7 South East Asian Studies
- Overview of 2010-2014 spring campaigns in northern SEA

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Outlines

- Background
- 7-SEAS 2010-2014 field campaigns
- Biomass-burning characterization in source/receptor region
- BB emission rates in Chiang Mai
Biomass-burning haze in SEA

Agricultural residue burning

Forest floor burning

Stoke and waste fire

Clear day

PM$_{2.5}$ ~ 10 µg m$^{-3}$

Hazy day

PM$_{2.5}$ ~ 150 µg m$^{-3}$
Biomass Burning: Regional

- Burning throughout SE Asia has a great deal of fine structure.
- Based on management practice or fuel type, there are widely varying meteorological sensitivities and climate impacts.
- This makes the SE Asian system more complex than most other parts of the world.
Spring Transport: Through South China Sea into Mid-latitude Storm Track
Fall Transport: Through South China Sea to Philippines and ITCZ

NRL COAMPS—OS® (U) VBBE 15.0km
Valid Time: 00:00Z 11 AUG 2007  Analysis: 00:00
Base Time: 00:00Z 11 AUG 2007

2007 Virtual Biomass Burning Experiment

Shaded 2m Total Tracer Mass Concentration (mg/m³)
Quick View: MISR 2001-2009
Aerosol Optical Depth
(Courtesy of Jianglong Zhang, UND)

- Chinese pollution and dust
- Indian Pollution
- Pan SE Asian Smoke
- Hanoi Superplume
- Thai and Myan. Pollution and Smoke
- Thai Pollution and Smoke
- Cambodia Smoke And Ho Chi Min
- Central Sumatra Burning
- Southern Kalimantan Burning
- Jakarta Superplume
Remote Sensing: A Fundamental Tool for SE Asian Science?

- Globally, we are at the pinnacle of remote sensing observations: Passive solar and IR, lidar, radar, and microwave.
- Space based remote sensing knows no international boundaries.
- Ground based Sun photometer and lidar sites are expanding regionally.
- Everything from fire detection to surface winds can be integrated or assimilated into models now.
- Simultaneously there is a proliferation of high resolution products which can help with scale issues.
- Almost all meteorological indicators are remote sensing based.
But, SE Asia has strong gradients in air pollution. But, persistent cirrus, low level clouds coupled with shallow water make SE Asia one of the most difficult places on the planet to model or utilize satellite data.
Investigate the impacts of aerosol particles on *weather and the total SE Asian environment*

In order to do this, we need input from seven science areas:

- Aerosol lifecycle and air quality
- Tropical meteorology
- Radiation and heat balance
- Clouds and precipitation
- Land processes and fire
- Oceanography (phys. and bio.)
- Verification, analysis and prediction
7-SEAS utilized regional sites

- Global Atmos. Watch (GAW)
- Current AERONET
- Enhanced (current & under dev.), AERONET under dev.
- Current Salinas lidar (MPLnet, Asian Skynet)
- Other lidar under dev.
South China Sea region renown for complicated vertical distribution of cloud and aerosol layers

Lidar measurements are necessary to constrain vertical scattering and extinction profile and assess efficacy of concurrent passive observations

Integration of NASA CALIOP satellite-borne polarization lidar observations (ESA/JAXA EarthCARE?)

Partners: Japan, Singapore, Taiwan, Philippines, and Vietnam.

Unprecedented coverage for active-profiling on lands surrounding the South China Sea, with support from NASA MPLNET/AERONET and Asian SKYNET.
7-SEAS activities since 2007

- 7 workshops and training courses
- 2007 VBBE (Virtual BB Experiment)

In-situ Experiments in northern SE Asia

- 2010 Dongsha Experiment
- 2011 Son La Campaign I
- 2012 Son-La Campaign II
- 2013 BASELInE I
- 2014 BASELInE II
Regional flow pattern in Spring northern SEA

Westerlies (high altitude)

Northeast monsoon
Low level transport

Updraft Flow
7-SEAS Spring field campaigns

Terra/MODIS true color image with AOD (2013/3/23)
7-SEAS 2010-2014 instrumentation

Chemistry
- High-Volume
- PS1
- Hg
- Mini-Volume
- Denuder

Toxin Chemistry
- mass concentration
- Dioxin
- Metal
- PAHs

Mercury Chemistry
- mass concentration
- gaseous mercury
- particulate mercury

Aerosol Chemistry
- mass concentration
- water soluble ions
- carbon composition
- levoglucosan

Physics
- CCN
- Lidar
- AOD, Radiation

NASA COMMIT- Son La
NASA ACHIEVE Yen Bai
NCU mobile 1 - Doi Ang Khang
NCU mobile 2 – Hengchun
NCU Mt. Lulin Dongsha supersites

Air quality mobile - Hengchun
2010 Dongsha Experiment

- A pre-study of 7-SEAS
- Capacity building
- To characterize aerosol chemistry and physics over BB source/receptor sites in northern SE Asia: TH-VN-TW
List of participating institutes

Taiwan – 14 institutes and EPA
National Central University, Academia Sinica, National Taiwan University, National Chung Hsing University, National Taiwan Ocean University, National ChiaoTung University, National Cheng Kung University, National Ilan University, National Pingtung University of Science and Technology, Cheng Shiu University, Chia Nan University of Pharmacy & Science, , Fooyin University, Fu Jen Catholic University, Yuan Ze University

Thailand -
Chiang Mai University, PCD

Vietnam -
- Vietnam Academy of Science and Technology
- Center for Environment Monitoring, Vietnam Environment Administration
- Middle of Central Regional Hydro-Meteorological Observatory, National Hydro–Meteorological Service of Vietnam

USA
NASA, NRL, NOAA, DRI
Atmospheric Environment

2013 Nov (78) special issue on:

“Observation, Modeling and Impact Studies of Biomass Burning and Pollution in the SE Asian Environment – From BASE-ASIA and Dongsha Experiment to 7-SEAS”

Guest Editors:
George Lin, NCU (nhlin@cc.ncu.edu.tw)
Hal Maring, NASA
Jeff Reid, NRL

28 papers – overview, aerosols/gases/toxics, remote sensing, modeling and impact studies.
7-SEAS/ Son La Experiments in northern Vietnam


Son La, Vietnam
AOD$_{500\text{nm}} = 1$

Population of Son La: 20,000 people

Meteorological Station ~660 m

0.5 km

3.3 km

2012/4/6 4:51pm (LT)
Looking south
Photo by Carlo Wang
Son La, Vietnam (2012)

\[ \text{AOD}_{500\text{nm}} = 2.7 \]

\[ \text{MOD}_{500\text{nm}} = ?? \]

PM1 & PM2.5 data during 2012 SonLa Experiment
Phase II: 2013-2015 7-SEAS/BASELInE

**B**iomass-burning

**A**erosols &

**S**tratocumulus

**E**nvironment:

**L**ifecycles and

**I**nteractions

**E**xperiment

- Lifecycle of biomass-burning aerosols from source to receptor regions in springtime northern SE Asia
- Aerosol-cloud interaction
Doi Ang Khang, Thailand
(a middle-size village nearby our station)
The mountain tip is where our site located

Valley breeze keeps the smoke near surface and even downslope transport

Local (bamboo) burning in the evening
Fires along roadway
Burned area

Canopy still looks green
We saw lots of forest fires.
Fires at night
2013 Doi Ang Khang field experiment

Air quality and aerosol in-situ

Chemistry sampling

Radiation
2014 Doi Ang Khang field experiment

Chemical platform

Lidar
Maeson (502m), Chiang Mai, Thailand (a downhill site to DAK) – 2014

Weather Probes

Doi Ang Khang (1536m)

Cimel

Radiation
Mean PM$_{2.5}$ = 72 ug m$^{-3}$
PM$_{2.5}$ – OC/EC at Doi Ang Khang

- **OC/EC can be used to identify sources** (Chow et al., 2004; Cao et al., 2005), for instance, 1.1 for mobile source and 2.7 for coal burning (Watson et al., 2001), **5.1 for forest fire** in (Pio et al., 2008).

- **OC and EC are highly correlated** with $R^2=0.88$.

(Provided by CT Lee)
Ambient Aerosol Composition

Anhydrosugar Ratios at Doi Ang Khang

- Consistent levoglucosan/mannosan (LG/MN) ratio (~15)
  → Mixed types of biomass fuel, including agricultural residues and hard wood (G. Engling)
K⁺/levoglucosan ratio: average at $0.77 \pm 0.54$ in 2013.

Low ratios indicate **smoldering burning** phase was predominant.
SON LA

STRUCTURE of SMOKE

SEM/EDX INDIVIDUAL PARTICLE ANALYSIS

Organic/tar

soot

Dust/Soil

aluminum silicates mixed with K, Fe

Fly Ash

K chlorides

Fe - rich

Ca - rich

Sulfates

Olga
Levoglucosan vs. nss-K⁺

Chiangmai (source) – Mt. Lulin (receptor)

- The correlation between Levoglucosan and nss-K⁺ is best at Chiangmai (source region), moderate at Lulin during BB event, but worst at Lulin during NBB period.
- It indicates that both Levoglucosan and nss-K⁺ are good BB tracers and Levoglucosan may be degraded during transport. (CT Lee)
Aging Ratio of Aerosol Species Due to Air Mass Transport

- **Aging Ratio (AR) = Species Ratio at Lulin / Species Ratio at Chiangmai**

<table>
<thead>
<tr>
<th>Ratios</th>
<th>nss-(\text{SO}_4^{2-})/nss-K(^+)</th>
<th>Oxalic acid/nss-K(^+)</th>
<th>C3/C4</th>
<th>OC/EC</th>
<th>WSOC/WIOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiangmai</td>
<td>4.0±1.0</td>
<td>0.7±0.1</td>
<td>0.3±0.0</td>
<td>5.7±0.6</td>
<td>1.7±0.6</td>
</tr>
<tr>
<td>(N=15)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lulin BB</td>
<td>9.3±4.9</td>
<td>1.3±0.5</td>
<td>0.6±0.2</td>
<td>9.0±14.2</td>
<td>11.3±12.5</td>
</tr>
<tr>
<td>(N=22)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AR</td>
<td>2.3</td>
<td>1.7</td>
<td>2.2</td>
<td>1.6</td>
<td>6.6</td>
</tr>
</tbody>
</table>

- The selected aerosol species ratios are all suitable to serve as aerosol aging indices. (CT Lee)
Cloud Condensation Nuclei (CCN)

- **CCN** – **Cloud Condensation Nuclei**
  Particles that can activate at a given supersaturation are defined as **Cloud Condensation Nuclei** for this supersaturation.

- **CN** – **Condensation Nuclei**
  Particle that form droplets at supersaturations ($\geq 400\%$). (John H. Seinfeld, 1998)

\[
\text{Activation Ratio} = \frac{N_{CCN}}{N_{CN}} \times 100\% 
\]

**Biomass Burning** → **Potential Source as CCN** → **Characteristics of BB-CCN**
CCN Activation Ratio Summary

More fresh BB

Doi Ang Khang (source)

Mt. Lulin (receptor)

Aged BB

Supersaturation

Activation ratio (CCN/CN)

This study (Doi ang khong)

Lathem (Fresh BB)

Lathem (Aged BB)

Bougiaitioti (Marine)

Patidar (Monsoon)

This study (Lulin)
2010

Hengchun site
(receptor)

Yen et al. (2013)
Transport of PM$_{2.5}$ – WRF/CMAQ simulation
(contributed by MT Chuang)

3/9-3/10 2010 Dongsha Experiment

3 km, horizontal

Cross-sectional transport
Mean values of atmospheric Hg in Vietnam are about 2.3~2.8 times of the Northern Hemisphere background value (1.7 ng m\(^{-3}\)), indicating sources other than the background air are influencing these sites. (GR Sheu)
Possible Hg emission sources include biomass burning, cement production, and coal fire power plants. (GR Sheu)
Mean values of atmospheric Hg during biomass burning season in northern Thailand season are comparable to those of other regions. (GR Sheu)
The PBDE concentrations in the atmosphere of Mt. Lulin were comparable to that of the Rural Area in Taiwan.

Urban Areas 31.7 pg/Nm³
Rural Areas 15.9 pg/Nm³
Metals Complex Areas 90.7 pg/Nm³

(DLC Wang)
At the Yen Bai supersite, ACHIEVE instrument setup for (a) AERONET/Cimel sunphotometer with polarization for cloud-mode operations, (b) the ACHIEVE mobile laboratory in action, and (c) a 18.4m inner dimension calibration tower, located at the west bank of the Red River, Vietnam, and 370m to the ACHIEVE radars.

Cloud radar at Yen Bai, northern Vietnam

ACHIEVE W-band reflectivity

CloudSat W-band reflectivity
ACHIEVE W-band 94 GHz cloud radar*

\[ n(D) = N_t f_{gam}(D) = N_t \frac{1}{\Gamma(\nu)} \left( \frac{D}{D_n} \right)^{\nu-1} \frac{1}{D_n} \exp \left( -\frac{D}{D_n} \right) \]

\( D_m = 10 \mu m \)

\( D_m = 12 \mu m \)

\( D_m = 20 \mu m \)

\[ n(D) = N_t f_{gam}(D) = N_t \frac{1}{\Gamma(\nu)} \left( \frac{D}{D_n} \right)^{\nu-1} \frac{1}{D_n} \exp \left( -\frac{D}{D_n} \right) \]

\( N_t = 100 \text{ cm}^{-3} \)

\( \nu = 4 \)

\( \nu = 2 \)

\( D_m = 1 \text{ mm} \)

\( D_m = 2 \text{ mm} \)

\[ \text{cloud: } \nu = 4, N_t = 50 \text{ cm}^{-3} \]

\[ \text{drizzle/rain: } \nu = 2, D_m = 1 \text{ mm} \]

\[ \text{drizzle/rain: } \nu = 2 \]

\[ \text{reflectivity (dBZ)} \]

\[ \text{spectral width} \]
Near-real time processed results from ACHIEVE/T-RECS W-band radar measurements, showing penetration of rain shaft through a stable, low-level stratiform cloud deck over the Yen Bai Meteorological Station, Vietnam, on 28 March 2013.
<table>
<thead>
<tr>
<th><strong>SMARTLabs/AERONET/MPLNET</strong></th>
<th><strong>Regional Instrumentation</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trace Gas – Column:</strong> O₃, NO₂, SO₂, HCHO, CO, H₂O; <strong>Surface:</strong> CO, CO₂, O₃, SO₂, NO, NOₓ/NOy; <strong>Profile:</strong> NO₂, (O₃ in progress)</td>
<td><strong>Organic Carbon</strong> (OC): OC₁ (120°C), OC₂ (280°C), OC₃ (480°C), OC₄ (580°C), OP (pyrolyzed organic carbon, e.g., anhydrosugars, dicarboxylic acids)</td>
</tr>
<tr>
<td><strong>Aerosol Optical Thickness:</strong> multi-spectral from UV to shortwave-IR, dust at longwave-IR, and extinction profile</td>
<td><strong>Elemental Carbon</strong> (EC): EC₁ (580°C – OP), EC₂ (740°C), EC₃ (840°C)</td>
</tr>
<tr>
<td><strong>Aerosol Microphysics/Chemistry:</strong> size, mass, type, CCN, hygroscopicity, scattering/absorption/extinction</td>
<td><strong>Water soluble ions:</strong> Na⁺, NH₄⁺, K⁺, Mg²⁺, Ca²⁺, Cl⁻, NO₃⁻, SO₄²⁻, nss-SO₄²⁻, NO₂⁻, F⁻</td>
</tr>
<tr>
<td><strong>Cloud Optical Thickness:</strong> multi-spectral from visible to longwave-IR</td>
<td><strong>Toxic:</strong> Mercury, PCDD/Fs (dioxin)</td>
</tr>
<tr>
<td><strong>Cloud Microphysics:</strong> size, liquid-/ice-water content, cloud-base/top/height, thermodynamic phase, Doppler fall-velocity, depolarization and reflectivity profiles</td>
<td><strong>Metal:</strong> Ti, Mn, Co, Ni, Cu, Zn, Mo, Ag, Cd, Sn, Sb, Tl, Pb, V, Cr, As, Y, Se, Zr, Nb, Ge, Rb, Cs, Ga, La, Ce, Pr, Nd, Sm, Eu, Gd</td>
</tr>
<tr>
<td><strong>Radiation Flux:</strong> surface solar and terrestrial irradiance</td>
<td><strong>UV radiation:</strong> spectral UV (erythemal) irradiance</td>
</tr>
<tr>
<td><strong>Meteorology:</strong> P, T, RH, wind, mixed-layer height, precipitation, visibility</td>
<td><strong>Supplementary data:</strong> sounding profile, sky image, particle spectroscopy/morphology, rainfall amount</td>
</tr>
</tbody>
</table>
Emission of air pollutants from biomass burning and air pollution monitoring in Chiang Mai, Thailand

Asst. Prof. Dr. Somporn Chantara
Chemistry Department and
Environmental Science Program,
Faculty of Science, Chiang Mai University

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Biomass types

- Rice straw
- Maize residue
- Leaf litter
Sampling sites in Chiang Mai Province
Biomass sampling
Combustion chamber

Environmental Chemistry Research Laboratory (ECRL), CMU
## Calculation of ERs

<table>
<thead>
<tr>
<th>Area type</th>
<th>Total area* (km²)</th>
<th>Burned area* (km²)</th>
<th>Year 2010</th>
<th>Year 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice field</td>
<td>1,013</td>
<td>111</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>Crop field</td>
<td>651</td>
<td>326</td>
<td>173</td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>11,109</td>
<td>3,073</td>
<td>615</td>
<td></td>
</tr>
</tbody>
</table>

* Source: Dontree et al. (2011)

- Forest area occupies the largest area in Chiang Mai (11-17 times larger than the area of rice field and crop field).
- The highest burned area was found in forest (>70%).
ERs of PM10

- ERs of PM10 in 2010 was ~1-5 times higher than those in 2011.
- 80-90% of ERs of PM10 in both years were emitted from forest burning.
Summary

• BB aerosol chemical, microphysical and radiative properties over Indochina region have been first characterized.

• Transport pattern of BB plumes from Indochina region is numerically described and verified by in-situ measurements.

• BB types in our sites nearby source region are identified.

• More to be studied...
More to be studied …

- Integration of chemical and physical data
- Optical and vertical profiling data
- Ground-based and satellite data
- Modeling and impact studies

- 7-SEAS campaign websites: 2010-2014 campaigns -
  http://aerosol.atm.ncu.edu.tw/7SEAS/index.html
Where to get…

- Images can always be found on the NRL aerosol webpage: http://www.nrlmry.navy.mil/aerosol/
- The big data repository for NRL and Navy is GODAE and the product will appear there as soon. http://www.usgodae.org/
- We are trying to push it to LANCE.