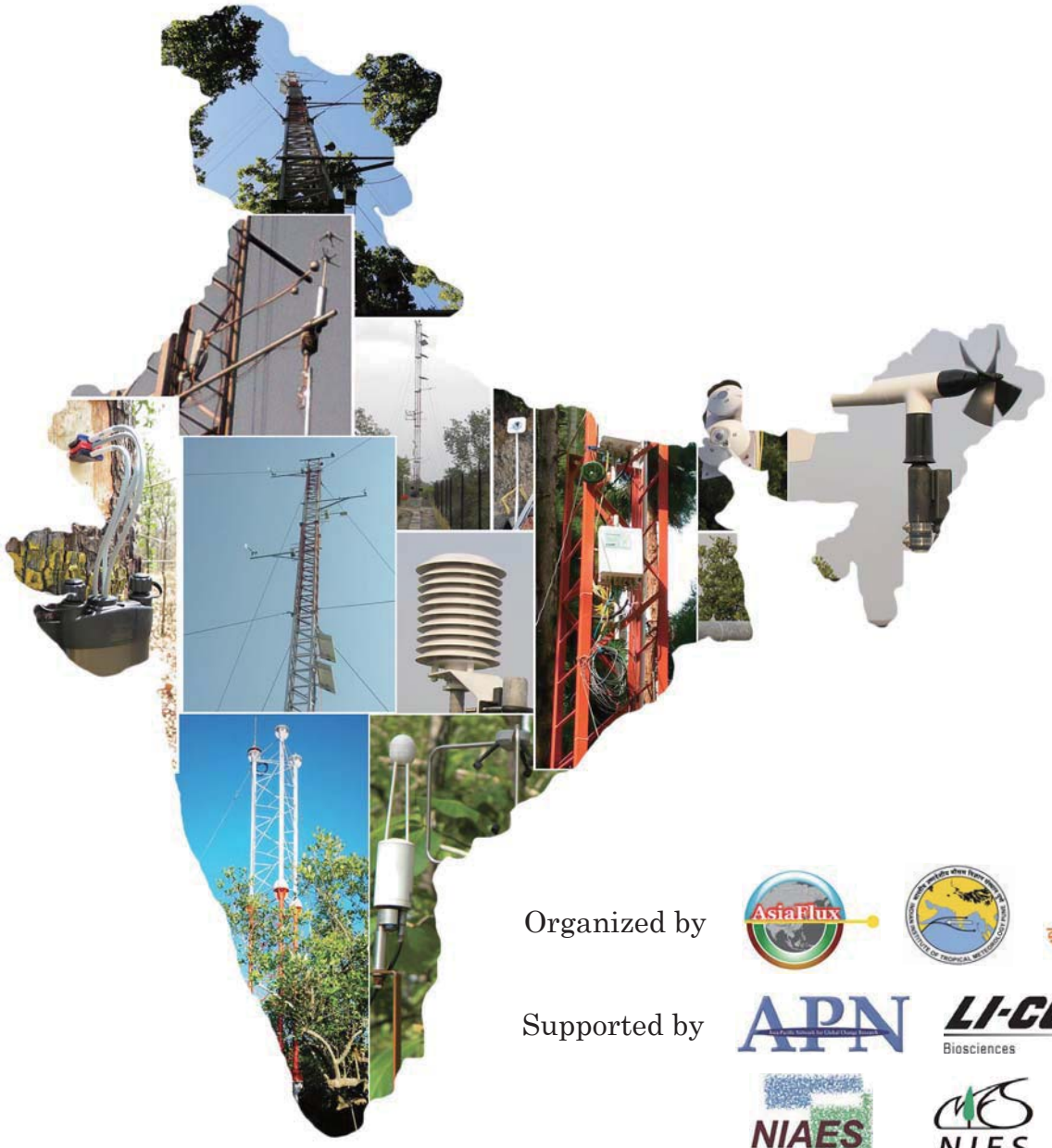
PROCEEDINGS

Joint conference of the AsiaFlux Workshop 2015 and

ISPRS（International Society for Photogrammetry and Remote Sensing）TC WG VIII/3：

Weather, Atmosphere and Climate StudiesWeather, Atmosphere and Climate Studies

Challenges and Significance of Ecosystem Research in Asia to Better Understand Climate Change



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Date　: 22-29 November 2015

Venue: Indian Institute of Tropical Meteorology, Pune, India

Joint conference of the AsiaFlux Workshop 2015 and
ISPRS（International Society for Photogrammetry and Remote Sensing）
TC WG VIII/3 : Weather, Atmosphere and Climate Studies

“Challenges and Significance of Ecosystem Research in Asia to Better Understand Climate Change”

November 22 – 29, 2015
Indian Institute of Tropical Meteorology
Pune, India

Organizers

- AsiaFlux
- Indian Institute of Tropical Meteorology (IITM), Ministry of Earth Sciences, Government of India
- Indian Space Research Organization (ISRO)

Local Organizing Committee

- V K Dadhwal (Indian Space Research Organization (ISRO), India)
- Chandra Shekhar Jha (Indian Space Research Organization (ISRO), India)
- R.Krishnan (Indian Institute of Tropical Meteorology (IITM), India)
- Gufran Beig (Indian Institute of Tropical Meteorology (IITM), India)
- Supriyo Chakraborty (Indian Institute of Tropical Meteorology (IITM), India)
- Vinu Valsala (Indian Institute of Tropical Meteorology (IITM), India)
- Yogesh Tiwari (Indian Institute of Tropical Meteorology (IITM), India)
- Akira Miyata (National Institute for Agro-Environmental Sciences (NIAES), Japan)
- Nobuko Saigusa (National Institute of Environmental Studies, Japan)
- Sawako Tanaka (National Institute of Environmental Studies, Japan)

Supported by

- Asia-Pacific Network for Global Change Research (APN)
- Indian Institute of Tropical Meteorology (IITM), India
- Indian Space Research Organization (ISRO), India
- LI-COR
- National Institute for Agro-Environmental Science (NIAES), Japan
- National Institute for Environmental Studies (NIES), Japan

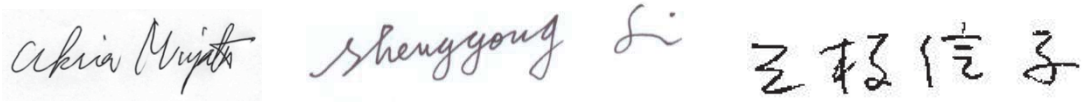
Venue

Indian Institute of Tropical Meteorology (IITM), Pune, India

Welcome to Joint Conference of AsiaFlux and ISPRS TC WG VIII/3

Welcome to the AsiaFlux Workshop 2015 in Pune, India. We are delighted to have our 13th international workshop in Indian Institute of Tropical Meteorology (IITM) as a joint conference with International Society for Photogrammetry and Remote Sensing (ISPRS) TC WG VIII/3. The theme of the joint conference, “Challenges and significance of ecosystem research in Asia to better understand climate change” well matches the missions of AsiaFlux to bring Asia's key ecosystems under observation to develop and transfer scientific knowledge to ensure quality and sustainability of life in Asia. It is fundamental for our community to understand relationship between terrestrial ecosystems and climate change through monitoring carbon and water cycles. As utilization of remote sensing is an important component of ecosystem monitoring and indispensable to upscaling tower-based fluxes, it is an excellent opportunity for AsiaFlux to have the workshop jointly with ISPRS, which has solid foundation in remote sensing and abundant experiences in its application to climate change studies.

This joint conference is a memorable event for AsiaFlux because this is the first meeting in India in our 17-year history. AsiaFlux was set up in East Asian countries, and has been expanding its network membership to Southeast and South Asian countries in accordance with a strategic plan of CarboAsia, which intends to promote our activities in tropical ecosystem and croplands for the carbon budget assessment covering the whole Asian terrestrial ecosystems. From the early stage of AsiaFlux, India has been attracting our interest because it has the second largest land area and population in Monsoon Asia next to China. With ambition to collaborate with scientists in India, AsiaFlux added an Indian member to the Steering Committee (the present Science Steering Committee) in 2008, but collaboration between AsiaFlux and India had been dormant until recently. The situation was changed by proactive involvement of Indian Space Research Organization (ISRO), which initiated a tower flux monitoring network in India and hosts this joint conference with IITM. The number of participants in AsiaFlux activities from other research institutes and universities in India has also been increasing. This joint conference is the best opportunity to promote these trends and to consolidate collaboration between AsiaFlux and the flux study communities in India. Session conveners and the local organizing committee of the joint conference have prepared the attractive program with a variety of sessions and more than 170 presentations including a considerable number of contributions from India. We truly hope that the joint conference will be the starting point of the new AsiaFlux, which encompasses flux communities from East Asia to South Asia.



Akira Miyata, Shenggong Li, Nobuko Saigusa
Chair and Vice-Chairs of AsiaFlux

भारतीय उष्णदेशीय मौसम विज्ञान संस्थान
(पृथ्वी विज्ञान मंत्रालय, भारत सरकार का एक स्वायत्त संस्थान)
डॉ. होमी भाभा मार्ग पाषाण, पुणे- ४११ ००८
INDIAN INSTITUTE OF TROPICAL METEOROLOGY
(An Autonomous Institute of the Ministry of Earth Sciences, Govt. of India)
Dr. Homi Bhabha Road, Pashan, Pune - 411 008. India
ESSO

डॉ. एम्. राजीवन
निदेशक

Dr. M. Rajeevan, FASc.
Director

Message

I am glad to know that an international conference the Asiaflux-2015 entitled "Challenges and Significance of Ecosystem Research in Asia to Better Understand Climate Change" is being organized for the first time in India in collaboration with Asiaflux and the National Remote Sensing Center, Hyderabad at IITM, Pune during November 22-29, 2015.

IITM is primarily involved in understanding the physics of monsoon through atmospheric and meteorological observations and modeling activities aimed at monsoon predictions from seasonal to climate time scales. The monsoon system is a complex process and is affected by a variety of physical, chemical and biological processes. The vegetation over the Indian subcontinent is highly diverse due to large multiplicity in its eco-climatic regimes but its role in modulating the monsoon system is relatively less understood. Realizing its importance the focus of IITM research has recently been extended to ecosystem scale through the establishment of tower based observational network which is currently in operation in a dense forest near Darjeeling and at a grass land ecosystem in Assam, north east India. Additionally, tower based observation is being started in a mangrove forest in southern India and the biogeochemical analysis of marine samples to study the carbon cycle processes is underway at the Andaman & Nicobar Islands in the Bay of Bengal and Lakshadweep Island in the Arabian Sea. Effort is in progress to establish meteorological towers at Sagar in central India and another one in the Western Ghat mountain range.

Within this framework, the organization of an international event consisting of a large number of scientific professionals from research and scientific organizations, manufacturing units of atmospheric and bio-meteorological sensors from all over the world would provide an ideal opportunity for the Fluxnet community especially in India and in general in South Asia. I believe that the IITM endeavor of the tower based observational network will add an important component in the Asiaflux network already operating in a large region of the Asian continent. It is heartening to know that more than 170 scientists will be deliberating on research issues ranging from atmospheric/meteorological sciences, earth observation, eco-system studies, hydrology, environmental and industrial monitoring, agriculture and regulatory applications etc. It will also encourage user adaptation of modern technology in the fields of micro and agro meteorology to promote eco-system research in India which is likely to be helpful for applications ranging from future climate to local resources management to policy framework.

I wish all the best for the organizers and the participants for a fruitful and a successful event.

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Program at a glance

	11/22-24	11/25	11/26	11/27	11/28, 29
8:30	LI-COR Training Course	Registration			Excursion
9:00		Opening Session 1	Session 3-1	Session 6	
9:30					
10:00					
10:30		Break and Photo	Break		
10:45			Session 3-2	Break	
11:00		Opening Session 2		Session7	
11:30					
12:00		Lunch	Lunch		
12:15					
12:30				Lunch	
12:45		Session 1			
13:00			Session 4		
13:15					
13:30				Session 8	
14:00					
14:30					
15:00		Break and Poster	Break and Poster	Rap up	
15:15					
15:30					
15:45		Session 2	Session 5		
16:00					
16:30					
17:00					
17:30					
18:00					
18:15		Moving to Banquet place			
18:30			**SSC and YSM Dinner hosted by Director		
19:00		*Banquet			

All sessions: Meghdoot Hall

*Training Course will be at Varahamihir Hall

**Banquet will be at Courtyard Marriott from 19:00~ on 25th.
(Rajiv Gandhi Infotech Park, Phase 1, Hinjewadi, Pune India)

***YSM will be at Varahamihir Hall from 18:30~ on 26th.

SSC will be at HPC Seminar Hall 18:30~ on 26th.

Dinner hosted by Director, IITM 19:00 ~ 21:00 on 26th.

Oral Session

Wednesday, 25 November			
08:30 - 09:00	Registration		
09:00 - 10:00	Opening and Welcome Address (Director, IITM)		
	Lightening the lamp		
	Over view of Asiaflux by Akira Miyata (Chair of AsiaFlux and NIAES, Japan)		
	And Supriyo Chakraborty (Co-Chair and AsiaFlux Workshop 2015 LOC, IITM, India)		
10:00 - 10:30		Shashi B. Verma (invited)	Micrometeorology: A journey
10:30 - 11:00	Group Photo and Break		
11:00 - 11:30		V K Dadhwal (invited)	Vegetation and soil carbon pools and fluxes in India and results from flux tower networks
11:30 - 12:00		Pinki Mondal (invited)	Decoupling the spatial and temporal vulnerability of agricultural systems to future climate changes
12:00 - 12:45	Lunch		
1: The role of climate, carbon cycle and human activities in tropical ecosystems (Chair: Yogesh K Tiwari, Kazuhito Ichii, Atul K Jain)			
12:45 - 13:00	1-1	Bikash Ranjan Parida	Climatic drivers of large-scale ecosystem change over India
13:00 - 13:15	1-2	Carole Helfter	Effect of terrain on tall tower measurements of heat and trace gas fluxes above a tropical forest
13:15 -13:30	1-3	Nishen Liang	Control and response of soil carbon dynamic of Asian tropical forest ecosystems
13:30 - 13:45	1-4	Takashi Hirano	A regrowing tropical peat ecosystem changed from a CO_2 source to a CO_2 sink after fire
13:45 - 14:00	1-5	Atul K Jain	Implementation of prognostic leaf area index in a land surface model: evaluation of water, energy and carbon fluxes in tropical Asia using flux net tower data
14:00 - 14:15	1-6	Justin Sentian	The impact of landuse change from forest to oil palm on soil greenhouse gas fluxes
14:15 - 14:30	1-7	San Win	Vulnerability assessment and climate change response: a preliminary study on coastal zones, mangrove, communities dependent on the coastal ecosystem, and climate change tackling in Myanmar
14:30 - 14:45	1-8	Pratima Gupta	Impact of black carbon on the ecosystem and climate change
14:45 - 15:00	Discussion		
15:00 - 15:45	Break and Poster		

2: Land surface fluxes using remote sensing data (Chair: V K Dadhwal, Joon Kim, C.S.Jha)			
15:45 - 16:00	2-1	Kaniska Mallick	Re-introducing radiometric surface temperature into John Monteith's formulation of Penman-Monteith equation
16:00 - 16:15	2-2	Rabindra K. Nayak	Net CO_2 sink potential of Indian ecosystem in present decade
16:15 - 16:30	2-3	Abhishek Chakraborty	Upscaling carbon fluxes over low land tropical rice ecosystem using flux tower and remote sensing data
16:30 - 16:45	2-4	Pei Yu Cao	Changes in flux-derived and satellite-derived vegetation phenology and its effects on ecosystem productivity
16:45 - 17:00	2-5	Satya Kushwaha P.S.	Evaluation of MODIS-based vegetation indices and flux tower data for estimating gross primary productivity of a moist deciduous sal forest in India
17:00 - 17:15	2-6	Kiran Chand Thumaty	Upscaling of ecosystem level carbon fluxes from eddy covariance flux towers to regional scale using enhanced vegetation index (EVI) based models – case study over central Indian deciduous forests
17:15 - 17:30	2-7	Rahul Nigam	Land surface net radiation fluxes and modelling of crop photosynthesis using Indian geostationary satellite observations and field measurements
17:30 - 17:45	2-8	Aniket Chakravorty	Applicability of satellite soil moisture in generating an analysis of energy and moisture flux: a data assimilation view point over India
17:45 - 18:00	2-9	Eva van Gorsel	Integration of forest inventory, eddy covariance and remote sensing data to assess impacts of disturbance on carbon uptake in a managed eucalyptus forest
18:00 - 18:15	Discussion		
19:00~	Banquet		

Thursday, 26 November

3: Soil-Plant-Atmosphere continuum: process mechanisms, novel techniques, responses, and feedbacks (Chair: Naishen Liang)			
09:00-09:30		John Grace (invited)	The soil-plant-atmosphere continuum (SPAC), concept and measurements
09:30 - 09:45	3-1	Mingyuan Du	Comparison of respirations of grassland and wetland on the Tibetan plateau
09:45 - 10:00	3-2	Yosuke Okimoto	CO_2 emissions through oxidative peat decomposition from three different tropical peat ecosystems
10:00 - 10:15	3-3	Seiichiro Yonemura	Relation between soil CO_2 efflux and soil CO_2 concentrations
10:15 - 10:30	3-4	Munemasa Teramoto	Long-term warming effect on soil respiration in warm-temperate evergreen broad-leaved forest in Kyushu
10:30 - 10:45	Break		
10:45-11:00	3-5	Ryuichi Hirata	Improvement of the soil submodel of the process-based terrestrial ecosystem model to apply tropical swamp forests
11:00-11:15	3-6	Jianxing Zhu	Spatial pattern and decadal variation of atmospheric wet nitrogen deposition in China
11:15-11:30	3-7	Kazuyuki Inumushi	Function of methanogenic community in mangrove soils as influenced by the chemical properties of the hydrosphere
11:30 - 11:45	3-8	P. M. Mohan	Influence of physical parameters on dissolved organic carbon (DOC) and inorganic carbon (DIC) in the surface seawater of Port Blair, Andaman islands, India
11:45 - 12:00	Discussion		
12:00-13:00	Lunch		
4. Observational aspects of ecosystem response to rainfall variability in monsoon regime (Chair: Anandakumar Karipot, Thara Prabhakaran)			
13:00-13:30		Kyaw Paw U Tha (invited)	Micrometeorological measurements, modeling, and trace gas exchanges from ecosystems in global networks: chronic challenges and promising developments
13:30-13:45	4-1	Abhijit Chatterjee	Biosphere-atmosphere exchange of CO_2, H_2O and energy over a high altitude forest at eastern Himalaya, India: preliminary results
13:45-14:00	4-2	N. R. Patel	Evaluation of energy balance components during transition phases of monsoon over cropland and forest ecosystem
14:00-14:15	4-3	Pramit Deb Burman Kumar	CO_2 and H_2O fluxes during wet and dry periods and associated boundary layer aspects
14:15-14:30	4-4	Jyoti Bhate Narayan	Variability of measured CO_2 and water vapour fluxes at rural site in south India
14:30-14:45	4-5	Anandakumar Karipot	Carbon and energy fluxes over a rainfed agricultural ecosystem in semi-arid indo-gangetic plains

14:45-15:00	Discussion		
15:00-16:00	Break and Poster		
5. Flux monitoring, climate change and sustainable agriculture (Chair: Joydeep Mukherjee, V.K.Sehgal)			
16:00-16:30		Joon Kim (invited)	Climate-smart agriculture's triple challenge for a complex paddy soil-rice system
16:30-17:00		M. Asaduzzaman (invited)	Flux transfer processes over crop field towards agricultural sustainability under climate change scenario
17:00 - 17:15	5-1	Karrin Alstad	Water, carbon, and methane flux analyses of crop and soil water gradients: a synthesis of three Picarro CRDS studies
17:15 – 17:30	5-2	Montri Sanwangsri	Estimation of evapotranspiration using eddy covariance technique in dry dipterocarp forest University of Phayao Thailand
17:30 – 17:45	5-3	Masayoshi Mano	Continuous CH_4 flux measurement of a double-crop paddy field in Bangladesh
17:45-18:00	5-4	Joydeep Mukherjee	Surface energy fluxes estimation in wheat (*triticum aestivum L.*) using Bowen ratio energy balance method in irrigated central Punjab, India
18:00-18:15	Discussion		
18:30 ~	YSM and SSC		
19:00-21:00	Director's Dinner, Meghdoot Complex, IITM		

Friday, 27 November

6. Linking Asiaflux and atmospheric chemistry communities: Reactive trace gas flux and aerosol formation in forest ecosystem (Chair: Akira Tani, Sheiichiro Yonemura, Yuzo Miyazaki)			
09:00 - 09:30		Nick Hewitt (invited)	Effects of large-scale land use change on local air quality
09:30 - 09:45	6-1	Akira Tani	Laboratory and field measurements of oxygenated VOC uptake by plants
09:45 - 10:00	6-2	Julia Drewer	Quantification of soil VOC fluxes in relation to greenhouse gas fluxes across a gradient of tropical land-use intensity in Malaysian Borneo
10:00 - 10:15	6-3	Ryuichi Wada	Observation of O_3 flux with the gradient method in red pine forest
10:15 - 10:30	6-4	Yuzo Miyazaki	Impact of nitrogen fertilization on the formation of biogenic organic aerosol in a deciduous broad-leaved forest
10:30 - 10:45	Discussion		
10:45 - 11:00	Break		
7. CO_2 and CH_4 observations and modelling over India and neighboring countries (Chair: Vinu Valsala, Yogesh Tiwari, Supriyo Chakraborty)			
11:00 - 11:30		Stephen Sitch (invited)	Changes in atmospheric composition and land-atmospheric interactions across the Asian region
11:30 - 11:45	7-1	Abha Chhabra	Recent observations of atmospheric CO_2 over India using OCO-2 data
11:45 - 12:00	7-2	Muraleedharan Krishnapriya	Variability of atmosphere CO_2 over India and its surrounding based on geos-chem transport model and satellite observations
12:00 - 12:15	7-3	Sneha Thakur	Characterization of surface CH_4 flux emission from GOSAT satellite data over selected agro-ecosystems in India
12:15 -12:30	Discussion		
12:30-13:30	Lunch		
8. Integrated analysis of greenhouse gases fluxes of Asia (Chair: Kazuhito Ichii, Prabir Patra, Nobuko Saigusa)			
13:30 - 14:00		Tazu Saeki (invited)	CO_2 flux estimation by top-down approach over Asian region
14:00-14:15	8-1	Kentaro Takagi	Semi-empirical gpp estimation of east Asian forests using MODIS vegetation indices
14:15-14:30	8-2	Kazuhito Ichii	Upscaling terrestrial CO_2 fluxes in Asia using an integrated database of eddy-covariance measurements
14:30-14:45	8-3	Shilpa Gahlot	Understanding carbon dynamics in India using a land-surface model
14:45-15:00	8-4	Prabir K. Patra	Asian methane emissions estimated by inverse modelling
15:00-15:15	Discussion		
15:15 - 15:30	Rapup		

Poster Session
Wednesday, 25 November 15:00-15:45
Thursday, 26 November 15:00-16:00

PO- 1	Anandakumar Karipot	Carbon dioxide, water vapour and energy flux observations over a semi-urban high altitude location over Western Ghats
PO- 2	Anirban Akhand	Tidal and seasonal variability of air-water carbon dioxide flux in the Hugli estuary
PO- 3	Mahesh Pathakoti	Atmospheric CO_2 variations over different contrasting sites of India
PO- 4	Jayashree Revadekar	Variability in airs CO_2 during active and break cycles of Indian summer monsoon
PO- 5	Kushal Kumar Baruah	Carbon dioxide exchange from a semi evergreen forest in Assam, India using eddy covariance technique
PO- 6	Kushal Kumar Baruah	Carbon fixation, carbon efflux and methane emission in relation to soil carbon stock in rice agro-ecosystem
PO- 7	Gnanamoorthy Palingam	Seasonal variation of pCO_2 in the Pichavaram mangrove waters, southeast coast of India
PO- 8 ☆	Pramit Deb Burman Kumar	CO_2 source characterization using isotopic techniques over a semi urban area in northern India during Indian summer monsoon 2014
PO- 9	R. Latha	Pre-monsoon CO_2 variations at a coastal station, Goa
PO- 10	Kumaresan S.	Health status of coral reef ecosystem at Lakshadweep island in relation to atmospheric CO_2
PO- 11	Reshma M. Ramachandran	Land use land cover dynamics of Eastern Ghats India using geospatial technologies
PO- 12 ☆	Sudhanshu Shekhar	Sedimentary characteristics of coral reef ecosystem at Agatti island Lakshadweep
PO- 13 ☆	Suraj Reddy Rodda	Estimation of net ecosystem carbon exchange for deciduous and mangrove forests of India using eddy covariance flux measurements
PO- 14 ☆	Joyson Ahongshangbam	Measuring net ecosystem exchange in mixed forest plantation using eddy covariance technique
PO- 15 ☆	Chaturvedula Nrisimha Ramkiran	Intra-seasonal variability of surface fluxes at Gadanki, a rural station in a complex hilly terrain
PO- 16	Gurunath Chinthalu Ramaswamy	Influence of global warming on Indian summer monsoon
PO- 17	Ponraj Arumugam	Assessment of RegCM-4.3.5.6 downscaled simulation's inter annual seasonal variability analysis of temperature and precipitation over northern India
PO- 18	Subharthi Chowdhuri	Mechanism of CO_2 and water-vapor flux transport from close to the ground under two very different stability regimes
PO- 19	Alagesan Arumubam	Conjunctive use of canal and alkali water in rice based cropping system in Tamil Nadu, India

PO- 20	Kaniska Mallick	Quantifying stomatal and aerodynamic controls of terrestrial latent heat flux over south-east Asian landscape with a Penman-Monteith framework
PO- 21	Kaniska Mallick	Land-atmosphere fluxes over semi-arid agroecosystems combining thermal remote sensing and Penman-Monteith model with special reference to India
PO- 22 ☆	Kazuya Okada	A study on the carbon decomposition process of residual biomass and CH_4 emission in the rice paddy field
PO- 23 ☆	Kenta Yagi	The variations of redox potential in paddy soil and effects on the methane emission from a periodically irrigated paddy field
PO- 24 ☆	Daiki Takeuchi	Effects of forest cutting on greenhouse gas dynamics and soil physico-biochemical properties in Japanese temparate forests
PO- 25	Amit Kumar	Net ecosystem exchange, ecosystem respiration and gross primary productivity in wheat in north western indo-gangetic plains
PO- 26 ☆	Amita Raj	Yield and nutrient uptake of rice as affected by elevated atmospheric temperature
PO- 27	B.S. Murthy	On the comparison of surface layer fluxes of CO_2 and moisture at a rural and a semi-rural station
PO- 28 ☆	Biswajit Kar	Trade-off association between CH_4 and N_2O emission under different cultivation practices of kharif rice A comprehensive study
PO- 29 ☆	Gulab Singh	Wheat biomass contribution to nitrous oxide emission under gangetic alluvial agro climatic environment
PO- 30 ☆	Mana Panya	Responding of net ecosystem CO_2 exchange on micrometeorological factor in dry dipterocarp forest using eddy covariance technique
PO- 31 ☆	Sandeep Malyan Kumar	Methane mitigation potential of azolla and cyanobacteria (blue-green algae) in rice
PO- 32 ☆	Sudipta Thakur	Determing surface energy balance component over potato field using aerodynamic resistance method
PO- 33	Sunayan Saha	Net exchange of CO_2 over a winter wheat ecosystem in peninsular India: biophysical and environmental controls
PO- 34 ☆	Susmita Karmakar	An assessment of N_2O flux density of winter wheat as influenced by soil environment
PO- 35	Vinay Sehgal Kumar	Surface energy fluxes pattern over irrigated cropland and sebs model validation by large aperture scintillometry
PO- 36	G.J. Bhagavathiammal	Impact of stratospheric ozone driven climate change on tropospheric composition and air quality over the Asian region

PO- 37	G.J. Bhagavathiammal	Trends and variability of tropospheric ozone measured from aura microwave limb sounder over Chennai (13.08^{o}N, 80.27^{o}E), India
PO- 38 ☆	Saurabh Sonwani	Particulate-bound polycyclic aromatic hydrocarbons in urban ecosystem of Delhi
PO- 39	Eva van Gorsel	Impact of the 2012-2013 summer heatwaves on forest productivity in eastern Australia
PO- 40	Iuliya Kurbatova	Carbon fluxes in tropical seasonal forest of southern Vietnam
PO- 41	Robert Borisovich Sandlerskiy (Iuliya Kurbatova)	Thermodynamical characteristics of Cat Tien tropical forests, based on remote sensing data
PO- 42	Minseok Kang (Joon Kim)	Filtering drainage-affected eddy covariance observations on a forest hill slope using dynamical process networks
PO- 43	Takahisa Maeda	Leaf phenology of a tropical monsoonal evergreen forest observed by a long-term record of canopy photographs , and influence of climate on green-up at Sakaerat (SKR), Thailand
PO- 44	Yoshiyuki Takahashi	Long-term monitoring of CO_2 exchange over a larch forest in central Japan
PO- 45	Guirui Yu	Modeling net ecosystem CO_2 exchange in northern china and the Tibetan plateau based solely on MODIS imagery
PO- 46 ☆	Kojiro Hirayama	Largescale evaluation of decadal forest biomass changes from repeated airborne LIDAR measurements in northern Japan
PO- 47	Mahendra N. Patil	Evaluating relationship between fluxes of heat and CO_2 using direct eddy covariance measurements
PO- 48	N. R. Patel	Sun-induced fluorescence from gome-2 for estimating net primary productivity of croplands in Indo-gangetic plains
PO- 49	N. R. Patel	Ecosystem respiration over a mixed forest plantation of northern India using MODIS-derived vegetation indices and flux-tower observations
PO- 50	N. R. Patel	Evaluation of Biome-BGC model for simulating biophysical attributes and carbon fluxes over mixed forest plantation in foot hills of lower Shiwalik
PO- 51	Vaithilingam Selvam	Eddy covariance measurements of methane and carbon dioxide fluxes over a mangrove ecosystem, southeastern coastal India
PO- 52 ☆	Srabanti Ballav	High resolution CO_2 transport simulation by the wrf-CO_2 model: South Asia

☆Represents Young Scientists (Students, Post Doc Fellow etc)

Oral Session

MICROMETEOROLOGY : A JOURNEY

Shashi B. Verma

Professor Emeritus, School of Natural Resources, University of Nebraska, Lincoln, NE U.S.A.

A few aspects of a forty-year (1972- 2012) journey in micrometeorology will be discussed. Primary scientific objectives were to: (a) quantify the seasonal and annual distributions of net ecosystem exchanges of mass and energy and (b) examine the roles of environmental and biophysical variables in governing these exchanges. Work focused on three ecosystems: agricultural crops, grasslands and wetlands. Instrumentation available at the time for use in such studies will be briefly outlined. Carbon dioxide and water vapor fluxes were measured in native tall grass prairies in Kansas and Oklahoma. A long-term interdisciplinary study on mass and energy exchanges in three (irrigated and rainfed maize- soybean) cropping systems in Nebraska will be discussed. Water productivity of these crops will be compared among different years of measurement and management practices in this study and against those from other locations. Methane fluxes, measured in wetlands in Minnesota, Nebraska and Saskatchewan will be outlined and dependence on relevant environmental variables will be examined. Concluding comments will include a few suggestions for young scientists in our scientific field.

VEGETATION AND SOIL CARBON POOLS AND FLUXES IN INDIA AND RESULTS FROM FLUX TOWER NETWORKS

Vinay Kumar Dadhwal

National Remote Sensing Centre (Indian Space Research Organisation), Hyderabad, India

Vegetation and soil carbon (C) either exists in the 'carbon pools' of the earth system (termed as stocks or reservoirs) or in the form of movement/exchange (flux) between these reservoirs. In view of the terrestrial biosphere's role as a major sink of carbon particularly in terms of CO_2 fixing by vegetation for photosynthesis, the concept of studying 'Soil and vegetation - atmosphere fluxes' has gained importance in the past few decades
Very few independent studies are being carried out at institutional level in India to account for the carbon flux estimates in the form of Net Ecosystem Exchange (NEE) of CO_2, and relevant gross and net primary productivity (GPP & NPP) for different vegetated ecosystems. An estimate of maximum CO_2 uptake of -18.73 gC $m^{-2}day^{-1}$ was observed in grassland ecosystem with seasonal variability. Another study using eddy flux tower over a re-vegetated manganese spoil dump suggested a Net Ecosystem Productivity (NEP = -NEE) of 28 KgC ha^{-1} day^{-1}.

The 'National Carbon Project' (NCP) has been taken up as an Indian Space Research Organisation - Geosphere Biosphere Programme (ISRO-GBP) initiative in 2007, which is envisaged to assess the country's total carbon pools, fluxes and net carbon balance for terrestrial biomes on annual basis using ground based measurements and satellite remote sensing data sets. NCP is an inter-disciplinary project addressing total C cycle of India and is carried out by integrating major components of vegetation & soil C pools and C fluxes at soil-vegetation-atmosphere interface. Methodology involves multi-institutional level national integrated ground sampling of vegetation and soil parameterization, establishment of network of eddy covariance flux towers across representative vegetation cover (forests, agriculture, plantations, grasslands etc.) to measure mass and energy fluxes and measuring of meteorological/environmental parameters. Up-scaling of the ground based measurements to regional/landscape and national level estimates is achieved through utilizing remote sensing data for creating spatial data bases, to be further used for modeling and periodic assessment of net carbon balance in India.

So far, 6 eddy flux towers have been established in representative forest and agriculture ecosystems (operational), for which total carbon sequestered and net ecosystem productivity has been estimated. Flux tower based estimates suggested net carbon sequestration of 585.52 ± 265.15 g C m^{-2} $y^{-1}$and 249 ± 20 g C m^{-2} $y^{-1}$for central Indian teak mixed deciduous forests and mangrove forests of Sundarbans respectively. Similarly flux tower based estimates for rabi season in tropical low land rice ecosystems suggested net carbon sequestration rate of 408.05 g C m^{-2} d^{-1}. Currently, remote sensing data derived vegetation indices such as EVI and LST are being used as explanatory variables in conjunction with the tower based estimates for data-driven and data-assimilation based GPP models to up-scale ecosystem level fluxes to regional level.
National level gridded (5 x 5 km) spatial estimate of forest phytomass has been completed. National level grid cell of 5km x 5km was generated for time series assessment and to analyse the trends in spatial distribution of forest cover (1930-1975, 1975-1985, 1985-1995, 1995-2005 and 2005-2013). Under the soil carbon pools component, around 2000 ground sampling point data pertaining to soil carbon pools has been collected and geospatial modeling of SOC pools have been achieved for selected states of India.

DECOUPLING THE SPATIAL AND TEMPORAL VULNERABILITY OF AGRICULTURAL SYSTEMS TO FUTURE CLIMATE CHANGES

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South Asia, particularly India, is predicted to be one of the most vulnerable regions in terms of agricultural sensitivity to future climate changes. Approximately 69% of India's population is rural, and over 55% of the working population relies on agriculture for sustenance and livelihoods. Indian smallholder farmers who own less than 2 ha of farmland represent 78% of the total Indian farmers and produce 41% of the country's food crops. These smallholder farmers are among some of the most vulnerable communities to climatic and economic changes due to limited access to technology, infrastructure, markets, and institutional or financial support in the case of adverse climatic events. Baseline information on agricultural sensitivity to climate variability will provide useful information for regional-level, and eventually state- and national-level, strategies and policies that promote adaption to climate variability. This study contributes to the climate impacts and responses literature by examining how cropping patterns across agro-ecological zones in India respond to variations in precipitation and temperature, and how smallholder farmers with different socio-economic characteristics respond to climate variability.

This study takes an integrated approach to understanding food-climate-land dynamics using satellite time-series data (2000-01 – 2012-13) for cropping patterns, climate data and census data for demographic and socio-economic factors. We developed multiple mixed-effect models (250 m to 1 km scale) to identify correlations between crop cover, climate parameters, and socio-economic indices. We find that winter daytime mean temperature (November–January) is the most significant factor affecting winter crops, irrespective of crop type, and is negatively associated with winter crop cover despite the differences in biophysical and socio-economic conditions across India. With pronounced winter warming projected in the coming decades, effective adaptation by smallholder farmers would require additional strategies, such as access to fine-scale temperature forecasts ahead of the planting season and heat-tolerant winter crop varieties.

[1-1]

CLIMATIC DRIVERS OF LARGE-SCALE ECOSYSTEM CHANGE OVER INDIA

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The main component of the terrestrial biosphere is vegetation that plays an active role in the climate system through altering the energy, water and momentum in the earth systems [Foley et al., 2000]. Climate change may have a strong impact on terrestrial ecosystems. In this context many studies have presented how climatic variations have caused major alterations in the composition and distribution of terrestrial ecosystems worldwide [Chapin et al., 2010]. There is a need to understand how ecosystem processes are influenced by the entire suite of perturbations, from solar irradiance, temperature, soil moisture, fires, and other disturbances. The projected climate change fueled by increases in greenhouse gases, has warned that it may have pronounced effects on agriculture, forestry, natural ecosystems and biodiversity [Christensen et al., 2013]. Currently, substantial gaps exist in our knowledge about the magnitude, direction of ecosystem change and location of carbon sink regions as well as in the underlying dominant mechanisms [Pan et al., 2011]. So there is little knowledge about the vulnerability of ecosystems to future climate change and its associated impact on biogeochemical cycles [Friedlingstein et al., 2006].

Commonly, precipitation and temperature are analyzed as two important climate drivers that affect plant growth and distribution albeit other climatic or non-climatic drivers (e.g. surface solar radiation, cloud clover, atmospheric CO_2 concentrations, land use change, nutrients) also regulate the vegetative phenology. For terrestrial biosphere, a direct influence of increase in surface temperature is obvious. Vegetation growth status is also highly dependent on monsoon-dominant climate over India as the spatial patterns of precipitation are highly shaped by the peculiar orographic features. Here, this study has analyzed the variations of vegetation activity over different ecosystems using the unprecedented nearly three decades of latest satellite vegetation records (i.e. Normalized Difference Vegetation Index (NDVI) 3g data) in conjunction with a satellite-driven ecosystem model (CASA-GFED3).

Spatially explicit grid point correlations between detrended monsoon season temperatures and NDVI for the early (1982–2000) and recent (2000–2011) periods were performed. Results exhibit that a large-scale positive correlations (except North Western India's drier regions) are observed comprising agriculture and forest ecosystems, especially during the early period. However, these positive correlations switch into negative correlations during the recent period. This is suggestive of temperatures induced stress. Furthermore, this study has analyzed variations of vegetation activity and carbon uptake strength in relation to other climatic drivers and in conjunction with the model simulations.

[1-2]

EFFECT OF TERRAIN ON TALL TOWER MEASUREMENTS OF HEAT AND TRACE GAS FLUXES ABOVE A TROPICAL FOREST.

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Eddy-covariance (EC) is widely used for continuous, spatially-integrated measurements of heat and trace gas fluxes in a variety of environments. Tall towers provide direct, in situ measurements over potentially large footprints but fluxes can be affected by measurement height and local topography. We report on two intensive field campaigns held in Malaysian Borneo during the first half of 2008. Fluxes of heat (latent, LE, and sensible, H) and carbon dioxide (CO_2) were measured at the Bukit Atur Global Atmospheric Watch (GAW) tower (4°58'49.10'' N, 117°51'19.12'' E) located in the Danum Valley conservation area, Sabah, Malaysia; the 100 m tall tower was situated on a hill leading to an effective measurement height of 200 m above the rainforest canopy. The terrain surrounding the measurement site consisted of forested rolling hills to the N, NE, S and SW of altitude in the range 500 m – 800 m a.s.l. and more uniform terrain elsewhere. Fluxes of CO_2 were measured by eddy-covariance at a height of 75 m atop the GAW tower; in addition, EC fluxes of latent and sensible heat were also measured at 30 m and 45 m on the tower.

The turbulent kinetic energy (TKE) profiles at the 3 heights exhibited diurnal cycles consistent with thermal generation of turbulence but lagged behind the mean diurnal cycle of the total solar radiation by ca. two hours (Fig 1a).

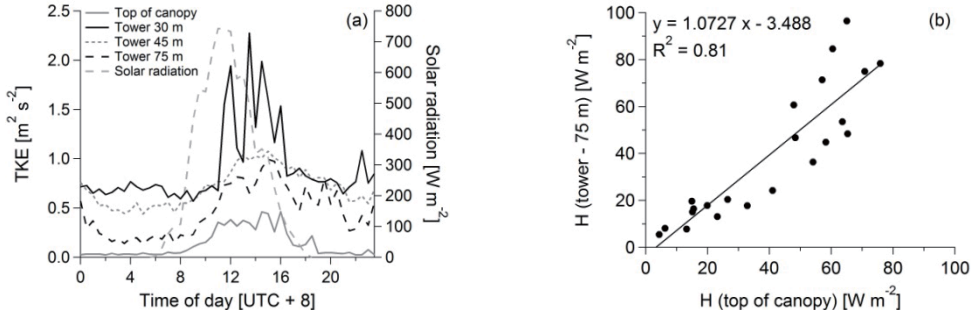

Figure 1: (a) turbulent kinetic energy (TKE) measured at the top of the canopy and at 3 heights on the Bukit Atur tower. The total solar radiation was measured at the Bukit Atur site; (b) comparison of sensible heat fluxes (H) measured at 75 m atop the tower and at the top of the canopy (valley).

Air flow over hills can be accompanied by complex streamline distortions leading to anisotropic pressure fields and local generation or consumption of turbulence. Pressure-strain interactions were the main sink of momentum at the site and also nearly cancelled out the daytime buoyancy production term of the TKE budget. Furthermore, the disruption to the air flow was more pronounced at the 30 m platform, especially in wind sectors entraining rolling hills. Horizontal and vertical turbulence could have been enhanced by low-frequency, terrain-generated eddies which can take several kilometers from the point of production to dissipate. Heat fluxes measured at 45 m on the tower were on average 8% - 11% (for LE and H, respectively) larger than at 75 m; the goodness of the linear fit was a function of wind direction suggesting that terrain-induced air flow distortions were more severe for wind sectors with steep hill slopes. The terrain perturbed the fluxes measured at the lower levels of the tower (30 m and 45 m) and there were indications of significant horizontal advection between levels 45 m and 75 m. Good agreement was found between H measured at 75 m on the tower and at the top of the canopy to the East of the tower (Fig. 1b; vertical and horizontal separation ca. 200 m and 1300 m, respectively) which suggests that the top measurement level was coupled to the valley, at least at daytime. The night time tower-canopy coupling was questionable due to mist formation and recurring stable atmospheric stratification. As a result, CO_2 fluxes were near zero at night and exhibited an early morning peak consistent with growth of the boundary layer. We estimate net annual uptake at 7.1 ± 1.0 tons CO_2-C ha^{-1} yr^{-1} which is consistent with values reported for other tropical forests, with respiration accounting for ca. 58% of the budget.

[1-3]

CONTROL AND RESPONSE OF SOIL CARBON DYNAMIC OF ASIAN TROPICAL FOREST ECOSYSTEMS

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The tropical ecosystems have been estimated to be a large carbon source (1.3 Pg C yr^{-1}) due to deforestation and forest degradation, even the global terrestrial carbon sink has been large (1.1 Pg C yr^{-1}) in recent decades. Reducing Emissions from Deforestation and Forest Degradation (REDD) is an effort to create a financial value for the carbon stored in forests, offering incentives for tropical region to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. The ultimate goal of this study is to update REDD mechanism through improved forest management by evaluation of effects of logging and land-use change on soil carbon emission of tropical forests. This study was conducted in a lowland primary forest at Pasoh Forest Reserve (PFR; 2º58' N, 102º18' E; 75~150m a.s.l.) and a mountainous tropical forests at Temenggor concession area (5º33' N, 101º36' E; 800~900m a.s.l.) in Peninsular Malaysia. Annual soil efflux at PFR was estimated to be about 37.6 tC ha^{-1} y^{-1}, with heterotrophic respiration contributed about 52%. Heterotrophic and root respiration showed opposite response to seasonal changes in soil temperature and moisture, with root respiration decreased in dry season (higher temperature) but increased in rainy season (lower temperature). Result indicate that water condition might be the key environmental factor that control the carbon sink (rainy season) and source (dry season) of tropical forests. About 50~65% biomass was harvested and soil temperature increased about 1.6ºC with the Sustainable Management System (SMS), resulting value of the carbon stock lost about 2,577 US$ ha^{-1}following the first year of logging. On the other hand, with the Reduced-Impact Logging system (RIL), only about 1,773 US$ ha^{-1} was lost following the first year of logging. Result suggests that this low-impact harvest system would achieve about 804 US$ ha^{-1} of REDD credit partially contributed from mitigating soil degradation of about 169 US$ ha^{-1}.

Key words: Automated chamber, LULUC, moisture, soil carbon, tropical ecosystem

[1-4]

A REGROWING TROPICAL PEAT ECOSYSTEM CHANGED FROM A CO_2 SOURCE TO A CO_2 SINK AFTER FIRE

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In Southeast Asia, a huge amount of peat has accumulated under peat swamp forest (PSF) over millennia. Fires have been widely used for land clearing after timber extraction, thus land conversion and land management with logging and drainage are strongly associated with fire activity. During recent El Niño years, tropical peatlands have been severely fire-affected and field fires enlarged. To investigate the impact of fires on the regional and global carbon balances, it is crucial to assess not only direct carbon emissions through the combustion of biomass and peat but also the change of net ecosystem carbon dioxide (CO_2) exchange (NEE) through vegetation regrowth after fire disturbance. However, there is little information on the carbon dynamics of tropical peat ecosystems damaged by fires. Therefore, we have measured NEE continuously since 2004 using the eddy covariance technique above a burnt PSF (2.34ºS, 114.04ºE) in Central Kalimantan, Indonesia (Hirano *et al.*, 2012). The site was burnt four times at least in the late dry seasons of 1997, 2002, 2009 and 2014, El Niño years. Although biomass and surface peat were burnt during fires, some trees survived fires and understory vegetation, chiefly consisting of fern plants, regrew rapidly after fires.

NEE was positive (a net CO_2 source) until a fire in September 2009 and depended on groundwater level (GWL); NEE became more positive as GWL lowered. However, NEE drastically changed to negative (a net CO_2 sink) after December 2009, which resulted from decrease in ecosystem respiration (RE) and increase in gross primary production (GPP, ecosystem photosynthesis). The RE decrease would be due to the loss of surface peat by combustion (fire subsidence) and its resultant GWL lowering. The GPP increase probably resulted from the rapid growth of fern plants under the conditions of moist peat soil and enriched nutrient supplied from burnt biomass and peat.

[1-5]

IMPLEMENTATION OF PROGNOSTIC LEAF AREA INDEX IN A LAND SURFACE MODEL: EVALUATION OF WATER, ENERGY AND CARBON FLUXES IN TROPICAL ASIA USING FLUX NET TOWER DATA

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In land surface models, phenology and leaf area index (LAI) regularly alters land surface boundary conditions by changing surface albedo, roughness, and surface water and energy fluxes. Therefore, they are the key variables for accurate estimation of seasonal variations of terrestrial ecosystem processes, such as photosynthesis and respiration, as well as land-atmosphere exchange of energy, water and carbon fluxes. In the modeling studies, LAI is prescribed through the use of satellite-based data, while the model accounts for prognostic phenology scheme leading to inconsistency between phonological stages and LAI seasonality. We implement tropical Asia Ecosystem (TAE)-specific prognostic LAI parameterization based on the leaf carbon content and environmental factors in a land surface model, the Integrated Science Assessment Model (ISAM) aimed at calculating continuous LAI consistent with the plant phonological development stages. This parameterizations account for light, water, and nutrient stresses, while allocating the assimilated carbon to leaf, stem, and root pools. The model parameters related to these processes were calibrated and evaluated using Site level flux net tower data. To quantify the implication of this new parameterization on the C, water, and energy fluxes, we perform two model experiments, one with prognostic LAI and other with satellite-based LAI. We investigate the advantages of using prognostic LAI for better estimation of the seasonal variation in water, energy and carbon assimilation fluxes. Our analysis reveals that better understanding of the environmental controls on phenology results in tropical Asia ecosystems can be accomplished by a better representation and implementation of phenology and LAI in a land surface model, which also improve the model results for land-atmosphere water, energy and carbon assimilation fluxes.

[1-6]

THE IMPACT OF LANDUSE CHANGE FROM FOREST TO OIL PALM ON SOIL GREENHOUSE GAS FLUXES

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Monocultures of oil palm have been expanding in SE Asia, and more recently also in Africa and South America, frequently replacing tropical forests. The limited data available clearly show that this conversion is associated with a potentially large greenhouse gas burden. The physical process of landuse change, such is felling, drainage and ploughing can significantly increase emissions of N_2O and soil CO_2 respiration and decrease CH_4 oxidation rates in the short term; and in the long-term regular nitrogen applications will impact in particular soil N_2O fluxes.

Current understanding of soil GHG fluxes associated with landuse change from forest to oil palm is not sufficient to provide reliable estimates of their carbon footprints and sustainability or advice on GHG mitigation strategies. To provide the necessary data we have installed a total of 60 flux chambers in logged forests, forest fragments and mature and young oil palm plantations within the SAFE landscape in SE Sabah. (Stability of Altered Forest Ecosystems; http://www.safeproject.net). Soil respiration rates, N_2O and CH_4 fluxes together with soil moisture, pH, mineral and total C and N are measured over a two year period. On the oil palm plantations we compare fluxes close to the stem, where fertiliser bags are placed, with those in between stems and also on areas where empty fruit bunches are spread. Here we will present the concept of our experimental work, data from our first 5 measurement campaigns and discuss the relevance to the policy maker.

[1-7]

VULNERABILITY ASSESSMENT AND CLIMATE CHANGE RESPONSE: A PRELIMINARY STUDY ON COASTAL ZONES, MANGROVE, COMMUNITIES DEPENDENT ON THE COASTAL ECOSYSTEM, AND CLIMATE CHANGE TACKLING IN MYANMAR

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Myanmar is country rich in natural resources. It situates in the area of Indo-Burma biodiversity hotspot, one of the most species-rich ecosystems in the world. It consists of diverse topographies including a 2400 km long coastal line; Rakhine coastal zone of 740 km, Ayeyarwaddy delta coastal zone of 460 km and Tanintharyi coastal zone of 1200 km. Regarding FAO report "The World's Mangroves 1980 – 2005, Myanmar stands at third largest area of 507,000 ha or 8.8% of mangroves in Southeast Asia of 4.9 million ha or nearly 35% of the world's total after Indonesia (59.8% of total Southeast Asia mangrove), Malaysia (11.7%), followed by Papua New Guinea (8.7%), Thailand (5.0%), Philippines (2.2%), Vietnam (2.1%), Cambodia (1.3%), Brunei Darussalam (0.3%), Timor-Leste (0.03%), and Singapore (0.01%). There is a low and flat dry zone, mountainous zones, and even snowcapped mountains in the northernmost part of the country, with forest covering over 46.69% of the total land area and a population of 53.14 million. But it is one of the most vulnerable countries in the region to the climate change. Natural resources and ecosystems are also being endangered by both natural and anthropogenic impacts. Local communities especially living in coastal line are more vulnerable to the climate change than others as they mainly rely on the coastal ecosystem services. This study is based on a comparative study between Thailand and Myanmar in 2012, practical field work of 18 years in forestry field and 3 years in environmental conservation and climate change negotiation experience, and secondary data sources. Research objectives are to assessment the vulnerability of communities, mangrove, and coastal ecosystems, to analyze status of mangrove, livelihoods and ecosystems, peak duration of dependency on ecosystem and its services, conservation and addressing climate change, and to classify the future status. This paper reports the results of research on the magnitude of vulnerability in a local community, the natural ecosystem with a focus on the mangrove, and the status of climate change response achieved through enhanced policy intervention by applying two specific -or- primary measures, mitigation and adaptation. Research has been framed with a literature review, technical analysis on data received by field research and data collected as secondary resources including population, socio-economic status, relies on natural resources, forest status, existing actions tackling climate change including people participation and policy interventions. Some species such as Rhizophora spp. and Lumnitzera species are cut for fulfilling daily needs of the local people. Ayeyarwaddy delta coastal zone is likely to be the most vulnerable to the climate change impacts and other natural disaster as its not much higher than sea level, and undergoing severe degradation of mangrove forest among three major coastal zones in Myanmar. Cyclone Nargis in 2012 proved that the natural shield has been weakened by the people in Ayeyarwaddy. Mangrove degradation are happening every year under the local people's requirement for their livelihoods, requirement of both the private sector and the state development programmes, limited law and policy enforcement. In depth research to support policy enhancement, law enforcement, conservation in terms of environment and ecosystem, alternative livelihood system for minimizing the local dependent on the coastal ecosystem, formulation of proper coastal zone management model, and ways and actions for enhancing local resilience to the climate change impacts should be carried out by applying advanced technologies and tools.

Key words: mangrove, coastal ecosystem, climate change, vulnerability, resilience

[1-8]

IMPACT OF BLACK CARBON ON THE ECOSYSTEM AND CLIMATE CHANGE

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In today's changing environment the ability of human kind to intuitively asses and manage the health risk has become fundamental for its survival and evolution. The current technological advancement is found insufficiently coping with vehicular growth which is anticipated to worsen the condition in future in India. Black carbon is a component of fine particulate matter which is associated with excess morbidity and mortality; also they impact on global and regional climate. Black carbon is transported from a source, the pollutant disperse into the surrounding air causing various effects to the flora and fauna inhabitants and the environment. Burning of fossil fuel is great sources of black carbon emission and also primary sources of energy consumption producing nitrogen oxides, Sulphur oxides, dust, soot, smoke and other suspended particulate matter. Black carbon emission causes negative impact directly or indirectly on the vegetation, weather and climate and on the aesthetic quality of the environment. This talk will deal with emission of black carbon its radiative forcing effects and its impact on climate change and the environment.

[2-1]

RE-INTRODUCING RADIOMETRIC SURFACE TEMPERATURE INTO JOHN MONTEITH'S FORMULATION OF PENMAN-MONTEITH EQUATION

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Radiometric surface temperature (T_R) measured through thermal infrared (TIR) remote sensing provides direct information on the land surface moisture status and surface energy balance partitioning. The Penman-Monteith (PM) formulation is the most versatile and physics based method for estimating the surface energy balance fluxes (sensible heat, H and latent heat, λE) from the terrestrial surfaces. The inherent link between the PM model and T_R emanates through the dependence of aerodynamic and stomatal conductance (g_B and g_S) on T_R, surface moisture, and radiative fluxes. In a seminal paper on thermodynamics of λE, John Monteith (1965) conceptualized a conductance-based λE formulation which later received universal recognition as a fundamental basis for λE and associated surface energy balance (SEB) modeling (Dolman et al., 2014). Monteith introduced a thermodynamic constraint in the reformulation of Penman's λE model, and his interpretation of the aerodynamic (physical) and stomatal/canopy (physiological) conductance pathways set out a primrose path for estimating λE from any unsaturated surface (Lascano & van Bavel, 2007; Dolman et al., 2014). However, the application of PM model in thermal remote sensing based SEB modeling is often hindered due to the unavailability of any direct method to integrate the T_R information into the PM equation and due to the lack of physical models expressing g_S and g_B as a function of T_R. The aim of the proposed research is to bridge this existing gap by re-introducing T_R into the PM model in a physical framework to improve the terrestrial λE estimation using an advanced T_R based PM framework, while also overcoming some of the major drawbacks of the currently available PM based λE algorithms. We simultaneously demonstrate a novel method to partition λE into component fluxes (evaporation, λE_E and transpiration, λE_T) through this physical integration of T_R into the PM formulation.

This study demonstrates a 'closure' of the PM model by utilizing the T_R observations in a way that treats g_B and g_S as internal unobserved components. The method combined T_R data with the standard surface energy balance equations and a modified advection–aridity hypothesis in order to derive a hybrid closure that does not require exogenous parametric sub-models of the surface to atmosphere conductance terms; instead the conductances are analytically retrieved. We call this the Surface Temperature Initiated Closure (STIC), which is formed by the simultaneous solution of multiple state equations. Taking the advantage of the psychrometric relationship between the temperature and vapor pressure, this method is also capable to retrieve the land surface wetness (M) from the gradients of T_R, surface dew point temperature (T_{SD}), air dew point temperature (T_D) and air temperature (T_A). STIC is driven with T_R, T_A, relative humidity (R_H), net radiation (R_N), and ground heat flux (G). High temporal resolution (half-hourly and daily) T_R measurements from multiple AsiaFlux eddy covariance networks and Moderate Resolution Imaging Spectroradiometer (MODIS) on-board Terra-Aqua sensors were used in conjunction with R_N, G, T_A, R_H measurements for estimating H and λE. The performance of STIC has been evaluated in comparison to the measurements of λE and H at multiple sites having variable surface moisture conditions. We found a RMSE of 32 to 45 W m^{-2} in λE and H estimates using tower observed T_R and reasonable estimates of land surface moisture availability (M) under the conditions of variable surface atmosphere coupling. RMSE was 38 (11%) (with MODIS Terra T_R) and 44 W m^{-2} (15%) (with MODIS Aqua T_R) in λE estimates, while the RMSE was 38 (9%) (with Terra) and 45 W m^{-2} (8%) (with Aqua) in H. STIC shows particular promise to efficiently capture the λE dynamics across different surface wetness and vegetation conditions. Performance of STIC was also good during the dry down period where λE is strongly governed by the deep layer soil moisture and where the majority of the λE models generally show poor performance. A high sensitivity of both M and λE was noted due to the uncertainties in T_R. A realistic response and modest relationship was also found when partitioned λE components (λE_E and λE_T) were compared to the observed soil moisture and rainfall. A pragmatic feedback was also obtained when the retrieved conductances were compared to the observed meteorological and biophysical variables. This method addressed some of the stumbling blocks that previously hindered the direct use of radiometric surface temperature into the PM formulation.

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[2-2]

NET CO_2 SINK POTENTIAL OF INDIAN ECOSYSTEM IN PRESENT DECADE

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The net ecosystem productivity (NEP) represents net carbon exchange between the terrestrial ecosystem and the atmosphere. It plays crucial role on the control of the atmospheric CO_2 at different time scales. Here we simulated NEP over India at monthly scale for the period 2000-2014 based on Carnegie–Ames–Stanford Approach (CASA) terrestrial ecosystem model. The driving parameters of the model includes satellite measured normalized difference in vegetation greenness index (NDVI), maps of soil and vegetation attributes, and climatic parameters such as radiation, precipitation and air-temperature. The NDVI data used here based on the measurements of Moderate- resolution Imaging Spectroradiometer (MODIS) sensor on board the NASA's Terra (EOS AM) and Aqua (EOS PM) satellites. As the CASA model parameterization is based on the long-term NDVI data from Global Inventory Modeling and Mapping Studies (GIMMS), we translated MODIS NDVI data in to the scales of GIMMS NDVI through linear regression procedure and the transformed data are used in the model. Our simulated NEP result suggests that Indian ecosystem is the net sink of atmospheric CO_2 during most of the years with mean of 19 TgC yr^{-1}. There exists significant inter-annual variability. Its comparison with the satellite measure atmospheric CO_2 suggest that the year with enhanced NEP budget correspond with reduction of atmospheric CO_2 and vice versa. Climate has the significant control on the variability of NEP over India.

[2-3]

UPSCALING CARBON FLUXES OVER LOW LAND TROPICAL RICE ECOSYSTEM USING FLUX TOWER AND REMOTE SENSING DATA

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Quantification of greenhouse gas exchanges between the ecosystem and the atmosphere is one of the key issues to assess the global budget of green house gases. Rice is the major food crop in India and generally it is cultivated in flooded soil condition. Assessments of spatio-temporal variations of CO_2 fluxes from it are important towards improving our understanding on the tropical low land rice ecosystems. Thus, an Eddy covariance system was established at Regional Agricultural Research Station, Maruteru, West Godavari to measure net CO_2/H_2O fluxes from flooded rice ecosystem. The eddy data and micro meteorological observations during *rabi* 2014 were analyzed to calculate half hourly fluxes using Eddypro software with dynamic metadata to accommodate changes in the crop height. Further, Net Ecosystem CO_2 Exchange (NEE) was gap filled and partitioned into Ecosystem respiration (RE) and Gross Primary Productivity (GPP) using R-eddyPro. Temperature-Greenness (TG) model was used to scale up the daily mean GPP of flooded rice field. It estimates GPP as a product of scaled Enhanced Vegetation Index (EVI) or canopy greenness and scaled Land Surface Temperature (LST) or environmental down-regulation. The TG model has advantages as it is entirely based on remote sensing observations and required no local meteorological parameters.

The NEE showed considerable diurnal and seasonal variation. The mean NEE varied from +4.33 to –12.58 μmol CO_2 m^{-2} s^{-1} , where, positive sign indicated net CO_2 emission into the atmosphere and negative sign denoted net CO_2 assimilation or uptake by the crop. The rice paddy ecosystem was behaving as a CO_2 source during night hours and a CO_2 sink during the day. Almost over the entire season, on daily basis, crop behaved as net CO_2 sink except few days during just after transplantation and few days in the maturity stage. The average NEE was positive in the Early Vegetative Stage (1-10 DAT) i.e. +0.671 gC m^{-2} day^{-1}, signifying the rice crop to be net carbon source. Then it gradually became negative or net carbon sink in the Late Vegetative Stage (11-20 DAT) i.e. -1.48 gC m^{-2} day^{-1}. Further, it declined in the tillering to panicle initiation stage (21-40 DAT) i.e. -5.89 gC m^{-2} day^{-1}. The reproductive stage (41-55 DAT) was found to have highest rate of CO2 influx i.e. -7.66 gC m^{-2} day^{-1}, whereas the heading to flowering stage (56-75 DAT) had influx of -5.35 gC m^{-2} day^{-1}, and Ripening (76 – 95 DAT) stage of -3.82 gC m^{-2} day^{-1}. During the harvesting stage (96-115 DAT) the rice crop acted as a carbon source with average NEE of 0.67 gC m^{-2} day^{-1}. Throughout the *rabi* season the net ecosystem CO_2 exchange was found to be -408.05 gC m^{-2}.

Total 39 cloud free MODIS EVI and LST images were obtained during the *rabi* season of 2014. Among these images 29 were used for model calibration and 10 were used for model validation. The product of scaled EVI –LST was derived and zonal mean of it were extracted over the fetch of the flux tower. The scaled EVI-LST product was linearly regressed with the respective daily mean GPP. Significant correlation ($p=0.05$) was obtained with $R^2= 0.74$ and slope (m) 2.97. The relationship was further utilized to map the daily mean GPP over the surrounding four districts i.e. West Godavari, East Godavari, Krishna and Guntur where similar kind of agricultural practices are followed for rice cultivation. The rice mask was used to identify the rice pixel. The T-G model based GPP was further validated with observed GPP and strong relationship was obtained with $R^2=0.79$ and SEE = 0.14 mol C m^{-2} d^{-1}. The study demonstrated the usefulness of TG model to upscale the GPP over tropical flooded rice ecosystem and also its capability to capture the spatio-temporal variations of GPP. Future study would be extended on the other crops (cotton and ground nut) towards quantifying their ecosystem exchanges.

[2-4]

CHANGES IN FLUX-DERIVED AND SATELLITE-DERIVED VEGETATION PHENOLOGY AND ITS EFFECTS ON ECOSYSTEM PRODUCTIVITY

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To accurately assess the change of phenology and its relationship with ecosystem productivity is one of the hot issues in global change research. In this study, we choose Haibei alpine frigid shrub (HBS) and Changbai Mountain temperate deciduous broad-leaved and coniferous mixed forest (CBM) as our research objects, and derive the phenological metrics including Start Of growth Season (SOS), End Of growth Season (EOS), and Growth Season Length (GSL) since 2003 via multiply methods, which based on the Eddy covariance data and the Normalized Difference Vegetation Index (NDVI). By combining the ground observation data of main species, we analyze the differences of phonological metrics between two kinds of data (GPP and NDVI), and multiple methods, then assess the impact of phenological change on ecosystem GPP.

[2-5]

EVALUATION OF MODIS-BASED VEGETATION INDICES AND FLUX TOWER DATA FOR ESTIMATING GROSS PRIMARY PRODUCTIVITY OF A MOIST DECIDUOUS SAL FOREST IN INDIA

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Eddy Covariance (EC) technique enables measurement of exchange of heat, mass and momentum on the desired time scale, from half-hourly to years. To find out the seasonal pattern of CO_2 exchange over the 30 m high canopy natural sal (*Shorea robusta*) forest, located in Barkot Forest Range of Dehradun in Uttarakhand, India, this study was conducted using EC technique for the post-monsoon (Dec-Feb) and pre-monsoon (Mar-May) seasons. The single unit IRGASON sensor was used for continuous measurement of carbon dioxide and water vapour exchanges over the forest. EC data was analysed at 8-day interval using *EddyPro* 5.1 (except for last four days of 2014). During post-monsoon season, the NEE varied with variation in PAR. During this period, the C intake rate by the forest was found to be >-2 g C/m^2/day except for the transition phase (Feb end and Mar), when NEE value was -1.877 g C/m^2/day. The post-monsoon mean C intake by the forest site was found to be -2.549 g C/m^2/day. During the study, gradual increase in vapour deficit pressure (VPD) was observed. VPD touched 16 kPa with start of pre-monsoon season, thereby indicating the onset of dry season and VPD remained above 16 kPa throughout the season. During this season, a decrease in the C intake was observed. The pre-monsoon NEE of the forest touched a low of -0.365 g C/m^2/day during mid-April. Decrease in carbon intake by the vegetation matched with the leaf fall period. Maximum leaf fall took place during mid-March to April. Day time ecosystem respiration (R_e) was computed using night time temperature function. In case of GPP, a reverse trend of NEE was found i.e. higher GPP during pre-monsoon than post-monsoon season, indicating more respiration by the ecosystem with increase in temperature. 1x1, 3x3 and 5x5 kernel MODIS vegetation indices (VIs) for the study area were compared with tower-based gross primary productivity (GPP). Best VI was identified based on R^2 for prediction of GPP for the Barkot and Rishikesh forest ranges on 8-day interval. Among the various indices, the 3x3 kernel wide range vegetation index (WDRVI) (R^2=0.64, $p<0.05$) and normalised difference vegetation index (NDVI) (R^2=0.63, $p<0.05$) were found promising to capture variability of GPP over space and time. Higher R^2 value of WDRVI agrees with the report by Gitelson *et al*. (2003), who found that for moderate to high leaf area index (LAI) (between 2 and 6), sensitivity of WDRVI was at least three times greater than that of the NDVI as study site LAI ranges between 2-4 throughout a year.

Keywords: EC, GPP, R_e, VI, VPD, WDRVI.

[2-6]

UPSCALING OF ECOSYSTEM LEVEL CARBON FLUXES FROM EDDY COVARIANCE FLUX TOWERS TO REGIONAL SCALE USING ENHANCED VEGETATION INDEX (EVI) BASED MODELS – CASE STUDY OVER CENTRAL INDIAN DECIDUOUS FORESTS

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Accurate estimation of carbon sequestered by vegetation in terms of gross primary productivity (GPP) at regional, national and global levels is important to understand feedbacks between terrestrial biosphere and the atmosphere in the context of global climate change. Eddy covariance flux towers provide continuous and accurate measurements of net ecosystem exchange (NEE) at different spatial and temporal scales which can be partitioned into GPP and ecosystem respiration (Re). The tower derived GPP numbers, though limited to the footprint, are accurate and are effectively used in different data-driven and data-assimilation modeling techniques that use remotely sensed satellite data as explanatory variables.

In the present study, we estimate regional level GPP using Temperature-Greenness (TG) model for teak mixed deciduous forests of central India for the years 2012 – 2014 using eddy flux data and Moderate Resolution Imaging Spectroradiometer (MODIS) based EVI (MOD13A2) and land surface temperature (LST – MOD11A2) data. The TG model estimates GPP as a product of scaled canopy greenness (EVI) and scaled temperature (LST) along with scalar m (with the unit of mol C m^{-2} day^{-1}).

Eddy covariance based carbon fluxes were measured at teak mixed deciduous forests of Betul in Madhya Pradesh, India, for the years 2012 – 2014. Continuous fast response measurements of mass (CO_2 & H_2O) and energy (sensible, latent and soil heat) fluxes along with slow response measurements of meteorological parameters were carried out at both the study sites using eddy flux towers during the study period. Flux data processing involved corrections to the raw flux data in terms of frequency response, air density (Webb-Pearman-Leuing), despiking of erroneous data and nighttime flux corrections (frictional velocity). Gap filling of data is achieved using Mean Diurnal Variation (MDV) and Marginal Data Sampling (MDS) methods. The corrected and gap filled data sets are subsequently analyzed for intra and inter-annual variability of CO_2 fluxes for estimation of NEE. The tower based NEE is further partitioned into temporal GPP and Re. In the present study, 16 day averages of tower based GPP were considered keeping in view, the 16-day composited of MODIS EVI and LST data sets.

Eddy flux based GPP estimates were analyzed as a function of scaled LST and scaled EVI derived from MODIS data (coefficient of determination, $R^2 = 0.81$) to generate spatial GPP estimates. Results suggested good agreement of tower based GPP with TG-model based GPP estimates during both leaf-on and leaf-off seasons in the study area. This study is however limited to the use of a sample of single eddy covariance station based GPP for validation. Installation of multiple eddy covariance flux stations within and across the forest types (or plant functional types) of the study area would add more value in validating satellite based regional GPP estimates. The scope of present study is further extended to estimate spatial GPP using other EVI-based models also viz., Greenness-Radiation (GR model), Vegetation-Index (VI) model and Vegetation Photosynthesis Model (VPM). Results are discussed.

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[2-7]

LAND SURFACE NET RADIATION FLUXES AND MODELLING OF CROP PHOTOSYNTHESIS USING INDIAN GEOSTATIONARY SATELLITE OBSERVATIONS AND FIELD MEASUREMENTS

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Land surface net radiation (R_n) is the driving force in the surface energy balance at the earth's surface and physiological processes in Soil-Plant-Atmosphere-Continuum (SPAC). Crop photosynthesis plays major role in carbon sequestration in agro-ecosystem. Climate projections are unable to provide realistic future scenario and trend of surface radiation regime as combination of shortwave and longwave at sub-regional scale and their impact on canopy photosynthesis. In India, rice crop occupies highest area with 40% contribution to India's agricultural production and 20% to total rice production in world. The present study was aimed (i) to estimate of daytime R_n at 8 km spatial resolution high temporal observations from Indian geostationary satellite K1 (Kalpana-1) sensor (VHRR) and *in situ* measurements on four-component net radiation from a network of INSAT-linked micrometeorological towers, known as Agro-Met Station (AMS), and (ii) to develop a function for canopy photosynthetic rates based on net radiation for transplanted rice from *in situ* measurements for upscaling with VHRR R_n estimates. Linear models of daytime net longwave radiation (R_{nld}) were developed for different seasons (summer, rainy, autumn and winter) based on net shortwave radiation (R_{nsd}) using AMS measurements. A two-stage upscaling of ground-measured albedo from AMS has been performed to derive K1VHRR land surface albedo (LSA). This combines multispectral reflectance at intermediate scales from the Advanced Wide Field Sensor on board Resourcesat-2 at Low Earth Orbiting (LEO) platform and the planetary (Earth-atmosphere-system) albedo from K1VHRR visible band at Geostationary Earth Orbiting (GEO) platform. The daily all-sky surface insolation product at 8 km spatial resolution from K1VHRR, LSA and linear functions for net longwave radiation were used to estimate daytime R_n. The monthly estimates of daytime R_n, R_{nsd}, R_{nld} from K1VHRR were compared with eight AMS station data in the independent years and with MERRA (Modern-Era Retrospective Analysis for Research and Applications) 2D (0.66° x 0.5°) global product on radiation fluxes. The R_{nsd} showed Root Mean Square Error (RMSE) ranging from 38 to 73 Wm^{-2} (11% to 22% of measured mean) with correlation coefficient (r) varying from 0.74 to 0.90 with respect to AMS while R_{nld} showed RMSE of 13 to 28 Wm^{-2} (17% to 36% of measured mean) with 'r' varying from 0.62 to 0.74. The daytime R_n estimates showed RMSE of 12% to 33% of measured mean (r = 0.70 to 0.93). The daytime monthly R_n from K1VHRR were resampled to MEERA 2D spatial resolution and were subsequently compared with the latter. This resulted into 9% to 38% RMSD between them. The diurnal canopy photosynthetic rate was measured by using portable photosynthesis system (LiCor : LI-6400, PSH-2919) at critical growth stages for *rabi* (January to April) transplanted rice in West Bengal at AMS location. The plot of R_n and canopy photosynthetic rate showed a significant (at $p \leq 0.05$) linear relationship (r = 0.79). This function was upscaled using K1VHRR R_n to estimate spatially distributed rice photosynthesis rate over West Bengal. It showed distinct spatial variation of rice photosynthetic rate within 8 to 16 μmol CO_2 m^{-2} s^{-1}. The combined use of such scaling functions and long-term (15-20 years) observations from current INSAT 3D and its follow-on series of 3D-R and 3D-S would help in characterizing net radiation fluxes and sub-regional scale rice photosynthesis and carbon sequestration pattern under changing radiation regime.

Key words: surface radiative flux, geostationary satellite, carbon sequestration

[2-8]

APPLICABILITY OF SATELLITE SOIL MOISTURE IN GENERATING AN ANALYSIS OF ENERGY AND MOISTURE FLUX: A DATA ASSIMILATION VIEW POINT OVER INDIA

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Soil moisture plays an important role in atmospheric phenomena by modulating the partitioning of insolation into sensible and latent heat flux. It also influences the influx of moisture into the atmosphere by regulating rate of evapotranspiration. These fluxes act as a major component of the interaction between land surface and atmosphere. Thus, it stands to reason that for an accurate estimation of atmospheric events one needs to have a good estimate of land surface fluxes. The flux estimates from the land surface models are shrouded in uncertainty because of the complex feedback mechanism between land and atmosphere. One of the ways to generate a good estimate of energy and moisture flux is by assimilating satellite retrieved soil moisture into a land surface model. This is achieved by using a data assimilation (DA) framework, which consists of three components: observation system, land surface model and the ensemble Kalman filter based data assimilation algorithm. The DA system essentially helps in minimizing the uncertainty in the soil moisture estimate, which in turn generates better flux estimates. The objective of this study is to check the applicability of two soil moisture products for use as the observation system in the DA framework. This is achieved by computing the uncertainty (uncertainty is represented as the variance of the random error or RMSE in the system) in both the observation systems. One of the observation systems is the SMOS level-3 soil moisture product and the other is ESA-CCI active-passive merged soil moisture. India has been selected as the study region as it was shown to be a hot spot for soil moisture interaction with precipitation. Triple colocation approach is used for computing RMSE, with respect to a reference data set, of the two soil moisture products. Preliminary analysis of the triple colocation RMSE estimates for ESA-CCI and SMOS soil moisture products show that ESA-CCI has lower uncertainty than SMOS, which suggest that ESA-CCI product is better suited for the DA system. RMSE values for SMOS are high especially in regions with high vegetation density. Fractional RMSE (fRMSE) is used to compare the spatial variability of uncertainty of the two soil moisture products, as fRMSE is independent of the variance of reference data set. fRMSE allows for more flexibility in comparing different error estimates and it is also representative of correlation between the true and measured signal.

[2-9]

INTEGRATION OF FOREST INVENTORY, EDDY COVARIANCE AND REMOTE SENSING DATA TO ASSESS IMPACTS OF DISTURBANCE ON CARBON UPTAKE IN A MANAGED EUCALYPTUS FOREST

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We used a combination of data from Forests NSW, eddy covariance , Landsat7 ETM+ imagery and modelling to estimate the variability of carbon uptake in the Bago-Maragle state forests. These native forests are managed and periodically undergo selective logging. Drought and pathogens/insects are further disturbances that have occurred within the last decade. The study area was divided into two major areas, one dominated by Eucalyptus darlympleana and E. delegatensis, the other dominated by E. pauciflora. Landsat imagery (2001 - 2014) has proven a unique data source for reconstructing forest disturbance history at a relatively high spatial resolution. We show that the drought events in 2003 and 2006 had a large impact on the biophysical properties of the forest which translated into a strongly reduced ability to sequester carbon. In 2003 the drought conditions led to an insect outbreak and eddy covariance data from the flux tower 'Tumbarumba' confirm that this disturbance turned the forest from being a strong sink of carbon to a source with the consequence that during a 9 month period, the forest lost carbon to the atmosphere. Ground based field measurements and satellite imagery show that species were affected differently. E. pauciflora was affected more strongly and the recovery was slower than the one observed in E. delegatensis dominated stands.

THE SOIL-PLANT-ATMOSPHERE CONTINUUM (SPAC), CONCEPT AND MEASUREMENTS

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Since its introduction in the 1960s, the SPAC is one of the most powerful paradigms in vegetation science, and remains the central concept of most models of water and gas exchange between vegetation and atmosphere. Around this concept it is possible to integrate the complex array of eco-physiological measurements, particularly in the field of plant water relations, in which the connection between the soil and the atmosphere is revealed. In this talk we ask: how easy has it been to measure the characteristics of the SPAC and how has our knowledge of ecosystem function, revealed in these measurements, been enhanced during the last 50 years by development of new instrumentation, by computer simulation, and by data mining. What are the remaining unknowns? Our journey over 50 years has taken us towards the development of networks of ecosystem observatories, supported by remote surveillance from space, and moved us closer to a deep understanding of the role of the land surface as part of the climate system.

[3-1]

COMPARISON OF RESPIRATIONS OF GRASSLAND AND WETLAND ON THE TIBETAN PLATEAU

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The Tibetan Plateau is the highest plateau in the world (average 4000m a.s.l.). Grassland occupies about 50% of the TP and acts as a carbon sink nowadays. It has a total alpine kobresia meadow area of 492,000 km^2 and wetland area of 64,000km^2, respectively. Although the alpine wetland is only one eighth of the alpine kobresia meadow, these alpine wetlands contain a large amount of soil organic carbon, which is estimated to compose about 0.2% of the global pool of soil carbon. It is suggested that a major climatic factor limiting production of the grassland and wetland ecosystem is the low thermo-conditions on the Tibetan Plateau. An increase in temperature may therefore increase the productivity of the ecosystem on the Plateau. It may also accelerate carbon releasing at the same time, especially when grassland degradation occurs. Therefore, understanding how environmental variables affect the processes of carbon fluxes variations in the alpine ecosystem on the Tibetan Plateau is extremely important. To address this issue, intensive field observations of energy balance and CO_2 flux has been introduced at an alpine kobresia meadow field at Haibei Alpine Meadow Ecosystem Research Station (37°37'N, 101°19'E, 3250m a.s.l.) since August 2001 and at a wetland field at Damxung (30°28'N, 91°04'E, 4280m a.s.l.) since June 2006 by a Japan–China cooperation project.

In this report, we focus on the ecosystem respiration of the two ecosystems by using recent 6 to 13 years data deduced from the eddy covariance (EC) observation data. Although the altitude of Damxung is about 1000m higher than Haibei, climate condition at Damxung was better (higher air temperature and almost the same precipitation for growing season) and the different ecosystem shows a very different respiration characteristics.

[3-2]

CO_2 EMISSIONS THROUGH OXIDATIVE PEAT DECOMPOSITION FROM THREE DIFFERENT TROPICAL PEAT ECOSYSTEMS

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Peat degradation occurs most rapidly and massively in Indonesia because of drainage, forest fire and deforestation of swamp forests. Indonesia's peat carbon pool has consequently become vulnerable and will potentially become a huge carbon source to the atmosphere. To know the function of tropical peatlands within global carbon cycles, it is crucial to determine net CO_2 exchange of peatland ecosystems with the atmosphere (NEE) resulting from the difference between vegetation photosynthesis, or gross primary production (GPP), and ecosystem respiration (RE) consisting of autotrophic and heterotrophic respirations. Nevertheless, the effects of peat degradation on the carbon balance of tropical peat ecosystems are not well understood; more field data must be accumulated.

The objectives of this study are to (1) assess CO_2 emissions through oxidative peat decomposition from the soil surface using field data of CO_2 efflux and (2) model a relationship between oxidative peat decomposition and ground water level (GWL). Furthermore, we measured variations of peat subsidence that could be partitioned into physical processes (compaction and shrinkage) and oxidative decomposition (determination of the contribution of oxidative decomposition to subsidence).

The study was conducted at three sites with different disturbance levels in Central Kalimantan, Indonesia: an almost undrained peat swamp forest (PSF) (UF), a drained PSF (DF) and a burnt drained ex-PSF (DB). The ex-PSF was burnt four times at least in 1997, 2002, 2009 and 2014, El Niño years. Soil CO_2 efflux was measured using the closed chamber method. The chamber was made of an opaque gray PVC cylinder (25 cm in diameter, 15 cm in height), in which a portable infrared gas analyzer (IRGA) (GMP343, VAISALA, Finland) and thermometer were installed. At each site, three trenched 1.0 x 1.0 m plots were established in September 2013 to exclude root respiration. Four PVC collars for the chamber were installed on the ground in each plot. During the measurement, the chamber was closed for 180 s. No fans were used to mix the air in the chamber. The measurement began in February 2014 and was conducted every month, except for November 2014 in DB and DF sites aftermath of forest fire. The measurement was repeated three times a day in the morning (10:00-10:40), noon (11:30-12:10) and afternoon (14:00-14:40). Soil CO_2 efflux was calculated from an increase in CO_2 concentration in the chamber headspace for the last 120 s of closing. CO_2 concentration was measured every 5 seconds, and its increasing rate was calculated by linear fitting using the least-square method. The gas analyzer was calibrated every 3 months using standard gases with two CO_2 concentrations.

GWL was monitored in the perforated PVC tubes at 30 minute intervals using a water pressure sensor (HTV-050KP, Sensez). Also, soil temperature at 5 cm in depth was measured hourly (Thermochron G type, KN laboratories). Variation of peat subsidence was measured monthly using an iron pipe installed in each plot, reaching to mineral soil.

This presentation shows seasonal variations of soil CO_2 emission through oxidative peat decomposition and environmental factors, based on the data collected over a year. According to the analysis of our data until Feb 2015, values of the CO_2 effluxes (mean ± 1 SD) were 1.43 ± 1.03, 1.21 ± 1.21 and 1.40 ± 1.16 mol m^{-2} s^{-1} in DF, DB and UF sites, respectively. The mean values were statistically indistinguishable from each other (Tukey's HSD, $p>0.05$). No diurnal variations of the CO_2 efflux were found.

[3-3]

RELATION BETWEEN SOIL CO_2 EFFLUX AND SOIL CO_2 CONCENTRATIONS

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Soil CO_2 emission is one of the important issues in the carbon cycles in the ecosystems. CO_2 emitted from soil bacteria, plant roots, and other organisms in soil, diffuses to soil surface driven by molecular diffusion and is released to the atmosphere. Vertical CO_2 concentration profile is principally determined by combination of vertical profiles of in-situ CO_2 emissions and soil gas diffusivity. Therefore, there is distinct linkage between soil CO_2 efflux (CO_2 emission from soil surface) and soil CO_2 concentrations.

In most studies, main target above-mentioned studies is to obtain soil CO_2 efflux because it means direct carbon loss from ecosystems. However, continuous monitoring of CO_2 efflux needs much efforts and tools, because soil CO_2 efflux is a variable by complex unit such as mmol m^{-2} day^{-1}. Monitoring of CO_2 concentrations is easier than soil CO_2 efflux because its unit (mmol m^{-3}) is essentially simpler than soil CO_2 efflux. So, monitoring of soil CO_2 concentration is one of the appropriate methods to temporally interpolate/extrapolate measured CO_2 efflux. Moreover, vertical CO_2 emission profile can be estimated from soil CO_2 concentration profiles with accurate estimates of vertical soil gas diffusivity profile.

We continued simultaneous measurements of CO_2 efflux and soil CO_2 concentrations in an arable field in the campus of NIAES (Yonemura et al., 2009) and in a cold-deciduous forest in Takayama-site (Yonemura et al., 2013; Kishimoto et al., 2015). Furthermore, we derived a methodology to estimate soil emission profile and soil gas diffusivity profile from known (Sakurai et al., 2015). The arable site and the forest showed distinct differences in the relation between soil CO_2 efflux and soil CO_2 concentrations. Results in other studies can be related to the two distinct types. We summarize relation between soil CO_2 efflux and soil CO_2 concentrations in this presentation and illustrates observational advantage of simultaneous measurements of soil CO_2 efflux and soil CO_2 concentrations.

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[3-4]

LONG-TERM WARMING EFFECT ON SOIL RESPIRATION IN WARM-TEMPERATE EVERGREEN BROAD-LEAVED FOREST IN KYUSHU

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Soil respiration is composed of heterotrophic respiration and plant root respiration, and is the second largest carbon flux in the terrestrial ecosystem. As the heterotrophic respiration increases exponentially with soil temperature, its positive feedback to the global warming has become a very important topic.

In the middle of December 2008, a multi-channel automated chamber measurement system was installed at the Miyazaki University Forests, which is a warm-temperate broad-leaved forest site in Kyushu. We prepared 10 trenched plots with 5 of them artificially warmed by +2.5ºC by infrared heaters 1.6 m above the soil surface for long-term measurement of warming effect on soil respiration.

The average soil respiration in the control and warmed plots were, respectively, 3.2 μmol CO_2 m^{-2} s^{-1} and 3.5 μmol CO_2 m^{-2} s^{-1} in 2009, 3.5 μmol CO_2 m^{-2} s^{-1} and 4.0 μmol CO_2 m^{-2} s^{-1} in 2010, 3.1 μmol CO_2 m^{-2} s^{-1} and 3.7 μmol CO_2 m^{-2} s^{-1} in 2011, 2.7 μmol CO_2 m^{-2} s^{-1} and 3.6 μmol CO_2 m^{-2} s^{-1} in 2012, 2.8 μmol CO_2 m^{-2} s^{-1} and 3.2 μmol CO_2 m^{-2} s^{-1} in 2013, 3.5 μmol CO_2 m^{-2} s^{-1} and 3.9 μmol CO_2 m^{-2} s^{-1} in 2014. On average, one degree warming increased heterotrophic respiration by 6.6% in 2009, 8.1% in 2010, 11.3% in 2011, 18.9% in 2012, and 7.6% in 2013, 8.9% in 2014. The warming effect showed an interannual variation, and the whole warming effect throughout the experimental period from 2009-2014 was 9.9%.

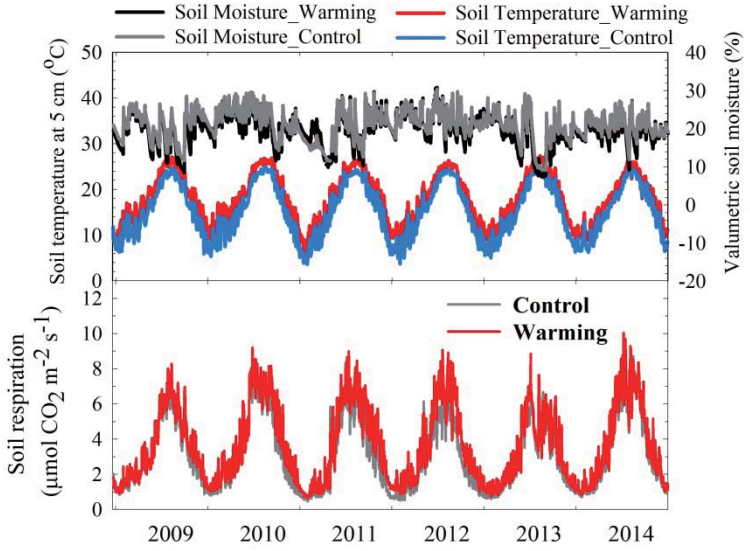

Fig1. Seasonal variations of soil temperature, soil moisture and CO_2 efflux from the end of 2008 to 2014.

[3-5]

IMPROVEMENT OF THE SOIL SUBMODEL OF THE PROCESS-BASED TERRESTRIAL ECOSYSTEM MODEL TO APPLY TROPICAL SWAMP FORESTS

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A conventional model (Vegetation Integrative Simulator for Trace Gases; VISIT) was applied to tropical peat forest data obtained from Palangkaraya (PDF) site in Kalimantan. The model cannot simulate carbon balance accurately because ecosystem respiration showed opposite seasonal variation with observed RE. The reason is that soil respiration process in the model lacks phenomena of tropical peat soil. Soil respiration process in conventional ecosystem model is controlled by only soil temperature and soil water content. In contrast, CO_2 release from peat is strongly regulated by water table. Soil respiration data obtained from chamber measurement in PDF site showed that the response of soil respiration to wetness is also different from that in conventional model. In order to improve the response of soil respiration, we modify soil submodel of the model. Ground water level is simulated by tank model. We modify soil respiration function using the relationship between ground water level and soil respiration.

[3-6]

SPATIAL PATTERN AND DECADAL VARIATION OF ATMOSPHERIC WET NITROGEN DEPOSITION IN CHINA

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Background and aims

Atmospheric nitrogen (N) deposition is an important component in the global N cycle, and understanding the spatio-temporal patterns and controlling factors of N deposition is useful to evaluate its ecological effect on terrestrial ecosystem and to provide scientific background for global change research. This study aimed at revealing the spatial pattern and decadal variation (1990–2010) of atmospheric N deposition in Chinese terrestrial ecosystems, and exploring its controlling factors.

Methods

In this study, we used two data sources to construct national-scale wet deposition maps (1990–2010) by Kriging interpolation. One data source was N deposition of approximate 300 sites which have been observed in China and openly published from 1990 to 2012. Another data source was measured N deposition of precipitation from 41 typical terrestrial ecosystems in 2013 by same analysing method.

Results

The results showed that atmospheric dissolved N deposition (DIN, including NH_4+–N and NO_3—N) in China increased apparently from 1990 to 2013, which increased from 11.11 kg N ha^{-1} a^{-1} in the 1990s to 13.87 kg N ha^{-1} a^{-1} in the 2000s. Atmospheric N deposition was highest over southern China and exhibited a decreasing gradient from southern to western and northern China. Atmospheric N wet deposition was theoretically comprised by dissolved N deposition (DIN) and non-dissolved N deposition (or particulate N deposition). Our results, derived from the data in 2013, total particulate N (TPN) accounted for 24% of total N while NH_4+–N and NO_3—N were 40% and 33% respectively, confirming that atmospheric wet N deposition was underestimated without including particulate N. Moreover, the decadal variation in atmospheric N deposition was primarily caused by increased in N fertilizer and energy consumption, and their effect could be well depicted by logarithmic equation.

Conclusions

Our findings conformed that atmospheric N deposition in China increased apparently since 1990, and anthropogenic activities were the main reasons for the increase in atmospheric N deposition.

Key words: nitrogen, dry deposition, wet deposition, spatial pattern, China

[3-7]

FUNCTION OF METHANOGENIC COMMUNITY IN MANGROVE SOILS AS INFLUENCED BY THE CHEMICAL PROPERTIES OF THE HYDROSPHERE

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The rate of carbon sequestration and the storage capacity in a coastal ecosystem is regarded as comparable to that in a terrestrial high carbon reservoir. Although the coastal ecosystem is potentially an additional source of greenhouse gas, methane (CH_4), this has been insufficiently quantified. Therefore, to understand the mechanisms that control CH_4 emissions in a coastal ecosystem, CH_4 emissions and related microbial properties were investigated in mangrove soils in this study.

Soil and gas samples were collected from several sites at different distances from the seashore in Soc Trang and Ca Mau, Vietnam and Sundarbans, India. Soil samples were incubated with various treatments such as anaerobic or aerobic incubation or the addition of different concentrations of seawater. The microbial properties of each soil sample were also analyzed.

Relatively high CH_4 fluxes and CH_4 production during aerobic incubation were detected at seashore sites in Soc Trang and Ca Mau. CH_4 production was reduced under anaerobic conditions compared to aerobic conditions. CH_4 production under anaerobic conditions increased with increasing cellulase activity, although the cellulase activity had a significant negative relationship with CH_4 production under aerobic conditions. Under anaerobic conditions, a mangrove soil with relatively high total organic C showed relatively high CH_4 production when 4-fold diluted seawater was added. Almost all of the excised DNA bands from polymerase chain reaction-denaturing gradient gel electrophoresis showed identical sequences related to archaea from the Class *Halobacteria*.

Therefore, the high potential of CH_4 emissions in the seashore site might have been derived from the alternate ebb and flow of the tide in the hydrosphere, which enhanced the cellulase activity by increasing the oxygen supply during the ebb period, which promoted the depolymerization of polysaccharides, and then enhanced anaerobic methanogenic activities during tidal flooding. The above results also indicated that the major archaea responsible for the CH_4 production requires a particular hydrospheric salt concentration.

[3-8]

INFLUENCE OF PHYSICAL PARAMETERS ON DISSOLVED ORGANIC CARBON (DOC) AND INORGANIC CARBON (DIC) IN THE SURFACE SEAWATER OF PORT BLAIR, ANDAMAN ISLANDS, INDIA

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Dissolved Organic Carbon (DOC) and Dissolved Inorganic Carbon (DIC) are the two important forms of the carbon available in the seawater. Generally, the carbon studies of ocean concern about below thermocline level because of the importance of refractory carbon in the carbon budget of ocean. Near surface waters studies have not been of great significance associated with its inconsistency and variability implicated upon it by a number of external factors such as temperature, wind, waves, tide, etc. However, the need of reality is highly essential for the oligotrophic waters as the surface waters play a major role to providing carbon to the coral reef environment. A study was mooted to understand surface to 15m depth waters carbon distribution, because this part of water has a major role to convert atmospheric carbon to seawater carbon.

Total three stations were fixed covering a distance of 5km which representing ship transist, fresh water input, mangroves and non mangrove environments. They were Chatham, North Bay and Carbyns Cove. The collection of waters covered surface, 5m, 10m and 15m. The parameters such as temperature, salinity and pH were studied insitu and in the laboratory DOC and DIC were estimated. The collection of water was carried out every month for a period of eight months starting from July (2014) to February (2015).

The surface temperature was comparatively higher than the 5m to 15m depth waters. Even though almost similar trend noticed, the temperature variation has its own way. It is also very interesting to note that October and November month exhibited higher temperature than July or February, which were close to the non rainy season. The salinity distribution clearly suggested the fresh water input from the terrestrial environment had its impact on the seawater salinity i.e., the fluctuation (4PSU) were more on the surface waters than the 5m to 15m depth (2PSU). In the present study, the surface waters of Chatham and Carbyns Cove region receiving fresh water input exhibited more fluctuation of salinity than North Bay which had almost negligible terrestrial input. The evaluation of pH stated that the regions with higher anthropogenic activities where more higher in pH than less disturbed region.

The dissolved Organic Carbon (DOC) and Inorganic Carbon (DIC) suggested that Chatham had comparatively higher concentrations than other two stations. However, it showed higher pH conditions might be due to comparatively higher temperature than other two stations. As per the physical law, as the temperature increases the retention capacity of CO_2 by the water reduces, thus liberating carbon dioxide from the seawater. So, where comparatively low temperature was noticed in other two stations provided higher retention of carbon and enhances the pH towards the lower end. Over and above, the rain water also may provide higher DIC through dissolution of CO_2 from the atmosphere. It was clearly supported by the month of November which exhibited higher DIC (171 - 393µM), when highest rainfall noticed during 2014 in Port Blair. Similarly, the DOC was lower during this period may be inferred that the environment undergo a kind of dormant stage with reference to biological activities.

MICROMETEOROLOGICAL MEASUREMENTS, MODELING, AND TRACE GAS EXCHANGES FROM ECOSYSTEMS IN GLOBAL NETWORKS: CHRONIC CHALLENGES AND PROMISING DEVELOPMENTS

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Eddy-covariance has been extensively used for decades, and is a fundamental technique employed in global networks designed to measure trace gas exchange from surfaces, such as evapotranspiration, carbon dioxide fluxes, and other greenhouse gas emissions including those of methane and nitrous oxide. Numerous other micrometeorological techniques also have been used, but frequently eddy-covariance has been favored. The limitations and challenges for some of these methods are presented and discussed. New methods of quality control, adjusting eddy-covariance data, and surface layer scaling are presented. The general challenges of network data quality reporting and usage are considered. Modelling is also presented, along with novel developments of connecting sophisticated land surface models to regional scale weather simulations.

[4-1]

BIOSPHERE-ATMOSPHERE EXCHANGE OF CO_2, H_2O AND ENERGY OVER A HIGH ALTITUDE FOREST AT EASTERN HIMALAYA, INDIA: PRELIMINARY RESULTS

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Bose Institute, a premier research organization under Ministry of Science and Technology, Govt of India has started monitoring CO_2, H_2O and energy fluxes over a high altitude Himalayan subalpine coniferous forest in eastern India as a part of the national network IndoFlux sponsored by Ministry of Earth Sciences. The observational site (27.04 ºN, 88.08 ºE) is situated at an altitude of 2286 m above mean sea level over eastern Himalaya in India. The forest vegetation is comprised mainly of Cryptomaria Japonica with the average height of 25 m. The site is in a highly complex terrain of Himalaya and situated in an absolute remote area with little anthropogenic activities. The eddy covariance fluxes and supporting measurements are carried out on a 50-m tall tower. Two closed path eddy covariance systems comprising of enclosed path gas analyzer (LI-7200,Licor, USA) and co-located 3D-sonic anemometer (Windmaster Pro, Gill Instruments, UK) have been installed both within (8 m) and above (38 m) the canopy. Half-hourly fluxes are calculated from the high resolution (10 Hz) data using EddyPro software (Licor, USA). Soil CO_2 flux at four locations around the tower and ambient CO_2 concentrations at eight levels on the tower are carried out using a four chamber soil-CO_2 flux system (LI-8100 A, Licor, USA). The observation has been started from March, 2015.

The present study reports the preliminary results of the forest-atmosphere exchange of CO_2 (FCO_2), H_2O (FH_2O) and Energy below and within canopy; the concentrations of CO_2 and its vertical profile and the soil-CO_2 fluxes over the forest site at eastern Himalaya in India. The diurnal variation shows high negative FCO_2 above the canopy during 1100-1300 hrs indicating high CO_2 absorption associated with photosynthesis. The average day-time CO_2 flux above the canopy was around -10 μmol m^{-2} s^{-1} and much higher than that within canopy (~0.4 μmol m^{-2} s^{-1}). CO_2 flux within canopy showed negative values only during 0900-1400 hrs associated to photosynthesis which was dominated by CO_2 emissions associated to the respiration by under-storey vegetation. FH_2O above the canopy showed ~3-4 times higher emission flux than within the canopy. The mean fluxes of sensible heat and latent heat above the canopy were ~ 68 and 77 watt m^{-2} respectively with the Bowen ratio of ~0.9 indicating a temperate coniferous forest. We observed emission flux of CO_2 ranging between 1.32 and 1.98 μmol m^{-2} s^{-1} from the forest floor with the maximum emission during day-time which could be associated to soil respiration and photo-degradation/decomposition of soil organic matter. The mean CO_2 concentration above and below canopy were almost equal (~390 ppmv) with minimum during day-time. The vertical profile shows higher CO_2 accumulation near ground at night which started decreasing during day-time till ~20 m and then increased gradually. Overall we observed that CO_2 sequestered by the forest was around 8-10 times higher than CO_2 liberated from the forest per unit area per day.

[4-2]

EVALUATION OF ENERGY BALANCE COMPONENTS DURING TRANSITION PHASES OF MONSOON OVER CROPLAND AND FOREST ECOSYSTEM

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The Southwest Monsoon System over subtropical India shows pronounced variation in rainfall and biological activity from dry (May-June) to wet period (July – September) and alter energy and water vapour exchanges and vice-versa. Understanding energy partitioning over terrestrial ecosystems during various phases of monsoon cycle holds key in parameterization of land-atmospheric processes of weather/climate forecast models. Eddy covariance measurements of CO_2 and H_2O were made at 10 Hz over cropland (Meerut) and mixed planation (Haldwani) sites and processed by EC method to obtain half-hourly fluxes. The missing data for the wet season were gap filled using the mean diurnal variation method. Fluxes of latent heat (LE, Wm^{-2}) and sensible heat (H, Wm^{-2}) and associated micrometeorological variables (net radiation, soil moisture, albedo) were derived and subsequently studied to understand variation in energy and water vapour fluxes for various transition phases of monsoon.

We also examine the subtle changes that occur in the components of surface energy balance between the break and the active phase over both cropland and forest plantation. The break phases have however not shown different energy balance components than that of the pre-onset phase. Bowen ratio has been found to be highly responsive to wetting events.

Cropland site : Sensible heat flux changes from 80 w m^{-2} to merely 10 w m^{-2} just after onset. Latent heat flux increased from 10 w m^{-2} to > 100 w m^{-2} after onset. Clear transition in Bowen ratio from pre-onset to onset and subsequent break spells. Bowen ratio remains above 1.0 during pre-onset and break periods, but decline rapidly to near zero during active phase.

Forest plantation site : Sensible heat flux is more dominant during pre-onset and break period. Somewhat equilibrium occurred during revival and clear transition from thermal to moist convection during active monsoon phase. Bowen ratio tend to be above 1.0 during pre-monsoon and break period. Decline rapidly after revival and became much lesser than 0.5.

[4-3]

CO_2 AND H_2O FLUXES DURING WET AND DRY PERIODS AND ASSOCIATED BOUNDARY LAYER ASPECTS

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Observations from the Cloud-Aerosol Interaction and Precipitation Enhancement Experiment – Integrated Ground Observation Campaign (CAIPEEX-IGOC) is used to illustrate the surface fluxes during the monsoon period over peninsular Indian region. The CAIPEEX-IGOC was aimed at better understanding of physics, dynamics and thermodynamics of atmosphere over peninsular India. This experiment has collocated ground as well as aircraft observational campaigns which make the gathered data quite comprehensive and the experiment one of its first kind in India. For present study, data from CAIPEEX-IGOC 2011 have been used which was held at Mahbubnagar (78^o 45' E, 17^o 4' N), Andhra Pradesh, India.

There are two-fold objectives of the present study.

1. To look at the diurnal variations of CO_2 and H_2O exchange processes over Indian peninsula during summer monsoon.
2. To investigate the role of clouds and convection on the aforementioned flux exchange processes in the dry and wet regimes.

For this purpose vertical kinematic fluxes of CO_2 and H_2O have been calculated using Eddy Covariance (EC) data sampled at 10 Hz by sensors installed at 6 m height on a 20 m tall micrometeorological tower deployed at the measurement site. Vertical wind (w in m s^{-1}) has been measured by 3D sonic anemometer-thermometer (Wind Master Pro, Gill Instruments, UK) whereas CO_2 (μ mole m^{-3}) and H_2O (gm kg^{-1}) concentrations have been measured by Infra-Red gas analyzers (IRGA model: LI-7500A Open Path CO_2/H_2O Analyzer, Licor Inc.). Time-average of column integrated LWP (Liquid water Path) for entire measurement duration measured by microwave radiometer (Radiometrics Corporation, USA) every 2 min has been used as a simple index for cloudy and non-cloudy conditions. Enhanced negative and positive values are reported in CO_2 and H_2O fluxes respectively during day time (06:00 IST to 18:00 IST). Peaks are observed around 12:00 IST in both of these fluxes. However, near-zero fluxes are observed during night time (18:00 IST to 06:00 IST). Interestingly no significant difference is found between 'wet' and 'dry' periods in terms of fluxes.

[4-4]

VARIABILITY OF MEASURED CO_2 AND WATER VAPOUR FLUXES AT RURAL SITE IN SOUTH INDIA

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The water vapour and carbon dioxide are important greenhouse gases responsible for warming of global atmosphere. These gases show variability at different scale due to modulations in net radiation, land-surface processes, anthropogenic emissions, seasonal and global circulation. Gadanki is a rural site in south India which is surrounded by agricultural and mountain forest region. Agriculture practices and forest cover influences concentration of these greenhouse gases on diurnal, sub-seasonal and seasonal scale. Also this site receives rainfall in both southwest and northeast monsoon season. Therefore this adds more complexity in the variability of greenhouse gases. In this work, we have investigated the diurnal, sub-seasonal and seasonal variability of CO_2 and water vapour at surface (10m) and the causes of these variation with respect to net radiation, amount of rainfall, changes in PBL height, agricultural practices and biomass burning. Our result shows that daily mean CO_2 concentration ranges between 360 to 410 ppmv which peaks in morning hours. We also observe that these greenhouse gases have prominent diurnal variations distinct in different seasons. The biomass burning during different seasons cause changes in CO_2 concentration. Rainfall and consequent changes in vegetation cover increase night time photosynthesis respiration which in turn increase the amount of CO_2 over this region. The detailed results will be presented in the conference.

[4-5]

CARBON AND ENERGY FLUXES OVER A RAINFED AGRICULTURAL ECOSYSTEM IN SEMI-ARID INDO-GANGETIC PLAINS

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India ranks first among the rainfed agricultural countries with nearly 60 % (approximately 86 M ha) of the total agro ecosystems falling in the rainfed category. These rainfed regions have limited access to irrigation, and soil and rain water conservation measures have high significance in improving the crop productivity. In changing climate scenario, improving the carbon sequestration potential of rainfed ecosystems are also of high significance. With sustainable land and crop management practices, soil and ecosystem carbon pools can be enhanced by increasing the residence time of carbon. Continuous measurement of carbon fluxes in rainfed agricultural ecosystems needs to be carried out to accurately evaluate the carbon sequestration potential and to better explain carbon cycle processes of such ecosystems.

Eddy covariance surface flux measurements have been carried out over a rainfed agro-ecosystem located over a semi-arid zone in Indo-Gangetic plains, near Varanasi, India. The 20-m flux tower is installed at the Southern Campus of Banarus Hindu University (BHU) at Barkacha, as part of the Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX). The tower is located over a fairly flat agricultural field growing sesame oil seed crop during southwest monsoon season. Two eddy covariance systems, consisting of Infrared gas analyzers (LI-7500A and LI 7200, Licor, USA), 3-D sonic anemometer-thermometers (Windmaster Pro, Gill instruments, UK) are installed on the tower at two heights, 5 m and 17 m. Soil heat flux, net radiation, soil moisture and soil temperature, along with other meteorological parameters are also measured on the tower. The measurement period include very dry and hot pre-monsoon conditions (May) with almost no vegetation, naturally grown grass after the first few rains in June and then the growing season of Sesame crop (July-September). CO_2, water vapour and energy fluxes are analyzed in relation to different crop growth stages and under different environmental conditions to understand the sensitivity of surface fluxes to different controlling factors. During peak crop growing periods, large daytime CO_2 fluxes up to -20 μ mol m^{-2} s^{-1} and relatively small nighttime fluxes close to 5 μ mol m^{-2} s^{-1} are observed at the site. In addition to the net ecosystem exchange estimate during the crop season, response of the fluxes to rain events, rainfall variability, air and soil temperature variations are also investigated.

CLIMATE-SMART AGRICULTURE'S TRIPLE CHALLENGE FOR A COMPLEX PADDY SOIL-RICE SYSTEM

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Climate-Smart Agriculture (CSA) aims to help the world achieve triple wins to prevent hunger through sustainably increasing agricultural productivity, reducing greenhouse gas emission, and building resilience to climate change. Rice is a leading food crop in the world along with wheat and maize; together they supply >50% of calories consumed by the world population. In the future, rice production must grow faster than the population. However, rice cultivation is also the largest source of human-related methane emissions which are expected to increase with a rising demand for food. In order to monitor changes, identify the triple wins, and compare the benefits with the associated costs, it is critical to develop indicators to evaluate progress and the required data to establish such indicators.

In this study, we assumed that paddy soil-rice system is a self-organizing hierarchical open system. Then, we developed indicators based on the framework of ecosystem structure and function. We focused on assessing the biotic, network and thermodynamic indicators derived from a decade-long field measurements of energy, matter and information flows in a typical paddy soil-rice system in Monsoon Asia. Biotic indicators were derived from many traditional measures, which include net ecosystem exchange (*NEE*) of carbon, gross primary productivity (*GPP*), ecosystem respiration (*RE*), crop coefficient (K_c), and water use efficiency (*WUE*). Network indicator was assessed using information flow dynamic process network analysis. Thermodynamic indicators used in this study are based on entropy balance ($^{dS}/_{dt}$) as well as indicators for self-organization such as energy capture (R_n/R_{snet}) and dissipation ability (i.e., thermal response number, *TRN*).

Our results show that the dynamic process network analysis delineated several subsystems in paddy soil-rice system, which were assembled (or disassembled) through the coupling (or decoupling) of feedback loops to form (or deform) newly aggregated subsystems – an evidence for self-organizing processes of a complex system. We demonstrate that the integration of the above-mentioned indicators provides better holistic representation of the system state. We note that more carbon uptake and better water use by the paddy soil-rice system may occur at the expense of more accumulation of entropy, i.e. an indication of system degradation. The analysis of long-term tower-based flux data helps identify whether one can achieve the CSA's triple wins (i.e., more production, more carbon uptake, and better resilience).

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FLUX TRANSFER PROCESSES OVER CROP FIELD TOWARDS AGRICULTURAL SUSTAINABILITY UNDER CLIMATE CHANGE SCENARIO

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The land surface processes over crop field are connected with the atmosphere through exchange of heat, momentum and moisture. These exchange processes have a great role in tuning the weather and climate. The interaction between crop surface and atmosphere are parameterized and depicted as radiative transfer (albedo), momentum transfer (roughness length) and the surface hydrology (sensible and latent heat transfer). All are independent and separable entities and governed by vegetation, soil and land use pattern. Hence the study of the flux related processes in turn can provide the ideas on crop growth status, crop vigor, actual evaporation from crop field and in many others. Under the changing climatic scenario, the sustainability issues of agriculture must be addressed. To foster the sustainability, there is a need of monitoring crop growth and water use pattern. For a large area this is possible only through estimation of energy balance over crop field. The process of estimation of the balance and crop growth monitoring will be discussed in detail in the full paper in view of climate change and sustainable issues.

[5-1]

WATER, CARBON, AND METHANE FLUX ANALYSES OF CROP AND SOIL WATER GRADIENTS: A SYNTHESIS OF THREE PICARRO CRDS STUDIES

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Picarro Cavity Ring-Down Spectroscopy (CRDS) systems are continuous high-frequency analyzers with exemplary performance characteristics. Here we present three studies demonstrating the capacity of the Picarro G2311 high-frequency flux system to characterize carbon, water and methane fluxes across contrasting environmental conditions, and to demonstrate the power of Picarro analyzers when applied to ecosystem scaling studies.

In a comparative study lead by the AmeriFlux QA/QC Tech Team from Lawrence Berkeley National Lab, U.S.A., five high-frequency eddy-covariance systems, including the Picarro G2311 flux system, were assessed within an alfalfa crop ecosystem near Davis, California, U.S.A. Results of experiments demonstrate the response of the flux system under variable irrigation condition and crop stage, and highlight the sensitivity in response of the Picarro G2311 under high and low carbon and water fluxes.

In a second study, the Picarro G2311 analyzer was applied to an assessment of methane fluxes of crop systems within the densely agriculture-allocated Willamette Valley in OR, U.S.A. Eddy-covariance derived methane fluxes were related to crop growth/harvest stage, LAI, soil moisture, as well as historic land use, since much of the crop lands in the Willamette Valley were established on historically wetland regions. At the relatively dry "Silverton" site, methane fluxes were predominantly negative, though periodic positive methane fluxes reduce the sink strength of the crop soil ecosystems. Comparisons to methane fluxes of crop ecosystems established in wetlands are assessed, and tall tower assimilations are used to consider the total crop ecosystem influence on whole valley methane budget.

In a third study, airborne eddy covariance measurements were conducted using a Picarro G2301-m analyzer by Purdue University at Harvard Forest, MA, U.S.A. To understand the driver-response relationship between soil moisture and carbon dioxide uptake by spatially inhomogeneous forest, carbon dioxide flux estimates are compared with NASA AirMOSS root zone soil moisture (RZSM) measurements.

The Picarro flux system is an important tool for deciphering the controls between soil moisture and carbon flux.

Understanding regional climate and management feedbacks to the carbon cycle is critical to resolving the primary uncertainties in the global carbon budget.

[5-2]

ESTIMATION OF EVAPOTRANSPIRATION USING EDDY COVARIANCE TECHNIQUE IN DRY DIPTEROCARP FOREST, UNIVERSITY OF PHAYAO THAILAND

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Evapotranspiration (ET) from forested watershed ecosystem plays an important role in the hydrological cycle and strongly influences the water balance such as in dry dipterocarp forest in northern part of Thailand, which is changing rapidly in the past decade. This study present the eddy covariance measurement result of evapotranspiration budgets covering one year data (2014) in Dry Dipterocarp Forest Flux Phayao Site Thailand (DPT), which is located in the University of Phayao (UP) in northern part of Thailand (coordinates: Latitude: 19º 02' 14.38" N, Longitude: 99º 54' 10.96" E at 512 m asl). The climate condition was tropical monsoon (means precipitation 1262 mm; 1998-2007) and slope terrain. The objectives of our study were: (1) to estimate daily and monthly patterns of ET in dry dipterocarp forest, (2) to investigate environmental control of ET. This is one of aspects that could help us to improve our understanding of water balance in dry dipterocarp forested watershed ecosystem. The results show that the daily patterns of ET was similar to normal distribution curve showing highest ET at noon approximately 58%,the rest was at evening 27% and in the morning 18% respectively. The average of ET was 4.55 (±1.85) mm day^{-1}. The highest ET was occurred in October (5.63 ±3.71 mm day^{-1}) relate with the wet-dry transition period, while minimum ET (2.04±0.94 mm day^{-1}) was found in March due to drought period. In addition, the enviromental control of daily ET were the net radiation, rest was soil temperature and air temperature respectively. While soil water content, rainfall and albedo were related in monthly patterns.

Keywords: Evapotranspiration, Eddy covariance technique, Dry dipterocarp forest
Acknowledgments: This research was supported by ThaiFlux network, and SEEN, UP, Thailand

[5-3]

CONTINUOUS CH_4 FLUX MEASUREMENT OF A DOUBLE-CROP PADDY FIELD IN BANGLADESH

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Since Bangladesh is the 6th highest rice producing country in the world (FAO, 2012), it plays a critical role in global CH_4 emissions from paddy fields. Indeed, Yan *et al.* (2009) reported that Bangladesh was the 3rd largest CH_4 emitting country with respect to rice-originating CH_4 emissions. However, because the value of Yan *et al.* (2009)'s study was based on inventory data, rather than in situ flux measurement, it lacked certainty. As far as we are aware, very few papers have reported CH_4 flux from paddy fields in Bangladesh using discrete sampling methods, i.e. the chamber method (e.g., Frei *et al.*, 2007; Ali *et al.*, 2012), and no papers reported it using a continuous measurement method, i.e. the eddy covariance method. We therefore started the first continuous CH_4 flux measurement using the eddy covariance method of a paddy field in Bangladesh, and are able to show whole-year CH_4 flux data and its budget in this study.

The study was conducted at the paddy field of Bangladesh Agricultural University at Mymensingh, Bangladesh (24º 43' 31.0" N, 90º 25' 27.3" E, 18 m a.s.l.). At the study field, rice is cultivated two times per year; the first crop is known as boro (post-monsoon rice) and is grown from January to May, and the second is called aman (monsoon rice) and is cultivated from August to December. An open-path CH_4 gas analyzer (Li-Cor, LI-7700) was installed with the ongoing eddy covariance system, which consisted of a sonic anemometer (Gill, R3) and a CO_2/H_2O gas analyzer (Li-Cor, LI-7500) on August, 2013. The data from the sonic anemometer and gas analyzers were collected by the LI-7550 (Li-Cor) at 10 Hz intervals. 30-minute average CH_4 fluxes were calculated using EddyPro software (ver. 5.2.0), applying the general methodology of corrections. For quality control, the policy of Mauder and Foken (2004) was selected, and the resultant missing data was completed using the mean diurnal variation method (Falge *et al.*, 2001). The data analyzed here was collected between August 11, 2013 and August 10, 2014.

Continuous CH_4 flux measurement revealed distinct seasonal variation (Fig. 1). The highest rate of CH_4 emission; about 0.6 to 0.8 g C m^{-2} d^{-1}, occurred during late summer fallow and early aman rice periods. A near continuous submerged ground with thick weed growth due to the summer rainy season could have led to preferable conditions for methanogenic bacteria that generate CH_4. As for the aman rice season, CH_4 flux decreased from the highest value to zero, likely reflecting air/soil temperature decrease from the summer to the winter season. Regarding the boro rice season, CH_4 fluxes were lower than those for the aman rice. These low CH_4 fluxes were probably caused by removal of rice straw after the harvest of aman rice, which decreases carbon supply for methanogenic bacteria, and intermittent submerged ground due to water management activity during the winter-spring dry season. The CH_4 budgets for the aman and the boro rice season are 25 and 5 g C m^{-2}, and for the winter and summer fallow season are 0 and 16 g C m^{-2}. Thus, the annual CH_4 budget is 45 g C m^{-2}, which is comparative to the upper values in a range of reported CH_4 budgets in Asia.

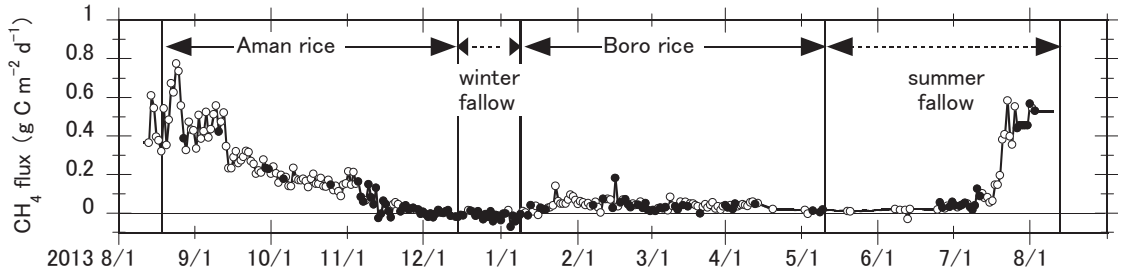

Fig. 1. Daily integrated CH_4 flux during the study period. Closed symbols represent that the missing data in a day amounts to more than half.

[5-4]

SURFACE ENERGY FLUXES ESTIMATION IN WHEAT (*Triticum aestivum* L.) USING BOWEN RATIO ENERGY BALANCE METHOD IN IRRIGATED CENTRAL PUNJAB, INDIA

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Proper water management is the need of the hour as water is scarce and seriously over exploited. For maximizing agricultural production proper irrigation scheduling and precise knowledge of crop water use under field conditions is required. Reliable estimation of surface sensible and latent heat flux is the most important process to appraise energy and mass (including water) exchanges among atmosphere, hydrosphere and biosphere. Bowen ratio-energy balance (BREB) method is one of the methods to estimate water use, calculate crop coefficients, investigate plant-water relations and evaluate crop water use models following that principle.Components of the surface fluxes of the energy balance equation were determined by using Bowen ratio energy balance (BREB), a gradient method that uses vertical gradients of temperature and vapour pressure in combination with point measurements of net radiation and soil heat flux. The BREB method estimates latent heat flux from a surface using measurement of air temperature and humidity gradients, net radiation, and soil heat flux. It is an indirect method, compared to methods such as eddy covariance and weighing lysimeters, which directly measure turbulent fluxes, and mass change of inside tank with growing plants, respectively. The BREB method has some advantages and disadvantages compared to other methods. Its advantages are simple automated measurements integrating latent heat fluxes over large areas continuously with unattended instruments, on fine time scales and not requiring information about the aerodynamic characteristics of the surface. The air temperature and vapour pressure gradients between two fixed heights within 2 m of the surface were measured to compute Bowen ratio.

In this study the surface energy fluxes were measured over irrigated wheat during winter (dry) season at Naraingarh seed farm, Punjab. Wheat crop (cv. PBW 343) was sown on first fortnight of November, during both the seasons 2010-11 and 2011-12. Study revealed that the net radiation flux (Rn) varied from 450 to 710 W m^{-2} during 2010-11 and 353 to 836 W m^{-2} during 2011-12 in different growth stages. The soil heat flux was higher during initial and senescence growth stages (12 to 14 % of net radiations) as compared to peak crop growth stages (7to 10 % of net radiations). The latent heat flux showed apparent correspondence with the growth which varied from 233 to 378 Wm^{-2} during 2010-11 and 221 to 576 Wm^{-2} during 2011-12 in different growth stages. The intercepted photosynthetically active radiations (IPAR) by the crop were also measured and maximum interception of 85.6 and 93.2 per cent was observed at 88 DAS during 2010-11 and 2010-12, respectively. Study also revealed that LAI was positively related with intercepted photosynthetically active radiation (IPAR). During the peak growth period, the soil heat flux (G) and Bowen ratio got reduced and the value of latent heat flux (LE) increased due to coincidence of maximum leaf area index (LAI) in that period.

EFFECTS OF LARGE-SCALE LAND USE CHANGE ON LOCAL AIR QUALITY IN SABAH, MALAYSIA

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One of the most widespread tropical crops is oil palm (*Elaeis guineensis*): global production now exceeds 35 Mt y^{-1}. Malaysia is the second largest producer of oil palm, producing 40% of global production, with about 13% of land area now occupied by oil palm plantations, compared with just 1% in 1974. There are enormous pressures to increase palm oil production, for food, domestic products and, especially, biofuels. Expansion of oil palm for biofuel production is predicated on the assumption that palm oil is an "environmentally friendly" fuel feedstock. However, our measurements show that oil palm plantations in Malaysia directly emit greater quantities of the oxides of nitrogen and volatile organic compounds than the rainforest they are replacing. These compounds lead to the production of ground-level ozone (O_3), an air pollutant that damages human health, plants and materials, reduces crop productivity and has effects on the Earth's climate. Our measurements also show that, at present, O_3 concentrations do not significantly differ over rainforest and adjacent oil palm plantation landscapes. However, our model calculations predict that if NO_x concentrations in Borneo are allowed to reach those currently seen over rural North America and Europe, ground-level O_3 concentrations will reach 100 ppbv and exceed levels known to be harmful to human health. Our study provides an early warning of the urgent need to develop policies that manage nitrogen emissions if the detrimental effects of palm oil production on air quality are to be avoided.

[6-1]

LABORATORY AND FIELD MEASUREMENTS OF OXYGENATED VOC UPTAKE BY PLANTS

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Volatile organic compounds (VOCs) are emitted from anthropogenic and biogenic sources. VOCs are involved in production of photochemical oxidants and secondary organic aerosols (SOA). Photochemical oxidants negatively affect human health and plant growth. SOA influences physicochemical properties of atmospheric aerosols, such as particle hygroscopicity and cloud condensation nuclei (CCN) activity.

We revealed that plant can absorb some oxygenated VOC (OVOC) species including methacrolein (MACR) and methyl vinyl ketone (MVK) (Tani et al., *Environ. Sci. Technol*., 2009, Tani et al., *Environ. Sci. Technol*., 2010). We suggest that forest vegetation is an important and significant sink of OVOC. However, so far only few studies have been conducted to qualify and quantify plant VOC uptake ability.

In the present study, we measured plant uptake of low-molecular weight of alcohols by plants in laboratory. Field measurement was also conducted to measure VOC exchange between a rice paddy field and atmosphere using a relaxed eddy accumulation method. The measurement was conducted in Mase research site maintained by NIAES, Japan. We used an automatic gas sampling device developed in our laboratory (Mochizuki et al., *Atmos. Environ.*, 2014).

Laboratory experiments revealed that plants can absorb many OVOC species including ketones, aldehydes and alcohols. Field measurement results will also be shown in our presentation.

[6-2]

QUANTIFICATION OF SOIL VOC FLUXES IN RELATION TO GREENHOUSE GAS FLUXES ACROSS A GRADIENT OF TROPICAL LAND-USE INTENSITY IN MALAYSIAN BORNEO

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Tropical forests support over two-thirds of the world's terrestrial biodiversity. However, between 35% and 50% of all closed-canopy tropical forests have already been degraded, and the rates of deforestation continue to rise. Increasingly, secondary forests, plantation mosaics and other human-modified habitats will dominate tropical landscapes leading to concerns that these anthropogenic alterations will elevate greenhouse gas (GHG) and other trace gas emissions such as volatile organic compounds (VOCs). Knowledge of GHG fluxes is skewed towards agricultural N_2O emissions after N fertilisation events in temperate regions, wetland CH_4 fluxes and temperate forest CO_2 fluxes and little is known about VOC fluxes from soil and litter in tropical forests and their speciation or about the links between GHG and VOC fluxes. VOC emissions are important as they directly and indirectly influence the concentrations and lifetimes of air pollutants and GHGs. For example, oxidation of VOCs generate tropospheric ozone which is a potent GHG. Within ecosystems, monoterpenes can mediate plant-microbe and plant- interactions and protect photosynthesis during abiotic stress. However, little is known about monoterpene composition in the tropics - a widely recognized major global source of terpenoids to the atmosphere. These knowledge gaps make it difficult for developing countries in the tropics, especially South East Asia, to develop effective mitigation strategies.

In this project, we are measuring GHG and VOC fluxes from the mineral soil and organic horizons at habitat types ranging from intact logged forest to mature oil palm in Malaysian Borneo (Sabah) within the Stability of Altered Forest Ecosystem (SAFE) project as part of the Human Modified Tropical Forests (HMTF) program. We are assessing the impact of logging and oil palm plantation on VOC and GHG fluxes. Flux measurements started in January 2015 and will be carried out every 2 months for 2 years in selected plots across the gradient. Additionally, other environmental parameters such as soil moisture, temperature, pH as well as vegetation and litter composition will be measured at the same time. GHGs are measured from static chambers and sampled into glass vials, analysed by GC-FID/ECD and VOC fluxes are measured from dynamic static chambers with air circulating and sampled onto adsorbent tubes (Tenax/Carbotrap) by 12V pumps and analysis by GC-MS-ATD for monoterpenes such as toluene, α-pinene, β-pinene, 3-carenene, α-phellandrene and limonene. Here we will present initial preliminary results showing higher VOC fluxes from tropical forest than younger oil palm but also higher VOC fluxes from mature oilpalm. Fertiliser induced N_2O fluxes were highest from mature oil palm. Gas fluxes will be co-analysed with other measured parameters to assess potential drivers of fluxes which will then allow to estimate changes in fluxes with continued land-use and other environmental or climatic changes.

[6-3]

OBSERVATION OF O_3 FLUX WITH THE GRADIENT METHOD IN RED PINE FOREST

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The emission and absorption of trace gases at the biosphere affects to atmospheric chemistry, and thus it makes influence with potential indirect effects on carbon cycle and climate (Ollinger *et al.*, 2002). We constructed and tested O_3 and NO_x flux measurement system with the gradient method at a meteorological tower in red pine forest (Site Code: FJY) in the autumn of 2014. We also measured CO_2 flux at the same meteorological tower for validation of the system by comparison with CO_2 flux determined by the eddy covariance method.

The heights of the forest canopy and the meteorological tower were 25 m and 32 m. Concentrations of O_3, NO_x and CO_2 were measured at two heights (26 m and 32 m) above the canopy by an ultraviolet absorption O_3 analyzer (Thermo: 49C), a chemiluminescence NO_x analyzer (Thermo: 42iTL) and an infrared absorption CO_2 analyzer (Licor: LI-820). The O_3 instrument was calibrated before the observation, and the NO_x and the CO_2 instruments were calibrated every three weeks at the observation site. The air was sampled every 300 seconds from each two vertical heights and supplied to the analytical instruments through PFA tube. Concentration of CO_2 was also measured by an infrared absorption CO_2 analyzer (Licor: LI-7500) at 26.5 m to determine CO_2 fluxes by the eddy covariance method. Wind speed and wind direction were measured at 26.5 m and they were used to obtain fluxes by the gradient and eddy covariance methods.

The CO_2 fluxes in the day time (9:00-16:00) in the autumn of 2014 were observed with the gradient and the eddy covariance method as -9.0±7.3 μmol m^{-2} s^{-1} and -8.6±6.5 μmol m^{-2} s^{-1}, respectively. The CO_2 flux obtained by the gradient method was slightly lower and more scattered than CO_2 flux obtained by the eddy covariance method; however these values reasonably agreed. We made sure the flux observation system with gradient method worked properly.

The observed O_3 concentrations at the two heights differed significantly; however the observed NO_x concentrations at the two heights were similar and there were no significant differences, which indicated that it was difficult to obtain NOx fluxes with gradient method in the red pine forest. Hourly averaged O_3 fluxes from 9:00 to 16:00 are shown in Fig 1. The data point at 9:00 shows one hour averaged data from 9:00 to 9:59. The primary result indicated that O_3 deposition in the red pine forest in the day time (9:00-16:00) was -5.7±5.9 nmol m^{-2} s^{-1}. Literature values of O_3 flux in the day time in autumn at a deciduous forest (Gerosa *et al.*, 2013) are also shown in Fig 1. Our primary result and the literature value were reasonably agreed. We observe O_3 flux in summer 2015, and would like to show it at the meeting.

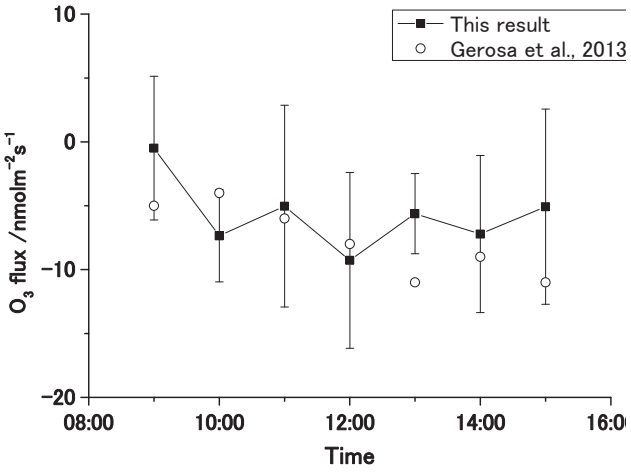

Fig. 1 O_3 flux observed in red pine forest in autumn

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[6-4]

IMPACT OF NITROGEN FERTILIZATION ON THE FORMATION OF BIOGENIC ORGANIC AEROSOL IN A DECIDUOUS BROAD-LEAVED FOREST

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Chronic increase in nitrogen (N) deposition from the atmosphere may change the atmospheric chemistry in the forest environment via possible changes in the forest nutrient cycle in soil-plant systems and leaf characteristics. This study investigated for the first time how N fertilization with 100 kgN ha^{-1} $year^{-1}$ of urea affected the formation of biogenic secondary organic aerosol (SOA) in a deciduous broad-leaved forest. The impact of N fertilization was investigated in the first- and second-postfertilization years based on a three-year-long time series of continuous filter-based, size-segregated aerosol chemical measurements. The N fertilization effects on the biogenic SOA, which includes organic molecular compounds of isoprene- and α-pinene-oxidation products, were obtained as differences between aerosol mass loadings obtained at the fertilized and unfertilized areas.

The fertilization resulted in an insignificant increase in the mass of methyltetrols, an oxidation product of isoprene, suggesting little effect of the N fertilization in the formation of isoprene-derived SOA at the forest site. By contrast, the mass concentrations of pinic acid, which is recognized as the first-generation oxidation product of α-pinene, showed a significant increase (~30%) at the fertilized area relative to those observed at the unfertilized area during the leaf-fall period of autumn. Our results indicate that the fertilizer-induced increase in pinic acid in autumn is attributable to the possible changes in the emission of α-pinene near the forest floor. Possible α-pinene emitter affected by the fertilization includes root/leaf litter/soil which appear to be a significant source of α-pinene within the forest canopy. We will also discuss the influence of the fertilization on soil, plant growth, and the foliar quantity and quality of trees in terms of the changes in the SOA mass and investigate possible factors that control the SOA formation after the fertilization.

CHANGES IN ATMOSPHERIC COMPOSITION AND LAND-ATMOSPHERIC INTERACTIONS ACROSS THE ASIAN REGION

Stephen Sitch[1] and Trendy modellers

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Land ecosystems currently moderate global climate change by absorbing over one quarter of the anthropogenic emissions of carbon dioxide (CO_2) on average every year (Le Quéré *et al*., 2015). This CO_2 'sink' is modulated by climate change and variability. For the historical period, 1901-2014, we analyse outputs from a suite of Dynamic Global Vegetation Models (DGVMs), driven with observed climatology, to quantify the regional trends in CO_2 and H_2O fluxes over the Asia region. Trends will be attributed to underlying processes, i.e. climate variability and change, changes in atmospheric CO_2 concentration, and land use and land cover changes (LULCC) (Sitch *et al.*, 2015).

Anthropogenic aerosols and tropospheric O_3 are short-lived and also affect atmospheric composition and climate regionally rather than globally, and are particularly relevant for Asia. Changes in aerosol burdens and surface [O_3] affect plant productivity, the carbon and water cycles, and therefore feedback on climate change (Sitch *et al*., 2007; Mercado *et al.*, 2009, Collins *et al.*, 2010). In this presentation we further explore changes in atmospheric composition over the Asia region, examine impacts on ecosystems, and biogeochemical cycles and land-atmosphere feedbacks (Sitch *et al.*, 2007; Mercado *et al.*, 2009; Collins *et al.*, 2010).

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[7-1]

RECENT OBSERVATIONS OF ATMOSPHERIC CO_2 OVER INDIA USING OCO-2 DATA

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The rapid increase in anthropogenic emissions of Green House Gases in particular Carbon-di-oxide (CO_2) has lead to serious concerns of warming of the Earth's climate and potential climate change impacts on all ecosystems. The atmospheric CO_2 concentration has increased by 40% from a pre-industrial level of 278 ppmv in 1750 to 390.5 ppmv in 2011 as a consequence of various human activities. Networks of surface in-situ greenhouse gas sensors provide precise and accurate measurements of CO_2 concentrations. However, their sparse and uneven global distribution results in large uncertainties in the natural carbon cycle for key regions such as tropical regions including India. Satellite based remote sensing measurements can provide an understanding of long-term spatial, temporal, diurnal and seasonal variabilities in atmospheric trace gases concentrations. Space-based measurements of XCO_2 (Column-averaged CO_2 dry air mole Fraction) may provide the most significant contributions to our understanding of the carbon cycle over the ocean and tropical land masses because these regions are poorly sampled by the existing ground-based network. In this direction, NASA had recently launched Orbiting Carbon Observatory-2 (OCO-2) as a new tool for studying and understanding the fundamental processes that control the accumulation of CO_2 in the atmosphere now and in the future. This study presents the recent results on spatio-temporal variability in atmospheric CO_2 concentrations over Indian region using the available Nadir and Glint observations of OCO-2 mission. We have observed mean XCO_2 concentration over India as 400 ($\pm$ 4) ppmv with latitudinal variations during the period 19 March-12 April, 2015. The detailed analysis of OCO-2 Nadir Observations indicates XCO_2 concentration over India in the range of 389-412 ppmv during the period 19 March to 03 April, 2015. Besides, the analysis of OCO-2 Glint Observations over India indicates XCO_2 concentration over India in the range of 390 to 408 ppmv during the period 04 April-12 April, 2015. Further, these results provide useful preliminary insights for understanding atmospheric variability of CO_2 over different landuse/landcover types and probable sources and sinks of CO_2 over Indian region.

[7-2]

VARIABILITY OF ATMOSPHERE CO_2 OVER INDIA AND ITS SURROUNDING BASED ON GEOS-CHEM TRANSPORT MODEL AND SATELLITE OBSERVATIONS

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We used the Goddard Earth Observation System Chemical (GEOS-CHEM) transport model global setup for simulating CO_2 for the years 2006 & 2013. The model is driven by GEOS meteorological fields along with surface boundary fluxes and anthropogenic inputs from different sources. The simulated results are stored every three hourly intervals. In this paper we are discussing the seasonal characteristics of simulated atmospheric CO_2 along with various uncertainties associated with the simulated results and input data bases. There exist good coherences between model and satellite observations. Simulated CO_2 shows strong seasonality near the surface which has been decreasing its strength upward. Amplitudes of the seasonal and annual cycles are stronger over the northern hemisphere, especially over the lands. The contributions from various processes in the control of atmospheric CO_2 annual growth rates over India and its surrounding oceans were budgeted for the respective years based on the model simulation.

[7-3]

CHARACTERIZATION OF SURFACE CH_4 FLUX EMISSION FROM GOSAT SATELLITE DATA OVER SELECTED AGRO-ECOSYSTEMS IN INDIA

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The quantification and characterization of feedback of agro-ecosystems to climate are essential on seasonal to annual time-scale. The ground-based measurements of 2010 did not show (approximately 3.3 Mt CH_4) alarming rate of methane emissions especially from Indian rice fields. However, the assessment of surface Green House Gas (GHG) emissions is needed to find out options for climate-resilient agriculture. The atmospheric concentrations of CO_2 and CH_4 are generally available as L3 data product through rigorous retrieval algorithm using observations in Short-Wave Infrared (SWIR) (1.56 to 1.72μm) band in Fourier Transform Spectrometer (FTS) payload at Greenhouse Gases Observing SATellite (GOSAT). These products have been used along with NOAA's ObsPack-GLOBALVIEW DATA to produce CO_2 and CH_4 surface emission fluxes which are available as L4A Product at 1° x 1° grid resolution. The present study was carried out to characterize and quantify the seasonal behaviour of surface CH_4 emissions from L4A product over two selected irrigated agro-ecosystems in India over sub-humid region of Indo-Gangetic Plain (IGP) and semi-arid region of Gujarat Plain and Hills Region (GPHR). The cluster of contiguous grids of 3 x 3 within the Region of Interest (ROI) representing agricultural land uses spread over trans, upper, middle and lower part of IGP were considered for analysis. The seasonal behaviour was studied for three agricultural years of June 2009 to May 2012 through time series plots of monthly means of each ROI. The annual CH_4 emission from agricultural region using GOSAT data was found to be about 8-9 Mt CH_4 which was about three times higher than reported over rice system in India using sparse ground samplings. The seasonal variability of CH_4 emissions showed primary and secondary peaks. The IGP showed the highest annual mean (88.11 mg CH_4 $d^{-1}m^{-2}$) of surface emission in Lower Gangetic Plain Region (LGPR) and the lowest annual mean (7.01 mg CH_4 $d^{-1}m^{-2}$) in Trans-Gangetic Plain Region (TGPR). These sub-humid irrigated agricultural regions with rice-wheat rotation showed substantially higher emissions than those in semi-arid irrigated agriculture (10.38 mg CH_4 $d^{-1}m^{-2}$ to 11.32 mg CH_4 $d^{-1}m^{-2}$) in GPHR. In IGP for an agricultural growing year (June 2009 to May 2010), the mean of CH_4 emissions for kharif (June to October) season showed higher emission flux with 51.04 mg CH_4 $d^{-1}m^{-2}$ than in rabi (November to April) Season (14.31 mg CH_4 $d^{-1}m^{-2}$), but coefficient of variation was found to be more in rabi season (77.8%) than in kharif (39.3%) season. In GPHR region for same year, the annual mean of CH_4 emissions for kharif and rabi season were 14.26 mgCH_4 $d^{-1}m^{-2}$ and 7.03 mg CH_4 $d^{-1}m^{-2}$, respectively but the coefficient of variation (CV) during kharif are more (30.37%) than in rabi (29.29%). The cloud persistence and possibility of continuous higher soil moisture through rainfall and irrigation are more during kharif in IGP than in semi-arid GPHR. These could probably lead to contrasting behaviour of surface emission of methane fluxes. Further investigation is being carried out to correlate land surface temperature, soil wetness and radiation or heat fluxes with variability in CH_4 fluxes.

CO_2 FLUX ESTIMATION BY TOP-DOWN APPROACH OVER ASIAN REGION

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Carbon dioxide (CO_2) is an important greenhouse gas with large impacts on the earth's climate and biosphere. Thus, an accurate estimate of the global and regional carbon budget is urgently required for understanding the contribution of anthropogenic and natural activities to the recent rise in CO_2 concentration. Precise measurements of atmospheric CO_2 at fixed ground sites, and from ships, aircraft, and balloons are available to elucidate CO_2 variations over the globe in recent decades. Top-down approaches (or atmospheric inverse modeling) using atmospheric transport models with these CO_2 observations are an effective way to estimate carbon fluxes at global and regional scales. We used the CCSR/NIES/FRCGC AGCM-based Chemistry Transport Model (ACTM) for simulations of various greenhouse gases and ozone depleting chemicals. Following validation of ACTM transport at regional and hemispheric scales, we conducted CO_2 flux estimations by using a Bayesian synthesis inversion framework. Monthly CO_2 fluxes were estimated for 84 regions (54 lands + 30 oceans) over the globe during the period of 1990−2011 with atmospheric CO_2 concentrations at 74 sites from Obspack GLOBALVIEW-CO_2 data product (2013). A priori fluxes are: (1) seasonally varying atmosphere-ocean exchange from Takahashi et al. (2009), (2) interannually varying fossil fuel fluxes (including cement production) from CDIAC, and (3) 3-hourly terrestrial biosphere fluxes from the Carnegie Ames and Stanford Approach (CASA) terrestrial biosphere model (annually balanced).

As a result of time-dependent inversions, mean total flux (excluding fossil fuel) for the period 1990−2011 is estimated to be −3.33 GtC/yr, where land (incl. biomass burning and land use change) and ocean absorb an average rate of −1.98 and −1.35 GtC/yr, respectively. The land uptake is mainly due to northern land (−1.57 GtC/yr), while the tropical and southern lands contribute −0.03 and −0.38 GtC/yr, respectively. Mean fluxes over Asia were estimated to be −0.26, −0.30, and −0.12 GtC/yr for Southeast Asia, South Asia, and East Asia, respectively, with interannual variations shown of an order of ±0.5 GtC/yr (Fig. 1(a)), which were generally correlated with Multivariate ENSO Index. East Asia shows largest seasonal amplitudes among the three Asian regions with an uptake rate of 4 GtC/yr in July and August (Fig. 1(b)).

We will also present some of the recent results based on the ongoing CO_2 flux intercomparison effort, following the RECCAP and APN projects on estimation of Asian greenhouse gases budget. Further collaborative effort will be required for disentangling the complex coupling between the natural and anthropogenic CO_2 fluxes over Asia regions.

Acknowledgements. This study is supported by Global Environment Research Fund (2-1401) of the Ministry of the Environment, Japan.

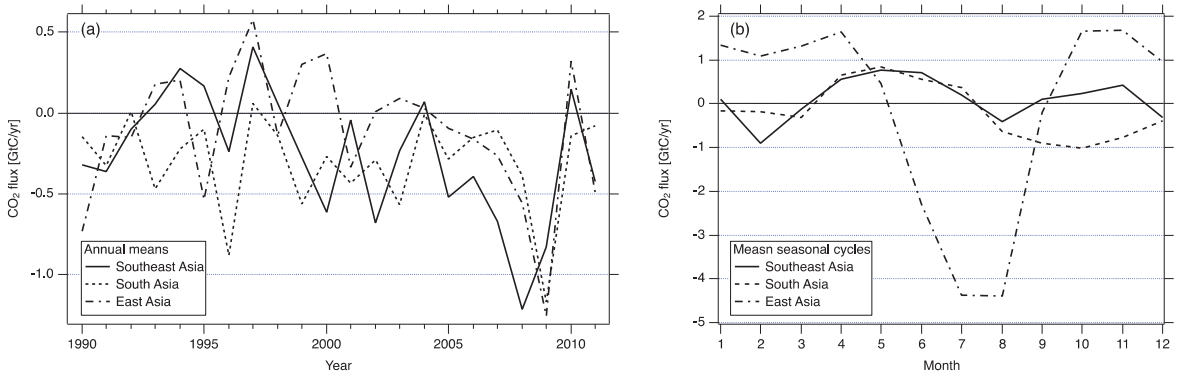

Fig. 1. (a) Annual mean time series and (b) average seasonal cycles of estimated CO_2 fluxes for three Asian regions.

[8-1]

SEMI-EMPIRICAL GPP ESTIMATION OF EAST ASIAN FORESTS USING MODIS VEGETATION INDICES

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This study aims to develop a simple semi-empirical model to estimate Gross Primary Production (GPP) of East Asian forests using the relationship between ecosystem photosynthetic parameters derived from eddy flux observation and remotely sensed MODIS (Moderate Resolution Imaging Spectroradiometer) vegetation indices. For this purpose, we used carbon flux and micrometeorology data obtained at 23 East Asian forests (71 site-years) to extract seasonal or inter-annual variation of the photosynthetic parameters. Target parameters were maximum GPP at light saturation (A_{max}) and the initial slope of the light-response curve (ϕ). Daily photosynthetic parameters were determined by the least-squares method using daytime half-hourly net ecosystem CO_2 exchange rate and the photosynthetic photon flux density (PPFD) within 7 days moving windows, and the monthly and yearly averages were calculated. Vegetation indices were evaluated using MODIS products of spectral reflectance (MCD43A4) and Leaf Area Index (LAI, MOD15A2). Enhanced Vegetation Index (EVI=2.5×[(ρnir-ρr)/(ρnir+6×ρr - 7.5×ρb+1)]) and Green Ratio (GR=ρg/(ρr+ρg+ρb)) were evaluated from the reflectance at the following wavebands; ρnir (841-876 nm), ρr (620-670 nm), ρb (459-479 nm), and ρg (545-565 nm). The MODIS LAI, EVI, and GR were obtained every 8-day, then those were aggregated as the monthly and yearly averages to compare with the photosynthetic parameters.

A clear linear relationship was obtained between the yearly or monthly averages of photosynthetic parameters and MODIS vegetation indices to explain inter-site and seasonal variations among studied forests (Figure). Monthly GPP of all studied forests was simulated with good performance using the obtained empirical linear relationships, where yearly and monthly average vegetation indices and half-hourly PPFD were used as the input variables.

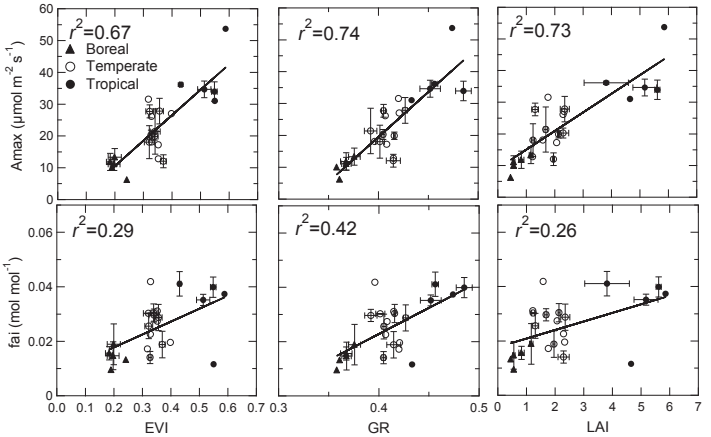

Figure. Relationship between annual averages of ecosystem photosynthetic parameters and MODIS vegetation indices

[8-2]

UPSCALING TERRESTRIAL CO_2 FLUXES IN ASIA USING AN INTEGRATED DATABASE OF EDDY-COVARIANCE MEASUREMENTS

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Dense observation networks are important to improve estimations of terrestrial carbon fluxes. Asia, which comprises about 30% of the global terrestrial gross primary productivity (GPP) and represents a significant terrestrial carbon sink, is one of several regions where observation networks have been sparsely distributed and unorganized. In this study, we collected existing available datasets of eddy-covariance measurements to empirically estimate terrestrial carbon fluxes in Asia using satellite observation-based data with a machine learning algorithm, namely, support vector regression (e.g. Yang et al. 2007; Saigusa et al. 2010). Specifically, we collected site observation data from the AsiaFlux database, CarboEastAsia database, Forestry and Forest Products Research Institute (FFPRI) Fluxnet, European Flux Database, and Arctic Observation Network (AON), and we conducted uniform data pre-processing by general quality control techniques, gapfilling, and flux-partitioning. We used MODIS-based products of vegetation index, land surface temperature, solar radiation, and land cover as explanatory variables.

The obtained estimates of GPP and net ecosystem exchange (NEE) were compared with available independent remote sensing-based estimations - MODIS-GPP product and GOSAT (Greenhouse Gases Observing Satellite) Level 4A product. The estimated annual GPP in Asia was 35 Pg C per year, which was higher than existing estimates from the MODIS GPP product. In addition, we found net carbon exchanges in high latitudinal regions (Siberia) that were very consistent with the GOSAT Level 4A product, which is based on atmospheric inversion studies. However, large discrepancies were found in low latitudinal areas such as in Southeast Asia. These results highlight the need for better observations particularly from tropical forests to thoroughly refine Asian carbon budget estimations.

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[8-3]

UNDERSTANDING CARBON DYNAMICS IN INDIA USING A LAND-SURFACE MODEL

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Increasing CO_2 concentration in the atmosphere due to anthropogenic emissions and land use/land cover change (LULCC) is responsible for anomalous temperature trends at local, regional and global scales. Hence, understanding the dynamics of carbon in the Earth System is central to the study of climate and climate change. Studies show that the terrestrial component of the global carbon cycle is the source of most of the uncertainties in our understanding of the carbon cycle. In the present study we aim to understand carbon dynamics in India and the spatio-temporal trends of carbon budget components such as gross primary productivity (GPP) and net primary production (NPP) over terrestrial ecosystems using Integrated Science Assessment Model (ISAM), a state-of-the-art land-surface model. As a first step, the model is calibrated with and evaluated against in situ and remote sensing-based observations. Even though many studies have estimated carbon stocks and fluxes in India using remote sensing data, national-scale modeling studies are rare. This study will lead to more accurate estimates of the terrestrial carbon cycle. The improved model will allow us to conduct numerical experiments and study regional-scale processes in the carbon cycle.

[8-4]

ASIAN METHANE EMISSIONS ESTIMATED BY INVERSE MODELLING

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Methane (CH_4) plays important roles in the air pollution chemistry and short-term forcing in global warming. Clear understanding of CH_4 emissions and loss budget is required to aid sustainable development of the future Earth's environment. We used an atmospheric chemistry-transport model (JAMSTEC's ACTM) for simulating atmospheric CH_4. An inverse modelling system has been developed for estimating CH_4 emissions (7 ensemble cases) from 53 land regions for the period 2002-2012 using measurements at 39 sites. The global net CH_4 emissions varied between 505-509 and 524-545 Tg/yr during 2002-2004 and 2010-2012, respectively (ranges based on 6 inversion cases), with a step like increase in 2007 in agreement with atmospheric measurement (ref. Figure 1 for the Asian region emissions). The inversion system did not account for interannual variations in radicals reacting with CH_4 in atmosphere. Our results suggest that the recent inventory of the EDGAR (version 4.2FT2010) overestimated global total emissions by at least 25 Tg/yr in 2010, because the inventory emission is inconsistent with CH_4 growth rate without a 6% systematic increase in CH_4 loss by chemical reactions. Increase in CH_4 emission after about 2004 originated in the tropical (including Asia) and southern hemisphere regions, with timing consistent with increases of non-dairy cattle stocks by 14-20% during 2012-2002 on head counts. All 7 inversions robustly estimated the interannual variations in emissions, but suggested a major increase of sites in the sparse observational network for constraining the seasonal cycle amplitude or phase consistently for all regions. The inverse model estimated CH_4 emission increase over the East Asia (China mainly) region in the range of 7-12 Tg/yr during the 2002-2006 and 2008-2012 periods, respectively, in contrary to 1-17 Tg/yr a priori emission (Figure 1b).

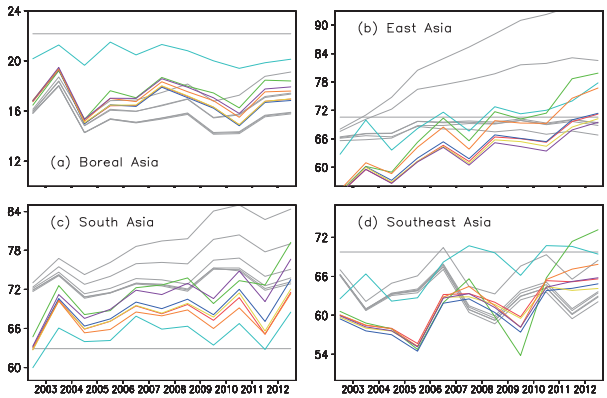

Figure 1: Annual mean terrestrial CH_4 emissions (units: Tg/year) as estimated by 7 differences inversion cases (CH_4ags, CH_4e42, CH_4enf, CH_4fix, CH_4fug, CH_4ong and CH_4ctl) for the period of 2002-2012, in comparison with the a priori emissions (grey lines). First and last years of inversion results are excluded in the analysis. [A P]

Poster Session

[PO-1]

CARBON AND ENERGY FLUXES OVER A RAINFED AGRICULTURAL ECOSYSTEM IN SEMI-ARID INDO-GANGETIC PLAINS

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India ranks first among the rainfed agricultural countries with nearly 60 % (approximately 86 M ha) of the total agro ecosystems falling in the rainfed category. These rainfed regions have limited access to irrigation, and soil and rain water conservation measures have high significance in improving the crop productivity. In changing climate scenario, improving the carbon sequestration potential of rainfed ecosystems are also of high significance. With sustainable land and crop management practices, soil and ecosystem carbon pools can be enhanced by increasing the residence time of carbon. Continuous measurement of carbon fluxes in rainfed agricultural ecosystems needs to be carried out to accurately evaluate the carbon sequestration potential and to better explain carbon cycle processes of such ecosystems.

Eddy covariance surface flux measurements have been carried out over a rainfed agro-ecosystem located over a semi-arid zone in Indo-Gangetic plains, near Varanasi, India. The 20-m flux tower is installed at the Southern Campus of Banarus Hindu University (BHU) at Barkacha, as part of the Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX). The tower is located over a fairly flat agricultural field growing sesame oil seed crop during southwest monsoon season. Two eddy covariance systems, consisting of Infrared gas analyzers (LI-7500A and LI 7200, Licor, USA), 3-D sonic anemometer-thermometers (Windmaster Pro, Gill instruments, UK) are installed on the tower at two heights, 5 m and 17 m. Soil heat flux, net radiation, soil moisture and soil temperature, along with other meteorological parameters are also measured on the tower. The measurement period include very dry and hot pre-monsoon conditions (May) with almost no vegetation, naturally grown grass after the first few rains in June and then the growing season of Sesame crop (July-September). CO_2, water vapour and energy fluxes are analyzed in relation to different crop growth stages and under different environmental conditions to understand the sensitivity of surface fluxes to different controlling factors. During peak crop growing periods, large daytime CO2 fluxes up to -20 μ mol m^{-2} s^{-1} and relatively small nighttime fluxes close to 5 μ mol m^{-2} s^{-1} are observed at the site. In addition to the net ecosystem exchange estimate during the crop season, response of the fluxes to rain events, rainfall variability, air and soil temperature variations are also investigated.

[PO-2]

TIDAL AND SEASONAL VARIABILITY OF AIR-WATER CARBON DIOXIDE FLUX IN THE HUGLI ESTUARY

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Estuaries intensely transform large amounts of carbon, delivered from rivers and transfer to the adjacent coastal zone. As a consequence of the complex biogeochemical re-working of allochthonous carbon in the sediment and water column, CO_2 is emitted to the atmosphere. In this way, estuaries play a significant role in global CO_2 cycle, as it emits 0.27±0.23 Pg C year $^{-1}$ throughout the globe.

The River Hugli is a macrotidal estuary with tidal amplitude of > 4 m. It is the main source of fresh water input in the largest mangrove ecosystem of the world – Sundarban and is dominated by fresh water discharge from the Ganges through Farakka dam, located 286 km upstream from the river mouth.

Diamond Harbour (22°8.78′ N, 88°9.0″E), is an important station at the transition of fresh water riverine zone and saline tidal zone of Hugli Estuary, located in the extreme upstream end of the mixing area. This coastal station is increasingly being affected by anthropogenic discharges due to a rise in economical exploitation and maritime activities.

In the present study, the variability of fugacity of CO_2 along with the CO_2 concentration in the ambient air has been monitored for a complete annual cycle. The observations were made over a diurnal cycle in the spring tide and neap tide days of each month. pH, total alkalinity, water surface salinity, water surface temperature, nutrients with other parameters were also measured. Computing the gas transfer velocities and the difference of CO_2 concentration between the ambient air and water surface, the atmosphere-hydrosphere fluxes in this site were estimated.

Atmospheric CO_2 concentration was found to be maximum during the month of January (388.3 ±1.6 µatm) and minimum was found during September (384.1 ± 1.5 µatm). The estimated gas transfer velocity was found maximum during pre monsoon and minimum during post monsoon.

Throughout the annual cycle, the fCO_2 (water) was found higher during the neap tide days than the corresponding spring tide days. The fCO_2 (water) was found highest during the monsoon (5106 µatm) followed by the pre-monsoon season (3992 µatm) and the least was observed in the post-monsoon season (3619 µatm). The atmosphere-hydrosphere CO_2 flux also varied in the same way since the variability of fCO_2 air was very minimal compared to the range of fCO_2 (water) variability. The evaluated fluxes were 545, 414 and 195µmol m^{-2} h^{-1} in monsoon, pre-monsoon and post-monsoon respectively. The fCO_2 (water) was found highest during the monsoon as this season marks an enhanced discharge and runoff from the nearby catchments thereby increasing the carbon load of the estuaries enhancing the heterotrophy of the site. While during pre-monsoon season the evaporation played a dominant role making the surface water rich in CO_2. On the contrary, both fCO_2 water and effluxes were substantially low in the post-monsoon season due to enhanced chlorophyll-a concentration along with suitable conditions for biological primary production and low gas transfer velocities. The fluxes were inversely proportional to salinity. During the diurnal sampling the same observations were made in high tide and low tide conditions. The present study suggests that, tide and season mainly regulates the fluxes in such monsoon dominated estuaries.

[PO-3]

ATMOSPHERIC CO_2 VARIATIONS OVER DIFFERENT CONTRASTING SITES OF INDIA

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Carbon dioxide (CO_2), methane (CH_4) and water vapor (H_2O) are three most importantgreenhouse gases in terms of their abundances and contribution towards global warming. In which, CO_2 is the main contributor towards climate change. Under the National Carbon Project (NCP), many studies have been initiated at NRSC to understand and estimate the CO_2 budget over India. Atmospheric CO_2 Retrieval and Monitoring (ACRM) is one of them to study the variability of atmospheric CO_2 at different parts of India.Different sites have been identified for atmospheric CO_2 observations to understand the source and sink processes for carbon emissions/absorptions under varied environmental conditions. Continuous monitoring of atmospheric CO_2 carried out at Shadnagar, Ponmudi hills, Nagpur and Gadanki,which are different environmental conditions in nature.

At Shadnagar, a high precision greenhouse gas analyzer was installed to generate baseline concentration as WMO recommended. Shadnagar is a tropical semi-arid region having less vegetation and away from highly populated city Hyderabad of Telangana state. Seasonal amplitude of CO_2 was maximum of 405 ppmv during April 2014 and minimum 390 ppmv in October 2014. This could have been due to less vegetation in premonsoon (drop in net photosynthesis rate) and heavier rainfall (scavenges CO_2) in October. Orographic effect as well as to see the diurnal and seasonal variations at a high altitude station which near or above the boundary layer, Ponmudi hills Western Ghats of Kerala, India have been identified.Diurnal peak amplitude during morning and evening are in the same phase and repeating at the same time. Maximum (minimum) peaks are observed at 0600 hrs IST (1400 hrs IST). During daily hourly variation of CO_2, the maximum (minimum) mixing ratios are 395.6 ppm (354.4 ppm) observed in October 2014. Hill terrains mostly influenced by anabatic (day time) and katabatic (night time) winds which transport air mass from the low level surface to high level and vice versa.

Gadanki is a tropical semi-arid station located near Tirupati inthe Chittoor district of Andhra Pradesh. It is a complex hillyterrain surrounded by dense forest and a very irregular mix ofagriculture, and has small-scale rural population. Atmospheric CO_2 observations over Gadanki and Nagpur stations expected to be less effected by water vapor in the atmosphere compared to Ponmudi. Since Ponmudi receives heavy rainfall during the season, water vapor effect on CO_2 mixing ratios are expected more. These respects have been studied and results discussed

Keywords: Atmospheric CO_2, Diurnal and seasonal, winds

[PO-4]

VARIABILITY IN AIRS CO_2 DURING ACTIVE AND BREAK CYCLES OF INDIAN SUMMER MONSOON

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The Indian monsoon (June to September) is one of the most dominant tropical circulation system in the general circulation of the atmosphere It exhibits a wide spectrum of variability on daily to centennial time scale. A substantial component of Indian Summer Monsoon (ISM) variability arises from the fluctuations on the intra-seasonal scale between active spells with good rainfall and weak spells/ breaks with little rainfall or dry conditions. Changes in circulation pattern during active and break cycles of Indian summer monsoon may have impact on transport and hence distribution of AIRS CO_2 An attempt is made in this study to examine the anomalies in circulation parameters and its impact on the distribution CO_2 at mid-troposphere during active and break cycles of ISM. For this purpose daily data for (1) AIRS retrieved mid-tropospheric CO_2; (2) zonal & meridional component of wind; (3) vertical velocity and (4) rainfall for the period 2003 to 2011 are analysed in the study. Study reveals that anomalous circulation patterns during active and break phases of ISM show resemblance with anomalous patterns of AIRS retrieved mid-tropospheric CO_2. Homogeneous monsoon regions of India show substantial increase in CO_2 levels during active phase. Analysis indicates that during active cycle strong monsoon circulation bring CO_2 over Indian region to increase their concentration over mid-troposphere.

[PO-5]

CARBON DIOXIDE EXCHANGE FROM A SEMI EVERGREEN FOREST IN ASSAM, INDIA USING EDDY COVARIANCE TECHNIQUE **

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Global environmental changes have far reaching consequences and its mitigation requires long term data collection, synthesis and action. Numbers of network monitoring sites have increased at global level but the measurement of CO_2, H_2O and energy fluxes by tower based measurement technique such as Eddy Covariance is a relatively new concept in India. A flux tower was installed at tropical semi evergreen forest of Kaziranga National forest, Assam, India during February, 2015. An integration of data from EC flux observations are used to work on the potential carbon strength of the forest and we tried to work out a relationship of CO_2 flux with other meteorological parameters. Some preliminary findings obtained from this tower on carbon dioxide exchange are presented. The recorded diurnal variation of CO_2 flux was within the range of 7.8899 μ mol $m^{-2}sec^{-1}$ to -7.9009 μ mol $m^{-2}sec^{-1}$. Maximum net radiation of 481.9887 wm^{-2} corresponds to negative CO_2 Flux of -5.1319 μ mol $m^{-2}sec^{-1}$ on the days of observation. PAR attained a peak of 1083.218 μ mol $m^{-2}sec^{-1}$ at around 11.00 A.M which paralled with CO_2 flux of -5.1319 μ mol $m^{-2}sec^{-1}$.Maximum soil heat flux of 36.66029 wm^{-2} was found to dictate positive CO_2 flux of 4.5203 μ mol $m^{-2}sec^{-1}$.A positive H_2O flux recorded at 11-12 A.M. was found to be associated with a negative CO_2 Flux. Latent heat flux showed a maximum of 173.8829 wm^{-2} along with positive CO_2 flux recorded at the same time. The CO_2 concentration varied from 405 ppm during day time to 430 ppm in the night time.CO_2 Flux was found to have relationship with meteorological parameters like PAR, latent heat flux, soil heat flux and soil temperature. Results presented here are compilation and synthesis of data for a brief period during later part of Feb, 2015 onward. Further Investigations are in progress.

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[PO-6]

CARBON FIXATION, CARBON EFFLUX AND METHANE EMISSION IN RELATION TO SOIL CARBON STOCK IN RICE AGRO-ECOSYSTEM

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The carbon (C) balance in an ecosystem is depended on two components i.e the addition of matter (C influx) to the rice crop system and removal of matter (C efflux). Two experiments were undertaken at North Bank Agro climatic Zone of Assam, India - one during the monsoon rice growing season (July- December) for 03 consecutive seasons (2012, 2013 and 2014) and another during the summer rice growing season (December-June) for 02 consecutive seasons (2012-2013 and 2013-2014). The objectives of the experiments were to assess the efficiency of rice genotypes for methane (CH_4) emission in relation to atmospheric C-fixation, C-efflux and C-storage in the soil. Four high yielding rice genotypes, viz. Ranjit, Gitesh, Swarnamahsuri and Mahsuri were selected for monsoon rice growing season and six high yielding rice genotypes viz. Bahadur, Cauvery, Dinanath, Joymoti, Kanaklata and Swarnabh were selected for summer rice growing season. Maximum cumulative CH_4 emission was recorded from the field planted with the genotype Mahsuri ($1.42 gm^{-2}$) and lowest from Gitesh ($1.08 gm^{-2}$) during monsoon season whereas Joymoti ($1.06 gm^{-2}$) and Dinanath ($0.76\ gm^{-2}$) during summer season. Differences in photosynthetic rate amongst the genotypes were observed accompanied by a strong influence of stomatal density of the flag leaf on photosynthesis. Photosynthesis is considered as key driver of soil C in rice agro-ecosystem. Soil carbon storage of 0.566 $MgCha^{-1}yr^{-1}$ during monsoon season and 0.505 $MgCha^{-1}yr^{-1}$during summer season were recorded in this study. Although an inverse relationship of CH_4 with carbon dioxide (CO_2) efflux was observed, monsoon and summer rice ecosystem has a good potential to store substantial amount of carbon in the soil and is considered as sinks of carbon.

Keywords: Photosynthesis, Methane, Rice genotypes, Soil carbon storage

[PO-7]

SEASONAL VARIATION OF pCO_2 IN THE PICHAVARAM MANGROVE WATERS, SOUTHEAST COAST OF INDIA

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The Pichavaram mangrove wetland, which occupies about 1400 ha, is located in the South East coast of India. The mangrove wetland has about 700 ha of dense forests and about 400 ha of water spread area criss-crossed by a number of small creeks and canals. In the present study, CO_2 concentration was estimated in eight different sites in the Picvaharam mangrove wetlands covering freshwater dominated zone, mangrove dominated zone and seawater dominated zone. Measurements were made bimonthly, covering three seasons, namely pre monsoon (July to September), -monsoon (October to December) and -post monsoon (January to March) during 2014-15. Water temperature, pH, salinity, dissolved oxygen (DO), total alkalinity (Talk), dissolved inorganic carbon (DIC), total organic carbon (TOC) were measured following standard methods.. The CO_2Calc software was used for the calculation of pCO_2 using the data on water temperature, salinity, pH, water pressure and total alkalinity. The spatial and temporal variations of pCO_2 showed the lowest value (ca. 66 µatm) in the seaward site during the pre monsoon season, whereas the highest value (ca. 7187 µatm) was recorded in the freshwater zone during the monsoon season. This fresh water region of estuaries is where the maximum turbidity zone typically occurs, which contributes to the intense heterotrophic activity and recycling of organic matter resulting in consumption of O_2 and CO_2 production. High pCO_2 values ranging from 2000 to >7000 µatm were recorded during low salinities (<20 ppt) and also during lowest pH range (7-7.5). The high values of pCO_2 in low salinity regime is mainly due to increased solubility of CO_2. Estimation of pCO_2 showed that it generally associates with lower tempersture. TAlk, DIC and pH all followed similar trend over the sampling time period. It is observed that high freshwater flows generally produced lower TAlk, DIC, and pH. The present study indicates that the CO_2 flux from the atmosphere to mangrove water seems to be more during moderate saline condition (15 to 20 ppt). The present study indicates Pichavaram mangrove waters are also rich in phytoplankton and its bloom also observed. The role of phytoplankton and its bloom in pCO_2 flux is being investigated.

[PO-8]

CO_2 SOURCE CHARACTERIZATION USING ISOTOPIC TECHNIQUES OVER A SEMI URBAN AREA IN NORTHERN INDIA DURING INDIAN SUMMER MONSOON 2014

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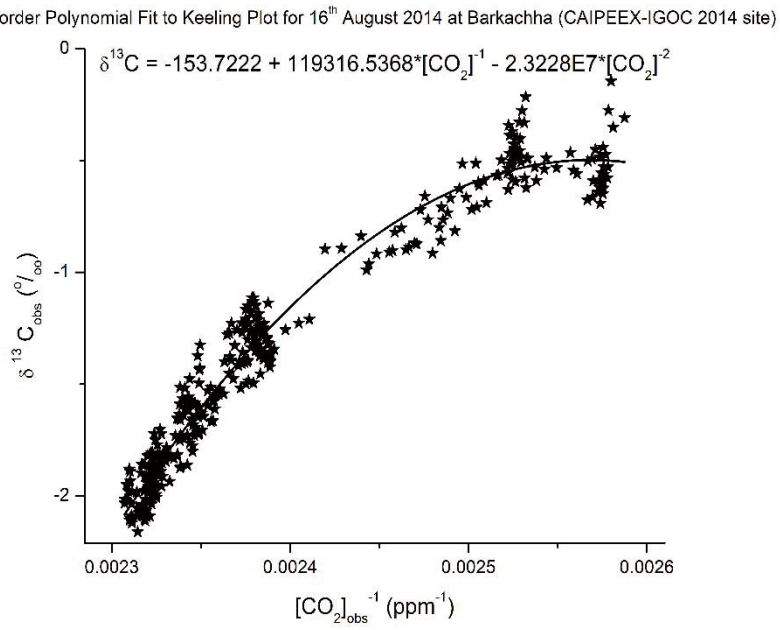
Identifying the sources and sinks of CO_2 and other green house gases is an important aspect of carbon cycle study. Isotopic analysis of atmospheric trace gases is widely used for this purpose. We have measured CO_2 concentration and its isotopic ratios over a semi-arid zone (Barkachha; 82^0 56' E, 25^0 13' N) over Indo-Gangetic plains, near Varanasi, India. An LGR Isotopic CO_2 Analyzer (Model: CCIA-46-EP) has been used for this purpose. The analyzer is calibrated periodically using NOAA CO_2 reference gas cylinder. The analyzer provided high frequency data of CO_2 concentration and isotopic values (both $\delta^{13}C$ and $\delta^{18}O$). CO_2 concentration and its carbon isotopic ratios have been used to study the inter-dependency of these two parameters and whether multiple sources are contributing to the total CO_2 concentration in the studied area.

Keeling plot analysis is an effective tool to identify the sources of CO_2. In this method $\delta^{13}C$ (in $^o/_{oo}$) is plotted as a function of $[CO_2]^{-1}$ (in ppm^{-1}) and the number of sources is estimated by studying their functional dependency. Above has been employed in present work to CO_2 data measured at Barkachha, India during the summer monsoon of 2014.



A characteristic Keeling plot (not included here) in a typical urban area at Pune, India shows a linear relation suggesting the presence of a single source. Being an urban site (Pune) the major source has been identified as fossil fuel. However, a quadratic dependence is observed between these two parameters at Barkachha which is shown in the adjoining figure. Mathematically, best fit can be expressed as $\delta^{13}C = -153.722 + 119316.5368*[CO_2]^{-1} - 2.32287E7*[CO_2]^{-2}$.

The quadratic nature suggests definite presence of multiple sources of CO_2 at the site. From synoptic features strong south-westerly monsoon wind is observed during this time resulting in advection of CO_2 from western parts of India. Being located on Indo-Gangetic plain this measurement site is densely populated. Present work shows requirement of more detailed study of $[CO_2]$ transport process in this direction as it has serious implications on local health as well as agricultural activities.

[PO-9]

PRE-MONSOON CO_2 VARIATIONS AT A COASTAL STATION, GOA

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Air quality and atmospheric CO_2 over a coastal station is influenced by air-sea interactions in coastal ocean, land-sea breeze circulations, coastal upwelling in addition to sources (emissions) and sinks (vegetation). The tropical station, Goa, located on the west coast of India is characterized by very high monsoon rainfall as it falls in the path of the Somali Jet. During pre-monsoon it is affected by multiple intense thunderstorms. Measurements of CO_2 and it turbulent flux have been made at Goa during pre-monsoon (March-June 2003). It is observed that monthly-mean CO_2 decreases by ~ 67 ppmv from March to May. With the onset of the SW monsoon, CO_2 increases from 292 ppmv to 356 ppmv, attributed to high monsoon winds induced coastal upwelling. As turbulent CO_2 flux is negligible (monthly mean maximum ~ -0.05 mg m-2 s-1), variations in CO_2 may be attributable to advection. Frequency distribution of wind direction indicates most of the time wind is from the Arabian sea (except a couple of hours during early morning land breeze). Back trajectory analysis indicates gradual shift of air mass orgin from near to the coast in March to the open sea during May. Thus it appears that local variability of CO_2 is due to marine air mass advection during pre-monsoon with relatively CO_2 rich air mass in March and less CO_2 air mass in May. Earlier measurements in the Arabian Sea reported maximum Chlorophyll 'a' and minimum partial pressure of CO_2 in sea waters off the west coast of India during pre-monsoon period. Seasonal variability of CO_2 at Goa seems to depend primarily on dynamics of air-sea interactions and advection of marine air. In-situ measurements of air-sea CO_2 flux and atmospheric CO_2 gradient across the land-sea interface may reveal details of space-time variability of CO_2 and the processes involved.

[PO-10]

HEALTH STATUS OF CORAL REEF ECOSYSTEM AT LAKSHADWEEP ISLAND IN RELATION TO ATMOSPHERIC CO_2

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The ecosystem of coral reef in Lakshadweep Islands is under threat due to the drastic coral bleaching and causing mortality of corals for which temperature plays a major role as a result of increasing level of atmospheric CO_2. In Lakshadweep Islands, the atmospheric CO_2 level was found to have fluctuated between 360 to 390ppm and occasionally found above the level of 400ppm. The CO_2 level was found coincided with primary productivity in the sea of Lakshadweep which was found to have ranged from 0.40mgC/m^3/hr to 0.98mgC/m^3/hr and the result showed that the atmospheric CO_2 was not effectively fixed by the phytoplankton. The nutrients such as Nitrite, Nitrate, Total phosphorous and Reactive silicate values were measured in the range of 0.152 - 0.721, 0.690 - 9.932, 0.633 - 3.423 and 3.468 - 10.396µmol/L respectively. The pH of Lakshadweep sea water was recorded well below 8 throughout the year. Hence, the process of acidification was assumed to be accelerated due to the more partial pressure of CO_2 over the sea surface at Lakshadweep Islands. In addition, it was expected that the progressive onset of ocean acidification would cause reduction of coral growth as well as retardation.

[PO-11]

LAND USE LAND COVER DYNAMICS OF EASTERN GHATS INDIA USING GEOSPATIAL TECHNOLOGIES

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India has 12 biogeographical provinces, 5 biomes and 3 bioregion domains. The biodiversity is affected by natural and anthropogenic factors and it will lead to habitat loss and biodiversity degradation in a particular region. Isolated pockets of hilly ranges are the sites of high endemism. If the native vegetation is getting lost, it is impossible to bring them back and the results lead to extinction of species. To understand the trend of biodiversity loss in a particular region on the time period, LULC change studies are good indicators. Land-use and land-cover changes will cause due to the direct and indirect drivers such as socio-economic, biophysical and climatic factors. Anthropogenic pressure inducing more stress on biodiversity and land use land cover. Here we are attempting to find the land use land cover dynamic in Eastern Ghats, one among nine floristic zone and unique landscape in India. Human activities such as mining, industrial developments, urbanization, dam construction and other are the major drivers of LULC in Eastern Ghats. The changes were mapped using remotely-sensed, multi-date, multi-sensor satellite data, topographic maps and vegetation cover maps from 1920 to 2014. Land use dynamics from topographic maps (1920) vegetation cover maps (1940 and 1960), MSS (1975 and 1985), OLI (2014-2015) sensors of Landsat, LISS I (1995) and LISS III (2005) of IRS satellites data were mapped using visual interpretation technique. The total land use and land cover classes are grouped into forest, scrub, grassland, water bodies and others. This analysis suggests that the vegetation cover is undergoing constantly negative change in terms of composition and extent. Large areas of forest converted into agricultural, plantations and industrial usage mining also very prominent in the area. Forests are getting degraded due to mining, deforestation and degradation activities. Impact of these changes on carbon fluxes and regional climate are being investigated.

***Key words*:** Land use land cover change, Eastern Ghats, Biodiversity degradation, Satellite data, Remote sensing

[PO-12]

SEDIMENTARY CHARACTERISTICS OF CORAL REEF ECOSYSTEM AT AGATTI ISLAND LAKSHADWEEP

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Environmental characteristics of the marine ecosystem in relation to sediment of Agatti Island, Lakshadweep were assessed with a view to understand the impact of physio-chemical variables of sediments on the health of the corals in this region. The sediment sample from different region of Agatti Island was collected in different season and various sedimentary parameters such as texture, sediment TOC, pH & CHN were analyzed. As far as texture was concerned, it was noted that high percentage of sand compare to silt and clay in the sediment. The total organic carbon in the sediment sediment was recorded between 0.577 and 3.926mgC/gm. The sediment pH was recorded between 7 and 8 and carbon percentage showed higher value of 11-12% followed by hydrogen and nitrogen. The value of water quality and other sediment parameters generally showed favorable for coral bleaching and ocean acidification. Therefore, the parameters related to alkalinity/acidity along with other parameters obtained through this study responded to the depletion of coral reef ecosystem and its fishery populations in Agatti Island, Lakshadweep.

[PO-13]

ESTIMATION OF NET ECOSYSTEM CARBON EXCHANGE FOR DECIDUOUS AND MANGROVE FORESTS OF INDIA USING EDDY COVARIANCE FLUX MEASUREMENTS

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Estimation of net ecosystem carbon exchange (NEE) across vegetation-atmosphere interface is important to understand feedbacks between terrestrial biosphere and the atmosphere in the context of global climate change. Eddy covariance flux towers provide continuous and accurate measurements of NEE at different spatial and temporal scales.

In the present study, we report NEE estimates for two different and contrasting forest ecosystems in India viz., central Indian teak mixed deciduous forests of Madhya Pradesh and Sundarban mangrove forests of West Bengal for the years 2012 – 2014. Continuous fast response measurements of mass (CO_2 & H_2O) and energy (sensible, latent and soil heat) fluxes along with slow response measurements of meteorological parameters were carried out at both the study sites using eddy flux towers during the study period.

Flux data processing involved corrections to the raw flux data in terms of frequency response, air density (Webb-Pearman-Leuing), despiking of erroneous data and nighttime flux corrections (frictional velocity). Gap filling of data is achieved using Mean Diurnal Variation (MDV) and Marginal Data Sampling (MDS) methods. The corrected and gap filled data sets are subsequently analyzed for intra and inter-annual variability of CO_2 fluxes for estimation of NEE for the study sites.

NEE of teak mixed deciduous forests followed phenological variations in leaf-on and leaf-off seasons, with mean monthly CO_2 sequestration at the rate of -25 µmol m^{-2} s^{-1} and -2 µmol m^{-2} s^{-1} during leaf-on and leaf-off seasons respectively. On the other hand, Sundarban mangroves showed less significant seasonal variations with mean monthly CO_2 sequestration at the rate of -11µmol m^{-2} s^{-1} and -6 µmol m^{-2} s^{-1} during winter and summer seasons respectively. Average annual net carbon sequestered for the teak mixed deciduous forests and mangrove forests was estimated to be 585.52±265 g C m^{-2} y^{-1} and 249 ± 20 g C m^{-2} yr^{-1} respectively. The closure of surface energy balance accounted for more than 78% for both the study sites. Overall results suggested both the forest types are substantial carbon sinks.

The present study is carried out as part of the National Carbon Project of the Indian Space Research Organisation, funded by ISRO-Geosphere Biosphere Program.

[PO-14]

MEASURING NET ECOSYSTEM EXCHANGE IN MIXED FOREST PLANTATION USING EDDY COVARIANCE TECHNIQUE

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Net ecosystem exchange between the terrestrial ecosystem and atmosphere is one of the major processes affecting the concentration of atmospheric CO_2 and its quantification is essential to assess the net sink or source nature of the ecosystem. The present study reports the results of net ecosystem exchange (NEE) measured by eddy covariance technique over a young mixed forest plantation in Terai Central Forest Division, Nainital district during 2014. The result showed that the plantation act as sink (i.e. negative NEE) in all the months with an average daily uptake between -1.29 g C/m^2/day to -3.77 g C/m^2/day. It was noticed that the mean daily NEE was low during January and February due to leafless condition of the plantation but started increasing in subsequent months until October and was highest in August with an uptake of -3.77 g C/m^2/day. During July, it was observed that the net carbon uptake was low. It may be due to stress condition of the plantation and low PAR availability. An attempt has been made by incorporating the other micro-meteorological data observed at tower site and showed non-favourable condition of the growth of plantation in July i.e. the lower soil moisture availability (<16%), higher air temperature (>30°C) and low photosynthetically active radiation (PAR) density (<300 W/m^2). The diurnal NEE variations was closely followed with the intensity of PAR density in all the months. The low NEE in year 2014 as compared to previous year reveals profound drought effect due to ENSO event. This study could be helpful in understanding environmental effects on carbon cycling of plantation forest in sub-tropical climate and in long-term it may provide new insight into the water and carbon balance of rapidly changing climate of lower Himalaya.

Keywords: Eddy Covariance, mixed forest, NEE, PAR, drought

[PO-15]

INTRA-SEASONAL VARIABILITY OF SURFACE FLUXES AT GADANKI, A RURAL STATION IN A COMPLEX HILLY TERRAIN

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The redistribution of energy across the Earth's surface is accomplished primarily through three processes: sensible heat flux, latent heat flux and ground heat flux. For understanding the temporal variability (over different scales, diurnal, intraseasonal and seasonal) of these processes in a variety of atmospheric conditions, a 50 m instrumented micrometeorological tower has been erected at Gadanki (13.5 N, 79.2 E), a remote site located in a tropical complex hilly terrain. The threshold time scale for the estimation of fluxes is determined by analyzing the turbulent scales in all seasons, using Ogive method. The wet and dry spells are identified using rainfall measurements at Gadanki and over southern peninsular India by Indian Meteorological Department (1° x 1° high-resolution data). Using the above data sets, intra-seasonal variability of fluxes is studied in detail. The sensible heat (SH) flux is high in dry spell and low in wet spell, whereas latent heat (LH) flux is high in wet spell and low in dry spell. Because of the availability of soil moisture plays a major role in variability of fluxes in dry and wet spell. The difference in SH and LH fluxes is small during the dry spell, whereas it is large during the wet spell.

[PO-16]

INFLUENCE OF GLOBAL WARMING ON INDIAN SUMMER MONSOON

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The tropics occupy approximately 40% of Earth's land surface area and critically regulate many Earth system processes also the global monsoons are influenced by the tropics. Tropical terrestrial ecosystems represent a major reservoir of terrestrial carbon and involves in recycling more carbon dioxide and water than any other biomes, thus playing a pivotal role in determining Earth's energy balance, which drives global systems of temperature and precipitation. Under a changing climate the global monsoons system is poorly understood. In this study we have analyzed the NOAA ESRL monthly mean CO_2 data for the recent warmest years (2007-2015). During 2007 the average CO_2 was 382.92 ppm, which has increased to 403.26 ppm up to April 2015. The corresponding Indian summer monsoon rainfall in cm for the years (2007-106 %, 2010-102 %, 2011 -102 %, 2014- 88%, 2015 --). The analyses of NOAA CO_2 and Indian summer monsoon seasonal rainfall data contradicts the notion that the global warming trend is favorable for Indian monsoon. It is suggested that the Indian monsoon is a complicated system and deserves deeper understanding.

[PO-17]

ASSESSMENT OF REGCM-4.3.5.6 DOWNSCALED SIMULATION'S INTER ANNUAL SEASONAL VARIABILITY ANALYSIS OF TEMPERATURE AND PRECIPITATION OVER NORTHERN INDIA

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A latest version of Regional Climate Model (RegCM-4.3.5.6) is updated and developed available for public use with new land surface, planetary boundary layer, and air–sea flux schemes, a mixed convection and tropical band configuration, modifications to the pre-existing radiative transfer and boundary layer schemes, and a full upgrade of the model code towards improved flexibility, portability, and user friendliness. In this study almost the whole Northern India was taken for downscaling purpose, covering with the high Himalayan Orography. Climate prediction over the Himalayan is a highly challenging task due to the highly variable altitude and orientation of orographic barriers. Surface characteristics also play a mandatory role in climate simulations and need appropriate representation in the models. In this study, two land surface parameterization schemes (LSPS), the Biosphere-Atmosphere Transfer Scheme (BATS) and the Common Land Model (CLM, version 3.5) in the regional climate model (RegCM – 4.3.5.6) have been tested over the Himalayan region for various seasons (DJF, MAM, JJA, SON) in a year. In this study RegCM-4.3.5.6 is used for predicting the future climate (2001-2025) with Dynamic Downscaling for the IPPC scenario A1B, EH5OM-GCM (Global Circulation model) datasets. These output are validated with CRU Data sets. Maximum temperature gave R^2=0.866 in 10 year's average (2001-2010) of DJF season and R^2=0.846, R^2=0.766, R^2=0.812 are respectively in the MAM, JJA and SON seasons. Minimum temperature gave R^2=0.8586 in 10 year's average (2001-2010) of DJF season and R^2=0.867, R^2=0.854, R^2=0.836 are respectively in the MAM, JJA and SON seasons. Precipitation gave R^2=0.678 in 10 year's average (2001-2010) of DJF season and R^2=0.712, R^2=0.724, R^2=0.675 are respectively in the MAM, JJA and SON seasons. Overall, maximum temperature is 90% correlated with CRU data while the minimum temperature is 92% and rainfall is 65% correlated with CRU observed datasets.

[PO-18]

MECHANISM OF CO_2 AND WATER-VAPOR FLUX TRANSPORT FROM CLOSE TO THE GROUND UNDER TWO VERY DIFFERENT STABILITY REGIMES

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The turbulent transport characteristics of the CO_2 and water-vapor fluxes, have been investigated comprehensively using the eddy-covariance observations from a micrometeorological tower over a semi-arid rural region in southern India during the CAIPEEX-IGOC 2011 campaign. The dataset has been chosen from the morning period when the boundary layer is at its growing phase, receiving the solar heating and encroaching to the residual layer lying above. Two extreme stability conditions i.e. very-unstable and close-to-neutral, encountered close to the ground, have been the focus of this study to illustrate the difference in transport mechanisms of the CO_2 and water vapor fluxes. It has been found that in the very-unstable regime, the large scale Rayleigh-Benard cells transport the bulk of the scalar fluxes from their source point to almost the top of the boundary layer, whereas when it's in close-to-neutral regime the hairpin vortices take up the role of the transport. It has also been hypothesized that the Reynold's analogy holds well for the close-to-neutral regime, thus allowing the first step towards parametirizing the CO_2 and water-vapor flux transport by using the same diffusivity co-efficient as for the momentum.

[PO-19]

CONJUNCTIVE USE OF CANAL AND ALKALI WATER IN RICE BASED CROPPING SYSTEM IN TAMIL NADU, INDIA

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The field experiments were conducted in sodic soil having the pH 8.7 , EC 0.2 dSm^{-1} and ESP 25 % . during October 2012-13 and 2013-14 by raising rice cultivar TRY-1 subsequently, upon harvest of rice, vegetable crops were raised and during 2013, the experiment was laid out in alkali soil (pH – 8.7, EC – 0.21 dS/m, ESP – 25.0). During summer, sowing of vegetable crops were taken and harvested in staggered manner depending upon the maturity of the crop up to September 2014. Results of the experiments revealed that significant yield differences were observed for irrigation treatments and methods of planting in both the years of the study. Canal water irrigation gave high yields (6.23 and 6.30 t / ha respectively during 2012-13 and 2013-14) with the corresponding straw yield of 7.49 and 7.72 t/ha. Lowest grain and straw yields were recorded for alkali water irrigation (4.45 and 4.31 t/ha grain and 5.26 and 5.34 t/ha straw respectively during 2012-13 and 2013-14). Among methods of planting, square planting registered high grain yield (5.85 and 5.90 t/ha respectively during 2012-13 and 2013-14) followed by line planting and machine planting. Conventional planting had poor yield in terms of grain and straw as compared to the other methods of planting. The interaction effect of irrigation treatment and methods of planting was found to be significant. Canal water irrigation combined with square planting had high grain yield followed by canal water and line planting combination. Four different vegetable crops were raised in the second season during summer 2013 after harvest of rice in each main plot which received different irrigation treatments (during rice cropping). The performance of vegetables was superior in the plots receiving canal water irrigation followed by cyclic irrigation with canal and alakali water. However the poor performance of vegetables was obtained in the plot irrigated with alkali water by registering the low yield. Among the different vegetable grown, brinjal registered the higher yield of 16.8 t ha^{-1} by irrigation of canal water with maximum income of Rs. 3.024 lakhs /ha. Next to brinjal, the performance of vegetable crops okra hybrid was better than the rest of vegetables viz. cluster bean and vegetable cow pea. Performance of vegetable under cyclic irrigation with 1:1 ratio of canal and alkali water showed that brinjal registered highest income of Rs. 2.592 lakhs /ha following okra (Rs. 0.879 lakhs/ha) and vegetable cowpea (0.457 lakhs /ha). The lowest income of 0.4144 lakhs /ha was recorded by cluster bean. During 2014 summer after the harvest of rice crop, the each main plot was divided into 4 sub-plots and different vegetable crops viz., Okra, Cluster bean, Lab-lab and vegetable cow pea were sown following the harvest of rice crop in the same experimental plot during June 2014. All the vegetables performed well in M_2 treatment (Irrigating rice with canal and vegetable crops with alkali water) followed by Irrigating rice with canal and alkali water at the ratio of 1:1 conjunctive mode subsequently irrigating vegetable with alkali water (M_3). The plot received both rice and vegetable with alkali water registered the lowest yield. Among the vegetables tried, Okra registered the highest yield of 6.83 t/ha in canal water irrigation. It also recorded the highest income of Rs. 1.866 lakh/ha. The results revealed that the highest yield of okra>cluster bean>lab-lab> vegetable cow pea were registered by different mode of irrigation treatments. Although the yield of cluster bean was superior over vegetable cow pea the income from the vegetable cowpea excelled due the highest market price.

[PO-20]

QUANTIFYING STOMATAL AND AERODYNAMIC CONTROLS OF TERRESTRIAL LATENT HEAT FLUX OVER SOUTH-EAST ASIAN LANDSCAPE WITH A PENMAN-MONTEITH FRAMEWORK

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The latent heat flux (λE) (or evapotranspiration, E) couples the terrestrial water and carbon cycles and the Penman-Monteith (PM) model is a physically based and pragmatic method to directly quantify E. One of the fundamental vigour of the PM model is associated with its intrinsic capacity to express E by combining the physical (radiation and meteorological), ecophysiological as well as ecohydrological signatures within an elegantly constrained thermodynamic formulation. The most important physical and ecophysiological (or ecohydrological) state variables regulating E within the PM model are the aerodynamic conductance exerted by the near-surface boundary layer and the stomatal (or surface) conductance exerted by the vegetation, respectively. Despite receiving universal acclaim due to sound physical realism for quantifying the terrestrial water flux, large scale application of the PM model suffers from unavailability of any physical expression that quantifies the stomatal and aerodynamic behaviour of water vapor transfer within the soil-plant-atmosphere-continuum. The inadequacy of the current approaches used to represent stomata and dynamics of the quasi-laminar boundary layer compromises the quality of the information in PM based E models.

Here, we present a novel approach to physically retrieve the aerodynamic and stomatal conductances (g_B and g_S). Subsequently, we perform a quantification of the controls of both the conductances on E. The proposed research is built on an emergent method, Surface Temperature Initiated Closure (STIC), which physically integrates the radiometric surface temperature (T_R) into the PM formulation for concurrently estimating the conductances as well as E. STIC is formed by the simultaneous solution of multiple state equations. These state equations were formed by combining T_R data with the standard surface energy balance equations and a modified advection–aridity hypothesis in order to derive a hybrid closure of the PM model that does not require specifications of g_B and g_S. Hence, these two quantities are analytically retrieved. In STIC, both the conductances are physically constrained by near surface moisture availability, atmospheric vapor pressure deficit (D_A) and radiative fluxes. STIC is driven with T_R, air temperature (T_A), relative humidity (R_H), net radiation (R_N), and ground heat flux (G). High temporal resolution (half-hourly) measurements from different eddy covariance stations of the AsiaFlux network were used for estimating the conductances and quantifying their controls on E. Our analysis revealed a direct relationship between retrieved g_B and observed sensible heat (H) for different classes of wind velocity and a strong exponential relationship ($R^2 = 0.8$) between g_B and the surface air temperature difference ($T_R - T_A$). This confirms the theoretical hypothesis that at extremely high atmospheric turbulence (i.e., high g_B), a strong coupling between the surface and the atmosphere causes T_R and T_A to converge. Linking g_S with independently measured λE revealed a distinct linearity and the slope of the relationship varies with T_R. This supports the theoretical finding of Monteith (1981), who postulated that g_S decreases linearly with increasing λE when T_R changes (following an inverse hyperbolic relation). A quasi-linear relationship was found between g_S and observed λE for different levels of D_A. Due to the stomatal regulation that tends to keep the λE constant when the D_A changed from low (0 – 10 hPa) to high magnitude (>20 hPa) there was a tendency of g_S to decrease with increasing D_A without any change in the λE. Six linear and cubic relationships fitted the data between g_S and λE with a correlation coefficient of 0.40 ($0< D_A <5$ hPa), 0.45 ($5< D_A <10$ hPa), 0.61 ($10< D_A <15$ hPa), 0.80($15< D_A <20$ hPa), 0.75 ($20< D_A <25$ hPa), and 0.70 ($D_A >=25$ hPa), respectively. Similar controls were found in the spatial domain when STIC was implemented with thermal and optical remote sensing data from MODIS (Moderate Resolution Imaging Spectroradiometer) on-board Terra-Aqua sensors at 1 km spatial resolution.

[PO-21]

LAND-ATMOSPHERE FLUXES OVER SEMI-ARID AGROECOSYSTEMS COMBINING THERMAL REMOTE SENSING AND PENMAN-MONTEITH MODEL WITH SPECIAL REFERENCE TO INDIA

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Semi-arid drylands comprise 15% of the global terrestrial surface and are characterised by active land-atmosphere interactions, strong dynamics in evaporative potential, large magnitude of land surface temperature, and limited water resources for both agriculture and urban use. Such unique combination of impaired surface moisture availability and strong surface-to-air coupling in the semi-arid landscapes makes the specification of land-atmosphere flux components, in particular evapotranspiration (E) and sensible heat flux (H), more sensitive to the boundary conditions, a situation that is often confounded by extreme heterogeneity of these landscapes.

Radiometric surface temperature (T_R) measured through thermal infrared (TIR) remote sensing provides direct information on the land surface moisture status and surface energy balance (SEB) partitioning. Similarly the Penman-Monteith (PM) model is the most pragmatic and the only physical model for estimating SEB fluxes from the terrestrial surfaces. Considering the centrality of TIR remote sensing and the PM model, here we present a novel modeling technique by leveraging their combined strength for estimating E (and H) over a semi-arid agricultural ecosystem in the Gujarat State of western India. The state has a dominant rice-wheat growing belt that extends over the northern, western and central parts of Gujarat and reliable E quantification can significantly affect the agricultural water resource management, planning and decision support systems across a range of spatio-temporal scales over this region.

The proposed research is built on an emergent method, Surface Temperature Initiated Closure (STIC), which physically integrates T_R information into the PM formulation for estimating E, H, conductances, and E components (i.e., evaporation, E_E and transpiration, E_T). STIC combined T_R data with the standard SEB equations and a modified advection–aridity hypothesis for deriving a hybrid closure that does not require specifications of the surface to atmosphere conductance terms; instead the conductances are analytically retrieved. STIC is formed by the simultaneous solution of multiple state equations. Taking the advantage of the psychrometric relationship between the temperature and vapor pressure, this method is also capable to retrieve the land surface wetness (M) from the gradients of T_R, surface dew point temperature (T_{SD}), air dew point temperature (T_D) and air temperature (T_A) to constrain the conductances. STIC is driven with T_R, T_A, relative humidity (R_H), net radiation (R_N), and ground heat flux (G). Thermal and optical remote sensing data from MODIS (Moderate Resolution Imaging Spectroradiometer) on-board Terra-Aqua sensors and AATSR (Advanced Along Track Scanning Radiometer) at 1 to 5 km spatial resolution was used for generating spatially explicit E (and H) over 100 km x 100 km study region. The retrieval of spatial scale R_N and G was based on the standard radiation balance and thermal inertia principles. The estimation of spatially explicit T_A and R_H was based on a novel day-night T_R and thermodynamic principles, respectively. The performance of STIC has been evaluated in comparison to the high temporal frequency measurements of E and H though a large aperture scintillometer (LAS) (Kipp and Zonen LAS 150) and micrometeorological tower at multiple locations. We found a root-mean-square-error (RMSE) between 15 to 18 percent and mean absolute percent deviation (MAPD) between 18 to 20 percent in E and H estimates. An intercomparison of the evaporative flux retrieval for six consecutive summer months (May to October) from year 2007 to 2009 revealed the efficacy of STIC to potentially capture the E and H dynamics during drought (2009) and normal monsoon years (2007 and 2008). The H dynamics of STIC significantly captured the scintillometer observations during extremely dry period of August 2009 when H was increased by 25% as compared to the normal rainfall years. STIC also showed particular promise during the dry-down period where E is strongly governed by the deep layer soil moisture. A high sensitivity of the scheme was noted due to the uncertainties in T_R. A realistic response was also found when the retrieved conductances were compared to the observed meteorological and biophysical variables. This method addressed some of the stumbling blocks that previously hindered the direct use of T_R into the PM modeling system.

Keywords: Surface energy balance, evapotranspiration, Penman-Monteith, semi-arid, scintillometer, thermal remote sensing

[PO-22]

A STUDY ON THE CARBON DECOMPOSITION PROCESS OF THE RESIDUAL BIOMASS AND CH_4 EMISSION IN THE RICE PADDY FIELD

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In a rice field, residual biomass input in the paddy soil after the harvest is decomposed by microbe with time. It is very likely that the greenhouse gases such as CO_2 and CH_4 generated by the decomposition released into the atmosphere. From the difference in residue treatment, the amount and period of GHGs emissions will change. A lot of open burning treatment is carried out around the rice field in which we observe. However, we don't understand the carbon budget and GHGs emissions between the paddy fields and the atmosphere in consideration of open burning enough. Therefore, in this study, we regularly collected Coarse Organic Matter (COM) in paddy soil and estimated carbon emissions by analyzing the decrease in carbon content of COM. In addition, we also estimated the effect of open burning on the carbon decomposition by dividing the target field into two areas on whether or not do open burning. From survey results, Carbon content of COM input in the paddy soil just after the harvest was estimated 344±87gC/m^2 in non-open burning (NB) area, 255±44gC/m^2 in open burning (B) area on the four years average of 2011-2014. Decrease in COM was accelerated at the warming season between April and June. On the other hand, little decomposition and no difference was seen between both areas during rice cultivated season. (July-November) In spite of this result, CH_4 emission of non-open burning area was about three times higher than open burning one during cultivated season. To look into the causes, we investigated the organic matter which was more minute (less than 1mm) by gravity separation experiment.

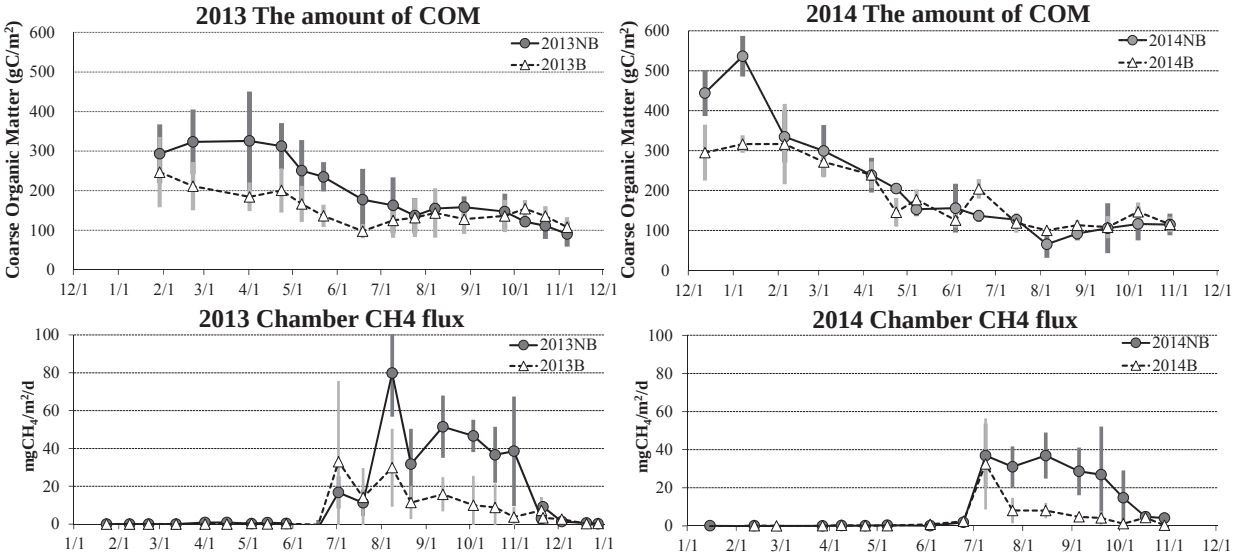

Figure. Seasonal changes of COM and CH_4 flux (2013-2014)

[PO-23]

THE VARIATIONS OF REDOX POTENTIAL IN PADDY SOIL AND EFFECTS ON THE METHANE EMISSION FROM A PERIODICALLY IRRIGATED PADDY FIELD.

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Paddy fields are one of the largest source of CH_4 emission. CH_4 has significant contribution to the global warming next to CO_2 and its global warming potential is about 21 times as large as same amount of CO_2. CH_4 is generated by decomposition of organic matter in soil under anaerobic condition. Redox Potential (Eh) that is the most suitable index representing soil aerobic condition has close relation to CH_4 emission. It is said that CH_4 is generated when Eh shows less than -200mV.

In this study, Eh in paddy soil was measured during rice cultivated season at a periodically irrigated paddy field, and some effects on the CH_4 flux from paddy soil was investigated.

3-days flood and 4-days drained condition were regularly repeated at the observation site from late-June to early October every year. Eh under flooded condition was measured during irrigated term. CH_4 flux was also measured by the aerodynamic gradient technique through rice season.

From the periodical-term point of view, Eh showed rapid decrease in 20 hours from the beginning of flood condition, and finally became between 0mV and -100mV, and kept approximately constant for several days. Lower Eh was shown in later rice season. Eh was almost suitably modeled as a function of irrigation time.

During an irrigation period for three days, higher CH_4 emissions were shown under lower Eh conditions as shown in Fig.1. From the seasonal-term point of view, however, no significant relationship between Eh and CH_4 fluxes. Rapid rise of CH_4 flux in early August and gradual decrease between late August and September were shown. It is suggested that seasonal change of CH_4 flux is affected by seasonal changes of air temperature and the growth level of rice plants.

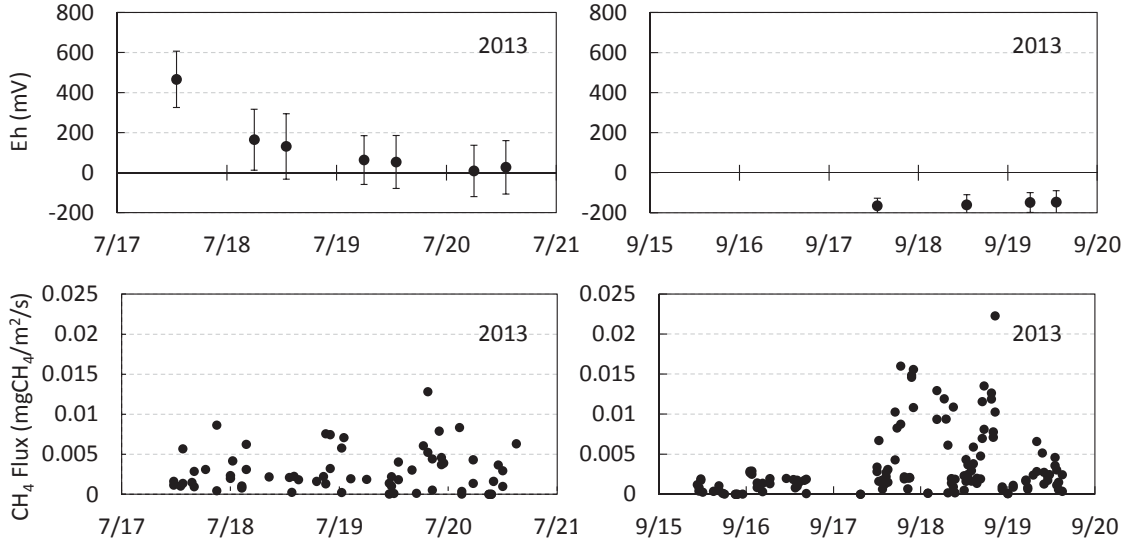

Fig.1. Eh and CH_4 flux during an irrigation period for three days

[PO-24]

EFFECTS OF FOREST CUTTING ON GREENHOUSE GAS DYNAMICS AND SOIL PHYSICO-BIOCHEMICAL PROPERTIES IN JAPANESE TEMPARATE FORESTS

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There are still needs of further investigations to understand the effects of forest cutting on dynamics of greenhouse gasses including carbon dioxide (CO_2) and methane (CH_4). In this study, we investigated greenhouse gas dynamics and soil physico-biochemical properties in 4 Japanese temperate forests where thinning and/or clear-cutting have been conducted.

Four Japanese temperate forests were in Hyogo (34.8° N, 134.5° E), Kochi (33.6° N, 133.7° E), Chiba, (35.3° N, 139.9° E), and Fukushima (37.3° N, 140.6° E). In a forest of Hyogo (Hyogo forest), soils were collected at 2 uncut points in August 2012. In a forest of Kochi (Kochi forest), thinning was conducted at 9 points in October 29th 2012. Soils were collected at thinned points of Kochi forest, before, immediately after, and 1month after the thinning. In Kochi forest, soils at 6 points, where clear cutting was conducted in September 2012, were also collected 3 months after the clear-cutting. In a forest of Chiba (Chiba forest), thinning was conducted at 4points in December 24th 2013, where soils were collected before, immediately after, and 3-12 months after the thinning. Two uncut points were also set nearby 4 thinned points. In a forest of Fukushima (Fukushima forest), cutting was conducted at 4 points in November 2014, where soils were collected before or immediately after the cutting. Soils in 0-10 cm depth from surface were collected in all forests by both core and bulk samplings. Bulk sampled soils were sieved ($\leqq$ 2 mm) before analysis. Analyzed soil physico-biochemical properties were mass-volume relations, pH, electrical conductivity, total carbon and nitrogen, inorganic nitrogen, and microbial biomass. Aerobic soil incubation for 1 week was conducted to measure CO_2 production and CH_4 uptake. Field CO_2 and CH_4 fluxes were also measured in forests of Chiba (in June and October 2014) and Fukushima (in November 2014) by the closed-chamber method. CO_2 and CH_4 concentrations were determined with gas chromatographs equipped with thermal conductivity detector and hydrogen flame ionization detector, respectively.

Soils from Hyogo forest, which were collected at uncut points, showed spatial variations of CO_2 production depending on soil inorganic nitrogen amounts. CH_4 uptake in soils from clear-cut points of Kochi forest was obviously lower than CH_4 uptake in other soils from Kochi forest. Low CH_4 uptake in soils from clear-cut points was considered to result from restricted organic matter decomposition due to total carbon decrease following with forest cutting. CO_2 production and CH_4 uptake of Chiba forest soils from thinned points tended to be higher than that of other Chiba forest soils from uncut points. High CO_2 production and CH_4 uptake of soils from thinned points in Chiba forest were probably due to improvement of microbial activity. The improved microbial activity was considered to result from enough organic matter supply from cut tree residue and rich understory vegetation, and increased sunlight inputs resulting from thinning. Field CO_2 efflux (ca. 120 mg C m^{-2} $hour^{-1}$) at thinned points of Chiba forest in June 2014 was ca. 2-fold higher than uncut points. However, CO_2 and CH_4 fluxes in Chiba forest in October insignificantly differed between thinned and uncut points, probably due to low air temperature in the measurement season. In Fukushima forest, field CO_2 efflux (ca. 70 mg C m^{-2} $hour^{-1}$) and CH_4 influx (ca. 0.2 mg C m^{-2} $hour^{-1}$) before the thinning tended to be high after the thinning, probably due to aeration of subsurface soil by soil disturbance. In the conference, we will also present recent (after 2015) data of greenhouse gas dynamics and soil physico-biochemical properties in Chiba forest.

[PO-25]

NET ECOSYSTEM EXCHANGE, ECOSYSTEM RESPIRATION AND GROSS PRIMARY PRODUCTIVITY IN WHEAT IN NORTH WESTERN INDO-GANGETIC PLAINS

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Net ecosystem exchange of carbon dioxide (NEE) was estimated in wheat crop in middle Indo-Gangetic Plains, at India Agricultural Research Institute, New Delhi, India during 2013-2014. Diurnal variations in mean NEE ranged from +0.38 to -0.85 mg $m^{-2}sec^{-1}$ during the crop growth period. The daily average NEE over the crop season varied from +01.72 to -9.52 g C m^{-2} day^{-1}. Diurnal carbon dioxide uptake in wheat started to increase at around 0700h, reached a peak at between1100–1300h, and then decreased after 1900h. Carbon uptake became dominant in late vegetative to reproductive stage and the wheat field turned into a carbon source after maturity. Highest NEE was observed during heading stage with an uptake rate -5.63 g C m^{-2} d^{-1}. The mean and cumulative NEE was -3.55 g C m^{-2} d^{-1} and -435.18 g C m^{-2} respectively during the crop growth period. The changes in leaf area index (LAI) were directly proportional to the daily variation in net ecosystem production (NEP) at different crop stages i.e. vegetative stage LAI 1.3, NEP 3.03 g C m^{-2} day^{-1}; reproductive stage LAI 4.6, NEP 5.6 g C m^{-2} day^{-1}; maturity stage LAI 2.4, NEP 2.3 g C m^{-2} day^{-1} in wheat. The daily ecosystem respiration (Re) varied from 0.033 to 9 g C m^{-2} $d^{-}1$. The maximum Re (4.57 g C m^{-2} d^{-1}) and gross primary productivity (GPP) (10.72 g C m^{-2} d^{-1}) were observed during heading stage. Significant positive correlation was observed between GPP and photosynthetic active radiation ($r= 0.59$) at $p\leq 0.01$.

[PO-26]

YIELD AND NUTRIENT UPTAKE OF RICE AS AFFECTED BY ELEVATED ATMOSPHERIC TEMPERATURE

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Rice is a major staple cereal crop grown in South and Southeast Asia. Climate change associated with rise in temperature has adverse impact on rice crop. It is therefore important to determine how rice yield and nutrients uptake are influenced by elevated temperature as it would have crucial implications on future food security of this highly-populated region of the world. An experiment was carried out during the kharif season of year 2013 inside Temperature Gradient Tunnel (TGT) Facility developed by the Centre for Environment Science and Climate Resilient Agriculture (CESCRA), in IARI farm (New Delhi, India), to study impact of elevated temperature on yield and nutrient uptake of rice crop. The area inside the tunnel was divided into 5 parts having 5 different temperature treatments. Four nitrogen (N) doses i.e., N0: no N (control), N1: 0.8 g N pot^{-1}, N2: 0.6 g N pot^{-1} and N3: 1.0 g N pot^{-1} was applied in all 5 temperature treatments. Results showed that grain and biomass yield of rice crop significantly decreased with rise in temperature inside the TGT. With recommended N dose yield, reduction of rice was 26.6% with rise in temperature by 3.9ºC but application of 125% N can prevent the yield loss by 5.4% as compared to 100% recommended N treatment. Yield parameters like number of tillers, number of panicles per pot, panicle length, number of grains per panicle and harvest index of rice decreased significantly with rise in temperature. Spikelet sterility of rice increased with increase in temperature. Uptake of nitrogen, phosphorus and potassium decreased with increase in temperature. Agronomic as well as recovery efficiency of rice crop decreased with increase in temperature.

Key words: Elevated temperature, Nutrient uptake, Rice, Yield

[PO-27]

ON THE COMPARISON OF SURFACE LAYER FLUXES OF CO2 AND MOISTURE AT A RURAL AND A SEMI-RURAL STATION

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Surface layer fluxes are measured employing eddy covariance method) at rural (Mesra, Ranchi) and semi rural (Mahabubnagar,M.nagar) stations both located at eastern latitudes of India. The first station had tall Sal tress about 100 m east of the tower site and is inhabited considerably on the eastern and southern sides of the site. The second one is rather partially cultivated and sparsely populated with lesser vehicle passage except for an occasional train passing by the eastern side of the tower site. Both the sites qualify for complex canopy but having a desirable, practically homogenous upwind fetch of land.

Observations were made at Mesra during start of winter (November) with clear skies and at M.nagar during post SW monsoon period (October). Day time CO_2 fluxes at both stations show significant negative flux due to uptake by plants during 8-10 am thereafter the fluxes reduce significantly. CO_2 fixation is an order more at Mesra than at M.nagar and during this period CO_2 fixation is also rapid with a reduction of 50 ppm and 130 ppm respectively. The minimum (maximum reduction) occurs with about an hour time lag. At Mesra reduction of CO_2 flux is quicker so is the increase in CO_2 thereafter, while at M.nagar CO_2 apparently stays at a steady level for longer time and slowly increases.

Moisture flux at Mesra during this period measures about 200 Wm^{-2} while at M.nagar it is higher at 350 Wm^{-2}. At Mesra, soil heat flux tends to be positive after 12 hr noon only.

The difference in pattern of reduction in CO_2 at these two stations shows the influence of anthropogenic activities having, over photosynthesis fixation by plants. Even an order more strong photosynthesis (negative CO_2 flux) at Mesra is also unable to bring down CO_2 as effectively and maintain it that way as in M.nagar with much less CO_2 flux. The variations in LE and soil heat flux are the outcomes of meteorological influence of the respective stations. Former station with much lower temperatures as evidenced by the net radiation values produces a relatively less LE whereas higher temperatures combined with availability of soil moisture result in higher LE in the later. During winter, soil is covered with dew at Mesra, this should have restricted soil heat flux attaining positive values before noon.

[PO-28]

TRADE-OFF ASSOCIATION BETWEEN CH_4 AND N_2O EMISSION UNDER DIFFERENT CULTIVATION PRACTICES OF KHARIF RICE – A COMPREHENSIVE STUDY

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Crop management practices have a significant impact on greenhouse gas (GHG) emissions rates. Recent findings clearly indicated that methane (CH_4) and nitrous oxide (N_2O) emission in rice paddy fields are in trade off relationship. A two year field study (2013 and 2014) was conducted to simultaneously measure CH_4 and N_2O emissions from rice paddies under various agricultural managements schedule like water regimes (irrigated and rainfed), transplanting dates (27th June and 12th July), and nutritional amendments (synthetic fertilizer where N as ammonium sulphate, P and K as per recommended dose and vermicompost). Rainfed situation incurred a drop in CH_4 fluxes triggering substantial N_2O emission. Ammonium sulphate application tended to reduce CH_4 emissions but significantly increased N_2O emissions. Results indicated that rice growth stages played crucial role in GHGs emission. Major CH_4 fluxes occurred during panicle initiation to flowering stage whereas flowering to milking stage was responsible for N_2O emission. Both the gases showed significant interrelationship at specified growth phases in each year. During 1st season significant associations were noticed between both GHGs at flowering and milking stages (R^2 = 0.93 and 0.90 respectively) due to ammonium sulphate fertilization. Similar trend was observed due to moisture regimes at panicle initiation stage where R^2 = 0.85 and 0.93 respectively for irrigated and rainfed situation. Whereas in 2nd rice season close relationship was found between these two gases during panicle initiation under two transplanting dates (R^2= 0.75 and 0.84 for 27th June and 12th July respectively) and for vermicompost application and irrigated condition (R^2= 0.80 and 0.79 respectively). In addition seasonal average of CH_4 and N_2O emissions were also correlated with rice production under various management practices in both the seasons. As a main theme of the work we can say that GHGs emissions may control to some extent optimizing rice productivity through implementing crop and location specific management practices. Management should be focused on modification of ITK (Indigenous traditional knowledge).

Key words: ITK , Methane, Nitrous oxide, trade off relation, rice yield

[PO-29]

WHEAT BIOMASS CONTRIBUTION TO NITROUS OXIDE EMISSION UNDER GANGETIC ALLUVIAL AGRO CLIMATIC ENVIRONMENT

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Plant biomass played a pivotal influence on N2O emission. To establish the fact two year field experiment was performed in the Gangetic West Bengal, India to examine the role of winter wheat growth parameters on nitrous oxide (N2O) emission along with production potentiality. Wheat variety K0307 was taken into account for the study with various nutritional amendments (100% synthetic, 50%synthetic+50%organic and 100% organic as vermincompost) and sown on three different dates at 15 days intervals starting from 30th October. Over the 2012-13 and 2013-14 wheat cropping season nitrous oxide emissions was depended on nutritional approaches and dates of sowing and showed a pronounced inter-annual variation. Maximum emission was noticed due to 100% chemical fertilizer application especially for the third date of sowing in both the years. There was also a distinct variation in nitrous oxide emission due to various dates of sowing. Study revealed that significant associations among plant height, dry matter content of root and shoot part of wheat crop and nitrous oxide emission after targeted time interval influenced by specific factors. Some compromising association was established between the production component and N2O emission. (R2 =0.77 and 0.89 for consecutive two dates of sowing during 2012-13 but for 2013-14 third date of sowing showed close relations with N2O (R2 = 0.91). Vermicompost had also some crucial role in N2O emission and Yield of wheat during 2013-14 (R2 = 0.74). Results indicated that nitrous oxide emission from soil during winter wheat crop cultivation may also be influenced by crop biomass production at different time interval. So it is concluded that wheat plants and its growth attributes may have potential contribution in nitrous oxide emission.

Key words: Date of sowing, Growth parameters, nitrous oxide, nutrients, yield.

[PO-30]

RESPONDING OF NET ECOSYSTEM CO2 EXCHANGE ON MICROMETEOROLOGICAL FACTOR IN DRY DIPTEROCARP FOREST USING EDDY COVARIANCE TECHNIQUE

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The carbon storage in tropical forest is an important part of global carbon sink. This processes are controlled by photosynthesis and respiration processes of plant. Generally, in dry season dipterocarp forest ecosystems become dry and face the wildfire risk that may effect to the forest function such as ecosystem service. This study aims to estimate carbon dioxide exchange between atmosphere and terrestrial ecosystem under the micrometeorological factors. The study area located in dry dipterocarp forest flux Phayao site Thailand (DPT: 19° 02' 14.38" N, 99° 54' 10.96" E, 512 msl., relatively high slope) Phayao, Thailand. The data from eddy covariance technique was analyzed since January until December in 2014

NEE was -6.63 to 3.11 μmol m-2 s-1 (-1.74±1.61 μmol m-2 s-1 or 661± 49 gC m-2 yr-1) and the maximum was found in October (-4.05 μmol m-2 s-1), while minimum was in March (1.26 μmol m^{-2} s^{-1}). The diurnal pattern of averaged annual NEE were correlated using polynomial regression (R2=0.98) with the diurnal pattern of mean annual PAR (photosynthetically active radiation) and soil water content (R2=0.64). While, the monthly pattern of average NEE was correlated by polynomial regression with monthly mean air temperature (R2=0.74), relative humidity (R2=0.57), soil temperature (R2=0.54) and soil water content (R2=0.50), respectively. In conclusion, NEE in diurnal pattern were controlled by PAR and soil water content, while in monthly pattern, air temperature, relative humidity, soil temperature and soil water content were the main factor for environmental control respectively. However, evaluation of the carbon sequestration potential should be based on long-term monitoring.

Keywords: Net Ecosystem CO2 Exchange, Dry dipterocarp forest, Eddy covariance technique

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[PO-31]

METHANE MITIGATION POTENTIAL OF AZOLLA AND CYANOBACTERIA (BLUE-GREEN ALGAE) IN RICE

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Methane (CH_4) is second most potent greenhouse gas after carbon dioxide. Mitigation of CH_4 emission from soil is important for combating climate change. Rice cultivation under submerged condition facilitates CH_4 production in soil. An experiment was conducted using different types of fertilizers for sources of nitrogen (N) in rice paddy soil to evaluate their effect on CH_4 emission and plant growth during flooded rice cultivation. The treatments consisted of T1– urea (120 kg N ha-1), T2- urea (95 kg N ha-1) plus azolla (30 kg N ha-1), T3- urea (90 kg N ha-1) plus blue-green algae (BGA) (25 kg N ha-1) and T4- urea (65 kg N ha-1) plus BGA (25 kg N ha-1) plus azolla (30 kg N ha-1). Cumulative CH4 was highest in urea treated (T1) plots (31.80 kg ha-1), while the lowest CH_4 emission was recorded in urea plus BGA plus azolla (T4) plots (24.38 kg ha-1). Total seasonal CH_4 emissions were reduced by 8.29 %, 12.88 %, and 15.30 % of application of with BGA, azolla, and BGA plus azolla respectively over urea application. Economical yield was found to be statistically at par in all the fertilizers treatments. Therefore, based on this field study it could be suggested that application of BGA and azolla singly or in combination has potential to significantly reduction of CH_4 emission from flooded rice soil.

Keywords: Rice soil, Methane, Cyanobacteria and Azolla

[PO-32]

DETERMING SURFACE ENERGY BALANCE COMPONENT OVER POTATO FIELD USING AERODYNAMIC RESISTANCE METHOD

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Considering the increase of water demand for agriculture, estimation of evaporative losses becomes significantly important. The latent energy flux (LE) estimation can provide better solution to water management as it is directly related to evapo-transpiration (ET). An investigation was carried out to estimate the surface energy balance components over potato field in 2014-15 in the lower Gangetic Plains of West Bengal, India. With the help of micromet tower, data on temperature, humidity and wind speed were collected at seven days interval covering different crop growth stages on diurnal basis. Simultaneously, the soil heat flux, plant height, LAI, etc., were also measured. The diurnal and seasonal variations of constants related to momentum and flux transfer were studied along with sensible, soil and latent heat fluxes. It has been observed that sensible heat flux varied between 1.87 W m^{-2} to 7.7 W m^{-2} on diurnal basis. On the other hand the variation of soil heat flux was not so high throughout the growing season. The latent energy was lower during initial crop growth stage and first leaf drying stage. During these two stages irrigation was not given and the moisture condition of the field was reflected in LE values. At 50% leaf drying stage the net radiation was higher (350 W m^{-2}), hence relatively higher LE was observed at this stage although the field condition was dry. The estimation of latent energy flux thus help the irrigation scheduling of a crop like potato.

Keywords: Energy balance, ET, Latent energy, Potato.

[PO-33]

NET EXCHANGE OF CO_2 OVER A WINTER WHEAT ECOSYSTEM IN PENINSULAR INDIA: BIOPHYSICAL AND ENVIRONMENTAL CONTROLS

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Net ecosystem exchange (NEE) of CO_2 of wheat (*Triticum aestivum*) grown in *deccan* plateau of peninsular India was quantified using an open path eddy covariance technique. The crop was raised as irrigated during November, 2014 – February, 2015 in the shallow and less productive soil of the farm of ICAR-National Institute of Abiotic Stress Management, Baramati (Latitude: 18°09' N, Longitude: 74°30' E, average elevation: ~ 550 m AMSL) situated in the water scarcity zone (MH-6) of Maharashtra state of India. The crop dynamics was monitored using a spectroradiometer that could detect changes, particularly around 60 DAS or 1000 °C-Day of heat unit accumulation (GDD) when the crop was changing from vegetative to reproductive phase. In different phases, *viz.* sowing to crown root initiation (CRI), CRI to maximum tillering, maximum tillering to anthesis, flowering to dough and dough to maturity, the net daytime CO_2 exchange rates were 3.3, -2.0, -8.0, -7.5 and -3.1 µmol $m^{-2}s^{-1}$, respectively wherein positive values of exchange rate indicated net upward movement of CO_2 *i.e.* from crop surface to the atmosphere above and negative values the opposite. Vegetation indices, *viz.* WBI, NDWI, hBR, hNDVI and PRI, computed from 1 nm interval spectral reflectance data in the 350-2500 nm region, showed significant correlations (correlation coefficient, r >0.70, p>0.05; for WBI p >0.01) with the daytime NEE (NEEd). The relation between the eddy covariance based half-hourly net CO_2 flux (1100-1630 hr local mean time) and corresponding net photosynthesis of leaves during flag leaf and milking stages, measured using a portable photosynthesis system (GFS-3000, Walz), was also statistically significant (r =0.36, p =0.01) wherein high net photosynthesis rates were generally associated with high rates of net CO_2 transfer from atmosphere to the crop below. Seasonal average half-hourly daytime dynamics shows that mid-noon (1200-1300 hr local mean time) peak rates of net CO_2 exchange rate coincided with that of net radiation when soil temperature was low or favourable and air temperature as well as vapour pressure deficit (VPD) remained well below their peak values. The influence of environmental variables on daytime net CO_2 exchange rate (NEEd) was most vivid during the reproductive phase wherein net radiation, insolation, soil moisture, soil temperature, ambient temperature and VPD were found to be significantly correlated with NEEd (r: 0.43-0.74, p<0.05). Overall, soil and air temperature appeared to be the more important controlling factors for NEEd as those significantly influenced the exchange rates in both the vegetative and reproductive phases. A second order polynomial equation fitted into the relationship between NEEd and GDD could explain 77 % of the variation in NEEd (Fig.1). For the wheat which had a grain yield of 3.7 t ha^{-1} and 4.2 as the peak value of area average LAI, the daytime average CO_2 sink value between sowing and harvesting was computed as -4.6 µmol m^{-2} s^{-1}. Net available energy could explain 93 % of variation in turbulent fluxes of sensible and latent heat thereby validating the CO_2 flux measurements by the eddy covariance method (Fig. 2).

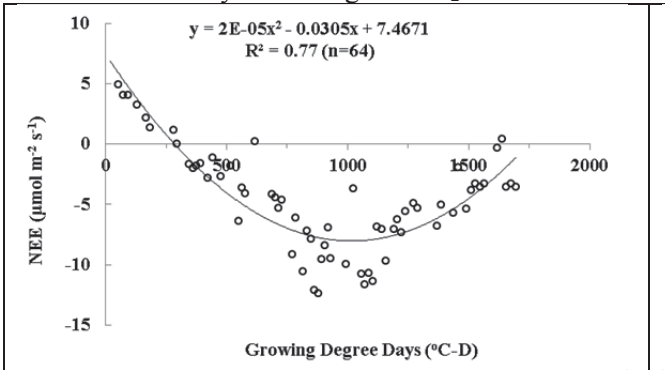

Fig. 1. Seasonal dynamics of daytime net CO_2 flux (NEEd) over Wheat (Nov-14 to Feb15)

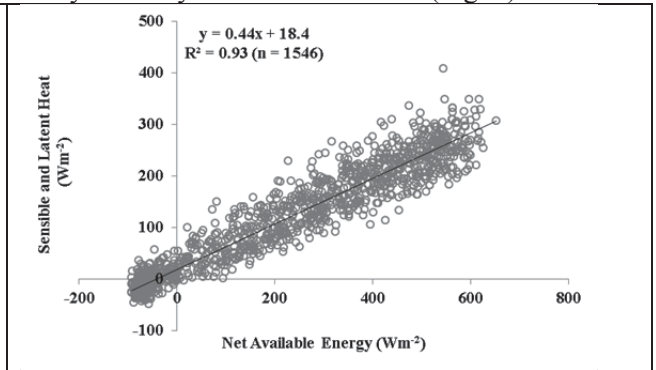

Fig. 2. Validation of net CO_2 flux over wheat through energy balance closure (Nov-14 to Feb15)

[PO-34]

AN ASSESSMENT OF N_2O FLUX DENSITY OF WINTER WHEAT AS INFLUENCED BY SOIL ENVIRONMENT

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Agricultural soils are major contributor of greenhouse gases emission as soil contains large amounts of carbon and nitrogen. However, these emissions are strongly influenced by soil properties which regulate the rapid nitrification and denitrification in crop soil. Fluctuations in the nitrous oxide (N_2O) flux from wheat (*Triticum aestivum* L. Var. HD2733) were investigated over two consecutive winter seasons of 2012-13 and 2013-14 in the New Alluvial Agroclimatic Zone of West Bengal, India. Experiment was designed with three dates of sowing (30th October, 15th November and 30th November) along with three different nutritional amendments viz. 100% synthetic fertilizer, 50% synthetic+50% organic and 100% organic fertilizer (vermicompost as source of N, P and K). In this study we have analyzed soil organic carbon content, pH, electrical conductivity and soil available phosphorus and moisture content to find out their importance on N_2O emissions from wheat crop after specific time interval. Results focused on seasonal change in N_2O emission, varied from -7.25 to 10.83 g/m^2/day during 2013-14 and 0.23 to 10.92 g/m^2/day during 2012-13. Dates of sowing and applied fertilizer had some influence on N_2O flux density. Significant correlations between soil parameters and N_2O flux rates were observed at different time span. Results also indicated that there was an increasing trend of N_2O emission with increasing soil organic carbon content. Here increased soil C:N ratio may be responsible to increase N_2O emission. While soil moisture content played an important role in controlling flux rates of N_2O as the gas tended to decrease with increasing soil moisture. Differences in the magnitude of N_2O emissions at varying soil moisture were due to available substrate N and the predominance of nitrification under aerobic conditions. Differences in N_2O emissions at varying soil EC was also measured .Thus it can be concluded that soil or edaphic factors are the main driving force for soil microbial activities which regulate N_2O flux potentiality in crop soil.

Key words: Available phosphorus, EC, Moisture content, N_2O flux, Organic carbon, pH, wheat

[PO-35]

SURFACE ENERGY FLUXES PATTERN OVER IRRIGATED CROPLAND AND SEBS MODEL VALIDATION BY LARGE APERTURE SCINTILLOMETRY

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Scintillometry is one of the best tools for measuring areal averaged sensible heat flux and frictional velocity and finally estimating latent heat flux, actual evapotranspiration, bowen ratio and evaporative fraction from a landscape. These fluxes/parameters over a cropland are important to understand the interaction between the crop surface and atmosphere including practical applications in crop yield prediction and water resources management. A large aperture Scintillometer (LAS) instrument of Kipp & Zonen-Mk II make has been installed in the experimental farm of Indian Agricultural Research Institute, New Delhi, covering a path length of 990 m over intensively cultivated irrigated cropland. The LAS is complemented with an automatic meteorological station having a pyranometer, net radiometer, temperature and wind speed sensors at two heights, wind direction sensor and a soil heat flux plate at 10cm depth. This study describes the results of diurnal and seasonal patterns of radiation, sensible and latent heat fluxes and evaporative fraction observed during fallow period followed by kharif and rabi crop seasons of 2014-15. The LAS footprint was mainly dominated by maize crop during kharif and wheat during rabi. The observations on crop phenology, growth (LAI and height) and soil moisture were recorded at fortnightly interval along the LAS path length at regular sampling distance. The diurnal pattern of fluxes at different growth stages of the crop and their seasonal patterns were analyzed in relation to crop parameters and soil moisture. The partitioning of energy among sensible, latent and soil heat fluxes were compared for fallow, kharif and rabi crop seasons. The SEBS (Surface Energy Balance System) model coded in Python was setup for the study area to compute net radiation flux, turbulent fluxes of sensible and latent heat, evaporative fraction and actual evapotranspiration from satellite remote sensing measurements in combination with meteorological observations. The land surface physical parameters of albedo, emissivity, temperature, vegetation index etc., from spectral reflectance and radiance measurements by MODIS sensor were used as input to SEBS model. The model estimated fluxes and parameters were validated with LAS measurements at different time during the year. The detailed analysis of diurnal and seasonal fluxes and model validation results will be presented.

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[PO-36]

IMPACT OF OZONE DRIVEN CLIMATE CHANGE ON ATMOSPHERIC COMPOSITION AND AIR QUALITY OVER THE ASIAN REGION

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An attempt has made to explain the influence of Ozone driven Climate change on atmospheric composition and air quality index using measurements from MIPAS (Michelson Interferometer for Passive Atmospheric Sounding), Aura MLS (Microwave Lime Sounder), SBUV (Solar Backscatter Ultraviolet spectrometer) and SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Cartography) data. Air Quality Index is obtained from World Air Quality Index website and Central Pollution Control Board, India. Degradation of Air Quality is the most important environmental Hazard, facing in modern years. Transport and Circulation of atmospheric trace gases contribute to changes in climate and Air quality. From this analysis with the help of different datasets, it is found that the concentration of ozone change leads to Climate change and probably a change in Air Quality. This study further extended to analyze the tropospheric ozone variation in response to stratospheric variation. The detailed analysis will be carried out and the results will be presented in the meeting.

[PO-37]

TRENDS AND VARIABILITY OF TROPOSPHERIC OZONE MEASURED FROM AURA MICROWAVE LIMB SOUNDER OVER CHENNAI (13.08^{O}N, 80.27^{O}E), INDIA

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This work mainly focuses to analyze the variability of Ground level ozone using Aura Microwave Limb Sounder (MLS) measurements from 2004-2014. Tropospheric Ozone is a global air pollution problem and an important green house gas. It is a powerful oxidant that damages human health and natural environment and climate system. Aura MLS provides useful information atmospheric chemical constituents, climate change. Ozone has recognized as a significant factor in determining air quality issue, this study presents the climatological, seasonal variability of tropospheric ozone, in turn how the tropospheric ozone affect air quality and climate system at Chennai, India using MLS data.

[PO-38]

PARTICULATE-BOUND POLYCYCLIC AROMATIC HYDROCARBONS IN URBAN ECOSYSTEM OF DELHI

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In the present study, concentrations of particulate-bound polycyclic aromatic hydrocarbons (p-PAHs) were investigated to examine the status, characteristics and sources of atmospheric p-PAH pollution in the urban ecosystem of Delhi, India. The mean Σ_{16} PAHs concentration during sampling period (July 13 to January 14) was 61.47±8.97 ngm^{-3} for Delhi. The observed concentrations of total p-PAHs were 33.38 and 71.43 ngm^{-3} for background site and 38.80 and 84.87 ngm^{-3} for traffic site in monsoon and winter season seasons, respectively. Particulate PAH profiles were dominated by 5-, 4- and 3-ring at both the sites in Delhi. Principal component analysis (PCA) was used to identify potential sources of PAHs. Thus, overall study signifies that particulate PAHs concentration in Delhi, India is mostly governed by traffic emission and coal combustion related sources.

[PO-39]

IMPACT OF THE 2012-2013 SUMMER HEATWAVES ON FOREST PRODUCTIVITY IN EASTERN AUSTRALIA

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The frequency of extreme heat events in Australia has changed. Heatwaves and droughts have been reported to cause reductions in primary productivity and it was postulated that an increase in drought frequency could turn temperate ecosystems into carbon sources, thereby contributing to a positive carbon-climate feedback. Eucalyptus trees are known to be among the most adaptive plant species on Earth, allowing them to thrive under some of the hardiest ecological conditions. During the summer of 2012-2013, Australia experienced the warmest summer on record and a series of particularly intense heatwaves, which strongly affected the temperate regions in SE Australia. We have used continuous eddy covariance measurements of ecosystem-scale carbon dioxide fluxes to analyse the ecosystem response to these extreme weather conditions. We will show the short time consequences of primary productivity and ecosystem respiration to the record temperatures and under increasingly low soil moisture conditions.

[PO-40]

CARBON FLUXES IN TROPICAL SEASONAL FOREST OF SOUTHERN VIETNAM

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Joint Vietnam-Russian tropical research and test center are involved in the complex ecological studies in Vietnam. In 2009 year investigations of soil CO_2 fluxes were begun in the southern of Vietnam in territory of Cat Tien national park (N 11°27', E 107°24'). In November 2011 year the carbon studies were expanded and the first eddy covariance tower was erected. The study area is described as a tropical monsoon valley tall-stand forest at altitude about 156 m above sea level. Canopy height is ~ 37 m. Forest has 3-5 canopy sub-stages and rich biodiversity (80 tree species), predominant spp. on drained plots are Lagerstroemia calyculata (Lythraceae), Haldina cordifolia (Rubiaceae), Tetrameles nudiflora (Datiscaceae), Afzelia xylocarpa (Caesalpiniaceae), Sterculia cf. cochinchinensis (Sterculiaceae). Soils are medium-rich ultisols over basalt rock. Climate is tropical monsoon with 2 seasons: dry winter (each month from December to March has less than 100 mm of rain) with temperature of +24...+28 and rainy summer with +26 on average. Total year precipitation is 2518 mm (Dong Xoai meteorological station, 1981-2010).

Ecosystem CO_2 fluxes were investigated under canopy of forest at the height 50m. Eddy covariance system consisted of LI-7500A open-path gas analyzer and CSAT3 sonic anemometer. All the standard EC procedures were applied to the raw 10-Hz data including time-lag compensation, block average, WPL-correction, planar fit, low- and high-frequency corrections etc. in EddyPro software (LI-COR Inc., USA). Soil respiration fluxes were estimated by chamber methods on the base of gas analyzer LI-810 (LI-COR Inc., USA).

Generally our studies have allowed to estimate spatial and temporal variations of net ecosystems exchange, soil respiration, ecosystem respiration, gross primary production and their depending on environmental factors. The results of researches have confirmed strong seasonality of CO_2 fluxes connected with regime of precipitations. For period of our studies seasonal tropical forest of southern Vietnam was strong sink for CO_2 about -400 $gC \bullet m^{-2} \bullet y^{-1}$.

[PO-41]

THERMODYNAMICAL CHARACTERISTICS OF CAT TIEN TROPICAL FORESTS, BASED ON REMOTE SENSING DATA

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Study of energy and matter transformation in ecosystems are carried out at permanent study areas, at the points with years of research data covering structures and processes in the local ecosystems. Thus, measurements of eddy-covariance systems allow characterizing the area, in the best case, a few square kilometers. The development of remote methods of research, in particular multi- and hyperspectral satellite imagery allows to extrapolate the parameters of the functioning of ecosystems at local level, in a particular point in space, to the landscape level, with the assessment of parameters for land cover entire regions. Developed in the last decade, the thermodynamic approach to the environment, based on the remote multi- and hyperspectral allows to obtain data estimates of the basic parameters of converting solar energy by ecosystem at the moments of the shooting, which in combination with high-frequency eddy-covariance measurements should ultimately contribute to the creation of a single measuring system of ecosystem functioning parameters in a wide range of scales. Estimates of thermodynamic variables in the local and regional levels have shown that the key role in the formation of mesoclimate is owned by forest vegetation, and during its active working forest act as "biotic pump", intensifying the cycle of water and pumping it to the continental regions. For the global level it is shown that greater contribution to the global circulation climate can be attributed to boreal and tropical forests of the northern hemisphere. Installation of the Eddy-covariance complex in the National Park Cat Tien with its long history of research on the state of soil and vegetation cover creates a unique opportunity to assess the parameters of energy conversion of tropical monsoon forest ecosystems with a combination of remote sensing and Eddy-covariance.

Method of calculation of the reflected solar energy by Landsat 8 OLI multispectral scanner imagery is described in the relevant manuals. Image brightness values in bands are converted into the stream of radiation reflected by the Earth's surface (Wt/m^2), the influx of energy is measured according to the solar constant (taking into account the sun angle and the distance from the Earth to the Sun), the absorbed energy – the difference between influx and reflected energy. On long-wavelength band the general heat flux (Wt/m^2) and the temperature of the active surface (C^o) are calculated. Exergy measurement (effective yield of the system, the expenditures of energy for evaporation) for multispectral scenes through the distance between the spectral energy distribution of the absorbed solar energy and equilibrium state - hypothetical absorption of solar energy is proportional to the energy distribution in the spectrum of the solar constant. The deviation of the absorption spectrum of the real equilibrium is measured at the increment of Kullback information. Bound energy is calculated as the product of the heat flux and the entropy of the reflected solar energy. The increment of internal energy is evaluated as absorbed energy minus net exergy and related energy. To estimate the direct cost of energy used in the biological production difference in the reflected energy in the red and near-infrared regions - the index of production (vegetation index) is used. The components of energy balance were assessed as a percentage of the incoming solar radiation.

In the present report we examine the spatial variation of the thermodynamic characteristics calculated for multispectral Landsat 8 OLI with a spatial resolution of 30x30 m for the western part of the National Park Cat Tien (area of 400 km^2) during the end of the wet season (November 2014) and the middle of the dry season (February 2014). As a result of the comparison of the thermodynamic characteristics calculated for two terms, we can say that the monsoon rainforest increasing moisture at a constant solar radiation level leads to increases the absorption of solar energy and energy costs for evaporation, while maintaining the other components of the balance at almost the same level.

This work was supported by the Russian Science Foundation, the project N 14-27-00065.

[PO-42]
FILTERING DRAINAGE-AFFECTED EDDY COVARIANCE OBSERVATIONS ON A FOREST HILL SLOPE USING DYNAMICAL PROCESS NETWORKS

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Observation of net ecosystem exchange (NEE) of carbon dioxide (CO_2) by the eddy covariance (EC) technique in a hilly terrain affected by drainage flow is a difficult problem because the lateral advective CO_2 flux is not negligible in these circumstances. Downslope drainage can result in overestimation of respiration at the bottom of a hill slope, and underestimation at the top. A multi-level CO_2 concentration vertical profile from the ground to above the canopy has been measured along with above-canopy EC flux measurements at the top and bottom of a hill slope i.e., the GDK and GCK flux sites of KoFlux from 2008 to 2010. To infer the timing, relative strength, direction, and location of CO_2 advection from the uphill to the downhill, we constructed an information flow dynamical process network (DPN) based on the observed multi-level CO_2 concentrations. A site-specific quality control filter is developed to identify data strongly affected by CO_2 advection, by eliminating observations while strong downslope information flow exists in the DPN. This site-specific filter considerably solves the discrepancy between the general theoretical corrections. This research provides the methodological foundation both for the general characterization of advection using a DPN and for its application as site-specific filter for EC observation located at hilly and complex terrain.

Acknowledgment. This work was funded by the Korea Meteorological Administration Research and Development Program under Grant Weather Information Service Engine (WISE) project, 153-3100-3133-302-350.

[PO-43]

LEAF PHENOLOGY OF A TROPICAL MONSOONAL EVERGREEN FOREST OBSERVED BY A LONG-TERM RECORD OF CANOPY PHOTOGRAPHS , AND INFLUENCE OF CLIMATE ON GREEN-UP AT SAKAERAT (SKR), THAILAND

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The leaf phenology of the tropical monsoonal evergreen (dry evergreen) forest around the Sakaerat (SKR) flux monitoring tower, Thailand (14°29'33"N, 101°54'59"E) during 8 years since 2007 has been analyzed by the numerical method to objectively detect seasonal variations of phenology of forest canopy by a series of daily fixed view photographs (Maeda and Gamo, 2004, patented). The image analysis utilizes the seasonal patterns that appear in the time series of 'RGB normalized intensities', i.e., monochromatic intensity (brightness) of individual RGB channels normalized by panchromatic intensity, over the field of the view of daily digital images (Fig. 1). The forest canopy around the SKR flux tower is dominated by *Hopea ferrea*, evergreen dipterocarp species. The upper panels in Fig. 2 shows the time series of the RGB normalized intensities in typical years. For the case of the evergreen forest around the SKR tower, rapid increase of the normalized intensity of green channel (green-up) corresponding to emergence of new leaves covering the canopy can be detected around 150-300 DOY, in the rainy season in Thailand. In the previous AsiaFlux workshop in 2011, we reported that this green-up in the rainy season was delayed in 2009 due to the draught associated with the El Niño phenomenon. Some more discussions about relationship between the timings of green-up and climate, based on the 8-years record that includes various climatic conditions, are presented. The result shows that the timing of emergence of new leaves of *Hopea* trees in the SKR site varies year by year in the order of months, and is mostly water-limited, and initiated only when the soil water content near the surface keeps 0.15-0.2 m^3/m^3 continuously for more than 2 weeks.

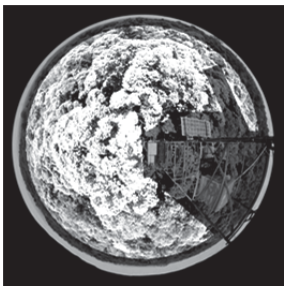

Fig. 1. The field of the view of the canopy photographs.

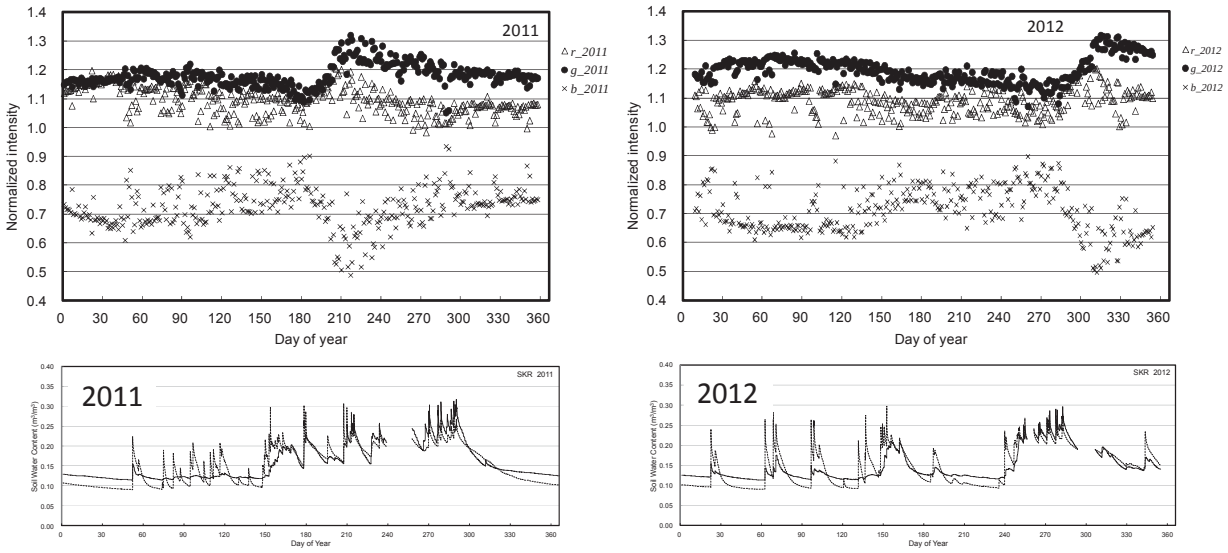

Fig. 2 Examples of seasonal variations of the RGB normalized intensities (*r*, *g*, *b*) of the forest canopies on the community scale in the SKR flux site, in the years with earlier green up (2011, left) and delayed green up (2012, right). Lower panels are the seasonal variations of the in-situ soil water contents at the depths of 10cm and 50cm in the corresponding years to the upper panels.

[PO-44]
LONG-TERM MONITORING OF CO_2 EXCHANGE OVER A LARCH FOREST IN CENTRAL JAPAN

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We report the 9-year (2006-2014) measurements of the net ecosystem CO_2 exchange flux (NEE) over a larch forest on foothill of the Japanese highest mountain Mt. Fuji. Larch forests are widely distributed in high latitude region and are dominant vegetation types especially in the north-eastern Eurasia. We focus characteristics of temporal variations in NEE and their relationships with environmental factors and phenology in forest stand. We evaluate year-to-year variations in the seasonal patterns of flux-components and investigate factors controlling the NEE. Frequent reduction of light-availability due to passage of seasonal rain front likely restrict photosynthetic CO_2 uptake at this site. NEE, Gross primary production (GPP) and ecosystem respiration (RE) showed inter-annual variations in their seasonal pattern. Length of growing season was different among the years. The difference is mainly due to the difference in timing of when leaf scenescence progressed to a certain level that is closely controlled by temperature.

[PO-45]

MODELING NET ECOSYSTEM CO_2 EXCHANGE IN NORTHERN CHINA AND THE TIBETAN PLATEAU BASED SOLELY ON MODIS IMAGERY

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An important goal of studying carbon cycle is to accurately quantify net ecosystem CO_2 exchange (NEE) between terrestrial ecosystems and the atmosphere. NEE is a small difference between two large fluxes of gross primary production (GPP) and ecosystem respiration (Re). In this study, we developed a Remote Sensing Model for NEE (NEERSM) based on the PCM and the ReRSM, both of which are separately used for modeling variations in GPP and Re. The NEERSM were driven by the Enhanced Vegetation Index (EVI), the Land Surface Water Index (LSWI) and the Land Surface Temperature (LST) from MODIS data. Multi-year eddy CO_2 flux data of five vegetation types in Northern China (including temperate mixed forest and temperate steppe) and the Tibetan Plateau (alpine shrubland, alpine marsh and alpine meadow-steppe) from the Chinese Terrestrial Ecosystem Flux Research Network (ChinaFLUX) were used to assess model performance. The model parameters were gained from three approaches. The first were directly derived from the PCM and the ReRSM. The second were calculated from the semi-empirical equations of model parameters of the PCM and the ReRSM. The third were fitted by using the flux-observed NEE. Comparison analyses showed that the performance of the NEERSM with the parameters from the third approach was better than that from the first or the second approach, which could explain 50%~79% of the variations among five vegetation types. In most cases, the seasonal and interannual variation in the NEERSM-estimated NEE was consistent with the flux-observed NEE irrespective of vegetation type. By gathering all site-years data across five vegetation types, the NEERSM-estimated NEE could explain approximately 77% of the variation in the flux-observed NEE on 8-day average, 84% of the variation on month average, and 88% of the variation on year average. Above analyses indicated that the NEERSM performed well in NEE estimation at site scale. Since the driving variables were all from the remote sensing data, the NEERSM has a potential of estimating regional NEE.

Keywords: Net ecosystem CO_2 exchange (NEE); Gross primary production (GPP); Ecosystem respiration (Re); Eddy covariance; MODIS imagery; NEERSM

[PO-46]

LARGESCALE EVALUATION OF DECADAL FOREST BIOMASS CHANGES FROM REPEATED AIRBORNE LIDAR MEASUREMENTS IN NORTHERN JAPAN

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Valid estimation of terrestrial carbon cycle depends strongly on the accurate estimation of changes of global forest carbon stock. Airborne light detection and ranging (LiDAR) is expected to be an effective method to measure the forest vertical structure. To estimate forest biomass changes, forest vertical structure is critical information. We examined the feasibility of estimating changes of forest biomass from two airborne LiDAR measurements of forest height acquired 10 yr apart (2004 and 2014) over the Teshio Experimental Forest (225 km^2) of Hokkaido University in northern Japan. LiDAR data were collected in 2004 (2014) from a flight altitude of 1900 m (1980 m), and the pulse density is 0.6 pulses m^{-2} (1.2 pulses m^{-2}) with a footprint diameter of 0.72 m (0.68 m). We compared the logged timber volume and the biomass at 19 plots in the experimental forest during the 10 years with the LiDAR mean canopy height decrease at each plot area (289-93,959 m^2), and obtained a linear relationship between them. The slope of the equation was coincident with the slope obtained from the linear relationship between LiDAR mean canopy height and the timber volume or the biomass in 2004 (Takagi et al., 2015). Whole the area of the experimental forest (225 km^2) was divided into 23,502 cells having 1 ha cell size, and the averages of the decadal changes in the canopy height, timber volume, and biomass were obtained for each cell, where the timber volume and the biomass were estimated using the linear relationship between LiDAR mean canopy height and the ground-estimated values. Excluding the logged plots, the average (±SD) canopy height increase of the 23,146 cells was 0.0494 ± 0.0804 m $year^{-1}$, increase in the timber volume was 1.02 ± 1.66 m^3 ha^{-1} $year^{-1}$, and the biomass increase was 0.404 ± 0.656 MgC ha^{-1} $year^{-1}$. This biomass increase rate was similar to the lowest limit of the range of the annual net ecosystem CO_2 exchange rate (0.44 to 2.6 MgC ha^{-1} $year^{-1}$) obtained at tower flux sites in Hokkaido (Aguilos et al., 2014).

[PO-47]

EVALUATING RELATIONSHIP BETWEEN FLUXES OF HEAT AND CO_2 USING DIRECT EDDY COVARIANCE MEASUREMENTS

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Surface to atmosphere exchange is one of the topics that need specialized attention in the numerical models for weather and climate simulation. This exchange is defined by the drag coefficient (CD) which derived from the high frequency observations. We conducted the tower based eddy covariance measurements during the Integrated Ground Observation Campaign (IGOC) of Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX) at Mahabubnagar, India (16°44'N, 77º59'E) in the monsoon season of 2011. We used these observations to compute the fluxes of heat, momentum, CO_2 and surface layer stability by the eddy covariance technique. The analysis reveals that an increase in soil moisture and vegetation cover facilitated for increase in uptaking the CO_2 locally. Also CO_2 flux is decreased with an increase in the heat fluxes. The CO_2 flux was positive (negative) during stable (unstable) conditions and the stability regime was well depicted by the wind observations rather than other turbulent observations.

[PO-48]

SUN-INDUCED FLUORESCENCE FROM GOME-2 FOR ESTIMATING NET PRIMARY PRODUCTIVITY OF CROPLANDS IN INDO-GANGETIC PLAINS

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Agro-ecosystems have received less attention by carbon science groups across world in-spite of they covers around 15 million km2 all over the world and about more than half of land area in India. Besides there are evidences that intensively managed agro-ecosystems act as a CO2 sink in the terrestrial biosphere. Reliable and continuous databases on primary productivity of agro-ecosystems on a national scale also provide useful information on food security related issue such as human carrying capacity.

Space-based crop monitoring is a key to food security and recently evolved spectroscopy is all set to improve crop monitoring because it enables monitoring of photosynthesis through detection of key physiological attributes namely (i) xanthophyll cycle pigments and (ii) chlorophyll fluorescence (Chl-F). In past, performance of traditional remote sensing based vegetation indices as direct surrogate or as input of light use efficiency (LUE) models for estimating agricultural productivity remains highly uncertain especially in managed croplands. These ecosystem models in general underestimate and process-based crop model overestimate the potential productivity of crops under actual field conditions. Complementing reflectance-based indices, recently space-based estimates of sun-induced chlorophyll fluorescence (SIF) became available for large-area estimate of crop productivity. We, therefore, examine comparative performance of SIF and vegetation index (VI) for estimating net primary productivity of managed agricultural lands in Indo-Gangetic plains (IGP).
We have used monthly averages of SIF retrievals over India at 0.5 degree resolution from the Global Ozone Monitoring Experiment-2 (GOME-2) instrument onboard the MetOp-A platform for three agricultural year cycle, i.e. May to April for each of three years (2007-08, 2008-09 and 2009-10). These GOME-2 SIF retrievals mainly corresponds to 740 nm emission feature in spectral window. For the same period, monthly composites of MODIS based NDVI at 0.05 degree resolution obtained from online databases of VIP (vegetation index/phenology) lab. We have applied simple integration procedure over twelve month of SIF and NDVI to generate time-integral of SIF and integrated NDVI (iNDVI) for each individual year. Inventory based cropland NPP at district level was prepared based on area and yield statistics of major crops for year 2003-04 and crop specific conversion factors. Biomass partitioning factor (harvest index), moisture content and root:shoot ratio databases for major crops were compiled from literature on Indian agro-ecosystems. Cropland NPP of districts falls in IGP area (Rajasthan, Punjab, Haryana and UttarPradesh) were used for establishing relations with SIF and VI based measures. Approximately 115 districts having dominantly agricultural lands and covering major fraction of individual SIF grid were used for regression analysis. Results revealed that cropland NPP(t/ha) seem to have strong link with SIF as compared to commonly used vegetation index, NDVI. However, both integral of SIF and NDVI over agricultural year exhibit exponential form of relation with crop NPP. Irrespective of years and explanatory variables, linear fit yielded significant but comparatively less coefficient of determination (R2). The amount of variance in NPP explained by SIF was more or less above 70%. The variance explained by iNDVI ranges from 60 to 67%. Overall this study indicate that SIF at improved space-time resolution in future would provide a scope of improving projection of agricultural productivity and reducing uncertainty in carbon budgeting

[PO-49]

ECOSYSTEM RESPIRATION OVER A MIXED FOREST PLANTATION OF NORTHERN INDIA USING MODIS-DERIVED VEGETATION INDICES AND FLUX-TOWER OBSERVATIONS

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Terrestrial ecosystem respiration (Re) plays an important role in the global carbon balance of terrestrial ecosystem. Accurate estimation of Re is crucial in assessment of regional to global carbon budget. Variations in environmental drivers such as air temperature and soil moisture account for most of the seasonal fluctuations of ecosystem respiration. In this study, continuous measurement of carbon dioxide exchange in 2014 was made over a young mixed forest plantation of Terai Central Forest Division, Nainital, India using the eddy covariance (EC) technique. The night-time net ecosystem exchange (NEE) was considered as night-time respiration (autotrophic and heterotrophic) as there is no photosynthesis during night. The temperature dependence of night-time respiration were derived using non-linear optimization model between night-time NEE and corresponding night-time temperature and subsequently used in the model to estimate the daytime respiration. The model explained about 32.04% to 85.59% variation in Re ($p=<0.05$) throughout the season. Seasonally, the biophysical parameters such as leaf area index (LAI) and the leaf chlorophyll content explained majority of the R_e variations in the plantation. The study also attempted to examine the direct relationships between R_e and photosynthesis-related vegetation indices. MODIS surface reflectance data (MOD09) at 500 m spatial and 8-day temporal resolutions were used to derive various vegetation indices such as normalized vegetation difference index (NDVI), enhanced vegetation index (EVI), soil adjusted vegetation index (SAVI), wide dynamic range vegetation index (WDRVI), visible atmospherically resistant index (VARI), green chlorophyll index (GI). The linear relationship between various vegetation indices and 8-day R_e was found significant with R^2 values varying from 0.30 to 0.67 ($p=<0.05$). Among the selected indices, the EVI showed stronger relationship with ecosystem respiration ($R^2 = 0.67$, SEE = 1.42 F = 63.7, $p = 0.001$) than other indices. This may be due to saturation of NDVI at high vegetation cover and more sensitivity of NDVI to background reflectance. The seasonal course of R_e in forest plantation begins in March and continued to increase with increase in air temperature. The average rate of R_e was found to be 4.31 $gC/m^2/day$, reaching to a maximum of 9.45 $gC/m^2/day$ during growing period. The seasonal effect of temperature (Q10) on ecosystem respiration was also examined and it was found that there was an overall increasing trend in (Q10) from beginning of the growing season i.e. February to November. The Q10 value ranged from 1.19 to 4.78 throughout the year with an average of 2.51. This may be due to enhanced maintenance cost of respiration with increased biomass. The results demonstrated that simple remote sensing-based vegetation indices can provide better correlations with Re and could be helpful for the development of future Re models over a large spatial scale. Also a new realistic model could be developed with higher accuracy by considering the sensitivity of air temperature and the soil moisture.

Keywords: Ecosystem respiration, eddy covariance, MODIS, Q10, vegetation indices.

[PO-50]

EVALUATION OF BIOME-BGC MODEL FOR SIMULATING BIOPHYSICAL ATTRIBUTES AND CARBON FLUXES OVER MIXED FOREST PLANTATION IN FOOT HILLS OF LOWER SHIWALIK

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In this study, the BIOME-BGC, a process-based terrestri al ecosystem model was implemented for simulating photosynthesis and respiration processes at landscape scale. We hypothesize applicability of Biome-BGC to simulate carbon fluxes of mixed plantation forest at eddy covariance flux-tower site in Terai Central Forest Division, Nainital, India. The model was driven at a daily time scale for 10-year period (2001-2010) with the meteorological values of the daily maximum, minimum, and average air temperatures, precipitation, daytime VPD, and solar radiation. GPP is estimated by combing the Farquhar biochemical model (Farquhar et al., 1980) with the stomatal conductance model (Jarvis, 1978). Ecosystem respiration (RE) is calculated as the sum of autotrophic and heterotrophic respiration (AR and HR). Look-up table parameters for mixed plantation forest were re-defined with observed values and literature sources on plantation forest from India. Model was run in a spin-up mode for 10 years. In-situ field measurements of LAI and NPP were carried out during 2009-2010 for model validation. Moreover, continuous measurements of CO_2 and H_2O from flux-tower during active growth period (April- October, 2009) being processed with standard eddy covariance data processing protociols. Fluxes of GPP, RE and NEE were derived daily and used in validating model simulated fluxes on monthly basis.

Model could simulate inter-annual pattern of NPP of forest plantation which is linked to precipitation anomalies. Model simulations of mixed plantation at tower site shows that simulated LAI reasonably matches with in-situ field measurements. The RMSE and R^2 associated with 1:1 line plot were 0.9 and 0.52. Furthermore, temporal pattern of model simulated LAI coincides with up-scaled LAI based on fine and moderate resolution satellite data. While comparing against field NPP, Biome-BGC gave under-estimates of NPP compared to inventory based NPP for mixed plantation forest and other biomes (Teak, Eucalyptus, poplar). Model simulated GPP of Mixed plantation agreed well with the measured GPP from flux tower. However, ecosystem respiration largely overestimated because of constant value (2.0) of Q10 used in model which is on higher side as evident from flux-tower observation.

[PO-51]

EDDY COVARIANCE MEASUREMENTS OF METHANE AND CARBON DIOXIDE FLUXES OVER A MANGROVE ECOSYSTEM, SOUTHEASTERN COASTAL INDIA

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Tropical coastal mangrove ecosystems are one of the most productive ecosystems of the world. Mangrove forests and wetlands contribute significantly to the greenhouse gas budget due to their source/ sink contributions on two of the most important greenhouse gases, carbon dioxide (CO_2) and Methane (CH_4). Like all other wetlands, mangroves also take part in the global carbon cycle by holding organic carbon in biomass, soils and sediments. Soil conditions determine the emission of CO_2 and CH_4: CO_2 emissions are highest when soils are aerated, while CH_4 fluxes are largest when flooded, the opposite to CO_2. In anoxic conditions, mangrove sediments are sources of CH_4. Methane emission depends on complex biogeochemical processes as well as the atmospheric conditions existing in the mangrove ecosystem. All these lead to uncertainty on the greenhouse gas emission/ sink potential of mangroves. Such uncertainty can be resolved by reliable and long term measurements over such ecosystems, which are scarce.

The present study reports initial results from the eddy covariance (EC) flux measurements carried out over Pichavaram mangrove forest, located at the coastal southeastern peninsular India, as part of the IndoFlux network supported by Ministry of Earth Sciences, Govt. of India. It is a small mangrove ecosystem of about 1400 ha with 700 ha of dense mangroves. The climate in Pichavaram is sub-humid with very warm summer (> 30^o C). It receives an annual rainfall of about 1310 mm, mostly during northeast monsoon season (October-December). The bathymetry survey shows that the entire ecosystem is very shallow and depth in most the areas ranges from 0.5 to 1m. The tide in Pichavaram mangroves is micro and diurnal and tidal amplitude within the mangroves varies from 0.48 m to 0.73 m (November) during the monsoon season and from 0.40 to 0.67 m during the post monsoon season (March). Pichavaram mangrove has 12 species of mangrove plants and community structure indicates one species namely, *Avicenna marina* is the most dominant one. The average height of trees is about 5 m.

A nine meter tall EC flux tower has been established at the site. The EC system consists of open path CH_4 analyzer (LI-7700, Licor, USA), enclosed path CO_2-H_2O gas analyzer (LI-7200, LiCor, USA) and three dimensional sonic anemometer-thermometer (Windmaster Pro, Gill instruments, UK). Soil CO_2 flux and air CO_2 profile measurements are carried out using a four chamber (LI-8100, LIcor, USA). Supporting measurements include air temperature and humidity, wind speed and direction, net radiation, photosynthetic active radiation, rainfall, soil moisture and temperature, soil heat flux, leaf area index, etc. The study will present characteristics of CH_4 and CO_2 fluxes, surface energy balance components, and their seasonal variations in relation to soil and atmospheric conditions.

[PO-52]

HIGH RESOLUTION CO_2 TRANSPORT SIMULATION BY THE WRF-CO_2 MODEL: SOUTH ASIA

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Anthropogenic CO_2 is one of the important greenhouse gas and very likely to have the largest contribution to warming of the Earth's atmosphere and climate change since the industrial revolution in 1750s. Therefore, we need better understanding of global and regional scale carbon budget in terms of the anthropogenic CO_2 uptake by the terrestrial biosphere and oceans. During recent time, the high resolution forward transport model simulations of CO_2 at hourly to synoptic timescales have attracted considerable interest. This is because the coarse resolution global models show large model-observation CO_2 concentration mismatches due to unresolved sub-grid scale processes, e.g., the heterogeneity of surface fluxes, model topography and transport. Extensive CO_2 research on higher resolution forward transport model simulation are carried out over the United State, Europe and East Asia, however fewer studies are made over South Asia.

Recently, a high resolution regional forward transport model WRF-CO_2 set-up at Jadavpur University, India in collaboration with Department of Environmental Geochemical Cycle Research (DEGCR)/Japan Agency for Marine-Earth Science and Technology (JAMSTEC) for the simulations of CO_2 concentration as non-reactive trace gas. This model was initially implemented for East Asian region (Ballav et al., 2012, 2015). The model had successfully simulated the main features in spatio-temporal scale variation of CO_2 concentration at surface sites and tall tower measurements. Overall, results of the study showed significant improvement in CO_2 transport simulation due to incrementation of horizontal resolution in finer scale than global models.

Now, this model is being setup for South Asian region for better understanding the spatial and temporal CO_2 dynamics over this region. It is important to mention that this region is categorized by widely varying landscape. The simulated domain is define on Mercator projection centered at 24°N and 96°E having grid points 200×190. The domain covers Thar Desert land masses in the west, Tropical rainforest in Malaysia and Indonesia in the south, China in the north, complex topography of Himalaya, Arabian and Bay of Bengal sea shore and Gangetic plain land in the middle, and cost of Indian Ocean in the east. It has horizontal resolution 27X27 Km and vertical resolution 30 η layer. The model simulations are in progress and results will be discussed during the presentation.

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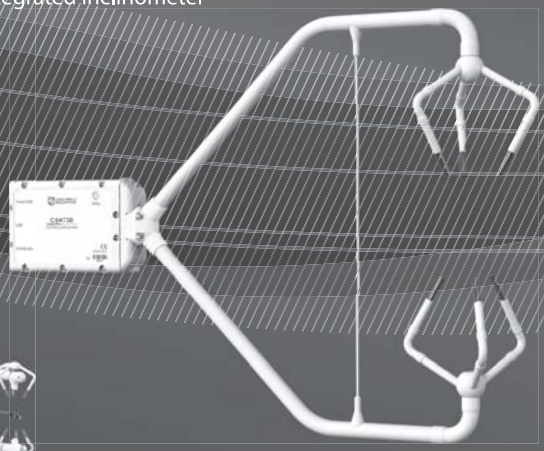

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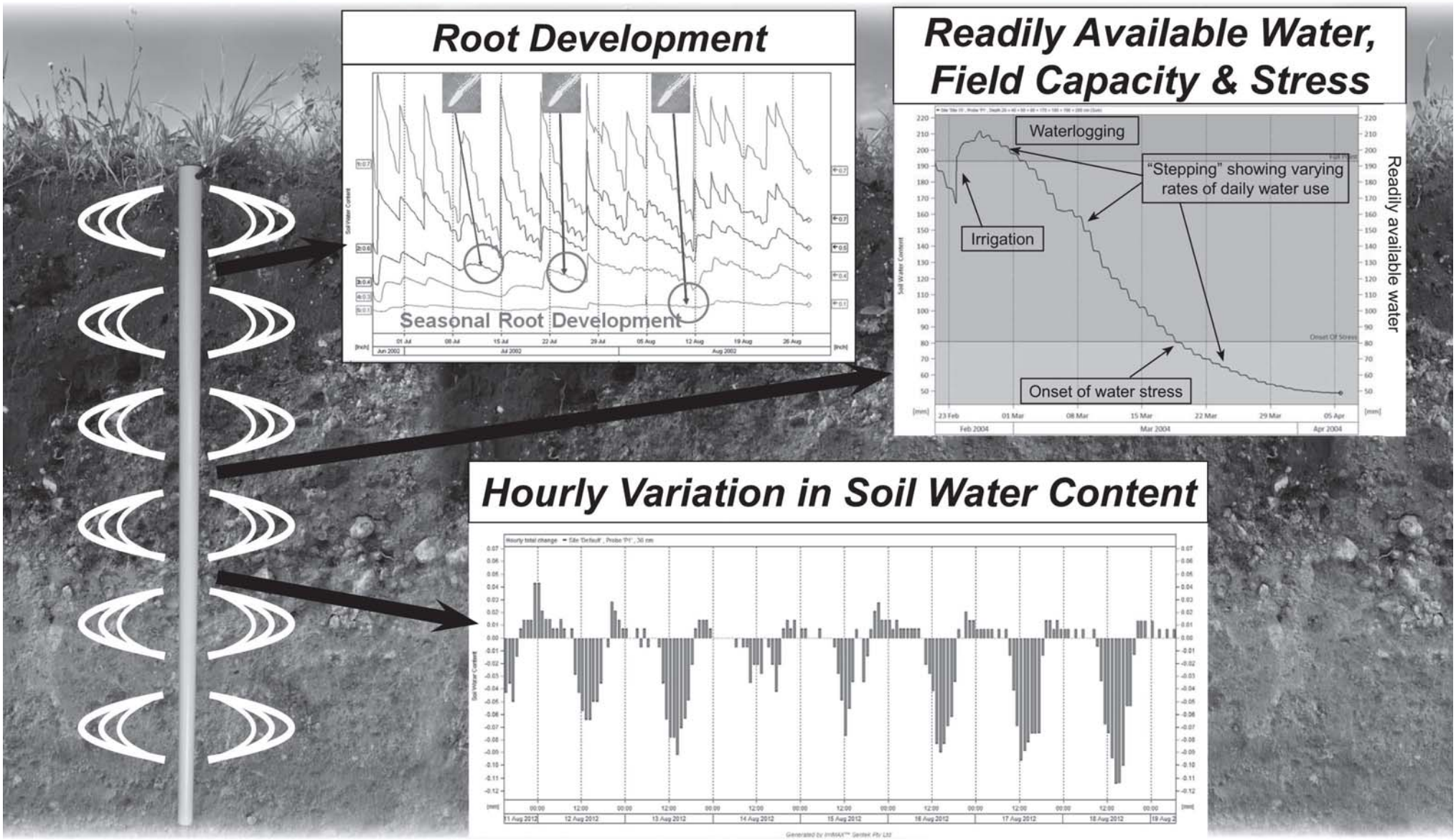

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