Sensitivity Studies of Mesospheric Iron Layer Using a Whole Atmosphere Community Climate Model

NATURAL ENVIRONMENT RESEARCH COUNCIL

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1. Introduction

The mesosphere lower thermosphere (MLT) region (~80-120 km) connects the atmosphere below with the space above, and is a region of increasing scientific and practical interest. For example, recent studies show that the weather forecasts are significantly improved by extending numerical weather predication models from the stratosphere to the upper mesosphere. The ablation of the interplanetary dust particles entering the atmosphere provides a source of metal atoms in the MLT, and the resulting layers of metal atoms and ions offer a unique way to understanding the coupling of atmospheric chemistry and dynamical processes, as well as testing the accuracy of climate models in the MLT. Recently we have successfully incorporated the chemistry of Na, Fe, Mg and Ca into the NCAR Whole Atmosphere Community Climate model (WACCM). Here we will investigate the WACCM model performance in the MLT region and focus on the simulated iron layer due to the meteoric input function and polar mesospheric clouds (PMCs).

2. WACCM model

- Whole Atmosphere Community Climate Model uses NCAR CESM software framework.
- σ-p coordinates from surface to 140 km (~1.5km in LS and 3 km in MLT).
- Detailed dynamics/physics in the Troposphere/Stratosphere/Mesosphere/Thermosphere.
- Detailed chemical processes in the atmosphere.
- Includes long/short-lived species, and additional surface source gases, radical species.
- Ion chemistry and other key parameters (solar cycle, solar proton events).
- Detailed 3D emission inventories of natural and anthropogenic surface sources.
- Dry/wet deposition of soluble species.
- Lightning and Aircraft production of NOx.
- Includes heterogeneous processes, photolysis reactions and gas-phase reactions.
- Option of data assimilation from available meteorological analyses (i.e., GEOS data).
- Metal chemistry (Na, Fe, Ca, Mg) are now added in the WACCM model.

3. Iron Meteoric Input Function (MIF)

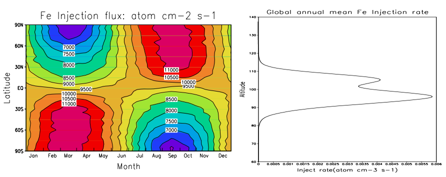

Fig 1. Fe meteoroid fluxes and annual mean injection rate from an astronomical ablation model

4. WACCM model experiments

Run	Fe chemistry	MIF	PMC	period
WACCM	No	No	No	2000-2012
WACCM-GEOS	No	No	No	2004-2010
WACCM-FE-FIXED	Yes	Constant	No	2000-2012
WACCM-FE-MIF	Yes	Varying	No	2000-2012
WACCM-PMC-FE-MIF	Yes	Varying	yes	2000-2012
WACCM-PMC-FE-MIF-NOEVAP	Yes	Varying	yes, no evaporation	2000-2012
WACCM-PMC-FE-MIF-GEOS	Yes	Varying	yes	2004-2010

5. WACCM performance in the MLT region

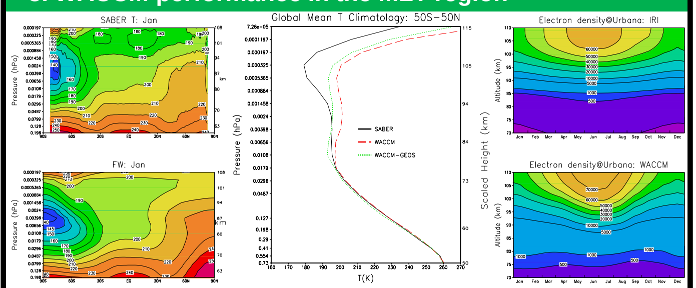

Fig 2. Comparison of climatological temperature and electron density with SABER measurements and International Reference Ionosphere (IRI) data.

6. Fe density comparison with Lidar measurement

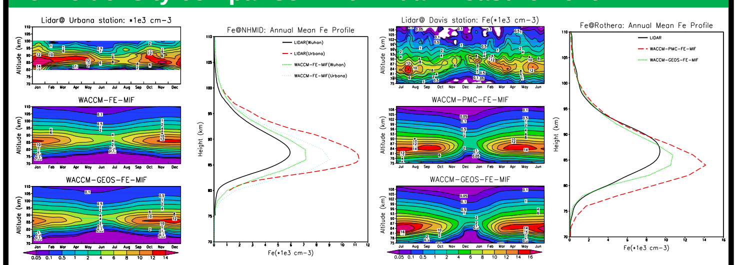

Fig 3. Monthly Mean and Annual mean Fe density between Lidar measurement and WACCM simulations for selected stations

7. Fe at polar region

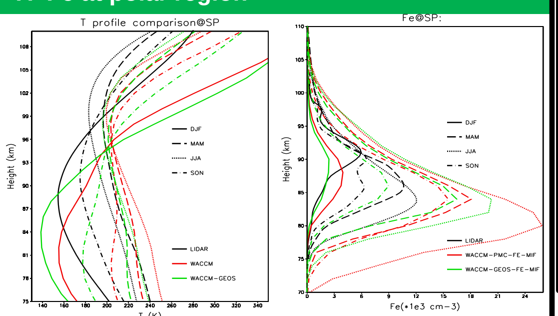

Fig 4. Seasonal averaged T and Fe at Southern pole

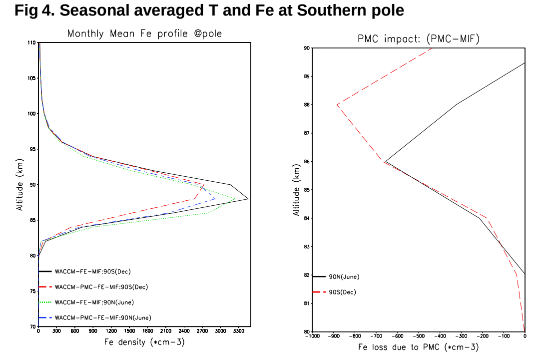

Fig 5. Fe profiles and Fe removal due to PMCs for polar regions.

8. MIF impact on the modelled Fe

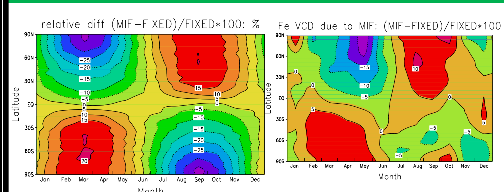

Fig 6. Relative difference between seasonal and fixed MIF used in the model (left) and modelled Fe abundances relative difference due to MIF

9. Fe Abundances ($10^9 cm^{-2}$)

	Lidar	Model	(%)
Urbana (40N)	11.0	9.98	-9.27
Wuhan (30N)	7.5	8.79	17.2
Rothera (68S)	12.3	13.26	7.80
Davis (69S)	11.3	13.0	15.04
South Pole(90S)	9.7	14.48	49.27

Summary and Conclusions

- Successfully added mesospheric Iron chemistry into the NCAR WACCM 3-D chemistry-climate model.
- Seasonal variation of metal injection fluxes (meteoric input function) (**Fig. 1**).
- WACCM captures the general feature of observed T and electron density for the MLT region (**Fig. 2**). However, WACCM is too warm in the upper mesosphere (**Fig. 2**) and has a slightly lower /colder polar summer mesopause with warm winter (**Fig. 4**)
- Overall, WACCM does a reasonably good job in simulating the mesospheric Fe layers (**Fig. 3**) and total Fe abundances. However, the modelled Fe density at summer period is less than observations . The model also largely overestimates the observed winter Fe density (**Figs. 3 and 4**), which is caused by the simulated T in WACCM (free running or nudged WACCM) (**Figs. 2, 4**).
- More and higher level of Fe removal due to PMC in Southern pole (**Fig. 5**).
- Seasonal MIF has a larger contribution to the modelled total column abundances of Fe in Northern high latitude than southern high-latitudes (**Fig. 6**).