New England Regional Assessment (NERA)- Climate Scenarios

From The National Assessment to the Regional Assessment

Climate model predictions provide the estimates that have stimulated much of the national and international debate concerning the importance and the nature of future climate in the face of rising concentrations of greenhouse gases in the atmosphere. These model projections provide estimates for many of the climatic variables of importance to society, and hence, the model predictions provide a key framework for assessing the impacts of climate change. Because of limitations in our understanding of the climate system and in computational resources, and because we cannot know precisely what emissions will occur, the climate models employed by scientists around the world have different characteristics and simplifications. Therefore, these models provide somewhat different simulations of the future climate. Consequently, the model predictions are said to only provide an estimate, or "scenario", of **possible** future climates. The first U.S. National Assessment is based on a climate information strategy of providing a physically-consistent climate foundation for regional and sector assessments to be utilized by every team, with the opportunity for teams to perform additional independent analyses.

The strategy for providing climate scenarios for regional and national impact assessment is based on several key needs. First, a historical climate record is needed in order to have a basis for assessing the importance of climate and climate change. Second, the range of future climates used in the assessment process must be sufficiently broad to reflect the levels of uncertainty in models and in our projections of how society may evolve. Third, the assessment must reflect the range and character of natural variability (like El Nino) and a sense of the spatial variability of climate. Fourth, the period of model predictions must overlap with the period of historical observations in order to evaluate the capabilities of the models. Finally, the assessment process should include opportunities to determine thresholds or limits in human and ecosystem adaptability. The selection of the set of climatic information for the assessment must also recognize both time and human constraints. For these reasons, the climate scenarios being provided to each team form a **minimum basi**s for their assessment.

Three historical data sets are available for use in the National Assessment. (1) The United States Historical Climatology Network (HCN) data set, which is maintained by the National Climatic Data Center, contains monthly averaged maximum, minimum, and mean temperature and total precipitation data for 1200 of the highest quality observing stations in the continental United States for the period 1895 to 1997. (2) The Daily Historical Climatology Network data set, which contains observations for 187 high-quality stations in the contiguous U.S. for the 1910-1997 time period, and observations for 1000 stations in the contiguous USA for the 1948-1997 time period. (3) The VEMAP (Vegetation/Ecosystem Modeling and Analysis Project) spatially-uniform 1° x 1° record (1895-1993), which is based on 8000 HCN and U.S. Forest Service and Bureau of Land Management Sno-Tel stations.

Each of the climate simulations is based on models that include both the ocean and the atmosphere, and for which the atmospheric greenhouse gas concentrations and sulfate emissions evolve with time. Climate simulations that will be used for the U.S. Assessment include those from the United Kingdom's Hadley Centre for Climate Prediction and Research (HADCM2) and the Canadian Centre for Climate Modeling and Analysis (CGCM1). Model simulations using the National Center for Atmospheric Research Climate System Model (NCAR CSM) and Department of Energy Parallel Climate Model (DOE PCM) runs are also expected to become available to the synthesis team for examination. Variables that will be provided to the assessment teams include surface air temperature, maximum and minimum surface air temperature, total precipitation, soil moisture, solar radiation, wind speeds, humidity, and sea-level.

As for all simulations, the model simulations adopted by the assessment process have limitations. Foremost are questions whether these limited models will provide sufficient richness to describe the character of natural variability or the appropriate magnitude of climate response needed to achieve a realistic analysis of climate impacts. Because of this and other limitations, an assessment approach is being encouraged that also allows individual regions or sectors to consider **"what if"** cases that reflect educated guesses based on the nature and importance of specific regional and sector vulnerabilities.

The historical data and model projections provide an encompassing basis for assessing climate impacts. The historical record indicates that the greatest U.S. warming over the last century has occurred in the northeast and southwest. The southeast is one of the handful of places in the world indicating some cooling. The historical record also indicates that the U.S. has experienced modest increases in precipitation, with the exception of the precipitation decreases in the upper Great Plains area and parts of Alaska. The climate models predict warmer temperatures throughout the world for increased greenhouse gas concentrations. The amount of warming more than doubles over the United States in both models between the two periods of study (2025-2034 and 2090-2099). The HADCM2 model predicts a greater than 4 degrees C mean annual near-surface temperature increase over the western U.S. in 2095, whereas CGCM1 indicates a greater than 6 degrees C increase over the central U.S. for the same interval. The total annual precipitation ratios for the decade 2025-2034 and 2090-2099 indicate that both models predict increasing precipitation throughout most of the world as a direct effect of warmer temperatures. On an annual average basis, both models indicate rather modest mean annual precipitation differences for the U.S., with the exception of a large predicted increase in the precipitation off the California coast. On a seasonal basis, however, the changes are larger.

The New England Regional Assessment

The New England Regional Assessment (NERA) of changes in climate and climatic variability functions to evaluate/estimate the potential impacts of future climate regimes on various aspects of New England living. The evaluation of the potential impacts into the future depends upon the interaction of complex 1) climate, 2) ecological, and 3) socioeconomic systems. To address the first of these systems, the National

Assessment has provided a series of data sets of both historical climate and future climate **<u>"scenarios"</u>** for the New England region. The NERA effort has focused on three physical climate variables for consideration as impact agents, 1) Minimum Temperature; 2) Maximum Temperature; and 3) Precipitation, with all three evaluated on annual and seasonal time scales. Assessment procedures are directed to evaluate potential impacts centered on the years 2030 and 2100 as near and long-term scenarios, respectively.

The VEMAP2 Historical Gridded Record is provided to represent climate conditions representing patterns of natural variability for the three physical climate variables across our region spanning from 1895-1993. This data set is derived from the National Climatic Data Center U.S. Historical Climate Network (HCN) and additional cooperative network stations, plus U.S. Forest Service and Bureau of Land Management SnoTel stations for high elevation precipitation. Data from approximately 8000 stations for the contiguous U.S. were statistically in-filled to create continuous records. These data were then spatially interpolated onto a half-degree lat/long grid, which accounted for both elevation and rainshadow effects. The New England region includes 128 half-degree latitude/longitude grid cells. Monthly means for all variables represents the finest temporal resolution used to generate yearly and seasonal means.

Climate Scenarios project model estimates of the physical variables into the future. However, it is very important to understand the limitations of these predicted estimates. While scientific understanding of the Earth's climate system has progressed greatly over recent decades, accurate localized predictions of temperature and precipitation patterns have yet to be realized. At the same time, the demand for quality localized predictions is great. A basis is needed for considering the importance of possible impacts and possible mitigation strategies. Therefore**, <u>the New England Regional Assessment provides climate simulations to serve only as "possible future scenarios"</u>**. Actual climate changes in the future may be weaker, greater, and in different character than those presented here.

The regional assessment relies heavily on the predictions from two global ocean-atmosphere coupled models, namely the Canadian Centre for Modelling and Analysis's Canadian Global Coupled Model (CGCM1) and the Hadley Centre's model (HadCM2). Predictions from these models have been interpolated on the VEMAP2 half-degree grid. As with the VEMAP Historical Gridded Record, the New England region includes 128 half-degree lat/long grid cells and monthly means for all variables represent the finest temporal resolution we used to generate yearly and seasonal means.

These two models were provided to the regional assessment to facilitate the integration of regional and sectoral findings into the more inclusive U.S. National Assessment. As such these model estimates provide a common tool for inter-regional comparisons. While the National Assessment Synthesis Team (NAST; entity responsible for generating the national report based upon regional and sectoral outcomes) urges all regions to use this common set of modeling tools, regions are not limited to these. Therefore, additional models have been used to form an "envelope" of model predictions for comparisons with the CGCM1 and HadCM2. These models include the CSIRO-MK2, ECHAM4, GFDL-R15, and CCSR.

The models simulate the effective greenhouse gas forcing change corresponding to that observed from 1850 to the present, and assume a 1% per annum greenhouse gas increase thereafter. The cooling effects of sulfate aerosols are included by increasing the Earth's surface albedo (based on a sulphur cycle model). The comparisons include each model's hindcasted and forecasted estimates of Mean Temperature and Precipitation Anomalies relative to the 1961-1990 means.

Summary of Possible Climate Scenarios

Global mean temperature change

The historical temperature change and scenarios of possible future temperature change are presented relative to the 1961-1990 mean temperature. On the scale of the projected possible future changes, modeled values are in good agreement with historical data. The CGCM1 and HadCM2 scenarios for the future are well within the envelope of other models. Model scenarios suggest that global temperatures may increase by +0.5 to +1.0 degrees C by 2030 and from +3 to +4.5 degrees C by 2100, according to HadCM2 and CGCM1 respectively. For comparison, the average global temperature increased by roughly +0.5 degrees C during the historical period of 1850-1994.

Global mean precipitation change

The historical precipitation change and scenarios of possible future precipitation change are presented relative to the 1961-1990 mean. On the scale of the projected possible changes in the future, modeled values are in good agreement with historical data. The HadCM2 scenarios of the future are well within the envelope of those of other models. The CGCM1 scenario is near the low end of the envelope of projections. Model scenarios suggest that global precipitation may change by –2% to +2% by 2030 and by +2% to +8% by 2100, according to CGCM1 and HadCM2 respectively. For comparison, during the historical period of 1900-1994, global average precipitation increased +3%, and fluctuated within a range of –3% to +3%.

New England average minimum temperature change

Model scenarios of possible average minimum temperature change are presented relative to the 1961-1990 mean. Possible future scenarios suggest that average minimum temperatures may increase by +1 degrees C by 2030 and by +3 to +5 degrees by 2100, according to HadCM2 and CGCM1 respectively.

New England average maximum temperature change

Model scenarios of possible average maximum temperature change are presented relative to the 1961-90 mean temperature. Possible future scenarios suggest that average maximum temperatures may increase by +1 degrees C by 2030 and by +2 to +4 degrees C by 2100, according to HadCM2 and CGCM1 respectively.

New England precipitation change

Model scenarios of possible precipitation change are presented relative to the 1961-90 mean. Possible future scenarios suggest that precipitation may change from –2% to +10% by 2030 and from +5% to +25% by 2100, according to CGCM1 and HadCM1 respectively.

Seasonal distribution of New England average minimum temperature change

For each season, model scenarios of average minimum temperature change are presented relative to the 1961-1990 mean. Possible future scenarios suggest that average minimum temperatures may increase more in the winter than in other seasons. According to HadCM2 and CGCM1 respectively, by 2030 minimum temperatures may be +1 degree C warmer in Spring, Summer and Fall, and +1 to +2.5 degrees C warmer in winter. By 2100, minimum temperatures may rise +2 to +6 degrees C in Spring and Summer, +3 degrees in Fall, and +4 to +7 degrees C in winter.

Seasonal distribution of New England average maximum temperature change

For each season, model scenarios of possible average maximum temperature change are presented relative to the 1961-1990 mean. Future scenarios suggest that maximum temperatures may be +1 degrees C warmer in all seasons. By 2100, future scenarios suggest that temperatures may have rise +2 to +5 degrees by 2100, according to HadCM2 and CGCM1 respectively.

Seasonal distribution of New England precipitation change

For each season, model scenarios of possible precipitation change are presented relative to the 1961-90 mean. Precipitation changes may not be uniformly distributed throughout the seasons. According to CGCM1 and HadCM2 respectively, by 2030, precipitation may change -10% in Spring, -10% to +20% in Summer, -5% to +5% in Fall and winter. By 2100 precipitation still may not have changed in Summer, and may be 0 to +25% higher in the other seasons.

Spatial distribution of New England average miminum temperature change

Within the New England region, model scenarios of possible average minimum temperature change are presented relative to the 1961-90 mean. Both scenarios suggest within region spatial heterogeneity of the warming trend. By 2100, the HadCM2 scenario has a roughly +0.5 degree variation over the region, with the warming greatest in the Northeast and least in the west. For comparison, CGCM1 has a roughly +1.5 degree variation over the region with the warming greater inland and lower coastally.

Bullet-Summary of Possible Climate-Scenarios

- Scenarios of “possible” climate change resulting from rising greenhouse gas concentrations are provided. These scenarios have many shortcomings, and are not intended as forecasts of future conditions. **The scenarios are intended only as “what-if” scenarios to form a basis for discussion.**

- As directed from the National Assessment, two climate models form the basis of the climate scenarios for the New England Regional Assessment, CGCM1 and HadCM2. On the scale of changes in the scenarios of the future, both models represent the global historical data comparatively well.

- Both model scenarios presented suggest that mean temperature and mean precipitation may increase over New England. One model scenario suggests relatively larger temperature changes (CGCM1), the other model suggests relatively larger precipitation changes (HadCM2).

- Both model scenarios presented suggest that average minimum and average maximum temperatures may increase over New England. The increase in average minimum temperatures may be particularly large, and may occur predominantly in winter.

- Both model scenarios presented suggest that temperature and precipitation changes may not be spatially uniform over New England. One model suggests that the increase in average minimum temperature may occur disproportionately in the Northeast portion of the region. The other model (CGCM1) suggests that the increase in average minimum temperature may be greatest over the inland portions of New England, and may be somewhat less in coastal regions.