Model analysis of interannual variability of Asian Tropopause Aerosol Layer (ATAL): Transport pathways, sources, and composition

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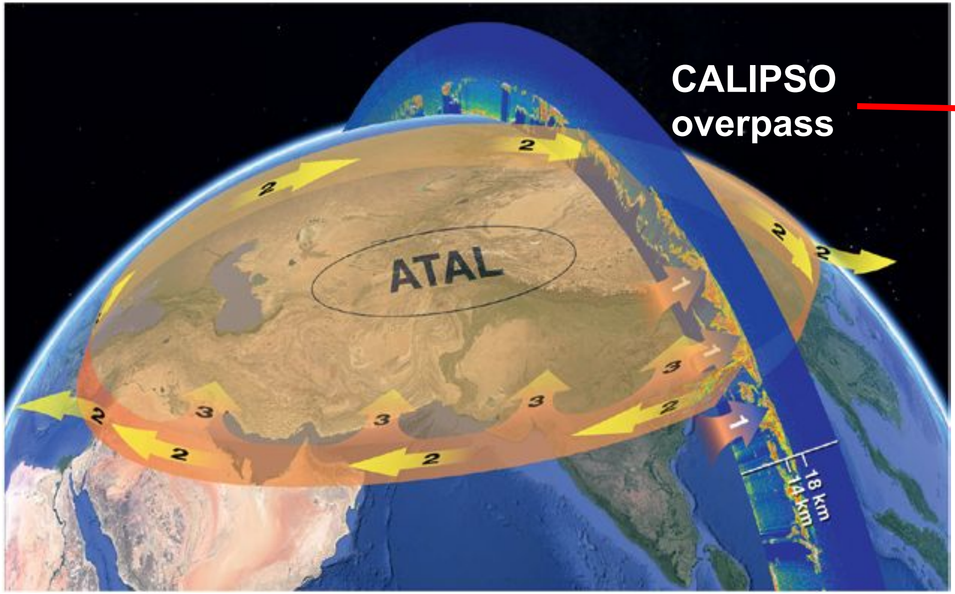
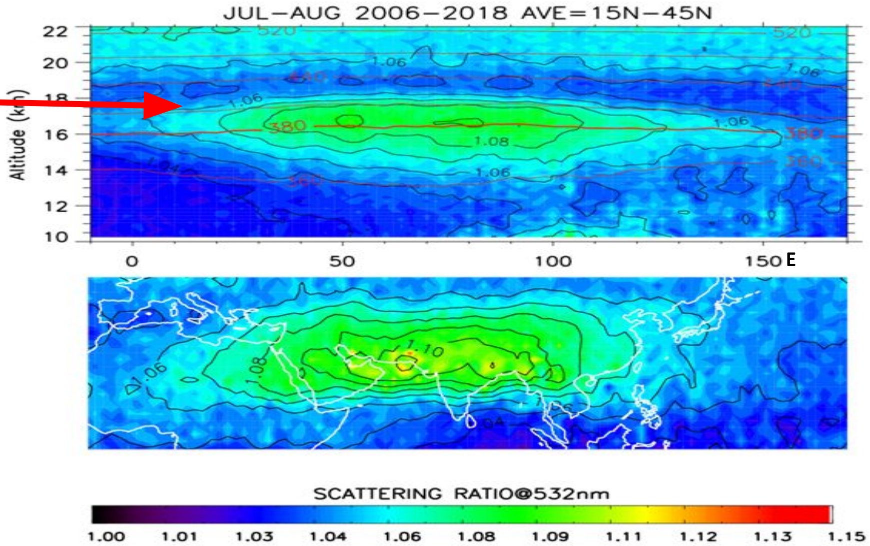
IGC9, May 2019

Background: Asian Tropopause Aerosol Layer (ATAL) research at NIA/LaRC





Figures adapted from *Vernier et al. (2015, 2018)*

- Deep convection from the Asian Summer Monsoon transports air masses from PBL to UTLS *(Randel et al., 2010; Lau et al., 2018*)

- ATAL - a maximum of nonvolcanic aerosol near the tropopause confirmed by CALIPSO (*Vernier et al., 2011*) and SAGE II (*Thomason and Vernier, 2013*).

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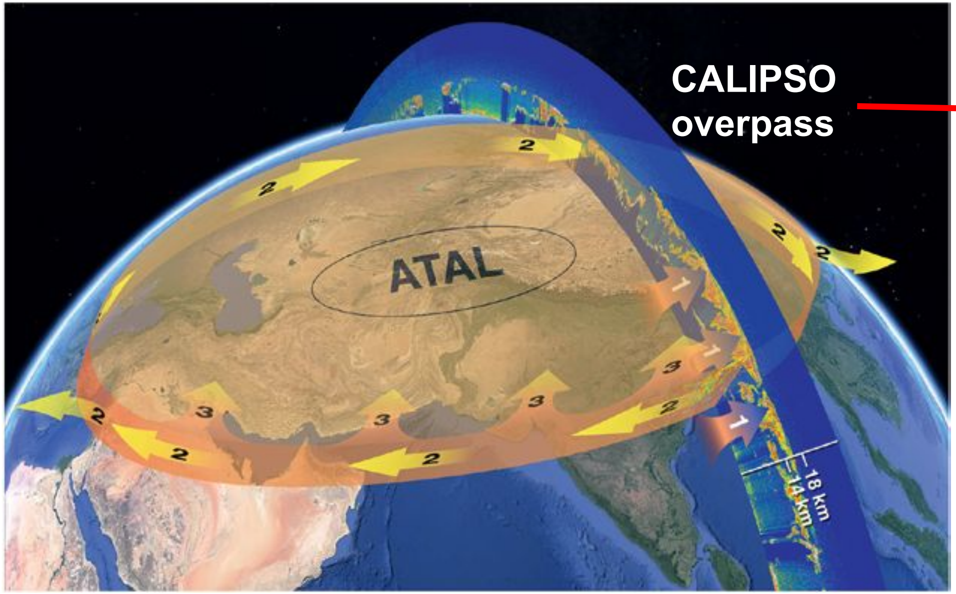

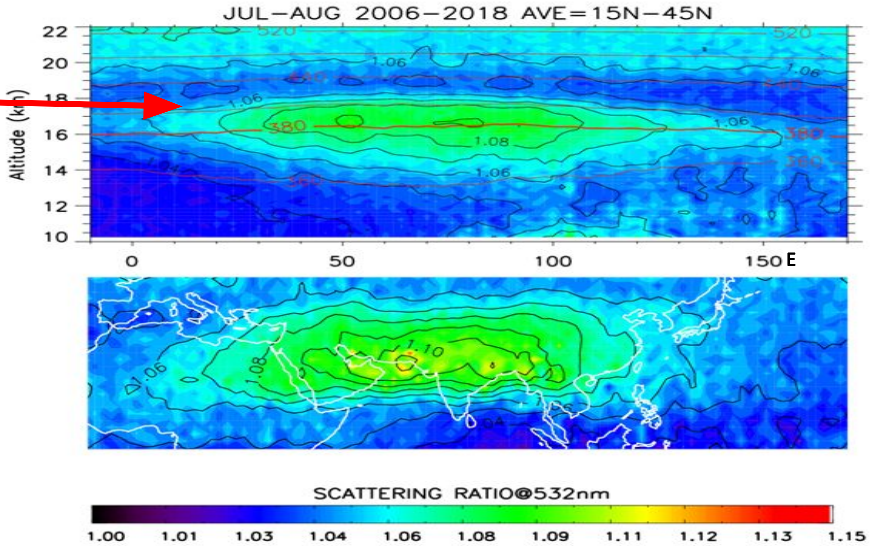

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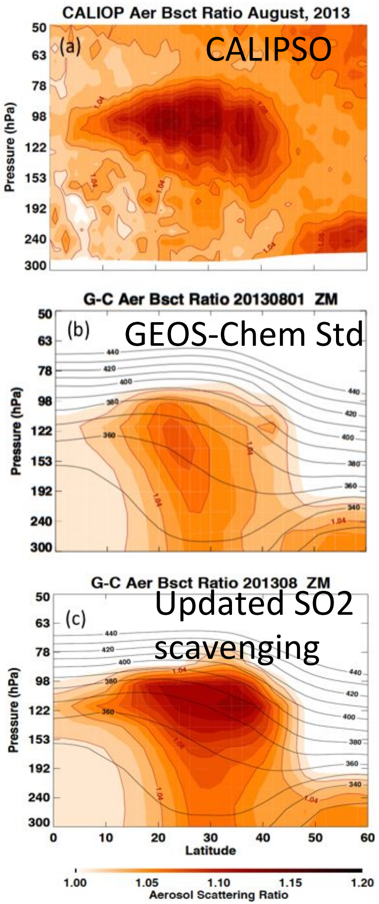
Recent efforts at NIA/LaRC

- Nitrate/nitrite aerosols during 2017 balloon campaign at Hyderabad [17.37 N, 78.48E] (*Vernier et al., 2019, in prep*.), which agrees with previous GEOS-Chem simulations (*Gu et al., 2016 ACP*).

- Balloon Measurements of Tropopause Cirrus Cloud (*Pandit et al., 2019, in prep.*).

Sources and composition of ATAL



Scavenging of SO_2

- Treatment of SO_2 scavenging in convective updrafts improved using Henry's law.
- Shape and magnitude of ATAL agree well with CALIPSO.

Fairlie et al., 2019, to be submitted

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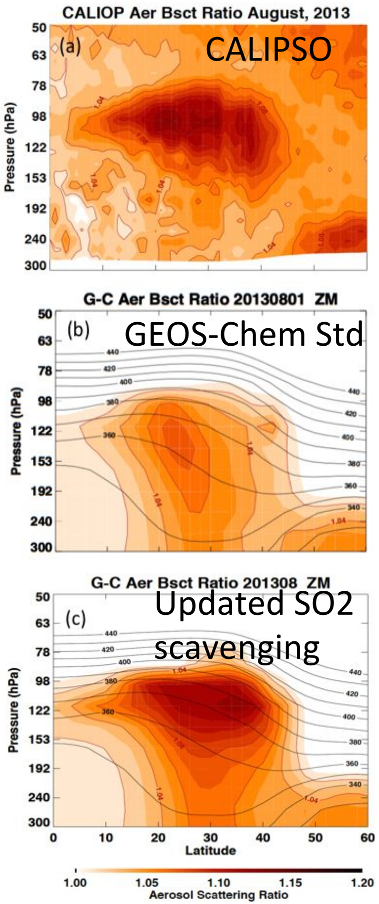

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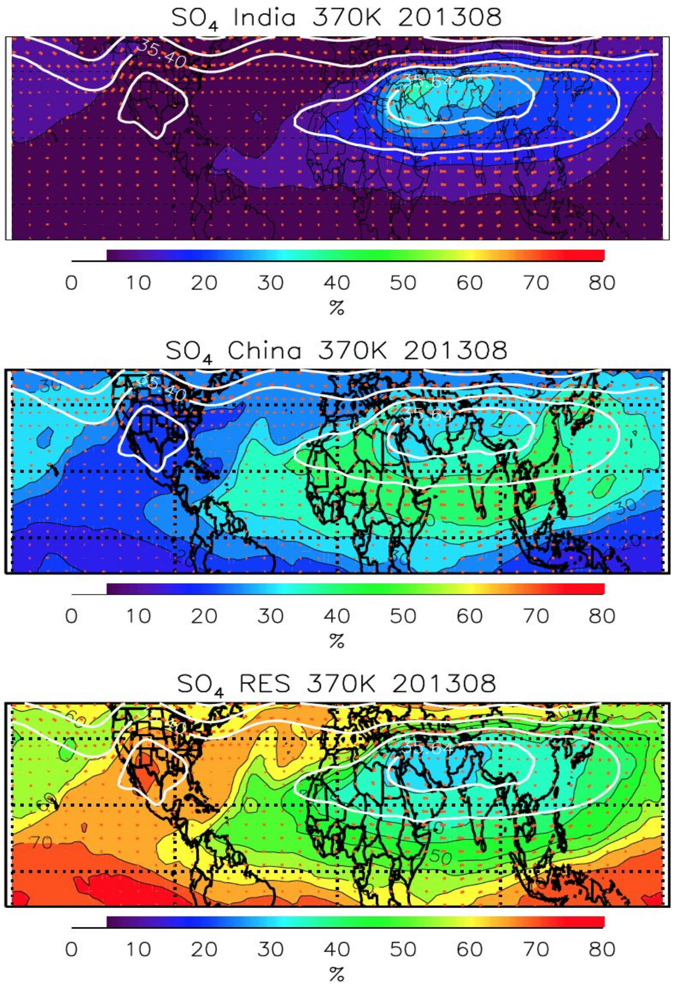
Source attribution study

- Our GEOS-Chem analysis shows that Indian+China emissions contribute ~60 % of sulfate.
- Neely et al. (2014) previously reported that anthrop. emissions in India+China contribute only ~30% of sulfate aerosol in ATAL.



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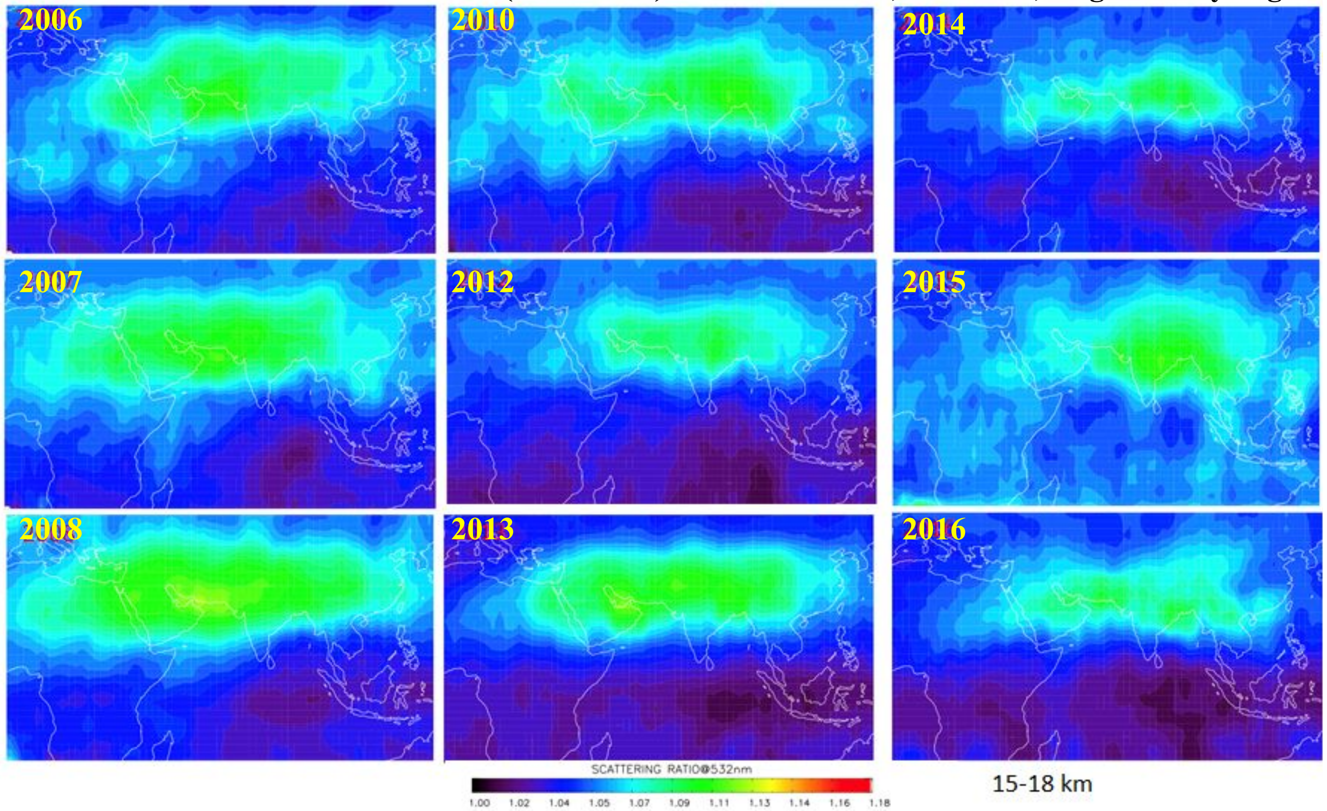
What are the contributing factors to the interannual variability of ATAL?

Aerosol backscatter ratio SRaer/SR(aer+molec) from CALIPSO, 15-18 km, Aug monthly avg



Modified from Vernier et al. (JGR 2015)

Motivation:

- Reduction in aerosol backscatter area (from 2006-2008 to 2014-2016).
- Significant change in adjacent years, e.g., 2012 vs 2013, 2014 vs 2015.
- ATAL composition variability.

Methods:

- MERRA2-GMI (existing long-term simulation, 2006-2016) c180, GMI chemistry, GOCART aerosol (Luke Oman, Susan Strahan, NASA GSFC).
- GEOS-Chem v11 (2014-2015), with perturbation experiments.

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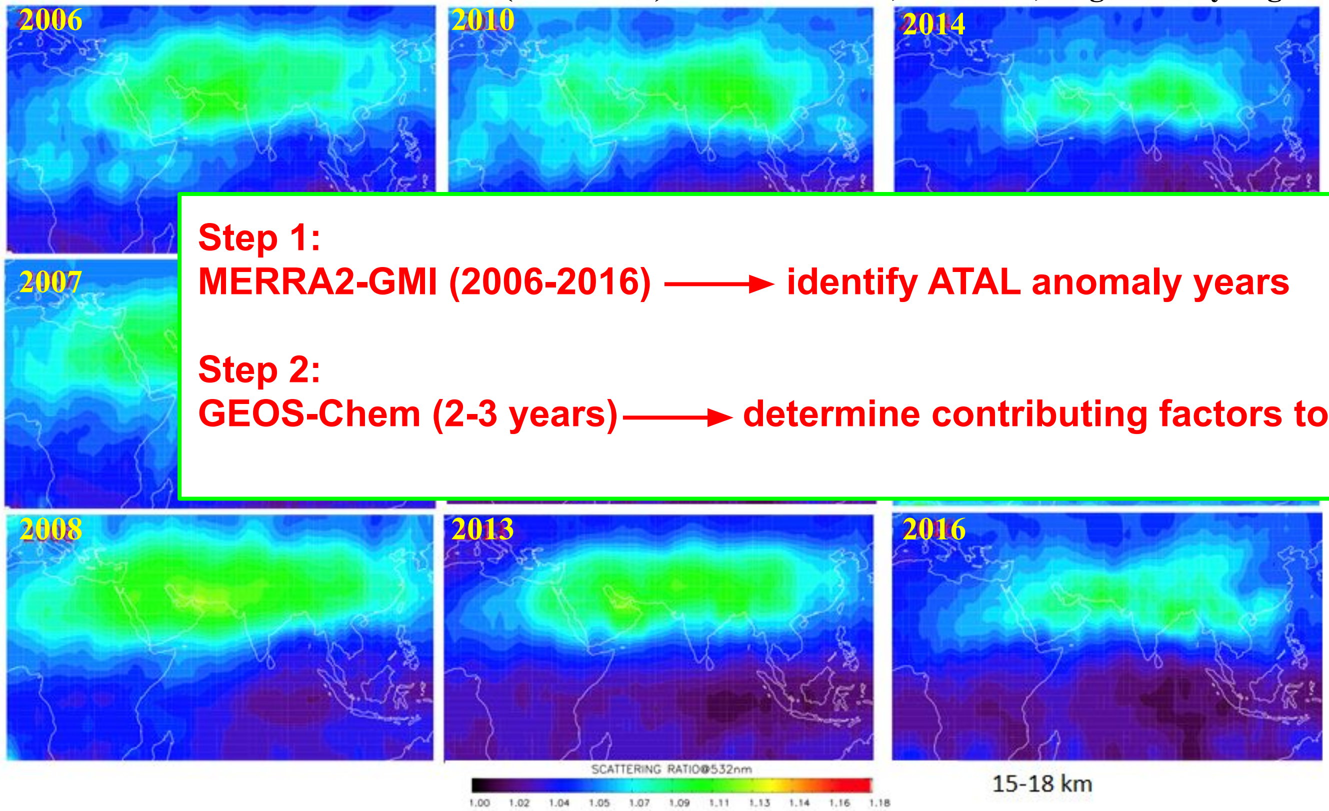

Step 1:
MERRA2-GMI (2006-2016) ⟶ identify ATAL anomaly years

Step 2:
GEOS-Chem (2-3 years) ⟶ determine contributing factors to IAV

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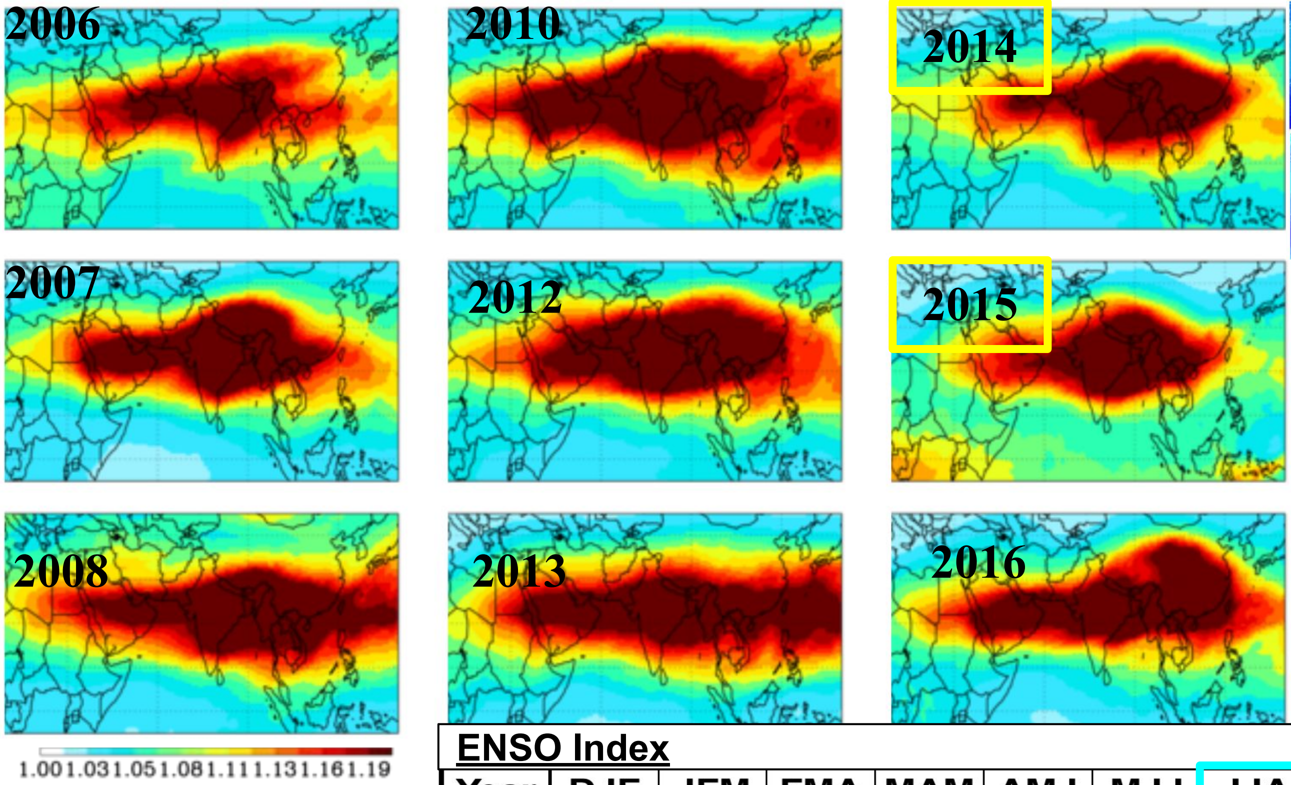
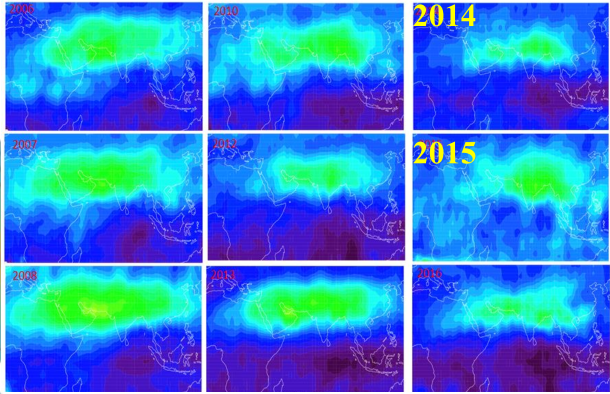
ATAL IAV: Aerosol backscatter ratio from MERRA2-GMI

Total aerosol backscatter ratio from 75-120 hPa



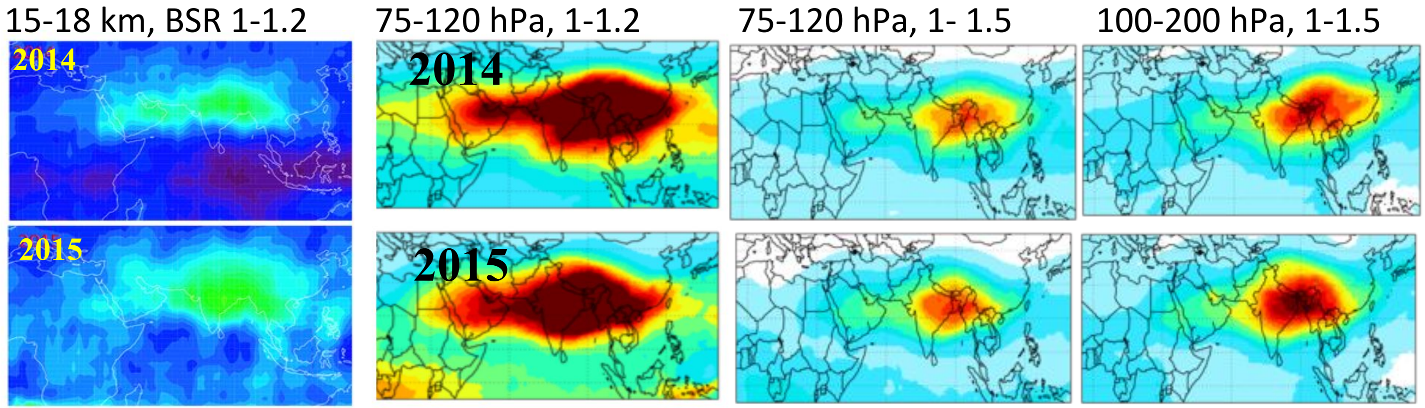


- Reduction in aerosol backscatter area (from 2006-2008 to 2014-2016) as shown by CALIPSO is not seen in the model.
- Simulated total aerosol BSR is higher in 2014 compared to 2015.

ENSO Index

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2014	-0.36	-0.35	-0.16	0.14	0.33	0.26	0.13	0.09	0.22	0.45	0.57	0.65
2015	0.65	0.63	0.68	0.78	0.95	1.15	1.38	1.63	1.90	2.18	2.38	2.62

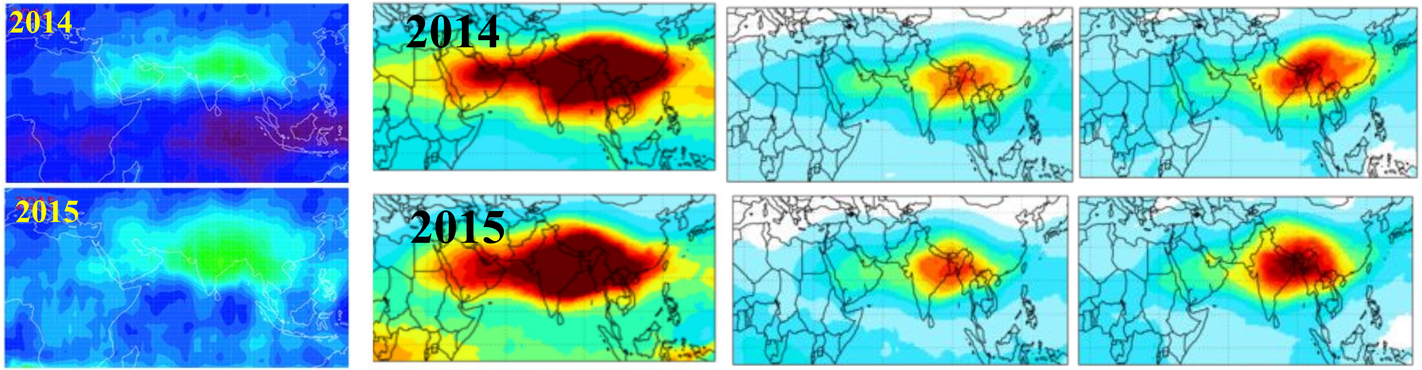
ATAL IAV: Aerosol backscatter ratio from MERRA2-GMI and GEOS-Chem, 2014 vs 2015



When sampled at lower altitudes, model starts to agree better with CALIPSO.

ATAL IAV: Aerosol backscatter ratio from MERRA2-GMI and GEOS-Chem, 2014 vs 2015

15-18 km, BSR 1-1.2 | 75-120 hPa, 1-1.2 | 75-120 hPa, 1- 1.5 | 100-200 hPa, 1-1.5



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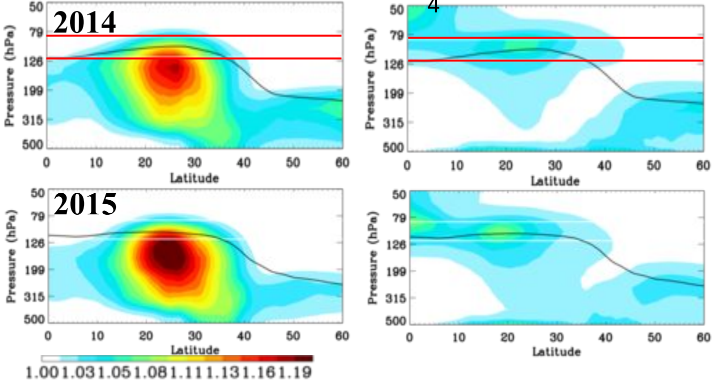
NIT BSR 30-105 E | SO_4 BSR 30-105 E



SO_4 layer located at a higher altitude than NIT.

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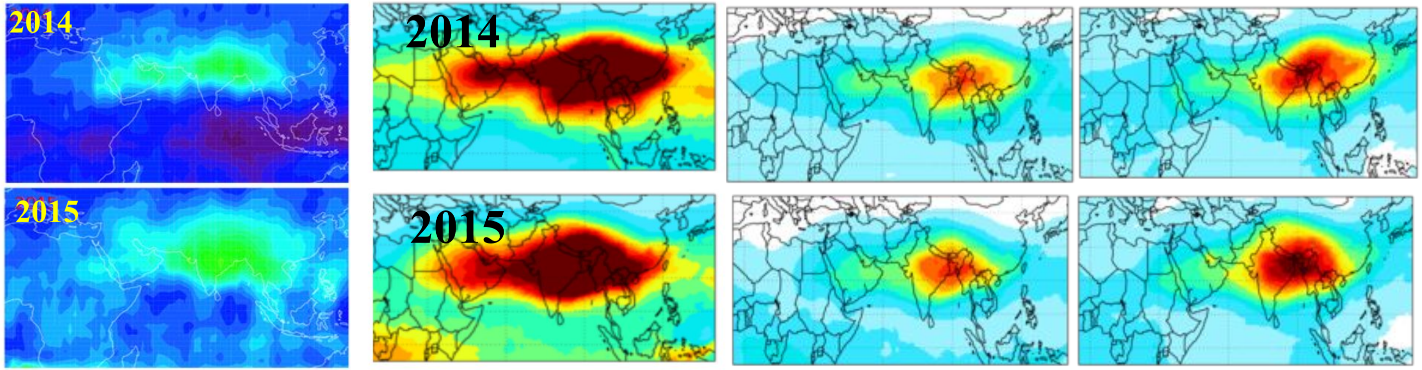

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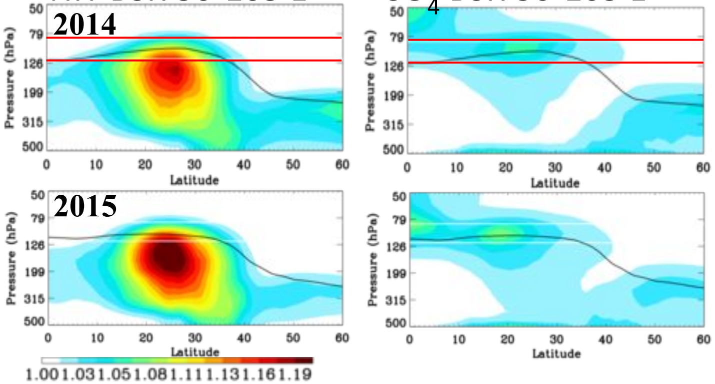
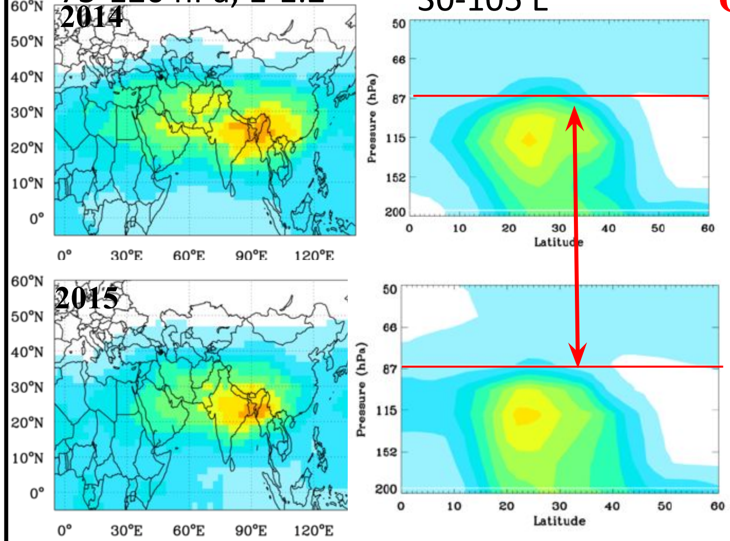


SO_4 layer located at a higher altitude than NIT.

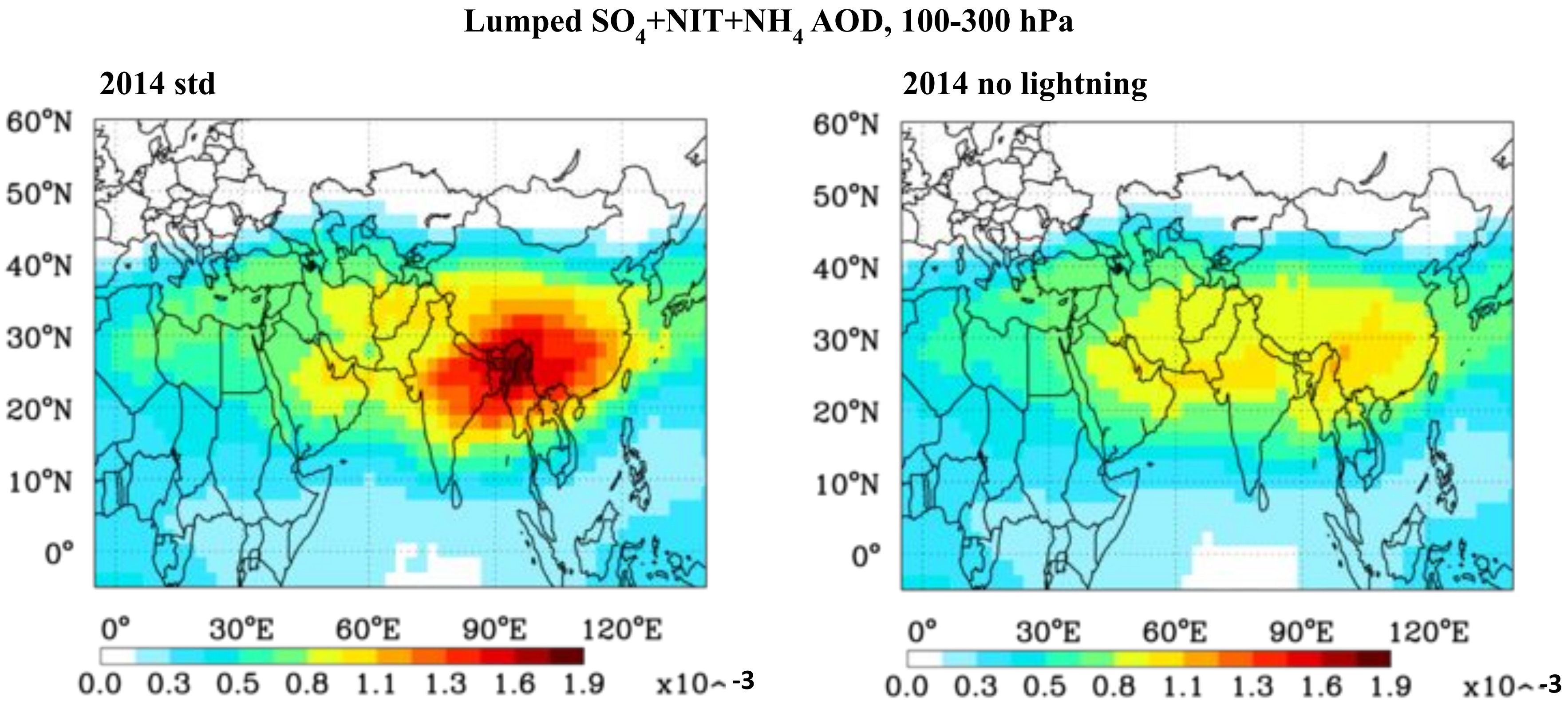
75-120 hPa, 1-1.2 | 30-105 E

GEOS-Chem Aerosol BSR



- ATAL is stronger but at a lower altitude in 2015 (vs. 2014).
- The altitude of ATAL in the model might be biased low.

Impact of lightning NOx emissions on NIT in ATAL



- Lightning could increase total AOD in ATAL core (AOD > 0.8e-3) by up to 57%, and ~10% on average.

Summary

- Reduction in ATAL aerosol backscatter area (from 2006-2008 to 2014-2016) as shown by CALIPSO is not seen in MERRA2-GMI.

- NIT, SO_4, and OC are the major composition of ATAL in both MERRA2-GMI and GEOS-Chem. The altitude of ATAL in the model might be biased low.

- Lightning NOx emissions significantly contribute to ATAL AOD (~10% on average in 2014 as simulated by GEOS-Chem).

Future work

- Perturbation simulations to determine the relative contributions of China/India emissions.

- Use tracers (e.g., CO, Rn-222) in the model to examine the effect of El Nino on transport in 2015.

- Conduct GEOS-5 simulations in both 2x2.5 and 0.5x0.667 resolutions to study the impact of model resolution on vertical transport in the ATAL region.

Acknowledgement: this study is supported by NASA ACMAP program.