3.4 NASA SPACE GRANT SUCCESSES WITH METEOROLOGY STUDENTS AT PLYMOUTH STATE UNIVERSITY

James P. Koermer*
Plymouth State University, Plymouth, New Hampshire

William P. Roeder
45th Weather Squadron, Patrick Air Force Base, Florida

1. Introduction

The National Aeronautics and Space Administration (NASA) has always maintained a strong interest in supporting Science, Technology, Engineering and Mathematics (STEM) education, since they see the need to seed sources for producing skilled workers in these disciplines. The NASA Space Grant Program was created to provide educational institutions within a state with a means for more direct educational funding primarily, but not totally, dedicated to support graduate and undergraduate students enrolled in STEM-related disciplines. This NASA program funds fellowships, scholarships, research and related student travel, and other educational endeavors.

The NASA Space Grant Program is organized by states (and Puerto Rico). Each state has their own Space Grant Consortium and proposes activities to be performed that support NASA goals. If funded, the Consortia then report back to NASA on their progress and results and their programs are constantly being reevaluated.

In 1999, the Plymouth State University (PSU) (then College) Meteorology Program was invited to join the NASA-funded New Hampshire Space Grant Consortium (NHSGC) as an affiliate member. Initially, the support was used to fund 10 small undergraduate scholarships and some partial summer stipends for two undergraduate students to work on research projects. Over the years, as the budget increased and after PSU added a Master of Science degree program in Applied Meteorology, the support was expanded to include graduate fellowships and summer research support.

This paper will highlight the results of the NHSPC program at PSU based on the accomplishments of the students and their careers after leaving PSU.

*Corresponding author address: Dr James P. Koermer, MSC #48, 17 High Street, Dept. of Atmospheric Science and Chemistry, Plymouth State University, Plymouth, NH, 03264; e-mail: koermer@plymouth.edu

A great deal of emphasis will be placed on significant student achievements from summer research projects on convective winds, which have been ongoing at the Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS) for the past 6 years with the strong support of the U.S. Air Force 45th Weather Squadron (45 WS) and the NASA Applied Meteorology Unit (AMU).

2. Overview of the PSU NHSGC Program

During the first 10 years (2001-2010) of NHSGC participation, PSU has supported a total of 59 different students with 44 receiving undergraduate scholarship assistance, seven getting partial graduate fellowships, and 26 undergraduates and three graduate students sponsored for participating in summer research activities at Plymouth State or other venues. Some students have received both scholarships and/or fellowships along with research support. Table 1 depicts the student breakdown by gender for the various types of support.

Table 1. Gender breakout of student recipients receiving PSU NHSGC support from 2001-2010.

Type of Support	Female	Male
Undergrad Scholarships:	30	19
Graduate Fellowships:	7	1
Undergrad. Research:	10	16
Graduate Research:	0	4

Included in the above numbers, there has been one ethnic minority female student who received some scholarship support during all of her four years as an undergraduate student and another female minority graduate student who received significant fellowship support. The program is geared as much as feasible towards minorities and/or other traditionally under-represented groups, such as females. However, the number of female students in either the PSU undergraduate or graduate meteorology programs has sometimes been quite variable. During this past 10+ year period, female students have varied from 15% to 50% of enrolled undergraduate meteorology students. Since the PSU graduate program started in 2005, the female PSU enrollments have ranged even more widely from 10% to 80%.

Over this period, NASA has provided funding of approximately $310K with PSU contributing an additional institutional cash supplement of $75K and in-kind matches of nearly $320K through waived overhead, faculty oversight of and participation in supported research activities, and administration of the program.

Nearly one-third of the total cash resources were used to fund small scholarships or graduate fellowships. Undergraduate scholarships were usually set at $1,000 per year and were renewable for up to 4 years, if the student was making satisfactory progress towards the graduation and maintained a minimum cumulative Grade Point Average of 3.0. Graduate fellowship funds usually augmented some other funding sources to provide some additional and more reasonable financial support to graduate students.

Most of the remaining NHSGC funding was used to support students involved at PSU or elsewhere in research activities. Funding was used for summer stipends and travel support, where applicable either for the summer or to present papers on their research at a scientific conference(s). Initially, during the first 4-5 years, most students worked on summer projects at PSU. Since 2005 when more funding started to become available from an added Work Force Development Program, nearly all supported PSU students now have been doing their summer research at KSC/CCAFS in Florida except for one student, who was selected for the NASA Academy Program and worked out of NASA Marshall Space Flight Center in Huntsville, AL.

Another requirement for a PSU undergraduate student accepting a Space Grant scholarship is to sign up for two credits of Senior Research during both of the last two semesters of their study. In most cases, these students had participated in 10-week summer research projects, which most choose to continue to work on during the subsequent academic year as their main research focus. The summer research projects may have been sponsored through other agencies, such as the Federal Aviation Administration (FAA), the National Oceanic and Atmospheric Administration (NOAA), etc., or the student could have been directly supported through the Space Grant. In any case, the PSU undergraduate students, supported partially or fully by Space Grant funds, have racked up an impressive list of research accomplishments including 31 conference papers. Many of these papers will be referenced later in this paper.

Since PSU just started its M.S. Program in Applied Meteorology in 2005, the Space Grant funding opportunities for graduate students have been more limited, but still have produced excellent results. Of 10 students receiving NASA support, eight have graduated and two are still in the process of finishing the program. Of the eight graduates, seven completed the thesis option with three of their theses directly tied to research projects started over the summer at KSC/CCAFS. The non-thesis option students still must complete a detailed research project and paper, just not as extensive as a thesis. Three of the thesis projects directly related to NASA support and these will also be briefly described.

3. Examples of Student Research Activities

Fostering greater student involvement in real research activities is the major goal of the PSU NASA Space Grant scholarship/fellowship and summer support program. Initially, we had some FAA-funding for follow-up work on the Mount Washington Icing Sensors Project (MWISP), which was a major field campaign to examine the feasibility of remotely detecting icing conditions. Ryerson *et al*. (2000) provides an overview of the MWISP campaign. NASA-supported PSU students developed a detailed icing climatology for Mount Washington (Markle *et al*. 2001, Gillman *et al*. 2002). Other students (Blackey *et al*. 2002) examined analyzed cloud particle habits. Another student (Stanley et al. 2002a, Stanley et al. 2002b) evaluated the performance of operational Air Force and National Weather Service (NWS) Aviation Weather Center (AWC) and experimental National Center for Atmospheric Research (NCAR) low-level icing model forecasts for the rugged alpine environment around Mount Washington, New Hampshire.

The student work on the cloud particle analysis revealed some serious problems with a common software package used to analyze cloud particle data. As a result, a student coordinated with the software developer to fix several problems. Stanley's model performance study showed degraded performance of the operational icing models in areas of rugged terrain and the much better performance of the NCAR experimental model. She also verified a manual decision-tree technique used by the Air Force, which was designed to provide now-casts of icing type and intensity using radiosonde data for input. However, she also tested the technique using ETA-model forecast data as input and found it also out-performed the operational techniques for the area and did nearly as well as the NCAR technique.

Another student (Shuman et al. 2001) worked on a Cooperative Program for Operational Meteorology, Education and Training (COMET) Partner's Project with a forecaster from the NWS Office in Brookhaven, NY. He studied heavy precipitation events associated with the remnants of tropical cyclones, which had made landfall and exhibited enhanced precipitation due to topography.

Several of the NASA-supported students were able to present papers on their synoptic meteorology course research projects. Rothman (2001) looked at tropical cyclone potential intensity index. Blackey *et al*. (2003) examined using the Adjusted Dry Adiabatic Method (ADAM) for temperature forecasting. Komarek *et al*. (2003) did a case study on Sub-tropical Storm Gustav. Chan (2004) used radiosonde data to determine the statistical properties of convection. Cordeira *et al*. (2005) studied and the precipitation and track characteristics of Alberta Clippers. Fusco *et al*. (2006a) examined a 2005 Columbus Day flooding event in New Hampshire.

Another independent student research project (Nahmias and Zabransky 2004) statistically looked at the basic characteristics GPS-based Integrated Precipitable Water (IPW) in the northeast using Soumi-Net and other GPS IPW data.

Other student projects have included the New England Air Quality Study (NEAQS) campaign during the summer of 2002 and the International Consortium for Atmospheric Research on Transport and Transformation (ICARTT) campaign (Koermer *et al.* 2005a) during the summer of 2004. NASA Space Grant funds were used to partially support two students during each of these campaigns, who were assisting faculty (on a 24/7 basis) in developing daily planning forecasts used by campaign participants. These forecasts were extremely important for positioning the NOAA ship, Ron Brown, in the Gulf of Maine to make critical air quality measurements. One of the participating students in ICARTT also helped out tremendously in a comparison study (Koermer *et al*. 2005b) of the synoptic situations during each of these field campaigns. Follow-on related student research focused on first developing regional case studies for the northeast (Fusco *et al*. 2006b) and then later for other regions of the continental United States (Bixby *et al*. 2007).

During the summer of 2005, PSU started a relationship with the KSC Weather Office and the 45 WS at CCAFS and the related research has become one of the main focal points of the PSU research supported by the NASA Space Grant Program, which appreciates collaboration with other agencies. These supported activities will be covered in greater detail in the subsequent sections of this paper.

PSU also used Space Grant funds to partially support John Sears, another PSU undergraduate student, for him to attend the Summer 2008 NASA Academy at the NASA Marshall Space Flight Center (MSFC). While at MSFC, he studied the relation of hurricane intensity to satellite-derived sea-surface heights and temperatures (Sears 2009).

4. History of NASA-related Research Activities

Although lightning is by far the most pressing weather factor for the Florida space complex, convective winds also pose significant problems and account for the second highest number of advisories/warnings issued by the 45 WS. These phenomena generally have received much less research attention for this region and many of the wind tools and techniques, used by forecasters, were based on limited data or were designed for mid-west convection. So, it was mutually decided that this area would be a good niche for PSU to study.

This region also provides some unique observational resources for studies. Foremost among them, is the weather tower network depicted in Figure 1.

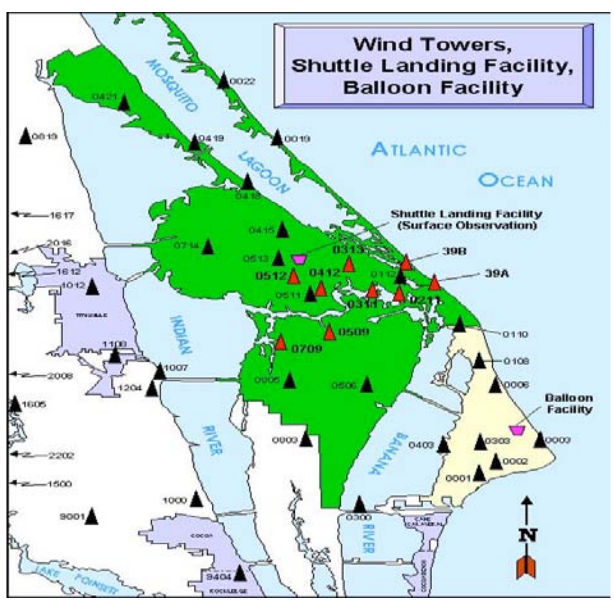

Figure 1. Weather towers at CCAFS/KSC (from Cummings *et al*. 2007).

There are 45 weather towers at CCAFS/KSC many of which are multi-instrumented with sensors at various altitude levels and some at the same level, but on opposite sides of the tower to avoid the tower corrupting the wind measurement. Data used included 5-minute peak winds from these towers for the warm-season months of May through September, eventually for the 15-year period of 1995 through 2009.

Other corresponding data used have included very detailed hourly and special manual surface from the NASA Shuttle Landing Facility (KTTS); NEXRAD radar data for KMLB (Melbourne, FL); KXMR radiosonde observations for CCAFS; flow regime (Lericos *et al.* 2002; Lambert 2002 and 2007) from the NASA Applied Meteorology Unit; and other surface and upper air data from the Plymouth State Archived Data online web site (http://vortex.plymouth.edu/u-make.html).

The initial effort started with an incoming PSU graduate student, Andrew Loconto, working with this paper's authors during the summer of 2005. The initial objective was to update parts of a previous convective wind climatology (Sanger 1999) for KSC/CCAFS, which was based on only four years (1994-1998) of data, one of which (1994) was later discovered to be flawed because of archival problems. The climatology at this point concentrated only on warm-season convective events that produced warning-level ≥ 35 kt) winds. Loconto *et al.* (2006) based the new climatology on 9 years of warm-season (May-Sep) from 1995 through 2003. After performing extensive additional manual and automated quality control of the data, winds were examined and matched with convective events, eliminating those associated with strong synoptically-driven pressure gradients such as those induced by tropical cyclones or strong cold air mass intrusions, which were more common during the early and latter parts of the warm-season. Because of time and data constraints, the most significant shortcomings of this initial effort were not being able to include the non-warning level events in the study and not having access at that time to high resolution radar data. However, the updated climatology, summarized in Loconto *et al*. (2006) provided valuable information for training and assisting 45 WS forecasters.

Loconto (2006) continued to work in this area over the next 18 months for his master's thesis research. He also examined and evaluated several of the forecasting aids used by 45 WS personnel and did some additional work on a more limited dataset in an attempt to develop several improved statistical and radar techniques for predicting convective winds in the area. His findings, based on relatively small datasets, showed promise, but more data and study was needed to affirm his results.

During the summer of 2006, two PSU undergraduate students, Kristin Cummings and Elizabeth Dupont, added two more years (2004-2005) to the climatology and also included non-warning convective events for all years. They also added many new features to the climatology, such as tower location, flow regime relationships, Gumbel probability distributions, GPS IPW correlations, etc. Most of their efforts for the 1995-2005 climatology are summarized in Cummings *et al.* (2007). Their work continued through the following academic year as a senior research projects and they each used 1-minute tower data for individual case studies examining lightning density relationships (Cummings 2007), and lead-time for the development of peak winds (Dupont 2007).

Two more PSU undergraduates, Heather Dinon and Matthew Morin, greatly added to the previous work during the summer of 2007 by acquiring and analyzing high resolution NEXRAD data for KMLB for all warning-level convective events covering the entire 11-year (1995-2005) warm-season period of record. Using these additional data, they reanalyzed all of these events to fine tune start and end times for the periods and to eliminate a few non-supported events, which were not associated with convection. They also added a small number of convective events not previously identified. With this updated information, they revised the overall climatology and developed a new radar-based climatology (Dinon *et al.* 2008) for warning-level events as their senior research..

With the senior research assistance of another Space Grant scholarship student, the authors also studied the contribution of the far inland weather towers to convective wind forecasting (Koermer and Roeder, 2008). This study was done to help 45 WS decide on the cost-effectiveness of those towers for their operations. Previous analysis had shown that these towers were often available less than 70% of the time due to difficulty in maintaining them due to access difficulties. Even when available, they contributed little advance warning of convective winds, i.e. the convective winds at CCAFS/KSC tend to be generated in the immediate local area as opposed to be generated quasi-continuously as thunderstorms move into the area. This reinforced the role played by local low-level boundaries in convective winds at CCAFS/KSC, as reported by Dinon et al. (2008).

The following summer, two more PSU undergraduates, Christopher Ander and Adam Frumkin, added two more years (2006-2007) to the overall climatology and expanded the radar climatology to add all non-warning-level convective events. These activities required extensive downloads of additional KMLB radar data and subsequent analysis, which again continued and served as their senior research project. Ander *et al.* (2009) provides a succinct summary of their research results.

During the summer of 2009 Mary Szpak, an undergraduate student from Harvard University, assisted by adding 2008 data to the basic climatology. This was done as part of her summer internship with KSC. Using much larger datasets, Mitchell McCue and James (Jared) Rennie, two PSU graduate students, started some in-depth follow-up on to several of Loconto's preliminary concepts for improving convective wind prediction and examined some new statistical predictive techniques for their thesis research projects. McCue concentrated on using KXMR radiosonde data to better predict convection and associated winds several hours in advance (McCue *et al.* 2010; McCue 2010). Rennie studied shorter term "nowcast" statistical forecast techniques based on radar data (Rennie *et al.* 2010; Rennie 2010).

During the summer of 2010, Katie Laro, a PSU junior, added 2009 data to the convective wind climatology, expanded work on flow regime relationships, and updated the entire 15-year (1995-2009) climatology (Laro 2011).

Also during the summer of 2010, Alexander Jacques, a PSU graduate student, worked on a regional USPLN lightning stroke verification study in conjunction with WSI Inc. using the KSC/CCAFS lightning network databases for ground truth (Jacques *et al.* 2011). This study was done independently of the research supported by the 45 WS, but partially supported by the NASA Space Grant.

5. Some Convective Wind Research Results

From the superb contributions of 11 students, the convective wind climatology has undergone many updates and expansions since it was first started. As a result, only some of the latest results or unique findings will be presented in this section. Figure 2 shows the number of days with and without convection during the warm season months (May-Sep) of 153 days over the entire 15-year period of record (1995-2009). The fewest number of convective days were observed during 2006 with the largest number occurring in 2009.

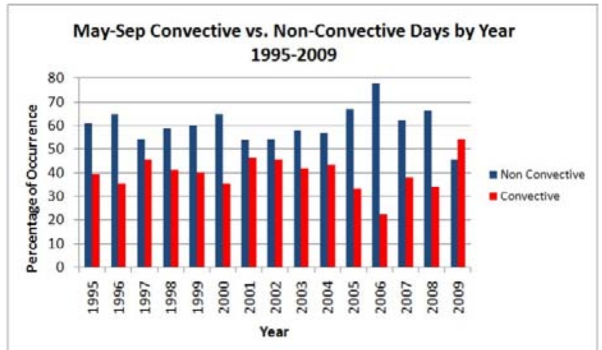

Figure 2. Distribution of warm season non-convective and convective days by year over the 15-year period of record (from Laro 2011).

A convective period was defined as "*a period beginning at the top of the hour when convection in the area first occurs and ending at the top of the hour after the last evidence of convection that is followed by a break in convective activity for a period of 6 hours or more*." Hence, some convective days could have more than one convective period. The yearly distribution of these warm season periods by wind speed categories is given in Figure 3.

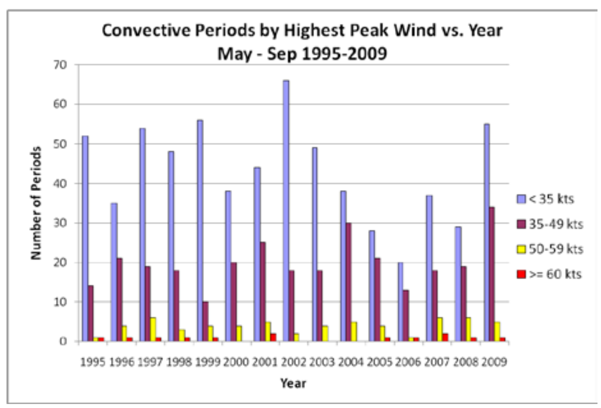

Figure 3. Convective periods broken down by year and wind speed category. Winds ≥ 35 kt constitute warning-level events.

Figure 4 shows the monthly distribution for these convective/non-convective days. July usually averages more convective wind periods than the other months, followed closely by August and June, with September and May usually having the fewest convective days.

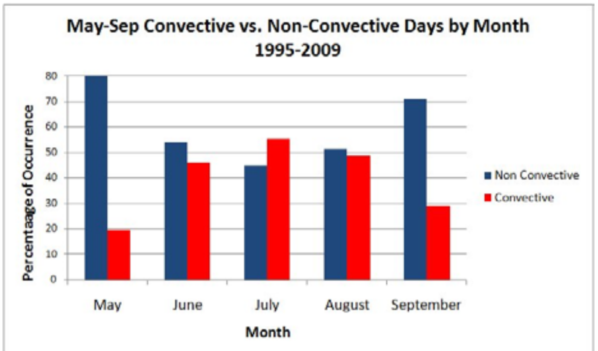

Figure 4. Distribution of non-warning-level and warning-level periods by month (from Laro 2011).

Figure 5 shows the average monthly number of convective events by the various speed categories that were used in Figure 3 for the entire period of record. July is associated with the largest number of warning level events. Convective periods with winds exceeding the 50 kt occur on average less than two times per month and are most likely during the warmest months (Jun-Aug), but can occur during any of the warm months.

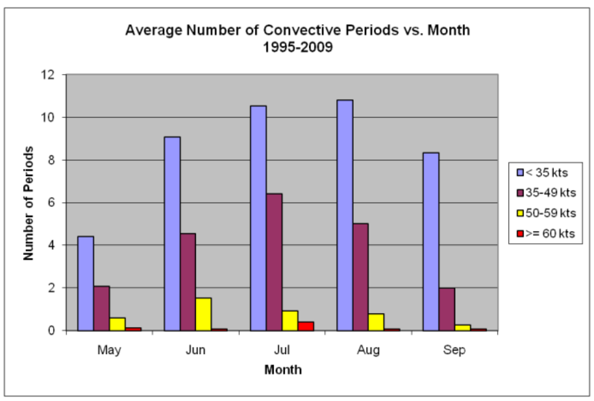

Figure 5. Average monthly convective periods by speed categories.

Lericos *et al.* (2002) and Lambert (2002) have shown the importance of the synoptic flow to central Florida lightning activity. They characterized and defined the flow regimes according to the descriptions in Table 2 and based their ridge positioning on the average surface-700 mb layer winds from the soundings at Miami, Tampa, and Jacksonville. Lambert (2007) included data from the 10 UTC CCAFS soundings, which helped eliminate many of the "Missing" cases.

Table 2. Florida flow regimes and how they are defined based on the position of the subtropical ridge.

Flow Regime	Subtropical Ridge Position
SW-1	South of Miami
SW-2	Between Miami and Tampa
SE-1	Between Tampa and Jacksonville
SE-2	North of Jacksonville
NW	Far to South into Gulf/strong
NE	Far to north into SE US/strong
Other	Position and flow not well defined
Missing	Insufficient data to define

These flow regimes also show a solid relationship with both convective events and strong convective winds. SW-1, SW-2, and SE-1 are associated with the majority of the convective events (see Figure 6), but also that westerly component flow regimes, especially SW-1 and SW-2, are usually prevalent and are most likely associated with the strongest convective wind events over the warm season (see Figure 7).

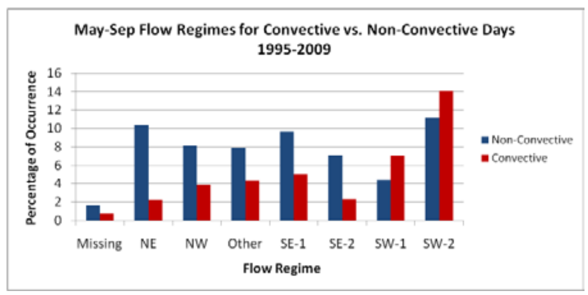

Figure 6. Distribution of the non-convective and convective days by flow regime during the warm season.

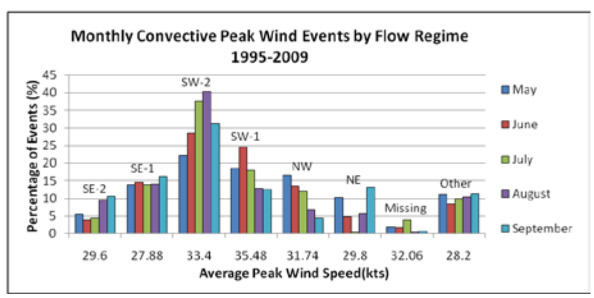

Figure 7. Flow regimes associated with convective wind events by month with their associated average peak wind speeds.

Diurnal variability is also an important consideration for 45 WS forecasters. Figure 8 shows the very strong association with diurnal heating and cooling with most convection occurring during the warmest hours of the day and least during the coolest early morning hours. However, as shown in Figure 9, even though the incidence of convection is less during those morning hours, the strength of the associated convective winds does not vary much diurnally.

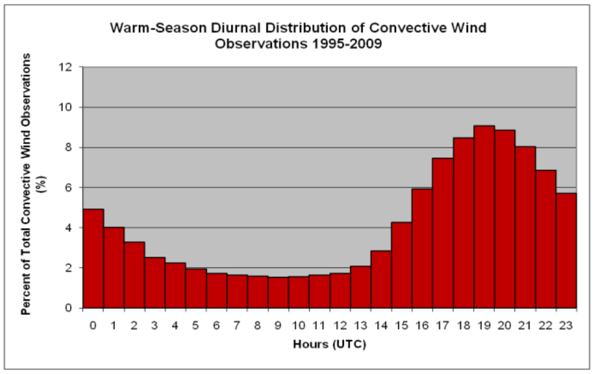

Figure 8. Diurnal variation of convective wind observations by percentage of those peak wind observations used to examine the various convective periods.

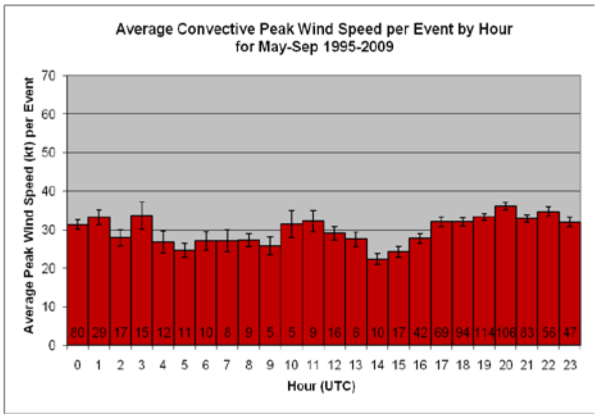

Figure 9. Diurnal distribution of the average maximum peak wind speeds associated with the various convective periods at the various times. The number near the bottom of the bars is the number of observations used for this hourly average.

There are many other aspects and charts associated with the convective wind climatology, where the events are categorized by tower sensor heights and tower locations. However, some of the most useful tools developed have been Gumbel probability equations and their resulting curves. The equations let users put in any peak wind threshold and it will yield a probability that that threshold could be exceeded during a convective event. This is excellent information for assisting 45 WS customers, many of who have very unique wind constraints. Figure 10 shows the expected observational frequency in 5-knot wind speed categories and the associated Gumbel probability equation and plot for an average warm season. Figure 11 shows the Gumbel results for the various warm season months and some specific stronger wind thresholds.

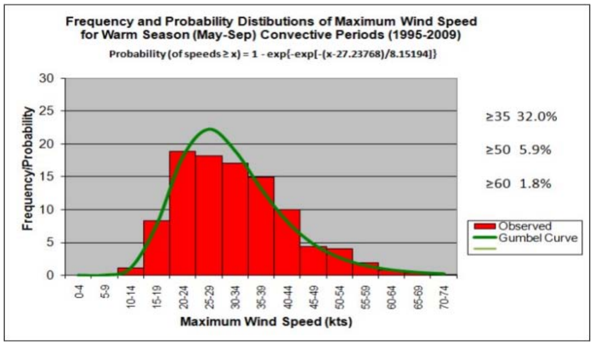

Figure 10. Distribution of maximum peak winds in 5-knot categories for an average warm season and the associated Gumbel probability curve and some probabilities for some specific peak wind thresholds are shown.

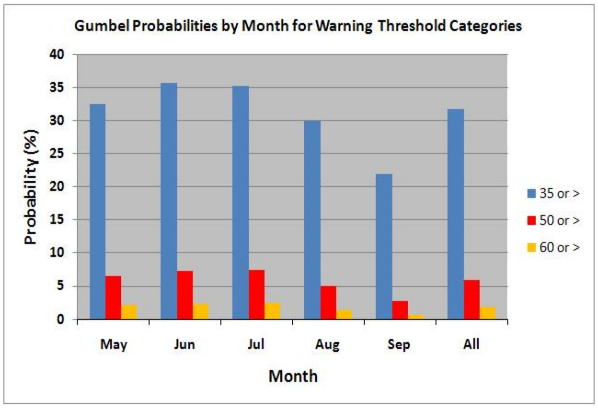

Figure 11. Probabilities by warm season months that peak winds with convective systems will exceed warning thresholds of ≥ 35, ≥ 50, and ≥ 60 knots, based on the monthly Gumbel equations.

Another useful facet of the climatology deals with relating the convective wind events with radar reflectivity characteristics. The KSC/CCAFS region in the summer is characterized by moist and unstable air. Convection does not need much of a trigger and can even generate outflow boundaries that can trigger additional events. There are also sea, river, and lake breeze boundaries that can act as trigger mechanisms. The collision of these various boundaries can act as an even stronger trigger for convection.

PSU students (Dinon *et al.* 2008; Ander *et al.* 2009; Laro 2011) examined a variety of convective cell characteristics associated with the maximum peak wind event in Table 3. The study initially focused on the warning-level wind events, but then was expanded to also examine all convective episodes including those with lower criteria winds. These criteria examined cell initiation categories of "Sea Breeze Front (SBF)", "OutFlow Boundary (OFB)", combined "SBF and OFB" interactions, or "no SBF or OFB" relationships. Cell structure was characterized as "linear", "individual" or "cluster". Cell strength was classified as "weak (< 45 DBZ)", "moderate (45-55 DBZ)", or "strong (> 55 DBZ)". The movement of the cell group and individual cell motion was also examined. Finally, the location of the maximum peak wind was categorized as "behind", "overhead" or "ahead" of the suspected cell producing the wind.

Key operationally useful findings include the following:

- Nearly 60% of warning level events are associated with interaction with a SFB and/or OFB with about half of those events involving both (see Figure 12),
- On the other hand nearly, over 65% of non-warning events occur when there are no SBFs or OFBs in the vicinity (see Figure 12).
- Cells in linear structures were associated with about 55% of warning-level events, whereas only about 5% on non-warning events are associated with this type of structure (see Figure 13),
- Cell group and individual cell movement for warning level events was predominately towards a northeasterly (NE) direction (e.g. from the southwest) with cells having a slightly more northerly bias (see Figure 14), and
- About 83% of warning level peak winds occurred when the cell was generally overhead (see Figure 15).

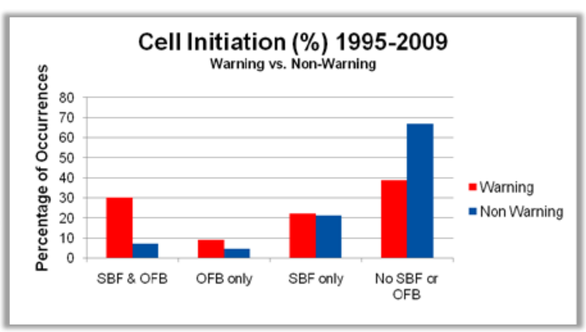

Figure 12. Cell initiation relationships for warning and non-warning level convective wind events associated with SBFs and/or OFBs over the 15-year warm season period of record (after Laro 2011).

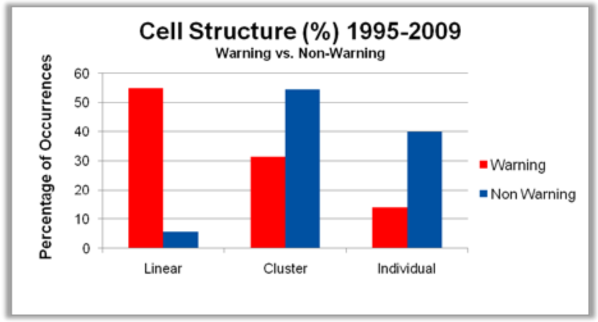

Figure 13. Cell structure of cell(s) associated with warning and non-warning level convective wind events over the 15-year warm season period of record (after Laro 2011).

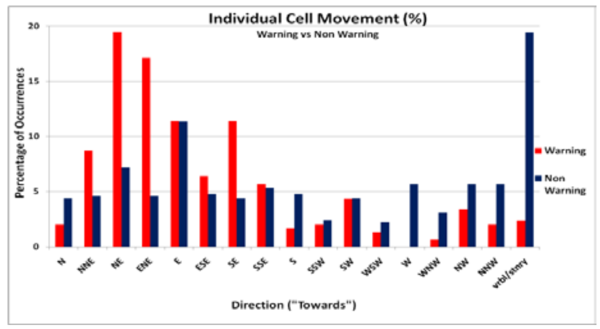

Figure 14. Individual cell movement of cell most likely associated with the maximum peak wind location for warning and non-warning level convective events for the 1995-2009 warm seasons.

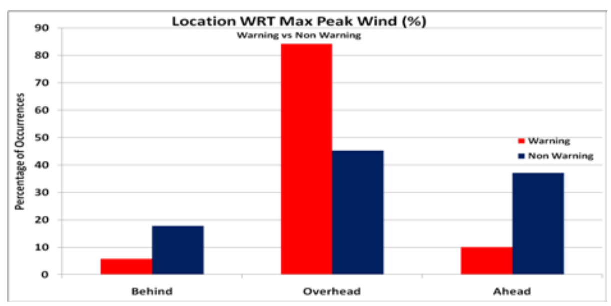

Figure 15. Location of the maximum peak wind observed relative to the likely cell that produced it, averaged over the 1995-2009 warm seasons.

The majority of the convective wind climatology and convective wind forecast tools for the KSC/CCAFS region were constructed through the fine efforts of PSU undergraduate students supported through the NASA Space Grant both on site during the summer and back at Plymouth during the subsequent academic year. More details on this research can be found at:

http://vortex.plymouth.edu/conv_winds.

6. Future Work

As cited earlier, PSU graduate students have recently finished promising studies (McCue 2010; Rennie 2010) on using KXMR radiosonde and KMLB radar data with CART algorithms to produce short-term or nowcast predictions of convection. The radiosonde technique requires additional testing with additional independent data. These data have already been collected for 2010 and the plan is to collect additional data for 2011. One of the radar techniques is being considered for operational evaluation by the 45 WS during the summer of 2011.

Work has already started on preparing a journal article summarizing the convective wind climatological results for the CCAFS/KSC area.

The 45 WS has recently installed a dual polarization radar to monitor the KSC/CCAFS area (Roeder et al., 2009; Roeder and Short, 2009). These data will be examined to determine their use in convective wind and lightning prediction, since most of the dual polarization work elsewhere seems to be focused on hail prediction. Loconto (2006) and Rennie (2010) have shown some interesting relationships with convective outcomes and the location of maximum reflectivity versus the freezing level. Dual polarization offers the promise of better observing this level. In addition, dual polarization radar will be able to identify the distribution of hydrometeor species, number density, and size distribution, relative to temperature level. These capabilities should prove useful in predicting the occurrence and intensity of convective winds.

7. Meeting Space Grant Goals

Most of the climatological information, briefly summarized in this paper, was produced by Space Grant supported students and can be extremely useful to Air Force forecasters trying to decide whether convection in their KSC/CCAFS area of responsibility is more likely going to result in winds strong enough to require a warning. This addresses one goal of the Space Grant Program, which is to improve collaboration between NASA-related endeavors and academic institutions in order to generate research useful for supporting NASA missions.

Another goal is to keep students in STEM disciplines to aid in the eventual development of the future work force, important to NASA and other national interests. Student support towards this goal would be considered successful, if the outcomes were staying in the STEM discipline and ultimately graduating; going on further to obtain a graduate degree(s) in STEM areas; or moving into the STEM workforce. In satisfying this goal, PSU has only had three of 60 uniquely supported students not continue and stay in or obtain degree in their major. The majority of other 57 students have graduated with BS or MS degrees of which 9 are currently making satisfactory progress in their degree programs. Of nearly 50 undergraduate students supported nearly half went onto STEM graduate programs and four of them are currently enrolled in PhD programs. Another 20 are now working STEM-related positions with government, industry, or science/math teaching.

Of the 11 students more recently supported for summer research at KSC/CCAFS and one at MSFC, three of four graduate students completed their degree and one is in-progress. Two are now working in NOAA-related positions and one recent graduate is currently seeking employment. The other has nearly completed his MS. Of the eight undergraduate students, all except one currently enrolled in the undergraduate program, have gone on to graduate programs. Two have just started PhD programs and the others are in various stages of MS programs. One former student on the PhD track first worked at NASA MSFC.

For a relatively small investment, the support provided by the NASA Space Grant Program has been very beneficial and has helped to encourage PSU students to stay in STEM disciplines, graduate, and go forward for advanced degrees or STEM-related positions in the workforce. The funding of summer research opportunities in support of NASA activities has an outstanding track record of encouraging students to pursue their degrees, look for additional opportunities and/or work in important STEM areas.

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9. References

Ander, C.J., A.J. Frumkin, J.P. Koermer, and W.P. Roeder, 2009. Study of sea-breeze interactions which can produce strong warm-season convective winds in the Cape Canaveral area, *Joint session of the 16th Conf. on Air-Sea Interaction and the 8th Conf. on Coastal Atmospheric and Oceanic Prediction and Processes* , Amer. Meteorol. Soc., Phoenix, AZ.

Bixby, B.M., K.M. Francoeur, L.L. Landry, M.J. Pierce, L.B. Aviles, E.G. Hoffman, J.P. Koermer, S.T. Miller, and J. Zabransky, 2007: Development of regional ozone case studies as tools for air quality forecasting, *Ninth Conf. on Atmospheric Chemistry,* Amer. Meteorol. Soc., San Antonio, TX.

Blackey, C., S. Clarke, W. Rowland, and E. Hoffman, 2003: A study of the Adjusted Dry Adiabatic Mix-out (ADAM) temperature forecasting method in the northeast. *28th Annual Northeastern Storm Conf.,* Saratoga Springs, NY.

Blackey, C.W., J.E. Rozak, W.G. Schmitz, J.P. Koermer, and B.D. Keim, 2002: Mt. Washington Icing Sensors Project (MWISP) cloud particle habit analysis, *Sixth Symposium on Integrated Observing Systems*, American Meteorological Society, Orlando, FL.

Chan, R., 2004: Using radiosonde data to determine statistical properties of convection. *Third Annual Student Conf.*, Amer. Meteorol. Soc., Seattle, WA.

Cordeira, J. A. Loconto, K. Ouellette, M. Wellman, and E. Hoffman, 2005: A statistical analysis of precipitation and track of Alberta Clippers, *30th Annual Northeastern Storm Conf.,* Burlington, VT.

Cummings, K.A., 2007. Warm-season convective wind event for the Florida Space Coast: A case study - 23 July 2005. *Senior Research Paper*, Dept. of Chemical, Earth, Atmospheric and Physical Sciences, Plymouth State University, Plymouth, NH.

Cummings, K.A., E.J. Dupont, A.J. Loconto, J.P. Koermer, and W.P. Roeder, 2007: An updated warm-season convective wind climatology for the Florida Space Coast, *16th Conf. on Applied Climatology*, Amer. Meteorol. Soc., San Antonio, TX.

Dinon, H.A., M.J. Morin, J.P. Koermer, and W.P. Roeder, 2008. Convective winds at the Florida Spaceport: year-3 of Plymouth State research, *13th Conf. on Aviation, Range, and Aerospace Meteorology,* Amer. Meteorol. Soc., New Orleans, LA.

Dupont, E. J., 2007. A case study of a warm-season convective wind period on the Florida Space Coast *Senior Research Paper*, Dept. of Chemical, Earth, Atmospheric and Physical Sciences, Plymouth State University, Plymouth, NH.

Fusco, A.R., G. G. Garner, S. L. O'Clair, C.J. Sheehan, 2006a: The development and investigation of eight northeast air quality case studies, *Fourth Annual Student Conf.*, Amer. Meteorol. Soc., Atlanta, GA.

__________, G.G. Garner and E.G. Hoffman, 2006b: Meteorological and hydrological aspects of the Columbus Day weekend 2005 flooding event in Cheshire County, New Hampshire, *31st Annual Northeastern Storm Conf.*, Saratoga Springs, NY.

Gillman, J.H., B.J. D'Agostino, Markle, T.O., N.C. Witcraft, J.P. Koermer, and B.D. Keim, 2002: Regional synoptic climatology study of the Mt. Washington area, *13h Symposium on Global Change and Climate Variations*, Amer. Meteorol. Soc., Orlando, FL.

Jacques, A.A., J.P. Koermer, and T.R. Boucher, 2011: Comparison of the United States Precision Lightning Network™ (USPLN™) and the Cloud-to-Ground Lightning Surveillance System (CGLSS), *Fifth Conference on the Meteorological Applications of Lightning Data*, Amer. Meteorol. Soc., Seattle, WA.

Koermer, J.P., J. Zabransky, E. Hoffman, T. Bray, R. Cloutier, J. Cordeira, M. DiProfio, A. Loconto, and M. Wellman, 2005a: Planning forecasts for the coastal and offshore air quality measurement activities for the ICARTT summer 2004 campaign, *Sixth Conf. on Coastal Atmospheric and Oceanic Prediction and Processes*, Amer. Meteorol. Soc., San Diego, CA.

Koermer, J.P., J.M. Cordeira, and E.G. Hoffman, 2005b: Meteorological differences between NEAQS 2002 and ICARTT/NEAQS 2004, *Atmospheric Science and Air Quality Conf.,* Amer. Meteorol. Soc., San Francisco, CA.

Koermer, J.P., and W.P. Roeder, 2008: Assessment of the importance of certain wind towers in the Cape Canaveral AFS/Kennedy Space Center mesonet for predicting convective winds, *13th Conf. on Aviation, Range, And Aerospace Meteorology*, Amer. Meteorol. Soc., New Orleans, LA.

Komarek, J.P., E.J. Rozak, K.T. Younie, and E.G. Hoffman, 2003: A case study of Subtropical Storm Gustav, *28th Annual Northeastern Storm Conf.,* Saratoga Springs, NY.

Lericos, T.P., H.E. Fuelburg, A.I. Watson, and R.I. Holle, 2002: Warm season lightning distributions over the Florida Peninsula as related to synoptic patterns. *Weather and Forecasting*, 17, 83-98.

Lambert, W.C., 2002. Statistical short-range guidance for peak wind speed forecasts on Kennedy Space Center/Cape Canaveral Air Force Station: Phase I results. NASA Contractor Report CR-2002-211180. 39 pp.

Lambert, W.C., 2007. Objective Lightning Probability Forecasting for Kennedy Space Center and Cape Canaveral Air Force Station, Phase II. NASA Contractor Report CR-2007-214732. 59 pp.

Laro, K.L., 2011: Warm season convective wind climatology for the CCAFS/KSC area. *10th Annual Student Conference,* Amer. Meteorol. Soc., Seattle, WA.

Loconto, A.N., 2006: Improvements of warm-season convective wind forecasts at the Kennedy Space Center and Cape Canaveral Air Force Station. *M.S. Thesis*, Dept. of Chemical, Earth, Atmospheric and Physical Sciences, Plymouth State University, Plymouth, NH.

Loconto, A.N., J.P. Koermer, and W.P. Roeder, 2006: An updated warm-season convective wind climatology for Cape Canaveral Air Force Station/Kennedy Space Center, *12th Conf. on Aviation Range and Aerospace Meteorology*, Amer. Meteorol. Soc., Atlanta, GA.

Markle, T.O., N.C. Witcraft, J.P. Koermer, B.D. Keim, and M.K. Politovich, 2001: A detailed study of the observational data for the Mt. Washington area over the past 45 years, *12th Symposium on Global Change and Climate Variations*, American Meteorological Society, Albuquerque, NM.

McCue, M.H., 2010. Validations and development of existing and warm-season convective wind forecasting tools for Cape Canaveral Air Force Station and Kennedy Space Center. *M.S. Thesis,* Dept. of Atmospheric Science and Chemistry, Plymouth State University, Plymouth, NH.

McCue, M.H., J.P. Koermer, T.R. Boucher, and W.P. Roeder, 2010: Validations and development of existing and new RAOB-based warm-season convective wind forecasting tools for Cape Canaveral Air Force Station and Kennedy Space Center, *22nd Conf. on Climate Variability and Change*, Amer. Meteorol. Soc., Atlanta, GA.

Nahmias, M.H. and J.R. Zabransky, 2004: A statistical examination and case study of Integrated Precipitable Water (IPW) in northern New England. *Eighth Symposium on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface*, Amer. Meteorol. Soc., Seattle, WA.

Rennie, J.J, 2010. Evaluating WSR-88D methods to predict warm-season convective wind events at Cape Canaveral Air Force Station and Kennedy Space Center. *M.S. Thesis*, Dept. of Atmospheric Science and Chemistry, Plymouth State University, Plymouth, NH.

Rennie, J.J., J.P. Koermer, T.R. Boucher, and W.P. Roeder, 2010: Evaluation of WSR-88D methods to predict warm-season convective wind events at Cape Canaveral Air Force Station and Kennedy Space Center. *22nd Conf. on Climate Variability and Change*, Amer. Meteorol. Soc., Atlanta, GA.

Roeder, W.P., T.M. McNamara, B.F. Boyd, and F.J. Merceret, 2009: The new weather radar for America's space program in Florida: An overview, *34th Conference on Radar Meteorology*, 5-9 Oct 09, Paper 10B.6, 9 pp.

Roeder, W. and D. A. Short, 2009: The new weather radar for America's space program in Florida: Scan strategy design, *34th Conference on Radar Meteorology*, 5-9 Oct 09, Paper P6.2, 6 pp.

Rothman, G.S., 2001: Development of tropical cyclone potential intensification index, *18th Conf. on Weather Analysis and Forecasting and the 14th Conf. on Numerical Weather Prediction*, Amer. Meteorol. Soc., Ft. Lauderdale, FL.

Ryerson, C.R., M.K. Politovich, K.L. Rancourt, G.G. Koenig, R.F. Reinking, and D.R. Miller, 2000: Overview of Mt. Washington Icing Sensors Project. Preprints, *38th AIAA Aerospace Sciences Meeting and Exhibit*, Miami, FL, AIAA, Paper AIAA-2000-0488.

Sanger, N., 1999. CCAFS microburst climatology. *M.S. thesis*, Dept. of Meteorology, Texas A&M University, College Station, TX.

Sears, J.T., 2009. Understanding hurricane intensity using sea surface height and temperature information, *Eigth Annual Student Conf.,* Amer. Meteorol. Soc., Phoenix, AZ.

Shuman, M.P., J.P. Koermer and S.D. Reynolds, 2001: Heavy precipitation events from tropical cyclone remnants in the eastern United States, *Symposium on Precipitation Extremes: Prediction, Impacts, and Responses*, American Meteorological Society, Albuquerque, NM.

Stanley, R.J., J.P. Koermer, C.C. Ryerson, I. Gotchel, D.R. Brooks, C.E. Wallace and D.E. Knapp, 2002a: Forecasting aircraft icing in complex terrain, *Third Symposium on Environmental Applications: Facilitating the Use of Environmental Information*, Amer. Meteorol. Soc., Orlando, FL.

_____________, J.P. Koermer, and C.C. Ryerson, 2002b: Evaluation of low-level icing forecasts from Mt. Washington summit observations, *10th Conf. on Aviation, Range, and Aerospace Meteorology*, Amer. Meteorol. Soc., Portland, OR.