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An examination of the impact of air from China on summertime air quality in Japan before, during, and after the Beijing Olympics

Gary A. Morris
Valparaiso University, gary.morris@valpo.edu

Hajime Akimoto
Acid Deposition and Oxidant Research Center, Niigata, JAPAN

Masayuki Takigawa
Research Institute for Global Change, JAMSTEC Yokohama, JAPAN

Jun Hirokawa
Faculty of Environmental Earth Science, Hokkaido Univ., Sapporo, JAPAN

Fumio Hasebe
Faculty of Environmental Earth Science, Hokkaido Univ., Sapporo, JAPAN

See next page for additional authors

Authors
Gary A. Morris, Hajime Akimoto, Masayuki Takigawa, Jun Hirokawa, Fumio Hasebe, Masatomo Fujiwara, Koji Miyagawa, Nicholay Krotkov, Jacquie Witte, Yugo Kanaya, Nathan Kellams, and Ted Pietrzak

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An examination of the impact of air from China on summertime air quality in Japan before, during, and after the Beijing Olympics

G. Morris[1], H. Akimoto[2], M. Takigawa[3], J. Hirokawa[4], F. Hasebe[4], M. Fujiwara[4], K. Miyagawa[5], N. Krotkov[6], J. Witte[7], Y. Kanaya[3], N. Kellams[1], and T. Pietrzak[8]

[1] Dept. of Physics & Astronomy, Valparaiso Univ., Valparaiso, IN; [2]Acid Deposition and Oxidant Research Center, Niigata, JAPAN; [3]Research Institute for Global Change, JAMSTEC Yokohama, JAPAN; [4]Faculty of Environmental Earth Science, Hokkaido Univ., Sapporo, JAPAN; [5]Aerological Observatory, Japan Meteorological Agency, Tsukuba, JAPAN; [6]GEST Center, Univ. of Maryland Balt. Co., Baltimore, MD; [7]Atmospheric Chemistry & Dynamics Branch, NASA Goddard Space Flight Center, Greenbelt, MD; [8]Dept. of Meteorology, Valparaiso University, Valparaiso, IN

Abstract

During July – September 2008 pollution controls in China associated with the Beijing Olympics led to emissions reductions of up to 43%, as observed by NASA satellite instruments. Pollution from China has an impact on air quality throughout East Asia. In this poster, we examine the impact of China's pollution on Japan through the use of Aura satellite data (2005 – 2009), ozonesonde data (2000 – 2009), and data from air quality surface monitors (2000 – 2009). We also examine the year-to-year variability in meteorological flow regimes through trajectory model simulations of transport to Japan from the areas around Beijing and Shanghai, China and around Seoul, South Korea in order to apportion remote sources of pollution. Data link the 6 August 2008 pollution event in Hokkaido to the Beijing region. We also find impacts of air from China on mean August ozone concentrations in Hokkaido and Kyushu, and significant trends in July – September tropospheric ozone profiles since 2000, particularly between 5 – 10 km, using the Sapporo ozonesonde data set from the Japan Meteorological Agency (JMA, 2000 – 2009) and the our ozonesondes launched from Hokkaido University (2008 – 2009).

6 August 2008 Pollution Event

Figure 1. Sapporo skies were noticeably hazier on 6 Aug. Both photos were taken at ~ 2 pm local time. The arrows mark the same geographic point. Surface monitors in Beijing recorded high levels of pollution 3 – 9 Aug. 2008. Models suggest transport from near Beijing to Hokkaido around 6 Aug (see Fig. 5 below).

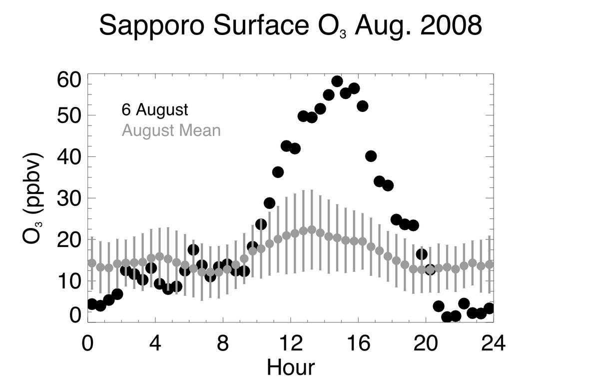

Figure 2. 30-minute average data at Hokkaido Univ. (Sapporo, Japan) show O_3 peaked > 60 ppb on 6 Aug. data (black dots) when skies were hazy show. The Aug. mean data (gray) show typical afternoon peaks < 30 ppb.

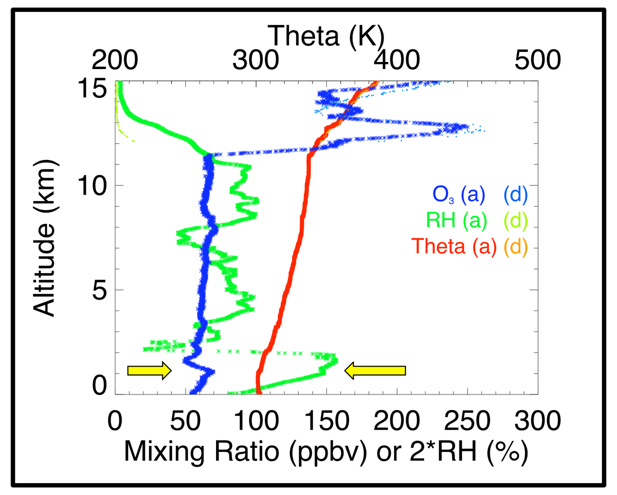

Figure 3. Data from the 6 Aug. ozonesonde launched at Hokkaido Univ. shows elevated O_3 at the top of the mixed layer. Air in this layer is also humid, suggesting origins near the surface.

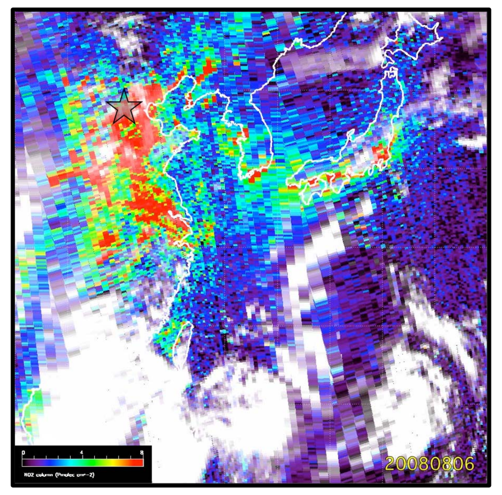

Figure 4. Trop. NO_2 column on 6 Aug. is typical. Beijing is marked by the star. Purple~1; blue-green ~ 4; red > 8 ×10[15] molecules/cm². Courtesy E. Celarier (NASA GSFC).

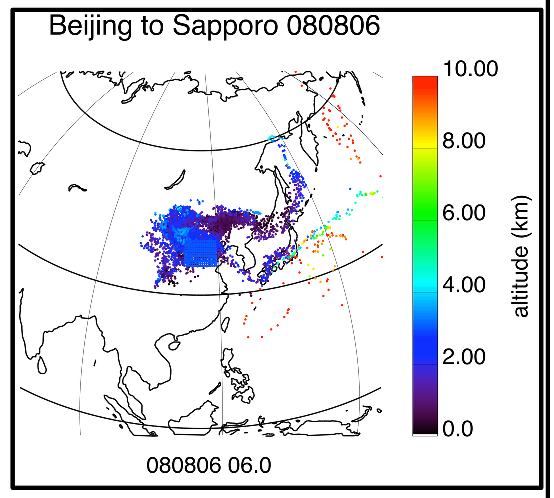

Figure 5. NASA GSFC Trajectory Model (Schoeberl & Sparling, 1995) indicates air on 2 – 4 Aug. near Beijing arrives in Hokkaido on 6 Aug. The kinematic model (KTM) is run with NCEP re-analysis winds (1°×1° grid). See also the Aug. '08 computer animation.

NASA Aura Satellite – OMI SO_2 Data

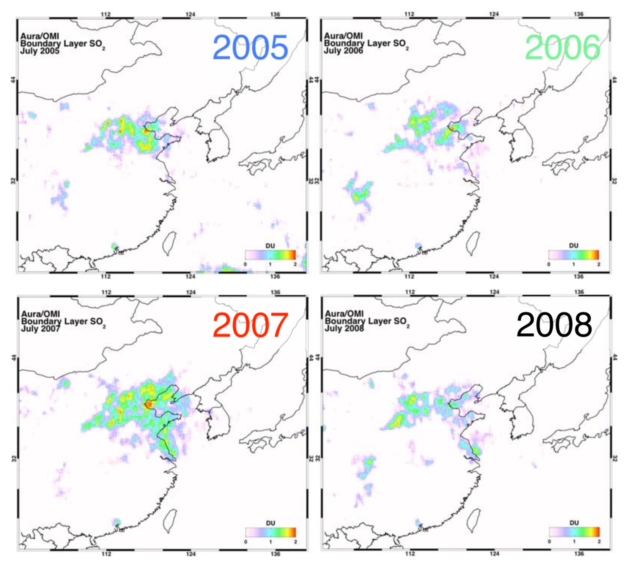

Figure 6. July mean boundary layer SO2 (DU) from the Aura OMI instrument shows 2008 values relatively lower than 2005 – 2007 values, likely due to emissions restrictions imposed by China around Beijing for the 2008 Olympics Games.

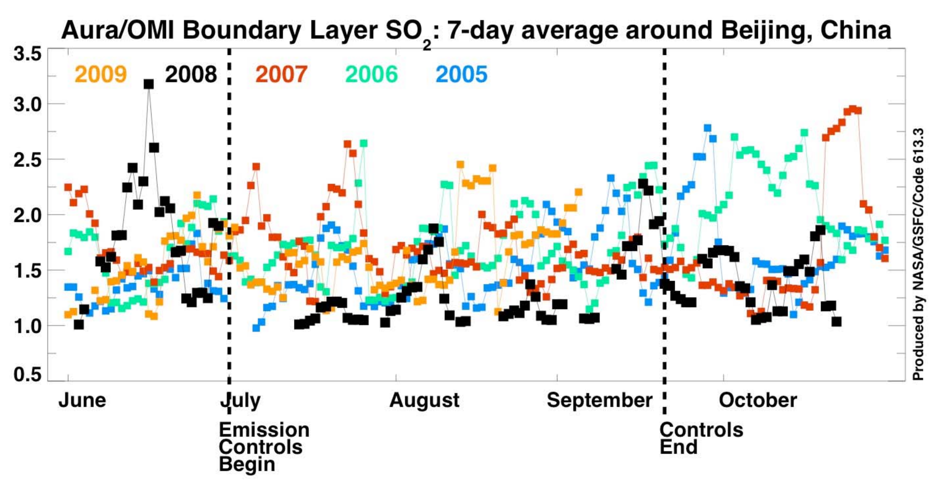

Figure 7. Running 7-day average column SO_2 (DU) for the 1 July – 31 October periods 2005 - 2009 from the Aura OMI instrument shows 2008 values ~13% lower than 2005 – 2007 values. Decreases were also observed for column NO_2 (43%) and CO (~12%). See *Witte et al.* (2009) for details.

Sapporo O_3 & SO_2 Observations

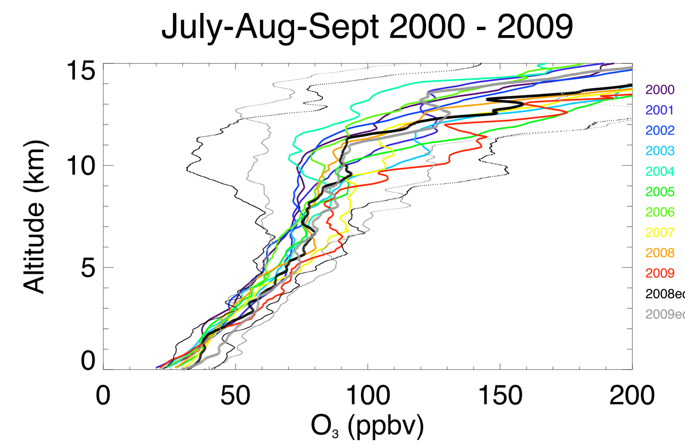

Figure 8. Mean O_3 profiles from Sapporo soundings. The black & gray lines (thick = mean, thin = 1σ) are from the EnSci electrochemical cell (ECC, Komhyr, 1986) systems (KI) launched during Aug. 2008 & 2009 by G. Morris at Hokkaido Univ. All others are KC96 (CI) sondes, typically launched ~1 per week by the Japan Meteorological Agency (JMA).

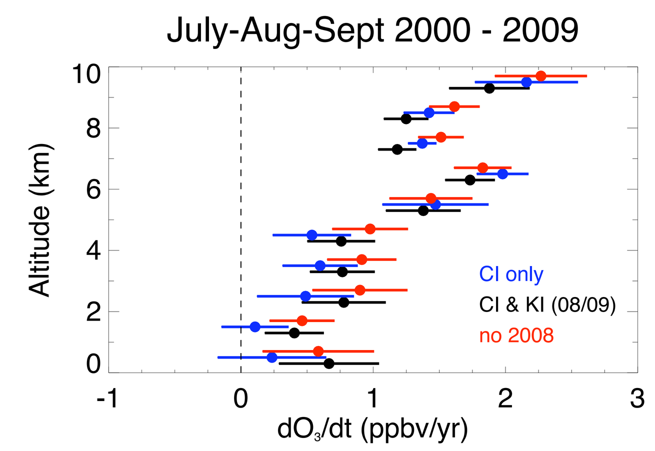

Figure 9. O_3 profile trends in 1 km bins as derived from the data plotted in Fig. 8, including (black) and excluding (blue) the ECC data, and excluding 2008 (red). Error bars are 1σ. Trends w/ and w/out 2008 data: 7 – 10 km = (1.44 ± 0.38) and (1.80 ± 0.41) ppb/yr; 2 – 5 km = (0.7677 ± 0.0097) and (0.930 ± 0.041) ppb/yr. The differences may be due in part to the pollution controls in China during the 2008 Beijing Olympic Games.

Figure 10. This dual instrument payload was launched on 18 flights from Hokkaido Univ. in Aug. 2008 and 2009. From left to right are the RS80-15N radiosonde, the standard En-Sci 2Z ozonesonde, and a second ozonesonde with SO_2 filter (the circled white tube). When SO_2 is present, the standard, unfiltered ozonesonde effectively measures $[O_3] – [SO_2]$. By differencing the filtered (right) and unfiltered (left) ozonesonde measurements, we can deduce $[SO_2]$. Lab tests indicate the filters do not destroy O_3 while they are 85 – 100% effective at destroying SO_2.

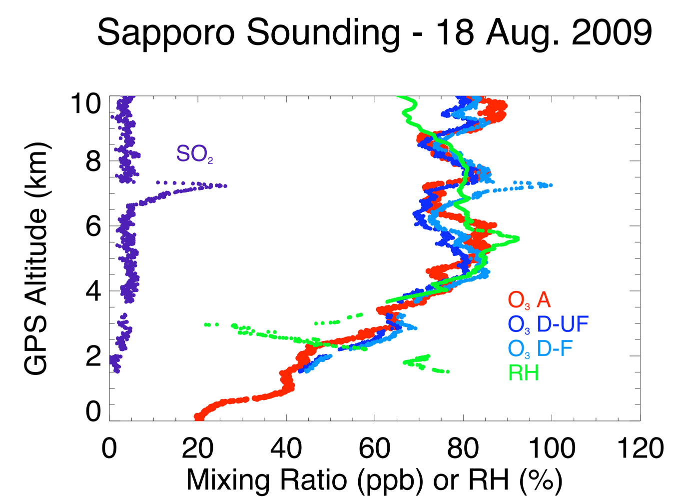

Figure 11. A SO_2 feature appears near 7.3 km on the descent of the 18 Aug. 2009 launch. The ascending (A) O_3 profiles for both the filtered (F) and unfiltered (UF) sondes are identical. The descending (D) F sonde shows an ozone peak at 7.3 km while the UF sonde shows an O_3 decrease, similar to the ascending profile. The KTM suggests air mass origins <4 km near Beijing. Our hypothesis is that strong convection along a front lifted air with high SO_2 and O_3 from near the surface on 16 - 17 Aug. to ~7.5 km, where it was transported rapidly to Hokkaido and observed.

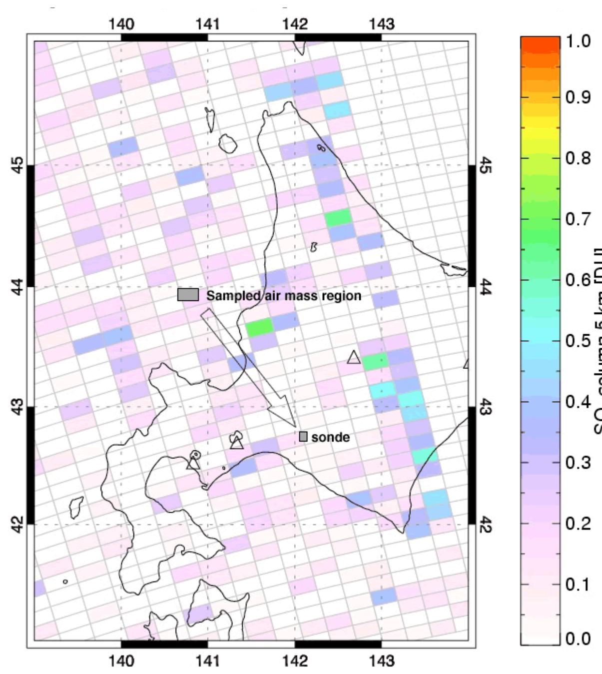

Figure 12 (left). A special Aura OMI high-resolution retrieval shows SO_2 near Hokkaido on 18 Aug. 2009. The OMI overpass was at ~3:40 UT while the sonde SO_2 feature was detected at ~6:55 UT. Marked on the map are the positions of the sonde at the time it detected SO_2 (see Fig. 11) and the projected location of that air mass at the time of the OMI overpass, based on sonde-measured wind speed and direction. The sonde column SO_2 is 0.25 DU, similar to the OMI columns near the projected air mass location at the time of the overpass.

References and Acknowledgements

Komhyr, W.D. (1986), Operations Handbook: Ozone measurements to 40 km altitude with mode 4A electrochemical concentration cell (ECC) ozonesondes (used with 1680-Mhz radiosondes), *NOAA Technical Memorandum ERLARL-149*.

Krotkov, M. A., B. McClure, R. R. Dickerson, S. A. Carn, C. Li, P. K. Bhartia, K. Yang, A. J. Krueger, Z. Li, P. Levelt, H. Chen, P. Wang, and D. R. Lu (2008), Validation of SO_2 retrievals from the Ozone Monitoring Instrument (OMI) over NE China, *J. Geophys. Res., 113, D16S40, doi:10.1029/2007JD008818.*

Schoeberl, M. R. and L. Sparling (1995), Trajectory Modeling, in *Diagnostic Tools in Atmospheric Physics,* G. Fiocco and G. Visconti eds., Proceedings of the International School of Physics "Enrico Fermi", Vol. 124, 289 – 306.

Witte J. C., M. R. Schoeberl, A. R. Douglass, J. F. Gleason, N. A. Krotkov, J. C. Gille, K. E. Pickering, N. Livesey (2009), Satellite observations of changes in air quality during the 2008 Beijing Olympics and Paralympics, Geophys. Res. Lett., 36, L17803, doi: 10.1029/2009GL039236.

All data can be found at http://physics.valpo.edu/ozone/fulbrightdata.html. Email questions to Gary.Morris@valpo.edu

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Trajectory Analyses and Surface O_3 Data

Figure 13. A Google Map shows the regions in which the KTM data were analyzed. Balloons show the corners of the source regions and pins show the corners of the analysis regions. While this poster focuses on Hokkaido and Kyushu, future work will perform similar analyses on other regions within Japan.

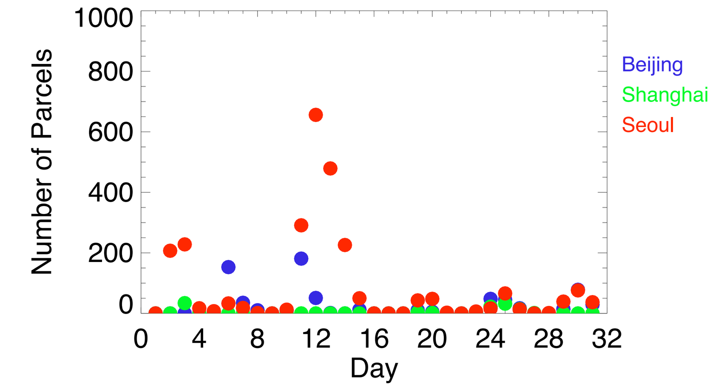

Figure 14. The advection of air from 3 source regions arriving in the Hokkaido region < 2.5 km during 2008 is simulated with the KTM (see Fig. 5). The model suggests 6 – 7 and 11 – 12 August as days with influence from Beijing, while 2 – 3, 11 – 14 August are days with influence from Seoul. Shanghai air masses rarely reached Hokkaido during August 2008.

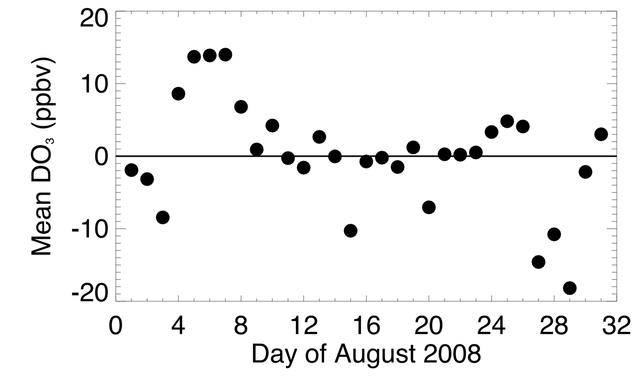

Figure 15. Sapporo Center, Shinoro, and Hokkaido Univ. 7 am – 7 pm average O_3 data for 2008. A residual is computed by subtracting the monthly from daily mean at each site. The 3-site average residuals are plotted. A strong peak occurs around 5 – 7 Aug., but not around 11 – 12 Aug. Mean Beijing air quality for 4 – 5 Aug. = 88 ± 12 while for 10 – 11 Aug. = 33 ± 14, which may explain the difference. Beijing data from http://www.bjepb.gov.cn/bjhb.

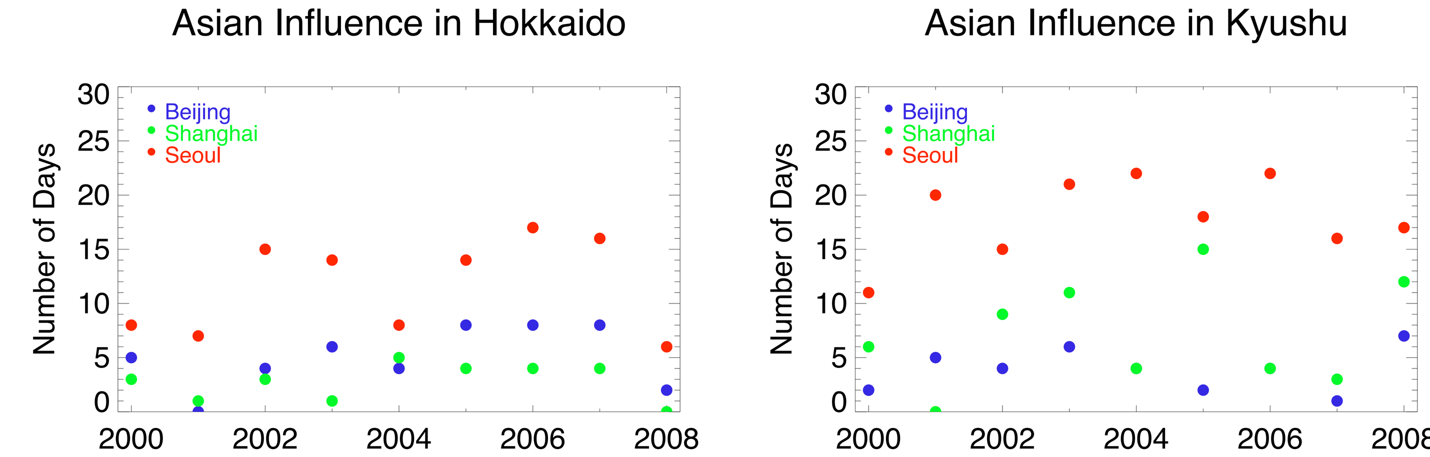

Figure 16. Number of days each August with > 100 KTM parcels below 2.5 km above Hokkaido (left) and Kyushu (right) originating around Beijing, Shanghai, and Seoul. Data from 2008 shows less than average Asian influence in Hokkaido but was a more typical in Kyushu.

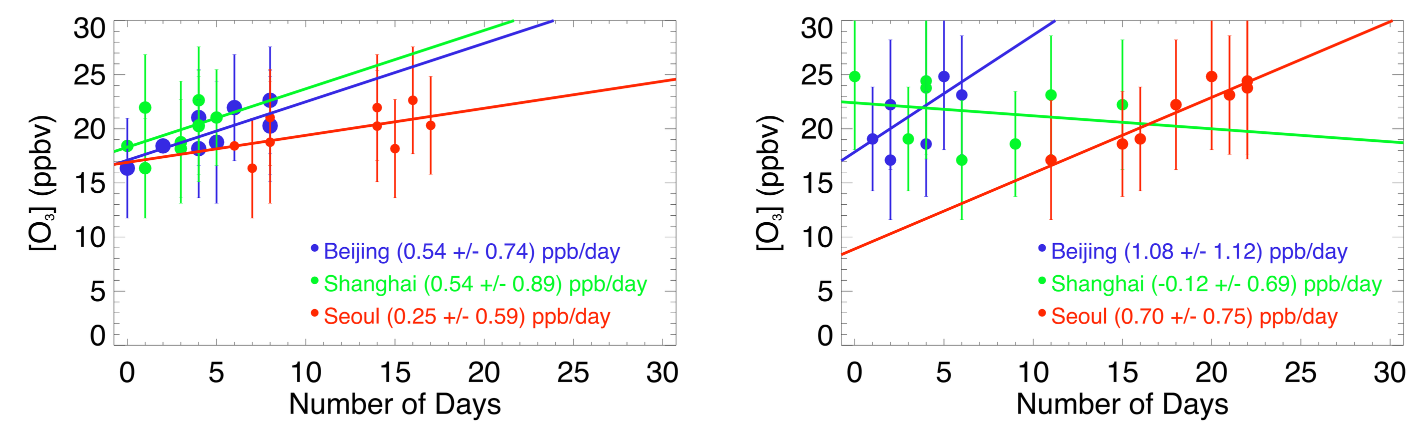

Figure 17. August 2000 – 2008 monthly mean surface monitor O_3 in Hokkaido (left) and Kyushu (right) (data from www.nies.go.jp) versus the number of days with >100 KTM parcels from Beijing, Shanghai, and Seoul (see above Fig. 16). Beijing has a strong influence in both locations, while Seoul impacts Kyushu more than Hokkaido.

Conclusions and Future Work

- Surface O_3 in Hokkaido on 6 Aug. 2008 was enhanced by the arrival of air from China.
- Data from OMI on NASA's Aura satellite suggest decreases in pollution during the 2008 Beijing Olympic period as compared to 2005 – 2007 data. (SO_2: –13%, NO_2: –43%).
- Sapporo ozonesonde data show statistically significant positive trends 2 – 10 km. Trends are higher 2 – 5 and 7 – 10 km when 2008 data are excluded, suggesting Olympic pollution controls in China may have been effective. Further investigation is needed.
- The 18 Aug. 2009 sonde found a peak of high O_3 and high SO_2 at ~7.3 km that may have been lofted from the surface by strong convection near Beijing 24 – 48 hours earlier. This mechanism may be related to the trends aloft in the Sapporo sonde data.
- Higher summertime surface O_3 in Hokkaido and Kyushu is linked to air transported from the continent. Arrival of air from Beijing significantly influences surface O3 at both locations, while air from Seoul more strongly influences Kyushu.