Section V

General Technical Comments on Climate Change

Comment 1: Answers to Five Questions Posed at the Conference

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1. *What are the projections of global average temperature increase?*

The Intergovernmental Panel on Climate Change (IPCC), assuming a "business as usual" scenario of emissions, projected a 0.3°C temperature increase per decade, with an uncertainty range of 0.2°C to 0.5°C per decade. The authors of the recent update of the IPCC study looked at the many papers that have been published since the original report and decided that there was no scientific need to adjust this earlier projection.

Climatologists have long recognized that the natural variability of the climate system is sufficiently large that the warming generated by human-induced emissions will not be clearly visible in the global data until the end of this century or later. Even so, the impatience of everyone to see progress in specifying the global rate of change has led groups to make comparisons of model calculations with the heating deduced from global data sets.

A number of groups have attempted such comparisons. They conclude that the global average surface temperature has increased approximately a half degree in the last 100 years, whereas climate models retrospectively forecast an increase over the same period of between a half degree and one degree. Taken at face value, these comparisons favor those models that project the smallest future heating, but when they are viewed in the context of the large natural variability, the comparisons merely remind us that it will be some years or decades before the question of the rate of heating can be answered observationally. It should also be remembered that the same natural variability will prevent the 0.3°C-per-decade warming from being a steady increase.

Sea level is projected to rise 6 cm per decade, with an uncertainty range of 3 to 10 cm per decade.

2. *What are the prospects for projecting regional climate change?*

The regional effects projected by IPCC are as follows: Land surfaces will warm more rapidly than the ocean. In winter, high northern latitudes will warm more than the global mean. Temperature increases in southern Europe and central North America will be larger than the global mean and be

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These projections are both coarse and uncertain and of little help to planners interested in preparing for climate change at a specific locality. Therefore, there is a vigorous effort underway in various laboratories to improve the ability of climate models to simulate the sensitivity of regional climate to increases in infrared-trapping gases in the atmosphere.

Much of the difficulty in foreseeing regional changes arises from the fact that global climate models are themselves coarse grained (i.e., a single point used for calculation in the model represents a large area on the surface of the earth, and important features on the surface such as mountains can be represented only crudely). Limitations in computer speed and memory prevent modelers from quickly increasing the spatial resolution of global climate simulations.

The approach that may be most effective for promptly producing improvements consists of imbedding a fine-mesh regional model of an area of particular interest into a global climate model. To the extent that features in the local regions (such as mountains, shorelines, and areas of vegetation) can be thought of as processing large-scale flows of the atmosphere to produce the detailed local climates, this approach can be expected to produce progress in our ability to project regional climate changes.

3. *Do the climate models produce outlooks for a group of climate variables closely related to societal impacts?*

Many variables are involved in general circulation model (GCM) calculations and could, in principle, be retained and displayed as time series. Those directly produced at each level above each model grid point include pressure, density, temperature, wind, humidity, downflowing and upwelling radiation (both solar and long wave), and any cloud at that point. At the surface, both precipitation and evaporation are computed and soil moisture is derived. For the ocean portion of the model, variables such as salinity and the area of sea ice are also calculated. Additional variables could be derived (e.g., amount of cloud cover or ocean-wave height). Newer models are beginning to include the concentrations of a few chemicals as variables.

Some of these variables — in particular soil moisture — are now routinely computed because of requests from scientists interested in responses of agriculture to climate changes. Variables not now retained in the data sets produced by model calculations could, if needed, be stored for later use, and new variables derivable from the ones already calculated could be added to the calculation, but always at a sacrifice of the length of time that can be simulated with a fixed computer resource.

4. *What is the feasibility and what are the costs of proposed geoengineering options for responding to climate change?*

For the most part, proposed geoengineering plans have not been studied in any detail and no answer to the question is possible. The reason for the lack of study arises from the fact that most such proposals involve complex systems, so a great deal of work needs to be done to convert the idea into one that can be quantified in a climate or related model.

For example, the notion suggested by a laboratory experiment — that iron fertilization of certain ocean areas might enhance biological activity and, through this activity, the ocean storage of atmospheric carbon — will require extensive work on ocean biology and integration of this biological knowledge into calculations of carbon fluxes to and from the ocean and transfers within the oceans. The ocean biological system is sufficiently complicated that a single ocean experiment now would not provide final answers. If changes in carbon fluxes were observed in such an experiment, one would not necessarily know the chain of events that produced the changes; thus, the experiment could not readily be scaled up. Further, without additional knowledge of the oceanic carbon cycle, one would not know whether the carbon taken up would stay stored for the centuries required or whether unacceptable shifts in the ocean food-chain might be an accidental result of the plan. Thus, decades of work, large teams of scientists, and a large amount of funding for field observations and model experiments would be required to begin to assess the feasibility of the proposal.

Some of these steps are underway. Scientists familiar with ocean biology in the suggested regions have studied the proposal and presented arguments that the net long-term carbon storage would be small, thus beginning the usual scientific process of testing a new idea. Other groups have also begun to apply what they already know to the question. If work over several years by many groups shows a favorable possibility for carbon storage and a lack of troublesome side effects, we should then expect plans to be formulated for some sort of field test of the proposal.

The iron fertilization suggestion envisions a method of removing one of the causes of human-induced climate change from the atmosphere. In that respect, it is similar to the proposal that we plant trees to remove carbon from the air. Most other geoengineering proposals, however, are designed to counteract one feature of the resulting climate change and, as such, have a defect that slows their consideration. A major climate-change event, such as the one that we are now inducing, is complex, involving all aspects of weather and climate — cloudiness, wind, temperature, and precipitation. The defect of most geoengineering proposals is they attempt to slow one kind of climate change (temperature increase) by the creation of another kind of climate change (e.g., change in cloudiness or atmospheric transparency). So far, none of the proposals has included a careful study of the effects of the different kinds of climate change that would be produced by the proposed action.

Finally, all geoengineering proposals share the problem that their true impacts are as difficult to project as the impact of additional carbon dioxide in the atmosphere. We see evidence in the preparations for the meeting to be held in Rio that a rough estimate of the global average rate of climate change may be sufficient to trigger actions to slow that rate of change. But a much more precise calculation would likely be required before people would intentionally set about to modify the climate.

5. *What climate variables co-vary with global average temperature?*

Both average absolute humidity and global rainfall should increase as temperature increases. However, the rainfall would not be distributed evenly or even proportionally to current rainfall. The estimate from IPCC is that precipitation will increase in winter in mid latitudes and at all seasons in high latitudes and in the tropics.

Scientists have speculated about whether atmospheric variability will change as temperature increases, or whether the strength of hurricanes will increase with higher surface temperatures, but no conclusions are yet possible.

It is, of course, very likely that the frequency of hot spells will increase and the frequency of cold spells will decrease in a hotter climate, but, again, giving details of such a change will require improved regional calculations.