Improving Aerosol Simulations over South Asia for Climate and Air Quality Studies

Xiaohua Pan *[1,2], Mian Chin [2], Peter Colarco [2], Huisheng Bian [3,2], Ritesh Gautam [4]
*xiaohua.pan@nasa.gov ; [1] ORAU; [2] NASA Goddard Space Flight Center;
[3] Univ. of Maryland, Baltimore County; [4] Indian Institute of Technology (IIT) Bombay

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1. BACKGROUND AND MOTIVATIN

Atmospheric pollution over South Asia attracts special attention due to its effects on regional climate, the water cycle, and human health. These effects are potentially growing owing to rising trends of anthropogenic aerosol emissions found there. However, it has been proved quite challenging to adequately represent the aerosol spatial distribution and magnitude over this critical region in global models (Pan et al. 2014), with the surface concentrations, aerosol optical depth (AOD), and absorbing AOD (AAOD) significantly underestimated, especially in October-January when the agricultural waste burning and anthropogenic aerosol dominate over dust aerosol (Figure 1 and 2).
In this study, we aim to investigate the causes for such discrepancy in winter by conducting sets of model experiments with NASA's GEOS-5 in terms of (1) spatial resolution, (2) emission amount, and (3) meteorological fields.

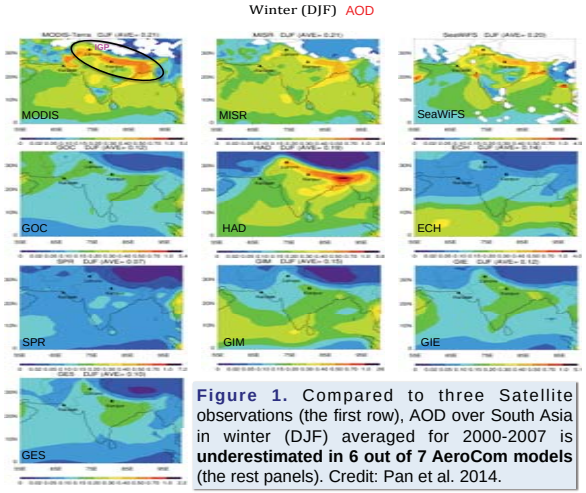

Figure 1. Compared to three Satellite observations (the first row), AOD over South Asia in winter (DJF) averaged for 2000-2007 is **underestimated in 6 out of 7 AeroCom models** (the rest panels). Credit: Pan et al. 2014.

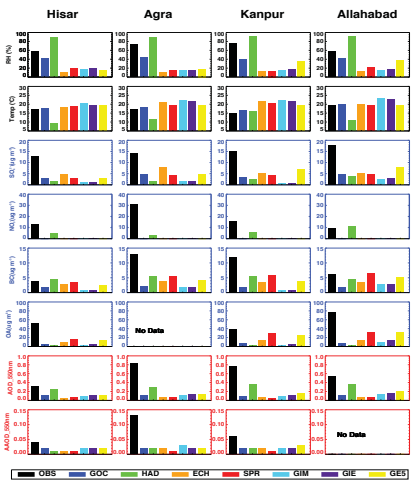

Figure 2. Aerosol surface mass concentration and optical depth are **underestimated** compared to ISRO-GBP campaign measurement at 4 IGP stations in Dec. 2004. Credit: Pan et al. 2014.

Table 1. AeroCom models used in Figure 1 and 2

Model	Abbr.	Emission [a]	Met. field	Grids	More* Species	Modelers
GISS-modelE.A2.HCA-IPCC	GIE	A2-ACCMIP	NCEP winds	2.5x2	NO_3	Kostas Tsigaridis Susanne Bauer
GISS-MATRIX.A2.HCA-IPCC	GIM	A2-ACCMIP	NCEP winds	2.5x2	NO3	Kostas Tsigaridis Susanne Bauer
SPRINTARS-v384.A2.HCA-IPCC	SPR	A2-ACCMIP	NCEP (T, V)	1.1x1.1	---	Toshihiko Takemura
GOCART-v4.A2.HCA-0	GOC	A2-MAP	GEOS-4 DAS	2.5x2	---	Thomas Diehl Mian Chin
HadGEM2-ES.A2.HCA-0	HAD	A2-MAP	ERA-interim	1.8x1.2	NO_3	Nicolas Bellouin
GEOS5.A2.HCA-0	GE5	A2-MAP	MERRA (T, V, Q)	2.5x2	---	Peter Colarco Xiaohua Pan
ECHAM5-HAMMOZ.A2.HCA-0	ECH	A2-MAP	ECMWF analysis	1.8x1.8	---	Kai zhang Philip Stier Johann Feichter

NOTE: Commons of these models
1. CTMs driven by meteorology.
2. With Phase 2 anthropogenic emissions
3. * With dust, sea salt, sulfate, black and organic carbon. Dust and sea salt emissions are calculated by each model.

2. EXPERIMENT DESIGNS WITH GEOS5

Table 2. Sensitivity experiments configurations

Name	Horizontal resolution	Anthropogenic emission	Meteorological field
CTL [a]	1x1	HTAP v2.2 [b]	Replay MERRA T, V, Q [c]
EXP_two	2x2	Same as CTL	Same as CTL
EXP_half	0.5x0.5	Same as CTL	Same as CTL
EXP_2xC	1x1	Double Anthrop. BC & OC	Same as CTL
EXP_free	1x1	Same as CTL	No replay
EXP_free_2xC	1x1	Double Anthrop. BC & OC	No replay

a. GEOS5 model has dust, sea salt, sulfate, black and organic carbon aerosols.
b. HTAP (The Task Force on Hemispheric Transport of Air Pollution) is an international scientific cooperative effort to improve the understanding of the intercontinental transport of air pollution across the Northern Hemisphere.
c. GEOS5 replays MERRA (NASA MODERN ERA-RETROSPECTIVE ANALYSIS FOR RESEARCH AND APPLICATIONS) T (temperature), V (wind), and Q (specific humidity).

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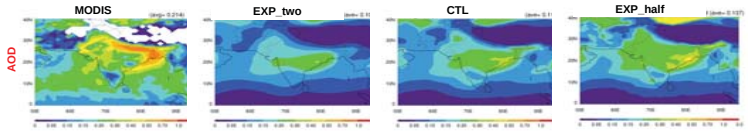
- We acknowledge MODIS, MISR, SeaWiFS, AIRS and AERONET, ISRO-GBP teams for the data.

3. RESULTS

A) Test Whether the Model Spatial Resolution is Inadequate



NOTE: this study focuses on the winter of Dec2008-Jan2009

Figure 3. Compared to the satellite AOD from MODIS, the overall magnitude of AOD **increases** with the increase of spatial resolution from 2 degree (EXP_two) to half degree (EXP_half). However, the feature of high AOD over IGP region is still not captured in higher resolution.

B) Test Whether the Anthropogenic Emission is Inadequate

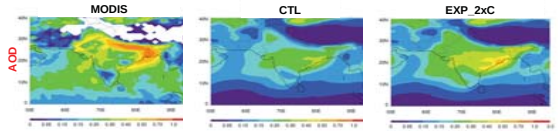


Figure 4. The overall amplitude of AOD **increases** with the doubling anthropogenic OC and BC emissions in EXP_2xC. However, the feature of high AOD over IGP region is still not captured.

C) Test Whether the Meteorological Fields are Poorly Represented

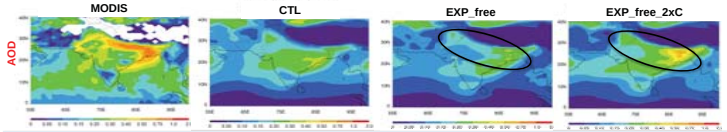


Figure 5. The feature of high AOD over IGP region was captured better in EXP_free and thus in EXP_free_2xC.

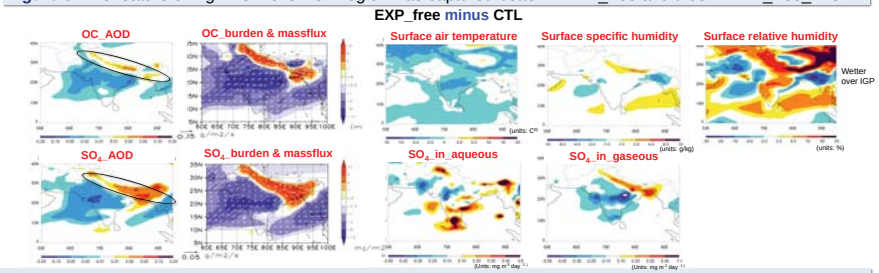


Figure 6. Difference between EXP_free from CTL. The OC and sulfate AOD are higher over IGP in EXP_free. The relative humidity (RH) and wind are better simulated in EXP_free

4. CONCLUSIONS

- **Realistic meteorological fields, especially wind and relative humidity, are essential to adequate represent the high AOD over IGP (Indo-Gangetic Plain).**
- Higher spatial resolution and anthropogenic emission also contribute to the improvement of amplitude of AOD
- Other factors, such as lack of nitrate and low cloud in GEOS5, are critical as well, which are under investigation

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