Atmospheric River Analysis and Forecast System (AR-AFS): Sensitivity of Precipitation Forecasts in the U.S. West Coast to Microphysics and PBL Parameterizations

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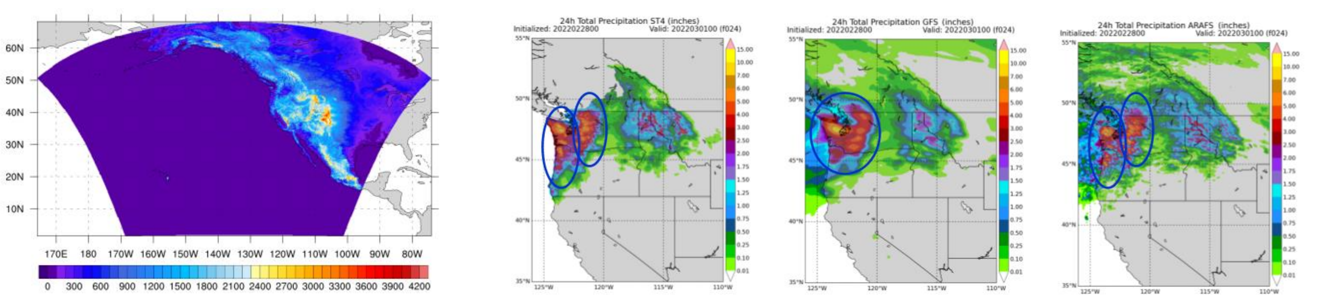
1. Introduction

A high-resolution regional Atmospheric River Analysis and Forecast System (AR-AFS) has been developed to provide numerical guidance for Atmospheric River (AR) forecasts and AR Reconnaissance (AR Recon). In the near real-time tests in 2022 and 2023 AR seasons, it was found that AR-AFS produced a larger negative bias in precipitation forecast than the NCEP Global Forecast System version 16 (GFSv16). Given the important role of microphysics and planetary boundary layer (PBL) processes in the numerical simulations, we examined the precipitation forecast sensitivity to the GFDL microphysical scheme, Thompson microphysics scheme, turbulent kinetic energy (TKE)-based moist hybrid eddy-diffusivity mass-flux (EDMF-TKE) PBL scheme, and Yonsei University (YSU) PBL scheme from the Common Community Physics Package (CCPP). We briefly summarize our experimental results here.

2. AR-AFS Model

AR-AFS is based on the FV3 dynamical core and uses initial and boundary conditions from 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 in the AR-AFS near real-time tests include GFS-Noah land surface, Thompson microphysics, EDMF-TKE PBL, and YSU PBL. Fig. 1 shows the model domain. It also demonstrates the capability of AR-AFS in capturing the finer structures of the observed heavy precipitation associated with an AR storm better than GFSv16, even though it predicted less precipitation than GFSv16 by about 3% over the whole domain.



Orography (meter) Stage-IV GFSv16 AR-AFS

Fig. 1: AR-AFS domain (Left) and the 0-24-h accumulated precipitation ending at 00 UTC 01 March 2022 from Stage IV (ST4), GFSv16, and AR-AFS forced by the GFSv16. The Stage IV precipitation is used as the truth. The regional averages of 24-h precipitation over the regions with a cut-off of 0.1 inches in ST4 are 1.19 inches in ST4, 1.13 inches from GFSv16, and 1.09 inches from AF-AFS.

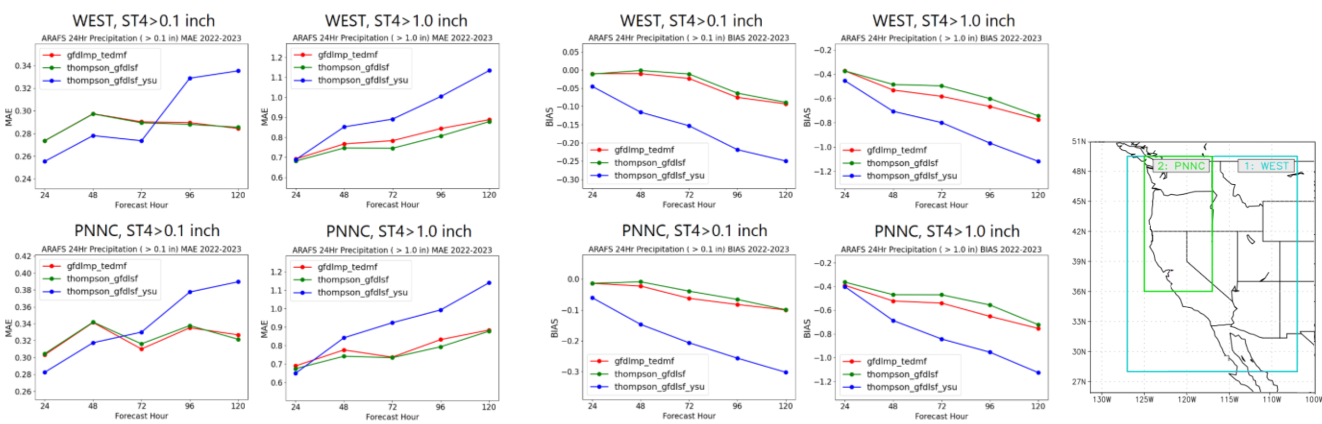
3. Experiments

Our experiments use a collection of atmospheric physical parameterizations under CCPP. Three CCPP suites (Tabel 1) are tested in our experiments, (1) *gfdlmp_tedmf*, (2) *thompson_gfdlsf*, and (3) *thompson_gfdlsf_ysu*. The comparison is made using 25 AR-AFS forecast cycles from the 2022 AR season and 15 cycles from the 2023 AR season for precipitation forecasts over the U.S. West Coast. All forecasts were initialized during the Intensive

Observation Periods (IOPs) of active ARs at 00 UTC. The hypothesis is that the Thompson microphysics scheme and YSU PBL scheme are more suitable for simulating AR associated precipitations. Fig. 2 shows the Mean Absolute Errors (MAEs) and Average Errors (biases) of precipitation forecasts from the AR-AFS, verified against Stage IV (ST4), with the three CCPP physics suites. The results are verified in the regions with a precipitation cut-off of 0.1 and 1.0 inches in ST4 over two domains in the U.S. West Coast (Fig. 2c). The MAE of *thompson_gfdlsf_ysu* is similar or smaller (by about 1%-7%) to that of *gfdlmp_tedmf* and *thompson_gfdlsf* at short lead times, but increases dramatically at long lead times. MAE of *thompson_gfdlsf* is overall similar with that of *gfdlmp_tedmf* and is slightly smaller than *gfdlmp_tedmf* at all leads with the higher cut-off of 1.0 inches. Consistently high negative biases in precipitation forecast with tested physics schemes are also found (Fig.2b).

Table. 1. Overview of CCPP Suites used in the experiments with AR-AFS

Experiments/Suites	*gfdlmp_tedmf*	*thompson_gfdlsf*	*thompson_gfdlsf_ysu*
Microphysics	GFDL	Thompson	
PBL	EDMF-TKE		YSU
Surface layer	GFDL		
Land surface	GFS-Noah		
Convection	SAMF		
Radiation	GFS-RRTMG		



(a) MAE (b) bias (c) Domains

Fig. 2: AR-AFS's performance with three CCPP suites for (a) MAEs and (b) biases of the 24h precipitation forecasts with two cut-off values over two domains. (c) U.S. West Coast domain (WEST) and Pacific Northwest and Northern California regional domain (PNNC) follows Lord et al. (2023).

4. Summary

For the 2022 and 2023 AR seasons, the use of Thompson microphysics scheme and GFDL surface scheme showed a potential to improve AR associated precipitation forecasts. The interesting fact that the combination of Thomspon scheme and YSU scheme has lower MAEs at short leads but higher MAEs at long leads needs further investigation. The high negative biases from AR-AFS with tested physics schemes also suggest that more experiments are needed with detailed analyses.

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.