What Can TCAP Observations Tell Us about Temporal Aerosol Changes and Their Impact on Daily Radiative Forcing?

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1. Motivation

- The eastern coast of North America is an area that is strongly affected by anthropogenic and natural aerosol.
- The large variation among the model predictions of *direct aerosol radiative forcing* (*DARF*) for this coastal region has motivated the recent (2012-2013) ***Two-Column Aerosol Project*** (***TCAP***), with focus on the temporal changes of chemical, microphysical and optical properties of aerosol and their impact on the DARF.
- Commonly, observational-based calculations of *daily average* DARF involve "constant aerosol properties" assumption: aerosol properties are assumed either constant or do not vary strongly during a given day.

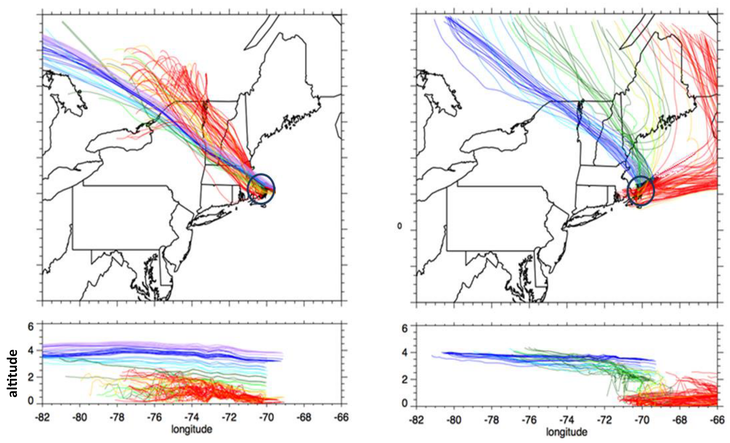

Fig. 1. Example of WRF-simulated air mass back-trajectories passing over **Cape Cod** (circle) at different altitudes ranging from 0 to 5 km (identified by different colors) for two days: 17 July (left) and 22 July (right).

2. Ground-based Measurements

- During TCAP, the ground-based ***Atmospheric Radiation Measurement*** (***ARM***) ***Mobile Facility*** (***AMF***) was deployed on **Cape Cod** (**Fig. 1**), which is generally downwind of large metropolitan areas including Boston, Massachusetts.
- The AMF site (41.87°N; 70.28°W) was equipped with a suite of instruments (**Fig. 2**) for sampling aerosol, cloud and radiative properties, including a Multi-Filter Rotating Shadowband Radiometer (MFRSR), a Scanning Mobility Particle Sizer (SMPS), an Aerodynamic Particle Sizer (APS), Aerosol Chemical Speciation Monitor (ACSM) and a three-wavelength nephelometer.

Fig. 2. Images of the AMF site with a suite of instruments from the air (top) and ground (bottom).

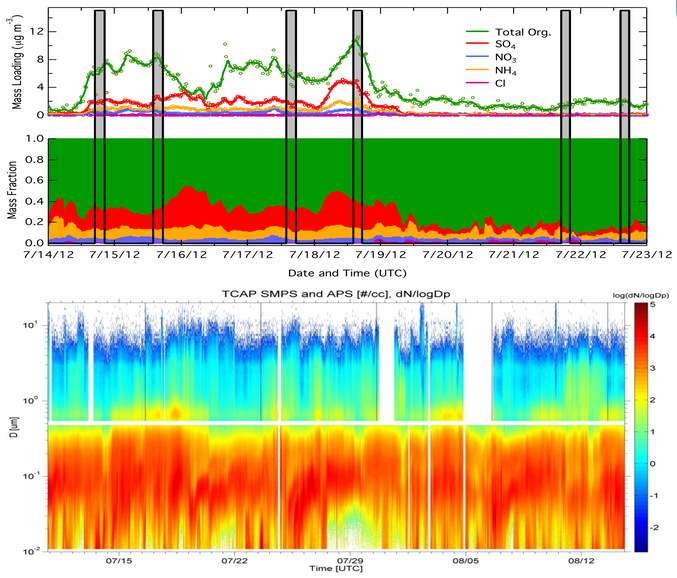

Fig. 3. Time series of ACSM chemical properties – mass loading and mass fraction (top panel) and combined SMPS-APS number size distributions (bottom panel). The shading indicates complementary aircraft flight periods (top panel).

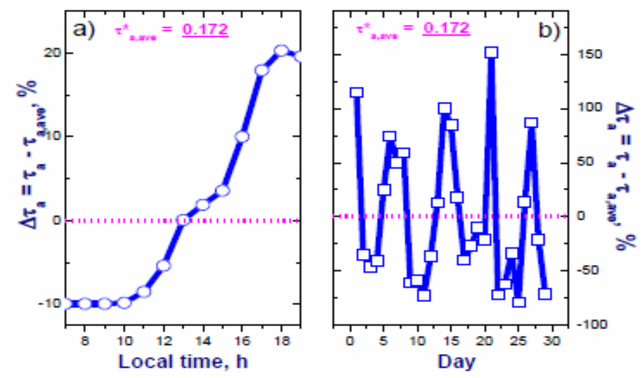

Fig. 4. Average diurnal (a) and day-to-day (b) variability of MFRSR aerosol optical depth τ_a at 0.5μm wavelength as percent departure from the 29-day average aerosol optical depth ($\tau^*_{a,\,ave}$).

4. Summary

- Diurnal changes of aerosol optical depth observed on Cape Cod during the TCAP are strong (*Kassianov et al*., 2013).
- Errors in the 24-h average DARF associated with under-sampled diurnal changes (e.g., morning only) of aerosol properties can be large (up to 100%). An accurate prediction of 24-h average DARF should involve data collected before and after local noon.
- Accurate 24-h average DARF can improve observational-based DARF estimates at climatologically relevant time scales ranging from months to years. These estimates are an important constraint for model predictions of aerosol impact on Earth's radiation budget.

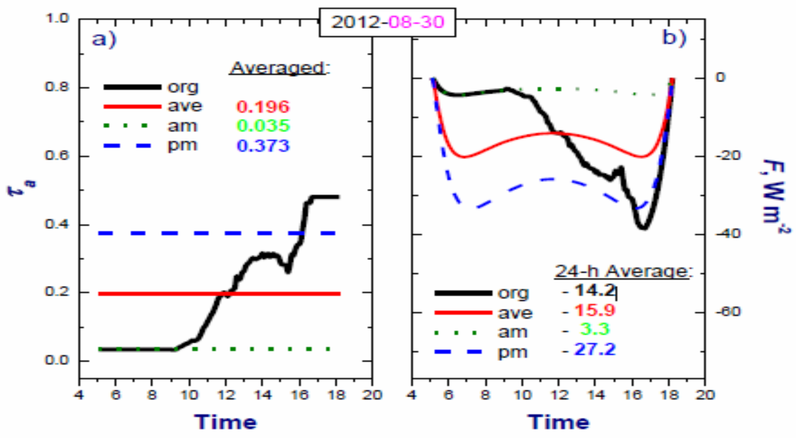

Fig. 5. Time series of the original (black), daily-averaged (red), morning-averaged (green) and evening-averaged (blue) τ_a values (a), and the corresponding instantaneous DARF values (b). The 24-h average DARFs are also included (b).

3. Temporal Changes

- The *near-surface* aerosol chemical and microphysical properties (**Fig. 3**) and optical properties (not shown) do not reveal noticeable diurnal changes. In contrast, the aerosol optical depth τ_a shows large diurnal (~30% range on average) and day-to-day (up to 150%) changes (**Fig. 4**). The same is true for the corresponding DARFs (**Fig. 5**).
- Results obtained for all phase 1 TCAP days (*Kassianov et al*., 2013) illustrate importance of sampling issue: aerosol properties sampled in the morning/evening may not be representative of conditions over the entire day of interest (e.g., "am" versus "pm"; **Fig. 5**). Thus, a reliable estimation of the 24-h DARF may be thwarted (**Fig. 5**) by data (e.g., MODIS/AERONET) with *incomplete* temporal coverage .

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Reference:
Kassianov, E., and co-authors, 2013: *Do diurnal aerosol changes affect daily average radiative forcing*? **GRL**