Observed Trends in Hurricane Behavior

James Kossin

NOAA's National Centers for Environmental Information
Center for Weather and Climate
Madison, WI
james.kossin@noaa.gov

IOGP / JCOMM / WCRP Workshop
Sunbury, UK
25–27 September 2018

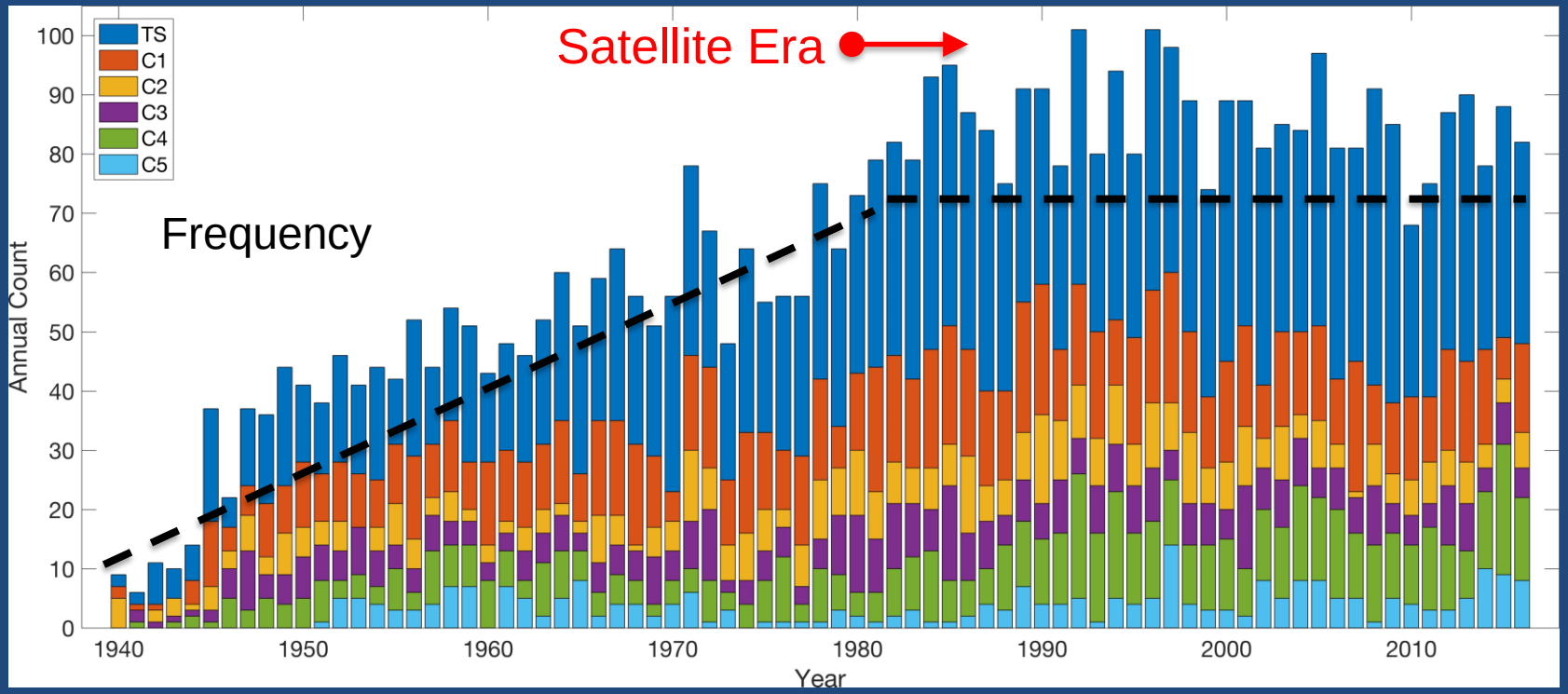
How have tropical cyclones (hurricanes) changed?

How will they change in the future?

Can we *detect* any past trends (i.e., how sure are we that an observed trend isn't due to data issues or natural variability)?

If so, can we *attribute* any part of them to human-caused warming?

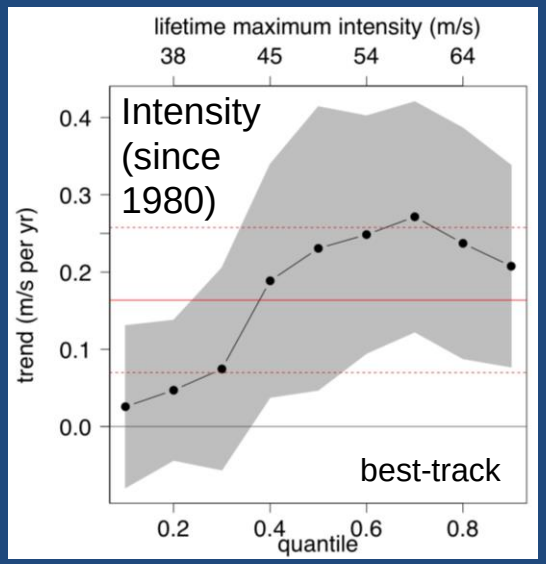
Are there trends projected by numerical models (e.g., CMIP-5) that are consistent with past observed trends?

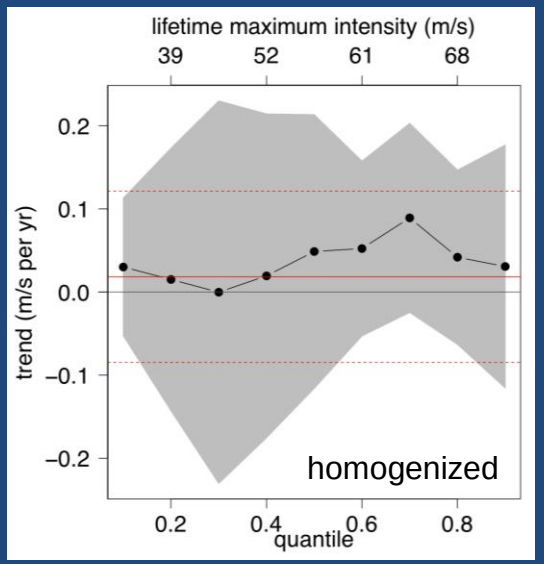


Kossin, J. P., T. L. Olander, and K. R. Knapp, 2013: Trend analysis with a new global record of tropical cyclone intensity. *J. Climate*, **26**, 9960-9976.

Records of frequency and particularly intensity are *highly* heterogeneous.

Best-track: location and intensity every 6 hours for lifetime of every storm.



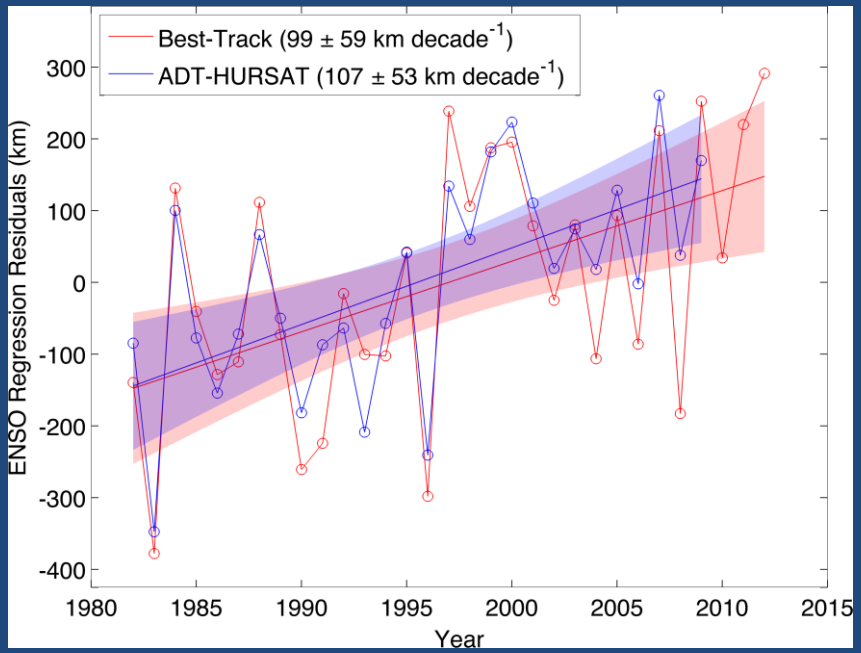


Are there other measures of tropical cyclone behavior that may be comparatively more consistent over longer time periods?

Two metrics considered here:

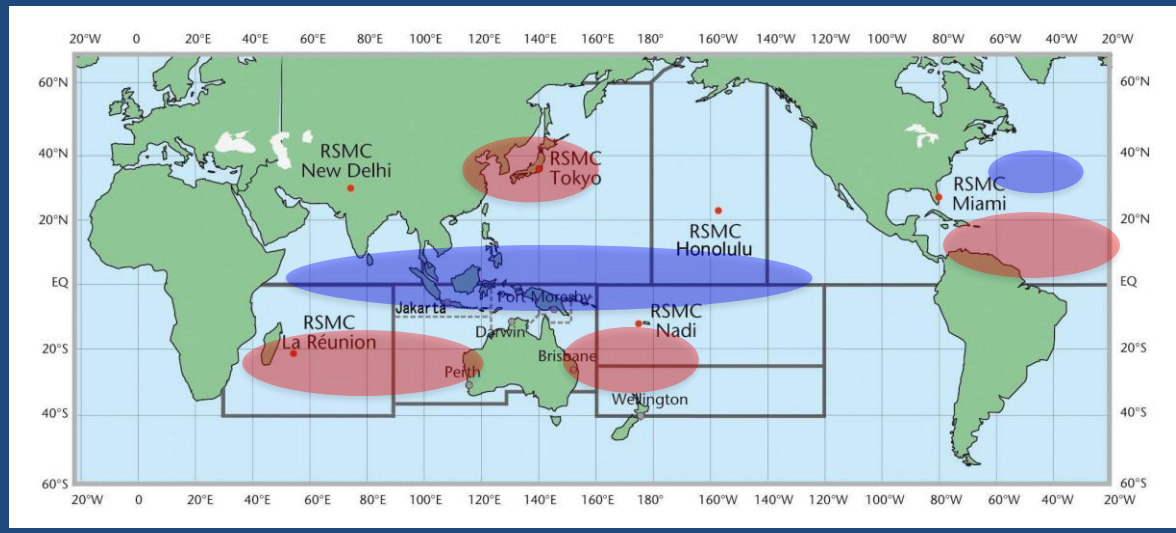
1) The locations where tropical cyclones reach their peak intensity.
2) Their speed of translation.

Annual-mean latitude of peak TC intensity

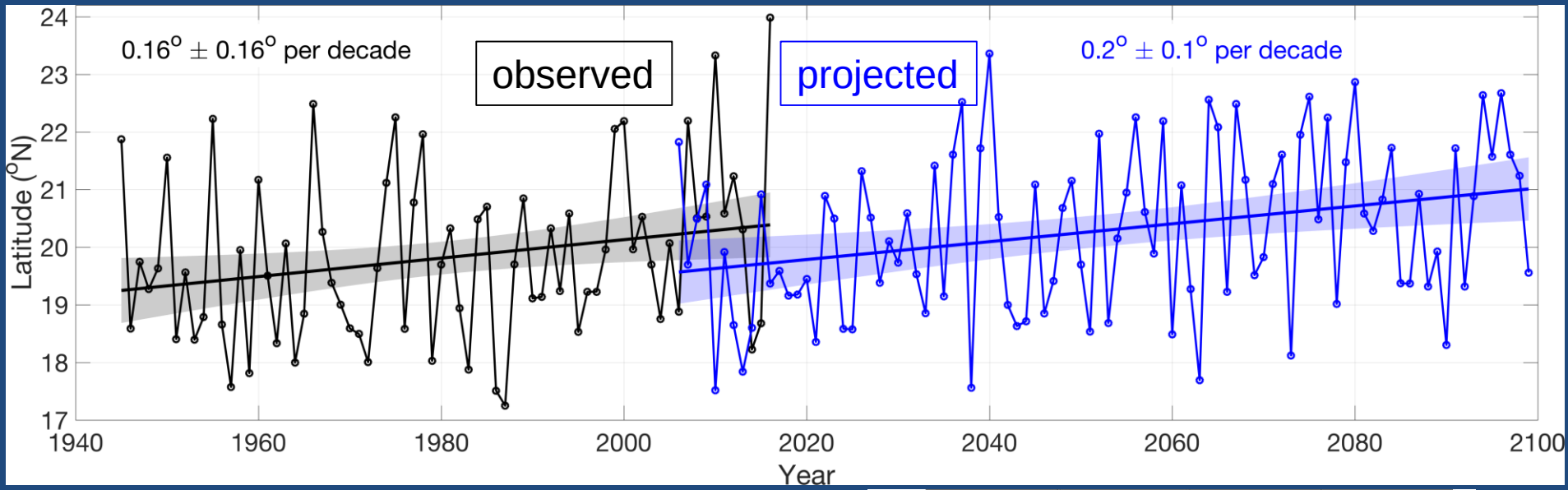


The migration rate is consistent with the independently-measured rate of tropical expansion, which has been partly attributed to human activity.

Kossin, J. P., K. A. Emanuel, and G. A. Vecchi, 2014: The poleward migration of the location of tropical cyclone maximum intensity. *Nature*, **509**, 349-352.

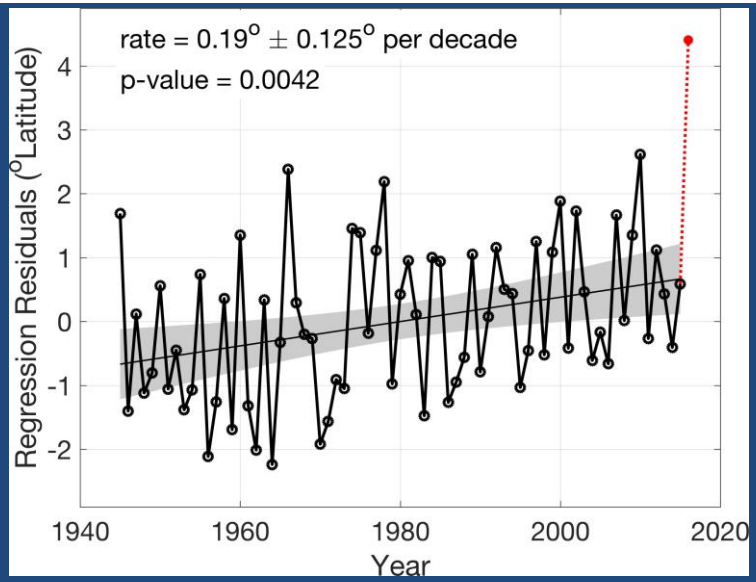


Longer-term observed trends and projections



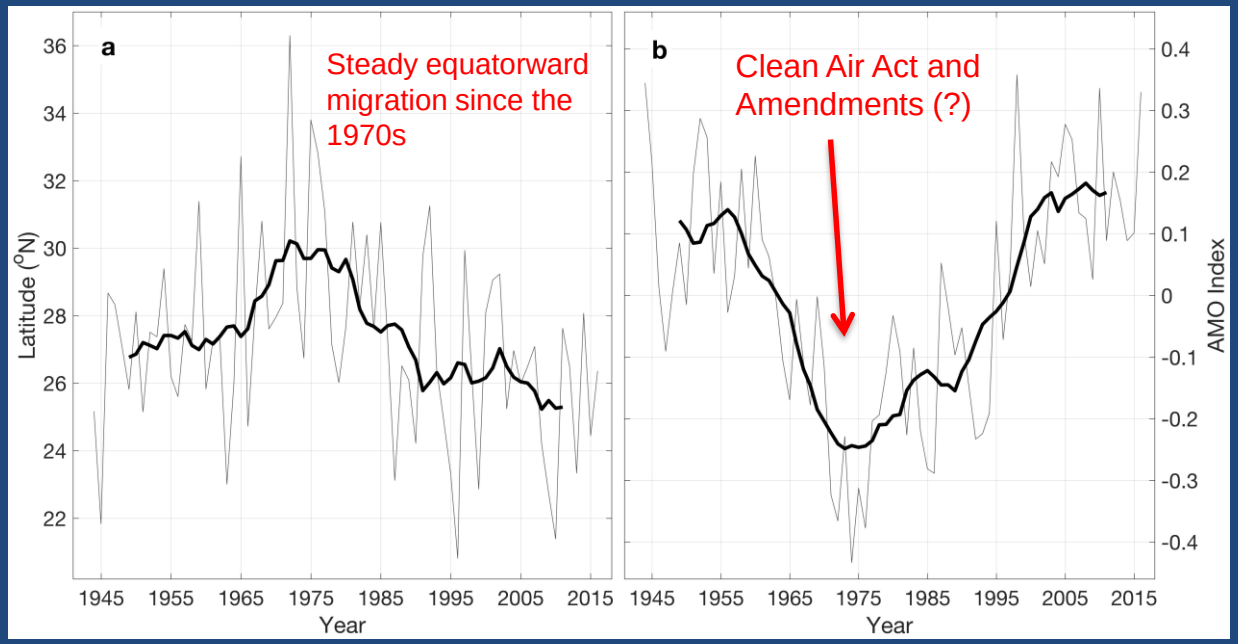
Can we separate part of the trend from natural variability?

Western North Pacific known dominant modes of natural variability:
ENSO (inter-annual)
PDO (decadal)



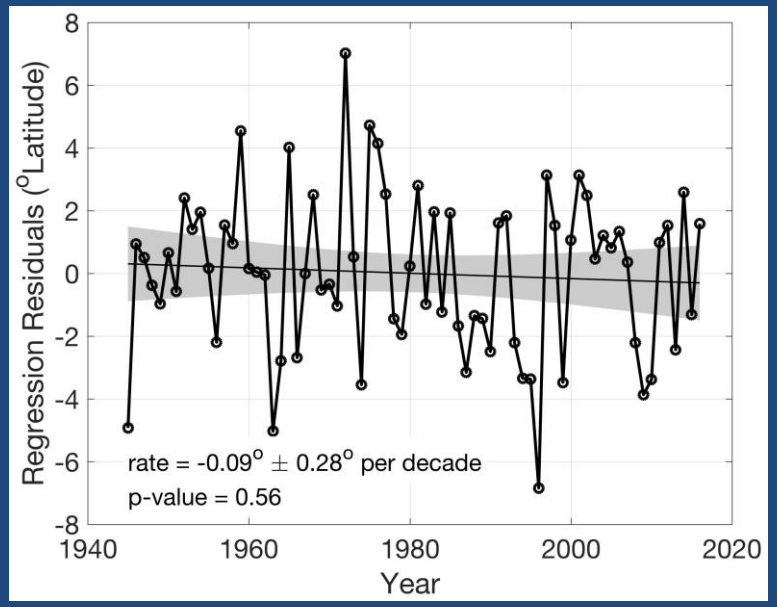
Kossin, J. P., K. A. Emanuel, and S. J. Camargo, 2016: Past and projected changes in western North Pacific tropical cyclone exposure. *J. Climate*, **29**, 5725-5739.

North Atlantic



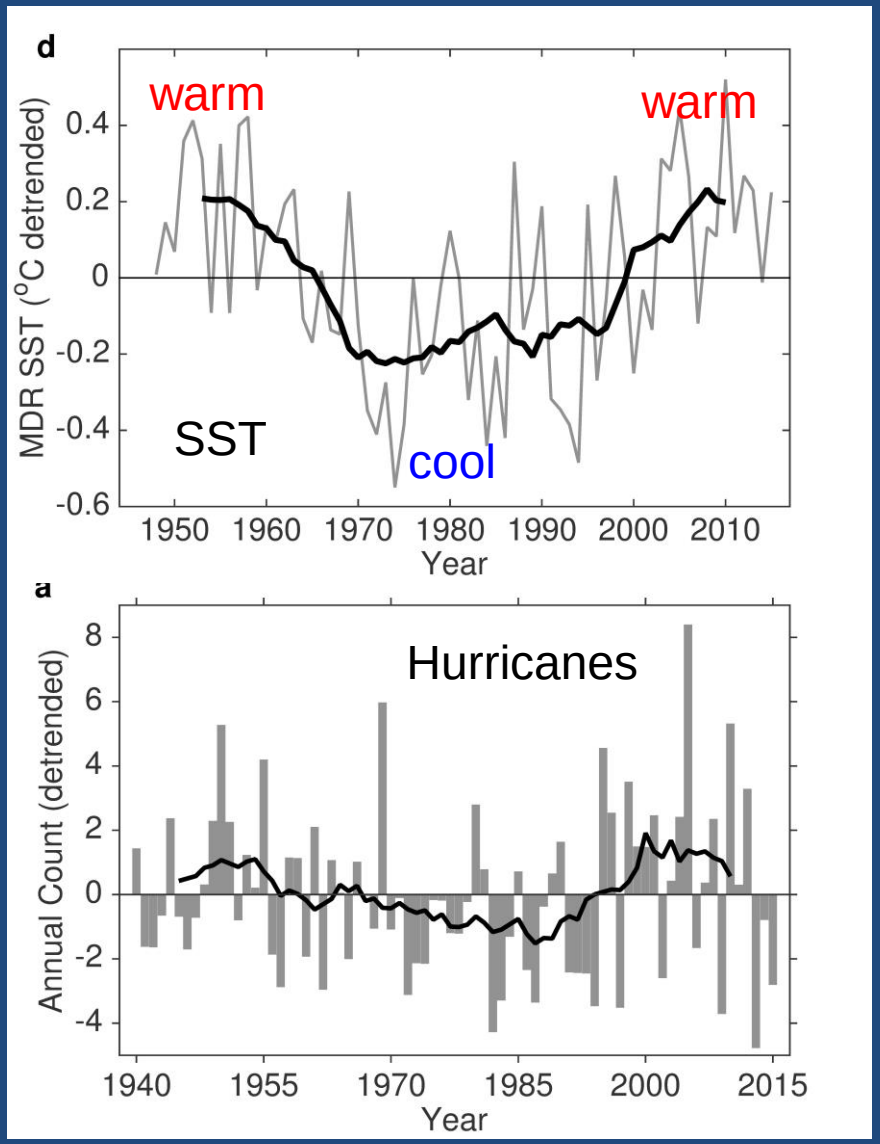
No long-term trend.

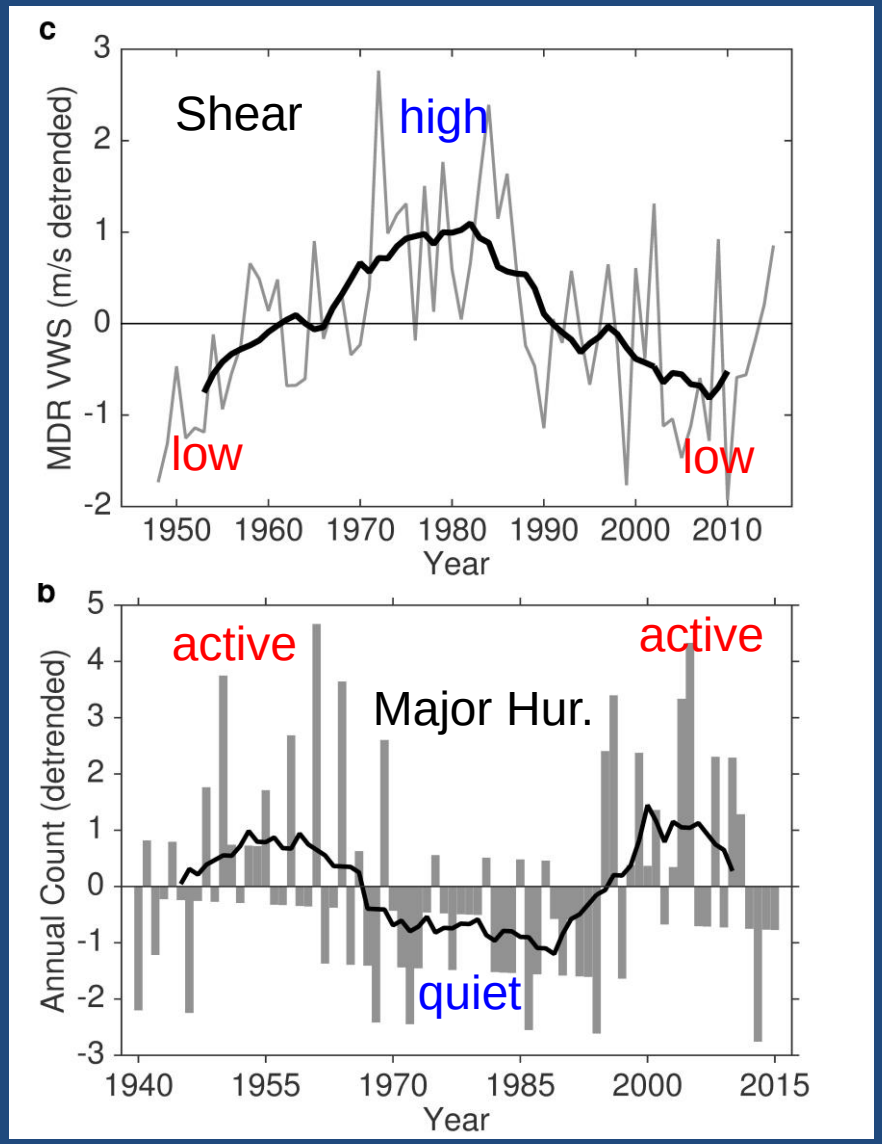
But there is uncertainty about what's driving the Atlantic Multi-decadal Oscillation



Kossin, J. P., 2018: Comment on "Spatial and temporal trends in the location of the lifetime maximum intensity of tropical cyclones". *Atmosphere*, **9**, 241-244.

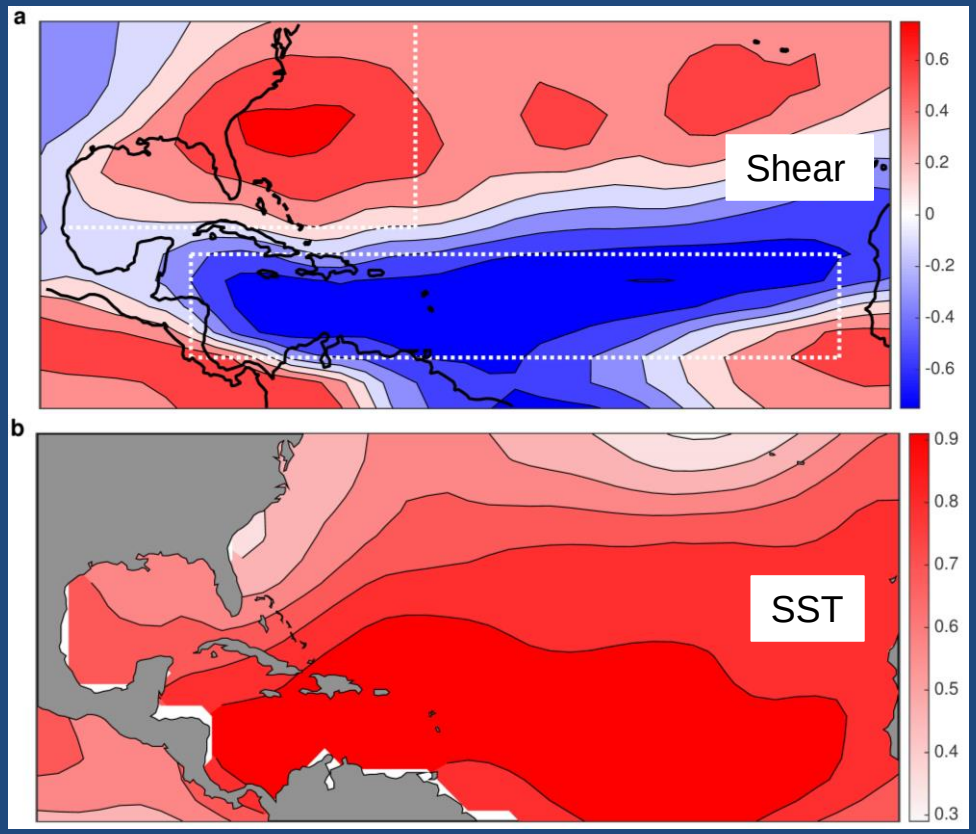
Multi-decadal variability of sea surface temperature (SST) and vertical wind shear (VWS), and basin-wide Atlantic hurricane activity

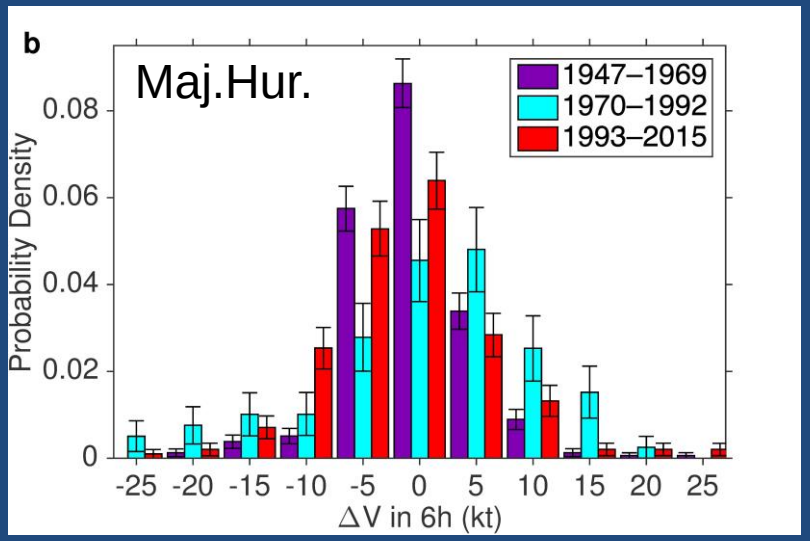




Kossin, J. P., 2017: Hurricane intensification along United States coast suppressed during active hurricane periods. *Nature*, **541**, 390–393, doi:10.1038/nature20783.

Patterns of variability of shear and SST (1948–2015)





During quiescent (cool) periods, major hurricanes that approach or move along the U.S. coast are 3 to 6 times more likely to rapidly intensify.

Fewer hurricanes, but more dangerous and harder to forecast. Overall risk is lower, but singular events can pose greater risk.

Kossin, J. P., 2017: Hurricane intensification along United States coast suppressed during active hurricane periods. *Nature*, **541**, 390–393, doi:10.1038/nature20783.

Tropical cyclone translation speed

Depends only on best-track position. Inaccuracies of individual positions along the track should mostly “average out”. Insensitive to intensity data issues.

Is TC translation speed changing? Theory suggests slowing with warming.

If yes, this could have profound influences on local rainfall impacts.

> Local rainfall amount is proportional to rain-rate and inversely proportional to translation speed (e.g., Harvey).

Clausius-Clapeyron: water vapor increases by ~7% per °C of global-mean surface temperature increase. Rain-rates near the centers of tropical cyclones behave similarly.

As little as a 7% per °C slowdown in mean TC translation speed would ostensibly double the increase in local rain-fall impacts due to rain-rate increases.

Change in TC translation speed
68-year period 1949–2016

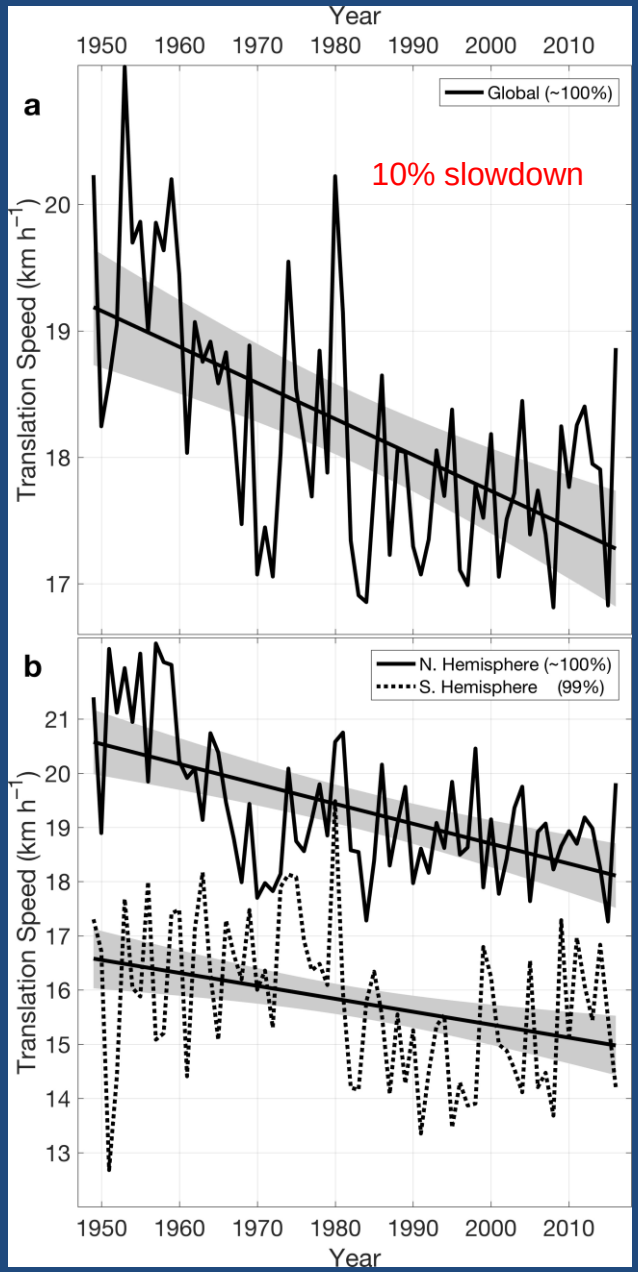
Global-average surface temperature has increased by about 0.5°C over this period.

It's not clear yet whether the two are linked.

The change varies by region and latitude, but slowing is found in every basin except the Northern Indian Ocean.

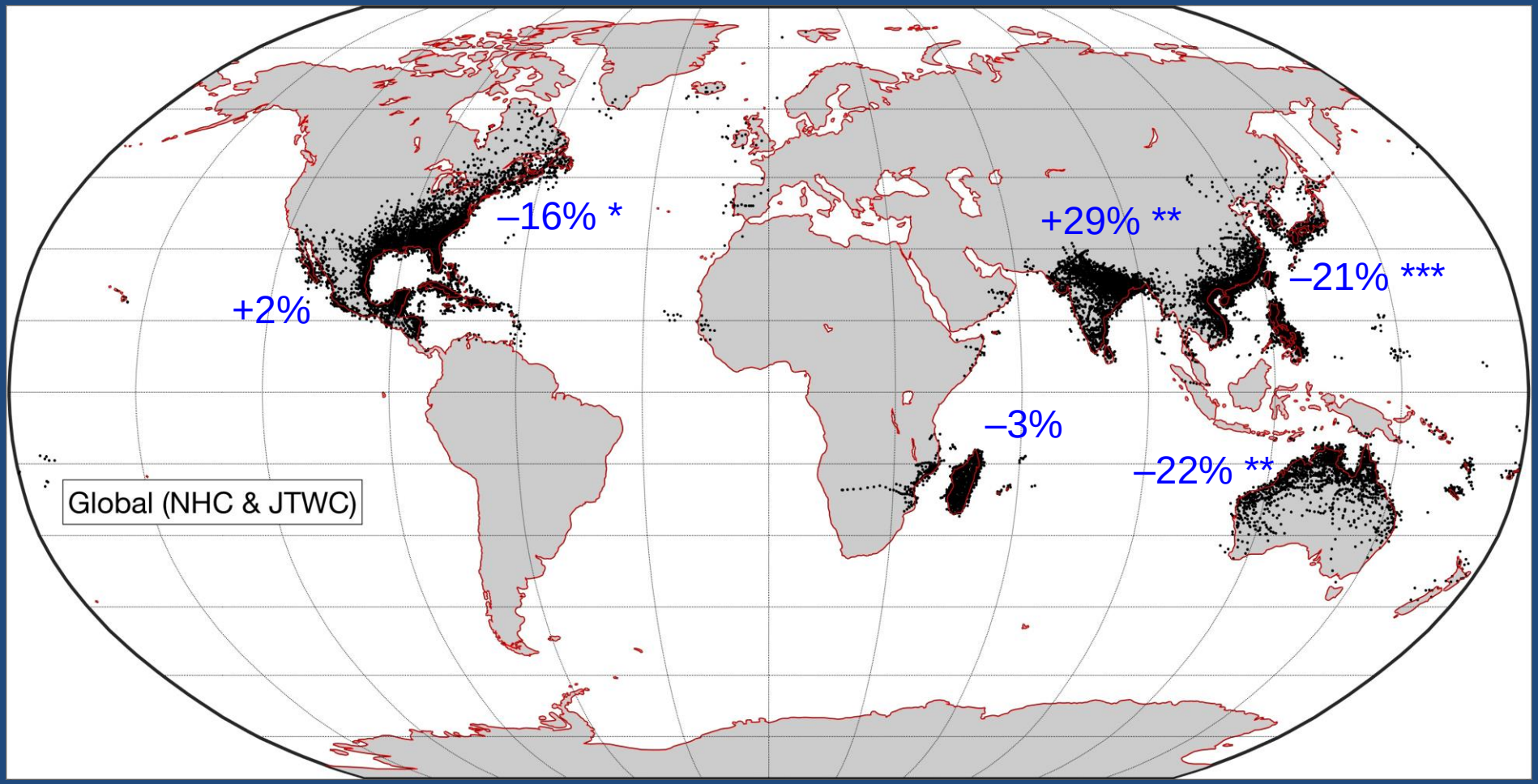
The slowdown is greatest in the western North Pacific (16%) and the region around Australia (14%).

There has been a 6% slowdown in the North Atlantic.



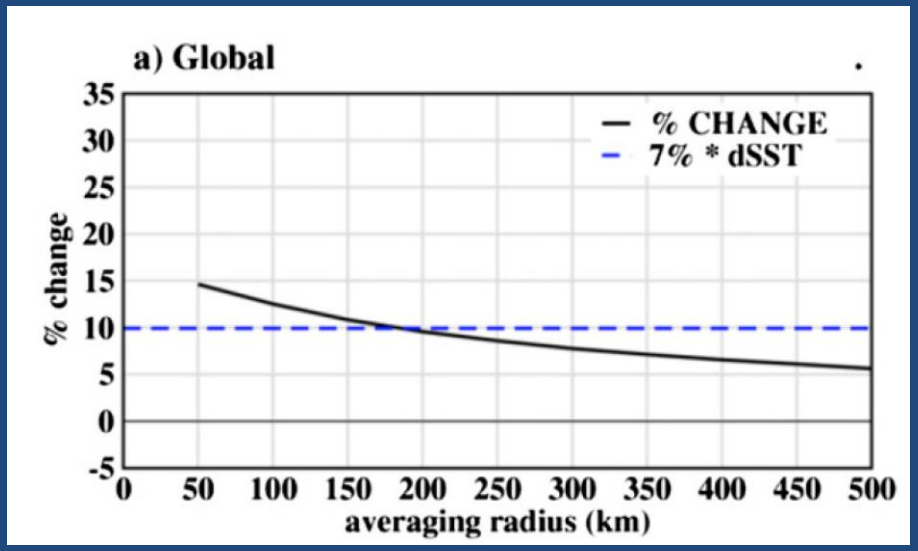
Kossin, J. P., 2018: A global slowdown of tropical cyclone translation speed. *Nature*, **558**, 104-108.

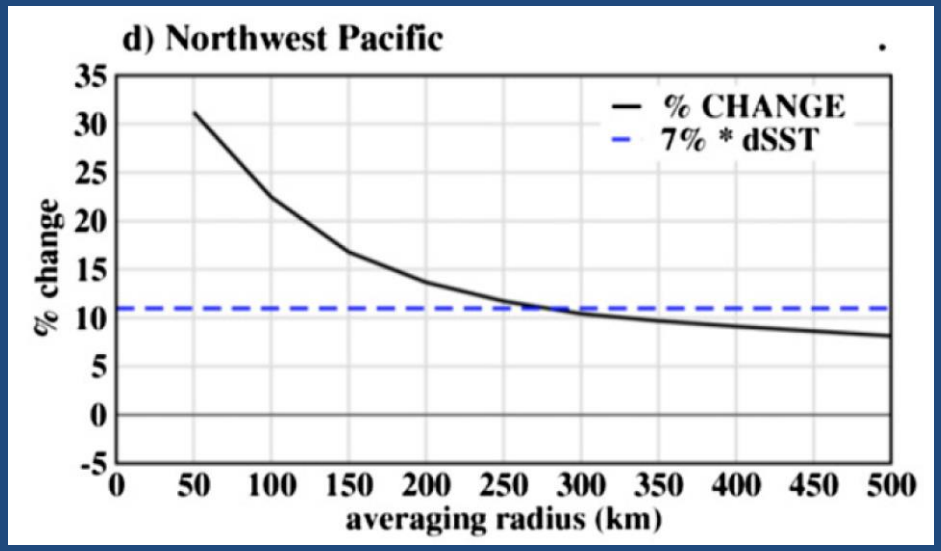
The potential impact of slowing TC translation speed on local rainfall amounts is most relevant for TCs over land.



Kossin, J. P., 2018: A global slowdown of tropical cyclone translation speed. *Nature*, **558**, 104-108.

Simulated changes in tropical cyclone rain-rates





~ 7% per degree

Note that the rain-rate increases are greatest under the eyewall and decrease with increasing distance from TC center. The increase in local rainfall amount due to a slowdown would be the same everywhere.

Knutson, T. R., J. J. Sirutis, M. Zhao, R. E. Tuleya, M. Bender, G. A. Vecchi, G. Villarini, and D.Chavas, 2015: Global projections of intense tropical cyclone activity for the late twenty-first century from dynamical downscaling of CMIP5/RCP4.5 scenarios. *J. Climate*, **28**, 7203–7224.

Closing Remarks

Moving beyond frequency- and intensity-based measures of hurricane activity allows for greater confidence in the analysis of longer time series.

When we do this, trends emerge that are difficult to explain entirely as due to natural variability.

Regardless of cause, the observed changes have substantially affected the risk landscape.

Numerical projections suggest that the poleward migration of hurricanes will continue in the 21st century. There is less evidence for continued slowing (work in progress).

The Atlantic continues to march to a different drummer. It remains unclear whether we will ever see a period of hurricane quiescence comparable to that observed in the 1970s to 1980s. Still, there is some expectation, based on natural decadal variability, that the pendulum will swing toward greater quiescence at some point.

However, if we do in fact enter another cool period, we may experience more rapidly intensifying hurricanes near the U.S. coast.

Bibliography

Knutson, T. R., J. J. Sirutis, M. Zhao, R. E. Tuleya, M. Bender, G. A. Vecchi, G. Villarini, and D.Chavas, 2015: Global projections of intense tropical cyclone activity for the late twenty-first century from dynamical downscaling of CMIP5/RCP4.5 scenarios. *J. Climate*, **28**, 7203–7224.

Kossin, J. P., 2018: A global slowdown of tropical cyclone translation speed. *Nature*, **558**, 104-108.

Kossin, J. P., 2018: Comment on “Spatial and temporal trends in the location of the lifetime maximum intensity of tropical cyclones”. *Atmosphere*, **9**, 241-244.

Kossin, J. P., 2017: Hurricane intensification along United States coast suppressed during active hurricane periods. *Nature*, **541**, 390–393, doi:10.1038/nature20783.

Kossin, J. P., K. A. Emanuel, and S. J. Camargo, 2016: Past and projected changes in western North Pacific tropical cyclone exposure. *J. Climate*, **29**, 5725-5739.

Kossin, J. P., K. A. Emanuel, and G. A. Vecchi, 2014: The poleward migration of the location of tropical cyclone maximum intensity. *Nature*, **509**, 349-352.

Kossin, J. P., T. L. Olander, and K. R. Knapp, 2013: Trend analysis with a new global record of tropical cyclone intensity. *J. Climate*, **26**, 9960-9976.