# Evaluation of WRF Radiation and Microphysics Parameterizations for Use in the Arctic

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## Introduction

The Weather Research and Forecasting (WRF) model is being used for applications in the polar regions ranging from real-time forecasting to regional climate simulations. A key to the performance of WRF in the polar regions is the evaluation and identification of an ideal suite of WRF physics parameterizations that best represent the polar atmosphere. This study evaluates 32 combinations of WRF 3.4.1 shortwave radiation, longwave radiation, and microphysics in month-long regional climate simulations over four months and two domains (256 sims). The results are of the simulations are statistically compared against surface meteorology and radiation observations from Barrow, Alaska and Summit Camp, Greenland. The end goal is the identification of a preferred combination(s) of radiation and microphysics parameterizations for use in the Arctic.

## Methodology

WRF Configuration:

- WRF 3.4.1 (released 08/2012)
- Model forcing:
  Lateral/Boundary – ERA-Interim
  Sea-ice – NSIDC Near-Real-Time
- 2x – Horizontal Domains:
  Alaska – centered on Barrow, AK
  Greenland – centered on Summit Camp
  Dom. 1 – 30 km, Dom. 2 – 10 km
  -one-way nesting
- Timestep: D1 – 180 s, D2 – 60 s
- Vertical – 40 levels, 50 mb top
- The simulations start on the last day of the previous month, run the entire month, and the first 24 hours are discarded.
- 4x – Dates: July 2011, October 2011, January 2012, April 2012
- Non-varying physics parameterizations:
  Land Surface – Noah LSM (2), Boundary Layer – MYJ (2)
  Surface Layer – Eta (2), Cumulus – Grell-Devenyi (3)
  Fraction Sea Ice – Y (1), SST Update – Y (1)
- 4x – Radiation Combinations (longwave / shortwave):
  RRTM/Godd. (1/2), CAM (3/3), RRTMG (4/4), N. Goddard (5/5)
- 8x – Microphysics Options:
  Lin (2), WRF-SM5 (4), WRF-SM6 (6), Goddard (7), New Thompson (8), Morrison (10), Stony Brook (13), WRF-DM6(14)

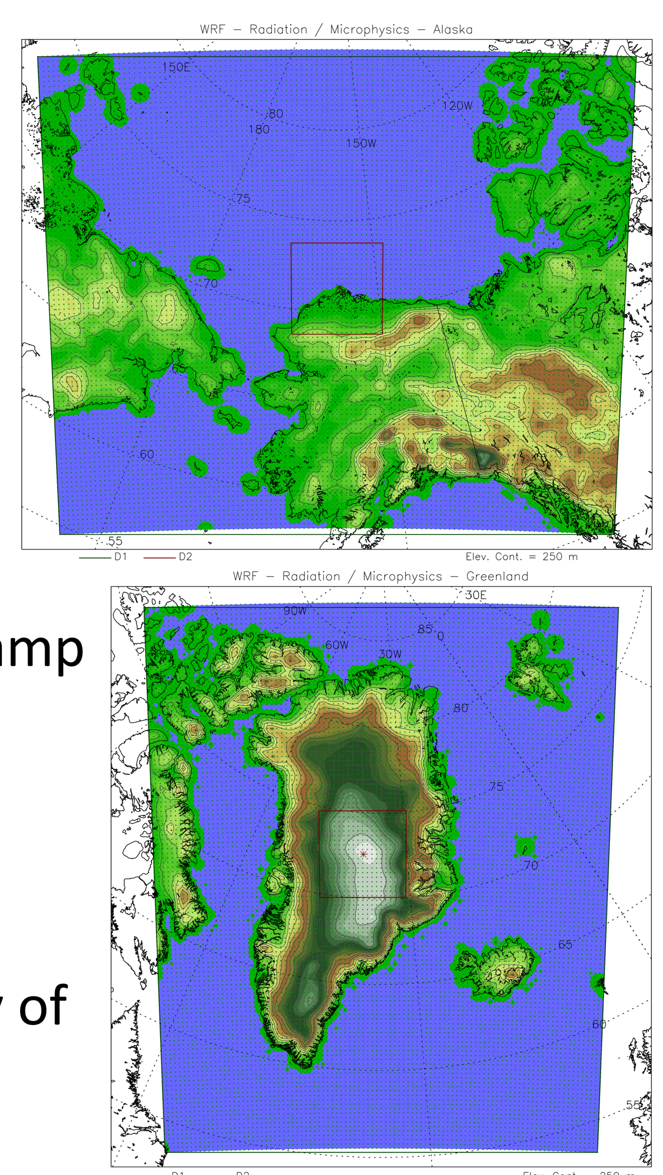

**Fig. 1: Geographic map indicating the 30 km (D1) and the 10km (D2) domains for the Alaska and Greenland simulations.**

Observations:

- The WRF simulations are compared against observations to determine the better performing physics parameterizations
- Observations: temperature and dew point at 2 m, wind speed and wind direction at 10 m, surface pressure, downwelling shortwave radiation, and downwelling longwave radation
- In the near future, radiosonde, ice-water path, and liquid-water path observations will be included in the analysis
- Barrow, AK: DOE ARM North Slope of Alaska Facility
- Summit Camp: Met. - NOAA-Global Monitoring Division,
  Rad. – Steffen Research Group, Univ. of Colorado

Statistical Comparison:

- Values from WRF are extracted using the WRF time series ability for the nearest model point to Barrow and Summit.
- Hourly averages created from the 1m/3m WRF time series.
- Hourly averages created from 1-minute observations.
- Time series plots (Fig. 2) are created for each meteorological and radiation variable.
- Statistical measures of Bias, RMSE, and Correlation are calculated for each variable.
- Each of the 32 physics configurations are ranked (Fig. 3) in each statistical category (Bias, RMSE, and Corr.) for each variable.
- The rankings of the statistical measures are averaged for each variable for each physics configuration. The standard dev. is also calculated.
- This process is repeated for each variable (6), for each site (2), for each domain (2), and for each month (4).
- Different aggregations (e.g. by site, by month, by surface met.) are created to evaluate the relative performance of each WRF physics configuration.

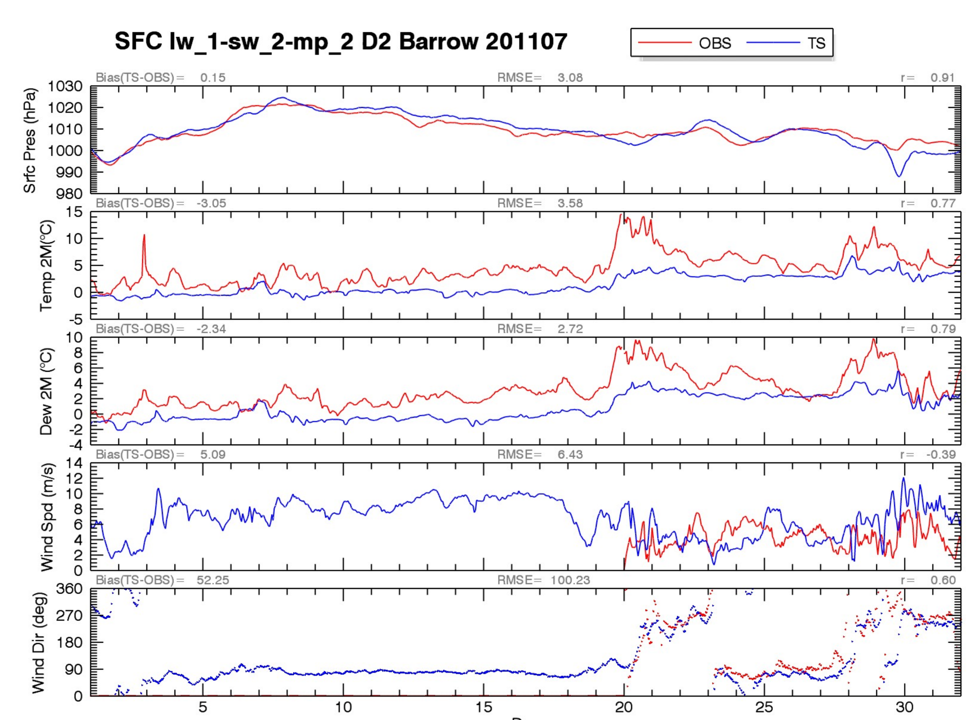


**Fig. 2: Time series plot comparing WRF simulation results to observations for P sfc, T 2m, $T_d$ 2m, WS 10m, and WD 10m for Barrow, Domain 2, July 2011.**

| Barrow - D2 - 201107 | P_SFC | | | | | T_2M | | | | | TD_2M | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WRF Configuration | BIAS | RMSE | CORR | AVG | STD | BIAS | RMSE | CORR | AVG | STD | BIAS | RMSE | CORR | AVG | STD |
| lw_1-sw_2-mp_2 | 5 | 12 | 16 | 11.0 | 5.6 | 22 | 22 | 10 | 18.0 | 6.9 | 23 | 20 | 5 | 16.0 | 9.6 |
| lw_1-sw_2-mp_4 | 14 | 25 | 28 | 22.3 | 7.4 | 18 | 17 | 7 | 14.0 | 6.1 | 17 | 16 | 14 | 15.7 | 1.5 |
| lw_1-sw_2-mp_6 | 13 | 19 | 28 | 20.0 | 7.5 | 12 | 12 | 17 | 13.7 | 2.9 | 11 | 15 | 24 | 16.7 | 6.7 |
| lw_1-sw_2-mp_7 | 7 | 2 | 3 | 4.0 | 2.6 | 10 | 14 | 20 | 14.7 | 5.0 | 16 | 14 | 11 | 13.7 | 2.5 |
| lw_1-sw_2-mp_8 | 3 | 1 | 1 | 1.7 | 1.2 | 14 | 13 | 15 | 14.0 | 1.0 | 13 | 11 | 3 | 9.0 | 5.3 |
| lw_1-sw_2-mp_10 | 1 | 9 | 17 | 9.0 | 8.0 | 5 | 11 | 30 | 15.3 | 13.1 | 2 | 7 | 30 | 13.0 | 14.9 |
| lw_1-sw_2-mp_13 | 6 | 21 | 30 | 19.0 | 12.1 | 3 | 2 | 23 | 9.3 | 11.8 | 5 | 4 | 16 | 8.3 | 6.7 |
| lw_1-sw_2-mp_14 | 8 | 17 | 27 | 17.3 | 9.5 | 5 | 8 | 26 | 13.0 | 11.4 | 15 | 20 | 28 | 21.0 | 6.6 |
| lw_3-sw_3-mp_2 | 32 | 29 | 19 | 26.7 | 6.8 | 27 | 26 | 19 | 24.0 | 4.4 | 28 | 27 | 20 | 25.0 | 4.4 |
| lw_3-sw_3-mp_4 | 25 | 32 | 32 | 29.7 | 4.0 | 29 | 32 | 31 | 30.7 | 1.5 | 29 | 31 | 31 | 30.3 | 1.2 |
| lw_3-sw_3-mp_6 | 29 | 31 | 31 | 30.3 | 1.2 | 29 | 27 | 18 | 24.7 | 5.9 | 27 | 25 | 20 | 24.0 | 3.6 |
| lw_3-sw_3-mp_7 | 26 | 16 | 10 | 17.3 | 8.1 | 31 | 30 | 22 | 27.7 | 4.9 | 32 | 32 | 18 | 27.3 | 8.1 |
| lw_3-sw_3-mp_8 | 31 | 30 | 21 | 27.3 | 5.5 | 28 | 28 | 27 | 27.7 | 0.6 | 31 | 30 | 25 | 28.7 | 3.2 |
| lw_3-sw_3-mp_10 | 30 | 28 | 20 | 26.0 | 5.3 | 32 | 31 | 24 | 29.0 | 4.4 | 25 | 26 | 26 | 25.7 | 0.6 |
| lw_3-sw_3-mp_13 | 20 | 11 | 5 | 12.0 | 7.5 | 8 | 6 | 2 | 5.3 | 3.1 | 24 | 24 | 10 | 19.3 | 8.1 |
| lw_3-sw_3-mp_14 | 10 | 8 | 14 | 10.7 | 3.1 | 25 | 25 | 6 | 18.7 | 11.0 | 30 | 28 | 6 | 21.3 | 13.3 |
| lw_4-sw_4-mp_2 | 15 | 5 | 12 | 10.7 | 5.1 | 15 | 14 | 9 | 12.7 | 3.2 | 20 | 16 | 6 | 14.0 | 7.2 |
| lw_4-sw_4-mp_4 | 19 | 13 | 12 | 14.7 | 3.8 | 19 | 20 | 14 | 17.7 | 3.2 | 21 | 19 | 6 | 15.3 | 8.1 |
| lw_4-sw_4-mp_6 | 11 | 20 | 25 | 18.7 | 7.1 | 26 | 29 | 32 | 29.0 | 3.0 | 25 | 29 | 32 | 28.7 | 3.5 |
| lw_4-sw_4-mp_7 | 18 | 10 | 11 | 13.0 | 4.4 | 9 | 7 | 1 | 5.7 | 4.2 | 8 | 6 | 4 | 6.0 | 2.0 |

**Fig. 3: Rankings of statistical measures of Bias, RMSE, and Corr. for each physics configuration for Barrow, Domain 2, July 2011. The mean and standard dev. for the three statistical rankings are also calculated.**

## Results

| Key: Radiation (lw_#-sw_#) | 1-2 : RRTM/Goddard | | 3-3 : CAM | | 4-4 : RRTMG | | 5-5 : New Thompson | |
|---|---|---|---|---|---|---|---|---|
| Microphysics (mp_#) | 2:Lin | 4:WRF-SM5 | 6:WRF-SM6 | 7:Goddard | 8:N.Thompson | 10:Morrison | 13:Stony Brook | 14:WRF-DM6 |

Total – Variables/Months/Domains:

- The radiation parameterizations is the significant factor in the results
- RRTMG rad does consistently well
- RRTM/Goddard is consistently the lower performing radiation combo
- N.Thompson radiation does better in Barrow, CAM at Summit
- Goddard mp is consistently at the top of the rankings within a selected radiation combination

| Barrow - Total | | | | | Summit Camp - Total | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Rank | AVG | STD | COMBO | | Rank | AVG | STD | COMBO | |
| 1 | 13.12 | 6.35 | lw_4-sw_4 | mp_7 | 1 | 10.84 | 6.40 | lw_4-sw_4 | mp_7 |
| 2 | 13.69 | 8.21 | lw_4-sw_4 | mp_10 | 2 | 11.76 | 6.47 | lw_3-sw_3 | mp_7 |
| 3 | 14.77 | 10.33 | lw_4-sw_4 | mp_13 | 3 | 12.48 | 8.08 | lw_4-sw_4 | mp_8 |
| 4 | 14.97 | 8.26 | lw_4-sw_4 | mp_8 | 4 | 12.84 | 6.78 | lw_3-sw_3 | mp_14 |
| 5 | 15.03 | 9.56 | lw_5-sw_5 | mp_7 | 5 | 12.87 | 9.04 | lw_3-sw_3 | mp_10 |
| 6 | 15.42 | 9.49 | lw_5-sw_5 | mp_8 | 6 | 12.92 | 7.72 | lw_3-sw_3 | mp_8 |
| 7 | 15.44 | 8.58 | lw_5-sw_5 | mp_10 | 7 | 13.32 | 6.67 | lw_4-sw_4 | mp_14 |
| 8 | 15.56 | 10.25 | lw_5-sw_5 | mp_14 | 8 | 13.87 | 6.59 | lw_4-sw_4 | mp_4 |
| 9 | 15.64 | 7.20 | lw_3-sw_3 | mp_2 | 9 | 14.02 | 6.27 | lw_4-sw_4 | mp_6 |
| 10 | 15.76 | 6.19 | lw_4-sw_4 | mp_2 | 10 | 14.09 | 6.66 | lw_4-sw_4 | mp_2 |
| 11 | 15.79 | 7.64 | lw_3-sw_3 | mp_6 | 11 | 14.29 | 6.91 | lw_3-sw_3 | mp_2 |
| 12 | 15.80 | 10.42 | lw_5-sw_5 | mp_13 | 12 | 14.38 | 6.58 | lw_3-sw_3 | mp_6 |
| 13 | 15.91 | 8.95 | lw_1-sw_2 | mp_7 | 13 | 14.41 | 9.37 | lw_4-sw_4 | mp_10 |
| 14 | 15.96 | 6.85 | lw_4-sw_4 | mp_4 | 14 | 14.52 | 7.45 | lw_3-sw_3 | mp_4 |
| 15 | 16.08 | 7.86 | lw_3-sw_3 | mp_4 | 15 | 15.82 | 8.33 | lw_5-sw_5 | mp_10 |
| 16 | 16.15 | 7.60 | lw_3-sw_3 | mp_7 | 16 | 17.08 | 10.22 | lw_4-sw_4 | mp_13 |
| 17 | 16.22 | 8.71 | lw_4-sw_4 | mp_14 | 17 | 17.48 | 9.34 | lw_5-sw_5 | mp_7 |
| 18 | 16.24 | 8.75 | lw_3-sw_3 | mp_13 | 18 | 17.54 | 6.91 | lw_5-sw_5 | mp_13 |
| 19 | 16.43 | 9.74 | lw_3-sw_3 | mp_10 | 19 | 17.71 | 8.06 | lw_1-sw_2 | mp_7 |
| 20 | 16.53 | 7.83 | lw_3-sw_3 | mp_14 | 20 | 17.75 | 8.80 | lw_1-sw_2 | mp_2 |
| 21 | 16.63 | 9.41 | lw_5-sw_5 | mp_6 | 21 | 18.01 | 9.67 | lw_5-sw_5 | mp_14 |
| 22 | 16.64 | 8.45 | lw_3-sw_3 | mp_8 | 22 | 18.04 | 7.44 | lw_1-sw_2 | mp_14 |
| 23 | 16.65 | 9.84 | lw_1-sw_2 | mp_8 | 23 | 18.30 | 9.71 | lw_1-sw_2 | mp_8 |
| 24 | 16.76 | 11.20 | lw_5-sw_5 | mp_2 | 24 | 18.35 | 9.72 | lw_3-sw_3 | mp_13 |
| 25 | 17.03 | 7.18 | lw_4-sw_4 | mp_6 | 25 | 18.66 | 10.36 | lw_5-sw_5 | mp_6 |
| 26 | 17.08 | 9.05 | lw_1-sw_2 | mp_2 | 26 | 18.66 | 7.89 | lw_1-sw_2 | mp_4 |
| 27 | 17.53 | 10.73 | lw_1-sw_2 | mp_13 | 27 | 18.69 | 9.83 | lw_5-sw_5 | mp_4 |
| 28 | 17.63 | 9.00 | lw_5-sw_5 | mp_4 | 28 | 18.88 | 10.88 | lw_5-sw_5 | mp_8 |
| 29 | 17.65 | 7.94 | lw_1-sw_2 | mp_4 | 29 | 19.47 | 7.53 | lw_1-sw_2 | mp_6 |
| 30 | 17.85 | 8.55 | lw_1-sw_2 | mp_6 | 30 | 20.21 | 10.56 | lw_5-sw_5 | mp_2 |
| 31 | 18.24 | 8.61 | lw_1-sw_2 | mp_14 | 31 | 21.44 | 10.30 | lw_1-sw_2 | mp_10 |
| 32 | 19.03 | 11.08 | lw_1-sw_2 | mp_10 | 32 | 21.50 | 10.46 | lw_1-sw_2 | mp_13 |

Energy Budget (T_2m, SW_d, LW_d):

- RRTMG is consistently the best when looking at radiation and temp
- N.Thompson performs poorly
- CAM radiation is overall the second best option
- Goddard provides the best microphysics results
- Beyond the Goddard, sorting the microphysics is not as clear

| Barrow - Energy Budget (T_2m, SW_d, LW_d) | | | | | Summit - Energy Budget (T_2m, SW_d, LW_d) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Rank | AVG | STD | COMBO | | Rank | AVG | STD | COMBO | |
| 1 | 11.47 | 4.11 | lw_4-sw_4 | mp_7 | 1 | 8.99 | 4.69 | lw_4-sw_4 | mp_7 |
| 2 | 13.32 | 8.34 | lw_4-sw_4 | mp_13 | 2 | 11.08 | 4.40 | lw_3-sw_3 | mp_7 |
| 3 | 13.36 | 5.77 | lw_4-sw_4 | mp_10 | 3 | 11.28 | 6.50 | lw_4-sw_4 | mp_8 |
| 4 | 14.19 | 8.35 | lw_1-sw_2 | mp_13 | 4 | 11.31 | 5.36 | lw_4-sw_4 | mp_6 |
| 5 | 14.22 | 6.84 | lw_1-sw_2 | mp_6 | 5 | 11.33 | 4.08 | lw_4-sw_4 | mp_14 |
| 6 | 14.61 | 4.70 | lw_4-sw_4 | mp_4 | 6 | 11.34 | 5.58 | lw_4-sw_4 | mp_4 |
| 7 | 14.78 | 6.14 | lw_3-sw_3 | mp_10 | 7 | 11.36 | 7.29 | lw_3-sw_3 | mp_8 |
| 8 | 14.81 | 6.98 | lw_4-sw_4 | mp_8 | 8 | 11.74 | 5.26 | lw_3-sw_3 | mp_14 |
| 9 | 14.85 | 5.83 | lw_3-sw_3 | mp_13 | 9 | 11.83 | 8.62 | lw_3-sw_3 | mp_10 |
| 10 | 14.88 | 6.75 | lw_1-sw_2 | mp_4 | 10 | 13.25 | 5.26 | lw_4-sw_4 | mp_2 |
| 11 | 14.90 | 5.99 | lw_3-sw_3 | mp_6 | 11 | 13.63 | 7.44 | lw_4-sw_4 | mp_10 |
| 12 | 15.01 | 7.13 | lw_1-sw_2 | mp_7 | 12 | 14.01 | 5.58 | lw_3-sw_3 | mp_4 |
| 13 | 15.56 | 6.11 | lw_3-sw_3 | mp_4 | 13 | 14.42 | 5.06 | lw_3-sw_3 | mp_2 |
| 14 | 15.94 | 5.74 | lw_3-sw_3 | mp_2 | 14 | 14.52 | 5.04 | lw_3-sw_3 | mp_6 |
| 15 | 15.99 | 5.03 | lw_4-sw_4 | mp_2 | 15 | 15.79 | 7.15 | lw_5-sw_5 | mp_10 |
| 16 | 16.17 | 4.45 | lw_4-sw_4 | mp_6 | 16 | 17.11 | 6.71 | lw_1-sw_2 | mp_7 |
| 17 | 16.36 | 4.58 | lw_5-sw_5 | mp_10 | 17 | 17.80 | 6.49 | lw_4-sw_4 | mp_13 |
| 18 | 16.78 | 6.08 | lw_3-sw_3 | mp_8 | 18 | 17.99 | 6.17 | lw_5-sw_5 | mp_7 |
| 19 | 16.88 | 7.35 | lw_1-sw_2 | mp_8 | 19 | 18.17 | 6.75 | lw_1-sw_2 | mp_2 |
| 20 | 16.90 | 7.58 | lw_1-sw_2 | mp_14 | 20 | 18.74 | 7.81 | lw_5-sw_5 | mp_14 |
| 21 | 16.93 | 7.16 | lw_5-sw_5 | mp_7 | 21 | 19.04 | 5.70 | lw_1-sw_2 | mp_14 |
| 22 | 16.99 | 6.94 | lw_3-sw_3 | mp_7 | 22 | 19.27 | 5.81 | lw_3-sw_3 | mp_13 |
| 23 | 17.14 | 6.51 | lw_3-sw_3 | mp_14 | 23 | 19.34 | 7.94 | lw_5-sw_5 | mp_4 |
| 24 | 17.24 | 6.15 | lw_4-sw_4 | mp_14 | 24 | 19.61 | 8.56 | lw_5-sw_5 | mp_6 |
| 25 | 17.36 | 8.14 | lw_1-sw_2 | mp_2 | 25 | 19.66 | 8.69 | lw_1-sw_2 | mp_8 |
| 26 | 17.74 | 6.01 | lw_5-sw_5 | mp_8 | 26 | 19.83 | 5.96 | lw_1-sw_2 | mp_4 |
| 27 | 17.90 | 8.17 | lw_5-sw_5 | mp_6 | 27 | 20.13 | 6.20 | lw_1-sw_2 | mp_6 |
| 28 | 17.93 | 10.77 | lw_1-sw_2 | mp_10 | 28 | 20.16 | 4.26 | lw_5-sw_5 | mp_13 |
| 29 | 18.42 | 9.94 | lw_5-sw_5 | mp_13 | 29 | 20.64 | 6.31 | lw_1-sw_2 | mp_13 |
| 30 | 18.65 | 7.93 | lw_5-sw_5 | mp_14 | 30 | 21.36 | 7.63 | lw_5-sw_5 | mp_8 |
| 31 | 19.14 | 7.77 | lw_5-sw_5 | mp_4 | 31 | 22.51 | 7.63 | lw_1-sw_2 | mp_10 |
| 32 | 20.65 | 9.23 | lw_5-sw_5 | mp_2 | 32 | 23.30 | 6.30 | lw_5-sw_5 | mp_2 |

July 2011 / April 2012 – Total:

- There is some variation from month to month in the results
- RRTM/Goddard performs reasonable in July and poor in April
- CAM performs poor in July and good in April
- RRTMG radiation and Goddard microphysics continues to out perform all others

| July 2011 - Total | | | | | April 2012 - Total | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Rank | AVG | STD | COMBO | | Rank | AVG | STD | COMBO | |
| 1 | 10.28 | 9.53 | lw_4-sw_4 | mp_13 | 1 | 10.17 | 6.21 | lw_4-sw_4 | mp_7 |
| 2 | 10.56 | 7.95 | lw_4-sw_4 | mp_7 | 2 | 10.50 | 6.33 | lw_3-sw_3 | mp_7 |
| 3 | 12.22 | 7.05 | lw_4-sw_4 | mp_10 | 3 | 11.69 | 6.43 | lw_3-sw_3 | mp_6 |
| 4 | 13.47 | 8.10 | lw_1-sw_2 | mp_7 | 4 | 12.07 | 8.78 | lw_5-sw_5 | mp_10 |
| 5 | 13.60 | 6.63 | lw_4-sw_4 | mp_2 | 5 | 12.61 | 7.17 | lw_3-sw_3 | mp_4 |
| 6 | 13.96 | 9.02 | lw_1-sw_2 | mp_8 | 6 | 12.65 | 6.26 | lw_3-sw_3 | mp_2 |
| 7 | 14.18 | 8.07 | lw_4-sw_4 | mp_8 | 7 | 12.67 | 7.15 | lw_3-sw_3 | mp_14 |
| 8 | 14.54 | 10.63 | lw_5-sw_5 | mp_13 | 8 | 13.17 | 5.97 | lw_4-sw_4 | mp_6 |
| 9 | 14.56 | 7.65 | lw_4-sw_4 | mp_4 | 9 | 13.36 | 7.05 | lw_4-sw_4 | mp_4 |
| 10 | 14.65 | 8.16 | lw_1-sw_2 | mp_6 | 10 | 13.50 | 9.07 | lw_4-sw_4 | mp_8 |
| 11 | 14.68 | 10.66 | lw_4-sw_4 | mp_14 | 11 | 13.71 | 9.01 | lw_3-sw_3 | mp_8 |
| 12 | 14.74 | 7.11 | lw_1-sw_2 | mp_4 | 12 | 13.97 | 6.53 | lw_4-sw_4 | mp_2 |
| 13 | 15.60 | 11.32 | lw_1-sw_2 | mp_13 | 13 | 14.03 | 8.71 | lw_3-sw_3 | mp_10 |
| 14 | 15.68 | 11.66 | lw_1-sw_2 | mp_10 | 14 | 14.03 | 10.91 | lw_5-sw_5 | mp_8 |
| 15 | 16.07 | 11.11 | lw_3-sw_3 | mp_10 | 15 | 14.07 | 9.63 | lw_4-sw_4 | mp_10 |
| 16 | 16.51 | 8.47 | lw_5-sw_5 | mp_7 | 16 | 14.15 | 10.22 | lw_5-sw_5 | mp_7 |
| 17 | 16.54 | 8.78 | lw_4-sw_4 | mp_6 | 17 | 14.39 | 10.22 | lw_5-sw_5 | mp_14 |
| 18 | 16.72 | 8.08 | lw_1-sw_2 | mp_14 | 18 | 14.43 | 6.57 | lw_4-sw_4 | mp_14 |
| 19 | 16.75 | 10.08 | lw_3-sw_3 | mp_13 | 19 | 15.56 | 9.73 | lw_5-sw_5 | mp_6 |
| 20 | 16.90 | 9.53 | lw_5-sw_5 | mp_14 | 20 | 16.24 | 9.94 | lw_5-sw_5 | mp_4 |
| 21 | 17.82 | 9.09 | lw_5-sw_5 | mp_6 | 21 | 16.49 | 7.13 | lw_5-sw_5 | mp_13 |
| 22 | 17.85 | 7.13 | lw_5-sw_5 | mp_10 | 22 | 16.82 | 11.44 | lw_5-sw_5 | mp_2 |
| 23 | 17.90 | 8.86 | lw_1-sw_2 | mp_2 | 23 | 19.53 | 7.50 | lw_1-sw_2 | mp_7 |
| 24 | 19.00 | 8.49 | lw_3-sw_3 | mp_14 | 24 | 19.79 | 8.81 | lw_4-sw_4 | mp_13 |
| 25 | 19.32 | 7.75 | lw_3-sw_3 | mp_2 | 25 | 20.17 | 7.91 | lw_3-sw_3 | mp_13 |
| 26 | 19.47 | 8.78 | lw_3-sw_3 | mp_6 | 26 | 20.49 | 8.61 | lw_1-sw_2 | mp_2 |
| 27 | 19.75 | 6.90 | lw_5-sw_5 | mp_4 | 27 | 20.58 | 6.72 | lw_1-sw_2 | mp_14 |
| 28 | 19.78 | 7.84 | lw_3-sw_3 | mp_7 | 28 | 21.54 | 7.21 | lw_1-sw_2 | mp_4 |
| 29 | 19.83 | 8.10 | lw_3-sw_3 | mp_8 | 29 | 21.86 | 6.76 | lw_1-sw_2 | mp_6 |
| 30 | 20.03 | 7.37 | lw_5-sw_5 | mp_8 | 30 | 22.40 | 9.54 | lw_1-sw_2 | mp_8 |
| 31 | 20.21 | 8.64 | lw_5-sw_5 | mp_2 | 31 | 25.57 | 8.46 | lw_1-sw_2 | mp_10 |
| 32 | 20.78 | 9.33 | lw_3-sw_3 | mp_4 | 32 | 26.65 | 7.66 | lw_1-sw_2 | mp_13 |


| Key: Radiation (lw_#-sw_#) | 1-2 : RRTM/Goddard | | 3-3 : CAM | | 4-4 : RRTMG | | 5-5 : New Thompson | |
|---|---|---|---|---|---|---|---|---|
| Microphysics (mp_#) | 2:Lin | 4:WRF-SM5 | 6:WRF-SM6 | 7:Goddard | 8:N.Thompson | 10:Morrison | 13:Stony Brook | 14:WRF-DM6 |


## Conclusions

- The RRTMG radiation combination and the Goddard microphysics consistently out performs all other radiation and microphysics schemes in nearly every comparison.
- The RRTM/Goddard radiation and the Lin, WRF-SM5, and WRF-SM6 microphysics schemes consistently, although not exclusively perform poorly.
- There is a monthly/seasonal dependence on the results. There is some variation by site.