Application of satellite BrO measurements to the analysis of the regional characteristics of Arctic ozone depletion events

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Ozone depletion events (ODEs) in the Arctic troposphere

- Occur in spring due to the catalytic loss driven by bromine chemistry.

- Bromine monoxide (BrO) indicates the extent of ODE.

\[
\text{Br} + \text{O}_3 \rightarrow \text{BrO} + \text{O}_2 \\
\text{BrO} + \text{BrO} \rightarrow 2\text{Br} + \text{O}_2 \quad \text{(Rate limiting step)}
\]

→ O₃ and BrO show the negative correlation during the ODEs.

Zeng et al. (2006)
Tropospheric BrO vertical column densities (VCDs)

- OMI and GOME2 have observed total BrO columns.

- Stratospheric BrO is estimated to obtain tropospheric BrO columns.
  - 20\textsuperscript{th} method: The lowest 20\textsuperscript{th} percentile of latitudinally binned BrO.
  - RAQMS method: Using the model results of regional air quality modeling system (RAQMS) scaled by the latitudinal 20\textsuperscript{th} percentile.
  - SCIA-2ND method: Stratospheric measurements by SCIAMACHY, extrapolated down to the tropopause height.

- Based on the comparison with ARCTAS DC-8 aircraft measurements, four tropospheric BrO VCDs are used in this study.
  - OMI-20\textsuperscript{th}, OMI-RAQMS, GOME2-20\textsuperscript{th}, and GOME2-SCIA2ND
Tropospheric BrO enhancement vs. Sea ice distributions

April 2008

Monthly mean tropospheric BrO VCDs (OMI-20\textsuperscript{th} method)

Canadian Archipelagoes

East Siberian Sea

Chukchi Sea

Alaska

SEP 2007

APR 2008

Sea Ice distribution (NIMBUS-7)
The level of $O_3$ at Barrow shows a stronger 1-D delayed correlation→ transport of air mass from high-BrO regions (where $O_3$ is depleted)
Transport pattern comparison between ODE and non-ODE days

→ Using backtrajectories (2-day) simulated by the polar version of MM5.

→ Transport affects the ODE at Barrow, but not Alert.

(Colorbar: the frequency of transport passing over for each region)
ODEs from aircraft measurements (ARCTAS DC-8 and ARCPAC WP-3D)

- The Chukchi Sea is a strong source region for ODEs in northern Alaska.
- Stronger ODE shows more enhanced tropospheric BrO VCDs.
Vertical $O_3$ profiles from ozonesonde measurements

- Transport influence
- Below 500 m

- Local influence
- Strong correlation above 1km
  $\Rightarrow$ Free tropospheric BrO
Vertical stability (temperature variation)

Barrow and Resolute: Stable boundary layer
Churchill: Unstable condition near the surface
Conclusions

• Satellite measurements show two high-BrO regions (Canadian Archipelagoes, and the Chukchi Sea and the East Siberian Sea). These high-BrO regions are well matched with the first year sea ice regions.

• Usually ODEs occur locally. However, ODEs in the northern Alaska Regions are influenced by the transport of O$_3$-poor air mass. ARCTAS and ARCPAC aircraft measurements with satellite BrO VCDs show O$_3$-poor air mass is transported from high-BrO regions.

• Vertical structure of ODE is quite different regionally. ODEs at Barrow are limited in the boundary layer. But ODEs at Resolute and Churchill are surprisingly deep (1-1.5 km), implying free tropospheric BrO.

• Vertical stability is strongly related to the vertical pattern of ODE. Churchill shows strong vertical mixing during ODE, indicating free tropospheric BrO from the surface. In contrast, deep ODE at Resolute occurs above stable boundary layer, suggesting the possibility of free tropospheric BrO production indirectly.