Impacts of the Atlantic Warm Pool on Atlantic Hurricanes

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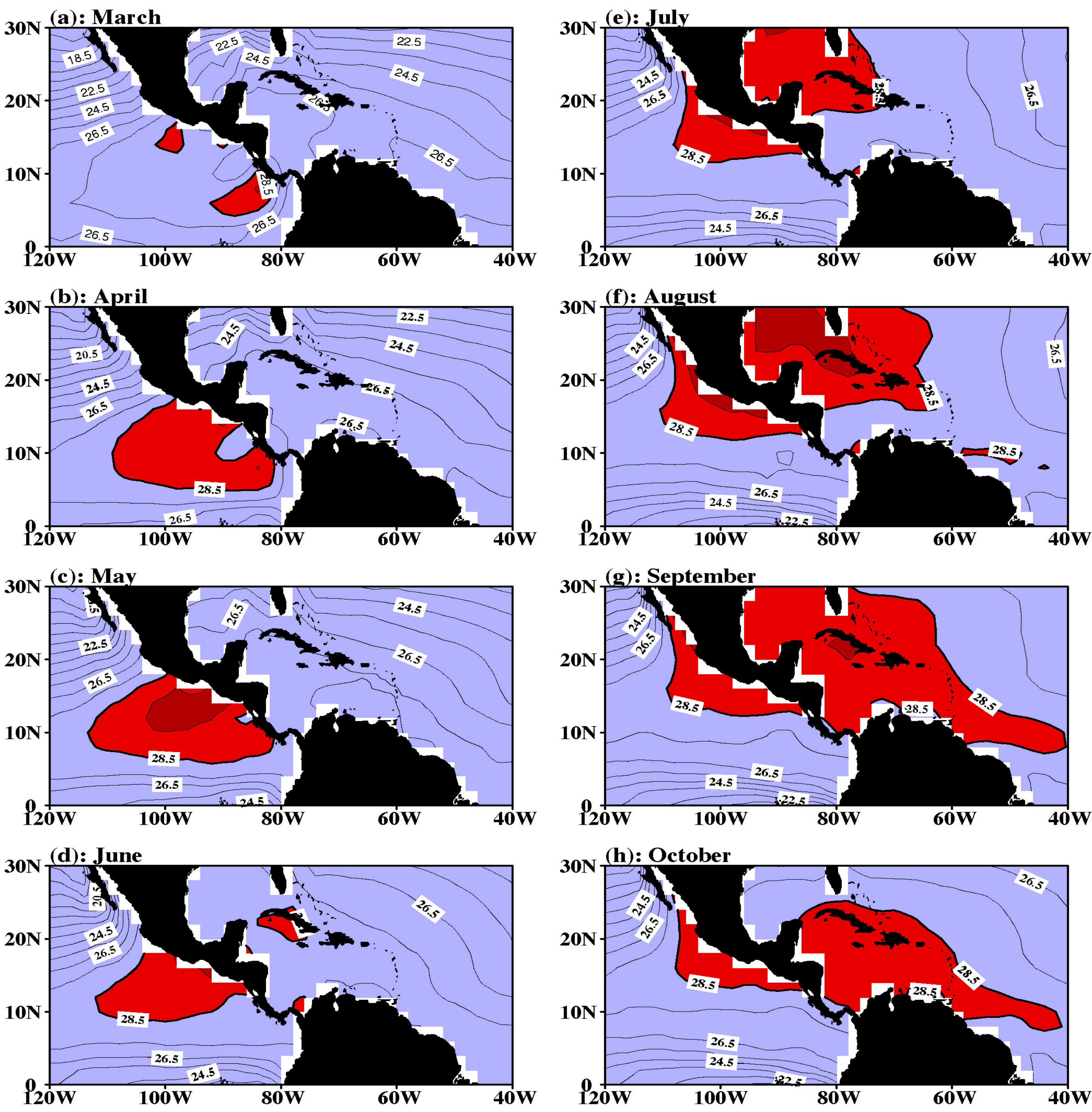
National Oceanic & Atmospheric Administration

Western Hemisphere warm pool (WHWP)

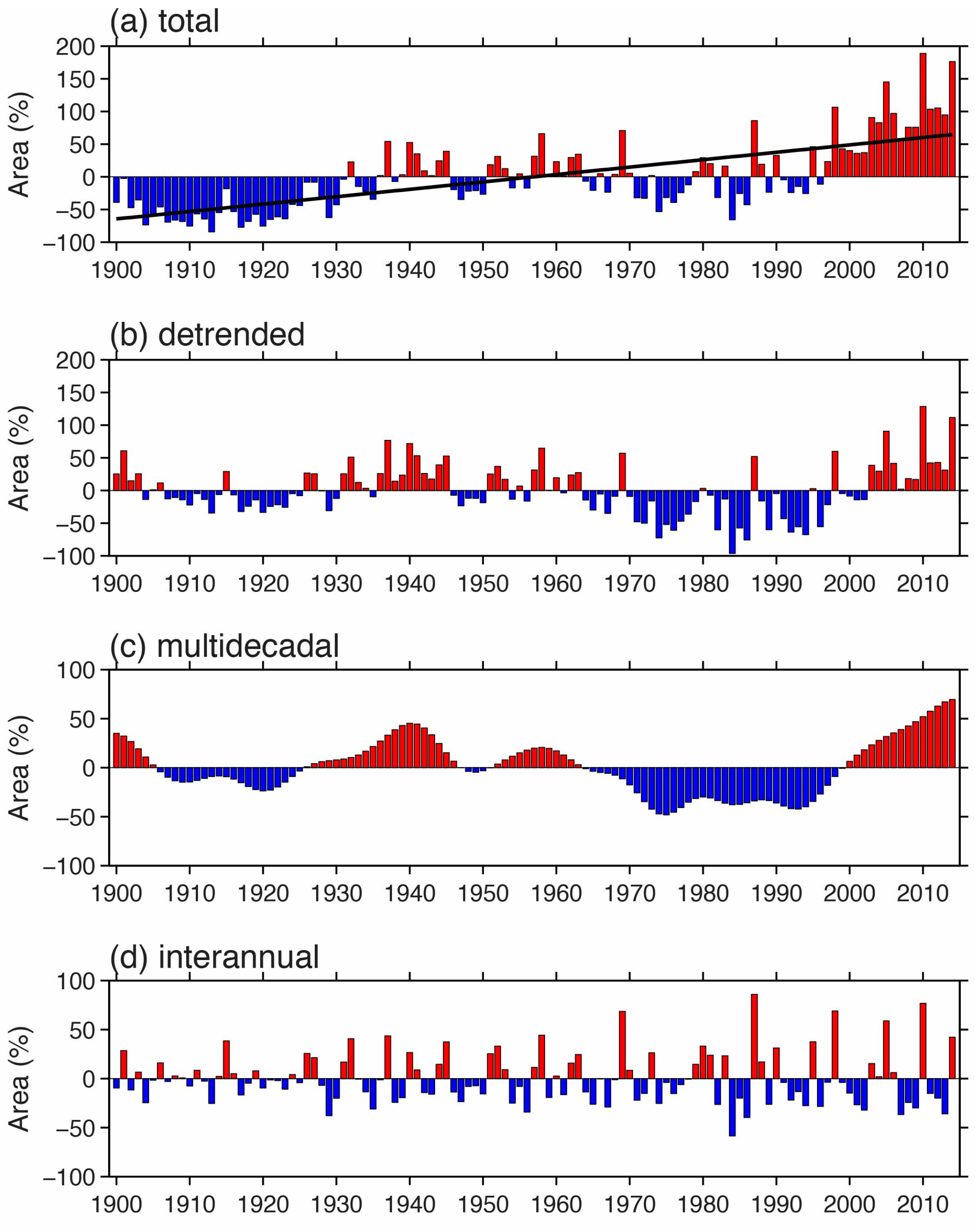
SST ≥ 28.5°C

Focus on the Atlantic side of the WHWP (AWP).

Wang and Enfield (2001, 2003)

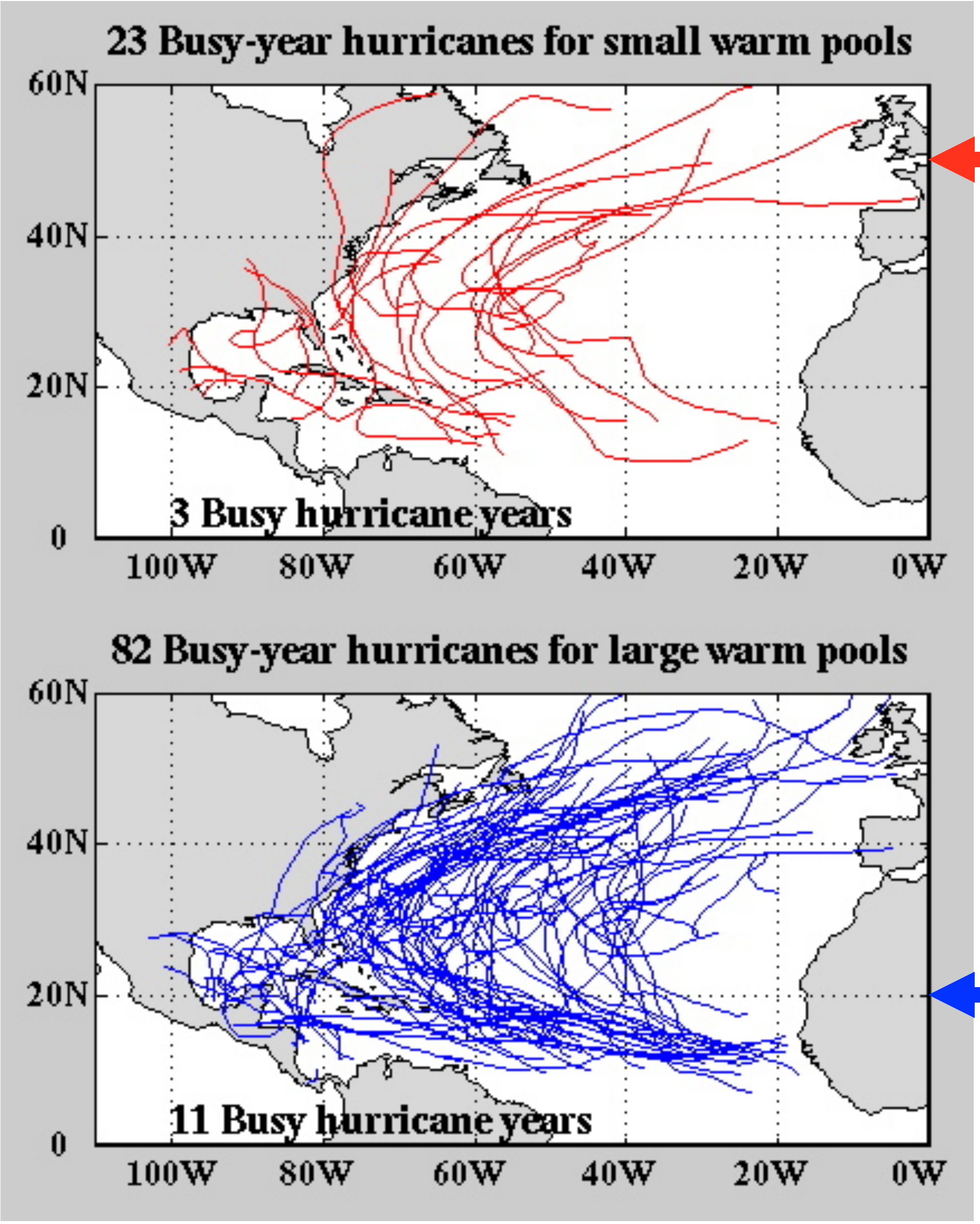


Atlantic warm pool (AWP) area anomaly indices from 1900 to 2014



Wang (2015, *BAMS*)

Past 54 Years of Tropical Storms and Atlantic Warm Pools



Of the 18 years with small warm pools

3 busy years, 23 storms

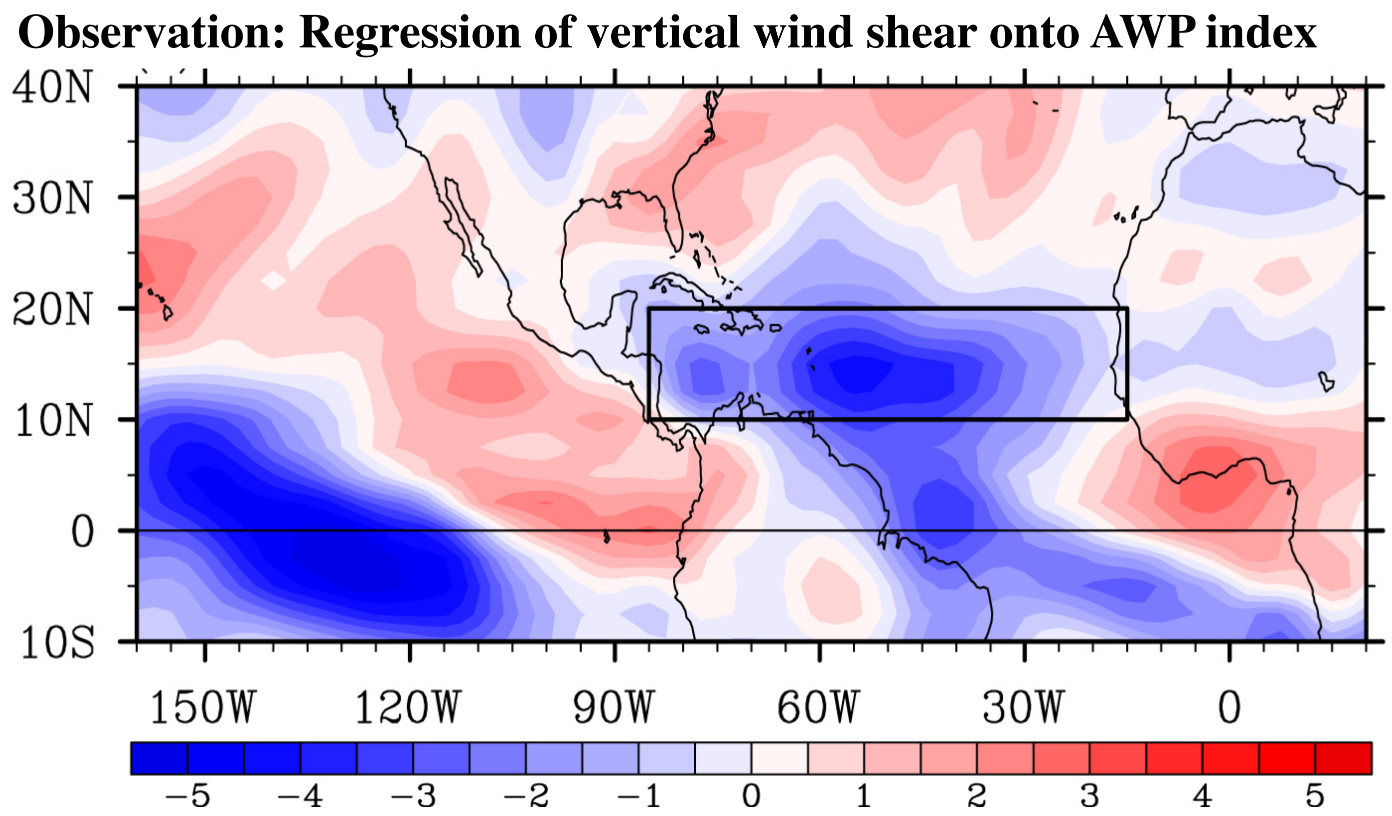
Busy hurricane years

= years for which the number of season hurricanes fall within the top tercile of all years

Of the 18 years with large warm pools

11 busy years, 82 storms

Why does the Atlantic warm pool (AWP) affect hurricanes?



Large (small) AWP => Low (high) wind shear => More (less) hurricanes

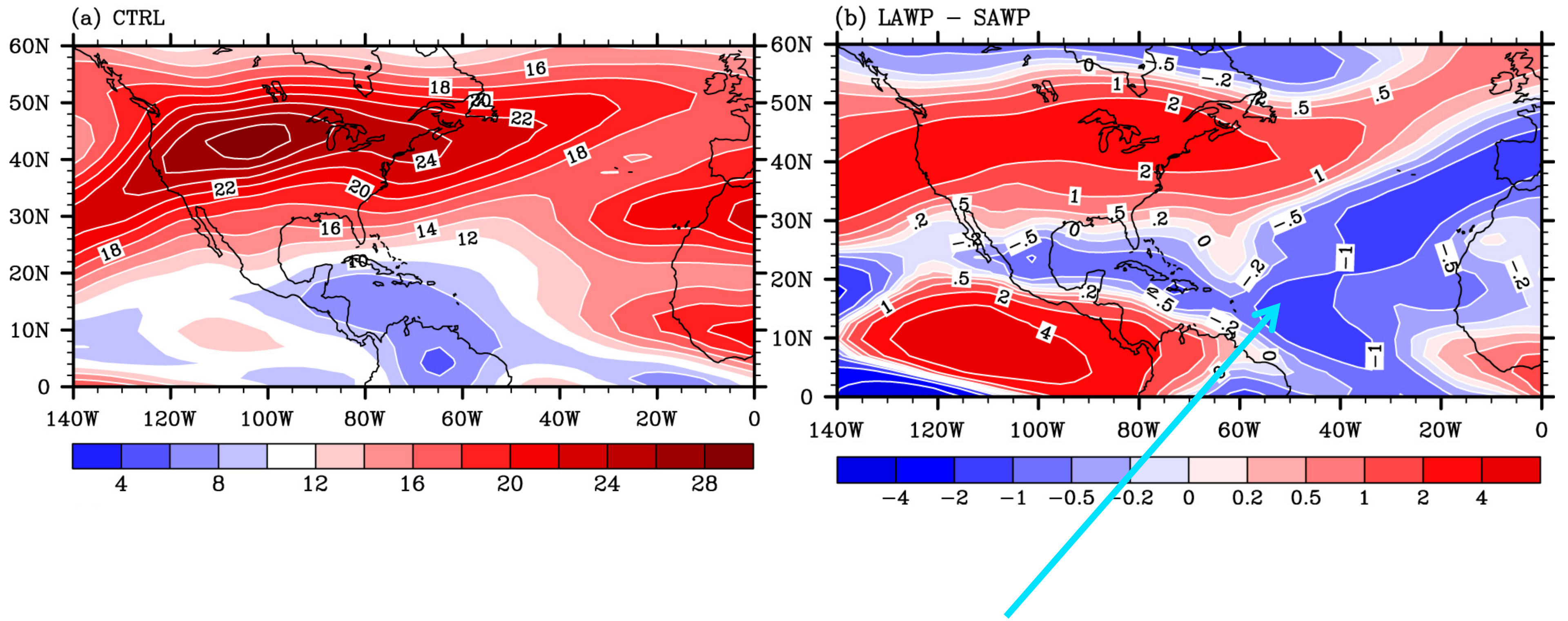
Atmospheric GCM Experiment Designs for Studying the AWP

- **The control (CTRL) ensemble (with 18 members) run: Climatological SST is prescribed globally.**

- **The large AWP (LAWP) ensemble run: SST composite for large AWP is used in the AWP region; Climatological SST is used outside the AWP.**

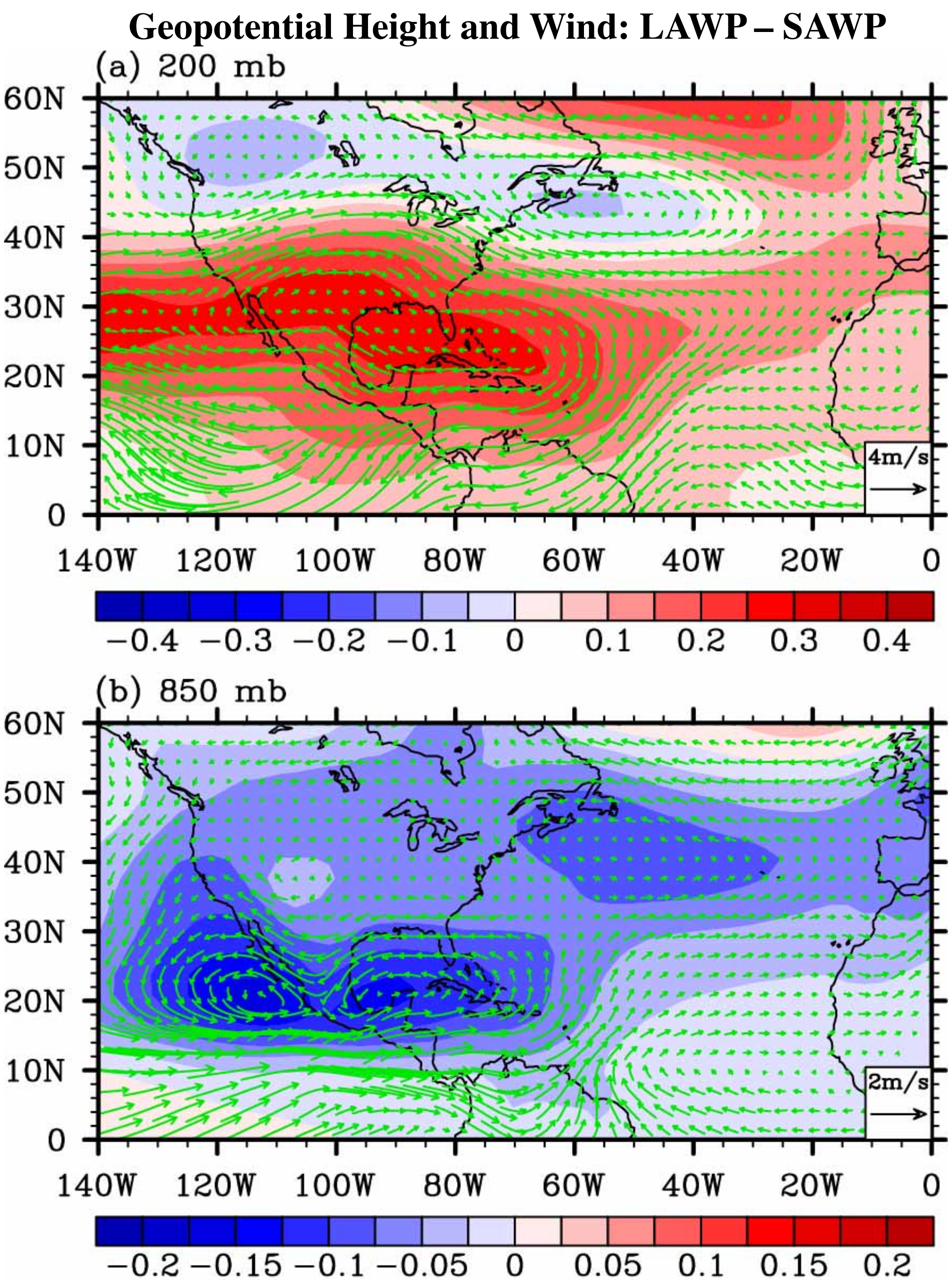
- **The small AWP (SAWP) ensemble run: SST composite for small AWP is used in the AWP region; Climatological SST is used outside the AWP.**

GCM Results: Vertical Wind Shear between 200-mb and 850-mb



Large AWPs reduce vertical wind shear in the hurricane main development region (MDR) that favors Atlantic hurricanes.

Mechanism of Wind Shear Change Induced by the AWP

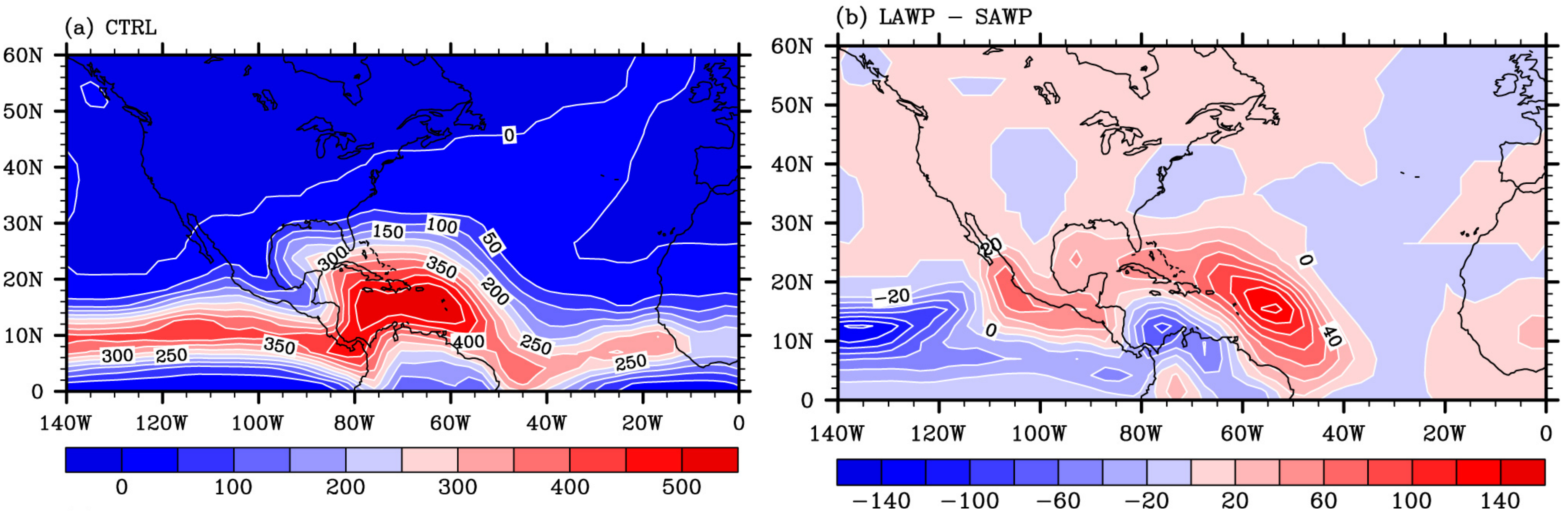


Gill's (1980) physics: Baroclinic response to an AWP heating.

Anomalous anticyclone at 200-mb

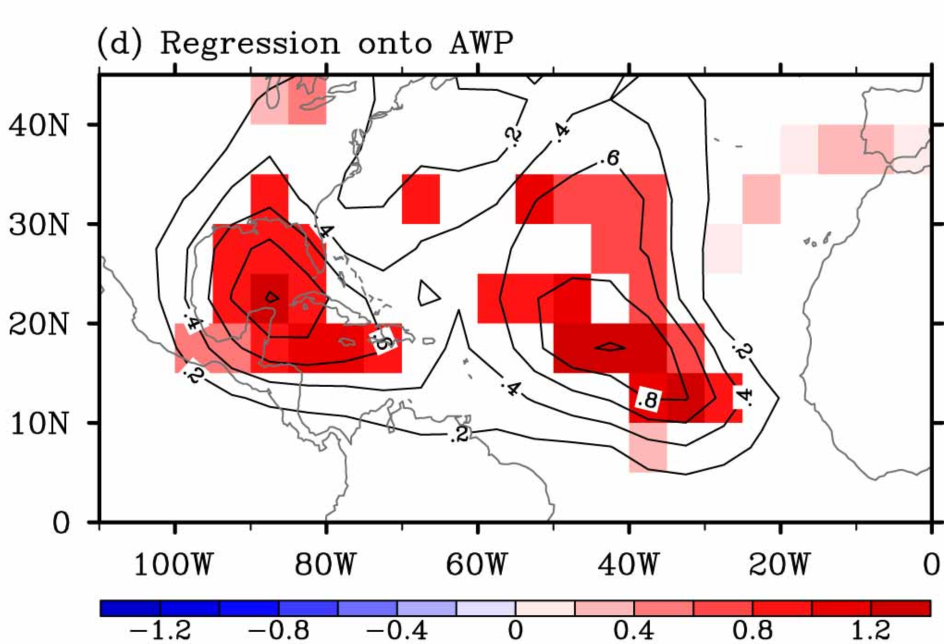
Anomalous cyclone at 850-mb

GCM Results: Convective Available Potential Energy (CAPE)



A large AWP tends to increase CAPE due to the increased near-surface air temperature and water vapor content, which provides the fuel for moist convection and thus increases Atlantic hurricane activity.

Impact of the AWP on the hurricane track: Observations



- **Regression of hurricane track density onto AWP index is positive everywhere, consistent with that large AWPs increase hurricane activity overall.**
- **Two maxima.**
- **Maximum is oriented in a south-to-north direction far away from the U.S., indicating that large AWPs tend to move hurricanes northward without making landfall in the U.S.**

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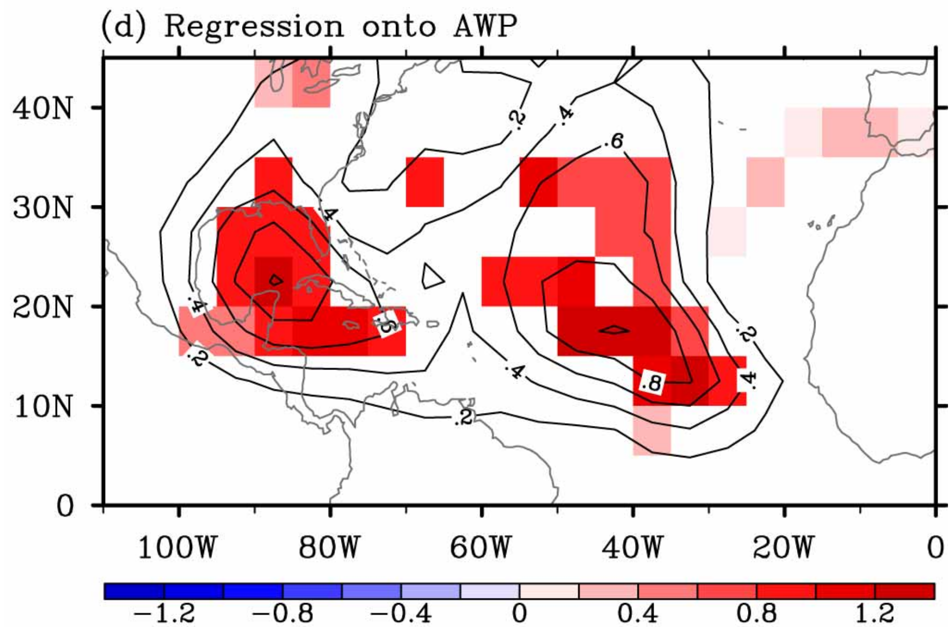

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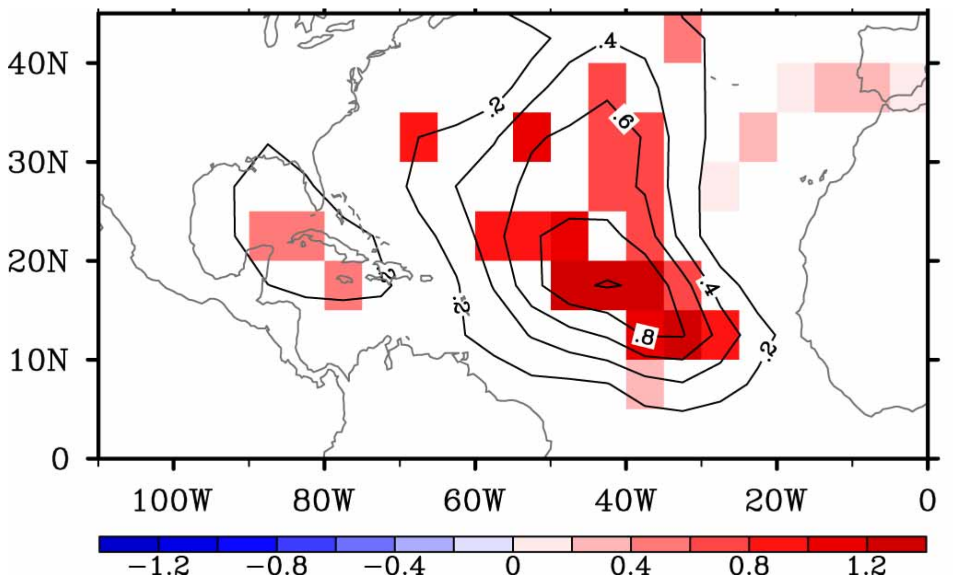

Exclude hurricanes that form in the IAS

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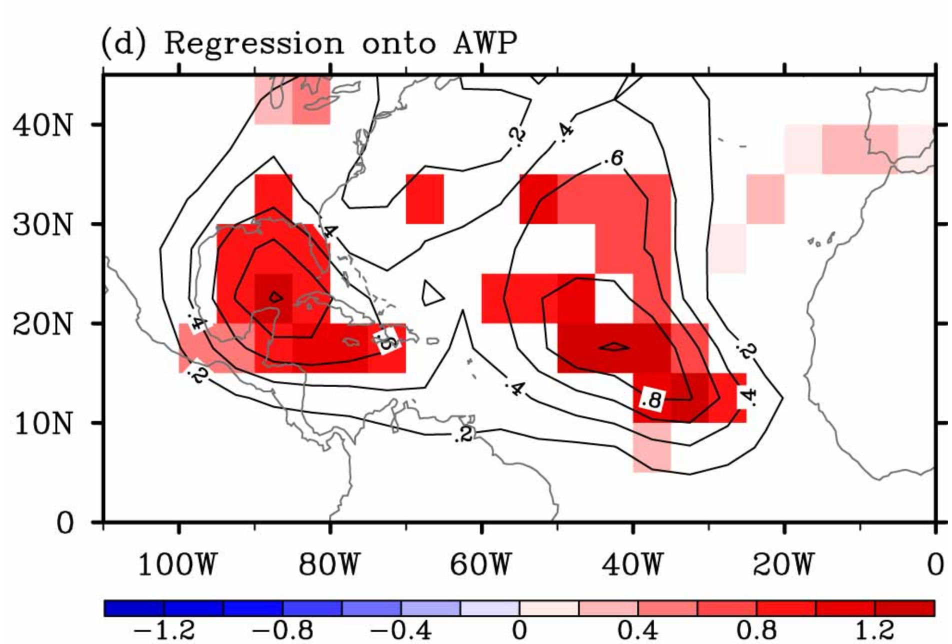

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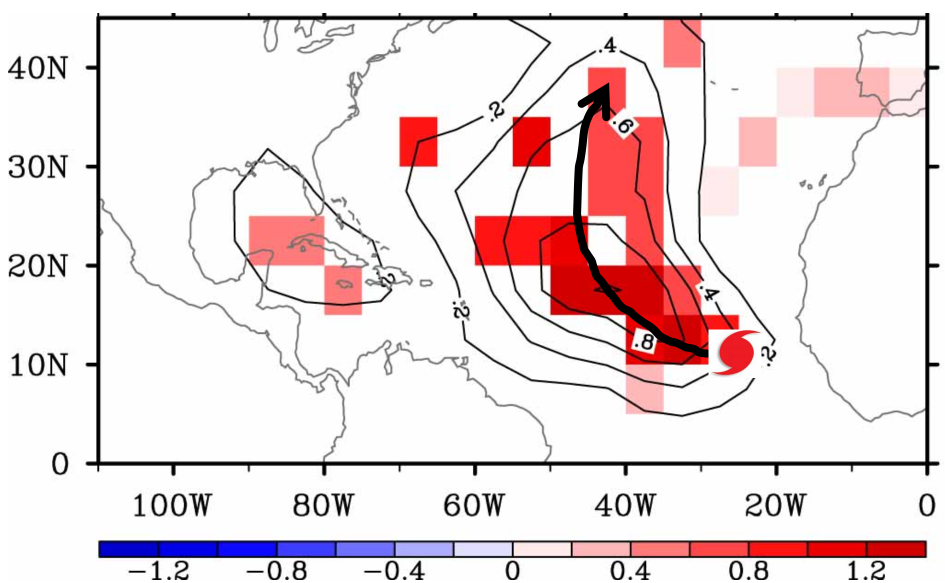


Exclude hurricanes that form in the IAS

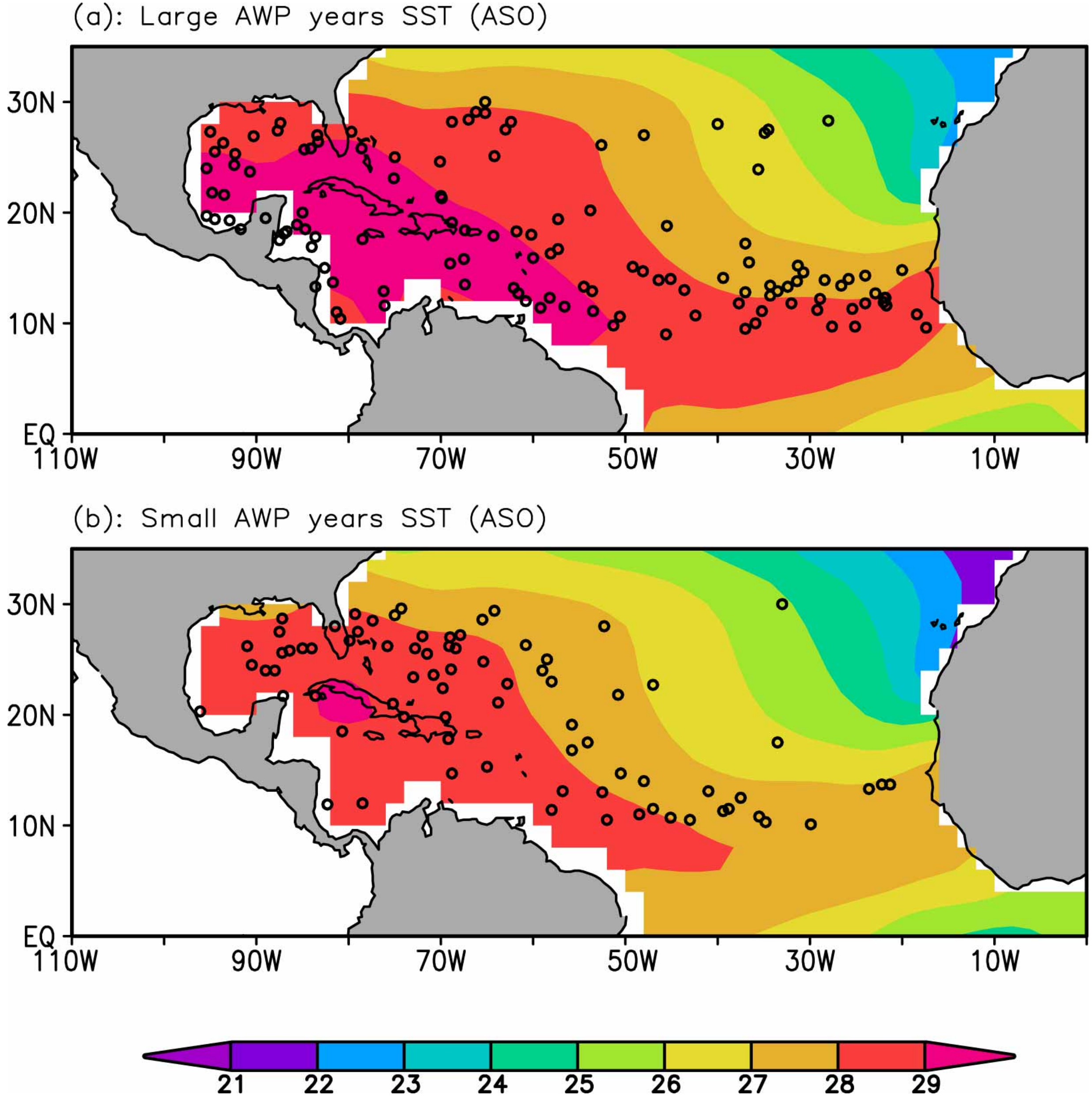
Impact of the AWP on the hurricane track is via two ways:

- **AWP variability changes the hurricane genesis location and then the hurricane track.**

- **AWP variability induces the changes of atmospheric circulation pattern to influence the hurricane track.**

Wang et al. (2011, *GRL*)

AWP-related shift of the Tropical Cyclone (TC) genesis location



Large AWPs (126 TCs)

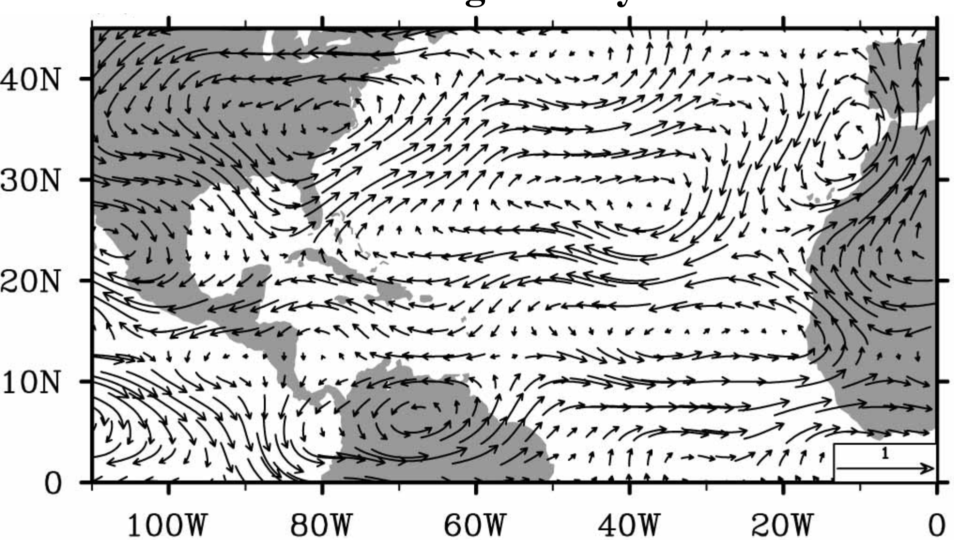
Small AWPs (79 TCs)

- **More TCs formed east of 40°W in large AWP years.**
- **TCs formed further eastward are less likely to make landfall in the U.S.**

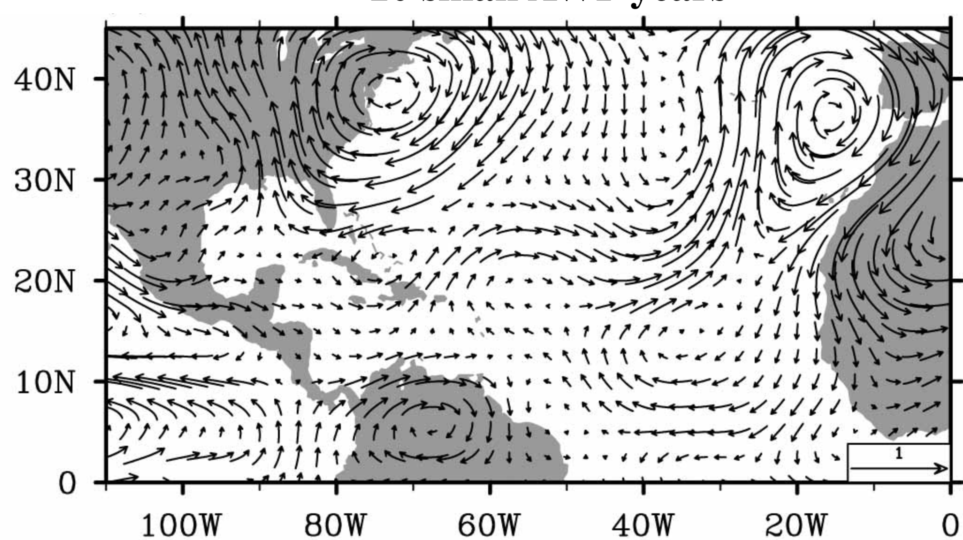
The Observed Hurricane Steering Flows Associated with the AWP

Large AWPs induce eastward and northeastward flows that steer hurricanes away from the U.S.

10 large AWP years



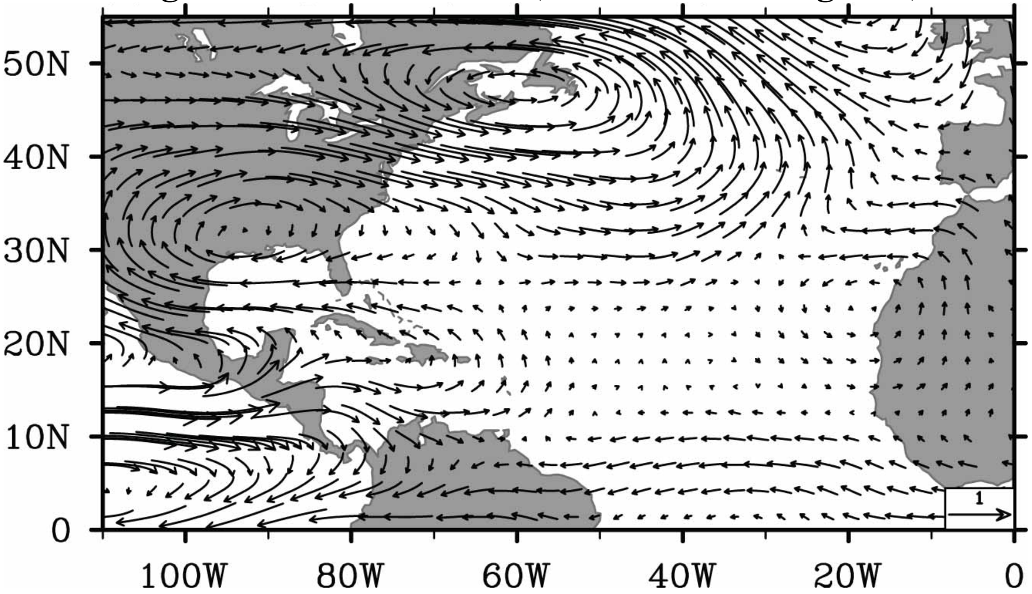
10 small AWP years



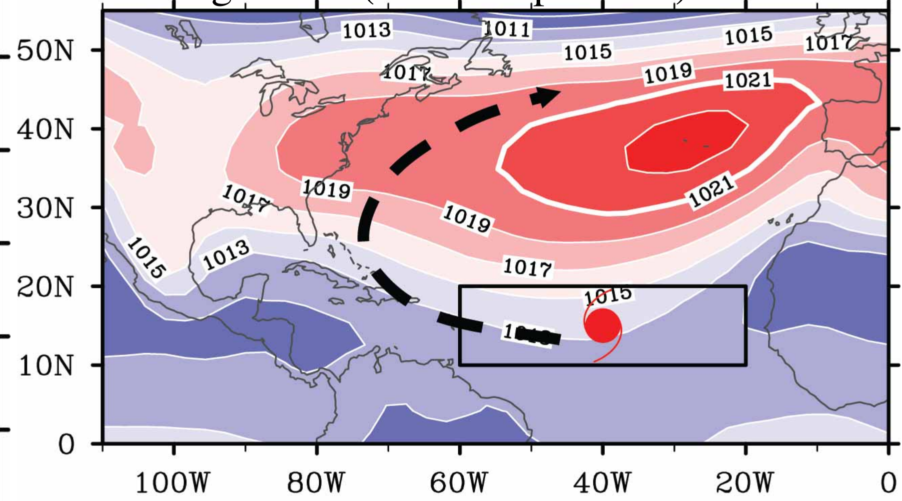
The hurricane steering flow is defined as the vertically-averaged wind from 850-mb to 200-mb (Dong and Neumann 1986).

Hurricane steering flow and subtropical high induced by the AWP: GCM experiments

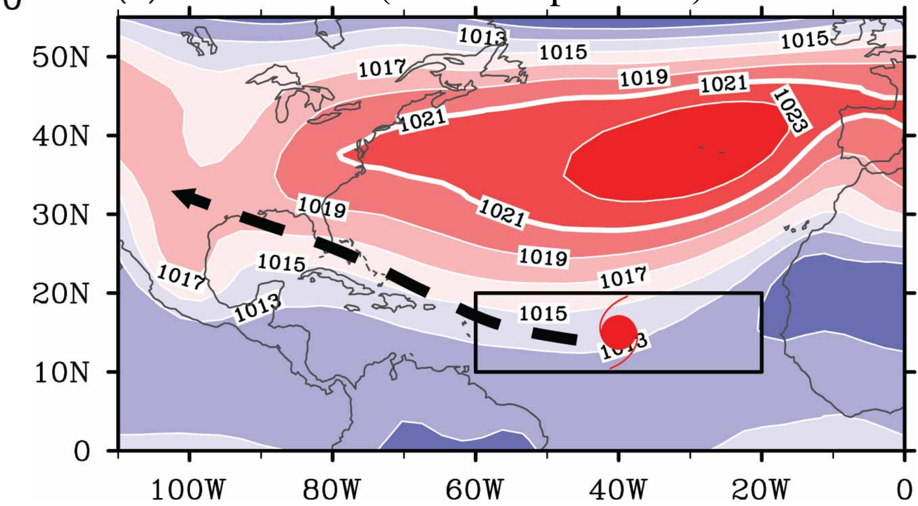
Large AWP – Small AWP (hurricane steering flow)



(a) Large AWP (sea level pressure)



(b) Small AWP (sea level pressure)



Summary

- **A large (small) Atlantic warm pool (AWP) increases (decreases) the number of hurricanes.**

- **Mechanisms: A large (small) AWP reduces (enhances) vertical wind shear and increases (decreases) atmospheric instability.**

- **A large (small) AWP is unfavorable (favorable) for hurricanes to make landfall in the southeast United States. This is consistent with that no hurricanes made landfall in the southeast U.S. during the past 10 years, or hurricanes moved northward such as Hurricane Sandy in 2012.**

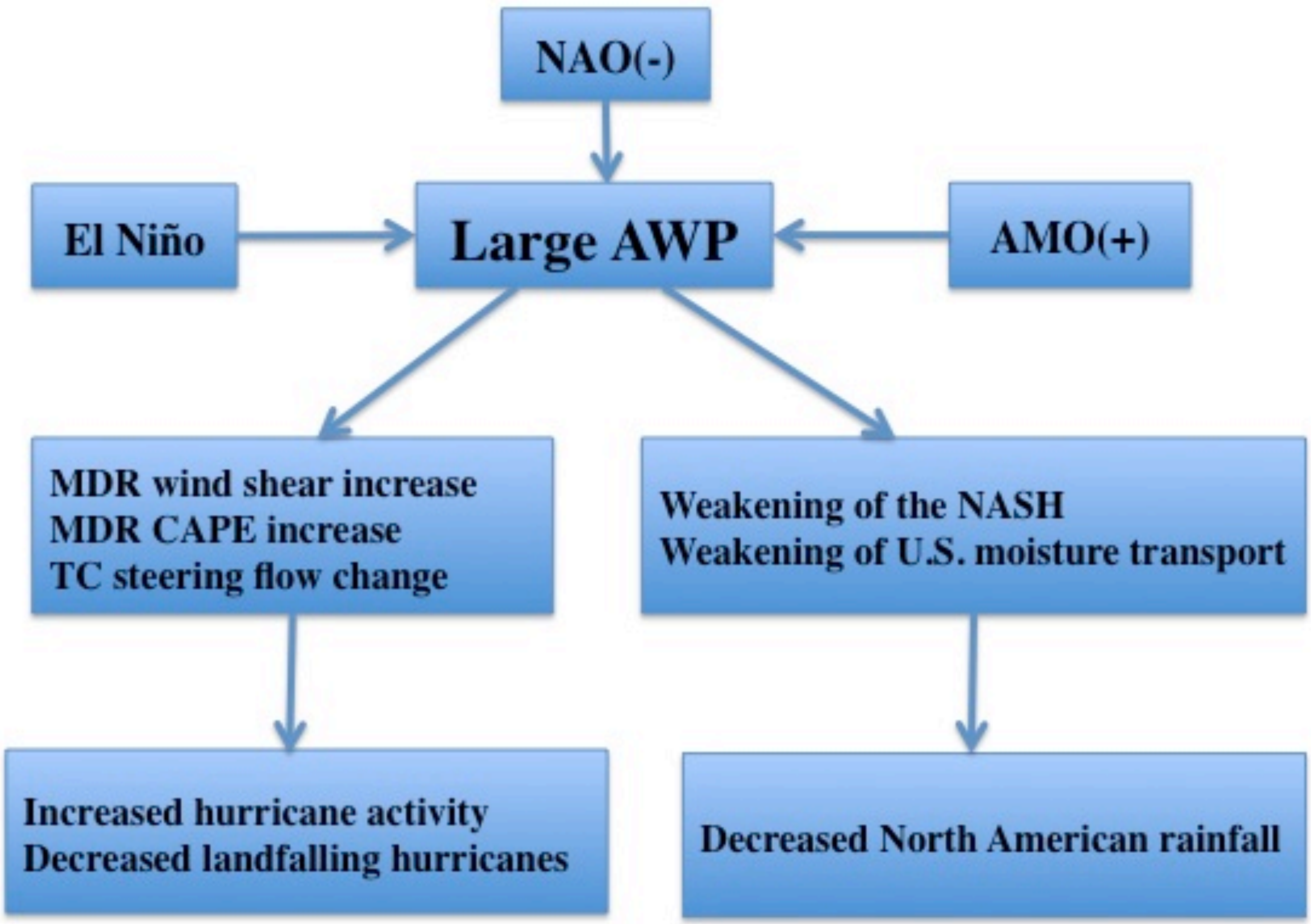
- **Mechanisms are the AWP-induced TC steering flow and the AWP-related shift of the TC genesis location.**

Thank you for your attention!

Questions?

Discussions?

Backup Slides


NAO(-)
El Niño
Large AWP
AMO(+)
MDR wind shear increase
MDR CAPE increase
TC steering flow change
Weakening of the NASH
Weakening of U.S. moisture transport
Increased hurricane activity
Decreased landfalling hurricanes
Decreased North American rainfall

Why Study the Atlantic Warm Pool (AWP)?

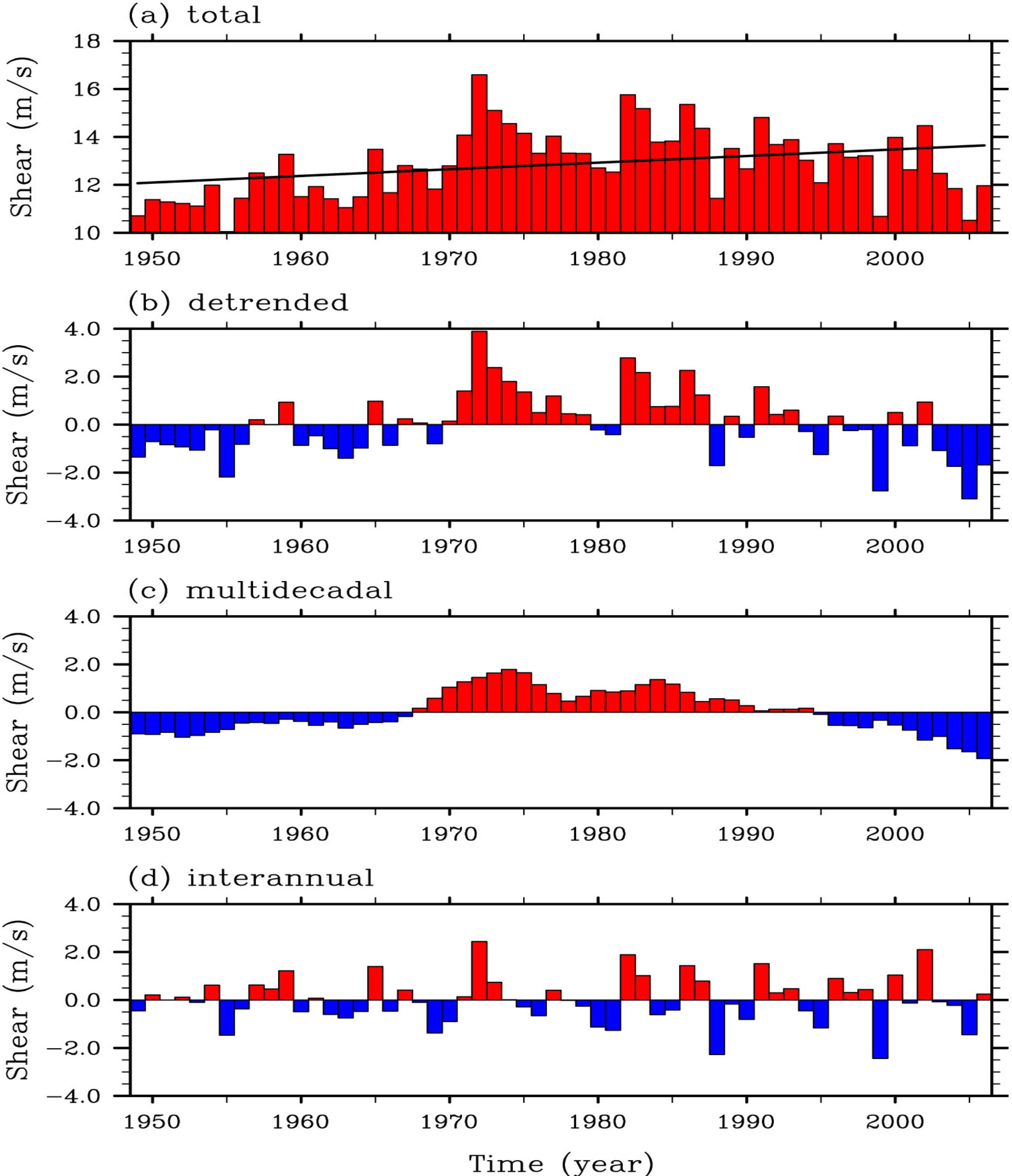
- **ENSO impacts climate mainly in winter; we need a value-added paradigm for *summer* climate prediction. This is the priority season for the AWP region, and ENSO is insufficient.**

- **The Indo-Pacific and Atlantic compete with each other and the atmosphere responds to inter-basin anomalies. We can no longer afford to make projections based on the Pacific only.**

- **Warm pool size (≥28.5°C) is an expression of SST anomalies, but is an index weighted toward regions of maximum SST where deep convective heating occurs.**

- **The AWP is the path of or a birthplace of Atlantic hurricanes.**

- **CLIVAR endorsed an international program called IASCLIP (Intra Americas Study of Climate Processes).**

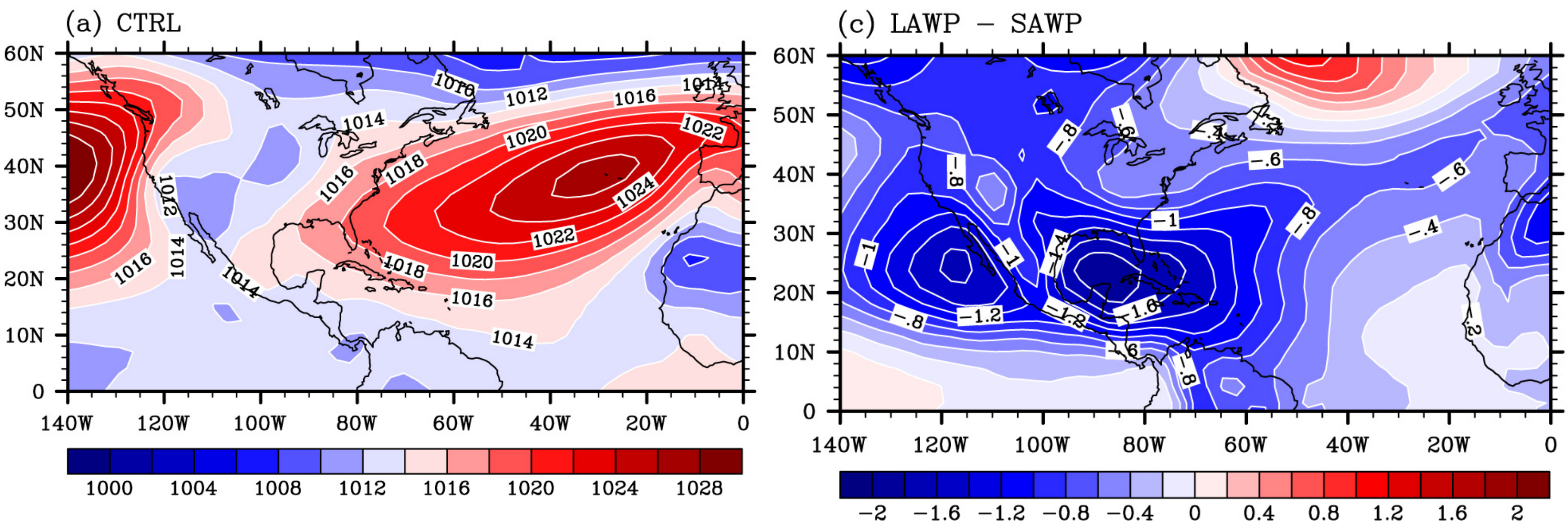


VWS during Jun-Nov in the Atlantic MDR.
Wang et al. (2008, *G*^{3})

- **VWS in the MDR does show the AMO signal.**
- **Global warming is associated with an increase of VWS.**
- **VWS shows a multiscale variability.**

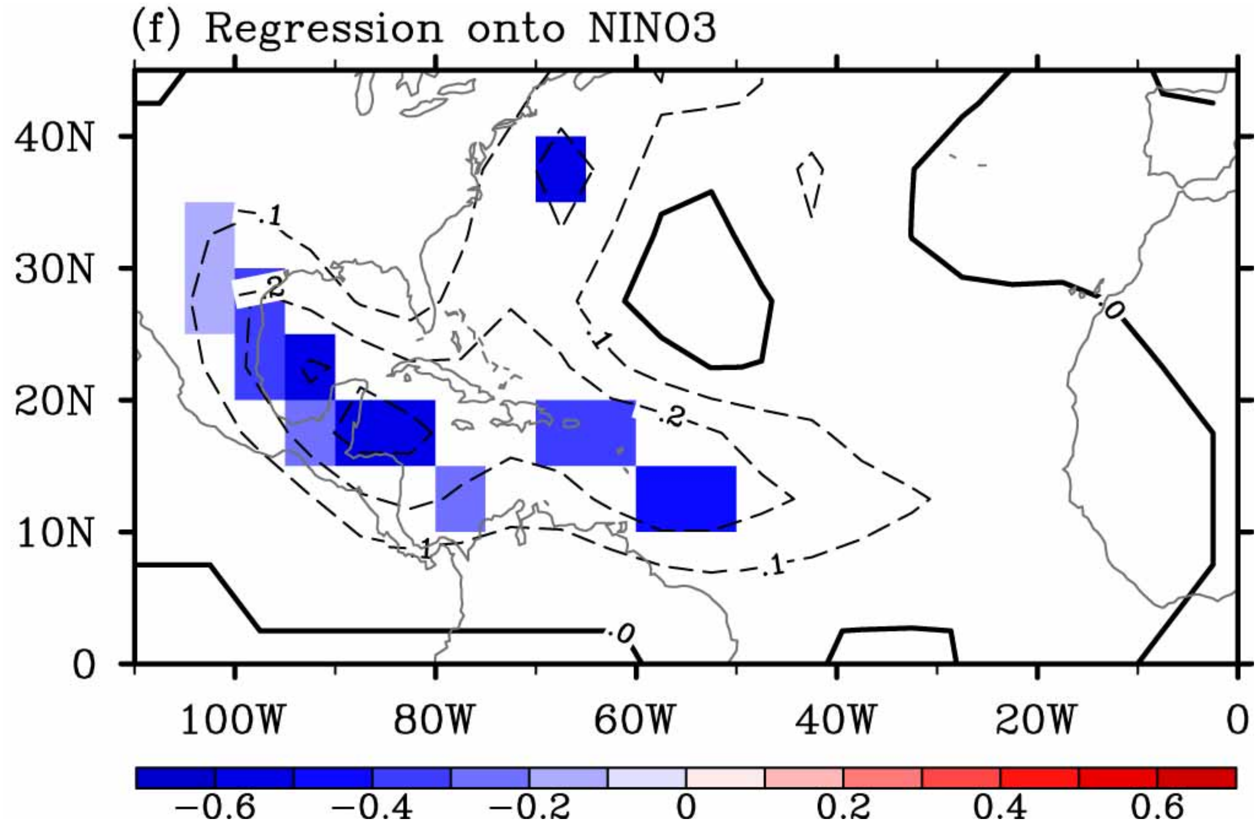
Impact of AWP on the North Atlantic Subtropical High (NASH)

SLP response to AWP variability in JJA



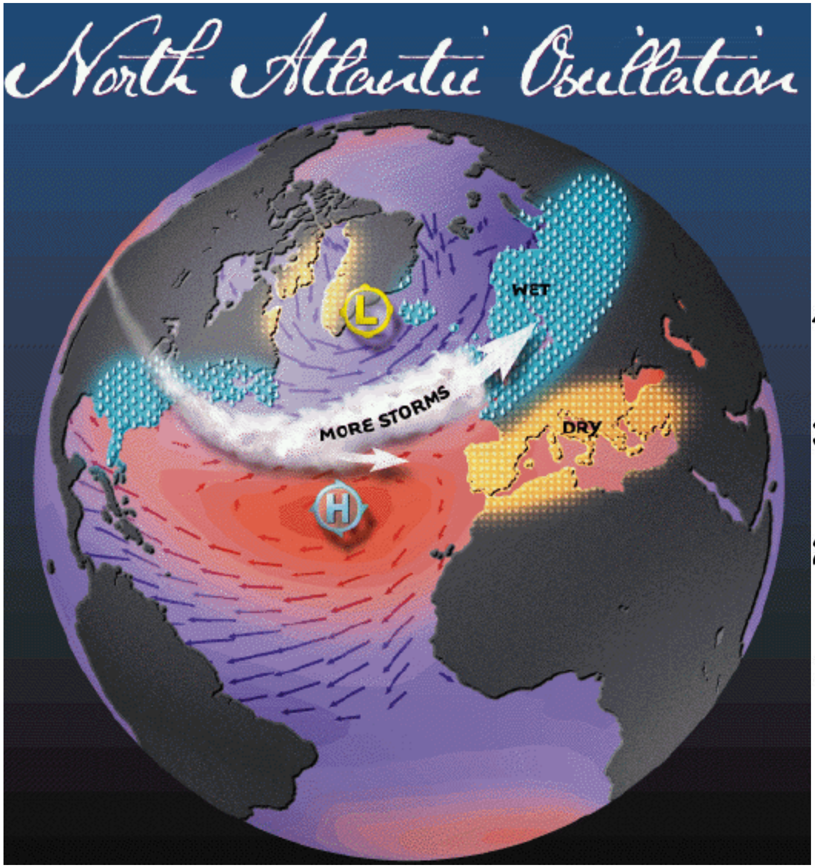
AWP weakens the NASH (especially at its southwestern edge) and strengthens summer continental low over the North American monsoon region.

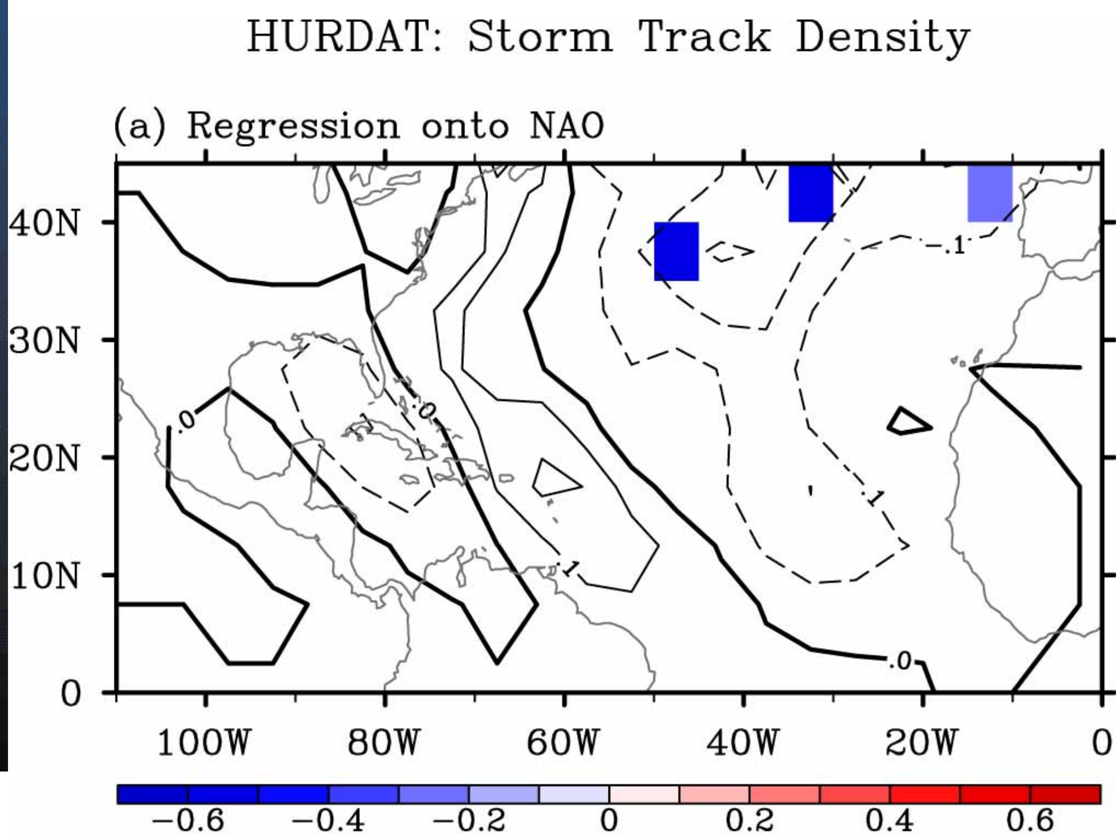
Impact of ENSO on the TC track



La Niña (El Niño) tends to enhance (suppress) the possibility for a TC to make landfall in Central America, Caribbean Islands and the southeastern United States.

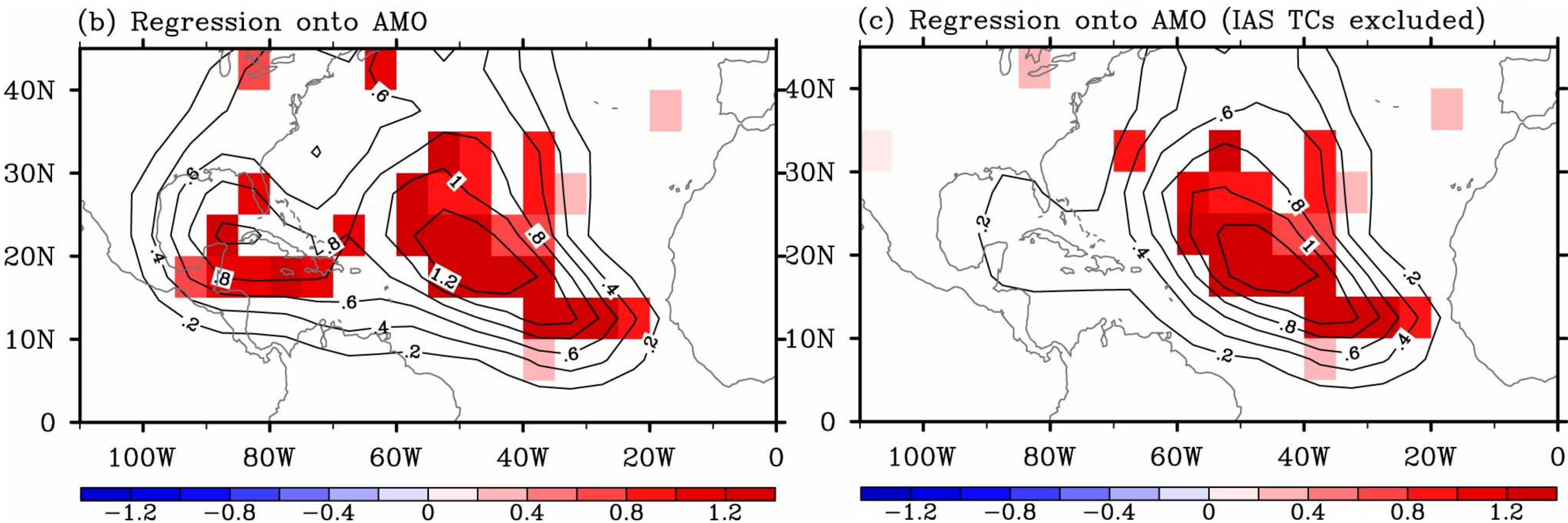
Impact of the North Atlantic Oscillation (NAO) on the TC Track





The regression is not significant.

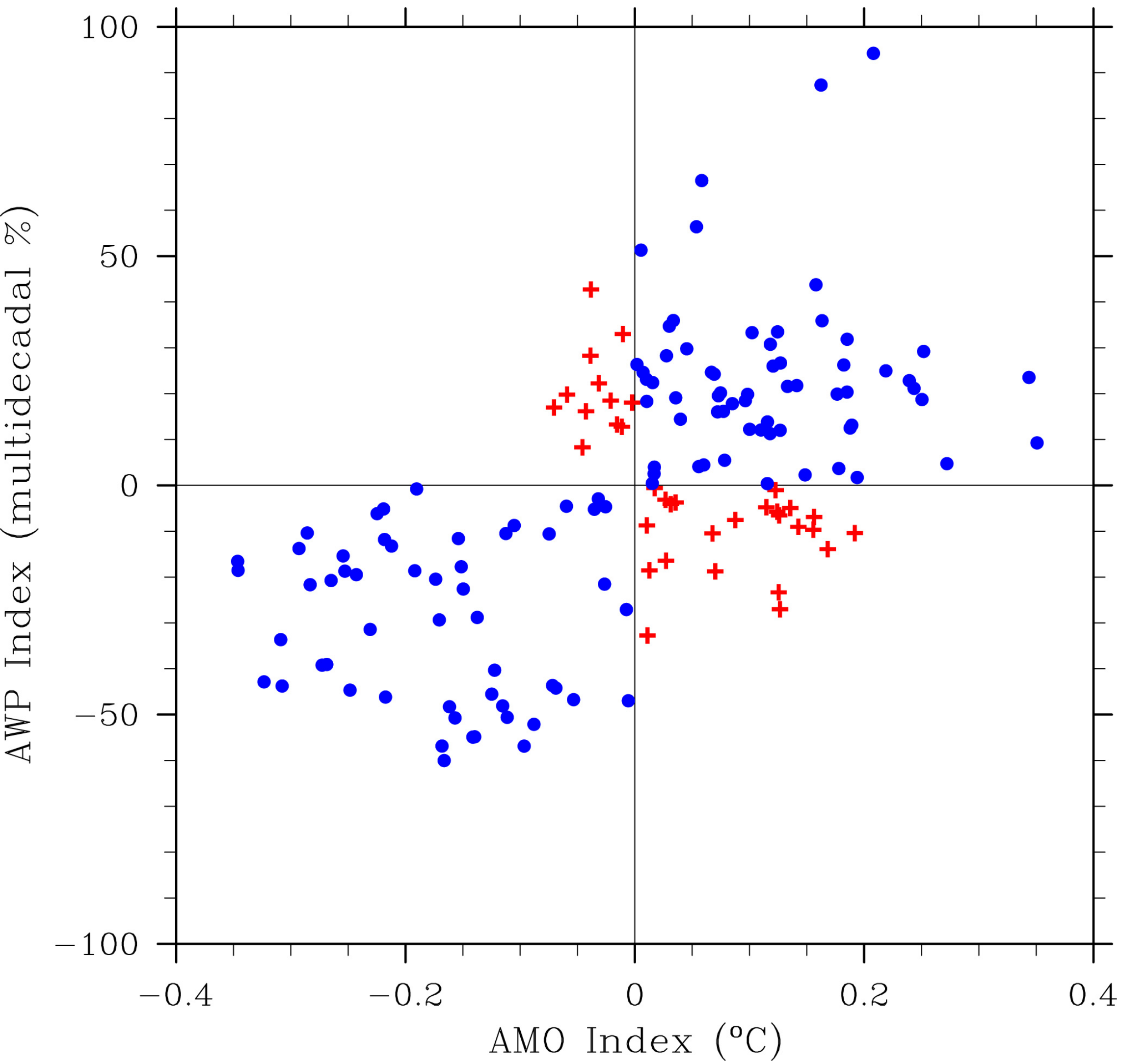
Regression of TC Track Density on AMO Index



Exclude TCs that form in the IAS

The patterns are similar to those by the AWP, indicating that influence of the AMO (Atlantic Multidecadal Oscillation) operates via the AWP-induced mechanisms (Wang et al. 2008, *G*[3]).

AWP acts as a link between the AMO and Atlantic TCs



- **About 80%, large (small) AWPs occur during warm (cool) phases of AMO; Other 20% occurs in transition phases.**
- **Climate response to NA SST is primarily forced at low latitude (Sutton & Hodson 2007, *JC*; Wang et al 2008, *JC*); the latter is forcing the former (e.g., Hoerling et al. 2001, *Science*).**
- **AWP is the path of or a birthplace for Atlantic TCs.**

Wang et al. (2008b)

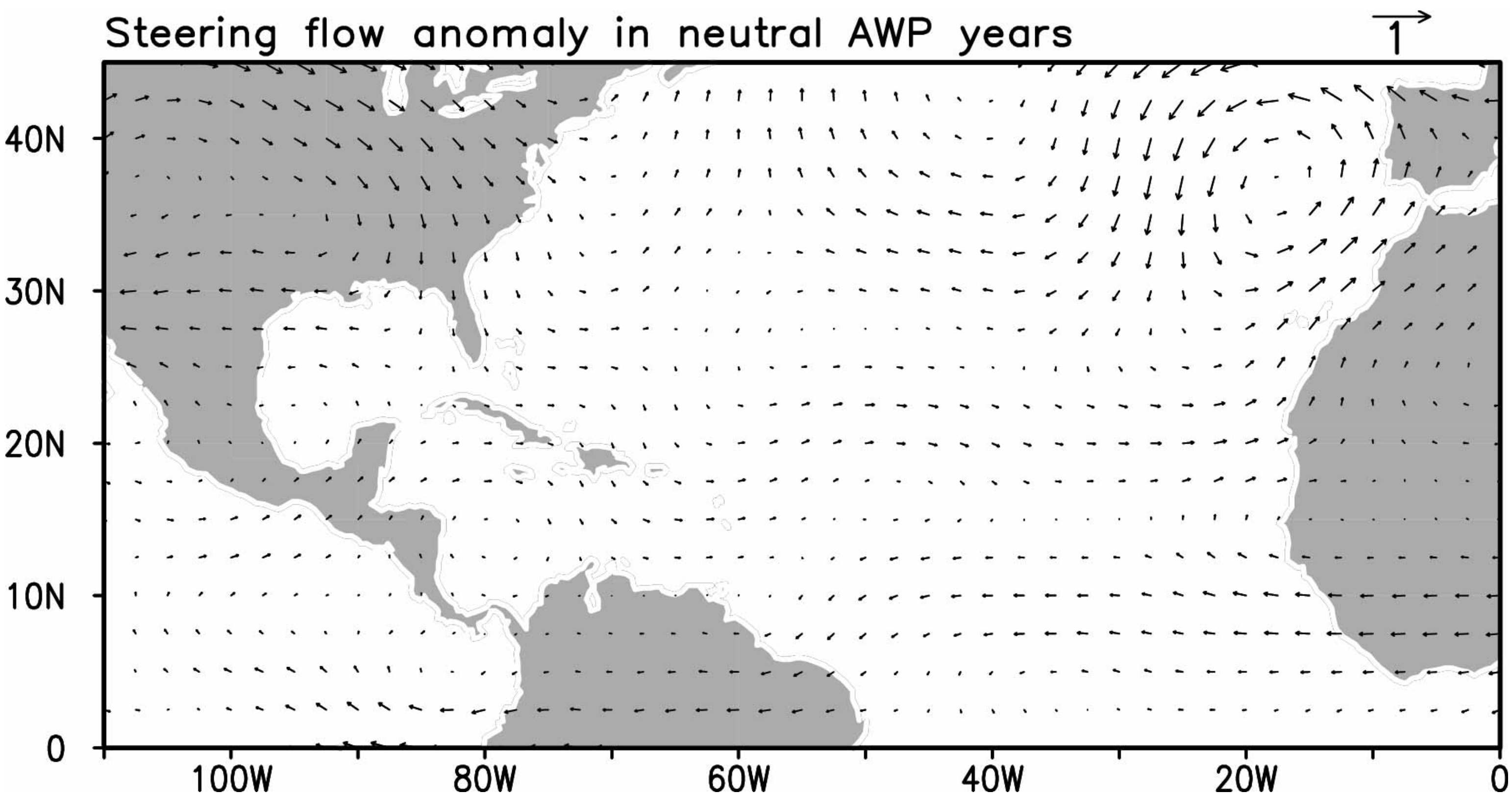
Hurricanes formed in the MDR during 1970-2009

	Hurricanes	Landfalling Hurricanes	Ratio
10 Large AWPs	31	7	0.23
10 Small AWPs	13	5	0.38

↑ 40%

- **Large AWPs increase the number of hurricanes in the MDR.**

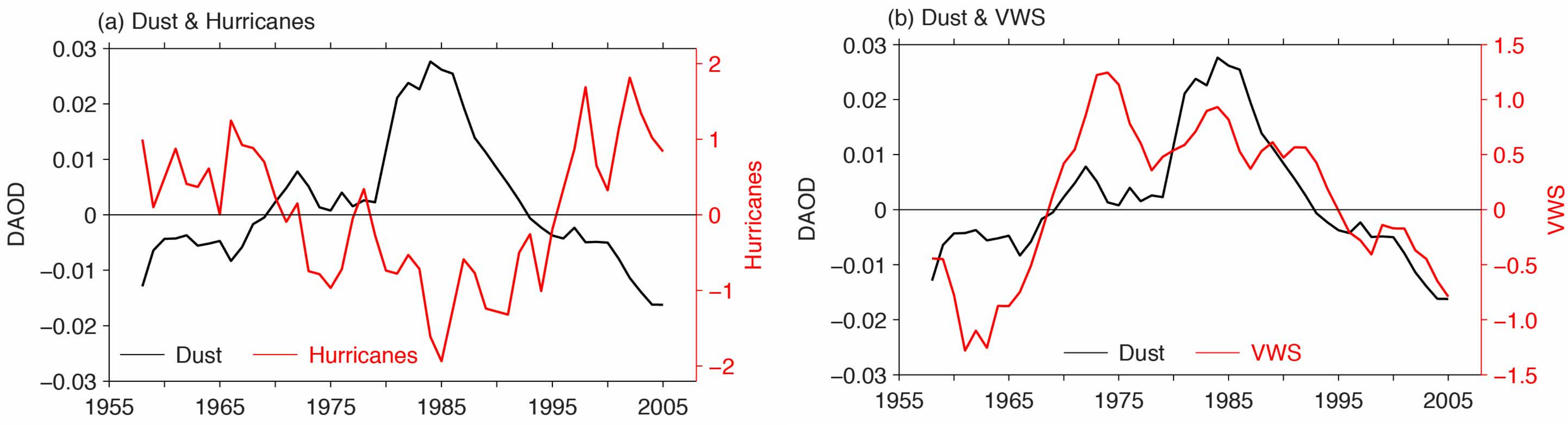
- **Large AWPs decrease the ratio of U. S. landfalling hurricanes by 40%.**



The hurricane steering flow anomalies in neutral AWP years are very small in comparison with large/small AWP years, indicating that AWP variability plays a key role for the hurricane steering flow change.

Wang et al. (2011)

Dust and Hurricanes on Multidecadal Timescales



- **When dust concentration in TNA is low (high), the number of Atlantic hurricanes is more (less).**

- **This is because dust changes meridional air temperature gradient via dust-radiation processes and alters zonal winds (thermal wind balance) and then vertical wind shear (VWS).**

Wang et al. (2012, JC)