

Testing and Evaluation of WRF Reference Configurations

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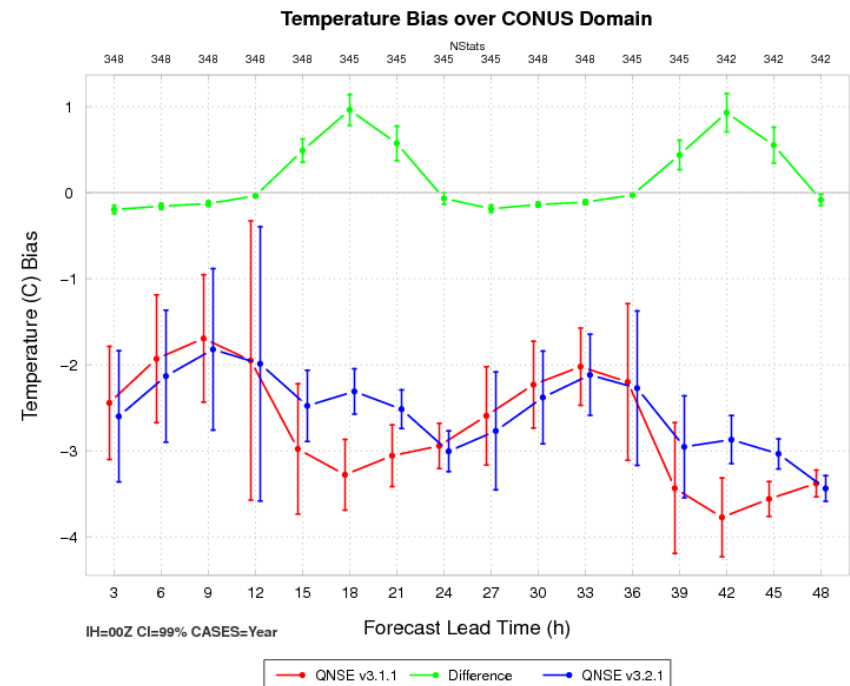
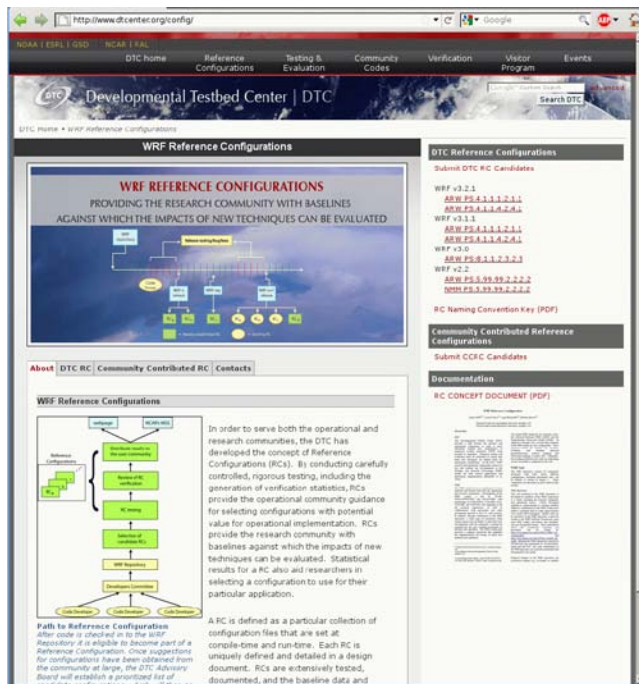
National Center for Atmospheric Research (NCAR)

12th Annual WRF User's Workshop

22 June 2011

Overview

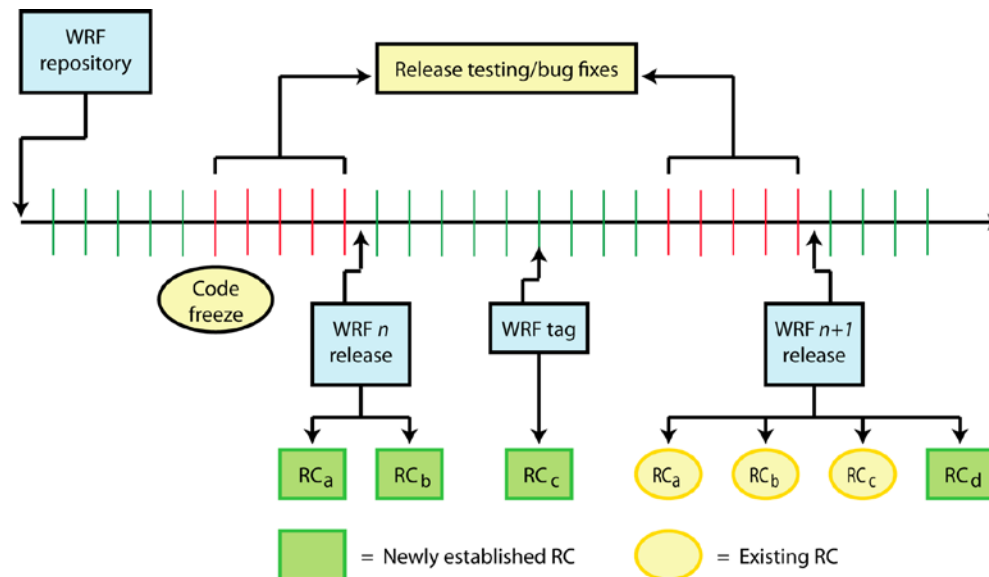
- Description of Reference Configuration (RC) concept and the function of the Developmental Testbed Center (DTC) in RC efforts
- Verification results from two WRF-ARW configurations tested with version 3.1.1 and version 3.2.1



RC Description

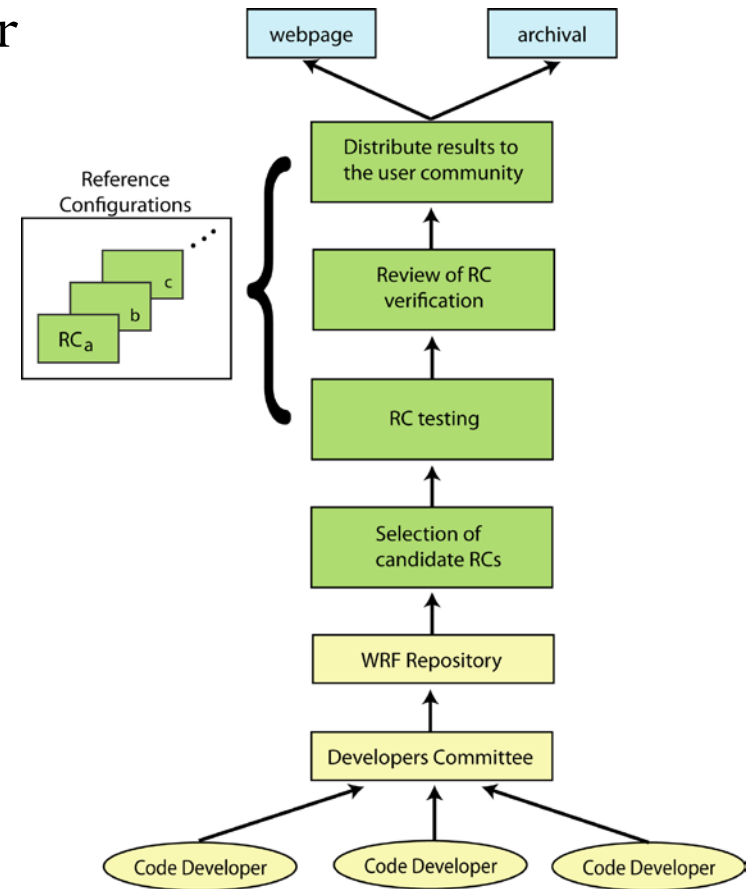
RC Concept

- **Concept:** Rigorously test and evaluate select WRF configurations
- **Goal:** Provide well-documented baseline verification results for specific configurations of WRF that are broadly distributed to the numerical weather prediction community
- Beneficial to both the operational and research communities



RC Concept: Function of the DTC

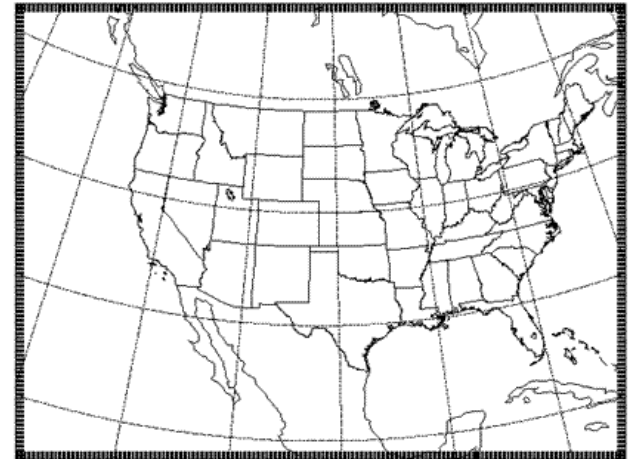
- The Developmental Testbed Center
 - Establishes RCs, performs testing and evaluation, and disseminates results
 - Runs end-to-end system and generate verification results using appropriate verification techniques
 - Retest relevant RCs based on latest WRF release
 - Solicits and facilitates input from user community for Community Contributed Reference Configurations (CCRCs)



RC Testing & Evaluation

Experiment Design

- **End-to-end system:** WPS, WRF, WPP, and MET (v3.0.1)
- **Test Period:** 2 June 2008 – 31 May 2009
- **Retrospective forecasts:** 48-h forecasts initialized every 36 h
- **Domain:** 15-km CONUS grid
- **Physics suite** for each configuration:



WRF-ARW computational domain

| Physics Suite | AFWA Configuration | QNSE-replacement Configuration |
|--------------------|---------------------------------|--------------------------------|
| Microphysics | WRF Single-Moment 5 | WRF Single-Moment 5 |
| Radiation (SW/LW) | Dudhia/RRTM | Dudhia/RRTM |
| Surface Layer | Monin-Obukhov similarity theory | Quasi-Normal Scale Elimination |
| Land Surface Model | Noah | Noah |
| PBL | Yonsei University | Quasi-Normal Scale Elimination |
| Convection | Kain-Fritsch | Kain-Fritsch |

Model Verification

- **Verification stratifications** include temporal and spatial aggregations
- **Grid-to-point** verification for surface and upper-air temperature, dew point temperature, winds
 - Bias-corrected root mean square error (BCRMSE) and mean error (bias)
- **Grid-to-grid** verification for 3-h and 24-h QPF
 - Gilbert Skill Score (GSS) and frequency bias
- **Confidence intervals (CIs)** computed at the 99% level
- **Pair-wise difference** technique applied by computing difference between versions (v3.2.1 – v3.1.1)



Verification domain

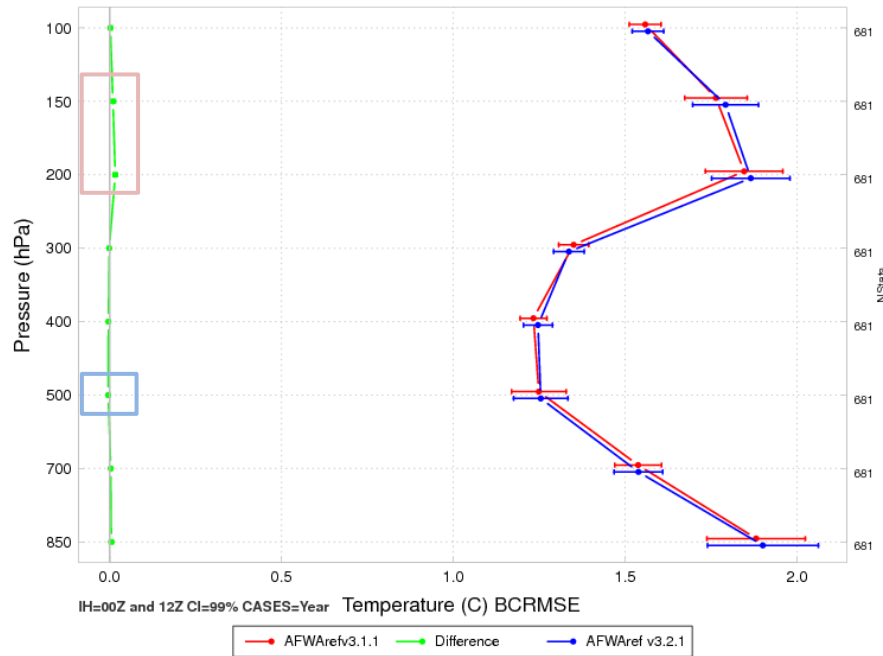
Establishing Significance

- Identified **statistically significant (SS)** differences between configurations as well as **practically significant (PS)** differences
 - Large dataset increases number of pair-wise differences - not always practically meaningful
 - SS: Objectively determined by using pair-wise difference technique
 - PS: Censored data to highlight pair-wise differences greater than a specified value
 - WMO requirements for operational measurement uncertainty:
 $T/T_d > 0.1$ K, wind > 0.5 ms⁻¹, and precip. accumulation > 0.1 mm

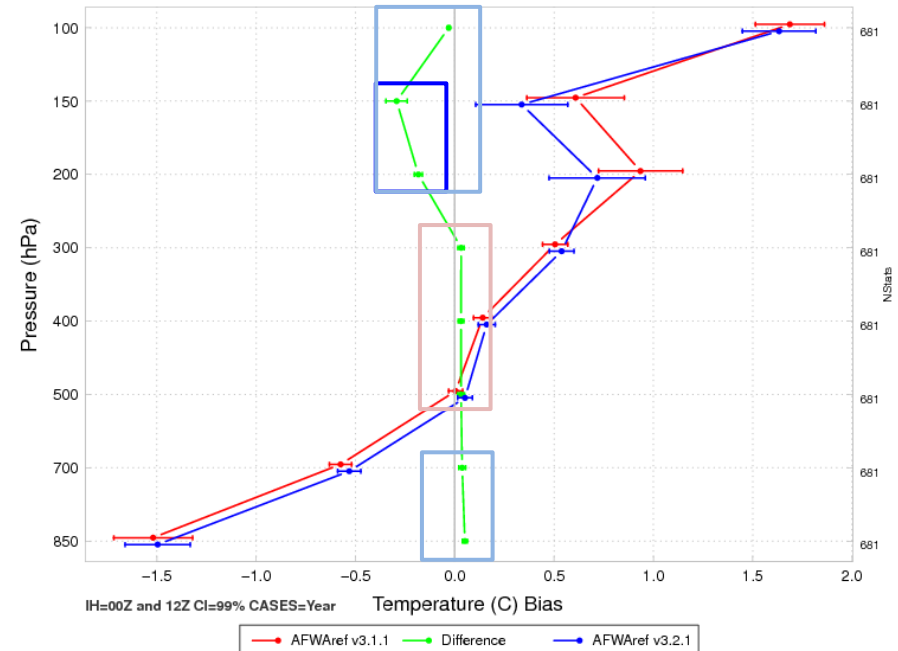
Verification Results

AFWA: Upper Air Temperature

Temperature BCRMSE over CONUS Domain
48-h Lead Time



Temperature Bias over CONUS Domain
48-h Lead Time



Upper Air SS/PS Tables

SS (light shading) and PS (dark shading) differences for the annual aggregation of upper air temperature, dew point temperature, and wind *BCRMSE* and *bias*

AFWA: v3.2.1 – v3.1.1

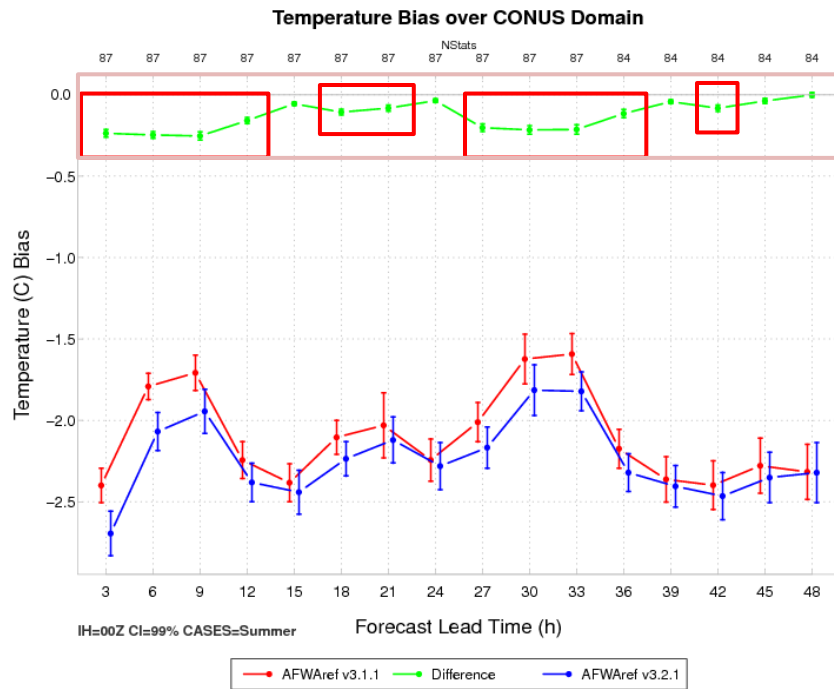
QNSE: v3.2.1 – v3.1.1

| Annual | | | | | | | | | | | | |
|-------------|-----|--------|--------|-----------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Temperature | | | | Dew Point Temperature | | | | Wind | | | | |
| f12 | f24 | f36 | f48 | f12 | f24 | f36 | f48 | f12 | f24 | f36 | f48 | |
| BCRMSE | 850 | -- | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.1.1 | -- | v3.1.1 |
| | 700 | -- | -- | v3.1.1 | -- | v3.1.1 | v3.1.1 | -- | -- | -- | -- | -- |
| | 500 | -- | -- | -- | v3.2.1 | -- | -- | -- | v3.2.1 | -- | -- | v3.2.1 |
| | 400 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | v3.2.1 |
| | 300 | v3.1.1 | v3.1.1 | -- | -- | -- | -- | -- | v3.2.1 | -- | v3.2.1 | -- |
| | 200 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | -- | -- | -- | -- | -- |
| | 150 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | -- | v3.2.1 | -- | -- | -- |
| Bias | 100 | -- | -- | -- | -- | -- | -- | -- | v3.2.1 | v3.2.1 | -- | -- |
| | 850 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | -- | -- | -- | v3.2.1 | v3.1.1 | v3.1.1 |
| | 700 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | -- | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 |
| | 500 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.2.1 | v3.2.1 | -- | -- | -- | -- | -- |
| | 400 | -- | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | -- | v3.2.1 | -- | -- | -- |
| | 300 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| | 200 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | -- | -- | -- | v3.1.1 | v3.1.1 | -- | -- |
| | 150 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | -- | -- | -- | -- | v3.2.1 | v3.2.1 | v3.2.1 |
| | 100 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | -- | -- | -- | -- | v3.2.1 | v3.2.1 | v3.2.1 |

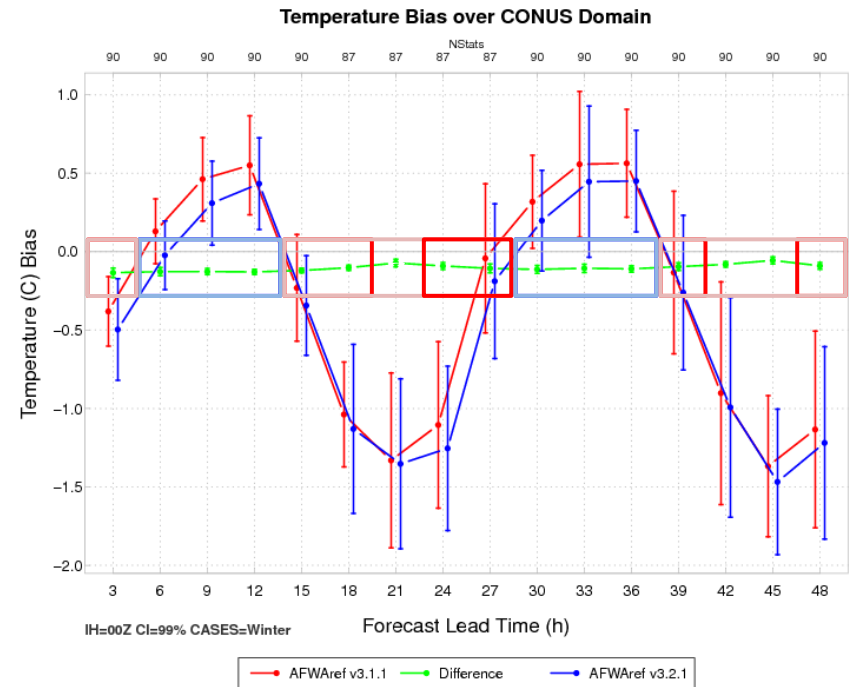
| Annual | | | | | | | | | | | | |
|-------------|-----|--------|--------|-----------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Temperature | | | | Dew Point Temperature | | | | Wind | | | | |
| f12 | f24 | f36 | f48 | f12 | f24 | f36 | f48 | f12 | f24 | f36 | f48 | |
| BCRMSE | 850 | -- | -- | -- | v3.2.1 | -- | -- | -- | -- | v3.2.1 | -- | -- |
| | 700 | -- | v3.2.1 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | 500 | -- | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | -- | -- | v3.2.1 | -- | -- | v3.2.1 |
| | 400 | -- | v3.2.1 | v3.2.1 | v3.2.1 | -- | -- | -- | -- | v3.2.1 | v3.2.1 | -- |
| | 300 | -- | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | -- | -- | v3.2.1 | v3.2.1 | v3.2.1 |
| | 200 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | -- | -- | -- | -- | v3.2.1 |
| | 150 | -- | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | -- | -- | v3.2.1 | -- | -- |
| Bias | 100 | -- | v3.2.1 | v3.1.1 | v3.1.1 | -- | -- | -- | -- | v3.2.1 | -- | -- |
| | 850 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.2.1 | v3.2.1 | v3.1.1 | -- | -- | v3.2.1 |
| | 700 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | v3.2.1 | v3.2.1 | -- | -- | -- |
| | 500 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | -- | -- |
| | 400 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | -- | -- | -- | -- | v3.2.1 | v3.2.1 | -- |
| | 300 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | -- | -- | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 |
| | 200 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | -- | -- | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 |
| | 150 | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | -- | -- | -- | -- | -- | v3.2.1 | v3.2.1 |
| | 100 | v3.2.1 | -- | -- | -- | -- | -- | -- | -- | -- | v3.2.1 | v3.2.1 |

AFWA: 2-m Temperature

Summer Season

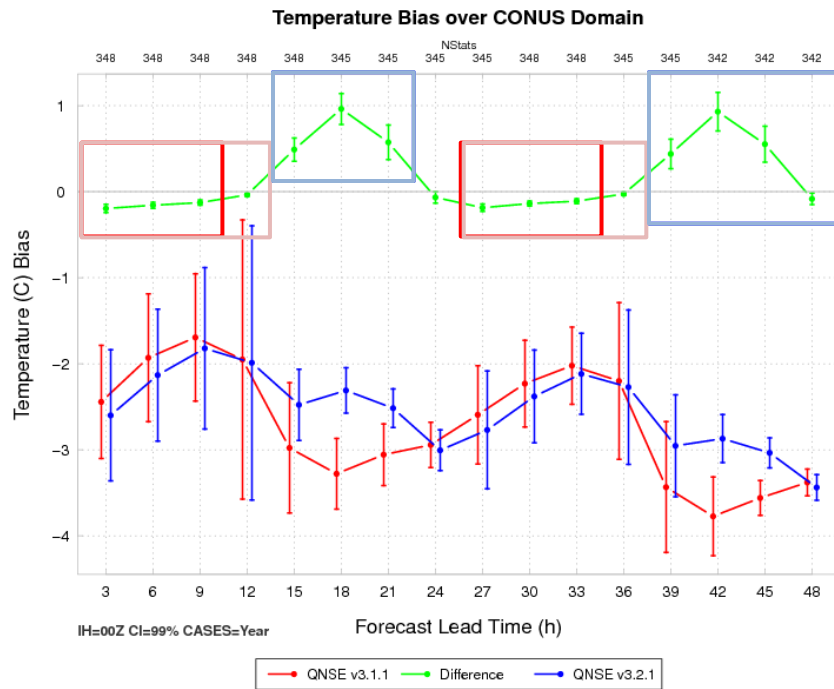


Winter Season

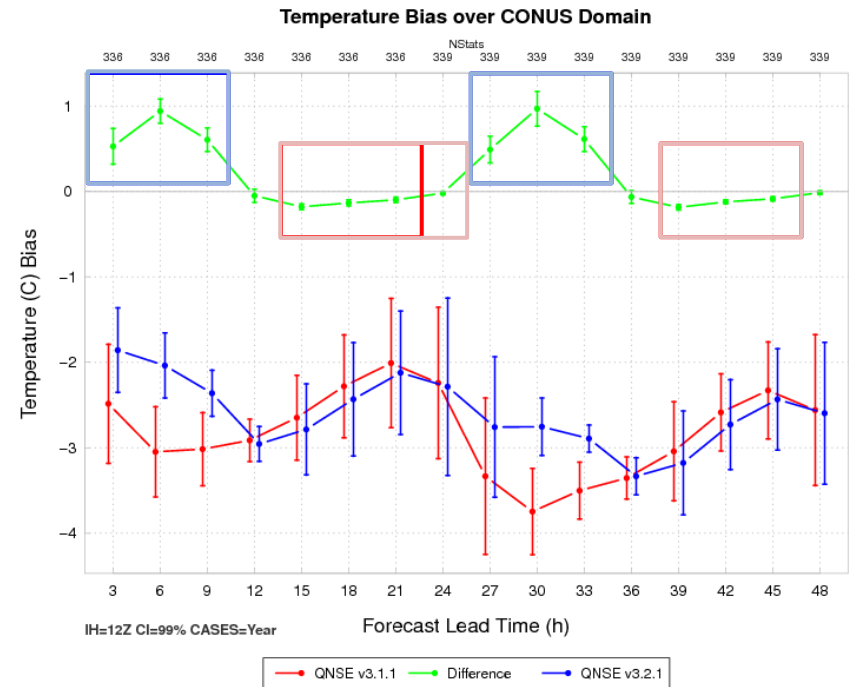


QNSE: 2-m Temperature

00 UTC initialization



12 UTC initialization



2-m Temperature SS/PS Tables

SS (light shading) and PS (dark shading) differences for *BCRMSE* and *bias* by init time, lead time, and season

AFWA: v3.2.1 – v3.1.1

| | | | f03 | f06 | f09 | f12 | f15 | f18 | f21 | f24 | F27 | f30 | f33 | f36 | f39 | f42 | f45 | f48 | |
|--------|--------|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| BCRMSE | 00 UTC | Initializations | Annual | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.1.1 | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | -- | v3.1.1 | |
| | | | Summer | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.1.1 | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | v3.2.1 | -- |
| | | | Fall | v3.1.1 | -- | v3.2.1 | -- | -- | -- | -- | v3.1.1 | v3.1.1 | -- | -- | -- | -- | -- | -- | v3.1.1 |
| | | | Winter | v3.1.1 | -- | -- | v3.2.1 | -- | -- | -- | v3.1.1 | v3.1.1 | -- | -- | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 |
| | | | Spring | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.1.1 | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | v3.1.1 | -- | -- | v3.1.1 |
| | 12 UTC | Initializations | Annual | -- | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | -- | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| | | | Summer | -- | -- | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | v3.2.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| | | | Fall | -- | -- | -- | v3.1.1 | v3.1.1 | -- | -- | -- | -- | v3.1.1 | -- | v3.1.1 | v3.1.1 | -- | -- | -- |
| | | | Winter | -- | -- | -- | v3.1.1 | v3.1.1 | -- | -- | -- | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | -- |
| | | | Spring | -- | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | -- | -- | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| Bias | 00 UTC | Initializations | Annual | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | |
| | | | Summer | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- |
| | | | Fall | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| | | | Winter | v3.1.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| | | | Spring | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| | 12 UTC | Initializations | Annual | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| | | | Summer | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| | | | Fall | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| | | | Winter | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.2.1 | v3.2.1 | v3.2.1 |
| | | | Spring | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| BCRMSE | 00 UTC | Initializations | Annual | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | -- | v3.1.1 | |
| | | | Summer | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.2.1 | -- | -- | v3.1.1 |
| | | | Fall | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | -- | v3.1.1 |
| | | | Winter | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.1.1 | v3.1.1 |
| | | | Spring | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | -- | v3.1.1 |
| | 12 UTC | Initializations | Annual | -- | v3.2.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | v3.2.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| | | | Summer | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | v3.2.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| | | | Fall | -- | v3.2.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| | | | Winter | v3.1.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| | | | Spring | -- | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| Bias | 00 UTC | Initializations | Annual | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.2.1 | v3.2.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | |
| | | | Summer | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 |
| | | | Fall | v3.1.1 | v3.1.1 | v3.1.1 | - | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | |
| | | | Winter | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | -- | -- | v3.1.1 | -- | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 |
| | | | Spring | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.2.1 | v3.2.1 | v3.2.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.2.1 | v3.2.1 | v3.2.1 | -- |
| | 12 UTC | Initializations | Annual | v3.2.1 | v3.2.1 | v3.2.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.2.1 | v3.2.1 | v3.2.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | -- |
| | | | Summer | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.2.1 |
| | | | Fall | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | |
| | | | Winter | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | -- | -- | v3.2.1 | v3.2.1 | v3.2.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |
| | | | Spring | v3.2.1 | v3.2.1 | v3.2.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 | v3.2.1 | v3.2.1 | v3.2.1 | -- | v3.1.1 | v3.1.1 | v3.1.1 | v3.1.1 |

QNSE: v3.2.1 – v3.1.1

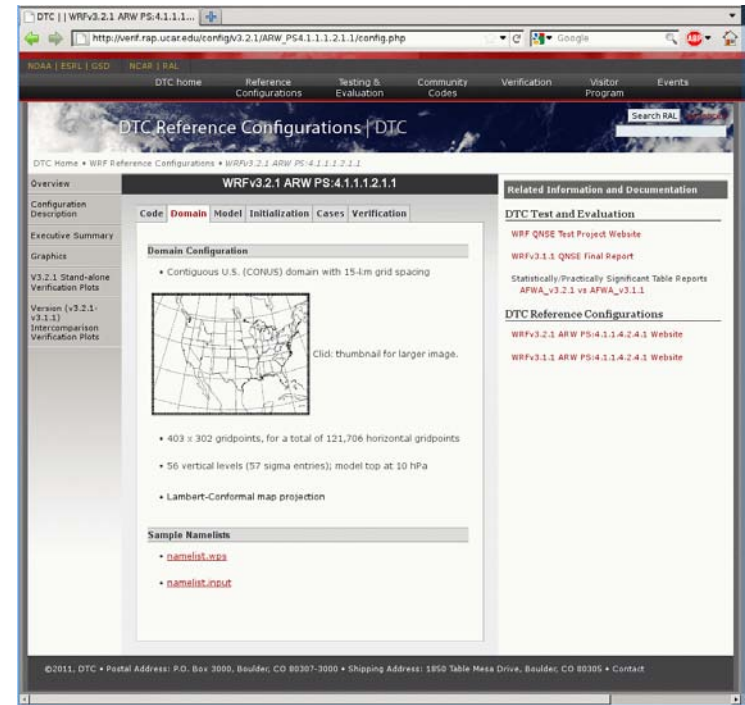


Summary

- Results from the two RCs vary based on forecast variable, initialization, temporal/spatial aggregations, etc.
- Configuration descriptions, executive summaries, graphics, documentation, and a full suite of verification results are found at:

AFWA: http://verif.rap.ucar.edu/config/v3.2.1/ARW_PS4.1.1.4.2.4.1/index.php

QNSE: http://verif.rap.ucar.edu/config/v3.2.1/ARW_PS4.1.1.1.2.1.1/index.php



Current/Future Activities

- Reference Configuration efforts with WRF v3.3
 - Retest AFWA and QNSE RCs
 - Assess performance of each configuration individually
 - Comparison of each configuration for v3.2.1 versus v3.3
 - Test new RCs
 - Hurricane WRF (HWRF) 2011 Operational Baseline
 - North American Mesoscale (NAM) model physics suite
 - WRF Rapid Refresh (RR) physics suite
- Solicit WRF community for additional RCs and CCRCs
- For more information: <http://www.dtcenter.org/config/>



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