Forecasting During Eyewall Replacement Cycles

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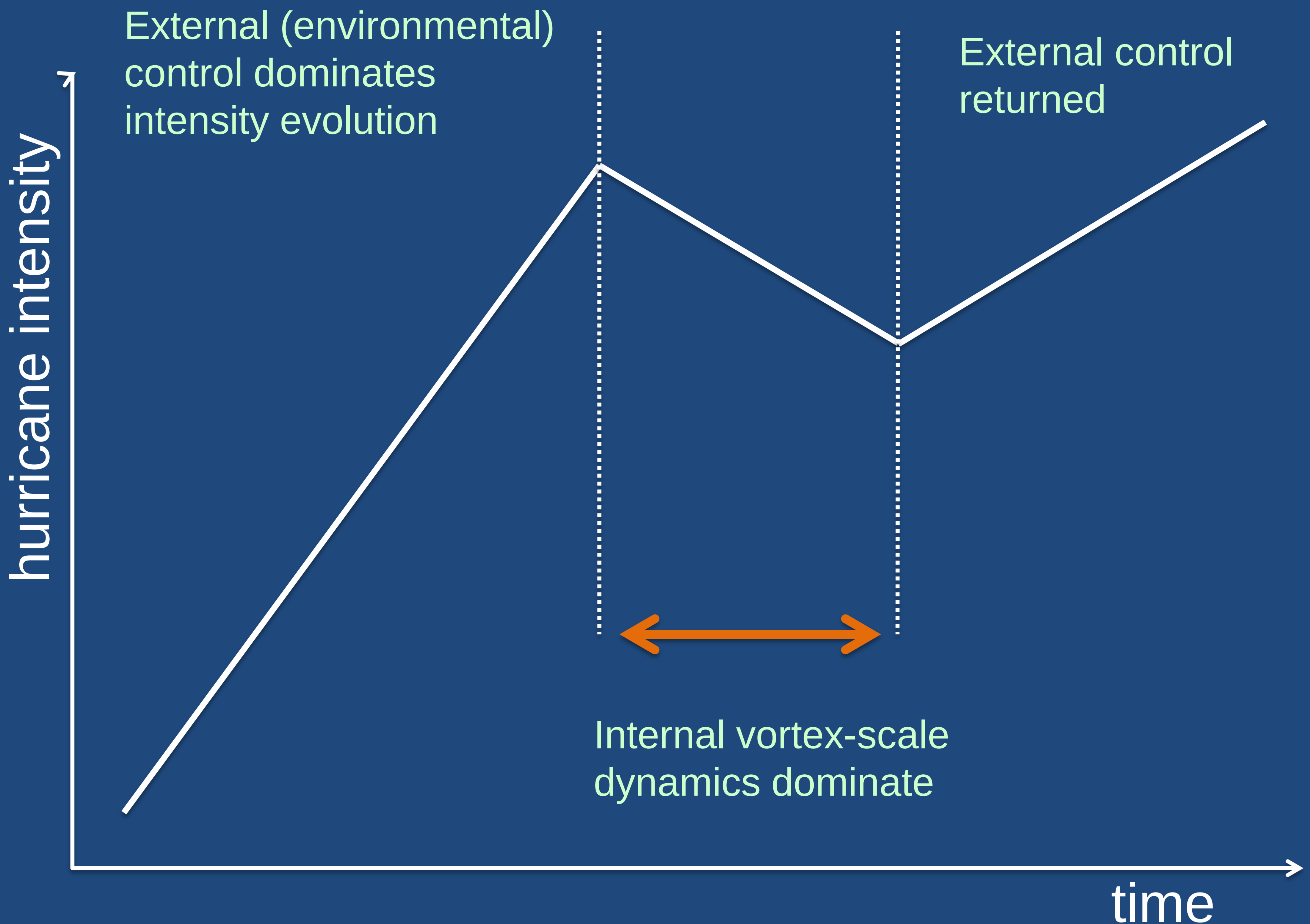
RA-IV Workshop on Hurricane Forecasting and Warning
National Hurricane Center, Miami, FL
29 April – 10 May, 2019



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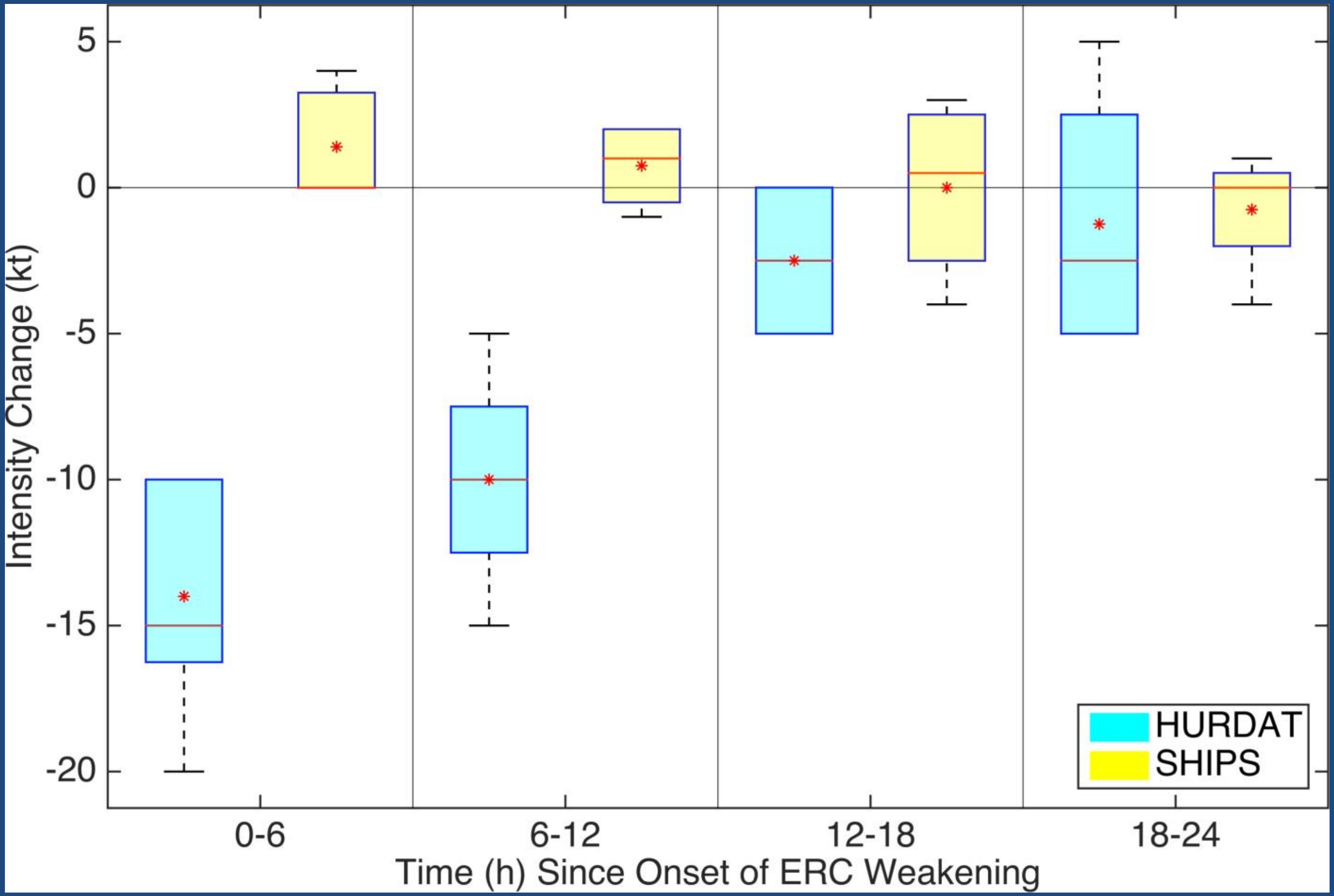
Observed intensity change versus SHIPS forecasts during ERCs



E-SHIPS Model

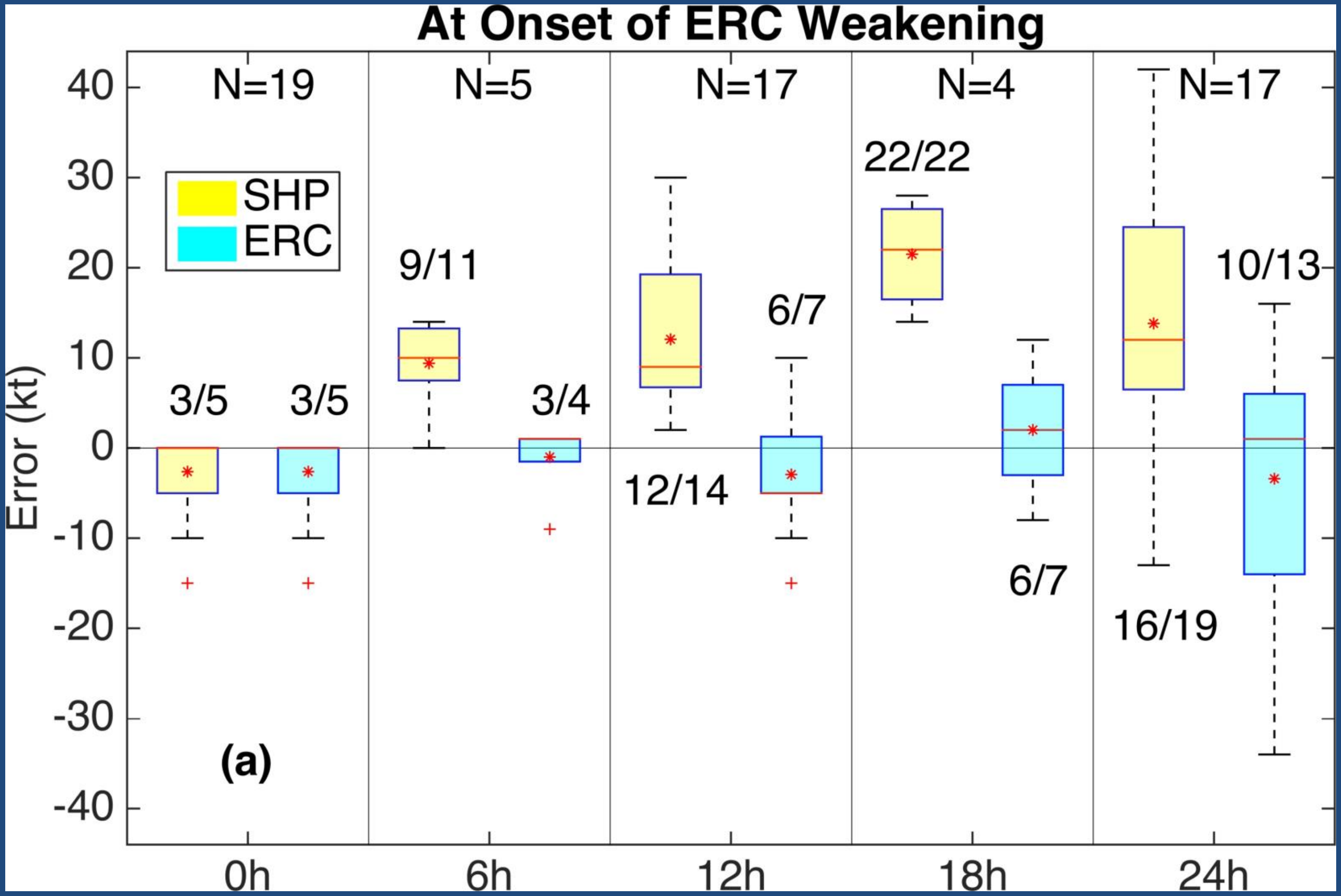
** DSHIPS INTENSITY FORECAST ADJUSTED RELATIVE TO ONSET OF ERC WEAKENING PHASE **

TIME (HR)	0	6	12	18	24	36	48	60	72	84	96	108	120
>24HR AGO (DSHIPS)	105	109	108	108	108	57	36	30	26	DIS	DIS	DIS	DIS
18HR AGO	105	104	103	103	103	52	31	25	21	DIS	DIS	DIS	DIS
12HR AGO	105	102	101	101	101	50	29	23	19	DIS	DIS	DIS	DIS
6HR AGO	105	99	96	95	95	44	23	17	DIS	DIS	DIS	DIS	DIS
NOW	105	96	90	87	86	35	DIS	DIS	DIS	DIS	DIS	DIS	DIS
IN 6HR	105	109	100	94	91	68	47	41	37	DIS	DIS	DIS	DIS
IN 12HR	105	109	108	99	93	89	68	62	58	32	32	32	32

D-SHIPS: temporary "patch" for SHIPS while over land

E-SHIPS: temporary "patch" for SHIPS during ERCs

Intensity forecast error reduction



E-SHIPS provides objective quantitative guidance for adjusting intensity forecasts during an ERC

The PERC and M-PERC models provide guidance on **when** to apply E-SHIPS

PERC (Probability of ERC) Model

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** PROBLTY OF AT LEAST 1 SCNDRY EYEWL FORMTN EVENT AL142018 MICHAEL    10/09/2018  18 UTC **
TIME(HR)   0-12  12-24(0-24)  24-36(0-36)  36-48(0-48)
CLIMO(%)    27      28( 47)      28( 62)       0( 62)     <-- PROB BASED ON INTENSITY ONLY
PROB(%)     22       6( 27)       8( 33)       0( 33)     <-- FULL MODEL PROB (RAN NORMALLY)
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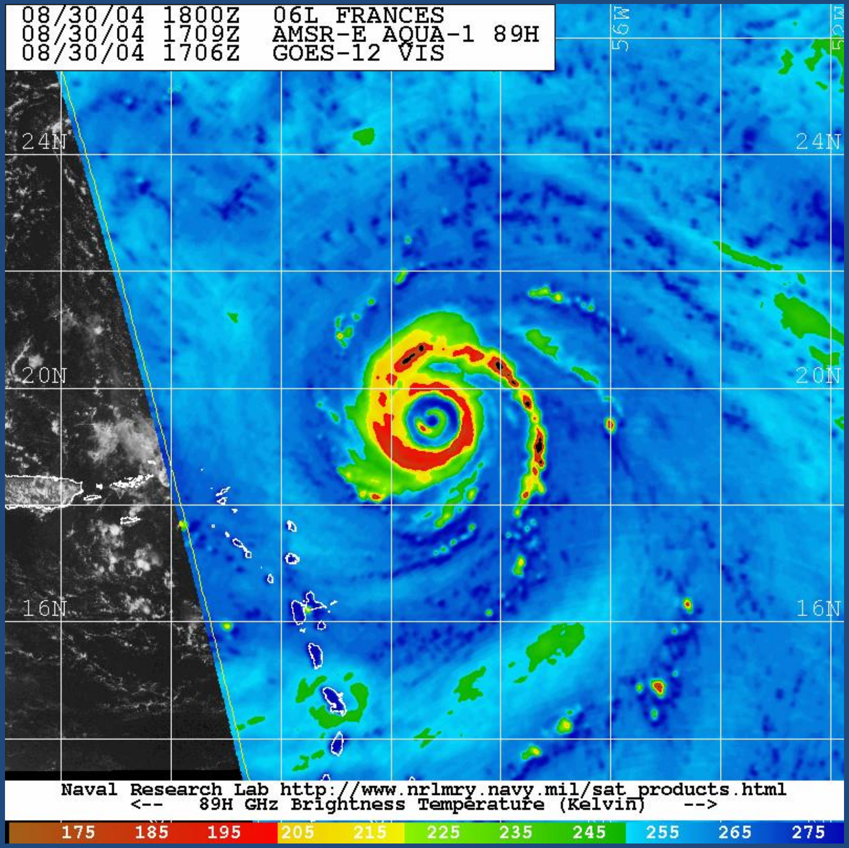
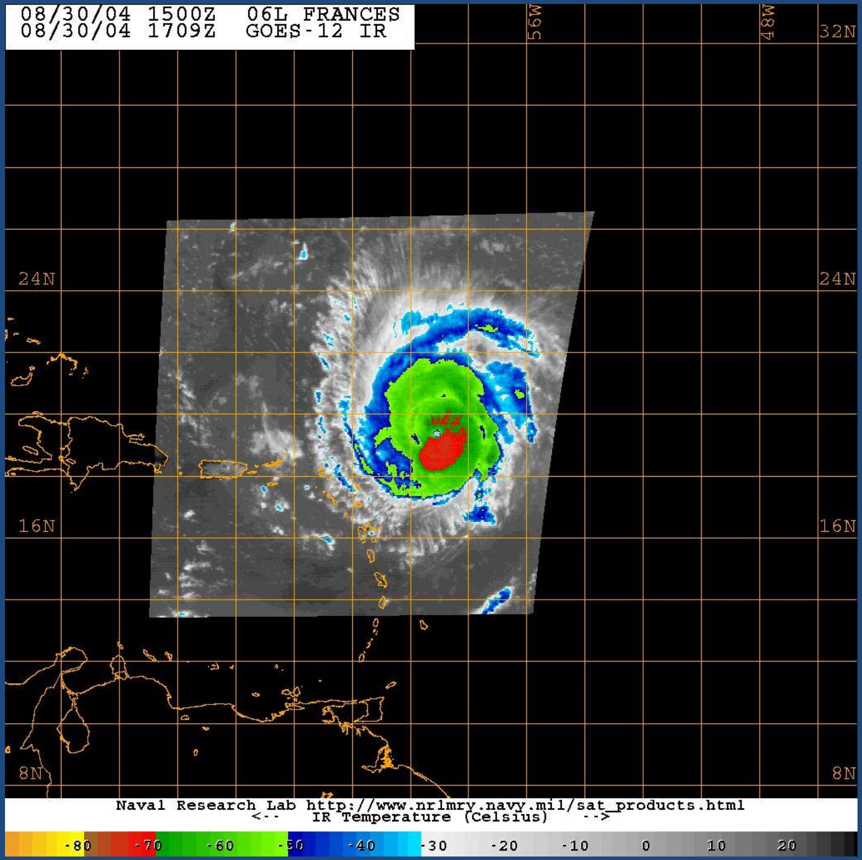
TABLE 2. SHIPS features applied to the Bayes probabilistic model in the North Atlantic.

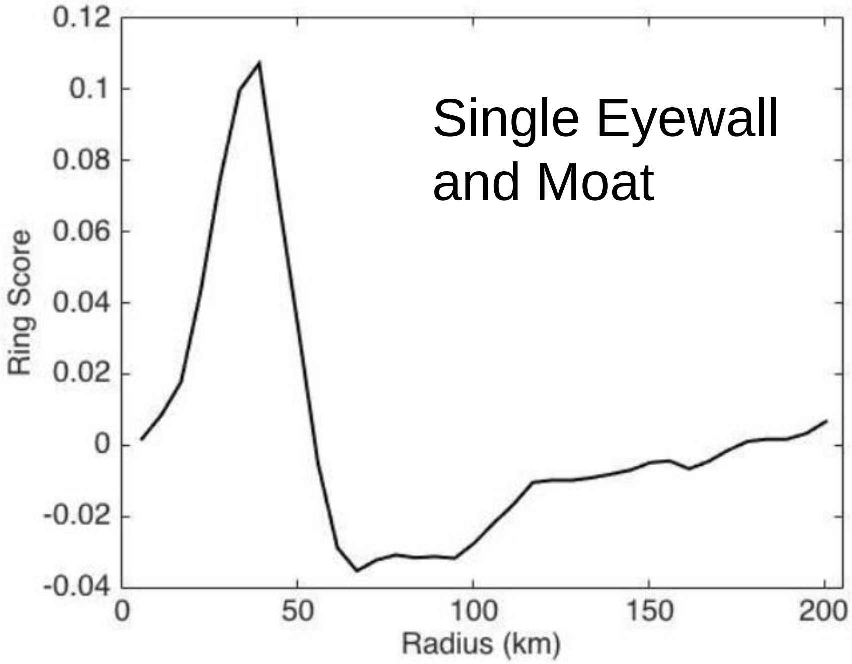
SHIPS feature	Description	Preference for secondary eyewall formation
VMX	Current intensity	Stronger
LAT	Latitude	Further south
D26C	Climatological depth of 26°C ocean isotherm	Deeper
U200	200-hPa zonal wind (200–800 km from center)	Weaker (near zero), very narrow range
RHHI	500–300-hPa relative humidity	Moister
TWAC	0–600-km average symmetric tangential wind at 850 hPa from NCEP analysis	Stronger
PENC	Azimuthally averaged surface pressure at outer edge of vortex	Lower
SHRD	850–200-hPa shear magnitude	Weaker, narrow range
VMPI	Maximum potential intensity	Higher, very narrow range
IR00–05	Standard deviation (from axisymmetry) of GOES infrared brightness temperature between 100 and 300 km	Smaller (more axisymmetric)
IR00–16	Average GOES infrared brightness temperature between 20 and 120 km	Colder, narrow range

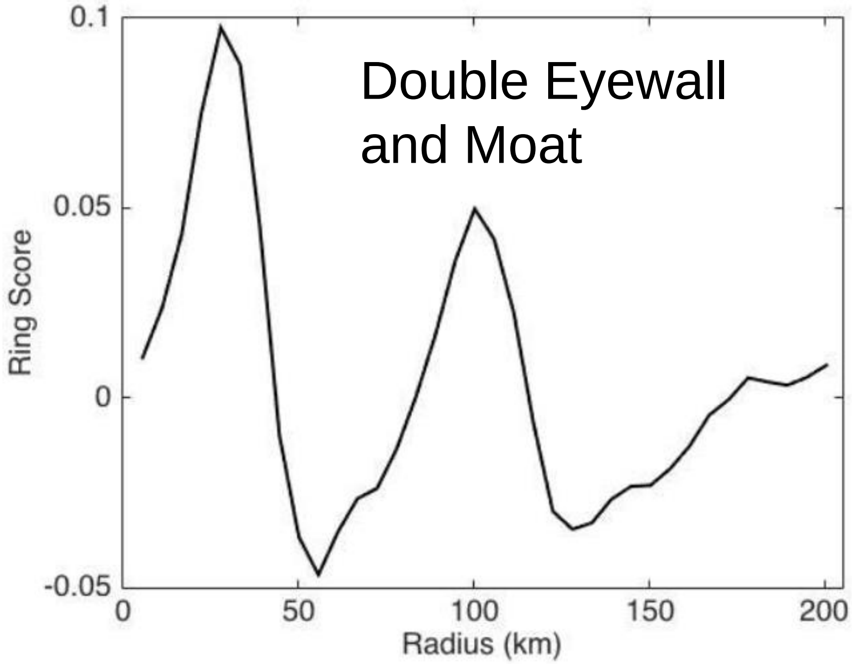
M-PERC model

Use satellite microwave imagery to detect ERC onset

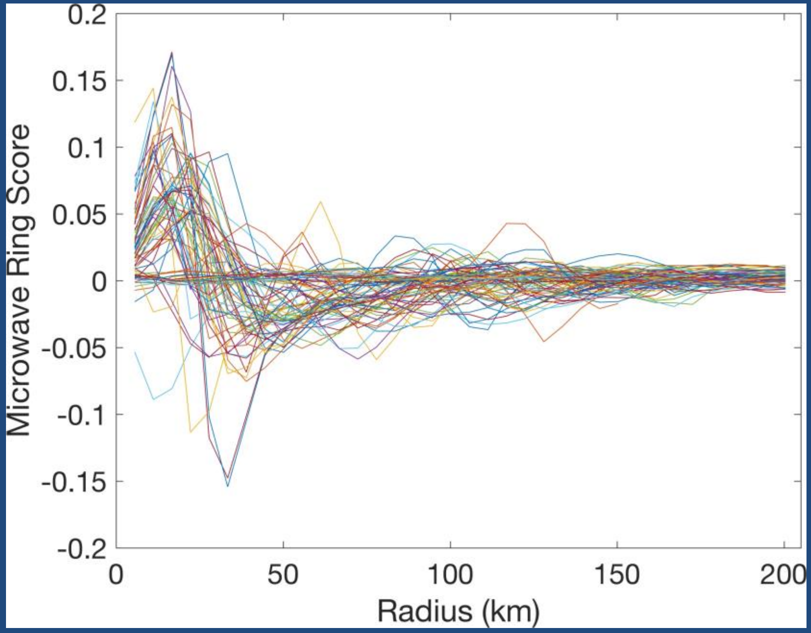








Microwave profiles



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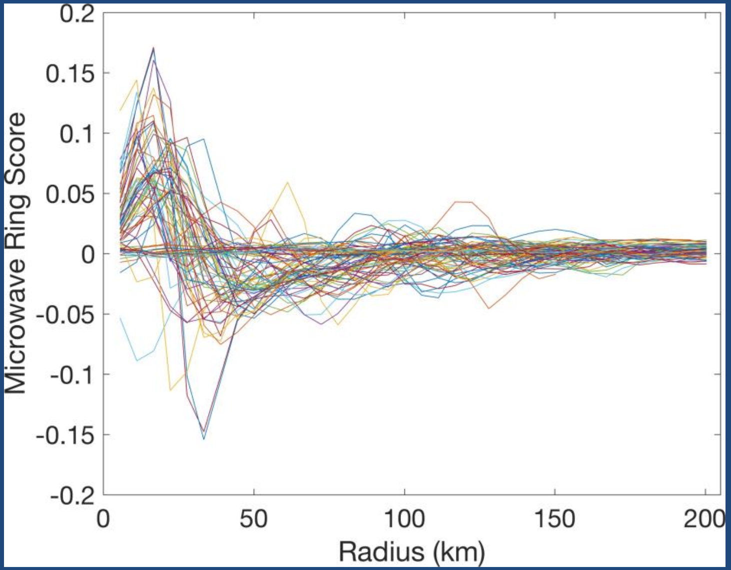
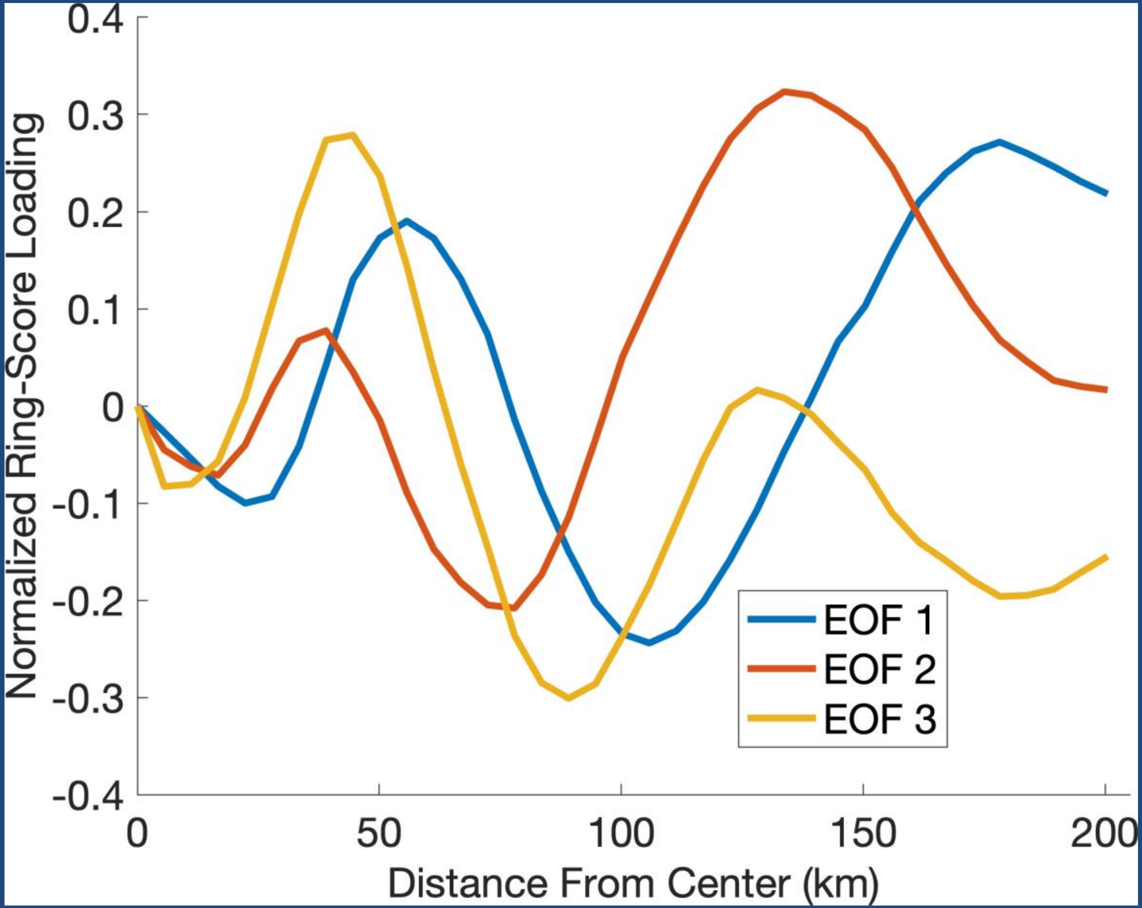
Isolate the leading patterns of microwave profile variability



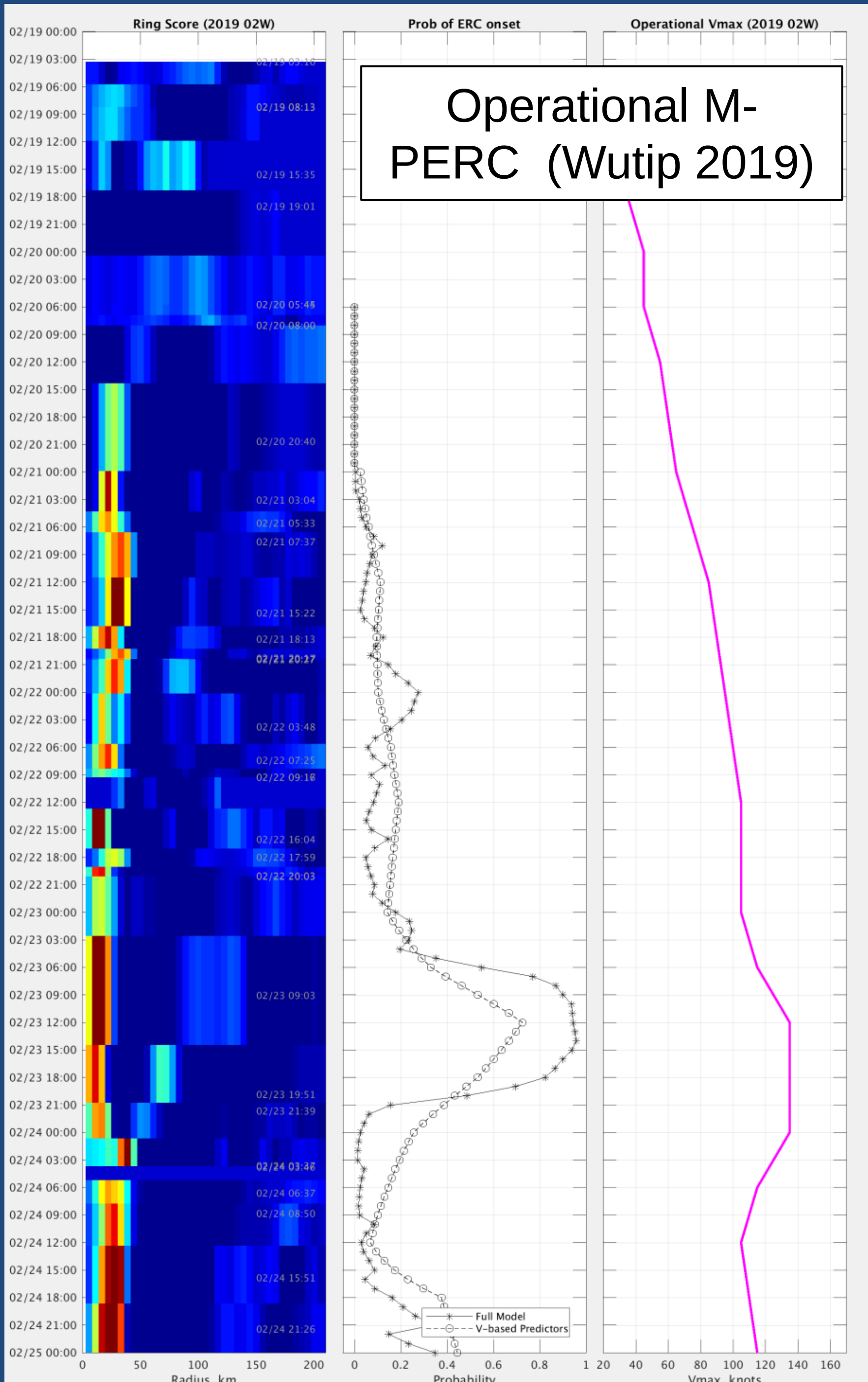


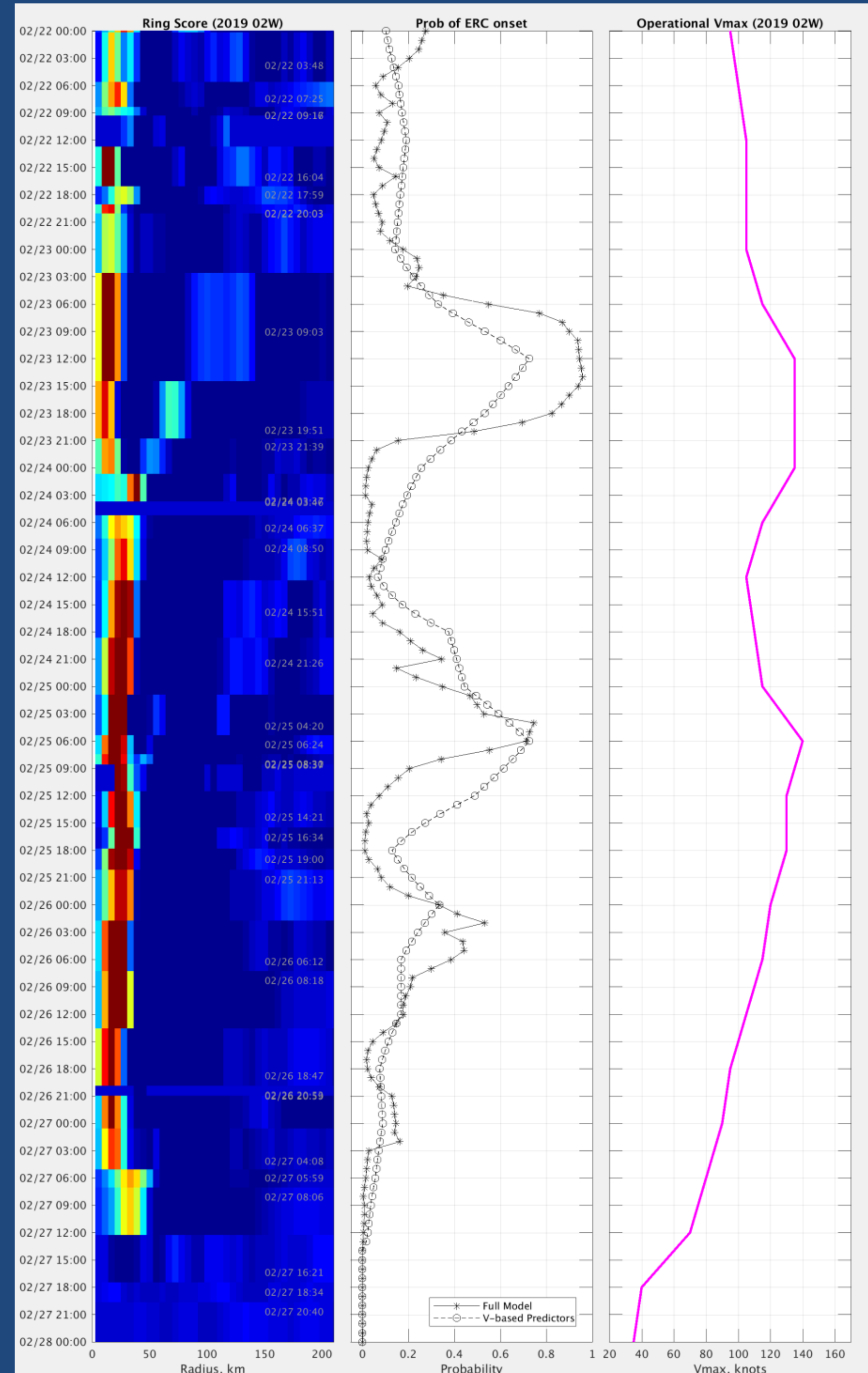
M-PERC model predictors

Table 1. List of M-PERC predictors, as selected by a backward-stepping procedure. The PC-based predictors represent the microwave-based contribution to the model, and the Vmax-based predictors represent the intensity-based contributions.

Predictor	Description
PC3	PC 3
PC5	PC 5
PC8	PC 8
PC1-12	12 h change in PC 1
PC2-06	6 h change in PC 2
PC2-18	18 h change in PC 2
PC3-06	6 h change in PC 3
PC3-12	12 h change in PC 3
PC3-18	18 h change in PC 3
PC3-24	24 h change in PC 3
PC4-18	18 h change in PC 4
PC5-18	18 h change in PC 5
PC7-24	24 h change in PC 7
PC9-12	12 h change in PC 9
PC9-24	24 h change in PC 9
Vmax	Current intensity
Vmax-12	12 h change in Vmax
Vmax-18	18 h change in Vmax

Operational M-PERC (Wutip 2019)

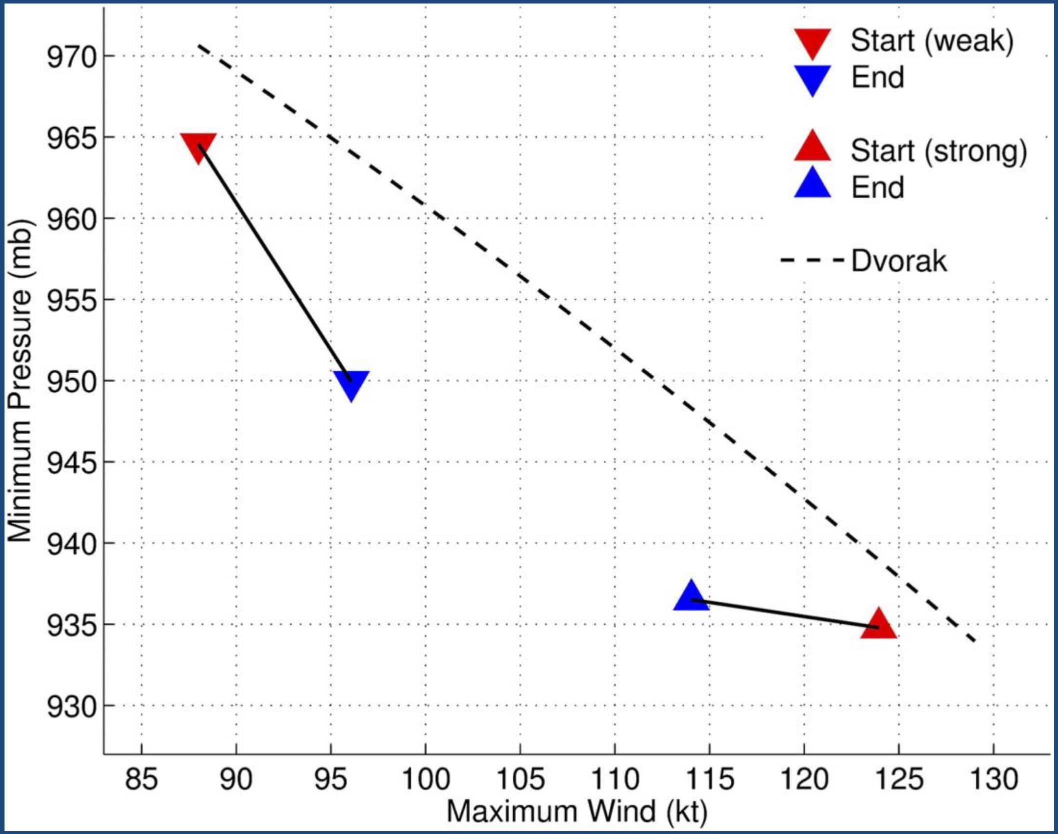




ERCs also affect the tropical cyclone wind-pressure relationship

Strong storms: smaller pressure rise with larger wind decrease

Weak storms: larger pressure fall with smaller wind increase



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Summary (part 1)

There are models presently in place that can provide objective intensity forecast guidance during ERCs.

The models were initially developed for the Atlantic basin, but the M-PERC model has been performing well in all basins.

The M-PERC model is available in real-time for all basins:

http://tropic.ssec.wisc.edu/real-time/archerOnline/web/index_erc.shtml

Part 2: Climate Change Impact on Hurricanes

Multiple choice:

How confident are you that human activity has changed tropical cyclone behavior in any substantial way?

1) Almost certainly not
2) Probably not
3) About as likely as not
4) Probably has
5) Almost certainly has

Tropical cyclone hazard

Strongly modulated by climate
Driven both **randomly** and **systematically** on range of time-scales

El Niño	1 to 2 years	What is El Niño doing this year?
Decadal/Interdecadal	10 to 40 years	What phase of the AMO or PDO?
Climate change	20 to 100+ years	

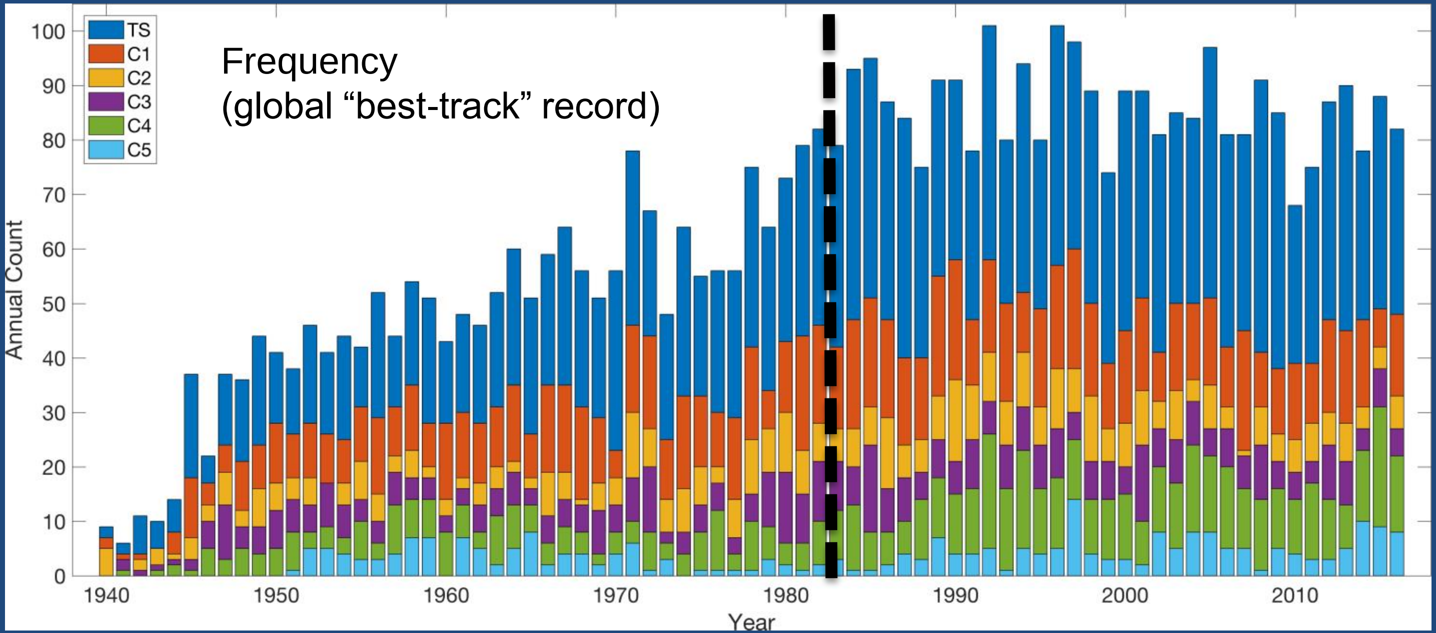
To focus on climate change, we're usually looking for

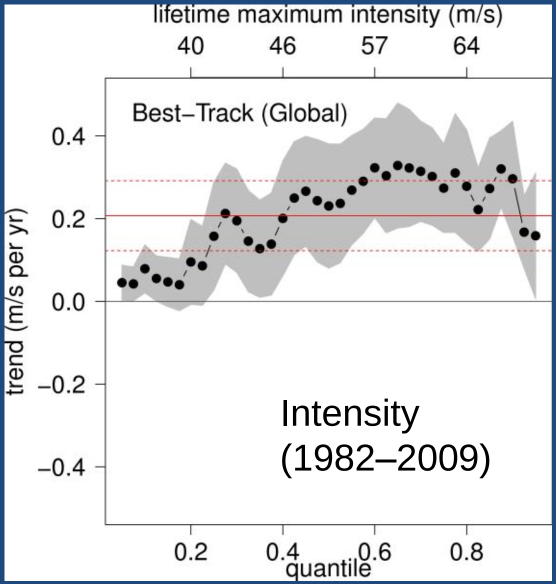
past trends not easily explained by natural variability

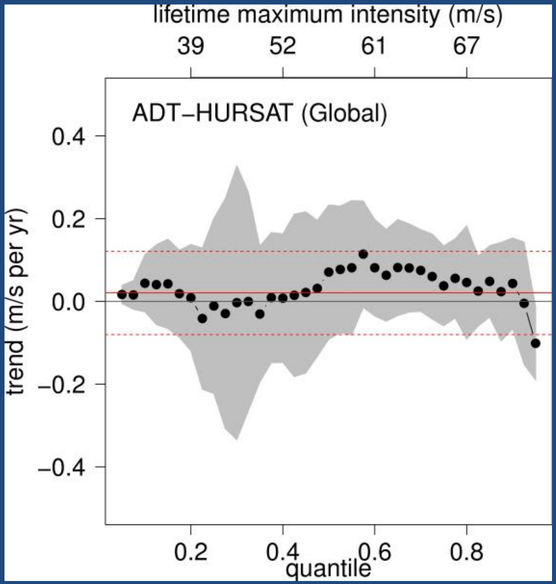
and

projected trends in numerical models with GHG (e.g. CMIP-5)

Past trends







Frequency and **especially** intensity data are very inconsistent over time.

Are there other measures of tropical cyclone behavior that should be comparatively more consistent over longer time periods?

Two metrics considered here:

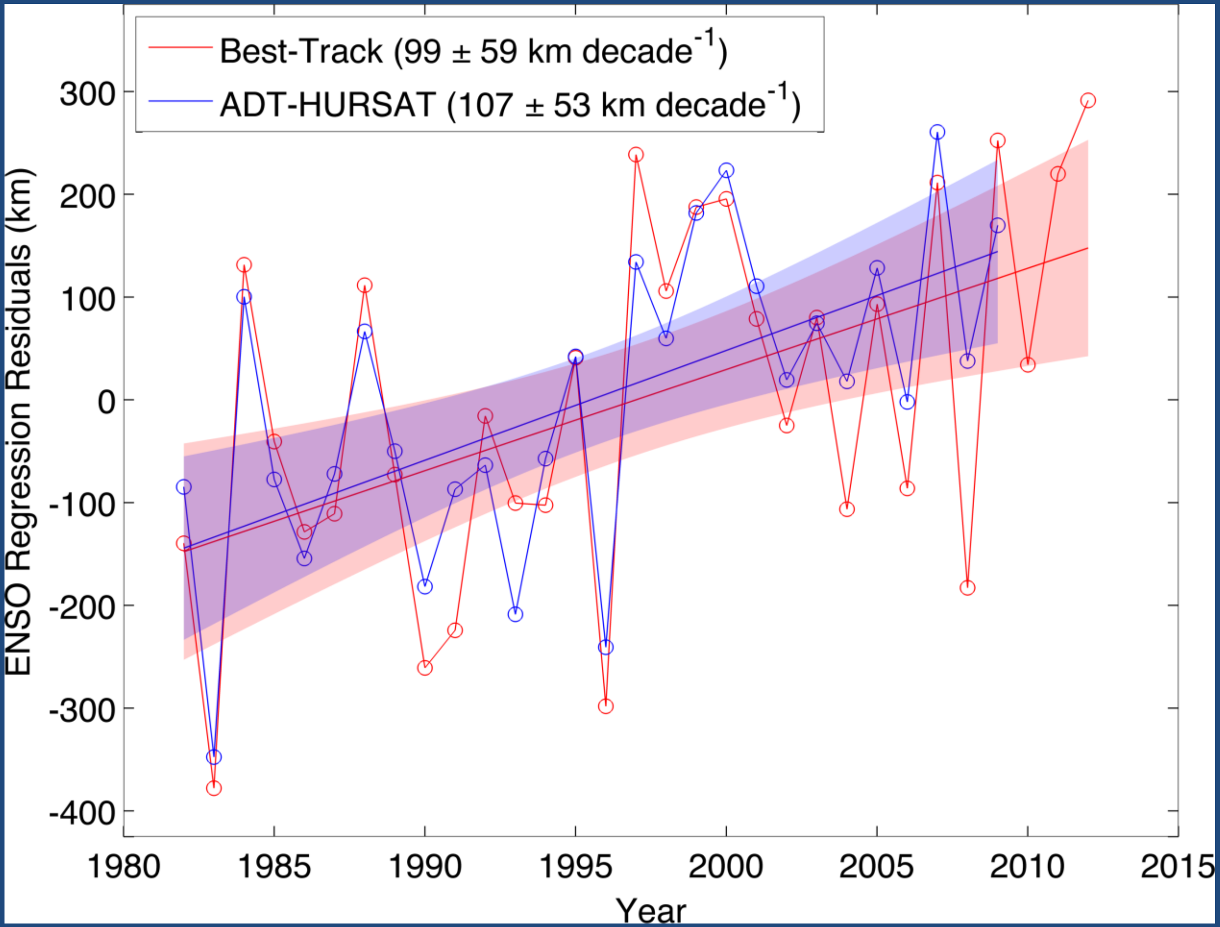
1) The locations where tropical cyclones reach their peak intensity.

Only need to know that a storm is at peak intensity, regardless of what the intensity actually is.

2) Their speed of translation.

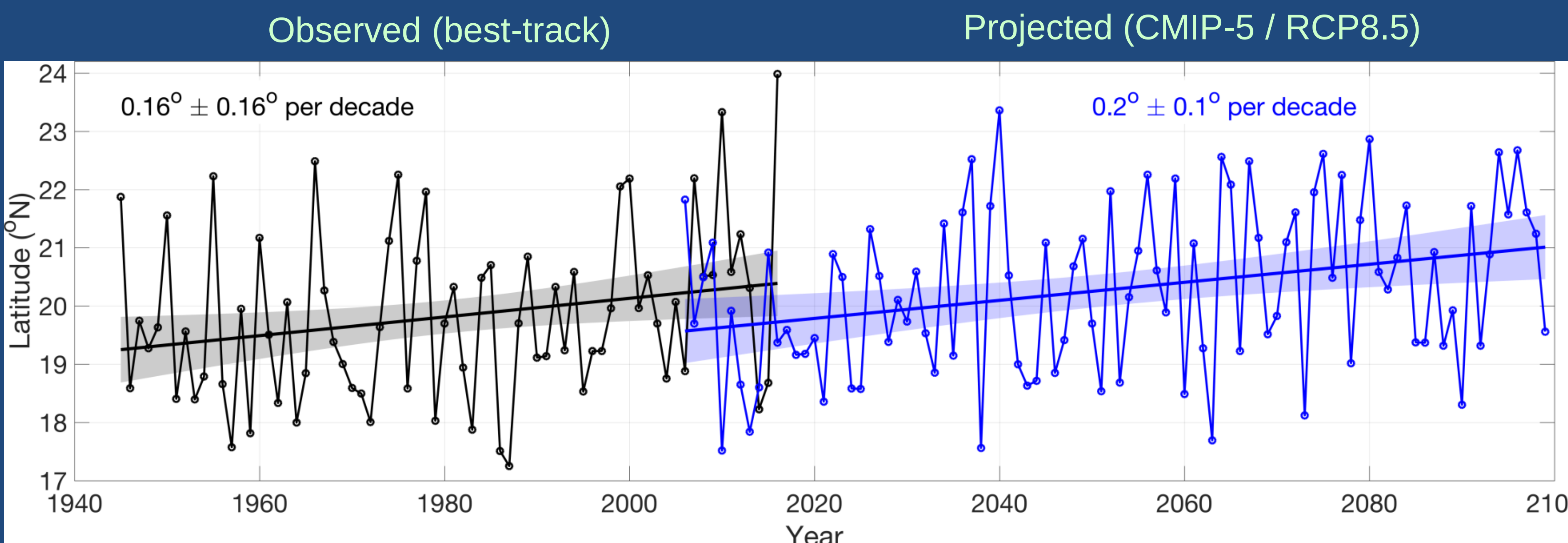
Only need to know positions, which are averaged along track.

Global poleward expansion of peak intensity



The poleward migration rate is consistent with the independently-measured rate of tropical expansion, which has a human fingerprint on it.

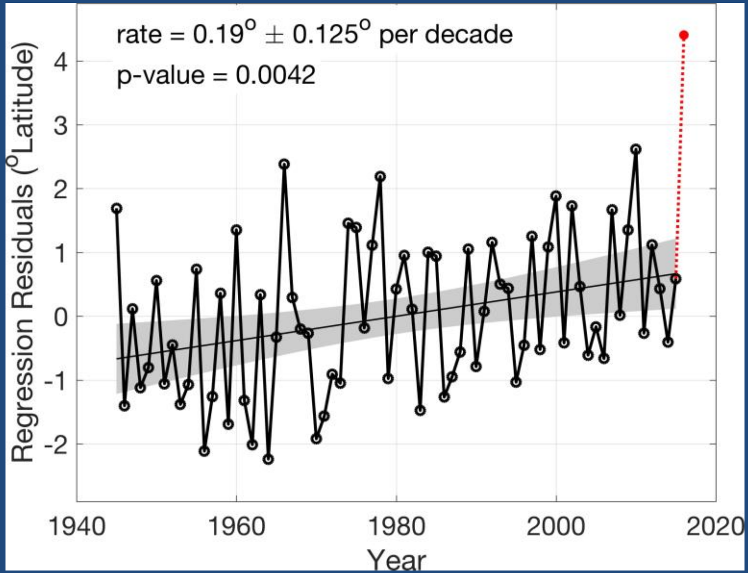
Longer-term (>50 years) trends in the western North Pacific



Can this trend be explained by natural variability?

Western North Pacific natural variability:

El Niño (inter-annual)
Pacific Decadal Oscillation (decadal)



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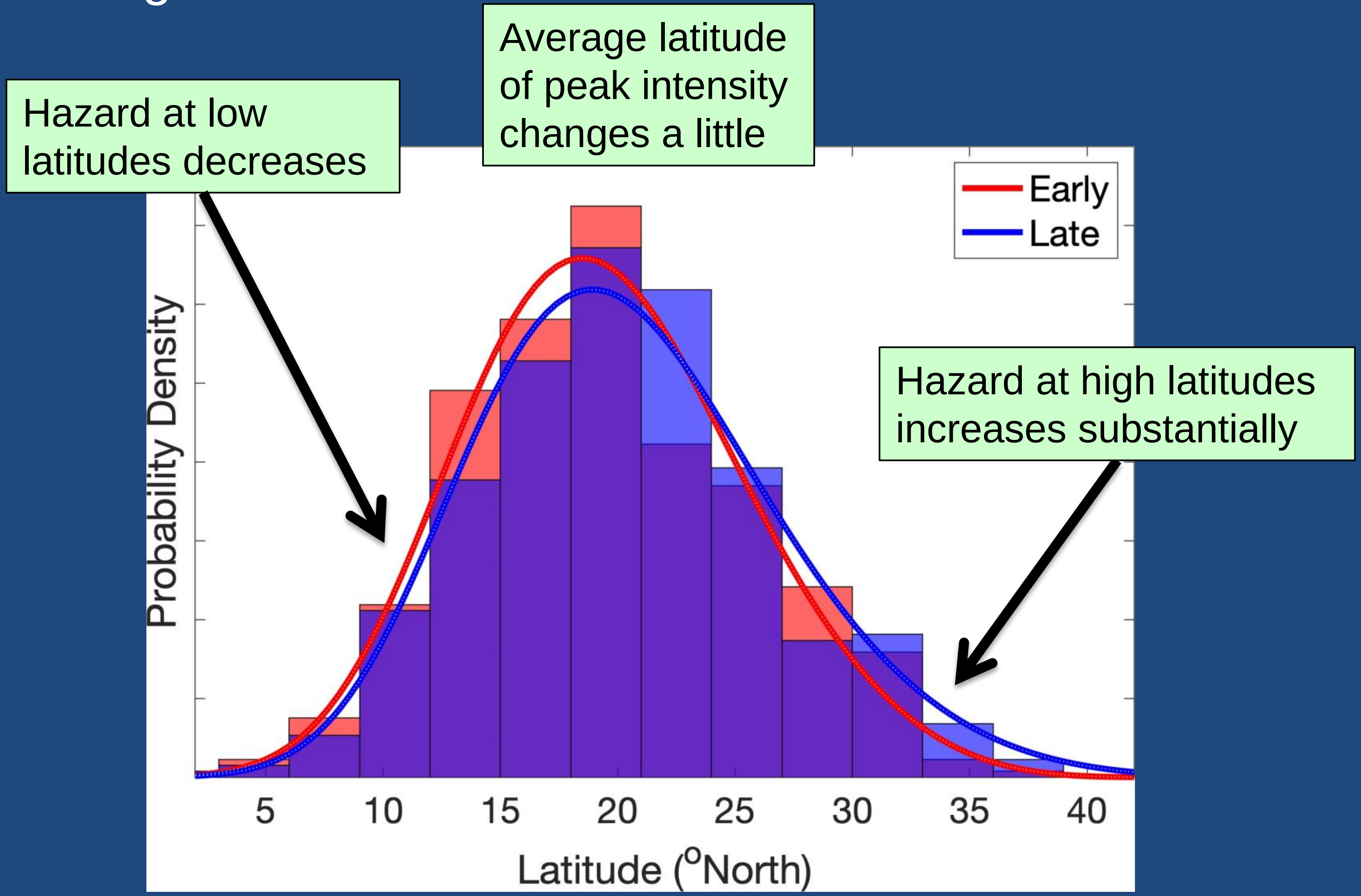
Changes in regional hazard



Philippines **Taiwan** **Japan**

Eastern China

Metric #2:
Changes in tropical cyclone translation speed

Tropical cyclone translation speed

Local rainfall amounts are proportional to rain-rate and inversely proportional to translation speed.

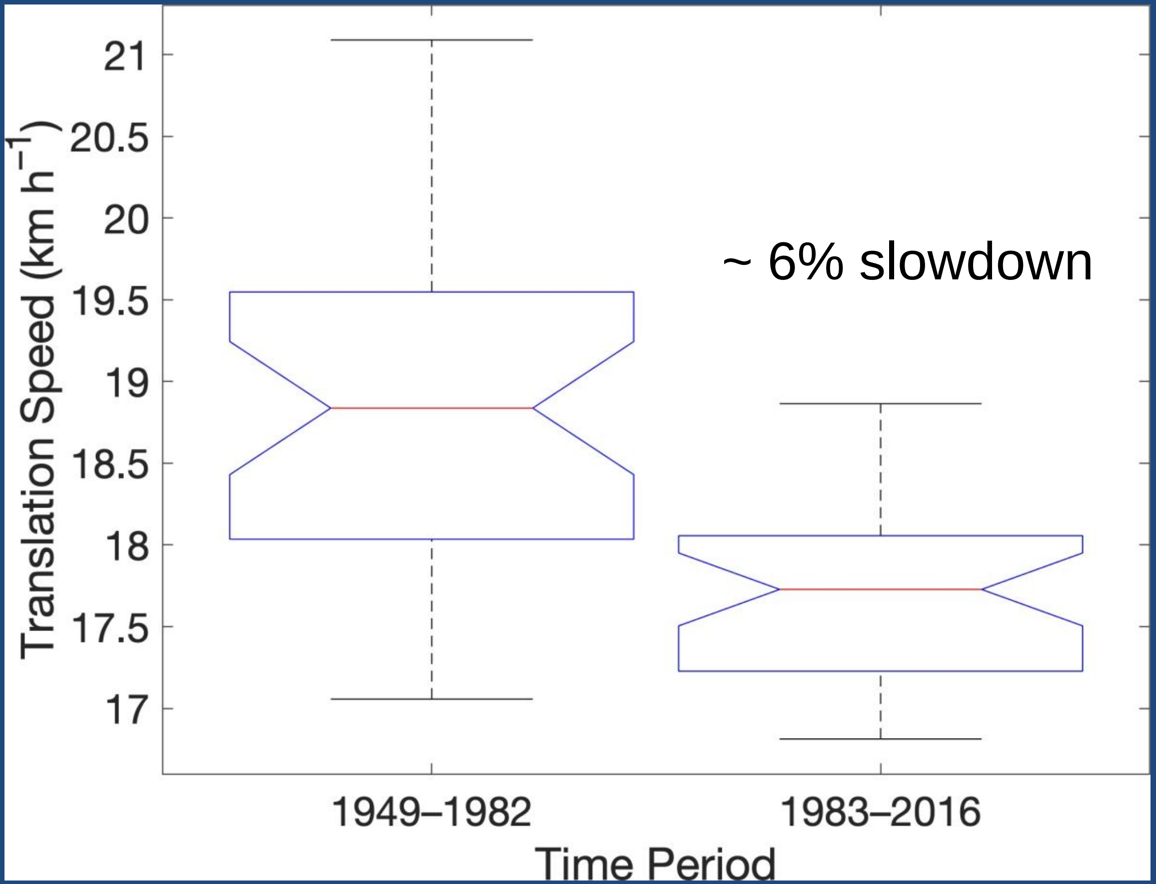
Rain-rates increase by about 7% per °C of warming. A slowdown of as little as 7% would **double** the effect of a 1°C warming.

Examples of slow moving storms:

Hurricane Harvey (2017) in Texas USA
Hurricane Florence (2018) in North Carolina USA
Typhoon Nari (2001) in Taiwan
Cyclone Idai (2019) in Mozambique

All of these storms caused extreme local rainfall amounts because of their slow translation speed.

Global change in TC translation speed

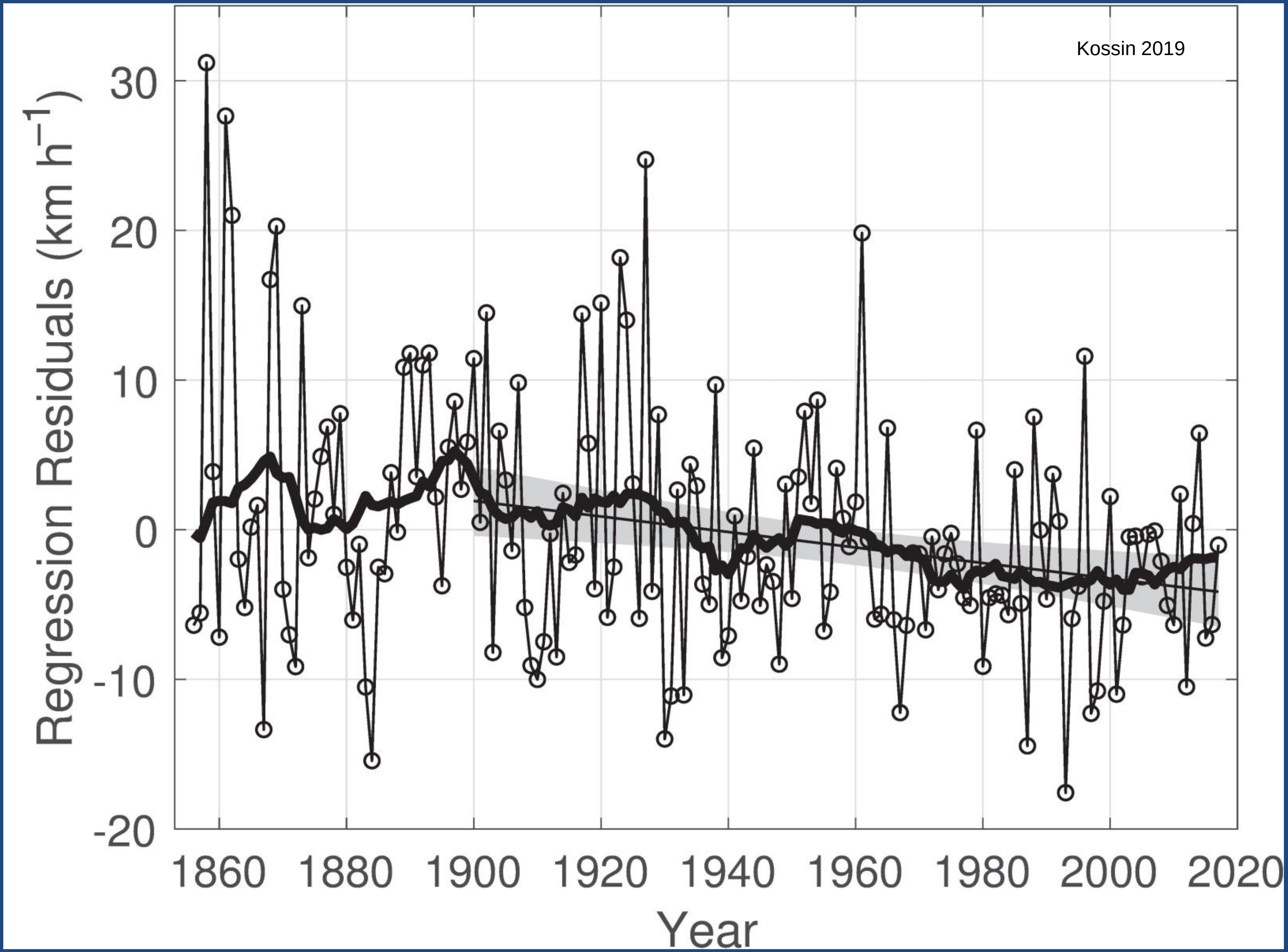


Global-average surface temperature has increased by about 0.5°C over this period.

The magnitude of the slowdown varies by region, but slowing is found in every basin except the Northern Indian Ocean.

Significant slowing is found **over land** in the Atlantic, western North Pacific, and Australia.

17% slowdown over CONUS over past 118 years



Closing Remarks

We seem to have reached the point of confidently detecting a human fingerprint on observed changes in tropical cyclone behavior, and these changes can have a substantial impact on risk.

Depending on the time horizon of interest, these climate change signals will play a role, possibly a large role, in future event probabilities and return periods.

Multiple choice:

How confident are you that human activity has changed tropical cyclone behavior in any substantial way?

1) Almost certainly not
2) Probably not
3) About as likely as not
4) Probably has
5) Almost certainly has

References

Eyewall replacement cycles

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