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Weather on the Go: An Assessment of Smartphone Mobile Weather Applications Use among College Students

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ABSTRACT

Millions of people in the United States regularly acquire information from weather forecasts for a wide variety of reasons. The rapid growth in mobile device technology has created a convenient means for people to retrieve this data, and in recent years, mobile weather applications (MWAs) have quickly gained popularity. Research on weather sources, however, has been unable to sufficiently capture the importance of this form of information gathering. As use of these apps continues to grow, it is important to gain insight on the usefulness of MWAs to consumers. To better examine MWA preferences and behaviors relating to acquired weather information, a survey of 308 undergraduate students from three different universities throughout the southeast United States was undertaken. Analyses of the survey showed that smartphone MWAs are the primary weather forecast source among college students. Additionally, MWA users tend to seek short-term forecast information, like the hourly forecast, from their apps and spend very little time using the app itself. Results also provide insight on daily MWA use by college students as well as perceptions of and preferential choices for specific MWA features and designs.

The information gathered from this study will allow other researchers to better evaluate and understand the changing landscape of weather information acquisition and how this relates to the uses, perceptions, and values people garner from forecasts. Organizations that provide weather forecasts have an ever-growing arsenal of resources to disseminate information, making research of this topic extremely valuable for future development of weather communication technology.

CAPSULE

A survey of undergraduate students was undertaken to examine preferences and behaviors relating to modern sources of daily weather forecast information and to establish smartphones applications as an important medium.

1. INTRODUCTION

The atmosphere is always changing, and its conditions influence our daily lives, influencing what we choose to do and how we go about our day. Weather's dynamic nature, however, means that factors such as temperature, precipitation, and wind are often constantly in flux. It is no wonder people want to know the individual effects forecast conditions will bring so that they can plan accordingly.

Millions of people in the United States regularly obtain essential information from weather forecasts for a wide variety of reasons (Lazo et al., 2009). With weather being perhaps the most routinely sought-after type of information, it is imperative to understand the many facets of how and why people procure this information, starting with their sources and then how people use their acquired knowledge in day-to-day activities. The rapid growth in mobile device technology has created new contemporary means for people to access weather forecasts, pointing to the need to update past literature in this specific niche of weather research.

With the onset of smartphones and the increasing use of mobile weather applications (MWAs) today, this technology is rapidly becoming the public face of weather forecasting, (the entity that the public most associates with weather forecasts). A *smartphone* is defined as "a cellphone that includes additional software functions as email or an internet browser" (smartphone, 2016). An *application* (abbreviated as app) is defined as a program downloaded onto smartphones that serves a specific purpose for the user (app, 2016). Therefore, a MWA is a program available on smartphones that can provide weather forecasts and additional related information. Some smartphones may already have a MWA pre-loaded onto a phone for consumers to use. However, consumers can choose to download any MWA they desire through online marketplaces they access with their smartphones. This study evaluates and works to understand the changing landscape of weather information acquisition and how this relates to the uses, perceptions, and benefits people garner from forecasts. The research addresses the following questions:

1. Are smartphones the most popular source for weather forecast information among respondents?
2. What specific reasons do respondents have for choosing their favorite MWA?
3. How do geographic and demographic factors influence MWA use?

With these research questions, the study hopes to build on past literature relating to sources of weather forecasts and fill the gap in the meteorological literature on our society's preferences for where they obtain weather information. This knowledge on communicating weather information through mobile smartphone technology will enhance the weather enterprise's capability to better understand and grasp the quickly changing communication landscape. Additionally, companies and organizations within the weather enterprise that provide weather forecasts have an ever-growing arsenal of resources to disseminate information, making research on this topic extremely valuable for future development in weather communication technology.

2. SMARTPHONES AND WEATHER

Cellular phones and mobile devices are ubiquitous in modern society, and their day-to-day functions are becoming increasingly important for cell-phone owners and consumers of information. A 2011 Pew Research Center study found that 95% of the "millennial" generation (ages 18-34) and 85% of all American adults own cellular phones. Today's college students, who align mostly with the millennial generation, have the highest rate of cell phone use compared to any other generation, with research in 2012 indicating that 62% of undergraduate college students own a smartphone, up from 55% in the previous year (Dahlstrom et al., 2012). Cell phone and smartphone ownership has risen even more in just the last few years. An updated Pew Research Center fact sheet identifies that 100% of young adults (18-29) now own a cell phone, with 94% of the same age group owning a smartphone (Pew Research Center, 2018).

With the rise in smartphone use, applications (apps) on these devices are also soaring in popularity. Surveys of the American public found that, between 2009 and 2011, nearly twice as many adults were downloading apps to their phones, increasing from 22% to 38% (Purcell, 2011). This number has since soared to 77% of adult smartphone owners, indicating the continued surge in ubiquity of smartphone apps (Olmstead and Atkinson, 2015). Adults are most likely to download apps that provide continuous information on news, weather, sports, and finance (Purcell, 2011). While most popular mobile apps revolve around games and entertainment, apps for weather come in a close second followed by social media apps and those used for travel and navigation (Purcell, 2011). More recent research on app usage by adult smartphone owners is in line with previous studies, while also adding other popular uses for apps including shopping, dating, and reading electronic books (Rainie and Perrin, 2017).

Americans, especially younger generations, constantly seek information and expect to have immediate results. The added value of convenience is certainly a motivating factor in what options and sources they choose (Oblinger and Oblinger, 2005). Students value convenience over many other factors and therefore turn to their smartphones and mobile devices to quickly access information (Bomhold, 2013). Given the smartphone's advantage in accessibility over other sources of weather information, it's no wonder that MWAs, like other smartphone apps, are rapidly gaining popularity as well (Hickey, 2015). Because younger generations will continue their use of smartphone apps, MWAs will experience continued growth in usage, and research into this technology will yield insights on the consumption of MWA information and on MWA features that are most useful to consumers.

Information-seeking and consumption behavior are rapidly changing as a result of continually evolving technology (Handmark, 2010; Zickuhr, 2011; Pew Research Center, 2018), and previous research on sources of weather information such as that undertaken by Corso (2007), Lazo et al. (2009), Demuth et al. (2011), and Grotticelli (2011) indicated that television was the most popular medium for weather forecast acquisition. Though the work on the type of information sought from forecasts remains relevant, the research is potentially less applicable today because of their omission of smartphones and mobile devices as a weather forecast source.

More recent research has captured smartphone use for retrieving weather information. A study of residents in Ontario found that the use of cell phone apps for weather information was not as popular as other modes, including talking with family and friends, local radio, and The Weather Network, a Canadian cable weather television channel (Silver, 2015). A separate survey in 2015 revealed that MWAs are the preferred source for weather information, surpassing the more traditional source of television (Hickey, 2015), illustrating the importance of the research undertaken here.

Other recent studies look directly at MWAs and their content. Yoder-Bontrager et al. (2017) analyzed information retrieved from focus groups to better understand the reception of smartphone weather warnings and design of weather warning features on MWAs. They determined that the content of the warning information is important to participants and suggests that future MWA developers focus on the information disseminated in alerts rather than directing attention to increasing ways of alerting the smartphone owner. Additionally, one study looked at 39 of the most popular MWAs from the United States, the United Kingdom, and Italy, analyzing their design, displays of information, and relating this to the future of communicating uncertainty information (Zabini, 2016).

The use of smartphones to access weather information has certainly shown explosive growth in recent years. Two models, the diffusion of innovations theory (DIT) and the technology acceptance model (TAM), may foster understanding of the rising popularity of smartphones in accessing weather forecasts (Chan-Olmsted et al., 2013). The concepts of relative advantage, complexity, and compatibility from DIT help to explain the adoption of a new product or concept (Rogers, 1995). In the case of MWAs, if the apps are seen to be more valuable than a traditional weather source like television or a newspaper, then the app will likely become the preferred choice. Further, if a MWA is easy to use and aligns well with individual lifestyles it is likely to be adopted.

Similar to DIT, TAM emphasizes ideas of relative usefulness and ease of use, both of which have been shown to influence why mobile news applications are widely used by the public (Davis et al., 1989). If the user does not believe the product offers much utility, the new technology will not likely be successful (Chan-Olmsted et al., 2013). Additionally, the perception that a technology or product is easy to use and provides an added benefit to the user strongly correlates not only with current usage rates but also with predicted future use (Davis 1989).

Understanding both where people turn for weather information and the reasons and motivations for how people access and consume weather forecasts is fundamental to learning about how to best communicate weather (Demuth et al., 2011). The landmark study on sources and personal interpretation of weather data by Lazo et al. (2009) found that most people use weather forecasts for the city or area in which they live (87% usually or always). Location, timing, probability, and type of precipitation along with forecast temperatures are seen as most valuable to users (Lazo et al., 2009). This study also found that people use weather forecasts mostly to stay informed about the weather (72% usually or always), but other popular uses include how to dress and how to plan activities that could be affected by the weather (Lazo et al., 2009).

The acquisition, use, and understanding of weather information are all interrelated and affect one another, and factors like gender can certainly play a role in the gathering and interpretation of weather information. In a study looking at sources of weather information during a hurricane evacuation, gender was found to have a significant effect on one's perception of credibility of sources of information. Females, compared to their male counterparts, exhibited a higher perceived credibility for most sources of weather information, including family and friends, the local tourism office, The Weather Channel, and the newspaper (Cahyanto and Pennington-Gray, 2015). Demuth et al. (2011) uncovered differences in how males and females use weather forecasts, where women were more likely to use weather information to plan events, choose appropriate clothing to wear, and stay updated on weather conditions. However, analysis of gender differences in MWA use is missing from the weather communication literature.

The private sector of the weather enterprise has taken advantage of the growing use of mobile apps, with various companies and organizations having introduced some of the most well-known MWAs used by Americans today (Nagle, 2014). Since the mid to late 2000s, a number of companies have joined the mobile technology market, creating their own MWAs. With all signs indicating the continued surge in MWA use among the American public, it is imperative that all areas of the weather enterprise, including the public sector and academia, continue advancing research in weather and communication, especially as it relates to mobile devices. These findings can be used to improve MWAs and increase their appeal and usefulness to a larger demographic. While this study analyzes MWA use and preferences relative to daily weather forecasts, the information provided in this research also lays the foundation for further investigations into the communication of severe weather and other time-sensitive crises via smartphones. Understanding how smartphones and MWAs fit into the weather communication landscape will be of value to many organizations that provide life-saving information to the public.

3. DATA AND METHODS

Following approval by the Institutional Review Board (IRB) at East Carolina University, a 28-item survey was administered to college students in introductory geography courses from East Carolina University, the University of Georgia, and the University of South Carolina to gather the data needed to address the research questions (Figure 1). College students were surveyed because they have a high rate of smartphone usage (Zickuhr, 2011; Pew Research Center, 2018). Additionally, because the undergraduate college student generation will continue using smartphones and other new technologies that arise in the future, it is important to document their use of smartphones and apps because it will be their uses and demands that are most likely to shape future products.

Introductory college classes were sampled to ensure that those completing the survey had diverse academic interests rather than sampling from upper-level courses with students who have already declared specific majors. The survey used in this study was administered using the Qualtrics survey software. Emails with a survey link and brief message were sent to professors at each of the three schools, who agreed to assist in the study. They then forwarded the emails to undergraduate students in the introductory Geography courses. Participants were self-selected among those who received the invitation e-mail, and no incentives were offered. Because the number of students who received the email is unknown, a response rate cannot be determined.

Before the survey was distributed, it was pre-tested with a small group of non-meteorology students at East Carolina University. Feedback was solicited on the content, syntax, and understandability of the survey using methods described by Presser et al. (2004). The survey was then modified and finalized based on the results of the pretest. Survey responses were analyzed statistically and through content coding for the open-ended responses.

a. Survey Structure

To build on past studies regarding sources of weather information (Lazo et al. 2009; Morss et al. 2011), the survey employed similar questions. While a direct comparison between studies is not possible, using similar questions serves to build our knowledge on using MWAs.

The survey solicited demographic information, including age, gender, race, education, family income, and the zip code of the location respondents identify as home. Following these questions, participants were asked about weather forecasts in general, specifically where they acquire forecast information, the importance of different elements or aspects of a weather forecast, and their overall level of confidence in weather forecasts, regardless of source. The next set of questions shifted to mobile devices and MWAs, asking respondents about their ownership of cell phones and smartphones. Respondents were then prompted to select answers that best describe their daily smartphone habits, preferences for MWAs, and their perception of and confidence in specific MWA features. For the purposes of this study, the use of "MWA features" refers to different characteristics of MWAs that provide users with information on specific aspects or elements of a forecast. An example of this would be the hourly forecast *feature* on a

MWA, which provides information on forecast temperatures, precipitation chances, and sky cover, three *aspects* or *elements* of a general weather forecast. The final survey question asked respondents if they had any suggestions or recommendations for how their MWAs or how MWAs in general could be improved. Most questions consisted of multiple-choice options where respondents chose one answer from a list. Some questions specified "other" as a choice, which allowed participants to supply an answer that was not listed. Strategies from Smyth et al. (2009) were implemented to seek thorough open-ended responses from participants. Other survey questions featured a 5-point Likert scale (1 = not at all important, 5 = extremely important) to gauge the level of agreement with the statements provided and for questions involving confidence in MWA forecasts and the level of satisfaction with the MWAs.

To increase the number of completed survey responses, respondents were not required to answer any question before proceeding to the next item in the survey. Therefore, individual survey items have varying numbers of responses, with 308 out of 311 respondents completing a majority of the survey.

b. Analytical Methods

Both quantitative and qualitative analytical techniques were employed to analyze the survey data. For the purposes of this research, Likert-scale questions were designated as continuous variables, because while these questions have a specific number of items (categories) from which respondents choose, past research indicates that opposite ends of the Likert spectrum ("not important at all" and "very important," for example) are understood by respondents to be a continuum similar to interval-based questions (Willits et al., 2016). To better understand the association between different factors pertaining to the respondents, Chi square tests and non-parametric Kruskal-Wallis and Mann Whitney U analysis of variance (ANOVA) tests were applied to variables. The Chi square test was used when survey answers were categorical; Kruskal-Wallis was used when these answers were continuous. It should be noted that the Kruskal-Wallis test was used when analyzing three independent groups, while the Mann-Whitney U ANOVA test (a test equivalent to the Kruskal-Wallis test) was used when comparing two independent groups. Kruskal-Wallis and Mann-Whitney U ANOVA tests were employed to analyze continuous Likert-scale variables with universities and gender as independent variables. The Kruskal-Wallis test can signal a significant difference between groups, but it does not explicitly state the relationship of the statistical difference between specific groups. Therefore, the Dunn post-hoc test was employed to uncover the particular differences in the independent groups.

Additionally, cross tabulation analyses comparing two sets of data were used to uncover relationships between variables and answers from respondents. Survey responses that included "not on my app" were not considered in the statistical analysis process because the study only considers respondents who have the relevant experience with specific MWA features. A Cramer's V post-hoc test is undertaken with statistically significant Chi square results to determine if there is an association between the different variables that may explain why the results returned as statistically significant.

With open-ended survey responses, content analyses were performed by two researchers, who coded the answers into categories to gain a clearer picture of main ideas and themes. Categories were determined through directed content coding strategies, where one coder identified important themes and concepts that were prevalent on respondent answers (Hsieh and Shannon, 2005). Initial categories were created, and classes with overlapping ideas were consolidated. After both coders separated responses on their own, a Cohen's Kappa test was used to verify the reliability of the content coding to ensure valid results and inter-rater agreement (Cohen, 1960). For Cohen's Kappa 1.00 represents perfect reliability and 0.00 no reliability. The agreement (α) was calculated to be 0.955, which shows near perfect reliability for the dataset.

The analyses of survey responses both with quantitative statistical tests and qualitative content-coding of open-ended suggestions from responses address the research questions for this study.

4. RESULTS

a. Characteristics of the Respondents

A total of 308 complete responses were collected between October, 2016 and January, 2017, with 135 (44%) from East Carolina University, 75 (24%) from the University of Georgia, and 98 (32%) from the University of South Carolina. Most of the student respondents are between the ages of 17 and 22. The predominant race represented is white at nearly 80%, with Black and Asian rounding out the top three. There were more females than males who answered the survey (51.9%). Because most of the respondents are undergraduate students, a large majority had some college credit with no degrees (88.3%), followed by less than a tenth with an associate's degrees (6.5%) or a Bachelor's degree (4.2%). Of the 308 respondents, only 1 person did not own a cell phone and 2 others did not own a smartphone. Most respondents have owned a cell phone for at least 4 years (92.8%), while over 96% of respondents have owned a smartphone for at least 2 years.

b. Sources for acquiring weather forecast information

Among the college students surveyed, MWAs were overwhelmingly the most frequently used choice to access forecast information, with over 80% checking their MWA at least once a day (Table 1). The second most favored option was friends and family. Most respondents seldom use the newspaper or the NOAA Weather Radio to retrieve weather forecasts.

Including default MWAs that are oftentimes pre-loaded onto a smartphone, more than half (55%) have only one MWA, while more than 35% have two MWAs. Of those surveyed, 91.8% have never paid for a MWA, and the 25 people who have paid often do not pay more than $3.00.

c. Reasons for choosing MWAs

Participants were asked to identify both the primary reason and secondary reasons for choosing their preferred MWA. Nearly 32% chose their MWA because it is easy to use, while about 23% of people prefer their MWA because it came as the default MWA on their smartphone (Figure 2). The design and graphics on MWAs seem to be less important to respondents, with only 3.6% picking this as their primary reason.

A critical component of MWA preference among respondents relates to whether or not they switch from the pre-loaded MWA on their smartphone. Of the 305 people who responded to this question, 39.3% switched to a different MWA. Nearly 70% of those respondents who switched said they prefer their new MWA more because it offered more information and details, while ease of use, understandability, and graphics were cited as reasons among at least 15% of those who switched (Figure 3).

In addition to preferred characteristics of MWAs, the perceived importance of various elements of a weather forecast may influence which MWA individuals choose. Survey results indicate that respondents want detailed information on the chance, location, and timing of expected precipitation (Table 2). The type of precipitation was somewhat less important, along with specific details on precipitation amounts. Forecast high and low temperatures were reported to be important or very important and over 60% of respondents found humidity to be important or very important. Cloud cover and wind direction was of less concern.

The range of forecasts available can influence choice of a MWA. Three types of forecasts stand out among respondents, with the hourly forecast, forecast chance of precipitation, and 5-Day forecast all with over 80% of respondents deeming as important or very important (Table 3).

The results in Table 3 may, at least in part, relate to how confident respondents are in forecasts overall from all sources and how confident they are in forecasts available on MWAs. Most respondents report that they are confident in a weather forecast, regardless of where they retrieve the information (69.2%), while 21.4% are neutral. For specific MWA features, most respondents trust the hourly forecast, with over 85% being confident or extremely confident (Table 4). For forecasts with longer lead times of more than 5 days, the decay in confidence for MWA users increases, similar to the findings from previous research (Lazo et al., 2009).

d. Influence of geographic and demographic factors

The final research question investigates the connection between respondents' demographics and how this information relates to MWA preferences and usage patterns. Chi square and Kruskal-Wallis and Mann-Whitney U ANOVA tests were conducted to compare respondent information between schools and between gender. Because age, race, education level were all relatively uniform in the sample, they were not analyzed.

There are some statistically significant geographic differences between the three schools, as shown in Table 5. A post-hoc analysis found that the perceived importance of precipitation amount by UGA students was lower compared to both ECU and USC. Further, there is a statistically significant result between schools with respect to the perceived importance of the weather video feature (UGA had lower perceived importance in this feature). At the same time, no geographic differenced was found with respect to confidence in MWA features, likely reflecting the overall confidence in forecasts discussed above.

In comparing genders, statistically significant results were found such that men perceived wind speed and wind direction to be more important compared to women (Table 6), and more men than women find the satellite and radar features on MWAs to be important. Again, no difference was found with respect to confidence.

One Chi square test returned as statistically significant with regard to the three universities (Table 7), specifically the primary reason why respondents choose their MWA. A lower percentage of students at USC chose “easy to use” as the most important reason for choosing their MWA compared to UGA and ECU. Additionally, the numbers of students who chose “easy to understand” at UGA and “default” at ECU were less compared to the two other schools. However, with a Cramer’s V value of 0.174, this post hoc result reveals schools have a minimal association with respondents’ primary reasons for choosing their favorite MWA. With respect to gender, statistically significant associations were found for respondents who use their MWAs between midnight and six in the morning, with women more likely to use their phones during the early overnight hours compared to men (Table 8). Additionally, a statistically significant association was found between gender and the amount of MWAs a respondent reported having on their device, where men reported having more MWAs than women.

e. Suggested changes to improve MWAs

Finally, respondents were prompted to provide suggestions for how they think MWAs could be improved. Of the 308-total surveyed, 256 provided suggestions, totaling 280 suggestions, 46 of which said they would not make changes (Table 9). Respondent suggestions centered on better information or features (24.3%), overall MWA design/ customization (18.9%), and improved accuracy (17.9%). While the categories for radar and notifications could have been consolidated with the information and features category, there were a number of responses that targeted these separate items directly. One of the suggestions for radar and notifications included having an enhanced radar that scans the atmosphere more frequently, while a suggestion for the notifications category included having a setting that alerts users when the forecast changes unexpectedly.

5. DISCUSSION/CONCLUSION

Past research has established the foundation to further explore where people gain information on weather forecasts, but with the rapid growth in mobile device technology that affords much convenience for users, even the most recent studies have been unable to adequately capture the use of MWAs to obtain weather information. This research is aimed at filling the gap in the areas of mobile smartphone technology and its role as a dominant weather source among college students, while also updating existing literature on sources of weather information.

Demographic information about respondents revealed a rather homogenous sample. A majority of participants were white, young college students. An overwhelming majority of those surveyed use smartphones regularly for forecasts, while the second most popular choice was conferring with friends and family. Over 90% do not use newspapers or NOAA Weather Radios for forecasts.

This research uncovered information on what sources of weather information are the most popular among respondents and reasons why specific MWAs were preferred over others. When asked for the single reason respondents prefer their favorite MWA, ease of use, understandability, and being the pre-loaded default on the device were the top choices. When allowed to expand their reasoning, the level of detail in a MWA along with the design and graphics of an app were viewed as important reasons. While most do not switch from their default MWA, approximately 39% have moved to another app because they were not satisfied with factors like the depth of information or they reported that their current MWA is too complicated. It is important to note that while the research identified which MWAs are most popular among respondents, the specific MWA does not matter as much as the perceived importance and user confidence in MWA features, which are important contributions of this research.

Most respondents found the hourly and 5-day forecast to be most useful, as well as severe weather alerts and current conditions, and most were also confident in these features. Two complementary questions provide additional information to address MWA preference. Results from a cross-tabulation analysis indicate that perceived importance of weather forecast aspects did not affect which apps participants chose.

The final research question sought to analyze gender and university differences with the many variables analyzed in the survey. Although most analyses using Chi square and the non-parametric Kruskal-Wallis and Mann Whitney U ANOVA tests were not statistically significant, a statistically significant relationship was found between schools and some MWA use. A Kruskal-Wallis test revealed that students at both ECU and USC placed more importance on information about the amount of precipitation in a forecast than did students at UGA. Additionally, students at ECU were more confident in the pollen count feature on a MWA than UGA students and believed that weather videos were more important than UGA students. For analyses looking at gender, men seemed to find wind speed and direction more important than women; men also place more importance in the satellite and radar feature.

The reasons for these results are not clear and suggest the need for further investigation. While there have been studies addressing gender differences in the use of forecasts (Demuth et al. 2012), the focus was on the importance of attitudes on family roles in a household, thus addressing a different set of users. The data in this study may be a result of subtle differences in weather experiences, an artifact of the survey questions or a reflection of the interests of survey respondents. Additional research is warranted to sort through these findings.

The fact that most respondents do not switch from their default MWAs signifies that most students are satisfied with the quality of their default MWA and therefore do not feel compelled to switch. Corporations and organizations in the weather enterprise that are able to forge relationships with cell phone service providers or technology companies will likely have the most success with their products, as they are most likely to be used by consumers.

The use of MWAs and MWA choice are important, but information about how people use MWAs helps paint a more complete picture. Respondents want to know about precipitation and temperature. Nearly every aspect of precipitation (chance, timing, location, and type) was perceived as important aspects of a forecast, while the forecast high and low temperatures and the timing of these temperatures were valuable for those surveyed, which was the case in Lazo et al. (2009).

Valuable information was gathered from the many suggestions offered by respondents in the open-ended portion of the survey which asked for suggested changes or additions to MWAs. Some advocated for the addition of new MWA features tailored to active lifestyles that could better pinpoint how the weather would impact them throughout the day. Others proposed features would provide advice on what to wear and how to prepare based on the forecast. Increased accuracy was another common theme, as well as improved design and the ability to customize a MWA to an individual's own liking.

The data collected from the analyses of the survey highlights a wealth of information about college students and their use of smartphones and MWAs for acquiring weather forecast information. As a result, this study builds on previous studies by Lazo et al. (2009) and Demuth et al. (2011) on sources of weather forecast information and how respondents use the information daily, in this case focusing on an important demographic segment of weather forecast consumers. Lazo et al. (2009) found that local television and other media were the most common mode for retrieving daily weather information; this study, however, brings to light a younger generation's habits and the implications that will change the paradigm of communicating weather information well into the future.

With students' on-the-go lifestyles and their demand for information that allows them to plan for the near future, a MWA offers a compatible, convenient, and useful alternative to local television, radio, and other weather forecast sources, all of which correspond with several aspects from the Diffusion of Innovations Theory (DIT) (Rogers 1995) and the Technology Acceptance Model (TAM) (Davis et al., 1989). MWAs provide the information that respondents find important in a forecast, and the portable nature of smartphones and MWAs allows students to take the forecasts with them wherever they go without having to wait for information that is delivered at specific times on other sources. The high smartphone usage rates among a majority of respondents makes MWAs highly accessible. With weather information only a few taps away, little effort is required to obtain valuable forecast details that students can use to plan. MWAs are also often pre-loaded onto consumers' phones at the time of purchase, making weather information available to almost everyone with a smartphone who chooses to use a weather app.

This study highlights the potential improvements that can be made to MWAs to garner even more favorability among a young demographic. From the most liked and disliked MWA features to the many suggestions provided by respondents, organizations that want to continually improve their product have important information they can consider when updating their MWAs. Public sector agencies like the National Weather Service may consider using MWA technology to reach a changing demographic that clearly uses mobile technology on a regular basis.

While the focus for this research is on commonplace everyday weather situations, connections can be drawn and applied to severe weather situations that pose a more significant threat to life and property. Many MWAs have special weather alerts that can warn users of impending inclement weather. Additionally, the National Weather Service along with partner government agencies have the capability to send out geographically relevant notifications to cell phone users for extreme severe weather, America's Missing: Broadcast Emergency Response (AMBER) alerts, and both local and national emergencies in the form of the Wireless Emergency Alert (WEA) system (National Research Council, 2011). These warning technologies can serve to benefit from the information in this study relating to MWA usage patterns and preferences.

While the study presents important information, there are several limitations that should be addressed. The information from the research, while valuable, is not generalizable. The study only assesses the use of MWAs by college students who were chosen from specific classes in Geography programs in the Southeast. Respondents were similar demographically and geographically, which does not allow for broad conclusions of the American public as a whole. Additionally, the survey was disseminated in the Fall and Winter months. This could impact survey results as the presence or lack of significant weather events may have affected respondents' answers to questions.

As mentioned by Lazo et al. (2009), a more consistent, nationally representative effort to reassess the public's sources and uses of weather information would be helpful in guiding policy and practices within the weather enterprise. Because the study was limited in its geographic and demographic scope, the study can be expanded to include more participants encompassing a larger study area. Additionally, while surveys are effective tools for social science research, other methods, including qualitative interviews and focus groups should be considered to extract deeper and richer information from MWA users. There are also new technologies and methods for smartphone research that can help reduce issues of self-reporting biases in surveys and respondent accounts of their actions. Currently, software and other types of mechanisms can extract information directly from smartphones, providing information about the user (Raento et al., 2009; Antonić et al., 2016). New strategies of information collection, especially in the realm of smartphone usage, will be of immense value to future researchers in the weather enterprise who continue investigating communication and how to better accommodate the people who use weather app products to stay informed about the weather.

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FIGURE LIST

APPENDIX

Table 1: Frequency of Weather Sources Accessed by Respondents (%)

Source for Weather Information	Frequency of which source is used		
	At Least Once a Day	At Least Once a Week	Rarely or Never
Mobile Phone (Smartphone App)	80.8	16.6	2.6
Friends/Family	17.3	65.4	17.3
Other Internet Sites	9.4	29.6	60.9
Local Television	6.8	31.3	61.9
National Weather Service Website	6.5	29.1	64.4
Commercial/Public Radio	5.6	30.7	63.7
Cable Television	4.9	24.5	70.6
NOAA Weather Radio	1.3	7.5	91.2
Newspaper	1.3	5.6	93.1

Table 2: Respondents' Perceived Importance of Aspects of Forecasts (%)

Forecast Aspect	Level of Importance		
	Important/Very important	Neutral	Not at all important/Not important
Chance of precip	92.4	4.2	3.3
When precip occurs	90.0	6.7	3.4
Low temperature	86.7	9.7	3.6
Where precip occurs	84.5	11.5	3.9
High temperature	83.4	10.0	3.6
Type of precip	78.5	14.9	6.7
Time of day of high temperature	65.8	19.4	14.8
Time of day of low temperature	63.0	21.8	15.2
Humidity	60.2	21.3	18.5
Amount of precip	59.4	23.9	16.7
Chance of different amounts of precip	43.5	36.2	20.4
Wind speed	38.5	31.5	30.0
Pollen count	34.8	30.0	35.2
Cloud cover	25.2	34.6	40.3
Wind direction	13.6	31.8	54.6

Table 3: Respondents Identifying Importance of Specific MWA Features (%)

MWA Feature	Level of Importance		
	Important/Very Important	Neutral	Not at all important/Not important
Hourly forecast	87.4	8.2	4.4
Chance of precipitation	87.3	9.8	2.9
Current information	85.5	9.6	5.0
Severe weather alert	84.8	10.9	4.3
5-Day forecast	81.1	13.9	5.0
10-Day forecast	50.0	25.2	24.8
Satellite and radar	43.8	29.9	26.3
Pollen count	34.8	35.6	29.6
Lightning detection alert	26.0	33.3	40.7
Airport delays	25.7	32.4	41.9
UV index	25.6	36.3	38.1
News headlines about weather	25.5	35.1	39.4
10+ Day forecast	19.9	40.4	39.7
Weather videos	13.7	34.5	51.8
Advertisements	8.2	17.9	73.9

Table 4: Respondents' Confidence in Specific MWA Forecast Features (%)

MWA Feature	Level of Confidence		
	Confident/Very Confident	Neutral	Not confident at all/Not confident
Hourly forecast	85.2	12.2	2.6
Severe weather alert	73.8	19.9	6.3
Rain notification alert	70.4	27.7	1.9
5-Day Forecast	66.0	26.7	7.3
Lightning detection alert	49.8	40.4	9.8
Pollen count	35.3	51.9	12.8
Lakes, rivers, oceans forecast	33.9	56.5	2.5
10-Day forecast	26.1	42.3	31.7

Table 5: Statistically Significant Kruskal-Wallis Test Differences in MWA Preference and Use by University

Importance of Weather Forecast Elements					
Survey Item	Mean Likert Scores	Kruskal-Wallis Test Result	Degrees of Freedom	KW significance	Dunn Post-Hoc Test
Amount of Precipitation	ECU: 3.754 UGA: 3.133 USC: 3.646	$\chi^2(2) = 19.736$	2	0.000*	ECU-UGA: p = 0.000* UGA-USC: p = 0.004*
Importance of MWA Features					
Survey Item	Mean Likert Scores	Kruskal-Wallis Test Result	Degrees of Freedom	KW significance	Dunn Post-Hoc Test
Weather videos	ECU: 2.527 UGA: 2.070 USC: 2.410	$\chi^2(2) = 7.058$	2	0.029*	ECU – UGA p = 0.034*
Confidence in MWA Features					
Survey Item	Mean Likert Scores	Kruskal-Wallis Test Result	Degrees of Freedom	KW significance	Dunn Post-Hoc Test
None		N/A	N/A	N/A	N/A
*statistically significant association at 0.05 significance level					

Table 6: Statistically Significant Mann-Whitney U Test Differences in MWA Preference and Use by Gender

Importance of Weather Forecast Elements				
Survey Item (Importance of Forecast Elements)	Mean Likert Scores	Mann-Whitney U Test Result	Degrees of Freedom	MWU Significance
Wind speed	Male: 3.229 Female: 2.975	*U* = 9769.5	1	0.022*
Wind direction	Male: 2.604 Female: 2.270	*U* = 9394.0	1	0.005*
Importance of MWA Features				
Survey Item (Importance of MWA Features)	Mean Likert Scores	Mann-Whitney U Test Result	Degrees of Freedom	MWU Significance
Satellite and radar	Male: 3.635 Female: 2.909	*U* = 6321.0	1	0.000*
Confidence in MWA Features				
Survey Item (Importance of MWA Features)	Mean Likert Scores	Mann-Whitney U Test Result	Degrees of Freedom	MWU Significance
None		N/A	N/A	N/A
* significant at 0.05 level				

Table 7: Chi Square Analyses on MWA Preference and Use by University

Feature	Result	Degrees of Freedom	Significance	Cramer's V Association
Favorite Weather App	$\chi^2 = 6.545$	6	0.365	
Primary Reason for MWA	$\chi^2 = 15.448$	8	0.051*	0.174
Default Switch?	$\chi^2 = 0.105$	2	0.949	
Time of Day for MWA Use				
12-6AM	$\chi^2 = 0.798$	2	0.671	
6-8AM	$\chi^2 = 1.101$	2	0.577	
8-11AM	$\chi^2 = 0.518$	2	0.772	
11-1PM	$\chi^2 = 0.337$	2	0.845	
1-4PM	$\chi^2 = 2.275$	2	0.321	
4-7PM	$\chi^2 = 3.704$	2	0.157	
7PM-12AM	$\chi^2 = 0.948$	2	0.623	
MWA Use				
Pay for App?	$\chi^2 = 0.922$	1	0.631	
Number of MWAs on Phone	$\chi^2 = 1.436$	4	0.838	

* significant at 0.05 level

Table 8: Chi Square Analyses on MWA Preference and Use by Gender

Feature	Result	Degrees of Freedom	Significance	Cramer's V Association
Favorite Weather App	$\chi^2 = 3.738$	1	0.291	
Primary Reason for MWA	$\chi^2 = 3.057$	5	0.691	
Default Switch?	$\chi^2 = 0.422$	1	0.516	
Time of Day for MWA Use				
12-6AM	$\chi^2 = 4.786$	1	0.034*	0.122
6-8AM	$\chi^2 = 0.063$	1	0.801	
8-11AM	$\chi^2 = 1.439$	1	0.230	
11-1PM	$\chi^2 = 0.178$	1	0.673	
1-4PM	$\chi^2 = 0.175$	1	0.676	
4-7PM	$\chi^2 = 1.128$	1	0.288	
7PM-12AM	$\chi^2 = 0.004$	1	0.947	
MWA Use				
Pay for App?	$\chi^2 = 2.344$	1	0.126	
Number of MWAs on Phone	$\chi^2 = 11.429$	2	0.003*	0.194
* significant at 0.05 level				

797 Table 9: Content Coding Categories and Corresponding Examples

Category	Value	Example	Percent of Total
1	No changes suggested	"I wouldn't make any changes."	16.4%
2	Accuracy	"Better accuracy."	17.9%
3	Information and Features	"Provide a suggestion for articles of clothing to wear."	24.3%
4	Design/More User-Friendly/Customization	"Simple to understand picture representation of the upcoming weather."	18.9%
5	Radar	"Having an easier local radar to see what is going occur without difficulties."	7.5%
6	Location	"If the app could update your location's weather while traveling."	4.6%
7	Notifications (Severe weather and other alerts)	"I think notifications for change in predicted weather would be convenient to have."	5.7%
8	Advertisements	"No advertisements."	2.9%
9	Miscellaneous	"I would like humor to be added into a forecast, as it seems often they are somewhat bland."	1.8%

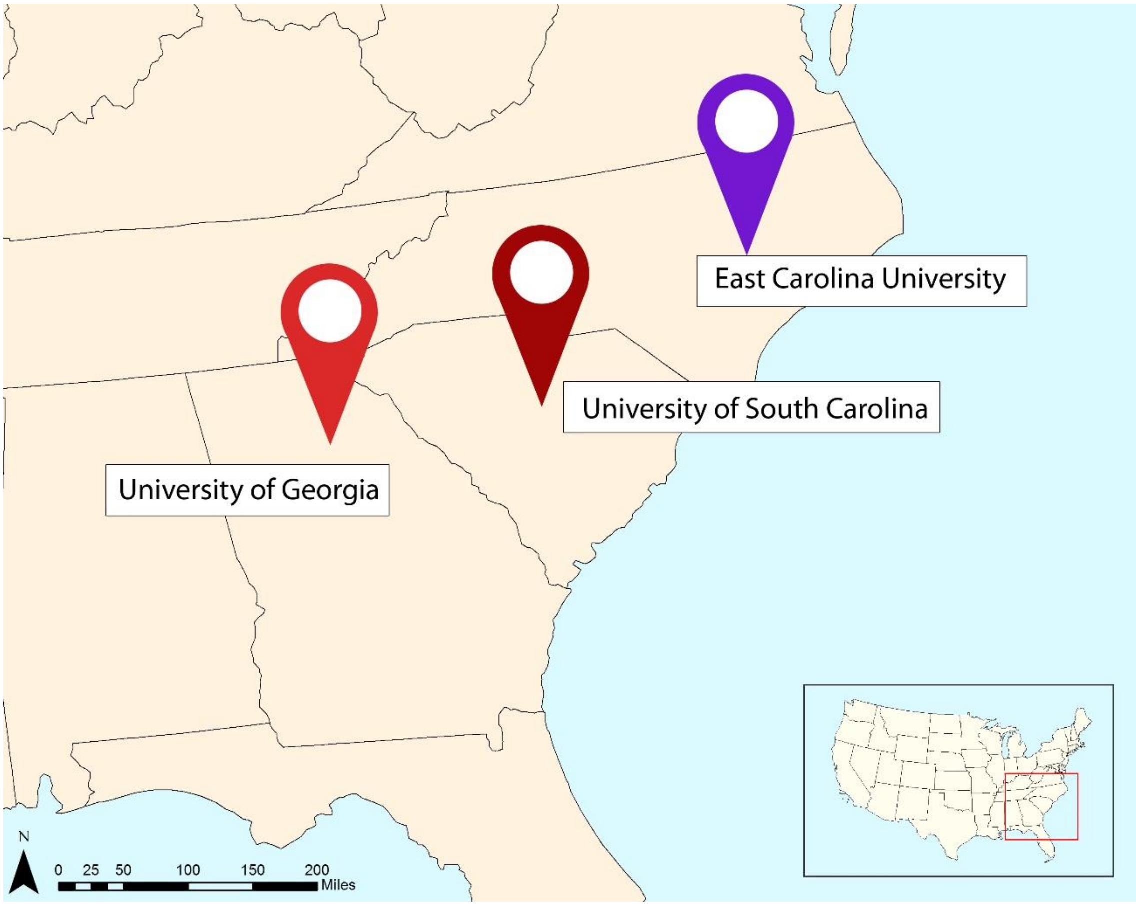

Figure 1: Three universities from which surveys were collected

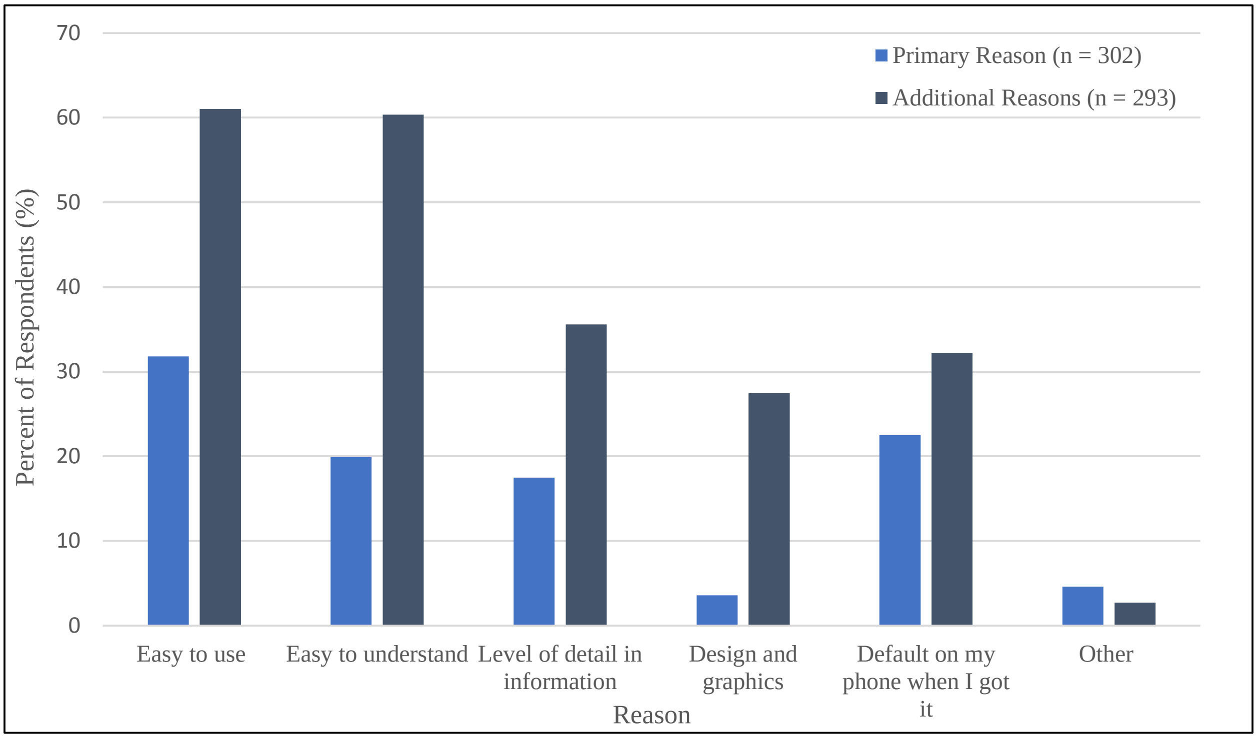

Figure 2: Respondents' Reasons for Choosing MWAs

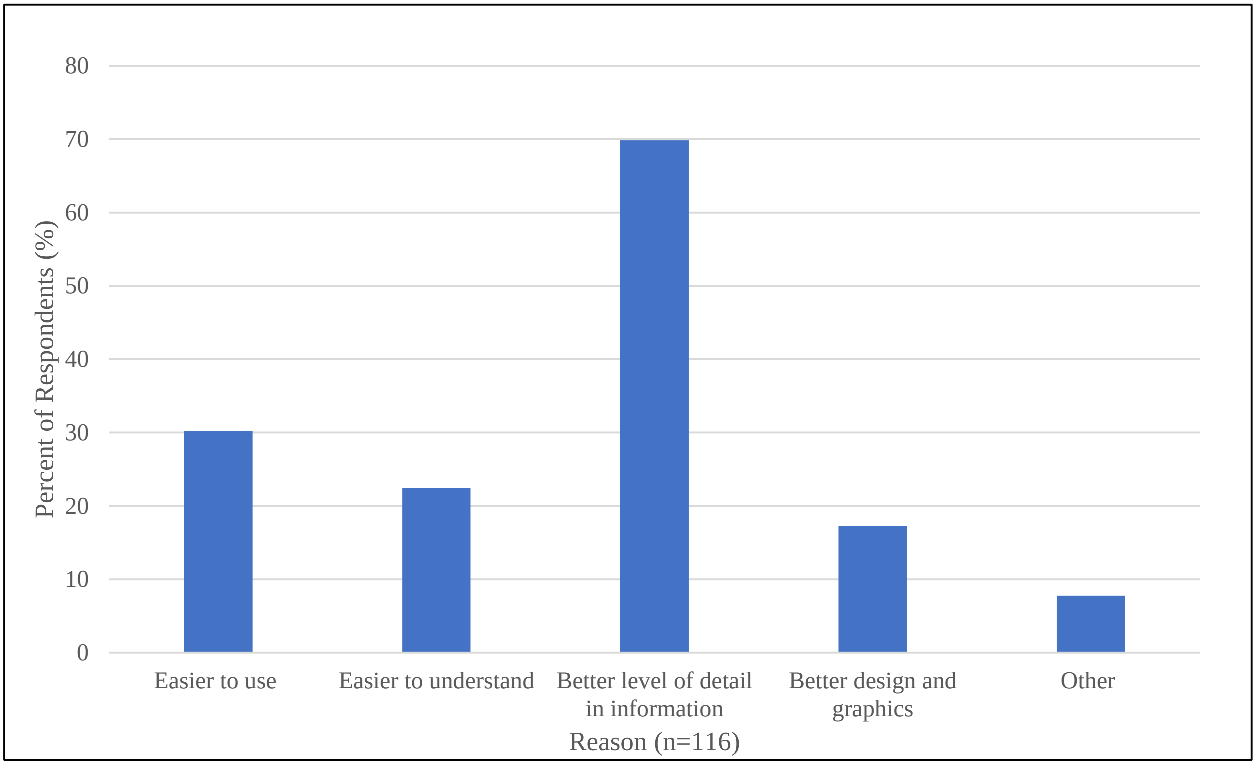

Figure 3: Respondents' Reasons for Switching from Default MWA