Beijing Olympics: The impact of regional air pollution controls on AOT

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Motivation and Research Question

- *Context*: Role of (anthropogenic) aerosol in climate system unclear
- *Situation*: Air quality measures for Beijing Olympics
  - Traffic restrictions (car load cut by 1/2)
  - Factory closures
  - Measures in area of about 100–200 km radius
  - 20 July – 20 September 2008
- *Question*: Do Beijing air quality measures register in atmospheric aerosol load (aerosol optical thickness, AOT)?

Approach and Data

- Analysis
  1. Absolute changes in AOT
  2. Changes in AOT relative to situation expected under meteorological conditions
- Data
  - Terra MODIS AOT data (MOD08 collection 5)
  - ECMWF analysis data (wind, relative humidity)
  - TRMM multi-satellite precipitation analysis
  - all daily data, 1 August – 20 September, 2002–2008, 1 degree
  - Summers 2002–2007 as reference period

First Glance Analysis: Absolute Changes

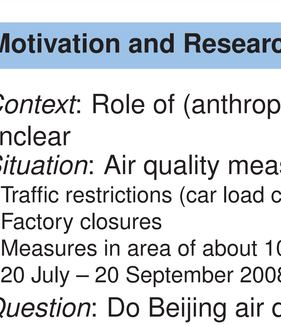

Figure 1: August 2008 mean AOT vs. mean August AOT in the reference period (2002–2007). The figure shows relative change, negative values indicate a smaller AOT in 2008. White pixels are missing data. 1: Beijing, 2: industrialized area NW of Beijing.

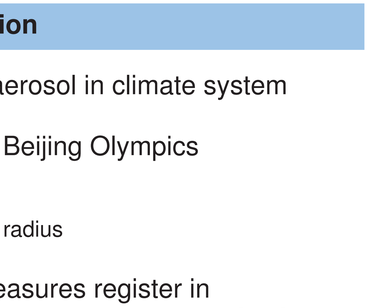

Figure 2: Development of AOT over the summer of 2008 (red) and mean daily AOT of a 500 km radius region (blue). The 500 km mean daily AOT values of the years 2002–2007 are given in grey.

- Small AOT reduction in Beijing (about 10–15%)
- Ambiguous spatial pattern (figure 1, could be natural variability)
- Large AOT variations during summer 2008 (figure 2)

AOT and Meteorology: Analysis

- Meteorological conditions (previous day and same day wind, precipitation, relative humidity) influence AOT
- Figure 3 shows the relationship between previous day wind conditions and the logarithm of AOT. Winds from south and south-west favour large *log*(*AOT*). The industrial cities of Tianjin and Tangshan lie in that direction (100–150 km distance)

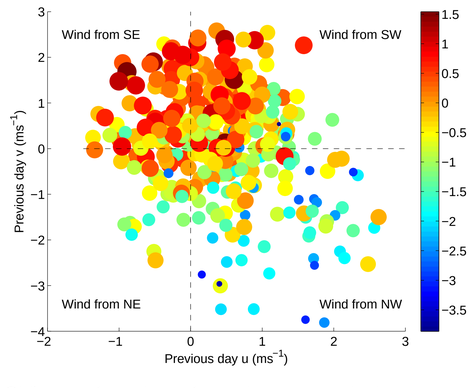

Figure 3: *log*(*AOT*) as a function of previous day wind components for summer 2002–2007. The size of the dots is scaled with *log*(*AOT*).

AOT and Meteorology: Neural Network Predictions

- *Idea*: Predict AOT for 2008 based on meteorological conditions, assuming no air quality measures.
- *Approach*:
  - Train a neural network with meteorological and *log*(*AOT*) data for 2002–2007
  - Use network to predict summer 2008 *log*(*AOT*) based on summer 2008 meteorology
  - Compare predictions and observations

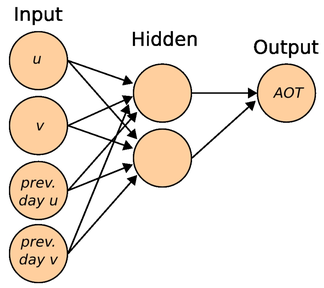

Figure 4: Neural network setup. This case shows a network considering only wind components. Figure adapted from Cburnett, commons.wikimedia.org

Neural Network Validation and Application

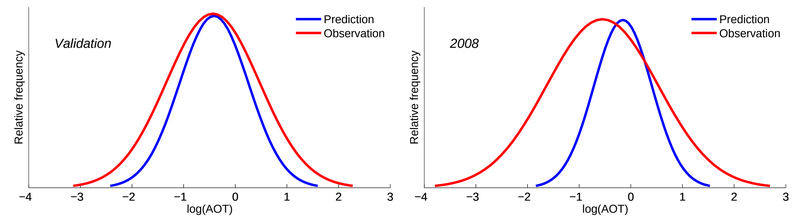

Figure 5: Probability density functions (pdf) of daily *log*(*AOT*) observations (red) and predicted values (blue) for Beijing (local grid cell). Left: validation data set (randomly chosen from summers 2002–2007), right: summer 2008.

- Network seems to correctly predict situations without air quality measures (figure 5, left-hand side)
- Summer 2008 aerosol is shifted to smaller values relative to the predictions (figure 5, right-hand side)

Aerosol Deviation from Predictions by Region

- Deviation of observations from predictions computed for local pixel and regions around Beijing with various radii (table 1)
- Statistically significant reductions in Beijing and the immediate surroundings

Table 1: Output from the neural network simulations compared with log(AOT). The columns are regions of varying radii (in km). σ: standard deviation of predicted *log*(*AOT*), C_v: correlation of network output with validation data set, $P(t)$: probability that predicted and observed *log*(*AOT*) values belong to the same distribution (Student's t test). $n(P(t) < 0.05)$: number of cases in which $P(t)$ was smaller than or equal to 0.05 out of a total 10 model training repeats.

	Local	150	300	400	500	1000	3000
Median deviation (σ)	-0.76	-0.48	-0.37	-0.30	-0.38	-1.18	-0.84
C_v	0.73	0.75	0.79	0.75	0.70	0.60	0.71
$P(t)$	0.01	0.01	0.05	0.17	0.12	0.00	0.06
$n(P(t) < 0.05)$	10	9	1	2	3	10	2

Conclusions

- Aerosol load reduced 10–15% in and around Beijing
- In meteorological context, reduction is 0.5–0.75 standard deviations (small relative effect)
- Reduction is statistically significant
- Effect is mostly local

More information: Cermak, J. & R. Knutti (2009) Beijing Olympics as an Aerosol Field Experiment. *Geophysical Research Letters*, 36, L10806. doi:10.1029/2009GL038572

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