A surprising TC-winter relationship and its implications for scatterometry in climate

19 August 2009

Robert Hart (rhart@fsu.edu)
Ryan N. Maue, Ben Schenkel

Florida State University

moe.met.fsu.edu

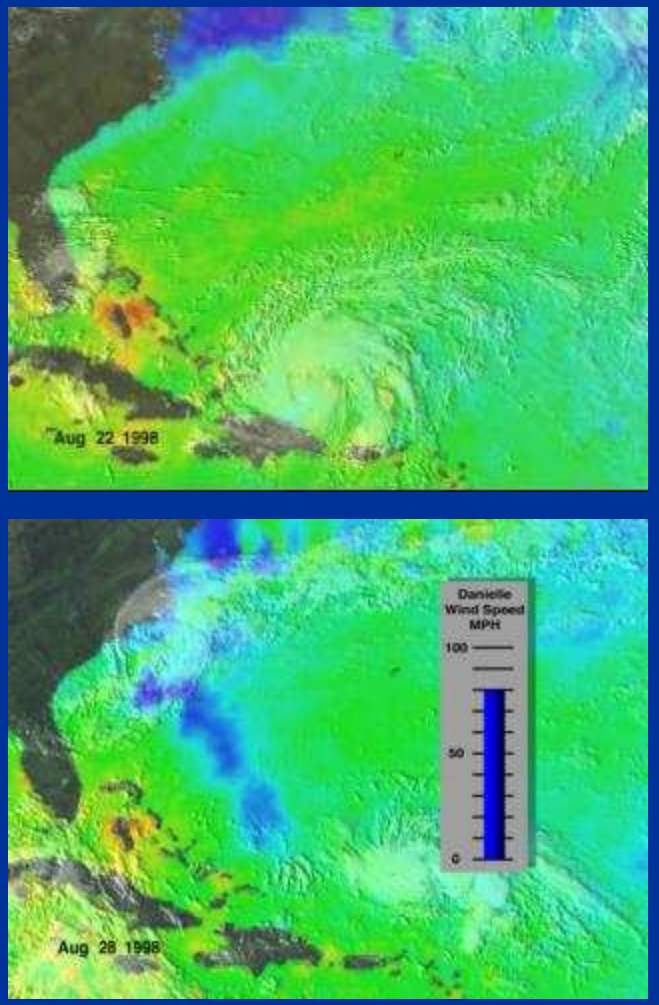
Collaborators: K. Emanuel, L. Bosart, J. Elsner,, M. Watson

Difficult but fundamental questions

- How long does the climate “remember” a TC has occurred?
- How is this memory accomplished?
- Are TCs incidental or forcing mechanisms in climate?
  - Oceanic transport: Emanuel (2001) ; Sriver and Huber (2007)
- If they are forcing mechanisms, is there a relationship to the subsequent winter following anomalous TC activity?
- Are there significant biases in GCMs and related products (reanalyses) because they cannot produce realistic TCs?
- What are the implications of this role for scatterometry’s future?

Generation of memory: oceanic upwelling

- How long does it take for the upwelling-induced cooling to return (warm) to a *changing* climatology?



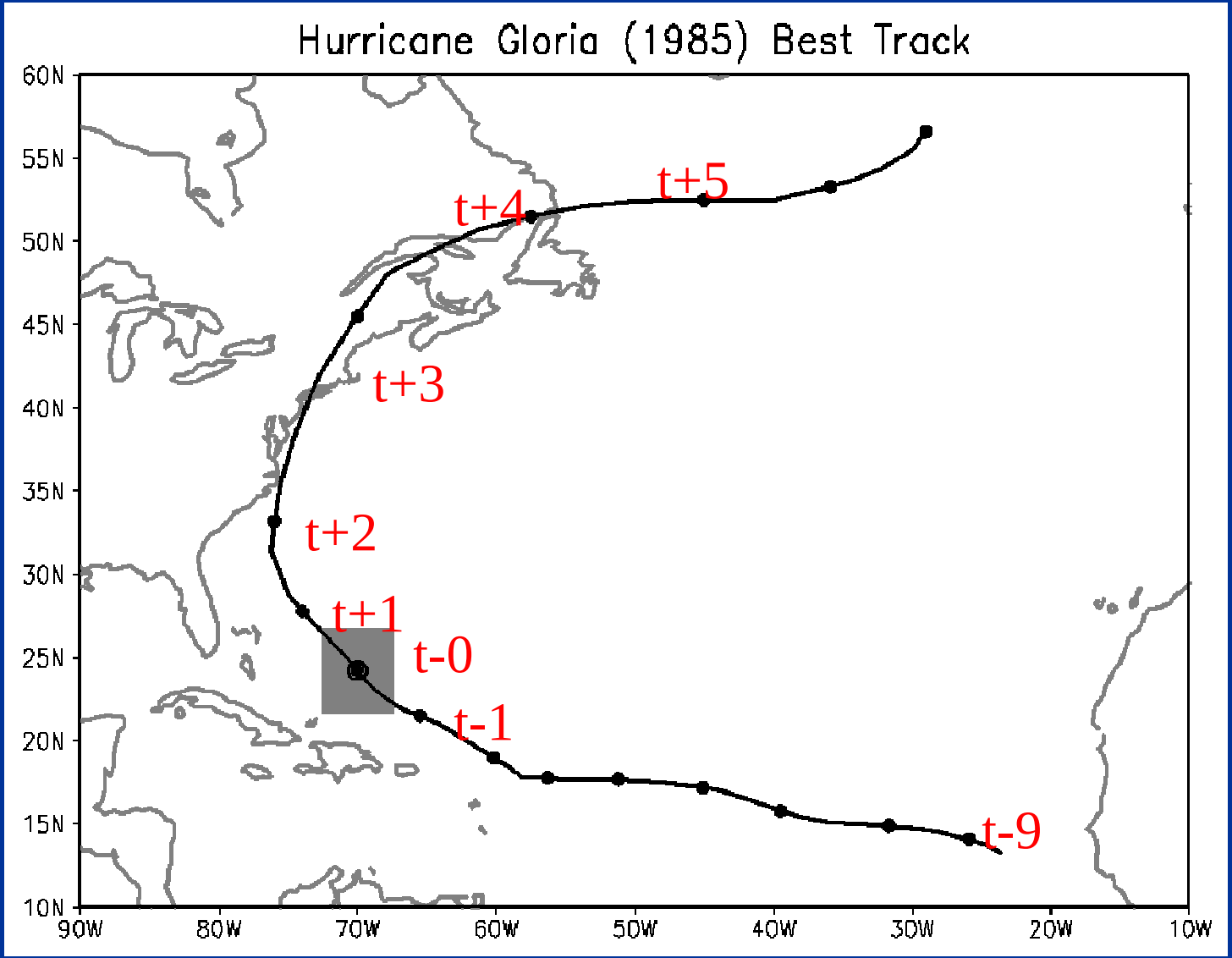
http://svs.gsfc.nasa.gov/vis/a000000/a001000/a001066/

Memory of TC Analysis

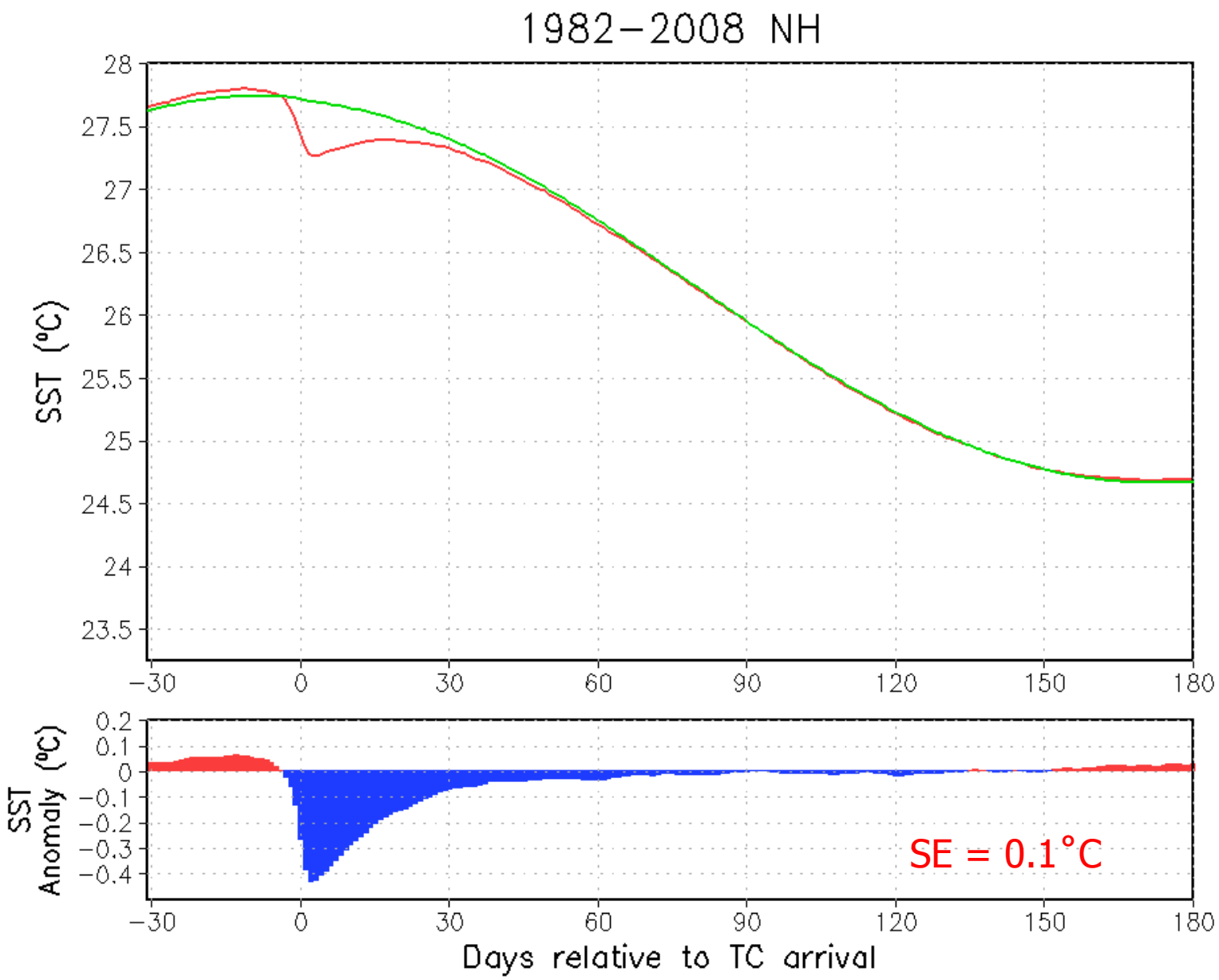
- Examine SST and atm. change prior to & after TC passage
- Using:
  - ERA40, JRA, MERRA, NODC 0.25° global SST (daily)
- Period: 1982-2008 [NATL, EPAC, WPAC basins]
- Compare against *evolving* climatology
- *Monthly Weather Review (2007,8)*

Memory/Footprint Calculation:

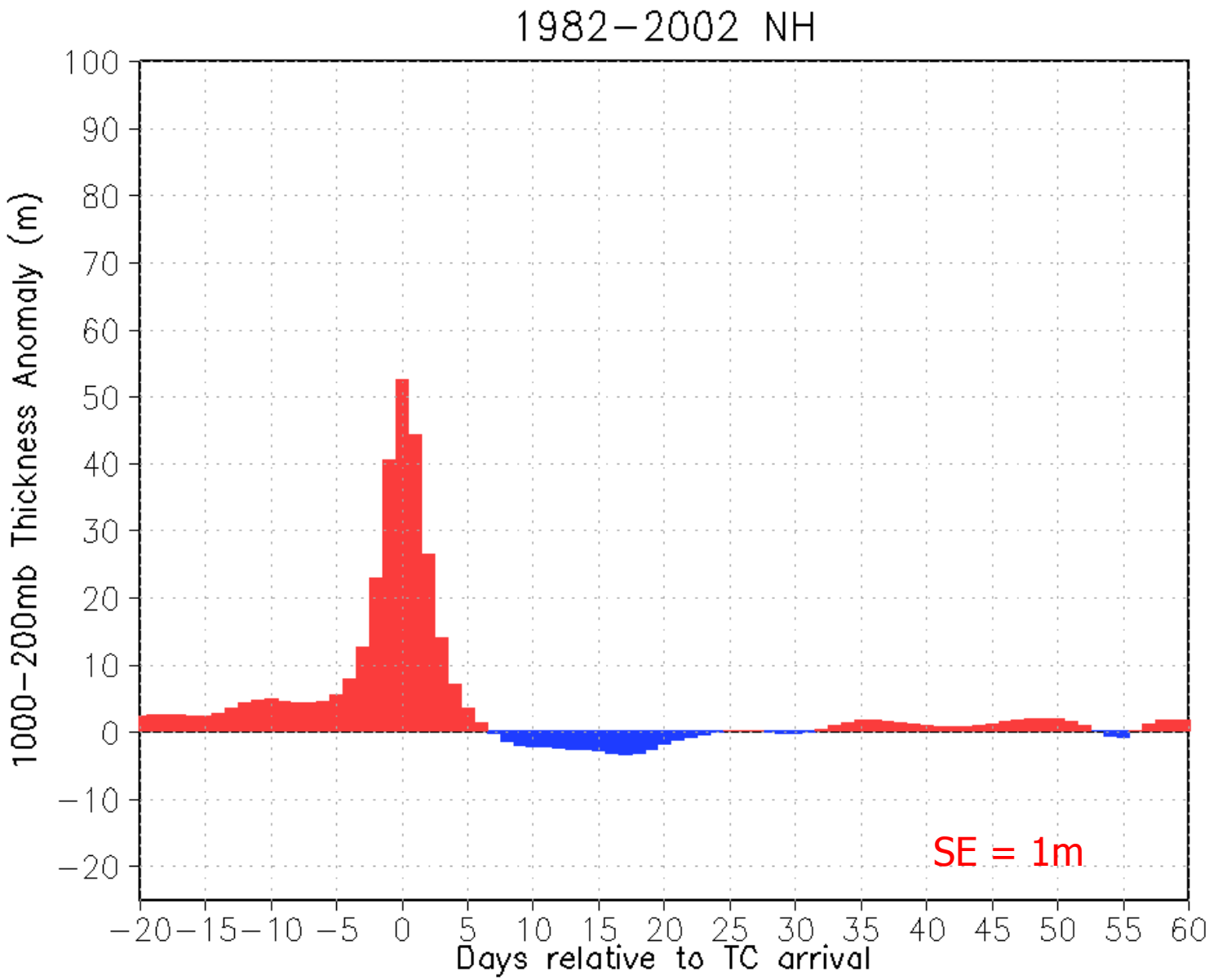
What happens to the atmosphere and upper ocean in the box days to weeks after a TC passes?



SST Footprint: 6 month view



ERA40: 1000-200mb Thickness footprint



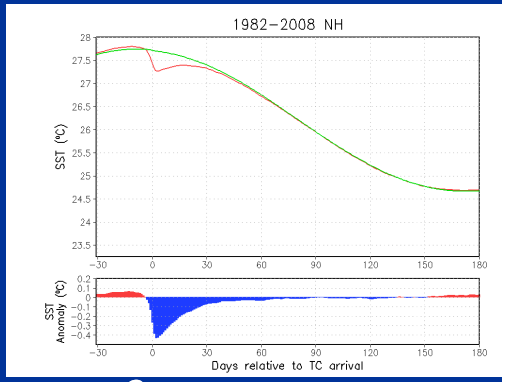
Local consequences

- Insolation that would have been used for ocean evaporation and sensible heating of atmosphere is now instead used to warm the anomalously cool water
- Vertical temperature flux vector is reversed
- Atmosphere above the TC path also becomes drier given the decreased evaporation
- Tropospheric redistribution of moist static energy
- Are there aggregate hemispheric consequences of this?

Possible Aggregate Consequences

- Shifting of the SST-atmosphere “clock”
  - (Climatological mean 1-2month lag between atmosphere and SST extrema due to differing heat capacity and inertia)
- Kinetic energy & power redistribution
- Implications on broader circulation:
  - Large scale gradients
  - Land-ocean temperature contrast driving preferred Rossby wave pattern
  - Less work to be done during winter?

A Thermodynamic Contribution: Sensible Heating Contribution and Atm-SST Clock



- Space-time conversion
- SST: Memory of 2-3 mon. for 5° TC swath
  - Calculation performed for 5°N to 35°N
  - Average spatial coverage of TC swath is 75 degrees^2
  - 50 NH TCs on average
  - Ignore overlap by TCs, cos(latitude), seasonality
  - Approximately 25% of the surface area between 5°N and 35°N is covered by part of a 5°x5° TC swath
  - ⇒The 5°-35°N spatial average memory is about three weeks
  - ⇒The NH spatial average memory is about two weeks

- Energetically, a highly anomalous TC season has the ability to shift the "atmosphere-SST relationship clock" by two weeks

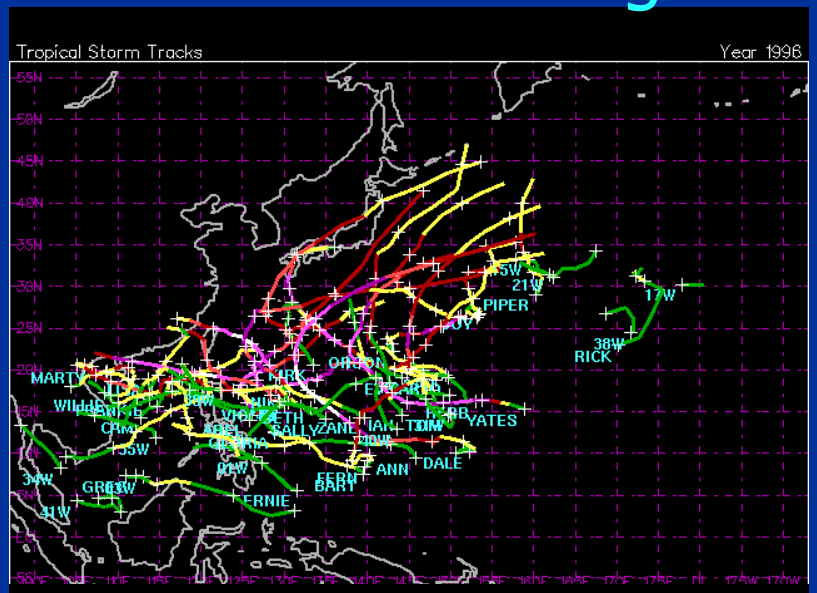
A Kinetic Contribution: % of hemispheric surface wind power dissipation (PD; Emanuel) from TCs?

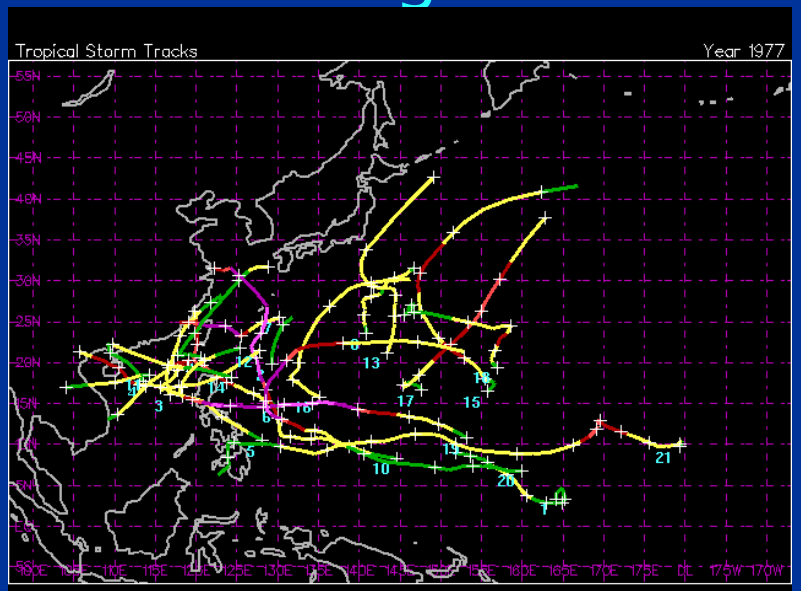
- PD ≈ Time, areal integral of cubed wind speed
- NH ocean mean wind: ≈ 8 m/s [QuikSCAT]
  - $PD_{NH} \approx 365days*86400s*2\pi*(6.37x10^6\ m)^2*(8\ m/s)^3$
- TC ocean mean wind within 500km: ≈ 20m/s [HWIND]
  - $PD_{TC} \approx 7days*86400s*\pi*(500x10^3\ m)^2*(20\ m/s)^3*50\ TCs$
- Swanson (2008): Argues to remove TCs from reanalysis
- Ratio: $PD_{TC} / (PD_{NH} - PD_{TC}) \approx 10\%$

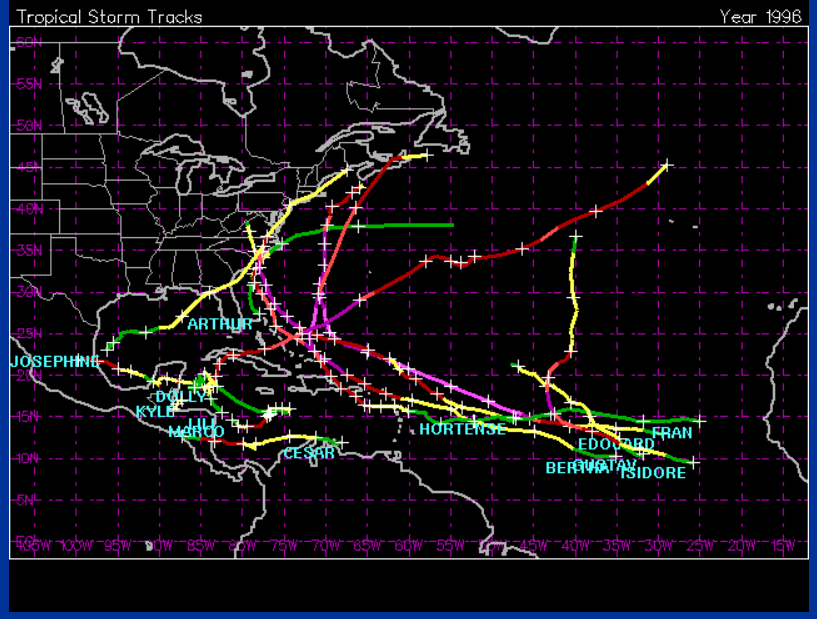
Hypothesis

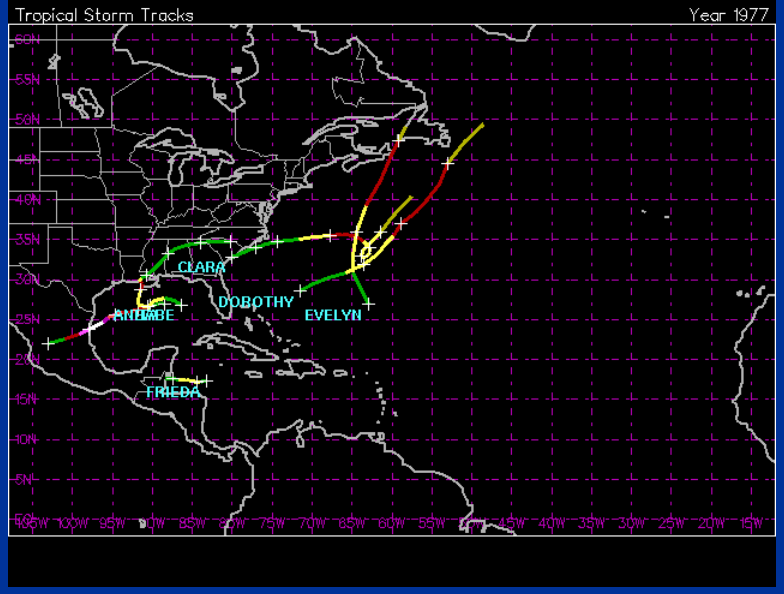
- This shift in atmosphere-SST relationship due to anomalous TC activity redistributes energy usage, even into winter given the memory length and overall conservation
- In autumns when the TC activity is enhanced, TCs have contributed more than normal toward the heat redistribution and have accelerated the SST clock
- In these years, the subsequent role of other methods (MMC, baroclinic eddy activity) might be suppressed since there is less "climate" work to be done
- Initial measures of activity to compare:
  - TC: Count of recurving TCs (form < 30˚N reach > 40˚N)
  - Winter: Meridional flux of three-month (JFM) mean winter as one measure of winter activity [MMC]

Example Years: 1996 vs. 1977
19 “Recurving” storms vs. 4 “recurving” storms







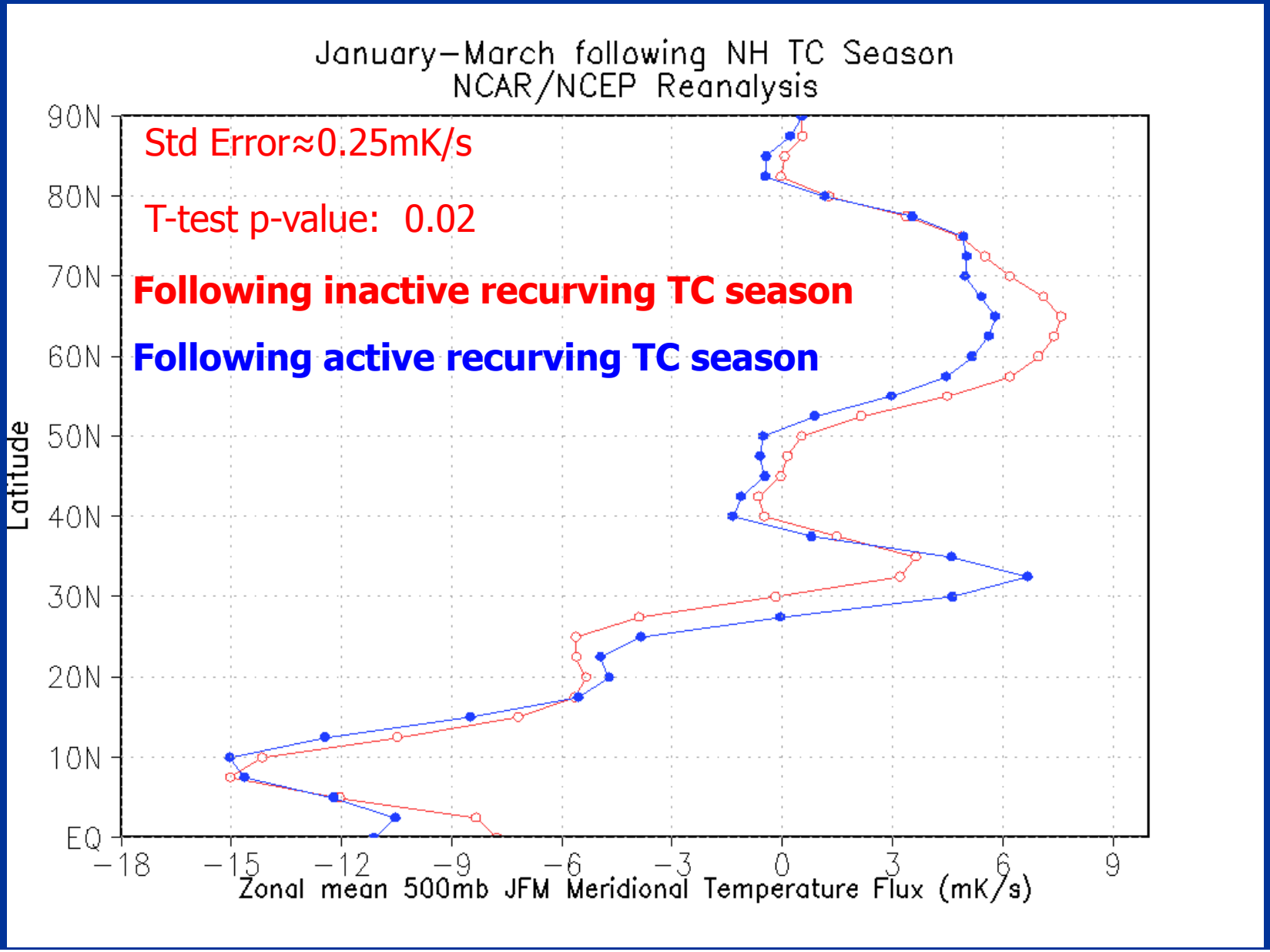


Images courtesy of Unisys

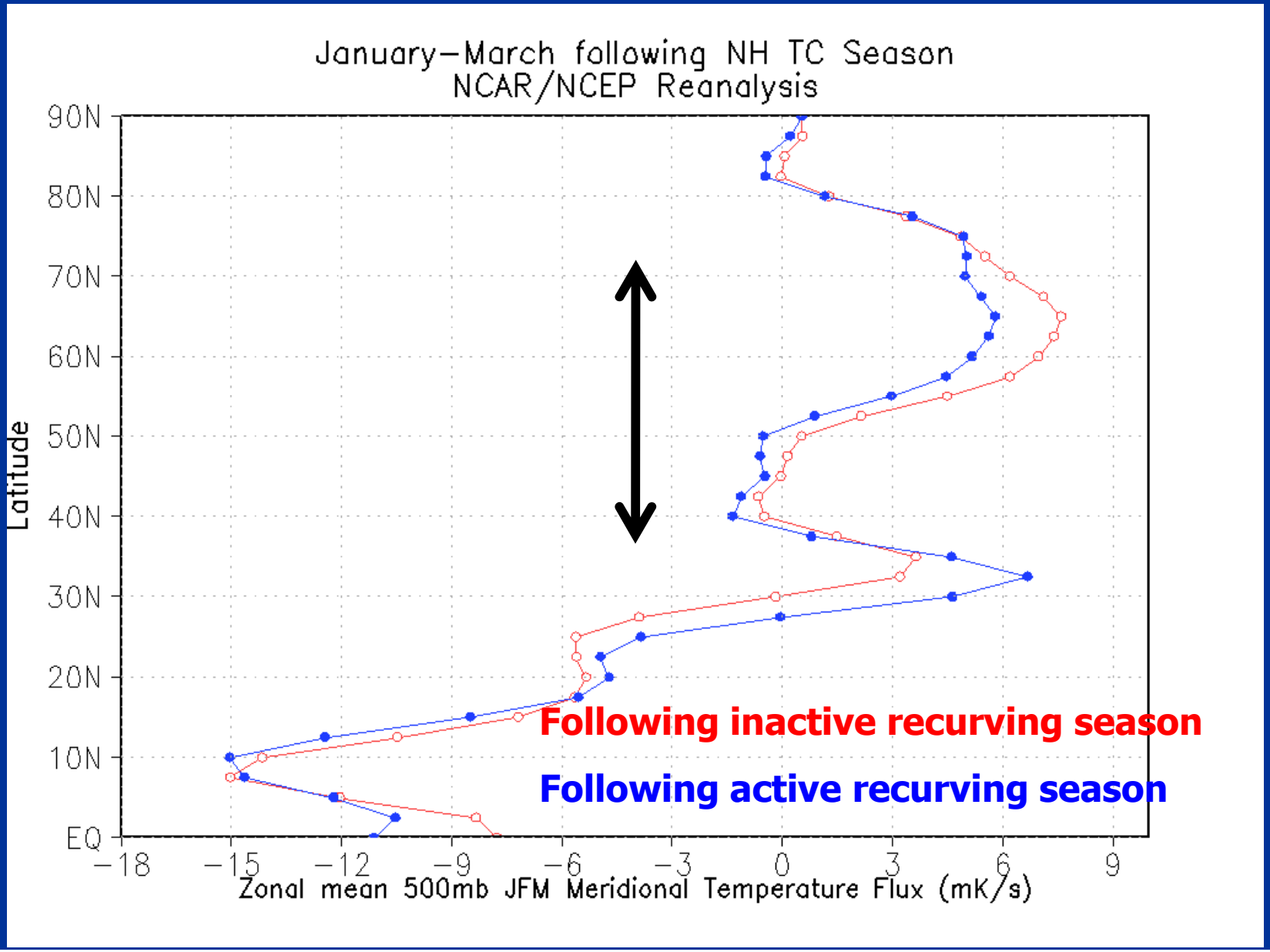
Results: Recurving TC climatology

- Mean number of NH recurving TCs is 9
  - Q1: 5 "inactive" recurving year threshold
  - Q3: 12 "active" recurving year threshold
- Surprisingly stable measure of extremes:
  - 1948-2005: Q1: 6, Q3: 12
  - 1955-2005: Q1: 5, Q3: 12
  - 1979-2005: Q1: 5, Q3: 12
- Range: 2-19 [hence, wildcard….]
- Let's now look at the winter that follows Q1 and Q3 TC seasons

Results: 500mb Composite mean flux difference



Let's broaden things and seek what regions of TC activity most relate to this latitude average flux

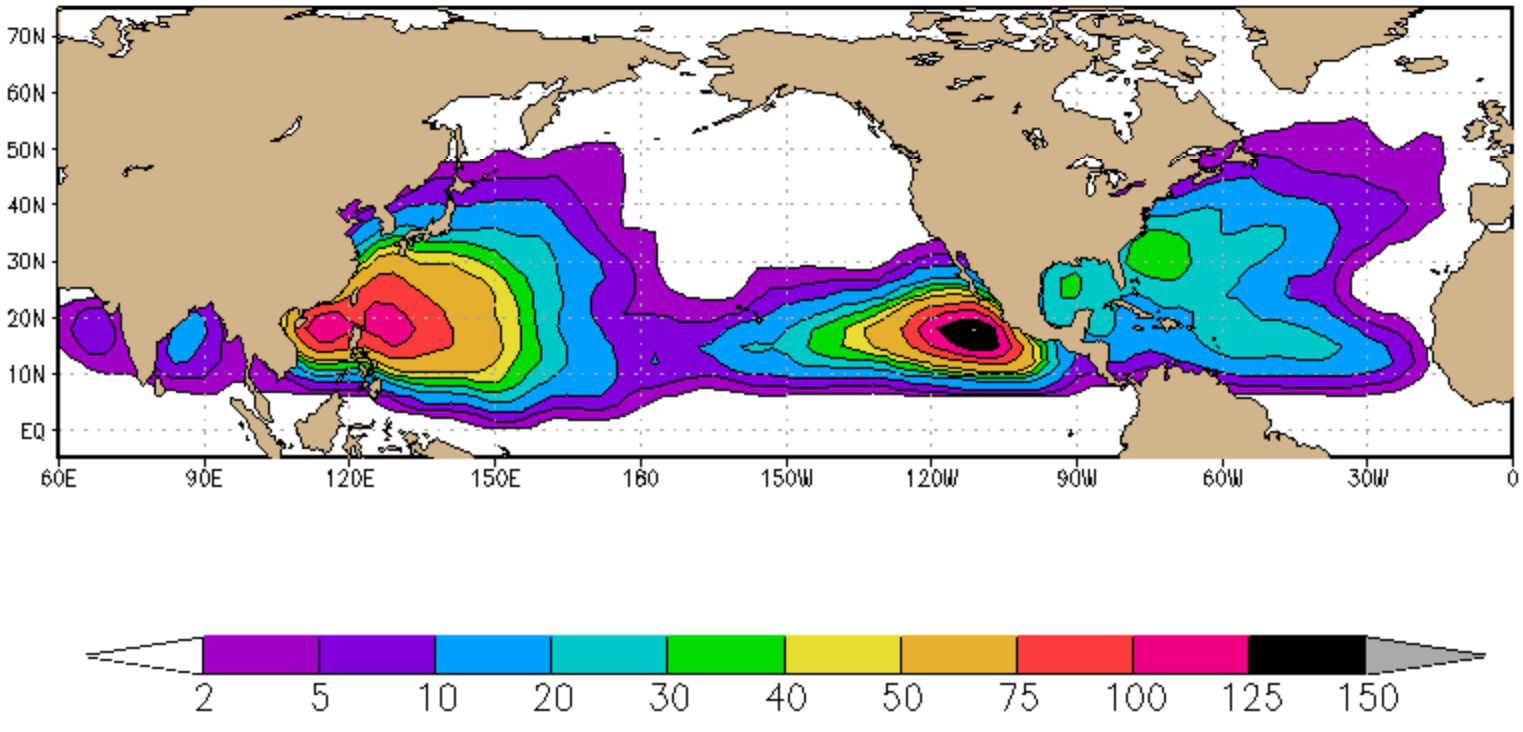


Count vs. ACE/PD

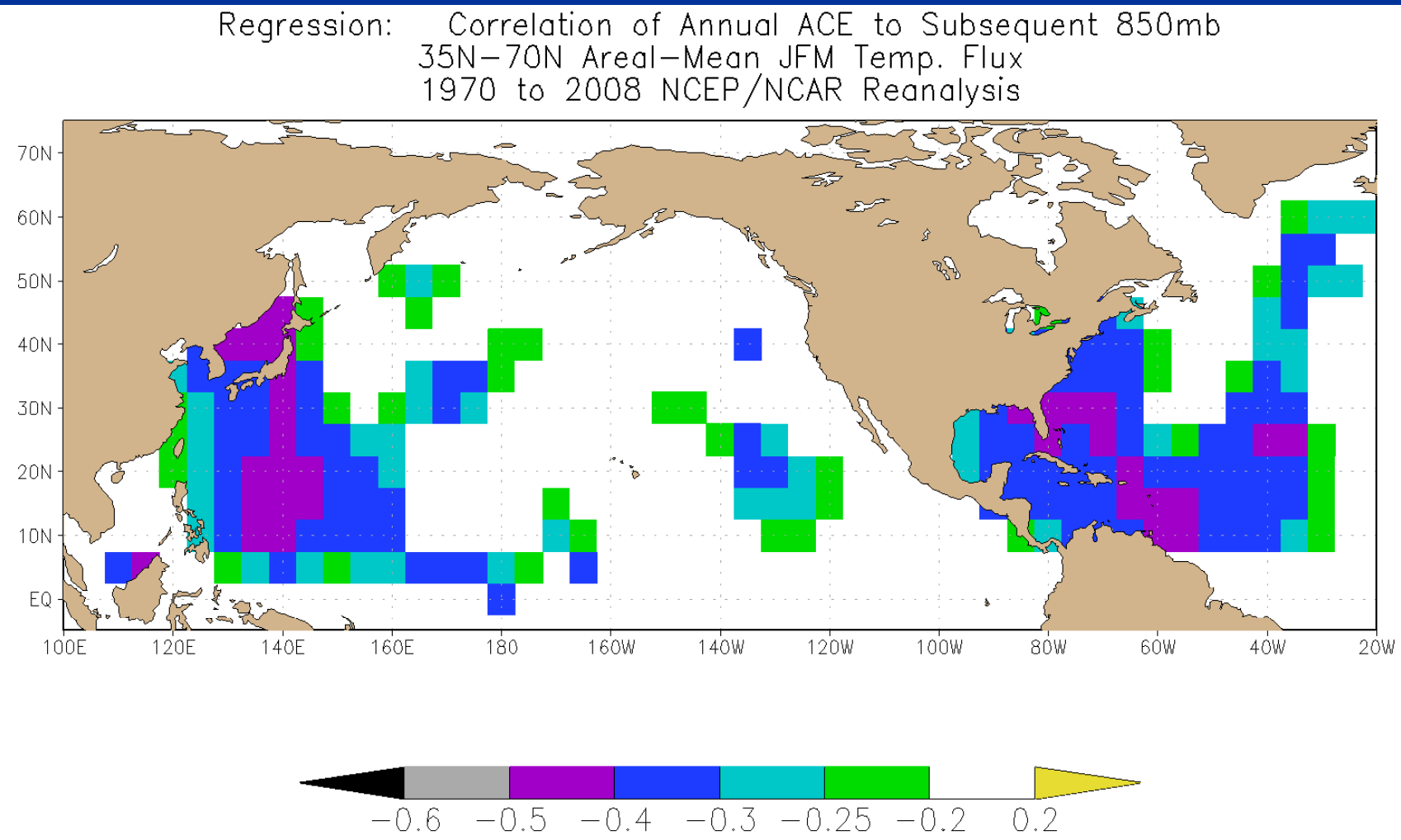
Count is very unsatisfying. Consider Emanuel analogy to earthquakes.

Let's examine what AREAS of TC energy are most related to subsequent winter anomalies

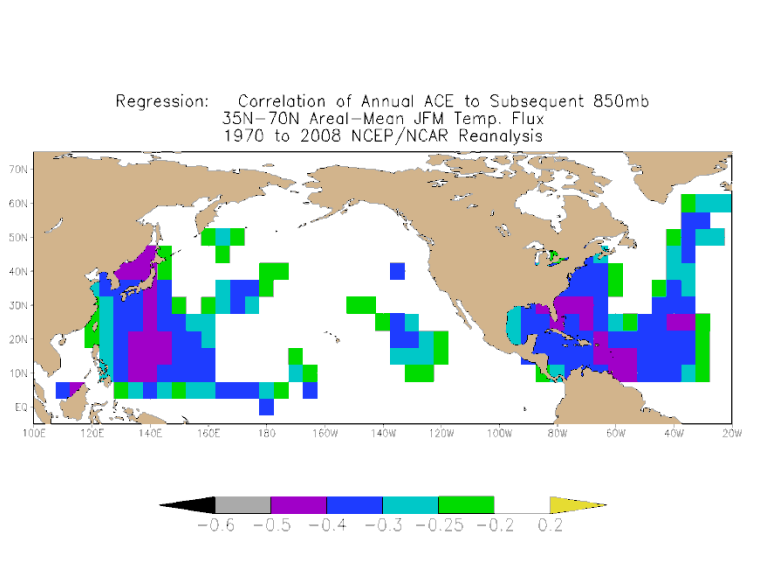
Normalized Average ACE: 1970-2008

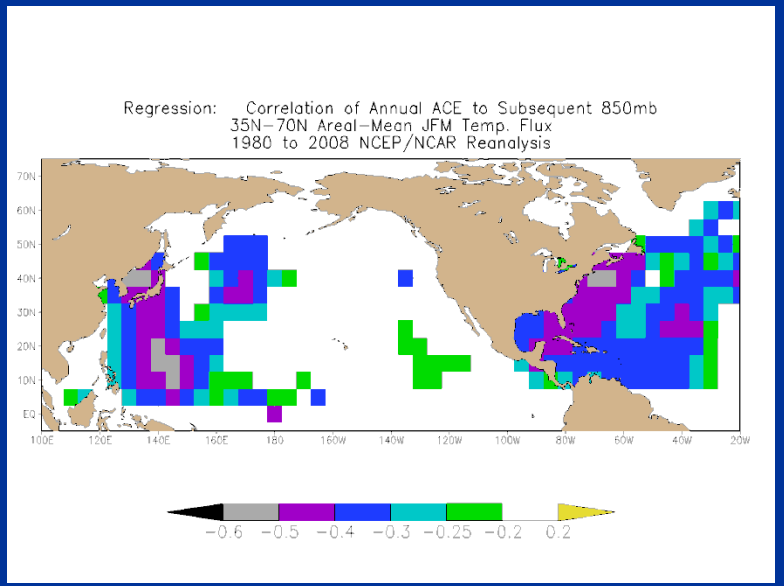


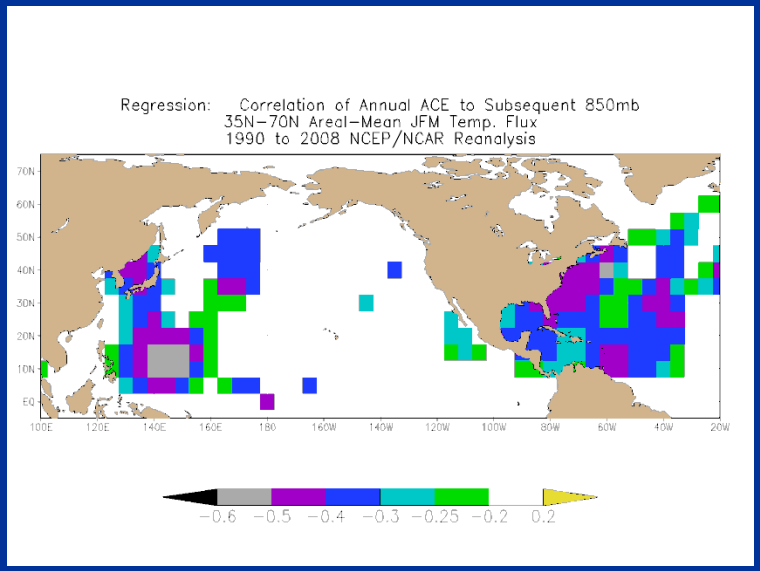
How well does regional TC energy predict 850mb winter climate?



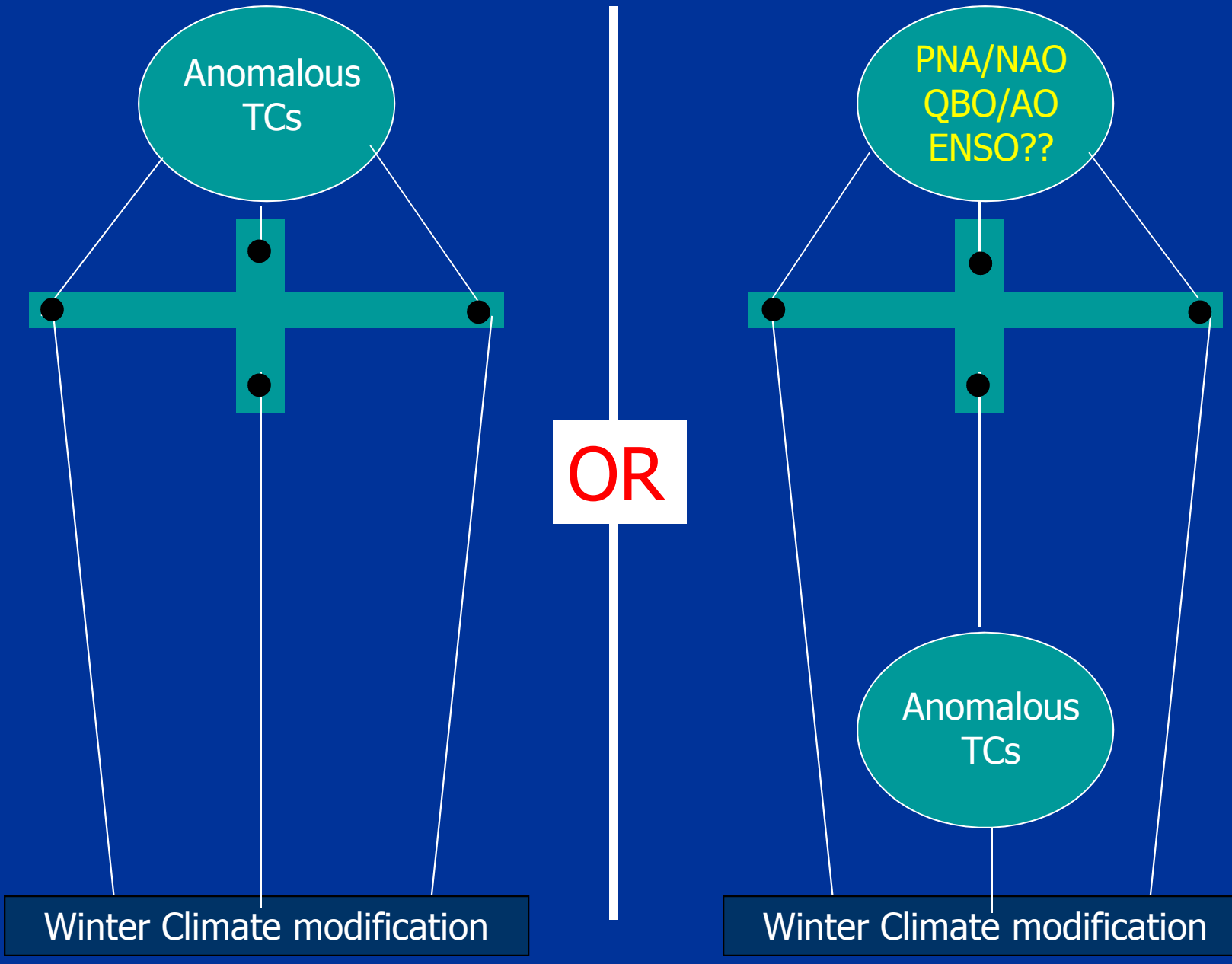
Variability with period of record?







Puppet master or puppet?



Puppet master or Puppet?

- While it is impossible currently to isolate the role of TCs in climate, the prior and following results argues their role may not be passive
  - When you try to predict the winter flux anomaly, no combination of existing teleconnection indices (ENSO, NAO, etc.) can currently beat variance explained by the prior season's TC activity.
  - In other words, the best predictor of the upcoming winter's large scale climate (meridional flux) is the prior season's TC activity.

Implications for scatterometry and its role in climate

- The magnitude of the SST cold wake and its duration is dependent on the strength and size of the TC wind field.

- Existing reanalyses, unless superob-ed (e.g. JRA), grossly under represent the TC wind field itself. Thus existing reanalyses absolutely need surface wind observations everywhere to correctly capture the TC role and feedbacks from a coupled ocean.

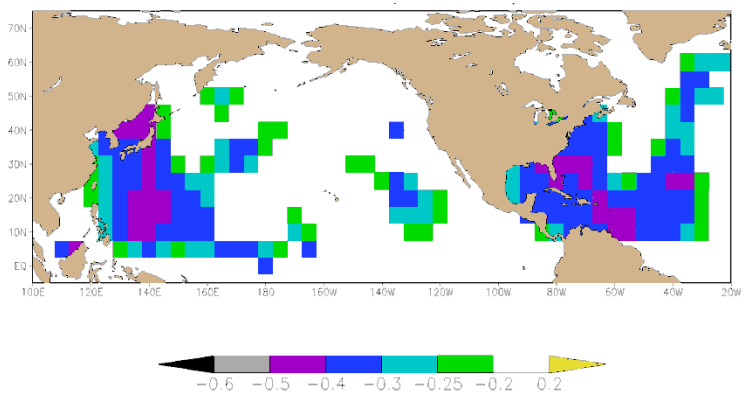
- By not incorporating directly in GCMs and reanalyses, through assimilation, observations such as QuikSCAT, a nontrivial amount of global kinetic and thermodynamic energy is being wrongly placed. Where is it going? What are implications on climate change forecasts being debated by IPCC and others?

Acknowledgments

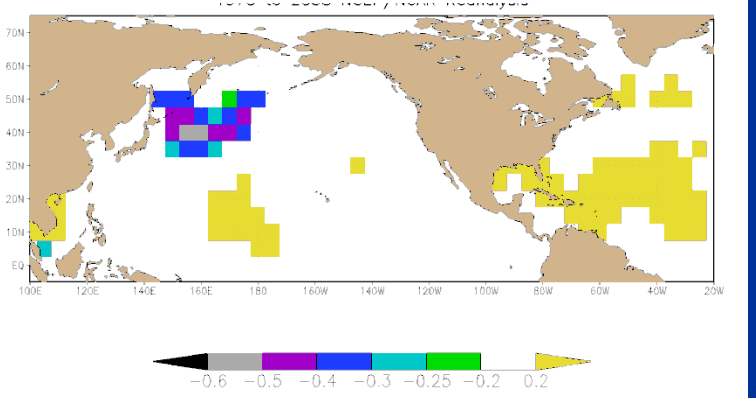
- National Science Foundation
  - NSF ATM-0842618
- NASA
  - NASA NNX09AC43G
- BIOS/Risk Prediction Initiative
  - RPI/BIOS RPI08-2-001

How does relationship change with height?

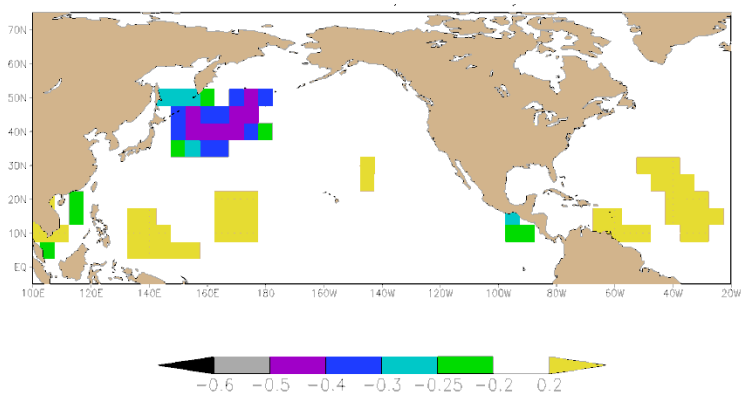
850mb



700mb



600mb



500mb