Maldives AUAV Campaign (MAC)

Observing Aerosol-Cloud-Radiation-Climate Interactions Simultaneously from Three Stacked Autonomous Unmanned Aerial Vehicles (AUAVs)

Report of the Field Campaign Held from March 05 to March 31 2006 at the Island of Hanimaadhoo, Maldives.

V Ramanathan
Chief Scientist, MAC
Center for Atmospheric Sciences and the Center for Clouds, Chemistry and Climate
Scripps Institution of Oceanography, University of California at San Diego

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Hanimaadhoo Airport

Hanimaadhoo Island

From March 6 to March 31 2006, we probed the polluted atmosphere over the N. Indian Ocean with light weight Unmanned Aerial Vehicles (or UAVs) fully equipped with instruments. This UAV campaign launched from the Maldives laid a solid foundation for the use of UAVs to study how human beings are polluting the atmosphere and their impact on climate, including global warming.

Particles in the pollution enter the clouds from below; producing more cloud drops; the clouds in turn reflect more sunlight back to space. In addition the particles suppress rainfall. The particles also directly scatter and absorb sunlight, thus shielding the surface from sunlight. These and other interactions between particles in pollution, clouds and reflected solar radiation are one of the fundamental challenges in the global warming problem, which we need to resolve before we can reliably answer questions such as: How large is the global warming going to be in the future?

It is this particles-cloud-solar radiation interaction which we were observing with UAVs. It requires one aircraft below the cloud to observe the nature and number of particles entering the cloud and the amount of sunlight penetrating through the cloud and the particles; one inside the cloud to document how the clouds are responding to the particles; and one above the clouds to measure the sunlight reflected by clouds and the particles that are exported out of the clouds. We need all three aircraft in stacked formation measuring simultaneously over the same cloud system… we need the 3 aircraft observing the same cloud within a fraction of a minute of each other, in view of the fast time life times of most clouds.

During the four weeks in March 2006 at Maldives, we proved that light weight UAVs are uniquely suited to conduct such an experiment. MAC logged over 120 flight hours that included 55 takeoffs and 18 science mission. The science missions collected data on pollution and dust transported from S. Asia, Arabian and SW Asian deserts and their impacts on global dimming at the sea surface, the energy absorbed in the atmosphere and cloud properties. We made direct measurements of the role of black carbon in the solar heating of the atmosphere. Hundreds of polluted and dusty shallow cumulus clouds were penetrated with the in-cloud aircraft. The above cloud and below cloud UAVs were stacked within ten seconds of the in-cloud UAV with minimal pitch such that reliable solar radiation measurements could be made. The UAVs were flown not only in stacked formation but also in tandem (wing tip to wing tip with 1 km apart) formation to validate the reliability and repeatability of the airborne sensors.

Measurements were made within the boundary layer in the vicinity of the Maldives Climate Observatory at Hanimaadhoo (MCO_H), an ABC_Super observatory. MCO_H instruments that were nearly identical to the airborne instruments were used to validate the UAV data. Real time data and in-cloud video transfer from the UAV to the ground station greatly enhanced the quality of data collection by allowing us to control the altitude of cloud penetration.

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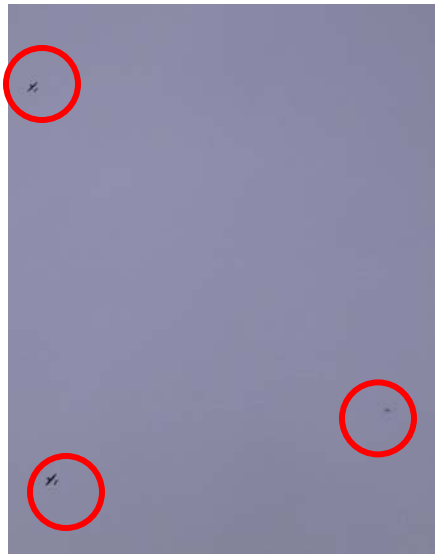
In spite of operating in a hot-humid climate in a remote part of the world and that too in a commercial airport, the mission ended with a loss of only one UAV among the 6 UAVs that were in operation. The loss of the one UAV was due to an improper battery, a freak error that is never bound to happen again. All in all MAC demonstrated the ability of light weight UAVs to conduct complex science missions and collect unique data sets on a problem of great importance to climate change and global warming.

It is my hope that many scientists will scrutinize the conduct of this campaign and the data we collected to learn about the MAC campaign and improve upon it. Based on MAC's success, it is possible that in about five years from now, hundreds of such light weight UAVs will be documenting how human beings are polluting the planet and hopefully provide an early warning system for potential environmental disasters in the future. The following translated MAC from a mere dream and vision into a reality (see the attached participants list):

Mr. Hung Nguyen, the mission manager who directed the flight missions and helped me with the overall conduct of the campaign; The scientists in my lab, Drs. Greg Roberts, Muvva Ramana and Craig Corrigan who designed and developed the instruments; Dr. Greg Roberts who integrated the instruments with the UAVs; the ground support and flight crew of The Advanced Ceramics Research for the Manta UAV, the 3-UAV stacker software and for operating the UAVs and ensuring the safe data collection at Hanimadhoo; the Scripps Institution of Oceanography and UCSD's engineering facilities that built some of the instruments and data integration packages; and Droplet Measurement Technologies who built the cloud physics instruments The advisory committee consisting of Drs. Jay Fein, Dave Fahey, Joachim Kuettner, Hal Maring and Cheryl Yuhas provided expert guidance of MAC; NASA-Dryden provided advice on safe conduct of flights in the field; Dr Jay Fein nurtured the UAV work in my lab for nearly 3 years; to Dr. Chet Koblinsky for providing the start up funding for MAC and funding the ABC observatory at Hanimaadhoo; and to Hal Maring& Cheryl Yuhas for a fast response to fund MAC.

Finally grateful thanks are to the National Science Foundation, the National Oceanic and Atmospheric Administration and NASA for supporting this campaign and for guiding it; and to Scripps Institution of Oceanography and the Vetlesen foundation for generously supporting my lab for the last 15 years. We are deeply indebted to the Govt of Maldives for its unprecedented cooperation and help without which MAC would have remained just a dream.

Take Off at Hanimaadhoo Airport



3 UAVs stacked

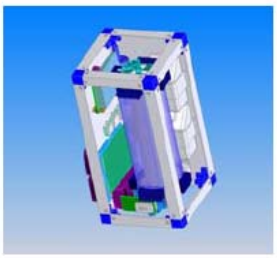
Instrument Payload

MAC_5 About to Enter Trade Cu

MAC TEAM

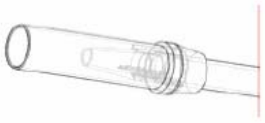
Condensation Particle Counter
Weight: 0.87 kg
Dimensions: 250 x 120 x 70 mm
Measure: # /cc for D > 10 nm

Optical Particle Counter
Weight: 0.30 kg
Dimensions: 96 x 60 x 34 mm
Measure: size distr. 0.3 - 3 um

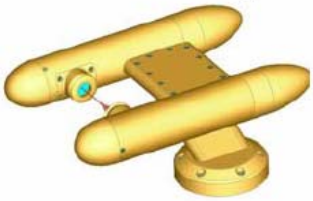


Cloud Condensation Nuclei Counter
Weight: 3 kg
Dimensions: ca. 100 x 100 x 200 mm
Measure: # /cc for supersat. > 0.2%

Aethalometer
Weight: 0.8 kg
Dimensions: 140 x 110 x 75 mm
Measure: absorbing aerosol



Aerosol Inlet
Weight: 0.037 kg
Dimensions: 10 Ø x 200 mm
Designed to minimize bias to aerosol size distribution



Cloud Droplet Probe
Weight: 1.42 kg
Dimensions: 216 x 115 x 100 mm
Measure: drop size distr. 0.7 - 70 µm
NOTE: electronics in fuselage

Pyranometer
Weight: 0.2 kg
Dimensions: 80 Ø x 100 mm
Measure: Irradiance 305 – 2800 nm

PAR radiometer
Weight: 0.03 kg
Dimensions: 24 Ø x 25 mm
Measure: Irradiance 400 – 700 nm

Spectral Radiometer
Weight: NA
Dimensions: 150 x 90 x 15 mm
Measure: 350 - 1150 nm 256 channels

AUAV instruments for above, in and below cloud platforms

List of Participants

Scripps Institution of Oceanography

Unmanned Aerial Vehicle Team: C. Corrigan, H. Nguyen, M. V. Ramana, V. Ramanathan and G. Roberts

Maldives Climate Observatory at Hanimaadhoo Team: C. Corrigan, D. Kim, D. Lubin, M.V. Ramana, V. Ramanathan and P. Siva

Data Analysis Team: F. Li and A. Zhu

Advanced Ceramics Research

Flight Operations: E. Berzins, P. Corcoran, E. Hooper, M. Intschert, J. Mingo, A. Mulligan, M. Patterson, R.A.G. Pineda, M. Pobloske, J. Robinson, L. Wardell, N. White.

Advisory Committee

NOAA: D.W. Fahey
UCAR: J. Kuettner
NASA-Dryden: R. Curry, C. Jennison

Agency Advisory Committee

NSF: J. Fein
NASA H. Maring, C. Yuhas
NOAAC. J. Koblinsky

MALDIVES CLIMATE OBSERVATORY AT HANIMADHOO
AN ABC SUPER SITE SPONSORED BY UNEP