CMAS SOUTH AMERICA

COMMUNITY MODELING AND ANALYSIS SYSTEM

TOWARDS A COUPLED AEROSOL-CHEMISTRY-ATMOSPHERE INTERACTIONS IN BRAZILIAN GLOBAL MODEL: DESIGN & PROGRESS

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Abstract: Atmospheric aerosols and trace gases have been increasingly recognized as a key component of the highly dynamic and complex global system. The two-way feedback between meteorology and chemistry are important and is a strongly coupled process. The new version of the CPTEC global model, Brazilian Atmospheric Model (BAM), has new dynamics and state-of-the-art physical processes. However, it does not yet have a model of aerosols and chemistry. In this work, we propose a design for the implementation of aerosol-chemistry-atmosphere interactions in BAM with the objective of improving the forecast of weather and seasonal climate in Brazil. The design comprises of three phases: initialization phase, computational phase, and the validation phase. The initialization phase is being completed and the computational phase is in progress.

***Keywords*:** aerosol-chemistry-atmosphere interactions, Brazilian Global Model.

INTRODUCTION

The representation of the trace gases and aerosols has become imperative in current numerical models for weather, air quality and climate prediction. The two-way feedback between the atmosphere and its chemistry is a strongly coupled process that has remained a challenge to the modeling community. The existing state-of-the-science global aerosol-chemistry climate models were developed using lab/field data mostly from the Northern Hemisphere, they may not necessarily represent the chemistry and aerosol formation for Brazil where the meteorological/climate conditions and emission sources are quite different. For example, studies indicate large disagreements among models over Northern Hemisphere and Southern Hemisphere for black carbon burden and deposition fluxes (Lee et al., 2013). Most of the models indicate deficiencies with O_3 precursor emissions resulting in low bias in the Southern Hemisphere (Young et al., 2013). Apart from this, the Southern Hemisphere has different but fewer, and more localized sources of anthropogenic emissions.

Brazilian Global Atmospheric Model (BAM, Figueroa et al., 2016, & references therein) is the new operational model of the Center for Weather Forecasting (CPTEC/INPE) and a first step towards developing the next generation non-hydrostatic/ hydrostatic global dynamic core, which can be used for a wide range of horizontal resolution O(1-200 km). Double-moment microphysics scheme with predicted droplet concentration is used. The vertical diffusion is a modified version of the local PBL Mellor-Yamada Level 2.0 closure scheme. Shallow convection scheme is from Park and Bretherton and modified Grell Devenyi developed at CPTEC/INPE is for deep convection. The radiation scheme for short wave and long wave is the Rapid Radiative Transfer Model for GCMs. There is no representation of aerosols or chemistry in BAM.

The aforementioned factors in addition to the presence of rich Amazonian biosphere and its influence over the continent justify the need for the implementation of the aerosol-chemistry-atmosphere interactions in BAM. The strategy is to first port the aerosol-chemistry modules from one of the existing state-of-the-science global aerosol-chemistry numerical models in BAM followed by improvement of its performance over Brazil against the factors stated above. In this work, we propose the design for this implementation, its progress and challenges therein. In addition, we contemplate to have remarks & suggestions on our design and a possible collaboration at the CMAS conference.

METHODS

A prime task in the implementation includes the evaluation of the global aerosol-chemistry models for their performance over Brazil (see Alvim et al., 2017 for one such assessment). The design for the implementation is enumerated below:

1. Develop a pre-run configuration in BAM to facilitate compiling external modules and performing short test runs
2. Identify dependencies in the module and map them to BAM environment
3. Identify the necessary meteorological inputs

4. Build a driver/ interface in BAM to includes routines from the modules
5. Define trace gases & aerosols in BAM
6. Read the emissions in BAM parallel environment
7. Develop routines for outputs and restarts, if any
8. Introduce computational calls in BAM through the interface
9. Perform short simulations to evaluate the new parameterization and compare
10. Improve discrepancies in the new parameterization, if any

FINDINGS AND ARGUMENT

The implementation is categorized into 3 phases: initialization phase, computational phase and validation phase. The Initialization phase is completed. It includes:

a. Understanding the workflow of aerosol-chemistry modules in their respective climate models.
b. Developing a pre-run setup to facilitate the inclusion of subroutines in BAM and perform short runs
c. Introducing trace gases and aerosol species in BAM
d. Identifying the input meteorological variables required for the computational phase
e. Reading the emissions in BAM parallel environment

The computational phase is ongoing and includes passing or referencing the meteorological fields through the interface into the chemistry modules, introduce modules routines pertaining to chemistry calculations and preparing outputs and restarts. The validation phase will include designing short and long simulations to check the performance of BAM with the new parameterization and improve further.

CONCLUSIONS

Implementing the aerosol and chemistry parameterization in BAM is different compared to coupling of the other Earth system components like ocean, land, sea ice requiring only a coupler that facilitates exchange of variables across it at a preset time. The modules here must not only integrate with the atmospheric model, their output and restart variables must be accommodated in the host climate model. The module poses strict requirements on:

- the attributes (shape, dimensionality, global/local scope) of the variables,
- arguments in a subroutine call,
- place where a function or subroutine is called in the model,
- updating, referencing and dereferencing variables
- accommodating restart and output variables etc.

The biggest challenge is the presence of atmospheric variables those are required for aerosol-chemistry interactions. In some instances, the host model undergoes critical changes that may reflect adversely on other processes; lay dormant until long simulations etc. The implementation work is ongoing and the group is looking for helpful suggestions and collaboration with a model-developing group.

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