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PALEOCLIMATE VALIDATION OF A NUMERICAL CLIMATE MODEL

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ABSTRACT

An analysis planned to validate regional climate model results for a past climate state at Yucca Mountain, Nevada, against paleoclimate evidence for the period is described. This analysis, which will use the GENESIS model of global climate nested with the RegCM2 regional climate model, is part of a larger study for DOE's Yucca Mountain Site Characterization Project that is evaluating the impacts of long term future climate change on performance of the potential high level nuclear waste repository at Yucca Mountain. The planned analysis and anticipated results are presented.

INTRODUCTION

An assessment of regional climate change long into the future, needed to address regulatory compliance and site suitability questions for the potential high-level radioactive waste repository at Yucca Mountain, Nevada, involves an ongoing numerical climate modeling effort sponsored by the Department of Energy's Yucca Mountain Site Characterization Project. Several types of model validation exercises are planned during the course of this study to provide confidence in the simulation capability of the model. These validation efforts include a recently initiated effort to validate model simulations against paleoclimate data for a selected global climate state for 16,000 years ago, for which a useable paleoclimate data base exists. During this period, the regional climate in the vicinity of Yucca Mountain was considerably different than at present, as evidenced by the paleoclimatic record of the period. In addition to its value in providing a basis for validating the numerical model, past climate states different from today's are of interest to the project's Future Climate Study, because of their utility in evaluating any impacts of future climate change on the waste isolation characteristics of the potential repository. A description of the planned effort is presented below.

DESCRIPTION

The current arid climate in the region of Yucca Mountain can be expected to change significantly in the future. Establishing defensible bounds on the nature of climate for the next 10,000 to 100,000 years is relevant to establishing whether or not the site is a suitable location for a high-level nuclear waste geologic repository and whether the repository system will perform adequately to safely isolate radionuclides from the public for future generations.

To build a complete and defensible picture of the expected limits on future climate over the period of concern requires synthesizing all relevant information on current and past global, regional and Yucca Mountain local climates, and incorporating this information into a set of reasonably probable bounding future climate scenarios for the next 100,000 years. General circulation models (GCMs), which have been undergoing rapid development in recent

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years, are one source of insight on future climate conditions which will be used.

The work reported here is a continuation of work presented at earlier high-level radioactive waste conferences.[1] In that preliminary work, initial validation runs of a regional climate model (RegCM) were performed with the MM4-BATS code to assure that the model adequately represented current climate conditions for the region, when measured current climate data were used as boundary condition input to the model.[2] A subsequent validation phase will attempt to reproduce current climate results for the region using a selected global climate model nested with a selected regional climate model. Based on the results of considerable model development work and preliminary validation work for present climate conditions reported elsewhere, one can expect the model behavior to reflect basic climate conditions, subject to uncertainties in model input and recognizing model limitations.

As a further validation exercise, mentioned above, the nested GCM/RegCM model will be run for climatic conditions of 16,000 years ago, for which considerably different model simulations are expected. These paleoclimate simulations can be compared with interpretations of available paleoclimate evidence for that time. This effort will be performed in conjunction with the Paleoclimate Model Intercomparison Project (PMIP),[3] which is a large-scale activity involving a variety of models and numerous participating organizations.

For this work, the GCM used is the GENESIS model developed at NCAR.[4] The GCM generates continuously updated conditions, which are supplied as boundary conditions to the nested Regional Climate Model, RegCM2.[5,6] Output from the model includes values of climate parameters, such as temperature and precipitation, which can be used to provide input to hydrologic models.

Selecting a past climate state for the validation exercise involves identifying a state for which sufficient paleoclimate evidence exists to make a detailed comparison with model output, one which will be sensitive to model input and modeling effects, and which is likely to provide results of interest to the longer-term objective of bounding future climate states that may negatively impact repository performance. The simulation of the climate of 16,000 years ago, therefore, will be analyzed with particular attention to the Yucca Mountain region. The western United States was generally cooler and substantially wetter around that time. Thus, this time makes for a relevant test of the modeling system's capability to realistically simulate a climate scenario of interest to the Yucca Mountain Project.

Having selected a model and a climate state to simulate, one must then specify initial and boundary conditions for the selected climate state. Four key types of information are needed as input to the global model to represent a modeled climate state. These include spatial and temporal distributions of: solar insolation, ice sheet configuration, sea surface temperature, and atmospheric composition. Well established codes exist for modeling the effects of orbital perturbations that dominate solar insolation distribution. For this work, the codes of Berger[7] are used. In addition, codes for ice sheet reconstructions for the past 22,000 years are also reasonably well established and available. For this analysis, the ice sheet reconstructions developed by Peltier[8] are used. Sea surface temperature distribution and atmospheric composition are subject to greater uncertainty. However, global reconstructions of sea surface temperature fields do exist and have been used in climate modeling experiments. Moreover, the GENESIS model has the capability to simulate sea surface temperatures, albeit with a crude passive mixed layer ocean. For this work, sea surface temperature distributions will be based on either climatological sea surface temperatures from Shea,[9] and/or predictions from a slab mixed layer ocean model. Atmospheric gas composition is the final key parameter needed for the model simulations. Atmospheric CO_2 concentration is a particularly important component from the standpoint of global warming and can be taken from the published measurements based on ice core studies. For this analysis, the ice core record of Barnola[10] will be used.

Using these global scale initial and boundary conditions, the model is then exercised for a specified simulation period of order five years. The resulting modeled typical behavior on both global and regional scales is evaluated to establish the degree to which the simulated behavior is consistent with paleoclimate interpretations. Paleoclimate data available for the Western U.S. from such sources as dry lake bed depositional strata, analysis of pollen, ostracod species, pack rat middens, and isotope studies, for example, indicate a climate perhaps an average of 7°C cooler and roughly one and half to three times more precipitation than at present in the Yucca Mountain region.[11,12] Global conditions at that time were those of a climate state just entering the transition from the last ice age to the present interglacial period. Model calculations are expected to be consistent with these cooler and wetter conditions, indicative of larger ice sheets and different sea surface temperature distributions on prevailing wind flow patterns.

One must recognize, however, that the degree of comparison possible between the model output and the paleoclimate interpretations is much more limited than for current local climate description. Interpretations of geologic data, which serve as proxies for the climatic parameters of interest are subject to several uncertainties, both in dating of samples and conversion to climatic values. Similarly, the limited simulation periods possible with current computer technology and resources and the uncertainty associated with model input for the distant past, further constrain the ability to establish detailed comparisons. However, the models are expected to be sensitive enough and the body of empirical evidence substantial enough to demonstrate the model's ability to capture fundamental trends.

RESULTS

Results provided by this work are important for at least three reasons. First, if it can be demonstrated that the numerically simulated climate agrees with that provided by paleoclimate data to within experimental uncertainty, additional confidence in the simulation capability of the model will be gained. Secondly, the regional scale resolution of the model is useful in providing insight into localized conditions for which the paleoclimate record may be quite sparse. And thirdly, modeling results are valuable in providing estimates of relevant climatological variables, such as precipitation, runoff, surface evapotranspiration, and temperature, which may be difficult to determine directly from paleoclimatic evidence. This last consideration is particularly relevant to repository long-term waste isolation concerns, in that such parametric information is needed to model the subsurface hydrology, which is anticipated to provide the dominant pathway for potential release of radionuclides to the accessible environment.

CONCLUSIONS

We believe that selected paleoclimate states are sufficiently well defined by physical evidence, and that climate simulation models are sufficiently sensitive to permit their intercomparison. Preliminary results of an effort to build confidence in the simulation capability of the selected numerical climate models on a regional scale through comparisons with present day climate data are extended to a comparison of the model's capability against regional paleoclimatic evidence. Validating model results through such comparative evaluations are anticipated to provide an indication of the degree to which numerical models can be used to understand climate behavior.

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