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Supplement of

Observational data from uncrewed systems over Southern Great Plains

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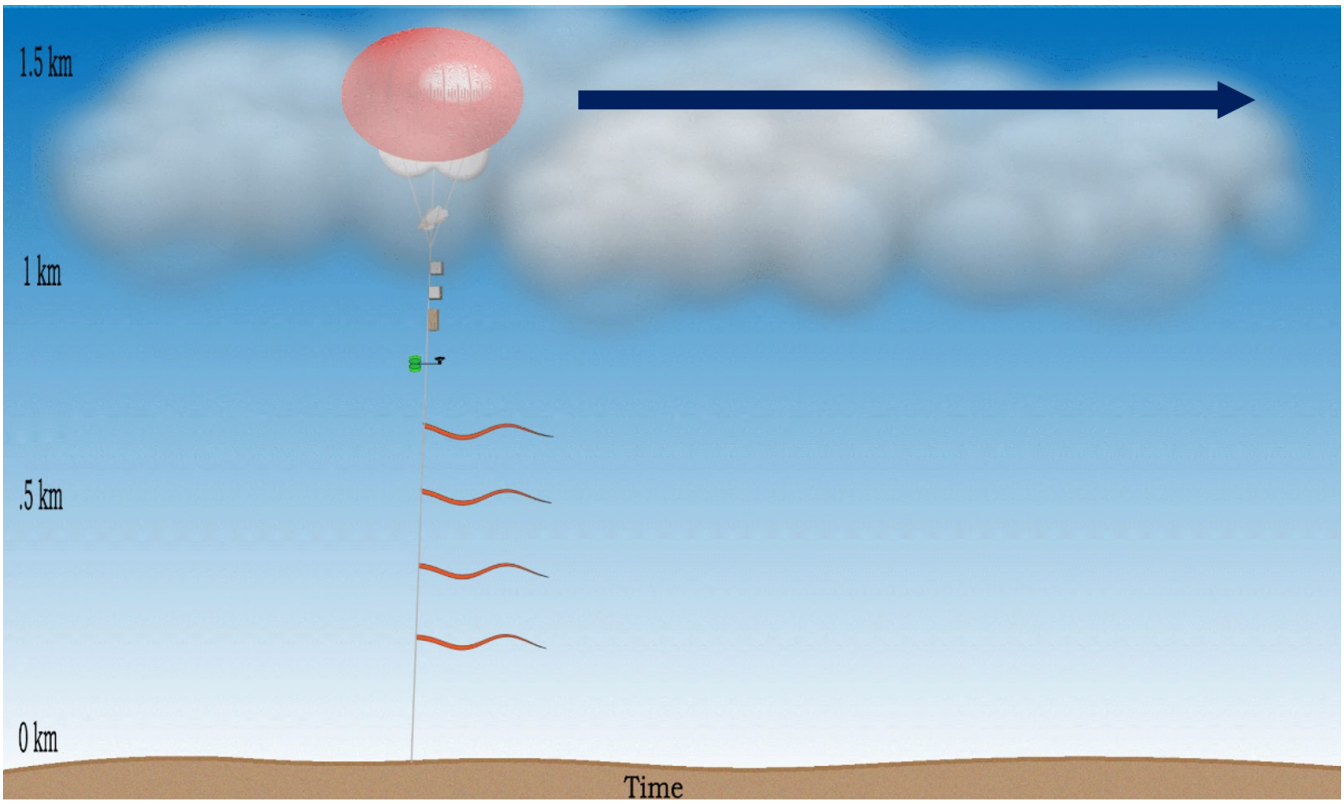


Figure S1. TBS typical loitering flight pattern at the cloudy condition.

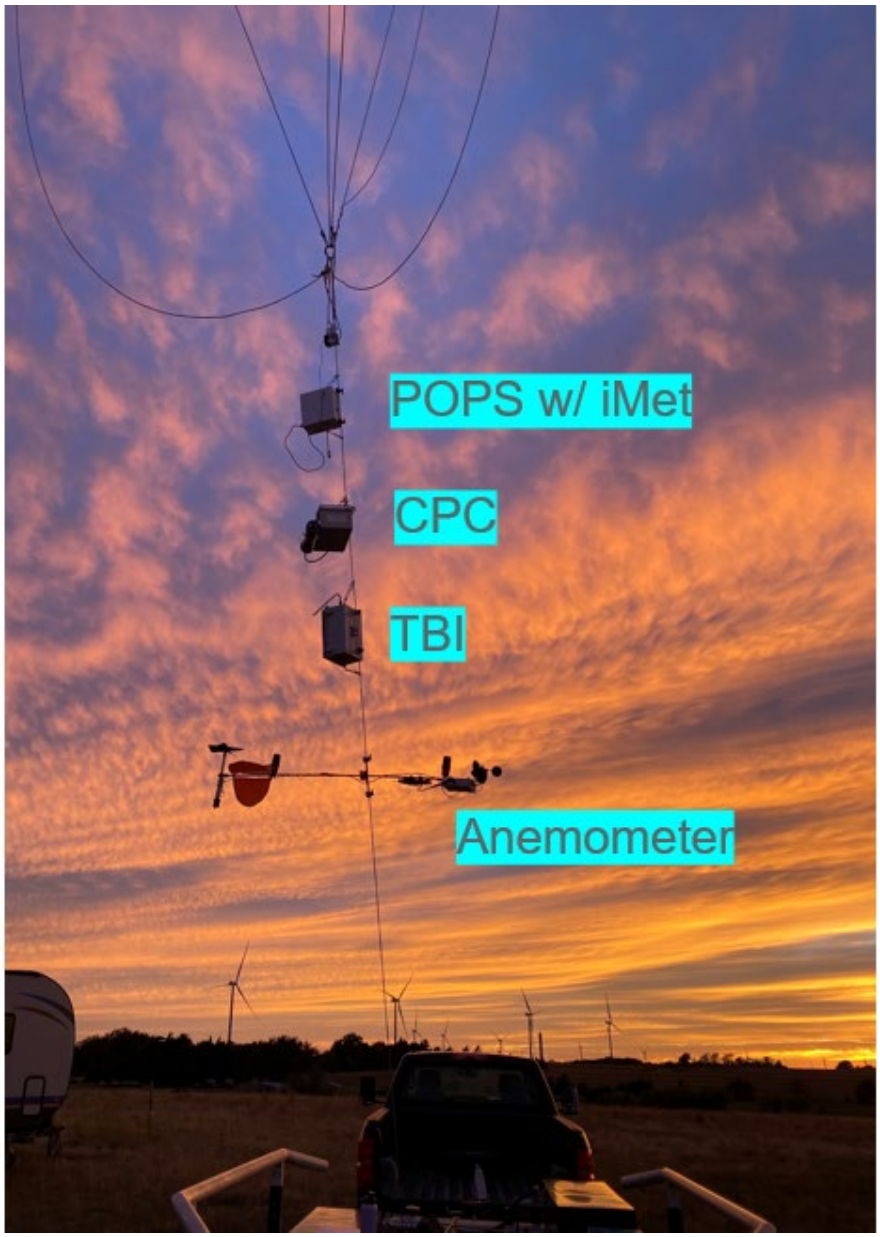


Figure S2 Typical TBS payload at the SGP site included POPS, iMet, CPC, and TBI..

Figure S3. The iso-kinetic inlet tip – photo taken during flight on Nov. 13, 2021

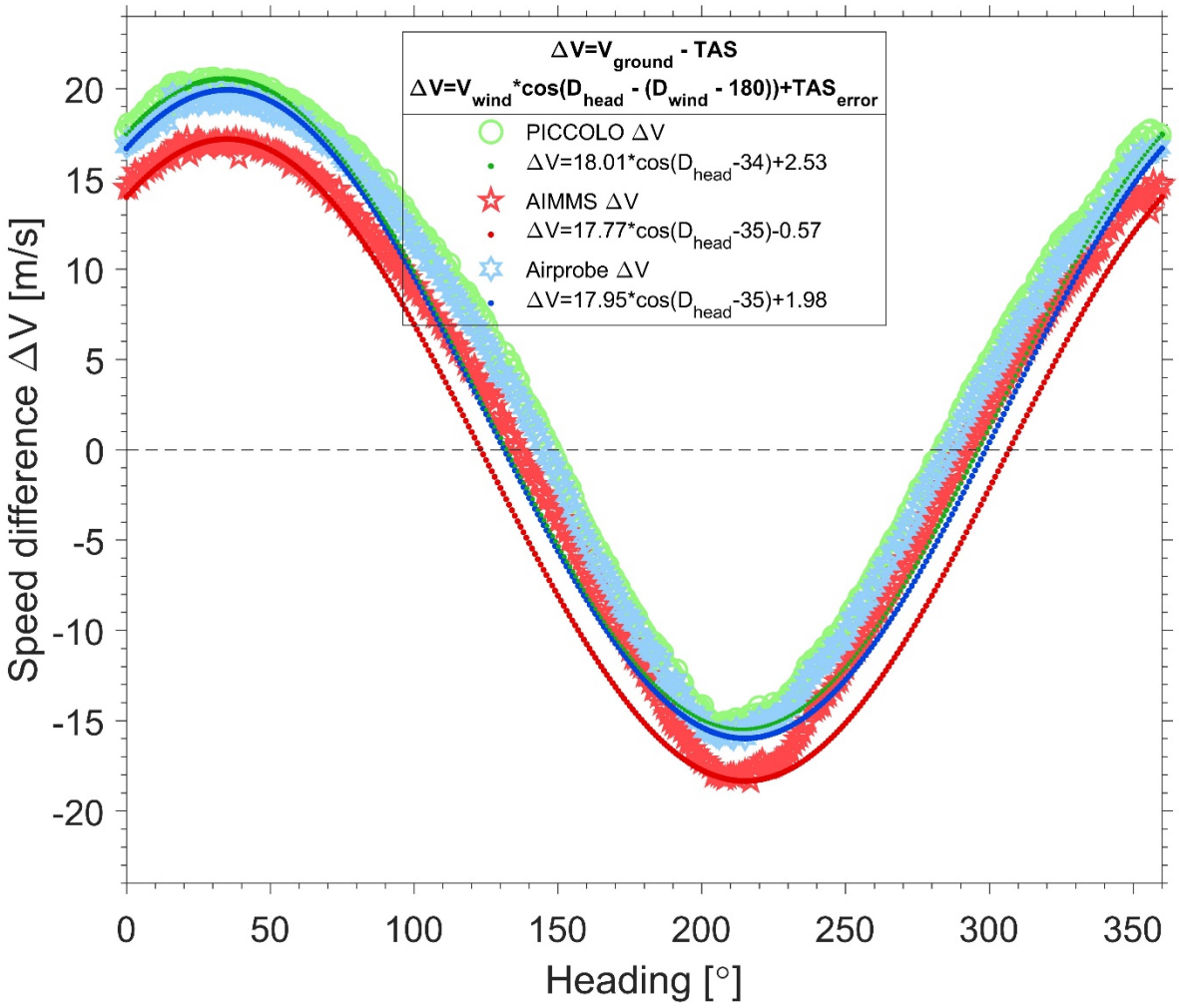


Figure S4, TAS comparison among AIMMS-30, PICCOLO, and Airprobe sensors from a flight on 11/08/2021

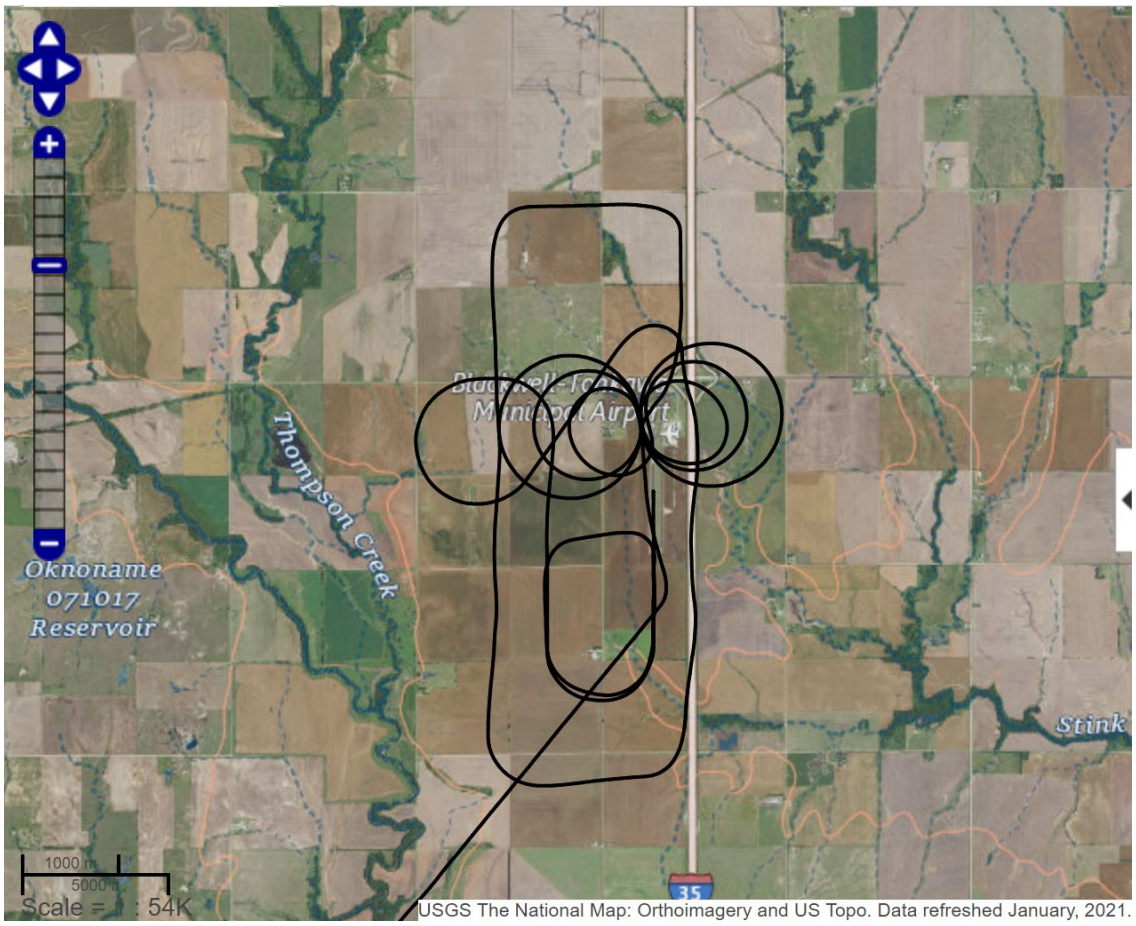
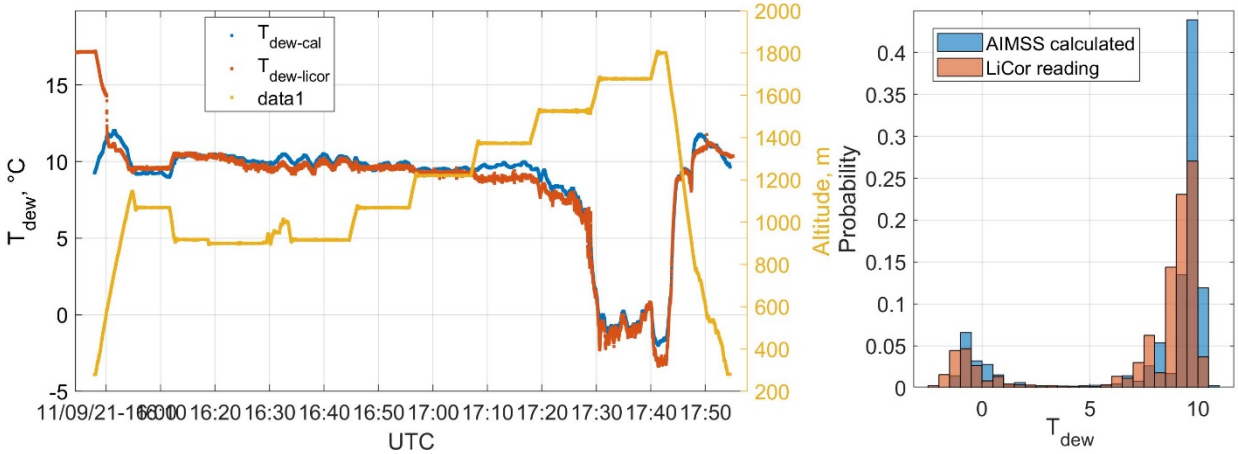


Figure S5. Flight pattern from one of the AIMMS-30 calibrations on 11/11/2021 (web map browser © 1994-2021 The MathWorks, Inc.)



(a) (b)

Figure S6. Dew point comparison between the LiCor Sensor measured values and values derived from the AIMMS temperature and RH measurements. (a) time series plot of the data from a flight on

11/09/2021; yellow line depicts altitude profile; (b) the probability distributions for the “ladder” pattern period between 16:35 – 17:40, 11/09/2021

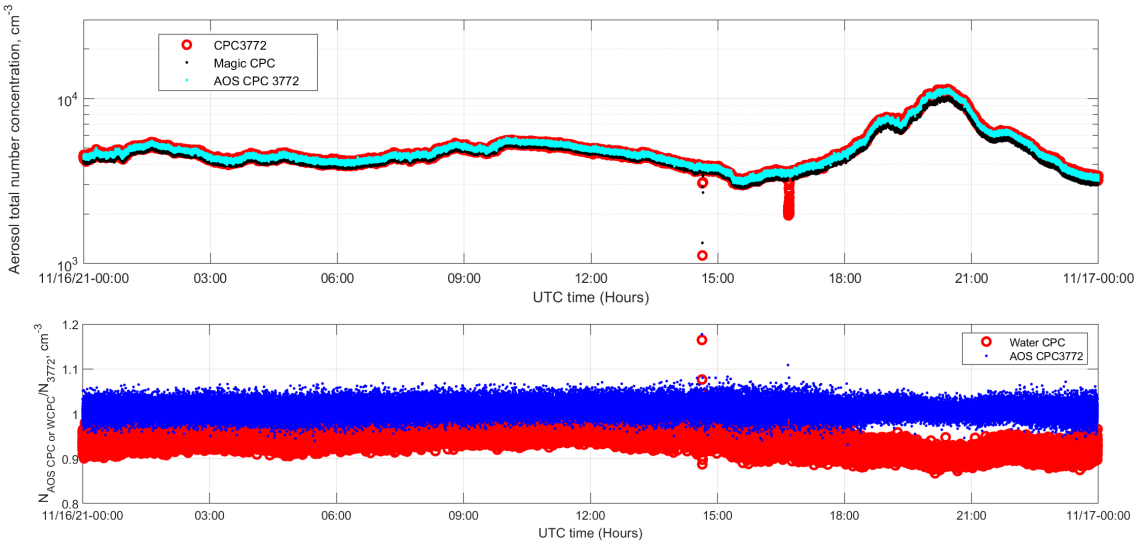


Fig S7. The time series plot of the AGMS CPC 3772 and Magic CPC compared with the AOS CPC 3772.

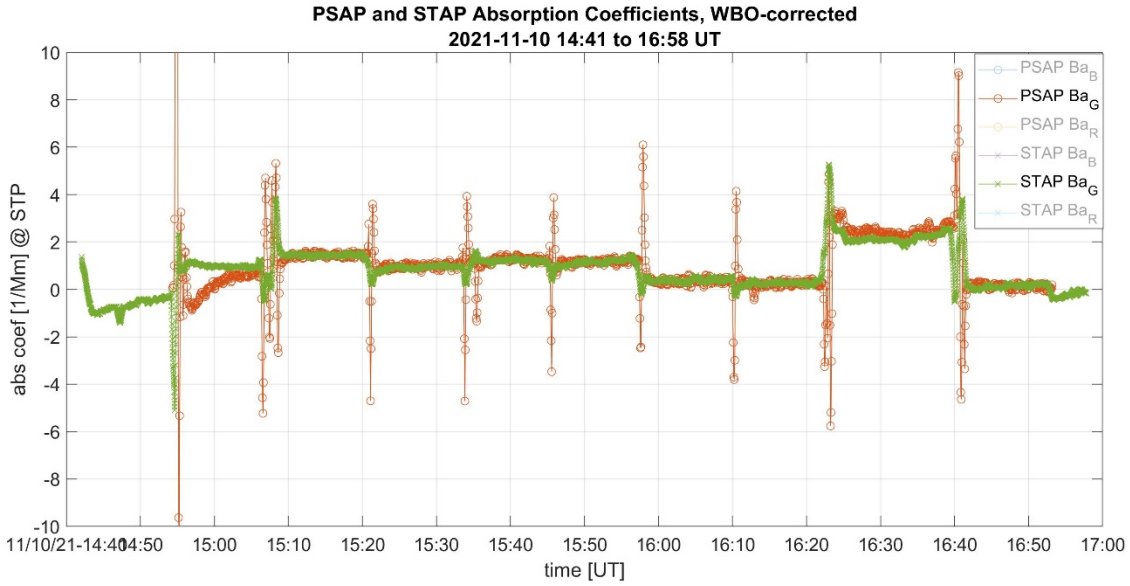


Fig S8. The time series plot of the AGMS PSAP compared with the STAP using the PSL particles of different sizes (203 nm, 269 nm, 303 nm, 400 nm, 450 nm, 496 nm, 707 nm, 903 nm). Note that the data from only one wavelength (green) is shown for clarity.

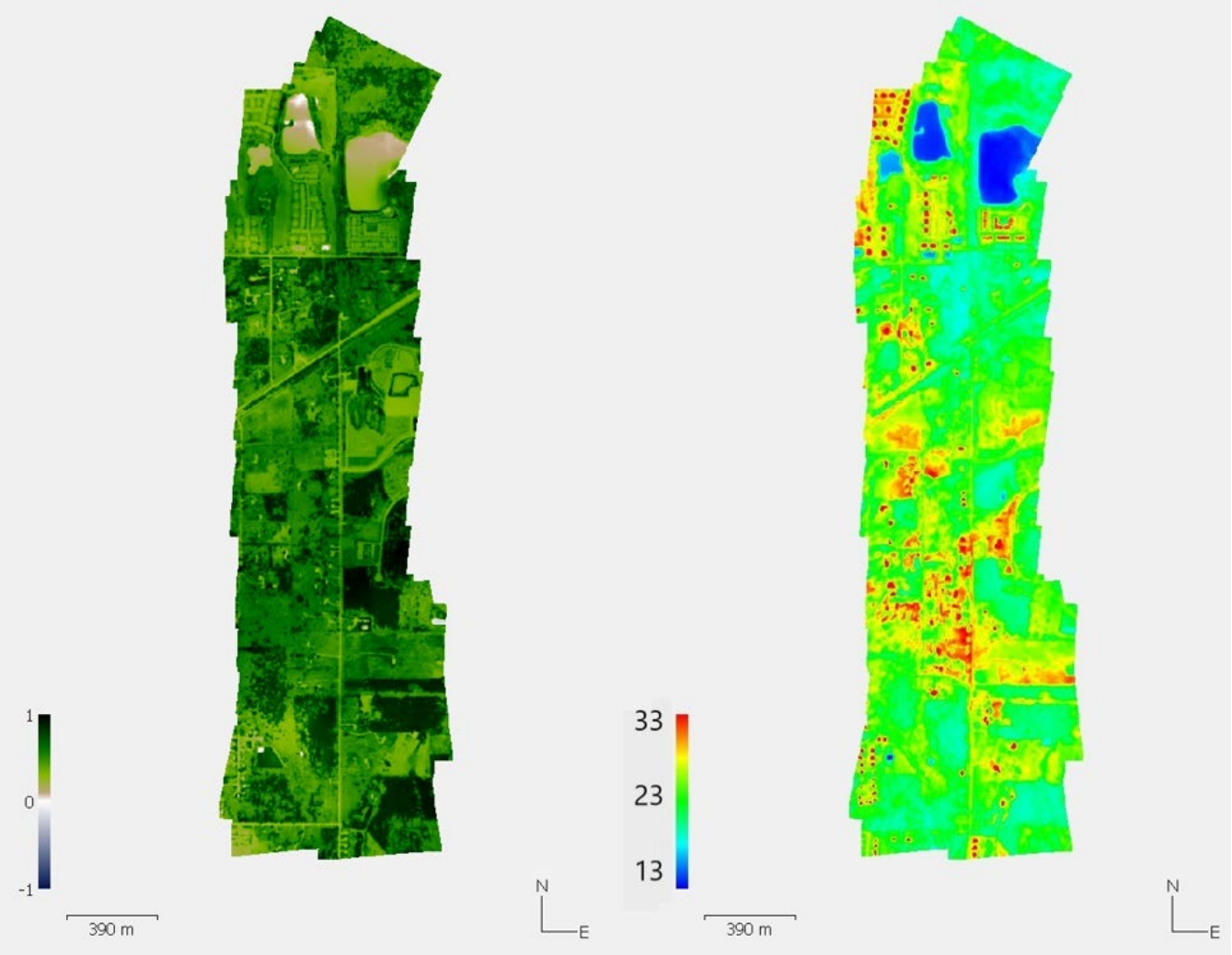


Figure S9. Multispectral images (right: surface temperature; left: GNDVI) from the Altum camera during a deployment in March, 2021 over Starkville, MS.

Table S1. Description of the TigerShark Configuration.

Parameter	Description	Unit
Aircraft Manufacturer	Navmar Applied Sciences Corporation	[-]
Aircraft Type	TigerShark	[-]
Aircraft Model	Block 3 XP	[-]
Aircraft Registration Number	N459MS	[-]
Propeller Type	2 blades	[-]
Engine Model	Herbrandson 372	[-]
Engine Serial Number	N/A	[-]
Engine Modifications	None	[-]
Engine Performance	32 hp / 8000 rpm 6500 rpm with 32" x 18" 2-blade propeller	[-]
Maximum Takeoff Weight	515	[lbs]
Length	14.25	[ft]
Height	3.42	[ft]
Wingspan	21.25	[ft]
Payload Capacity	100	[lbs]
Endurance	8 – 12	[hrs.]
Max Speed	80	[kts]
Cruise Speed	60	[kts]
Wing Incidence Angle	+4	[deg]

Table S2. The instruments integrated in the AGMS.

Instrument	Description	Source/Supplier
Condensation Particle Counter (CPC, model 3772)	Total aerosol concentration >0.007 μm	TSI Inc.
Water-based Condensation Particle counter (Magic™ CPC)	Total aerosol concentration >0.007 μm	Aerosol Devices Inc.
Ultra-Hidh Sensitivity Aerosol Spectrometer (UHSAS)	Aerosol size distribution (0.60-1 μm)	DMT Inc.
Particle soot absorption photometer (PSAP)	The optical extinction coefficient for absorption at three wavelengths (470, 522, 660 nm)	Radiance Research

Table S3. TBS deployment at the SGP observatory in 2021

SGP Site	2021 Operating Month	Operating Dates in Month	Accumulated Flight Hours (hr:m)	Operating Hours (UTC)	Maximum Operating Altitude (m)	Sky Conditions
CF	February	1, 5, 6, 9, 11	19:15	15-24	900	Clear skies 2/1; Cloud bases 300m - 3.80km 2/5, 2/6, 2/9, 2/11
EF36	February	5, 6	8:38	16-24	520	Cloud bases 300m - 2.8km
EF9	February	N/A	N/A	N/A	N/A	N/A
CF	May	12, 13, 17, 19, 20, 21	28:36	13-24	1400	Cloud bases 300m - 5.6km 5/12, 5/ 13, 5/17, 5/19, 5/20 5/21
EF36	May	13	6:00	16-24	1400	Cloud bases 2.0km - 2.3km on 5/13
EF9	May	17, 19, 20	13:17	15-24	1020	Cloud bases 500m - 6.3km 5/17 to 5/20
CF	July	19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30	40:21	13-22	1500	Cloud bases 300m - 7.6km on 7/19 to 7/30
EF36	July	21, 22, 23, 24, 25, 26	19:03	13-23	1000	Cloud bases 400m - 7.7km on 7/21 to 7/26
EF9	July	27, 28, 29	11:33	15-22	1160	Cloud bases 1.5km - 7.5km on 7/27 to 7/29
CF	October	4, 5, 6, 7, 8, 10, 11, 13, 14, 15	33:39	14-24	1500	Clear skies 10/5, 10/8, 10/11 ; Cloud bases 200m - 7.9km on 10/4-10/7, 10/10, 10/13-10/15
EF36	October	6, 7	8:26	13-23	1215	Cloud bases 2.2km - 5.7km on 10/6, 10/7
EF9	October	13, 14	5:39	14-24	1100	Cloud bases 650m on 10/14

Table S4. TigerShark November deployment at the SGP observatory

Date	Takeoff (CT)	Landed (CT)	Flight Time (hours)	Total Flight Time
11/8/2021	8:42	9:12	0.50	0.5
11/9/2021	9:57	11:54	1.95	2.45
11/10/2021	Weather / Soft Down Day			
11/11/2021	8:34	11:58	3.40	5.85
11/12/2021	Weather / Hard Down Day			
11/13/2021	9:15	13:19	4.07	9.92
11/14/2021	12:18	13:04	0.77	10.68
11/15/2021	8:26	11:46	3.33	14.02
11/16/2021	8:38	10:00	1.37	15.38

Table S5. Information of the merged TBS data product.

Variable	Units	Valid Range	Input data stream
Ceilometer boundary layer height candidates (up to 3)	m AGL	N/A	ceilpblht.a0
Quality of ceilometer boundary layer height candidates (up to 3)	1	[1,3]	ceilpblht.a0
Ceilometer cloud base height candidates (up to 3)	m AGL	[0,7700]	ceilpblht.a0
Quality of ceilometer cloud base height candidates (up to 3)	1	[1,3]	ceilpblht.a0
Condensation particle counter (CPC) altitude	m MSL	[0,2000]	tbscpc.b1
Condensation particle counter latitude	degree N	[-90,90]	tbscpc.b1
Condensation particle counter longitude	degree E	[-180,180]	tbscpc.b1
Total number concentration from CPC for particles > 10 nm	$1/cm^{-3}$	[0,20000]	tbscpc.b1
Quality of CPC total number concentration for particles > 10 nm	1	[1,3]	tbscpc.b1
Air temperature of iMet radiosonde corrected for solar radiation	deg C	Site specific	tbsimet.a1
Raw air temperature of iMet	deg C	Site specific	tbsimet.a1
Ascent rate of iMet	m/s	[-20,20]	tbsimet.a1
Battery voltage of iMet	V DC	[2,7]	tbsimet.a1
Frostpoint of iMet	deg C	[-40,40]	tbsimet.a1
Ascent rate of iMet derived from GPS	m/s	[-20,20]	tbsimet.a1
Atmospheric pressure derived from GPS altitude, temperature, and relative humidity of iMet	hPa	Site specific	tbsimet.a1
Altitude derived from atmospheric pressure of iMet	km MSL	[0,2]	tbsimet.a1
Relative humidity of iMet	%	[0,100]	tbsimet.a1
Air temperature from iMet relative humidity sensor	deg C	Site specific	tbsimet.a1
Potential temperature from iMet	deg K	[233,313]	tbsimet.a1
Total column water from iMet	mm	[0,50]	tbsimet.a1
Water vapor mixing ratio from iMet	ppmv	[0,10000]	tbsimet.a1
Air temperature of iMet XQ2 corrected for solar radiation	deg C	Site specific	tbsimetxq2.b1
Atmospheric pressure of iMet XQ2	hPa	Site specific	tbsimetxq2.b1
Relative humidity of iMet XQ2	%	[0,100]	tbsimetxq2.b1

Air temperature from iMet XQ2 relative humidity sensor	deg C	Site specific	tbsimetxq2.b1
Altitude from iMet XQ2 GPS	m MSL	Site specific	tbsimetxq2.b1
POPS aerosol number concentration between 135 – 150 nm	$1/cm^{-3}$	N/A	tbspops.b1
POPS aerosol number concentration between 150 – 170 nm	$1/cm^{-3}$	N/A	tbspops.b1
POPS aerosol number concentration between 170 – 195 nm	$1/cm^{-3}$	N/A	tbspops.b1
POPS aerosol number concentration between 195 – 220 nm	$1/cm^{-3}$	N/A	tbspops.b1
POPS aerosol number concentration between 220 – 260 nm	$1/cm^{-3}$	N/A	tbspops.b1
POPS aerosol number concentration between 260 – 335 nm	$1/cm^{-3}$	N/A	tbspops.b1
POPS aerosol number concentration between 335 – 510 nm	$1/cm^{-3}$	N/A	tbspops.b1
POPS aerosol number concentration between 510 – 705 nm	$1/cm^{-3}$	N/A	tbspops.b1
POPS aerosol number concentration between 705 – 1380 nm	$1/cm^{-3}$	N/A	tbspops.b1
POPS aerosol number concentration between 1380 – 1760 nm	$1/cm^{-3}$	N/A	tbspops.b1
POPS aerosol number concentration between 1760 – 2550 nm	$1/cm^{-3}$	N/A	tbspops.b1
POPS aerosol number concentration between 2550 – 3615 nm	$1/cm^{-3}$	N/A	tbspops.b1
POPS total number concentration including particles < 135 nm			
POPS altitude	m MSL	[0,2000]	tbspops.b1
POPS latitude	degree N	[-90,90]	tbspops.b1
POPS longitude	degree E	[-180,180]	tbspops.b1
Anemometer wind speed	m/s	[0,40]	tbswind.a1
Anemometer vertical wind speed	m/s	[0,40]	tbswind.b1
Anemometer 1s wind gust	m/s	[0,40]	tbswind.b1
GNSS-derived wind direction	degree	[0,360]	tbswind.b1
Anemometer and GNSS heading sensor altitude	m MSL	[0,2000]	tbswind.b1
Anemometer and GNSS heading sensor latitude	degree N	[-90,90]	tbswind.b1
Anemometer and GNSS heading sensor longitude	degree E	[-180,180]	tbswind.b1