tiegcm2.0 Documentation

Release 2.0

NCAR High Altitude Observatory

March 21, 2016

HAO is pleased to announce the release of version 2.0 of the Thermosphere Ionosphere Electrodynamics General Circulation Model (TIEGCM).

Contents:

RELEASE NOTES FOR TIEGCM 2.0

Release date March, 2016

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Download page http://www.hao.ucar.edu/modeling/tgcm/download.php

This is a summary of modifications made to the tiegcm since the release of tiegcm1.95 (June 21, 2013)

1.1 New Features

2.5-degree resolution

Dynamical filters have been tuned for 2.5-degree horizontal resolution (with four grid-points per scale height in the vertical coordinate). Users are encouraged to run the model at the 2.5-degree resolution, as it can produce a more realistic ionosphere than the 5-degree model. However, 2.5-degree resolution is not recommended for earlier versions of the model. All benchmark runs and source history files are available at both 5-degree and 2.5-degree resolutions.

Helium

Helium is now calculated as a major species. If a source history without helium is used, helium will be initialized to a global value (1.154e-6 mmr), and will evolve from there. Helium is always saved on primary histories, and can be saved on secondary histories as 'HE'. The namelist input flag CALC_HELIUM can toggle this calculation on or off, but it is on by default. Thanks to Eric Sutton for leading this effort. See Sutton et al. (2015), JGR, 120, 6884, doi:10.1002/2015JA021223 for details of the implementation and results.

Argon

Argon is now calculated as a minor species. Argon is always saved on primary histories, and can be saved on secondary histories as 'AR'.

Parallel Dynamo

The electro-dynamo code was parallelized with pure MPI. Transformations between the geographic and geo-magnetic grids in the MPI environment are accomplished with the Earth System Modeling Framework (ESMF library). This results in a performance speed-up of about 25% at the 5-degree resolution, and almost 50% at the 2.5-degree resolution when using 64-processors on the NCAR yellowstone system.

IGRF12

The geomagnetic field was updated to the International Geomagnetic Reference Field version 12, and annual secular variation is included for the years 1900-2015. Extrapolation of secular variation through the year 2020 is performed.

Lower Boundary Condition

A zonal mean climatology of u, v, T, and z was implemented at the lower boundary by Astrid Maute, following work by Mac Jones using a combination of MSIS and HWM empirical models, and UARS data. See Jones et al. (2014), JGR, 119, 2197, doi:10.1002/2013JA019744. The climatology is based on monthly means, and is

applied by specifying an input file (similar to GSWM and other tidal specifications). If no input file is specified, a flat lower boundary (u=v=0, Tn=181 K, z=96.4 km) is employed as in the past. Other zonal mean climatologies can be used by generating and specifying a different file.

Non-Migrating Tides

GSWM non-migrating tides are turned on in the default namelist inputs for 2.5-degree resolution only. They can be used with either resolution but are only recommended at 2.5-degree. Migrating tides are on be default at both resolutions. All GSWM tides are switchable on/off simply by specifying or not specifying an input file.

Additional Diagnostic Fields

Many additional diagnostic fields are available as optional outputs on secondary files, including RHO, N2, HE, AR, ZGMID, EFLUX, NFLUX, ALFA, CUSP, and DRIZZLE, TEC, conductivities, ExB velocities, currents, cooling and heating rates. See the Namelist Input File section of the User Guide, scripts/master.inp, and src/diags.F.

Pressure/Altitude Coordinates

For altitude-registering of output fields, see Grid Structure and Resolution section of the User Guide for an explanation of the pressure grids, reference pressure, geometric v. geopotential height, and interfaces v. midpoints. See also Altitude Coordinates in the TIEGCM for a detailed explanation of the relationship between the Pressure and Altitude coordinates in the TIEGCM.

1.2 Functional Changes

Namelist Input

The comment character in namelist input files is now and exclamation point (!) (formerly it was a semi-colon). This was changed to conform to the Fortran standard. If you have many input files with the ';' comment character, use the change_nlcomment script in the scripts directory to replace the comment chars. However, we strongly urge that for v. 2.0, users start over with new namelist input files using the examples in scripts/.*inp as templates. Also use the new example job files in scripts/*.job. Reading the input file was simplified in the source code (see src/input_read.F), and in the job scripts, the input file is an argument to the program rather than redirected as unit 5.

Time Step

The recommended and default time steps are now 60 s at 5-degree resolution and 30 s at 2.5-degree resolution. We strongly urge users to use the recommended time steps. Changing the time step will change the model results. Sometimes it may be absolutely necessary to shorten the time step, e.g., during a major storm, but in that case it is advisable to do so for only as long as absolutely necessary to get through the peak of the storm.

Shapiro Filter

The Shapiro filter factor was reduced to 3.0e-3 for the default time step, and now changes if the time step is changed. This minimizes but does not eliminate varying results for different time steps. The filter factor = 3.0e-3 x (time step)/(default time step), i.e., it is reduced for shorter steps (see "shapiro" in src/cons.F).

FFT Filters

The polar FFT filters were re-tuned for the 2.5-degree resolution model (no change at 5-degree).

O+ Floor

A double-Gaussian shaped floor (in latitude and altitude) is applied to O+ at low-to-mid latitudes in the F-region in order to keep the model stable when the ionosphere gets very low in density. It can be turned off in the namelist inputs but this is not recommended. See Namelist parameter ENFORCE_OPFLOOR

O+ Diffusion Limiter

An optional O+ diffusion coefficient limit can be supplied as a namelist input. This can improve model stability in the topside F-region, but it is only recommended as a last resort since it will change model results. See Namelist parameter OPDIFFCAP

1.3 Bug Fixes

Reduced Temperature

The reduced temperature (Ti+Tn)/2 was erroneously coded in the O+ transport routine as (Ti+Te)/2 (which is actually the plasma temperature). This bug has been there for a long time, probably dating back to the TIGCM in the 1980's. This was corrected, which makes small but significant changes in the ionosphere, particularly in the vicinity of the F2 peak. NmF2 generally changes by <10%, but this is nevertheless a significant correction. The model is also somewhat less stable at 2.5-degrees due to this correction. Note that the plasma temperature is also used in O+ transport but this was correctly defined in the code.

Other Miscellaneous Corrections

- The domain decomposition was adjusted so that the model can run with 4 processors

- ZG, ZGmid and DEN extrapolation to the top level was corrected.

- GLAT and ALT input/output to apex.F90 was updated

- A problem using ESMF with a single processor was fixed.

1.4 Make/Build System

Platforms

The TIE-GCM can be run on the NCAR yellowstone supercomputer or on Linux desktop computers. Some users have run it on PC and Mac, and desktops and laptops, but the setup may require some re-configuration by the user. Compiling with MPI is now required on any platform, but the model may still be run using a single processor. We recommend 4 to 16 processors for the 5-degree resolution model and 8 to 64 processors for the 2.5-degree resolution model.

Compilers

The TIE-GCM can be run on three Fortran compilers for Linux desktop systems: Intel, PGI, and GNU gfortran. On the NCAR yellowstone system, only Intel is used. Intel is the default compiler, because it consistently out-performs the other compilers.

ESMF Library

The parallel dynamo now requires that the ESMF library be linked. The NetCDF library is also still required. See Grid Structure and Resolution for more information.

Note: A warning for user's of previous revisions of TIEGCM: Do not use old namelist input files or job scripts from previous revisions. Copy the default files from the scripts/ directory, and modify them for your own runs. Also, for initial runs, do not build/execute the model in an old execdir. Instead, allow the job script to make a new execdir for you.

1.5 Benchmarking Utility

Tgcmrun

Tgcmrun is a Python code (in the tgcmrun/ directory) that can be used to make selected benchmark runs of the model in a semi-automated fashion. Tgcmrun can be executed interactively on the command line, or a series of runs can be submitted from a simple shell script using command-line arguments. See example scripts 'run_*' or type 'tgcmrun -h' in the tgcmrun directory a usage statement. The tgcmrun directory takes the place of the former 'tests'

1.6 License

Academic Research License

The open-source academic research license was updated. This license requires that any derivatives of the model also be open-source, that the model can be used for academic research purposes only, and that the code cannot be sold. The updates clarify that the prohibition on sales includes derivative products as well as code, and that operational use is not permitted. Any existing licenses for v. 1.9* are replaced by this license for v. 2.0. See the file `tiegcmlicense.txt` here and in the src directory.

TIEGCM VERSION 2.0 BENCHMARK RUNS

Note: Benchmark results (pdf plot files) for version tiegcm2.0 are available here: Post-processing of TIEGCM benchmarks

Benchmark runs are provided in three groups: full-year climatology, seasonal, and solar storm events. Here is a table of runs at 2.5-degree model resolution (there is also a set at the 5-degree resolution):

```
Full-year climatologies (solar min,max):
  tiegcm_res2.5_climatology_smax     Full-year climatology at solar maximum conditions
  tiegcm_res2.5_climatology_smin     Full-year climatology at solar minimum conditions

Seasons (Equinox, Solstice, solar min,max):
  tiegcm_res2.5_decsol_smax          December Solstice, solar maximum (days 355-360)
  tiegcm_res2.5_decsol_smin          December Solstice, solar minimum (days 355-360)
  tiegcm_res2.5_junsol_smax          June Solstice, solar maximum    (days 172-177)
  tiegcm_res2.5_junsol_smin          June Solstice, solar minimum    (days 172-177)
  tiegcm_res2.5_mareqx_smax          March Equinox, solar maximum    (days 80-85)
  tiegcm_res2.5_mareqx_smin          March Equinox, solar minimum    (days 80-85)
  tiegcm_res2.5_sepeqx_smax          September Equinox, solar maximum (days 264-269)
  tiegcm_res2.5_sepeqx_smin          September Equinox, solar minimum (days 264-269)

Solar storm events (Heelis/GPI and Weimer/IMF,GPI):
  tiegcm_res2.5_dec2006_heelis_gpi   December 2006 storm, Heelis/GPI        (days 330-360)
  tiegcm_res2.5_dec2006_weimer_imf   December 2006 storm, Weimer/IMF,GPI    (days 330-360)
  tiegcm_res2.5_jul2000_heelis_gpi   July 2000 storm,     Heelis/GPI        (days 192-202)
  tiegcm_res2.5_jul2000_weimer_imf   July 2000 storm,     Weimer/IMF,GPI    (days 192-202)
  tiegcm_res2.5_nov2003_heelis_gpi   November 2003 storm, Heelis/GPI        (days 323-328)
  tiegcm_res2.5_nov2003_weimer_imf   November 2003 storm, Weimer/IMF,GPI    (days 323-328)
  tiegcm_res2.5_whi2008_heelis_gpi   Whole Helio Interval 2008 Heelis/GPI   (days 81-106)
  tiegcm_res2.5_whi2008_weimer_imf   Whole Helio Interval 2008 Weimer/IMF,GPI (days 81-106)
```

Note: Climatology and Seasonal runs were made with constant solar conditions as follows:

- Solar Minimum Conditions:

  POWER = 18.
  CTPOTEN = 30.
  F107 = 70.
  F107A = 70.

- Solar Maximum Conditions:

POWER = 40.
CTPOTEN = 60.
F107 = 200.
F107A = 200.

Note: Explanation of terms for Storm Case Benchmarks:

- *Heelis*: The Heelis Potential Model was used for high-latitude ion drift velocities

- *Weimer*: The Weimer Potential Model was used for high-latitude ion drift velocities

- *GPI*: Runs used GeoPhysical Indices data with Kp, and solar flux f10.7d, f10.7a

- *IMF*: Runs used IMF/OMNI data with Solar Wind density and velocity

2.1 Selected Results of TIEGCM2.0 Benchmark Runs

Note: Benchmark results (pdf plot files) for version tiegcm2.0 are available here: Post-processing of TIEGCM benchmarks

Results of the benchmark runs are available in 2d plots of time series, grid slices, and maps. These are multi-page PDF files, arranged as follows:

- Files with "singleut" in their names contain instantaneous maps and slices

- Files with "utvert" in their names contain ut vs pressure plots (daily or hourly histories)

- Files with "utlat" in their names contain ut vs latitude plots (daily or hourly histories)

2.1.1 Instantaneous and time series plots for all fields

All fields are:

'TN','UN','VN','WN','O2','O1','N2','NO','N4S','HE','NE','TE','TI','TEC','O2P','OP',
'POTEN','UI_ExB','VI_ExB','WI_ExB','DEN','QJOULE','HMF2','NMF2','Z'

At 5-degree model resolution:

- Climatology Benchmark Runs at 5.0-deg resolution

- Seasonal Benchmark Runs at 5.0-deg resolution

- Storm Case Benchmark Runs at 5.0-deg resolution

At 2.5-degree model resolution:

- Climatology Benchmark Runs at 2.5-deg resolution

- Seasonal Benchmark Runs at 2.5-deg resolution

- Storm Case Benchmark Runs at 2.5-deg resolution

2.1.2 Instantaneous and time series plots for selected fields

Selected fields are:

'TN','UN','VN','WN','HE','NE','TE','TI','HMF2','NMF2','POTEN','Z'

At 5-degree model resolution:

- Climatology Benchmark Runs at 5.0-deg resolution
- Seasonal Benchmark Runs at 5.0-deg resolution
- Storm Case Benchmark Runs at 5.0-deg resolution

At 2.5-degree model resolution:

- Climatology Benchmark Runs at 2.5-deg resolution
- Seasonal Benchmark Runs at 2.5-deg resolution
- Storm Case Benchmark Runs at 2.5-deg resolution

2.1.3 Namelist input files used for the 2.5-deg benchmark runs

These are the namelist input files used for making the 2.5-degree resolution benchmark runs. Note that a few of the 2.5-deg runs need to be run at a shorter timestep than the default of 30 seconds to maintain numerical stability. Also note that the 5-degree full-year climatology run can be completed on yellowstone in 12 hours WC, but the 2.5-deg model has to be restarted several times to reach a full year.

- Climatology Benchmark Runs (full-year):

    - Solar max climatology

    - Solar min climatology

- Seasonal Benchmark Runs (5-day runs):

    - December solstice solar max

    - December solstice solar min

    - June solstice solar max

    - June solstice solar min

    - March equinox solar max

    - March equinox solar min

    - September equinox solar max

    - September equinox solar min

- Storm Simulations:

    - December, 2006 storm (Heelis/gpi)

    - December, 2006 storm (Weimer/gpi,imf)

    - July, 2000 storm (Heelis/gpi)

    - July, 2000 storm (Weimer/gpi,imf)

    - November, 2003 storm (Heelis/gpi)

    - November, 2003 storm (Weimer/gpi,imf)

  – 2008 Whole Heliosphere Interval (Heelis/gpi)

  – 2008 Whole Heliosphere Interval (Weimer/gpi,imf

2.2 Model Output History Files of the tiegcm2.0 Benchmark runs

Model output history files are stored in CF-compliant netCDF format. Benchmark history files for tiegcm2.0 are available via the Globus Research Data Sharing Service. The history files are stored at the "NCAR Data Sharing Service" *Globus* shared endpoint. (for users with an NCAR/CISL login: this endpoint is /glade/u/datashare/tgcm)

See these CISL docs for information regarding the NCAR Data Sharing Service:

- NCAR Data Sharing Service
- Globus file transfers (see especially "Transferring files with the webh interface")
- Retreiving data from a shared endpoint

Here is a summary procedure for accessing the tiegcm2.0 benchmark data:

Note: You do *NOT* need to have an NCAR user account or token to retrieve this data.

- You must have or create a Globus account. If your institution/organization has a Globus data sharing endpoint, you can use your institutional authorization to login to Globus. Otherwise, you can create a Globus personal account to transfer files to your personal laptop or desktop computer.
- Log in to your Globus account, and click on "File Transfer"
- To reach the NCAR/TIEGCM source endpoint, click in the "Endpoint" text box on the left, and type "TIEGCM v2.0". It should retrieve directory contents, and show a "benchmarks" folder.
- Next, establish your destination endpoint on the right. This is either your institutional endpoint, or the username of your personal Globus login.
- Select the locations/files you want to download from the left side, and the destination location on the right, then click the right arrow at the top to begin the transfer.

Here's a screen shot of a Globus file transfer from the TIEGCM v2.0 endpoint to my personal Macbook Pro: Globus_screenshot.png

In each of the 6 benchmark groups are folders for each run, with folders containing the history files (hist), post-processing (proc), and scripts and log files (stdout). Individual files or whole directories can be downloaded.

GLOSSARY

Heelis The Heelis Potential Model is optionally used for high-latitude ion drift velocities Namelist input setting: POTENTIAL_MODEL = 'HEELIS'

Weimer The Weimer Potential Model is optionally used for high-latitude ion drift velocities Namelist input setting: POTENTIAL_MODEL = 'WEIMER'

GPI Geophysical indices data can optionally be used to drive the model, including 3-hourly Kp, and F10.7 Solar Flux (average and daily). Namelist input setting: GPI_NCFILE = '$TGCMDATA/tiegcm2.0/gpi_1960001-2015365.nc'

IMF Interplanetary Magnetic Field data from OMNI, used to drive the Weimer potential model. Example namelist input setting: IMF_NCFILE = '$TGCMDATA/imf_OMNI_2006001-2006365.nc'

Globus Globus Data Sharing Service for scientific research. The tiegcm2.0 benchmark history files and post-processing are available via Globus. See *Model Output History Files of the tiegcm2.0 Benchmark runs* for more information.

- User's Guide
- Model Description
- *search*