Atmospheric River Analysis and Forecast System (AR-AFS): Atmospheric River Reconnaissance 2021 Dropsonde Data Impact Study on California Precipitation Forecasts

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1. Introduction

Atmospheric rivers (ARs) are narrow corridors of concentrated atmospheric moisture which are responsible for the majority of extreme rainfall over western North America. G. Wick, et al. [1] showed that numerical weather prediction (NWP) models can have large forecast errors in predicting ARs. AR Reconnaissance (ARR) campaigns plan and deploy aircraft over the northeast Pacific to collect observations to support improved AR forecasts. This paper describes the application of the Atmospheric River Analysis and Forecast System (AR-AFS), a stand-alone high-resolution regional model, to study AR 2021 dropsonde data impact on the forecast of AR-related precipitation in California.

2. AR-AFS Model

AR-AFS is based on the FV3 dynamical core and uses initial and boundary conditions from the NCEP operational Global Forecast System version 16 (GFSv16). The AR-AFS model has 64 vertical layers and a fine horizontal resolution of 3 km over the Northeast Pacific and Western North America, and provides 5 day forecasts. The physics parameterizations include the GFS land surface scheme, Thompson microphysics scheme, and hybrid eddy-diffusivity mass-flux (EDMF) PBL scheme. Figure 1 shows the model domain, a forecasted AR landing on California, and the AR-introduced heavy precipitation.

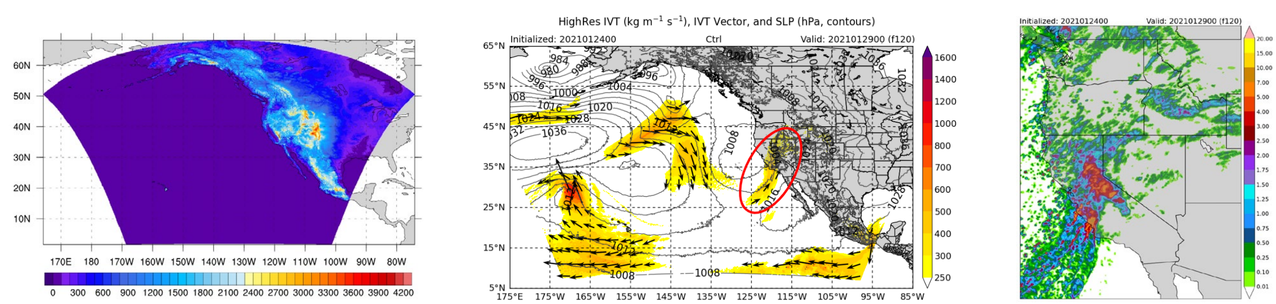

Figure 1 AR-AFS AR forecast (initialized on 00Z Jan 24, 2021 and valid on 00Z Jan 29, 2021). Left: AR-AFS domain; Middle: IVT (Integrated Water Vapor Transport) and an AR (the orange band inside the red circle); Right: 24-hour precipitation on West Coast.

3. Data Experiments

We examine the impact of the AR supplemental observation dropsonde data on the forecast of an AR in California on January 23-29, 2021. It was a scale 2 AR event that impacted Central California with heavy rainfall. Six consecutive intensive observation periods (IOPs) were executed by flights sampling the same synoptic system from January 23 to 28, 2021. GFSv16 control (Ctrl) and denial experiments (Deny) were conducted by using or denying the dropsonde data in the Data Assimilation of the model. AR-AFS model uses GFSv16 Ctrl and Deny outputs as the initial and boundary conditions for its Ctrl and Deny runs.

A series of analyses were conducted to compare Ctrl and Deny in high precipitation regions for individual IOPs or consecutive IOPs. Ctrl gives overall better precipitation forecasts in terms of magnitudes and locations. Sample analysis results are shown in Figures 2-3. Among the average precipitation from Ctrl, Deny, and observation (Stage IV), 4 out of 5 IOPs have a positive impact on precipitation in both selected regions (Fig. 2). In Figure 3a, the same two objects (precipitation >=2 inches) matched with the observed are found in both Ctrl and Deny, but Ctrl has a higher average rate (0.97) than Deny (0.93). This indicates a higher overall similarity (closer locations, a bigger overlap, etc.) between the Ctrl and observations. For a threshold of 2.5 inches (Fig. 3b), all 4 observed objects match the 4 objects in Ctrl but only 3 matched objects are found in Deny.

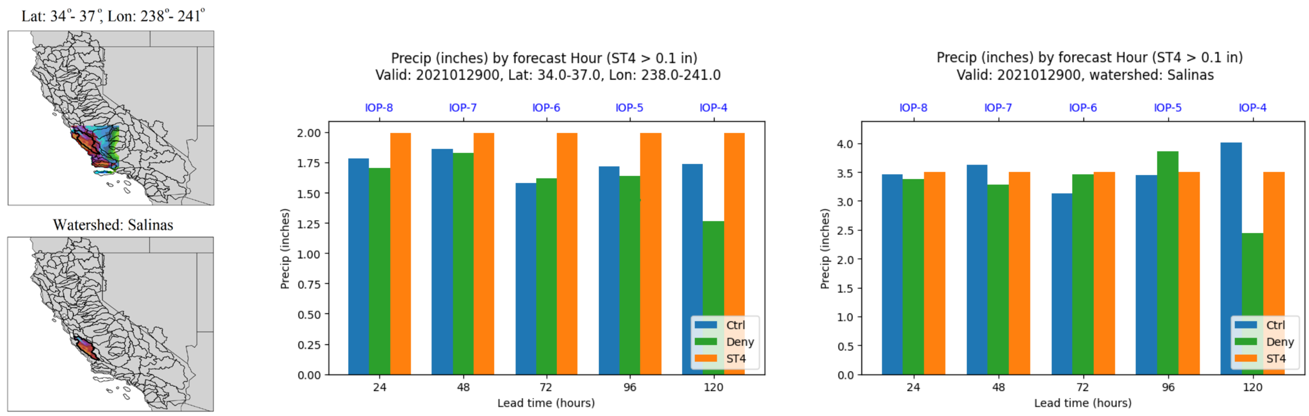

Figure 2 Region average of 24-hour precipitation of AR-AFS Ctrl, AR-AFS Deny, and Stage IV (observation). Forecasts are initialized on 00Z Jan 24, 2021, and valid on 00Z Jan 29, 2021. Left: a high precipitation region and a watershed. Middle and Right: the average precipitation with a cut-off of 0.1 inch over the region and the watershed.

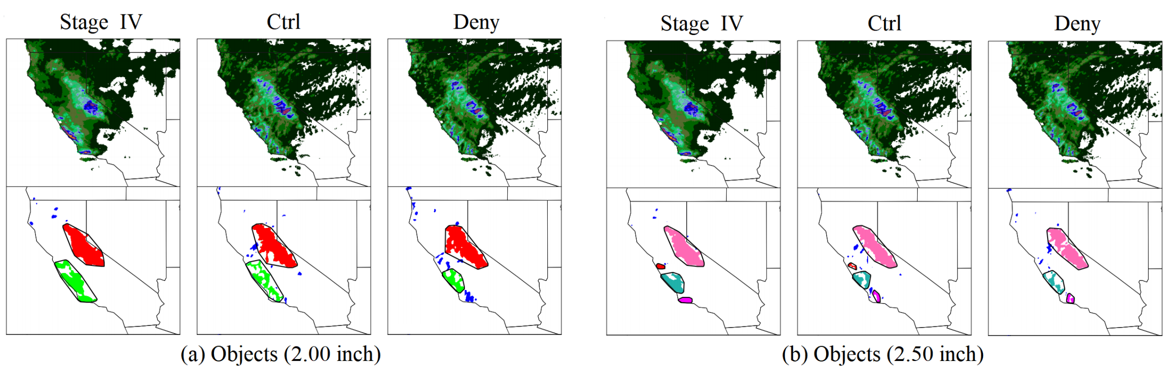

Figure 3 Mode Verification [2] of 24-hour precipitation of AR-AFS Ctrl, AR-AFS Deny, and Stage IV (observation). Forecasts are initialized on 00Z Jan 28, 2021, and valid on 00Z Jan 29, 2021. (a) Objects defined as precipitation >=2 inches. (b) Objects defined as precipitation >=2.5 inches.

4. Summary

AR-AFS is developed and applied to the data impact study of ARR. Positive impacts on the AR-AFS forecast skill using dropsondes data are found from consecutive IOPs in January 2021 for California. The study also supplements the concurrent GFS Ctrl and Deny experiments as AR-AFS uses GFS as its initial fields. In addition, the high resolution of AR-AFS helps with the study of data impact on small regions of interest.

References

[1] Wick, G. A., Neiman, P. J., Ralph, F. M., & Hamill, T. M. (2013). Evaluation of Forecasts of the Water Vapor Signature of Atmospheric Rivers in Operational Numerical Weather Prediction Models, *Weather and Forecasting*, *28*(6), 1337-1352.

[2] Davis, C.A., Brown, B., & Bullock, R. (2006). Object-Based Verification of Precipitation Forecasts. Part II: Application to Convective Rain Systems. *Monthly Weather Review, 134*, 1785-1795.