Absorption Spectral Variation to Illustrate Regional and Seasonal Asian Aerosol Variation

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Ongoing urbanization and industrialization in Asia contributes to many different aerosol types

- Adds to more uncertainty in global climate
  - Which aerosol type is dominant?
  - Which aerosol type has more effects on the global radiation budget?
- Different types of aerosols have been known to cause different types of health issues as well
  - Fine mode versus coarse mode aerosols
  - Secondary aerosols
Absorption Angstrom Exponent ($\alpha_{abs}$)

- Log–slope of AAOD or $\tau_{abs}$ (440–870nm)
- $\alpha_{abs} < 1$: pollution, aged aerosols, background aerosol type, and even instrument noise artifacts
- $\alpha_{abs} \sim 1$: submicron black carbon (BC)
- $1 < \alpha_{abs} < 2$: urban pollution
  - Weakly absorbing OC, sulfate and biomass aerosols
- $\alpha_{abs} > 2$: light absorbing organic carbon and mineral dust
Absorption spectral variation ($\delta \alpha_{\text{abs}}$)
- Slope of $\alpha_{\text{abs}}$ between 440 and 870 nm
- Separates strong absorbing from weak absorbing particle influences
- $\delta \alpha_{\text{abs}} > 0$ – strong absorbing pollution aerosols
- $\delta \alpha_{\text{abs}} < 0$ – weak absorbing pollution aerosols
- $\delta \alpha_{\text{abs}} \sim 0$ – complex mixtures
AERONET Sites

- Beijing
- Xianghe
- SACOL
- Taihu
• Majority of data points fall between $\alpha_{\text{abs}}$ of 1 and 2 – pollution range
• Positive $\delta \alpha_{\text{abs}}$ – strong absorbing particles (major contribution)
• Negative $\delta \alpha_{\text{abs}}$ – weak absorbing particles (minor contribution)
• Dust region – $\delta \alpha_{\text{abs}} > 0$, $\alpha_{\text{abs}} > 0$
Majority of extreme aerosol loading events are in summer at SACOL. Maximum $t$ is more often during spring. Negative $\Delta \alpha_{abs}$ during summer (e.g. biomass). Heavy overlap due to many particles having similar $\alpha_{abs}$ values but not necessarily similar type.
Fine mode is correlated with large $\tau$ and $\delta\alpha_{\text{abs}} > 0$.

$\delta\alpha_{\text{abs}} < 0$ has primary contributions from fine mode and minor contribution from coarse mode.

SACOL has main contribution from coarse mode absorbing particles.
- $\delta \alpha_{abs} > 0$ associated with winter and spring months
- $\delta \alpha_{abs} < 0$ associated with summer and autumn months
- SACOL has largest variability of $\delta \alpha_{abs}$ in spring
- Beijing has largest variability overall
- Less overlap of overall aerosol variation with this method
Spectral Variation–Case Study

- Our previous study used $\delta \alpha$ to identify three types of aerosol plumes
  - Dust dominated mixture
  - Pollution dominated mixture
  - Pollution only
- We apply the $\alpha_{\text{abs}}/\delta \alpha_{\text{abs}}$ technique to the same cases and compare with backtrajectory analysis.
The \( \alpha_{abs}/\delta\alpha_{abs} \) plot shows large variability with \( \delta\alpha_{abs}>0 \) and \( \alpha_{abs}>2 \).

**Small** \( \alpha, \alpha_{abs}>2, \delta\alpha_{abs}\sim1, \) and \( \omega_0 \) of 0.94 denote strong mineral dust signature with some degree of chemical/physical interactions.

- \( \alpha_{abs}/\delta\alpha_{abs} \) plot shows majority of data points with \( \delta\alpha_{abs}>0; 1<\alpha_{abs}<2 \).
- **Large** \( \alpha, \alpha_{abs}\sim1.8, \delta\alpha_{abs}\sim0.6, \) and \( \omega_0 \) of 0.92 denote strong absorbing pollution signature.
$\alpha_{abs}/\delta\alpha_{abs}$ plots show data points with $\delta\alpha_{abs}>0$, $\delta\alpha_{abs}<0$ and variability of $a_{abs}$ values.

- Large $\alpha$, $\alpha_{abs} \sim 4$, $\delta\alpha_{abs} \sim 0.4$, and $\omega_o$ of 0.95 denote complex mixture of dust and pollution.
- Low $\delta\alpha_{abs}$ can also indicate large fraction of dust that has not reacted with pollution.
Summary

- $\delta\alpha_{\text{abs}}$ has the ability to show more variation in aerosol type and its subsequent contribution to overall AOD
- Can be used in conjunction with other parameters ($\alpha$, $\alpha_{\text{abs}}$, and $\delta\alpha$)
- Strong seasonal dependence on aerosol type
- Can be used to demonstrate chemical characteristics of aerosols
Future Work

- Develop an unsupervised aerosol classification scheme
- Utilize data from other platforms to test scheme
  - Aircraft and satellite data
  - Field Campaigns
- Determine correlation of aerosol type with adverse effects on human health
References

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Thank You
Extra Slides
Case I – Dust Case

- $\alpha_{\text{abs}}/\delta \alpha_{\text{abs}}$ plot shows majority of data points with $\delta \alpha_{\text{abs}} > 0$ and $\alpha_{\text{abs}} > 2$
  - Chemical data with $[\text{Ca}^{++}] = 272$ pptv show moderate dust loading
  - 2 of 3 trajectory lines pass through the Gobi Desert
    - 1 line passes just east of Shanghai; cluster of data points in pollution region
  - Aerosol event passes through Xianghe and Shirahama AERONET sites
    - More mineral dust influence at Xianghe and northern Japan than at Shirahama site
  - Aerosol event reaches DC-8 in Eastern Remote Pacific
    - Small $\alpha$, $\alpha_{\text{abs}} > 2$, $\delta \alpha_{\text{abs}} \sim 1$, and $\omega_0$ of 0.94 denote strong mineral dust signature with some degree of chemical/physical interaction
Case II – Pollution Case

- $\alpha_{abs}/\delta\alpha_{abs}$ plot shows majority of data points with $\delta\alpha_{abs} > 0$ and $1 < \alpha_{abs} < 2$
  - Chemical data with $[Ca^{++}] = 111$ pptv show weak dust loading
  - All 3 trajectory lines pass through large urban centers of central Asia
  - Aerosol event passes through Xianghe and Shirahama
    - AOD is higher at both sites due to mineral dust (Shirahama) and mineral dust/pollution (Xianghe)
    - Trajectory line from Taklamakan desert passes directly over Shirahama but heavy deposition between source and DC-8 aircraft ($\delta\alpha << 0$) indicates a small volume of mineral dust reaches eastern Pacific.
  - Aerosol event reaches DC-8
    - Large $\alpha$, $\alpha_{abs} \sim 1.8$, $\delta\alpha_{abs} \sim 0.6$, and $\omega_o$ of 0.92 denote strong absorbing pollution signature
Case III – Mixture (Dust Dominant)

Case IV – Mixture (Pollution Dominant)

- $\alpha_{abs}/\delta\alpha_{abs}$ plots show data points with $\delta\alpha_{abs}>0$, $\delta\alpha_{abs}<0$ and wide variability of $\alpha_{abs}$ values
  - Chemical data with $[Ca^{++}] = 843$ and 449 pptv, respectively show extreme dust loading
  - Trajectory lines pass through the Gobi and Taklamakan deserts as well as central/eastern Asia
  - Aerosol event passes through Xianghe and Shirahama
    - Pollution trajectory line passes over Shirahama
    - Dust trajectory line passes over Xianghe ($\alpha < 0$)
    - $\alpha_{abs}$ is the highest of all cases at Xianghe but lowest at Shirahama
      - Shows strong mixed nature of aerosol event
  - Aerosol event reaches DC-8
    - Large $\alpha$, $\alpha_{abs} \sim 4$, $\delta\alpha_{abs} \sim 0.4$, and $w_o$ of 0.95 denote complex mixture of dust and pollution
    - Low $\delta\alpha_{abs}$ can also indicate large fraction of dust that has not reacted with pollution