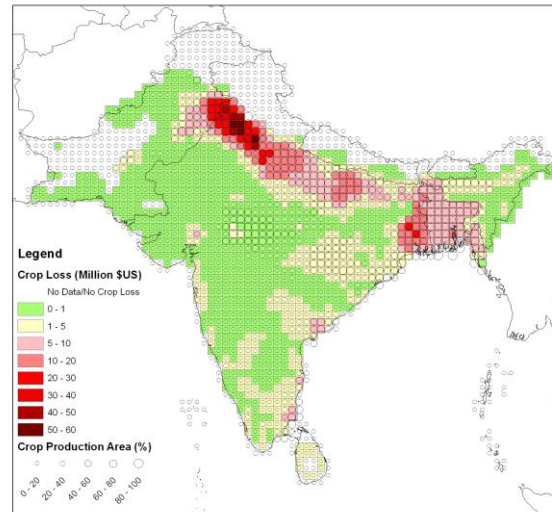


# Introduction of Crop Impact Assessment



Lisa Emberson & Patrick Büker



# Introduction of Crop Impact Assessment

## Talk Outline

- O<sub>3</sub> and crop loss in South Asia
- The Malé Crop Impact Assessment Project
- Links to external organisations (e.g. APCEN, LRTAP, ABC, GAP Forum)
- The future of O<sub>3</sub> crop impacts in South Asia

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# Ground level Ozone ( $O_3$ ) pollution

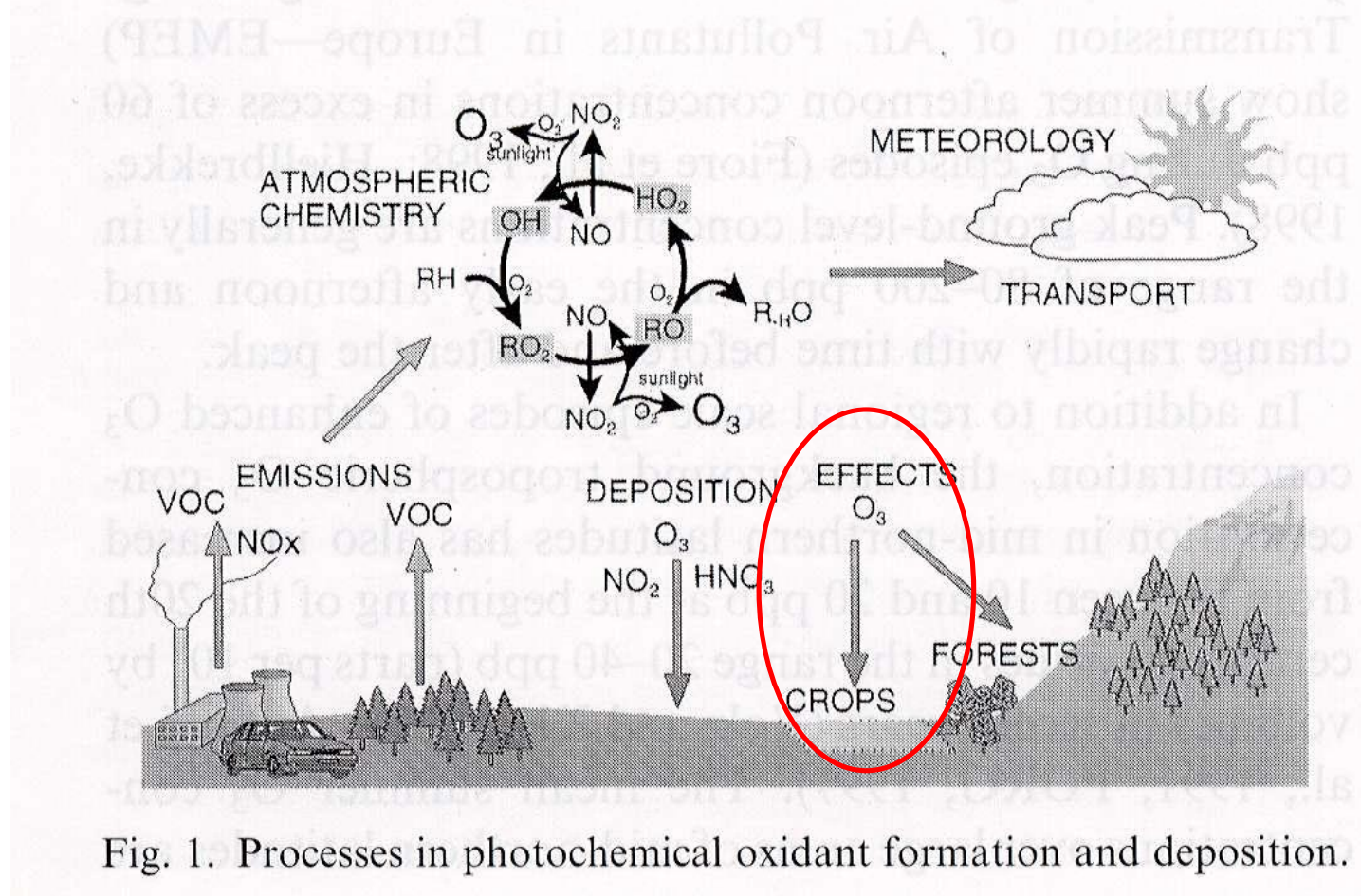
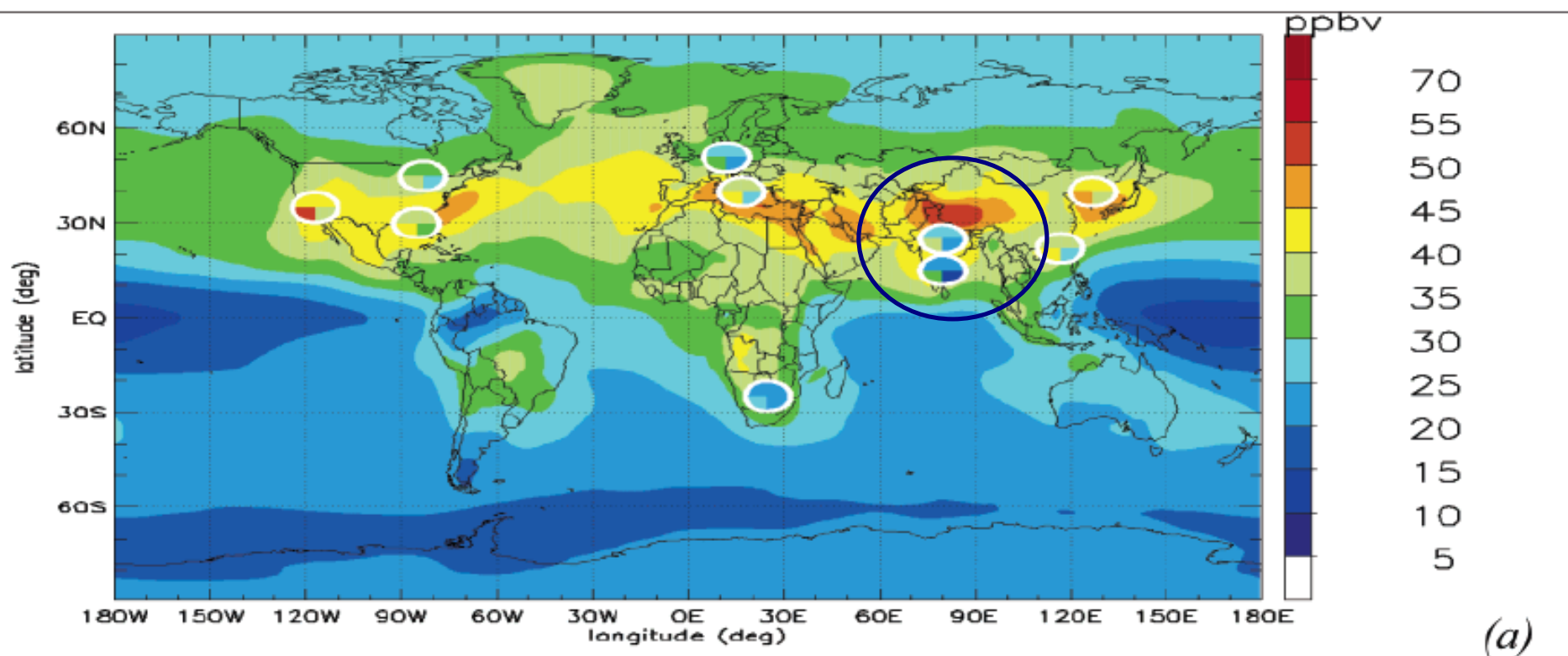


Fig. 1. Processes in photochemical oxidant formation and deposition.

$O_3$  is a **rural pollutant** reaching high concentrations in rural/agricultural areas

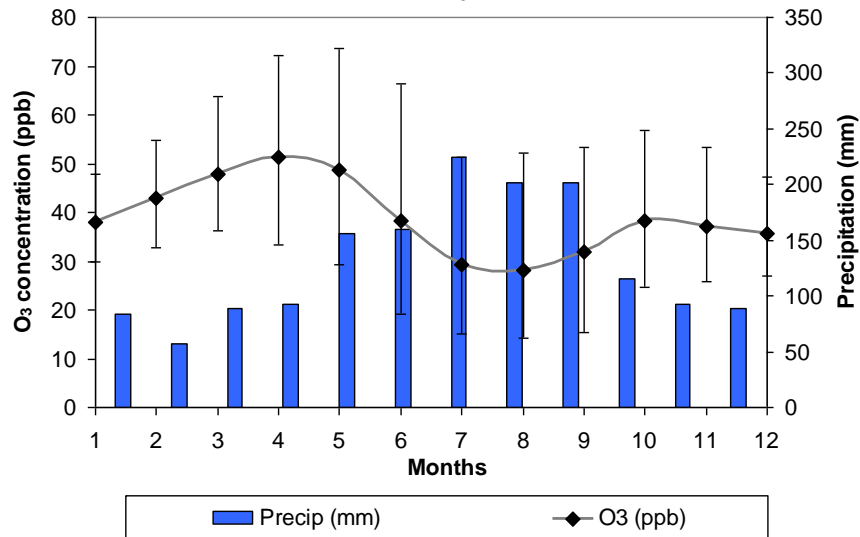
$O_3$  is **3<sup>rd</sup> most important GHG**..important for climate change

# Current (year 2000) ground level ozone ( $O_3$ ) concentrations

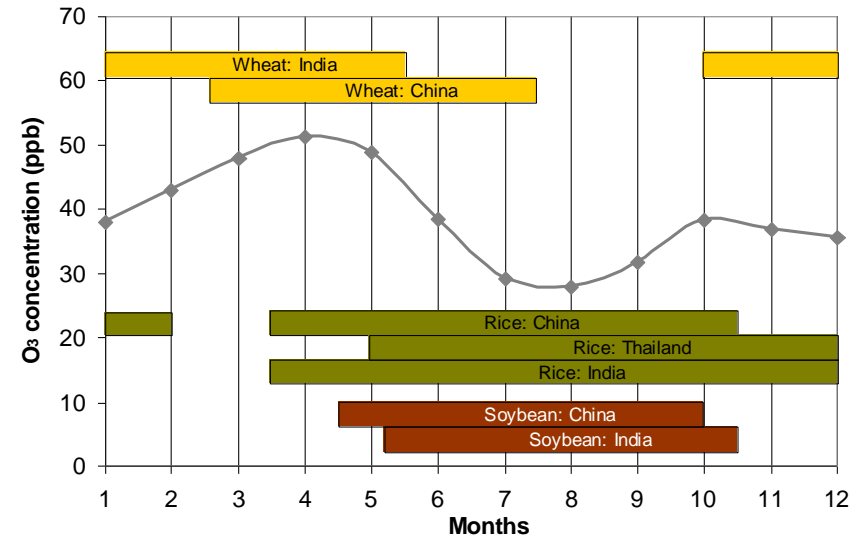


Europe	$36.6 \text{ ppb} \pm 4.2$
United states	$38.7 \text{ ppb} \pm 4.9$
South Asia	$45.0 \text{ ppb} \pm 6.9$

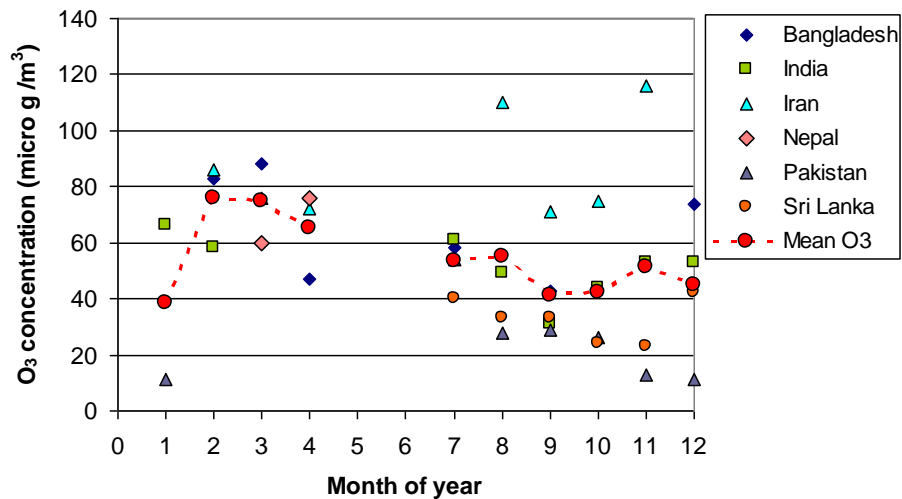
EANET data for all O<sub>3</sub> sites 2000-2005



## Importance of Phenology



Seasonal O<sub>3</sub> Concentrations for South Asia



**SEI** STOCKHOLM  
ENVIRONMENT  
INSTITUTE

5<sup>th</sup> Malé Declaration meeting,  
Colombo, Sri Lanka



# Evidence of ground level ozone (O<sub>3</sub>) impacts on crops are current day concentrations

O<sub>3</sub> injury to wheat, **Pakistan**  
(courtesy of A. Wahid)



O<sub>3</sub> effects on plants include:

- Foliar / visible injury
- Accelerate senescence
- Reduce plant growth
- Alter plant metabolism
- Reduce crop yield

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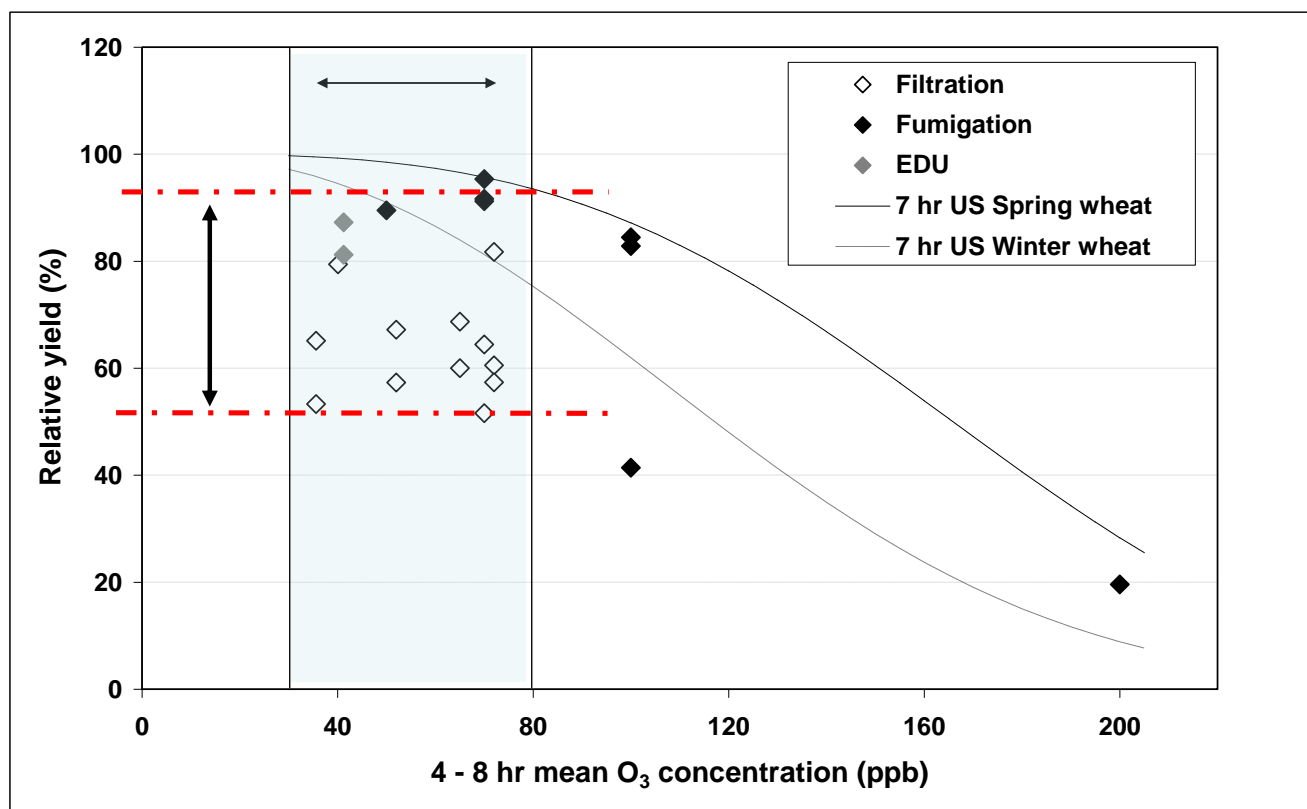
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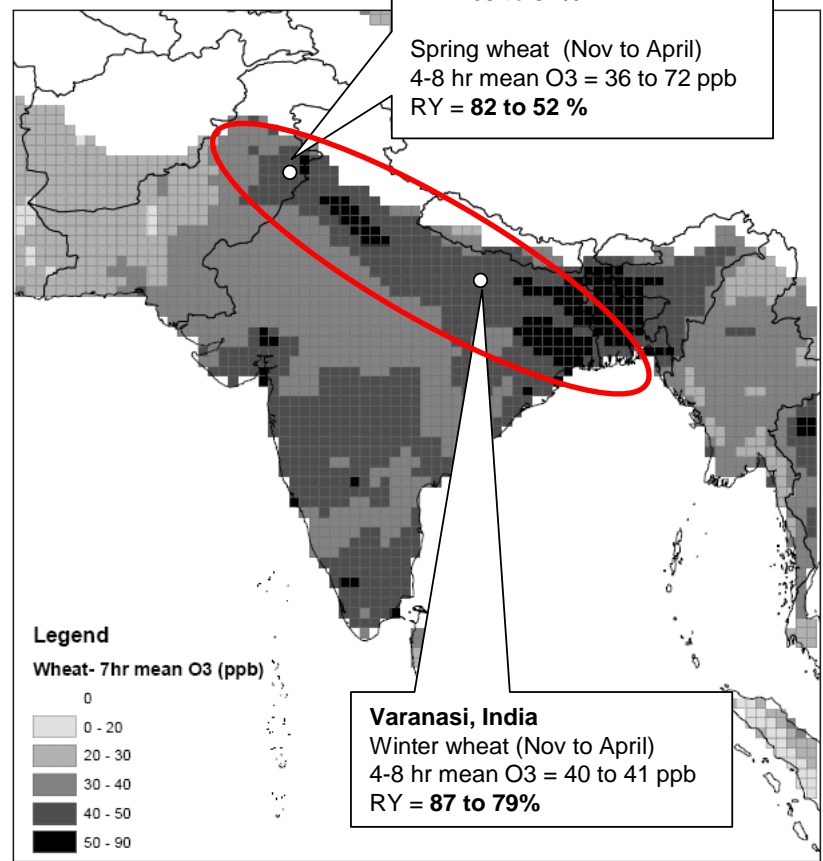
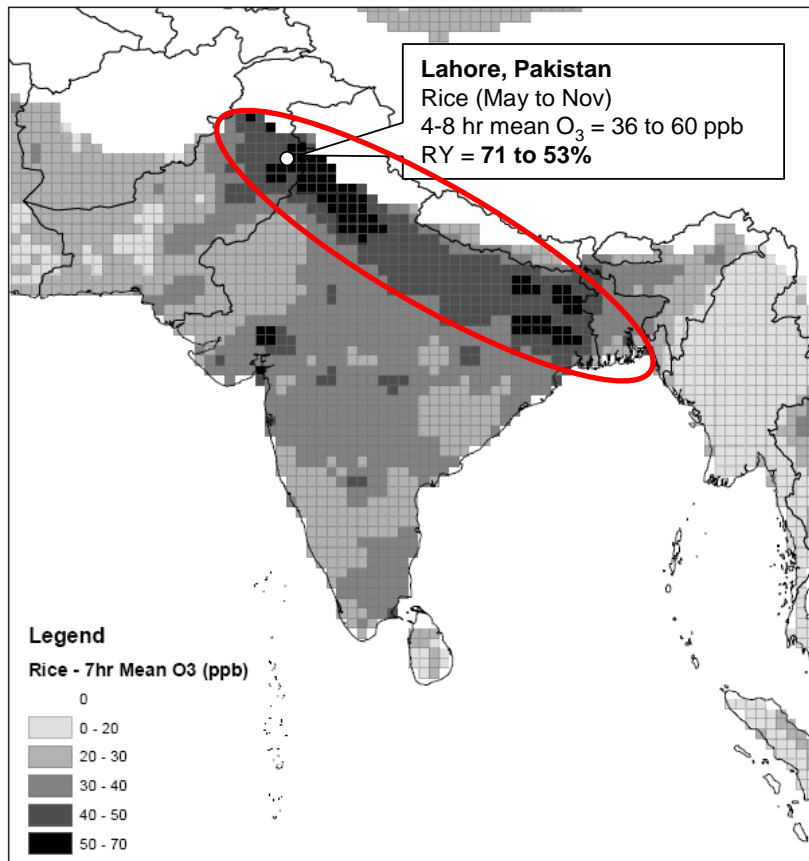
O<sub>3</sub> effects on plants include:

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# Experimental data for wheat showing yield response to ozone ( $O_3$ ) concentrations



Crop variety, experimental conditions, environmental conditions,  $O_3$  exposure pattern



**Indo-Gangetic Plain**  
The most important agricultural region in South Asia



**SEI** STOCKHOLM  
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# Malé Crop Impact Assessment Project in conjunction with Air Pollution Crop Effect Network (APCEN)

- i. Perform “provisional” risk assessments
- ii. Conduct Malé experimental studies - using standardised experimental protocols - “ground-truth” risk assessments
- iii. Develop socio-economic assessment methods and policy engagement

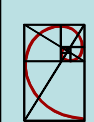
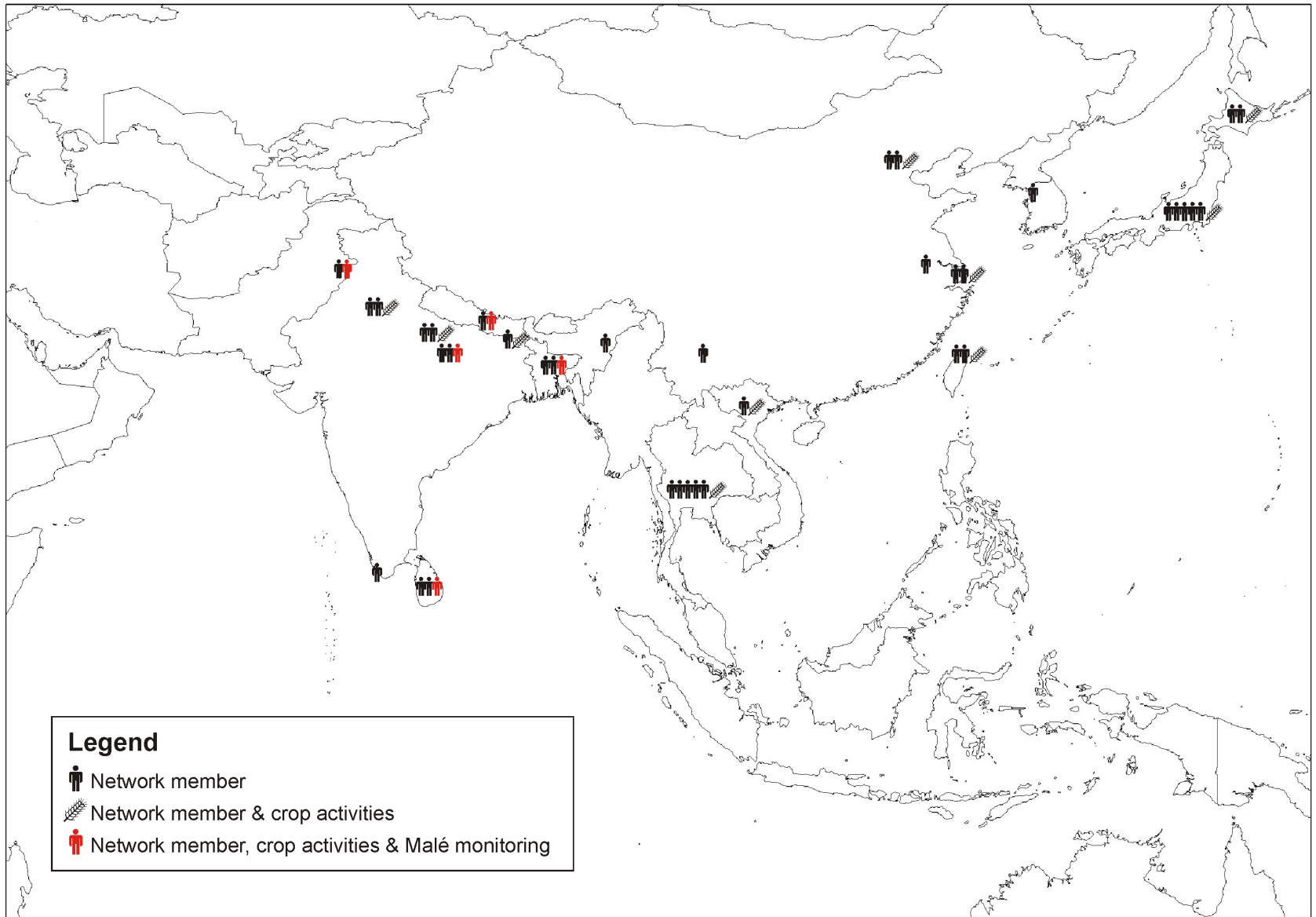
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# APCEN (Air Pollution Crop Effect Network)

- Provide technical support to the Malé experimental campaign
- To help in translation of science to policy

Region	Network Members	Countries / regions represented
Africa	14	Egypt, Kenya, Mozambique, South Africa, Zimbabwe, Zambia, Tanzania, Botswana
Asia	55	India, Japan, Nepal, Pakistan, P.R. China, Philippines, South Korea, Sri Lanka, Taiwan, Thailand, Bangladesh
The Americas, Europe and Australia	18	Australia, Chile, Sweden, UK, USA, Brazil, Germany



**SEI**

STOCKHOLM  
ENVIRONMENT  
INSTITUTE

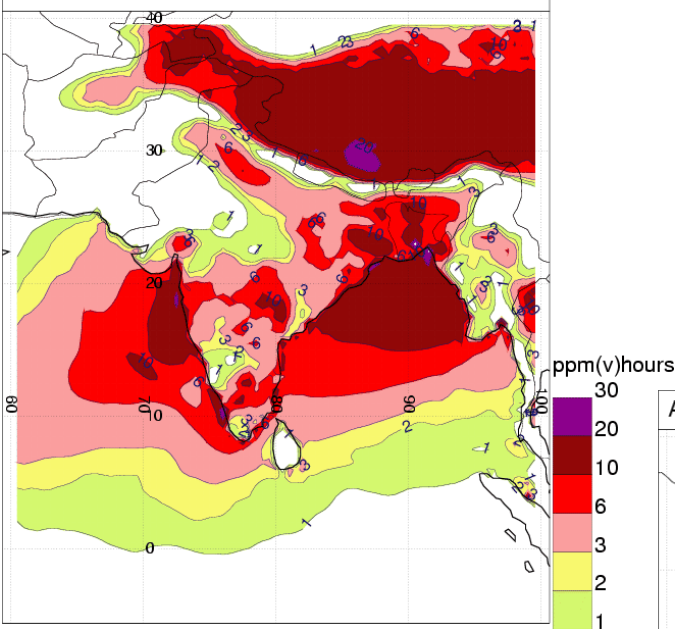
**5<sup>th</sup> Malé Declaration meeting,  
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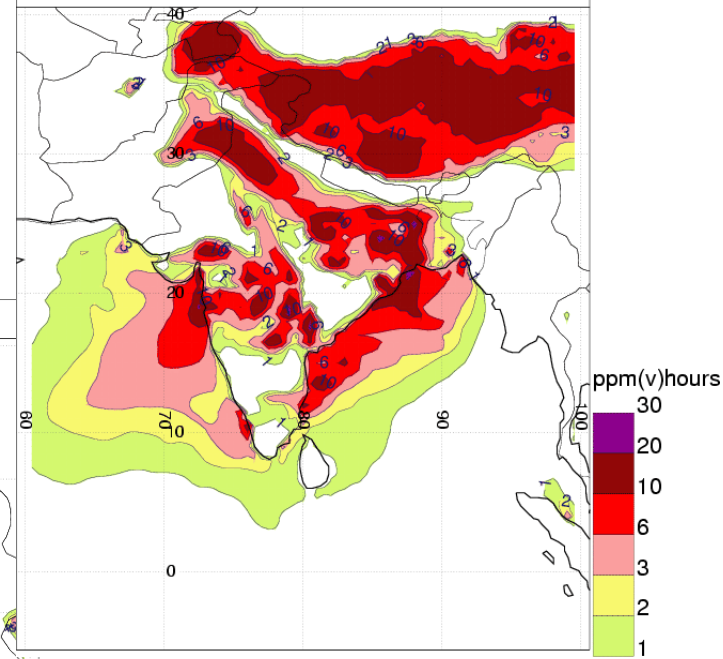
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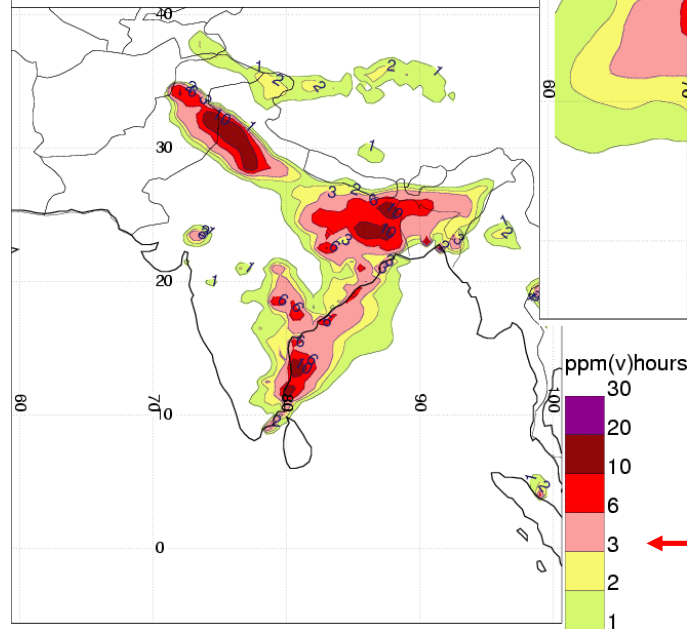
AOT40 calculated for Jan-March 2000



AOT40 calculated for September-November 2000



AOT40 calculated for May-July 2000



**MATCH photochemical model (0.5 x 0.5° grid)**  
**TRACE-P emissions (Streets et al. 2003); ECMWF modelled meteorology (2000)**

**AOT40 - European critical level for O<sub>3</sub> effects (3 ppm.hrs)**

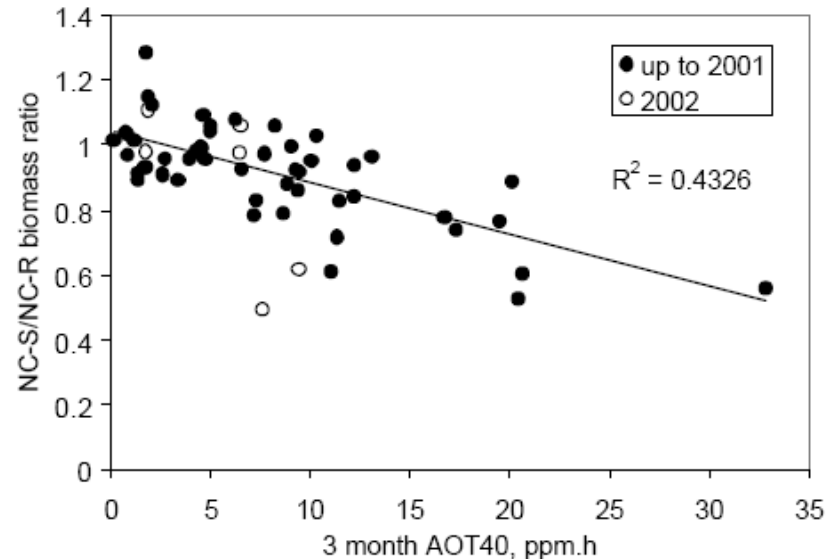
**Engardt (2008)**

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# Malé experimental studies

## Bio-monitoring and Chemical Protectant Studies

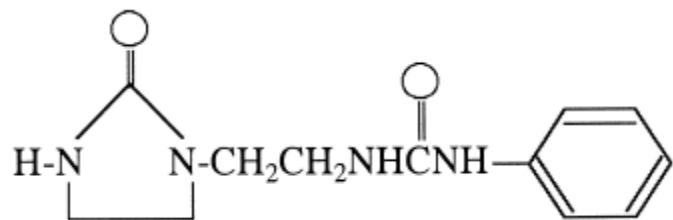


*Buse et al. 2002/2003*

- Established bio-indicator in Europe and North America
- Sensitive and resistant clones so can assess magnitude of air pollution impacts on visible injury & biomass.

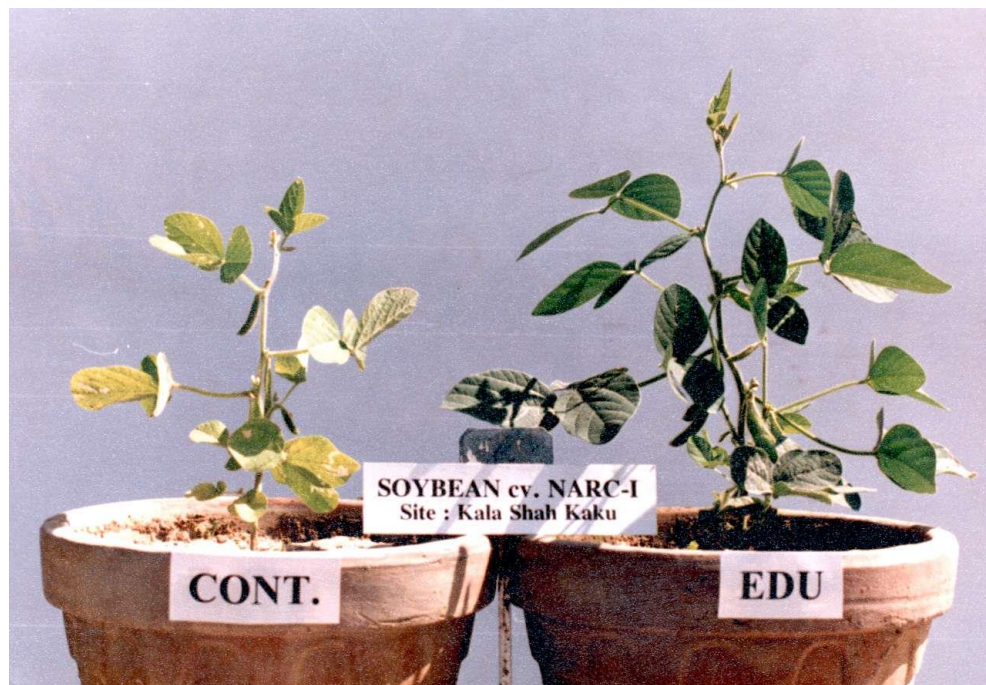
# Malé experimental studies

## Bio-monitoring and Chemical Protectant Studies



*Structural formula for N-(2-(2-oxo-1-imadazolidinyl)ethyl)-N'-phenylurea*

*abbreviated as EDU for ethylenediurea*



*Pakistan soybean cv. NARC-1 showing protective effect of EDU at a roadside rural site in Lahore, Pakistan (photo courtesy of A. Wahid)*

EDU suppresses acute and chronic ozone injury on a variety of plants under ambient O<sub>3</sub> conditions (Godzik & Manning, 1998)

# Malé experimental studies

Country	India	Pakistan	Bangladesh	Nepal	Sri Lanka
Malé member	Prof. Agrawal	Prof. Shamsi	Prof. Sattar, Dr. Islam	Prof. Lal Amgain	Dr. A. Perera
Location	Varanasi	Lahore	Mymensingh	Rampur	Paradeniya
Clover-clone bio-monitoring	×	2007 2008 Biomass loss~10%	2007 2008 Biomass loss~20%	×	×
EDU Chemical protectant	2006-2008 Yield loss~40% wheat, mung bean, spinach, potato	2007-2008 Yield loss~15-65% mung bean, spinach,	2008 Yield loss~15-52% mung bean, potato	2008 Yield loss~52% mung bean	2007-2008 Yield loss~5%* mung bean

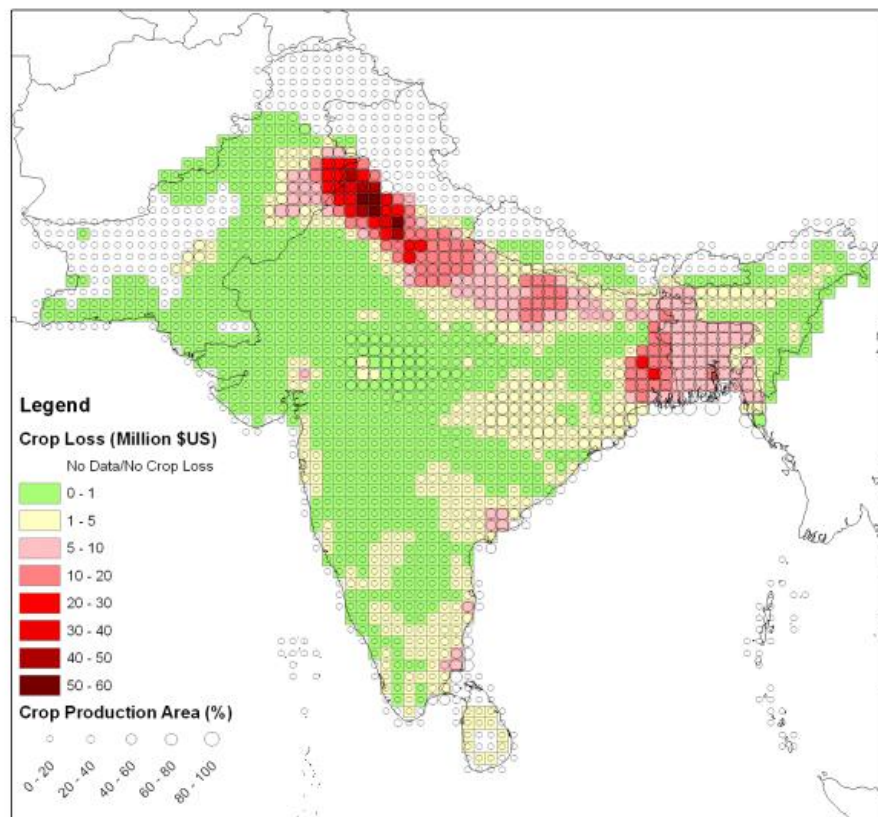
**Bhutan - Passive sampler monitoring study**

**Maldives and Iran - Not participated in Phase III, Phase IV?**

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# Provisional economic loss estimates for crops in South Asia



Wheat, Rice, Soybean, Potato

European AOT40 dose-response relationships

FAO crop production, distribution and producer price data for 2000

MATCH modelled  $O_3$  concentrations for 2000

Loss estimated at **US\$ 3.9 Billion**

India (US\$ 3.1), Pakistan (US\$ 0.35) and Bangladesh (US\$ 0.4)

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Association of south east Asian nations (ASEAN)



Acid deposition Monitoring Network in East Asia (EANET)



Air pollution Information Network for Africa (APINA)



Clean Air Initiative - Asia



Male Declaration - South Asia



Central Asian Republics

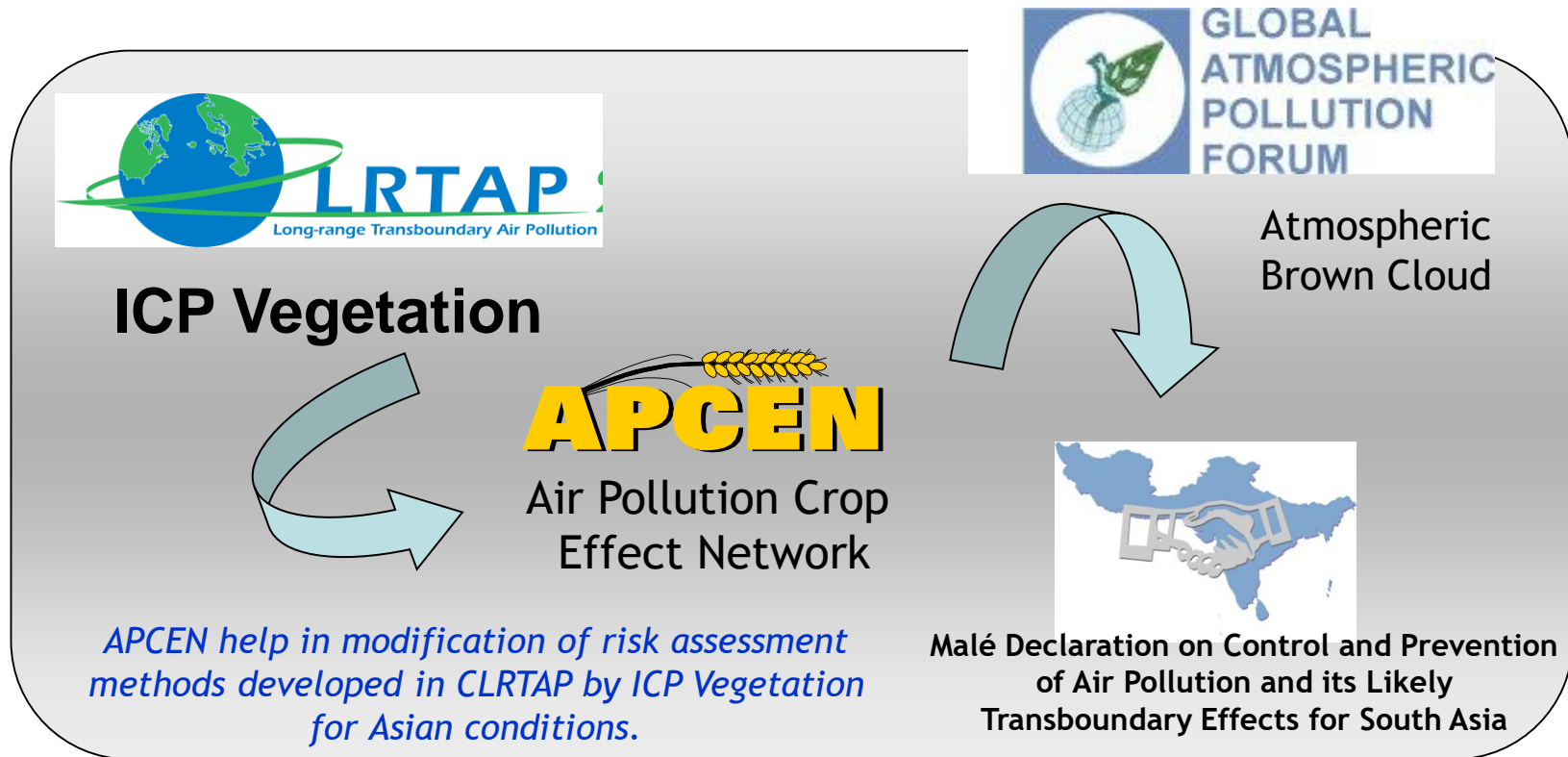


Inter-American Network for Biospheric-Atmospheric Studies (IANABIS)



“Working to bring together regional networks, international organisations and other stakeholders to develop effective policies and programmes to protect public health and the environment from the harmful effects of atmospheric pollution”

# Linkages between different organisations for **Crop Impact Assessment**



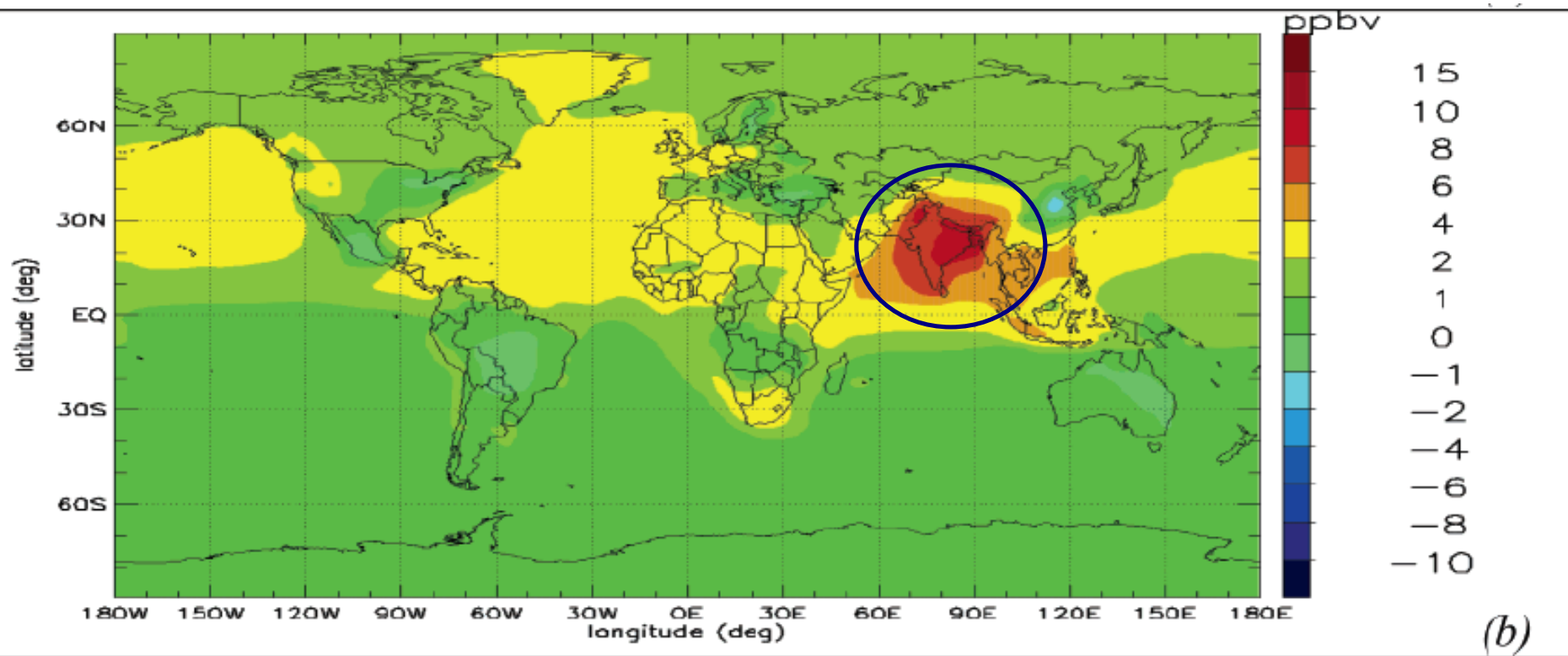
Malé Declaration (via UNEP Asia) formally requested link with CLRTAP - request has been formally accepted by CLRTAP WGE, Task Forces and their ICPs

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# $\Delta$ in surface ozone between 2000 and 2030 current legislation scenario



## CLE2000 - CLE2030

Europe  $+1.8 \pm 1.5$   
United states  $+1.3 \pm 2.4$   
South Asia  $+7.2 \pm 1.9$

Dentener et al. (2006)

# The future of O<sub>3</sub> crop impacts in South Asia

- International agreements to curb O<sub>3</sub> precursor emissions
- Co-ordinated experimental campaigns for South Asia
- Crop breeding programmes to reduce sensitivity in crop varieties
- Understanding the role of O<sub>3</sub> on food security and poverty
- Understanding the interaction between O<sub>3</sub> and climate change
- Improved communication between policy makers, stakeholders and scientists

## Ozone: a threat to food security in South Asia

### Key Findings

- Ground level ozone (O<sub>3</sub>) contributes to climate change and is capable of causing substantial damage to agricultural crops.
- Studies have shown that today's O<sub>3</sub> concentrations are capable of reducing crop yields by between 5 and 50% at agriculturally important locations across Asia.
- Economic losses in crop production could be in the region of \$4 billion per annum for staple crops in South Asia.
- The poorer and hence more vulnerable sectors of society may well be most likely to suffer as a result of losses in crop productivity.
- O<sub>3</sub> concentrations are increasing rapidly in Asia and the situation looks set to worsen considerably in the future if nothing is done to curb emissions.
- O<sub>3</sub> impacts depend upon local meteorology and CO<sub>2</sub> concentrations. It is important to understand the role of climate change in determining O<sub>3</sub> related yield losses.
- The combination of O<sub>3</sub> with climate change has serious implications for continued food security in the region.

### What is ground level ozone (O<sub>3</sub>)?

Ground level ozone (O<sub>3</sub>) is the atmospheric pollutant most likely to threaten global food production due to its high toxicity to arable crops and prevalence over important agricultural regions. O<sub>3</sub> is a secondary pollutant formed from chemical reactions of primary pollutants (nitrogen oxides and volatile organic compounds) occurring under the action of sunlight. These reactions occur continually in polluted air masses such that O<sub>3</sub> concentrations tend to be higher at distances (sometimes up to thousands of kilometres) away from the initial polluting source (i.e. urban or industrial areas). This makes O<sub>3</sub> the pollutant most likely to affect agriculture regions with elevated O<sub>3</sub> concentrations frequently crossing broad geographical regions and crossing international boundaries. Ground level O<sub>3</sub> is also the third most important greenhouse gas behind carbon dioxide and methane, and has been shown to adversely affect human health at elevated concentrations, as such there would be substantial co-benefits in emission reductions to control O<sub>3</sub> pollution.

### To what extent does ozone decrease crop yields?

Rapid industrialisation and economic growth across much of Asia has resulted in increased emissions of O<sub>3</sub> precursor pollutants and elevated O<sub>3</sub> concentrations. Since the mid 1990s, field experiments to assess O<sub>3</sub> effects on crops have been performed in Asia (see Box 1). These studies have clearly demonstrated that current day levels of O<sub>3</sub> are causing substantial yield losses and changes in crop quality in a wide variety of important crop genres in the region including rice, wheat, soybeans, maize, beans, oilseeds, ground, chickpeas and peanuts. The evidence of such yield losses has encouraged organisations such as UNEP to consider O<sub>3</sub> as a serious threat to con-

### Box 1. Experimental Evidence

Field studies are a common experimental method used in Asia comparing crops grown in "clean" air ("cleaned" air with those in "ambient" air that may contain pollution. These studies have shown that a large number of local crops and cultivars are extremely sensitive to O<sub>3</sub> at present day concentrations (e.g. Figure 1).



Figure 1. The effect of air filtration on Pigeon pea plant (Cajanus cajan) during the 1992-1993 growing season close to Lahore, Pakistan. The plant on the left has been grown under conditions where O<sub>3</sub> has been filtered from the air; the plant on the right under the ambient O<sub>3</sub> concentrations present at the location. (Courtesy of Prof. Abdul Wahid)

# Acknowledgements

Thanks to the Swedish International Development Agency for funding the important work presented in this talk.



APCEN website:

<http://www.sei.se/apcen/>