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## 1. INTRODUCTION

The impact of blowing and drifting snow onto highways continues to be a major winter maintenance concern across most of the United States. In addition, the presence of blowing snow reduces driver visibility and presents a significant safety and mobility concern. In lieu of widespread mechanical blowing and drifting snow suppression, the use of maintenance actions is required to maintain a desired level of service of roadways during blowing snow weather conditions. The support of the maintenance efforts during blowing snow conditions utilizing a maintenance decision support package has been identified as a priority research area by a state pooled fund research program designed to develop an operationally deployed Maintenance Decision Support System (MDSS) (Hart, 2003).

## 2. BACKGROUND

The management of blowing and drifting snow onto and across roadways has received considerable attention over the past three decades. Significant research on the design and implementation of barriers to control the drifting of snow onto roadways has resulted in dramatic growth in their application since the 1970s. It has been estimated that it costs one-hundred times more to plow snow drifts from the pavement than to construct and maintain snow fences (Tabler, 1994). However, as effective as snow fences can be, it is not reasonable to construct snow fences in all areas.

The importance of knowing the geospatial distribution and timing of blowing snow events extends beyond surface transportation

impacting interests ranging from avalanche prediction to agriculture. The effect of this broader interest has resulted in various numerical approaches to simulate and/or predict the redistribution of snow mass through wind driven actions. More extensive methods used to predict snow mass transport involve coupled blowing snow and atmospheric models resulting in a three-dimensional depiction of blowing snow events such as SnowTran-3D (Liston and Sturm, 1998) and PIEKTUK-D (Dery and Yau, 2001). Other blowing snow models exist with less computational complexity, but still incorporate meteorological conditions (observed and predicted) to provide a horizontal distribution of snow mass. These distributed models include the Variable Infiltration Capacity model (Bowling, et al., 2004) and the Prairie Blowing Snow Model (Essery et al., 1999).

The challenges with all blowing snow models within a highway's operations framework relate to satisfying proper initialization and the computational requirements for depicting the fine-scale structure of transient blowing snow events along a roadway. The less complicated horizontally distributed (non-atmospheric model coupled) blowing snow models are better suited for the computational resources found within the surface transportation weather service provider community. However, the initialization challenges associated with land-surface characteristics, resolution of snow pack conditions adjacent to and along the roadway, and the appropriate representation of blowing snow model results in maintenance operations context are significant.

## 3. WINTER MAINTENANCE BLOWING SNOW MODEL

To better understand the physical, computational, and operational aspects of providing blowing snow analyses and predictions for winter maintenance operations, the University of North Dakota (UND) Surface Transportation Weather Research Center (STWRC) has

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developed a two-dimensional road environment blowing snow (REBS) modeling system. The specific research requirements of the snow transport modeling system is to provide an approximation of blowing snow conditions along a roadway network for the estimation of impacts to winter maintenance operations, the estimation of driver visibility, and the energy flux of snow mass-related heat transfer due to blowing and drifting snow on pavement surfaces. The research efforts have been developed in accordance with operational requirements for blowing snow predictions for the multi-state MDSS efforts.

### 3. METHODOLOGY

The UND Roadway Environment Blowing Snow model depicts the temporal and spatial evolution of a column of sublimating snow as it is advected through a roadway environment. The extent of the roadway environment varies with terrain, but is generally considered to be the 1000-meters normal to the upwind side of the road. The REBS model is based upon the Prairie Blowing Snow Model (PBSM) and generates hourly values for the total particle number concentration of blowing snow, a snow particle size distribution, and an estimate of snow mass flux vertical profiles through the sublimation layer along a road network.

Initialization of the REBS land-surface conditions are provided by a geospatial method that incorporates video mapping of vegetative conditions immediately prior to the winter maintenance season. Additional static information on fetch distances along the road network is derived from air photo analyses available from existing state and federal agencies. Snow cover estimation is updated daily from the interactive multisensor snow and ice mapping system (Ramsay, 1998). These data provide daily 4-kilometer quality controlled snow cover in a format easily incorporated into the REBS modeling environment.

Atmospheric inputs include predicted 2-meter air temperature, 2-meter relative humidity, and 10-meter wind speed and direction. The Weather Research and Forecasting (WRF) model (Skamarock et al., 2005) provides hourly model projections of required input atmospheric fields at a 10-kilometer resolution extending to 36-hours. To account for local terrain influences, the 10-kilometer WRF output is extracted and downscaled onto a 1-kilometer sub-domain for a

region bounding the road network containing the individual road segments supported by the modeling system. A decision tree is used to determine whether a threshold for blowing snow has been exceeded and which then triggers the blowing snow prediction portion of the modeling system. The threshold for determining blowing snow utilizes the criteria of a snow covered surface with an ambient air temperature of less than 8°C (Dery and Yau, 1999) and exceeding a critical threshold 10-meter wind speed. The determination of the critical 10-meter wind speed follows that proposed by Li and Pomeroy (1997).

### 4. OPERATIONAL TESTING

The REBS modeling system is being tested during a winter 2005-06 MDSS operational field experiment across the Upper Midwest. This test includes over 175 road segments on selected road networks within Colorado, Indiana, Iowa, Kansas, Minnesota, North Dakota, South Dakota, and Wyoming. Data are provided hourly for display within the MDSS graphical user interface available to all state department of transportation winter maintenance participants as well as research personnel. Forecasted blowing snow conditions are projected for a period of twenty-four hours beyond the current time. A detailed field validation effort is being conducted at the UND STWRC road weather field research facility to measure the effectiveness of the blowing and drifting snow algorithm relative to observed parameters of temperature, momentum, moisture, and snow mass flux.

The paper presentation includes preliminary results of field tests of the algorithm conducted as part of the ongoing state pooled fund research MDSS field trials.

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