Acid Deposition and Rains-Asia

Introduction

Earth's atmosphere is ever changing. Studies done in the past have suggested that human activities account for the most rapid changes in the earth's trace gases over the past two hundred years. Significant changes in the earth's atmosphere can have great implications both economical and political. The atmospheric changes not only influences the economics but can also destroy the earth's ability to sustain life. Therefore, a lot of research is being done to understand the atmospheric chemistry and the impact that human activity has on degrading the earth's environment.

Some of the research on atmospheric chemistry are based on model studies that simulate the future climatic and environmental conditions based on the observed values from the past. This report provides an insight to one such effort. The paper focuses on anthropogenic sulfur emissions in Asia and their growing problems with acid deposition.

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Task 1: Background study

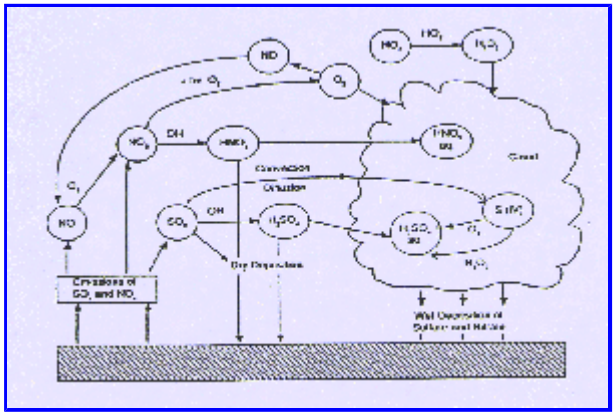
What is acid deposition ? What are aerosols, and what roles do they play in atmospheric chemistry ? Explore the general purpose of Rains-Asia software and its capabilities.

Acid Deposition

Gases like SO_2 and NO_x are emitted by cars, coal fired generators, non-ferrous smelters, volcanic eruptions, etc. Because of high oxidation potential of the atmosphere, these gases are

oxidized to form sulfates and nitrates through gaseous and aqueous phase processes. Besides these SO_2 and NO_x, some organic acids are also produced during the oxidation of emitted organic compounds. Result of these reactions is the existence of acids in gas phase (HNO_3, HCl, HCOOH, CH_3COOH, etc.), in aerosol phase (sulfates, nitrates, chlorides, organic acids, etc.) and in the aqueous phase. The following schematic flow diagram explains the transformation of these species.

Figure 1. Flow diagram for the deposition of SOx and NOx emissions.



These compounds can be carried great distances and deposited anywhere from a few hundreds to a few thousand kilometers from the source area. Dry and wet deposition of these acid particles are known as acid deposition. The removal of acid material by rain is called acid rain. Even though the term acid rain implies removal only by wet deposition, it is important to keep in mind that the effects attributable to acid rain are in fact, a result of both wet and dry depositions. For further information on acid rain:

 Environment Canada

 US EPA Acid Rain Program

Aerosols

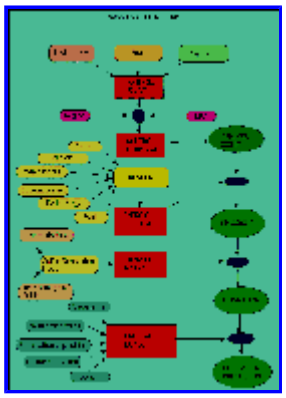
An aerosol is stable suspension of solid, or liquid particle or both, in air. The atmospheric particles maybe emitted or injected into the atmosphere by wind driven erosion, by accretion or nucleation from gaseous molecules, as happens particularly in the case of anthropogenic emissions. They serve as the media upon which most of the atmospheric reactions can take place. Aerosol particles are present not only in the troposphere but also in the stratosphere, as a layer of small particles centered around 25 km at the equator. In urban and industrial areas, most airborne aerosol particles are related to arise from human activities such as transportation, fuel combustion, industrial processes, solid waste and constructional activities. Agricultural operations also

increase the level of aerosol in the atmosphere.

Rains Asia

Rains Asia (Regional Air Pollution Information System) is an interactive software that provides an estimation of sulfur dioxide and sulfate emissions, and critical sulfur deposition loadings throughout the Asia. A schematic flow diagram of how these calculations are made is shown below.

Figure 2. Schematic flow diagram followed during the calculations of emissions and depositions in Rains Asia



This model predicts the future emissions and depositions, as well as the costs incurred to control these emissions under different scenarios, such as business as usual and best available control technology. The model can separate emissions due to different sectors such as total, agricultural, industrial, coal natural gas etc. The simulation range for the model is from the year 1990 to the year 2020. It further explores the emissions and depositions over the period of 1990 to 2020. The model uses observed values from 1990 to simulate for future years scenario. In this work, the results presented include all the sectors and the fuel types, unless specified. For further information on Rains Asia:

Rains Asia

Asian Problem

Quality of air in Asia is showing a steady rise in the concentration of anthropogenic gases. This is coupled with the Asia's growing population, its expanding economy, and its associated systems of energy consumption and production. By the year 2020, the level of sulfur emissions form Asia is predicted to exceed the combined emissions from Europe and North America.

Task 2 : Sulfur dioxide emissions

Estimate the amount of sulfur dioxide emitted by any country of your choice for 1990 and the simulated amount for 2000, 2010 and 2020. Observe the amount of increase in emissions under business as usual scenario, and with some type of control.

A comparative study using Rains Asia, on sulfate emissions for the years of 1990 through 2020 is made under different scenarios. Calculations are based on "no further control" scenario and with "best available technology" scenario for Asia. Results are tabulated in Table 1.

Table 1: Sulfur dioxide Emissions over Asia (ktons of SO2)

Scenario	1990	2000	2010	2020
No further control	33575.0	53008.8	78635.7	109823.0
Best available technology	33575.0	8183.8	11582.5	16138.6

A further study can be conducted on a regional basis, to know the country shares. For example, sulfur dioxide emissions from China, main share holder in Asia has been studied and the results are tabulated in Table 2. From the figures shown below, it is obvious that more than 60% of the emissions in Asia are from China.

Table 2: Sulfur dioxide Emissions over China (ktons of SO2)

Scenario	1990	2000	2010	2020
No further control	21908.3	34327.9	47840.0	60687.6
Best available technology	21098.3	4190.2	5568.2	6672.8

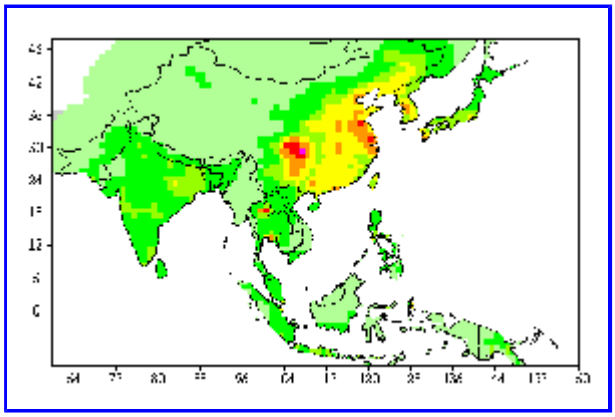
Similar studies can be conducted on the rest of the countries in Asia, under different scenarios depending on the economical and political conditions of that country. Such as base_bct (best control technology), base_act (advanced control technology)

Task 3 : Acid deposition

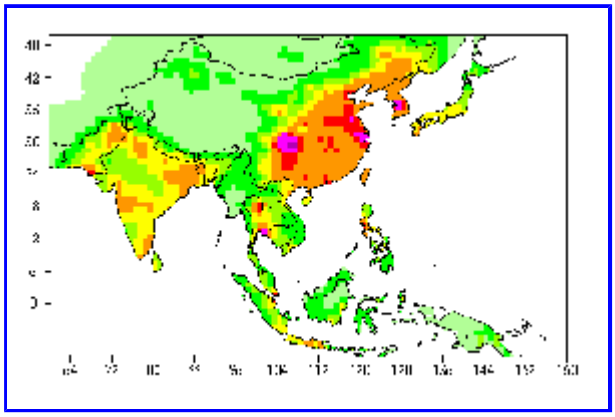
Estimate the amount of acid deposited on a country of your choice in 1990 and the subsequent years. Try different control scenarios for simulating the future depositions.

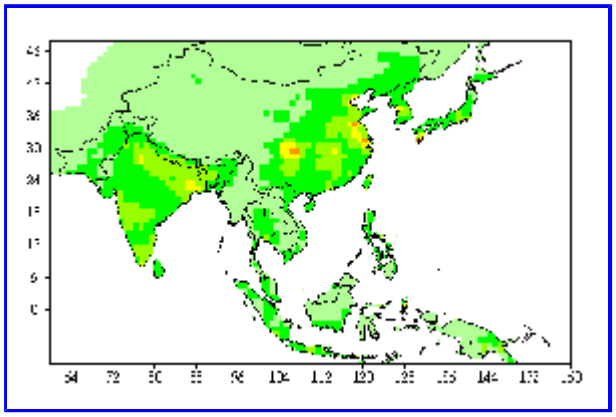
These sulfur dioxide and NO_x emissions are subjected to transport models to simulate the expected acid depositions over the regions. Because of the lateral transport of these species due to the wind factor, the effect of these emissions are felt not only at the source point, but also on the neighboring states. Rains Asia also provides an opportunity to find out what percentage of the deposition comes from the neighboring states at a particular site. Figures below show the level of deposition in 1990 and 2020 under two different scenarios.

Figure 3. Acid Depositions under no further control scenario for the year of 1990



Figures 4 &5. Acid Depositions under no further control and best available technology scenarios for the year of 2020 respectively





Similar kind of analysis can be made on a regional basis as in case of emissions.

Task 4 : Effect of Lateral Transport

Explore the amount of sulfur deposited in a given country from its own emissions as well as emissions from other country.

As mentioned in Task 3, because of the wind factor, gases emitted are transported over thousands of kilometers before they precipitate out as dry or wet deposition. Rains Asia provides an opportunity to explore the map of acid deposition, to study the effect of lateral transport. One such study has been conducted to show its effect. This is a site in north west Burma (latitude: 24 & longitude: 95). Notice that under different scenarios, the deposition in Burma due to Burma's own emissions is only between 5% - 12%. The rest comes from the neighboring countries.

Table 3. Depositions due to lateral transport from the neighboring countries at

a site northwest in Burma (Lat: 24 & Lon: 95) in mg.m2/yr

Scenario/ year / Country	base_nfc/ 1990	base_nfc/ 2020	base_bat/ 2020
Burma	6	13	11
India	44	189	70
China	5	13	1
Nepal	1	3	2
Pakistan	1	5	0
Bangladesh	6	28	9

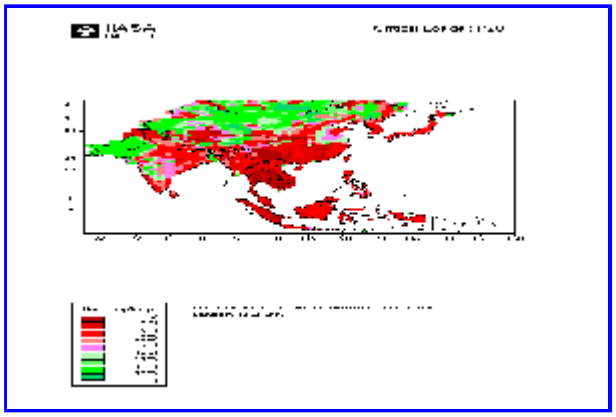
We can also find out the contribution on a regional basis. For example, of the 44 units of deposition due to emissions from India, we can find out how much of it is from northern India, how much of it is from southern India, etc. Similar explorations can be conducted over other parts of Asia to get a better insight of the lateral transport effect.

Task 5 : Critical loads and Excess Deposition

What is a critical load? Explore the exceedance of critical loads in a country of your choice under different percent exceedance levels and for future with different control scenarios.

A critical load is an estimate of the maximum allowable input of acid deposition that will not lead to reduced growth or other indirect damage to the ecosystems. This report has been prepared for a 20 percentile critical load, which means that about 80% of the ecosystem in each grid will have a low risk of being damaged when the acid deposition does not exceed this 20 percentile critical load. Critical loads for the years of 1990 and 2020 remains the same under different control scenarios as shown in the figure.

Figure 6. Critical loads of acid depositions for P20.



For a 20 percentile critical loading excess depositions for the years aof 1990 and 2020 were

simulated and the results are as follows.

Figures 7. Excess depositions for 20% critical loads for the year of 1990 under base_nfc scenario

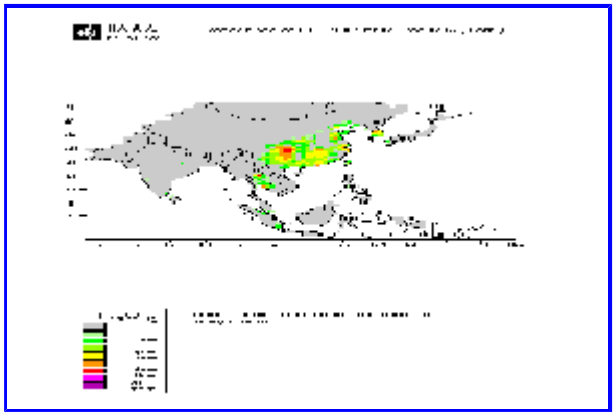
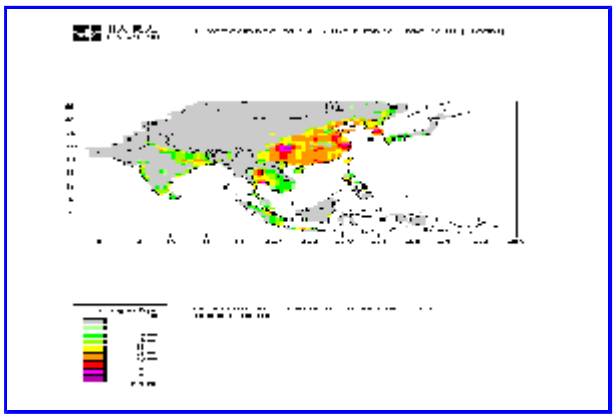
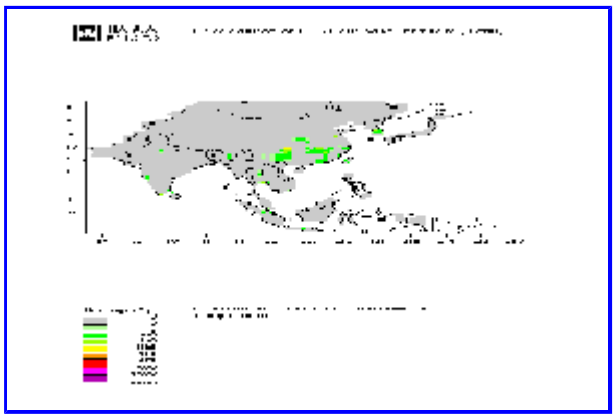


Figure 8 & 9. Excess depositions for 20% critical loads for the year of 2020 under base_nfc and base_bat scenarios.





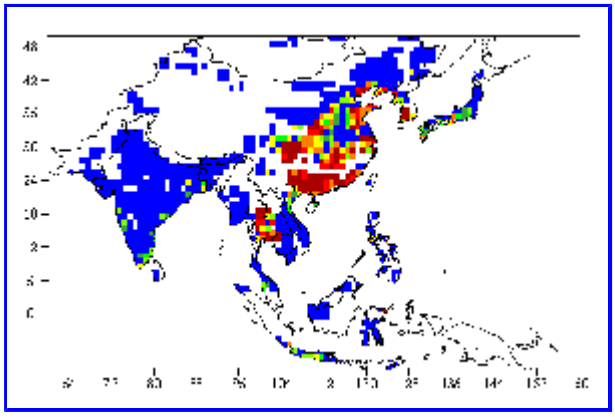
Critical loadings and excess depositions can be calculated for other emission scenarios, at different loading levels on regional basis, depending on what's reasonable with the economical and environmental conditions of that area.

Task 6: Percentage Ecosystem Damage

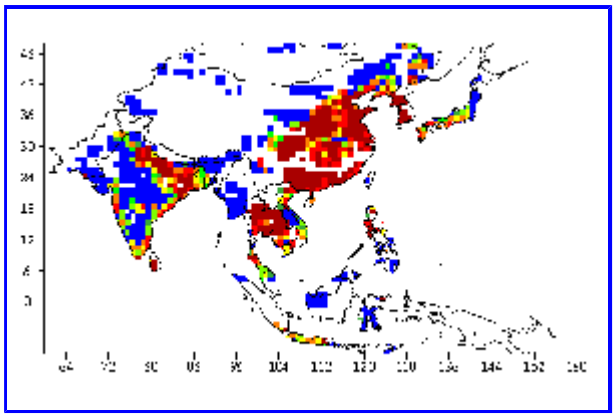
Investigate the amount of damage caused by acid deposition on a given country for 1990 and the subsequent years with different control strategies.

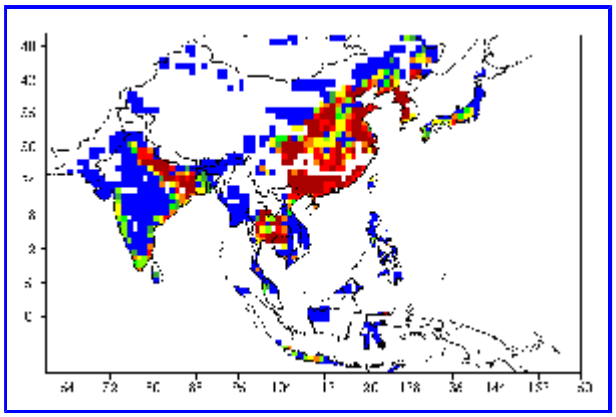
In this task, we can the see the percentage of ecosystem damaged with sulfur depositions above the critical loads in a given scenario. This has been studied for both the base_nfc and base_bct (basic control technology) scenarios over Asia for the years of 1990 and 2020. The figures below show the percent ecosystem damaged due to agricultural sources.

Figure 10. Percentage of ecosystem damage in agriculture sector for the year of 1990 under base_nfc scenario.



Figures 11& 12. Percentage of ecosystem damage in agriculture sector for the year of 2020 under base_nfc and base_bct scenarios.





Similarly, ecosystem damaged from other sectors such as rice paddies production can be studied under all possible scenarios.

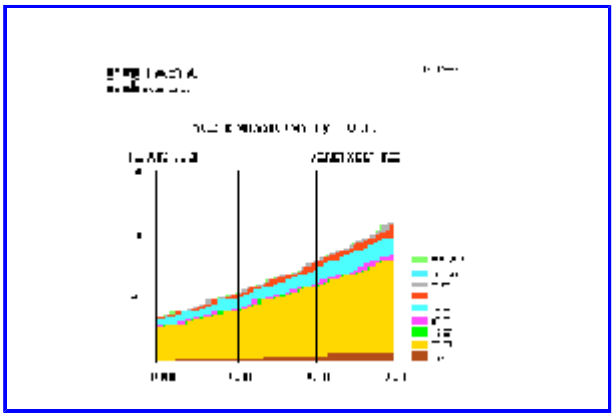
Task 7: Cost for Controls

Explore the costs of controlling sulfur emissions with different control strategies. Compare them with the costs from 1990 and future years.

In this task we will explore the costs to reach the emission limits expected under base_nfc and base_bat scenarios by fuel over the years of 1990 and 2020. Similar kind of study can be conducted per sector, under which we can study the emission levels expected under different scenarios and there abatement costs in that sector and in that region.

Figure 13 &14. Sulfur dioxide emissions and there abatement costs by fuel under base_nfc

scenario over entire Asia.



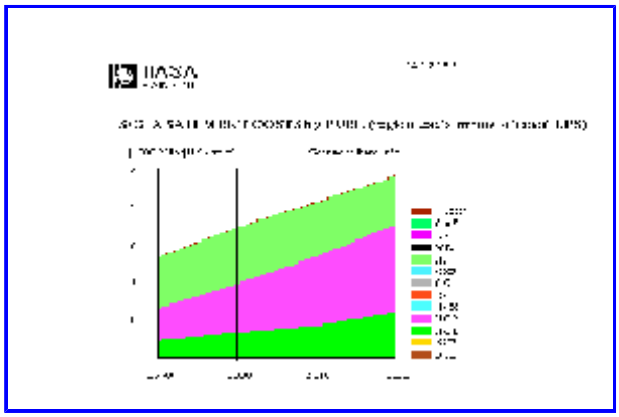
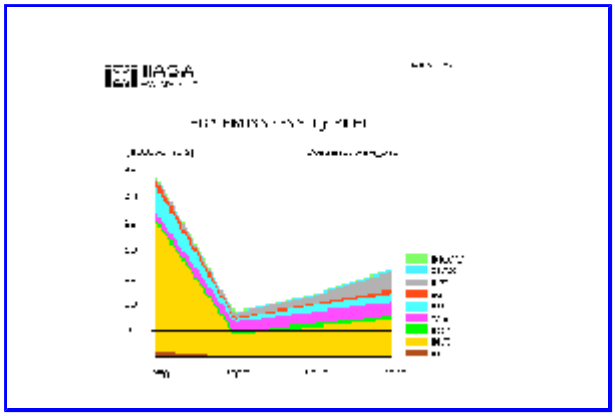
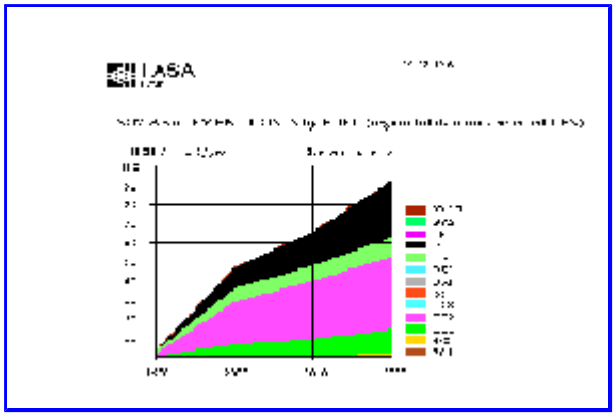


Figure 15 &16. Sulfur dioxide emissions and there abatement costs by fuel under base_bat scenario over entire Asia





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