Planned Measurements from Unmanned Aircraft During the ATOMIC and EUREC^{4}A Campaigns

Gijs de Boer[1,2], Janet Intrieri[1]

Jackson Osborn[1,2], Trish Quinn[1], Tim Bates[1,3], Chris Fairall[1], Greg Roberts[4,5], Mhosen Bagheri[6],

1) NOAA National Oceanic and Atmospheric Administration, U.S. Department of Commerce

2) University of Colorado Boulder

3) University of Washington

4) cnrs

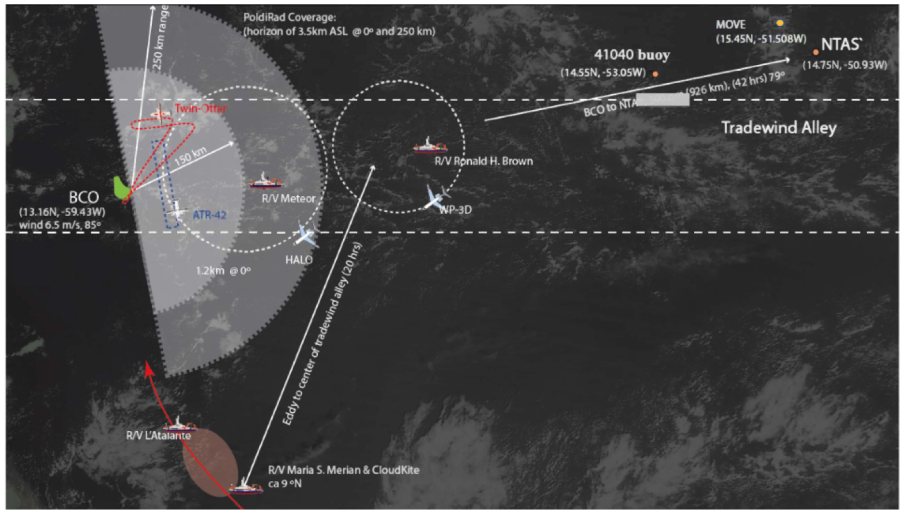
5) Scripps Institution of Oceanography, UCSD

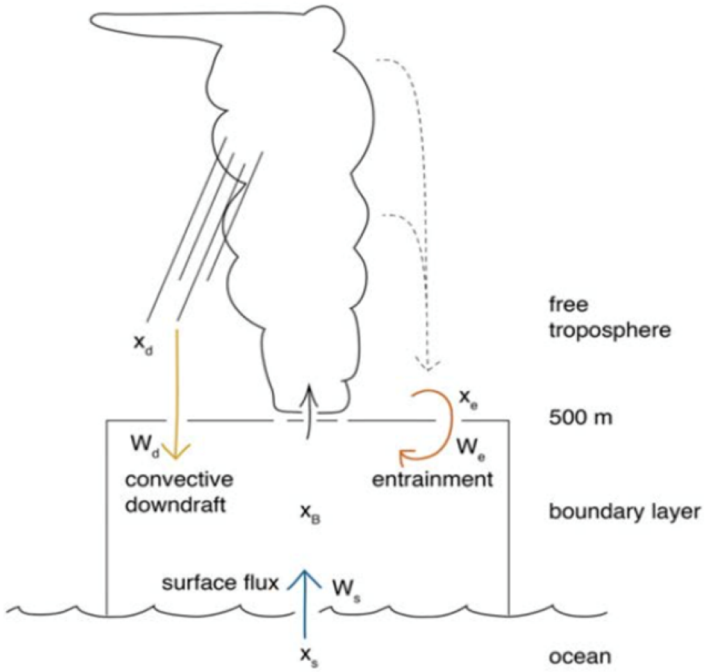
6) Max-Planck-Gesellschaft

PSD Seminar on ATOMIC, 1 November 2019

ATOMIC Scientific Objectives

- **Primary ATOMIC Objectives:**
  - Elucidate the processes and case-and-effect relationships between aerosols and cloud microphysics which influence cloud optical and structural properties
  - Determine the amounts of marine and continental aerosol in the region and the impacts on cloud properties and the clear-sky radiation budget
  - Collect distributed measurements of waves, surface fluxes, cloud cover, and state parameters of both the upper ocean and lower atmosphere
- **UAS-Specific Objectives**
  - Demonstrate UAS capabilities for observing and understanding upper-ocean processes, air-sea interactions, and shallow atmospheric convection in the tropical Atlantic Ocean
  - Collect detailed observations of BL thermodynamic structure, distributions of vertical velocity at cloud base, the vertical and horizontal extent of cold pools, turbulence intensity, IR brightness temperature of the surface, map boundary layer response to surface features, aerosol properties, cloud microphysical properties





Aircraft

L3 Latitude, LLC FVR-55

- Vertical take-off and land (VTOL - battery power) from a flight deck constructed on top of the two containers on the fantail
- Piloted by 2 Latitude pilots with operations overseen by 1 AOC personnel
- Flights will be conducted within 10 km of the ship during daylight and night
- Flight duration (payload & fuel) is estimated at 3-5 hours with an altitude ceiling of 12,000’
- D-GPS for aircraft yaw and orientation and location relative to flight deck
- Flights restricted to wind speeds < 30 knots, sea state up to 3, and no precipitation.

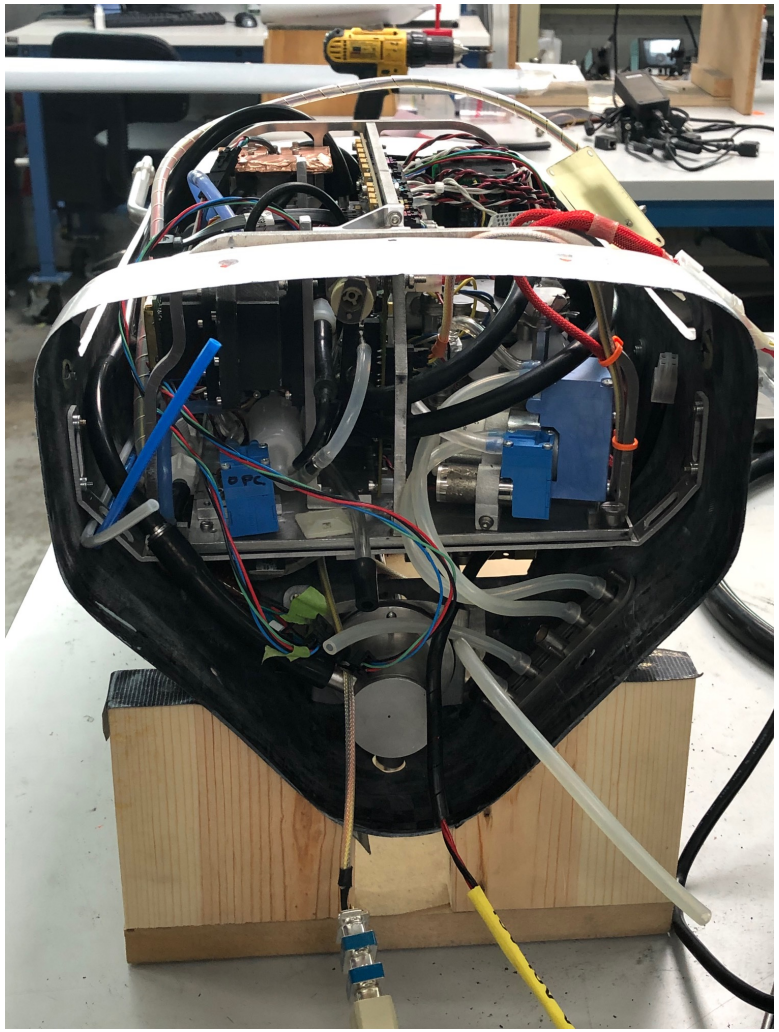
Payloads

- **PSD *miniFlux*** for the measurement of atmospheric thermodynamic state, turbulence, winds, & sfc/sky IR temperature)
  - Multi-hole pressure probe (MHP), fine-wire array, IR thermometers, thermistor, redundant PTH sensors, inertial navigation system
- **PMEL Clear Sky** for the measurement of aerosol microphysical, chemical, and optical properties;
  - Condensation particle counter (MCPC), absorption photometer (ABS), chemical filter sampler, optical particle spectrometer (POPS), sunphotometer, T/Humidity
- **PMEL Cloudy Sky** for the measurements of aerosol – cloud interactions
  - Optical particle spectrometer (POPS), miniature scanning electrical mobility sizer (mSEMS), cloud droplet probe (CDP), Temp/Humidity

Aircraft and Payloads: PSD *miniFlux*

The PSD *miniFlux* provides measurements of P, T (in situ, sfc and sky), RH, & 3-dim winds, turbulence (from MHP and fast response hot and cold wires) and includes a custom data-logging system which logs relevant information at high rates (up to 1 kHz) to allow for eddy covariance calculation of fluxes of heat and momentum.

Aircraft and Payloads: PMEL Clear & Cloudy Sky



The PMEL payloads provide measurements of total aerosol concentration^, particle absorption^, chemical composition^, aerosol particle size distribution, temperature, pressure, humidity and cloud droplet size distribution*.

^ Clear sky payload only * Cloudy sky payload only

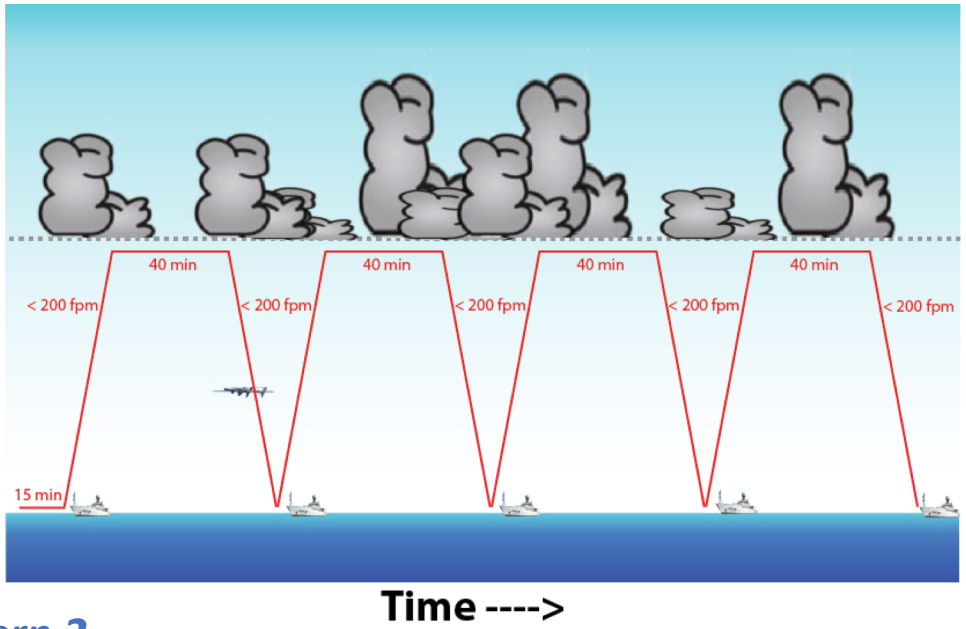
Planned Flight Patterns: PSD *miniFlux*

miniFlux Payload Pattern 1

Primary Objectives: Cloud-base mass flux, thermodynamic structure, turbulence statistics.

General Flight Pattern:

- Extended flights just below cloud base (400 m diameter circles or racetrack at 20 m below ceilometer cloud base for 30-40 mins)
- Slow profiles to near-sfc environment
- Statistical sampling near surface (400 m circles for 15 minutes)



miniFlux Payload Pattern 2

Primary Objectives: Map out extent of cold pools or other gradients.

General Flight Pattern:

- Complete slow vertical profile using 400 m circle to the top of the boundary layer and back to surface
- Complete a stair step survey flight over the lower atmosphere at ~50 m vertical intervals
- Complete second slow vertical profile to the top of the boundary layer

Planned Flight Patterns: PMEL Clear/Cloudy Sky

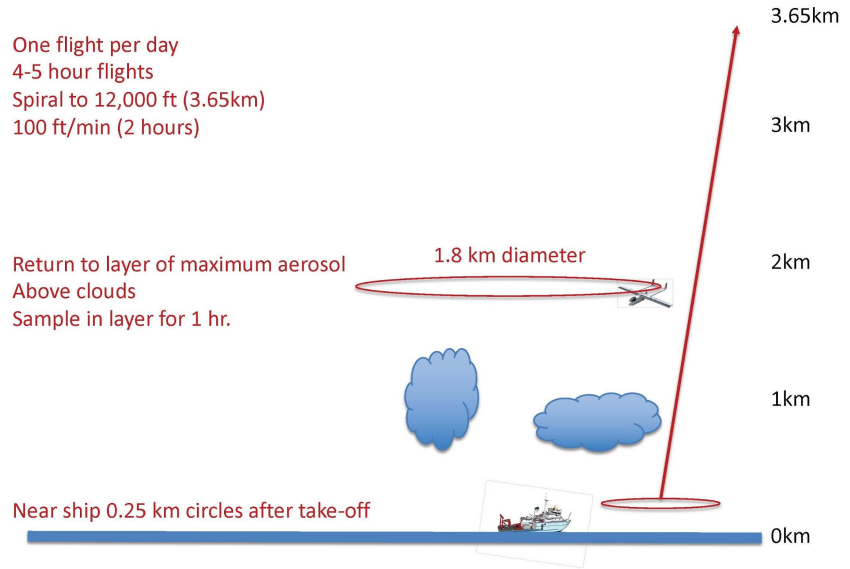
PMEL Clear Sky Payload Pattern

Primary Objectives: Measure direct radiative effect of aerosol particles

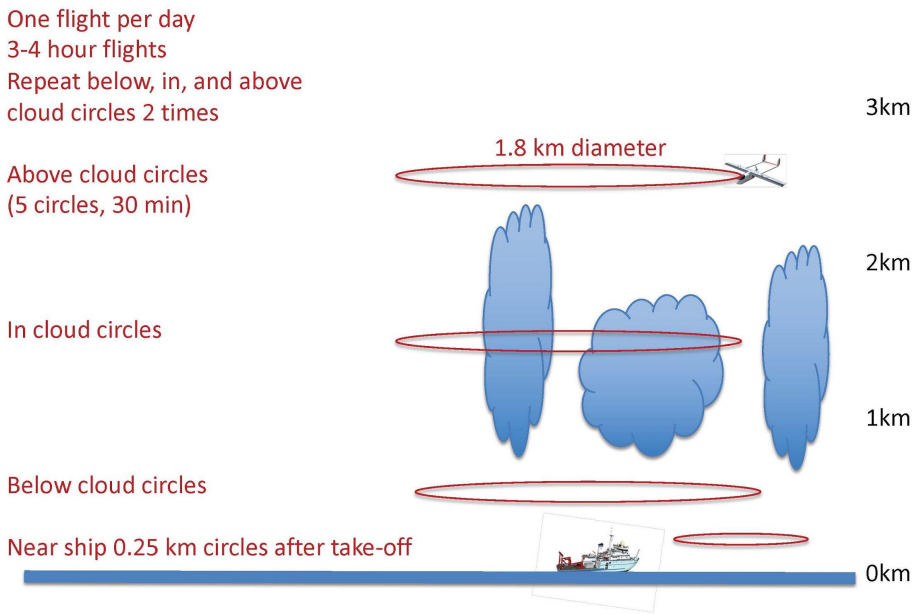
General Flight Pattern:

- 10-15 minutes next to ship at 30 m for near surface statistics and intercomparison with ship-borne instrumentation
- Slow profile to 12000’ through clear sky column
- Targeted observing of detected aerosol layers in very large circle to collect filter measurements

HQ-55 UAS Clear Sky Payload Flight Plan



HQ-55 UAS Cloudy Sky Payload Flight Plan



PMEL Cloudy Sky Payload Pattern

Primary Objectives: Measure aerosol-cloud interactions and evaluate aerosol gradients across cloud boundaries

General Flight Pattern:

- 10-15 minutes next to ship at 30 m for near surface statistics and intercomparison with ship-borne instrumentation
- Slow profile to ceilometer cloud base and conduct extended sampling at this altitude
- Repeat extended sampling within the cloud layer and above

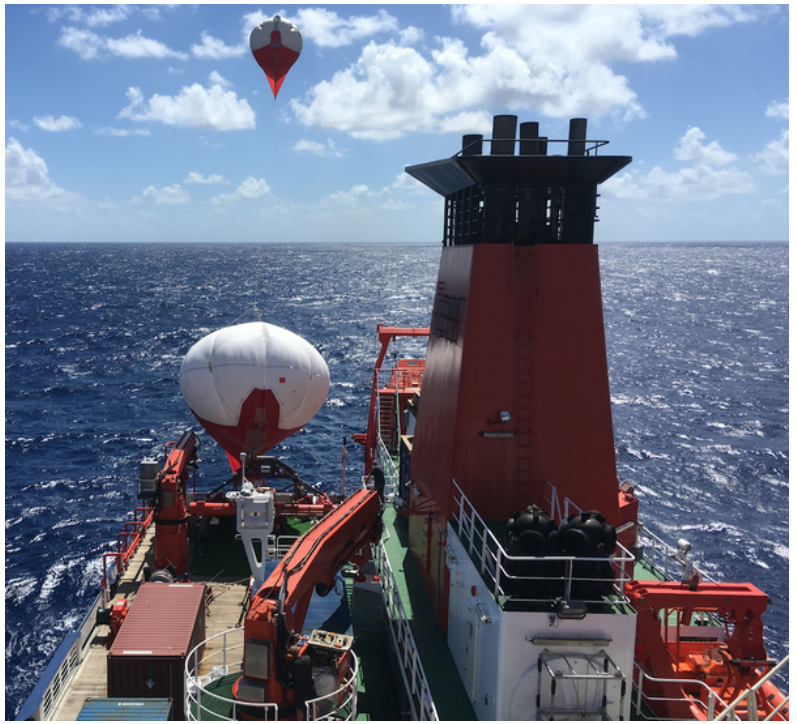
Additional Unmanned Systems

Boreal UAS (Centre National de Recherches Météorologiques):

- *Condensation Particle Counter:* Total aerosol concentrations (dp > 0.01 µm)
- *Optical Particle Counter:* Aerosol size distributions (0.3 µm < dp < 3 µm)
- *Multi-hole Turbulence Probe:* 3D wind, boundary layer turbulence and fluxes
- *Sea Surface Temperature:* IR sensor during low altitude legs (< 100 m.asl)
- *Radar altimeter:* Sea state including wave height, speed and direction
- *Pyranometer:* Total hemispherical solar irradiance (0.4 µm and 01.1 µm)
- *State Parameters:* Temperature, pressure and relative humidity

Cloud Kite (Max Planck Institute; from R/V Maria S. Merian and R/V Meteor):

- *MPIDS Holographic system*: 3D particle position and size distribution
- *2D PIV*: 2D particle position and velocity field
- *1D Static Wind Probe*: 100 Hz winds with PT-100 temperature, 3 extra anemometers
- *LWC-300*: 30Hz liquid water content from 0 to 3 g/m3
- *Fast CDP*: droplet size and number concentration (diameter between 2µm-50µm)
- *INS*: System attitude
- *State Parameters:* Temperature, pressure and relative humidity
- Hotwire: Dantec mini-hotwire ultra-fast thermometer (10 kHz)
- CCN Counter: Nanoscan SMPS Model 3910, 10-420 nm, 13 bins



UAS Summary

- NOAA plans to deploy the L3 Latitude, LLC FVR-55 unmanned aircraft system to make measurements of atmospheric thermodynamic state, winds, turbulence, aerosol physical and chemical properties, cloud microphysical properties and IR surface brightness temperature during the ATOMIC campaign.
- This aircraft will be deployed from the R/V Ronald H. Brown during both legs 1 and 2 of ATOMIC, with a goal of operating the aircraft for 8-12 hours per day as frequently as possible (weather, operations permitting).
- Various flight patterns will be conducted to capture different perspectives on the key quantities listed above
- Additional unmanned systems will be deployed to make complementary measurements as part of the EUREC^{4}A project, including a long-endurance unmanned aircraft (BOREAL) and tethered balloon systems (CloudKite) deployed from the R/V Maria S. Merian and R/V Meteor.
- The FVR-55 work is supported by the NOAA Physical Sciences Division, NOAA Climate Program Office, NOAA Unmanned Aircraft Systems Program Office and the NOAA Pacific Marine Environmental Laboratory.
- Additionally, extensive outreach activities are planned…

Outreach Activities

Prior to the first leg (January 4) -- A media event and VIP tour of the Ron Brown

Press conference [OAR Comms]; instrument 2-pagers, website, NOAA logo items, etc.; meet/greet with local and national government representatives, US Ambassador or Embassy staff, Barbados officials, local dignitaries including Prime Minister of Barbados, the Ministers of Education, Port Authority, Agriculture, etc. Trish, Janet, Chris, and Sandy Lucas to talk and provide tour information

Port day between Leg 1 and 2 (January 27)

Tour of RHB for school children to be coordinated with the Ministry of Education and with the Barbados Council for Science and Technology

Prior, during and after the ATOMIC field campaign

A social media campaign (Twitter, Facebook, Climate.gov, etc.) managed by NOAA-OAR

Late January/Early February - organized by Barbados folks

Possible 2-day workshop developed to highlight the ATOMIC and EUREC4A field studies as well as celebrate the 50th anniversary of the Barbados Oceanographic and Meteorological EXperiment (BOMEX- 1 May to 28 July 1969) as a joint project of seven US departments and agencies with the cooperation of Barbados