APN CAPaBLE

- Making a Difference –

Scientific Capacity Building & Enhancement for Sustainable Development in Developing Countries

Greenhouse Gas (GHG) and Aerosol Emissions under Different Vegetation Land-use in the Mekong River Basin Sub-region

Final Report for APN CAPaBLE Project: CBA2006-06NSY-Towprayoon

JGSEE

The Joint Graduate School of Energy and Environment

Greenhouse Gas (GHG) and Aerosol Emissions under Different Vegetation Land-use in the Mekong River Basin Sub-region

Project Reference Number: CBA2006-06NSY-Towprayoon

Final Report submitted to APN

Overview of project work and outcomes

Non-technical summary

The Mitigation of greenhouse gas and aerosol emissions from biogenic sources and biomass burning activities associated to different vegetation land use requires know-how transfer to regional scientists to develop appropriate emission inventories.
During this one year project, focus was on measurement and evaluation of Greenhouse Gas and aerosols emissions from biogenic and biomass burning activities in forests and paddy fields in the Mekong River Basin Sub-Region (MRBSR), on the transfer of methodologies and procedures developed in Thailand to the counterparts in Cambodia, and on training of regional scientists and policy makers.

Objectives

The project overall objectives are:

- To provide capacity building to scientists of the MRBSR on emission inventory of GHG and aerosol from biogenic and biomass burning activities associated to different vegetation land use, biogenic and biomass burning activities being the two major sources of air pollutants in the region.
- To provide scientifically sound decision support information to policy makers for formulation and implementation of control strategies contributing to improving the regional air quality, and to mitigating global warming, in order to contribute to the sustainable development of the region.

Amount received and number years supported

Amount of APN-CAPaBLE grant received: 30,000 US$
Number of years granted: 1 year (2006-2007)

Achievements

The work achieved in this project can be summarized as follows:

Activity 1: Classification of vegetation land use and set-up of GIS maps of emissions from biogenic and biomass burning activities in the MRBSR, including Thailand, Cambodia, Lao PDR and Vietnam. This activity is composed of the following elements:

(1) Classification of vegetation land use in the MRBSR, with focus on forest and paddy field, with detailed information on water supply and water management for cultivation, etc.
(2) Identification of biomass burning activities using satellite data.
(3) Set-up of a methodology to estimate GHG and aerosol emissions from biogenic and biomass burning sources associated to forest and paddy fields.
(4) Establishment of corresponding emission maps.

Activity 2: Setting and transfer of field experiment procedures and methodology developed in Thailand to counterparts in Cambodia. The components of this activity are:

(1) Finalizing field experiment procedures developed and tested in Thailand. Regarding emissions from biogenic activities, measurement experiments on GHG were developed and tested at selected sites in Trat and Nakhon Ratchasima for forest and in Samutsakorn for paddy fields, while emissions from biomass burning were measured from experiments conducted in Chiangmai for forest fire, and Chainat,

Suphanburi, Nakhon Sawan, and Khon Kaen for paddy field burning.

(2) Transfer of field measurement procedures to counterparts in Cambodia. To this end, hand-on training was conducted in Cambodia in March 2007.

(3) Monitoring of measurement data collected by Cambodian counterparts. For GHG from biogenic emissions, collected samples were sent to Thailand for chemical analysis. For the estimation of biomass burning emission, Cambodian counterparts sampled biomass to determine the biomass loads, and conducted expert interview using questionnaires to evaluate biomass burning activities in forests and paddy fields.

Activity 3: Organization of a training workshop for capacity building and dissemination of scientifically sound decision support information to scientists and policy makers of the MRBSR. It included the following components.

(1) Capacity building of scientists in the region on measurement procedures and methodology for estimation of GHG and aerosol emissions from biogenic and biomass burning activities.

(2) Transfer of scientifically sound decision support information to regional policy makers.

Relevance to the APN CAPaBLE Programme and its Objectives

The project contributed enhancing the capacity of scientists from the Mekong River Basin Sub-Region in GHG and aerosol emission inventories, and provided policy makers of Asia-Pacific region with relevant scientific information for formulation of appropriate control strategies enabling regional air quality improvement and global warming mitigation. The major outcome from the undertaken activities relies on the contribution and involvement of countries from the region in the international effort to improve GHG and aerosol emission inventories, and ultimately to the regional sustainable development.

Self evaluation

Referring to the initial plan presented in the proposal, the following targets were achieved:

(1) GIS maps of emission of GHG and aerosol from biogenic and biomass burning activities associated to forest and paddy fields in the MRBSR were obtained for each country included in the project for the selected base Year 2002.

(2) Monitoring of GHG and aerosol emission from biogenic and biomass burning activities in Cambodia using the methodology and measurement procedures developed in Thailand was implemented.

(3) More than 30 scientists and policy makers from Cambodia, Lao PDR, Myanmar, Thailand and Vietnam, were trained on the capacity building framework and scientifically sound decision support information developed in this project to improve the regional GHG and aerosol emission inventory.

Potential for further work

Preliminary results obtained for Thailand and Cambodia confirmed the importance of biogenic and biomass burning activities as source of air pollutants in the region. However, the monitoring of these emissions is still limited in the MRBSR, and their inventory is affected with high uncertainties, as underlined by many participants of the training workshop organized within this APN-CAPaBLE project. Therefore, further works on implementing measurements and transferring know how skills for estimation of those emissions in the MRBSR should be pursued and regularly evaluated.

Publications

(1) A website reporting on the APN project activities and events including downloadable teaching materials developed for the international training workshop, is available at: http://www.jgsee.kmutt.ac.th/Apn/index.html.

(2) CD-ROMs and workshop materials of the international training workshop on Inventories of Greenhouse Gases and Aerosol Emissions Associated to Different Vegetation Land Use in the Mekong River Basin Sub-region, organized during 1-3 May 2007 in Bangkok, have been produced and provided to all participants of this event.

(3) Two international journal publications and conference papers on the results obtained via this project are also planned to be produced during the period 2007-2008.

Acknowledgments

The APN CAPaBLE program and the Joint Graduate School of Energy and Environment, are acknowledged respectively for the funding, and the facilities and equipments provided to perform and accomplish the activities of this project.

Technical Report

Foreword

This technical report describes the activities and results obtained as part of the Asia Pacific Network CAPaBLE Project entitled: Greenhouse gas (GHG) and aerosol emissions under different vegetation land use in the Mekong River Basin Sub-region

This one year project enabled developing capacity building activities to transfer know-how and technology to scientists and policy makers of the Mekong River Basin Sub-Region (MRBSR) related to inventory of GHG and aerosol emissions from biogenic and biomass burning activities associated to different vegetation land use. Also, it contributed to raise awareness in the region on the implications of these emissions on regional air quality and global warming.

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1. Introduction

South East Asia covers an area of 410 million hectares with forest and agricultural land representing about 77% and 20% of the total area, respectively. The agricultural land use in South East Asia has expanded only slightly from 16.8% of total land area in 1975 to 19.6% in 1992, and for the period of 1990-1995, the Asia Pacific forests observed a reduction by 17 million hectares, with the fastest rate in the Mekong region (1.6% per year) and in South East Asia (1.3% per year). Changes in land use reflect actually the development of intensive agriculture, which constitutes the major economic activity in South-East Asia. Burnings for land clearing and intensive agricultural activities result in the increase of GHG and aerosol emissions in the region, which are of main concern for their impacts on the regional air quality and global climate change. To go towards a sustainable development of the region, GHG and aerosols emission inventories related to these activities should be established to provide scientific information relevant for the formulation of appropriate control and mitigation strategies, and for raising awareness on their negative impacts of the population involved in deforestation and intensive cultivation. However, these are still scarce in many areas of the Asia-Pacific region, due to lacks of reliable measurement data and scientific understanding.

In order to meet this regional ultimate need, we developed this project with special emphasis on capacity building and on the transfer of technology and know-how, related to estimation and inventory of emissions from biogenic and biomass burning activities in forests and paddy fields, to scientists and policy makers of the MRBSR.

2. Description of conducted activities

In order to achieve the overall objective of capacity building and scientifically sound decision support information dissemination to scientists and policy makers of the MRBSR, the following 3 activities were conducted.

(1) Classification of vegetation land use and set up of GIS maps of GHG and aerosols emissions from biogenic and biomass burning in the MRBSR.

(2) Setting and transfer of field experimental procedures developed in Thailand to counterparts in Cambodia.

(3) Organization of an international training workshop for capacity building and scientifically sound decision support information dissemination to scientist and policy makers in the region.

Based on the characteristics of the MRBSR vegetation coverage, forests and paddy fields were selected as the vegetation of interest for development of field measurement procedures. On the other hand, considering their impacts on regional air quality and global warming, as well as their potential emission intensity, the compounds of interest considered are methane (CH_4) and nitrous oxide (N_2O) for biogenic emission investigation, and carbon monoxide (CO) and total particulate matter or aerosols (TPM) for biomass burning.

2.1 Activity I – Classification of vegetation land use and set-up of maps of GHG and aerosol emissions from biogenic and biomass burning activities in MRBSR

2.1.1 Classification of vegetation land use in MRBSR

To classify the vegetation land use of the MRBSR, we developed a Geographic

Information System (GIS), incorporating a database of digital maps of the 4 countries included in the project, i.e. Cambodia, Lao PDR, Thailand and Vietnam. Geographic data and their associated attributes, such as vegetation types, secondary data collected from literature review, from governmental agencies in charge of land development or land use management, e.g. Land Development Department in the case of Thailand, and from field surveys.

Two types of vegetation land use are considered in this project: forest and paddy fields. Regarding forest, 6 types were identified in Thailand including, mixed deciduous forest, dry evergreen forest, dry dipterocarp forest, moist evergreen forest and hill evergreen forest. These 6 types were selected on the basis of the calculation method established to estimate biogenic emissions from forest, since emission factors to be used are specific to the type of vegetation. Likewise, for biogenic emissions from rice fields, the emission factors are function of the water management system used for rice cultivation, and hence the classification of paddy fields was categorized in two major classes, i.e. rainfed and irrigated areas.

From the developed general GIS, the 1:250,000 scale map of vegetation land use including only forest and paddy fields was created, in order to serve as the base layer for locating emission areas.

2.1.2 Assessment of biomass burning activities using satellite data

Biomass burning activity can be assessed using 3 main methods:

(1) **Remote sensing.** This method provides an overview of biomass burning activities, in terms of spatial distribution and seasonal variability. However, remote sensing observations are still affected with high uncertainties, due to either interferences from clouds, or interferences from other sources, or lack of sufficient resolution to correctly estimate the burned area, etc. Consequently, the amount of biomass fuel from which is issued the emission can only be roughly estimated.

(2) **Survey using interview questionnaire.** This method provides information on biomass burning activities from observations by stakeholders or involved "observers", e.g. forest officers, environmental officers, or farmers. The obtained data document gives a statistical overview of the situation. However, they can be biased by the questionnaire content, type of interviewees, and number of samples or population accounted in the survey. Moreover, it is very time consuming in sample collection. It may be replaced by expert interview using a questionnaire, when a cross-check for confirmation of data available through collection by other methods is made.

(3) Field survey. This method provides probably the most reliable data in terms of burned area, type of biomass fuel, and quantity of burned biomass. However, it is highly time consuming to conduct a comprehensive field survey at national or regional scale to obtain a representative overview of the investigated biomass burning activities, in terms of spatial and temporal distribution. Nevertheless, it can serve as reference data to calibrate those obtained from remote sensing on area and biomass burned.

Due to time limitation, the method using remote sensing was selected for the assessment of biomass burning activities in this project. The satellite data used are from the Asia-Pacific Network for Disaster Mitigation Using Earth Observation Satellite (ANDES) research program enabling to daily observe biomass burning activities in the MRBSR. The Year 2002 was selected as the base year, considering the completeness of the data set. Further information on the ANDES research program can be obtained from http://www.affrc.go.jp/ANDES/. The daily data was processed into monthly data in order to investigate the seasonal variability of the investigated activities. In order to check the reliability of the satellite data, in particular in terms of geographic distribution, a set of field and interview questionnaire surveys were conducted in Thailand, and expert interviews were carried out in Cambodia.

2.1.3 Calculation methodology for estimating GHG and aerosol emissions from biogenic and biomass burning

2.1.3.1 Emissions from biogenic activities

Biogenic emissions from forest can be estimated using the following equation:

$E = A \times EF$ *(Equation 1)*

E is the emission of the compound x (mg/year), A is the land area of the forest vegetation (m^2), and EF is emission factors ($mg\ m^{-2}\ d^{-1}$)

In order to perform these biogenic emissions calculations the type of forest considered is to be identified as the emissions factors to be applied are vegetation (soil) specific. Emission factors are reported in Table 1.

Table 1: Emissions factors for major types of forest found in the MRBSR

	Emission Factors	
Types of forest	CH_4	N_2O
Mixed deciduous forest	-0.8	0.3
Dry evergreen forest	-1.5	0.4
Dry dipterocarp forest	-0.8	0.3
Moist evergreen forest	-1.4	0.1
Hill evergreen forest	-2.4	0.3

Vanitchang and Chidthaisong (personal communication)

Biogenic emissions from paddy fields can be estimated using the following equation:

$CH_4 = Area \times EFw \times t$ *(Equation 2)*

EFw is the emission factor ($kg\ CH_4\ ha^{-1}\ day^{-1}$), t is the cultivation period of rice (day), and A is the harvested area of rice (ha)

The emissions factor indicated in Equation 2 accounts for the differences in water regime during the rice cultivation period. Values are reported in Table2.

Table 2: Water management system for rice fields

Water management	Emission Factor ($mg\ m^{-2}\ d^{-1}$)	
Irrigated (Single aeration)	CH_4	N_2O
Rain fed	97.2	0.29
	45.7	0.29

Towprayoon et al. (2005 & personal communication)

2.1.3.2 Emissions from biomass burning activities

a) Estimation of amount of biomass burned:

In order to estimate the amount of biomass burned per year as a result of vegetation fires the following general equation is used:

$M = A \times B \times \alpha$ *(Equation 3)*

M is the amount of biomass burned per year, (kg/year), A is the area of land cleared (burned) per year (m^2 per year), B is the above ground biomass density (kg/ m^2), and α is the Fraction of above ground biomass burned

In the case of crop residues burning, the amount of biomass burned is determined using a modified version of the expression given in the IPCC revised guidelines (1996) and also used in works of Hao and Liu (1994) or Streets *et al*., (2003). It is as follows:

$M = P \times D \times B \times F \times \alpha$ *(Equation 4)*

M is the total mass of crop residue burned in field (kg), P is the crop production (kg), D is the crop specific residue to product ratio, B is the dry matter fraction (or biomass load if P is expressed in unit of surface instead of unit of mass), F is the percentage of dry matter residues burned in field, and α is the burning efficiency

Data and their sources for both forest fires and rice residues burning are reported in Table 3.

Table 3: Data for estimation of amount of tropical forest and crop residues burned in Asia

Tropical Forest	Biomass load range (kg/m^2)		Burning efficiency	
	10[a]		0.2[b]	
Crops	Residue-to-crop ratio	Dry matter fraction	Dry matter burned in field**	Dry matter burned in field***
Rice	1.76[c]	0.85[d,e,f]	25%[d,e]	17%[d,e]

[a]IPPC (1996); [b]Levine (2000); [c]Koopmans and Koppejan (1997) [d]Hao and Liu (1994); [e]Streets et al., (2003); [f]OEPP, Thailand (1990)

b) Estimation of emissions from biomass burning:

The amount of atmospheric emissions generated annually by biomass burning can be estimated by the product of the amount of dry biomass burned (*Equation 1* or *2*) and the emission factor of a specific pollutant, as follows:

$E_x = M \times EF_x$ *(Equation 5)*

E is the emission of the compound x (g/year), M is the mass of dry matter burned (kg dm/year), and EF the emission factor of the compound x (g/kg dm burned)

A comprehensive study from Andrea and Merlet (2001) provides emission factor for various types of biomass burning including tropical forest fires and crop residues burning. These are reported in Table 4.

Table 4: emissions factors

	Tropical Forest	Crop residues
Compounds	Emission Factors (g/kg)[a]	
CO_2	1580 ± 90	1515 ± 177
CO	104 ± 20	92 ± 84
CH_4	6.8 ± 2.0	2.7
N_2O	0.20	0.07
NOx	1.6 ± 0.7	2.5 ± 1.0
TPM*	20[b]	10[b]

[a]Andrea and Merlet (2001); [b]Levine (2000)

2.1.4 GIS maps of GHG and aerosol emissions from biogenic and biomass burning activities in MRBSR

In order to prepare the GIS maps of GHG and aerosol emissions from biogenic and biomass burning activities, the GIS map of vegetation land use of the MRBSR was first created as described in section 2.1.1, to serve as the base layer for locating the emission areas.

For biomass burning emission, the emission areas were identified based on the hotspots detected by ANDES as described in section 2.1.2. Each monthly dataset was processed to geo-reference the detected hotspots, and prepare the monthly hotspots maps, enabling to overview the spatial distribution of biomass burning activities. As these latter are highly randomized, a gridded layer of 12 km x 12 km was set to support the development of a systematic emission map, easy to use for monitoring or modeling biomass burning emission. After overlaying the vegetation and the hotspots maps to classify hotspot per type of vegetation, the 12 km x 12 km grid layer was added. The emission calculation equation was then incorporated in the GIS to compute the emissions for each grid. Monthly maps of CO and TPM emitted from forest fires and paddy field burnings are hence obtained, enabling to investigate the areas and time period of intense biomass burning.

For GHG emission from biogenic activities, the emission areas are actually directly identified from the type of vegetation. By incorporating the emission calculation into the GIS to compute the emission of each type of vegetation on an annual basis, GIS maps of CH4 and N2O emissions from biogenic activities for forest and paddy fields can be obtained. Seasonal or monthly maps can also be prepared when the corresponding emission calculation equations are first determined.

2.2 Activity II – Setting and transfer of field experiment procedures to Cambodian counterparts

A three days visit to Cambodia was organized during 19-22 March 2007 to set and transfer field measurement procedures developed in Thailand to Cambodian counterparts, who are governmental officers of the Climate Change Office, Ministry of Environment, Cambodia. These experimental protocols are focused on field measurements of GHG and aerosol emissions from biogenic sources and biomass burning activities. They were developed, finalized and tested in Thailand. For emissions from biogenic activities, measurement experiments on GHG were conducted at selected sites in Trat and Nakhon Ratchasima for forest and in Samutsakorn for paddy fields, while emissions from biomass burning were measured from experiments carried out in Chiangmai for forest fire, and Chainat, Suphanburi, Nakhon Sawan, and Khon Kaen for paddy field burning.

For the hands-on training in Cambodia, to demonstrate and transfer technical skills on field experimental measurement procedures, the following study sites were selected: Kirirom National Park for experiments related to emissions from forest areas and the Cambodian Agriculture Research and Development Institute (CARDI) for those in relation with emissions from paddy fields.

For the hands-on training in Cambodia, to demonstrate and transfer technical skills on field experimental measurement procedures, the following study sites were selected: Kirirom National Park for experiments related to emissions from forest areas and local farmer's paddy fields under rainfed conditions.
Currently, follow-up activities are on-going by Cambodian counterparts in order to measure biogenic fluxes of greenhouse gases and collect data for estimate emissions from biomass burning. The measurement will continue to cover the whole cropping season. Gas samples will be taken weekly from paddy field and bi-weekly from forest surface. It is expected that this will produce a preliminary emission factor and important basis for further development of more specific emission factors for Cambodia.

Photo 1: Know-how transfer on experimental procedures for measurement of GHG from forest and paddy fields

Photo 1 above shows the activities during Cambodia visit. We demonstrated to Cambodian colleagues how gas samples be taken from forest soil surface and paddy fields. Demonstrations also included the needed instruments and how they worked. Possible errors that may arise during gas sampling such as site disturbance, temperature monitoring, chamber height measurements, and practical approaches how to minimize such errors. Such demonstrations together with *in situ* training allowed the Cambodian colleagues to primarily familiarize themselves to the technique and discussed various points from both forest and paddy fields, ensuring that they have basic understanding of biogenic emission measurements necessary for performing task thereafter.

Subsequently, a protocol for methane and nitrous oxide sampling procedures were summarized and given to them as reference (See Appendix 6)

For the estimation of emissions from biomass burning, the Cambodian counterparts collected biomass samples following the forest biomass and paddy residues (rice straw and stubbles) sampling guidelines developed in this project and illustrated in Photos 2-3, to determine the biomass loads. After sampling, the sampled biomass is to be weighted, sun-dried, and weighted again, in order to determine the dry mass of each sample. Each sample is to be referenced in details, e.g. the reference number, UTM or geo-reference of the location where the sample was collected, date of sampling, type of biomass, etc., in order to complete the GIS database used for the preparation of the emission maps.

Photo 2: Sampling of paddy residues

Photo 3: Sampling of forest biomass

On the other hand, expert interviews were also conducted using questionnaires specially developed for this project to evaluate biomass burning activities in forests and paddy fields. Four types of questionnaire were prepared: (1) Questionnaire to Rice farmers, (2) Questionnaire to Agricultural Officers, (3) Questionnaire to Forest Officers, and (4) Questionnaire to Environmental Officers. Detailed content of these questionnaires is provided in Appendix 3. For each questionnaire type, 3-5 experts were selected to give their opinions through interview, as illustrated in Photo 4

Photo 4: Conducting an expert interview

2.3 Activity III – Organization of an international training workshop

An international training workshop entitled "Inventories of Greenhouse Gases and Aerosol Emissions Associated to Different Vegetation Land Use in the Mekong River Basin Sub-region", was organized during 1-3 May 2007, in Bangkok, Thailand, in order to transfer the technology and know-how skills developed as part of Activity I and II. One of the main objectives of organizing this workshop was to offer a forum for discussion to regional scientists and policy makers to share information on GHG and aerosol emission inventory status in each country, as well as on related issues.
Participants from the 4 countries included in the project, i.e. Cambodia, Lao PDR, Thailand and Vietnam, joined the workshop. Delegates from Myanmar also participated, to complete the regional overview. The detailed program and agenda of the workshop is included in Appendix 1, and is summarized as follows:

a. **Day I** was dedicated to keynote lectures by experts in the major fields involved in the inventory of GHG and aerosol emissions from biogenic and biomass burning activities, and to country reports on GHG and aerosol emission inventory and future development by representatives from each of the MRBSR's 5 countries.
b. **Day II** was focused on GHG and aerosol emissions from biomass burning. Experts from Thailand and USA involved in the project delivered keynotes introducing background knowledge and information on methodology and approach to develop this type of emission inventory. Hands-on sessions were set in order to offer to the participants an opportunity to practice on concrete examples of estimation calculations and GIS emission map preparation.
c. **Day III** was set on the inventory of GHG and aerosol emissions from biogenic activities. Lectures on field experiment measurement techniques of GHG emission in paddy fields and forests were provided. The calculation methodology to estimate the emission was described. Hands-on sessions on GHG emission measurement using close chamber system, and on the preparation of GIS emission maps were performed.

In order to assess this workshop in terms of effectiveness of technical and know-how skills transfer to regional scientists, and of scientific decision support information dissemination to policy makers, an evaluation form was provided to all participants. Also, this evaluation aimed at evaluating their appreciation on the capacity building framework developed in this project, in terms of meeting their needs and expectations regarding GHG and aerosol emission inventory. The overall results of this evaluation are reported in appendix 4 (Table 4A)

3. Results and discussion

3.1 Vegetation land use in MRBSR

The land use of the 4 countries of the MRBSR part of this study is classified in 3 major categories and is reported in Table 5. The corresponding GIS map is displayed in Figure 1. According to this land use classification, it results that Thailand, with 170,157 km^2, has the largest forest area, followed by Lao PDR, Cambodia and Vietnam. However, with regards to the ratio of forest to total land, Cambodia and Lao PDR, , are largely ahead in the region with about 60% of the country covered with this forest. Concerning paddy fields, Thailand and Vietnam possess the highest numbers. This reflects the position of these two countries as major world producers of rice.

Table 5: Land surface of forest and paddy fields (km^2)

Type	Thailand	Cambodia	Lao PDR	Vietnam
Forest	170,157 (33%)	108,990 (61%)	142,602 (60%)	58,613 (18%)
Paddy fields	105,754 (21%)	17,024 (9%)	2,556 (1%)	48,611 (15%)
Others	237,450 (46%)	55,021 (30%)	91,642 (39%)	223,809 (67%)
Total	514,361	181,035	236,800	331,033

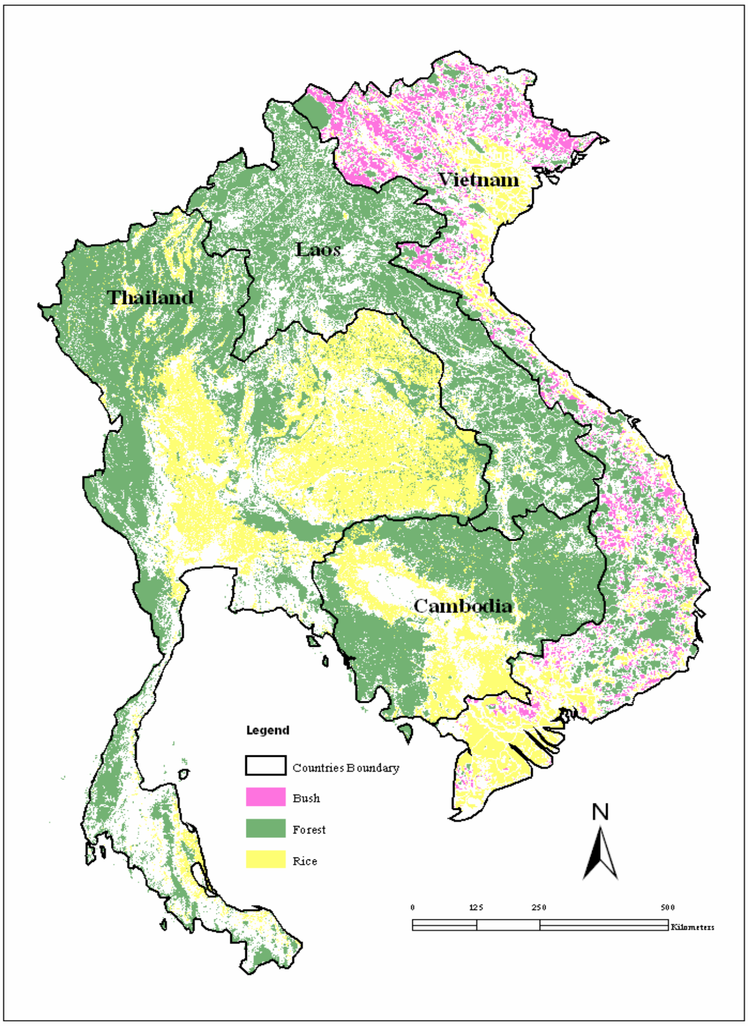

Figure 1. Land-use map of countries of the MRBSR (2000)

3.2 Biomass burning emissions

The biomass burning activities observed by ANDES for the 4 countries included in this project are reported in Figures 2-5, both for fire counts and burned areas. This latter is converted from the fire counts using the resolution of the satellite sensor, which was quite coarse in this case since it was of 2.7 km x 2.7 km. Consequently, each detected fire count was assumed to correspond to a 2.7 km x 2.7 km burned area. Results from Figures 2-5 indicate that the peak season of forest fires in Thailand, Cambodia, Lao PDR, and Vietnam runs from January to April. Indeed forest fires are significantly detected from October onward, i.e. starting month of the dry season in the region. Regarding paddy field burnings, the peak season is also observed during the period January-April in Thailand, Lao PDR and Cambodia, while Vietnam displays a different pattern with frequent burning occurring through out the year. In terms of absolute values for fire counts, and therefore of corresponding burned areas, Thailand is the country most affected by forest fires, followed by Cambodia, Lao PDR and Vietnam. Regarding paddy fields burning, Thailand and Vietnam are far ahead. The particular seasonal pattern of paddy field burning in the case of Vietnam seems to confirm an agro-intensification of rice production in this country. Detailed information on monthly fires counts and corresponding areas of land burned in 2002 for each of the 4 countries of the MRBSR considered in this project is reported in appendix 5 (Table 5A and 5B). Individual maps of fire hotspots for Thailand, Cambodia, Lao PDR and Vietnam for the year 2002 are also reported in appendix 5 (Figure 5A, 5B, 5C and 5D).

Thailand

a) Forest vegetation b) Paddy fields

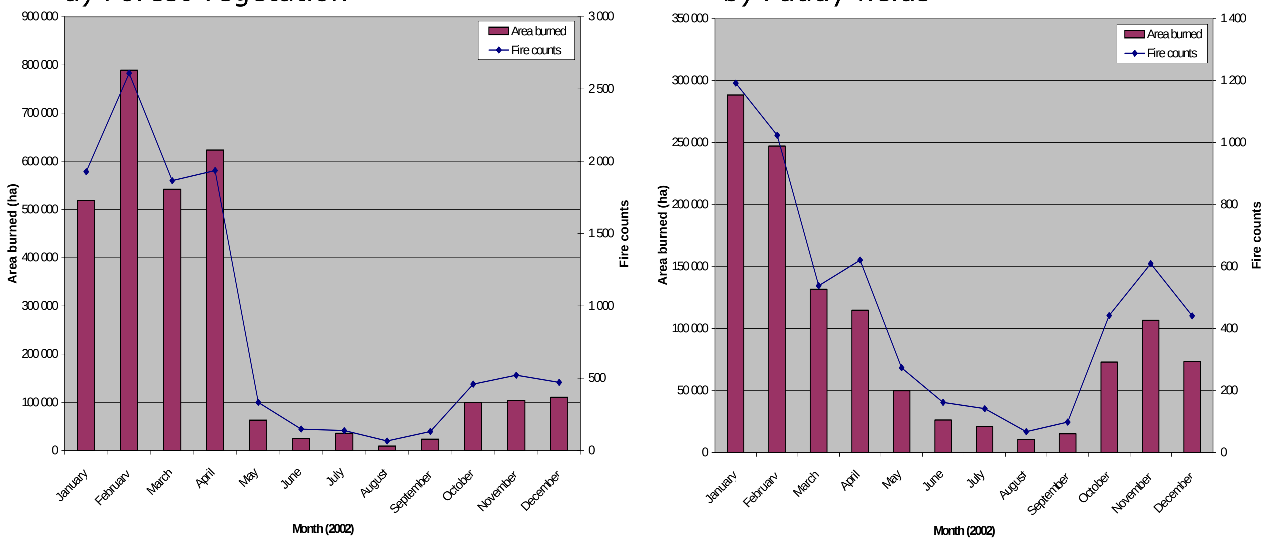

Figure 2. Monthly Fire counts and corresponding area of biomass burned in Thailand during 2002 for a) forest vegetation, and b) paddy fields

Cambodia

a) Forest vegetation b) Paddy fields

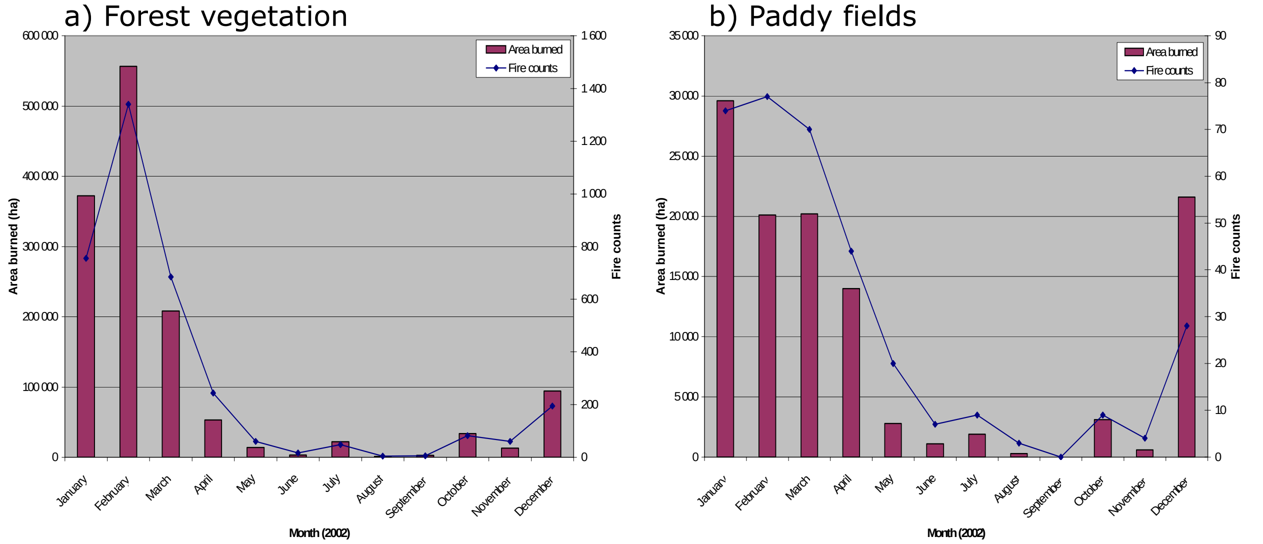

Figure 3. Monthly Fire counts and corresponding area of biomass burned in Cambodia during 2002 for a) forest vegetation, and b) paddy fields

Vietnam

a) Forest vegetation b) Paddy fields

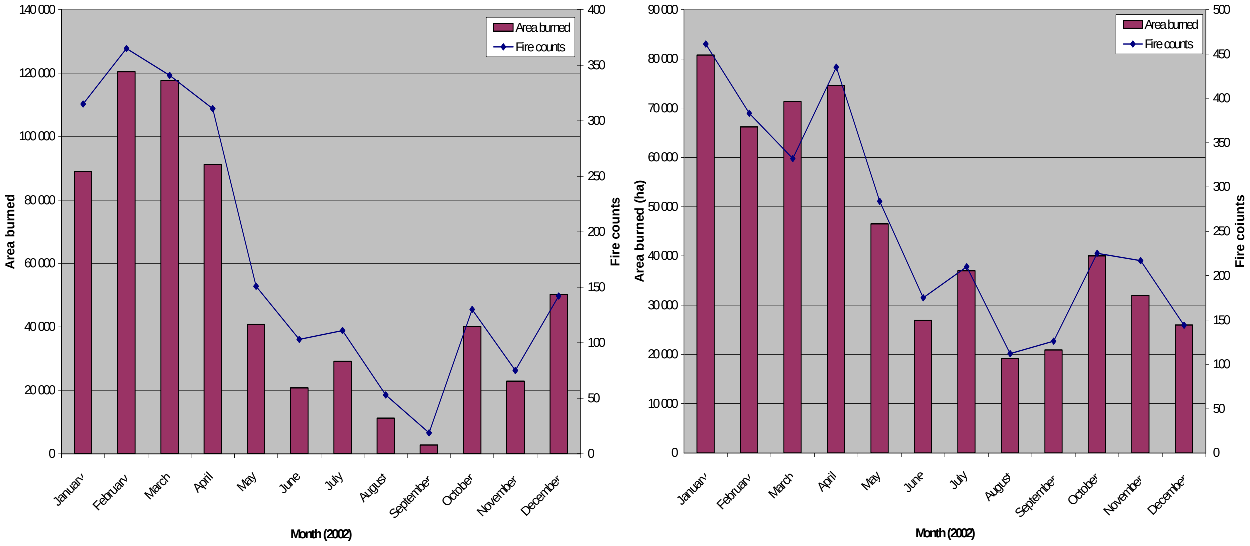

Figure 4. Monthly Fire counts and corresponding area of biomass burned in Vietnam during 2002 for a) forest vegetation, and b) paddy fields

Lao PDR

a) Forest vegetation b) Paddy fields

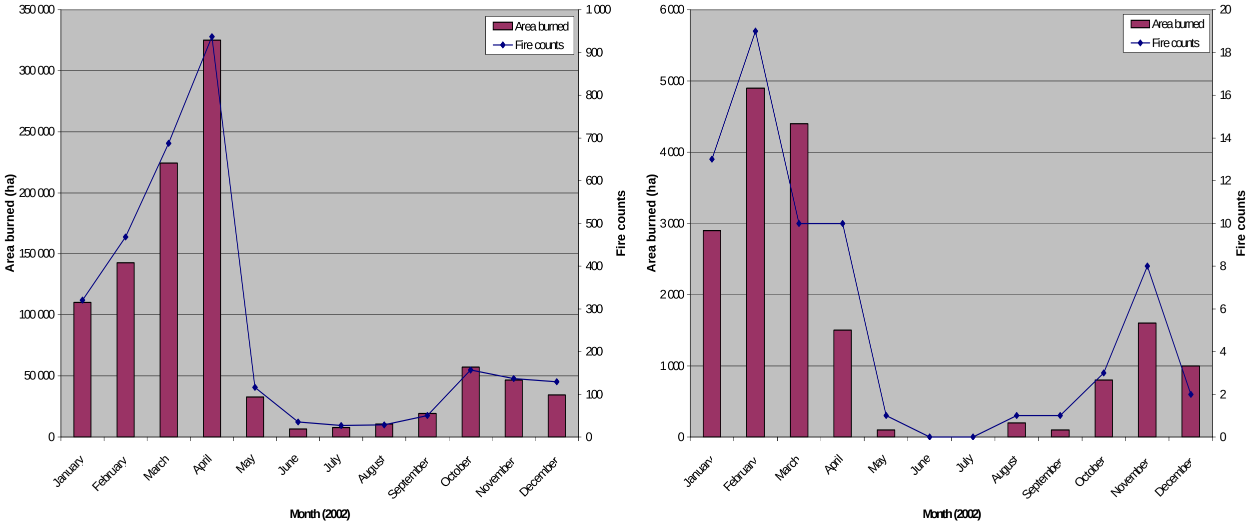

Figure 5. Monthly Fire counts and corresponding area of biomass burned in Lao PDR during 2002 for a) forest vegetation, and b) paddy fields

Based on satellite data of area burned, and using the data of biomass loads and emission factors reported in Tables 3 and 4, total amount of biomass burned and emissions of CO and TPM are computed. The results obtained are reported in Tables 6 and 7. The corresponding emission maps of CO and TPM are produced for each month of the Year 2002, with a grid resolution of 12 km x 12 km. All the gridded monthly maps are gathered in Appendix 5. In order to investigate the spatial distribution of biomass burning during the peak season of January to April, the emission maps of CO and TPM for this period are reported in Figures 6 and 7. It is observed that in Thailand, biomass burning and related air pollutant emissions are concentrated in the north of the country, especially in February, March and April. For Cambodia, the burning occurrence is mainly located in the east, around Tonle Sop basin, mostly in January and

February. In Vietnam, the southern part of the country is the most affected region, while in Lao PDR, biomass burning seems to be equally distributed around the country, although a higher frequency is observed in the north during March and April. Concerning the emissions of CO and TPM, it is to be mentioned that the total CO emission obtained in this project is about 10 times lower than that reported by Streets *et al.*, 2003. As the emission factors being considered in these calculations are from Andreae and Merlet, 2001, for both studies, the observed differences can only come from the discrepancy in biomass load, and more particularly in area burned. Actually, in this study the used gridding system is of 12 km x 12 km, while Streets *et al.*, 2003, chose to work with a 1° x 1°, i.e. approximately 100 km x 100 km, in order to investigate Asian biomass burning emissions. On the other hand, observations from field surveys in Thailand and Cambodia indicate that burned areas resulting from forest fires or paddy fields burning are much smaller than 1 km x 1 km grid. Preliminary results collected in Thailand on biomass burned, incorporating biomass load and fraction burned, show that the values obtained in the case of forest fires in the north of the country, i.e. in the area of dipterocarp and mixed deciduous forest, the main common types of forest vegetation in Thailand, Lao PDR and Cambodia, are quite lower than the mean values of all types of forest used by Streets *et al.*, 2003. The lower values observed are indications of the type of forest fires occurring in the region. Fires occurring in dipterocarp and mixed deciduous forest, are generally surface or ground fires, consuming only biomass accumulated on the ground surface or litter. Regarding the TPM emission factor, the first data in Thailand for forest fires and paddy field burnings are of the same range as that reported in the literature. However, the number of samples is still very limited, so that it cannot be considered as statistically significant yet, to state a final conclusion. These preliminary findings actually underline the important influence of local conditions or specificity on the emissions, especially those related to area of land and type of biomass burned. It is therefore of most importance to continue setting up field experiments and surveys to determine and monitor these parameters in the MRBSR, so as to be able to improve the mission inventory and its assessment. This information should be used to support the policy formulation on the control of biomass burning in the region under the ASEAN Transboundary Haze Agreement.

Table 6 Emissions from forest fires

	Amount of biomass burned (Tonnes)	CO (Kg)	TPM (Kg)
Thailand	*58,880,000*	*6,123,520,000*	*1,177,600,000*
Cambodia	*27,504,000*	*2,860,416,000*	*550,080,000*
Vietnam	*12,730,000*	*1,323,920,000*	*254,600,000*
Lao PDR	*20,348,000*	*2,116,192,000*	*406,960,000*

Table 7 Emissions from rice residues burning

	Amount biomass burned (Tonnes)	CO (kg)	TPM (Kg)
Thailand	*866,368*	*79,705,857*	*8,663,680*
Cambodia	*86,352*	*7,944,403*	*863,522*
Vietnam	*405,473*	*37,303,554*	*4,054,734*
Lao PDR	*13,106*	*1,205,785*	*131,064*

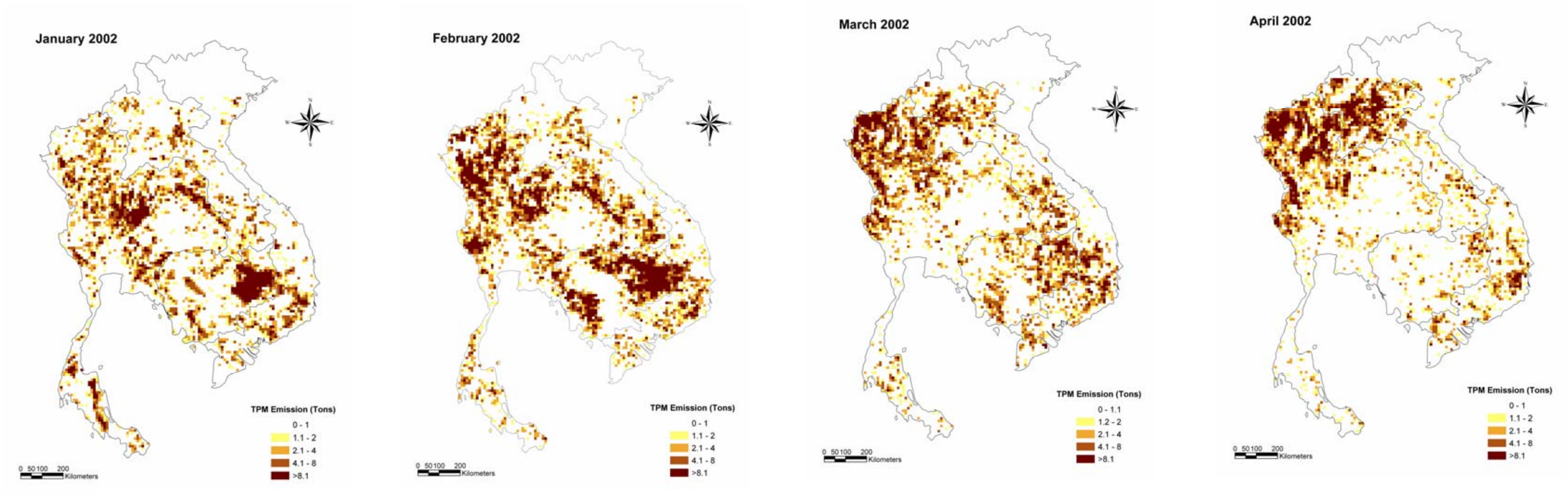

Figure 6. Maps of monthly CO emissions in the MRBSR during January-April 2002

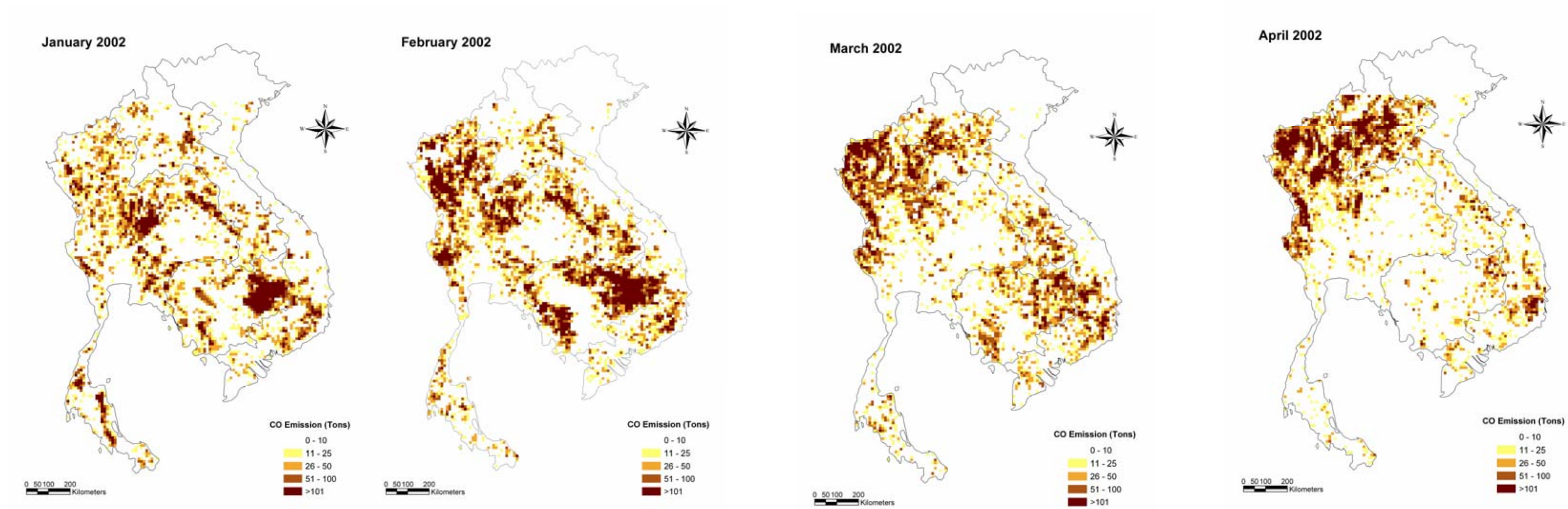

Figure 7. Maps of monthly TPM emissions in the MRBSR during January-April 2002

3.3 Biogenic emissions

3.3.1 Paddy fields

The aim of study methane and nitrous oxide emission in Thailand is to establish emission measurements procedure and emission factors. The outputs were used in *in situ* training in Cambodia and disseminated in the workshop organized later on. Figure 8 below is the example of methane and nitrous oxide fluxes through out rice planting periods, from which the emission factors were derived (Table 1). Water managements significantly affected methane and nitrous oxide. When paddy field water is drained, emission of methane decreased and of nitrous oxide increased. The accurate of emission estimate in greenhouse gas inventory at large scale, therefore, depends significantly on the accurate activity data on field managements.

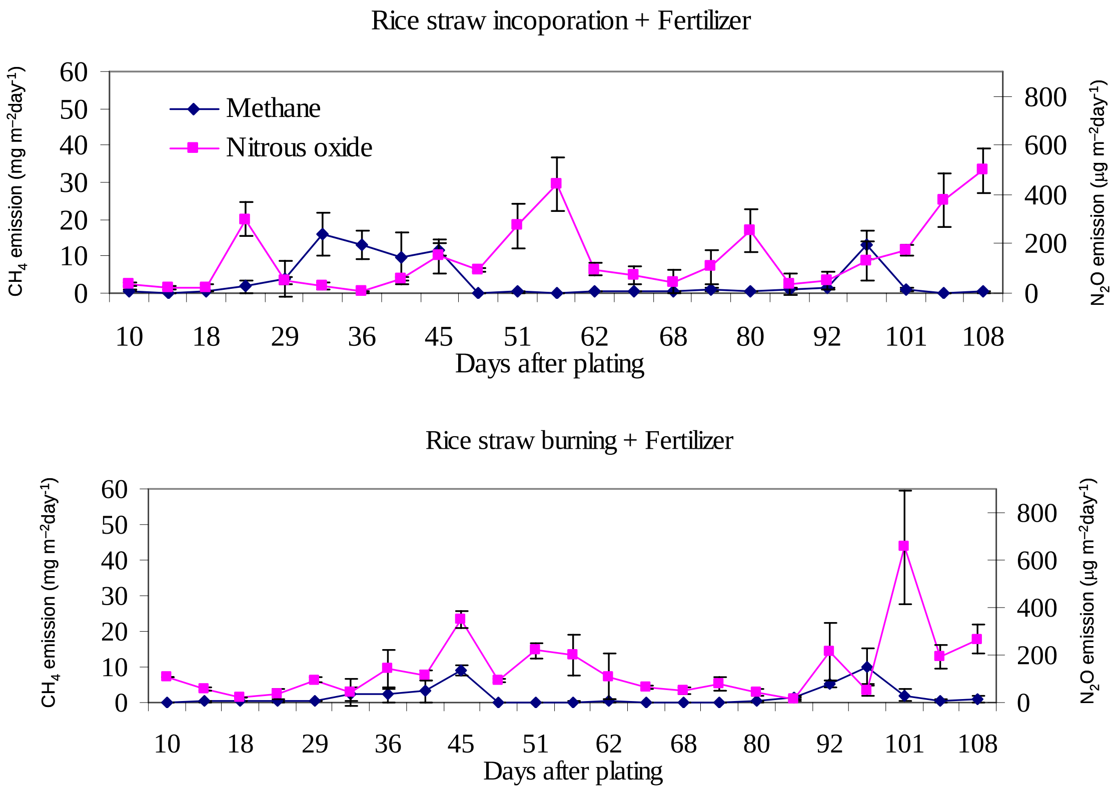

Figure 8. Methane and nitrous oxide emission from paddy fields in Thailand as affected by water managements

3.3.2 Forest

Methane and nitrous oxide emissions were measured in 4 forest types as mentioned earlier. The results are presented in Figure 9 below. Measurements were performed monthly for one year period. The forest category selected such that they represent the major forest ecosystem in the region. Basically, emission of both gases showed large seasonal variations. The ranges and average (in parenthesis) of emissions were 179.9 ~ 1009.8 (490.9 ±321.3), -248.1 ~ 830.7 (261.9 ±268.0), -499.5 ~ 1082.1 (46.1± 456.5) and -90.6 ~ 1121.3 (275.5±320.9) µg N_2O /m^2/d for N2O and -2.75 ~ -0.18 (-1.45 ±0.88), -6.68 ~0.24(-2.44 ±2.20), -2.09 ~ 0.24(-0.88 ± 0.90), and -1.64 ~ -0.11(-0.76 ±0.56) for methane in dry evergreen, hill evergreen, moist evergreen and

Mixed Deciduous and dry dipterocarp forest, respectively. Thus, most of forest soils act as N_2O sources and CH_4 sinks. The one-year average values were applied as the emission factors in this study. However, it should be noted that since there are large spatial and temporal variations in emission, intensive and wide-area coverage measurement campaign in forest soil should be carried out to obtain more accurate emission factor.

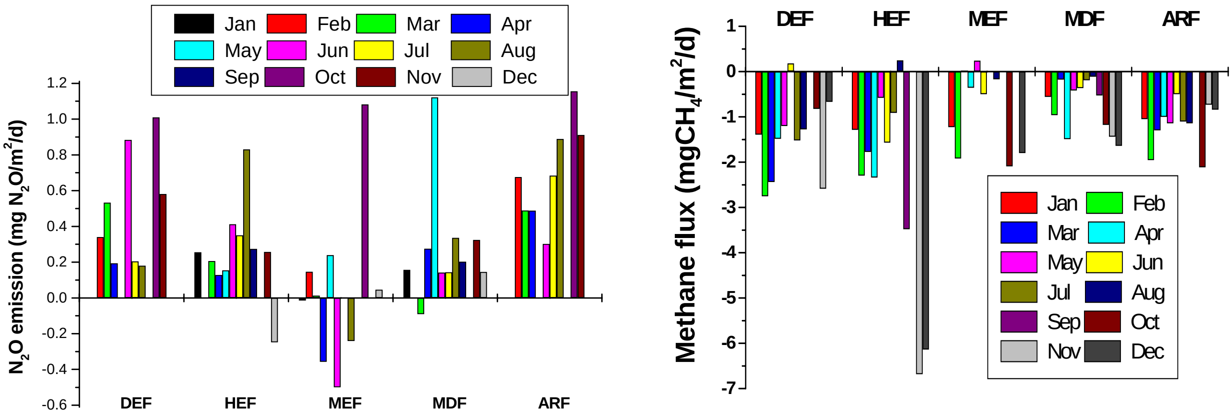

Figure 9. Emission of N_2O and CH_4 from forest soil; DEF (dry evergreen), HEF (hill evergreen), MEF (moist evergreen), MDF (mixed deciduous) and ARF (reforestation)

3.3.3 Emission of CH_4 and N_2O emission from paddy fields and forest in Thailand and Cambodia

Using the emission factors obtained from measurement in Thailand, emission of CH_4 and N_2O from the whole country was estimated, based on the total area and land use classification shown in Section 3.1. Estimation is only possible in these two countries because the information on land use classification in other countries is not available. Estimates were divided into irrigated and non-irrigated rice. Irrigated rice accounted for about 32% of the total CH_4 emission because rice is usually grown twice a year and emission per unit area for irrigated rice is about twice that of the rainfed. On the other hand, although rainfed rice area accounts for about 80% of total growing area, it contributed around 68% of total CH_4 emission (1.1 $\times10^6$ tons). However, only about 18% of total N_2O emission was from irrigated rice (Table 8).

Table 8. Estimated emission of CH_4 and N_2O from rice paddy in Thailand

Rice Field	Area ($\times10^6$ m^2)	Emission Factor ($mg/m^2/day$)		Biogenic Emission from Rice Field (Ton)	
		CH_4	N_2O	CH_4	N_2O
Irrigated first crop	14,686.34	97.623	0.2937	172,046.99	517.61
Irrigated second crop	14,686.34	97.623	0.2937	172,046.99	517.61
Rain-fed	130,393.82	45.71	0.2937	715,236.19	4,595.60
	Total			1,059,330.17	5,630.82

For forest, total CH_4 sink amounted to 144 ton but it acted as N_2O source of about 40 ton a year (Table 9). Based on the global warming potential of CH_4 and N_2O of 21 and 310, forest is considered as the net source of greenhouse gas (11,560 ton CO_2-equivalent per year).

Table 9. Estimated emission of CH_4 and N_2O from major forest types in Thailand

Type of Forest	Area ($\times 10^6$ m^2)	Emission Factor (mg/m^2/day)		Emission (Ton)	
		CH_4	N_2O	CH_4	N_2O
Moist evergreen	17,904.2	-1.390	0.077	-24.89	1.38
Dry evergreen	24,409.1	-1.530	0.420	-37.35	10.25
Hill evergreen	8,861.0	-2.400	0.315	-21.27	2.79
Mixed deciduous	56,873.0	-0.760	0.315	-43.22	17.91
Dry dipterocarp	22,977.5	-0.760	0.315	-17.46	7.24
Total				-144.2	39.6

In Cambodia, total CH_4 emission from rice field was 147 $\times 10^3$ ton and only about 23% was emitted from irrigated rice (Table 10). Similar to the case of Thailand, rainfed rice is the major source of CH4 emissions. On the other hand, 87% of total N_2O was emitted from non-irrigated rice. Since only deciduous forest type is available, we could be able to estimate CH_4 and N2O emission from this forest. The total emission of CH_4 and N_2O were -29 (sink) and 12 ton, respectively. Figures presenting spatial distribution of CH_4 and N_2O emission sources in both countries are given in Figure 10.

Table 10. Estimated emission of CH_4 and N_2O from paddy field and mixed deciduous forest in Cambodia

System	Area ($\times 10^6$ m^2)	Emission Factor (mg/m^2/day)		Emission (Ton)	
		CH_4	N_2O	CH_4	N_2O
Non-irrigated (first crop)	20,483.6	45.71	0.2937	112,356.64	721.92
Irrigated (second crop)	2,985.3	97.623	0.2937	34,971.96	105.21
	Total			147,328.60	827.13
Mixed deciduous Forest	38,188.3	-0.760	0.315	-29.022	12.030

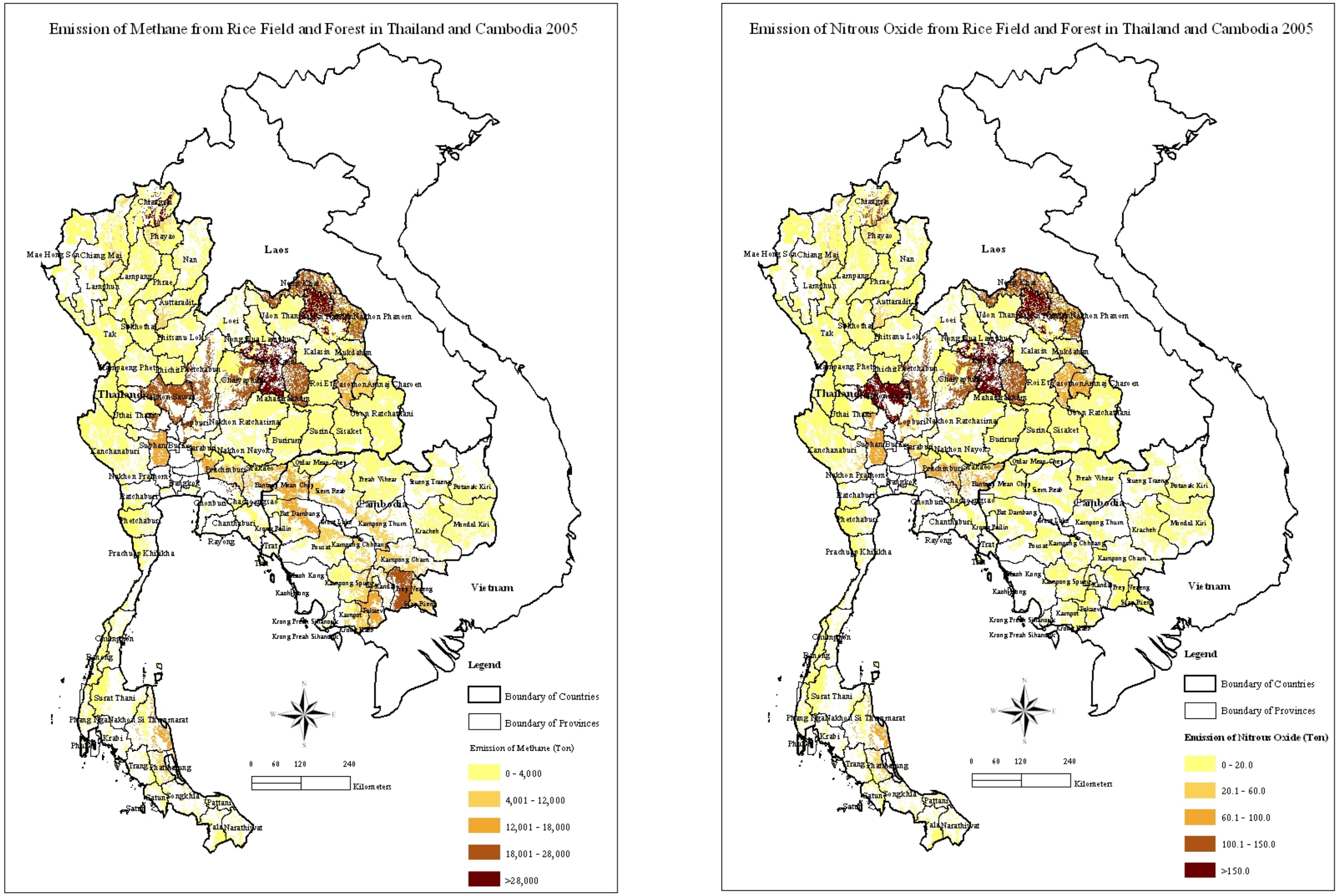

Figure 10. Total CH_4 and N_2O emission from paddy field and forest in Thailand and Cambodia

3.4 Capacity building and scientific decision support information dissemination

The capacity building and scientific decision support information dissemination to scientists and policy makers of the MRBSR was first accomplished through the organization of an international training workshop on "Inventories of GHG and Aerosol Emissions Associated to Different Vegetation Land Use in the Mekong River Basin Sub-Region", during 1-3 May 2007, in Bangkok, Thailand.
In addition to be a start-up of establishment of a regional network on GHG and aerosol emission inventory, which enabled the 5 countries of the MRBSR, including Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam, to compare their emission status and to exchange their experiences and lessons learnt in relation to emission inventory, the workshop helped participants to concretely realize the importance of biogenic and biomass burning activities as major sources of GHG and aerosol emissions at the national and regional scale through keynote lectures and through national emission maps, for forest and paddy fields. On the other hand, the analysis of the evaluation forms completed by the participants of this workshop revealed that 50% of them judged the theme and scope of the workshop good, and the other 50% EXCELLENT. This result confirmed the strong interest and need of scientists and policy makers in the region on GHG and aerosol emission inventory, and on capacity building for improving this latter. Moreover, keynote lectures delivered during the workshop were judged as of good quality by 70% of the participants, and as excellent by the reaming 30%. The same share of appreciation was obtained for presentations and hands-on sessions provided for biogenic and biomass burning emissions. This result reveals that the methodology and approach developed in the APN project are appropriate to be efficiently assimilated by the "learners" and implemented. Also, it has enabled to underline the importance of capacity building and scientific decision support information dissemination to scientists and policy makers in the MRBSR, in the domain of inventory of GHG and aerosol emissions from biogenic and biomass burning activities, considering their importance as significant sources of air pollution in the region.

The second activity of the project contributing to capacity building and scientific information dissemination concerns the demonstration and training activities provided to the Cambodian counterparts of this project to monitor GHG and aerosol emissions from biogenic sources and biomass burning activities, for both forest and paddy fields. Regarding biogenic activities, the training was focused on measurement using a close chamber system, while for biomass burning the technology transfer was focused on biomass sampling to determine biomass load and on expert interviews using the set of questionnaires prepared by the Thai experts involved in this project to cross-check the information on burning activities obtained from satellite data. For biogenic emissions, GHG samples collected are in the process of being collected and sent to Thailand for chemical analysis; the sampling is currently on-going. Concerning biomass burning, biomass sample collection is set in the case of forest, while for paddy fields it has not started yet since it should be conducted during the harvesting period or land preparation for new crop cultivation, which are generally held around end of July or beginning of August. On the other hand, preliminary results from interview of Cambodian experts in forestry and agriculture, confirm the spatial and temporal overall observations obtained from satellite data i.e. high burning frequency in January and February, around 90% of paddy fields in Cambodia are rain-fed and only paddy areas in the southeast region offer the possibility of 2 crops cultivation and so the use of fire for fast land clearing, fire is also used for land clearing of forest, the major types of forest vegetation are dipterocarp and mixed deciduous, and fires occurring in Cambodian forest are generally surface fires. In general, the procedures developed and transferred to the Cambodian counterparts, with regards to biomass burning, were well assimilated. They are currently performing follow-up measurements and sample collection in order to constitute a comprehensive data set of seasonal variability of biomass burning activity.

4. Conclusions and perspectives

This project on GHG and aerosol emissions under different vegetation land use in the MRBSR, under the APN-CAPaBLE program, led to the following main findings, in terms of capacity building and scientific decision support information dissemination to scientists and policy makers of the region:

(1) Biogenic and biomass burning are recognized to constitute one of the major sources of air pollutants in the region, especially GHG and aerosols.

(2) Better knowledge and understanding of these processes are required in the MRBSR, in order to improve the regional and national emission inventory, in particular for meeting the need of updating the national communications on GHG inventory, which is part of the commitments of the countries in the region to UNFCCC regarding the Kyoto Protocol.

(3) Methodologies and experimental procedures developed in Thailand have been evaluated by scientists of the MRBSR as appropriate for measurement and monitoring of local parameters related to biogenic and biomass burning emissions. Also, they are sufficiently simple to be well-assimilated, and efficiently implemented.

(4) The establishment of a regional network of scientists and policy makers on the inventory of GHG and aerosol emissions from biogenic and biomass burning activities, achieved in this project under the APN-CAPaBLE initiatives, has enabled to answer to the regional needs for improvement of the corresponding emission inventory. The methodology set-up to establish this emission inventory has also been judged appropriate since it has been developed by regional researchers and local experts in Thailand in close collaboration with their Cambodian counterparts, to provide effective support the regional study and experience sharing.

Based on these main findings, it would be highly recommended to develop future work as follows:

(1) To follow-up the network on GHG and aerosol emission inventory, and to broaden it to all other ASEAN countries and to other type of air pollution sources, especially those related to energy and agricultural activities.

(2) To develop R&D field experiments based on the methodologies and procedures set-up in this project in all countries of the MRBSR, including Cambodia, Lao PDR, Myanmar, Thailand and Vietnam, using the same capacity building approach as that transferred to our Cambodian counterparts, in order to establish the regional model of GHG and aerosol emission from biogenic and biomass burning sources.

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Appendices

APPENDIX 1:

Schedule of International Training Workshop

Workshop On

"Inventories of Greenhouse Gases and Aerosol Emissions Associated to Different Vegetation Land Use in the Mekong River Basin Sub-region"

1-3 May 2007
The Joint Graduate School of Energy and Environment (Fl. 2, Room EN3204),
King Monkgut's University of Technology Thonburi, Bangkok, Thailand

Agenda

First Day: 1 May 2007

08.30 – 9.00	**Registration**	
9.00 – 9.10	Report	**Dr. Sirintornthep Towprayoon** Deputy Director, JGSEE, Thailand
9.10 – 9.20	Welcome Address	**Dr. Bundit Fungtammasan** Director, JGSEE, Thailand
9.20-9.30	Opening Address	**Dr. Kraiwute Keitikomol** President of KMUTT, Thailand
9.30 – 10.00	Introduction of APN Project	**Dr. Sirintornthep Towprayoon** APN Project Leader, JGSEE, Thailand
10.00 – 10.15	**Coffee Break**	
10.15 – 11.15	Evidences & Modeling of Long-Range Transport of Air Pollutants	**Dr. Jerry Lin** APN Project Collaborator, Lamar University, USA
11.15-12.00	Application of Remote Sensing to Global Earth Environment Observation	**Dr. Chaowalit Silapthong** Director of Geo-informatics Office, GISTDA, Thailand
12.00 – 13.00	**Lunch Break**	
13.00 – 14.00	Forest Situation in the Mekong River Basin Sub-region	**Mr. Siri Akkaakara** Forest Fire Control Center, Department of Forestry, Thailand
14.00 – 14.30	Rice Cultivation and Management Practices in Thailand	**Ms. Dares Kittiyopas** Department of Agricultural Promotion, Thailand
14.30-15.00	Country Report on GHG Emissions from Biogenic Sources and Status on Aerosols Emissions from Open Biomass Burning in Thailand	**Dr. Amnat Chidthaisong** APN Project Principal Investigators, JGSEE, Thailand
15.00 – 15.15	**Coffee Break**	
15.30 – 17.30	Country Report on GHG Emissions and Aerosols Emissions Inventory and Future Development in Cambodia, Vietnam, Myanmar, and Lao PDR	**Mr. Chea Chan Thou** Ministry of Environment, Cambodia **Mr. Nguyen Mong Cuong** Ministry of Natural Resources and Environment, Vietnam **Mr. Ne Winn** National Commission for Environmental Affairs, Myanmar **Mr. Soulideth** Prime Minister's Office, Lao PDR
18.30 – 21.00	**Welcome Dinner**	

Second Day: 2 May 2007

08.30 – 9.00	**Registration**	
9.00 – 10.00	Emission Inventory Issues: Anthropogenic, Biogenic and Biomass Burning	**Dr. Jerry Lin** APN Project Collaborator, Lamar University, USA
10.00 – 10.15	**Coffee Break**	
10.15 – 10.30	Biomass Burning – Emissions calculation Methodology	**Dr. Sebastien Bonnet** APN Project Coordinator, JGSEE, Thailand
10.30 – 12.00	Hands-on Session I: Questionnaires on Land-use and Agricultural Practices	**Dr. Savitri Garivait** APN Project Principal Investigator, JGSEE, Thailand **Dr. Sebastien Bonnet** APN Project Coordinator, JGSEE, Thailand **Dr. Jerry Lin** APN Project Collaborator, Lamar University, USA
12.00 – 13.00	**Lunch Break**	
13.00 – 14.00	Demonstration of Open Burning Emissions Measurements & Visit of JGSEE Laboratory	**Dr. Savitri Garivait** APN Project Principal Investigator, JGSEE, Thailand **Ms. Ubonwan Chaiyo** JGSEE Laboratory Supervisor, JGSEE, Thailand
14.00 – 14.15	**Coffee Break**	
14.15 – 16.15	Hands on Session II: Calculation of Emissions from Biomass Open Burning	**Dr. Savitri Garivait** APN Project Principal Investigator, JGSEE, Thailand **Dr. Sebastien Bonnet** APN Project Coordinator, JGSEE, Thailand **Dr. Jerry Lin** APN Project Collaborator, Lamar University, USA
16.15 – 17.15	Conclusion Reports from Hands on Session I and II: Air Emissions from Open Biomass Burning in Cambodia, Lao PDR, Vietnam and Thailand	**Dr. Savitri Garivait,** **Dr. Sebastien Bonnet,** **Dr. Jerry Lin and** **All Participants**

Third Day: 3 May 2007

08.30 – 9.00	**Registration**	
9.00 – 9.45	Methodology for Measurement of Greenhouse Gases Emissions from Rice Field	**Dr. Sirintornthep Towprayoon** APN Project Leader, JGSEE, Thailand
9.45-10.30	Methodology for Measurement of Greenhouse Gases Emissions from Forest	**Dr. Amnat Chidthaisong** APN Project Principal Investigator, JGSEE, Thailand
10.30 – 10.45	**Coffee Break**	
10.45 – 12.00	Hands-on session I: Comparative Flux Measurement Using the Chamber Method	**Dr. Amnat Chidthaisong**
12.00 – 13.00	**Lunch Break**	
13.00 – 14.00	Flux estimation and Emission Factor Calculation	**Dr. Amnat Chidthaisong**
14.00 – 14.15	**Coffee Break**	
14.15 – 15.30	Hands on session II : Emissions Up-scaling and GIS-RS Mapping	**Dr. Amnat Chidthaisong**
15.30-16.00	Conclusion	**Dr. Sirintornthep Towprayoon**
16.00-16.30	Closing Ceremony	**Dr. Bundit Fungtammasan** Director, JGSEE, Thailand
18.00 – 21.00	**Farewell Party**	

APPENDIX 2:

List of Participants

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APPENDIX 3:

Training Workshop Teaching Materials

DAY I:

Invited lectures and country reports

Evidences & Modeling of Long-Range Transport of Air Pollutants

***C. Jerry Lin*, Ph.D., P.E.**
Department of Civil Engineering
Lamar University, Beaumont, TX

Inventories of Greenhouse Gases and Aerosol Emissions in the Mekong River Basin

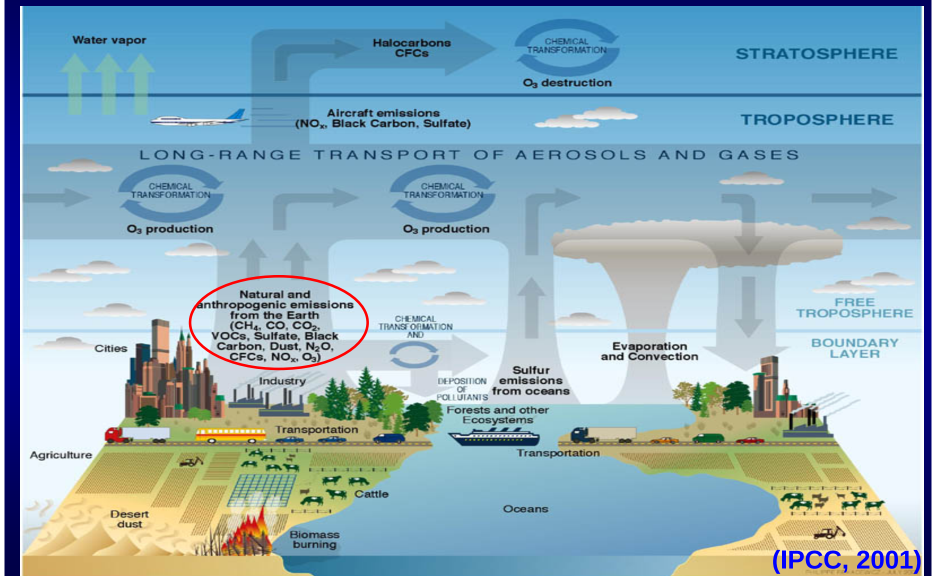
May 1, 2007

Long-Range Transport

Atmospheric transport of air pollutants within a moving air mass for a distance greater than *100* kilometers.

… European Environmental Agency

The Overall Picture



(IPCC, 2001)

General Characteristics of Long-Range Transport

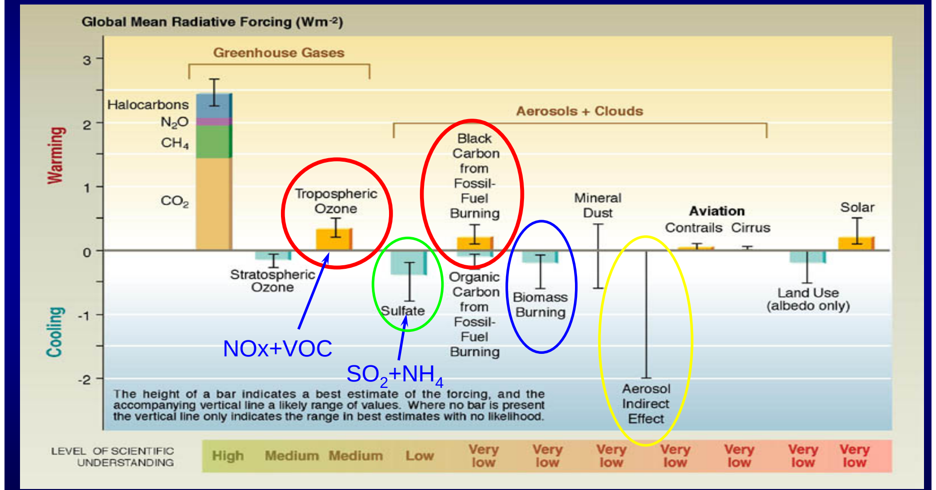
- The right kind of air pollutants
  - Long atmospheric lifetime
  - Chemically inert
  - Not readily removed by scavenging and deposition processes
- The favorable meteorological conditions
  - Prevailing winds
  - Vertical mixing and aloft of emitted pollutants

Greenhouse Gas Concentrations

GAS	Pre-1750 concentration	Current tropospheric concentration	GWP (100-yr time horizon)	Atmospheric lifetime (years)	Increased radiative forcing (W/m^2)
Concentrations in parts per million (ppmv)					
carbon dioxide (CO_2)	280	377.37	1	variable	1.66
Concentrations in parts per billion (ppbv)					
methane (CH_4)	730/688	1847/1730	23	124	0.5
nitrous oxide (N_2O)	270	319/318	296	1144	0.16
tropospheric ozone (O_3)	25	34	n.a.	hours-days	0.35
Concentrations in parts per trillion (pptv)					
CFC-11 (CCl_3F)	zero	253/250	4,600	45	0.34 for all halocarbons collectively, including many not listed here.
CFC-12 (CCl_2F_2)	zero	545/542	10,600	100	
carbon tetrachloride (CCl_4)	zero	93/92	1,800	35	
methyl chloroform (CH_3CCl_3)	zero	23/22	140	4.8	
HCFC-22 ($CHClF_2$)	zero	174/155	1700	11.9	
HFC-23 (CHF_3)	zero	1410	12,000	260	
perfluoroethane (C_2F_6)	zero	310	11,900	10,000	
sulfur hexafluoride (SF_6)	zero	5.2211	22,200	3,200	0.0025
trifluoromethyl sulfur pentafluoride (SF5CF3)	zero	0.1212	~ 18,000	~3,200 (?)	< 0.0001

(Blasing and Smith, 2006)

Climate Effects of Air Pollutants



(IPCC, 2001)

Particulate Matter (PM)

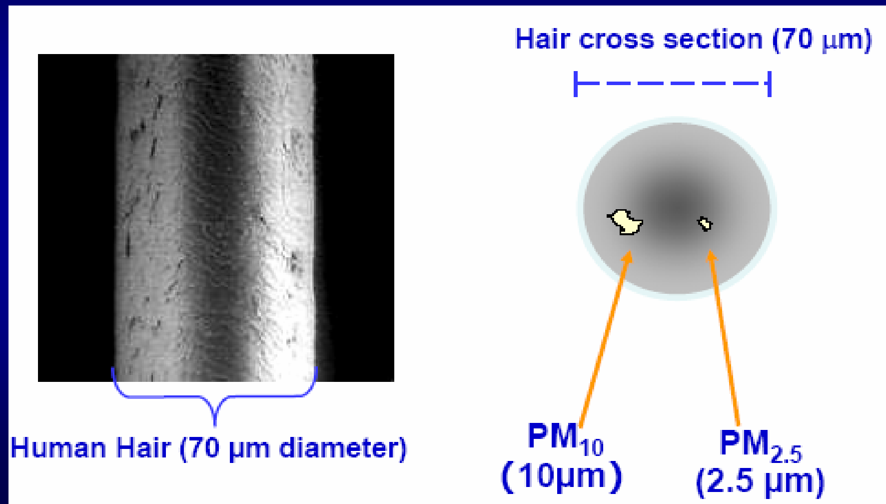
- From *emissions*
  - Ash
  - Elemental (black) carbon
- From *secondary formation*
  - Sulfate aerosol
  - Nitrate aerosol
  - Secondary organic aerosol
- From *natural process*
  - Dust storms
  - Volcanic emission

Particle Diameter (μm)	Time to Fall 1000 m
0.02	228 years
0.1	36 years
1.0	328 days
10.0	3.6 days
100.0	1.1 hours
1000.0	4 minutes
5000.0	1.8 minutes

Atmospheric lifetimes of aerosols vary greatly !!!

PM – how big are they?

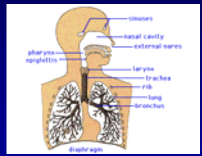
Complex mixture of small liquid and solid suspension in the air.



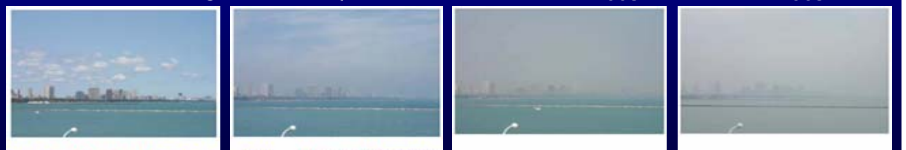
California Office of Environmental Health Hazard Assessment

Effects of PM

- Health Effects
  - Lung damages, Aggravated asthma, Acute respiratory symptoms, Cardiovascular illness, Premature death, Toxicity & carcinogen, etc.
- Welfare Effects
  - Aesthetic damages, acid and nutrient deposition (sulfate, nitrate), nutrient balance upsets, plant damages
- Visibility Reduction
  - Reduction of visual range by light scattering and absorption



1908 1968

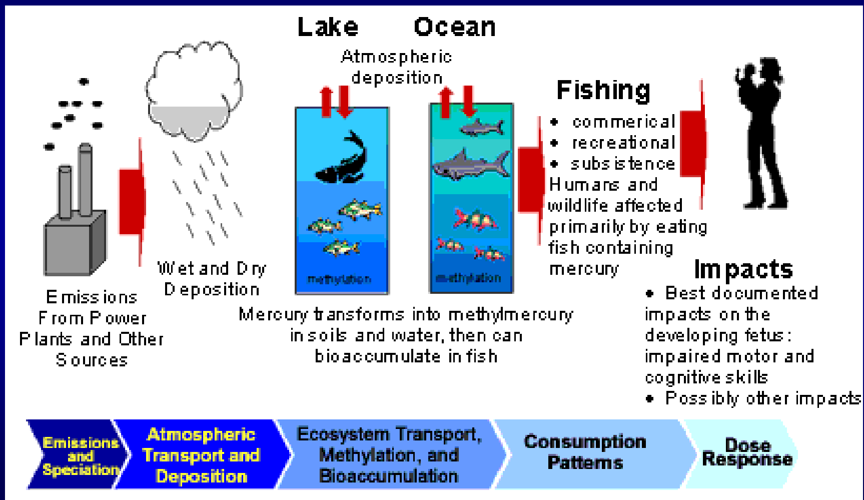


$PM_{2.5}$ < 10 ug/m³ (8/16/00) $PM_{2.5}$ = 20 ug/m³ (8/24/00) $PM_{2.5}$ = 30 ug/m³ (8/15/00) $PM_{2.5}$ = 35 ug/m³ (8/26/00)

Atmospheric Mercury

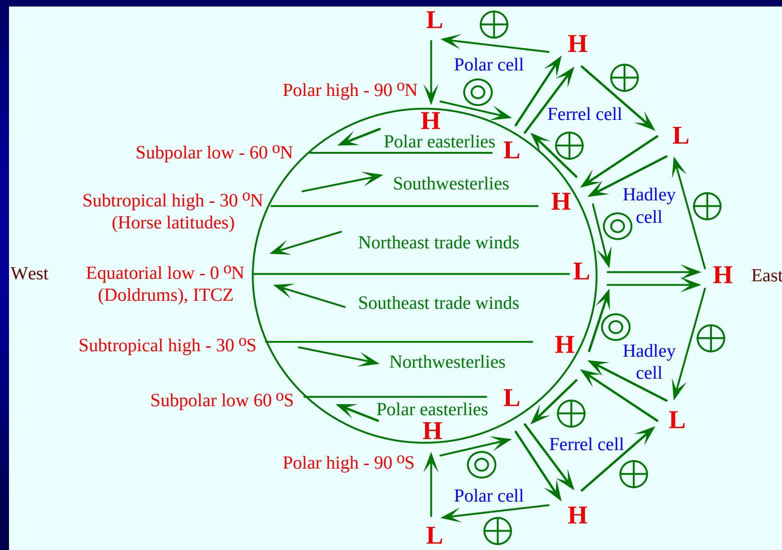
	Elemental (GEM)	Divalent (RGM, PHg)
Primary Source	Emissions	Emission, Products of Hg(0)
Abundance	> 95%	< 5 %
Phase	Gas	Gas, aqueous, solid
Water Solubility	Low (0.3 μM)	High (a few mM)
Henry's Constant	0.11 M/atm	$10^4 – 10^7$ M/atm
Lifetime	0.5 - 2 years	Days - Weeks
Transport	Long Range	Relatively short
Background Concentration	1~4 ng/m³	Up to 900 pg/m³ (RGM) 0.025~0.5 nM (Aq.)

Health Effects of Mercury



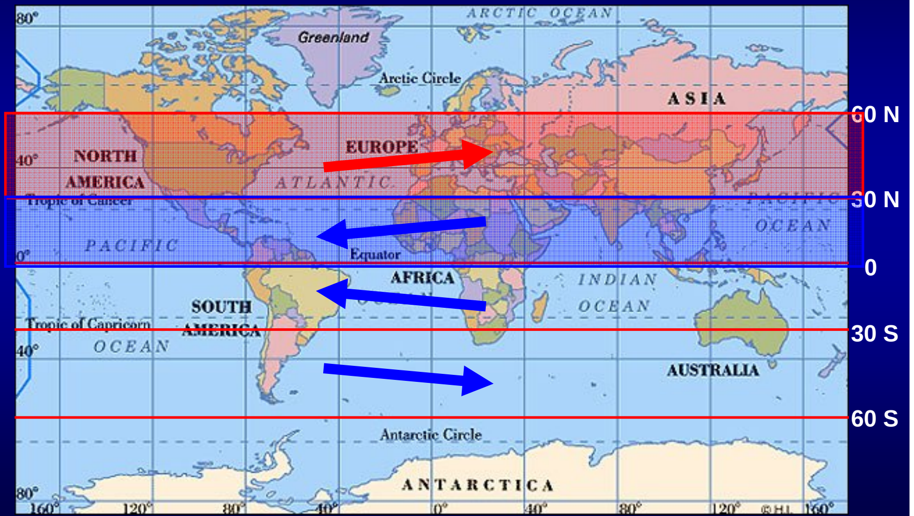
Source: USEPA

Global Circulation Cells



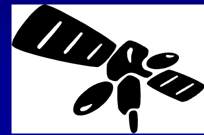
(Jacobson, 2002)

General Transport Patterns

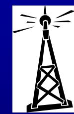


Identifying Long-Range Transport

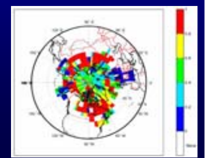
- Satellite observations – optical depth, spectro-radiometer, spectroscopy, optical images, etc.



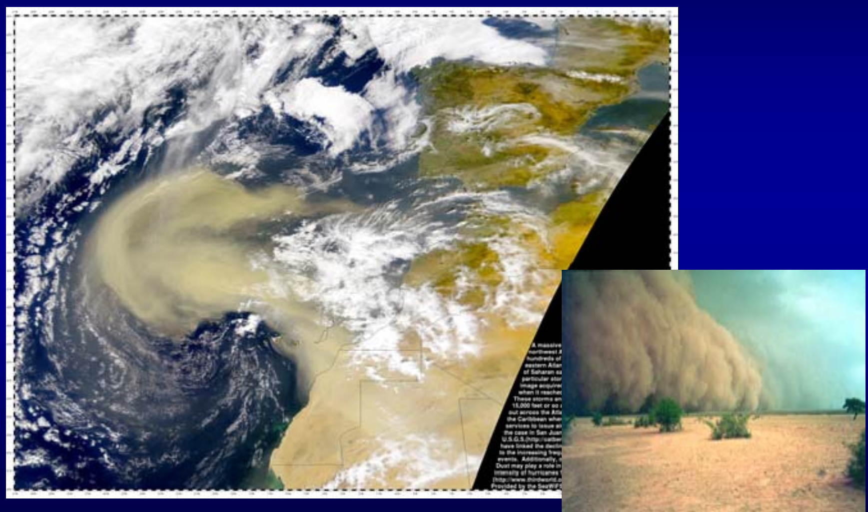
- Ground-based and aircraft observations – detect chemical signal of mixing ratios



- Modeling estimates – mathematically implementing emission and atmospheric processes for assessment



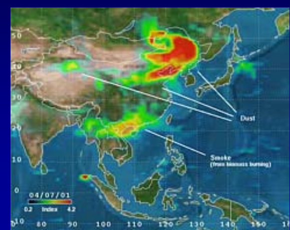
Dust Storm (Africa, Feb. 28, 2000)



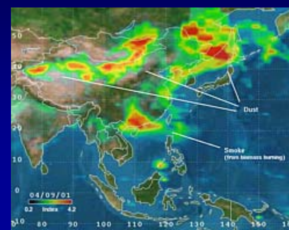
(NASA)

Asian Dust Event April 2001

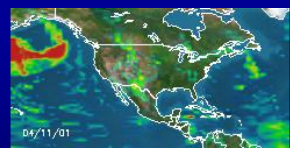
(4/7)



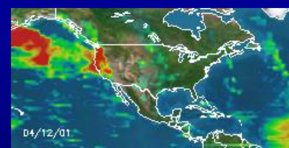
(4/9)



(4/11)



(4/12)



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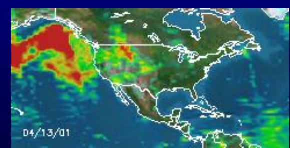

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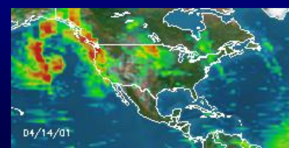
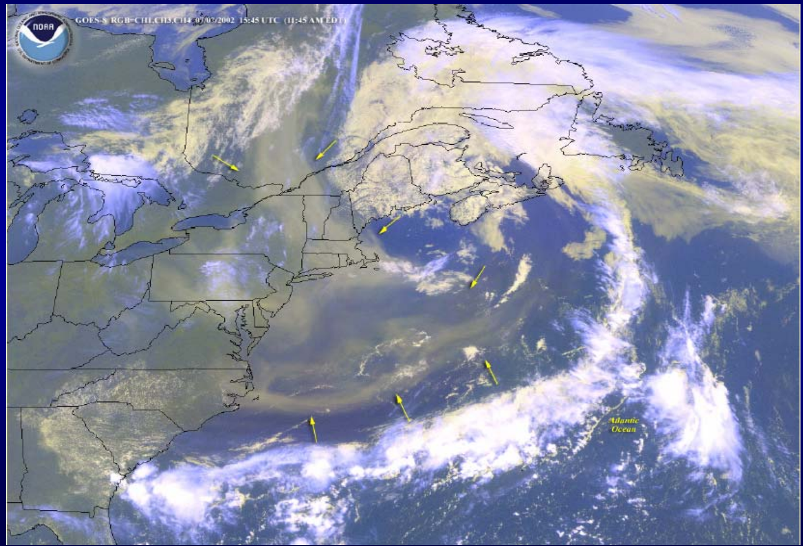


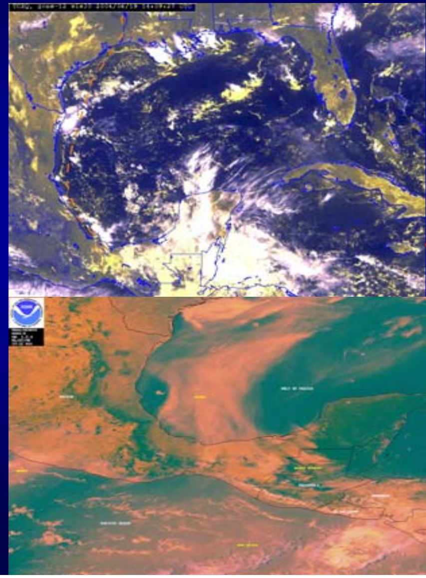
NASA TOMS

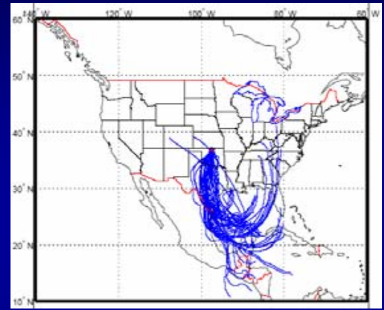
N. American Aerosol Outflow (NOAA TOMS)



July 2002

Smoke from Mexican Fires





2004 Smoke to Texas

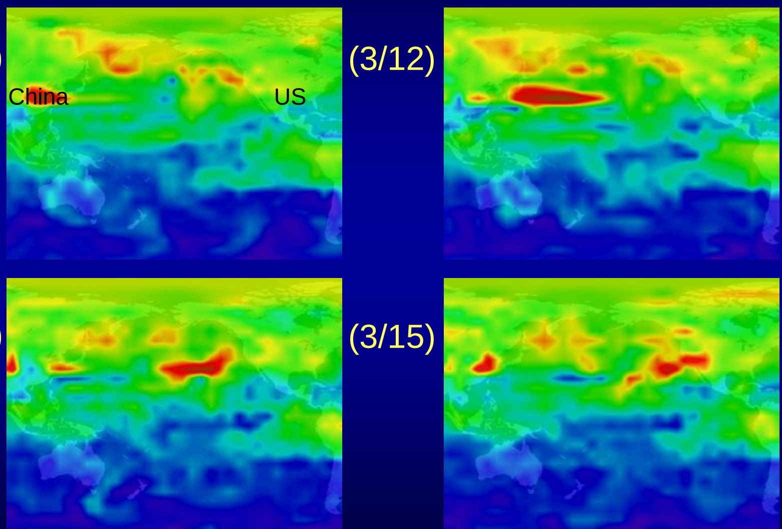
(NOAA MODIS)

2001 and modeling of SMOKE Transport (Chang & Lin, 2001)

Transport of CO, March 2000

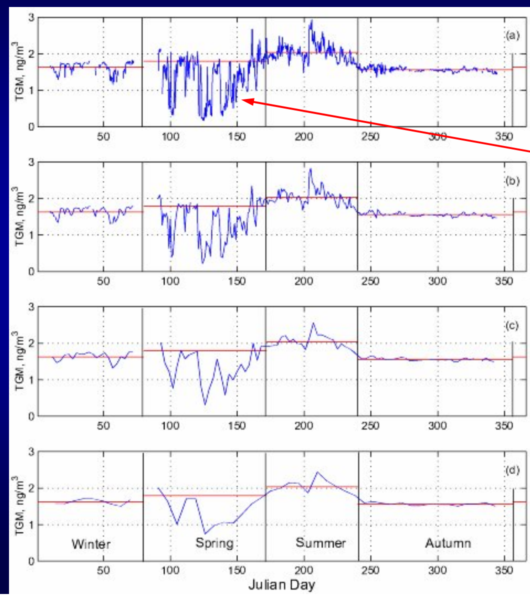
(3/10) (3/12)

(3/13) (3/15)

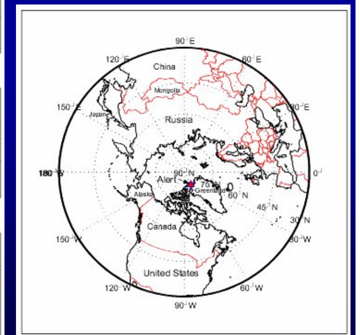


NASA MOPITT

Mercury Transport to the Arctic



Mercury depletion events (MDEs) observed during polar sunrise (Alert, Canada).



Lin *et al.*, 2001.

Conceptual Model of MDEs

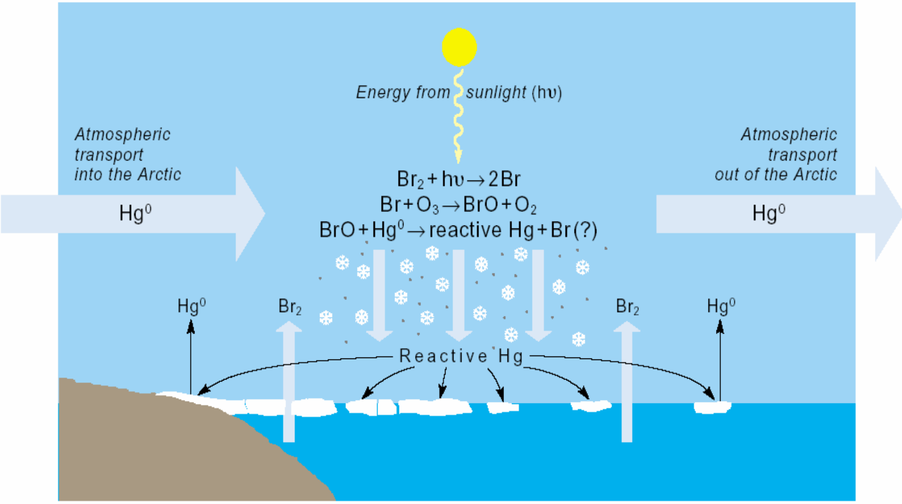
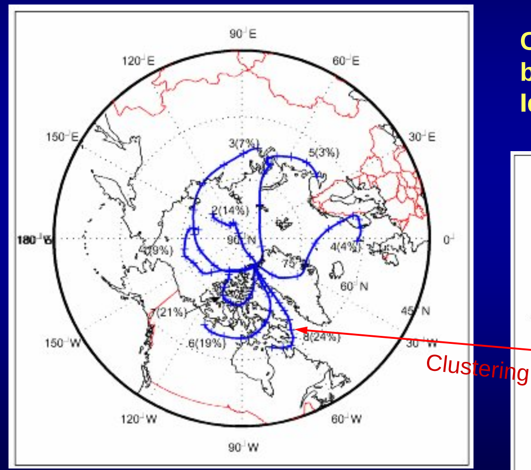
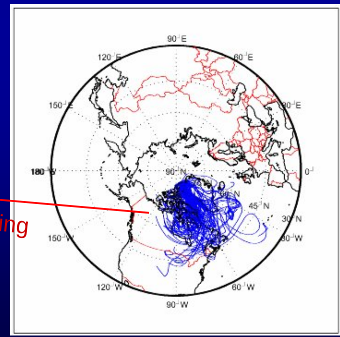


Figure courtesy: Arctic Monitoring and Assessment Programme

Long-range Transport Pathways



Cluster analysis of air mass back trajectories helps Identify transport pattern.

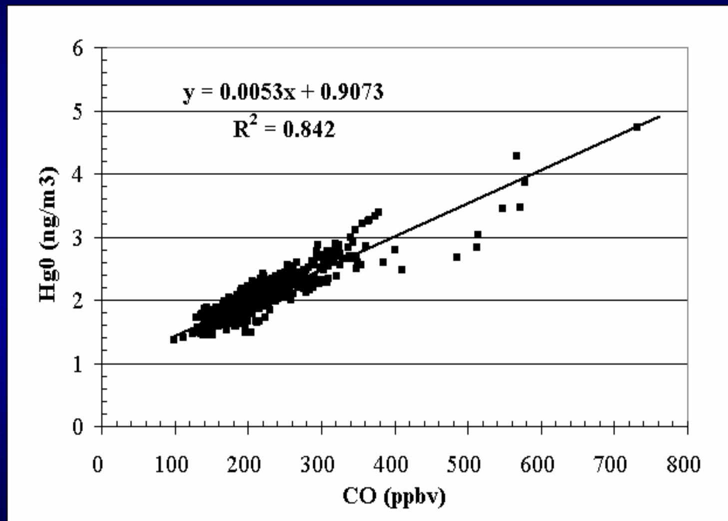


Lin *et al.*, 2001.

Hg and CO Observation at Mt. Bachelor & Okinawa

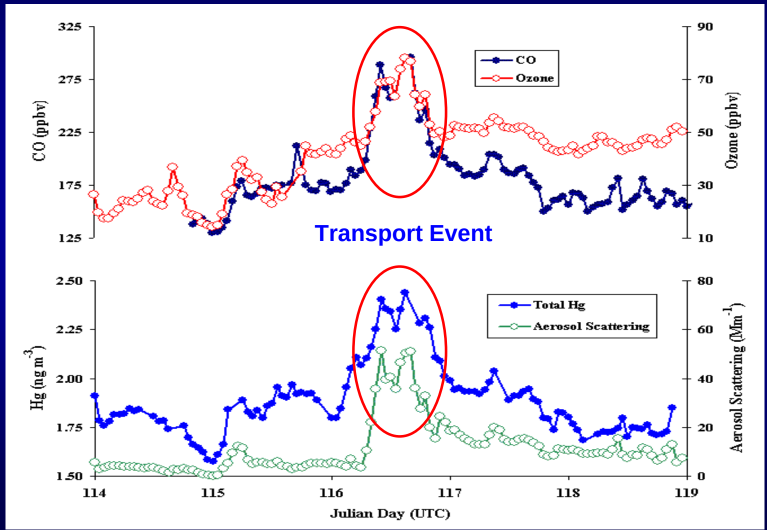
Slide courtesy: Eric Prestbo and Dan Jaffe

Hg^0 vs CO at Okinawa



Jaffe et al. (2005)

Hg^0 Transport to US west coast from Asia on April 25, 2004



Slide courtesy: Eric Prestbo and Dan Jaffe. Jaffe et al. (2005)

Impact of Long-Range Transport

- Causes the health and welfare effects in regions remote from the direct emission sources
- Increases the background air quality burden in other regions
- Creates difficulty in regulatory efforts for emission reduction
- Impacts on the biosphere in remote areas

Air Quality Models for Assessing Long-range Transport

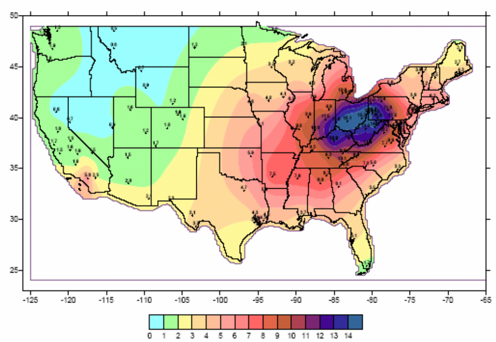
- *Research tool*
  - Models are representations of atmospheric processes
  - Advance understanding of transport and transformation of air pollutants
- *Assessment and planning tool*
  - Air quality impact assessment
  - Future air quality planning
- *Policy making tool*
  - Control strategy development
  - Cost/benefit analysis

Sulfate PM

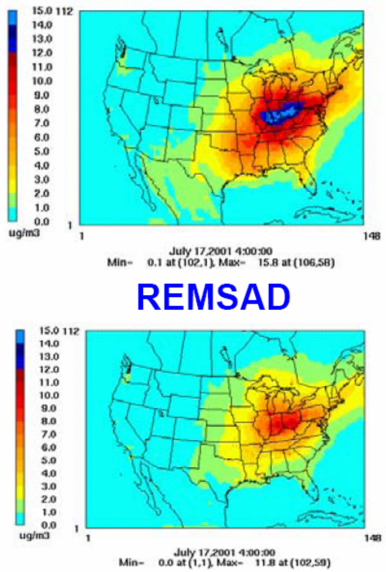
July 17 – Aug. 13, 2001 Average

Observed Data

SO4 from Castnet and STN
LM 8, July 17 - Aug 13, 2001

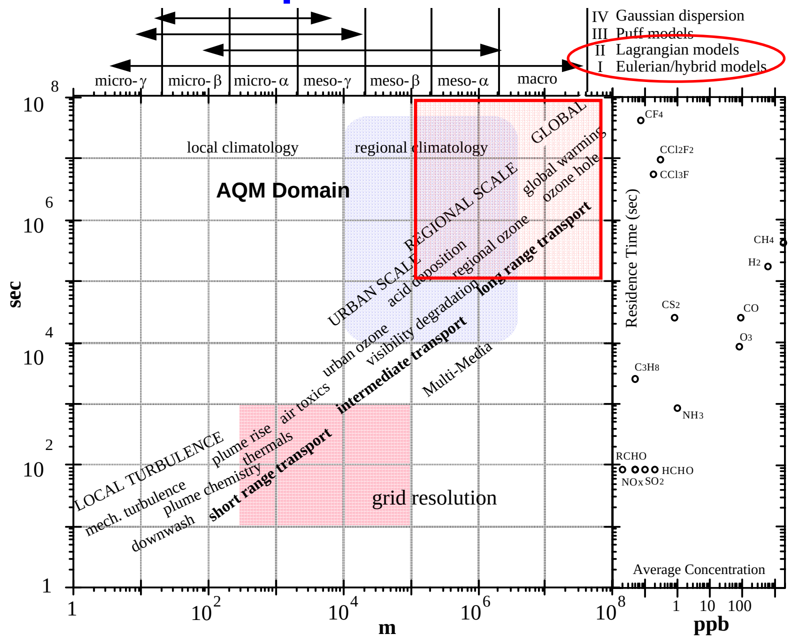


CMAQ

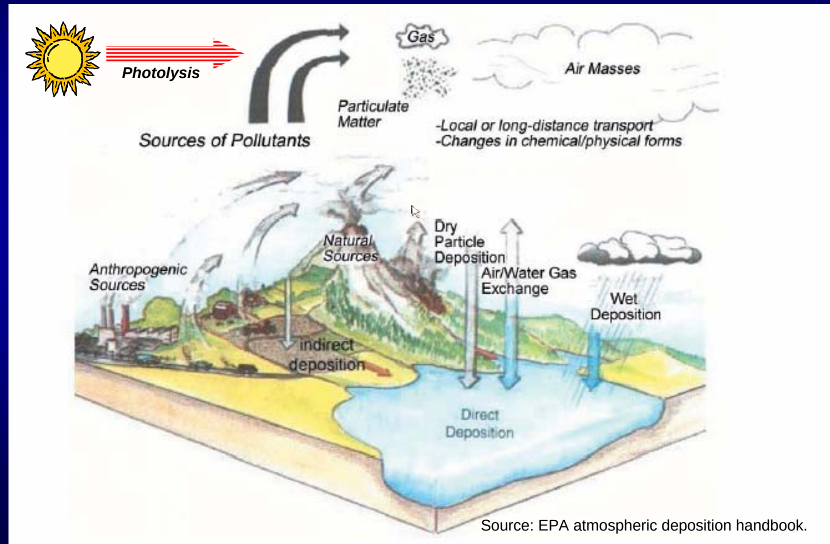


(Slide Courtesy: Carey Jang)

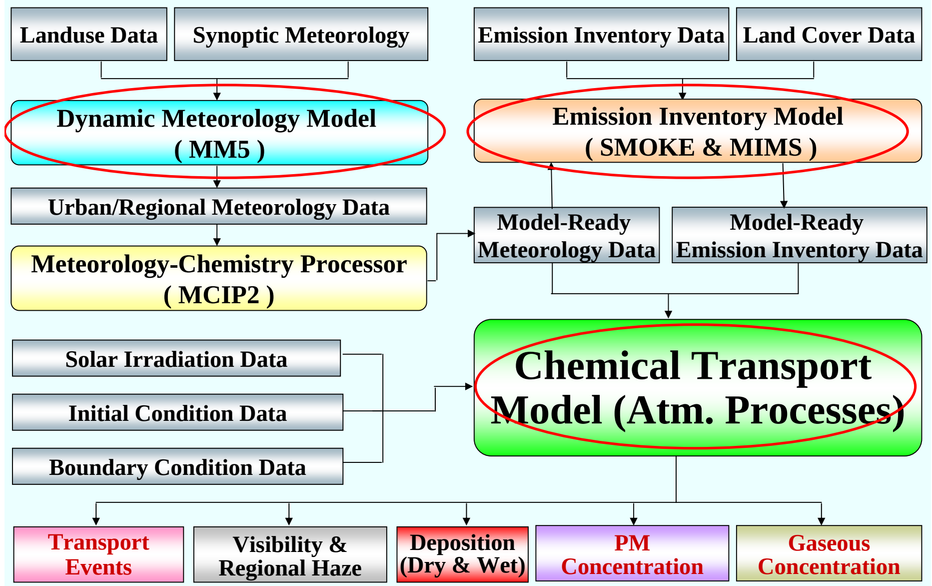
Atmospheric Model Scales



Modeling Schematics



Major Model Components



Major Atmospheric Processes

- Atmospheric transport
  - Advection (horizontal and vertical)
  - Diffusion (horizontal and vertical)
- Chemical transformation (gaseous, aqueous and heterogeneous reactions)
- Cloud processes (convection, mixing, evaporation & condensation cycles, and scavenging)
- Emissions (anthropogenic and natural)
- Deposition (dry and wet)
- Optical interactions (visibility reduction)

Governing Equations

Change due to advection

Change due to chemical production and loss

Change due to deposition (sinks)

$$\frac{\partial C_i}{\partial t} = -\nabla(VC_i) + \nabla(D\nabla C_i) + P_i - L_i + S_i - D_i + C_i$$

For each species

Total conc. change w.r.t. time

Change due to diffusion

Change due to emission

Change due to cloud process

Emission Sources

- Anthropogenic sources
  - Point: power plants, large industrial emission, etc.
  - Area: solvent evaporation, machineries, biomass burning, etc.
  - Mobile: vehicle, ship, aircraft, etc.
- Natural sources
  - Vegetation and soil emission
  - Volcano eruption, weathering, etc
  - Biomass burning emission
- Re-emission (mercury)
  - Caused by past mercury emission and deposition
  - Biotic and abiotic processes cause reduction of deposited Hg(II) back to volatile Hg^o

USEPA's ICAP Program

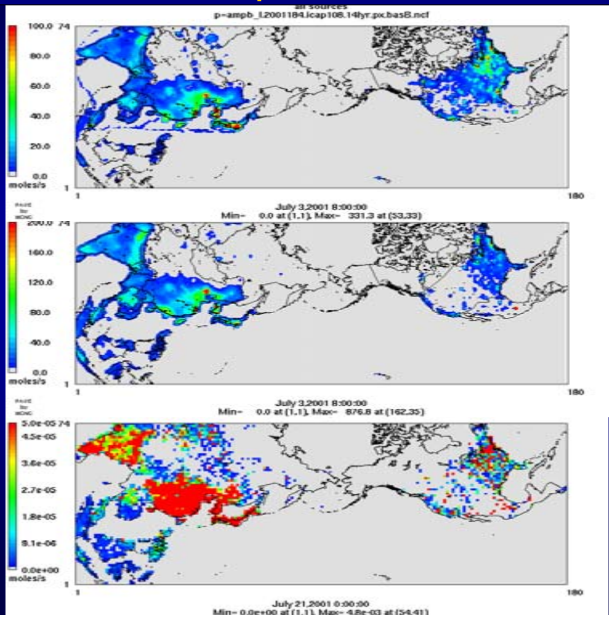
- Intercontinental transport and Climatic effects of Air Pollutants
- Assessing long-range transport and its impacts on the regional air quality and climate using USEPA's CMAQ "One-Atmosphere" Model (Byun et al., 1999)
  - What's the role of anthropogenic emissions from the U.S. and other regions in the air quality?
  - What's their role in the global distribution of air pollutants?
  - What is the contributions of emission source categories to regional air quality and climate?

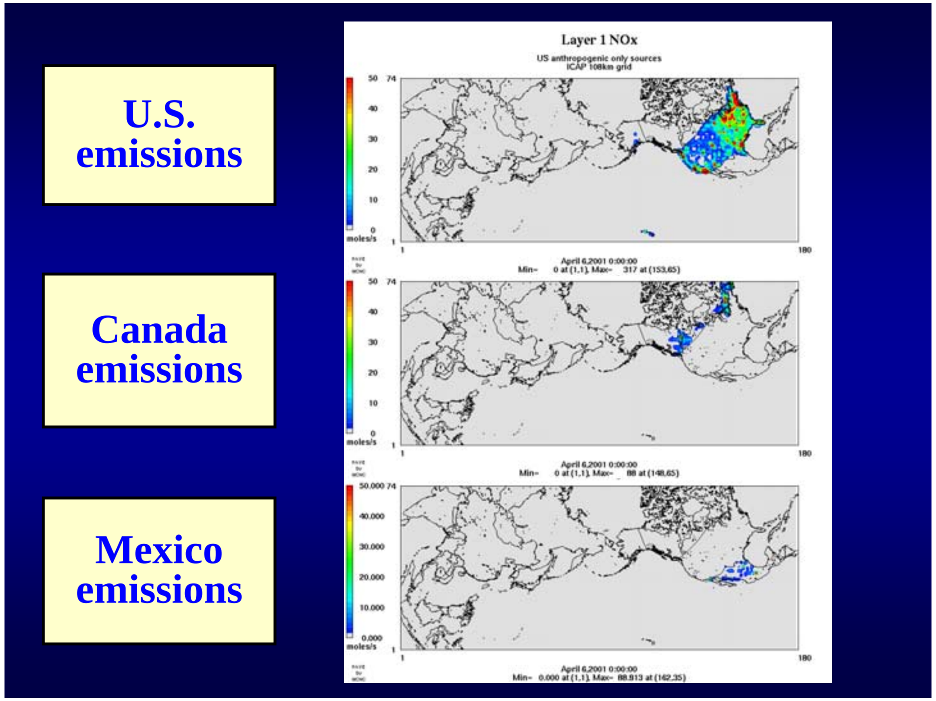
ICAP Emissions Data Preparation & Processing

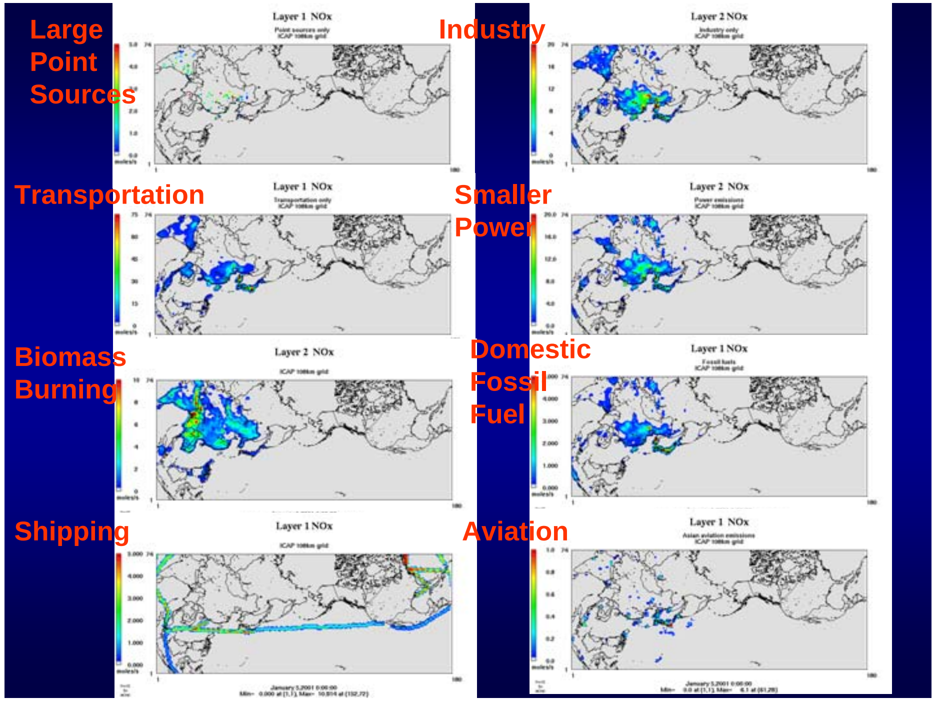
NO_x Emissions

VOC (PAR) Emissions

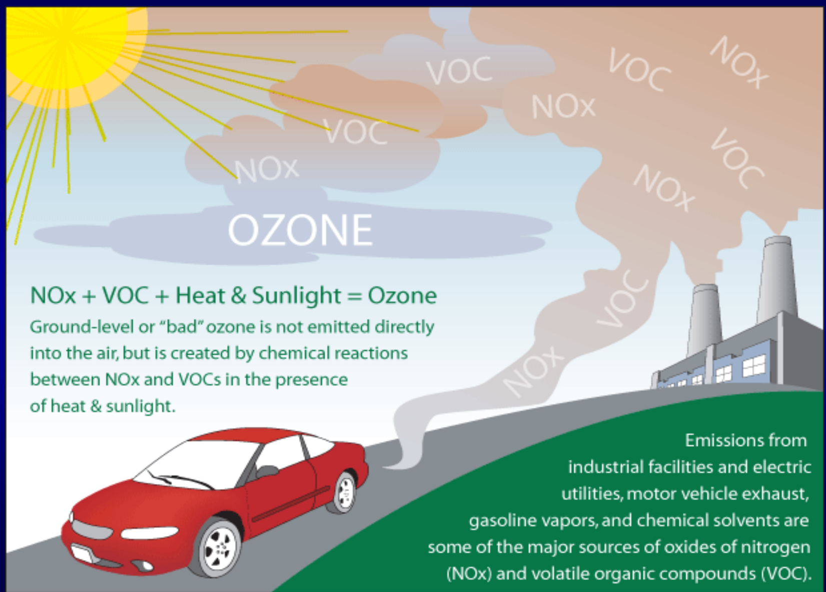
Mercury Emissions



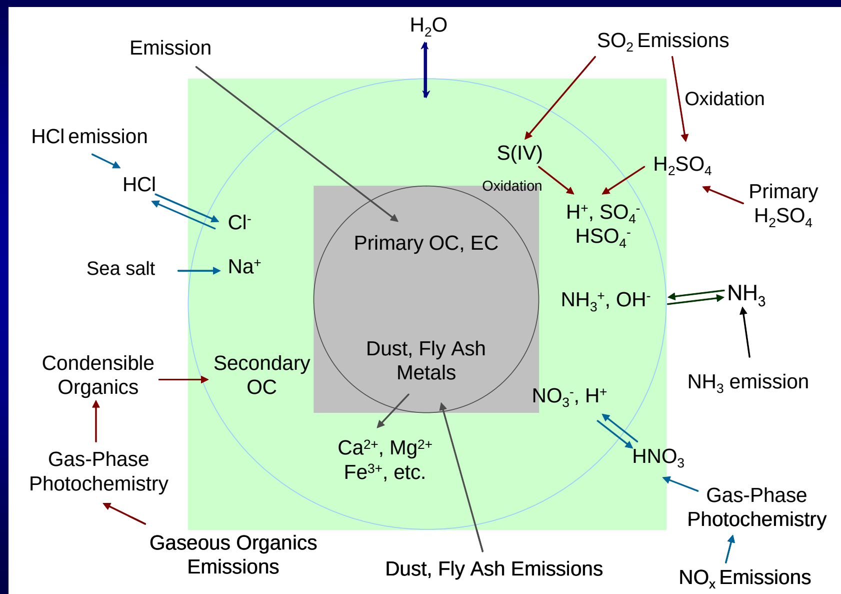




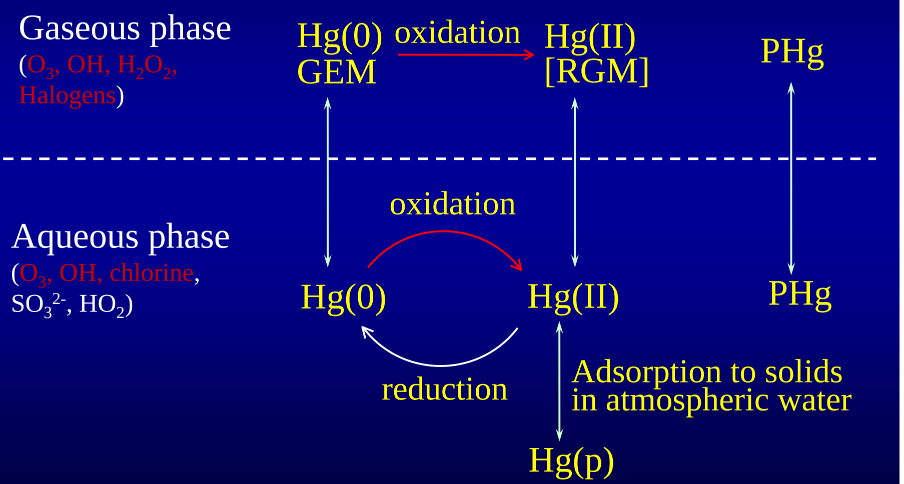
Ground-level O_3 Chemistry



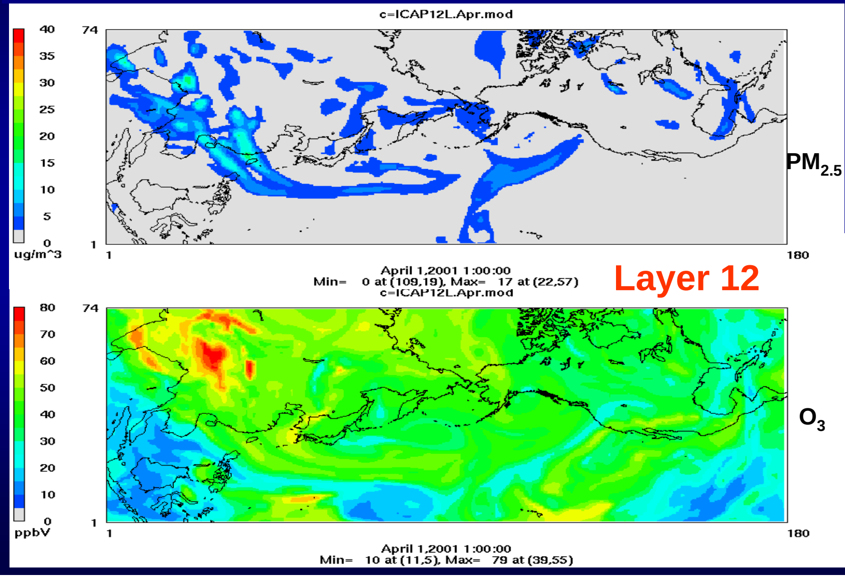
Aerosol Chemistry



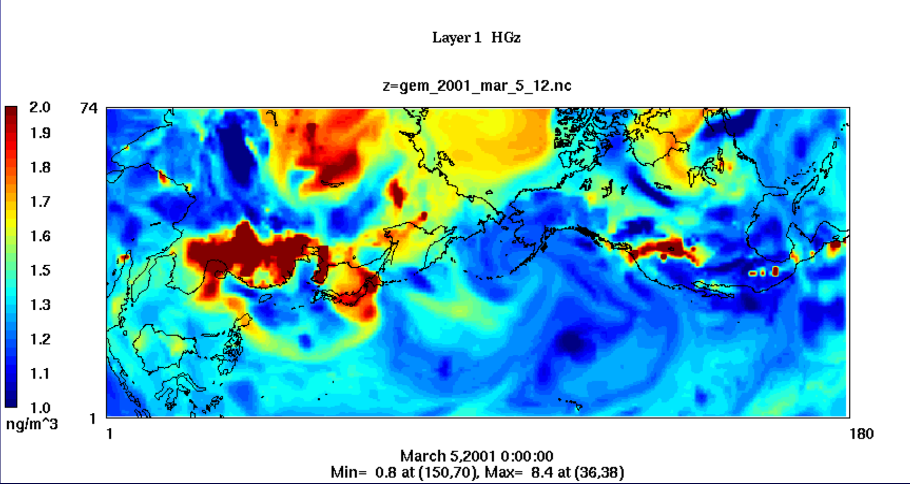
Mercury Chemistry



Transport of Ozone & $PM_{2.5}$

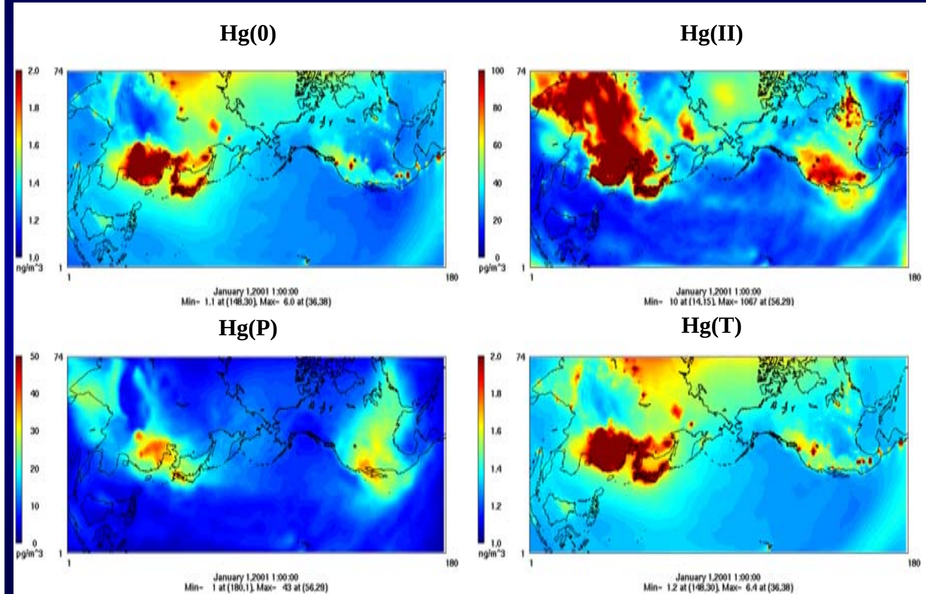


Intercontinental Transport of Hg

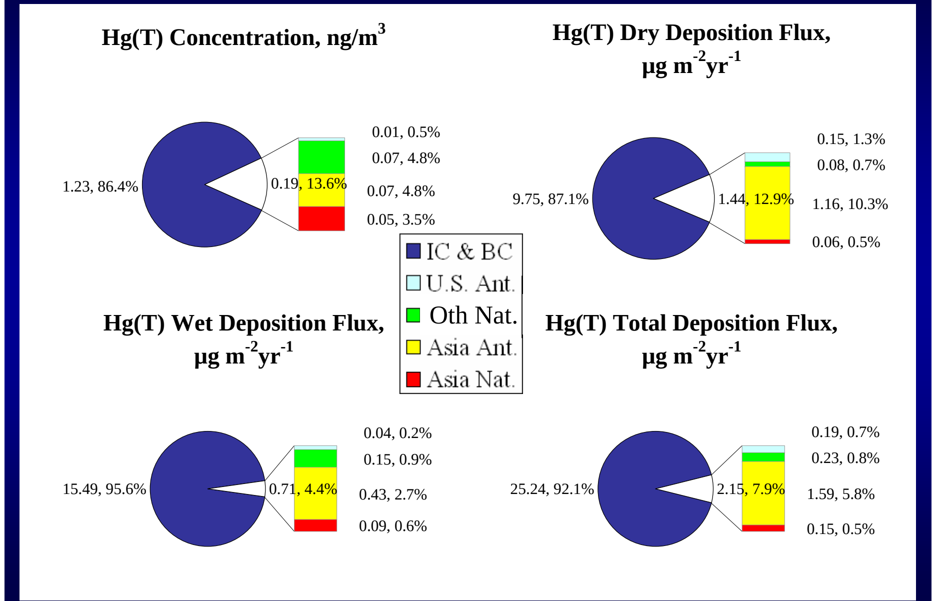


(Lin *et al.*, 2006)

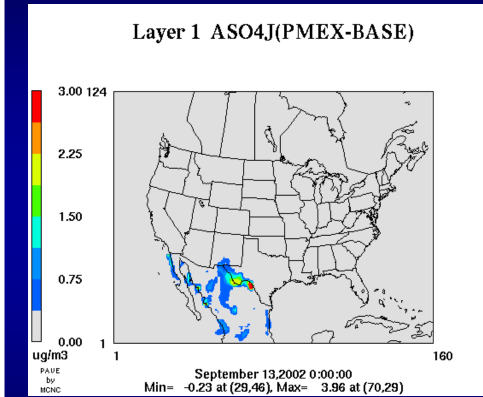
Annual Average Concentration



CMAQ Results for 2001 ICAP Domain

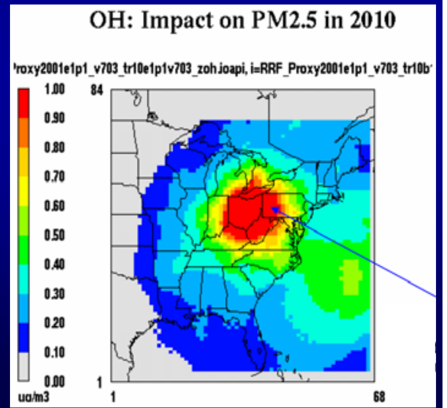


Trans-boundary Air Pollution



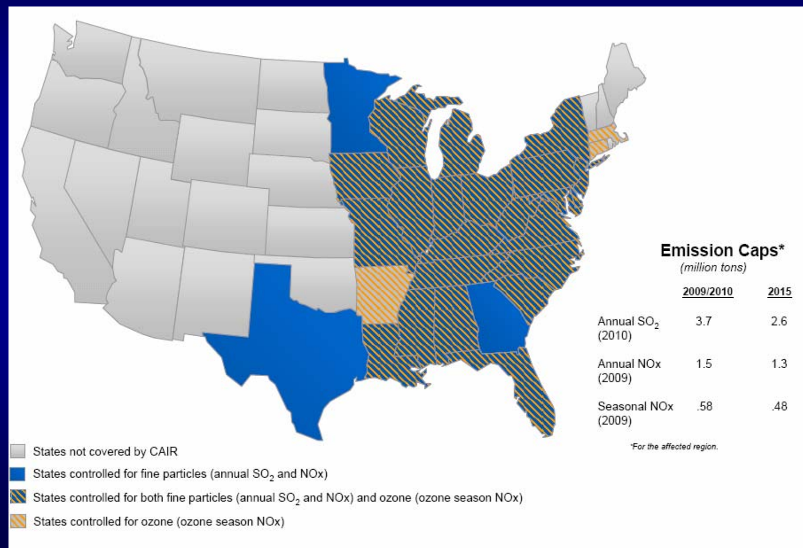
Mexican air pollution (aerosol sulfate) drifting to the United States.

The emission of the State of Ohio affecting the air quality in adjacent states.

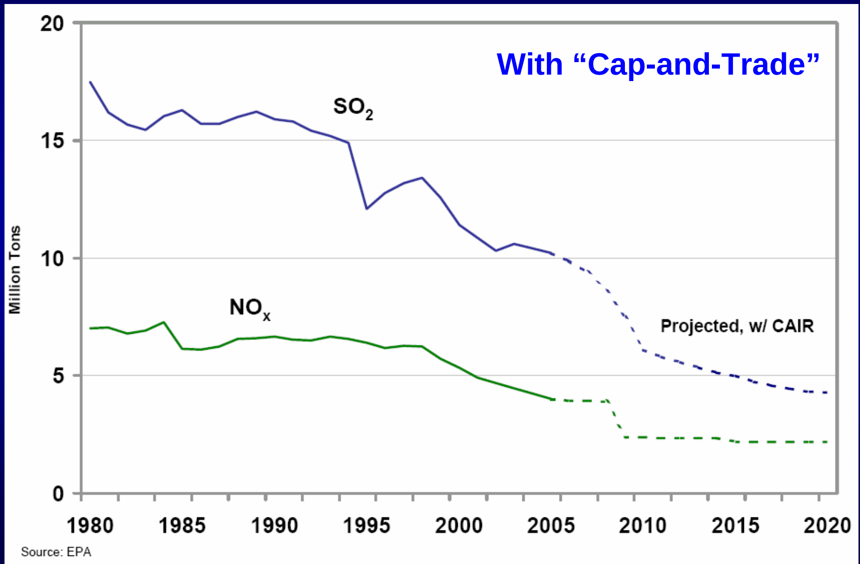


US Regional Planning Organizations (RPOs)

Clean Air Interstate Rule (CAIR)



Projected CAIR Reduction*

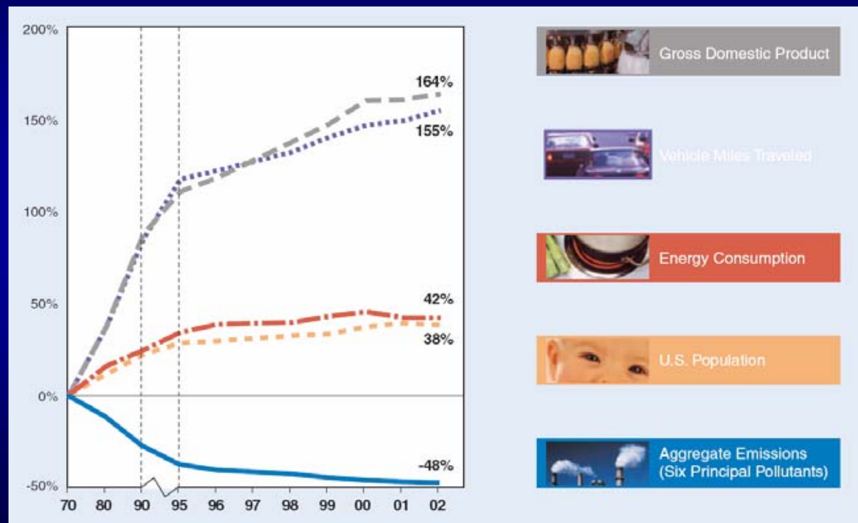


Air Quality Management Process

Key Elements for Regional AQM

- Good information (sound science) on the nature of air pollution problems
- Shared understanding of the problems
- Active involvement of different stakeholders
- Shared burden of control across contributing sources
- Define roles of each level of government involved
- Leadership and coordination at national and international levels

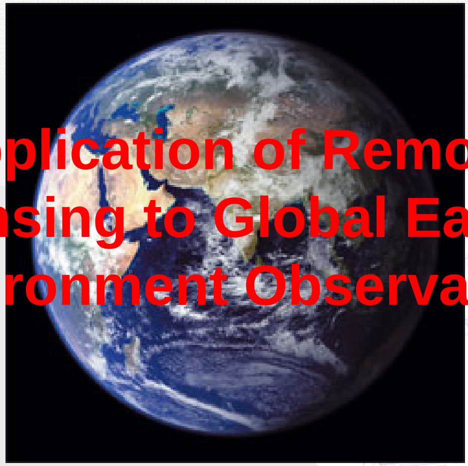
Economic Growth vs. Emission Reduction in the US



Source: USEPA

Summary

- Long-range transport of air pollutants of GHGs, PM and air toxins does occur, causing different pollution problems remote from direct emission sources.
- Technologies are available to identify and analyze the long-range transport events.
- Combined with measurements, 3-D atmospheric models are useful tools for assessing the long-range transport and project the emission reduction needs
- Economic growth and air emission reduction can be achieved simultaneously



Application of Remote Sensing to Global Earth Environment Observation

by Dr.Chaowalit Silapathong

Director of Geo-informatics Office
Geo-Informatics and Space Technology Development Agency

Contents

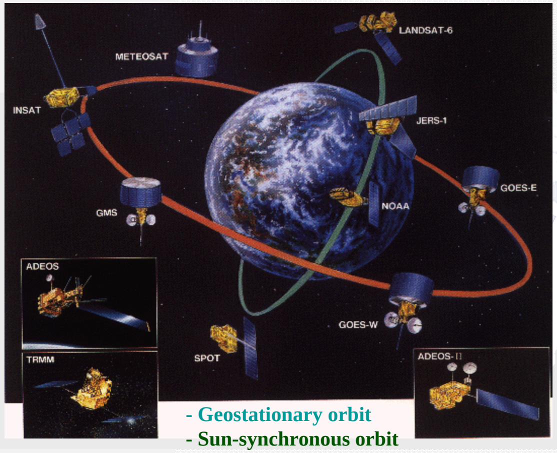
Why Remote Sensing: Earth Observation Systems

- **Improved understanding**: with a multitude of global scale observations **contributing to research into Earth System processes (Atmosphere, Ocean, Land)**;
- **Evidence**: Earth observations support the formulation of **authoritative scientific advice** – which is vital for governments when deciding to fund mitigation measures in response to global change, to react to impending crises in resource shortages, or to participate in agreements or conventions which require costly changes in national consumption patterns;
- **Monitoring and compliance**: we might expect to see increasing emphasis on **international policy measures** and treaties such as **the Kyoto Protocol** emerging in the future; Earth observations will play **an essential role in monitoring** such agreements, ensuring that countries meet their **legal obligations** in relation to challenges like reductions in fossil fuel emissions, or pollution dumping.The economic implications of such agreements can be enormous for countries and highly visible and public measures to deter 'cheating' will be an important part of their success;
- **Management and mitigation**: in support of increased **efficiency in providing basic resources** for future generations and in predicting and countering the worst effects of severe weather and natural disasters.

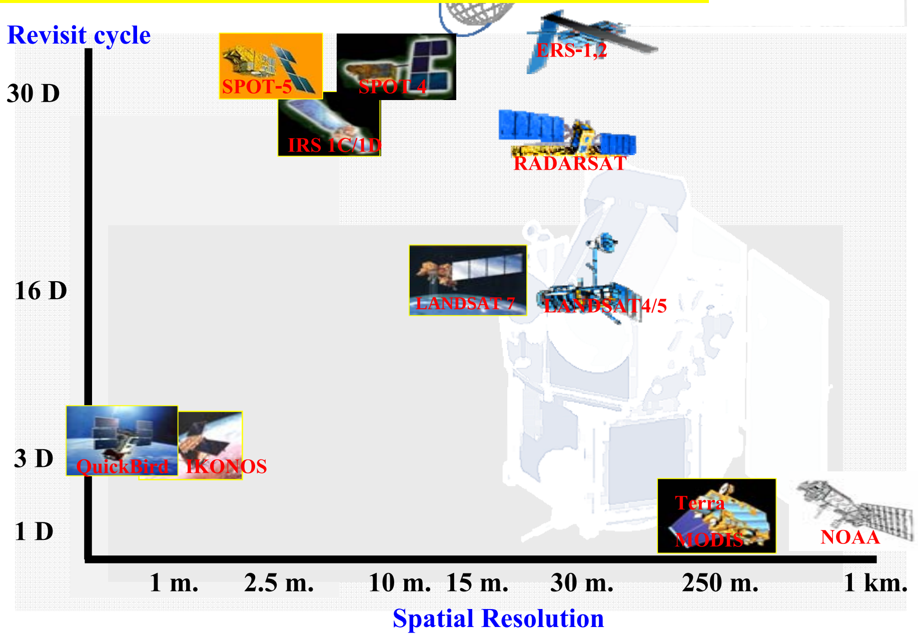
http://www.eohandbook.com

Earth Observation Satellites

- ดาวเทียมอุตุนิยมวิทยา (Meteorological Satellite)
- ดาวเทียมสำรวจทรัพยากร (Earth Resources Satellite)



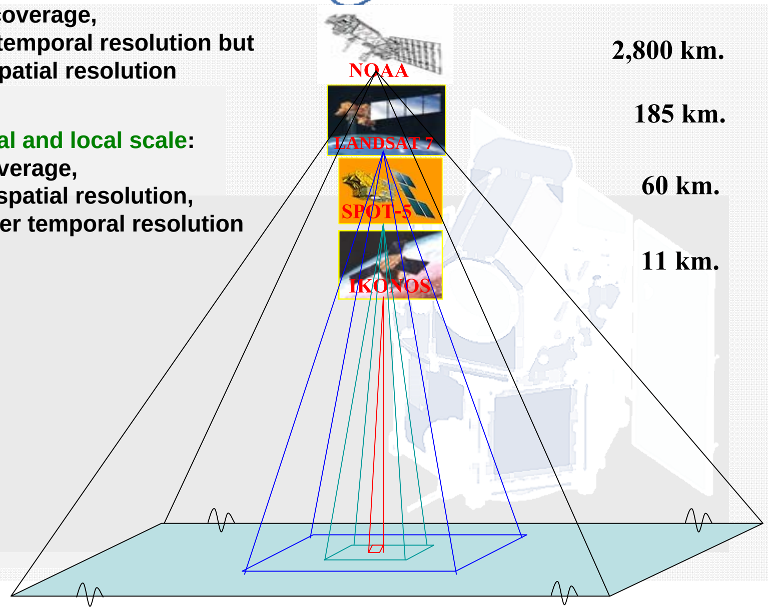
Earth Observation Satellites: revisit and resolution



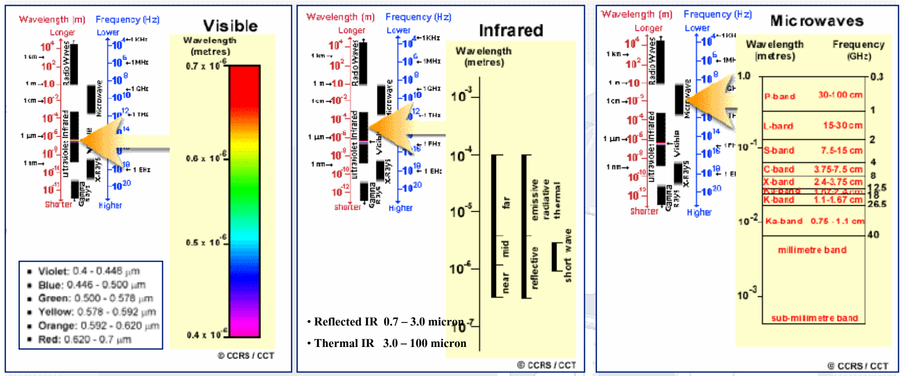
EOS: Coverage area

Global scale:
larger coverage,
higher temporal resolution but
lower spatial resolution

Regional and local scale:
less coverage,
higher spatial resolution,
but lower temporal resolution



Earth Observation Satellites
Various EMR range



Geo-Informatics Office

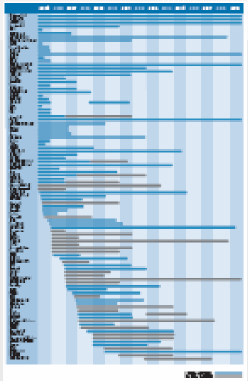
EOS Instruments

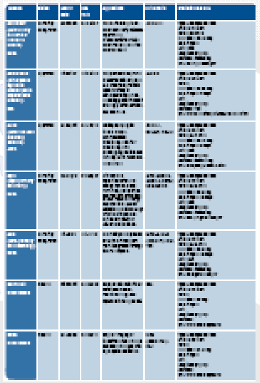
- Atmospheric chemistry instruments
- Atmospheric temperature and humidity sounders
- Cloud profile and rain radars
- Earth radiation budget radiometers
- High resolution optical imagers
- Imaging multi-spectral radiometers (vis/IR)
- Imaging multi-spectral radiometers (passive microwave)
- Imaging microwave radars
- Lidars
- Multiple direction/polarisation instruments
- Ocean colour instruments
- Radar altimeters
- Scatterometers
- Gravity, magnetic field, and geodynamic instruments

http://www.eohandbook.com

EOS Missions

- ~68 different Earth observation satellite missions are estimated to be currently operating (January 2005)
- ~23 missions are planned for launch before the end of 2005





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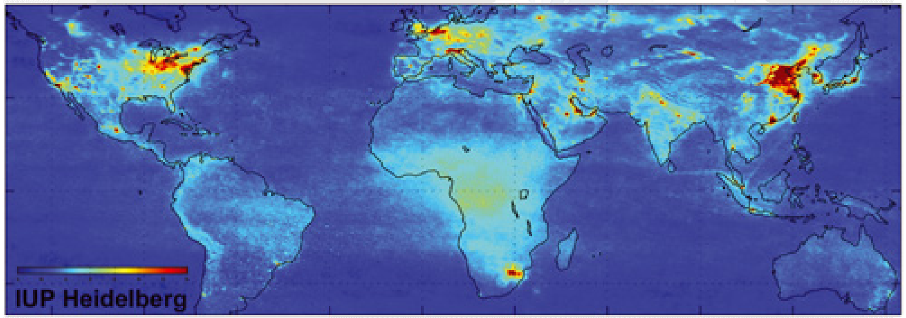
Potential of EO Satellites: Atmosphere, Ocean, Land

Potential of EOS: Atmosphere

Atmospheric chemistry instruments: trace gases emission

•Each atmospheric gas is characterized by its ‘absorption’ and ‘emission’ spectra which describe how the molecules respond to different frequencies of radiation.

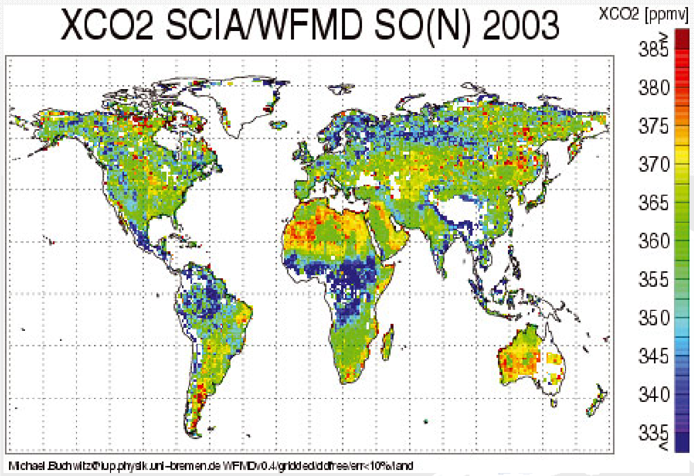
•Remote sensing instruments exploit these ‘signatures’ to provide information on atmospheric composition, using measurements over a range of wavelengths, between UV and microwave.



A global air pollution (nitrogen dioxide) map produced by SCIAMACHY on ENVISAT

http://www.eohandbook.com

Potential of EOS: Atmosphere



global estimates of CO2 concentrations in our atmosphere

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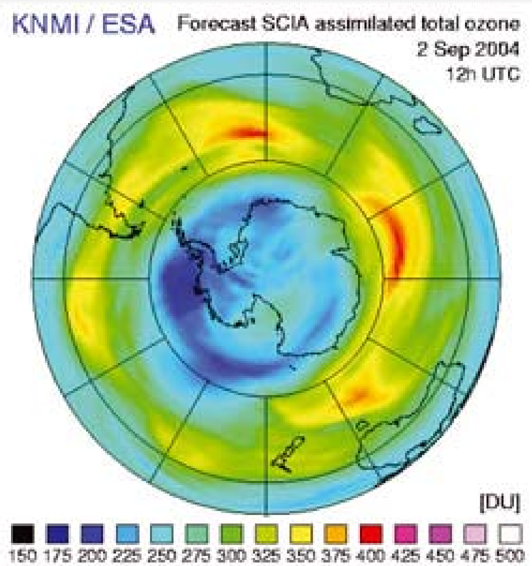
Potential of EOS: Atmosphere

Ozone study

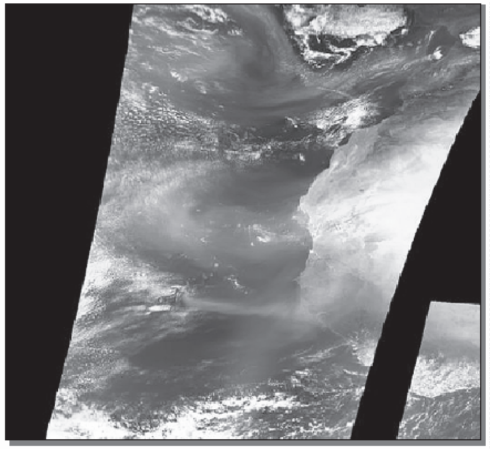


http://www.eohandbook.com

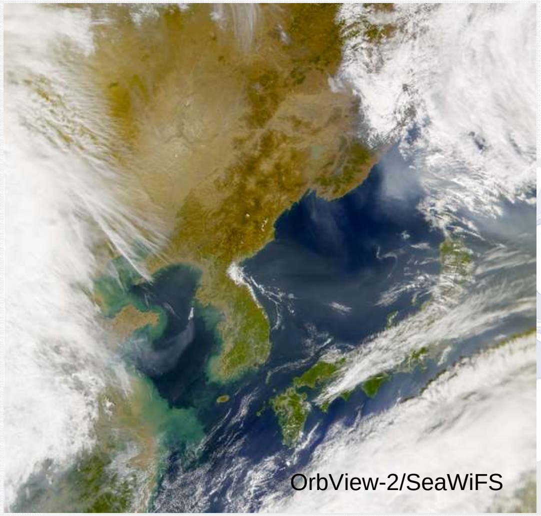
Potential of EOS: Atmosphere

**Aerosol product
10x10 km. resolution**

Terra MODIS Image of a Massive Sandstorm blowing off the northwest African desert. This sandstorm blanketed hundreds of thousands of square miles of the eastern Atlantic Ocean on February 29, 2000.



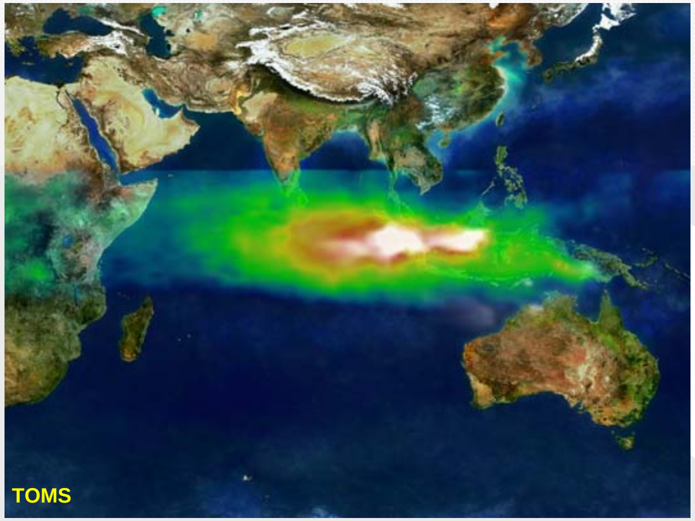
Potential of EOS: Atmosphere



SeaWiFS image of eastern Asia from October 14, 2001, shows large amounts of aerosol in the air. A few possible point sources of smoke, probably fires, are visible north of the Amur River at the very top of the image.

http://visibleearth.nasa.gov/

Potential of EOS: Atmosphere



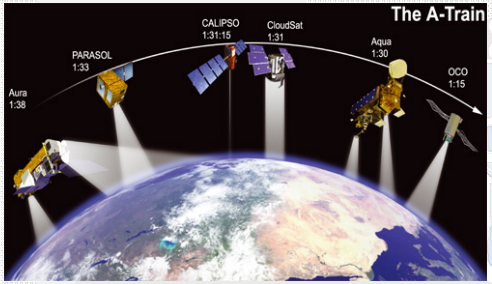
1997 smoke from Indonesian fires

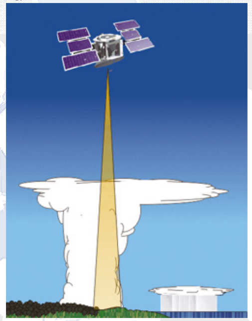
http://visibleearth.nasa.gov/

Potential of EOS: Atmosphere

Cloud profile and rain radars

These instruments are predominantly based on **active microwave radar systems**. Cloud profile radars use **very short wavelength** (mm) radar (typically 94GHz) to detect scattering from non-precipitating cloud droplets or ice particles thereby yielding information on cloud characteristics such as **moisture content and base height**.



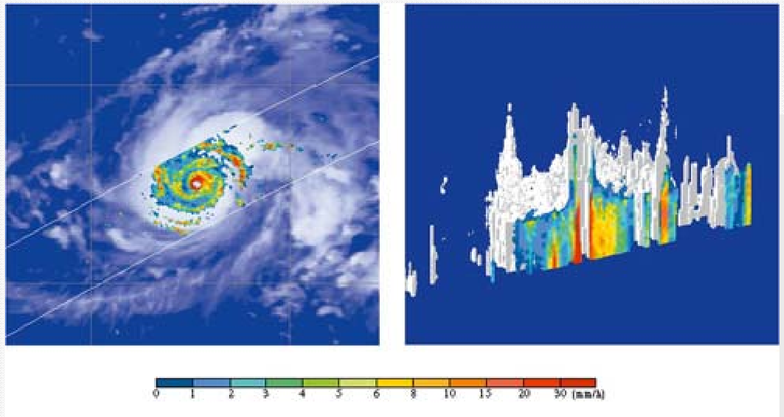


CloudSat will fly in orbital formation as part of a constellation of satellites including Aqua, Aura (multi-sensor platforms that are a part of NASA's Earth Observing System), CALIPSO (a NASA-CNES lidar satellite), PARASOL (a CNES satellite carrying a polarimeter), and OCO (NASA's CO2 measurement mission)

http://www.eohandbook.com

Potential of EOS: Atmosphere

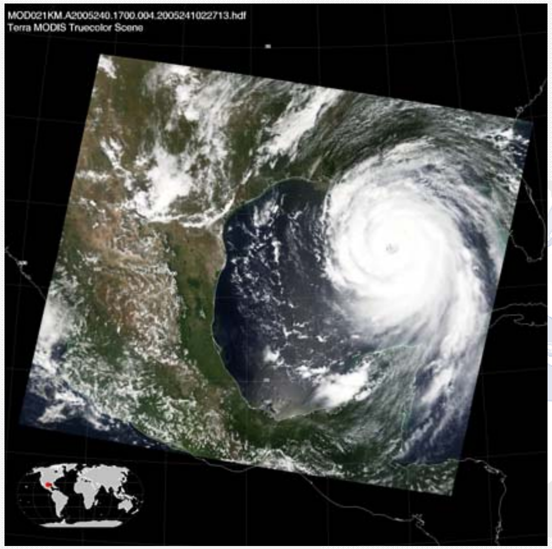
Cloud profile



The Precipitation Radar on TRMM provided new insights into the 3-D rain structure of storms

http://www.eohandbook.com

Potential of EOS: Atmosphere



Katrina: A Powerful Catagory 5 Hurricane
On August 28th 2005, the Terra-MODIS instrument captured this image of extremely dangerous Hurricane Katrina in the north central Gulf of Mexico moving steadily towards the U.S. Gulf Coast.

http://visibleearth.nasa.gov/

Potential of EOS: Ocean

Ocean color/biology

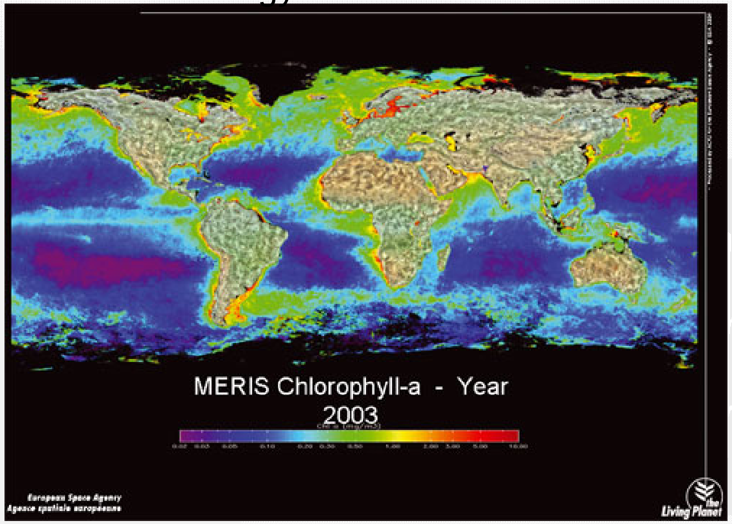
- Remote sensing measurements of ocean colour (ie the **detection of phytoplankton pigments**) provide the only global-scale focus on the biology and productivity of the ocean's surface layer.

- **Different shades of ocean colour reveal the presence of differing concentrations of sediments**, **organic materials and phytoplankton**. The ocean over regions with high concentrations of phytoplankton will appear as certain shades, from blue-green to green, depending on the type and density of the phytoplankton population there.

Potential of EOS: Ocean

Ocean color/biology

http://www.eohandbook.com

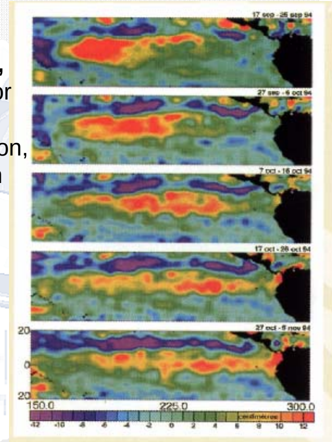


Global ocean chlorophyll measurements derived from MERIS (ENVISAT)

Potential of EOS: Ocean

Sea Surface Temperature

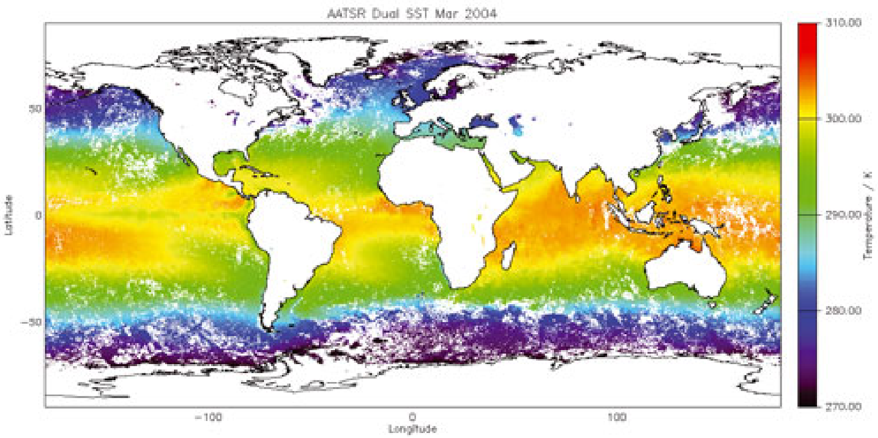
- Ocean surface temperature (**sea surface temperature, SST**) is one of the most important boundary conditions for the general circulation of the atmosphere.
- SST is also very sensitive to changes in ocean circulation, as demonstrated time and again by the El Niño-Southern Oscillation (ENSO) cycle.



Satellite altimetry and temperature measurements now provide unprecedented foresight of El Niño's arrival.

http://www.eohandbook.com

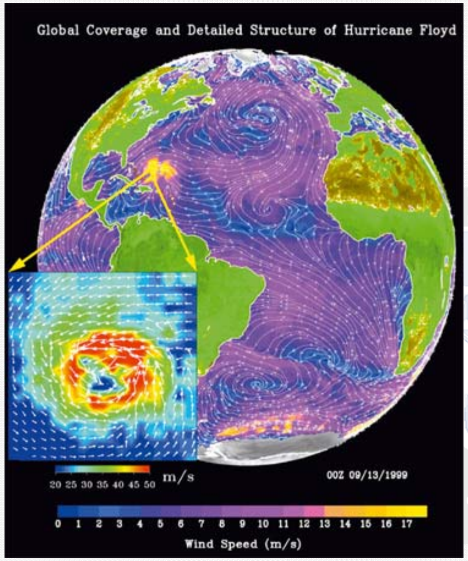
Potential of EOS: Ocean



*AATSR and its predecessors ATSR-1 and ATSR-2 (ENVISAT) have undertaken over 13 years of **Sea Surface Temperature** measurements with the accuracy required for climate research*

http://www.eohandbook.com

Potential of EOS: Ocean

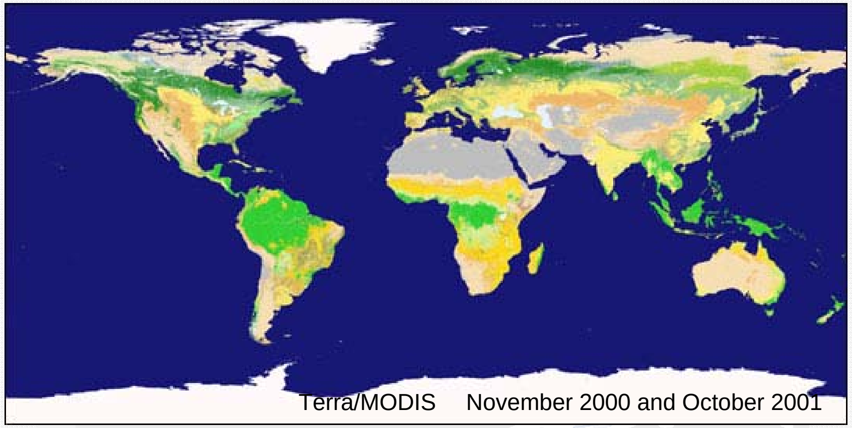


***Scatterometer** data can measure the horizontal wind speed and direction over sea surfaces. NSCAT data was used in September 1999 to monitor the size and movement of Hurricane Floyd.*

http://www.eohandbook.com

Potential of EOS: Land

Land Cover Mapping



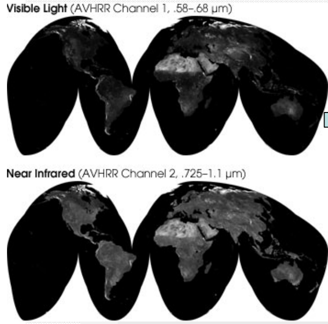
Terra/MODIS November 2000 and October 2001

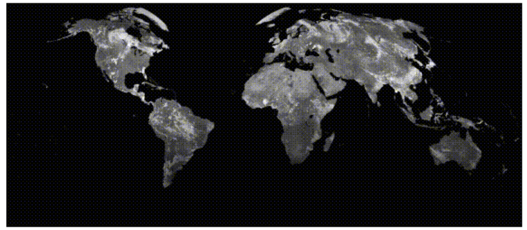
http://visibleearth.nasa.gov/

Geo-Informatics Office
Geo-Informatics and Space Technology Development Agency
(Public Organization)

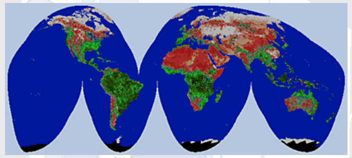
Potential of EOS: Land

Vegetation monitoring





NDVI



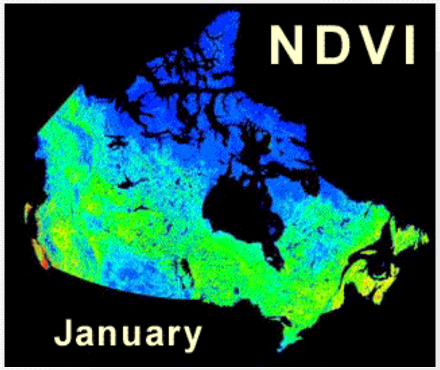
The possible range of values is between -1 and 1, but the typical vegetation range is between about 0.1 to 0.8.

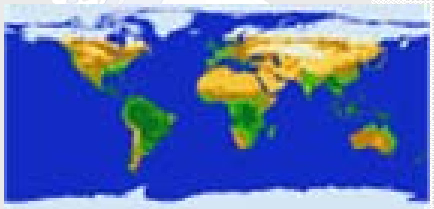
Surrounding soil and rock values are close to zero while the differential for water bodies such as rivers and dams have the opposite trend to vegetation and the index is negative.

Geo-Informatics Office
Geo-Informatics and Space Technology Development Agency
(Public Organization)

Potential of EOS: Land

Series of NDVI: Animation



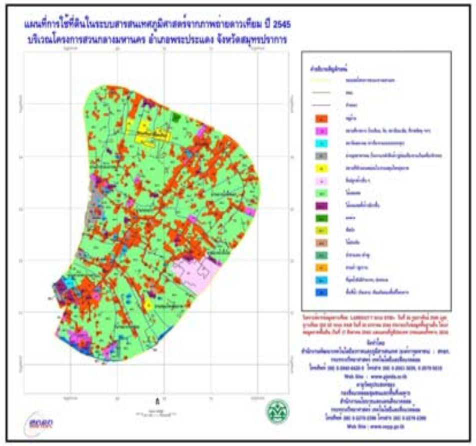


Geo-Informatics Office
Geo-Informatics and Space Technology Development Agency
(Public Organization)

Potential of EOS: Land

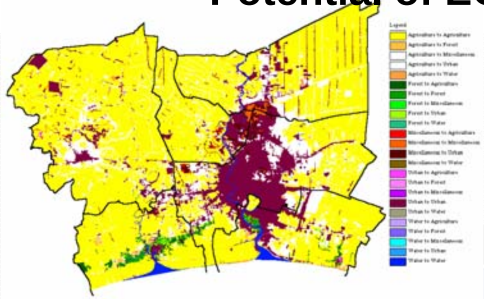
Land use and land cover mapping

LANDSAT and IRS-1C



Potential of EOS: Land

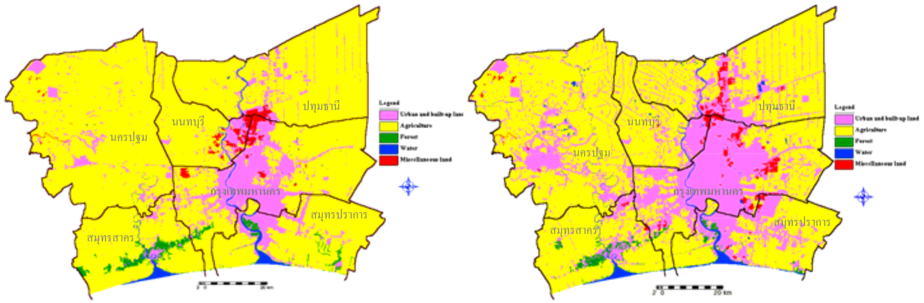
Urban Development and Urban Expand



Urban Land Use Change Map
of Bangkok Metropolis and vicinity
during 1988 and 2002

LANDSAT IRS-1C
and SPOT

Land use of Bangkok Metropolis and vicinity in 1988 Land use of Bangkok Metropolis and vicinity in 2002



Potential of EOS: Land

Urban extraction and road network

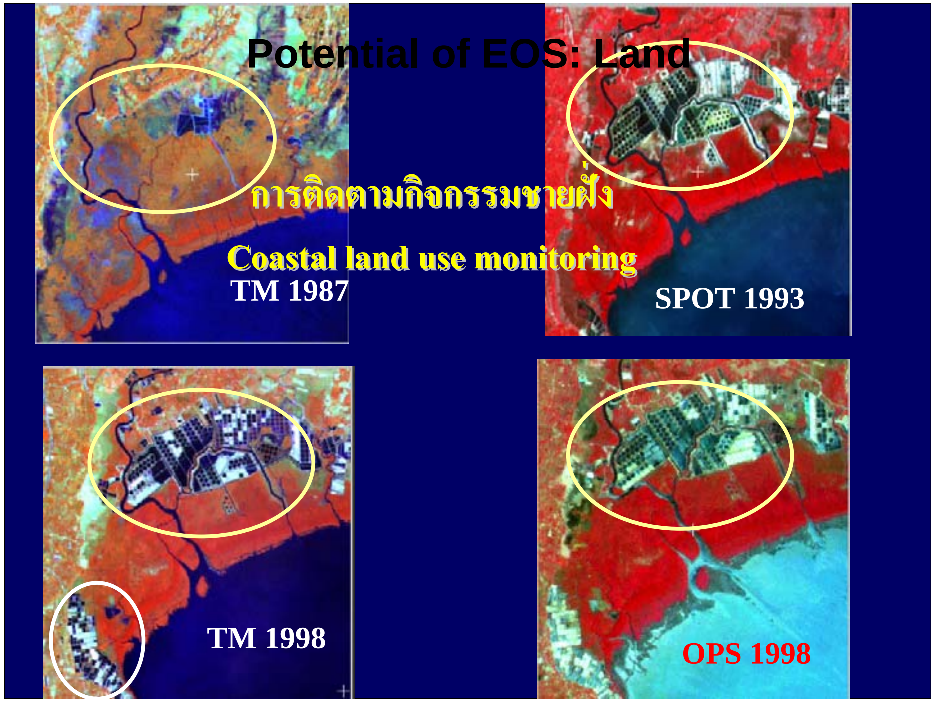
Laem Chabang Deep Seaport, Chonburi

IRS-ID LISS-III image with 24 m. spatial resolution

Pan sharpened color composite image with LISS-III data

IRS-ID PAN image 5.8 m. spatial resolution

Potential of EOS: Land



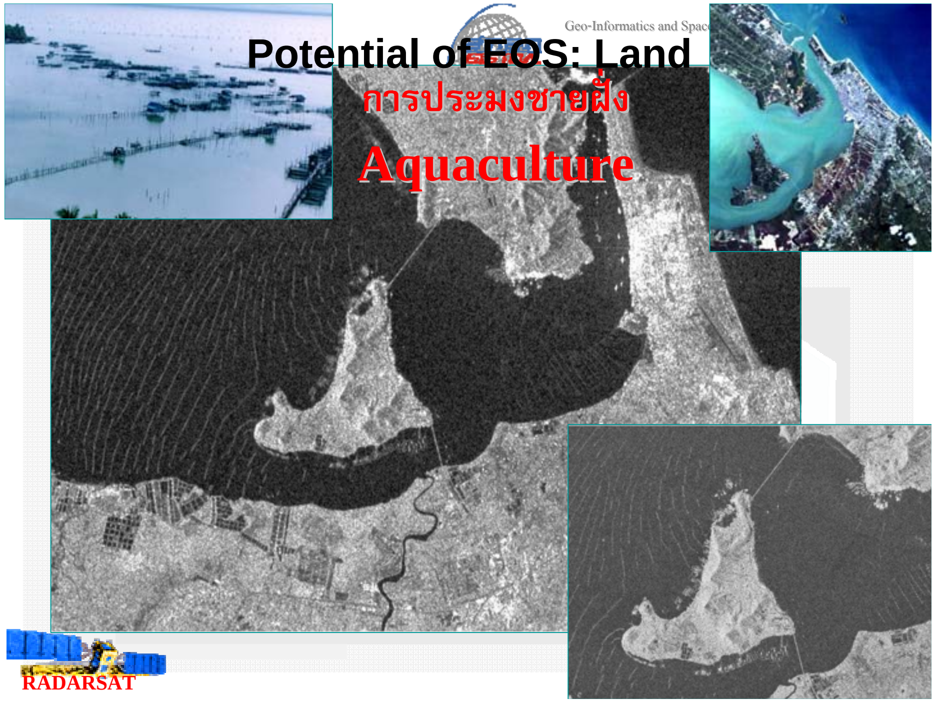
การติดตามกิจกรรมชายฝั่ง

Coastal land use monitoring

Potential of EOS: Land

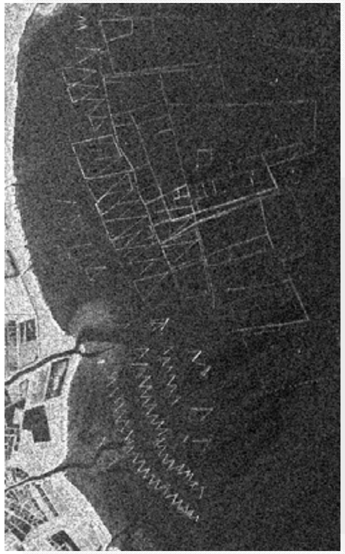
การประมงชายฝั่ง

Aquaculture



Potential of EOS: Land

Aqua-culture Monitoring

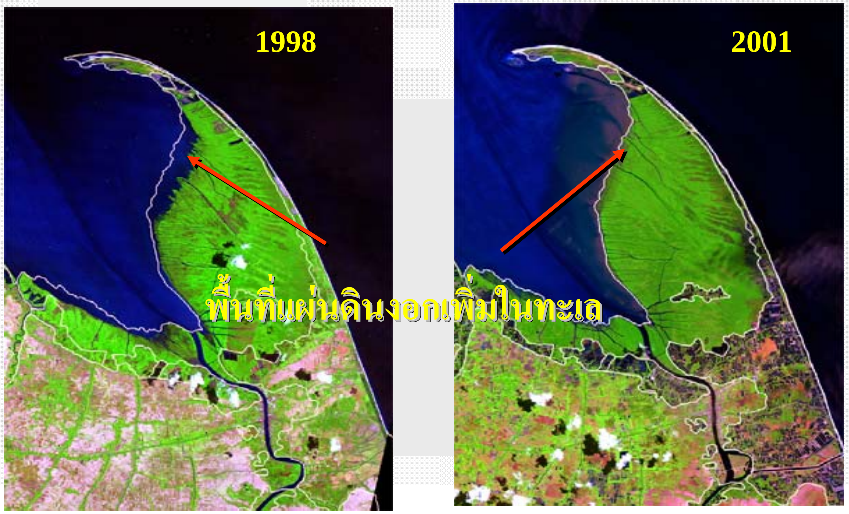


V - Shape

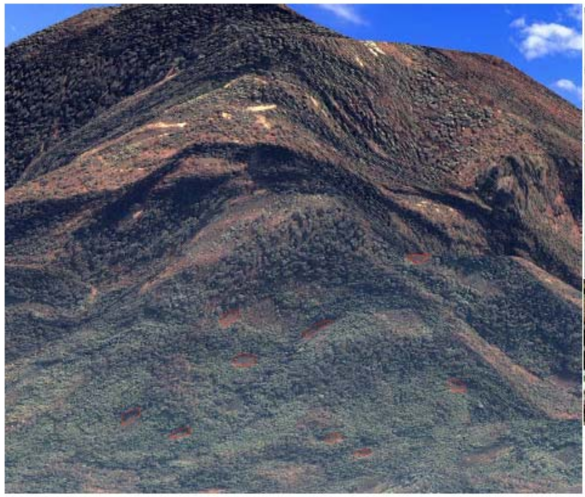
RADARSAT

Potential of EOS: Land

Coastal zone monitoring: Land aggregation



Potential of EOS: Land

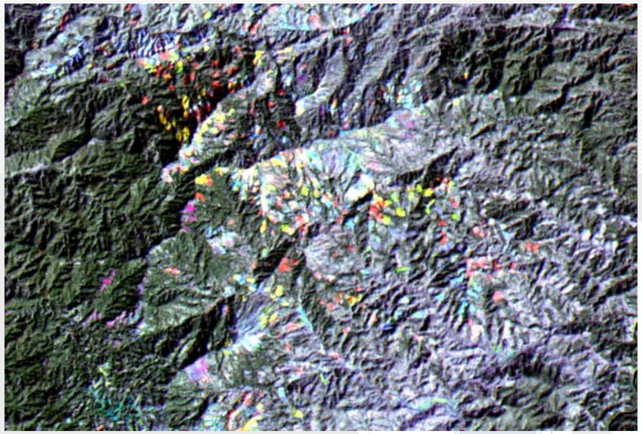


Poppy Field Monitoring

IKONOS-1
16 Feb 2004

Poppy Field Monitoring

LANDSAT-7 dated 5 Mar 2000, 12 Jan 2001 and 23 Feb 2002



White : Ac tive in 2000, 2001 and 2002
Red : Active in 2002, Non active in 2001 and 2000
Yellow : Continuously plant in 2001, 2002 and next year
Greenish blue : Active in 2001, Non active in 2000 and 2002

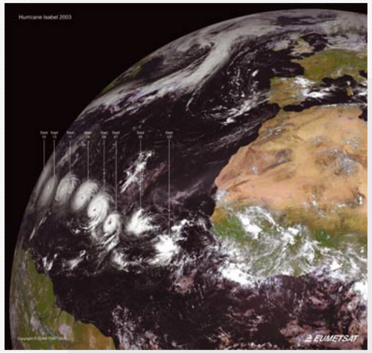
Role of EO Satellites on Global Environment Observation

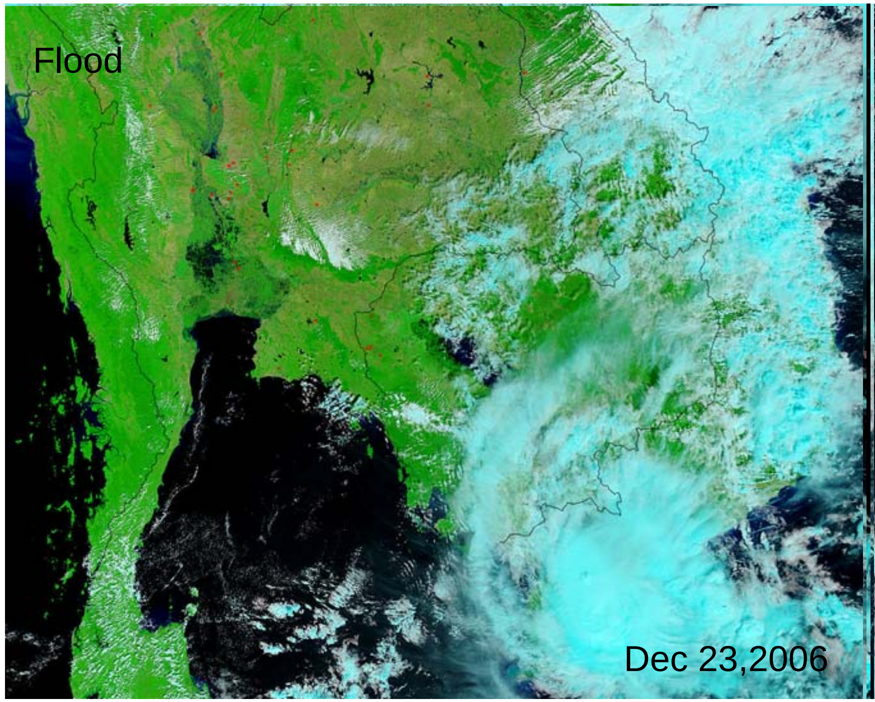
Role of EOS: Disaster Management

Hurricanes & tornadoes	Weather satellites are used extensively for detection and tracking of storms and contribute effectively to the forecasting capability. Recent satellite missions providing more detailed and frequent measurements of sea surface wind speed and tropical rainfall mapping have significantly improved forecasts.
Volcanic eruptions & earthquakes	In-situ systems and Global Positioning System (GPS) satellites provide valuable information on seismic and volcanic activity. EO satellites provide complementary data in support of disaster mitigation and response: interferometry techniques of radar sensors are used to monitor fault motions and strain, and signs of Earth surface deformation and topographic changes. Very high resolution sensors are used to map damage assessment, direct response efforts, and aid reconstruction planning. Satellite data is the primary information source employed by the 9 Volcanic Ash Advisory Centres operational world-wide which issue volcanic ash cloud warnings, an essential information source for international aviation safety.
Wildfires	A number of satellites now contribute routinely to each stage of wildfire hazard management world-wide, including: fire risk mapping using land cover and fire fuel assessments, moisture data, digital elevation maps, and meteorological information – all derived from satellite; fire detection and early warning; fire monitoring and mapping; burned area assessment.
Oil spills	Synthetic Aperture Radar (SAR) data is used as the basis for ocean surveillance systems for oil slick detection, to provide enforcement and monitoring capabilities to deter pollution dumping. The SAR data is processed within 1-2 hours of the satellite overpass and used by pollution control authorities to cue aircraft surveillance. Surveillance systems are currently operational in Norway, and Denmark, and under trial in the Netherlands, Germany, and the UK. SAR data and optical data are also used to develop information in support of major coastal oil spills, to assist in mapping pollution extent and managing the response.
Drought	Currently, multichannel and multi-sensor data sources from geostationary satellites and polar orbiting satellites are used routionely for determining key monitoring parameters such as: precipitation intensity, amount, and coverage, atmospheric moisture and winds. Instruments with spectral bands capable of measuring vegetative biomass are also used operationally for drought monitoring. The Famine Early Warning System (FEWS) in Africa, for example, exploits operational use of satellite technology to reduce the incidence of famine in sub-Saharan Africa by monitoring the agricultural growing season. Monitoring is carried out through "greenness maps" derived every 10 days from the AVHRR instrument, and from rainfall estimates.
Floods	Earth observation satellites are used for the development of flood impact prediction maps, contributing measurements of landscape topography, land use, and surface wetness for use in hydrological models. Weather satellites provide key information on rainfall predictions to assist flood event forecasting. Since optical observations are hampered by the presence of clouds, SAR missions (which can achieve regular observation of the earth's surface, even in the presence of thick cloud cover) are frequently used to provide near real-time data acquisitions in support of flood extent mapping.

Role of EOS: Disaster Management

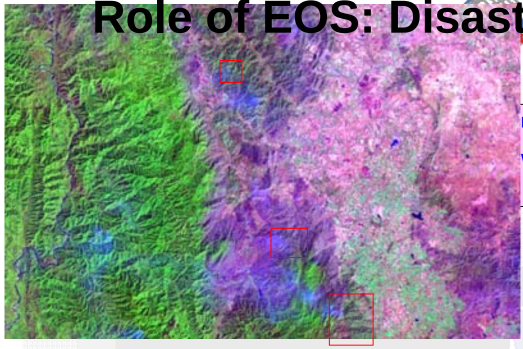
Strom detection and monitoring





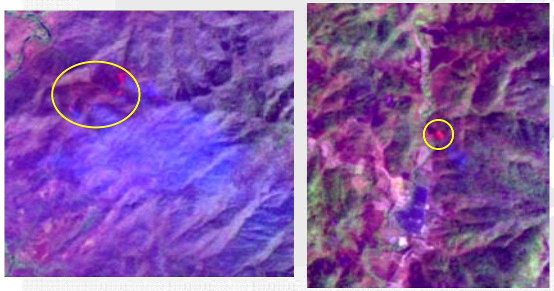
Role of EOS: Disaster Management

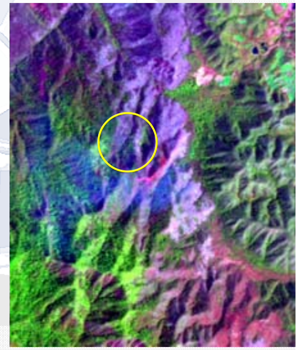
Forest Fire Monitoring



Requirements in different phases of fire ma'ment
Multi-temporal/spatial/spectral char'tics
Wildland fire and its behavior:
Fuel/weather/topography

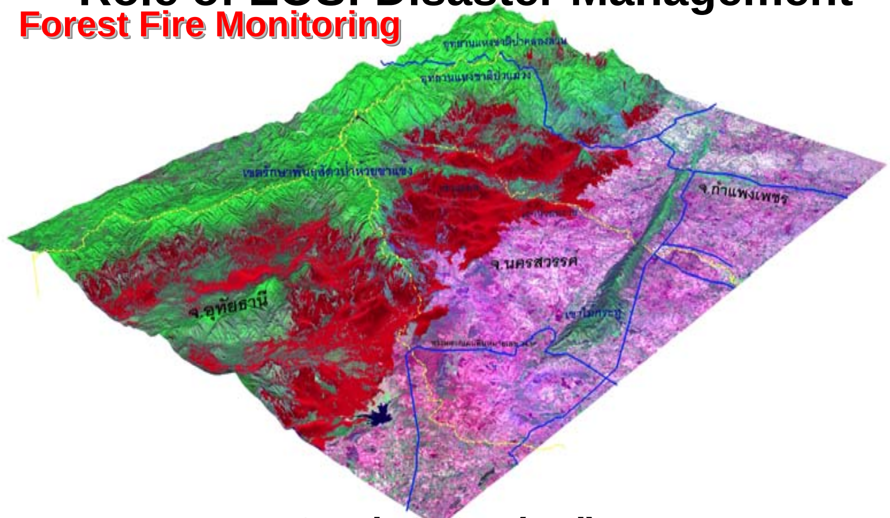
SPOT-5 dated 29 Jan 2005
Band 4 3 1
Amphoe Ban Kha, Ratchaburi Province





Role of EOS: Disaster Management

Forest Fire Monitoring

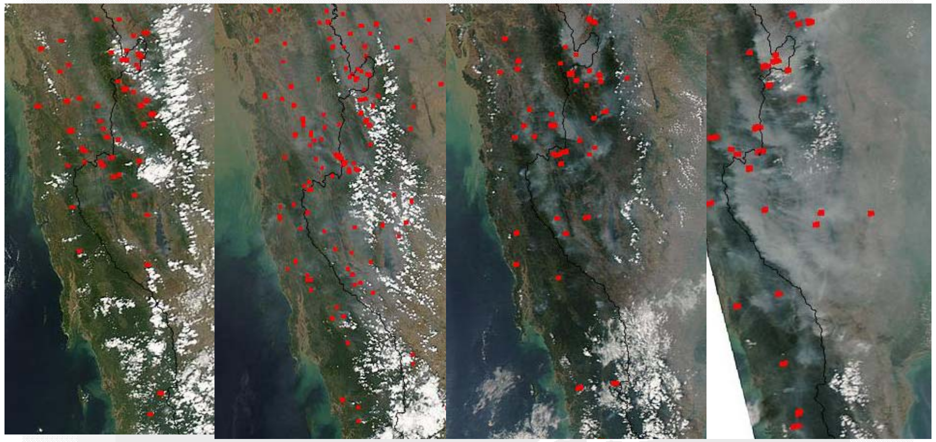


Burnt area on 16 Feb 2005 (red)

3D LANDSAT 5 TM dated 16 Feb 2005

Role of EOS: Disaster Management

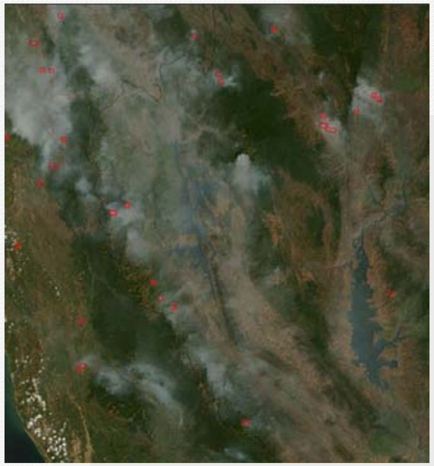
Daily forest fire situation monitoring from MODIS



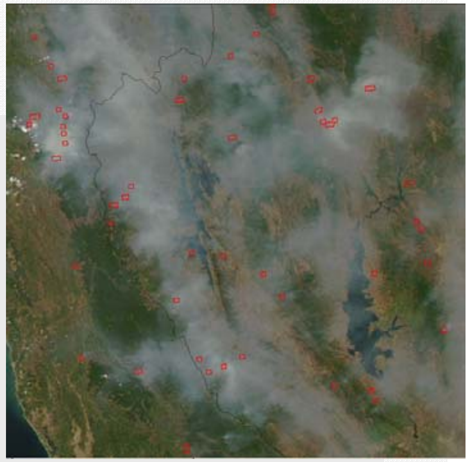
Hot spot and Smoke plume and haze observed by MODIS

Role of EOS: Disaster Management

Hot spot and Smoke plume and haze observed by MODIS



TERRA-MODIS morning

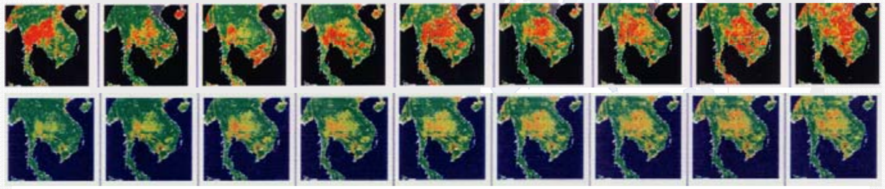


AQUA-MODIS afternoon

Role of EOS: Disaster Management

ANDES (*A*sia-pacific *N*etwork for *D*isaster Mitigation using *E*arth Observation *S*atellite)

Forest fire risk maps are developed based on the drought conditions of vegetation estimated from the time series dataset of ten-days-composite image of NOAA (NDVI) and SPOT-VG (LWCI: Leaf Water Content Index).



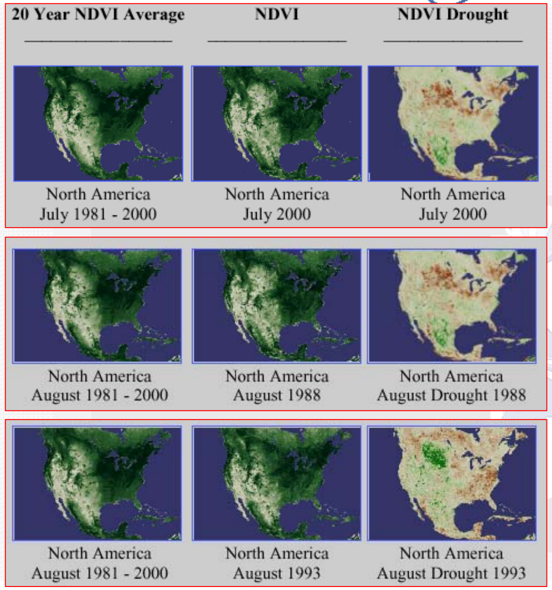
10-days composite images of NOAA/NDVI (upper: original, lower: LMF processed: Jan.- Mar.)

Vegetation condition: the amount of litters (fuels)

Forest Fire Risk Map

http://www.affrc.go.jp/ANDES/

Role of EOS: Disaster Management



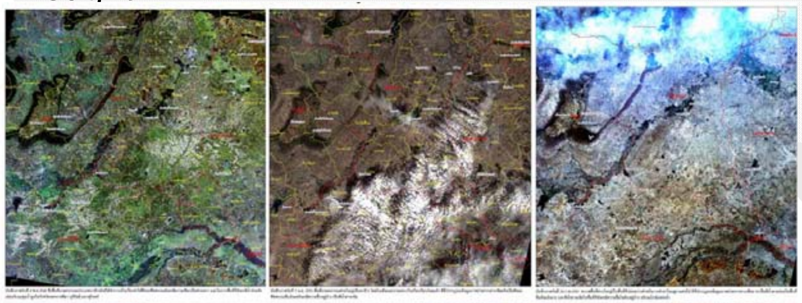
NDVI Drought Indication

Subtracting NDVI average and a specific NDVI

NASA GSFC

Role of EOS: Disaster Management

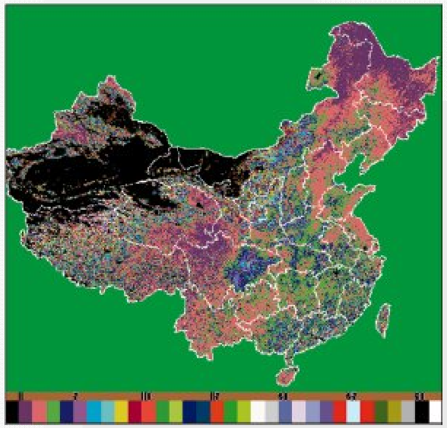
Drought



Surface water monitoring: multi-date data

Role of EOS: Disaster Management

Drought Monitoring in China with WSVI

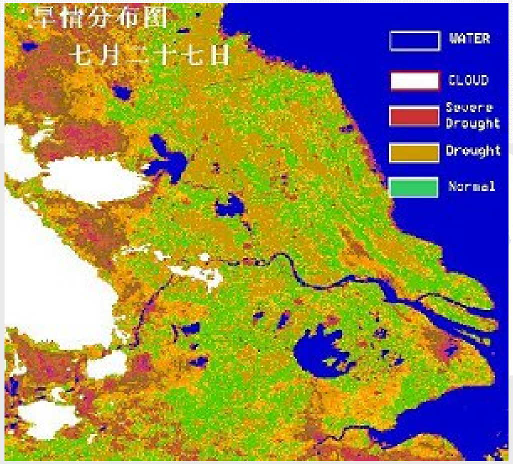


The monthly WSVI map of China in August 1994. The Water Supplying Vegetation Index (WSVI) is a new method to detect drought information by using meteorological satellite data.

www.eumetsat.de

Role of EOS: Disaster Management

Drought Monitoring in China with WSVI



WSVI image of the summer drought in the Jiangsu Province in 1994.

Geo-Informatics Office

Role of EOS: Disaster Management

Geo-Informatics and Space Technology Development Agency (Public Organization)

Tsunami

Geo-Informatics Office

Role of EOS: Disaster Management

Geo-Informatics and Space Technology Development Agency (Public Organization)

Tsunami 2004

Patong Beach, Phuket Island before and after the Tsunami Impact

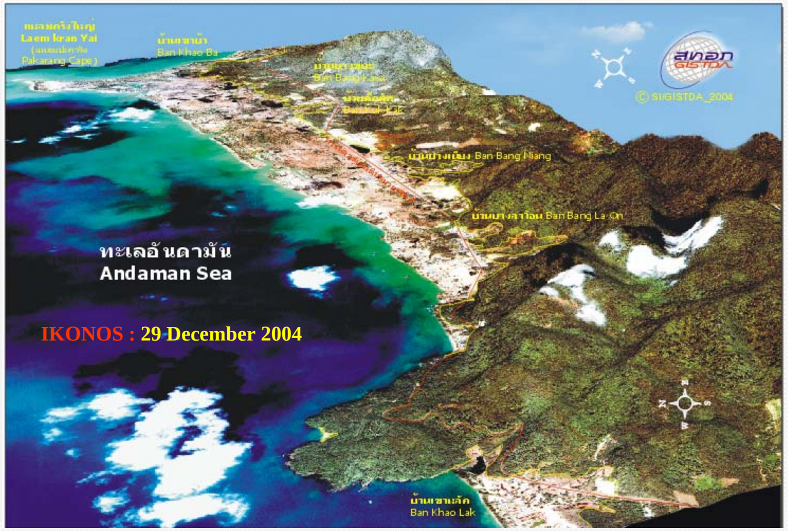
Destroyed Areas, Buildings, Roads, Beaches, Port and Flooded areas Patong Beach, Phuket

Geo-Informatics Office

Role of EOS: Disaster Management

Geo-Informatics and Space Technology Development Agency (Public Organization)

IKONOS Perspective Image of Phangnga Coast

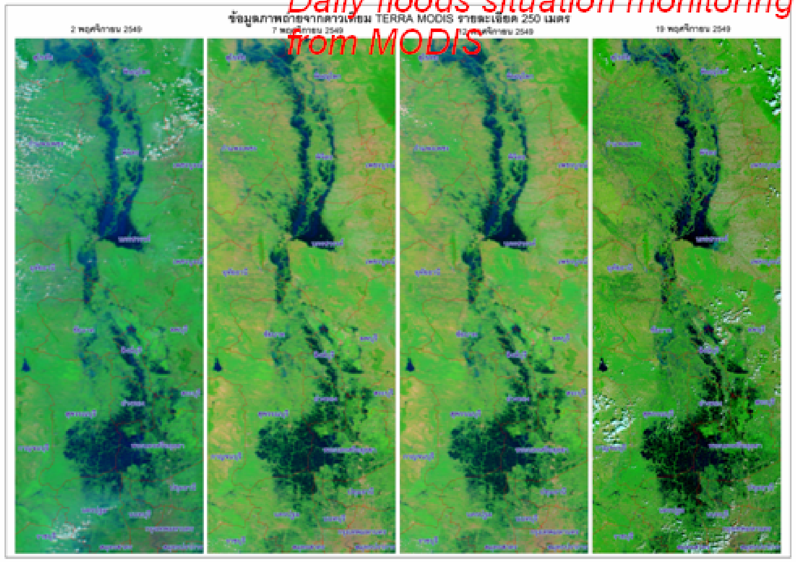


Role of EOS: Disaster Management

2006 Floods

Geo-Informatics and Space Technology Development Agency (Public Organization)

Daily floods situation monitoring from MODIS

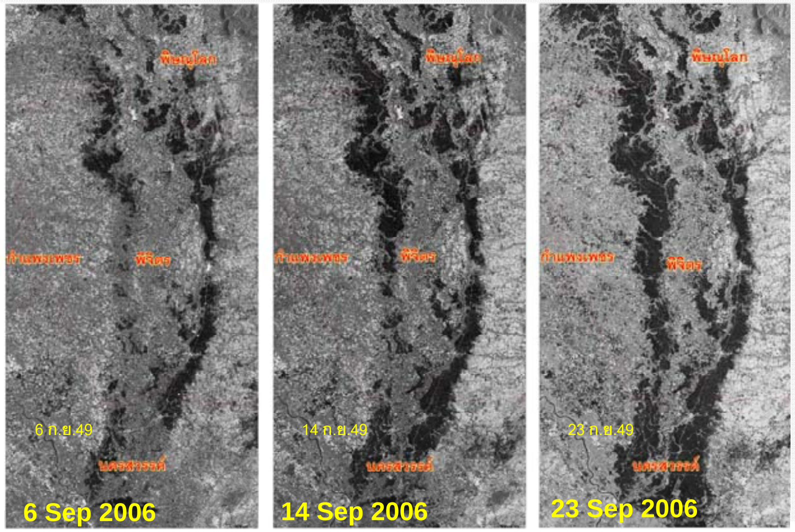


Role of EOS: Disaster Management

Floods 2006

Geo-Informatics and Space Technology Development Agency (Public Organization)

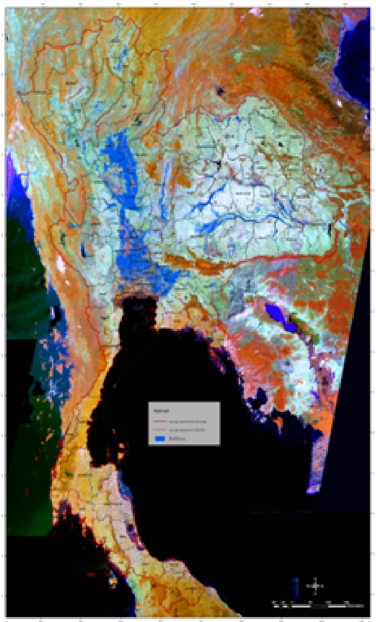
Flood Situation Monitoring using RADARSAT



Role of EOS: Disaster Management

2006 Floods

Geo-Informatics and Space Technology Development Agency (Public Organization)



Satellite data based flooded area for the whole country

Data from **RADARSAT**, LANDSAT, SPOT and ALOS

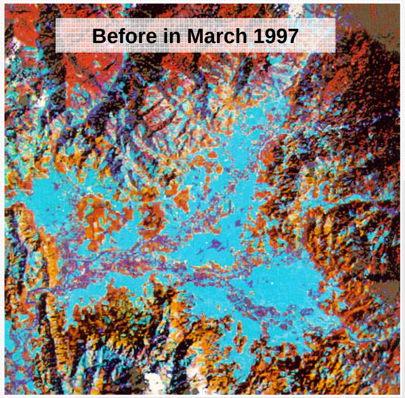
More than 400 images acquired and distributed to at least 30 related agencies

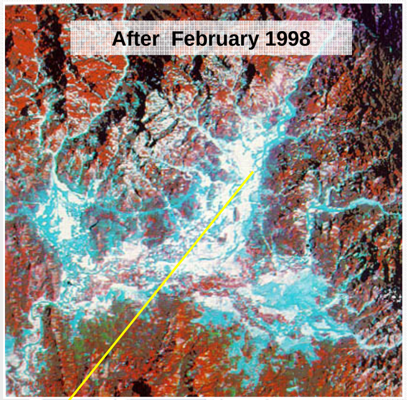
Role of EOS: Disaster Management

Geo-Informatics Office

Geo-Informatics and Space Technology Development Agency (Public Organization)

Nakhonsrithammarat

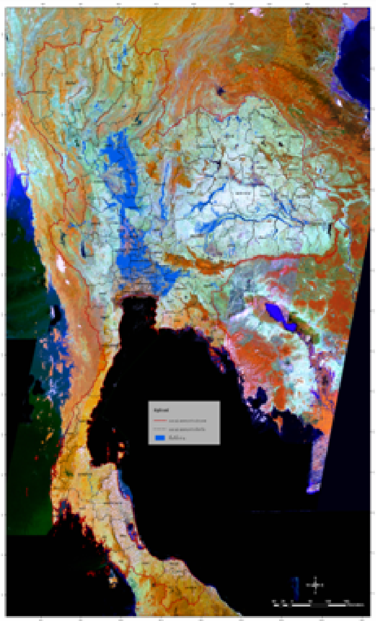




Landslide

Role of EOS: Disaster Management

2006 Floods



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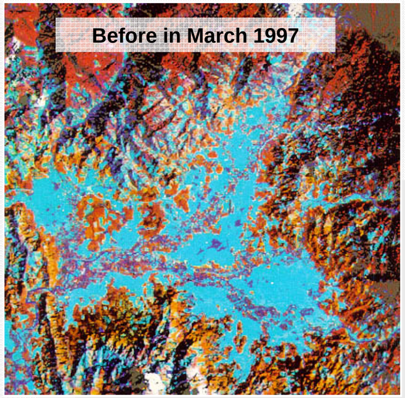
Geo-Informatics and Space Technology Development Agency (Public Organization)

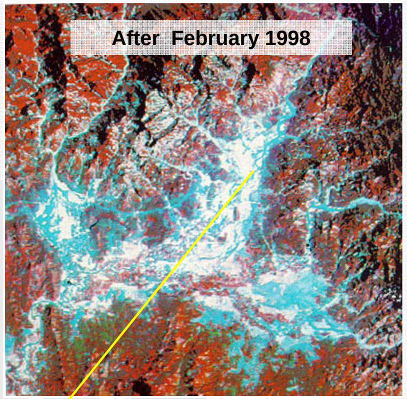
Role of EOS: Disaster Management

Geo-Informatics Office

Geo-Informatics and Space Technology Development Agency (Public Organization)

Nakhonsrithammarat



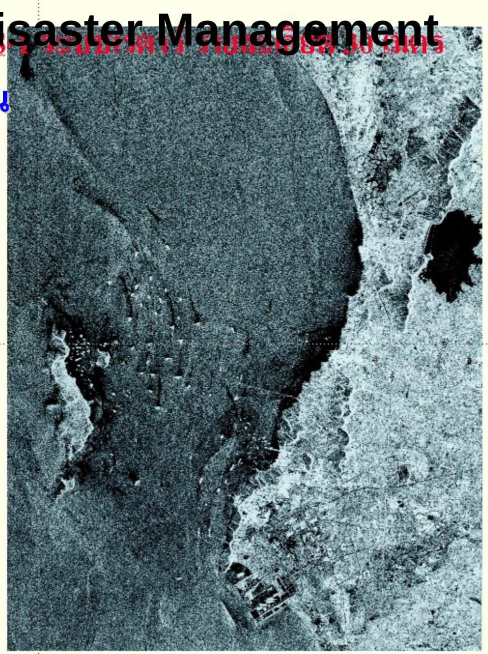


Landslide

Role of EOS: Disaster Management

มลพิษชายฝั่ง: คราบน้ำมัน

Songkhla



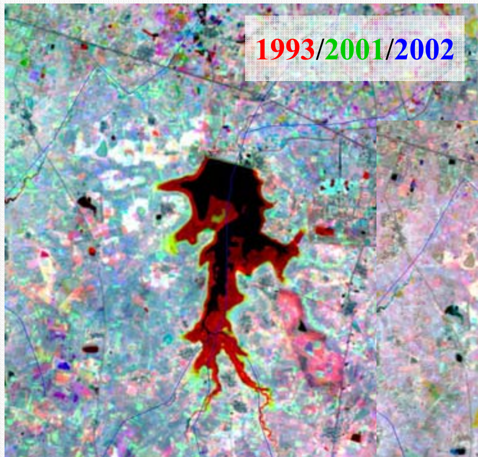
Chonburi

Oil spill detection

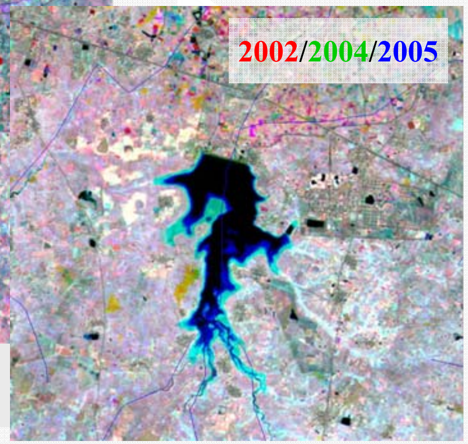
Water resource management

Geo-Informatics Office

Geo-Informatics and Space Technology Development Agency (Public Organization)



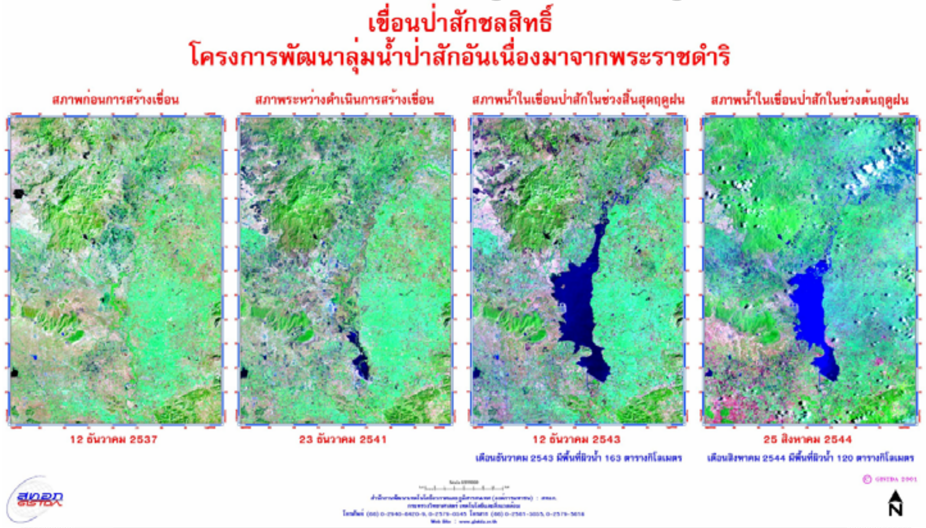
Surface Water Monitoring



Huai Ang Resevoir : Roiet
LANDSAT Multi-temporal

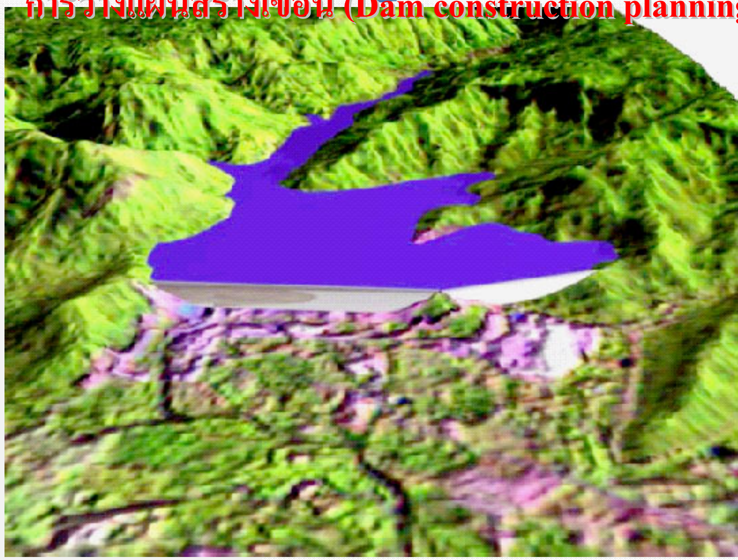
Water resource management

การพัฒนาชลประทาน (Irrigation management)

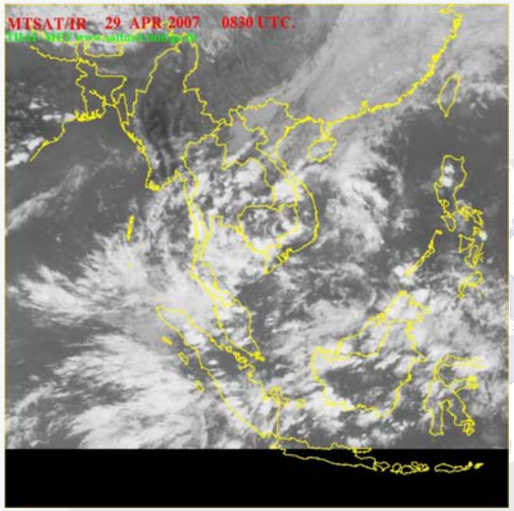


Water resource management

การวางแผนสร้างเขื่อน (Dam construction planning)



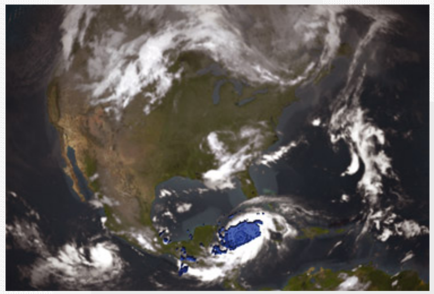
Weather and Climate

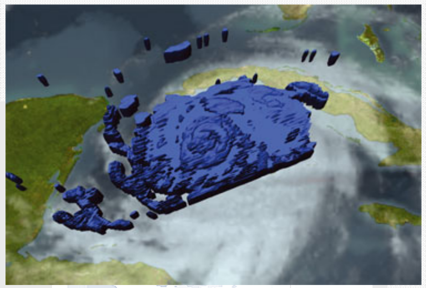


Weather forecasting

http://www.sattmet.tmd.go.th/newversion/mergesat.html

Weather and Climate

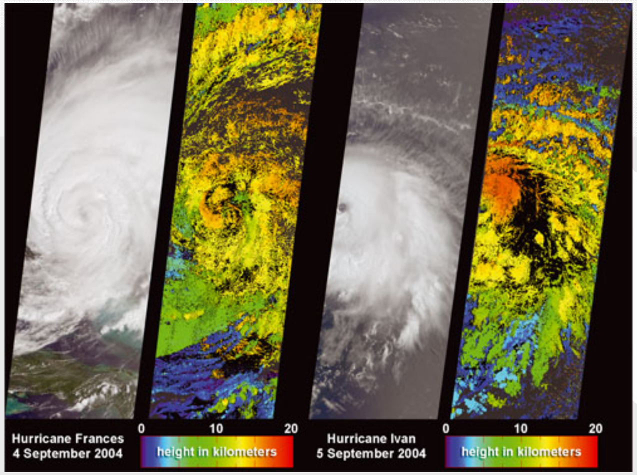




On the morning of 15th September 2004, the TRMM satellite captured a 3-D look inside Hurricane Ivan

Weather and Climate

Strom detection and monitoring



2-D cloud height maps generated by MISR on the Terra spacecraft

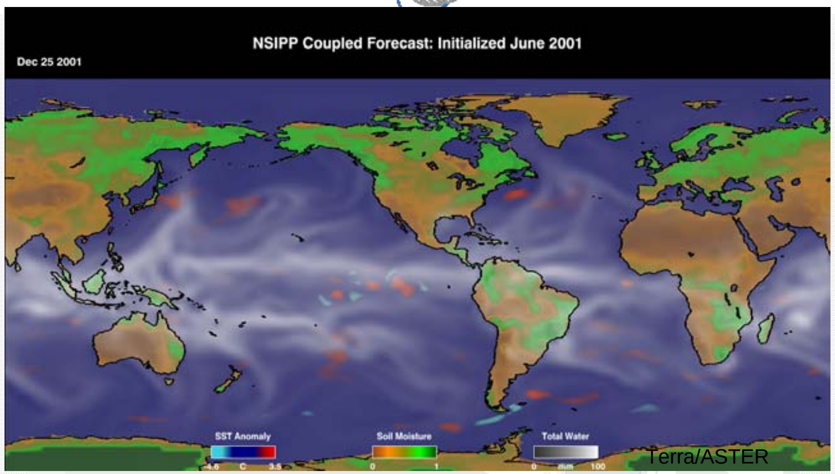
Weather and Climate

Strom detection

Typhoon Jelawat in East China Sea

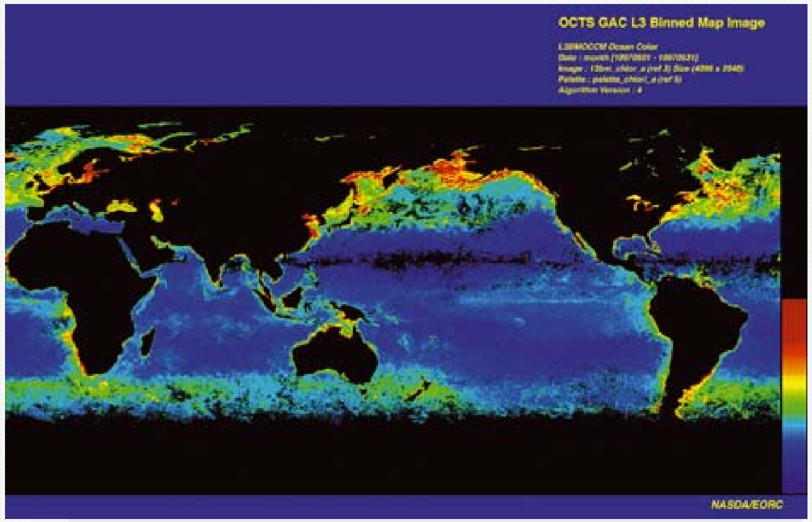
http://visibleearth.nasa.gov/

Weather and Climate

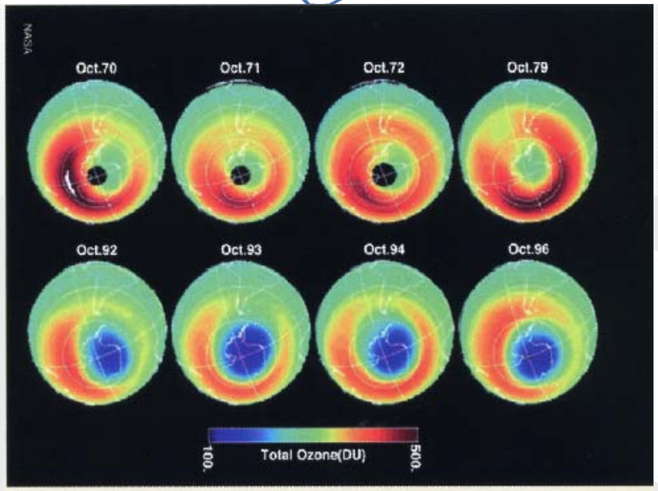


The colors in the ocean represent a departure from average surface temperature. Red pixels show where the model predicts there will be warmer-than-average temperatures, light blue shows cooler-than-average temperatures, and dark blue is average. The colors on land represent variation in soil moisture. Orange and brown hues show where the model predicts the soil will be dry; greens show where it will be wet. The grey hues overlying the world map represent regions of rainfall. Dark greys show where little rain is predicted to fall and light grey to white pixels show where there will be heavy rains.

Climate change



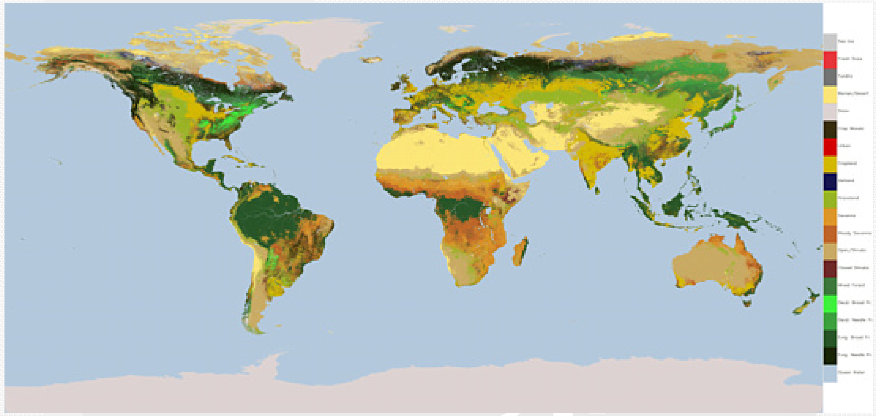
Weather and Climate



With each passing year over the last few decades, ozone concentrations over the South Pole have grown less during the months of September and October. These images show the progression of the ozone 'hole', as measured by the TOMS and SBUV instruments.

Ecosystem and Biodiversity

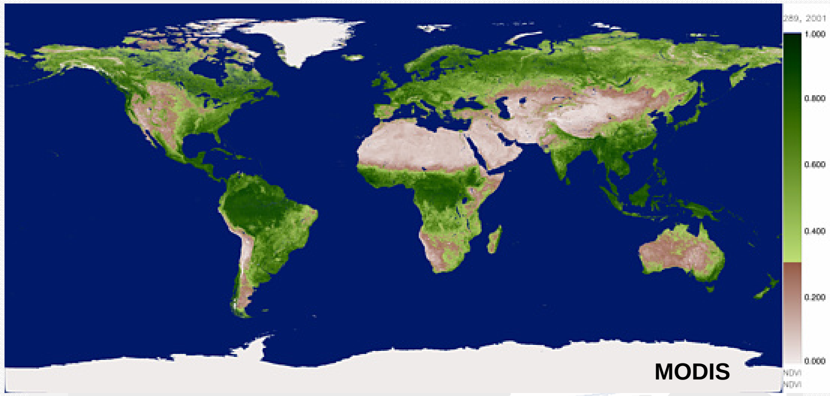
The One-Minute Land Ecosystem Classification Product



http://visibleearth.nasa.gov/

Ecosystem and Biodiversity

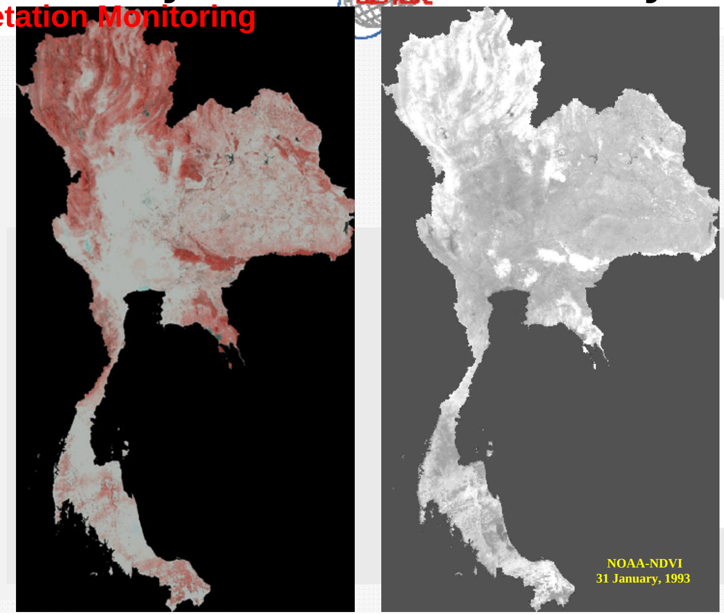
Green Vegetation Monitoring



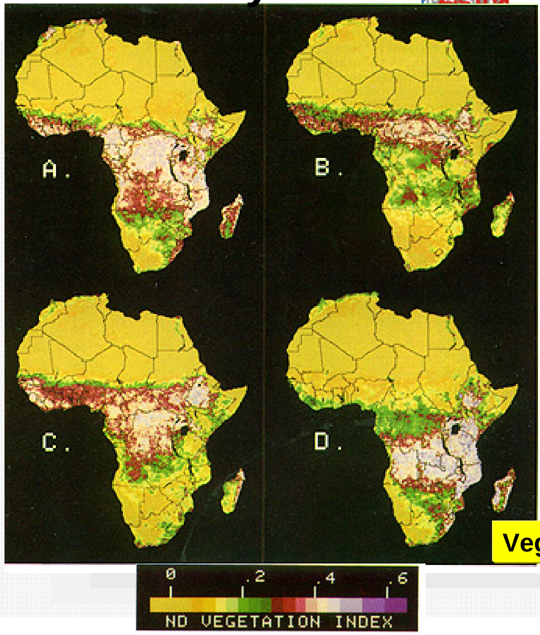
Filled Normalized Difference Vegetative Index (NDVI) Maps 16-Day Averages

Ecosystem and Biodiversity

Vegetation Monitoring



Ecosystem and Biodiversity



Seasonal changes in biomass

Africa:

A. April 12-May 2, 1982;

B. July 5-25, 1982;

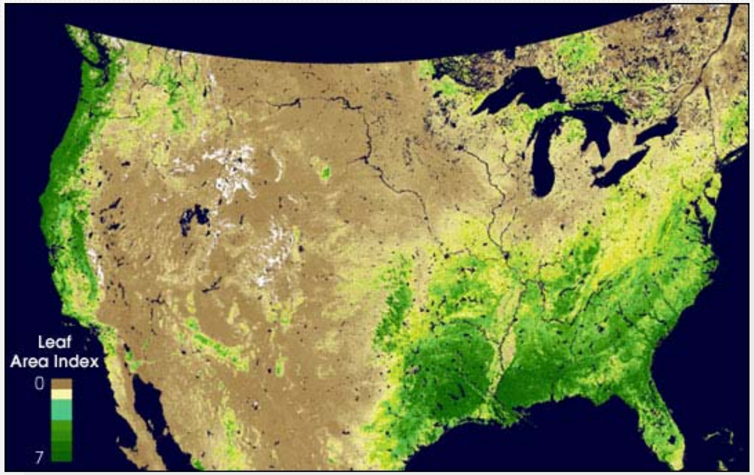
C. Sept. 27-Oct. 17, 1982;

D. Dec. 20, 1982-Jan. 9, 1983.

Vegetation Change Monitoring

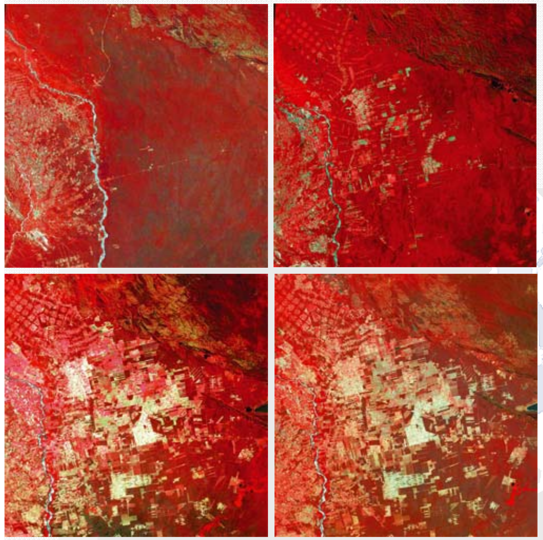
Ecosystem and Biodiversity

Vegetation/Biomass monitoring



http://visibleearth.nasa.gov/

Ecosystem and Biodiversity

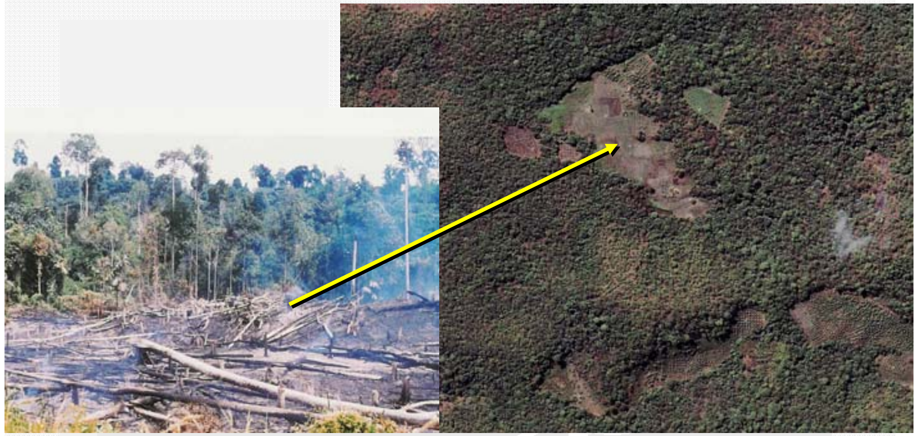


Deforestation Monitoring

LANDSAT time series (1975, 1992, 2000, 2002) images of large scale deforestation in the Amazon. Such images have raised global awareness of deforestation.

Ecosystem and Biodiversity

Deforestation



Geo-Informatics Office

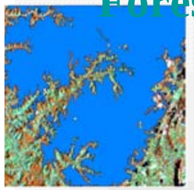
Ecosystem and Biodiversity

Geo-Informatics and Space Technology Development Agency (Public Organization)

Forest Monitoring

By LANDSAT

Deforest : Prekdad Canal, Ranong Province

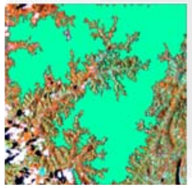


16 March 1992
area 142 sq.km.

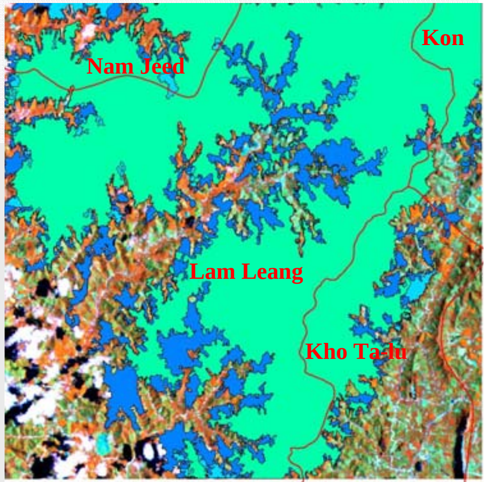
decrease 27 sq.km.

24 August 1998
area 115 sq.km.

decrease 5 sq.km.



18 April 2004
area 110 sq.km.



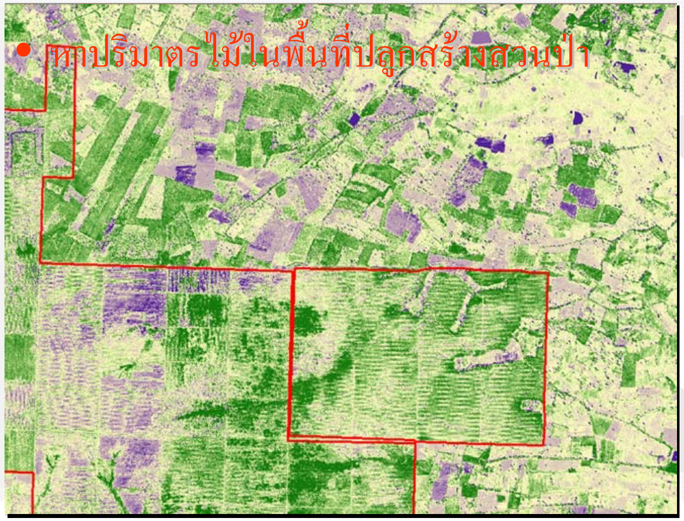
Total area 225 sq.km.

Geo-Informatics Office

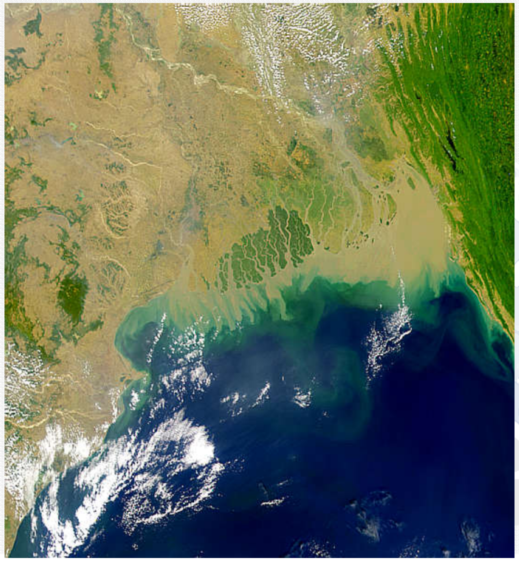
Ecosystem and Biodiversity

Geo-Informatics and Space Technology Development Agency (Public Organization)

Forest plantation



Ecosystem and Biodiversity



Coastal zone detection

This SeaWiFS image of the northern Bay of Bengal shows the heavy sediment outflow from the Ganges River and the protected mangroves of the Sundarbans.

Northern Bay of Bengal

http://visibleearth.nasa.gov/

Ecosystem and Biodiversity

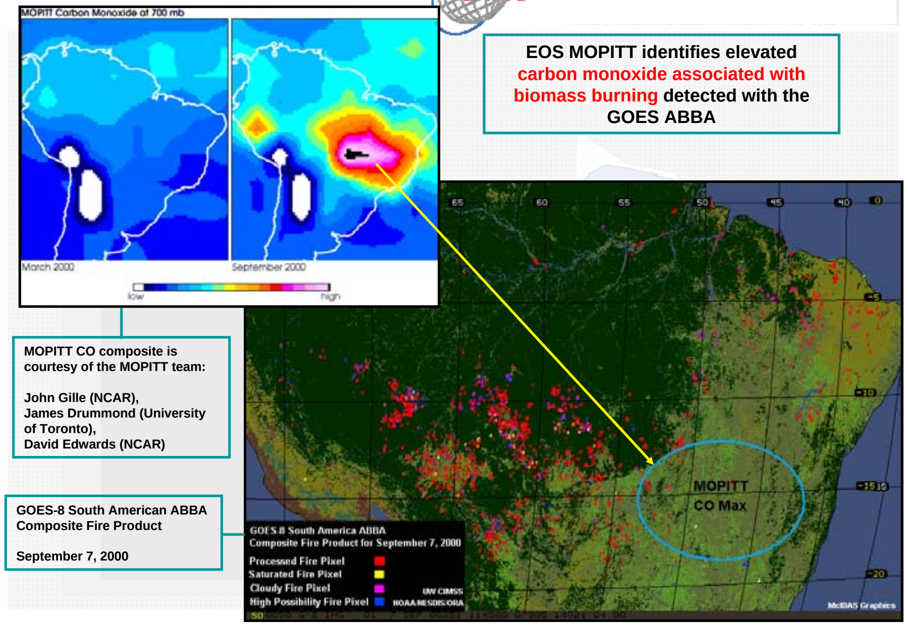
Phytoplankton bloom in Persian Gulf

There is a large amount of sediment clearly visible in the true-color image of the Persian Gulf, acquired on November 1, 2001, by MODIS. Carried by the confluence of the Tigris and Euphrates Rivers (at center), the sediment-laden waters appear light brown where they enter the northern end of the Persian Gulf and then gradually dissipate into turquoise swirls as they drift southward. The nutrients these sediments carry are helping to support a phytoplankton bloom in the region, which adds some darker green hues in the rich kaleidoscope of colors on the surface.

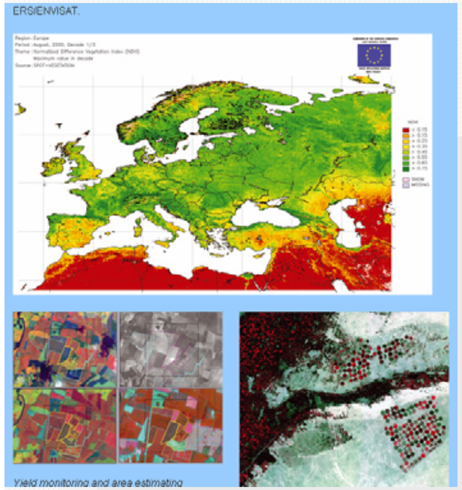
http://visibleearth.nasa.gov/

Ecosystem and Biodiversity

EOS MOPITT identifies elevated carbon monoxide associated with biomass burning detected with the GOES ABBA



Sustainable Agriculture

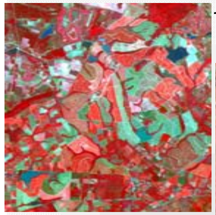


The programme supports decision-making at the European level – providing statistical input to the implementation of the EC's Common Agricultural Policy (CAP) and other activities of the Directorate General for Agriculture.
MARS has developed and implemented new methods and tools specific to agriculture using remote sensing, including:
anti-fraud measures: measures to combat fraud related to the implementation of the CAP; remote sensing is used in validating farmers' declarations of planted crops and acreages, and in optimising allocation of agri-environmental subsidies;
crop and yield monitoring: crop yield monitoring with agro-meteorological models and low resolution remote sensing methods, and area estimates using high resolution data combined with ground surveys.

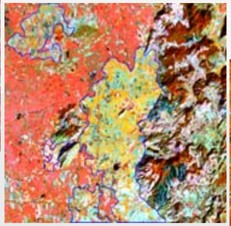
NOAA, LANDSAT, SPOT

Sustainable Agriculture

Economy Crop Mapping

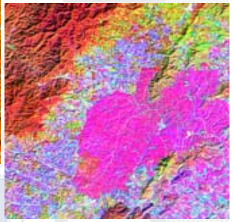


Pineapple



Sugar cane and cassava

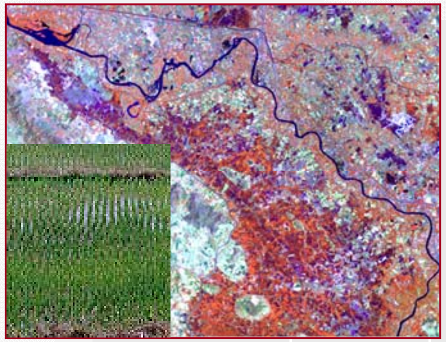
Rubber

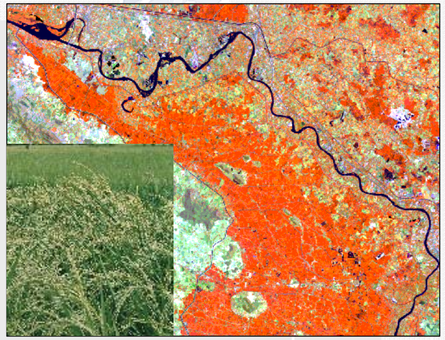


Oil Palm

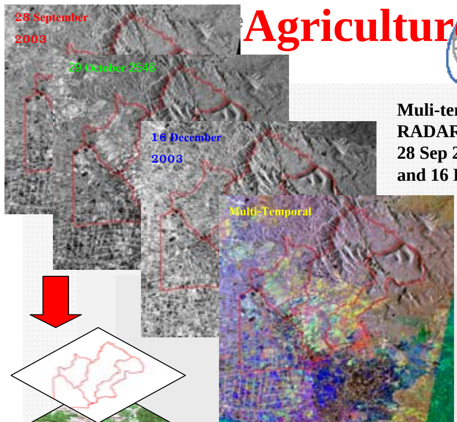
Sustainable Agriculture

Crop monitoring

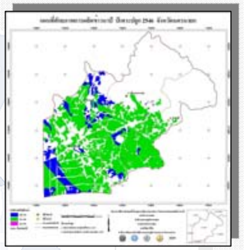




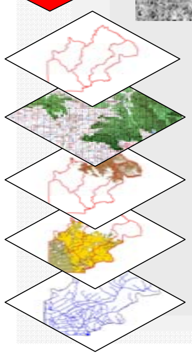
Agriculture : Rice Mapping



Muli-temporal RADARSAT data dated 28 Sep 2003, 29 Oct 2003 and 16 Dec 2003



Nakhon Nayok

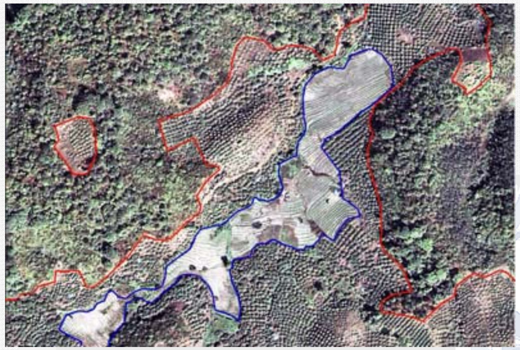


Rice Production Potential Map

Rice Mapping from RADARSAT Data

Rice Paddy area = 1,005 sq.km.

Economy Crop Monitoring



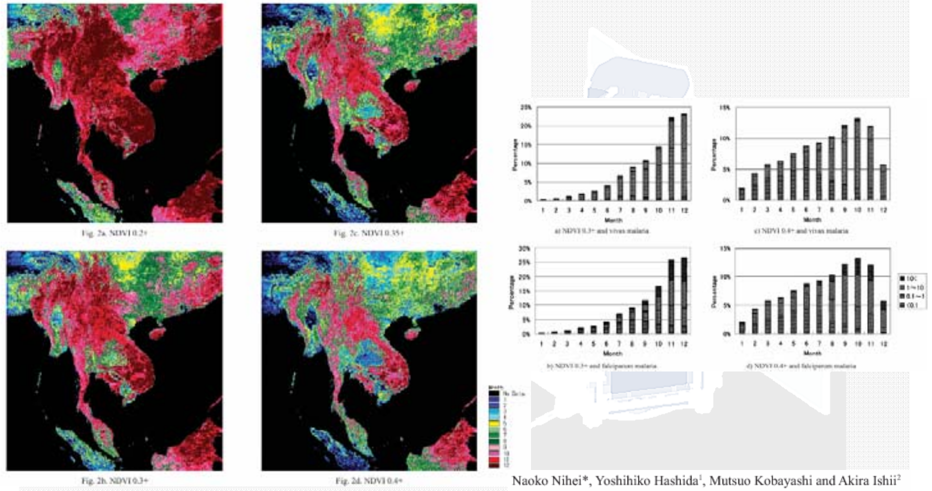
IKONOS dated 17 Mar 2002
Lychee Plantation :
Doi Suthep, Chiang Mai

Role of EOS: Human Health and Well-Being

Current health-related applications of satellite data include:

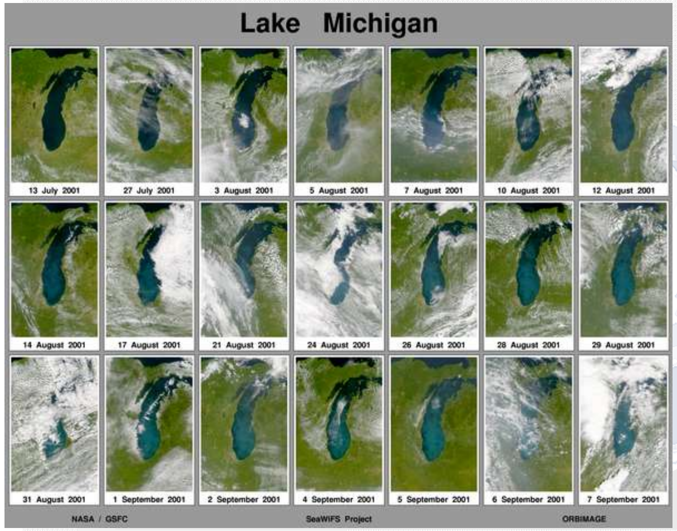
- detection of environmental factors associated with disease-vector habitats and human transmission risk;
- monitoring of air and water quality measures.

Malaria Endemic Area



Naoko Nihei*, Yoshihiko Hashida[1], Mutsuo Kobayashi and Akira Ishii[2]
Department of Medical Entomology, National Institute of Infectious Diseases,

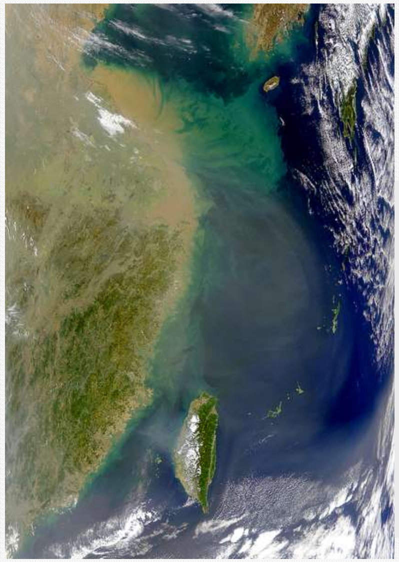
Role of EOS: Human Health and Well-Being



This series of images from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) aboard the Orbview-2 satellite shows the dramatic change in the color of Lake Michigan during the summer.

http://visibleearth.nasa.gov/

Role of EOS: Human Health and Well-Being



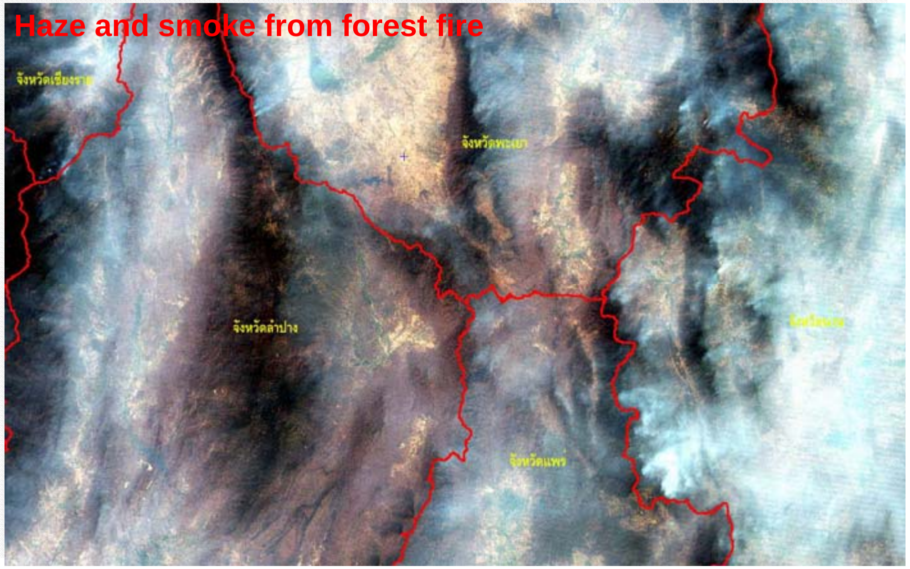
In this SeaWiFS image is another example of far-reaching aerosols from China. The large plume in the water is from the Yangtze River.

Chinese Dust in the Air and Mud in the Water

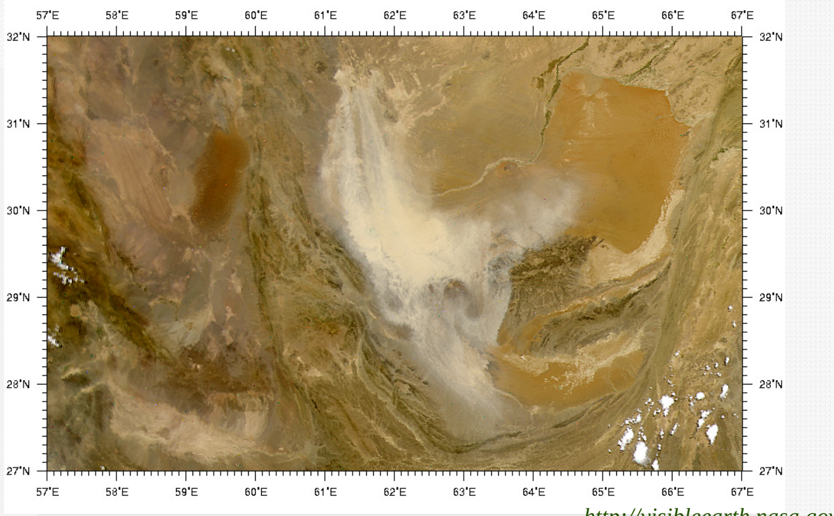
http://visibleearth.nasa.gov/

Role of EOS: Human Health and Well-Being

LANDSAT-5 10/03/2007



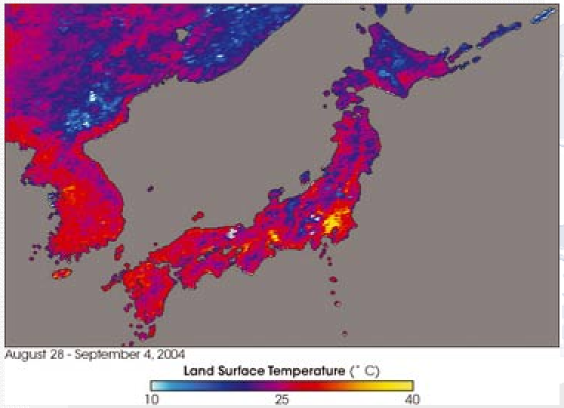
Role of EOS: Human Health and Well-Being



http://visibleearth.nasa.gov/

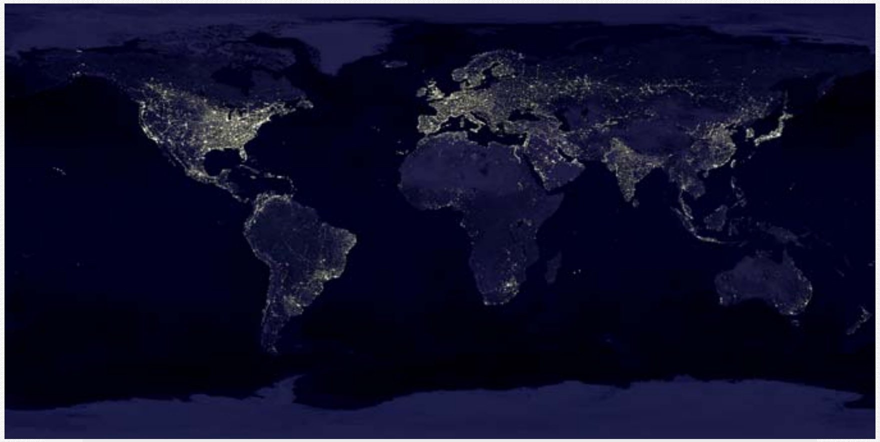
The Sea-viewing Wide Field-of-view Sensor (SeaWiFS) viewed this large dust storm over Iran, Afghanistan, and Pakistan today (May 18, 2001).

Energy Resource Management



*Weather forecasts are vital for **electricity demand forecasting**. Meteorologists noted a record-breaking hot summer in Japan in 2004 – with 68 days reaching more than 30□C. Urban heat island conditions are increasing demand for air conditioning and placing stress on electrical supply systems.*

Energy Resource Management



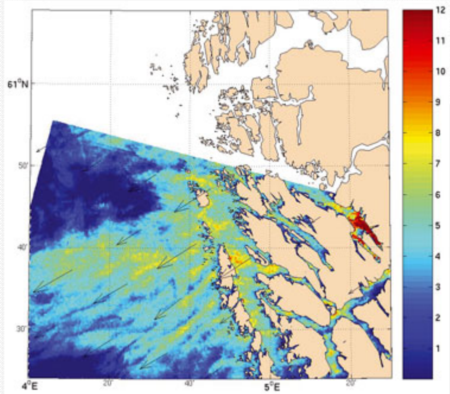
This image of Earth's city lights was created with data from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS)

http://visibleearth.nasa.gov/

Energy Resource Management

Satellite imagery is routinely used in exploration of **offshore oil basins** – including through oil ‘seep’ detection

Energy Resource Management



Coastal wind mapping using radar satellites

Conclusion

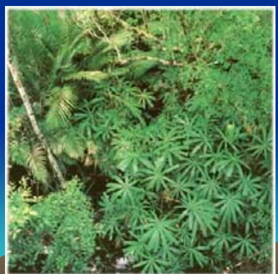
- Remote sensing (EOS) an effective tool for global environment observation
- ~ 100 EOS missions existing: Atmosphere, Ocean, Land

Evergreen Forest

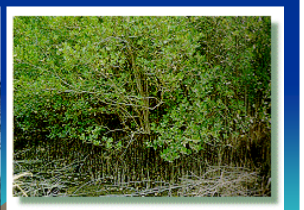

Tropical Rain


Hill Evergreen

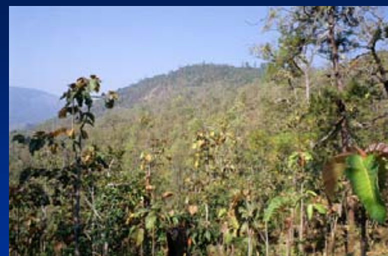

Dry Evergreen

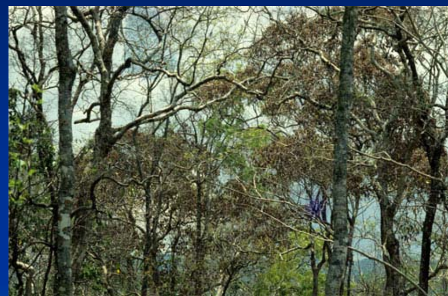

Peat Swamp


Pine


Mangrove

Non-Evergreen Forest
(Deciduous, seasonal)


Dry Dipterocarp


Mixed Deciduous


Savannah

Current Forest Situation (FAO,2007)

	Forest area,2005		
	Total forest, ha	% of land area	Forest plantation
Cambodia	10,447,000	59.2	-
Lao PDR	16,142,000	69.9	224,000
Myanmar	32,222,000	49	849,000
Thailand	14,520,000	28.4	3,099,000
Vietnam	12,931,000	39.7	2,695,000

Biomass & Carbon in Biomass (FAO,2007)

	Biomass		Carbon in Biomass	
	Per hectare, tons	Total m-tons	Per hectare, tons	Total m-tons
Cambodia	242.4	2,532	121	1,266
Lao PDR	184.2	2,974	92	1,487
Myanmar	196.6	6,335	98	3,168
Thailand	98.8	1,434	49	716
Vietnam	181.6	2,348	91	1,174

Causes of Forest Destruction

Convert into other landuse

Damaged by forest fire

Convert into other landuse

-Agricultural area (shifting cultivation)

-Human settlement

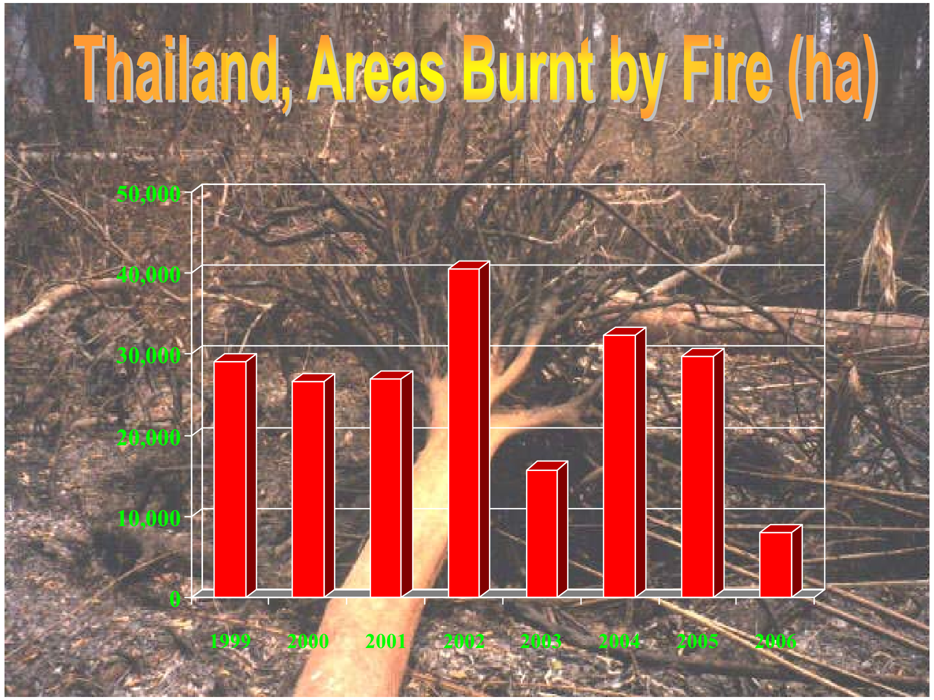
Rate of Deforestation (FAO,2007)

	Annual change rate, 2000-2005	
	ha	%
Cambodia	-219,000	-2
Lao PDR	-78,000	-0.5
Myanmar	-466,000	-1.4
Thailand	-59,000	-0.4
Vietnam	+241,000	+2

Causes of Forest Fire

100% from human activities

1. Gathering non-timber products 26 %
2. Agriculture debris burning, Slash and Burn 18 %
3. Incendiary fire 17 %
4. Carelessness 16 %
5. Hunting 15 %
6. Unidentified causes 8 %




ASEAN Agreement on
Transboundary Haze Pollution
2002 – agreement signed
2003 - entered into force


Thank You

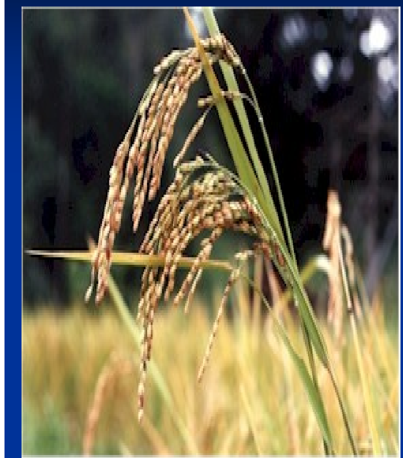
Rice Cultivation and Management Practices in Thailand

Presented by Wilaiwan Sornpoon…Department of Agricultural Extension

Introduction

- Thailand - 513,115 sq. km
- Thailand - 4 regions :
  1) Central regions – 20%
  2) Northeastern regions – 33%
  3) Northern regions- 33%
  4) Southern regions – 14%
- Thailand - 3 seasons
  1) Hot & dry season – Feb. to May
  2) Rainy season – June to Oct.
  3) Cool & dry season – Nov. to Jan.
- Agricultural areas - 41% (21 million ha)

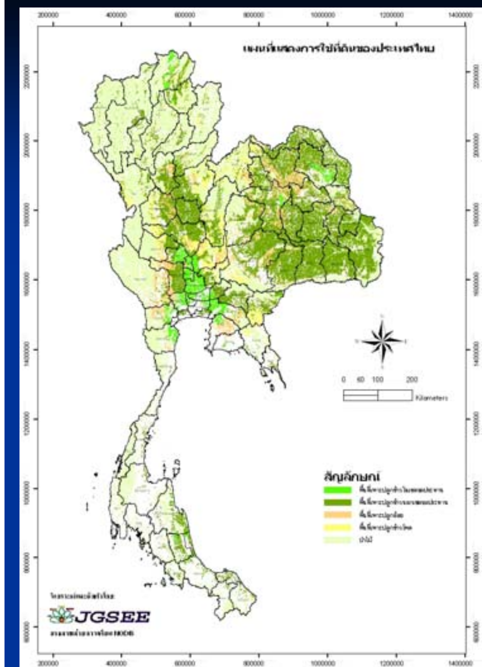
Introduction



- Agricultural areas are
  - 49% of paddy
  - 21% of field crops
  - 20% of fruit
  - 1% of flower
- Rice – staple food & most important crop
- Thailand is the world's leading exporter of rice.
- 27% of the total global rice was made by Thailand.

Agriculture is the main sector of Thailand's economy

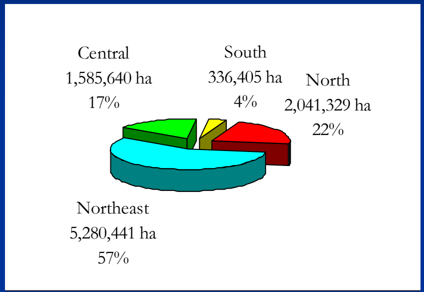
Introduction



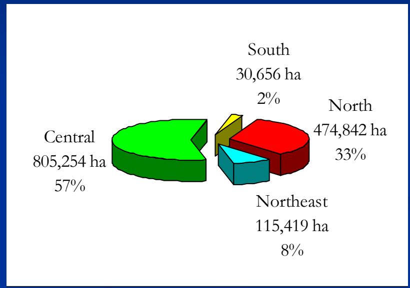
- Rice production could be classified into 2 main ecosystems:
  - ➢ rainfed lowland = 70 %
  - ➢ irrigated = 30 %
- Rice cropping:
  - ➢ rainfed area - 1 crop
  - ➢ irrigation area - > 2 crops

Introduction

- Rice Area in Different Regions of Thailand (Year 2005)



Wet Season Rice Areas

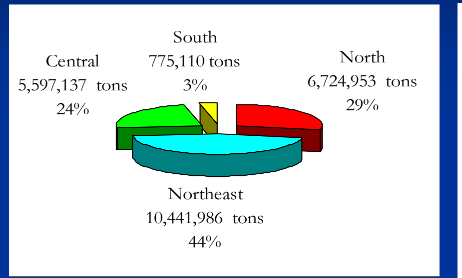


Dry Season Rice Areas

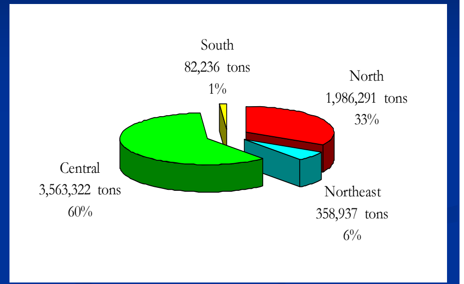
- rice area in wet season - 87 % (9.3 million ha)
- rice area in dry season - 13 % (1.4 million ha)

Introduction

- Rice Production in Different Regions of Thailand (Year 2005)



Wet Season



Dry Season

- Rice production in wet season - 80 % (23.5 million tons)
- Rice production in dry season - 20 % (6.0 million tons)

Land preparation process

- Irrigated area

Burnt area

plowing

Land leveling

Land preparation process

- Rainfed area

Burnt area

Plowing & harrowing

- used - hiring service

Planting process

- Irrigated area

Germinated Seed Broadcasting

Transplanting

Planting process

- Rainfed area

Dry Seed Broadcasting

Transplanting

- Direct dry seed broadcasting in dry soil is the common method of rice cropping in this area.
- Transplanting method is also used in the water controlled area.

Crop care process

Control weed & insects

Apply fertilizer

- Control weed & insects - hand operated sprayer & power sprayer
- Apply fertilizer - broadcasting by labor

Harvesting process

- In large field area
  - ➢ harvested by combine harvesting machine (35%)
  - ➢ 6,000 local combine harvester being use for hiring service
- In small field area
  - ➢ harvested by labor

Threshing process

Large scale mobile

Small scale mobile

- In small field area
  - ➢ paddy threshers are mainly use
  - ➢ 88 percent in hiring service

Drying process

- Sun drying is the most generally practice for farmers
- Farmers dry paddy for their consumptions and for seed reserves first
- The selling paddy are transported directly from farm to paddy markets, agri. co-operatives, or rice millers, to be operated with large scale dryer

Extension Programs

- Promote the change of burning cultivation into zero burning cultivation.
  - ➢ Enhance the farmer awareness of the burning impacts through the development of traditional practices supporting zero burning cultivation.
  - ➢ Development of farmer relationship – set up the farmer network to prevent and control burning in agricultural area.
  - ➢ Promote the incorporate rice residue for enrich the soil & control burning practices in rice cultivation.
  - ➢ Given incentives to farmer for doing proper controller burning practices.

Thank you… for your attention

Greenhouse Gas Emissions from biogenic sources and GHG Research Developments in Thailand

Amnat Chidthaisong

Joint Graduate School of Energy & Environment, King Mongkut's University of Technology Thonburi, Bangkok, Thailand

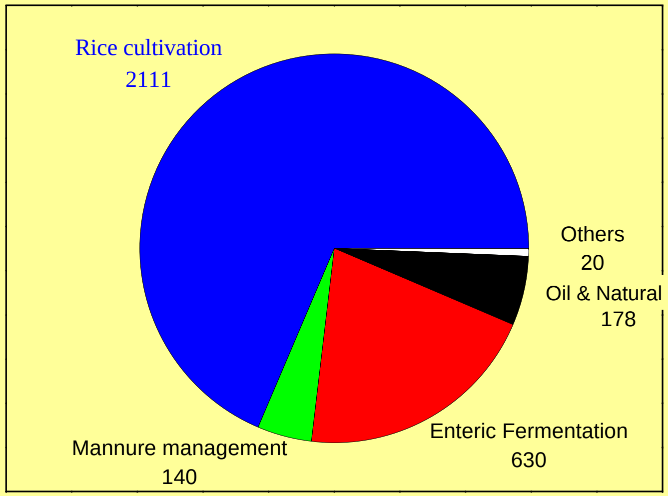
GHG & Sources

GHG	Sources	
	Biogenic	Abiogenic
CO_2	-	-Fossil fuel -Biomass burning
CH_4	-Wetland **-Paddy field** -Livestock/enteric fermentation -Wastes/Landfill **-Forest (soil)** -Termites	-Fossil fuel -Biomass burning/fires -Geological sources -Ocean/Hydrates
N_2O	-Agriculture (Cultivated soil, manure) -Forest/Natural vegetation -Ocean	-Fossil fuel/industrial processes -Aircraft -Biomass/Biofuel

First Thailand Greenhouse Gas Inventory 1994

GHGs	Emission (Gg)	CO_2-equivalent (Gg)	%
CO_2	202,458	202,458	71
CH_4	3,171	66,598	23
N_2O	56	17,317	6

Methane Emission from Thailand (Gg, 1994)



Current Inventory

➔Emission Factors calculated from;

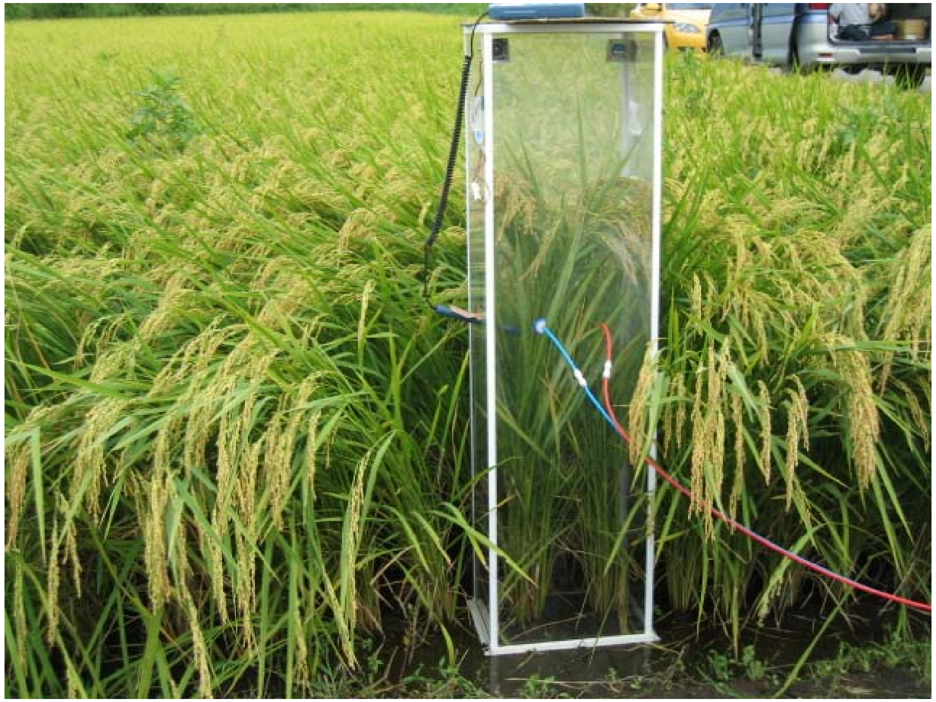
-Default scaling factors for water regimes and correction factors for organic amendments

-Derived using the average of the measurements conducted in four typical rice growing areas in Thailand (0.2595 g-CH_4 per sq m per d) which were under continuous flooding in the wet season during 1992 to1994

-The average methane emission rate was converted according to different water regimes and organic matter amendment using IPCC correction factors

Method for Emission Measurements

➔ Static Chamber methods



Current Procedures

Chamber enclosure

↓

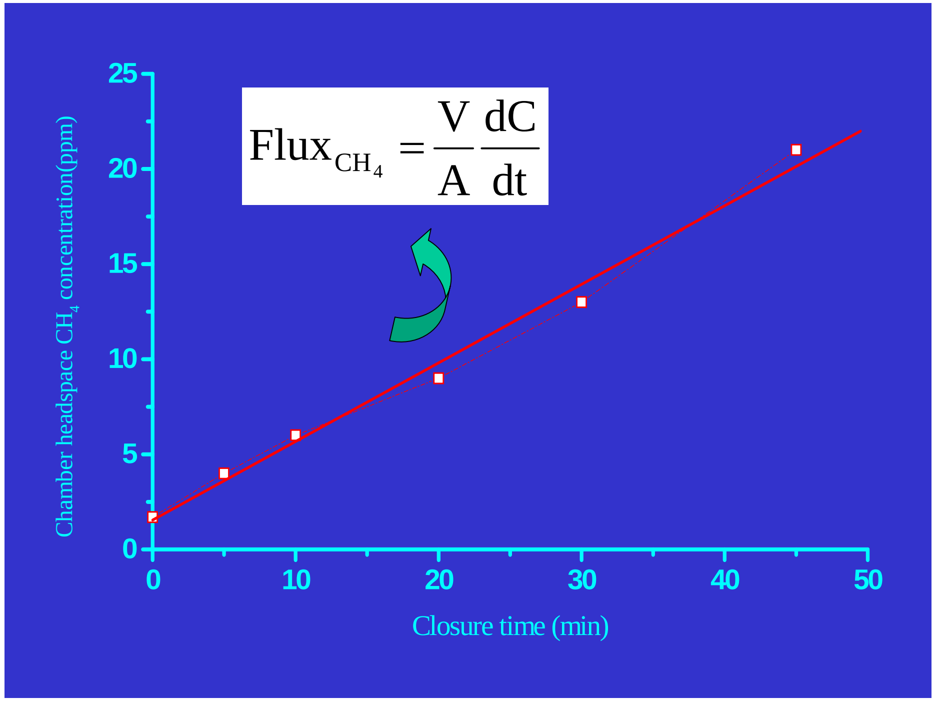
Gas samples

↓

Gas Chromatography

↓

Flux estimate



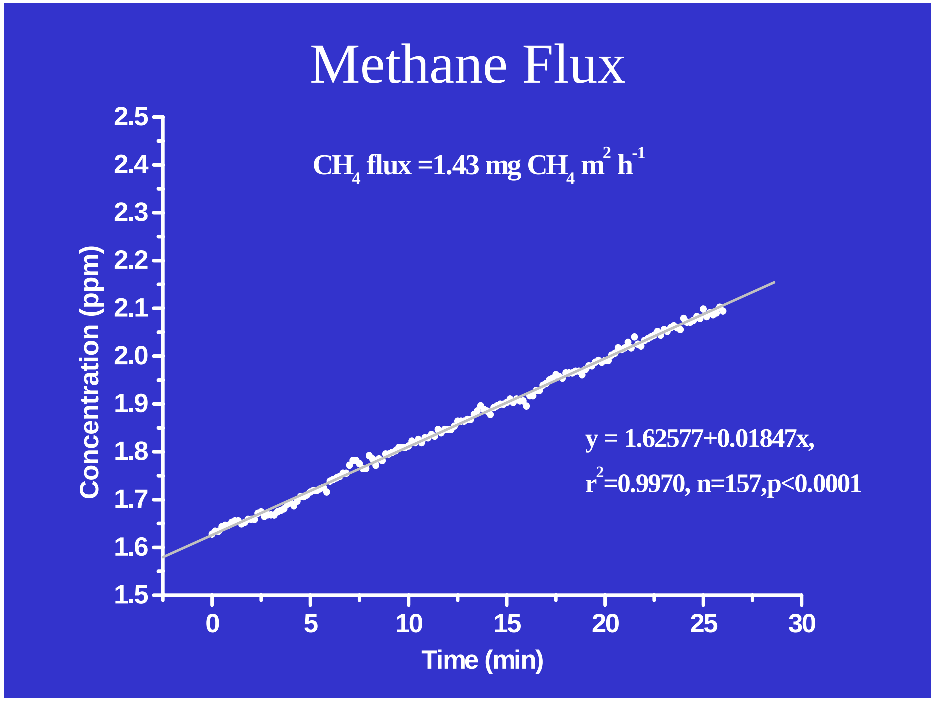


Table 3.1 Measured Methane Emissions in kg CH_4/ha/day from Various Rice Cultivation Areas, with and without Soil Amendments

Province	Soil series	NF	CF	CF+OM	Average
Pathum Thani	Rangsit	0.45	0.73	1.11	0.763
Ratchaburi	Nakornpathom	1.13	2.32	5.93	3.127
Surin	Roi-et	3.77	5.41	6.33	5.170
Chiangmai	Hang Dong	0.89	1.76	1.31	1.320
Average		**1.56**	**2.56**	**3.67**	**2.595**

Notes: NF = no fertilizer application
CF = with chemical fertilizer amendment
CF + OM = with both chemical and organic fertilizer amendment

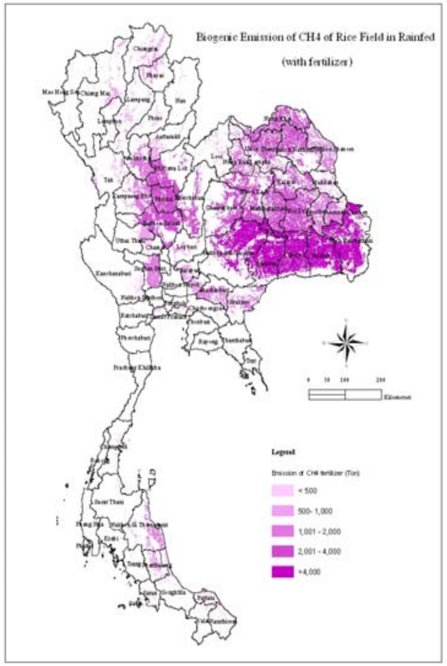
Source: Jermsawatdipong, *et al.* 1994.

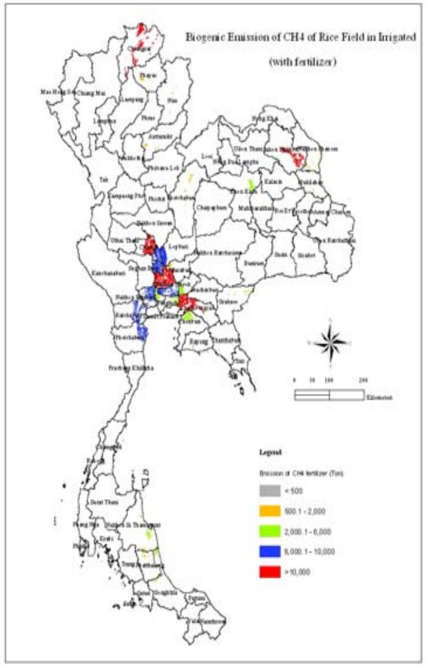
Table 3.2 Methane Emission Factors for Different Water Ecosystem and Organic Amendment

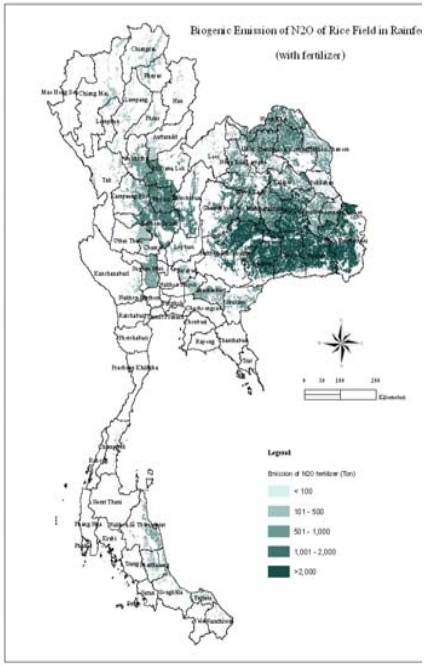
Category	Sub-category		Scaling factors for rice ecosystem	Correction factors for organic amendment	Emission factors kg CH_4/ha/day
Major rice					
Upland	Rainfed	–	0	1	0
	Irrigated	Continuously flooded + OM	1	2	3.120
		Continuously flooded	1	1	1.560
Low land	Rainfed	Flood prone	0.8	2	1.248
		Flood prone + OM	0.8	1	2.496
		Drought prone	0.4	1	0.624
		Drought prone + OM	0.4	2	1.248
	Deep water	Water depth > 100 cm	0.6	1	0.936
Second rice	Irrigated	Continuously flooded + OM	1	2	3.120

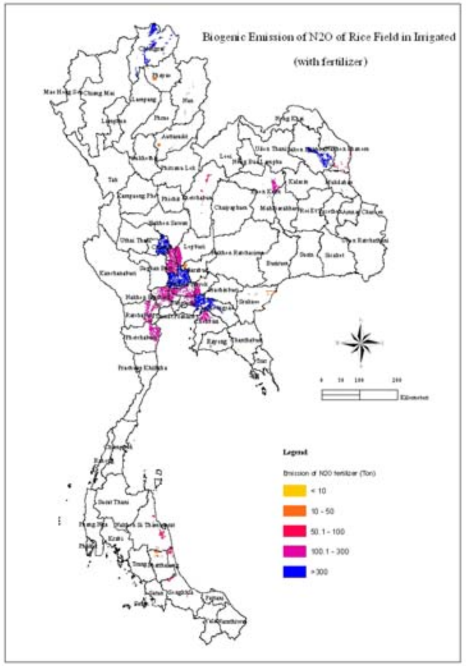
IPCC EF | Local EF

Category	Sub-category		Seasonal flux ($g\ CH_4/sq\ m$)	Cultivation area (ha)	CH_4 emission (Gg)	Local EF
Major rice						
Upland	Rainfed	–	0.00	34,048	0.00	0.00
Low land	Irrigated	Continuously flooded + OM	44.04	1,121,492	493.90	420
		Continuously flooded	18.72	1,121,492	209.94	210
	Rainfed	Flood prone + OM	14.98	1,100,926	164.87	165
		Flood prone	35.23	1,100,926	387.88	330
		Drought prone + OM	17.62	2,184,333	384.79	164
		Drought prone	7.49	2,184,333	163.56	327
	Deep water	Water depth > 100 cm	15.31	39,478	6.04	8
		Total		8,887,026	1,811.00	1623
Second rice	Irrigated	Continuously flooded	44.04	680,123	299.53	225
		Total Emissions		9,567,149	2,110.53	1,878





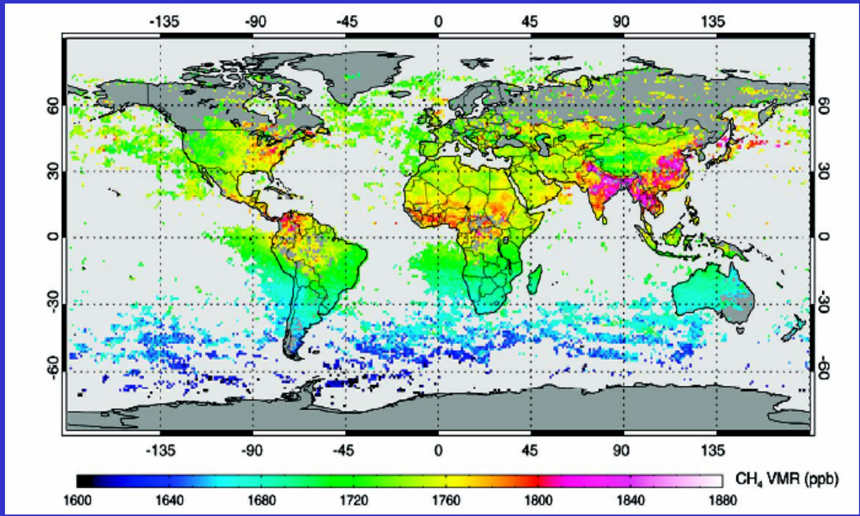




GHG fluxes in tropical forest

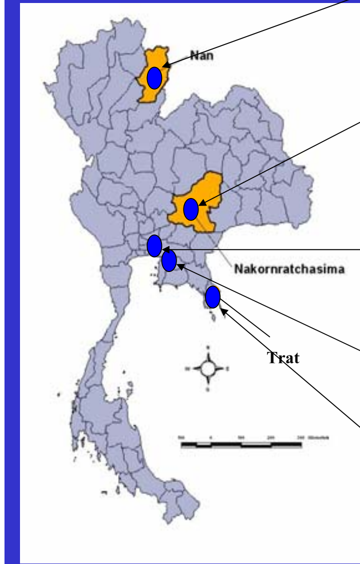
- Theme: **Soil processes, mechanisms vs. fluxes, mitigations**
- Compounds: **CO_2, CH_4, N_2O, SOC**
- Sites:
  - **Native forest,**
  - **Reforest,**
  - **Agriculture (maize, sugarcane, paddy field)**

CH_4 Emission from tropical forest



Frankenberg et al. (2005), Science, 308: 1010-1014.

Study site



Nan
- Hill Evergreen (HEF)
- Mixed Deciduous (MDF)

Nakornratchasima
- Dry Evergreen (DEF)
- Agriculture (AG: corn)
- Acacia Reforestation (ARF)

Cha Choeng Sao
- Agriculture (maize)
- Dry Evergreen

Chonburi
- Agriculture Sugarcane

Trat
- Moist Evergreen (MEF)

SK-DEF

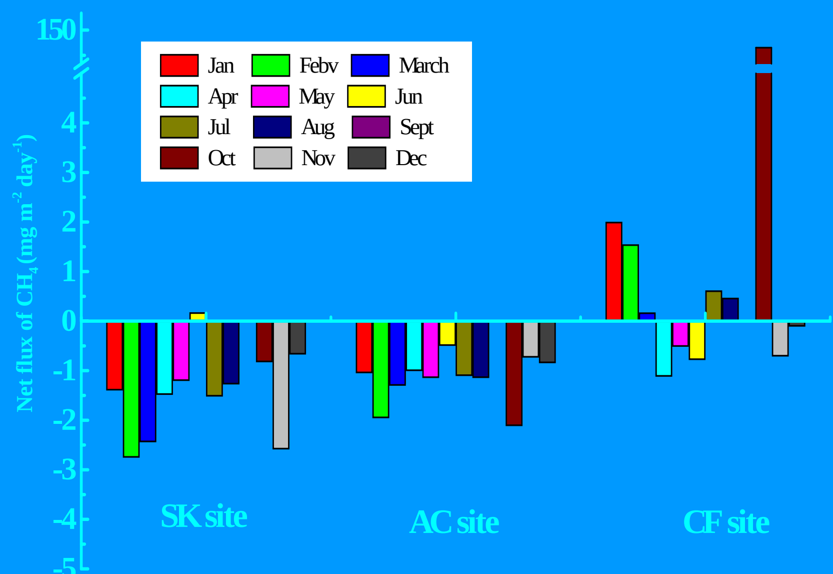
AC-**Acacia**

CF (Maize)

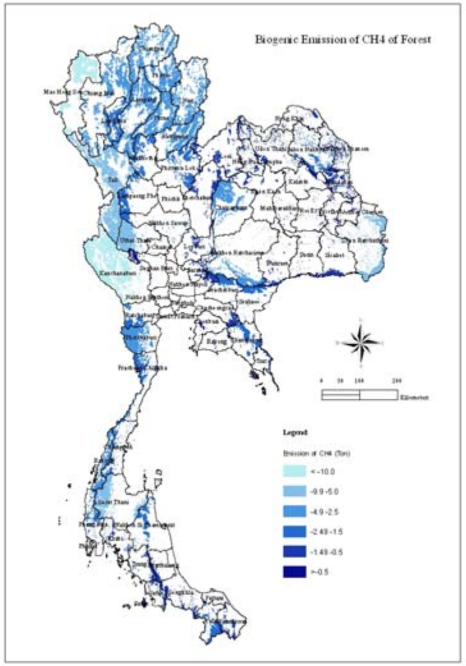
Land use and GHG flux

(Nakornratchasima)

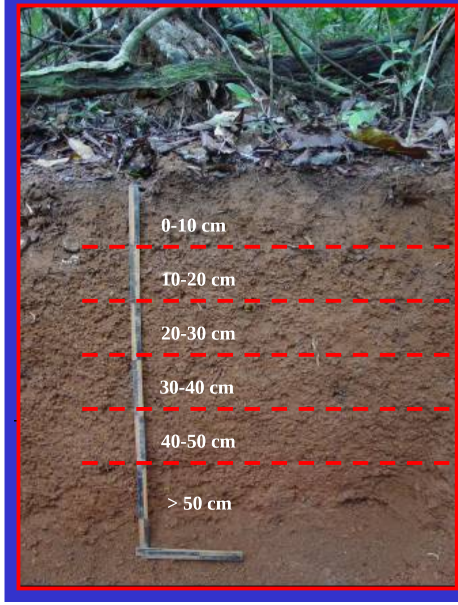
Net Methane flux (mg m^{-2} day^{-1})

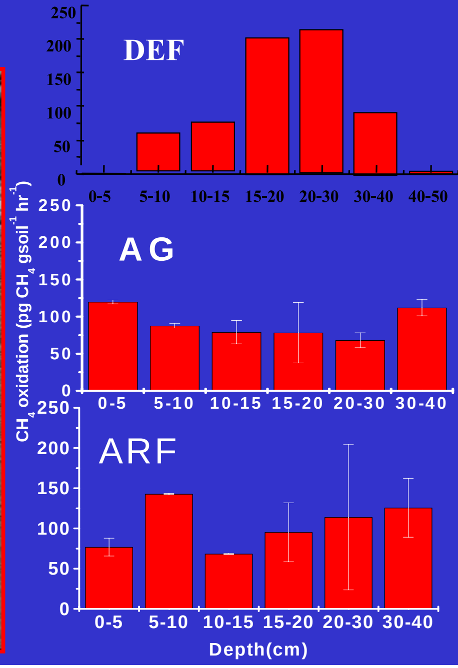


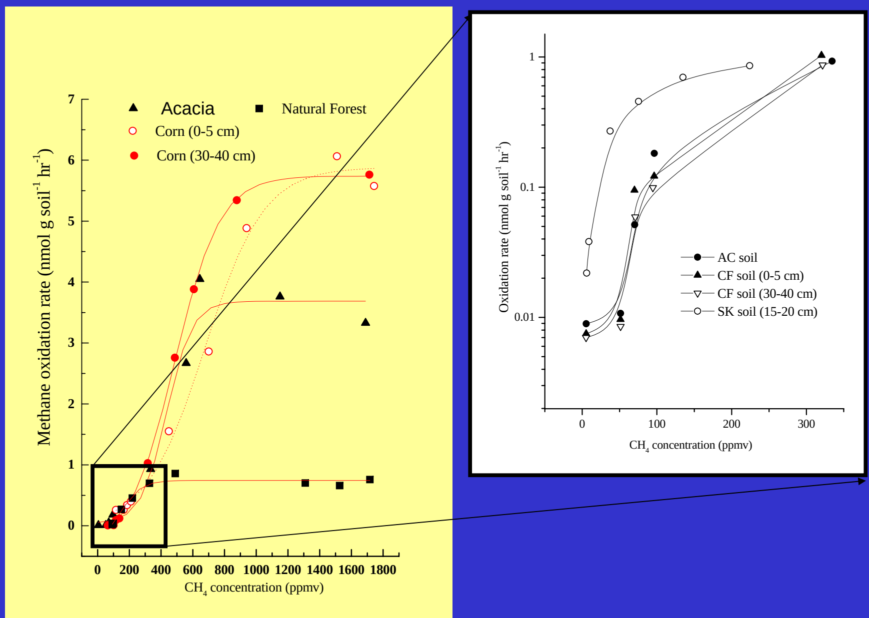
Supika et al., 2004



CH_4 oxidation in soil

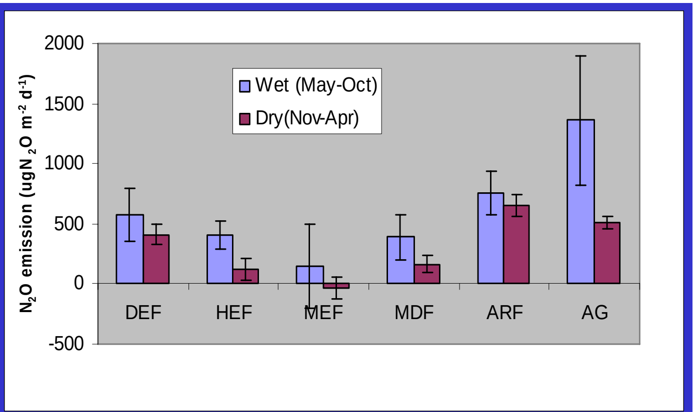






- **At ambient concentration, natural forest acts as an effective methane sink.**
- **Land use change from forest to agriculture reduces methanotrophic capacity of soils.**
- **Reforestation recovers partly methatrophic capacity of soils.**
- **Oxidation layers are in the subsoil.**
- **Methotrophic communities and their enzyme kinetics differ in soils under different land use. This is probably the main reason of different methanotrophic activity of soils.**

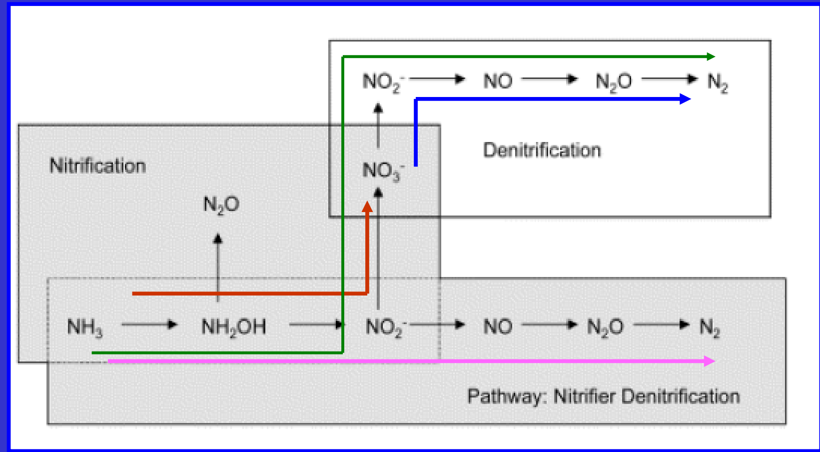
N_2O flux



The monthly average (±SD)
(μg N_2O m^{-2} day^{-1})

DEF	491±321
HEF	261.9±268
MEF	46±456
MDF	276±321
ARF	627±346
AG	829±851

Pathways of N_2O production



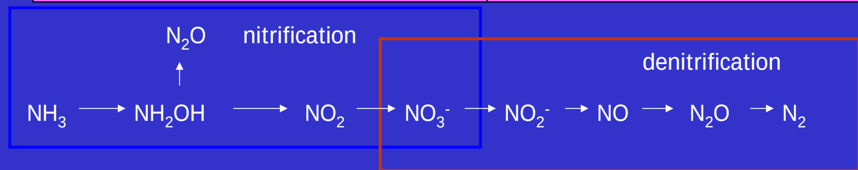
Wrage et. al., 2001

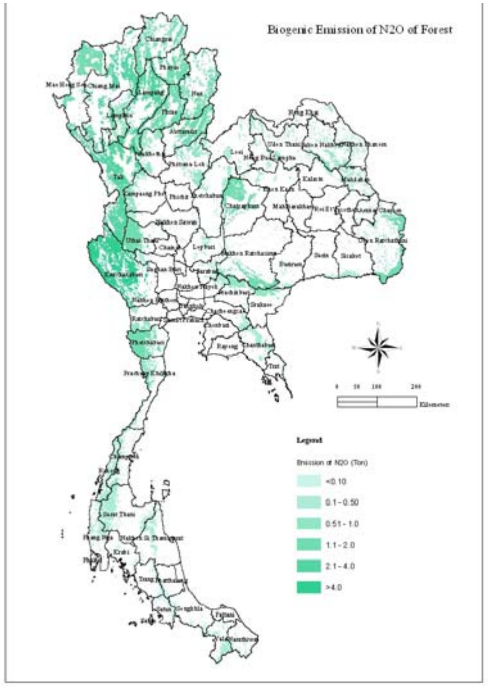
N_2O production

Forest type		DEF		HEF	
% WHC		30%	60%	30%	60%
N_2O production ($ngNgdw^{-1}$ d^{-1})	without addition	3,9±0,2	266±62	0,5±0,06	4.7±2.5
	with 10Pa C_2H_2	2,6±0,2	233±94	0,47±0.05	5.0±2.2
% Denitrification		**67%**	**88%**	**94%**	**100%**
Ammonium ($ugNH_4$-N/gdw)		233.33	54.44	466.67	101.11
Nitrate (μgNO_3-N/gdw)		18.06	13.55	45.16	22.58
Mineralization rate (μgNH_4-N gdw^{-1} d^{-1})		9.94	10.13	52.50	22.43
Total N (%)		0.075±0.0013		0.36±0.012	

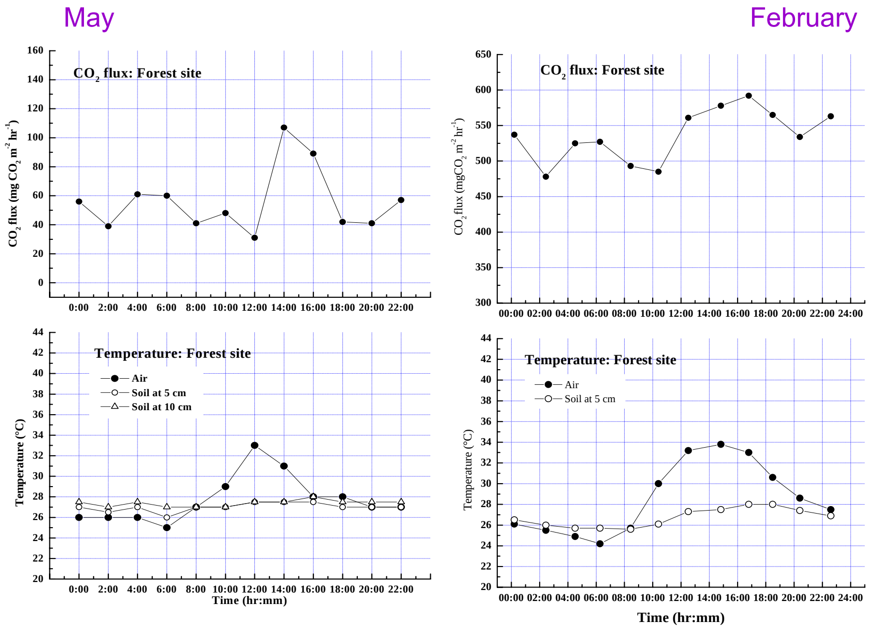
N_2O production

Forest type		**MEF**	
% WHC		**30%**	**60%**
N_2O production ($ngNgdw^{-1}$ d^{-1})	**without addition**	**0.87±0.01**	**437±19**
	with 10Pa C_2H_2	**0.79±0.04**	**107±44**
% Denitrification		**91%**	**24%**
Ammonium ($ugNH_4$-N/gdw)		**77.78**	**77.78**
Nitrate (μgNO_3-N/gdw)		**2.71**	**0.11**
Mineralization rate (μgNH_4-N gdw^{-1} d^{-1})		**14.06**	**13.29**
Total N (%)		**0.087±0.009**	

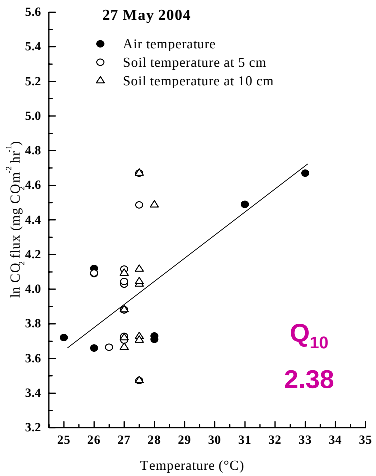


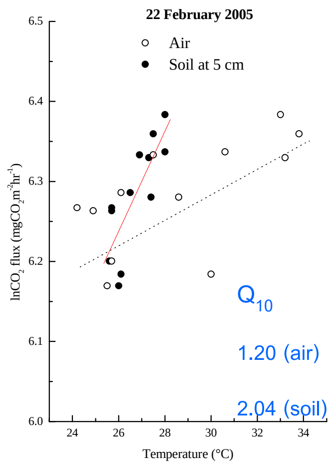


- Tropical soils under natural forests, re-grown forest and agriculture act as the net sources of atmospheric N_2O.
- Various factors affect the amount of N_2O emission (time of year, plot location and land cover type).
- Denitrification is the major pathway of nitrous oxide production at DEF and HEF. Couple nitrification-denitrification probably involves in producing nitrous oxide, especially at 60%WHC for MEF soil.
- Increasing soil moisture from 30 to 60%WHC stimulates nitrous oxide production rate 9.4, 68 and 502 times at HEF, DEF and MEF respectively.

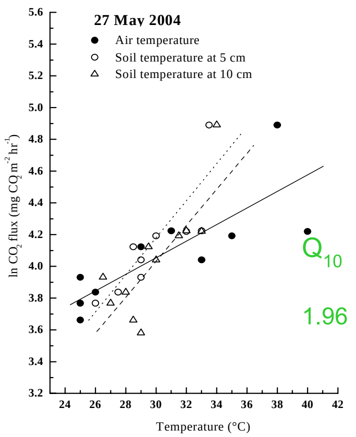


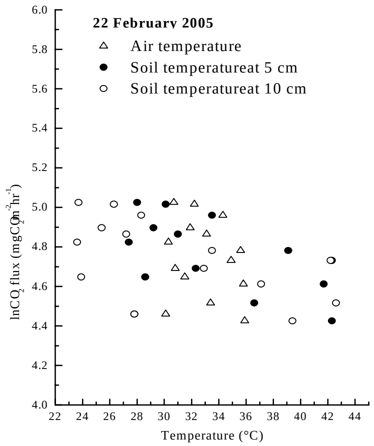
Forest site





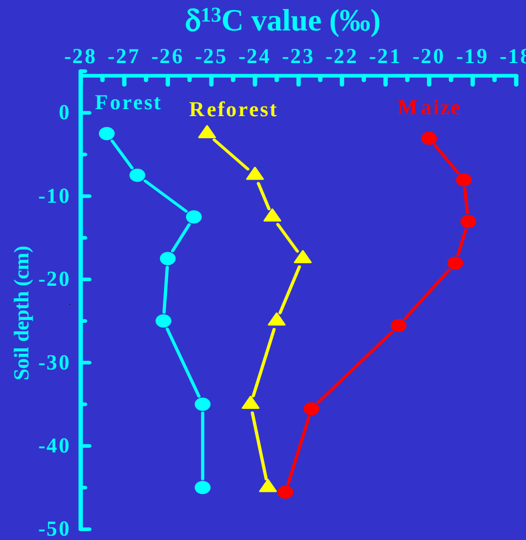
Agricultural site





- Maximum of CO_2 flux peaked later after temperature peaks about 2-4 hr.
- The daily pattern of soil CO_2 efflux showed significantly correlated with temperature.
- Q10 for Ag soil is higher than in Forest soil.
- Soil respiration rate usually increased with increasing soil moisture from air dry condition to about 75% WHC.
- Dry and wet soil were most sensitive to change in temperature for all soil layers.
- The subsoil (agricultural soil) is more sensitive to temperature change than surface soil.

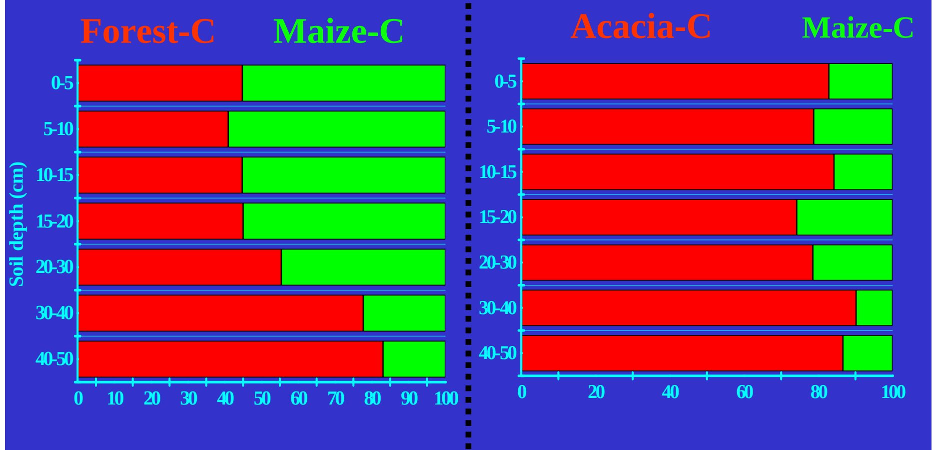
Stable Carbon Isotope of SOM

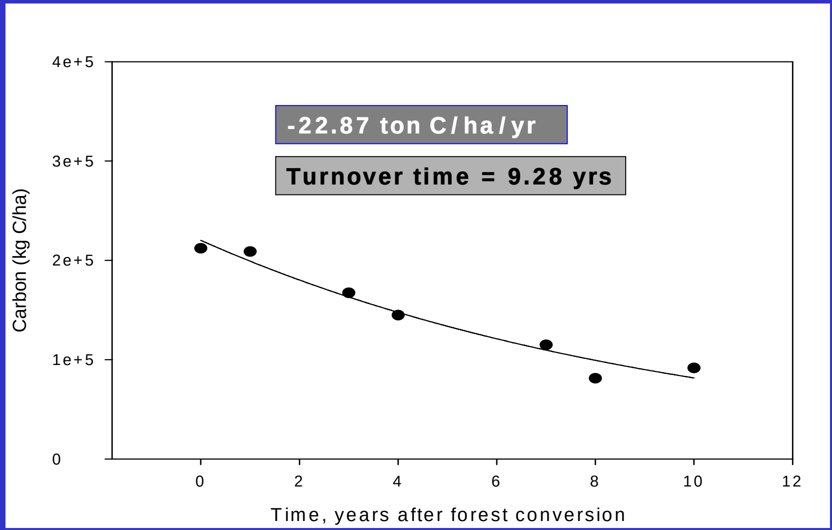


C dynamics & Land use change

Forest ➔ Maize cultivation

Maize cultivation ➔ Reforestation with *Acacia mangium* (AC)





New Developments on Researches

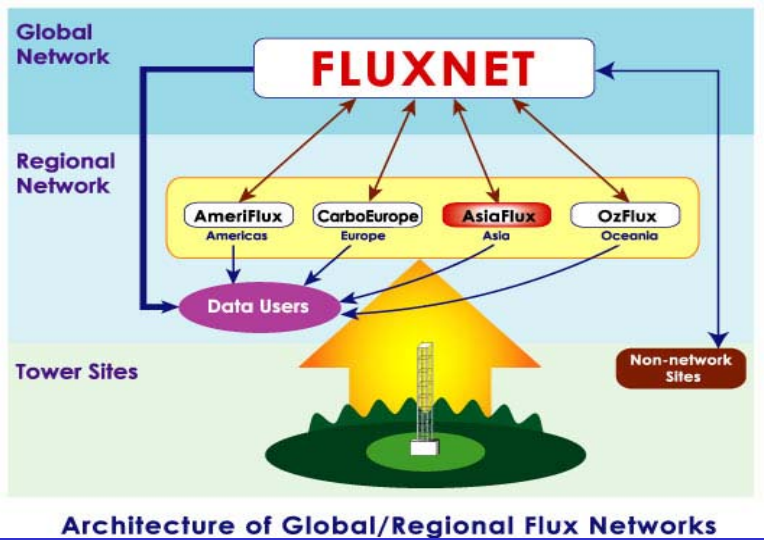
Earth System Science at KMUTT

- Pool resources & collaborate among interdisciplinary scientists
- Research oriented with course work for graduate education
- Long-term observation station (deposition, radiation, fluxes, hydrology, aerosols, other atmospheric chem. & physics, etc)

ThaiFlux Network

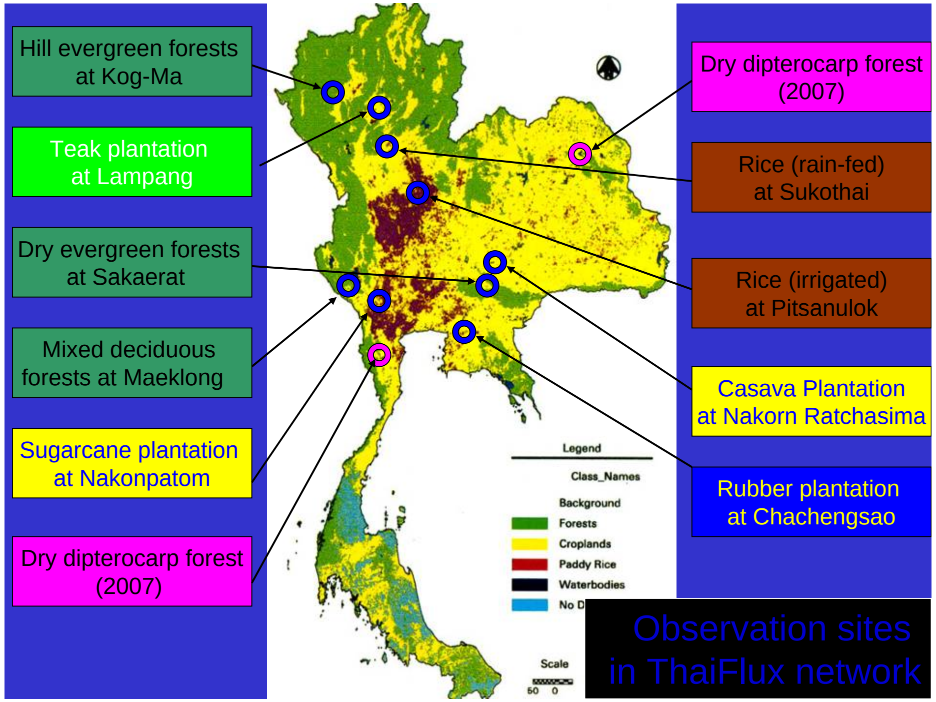
➔Addressing basic science and synthesizing the information & knowledge on trace gases and energy fluxes in Thai ecosystems

ThaiFlux Network is part of AsiaFlux



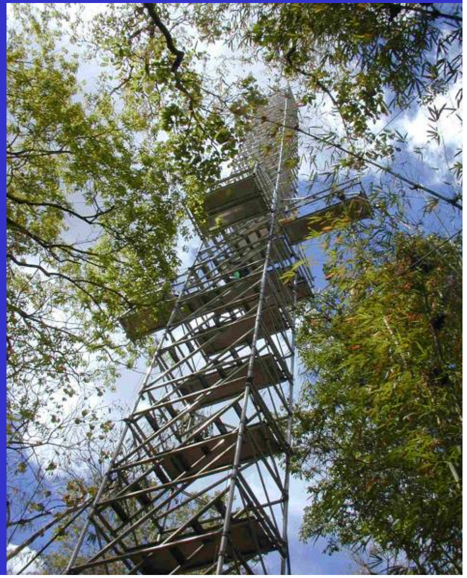
Objectives

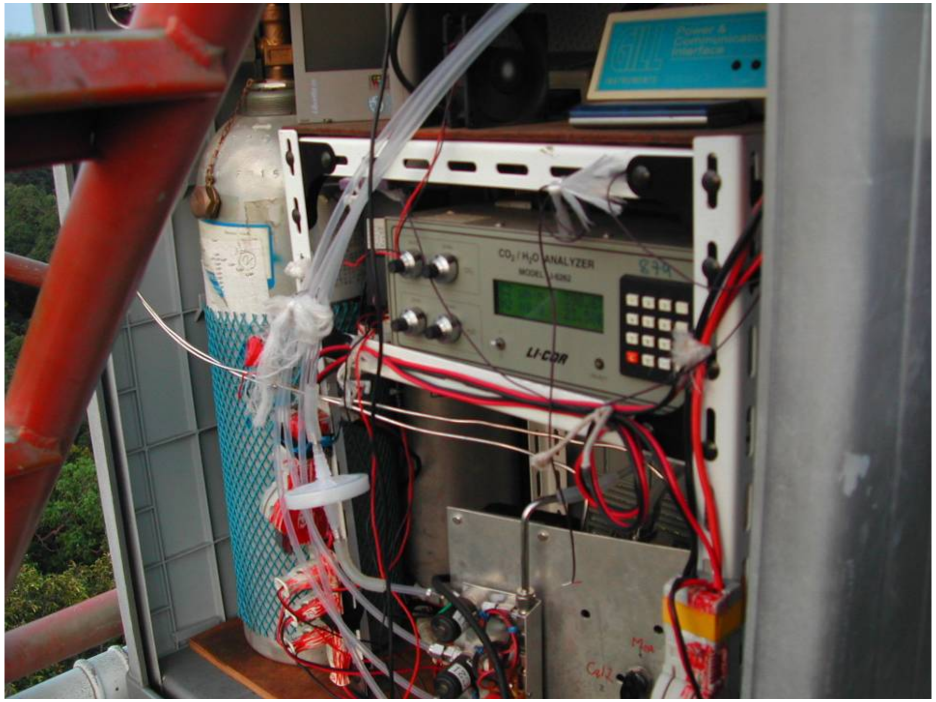
- Collaboration among researchers
- Information exchanges
- Organizing scientific meeting and workshop on flux studies
- Organizing training courses on important scientific techniques
- Seeking research funds.



Flux observation site at Sakaerat

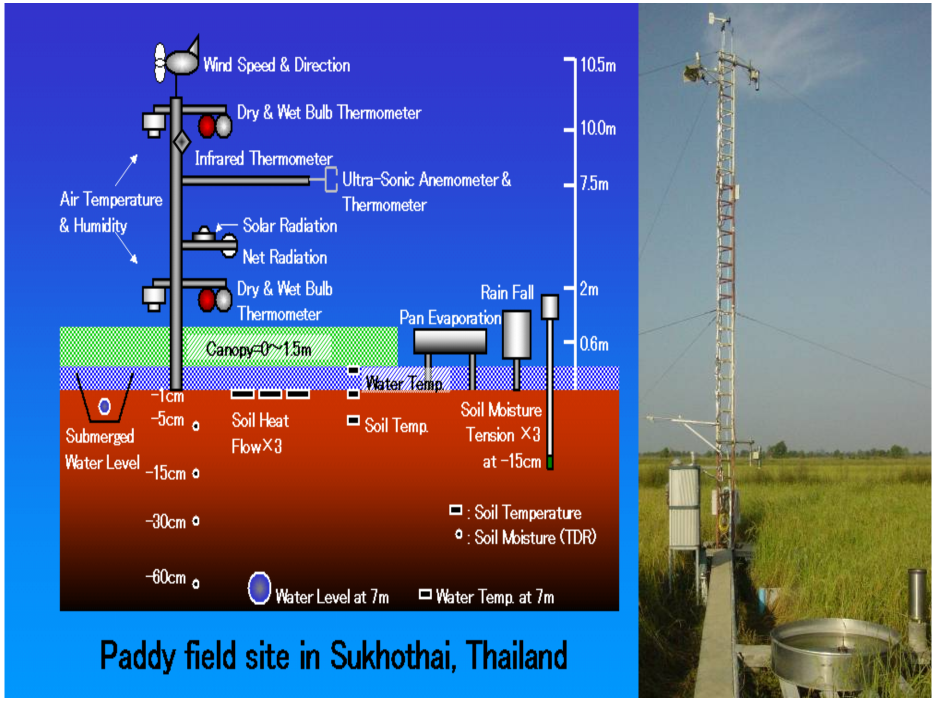
Flux observation site at Maeklong



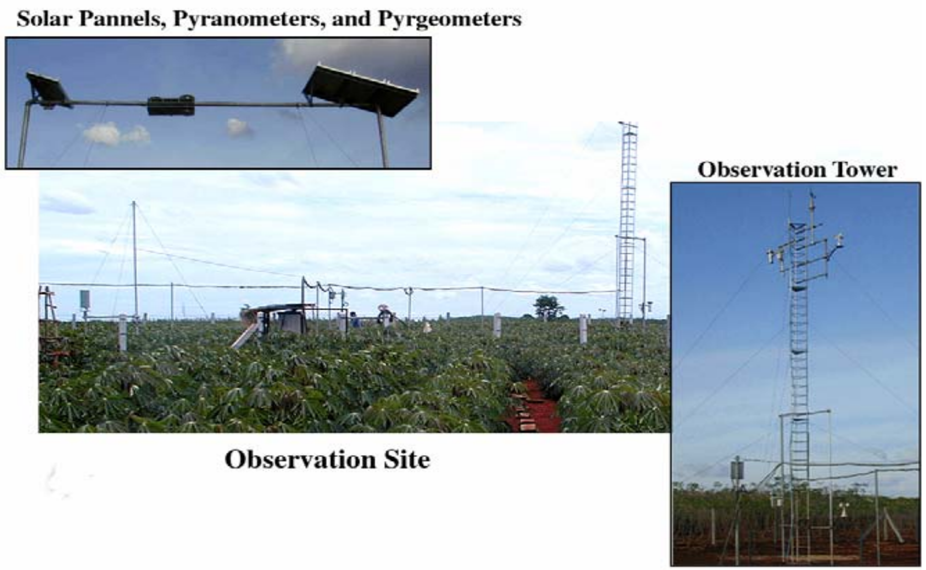


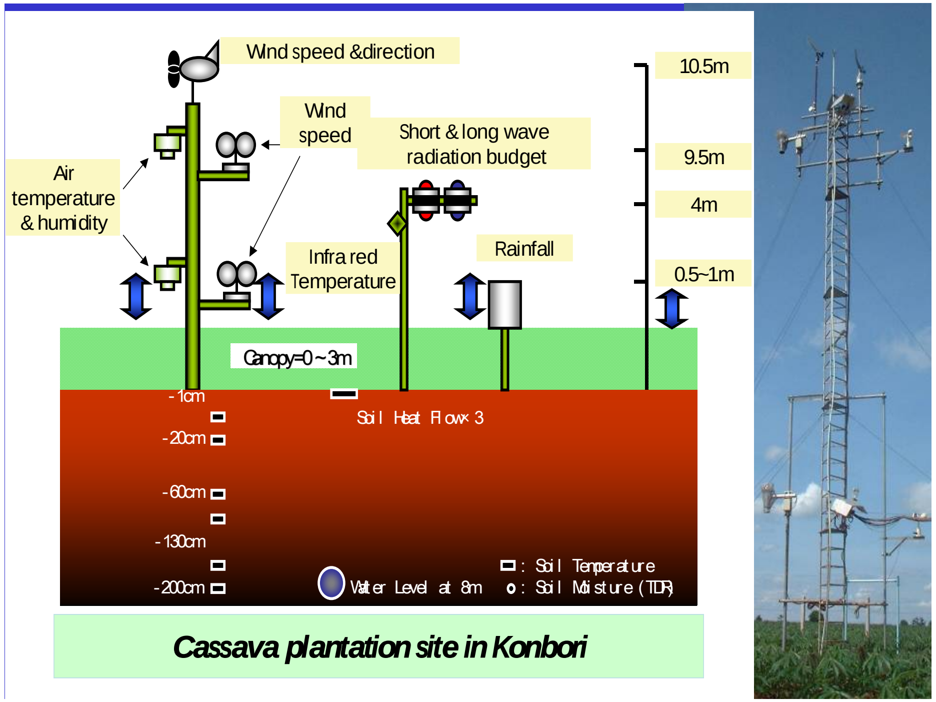
- **Solar radiation :** Pyranometer (EKO, ML020VM), Height:45 m, Pyranometer (Kipp & Zonen,CNR1), Height:45 m
- **Reflected solar radiation :** Pyranometer (EKO), Height:45 m, Pyranometer (Kipp & Zonen, CNR1), Height:45 m
- **PAR :** Quantum sensor (EKO, ML020P), Height:45 m, 15 cm (forest floor)
- **Downward long-wave radiation :** Pyrgeometer (Kipp & Zonen, CNR1), Height:45 m
- **Upward long-wave radiation :** Pyrgeometer (Kipp & Zonen, CNR1), Height:45 m
- **Air temperature :** Pt resistance thermometer (Vaisala, HMP45A), Height: 45, 30m
- **Soil temperature :** Pt resistance thermometer, Depth:1.0, 5.0, 10, 20, 50 cm
- **Humidity :** Humicap hygrometer (Vaisala HMP45A), Height:40, 35,20,5 m
- **Surface temperature :** Infrared radiative thermometer (Horiba, IT340), Height:40 m
- **Soil heat flux :** Heat sensor (EKO, MF-81), Depth:2.0 cm
- **Wind speed :** Cap anemometer (Yokokawa A702), Height:47 m, Sonic anemometer (Kaijo SAT540), Height: 45 m
- **Wind direction :** Wind vane (Yokokawa A802), Height:47 m, Sonic anemometer (Kaijo SAT 540), Height:45 m
- **Soil moisture :** Water content reflectometer (Campbell, CS615), Depth: 10, 50 cm
- **Precipitation :** Tipping-bucket rain gauge(Yokokawa B-011), Height: 47 m

Flux observation site at Sukhothai



Observation site at Nakon ratchasima





Flux
at Chachoengsao

Canopy light distribution

- LAI
  - Fisheye photograph
  - LAI-2000 canopy analyzer
- PPF
  - Line quantum sensor

Thank You

➔NIES GHG Inventory Team--Japan

➔Joint Graduate School of Energy & Environment (JGSEE), King Mongkut's Univ. of Technology Thonburi---Thailand

➔APN—Financial supports

Training Workshop on Greenhouse Gases and Aerosol Emissions under Different Vegetation Land Use in the Mekong River Basin Sub-Region"

1-3 May 2007, Bangkok< Thailand

Greenhouse Gases Inventory and Future Development in Cambodia

Prepared by Mr. CHEA Chan Thou, Ministry of Environment Cambodia

History of GHGs Inventory in Cambodia (1)

- The Cambodian Ministry of Environment (MoE) is the National Focal Point for the UNFCCC and the Kyoto Protocol
- Cambodia ratified the UNFCCC on 18 December 1995. It entered into force on 17 March 1996
- Cambodia acceded to the Kyoto Protocol on 04 July 2002

History of GHGs Inventory in Cambodia (2)

- 1999-2001: started the first climate change project to help prepare the Initial National Communication which was submitted to the 8th Conference of the Parties (CoP) in 2002.
- The document presents the results of the national GHG inventory for year 1994, GHG mitigation options and an assessment of vulnerability and adaptation to climate change.

History of GHGs Inventory in Cambodia (3)

- The phase II project (2002-2003), has conducted for improving activity data and emission factor in the forestry sector in Cambodia with main objectives to develop database on emission factors, to improve activity data and develop local emission factors and to conduct uncertainty analysis for the GHG inventory.
- In 2005, the APN funded project under CAPaBLE program has been conducted in Cambodia with the main objective to improve the estimation of GHG emission and removal from LULUCF. The result of this study will contribute to the preparation of the Cambodia's Second National Communication.

Methodology (1)

- Cambodian National GHG inventory was developed using the base year of 1994 and revised IPCC 1996 and covered 5 sectors:(i) Energy, (ii) Industry, (iii) Agriculture, (iv) Waste, and (v) Land Use Change and Forestry.

- It is mandatory to cover 3 main GHGs: carbon dioxide (CO2),methane (CH4), and nitrous oxide (N2O), but the other gases such as carbon monoxide (CO), sulphur dioxide (SO2), nitrogen oxides (NOx), and nonmethane volatile organic compound (NMVOC) are also considered wherever data are available.

Methodology (2)

- The basic calculating emissions is based on the equation:

  Emission = Activity Data x Emission Factor
- In case if activity data were not available we used several assumptions based on studied and interviewed
- Local emission factors were also not available we used the IPCC default values or emission factors developed by regional countries such as Thailand, Philippines or Indonesia.

Methodology (3)

- Each GHG has different contributions to the total greenhouse effect, which can be expressed as global warming potential (GWP)
- GWP is expressed in tonnes (or units) of CO2 equivalent (CO2-eqv.) emissions per tonne (or unit) of GHG emissions
- CH4 has 21 tonnes of CO2-eqv. andN_2O has 310 tonnes of CO2-eqv. emitted.

Result of 1994 GHG inventory (1)

- In 1994, Cambodia emitted some 59,708 Gg and removed some **64,850 Gg** of CO2-eqv. Thus Cambodia was a net carbon sink country with a net total carbon removal of 5,142 Gg of CO2-eqv.
- Land use change and forestry accounted for most of the emissions and removals of greenhouse gases in 1994.
- LULUCF represented 81.2% of greenhouse gases emissions, followed by agriculture with 15.5% and energy with 2.8%.

Result of 1994 GHG inventory (2)

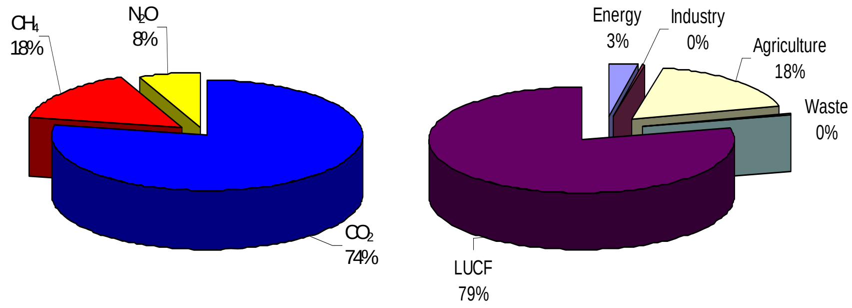
1994 GHG Emissions and Removals by Sectors ('000 ton)

Source/Sink	1994*	
Emissions		
Energy	1,881	(2.8%)
Industrial Processes	50	
Agriculture	10,560	(15.5%)
Waste	273	(0.4%)
Land use change and forestry	55,216	(81.2%)
Total Emissions	**67,980**	**(100%)**
Removal by land use change and forestry	-73,122	
Net Emissions	**-5,142**	

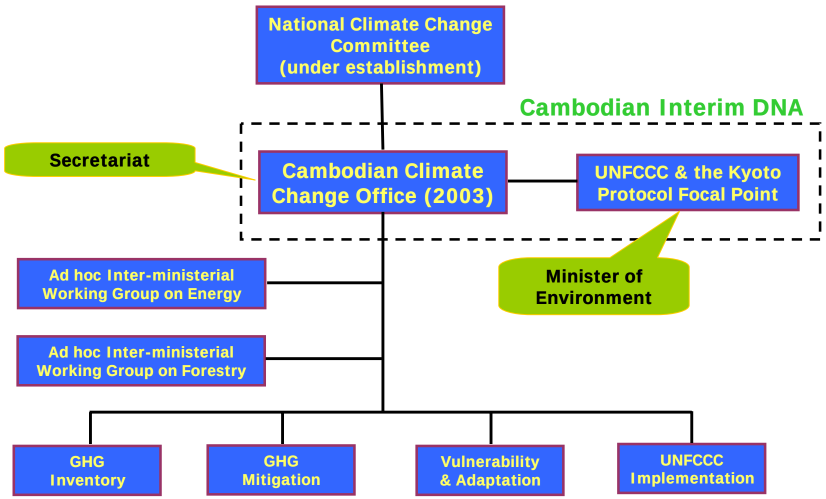
Result of 1994 GHG inventory (3)

a. 1994 Percentage Share of the Three Main GHGs

b. Total CO_2 Equivalent Emissions by Sectors



Climate Change Institutional Framework in Cambodia



Problems and constraints (1)

- The main problem for Cambodia for establishing its National GHG inventory are data availability and lack of local emission factors.
- Some non-available activity data were derived using assumptions.
- some uncertainties still exist due to the current weak data management in most line ministries.
- Most of emission factors used in the study was IPCC default values and some emission factors developed by neighboring countries such as Thailand, Philippines and Indonesia.

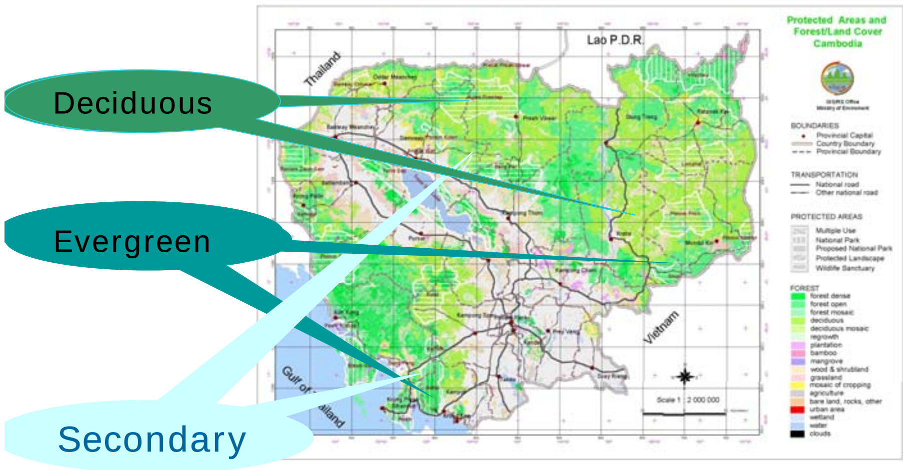
Problems and constraints (2)

- Limited financial resources: funding for climate change activities depends on donors and their priorities
- Lack of climate change research/training institutions in the country;
- Relatively low technical capacity of local staff;
- Limited incentives for qualified government staff;
- Inter-agency cooperation and coordination issue;
- Lack of qualified national experts in the country;
- Non-comprehensive national climate change policies/strategy.

The Estimation of Biomass Growth Rate under the APN-CAPaBLE Project (1)

- The field survey focused on the main forest types which play an important role as the key source/sink categories:
  - Evergreen forest;
  - Deciduous forest; and
  - Secondary forest;
- Two different locations of field measurements were conducted for each forest type;
- The objectives of field surveys are to: (i) identify type, species and number of trees in three selected forest types; (ii) estimate the aboveground biomass of tress in these selected forest types; and (iii) estimate the annual biomass increment of the selected forest types.

Location of Studied



The Estimation of Biomass Growth Rate under the APN-CAPaBLE Project (3)

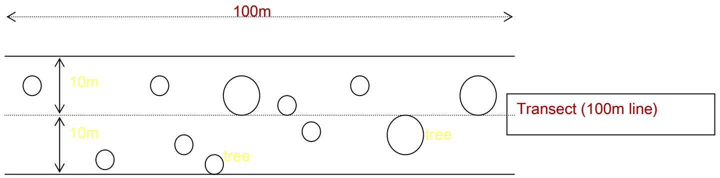
- The methodology for field survey followed by *Hairiah K. et al. (2001): Methods for sampling carbon stocks above and below ground* and the final report of the Cambodia Climate Change Enabling Activity Project's Phase 2 (2003).
- The measurement consists of two parts:

  (i) non-destructive sampling for the trees, including diameter and height of living tress and necromass;

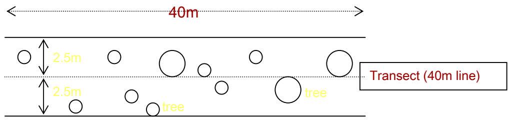
  (ii) destructive sampling for the understorey, necromass, and living tree biomass.

The Estimation of Biomass Growth Rate under the APN-CAPaBLE Project (4)

- Sampling protocol for living tree biomass and tree necromass (Diameter >30 cm): Sample area: 20m x 100 m = 2000 m^2;

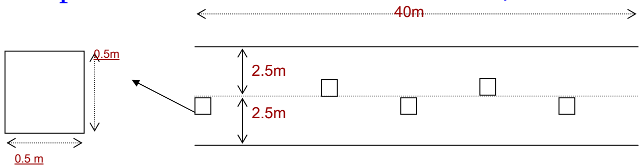


- Sampling protocol for living tree biomass and tree necromass (Diameter from 5-30 cm): Sample area: 5m x 40 m = 200 m^2 within in the sample size Diameter >30cm



The Estimation of Biomass Growth Rate under the APN-CAPaBLE Project (5)

- Sampling protocol for destructive sampling in 1 m^2: Sample area: 5m x 40 m = 200 m^2;



- *Living tree biomass:* set up randomly a sampling frame of 0.5m x 0.5m in each quadrate with trees less than 5 cm DBH, i.e. seedling or saplings, are harvested within the 1m x 1m quadrate;
- *Coarse litter:* crop residues, all unburned leaves and branches;
- *Fine litter:* dark litter, including all woody roots which partly decomposed;
- *Sun dry:* living tree biomass, coarse litter and fine litter are dried using sun-light.

Future Development

- Climate change education and awareness raising;
- Climate change national institutional strengthening;
- CCCO managerial and technical capacity strengthening;
- UNFCCC and the Kyoto Protocol implementation;
- Prepare the Second National Communication including:
  - Greenhouse gas (GHG) inventory development for 2000;
  - Vulnerability and adaptation assessment;
  - GHG mitigation analysis;
  - Technology transfer; research and systematic observation; capacity building; education, training & public awareness.
- Improve international cooperation and networking.

Training Workshop on GHG emission inventories
Bangkok, 1-3 May 2007

ACTIVITIES ON GHG EMISSION INVENTORY IN VIETNAM

Mr. Nguyen Mong Cuong
Research Center for Climate Change and Sustainable Development

Contents

1. Introduction

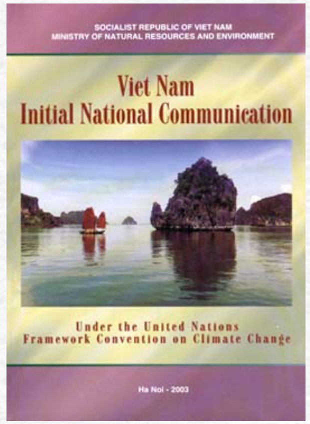
- Viet Nam (8º27-23º23 N and 102º08-109º30 E) with the land area of 330,990 km2 located in Southeast Asia, It's stretching 1,650 km from north to south consists of 3,260 km of coastline and about 3,000 small islands.
- Three quarters of the land is mountainous and hills with the elevation mostly from 100 to 1000m.
- The population of Viet Nam was 77,6 million (2000) with average annual growth rate of 1.36%
- It is predominantly an agricultural country with 74% of its population are involved in agriculture.

1. Introduction (Cont.)

- The forest areas are 9.3 million ha, forest coverage increases from 27% in 1991 to 33.2% in 2000.
- The agricultural lands are 7.4 million ha
- The average annual GDP growth rate was 7.5% during 1990-2004. GDP per capita (2004) 560 USD
- Sectoral contribution to GDP (2000):
  - Industry: 36.7%
  - Services: 38.7%
  - Agriculture, Forestry, Fishing: 24.5%
- Viet Nam ratified UNFCCC on 16 November 1994 and Kyoto Protocol on 25 September 2002.

Institutional arrangements for preparing National Communications included GHG emission inventory

2. Activities on GHG emission inventory



- Completed National GHG Inventories for 1990, 1993, 1994 and 1998.
- National GHG Inventories focused on CO_2, CH_4 and N_2O in:
  - Energy
  - Industrial Processes
  - Agriculture
  - Land Use and Land Use Change and Forestry (LULUCF)
  - Waste

2. Activities on GHG emission inventory (Cont.)

- The Methodology of GHG emission inventory followed the guidance of the IPCC revised version 1996
- Data: The data mainly is collected from General Statistics Office, some of data come from Ministry offices, some data and information come from researches and studies of related science and technology institutes.

2. Activities on GHG emission inventory (Cont.)

2.1. 1994 National GHG Inventory

a. Energy sector

- GHG emissions from fuel combustion:
  - ✓ In 1994, Viet Nam produced 6.2 million tons of coal, 7.1 million tons of oil. All crude oil is exported.Coal is partly exported, partly goes to meet domestic needs. Firewood remains an important fuel source in the Viet Nam energy structure. It occupies 56% total domestic fuel consumption.
  - ✓ GHG emissions by fuel combustion in 1994 were estimated at 21.580 million tons of $C0_2$; 120.509 thousand tons of CH_4 and 1.756 thousand tons of N_20.
  - ✓ $C0_2$ is mainly emitted by coal and oil combustion, meanwhile CH_4 and N_20 from biomass burning.

  The total GHG emissions by fuel combustion are 24.655 million tons of $C0_2$ equivalent

2. Activities on GHG emission inventory (Cont.)

- **GHG fugitive emission:**

  GHG fugitive emission is mainly generated by coal, oil and gas exploitation and transportation.

  - ✓ CH_4 fugitive emission from coal exploitation in 1994 was 39.749 thousand tons.
  - ✓ CH_4 fugitive emission from oil and gas exploitation in 1994 was 7.015 thousand tons.

  The total CH_4 fugitive emission from coal, oil and gas exploitation in 1994 was 46.764 thousand tons.

- **GHG emission from energy sector activities :**

  The total emission from energy sector activities (electricity generation, industry and construction, transport, services/commerce, household, agriculture, forestry and fishery…) was 25.637 million tons of CO_2 equivalent

2. Activities on GHG emission inventory (Cont.)

b. **Industrial processes**:

- Industrial processes and industrial products were manufactured or used in Viet Nam in 1994 relating to the emissions of CO_2, CH_4, NO_x, NMVOC, CO and SO_2
- The total CO_2 emission from industrial processes was 3.807 million tons, mainly from construction material manufacturing: cement production occupied 2.677 million tons; lime baking 651 thousand tons and steel rolling 475 thousand tons.

2. Activities on GHG emission inventory (Cont.)

c. **Land use and land use change and forestry (LULUCF):**

- Estimation of CO_2 emission and sequestration in this sector was focused on the following activities:
  - ✓ Change in forest area and woody biomass stocks in natural and planning forests.
  - ✓ Forestry and grassland conversion, forest exploitation.
  - ✓ Forest natural renovation in abandoned farmland.
- Estimation of GHG emissions / up takes:
  - ✓ CO_2 sequestration by forest biomass growth: in 1994, Viet Nam had 8.252 million ha of natural forest, 1.049 million ha of planning forest and 9.778 million ha classified as forestland without forest. The total planning trees in 1994 are 350 million. CO_2 being sequestered by forest is 39.272 million tons.

2. Activities on GHG emission inventory (Cont.)

- CO_2 emission from forest and grassland conversion: in 1994, there were 338, 000 ha of land use change, in which 40,600 ha under evergreen forest.

  GHGs emissions from these activities were estimated as below:

  - CO_2 : 56.72 million tons
  - CH_4 : 0.18 million tons
  - N_2O : 0.00124 million tons
  - CO : 1. 57 million tons
  - NO_x : 0.0447 million tons

2. Activities on GHG emission inventory (Cont.)

CO_2 sequestration by natural regeneration in abandoned farmland.

The natural regeneration of forest in abandoned farmland or degraded forest for the period of about 20 years is 820,000 ha. Estimated CO_2 absorbed amount is 11.05 million tons.

- CO_2 emission in the Inventory year by soil from previous land use change and management.

  Estimated CO_2 emission amount is 8.824 million tons.

  The total GHGs emitted into the atmosphere by LULUCF sector in 1994 are 19.38 million tons of CO_2 equivalent.

2. Activities on GHG emission inventory (Cont.)

d. Agriculture:

- Livestock:

  CH_4 emission from livestock sector is 465.565 thousand tons, 336.585 thousand tons of which is from enteric fermentation and 128.980 thousand tons from manure management.

- Rice cultivation:

  The total rice cultivated area in 1994 is 6.599 million ha, more than 60% of which under constantly flooded irrigation, the rest is not constantly irrigated and mostly relies on rainfall.

  The total CH_4 emission from wetland rice field is 1559.7 thousand tons among which , 873.8 thousand tons in the North and 685.9 thousand tons in the South of Viet Nam

2. Activities on GHG emission inventory (Cont.)

- Prescribed burning of savanna:
  - ✓ The main emission source in this sub-sector is savanna prescribed burning due to slash and burn farming practices of the mountainous ethnic minorities.
  - ✓ The total emissions in this sub-sector are 15.91 thousand tons of CH_4 , 417.5 thousand tons CO, 0.20 thousand tons N_20 and 7.11 thousand tons NO_x
- Field burning of agricultural residues.

  The emissions in this sub-sector are as follows: 51.72 thousand tons CH_4 , 1086.07 thousand tons CO, 1.19 thousand tons N_2O and 43.17 thousand tons NO_x

2. Activities on GHG emission inventory (Cont.)

- Agricultural soil:

  The total emission in this sub-sector is 26.02 thousand tons N_2O, including:
  - ✓ N_2O emitted directly from soil: 16.63 thousand tons
  - ✓ N_2O emitted directly from animals: 0.004 thousand tons
  - ✓ Indirectly N_2O emission: 9.39 thousand tons
- The total GHG emissions from agricultural sector are 52.45 million tons of CO_2 equivalent

2. Activities on GHG emission inventory (Cont.)

e. Waste

- **Municipal solid waste.**
  Estimated CH_4 emission from waste is 66.298 thousand tons, mainly from big cities.
- **CH_4 emission from domestic and commercial waste water is 1.027 thousand tons**
- **CH_4 emission from industrial waste water processing is 0.79 thousand tons**
- **N_2O emission from human is 3.66 thousand tons.**

The total GHGs emissions in waste sector are 68.115 thousand tons CH_4, 3.66 thousand tons N_2O equal to 2.565 million tons of CO_2 equivalent

2. Activities on GHG emission inventory (Cont.)

- **The total GHG emissions in 1994 in Viet Nam were 103.839 million tons of CO_2 equivalent, It is 1.4 tons CO_2 equivalent per capita.**
- **GHG emissions from energy sector was 25.637 million tons of CO_2 equivalent, accounted for 24.7% of total national emissions; forestry and land use change: 19.380 million tons of CO_2 equivalent, accounted for 18.7 %; agricultural sector : 52.450 million tons of CO_2 equivalent, accounted for 50.5 %; industrial processes and waste sector : 3.807 and 2.565 million tons of CO_2 equivalent , accounted for 3.7 % and 2.4 % respectively (figure 1,2,3,4)**

Figure 1: CO_2 Emissions and Sink from Various Sub-sector in 1994

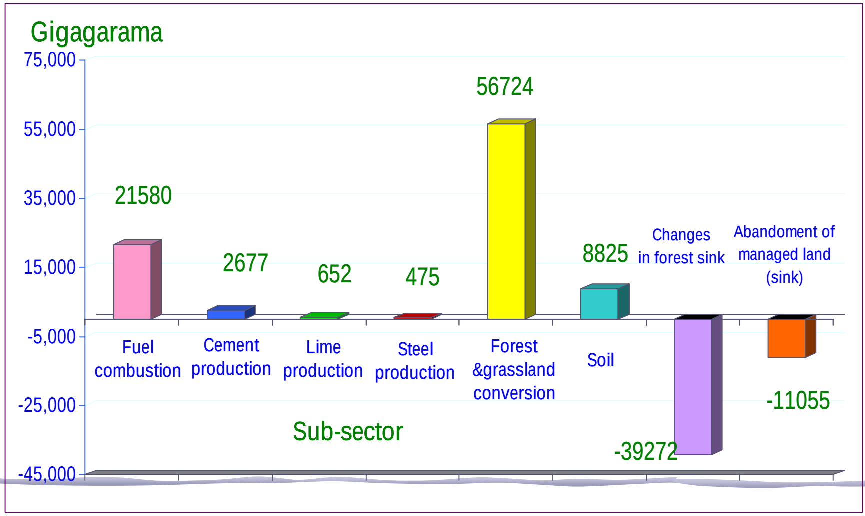
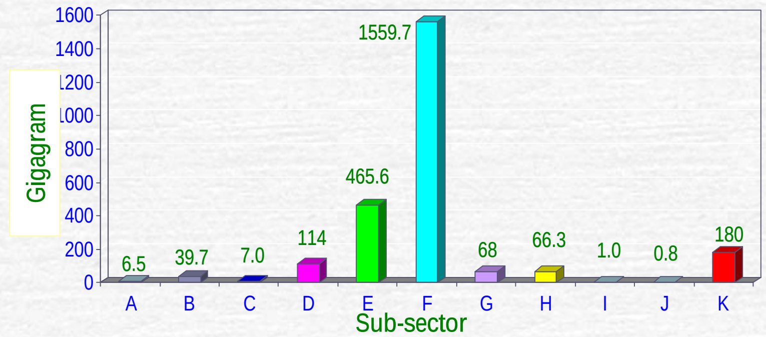


Figure 2: CH_4 Emissions from Various Sub-sector in 1994



A Fuel combustion
B Fugitive emissions from coal mining
C Fugitive emissions from oil & gas systems
D Burning of traditional biomass fuels
E Livestock enteric fermentation and manure management
J Industrial wastewater treatment
F Flooded rice fields
G Burning of agricultural residues &savannas
H Landfills
I Domestic & commercial wastewater treatment
K On-site burning of forest

Figure 3: N_2O Emissions from Various Sub-sector in 1994

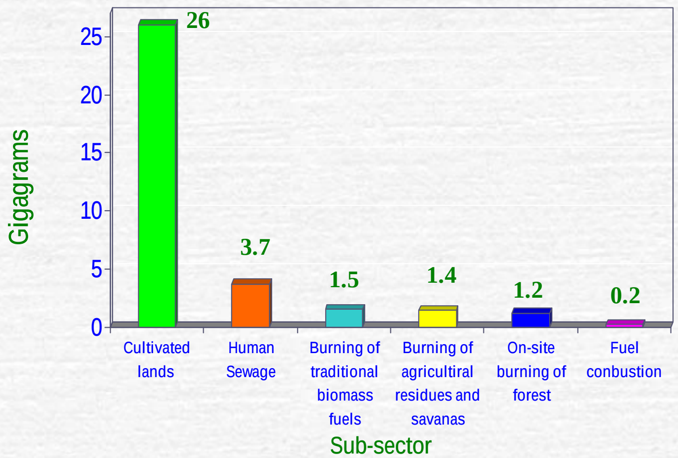
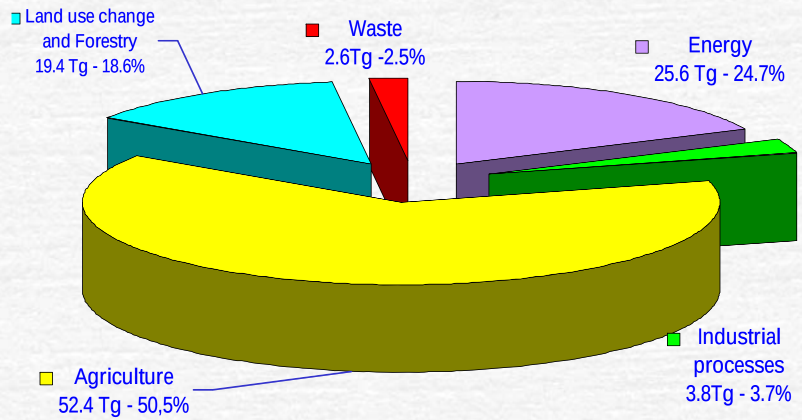


Figure 4: GHG Inventory Results in 1994



National GHG Inventory in 1994

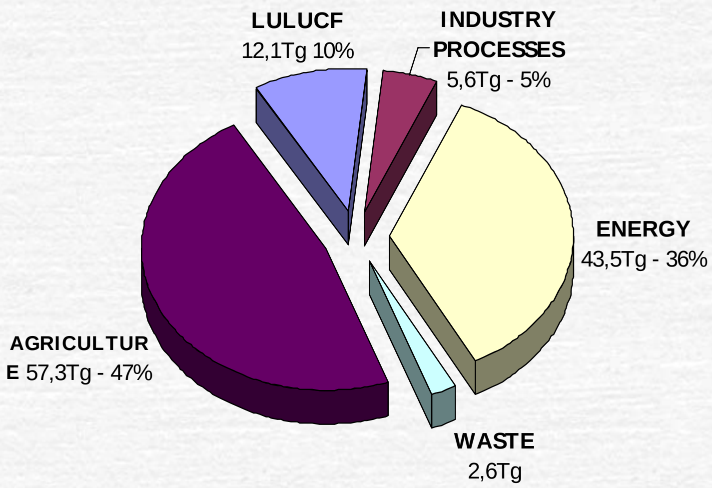
Sector	CO_2 *Equivalent (Tg)*	%
Energy	25.6	24.7
Industrial Processes	3.8	3.7
Agriculture	52.4	50.5
Land Use Change and Forestry	19.4	18.6
Waste	2.6	2.5
Total	103.8	100

2.2. 1998 National GHG emission inventory

Funding by MONRE through climate change annual operation financial sources.

- **The IPCC 1996 revised guidelines for GHG inventories was used**
- **Based on 1998 GHG data, the largest emission source was agriculture with 57.3 Tg CO2 equiv., representing 47% of the total emission, this was followed by the energy sector with 43.5 Tg CO2 equiv. Or 36% of the total emission; LULUCF, with 12,1 Tg CO2 equiv. Or 10% of the total; Industrial process, with 5.6Tg CO2 equiv.**
- **Total emission in 1998 (121 Tg CO2 equivalent) was 17 % higher than that in 1994 in which the emission from the energy sector had increased by 1.7 times.**

Figure 5: GHG Inventory Results in 1998



National GHG Inventory in 1998

Sector	*CO_2 Equivalent (Tg)*	%
Energy	43.5	36
Industrial Processes	5.6	5
Agriculture	57.3	47
Land Use Change and Forestry	12.1	10
Waste	2.6	2
Total	121.1	100

2.3 GHG emission projection to 2020

For GHG emission projection to 2020, the major emission sectors: energy, agriculture and LULUCF were estimated.

- **GHG emissions in the period of 2000-2020 will be increased mainly causing by the fossil fuel consumption to meet energy demand in the country. Thus, in the future, energy sector will be a main GHG emission source in Viet Nam**
- **Emissions from the energy sector are projected to 105 million tons of CO_2 equivalent (2010) and 197 million tons of CO_2 equivalent (2020)**
- **GHG emissions in agriculture sector will be 58.2 million tons CO_2 equivalent in 2010 and 64.7 million tons in 2020**

2.3 GHG emission projection to 2020 (Cont.)

- **In Land use and land use change and forestry sector, the amount of CO_2 is projected to decline from 19.4 million tons in 1994 to 4.2 million tons in 2000 and the net sequestration of 21.7 million tons in 2010 and 28.4 million tons in 2020**
- **In conclusion, total GHGs emissions from the three main sectors in Viet Nam were projected at more than 140 million tons and 233 million tons of CO_2 equivalent in 2010 and 2020 respectively (figure 6).**

Figure 6: GHG Emission Projection in Vietnam

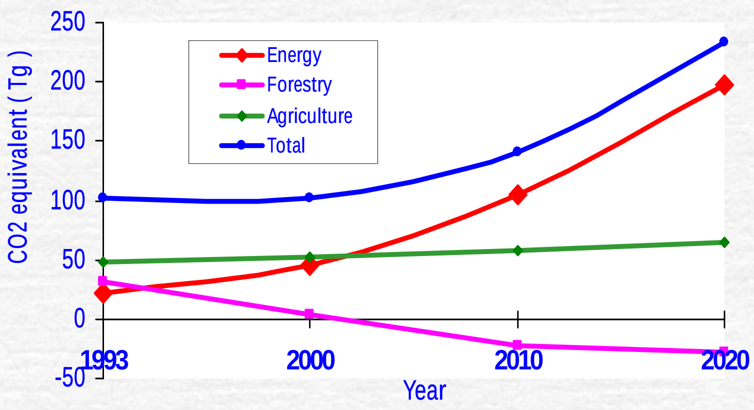
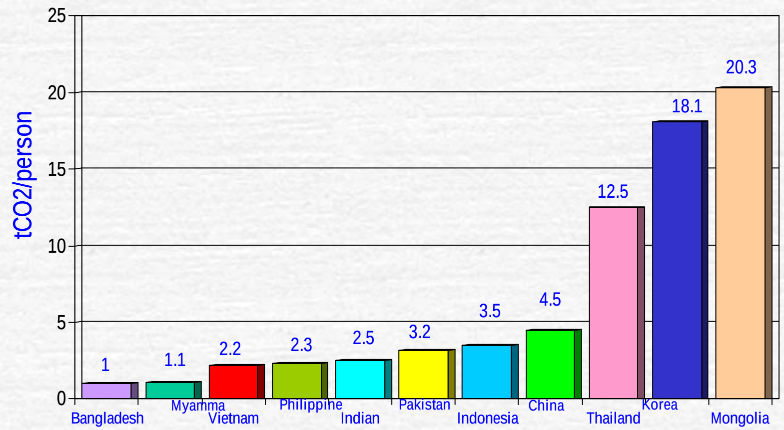


Figure 7: GHGs Emissions Rate in selected Asian Countries (2020)



Source: ALGAS Project, 1999

3. Major gaps on GHG inventory

- **CO_2, CH_4 and N_2O, NOx, CO, NMVOC and SO_2 data in the 5 source categories need to be updated and extended based on the COP8 Guidelines and to be stored in the existing GHG database;**
- **Inventory was not extensive and comprehensive due to the lack of data or poor data quality in certain source categories (e.g., not all industries and industrial processes were considered; data quality in agriculture and forestry sectors are not as good as those in fuel combustion sector);**

3. Major gaps on GHG inventory (Cont.)

- **The role of savannas and abandonment lands in CO_2 uptake needs to be studied;**
- **Activity data for solvent and other product use sector have not been collected and hence emission from this sector was not estimated;**
- **Lack of country-specific emission factors (e.g., coal, gas, and mining, soils, etc);**
- **Uncertainties for sources and sinks were not estimated;**
- **Capacity-building in IPCC methodologies for GHG inventory is still very much needed.**

4. Proposed activities in the National GHG Inventory in Viet Nam

- With the financial and technical support from UNEP/GEF, Viet Nam have been implementing project for the preparation of SNC to UNFCCC
- A national inventory for CO_2, CH_4, N_2O, CO, NOx, NMVOC and SO_2 will be undertaken for the year 2000 in 5 source categories: energy, industrial processes, agriculture, land-use and land use change and forestry and waste

4. Proposed activities in the National GHG Inventory in Viet Nam (Cont.)

- Appropriate national or regional emission/sink factors will be used to estimate GHG emissions/sinks where available;
- The database for CO_2, CH_4, N_2O, NOx, CO, NMVOC and SO_2 will be updated and improved. New inventory data for HFCs, PFCs, SF_6 (where available) for the year 2000 will be established and used as a basis for assessment and selection of mitigation options;
- The COP8 Guidelines will be used for reporting the National GHG Inventory;

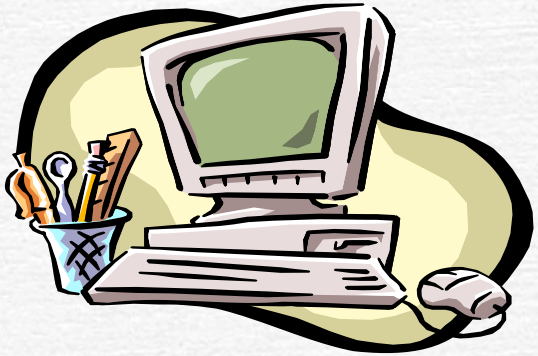
4. Proposed activities in the National GHG Inventory in Viet Nam (Cont.)

- New emission factors for specific activities will be applied;
- All concerned data will be collected, analysed and managed;
- The GHG inventory team based on the INC project will be reconstituted;
- A long-term programme on the improvement of future GHG inventories will be developed.

Conclusions

- A National GHG Inventory in Viet Nam for the year 2000 is an important component of Viet Nam SNC to UNFCCC, as it forms the basis for mitigation measures
- A reliable and accurate GHG inventory would also be very useful for the formulation of any projects
- Viet Nam hope to receive the technical and financial assistance from other International organizations and countries in carrying out a National GHG Inventories for the future and for the year 2000.

Thank you for your attention !



The Status of GHG Inventories Preparation in Myanmar.

Presented by

Ne Winn
National Commission for Environmental Affairs (NCEA)
1-5-2007

The status of Myanmar to prepare GHG inventories-

- The Government of Myanmar signed the United Nations Framework Convention on Climate Change (UNFCCC) on 11 June 1992 and ratified the convention on 25 November 1994.
- Also a party to several international and regional conventions and agreements relating to the environment, namely.
  - (i) Vienna Convention for the Protection of the Ozone Layer, 1985.
  - (ii) Montreal Protocol on Substances that Deplete the Ozone Layer, 1987.
  - (iii) London Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer, 1990.
  - (iv) United Nations Framework Convention on Climate Change 1992, and
  - (v) United Nations Convention to Conbat Desertification in those Countries Experiencing Serious Drought and lor Desertification, Particulary in Afria, Paris, 1994.

The ALGAS Project

- "Asia Least-cost Greenhouse Gas Abatement Strategy".
- a study by 12 Asian countries of national emissions of greenhouse gases (GHGs) in 1990.
- The Projections of GHGs emissions to 2020
- an analysis of GHGs abatement options in different economic sectors.
- also includes the formulation of national GHGs abatement strategies consistent with national development priorities.

- executed by ADB during 1995-1998 with funding of about $9.5 million from the GEF through the UNDP.
- Apart from Myanmar, the countries involved in the study are Bangladesh, People's Republic of China, India, Indonesia, Republic of Korea, Mongolia, Pakistan, Philippines, Thailand, Viet Nam and Democratic People's Republic of Korea (DPRK).

NTE undertook the country study

- with the active involvement of Governments through a designated national counterpart agency (NCA).
- drawn from different institutions of the country
- assisted in their tasks by a team of international technical experts (ITEs).
- involved a number of regional capacity building activities including training workshop on
- GHGs inventory preparation
- analysis of GHGs mitigation options
- empirical measurements of methane from rice paddies
- analytical modeling of the energy and forestry sectors
- preparation of project pre-feasibility report.

The outcomes of the ALGAS

- An assessment of energy, forestry and land-use change and agriculture sectors.
- formulation of a national least-cost GHGs abatement strategy
- a portfolio of least-cost GHGs abatement projects.
- a national GHGs action plan
- recommendations and future actions.

Situation on preparation of National Communication under UNFCCC

- has yet to submit Myanmar Initial National Communication.
- undertaking the Project on Preparation of Initial National Communication under the UNFCCC.

Linkages with past and ongoing climate change activities

- very limited activities on climate change
- based on the ALGAS project
- regularly participated in subsidiary Bodies meetings and the conference of Parties of the UNFCCC.

Project Management Team and National Study Team.

- A Project Management Team (PMT) and a National Study Team (NST) will be established under the auspices of the NCEA.
- A National Climate Change Committee (NCCC) to be chaired by the Sectary of NCEA will be established.

The NST will comprise six working groups dealing with

(i) GHG Inventory and Mitigation Options Analysis
(ii) Vulnerability and Adaptation Assessment.
(iii) Development and transfer of Environmentally Sound Technologies (ESTs)
(iv) Research and Systematic Observation
(v) Education, Training and Public Awareness.
(vi) Compilation of National Communication.

Previous activities under ALGAS.

- has undertaken a national GHG Inventory for Carbon dioxide, methane (CH4) and nitrous oxide (N_2O) for the base year 1990

Five source categories

- Energy [i.e, fuel combustion, energy industries, transport, commercial institution only (residential was not considered) and others].
- Industrial Processes
- Agriculture [i.e. enteric fermentation from domestic livestock; manure management and rice cultivation (CH_4) emission only], agricultural soils (N_2O emission only, prescribed burning of savannas and field burning of agricultural residues (CH_4 and N_2O emissions only)
- Land-Use change and forestry
- Waste (CH_4 emission only for solid waste disposal on land; wastewater treatment)

Gaps

The major gaps are

(i) CO2, CH4 and N2O data in the five source categories need to be updated and extended based on the COP8 Guidelines.

(ii) Lack of data or reliable data in certain source categories (e.g. methane emission from agricultural soils).

(iii) Lack of country - specific emission factors.

(iv) Uncertainties for sources and sinks were not estimated.

(v) Capacity-building in IPCC methodologies for GHG Inventory is still very much needed.

Proposed activities

- Carbon dioxide (CO_2), methane (CH4) and nitrous oxide (N_2O)
- Carbon monoxide (CO), nitrogen oxides (NOX) and non-methane volatile organic compounds (NMVOC), as well as sulphur dioxide (SO_2) will be undertaken for the year 2000.
- Five source categories.
- Energy (i.e. fuel combustion, energy industries; transport; commercial, residential; solid fuels).
- Industrial Processes.
- Agriculture (i.e. enteric fermentation from domestic livestock; manure management; rice cultivation, agricultural soils and field burning of agricultural residues).
- Land-Use Changes and Forestry.
- Waste.

Programmes containing measures to facilitate an Adequate Adaptation to Climate Change

- Previous activities.
- No previous studies on the vulnerability of Myanmar.
- Although eligible for funding for preparing NAPA.

Gaps

The Major gaps are-

(i) Lack of vulnerability assessment, including the integrated and quantitative vulnerability assessment.

(ii) Lack of cost-effective analysis of various adaptation options, including adaptation technologies.

(iii) Lack of national strategy and action plan for adaptation to climate change and its related disaster prevention, preparedness and management

(iv) Lack of expertise in the field of vulnerability and adaptation (V&A) assessment integrated assessment.

(v) Lack of assessment of the impacts of climate variability and extreme weather events on key socio-economic sectors.

(vi) Capacity building is urgently needed in V & A assessment, including training on relevant methodologies.

Thank You

Country Report on Greenhouse Gases & Aerosol Emissions Inventory & Future Development in Lao PDR

Soulideth Souvannalath
Environment Research Institute
Science, Technology & Environment Agency
Prime Minster's office
Vientiane, Lao PDR

I. Introduction

- The economic development in the Lao PDR is mostly relied on utilizing the natural resources
- The Government has implemented the innovative guideline in an attempt to gradually increase the ratio of highly economic growth since 1996.
- the stronger enhancement of the environmental protection and improvement policy on a number of the economic sectors to which it has been legislated for the purpose of achieving the socio-economic development

II. The Greenhouse Inventory for Lao PDR

- The assessment of the greenhouse gases based on the volume of tasks,
- The total multiplier used in this inventory was utilizing the absolute value of the IPCC
- The results, the emissions of the GHG of the various sectors as the indicated

in table:

Sectors	CO_2	CH_4	CO	N_2O	NO_x
Energy Sector					
Fossil Fuel Consumption	414.9				
Traditional biomass burned for energy		22.7 5	157. 92	0.12	4.18
Agriculture Sector					
Enteric fermentation		97.92			
Manure management		14.38			
Rice cultivation		158.97			
Forestry Sector					
Change in forest and woody biomass	-121,614.00	29.5	257.8	0.2	7.3
Forest conversion: Aboveground CO_2 released from on site burning	6,752.67				
Forest conversion: Aboveground CO2 released from off site burning	628.16				
Aboveground CO_2 released from decay	9,247.84				
Waste					
Landfills	11.2				
Waste water	0.23				
Grand Total:	**-104,570**	**312**	**258**	**0**	**7**

Source: Science Technology & Environment Agency, 2000 (STEA) * 1Gg = 109 g

III. Technology Needs and Priorities for Mitigating GHG Emission in Lao PDR.

Hydro Energy:

- **The annually average flowing water amount accounts: 8,500 cubic matres/**
- **Contribute to the Mekong River's: 35%, including rainy season is the amount of following water up to 80% and in dry season up to approximately 20% of the annually total amount of flowing water.**
- **The water utilization is mainly in the agriculture sector; for example, irrigation, fishery, cultivation, and animal husbandry.**
- **Apart from that, water is still used in the electric hydropower development that potentially possesses approximately 23,000 megawatts, within which less than 5% of the total potential gas been used.**

Forestry:

- Forest cover: 41% or 11.2 million hectares
- In Lao PDR, there are 20 national Biodiversity Conservation Areas,
- The forest resources have played the important roles in accumulating the national incomes, been the foodstuff and the additionally rural grass root people's incomes.
- Fire wood is the people's main energy.
  - About 85% have been used for household consumption.
  - The average of fire wood utilization is about 0.75 - 2.92 m3 or 0.58 - 2.26 T/ Pers / year

Minerals:

- The Lao PDR has variety of valuable mineral potentials, which those minerals have only been mined in a small scale.
- It has a large number of various types' coal deposits, which can be used, in the field of energy resources.
- Anthracite and lignite have been utilized in the manufacturing industry.
- Only a small amount of coal, which has been used as fuel energy for the people's handicraft of brick burning process.
  - Hydropower
  - The flowing river electric hydropower
  - The solar photovoltaic energy production
  - The biomass gasified electricity power

IV. Technological Options and Reduction of Greenhouse Gas Emissions in Lao PDR.

The Transportation Field

- Vehicle in the Lao PDR are composed of different types and brands with which its growth rate as rapidly increased annually; especially, motorcycles.
- The major of vehicles belong to private ownership and a large number of used vehicles imported from abroad.
- These vehicles do not only consume diesel, but also use a great deal of petrol.
- Therefore, those vehicles are considered the main cause of increasingly air pollution problems in big towns and cities nowadays.
- The scientific research and comparison of exhausted gas emission ranging from CO2, CO, NOx and other gases from a large number of different vehicles in the transportation system can be notice that, for example the usage of the mass or public transportation in big cities is the best choice.

Agriculture Field:

- **The Breeding of Masticating Animals**
- **The Wet Plantation**
- **The Use of Natural Fertilizers (Manure or Vegetable Waste matters)**

The Original Source of CH4 in Agriculture Field	The Reduction methods
Masticating Animals	Improve animal feeds through additional animal feed strategies
Wet Rice Plantation	Soil drying techniques
Use Natural Fertilizers	- Use biogas digester with a small scale cooking stove (8-16 m3) - Use biogas digester with a large scale cooking stove (>30 m3)

Forestry Field:

- The conservation areas construction
- The permanent cessation of slash - and - burn shifting cultivation method
- The forest administration management
- The forest rehabilitation
- The villagers' forest management

Toxic Waste Field:

- Waste water & polluted water from industry & handicraft
- Use of the fairly out-of-date technology, which modernized advanced countries have not allowed using any longer, and constituted less than 70%
- Caused by the use of fuel into the stream boiler such as, firewood, sawdust & wood shavings, diesel & bunker/ fuel oil, and coal
- Caused by the use of chemical substances into the process of production
- Caused by inappropriately eliminating practice of the waste material from factories themselves

V. Conclusion

- The socio-economic development must be implemented
- The utilization of advanced technology is considered which needs to be developed & resolved to suit the real situation of each field of work
- To make use of all existing technocrats' competency so as to systematically train them in the environmental field of work. Contribution for National Environmental Fund

Thanks

DAY II:

Biomass burning: Keynote and hands-on session lectures

Emission Inventory Issues: Anthropogenic, Biogenic and Biomass Burning

***C. Jerry Lin*, Ph.D., P.E.**

Department of Civil Engineering

Lamar University, Beaumont, TX

Inventories of Greenhouse Gases and Aerosol Emissions in the Mekong River Basin

May 2, 2007

Emission Inventory (EI)

… a current, comprehensive listing, by *source*, of air pollutant emissions associated with a *specific geographic area* for a *specific time interval* …

… USEPA

Why do we need EI data?

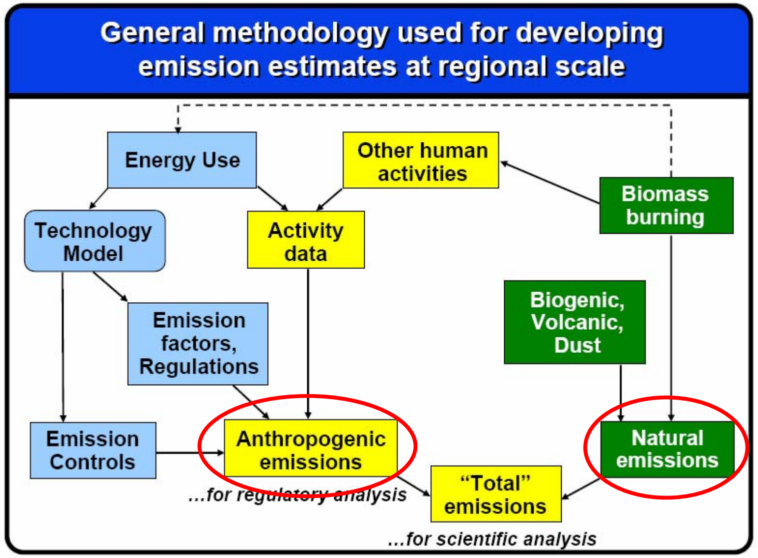
- To evaluate the existing air quality as related to air pollution problems
- To assess the effectiveness of air pollution policy
- To identify sources and general emission levels, patterns, and trends to develop control strategies
- To predict ambient pollutant concentrations through the use of atmospheric models
- To provide input for human health risk assessment studies
- To site ambient air monitors

Air Pollutants of Interest

- Greenhouse gases: CO_2, CH_4, CFC, N_2O …
- SO_2: health effects, acid rain, acid deposition, visibility …
- NOx: health effects, photochemical smog, O_3 formation, acid deposition, visibility …
- CO: health effects, O_3 formation …
- VOC: O_3 formation, secondary organic aerosol, visibility …
- Particulate matter (PM): health effects, visibility, cloud formation, climate change …
- Air toxins: mercury, lead, dioxin, toxic organics …
- NH_3: formation of secondary PM.

What needs to be done?

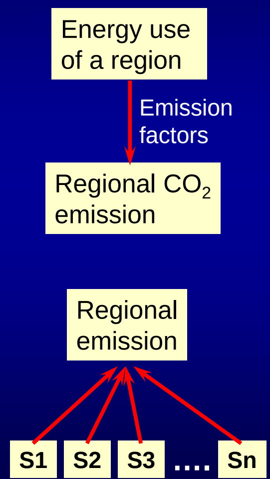
- Planning activities: plan out the procedures and identify sources
- *Inventory development*: data collection, emission estimation, measurements …
- QA/QC: ensure EI data quality
- Documentation: provide well-organized explanation of the data
- Maintenance and update: EI requires continuous updates



Slide Courtesy: David Streets

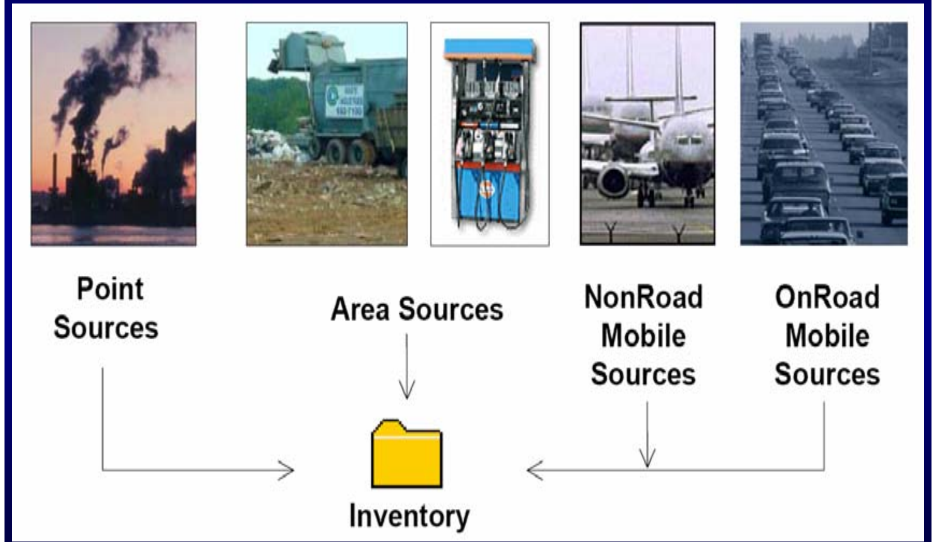
Top-down vs. Bottom-up

- Top-down estimate: EIs are developed based on data covering a large geographical area (i.e., regional or national levels)
- Bottom-up estimate: EIs are developed from the emission sum of individual sources to obtain the regional or national estimate



Anthropogenic Emission

Source Categories



Point Sources

- Source treated as an individual stationary source of emissions that release pollutants to the atmosphere.
- Emit large quantity of pollutants at higher elevation through stacks.

Examples of Point Source Emissions

- Fuel Combustion
- Waste disposal
- Food and agriculture industry
- Metallurgical industry
- Petroleum-related industries
- Mineral products industry
- Chemical process industry
- Wood products industry
- Storage tanks

Estimating Point Source Emissions

- Continuous emissions monitor (CEMs)
- Source testing (short-term measurement)
- Emission factors
- Material balance
- Fuel analysis
- Emission estimation models
- Engineering judgment (not recommended)

Estimating Point Source Emissions

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Emission Factors

$$E = R \times EF \times \frac{(100 - C)}{100}$$

Emission Quantity (E); Activity Level (R); Emission Factor (EF); Emission Control Factor (C)

USEPA AP-42 provide the emission factor estimates!
Available at *http://www.epa.gov/ttn/chief/ap42/*

Mass Balance

$$E_x = (Q_{in} - Q_{out}) \times C_x$$

Emission Quantity (E_x); Material Quantity Entering System (Q_{in}); Material Quantity Leaving System as Waste (Q_{out}); Concentration of Pollutant X (C_x)

Fuel Analysis

$$E_x = Q_f \times \frac{W_p}{W_f}$$

Emission Quantity (E_x); Fuel Use Mass (Q_f); Weight Ratio of Pollutant to Fuel ($\frac{W_p}{W_f}$)

Emission Models (EPA)

- Landfill air emissions estimation model
- TANKS: for fixed and floating-roof storage tank (for fuel, petroleum, chemicals ….)
- WATER: for wastewater collection and treatment systems
- *MOBILE:* for *on-road vehicles*
- *NONROAD:* for *non-road vehicles*

Available at *http://www.epa.gov/ttn/chief*

Area Sources

- Individual emissions do not qualify as Point Sources
- Represents numerous facilities or activities with small amounts of a given pollutant
- Do not generate emission at large quantity individually but the combined emission may be significant in the inventory area

Examples of Area Source Emissions

- Biomass burning
- Small fuel combustion units
- Cooking
- Agriculture emission
- Machinery emission
- Solvent evaporation
- Gasoline/diesel evaporation
- Construction emission
- Storage tanks
- *And Many Others!!!*

Estimating Area Source Emissions

- Emission factors (AP-42)
- Surveys
- Applying point source methods to area sources (bottom-up)
- Conducting local activity level surveys (bottom-up)
- Applying a top-down approach (e.g., allocating regional level emission estimates to the local level using spatial surrogates)

Mobile Sources

- Source is mobile and portable
- Source is generally Internal combustion powered
- Licensed for roadway use (on-road): automobiles, trucks, buses, motorcycles
- Not licensed for roadway use (non-road): planes, trains, boats, farm equipment, lawn & garden equipment, construction equipment

Estimating Mobile Source Emissions

Emission Model: Mobile 6

http://www.epa.gov/otaq/m6.htm

Calculations in Mobile 6

For on-road vehicles:

$$E = VMT \times EF \times K$$

- E: **Emission Quantity**
- VMT: **Vehicle Miles Traveled**
- EF: **Emission Factor Depending on *Speed, Roadway Type, Vehicle Type and Time Periods***
- K: **Conversion Factor**

Calculations in Mobile 6

For non-road vehicles:

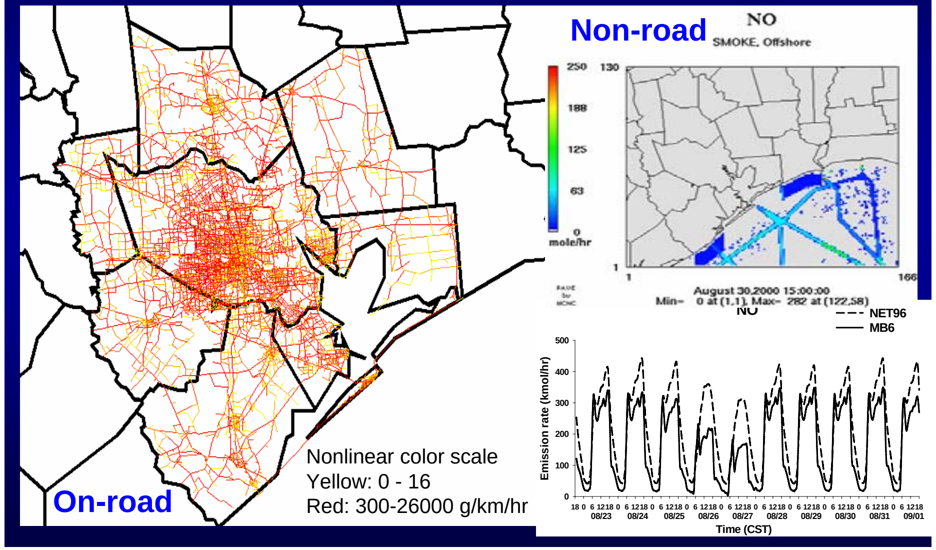
$$E = EF \times A \times L \times P \times N$$

- E: **Emission Quantity**
- EF: **Emission Factor**
- A: **Equipment Activities**
- L: **Load Factor Proportional to Rated Power**
- P: **Average Rated Power for Modeled Engines**
- N: **Equipment Population**

Important Model Inputs

- Vehicle Speed
- Ambient Temperature
- Gasoline Volatility
- Control Programs
  - – Inspection/Maintenance
  - – Reformulated gasoline
  - – Oxygenated Fuels
  - – New Vehicle Standards
- Registration Distributions

Model Output (Houston, TX)



Comments on Uncertainty

- Emission factors being out-of-date.
- Difficult to identify all emission sources
- Hard to capture emission in the event of system (or facility) upset
- Double counting of emission sources in different source categories
- Spatial surrogates based on GIS not representing the true allocations
- Fugitive emission (e.g., system leaks) may significantly contribute to emission quantity

Recommendations

- USEPA's AP-42 and the emission models are not perfect, but they are a good starting point
- Whenever possible, use measurment data to estimate emission factors
- The staff performing the emission inventory estimate needs to understand the emission process (to prevent overlook)

Biogenic Emission

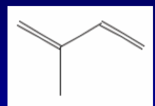
Biogenic (Natural) Emissions

- Natural emissions that are mediated through biological processes of soil and vegetation
- Represent a significant portion of the natural emissions of ozone precursors
- Estimated using Biogenic Emission Models (e.g., Biogenic Emissions Inventory System, BEIS; Global Biosphere Emission and Interactions Systen, BIoBEIS)

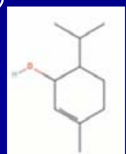
http://www.epa.gov/asmdnerl/biogen.html

What are emitted?

- Isoprene (2-methyl-1,3-butadiene)
  - Emitted from vegetation foliage, oak (mostly) but also citrus and eucalyptus. (Chinkin et al., 1996a, 1996b)



- Monoterpene (Piperitol)
  - Primarily emitted by pine, citrus, and eucalyptus.

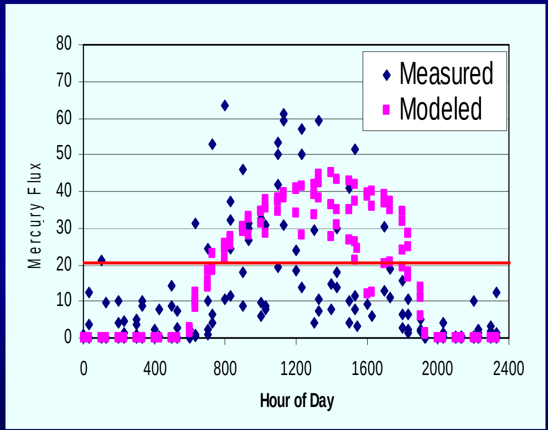


- Biogenic VOC
  - Emission of non-methane hydrocarbons (NMHC) through evapotranspiration process of vegetation
- NOx andN_2O
  - Emitted through microbial activities in soils, primarily from agricultural lands and grasslands
- CH_4
  - Emitted through anaerobic process in soils

Emission Characteristics

	Anthropogenic	Natural
Diurnal/Seasonal Variation	Depending on emission units, usually no significant variation	Strong variation due to temperature and irradiation changes
Spatial Distribution	Intense stationary source emission	Weaker, diffused emission
Vertical Distribution	Subject to plume rise	Emit to surface layer only
Emission Quantity	Relatively "well" characterized	Highly uncertain, subject to landuse changes
Emission Speciation	Complex, requires emission monitoring	Usually better understood

Temp./Irradiation Corrections



$$I = I_s C_L C_T$$

$$C_L = \frac{\alpha C_{L1} L}{\sqrt{1+\alpha^2 L^2}}$$

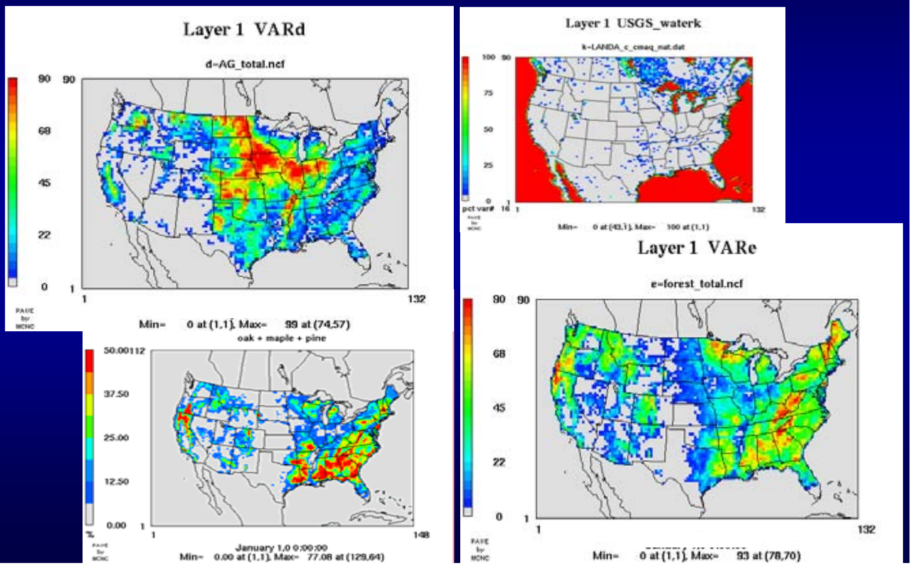
$$C_T = \frac{\exp[\frac{C_{T1}(T-T_s)}{RT_sT}]}{1+\exp[\frac{C_{T2}(T-T_m)}{RT_sT}]}$$

Guenther et al. (2005)

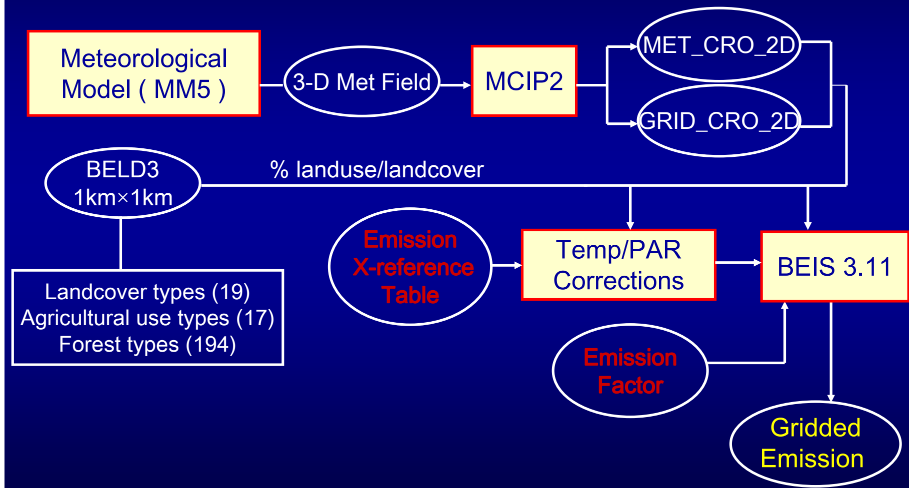
What are needed for biogenic emission estimate?

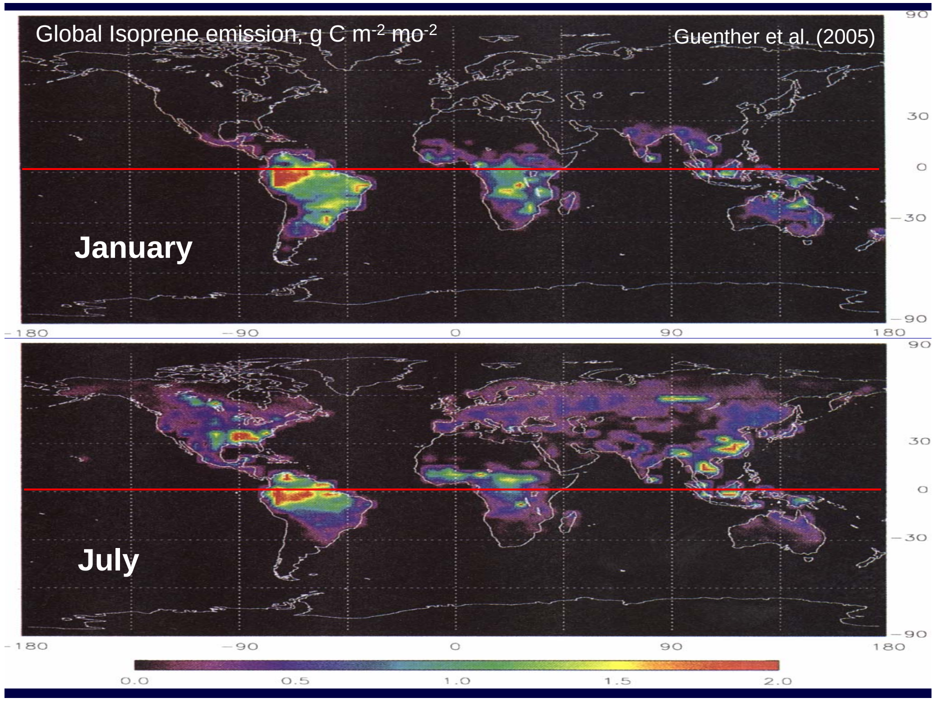
- Landuse/landcover data
- Vegetation distribution on land
- Photo-synthetically active solar radiation and temperature (usually from meteorological files)
- Measured emission factors and radiation/temperature correction factors

Example Landuse Categories



BEIS3 Data Flow

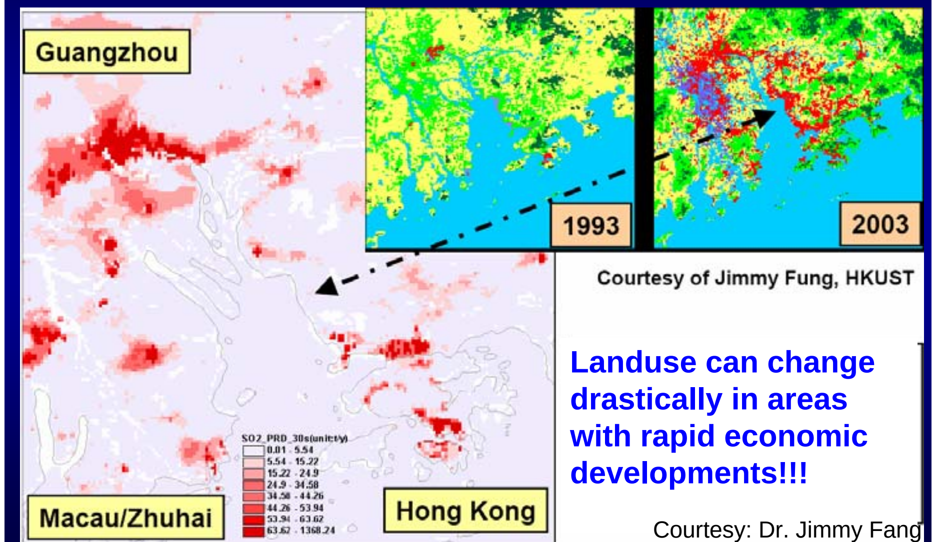




Comments on Uncertainty

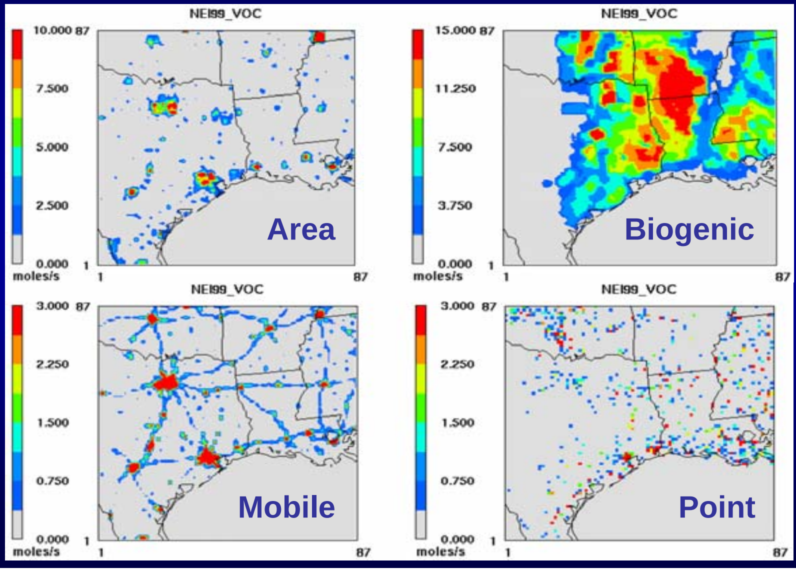
- Biogenic emission factors (I_S) for the same vegetation type are not universal
- Biogenic emission factors (I_S) reported only for a limited numbers of vegetation types
- Uncertainty in meteorological data (temperature and ground-level radiation) can significantly affect the estimate
- Certain required data for biogenic emission models are hard to find (LAI, vegetation types, distribution, and seasonal variation, etc.)
- Landuse change, especially in rapid growing region

Landuse Change (China Pearl River Delta Region)…



Spatial Distribution - Domain

Spatial Distribution of Emissions



Source Contribution in Domain

Emission Sources	Daytime Emission (%)						Nighttime Emission (%)					
	CO	NH_3	NO_x	SO_2	$PM_{2.5}$	VOC	CO	NH_3	NO_x	SO_2	$PM_{2.5}$	VOC
Mobile	43.8	2.1	10.3	0.7	0.2	2.0	61.3	4.9	32.7	2.9	0.4	5.0
Area	42.8	91.5	24.4	9.4	84.5	9.0	32.8	89.6	25.1	13.5	85.3	3.4
Point	13.4	6.4	49.6	89.9	15.3	3.5	5.9	5.5	35.9	83.6	14.3	9.8
Biogenic	0	0	15.7	0	0	85.5	0	0	6.3	0	0	81.8

Emission from Biomass Burning

Biomass Burning

- Burning of the world's living and dead vegetation for land clearing, land use change, and natural burning resulting from lightning-induced fires.
- Can be natural (e.g., forest fire) or man-made
- Majority (>90%) of biomass burning is human initiated
- Has increased significantly over the last 100 years.

Locations of Biomass Burning

- Tropical forests (Brazil, Indonesia, Colombia, Ivory Coast, Philippines, Thailand, Laos, Nigeria, Burma, Peru)
- Temperate forests (U.S., Europe)
- Boreal forests (Alaska, Canada, Siberia, China)
- Savanna grasslands (Africa)
- Agricultural wastes after the harvest (Asia, U.S., Europe)

A Global Issue!!

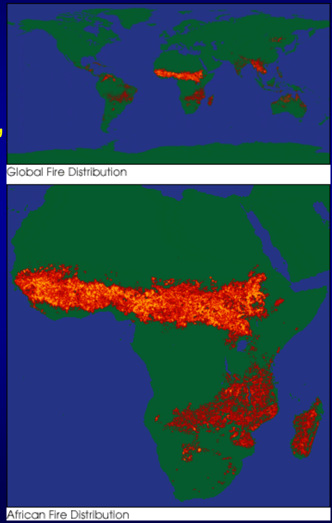
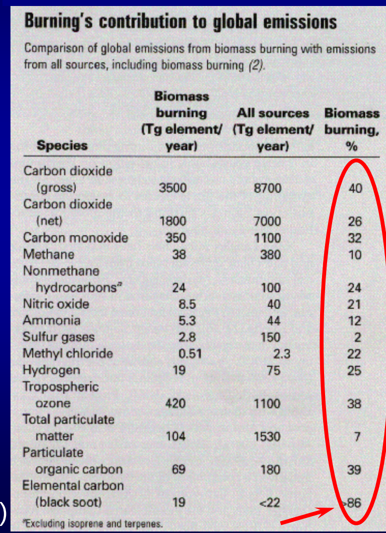


Photo Courtesy: NASA

Emissions of Biomass Burning

- Greenhouse gases (CO_2, and CH_4)
- Chemically active gases (CO, NOx, SO_2, C_2H_6, C_2H_4, C_3H_8, C_3H_6, etc.)
- Methyl bromide (CH_3Br)
- Atmospheric aerosol (black carbon, organic matter, K^+, Na^+, Ca^{2+}, Mg^{2+}, NH_4^+, H^+, Cl^-, H_2SO_4, HSO_4^-, SO_4^{2-}, NO_3^-, etc.)

(Levine et al., 1995)



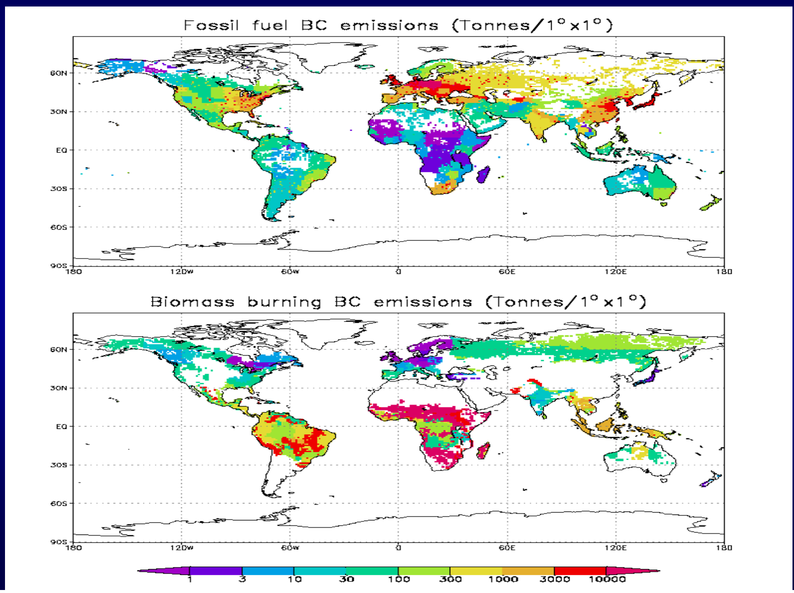
Burning's contribution to global emissions

Comparison of global emissions from biomass burning with emissions from all sources, including biomass burning *(2)*.

Species	Biomass burning (Tg element/ year)	All sources (Tg element/ year)	Biomass burning, %
Carbon dioxide (gross)	3500	8700	40
Carbon dioxide (net)	1800	7000	26
Carbon monoxide	350	1100	32
Methane	38	380	10
Nonmethane hydrocarbons[a]	24	100	24
Nitric oxide	8.5	40	21
Ammonia	5.3	44	12
Sulfur gases	2.8	150	2
Methyl chloride	0.51	2.3	22
Hydrogen	19	75	25
Tropospheric ozone	420	1100	38
Total particulate matter	104	1530	7
Particulate organic carbon	69	180	39
Elemental carbon (black soot)	19	<22	>86

[a]Excluding isoprene and terpenes.

Fossil Fuel vs. Biomass Burning



(GEIA, 2005)

Direct Impact of Biomass Burning

- Contribute to global warming
  - Production of greenhouse gases
  - Removal of CO_2 sink (vegetation)
  - Release of previously sequestered carbon within a short period of time
- Affect global radiation budget and climate through emission of particulates
- Alter the oxidizing capacity of the atmosphere and cause tropospheric ozone production through emission of reactive gases
- Contribute to stratospheric ozone depletion through emission of methyl bromide
- Create regional and trans-boundary haze problems

Other Indirect Impact

- Alter the biogeochemical cycling of nitrogen and carbon compounds from the soil to the atmosphere
- Change the hydrological cycle, i.e., run off and evaporation
- Affect the reflectivity and emissivity of the land
- Affect the stability of ecosystems and ecosystem biodiversity

Methodology of Estimating Biomass Burning Emissions

- Direct measurement of emission concentration downwind of the plume
  - Pros: direct reporting of pollutant concentration
  - Cons: no info on emission quantity per mass burned
- Emission Factor (EF) Method
  - Pros: report emission quantity per mass burned
  - Cons: high variation of estimated EFs
- Emission Rate Method
  - Pros: more consistent emission factors
  - Cons: requires more effort to obtain EFs

Better Data Quality

Biomass Burning Emission

$$Q(x) = M \times EF(x)$$

Emission Quantity of Species X (g)

Biomass Burned (kg)

Emission Factor of Species X (g/kg)

f (area burned, burning efficiency, biomass density, etc…)

f (vegetation type, burning conditions, species, etc…)

Biomass Burned (*M*)

$$M = A \times B \times \alpha \times \beta$$

Biomass Burned (kg)

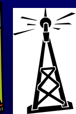
Area Burned (m^2)

Biomass Density (kg/m^2)

Fraction of Above Ground Biomass

Burning Efficiency

Seiler and Crutzen (1980)



Emission Factor (*EF*)

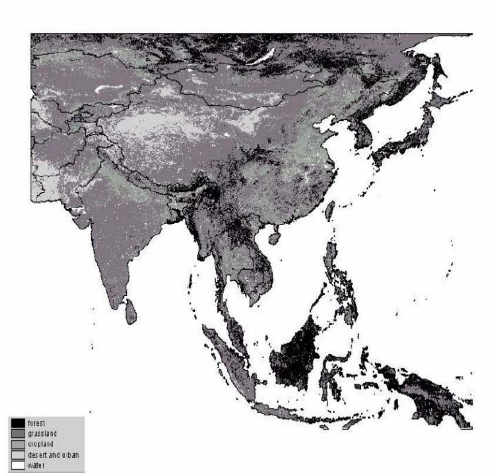
$$EF(x) = ER_{X/CO_2} \times \frac{MW_X}{MW_{CO_2}} \times EF_{CO_2}$$

Emission Factor of Species X (g/kg)	Emission Ratio, CO_2 as reference	Molecular Weight Ratio	CO_2 Emission Factor

$$ER_{X/CO_2} = \frac{X_p - X_b}{CO_{2p} - CO_{2b}}$$

p: within plume
b: the background

The Final Products …



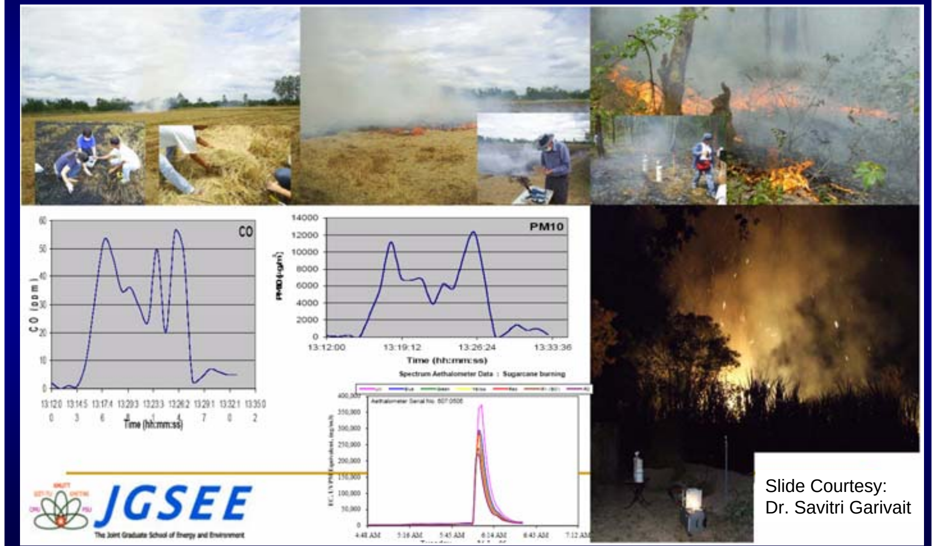
(Michel et al., 2005)

Vegetation Class	Biomass Density (g/m²)	Burning efficiency
evergreen needleleaf forest	36700	0.25
evergreen broadleaf forest	23350	0.25
deciduous needleleaf forest	18900	0.25
deciduous broadleaf forest	20000	0.25
mixed forest	22250	0.25
woodland	10000	0.35
wooded grassland	3300	0.4
closed shrubland	7200	0.5
open shrubland	1600	0.85
grassland	1250	0.95
cropland	5100	0.6

Vegetation Class	EF(BC)	EF(OC)
evergreen needleleaf forest	0.6	6
evergreen broadleaf forest	0.7	6.4
deciduous needleleaf forest	0.6	6
deciduous broadleaf forest	0.6	6
mixed forest	0.6	6
woodland	0.61	5
wooded grassland	0.62	4
closed shrubland	0.61	5
open shrubland	0.62	4
grassland	0.62	4
cropland	0.725	2.1

(g/kgdm)

Emission Uncertainty



Slide Courtesy:
Dr. Savitri Garivait

Comments on the Uncertainty

- Burning conditions (winds, RH, biomass moisture content, etc) strongly affect the emission factors.
- Difficulty in estimating burned biomass
- Laboratory measured emission factors may not be representative of field burning conditions

Repetitive, consistent measurements of biomass burning using well-defined methodology is critical !!!

Final Remarks

- Compiling emission inventory is a big job, using top-down approaches for a rough estimate is a good starting point
- Consider the emission inventory as a evolving datasets. Periodic review, update and careful documentation are necessary.
- Keeping data open to all stakeholders is important for detecting data gaps

Finding emission inventories is not a problem,…

Knowing how good they are is another matter …

… David Streets

Emission Inventory for Biomass Open Burning in the Mekong River Basin Sub-region

Savitri Garivait, *JGSEE*

International Training Workshop on
Inventories of Greenhouse Gases and Aerosol Emissions Associated to Different Vegetation Land Use in the Mekong River Basin Sub-region
May 2nd, 2007
JGSEE-KMUTT, Bangkok, Thailand

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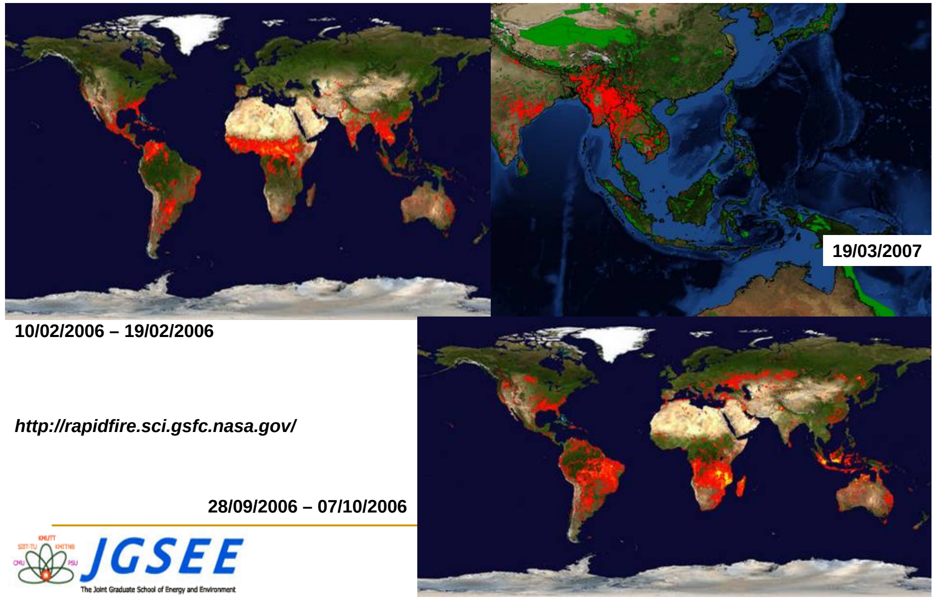
Biomass open burning – ASEAN countries



http://rapidfire.sci.gsfc.nasa.gov/

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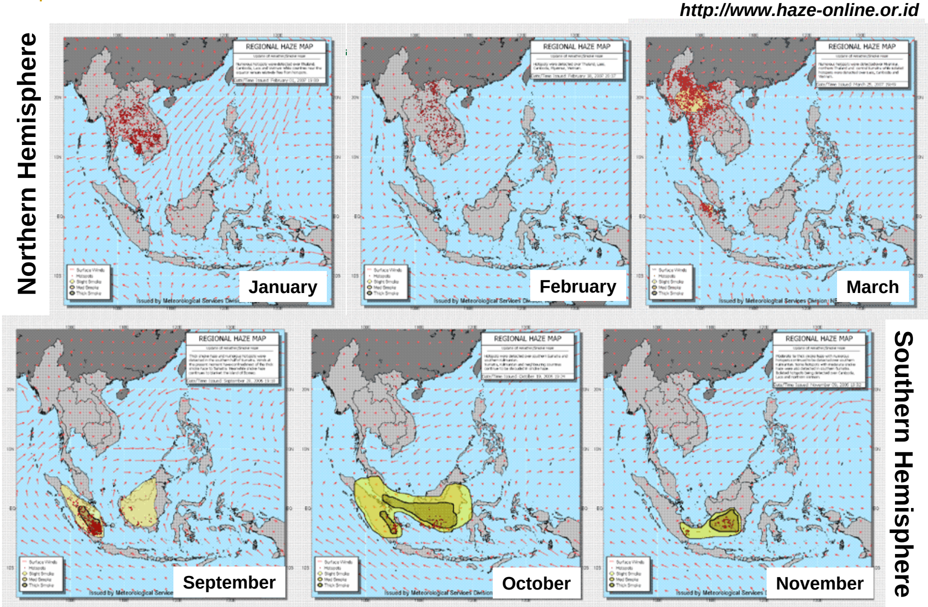
Biomass open burning – ASEAN countries

http://www.haze-online.or.id



Biomass open burning – ASEAN countries

Haze in Malaysia during Indonesian forest fire in1997

and in August 2005

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Biomass open burning – Thailand

Haze in Chiang Mai in 2007

Biomass burning – ASEAN countries

Biomass burning – ASEAN countries

Currently, eight countries (out of 10) composed of Brunei Darussalam, Cambodia, Lao PDR, Malaysia, Myanmar, Singapore, Thailand and Vietnam have signed the Agreement.

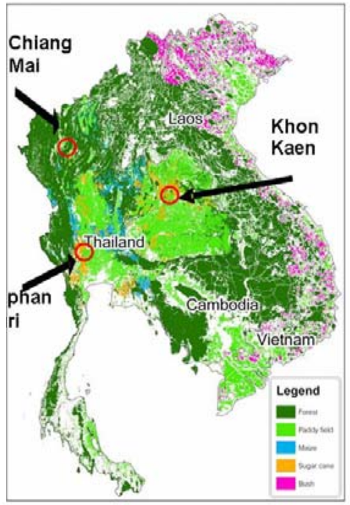
Biomass open burning in the MRBSR Countries?

HAZE originating from large-scale land and forest fires is characterized by a high concentration of particulate matter, which, among other effects, reduces visibility.

Examples of Biomass Burning in the MRBSR Countries.

Biomass Open Burning in the MRBSR Project by JGSEE

- Estimation of Pollutants Emissions from Biomass Burning in the Mekong River Basin Sub-Region (since May 2004)
- Rationale
  - Policy and Decision-Making Support Information
  - Biomass = Bioenergy Resource
    - Emissions from biomass open burning = Baseline of emission from biomass combustion sources
  - Biomass burning = Area source
    - Overlooked and underestimated

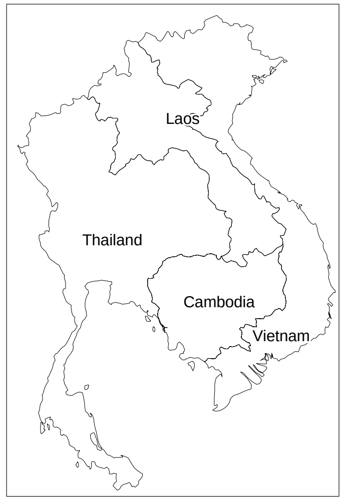


Biomass Open Burning in the MRBSR Project by JGSEE

- Objectives
  - To develop a database of emissions representative of the MRBSR
  - To develop a guideline for estimating the emissions based on field observation data
  - To initiate a capacity building on air quality modeling and monitoring using the developed database for the scientists of the region.

Biomass Open Burning in the MRBSR Project by JGSEE

- Scope
  - ✓ **Study site:** Thailand, Cambodia, Laos, Vietnam
  - ✓ **Vegetation:** Forest and Agricultural crops
  - ✓ **Pollutant of interest:** PM10 and PM2.5
- Working Team
  - ✓ Dr. Savitri Garivait
  - ✓ Dr. Sébastien Bonnet
  - ✓ 4 Research Assistants and Students



Biomass Burning Emission - Methodology

$$Q(x) = M \times EF(x)$$

Emission Quantity of Species X (g)

Biomass Burned (kg)

Emission Factor of Species X (g/kgdm)

f (area burned, burning efficiency, biomass density, etc…)

f (vegetation type, burning conditions, species, etc…)

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Biomass Burned (*M*)

$$M = A \times B \times \alpha \times \beta$$

Seiler and Crutzen (1980)

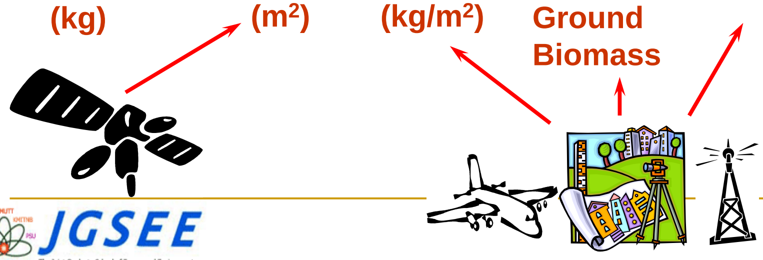
Biomass Burned (kg)

Area Burned (m^2)

Biomass Density (kg/m^2)

Fraction of Above Ground Biomass

Burning Efficiency



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Methodology of Estimating Emissions from Biomass Open Burning – Data Collection

Data Type	Data Collection Methods			
	Literature	Remote Sensing	Survey using Interview Questionnaire	Field Survey/ Lab
Land use	✓	✓		✓
Area burned (A) (m^2)	✓	✓	✓	✓
Biomass density (B) (kg/m2)	✓		✓	✓
Fraction of Above Ground Biomass (α)	✓	✓	(✓)	✓
Burning efficiency or fraction burned (β)	✓		(✓)	✓
Emission factor (EF)	✓			✓

1st Phase

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Sample collection – Before burning

Collection and weighing of fresh biomass for determination of moisture content and dry weight

Sample collection – During burning

Measurements of CO, CO_2 and PM10

Sample collection – After burning

Sampling of unburned biomass for the determination of fraction burned

Sampling of ash for the determination of fraction released to the Air

Sample collection – After burning

Observation of PM10 total filtration filters for qualitative analysis of the emissions prior to weighing for PM emission load determination

Sample processing at laboratory

Sample is dried in an oven at 105°C during 24 h for determination of dry weight and moisture content

Sample processing at laboratory

Sample is shredded for the first step size reduction

Sample processing at laboratory

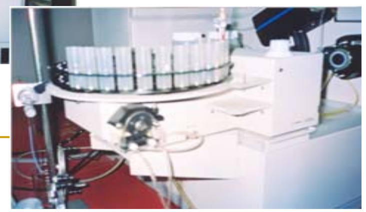
Shredded sample is put in a ball mill for ultimate size reduction required prior ultimate chemical analysis

Sample processing at laboratory

The same sample processing is applied to ashes

Sample analysis at laboratory

Carbon analysis using thermal method for determination of C% in samples before and after burning required for material balance analysis.



Samples before and after burning are digested and analyzed by ICP-MS for determination of elemental composition.

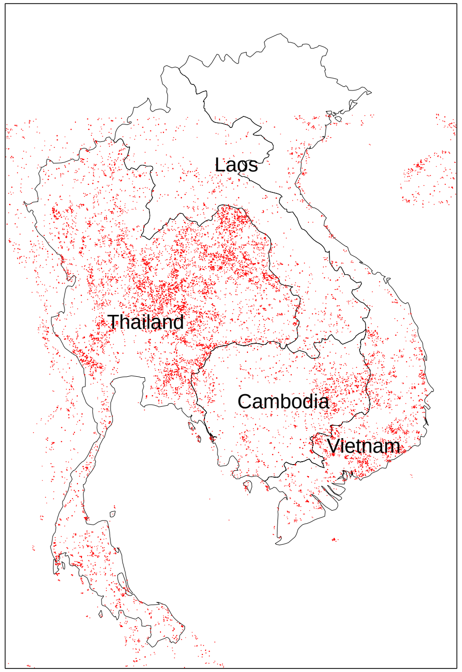
Satellite Data Processing

Original Data

- Daily basis
- Jan 1–Dec 31, 2002

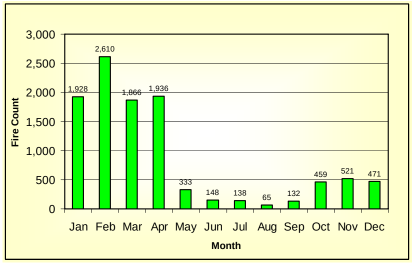
Processed Data

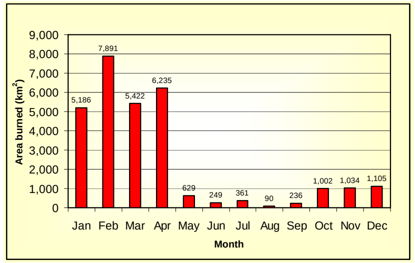
- Monthly basis
- Jan-Dec, 2002



Biomass Burning-THAILAND

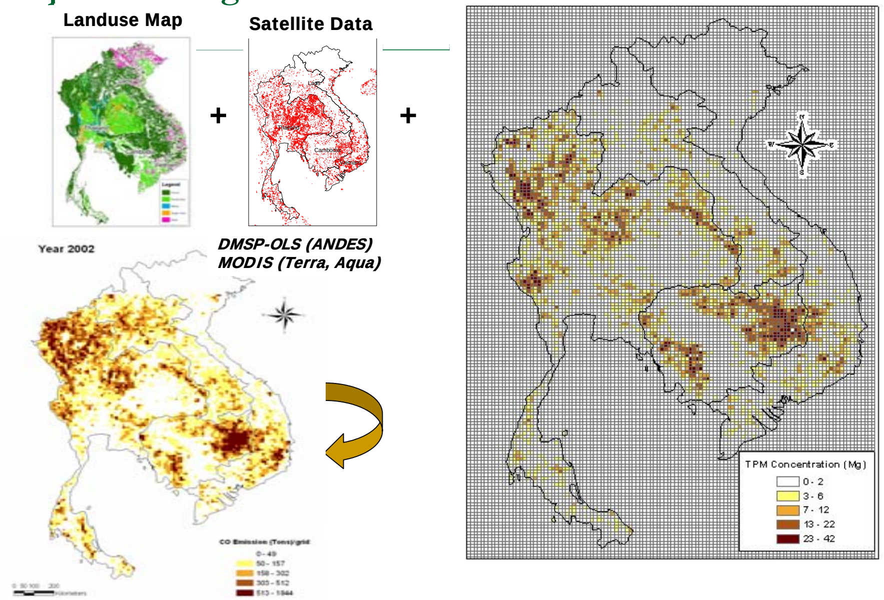
Forest





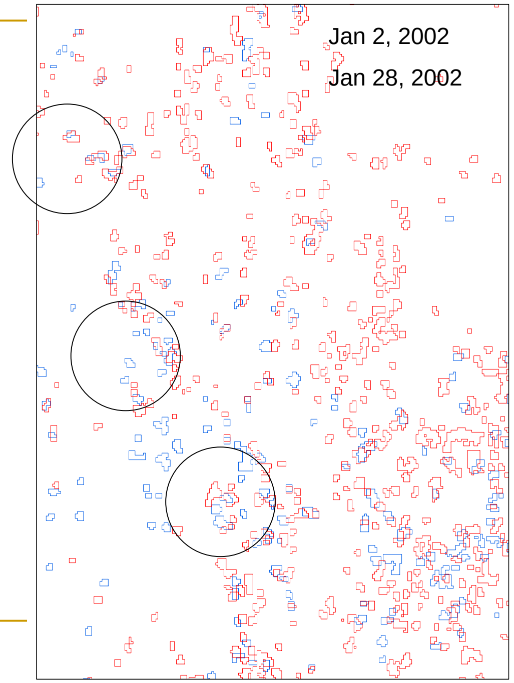
Annual accumulation = 29,440 km^2

Methodology of Estimating Emissions from Biomass Open Burning

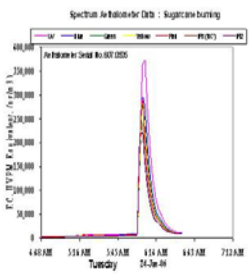


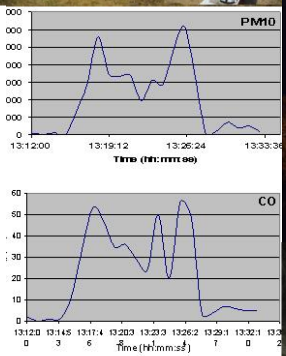
Examples of uncertainties – *Remote Sensing*

Fires occurred in the same area on two different days



Examples of uncertainties – *Field Surveys*





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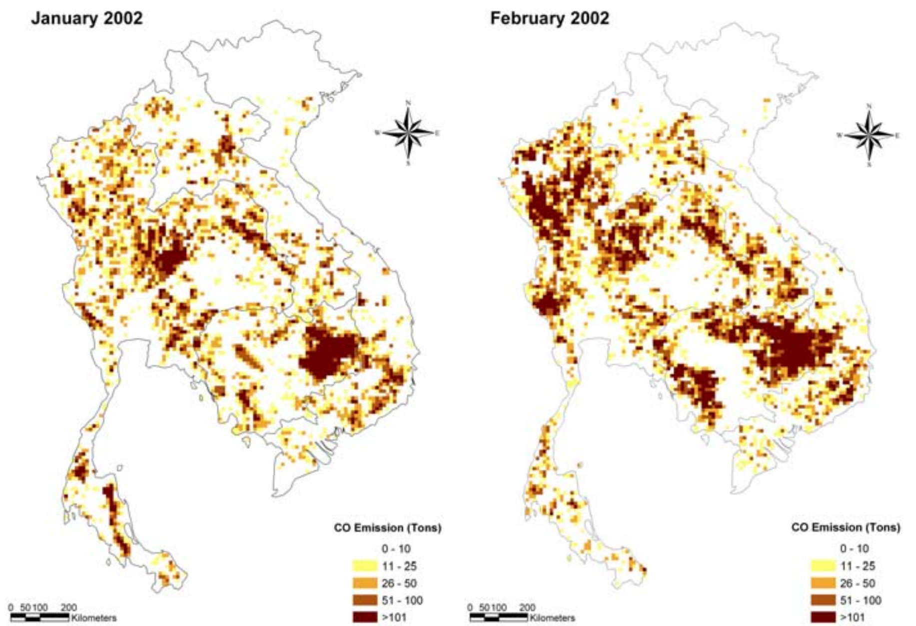
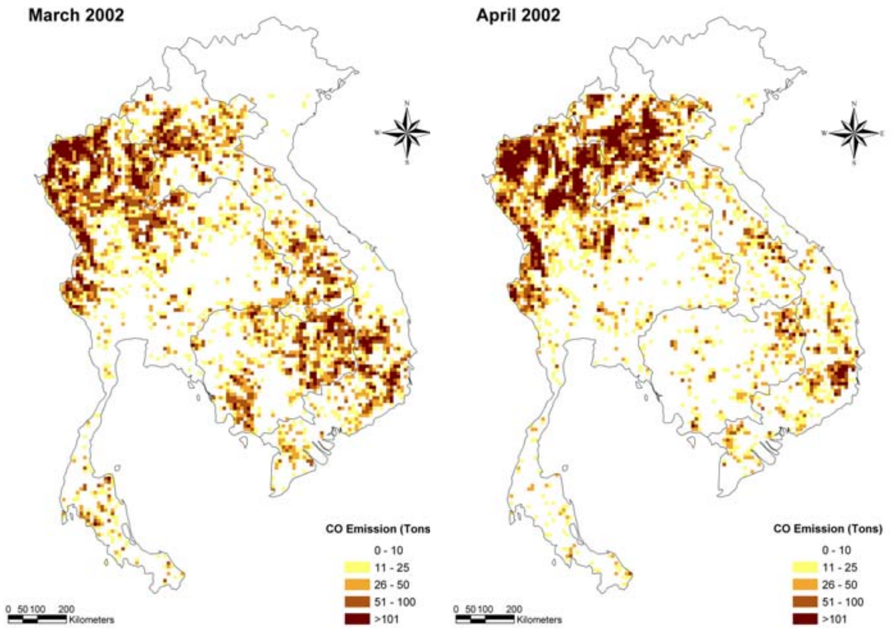
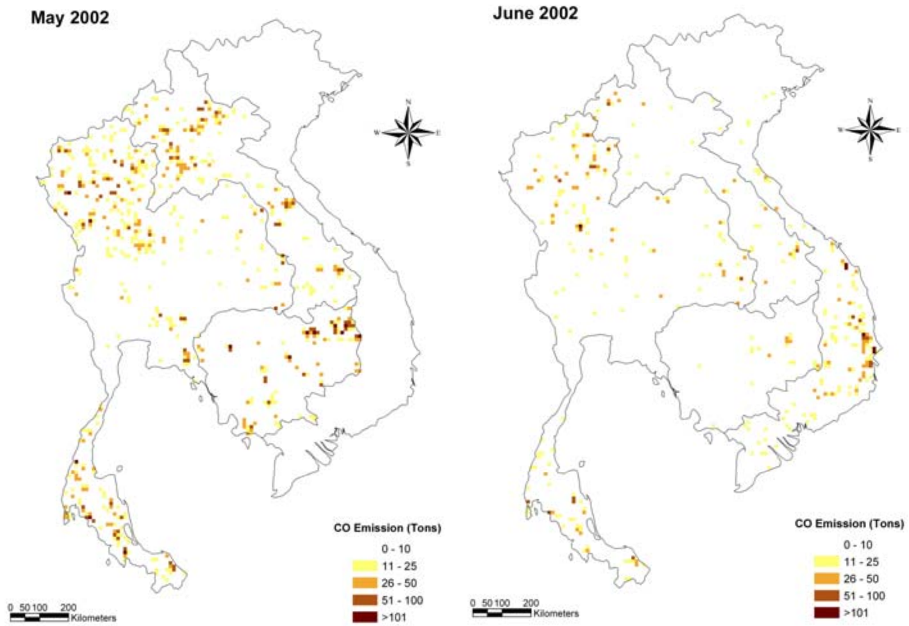
CO Emission



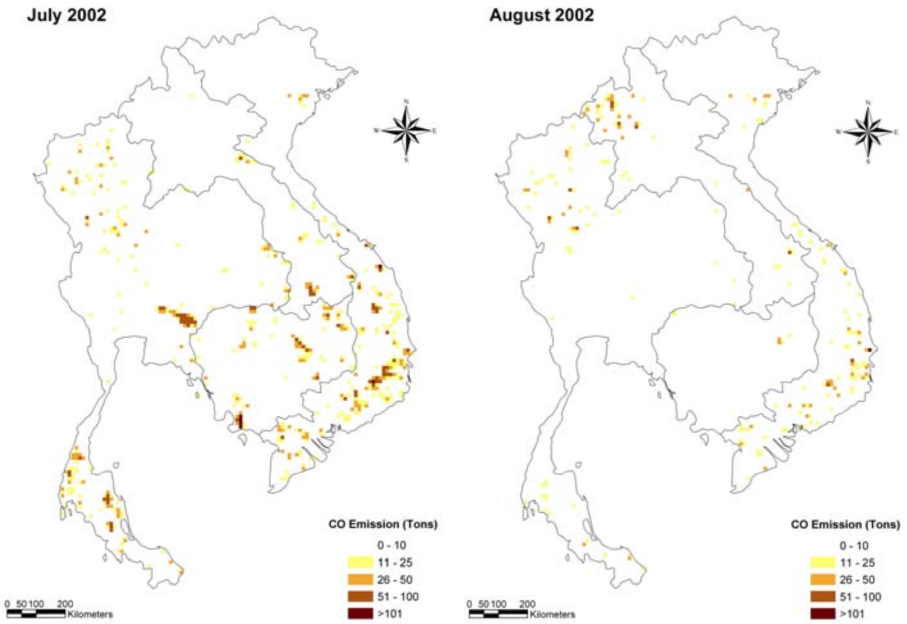
CO Emission



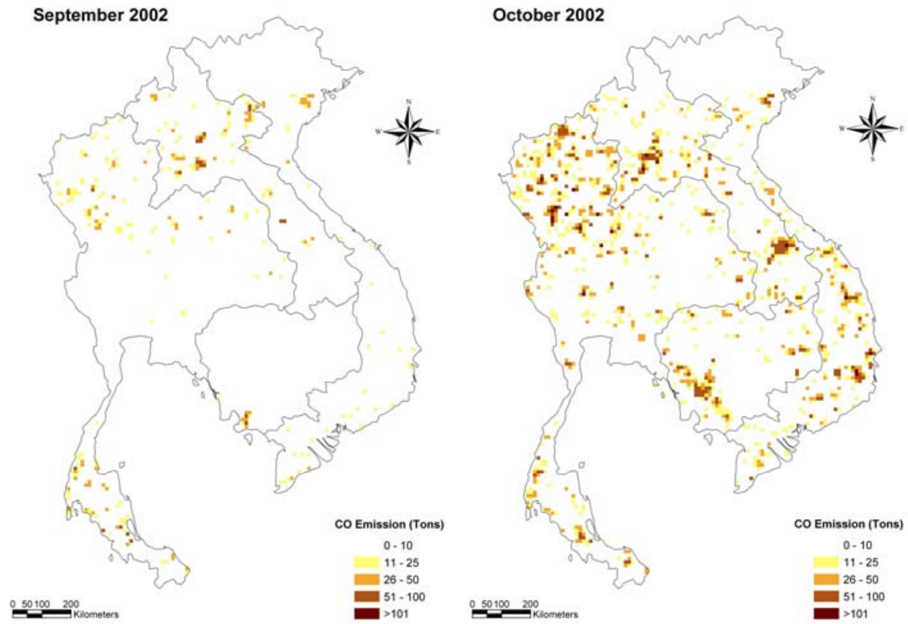
CO Emission



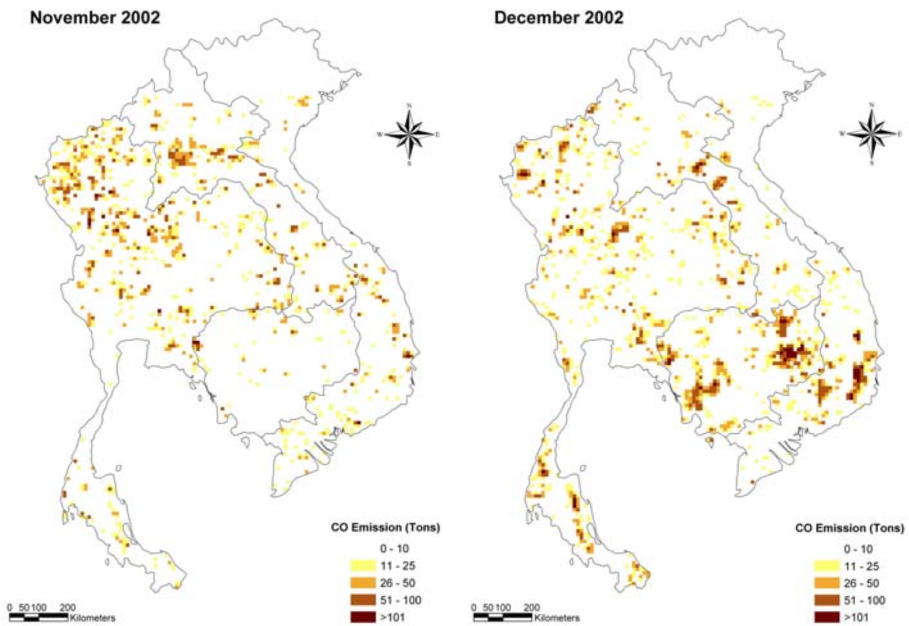
CO Emission



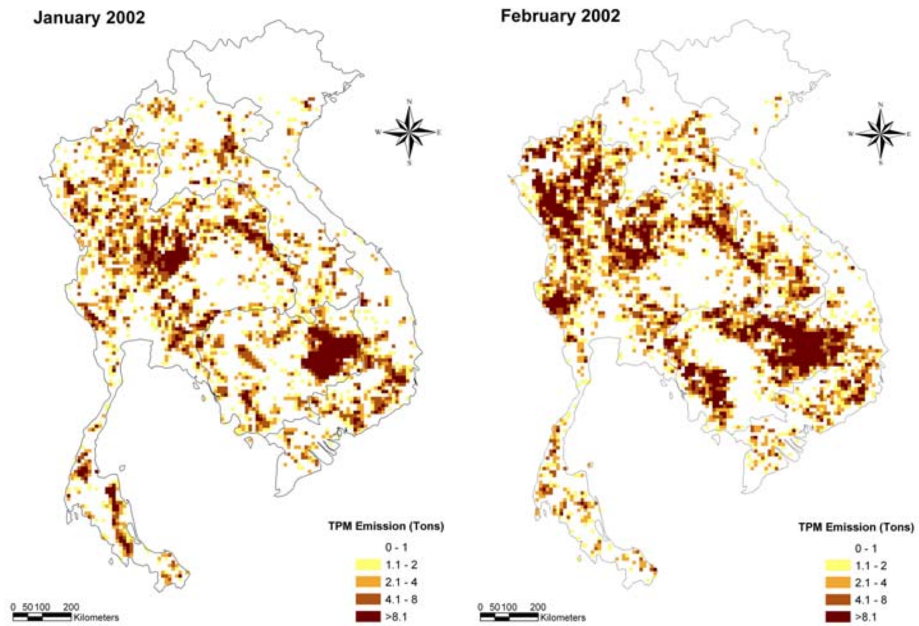
CO Emission

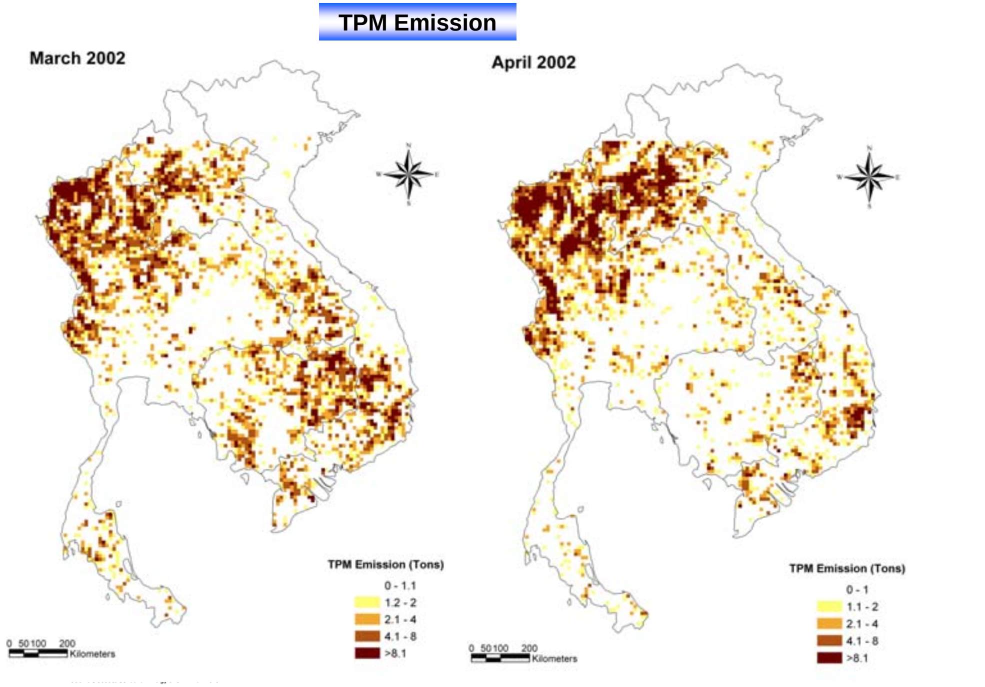


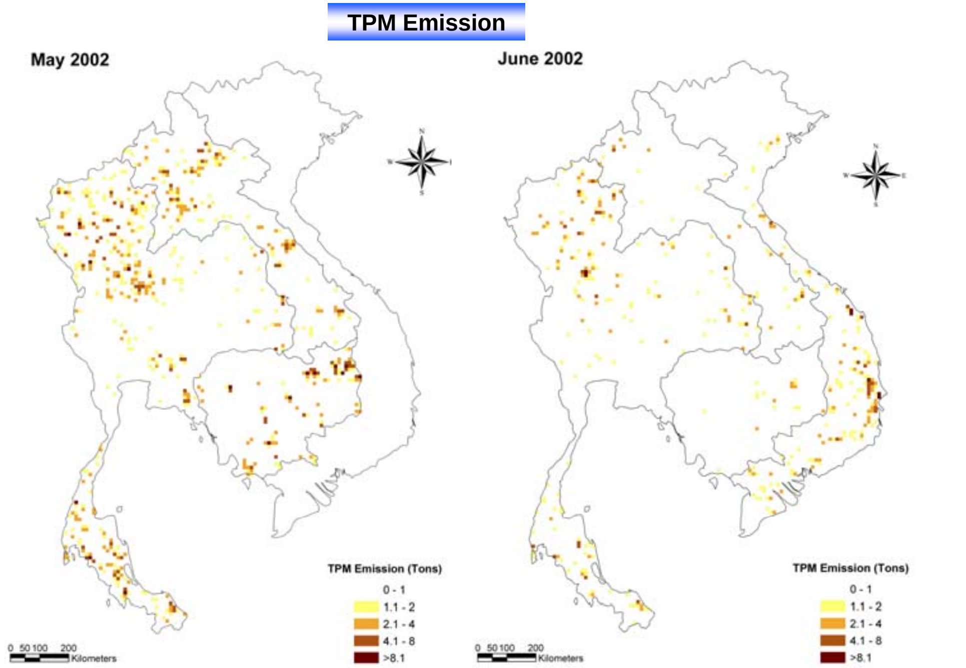
CO Emission

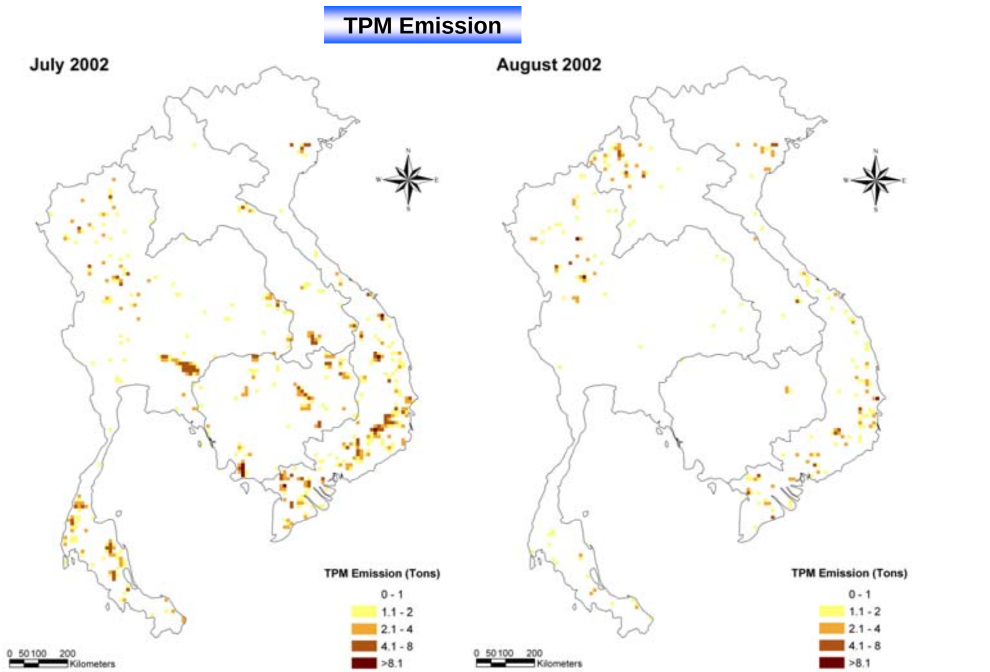


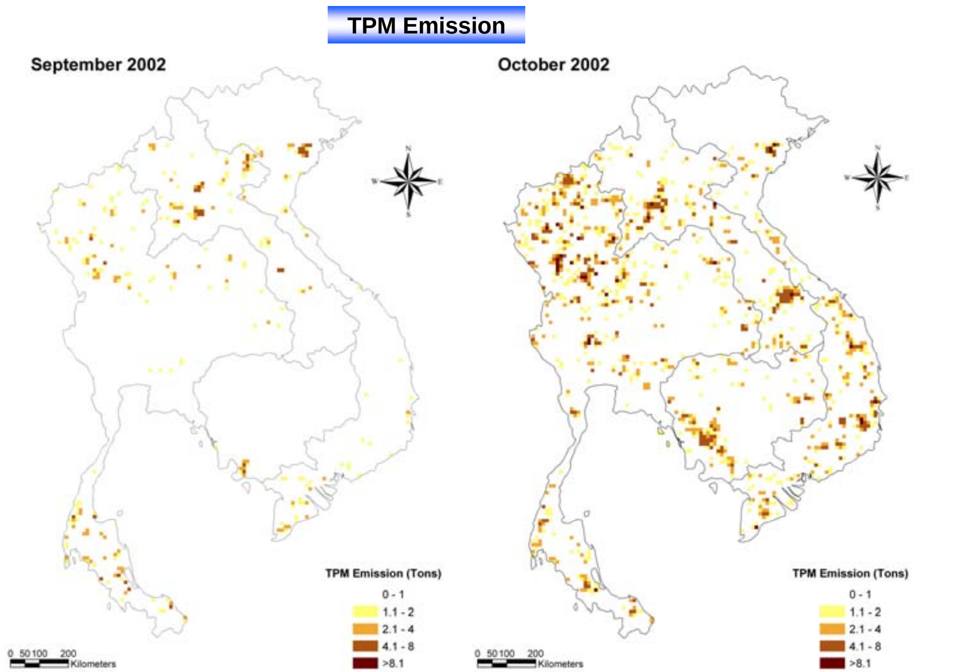
TPM Emission



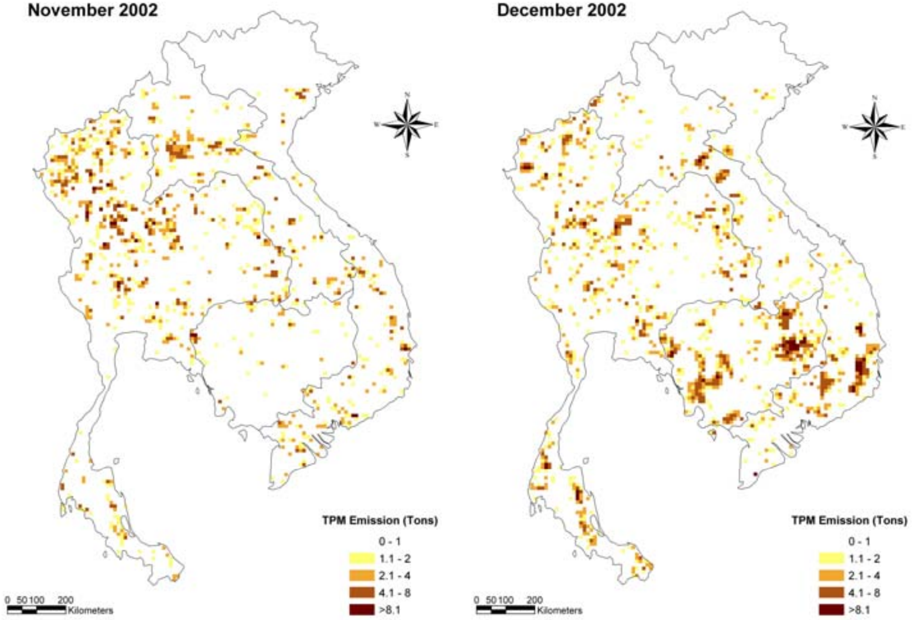

TPM Emission
March 2002
April 2002
TPM Emission (Tons)
0 - 1.1
1.2 - 2
2.1 - 4
4.1 - 8
>8.1
TPM Emission (Tons)
0 - 1
1.1 - 2
2.1 - 4
4.1 - 8
>8.1
0 50 100 200
Kilometers


TPM Emission
May 2002
June 2002
TPM Emission (Tons)
0 - 1
1.1 - 2
2.1 - 4
4.1 - 8
>8.1
0 50 100 200
Kilometers


TPM Emission
July 2002
August 2002
TPM Emission (Tons)
0 - 1
1.1 - 2
2.1 - 4
4.1 - 8
>8.1
0 50 100 200
Kilometers

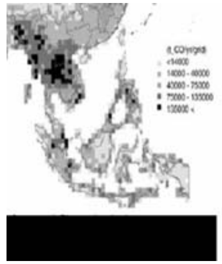

TPM Emission
September 2002
October 2002
TPM Emission (Tons)
0 - 1
1.1 - 2
2.1 - 4
4.1 - 8
>8.1
0 50 100 200
Kilometers

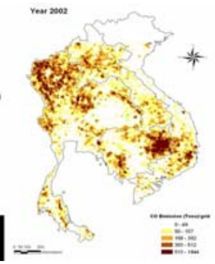
TPM Emission



Estimation of Emissions from Biomass Open Burning in MRBSR – Summary Findings

Grid cell = 12 km x 12 km
Total Emissions = 0.99 Tg CO





Grid cell = 1° x 1°
Total Emissions = 11.60 Tg CO

- Vegetation subjected to open burning: Forest>Agricultural fields
- Spatial distribution: Thailand>Vietnam>Cambodia> Lao PDR
- Temporal distribution:
  - High season: January-April
  - Low season: the rest ☞ Agricultural crops
- In Thailand agricultural areas subjected to burning throughout the year: intensive cultivation practice

☞ **Uncertainties are still HIGH**

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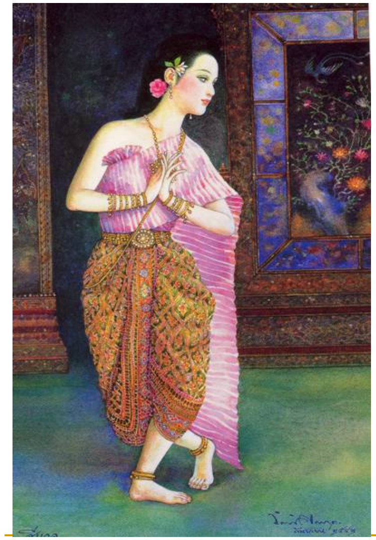
Acknowledgements



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ขอบคุณค่ะ

Khob Khun Kha

สวัสดีค่ะ

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Biomass Burning – Emissions Calculation Methodology

International Training Workshop on

Inventories of Greenhouse Gases and Aerosol Emissions Associated to Different Vegetation Land Use in the Mekong River Basin Sub-region

1-3 May 2007

Bangkok - Thailand

Dr. Sebastien Bonnet

Emissions from vegetation fires

- The general expression reported in the literature is as follows:
- Emissions from biomass burning:
  - $E = M \times EF$
    - E: total emission of the gaseous species considered
    - M: mass of dry matter burned
    - EF: species and source specific emission factor
- In the literature various methods are reported to determine the amount of biomass burned (M). These methods depend on the type of biomass burned considered.

Forest and crop residues

- Major types of biomass considered:
  - Forest including:
    - Dry evergreen forest
    - Dry dipterocarp forest
    - Moist evergreen forest
    - Hill evergreen forest
    - Mangrove forest
  - Agricultural residues including:
    - Rice straw, rice stubble,
    - sugarcane Topd/leaves
    - Maize stalk, maize husk

Amount of forest biomass burned

- Various studies have been published dealing with amount of biomass burned from various sources mainly in tropical regions (Seiler and Crutzen, 1980, Hao and Liu 1994, Streets *et al.*, 2003, etc.).
- The calculation methodology described in those studies is based from the one developed by Seiler and Crutzen (1980). It is as follows:
- Amount of biomass burned:
  - $M = A \times B \times \beta$
    - M: amount of above ground biomass burned
    - A: area of land burned
    - B: above ground biomass load (dry matter density)
    - β: fraction of biomass burned also termed burning efficiency

Parameters required to calculate amount of forest biomass burned

Biomass load range (kg/m^2)	5 -55[a]; 10[b] (7.5 – 22.5)
Burning efficiency	0.2[c]; 0.45[d]; 0.6[e]

[a]*Brown and Gaston (1996);* [b]*IPPC (1996);* [c]*Levine (2000);* [d]*Hao and Liu (1994);* [e]*Streets et al., (2003);*

Vegetation Class	Biomass Density (g/m^2)	Burning efficiency
evergreen needleleaf forest	36700	0.25
evergreen broadleaf forest	23350	0.25
deciduous needleleaf forest	18900	0.25
deciduous broadleaf forest	20000	0.25
mixed forest	22250	0.25
woodland	10000	0.35
wooded grassland	3300	0.4
closed shrubland	7200	0.5
open shrubland	1600	0.85
grassland	1250	0.95
cropland	5100	0.6

Michel *et al.*, 2005

Amount of crops residues burned

- The determination of amount of agricultural residues burned using default values found in the literature is reported similarly in works of Hao and Liu 1994; Streets *et al*., 2003; or IPCC 1996.
- The general expression used is as follows:
- <u>Amount of crop residues burnt</u>
  - $M = P \times D \times f \times \beta$
  - M: amount of crop residues burned per year
  - P: annual production of crop
  - D: ratio of residue to crop product
  - f: fraction of residues being burned
  - β: Fraction of above ground biomass burned (burning efficiency)

Parameters required to calculate amount of crop residues burned

Crops	Residue -to-crop ratio	Dry matter fraction	Dry matter burned in field**	Dry matter burned in field***	Burning efficiency
Corn	2.0[e,f]	0.40[e,f,g]	25%[e,g]	17%[e,d]	92%[e]
Rice	1.76[f]	0.85[e,f,g]	25%[e,g]	17%[e,d]	89%[e]
Sugarcane	0.3[f]	0.71[e,f,g]	25%[e,g]	17%[e,d]	68%[e]

[e]*Streets et al., (2003);* [f]*Koopmans and Koppejan (1997);* [g]*OEPP, Thailand (1990)*; **Data for South Asia ***Data for Rest of Asia

Emissions from vegetation fires - use of emission ratios

- Calculation of emissions from vegetation fires using emissions ratios either for forest fires or crop residues burning is reported in the literature and described in the IPCC revised guidelines 1996. The method is as follows:
- <u>Amount of carbon released to the atmosphere:</u>
  - $M(C) = M \times C$
    - M(C): Total mass of carbon released to the atmosphere
    - C: mass percentage of carbon in the biomass
    - M: amount of above ground biomass burned

Emissions from vegetation fires - use of emission ratios

- Amount of carbon released to the atmosphere as CO2:
  - $M(CO_2) = M(C) \times CE$
    - $M(C0_2)$: mass of carbon released as CO2 during the fire
    - M(C): Total mass of carbon released to the atmosphere
    - β: fraction of biomass oxidized also termed combustion efficiency
- Amount of species Xi released to the atmosphere:
  - $M(Xi) = ER(Xi) \times M(C0_2)$
    - M(Xi): amount species Xi produced by burning
    - ER(Xi): CO_2 normalized species emission ratio
    - $M(C0_2)$: mass of carbon released as CO_2 during the fire

Emission ratios

Emission Ratios		
Compound	Forest fires	Crop residues burning
CH_4	0.012 (0.009-0.015)	0.005 (0.003-0.007)
CO	0.06 (0.04-0.08)	0.06 (0.04-0.08)
N_2O	0.007 (0.005-0.009)	0.007 (0.005-0.009)
NOx	0.121 (0.094-0.148)	0.121 (0.094-0.148)

Ratios for carbon compounds are mass of carbon released as CH_4 or CO (in units of carbon) relative to mass of total carbon released from burning (in units of carbon); those for nitrogen compounds are expressed as the mass of nitrogen compounds released relative to the total mass of nitrogen released from the fuel (IPCC, 1996)

Emissions from vegetation fires - use of emission factors

- Calculation of emissions from vegetation fires using emissions factors is also widely reported in the literature including Hao and Liu 1994; USEPA, 2002; Streets *et al.*, 2003. The expression used is as follows:
- Emissions from biomass burning
  - $E = M \times EF$
    - E: total emission of the gaseous species considered;
    - M: mass of dry matter burned
    - EF: species and source specific emission factor

Emission factors

	Tropical Forest	Crop residues
Compounds	Emission Factors (g/kg)[a]	
CO_2	1580 ± 90	1515 ± 177
CO	104 ± 20	92 ± 84
CH_4	6.8 ± 2.0	2.7
N_2O	0.20	0.07
NOx	1.6 ± 0.7	2.5 ± 1.0
PM2.5	9.1 ± 1.5	3.9
TPM	6.5-10.5; 20[b]	13; 10[b]
OC	5.2 ± 1.5	3.3
BC	0.66 ± 0.31	0.69 ± 0.13

[a]Andrea and Merlet (2001); [b]Levine (2000)

Uncertainties

- Burned areas:
  - Satellite retrieval of hotspot and burned areas recently available after 1995
    - Sensor limitations,
    - orbital drift,
    - cloud and smoke occurrence, etc.
  - Aerial observation by plane and forest services
    - Incomplete and varying coverage

Uncertainties

- Burning efficiency:
  - It corresponds to the amount of fuel that is actually combusted
    - Fuel load,
    - fuel moisture,
    - vegetation type,
    - rate of spreading of the fire
    - Human intervention

Emission Factors

- Emission Factors:
  - The amount of chemically active trace species and aerosols released from a fire depends on:
    - Fuel type
    - Fire characteristics
      - Flaming: complete combustion lead to a larger fraction of oxidized species e.g. CO2, NOx
      - Smoldering: incomplete combustion lead to a larger fraction of reduced species e.g. CO, NH3 and NMVOC species
  - Seasonal and regional variation

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Use of Questionnaires for Estimation of Emissions from Biomass Burning

Savitri Garivait, *JGSEE*

International Training Workshop on
Inventories of Greenhouse Gases and Aerosol Emissions Associated to Different Vegetation Land Use in the Mekong River Basin Sub-region
May 2nd, 2007
JGSEE-KMUTT, Bangkok, Thailand

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Biomass Burning Emission - Methodology

$$Q(x) = M \times EF(x)$$

Emission Quantity of Species X (g)

Biomass Burned (kg) ← *f* (area burned, burning efficiency, biomass density, etc…)

Emission Factor of Species X (g/kgdm) ← *f* (vegetation type, burning conditions, species, etc…)

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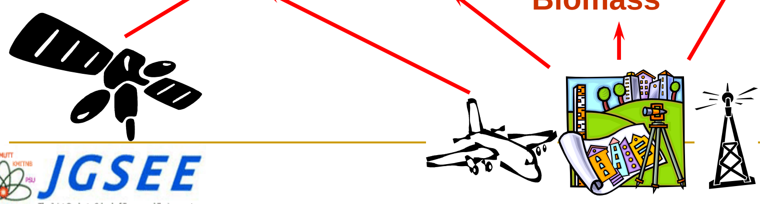
Biomass Burned (*M*)

$$M = A \times B \times \alpha \times \beta$$

Seiler and Crutzen (1980)

Biomass Burned (kg) | **Area Burned (m^2)** | **Biomass Density (kg/m^2)** | **Fraction of Above Ground Biomass** | **Burning Efficiency**



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Use of Questionnaires for Estimation of Emissions from Biomass Burning

- **Objectives**
  - To collect qualitative information on Activity Data
  - To collect statistic data on the Activity
  - To serve as data to cross-check the data from other sources
- **Scope**
  - Forest Fires
  - Agricultural Residues Burnings

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Examples of Questionnaires – Hands-on

- Forest Fires
  - Questionnaire to Forestry Officer
- Agricultural Residues Burning
  - Questionnaire to Agricultural Officer
  - Questionnaire to Farmers
- General Open Burning
  - Questionnaire to Environmental Officer

Practice I - Questionnaire to Forestry Officer

- Forest category
- Type of forest subjected to burning
- Types of biomass subjected to burning
- Time period (month – month) and frequency
- Time of the day that the burning occurs
- State of the residues before burning
- Duration for a burning of the whole plot
- Burning characteristics
- Total amount of area burned
- Characteristics of the residues after burning

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Practice II - Questionnaire to Rice Farmers

- Description of the plantation
- Description of the plantation of major rice/second rice/other crops
- Description of burning practice (to fill in only if the farmer practice slash and burn)
- Description of burning behavior
- Utilization of agricultural residues

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Examples of results obtained in Thailand – Area Burned

Type of land	Burned/Cultivated Area Ratio (%)
Forest	-
Major rice	50%
Second rice	75%
Sugarcane	50%
Maize	15%

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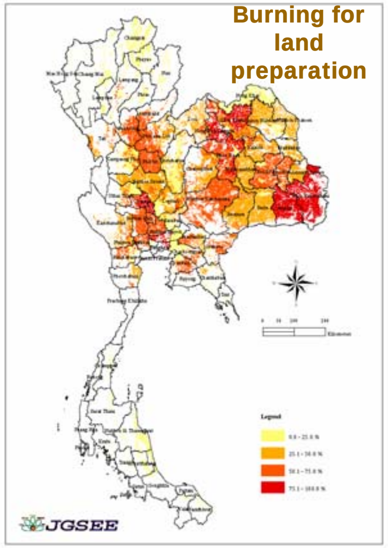
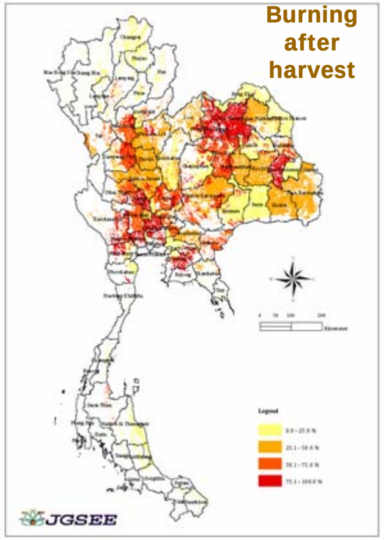
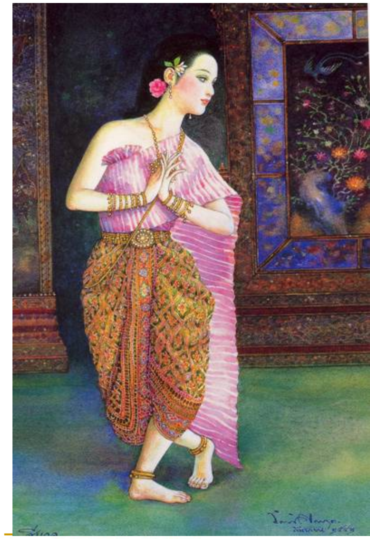
Examples of results obtained in Thailand – Rice straw burning





Acknowledgements



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Ref.: Country – Rice ☐☐☐☐

Rice
Questionnaire to Farmer

1. Farmer ID

First name and Last name	
Age Income (approx.) Cost of farming per crop (approx)	
Address (No., Street, District, County, …)	
Province and postal code	
Country	Cambodia

2. Description of the plantation

Address (No., Street, District, County, …)	
Province and postal code	
Country	Cambodia
Total owned plantation area (= L(m) x l(m))	Plantation area is divided into: _________ plots
Source of water for plantation	☐ Rainfall ☐ Irrigation ☐ Natural effluents (river, basin, lake, …) ☐ Pumped groundwater ☐ Others (Indicate) ________________________________
How many times is paddy planted per year?	
Is other crop planted in alternance with paddy? If yes, which one?	
Remarks	

3. Description of the plantation of major rice

Total area of the plantation (= L(m) x l(m))	 Plantation area is divided into: _________ plots
Planted species of paddy	
Total production (tons)	
Land preparation • Duration (number of days) • Period (month – month) • Method (animal or machine)	
Plantation • Duration (number of days) • Period (month – month) • Method (transplantation, broadcast, or others)	
Use of fertilizer • Type (organic or chemical) • Form (liquid or solid) • Number of times during the growth • Period (month – month)	
Harvesting • Duration (number of days) • Period (month – month) • Method (manual or machine)	
Use of burning	☐ Yes ☐ No Reason:
Period of burning	☐ Before land preparation Period (month – month) ☐ After harvesting Period (month – month) ☐ Other Period (month – month)
Remarks	

4. Description of the plantation of second rice – first rotation

Total area of the plantation (= L(m) x l(m))	 Plantation area is divided into: _________ plots
Planted species of paddy	
Total production (tons)	
Land preparation • Duration (number of days) • Period (month – month) • Method (animal or machine)	
Plantation • Duration (number of days) • Period (month – month) • Method (transplantation, broadcast, or others)	
Use of fertilizer • Type (organic or chemical) • Form (liquid or solid) • Number of times during the growth • Period (month – month)	
Harvesting • Duration (number of days) • Period (month – month) • Method (manual or machine)	
Use of burning	☐ Yes ☐ No Reason:
Period of burning	☐ Before land preparation Period (month – month) ☐ After harvesting Period (month – month) ☐ Other Period (month – month)
Remarks	

5. Description of the plantation of second rice – second rotation

Total area of the plantation (= L(m) x l(m))	Plantation area is divided into: _________ plots
Planted species of paddy	
Total production (tons)	
Land preparation • Duration (number of days) • Period (month – month) • Method (animal or machine)	
Plantation • Duration (number of days) • Period (month – month) • Method (transplantation, broadcast, or others)	
Use of fertilizer • Type (organic or chemical) • Form (liquid or solid) • Number of times during the growth • Period (month – month)	
Harvesting • Duration (number of days) • Period (month – month) • Method (manual or machine)	
Use of burning	☐ Yes ☐ No Reason:
Period of burning	☐ Before land preparation Period (month – month) ☐ After harvesting Period (month – month) ☐ Other Period (month – month)
Remarks	

6. Description of the plantation of other crop in alternance

Total area of the plantation (= L(m) x l(m))	 Plantation area is divided into: _________ plots
Type of planted crop	
Total production (tons)	
Land preparation • Duration (number of days) • Period (month – month) • Method (animal or machine)	
Plantation • Duration (number of days) • Period (month – month) • Method (transplantation, broadcast, or others)	
Use of fertilizer • Type (organic or chemical) • Form (liquid or solid) • Number of times during the growth • Period (month – month)	
Harvesting • Duration (number of days) • Period (month – month) • Method (manual or machine)	
Use of burning	☐ Yes ☐ No Reason:
Period of burning	☐ Before land preparation Period (month – month) ☐ After harvesting Period (month – month) ☐ Other Period (month – month)
Remarks	

7. Description of burning practice (to fill in only if the farmer practice slash and burn)

Reason of burning	☐ To facilitate land preparation ☐ To eliminate pests and insects ☐ To hunt rats or other animals ☐ Other (indicate): ____________________________
What type of residues is subjected to burning?	☐ Rice straw ☐ Rice stubbles ☐ Rice straw+stubbles ☐ Residues from alternate crop ☐ Other (indicate): ____________________________
Time period (month – month)	___________ - ____________ ☐ _______ days before land preparation ☐ _______ days after harvesting ☐ Other (indicate):_____________________________
Method of ignition	☐ Set fires at many spots of the plot ☐ Set only one spot and let the fire propagate ☐ Gather rice straw at one point of the plot and burn ☐ Set fires in parallele line ☐ Other (indicate): ____________________________
State of the biomass residues	☐ Very dry ☐ Dry ☐ Quite fresh ☐ Very fresh ☐ Other (indicate): _____________________________
At what time of the day the burning is conducted?	☐ Morning (indicate): __________________________ ☐ Afternoon (indicate): ________________________ ☐ Evening (indicate): __________________________ ☐ Other (indicate): _____________________________

8. Description of burning behavior

Duration for a burning of the whole plot	__________ hours for ____________m^2 plot size
Burning characteristics	☐ Long flaming ☐ Quite long flaming ☐ Half flaming and half smoldering ☐ Quite long smoldering ☐ Long smoldering ☐ Other (indicate): __________________________
Total amount of area burned	☐ Nearly the whole plot ☐ More than the half of the plot ☐ Less than the half of the plot ☐ Other (indicate): __________________________
Characteristics of the residues after burning	☐ All biomass is transformed into ash ☐ More than 80% of the biomass is burned ☐ More than 50% of the biomass is burned ☐ Less than 50% of the biomass is burned ☐ Other (indicate): __________________________
Remarks	

9. Utilization of agricultural residues

Agricultural residues is utilized after harvesting	☐ Yes ☐ No, all is burned
If yes, what is the purpose of utilization? (more than 1 answer is possible)	☐ To be incorporated into the soil as fertilizer ☐ As animal fodder ☐ To cover the soil ☐ To sow mushroom ☐ To sale ☐ To make compost ☐ To make fuel for cooking ☐ Other (indicate): __________________________
Remarks	

10. Awareness of negative impacts of open burning of agricultural residues

Is the farmer aware of negative impacts of open burning	☐ Yes ☐ No
If yes, what are they? (more than 1 answer is possible)	☐ Is banned by law ☐ Source of strong smoke ☐ Source of forest fires ☐ Source of traffic accidents ☐ Reduction of the soil quality ☐ Solidification of the soil surface ☐ Destruction of biological system of the soil ☐ Reduction of productivity ☐ Increase of use of fertilizer ☐ Increase of use of pesticides ☐ Reduction of soil capacity in absorbing water ☐ Change of rainfall pattern ☐ Increase drought period ☐ Other (indicate): ___________________________
Remarks	

Ref.: Country – Agr. Off. ☐☐☐☐

Questionnaire to Agricultural Officer

1. Officer ID

First name and Last name	
Age Position Affiliation	
Area (provinces or districts, region, …) in charge	
Area in charge is irrigated?	☐ Yes ☐ No
Area in charge is closed to a forest?	☐ Yes ☐ No
Remark	

2. Description of area in charge

Amount of area in charge (km^2)	
Number of provinces or districts in charge	
Types of planted crop	☐ Rice in an area of ________________ km^2 ☐ Sugarcane in an area of _____________ km^2 ☐ Maize in an area of ________________ km^2 ☐ Other (indicate): ___________________ in an area of ______________________ km^2
Types of planted crop that is subjected the most to burning (please rank)	______ Rice ______ Sugarcane ______ Maize ______ Other (indicate): ___________________
Remarks	

3. Description of burning of paddy fields

Types of residues subjected to burning	☐ Rice straw ☐ Rice stubbles ☐ Rice straw+stubbles ☐ Residues from alternate crop ☐ Other (indicate): ____________________________
Time period (month – month) and frequency (low, medium or high: ***contour the answer***)	• _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • Other (indicate): _________________________
Time of the day that the burning occurs	☐ Morning (_________ - _________) ☐ Afternoon (_________ - _________) ☐ Evening (_________ - _________) ☐ Night (_________ - _________) ☐ Other (indicate): _________________________
State of the residues before burning	☐ Very dry ☐ Dry ☐ Quite fresh ☐ Very fresh ☐ Other (indicate): _____________________________
Duration for a burning of the whole plot (approx.)	__________ hours for ____________m^2 plot size
Burning characteristics	☐ Long flaming ☐ Quite long flaming ☐ Half flaming and half smoldering ☐ Quite long smoldering ☐ Long smoldering ☐ Other (indicate): ____________________________
Total amount of area burned	☐ Nearly the whole plot ☐ More than the half of the plot ☐ Less than the half of the plot ☐ Other (indicate): ____________________________
Characteristics of the residues after burning	☐ All biomass is transformed into ash ☐ More than 80% of the biomass is burned ☐ More than 50% of the biomass is burned ☐ Less than 50% of the biomass is burned ☐ Other (indicate): ____________________________
Remarks	

4. Description of burning of sugarcane fields

Types of residues subjected to burning	☐ Dry leaves ☐ Top and trash ☐ Cane ☐ Dry leaves + top + trash ☐ Other (indicate): ___________________________
Time period (month – month) and frequency (low, medium or high: ***contour the answer***)	• _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • Other (indicate): ________________________
Time of the day that the burning occurs	☐ Morning (_________ - _________) ☐ Afternoon (_________ - _________) ☐ Evening (_________ - _________) ☐ Night (_________ - _________) ☐ Other (indicate): ________________________
State of the residues before burning	☐ Very dry ☐ Dry ☐ Quite fresh ☐ Very fresh ☐ Other (indicate): ____________________________
Duration for a burning of the whole plot (approx.)	__________ hours for ____________m^2 plot size
Burning characteristics	☐ Long flaming ☐ Quite long flaming ☐ Half flaming and half smoldering ☐ Quite long smoldering ☐ Long smoldering ☐ Other (indicate): ___________________________
Total amount of area burned	☐ Nearly the whole plot ☐ More than the half of the plot ☐ Less than the half of the plot ☐ Other (indicate): ___________________________
Characteristics of the residues after burning	☐ All biomass is transformed into ash ☐ More than 80% of the biomass is burned ☐ More than 50% of the biomass is burned ☐ Less than 50% of the biomass is burned ☐ Other (indicate): ___________________________
Remarks	☐ Burning before harvesting ☐ Burning after harvesting ☐ Other (indicate): ___________________________

5. Description of burning of maize fields

Types of residues subjected to burning	☐ Stalks + leaves + enveloppes ☐ Corn cobs ☐ Other (indicate): ___________________________
Time period (month – month) and frequency (low, medium or high: ***contour the answer***)	• _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • Other (indicate): ________________________
Time of the day that the burning occurs	☐ Morning (_________ - _________) ☐ Afternoon (_________ - _________) ☐ Evening (_________ - _________) ☐ Night (_________ - _________) ☐ Other (indicate): ________________________
State of the residues before burning	☐ Very dry ☐ Dry ☐ Quite fresh ☐ Very fresh ☐ Other (indicate): ____________________________
Duration for a burning of the whole plot (approx.)	__________ hours for ____________m^2 plot size
Burning characteristics	☐ Long flaming ☐ Quite long flaming ☐ Half flaming and half smoldering ☐ Quite long smoldering ☐ Long smoldering ☐ Other (indicate): ___________________________
Total amount of area burned	☐ Nearly the whole plot ☐ More than the half of the plot ☐ Less than the half of the plot ☐ Other (indicate): ___________________________
Characteristics of the residues after burning	☐ All biomass is transformed into ash ☐ More than 80% of the biomass is burned ☐ More than 50% of the biomass is burned ☐ Less than 50% of the biomass is burned ☐ Other (indicate): ___________________________
Remarks	☐ Gather all residues at a spot and burn ☐ Burn all over the planted area ☐ Other (indicate): ___________________________

6. Description of burning of other crop fields

Types of crops	
Types of residues subjected to burning	
Time period (month – month) and frequency (low, medium or high: ***contour the answer***)	• _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • Other (indicate): _______________________
Time of the day that the burning occurs	☐ Morning (_________ - _________) ☐ Afternoon (_________ - _________) ☐ Evening (_________ - _________) ☐ Night (_________ - _________) ☐ Other (indicate): _______________________
State of the residues before burning	☐ Very dry ☐ Dry ☐ Quite fresh ☐ Very fresh ☐ Other (indicate): ___________________________
Duration for a burning of the whole plot (approx.)	__________ hours for ____________m^2 plot size
Burning characteristics	☐ Long flaming ☐ Quite long flaming ☐ Half flaming and half smoldering ☐ Quite long smoldering ☐ Long smoldering ☐ Other (indicate): __________________________
Total amount of area burned	☐ Nearly the whole plot ☐ More than the half of the plot ☐ Less than the half of the plot ☐ Other (indicate): __________________________
Characteristics of the residues after burning	☐ All biomass is transformed into ash ☐ More than 80% of the biomass is burned ☐ More than 50% of the biomass is burned ☐ Less than 50% of the biomass is burned ☐ Other (indicate): __________________________
Remarks	

7. Other remarks

Remarks	Descriptions

Ref.: Country – Env. Off. ☐☐☐☐

Questionnaire to Environmental Officer

1. Officer ID

First name and Last name	
Age Position Affiliation	
Area (provinces or districts, region, …) in charge	
Area in charge includes	☐ Forest ☐ Agricultural
Remark	

2. Description of area in charge

Amount of area in charge (km^2)	
Number of provinces or districts in charge	
Types of forest	☐ Forest area in an area of ____________________ km^2 ☐ Agricultural area in an area of _______________ km^2 ☐ Other (indicate): __________________________ in an area of _____________________________ km^2
Types of biomass subjected to burning (***please rank, more than 1 answer is possible***)	______ T1. Forest ______ T2. Agricultural area, ***indicate crop***: _________________________ ______ T3. Garbage ______ T4. Wood waste ______ T5. Garden waste ______ T6. Other (indicate): ____________________
Remarks	

3. Description of burning occurred in the area in charge

Time period (month – month), frequency (low, medium or high: ***contour the answer***) and types of biomass	• __________ - __________ , (low, medium, high), Types:___________________________________ • __________ - __________, (low, medium, high), Types:___________________________________ • __________ - __________, (low, medium, high), Types:___________________________________ • __________ - __________, (low, medium, high), Types:___________________________________ • Other (indicate): _________________________
Time of the day that the burning occurs and types of biomass	☐ Morning (__________ - __________), Types:___________________________________ ☐ Afternoon (__________ - __________), Types:___________________________________ ☐ Evening (__________ - __________), Types:___________________________________ ☐ Night (__________ - __________), Types:___________________________________ ☐ Other (indicate): _________________________
Duration for a burning of the whole plot (approx.)	☐___________ hours/days for _____________km^2 plot size, Types:___________________________________ ☐___________ hours/days for _____________km^2 plot size, Types:___________________________________ ☐___________ hours/days for _____________km^2 plot size, Types:___________________________________ ☐___________ hours/days for _____________km^2 plot size, Types:___________________________________ ☐___________ hours/days for _____________km^2 plot size, Types:___________________________________ ☐___________ hours/days for _____________km^2 plot size, Types:___________________________________ ☐ Other (indicate): _________________________
Remarks	

4. Effect of biomass open burning on the area in charge

Area in charge is affected by biomass open burning	☐ Yes ☐ No
If yes, by what type of biomass and how is the intensity (low, medium, high: ***contour the answer***)?	• Types:________________________________ , (low, medium, high) • Types:________________________________ , (low, medium, high) • Types:________________________________ , (low, medium, high) • Types:________________________________ , (low, medium, high) • Types:________________________________ , (low, medium, high) • Other (indicate): ______________________
Types of impacts (***more than 1 answer is possible***)	☐ Heavy smoke ☐ Irritation of respiratory system ☐ Traffic/road accidents ☐ Reduction of visibility ☐ Fires on neighboring houses and infrastructure ☐ Other (indicate): ________________________
Possible strategies to reduce open burning (***more than 1 answer is possible***)	☐ Strengthen laws and regulations ☐ Increase enforcement ☐ Develop public participation ☐ Encourage better utilization of agricultural residues ☐ Encourgage information dissemination on its impacts ☐ Others (indicate): ___________________________
In your opinion biomass open burning is an environmental issues of	☐ National scale ☐ Regional scale ☐ Global scale ☐ Others (indicate): ___________________________
Remarks	

Ref.: Country – Forestry Off. ☐☐☐☐

Questionnaire to Forestry Officer

1. Officer ID

First name and Last name	
Age Position Affiliation	
Area (provinces or districts, region, …) in charge	
Area in charge is closed to an agricultural area	☐ Yes ☐ No
Remark	

2. Description of area in charge

Amount of area in charge (km^2)	
Number of provinces or districts in charge	
Types of forest	T1. __________________ in an area of ____________ km^2 T2. __________________ in an area of ____________ km^2 T3. __________________ in an area of ____________ km^2 T4. __________________ in an area of ____________ km^2 T5. __________________ in an area of ____________ km^2 T6. __________________ in an area of ____________ km^2 T7. Other (indicate): ___________________________ in an area of ______________________________ km^2
Types of forest subjected the most to burning (***please rank***)	______ T1. ____________________ ______ T2. ____________________ ______ T3. ____________________ ______ T4. ____________________ ______ T5. ____________________ ______ T6. ____________________ ______ T7. Other (indicate): ____________________
Remarks	

3. Description of burning of forest fires

Types of biomass subjected to burning	☐ Trees ☐ Litter ☐ Ground biomass ☐ Other (indicate): ___________________________
Time period (month – month) and frequency (low, medium or high: ***contour the answer***)	• _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • _________ - _________ (low, medium, high) • Other (indicate): ________________________
Time of the day that the burning occurs	☐ Morning (_________ - _________) ☐ Afternoon (_________ - _________) ☐ Evening (_________ - _________) ☐ Night (_________ - _________) ☐ Other (indicate): ________________________
State of the residues before burning	☐ Very dry ☐ Dry ☐ Quite fresh ☐ Very fresh ☐ Other (indicate): ____________________________
Duration for a burning of the whole plot (***approx.***)	__________ hours/days for ____________km^2 plot size
Burning characteristics	☐ Long flaming ☐ Quite long flaming ☐ Half flaming and half smoldering ☐ Quite long smoldering ☐ Long smoldering ☐ Other (indicate): ___________________________
Total amount of area burned	☐ More than 10 km^2 per burning ☐ More than 50 km^2 per burning ☐ More than 100 km^2 per burning ☐ More than 500 km^2 per burning ☐ More than 1,000 km^2 per burning ☐ Other (indicate): ___________________________
Characteristics of the residues after burning	☐ All biomass is transformed into ash ☐ More than 80% of the biomass is burned ☐ More than 50% of the biomass is burned ☐ Less than 50% of the biomass is burned ☐ Other (indicate): ___________________________
Remarks	

4. Other remarks

Remarks	Descriptions

APN CAPaBLE

Calculation of Emissions from Biomass Open Burning

Savitri Garivait, *JGSEE*

International Training Workshop on
Inventories of Greenhouse Gases and Aerosol Emissions Associated to Different Vegetation Land Use in the Mekong River Basin Sub-region
May 2nd, 2007
JGSEE-KMUTT, Bangkok, Thailand

JGSEE The Joint Graduate School of Energy and Environment

Biomass Burning Emission - Methodology

$$Q(x) = M \times EF(x)$$

Emission Quantity of Species X (g)

Biomass Burned (kg)

Emission Factor of Species X (g/kgdm)

f (area burned, burning efficiency, biomass density, etc…)

f (vegetation type, burning conditions, species, etc…)

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Biomass Burned (*M*)

$$M = A \times B \times \alpha \times \beta$$

Seiler and Crutzen (1980)

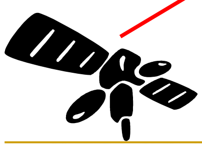
Biomass Burned (kg)

Area Burned (m^2)

Biomass Density (kg/m^2)

Fraction of Above Ground Biomass

Burning Efficiency



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Exercise I: Calculation of Emissions from Biomass Burning in MRBSR in 2002

- **Materials – Excel Spreadsheet**
  - **Area burned from satellite data (Hotspots detected by DMSP-ANDES satellite)**
  - **Above ground biomass density of different type of vegetation**
  - **EF (CO_2, CO, CH_4, NO_x, N_2O, TPM)**
- **Output**
  - **Emission estimation for each of the 4 countries**

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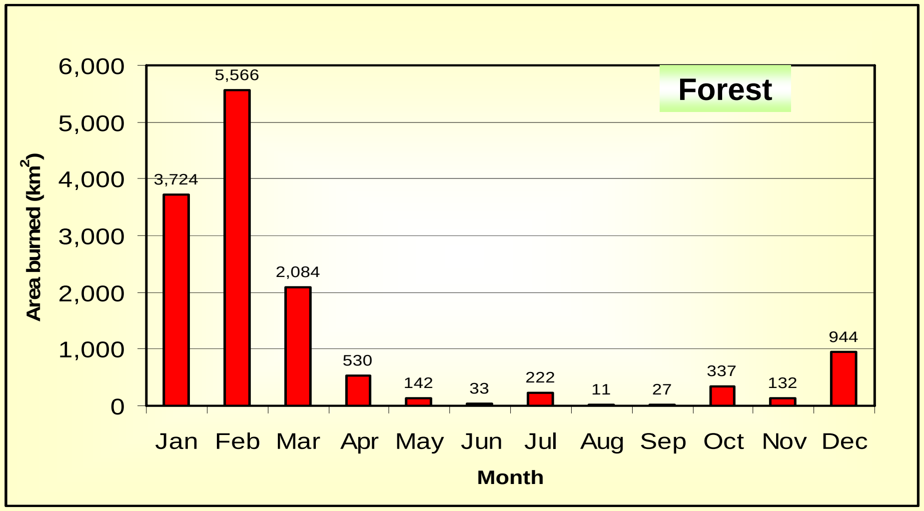
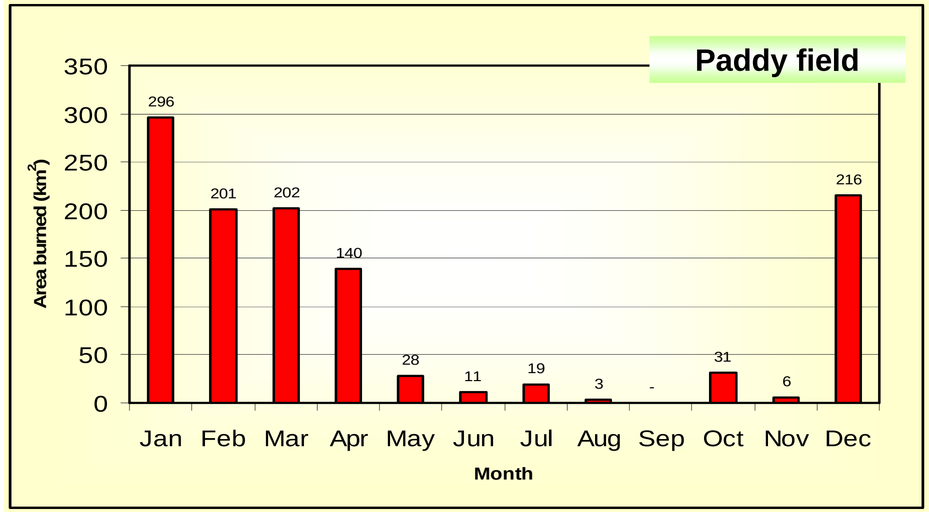
Exercise I: Calculation of Emissions from Biomass Burning in MRBSR in 2002

- Area burned – Cambodia



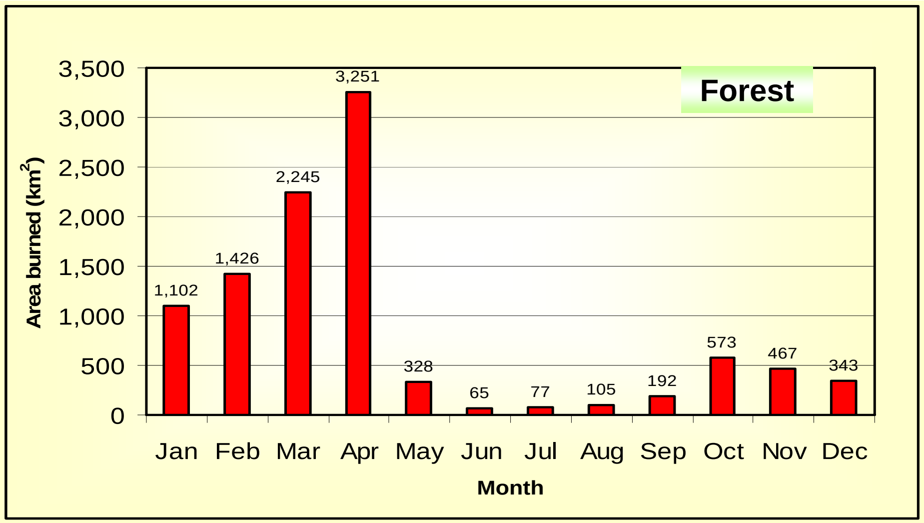
Exercise I: Calculation of Emissions from Biomass Burning in MRBSR in 2002

- Area burned – Cambodia



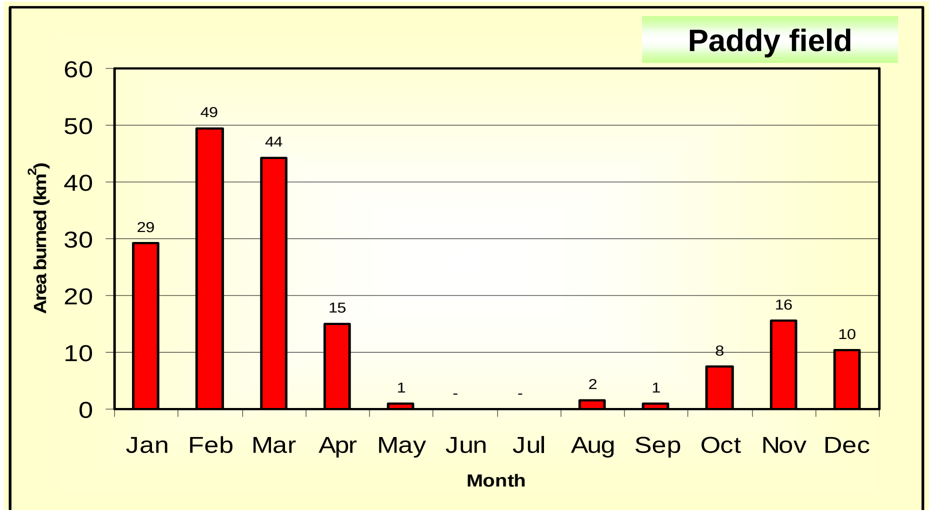
Exercise I: Calculation of Emissions from Biomass Burning in MRBSR in 2002

- Area burned – Lao PDR



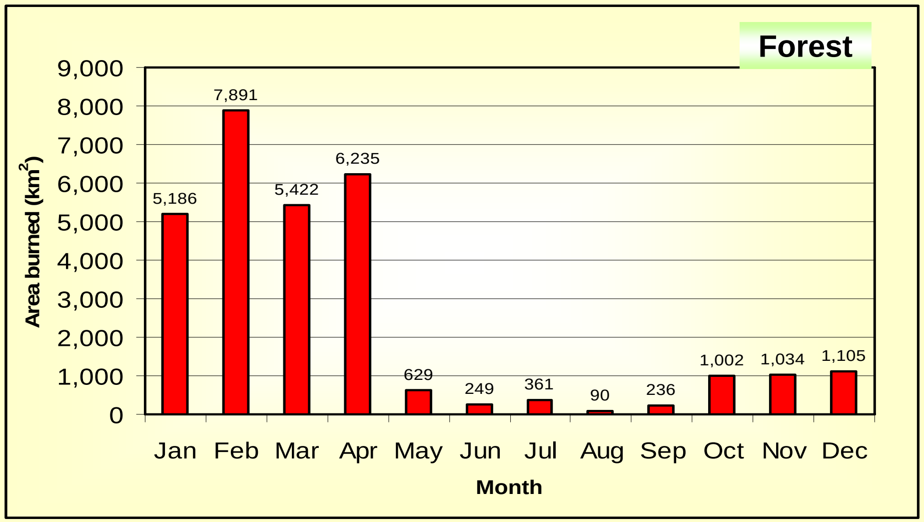
Exercise I: Calculation of Emissions from Biomass Burning in MRBSR in 2002

- Area burned – Lao PDR



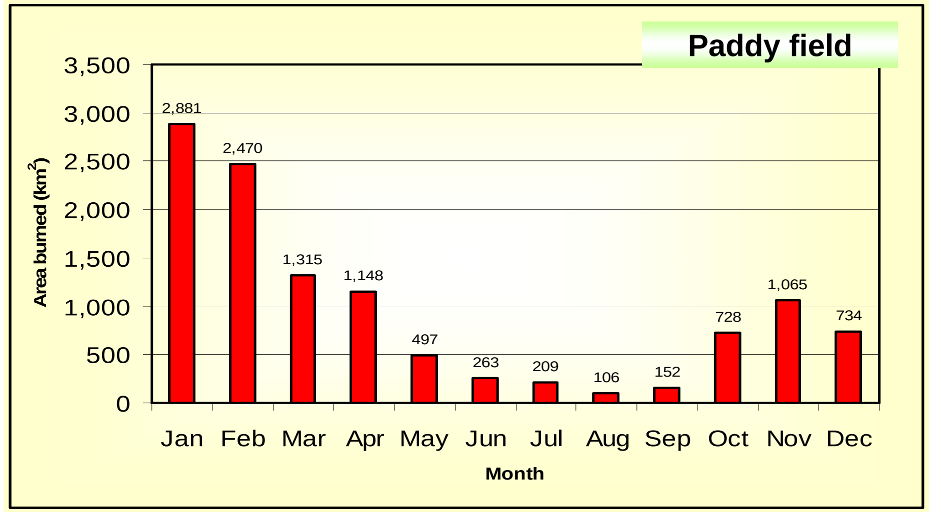
Exercise I: Calculation of Emissions from Biomass Burning in MRBSR in 2002

- **Area burned – Thailand**



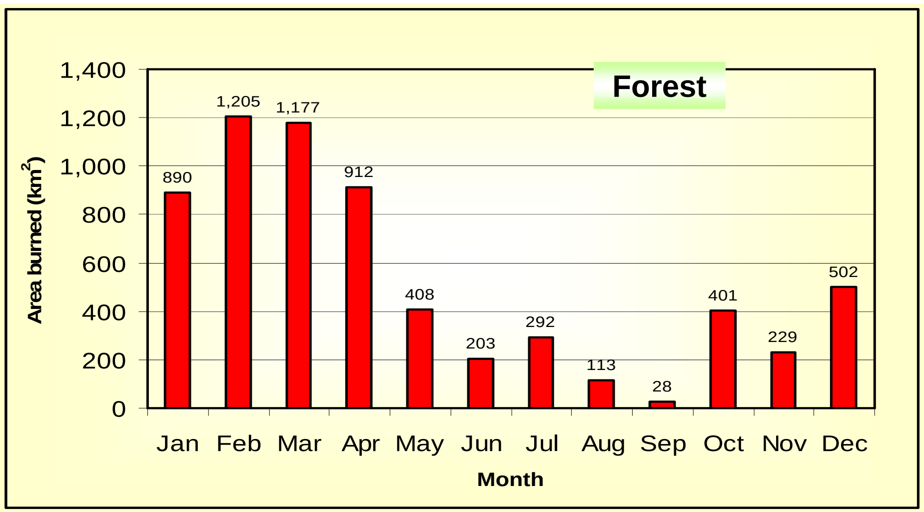
Exercise I: Calculation of Emissions from Biomass Burning in MRBSR in 2002

- **Area burned – Thailand**



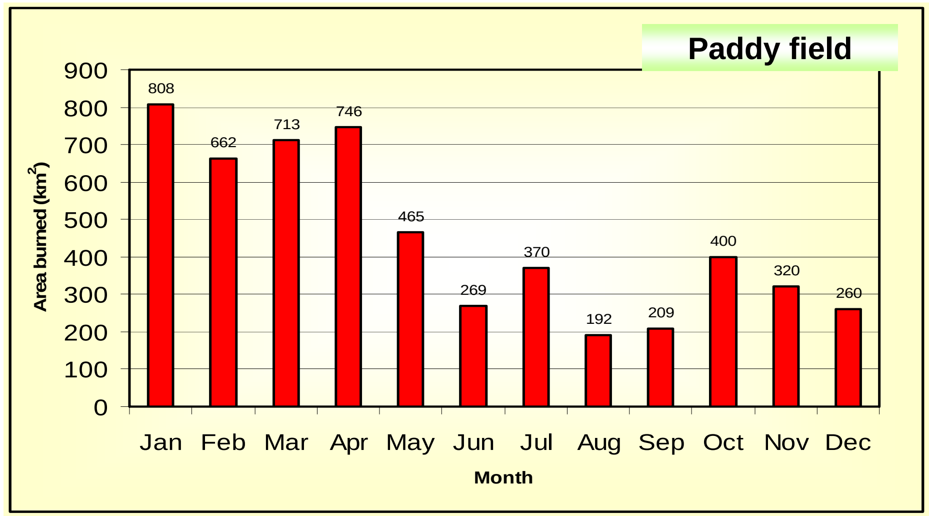
Exercise I: Calculation of Emissions from Biomass Burning in MRBSR in 2002

- **Area burned – Vietnam**



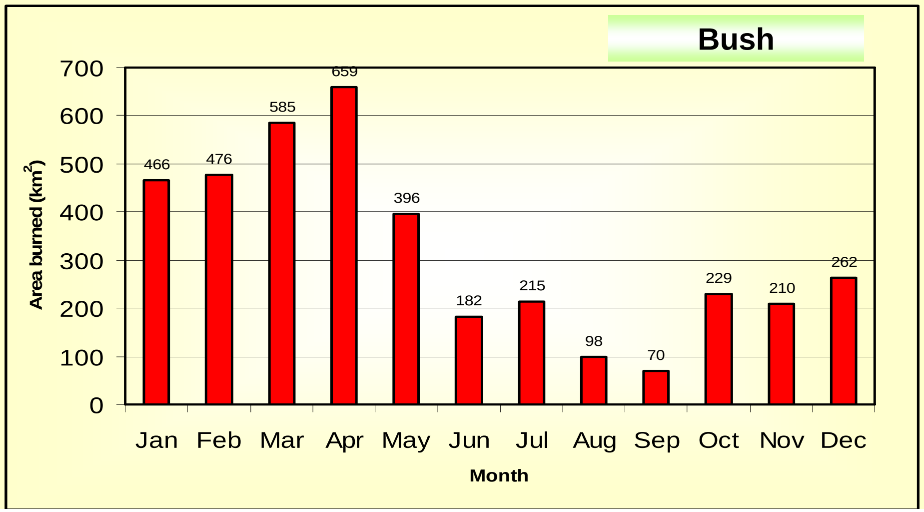
Exercise I: Calculation of Emissions from Biomass Burning in MRBSR in 2002

- **Area burned – Vietnam**



Exercise I: Calculation of Emissions from Biomass Burning in MRBSR in 2002

- **Area burned – Vietnam**



Exercise I: Calculation of Emissions from Biomass Burning in MRBSR in 2002

- **Example of Emission Factors**

Table 5. Emission Factors for Biomass Burning (g kg^{-1})[a]

Vegetation Type	SO_2	NO_x	NMVOC[b]	CO	BC	OC	NH_3	CO_2	CH_4
Savanna/Grassland	0.35	5.98	9.73	65	0.48	3.4	1.05	1613	2.3
Tropical Forest	0.57	2.45	19.32	104	0.66	5.2	1.3	1580	6.8
Extratropical Forest	1	4.6	21.79	107	0.56	9.15	1.4	1569	4.7
Crop Residue	0.4	3.83	15.7	92	0.69	3.3	1.3	1515	2.7

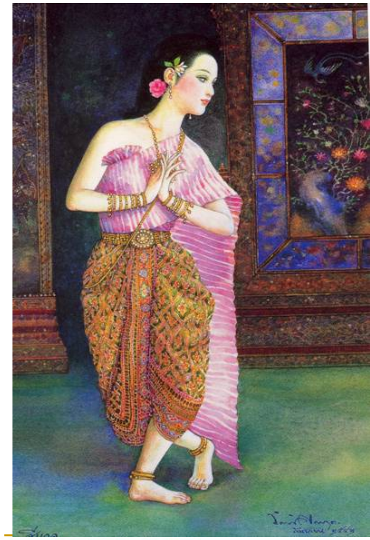
[a]Source: *Andreae and Merlet* [2001].
[b]An emission factor for NMVOC was derived by combining the emission factors of many individual NMVOC species from *Andreae and Merlet* [2001].

Streets et al., 2003

Exercise II: Spatial Distribution of Fires in February 2002

- **Materials – Excel Spreadsheet**
  - **Hotspots detected by DMSP-ANDES satellite**
  - **Above ground biomass density of different type of vegetation**
  - **EF (CO_2, CO, CH_4, NO_x, N_2O, TPM)**
- **Output**
  - **Emission map for each of the 4 countries**

Acknowledgements



Southeast Asia START
IHDP • IGBP • WCRP
Regional Committee

กรมควบคุมมลพิษ
POLLUTION CONTROL DEPARTMENT

APN
Asia-Pacific Network for Global Change Research
CAPaBLE

ขอบคุณค่ะ
Khob Khun Kha
สวัสดีค่ะ
Sawasdee Kha

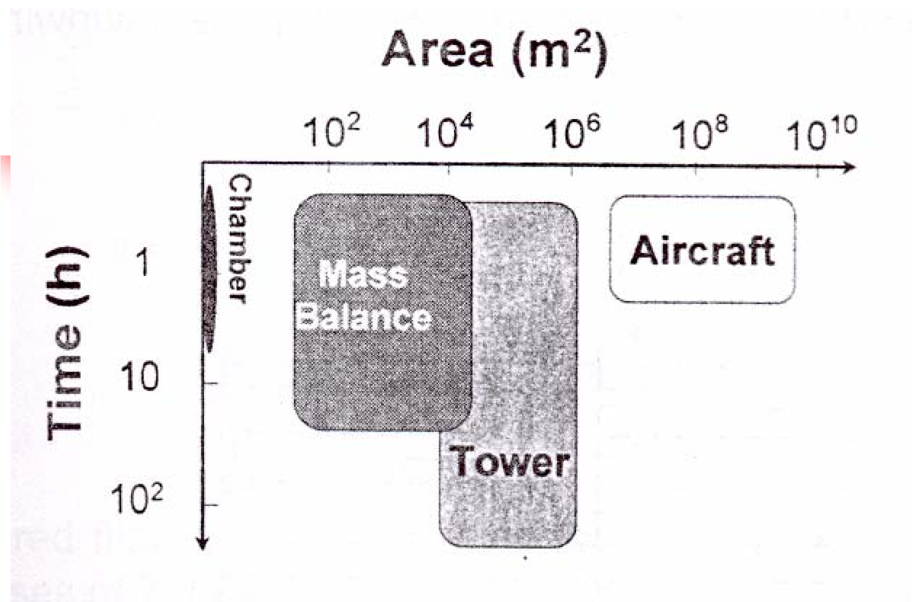
DAY III:

Biogenic emissions:
Keynote and hands-on session lectures

I. Close Chamber Method to Measure CH_4 and N_2O fluxes from rice field and forest

Amnat Chidthaisong,
JGSEE, May 3, 2007

- **Several techniques exist, and each has advantages and disadvantages**
- **No single approach is applicable to all studies**



Chamber method

Chamber

- **Restricts the volume of air exchange across the covered surface**
- **Any net emission or uptake can be measured as a concentration change**
- **Valid only when there is no significant perturbation**

Advantages of enclosure method

➔ low cost

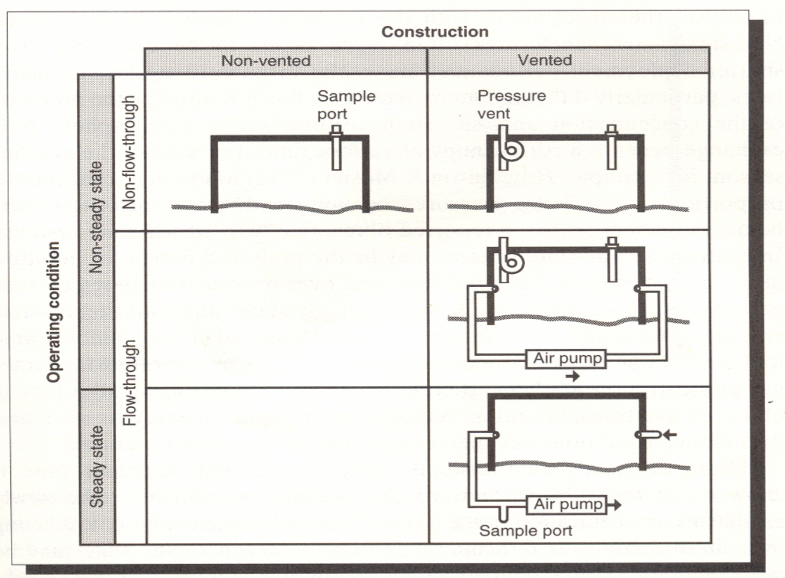
➔ simple to operate

➔ especially useful for addressing research objectives served by discrete observation in space and time

➔ in combination with appropriate sample allocations, it is adaptable to a wide variety of studies on local to global spatial scales

➔ particularly well suited to *in situ* and laboratory-based studies addressing physical, chemical and biological controls of surface-atmosphere trace gas exchange.

Enclosure type



Non-vented

➔ **good for short deployment period and low exchange rate**

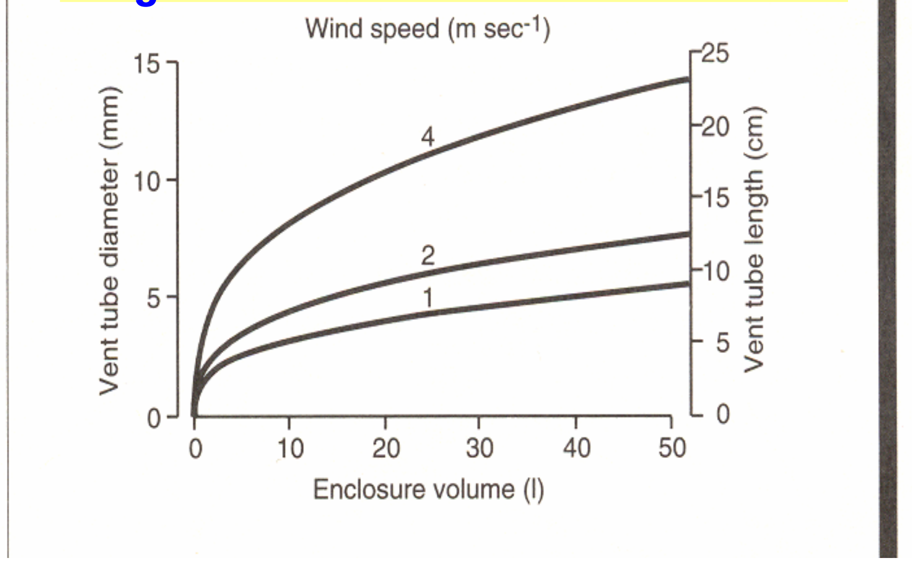
➔ **particularly applicable if the minimum detectable flux is limited by precision of the concentration analysis**

Vented-enclosure

➔ good for monitoring at fixed locations over extended or repeated time periods

➔induced smaller changes in the subsurface trace gas concentration gradient, thus resulting in not only a small bias in observed rates but also more rapid recovery to near pre-disturbance conditions.

Venting may be achieved by using appropriate vent tube diameter and length.



Chamber geometry

- Small volume:basal area ratios

➔more rapid concentration increases

➔the more rapid feedback to the concentration gradient driving molecular diffusion across the surface

- Large volume:basal area ratios

➔require longer sampling intervals to obtain a detectable concentration difference

➔more constant rate of concentration change within the enclosed air.

In general:

➔V:A (or height) should be small enough that a change in concentration can be measured over as short a time as logistically possible.

➔and V:A should be large enough to minimize disturbance of the enclosure surface

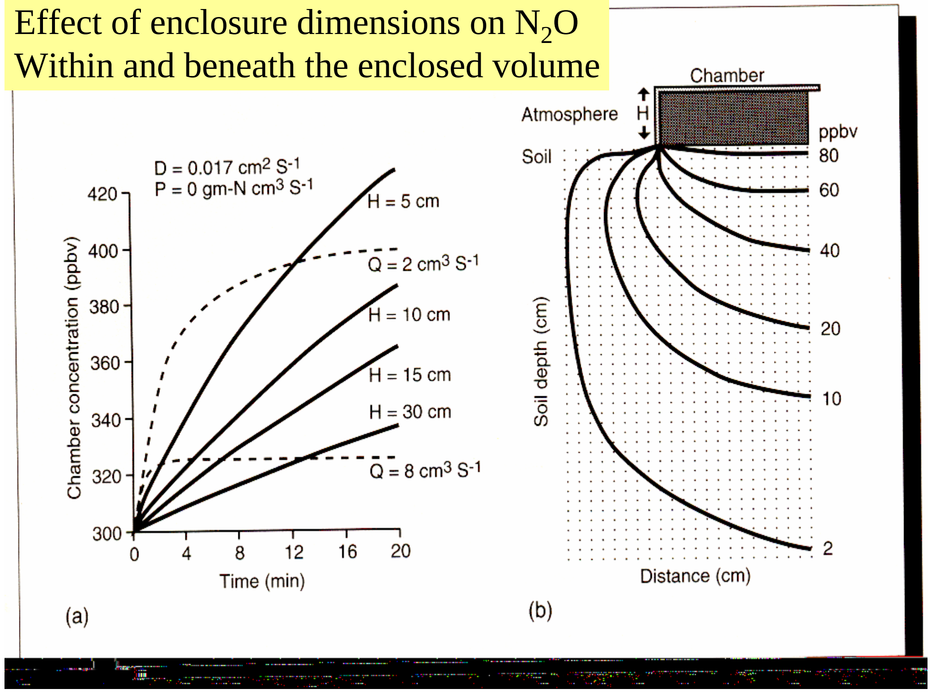
For example:

➔large exchange rate is best served by chambers with large V:A ratios and short deployment period.

➔small chambers and longer deployments are more applicable to low-flux site.

- **Reported V:A ratios differ widely but are typically greater than 15 cm in field studies.**
- **Overall measurement periods are generally in the range of 20-40 min.**
- **When possible, measurement periods should be chosen such that the rate of concentration change can be assumed constant and therefore modeled using linear regression.**

Effect of enclosure dimensions on N_2O
Within and beneath the enclosed volume



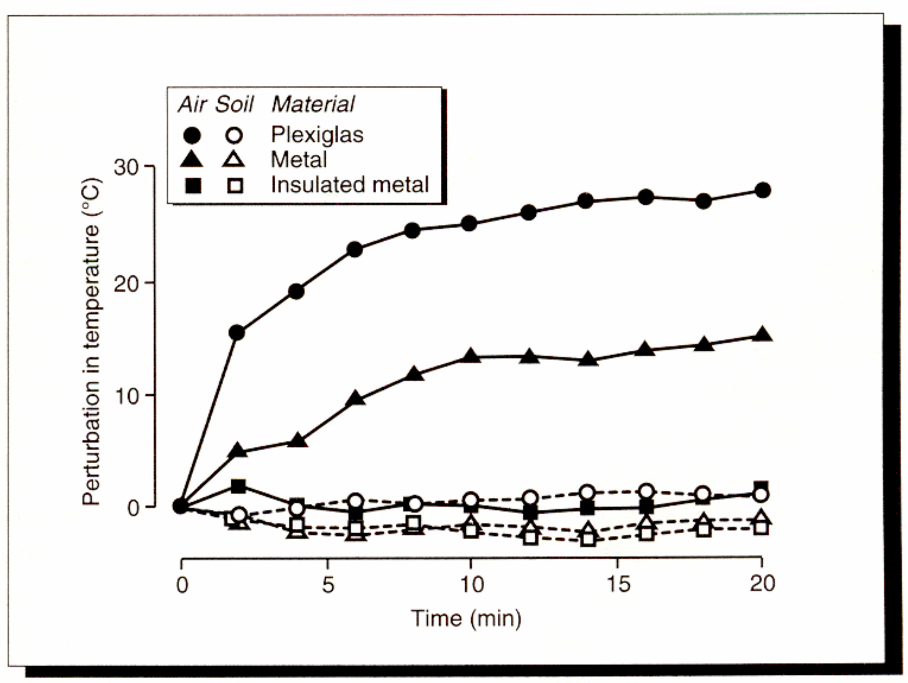
Chamber shape

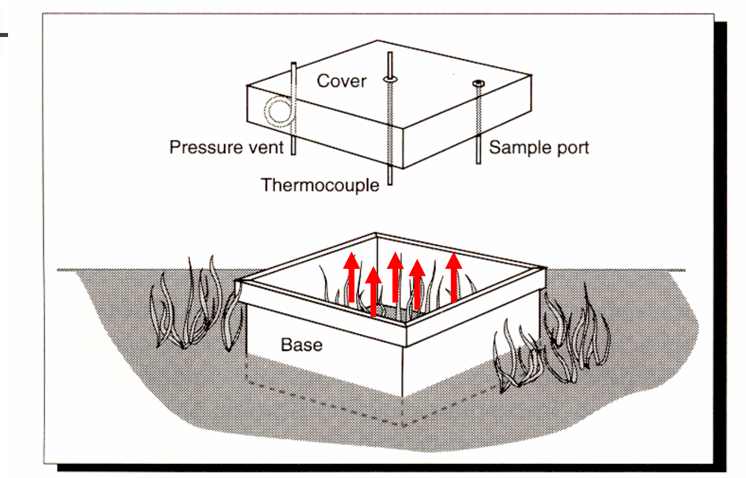
- Any chamber geometry is acceptable as long as it does not inherently restrict mixing within the enclosed air volume, though cylindrical and rectangular chambers are commonly used.
- The most common basal areas are on the order of 500-900 cm^2, but typically 175 cm^2 to 1 m^2 is used for field study.

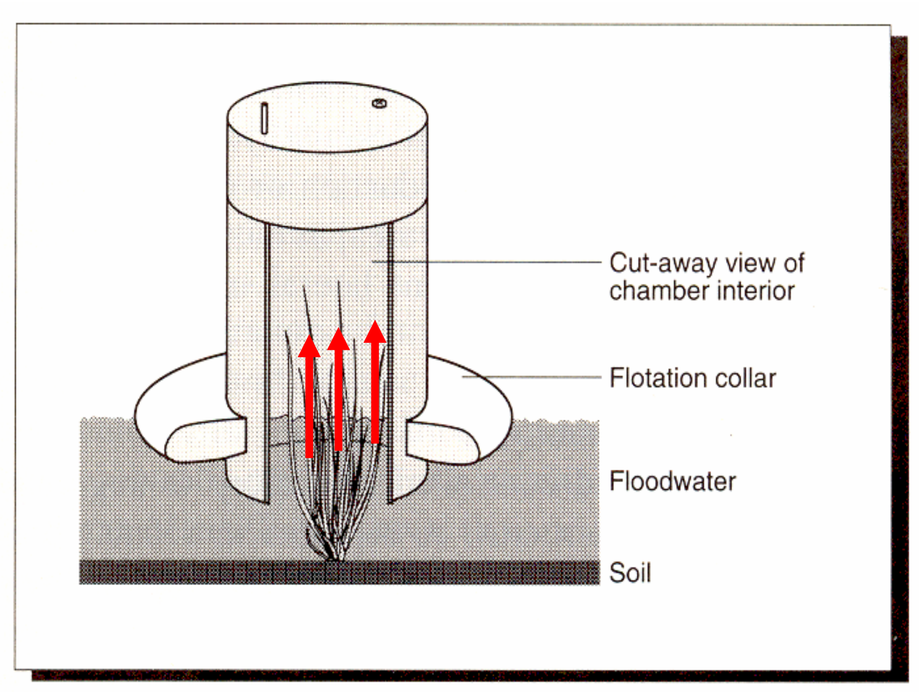
- **Selection of basal area is largely defined by the scale of the questions addressed by the research objectives and sampling allocation.**
- **Sometimes should be small enough that environmental controls can be assumed uniformly distributed over the enclosed surface (such as steep environmental gradients).**

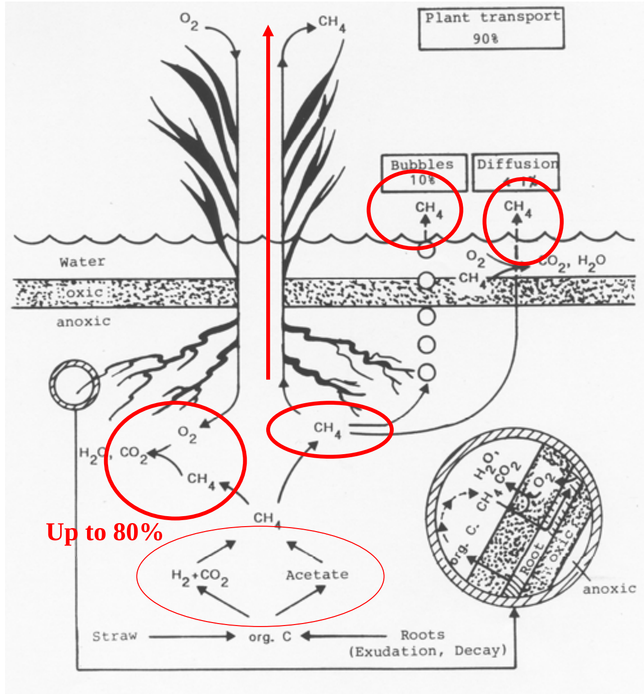
Material/Fabrication

- Importance is all materials be inert, i.e. non-permeable, non-reactive and not a source or sink for the gas species of interest.
- Aluminium, stainless steel and various plastics are good for non-reactive gases such as CH_4 and N_2O.
- For reactive gas such as NOx, NH_3, or sulfur gases: glass, Teflon, or another inert material is required.



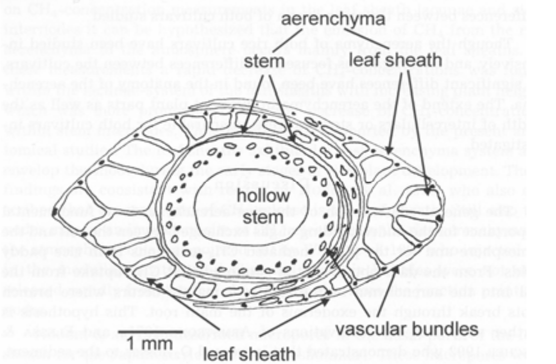




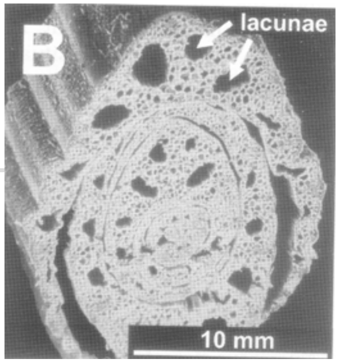


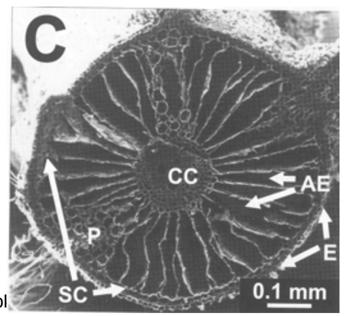
Emission of CH_4 in rice paddy and some wetlands

Aerenchyma of rice



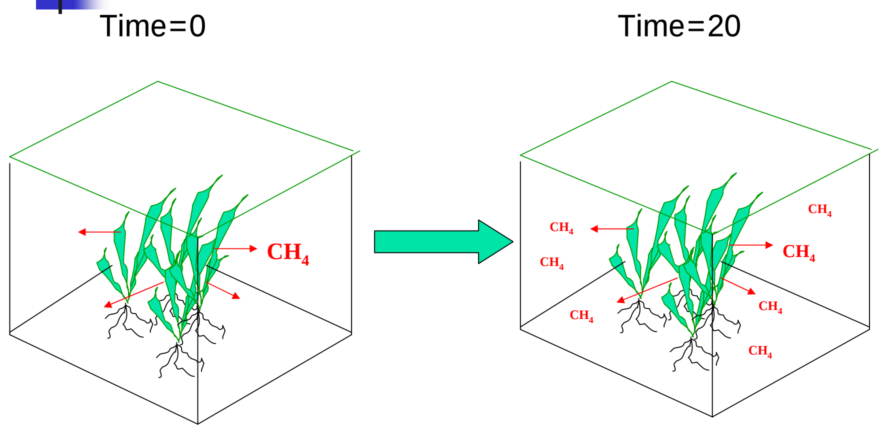
stem





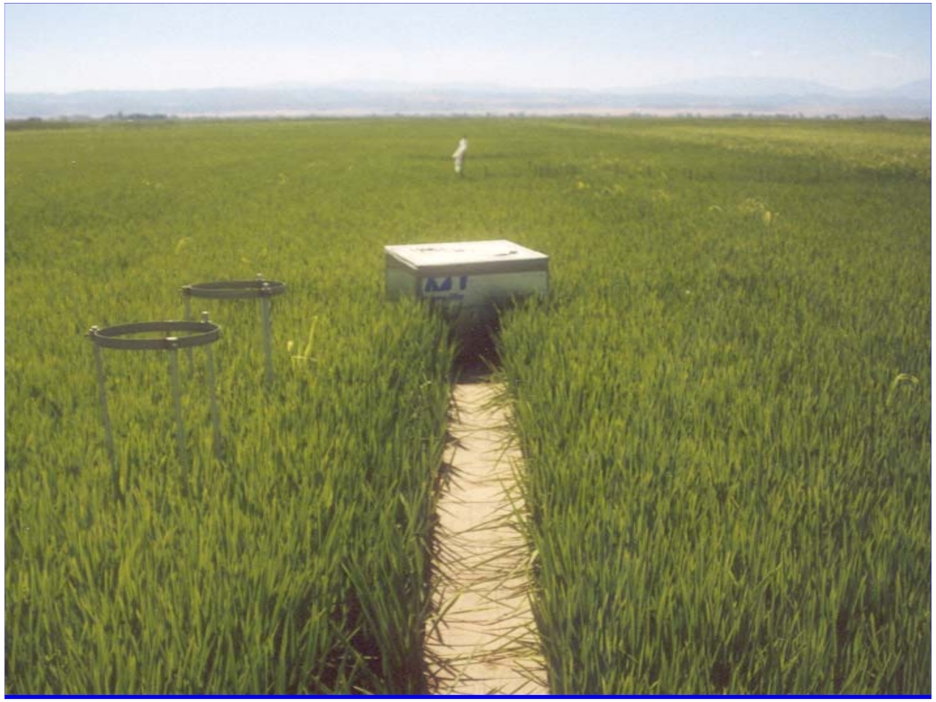
root

Butterbach-Bahl 2000



Sampling port

- Syringe sampling can be accommodated by a self-sealing septum or a value with fitting.
- Withdrawal volume should be small to avoid the change in pressure.

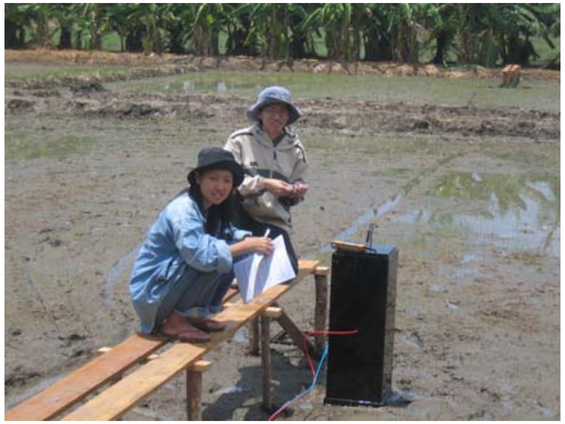


Six separate plots

Prepareing the wood bridg

Measurement of CH_4 and CO_2 flux

Chamber placement



Deployment in the field

- Minimize soil & plant disturbance
- No leak
- Sampling 1-2 m away from the chamber if possible

Sample handling and Analysis

- Test in the lab before use
- Analysis of air sample should be within a few hours following collection to minimize adverse storage effects.
- Loss or dilution of samples stored in syringes is often 2% or more per day.
- Glass container permits a longer storage times, but not without added potential for contamination by or leakage through the stoppers.

- **For N_2O, red rubber stopper serum vials ranking worst and screw-cap tubes with Hungate septa ranking the best for sample storage vials.**
- **As a regular practice, gas standard with known concentration should be handled, stored and analyzed regularly in the same manner as actual samples.**

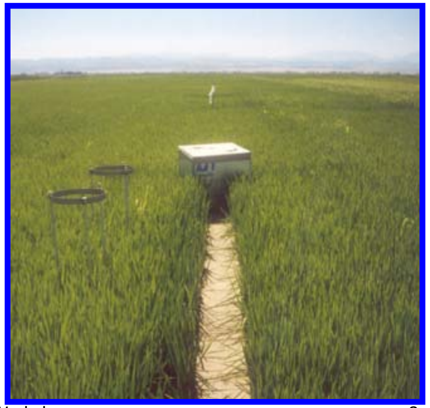
II. Hand-on Session: Comparative Flux Study

Amnat Chidthaisong,
JGSEE, May 3, 2007

We will compare:

- Two detection techniques:
  - Online, semiconductor-based sensor
  - Gas Chromatography

Method for Emission Measurements



Current Procedures

Chamber enclosure

↓

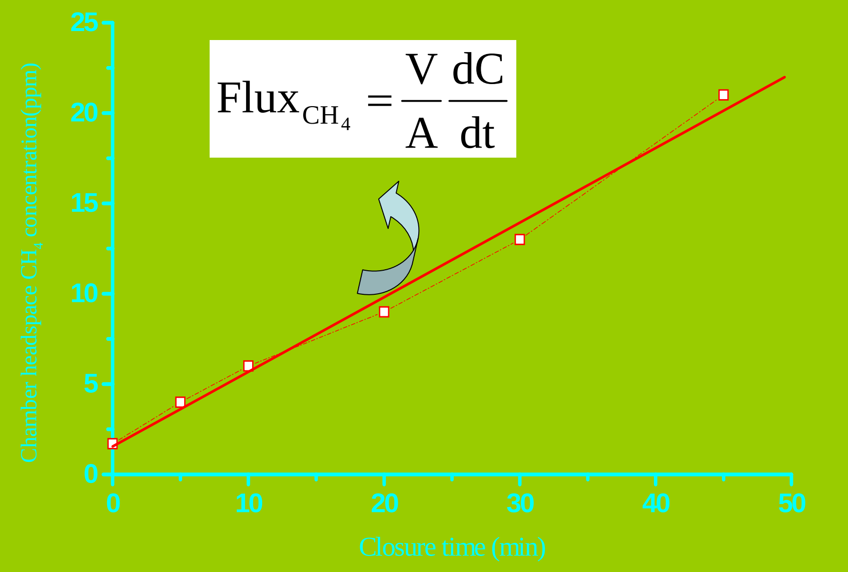
Gas samples

↓

Gas Chromatography

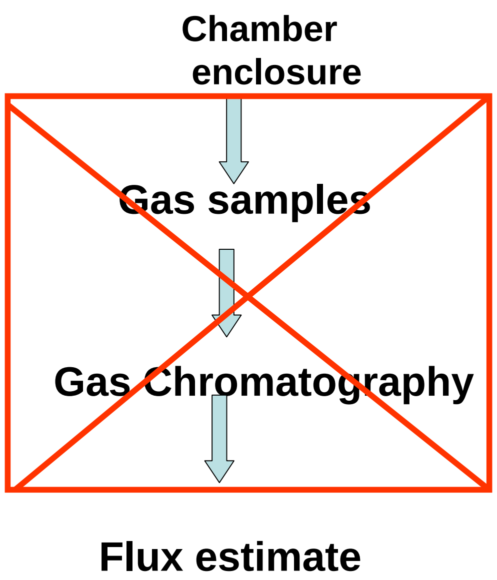
↓

Flux estimate

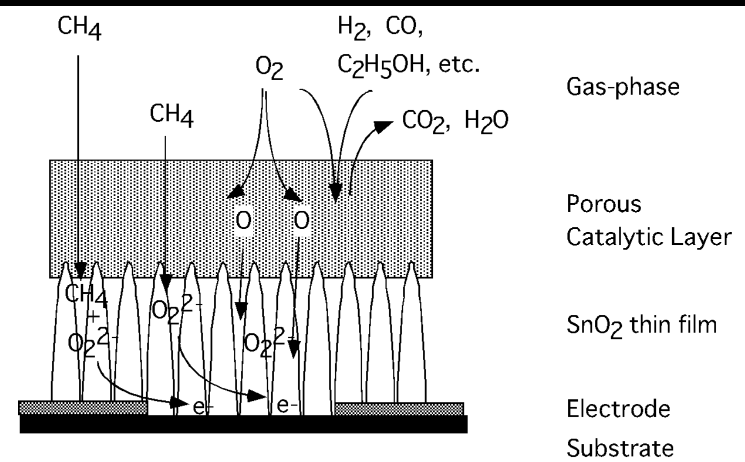


Drawbacks

- Time consuming
- Limited replication
- Expensive
- Accuracy concerns
- Not applicable in the remote area

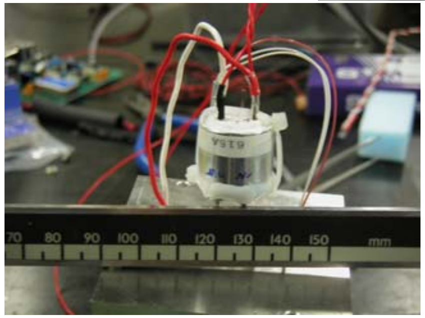


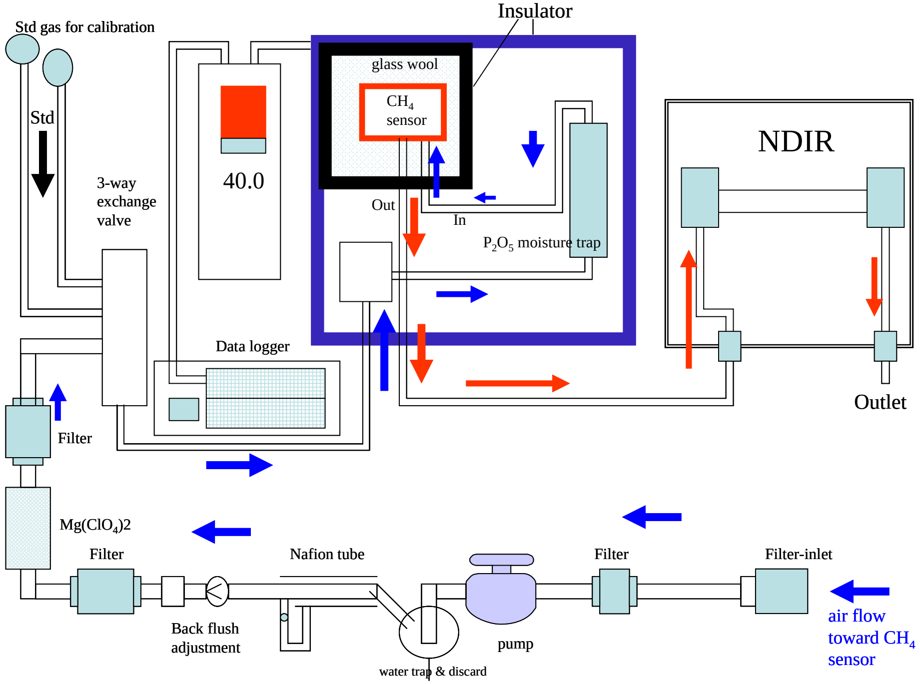
Sensing Mechanism

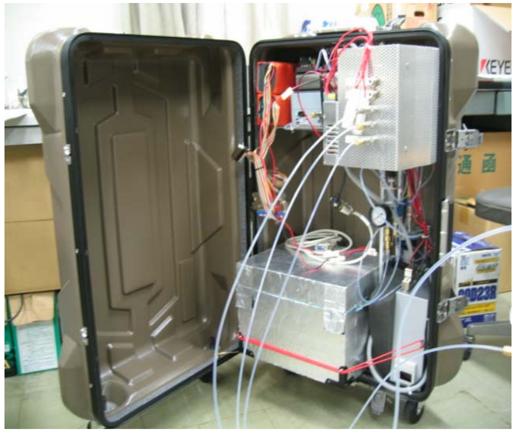


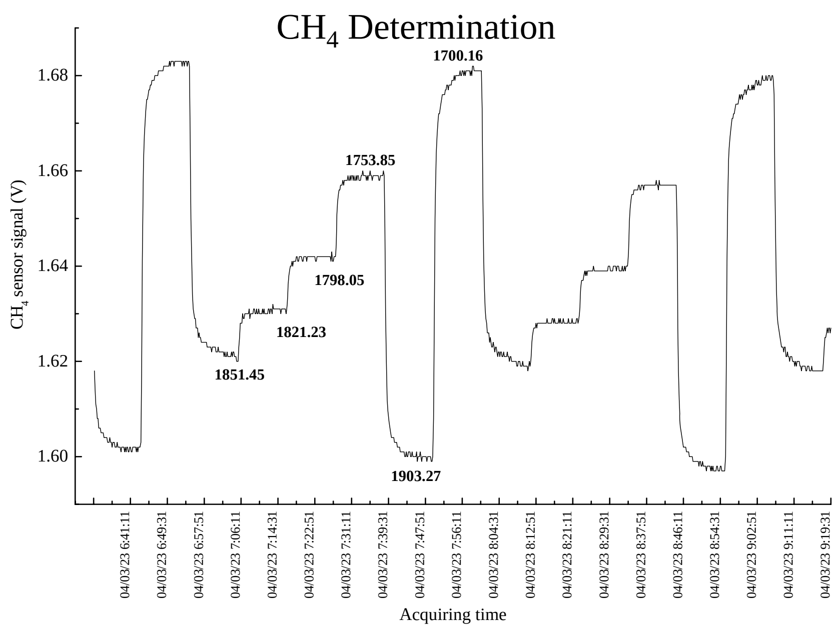
Conductiv... ions are released; proportio... reduced gas

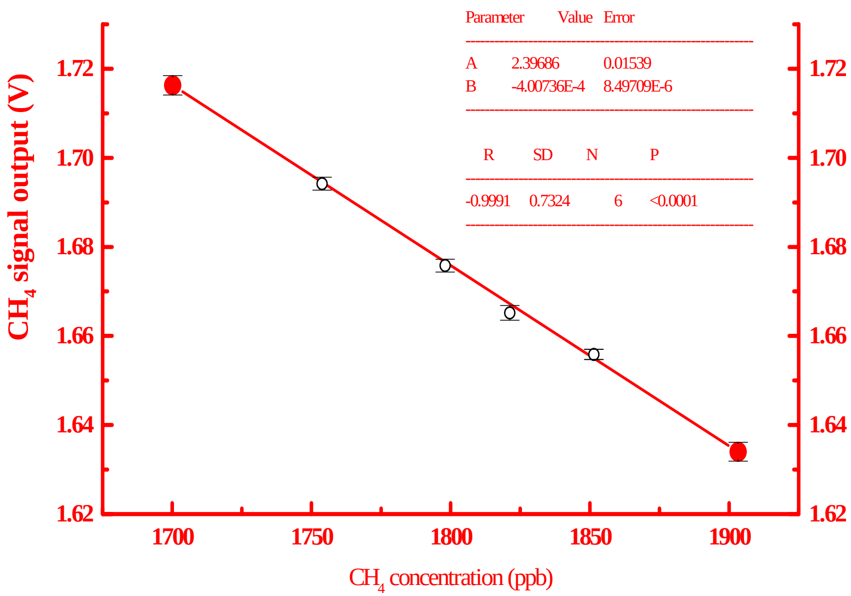
$R+O_2^{2-} \rightarrow RO+2e^-$



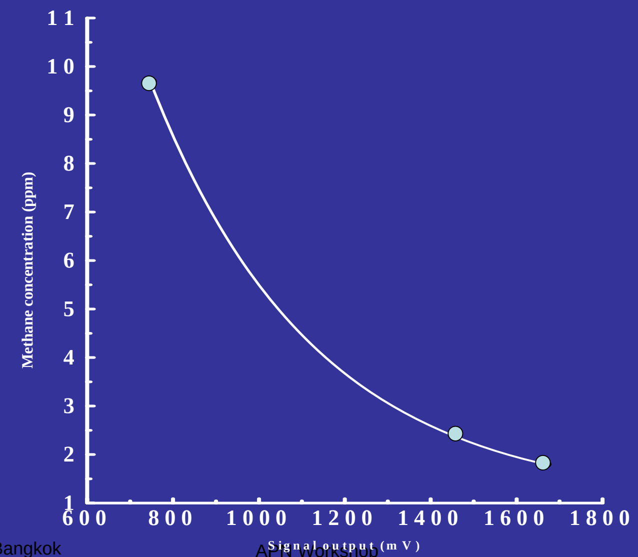

Insulator
Std gas for calibration
Std
glass wool
CH4 sensor
40.0
3-way exchange valve
Out
In
P2O5 moisture trap
NDIR
Outlet
Data logger
Filter
Mg(ClO4)2
Filter
Nafion tube
Filter
Filter-inlet
Back flush adjustment
pump
water trap & discard
air flow toward CH4 sensor

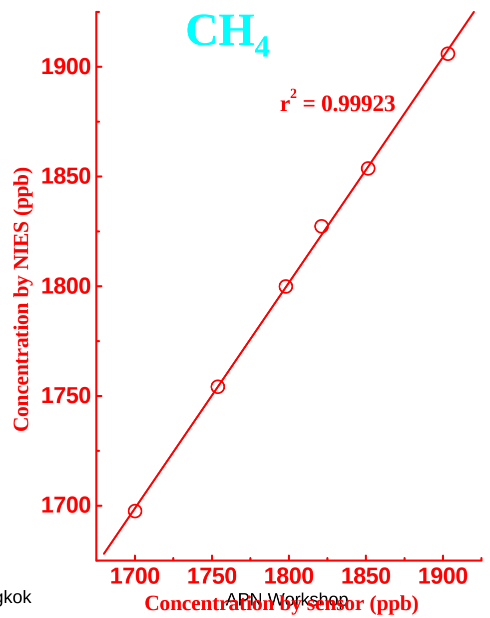



CH4 Determination
1700.16
1753.85
1798.05
1821.23
1851.45
1903.27
CH4 sensor signal (V)
1.68
1.66
1.64
1.62
1.60
Acquiring time

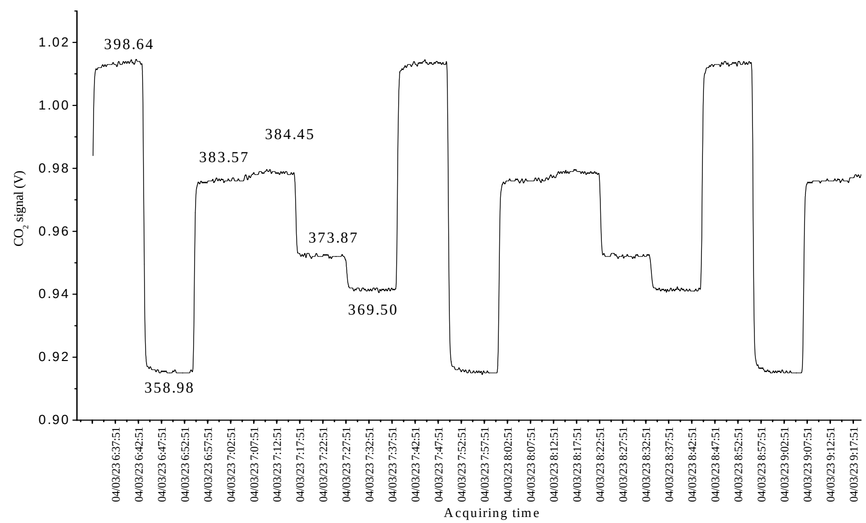


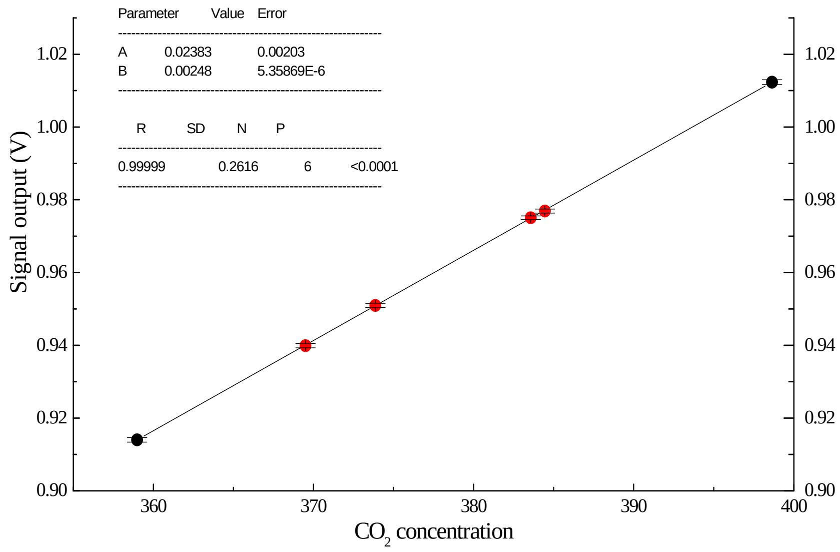
Measurement Range

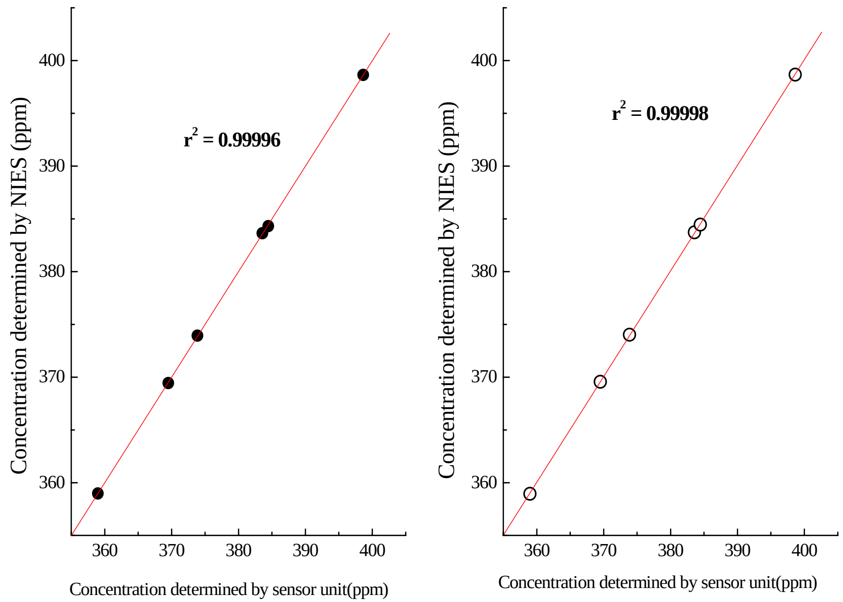




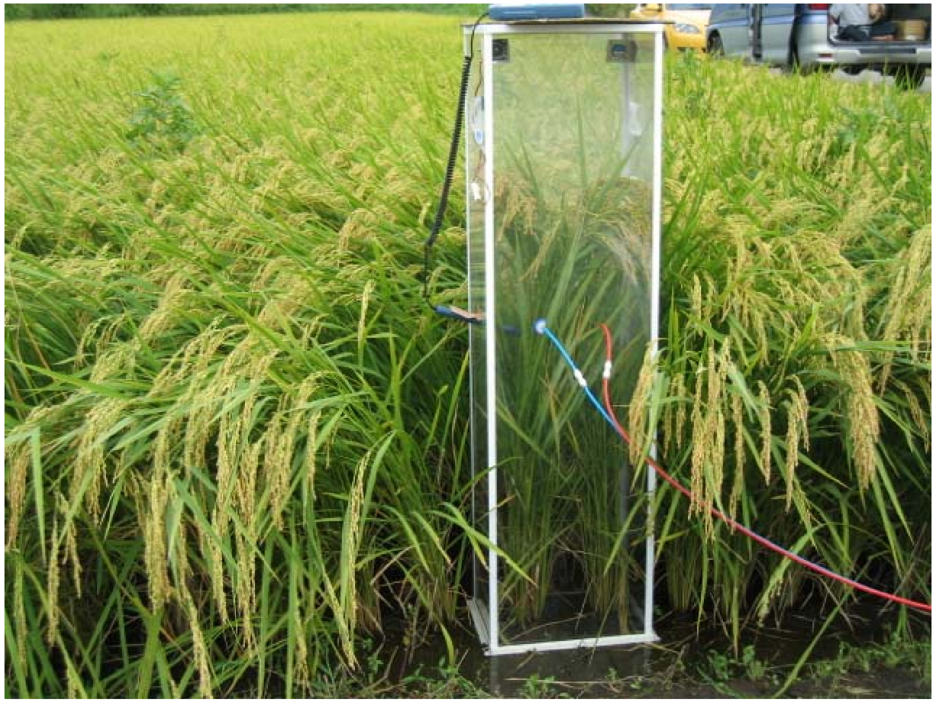
CO_2 Determination

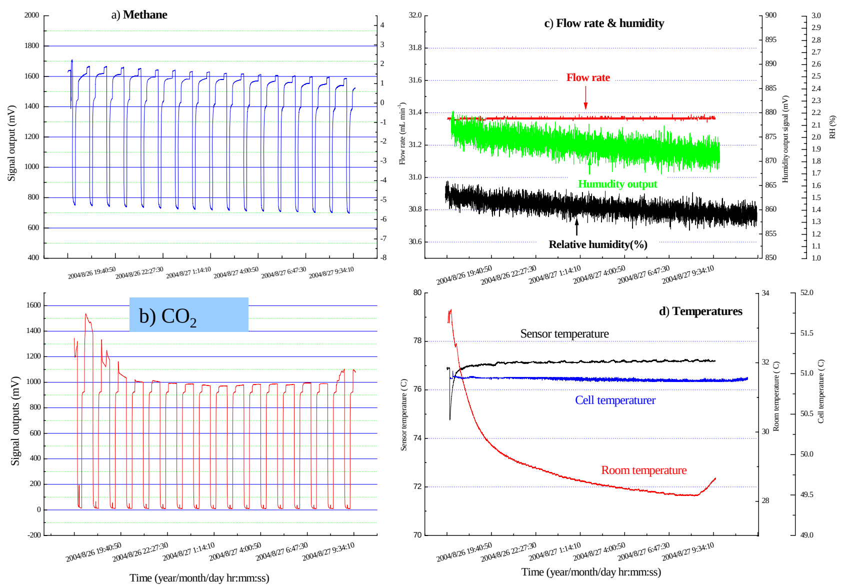


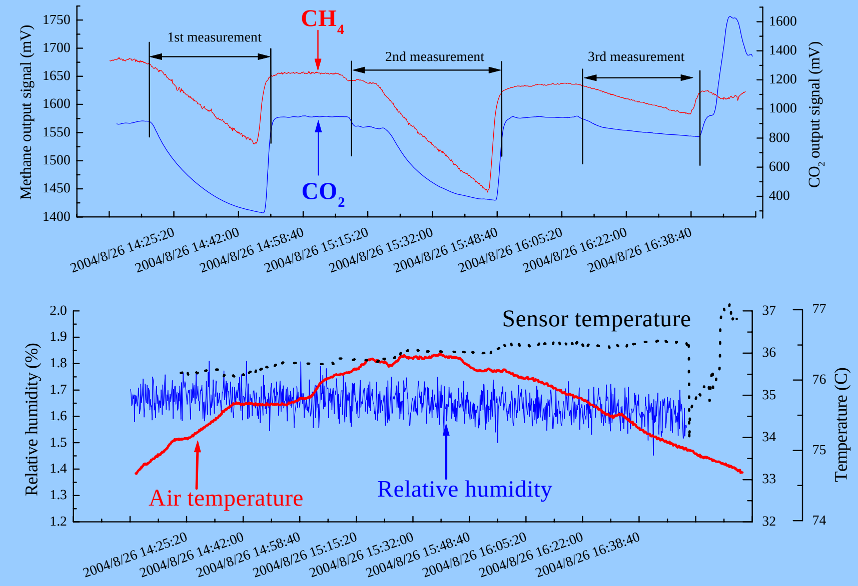

Parameter Value Error
A 0.02383 0.00203
B 0.00248 5.35869E-6
R SD N P
0.99999 0.2616 6 <0.0001
Signal output (V)
CO2 concentration


r2 = 0.99996
r2 = 0.99998
Concentration determined by NIES (ppm)
Concentration determined by sensor unit(ppm)

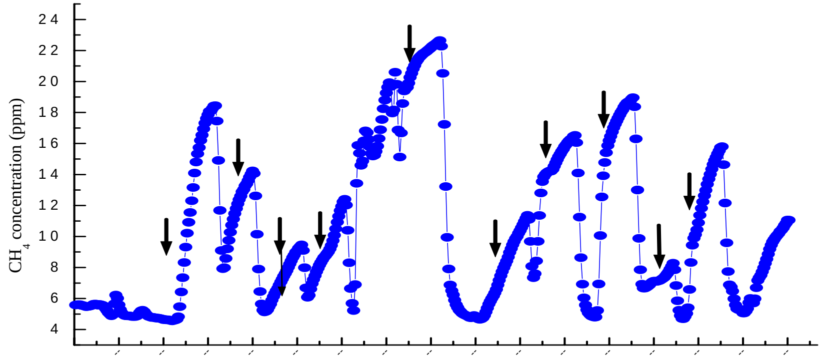

PROTEX



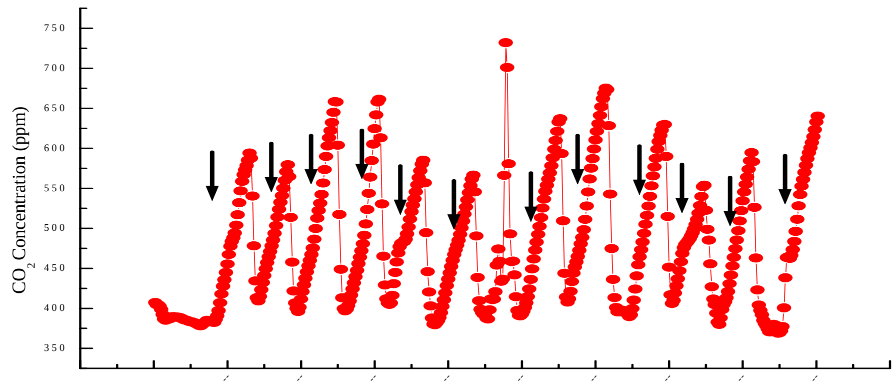




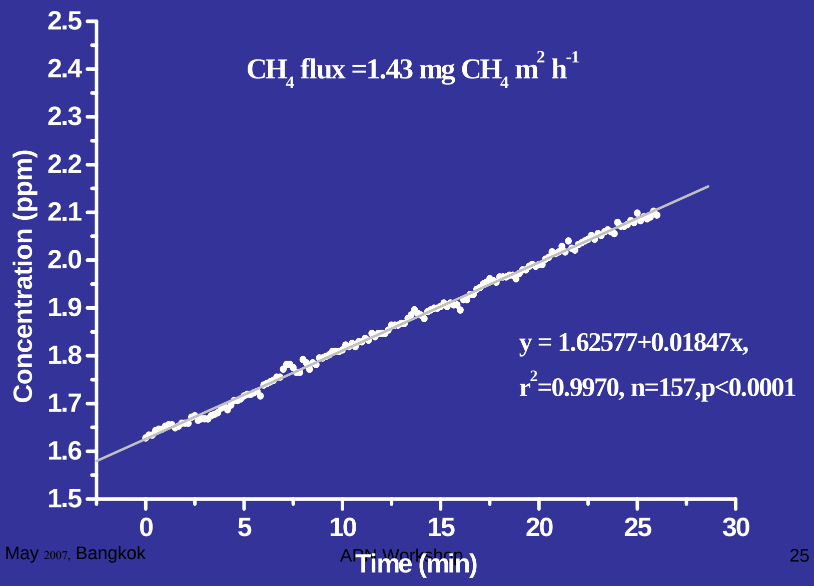
CH_4 measurements

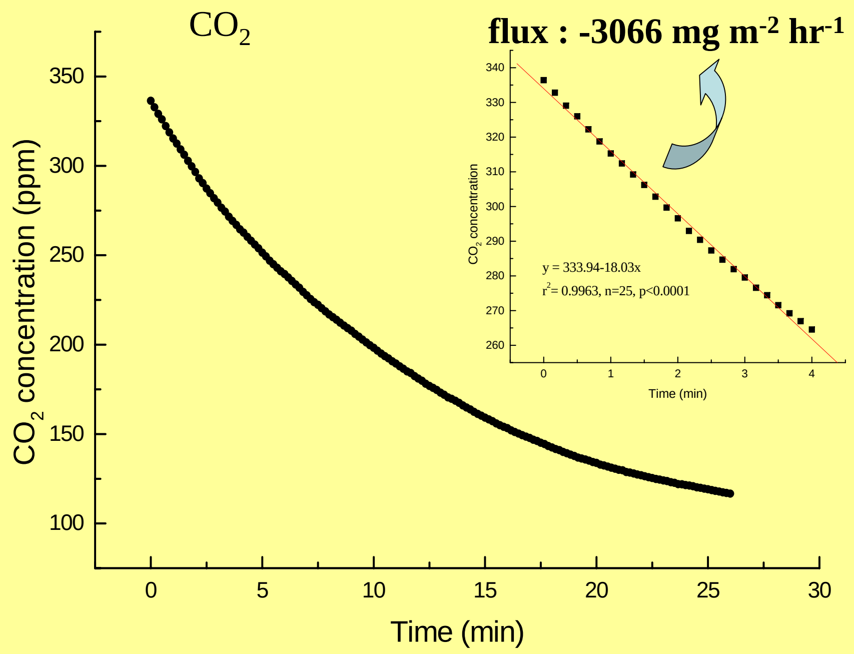


Measurement of CO_2



Methane Flux





Determining CH_4 by GC

Chamber enclosure

⇩

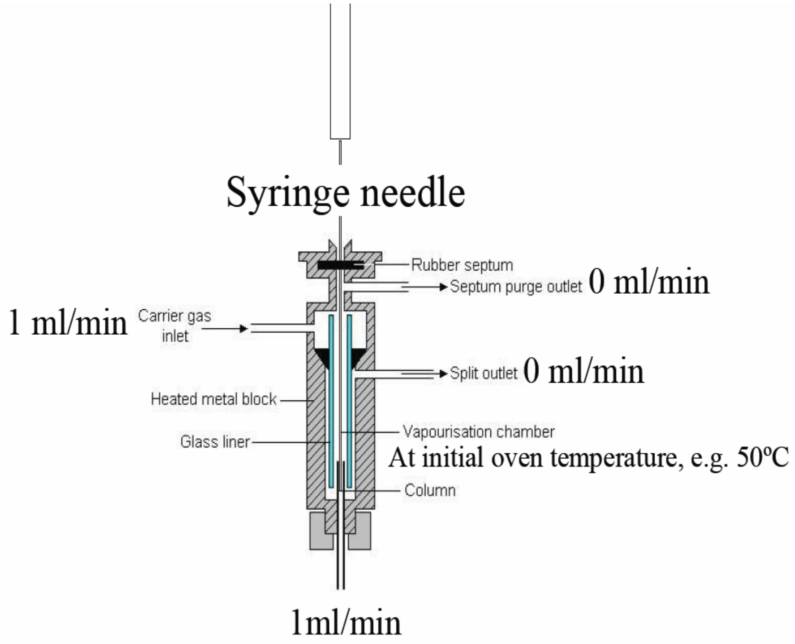
Gas samples

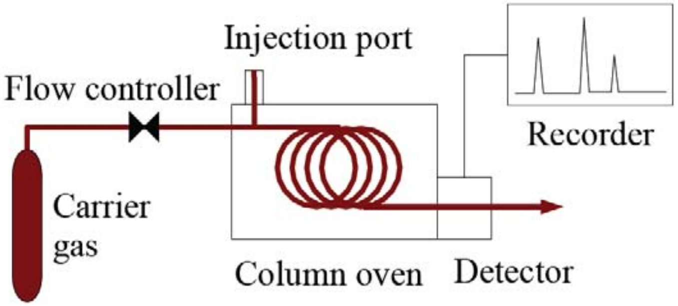
⇩

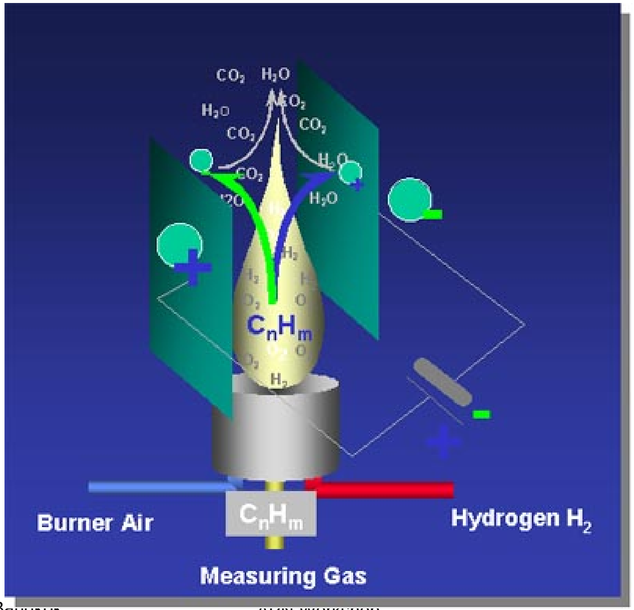
Gas Chromatography

⇩

Flux estimate




Injection port
Flow controller
Recorder
Carrier gas
Column oven
Detector


C_nH_m
Burner Air
Hydrogen H_2
Measuring Gas

III. Flux estimation

1. Assuming a model of the relation between concentration and time in the enclosure
2. Fitting the model to the observed concentration data
3. Predicting the exchange rate
4. Testing the credibility of the prediction

Minimal requirement:

➔ gas concentration as a function of time

➔ enclosure basal area

➔ volume of enclosed air

Mixing ratio must be converted to a mass or molecular basis using the ideal gas law, thus, temperature and pressure of the enclosed air:

$$C_i = \frac{q_i M_i P}{RT}$$

C_i = mass/vol concentration
q_i = vol/vol concentratio (e.g. ppmv)
P = pressure
R = univeral gas constant
T = Kelvin

- Examples:

➔ 1.7 ppmv of CH_4 (current atmospheric concentration of CH_4) = 1.13 mg m^{-3} at 20°C and 1 atm

➔ 310 ppbv of N_2O = 0.57 mg m^{-3}

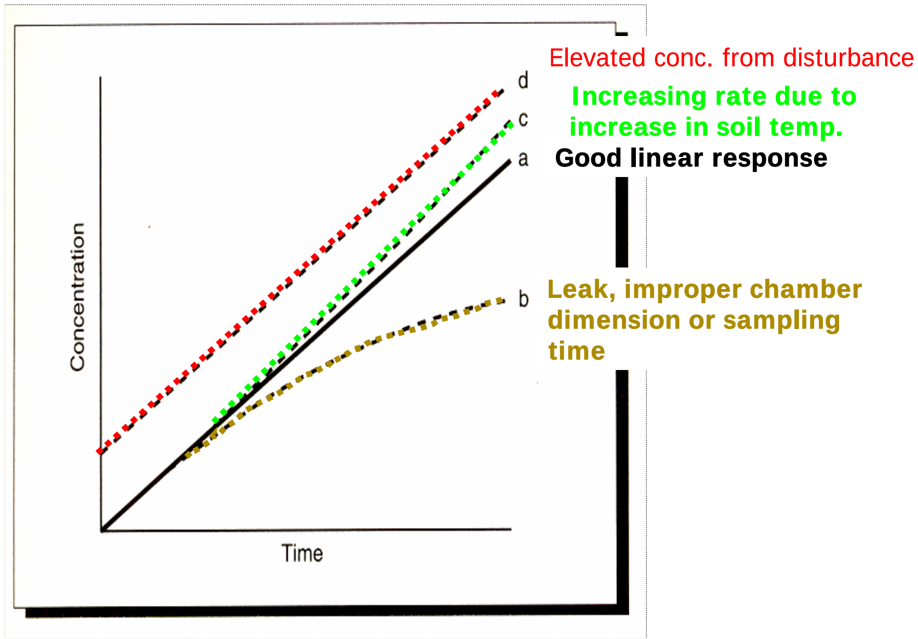
$$C_{CH_4} = \frac{\left(\frac{1.7\ m^3}{10^6\ m^3}\right) \times \left(16\ \frac{g}{mol}\right) \times 1\ atm}{\left(8.2058 \times 10^{-5}\ \frac{m^3 \cdot atm}{K \cdot mol}\right) \times (273 + 20)\ K}$$

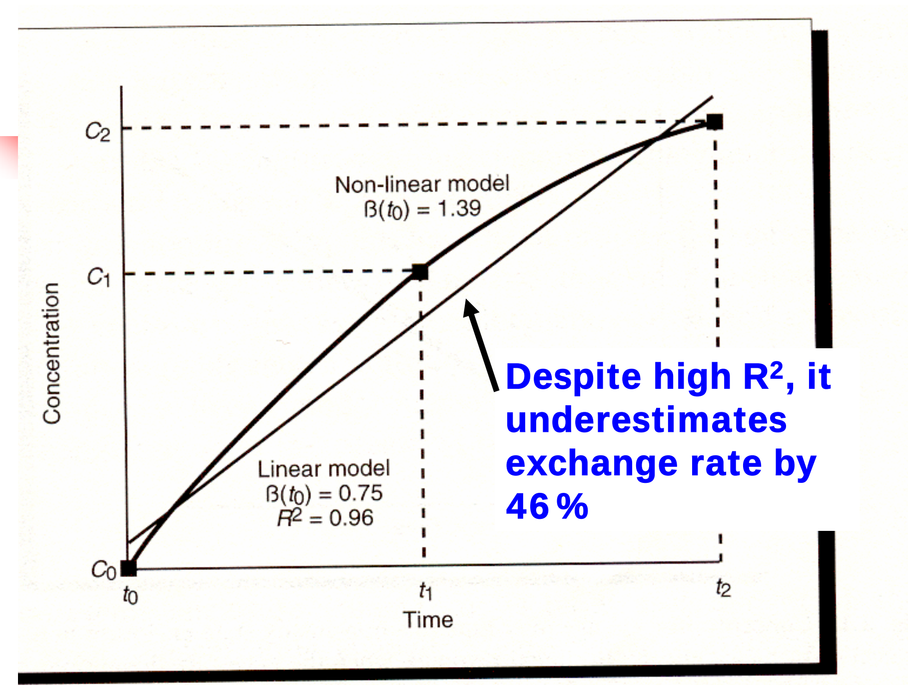
If enclosure dimension, deployment period and measurement protocol are appropriate, a linear model may be adopted. This method assumes a constant exchange rate over the period of observation

$$Flux_{CH_4} = \frac{V}{A}\frac{dC}{dt}$$

Verifying the model: qualitative examination of a scatter plot of actual vs. predicted concentration over time is often the most effective mean.

➔ This should be used to both identify and screen observations objectively that do not meet model expectation (site disturbance, improperly sealed enclosure, sample handling, storage or analytical difficulties, enclosure dimensions or deployment time not suited to exchange rate measured.





- ➔should apply statistic test (simple *t*-test is acceptable) for the significance of slope parameter
- ➔rate should reported only when significant correlation was found

More—other sources of errors

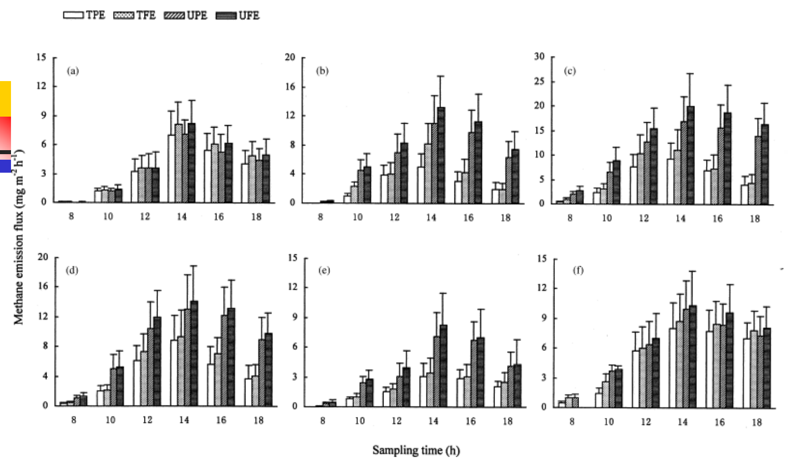
- Overall precision is dependent upon pooled precision of all parameters involved in calculation.

➔chamber volume:basal are ratio, a 1 cm error in the measurement of height for enclosures 20 or 50 cm tall corresponds to a 5 or 2% error in flux estimate.

➔1% error in concentration results from a 3°C error in the estimate of air temperature or a 1 kPa (7.6 mmHg) error in the estimate of total pressure.

Other considerations

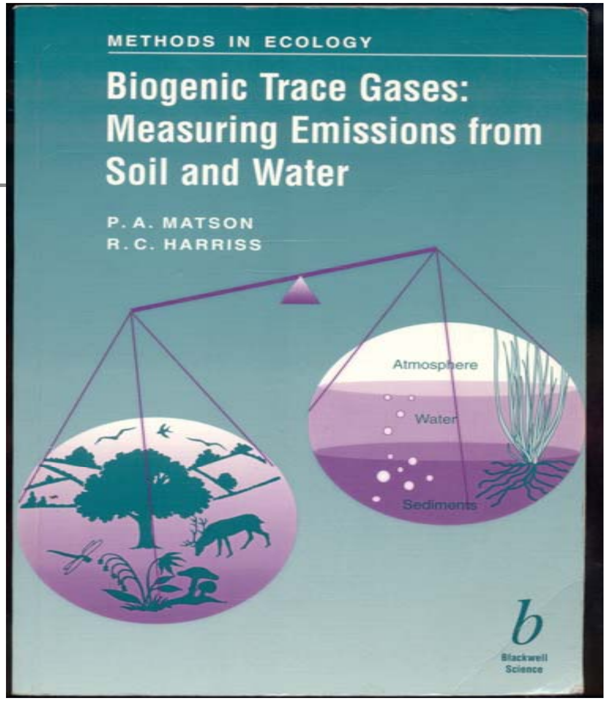
- Spatial and temporal variations
- Sampling points



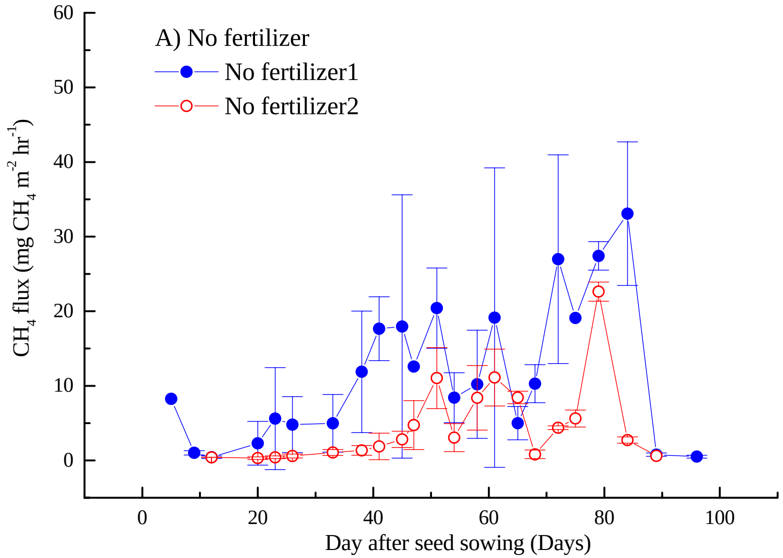
- Diurnal variations in methane emission flux (mg m^{-2} h^{-1}) during different growth stages of rice: (a) initial tillering stage; (b) full tillering stage; (c) young panicle differentiation stage; (d) booting stage; (e) complete heading stage; (f) ripening stage. TPE, rice–duck complex ecosystem in the plot experiment; TFE, rice–duck complex ecosystem in the field experiment; UPE, conventional rice field in the plot experiment; UFE, conventional rice field in the filed experiment.

Huang at al., 2004

More Details can be found in:



Emission Factor➔ mg CH_4 / m_2 / day



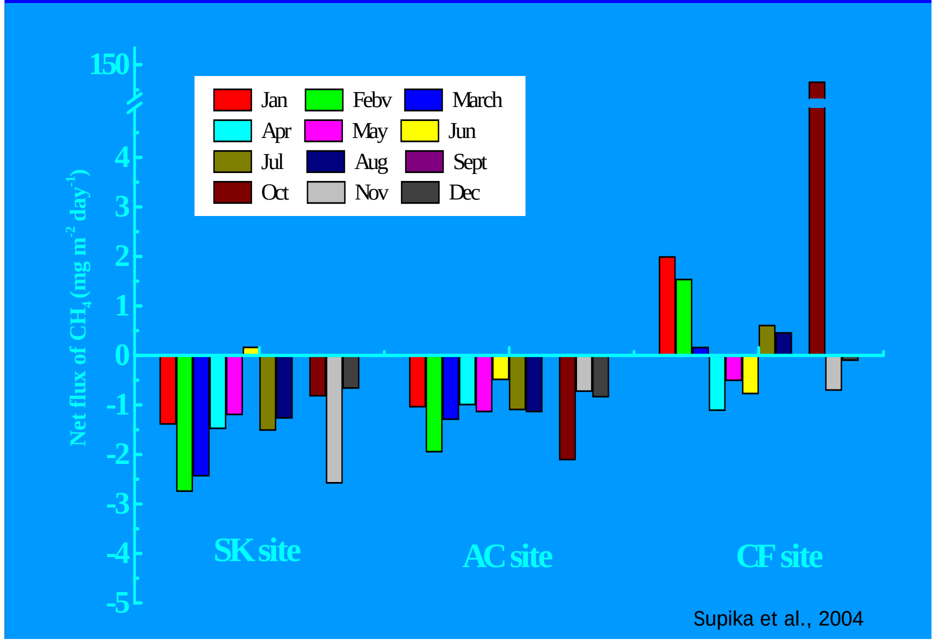
Paddy field emission

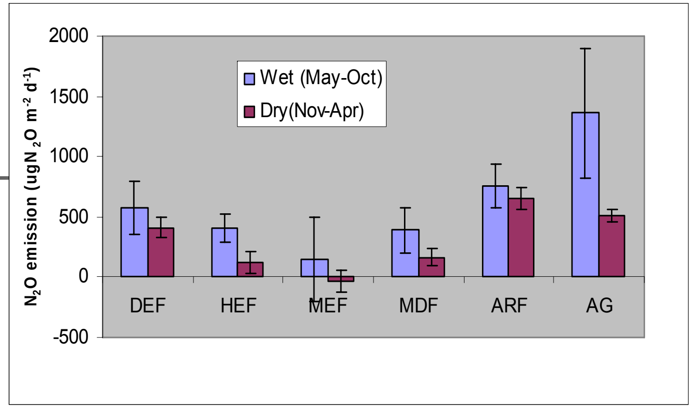
Treatment	CH_4 flux g m^{-2}	mg/m^2/day
Control	18.5	154
Chem.	11.0	92
Manure	13.8	115

Forest emission factor

- Measurement for one year
- Convert to mg/are/day or any suitable format

Net Methane flux (mg m^{-2} day^{-1})





The monthly average (±SD) (μg N_2O m^{-2} day^{-1})

DEF	491±321
HEF	261.9±268
MEF	46±456
MDF	276±321
ARF	627±346
AG	829±851

APPENDIX 4:

Training Workshop Evaluation

OVERALL EVALUATION OF WORKSHOP BY PARTICIPANTS

Table 4A: Evaluation of workshop

Detail	Percentage from Questionnaire (%)			
	Excellent	**Good**	**Fair**	**Poor**
1. Organization				
1.1 Suitability of the program arrangement	47.06	52.94	0.00	0.00
1.2 Time schedule	17.65	58.82	17.65	5.88
1.3 Logical sequencing of presentation	29.41	70.59	0.00	0.00
1.4 Keynote lectures	35.29	58.82	5.88	0.00
Comments:	- The meeting time/day is too long - Very good team work			
2. Scientific contents				
2.1 Workshop theme and scope	47.06	52.94	0.00	0.00
2.2 Keynote lectures	29.41	70.59	0.00	0.00
2.3 Presentations	29.41	70.59	0.00	0.00
Comments:	- Scientific contents is very good, but the background of some participants is not enough (myself) - Should be on-going - Some presenters took more time to deliver their talks than allocated in the schedule. - Maximum number of slides for presentation should have been recommended to the presenters in advance			
3. Facilities				
3.1 Accommodation	0.00	85.71	14.29	0.00
3.2 Transportation	12.50	68.75	12.50	6.25
3.3 LCD projector, Microphone, etc.	23.53	64.71	11.76	0.00
3.4 Documentation	23.53	64.71	11.76	0.00
3.5 Information desk and staff	35.29	64.71	0.00	0.00
Comments:	- The meeting area is so far and the circle table is not good			
4. Overall impression	18.75	81.25	0.00	0.00
5. Further comments/suggestions	- Very useful and informative workshop			

1 May 2007:	38	persons
2 May 2007:	27	persons
3 May 2007:	31	persons

APPENDIX 5:

Biomass Burning Data and Emission Maps

Table 5A: Forest fire counts and area burned (ha) (2002)

	Thailand		Cambodia		Vietnam		Lao PDR	
	Fire counts	Area burned	Fire counts	Area burned	Fire counts	Area burned	Fire counts	Area burned
January	1,928	518,600	756	372,400	315	89,000	320	110,200
February	2,610	789,100	1,340	556,600	365	120,500	468	142,600
March	1,866	542,200	685	208,400	341	117,700	687	224,500
April	1,936	623,500	244	53,000	311	91,200	937	325,100
May	333	62,900	60	14,200	151	40,800	116	32,800
June	148	24,900	16	3,300	103	20,800	35	6,500
July	138	36,100	48	22,200	111	29,200	27	7,700
August	65	9,000	4	1,100	53	11,300	28	10,500
September	132	23,600	6	2,700	19	2,800	50	19,200
October	459	100,200	83	33,700	130	40,100	157	57,300
November	521	103,400	61	13,200	75	22,900	137	46,700
December	471	110,500	195	94,400	142	50,200	129	34,300
Total (1 year)	10,607	2,944,000	3,498	1,375,200	2,116	636,500	3,091	1,017,400

Table 5B: Rice fire counts and area burned (ha) (2002)

	Thailand		Cambodia		Vietnam		Lao PDR	
	Fire counts	Area burned	Fire counts	Area burned	Fire counts	Area burned	Fire counts	Area burned
January	1,191	288,100	74	29,600	461	80,800	13	2,900
February	1,023	247,000	77	20,100	383	66,200	19	4,900
March	538	131,500	70	20,200	332	71,300	10	4,400
April	621	114,800	44	14,000	435	74,600	10	1,500
May	273	49,700	20	2,800	284	46,500	1	100
June	162	26,300	7	1,100	175	26,900	0	0
July	141	20,900	9	1,900	210	37,000	0	0
August	67	10,600	3	300	112	19,200	1	200
September	98	15,200	0	0	126	20,900	1	100
October	442	72,800	9	3,100	225	40,000	3	800
November	609	106,500	4	600	217	32,000	8	1,600
December	441	73,400	28	21,600	144	26,000	2	1,000
Total (1year)	5,606	1,156,800	345	115,300	3,104	541,400	68	17,500

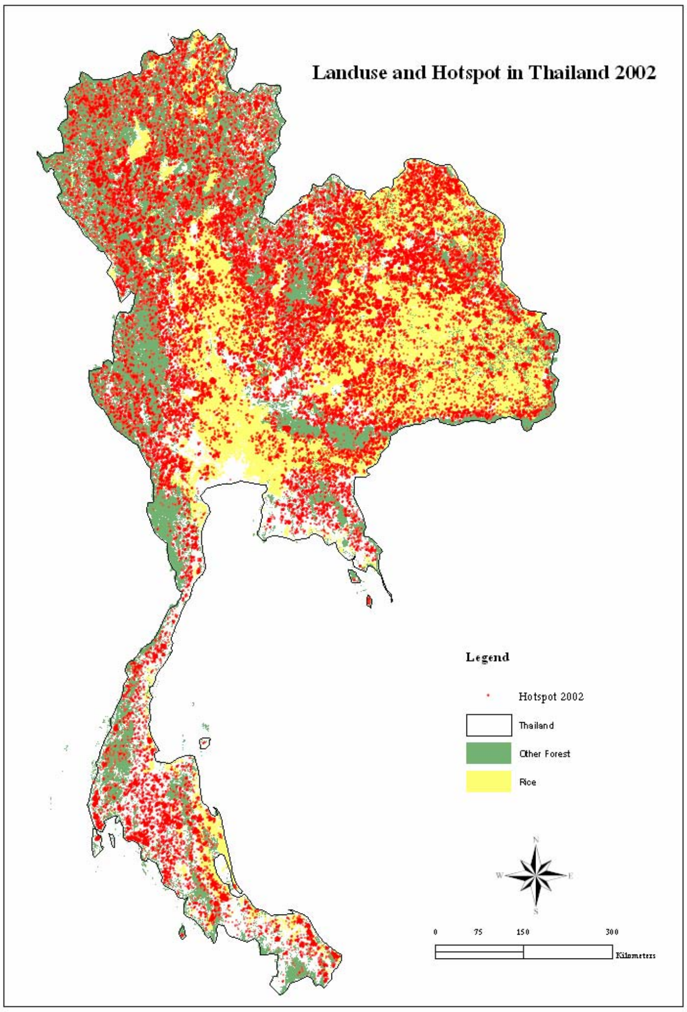


Figure 5A. Maps of fire hotspots in Thailand (2002)

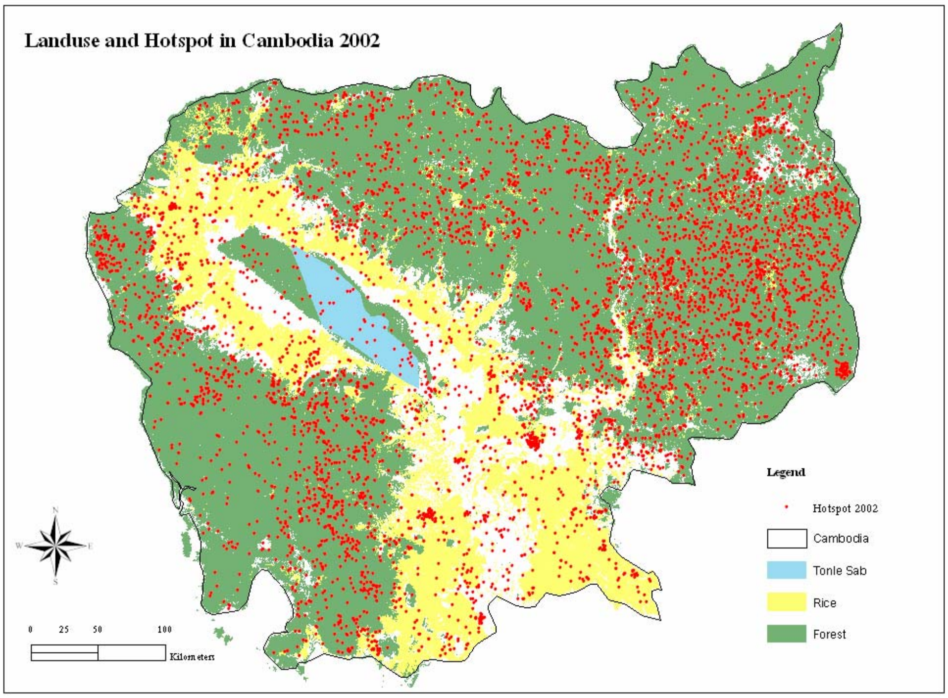


Figure 5B. Maps of fire hotspots in Cambodia (2002)

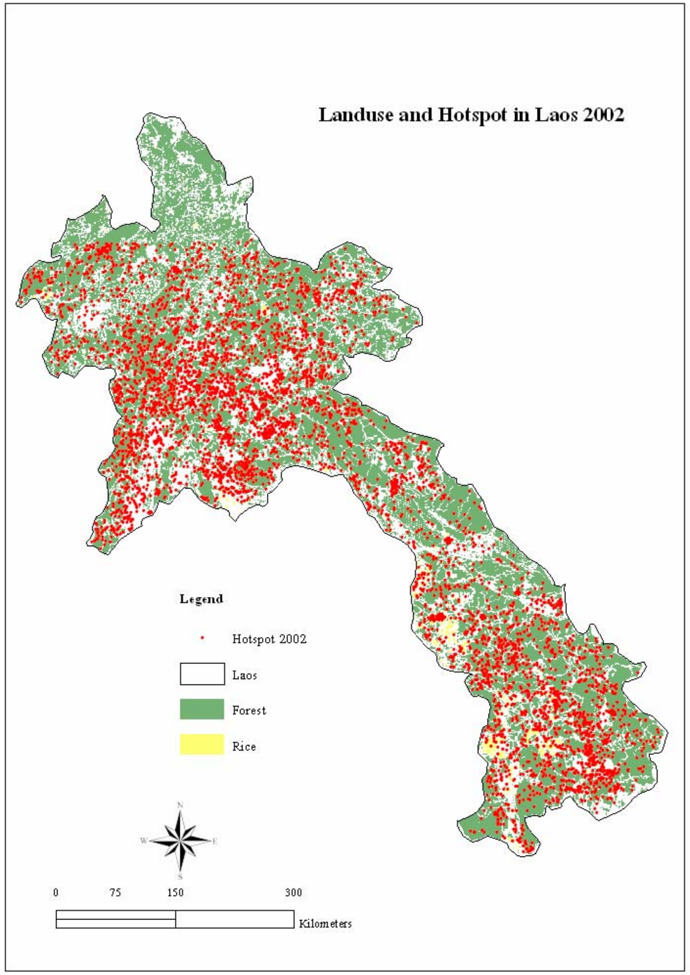


Figure 5C. Maps of fire hotspots in Lao PDR (2002)

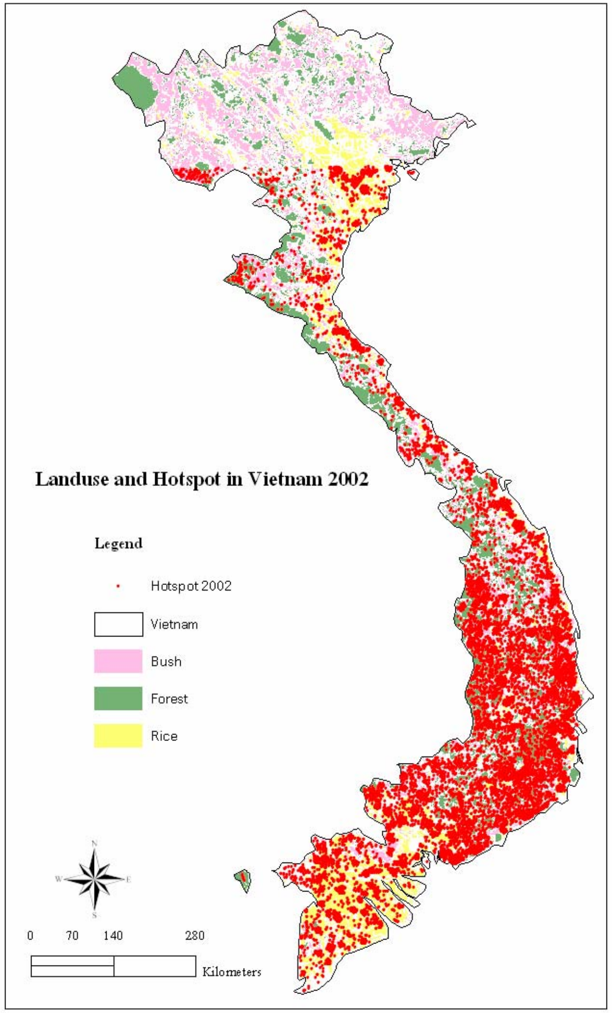


Figure 5D. Maps of fire hotspots Vietnam (2002)

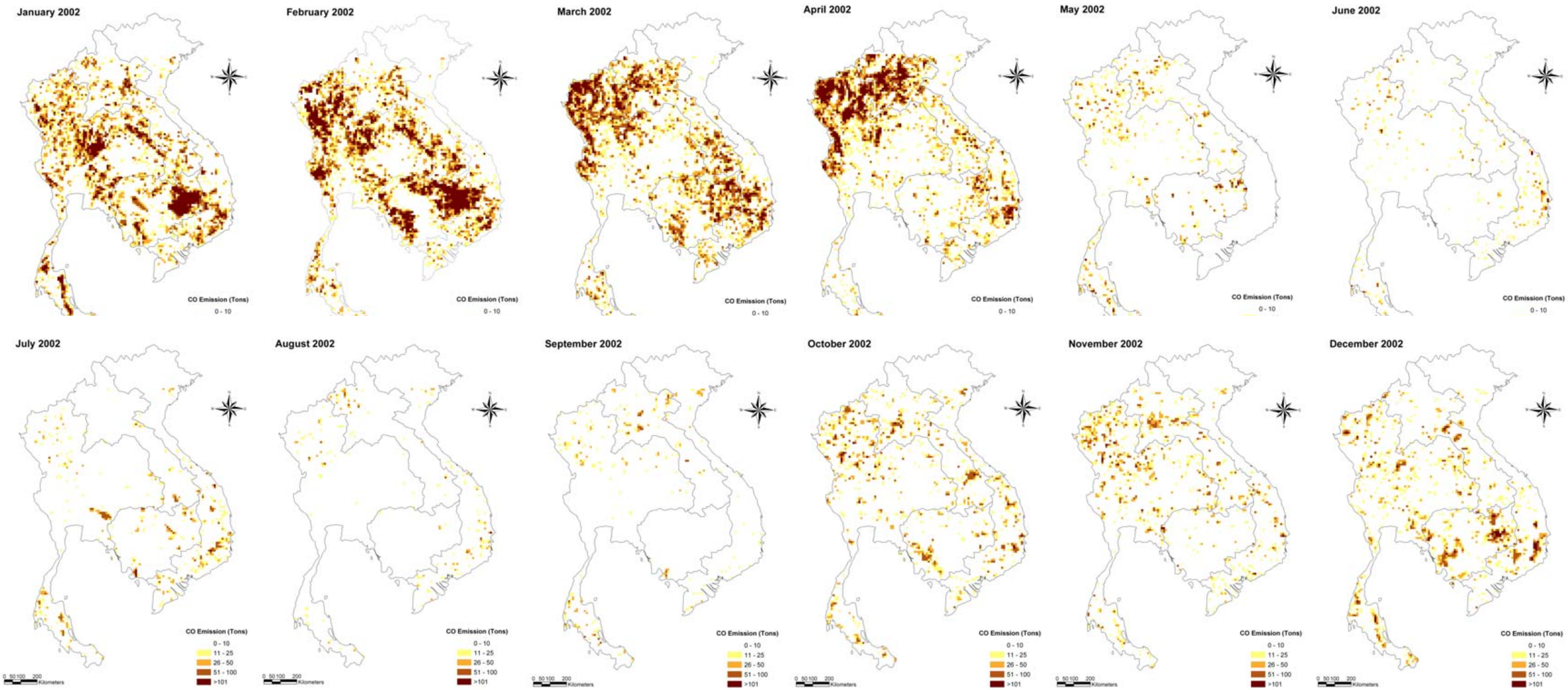


Figure 5E. Maps of monthly CO emissions in the MRBSR in 2002

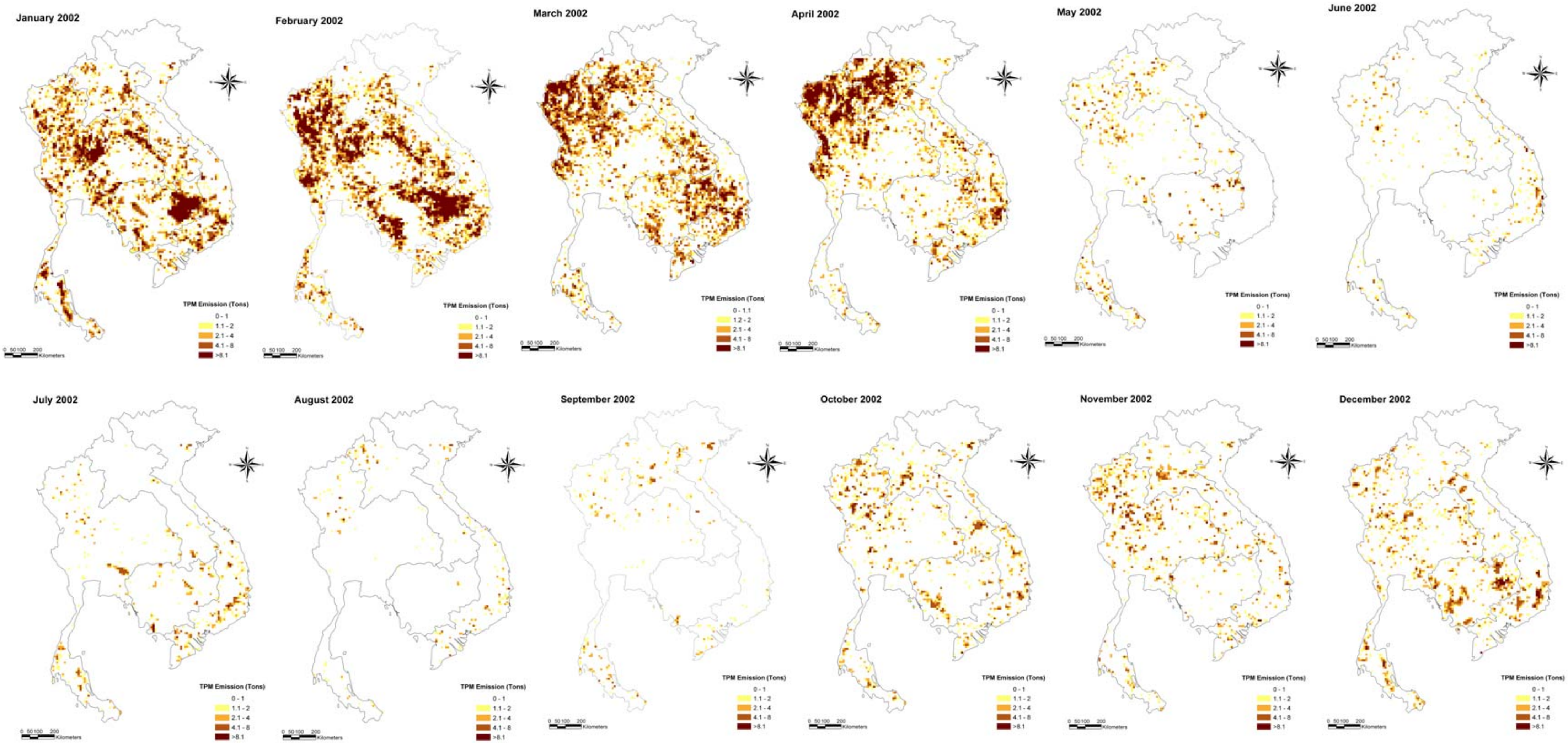


Figure 5F. Maps of monthly TPM emissions in the MRBSR in 2002

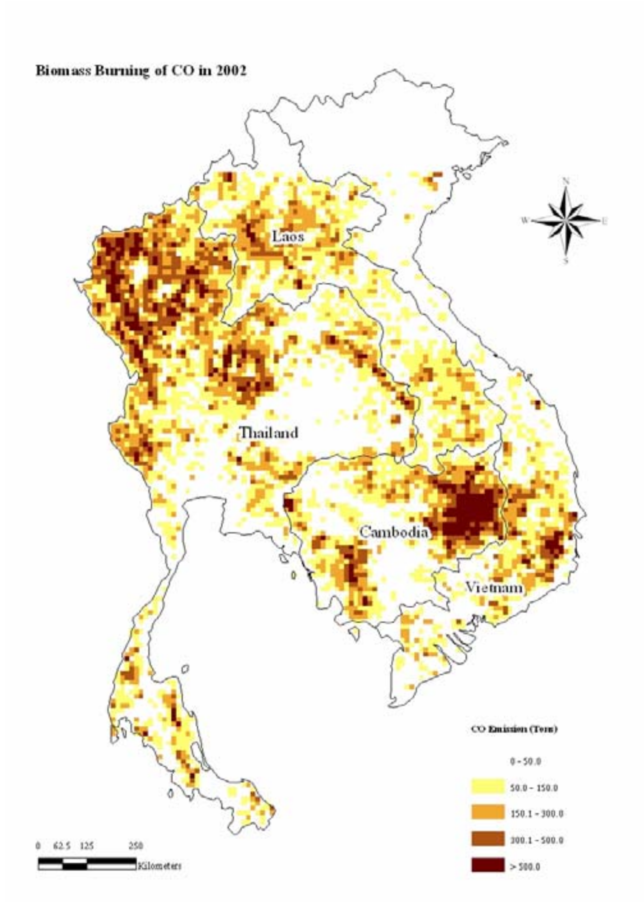


Figure 5G. Maps of CO emissions in the MRBSR for the year 2002

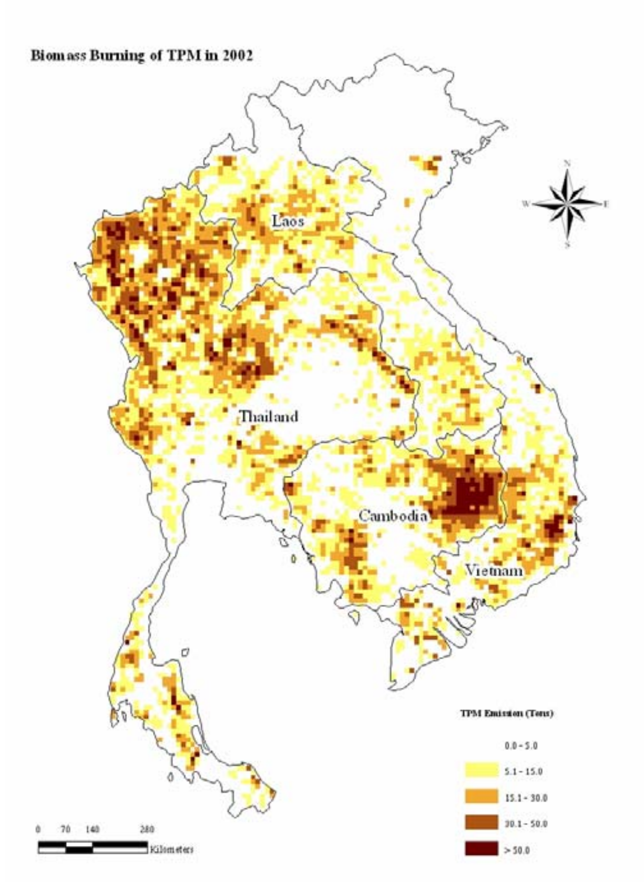


Figure 5H. Maps of TPM emissions in the MRBSR for the year 2002

APPENDIX 6:

Biogenic Emission Maps

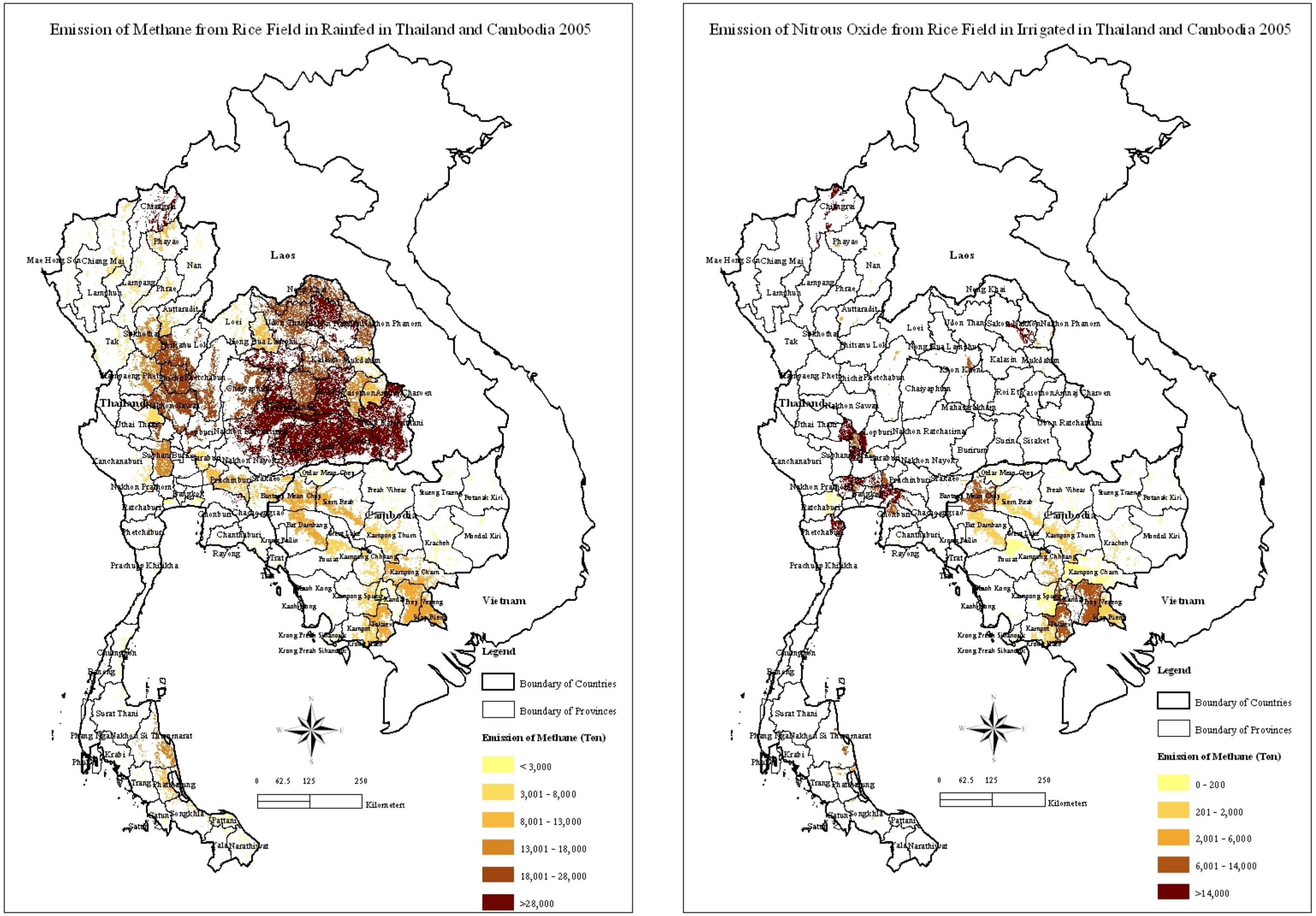


Figure 6A. Methane and nitrous oxide emissions from rainfed paddy fields in Thailand and Cambodia (2005)

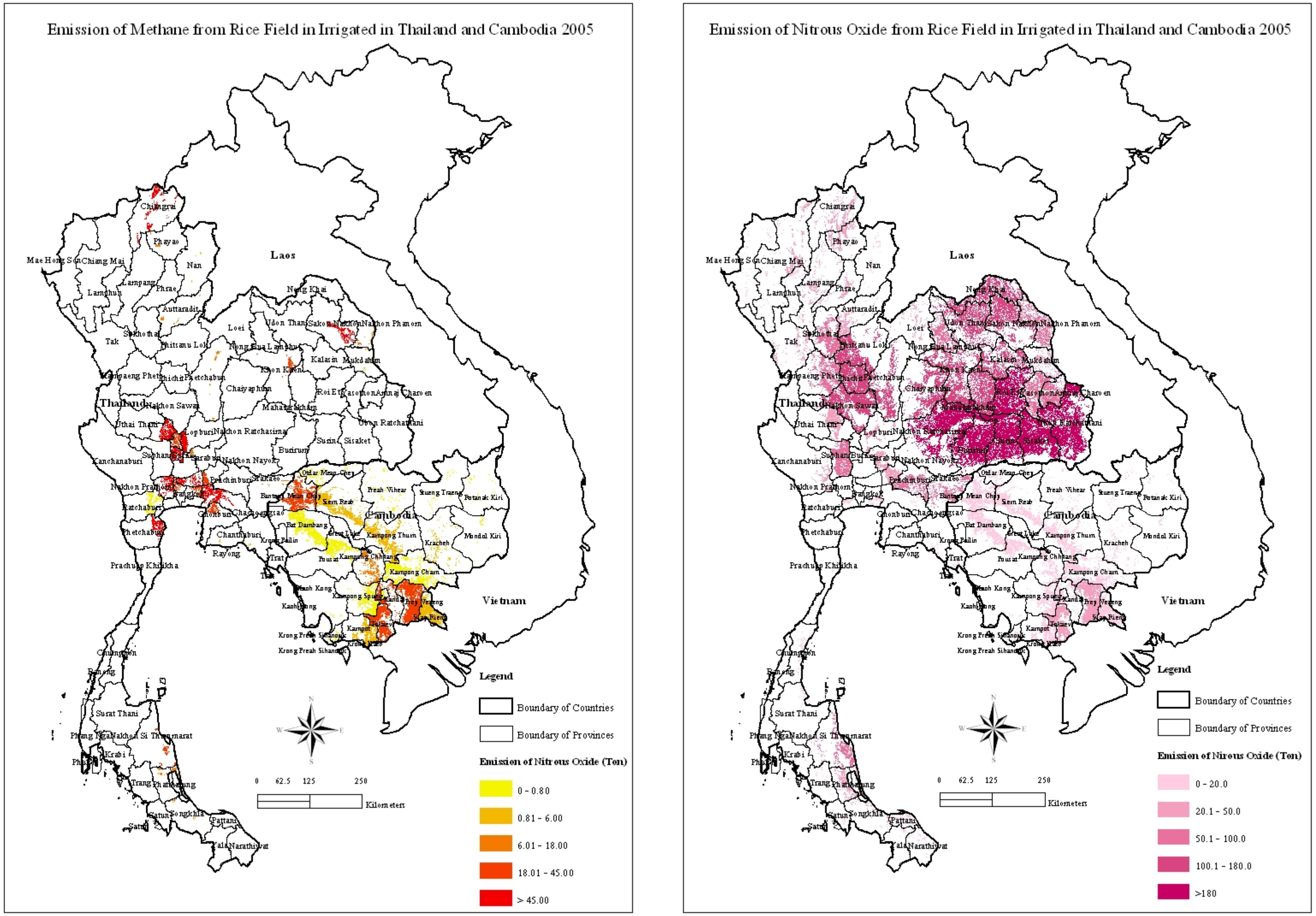


Figure 6B. Methane and nitrous oxide emissions from irrigated paddy fields in Thailand and Cambodia (2005)

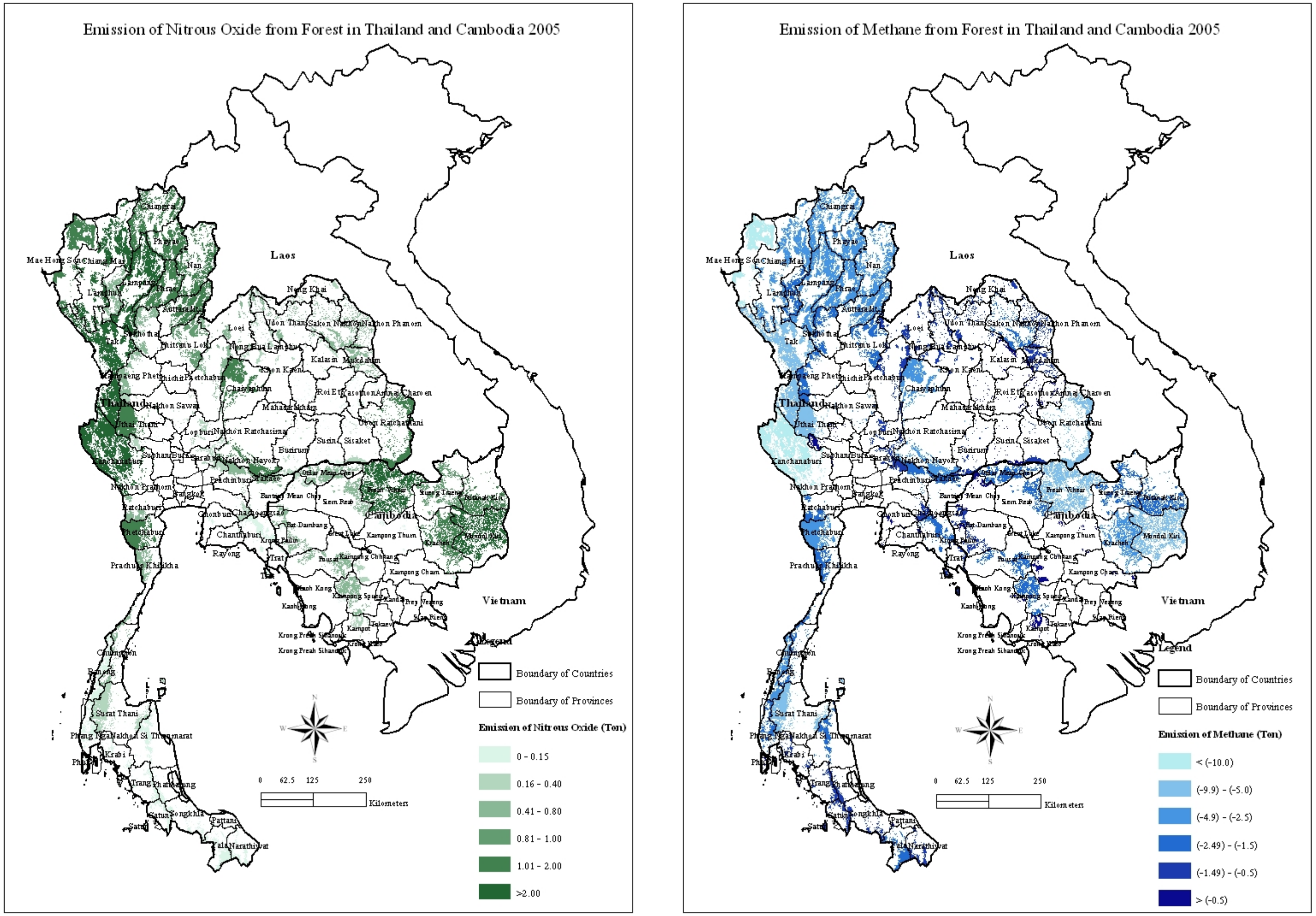


Figure 6C. Methane and nitrous oxide emissions from forest in Thailand and Cambodia (2005)