Climatology of the Tropical Northern Atlantic using Radio Occultation

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(1) Background

The Tropical North Atlantic and Caribbean (TNAC) region is well-studied in terms of hurricane formation and intensity. An annual atmospheric phenomenon which affects hurricane formation and intensity is the Saharan Air Layer (SAL).

The SAL is a layer of dry, warm, dusty air which originates over the Sahara Desert and travels wet over the TNAC region. It's most active, meaning it reaches the furthest west, in the late spring and early summer. It can cover areas larger than the contiguous United States and ha been known to reach as far west as the Caribbean Sea and Gulf of Mexico.

Research has shown that the SAL plays a strong role in determining where hurricanes form, as well as their intensity. Most research that has been done on the SAL either uses passive observations, such as infrared channels from satellites, or strategically launched radiosondes. While both useful, there is still a lot to be discovered.

We theorized that radio occultation (RO) observations could be used to study the SAL in more depth, but first we had to find out how well RO could detect the SAL.

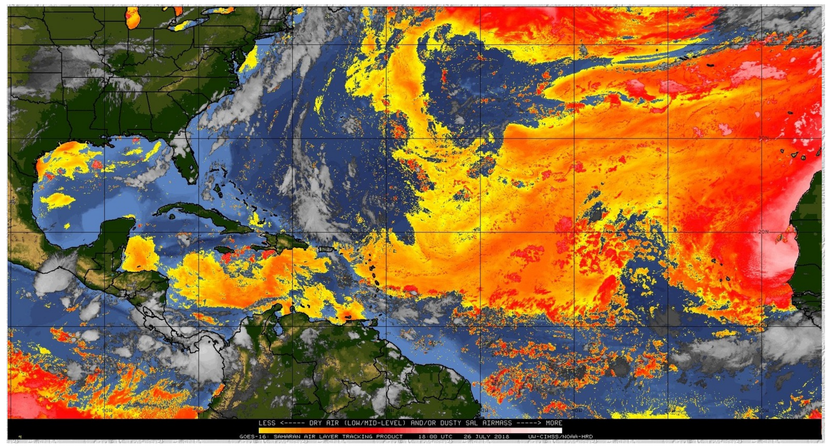

Image retrieved from CIMMS (https://tropic.ssec.wisc.edu/misc/sal/info.sal.m8split.htm)

(2) SAL Identification

A major research point for us was determining if we could identify the SAL using RO profiles. In a 2023 summer project, Alegrias (2024) not only looked into SAL identification with RO, but she also compared it with profiles located in other air masses over the TNAC region.

By looking at the side-by-side mean profiles in Figure 1, there's a distinct SAL signature in the left-hand profile, whereas the right-hand profile doesn't have the distinct dry layer.

These results led to us wanting to compare averaged profiles like the ones in Figure 1 to climatology.

We want to determine just how much SAL profiles stand out and if the SAL can be identified with RO alone.

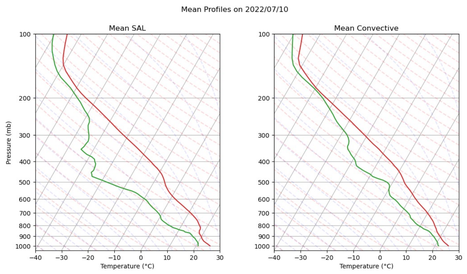

Figure 1: Averaged Skew-T Plots of Profiles in SAL and Convective Environments on 2022/07/10, respectively. Green lines (left) represent dewpoint (◦C) and red lines (left) represent temperature (◦C).

(3) Climatology: What has been done?

When searching for past work done on the climatology of the TNAC region, we were surprised that there has not been more research done, especially when not directly coupled with hurricanes and their specific climatology.

Jordan (1958) presented temperature and humidity soundings on a monthly temporal resolution, averaged over 10 years, as well as an average hurricane season sounding (July-October). Since publication, these soundings have served as the benchmark for which to compare more modern soundings against. They created the average soundings using data from a grouping of three radiosonde stations located in the Caribbean.

Dunion and Marron (2008) expanded on the work done by Jordan (1958), also using data from three radiosonde stations in the Caribbean, but only using data from one year. They noted that Jordan (1958) had been unaware of the SAL and its presence needed to be accounted for in any future work done on the climatology of the TNAC region.

Dunion (2011) expanded on the work done in Dunion and Marron (2008) and averaged the radiosonde data from the same three stations over 7 years. They came up with a set of mean soundings representing the TNAC instead of just one.

Since the above studies relied mainly on radiosondes, their coverage was limited.

(4) Climatology Based on RO

Proposed guidelines:
Time period: March 2020–March 2024
Horizontal resolution: 5° x 5° boxes
Vertical resolution: still under investigation, but currently 100 levels
Temporal resolution: seasonal and monthly

For the purpose of our study region for this climatology, we defined the geographic boundaries as 0° to 40°N and 100°W to 15°E.

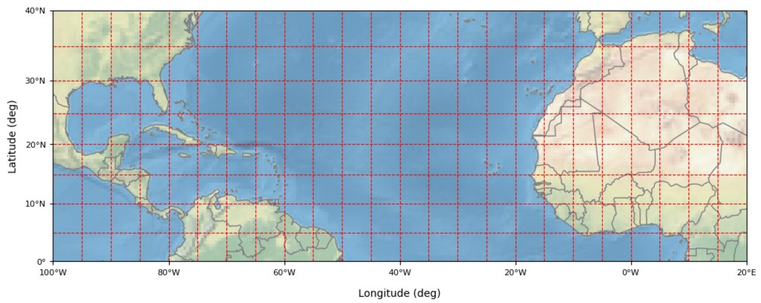

Figure 2: A map of the TNAC region showing the proposed 5° bins

Datasets:

Mission	Availability (within the proposed time window)
COSMIC-2	March 2020-March 2024
GeoOptics	March-October 2022
Kompsat-5	March 2020-March 2024
Metop-B	March 2020-March 2024
Metop-C	March 2020-March 2024
Paz	March 2020-March 2024
Planet-IQ	April 2023-January 2024
Spire	September 2021-July 2023, January-March 2024
TDX	March 2020-March 2024
TSX	March 2020-March 2024

Table 1: A list of CDAAC-available missions and their availability during the proposed time window for the climatological dataset.

(5) Climatological Comparison

Dunion (2011) contained two tables with the averages of temperature, dewpoint, and relative humidity from both their climatological assessment and that of Jordan (1958). For an initial assessment, we decided to use averaged temperature, relative humidity, and dewpoint values from RO profiles located in the region outlined in Figure 3.

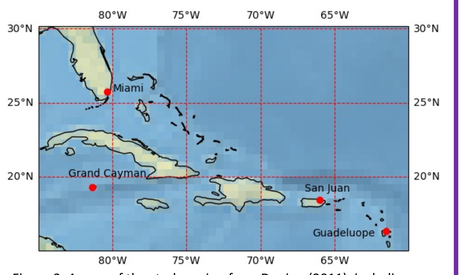

Figure 3: A map of the study region from Dunion (2011), including our 5° bins and the locations of the four stations they used.

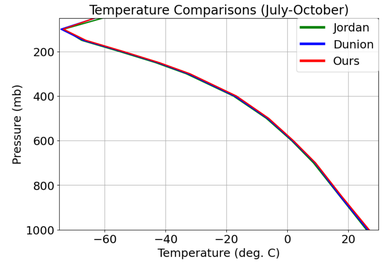

Figure 4: A comparison of the averaged temperature values over the Caribbean Sea from Jordan (1958), Dunion (2011), and our gridded product.

Figure 4 shows a comparison of averaged temperature values from Jordan (1958), Dunion (2011), and our gridded climatology. The temperature values for our climatology match the previous two fairly well, considering the difference in coverage (radiosonde stations versus RO). However, this serves as a good benchmark for comparing averages from the larger TNAC region with this smaller area.

(6) Where do we go from here?

1) Continue work on the climatology – there is still plenty of work that has yet to be done for the creation, validation, and comparison of our product.

2) Return to our original question, which is: Is it possible to come up with a way to diagnose the SAL using only RO data?

To answer the second question, we would need to continue with previous research, which includes, but is not limited to:
a. Classification of profiles into subsets: SAL, MLDAI, Convective
b. Compare the various profiles vs climatology

References

Alegrias, S., Sjoberg, J., Huelsing, H., Braun, J. Capturing the Transition Between Saharan Air Layer and Convective Environments Using Radio Occultation. Poster presented at: 2024 American Meteorological Society Meeting; January, 2024; Baltimore, MD.

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