B-54 Special collaborative studies for the assessment of integrated sustainable development policies to mitigate climate change based on AIM (Asia-Pacific Integrated Model)

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Total Budget for FY2000-FY2004 546,570,000 Yen (**FY2004**; 106,863,000 Yen)

Key Words Integrated assessment, Climate change, Asia-Pacific region, Simulation model, Policy design

1. Introduction

The Asia-Pacific Integrated Model (AIM) is a set of computer simulation models for assessing policy options on sustainable development particularly in the Asia-Pacific region. It started as a tool to evaluate policy options to mitigate climate change and its impacts, and extended its function to analyze other environmental issues such as air pollution control, water resources management, land use management, and promotion of environmental industry. More than 20 models have been developed so far, and they are classified into emission models, climate models and impact models from the viewpoint of climate policy assessment. These models have been used as single models or in combination depending on policy needs. They have contributed not only to governments in the Asian region, but also to international organizations such as IPCC, UNEP, Eco Asia, ESCAP, and OECD.

The successful implementation of greenhouse gas mitigation options necessitates overcoming many technical, economic, political, social and cultural and/or institutional barriers. It is essential that the mitigation policies adopted achieve the goals of sustainable development without causing serious economic impacts. We have assessed the impacts of climate policies with regard to enhancing co-benefits and penetration of energy efficient technologies. The model has been applied to several countries in the Asia-Pacific region such as Japan, China, India, Korea, Thailand, Malaysia and Vietnam. This has been achieved through collaboration with researchers from these countries. The AIM international workshop, training workshops and greenhouse gas stabilization workshop have been held to improve AIM models and to support transferring the AIM model to developing countries in Asia.

2. Research Objective

The AIM work has focused on the possibilities of reducing GHG emissions like CO_2 in the Asian-Pacific region. While discussing climate change policy to stabilize CO_2 concentration in the atmosphere, policy integration with the local or domestic environmental and economic policies becomes an important political issue. This is true not only for developing countries in Asia but also for developed countries including Japan. This research analyses GHG emission reduction and adaptation policies in the developing Asia-Pacific countries through cooperation with institutes in these countries. It is essential to design the climate change policies integrating other policies such as pollution reduction, because GHG emissions reduction policy per se has relatively low priority in developing countries. The scenarios on climate policies consider socio-economic development in the future through likely domestic policies. They also consider international policies, which include collaboration among Annex-I countries and between Annex-I and non-Annex-I countries. In the previous AIM model analysis, the simple climate model had been developed. A feature of this research is the attempt to integrate the global circulation model (GCM) with the existing AIM models. Thus the main object of this research is the development of new models, their integration, and application to Asia-Pacific countries in collaboration with the foreign institutes.

3. Research Method

We have been developing the AIM model to assess climate policies and their impact. AIM model consists of emission model, climate model and the impact model. In this research, besides these models, new models (which includes a GCM model) and the future scenarios on socio-economy have been developed and applied to the Asia-Pacific countries. The detailed description of each model is presented in the subsequent sections. Based on the simulation results, the climate policy impacts and their effectiveness are discussed.

4. Result

(1) Regional studies for sustainable development and model dissemination

1) Regional studies for the assessment of integrated sustainable development policies to mitigate climate change

Climate policy integrated with local environmental policies and economic policies in the Asia-Pacific region were evaluated using the improved AIM models. The models were applied to Asian countries such as Japan, China, India, Korea, Thailand and Indonesia, and the effectiveness of the policy integrations between local air-pollutant reductions policy and GHG reductions policy was assessed through regional studies.

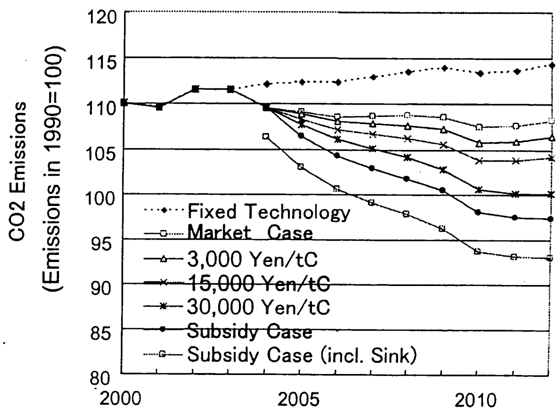


Fig. 1 CO_2 emissions projections in Japan from 2000 to 2012.

The Japanese AIM/Enduse model has been updated and applied to estimate CO_2 reduction policies. Several cases are analyzed including a fixed technology case, a market case, carbon tax cases and subsidy cases. Fig. 1 shows emission projections through 2012. The emissions in 2010 are estimated to increase 5.8% compared to 1990 level with 3,000 yen/t-C tax case and 0.6% with 30,000 yen/t-C tax case. Also estimated is the amount of subsidies for achieving 2% reduction of CO_2 emissions compared to 1990 level. The tax amount of 45,000 yen/tC is required if this should be achieved without subsidy.

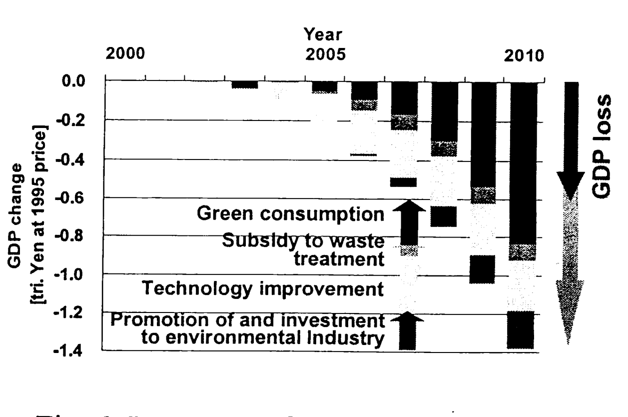


Fig. 2 Recovery of GDP loss caused by greenhouse gas mitigation policies

The countermeasures to achieve the Kyoto targets may result in economic losses. It is important to investigate options to recover such economic losses. Fig. 2 shows the GDP losses caused by GHG mitigation policies in Japan as well as the recovery by the increase of investment to environmental industry, technology improvement, subsidy to waste treatment and promotion of green consumption. The analysis shows that almost 0.8 trillion Japanese Yen can be recovered with the combination of such policies.

Fig.3 shows the CO_2 emissions projections in India in 2030. 495 large point sources (LPS) are identified that contribute more than 60% of all India emissions in 2030. The sectoral shares indicate that LPS emissions would continue to be major contributors to national CO_2 and SO_2 emissions in future. It was found that there was high degree of positive correlation between measures for CO_2 reduction and other air pollutant reductions.

The model is extended to evaluate non-CO_2 gases such as CH_4 and N_2O. CH_4 emissions from coal production, oil and gas production, manure management and municipal solid waste are high in India. CH_4 emissions reach about 24 Tg-CH_4 by 2030 from 18.6 Tg-CH_4 in 2000 for the base case scenario. N_2O emissions increase from about 308 Gg-N_2O to reach 806 Gg-N_2O in 2030. Over the thirty year period shares in total emissions for agriculture and livestock related emissions reduce. However those from waste and coal mining rise gradually.

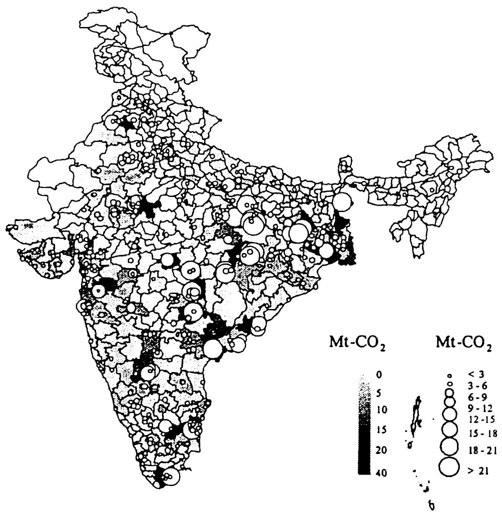


Fig.3 Regional distribution of CO_2 emissions in India in 2030 in reference scenario.
Note: Circles show emissions from large point sources.

The country enduse model is also extended to a global scale for the analysis of GHG reduction potential. Sectoral and regional GHG reduction potentials are estimated and cost-effective countermeasures in developed and developing countries are identified. It was found that there is high potential to reduce CO_2 and CH_4 from energy industry, CO_2 from transportation sector, and industrial sectors. AIM international workshops and COP side events were held to revise and disseminate the AIM model.

2-1) International collaborative studies for evaluating the effects of CDM (Clean Development Mechanism)

The direct effects and ancillary benefits of CDM cooperation have been analyzed through the development of a technology model (AIM/Local-China) and its applications to Beijing City and China's iron and steel industry. Fig.4 shows SO_2 emissions under five scenarios. They are a reference scenario

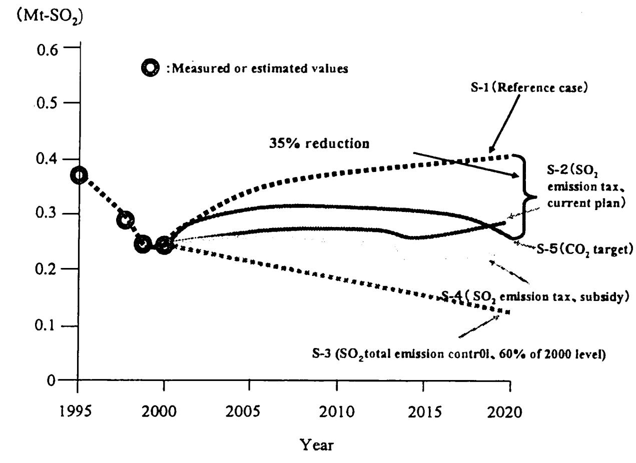


Fig.4 SO_2 emissions projection in Beijing

(S-1), a scenario with current SO_2 emission tax (S-2), a scenario where total SO_2 emission is constrained to 60% of SO_2 emission in 2000 (S-3), a scenario with SO_2 tax and subsidy (S-4), and a scenario with CO_2 emissions constraint (S-5). It is shown that 35% SO_2 reduction is possible in S-5 scenario compared to the reference case emission.

The study is extended to address the impacts of CDM cooperation on the national economic development in the host country. A top-down type macroeconomic model based on the computable general equilibrium model for China (AIM/Material-China) has been developed. In this study the top-down approach is linked to the bottom-up approach by adopting the technology efficiency improvement information from the technology model. Funds for CDM cooperation are treated as additional investment. Overall impacts of CDM cooperation on China's national GHG emissions as well as pollutant emissions are estimated using AIM/Material-China model. The effects of CDM cooperation on recovering China's GDP loss from domestic pollution control have been analyzed.

2-2) Non CO_2 GHG Emissions in India: Linking Bottom analysis to CGE model

One of the major issues facing India and other South Asian nations today is the rising energy demand essential to facilitate economic growth. South Asia today is grappling with energy shortfalls. The region is also home to several of the most polluted cities in the world. Traditionally most studies have focused on CO_2 emissions. However the growing emissions and importance of abating non-CO_2 gases cannot be underplayed. The major sources of non-CO_2 emissions include agriculture and waste. Data surveys have been done to identify past emission profiles of non-CO_2 gases, its sources and mitigation options.

The sectors to which the various removal processes were applied include the coal sector, natural gas, manure management, enteric fermentation, paddy and municipal solid waste sector. Most of the technologies studied are under various stages of use and development in developed countries like the US and several of the EU countries. The major source for technical information on removal processes has been USEPA reports and consultation with sector experts. For India it is assumed that these technologies would become available for application on an appropriate scale from 2010. Using the AIM/Enduse (India) model the Marginal Abatement Cost (MAC) curve for CH_4 for 2020 was developed. The MAC illustrates the amount of reductions possible at various values for CH_4. The results from the preliminary analysis for the year 2020 are presented in Fig. 5. Such marginal abatement cost curves are used to estimate the elasticity of substitution for GHGs in CGE models, which use Constant Elasticity of Substitution production functions.

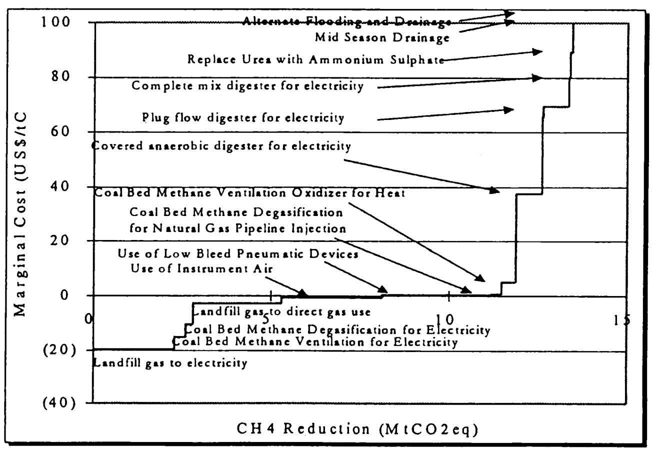


Fig. 5 Marginal Abatement Cost curve for CH_4 (For Year 2020)

(2) Development of integrated assessment model and integration framework

A family of AIM models has been developed to estimate GHG emissions in Asia-Pacific region and to identify incentives to promote the climate policies in developing countries. The following models have been developed or revised; AIM/Enduse model for assessing the GHG emissions reduction and air pollution reduction in the local area, AIM/Material model to estimate the CO_2 emissions and material balance change through economic activities, AIM/Trend model to evaluate the energy demand and the related pollution emissions in 42 Asia-Pacific countries, AIM/CGE, a global computable general equilibrium model, to assess the economic impacts on Asian-Pacific countries taking into consideration international trade, and AIM/Impact model to estimate the climate change impacts. These models have also been soft linked to verify the consistency of the results.

Fig. 6 shows the model interface to assess marginal abatement cost curve in AIM/Enduse model and the example of the Chinese power sector. AIM/Enduse can calculate, among other things, marginal abatement cost and reduction potential of each technology option in each sector. Such results are extremely useful for planning resources, prioritizing investments and other policies for supporting desired technology options. Fig. 7 shows a result of AIM/Impact comparing potential productivity of wheat in 2050 in various regions of the world in two scenarios – with and without adaptation measures. The adaptation measures considered are introduction of heat tolerant seeds and advancement of plantation time. AIM/Impact can thus be effectively used for evaluating adaptation policies.

The set of AIM models can enable integrated assessment of climate change, local environment and impacts. They have been effectively used for carrying out such assessments for Japan as well as other Asian countries. Through several training workshops and international symposiums, the models and their results have been widely disseminated among researchers and policy makers in China, India, Thailand and Korea.

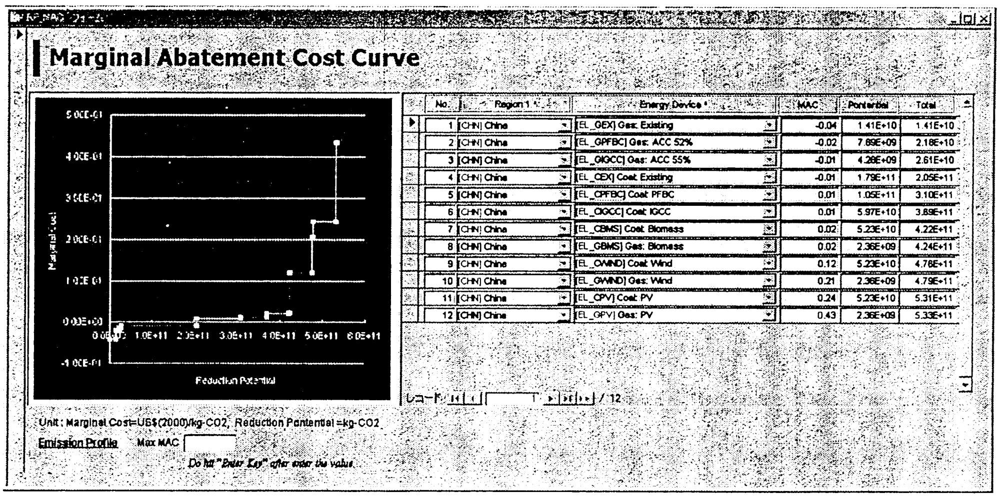
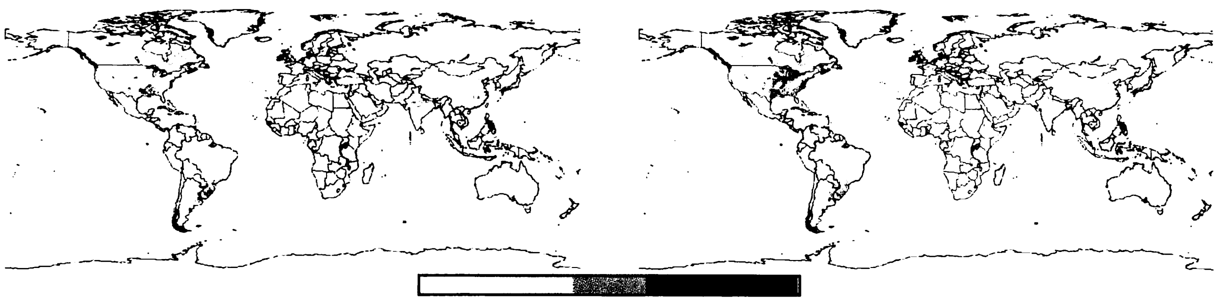


Fig. 6 Module to estimate regional abatement costs (Example is data for the power sector in China)



With adaptation Without adaptation

Note: Adaptation includes introduction of heat tolerant seeds and advancement of plantation time.

Fig. 7 Changes in winter wheat productivity in 2050

(3) International collaborative studies for scenario developments and model comparisons

Several scenarios have been discussed and quantified for collaboration with international organizations and projects such as IPCC, Millennium Ecosystem Assessment Project, ACROPOLIS (Assessing Climate Response Options: POLIcy Simulations), UNEP GEO (Global Environment Outlook) and Eco Asia. Future GHG emissions have been estimated as quantitative pathways along storylines. Scenario comparison is effective to estimate the range of future emissions so as to reflect current understanding and knowledge about underlying uncertainties and to evaluate policy options to cope with climate change.

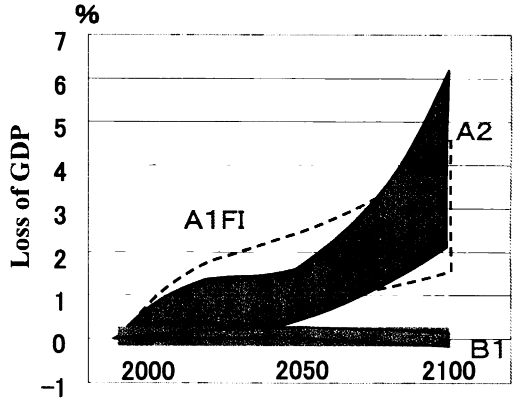


Fig. 8 The economic losses to achieve 550ppmv CO2 atmospheric stabilization target under different scenarios

From the CO_2 concentration scenarios based on the SRES scenario of IPCC, the economic and environmental impacts are estimated. Fig. 8 shows the economic losses to achieve atmospheric stabilization of 550ppmv CO_2 concentration under three SRES scenarios. The economic impacts are large under A1FI and A2 scenario while that of B1 is small.

The long-term CO_2 and SO_2 emissions from 1990 to 2300 for stabilizing CO_2 concentration in atmosphere are estimated by scenarios using AIM/SSG (stabilization scenario generator). Fig. 9 shows the CO_2 emissions by CO_2 stabilization scenarios. It is found that after 2150 when stabilization of the atmospheric CO_2 concentrations is achieved, further efforts have to be done to keep maintain the stabilization levels. The emissions range is small in 2300 among different stabilization levels compared to that of 2100.

Mitigation and stabilizations have extensively been reviewed and the emissions scenarios database has been updated. Quantitative analyses on GDP, population, carbon intensity, energy intensity and carbon tax have been done at a regional level in SRES 4 regional aggregations and also at a global level.

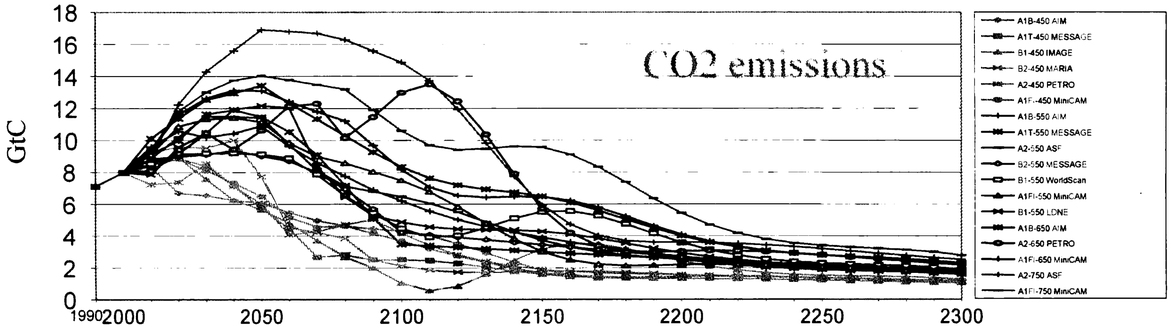


Fig. 9 CO2 emissions in long term

Scenarios have also been developed for UNEP/GEO3. Four scenarios were developed and quantified. They are the Market First, a Policy First, the Security First and the Sustainability First scenarios. The Markets First scenario envisages a world in which market-driven developments converge on the values and expectations that prevail in industrialized countries. In a Policy First world, strong actions are undertaken by governments in an attempt to reach specific social and environmental goals. The Security First scenario assumes a world of great disparities, where inequality and conflict prevail, brought about by socio-economic and environmental stresses. Sustainability First depicts a world in which a new development paradigm emerges in response to the challenge of sustainability, supported by new, more equitable values and institutions. Fig. 10 illustrates an analysis of GEO3 scenarios. It shows changes in energy-related CO_2 emissions by 2032 relative to 2002. Although the change in CO_2 emissions is the highest for India, the absolute increase in CO_2 emissions is highest in China.

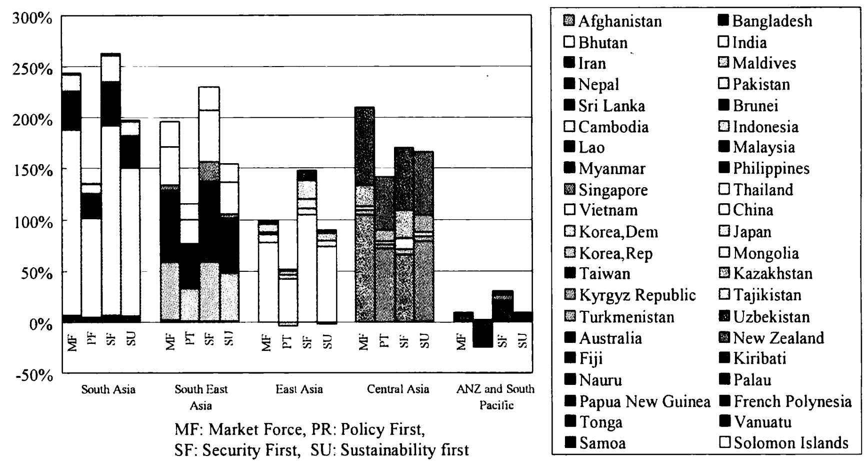


Fig. 10 Change in energy-related CO2 emissions by 2032 relative to 2002

Comparison of stabilization target scenario has been done in EMF (Energy Modeling Forum). EMF 19 studied the economic and climatic impacts of three emission scenarios targeting 550 ppmv atmospheric concentration, and three tax scenarios. The profiles of energy consumption and economic losses of each policy scenario are compared to the reference scenario. The model also estimates that global mean temperature will increase 1.7-2.9 °C in 2100, and the sea level will rise 40-51 cm, compared to the 1990 levels under the EMF scenarios. Impacts on food productivity and malaria infection are estimated to be very severe in some countries in the Asian region. EMF21 examined non-CO_2 gases (CH_4, N_2O and F gases). A recursive dynamic CGE (Computer General Equilibrium) model has been developed to analyze greenhouse gas reduction options including non-CO_2 gas abatement technologies. Multi-regional, multi-sectoral and multi-gas

CGE model and a simple climate change model were used to simulate long-term climate stabilization emission path. Preliminary results showed that multi gas mitigation options including CH_4 and N_2O abatement technologies will reduce GDP loss more than CO_2 only mitigation options for long-term climate stabilization, even though CO_2 mitigation options will reduce not only CO_2 emissions but non-CO_2 gas emissions simultaneously.

ACROPOLIS examines environmental effect with the assumption of energy efficiency improvement, and externalities of air pollutants. Efficiency improvement by application of efficiency standards leads to reduction of primary energy demand, final energy demand, as well as CO_2 emissions. The effect of efficiency improvement in transport and services sectors is lower than the effect of efficiency improvement in industrial and residential sectors. Internalizing the externality of local pollutants (SO_2 and NOx) and the global pollutant (CO_2) simultaneously leads to reduction in all emissions but the effect is less on CO_2 (around 3% by 2050 over reference case) as compared to SO_2 and NOx (around 17% by 2050 over reference case). One of the primary reasons for this result is that the level of tax applied for SO_2 emissions is very high as compared to the level of tax for CO_2 emissions. The results also show that there are variations among regions but the general tendencies of energy systems, emissions and costs remain same for all the regions.

(4) Study of the estimation of new climate change scenarios based on new emission scenarios

We have examined the effect of sulfate aerosols on global warming by comparing results from common scenario runs with multi-CGCMs. The most dominant geographical response due to the cooling effect of aerosols appears as a reduction of the magnitude of global warming patterns, in spite of the non-uniform distributions of sulfate aerosols.

IPCC Technical Supporting Unit requested the radiative forcing with stratospheric adjustment for each scenario experiment. To cope with these requirements, the radiative forcing with stratospheric adjustment has been calculated. Changes in the radiative forcing between the pre-industrial revolution and the present periods are 2.2 Wm^{-2} and 2.4 Wm^{-2} with and without the stratospheric adjustment, respectively.

In order to perform 21st century scenario experiments for IPCC Forth Assessment Report, the atmospheric concentrations of sulfate aerosols have been calculated for all the SRES emission scenarios (A1B, A1T, A1FI, A2, B1 and B2) of sulfur dioxide. A chemical transport model MASINGAR developed at the MRI is used for calculating the aerosol concentration. The MASINGAR includes nss-sulfate, carbonaceous, mineral dust and sea-salt aerosols, and accounts for advective transport, subgrid-scale eddy diffusive and convective transport, surface emission, and dry/wet depositions as well as chemical reactions. The advective transport is calculated using a three-dimensional semi-Lagrangian transport scheme. The MASINGAR is coupled with the MRI/JMA98 GCM but, for the present purpose, nudged to atmospheric fields obtained from a simulation with a coupled atmosphere ocean model. As a result we are ready for performing the 21st century scenario experiments. A comparison of the column integrated atmospheric aerosols for A2 and B2 scenario between those provided by IPCC (2001) and those calculated here reveals some discrepancy between them, suggesting that the atmospheric aerosols depend on the chemical transport models to some extent.

We have performed the global warming experiments using the aerosol concentration scenario. Fig. 11 shows the temporal changes in annual and global mean surface air temperature (TSA) and precipitation (PR). Each ensemble member is also shown for A1B, A2 and B1 scenarios. Both TSA and PR rise associated with the increase in GHGs in each scenario. Annual variability and dispersion among ensemble members is greater in PR than in TSA. TSA rises about 2.4, 2.1, 3.2, 2.7, 1.7 and 2.0 degrees centigrade for A1B, A1T, A1FI, A2, B1 and B2 scenarios, respectively, between the periods 1961-1990 and 2071-2100.

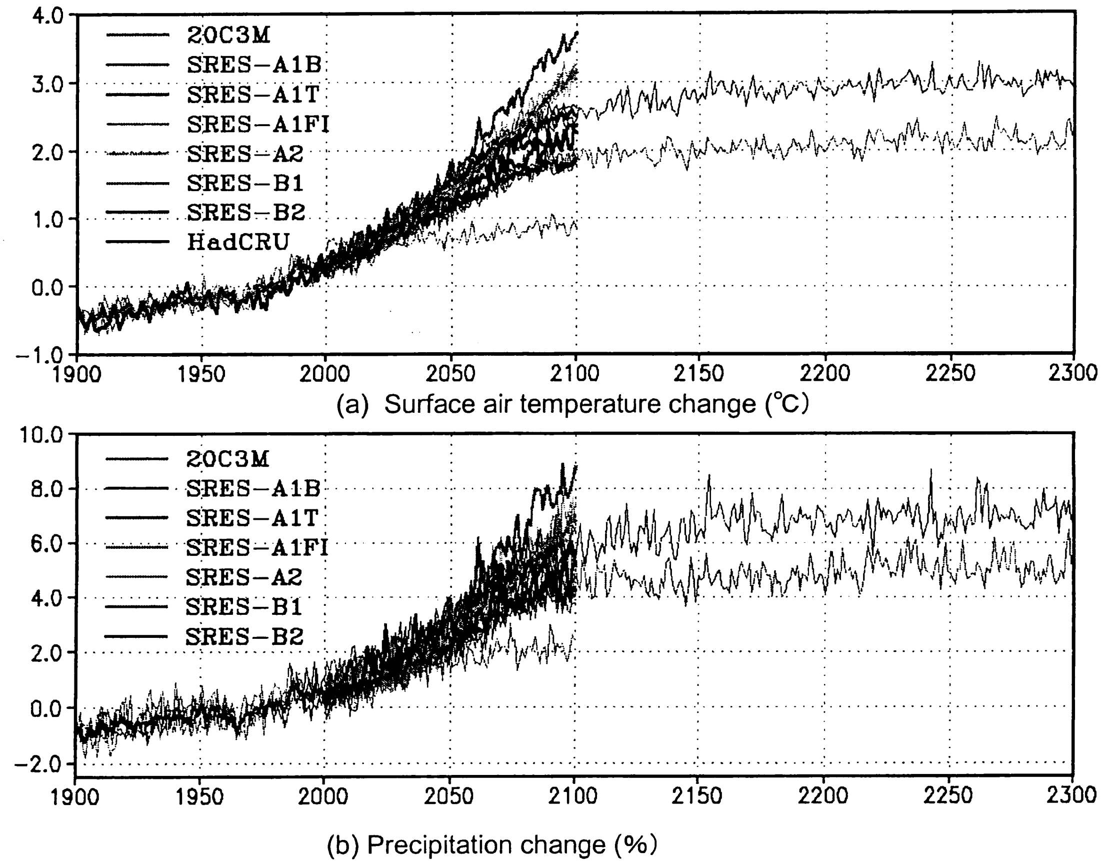


Fig.11 (a) Changes in global and annual mean surface air temperature (degrees centigrade) from the average of for 1961-1990of 20C3M runs. (b) Same as (a) but for precipitation (%). Thin line shows individual runs for ensemble experiments. Black line in (a) shows observed anomaly from the average for 1961-1990 by Jones et al. (2001)[1].

5 Discussion

In order to achieve the stabilization of climate, the GHG emissions should be reduced a great deal not only in developed countries but also in developing countries. For this purpose, a key issue is integration of climate policy with economic development and other environmental policies that have higher priority than the CO_2 emissions reduction. Countermeasures to integrate climate policy and economic development policy have been assessed based on the regional and global model development and application to Asia-Pacific countries in cooperation with researchers in developing countries.

The research team has worked on a variety of models capable of analyzing a whole gamut of policies and issues concerning climate change. The AIM/Enduse model is being linked to the AIM/CGE model for analyzing global non-CO_2 emission trends. This study is in collaboration with the EMF. This Global general equilibrium model has also been used to analyze the international trade effects. The AIM/Material model has been further developed to study the impacts of local pollution on the health of individuals. This study is being carried out for China. The AIM/Impact model has been used to study issues in adaptation, especially studies relating to trends in global rice and wheat productivity. Also the Meteorological Research Institute (MRI) has developed a model MASINGER to estimate three-dimensional distribution of sulphate aerosol and has analyzed the impact of GHGs on climate change for the 21st century using the six IPCC SRES scenarios. These outputs are being used for impact studies.

We have also continued our collaboration with the researchers in Asia countries such as China, India, Korea, Thailand, Malaysia and Indonesia and developed each country enduse model. The main aim of the collaborative process is to build capacity among researchers in these developing countries so that they can themselves modify these models and study issues pertaining to climate change in their respective countries. Three young researchers have been nominated as IPCC lead authors for the 4th Assessment Report. Thus through capacity building and collaboration it is believed that the developing countries would have capacity to identify, analyze and address their issues concerning climate change and sustainable development.

Reference

1) Jones, P. D., Osborn, T. J., Briffa, K. R., Folland, C. K., Horton, E. B., Alexander, L. V., Parker, D. E. and Rayner, N. A. (2001) Adjusting for sampling density in grid box land and ocean surface temperature time series. J. Geophys. Res., 106, D4, 3371-3380.