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WRF QNSE Test and Evaluation

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Introduction: The Developmental Testbed Center (DTC) performed testing and evaluation (T&E) to assess the performance of a new planetary boundary layer (PBL) and surface layer scheme available in the Weather Research and Forecasting (WRF) model. The Advanced Research WRF (ARW) dynamic core was used for both configurations and two versions of WRF were tested, one based on v3.1.1+ and the other v3.2.1.

Experiment Design

Code

The end-to-end forecast system employed the WRF Preprocessing System (***WPS***), ***WRF***, WRF Post Processor (***WPP***) and Model Evaluation Tools (***MET***) software packages.

Forecast Period

Forecasts were ***initialized every 36 hours*** and run ***out 48 hours*** from ***2 June 2008 - 31 May 2009***.

Initial and Boundary Conditions

ICs and ***LBCs*** were derived from the *0.5 x 0.5 degree* ***GFS***. ***LoBCs*** utilized AFWA's ***AGRMET*** output. The ***SST*** field was initialized from the ***FNMOC*** product.

Model Configuration

A ***15-km*** contiguous U.S. (CONUS) grid was employed (Fig. 1) such that it covered complex terrain, plains, and coastal regions for worldwide comparability.

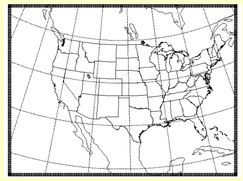

Figure 1. *Map showing the boundary of the WRF-ARW computational domain.*

Configuration 1: *B*ased on ***AFWA's Operational Configuration***

Configuration 2: Substituted in the ***QNSE scheme*** for the PBL and surface layer parameterizations

Table 1: *Physics suite used for each model configuration.*

Physics Scheme	AFWA configuration	QNSE replacement
Microphysics	WRF Single-Moment 5	WRF Single-Moment 5
Radiation (SW/LW)	Dudhia/RRTM	Dudhia/RRTM
Surface Layer	Monin-Obukhov similarity theory	QNSE
Land Surface Model	Noah	Noah
Planetary Boundary Layer	Yonsei University scheme	QNSE
Convection	Kain-Fritsch	Kain-Fritsch

Model Verification

Grid-to-point comparisons for surface and upper air data and ***grid-to-grid*** comparisons for QPF, were used to generate objective verification statistics, including:

- ***Bias-corrected Root Mean Square Error*** *(BCRMSE)* and ***Mean Error*** *(Bias)* for:
  - Surface and Upper Air: temp, dew point temp and winds
- ***Gilbert Skill Score*** *(GSS)* and ***Frequency Bias*** *(FBias)* for:
  - 3-hr and 24-hr precipitation accumulation intervals

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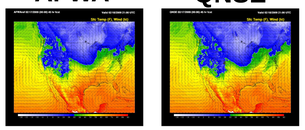
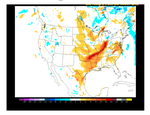
Test and Evaluation Results

Highlighting differences between AFWA/QNSE v3.2.1

AFWA QNSE



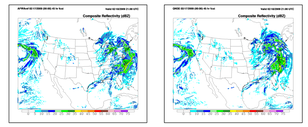
Difference (AFWA-QNSE)



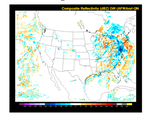
Graphics

Example plots of surface temperature and wind (left) and composite reflectivity (right) from the AFWA configuration, QNSE configuration and the difference field for one particular valid time.

AFWA QNSE



Difference (AFWA-QNSE)



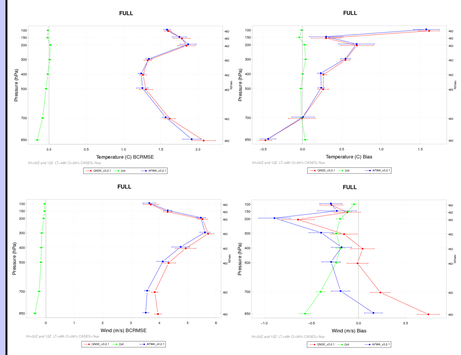
Confidence

Confidence intervals (CIs), at the 99% level, were applied to each verification metric, using the standard error estimates about the median for the surface and upper air statistics and a bootstrapping technique for precipitation.

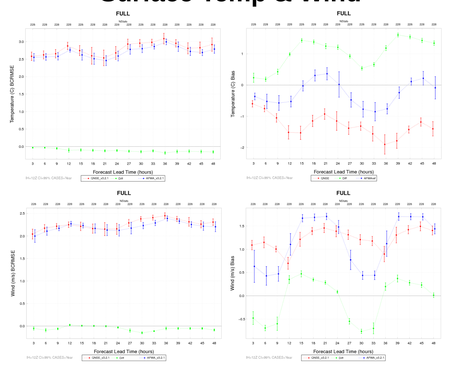
Differences

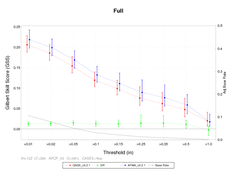
Both configurations were run on the same cases allowing for a ***pair-wise difference*** methodology to be applied by computing AFWA-QNSE.

Upper Air Temp & Wind



Surface Temp & Wind





3-h Accum Precip

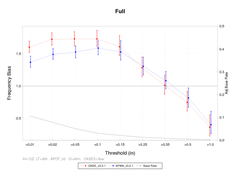


Table 1. *SS (light) and PS (dark) pair-wise differences for the AFWA and QNSE configurations (where the highlighted version is favored) for upper air T, T_d and Wind BCRMSE and bias by pressure level and forecast lead time.*

		Annual											
		Temperature				Dew Point Temperature				Wind			
		f12	f24	f36	f48	f12	f24	f36	f48	f12	f24	f36	f48
BCRMSE	850	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA
	700	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA
	500	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA
	400	--	--	--	AFWA					AFWA	AFWA	AFWA	AFWA
	300	QNSE	QNSE	--	--					AFWA	--	AFWA	AFWA
	200	QNSE	QNSE	QNSE	QNSE					--	--	--	AFWA
	150	AFWA	--	AFWA	AFWA					AFWA	AFWA	AFWA	AFWA
	100	AFWA	AFWA	--	AFWA					AFWA	AFWA	AFWA	AFWA
Bias	850	QNSE	QNSE	--	--	QNSE	QNSE	QNSE	QNSE	AFWA	AFWA	AFWA	AFWA
	700	AFWA	AFWA	AFWA	--	QNSE	QNSE	QNSE	QNSE	QNSE	QNSE	AFWA	AFWA
	500	AFWA	AFWA	AFWA	AFWA	QNSE	QNSE	QNSE	QNSE	QNSE	QNSE	QNSE	QNSE
	400	AFWA	AFWA	--	--					QNSE	QNSE	QNSE	QNSE
	300	--	QNSE	QNSE	QNSE					QNSE	QNSE	QNSE	QNSE
	200	QNSE	QNSE	QNSE	--					QNSE	QNSE	QNSE	QNSE
	150	--	--	AFWA	AFWA					QNSE	QNSE	QNSE	QNSE
	100	QNSE	--	--	--					QNSE	--	--	QNSE

Significance

The CIs on the pair-wise differences for two configurations objectively determines whether they are ***statistically significant (SS)***.

Practical significance (PS) was determined by censoring the data to highlight pair-wise differences of T/T_d>0.1K, Wind>0.5ms^{-1} and Precip Accum>0.1mm.

Table 2. *SS (light) and PS (dark) pair-wise differences for the AFWA and QNSE configurations for sfc T, T_d and Wind BCRMSE and bias by forecast lead time and init time.*

Annual			f03	f06	f09	f12	f15	f18	f21	f24	F27	f30	f33	f36	f39	f42	f45	f48
BCRMSE	00 UTC Initializations	Temperature	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA
		Dew Point	--	QNSE	QNSE	QNSE	QNSE	--	AFWA	AFWA	QNSE	QNSE	QNSE	QNSE	--	--	AFWA	AFWA
		Wind	QNSE	QNSE	QNSE	--	AFWA	AFWA	AFWA	--	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA
	12 UTC Initializations	Temperature	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA
		Dew Point	QNSE	AFWA	AFWA	AFWA	--	QNSE	QNSE	--	--	AFWA	AFWA	AFWA	--	--	--	--
		Wind	AFWA	AFWA	AFWA	QNSE	--	--	--	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA
Bias	00 UTC Initializations	Temperature	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA
		Dew Point	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	QNSE	QNSE	AFWA	AFWA	AFWA
		Wind	QNSE	QNSE	QNSE	QNSE	AFWA	AFWA	AFWA	QNSE	QNSE	QNSE	QNSE	--	AFWA	AFWA	AFWA	QNSE
	12 UTC Initializations	Temperature	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA
		Dew Point	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	QNSE	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	QNSE
		Wind	AFWA	AFWA	AFWA	QNSE	QNSE	QNSE	QNSE	QNSE	AFWA	AFWA	AFWA	QNSE	QNSE	QNSE	QNSE	--

Summary

Summary: In general, when examining the AFWA and QNSE configuration run with WRF v3.2.1, the AFWA configuration was favored more often. However, the QNSE configuration was favored for some metrics at certain levels, lead times and thresholds. It should be noted, though, that the relative magnitude of the SS differences favoring the AFWA configuration are generally larger, leading to a greater number of PS results favoring the AFWA configuration. Rigorously testing and evaluation under a carefully controlled environment was conducted allowing for both of these configurations to be designated as DTC Reference Configurations (RCs).

For full details and results of the QNSE T&E project, see: **http://verif.rap.ucar.edu/eval/afwa_rc_test/**
For information and results related to these and other DTC RCs, see: **http://www.dtcenter.org/config/**