Lightning activity accompanying tropical cyclones

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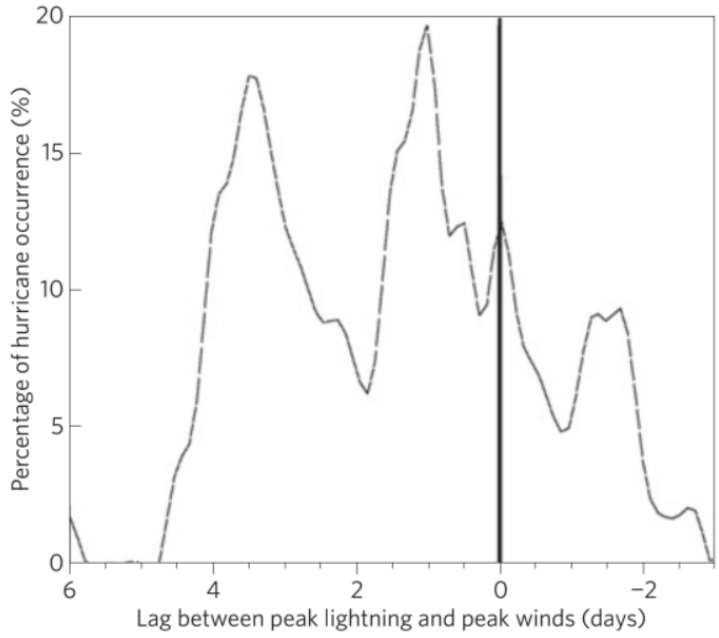
Content

Introduction

- Cyclones are dangerous atmosperical phenomena
- Lightning accompanying cyclones first measured in 1980s
- Good prediction of cyclone trajectory by meteorilogical metod
- Possible usage of lightning activity chynges in intensity prediction

Motivation

- Samsury and Orwille 1994 – hurricanes Hugo and Jerry
- Price et al. 2009 – wind and lightnings correlation



- Ringhausen et al. 2021 – combination of land and satelites data

Tropical cyclones

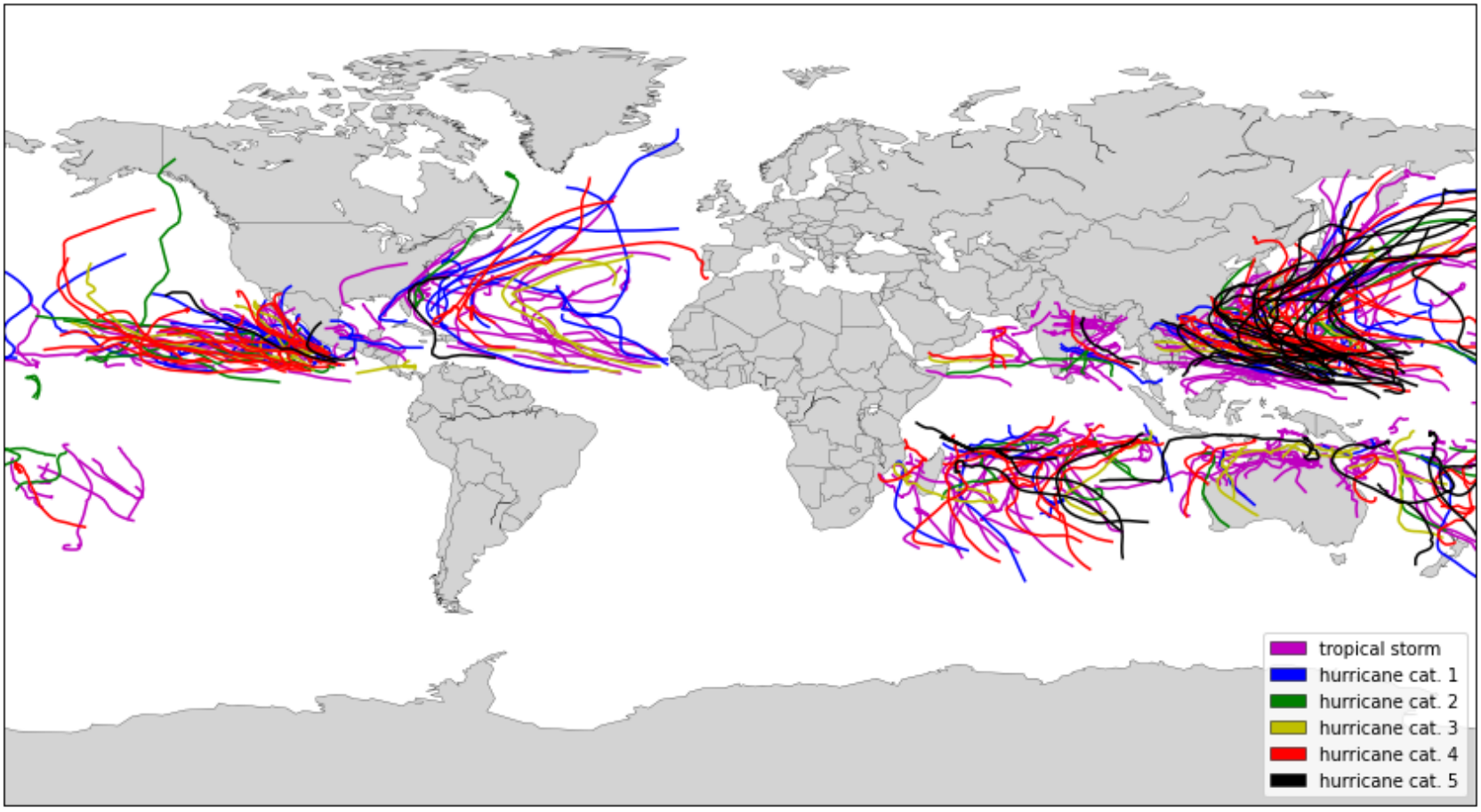
- life cycle
  - tropical disturbance
  - Corriolis force -> rotation
  - tropical depression
  - inceasing rotation
  - dismiss (sometimes associated with landfall)

category	wind speed [km/h]	wind speed [kt]
tropical depression	$\leq$62	$\leq$33
tropical storm	63–118	34–63
hurricane category 1	119–153	64–82
hurricane category 2	155–177	83–95
hurricane category 3	178–208	96–112
hurricane category 4	209–251	113–136
hurricane category 5	$\geq$252	$\geq$137

Table 1: Saffir-Simpson scale

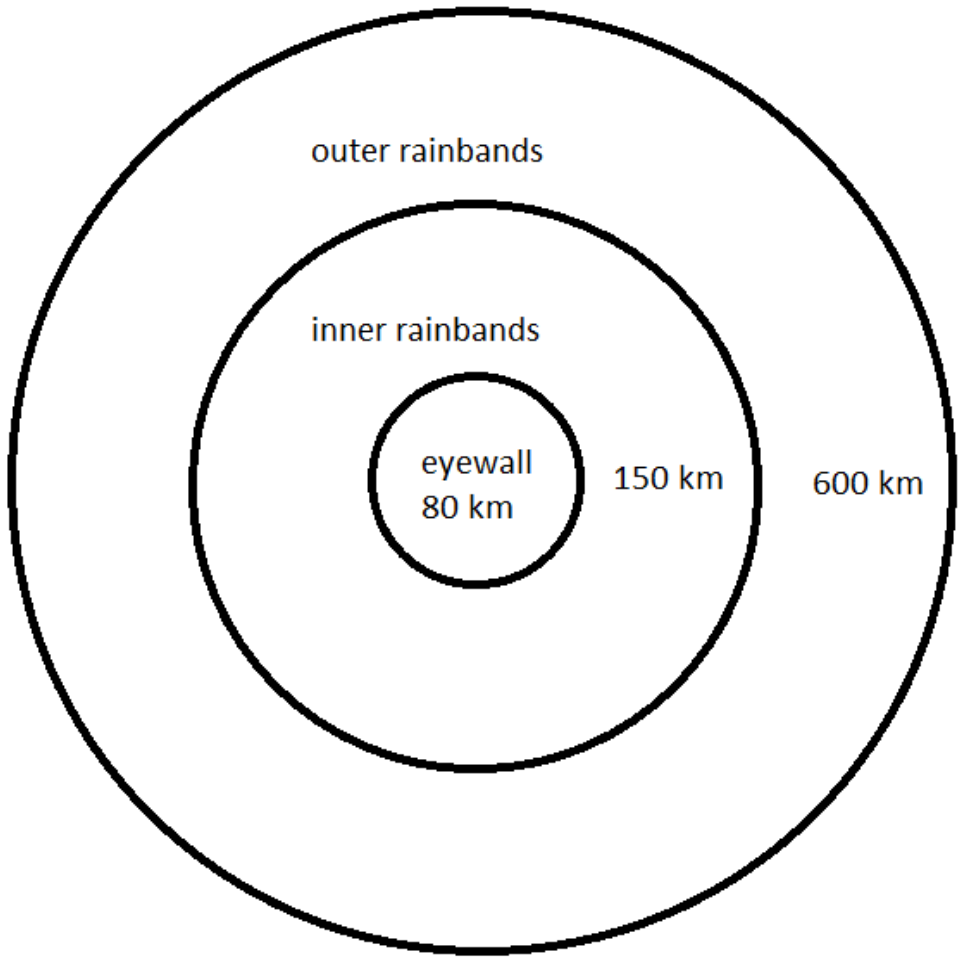
Tropical cyclones

- 429 cyclones
- 2012-2017
- all intensities (Saffir-Simpson scale)
- all basins



Tropical cyclones – structure

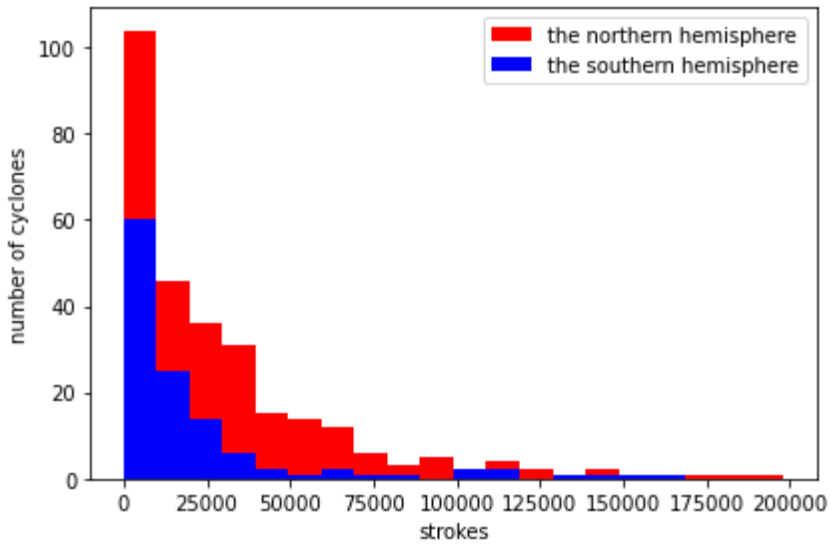
- three main parts
- inner rainbands ussually lower lightning density



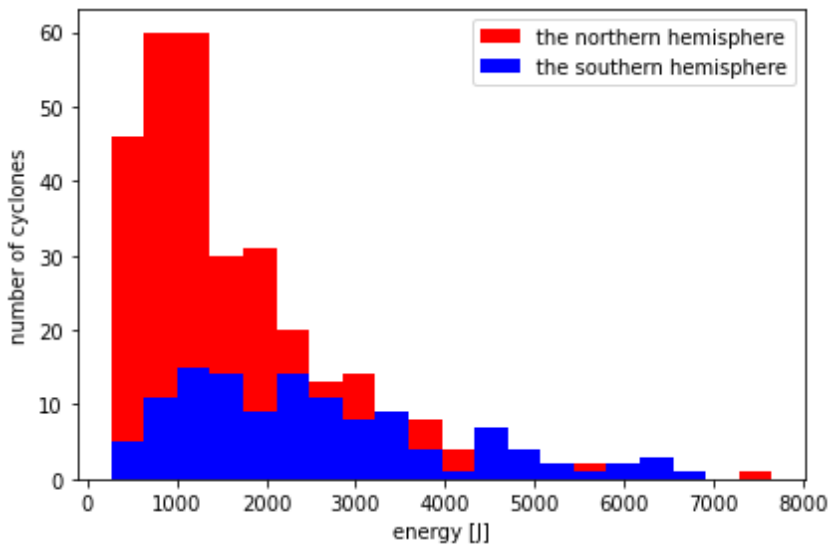
Methodology

- World Wide Location Network (WWLLN) + effectivity corrections
- International Best Track Archive for Climate Stewardship (IBTrACS)
- linear regression of cyclone location in time
- distance $<$10 km and time $<$1 s to join strokes in flash
- energy relevance – estimated error $<$70 % and at least 3 stations
- lognormal distribution of stroke energy -$>$ median
- Spearman correlation coeficient (nonlinear correlation)

Results – hemisphere differences



(a) number of strokes

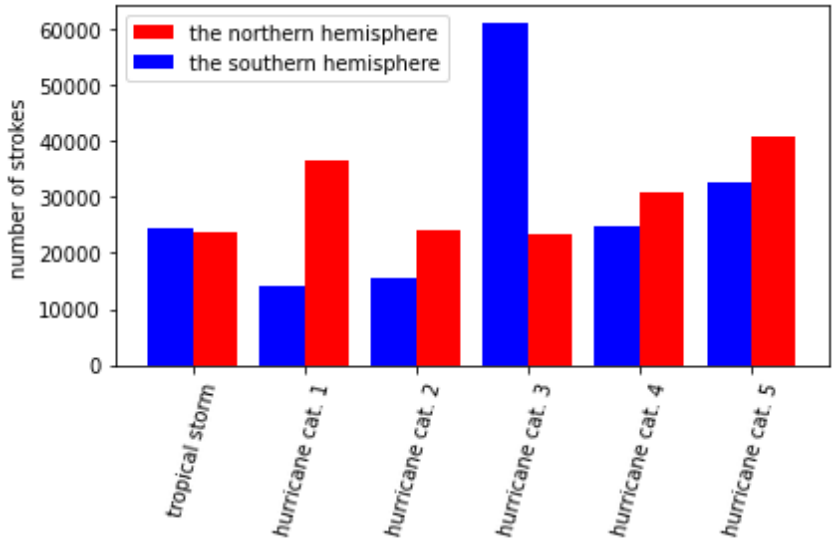


(b) median energy

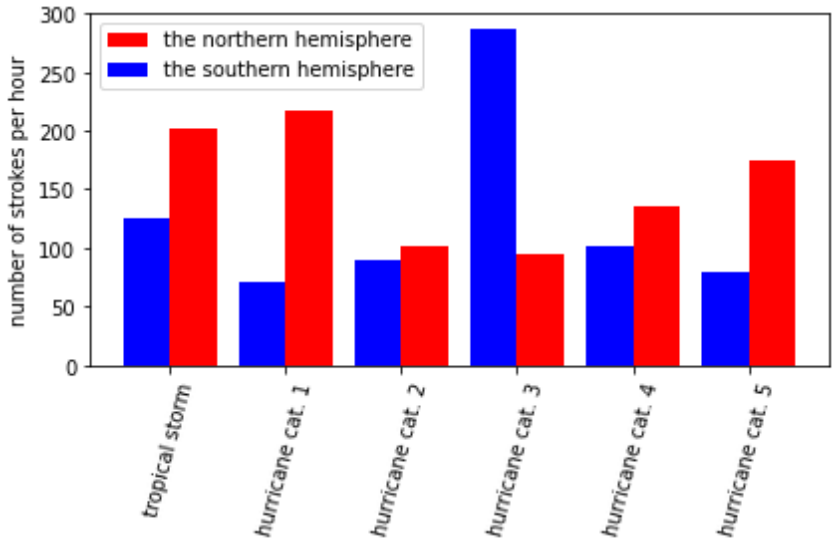
Results – different basins

basin	strokes	strokes/hour	E [kJ]	multiplicity
northern hemisphere				
Indian Ocean	20 434	152	2.19	1.27
Northern Atlantic	50 113	311	1,71	1.49
Northeast Pacific	23 416	150	1.16	1.50
Northwest Pacific	25 118	148	1,10	1.36
southern hemisphere				
Southern Indian	27 811	126	2,83	1.36
Southern Pacific	22 337	105	1.82	1.33

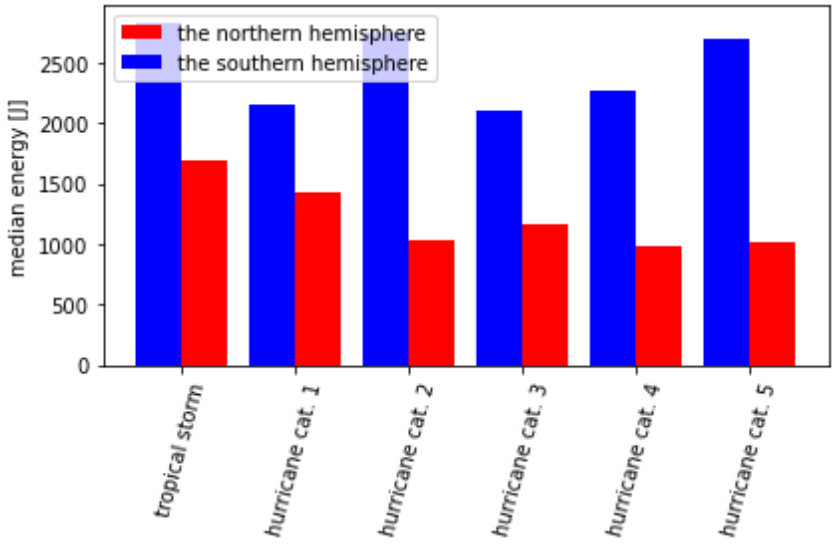
Results – different cyclone intensities



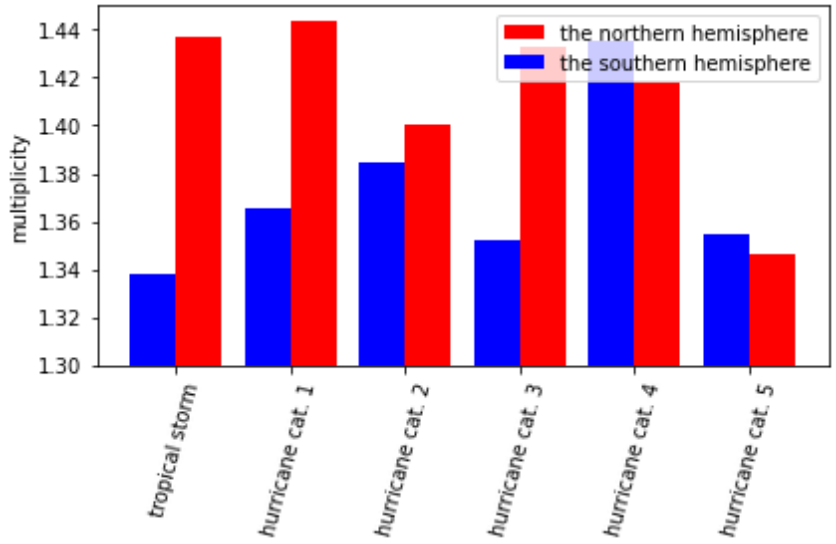
(a) Number of strokes



(b) Strokes per hour

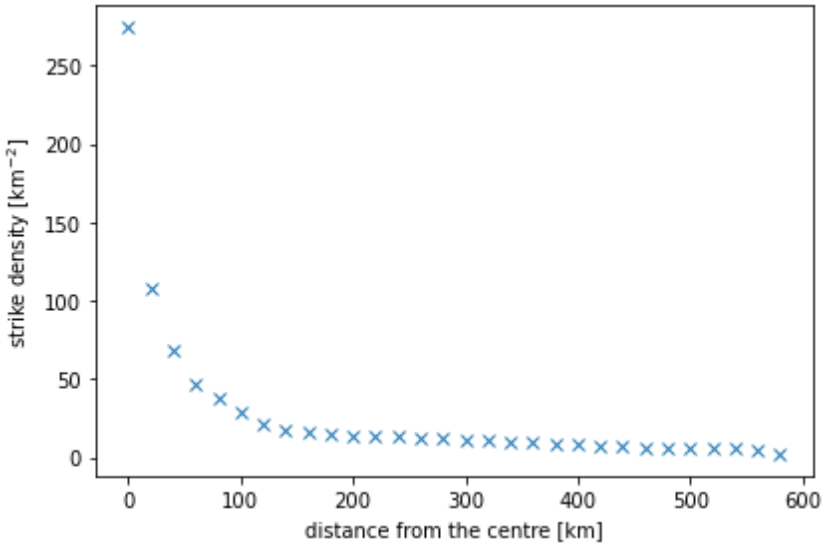


(c) Energy

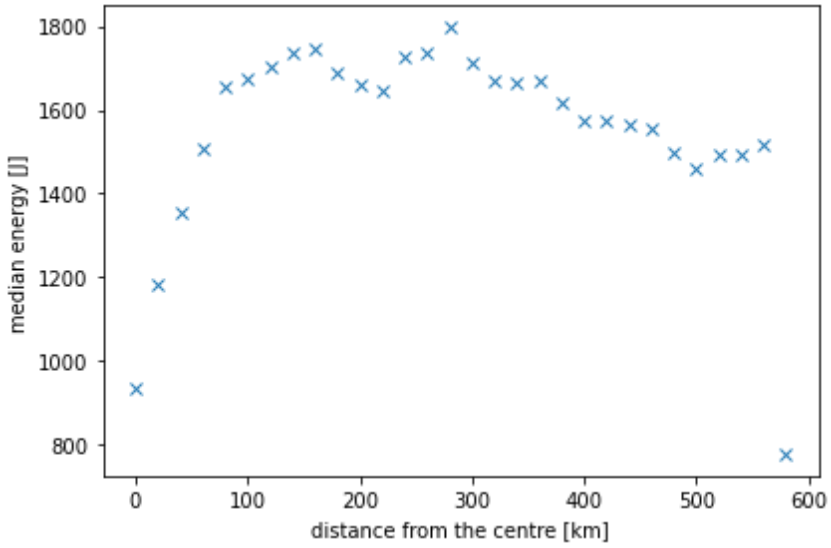


(d) Multiplicity

Results – radial distribution

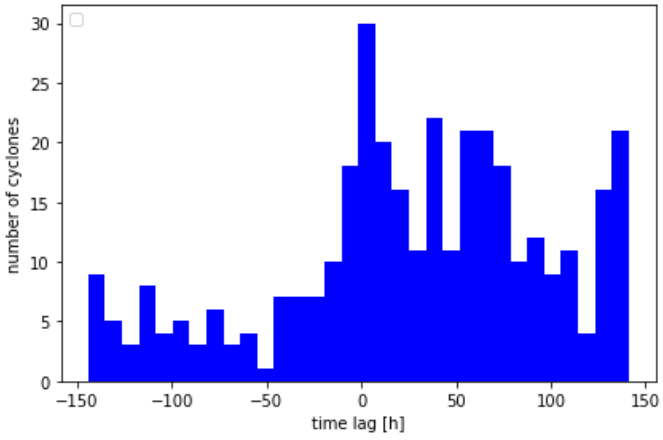


(a) stroke density

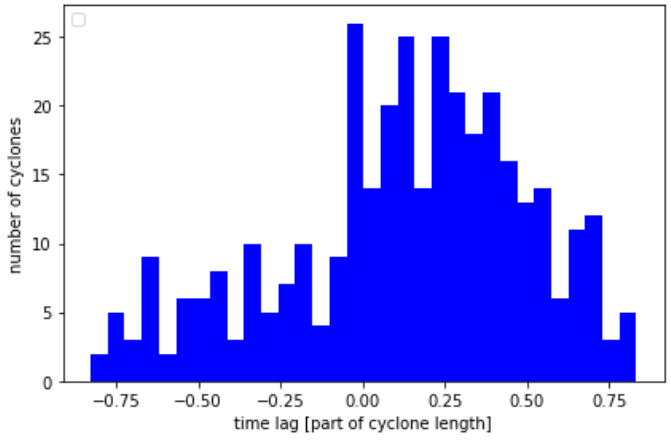


(b) median energy

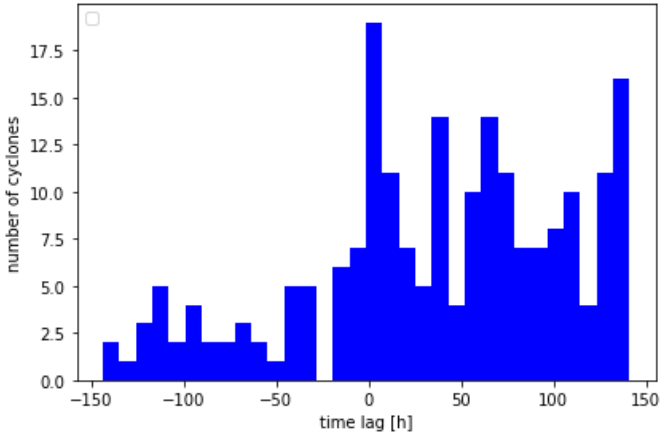
Results – correlation with the wind speed



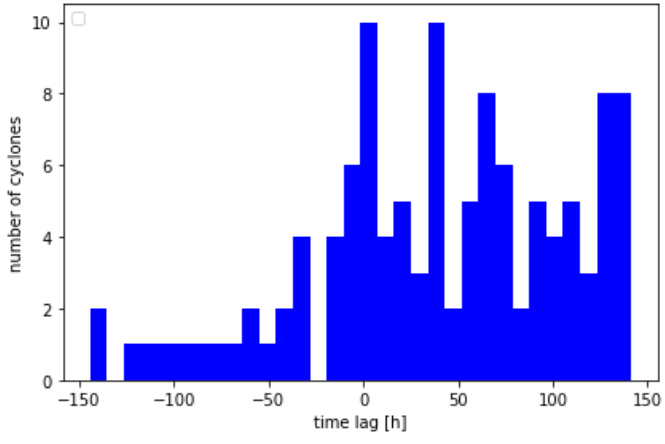
(a) absolute time, mean 26,8 h



(b) relative time, mean 13%



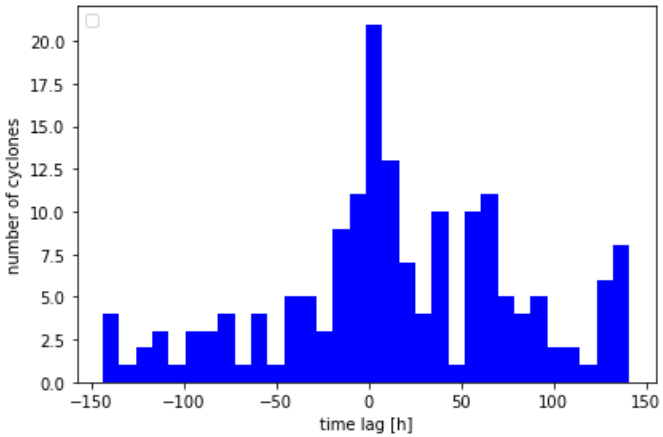
(c) no landfall, mean 36,5 h



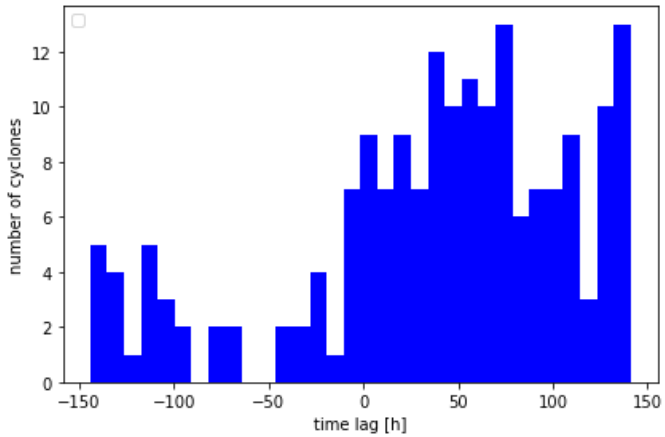
(d) no land stroke, mean 40,1 h

Correlation – intensities

- hurricanes tend to be longer
- long stroms more similar to short storms than hurricanes
- short hurricanes more similar to long hurricanes than storms



(a) tropical storm, mean 15,0 h

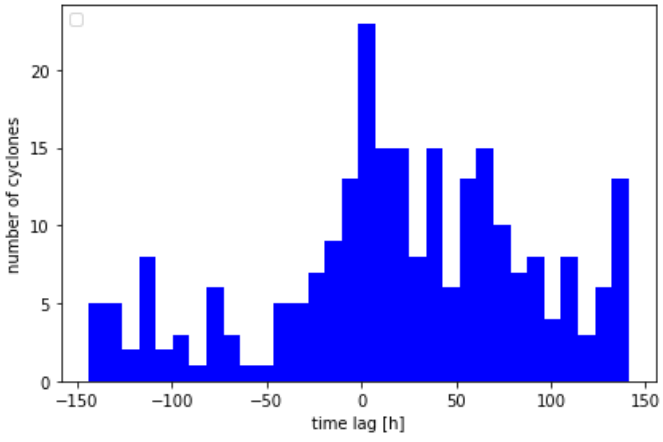


(b) hurricanes, mean 37,8 h

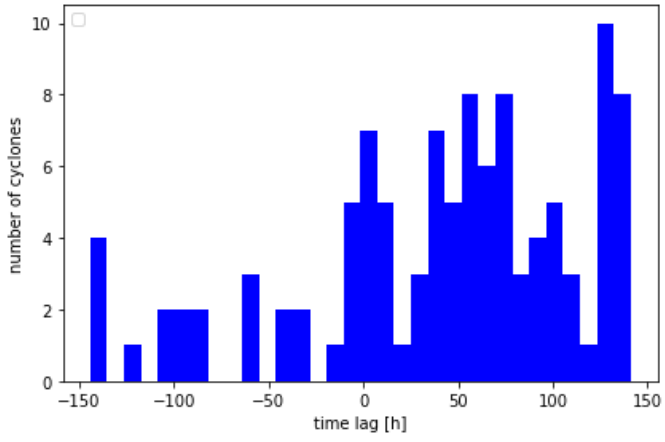
Correlation – different basins

basin	mean [h]	median [h]	# cyclones
Indian Ocean	14.4	6	25
Norhtern Atlantic	-2.1	3	44
Northeast Pacific	49.8	60	75
Norhtwest Pacific	10.2	15	101
Southern Indian Ocean	51.8	66	67
Southern Pacific	23.6	39	41
northern hemisphere	20.5	21	245
southern hemisphere	41.1	54	108

Correlation – hemispheres

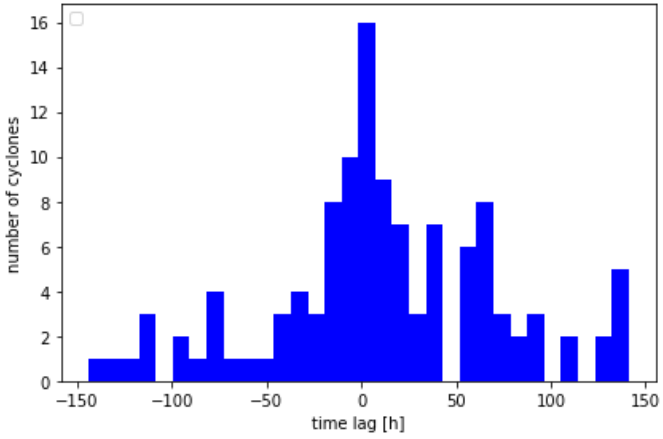


(a) northern hemisphere, mean 20,5 h

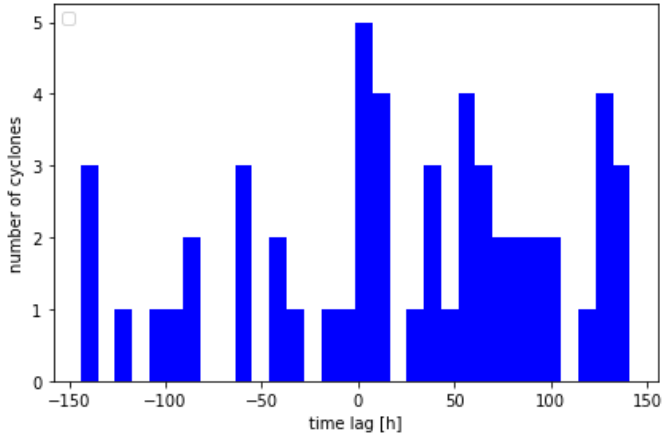


(b) southern hemisphere, mean 41,1 h

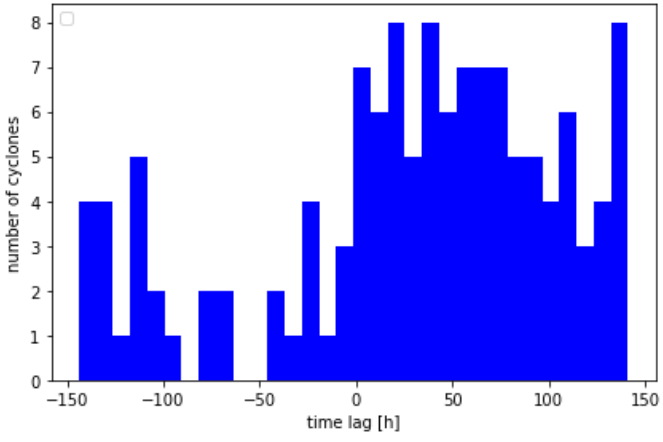
Correlation – hemispheres and intensities



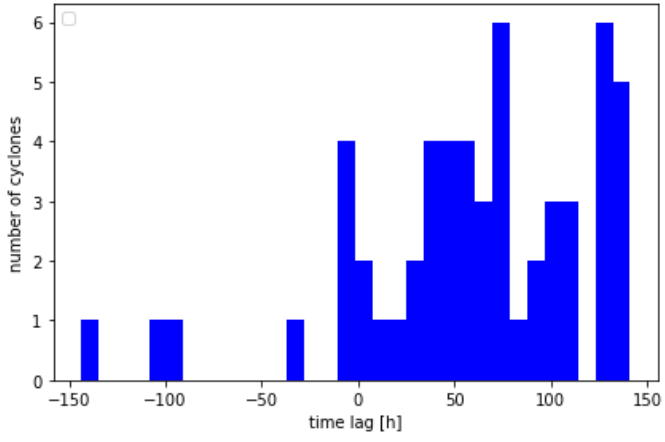
(a) northern hemispehere, tropical storms, mean 11,6 h



(b) southern hemispheres, tropical storms, mean 22,6 h

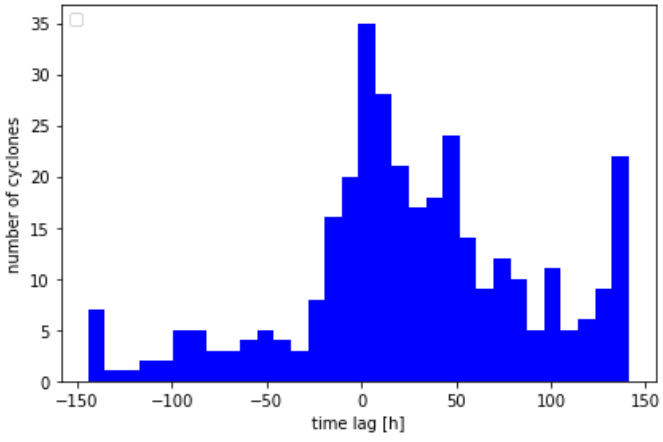


(c) northern hemisphere, hurricanes, mean 28,7 h

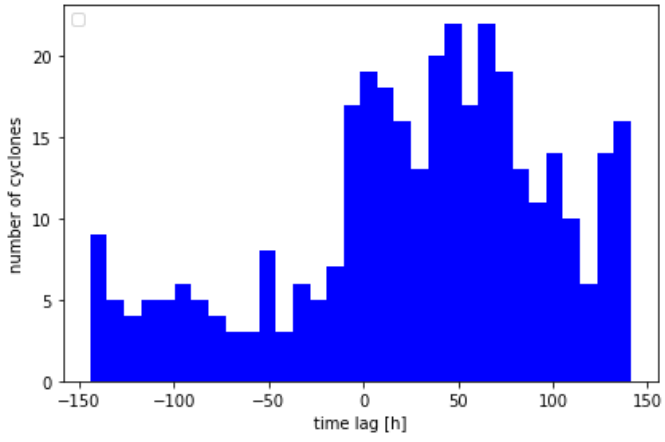


(d) southern hemisphere, hurricanes, mean 59,0 h

Correlation – radial parts



(a) eyewall, mean 27,3 h

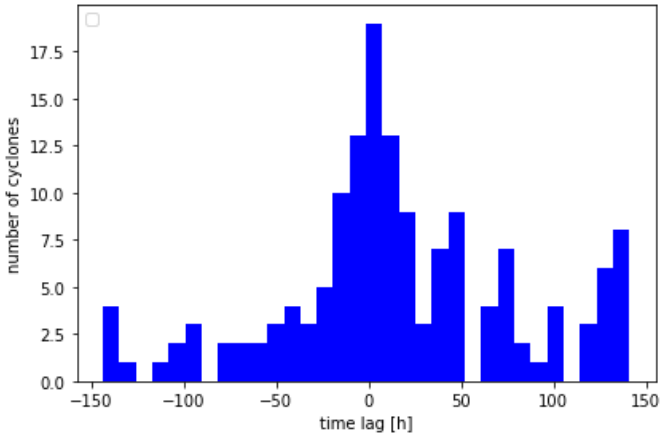


(b) outer rainbands, mean 28,3 h

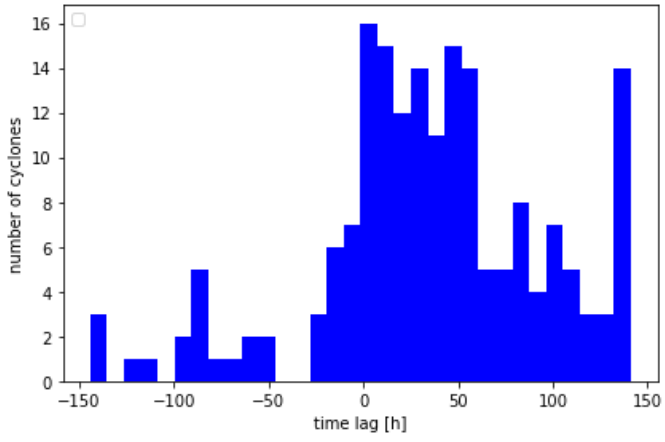
Correlation in eyewall – different basins

basin	mean [h]	median [h]	# cyclones
Indian Ocean	5.2	6	22
Southern Atlantic	11.6	13.5	42
Southeast Pacific	23.4	21	71
Southwest Pacific	28.5	22.5	98
Southern Indian Ocean	39,0	42	64
South Pacific	41.7	48	38
northern hemisphere	21.7	18	233
southern hemisphere	40.0	43.5	102

Correlation in the eyewall – intensities

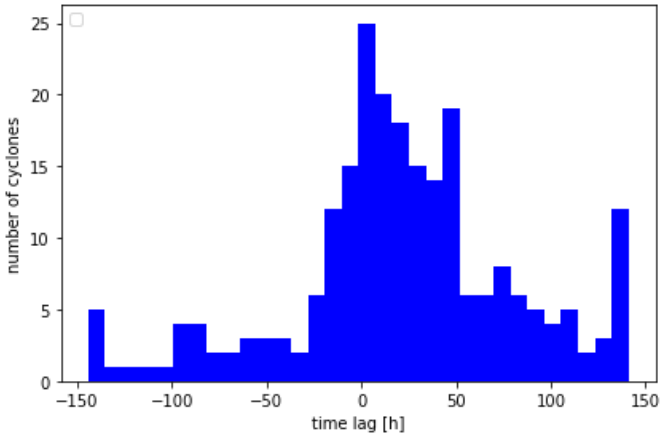


(a) tropical storm, mean 16,4 h

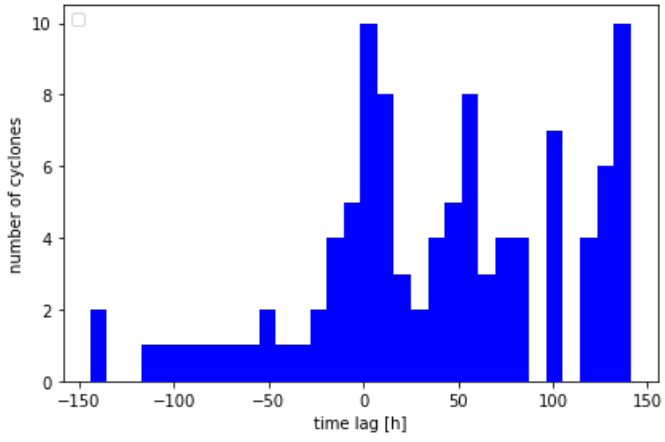


(b) hurricanes, mean 36,1 h

Correlation in the eyewall – hemispheres

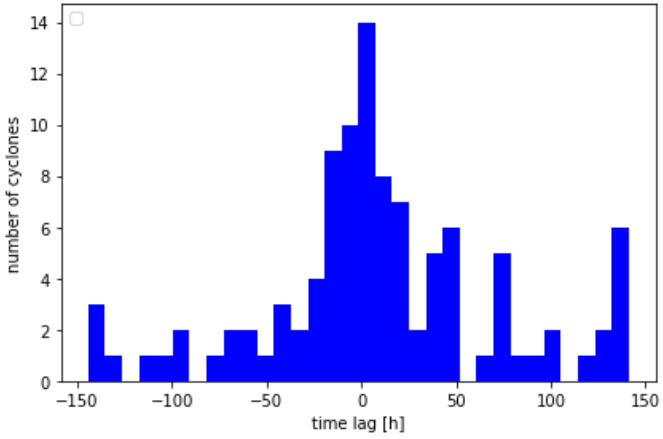


(a) northern hemisphere, mean 21,7 h

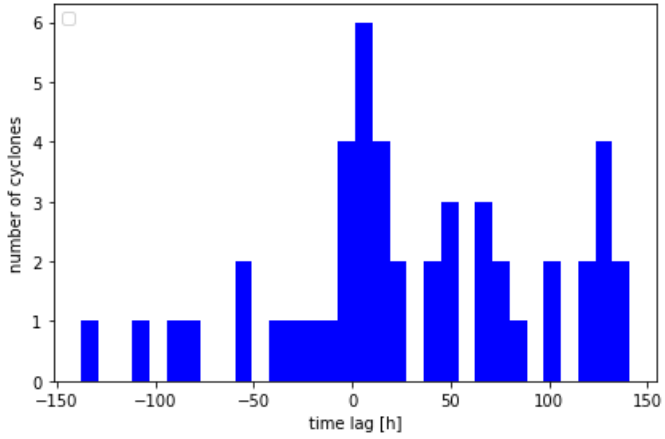


(b) southern hemisphere, mean 40,0 h

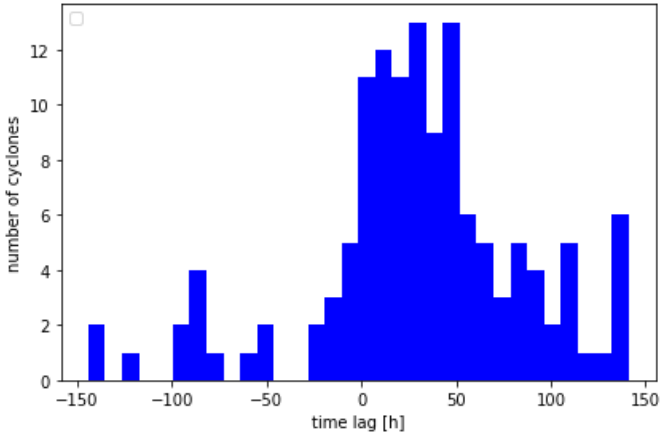
Correlation in the eyewall – hemispheres and intensities



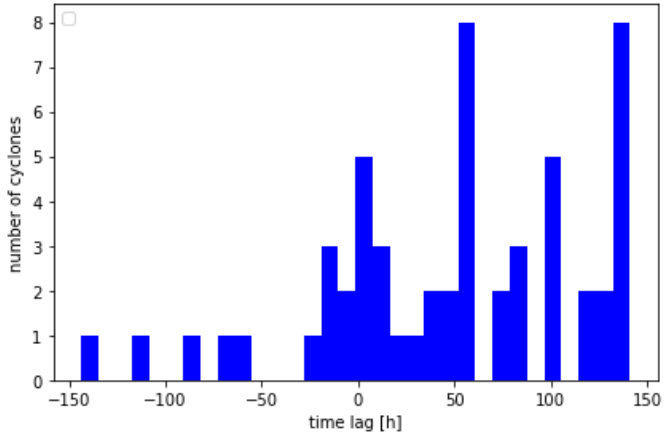
(a) northern hemispehere, tropical storms, mean 10,5 h



(b) southern hemispheres, tropical storms, mean 29,3 h



(c) northern hemisphere, hurricanes, mean 30,0 h

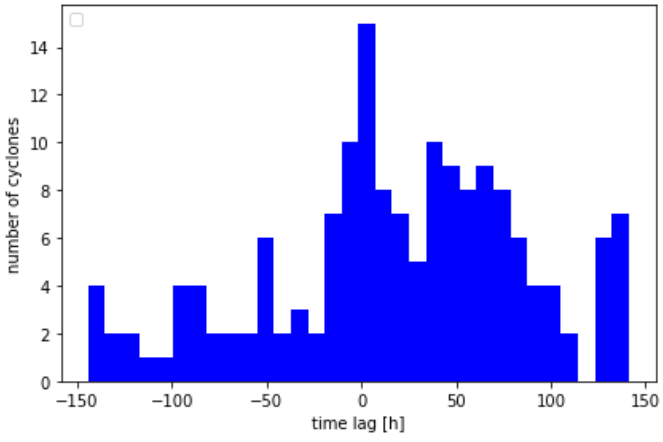


(d) southern hemisphere, hurricanes, mean 49,1 h

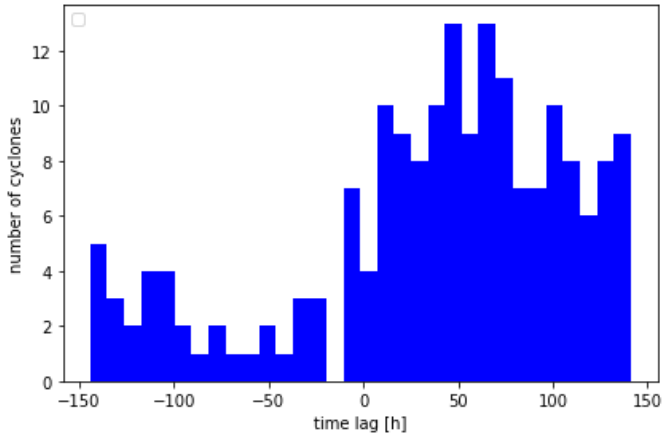
Correlation in the outer rainbands – different basins

basin	mean [h]	median [h]	# cyclones
Indian Ocean	-1.4	3	26
Northern Atlantic	2.7	9	41
Northeast Pacific	50.8	63	74
Northwest Pacific	16.4	21	98
Southern Indian Ocean	51.0	57	67
Southern Pacific	23.9	42	39
northern hemisphere	22.7	33	239
southern hemisphere	41.0	49.5	106

Correlation in the outer rainbands – intensities

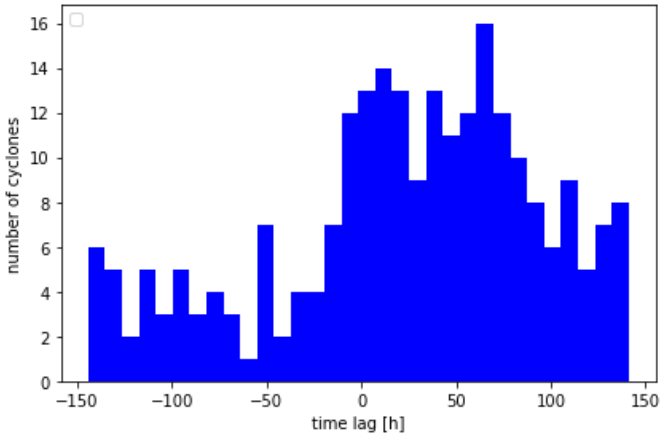


(a) tropical storm, mean 18,7 h

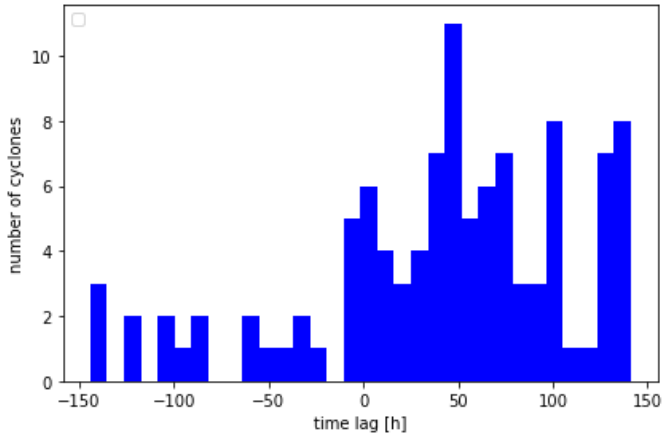


(b) hurricanes, mean 36,9 h

Correlation in the outer rainbands – hemispheres

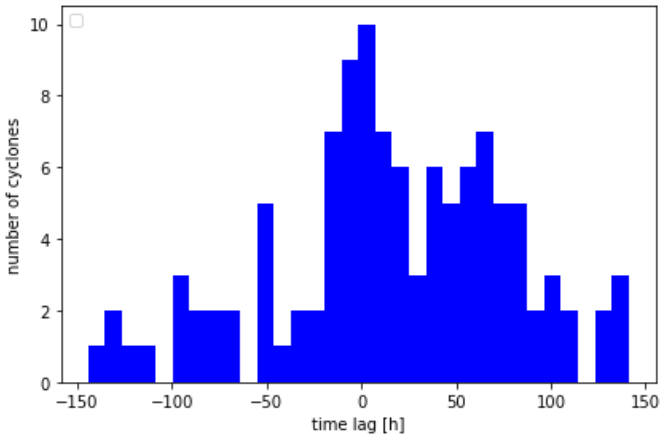


(a) northern hemisphere, mean 22,7 h

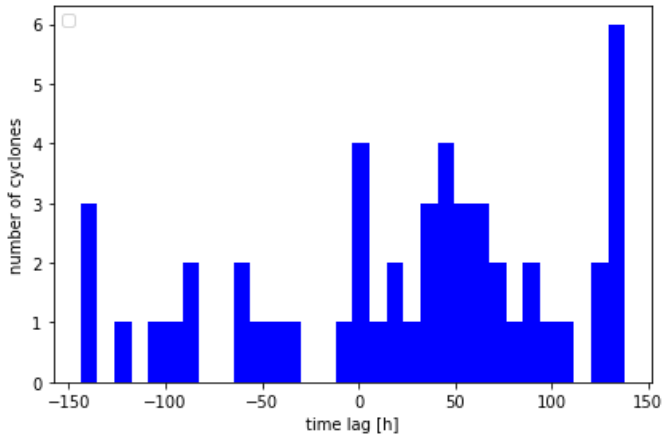


(b) southern hemisphere, mean 41,0 h

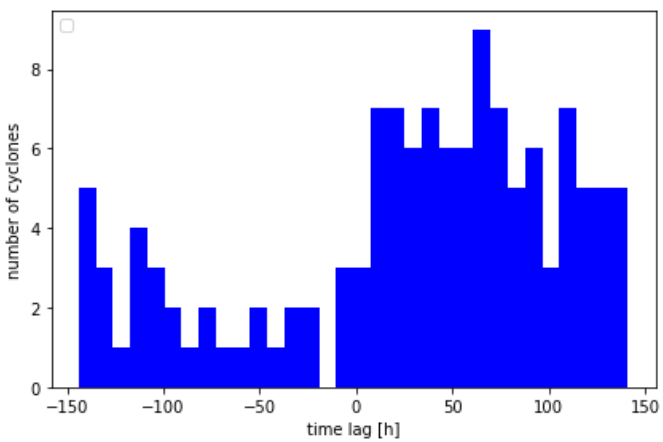
Correlation in the outer rainbands – hemispheres and intensities



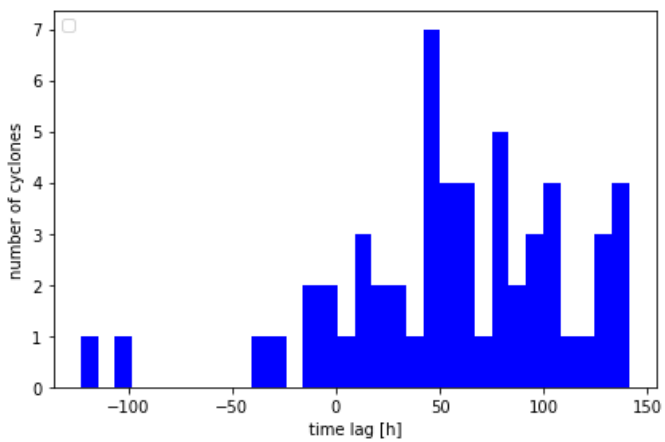
(a) northern hemispehere, tropical storms, mean 16,4 h



(b) southern hemispheres, tropical storms, mean 24,1 h



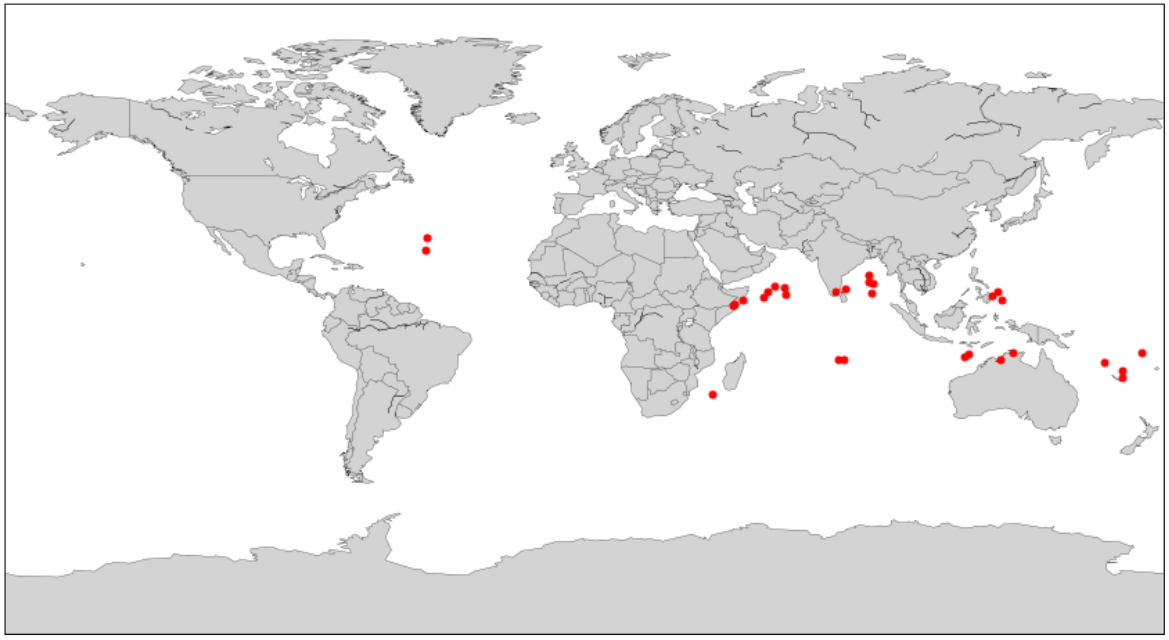
(c) northern hemisphere, hurricanes, mean 28,4 h



(d) southern hemisphere, hurricanes, mean 56,1 h

Results – superbolts

- 29 superbolts (energy over 1 MJ)
- - eyewall – 1 lightning
  - inner rainbands – 7 lightnings
  - outer rainbands – 21 lightnings
- - tropical storms – 25 lightnings
  - hurricane cat. 2 – 1 lightning
  - hurricane cat. 3 – 1 lightning
  - hurricane cat. 4 – 2 lightnings
  - hurricane cat. 5 – 1 lightning



Summary

- Large dataset
- Hemisphere differences found
- Decreasing stroke density with increasing distance from the center
- Confirmation of lightning activity preceding changes in cyclone intensity
- Differences in lag time among intensities and hemispheres
- Low number of superbolts

Literature

- Samsury, C. E.; Orwille, R. E.;Cloud-to-Ground Lightning in Tropical Cyclones: A Study of Hurricanes Hugo (1989) and Jerry (1989). *Monthly Weather Review*, 122(8):1887-1896, 1994
- Price, C.; Asfur, M.; Yairr Y.; Maximum hurricane intensity preceded byincrease in lightning frequency. *Nature Geoscience*, 2(5):329–332, 2009.
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- Ringhausen, J. S.; Bitzer, P. M. An In-Depth Analysis of Lightning Trends in Hurricane Harvey Using Satellite and Ground-Based Measurements. *Journal of Geophysical Research: Atmospheres*, 126(7), 2021.