RRTMG within WRF: An Extensive Assessment of Performance

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Introduction

Properly diagnosing the radiation budget in numerical weather prediction (NWP) is imperative due to the downstream impacts on clouds, surface energy budget and interactions with other aspects of model physics. This study aims to **evaluate the forecast performance of differing long- and short-wave radiation schemes** available in the Weather Research and Forecasting (WRF) model. The baseline, or reference, physics suite uses the **Dudhia short-wave radiation scheme** (Dudhia 1989) and the **Rapid Radiative Transfer Model (RRTM) long-wave radiation scheme** (Mlawer et al. 1997). The comparative configuration substitutes the radiation schemes with the **updated RRTM schemes** (**RRTMG**; Iacono et al. 2008). The focus is on evaluating the **seasonal and regional differences** of surface variables through the use of **traditional verification statistics** as well as observations from **Surface Radiation Budget Network (SURFRAD) network**.

Experiment 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) v4.1***

Retrospective forecasts

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

Model Configuration

15-km domain covers the CONUS region (see below) in order to capture complex terrain, plains and coastal regions

WRF-ARW configurations

Microphysics	WRF Single-Moment 3
Radiation (SW/LW)	Dudhia/RRTM (REF) RRTMG/RRTMG (RRTMG)
Surface Layer	Monin-Obukhov similarity theory
Land Surface Model	Noah
PBL	Yonsei University
Convection	Kain-Fritsch

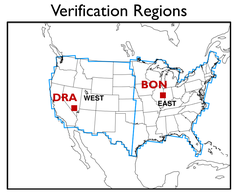
RRTMG Features

- Monte Carlo Independent Cloud Approximation (McICA; Pincus et al. 2003) method used to represent sub-grid cloud variability
- More comprehensive two-stream algorithm for scattering calculations

Model Verification

- **Verification statistics** are stratified temporally and spatially; spatial aggregations included *CONUS-East* and *CONUS-West*
- **Grid-to-point** verification for *surface* and *upper-air temperature, dew point temperature,* and *winds*
- **Confidence intervals** (CIs) computed at the 99% level
- **SURFRAD network**
  - Network of 7 operational stations over different climatological and topographical regions with varying land use types → case study will focus on the **Desert Rock, NV (DRA)** and **Bondville, IL (BON)**
  - Applied ±9 minute time window at the top of the hour to calculate mean, median, 10th and 90th percentile values within the sample and provide range
    - ✓Using instantaneous values may not be representative under cloudy skies

Computational Domain & Verification Regions



Summary

- Largest differences were typically seen after the 12-h forecast lead time, where RRTMG typically had higher median 2-m temperature and 2-m dew point temperature biases; distinct differences noted regionally and seasonally
- Under clear sky conditions, RRTMG was better able to represent the downwelling SW radiation profile when comparing to SURFRAD data, and RRTMG typically had higher downwelling LW radiation values than REF
- Further information about aspects of the testing are available on the project's webpage: http://www.dtcenter.org/eval/meso_mod/afwa_test/wrf_v3.3.1/index.php

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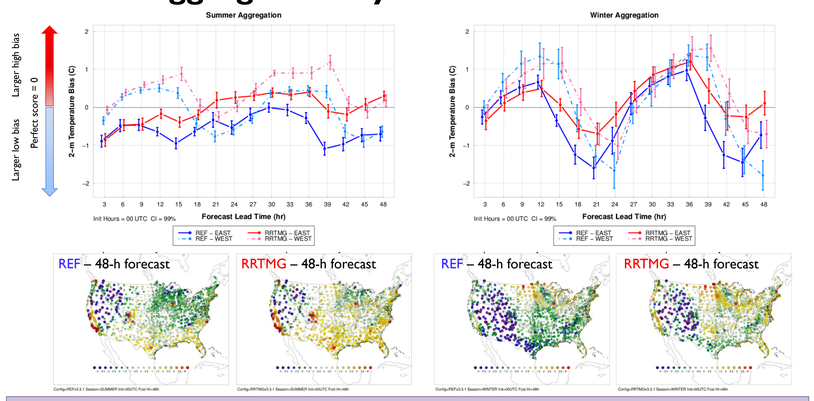
Verification Results

Aggregations by forecast lead time

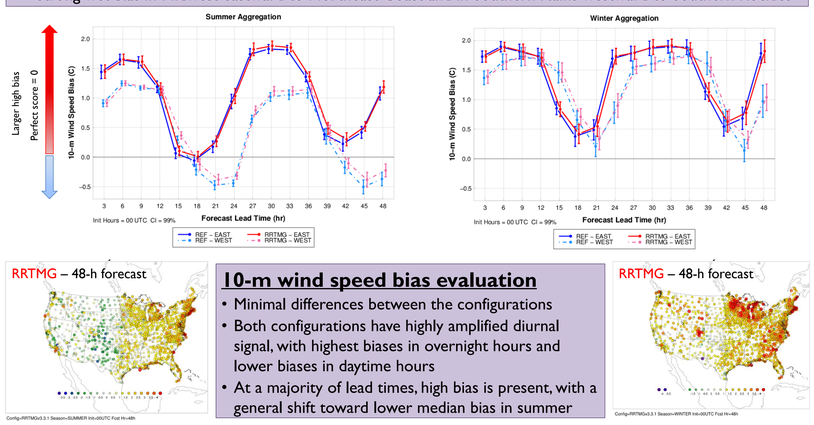


2-m temperature bias evaluation

- After the 12-h lead time, RRTMG has higher median bias values in both seasons and regions
- Diurnal signal in bias strongest in the winter and for the West in the summer
  - Warm bias in the overnight/early morning hours with REF typically closer to observations
  - Unbiased forecast or cold bias in the afternoon/early evening hours with RRTMG typically closer to observations
- Point verification at 48-h forecast lead time highlights the regional differences, with emphasis on colder bias in the Midwest and West in the summer and overall cooler biases in the winter for REF

2-m dew point temperature bias evaluation

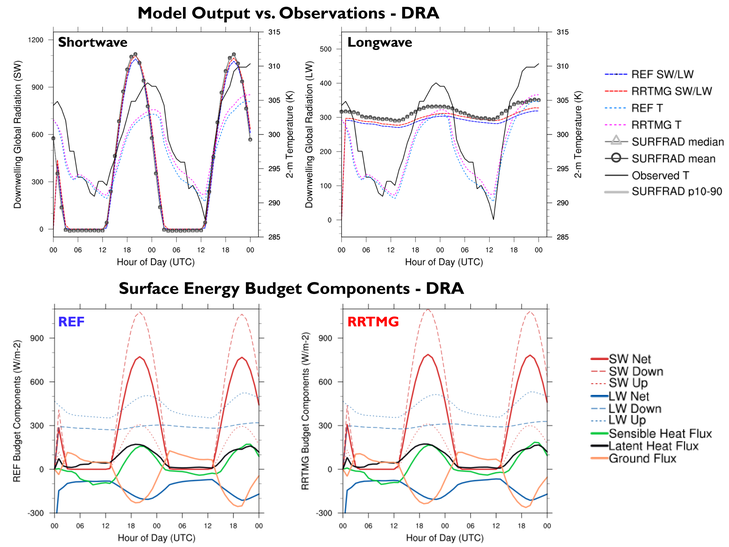
- Summer:
  - Both configurations have diurnal signal with notable differences between East and West regions
  - Drier biases in overnight (with exception to valid times ~00 UTC) and across areas in the southern West region
  - Strong wet bias over Midwest, especially for RRTMG
- Winter:
  - Frequently, overall wet bias, with most lead times after 15-h showing RRTMG with wetter median biases than REF
  - Strong wet bias in Midwest eastward to Northeast Coast and in Southern Plains westward to Southern Rockies



10-m wind speed bias evaluation

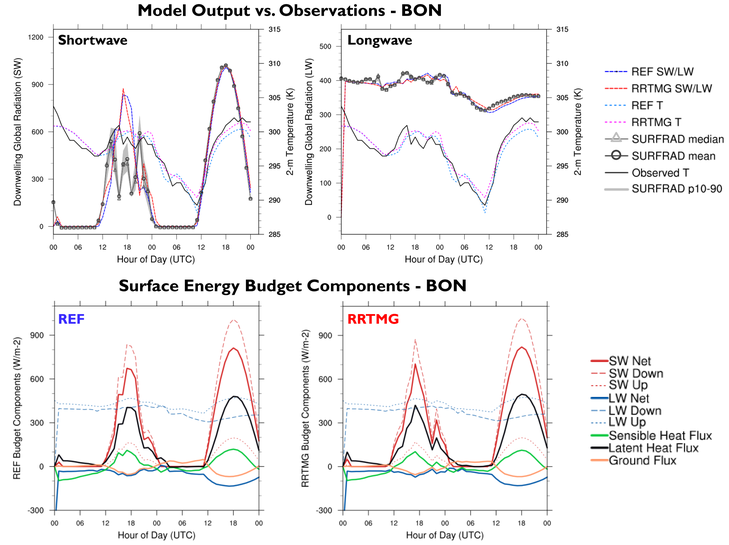
- Minimal differences between the configurations
- Both configurations have highly amplified diurnal signal, with highest biases in overnight hours and lower biases in daytime hours
- At a majority of lead times, high bias is present, with a general shift toward lower median bias in summer

Case Study: 13 June 2008 00 UTC Initialization



Desert Rock, NV (DRA) Evaluation

- Both day 1 and day 2 of forecast period are clear and both configurations produced radiation profiles consistent with clear skies
- Peaks in downwelling SW radiation for RRTMG are closer to SURFRAD observations
- In general, temperature profiles match aggregated results in the West, with both configurations having cold biases during daytime hours and RRTMG being closer to the observations than REF
- While both configurations have lower downwelling LW values, RRTMG has higher values, which may lead to higher surface temperature, consistent with the aggregated results
  - Other factors such as PBL height may be affecting forecast performance



Bondville, IL (BON) Evaluation

- Day 1 of forecast period is cloudy during daytime
  - SURFRAD observations (median, mean, 10th and 90th percentiles) show variability in SW observations during cloudy conditions
  - Investigation of radiation and fluxes, specifically SW, show both configurations capture presence of cloudiness, although, there is not a defined better performer
- Day 2 of forecast period is a clear day, which is forecast well by both configurations
  - While differences are small, RRTMG better captures peak in SW
  - This is reflected in 2-m temperature; RRTMG is closer to the observations than REF
- Considering LW, both configurations perform well compared to SURFRAD observations