Towards Attribution of Hurricane Activity Changes

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1-GFDL; 2-Princeton/AOS; 3-U. Miami; 4-U. Wisc.-Milw.; 5-Old Dominion U.

- How do we attribute?
  - Two part attribution: A -> B ; B -> Hurricanes

- Can we say what drove recent Atlantic increase?
Measure of Activity

- Which measure?
  - Hurricane count
  - Landfalling storm count
  - Extremes in intensity
  - Shifts in mean intensity
  - Integrated intensity

- Must balance demand with current ability to detect/attribute.
  - Obs, models and theory limit.

- Must communicate differences

Atlantic Tropical Cyclone Power Dissipation Index Anomalies: Observed and Based on Sea Surface Temperature
Anomalies relative to 1981-2000 average; $2.13 \times 10^3$ m$^3$/s$^2$

**Based on Absolute SST**
- Annual Observed PDI (1946-2007)
- Five-year Observed PDI (1946-2007)
- Five-year PDI based on observed absolute SST (1946-2007); $r = 0.79$

**Observed Activity**
Absolute MDR SST
If causal, can attribute.

e.g. CCSP-3.3

Storm count*duration has been principal control of historical PDI changes
(Maue and Hart (2007))

**Vecchi, Swanson and Soden**
(2008, Science)
Observed Activity

Absolute MDR SST
If causal, can attribute.

Vecchi, Swanson and Soden (2008, Science)

Relative MDR SST
If causal, cannot attribute.
Atlantic Tropical Cyclone Power Dissipation Index Anomalies: Observed and Based on Sea Surface Temperature
Anomalies relative to 1981-2000 average: $2.13 \times 10^7$ m$^2$ s$^{-1}$

**Based on Absolute SST**
- Annual Observed PDI (1946-2007)
- Five-year Observed PDI (1946-2007)
- Five-year PDI based on observed absolute SST (1946-2007); $r = 0.79$
- Statistical Five-year PDI downscaling of global climate models (1946-20100)
  - Individual model
  - Average of 24 models

**Based on Relative SST**
- Annual Observed PDI (1946-2007)
- Five-year Observed PDI (1946-2007)
- Five-year PDI based on observed relative SST (1946-2007); $r = 0.79$
- Statistical Five-year PDI downscaling of global climate models (1946-20100)
  - Individual model
  - Average of 24 models

High-resolution model activity change
- Emanuel et al (08), Knutson et al (08)
- Oouchi et al (06), Bengtsson et al (07)

Vecchi, Swanson and Soden (2008, Science)
Observations

- Hurricane databases **NOT** built as climate data records.

- Efforts must continue to:
  - Identify issues
  - Homogenize when possible
  - Estimate uncertainty
Adjustment changes sign of hurricane count trend

Vecchi and Knutson (2009, in prep.)
GFDL C-X HiRAM GCMs

Family of global atmospheric models designed for better-representing tropical cyclone frequency. **C90 - 1°**, C180=1/2°, C360=1/4°, C720=1/8°


Adapted from AM2 with:

- Deep convection scheme adapted from Bretherton, McCaa and Grenier (MWR, 2004)
- Cubed sphere dynamical core
- Changes to parameterizations of cloud microphysics
- C90 Atm. resolution of 1°x1°

Explore C90 Model

North Atlantic Tropical Storms*

*lasting 2 days or more

AGCM with and without tropical-mean SST change

North Atlantic TS Count

Year


Vecchi et al (2009, in prep.)
**1982-94 and 1995-2007 PDFs of NA TS Count**

* lasting two days or more

**2005 Observed**

**OBSERVED ATLANTIC TS COUNTS**

- 1982-1994
  - $\mu = 6.9231; \sigma^2 = 6.6864$
  - $\mu = 11.231; \sigma^2 = 13.562$

- 1995-2007

**C90 ATLANTIC TS COUNTS**

- 1982-1994
  - $\mu = 6.9872; \sigma = 8.0639$
  - $\mu = 10.231; \sigma^2 = 12.178$

- 1995-2007

**C90 ATLANTIC TS COUNTS - no mean SSTA**

- 1982-1994
  - $\mu = 6.2821; \sigma^2 = 6.3563$
  - $\mu = 9.9487; \sigma^2 = 15.536$

- 1995-2007

**C90 ATLANTIC TS COUNTS - no mean SSTA and no interannual**

- 1982-1994
  - $\mu = 7.9; \sigma^2 = 3.49$
  - $\mu = 11.3; \sigma^2 = 2.61$

Vecchi et al (2009, in prep.)

**2005: decadal pattern of SSTA and interannual variability.**

16-Dec-2009

Gabriel Vecchi, NOAA/GFDL, Princeton, NJ
Shift in mean TS counts attributable to “AMO” SST change across 1994-1995

What drove this SST change? Internal variability? Aerosols? Combination?


Response to “AMO” forcing

Vecchi et al (2009, in prep.)
Conclusions

• It is premature to conclude that human activity--and particularly greenhouse warming--has already had a detectable impact on Atlantic tropical storm frequency or PDI.

• Atlantic TS frequency appears controlled by SST changes in the Atlantic relative those in other basins:
  – To attribute Atlantic TS changes need to attribute pattern of SST change (has not been done).

• Change in mean TS frequency across 1994-95 attributable to “AMO-ish” SST change
  – What drove SST?
  – What about shift in variance?
Idealized Forcing Experiments

If local SST the dominant control, as opposed to relative SST:

• Similar Atlantic Response to Atlantic and Uniform F’cing
• Little Pacific Response to Atlantic compared to Uniform
North Atlantic Response to Idealized SST

Change in Annual NA Storms from Idealized SST:
NATL, GLO, EQU

- **Atlantic Forcing**
- **Uniform Forcing**
- **Near-equatorial Forcing**

Similar TS frequency response to:
0.25° local warming
4° global cooling

Vecchi et al (2009, in prep.)