Environmental Pollution 195 (2014) 292–307

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Interactions between biomass-burning aerosols and clouds over Southeast Asia: Current status, challenges, and perspectives

Neng-Huei Lin [a, b, *], Andrew M. Sayer [c, d], Sheng-Hsiang Wang [a], Adrian M. Loftus [c, e], Ta-Chih Hsiao [f], Guey-Rong Sheu [a], N. Christina Hsu [c], Si-Chee Tsay [c], Somporn Chantara [b]

[a] Department of Atmospheric Sciences, National Central University, Chung-Li, Taiwan
[b] Chemistry Department and Environmental Science Program, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand
[c] Goddard Space Flight Center, NASA, Greenbelt, MD, USA
[d] Universities Space Research Association, Columbia, MD, USA
[e] Oak Ridge Associated Universities, Oak Ridge, TN, USA
[f] Graduate Institute of Environmental Engineering, National Central University, Chung-Li, Taiwan

ARTICLE INFO

Article history:
Received 2 March 2014
Received in revised form
8 June 2014
Accepted 28 June 2014
Available online 30 July 2014

Keywords:
Biomass-burning aerosol
Aerosol–cloud interaction
7-SEAS
Remote sensing
Aerosol chemistry
Southeast Asia

ABSTRACT

The interactions between aerosols, clouds, and precipitation remain among the largest sources of uncertainty in the Earth's energy budget. Biomass-burning aerosols are a key feature of the global aerosol system, with significant annually-repeating fires in several parts of the world, including Southeast Asia (SEA). SEA in particular provides a “natural laboratory” for these studies, as smoke travels from source regions downwind in which it is coupled to persistent stratocumulus decks. However, SEA has been under-exploited for these studies. This review summarizes previous related field campaigns in SEA, with a focus on the ongoing Seven South East Asian Studies (7-SEAS) and results from the most recent BASELInE deployment. Progress from remote sensing and modeling studies, along with the challenges faced for these studies, are also discussed. We suggest that improvements to our knowledge of these aerosol/cloud effects require the synergistic use of field measurements with remote sensing and modeling tools.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Every boreal spring the populations of Southeast Asia (SEA) and southern China burn fields to clear the ground in preparation for planting crops. As a result, significant amounts of greenhouse gases, chemically active gases, and atmospheric light-absorbing aerosols are produced by biomass-burning processes on an annual basis (*cf.* Koppmann et al., 2005; Akagi et al., 2011; Reid et al., 2005a,b; Hsu et al., 2012; and references therein). While the fires pervade relatively dry and cloud-free regions (particularly in northern Myanmar, Thailand, and Laos), the smoke plumes can stretch hundreds of kilometers into cloudy areas (i.e., northern Vietnam, Hong Kong, and southern China). Such darkened (brown-tinted) clouds are often seen in satellite images during the burning season, as shown in Fig. 1a. Also observed by lidar measurements (Fig. 1b), these large-scale biomass-burning aerosols over SEA interact extensively with clouds during peak burning in March–April. Downwind from smoke source regions, the aerosol-cloud system is tightly coupled, which provides a novel natural laboratory for exploring the micro- and macro-scale relationships of the complex interactions under active stratiform convection (*cf.* Tsay et al., 2013 for an overview). Furthermore, while much research on aerosol–cloud-precipitation interactions has focused on marine stratocumulus, SEA presents a unique opportunity for investigating these interactions over land where major sources of anthropogenic aerosols exist.

Collectively, these interactions have been recognized by the Intergovernmental Panel for Climate Change and others as having the largest uncertainties of various components of the radiative forcing to the Earth-atmosphere system, leading to many attempts to reduce these uncertainties over the past few decades (e.g., Haywood and Boucher, 2000 for an earlier review). Uncertainties are large not just for the radiative effects from anthropogenic aerosols (which are strictly what is dealt with in discussions of global radiative forcing), but also those from natural aerosol particles. Stevens and Feingold (2009) provide a summary of the different ways in which aerosols are thought to be able to influence cloud development; although often discussed as individual

---

* Corresponding author.
E-mail address: nhlin@cc.ncu.edu.tw (N.-H. Lin).

http://dx.doi.org/10.1016/j.envpol.2014.06.036
0269-7491/© 2014 Elsevier Ltd. All rights reserved.

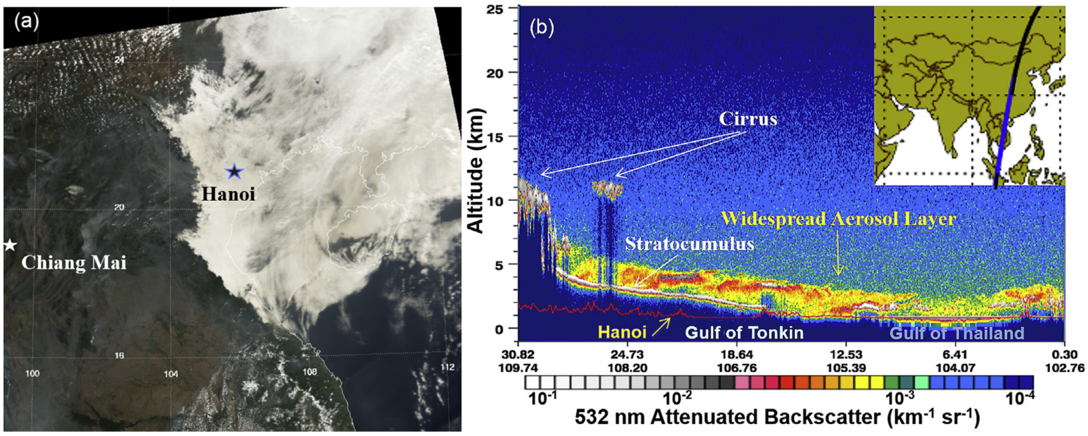

Fig. 1. On 7 March 2010 over Southeast Asia, (a) MODIS/Aqua true-color image depicting smoke plumes over Thailand due to forest fires and agricultural burning, and (b) nighttime transect (inset) of CALIOP 532 nm attenuated backscatter revealing a prominent layer of smoke aerosols overlying and overlapping with the stratiform cloud deck from ~16°N to ~27°N. As well as source regions in the west of panel (a), smoke aerosols are visible over the widespread stratiform clouds from northern Vietnam to southern China.

separate effects, in reality multiple mechanisms may be in operation at once (e.g., Altaratz et al., 2014). Concerning low-level water clouds, Andreae (2009) indicated that increased atmospheric aerosol loading (e.g., aerosol optical depth, AOD or τ) may lead to increased availability of cloud condensation nuclei (CCN). For a given liquid water content, this would then lead to clouds composed of smaller and more reflective (brighter) droplets as compared to a cloud forming in an air mass with fewer CCN (the *cloud albedo* effect; Twomey, 1977). Having smaller droplets may delay the onset of precipitation, increasing the cloud's lifetime and the altitude to which it rises in the atmosphere (Squires, 1958; Albrecht, 1989; Pincus and Baker, 1994). Even prior to the satellite era, some observational evidence for these phenomena had been amassed (e.g., Conover, 1966; Warner and Twomey, 1967; Warner, 1968). For light-absorbing aerosols (such as smoke), this absorption can result in increasing stability of the atmosphere, affecting cloud vertical development, and atmospheric heating, which can lead to the evaporation or hinder formation of clouds (e.g., Ackerman et al., 2000; Johnson et al., 2004). As well as radiative effects, monitoring of aerosols from biomass burning is of interest for health reasons as they are composed largely of fine carbonaceous particles, which are associated with cardiovascular mortality and respiratory infections (e.g., Oberdörster et al., 1995; Silva et al., 2013).

The directly-emitted aerosol particles undergo various atmospheric aging processes, including adsorption or condensation of gases, coagulation with preexisting aerosols, and oxidation (Zhang et al., 2008). These processes alter the particles' physicochemical properties and hygroscopicity (Engelhart et al., 2012), which change their propensity to behave as CCN and adds complexity and uncertainty to global climate model (GCM) simulations. Therefore, investigations into transitions of particle morphology, hygroscopicity, and optical properties from sources to sinks are crucial (Reid et al., 2005b; Zhang et al., 2008). Despite the fact that SEA is a major biomass-burning source region (Duncan et al., 2003; Streets et al., 2003), it has been the subject of fairly few field campaigns on this topic, with most prior ground/flight-based work on biomass-burning aerosols performed in Africa or South America (see Section 3.1). The most extensive campaigns in SEA to date have been a series of Seven South East Asian Studies (7-SEAS, Reid et al., 2013) field campaigns (Lin et al., 2013; Tsay et al., 2013). In this paper, we first provide a survey of remote sensing observations of biomass-burning aerosols and clouds, following a summary of the tools and datasets of remote sensing presently available for aerosol, cloud and precipitation studies. Secondly, we briefly review regional campaign/field studies concerning biomass-burning aerosols and related pollutants and summarize the (chemical, physical, and optical) properties of biomass-burning aerosols observed primarily during the 2013 7-SEAS campaign. Thirdly, we briefly review the modeling and impact studies of aerosols on clouds and precipitation. Finally, we discuss challenges related to this topic and provide a perspective on studying the interactions between aerosols and clouds, particularly in SEA.

2. Remote sensing of biomass-burning aerosols and cloud systems

Neither numerical modeling nor remote sensing have the capability to fully resolve the unknowns associated with aerosol-cloud interactions, although through a combination of global analyses and case studies, often combining both observations and modeling, progress has been made towards this goal. This section focuses on recent developments in the field, from a spaceborne remote sensing perspective. There exists a suite of spaceborne (Table 1) and ground-based (Table 2) remote sensing instrumentation suitable for smoke aerosol-cloud interaction studies in SEA, particularly since the late 1990s. From a satellite perspective these cover a wide variety of instrument types, including passive imaging radiometers/spectrometers (on polar-orbiting and geostationary platforms), microwave radiometers, and active sensors. Each has its own capabilities and drawbacks. Of particular note in recent years was the launch of the CALIPSO mission in 2006, which has greatly enhanced our observational capabilities for aerosol vertical distribution (Campbell et al., 2008; Winker et al., 2013) and been of benefit for evaluation and improvement of global models (e.g., Yu et al., 2010). Prior to CALIPSO, MISR had been used to monitor aerosol plume injection heights in SEA (e.g., Tosca et al., 2011), although is typically only able to obtain plume heights near source locations, where there is sufficient visual contrast to estimate height via parallax shifts between MISR cameras. Ground-based sensor networks, mainly sunphotometer, sky-radiometer and lidar, are more limited in spatial extent but typically offer a higher data collection rate and enhanced measurement/retrieval capabilities as compared to spaceborne instruments. Due to this more limited spatial coverage, most regional-scale studies rely heavily on satellite data while ground-based measurements are used as validation tools for the satellite products or as a complimentary baseline during intensive field campaign activities.

Download English Version:

https://daneshyari.com/en/article/4424410

Download Persian Version:

https://daneshyari.com/article/4424410

Daneshyari.com