Impact of WindBorne Data on NCEP Operational GFS Tropical Cyclone Forecasts

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1. Introduction

Accurate prediction of tropical cyclones (TCs) heavily depends on the accuracy of model initial states over the ocean, where atmospheric observations are relatively sparse compared to land. WindBorne Systems has developed an innovative balloon-based observation system that deploys constellations of balloons to collect data throughout the troposphere over extended periods. These WindBorne weather balloons gather atmospheric vertical profiles of pressure, temperature, humidity, wind speed, and wind direction, supplying valuable in-situ data to fill observation gaps over the ocean. This study investigates the impact of assimilating WindBorne balloon data on NCEP's operational Global Forecast System (GFS) predictions for TC track and intensity. Our goal is to understand how these supplementary WindBorne observations influence GFS analysis and forecast errors for TCs, ultimately providing insights to enhance the operational GFS system.

2. Model and Experiments

In this study, we utilize the NCEP operational GFS version 16 (GFSv16) to assess the impact of WindBorne balloon data on GFS forecasts during the summers of 2022 (August 5 to October 20) and 2023 (August 5 to October 30). GFSv16 employs a finite volume cubed-sphere dynamical core and enhanced GFDL microphysics. The model has 127 vertical layers with a model top at 80 km and a horizontal grid resolution of 13 km. The data assimilation (DA) system utilizes a 4-Dimensional Hybrid EnVar with Incremental Analysis Update (4D-IAU).

The WindBorne data from the summers of 2022-2023 were not assimilated in the operation (AVNO) run. The Global WindBorne experiment (WBRA) was conducted by incorporating these observations into GFSv16 for both the DA system and model forecasts.

3. Results

The standard NCEP *Metplus* verification system is used to evaluate the WindBorne experiment against the operational (OPR) run. Compared to the ECMWF analysis, the global verification metrics are very similar between the two runs, with slightly better forecast skill observed when using the WindBorne data. The most significant improvements were seen in temperature forecasts (95% significance) at 500-700 hPa and wind forecasts (99.9% significance) at 700-1000 hPa with a 72-hour lead for the summer of 2023 (not shown).

One objective of this study was to evaluate the impact of WindBorne data on the GFS forecast skill for tropical cyclone (TC) track and intensity. For the summer of 2022, incorporating WindBorne data improved the average tropical cyclone track forecast by up to 18% over the Atlantic. In the summer of 2023, WindBorne data led to a 15% improvement in the average tropical cyclone track forecast over the Atlantic. When combining data from both summers, the GFS forecast for tropical cyclone tracks over the Atlantic showed enhanced accuracy from 36 to 144 hours, with up to a 12% improvement in forecast skill at the 132-hour lead time (Figure 1a). Additionally, WindBorne data improved tropical cyclone track forecasts over the East Pacific, achieving up to a 13% increase in forecast skill across all lead times (Figure 1b). In the West Pacific, WindBorne data improved track forecast skill during the summer of 2022, especially at longer leads (84-156 hours). However, in the summer of 2023, the use of

WindBorne data led to a degradation in forecast skill in the West Pacific, resulting in an overall decline for the combined 2022-2023 period (not shown).

For intensity forecasts, WindBorne data demonstrated improvements over the Atlantic and East Pacific, but these gains were generally limited to forecasts up to 4 days in advance. Consistent with the track forecast impacts in the West Pacific, intensity forecasts for this region were mostly degraded, particularly due to the summer of 2023. Despite this, there was a slight average improvement in intensity forecasts for the summer of 2022 (not shown).

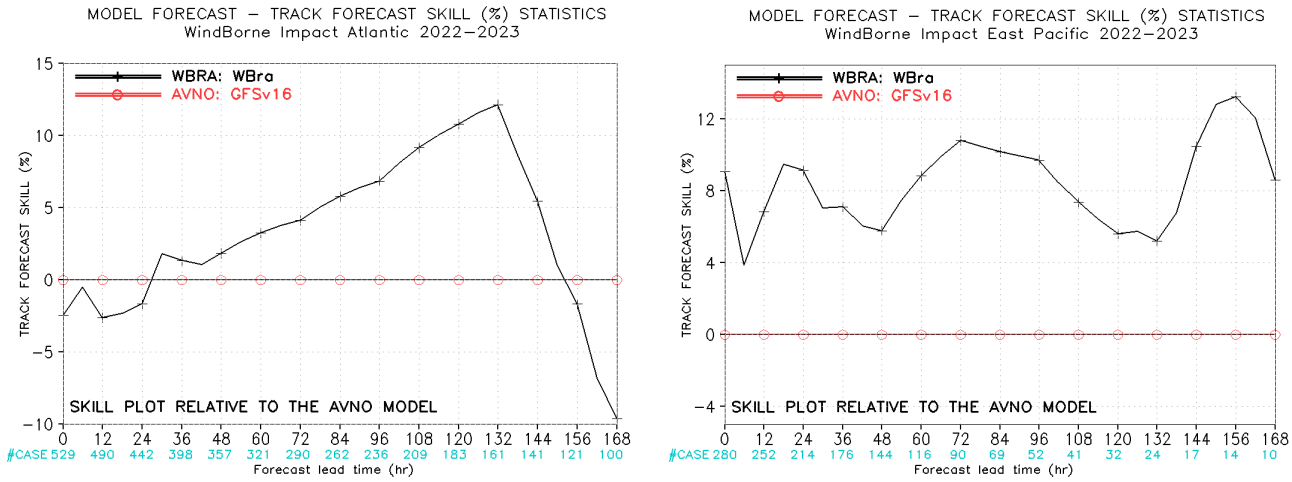

Figure 1. Track forecast skill from GFSv16 operational runs (AVNO) and WindBorne experiments (WBRA) for the summer of 2022-2023. Panel (a) (left) displays the average skill over the Atlantic, while Panel (b) (right) shows the average skill over the East Pacific. The period for the summer of 2022 is from August 5 to October 20, and for 2023, from August 5 to October 30.

4. Summary

This study highlights the positive impact of WindBorne data on GFS forecast skill during the summers of 2022-2023. By comparing outputs from both GFS operational runs and WindBorne experimental runs with the ECMWF analysis, the study demonstrated that WindBorne observations effectively addressed data gaps over the ocean in the DA process. Assimilating WindBorne data improved model initial conditions, as indicated by a reduced cold bias in temperature, dry bias in specific humidity, and low bias in wind (not shown). These enhancements led to a more accurate model environment, significantly improving wind and tropical cyclone track predictions over the Atlantic and East Pacific. Consequently, the WindBorne experiment resulted in reduced forecast errors in these areas. These findings provide valuable insights for NCEP and support ongoing efforts to integrate real-time WindBorne data into the operational GFSv16 system.