User Guide

Goddard Radiation Scheme for NU-WRF
Version 2014

Document Revision: 1
16 June 2014

Authors: Toshi Matsui[1&2], Jossy P. Jacob[3]

[1]NASA Goddard Space Flight Center
[2]ESSIC UMCP
[3] Science Systems and Applications Inc

Table of Contents

1. Overview **2**
1.1 Enhancements **2**
2. Using the Software **3**
References **4**

1. Overview

The Goddard radiation schemes have been developed over the past two decades at NASA Goddard for use in general circulation models (GCMs) (Chou and Suarez, 1999, 2001, details in Table 1), and it has been incorporated and tested in the WRF (Shi et al. 2010 and 2014, Ma et al. 2012). For this, the Goddard radiation package has been customized and optimized for the scale of storm-resolving simulations (dx: 1~6km). These modifications include (i) the short-wave radiation code was optimized for computational speed (improved by a factor of 2) skipping cloud-overlapping scheme used in global model; (ii) cloud microphysics assumptions made closely to that of the Goddard microphysics; (iii) the aerosol direct effect on both long-wave and short-wave radiation has been accounted from the GOCART aerosols mass concentration; (iv) radiation physics routines is one-dimensionalized for computational efficiency (improved by a factor of 1.5). History of enhancements is described at the top of source code (`module_ra_goddard_2014`).

Wavelength	SW (Solar)	LW (thermal)
Flux solution	Two-stream adding method	Schwarzchild equation
Number of bands	UV&PAR(8 bands) Solar-IR(3 bands)	10 bands
Optical approximation	Delta-Eddington approximation (for scattering and transmission)	Henyen-Greenstein function (for scattering), One/two-parameter scaling, modified k-distribution (for absorption)
Optical parameters	H_2O, O_2, O_3, CO_2, condensates (cloud water, cloud ice, snow, rain, and graupel), aerosols (sulfate and precursors, dust, black carbon, organic carbon, sea salt)	H_2O, O_3, CO_2, trace gases (N_2O, CH_4 , CFC11, CFC12, CFC22), condensates (cloud water, cloud ice, snow, rain, and graupel), aerosols (sulfate and precursors, dust, black carbon, organic carbon, sea salt),
Accuracy	Heating rate error within 5% accuracy in comparison with a LBL model.	Cooling rate error within 0.4K/day in comparison with a LBL model.

Table 1 The major characteristics of Goddard Radiation module.

1.1 Enhancements

Goddard radiation version 2014 was released in June 2014 along the release of NU-WRF version v7-3.5.1 and includes the new features of the NU-WRF V7-3.5.1. Upgrades from the previous version v2011 include i) coupling with new Goddard 4ICE scheme with effective radius parameters, ii) completely replaced cloud single-scattering properties by those of G-SDSU, iii) add new skip options for faster radiation calculation, and iv) some bug fixes. History of enhancements is described at the top of source code (`module_ra_goddard_2014`).

2. Using the Software

Since Goddard Radiation 2014 package is included in the WRFV3 physics package, you can choose this scheme by simply changing WRFV3's `namelist.input` file.

```
&physics
 mp_physics                          = 56,     56,     56,
 gsfcgce_hail                        = 0,
 gsfcgce_2ice                        = 0,
 mp_zero_out                         = 2,
 mp_zero_out_thresh                  = 1.e-12,
 ra_lw_physics                       = 56,     56,     56,
 ra_sw_physics                       = 56,     56,     56,
 goddardrad_2014_skip                = 0
```

Goddard Radiation 2014 packages is identified as `56` for both shortwave (`ra_sw_physics`) and longwave (`ra_lw_physics`) options. Microphysics (`mp_physics`) must be Goddard 4ICE microphysics (`=56`) or Goddard 3ICE microphysics (`=55`), since Goddard radiation 2014 scheme requires mass mixing ratio as well as effective radius arrays of all hydrometeors passed from Goddard 4ICE/3ICE schemes. This new radiation scheme also features "skipping" option (`goddardrad_2014_skip`). If it is turn on (`goddardrad_2014_skip=1`), radiation flux, radiative heating rates, TOA/BOA flux are computed on NxN averaged column (N ranges from 1~3, where N=1 is no skipping, N=2 is 2x2=4 grid skipping, N=3 is 3x3=9 grid skipping). This option will be useful for operational weather forecasting or high-resolution computer intensive large-domain simulation.

Same as 2011 Version, when WRF-CHEM GOCART is used to simulate various atmospheric aerosols, Goddard Radiation 2014 automatically accounts for aerosol direct effect (scattering and absorption of radiation). Module that account for aerosol single-scattering properties is present in `module_gocart_coupling.F`.

References

Chou M.-D., and M. J. Suarez, 1999: A solar radiation parameterization for atmospheric studies. NASA Tech. Rep. NASA/TM-1999-10460, vol. 15, 38 pp

Chou M.-D., and M. J. Suarez, 2001: A thermal infrared radiation parameterization for atmospheric studies. NASA/TM-2001-104606, vol. 19, 55pp

Ma, P.-L., K. Zhang, J.-J. Shi, T. Matsui, A. Arking, (2012): Direct Radiative Effect of Mineral Dust on the Development of African Easterly Wave in Late Summer, 2003-2007, *Journal of Applied Meteorology and Climatology*, 51, 2090–2104.

Shi, J. J., T. Matsui, W.-K. Tao, C. Peters-Lidard, M. Chin1, Q. Tan, and E. Kemp (2014), Implementation of an Aerosol-Cloud Microphysics-Radiation Coupling into the NASA Unified WRF: Simulation Results for the 6-7 August 2006 AMMA Special Observing Period, *Quarterly Journal of the Royal Meteorological Society.* doi: 10.1002/qj.2286

Shi, J. J., W.-K. Tao, T. Matsui, A. Hou, S. Lang, C. Peters-Lidard, G. Jackson, R. Cifelli, S. Rutledge, and W. Petersen (2010), Microphysical Properties of the January 20-22 2007 Snow Events over Canada: Comparison with in-situ and Satellite Observations, *Journal of Applied Meteorology and Climatology*. 49(11), 2246–2266.