Teacher Background Information:
Computer Models and Climate Prediction

The most powerful tools available today for assessing future climate are "general circulation models" (GCMs), 3-dimensional computer generated representations of the atmosphere, ocean, cryosphere and land surface. This type of modeling has developed rapidly since the early 1990's and the current models are now able to simulate many aspects of the climate system with a useful level of skill. However, clouds, the hydrological cycle, and the treatment of the land surface still remain the largest areas of uncertainty in climate models, and are generally the cause of the largest inter-model difference. In addition, they are much more effective when dealing with large spatial scales (hemispheres); at regional scales, their skill level is much lower.

Research institutions involved in climate research and GCM modeling are bound by international guidelines and set boundary conditions for their models which include the 1979-1988 sequence of observed monthly sea surface temperatures and sea ice, an atmospheric CO_2 concentration of 345 ppmv, and a value of 1365 Wm^{-2} as the solar constant. Among the most famous worldwide for their modeling results are the United Kingdom Meteorological Office (UKMO), the Oregon State University (USO) in Corvallis. OR and the National Center for Atmospheric Research (NCAR) in Boulder , CO.

Many climate modelers feel that by the middle of the 21st century there could be a doubling of the greenhouse gas concentration over the mid-1900's level. As a result, global warming models are projecting a 2-5 degree C rise in the global average temperature, and as much as 2-3 times more than that in the Arctic. These projections are shown in the graph below. The shaded area indicates what they think the change will be in temperature. The high scenario depends on whether humans continue to use fossil fuels at an increase of 2% per year, and the low scenario assumes that the world takes effective action to limit their use. These numbers are very close to those adopted in the most recent report of the International Panel on Climate Change (IPCC).

It is important to remember that this is not only a problem in geophysics; it involves economics as well as political science. It is very difficult to forecast with any degree of accuracy what mankind will decide to do, and those actions will ultimately depend on the development of new technologies, such as the efficient use of energy, adoption of safe nuclear reactors, and a slowing of the present growth of world population.

For human beings, global warming could mean many different things, as shown by the variable results of most GCMs. In the map below, the shaded area indicate regions where the average temperatures are somewhere between 2 and 18 degree C, with an average temperature of about 10 degrees C. This area is referred to as the "comfort zone" by geographers and anthropologists because it is the area of the world where most of the wealthy and industrialized counties are located. The region between the two shaded areas is the area of the tropics where most of the poor countries exist, and where there are ongoing problems with disease and famine. According to some climate models, this "comfort zone" would shift northward as the world warms.

Even more important than changes in temperature are changes in moisture. Precipitation has been changing over the past several decades at the same time as temperature. A look at the subtropical regions of the Northern Hemisphere (5-35 degrees N latitude) will show that the annual rainfall has been decreasing since around 1955, while in the northern part of the Northern Hemisphere (35-70 degrees N latitude), it has actually been decreasing. In other words, while the higher latitudes have become wetter, the equatorial zones have become drier.

Some computer models show that central North America, as well as central Eurasia could experience a drying out in summer. A mid-west farmer does not need to be convinced of this idea; he knows that a warmer summer means a dry summer. The same may not be true for winter months, however. The NCAR models predict that if anything, the winters of North America will be getting wetter. In a way, this is reassuring because it suggest that farmers in the mid-west could switch from corn, which has a high water requirement, to winter wheat, which will grow well with much less moisture, offering a possible way for agriculture to adapt to possible changes.

It is interesting to note that according to the models, the subtropics could become wetter, but that in reality over the past several decades, the subtropics of North America have actually been drying out. This could suggest a slowing in the tropical drying trend that has plagued famine -prone North Africa and northeast Brazil for several years and an increase in rainfall. While it is obviously too soon to make any prediction, this scenario is a definite possibility, along with several others.

We are now in a period when climate models, however much improved, are still far from representing the real climate system. We have to consider the model forecasts with a definite degree of caution and skepticism. An intelligent approach, at this point, would be to accept the notion that climate change of some sort is more or less inevitable, and then to prepare for it. In his book, The Genesis Strategy, climatologist Stephen Schneider recalls the Old Testament story of Joseph in Egypt. Joseph is credited with making the first accurate climate forecast and persuading Pharaoh to store some of the wheat of Egypt during the plentiful years, so that they would have some during the seven years of famine,