Atlantic tropical cyclones and climate: observed changes

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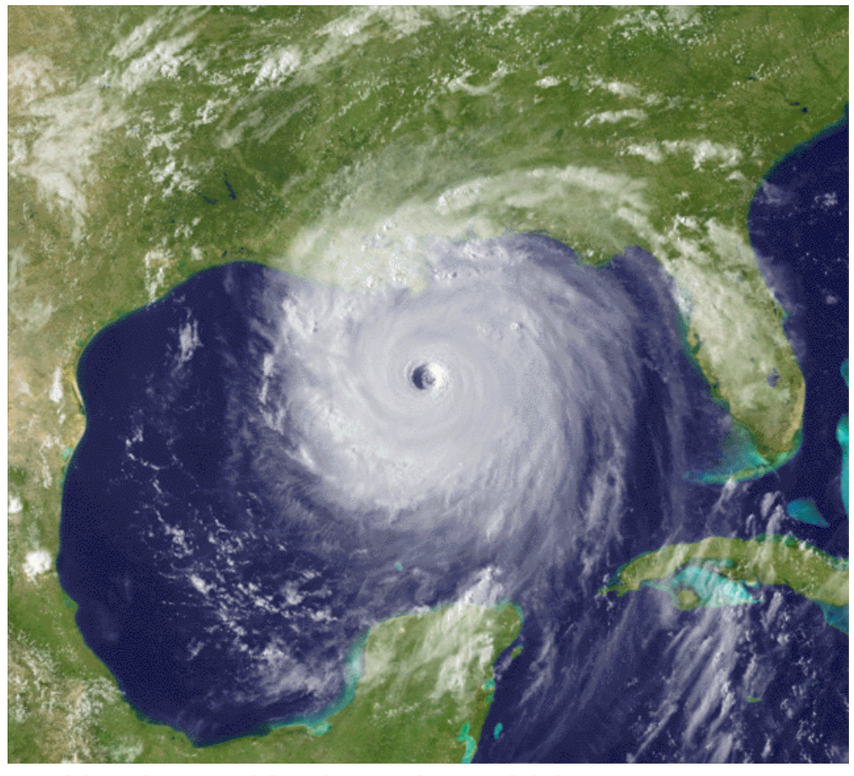
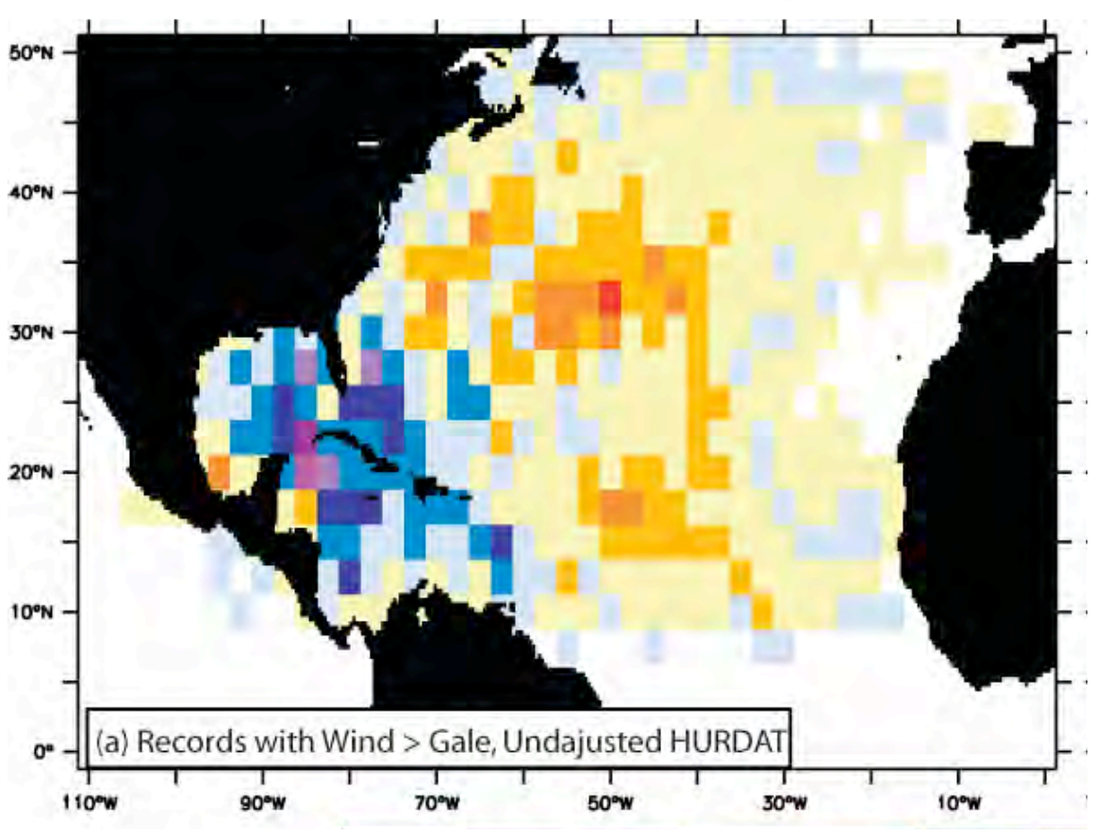
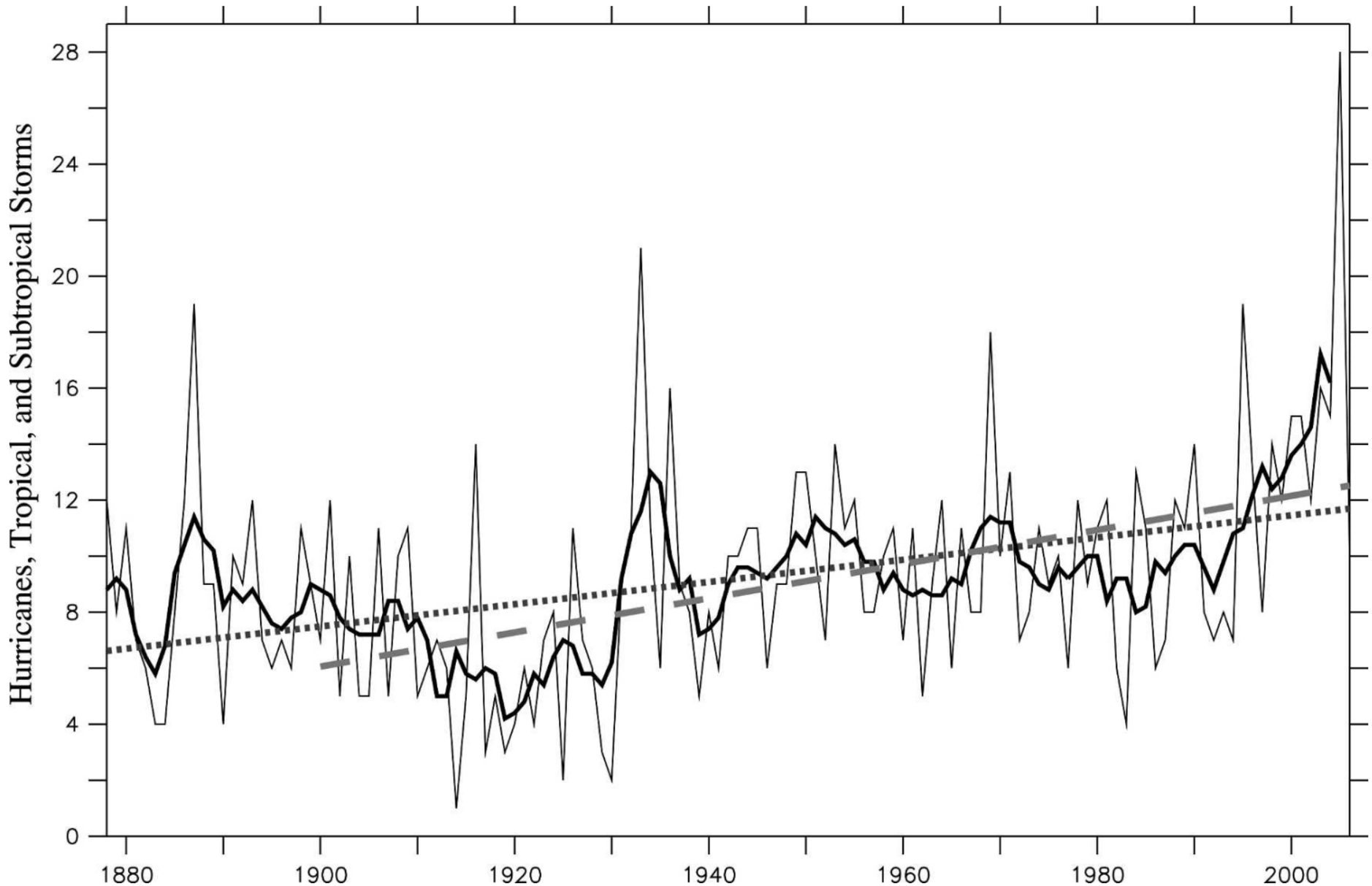


Hurricane Katrina, Aug. 2005

Trend in storm track density (1878-2006)

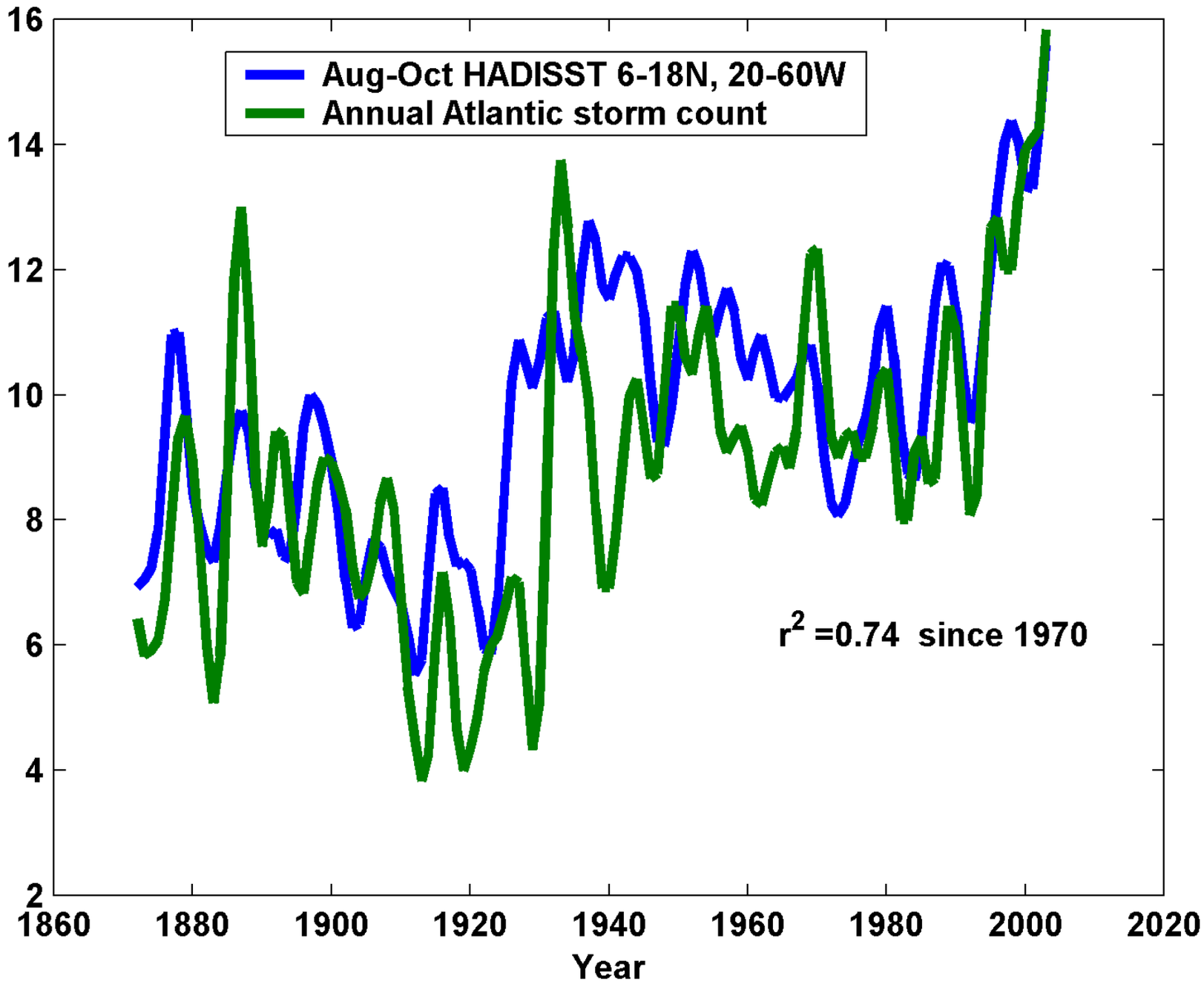


Clear increase in recorded number of Atlantic tropical storms since late-19th Cy.



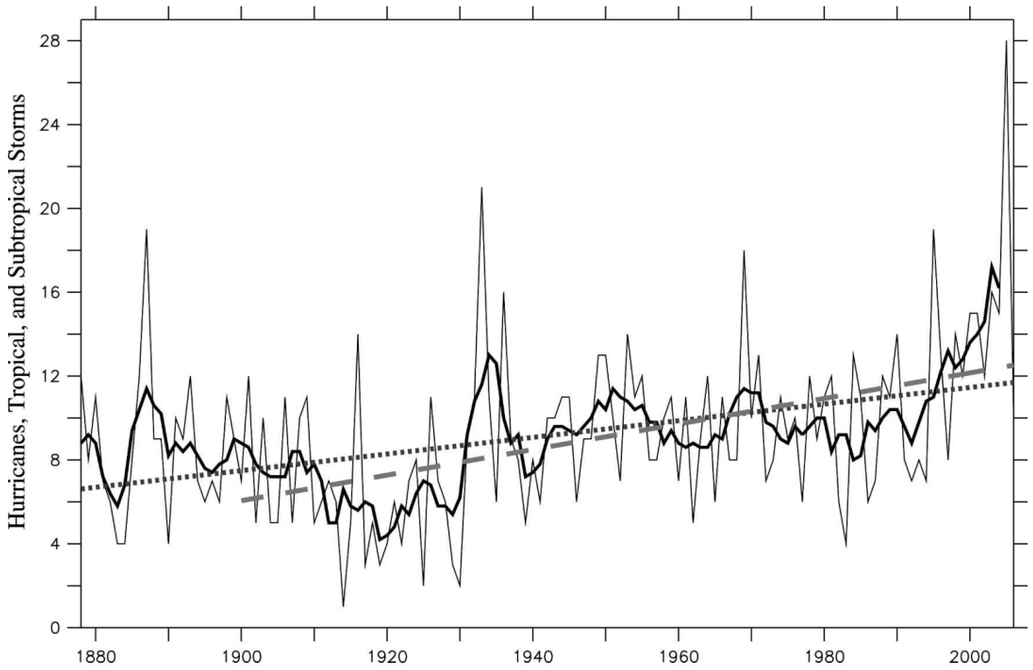
Source: Vecchi and Knutson , J. Climate, 2008.

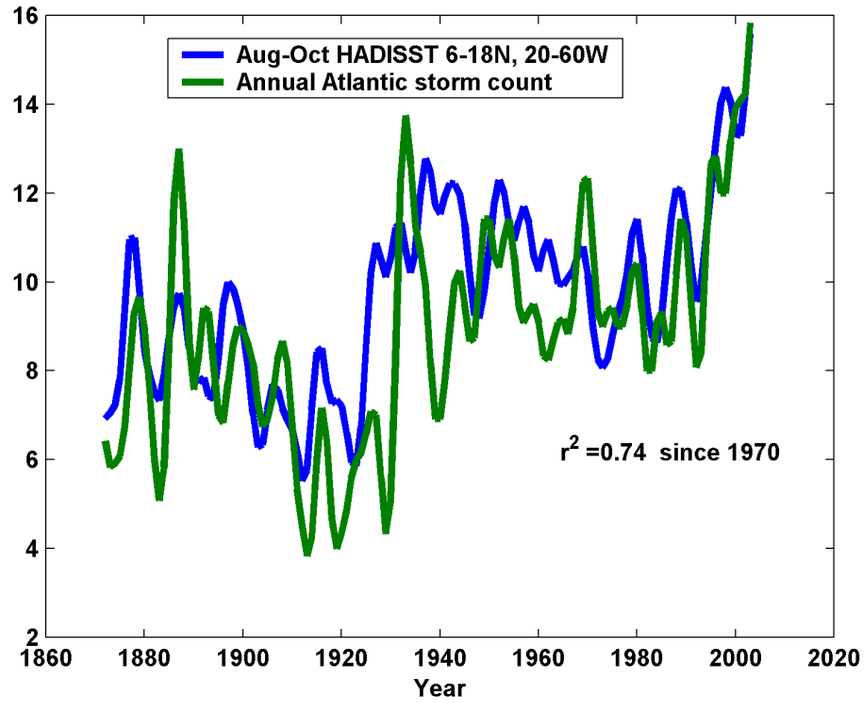
Records of Atlantic TS Frequency well-correlated to Atlantic SST



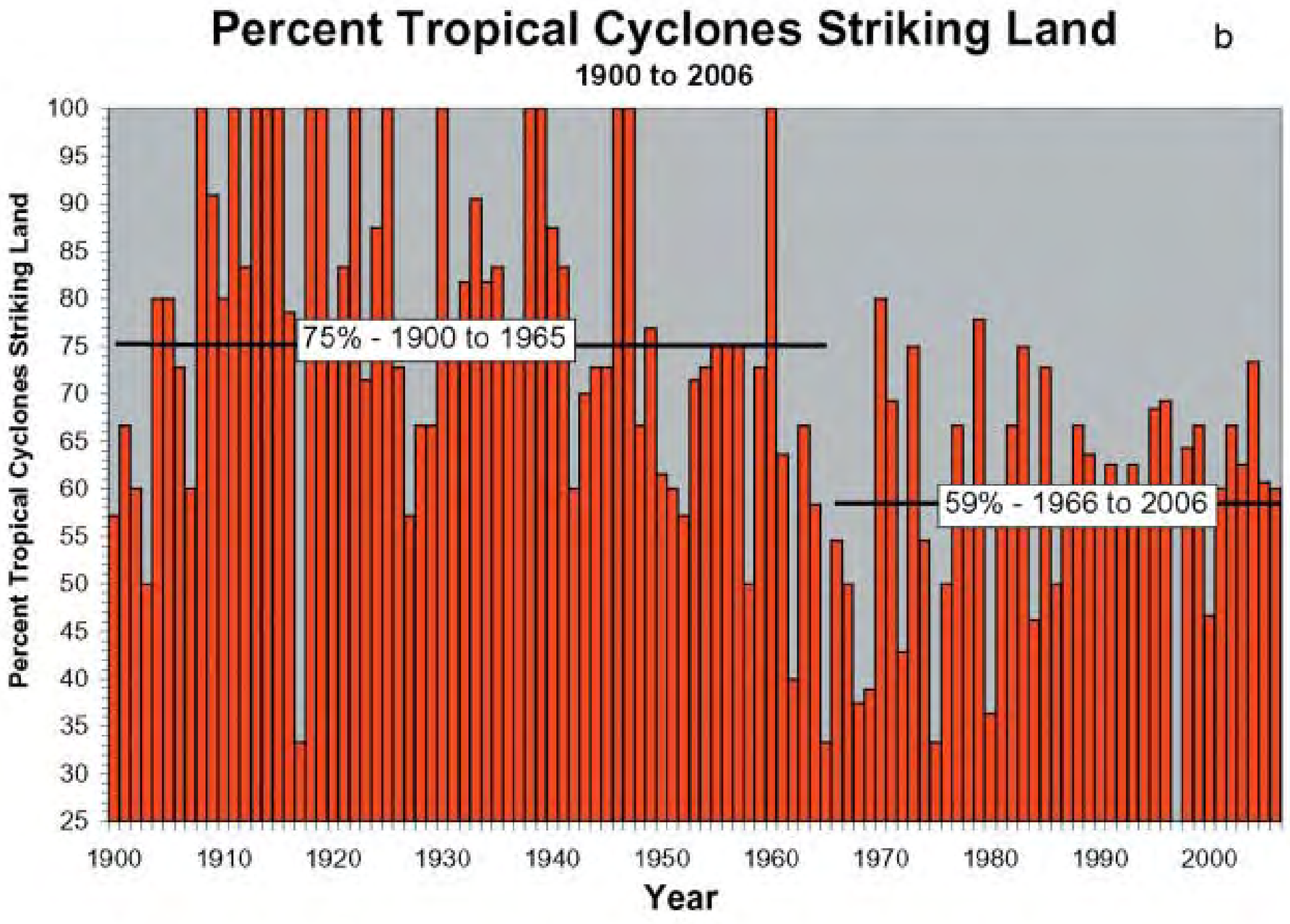
Source: Emanuel (2006); Mann and Emanuel (2006) EOS. See also Holland and Webster (2007) *Phil. Trans. R. Soc. A*

Real change in TS frequency?



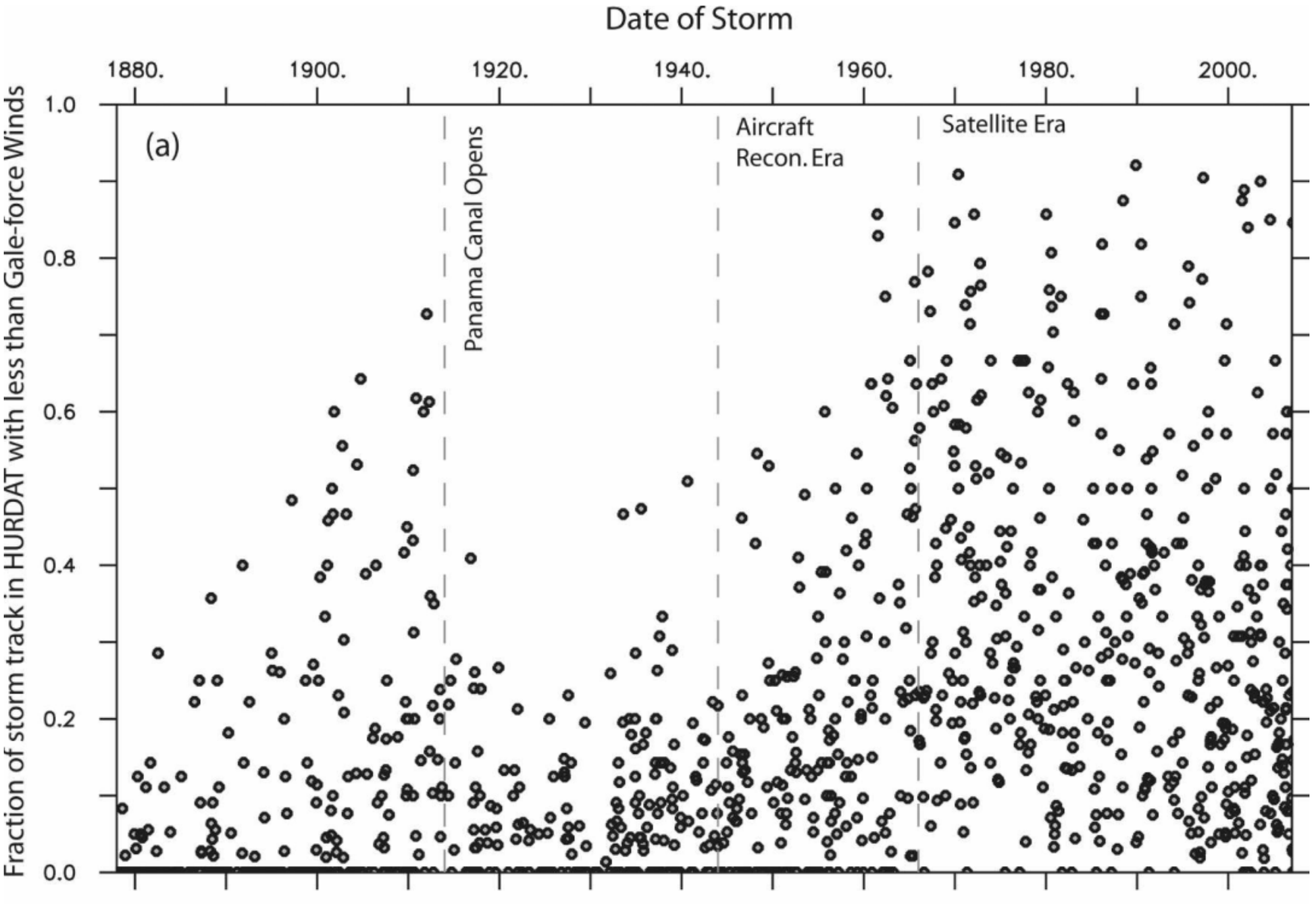


Characteristics of recorded storms exhibit strong secular changes, e.g., fraction of storms hitting land



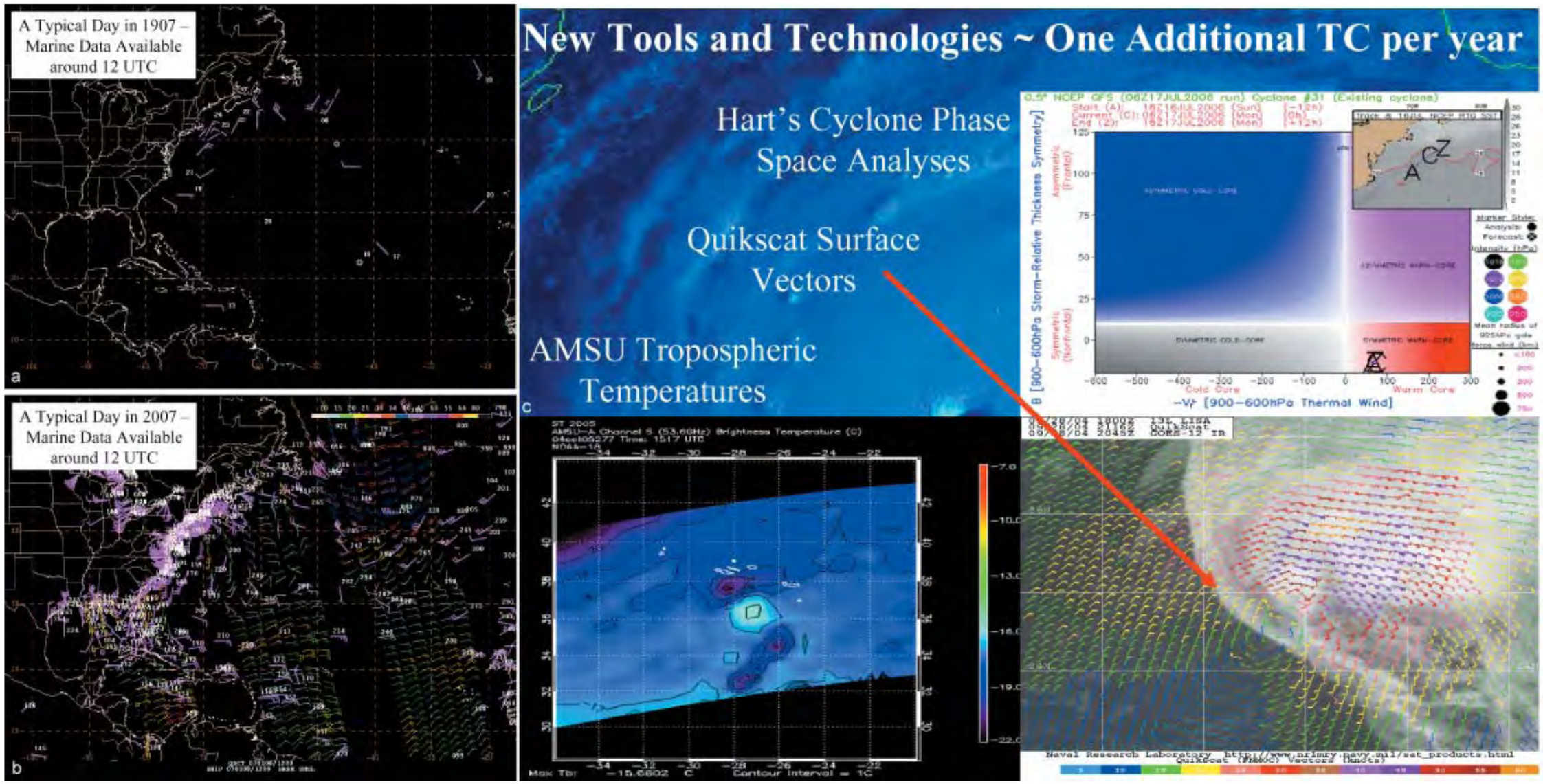
Source: Landsea, EOS, 2007.

Characteristics of recorded storms exhibit strong secular changes, e.g., time as tropical depression



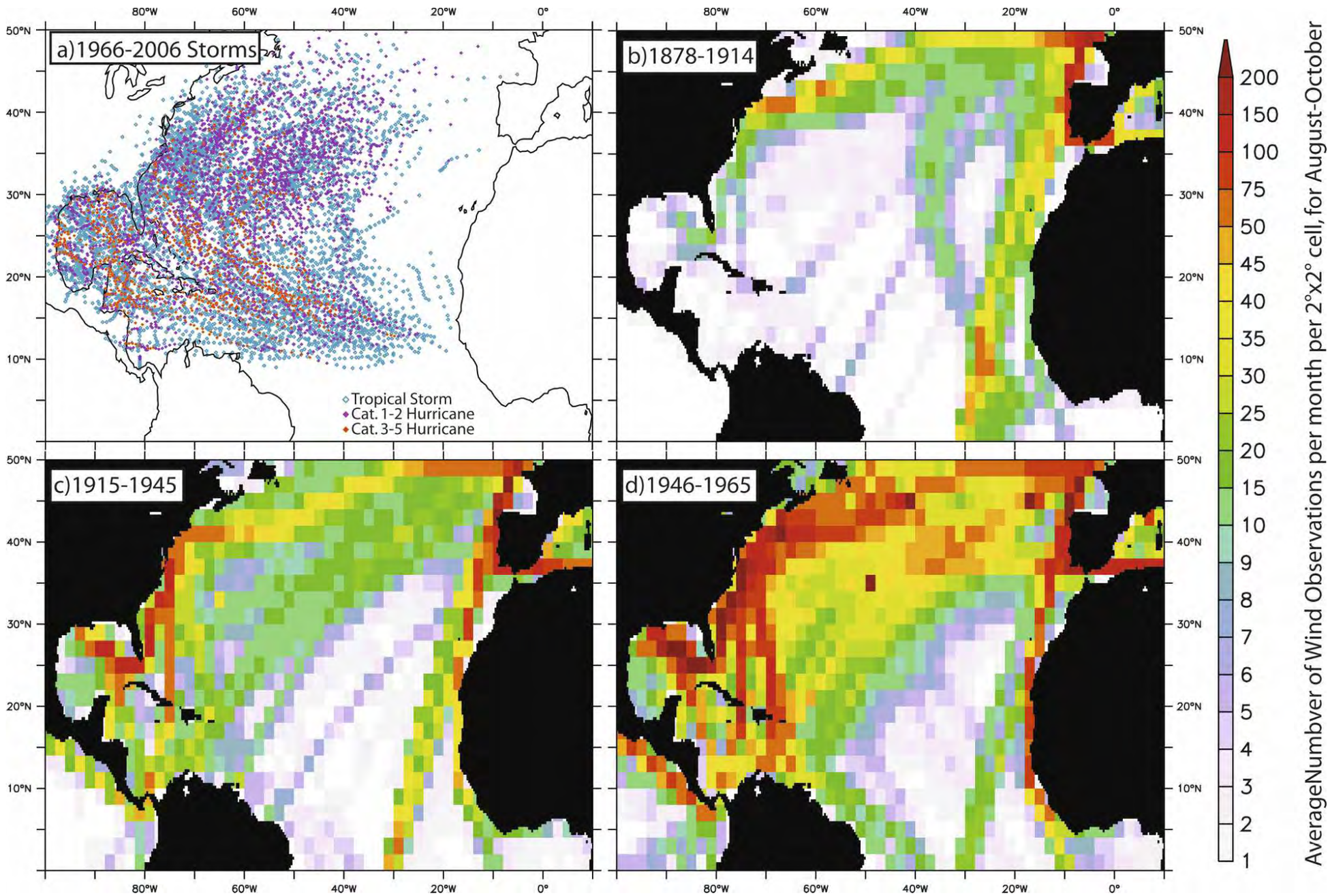
Source: Vecchi and Knutson , J. Climate, 2008.

Ability to observe cyclones has also changed with time: e.g., new technologies



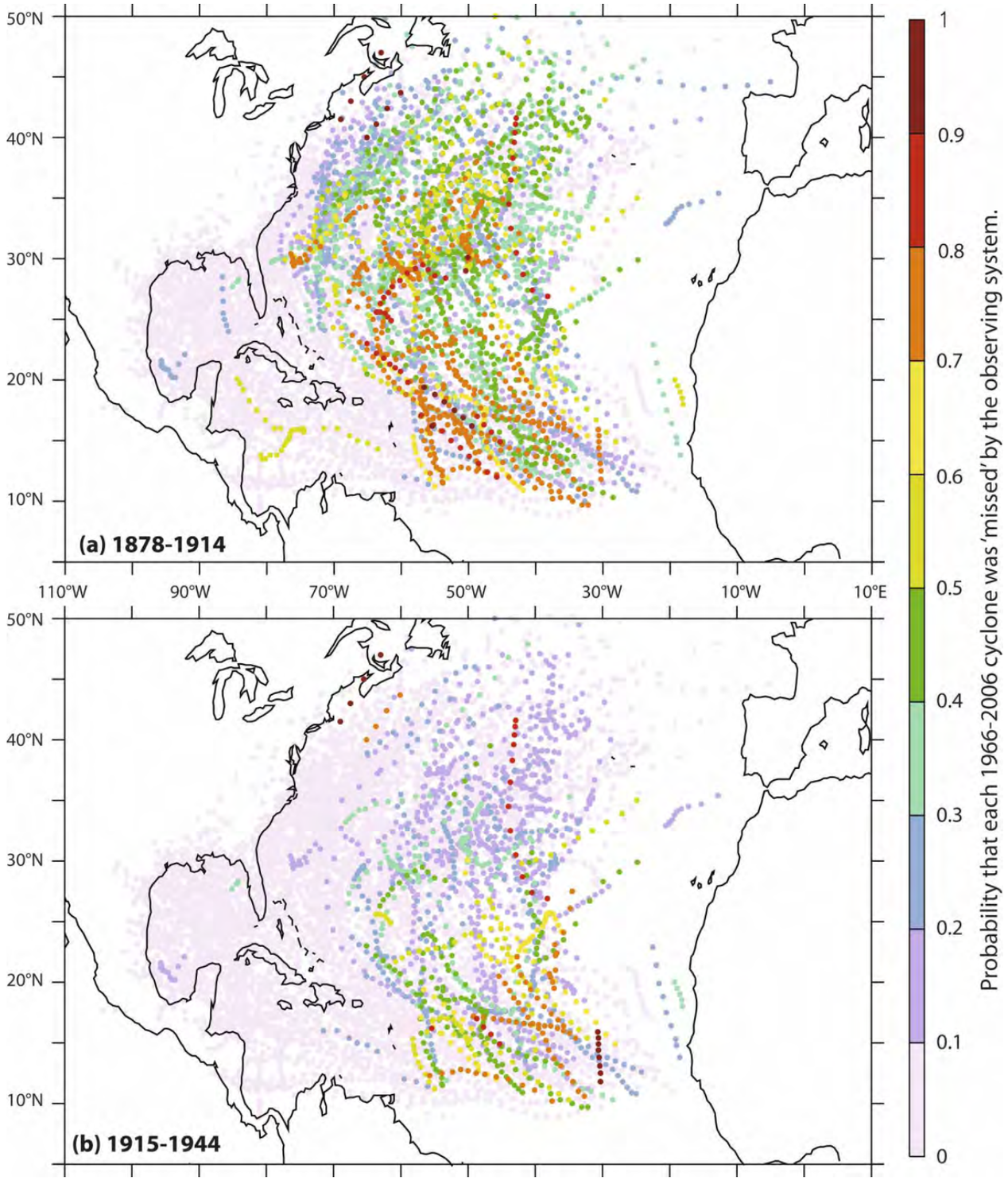
Source: Landsea, EOS, 2007.

Ability to observe cyclones has also changed with time: e.g., ship track density



Source: Vecchi and Knutson , J. Climate, 2008.

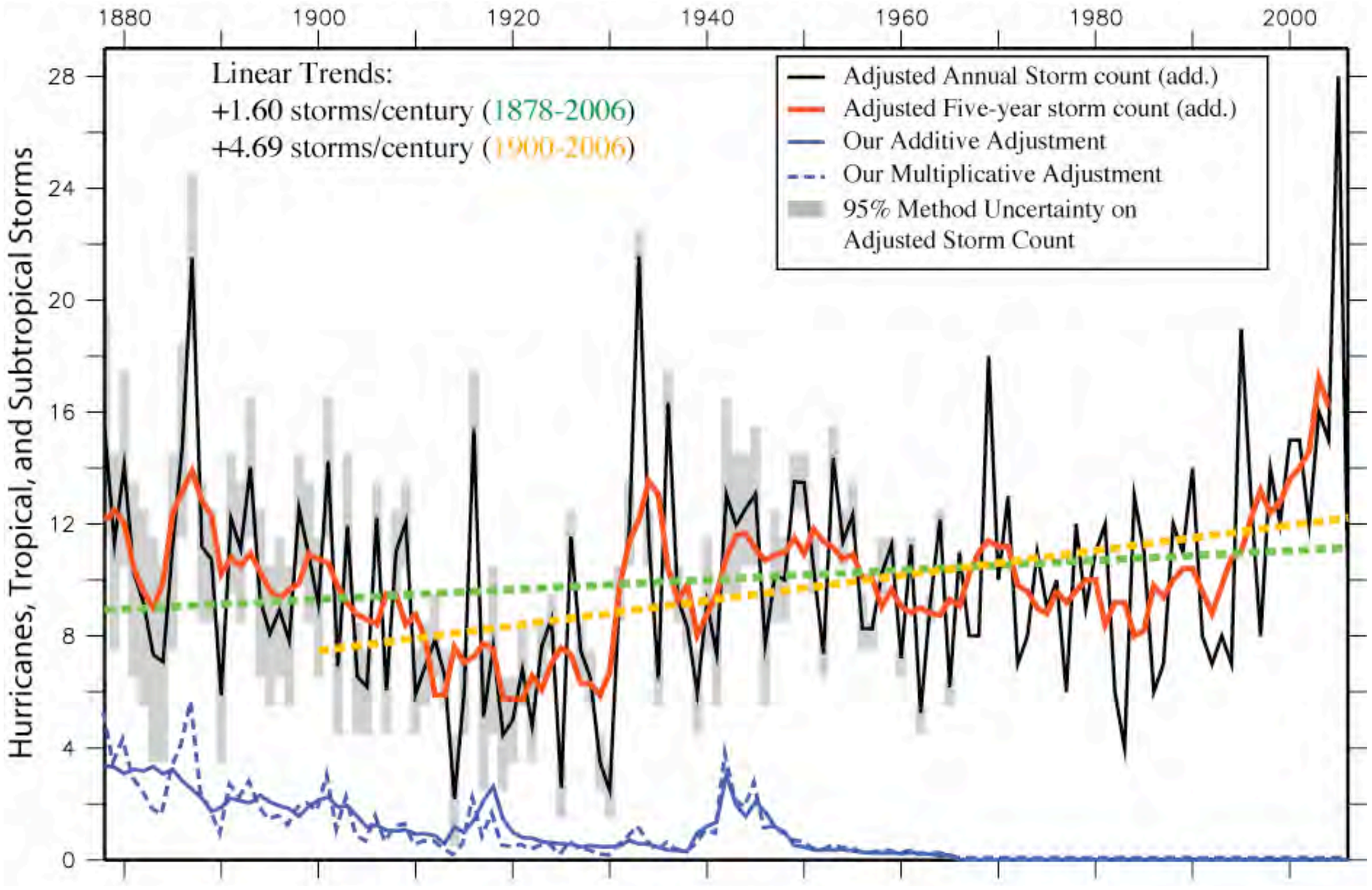
Probability we cannot exclude a storm from having been missed



- Storms near land least likely to have been "missed"
- "Detectability" increases with time.

Source: Vecchi and Knutson , J. Climate, 2008.

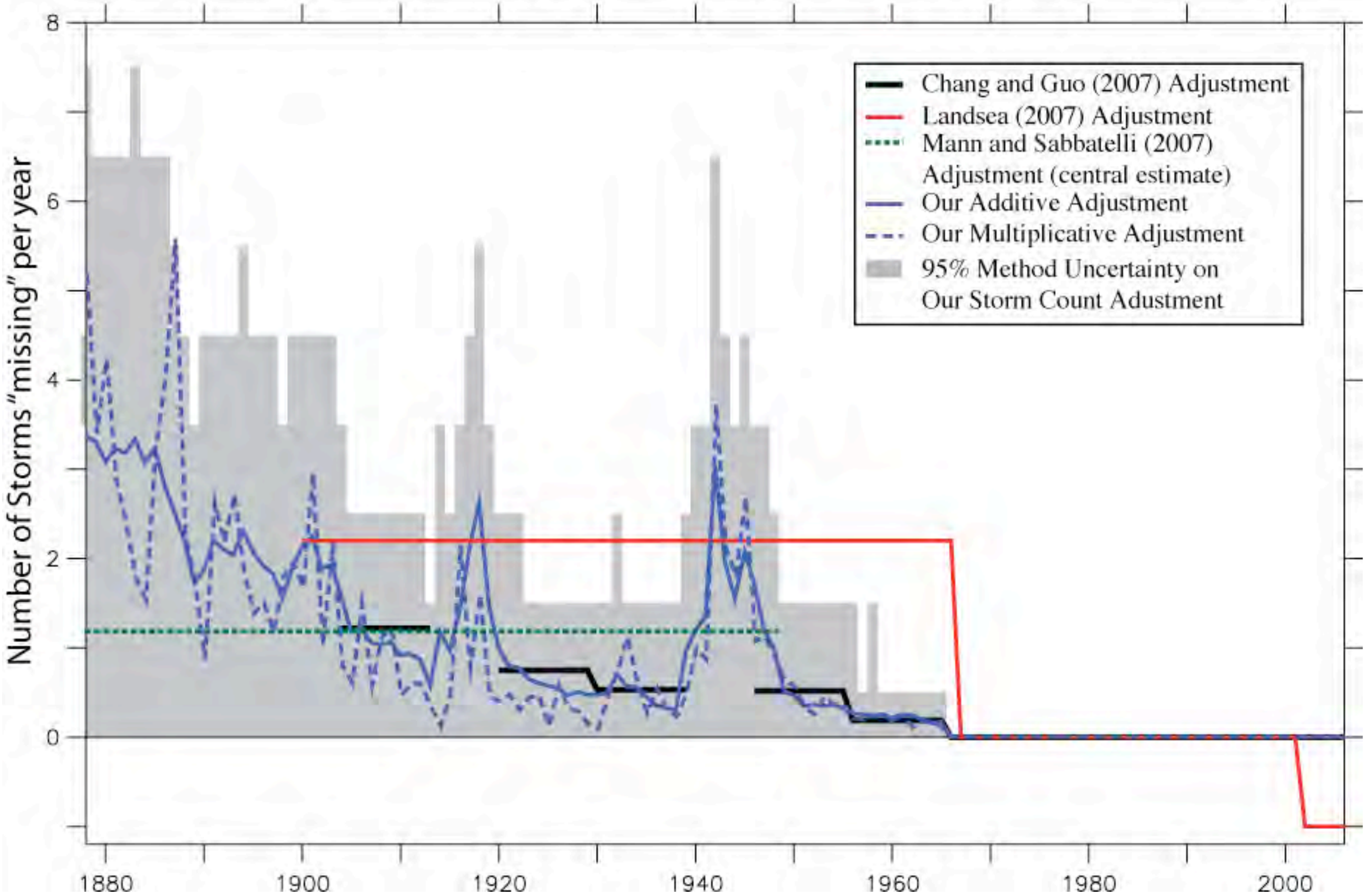
Atlantic Tropical Storm counts show no significant trend from 1878 after adjusting for 'missing storms' based on ship track densities.



Trend from 1878-2006: Not significant (p=0.05, 2-sided tests, computed p-val ~0.2)
Trend from 1900-2006: Is significant at p=0.05 level

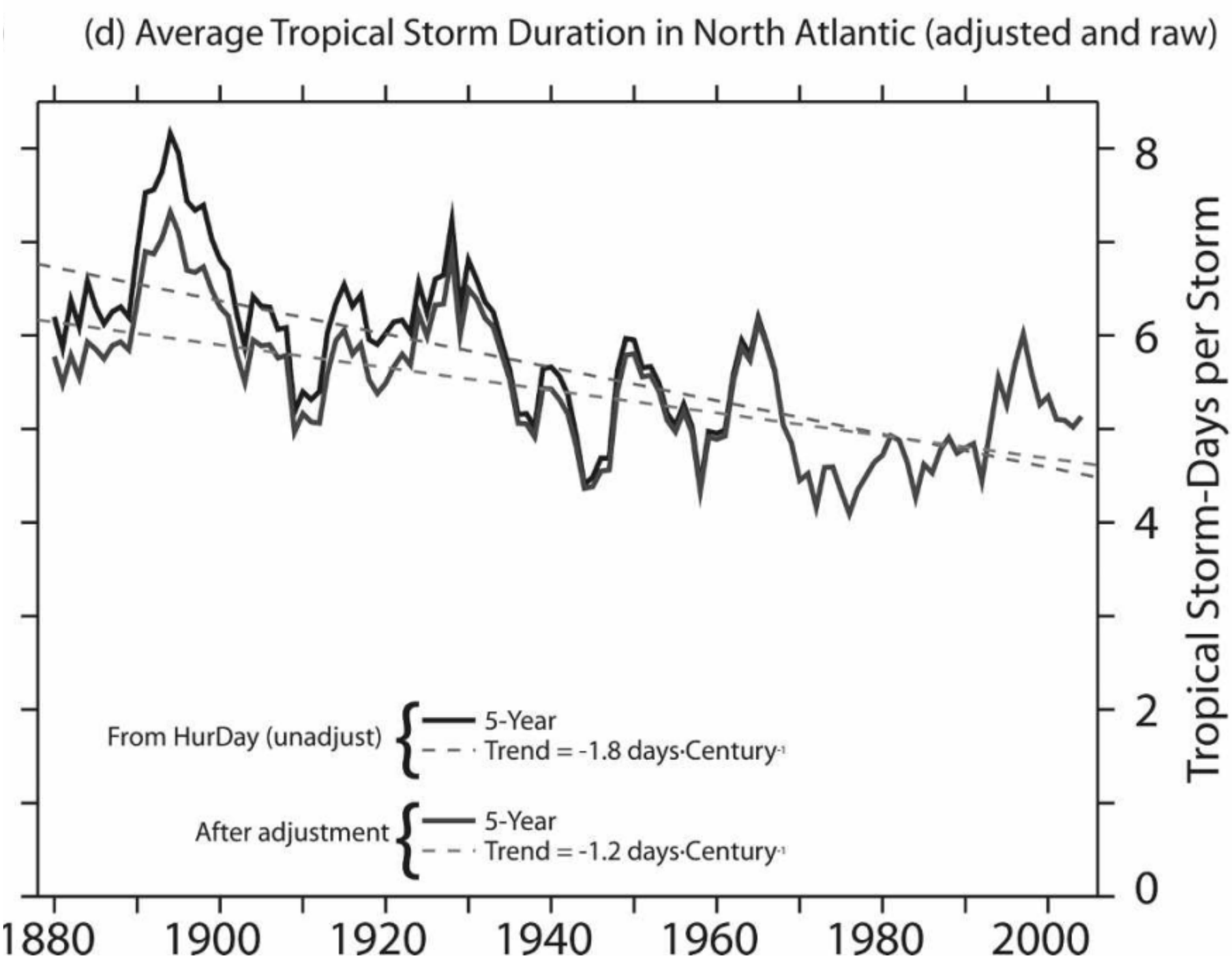
Source: Vecchi and Knutson, J. Climate, 2008.

Missing storm adjustments to HURDAT storms (1878-2007)



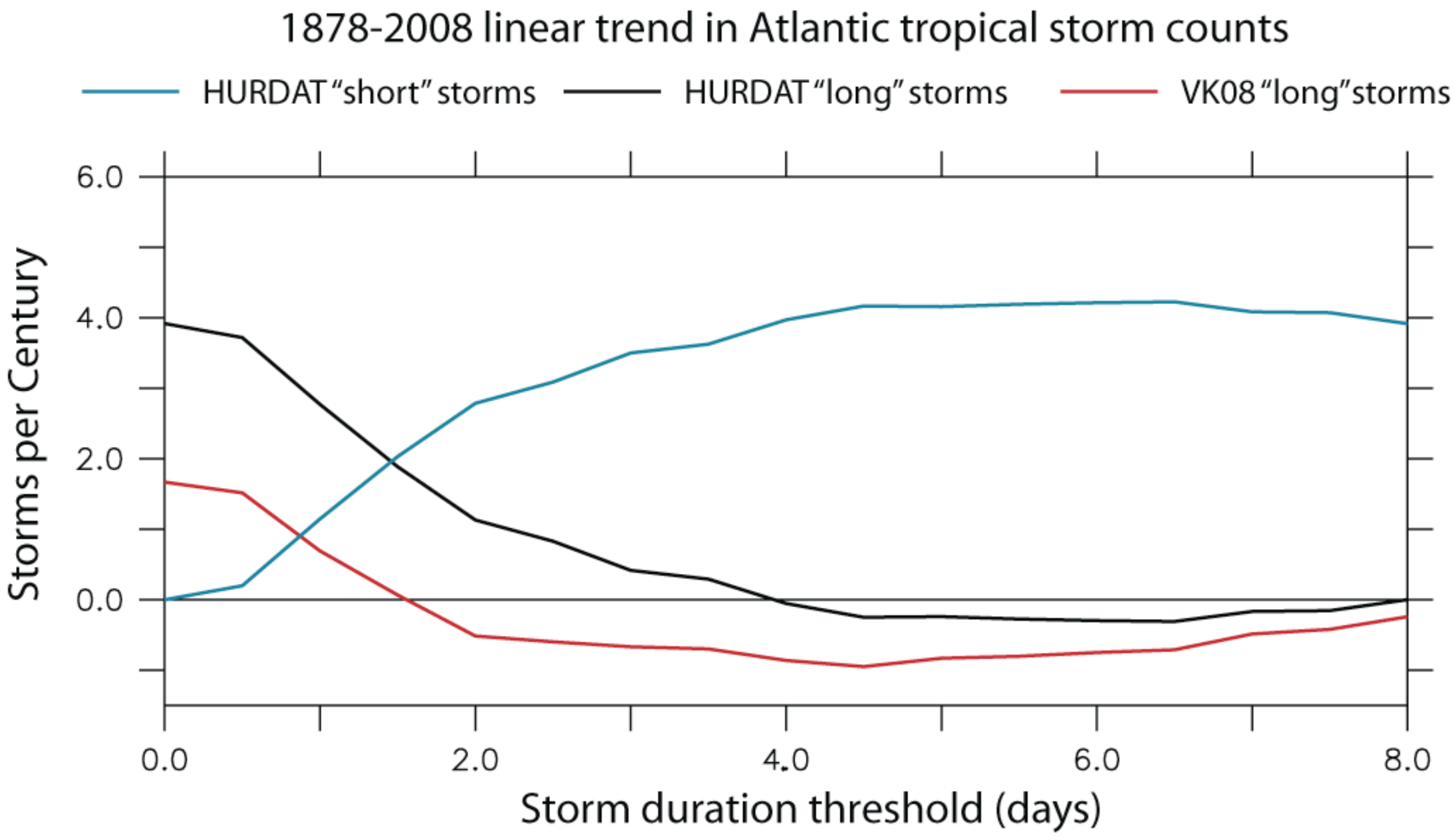
Source: Vecchi and Knutson, J. Climate, 2008.

Tropical storm duration exhibits a large decrease, even with adjustment: why?



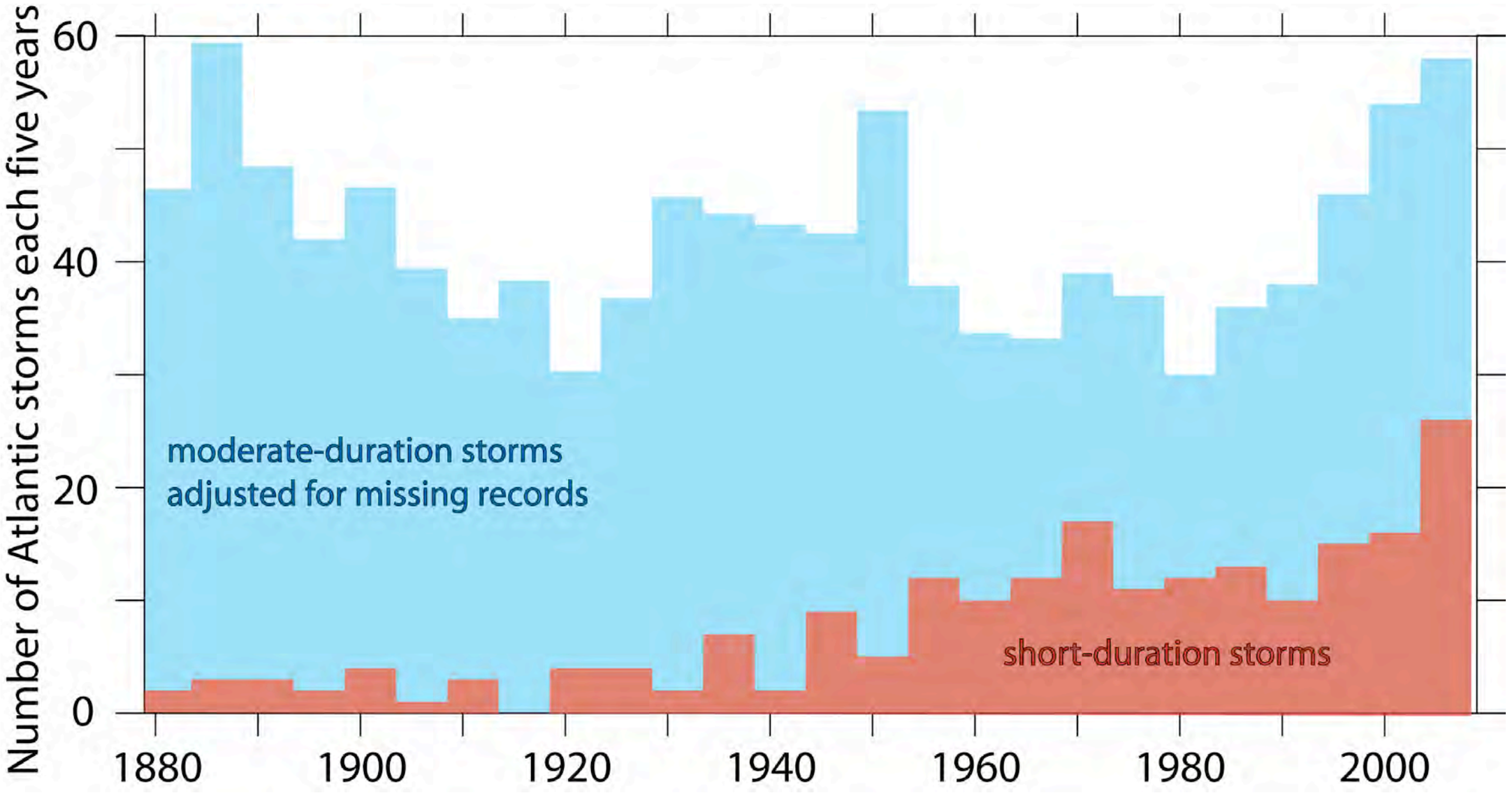
Source: Vecchi and Knutson, J. Climate, 2008.

Recorded increase in storm counts comes from short duration storms



Source: Landsea, Vecchi, Bengtsson and Knutson, J. Climate, 2010.

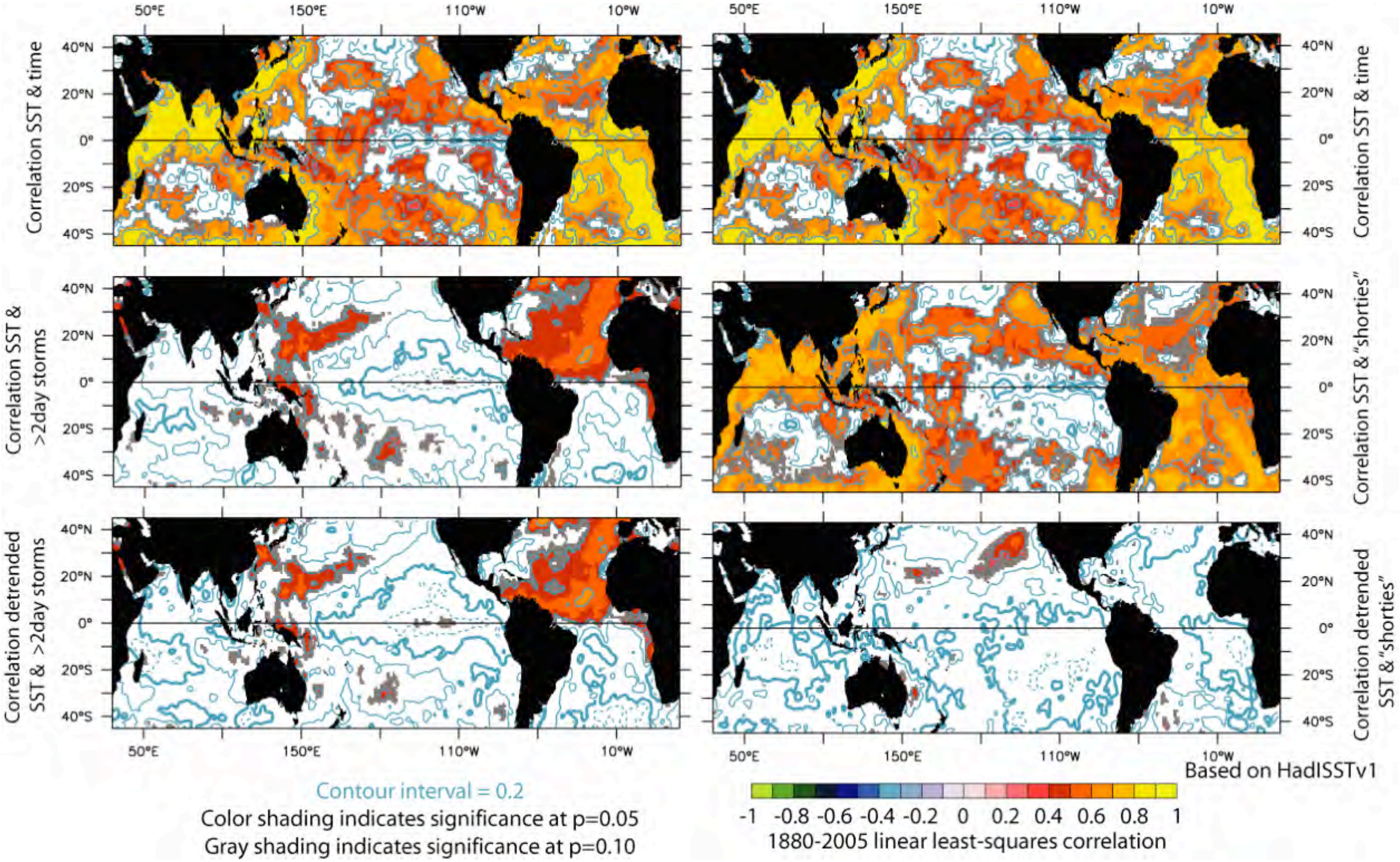
Atlantic tropical storms (< 2 day duration) show a strong rising trend, but storms of >2 day duration--adjusted for missing storms--do not show a trend.



Adapted from: Landsea, Vecchi, Bengtsson and Knutson, J. Climate, 2010.

>2day duration storms show a physically-sensible correlation to SST

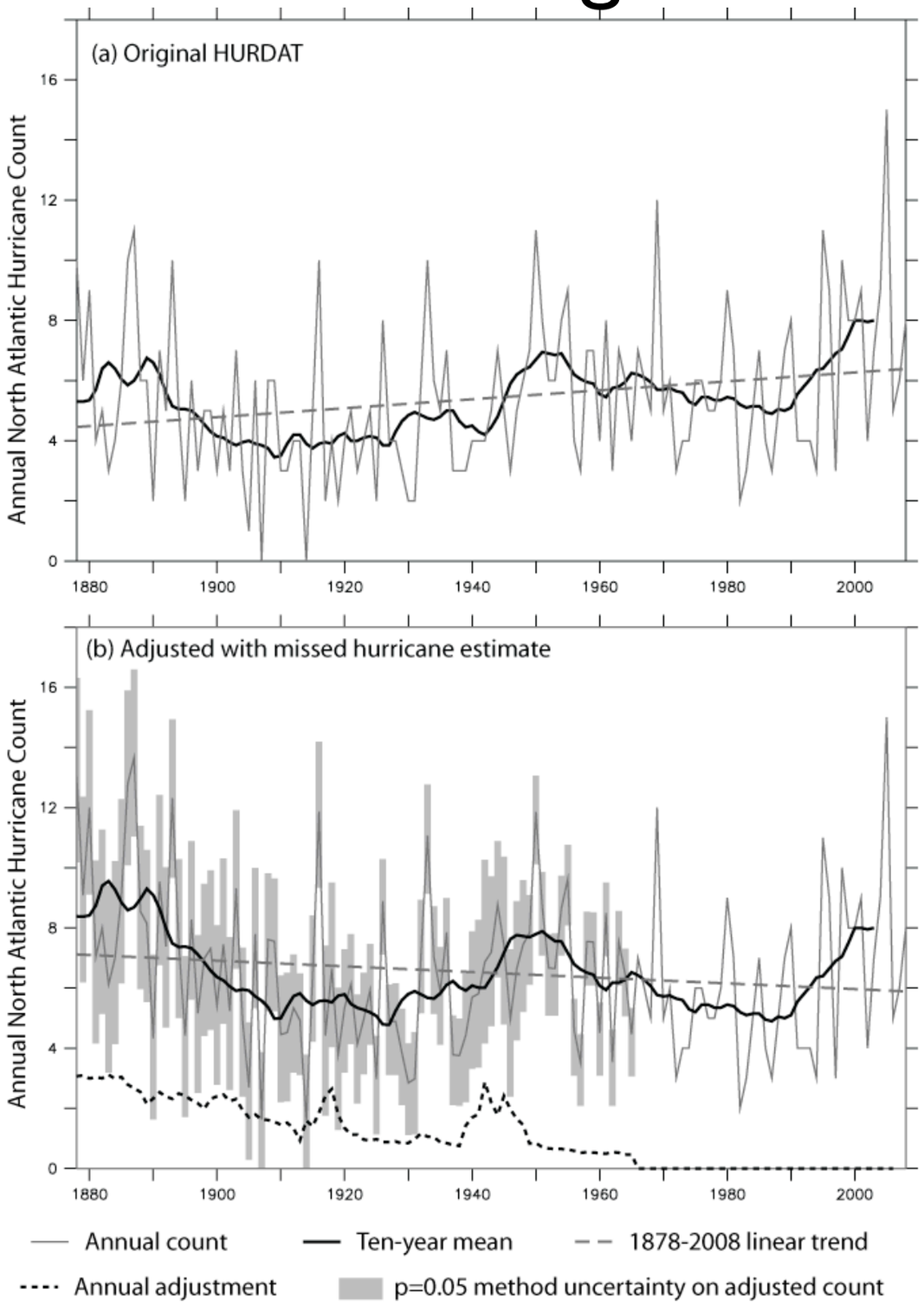
Short duration storms don't exhibit correlation to SST beyond sharing trend



Adapted from: Villarini, Vecchi, Smith and Knutson, J. Geophys. Res., 2011.

Hurricane frequency

Adjustment to hurricane counts leads to a nominal long-term decrease in hurricanes.

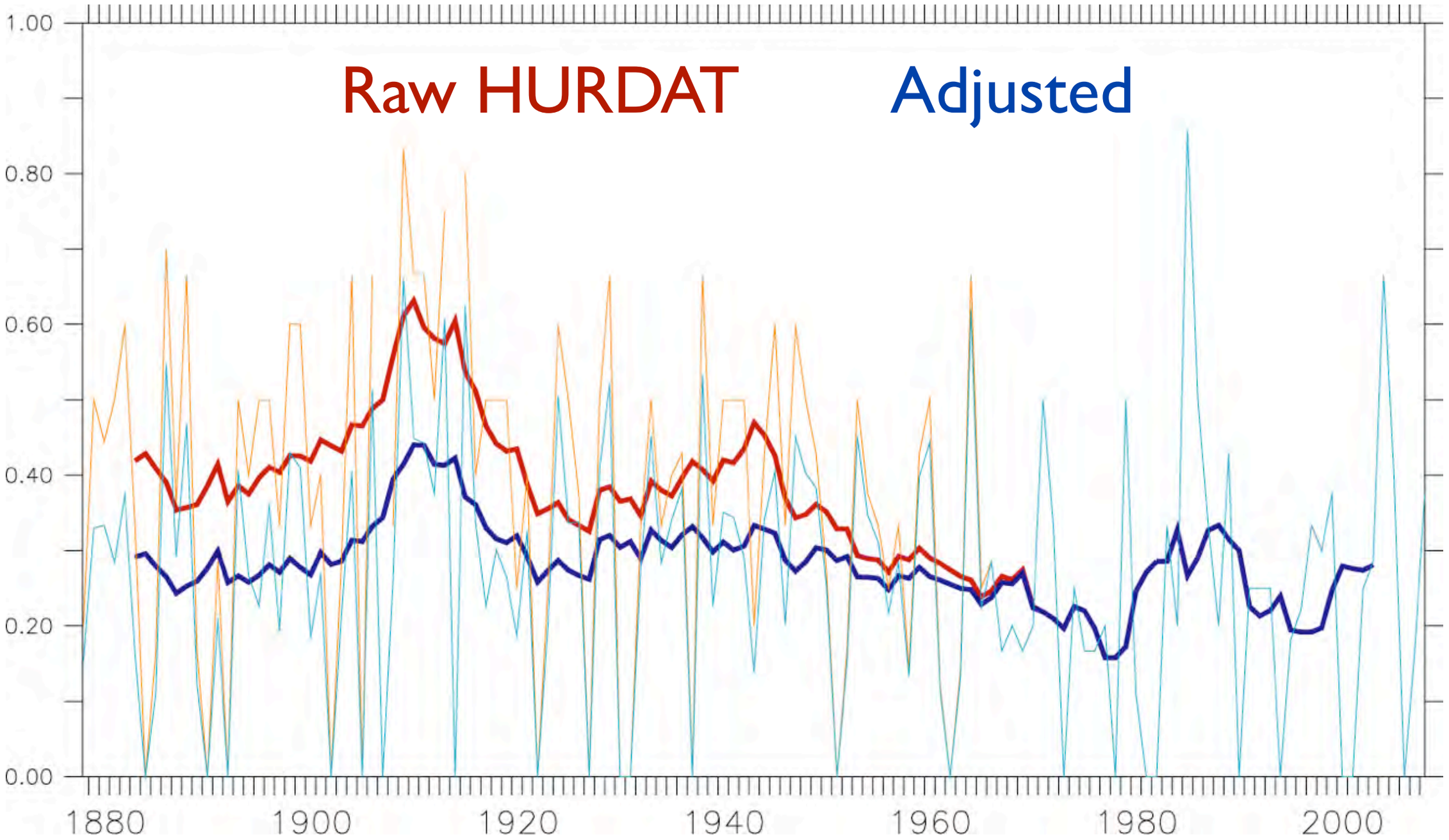


Significant increase in HURDAT recorded hurricane frequency

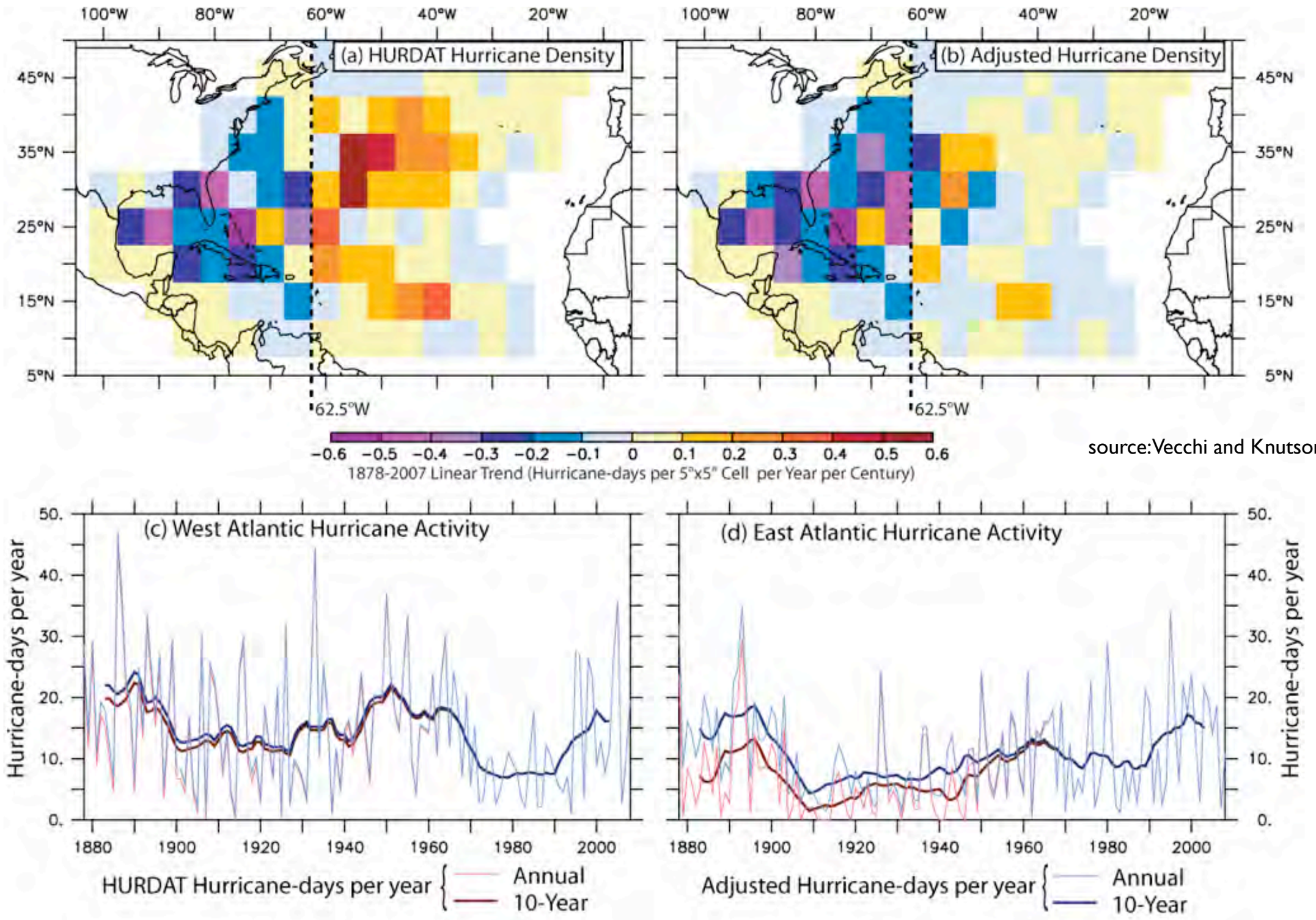
Accounting for observing system changes, cannot reject null hypothesis of no long-term change in frequency.

source: Vecchi and Knutson (2011, J. Climate)

Fraction of Hurricanes Making U.S. Landfall as Hurricanes



Hurricane activity shifts eastward in long-term (similar change in TSs)

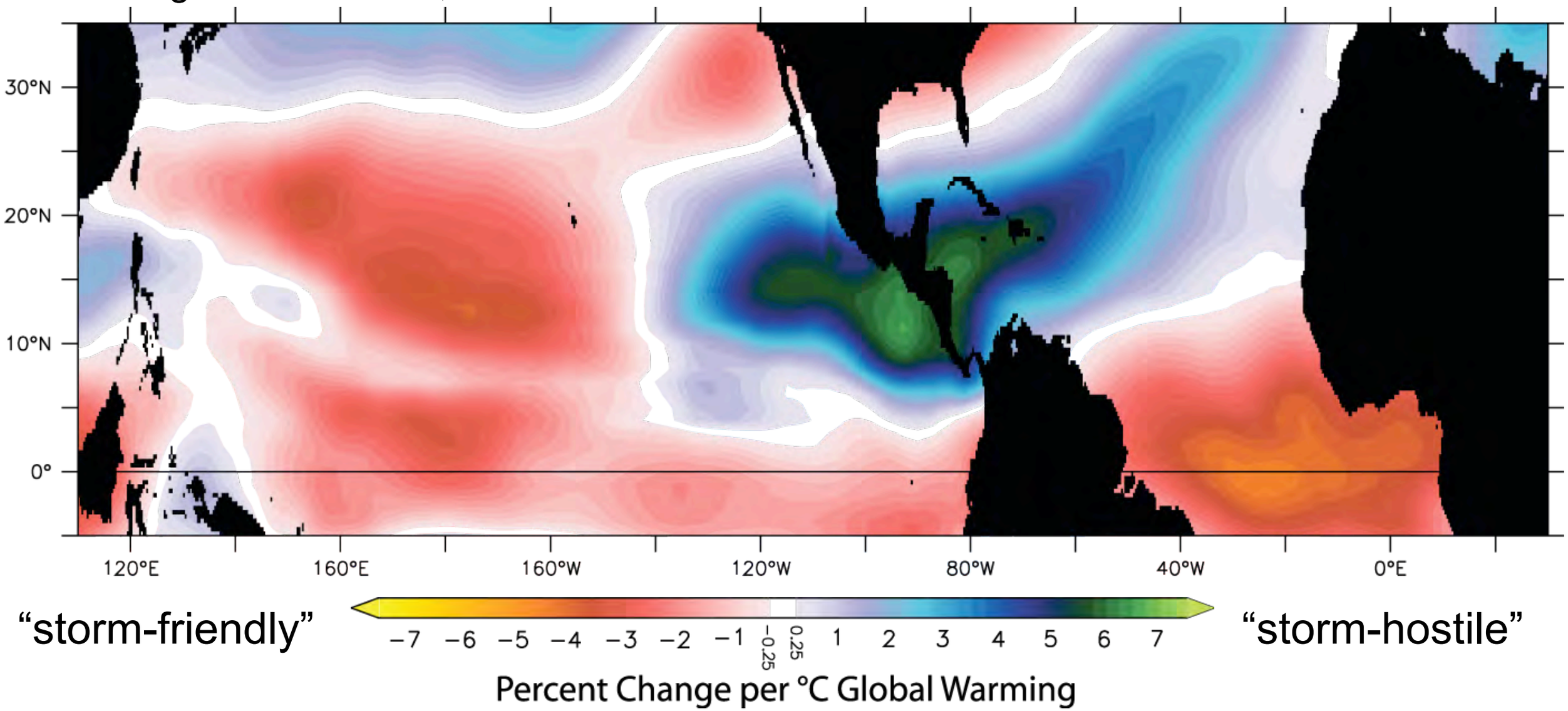


source:Vecchi and Knutson (2011)

Projected 21st Century Changes in Vertical Wind Shear

from Vecchi and Soden (2007, GRL)

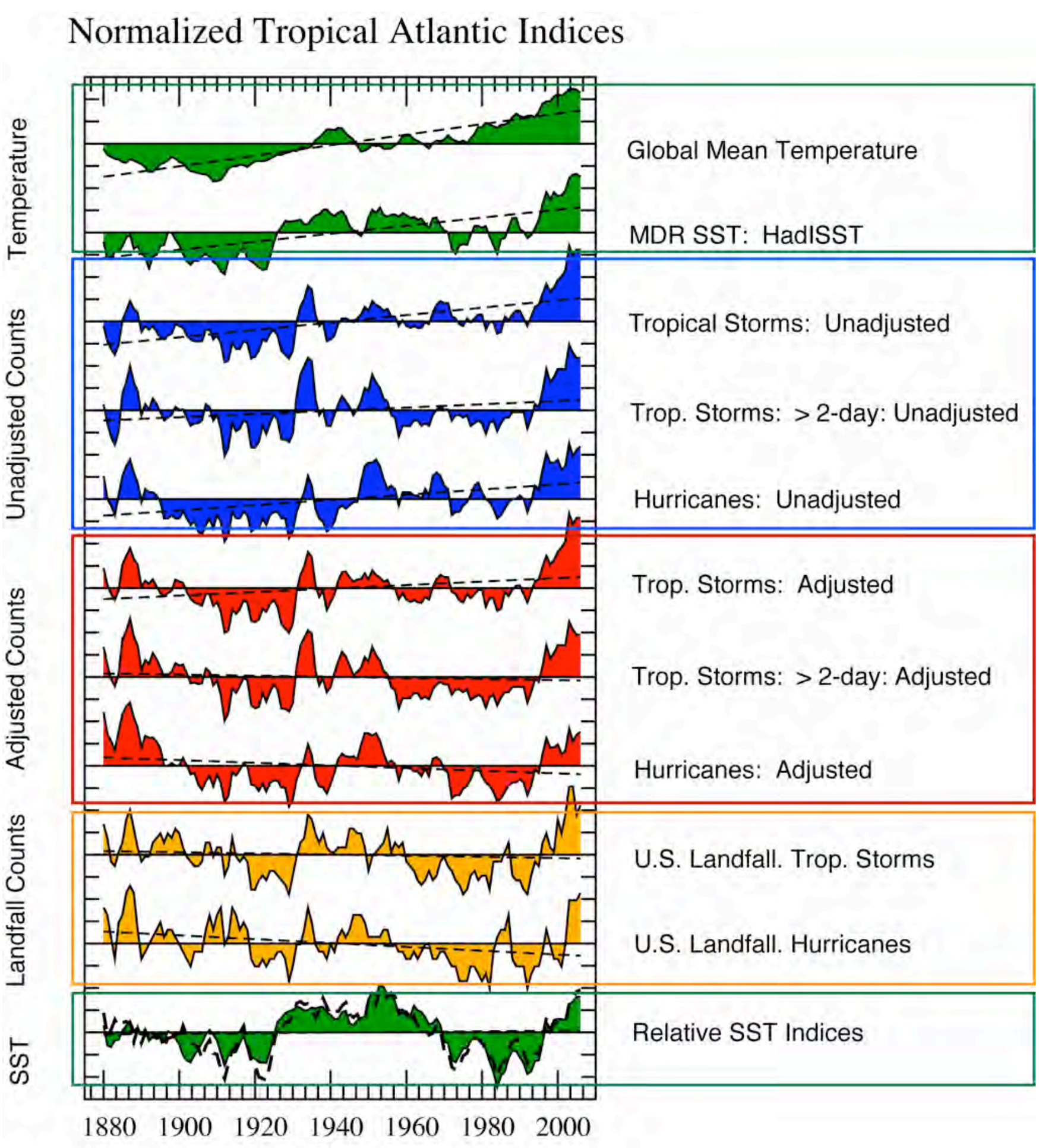
Average of 18 models, Jun-Nov



"storm-friendly" "storm-hostile"

Over swath of tropical Atlantic and East Pacific, increased wind-shear.

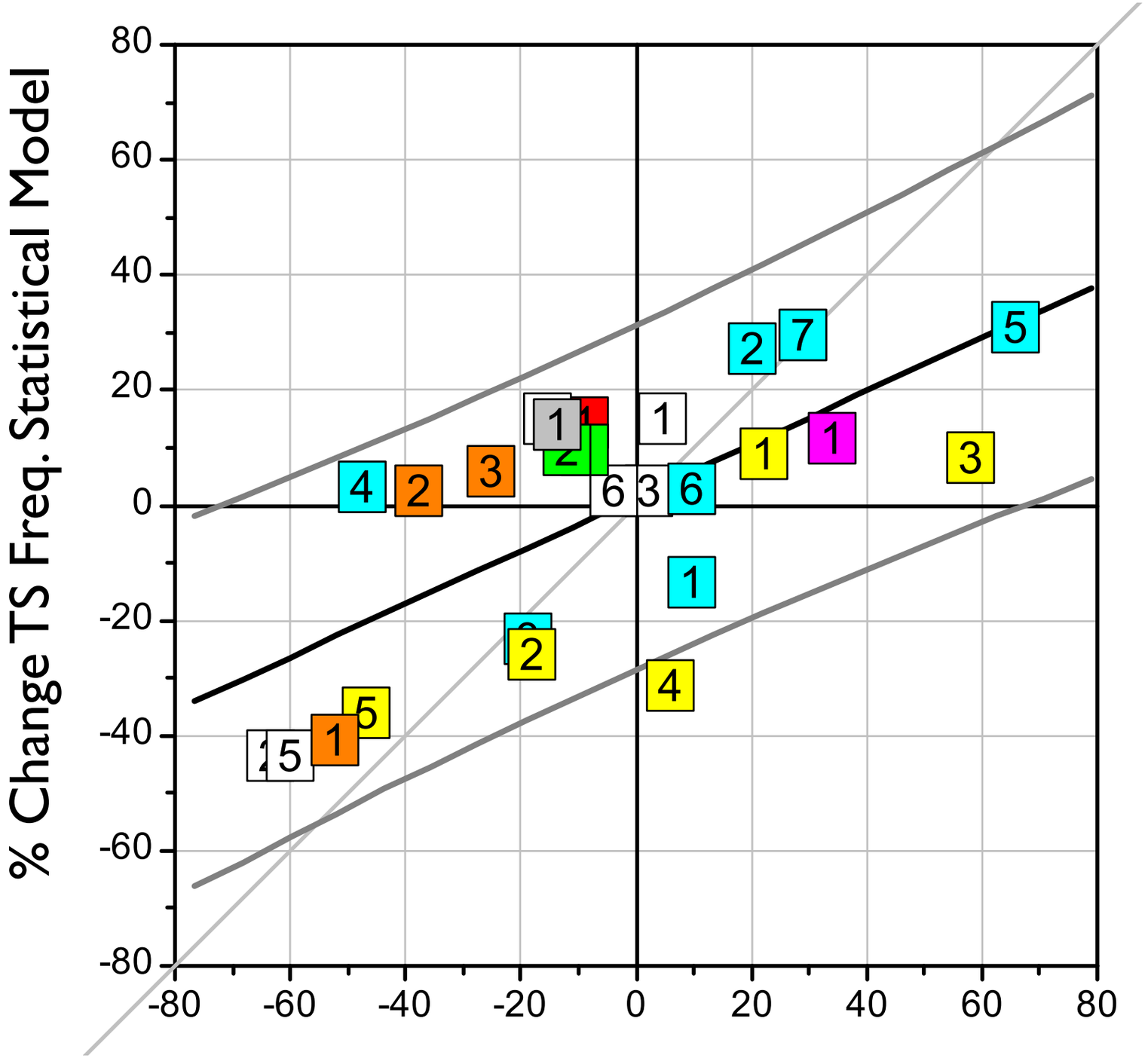
If (**big IF**) eastward shift is real, is it response to anthropogenic increase in shear?



Sources:

Vecchi and Knutson (2008)
Landsea et al. (2010)
Vecchi and Knutson (2011)

Statistical model built on homogeneized SST gives results consistent with high-resolution dynamical downscaling techniques



Knutson et al. (2008)
1. GFDL CM2.1

Zhao et al. (2009)
1. GFDL CM2.1 (Reynolds)
2. UKMet HadCM3 (Reynolds)
3. Max Planck-ECHAM5 (Reynolds)
4. GFDL CM2.1 (HadISST)
5. UKMet HadCM3 (HadISST)
6. Max Planck-ECHAM5 (HadISST)

Emanuel et al. (2008)
1. NCAR CCSM3.0
2. CNRM-CM3
3. CSIRO-Mk3.0
4. Max Planck-ECHAM5
5. GFDL CM2.0
6. MIROC-Medres
7. MRI CGCM2.3.2

Oouchi et al. (2005)
1. MRI CGCM2.3

Bender et al. (2010)
1. UKMet HadCM3
2. Max Planck-ECHAM5
3. MRI CGCM2.3.2

Bengtsson et al. (2007)
1. CNRM with T213 AGCM
2. CNRM with T959 AGCM

Gualdi et al. (2009)
1. INGV-ECHAM4 2×CO_2

Sugi et al. (2009)
1. MRI CGCM2.3.2 (20 km)
2. MIROC-Hires (20 km)
3. MRI CGCM2.3.2 (60 km)
4. MIROC-Hires (60 km)
5 CSIRO-Mk3.0 (60 km)

Villarini et al (2011, J. Clim. in press)

Summary

- Changes in observing practices have left a mark on our hurricane databases:
  - We will never know with certainty what TS or hurricane frequency was at the beginning of 20th Century
  - We can estimate what the influences of changing observing systems have been.
- Increase in TS frequency driven by increase in very short duration storms, which appears to be spurious.
- Century-scale decrease in West Atlantic hurricane and TS activity.
- No observed long-term change in U.S. landfalling activity.

- It is premature to claim an anthropogenic increase in basin-wide Atlantic TS or hurricane frequency.
  - Cannot reject null that frequency has not changed (no detection)
  - Competing dependence on SST (local and remote) prevents two-step attribution
- Homogenized historical records and dynamical models are consistent with the interpretation that relative Atlantic SST is key index
  - It's not a warm/cool Atlantic, but a warm**er**/cool**er** Atlantic that is key
  - Currently precludes attribution to greenhouse forcing, implies small changes, large variability.