OMI Measurements of Bromine Monoxide and Implications for Missing Sources of Polar Bromine in GEOS-Chem

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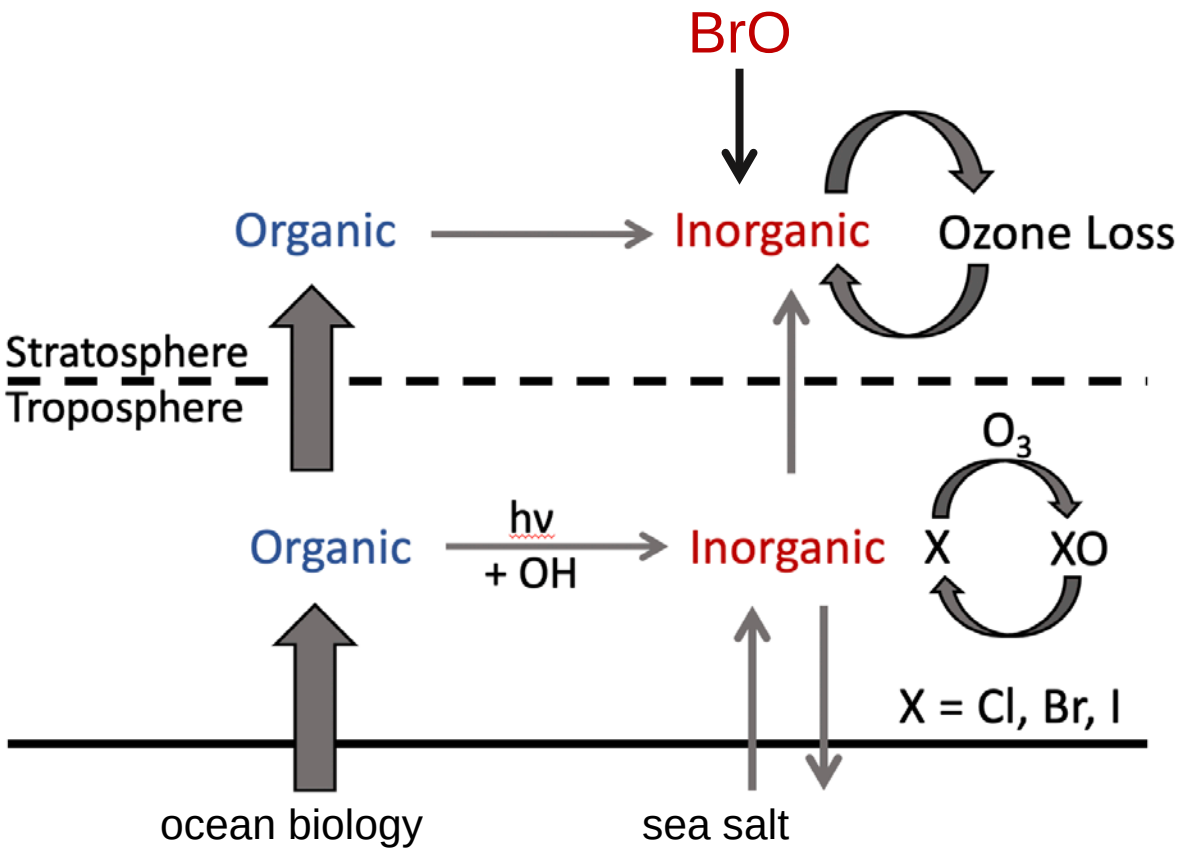
NASA POSTDOCTORAL PROGRAM

Background

- Bromine Monoxide (BrO) is the most frequently measured inorganic bromine compound
  - Measured by the Ozone Monitoring Instrument (OMI), GOME-2, and TROPOMI
  - Stratosphere is a large fraction of column measurements

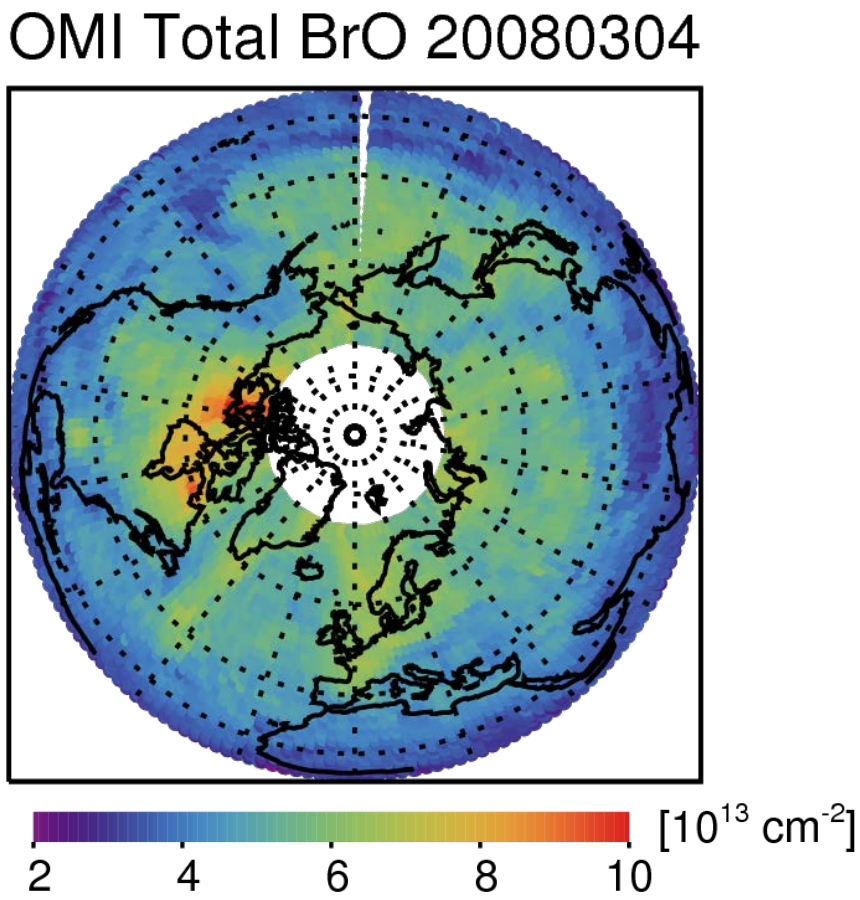
- Tropospheric bromine:
  - Lowers ozone, alters NO_x and HO_x cycles, and increases Hg bio-uptake
  - Marine and polar sources (algae and sea salt)
  - Polar sources not included in GEOS-Chem



Research Goals

- Polar spring “bromine explosion” events
  - Not included in GEOS-Chem model
  - Associated with near complete removal of surface ozone
  - Detectable by OMI (e.g., Choi et al., 2018)
  - Potential mechanisms: blowing snow, first year sea ice, snowpack

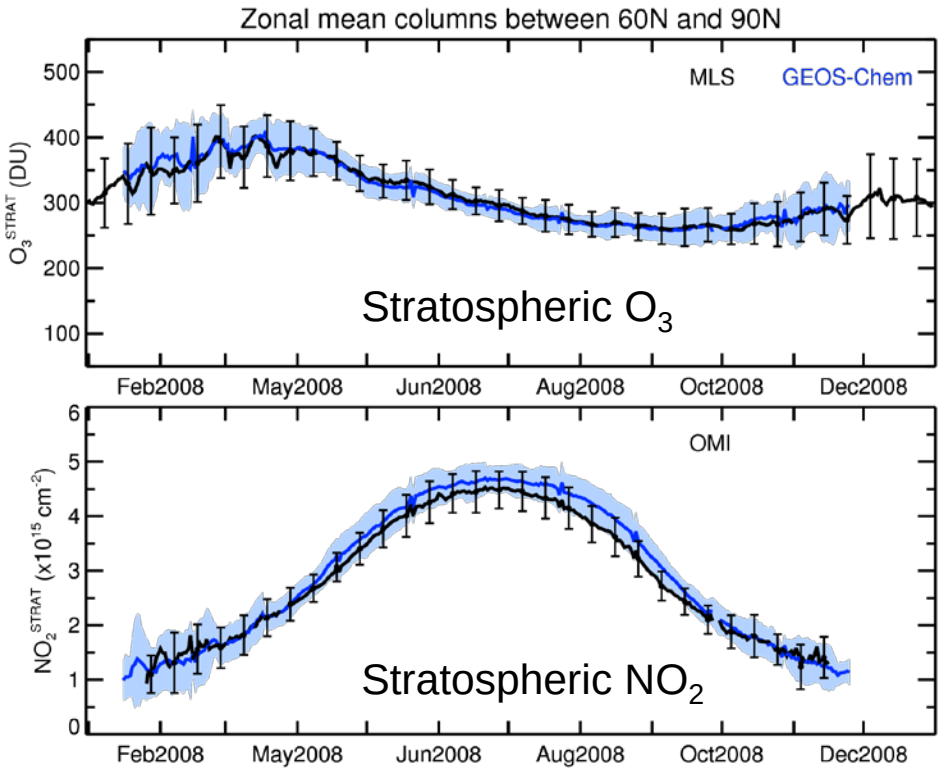
- Development of a simplified polar climatology
  - Identify regions of elevated bromine using OMI BrO
  - Requires accurate estimate of stratosphere
  - Towards assimilation in GMAO GEOS-Composition Forecast system



GEOS-Chem Stratospheric Bromine Monoxide (BrO)

- Simulated for 2007 – 2010
  - MERRA-2 reanalysis meteorology
  - GMI stratospheric chemical mechanism
  - Sea-salt debromination turned off

- Stratospheric BrO sensitive to reactions with O_3 and NO_2
  - Microwave Limb Sounder (MLS) retrieves profiles of O_3
  - OMI stratospheric NO_2 calculated using a climatology



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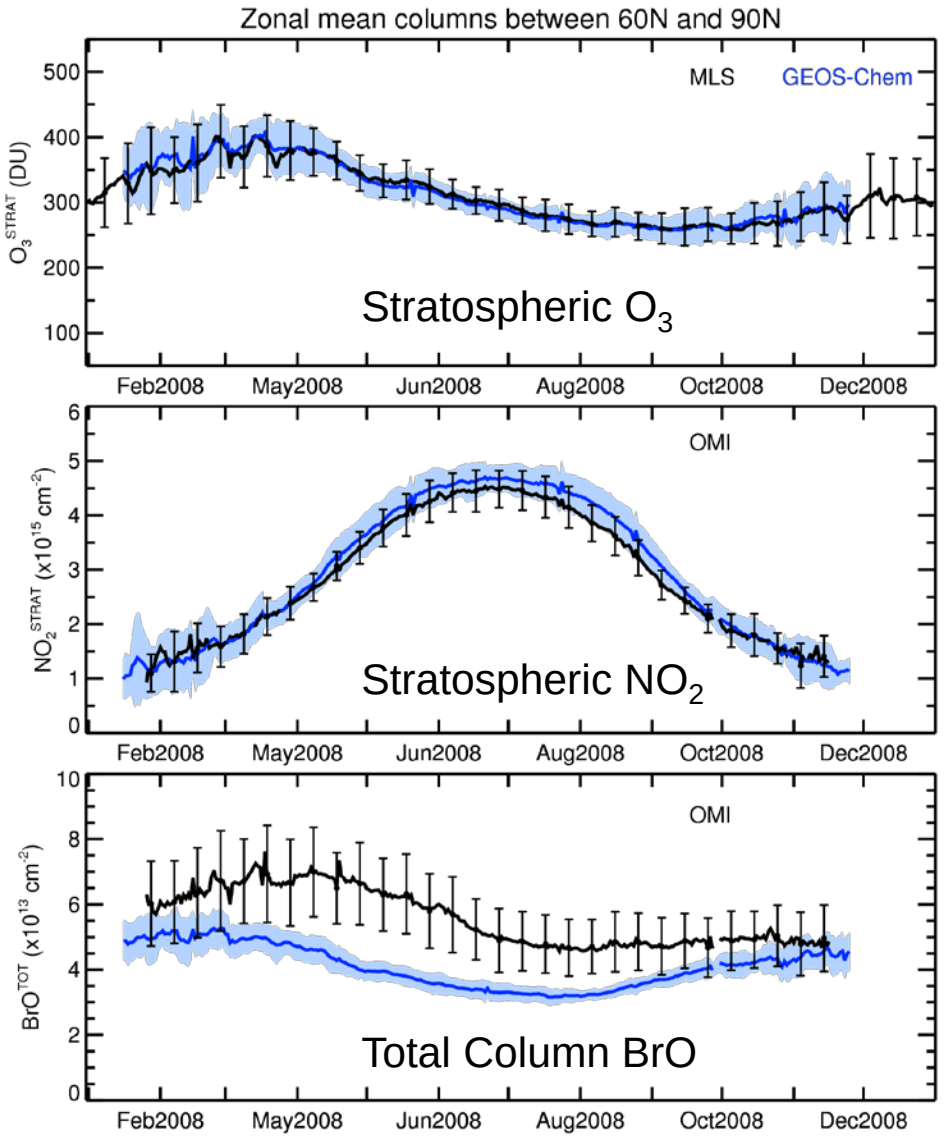
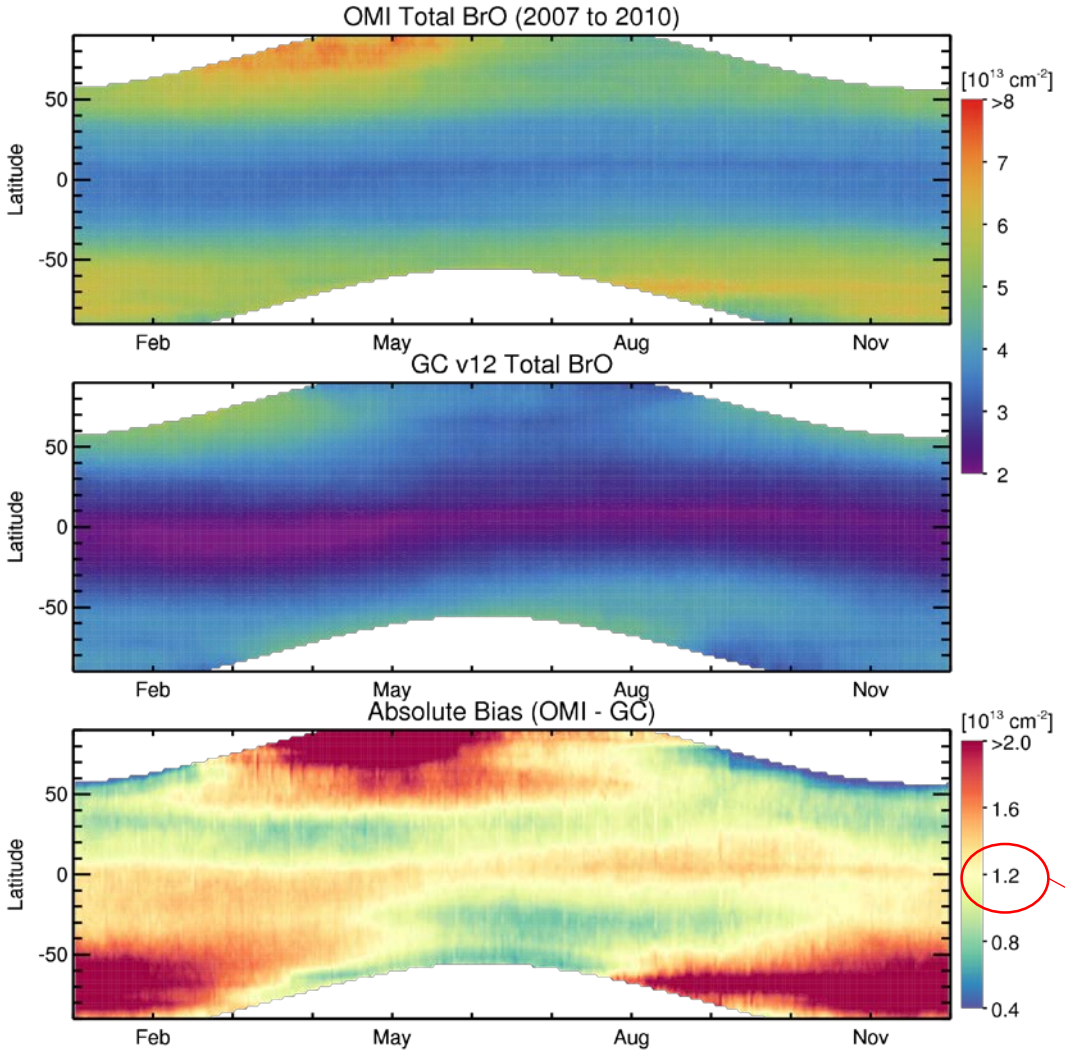
- GEOS-Chem total column BrO biased low
  - Stratospheric loading of bromine in close agreement with WMO Ozone Assessment recommendation (~ 20 ppt)
  - OMI total column adjusted for ~0.5 ppt tropospheric BrO (Brockway et al., in prep)



Global Total Column BrO



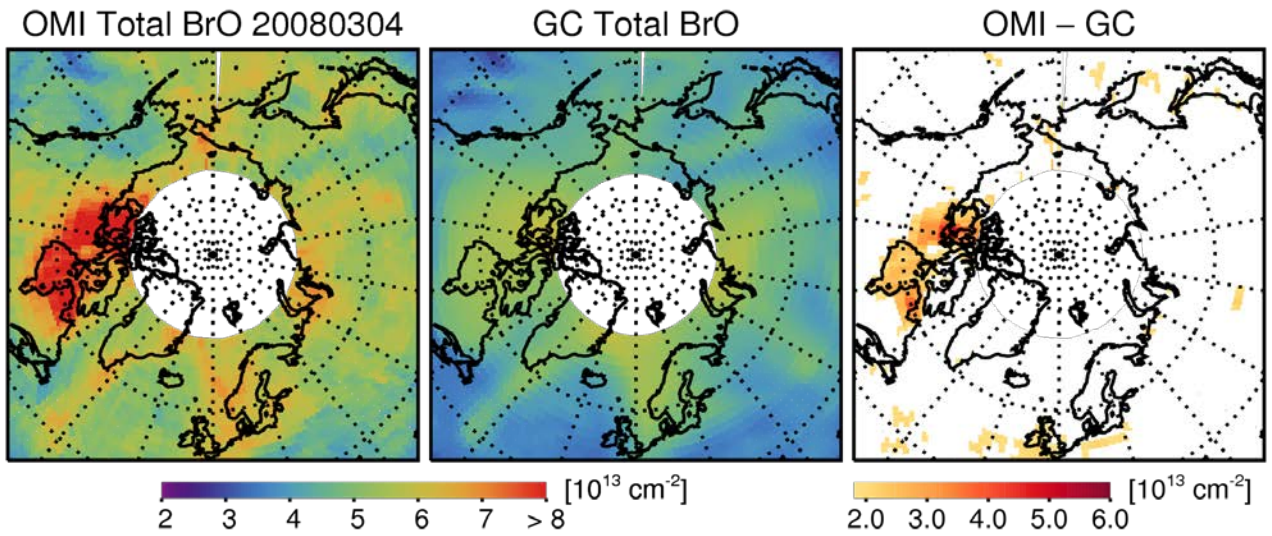
- GEOS-Chem biased low compared to OMI
  - 50S to 50N: **$1.2 \pm 0.2 \times 10^{13}$ molec cm^{-2}**
  - Consistent with GOME BrO – global model comparisons (Falk & Sinnhuber et al., 2018; Fernandez et al., 2019)

Potential sources of bias:

1. Free troposphere
   - Heterogeneous recycling, washout rates
2. Stratosphere
   - $BrONO_2$ reaction kinetics
   - Stratospheric bromine loading

Non-polar (50S to 50N) mean bias

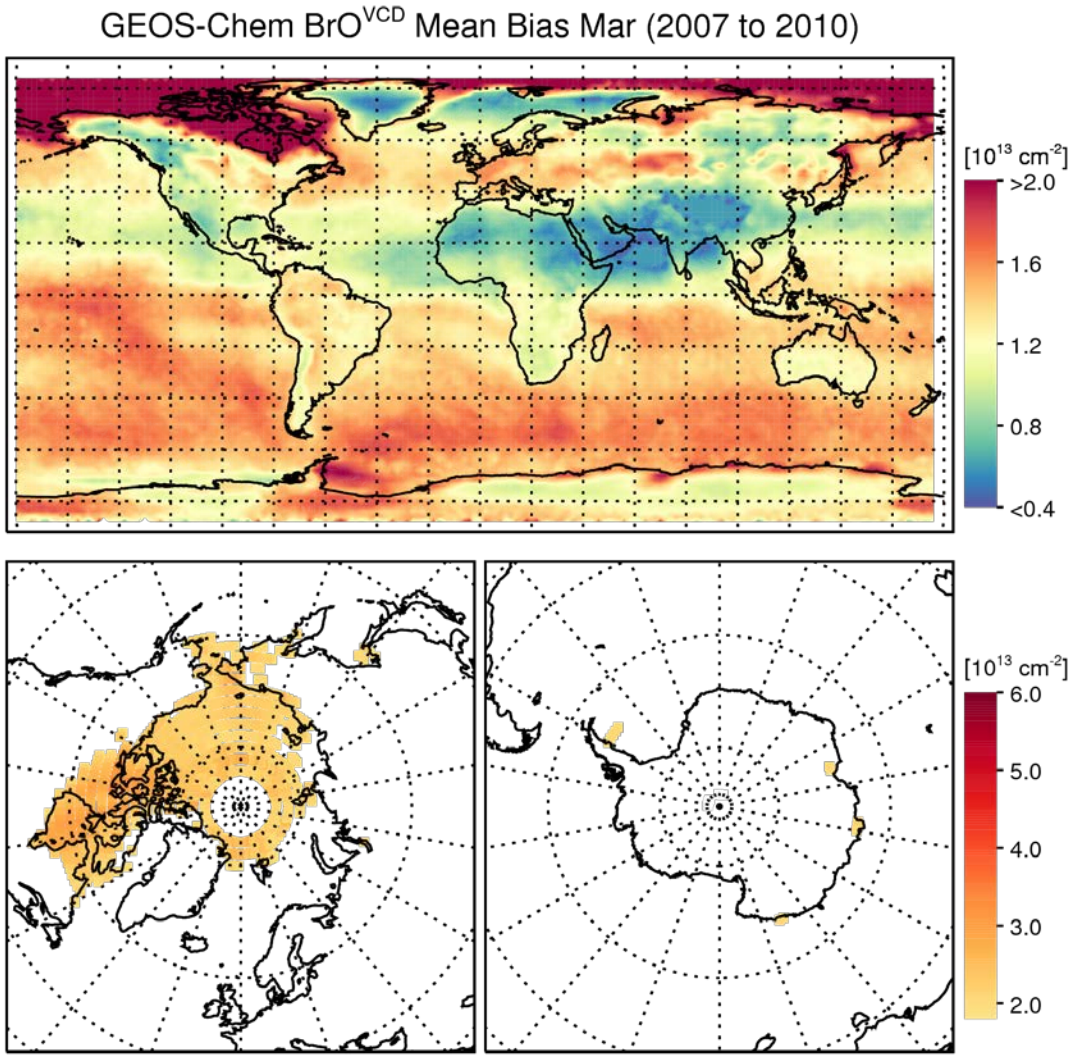
Arctic Spring



- Dynamically variable stratosphere in early spring
  - Able to isolate elevated BrO

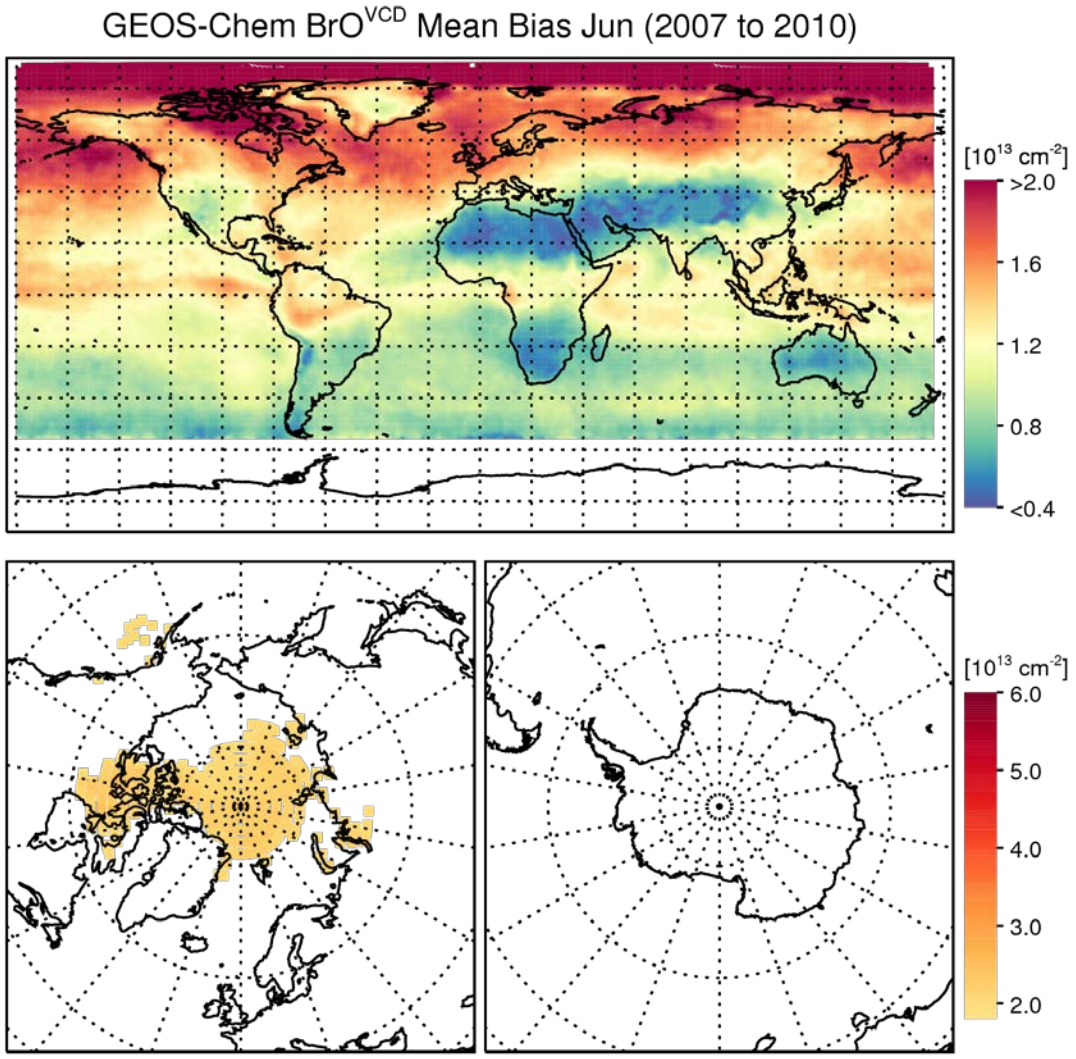
- Preliminary analysis:
  - Threshold = non-polar mean bias + 3σ
    1.8×10^{13} molecules cm^{-2}
  - Calculate monthly mean climatology

Arctic Spring



- Large bias in polar spring expected
  - Seen prominently March to May
- Consistent with missing snow/ice source
  - Proposed mechanisms: blowing snow, first year sea ice, snow pack chemistry
  - Can simplified climatology improve monthly mean surface ozone?

Arctic Summer

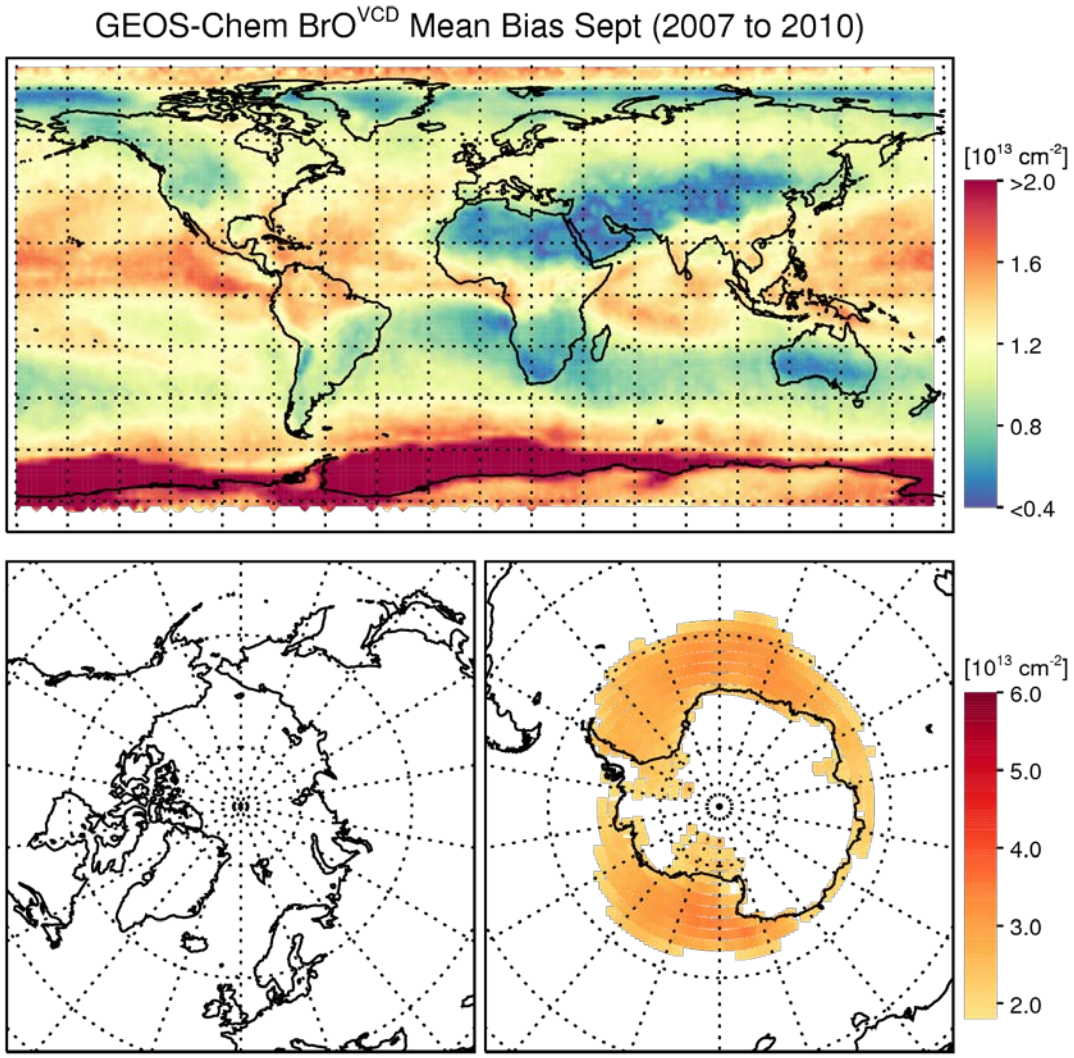


- Lower bias in Arctic June
  - No significant bias in July and August
- Late spring seasonality
  - Increase in stratospheric NO_2, larger role in $BrONO_2$ kinetics
  - Investigate impact of:

$$BrO + NO_2 + M \rightarrow BrONO_2 + M$$

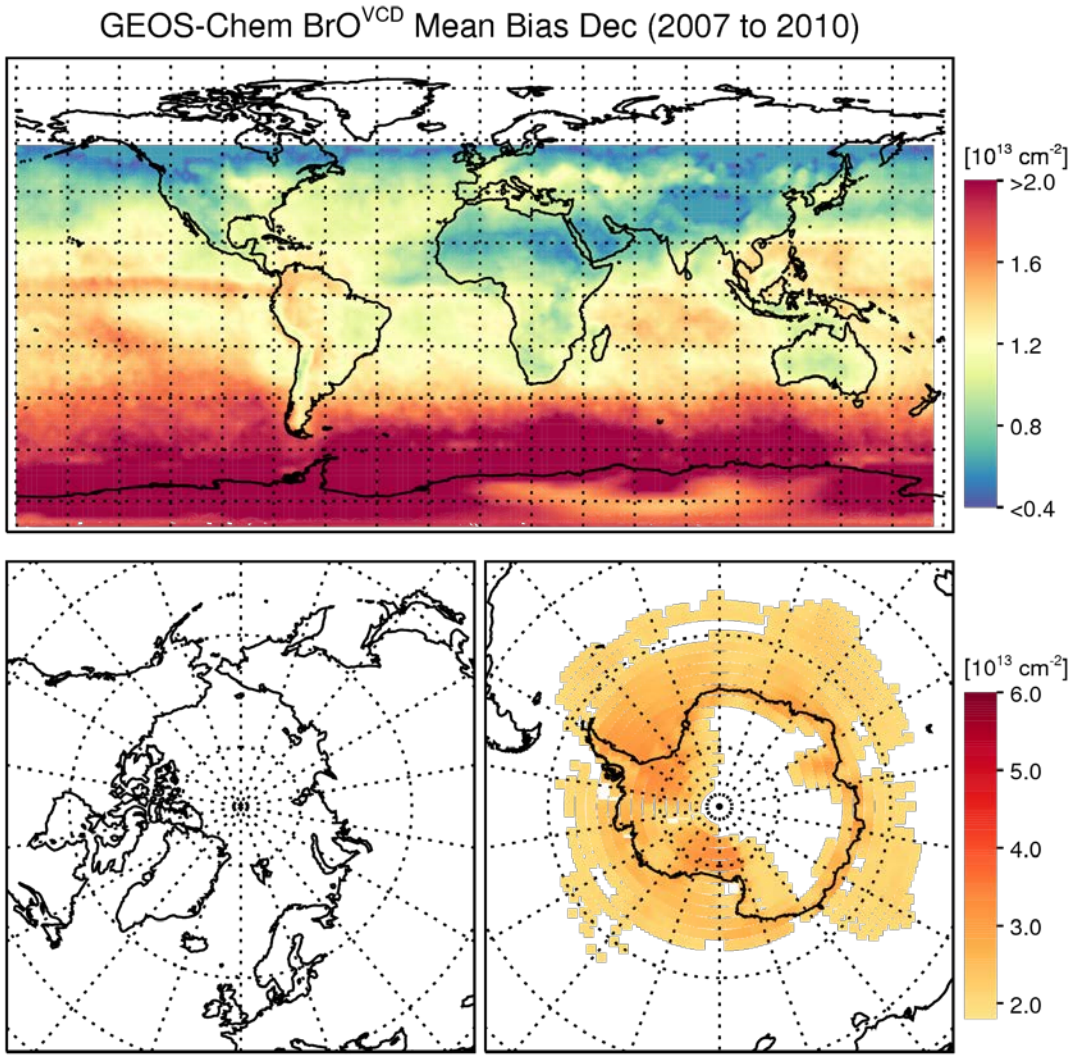
$$BrONO_2 + HCl \xrightarrow{het} BrCl + HNO_3$$

Antarctic Spring

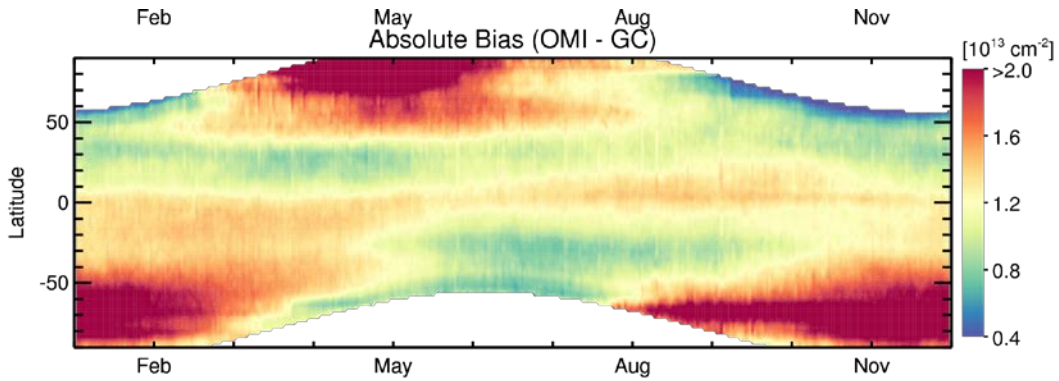


- Large bias in polar spring expected
  - Seen prominently September to November
  - Bias persistent for spring and summer

Antarctic Summer



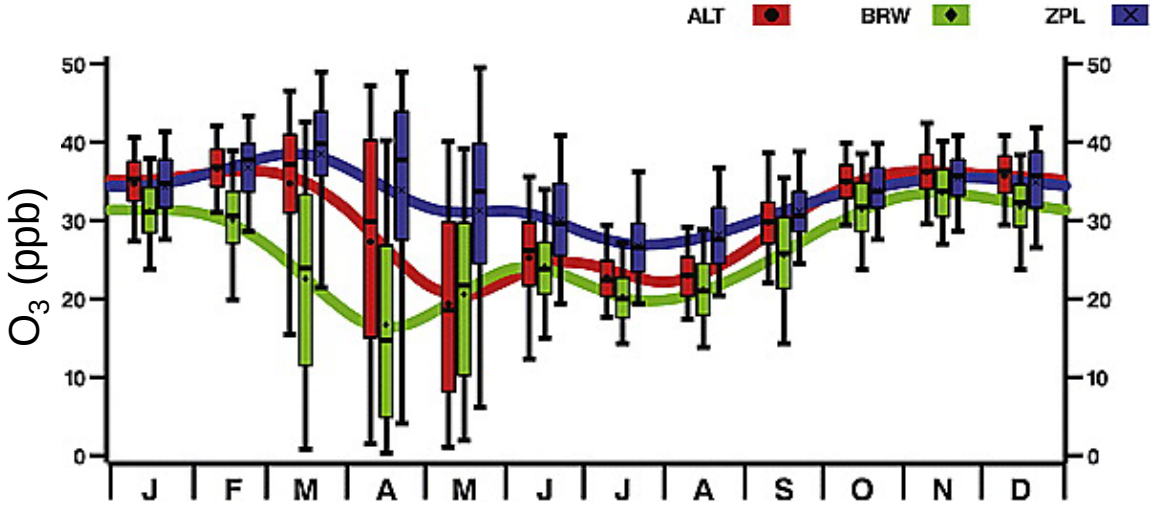
- Persistent bias in southern ocean
- Likely multiple sources for bias
  - Sea salt aerosol debromination
  - Biogenic short-lived organic bromine



Summary and Future Directions

- GEOS-Chem stratosphere can:
  - Capture the expected bromine loading and daytime chemistry
  - Identify missing polar tropospheric sources using OMI
- Test ability of climatology to reproduce monthly mean ozone observations
  - Compare to station O_3 and BrO
  - Future: investigate daily BrO flux

9 year Surface Ozone Record



Bottenheim and Chan *JGR* (2006)
Zeppelinfjellet, Norway (78°N)
Alert, Canada (82°N)
Barrow, Alaska (71°N)