A Blowing and Drifting Snow Algorithm Supporting Winter Road Maintenance Decision Making

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Outline

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Problem Statement & Objectives

- Blowing snow in the roadway presents a serious challenge to winter maintenance activities and driver safety

- Current project is to develop a roadway environment blowing snow modeling system
  - Incorporation of mesoscale weather models
  - Integration with blowing snow model tailored to the roadway environment
  - Validation across broad terrain settings

- Operational testing & deployment
Snow Mass Flux Prediction

- Two critical layers monitored
  - Saltation Layer (where snow creeps/rolls in short trajectories)
  - Suspension Layer (where lofted snow attains a height that impairs driver visibility)
Blowing Snow Characteristics

- Critical variables include:
  - Extent and age of snow cover adjacent to road
    - Influenced by roadway geometry and vegetative cover
  - Land cover and terrain adjacent to road
  - Wind strength and its orientation relative to the road surface direction
  - Past, present and future air temperature and relative humidity
  - Amount of incident solar radiation
Methodology: Initialization Activities

- **Data Assimilation**
  - Supports model initialization and follow-up validation efforts
  - Utilizes the NOAA ESRL Local Analysis and Prediction System (LAPS)
    - 10-kilometer grid extending across 70% of the United States
    - Hourly assimilation cycle

- **Mesoscale Model**
  - Provides background fields of atmospheric dependent data
  - Models incorporated include
    - 6-member WRF ensemble
    - Workstation ETA
    - Models discretized to a 10-kilometer domain (same as the LAPS domain)

- **Downscaled Model Data to 1-kilometer**
  - Constructs fine resolution fields of winds and temperature
  - Accounts for local variations in land-cover and terrain
Methodology: Initialization Activities

- **Land Surface / Land-Use Characterization**
  - Provides a detailed reference of significant vegetative and terrain features along roadway
  - Used to generate a database for each road reference point that initializes static physical features used within the blowing snow model
  - Utilizes air photo and land resource satellite imagery to delineate critical features:
    - Fetch distances along the roadway at 1-kilometer resolution
    - Evaluation of sharp changes in terrain and vegetation features adjacent to roadway
  - Will be used to construct and utilize a blowing snow susceptibility index along roadways
Methodology: Blowing Snow Model

- **Blowing Snow Model**
  - Generates snow mass flux estimates within saltation, $Q_{salt}$, and suspension layers, $Q_{susp}$
  - Algorithm based upon modified Prairie Blowing Snow Model*

- **Roadway Visibility Model**
  - Utilizes mass flux within suspension layer, $Q_{susp}$
  - Visibility determined by $\log(Vis) = -0.773\log(Q_{subl}) + 2.845$ **

- **Pavement Drift Model**
  - Identifies presence of rolling/creeping snow that impacts ice formation on road surface
  - Utilizes mass flux within saltation layer, $Q_{salt}$, to determine drift density

- **Model output provide for future 30-hour period**


Computational Framework

Road Environment Blowing Snow (REBS) Model

- Data Assimilation
- Mesoscale Model
- Model Downscaling to 1-kilometer
- Pavement Snow Drift Model
- Road Environment Characterization
- Blowing Snow Model
- Roadway Visibility Model

Cycling
Focus Research Areas

One 10-kilometer Primary MDSS Domain

Each 1-kilometer Domain Focuses on Specific Winter Maintenance Routes

Ten 1-kilometer Blowing Snow Domains
UND Winter 2005-06 Operational Testing

- Validation of blowing snow research is part of the Pooled Fund Study Maintenance Decision Support System (PFS MDSS) Field Tests
  - 1 November 2005 to 15 March 2006
- Resulting technology to be incorporated as part of the PFS MDSS package
- To monitor progress
  [http://stwrc.rwic.und.edu](http://stwrc.rwic.und.edu)

For information on the PFS MDSS
[http://mdss.meridian-enviro.com](http://mdss.meridian-enviro.com)

= PFS MDSS States
Operational Testing & Deployment

- Presently supports blowing snow alerts within the PFS MDSS graphical user interface

- Provides route-specific alerts
  - 183 winter maintenance routes across eight states
  - Hourly forecasts through 24-hours
  - Alerts provided for four levels
    1. No Risk – No Blowing Snow Expected
    2. Slight Problem : 0 > Q_{\text{susp}} < 50 \text{ g m}^{-2} \text{ s}^{-1}
    3. Problematic : 50 \text{ g m}^{-2} \text{ s}^{-1} > Q_{\text{susp}} < 100 \text{ g m}^{-2} \text{ s}^{-1}
    4. Severe : Q_{\text{susp}} > 100 \text{ g m}^{-2} \text{ s}^{-1}
Preliminary Findings

• Results this winter indicate the advantages of 1-kilometer data resolution primarily beneficial for coarse terrains
  – Will permit future larger (tailored) grid spacing for non-obstructed terrain . . . Reduce computational requirements!
  – Higher resolution grids are as important for temperature fields as for wind fields . . . Strong blowing snow model dependency on temperature for initiation of saltation.

• Land-use / land-cover / snow pack accounting are crucial for fine-resolution depiction of drifting snow
  – Incorporation of a blowing snow susceptibility index along routes will provide improvement in spatial definition of drifting snow
Preliminary Findings

- Importance of the blowing snow varies greatly between users of the road and maintainers of the road
  - Winter pavement condition models must account for drifting snow in addition to falling snow
Ongoing Work

- Validation activities are underway across all PFS MDSS states
  - Focused validation activities ongoing at the UND Road Weather Research Facility (www.stwrc.rwic.und.edu)
  - Field observations include use of video disdrometers for detailed measurements of snow mass flux
- Addition of broader precipitation inputs for snow pack accounting
- Evaluation of historical hourly weather observations to establish blowing snow climatology
Future Work

- Incorporation of visibility predictions within the PFS MDSS interface and as part of 511 messages

- Addition of drifting snow into mass and energy balance computations within pavement conditions models

- Optimization and parallelization of codes to improve run-time efficiencies
  - Present codes require too great of computational resources to be sustained in an operational setting such as MDSS
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