A Pre-Proposal for Aerosol Science Investigations in the United Arab Emirates

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Summary:

We propose to deploy the Mobile Atmospheric Aerosol and Radiation Characterization Observatory (MAARCO), a portable aerosol laboratory, to the United Arab Emirates in conjunction with efforts by Brent Holben of NASA/GSFC. MAARCO will be equipped with an MPLNet micropulse lidar, and Aeronet sun photometer, and a complete radiation and aerosol sampling system (see appendix.) It will provide near continuous data on aerosol optical depth, vertical profile concentration, and chemistry. We will also cooperate with airborne missions to provide aerosol chemistry data as well as lend expertise in dust and pollution particle sizing. We will also support the entire mission with continuous mesoscale aerosol forecasting. This component of the UAE mission will be used to support NASA calibration/validation efforts for MODIS, MISR, and GLAS. Summary mission information is at http://aeronet.gsfc.nasa.gov/uae_2004/uae_2004.html.

Rationale:

The Persian Gulf has one of the largest aerosol burdens in the world with frequent dust storms, smoke advection from the Indian subcontinent, and its own high emission rates of pollution from the petroleum industry. Particle size distributions and chemistries are highly variable. In addition, the Persian Gulf exhibits extremely complicated meteorology, with variable sea surface temperatures, enormous latent heat fluxes, abrupt topography and strong mesoscale circulations. This combination of factors makes both modeling and remote sensing in the region extremely difficult. Consequently, this is one of the few regions of the world that can be used to fully stress aerosol algorithms and assumptions. However, because of the political environment of the region, the Persain Gulf is mostly unstudied.

In 2003 AERONET deployed one of its first upgraded Sun photometers with the ability to measure optical depth out to 1.6 μm. With this deployment, Brent Holben, NASA GSFC, initiated cooperation with a United Arab Emirates (UAE) funded research effort to study the feasibility of cloud seeding in the Persian Gulf. This study includes the use of two research aircraft and the cooperation of the South African Meteorological service and the National Center for Atmospheric Research (NCAR). Mr. Holben is now pursuing a NASA sponsored field mission to study aerosol particles in this typically closed region. It is anticipated that UAE will provide technical and logistical support.

This coupled with the ongoing cloud seeding study makes a joint aerosol study in the region both financially and scientifically attractive.

There are a number of significant scientific questions that need to be addressed for the Persian Gulf region. First, because the ratio of fine to coarse mode particles is highly variable there is a significant potential for artifact and errors in remote sensing retrievals from Sun/sky inversions, satellite optical depth algorithms (e.g., MODIS, MISR), and ground and space based lidar data (e.g., GLAS). Second, because there is a variable aerosol coarse mode, the formation of soluble secondary species on dust particles can be studied along with the impact of giant cloud condensation nuclei on cloud properties. Third, because cloudless skies are fairly common in the UAE, and aerosol loadings are variable, the region is ideal for ground-based studies of direct radiative forcing. In addition, the variable fine/coarse partition of aerosol particles makes infrared forcing studies feasible. Lastly, the sharp contrasts between land and water, as well as the high surface heating and evaporation over the Persian Gulf makes the region a good place to stress meteorology models.

Proposed work:

As part of this mission it is critical that accurate measurements of particle vertical distribution, size and chemistry be made. We propose to deploy the Naval Research Laboratory's Mobile Atmospheric Aerosol and Radiation Characterization Observatory (MAARCO), a portable aerosol laboratory, to the United Arab Emirates for at least 4 months in conjunction with efforts proposed by Brent Holben, NASA GSFC. This laboratory, manufactured from a standard 20' shipping container, houses a fairly complete set of meteorological, radiation and aerosol instrumentation. The container can be shipped to almost anywhere in the world or be operated onboard an oceanographic research vessel. Instrumentation includes an MPLNet micropulse lidar (MPL), an Aerosol Robotic Network (AERONET) Sun photometer, a complete set of solar and infrared radiometers, the ability to release GPS radiosondes, aerosol particle samplers for inorganic and organic analysis, and both fine and coarse mode particle sizers. Filter and impactor samples will be submitted to the Desert Research Institute (DRI) and UC Davis for analysis by ion chromatography, GCMS, XRF and single particle analysis/SEM. These instruments and measurements will give us the required radiative and microphysical information needed to succeed in studying the scientific questions discussed in the rationale listed above. We will also apply our expertise in aerosol microphysics and radiation to the airborne component.

We will also provide extensive meteorological support to the mission. This will be through daily runs of the Coupled Ocean Atmosphere Modeling and Prediction System (COAMPS^{TM}) mesoscale model. This model will be operated at least at 9 km resolution with forecasts out to 3 days. Included in COAMPS is an imbedded aerosol model that has shown outstanding fidelity for dust and oil fires in the region.

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Appendix MAARCO Instrumentation:
MAARCO Mobile Atmospheric Aerosol and Radiation Characterization Observatory

The Mobile Atmospheric Aerosol and Radiation Characterization Observatory (MAARCO) is a standard 20'x8' climate controlled CONEX shipping container that has been modified to function as an easily-shipped laboratory for siting overseas, in remote areas, or on sea-going vessels. Its purpose it to perform basic research on atmospheric aerosols, gasses, and radiation (visible and IR light) in difficult to deploy regions. MAARCO will assist in validating aerosol and weather models as a ground station and often be used in conjunction with research aircraft. All MAARCO requires is input power (110, 220, or 240 3-phase), though it can utilize generators. MAARCO also has the capability to utilize telecommunications links for real time remote displays when available.

The MARCO container is 'mobile' in the sense that it can be easily moved it to new sites to perform research. One of the primary obstacles in performing research overseas is the difficulty in finding adequate facilities at good site locations. Most aerosol instruments prefer, if not require, climate controlled environments for stable, consistent operation. These conditions are not readily available in remote or foreign sites. Radiation instruments are for the most part less sensitive to changes in the environment, but are also much more valuable when run in conjunction with other instruments to fully characterize the local environment.

As an integrated laboratory, the MAARCO contains a suite of aerosol particle and gas instruments including the following:

	Instrument	Power Usage	Net Power	Shipping Weight	Weight of Instrument	Net weight
1	Aeronet Sun Photometer:	solar	0	30 kg	26 kg	30 kg
2	Pyranometers, 2	solar	0	1 kg	930 g	2 kg
3	Pyrgeometers, 2	solar	0	1.2 kg	1050 g	2.4 kg
4	Pyrheliometer	solar	0	1 kg	700 g	1 kg
	CV2 ventilation unit – 4 total	12 V DC, 1.25 A 5 W continuous, 10 W heating	40 W	1 kg	1 kg	4 Kg
	Solar tracker	115 VAC 150 VA power	150 VA	45 kg	30 kg	45 kg
5	Total Sky Imager	115 VAC 50-600 W depending on whether heater is on	600 W	30 kg	20 kg	30 kg
6	Nephelometer	24 +/- 4 VDC at 5A, 175 W maximum	175 W	30 kg	23 kg	30 kg

7	Aerodynamic Particle Size	85 to 264 VAC, 100 W	100 W	27 kg	17 kg	27 kg
8	TSP filter Pump	115 V, 60 Hz, 15 Amp	1725 W	25 kg	22 kg	25 kg
9	Tapered Element Oscillating Mass Balance	115 V, 60 Hz, 1 Amp	115 W	90 kg	75 kg	90 kg
	TEOM Pump	115 V, 60 Hz, 5.3 Amp	1000 W	16 kg	15 kg	16 kg
11	Optical Particle Counters	115 V, 60 Hz, 5.3 Amp	400 W	100 kg	90 kg	100 kg
12	SO2 Monitor	105-125 VAC, 60 Hz, 10(Watts	100 W	24 kg	20 kg	24 kg
13	Ozone monitor	90-110VAC, 60Hz, 150 Watts	150 W	20 kg	16 kg	20 kg
14	MOUDI sampler	115 VAC, 60 Hz, 0.3 A	35 W	15 kg	13 Kg	15 kg
15	MPL LIDAR	115 VAC, 60 Hz, ~ 5A	575 W	120 kg	40 kg	120 kg
16	Weather Station	solar		60 kg	50 kg	100 kg
15	Mini-Rawinsonde System (MRS) AN/UMQ-12		100 W	50 kg	45 kg	50 kg
	Radiosondes, 50	battery		0.75kg ea		38 kg
17	Laptop computers, 5	5@ 80 W	400 W	3 kg ea	2.5 kg ea	15 kg
	Rack computers, 2	2@ 200 W	400 W	10kg ea	9kg ea	20 kg
	Racks, 3			30 kg	30 kg	90 kg
18	Scaffolding			50 kg	50 kg	50 kg
	Ladders, 2			15 kg	15 kg	15 kg
	Batteries/UPS, 5			20 kg ea	18 kg ea	100 kg
	NET Equipment		7 kW			1060 kg
	MAARCO container	220V 3-phase, or 110 V, 60 Hz. Up to 200 Amps	AC/heater and light only: 4 kW		2040 kg	2040 kg
	NET TOTAL		10 kW normal operation.			3100 kg

1. The AERONET (AErosol RObotic NETwork) program is an inclusive global federation of ground-based remote sensing aerosol networks. The goal is to assess aerosol optical properties and validate satellite retrievals of aerosol optical properties. Data from this collaboration provides globally distributed observations of spectral aerosol optical depths, inversion products, and precipitable water in geographically diverse aerosol regimes. Direct sun measurements are made in eight spectral bands to derive aerosol optical thickness (AOT). In addition, this instrument measures the sky radiance in four spectral bands to acquire aureole and sky radiances observations through a large range of scattering angles from the sun to retrieve size distribution, phase function and aerosol optical thickness.

2. MPL LIDAR: The MPL LIght Detection And Ranging is a single channel (523nm), autonomous, eye-safe system used to determine the vertical structure of clouds and aerosols. The MPL data is analyzed to produce optical properties such as extinction and optical depth profiles of the clouds and aerosols. It is valuable also for locating atmospheric layers of interest for aircraft sampling, and to assist in interpreting the sun photometer, pyrgeometers, pyranometers, and perheliometer radiation (visible and IR light) instrument data. The primary goal of MPLNET is to provide long-term data sets of cloud and aerosol vertical distributions at key sites around the world. The long-term data sets will be used to validate and help improve global and regional climate models, and also serve as ground-truth sites for NASA/EOS satellite programs.

3. Pyranometers. Kipp & Zonen CM 21 Pyranometers measure incoming global solar radiation (0.3 to 2.8 μm spectral range). We use two pyranometers on MAARCO: one in direct sunlight to give total solar irradiance, and one on the solar tracker shaded by

tracker balls (that block the sun and shade the pyranometers) to measure diffuse sky irradiance.
4. Pyrgeometers: Kipp & Zonen CG 4 Pyrgeometers provide high accuracy infrared radiation (IR) measurements, from 4.5 to 42 µm. We use two pyrgeometers on MAARCO: one in direct sunlight to give total IR irradiance, and one on the solar tracker shaded by tracker balls (that block the sun and shade the pyranometers) to measure diffuse sky IR irradiance.
5. Pyrheliometer: Our Kipp & Zonen pyrheliometer is mounted on our solar tracker – allowing it to constantly point at the sun during daylight hours. It is designed for unattended normal incident direct solar radiation measurements, from 0.2 to 4.0 µm.
6. Total Sky Imager: Our total sky imager is an automatic camera system that collects real-time images of the entire visible sky at set intervals (up to 1 per minute), processes the data to determine percentage cloud cover, and saves the images for later reference. These data and images are valuable for determining the relative impact of clouds on the measurements taken by other instruments in the MAARCO observatory.
6. Nephelometer: The nephelometer measures aerosol light scattering properties of the air pulled into the nephelometer chamber by subtracting light scattered by atmospheric gasses, the walls of the instrument and the background noise in the detector from the light scattering measurement. Besides characterizing the light scattering properties of particles in the air, it provides data on aerosol particle sizes and concentrations in the sampled air.
7. Aerodynamic Particle Sizer. We use an APS 3321 to determine aerodynamic diameter and light-scattering intensity. The APS provides high-resolution, real-time aerodynamic measurements in the range from 0.5 to 20 micrometers. It also measures light-scattering intensity in the equivalent optical size range of 0.37 to 20 micrometers. Because it provides paired data (aerodynamic diameter and light-scattering intensity) for each particle, the APS provides clues to the makeup of the aerosol particles.
8. **Optical particle counters:** These are probes typically mounted on aircraft but have been modified for ground operation.
9. TSP filter: Total suspended particulates are collected in our air filter system for later mass, elemental composition, and particle morphology analysis.
10. Tapered Element Oscillating Mass Balance: TEOM is an extremely sensitive aerosol mass instrument; it continuously (real-time) measures the mass or 'weight' of the particles that are collected from air as it passes through a filter. This real-time mass measurement is valuable for correlation with the other particle and gas measuring instruments, and to understand current atmospheric conditions, allowing users to identify episodes and determine trends in real time.. Also, the filter can be later analyzed for elemental composition and particle morphology.
11. SO_2 Monitor: The SO2 monitor provides a continuous, and a time averaged measurement of sulfur dioxide in the atmosphere. As SO2 is a reactive compound that can modify aerosol particles, and is correlated to visibility degradation and industrial processes, we measure this compound for chemistry, and to gain clues to the origin of the air mass we are sampling.
12. Ozone monitor: The ozone monitor provides a continuous, and a time averaged measurement of ozone in the atmosphere. Ozone is also a reactive compound that can modify aerosol particles, and is correlated with industrial processes and smog. We track

ozone to understand the changing atmospheric chemistry, and to get clues to the origin of the air mass.

13. MOUDI sampler: The MICRO-ORIFICE, UNIFORM-DEPOSIT IMPACTOR atmospheric aerosol particle sampler is a precision cascade impactor for collecting size-fractionated aerosol particle samples for gravimetric (mass or 'weight') and chemical analysis. It size-fractionates the sampled aerosol particles into ten size bins, over wide size range, 0.056 – 18 μm.

14. Weather Station: The weather station provides local weather conditions including wind speed, direction, humidity, temperature, and solar radiation.

15. Rawinsonde system: The rawinsonde system utilizes balloons to lift instrument packages though the troposphere to continuously measuring wind speed, direction, elevation, and humidity as the balloons ascend. This provides data to correlate with the vertical structure of clouds and aerosols observed by the MPL Lidar system, and to understand the local weather conditions.