

Concept Paper

on



Asian Brown Clouds

**Air Pollution in the Indo-Asia-Pacific Region:
Impact on Climate and the Environment**

*Integration of Science, Impact Assessment, Policymaking and
Regional Capacity Building*

V. Ramanathan and P. J. Crutzen



*Center for
Clouds,
Chemistry &
Climate*



**DRAFT 1.1
May 2001**

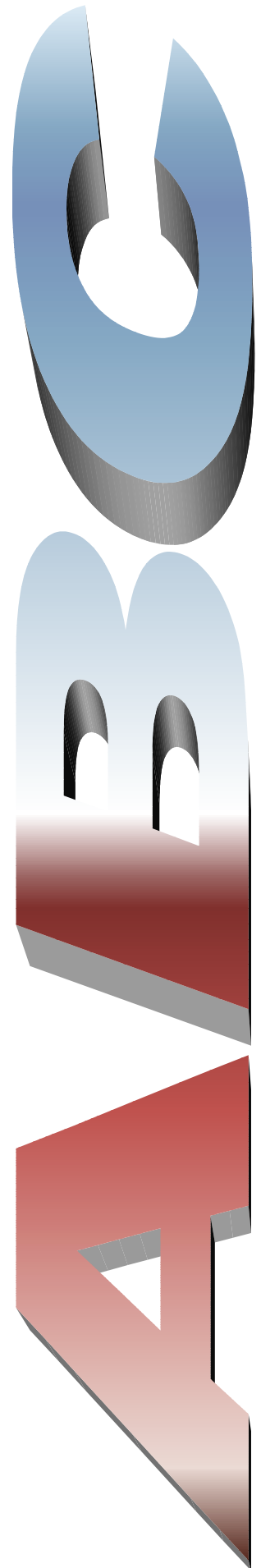


Table of Contents

| | |
|--|----------|
| Executive Summary | 1 |
| BACKGROUND | |
| 1. The Indian Ocean Experiment | 2 |
| 2. Malé Declaration | 2 |
| 3. Need for Collaboration | 2 |
| KEY ISSUES AND CHALLENGES | |
| 4. The new concept | 3 |
| 5. Intrinsic synergy and strategic collaboration with UNEP | 5 |
| PROPOSAL | |
| 6. Short-term | 6 |
| 7. Medium-term | 6 |
| 8. Long-term | 8 |
| 9. Budget and timeframe | 8 |

Executive Summary

About 60% of the world's population of 6 billion live in Asia. The recent decades witnessed impressive economic development in the region. Fueled by growing population, globalization and the information technology revolution, this development has resulted in higher demands for energy, mobility and communications. The scope and magnitude of the environmental consequences of these demands are far reaching, especially with respect to air pollution at local and regional levels. There is a growing public awareness within Asia on the potential health impacts of air pollution. It is important to note that this concept paper takes a broad view of air pollution that includes indoor, rural and urban air pollution.

The most visible impact of air pollution is the haze, a brownish layer of pollutants and particles from biomass burning and industrial emissions, that pervades most regions in Asia. A recent international study, the Indian Ocean Experiment (INDOEX), has revealed that this haze is transported far beyond the source region, particularly during the dry season. The discovery of the so-called Asian haze by INDOEX scientists, a 3 kilometers thick brownish layer, hovering over most of the tropical Indian Ocean, South, Southeast and East Asia is a clear evidence of the magnitude of the problem. The haze consists of sulfates, nitrates, organics, black carbon, fly ash amongst several other pollutants. Its most direct effects include a significant reduction in the solar radiation reaching the surface; a 50 to 100% increase in solar heating of the lower atmosphere; suppression of rainfall; reduction in agricultural productivity; and more importantly adverse health effects.

With respect to health effects, indoor air pollution is just as important. For example, a recent study by the East-West Center in Honolulu estimates that indoor air pollution from biofuel cooking causes about one half million premature deaths per year in India. Potential indirect effects of the haze include cooling of the land surface; increase in the frequency and strength of thermal inversion that traps more pollution; reduction in evaporation; drying of the soil; and disruption of the monsoon rainfall patterns.

These far reaching environmental effects have raised major questions about sustainability of the rapid development in the region, particularly since the emission of particles from the region is expected to double in the next twenty years. It is our perception that air pollution ranks among the top environmental issues in the region, even surpassing important issues, such as global warming, largely due to its potential effects on health, agriculture and water budget. A survey conducted by the Asian Development Bank a few years ago found that senior environmental policymakers in the region share this perception. As early as 1992, the World Bank, in its annual *World Development Report*, highlighted the health threat posed by particulate air pollution. Furthermore, there are consequences for the hydrological cycle, climate and the global ozone budget.

In spite of the advances by INDOEX, significant scientific uncertainties remain. We do not know the answers to basic questions such as: How does the solar heating in the haze affect the monsoonal rainfall? How does the reduction of solar energy to the surface affect the water budget and soil moisture? Does the haze amplify or ameliorate the warming due to greenhouse gases? How does air pollution from Asia affect the worldwide concentrations of ozone and other pollutants? On the policy side, the evidence of longrange transport of the haze complicates potential prescriptions for dealing with the problem, as responses must be coordinated among sovereign nations.

This concept paper articulates a strategy to understand the air pollution issue in this broader context and help policymakers arrive at informed decisions. We build on the strengths of the INDOEX science team (of over 200 scientists around the world) which has established a record in conducting big-science that cuts across national and disciplinary boundaries. It is also proposed to work together with the United Nations Environment Programme (UNEP) to translate scientific findings into policy options for action.

BACKGROUND

1. The Indian Ocean Experiment

Since 1995, scientists have been collecting data over the Indian Ocean as part of INDOEX. Led by C⁴ (Center for Clouds, Chemistry & Climate), INDOEX field experiments culminated in an Intensive Field Phase during January to April of 1999 with participation of over 200 scientists from about 60 institutions in 13 countries in Asia, Europe and the USA. In collaboration with the government of the Maldives, C⁴ operated a surface observatory in the country to detect the longrange transport of atmospheric pollution. For more information visit the project's website <www-indoex.ucsd.edu>.

INDOEX results show widespread pollution over large sections of the region. In Spring 1999, scientists were surprised to find a dense brownish pollution haze layer about the size of the continental US over the Indian Ocean, South Asia, Southeast Asia and China. INDOEX results indicate pollutants scatter and absorb incoming solar radiation and thus reduce up to 10% of the solar energy reaching the ocean and 10 to 20% over land surfaces. These findings have raised serious questions concerning the impact of atmospheric pollution of that magnitude on health, the regional monsoon hydrological cycle and wind systems, marine life, and especially the plant ecosystem and agriculture, which depends on sunlight for photosynthesis. If such a haze layer regularly covers agricultural areas, optimal crop yields could be reduced proportionally with the reduction of sunlight. More than half of the world's population is concentrated in the Asia-Pacific region, thus the effects of atmospheric pollution could be very large.

2. Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia

UNEP Regional Resource Center for Asia and the Pacific (RRC.AP), through its recent success in articulating the *Malé Declaration* is entering the stage of strengthening the monitoring network. Male' Declaration was adopted by 8 South Asian countries and makes provisions for tackling the transboundary air pollution through intergovernmental cooperation. For more information visit the Male' Declaration website <www.rrcap.org/issues/air/maledec>.

We thus envision great possibilities for constructive interaction between science and policymaking at the working level, for the better management of the environment, and for ensuring the sustainability of the economic development of the region without a serious threat of environmental degradation. We note that industrial pollution is mainly of urban origin while biomass burning is mainly of rural origin. It should also be noted that air pollution in or near cities would be even much larger with contributions both from biomass burning and fossil fuel combustion. With accelerating urbanization and a high population growth rate, megacity air pollution is assured to become a major problem of the future in the Asia-Pacific region.

3. Need for Collaboration

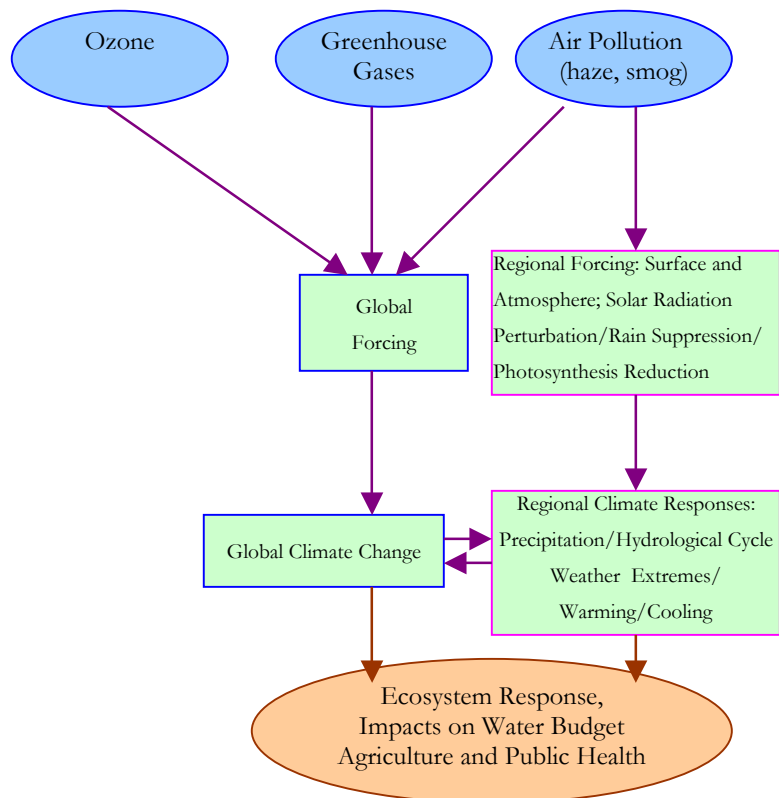
The longrange transport of the haze was an important finding. For example, the persistent haze over the Bay of Bengal was traced to emissions from South and Southeast Asian countries. Cooperation across international boundaries is required for understanding the environmental impacts of the haze and for effective mitigation measures. In order to make this happen, we are proposing a synergistic cooperation and collaboration between the INDOEX scientists and UNEP RRC.AP.

The INDOEX group is entering the next phase of examining the impacts of this haze on the regional climate, monsoon, water cycle, agriculture and health. In parallel with this activity, the INDOEX group recognizes the scientific need and importance of dealing with the entire Asia-Pacific region (instead of only India and the tropical Indian Ocean) and has started to take steps to broaden the scope of its activity. Interaction with a regional body such as UNEP RRC.AP would significantly enhance the development of this next phase as well as provide a crucial link to the policy arena.

KEY ISSUES AND CHALLENGES

4. The New Concept

A more complete picture of the roles and interactions of greenhouse gases, aerosols and ozone is urgently needed. Problems such as haze, smog, and acid deposition fall under the general category of air pollution. The aerosols and high level of ozone that result from rural and urban air pollution are part of the global warming issue since they could induce climate change by altering the radiative balance of the planet. Their presence can also have ecosystem impacts, notably on agriculture and public health. Thus, there is a need to assess the impacts under one common framework, which is the goal of the proposed strategy for *Project Asian Brown Cloud (ABC)*.



The New Framework: Interactions between Global and Regional Process

It is now undisputed that primary air pollutants and their chemical products could be transported over distances of many thousands of kilometers. Thus, emissions in one country can cause damage in other countries through transboundary and even transcontinental transport. This transport of pollutants converts local issues into regional and global concerns. Thus this issue cannot be addressed by individual national efforts alone. Past experience has demonstrated that the most effective way of tackling air pollution is through international cooperation which is the essence of this proposed strategy. We should consider the effects on global as well as regional scales with emphasis on the following:

Impacts on the Regional and Global Physical Climate System

- both by direct back-scattering and absorption, the haze causes reduction of the solar radiation reaching the surface by more than 10% above large areas and adds significant heating to the atmosphere

- the resulting alterations of spatial gradients of atmospheric temperatures can shift the monsoon precipitation systems, drying out the northern and northwest sector of South Asia while increasing rainfall over the oceans

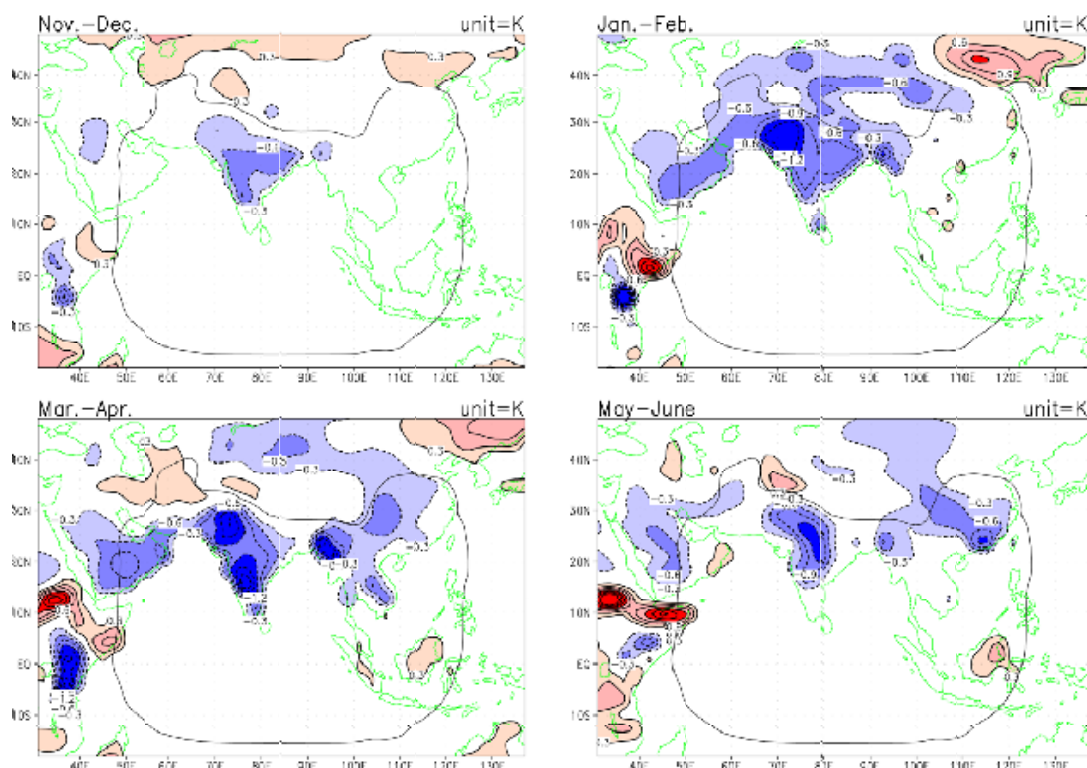
Impacts on Regional Watercycle and Agriculture

In turn, the haze could have potential impacts on agriculture by

- impeding plant growth and vitality due to ozone and deposition of pollutants
- reducing surface irradiance available for photosynthesis
- altering the regional winter monsoon hydrological cycle

Given the rapid increase in population with associated increased demands on wheat, rice and other cereals in South Asia, drastic changes in pollution control and land use may be required in the near future to assure ample food supplies and limited environmental degradation.

Simulation of Aerosol Effect on Surface Temperature



Land surface temperature change (warming in red and cooling in blue) as simulated by the National Center for Atmospheric Research's Community Climate Model 3 initiated with INDOEX aerosol data. An ellipse-like contour in each panel denotes the area where $F(A)$, aerosol atmospheric forcing, exceeds 3 W/m^2 (current greenhouse forcing from CO_2 and other gases is 2 W/m^2). In this experiment, the ratio "R", surface forcing / atmospheric forcing, is -0.9 on the average.

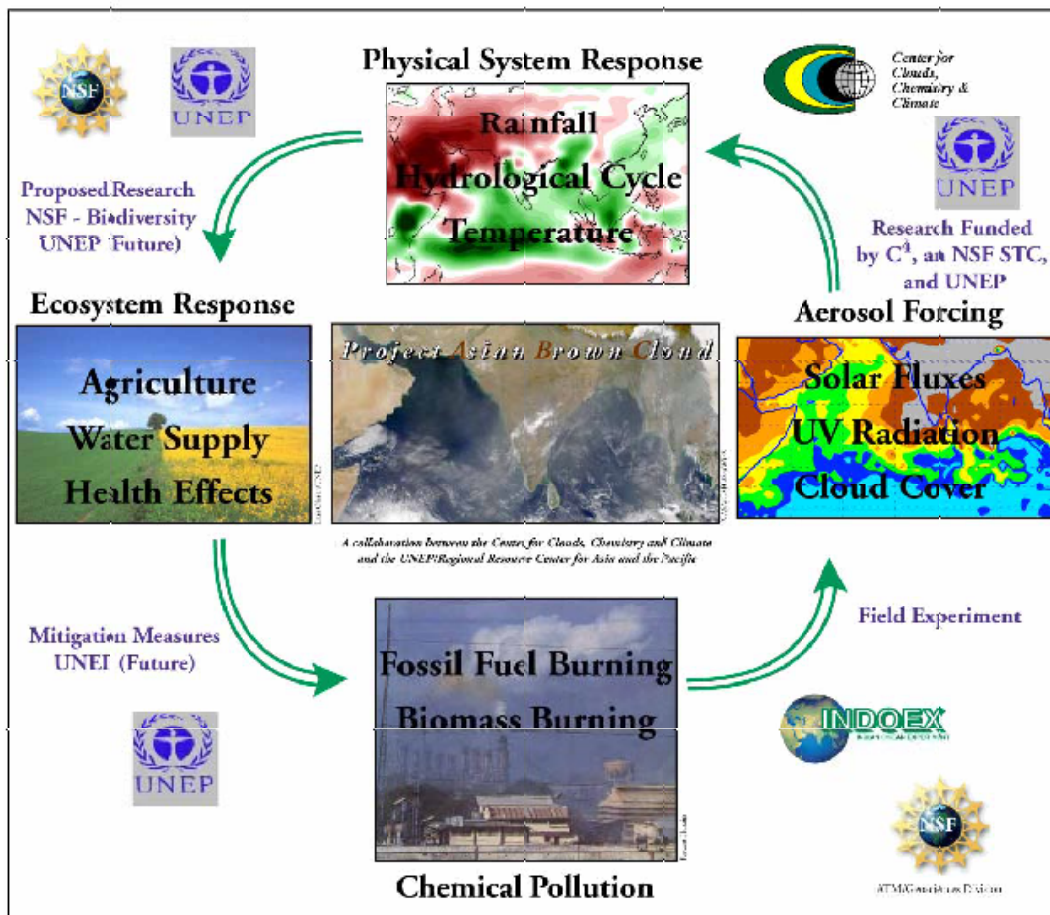
Impacts on Human Health

Recent studies in the US by the Health Effects Institute (HEI) in Cambridge, Massachusetts, found that death rate in the 90 largest US cities rise on average 0.5% with each 10 micrograms per cubic meter increase in PM_{10} loadings (aerosols less than 10 micrometers in diameter)

5. Intrinsic Synergy and Strategic Collaboration with UNEP

Scientific endeavors initiated by INDOEX have already produced a valuable scientific base for studying pollution impacts in the region. Since regional scientists are strongly involved in INDOEX, continuation of this initiative in close partnership with UNEP RRC.AP will further strengthen scientific knowledge as well as capacity building in the region. Scientific findings and developments need to be properly disseminated for policymakers to ensure informed decision-making. Currently, the communication gap between policymaking processes and scientific developments are wider in Asia than in Europe or North America. The development of the *Convention on Long-Range Transboundary Air Pollution* in Europe and the *Malé Declaration* are excellent examples of scientifically supported policy developments, which is also the essence of the proposed strategy.

Strategic partnership between INDOEX and UNEP RRC.AP would create unprecedented synergy. UNEP RRC.AP has established a network of policymakers and experts in the field of air pollution in the region, thus it could play a major role in disseminating scientific findings, such as those from INDOEX, bridging the gap between science and the policymaking process.



Interaction between Human Activities and Natural Systems. Project ABC links INDOEX and follow-on studies in regional climate and environmental changes with the policy and decision making process.

PROPOSAL: THE ABC STRATEGY

The underlying principles of this program include promoting regional capacity building and facilitating interaction between scientific and policymaking processes.

The INDOEX community is greatly interested in expanding its activities to study the broader Asia-Pacific region. This desire is necessitated by the transboundary nature of the Indo-Asian haze and its potential large-scale impact on regional weather, water cycle and monsoons in the context of global warming. Ultimately, these are fundamental issues that determine the quality of life. However, we need to assess the direct regional impacts of air pollution and distinguish such effects from regional changes occurring due to global warming.

Integrating INDOEX science with UNEP's activities in policy and impact assessment arenas gives a great opportunity to develop the science of observations, modeling and impact assessment with productive cooperation and interaction with policymakers. INDOEX scientists and UNEP had a series of discussions and propose the following three-phase approach: short-term, medium-term and long-term.

6. Short-term, January – August 2001

Recognizing the importance of INDOEX findings, UNEP has commissioned C⁴ to provide a study on the impacts of the haze on climate, health and agriculture in the Asia-Pacific region. The summary report will be available by end of August 200. The budget for this phase is US\$ 50,000 plus core funding from C⁴.

7. Medium-term, October 2001 to September 2003

A core funding of US\$ 1.5 million is needed for the first year and US\$ 1.6 million for the second year. Additional funding will be mobilized from agencies in the US, Europe and Japan. The core funding is proposed to be used primarily in the Asia-Pacific region for capacity building, while funding from the US, Europe and Japan will be used for their part of the research efforts.

INDOEX studies conducted during 1998-1999 and subsequent satellite data analyses in 2000-2001 indicate a great variability in the Asian haze; thus a long-term observation program is necessary.

Climate Observation Program

It is proposed to establish three surface observatories equipped with radiation, aerosol and chemistry instruments. One station is to be located on Hanimaadhoo Island of the Maldives in the tropical Indian Ocean and another in the Bay of Bengal to monitor the transport of the haze during the northeast monsoon. The third station would be in Nepal to observe the haze pushing against the Himalayan mountains. These stations will complement in monitoring the longrange transport of atmospheric pollution, thus will be key components for the implementation phase of the *Malé Declaration*.

The Maldivian government is keenly interested in designating an ecological reserve on Hanimaadhoo surrounding the land where the observatory will be built. Keeping the spirit of this commitment, we plan to operate the site with renewable power - wind and solar, only using fossil fuels as back-up. Funding for this power source will be sought, since it will increase the initial cost. We have been encouraged by the Maldivian Ministry of Home Affairs, Housing and Environment to present the Hanimaadhoo power plan to the Global

Environmental Facility (GEF) Program. This renewable power plan will also be considered for other stations pending feasibility and availability of resources.

Together with satellite observations, data from these sites will provide critical coverage to understand the long-term build up of atmospheric pollutants in the Indian Ocean/South Asian region and gain insights on the role of transboundary transport of pollutants. When these data are integrated with air pollution data from various cities and surface stations in Asia, we will have a better understanding of how air pollution is transported and its impacts on the Asia-Pacific region.

Toward the goal of regional capacity building, the station in the Maldives will serve as a premier regional training facility for students and scientists from Asian-Pacific, as well as the tropical calibration site for all atmospheric pollution instruments in the region.

During this period, C⁴ will coordinate the research and linkage with the disciplines of agriculture, marine bio-diversity and public health, while UNEP RRC.AP will facilitate outreach programs to regional institutions and policymakers.

Agriculture

While the effect of rising levels of carbon dioxide on agricultural productivity received attention in the past, the role of anthropogenic aerosols in regulating crop yields in South Asia is yet to be addressed. As demonstrated by a Georgia Institute of Technology study in 1999 using China as a case study, aerosols may have a significant effect on rice and wheat crop yields due to reduction of solar energy at the earth's surface. The impact of environmental pollution on agriculture in South Asia can be even more significant. Wheat in India is sown in November-December and harvested in April-May. During the entire wheat season, the average rainfall, per a study by the Indian Agriculture Research Institute in 1994, is between 25.6 and 150 mm only and can be affected by changes in the regional hydrological cycle caused by aerosols. Thus, wheat crop yield in South Asia could be particularly vulnerable to the Asian haze which intensifies during the winter monsoon.

In the next two years, proposed research will include:

- conduct numerical experiments with a variety of highly sophisticated mathematical models (WTGROWS) or Wheat Grow Simulator developed by the Indian Agriculture Research Institute, MACR or the MonteCarlo Aerosol-Cloud Radiation model of C⁴, and the National Center for Atmospheric Research (NCAR) Aerosol Assimilation Model and NCAR Community Climate Model (CCM),
- promote extensive participation of Asia-Pacific students and scientists
- facilitate close interaction with UNEP RRC.AP for impact assessment

Public Health

Statistical studies like the ones done for the US urban centers have now been conducted in a few Asian megacities, such as Beijing and New Delhi. Some of these studies have found significant differences in dose-response parameters compared to the US studies. There is thus a need to consider implementing additional studies in other cities such as Calcutta, Mumbai, Dhaka, Bangkok, Karachi and Jakarta. Efforts will be made to highlight research programs already done or underway in the region to track correlation of health impacts with the movement of the pollution haze.

8. Long-term, October 2003 - September 2006 and beyond

A core funding of US\$ 2.8 million per year is estimated for this phase. Additional funding will be mobilized from agencies in the US, Europe and Japan. The core funding will be used primarily in the Asia-Pacific region, while funding from the US, Europe and Japan will be used for their part of the research efforts.

1) As part of this long-term program, additional observatories will be built along the Pacific Rim and in western China (to measure the desert aerosols).

2) An Asia-Pacific scientist and student exchange program will be developed in climate, chemistry, water cycle, agriculture, and health aspect prediction with the ultimate goal of creating a modeling center for Asia.

3) A data access system will be established for rapid distribution throughout Asia-Pacific region, to enhance climate research as well as regional weather forecasting and impact assessment in agriculture and public health.

4) A comprehensive program will be developed and implemented for understanding the nature and scope of environmental issues facing Asia-Pacific, and develop a framework for assessing past and future impacts. This program will include integration of satellite data with regional surface data, global atmospheric chemistry and climate models in correlation with critical data from public health, agriculture, and marine and terrestrial ecology. Specifically, in the area of capacity building, it will include field experiments to facilitate active collaboration with regional scientists and practical training for regional students and post graduates. We will also explore and establish linkages with the Third World Academy of Science through the International Center for Theoretical Physics in Trieste, Italy.

5) In the long-term, the agriculture program will be gradually expanded to include Pakistan, China and particularly Indonesia, Thailand and Vietnam, the region's main rice producers. Of particular interest, to complement and to validate modeling studies, in-situ observations will be set up to provide critical data input for the models. The agriculture models will use climate data generated by the climate side of this program. Future collaboration could be with the International Rice Research Institute in the Philippines looking at possible genetic remedies, taking advantage of the CO₂ increase but hardy to atmospheric pollution and drought.

6) Epidemiologists will be encouraged to work with pathologists in the field to make case studies of deaths caused by atmospheric pollution. Asian institutions, through UNEP RRC.AP and the World Health Organization (WHO), will be paired with those in the US, Europe and Japan for comparative studies and exchange programs.

Particularly, through UNEP RRC.AP, Asian institutes and universities will be paired with INDOEX member institutions in the US, Europe and Japan for an effective scientific exchange program.

It is also proposed to organize a major Asia-Pacific Experiment of the size of INDOEX or larger starting the sixth year. Funding request beyond the fifth year could be a steady state or could be increased depending on further expansion and evolution of the program.

9. Proposed timelines and estimated budget, Oct 2001 – Sep 2003

| | YEAR 1 | | | | | | | | | | | | YEAR 2 | | | | | | | | | | | | COMMENTS | | | |
|--|-----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 2001 | | 2002 | | 2003 | | 2004 | | 2005 | | 2006 | | 2007 | | 2008 | | 2009 | | | | | | | | | | | |
| | J | A | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | | A | S | |
| Short Term (Jan- Aug 2001) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Impact Assessment I | 50 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Medium Term (year 1-2) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Surface Observation Program | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Construct+Equip Haniimaadhoo, Maldives | | | 4 | 0 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | |
| Solar Energy Program | | | 2 | 0 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | |
| Calibration Program | | | | 3 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| Construct+Equip station in Bidur, Nepal | | | 2 | 5 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| Construct+Equip station in Bay of Bengal | | | 1 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| Solar Energy (Bidur and BOBengal) | | | 2 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| Data Analysis and training | | | 5 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Visitor and Exchange Program | | | 5 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Transboundary Transport Assessment | | | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Agriculture Program | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Numerical experiments | | | 3 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Visitor and exchange program | | | 4 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Climate-Agriculture integration | | | | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Impact Assessment | | | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Public Health | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Statistical studies | | | 4 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Visitor and exchange program | | | 5 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Climate-Health integration | | | | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Impact Assessment | | | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Economic Impacts | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Quantification of pollution damage | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Visitor and exchange program | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Impact Assessment | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL PROPOSED BUDGET* | 50 | 1 | 5 | 0 | 0 | 1 | 6 | 0 | 0 | 1 | 6 | 0 | 0 | 1 | 6 | 0 | 0 | 1 | 6 | 0 | 0 | 1 | 6 | 0 | 0 | 1 | 6 | 0 |

*additional direct and indirect cost to partner universities are not included

9. Proposed timelines and estimated budget, Oct 2003 – Sep 2006

| (in thousand US\$) | YEAR 3 | | | | | | | | | | | | YEAR 4 | | | | | | | | | | | | YEAR 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------------|---|---|-----------|---|---|-----------|---|---|-----------|---|---|--------|---|---|-----------|---|---|-----------|---|---|-----------|---|---|--------|---|---|-----------|---|---|-----------|---|---|-----------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 3 | | | 2 0 0 0 4 | | | 2 0 0 0 5 | | | 2 0 0 0 6 | | | 0 3 | | | 2 0 0 0 4 | | | 2 0 0 0 5 | | | 2 0 0 0 6 | | | 0 3 | | | 2 0 0 0 4 | | | 2 0 0 0 5 | | | 2 0 0 0 6 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | | | | | | | | | | | | |
| Long Term (year 3-5 and beyond) | Budget (000 US\$) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Surface Observation Program | Budget (000 US\$) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Data collection & Analyses | 1 | 0 | 0 | | | | | | | | | | 1 | 0 | 0 | | | | | | | | | | | | | 1 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Operation and maintenance | 6 | 0 | 0 | | | | | | | | | | 6 | 0 | 0 | | | | | | | | | | | | | 6 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| New observatory in Pac Rim country 1 | 3 | 0 | 0 | | | | | | | | | | 0 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| New observatory in Pac Rim country 2 | 2 | 0 | 0 | | | | | | | | | | 0 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| New observatory in Pac Rim country 3 | 1 | 0 | 0 | | | | | | | | | | 0 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Solar Energy program | 1 | 0 | 0 | | | | | | | | | | 0 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| New observatories, ops and maintenance | 6 | 0 | 0 | | | | | | | | | | 6 | 0 | 0 | | | | | | | | | | | | | 6 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Data analyses, calibration and training | 1 | 0 | 0 | | | | | | | | | | 1 | 0 | 0 | | | | | | | | | | | | | 1 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Visitor and exchange program | 7 | 0 | 0 | | | | | | | | | | 1 | 5 | 0 | | | | | | | | | | | | | 2 | 8 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Field study | 1 | 0 | 0 | | | | | | | | | | 2 | 0 | 0 | | | | | | | | | | | | | 3 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Transboundary transport assessment | 6 | 0 | 0 | | | | | | | | | | 8 | 0 | 0 | | | | | | | | | | | | | 1 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Agriculture Program | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Numerical experiments | 5 | 0 | 0 | | | | | | | | | | 5 | 0 | 0 | | | | | | | | | | | | | 5 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Expansion to rice producing countries | 5 | 0 | 0 | | | | | | | | | | 1 | 0 | 0 | | | | | | | | | | | | | 1 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Visitor and exchange program | 2 | 0 | 0 | | | | | | | | | | 3 | 0 | 0 | | | | | | | | | | | | | 3 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Climate-Agriculture integration | 6 | 0 | 0 | | | | | | | | | | 6 | 0 | 0 | | | | | | | | | | | | | 6 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Field studies | 1 | 5 | 0 | | | | | | | | | | 1 | 5 | 0 | | | | | | | | | | | | | 1 | 5 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Impact Assessment | 4 | 0 | 0 | | | | | | | | | | 6 | 0 | 0 | | | | | | | | | | | | | 8 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Public Health | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Statistical studies | 2 | 0 | 0 | | | | | | | | | | 2 | 0 | 0 | | | | | | | | | | | | | 2 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Visitor and exchange program | 2 | 0 | 0 | | | | | | | | | | 4 | 0 | 0 | | | | | | | | | | | | | 5 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Climate-Health integration | 5 | 0 | 0 | | | | | | | | | | 5 | 0 | 0 | | | | | | | | | | | | | 5 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Field studies | 1 | 5 | 0 | | | | | | | | | | 1 | 5 | 0 | | | | | | | | | | | | | 1 | 5 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Impact Assessment | 4 | 0 | 0 | | | | | | | | | | 4 | 0 | 0 | | | | | | | | | | | | | 4 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Economic Impacts | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Quantification of pollution damage | 2 | 0 | 0 | | | | | | | | | | 2 | 0 | 0 | | | | | | | | | | | | | 2 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Visitor and exchange program | 6 | 0 | 0 | | | | | | | | | | 6 | 0 | 0 | | | | | | | | | | | | | 6 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Impact Assessment | 4 | 0 | 0 | | | | | | | | | | 4 | 0 | 0 | | | | | | | | | | | | | 4 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Data Access System | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Development and testing | 7 | 0 | 0 | | | | | | | | | | 7 | 0 | 0 | | | | | | | | | | | | | 7 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Operations and training | 0 | 0 | 0 | | | | | | | | | | 0 | 0 | 0 | | | | | | | | | | | | | 0 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Integrated Computer Model for A-P | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Development and testing | 2 | 0 | 0 | | | | | | | | | | 2 | 0 | 0 | | | | | | | | | | | | | 2 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Visitor and exchange | 5 | 0 | 0 | | | | | | | | | | 5 | 0 | 0 | | | | | | | | | | | | | 5 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Student/Scientists Exchange program | 5 | 0 | 0 | | | | | | | | | | 5 | 0 | 0 | | | | | | | | | | | | | 5 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Planning for Asia-Pacific experiment | 5 | 0 | 0 | | | | | | | | | | 5 | 0 | 0 | | | | | | | | | | | | | 5 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL PROPOSED BUDGET* | 2 | 8 | 0 | 0 | 2 | 8 | 0 | 0 | 2 | 8 | 0 | 0 | 2 | 8 | 0 | 0 | 2 | 8 | 0 | 0 | 2 | 8 | 0 | 0 | 2 | 8 | 0 | 0 | 2 | 8 | 0 | 0 | 2 | 8 | 0 | 0 | 2 | 8 | 0 | 0 | 2 | 8 | 0 | 0 | 2 | 8 | 0 | 0 | 2 | 8 | 0 | 0 | 2 | 8 | 0 | 0 | 2 | 8 | 0 | 0 |

*additional direct and indirect cost to partner universities are not included