P5.3 THE ROLE OF A STRATOSPHERIC INTRUSION IN THE EVOLUTION OF THE DOUBLE TROUBLE STATE PARK WILDFIRE

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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.

The EAMC modeling system produces real-time predictions of mesoscale weather conditions on three domains, focusing on the north-central and northeast United States for the highest resolution simulations. Shortly after the modeling system became operative in real time, a large and damaging wildfire occurred in

Figure 1: Map showing the location of the Double Trouble State Park (red star). The fire icon indicates the approximate location of the origin of the wildfire.

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Time (EDT)	Activity Reported
1015	wind: west at 8 mph, gusting to 20 mph; temp: 75; RH: 62%
1300	Estimated start time of fire
1314	Direct Attack on fire by NJFFS firefighters begins
1325	40 mph winds reported at fire site; Direct Attack abandoned
1326	Backfiring operations begin north and east of the fire
1331	Request for Garden State Parkway to be closed
1335	Backfiring operations begin south of the fire
1347	Request for aerial support for fighting the fire
1351	Fire jumps Double Trouble Road and approaches the Garden State Parkway
1400	Fire is officially declared to be a Major Fire
1401	Fire has crossed the Garden State Parkway
1408	First report of a house being burned
1418	Wind shift reported on the fire line
1423	Fire crews prepare for structure protection
1451	Wind shift to the north reported; former right flank of the fire becomes the head fire
1457	Lakewood Tower reports winds from the north at 35 mph
1536	Big wind shift reported on the fire line
1537	Lakewood Tower reports winds shifting to the East, North East
1538	Right flank becomes head fire
1553	Fire has been diverted south of the line of homes located just east of the Garden State Parkway
1559	Wind shift reported on fire line; Electric lines down roadway
1601	House on fire
1604	Evacuation order issued for homes in the area
1610	Wind shift reported on fire line
1624	Wind shift reported on fire line; wind shifts cause fire to spread rapidly towards south, directly towards a crew
1655	East flank of fire reported to be growing; fire crews respond to quell
1713	Fire west of the Garden State Parkway reported to be contained
1736	Fire under control
1748	Winds diminish to 20 mph

Table 1: Sequence of events during the Double Trouble Fire on June 2, 2002 (taken from NJFFS, 2003). All times are EDT (UTC - 4 hours). Blue entries indicate weather-related observations.

east-central New Jersey, in the Double Trouble State Park, on June 2, 2002 (Fig. 1). The fire caused substantial property damage and forced the closure of a state highway, leading to major traffic difficulties throughout southern New Jersey during a high-volume summer travel period. The EAMC real-time prediction system simulated the meteorological conditions associated with the wildfire. Preliminary analysis of the modeling results suggested that meteorological processes aloft played an important role in the development of the surface weather conditions that contributed to the rapid spread of the fire. Although the EAMC simulations depicted these meteorological conditions independently on both a 12 km grid and a 4 km grid, all of the results presented here are from the 4 km simulation.

2. OBSERVED WEATHER AND FIRE BEHAVIOR

Table 1 summarizes the variations in weather conditions, fire behavior, and firefighting activities as reported by the New Jersey Forest Fire Service personnel working to control the wildfire (NJFFS, 2003). The fire started from a camp fire that had been left smoldering the night before. The fire was small enough to escape detection at fire observation towers until 1300 EDT (1700 UTC), due to poor visibility and high relative humidity in the morning (Steve Maurer, NJ Forest Fire Service, personal communication). However, 25 minutes after the initial observation and 10 minutes after the initial attack, the fire was found to be growing too rapidly to be contained. The fire crews were forced to retreat and light back fires in an effort to deprive the fire of fuel. Surface weather observations at that time indicate a 10 m/s wind speed and surface relative humidity around 30%.

The National Weather Service office in Mount Holly, NJ provided a spot forecast for the fire location, shown in Table 2. The forecast shows the winds growing in magnitude through the afternoon and then decreasing in the early evening, with relative humidity varying between 30% and 50% during the same time period. The sometimes rapid and unpredictable wind shifts noted by the fire fighters did not appear in the spot forecast.

The EAMC simulation of the event indicates a sharp increase in the surface winds at 1700 UTC (1300 EDT), the same time that the fire started to grow rapidly (Fig. 2). Additionally, the simulation results suggest a substantial local reduction in relative humidity values, to 30% and below. Strong winds (Byram, 1954; Fahnstock, 1965; Brotak and Reifsnyder, 1977, and Simard et al., 1987) and low relative humidity (Lansing, 1939; Davis 1969; Simard et al. 1987) are known to be conducive to large fire development and rapid fire spread, and the model suggests that there were substantial local variations in these quantities at the time of the fire (Fig. 3a,b).

The temporal variations in wind direction (not shown) are similarly interesting, particularly in the context of the variations in wind direction observed by

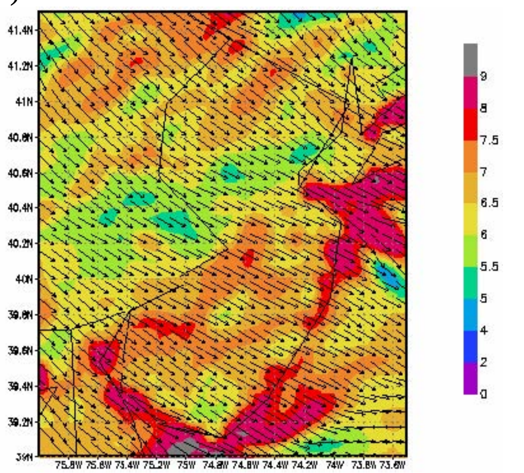
Time	Temp	RH	Wind Conditions
1500 EDT	82 ˚F	28%	WNW 16 GUST 28 MPH
1700 EDT	80 ˚F	27%	WNW 16 GUST 26 MPH
1900 EDT	77 ˚F	30%	NW 14 GUST 22 MPH
2100 EDT	71 ˚F	35%	NW 12 GUST 18 MPH
0000 EDT	63 ˚F	45%	NW 8 MPH
0300 EDT	57 ˚F	55%	NW 5 MPH
0600 EDT	55 ˚F	65%	NW 5 MPH

Table 2: Spot forecast issued by the Mount Holly National Weather Forecast Office. All times are EDT (UTC - 4 hours).

the firefighters. The difficulties they faced when trying to anticipate wind shifts and to handle the consequent changes in fire behavior (e.g., flanks becoming head fires, causing the fire to spread rapidly in a new direction) were great. The simulation results do indicate a greater variability in the wind direction than appeared in the National Weather Service spot forecast. However, the model was unable to reproduce the variations reported by the firefighters, mostly because the horizontal resolution of the simulation is not sufficient to resolve many of the observed changes. Nevertheless, preliminary higher resolution simulations (not shown) demonstrate the potential to capture wind variations on this scale. Eventually, a fully coupled fire-

Figure 2: Time series of surface relative humidity (blue line) and wind speed (yellow line) during the Double Trouble State Park wildfire. All times are UTC (EDT + 4 hours).

a)



b)

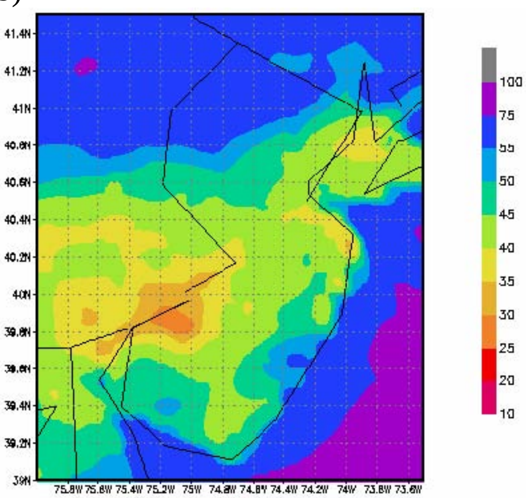


Figure 3: Horizontal plots of simulated: a) wind speed and wind vectors (in m/s) and b) surface relative humidity (in %) valid at 1700UTC (1300 EDT).

atmosphere model might be necessary to address these features, as it is likely that the fire itself was generating some of the rapid variations in wind direction and speed observed on the fire line.

3. ATMOSPHERIC CONDITIONS ALOFT

Since there are no local rawinsonde balloon observations available for the time of the fire, the simulation results provide our only means of assessing the local atmospheric conditions aloft. A skew-T log-P diagram from 1300 EDT (1700 UTC) at the fire location reveals that there was very dry air in place above the fire (Fig. 4). The vertical wind profile reveals that there were substantially stronger winds above the surface layers. Fig. 5 shows a time-height cross section of wind speeds, as well as the depth of the mixed layer, at the fire location from June 1st through June 2nd. There is a strong indication that the simulated mixed layer deepened such that dry (see Fig. 4), higher-momentum air aloft was able to mix downward to the surface. This mechanism appears to be responsible for the strong drying and the sudden increase in wind speed that appears in the simulation and observations of this event.

In order to improve our ability to predict when the surface mixed layer will tap into dry, high-momentum air aloft and thus increase the probability that an existing fire might grow out of control, it is useful to understand the ultimate source of the air above the surface layers. A vertical cross section of relative humidity suggests that a tropopause fold was present in the northeastern United States at this time (Fig. 6). It is well-known that

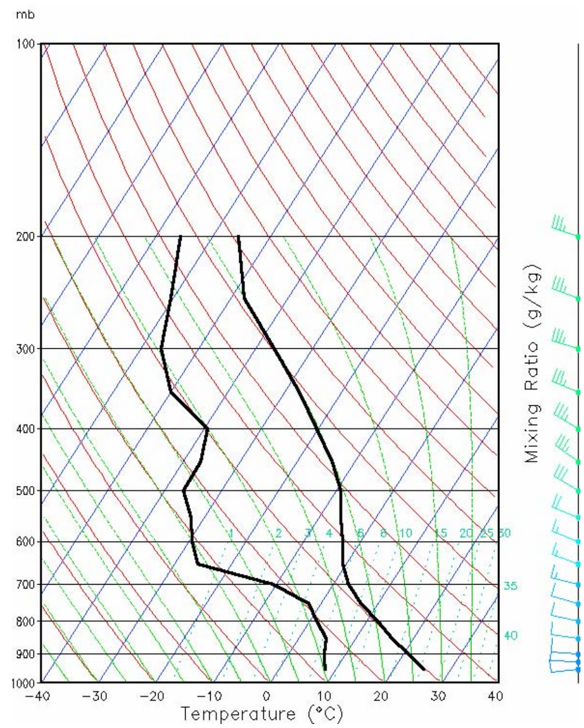


Figure 4: Simulated Skew-T Log-P diagram and wind profile valid at 1700UTC (1300 EDT).

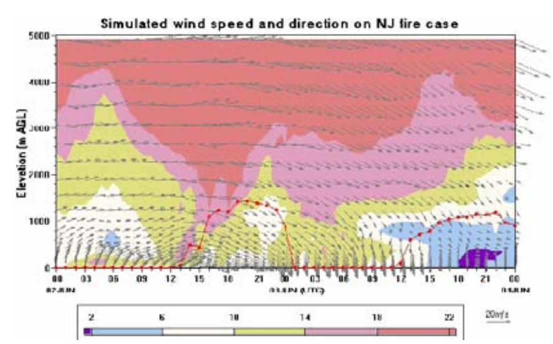


Figure 5. Time-height cross section of wind speed and horizontal wind direction at the fire location. The red line represents the mixed-layer height. All times are UTC (EDT + 4 hours).

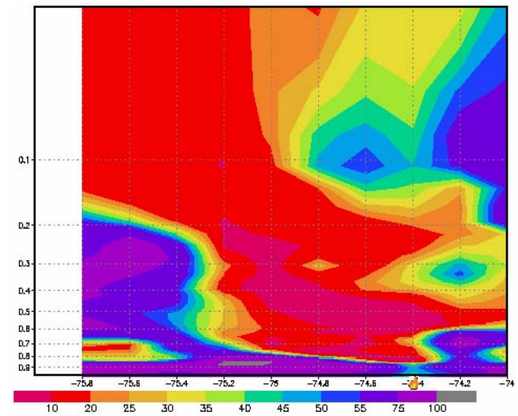


Figure 6: Northwest-southeast vertical cross section of simulated relative humidity (in %) valid at 1700UTC (1300 EDT). The fire icon between the color bar and the cross section indicates the fire location.

tropopause folds can transport very dry stratospheric air downward into the troposphere (Stohl et al., 2003). The simulation results suggest that a tropopause fold was modifying the air throughout the northeastern United States such that dryer than normal conditions prevailed throughout the upper troposphere. This feature is often referred to as a stratospheric intrusion (see e.g. Holton et al., 1995). It is noteworthy that the air near the ground across southeastern Pennsylvania and central New Jersey was the driest anywhere in the region, just as the fire began (Fig. 3). Observation stations south of Philadelphia, PA and in southern New Jersey reported a surface relative humidity of less than 20% on the day of the fire, lending credence to the simulation results (Mount Holly NWS, personal communication). Since stratospheric intrusions are generally straightforward to diagnose in simulations, they are potentially useful for developing new fire-weather indices, particularly if stratospheric intrusions are found in the vicinity of other rapidly-growing fires. It is quite possible to develop an index that would detect the presence of these features and predict when a surface-based mixed layer might interact with dry air descending from the stratosphere

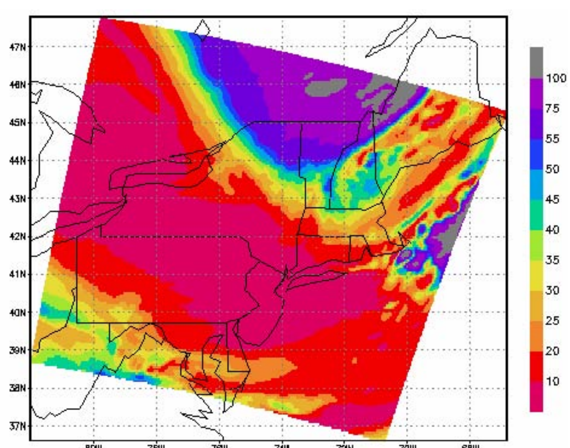


Figure 7: Horizontal plot of 500 hPa relative humidity (in %) valid at 1700UTC (1300 EDT).

Additional analyses of the simulation results for this event suggest an alternative possible source of the dry air. Fig. 7 shows a horizontal plot of simulated relative humidity at the 500 hPa level. There is evidence here that the dry air in the mid levels also spread far to the west, and that the overall pattern at this level is not consistent with the shape of the tropopause fold. An examination of earlier simulation times reveals that the ultimate source of this dry air was the Rocky Mountains. Elevated mixed layers from high elevation areas are also known to be source of mid-level dry air downstream (see e.g. Carlson et al., 1983). For this particular case, additional analyses are necessary to establish which process was dominant, or if they were both important.

4. CONCLUSION

The Double Trouble State Park wildfire in east-central New Jersey was a major fire that caused many difficulties for fire fighters, and destroyed some $400,000 worth of property. The tools available to the fire fighters and the National Weather Service were helpful in effectively fighting the fire and preventing any loss of life or catastrophic loss of property. The products under development by the EAMC are designed to augment fire-weather tools already available to the firefighters and National Weather Service fire weather forecasters.

Results from EAMC simulations of the weather associated with this wildfire suggest that there is much to be learned about interactions between the air aloft and the surface weather conditions that are known to influence fire behavior. Some of the results suggest that even atmospheric conditions in the stratosphere can have an impact on the evolution of some fires. There is a clear indication that new products designed to take advantage of weather conditions aloft simulated by atmospheric models could provide additional predictive power and early warnings atmospheric conditions conducive to rapid fire growth.

Case studies built around mesoscale weather simulations like the one presented here have the potential to radically alter our understanding of fire-weather interactions. Building new indices based on a physical understanding of how a fire modifies the atmosphere and how the atmosphere can impact fire behavior is an active area of National Fire Plan research. The EAMC is developing similar case studies for significant wildfires both in the eastern region and throughout the United States and the world, in an effort to better understand these interactions and to improve all facets of fire-weather interaction prediction, assessment, and understanding.

5. REFERENCES

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