Composition of Asian Tropopause Aerosol Layer and North American Tropospheric Aerosol Layer

Pengfei Yu, Owen Brian Toon, Ryan R. Neely, Bengt G. Martinsson and Carl A. M. Brenninkmeijer

ATOC, LASP, University of Colorado at Boulder

Feb. 2015, NCAR
Motivation I: previous studies show pathway from Trop to Stratosphere, i.e. Asian summer monsoon

Transport pathways of carbon monoxide in the Asian summer monsoon diagnosed from Model of Ozone and Related Tracers (MOZART)

Mijeong Park, William J. Randel, Louisa K. Emmons, and Nathaniel J. Livesey

Asian Monsoon Transport of Pollution to the Stratosphere

William J. Randel, Mijeong Park, Louisa Emmons, Doug Kinnison, Peter Bernath, Kaley A. Walker, Chris Boone, Hugh Pumphrey
Motivation II: Impacts of emissions on stratospheric aerosols may explain part of “warming hiatus”
CARMA is a Sectional Aerosol Microphysics/radiation model coupled with CAM5

CAM5/CARMA Model

1. Emissions
   - POA/BC: GFEDv3&FINN, GAINS
   - Sea Salt: Fan and Toon (2011)
   - Dust: Su and Toon (2009)
   - Sulfate: English et al. (2011)
   - VOC: monoterpenes, isoprene, benzene, toluene and xylene

2. Chemistry
   - SOA: Gas/Particle partitioning
   - Sulfur chemistry
   - Aqueous chemistry

CAM5  CARMA

3. Nucleation

4. Condensational growth
   - Wt %: Tabazadeh et al. (1997)

BHN: Zhao and Turco (1995)
H₂O vp over H₂SO₄: Lin and Tabazadeh (2001)
H₂SO₄ vp: Giauque (1959), Ayers et al. (1980), Kulmala (1990)

1.9°x2.5° resolution

Dynamics/Transport
   - CAM5

CARMA 20*6=120 bins

5. Coagulation
   - Brownian

6. Dry deposition

7. Aerosol activation/cloud Evaporation

8. Wet deposition

CARMA is coupled with CAM5 by Charles Bardeen, ACD, NCAR
56-level CAM5/CARMA has similar vertical resolution around UTLS compared with WACCM.
CARMA has wider size range of aerosols than MAM.

POA includes biomass burning organics, anthropogenic organics, marine organics and biological particles.
Model captures 89% of AeroNet AOD on average

Aeronet AOD average from 2009 to 2011

$y = 0.8887 \times x$

$R = 0.82229$

- Purple: $x < 0.1$
- Blue: $0.1 \leq x < 0.2$
- Cyan: $0.2 \leq x < 0.3$
- Orange: $0.3 \leq x < 0.4$
- Yellow: $0.4 \leq x < 0.5$
- Red: $0.5 \leq x < 0.6$
CARMA predicts aerosol layer in UTLS over Asia and North America

Extinction Ratio at 1020 nm

Total extinction/molecular extinction

\[
\text{Extinction Ratio} = \frac{\text{aerosol extinction} + \text{molecular extinction}}{\text{molecular extinction}}
\]

Thomason and Vernier, 2013
CARMA extinction ratio has maximum in ATAL and NATAL

Extinction Ratio at 1020 nm

Thomason and Vernier, 2013
Both CARMA and CARIBIC shows strong gradient of S/C ratio from Europe to Asia.
Asian Tropopause Aerosol Layer is mainly composed of Organics and Sulfate
ATAL’s organics are composed of POA and SOA; NATAL’s are composed of SOA.
In the UTLS, organics and sulfate dominate.
Organics Mass Fraction compared with SEAC4RS data
Organics contributes to extinction at UTLS
Sulfate effective radius is between 0.1 to 0.18 um in stratosphere.

Mixed particles effective radius at UTLS is 0.16 um.
ATAL intensity increases by 25% from 2000 to 2010.
ATAL intensity increases by 25% from 2000 to 2010

JJA

Vernier et al., GRL, 2015
Conclusions

- At UTLS, \textit{sulfate mass} \approx \textit{organics mass}; above UTLS, sulfate dominates;
- Mixed particle effective radius is roughly 0.16 um in UTLS;
- CARMA does predict ATAL and NATAL during JJA;
- ATAL is mostly composed of organics and sulfate;
- NATAL is mostly composed of SOA, with sulfate as background;
- ATAL intensity increases by 25% from 2000 to 2010.
Contact Info:

Pengfei Yu
pengfei.yu@colorado.edu
University of Colorado, Boulder

Thanks Charles Bardeen (NCAR)
Mike Mills (NCAR)

Yellowstone (NSF&NCAR)

@ Houston, SEAC^4RS, Sep.2013