# SKYWARNEWS

National Weather Service State College, PA - Fall 2005

*"Working Together To Save Lives"*

**Editors: John La Corte and Dave Ondrejik**

## Lake Effect Snow

**By Michael Dangelo, Senior Forecaster**

Many times during each winter you may hear that "Lake Effect" snows are on their way to Central PA. What are they, and how do they happen?

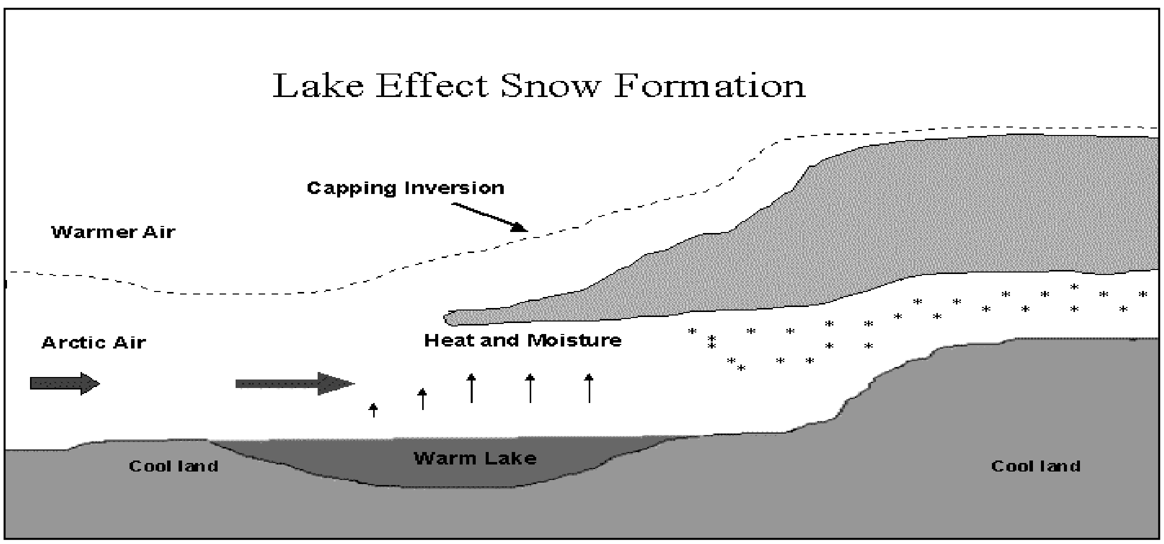



**Figure 1 - How Lake Effect Snows form.**

Lake Effect snows are snows that only happen because of cold air crossing the (relatively) warmer waters of the Great Lakes. If the lake was not there, the snows would not otherwise happen.

Typically, lake effect clouds and snows occur behind cold fronts, when the cold air is coming from the northwest. The warm lake water keeps the air right over the water very warm and moist. This condition (when warm air is under colder air, and rises rapidly) is termed "instability." This warm/moist air rises almost uncontrolled up through the cold air, forming clouds, ice crystals, and then snow.

The depth of this unstable layer is important, because it determines how high the clouds can grow, and therefore how intense the snow can be. The top of lake effect clouds are usually no more than 3 to 7 thousand feet tall. Despite being relatively small when compared to a summertime thunderstorm, lake effect clouds can produce lightning and thunder during very intense events.

Lake effect cloud growth is limited because most lake effect snows happen with high pressure building in after a cold front has passed. There is sinking, warming air aloft in the middle of the high pressure system. As this warm, dry air descends, it forms what is known as a "capping inversion." The cold, dense air at the surface is left as just a thin layer – trapped under the warmer air aloft. This inversion (when warm air is above cold air), or "cap," will usually make it all the way to the ground, squashing the unstable layer altogether. Another thing that can stop the lake effect snow machine is a switch of the winds (to a more southerly direction).

Some factors that affect the location, orientation, amount and intensity of lake effect snows are:

- The temperature of the air crossing the lake (how cold),
- The temperature of the lake water (how warm),
- The wind directions and speeds from the surface to the top of the clouds,
- The duration of the winds across the lake,
- The topography of the land that the lake effect clouds and snows are moving over.

**Temperatures:**

Lake effect snows will usually begin when the difference between the temperature of the lake water and the air about 5 thousand feet above the lake reaches at least 13 degrees Celsius (about 23 degrees Fahrenheit). Lake Erie water temperatures are usually in the 60s (Fahrenheit) at the beginning of autumn. However, the surface of Lake Erie does freeze up almost completely every winter, since it is the shallowest of all of the Great Lakes. Lake effect snow will not develop when the lake is frozen because ice transfers much less energy and moisture to the air than liquid water. But, it takes a long time (months) for the water to cool down. So, as the air becomes colder in the fall and winter, this temperature difference between the lake water and air temperature will increase, and the lake effect snows can become more widespread and more intense.

**Winds:**

Lake effect snows can take different shapes: either long, narrow "bands," or more-compact, individual "cells." Whether the snow is more banded or cellular, is controlled by the wind direction(s) in the cloud layer. Cells of lake effect snow usually move along, and do not sit in one place as long as bands of snow can. More intense/heavy snow can occur when the narrow, focused bands sit in place for a long time.

If the wind speeds are weak, the lake effect snows may not reach very far inland. Conversely, if the winds are stronger, they can carry the snow farther inland. If the winds change direction drastically with height (wind shear), the bands or cells may break up (or even intensify).

The direction of the winds as they move across the lake is known as the "fetch." For example, if the winds cross the lake perpendicular to the lake's long axis, the time that the cold air spends over the water is lessened. This is known as a "short fetch." This can reduce the inland travel of the snows. A short fetch for Lake Erie is a north-northwest wind. Winds that direct the cold air along the longest axis of the lake spend much more time over the water. This is known as a "long fetch." A long fetch can send more moisture into the clouds, and produce longer, more intense snow bands. A long fetch for Lake Erie comes when the winds are from the west-southwest. That situation has given Buffalo, NY some of the greatest lake effect snowfalls in history.

Figure 2 - Lake Effect Snow Bands generated by the Great Lakes (Lake Erie is in the lower right). Note the otherwise sunny conditions (dark areas) over the Upper Great Lakes.

Since lake effect snow bands and cells are usually rather small (they can be less than a mile wide) when compared to the vast snow shield from a large winter storm (which can cover many states), lake effect snows are very unevenly distributed. Your neighbor a half a mile away can pick up several inches, while you get little or none!

Winds and temperatures favorable for lake effect snows can last for hours, or even days. Obviously, the longer these conditions last, the more potential there is for the snows to pile up. Usually, the snows end as the capping inversion lowers, or when the winds switch to a more southerly (less favorable, and usually a warmer) direction.

**Topography:**

The topography of Pennsylvania also helps to lift the already-unstable and moist air. The elevations rise nearly 1500 feet from the Erie lakeshore to Western Warren County, a distance of only 20 miles. This mechanical lift is almost one-third the depth of a typical lake effect cloud and adds to the lift generated by the instability. The additional lift serves to increase the intensity of the snows. Topography also adds an extra complexity to the forecast. Windward-facing slopes and tops of the mountains can often pick up much more snow than the leeward slopes.

In Central Pennsylvania, most of the lake effect snow comes from Lake Erie. That is why the region from Lake Erie to 40 or 50 miles inland is known as the "Lake Effect Snow Belt." The most lake effect snow falls there. Other sections of

PA do receive lake effect snows, but to a lesser degree. Lake effect snows will often reach into Western and Central PA, but rarely into the southeast part of the state.

Occasionally, the mostly-open (unfrozen) waters from Lake Huron can enhance the Lake Erie-generated snows. More rarely, the wind directions can be favorable for lake effect snow bands off Lake Ontario to reach down into the Northern Tier, and Northeastern sections of PA, or even into our Susquehanna Valley counties. There was one event a few years ago in which a single lake-effect band from Lake Ontario reached all the way into Lancaster County, and produced an inch of snow on the PA Turnpike near Mount Hope.

**Conclusion:**

All these factors lead to a great challenge when trying to forecast the location, duration, intensity, and impact of these lake effect snow events. However, your National Weather Service will issue Snow Advisories when an average of 3 to 5 inches of snow is expected to fall in 12 hours or less, and Snow Warnings when 6 or more inches is expected in 12 hours or less.

## What Happens to Bugs in the Winter

**by Kevin Lipton, General Forecaster**

As the weather gets colder, and the days shorter, we usually see fewer bugs around outside, until one day – they may be difficult to find at all. Does that mean they simply vanish, only to reappear when the weather warms the next spring? Or do they all take cover in our warm homes, only to get out when balmy weather returns?

Insects, similar to birds, are cold-blooded. In other words, their internal temperatures are highly dependent on what the environmental temperature is. This is different than warm-blooded animals, such as humans, which maintain a relatively steady internal temperature, independent of their external temperature. Thus, for insects, colder weather can severely impact their daily activities, even to the point of death. So – with this sensitivity to external temperatures – how in the world can insects survive the winter? Well, different insects have various ways of coping with colder weather. One method of coping is by simply migrating to a warmer location. Obviously, only insects with wings can do this – and only a select few of them. Butterflies are one type of insect that migrate to warmer climes – in particular, the Monarch Butterfly often migrates to areas of northern Mexico. Other types of butterflies migrate to the southern United States during wintertime.

Another way in which some insects survive the winter is by slowing their activities into a “dormant” state. This “dormant” state is also known as diapause. During this state, insects remain inactive – all activities are temporarily suspended. Insects neither grow nor develop during this state – and their metabolic rate is kept just high enough to barely keep them alive. This is essentially a “hibernation” state. Additionally, insects reduce the water content of their bodies, which reduced the threat of them freezing to death. Perhaps more shockingly, many hibernating insects actually build up glycerol in their bodies during the fall, which acts as an antifreeze during the cold winter months.

Some insects, such as honey bees, cluster tightly together during winter months in hives, allowing the temperature of the hive to remain warmer than outside by vibrating their wing muscles. Where do they get the energy to do this? It's in the honey they collect during the warmer months!

Many other insects remain alive through the winter through a process known as "overwintering." However – they do this in different forms. One way of "overwintering" is by existing as immature larvae. For instance – caterpillars often do this by sheltering themselves with heavy covers of leaf litter, while grubs tend to burrow more deeply into the soil. Other insects overwinter as nymphs – which means they exist in a smaller, immature form of their parents. They nymphs sometimes overwinter in waters of ponds and streams – and even beneath ice. They even feed and grow during the winter months. Some of these nymphs include dragonflies and stone flies, as well as springtails. In fact – sometime springtails can be seen on snow during the winter on relatively mild days – their hopping motion gives then the nick name of "snow flea."

Several other insects and insect-like creatures overwinter as eggs – which were deposited by adults during the fall. Spiders often do this – they lay eggs during the fall, which then remain encased in egg sacs until the warm weather returns.

Of course – the easiest way to overwinter for any insect is to seek shelter in a warmer environment – which many spiders and ladybugs try to do during the late fall – such as entering homes!

Needless to say, insects do not simply disappear when the colder weather arrives. Although many do not survive the long, harsh winter, many insects do remain alive, just in a less active state during winter, only to become more active when spring arrives. Or, they just move to a more conspicuous location than during the warmer months. So – next time you wonder where all the bugs have gone – you just have to look harder, and you just might find them! But don't expect them to move terribly fast.

## A warm dry summer

**by John La Corte, Senior Forecaster**

After enduring 2 consecutive cool-wet summers, most of the state rebounded in grand fashion with a warm dry summer of 2005.

The "traditional" summer is marked by the months of June, July and August. This year saw the warm dry weather set in early and last right through the end of August, before the remnants of hurricane Katrina marked a change in the pattern bringing some cooler and drier weather.

While a dry summer can adversely impact local agriculture, the outdoor recreational community usually welcomes long periods with little or no precipitation. This year they were not disappointed as the summer ended up drier than normal over most of the state. Figure 1 shows that while most of the region remains abnormally dry, there have been no drought declarations. The main impacts as reported to the National Drought Mitigation Center have been reduced crop yields over some central parts of the state, and some water restrictions near the cities of Pittsburgh and Philadelphia. While it was dry, it was nowhere near the driest summer in history.

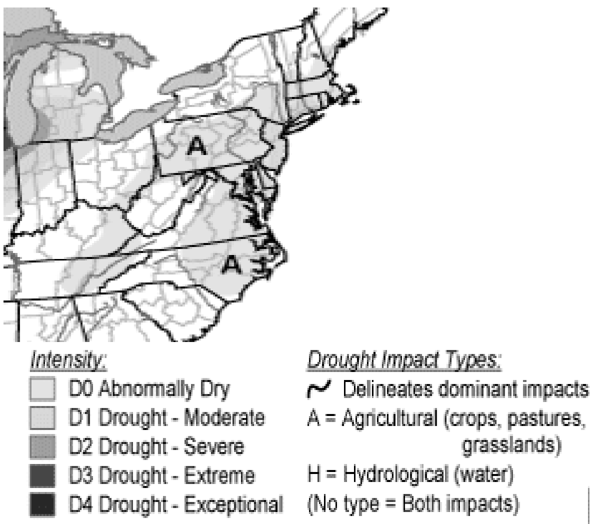



**Figure 1. U.S. Drought Monitor <u>http://www.drought.unl.edu/dm/monitor.html</u> shows abnormally dry conditions persisting into September.**

### Seasonal Summary

Table 1 shows that most of the state ended up much above normal for the summer months of June through August. Locations averaged anywhere from around 2 degrees to nearly 4 degrees above normal for the season. In fact it was the third warmest summer in history at the airport in Harrisburg. Averaging 76.6 degrees, the summer was 3.1 degrees above normal, ranking behind only the summers of 1966 and 1999 for warmth.

1966 - 77.6 (4.1 DEGREES ABOVE NORMAL)
1999 - 76.8 (3.3 DEGREES ABOVE NORMAL)
2005 - 76.6 (3.1 DEGREES ABOVE NORMAL)

Table 1 also summarizes the seasonal precipitation around the region. Rainfall was anywhere from 1 to more than 3 inches below normal for most reporting sites. The exceptions were at Bradford and Williamsport where the visit at the end of August by the remnants of Hurricane Katrina managed to push both of those sites above normal for the summer.

| | Temp | +/- | Rain | +/- |
|---|---|---|---|---|
| **Altoona** | **70.7** | 0.9 | **9.25”** | **-1.14** |
| **Bradford** | **66.0** | 1.8 | **16.60”** | **+2.95** |
| **Erie** | **73.2** | 3.1 | **9.68”** | **-2.09** |
| **Harrisburg** | **76.6** | 3.1 | **9.44”** | **-1.00** |
| **Philadelphia** | **77.8** | 2.4 | **10.19”** | **-1.31** |
| **Pittsburgh** | **73.5** | 2.8 | **11.40”** | **-0.06** |
| **State College** | **73.2** | 3.9 | **7.85”** | **-3.39** |
| **Williamsport** | **73.9** | 3.5 | **14.49”** | **+2.58** |

**Table 1. Summer of 2005 summary for temperature and precipitation**

The summer of 2005 can be compared with the very wet and cool conditions of the previous summer. It might be remembered that we saw the region inundated by the remnants of several tropical systems, resulting in Harrisburg and Williamsport observing their 4th wettest summers in history. Record flooding followed in September from the heavy rains as the dying tropical cyclones crossed the area. This season contrasted with most of the area only observing between 40 and 70% of the rain that fell a year ago.

Another measure of how warm it was can be inferred from the number of days it reaches 90 degrees or more during the summer. On average in Harrisburg the high temperature can be expected to top 90 about 16 times a summer. This year the mercury topped 90 degrees 24 times. In Williamsport the high temperature hits 90 or higher about 13 times a summer on average. This year they also saw 24 days with the temperatures of 90 or above. It might be recalled that last summer in Harrisburg it hit 90 just 3 times, in Williamsport it happened just once.

This year the ENSO is trending toward neutral conditions, meaning the equatorial Pacific Ocean temperatures are expected to remain near normal through early next year. Unfortunately when the ENSO is neutral, the predictability for the upcoming season's weather suffers, especially in the northeast United States. While the CPC feels that about the western 2/3rds of the country will be warmer than normal, locally they feel that there are equal chances that we will be either near,

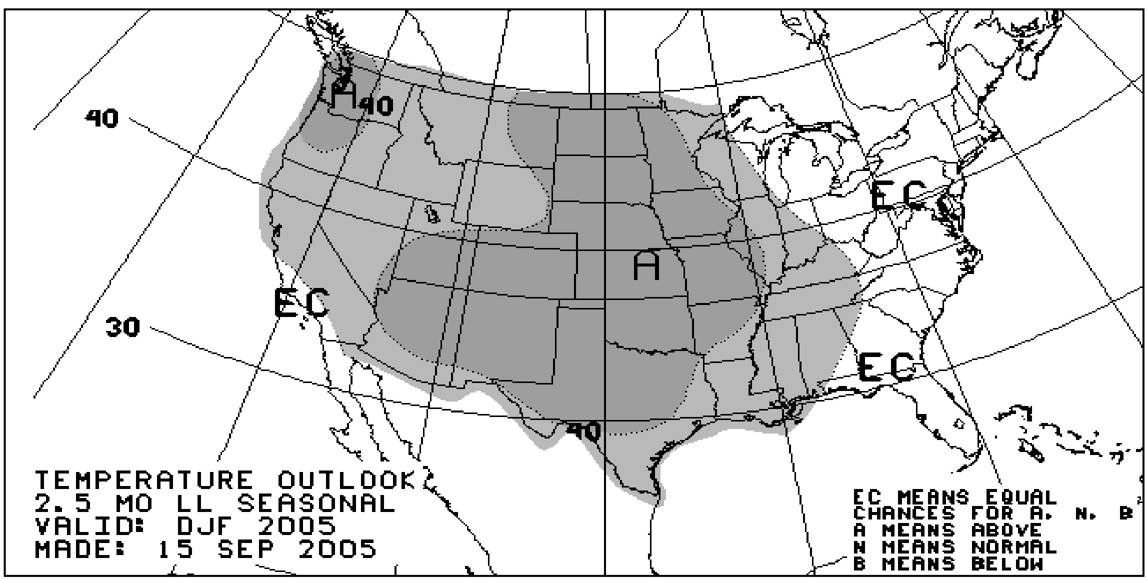



**Figure 2. CPC Winter Temperature Outlook**

## Seasonal Outlook

What does the upcoming winter hold in store for the region? The Climate Prediction Center (CPC) employs a very complex system that monitors and predicts a number of atmospheric indices, the most notable being the state of the "ENSO", or El Nino Southern Oscillation. This warming or cooling of the equatorial ocean waters in the central and eastern Pacific Ocean has huge ramifications on global weather patterns.

above or even below normal. While that sounds like a hedge, what it is saying is that under the current state of the ENSO, there is little or no predictability for the upcoming season.

So while the CPC forecast is really the "official" forecast for the country, we can always look elsewhere for other opinions. The always entertaining Old Farmer's Almanac is actually calling for a record breaking cold and snowy winter here in central Pennsylvania. They feel December and January will be especially

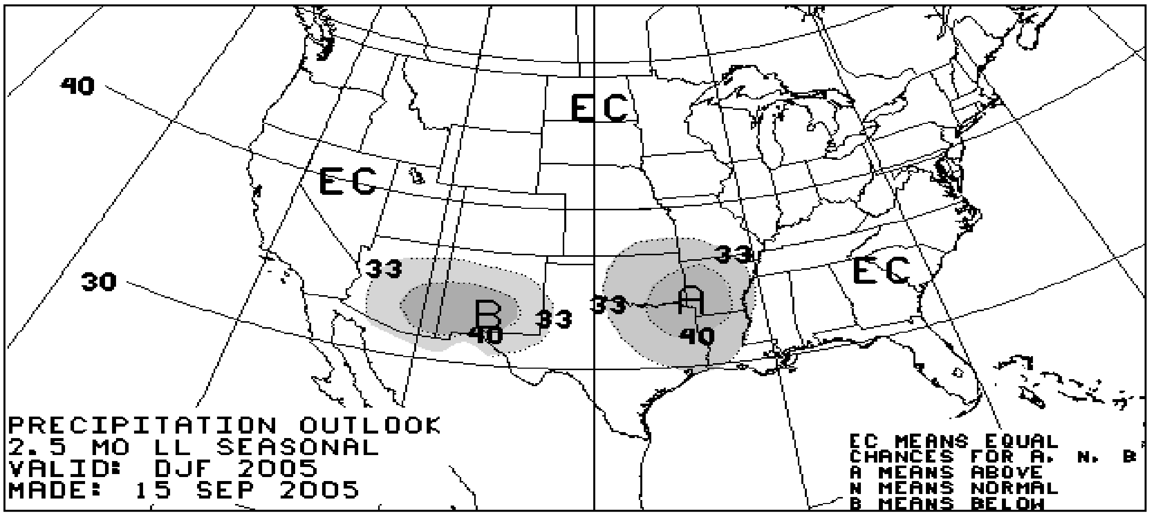



**Figure 3. CPC Winter Precipitation Outlook**

harsh with the end of the winter moderating some.

The office of the State Climatologist however has a different take on matters. They researched data back to the beginning of the last century. After looking up the 10 warmest summers since 1900, they found that 7 out of 10 times the following winter averaged warmer than normal. They believe that December has a good chance of being close to normal, but that the winter starting in January will turn warm and continue well above normal through February.

So take your pick, warm or cold? Snowy or not? As usual, we will all know for sure sometime around the Vernal Equinox (next spring). Stay tuned.

## Meteor Showers during the Upcoming Winter

**by Barry Lambert, Senior Forecaster**

Hydrometeors (precipitation we know as rain, snow, sleet and hail) have distant cousins that are literally from out of this world. Meteoroids (commonly called shooting stars), and their frequent, sometime brilliant luminary display during more prominent meteor showers, are tiny particles only about the size of a grain of sand that originate from the residue of comets. The lone exception to this is the Gemenid meteoroids which are tiny fragments from the Asteroid named 3200 Phaeton.

The quick, (but occasionally long) trail of light seen is caused by the meteoroids “compressing and heating” the air ahead of them as they encounter the Earth’s upper atmosphere at a speed of 10 miles per second (36,000 miles per hour!).

There are typically 10 to 12 “common” meteor showers each year. Depending on the location which the earth passes through this debris trail, you could end up seeing 15 to 25 meteoroids per hour streak through the sky (a common meteor shower), or a “meteor storm” with hundreds to thousands of meteoroids falling. Notable meteor storms occurred over northern France on April 26, 1803 (during the Lyrids), and the Leonids in November of 1799, 1833, 1866 and 1966. The Leonids (fragments of the Comet Temple-Tuttle) peak at a frequency of approximately 33 years (the comets orbital period around the sun). So, although the Leonids are referred to as “the King of the Meteor Showers”, by the years given above, this year is not expected to be one of the more memorable displays.

Below is a listing of the major meteor showers and their respective dates this fall and winter (in the case of the “Major” events) to see the glowing trails of heated air in front of the tiny celestial particles.

Orionids October 15-19, 2005
Maximum Oct. 21 @ 313 AM EST

Leonids November 13-20, 2005
Maximum Nov. 17 @ 817 AM EST

Northern Taurids Oct. 12 – Dec. 2, 2005
Maximum Nov. 4-7

Southern Taurids Sep.17 – Nov.27, 2005
Maximum Oct. 30 - Nov. 7

Geminids December 6-19, 2005
Maximum Dec. 14 @ 924 PM EST

Ursids December 17-25, 2005
Maximum Dec. 22 @ 553 AM EST

Quadrantids Dec. 28, 2005 – Jan 7, 2006
Maximum Jan. 3 @ 1120 AM EST

Happy star gazing!

# The 2005 Hurricane Season

**by John La Corte, Senior Forecaster**

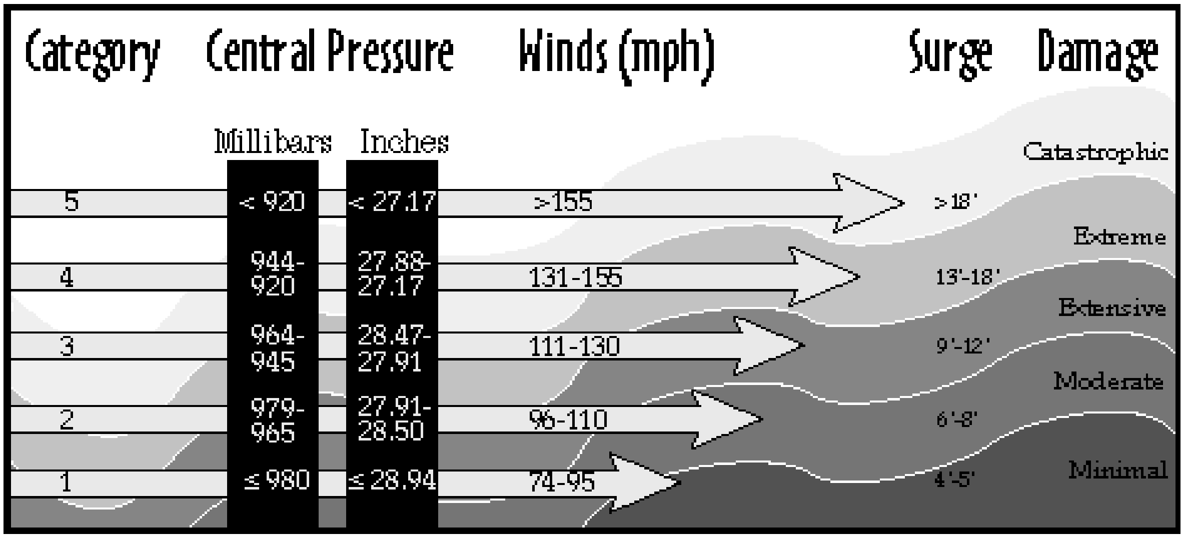
It was late September last year when the final visit to the region was made by one of the season’s many tropical cyclones. In 2005 there were 15 named tropical storms, 9 of which attained hurricane status. In all we were affected in some way by at least 4 of the storms as they moved out of the tropics into the mid latitudes and the result was some of the worst flooding in Pennsylvania in over a decade. The season started at the end of July and the last storm of the season finally died on December 3rd.

This year the season got off to a furious and early start. The first storm, Arlene was named in June 8th and as of the last week in September we have already had 17 storms earn names in the Atlantic.

The season has already been record setting in a number of ways. There were 5 named storms in July, the most ever for the month since hurricanes started being tracked in the mid 1800’s. Combined with the 2 storms that formed in June, 2005 became the first year in history that so many storms have formed that early in the year.

Hurricane Dennis formed in July, it was the earliest storm to reach category 4 status in the Caribbean (Saffir Simpson Hurricane scale, Figure 1). It also was also the strongest hurricane to ever form so early in the season. Dennis moved up over Cuba causing heavy damage and eventually made landfall on the Florida panhandle near Navarre Beach as a category 3 hurricane.

If Dennis wasn’t an ominous enough sign of a severe hurricane season, it was




| Category | Damage |
|---|---|
| 1 | some damage to trees, shrubbery, and unanchored mobile homes |
| 2 | major damage to mobile homes; damage buildings' roofs, and blow trees down |
| 3 | destroy mobile homes; blow down large trees; damage small buildings |
| 4 | blow down all signs; damage roofs, windows, and doors; completely destroy mobile homes; lower floors of structures near shore are damaged by flooding |
| 5 | extensive damage to homes and industrial buildings; blow away small buildings; structures within 500 meters of shore on the lower floors which are less than 4.5 m (15 ft) above sea level are damaged |

**Figure 1. Saffir Simpson Hurricane Scale**

followed by Emily which proved to be an even stronger storm in the Caribbean. After forming east of Granada during the second week of the month, it moved steadily westward through the Caribbean strengthening to just below category 5 status before slamming into the Yucatan Peninsula near Cozumel.

The season so far has culminated with the development of Hurricane Katrina, a horrific storm. Katrina formed in the Bahamas and moved southwestward across southern Florida as a relatively weak hurricane. After emerging over the southeastern Gulf of Mexico, Katrina became a monster and took aim at the Louisiana-Alabama coast line. After deepening to category 5 status, the storm weakened only slightly just before landfall and hit the coast as a strong category 4 storm. It was in fact the 4th most intense hurricane to ever form in the Atlantic basin since records have been kept.

Of course the affects of Katrina are by now widely known. Devastating flooding occurred in the city of New Orleans when the city's levee system failed in at least 2 places. This resulted in nearly 80% of the city being inundated and caused as yet an untold number of dead, and damage that will reach many billions of dollars.

On the heels of Katrina came 3 storms of relatively little importance, Lee, Maria and Nate. All managed to stay out over the Atlantic and cause few if any problems. After Nate came Ophelia. She meandered a bit off the southeast Atlantic coastline before slowly moving along the North Carolina coast. Ophelia wasn't remarkable intensity-wise, but it did manage to cause severe beach erosion due to the long period of time the storm lingered very near the shoreline.

The latest storm as of this writing was Rita. Another blockbuster hurricane in the Gulf of Mexico, Rita became the 3rd most intense hurricane ever in the Atlantic basin. Luckily for residents along the Gulf coast, Rita weakened considerably before coming ashore. After reaching category 5 status on September 22nd, Rita weakened to a strong category 3 storm as it hit near the Texas-Louisiana border on September 24th. While causing a great deal of damage, even causing the re-flooding of many areas in New Orleans, it could have been much worse had Rita maintained her category 5 fury.

### Hurricane Activity

What is causing the unprecedented hurricane activity? While there is a known correlation to decreased tropical activity in the Atlantic basin during El Nino years, and some point to global warming as a culprit when seasons are unusually active, research suggests that hurricane frequency tends to be governed mostly by what is referred to as a multi-decadal signal. This is a cycle of oceanic and atmospheric conditions that alternatively supports or suppresses hurricane activity, and it is believed to last about 20 years. The current increase in activity began about 1995, which places us in the middle of a period of higher than usual activity. Individual years may vary, but it looks like we should expect another 10 years or so of above normal tropical cyclone activity in the Atlantic basin.

## FROST - a year-round experience in Pennsylvania!

**By Paul Knight, State Climatologist and John La Corte, Senior Forecaster**

The Pennsylvania State Climate Office has initiated a new observation program known as FROST (Frost, Rain, Optics, Snow and Thunder). This program will be composed of a network of volunteers who will take daily observations and document significant weather events. These observations will be recorded through an easy-to-use web based entry form. We are specifically looking for individuals not already in a weather network.

Our goal is to gather the data from as many parts of Pennsylvania as we can find, especially in lesser populated areas. This data will be collected, assessed and displayed in an easily accessible format on the CoCoRaHS website which can be found at http://www.cocorahs.org/.

Each volunteer is requested to record data in the following categories: Daily Rain, Intense Rain, Number of Thunder Claps, Daily Snow, Snowflake Shape, Optical Effects and occurrences of frost. Volunteers receive online training with instructions and an occasional training seminar offered in specified locations in the state. Each volunteer will receive a packet with instructions on instrument sighting and measurement techniques. The FROST web site is at: **http://climate.met.psu.edu/data/frost/** All new volunteers will find reporting and data entry procedures on the CoCoRaHS website.

Since the program has just begun, the PA Climate Office is still in the process of recruiting volunteers. Each volunteer will be providing valuable information that will be used to expand our climatological record as well as verify daily forecasts. We are expecting to award the first dozen volunteers from NWS contacts a free rain gauge! So, please spread the word to help out your state climate office. Email **psc@mail.meteo.psu.edu** today if you have any questions.

This request for volunteer observations is in addition to any reports you would normally pass along to the National Weather Service.

Sincerely,
The PA State Climate Office

## Central Pennsylvania's Cool Season Severe Weather - Narrow Cold Frontal Rainbands (NCFRs)

**By Greg DeVoir, Senior Meteorologist**

As central Pennsylvania moves through autumn, a meteorologist's fancy shifts from memories of summer's violent storms and oppressive heat to the arrival of winter and its often chilly and snowy extremes. But, as anyone who routinely follows the weather will attest, the transition is hardly ever a smooth one.

Meteorological autumn sets in over Pennsylvania as successive Canadian cold fronts cross Pennsylvania with increasing frequency between September and November. Many can pack a significant and dangerous punch with a combination of strong wind gusts and locally heavy rainfall. A key small scale feature often associated with such significant events is the Narrow Cold Frontal Rain Band (NCFR).

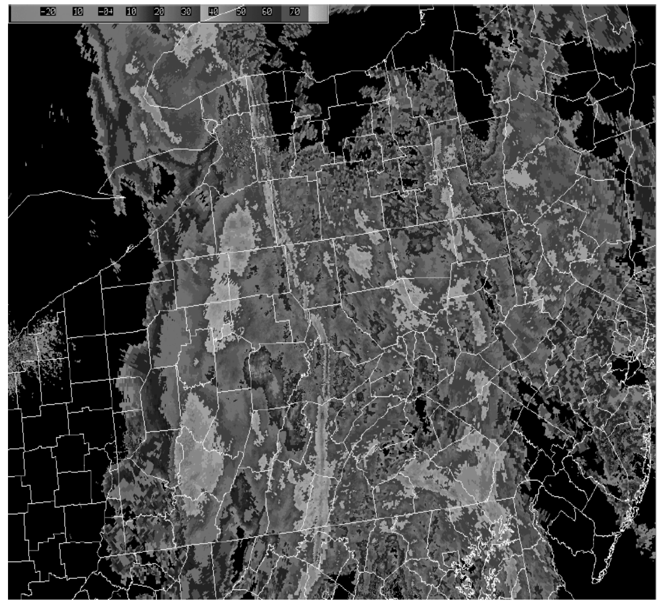


**Figure 1. Regional Doppler radar imagery showing NCFRB slicing across central Pennsylvnaia at 1142 am on December 23, 2004.**

NCFRs form when a sharp, forward-moving cold front interacts with abundant moisture and limited instability ahead of the frontal boundary. The presence of strong low-level shear (rapidly changing wind speed and direction close to the ground) across the front results in an intense and nearly vertical (upright) updraft, producing an intense, narrow band of heavy precipitation known as an NCFR. The arrival of an NCFR is signaled by a nearly instantaneous burst of heavy rain and wind, often resulting in widespread tree and power line damage, especially prior to autumnal leaf drop. The strong wind and heavy rain are usually short-lived, but the damage can be extensive.

NCFRs usually occur a few to several times each year. While they can occur at any time of year, they are most likely during the fall when strong Canadian weather systems penetrate southward into the contiguous United States, when temperatures and humidity levels (and hence instability) have dropped.

Examples of NCFRs within the past 12 months include November 25, 2004, December 23, 2004 (shown in Fig. 1), January 13-14, 2005, and most recently September 29, 2005 (shown in Fig. 2). On September 29, severe wind gusts and damage occurred as a cold front and NCFR blasted across Central Pennsylvania between 4 am and 8 am. Climatologically and historically speaking, Pennsylvania does not typically see severe weather at that time of the day, since the instability that drives most severe weather/damaging thunderstorm winds is lacking during the late night and early morning hours. However, this was not a preventive factor in this case, since NCFRs require only neutral to slight instability to develop and affect a wide area.

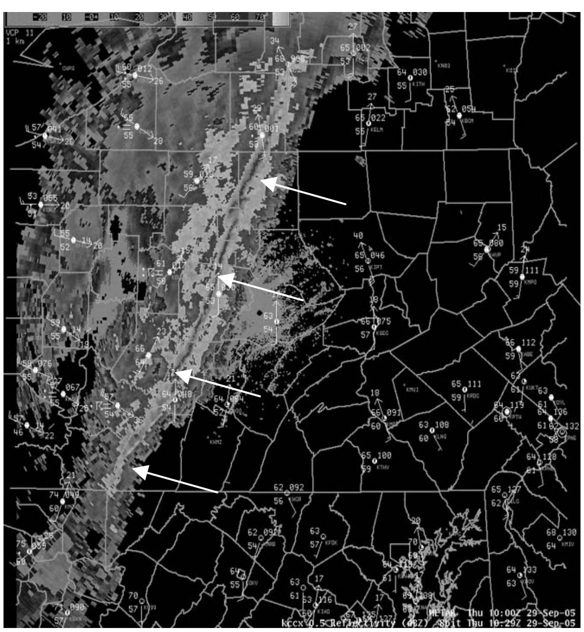


**Figure 2. Regional Doppler radar reflectivity of NCFR over central Pennsylvania at 529 am on September 29, 2005.**

Be alert for potential NCFRs throughout the fall and early winter, and be sure to report any damage to your local law enforcement and/or the National Weather Service in State College, PA.

## Atmospheric Optical Phenomena

**By Barry Lambert, Senior Meteorologist**

**Rainbows,** supernumerary arcs, lunar rainbows, halos, sundogs, and sun pillars are all examples of atmospheric light reflection and refraction by raindrops and ice crystals.

**Rainbows** (made up pf the seven colors – red, orange, yellow, green, blue, indigo and violet) are always observed in the same location relative to both the viewer and the sun (which is at the viewer's back). A rainbow is formed by light refracted twice, and reflected once inside a raindrop. The exact angle between the emerging light from the raindrop and the observer dictates what color is seen.

The angle between the ray of incident light from the sun and the outer (red) edge of the rainbow is always 42 degrees (slightly less for the other 6 colors of the rainbow). You can see the biggest arc of a rainbow (highest in the sky) just prior to sunset.

The clarity of a rainbow is related to the size of the rain drops. Larger drops (diameters of a few millimeters) produce sharp colors and boundaries, while smaller drops (diameters of about 0.01 millimeters) lead to overlapping, faint colors.


**Secondary Rainbows** develop from two internal reflections and the rays of light exit the raindrop at an angle of 50 degrees rather than 42 degrees, which creates the secondary bow outside of the primary one. Another interesting feature of secondary rainbows is that the arrangement of colors is reversed.

**Supernumerary Arcs** are faint arcs just inside and near the top of the primary bows. They form from the interference of light along specific rays within the drop. When two rays of light are scattered in the same direction within the raindrop, they could interfere with each other. If the rays "constructively" interfere with each other then a brightened color occurs. Conversely, when the interference is destructive, the brightness of the color is reduced.

**Lunar Rainbows and Fog Bows** are much fainter compared to those produced by sunlight. In the case of lunar rainbows (top image), the obviously dimmer amount of light from the moon is the reason optical dimming, while very small cloud droplets cause a fog bow (bottom photo) to lack much definition to the colors. Lunar rainbows have been infrequently observed since the time of Aristotle. Both lunar rainbows and fog bows occur in the same manner as rainbows, which is by refracted and reflected moon and sunlight.

This **fog bow**, created by headlight of a car, also contains a Brocken spectre (distorted shadow) and glory (bright light refection at the center).

**Sundogs** are often seen on a cold, sunny morning or evening when the sun is low in the sky and the air is filled with ice crystals. The sunlight is refracted (bent) by the ice crystals creating an image of the sun on either or both sides of the sun.

**Halos** are formed when sunlight is refracted by ice crystals, often found in a thin, high-level cirrus or cirrostratus cloud. The typical total angle of the two refractions from the original path of the sunlight is 22 degrees. Therefore, a ring of light is observed at 22 degrees from the sun or moon.

**Tangential Arcs** are patches of bright light occurring along a halo. This occurs when sunlight is refracted by falling hexagonal ice crystals with their long axis oriented horizontally.

Below is a photo of a halo (large circle), sundog (bright on the left side of the halo), and tangential arc (top of the halo) occurring all at once.

**Light Pillars** occur when bright light passes through a part of the atmosphere containing a large number of ice crystals (which are found in various sizes and shapes as stars, needles, columns and plates). Sun pillars are the most common form of light pillars, which can also be produced by moonlight and strong artificial light such as a street lamp. The pillars are a thin channel of light that extend vertically above and below the light source. Most sun pillars are noted when the sun is 6 degrees or less above the horizon.

**Glories** always occur directly opposite the sun, and are centered at the "antisolar point" Therefore, they occur below the horizon, except at sunrise and sunset.

You can witness a glory whenever mist or cloud is beneath you and the sun breaks through to shine on it. Glories can often be seen on while standing on a mountain or hillside with clouds below, also from aircraft and in sea fog and even indoors.

A glory is created when light is scattered backwards by individual small water droplets.

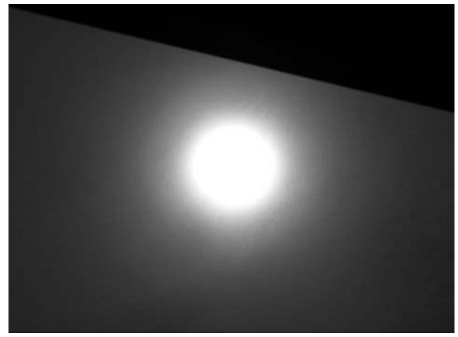
They have a bright centre but not nearly as bright as the corona's aureole. The rings of a glory are delicately colored, similar to those of a corona, blue on the inside changing through greens to red and purple on the outside. The ring intensities decrease much more slowly than those of the corona and three or four rings are sometimes visible.

Shadows converge on the antisolar point and so glories are nearly always accompanied by your shadow, or in this case, that of the aircraft you are in. When the shadow is grotesquely distorted by perspective it is called a "Brocken spectre".

**A corona** is typically seen around the sun (top photo) or moon (bottom photo) when a veil of thin clouds (made of small water droplets or ice) covers the sky.  Lunar coronae are witnessed much more frequently than those around the sun. They are seen when the clouds are thin enough that each single corona light ray reaching the eye is scattered or diffracted by only one droplet. Obviously, the whole corona is made up of a large number of droplets individually scattering the moonlight or sunlight.

Sometimes as clouds pass over the moon (or sun) the corona shrinks and swells as different sized droplets mould it. Small droplets make the largest coronae with aureoles a few moon diameters across.

There are no pure, individual colors in coronae. Corona and iridescent colors often have components from two or more quite different wavelengths resulting form the overlap of different diffraction orders. This is what gives the iridescent colors their special "vibrant" quality.



## Ensemble Forecasting and Training

**By Richard Grumm, Science and Operations Officer**

The National Weather Service office in State College commenced using ensemble forecast data to improve weather forecasting in Pennsylvania in 1999. Since that time, the office has taken a lead in using ensemble forecast data in the forecast process. The office has also become actively involved in training related to using ensemble forecast data.  This article will explain what an ensemble prediction system is and the training activities our office as conducted to use ensemble data more effectively.

Historically, weather forecasts beyond about 6-hours are produced using output from numerical weather prediction (NWP) model. The model typically is provided a set of initial conditions or simply a "snap shot" of what the weather was at a specified point in time. This initialization process is accomplished four times a day. Once the model has been initialized it runs to a specified forecast time, producing "snap shots" of what the weather might be at 3 hourly time intervals. Global models require knowledge of conditions over the entire planet while regional models require data over the region of interest.

Until the late 1990s, only a few "deterministic" models were run as described above. Occasionally, the models would miss significant weather events or the two primary models would produce widely different forecasts. The poor forecasts are often attributed to missing information during the initialization of the model and the mathematical equations used to produce the forecasts. Believe it or not, small errors in the initial conditions, referred to as uncertainty in initial conditions, are often the source of very large errors in model forecasts. Other sources in the uncertainty also included the mathematical equations used to forecast the weather at some future time, which can also be quite large.

To overcome the uncertainty in initial conditions, different set of initial conditions can be used to make forecasts from a single model. The National Weather Service began running its global forecast model with varied initial conditions in the late 1990s. More recently, using different initial conditions and different models, a more advanced ensemble prediction system was developed to forecast over North America. This system has the advantage of both varying initial conditions and varying the mathematical methods used to make the forecasts.

These ensemble forecast systems allow for the production of more probabilistic weather forecasting and they help identify areas of high uncertainty in weather forecasting. Ensemble forecasting methodologies and products will increase over the coming years and forecasters will have to learn how to use these products.

The National Weather Service in State College produces products from the ensemble prediction system to aid in forecasting. Locally, we have been training our staff on how to use ensemble forecast products since 2000. Our office recently was invited by the World Meteorological Organizations (WMO) to teach meteorologists in other countries about using ensembles in the forecast process. A representative from our office attended WMO workshops in Brasilia, Brazil in January and in Shanghai, China in April of 2005. In Brasilia, forecasters from South and Central America and the Caribbean region were instructed about ensemble and ensemble forecasting techniques. In Shanghai, meteorologist from Asia, Indonesia, India, Pakistan and the Middle East were provided similar instruction. Our office is also actively involved in a national training program to use of ensembles in producing more accurate forecasts of winter storms.

**Picture from Shanghai China. Rich is in the front row, 5th from the left.**

**Editors Note: Ensemble forecasting is cutting edge technology and Mr. Grumm has been instrumental in spreading this science throughout the NWS and the world. Mr. Grumm is one of the world's leading experts in this field and we are honored to have his expertise at the State College office.**

## New Office Location – FINALLY!!!!

**By Dave Ondrejik, Warning Coordination Meteorologist**

By the time this newsletter arrives to you, we should be in our new building and hopefully the move went smoothly for us…and transparent for you.

How does one accomplish this monumental task??? Well, with a lot of help from your friends and excellent leadership in planning. Out Electronics System Analyst (ESA) Les Thario has been leading this daunting task for more than a year.

During the move we will be sending a contingent of staff to the Binghamton, NY office to issue forecasts for central Pennsylvania and the change should be transparent to all our users.

Anyway, our new mailing address is:

National Weather Service
328 Innovation Bvld
Suite 330
State College, PA 16803

We will be keeping the same number for you to report weather information (1-800-697-0010).

At this point, we are planning for an Open House in the Spring/Summer of 2006 to show off our new building and technology. When the date is set, we will send each of you the information.

Thanks again for each and every spotter report you send. They are very valuable in completing the National Weather Service's mission.

**Above is a picture of new office building at Innovation Park. We will be occupying a portion of the third floor. Note the satellite dish on the roof is the main satellite dish through which we obtain all our weather data.**

SKYWARNEWS

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227 West Beaver Ave
Suite #402
State College, PA 16801

**TO:**