Charney, Joseph J.; Bian Xindi; Potter, Brian E.; Heilman,
Warren E. [2003]. Low level jet impacts on fire evolution in
the Mack Lake and other severe wildfires. In: 2d International
wildland fire ecology and Fire Management Congress: 5th
symposium on Fire and forest meteorology; 2003 November
16-20; Orlando FL. Boston, MA: American Meteorological
Society: 1.5. [Available only on CD-ROM]

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# LOW LEVEL JET IMPACTS ON FIRE EVOLUTION IN THE MACK LAKE AND OTHER SEVERE WILDFIRES

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## 1. INTRODUCTION

The 2000 fire season brought to the forefront the issue of severe wildland fires in the United States. To address the need for new research and for the development of predictive tools for managing wildland fires, Congress allocated funding under the National Fire Plan (NFP) to better equip government agencies to fight and study forest fires. As part of the NFP research agenda, the Eastern Area Modeling Consortium (EAMC) was established as one of five Fire Consortia for the Advanced Modeling of Meteorology and Smoke (FCAMMS). The centerpiece of the EAMC is an MM5-based modeling system designed to improve understanding of interactions between mesoscale weather processes and fires, and to develop better smoke transport assessments and predictions.

Mesoscale atmospheric models have demonstrated skill at the short-term prediction and assessment of real-time weather situations associated with fire danger and fire behavior (see e.g. Charney et al., 2003a,b). However, an additional application for which mesoscale models are well-suited is the simulation of weather conditions associated with historical severe wildfire cases. Simulations of large wildfires in the past can be used to better understand any atmospheric contribution to the observed fire behavior and to develop new fire-weather indices that enable fire weather meteorologists and fire managers to anticipate when similar conditions might develop during future fires. For this study, the MM5 modeling system employed by the EAMC was applied to the Mack Lake fire (Fig. 1) which occurred on May 5th, 1980 near Mio, Michigan (Simard et al., 1983).

## 2. OBSERVATIONS

The Mack Lake fire started as a prescribed burn that was ignited in jack pine slash at 1030 EDT (1430 UTC) on May 5th. By 1206 EDT (1606 UTC), the fire had spotted into a neighboring timber stand, and at 1215 EDT (1615 UTC) it crossed Michigan Highway 33 and became a wildfire. Over the next 6 hours, the fire consumed 20,000 acres, destroyed 44 homes and buildings, and caused one death. The fire was contained 30 hours after ignition, having consumed a total of 24,000 acres. While the Mack Lake fire is the largest fire on record for the Huron National Forest since 1911, Simard and Blank (1982) found that fires in excess of 10,000 acres occur in the area on average every 28 years.

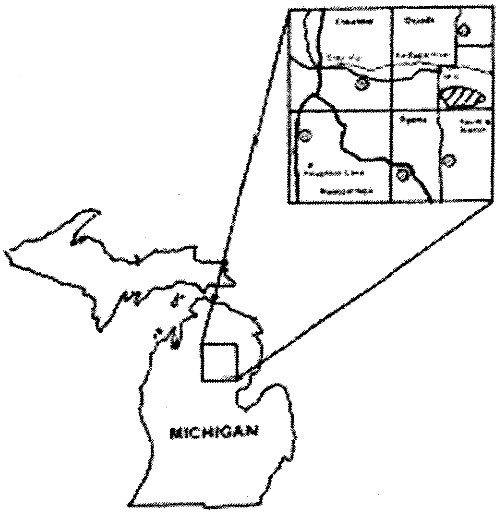

Figure 1: Map showing the location of the Mack Lake fire (Simard et al., 1983). The diagonal shaded area in the inset shows the burned area. Mio, MI is located at the crossroads just north of the fire.

The environmental conditions for the 1980 fire season were slightly dry, with a Palmer Drought Index of 1.17 on the day of the fire, indicating a slight but insignificant soil moisture deficit. The National Fire Danger Rating System (NFDRS) Burning Index (BI) had varied from low to extreme through the month of April, with values in the very high range on May 5th. A high pressure system dominated the synoptic weather pattern for the 5 days leading up to the fire. On the day of the fire, a cold front approached Mack Lake, passing through the area just after 1400 EDT (1800 UTC) (Fig. 2). Upper air data from three rawinsonde stations in the region, at Sault Ste. Marie, MI (SSM), Green Bay, WI (GRB), and Flint, MI (FNT), indicated the presence of a weak low-level jet (LLJ) in the Great Lakes region (Fig. 3). Note that the LLJ is readily apparent in the GRB and FNT soundings, but is not evident at SSM. According to the final analysis of Simard et al. (1983), high surface wind speeds (15 mph and above) and low relative humidity (21%) were major contributors to the escape of the prescribed fire.

## 3. SIMULATION RESULTS

In the early 1980s, atmospheric simulations were not readily available to fire weather forecasters or fire

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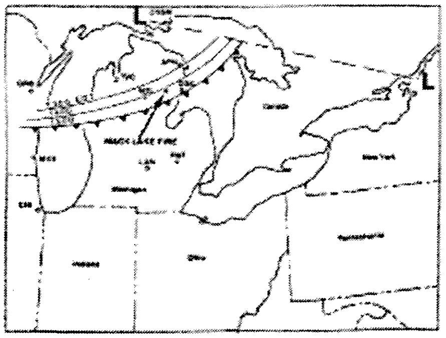

Figure 2: Location of the leading edge of the cold front on May 5th, 1980 (Simard et al., 1983). The northernmost front location was analyzed at 1300 UTC, followed by 1400 UTC, and 1500 UTC.

managers for the analysis of day-to-day weather situations. The forecasters relied upon surface observations and sounding data that were often far removed from the fire location when providing fire-weather forecasts. Atmospheric simulation systems, such as the EAMC MM5-based mesoscale modeling system, can be used to more fully explore the *in situ* atmospheric conditions, particularly the conditions aloft directly above the fire. The mesoscale simulation data can then be used to diagnose and understand the fire-atmosphere interactions that might have contributed to the growth of the fire.

For the Mack Lake fire, the available soundings (SSM, GRB, and FNT) were all at least 175 km distant from the fire location. The EAMC mesoscale model, which simulates the atmospheric conditions on a 4 km grid, can provide a much more locally valid depiction of the atmospheric structures on the day of the fire. Furthermore, the mesoscale model can depict the conditions at the time of the fire, rather than at 0000 or 1200 UTC, which is when rawinsonde balloon observations are collected.

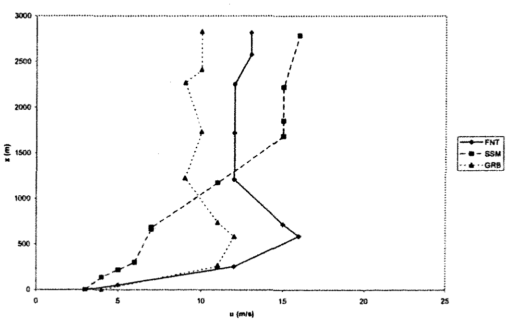

Figure 3: Vertical profile of observed wind speeds (in m/s) at Sault Ste. Marie, MI (SSM), Green Bay, WI (GRB), and Flint, MI (FNT) at 1200 UTC on May 5, 1980 (from Simard et al., 1983).

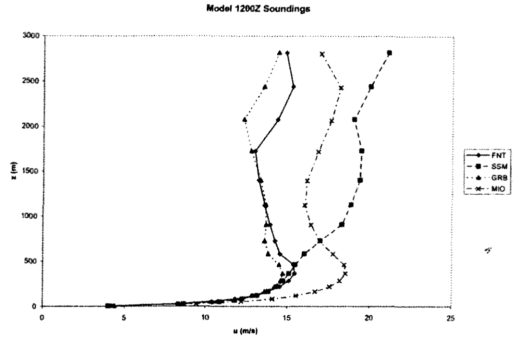

Figure 4: Vertical profile of simulated wind speeds (in m/s) at Sault Ste. Marie, MI (SSM), Green Bay, WI (GRB), Flint, MI (FNT), and Mio, MI (MIO) valid at 1200 UTC on May 5, 1980.

The simulated wind profiles at 1200 UTC for SSM, GRB, and FNT are shown in Fig. 4. Additionally, the simulated wind profile valid at Mio, Michigan, which is located within a few kilometers of the fire location, is shown for comparison. The model successfully reproduced the LLJ structures evident at FNT and GRB, while indicating almost no peak in the low level winds in the SSM sounding. The wind profile also indicates that there was a substantially stronger LLJ at Mio than at any of the upper air station locations.

Fig. 5 shows a horizontal plot of simulated winds at approximately 500 m above ground level. The upper air stations at FNT and GRB are both on the fringes of the jet structure, while a local minimum in the wind speed was located over SSM. However, over the fire location in the northern Lower Peninsula of Michigan, a strong maximum in the wind speeds is evident. Fig. 6 shows a horizontal plot of the simulated mixed layer heights at the time of the fire. At the fire location, the mixed layer

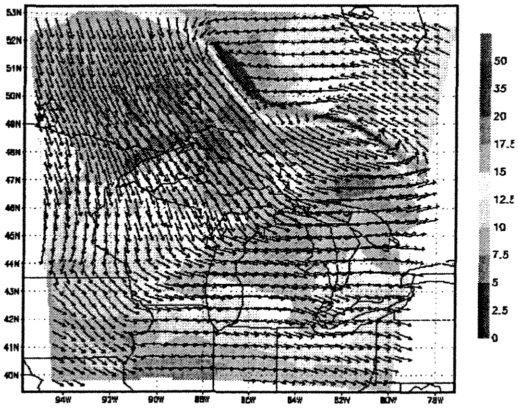

Figure 5: Horizontal plot of wind speed (shading) and direction (arrows) (in m/s) at an elevation of 500 m valid at 1200 UTC on May 5, 1980.

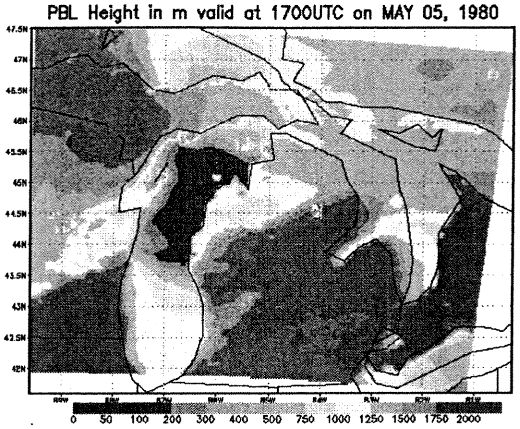

Figure 6: Horizontal plot of simulated mixed layer height (in m) valid at 1700 UTC on May 5, 1980.

heights exceed 1000 m. These two plots suggest the possibility that the surface mixed layer tapped into the momentum from the LLJ as it developed during the morning and early afternoon. This process is known to occur in other mesoscale weather phenomena such as dust storms (Pauley, et al., 1996) and severe convective storm environment (Danielsen, 1975).

The model results suggest that there was the potential for kinetic energy, as well as turbulent kinetic energy, associated with the LLJ to be been mixed down to the surface just before the fire grew out of control. If this process was important, it could have contributed strongly to the fire evolution in this case. Since mesoscale models routinely predict the occurrence, strength, and duration of LLJs in a variety of synoptic situations (Kaplan et al., 2000), it would be straightforward to develop an index that highlights locations where a deepening day-time mixed layer is expected to interact with a strong LLJ. Such an index could become an important early-warning tool that warns fire-weather forecasters and fire managers of the development of similar weather situations.

## 4. DISCUSSION AND CONCLUSION

This study has identified a strong LLJ that was present during the Mack Lake Fire, but that was not well-represented by the upper air observations available at the time of the fire. A mesoscale numerical simulation of the weather on the day of the fire suggests the possibility that momentum from the LLJ was mixed down to the surface as the day-time mixed layer developed on the morning of the fire.

The LLJ is an almost ubiquitous phenomena in the central and eastern United States, and in other parts of the world as well (Sjostadt et al., 1990). The LLJ can either occur as a surface-forced, planetary boundary layer phenomenon (Whiteman et al., 1997) or as an element of mid-latitude cyclogenesis and upper tropospheric jet streak dynamics (Uccellini, 1980). Byram (1954) and Brotak and Reifsnyder (1977) both discuss the possibility that a LLJ could be an important factor in the development of a large fire, but do not establish a causal connection between LLJs and extreme fire behavior. Since the feature is so common, both in relatively quiescent, high-pressure systems and in more dynamically active cyclogenesis situations, an index designed to predict scenarios when it could strongly influence a fire is potentially an important enhancement to existing fire-weather forecast tools.

Observations of severe fire events in other regions (e.g. DeCoste, 1968) indicate that there are other LLJ-fire configurations that can contribute to large fire growth. By simulating other large fires, both past and present, the relationship between LLJ and fire growth can be fully established.

This diagnosis of a mesoscale feature that is often undetectable in surface and radiosonde observations indicates the potential for mesoscale models to improve the fire-weather information available to fire fighters and fire managers. Since these simulations are available in a forecast mode, it is possible to warn fire managers days in advance when this type of phenomenon might impact their operations.

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