P1.1

RESULTS OF MESOSCALE METEOROLOGICAL MODEL SIMULATIONS OF TOPOGRAPHY EFFECTS ON MOUNTAIN PINE BEETLE (DENDROCTONUS PONDEROSAE) TRANSPORT AND DISPERSION

Brenda L. Moore* and Peter L. Jackson
University of Northern British Columbia, Prince George, British Columbia, Canada

1. INTRODUCTION

The Mountain Pine Beetle (MPB, *Dendroctonus ponderosae*) is a natural part of the forested ecosystem in western North America at endemic population levels. However, due to recent weather conditions and an abundance of mature Lodgepole Pine (*Pinus contorta*), the outbreak in central British Columbia has reached epidemic proportions, affecting over 7 million hectares of forest based on trees killed prior to the 2005 flight.

A number of strategies have been used to understand MPB and host interactions at the tree and stand scale through simulation (e.g. Raffa & Berryman, 1986; Safranyik et al., 1989; Mitchell & Preisler, 1991; Preisler & Mitchell, 1993; Powell et al., 1996; Logan et al., 1998; Powell et al., 1998; Logan & Bentz, 1999; Safranyik et al., 1999; Powell et al., 2000). These models are appropriate once the pioneer beetles have invaded the local region, but are not relevant in determination of movement between stands and over longer ranges. When MPB fly or are carried above the canopy, they are believed to be advected by the wind much like inert, neutrally buoyant particles. Under the warm and light-wind conditions when MPB are known to fly during summer, terrain-induced thermal circulations are likely to dominate the near-surface wind field. Therefore, the nature of the topography and its effect on local wind circulations will affect the dispersal of MPB. Resource managers could use a landscape-scale depiction of MPB dispersal in order to determine where to focus preventative measures against MPB epidemics.

2. PROJECT OVERVIEW

As a preliminary step in the production of a long-range MPB dispersal model, this research seeks to: (1) validate the models used and (2) explore fundamental relationships between topography, atmospheric flows and MPB dispersal. The latter of the two parts of this research project is presented here.

The Regional Atmospheric Modeling System (RAMS), (Pielke et al., 1992) is run to produce the 3-dimensional meteorological fields needed as input to HYPACT, a lagrangian particle dispersion model, that then models dispersal of the particles (MPB) (Turner & Hurst, 2001). The topography of the domain as well as the model initialization are idealized in order to clarify the effect of topography on local circulations. Once RAMS begins to run, heating of the surface during the day produces upward motion that could carry the beetles above the tree canopy. The topography of the surface should have a great effect on the strength and duration of these circulations and should, in turn, affect the dispersal capabilities of MPB. As a control, a completely flat landscape has first been simulated. Two other landscapes consist of a sinusoidal mountain-valley system running in either a north-south or an east-west direction. This tests the effect of each of 4 different aspects (north-, south-, east- and west-facing slopes at potentially limiting MPB transport and dispersal over the landscape. HYPACT emits a specified number of beetles at specified sites within the domain to determine the effect of release site on resultant concentration.

3. METHODS

3.1 Model Initialization

In order to simulate topographically-induced circulations, a horizontally homogeneous initialization in RAMS was employed based on a single vertical profile. In order to select soundings with which to initialize RAMS, dates of probable or known MPB peak emergence and

---

* *Corresponding author address:*
Brenda L. Moore, University of Northern British Columbia, Environmental Science Program, 3333 University Way, Prince George, BC, Canada V2N 4Z9; e-mail: moore1@unbc.ca

flight were considered based upon a synoptic climatology of MPB emergence (Murphy & Jackson, 2004). The dates were divided into two categories based upon upper-level patterns of regional winds: upper-level ridge to the east (of the study area) and upper-level ridge to the west. Due to the prevalence of both of these synoptic patterns, it was decided to use two different initializations with data collected from the local upper air station (ZXS, Prince George, B.C.). The individual dates were selected based upon being the most representative of the group (statistically based upon RMSE for temperature and dewpoint temperature and RMSVE for combined wind speed and direction).

Each model run was initialized at 12Z (12:00 UTC = 04:00 PST) and allowed to run for a 24-hour period. The horizontal model grid is 91x91, with 1000m grid spacing (relatively fine grid spacing to allow the model to resolve the topography) and centered over Prince George, B.C. There were 42 vertical levels with grid spacing starting at 25m at the surface and gradually stretching to a maximum of 1000m near the model top. Cyclic boundary conditions were also employed, allowing for essentially an infinite grid, wrapping from one edge to the other. The vegetation type was set to “evergreen needleleaf tree” to increase the roughness length to simulate a mature lodgepole pine forested landscape.

3.2 Domain Topography

To determine the effect of topography on local circulations (and in turn how that affects the movement of MPB that are carried above the canopy), several idealized sinusoidal topography schemes were produced.

The control simulation is a flat landscape, with the elevation set to coincide with the elevation of the radiosonde release location in Prince George which was used to initialize the model. The sinusoidal model topography had ridges running either North-South or East-West in order to show the effect of aspect on local wind circulations. The effect of slope was also tested by producing five topography schemes with variable amplitudes.

In order to insure the relevancy of model output, the idealized terrain was produced such that the slopes represented in the sinusoidal waves are statistically similar to those retrieved from GIS data of the Prince George region.

4. PRELIMINARY RESULTS

The combinations of topography orientation (ridges running East-West or North-South), upper-level meteorology (ridge to the east or west of Prince George), and 6 artificial topography schemes (maximum slopes of 0% (flat), 2%, 4.75%, 7.85%, 14.1% and 20.35%) were used to produce 22 RAMS simulations and associated meteorological data.

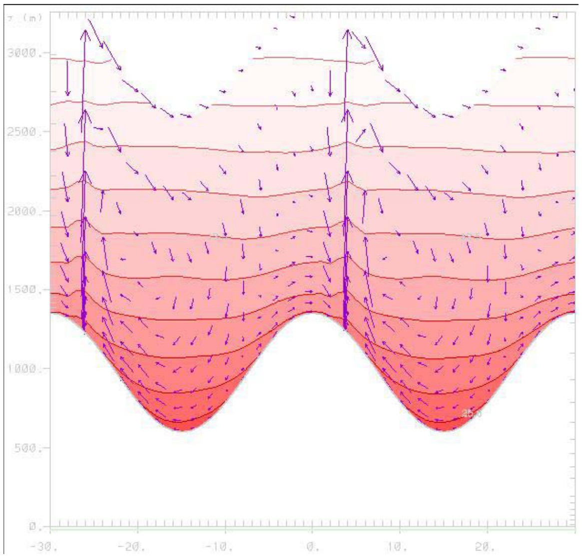

Figure 1: Representative cross-sectional plot of wind vectors during anabatic/katabatic circulation [E-W topography with upper level ridge to the east, Smax 7.85% at 19Z (12:00 PDT)]

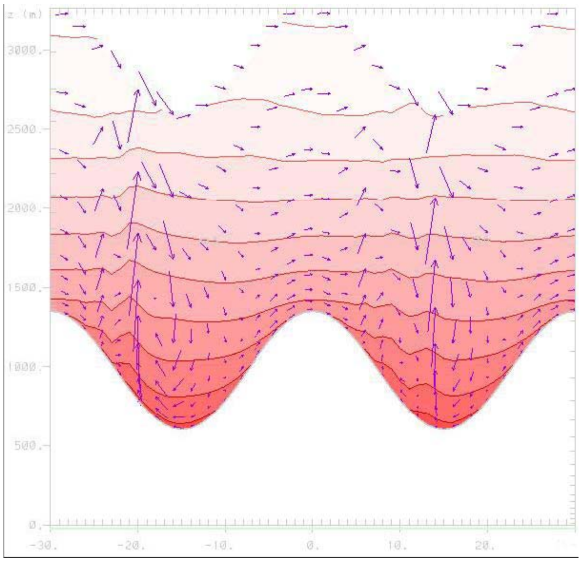

Figure 2: Representative cross-sectional plot of wind vectors during upper-level forced circulation [N-S topography with upper level ridge to the west, Smax 7.85% at 19Z (12:00 PDT)]

The resultant wind flow patterns could be divided into 2 distinct groups: cases exhibiting anabatic/katabic circulation patterns and cases exhibiting upper-level forced flow. Anabatic (upslope flow during the day) and katabatic (downslope flow during the night) flows were produced when the strongest component of the winds were blowing perpendicular to the topography (Figure 1). In these cases, the wind blowing across the peaks allowed for lighter winds in the valley bottom and a lee eddy sometimes formed. When winds were generally parallel to the underlying topography, the anabatic/katabatic flow was not established due to greater wind speeds in the valley bottoms (Figure 2).

5. FUTURE WORK

Future work will entail running HYPACT using the 3-dimensional meteorological fields produced by RAMS in order to advect the MPB across the artificial landscapes. Statistical analyses will be performed to determine the effect of upper-level meteorology, topography orientation, and slope on the transport and dispersion of MPB.

6. ACKNOWLEDGEMENTS

Funding for this work is provided by the Natural Resources Canada / Canadian Forest Service Mountain Pine Beetle Initiative.

7. REFERENCES

Logan, J.A. and Bentz, B.J. 1999. Model analysis of mountain pine beetle (Coleoptera: Scolytidae) seasonality. Environmental Entomology. **28**(6): 924-934.

Logan, J.A., White, P., Bentz, B.J. and Powell, J.A. 1998. Model analysis of spatial patterns in mountain pine beetle outbreaks. Theoretical Population Biology. **53**: 236-255.

Mitchell, R.G. and Preisler, H.K. 1991. Analysis of spatial patterns of lodgepole pine attacked by outbreak populations of the mountain pine beetle. Forest Science. **37**: 1390-1408.

Murphy, B. D. and P.L. Jackson 2004. A synoptic climatology for the emergence and flight of the mountain pine beetle (Dendroctonus ponderosae Hopkins) in thecentral-interior of British Columbia. *Preprints, 16th Conference on Biometeorology and Aerobiology.* Amer. Met. Soc., Vancouver, British Columbia, August 22-26, 4pp.

Pielke, R.A., Cotton, W.R., Walko, R.L., Tremback, C.J., Lyons, W.A., Grasso, L.D., Nicholls, M.E., Moran, M.D., Wesley, D.A., Lee, T.J. and Copeland, J.H. 1992. A comprehensive meteorological modeling system – RAMS. Meteorology and Atmospheric Physics. **49**: 69-91.

Powell, J., Kennedy, B., White, P., Bentz, B.J., Lodan, J and Roberts, D. 2000. Mathematical elements of attack risk analysis for mountain pine beetles. Journal of Theoretical Biology. **204**: 601-620.

Powell, J.A., Logan, J.A and Bentz, B.J. 1996. Local projections for a global model of mountain pine beetle attacks. Journal of Theoretical Biology. **179**: 243-260.

Powell, J., Tams, J, Bentz, B.J. and Logan, J. 1998. Theoretical analyais of “switching” in a localized model for mountain pine beetle mass attack. Journal of Theoretical Biology. **194**: 49-63.

Preisler, H.K. and Mitchell, R.G. 1993. Colonization patterns of the mountain pine beetle in thinned and unthinned lodgepole pine stands. Forest Science. **39**: 528-545.

Raffa, K.F. and Berryman, A.A. 1986. A Mechanistic Computer Model of Mountain Pine Beetle Populations Interacting with Lodgepole Pine stands and its Implications for Forest Managers. Forest Science. **32**: 789-805.

Safranyik, L., Barclay, H., Thomson, A. and Riel, W.G. 1999. A population dynamics model for the mountain pine beetle, *Dendroctonus ponderosae* Hopk, (Coleoptera: Scolytidae). Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Information Report BC-X-386.

Safranyik, L., Silversides, R., McMullen, L.H. and Linton, D.A. 1989. An Empirical Approach to Modeling the Local Dispersal of the Mountain Pine Beetle (*Dentroctonus ponderosae* Hopk.) (Col., Scolytidae) in relation to sources of attraction, wind direction and speed. Journal of Applied Entomology. **108**: 498-511.

Turner, R. and Hurst, T. 2001. Factors influencing volcanic ash dispersal from the 1995 and 1996 eruptions of Mount Ruapehu, New Zealand. Journal of Applied Meteorology. **41**: 12-29.