SUPPLEMENT

THE TROPICAL WARM POOL INTERNATIONAL CLOUD EXPERIMENT

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TABLE S1. In situ and remote-sensing instruments in the ARM UAV suite of instruments installed on the Proteus.

Instrument	Operating range	Derived parameters	Description
Cloud particle imager (CPI)	10 μm to ~ 1 mm	2.3-μm-resolution images, size distributions	Images recorded on CCD array
Cloud aerosol spectrometer (CAS)	0.35–50 μm	Size distributions	Detects forward scattered light from small particles
Cloud droplet probe (CDP)	2–50 μm	Size distributions	Open-path probe-detecting forward-scattered light from small particles
Cloud imaging probe (CIP)	50 μm–1.6 mm	Size distributions; two-dimensional images	Shadowing of photodiodes
Counterflow virtual impactor (CVI)	Particles > 5 μm included in bulk estimates	Bulk measure of IWC	Evaporator probe
Nevzorov probe	Bulk measurement	LWC, TWC	Hot-wire probe
Cloud integrating nephelometer (CIN)	Bulk measurement	βe, asymmetry parameter	Detects directional scattering of scattered light
Sandia dual-path laser hygrometer (TDL)	Vapor measurements to 1ppmv at 50 Hz	Water vapor	Near-infrared laser absorption spectroscopy at short (13.4 cm) and long (403 cm) paths
Cryogenic hygrometer (CR2)	Measures T_f to –105°C, response time of 10–20 s	Water vapor	Closed-cycle cryogenically cooled mirror
High-altitude fast-response in situ CO_2 analyzer	±0.1 ppmv	CO_2 mixing ratio	Absorption to 4.6 μm measured relative to reference gas of known concentration
MicroMaps CO instrument		CO mixing ratio and total column tropospheric CO	Multichannel gas filter radiometer
Infrared thermometers (IRTs)	Two, operating from 8–10 and 9.6–11.5 μm	Brightness temperature	Two 2.5° field-of-view downwelling infrared thermometers
Pyrgeometers	4–40 μm	Radiance	CG4 model: zenith on level platform; nadir pod; nadir gold covered
Pyranometers	0.4–4. μm	Radiance	Five Kipp and Zonen CM-22s: zenith on level platform, zenith fixed, nadir pod, nadir pod (single inner dome), pod (silver covered)
Spectral radiance package (SRP)	Three, from 385–1050, 720–800, and 1300–1500 nm	Upwelling spectral radiance	Narrow field of view
Diffuse field camera (DFC)	Two, centered at 645 and 1610 nm	Directional dependence of radiance	Imaging cameras measuring hemispheric upwelling radiance
MicroAir data transducer (MADT)		Pressure, pressure altitude, temperature, mach number, true air speed	Measurements of payload and atmospheric state parameters

Table S2. Instrumentation on the Egrett.		
Instrument	**Measurement**	**PI**
Basic meteorology and position	Pressure, temperature, wind, GPS (1 Hz)	Jorg Hacker, Airborne Research, Australia
DMT single-particle soot photometer (SP-2)	Aerosol particle size distribution (0.2–1.0 μm), light-absorbing fraction and composition	Hugh Coe, University of Manchester, United Kingdom
2 × TSI-3010 condensation particle counter (CPC)	Total condensation particles > 10 nm and > 80 nm	Martin Gallagher, University of Manchester, United Kingdom
DMT cloud, aerosol and precipitation spectrometer (CAPS)	Cloud droplet spectrum, aerosol/small particle asymmetry, aerosol refractive index, (diameter 0.3–2,000 μm)	Andy Heymsfield, NCAR, Boulder, Colorado
DMT cloud droplet probe (CDP)	Cloud particle size distribution (diameter 2–62 μm)	Martin Gallagher, University of Manchester, United Kingdom
SPEC cloud particle imager CPI-230	Cloud particle/ice CCD images, (diameter 10–2,300 μm)	Martin Gallagher, University of Manchester, United Kingdom
Buck Research CR-2 frost-point hygrometer	Ice-point temperature (20 s, ±0.1°)	Reinhold Busen, DLR, Germany
Open-path tuneable diode laser hygrometer	Water vapor concentration (1 s, ±1 ppmv)	Jim Whiteway, York University, Canada
Closed-path tuneable diode laser hygrometer	Water vapor concentration (1 s, ±1 ppmv)	Geraint Vaughan, University of Manchester, United Kingdom
CO analyzer	Carbon monoxide (1 Hz, ± 2 ppbv)	Andreas Volz-Thomas, FZ Jülich, Germany
Miniature gas chromatograph	Halocarbons (C1, Br, I; 3–6 min, ± 5%)	Neil Harris, University of Cambridge, United Kingdom
TE-49C UV ozone sensor	Ozone concentration (± 2 ppbv, 10 seconds)	Reinhold Busen, DLR, Germany
Automatic tube sampler (ATS), 15 samples per flight	C4–C9, nonmethane hydrocarbons, monoterpenes and OVOCs	Alastair Lewis, University of York, United Kingdom
NO and NO_2 chemiluminescent detector*	± 200 ppt at 10 Hz (± 30 ppt at 4-s integration)	Andreas Volz-Thomas, FZ Jülich, Germany

*Alternates (only one flown at any time).

Table S3. Twin Otter payload.		
Instrument	**Measurement**	**PI/Institute**
95-GHz cloud radar	Radar reflectivity (minimum ~–35 dBZ)	S. Dinardo, Jet Propulsion Laboratory, NASA
532-nm lidar	Backscatter power, depolarization ratio	J. Whiteway, York University

Table S4. Dornier payload.		
Instrument	**Measurement**	**PI**
Aventech AIMMS-20 probe	GPS position, pressure, temperature, relative humidity, winds, 1 Hz	David Davies, ARSF, United Kingdom
Aerodyne aerosol mass spectrometer	Aerosol size and composition, 30–2,000* nm	Hugh Coe, University of Manchester, United Kingdom
TSI3010 condensation particle counter	Aerosol concentration > 10 nm, 1 Hz	Martin Gallagher, University of Manchester, United Kingdom
Grimm optical particle counter model 1.108	Aerosol size distribution (0.3–2* μm, bins 0.1–0.2 μm, 0.16 Hz)	Martin Gallagher, University of Manchester, United Kingdom
Ultrahigh sensitivity aerosol spectrometer	Aerosol size distribution (0.3–0.8 μm, 7.5-nm bins, 1 Hz)	Martin Gallagher, University of Manchester, United Kingdom
DMT aerosol spectrometer probe ASP-100	Aerosol size distribution (0.2–2* μm, bins 0.03–0.5 μm, 0.1 Hz)	Martin Gallagher, University of Manchester, United Kingdom
Forward scattering spectrometer probe (FSSP)	Aerosol and cloud droplet size distribution (0.5–32 μm, bin 0.8 μm, 0.1 Hz)	Martin Gallagher, University of Manchester, United Kingdom
Particle soot absorption spectrometer (PSAP)	Black carbon concentration (aerosol) (± 1 $\mu g\ m^{-3}$, 0.2 Hz)	Andreas Minnikin, DLR, Germany
Filters	Coarse aerosol composition, whole flight accumulation	Keith Bower, University of Manchester, United Kingdom
2B technologies model 202 ozone monitor	Ozone concentration (± 2 ppbv, 0.1 Hz)	Alastair Lewis, University of York, United Kingdom
Aerolaser AL5003	Carbon monoxide concentration (± 1 ppbv, 1 Hz)	Alastair Lewis, University of York, United Kingdom
Automatic tube sampler (ATS), 15 samples per flight	C4–C9, nonmethane hydrocarbons, monoterpenes and OVOCs	Alastair Lewis, University of York, United Kingdom
Chemiluminescence/catalysis	$NO/NO_x/NO_y$	James Lee, University of York, United Kingdom
Miniature gas chromatograph	Halocarbons (Cl, Br, I; 3–6 min, ± 5%)	Neil Harris, University of Cambridge, United Kingdom

*Upper bound limited by inlet efficiency.

Table S5. ECO-Dimona instrumentation.		
Instrument	**Measurements**	**Supplier**
LiCor 7500 IR gas analyser	Water vapor (H_2O) CO_2	LiCor
TP3 dewpoint system	Air temperature and dewpoint	Meteolabor
BAT probe	Wind, turbulence (50 Hz), pitot static, fluxes	ARA
FUST sensor	Fast air temperature	ARA
PT100	Air temperature	ARA
Eppley radiometers	Solar and terrestrial radiation up- and downwelling	Eppley
Heimann KT15	IR surface temperature	Heimann
Riegl LD90	Laser altimeter for flying height and vegetation structure	Riegl
VegMeter	NDVI	ARA
OTS RT3003 INS/GPS	Position, altitude, attitude, accelerations (100 Hz)	OTS