Persistent Atmospheric and Oceanic Anomalies in the North Atlantic Ocean from Summer 2009 to Summer 2010

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Main Results

Combination of El Niño, long-persistent negative phase of the NAO, and the long-term trend results in the record-breaking positive SSTA in the Hurricane Main Development Region in boreal Spring and Summer of 2010

1: Questions

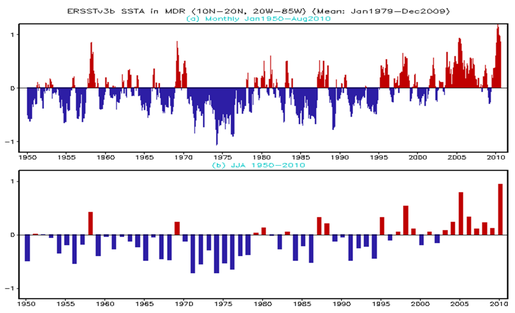
Q1: What physical processes cause the record-breaking SSTA in the North Atlantic in 2009-2010?

Q2: What is the contribution of the NAO?

Q3: What is the impact of ENSO on the North Atlantic anomalies?

Q4: Is it a long-term trend or short-term fluctuation?

Q5: Is there any application in prediction?



Record-breaking MDR SSTA in 2010 since 1950

(MDR: Hurricane Main Development Region, 10N-20N, 20W-85W)

2: SUMMARY

A. The SSTA in the tropical North Atlantic during summer 2009-summer 2010 represented a typical response to ENSO, preconditioned and amplified by the influence of a strong and persistent negative phase of the NAO. The long-term trends enhanced the warming in the high and low latitudes and weakened the cooling in the middle latitudes. The combination of these 3 factors caused the record-breaking positive SSTA in the MDR in the boreal spring and summer of 2010.

B. The persistent negative phase of the NAO was associated with active thermodynamic air-sea interaction in the North Atlantic basin. Surface wind anomalies associated with the NAO altered the ocean surface heat flux and changed the SSTA, which was likely further enhanced by the positive wind speed-evaporation-SST feedback. The total heat flux was dominated by the latent and sensible heat fluxes, while the short-wave radiation contributed to the tropical SSTA to a lesser degree.

C. Sensitivity experiments with an AGCM forced by observed SST in the Atlantic Ocean alone suggested that the Atlantic SSTA, which was partly forced by the NAO, had some positive contribution to the persistent negative phase of the NAO. Therefore, the persistent NAO condition was partly an outcome of the global climate anomalies and the ocean-atmosphere feedback within the Atlantic basin.

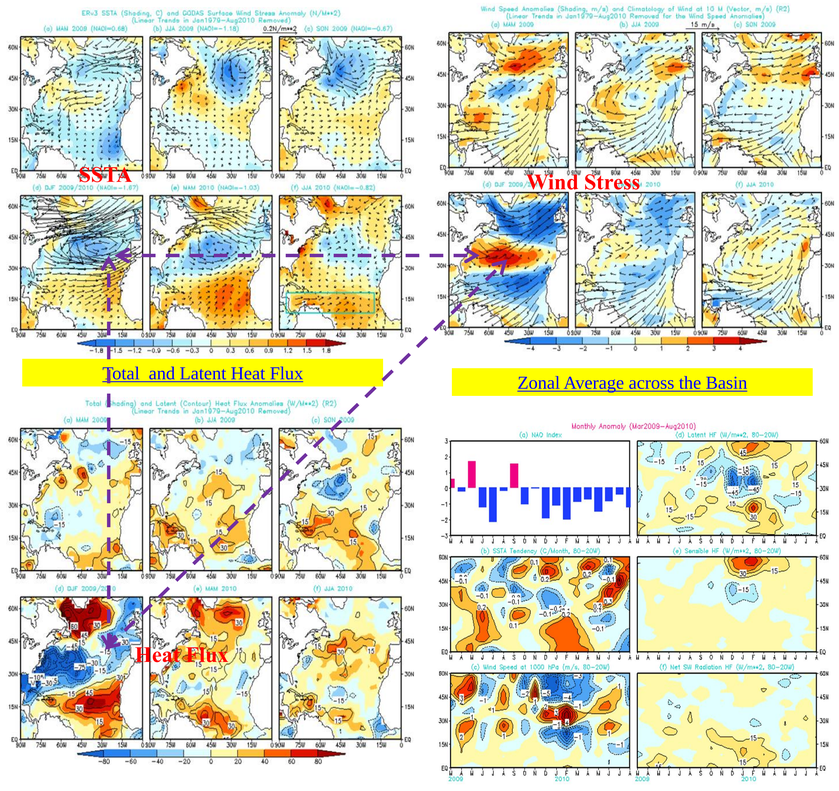
D. Based on the statistical relationship, the SSTA pattern in the North Atlantic can be reasonably well predicted by using preceding ENSO and NAO as predictors.

E. 2009-2010 summer SSTA in North Atlantic was different from the observed trend signal. It was mainly a short-term fluctuation, but the long-term tend had significant contribution. Also, persistent NAO anomalies might be linked to the subsurface ocean temperature anomalies, and probably to the variation of the Gulf Stream extension.

3: Air-Sea Interaction: Thermodynamical Processes

Seasonal Mean SST & Wind Stress Anomalies

Seasonal 10m Wind & Anomaly Wind Speed



Total and Latent Heat Flux

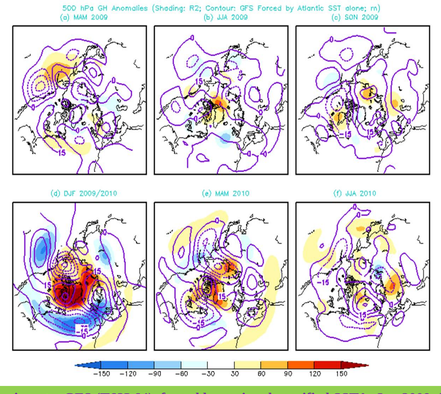
Zonal Average across the Basin

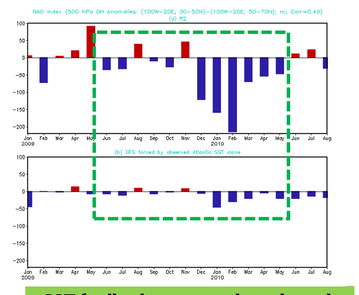
A: The persistent negative phase of NAO was associated with active thermodynamic a-o interaction.
B: Surface wind anomalies associated with NAO altered the ocean surface heat flux and changed the SSTA, which was likely further enhanced by the positive wind speed-evaporation-SST feedback.
C: The total heat flux was dominated by the latent and sensible heat fluxes, while SW radiation contributed to the tropical SSTA to a lesser degree.

4: Dynamical Feedback

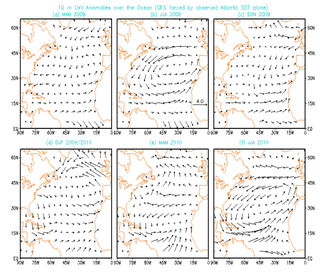
H500: About 20% of observed anomaly amplitudes simulated in the GFS simulations; R2: shading

NAO: **Its phase is well reproduced by the regional SSTA forced experiment, but its amplitude is largely underestimated**





SST feedback on atmosphere through altering surface wind



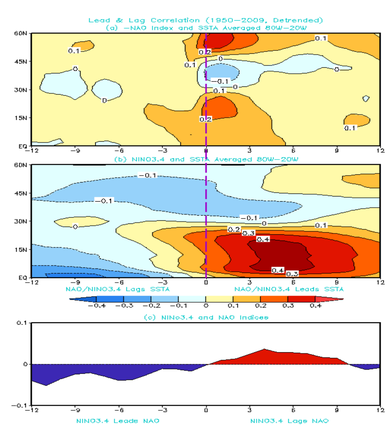
Experiments: GFS (T62L64) forced by regional specified SSTA, Jan 2009-Aug 2010:
Observed SSTA in the Atlantic Ocean from 30°S to the northern pole and climatology SST elsewhere. Sea ice is specified as observed. Nine ensemble number integrations. Anomalies are the departure from monthly mean climatology of 50 year integration forced by climatological SST

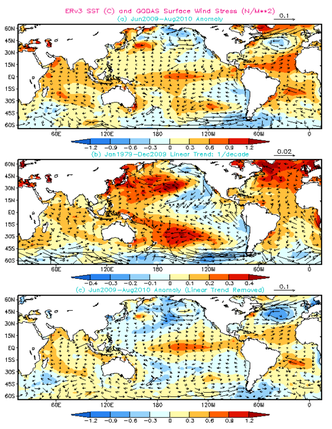
SST feedback on atmosphere through altering surface wind, that enhances the persistency of the A-O anomalies. However, its contribution is relatively small.

5: Statistical Relationship and Impact of Long-term Trend

NAO's impact on SST is mainly with 0-3 month lag. It is weaker than ENSO's impact. The tripole/horseshoe pattern consists with the SSTA in 2009-2010.
ENSO signals propagate into the tropical N. Atlantic in 3-8 months late, so the SSTA in the tropical N. Atlantic is a typical impact of ENSO in this period. ENSO affects the trade wind through atmosphere (PNA), then changes the SST through WES mechanism.
Preceding El Nino may slightly favor to the negative phase of NAO.

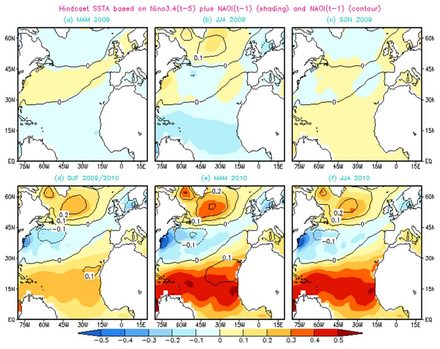
The anomalies are short-term fluctuation, but the long-term trend may account for about 1/3 of the warming in the tropical Atlantic and weakens the cooling in the middle latitudes of the North Atlantic by about 1/3.





6: Potential of Prediction Application

Using Nino3.4 (t-5) and NAO (t-1), the SSTA pattern can be well reconstructed
The contribution of NAO (El Nino) is mainly in high (low) latitudes
The amplitude of SSTA is largely underestimated

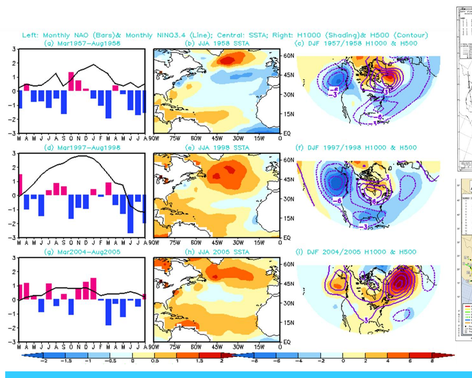


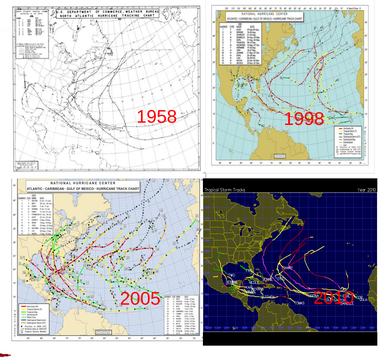
Pattern correlation of hindcast and observed SSTA (80°W-20°E, 0°-65°N):

Predictor / Season	NINO3.4 (t-5) index	NAO (t-1) index	Both NINO3.4 (t-5) and NAO (t-1) indices
MAM 2009	0.61	0.36	0.62
JJA 2009	0.16	-0.22	0.05
SON 2009	0.24	0.0	0.25
DJF 2009/2010	0.63	0.61	0.76
MAM 2010	0.73	0.62	0.82

Active Atlantic Hurricane Seasons in 1958, 1998, 2005, 2010
The Atlantic Accumulated Cyclone Energy (ACE) index is 121 in 1958, 182 in 1998, 248 in 2005, & 165 in 2010. For 1950-2009, the mean is 101 and the median is 88.

Combination of El Nino and negative phase of NAO favors warming in MDR: Cases of 1958, 1998, 2005





Based on the statistical relationship, the SSTA pattern and hurricane activity in the North Atlantic can be partially predicted by using preceding ENSO and NAO as predictors.

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