

1 *Supplement of*

2 **Clarifying the controlling factors of the seasonal variation of**
3 **droplet concentrations in marine low-level clouds**

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Table S1. Summary of G-1 aircraft sampling dates, time periods, weather conditions, and horizontal flight patterns used in this study. The descriptions of weather/cloud conditions and flight patterns are based on Wang et al. (2022).

Flight name	Date	Time period (UTC)	Weather/cloud conditions	Flight pattern
IOP1, 8	3 July 2017	11:00–13:39	Drizzling stratocumulus is associated with a cold frontal passage.	60-km legs near the ENA site
IOP1, 9	4 July 2017	09:02–11:38	Scattered cumulus clouds with a well-developed, but relatively dry boundary layer.	Lagrangian drift near the ENA site
IOP1, 10	6 July 2017	08:52–11:32	Solid stratocumulus cloud deck with embedded drizzle patches. Decoupled boundary layer (~1.5 km) deepening over the course of the day.	L-shaped legs near the ENA site
IOP1, 13	11 July 2017	10:35–13:32	Multilayer thick stratocumulus with drizzle and virga. Deepening boundary layer over the course of the day.	L-shaped legs near the ENA site
IOP1, 17	17 July 2017	10:20–12:44	Mixed cumulus and stratocumulus clouds. Early morning frontal passage followed by clearing and increasing winds.	L-shaped legs near the ENA site
IOP1, 19	19 July 2017	10:20–12:52	Deep, drizzling, dissipating cloud layer. Surface high pressure to the west of the Azores, but localized low pressure resulting in a deeper boundary layer at the ENA site.	L-shaped legs near the ENA site
IOP2, 2	21 January 2018	11:38–12:45	Deeper cumulus and pockets of open cells. Clouds are developing ahead of an approaching, quasi-stationary front.	L-shaped legs east of Lajes
IOP2, 3	24 January 2018	13:26–16:15	Multilayer stratus and drizzling open cells. Postfrontal event, approaching high pressure.	L-shaped legs near the ENA site
IOP2, 5	26 January 2018	11:30–14:35	Single-layer stratocumulus. The Azores are strongly influenced by surface high pressure whose center is to the northwest. Well-established subsidence inversion.	Lagrangian drift south of Lajes
IOP2, 6	28 January 2018	10:07–13:02	Scattered cumulus with open cells. High pressure is slowly moving in over the Azores.	Lagrangian drift south of Lajes
IOP2, 7	29 January 2018	10:01–13:07	Thin multi-layer stratocumulus. Complex synoptic context due to various boundaries, air masses located under and being advected by the high pressure.	L-shaped legs near the ENA site
IOP2, 9	1 February 2018	11:22–12:22	Thin dissipating stratus. Surface anticyclone holding steady with the Azores south/southeast of its center.	L-shaped legs near the ENA site
IOP2, 11	8 February 2018	13:22–16:46	Multilayer stratocumulus. The Azores high is situated to the west	L-shaped legs near the ENA site

			of the Azores, with light northerly flow over the islands.	
IOP2, 12	9 February 2018	13:06–14:48	Mixed cloud field, drizzling stratocumulus and cumulus. The Azores high is centered to the west-southwest of the islands, with lower-level winds from the west.	L-shaped legs near the ENA site
IOP2, 15	12 February 2018	11:36–14:34	Thin stratus. Strong inversion, trending more robust with time.	L-shaped legs near the ENA site
IOP2, 16	15 February 2018	13:26–15:02	Cumulus with some precipitation. Mission to intercept open cell cold air outbreak (CAO) conditions to the north of the ENA site.	60-km legs at multiple levels near the ENA site

Table S2. List of measurement parameters, instrumentation, and time resolution. The descriptions of instruments and units are based on Wang et al. (2022).

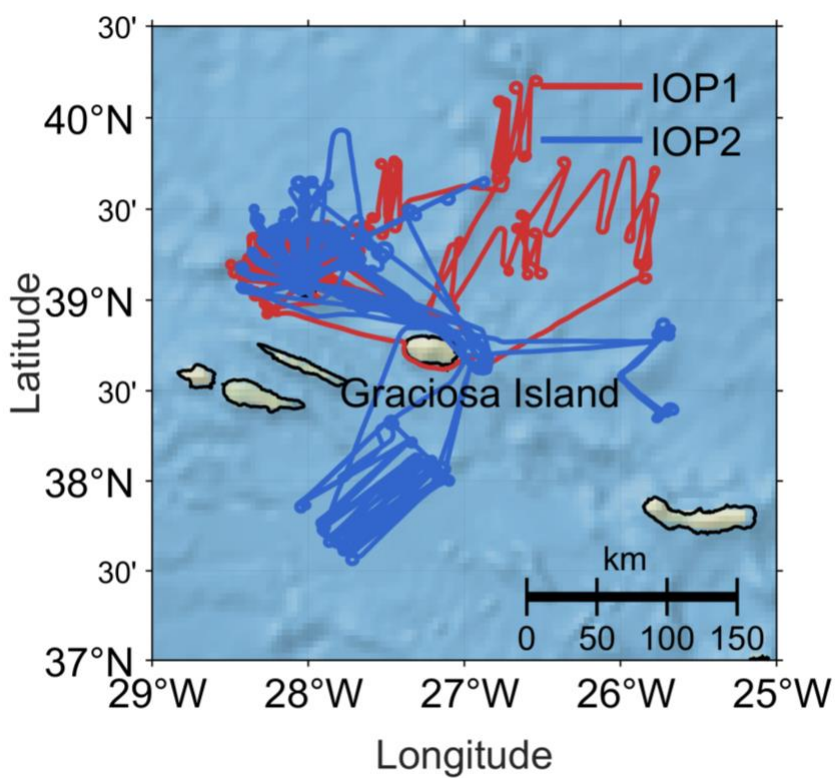
Parameters	Symbols	Instrument	Details / Resolution	Units	Site
Potential temperature	θ	Balloon-borne sounding system (Radiosondes; Vaisala RS92)	1 s or 5 m/s	K	ENA site
Water vapor mixing ratio	WV	Balloon-borne sounding system (Radiosondes; Vaisala RS92)	1 s or 5 m/s	g kg^{-1}	ENA site
Aitken mode aerosol number concentration	$N_{\text{ait-G}}$	Scanning Mobility Particle Sizer (SMPS, model 3938)	4 min	cm^{-3}	ENA site
Accumulation mode aerosol number concentration	$N_{\text{acc-G}}$	Scanning Mobility Particle Sizer (SMPS, model 3938)	4 min	cm^{-3}	ENA site
Particle number size distribution	PNSD_G	Scanning Mobility Particle Sizer (SMPS, model 3938)	4 min; size range: 10–500 nm	cm^{-3}	ENA site
Particle hygroscopicity	κ	Size-resolved cloud condensation nuclei counter measurement system (SCCN, Mei et al., 2013)	1–2 h; dry diameters: 40, 50, 75, 100, 150 nm	–	ENA site
Particle number concentration	$N_{10\text{nm-A}}$	Condensation Particle Counter (CPC)	1 s	cm^{-3}	G-1 aircraft
Particle number concentration	$N_{\text{FIMS-A}}$	Fast Integrated Mobility Spectrometer (FIMS, BNL)	1 s	cm^{-3}	G-1 aircraft
Aitken mode aerosol number concentration	$N_{\text{ait-A}}$	Fast Integrated Mobility Spectrometer (FIMS, BNL)	1 s	cm^{-3}	G-1 aircraft
Accumulation mode aerosol number concentration	$N_{\text{acc-A}}$	Fast Integrated Mobility Spectrometer (FIMS, BNL)	1 s	cm^{-3}	G-1 aircraft
Particle number size distribution	PNSD_A	Fast Integrated Mobility Spectrometer (FIMS, BNL)	1 s size range: 10–500 nm (isokinetic inlet)	cm^{-3}	G-1 aircraft
Liquid water content	LWC	Fast-Cloud Droplet Probe (FCDP, SPEC Inc.)	0.01 s (100 Hz)	g m^{-3}	G-1 aircraft
Cloud droplet number concentration	N_d	Fast-Cloud Droplet Probe (FCDP, SPEC Inc.)	1 s and 0.1 s size range: 2–50 μm	cm^{-3}	G-1 aircraft

24 **Table S3.** Summary of weighted values of factors controlling aerosol–cloud interactions during summer and winter.

Values	w	κ_{ait}	κ_{acc}	N_{ait}	N_{acc}	μ_{ait}	μ_{acc}	$\log_{10}\sigma_{\text{ait}}$	$\log_{10}\sigma_{\text{acc}}$
Summer (median values)	0.16	0.49	0.56	204.81	240.92	57.18	155.47	1.35	1.53
Winter (median values)	0.24	0.50	0.63	49.54	33.48	37.08	161.21	1.40	1.45

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28 **Figure S1.** Flight tracks of the G-1 research aircraft during summer (IOP 1) and winter (IOP 2).

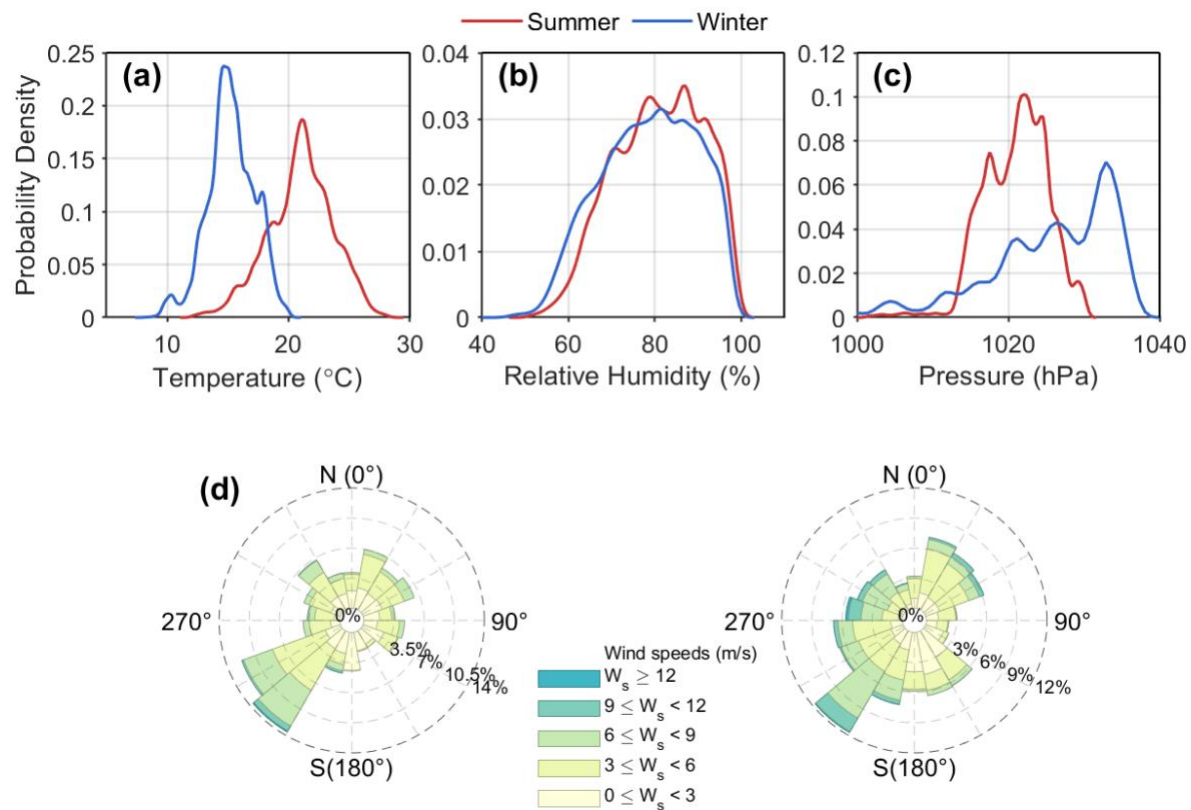


Figure S2. Probability density functions (PDFs) of 2-m temperature, 2-m relative humidity, and sea level pressure measured at the ENA site during summer (red lines) and winter (blue lines). Wind roses show surface wind conditions for summer (left, June to August 2017) and winter (right, December 2017 to February 2018).

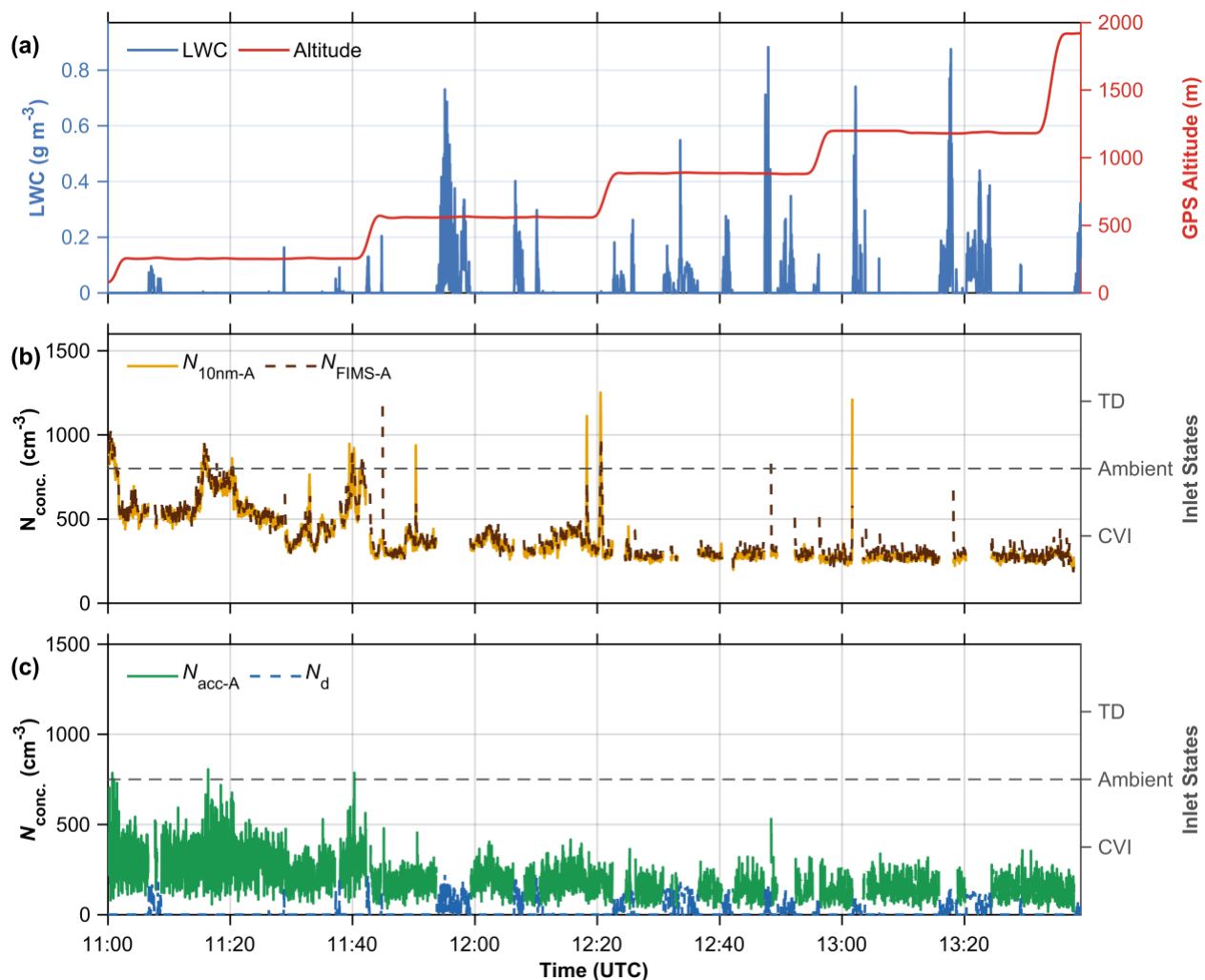


Figure S3. Time series of relevant measurements onboard the G-1 aircraft during the marine boundary layer event observed on IOP1, 8 (3 July 2017). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

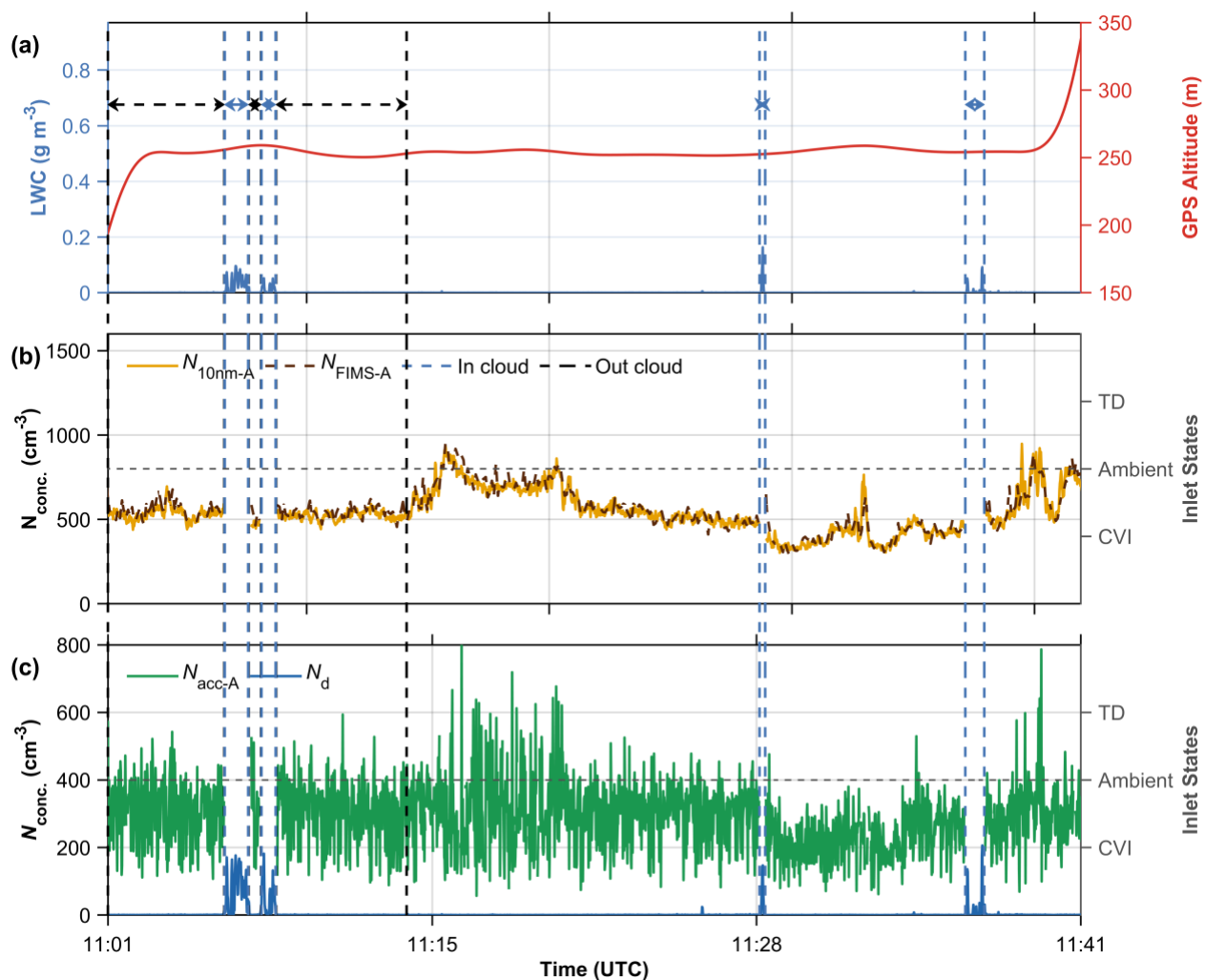


Figure S4. Time series of G-1 aircraft measurements illustrating the sample selection methodology using the first level-flight segment on IOP1, 8 (3 July 2017). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) (N_{10nm-A} , gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) (N_{FIMS-A} , brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols (N_{acc-A} , green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

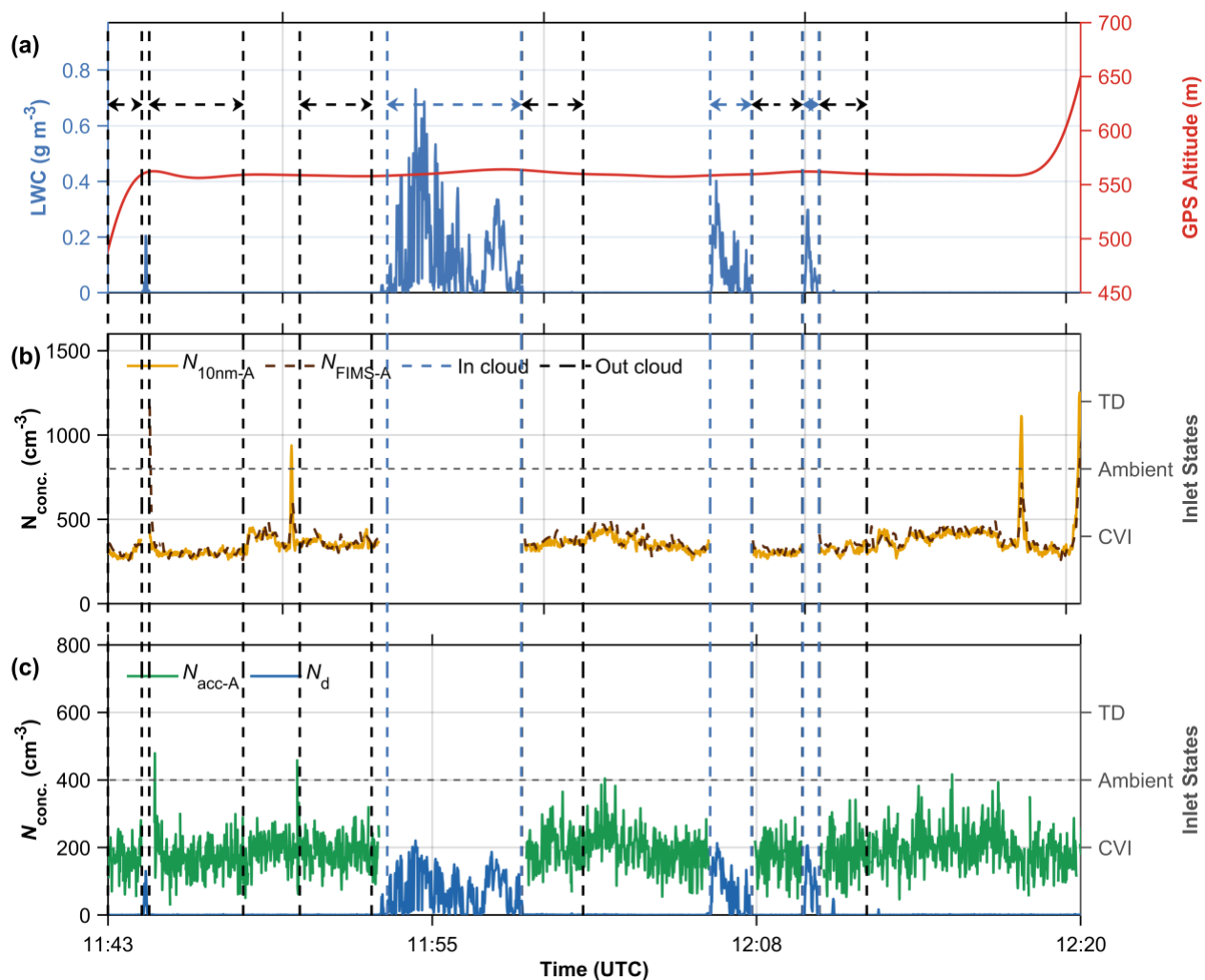


Figure S5. Time series of G-1 aircraft measurements illustrating the sample selection methodology using the second-level flight segment on IOP1, 8 (3 July 2017). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) (N_{10nm-A} , gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) (N_{FIMS-A} , brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols (N_{acc-A} , green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

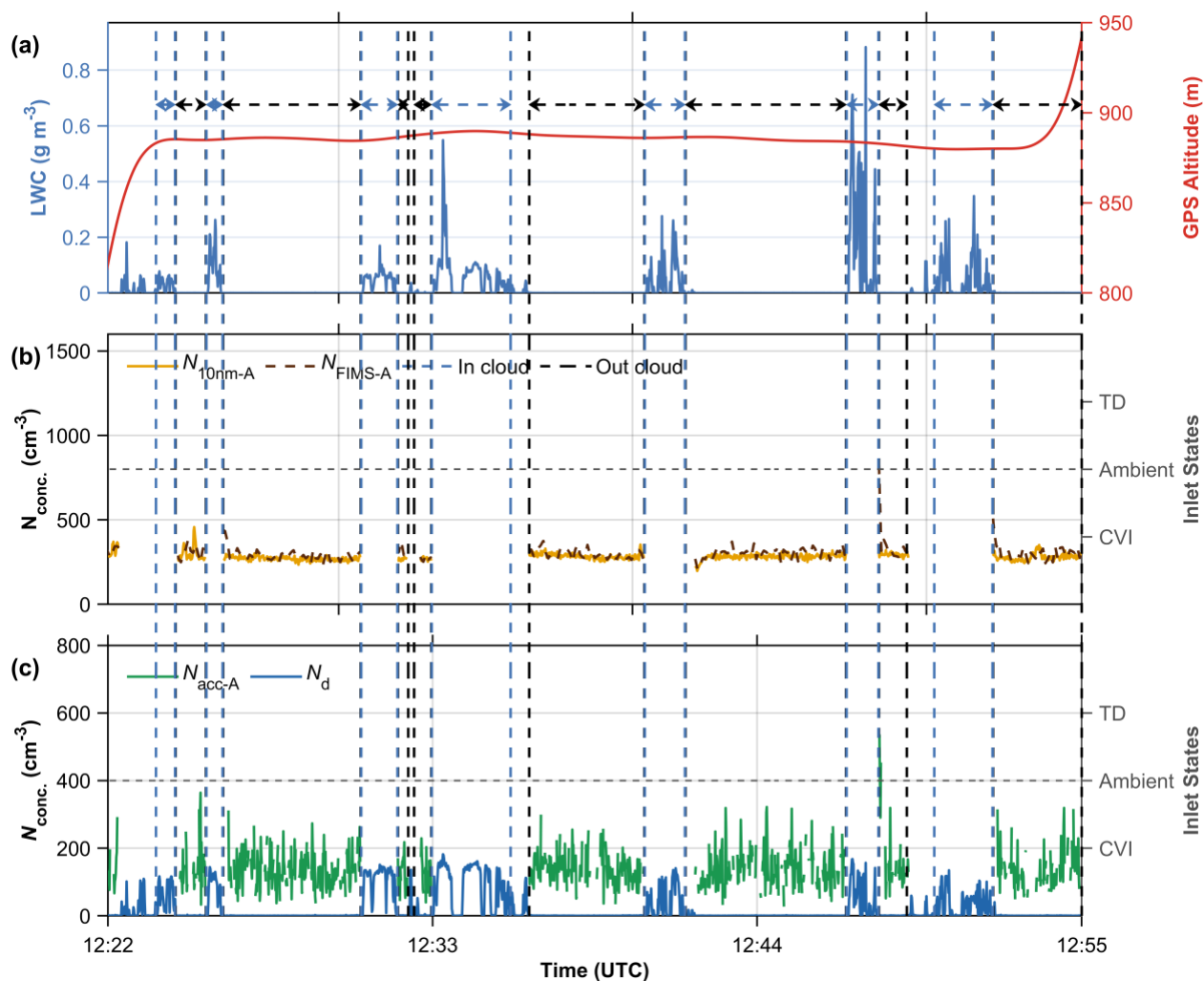


Figure S6. Time series of G-1 aircraft measurements illustrating the sample selection methodology using the third-level flight segment on IOP1, 8 (3 July 2017). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) (N_{10nm-A} , gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) (N_{FIMS-A} , brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols (N_{acc-A} , green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

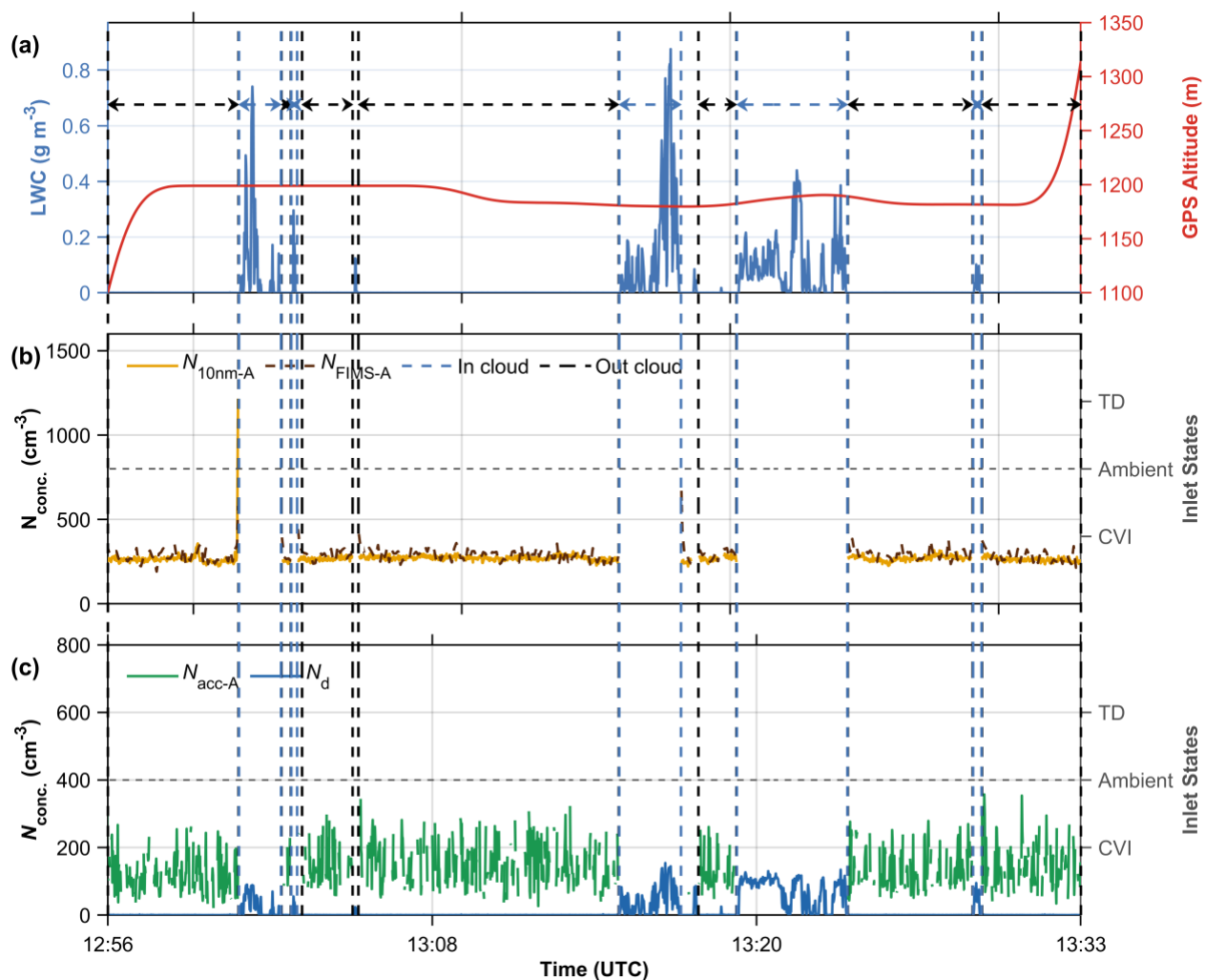


Figure S7. Time series of G-1 aircraft measurements illustrating the sample selection methodology using the fourth-level flight segment on IOP1, 8 (3 July 2017). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) (N_{10nm-A} , gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) (N_{FIMS-A} , brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols (N_{acc-A} , green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

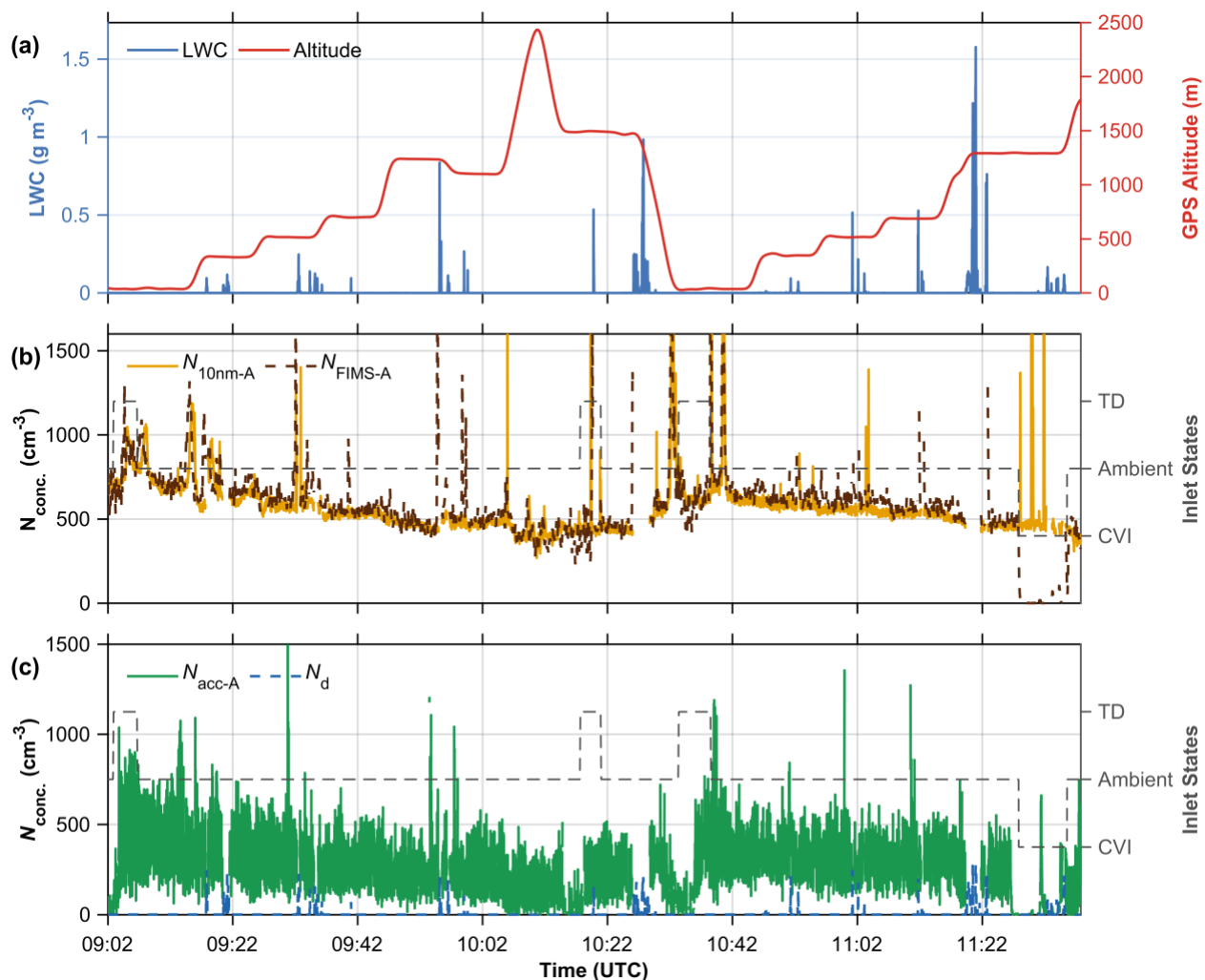


Figure S8. Same as Fig. S3 on IOP1, 9 (4 July 2017). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

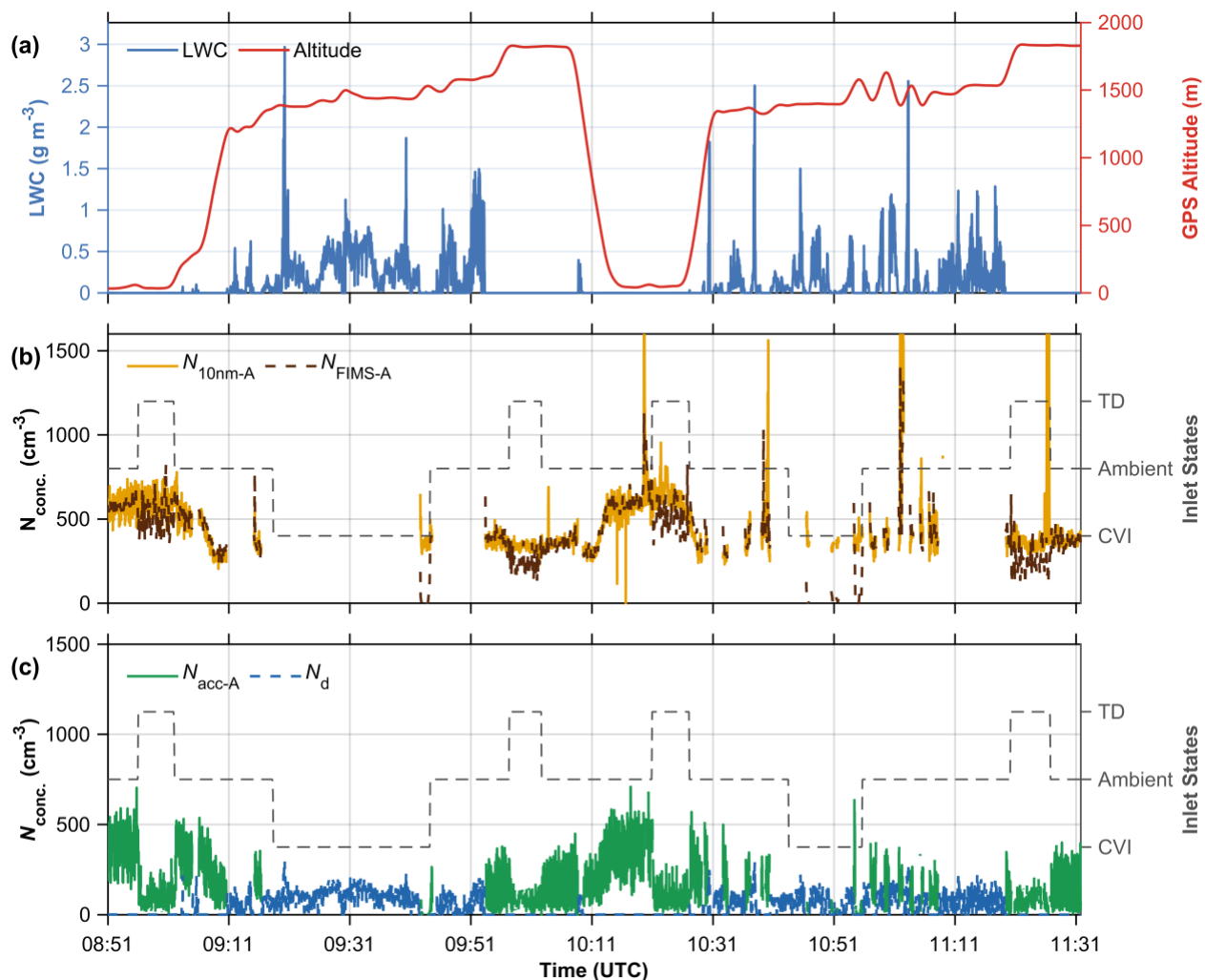


Figure S9. Same as Fig. S3 on IOP1, 10 (6 July 2017). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

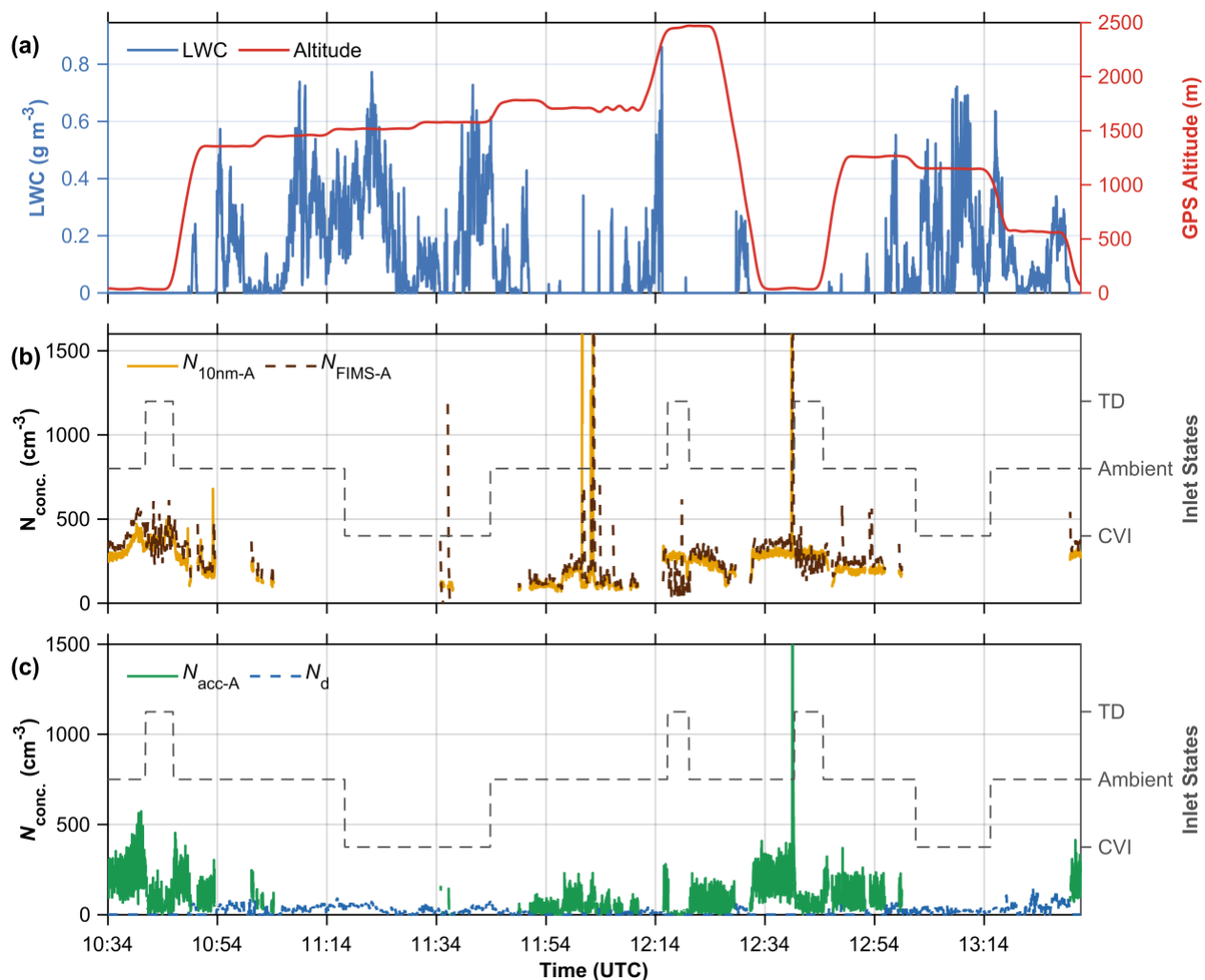


Figure S10. Same as Fig. S3 on IOP1, 13 (11 July 2017). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

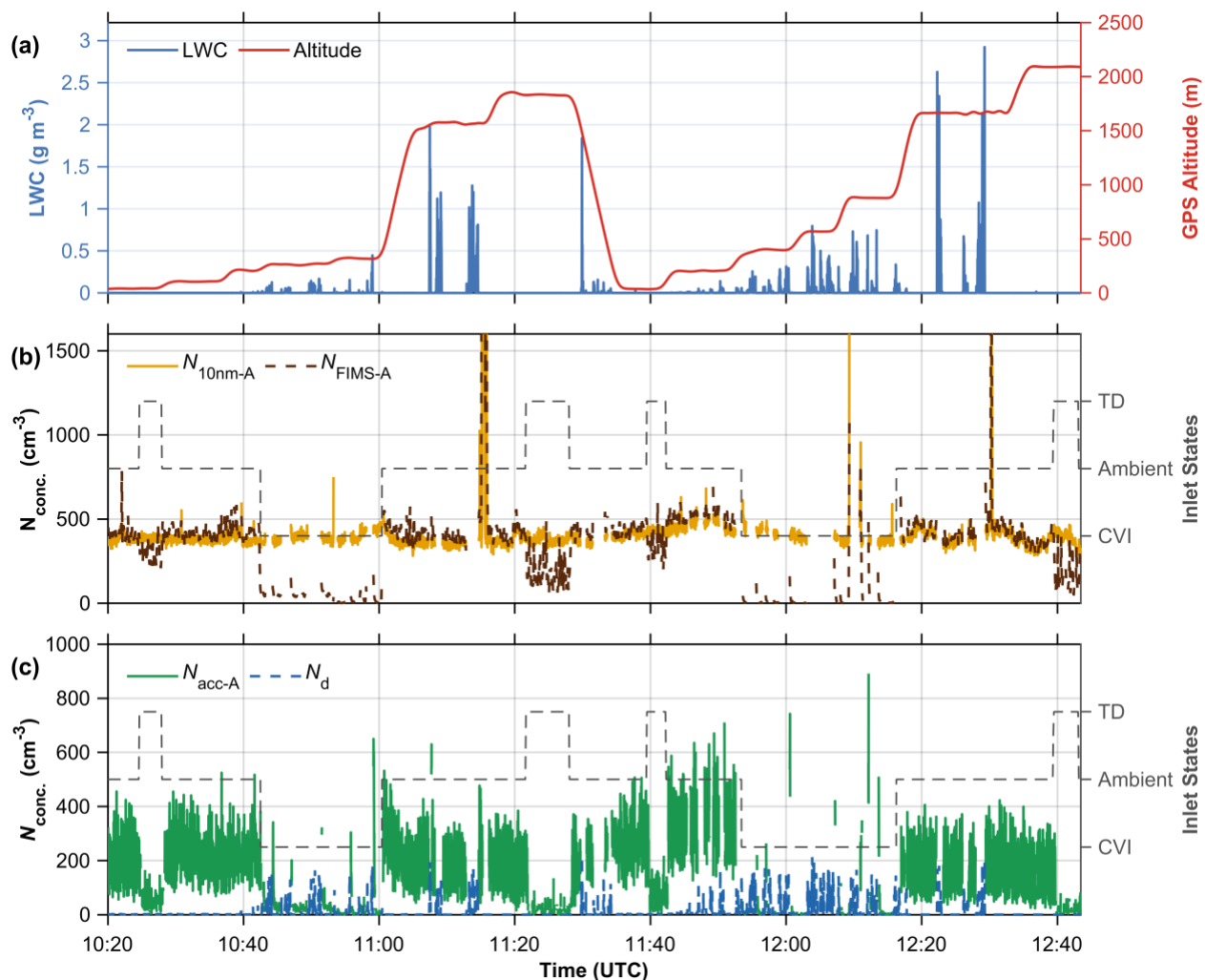


Figure S11. Same as Fig. S3 on IOP1, 17 (17 July 2017). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

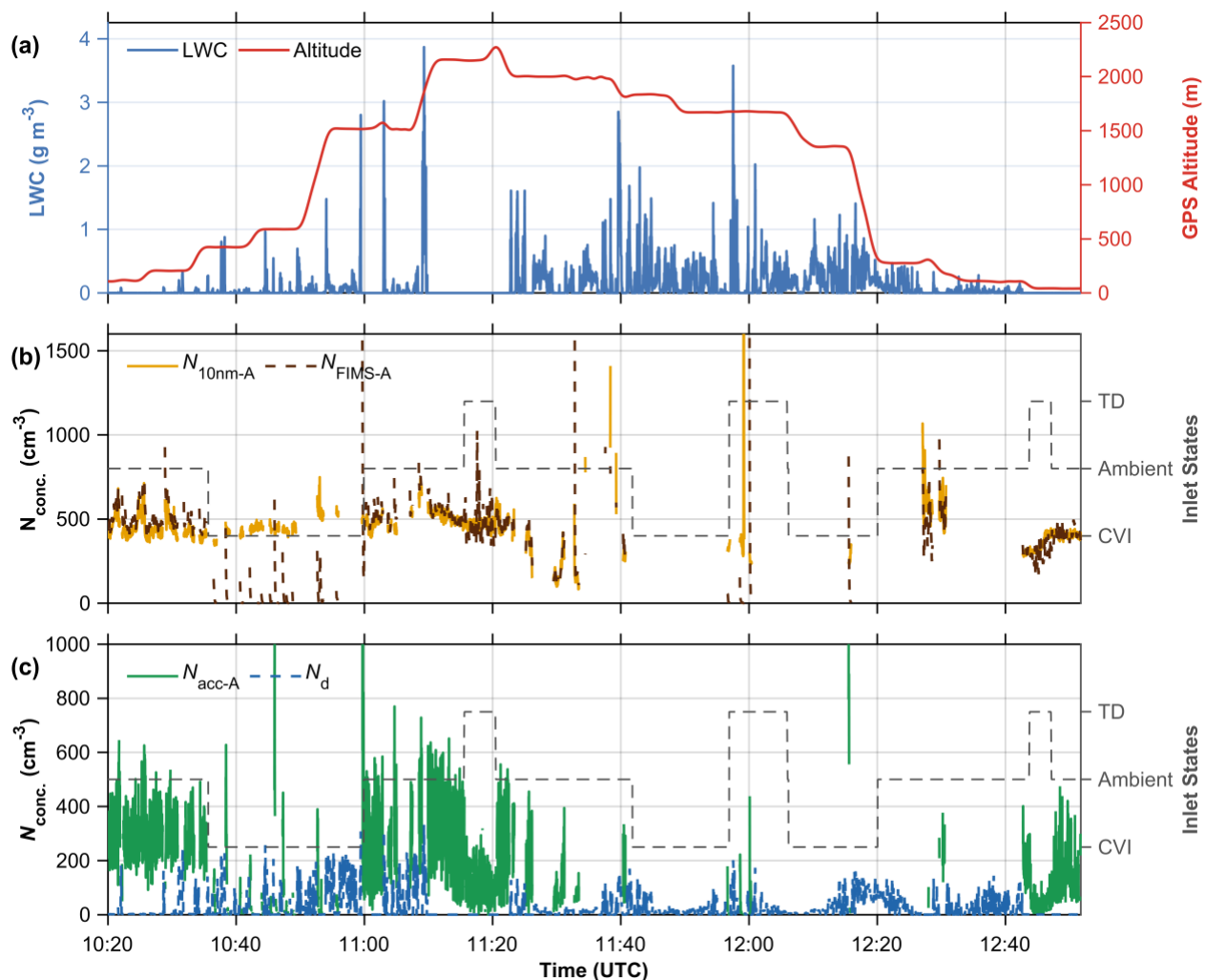


Figure S12. Same as Fig. S3 on IOP1, 19 (19 July 2017). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

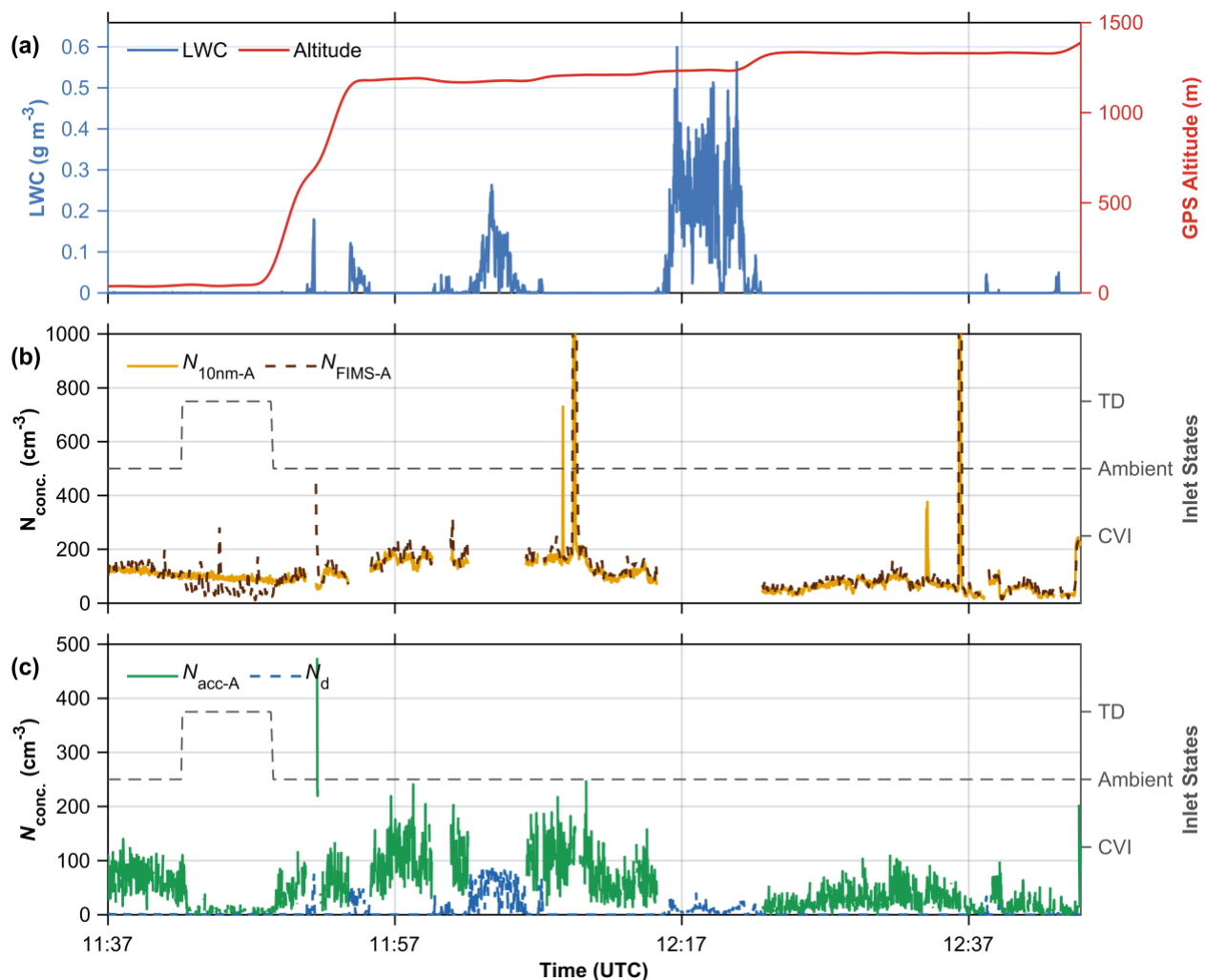


Figure S13. Same as Fig. S3 on IOP2, 2 (21 January 2018). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

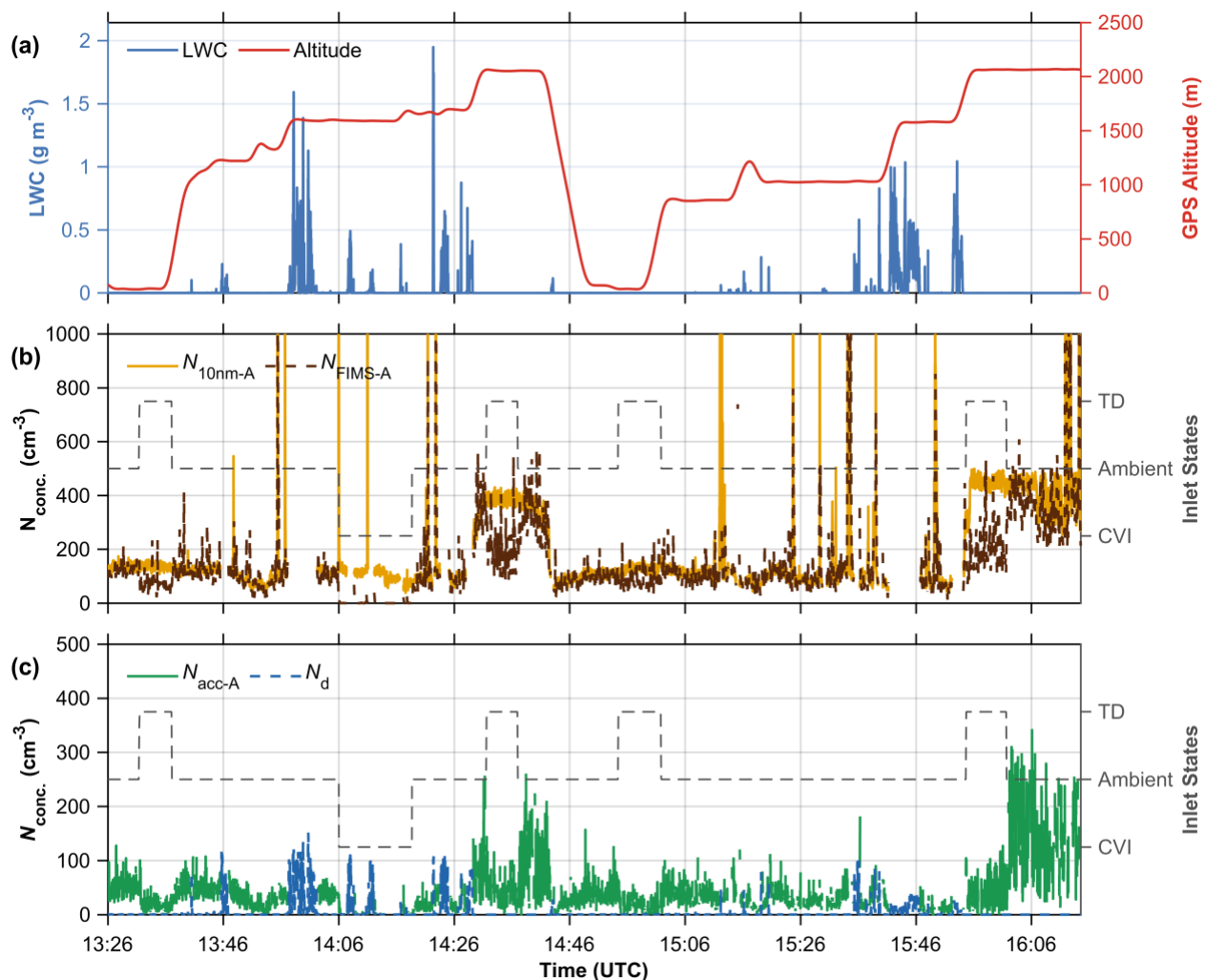


Figure S14. Same as Fig. S3 on IOP2, 3 (24 January 2018). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

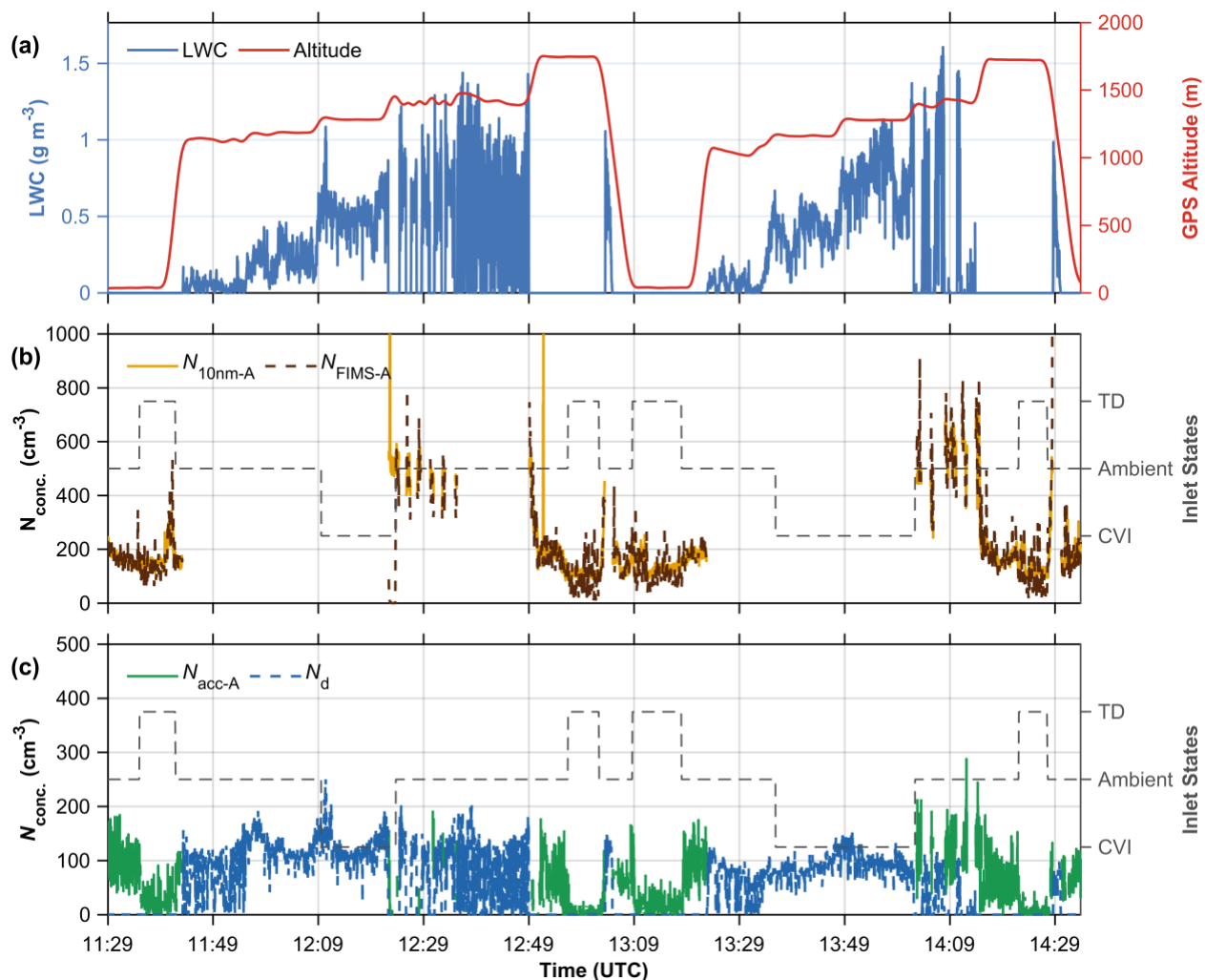


Figure S15. Same as Fig. S3 on IOP2, 5 (26 January 2018). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

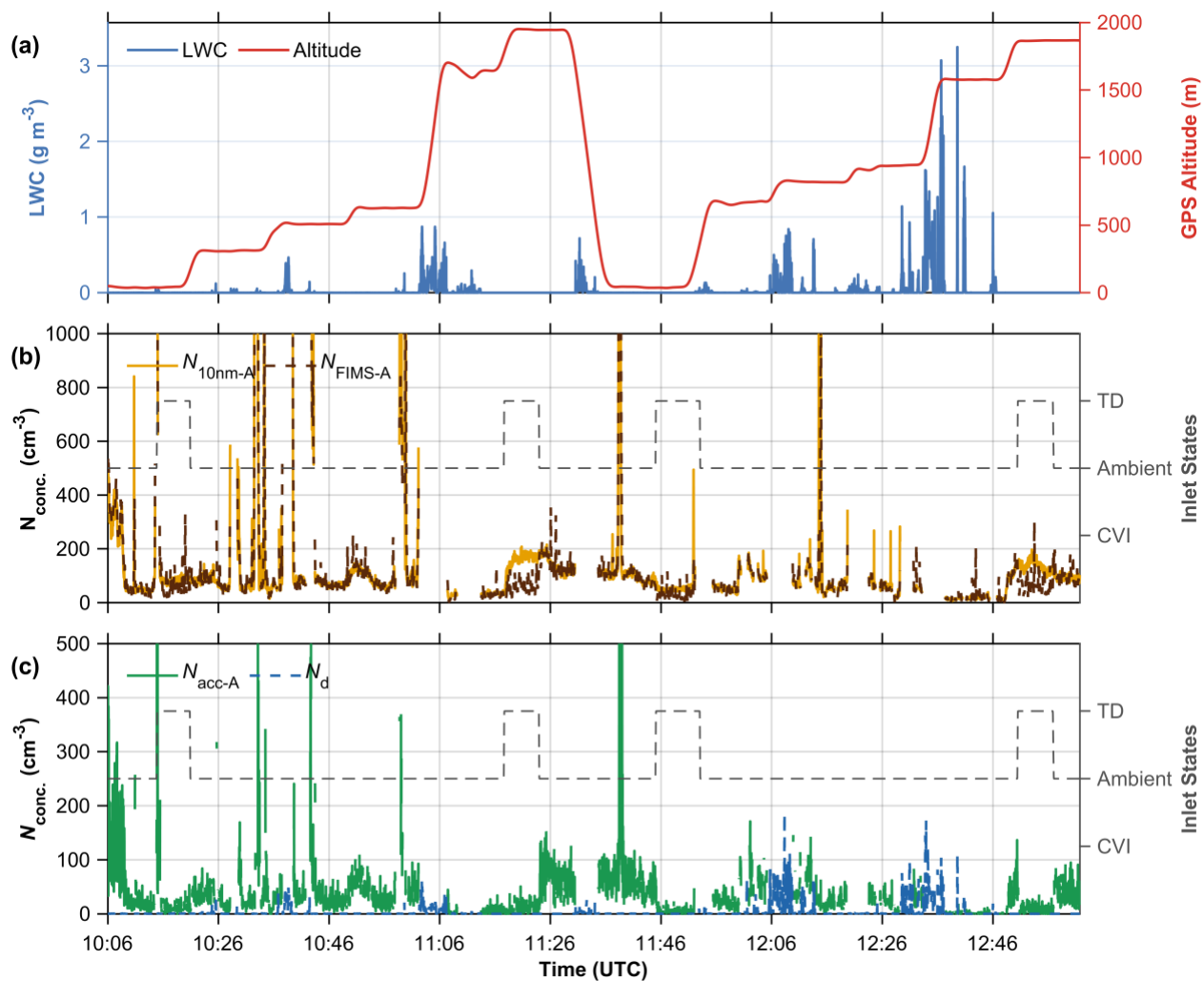


Figure S16. Same as Fig. S3 on IOP2, 6 (28 January 2018). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

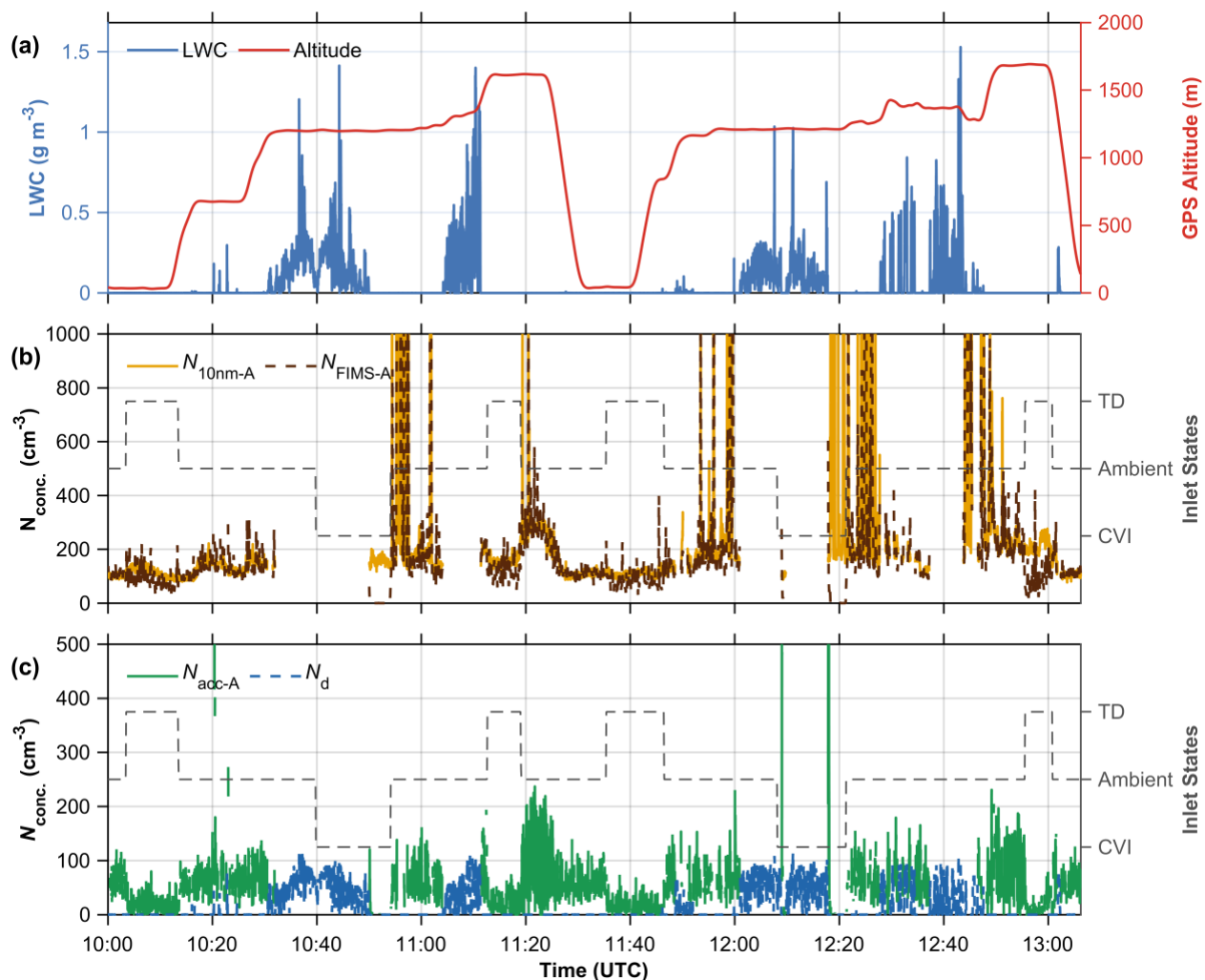


Figure S17. Same as Fig. S3 on IOP2, 7 (29 January 2018). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

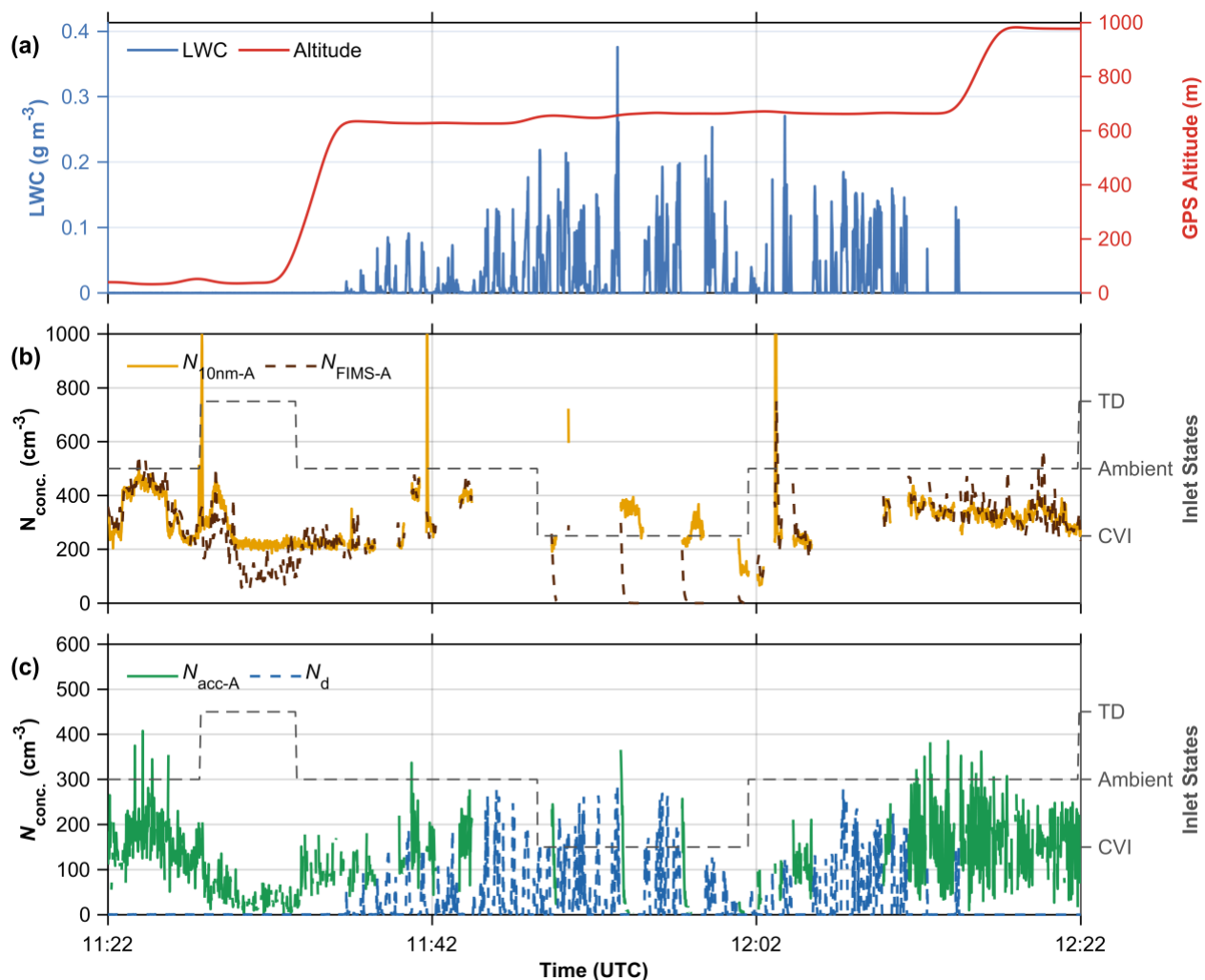


Figure S18. Same as Fig. S3 on IOP2, 9 (1 February 2018). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

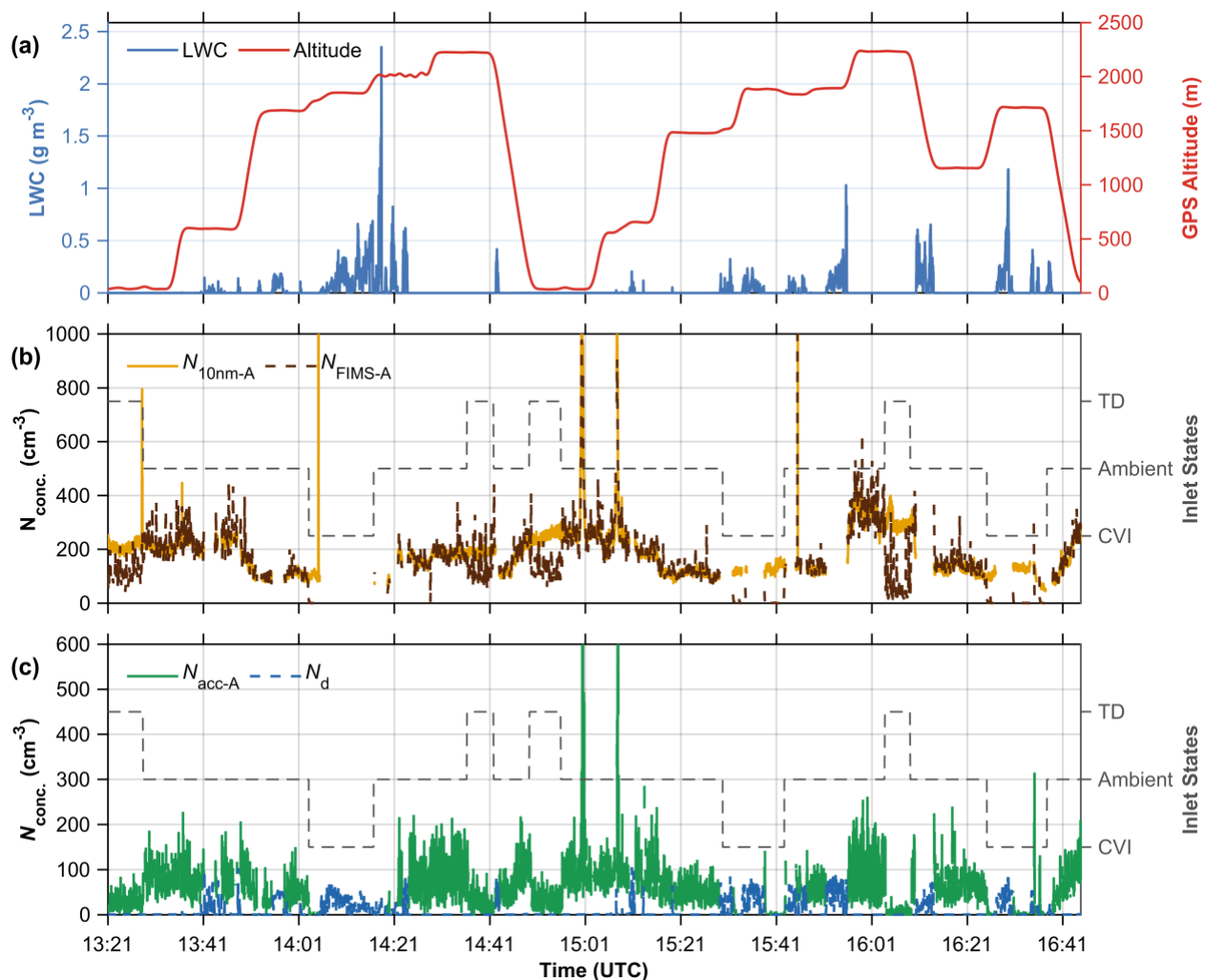


Figure S19. Same as Fig. S3 on IOP2, 11 (8 February 2018). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

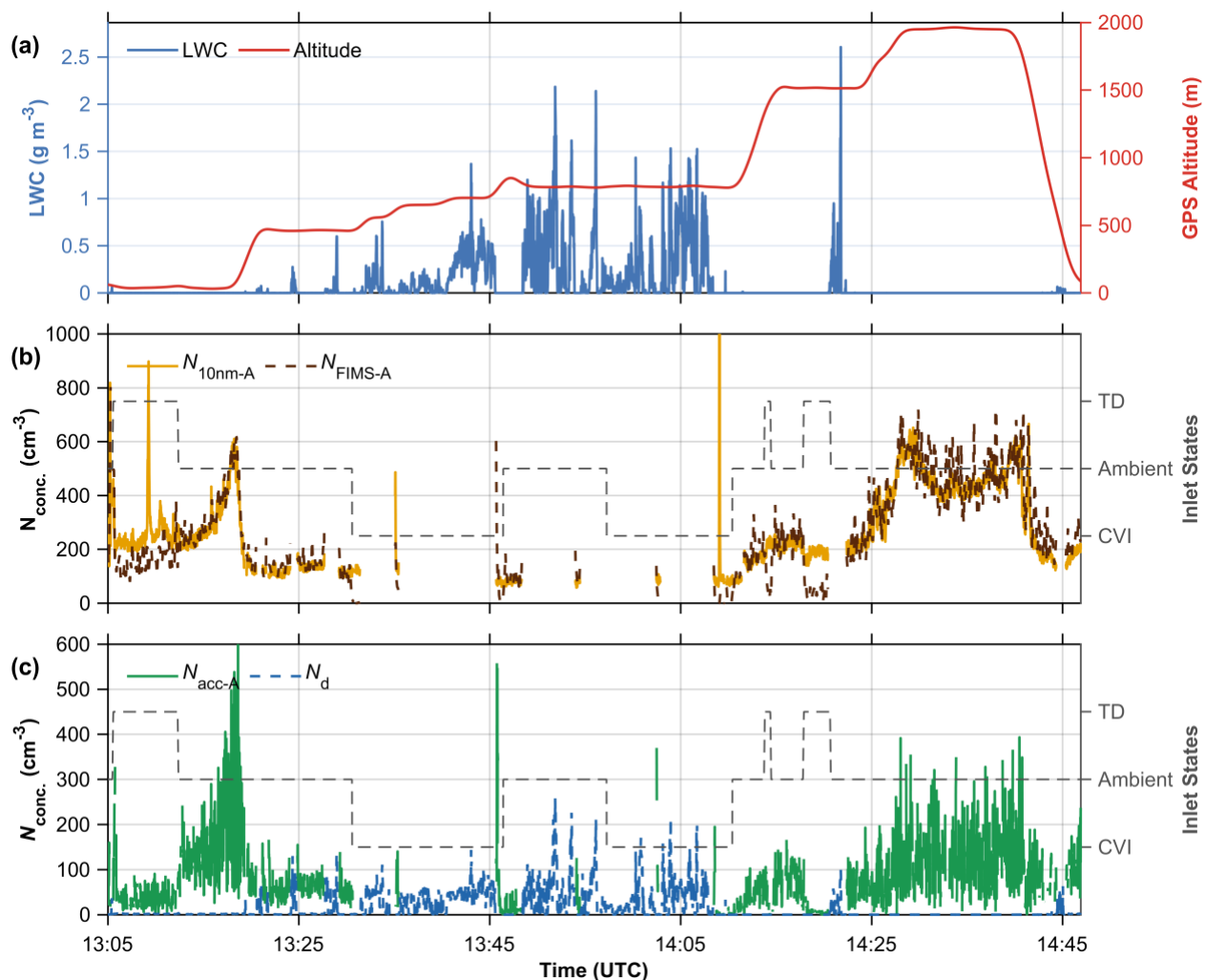


Figure S20. Same as Fig. S3 on IOP2, 12 (9 February 2018). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

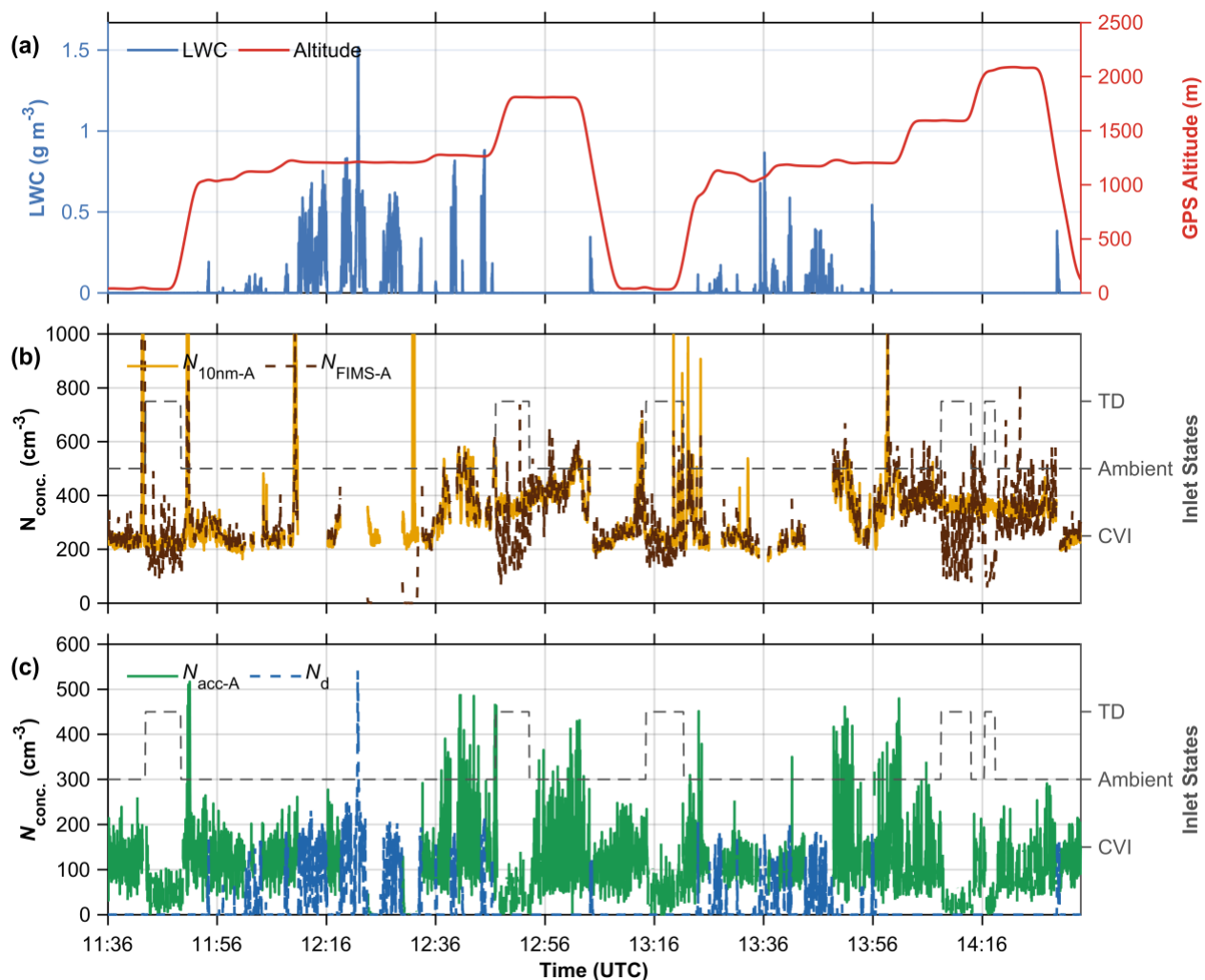


Figure S21. Same as Fig. S3 on IOP2, 15 (12 February 2018). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

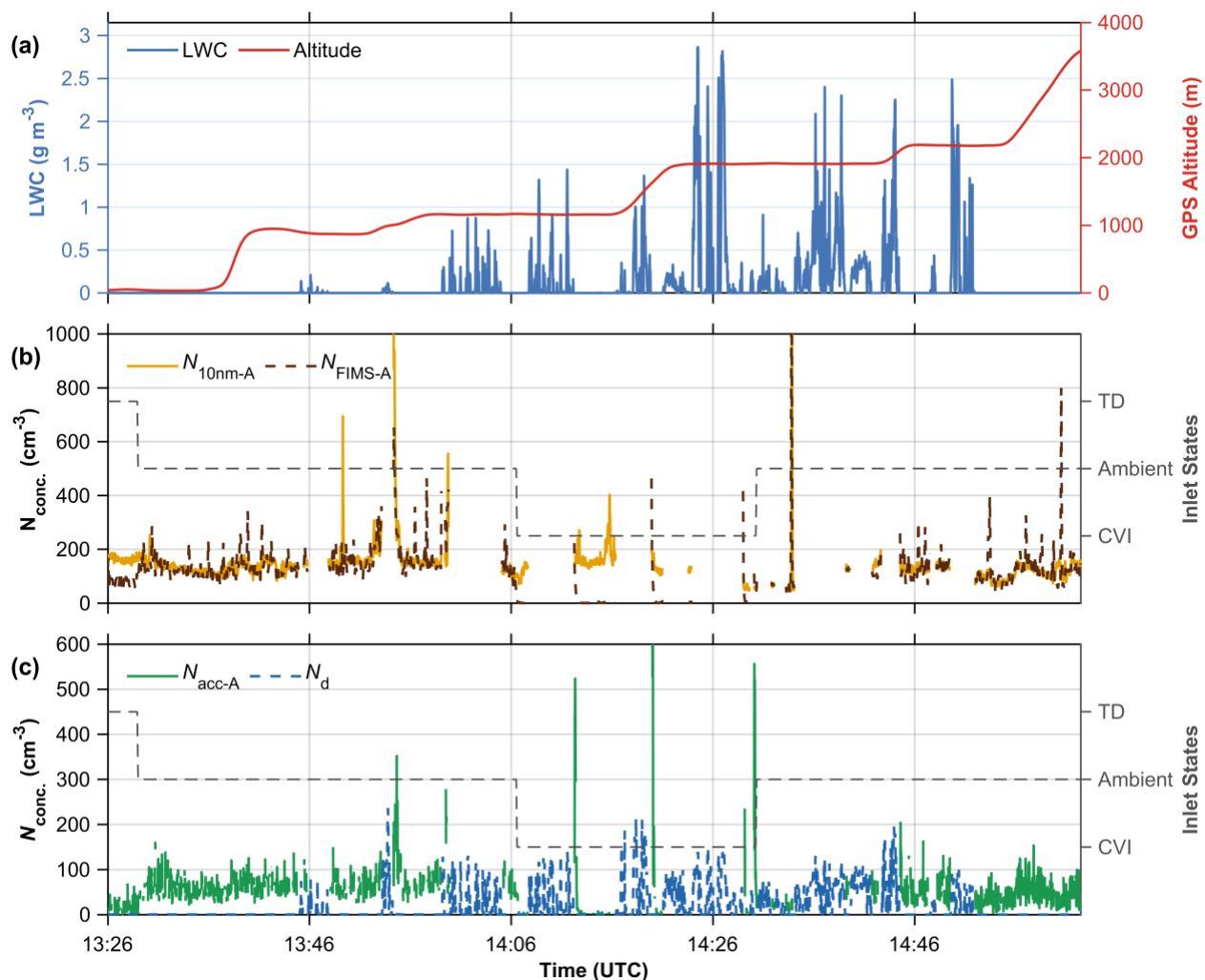


Figure S22. Same as Fig. S3 on IOP2, 16 (15 February 2018). (a) G-1 altitude (red line) and liquid water content (LWC) (blue line). (b) The total particle number concentration for particles larger than 10 nm measured by the condensation particle counter (CPC) ($N_{10\text{nm-A}}$, gold line) and integrated from the particle number size distribution measured by the fast integrated mobility spectrometer (FIMS) ($N_{\text{FIMS-A}}$, brown line). Samples were collected through an isokinetic inlet (Ambient), a thermodenuder inlet (TD), or a counterflow virtual impactor inlet (CVI). (c) The number concentration of accumulation-mode aerosols ($N_{\text{acc-A}}$, green line) and cloud droplet number concentration (N_d , blue line). Source data are provided as a Source Data file.

218 **References**

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