Global analysis of cyclone-induced compound precipitation and wind extreme events

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What are compound extreme events? Why should we care?

IPCC SREX:

- two or more extreme events occurring simultaneously or successively
- combinations of extreme events with underlying conditions that amplify the impact of the events
- combinations of events that are not themselves extremes but lead to an extreme event when combined

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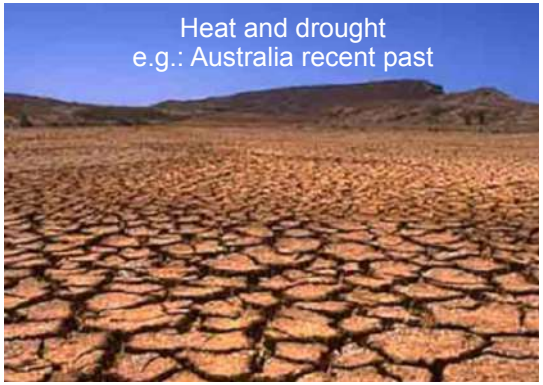

Crop decline or even failure
implications for bushfire weather

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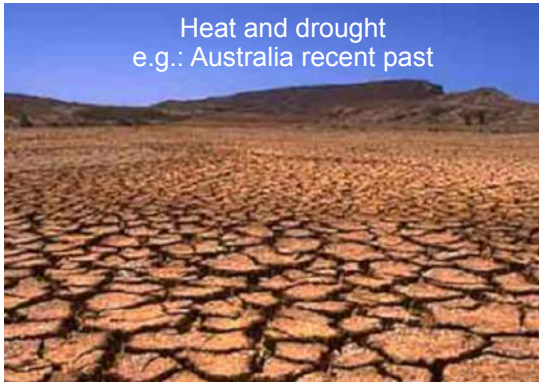

Crop decline or even failure
implications for bushfire weather

3.8 billions US$ loss
32 fatalities

Data, algorithms and compound event detection

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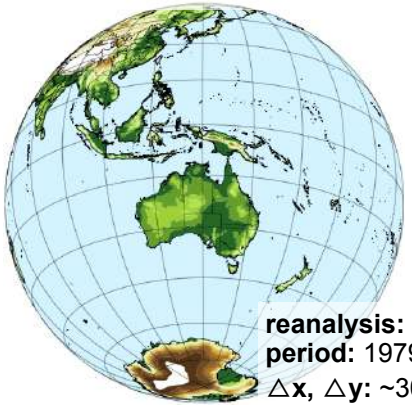
Data



reanalysis: ERA5
period: 1979–2018
△**x,** △**y:** ~30 km, globally

Data, algorithms and compound event detection

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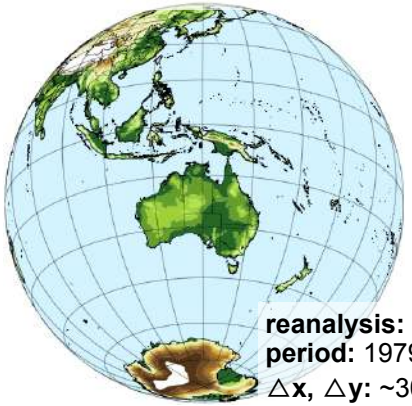

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- 3-hr data for sea level pressure
- 3-hr accumulated total **precipitation**
- max. 10-m **wind** gust within 3 hours

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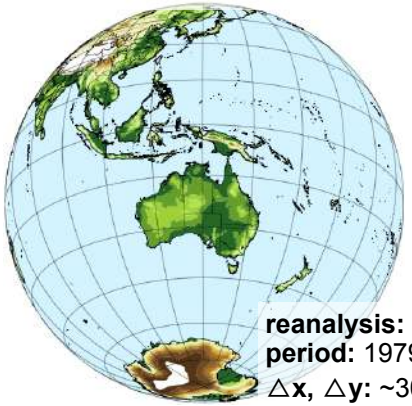

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cyclone detection & tracking algorithm
(Murray and Simmonds et al., 1991)

Data, algorithms and compound event detection

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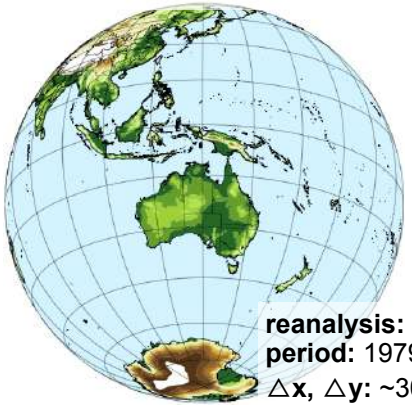

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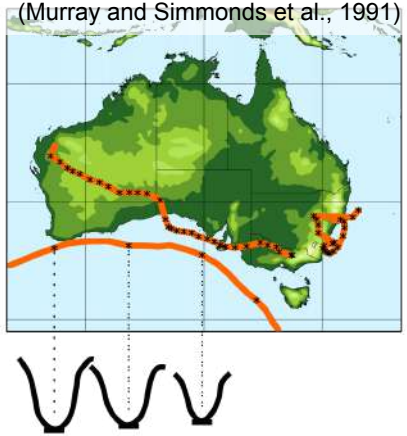

- Laplacian of SLP is used to identify local minima

Data, algorithms and compound event detection

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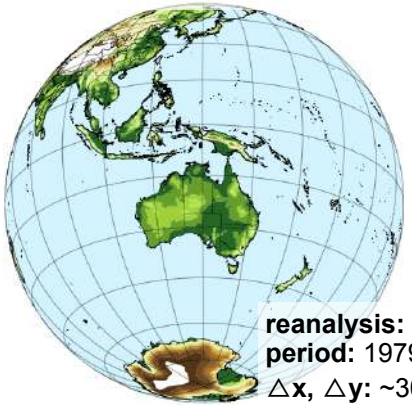

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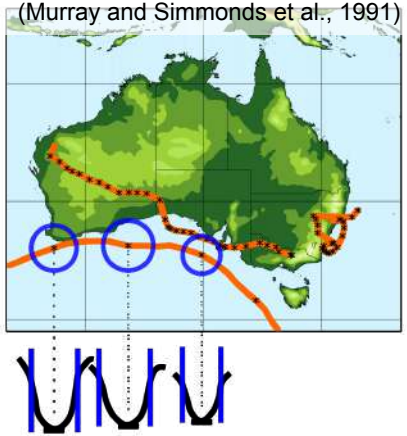

- Laplacian of SLP is used to identify local minima
- Inflection point is used to define an average radius around the cyclone centre
- Radius → impact area of cyclone

Data, algorithms and compound event detection

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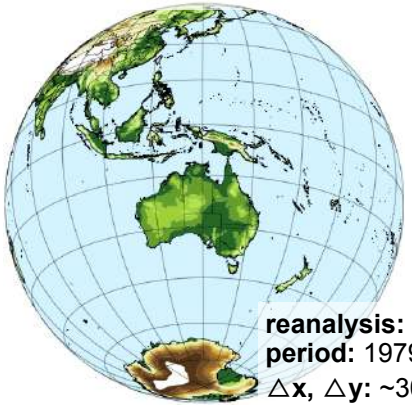

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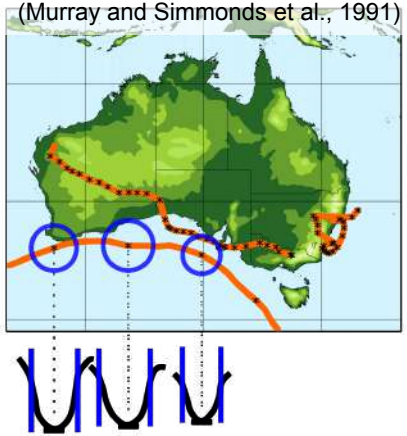

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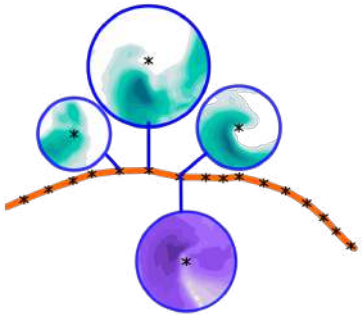
Compound event detection:
Wind and precipitation extremes



- compare against 98th seasonal percentile (wind and precipitation)
- more than 25% of grid points larger than p98
- Minimum 24 hours

Total cyclone numbers on Northern Hemisphere (40-yrs)

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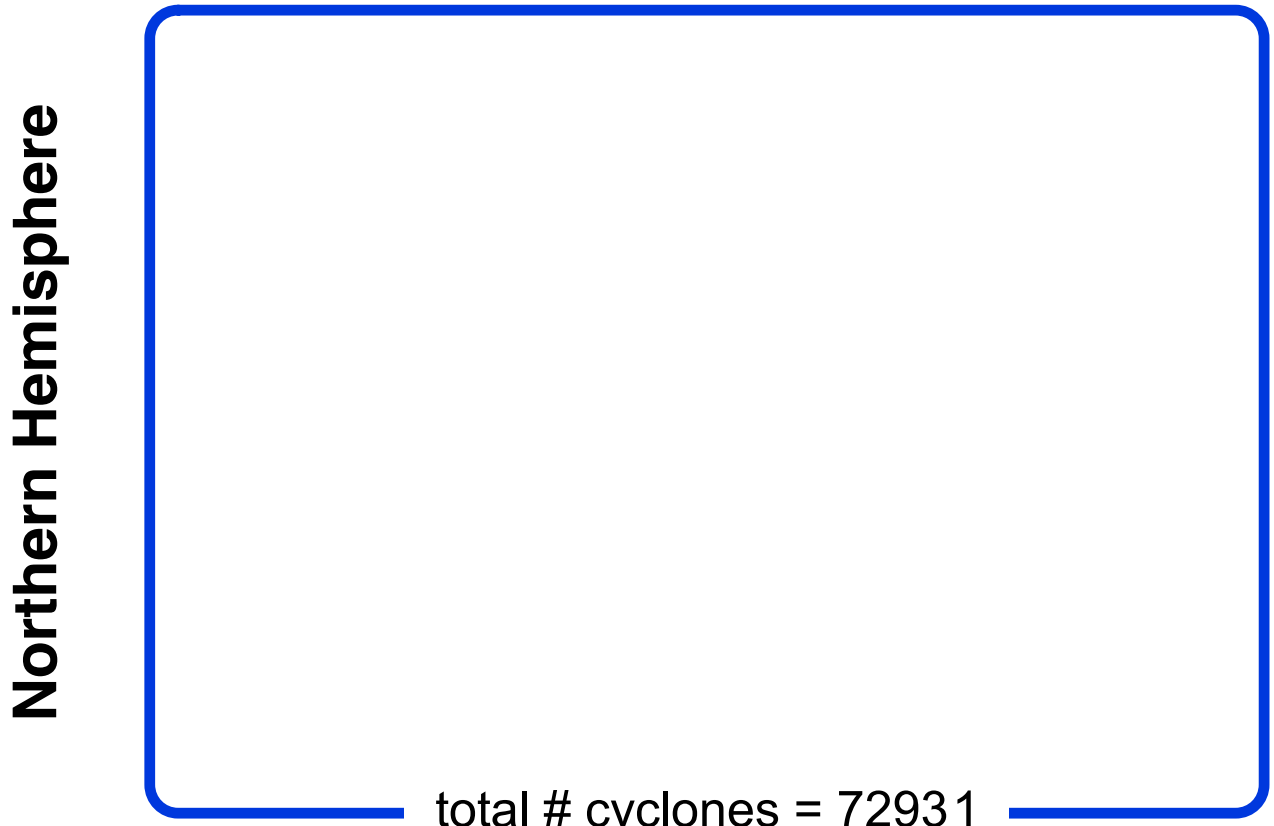
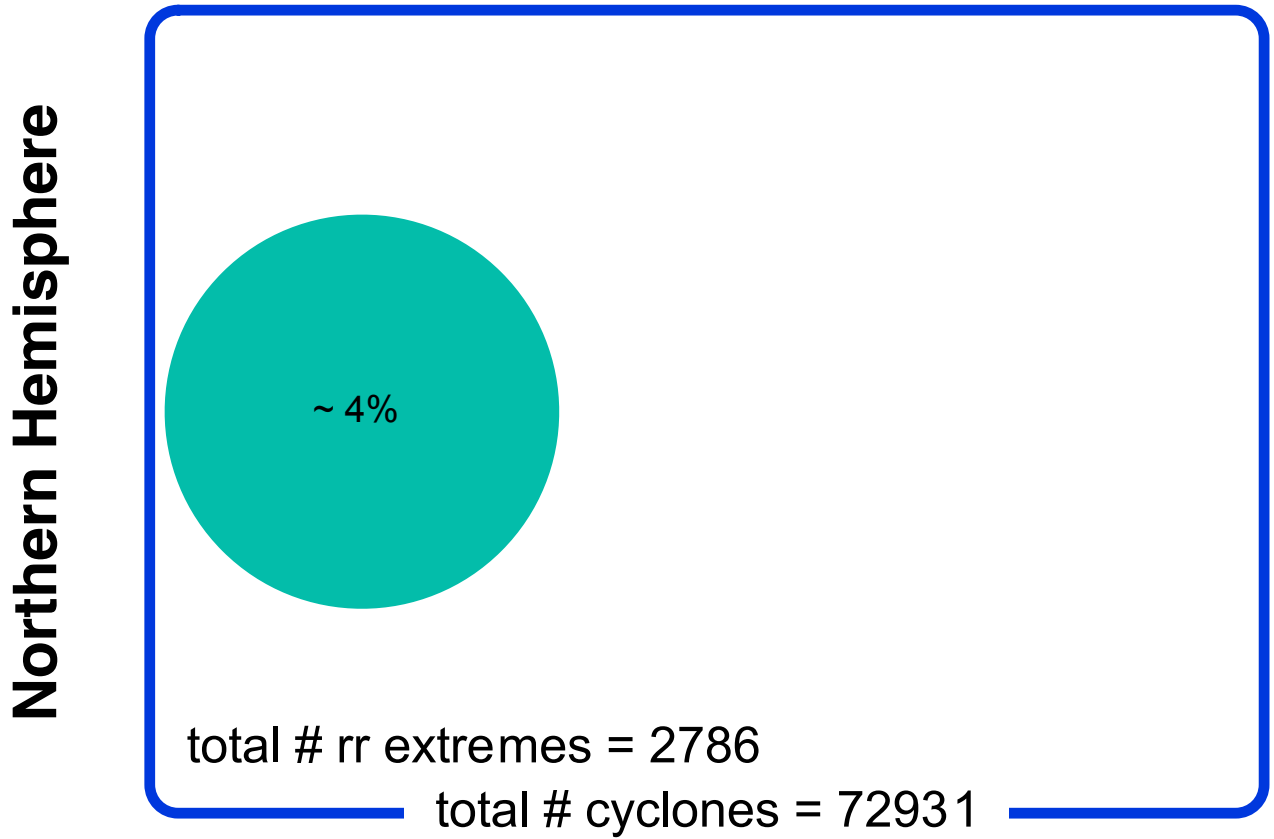


Cyclones with extreme precipitation event



Cyclones with extreme precipitation and wind events

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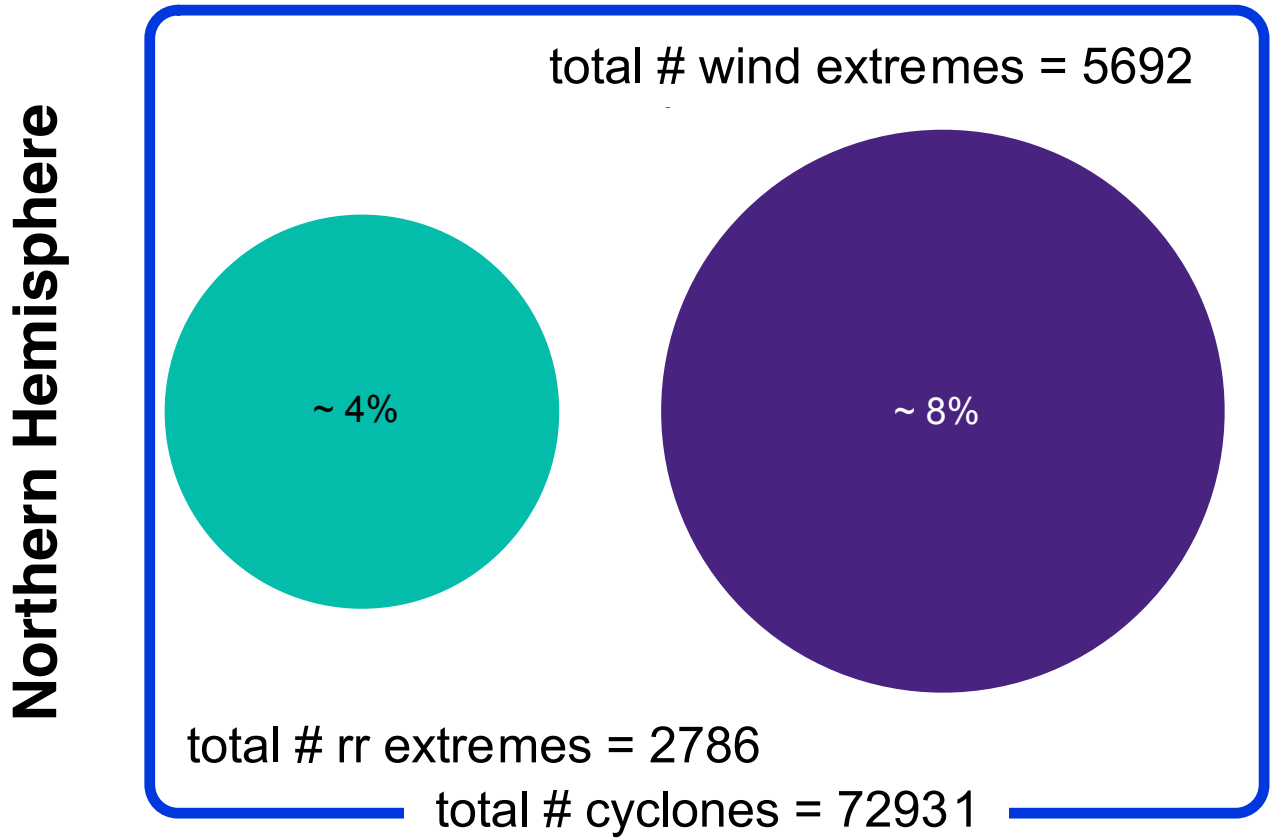
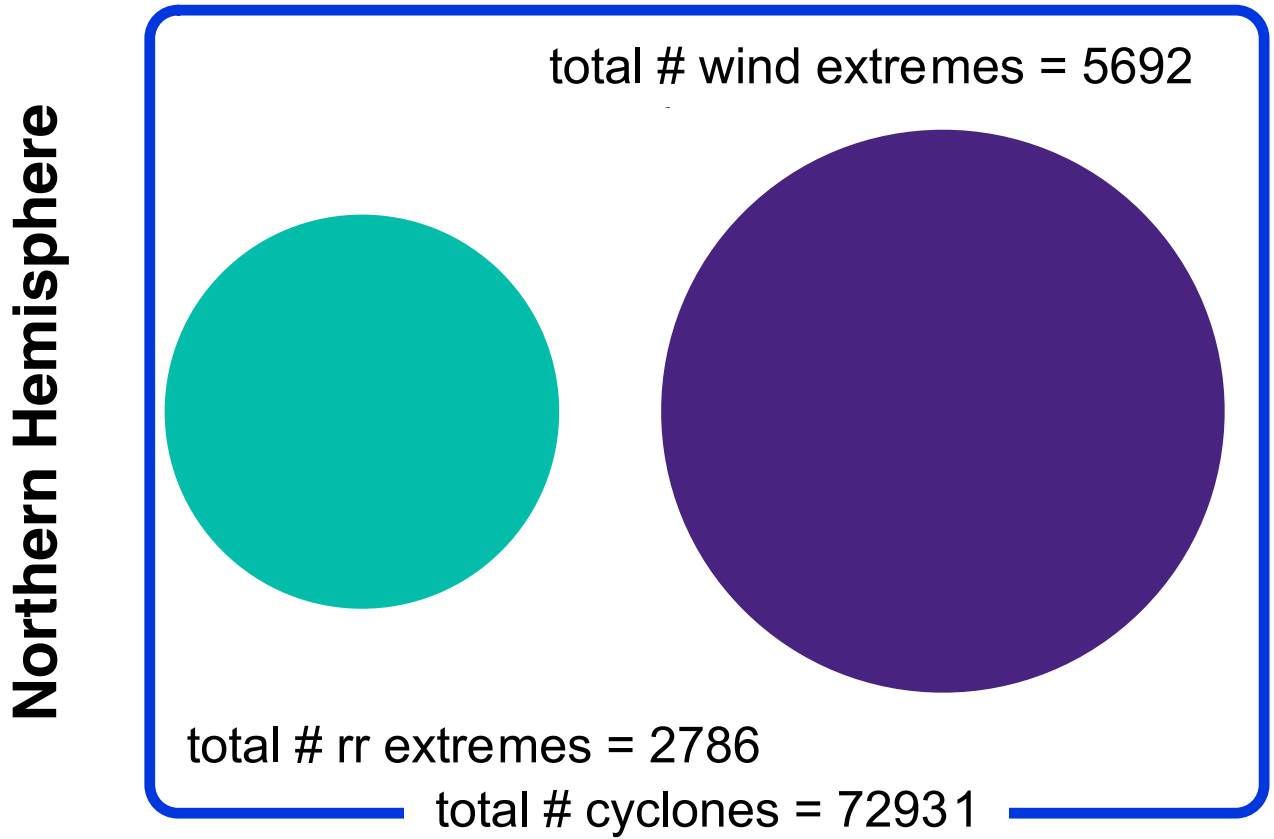


Cyclones with compound extreme precipitation and wind events



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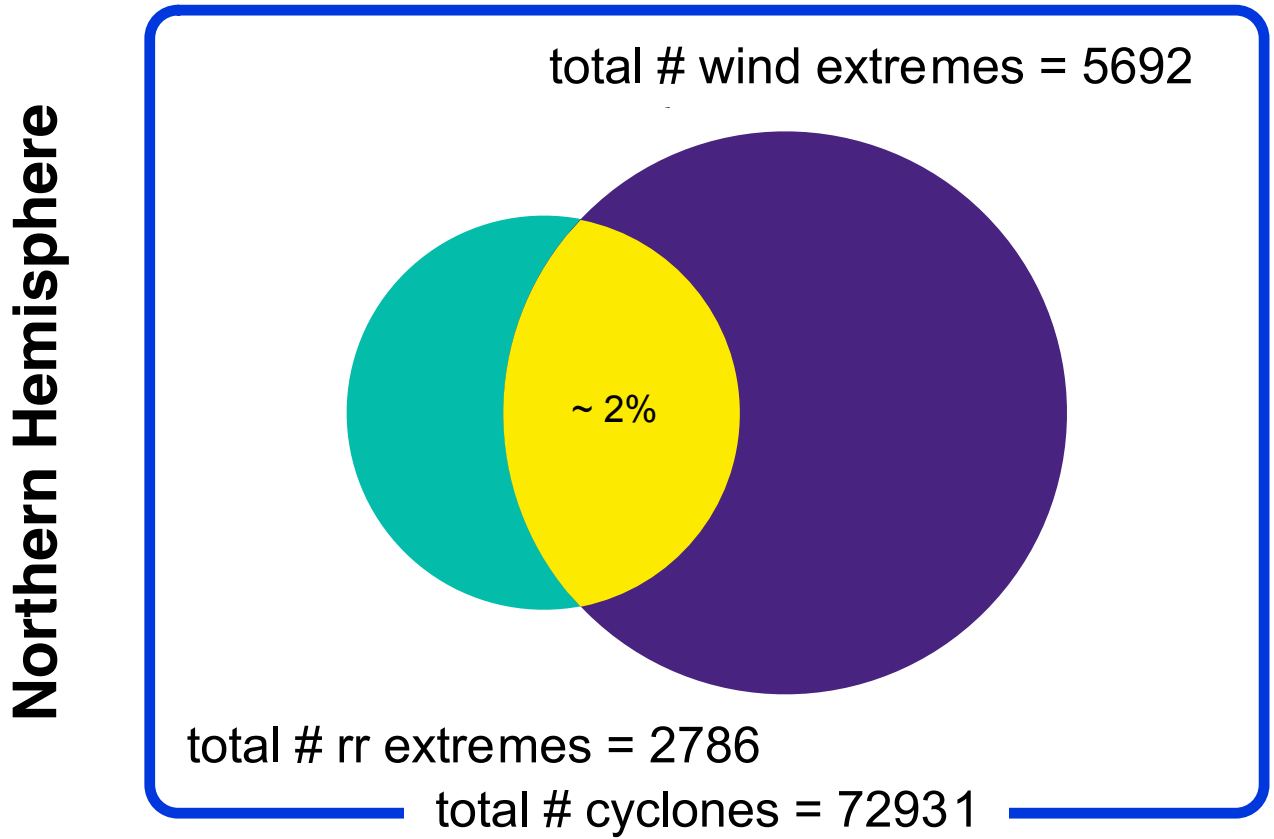

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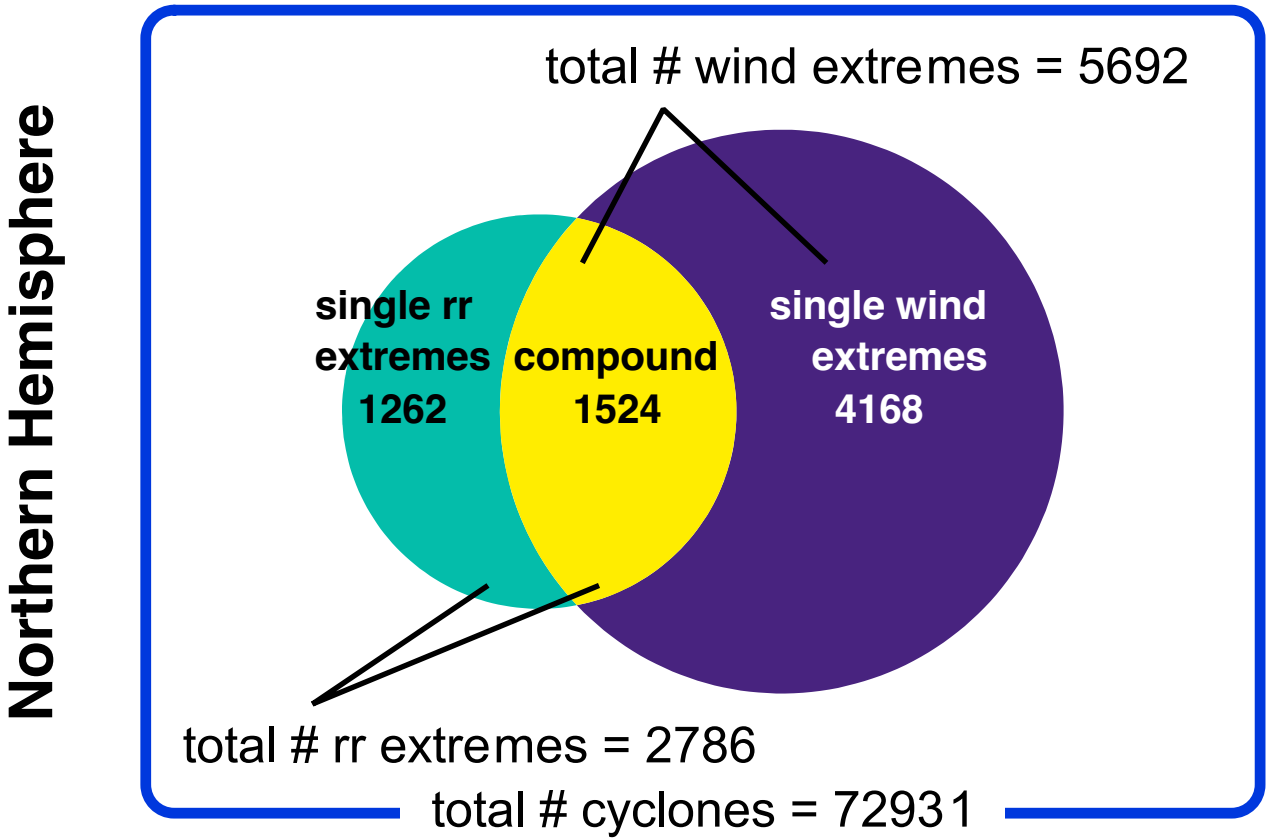

Frequency of precipitation, wind and compound extremes: Winter season (DJF)

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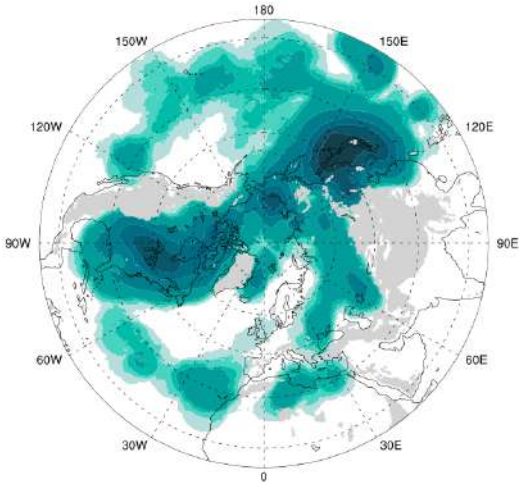
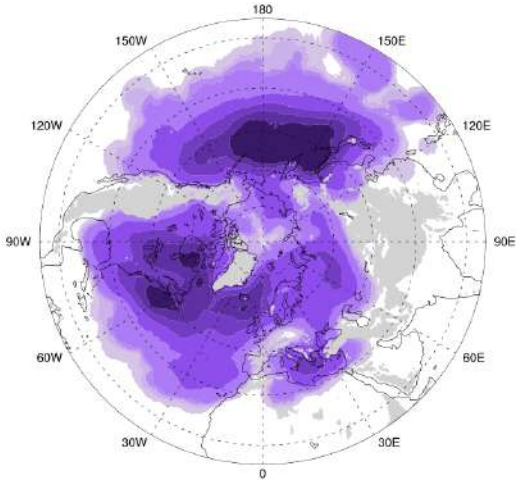
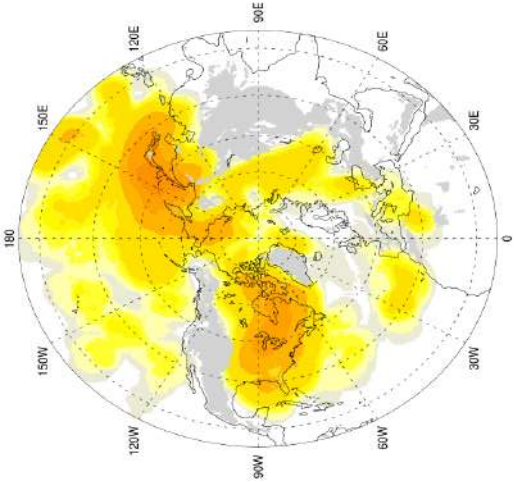
precipitation extremes

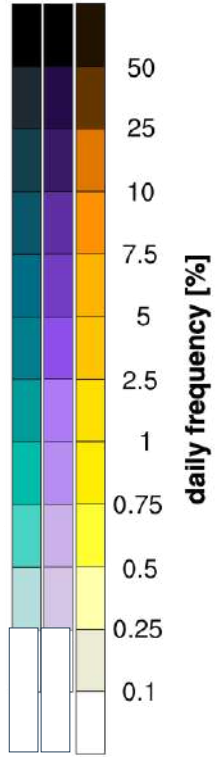


wind extremes



compound extremes





Compound extremes are limited by the number of extreme precipitation events

Grey area indicates topography higher than 1000 metres above sea level

Frequency of precipitation, wind and compound extremes for the Mediterranean Sea (DJF)

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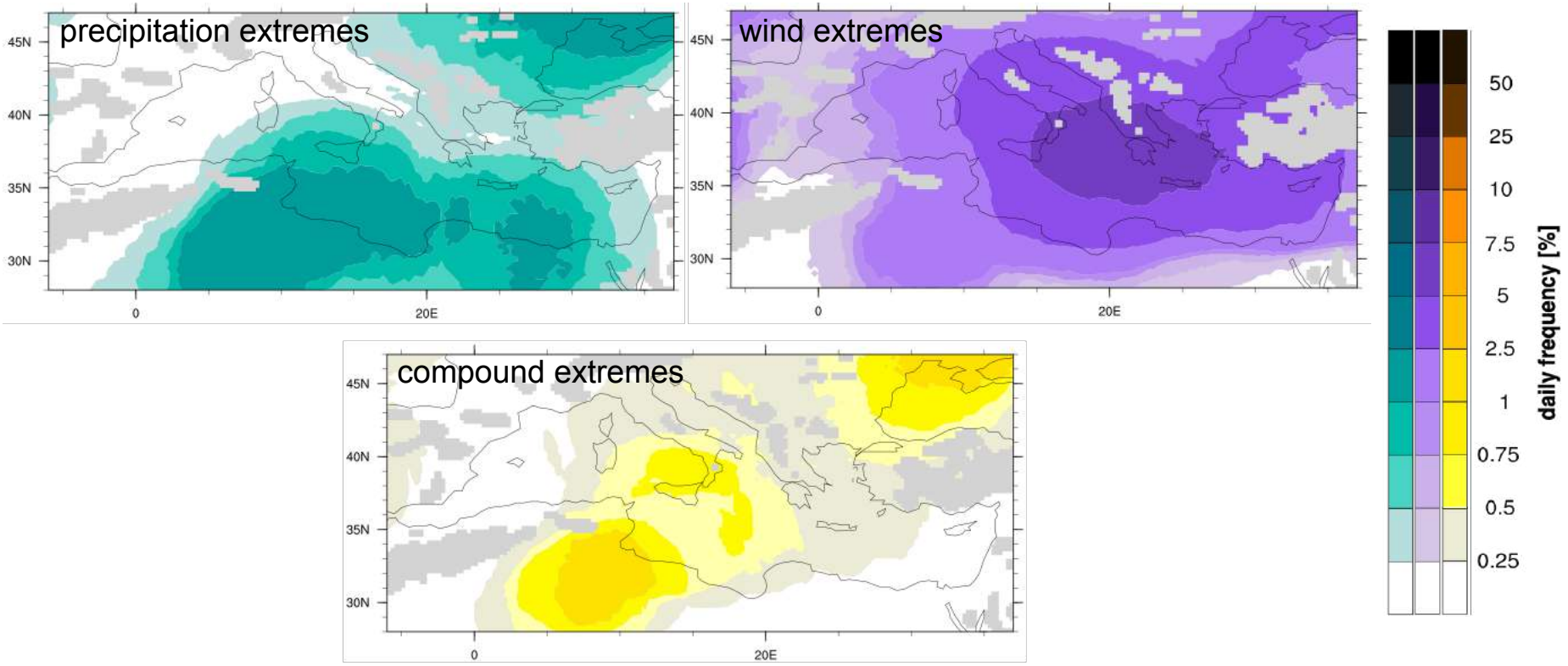

Central Mediterranean Sea is mostly affected by compound extreme events in the winter season

Grey area indicates topography higher than 1000 metres above sea level

Compound extreme events over the Mediterranean Sea

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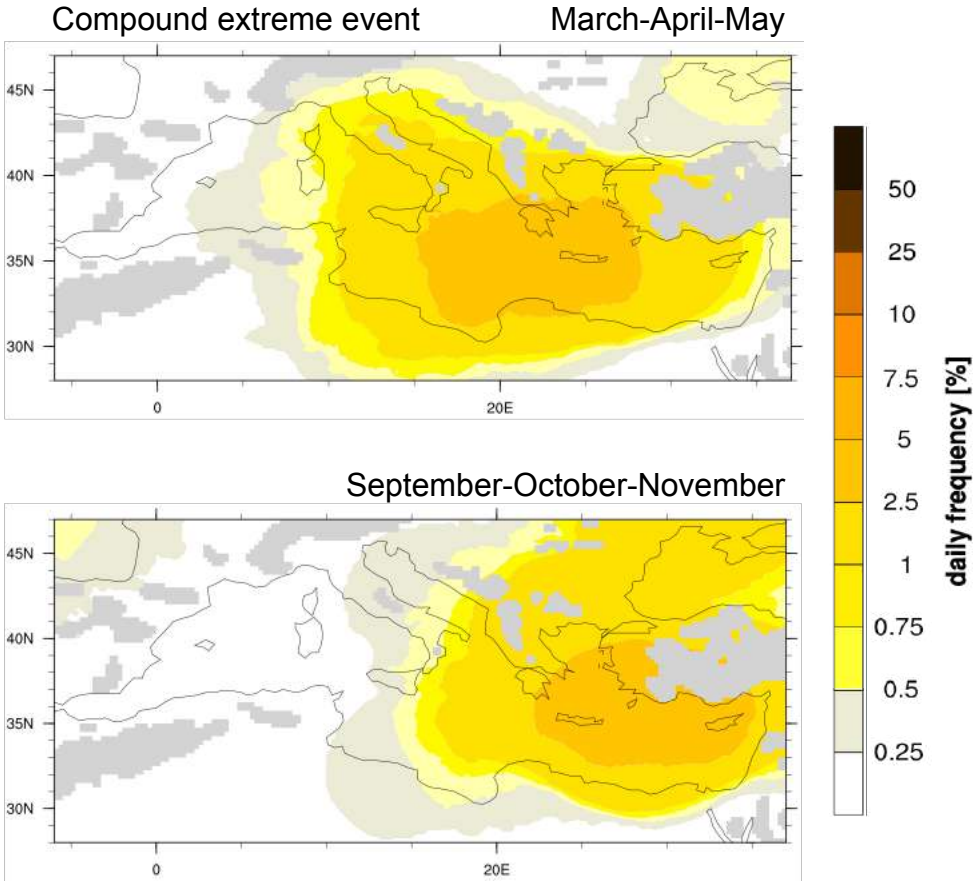
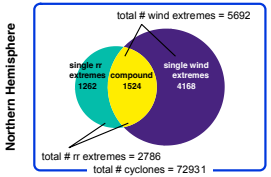


The eastern Mediterranean Sea is more affected by compound extreme precipitation and wind events in spring and fall

Grey area indicates topography higher than 1000 metres above sea level

Compound versus single extreme precipitation



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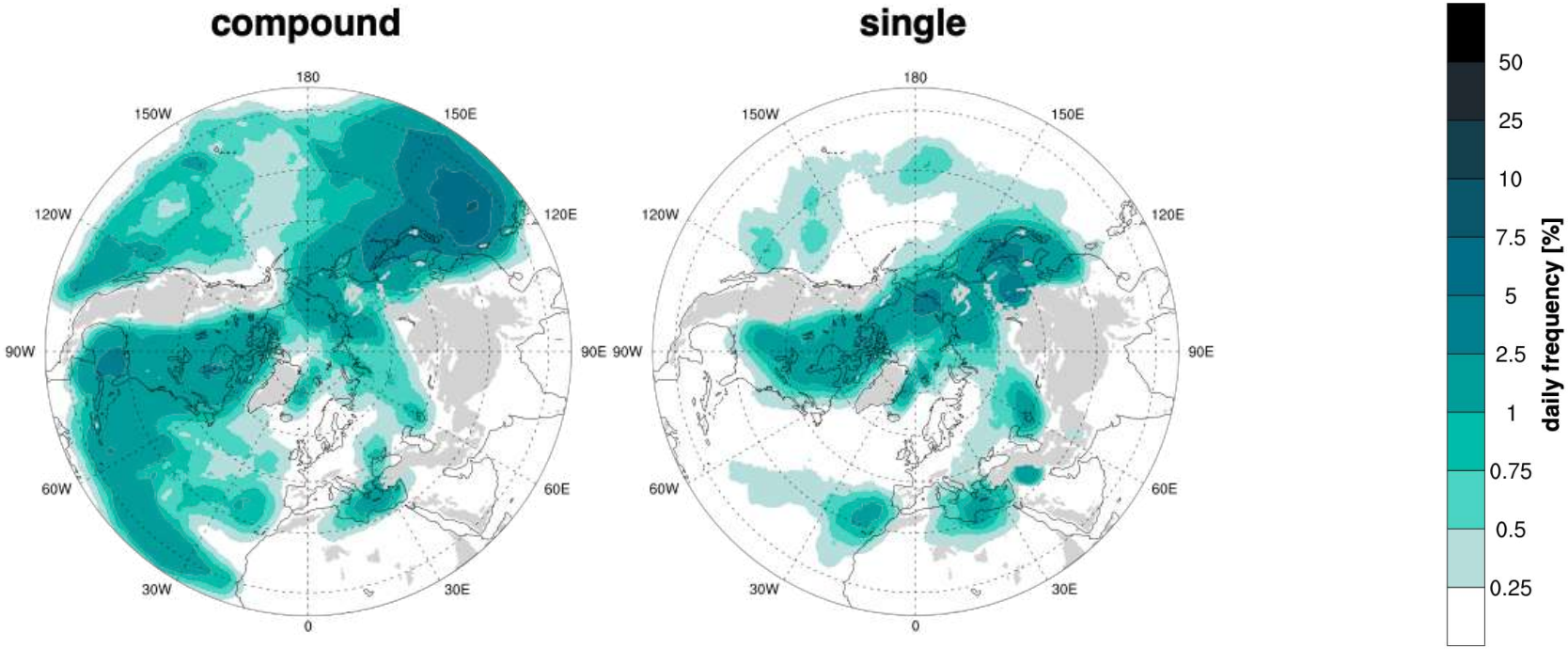
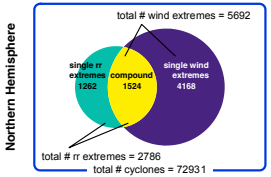


Compound and single precipitation extremes occur at similar locations over land, but over the ocean and in tropical cyclone regions, compound extremes events dominate

Compound versus single extreme wind



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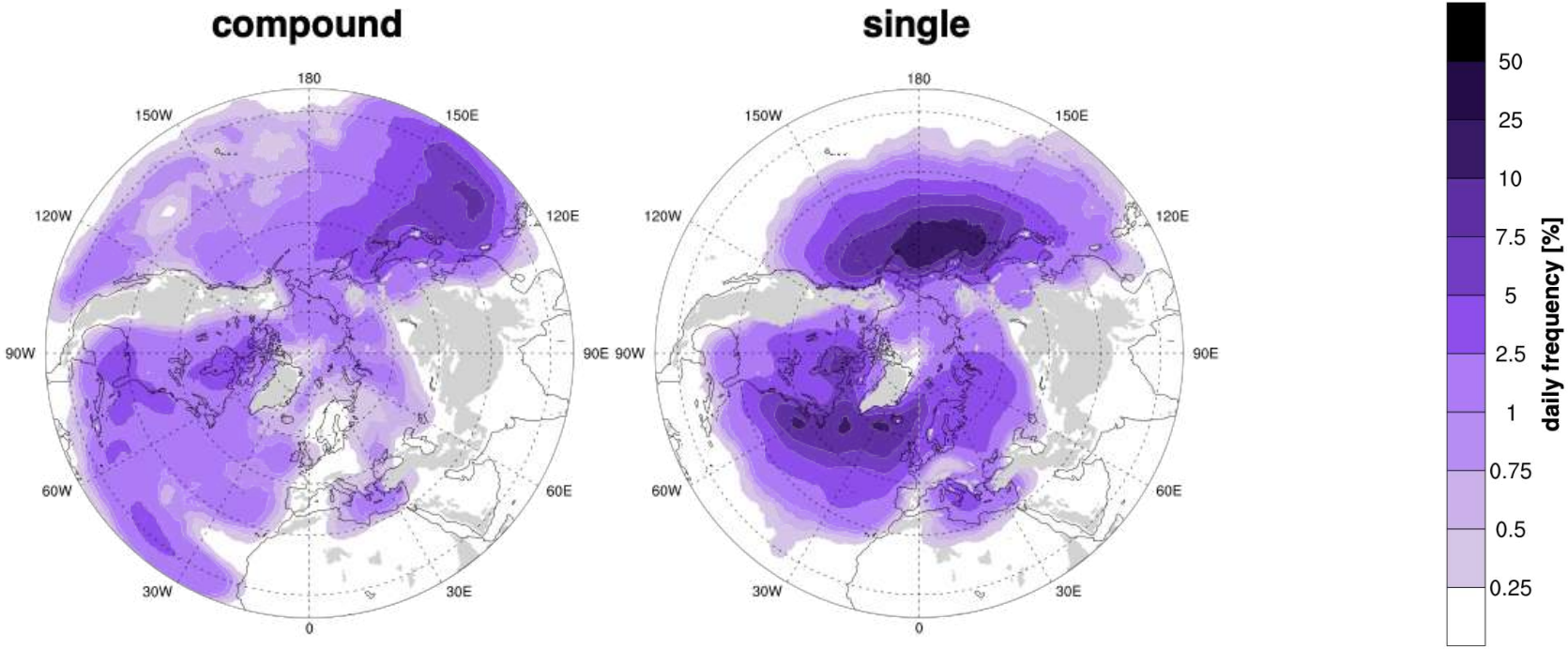

There are fewer compound wind extremes over the storm track region than single extremes. Generally, compound and single extreme wind events occur at the same location, except for the tropical regions.

Frequency of precipitation and wind extremes: Mediterranean

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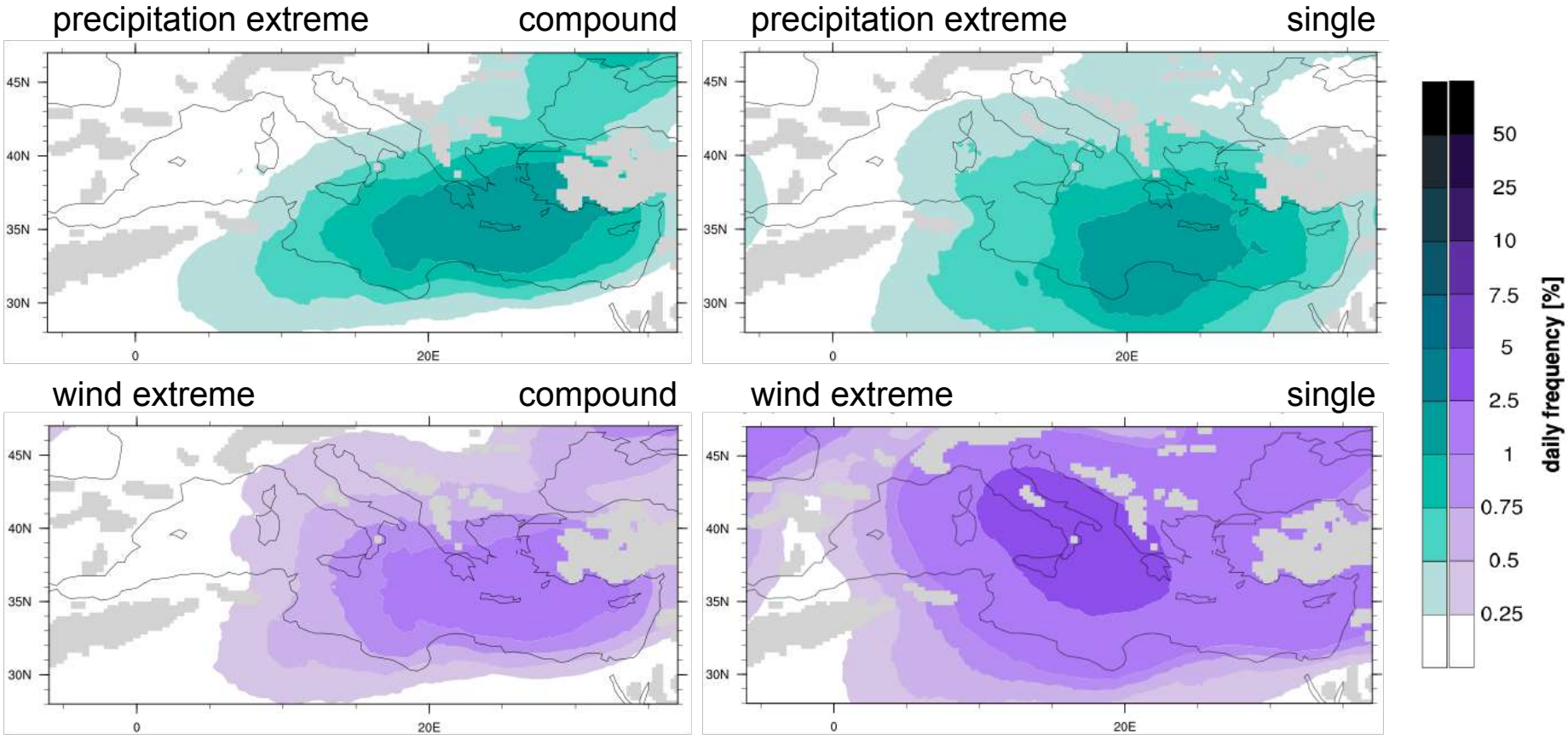

Temporal analysis of compound extreme events

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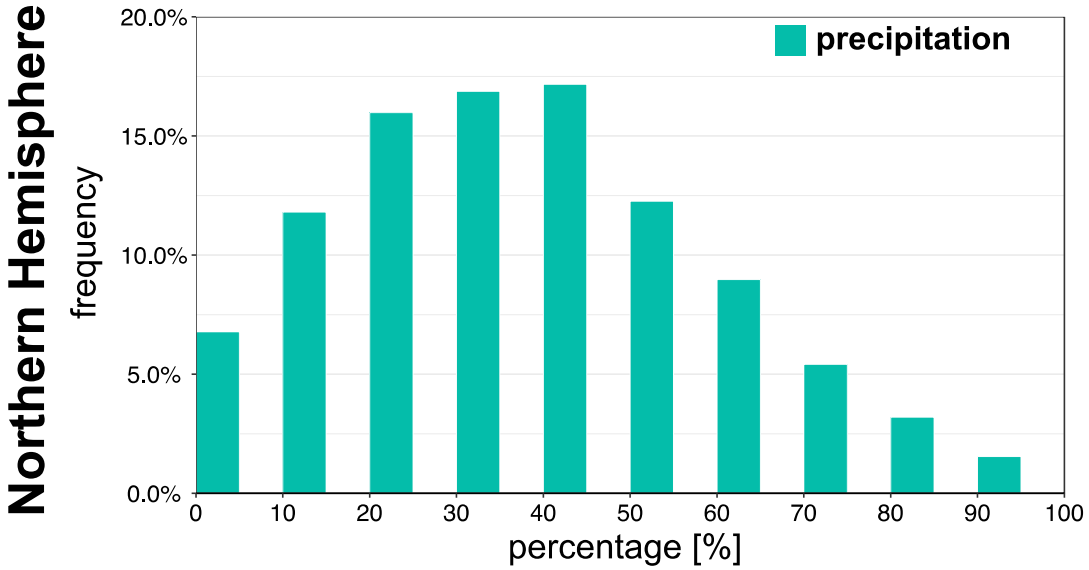

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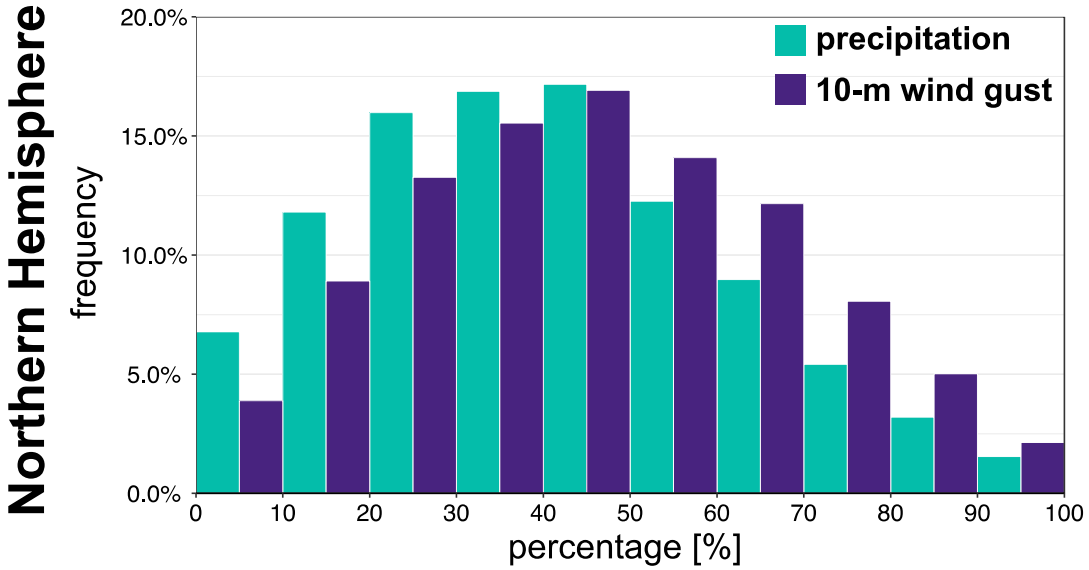

Precipitation extremes tend to occur slightly before or at the same time as the wind extreme in compound events.

Duration of compound and single extremes

Average cyclone life time (1) and average life time of extremes (2) within cyclones

Compound extremes			Single extremes	
precipitation [h]			precipitation [h]	
(1)	203.1 6.0		116.3 3.7	
(2)	68.6 3.0		36.0 0.7	
	33 %		31 %	

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Average cyclone life time (1) and average life time of extremes (2) within cyclones

	Compound extremes		Single extremes	
	precipitation [h]	wind [h]	precipitation [h]	wind [h]
(1)	203.1 6.0	203.1 6.0	116.3 3.7	157.5 2.2
(2)	68.6 3.0	89.9 4.0	36.0 0.7	43.3 0.7
	33 %	44 %	31 %	27%

Wind extremes last much longer with respect to the cyclones' lifetime in combination with a precipitation extreme

Take home message

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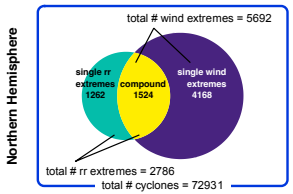

- Study investigates spatially large and coherent extreme events
- More than half of the precipitation extremes are involved in compound extremes, for wind extremes it is only one quarter
- Compound extremes are limited by the number of extreme precipitation events

Messmer and Simmonds, 2021 (WACE)

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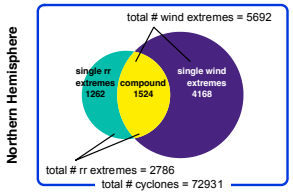

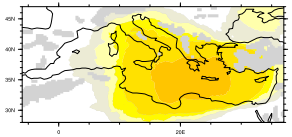

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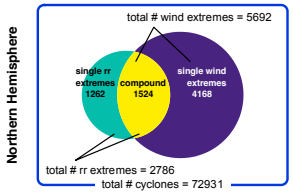

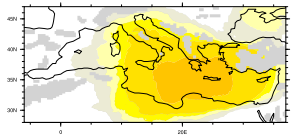

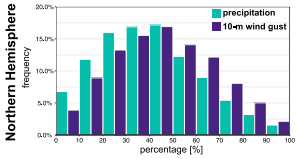

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- Compound extremes are limited by the number of extreme precipitation events
- The central (eastern) Mediterranean Sea is affected by compound extremes in the summer and winter (fall and spring) season
- Precipitation extremes tend to happen before or with the wind extremes
- The wind extremes in compound extreme events last longer compared to a single wind extreme

➢ This has potential implications for the future under climate change and increase in extreme precipitation events

Messmer and Simmonds, 2021 (WACE)

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THANK YOU FOR YOUR ATTENTION

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