The Importance of the NAO for the ENSO - Tropical Atlantic Teleconnection

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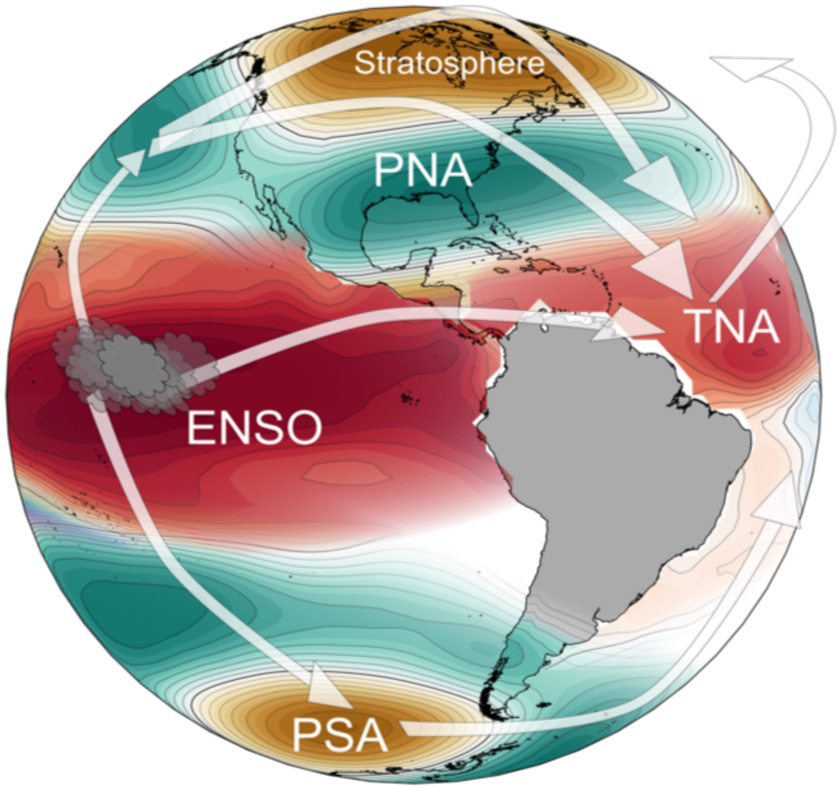

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Introduction

- The **teleconnection** to the tropical north Atlantic (TNA) following an El Niño Southern Oscillation (ENSO) event is one of the most robust teleconnections (García-Serrano et al. 2017).
- The main pathways for this teleconnection include (Jiang and Li, 2019):
  - **Extratropical pathway,** through projection onto the Pacific North American Pattern (PNA)
  - **Tropical pathway,** via a Matsuno-Gill type response and a westward propagating Kelvin wave
- The teleconnection produces a sea surface temperature (SST) anomaly in the TNA, peaking in boreal spring (March to May, MAM) (Lee et al. 2008).
- Over the Atlantic, two mechanisms can cause this SST anomaly, including:
  - Modified **trade winds** in the boreal winter (January to March, JFM), inducing a **Wind-Evaporation-SST (WES) feedback** (see fig.1A for trade winds - SST relationship, and fig.1B for areas where winds are more effective at generating an SST anomaly, see methods for index descriptions)
  - Adjustment of **atmospheric stability,** due to the Kelvin wave propagating a temperature anomaly

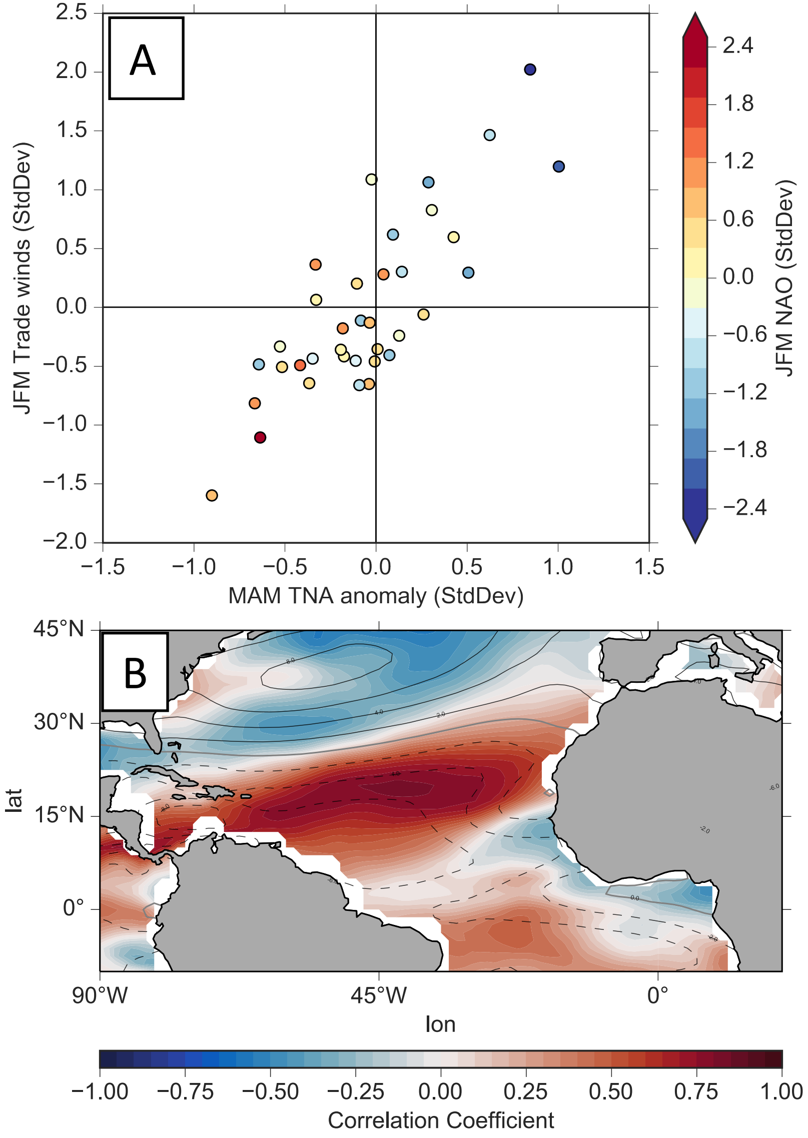

Figure 1) (A) Relationship between JFM trade winds, JFM NAO, and MAM TNA, (B) point-wise bivariant correlation (in color) between the JFM 850 hPa zonal winds and the SST anomaly over the same grid cell, with JFM 850 hPa zonal wind climatology in line contours

Aim of study

This study intends to extend our current understanding of how significant the influence of the North Atlantic Oscillation (NAO) is amid ENSO influencing the Tropical North Atlantic (TNA) region. Studies have shown the NAO is associated with a tripole SST pattern in the North Atlantic, but further analysis is needed to determine how this aspect interacts with the ENSO teleconnection.

Methods

- **Bivariant and partial correlations** define the critical areas impacted by ENSO, as well as the NAO. The PNA index characterizes the extra-tropical pathway, and the vertical shear over the tropical Atlantic represents the tropical pathway. The rationale behind using the vertical shear is that upper-level winds are modified following the propagation of a Kelvin wave (Sasaski et al. 2015).

- **Composites** of the JFM 850 hPa zonal winds and MAM SST are constructed using eight different scenarios based on filtering the October to February (ONDJF) Niño 3.4 index for ENSO events (using a +/- 0.5 standard deviation threshold) and the preceding JFM NAO index (see figure 2).

Index	Description
Niño 3.4 index	Area averaged SST anomaly [5°N-5 °S, 120°W-170°W]
TNA	Area averaged SST anomaly [5-25°N,305-345°E] (Taschetto et al. 2016)
Trade winds	Area averaged 850 hPa zonal wind [10-25°N, 290-345°E] (Jiang and Li, 2019)
NAO	Difference between the zonally averaged SLP at 35°N and 65°N from 80°W to 30°E (Li and Wang, 2003)
PNA	Difference between anomalies within 4 regions (Barston and Livezey, 1987)
Tropical Shear	Area averaged differences between 850 and 200 hPa zonal winds over the are of [10°N-10°S, and 320-355°E]

Variable	Dataset	Period
Zonal wind, sea level pressure (SLP)	JRA-55 (Kobayashi et, al., 2015)	1958-2016
Sea Surface Temperature	NOAA ERSSTv5 (Huang et. al., 2017)	1854-2016

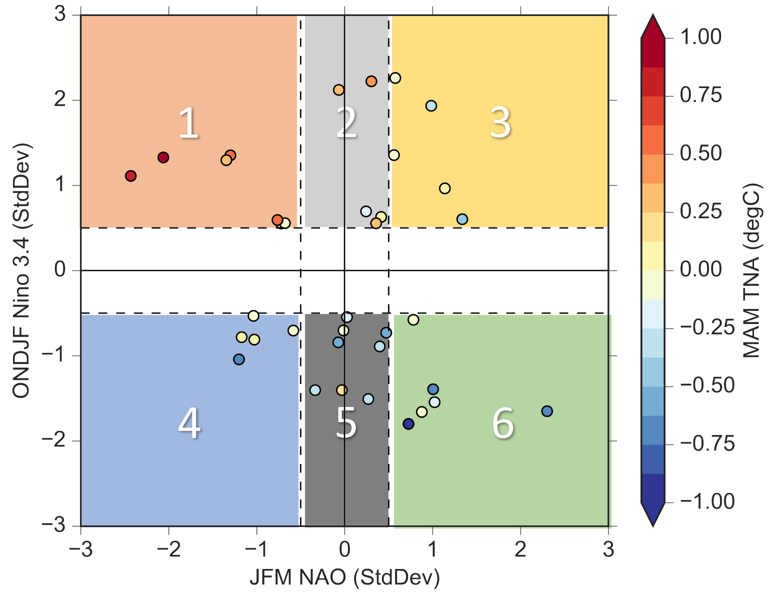

Figure 2) Sorting Method: The following figure depicts the separate scenarios that the datasets were sorted in. This includes (1) El Niño and -NAO, (2) El Niño and neutral NAO, (3) El Niño and +NAO, (4) La Niña and –NAO, (5) La Niña and neutral NAO, (6) La Niña and +NAO. Filtering also includes El Niño and all NAO, as well as La Niña and all NAO

Results: Correlation Analysis

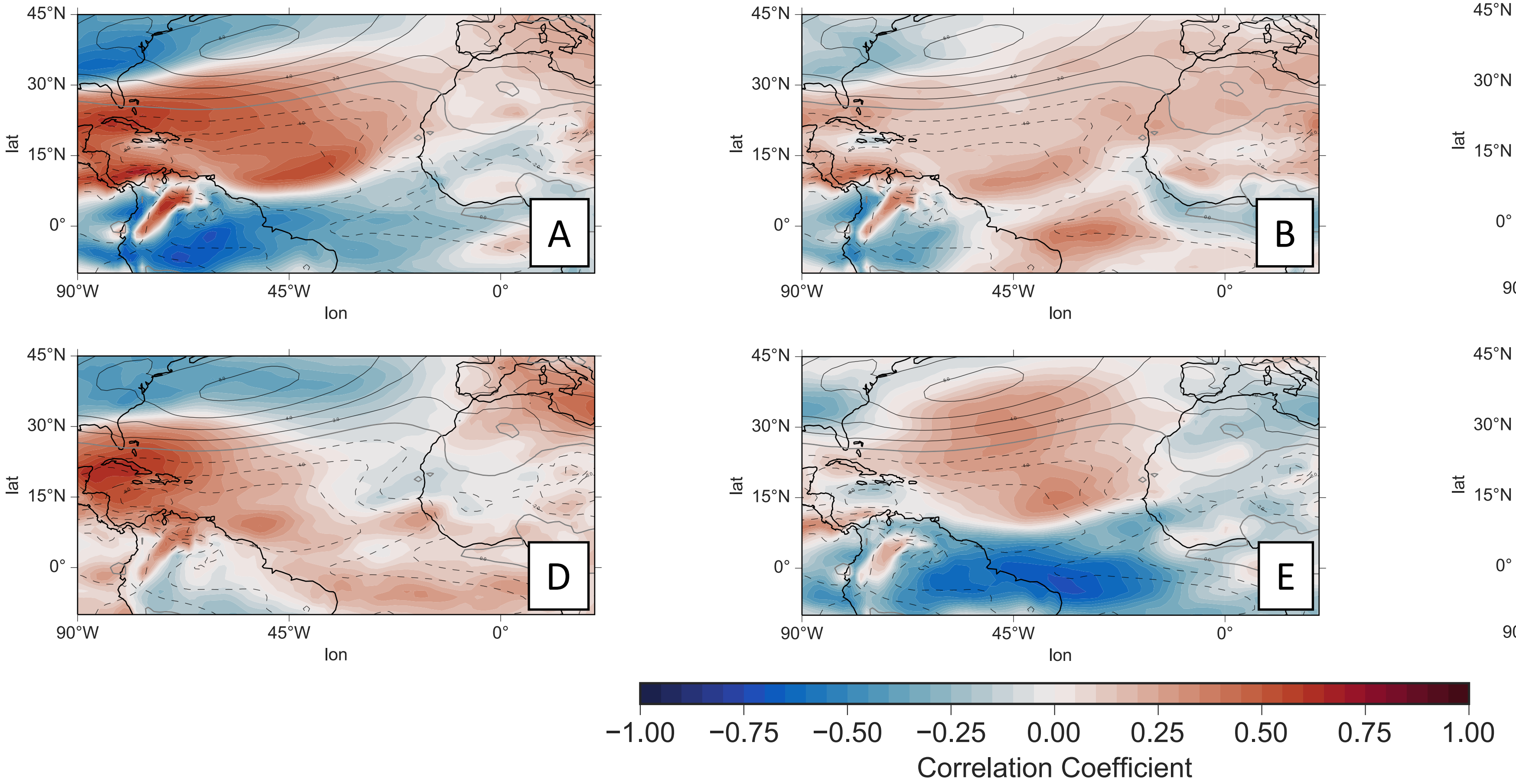

Figure 3) Partial Correlation Maps. (A) represents a point-wise correlation between the ONDJF Niño 3.4 index and the JFM 850 hPa zonal winds. (B) is the partial correlation between the ONDJF Niño 3.4 index and the JFM 850 hPa zonal winds while controlling for the the JFM PNA and the JFM tropical shear indices. (C) represents the difference between (A) and (B). (D) represents the pointwise correlation between the JFM PNA and the JFM 850 hPa zonal winds, while controlling for the JFM tropical shear index. (E) represents the pointwise correlation between the JFM tropical shear index and JFM 850 hPa zonal winds, while controlling for the JFM PNA index. (F) represents the pointwise correlation between the JFM NAO and JFM 850 hPa zonal winds while controlling for the JFM PNA and Niño 3.4 indices. Filled contours represent the correlation coefficient while the line contour represents the JFM 850 hPa zonal wind climatology.

Results: Correlation Analysis

- **ENSO** influences winds primarily in the tropical west and central Atlantic, and less so in the eastern tropical Atlantic (fig. 3a). Most of the signal was eliminated when controlling for the PNA and Atlantic shear (fig. 3b), indicating that these indices indeed represent the main teleconnection pathways (fig. 3c).

- The **extra-tropical pathway** (partial correlation of the JFM PNA, fig. 3d) show that the extra-tropical pathway only influences the western Atlantic.

- The **tropical pathway** (partial correlation of the JFM Atlantic shear, fig. 3e) indicates that influences act primarily on the central Atlantic only.

- Neither the extra-tropical nor tropical pathways are effective at creating a strong influence over the eastern Atlantic.

- **NAO influence** dominates the mid-latitudes, centered around 30^{o}N, and extends as far south as approximately 15^{o}N, and may have the most substantial influence over the eastern Atlantic. This influence may, however, be too far north to trigger a WES feedback.

Results: Surface Wind Composites

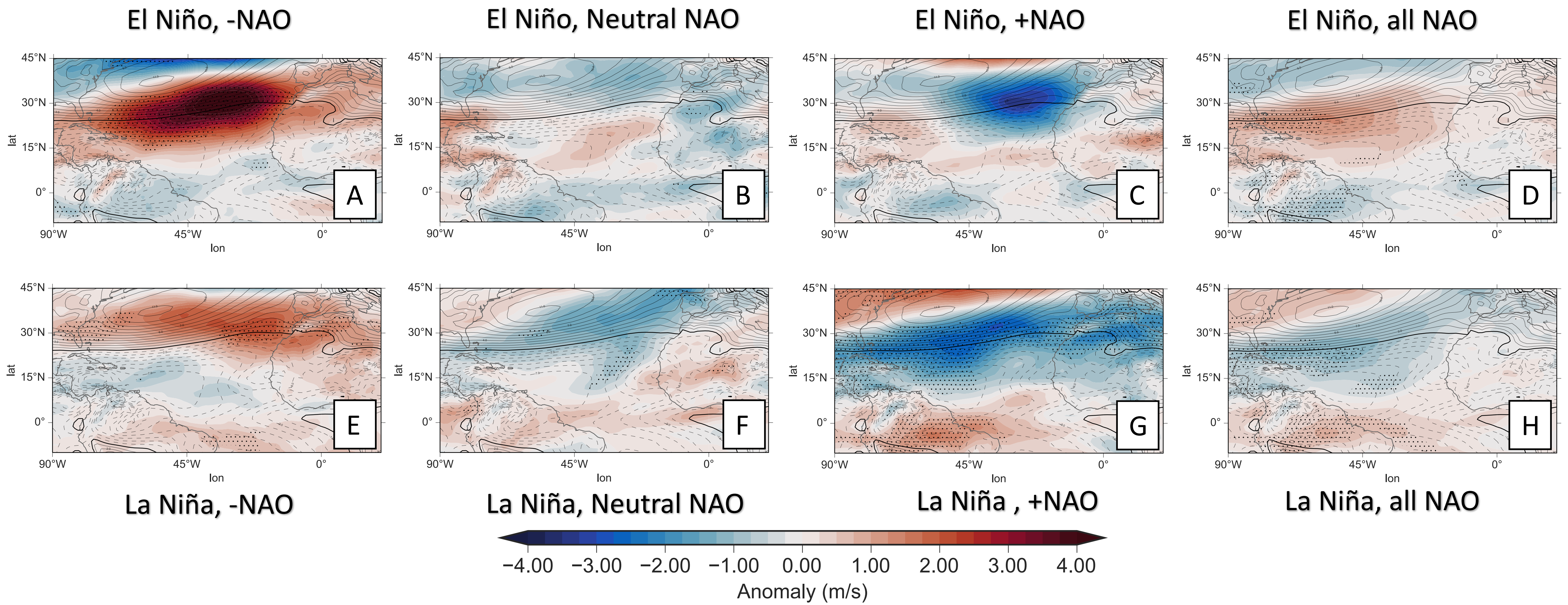

Figure 4) JFM 850 hPa zonal wind composites: The JFM 850 hPa zonal wind composites associated with the different scenarios for ENSO and the NAO. The type of sorting and number of events for each type are: (A) El Niño and –NAO (n=7), (B) El Niño and neutral NAO (n=5), (C) El Niño and +NAO (n=5), (D) El Niño and all NAO (n=17), (E) La Niña and –NAO (n=5), (F) La Niña and neutral NAO (n=8), (G) La Niña and +NAO (n=6), (H) La Niña and all NAO (n=19) . Filled contours represent the average anomaly, line contours represent the JFM 850 hPa zonal wind climatology, and dots represent statistically significant regions (at 95% level, using student t-test).

Results: Surface Wind Composites

- **West Atlantic anomalies** are primarily affected by the sign of ENSO and not from the NAO, indicating that the influence from ENSO overcomes any influence from the NAO. This relationship is consistent with the partial correlation, where the extra-tropical pathway dominates this area.

- **Central Atlantic anomalies** from the deep tropics to 15^{o}N are also consistent with the main driver being ENSO, as the sign of the NAO has little influence.

- **Central and eastern Atlantic anomalies** northwards of 15^{o}N show that the NAO dominates. This can be seen in both the El Niño (fig. 4a,c) and La Niña (fig. 4e,g). These anomalies may, however, be too far northwards to drive a WES feedback effectively.

- In composites that do not sort for NAO type (fig. 4d,h), the impact from the NAO (as seen in fig. 4a,c,e,g) is not present, indicating that the composite has potentially averaged out this influence. This is consistent given the anomalies for each type of NAO have similar magnitudes and locations, with opposite signs.

Results: Sea Surface Temperature Composites

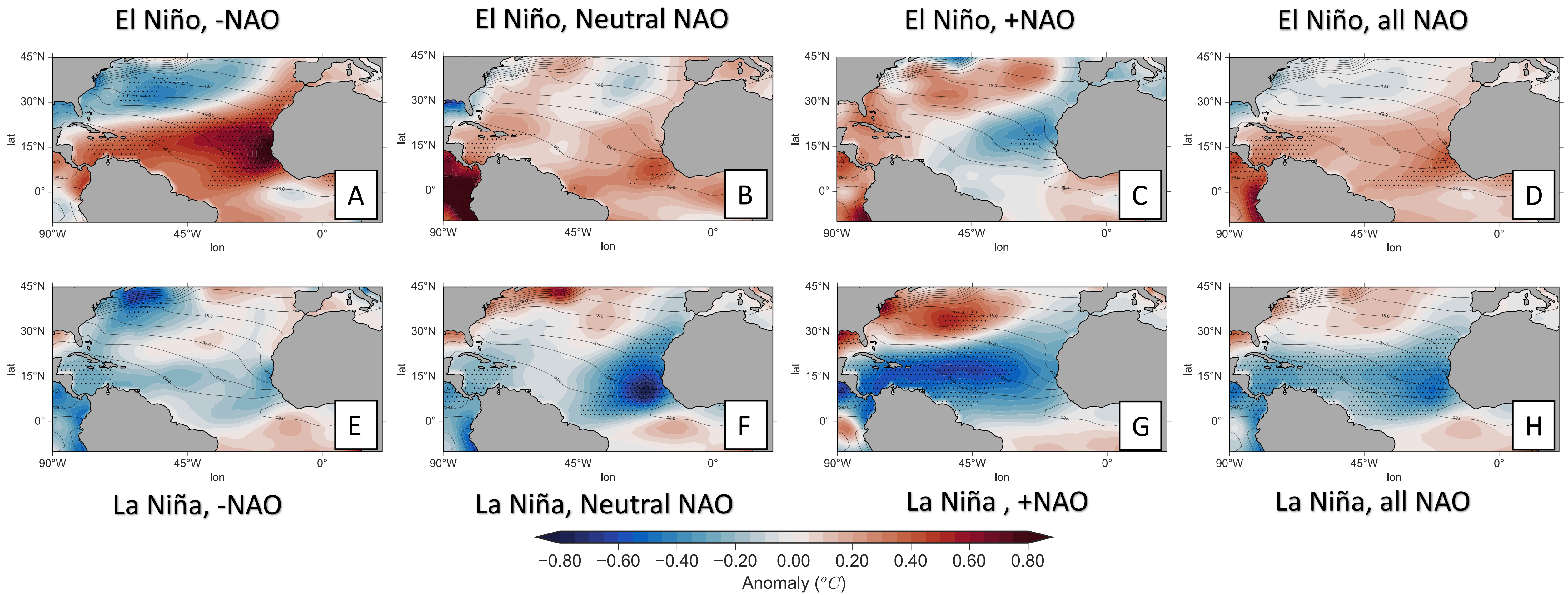

Figure 5) MAM SST composites: The MAM SST composites associated with the different ENSO and NAO phases for (A) El Niño and –NAO (n=7), (B) El Niño and neutral NAO (n=5), (C) El Niño and +NAO (n=5), (D) El Niño and all NAO (n=17), (E) La Niña and –NAO (n=5), (F) La Niña and neutral NAO (n=8), (G) La Niña and +NAO (n=6), (H) La Niña and all NAO (n=19) . Filled contours represent the average MAM SST anomaly, lines represent the JFM 850 hPa zonal wind climatology, and dots represent statistically significant regions (at 95% level, using student t-test).

Results: Sea Surface Temperature Composites

- **Western Atlantic SST anomalies** follow the sign of ENSO, further showing that the NAO has little influence in this area.

- When **ENSO and the NAO have opposite signs** (fig. 5a, g), the influences over the tropical Atlantic are constructive and create a vast, statistically significant SST anomaly.

- When the **NAO is neutral** (fig. 5b, f), only La Niña events have a significant anomaly in the central tropical Atlantic, which may indicate a difference in the strength of the tropical pathway compared to El Niño.

- When **ENSO and the NAO have the same sign** (fig. 5c, e), the NAO dominates the central to eastern areas during El Niño events, and cancels out during La Niña events.

Conclusion

- The influence of ENSO extends from the western to the central tropical Atlantic and drops off rapidly in the eastern Atlantic. The partial correlation analysis shows that the extratropical pathway dominates the western Atlantic, and the tropical pathway dominates the central Atlantic.

- The sign of the NAO dominates the eastern Atlantic wind anomaly, but when sorting events only by the Niño 3.4 index, this influence cancels out since +NAO and –NAO create approximately linear responses.

- The NAO and ENSO can be constructive or destructive when inducing SST anomalies. When the signs are opposite, a robust SST anomaly emerges. In contrast, when the signs are the same, the NAO dominates the signal over the central Atlantic for El Niño, and the combined influences cancel out during La Niña.

- Potential caveats to this analysis are that it does not take into consideration the month when ENSO terminates and the background state of the tropical Atlantic before the influence of ENSO, and will be included in the future.

- Overall, this shows that current studies of the teleconnection from ENSO to the tropical Atlantic are likely missing key differences when only sorting using the Niño 3.4 index, especially during El Niño events.

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