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GEOGRAPHICAL, METEOROLOGICAL, AND CLIMATOLOGICAL CONDITIONS SURROUNDING THE 2008 INTERSTATE-4 DISASTER IN FLORIDA

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1. INTRODUCTION

Drivers on central Florida's primary urban corridor, Interstate 4 (I-4) in Polk County, encountered a blinding mixture of smoke and fog that crept onto the highway during the early morning hours of January 9, 2008 (Figures 1 and 2). Seventy cars and trucks collided in the east bound lane near mile marker 47 resulting in five deaths and 38 injuries. Sheriff Grady Judd of Polk County described the conditions as "a wall of smoke and fog" (*Lakeland Ledger*, 2008). The dangerous conditions were the result of a prescribed burn and ensuing smoke that lacked surveillance. This paper examines the individual events leading to the deadly pile-up and suggests methods to reduce chances of a future repeat occurrence.

FIGURE 1
LOOKING WEST OVER THE ACCIDENT SCENE ALONG I-4 AFTER SUNRISE
Source: *Orlando Sentinel* (2008); used with permission

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FIGURE 2
LOOKING NORTH AT FIRE ON EAST SIDE OF OLD GRADE ROAD
Source: *Lakeland Ledger* (2008); used with permission

An examination of data available from the National Climatic Data Center (NCDC, 2008), which provides data on fog and smoke events from 1993 to present, reveals that six other similar smoke and fog accidents on major highways in Florida have occurred between 2001 and 2008, leaving 16 dead and 58 injured (Table 1). It should be noted that other smoke and fog incidents likely occurred before 2001, but were not submitted to NCDC. Like the 2008 Florida I-4 disaster, these incidents often occurred in the winter and spring. In a study examining a fog disaster in Florida, Turner and Pietrzyk (2000) noted that Florida's fog season is from December to February. Table 2 places the 2008 Florida I-4 disaster in context with other fog related incidents and ranks this event second (jointly with a California event) in terms of number of deaths, with five fatalities. If one considers the total number of deaths and injuries, this event ranks joint first (with a total number of 43).

TABLE 1
FLORIDA FOG RELATED TRAFFIC INCIDENTS ENHANCED BY SMOKE, RANKED BY INJURIES (DATA FROM NCDC, 2008)

Florida County	Date	Time (UTC)	Deaths	Injuries
Polk	1/9/2008	0900	5	38
Putnam	11/12/2003	0900	2	7
Flagler	2/17/2006	0700	1	7
Collier	12/15/2006	0900	1	3
Osceola	3/13/2007	1320	5	3
Polk	2/6/2001	0900	1	0
Polk	5/8/2001	1040	1	0

TABLE 2
TOP 5 FOG RELATED INCIDENTS IN THE UNITED STATES, RANKED BY DEATHS (DATA FROM NCDC, 2008)

County, State	Date	Time (UTC)	Deaths	Injuries
Sheboygan and Ozaukee, WI	10/11/2002	0800	11	0
Polk, FL	1/9/2008	0900	5	38
Sacramento, CA	12/11/1997	1510	5	26
San Joaquin Valley, CA	2/5/2002	1053	3	40
San Diego, CA	12/1/2000	1930	3	3

This region of Polk County has a history of problematic fire and smoke issues. This area was the site of a major wildfire during February 18-24, 2001. That wildfire consumed over 44.5 km^2 of grass, cypress, pine and palmetto trees, and shrubs that were located along and north of the I-4 corridor, over mainly rural portions of northern Polk County. A 10 mile stretch of I-4 was closed between Polk City and Lakeland due to the wildfire for nearly 10 days. The wildfire smoke plume occasionally reduced visibility and deposited ash over 100 km away.

Although widespread fog occurred the morning of the accident, it was the smoke combined with fog that created dangerously low visibility. Achtemeier (2003) coined the term "superfog" as a mixture of smoke or condensation nuclei and heated water vapor released from damp smoldering organic material mixing with cooler nearly saturated air, condensing and lowering visibilities to less than 3 m. Under light wind conditions and lowered night-time mixing heights, the dense smoke and fog concentrations meander with drainage flows through low terrain areas. Winds may vary considerably above and below shallow nighttime inversions. The standard National Weather Service (NWS) fire weather wind forecast level is 6.1 m (20 ft) above the vegetation, and can vary considerably with vegetation type. As air cools and becomes more dense, it sinks into areas of lower terrain. These drainage flows can be below the level of the wind forecast in forested areas.

2. PRESCRIBED BURN OUT OF CONTROL

The dangerous early morning limited visibility conditions were the result of a prescribed burn which took place just 2 km from the crash site. The Florida Fish and Wildlife Conservation Commission (FWC) initiated the proposed small (0.04 km^2) burn that went awry the previous afternoon. The Keetch Byram Drought Index (KBDI), which is related to soil dryness, is widely used for estimating wildfire potential (Keetch and Byram, 1968). Figure 3 shows the KBDI for January 8, 2008. With a KBDI of 550-599 (as also noted on the original burn permit) this means that the wildfire potential was severe.

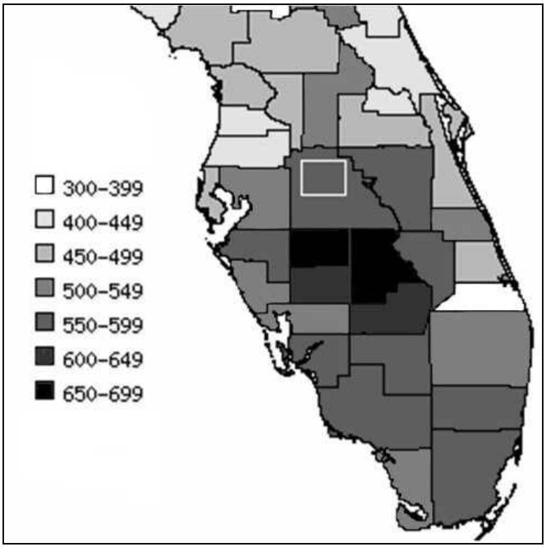

FIGURE 3
KEETCH BYRAM DROUGHT INDEX (KBDI) JANUARY 8, 2008

A freeze occurred a few days before the incident, killing many of the plants that were already dry due to drought conditions. This provided additional fuel for the prescribed burn, and ample opportunity for the blaze to grow out of control. At 1025 UTC on January 8, 2008, the burn manager obtained a spot weather forecast derived directly from the NWS model output statistics products through a web-based computer program provided by the Division of Forestry (DOF). The lowest relative humidity forecast was 60 percent at 1800 UTC. Interestingly, just prior to the burn initiation at 1500 UTC, winds were south-southeast at 1.5 ms^{-1} with a temperature of 25°C and a relative humidity of 63 percent; a value already near the forecast minimum. The NWS planning forecast, covering a broader area, predicted east winds at 2.7 ms^{-1}, becoming southeast at 3.6 ms^{-1} during the afternoon, with a maximum temperature of 27.7°C and a minimum relative humidity of 44 percent.

At the next FWC observation time, 1800 UTC, the relative humidity had plummeted to 29 percent while winds were south-southeast at 3.1 ms^{-1}. The sudden drop in humidity was caused in part by stronger winds up to 10 ms^{-1} just above the surface, mixing dry air above 1500 m with air at the surface as seen on the vertical profile of dewpoint, temperature, and wind at 1200 UTC in Figure 4.

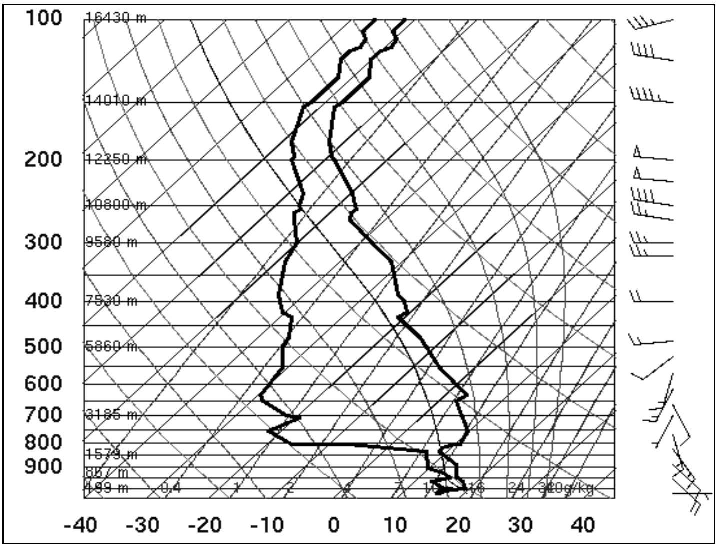

FIGURE 4
RUSKIN, FLORIDA VERTICAL PROFILE OF THE ATMOSPHERE TO 16430 METERS (SKEW-T DIAGRAM), 1200 UTC, JANUARY 8, 2008. (FROM LEFT TO RIGHT - DEWPOINT, TEMPERATURE, WIND BARBS IN KNOTS)

The circumstances surrounding the wildfire were investigated by a state of Florida multi-agency review team (FDOACS, 2008). Its summary noted that one hour after initiation the fire began to burn erratically, escaping the prescribed area (Table 3). At approximately 1630 UTC the burn manager requested DOF to respond. The DOF used mechanical, burn-out, and backfire suppression techniques in an attempt to control and contain the wildfire. The wildfire grew rapidly and was approximately 1.54 km^2 by 2200 UTC. Around 2200 UTC, the DOF notified the Florida Highway Patrol (FHP) and Department of Transportation (DOT) of the fire and the potential for smoke on the highway. Polk County Emergency Management then requested an official site-specific spot weather forecast for this event from the NWS. At approximately 2230 UTC the NWS spot forecast headlined that patchy dense fog was expected overnight with a mixing height of 60 m, near calm winds, and a Low Visibility Occurrence Risk Index (LVORI; Lavdas, 1996) of 10, which is the most severe. Control of the blaze was regained before sunset but smoldering and spot fires occurred overnight as fog began to develop.

TABLE 3
TIMELINE OF EVENTS LEADING UP TO THE JANUARY 9, 2008 WILDFIRE

Date	Approximate Time (UTC)	Event
Jan 8, 2009	1015	Original DOF spot forecast issued
Jan 8, 2009	1500	FWC site observation RH 63%
Jan 8, 2009	1515	Fire ignited
Jan 8, 2009	1630	DOF support requested
Jan 8, 2009	1800	FWC site observation RH 29%
Jan 8, 2009	2200	Wildfire reached maximum size
Jan 8, 2009	2200	DOF notifies FHP and DOT of potential for smoke on I-4
Jan 8, 2009	2238	NWS spot forecast issued
Jan 8, 2009	2300	Fire controlled
Jan 8-9, 2009	2300-1100	Fire smoldered over night
Jan 9, 2009	0915	Smoke drifted over highway and first accident occurred

3. OVERNIGHT: THE PILEUP

A video image captured several hours after the accident (Figure 5) clearly shows the area of smoke from the smoldering fire just north of I-4 mixing and spreading over a widespread but less dense area of fog. The smoke plume from the vehicle accident extends upward over a hill adjacent to the accident and over the superfog strata. This low level inversion, with nearly calm winds at the surface and stronger southeasterly winds around 100 m, is indicated on the morning sounding from Ruskin, Florida (Figure 6). In the evening hours of January 8, wind became light around sunset and remained near calm in the overnight hours while the relative humidity continued to increase to near 100 percent by 0900 UTC January 9 (Figure 7).

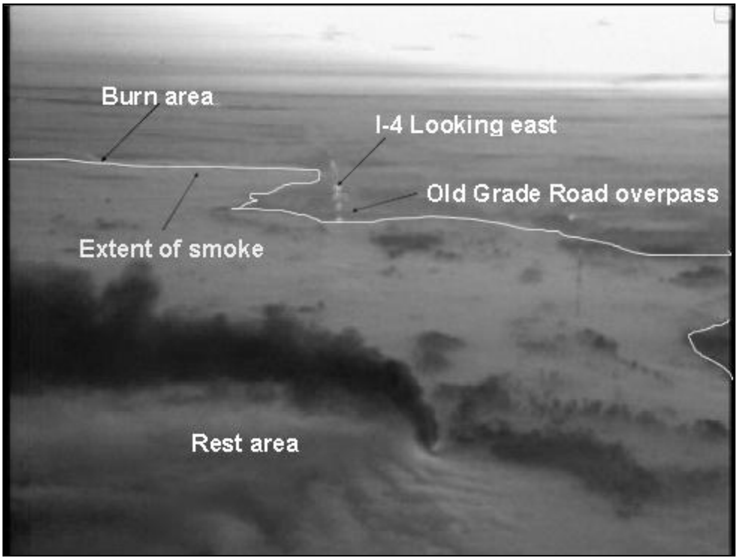

FIGURE 5
AERIAL VIDEO CAPTURE OF THE ACCIDENT SCENE AROUND SUNRISE
JANUARY 9, 2008
Source: *Lakeland Ledger* (2008); used with permission

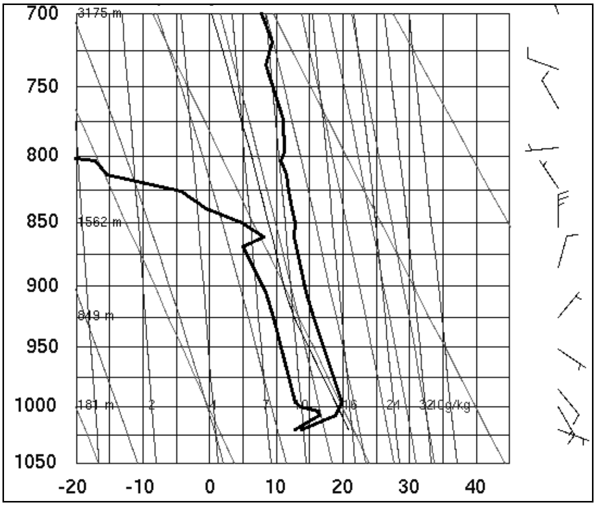

FIGURE 6
SKEW-T, VERTICAL PROFILE OF THE ATMOSPHERE TO 3175 M, RUSKIN, FLORIDA
(TRUNCATED SKEW-T DIAGRAM), 1200 UTC, JANUARY 9, 2008
(LEFT TO RIGHT: DEWPOINT, TEMPERATURE, WIND BARBS IN KNOTS)

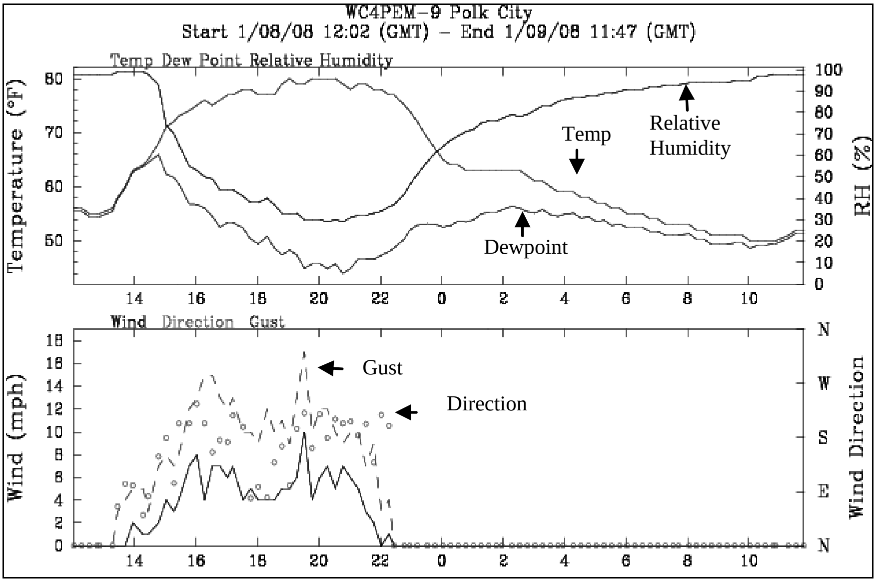

FIGURE 7
METEOGRAM FROM WC4PEM-9 POLK CITY, FLORIDA (28.19650, -81.78567, 36.8M), APPROXIMATELY 4 KM FROM CRASH SITE (MESOWEST)

The terrain in this area is nearly flat with only subtle rises and swampy sinks increasing microscale relative humidity. Vegetation changes with the terrain elevation, with oaks in higher areas, cypress in the low areas, and pine and palmetto between. Under very light easterly surface winds the smoke wound through low lying areas, but was partially corralled by a hill approximately 5 m above the surrounding terrain. Pushed by light easterly winds, the blanket of smoke meandered across flat terrain of varying vegetation then crept south along the hill and drained over the highway just after 0900 UTC (Figures 8 and 9). Visibility was further restricted as drivers went around an inclined curve prior to reaching the smoke. The accident occurred soon after.

FIGURE 8
DIAGRAM OF SMOKE PATH
Background Image: Google Earth

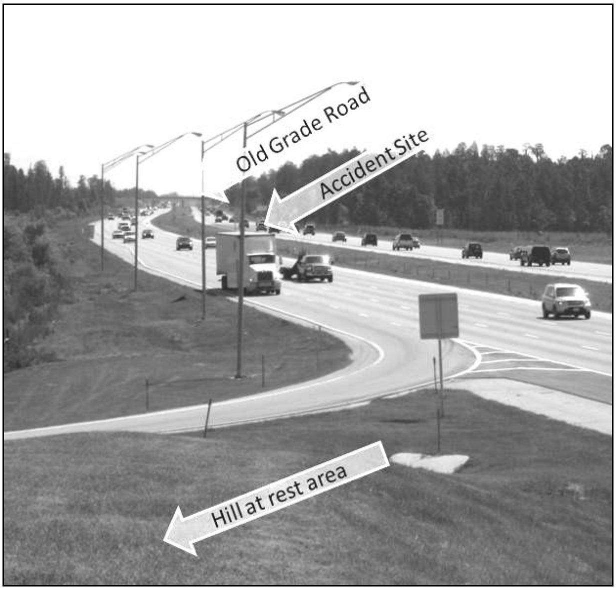

FIGURE 9
LOOKING NORTHEAST FROM THE REST AREA TOWARDS THE ACCIDENT SITE

4. POTENTIAL METHODS OF DETECTION/PREDICTION

Ellrod and Lindstrom (2006) looked at satellite fog detection techniques with major fog related highway accidents and found that accidents occur with rapid changes in visibility from dense patches or narrow bands moving over roadways. They also found that current satellite imagery lacks sufficient resolution for fog detection, particularly with shallow fog. Due to the small scale nature of this event, traditional remote sensing technologies are also lacking. The GOES-12 fog/stratus product (NESDIS) offers little insight into this event indicated by the black circle (Figure 10). The isolated smoke/fog pixels are present, but the smoke/fog density and visibility restrictions are difficult to ascertain. Similarly the closest NWS Automated Surface Observation System (ASOS) was at Gilbert Field airport in Winter Haven. The reported visibility there of 1.6-3.2 km between 0700 and 1100 UTC, with a few intermittent reports of 0.8-1.2 km, were not representative for the burn location situated 16 km away. The spatial distribution of visibility sensors is limited and other methods of detection must be considered.

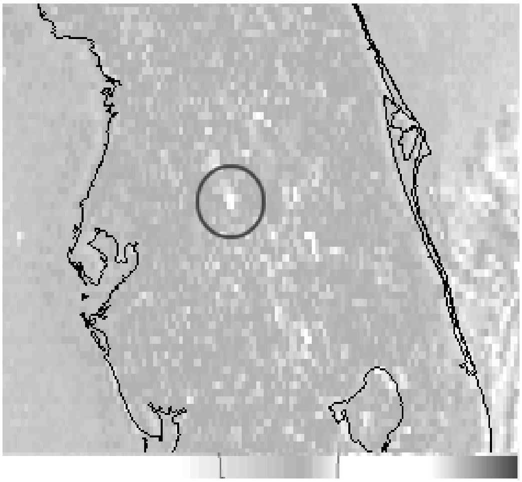

FIGURE 10
GOES-12 FOG/STRATUS PRODUCT 1015 UTC JANUARY 9, 2008

To illustrate wind effects during the overnight hours preceding the accident, the Weather Research and Forecasting Model (WRF; Michalakes *et al*., 2001) was run at 100 m resolution. The primary area of interest was around 2 km^2. The model shows the evolution of 2 m winds from a southeast direction that would push smoke away from I-4. Later winds in the model become near calm, invoking very light drainage winds (Figure 11). While the preliminary model results are promising, higher horizontal and vertical resolution is important for this scenario.

5. FUTURE PREVENTION

As with some other accidents, many geographical, meteorological, and climatological events converge. The prescribed burn grew out of control, was much larger than expected, and microscale processes affected smoke migration. This disaster incurred the largest death and injury total compared to any of the other smoke or fog events in Florida since 1993, when Storm Data smoke and fog events were initially recorded. This event ranks fifth in the country in terms of injuries, and second for deaths for smoke related accidents. Effective methods to monitor smoke and visibility were lacking. This illustrates the need for vigilance in monitoring hazardous visibilities on roadways.

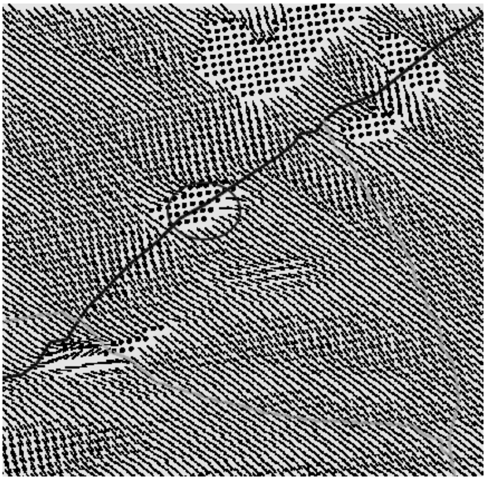

FIGURE 11
HIGH RESOLUTION (100 M) WRF 2 M WINDS
(CIRCLE INDICATES ACCIDENT AREA)

Ellrod and Lindstrom (2006) concluded that roadway visibility assessments require use of surface observations. They suggested environmental roadway sensors to detect low visibilities to quickly inform officials. The officials would then produce weather advisories for the media and for Variable Message Signs to reduce speed limits. Although caution signs were erected along the interstate and the Florida Highway Patrol made occasional passes through the area, it was not enough to prevent this accident.

Several courses of action exist to avoid future accidents that could result from a mixture of smoke and fog. Automated forecasts for prescribed burns should have some level of human oversight, particularly when near the urban interface. When fires are near urban thoroughfares, smoke management tools, including high resolution modeling, could be used to indicate microscale circulation that may carry smoke in unexpected directions and impact smoke sensitive areas. This event was beyond the resolution of effective satellite monitoring, but in-situ monitoring was possible if portable visibility sensors were available to report to the NWS, Highway Patrol, and ultimately to roadway signage. When visibility sensors are not available, human roadway observers spaced at short intervals could provide critical smoke information. Web cameras could also be installed in fog-prone areas and monitored by personnel to prevent such events from occurring. Such additional information could save lives.

6. ACKNOWLEDGEMENTS

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