

Supporting Information for "Aitken Mode Aerosols Buffer Decoupled Mid-latitude Boundary Layer Clouds Against Precipitation Depletion"

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Contents of this file

1. Table S1
2. Figures S1 to S8

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Table S1. Initial Aerosol Profiles for Simulations of ACE-ENA RF16 on July 15, 2017

Simulation	<i>Ctrl</i>	<i>HfAc</i>	<i>NoAit</i>	<i>HfAcNoAit</i>
Aitken Number (mg^{-1})				
<i>Free Troposphere</i>	236.3	236.3	0.5	0.5
<i>Transition</i>	87.2	87.2	0.2	0.2
<i>Surface</i>	102.8	102.8	0.2	0.2
Aitken Mass ($kg\ kg^{-1}$)				
<i>Free Troposphere</i>	3.80×10^{-11}	3.80×10^{-11}	7.60×10^{-14}	7.60×10^{-14}
<i>Transition</i>	1.89×10^{-11}	1.89×10^{-11}	3.80×10^{-14}	3.80×10^{-14}
<i>Surface</i>	2.73×10^{-11}	2.73×10^{-11}	5.46×10^{-14}	5.46×10^{-14}
Aitken Diameter (nm)				
<i>Free Troposphere</i>	50.2	50.2	50.2	50.2
<i>Transition</i>	55.5	55.5	55.5	55.5
<i>Surface</i>	59.4	59.4	59.4	59.4
Accum. Number (mg^{-1})				
<i>Free Troposphere</i>	41.1	20.6	41.1	20.6
<i>Transition</i>	44.3	22.2	44.3	22.2
<i>Surface</i>	66.3	33.2	66.3	33.2
Accum. Mass ($kg\ kg^{-1}$)				
<i>Free Troposphere</i>	2.23×10^{-10}	1.12×10^{-10}	2.23×10^{-10}	1.12×10^{-10}
<i>Transition</i>	3.80×10^{-10}	1.90×10^{-10}	3.80×10^{-10}	1.90×10^{-10}
<i>Surface</i>	6.18×10^{-10}	3.09×10^{-10}	6.18×10^{-10}	3.09×10^{-10}
Accum. Diameter (nm)				
<i>Free Troposphere</i>	151.9	151.9	151.9	151.9
<i>Transition</i>	176.9	176.9	176.9	176.9
<i>Surface</i>	181.9	181.9	181.9	181.9
Layers: <i>Surface</i> is 0-500m, <i>Transition</i> is 500-1200m, <i>Free Troposphere</i> is ≥ 1500 m				

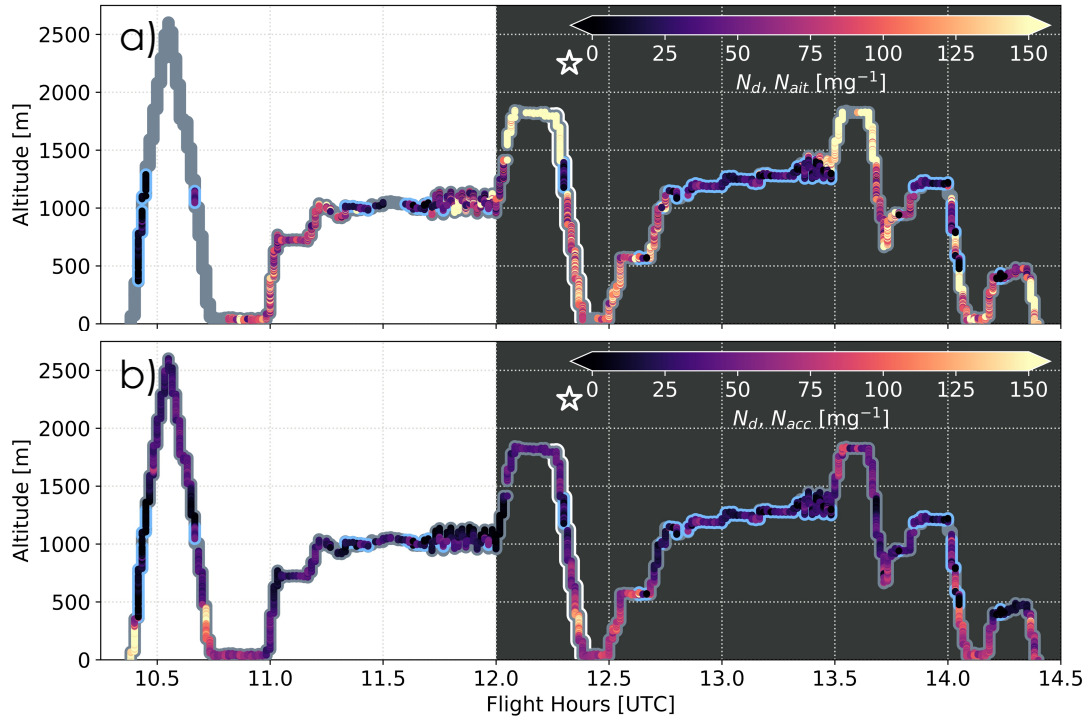


Figure S1. Altitude vs. time for RF16 as in Figure 1b but for a) Aitken and b) accumulation out-of-cloud aerosol number concentrations along with in-cloud droplet number concentration.

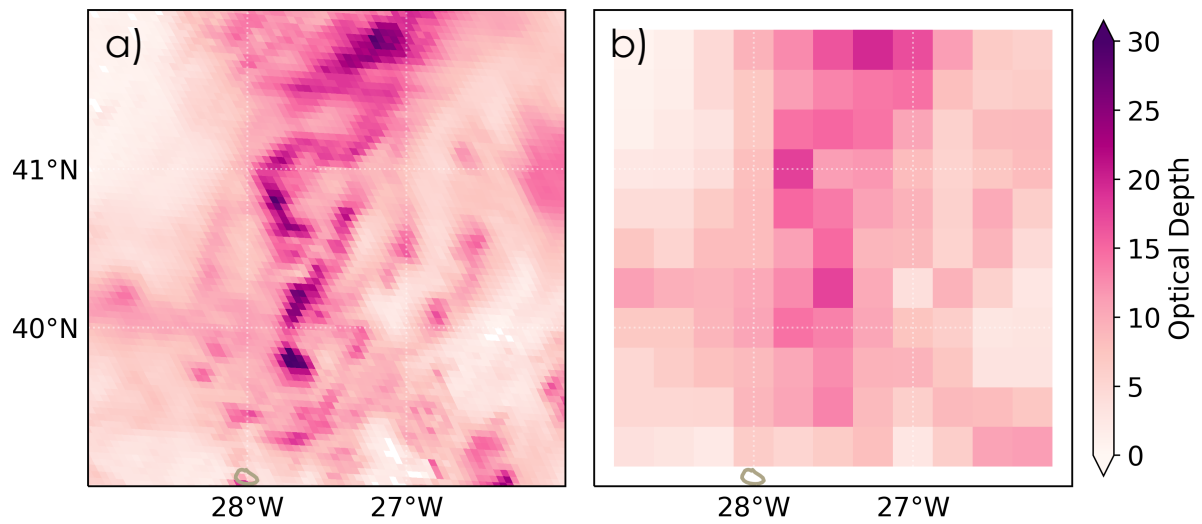


Figure S2. Example of satellite retrieval analysis using optical depth as an illustration: a) native ~ 3 km resolution and b) means computed for each $0.25 \times 0.25^\circ$ subdomain.

July 5, 2023, 8:55pm

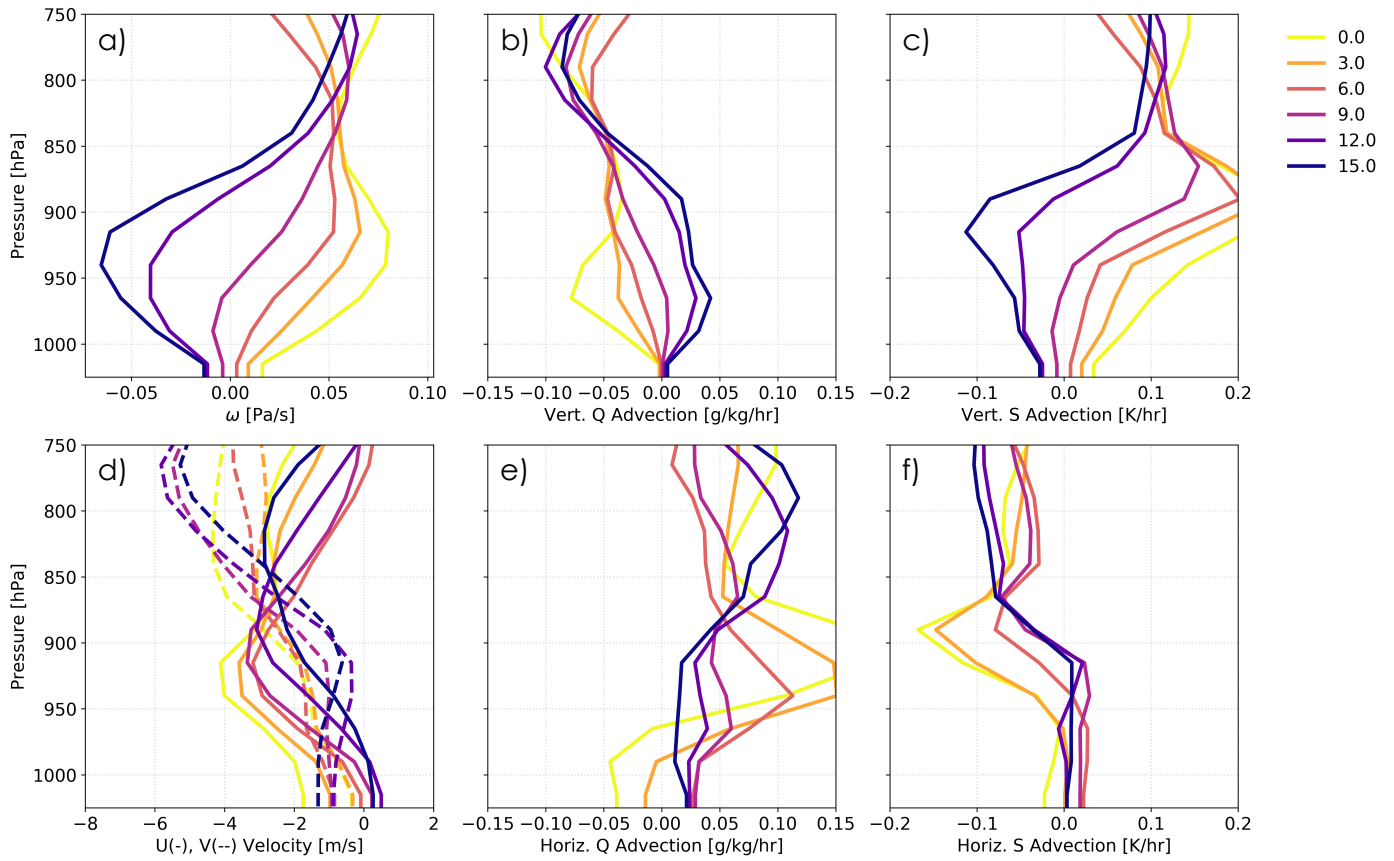


Figure S3. ERA5 soundings and forcings extracted for the ACE-ENA campaign: a) vertical velocity in pressure units, b) vertical water vapor advection, c) vertical sensible heat advection, d) u and v components of velocity, e) horizontal water vapor advection, and f) horizontal sensible heat advection. Lines are colored by hours in UTC.

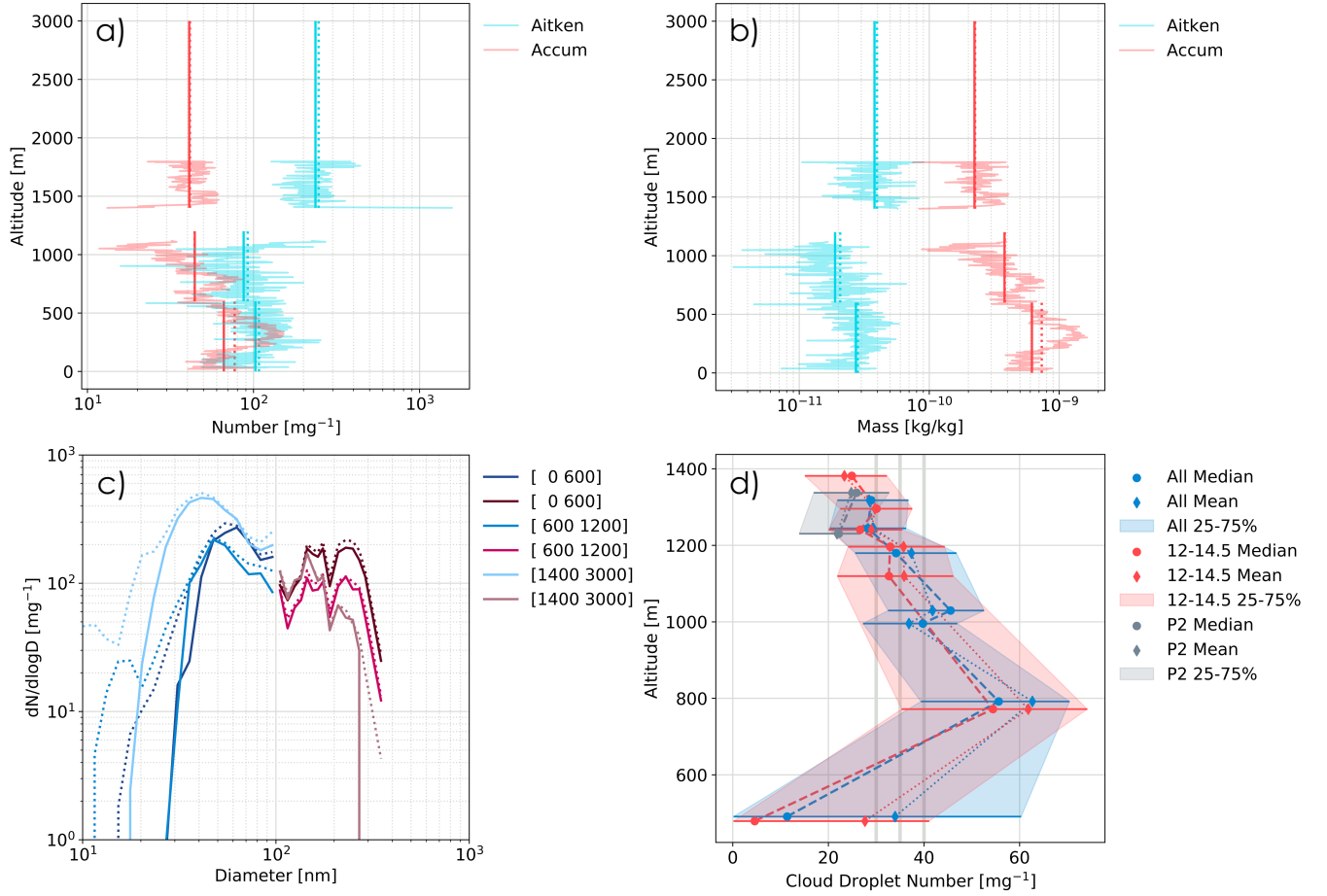


Figure S4. Developing initial aerosol and cloud droplet number concentration values used to observationally constrain SAM case study. Aitken (blue) and accumulation (red) aerosol a) number concentration and b) mass profiles from observational flight Profile 2. Median (solid) and mean (dashed) values are shown as thicker vertical lines for three reference layers: 0-600, 600-1200, and 1400-3000m (see Table S1 for values). c) Corresponding size distributions for these three layers for the Aitken (blues) and accumulation (reds) size ranges. d) Cloud droplet number concentration for median, mean, and 25-75 percentiles for all observational data (blue), model-observation comparison period (red), and Profile 2 (gray). Thicker grey reference lines are shown for N_d of 30, 35, and 40 mg^{-1}

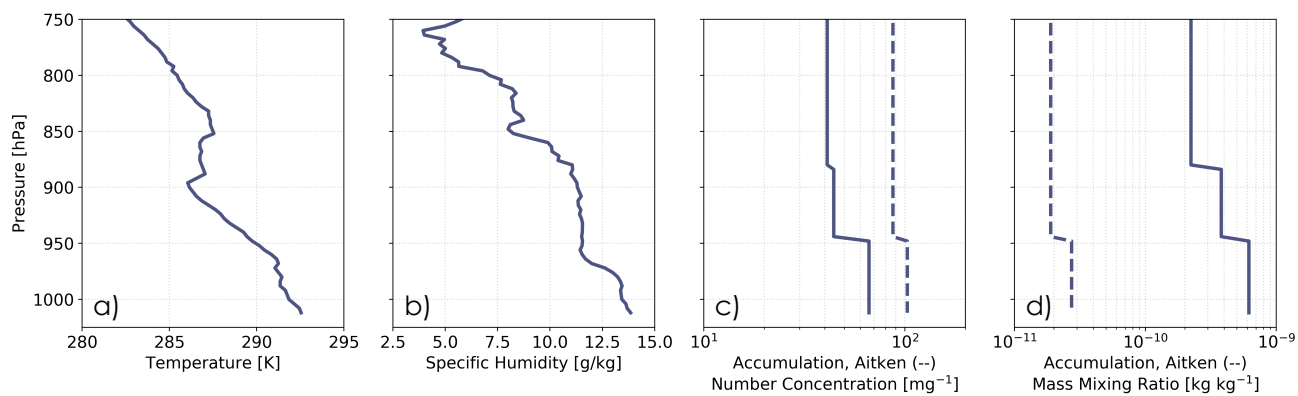


Figure S5. Profiles developed from ERA5 reanalysis, ENA site soundings, and observations that are used to initialize a) temperature, b) moisture, and aerosol c) number concentrations and d) mass mixing ratios for accumulation and Aitken modes.

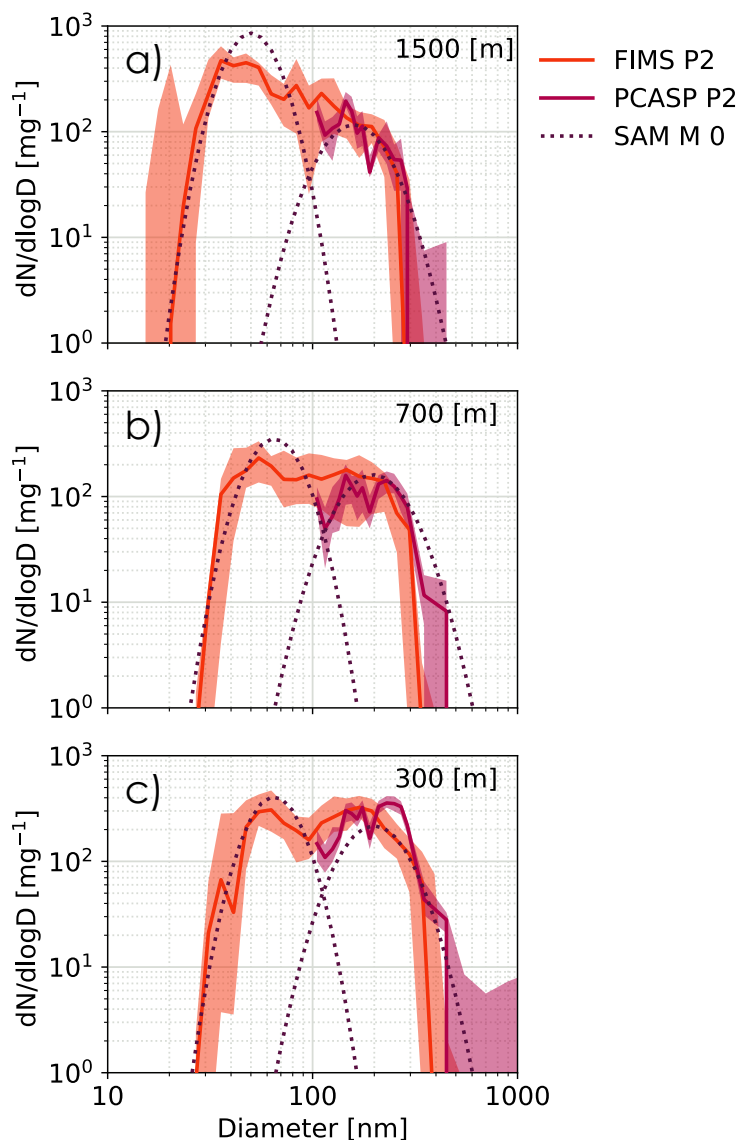


Figure S6. As in Figure 4 but showing observations only from Profile 2 (P2) and the initial aerosol modes used in the model (purple dashed). P2 is the aerosol profile used to develop aerosol initialization for the Ctrl SAM case. Model modes are shown separately to illustrate differences in modal width and behavior and to illustrate agreement with *in situ* aerosol from P2. Observations are within 100 m of the labeled SAM altitude level. Observations are included from two instruments: the FIMS (orange) and the PCASP (pink) which, respectively, resolve the majority of the Aitken and Accumulation mode sizes. *In situ* values are shown as median (solid) and 25-75% (shading) over P2.

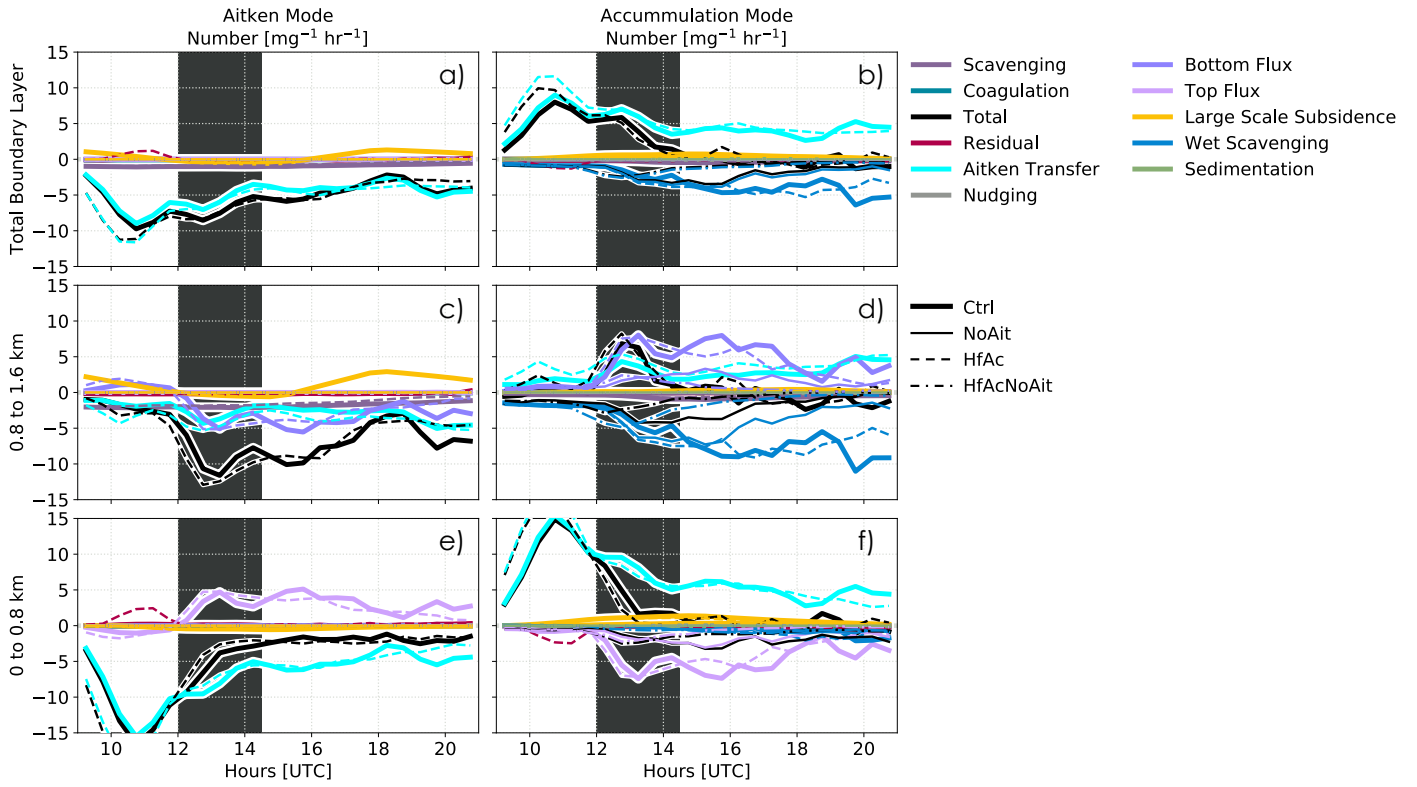


Figure S7. All budget terms contributing to the Aitken (a, c, e) and accumulation (b, d, f) number evolution over time. Budgets are separated into total (a-b), 0.8-1.6 km (c-d), and 0-0.8 km (e-f). Line appearance for sensitivity studies (*NoAit*, *HfAc*, *HfAcNoAit*) are detailed in the legend in addition to the *Ctrl*. The observational comparison period (12-14:30 UTC) is shaded grey.

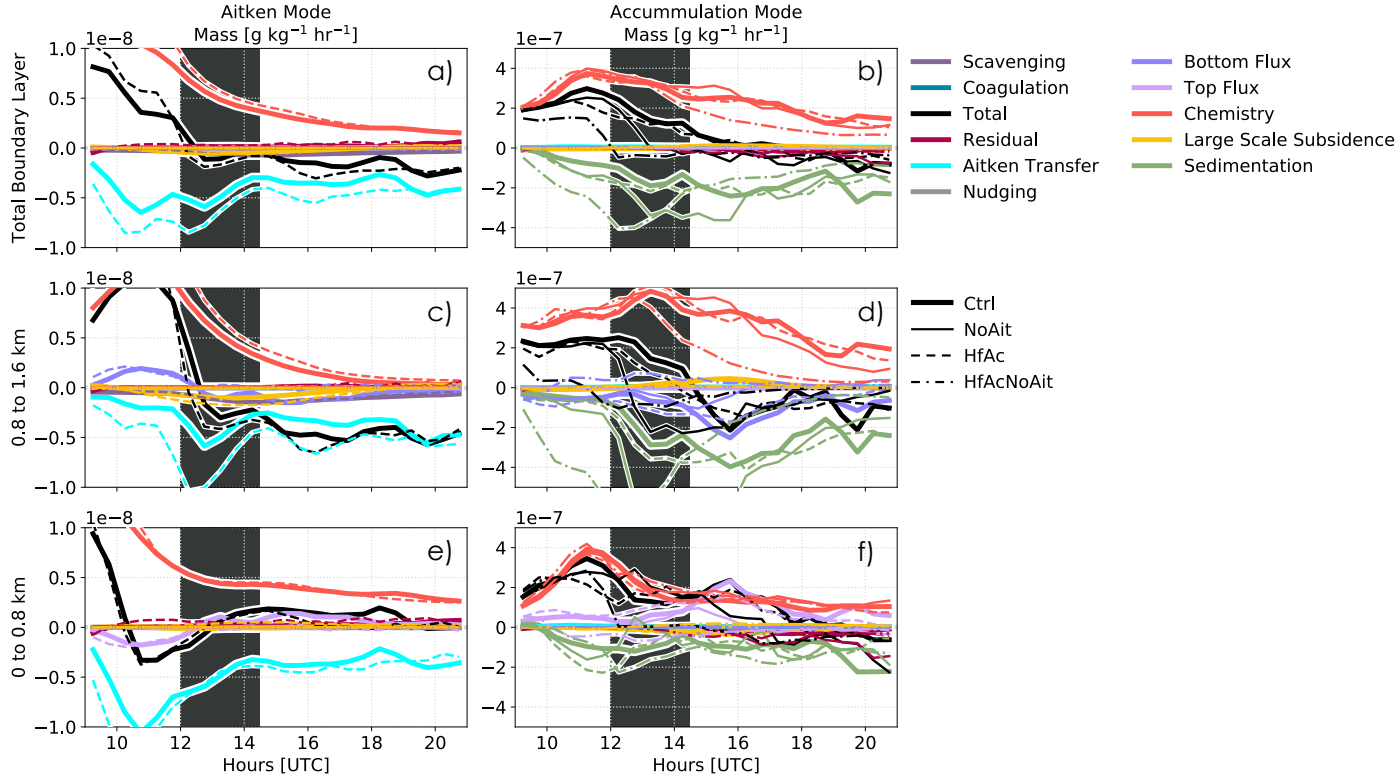


Figure S8. As in Figure S7 but for all budget terms contributing to the Aitken (a, c, e) and accumulation (b, d, f) mass evolution over time. Note Aitken mass contributions are shown on a different scale than the accumulation as they are much smaller.