DO VOLCANIC ERUPTIONS EFFECT HURRICANE STATISTICS?

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Why do we care?

- Eruptions emit aerosols - can answer geoengineering questions
- Mitigation of hurricane impacts requires understanding factors involved
- Can provide insight into effects of warming (the negative of aerosol forcing)

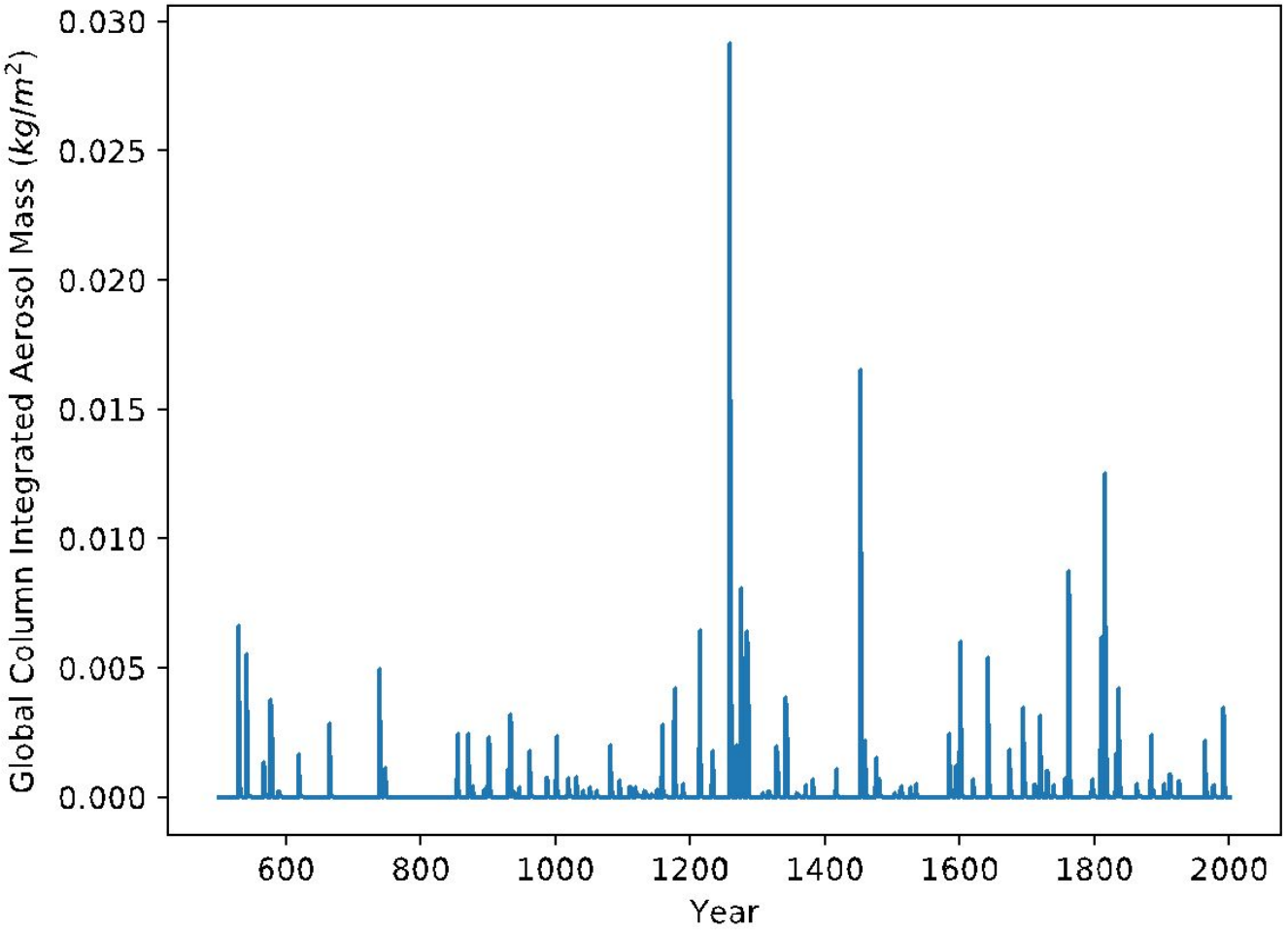
Methodology

- Data from CESM downscaled in WRF (control and forced 100 years of each)
- Parallelized downscaling for 10 years at a time
- WRF output used for cyclone tracking in TSTORMS
- ERAI also downscaled and compared to IBTRACS
- TSTORMS output for all runs gives probability distributions for different characteristics (wind speed, pressure, etc)
- Control and forced distributions compared using statistical diagnostics

CESM

- CESM data from LME runs used as boundary data input for WRF
- LME runs were from 850-2005
- Control runs absent eruptions
- Forced runs included eruptions reconstructed from ice core samples
- We used forced data from 2 years around 50 eruptions
- Control data from 1000-1100

CESM: Eruptions



WRF

- WRF used to dynamically downscale CESM data
- 1500-2000 core hours per year of simulation (roughly one million core hours total, including pre and post processing and debugging)
- WRF physics schemes were selected to balance cyclone studies and future drought studies in NA
- Also based on matching downscaled ERAI with IBTRACS

ERAI and IBTRACS

- To evaluate the accuracy of our approach we also used ERAI and IBTRACS data
- ERAI is reanalysis used in WRF downscaling
- IBTRACS is observational cyclone track data
- 1995-2005 used as comparison period
- Recent time period selected due to changes in observation technology

TSTORMS

- GFDL cyclone tracking software used to find storms in downscaled output and track them
- Finds cyclones based on vorticity, pressure, and warm-core threshold values
- Stored as storm if criteria are met for threshold amount of time
- 40 different sets of threshold values were explored for best match between ERAI and IBTRACS

Potential Intensity

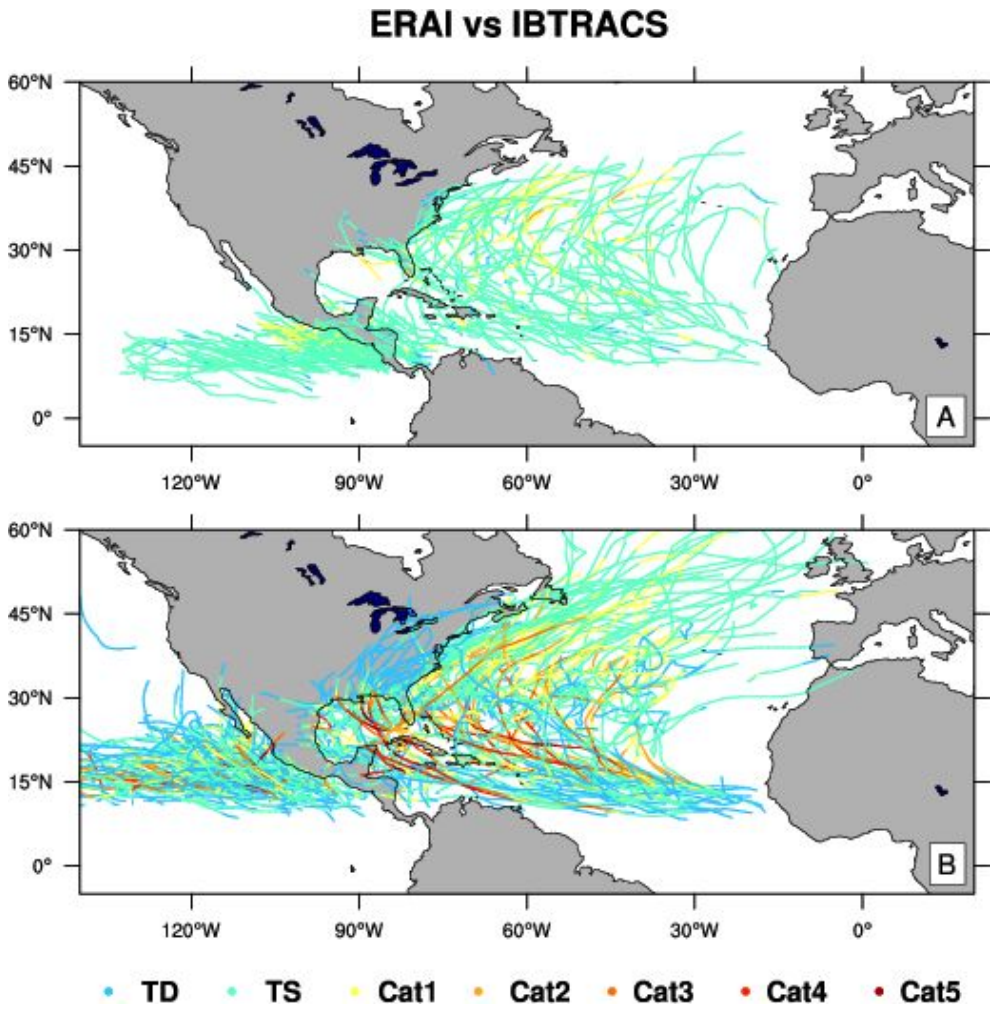
- In addition to downscaling we looked at the potential intensity of CESM data – what we might expect from WRF
- Theoretical maximum intensity based on thermodynamic environment

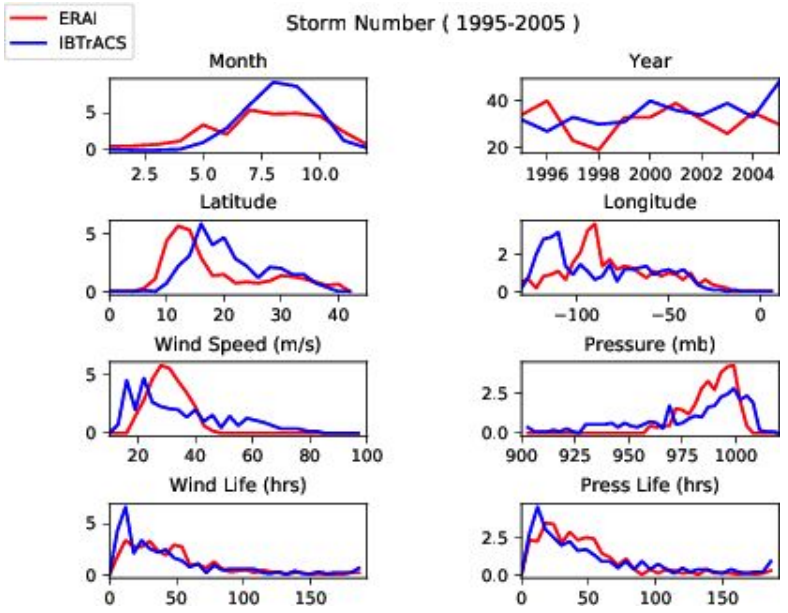
$$V_m \propto \sqrt{\frac{T_s - T_o}{T_o}(k^* - k)}$$

Diagnostics

- Calculated distributions of – wind speed, pressure, lifetimes, location, and frequency
- KS-tests performed on forced vs control for each type of distribution
- Also compared distribution means and percentiles
- Significance tests done on distribution means
- Correlation coefficients computed for eruption strength vs each metric

Results: ERAI vs IBTRACS





Average mean deviation: 0.096
Average percentile deviation: 0.18
Composite deviation: 0.135

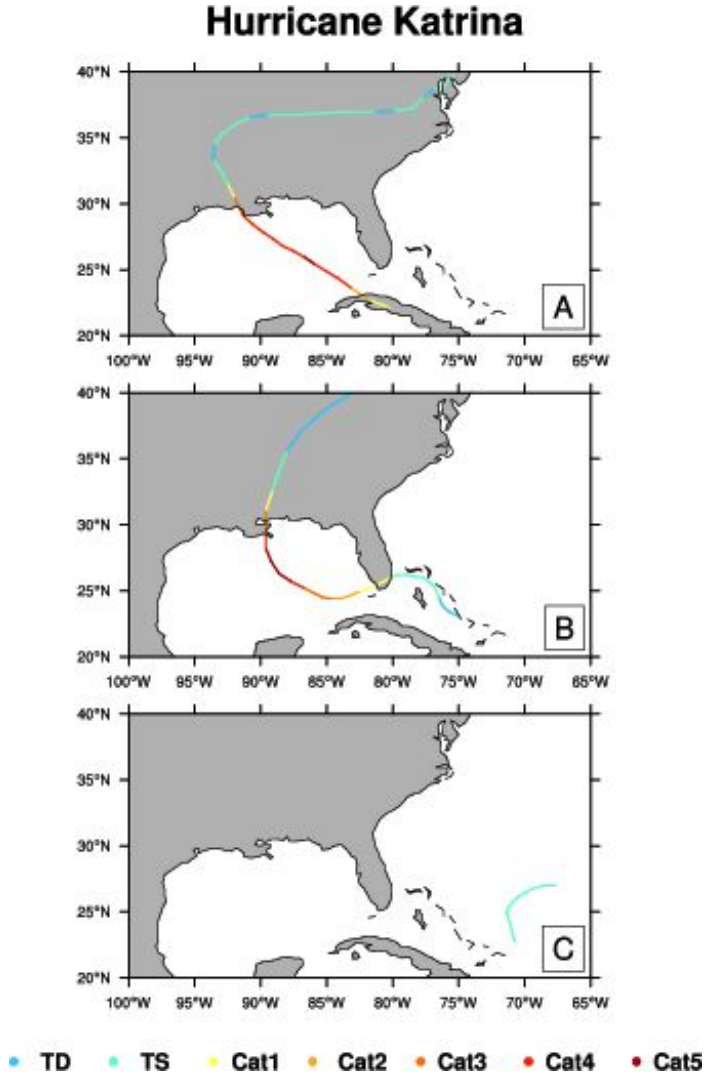
Results: ERAI vs IBTRACS

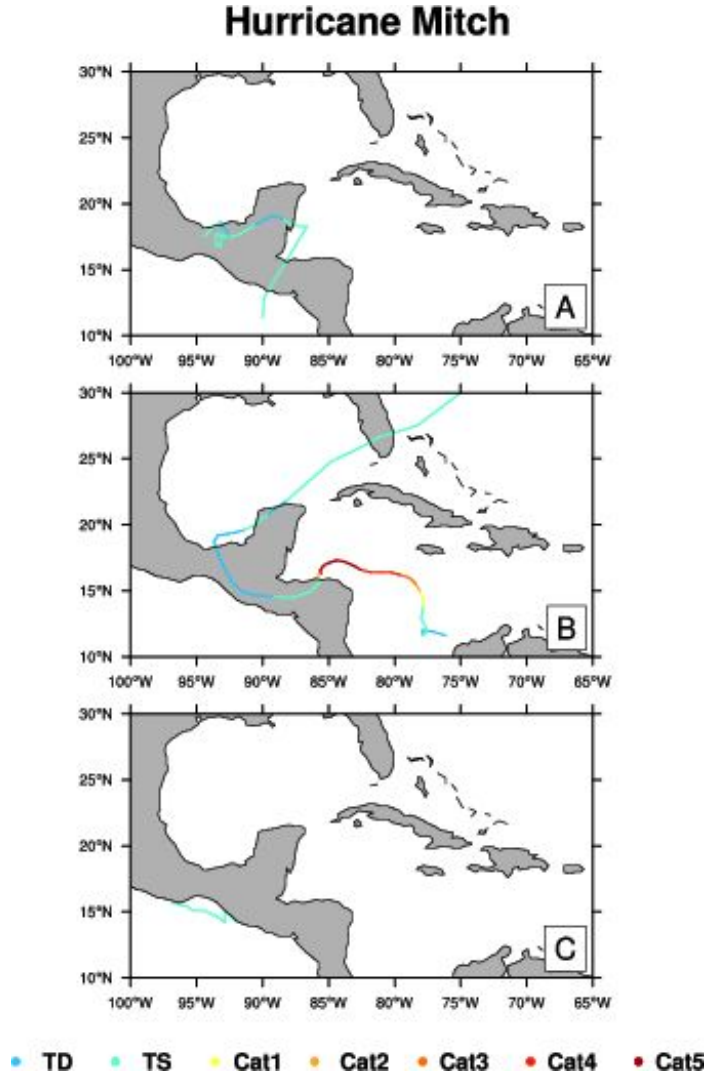
Averages	ERAI	IBTRACS
Month	7.65	8.24
Yearly Number	31.27	34.82
Latitude	18.23	21.39
Longitude	-80.72	-88.38
Max Wind (m/s)	30.26	34.87
Min Pressure (hPa)	988.56	979.65
Max to Avg Wind Time (hrs)	45.37	44.69
Min to Avg Pressure Time (hrs)	44.02	52.53

Results: ERAI vs IBTRACS

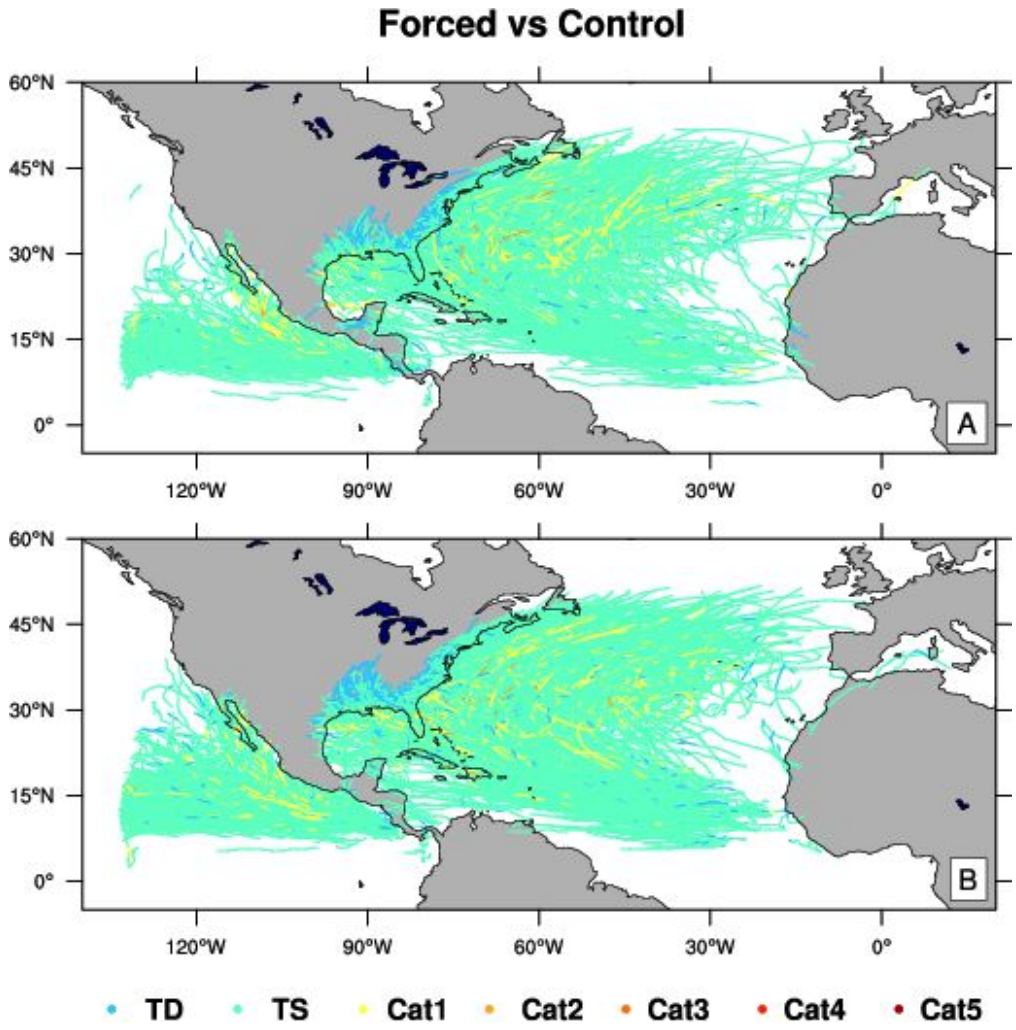
Percentiles	ERAI	IBTRACS
May-Nov	0.88	0.99
0-25N	0.78	0.73
100-50W	0.65	0.44
0-40 m/s	0.97	0.70
1020-980 hPa	0.81	0.62
0-100 hrs (wind)	0.94	0.91
0-100 hrs (pressure)	0.94	0.87

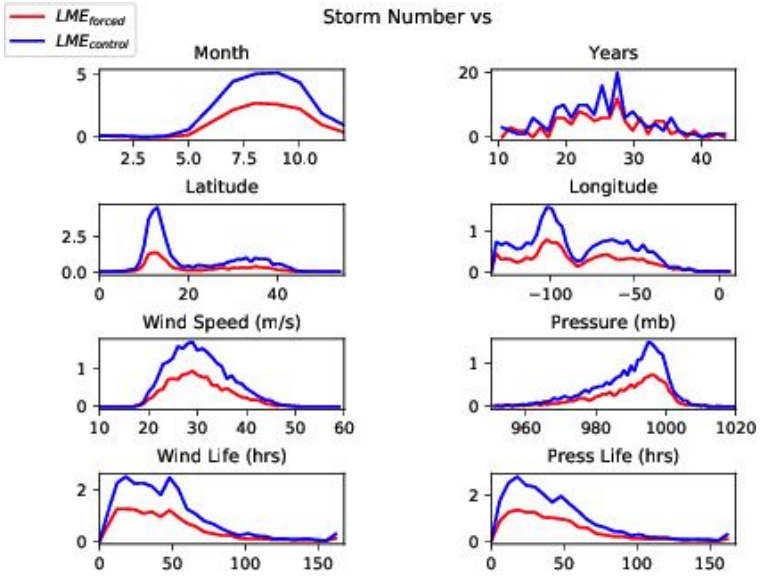
Results: Katrina and Mitch





Results: Control vs Forced (All Years)





Correlation coefficients show reduction in yearly number, intensity, and lifetime for forced data

Net effect consistent with control (null hypothesis)

Results: Control vs Forced (All Years)

Correlations between control and forced mean differences and eruption strength

Correlation Tests	Values
Peak Month	-0.11
Yearly Number	-0.23
Avg Latitude	0.02
Avg Longitude	0.22
Max Wind Speed	-0.32
Min Pressure	0.29
Max to Avg Wind Time	-0.09
Min to Avg Pressure Time	-0.28

Results: Control vs Forced (All Years)

KS-Tests	D-Value	P-Value
Month	0.0	1.0
Yearly Number	0.006	1.0
Latitude	0.004	1.0
Longitude	0.0	1.0
Max Wind	0.006	1.0
Min Pressure	0.006	1.0
Lifetime (wind)	0.002	1.0
Lifetime (pressure)	0.0	1.0

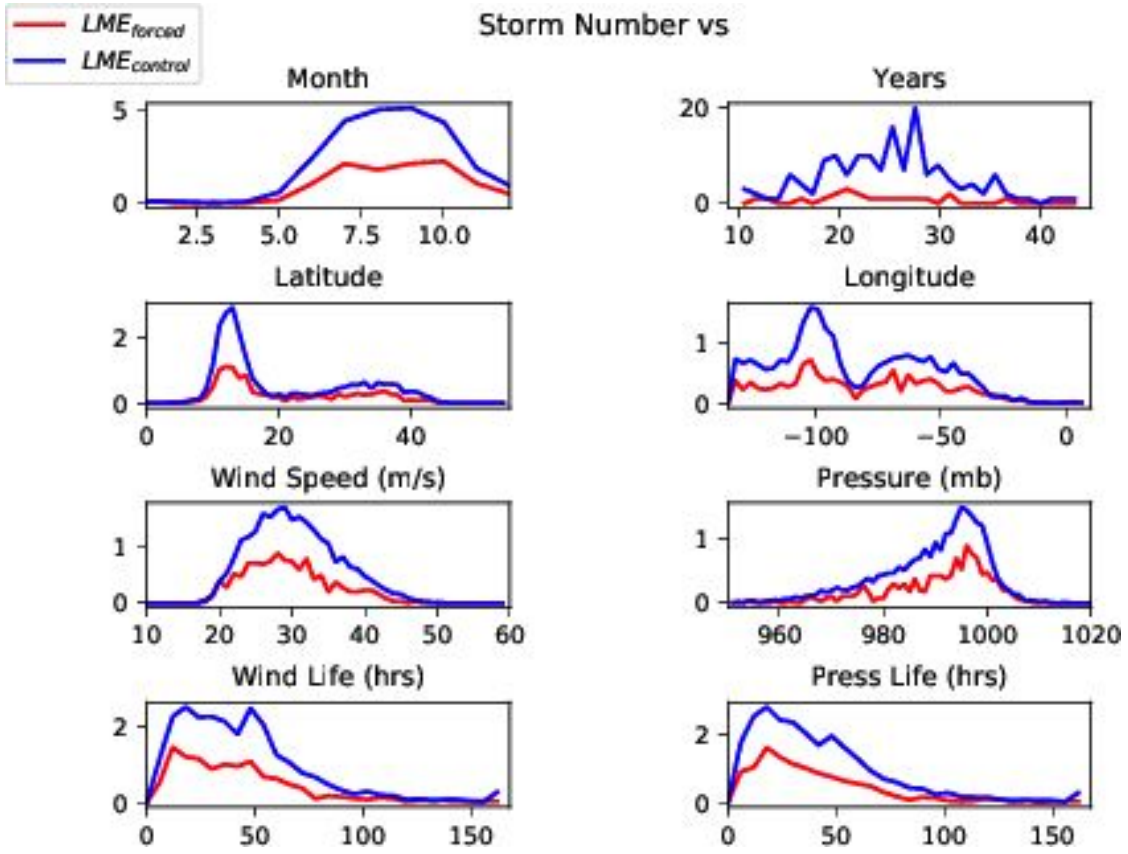
KS-tests strongly consistent with null hypothesis

Results: Control vs Forced (All Years)

Sig-Tests	% Greater	% Less
Month	0.513	0.474
Yearly Number	0.435	0.565
Latitude	0.494	0.506
Longitude	0.455	0.545
Max Wind	0.519	0.474
Min Pressure	0.513	0.487
Lifetime (wind)	0.565	0.435
Lifetime (pressure)	0.506	0.494

Significance tests also strongly consistent with the null-hypothesis

Results: Control vs Forced (Strongest)



Null hypothesis can only be rejected at the 70-80% confidence limit

1213 and 1815 eruptions have ~0.13 average mean deviation from control

1213 and 1815 eruptions have effects in the 80-98% significance range

Results: Control vs Forced (Strongest)

KS-Tests	D-Value	P-Value
Month	0.004	1.0
Yearly Number	0.018	1.0
Latitude	0.036	0.9
Longitude	0.038	0.86
Max Wind	0.024	1.0
Min Pressure	0.048	0.6
Lifetime (wind)	0.014	1.0
Lifetime (pressure)	0.012	1.0

KS-tests suggest consistence with the null-hypothesis

Results: Control vs Forced (Strongest)

Sig-Tests	% Greater	% Less
Month	0.461	0.513
Yearly Number	0.584	0.351
Latitude	0.487	0.513
Longitude	0.318	0.682
Max Wind	0.773	0.227
Min Pressure	0.286	0.714
Lifetime (wind)	0.675	0.325
Lifetime (pressure)	0.708	0.292

Lifetimes and intensities in the 70-80% significance range

Results: 1213 Eruption

Sig-Tests	% Greater	% Less
Month	0.63	0.357
Yearly Number	0.812	0.169
Latitude	0.747	0.253
Longitude	0.708	0.292
Max Wind	1.0	0.0
Min Pressure	0.0	1.0
Lifetime (wind)	0.896	0.104
Lifetime (pressure)	0.981	0.019

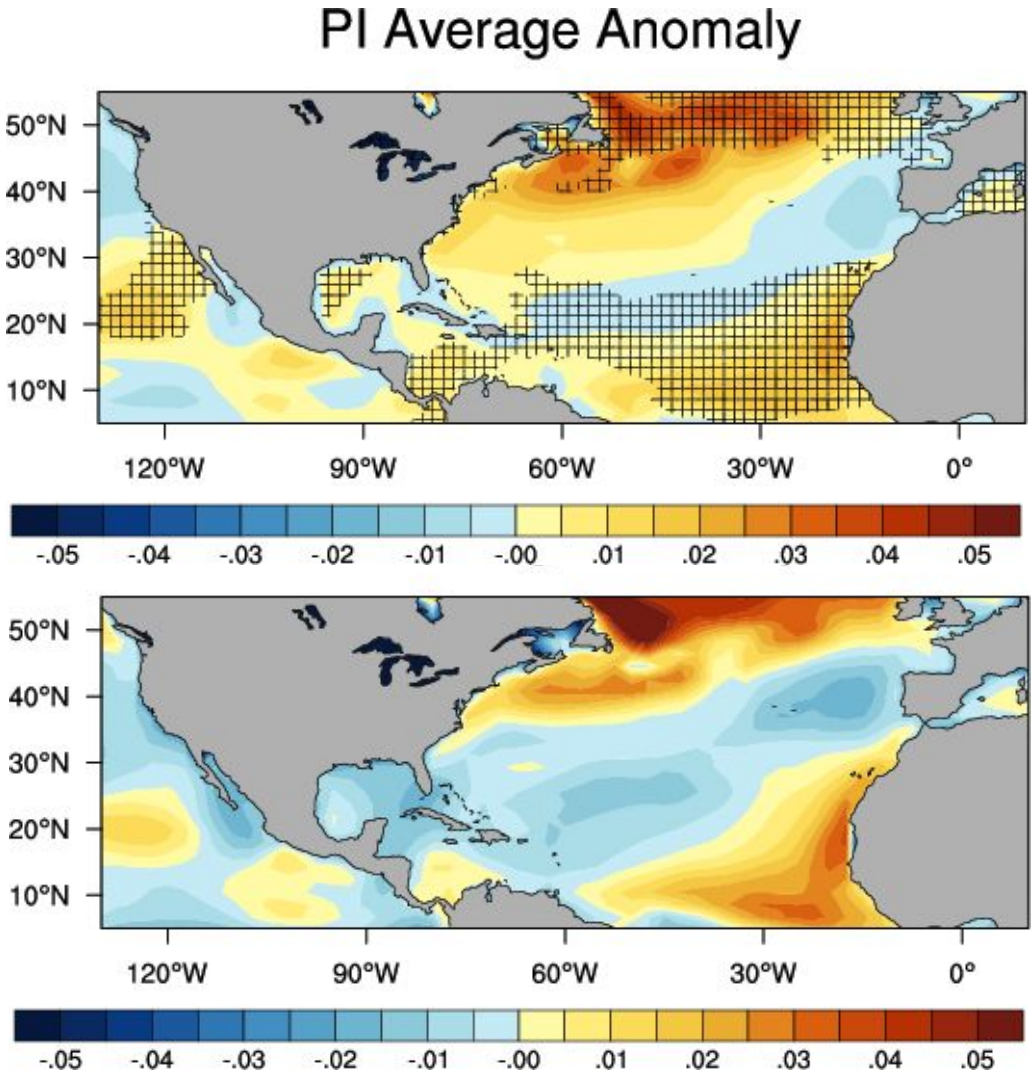
Lifetimes, intensities, and frequency in the 80-100% significance range

Results: 1815 Eruption

Sig-Tests	% Greater	% Less
Month	0.513	0.481
Yearly Number	0.883	0.084
Latitude	0.325	0.675
Longitude	0.195	0.805
Max Wind	0.831	0.169
Min Pressure	0.058	0.942
Lifetime (wind)	0.896	0.104
Lifetime (pressure)	0.942	0.058

Lifetimes, intensities, and frequency in the 80-95% significance range

Results: Potential Intensity

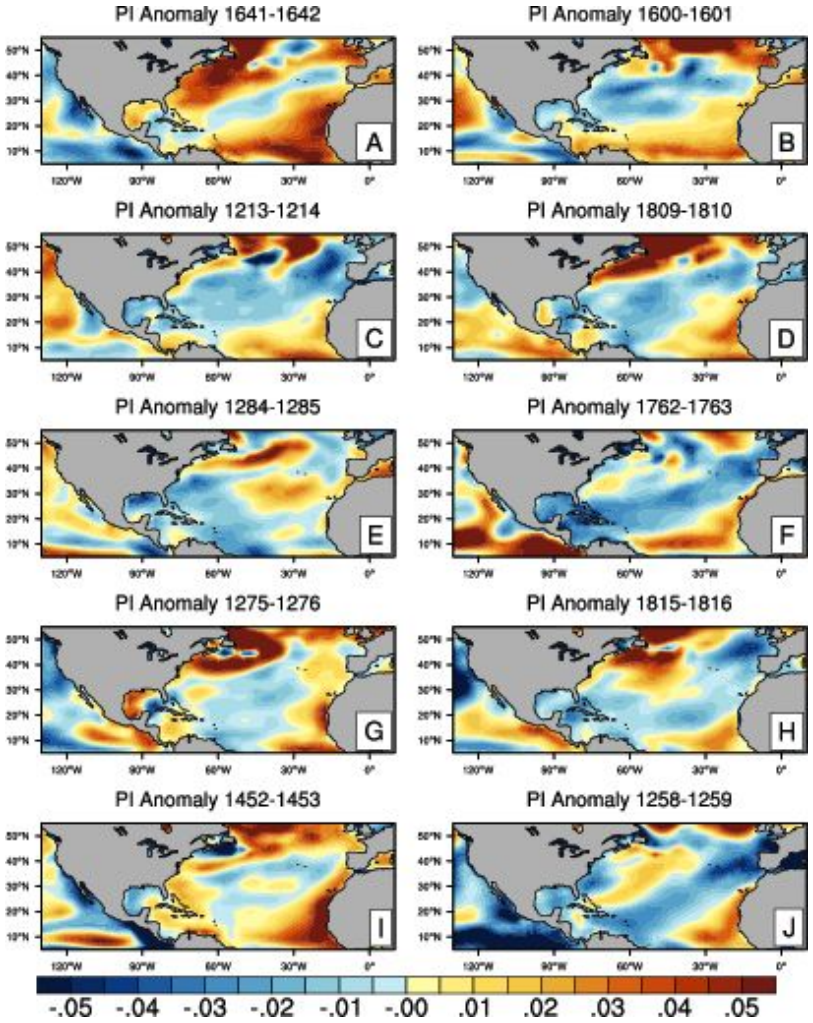


All eruptions: average difference is ~0.01

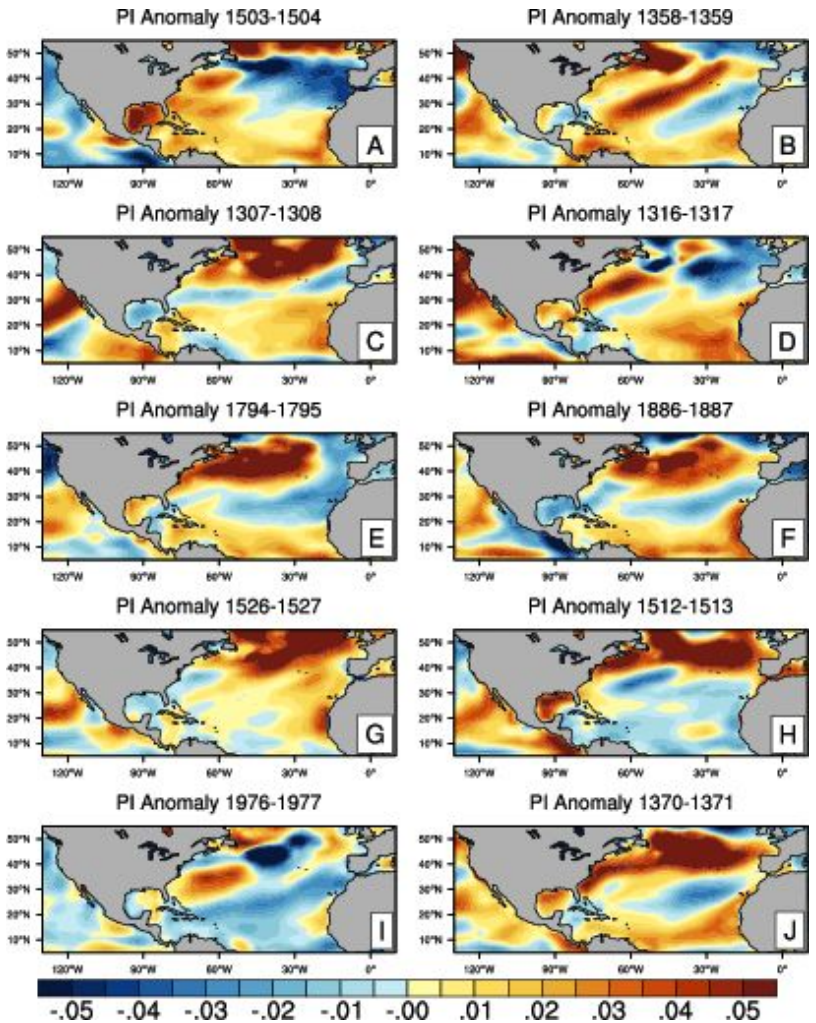
10 Strongest Eruptions: average difference is ~0.02

Results: Potential Intensity

Strongest 10 Eruptions



Weakest 10 Eruptions



Summary

- Correlations indicate that eruptions have effect on intensity, lifetime, frequency
- Aggregate effect of all eruptions in last millennium is non-significant
- Eruptions exceeding threshold strength can have a measurable effect
- Further work exploring ensemble of large eruptions with different initial conditions and strength profiles to look at significance 1213 and 1815 eruptions