Final Report
Research Project T1803, Task 44
Pavement Temperature

A NEXT-GENERATION LAND SURFACE MODEL FOR THE PREDICTION OF PAVEMENT TEMPERATURE

by

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16. ABSTRACT

To meet the information needs of highway maintenance managers, a system for real-time prediction of pavement temperatures was developed at the University of Washington. This system utilizes the NOAH land surface model (National Center for Environmental Prediction, Oregon State University, Air Force, Hydrologic Research Lab LSM) to estimate fluxes of energy to and from the pavement surface and resulting pavement surface temperatures. Data from real-time MM5 weather prediction model forecasts, performed twice-daily at the UW, were used as initial and boundary conditions in pavement temperature simulations. Results of these simulations were compared to observations and the system's forecast skill was verified

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1. INTRODUCTION

Many of the highway winter maintenance problems faced by the state can be related to a lack of adequate environmental information. One of the key variables of interest to maintenance managers is pavement temperature. Decisions on what type of snow and ice control method to employ during a given weather event can hinge critically on the temperature of the pavement. Unfortunately, pavement temperature is very poorly observed over much of Washington state. To address this problem, the Washington State Department of Transportation (WSDOT) has invested in an expanded pavement temperature observing network. For many "trouble spots" this has led to an improvement in highway maintenance managers' ability to make appropriate decisions; however, the value of this information extends just a few hours into the future as conditions rapidly change during the passage of weather systems. To address the need for additional pavement temperature information, the University of Washington (UW), in concert with WSDOT, developed an operational system for predicting pavement temperature across the state during the 0- to 48-hour future time period.

Like any substance on the earth's surface, pavement temperature is determined by meteorological conditions. The balance of energy fluxes into and out of the pavement surface determines the net change of energy in the surface layer. This increase (decrease) in energy results in heating (cooling) of the pavement surface. An example of this would be an area of pavement that, all other things held constant, received a large amount of solar radiation during a sunny day, increasing the energy contained in the pavement surface and, thus, pavement temperature. Traditionally, fluxes of energy at the earth's surface have been simulated by land surface models (LSM), which calculate these fluxes on the basis of given meteorological conditions. With a known initial state of the land surface, the change in internal energy is equated to a change in temperature over time. Such LSMs are known as energy balance models because they compute the balance of incoming and outgoing energy.

A prerequisite for running an energy balance model is adequate meteorological data. The UW Department of Atmospheric Sciences runs a real-time, high-resolution mesoscale weather prediction system twice a day that uses the Penn State/NCAR MM5 model. The output from the MM5 system provides forecasts of all the meteorological variables needed to run an LSM. This source of input data was used throughout this project to drive real-time forecasts of pavement temperature. The remainder of this paper describes the energy balance model selected and test results.

2. ENERGY BALANCE MODEL

A number of different energy balance LSMs are available publicly, all of which follow the same fundamental design and use the same theoretical concepts. The model chosen for this project was the National Center for Environmental Prediction, Oregon State University, Air Force, Hydrologic Research Lab Land Surface Model (NOAH LSM). The core of this model was developed at Oregon State University during the 1980s (Pan and Mahrt, 1987). Input for the model are values of air temperature, humidity, wind speed, pressure, downwelling longwave and solar radiation, and precipitation. An initial profile of ground temperature and available ground moisture from the surface to a specified depth is required. The model is integrated forward in time and produces forecasts of surface temperature at intervals throughout the forecast period.

In tests with observational data from sites in the Great Plains of the U.S., the model was shown to produce forecasts that agreed extremely well with observed ground temperatures.

However, during initial testing for this application in Washington State, the model displayed a tendency to produce forecasts that were significantly cooler than temperatures observed during the daytime. Further investigation found that certain fixed parameters describing the characteristics of the surface were actually not representative of pavement but, rather, described the character of loose soils present during model development experiments. For this experiment, these parameters, such as porosity of the medium, density, heat capacity and conductance, were taken from reference tables (Oke, 1987). Further testing showed that the model reproduced observed pavement temperatures much more closely with improved specification of the pavement's properties.

3. PAVEMENT TEMPERATURE FORECAST SYSTEM

Initially, the feasibility of incorporating pavement temperature forecasts into the real-time MM5 forecast system at the UW was investigated. These tests showed that it would not be possible to produce accurate pavement temperature forecasts in this way. The reason was that at the resolution of the MM5 (4-km horizontal grid spacing), pavement is not the primary surface characteristic; rather, forest and grassland dominate. Instead the researchers decided to run the LSM as a one-way coupled model, using MM5 forecast data as input but not feeding back into the MM5 to affect the atmospheric forecast. Under this construct, the LSM system was designed to run at specified points along the Washington state highway network, with each point run as an independent forecast but driven by the same MM5 dataset.

4. RESULTS

The UW/WSDOT Pavement Temperature Forecast System was run in real time, producing forecasts from 0 to 48 hours into the future, twice a day through winter 2002-2003. With observations of pavement temperature from approximately 40 WSDOT sites, a significant dataset existed for verification. Qualitatively, the UW/WSDOT pavement temperature system forecasts were generally quite accurate under a variety of meteorological regimes, from winter storms to summer heat. Typically, the pavement temperature errors were within 1-2°C of observations.

This experimental system continues to run in real time at the UW, with forecasts being produced twice daily as weather forecasts become available. These forecast pavement temperatures are provided to WSDOT maintenance personel through a variety of web pages that display the data in different formats. One example of these web pages is the I-90 Traveler Information page, at http://www.atmos.washington.edu/maciver/roadview/i90

5. SUMMARY

This project showed that reasonably accurate pavement temperature forecasts can be produced by running a one-way coupled LSM driven by mesoscale weather forecast model data. Several methods for optimizing the implementation of such an LSM system were explored, producing significant improvements in the accuracy of the forecasts. These forecasts have been made available to Washington highway maintenance personnel and should provide uesful guidance in snow and ice conrtol practices.

6. REFERENCES

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