FUTURE CLIMATE

U.S. Climate

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Climate Models

Scientists generally agree on the likely rise in the average global temperatures over the next century . Unfortunately, projecting the change in particular regions is more difficult. Nevertheless, there is a general consensus that temperatures will warm throughout the United States. However, scientists are unable to say whether particular regions will receive more or less rainfall; and for many regions they are unable to even state whether a wetter or a drier climate is more likely.

Virtually all published estimates of how the climate could change in the United States are the results of computer models of the atmosphere known as "general circulation models." These complicated models are able to simulate many features of the climate, but they are still not accurate enough to provide reliable forecasts of how the climate may change; and the several models often yield contradictory results. For the time being, however, these models are about all we have to say how the climate may change in particular areas.

Given the unreliability of these models, researchers trying to understand the future impacts of climate change generally analyze different scenarios from several different climate models. The hope is that, by using a wide variety of different climate models, one's analysis can include the entire range of scientific uncertainty. For all of these reasons, EPA reiterates the warning provided by all climate modelers to people considering the impacts of future climate change: *the projections of climate change in specific areas are not forecasts but are reasonable examples of how the climate might change*

Climate model projections fall broadly into two categories which are known as "CO_2 doubling" and "transient" scenarios. The "CO_2 doubling" scenarios represent the climate model's estimate of how the climate would change if the level of CO_2 in the atmosphere was doubled and the climate had several decades to reach a new equilibrium. These scenarios were particularly common with older versions of the climate models, which generally analyzed how climate might change without attempting to calculate how the ocean currents might change. They generally do not consider the cooling effect of sulfates or other aerosols.

More recently, elaborate models of the ocean currents have been added to the climate models. The transient scenarios mostly use these more elaborate "coupled ocean-atmosphere" models. Instead of simply calculating how the climate and oceans would respond to a doubling of CO_2, these models use the historic and projected changes in concentrations of greenhouse gases and calculate how the climate might change each year until some date in the remote future. Many of these model calculations include the cooling effects of sulfate aerosols.

Regional Temperatures

The historical temperature record shows that a rise in the global average temperature does not automatically imply that every part of the world warms. The cooling from sulfates may offset the warming in some areas. Moreover, natural fluctuations in the jet stream and other factors often can cause the Eastern United States to be unusually cool when the West is unusually warm (as well as the reverse). During the summer of 1988, when the East suffered severely hot and dry weather, cold relatively deep ocean water began to flow to the sea surface off the mid-Atlantic Coast, keeping the coastal zone unusually cool. Scientists have not ruled out the possibility that global warming could induce such shifts, which could lead to little or no warming in some areas while other areas warm by much more than the 1.0-3.5°C (3-8°F) expected for the world as a whole.

The region of the United States that has been the most thoroughly examined is the area from 35-50°N and 85-105°W. The transient climate model results suggest that if global temperatures warm 2.6°C, the combined impact of aerosols and greenhouse gases is likely to warm this region approximately 1.5-3.5°C (3-6.5°F) during winter. The same models suggest, however, that summer temperatures will warm between 0 and 0.5° C (less than 1°F). Our actual uncertainty for future temperature change is probably at least twice as great as these ranges suggest, because global warming is also uncertain.

Moreover, the cooling effect of aerosols may prove to be less than assumed by the climate models. When the effect of aerosols is eliminated, however, the same models estimate that summers could warm by 3.5-5°C (6-9°F), and winters by 4-5°C (7.5-9°F). Other climate models, which have estimated the impact of greenhouse gases but not aerosols, suggest that summers in that region could warm 1.2-4.4°C and winters by 1.2-5.8°C.

Temperature projections vary for other regions as well. For example, the Max Plank Institute's model suggests that California will warm approximately 1°C (2°F) in summer and 3°C (5°F) in winter, while the United Kingdom's Hadley Centre estimates that both winter and summer could warm by about 3°C (5°F).

Regional Precipitation

The nation's water resources are sensitive both to rising temperatures and changes in precipitation. Although scientists expect global temperatures to rise approximately 0.5 to 1.5°C (1-3°F) by the year 2050, most climate models suggest that warming over land--including the continental United States--will be greater than the warming over the sea. Because higher temperatures increase evaporation and plant transpiration, rainfall would generally have to increase just to maintain current levels of water availability. Holding other factors constant, the potential for evaporation and transpiration increases about 5-10% per degree (C) throughout most of the United States (Waggoner and Revelle 1990).

There is a general consensus that annual worldwide precipitation and evaporation will increase a few percent for every degree of warming. But there is considerably less certainty about rainfall in particular locations, and whether the rainfall will increase enough to offset the increased evaporation. Many scientists, however, believe that middle latitudes such as that of the United States will see drier summers: Assuming that the land warms more than the sea, evaporation over the land will increase by more than the evaporation over the sea that produces rainfall. Thus, summer rainfall may not increase by as much as evaporation.

For specific locations, however, it is currently impossible to confidently project even the direction, let along the magnitude or timing, of the seasonal or even annual changes in precipitation. In the Central North American region, the two models that include the effect of sulfates estimate that rainfall may increase slightly more than evaporation, leading to modest increases in soil moisture during both winter and summer.

A more pessimistic picture emerges, however, from the nine climate models that have considered the implications of greenhouse gases without the cooling effect of aerosols. During winter, precipitation changes range from a decline of 15 percent to an increase of 18 percent; during summer, the changes range from a decline of 8 percent to an increase of 6 percent. The scenarios that show an increase in precipitation also project warming of 4-5°C (7-9°F), which would generally cause evaporation to increase by 20 to 50 percent. Thus, all of the scenarios suggest that summers will be drier if the cooling effect of sulfates does not occur. Some of these models also suggest that winters could be drier, while others project wetter winters.

Whether or not annual or seasonal rainfall increases, many climate models project that rainfall will occur in a smaller number of heavier storms, and that the number of dry days is likely to increase. An Australian climate model, for example, projects that total rainfall in the Midwest will decline by about 5 percent, but that heavy rainstorms would occur 2 to 5 times as often. The National Center for Atmospheric Research also expects fewer but heavier rainstorms. The Max Plank Institute estimates that in central North America, 3-month-long dry spells could become about 50 percent more frequent with a 2°C warming.
