Greenhouse warming over Indian sub-continent

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Abstract. A hierarchy of climate models have been developed and applied to the problem of doubling the CO₂ concentration in the atmosphere. Currently available general circulation models include the most complete treatment of the global warming and are capable of providing changes in several of the meteorological parameters in time scales of half a century or even more. Much skill is gradually being achieved now for future climate simulations. In this paper, we have attempted to describe the response of the National Center for Atmospheric Research Climate Community Model (NCAR CCM), whose performance for northern hemispheric climate simulations was reported to be very satisfactory to Indian region. The seasonal (winter and summer) changes in surface temperature, rainfall and soil moisture expected over the Indian sub-continent due to doubling of CO₂ in the atmosphere as inferred from model output statistics are discussed. A probable scenario for sea level rise along the Indian coastline by the year 2030 AD as a result of ocean water's expansion due to global warming is outlined. These projections should not be treated as predictions of what is going to happen over the Indian sub-continent. Rather, they merely illustrate to what extent we might be affected by the future climate change.

Keywords. Global warming; climate models; ocean's thermal expansion; sea level rise; climate change over Indian sub-continent.

1. Introduction

A great deal of attention in the past few years has been focused on the scientific aspects of climatic change. Even though several groups in the world are today involved in monitoring and predicting those climate changes that may result from increase in atmospheric trace gases due to anthropogenic activities, it appears that a precise assessment of regional impact of the global warming still remains largely qualitative. While all scientists seem to agree that an increased loading of the atmosphere with radiatively active trace gases has been occurring and that these gases have been producing a greenhouse-like effect in the lower atmosphere, they do not agree on what the greenhouse effect may mean for precipitation or soil moisture in specific regions around the world. Nor is it clear yet how global warming might change the frequency and intensity of tropical cyclones. Nonetheless, global climate change as a result of increasing levels of trace gases in the atmosphere will surely be reflected in regional climate and at present a numerical modelling approach seems the only reliable way to assess the regional impacts of global warming.

The general circulation models (GCMs) have now reached a stage of development when they can be applied to give useful estimates of at least some aspects of climatic

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change. Already detailed model output statistics are beginning to show encouraging similarities to the observed climate (WMO 1991). It is true, however, that the climate simulations by the best of the present GCMs may have many deficiencies. The time scale of the ocean behaviour is much longer than the time scale of the atmospheric behaviour. The state-of-the-art ocean models are less successful than their atmospheric counterparts. It is for this reason that most GCMs of the atmosphere use a simple representation of the ocean which allows only a vertical exchange of heat in the upper layers of the ocean. Modelling the regional impact of increasing trace gases hinges fundamentally on getting the ocean response right. The recent simulations of CO$_2$-induced climate change performed with GCMs having appropriate ocean-atmosphere interaction and better representations of the cloud feedback and seasonal cycle have yielded a global mean surface temperature warming of 3.5 to 4.2°C, and an increase in global mean precipitation of 7 to 11% for about 2030 AD when it is expected that the equivalent CO$_2$ concentration in the atmosphere will have doubled (Schlesinger and Mitchell 1987). Moreover there is consistency between various GCMs for these global average results despite the fact that in terms of geographic distribution there is only qualitative rather than quantitative agreement. Difficulties in understanding the reasons for regional differences between the simulations of different models, and between these simulations and the real atmosphere have been discussed by Mitchell et al. (1987), who showed that the regional response of climate models is highly dependent on the unperturbed simulation i.e., on the control run in which the model is used to simulate present-day conditions. They pointed out that differences in control simulations must be taken into account when comparing results for different models (for example, on doubling the atmospheric CO$_2$); otherwise unduly pessimistic conclusions may be reached concerning the consistency of model results.

With these unpalatable facts before us, it might still be worthwhile to infer a plausible future climate for the Indian region based on the numerical results from NCAR CCM, one of the best known global climate models in the world, solely for the purpose of examining the type and magnitude of the likely impacts of climatic change. While the predicted changes in the gross features of the regional climate as inferred from NCAR CCM may be regarded as highly probable, it should be useful as a basis for sensitivity studies which can identify potentially important practical effects, and to plan on how best to cope with those effects which cannot be avoided.

In this paper, we present the distributions of temperature, rainfall and soil moisture over the Indian sub-continent for control and doubled CO$_2$ experiments performed with the NCAR general circulation model (known as CCM). These model-generated data sets were made available to us by the Climate and Global Dynamics Division of NCAR. Based on these model output statistics, the regional scenarios of possible changes in temperature, rainfall and soil moisture are examined and discussed. We have also applied the predicted surface temperature change due to doubling of CO$_2$ to a simple thermal expansion ocean model to estimate the probable increase in sea level by the year 2030 AD as a result of greenhouse warming. The expected change in sea level along the Indian coastline as inferred from these calculations is discussed here. It may be stressed that the projected scenario should be taken only as a broad picture of what the changed climate might be like in 2030 AD for the Indian sub-continent and should primarily be useful to set out our priorities for research and adapt planning strategies which are appropriately flexible and adaptable.