1.2 FORECASTING ADVERSE WEATHER IN THE BALTIMORE MD - WASHINGTON DC URBAN ZONE: DETECTION AND PREDICTABILITY ISSUES

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1. INTRODUCTION

The combined Baltimore, Maryland and Washington, DC (BWDC) urban region (~800 km^2) is home to nearly 8 million people. Adverse weather has a large impact on the many residents living in this region particularly regarding transportation. This combined metro region ranks near the top in having the second longest commute times of any urban region in the United States. Any amount of precipitation falling in any form can adversely impact commuting on the major roadways in this region. In particular, accumulation of wintertime precipitation in the form of snow, freezing rain or drizzle, and/or sleet is commonly viewed as the primary adverse weather condition that most negatively impacts all facets of the transportation sector.

Most significant wintertime precipitation events (e.g., snowstorms, blizzards, ice storms) for this region are generally well-forecast, although there are exceptions. These forecasts provide sufficient lead time (36-72 hours) to alert public and transportation interests to take appropriate preparedness actions. Other adverse weather occurs, both wintertime and non-wintertime, that is more subtle, smaller in areal and temporal scales, and present a challenge to forecasters. Some examples include very light (<12 mm) accumulation of wintertime precipitation (e.g., freezing rain or drizzle, snowfall), ice deposition directly from the air onto sub-freezing roadways like bridges and overpasses, and the freezing of residual moisture on wet pavement.

This paper elaborates on forecast challenges dealing with these subtle adverse wintertime weather conditions. During the presentation, examples will be presented to highlight these adverse conditions, their forecast predictability, and their associated societal impacts on transportation in this urban region. Urban planners need awareness of limitations of both existing observing networks to detect these conditions and limits of skill to forecast their occurrence reliably to better prepare and respond when these conditions occur (Fig. 1).

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2. ADVERSE WEATHER HAZARDS

To better frame predictability of more subtle adverse winter weather phenomena, it is worth noting the predictability of the overall occurrence of significant winter storms (i.e., anticipation in weather forecasts of those storms producing widespread snow or ice accumulation). Generally, for the BWDC region, predictability of these storms is generally on the order of 2-4 days. However, there are limits to predictabilty of the observed pattern of precipitation occurring across an urban-sized region.


Snow Stops Traffic Cold
Commuters Stranded; More Is Expected

Fig. 1. Headline from *The Washington Post*, 19 January 2000, page A1, after roughly 5-10 mm of snow fell across the BWDC region during afternoon rush hour the previous day.

In experiments on predictability of the 25 January 2000 major East Coast snowstorm that struck the BWDC region, Zhang et al. (2002) showed how small changes in model initial conditions and the representation of moist processes significantly alters mesoscale (<500 km) distribution of predicted precipitation. Their results suggest that with the current state-of-the-science in numerical modeling, predictability of mesoscale precipitation distribution for these types of storms is limited to less than 24 hours. Buzzia and Chessa (2002) report that for the same storm studied by Zhang, an ensemble prediction system (EPS) of high-resolution mesoscale models was able to show a potential storm 3-4 days out that would have helped forecasters to better anticipate this storm. However, they concede even EPS tools have limitations to predict the risk of extreme weather and mesoscale distribution of precipitation in the 24-48 hour range. Hence, while improvements in model and data assimilation methods continue, predictability issues in timing and extent of the mesoscale precipitation distribution remain.

a. Forecasting Subtle Light Wintertime Precipitation

As a review, Dabberdt (et al. 2000) presents issues and examples of winter weather on urban planning and management. Relatively light amounts of frozen precipitation (i.e., snow or sleet) and freezing precipitation (i.e., rain and/or drizzle freezing upon contact with the ground or object) represent not only a forecast challenge but a potential problem to transportation interests. Here, frozen/freezing precipitation amounts will be considered “light” if measuring less than 25 / 3 mm, respectively, over a 1 to 3 hour period. Quantitative precipitation forecast (QPF) guidance from numerical models, typically in the form of plan-view maps of 3-, 6- and 12-hourly accumulations, are one way forecasters assess precipitation amount and distribution. Other model dynamical fields are used by forecasters to help forecast light precipitation amounts. Based upon experience at the WFO-Sterling, on average during the first 6 hours, forecasts often, but not always, will capture the essence of a light wintertime precipitation event, including timing, intensity, and amounts. Forecasts out 6 and 12 hours will be less definitive but still express the general details of the light event. Forecasts beyond 12 hours and out through 24 hours will be fairly general with little details in timing and areal coverage of precipitation. Forecast skill decreases markedly beyond 24 hours and show little skill beyond 36 hours.

Experienced forecasters use model-based QPFs with caution when forecasting light amounts. The rationale here is that the models have inadequate physics and incomplete data initialization to accurately and consistently represent all light precipitation events. For example, present-day model QPF parameterization schemes do not account for slantwise convective processes, which are known to account for rapid saturation of an air column and subsequent formation of narrow (10-100 km-wide) banded precipitation structures. However, while numerical models do not adequately represent QPF from these banded precipitation situations, model forecasts of other dynamical fields (e.g., moisture, temperatures, mass) are often satisfactory and representative of the actual atmosphere and can be diagnosed for banded precipitation potential.

Wiesmuller and Zubrick (1998) show how anticipation of banded precipitation structures is incorporated in the forecast process at WFO-Sterling. They show how a tight gradient often exists between banded precipitation and precipitation-free regions over as narrow as 20-50 km (see their Fig. 4). However, they point out that current predictability limits preclude specifying a reasonably precise timing and location of each banded structure more than 1 or 2 hours from the onset of a precipitation from a band. Additionally, the northern edge of a banded structure will often move little and can serve as the demarcation line between precipitation and no-precipitation. For an urban region, this means that part of the region could experience wintertime precipitation while the rest of the region see no measurable amounts. Using these techniques, a forecast of no precipitation for the BWDC region is possible while areas 20-50 km south of the urban zone may experience lighter (or heavier) precipitation.

Additionally, the form (snow, sleet, etc.) light winter precipitation takes has predictability limits. Slight changes in temperature (~1°-2° C) and/or relative humidity in the vertical air column below 3 km can have significant impact on precipitation type (p-type). Owing to its proximity to the moderating influences of nearby marine areas (Chesapeake Bay/Atlantic Ocean) and its location relative to the Appalachian mountains, the BWDC urban region can experience differences in p-type during any given event. Again, numerical guidance from high resolution models is combined with observational data help forecasters determine p-type.

Certain situations offer more predictability of p-type. When the air column is forecast to remain well below freezing (at least -10° C) including the entire depth of the cloud layer, snow will be the predominate p-type. with a high level of predictability out 2-4 days. If the air column is warmer than about -12° C, and strong warm advection is present, local experience suggests predictability for p-type is on the order of 24 hours or less. Than p-type forecasting is more problematic. Model forecast errors of the vertical temperature profile below 1 or 2 km can be large (~ 5° C) in as little as 3 hours into the model forecast. This can lead to unanticipated p-type changes (e.g., from snow to sleet to freezing rain). Surface temperature ultimately determine the form of rain or drizzle is freezing or just liquid. Urban variations of 1-4 deg C in surface temperatures are typical. This impacts accumulations and causes in urban planners to be flexible in their winter road treatment programs.

b. Light precipitation detection

Detection of very light precipitation can be problematic, especially if surface-based observing systems do not detect it. For example, light freezing drizzle can be difficult to detect using National Weather Service (NWS) Weather Surveillance Radar (WSR)-88D, even when operated in its most sensitive "clear-air" scanning mode. Zubrick (2002) outlines use of the Federal Aviation Administration (FAA) c-band (5 cm) Terminal Doppler Weather Radar (TDWR) as being an effective way to monitor very light precipitation such as drizzle or rain. In the future, polarimetric radars will be better equipped to discriminate between differing precipitation types (rain vs snow vs drizzle).

c. Ice deposition on roads and walkways

Infrequently through the winter months, direct ice deposition on roads and walkways in the absence of precipitating clouds has been reported. Pavement temperatures are critical for this event to occur. Typically, meteorological conditions conducive to this occurring include surface temperatures at or below freezing for more than 4 hours, dew point depressions at shelter height less than 2 deg C, light or calm winds, and mostly clear skies. Bridge surfaces and other elevated roadways are most susceptible to experiencing this phenomena. Fog may or may not be present. The absence of any ice treatment on a road surface appears to be a necessary condition.

Under these conditions, localized deposition of 1 or 2 mm of ice directly from the atmosphere is possible on the aforementioned surfaces. These situations are most prevalent during the early portion of the winter before roadways have received ice treatment for the first wintertime precipitation event of the season. Direct ice deposition poses a particularly vexing forecast challenge, since NWS forecasters are often unaware of roadway temperatures and treatment strategies. With the implementation of the NWS National Digital Forecast Database (NDFD) (Glahn and Ruth, 2003), transportation officials can access hourly forecasts dry-bulb and dew point temperatures, sky cover, and surface winds for a specific point anywhere in the U.S. However, users must realize that predictability of these conditions is predicated on accurate forecasts of the antecedent conditions (temperatures, winds, sky cover) and knowing the status of road treatment schemes.

d. Icing of residual moisture on wet pavement

Development of a thin coating (< 2mm) of ice on road surfaces (commonly known as "black ice") can occur under the right conditions. One way for black ice to form is related to residual moisture initially in liquid form from recent precipitation remaining on a surface and then exposing that surface to freezing or sub-freezing temperatures. For example, during the winter, precipitation in the form of either rain, drizzle, or snow, falls onto pavement that is initially above freezing. Then, weather conditions become conducive to radiational cooling. These conditions might occur, for example, after a frontal or upper level trough passage during the nighttime. In the absence of strong advection, and if winds are light (typically during the hours from sunset to sunrise), drying of moisture from the pavement will be restricted. As the ground radiates and cools, any residual moisture will begin to freeze and dangerous black ice conditions will occur. Forecasting these conditions is again challenging since one must forecast the extent of drying by the wind and evaporation or sublimation. To highlight these conditions, WFO-Sterling will issue special weather statements typically from 1 to 10 hours in advance once these condition are recognized. However, instances occur all too frequently during the winter when just the right conditions occur with little advance warning.

A related mechanism that creates black ice conditions, is related to snow melt and re-freeze. Here, snow removal efforts typically push snow off well-traveled portions of roadways onto medians and shoulders. During daylight hours when solar insolation might be large and/or surface temperatures climb above freezing, the snow piles will melt and liquid will run off. Some of the runoff could flow back over the well-traveled portion of the roadways. Then, as nighttime approaches (or temperatures otherwise fall below freezing), any residual moisture from snow/ice melt will re-freeze, creating (again) black ice conditions. Most transportation agencies allow for this type of thaw-refreeze of water on roads and will keep road treatment crews available to re-treat problem icing areas. Some jurisdictions keep detailed maps of areas most likely to experience refreeze-icing conditions based upon the tilt of a road surface.

3. SUMMARY

This paper highlighted a few of the predictability and detection issues associated with more subtle adverse wintertime precipitation phenomena. Improvements in detection of subtle adverse winter precipitation have come through implementation of modernized observing systems, such as a network of doppler radars, ground-based thermal and wind profilers, increased resolution (both temporally and spatially) of satellite image data, and a more elaborate network of surface observations. In the future, better measurements of atmospheric moisture from both ground-based, GPS-based, and satellite-based systems will help forecasters better track moisture available for precipitation systems. WFO Sterling forecasters will continue to use and expand their local knowledge of subtle weather patterns to improve lead time and necessary forecasts of these patterns. Knowledge of the limits of these phenomena may help urban transportation planners deal with the effects of such weather and provide better response when they occur.

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