Impact of Dropsonde Data on GFS Forecast Performance: Analysis from the 2023-2024 Atmospheric River Reconnaissance

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Introduction

Atmospheric Rivers (ARs) are a significant global weather phenomenon, responsible for the majority of the horizontal water vapor transport outside the tropics. They serve as a crucial source of precipitation and water supply for the U.S. West Coast. AR Reconnaissance (ARR) plays a crucial role in supporting water management and flood control objectives in the western United States. Notably, ARR observations have been officially incorporated into the U.S. National Winter Season Operations Plan. During the winter of 2023-2024, AR Recon campaigns successfully conducted 40 Intense Observing Periods (IOPs) using Air Force WC-130 and NOAA G-IV flights from November 15, 2023, to February 29, 2024. These flights gathered valuable supplementary data through dropsonde measurements of water vapor, temperature, and winds within and around ARs (Figure 1).

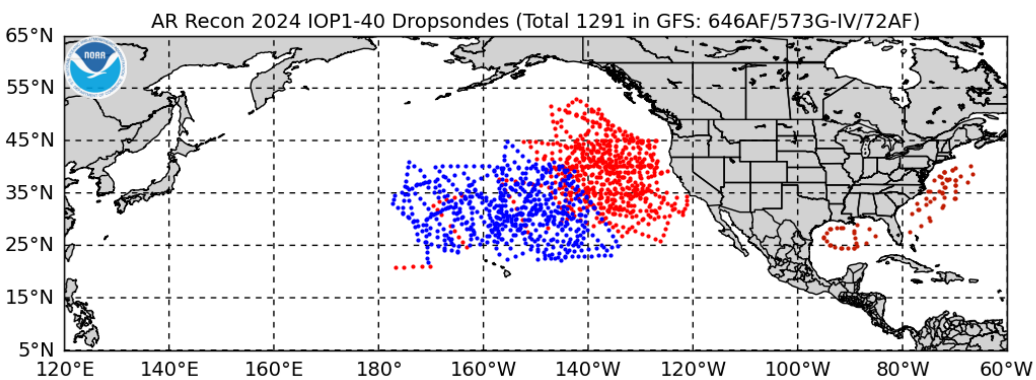

Figure 1. Distribution of dropsondes during the winter of 2023-2024 from Atmospheric Rivers Reconnaissance campaigns. The 1291 total dropsondes are categorized by aircraft type: Air Force WC-130 (red and brown) and NOAA G-IV (blue).

Model and Experiments

In this study, we utilized the NCEP operational GFSv16 to evaluate the impact of supplemental dropsonde observations from the Atmospheric River Reconnaissance (ARR) during the winter of 2023-2024. GFSv16 is the operational global forecast system at NCEP, employing a finite volume cubed-sphere dynamical core and advanced GFDL microphysics. The model features 127 vertical layers extending up to 80 km, with a horizontal grid resolution of 13 km. The data assimilation (DA) system utilizes a 4-Dimensional Hybrid EnVar with Incremental Analysis Update (4D-IAU) technique.

For our analysis, dropsonde data collected during the 40 IOPs of the ARR 2023-2024 campaign were assimilated into the operational (Ctrl) runs. Additionally, near real-time global denial (Deny) experiments were conducted by excluding dropsonde data in the GFSv16, affecting both the DA and model forecast components.

Results

We employed the standard NCEP Metplus verification system to evaluate the Deny experiment in comparison with the operational run. Relative to the ECMWF analysis, forecast skill demonstrated some improvement, particularly in the Pacific North American (PNA) region (180-320°E, 20-75°N), for geopotential height, temperature, and winds when supplemental dropsonde data were incorporated. However, these improvements were not statistically significant.

One objective of this study was to assess and document the impact of dropsonde data on GFS forecast skill for landfalling ARs and their associated precipitation. We calculated the Threat Score (ETS) and Mean Absolute Error (MAE) for GFS precipitation forecasts over the U.S. West Coast domains (as outlined in Lord et al., 2023) from the 40 IOPs (Figure 2). The results indicate a generally positive impact, with improvements of 1%–6% in ETS across the 24–96 hour forecast range, and more pronounced effects at shorter lead times. Most of the improved forecast cases are associated with improvement in moisture prediction and AR landfalling in the operational run (not shown).

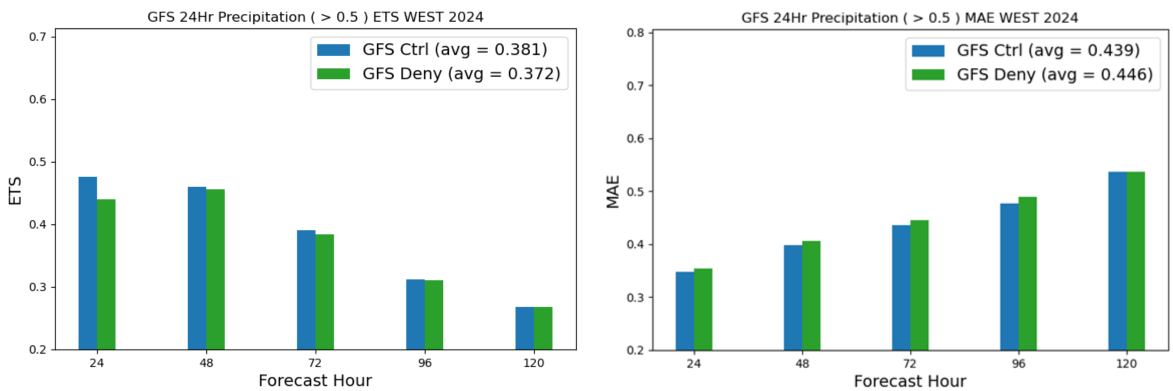

Figure 2. The accumulated 24-hour precipitation Threat Score (ETS, left) and Mean Absolute Error (MAE, right) from the GFSv16 operational forecast (Ctrl, blue) and the data denial (Deny, green) experiments for the 40 IOP cases over the U.S. West domain (107°-127°W, 28°-49.5°N). Stage IV precipitation data are used as the verification standard, with forecasts evaluated against accumulated 24-hour precipitation amounts of at least 0.5 inches.

Summary

This study highlights the positive impact of dropsonde data on GFS forecast skill during the 2023-2024 ARR. The inclusion of ARR observations filled critical data gaps in the DA process, resulting in improved model initial conditions: reduced cold bias in temperature, dry bias in specific humidity, and low bias in wind (not shown). These enhanced initial conditions created a more accurate modeling environment for predicting ARs and their associated precipitation. The improvements in precipitation forecasts over the U.S. West Coast were linked to better moisture and water vapor transport predictions, leading to more accurate AR landfall forecasts.

Reference:

Lord, S.J., X. Wu, V. Tallapragada. and F.M. Ralph, 2023. The Impact of Dropsonde Data on the Performance of the NCEP Global Forecast System during the 2020 Atmospheric Rivers Observing Campaign. Part I: Precipitation. *Weather and Forecasting*, **38**, 17–45.