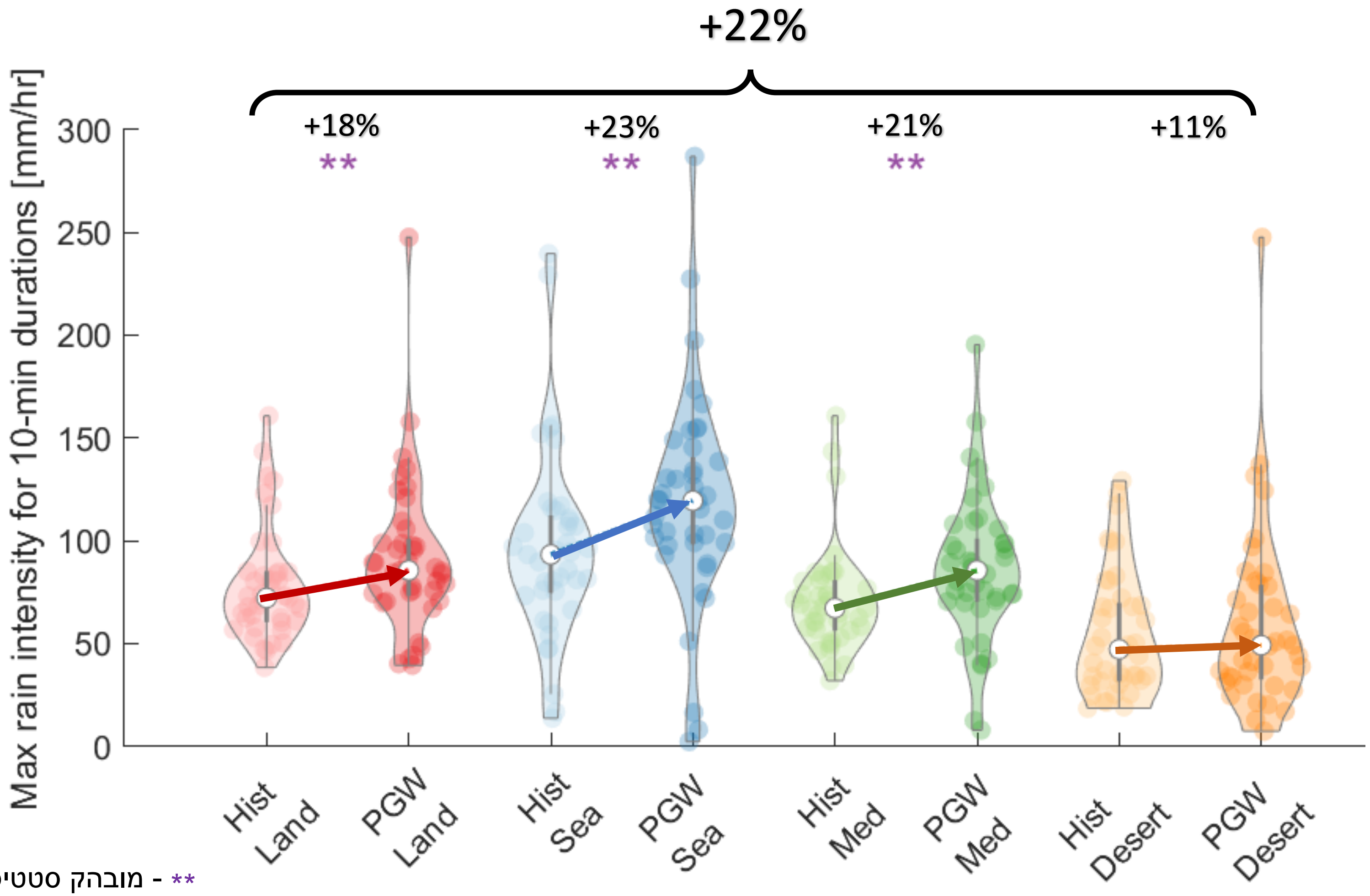
HPEs under climate change – **Total** rainfall





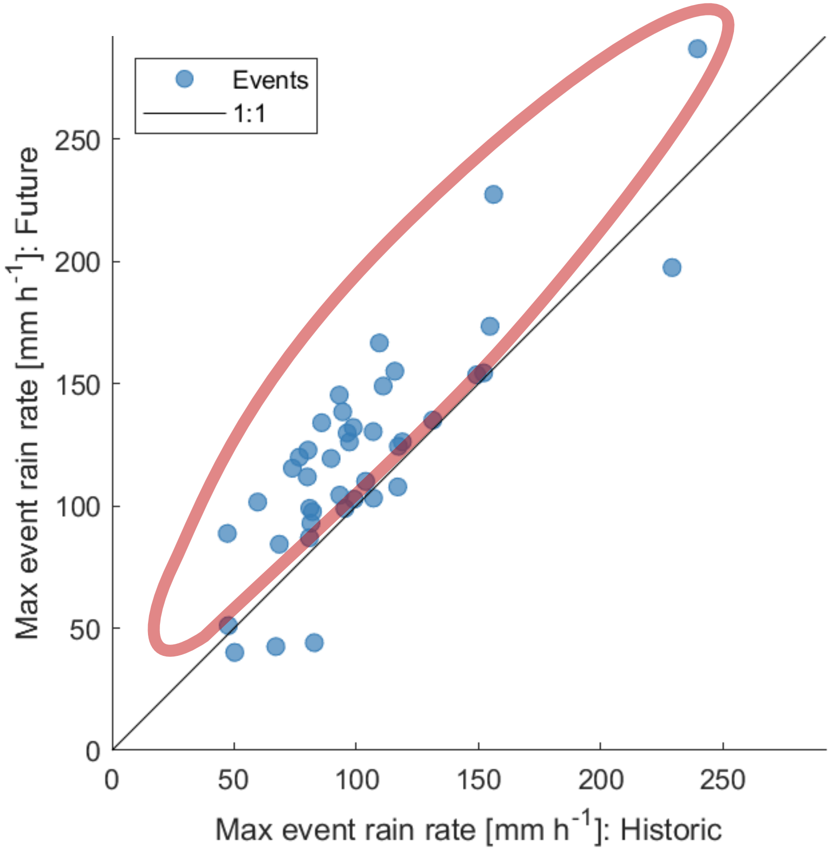
HPEs under climate change – **Max** rain rate

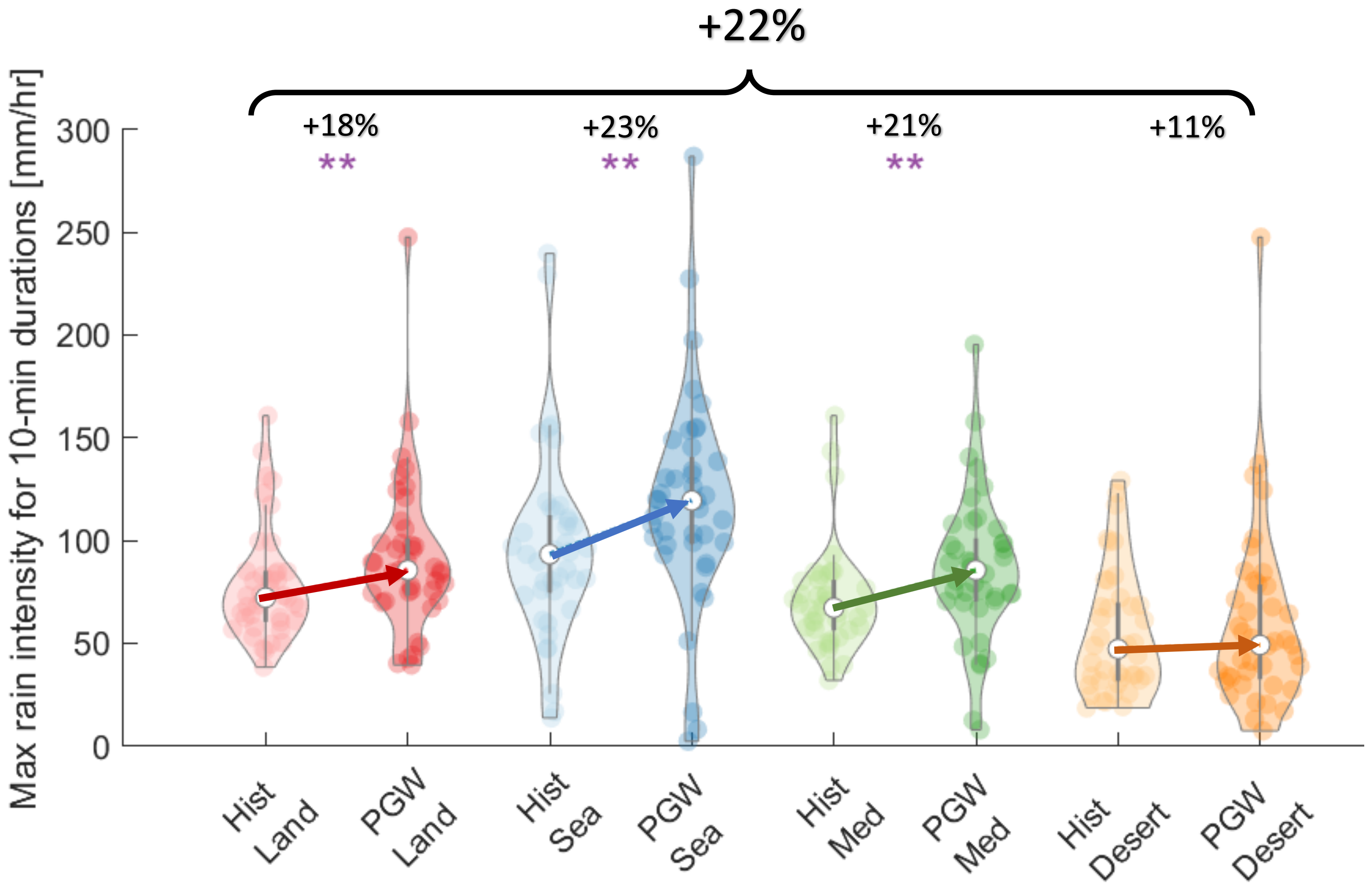




** - מובהק סטטיסטית (α=5%)

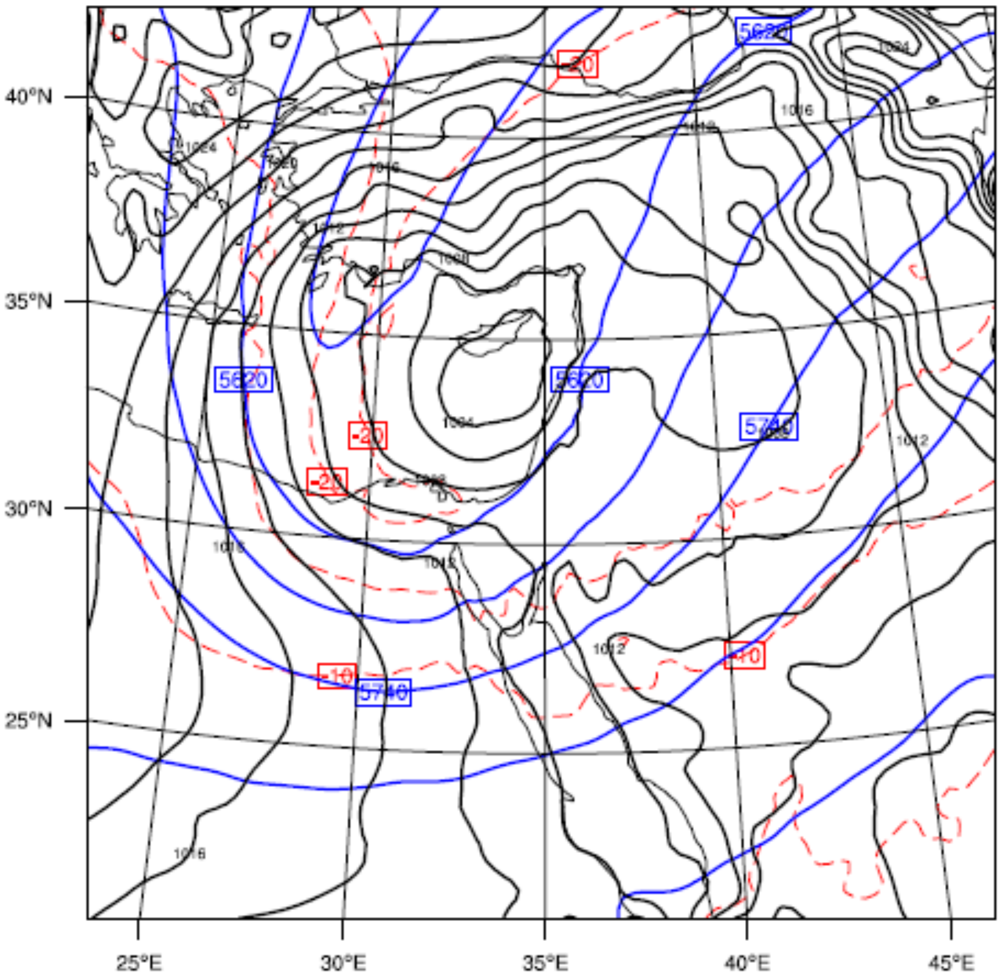
HPEs under climate change – **Max** rain rate



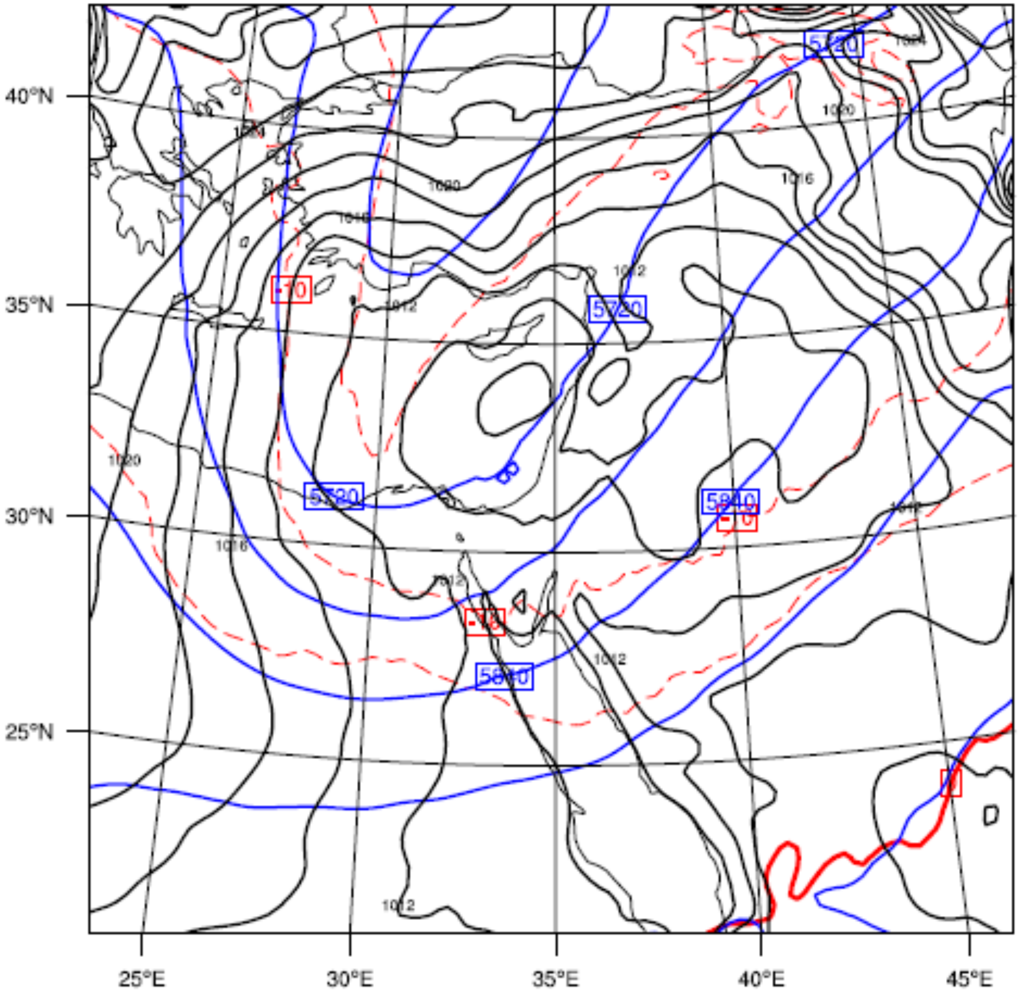


Meteorological causes for changes in rainfall patterns (initial results)

Historic HPE #1



PGW HPE #1



Meteorological causes for changes in rainfall patterns (initial results)