

# P59 Inter-Comparison of the WRFv3.3.1 AFWA Operational and the RRTMG-Replacement Configurations



Michelle Harrold\*, Jamie Wolff, John Halley Gotway, Paul Oldenburg, and Zachary Trabold

National Center for Atmospheric Research/Research Applications Laboratory, Boulder, Colorado

\*harrold@ucar.edu

**Motivation:** The Developmental Testbed Center (DTC) performed extensive testing and evaluation with the Advanced Research WRF (ARW) dynamic core for two physics suite configurations with a goal of assessing the performance of the updated Rapid Radiative Transfer Model (RRTMG) long- and short-wave radiation schemes. This work was done at the request of our sponsor, the Air Force Weather Agency (AFWA).

## Experimental Design

### Code

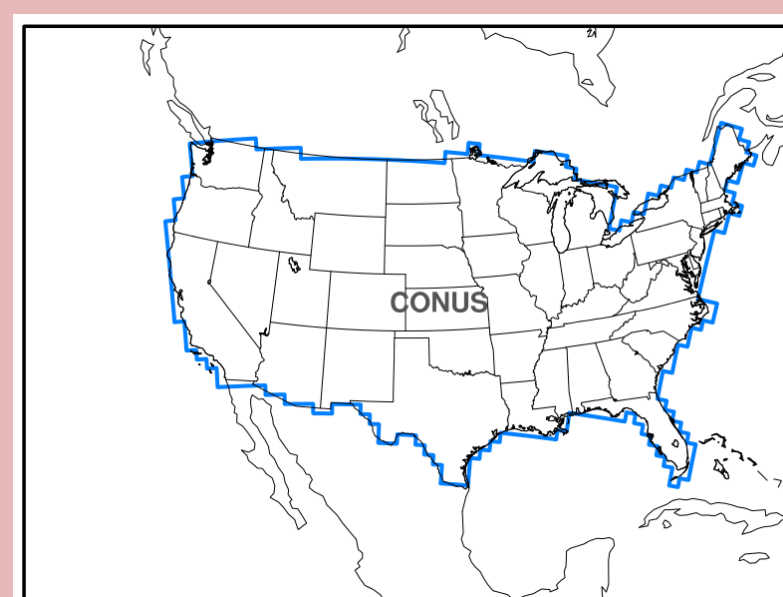
End-to-end forecast system consisted of the WRF Preprocessing System (WPS) v3.3.1, WRF v3.3.1, Unified Post Processor (UPP) v1.0, and Model Evaluation Tools (MET) v3.0.1, and included all relevant bug fixes to the codes.

### Retrospective Forecast Period

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

### Model Configuration

A 15-km contiguous United States (CONUS) grid was selected for this test, in order to incorporate complex terrain, plains, and coastal regions, allowing for worldwide comparability.



Boundary of the WRF-ARW computational domain. The blue line represents the CONUS verification region.

Physics suites used for the model configuration comparison:

Physics Suite	AFWA Operational Configuration	RRTMG-replacement Configuration
Microphysics	WRF Single-Moment 5	WRF Single-Moment 5
Radiation (SW/LW)	Dudhia/RRTM	<b>RRTMG/RRTMG</b>
Surface Layer	Monin-Obukhov similarity theory	Monin-Obukhov similarity theory
Land Surface Model	Noah	Noah
Planetary Boundary Layer	Yonsei University	Yonsei University
Convection	Kain-Fritsch	Kain-Fritsch

### Model Verification

- **Grid-to-point** verification for surface and upper-air temp, dew point temp, and winds
  - BCRMSE, bias, and GO index
- **Grid-to-grid** verification for 3-h and 24-h QPF
  - GSS and frequency bias
- Confidence intervals (CIs) computed at the 99% level
- Pair-wise (PW) difference technique (AFWA – RRTMG)
- Statistical significance (SS) & practical significance (PS)
  - SS: Objectively determined by PW difference technique
  - PS: Test results filtered to highlight PW differences greater than a specified value ( $T/T_d > 0.1$  K, Wind  $> 0.5$  ms<sup>-1</sup>)

**Acknowledgments:** The Developmental Testbed Center is funded by the National Oceanic and Atmospheric Administration (NOAA), the Air Force Weather Agency (AFWA), and National Center for Atmospheric Research (NCAR). NCAR is sponsored by the National Science Foundation (NSF).

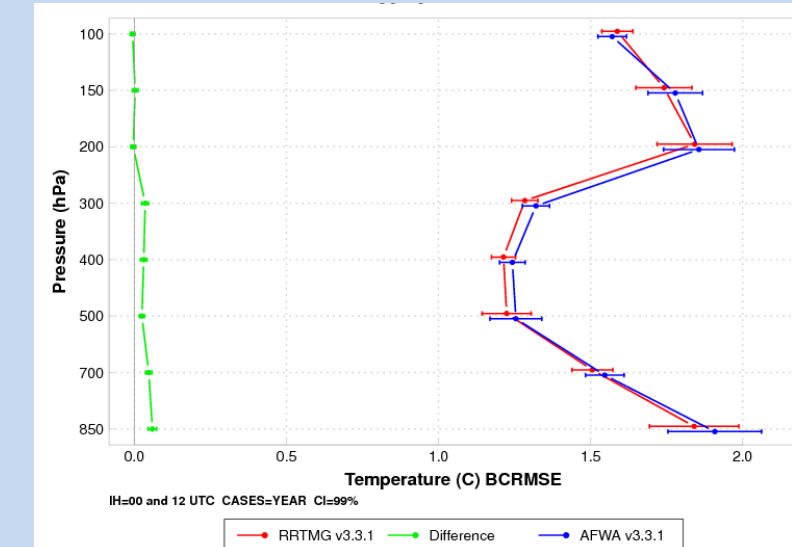
## Verification Results

### SS/PS Tables: SS (light shading) and PS (dark shading) differences (AFWA – RRTMG)

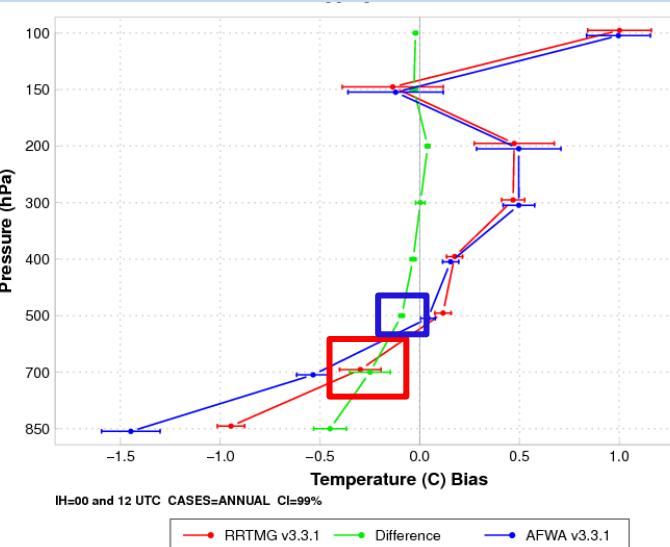
Upper Air Temperature	Annual				Summer				Winter			
	f12	f24	f36	f48	f12	f24	f36	f48	f12	f24	f36	f48
850	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG
700	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG
500	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA
400	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG
300	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG
200	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA
150	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG
100	RRTMG	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA	AFWA

Surface Temperature	Season															
	f03	f06	f09	f12	f15	f18	f21	f24	f27	f30	f33	f36	f39	f42	f45	f48
BCRMSE	Annual	RRTMG	AFWA	AFWA	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG
	Summer	RRTMG	AFWA	AFWA	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG
	Winter	RRTMG	AFWA	AFWA	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG
Bias	Annual	AFWA	AFWA	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG
	Summer	RRTMG	RRTMG	AFWA	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG
	Winter	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG	RRTMG

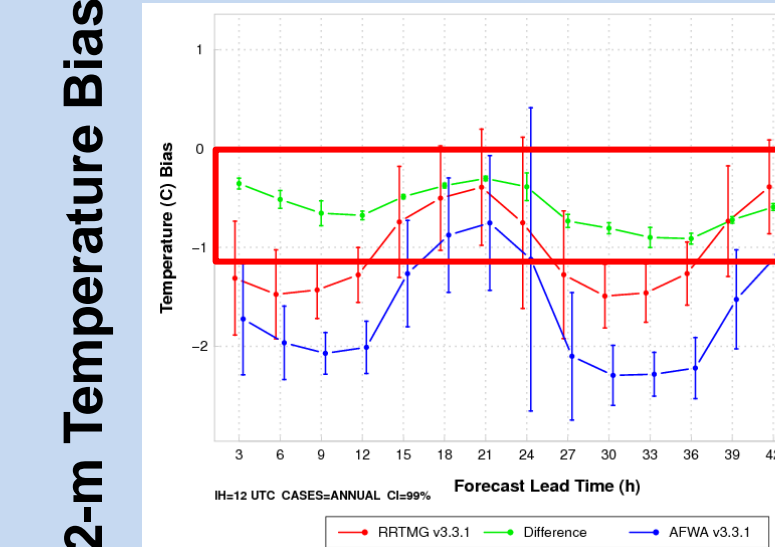
Annual Temp. BCRMSE (f48)



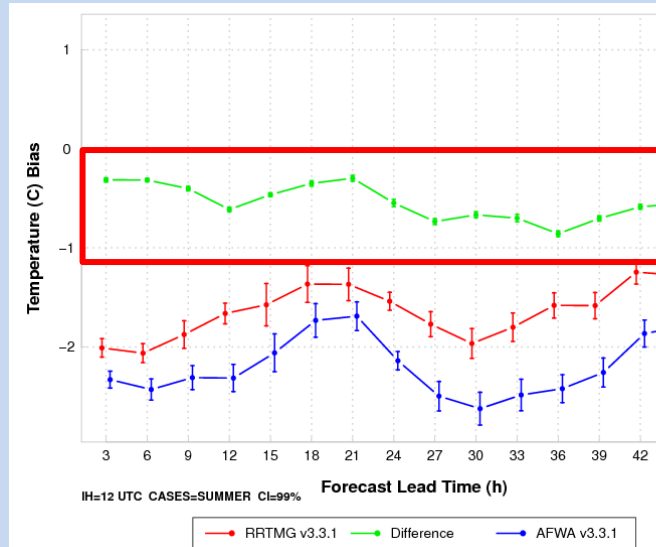
Annual Temp. Bias (f48)



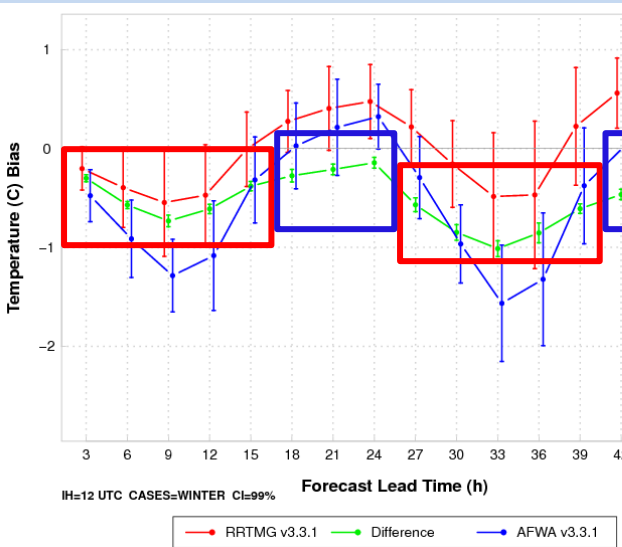
Annual – 12 UTC Inits



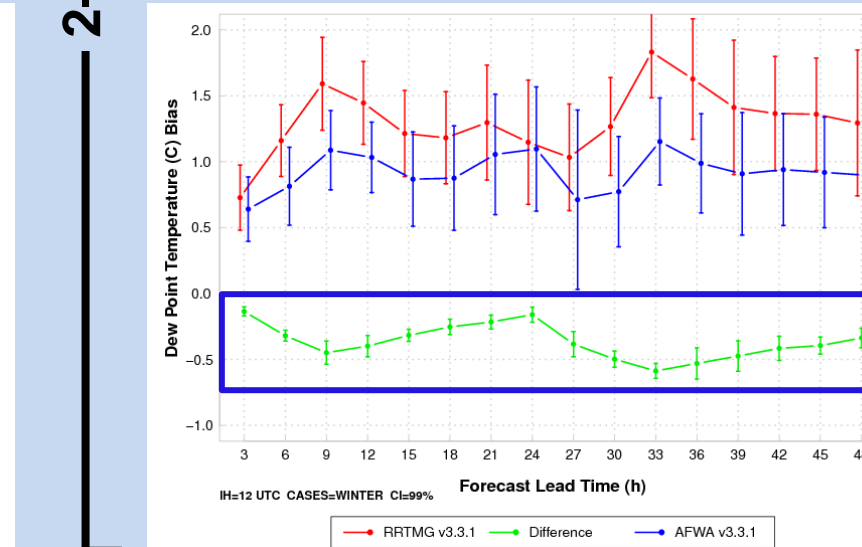
Summer – 12 UTC Inits



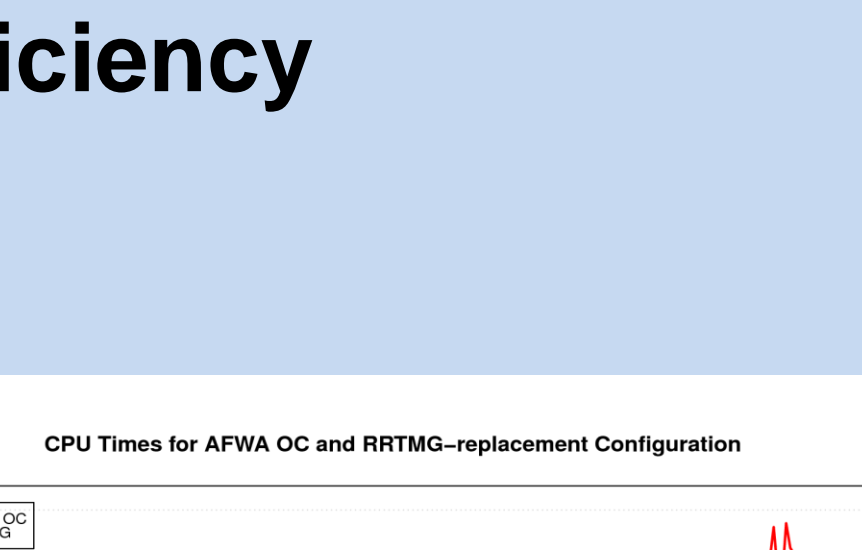
Winter – 12 UTC Inits



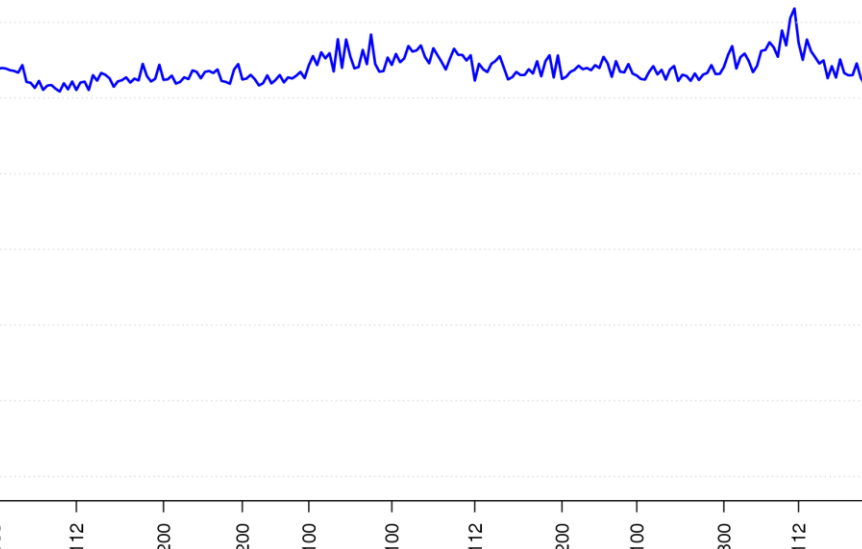
Annual – 12 UTC Inits



Summer – 12 UTC Inits



Winter – 12 UTC Inits



## General Operations (GO) Index

Skill scores (S) calculated for a variety of variables, levels, and lead times:

$$S = 1 - \frac{(RMSE_{RRTMG})^2}{(RMSE_{AFWA})^2}$$

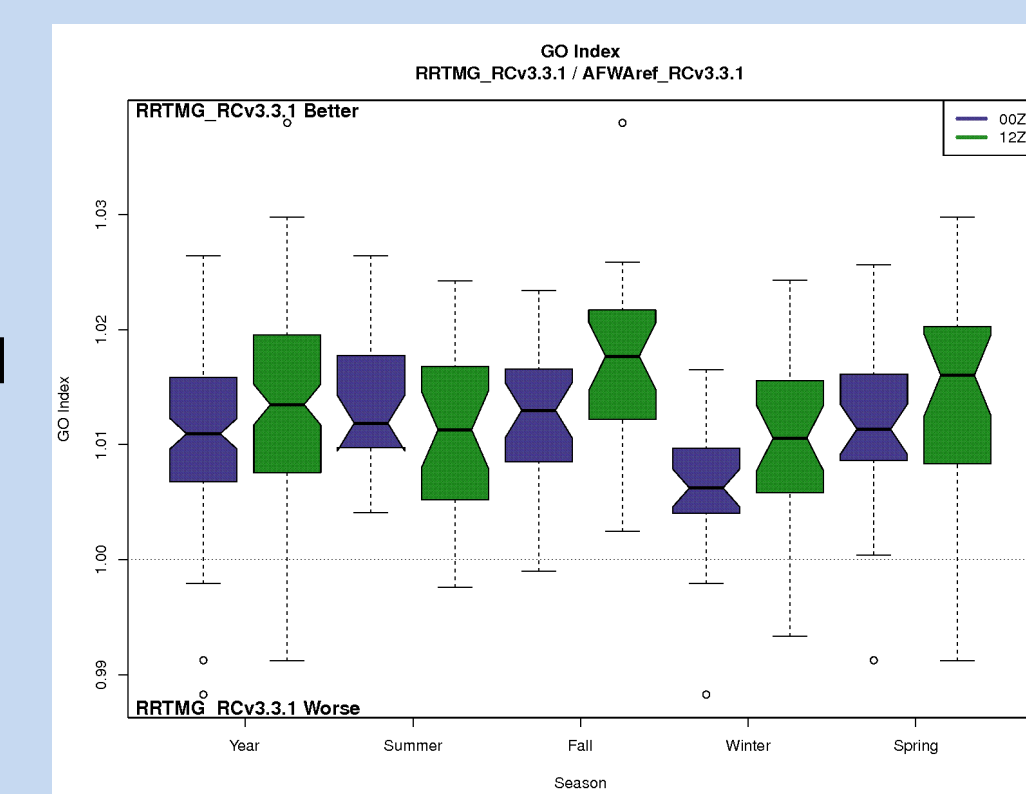
Predefined weights ( $w_i$ ) are applied for each variable, level, and forecast hour and then a weighted sum,  $S_w$ , is computed:

$$S_w = \frac{1}{\sum_i w_i} \left( \sum_i w_i S_i \right)$$

Once  $S_w$  is computed, the index value (N) is defined as:

$$N = \sqrt{\frac{1}{1 - S_w}}$$

N values **less than one** indicate the **AFWA configuration has higher skill** and values **greater than one** indicate the **RRTMG configuration has higher skill**



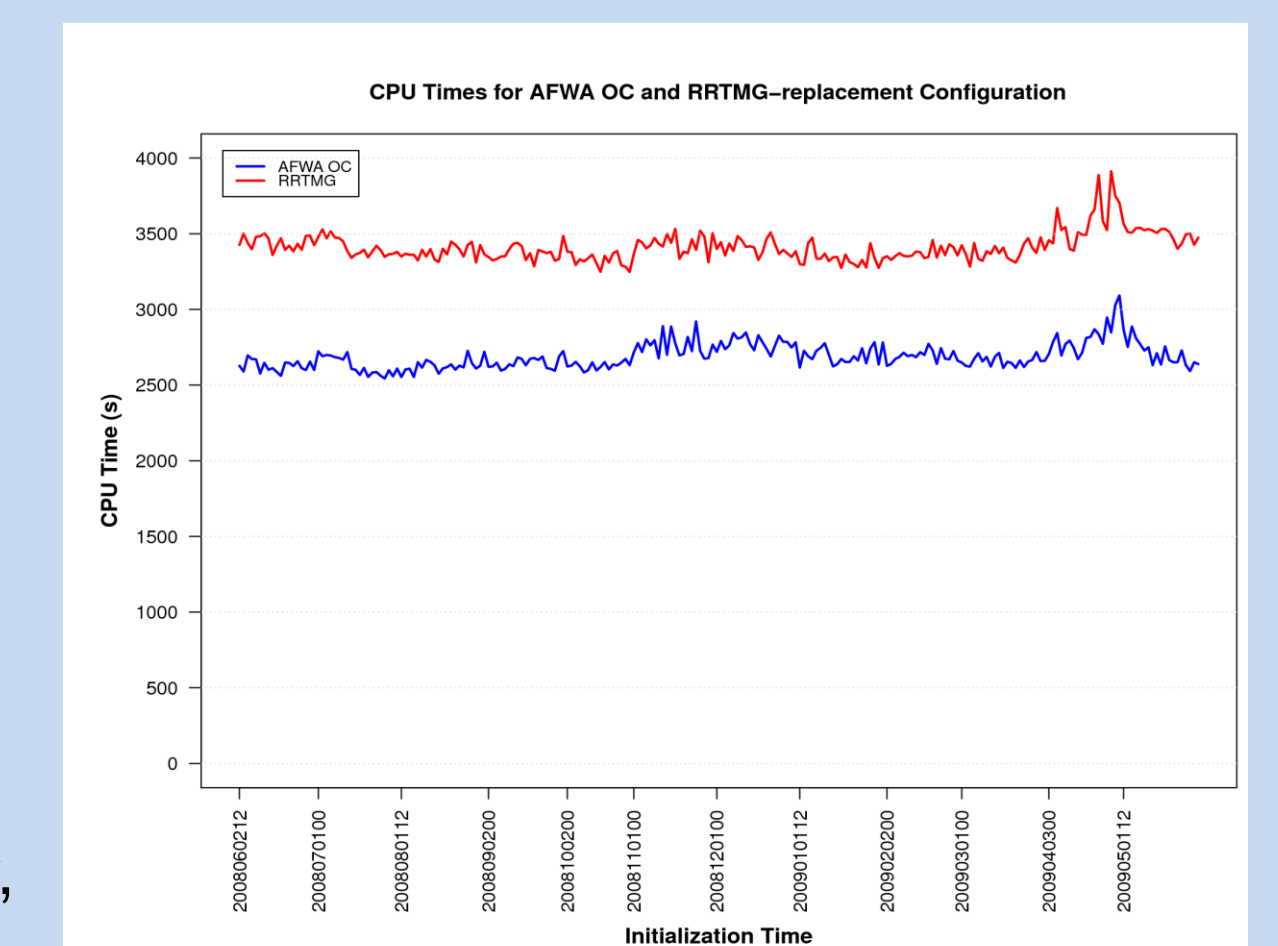
Regardless of initialization or temporal aggregation, the **RRTMG configuration displays more skill than the AFWA configuration** when considering the GO Index

## Computational Efficiency

- CPU time required to run WRF (243 initializations, out to 48 hours) was calculated to assess the computational demands of RRTMG long- and short-wave radiation schemes

- Testing was conducted on an IBM system utilizing 64 processors

- **Updated RRTMG schemes** consistently had longer computational run times than the RRTM/Dudhia schemes, on average taking **~27% longer to run to completion**; however, the updated RRTMG schemes displayed an overall increase in forecast performance



## Summary and Future Activities

- Overall, there were a large number SS and PS pair-wise differences; however, **more PS pair-wise differences indicated the RRTMG configuration out-performed the AFWA configuration**. This result is also reflected in the GO Index.
- Configuration descriptions, executive summaries, graphics, documentation, and a full suite of verification results are found at:
  - [http://www.dtcenter.org/eval/afwa\\_test/](http://www.dtcenter.org/eval/afwa_test/) (Results shown here for the v3.3.1 inter-comparison)
  - <http://www.dtcenter.org/eval/config/> (Stand-alone)
- Extensive T&E currently being conducted for AFWA:
  - **Functionally similar operational environment**, including integration of data assimilation with 6-hour “warm” start
  - Inter-comparison of **Noah land surface model versions** (WRFv3.3.1 vs. WRFv3.4)