Supplementary material to "The Rapidly Changing Greenhouse Gas Budget of Asia"

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The rapidly changing greenhouse gases (GHG) budget of Asia

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Rapid economic growth in many Asian countries has resulted in increased energy demand, which in turn is leading to increasing the global share of greenhouse gas emissions by the region (Raupach et al. 2007; Le Quere et al. 2009). An understanding of the natural carbon exchange over the land and oceans due to tropical climate variability is also required for calculating interannual to interdecadal variations in atmospheric CO_2 (Patra et al., 2005).

An international workshop was organized through financial supports from (1) the Asia Pacific Network (APN) funded project (ARCP2011-11NMY-Patra/Canadell), the Indian Space Research Organisation (ISRO) Geosphere-Biosphere Project (GBP) (ATCTM) at the Physical Research Laboratory (PRL), Ahmedabad. The main aim of this 1st APN workshop was to assess resources available currently among the international research community working on various aspects of earth system sciences with a focus on South and Southeast Asia. The key issue discussed was the availability of data and models to work towards the establishment of the GHG budget for these two regions based on synthesis and reconciliation of top-down (atmospheric observations and inverse models) and bottom up estimates (ground based flux observations and terrestrial models). These included atmospheric measurements of GHGs, classifications of land cover and soil properties, coastal ocean biogeochemistry, forest and agriculture inventories, and remote sensing based estimates. The target GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxides (N_2O).

Pep Canadell (GCP/CSIRO, Australia) highlighted the rapid emissions growth rates of countries in the region in 2010 superseding previous expectations and showing little effect of the Global Financial Crisis (e.g., China 9.9%, India 9.0%, South Korea 8.8%, Indonesia 7.6%). The growing global share of emissions from Asian countries is increasing the uncertainty of the global carbon budget, and more so for the targeted regional budgets; uncertainty reduction is one of the main goals of the APN effort.

Top-down observations and modeling. Michel Ramonet (IPSL/LSCE) highlighted the needs for high quality measurements, which are set at accuracy of 0.1 ppm, 2 ppb and 0.1 ppb for CO_2, CH_4 and N_2O, respectively for the upcoming Integrated Carbon Observation System (ICOS) project. Prabir Patra (RIGC/JAMSTEC) set a target for CO_2 flux estimation

uncertainty for the South and Southeast Asia regions at 0.2 PgC/yr within the time span of the APN project of 3 years, by utilizing in situ and remote sensing observations in atmospheric-CO_2 inverse modeling.

The observations of most important anthropogenic GHGs are being conducted at ground based sites through national and international collaborations and onboard of commercial/research aircrafts. Initial datasets have been analyzed for understanding how regional sources and sinks (fluxes) interact with the atmospheric transport and chemistry using numerical models for simulating concentrations. One of the recent finding, based on atmospheric inverse modeling, is that the South Asia region has apparently acted as the net sink of CO_2 at a rate of 0.3±0.3 PgC/year during 2007-2008 (P. K. Patra), but most parts of the Asian region behave as a significant source of CH_4 and N_2O (K. Ishijima; RIGC/JAMSTEC). These results, however, show high uncertainty and lack of confidence at the sub-regional level so falling short from showing the role of the various GHG species on the Earth's climate system and any possible implications for climate policy development. The workshop identified the need for molecular and isotopic data of GHGs as a key development (N. K. Indira, CCMACS; M. Naja, AIRES).

The workshop also highlighted the importance of regional applications of atmospheric inversion modeling using unique regional observations not yet part of the global datasets and measurements from commercial airliners in and out of the region (e.g., CONTRAIL program from NIES/MRI/JAL by Y. Niwa, MRI; C.-H. Cho, NIMR; R. Lokupitiya, USJ; P. S. Swathi, CMMACS). The use of air pollutant species, such as carbon monoxide (CO), ozone (O_3), are shown to be effective for separating biomass burning and fossil fuel emissions, both dominant fluxes in the region (L. K. Sahu, PRL), and also useful for analyzing the detrimental effects of oxidants on crop yields (S. Lal, PRL). Ozone concentration over India increased at a linear rate of ~1.4% per year in the periods of 1950s and 1990s.

Bottom-up observations and modeling. A growing role of eddy-covariance flux towers is expected in the near future given the current deployment of a network in India under the ISRO-GBP and the institutions of the Ministry of Earth Sciences, Government of India. The well-established terrestrial ecosystem models, developed primarily for the temperate region, are tuned for light use-efficiency and soil moisture stress in order to adapt them for the regional conditions. Efforts are also underway for validating the modeled gross primary productivity and heterotrophic respiration under the National Carbon Project (NCP) (R. Nayak, NRSC). N. R. Patel (IIRS) suggested that agricultural net primary productivity (NPP) has increased in the past 50 years due both due to increased yield per hectare and overall extent of agricultural land. Explicit representation of crops in terrestrial modeling has been mostly ignored so far and will require the next generation of modeling development given the predominant role of agriculture in the region (E. Lokupitiya). Site level measurements of emission footprints are constructed for CH4 and N2O emissions from the rice and wheat cropping fields (D. Pandey, BHU) and also discussed their emission reduction potentials (I. Rusmana, IPB). Emerging new accounting techniques based on field observations, modeling and remote sensing are providing new estimates of CH_4 emissions from Indian rice paddy fields (3.4 Tg/yr) and livestock (11.7 Tg/yr) (K. R. Manjunath, SAC). Emissions from wetlands are still highly unconstrained, particularly for Southeast Asia where extensive tropical peatlands exist. The satellite products of normalized difference vegetation index (NDVI), land cover change and land cover change, soil properties and soil carbon mapping, and agricultural practices are all identified as critical inputs for identifying the processes involved in the exchange of carbon and nitrogen in terrestrial ecosystems (T. Bhattacharya, ICAR).

The transport of terrestrial carbon to the estuaries (33 TgC/yr) and emissions from coastal oceans (6.4 TgC/yr) of India illustrates the importance of lateral transport and the coastal zones (V. V. S. S. Sarma, NIO) and the need for an Asia-wide effort (N. H. Oh, SNU; A. Koripitan, IPB). The concept of ocean acidification was also discussed in the context of rapidly changing scenario of CO_2, and oxidized sulfur (SOx) and nitrogen (NOx) species (M.M. Sarin, PRL).

The meeting cemented a set of initial steps towards a regional collaboration among the scientists with interdisciplinary research background who are interested in working on the budget and attribution of GHG budget to the major regions in Asia. The collaboration aims to facilitate the sharing of existing and new observations and numerical model simulations, and to contribute to the long term implementation of the goals of the Regional Carbon Cycle Assessment and Processes (RECCAP) of the Global Carbon Project.

An improved scientific knowledge is indispensible for developing informed national policy on GHGs emission mitigation strategies and their implementation, based on the sound understanding of the behavior of natural ecosystems and intensity of the anthropogenic activity.

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