Impact of the Atlantic Warm Pool on North American Rainfall

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\[ \text{SST} \geq 28.5^\circ C \]

Focus on the Atlantic side of WHWP (AWP).
SST Composite of the Atlantic Warm Pool (AWP)

- ERSST data.
- AWP variability is large.
- Large AWPs are almost three times larger than the small ones.
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 only on the Pacific.

- Here we show that the AWP affects North American rainfall in both the cold and warm seasons, but with different mechanisms.

- The AWP is the path of or a birthplace of tropical cyclones.

- The moisture transport from the AWP is related to tornado activity in the central U.S.
Observations: Rainfall (GPCP) and SLP (Reanalysis)

Multiple regressions of rainfall & SLP onto Nino3.4 and AWP indices during the cold season (October to March)
Observations: Rainfall (GPCP) and SLP (Reanalysis)

Multiple regressions of rainfall & SLP onto Nino3.4 and AWP indices during the warm season (April to September)
SSTA composites for large and small AWPs are first computed by using ERSST version 3.

Coupled model is integrated for 1500 years without climate shifts.

Control (CTRL) run: The ocean and atmosphere are fully coupled except in the AWP region where we relax the model-produced SST to model climatological SST (from last 100 years of 1500 year model run).

Large AWP (LAWP) run: The ocean and atmosphere are fully coupled except in the AWP region where we relax the model-produced SST to model climatological SST added with large AWP SSTA composites.

Small AWP (SAWP) run: The ocean and atmosphere are fully coupled except in the AWP region where we relax the model-produced SST to model climatological SST added with small AWP SSTA composites.

The (LAWP – SAWP)/2 runs are taken as the AWP response.
Model rainfall & SLP response to the AWP: \((\text{LAWP} - \text{SAWP})/2\) runs

(a) October-March

(b) April-September

Dry
Moisture Budget in the Cold Season: (LAWP-SAWP)/2 runs

The change of \( \text{Div}Q_M \) can be further separated into change by mean circulation dynamics \( \delta MCD \) and change by thermodynamics \( \delta TH \):

\[
\delta MCD = -\frac{1}{g} \int_0^{P_s} (\bar{q}_S \nabla \cdot \delta \bar{U} + \delta \bar{U} \cdot \nabla \bar{q}_S) \, dp = \delta MCD_D + \delta MCD_A
\]

\[
\delta TH = -\frac{1}{g} \int_0^{P_s} (\delta \bar{q} \nabla \cdot \bar{U}_S + \bar{U}_S \cdot \nabla \delta \bar{q}) \, dp = \delta TH_D + \delta TH_A
\]

Conclusion: The wind divergence change is very important in the cold season rainfall.
Moisture Budget in the Warm Season: \((\text{LAWP-SAWP})/2\) runs

Conclusion: The moisture advection by wind change is important for the warm season rainfall in the central U.S.
The AWP induces a local (remote) response in the warm (cold) season: 
(LAWP-SAWP)/2 runs

- Baroclinic streamfunction mainly represents local diabatic heating, as shown by Gill (1980).
- Teleconnection effect is manifested in barotropic streamfunction.
- In the warm season, baroclinic streamfunction is much larger, suggesting that AWP induces a local change for rainfall.
- In the cold season, barotropic streamfunction is much stronger and resembles the negative phase of the PNA pattern, suggesting that AWP induces an indirect/remote effect via the Pacific.
Conclusion: Large (small) AWP reduces (enhances) the southerly Great Plains low-level jet which decreases (increases) the northward moisture transport & reduces (enhances) central U.S. rainfall in the warm season.
Conclusion: The AWP induces the cold SST anomalies in the tropical Pacific which teleconnect to influence North American rainfall in the cold season.
Initially, a large AWP affects the southeast Pacific via the AWP-induced regional Hadley circulation change.

Velocity potential and divergent wind at 200 mb in summer

Mean state

Effect of the AWP
• In summer, a AWP enhances the regional Hadley circulation.

• This leads to a strengthening of the easterly trade wind and cold SSTA in the tropical southeast Pacific.

• Then, the wind-evaporation-SST feedback further increases SSTA and propagates SSTA equatorward and westward.

• A La Niña-like SST pattern in winter.
Then, the AWP-induced La Niña-like SST anomalies produce a negative phase of the PNA pattern during the cold season. Associated with the PNA are a high pressure in the southern U.S. and thus a decrease of rainfall over there.
Summary

- In the warm season, a large AWP leads to a “Gill-type” response that weakens the North Atlantic subtropical high and reduces the northward moisture transport to the central U.S., and thus decreases rainfall in the central U.S.

- In the cold season, however, the effect of the AWP on North American rainfall is through the AWP-induced change in the Pacific: A large AWP induces the cold SST anomalies in the tropical Pacific which teleconnect to reduce rainfall in the southern U.S.

- The opposite is true for a small AWP.
SST forcing differences in the AWP

(a) LAW = CTRL (JJA)

(b) LAW - CTRL

(c) SAWP - CTRL (JJA)

(d) SAWP - CTRL
AWP (SST ≥ 28.5°C) area anomaly indices during June-November

In additional to seasonal cycle, AWP also shows interannual, multidecadal, and linear warming trend variations.

Wang et al. (2008, $G^3$)
Why and how does AWP affect climate/hurricanes?

- AWP is a source of moisture. Atmospheric low-level flows carry moisture from AWP to the central U.S. for rainfall there.
- AWP changes the N.A. subtropical high which in turn affects atmospheric circulation and then climate.
- AWP changes vertical wind shear and instability, then hurricanes.
Gill’s (1980) physics: Baroclinic response to an AWP heating.

Anomalous anticyclone at 200-mb

Anomalous cyclone at 850-mb

Wang et al. (2008, JC)