Absorption Spectral Variation to Illustrate Regional and Seasonal Asian Aerosol Variation

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Introduction

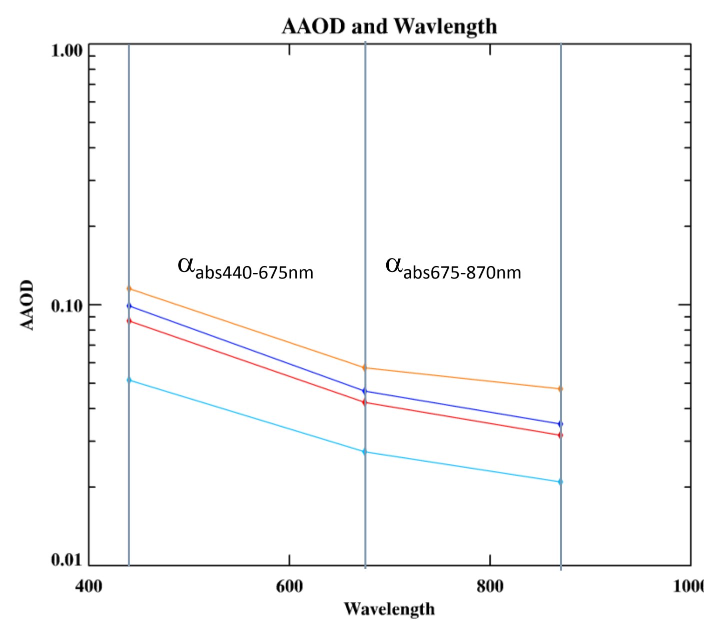
- Ongoing urbanization and industrialization in Asia contributes to many different aerosol types
  - Adds to more uncertainty in global climate
    - Which aerosol type is dominant?
    - Which aerosol type has more effects on the global radiation budget?
  - Different types of aerosols have been known to cause different types of health issues as well
    - Fine mode versus coarse mode aerosols
    - Secondary aerosols

Background

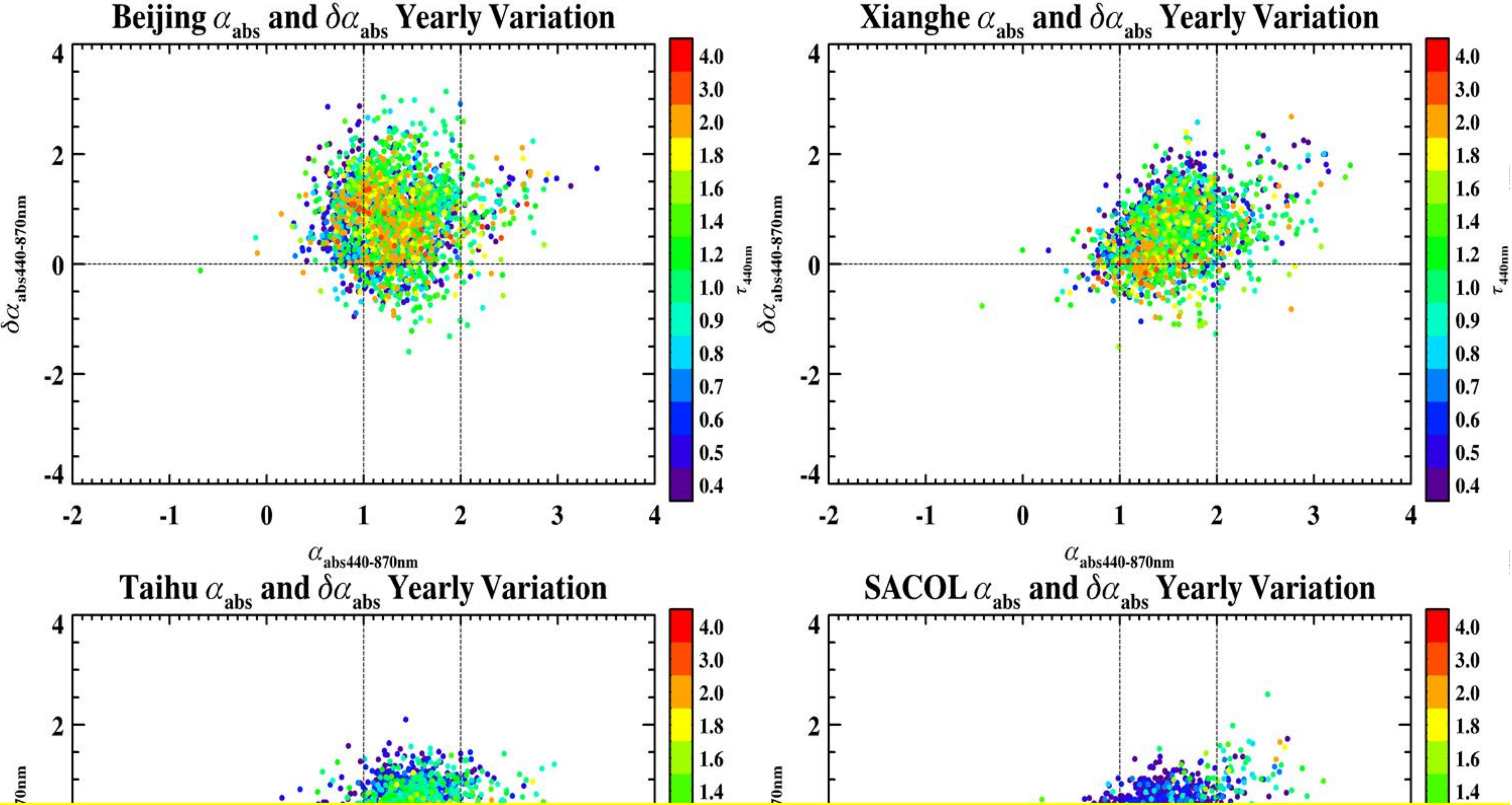
- Absorption Angstrom Exponent (α_{abs})
  - Log-slope of AAOD or τ_{abs} (440–870nm)
  - $\alpha_{abs} < 1$: pollution, aged aerosols, background aerosol type, and even instrument noise artifacts
  - $\alpha_{abs} \sim 1$: submicron black carbon (BC)
  - $1 < \alpha_{abs} < 2$: urban pollution
    - Weakly absorbing OC, sulfate and biomass aerosols
  - $\alpha_{abs} > 2$: light absorbing organic carbon and mineral dust

Background (cont'd)

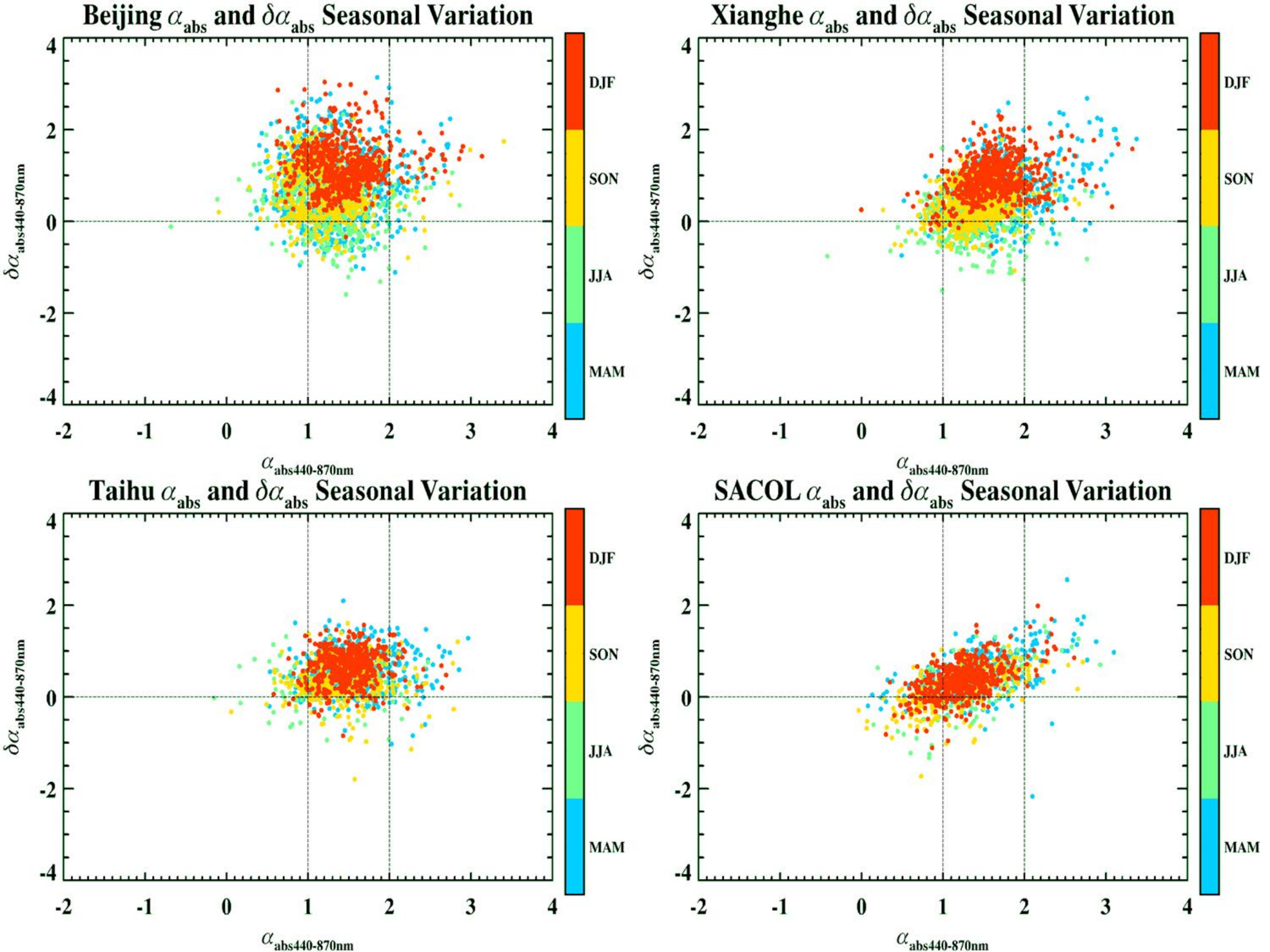
- Absorption spectral variation ($\delta\alpha_{abs}$)
  - Slope of α_{abs} between 440 and 870 nm
  - Separates strong absorbing from weak absorbing particle influences
  - $\delta\alpha_{abs} > 0$ – strong absorbing pollution aerosols
  - $\delta\alpha_{abs} < 0$ – weak absorbing pollution aerosols
  - $\delta\alpha_{abs} \sim 0$ – complex mixtures



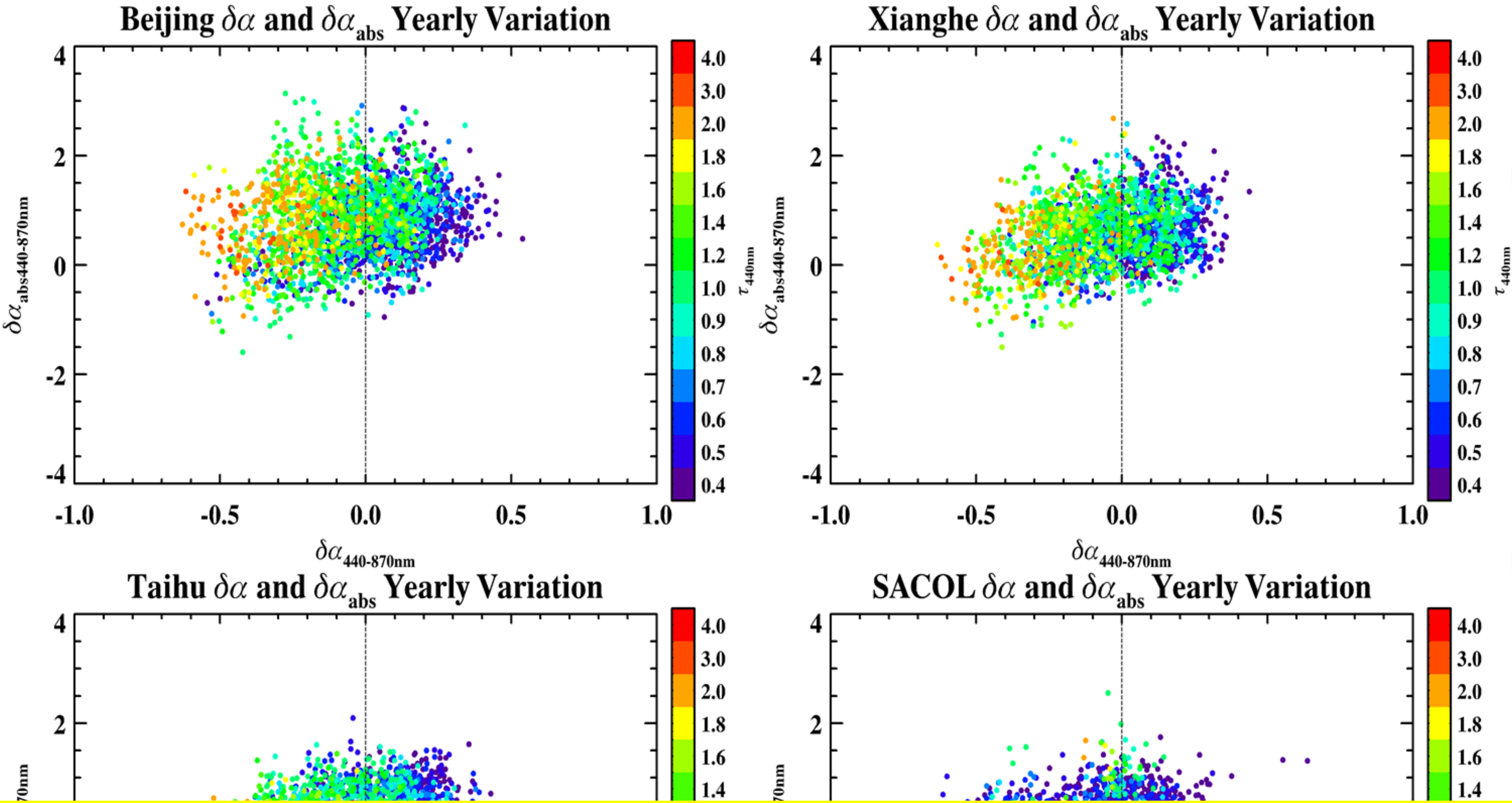

AERONET Sites
Beijing
Xianghe
SACOL
Taihu



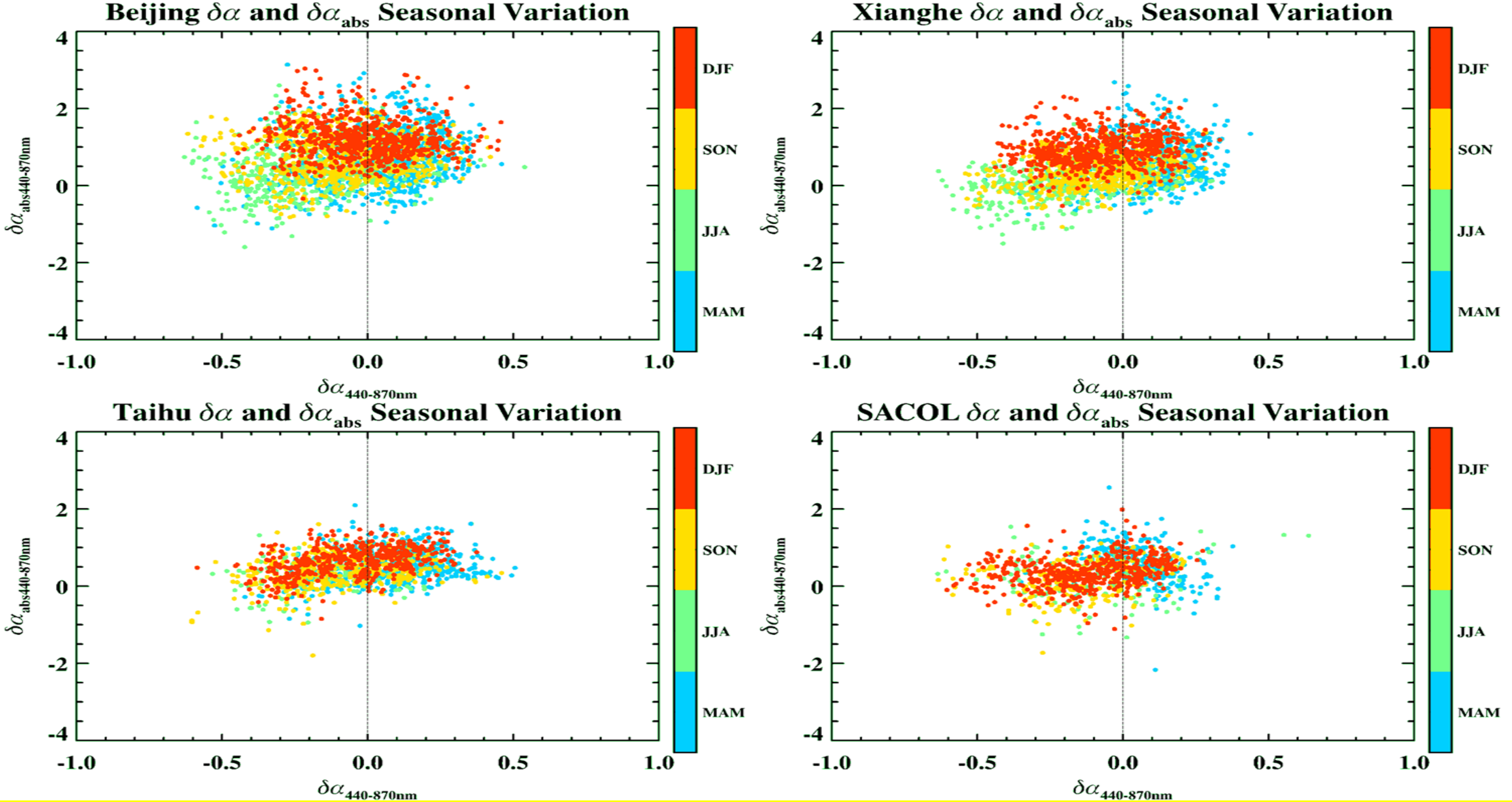
- Majority of data points fall between α_{abs} of 1 and 2 – pollution range
- Positive $\delta\alpha_{abs}$ – strong absorbing particles (major contribution)
- Negative $\delta\alpha_{abs}$ – weak absorbing particles (minor contribution)
- Dust region – $\delta\alpha_{abs} > 0$, $\alpha_{abs} > 0$



Beijing α_{abs} and $\delta\alpha_{abs}$ Seasonal Variation
Xianghe α_{abs} and $\delta\alpha_{abs}$ Seasonal Variation
Taihu α_{abs} and $\delta\alpha_{abs}$ Seasonal Variation
SACOL α_{abs} and $\delta\alpha_{abs}$ Seasonal Variation
$\delta\alpha_{abs440-870nm}$
$\alpha_{abs440-870nm}$
DJF
SON
JJA
MAM



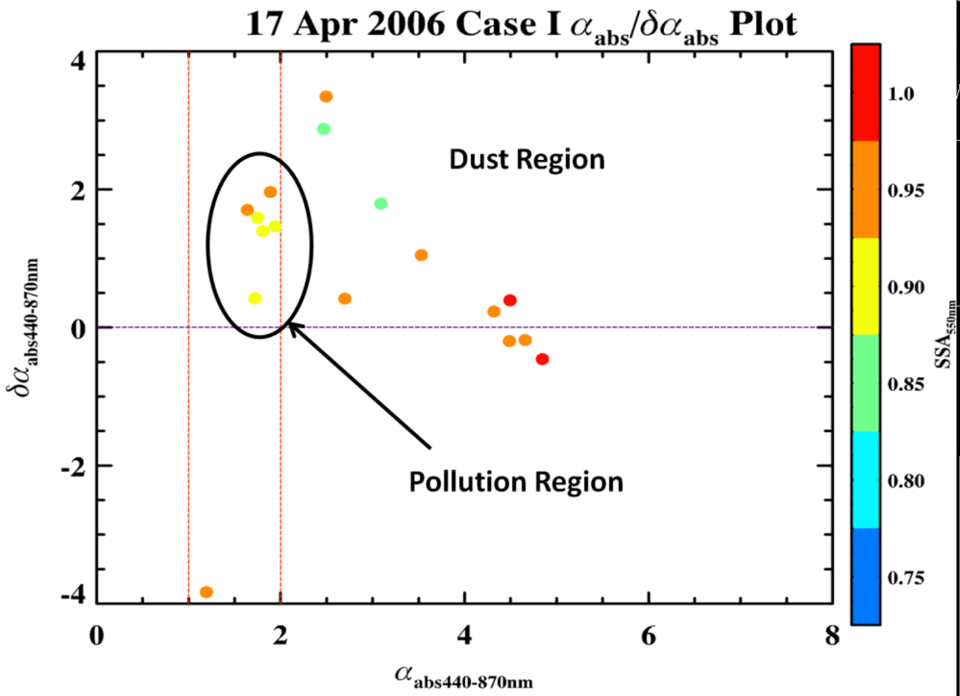
- Fine mode is correlated with large τ and $\delta\alpha_{abs} > 0$
- $\delta\alpha_{abs} < 0$ has primary contributions from fine mode and minor contribution from coarse mode
- SACOL has main contribution from coarse mode absorbing particles

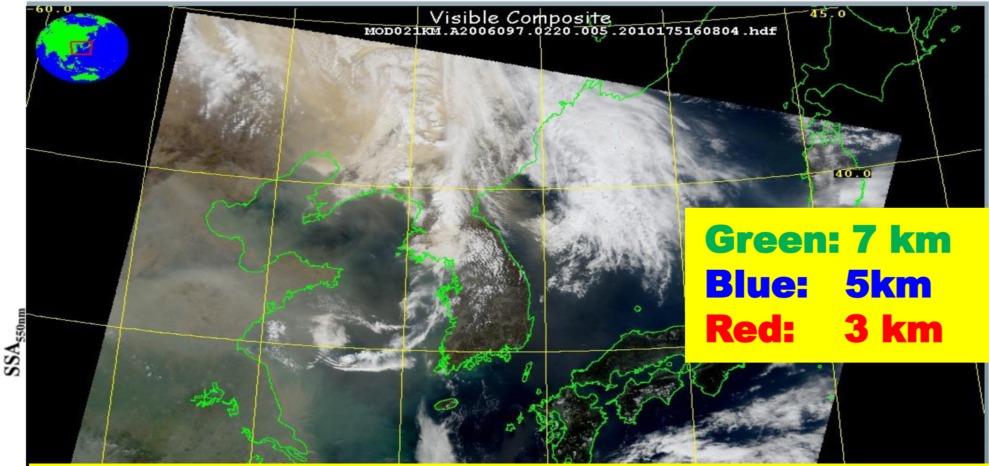


- $\delta\alpha_{abs} > 0$ associated with winter and spring months
- $\delta\alpha_{abs} < 0$ associated with summer and autumn months
- SACOL has largest variability of $\delta\alpha_{abs}$ in spring
- Beijing has largest variability overall
- Less overlap of overall aerosol variation with this method

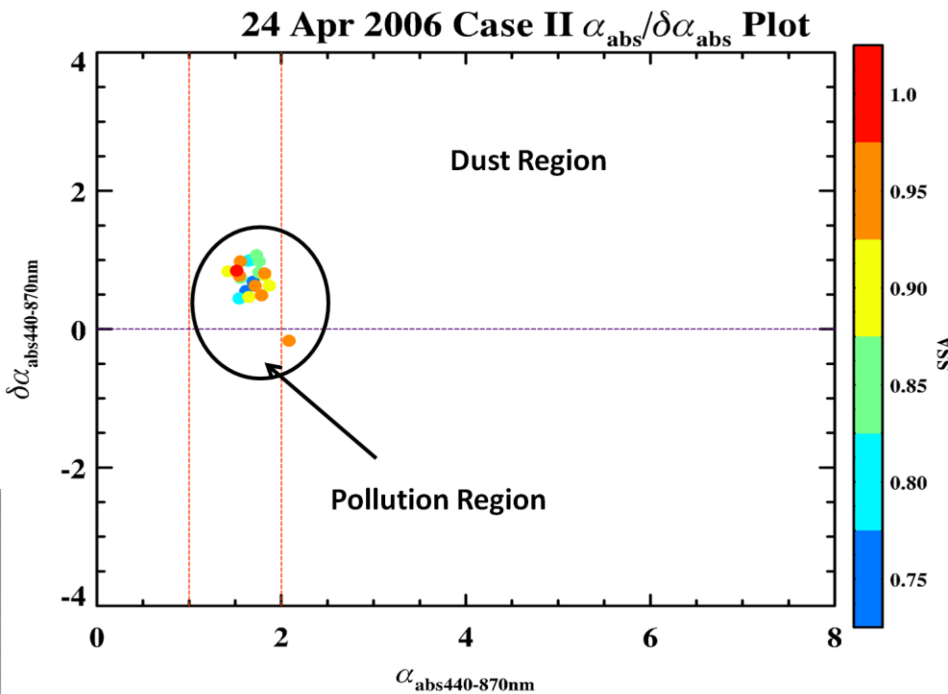
Spectral Variation–Case Study

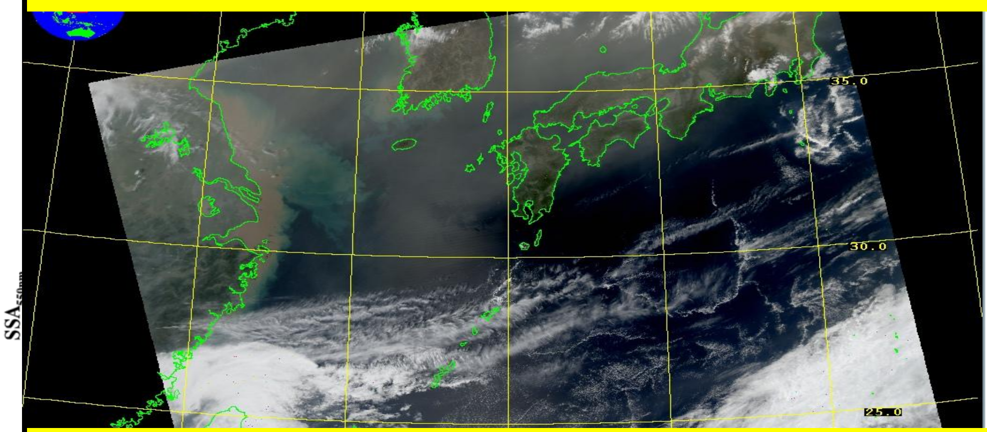
- Our previous study used $\delta\alpha$ to identify three types of aerosol plumes
  - Dust dominated mixture
  - Pollution dominated mixture
  - Pollution only
- We apply the $\alpha_{abs}/\delta\alpha_{abs}$ technique to the same cases and compare with backtrajectory analysis.



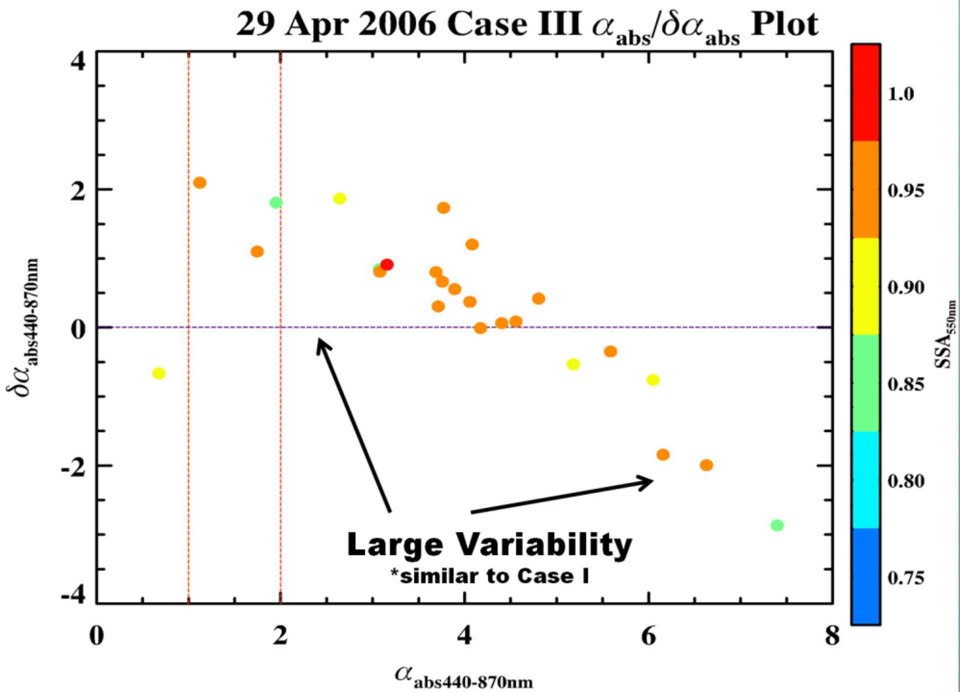


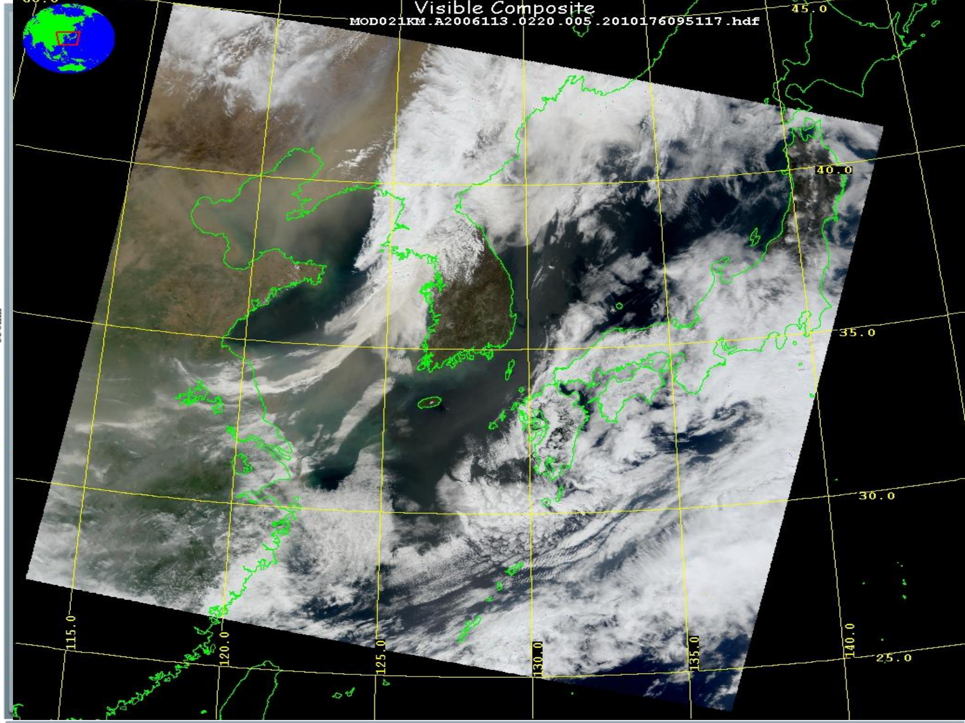
- $\alpha_{abs}/\delta\alpha_{abs}$ plot shows large variability with $\delta\alpha_{abs}>0$ and $\alpha_{abs}>2$
- Small α, $\alpha_{abs} > 2$, $\delta\alpha_{abs} \sim 1$, and ω_o of 0.94 denote strong mineral dust signature with some degree of chemical/physical interactions

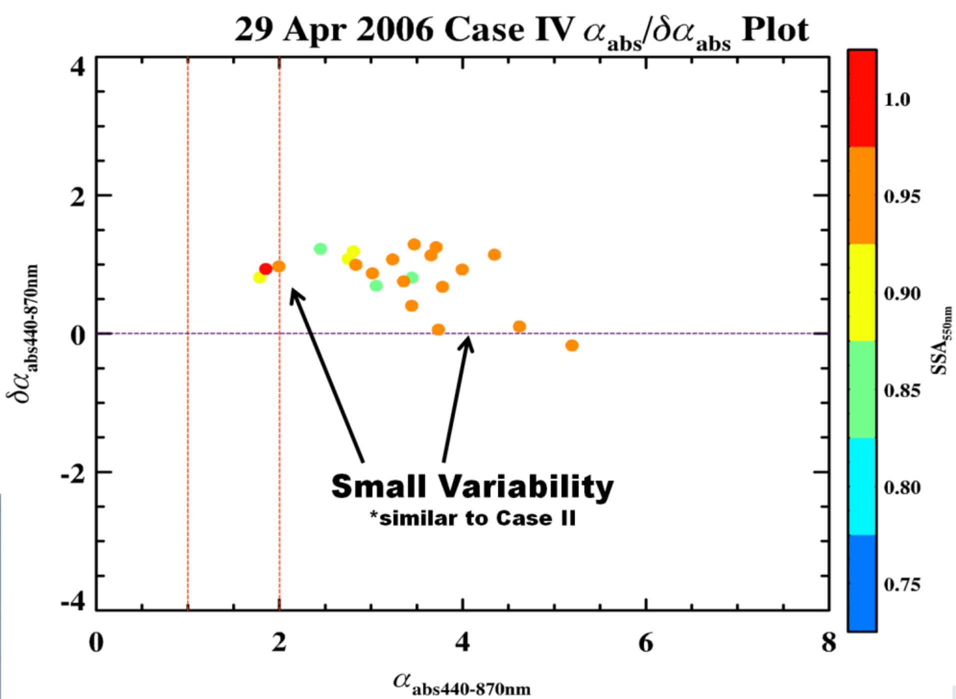


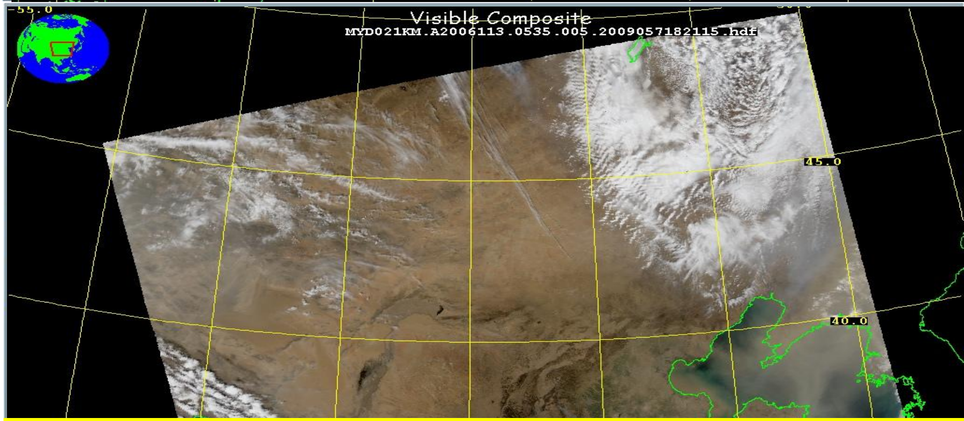


- $\alpha_{abs}/\delta\alpha_{abs}$ plot shows majority of data points with $\delta\alpha_{abs}>0$; $1 < \alpha_{abs} < 2$
- Large α, $\alpha_{abs} \sim 1.8$, $\delta\alpha_{abs} \sim 0.6$, and ω_o of 0.92 denote strong absorbing pollution signature









- **$\alpha_{abs}/\delta\alpha_{abs}$ plots show data points with $\delta\alpha_{abs}>0$, $\delta\alpha_{abs}<0$ and variability of a_{abs} values**
- **Large α, α_{abs} ~ 4, $\delta\alpha_{abs}$ ~ 0.4, and ω_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

- $\delta\alpha_{abs}$ 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 (α, α_{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

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Thank You

Extra Slides

Case I – Dust Case

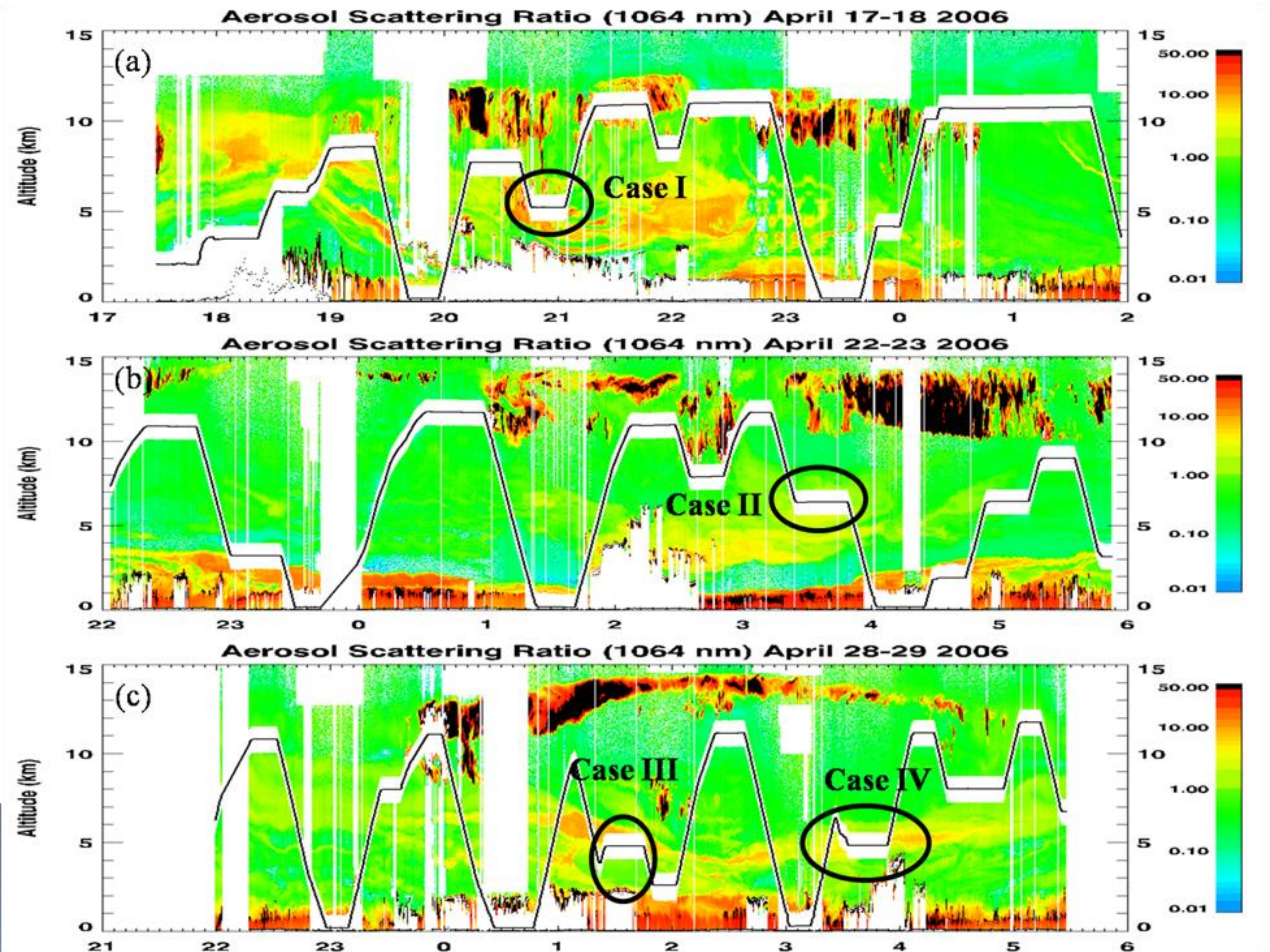
- $\alpha_{abs}/\delta\alpha_{abs}$ **plot shows majority of data points with** $\delta\alpha_{abs}>0$ **and** $\alpha_{abs}>2$
  - **Chemical data with $[Ca^{++}]$ = 272 pptv show moderate dust loading**
  - **2 of 3 trajectory lines pass through the Gobi Desert**
    - **1 line passes just east of 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** α, $\alpha_{abs} > 2$, $\delta\alpha_{abs} \sim 1$, **and** ω_o **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 ($\delta\alpha \ll 0$) indicates a small volume of mineral dust reaches eastern Pacific.**
  - **Aerosol event reaches DC-8**
    - **Large** α, $\alpha_{abs} \sim 1.8$, $\delta\alpha_{abs} \sim 0.6$, **and** ω_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** α_{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** ($\alpha < 0$)
    - α_{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** α, α_{abs} ~ 4, $\delta\alpha_{abs}$ ~ 0.4, and ω_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**



Aerosol Scattering Ratio (1064 nm) April 17-18 2006
(a)
Case I
Altitude (km)
Aerosol Scattering Ratio (1064 nm) April 22-23 2006
(b)
Case II
Altitude (km)
Aerosol Scattering Ratio (1064 nm) April 28-29 2006
(c)
Case III
Case IV
Altitude (km)
50.00
10.00
1.00
0.10
0.01