SALiNAS: An Emerging Aerosol Lidar Network Supporting the Seven Southeast Asian Studies (7SEAS) Campaign

James R. Campbell[1], Nofel Lagrosas[2], Nguyen Xuan Anh[3], Boon Ning Chew [4], Brent N. Holben, Neng-Huei Lin[6], Jeffrey S. Reid[7], Santo V. Salinas[8], Nobuo Sugimoto[9], Si-Chee Tsay[10], and Ellsworth J. Welton[11]

[1]*University Corporation for Atmospheric Research Visiting Scientist Programs, c/o Naval Research Laboratory, 7 Grace Hopper Ave. Stop 2, Monterey, California, USA 93943 (jamesc@ucar.edu)*
[2]*Ateneo de Manila University, Loyola Heights, Katipunan Ave., 1108 Quezon City, The Philippines (nlagrosas@ateneo.edu)*
[3]*Vietnam Academy of Science and Technology, Institute of Geophysics, A8 – 18 Hoàng Quốc Việt, Cầu Giấy, Hà Nội, Việt Nam (nxuananh0@gmail.com)*
[4]*Centre for Remote Imaging, Sensing and Processing, National University of Singapore, S17 Level 2, Lower Kent Ridge Road, Singapore 119260 (crscbn@nus.edu.sg)*
[5]*NASA Goddard Space Flight Center, c/o Code 614.4, Greenbelt, Maryland, USA 20771 (Brent.N.Holben@nasa.gov)*
[6]*Department of Atmospheric Sciences, National Central University, Chung-Li 320, Taiwan (nhlin@cc.ncu.edu.tw)*
[7]*Aerosol and Radiation Section, Naval Research Laboratory, 7 Grace Hopper Ave Stop 2, Monterey, California, USA 93943 (jeffrey.reid@nrlmry.navy.mil)*
[8]*Centre for Remote Imaging, Sensing and Processing, National University of Singapore, S17 Level 2, Lower Kent Ridge Road, Singapore 119260 (crsscsv@nus.edu.sg)*
[9]*Atmospheric Remote Sensing Section, National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki, Japan 305-8506 (nsugimot@nies.go.jp)*
[10]*NASA Goddard Space Flight Center, c/o Code 613.2, Greenbelt, Maryland, USA 20771 (si-chee.tsay-1@nasa.gov)*
[11]*NASA Goddard Space Flight Center, c/o Code 613.1, Greenbelt, Maryland, USA 20771 (Ellsworth.J.Welton@nasa.gov)*

1. OVERVIEW

The Seven Southeast Asian Studies (7SEAS; http://7-seas.gsfc.nasa.gov/) field campaign is an international and multi-disciplinary initiative designed to study the influence of aerosol particles on a wide range of physical and biospheric processes in the South China Sea (SCS) region. Research partners representing seven Southeast Asian countries (Indonesia, Malaysia, the Philippines, Singapore, Taiwan, Thailand and Vietnam), in partnership with colleagues in Japan and the United States, have offered or are presently deploying resources to support 7SEAS field-observational components. Through the U.S. National Aeronautics and Space Administration (NASA), Naval Research Laboratory base programs and the Office of Naval Research (ONR) comes additional support for satellite applications and global climate and aerosol modeling systems. Initiated in 2009, 7SEAS will feature a series of intensive observational periods (IOP) through mid-2013. Legacy activities are projected to continue afterwards indefinitely at participating SCS institutions and research sites.

This paper describes the Southeast Asian Lidar Network for Atmospheric Studies (SALiNAS; http://salinas.gsfc.nasa.gov), a newly-formed cooperative project tasked with coordinating 7SEAS lidar applications; including scientific priorities and collaborative research opportunities. Lidar-based measurements during the mission represent a crucial component of the strategy to observe and characterize regional aerosol physical properties and understand transport processes. In response, a number of portable and autonomous lidar instruments are being deployed to the area to compliment existing resources, including many passive radiometric sensors. SALiNAS includes participation from the Asian SKYNET (http://atmos.cr.chiba-u.ac.jp/) [1] and the NASA Micropulse Lidar Network (http://mplnet.gsfc.nasa.gov/) [2] projects, as well as university support in the Philippines, Singapore, Taiwan and Vietnam. Support also comes from the NASA Cloud Aerosol Lidar with Orthogonal Polarization (CALIOP) satellite project. Five ground sites are currently operating; four are autonomous/eye-safe and continuously-running, with the remaining instrument operated episodically. Two additional instruments are pending deployment, and another proposed. All are anticipated to become active within the window of primary intensive field operations. A depiction of the current SALiNAS configuration is shown in Fig. 1, and a list of sites and instrument specifications in Table 1.

The SCS represents the overwhelmingly dominant geographical feature in the region. Therefore, the

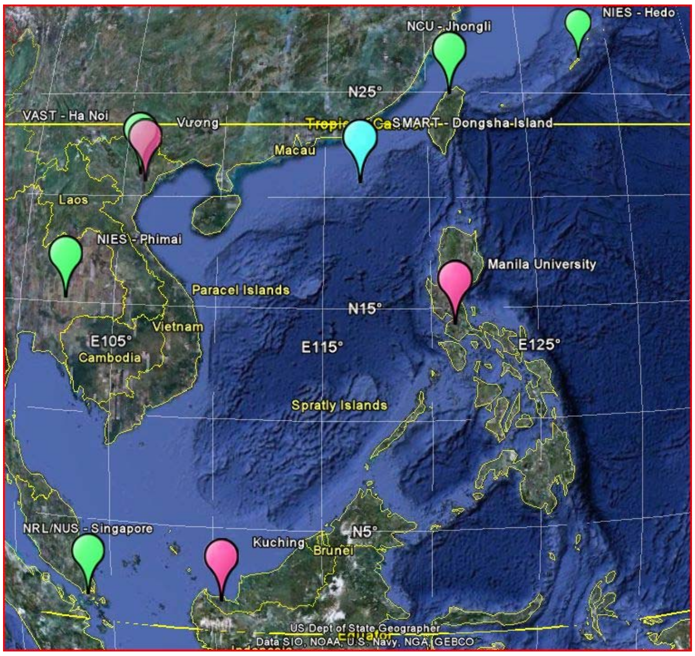

Figure 1. The Southeast Asian Lidar Network for Atmospheric Studies (SALiNAS) as of 8 March 2010. Instrument sites identified in the figure with accompanying color coding indicating those instruments that are presently operating (green), planned deployments (blue) and pending sites (violet).

enhancement of observing capabilities along surrounding lands, including those situated along climatologically-favored outflow trajectory paths to the north and east, will increase the density of observations collected for profiling aerosol structure, as well as their coincident observation in the presence of hydrometeor clouds. When combined with satellite-borne observations, including CALIOP and, soon, complimentary lidar systems launched into orbit by the European Space Administration, SALiNAS will yield remarkable coverage and provide the basis for many robust research opportunities.

2. SCIENCE OBJECTIVES

Southeast Asia and the SCS region are subject to widely varying aerosol conditions annually [4]. The site of vast economic growth over the preceding thirty years, the urban anthropogenic pall generated by a dense string of cities situated along the coastlines, stretching from southern China down the Malay Peninsula and from Borneo up through the Philippines, is persistent. Biomass burning activity has seasonal peaks during spring months within the Indochina Peninsula, and in fall months to the south over Malaysia and Indonesia. Springtime storms atop the Asian continental shelf advect Aeolian dust particles along outflow boundaries that intersect the northern boundaries of the SCS region during spring. This widely-varying mixture of sources and composition render a complex system of aerosol physical properties in what is otherwise a pristine marine environment.

The synergy between ground and satellite-based lidar applications during 7SEAS will lead to an improved characterization of aerosol physical properties in the presence of strong cloud-induced signals and relatively high solar background noise. Highlighted below are three areas of focus for SALiNAS observations that are considered vital to achieving these scientific goals for 7SEAS.

2.1 Observability and Validation

During 7SEAS, SALiNAS observations, in tandem with CALIOP and future satellite-based lidar measurements, will be considered to assess regional cloudiness and help characterize the effective observability of aerosols from ground and satellite-based platforms. Additionally, they will serve the dual purpose as validation datasets for these same instruments. The 7SEAS research domain stretches roughly from the equator northward to near 30º N latitude. The climate, therefore, reflects a gradient between tropical and sub-tropical regimes. Cloudiness is observed with increasing frequency to the south as associated with the onset of the East Asian Monsoon [5], the Madden Julian Oscillation (MJO) [6] and regional convection. As a consequence, optically-thin cirrus clouds are ubiquitous and, relatively few clear-sky observations are possible.

Table 1. SALiNAS instrument sites, coordinates, elastic channels and site-specific notes, including project affiliation. Site names with an accompanying asterisk indicate those that are (or planned as) autonomous and continually-running.

Site	Lat/Lon/MSL	Elastic Channels	Notes
Cape Hedo, Japan*	26.9º N, 128.3º E, 0.060 km	0.532, 1.064 μm	SKYNET; 0.532 μm depol; 0.607 μm N_2 Raman
Jhongli, Taiwan*	25.0º N, 121.2º E, 0.135 km	0.527 μm	MPLNET
Dongsha Island, Taiwan*	20.7º N, 116.9º E, 0.005 km	0.355 μm	MPLNET; depol; 2010 IOP, *Long-Term Planned*
Hanoi, Vietnam	21.1º N, 105.8º E, 0.010 km	0.355 μm	VAST; 0.386 μm N_2 and 0.408 μm H_2O Raman
Phimai, Thailand*	15.2º N, 102.6º E, 0.212 km	0.532, 1.064 μm	SKYNET; 0.532 μm depol; 0.607 μm N_2 Raman planned
Singapore*	1.3º N, 103.8º E, 0.030 km	0.527 μm	MPLNET; may swap to 0.532 μm elastic
Manila, Philippines	14.3º N, 121.1º E, 0.100 km	0.532, 1.064 μm	Manila Observatory; *Under Development*
Vương, Vietnam*	20.7º N, 106.1º E, 0.005 km	0.527 μm	MPLNET; *Proposed*
Kuching, Malaysia*	1.5º N, 103.3º E, 0.030 km	0.527 μm	MPLNET; *Under Development*

The complexity of the SE Asian sky scene can be conceptualized using the MPLNET Level 1.0 normalized relative backscatter data (0.527 μm; NRB) [7] collected at the Singapore SALiNAS site on 21 October 2009, and shown in Fig. 2. A shallow surface-detached aerosol layer, low cloudiness and some optically thin cirrus above 10.0 km above sea level (MSL) are apparent before the instrument is briefly shut down near solar noon (~ 0400 UTC). By 0600 UTC, when data collection restarts, a brief shower is occurring, and is followed by a transmissive cirrus cloud deck. A relatively deep aerosol layer is seen from this time through the remainder of the day, with diffuse, though stratified layering apparent to near 3.0 km MSL. From 1200 UTC through days end, optically thin cirrus are seen near and above 15.0 km MSL. Profiling of these clouds is intermittently limited by the presence of what are likely shallow altocumulus (i.e., liquid water) layers near and above 5.0 km MSL after 1800 UTC.

Clouds limit scene analyses for both ground and satellite-based passive sensors, and the depth of lidar profiling due to signal attenuation. Optically-thin clouds, when not properly screened, can bias passive algorithm retrievals. SALiNAS measurements will be used to identify the presence of optically-thin cirrus clouds in order to maintain the integrity of both ground and satellite-based passive radiometric measurements of SCS aerosol properties, and to evaluate the sensitivity and bias of passive retrieval algorithms for optical and radiative properties in the presence of hydrometeor scattering and attenuation. As validation datasets, SALiNAS observations can then be used to assess passive algorithm skill for all sky/cloud scenarios.

2.2 Transport and Evolution

In order to better understand the influence of aerosol-climate interaction, it is necessary to assess how injected plumes equilibrate, stratify (including their potential for convective lofting) and advect downwind from their source. Therefore, SALiNAS measurements will be considered during 7SEAS to investigate the evolution of aerosol optical and physical properties in both their source regions and downwind with respect to regional static stability and synoptic trajectories. Whereas injection scenarios can be erratic and difficult to parameterize near their source, as they depend greatly on winds, thermal structure (i.e., injection momentum, buoyancy and static stability) and source/lift efficacy, understanding the macrophysical nature of the downwind fetch reflects a crucial step towards investigating direct radiative effects and validating model simulations of the SCS aerosol system. The density of the SALiNAS sites combined with available satellite-borne observations, such as CALIOP, will be used to constrain the three-dimensional (3-D) regional aerosol field. With robust coverage, for nearly any seasonally varying transport/trajectory scenario [4], observations will be possible to assess the dynamic mechanisms influencing aerosol transport and microphysical change.

2.3 Data Assimilation and Model Evaluation

Recent work has identified possible trigger or tipping-point mechanisms linking direct aerosol effects and sea surface temperature perturbations with cloud coverage and the phase of regional oscillating circulation systems [8]. Global and regional model

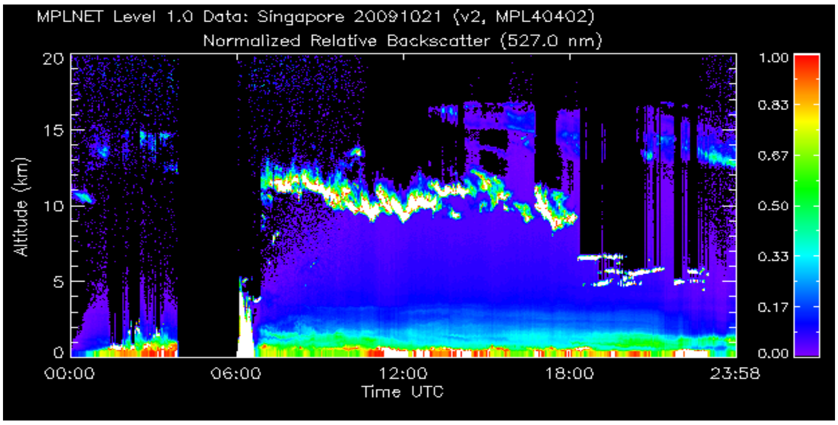

Figure 2. Micropulse Lidar Network Level 1.0 normalized relative backscatter data (0.527 µj; PhE*km^2/uj*us) for 21 October 2009 at Singapore from 0.0 – 20.0 km above mean sea level.

analyses and forecasts of the 3-D aerosol field are presently initialized by assimilating passive measurements and satellite-borne observations of aerosol optical depth (AOD) to constrain an initial 3D aerosol field simulated using source functions and input meteorological variables [9]. Though the process is reasonably efficient, information representing the crucial third (i.e., vertical) dimension is lacking. The expense of an inaccurate vertical analysis of aerosol structure is corresponding errors downwind, since trajectory paths within successive forecast runs will likely diverge with height. However, a system that is accurately constrained three-dimensionally will render more accurate forecasts of downwind advection and can be considered for direct radiative forcing effects on static stability and surface/TOA fluxes.

A system for assimilating CALIOP measurements of aerosol extinction is being tested using a global aerosol transport model, which follows previous efforts to assimilate regional lidar network measurements of Asian dust [10 *and references therein*]. In addition to ancillary measurements available for 7SEAS from SALiNAS, all sites are co-located with Sun-photometer instruments, and most include solar, UV and infrared direct and diffuse broadband radiation measurements. With this system of observations considered in tandem with corresponding satellite-based measurements from, for example, MODIS, MISR and CERES, we will evaluate model skill in analyzing 3-D aerosol analyses and transport scenarios in the SCS region, assesses and validate a system of radiative transfer calculations of cloud-cleared aerosol direct effects on thermal static stability and surface/TOA fluxes predicated on model output distributions, and perform closure experiments for each site using in-situ and model results.

3. REFERENCES

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