

## Known Issues in TIE-GCM v. 2.0

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### • Technical:

Model will crash in debug mode due to an underflow error in filter2. We have a simple patch for this but it isn't in the release or in the trunk.

Will get some differences from changing time step (especially in  $O^+$  and  $N_e$ ).

Still may need to reduce time step for some large storms (for 2.5-degree model). Should use recommended time step unless absolutely necessary to reduce it. In that case, the best procedure is to reduce time step for one day, and then go back to the recommended time step.

Setting cross-tail potential CT POTEN to near-zero value results in an artificial electric field at high latitude. The problem could be encountered, for instance, if doing a "zero-aurora" type experiment. The fix for this will be to increase the "critical" cross-over latitudes for the electric potential if CT POTEN is very low, e.g., below 5 kV.

Some fields may not be correct at the top of the altitude array, so use the top level with caution.

Zonal mean climatology at lower boundary does not work with the old Hough-mode tides (which are not currently being used by anybody, as far as we know).

Problems with AMIE input at  $5^\circ$  resolution (although it seems fine at  $2.5^\circ$  resolution).

The model will stop after 2025 because IGRF doesn't extrapolate further. We can change this to a warning and then keep the field constant post-2025.

Quartic solver for electron density can be inaccurate. This routine will be retired in favor of a simple iterative approach (already developed and tested).

TEC diagnostic is defined as only the integrated model column electron density — it does not include  $O^+$  above the model upper boundary, or  $H^+$  and  $He^+$  in the plasmasphere. This isn't a problem, but people need to understand what the diagnostic means since the name is potentially misleading.

We should force He,  $N_2$ , and maybe Mbar and/or  $\rho$ , onto secondary histories (and maybe primary histories) because otherwise conversions between mmr, vmr, and number density in the processing can go awry. In the meantime, be sure to include all major species in calculations.

We also should provide number density diagnostic output options, so people don't have to do their own conversions.

• **Scientific:**

Bugs found in elden.F ion chemistry cause production of  $N_2^+$  by  $O^+(^2D)$  and  $O^+(^2D)$  to be neglected. This causes underestimation of  $N_2^+$  densities and heating rates, which in turn cause a  $\sim 70$  K underestimation of F-region temperature and a  $\sim 10\%$  overestimation of NmF2. (I.e., fixing this bug will cause T to increase and NmF2 to decrease.) Note that this bug was fixed in TIME-GCM.

E-region electron density is still too low, particularly around the peak near 110 km.

Small deficit in ionization parameterization in one of the X-ray bands (1.8-3.2 nm)

$O_2^+ + e^-$  rate coefficient should be restored to  $1.95 \times 10^{-7} (300/T_e)^{0.7}$

*Still* not enough ionization (but dialing up X-rays increases NO too much...)

...perhaps the solution would be to restore solar H Ly- $\beta$  to its ancient values...

Day/night neutral temperature and density gradients in the upper thermosphere are too small.

Summer NmF2 and HmF2 are too low, particularly in the northern hemisphere.

Ionospheric winter anomaly, nighttime F-region, and related issues need to be evaluated and validated.

Minor error found in calculation of vertical velocities used for Joule heating.

CO<sub>2</sub> cooling rates are too low (compared to SABER), even though CO<sub>2</sub> at the lower boundary is unrealistically high.

Nitric Oxide is still not quite right. Low-to-mid-latitude values are pretty good, maybe even a little high, but the auroral production still seems a little small, especially during medium-to-large storms. Consequently, post-storm temperature recovery takes too long. Nevertheless, NO cooling isn't too different from SABER measurements, at least not compared to the CO<sub>2</sub> problem.

The default K<sub>zz</sub> at the lower boundary does not vary with day-of-year, resulting in insufficient semi-annual and annual variations. Optional daily varying K<sub>zz</sub> imposes semi-annual and annual variation, which improves composition and neutral density, but probably has too much amplitude. Also, it likely has a seasonal/latitudinal variation that is not well known. This is an important area for future development.

...not an exhaustive list!