

THE WEATHER SAFETY EDUCATION PROGRAM AT 45TH WEATHER SQUADRON

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1. INTRODUCTION

The 45th Weather Squadron (45 WS) conducts an extensive weather safety education program. This program is summarized below. The authors hope this paper will encourage increased and improved weather safety education by others.

2. BACKGROUND

The 45th Weather Squadron is the US Air Force unit that provides comprehensive weather services to America's space program at the US Air Force Cape Canaveral Air Force Station (CCAFS) and NASA Kennedy Space Center (KSC) (Boyd et al., 1993). These services are challenging because of the stringent operational requirements, subtle but dramatic weather, and dense and atypical network of local meteorological sensors.

Spaceport operations have stringent meteorological requirements. Weather can significantly impact the safety and success of the five main spaceport operations: 1) ground processing, 2) launch, 3) recovery, 4) special missions, and 5) personnel safety and resource protection.

Weather can endanger the over 5,000 ground processing operations each year (Boyd et al., 1995). Major ground processing operations include vehicle rollouts to the launch pads, stacking and destacking rocket segments, transporting and mounting and demounting payloads, large crane operations, etc.

During launch countdowns, the 45 WS forecasts and evaluates the Lightning Launch Commit Criteria (LCC) and User LCC. The Lightning LCC are a set of complex weather rules to avoid rocket-triggered and natural lightning (Roeder et al., 1999). The User LCC are limits for low altitude wind, cloud ceiling and visibility, temperature, and precipitation (Hazen et al., 1995). The 45 WS also supports other offices that are responsible for four other major launch functions: 1) Loads (vehicle stress as it counter-steers against upper level winds differing from planned to stay on trajectory) (Smith and Adelfang, 1992), 2) Toxic Dispersion (Parks et al, 1996), 3) Blast (casualties from broken windows in nearby towns if the rocket explodes) (Boyd et al., 2000), and 4) Debris (rocket parts falling outside allowed areas). Aeronautical engineers on the vehicle launch team evaluate Loads. The 45th Space Wing (45 SW) Range Safety evaluates Toxic Dispersion, Blast, and Debris (Boyd et al., 1999). The Space Shuttle also has Flight Rules for routine and emergency landings, and on-orbit support, which is provided by the NWS Spaceflight Meteorology Group at Johnson Space Center (Brody, 1997).

Weather can also significantly affect recovery operations. The best example is the at-sea recovery of the solid rocket booster motors after a Space Shuttle launch. Wind and wave conditions can make recovery unsafe, leading to a delay or scrub of a Shuttle launch.

The 45 WS also supports special missions, such as the Space Shuttle Ferry Flight (Priselac et al., 1997). Other special missions include transport of large components on oversized aircraft such as the Super Guppy, transport of large components on barges across the Gulf of Mexico to the east coast of Florida, and astronaut rescue exercises. Another special mission is space launch with radioactive material onboard (Boyd et al., 2004).

Weather can also significantly threaten personnel and resources. The 45 WS is responsible for a large suite of 24/7 weather watches, warnings, and advisories to protect over 25,000 people and over \$17 billion in assets. Many of these advisories have unusual criteria, long lead-times, and precise location requirements.

The subtle but dramatic weather in east central Florida contributes to the challenge of weather support of CCAFS/KSC. The formation of summer thunderstorms is dominated by many weak boundary line interactions. These boundaries include the sea breeze front off the Atlantic Ocean, the sea breeze front off the Gulf of Mexico, local river breeze fronts off the Indian and Banana Rivers, convective outflows, horizontal convective rolls, lake breeze fronts, washed out synoptic fronts and shear lines, cloud shadow boundaries, and soil moisture breeze fronts. The many interacting boundaries make forecasting the thunderstorms extremely difficult. Winter boundary layer winds can also be difficult to predict due to the complex frictional and stability environment. Over about a 25 km east-west distance the surface type changes from water to land three times. Forecasting the low altitude peak winds is especially difficult.

The 45 WS sustains and modernizes one of the densest networks of local weather instruments in the world (Harms et al., 2003) (Harms et al., 1998). This network is needed to detect the subtle local atmospheric patterns, which can dramatically change the weather. This network has over 900 weather sensors processing over 9 GB of data per day. It includes 44 weather towers, a 4-D lightning detection system, a cloud-to-ground lightning detection system, 31 surface electric fields, a local radiosonde, a 50 MHz tropospheric wind profiler, five 915 MHz boundary layer wind/virtual temperature profilers, surface weather stations, a modified WSR-74C weather radar, and others. The 45 WS network contributes to challenge of weather support to CCAFS/KSC due to the density and atypical nature of some of the sensors. The 45 WS also has direct access to the WSR-88D weather

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radar at National Weather Service/Melbourne and the National Lightning Detection Network.

The 45 WS also provides scientific and climatological support (Roeder and Harms, 2000), technical training, and liaison to technical organizations. The 45 WS facilitates operational research from various sources to improve its weather support. These sources include universities, interns, visiting scientists, national labs, and contractors, etc. One such contractor is the Applied Meteorology Unit, which is collocated with 45 WS operations and provides technology transfer and technique development to improve weather support to America's space program (Bauman et al., 2004) (Ernst and Merceret, 1995).

Finally, the 45 WS also provides weather safety education, as required by Air Force and local instructions. The remainder of this article discusses only this last duty of 45 WS, weather safety education.

3. 45 WS WEATHER SAFETY EDUCATION

Due to the numerous operational weather hazards faced by our customers, the 45 WS conducts an aggressive weather safety education program. An effective weather safety education program has three key elements: local relevance, practical advice, and effective teaching resources. The 45 WS program ensures local relevance by being both consistent and flexible. Consistency of the program is ensured by being climatologically based. Flexibility is ensured by responding to local weather events. The training is kept practical by using recommendations from the top experts in each field, consulting local experts, interviewing personnel with many years of local experience, and incorporating audience responses. The 45 WS developed many teaching resources, and assembled a large library of briefings, brochures, summary sheets, refrigerator magnets, digital images, websites, and others. These materials are continuously improved by working with the best communicators and weather safety experts available.

The 45 WS weather safety education program is organized into two main categories: 1) recurring training, and 2) targets of opportunity training. 'Recurring training' is done at the same time each year, which provides

consistency to the program. This makes the training more relevant to people, which increases their attention, and reduces the time they have to forget the information before the training is needed in the real world. Weather hazards with long seasons also receive refresher training throughout the season. The climatology of the relative contributions to deaths, injuries, and damages from each weather phenomena is used to design the training. 'Targets of opportunity' training is done just after significant local weather events, or just before significant weather is predicted. The 'recurring' and 'targets of opportunity' training are also 'just in time' training, i.e. done just before it is needed, and thus will be remembered and used by the trainees better.

Much of the 45 WS 'recurring training' piggybacks on state and national weather safety events, which are timed for the beginning of the respective hazardous weather seasons. These events include: 1) the 'Florida Hazardous Weather Awareness Week' during the third week in February, 2) the 'National Hurricane Awareness Week' during the third week in May, and 3) national 'Lightning Safety Awareness Week' during the last week in June. Florida Hazardous Weather Awareness Week includes all the main weather hazards for the state: lightning, tornadoes and thunderstorms (wind and hail), hurricanes and flooding, marine hazards (waterspouts, large surf, high winds, and rip currents), and wildfires and heat stress. 'Recurring training' consists of articles in facility newspapers and newsletters, looped briefings on local closed circuit television, global e-mail, and briefings to individual organizations. The timeline of the 45 WS 'recurring training' education program is shown in Figure 1.

As its name suggests, 'targets of opportunity' training is provided as opportunistic events occur. For example, if hazardous weather is forecast, reminder training will be issued. If the hazardous weather occurs and causes local casualties and/or damage, reminder training will also be issued, using the event to generate increased interest.

For either training category, briefings for individual organizations are always offered and points of contacts provided. These briefings are provided on request. All

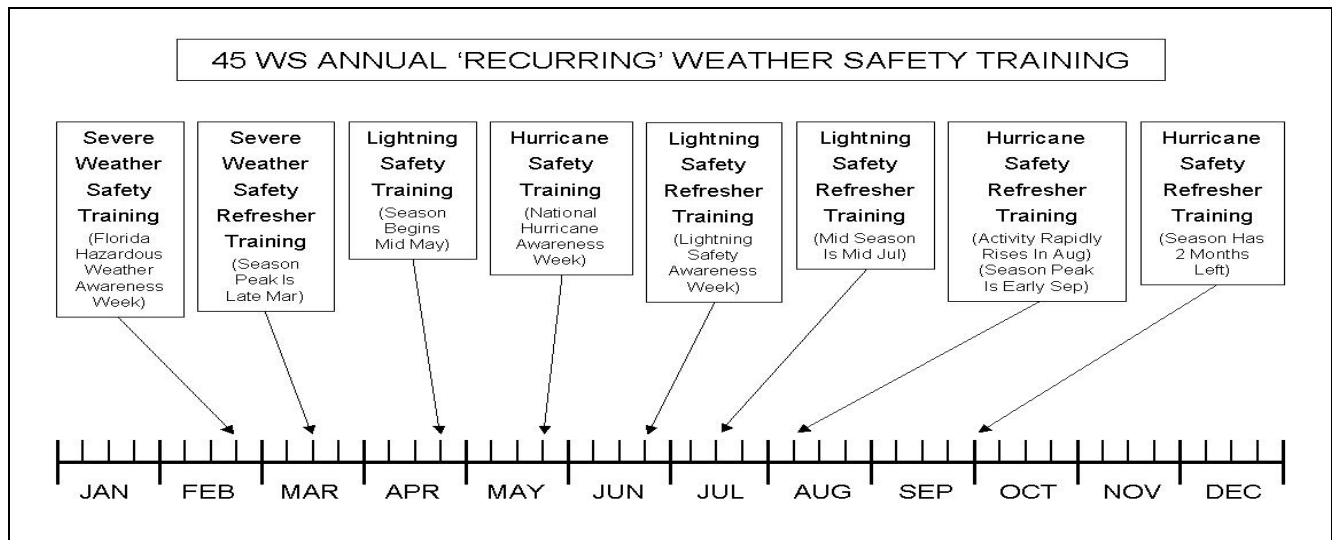


FIGURE 1. Annual timeline of 45 WS 'recurring training' weather safety education program.

organization-wide training is coordinated with the 45 SW and/or KSC safety offices to avoid duplication of effort and ensure consistent advice.

The most important weather threats to 45 WS customers are lightning, hurricanes, and tornadoes, which are discussed in further detail below. Other minor weather safety training is also briefly discussed.

3.1 Lightning Safety Education

Lightning is the most dangerous and frequent weather hazard affecting 45 WS customers. However, lightning has received scant attention, both nation-wide and in Florida, until recently. Therefore, the 45 WS has an extensive lightning safety program.

Florida is the 'Thunderstorm Capital' of North America (Figure 2), with central Florida being 'Lightning Alley' (Figure 3). Lightning is the leading cause of weather deaths in Florida, killing more than nearly all other weather combined (Figure 4). Florida has more lightning deaths and injuries than any other state (Table 1). The distribution of Florida lightning deaths by location and activity is shown in Figure 5. The most lightning casualties in Florida occur in open areas such as sports fields and beaches, so this receives the most attention. The other sources receive attention as warranted by their contribution, i.e. 2) water activities, 3) going under trees during thunderstorms, 4) farm and heavy equipment, 5) using corded telephones, and so forth.

Given the frequency of lightning casualties in Florida, there are many opportunities for 'targets of opportunity' training. For example, in August 03, lightning killed a local teacher while coaching a children's soccer match. This event received considerable local media attention. The 45 WS immediately piggybacked refresher lightning safety training on top of this media attention, while being sensitive to those in mourning, in the hope of preventing future casualties. More recently, three people in Florida were killed by three separate lightning incidents 17-18 May 04. All three were doing at-risk activities. This event was used to remind the 45 WS customers of lightning safety.

The current 45 WS lightning safety program began after 45 WS helped write the recommendations of the national Lightning Safety Group in 1998 (Holle et al., 1999). The 45 WS has adapted these recommendations into a 5-level process that is easier to teach and memorize (BAMS, 2003). The central Florida lightning season usually begins during May and ends during September (Figure 6), which is the earliest lightning season onset in the U.S. Unfortunately, the main national lightning safety event, Lightning Safety Awareness Week, occurs the last full week of June. Therefore, 45 WS schedules a separate lightning safety training initiative in late April, in addition to activities based on the national event. The national event has the advantage of occurring just before July, which is the peak of lightning activity and lightning casualties in many locations, including east central Florida. This is especially important because of the surge in outdoor at-risk activities over the Independence Day holiday in the U.S. The 45 WS provides an average of over 20 briefings per year to over 1,000 customers. A large number of support products have been developed for this training (Table 2).

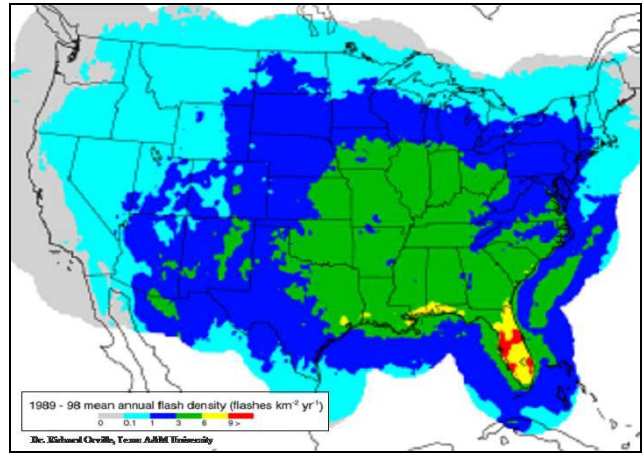


Figure 2. Average CONUS lightning flash density (1989-1998). (Orville, Texas A&M University).

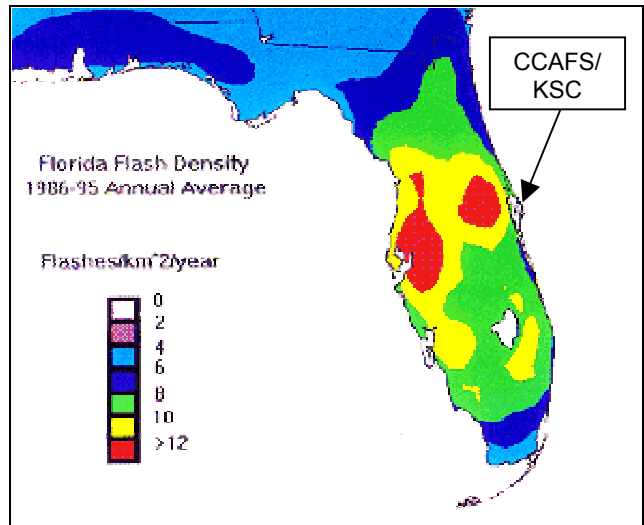


Figure 3. Average Florida lightning flash density (1986-1995) (National Weather Service/Melbourne).

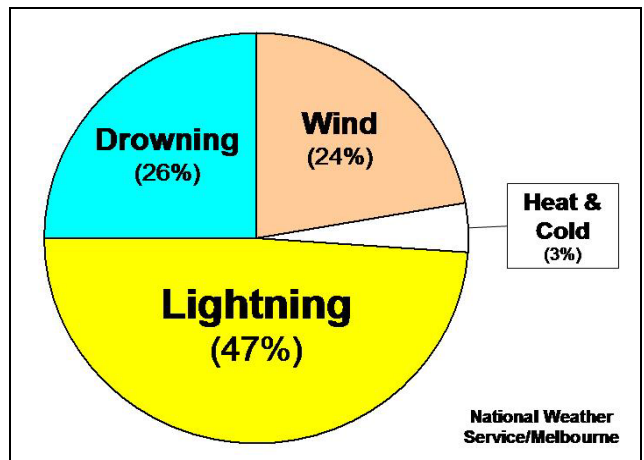


Figure 4. Causes of Florida weather deaths (1959-1999) (National Weather Service/Melbourne).

TABLE 1. Top states for lightning deaths (1959-2003) (Holle, 2004). (Update to Curran et al. (2000)).

LIGHTNING DEATHS		
RANK	TOTAL	PER CAPITA
1	FL	NM
2	TX	WY
3	NC	AR
4	OH	CO
5	NY	FL
6	TN	MS
7	LA	OK
8	CO	MT
9	MD	LA
10	PA	SD

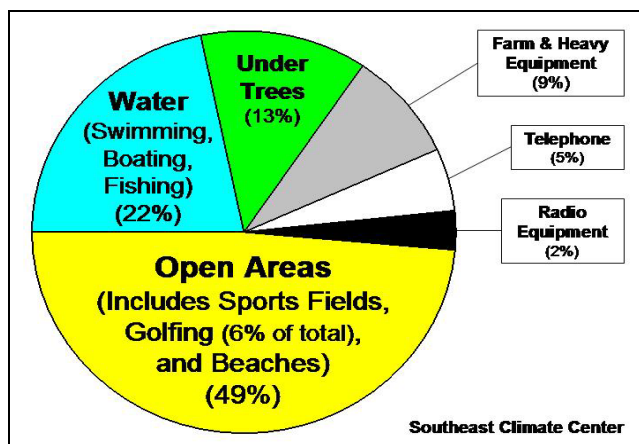


Figure 5. Causes of Florida lightning deaths (1959-1993) (Southeast Climatology Center).

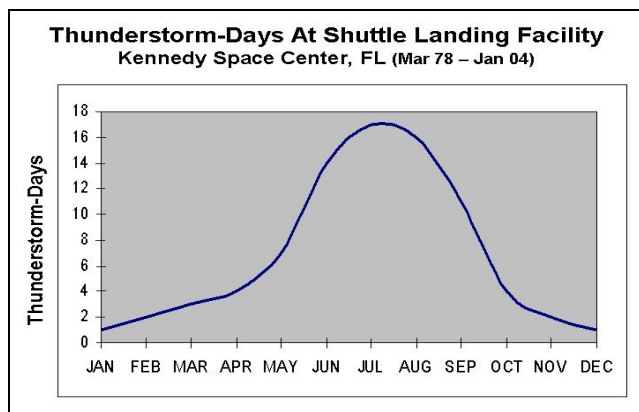


Figure 6. Thunderstorm-Days by month for the Shuttle Landing Facility at Kennedy Space Center, FL (Mar 78-Jan 04). (AFCCC, 2004).

The 45 WS is also very active in lightning safety public education, averaging over 30 briefings to nearly 3,000 people per year. This public education is done with the concurrence of the National Weather Service Forecast Office in Melbourne, FL. Schools receive special

emphasis. The 45 WS has also participated in many special events, such as the national Lightning Safety Awareness Week sponsored by the National Weather Service. This annual event is now always held the last full week of June. The 45 WS helped found this event and has been active in all phases since then, such as significantly contributing to the design and content of the website (www.lightningsafety.noaa.gov), the NWS lightning safety magnet design, and many others. The 45 WS also produced a lightning safety video with the city of Titusville under a grant from the State of Florida. The 45 WS has given many media interviews such as with Discovery Channel, Learning Channel, and BBC, etc. The 45 WS published several articles on lightning safety to aid others in teaching lightning safety (Table 3). The 45 WS is currently working with a local high school to produce a computer-animated video on lightning safety for children.

TABLE 2. Lightning safety training support materials. Most undergo continuous incremental improvement.

TYPE	DETAILS
Briefings	General Lightning Safety: 5 min, 15 min, 30 min, 45 min; Florida and U.S. versions; custom lengths on request. Specialty Topics: airfields, boaters, schools, children, and teaching lightning safety.
Handouts	Top-10 lightning safety tips Top-10 lightning safety myths Recommended websites list
Brochure	Bi-fold, 4 pages, 8.5 x 5.5 inch
Magnet	3 x 5 inch
Websites	45 WS: https://www.patrick.af.mil/45og/45ws/lightningsafety LSAW: www.lightning.noaa.gov
Newspapers	Canned articles
E-mails	Canned articles
Newsletters	Canned articles
Storyboard	30 x 40 inch printed foam-board
Image Library	350 digital images of lightning, and lightning impacts
Tabletop Display	8 x 6 Ft, commercially produced: lightning safety, 45 WS mission, hurricane preparedness
Posters	National Severe Storms Lab (1999), Lightning Safety Awareness Week: (2004, Torii Hunter, pro baseball) (2003, Siri Mullinix, pro soccer) (2001-2002, Vijay Singh, pro golf; Rocco Mediate, pro golf)
Slogans	When Thunder Roars, Go indoors! Lightning Kills--Play It Safe! (LSAW) If You Can See It, Flee It (NLSI) If You Can Hear It, Clear It (NLSI) Don't Get Fried, Go Inside! Don't Be A Fool, Get Out Of The Pool!

TABLE 3. Lightning safety articles by 45 WS.

TITLE	VENUE	REFERENCE
Lightning Safety For Schools: An Update	14th Symposium on Education in Meteorology	Roeder et al., 2005 (<i>submitted</i>)
Lightning Safety For Homes and Businesses	Disaster Safety Review, Institute for Business & Home Safety	Roeder and Willingham, 2004
Teaching Lightning Safety	Observer-The Magazine for Air Force Weather	Roeder, 2004
Lightning Safety For Schools And Other Public Buildings: An Update	Perspectives -- American Society Safety Engineers	Roeder and Vavrek, 2004
Lightning Safety Public Education – A Mandate For Broadcast Meteorologists	32nd Conference on Broadcast Meteorology	Roeder et al., 2003
Lightning Safety: It could save your life	Observer-The Magazine for Air Force Weather	Roeder, 2003a
Lightning—The Underrated Weather Hazard!	Road & Rec -The Air Force Journal of Occupational, Recreational, and Driving Safety	Roeder, 2003b
Lightning Safety—Mandate For Public Education	27th Annual Meeting Of The National Weather Association	Roeder et al., 2002
Lightning Safety For Schools	10th Symposium on Education in Meteorology	Roeder et al., 2001
Lightning Safety For Personnel At Cape Canaveral Air Station And Kennedy Space Center	Joint Army Navy NASA Air Force Safety & Environmental Protection Symposium	Roeder et al., 2000a
Lightning Safety Of Personnel And Launch Facilities At Cape Canaveral Air Station And Kennedy Space Center	National Interagency Coordination Group Conference on Lightning And Static Electricity	Roeder et al., 2000b
Lightning Safety For The General Public: Recommendations From The Lightning Safety Group	28th Conference On Broadcast Meteorology	Roeder and Madura, 1999

3.2 Hurricane Preparedness Education

Florida is frequently threatened by tropical cyclones. The personnel of 45 SW and KSC need to be aware of the threat and prepared to evacuate when necessary. This is especially important since the 45 SW and KSC facilities are on barrier islands with limited bridge access to the mainland. The 45 WS works with 45 SW Safety and Disaster Readiness and KSC Emergency Preparedness offices to provide hurricane preparedness training.

The official hurricane season for the Atlantic Basin is 1 June-30 November. The main annual training for hurricane preparedness is provided in conjunction with the National Hurricane Awareness Week, always the third week of May (www.nhc.noaa.gov/HAW2). This training consists of articles in the facilities' newspapers and newsletters, global e-mail, and recurring briefings over the facilities' closed circuit TV networks. The 45 WS also supports an annual 'hurricane day' that gives refresher training to KSC emergency preparedness workers. Since the hurricane season is 6-months long, refresher training is done in early August, just as Atlantic tropical cyclone activity usually begins to increase rapidly, rising to its peak in early September (Figure 7). A small amount of refresher training is done again at the start of October, to maintain awareness of the threat since two more months of hurricane season remain.

The hurricane preparedness training focuses on the main hurricane hazards and the need for advanced preparation. The main causes of hurricane deaths are

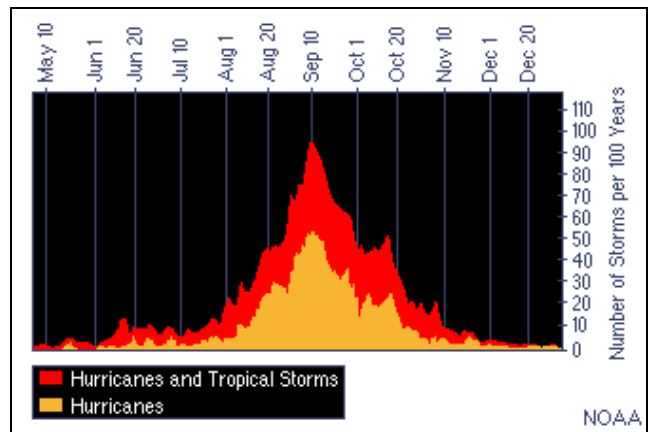


Figure 7. Tropical cyclone activity in the Atlantic Basin by time of year (National Hurricane Center).

shown in Figure 8. The preparations are classified by the chronological order of required actions: pre-season, approaching storm, evacuation, and recovery. Maximizing advanced preparation is vital since many personnel have duties to ready 45 SW and KSC facilities when hurricanes threaten, in addition to home and family needs. Advanced preparation also helps to avoid wasting time at crowded hardware and grocery stores, and to get ahead of the surge of traffic evacuating the coasts. The 45 WS has developed several resources to aid this training (Table 4).

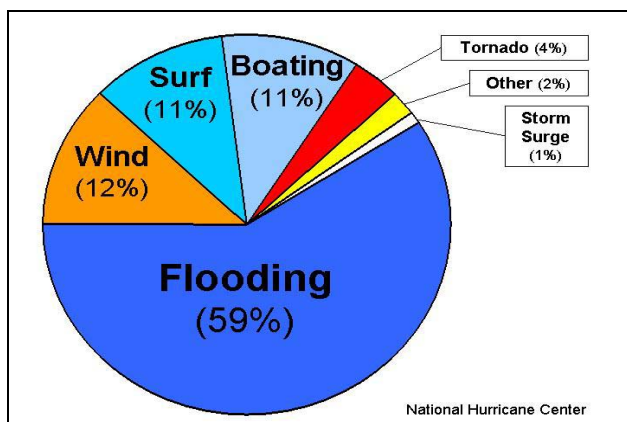


Figure 8. Causes of Hurricane Deaths (1970-1999), (National Hurricane Center)

TABLE 4. Hurricane preparedness support materials. Most undergo continuous incremental improvement.

TYPE	DETAILS
Briefings	Hurricane Preparedness, Hurricane Overview
Handout	45th Space Wing Hurricane Survival Guide (58 pp.)
Websites	45 WS: https://www.patrick.af.mil/45og/45ws 45 SW: https://www.patrick.af.mil/hurricane_prep/hurricaneprep.htm
Newspapers	Canned articles
E-mails	Canned articles
Newsletters	Canned articles
Storyboard	30 x 40 inch printed foam-board
Image Library	200 digital images of hurricanes and hurricane impacts
Tabletop Display	8 x 6 Ft, commercially produced: lightning safety, 45 WS mission, hurricane preparedness

3.3 Tornado Safety Education

The 45 WS area has two main seasons for strong tornadoes. The first season is late winter-early spring, usually February-April, and is associated with the passage of strong cold fronts. Recurring training for this strong tornado season is tied to the annual 'Florida Severe Weather Awareness Week', which is always the third third week of February. Tornado safety training is based heavily on the Department of Commerce (1995) tornado preparedness guide. A second round of recurring training is provided late in March, just before the climatological peak of this severe weather season. This second training advocates the use of NOAA Weather Radio (www.nws.noaa.gov/nwr), especially since many of these tornadoes occur at night, when sleepers may not hear outdoor warning sirens or hear warning announcements via the media. Also, some people may not have outdoor sirens in their communities.

The second season for strong tornadoes in east central Florida is associated with the rain bands and eye wall of land falling tropical cyclones. The training for these threats was previously discussed under hurricane preparedness training.

There is a third tornado season, but these are usually weak tornadoes that can occur with nearly any summer thunderstorm in Florida. These tornadoes are very small, shallow, and short-lived. This makes them difficult to detect and exceedingly tough to warn against. Fortunately, these tornadoes are usually F0-F1 in damage potential, so they are a comparatively lesser threat. The weather safety education program for these tornadoes is covered during the two strong tornado seasons.

3.4 Other Weather Safety Education

Florida Hazardous Awareness Week includes all the main weather hazards for this state: lightning, tornadoes and thunderstorms, hurricanes and flooding, marine hazards (waterspouts, large surf, high winds, and rip currents), wildfires and heat stress. Safety training for heat stress, rip currents, and wildfires is provided by 45 SW offices other than 45 WS.

3.5 Useful Websites

Websites useful in designing your own weather safety training programs are listed in Table 5, which is on the following page.

4. SUMMARY

The 45 WS provides comprehensive weather support to America's space program at Cape Canaveral Air Force Station and NASA Kennedy Space Center in Florida. Part of this support includes weather safety education for all launch customers and support staff. The 45 WS annual weather safety program is driven by climatology, but includes the flexibility to react to local real-world weather events. The program puts special focus on lightning, hurricanes, and tornadoes.

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TABLE 5. Useful weather safety websites.

ORGANIZATION	URL
LIGHTNING	
National Weather Service (Lightning Safety Awareness Week)	www.lightningsafety.noaa.gov
45th Weather Squadron (Lightning Safety)	https://www.patrick.af.mil/45og/45ws/lightningsafety (see 's' in 'https')
National Lightning Safety Institute	www.lightningsafety.com
University of Illinois/Chicago (Lightning Injury)	http://tigger.uic.edu/labs/lightninginjury/
Lightning Strike Electric Shock International (Support Group)	www.lightning-strike.org
HURRICANE	
National Hurricane Center	www.nhc.noaa.gov
National Hurricane Awareness Week	www.nhc.noaa.gov/HAW2
TORNADO	
Florida Disaster Preparedness (Florida Hazardous Weather Awareness Week)	www.floridadisaster.org/hwa
FLOOD	
National Weather Service Southern Region Headquarters (Turn Around, Don't Drown)	www.srh.noaa.gov/srh/tadd/
MULTIPLE HAZARDS	
National Weather Service	www.nws.noaa.gov/safety.html
National Severe Storms Laboratory (download coloring books)	www.nssl.noaa.gov (www.nssl.noaa.gov/edu/bm/bm_main.html)
NOAA Weather Radio	www.nws.noaa.gov/nwr
Federal Emergency Management Agency	www.fema.gov/tab_education.shtml
American Red Cross	www.redcross.org/services/hss/

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