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EXTRA-TROPICAL CYCLONE INTENSITY: COMPARING DIFFERENT MEASURES AND DIFFERENT REGIONS

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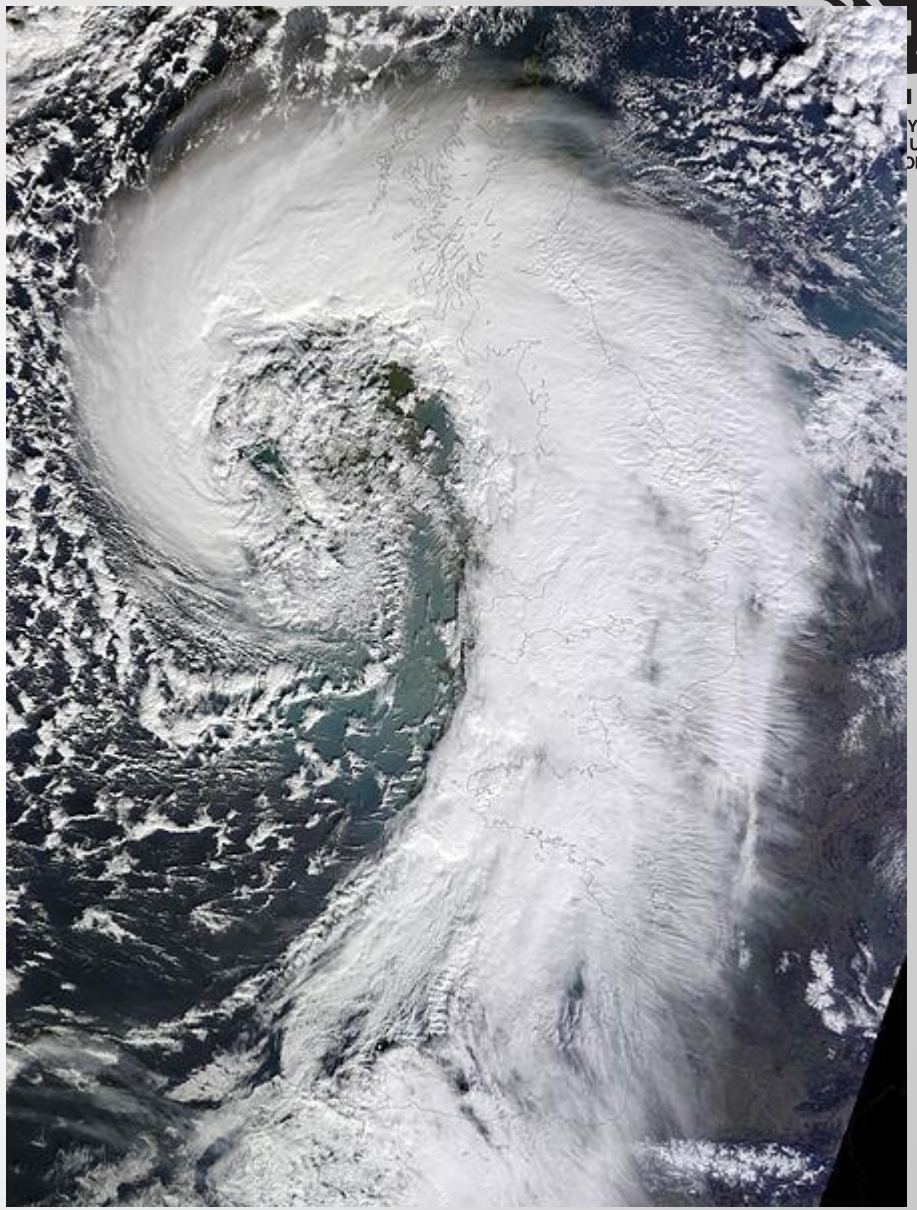
MOTIVATION

- Knowing how cyclone intensity measures differ per region and correlate with each other help us understand cyclones better
- Extra-tropical cyclones are one of the main causes of nature-related damage in Europe and can cause billions of dollars of damage
- The better we understand cyclones, the better we can forecast them and the earlier we can warn
- A better understanding will also help us to research how cyclones change in a warmer climate



photocredit: NASA Earth Observatory

QUESTIONS:

- How do cyclone intensity measures measures (e.g. max. vorticity, min. MSLP) differ for different geographical regions and different time periods

- How do cyclone intensity measures relate to each other?
  - Do the relationships differ between geographical areas?

- Can we find any trends?

METHODS:

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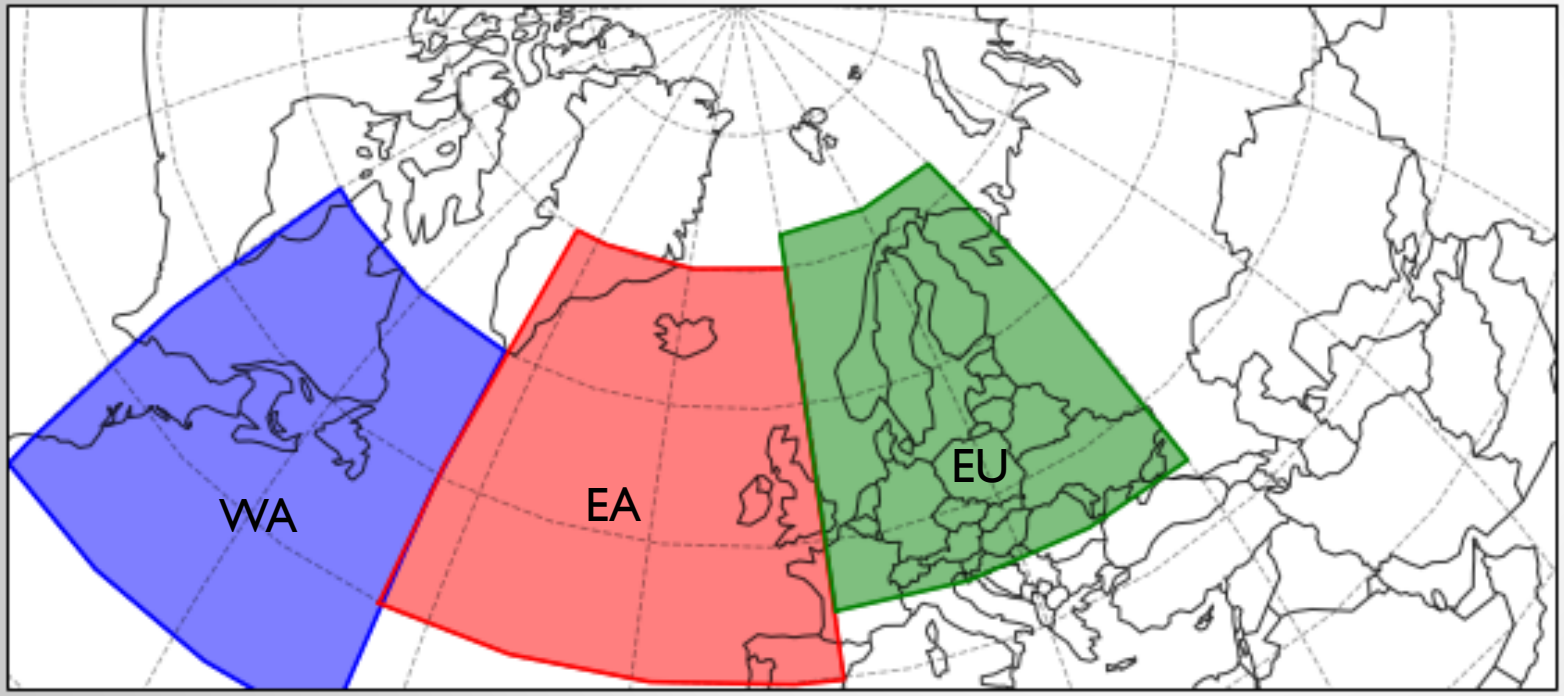
- Generate data by tracking mechanism TRACK
    - Data source = ERA5 data (1979-2020)
    - Cold season (October – March)
    - Cyclones tracked by localised vorticity maximum at 850 hPa
    - Cyclone filtering:
        - Livespan ≥ 2 days
        - Travelled distance ≥ 1000 km
        - Max vorticity ≥ $1x10^{-5}$ s^{-1}

- Every time step contains data e.g.:
    - Location of cyclone center (location of max. vorticity)
    - Max. vorticity
    - Min. MSLP
    - Wind gusts 3 degree radius from cyclone center
    - Wind gusts 6 degree from cyclone center

METHODS:

- Create geographical areas:



Cyclones are assigned to regions depending where they are at their strongest point (highest vorticity).
So not where they form!

VORTICITY DISTRIBUTIONS

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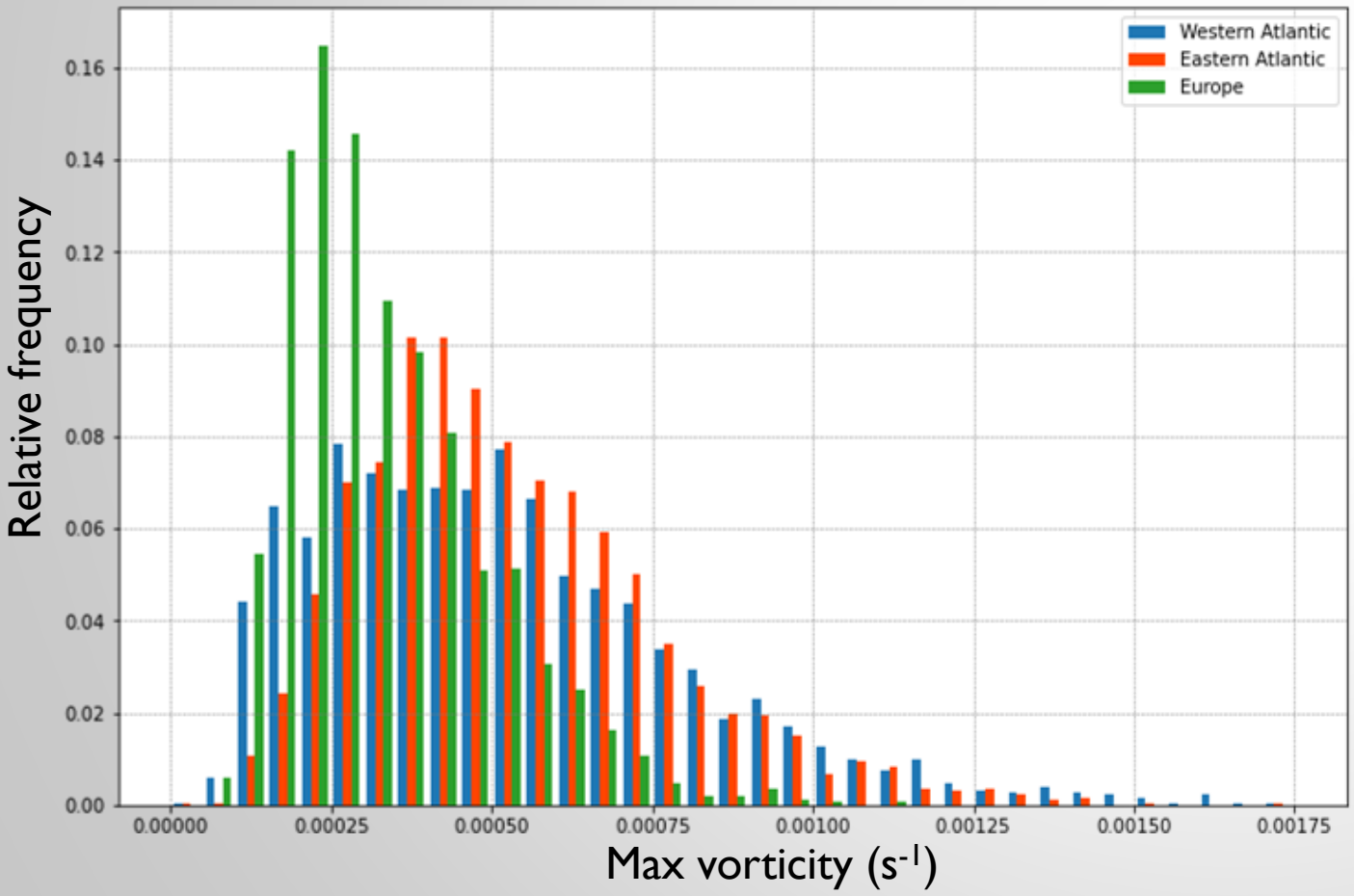
Cyclones – max 850 hPa vorticity



Vorticity statistics ($x10^{-4}$ s^{-1})	WA	EA	EU
Median	4.78	4.89	2.96
Mean	5.19	5.28	3.31
95%-interval	1.28 - 12.02	1.78 – 10.92	1.27 - 6.98

- WA and EA are not significantly different cyclone vorticity populations
- EA cyclones on average stronger (mean and median vorticity higher)
- However: WA has a stronger variance (so more extreme values).

PRESSURE DISTRIBUTIONS

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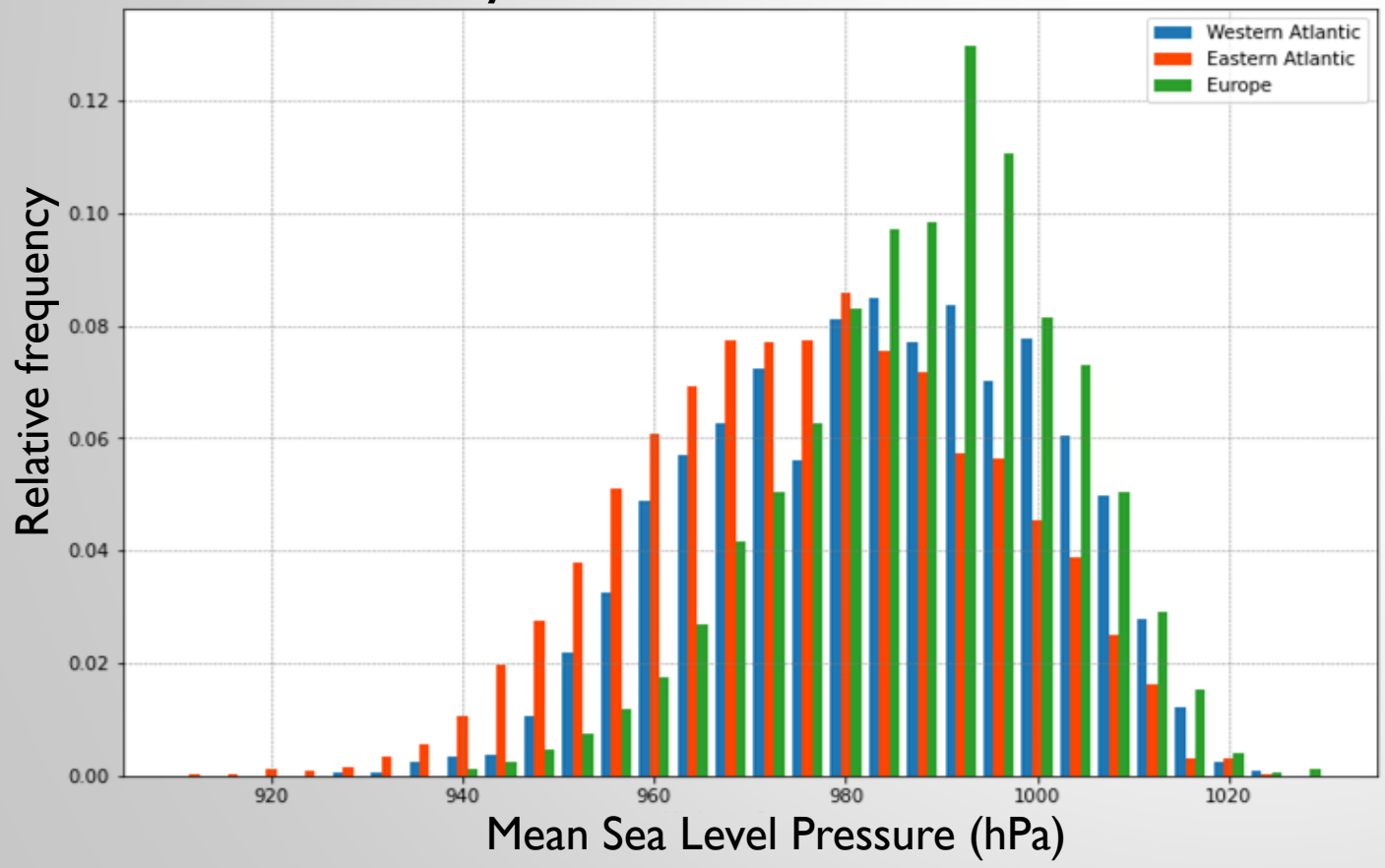
Cyclones – min MSLP



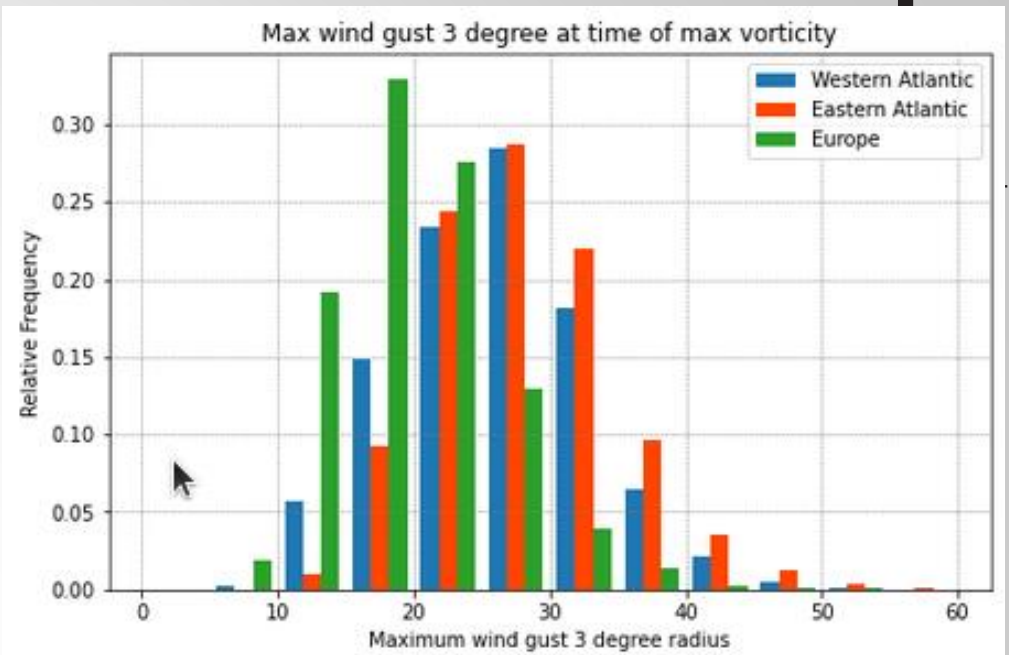
MSLP statistics	WA	EA	EU
Median	984.28	976.99	989.82
Mean	983.32	976.65	988.31
95%-interval	950.86 - 1012.23	942.29 – 1009.56	957.47 - 1013.16

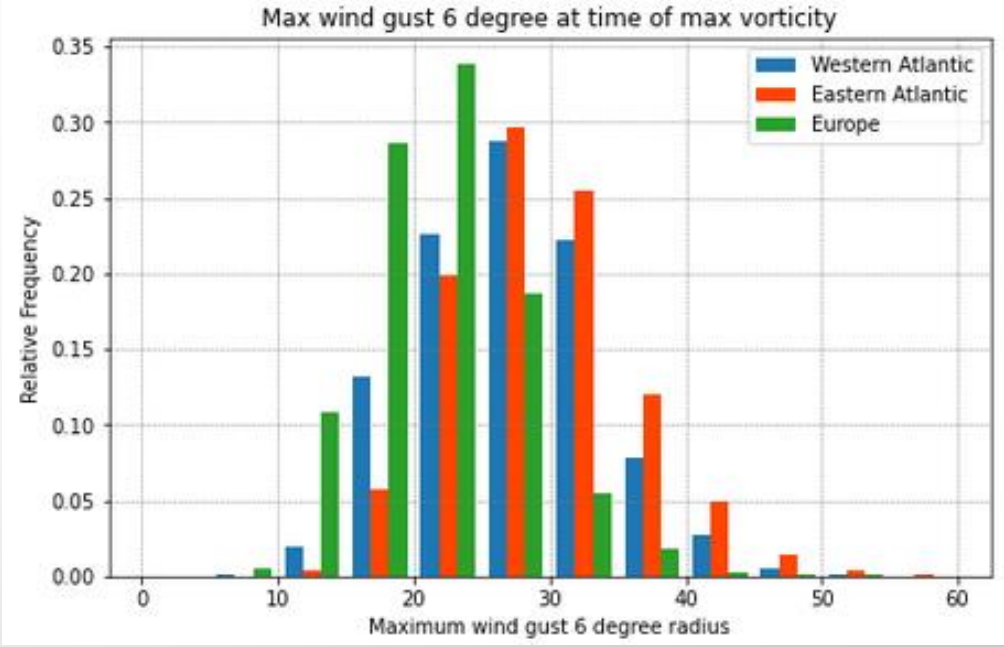
- The cyclone MSLP populations of all geographical areas are statistically different
- Cyclones in EU are weaker (higher MSLP)
- EA cyclones on average stronger (MSLP lower)

WIND GUST DISTRIBUTIONS

3 degree wind gust statistics (m/s)	WA	EA	EU
Median	26.14	27.52	19.39
Mean	25.94	28.19	19.98
95%-interval	12.88 - 40.15	16.21 - 42.9	10.31 - 33.12

6 degree wind gust statistics	WA	EA	EU
Median	27.15	28.96	21.33
Mean	27.19	29.51	21.72
95%-interval	15.36 – 40.93	18.09 – 43.46	11.93 – 34.12





CORRELATING PARAMETERS: 2D HISTOGRAMS

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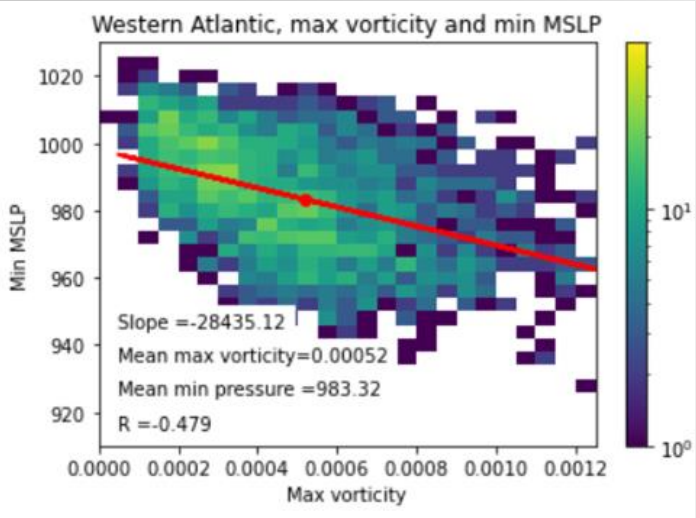
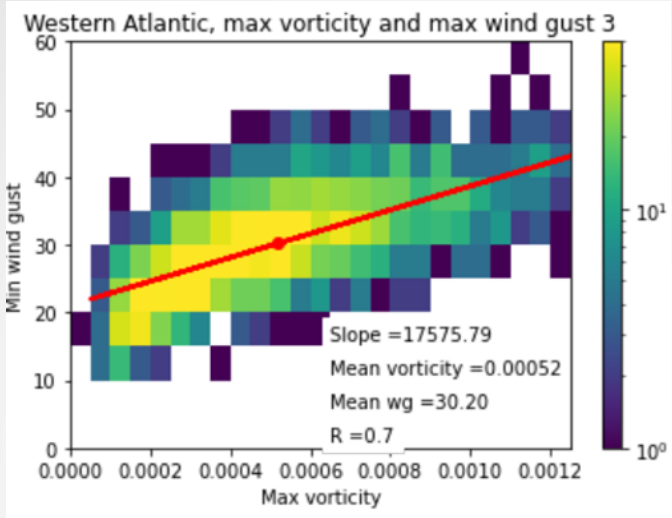
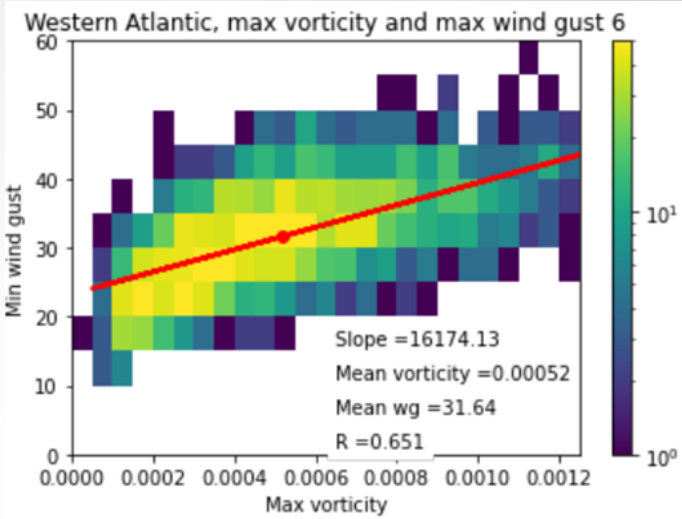
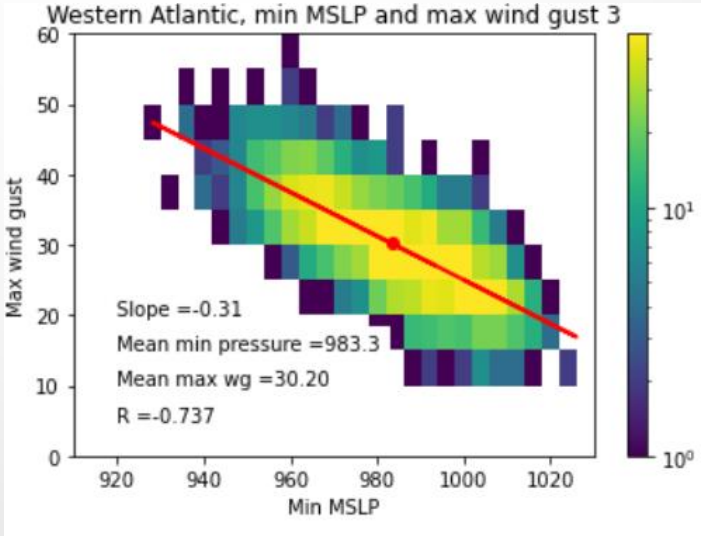
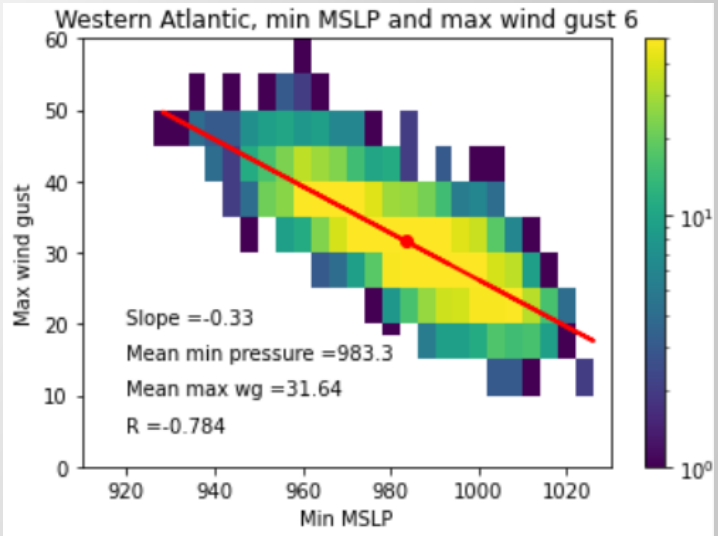






- **Western Atlantic**





MAIN RESULTS FOR CORRELATIONS BETWEEN PARAMETERS

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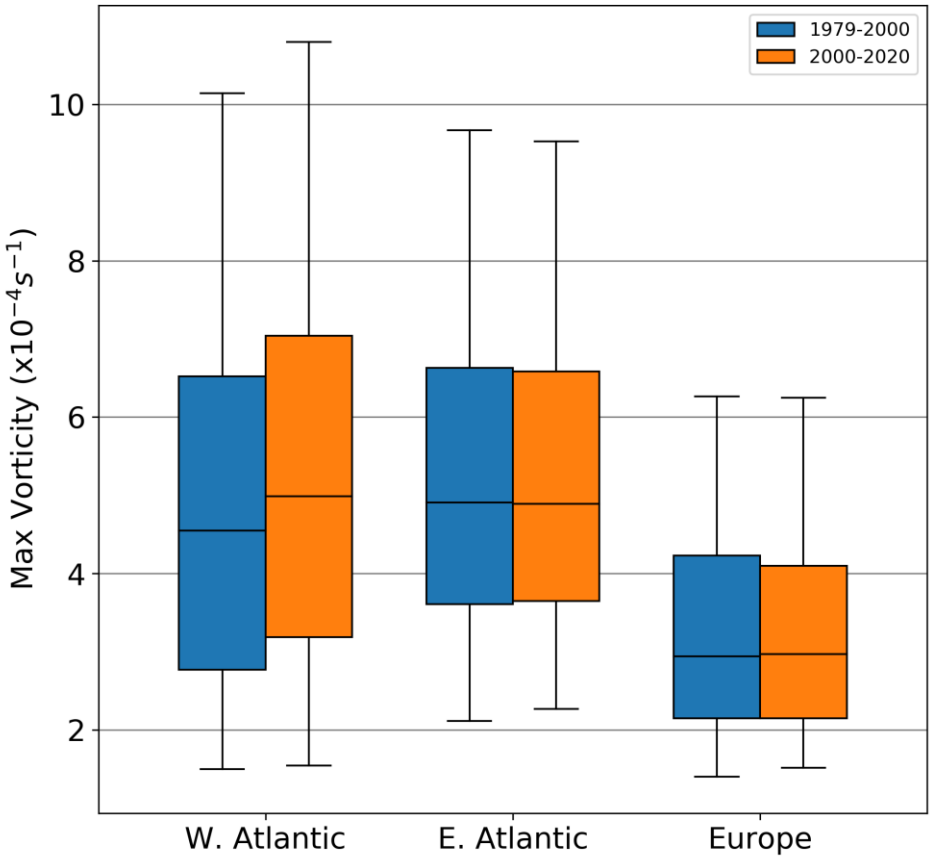
- MSLP overall stronger correlated with maximum wind gust than vorticity
- Remarkable:
  - max vorticity correlates stronger with 3 degree radius than 6 degree radius wind gusts
  - min MSLP correlates stronger with 6 degree radius than with 3 degrees radius wind gusts (for all regions!)
- Vorticity might tell you more about wind gusts the closer you get to the center of low pressure?

COMPARING TIME PERIODS



~1st half of ERA5 data (1979-2000 & 2000-2020)

- In the Western Atlantic, the parameters show an increase in cyclone strength (higher vorticity, higher wind speeds)
- Parameters in Eastern Atlantic and Europe show no statistically significant changes for vorticity

COMPARING TIME PERIODS: SUMMARIZING

Statistically different?	Western Atlantic		Eastern Atlantic		Europe	
max vorticity	yes	+	no	~	no	~
min pressure	no	-	no	+	yes	+
3 degree wind gusts	yes	+	no	-	yes	-
6 degree wind gusts	no	+	no	-	yes	-

+ Increasing trend

- Decreasing trend

~ Barely any difference

no : no significant difference ($p>0.05$)

yes : significant difference ($p< 0.05$)

no : $p=0.052$, no significant difference, but very close to threshold

- In the Western Atlantic, the parameters show an increase in cyclone strength (higher vorticity, higher wind speeds)
- Parameters in Eastern Atlantic show statistically significant changes in the Eastern Atlantic
- In Europe, the parameters that are statistically different, show a decrease in strength (higher min pressure, lower wind speeds).

TREND IN INTENSITY: WESTERN ATLANTIC

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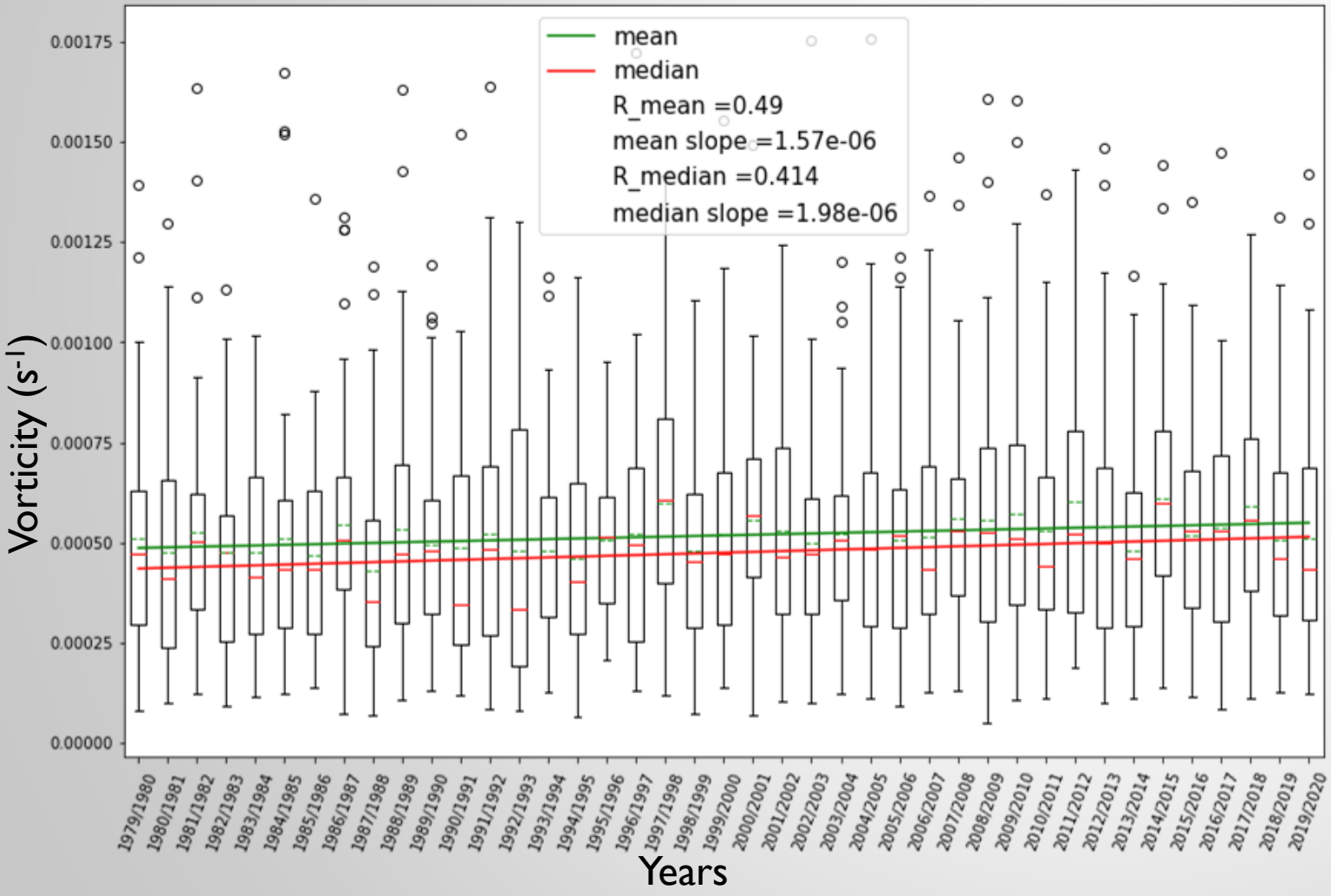
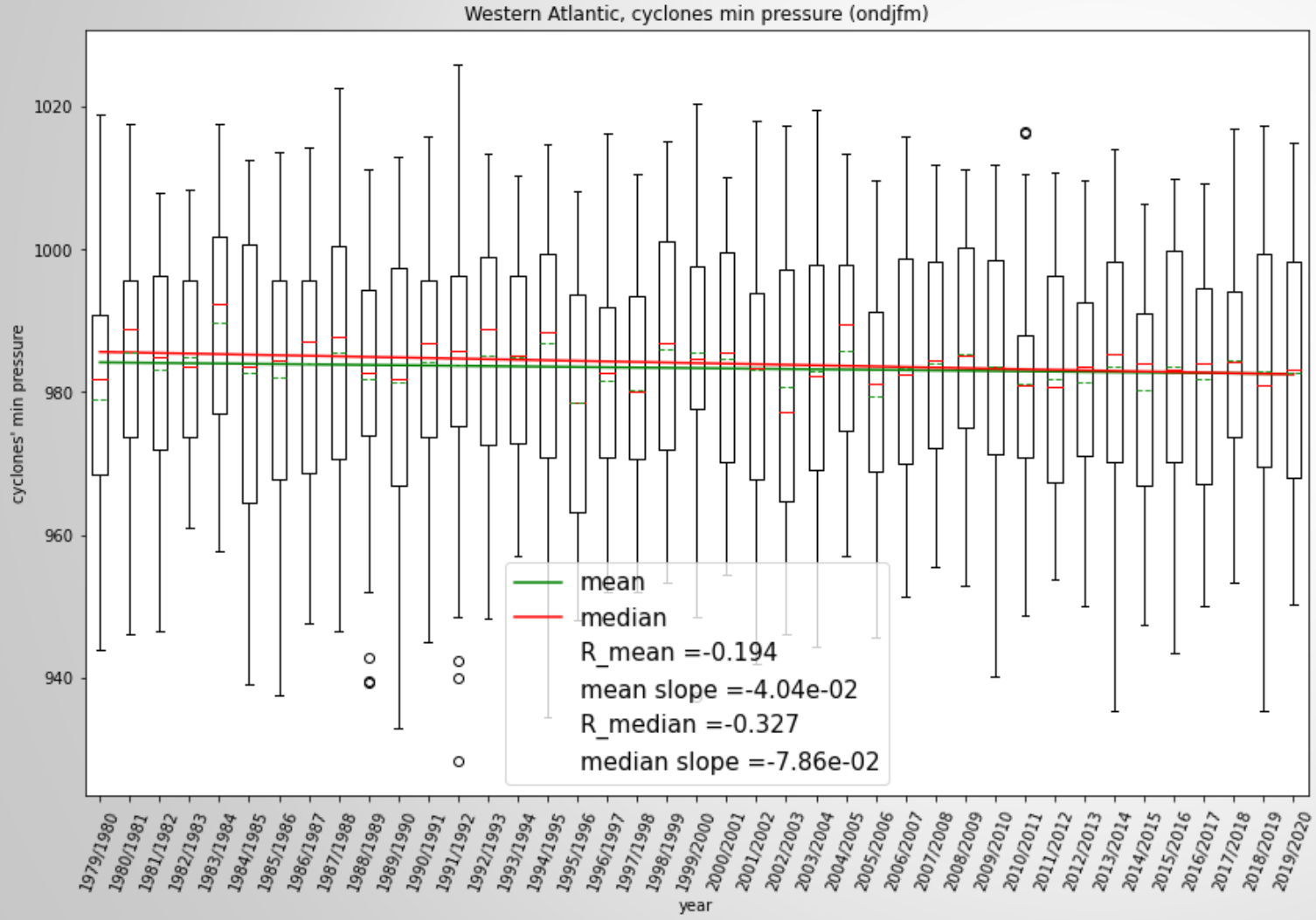
Western Atlantic – Vorticity



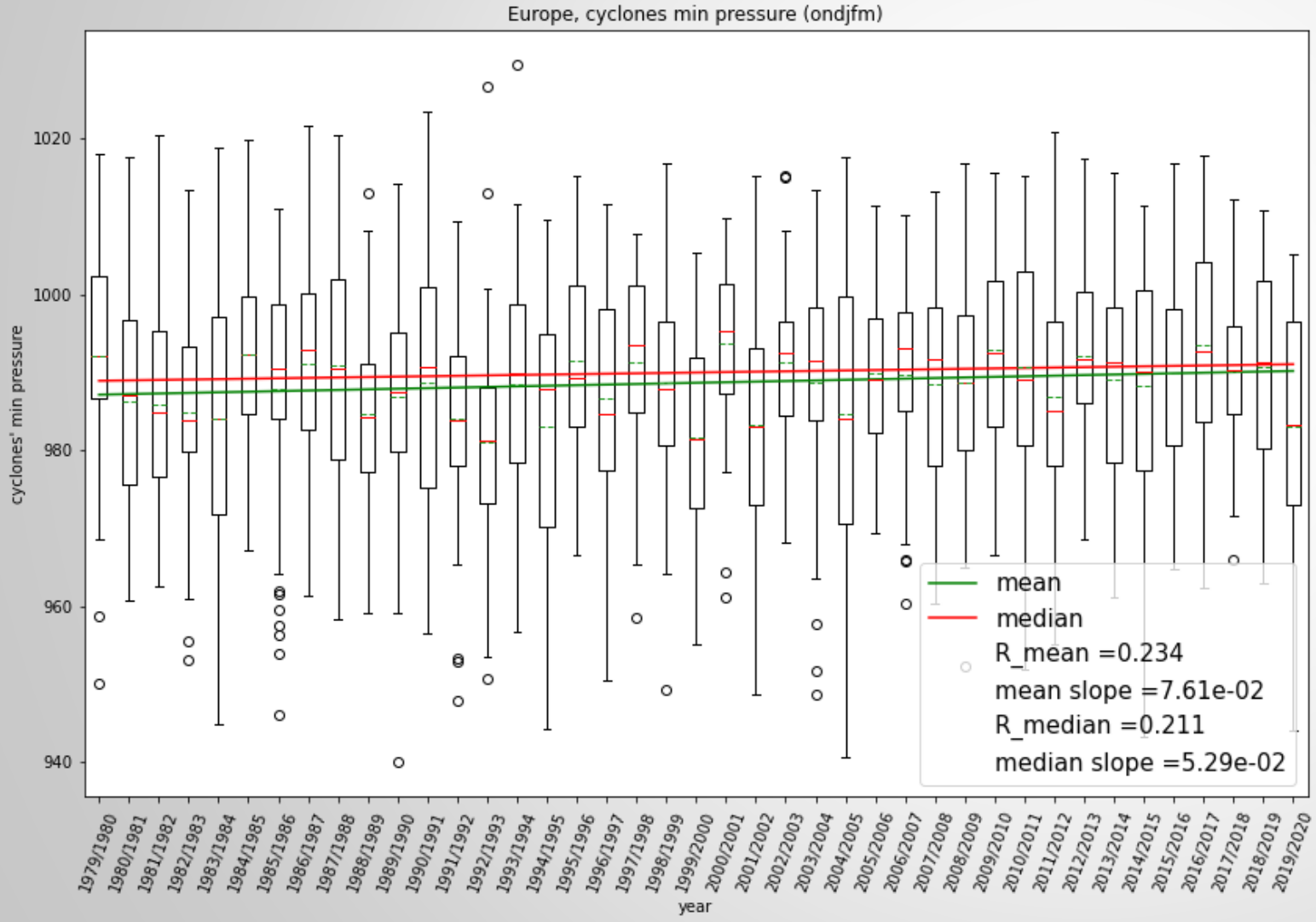
- Mean and median vorticity seems to increase for cyclones in WA
- Decent correlation coefficients

TREND IN INTENSITY: WESTERN ATLANTIC



- Mean and median MSLP seem to decrease for cyclones in WA
- Median has a decent correlation coefficient

TREND IN INTENSITY: EUROPE



- Mean and median MSLP seem to increase for cyclones in EA.
- Some correlation coefficient, but not too convincing

CONCLUSIONS

- The cyclone intensity measures have different values in different geographical region
- Cyclones statistically strongest in EA and weakest in EU
  - This is the case for vorticity, MSLP and wind gusts
- The relationships between the parameters also differ per region
  - But: all regions indicate a better correlation between wind gusts and vorticity when you make the radius smaller, and a higher correlation between wind gusts and MSLP when you make the radius bigger
- Cyclone intensity measures indicate stronger cyclones in WA, weaker cyclones in EU when we compare the 1st and 2nd half of the ERA5 dataset