

Extreme Radiational Cooling Differences Due To Soil Type

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Overview: Under ideal radiational cooling conditions, i.e. clear skies and calm winds, isolated locations along the coastal plain of eastern North Carolina often have much colder minimum temperatures than the surrounding area. Under ideal conditions it is not uncommon for some of these areas to have minimum temperatures that are 10 to 15 degrees colder than weather stations located nearby. These “cold spots” occur in areas that on the surface appear to be less than ideal for being colder, in that they occur near a large body of water (Atlantic Ocean), and are often located near smaller bodies of water such as swamps or bays. One such location is a remote automated weather station (RAWS) that is located in the Holly Shelter game land of Pender County, North Carolina. Between 2002 and 2008, this station has recorded single digit temperatures 13 times. Nearby at Wilmington, NC (ILM), records have been kept since the late 1800s. At this site, single digit temperatures have been recorded only 11 times. These “cold spots” have been noted up and down the coast of North Carolina (Image 1).

Motive: The interest in documenting this microclimate came from a spike in calls that we received from blueberry farmers each spring telling us that our forecast minimum temperatures were off by as much as 10 degrees on some nights. When forecast temperatures were thought to be near critical values that may produce a frost or freeze, they would use our forecast temperature as a guide and then subtract 10 degrees to get a more accurate value for their location. Data from our COOP observers confirmed that it may be slightly cooler near the blueberry farmers, but not to the extent that they claimed. Due to the gaps in data, and the consistent claims made by the farmers, could we be missing a microclimate that exists in our area?

Research: The first step taken to confirm the existence of colder microclimates was to use tools we had in the office as a first step. On a clear night and calm night where you could expect ideal radiational cooling conditions, by adjusting the color curve on the infrared satellite, the coolest locations in the CWA would become apparent. Over the course of a few ideal nights, by using the sampling tool in AWIPS, three large cold spots were found in our CWA (Image 2). The first cold spot was located roughly where the calls from the blueberry farmers came. The other two cold spots were more puzzling and unexpected because they were closer to the coast and therefore expected to be warmer. These other two cold spots however would prove to be the key in understanding why these cold spots may exist.

The research focused on the two cold spots located near the coast, one in the Green Swamp of Brunswick County and one in the Holly Shelter game land of Pender County.

Both the Holly Shelter and Green Swamp areas were selected because both had Remote Automated Weather Stations (RAWS) located within them and according to the information from the infrared satellite data, were much colder than the location of the blueberry farmers.

Both the Green Swamp RAWS, located at Supply, NC and the Holly Shelter RAWS, located at Back Island, had been calibrated recently so the data was thought to be good. The RAWS site at Back Island, which is location #3 (Image 2), was selected as the site to monitor because this station was the closest to the coldest spot in our CWA. To ensure that the RAWS station's data was accurate, on an ideal radiational cooling night in late October, a Davis weather station was installed next to the RAWS temperature sensor (image 3). The Davis station's temperature sensor had been placed in an ice bath prior to installation to ensure that it was also accurate. The next day the minimum temperature recorded with the RAWS sensor was 27.0 degrees Fahrenheit while the minimum temperature recorded with the Davis sensor was 26.6 degrees Fahrenheit. This confirmed that the RAWS sensor was accurate and could be used against others RAWS and ASOS sites nearby.

Over a week later on the night of October 30th, 2008, a large area of high pressure located over the Carolinas combined with a colder than normal air mass in place, characterized by 850 mb temperatures 1 standard deviation below normal, provided ideal radiational cooling conditions over eastern North Carolina. Hourly temperatures were plotted from 4 surrounding ASOS stations and the RAWS station at Back Island (Image 4). The ASOS stations used were: Wilmington, NC (ILM), Florence, SC (FLO), Lumberton, NC (LBT), North Myrtle Beach, SC (CRE), along with Back Island, NC (BKIN7), which is the RAWS station located in the Holly Shelter game land. While 3 out of the 4 ASOS sites are located more than 70 miles away from this site, Wilmington, NC (ILM) is located just 19 miles to the south-southwest of this site. Image 4 shows that the starting temperature at 5 pm on the evening of the 30th and the end temperatures at 9 am on the morning of the 31st of October are all very similar. The biggest difference in temperature occurs between 5 pm and 9 pm on the evening of the 30th, when radiational cooling is expected to be at its peak.

Forecasting: The temperature departure between Back Island and the surrounding area is at its maximum when radiational cooling conditions are ideal. An example of this occurred during a three day stretch in mid January of 2003. Between the 23rd and 24th, a deep cut off low at 500 mb moved from the Ohio Valley off the coast of the DELMARVA Peninsula, just north of eastern North Carolina. At the surface, low pressure well off the coast from Virginia, combined with high pressure over the Midwest produced a strong pressure gradient along with strong cold air advection (CAA). 850 mb temps were 3 standard deviations below normal during this time. With less than ideal radiational cooling conditions on the morning of the 23rd, partly due to winds but mostly cloud cover, both Wilmington and Back Island had the same minimum temperature (Image 5). By the morning of the 24th the pressure gradient was still tight; enough to

produce around a 10 mph wind at Back Island, but the skies were less cloudy, allowing for some cooling but far from ideal. Ideal radiational conditions were in place by the evening of the 24th into the morning of the 25th. This is when the largest temperature difference occurred between Wilmington and Back Island (Image 5). In summary, the most extreme temperature differences will occur under clear skies and calm winds, with some difference if the conditions are less than ideal, and no difference if radiational cooling effects are non-existent.

Soil Type: Synoptically speaking, it was apparent that typical criteria for good radiational cooling nights would determine when extreme differences would be possible in our CWA, but it still did not explain what made these areas unique. Past research in the Northeastern US showed that large minimum temperature extremes occurred in New Jersey in an area known as the Pine Barrens. These temperature extremes were related to soil type, where the Pine Barrens area had a soil that was a good radiator of heat. This research led me to study the soil types of the area as a possible explanation of the cold spot phenomena. The state of North Carolina soil type map (image 6), constructed in 1974, shows that the three cold spots in our CWA have similar soil types (soil type 43). Some isolated areas of the Green Swamp and especially the Holy Shelter game land, where Back Island is located, have soil type 41. Soil type 41 tends to not have as many clay particles in it as soil type 43. Both soil types 41 and 43 appear to be good radiators of heat and this allows for extreme minimum temperature departures from the surrounding area. Soil type 41, which is located in the Green Swamp and Holly Shelter game lands, is a slightly better radiator than soil type 43, due to content consisting more of sand. Image 1 which showed that these cold spots were not unique to our CWA, but existed up the coast, matches up well with image 7 which shows soil type 41 occurs up the coast of North Carolina in isolated pockets.

GFE: To incorporate these microclimates into the gridded forecast, edit areas were created in GFE that highlighted the cold spots. A smart tool was then created that would allow these areas to be modified based on how ideal the radiational cooling was. Based on past observations from the RAWS sites, along with infrared satellite data, the smart tool was tweaked so that within these colder spots, some variation did exist. This ensured that some of the coldest spots, such as the Holly Shelter game land, were 3 to 5 degrees colder than the first area of interest (blueberry farmers).

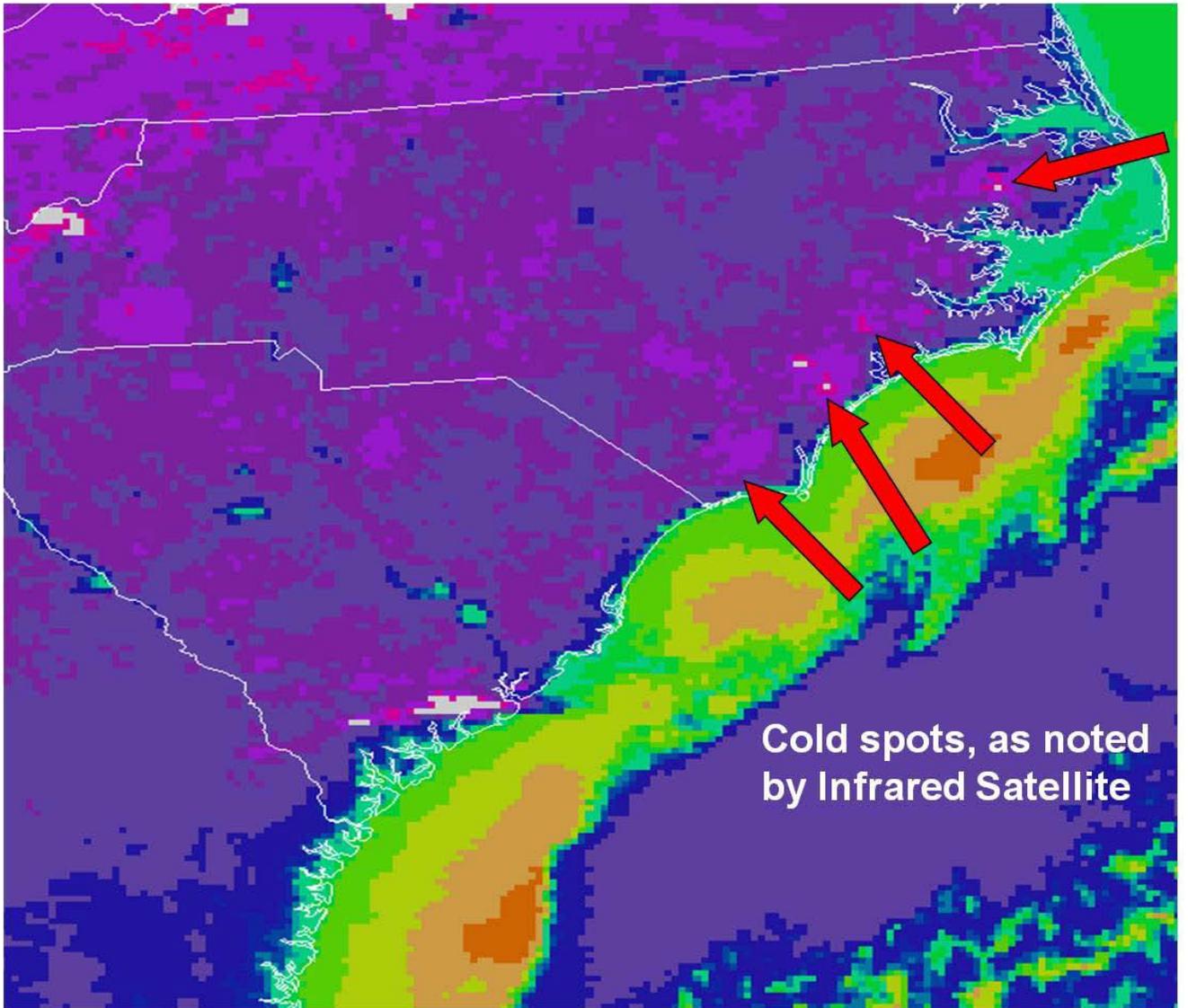


Image 1

Infrared satellite picture just after sunrise depicting the location of cold spots across eastern North Carolina. Under a clear sky, the infrared satellite is measuring the outgoing radiation from the ground, thus as a remote sensing tool it can measure areas of colder or warmer temperatures.

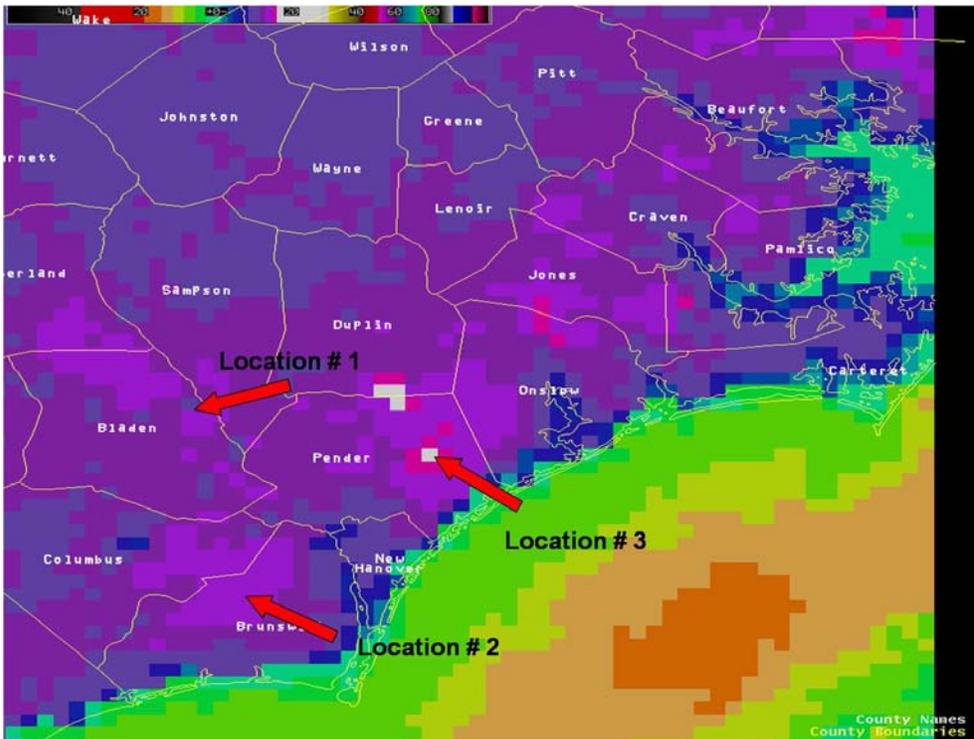


Image 2

This is Image 1, zoomed in. Location #1 corresponds to where the blueberry farmers are, Location #2 is the Green Swamp, and Location #3 is the Holly Shelter game land. Location #3 is where the Back Island RAWS site is located.



Image 3

The temperature sensor from the RAWS site (left) and the sensor of the Davis weather station (right).

October 30th - 31st, 2008

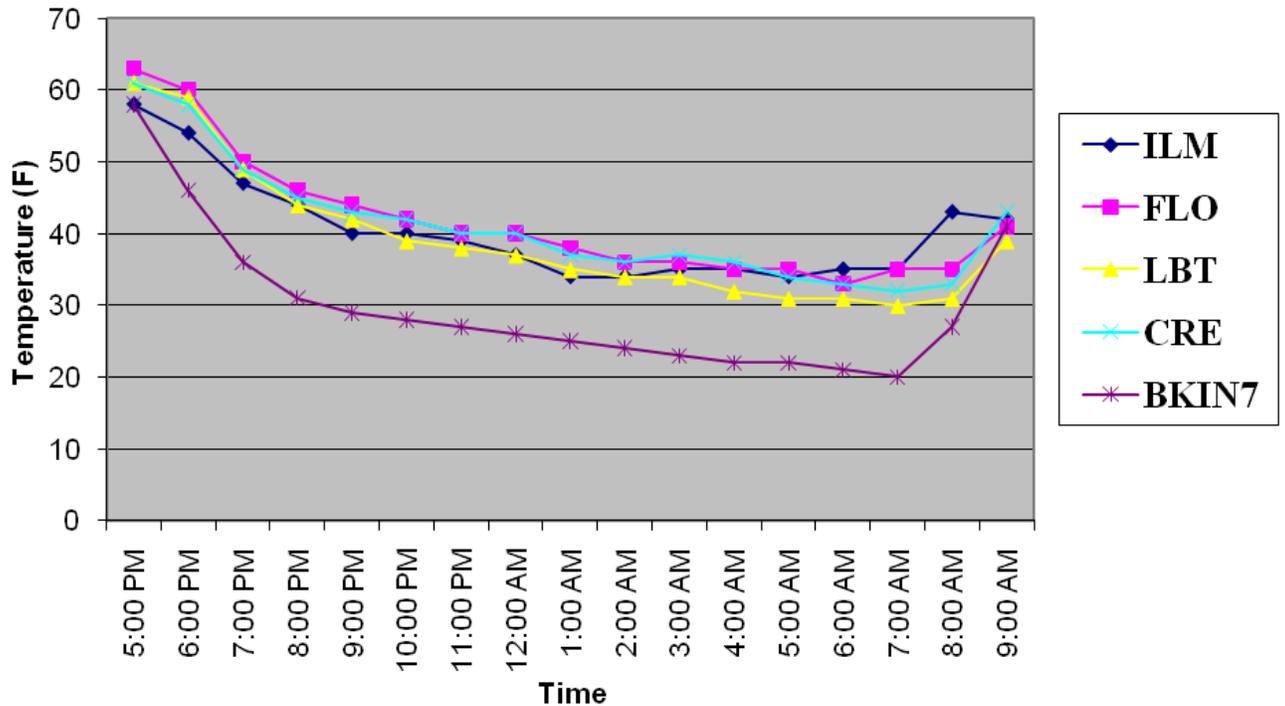


Image 4

Hourly temperature graph of surrounding ASOS sites Wilmington, NC (ILM), Florence, SC (FLO), Lumberton, NC (LBT), and North Myrtle Beach, SC (CRE) vs. the RAWS station at Back Island, NC (BKIN7), from the evening of October 30th into the morning of October 31st.

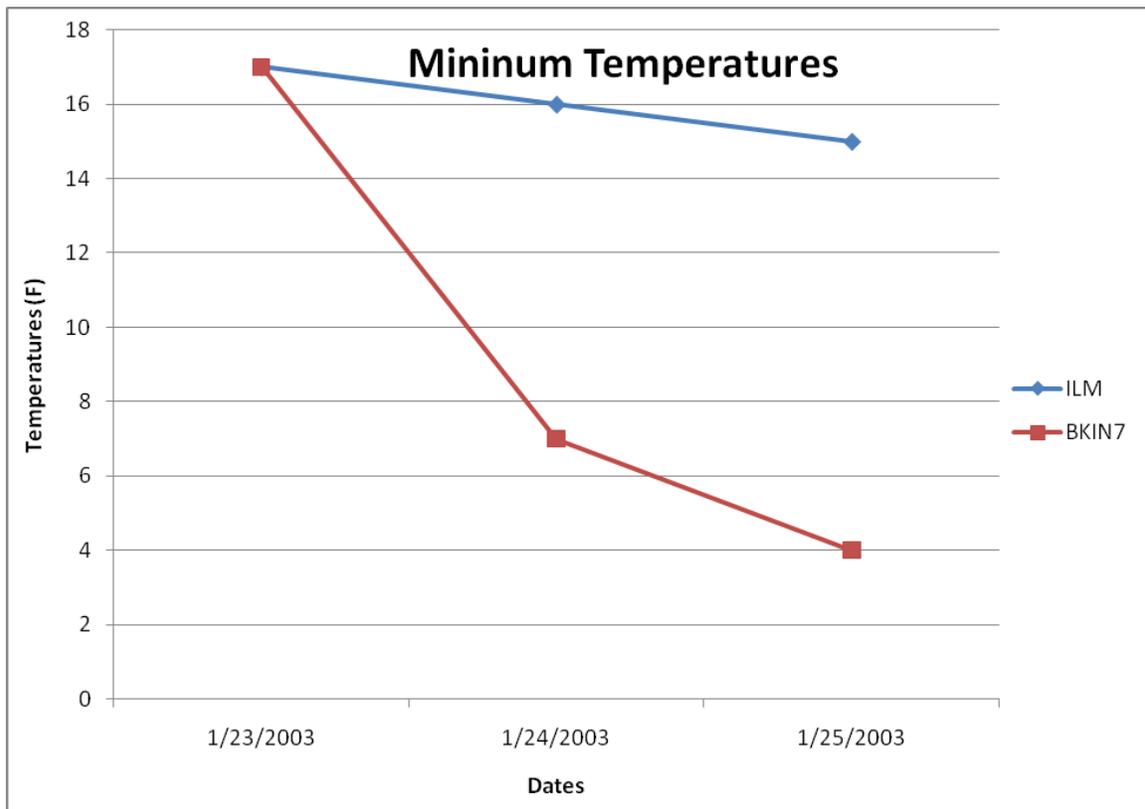


Image 5

Minimum temperature plot from January 23rd, 2003 through January 25th, 2003 for Wilmington, NC (ILM) and Back Island RAWS (BKIN7). Under poor radiational cooling conditions minimum temperatures from both sites were the same on January 23rd, 2003. As conditions for radiational cooling improved, the difference in minimum temperatures increased between the two sites, with a maximum difference on January 25th, 2003 under the best radiational cooling conditions.

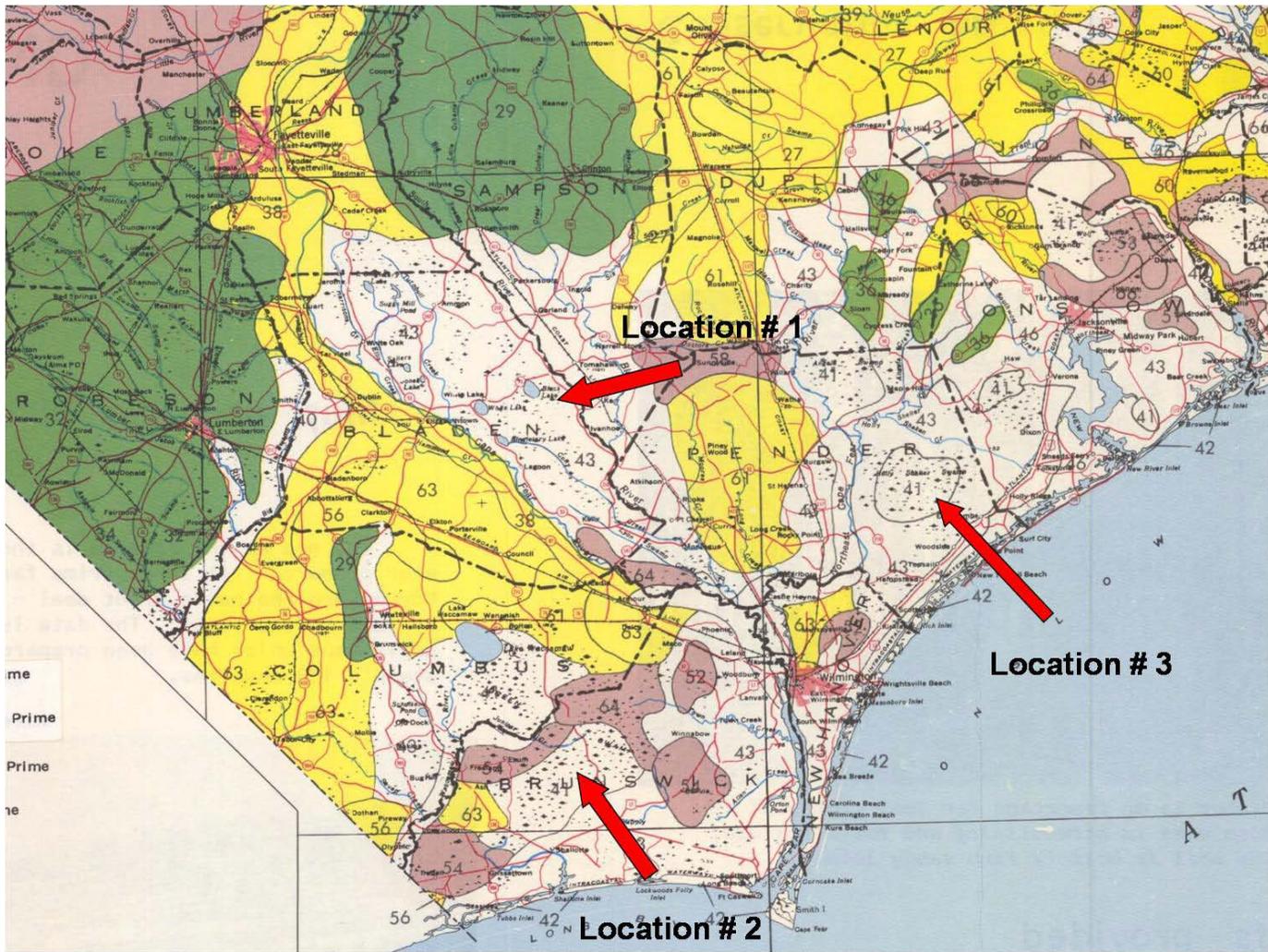


Image 6

Soil type map from the State of North Carolina (1974). Soil type 43 is most common for Location #1 while soil type 41 is most common for Location #2 and #3.

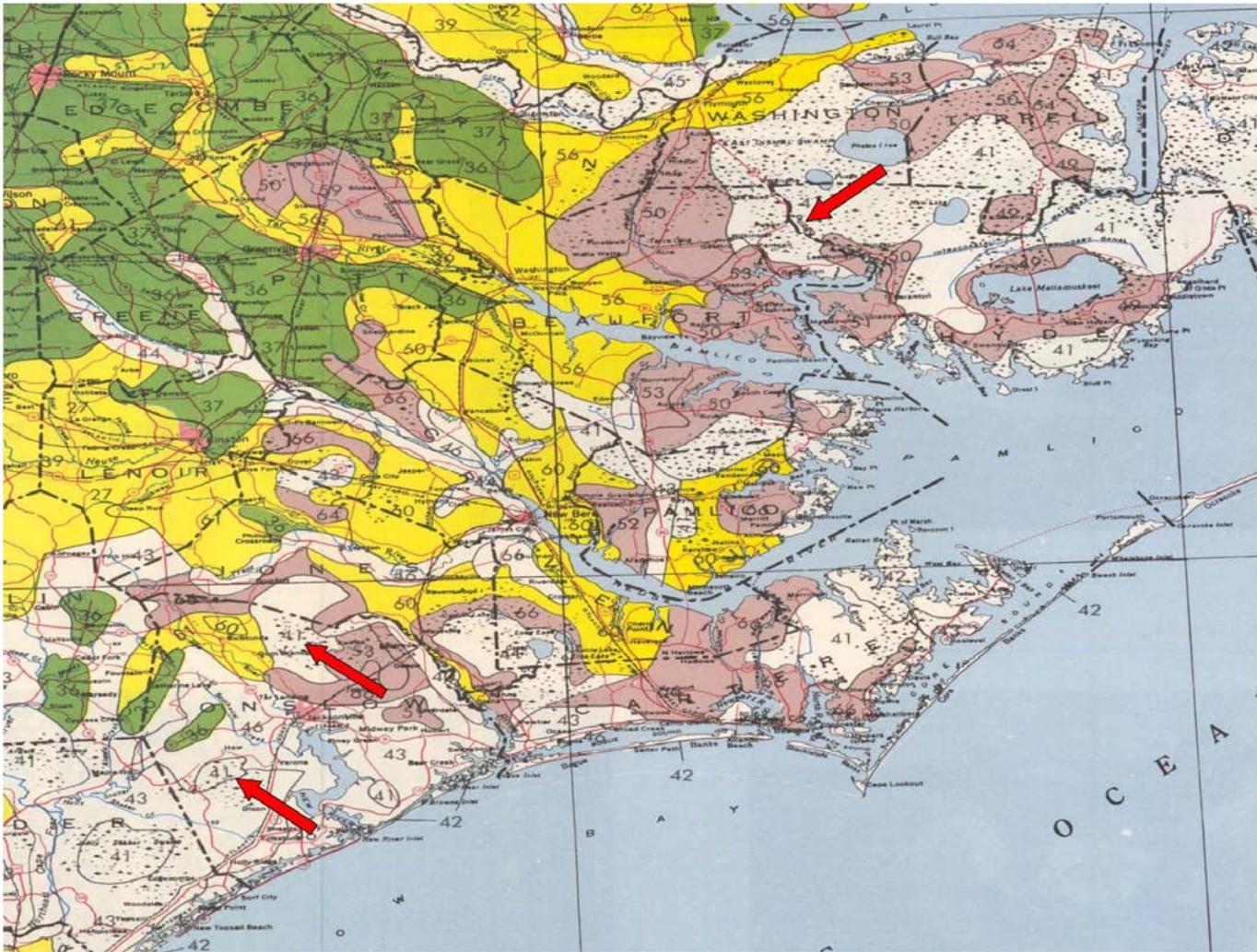


Image 7

Soil type map from the State of North Carolina (1974). This map focuses farther up the coast near the Outer Banks. Soil type 41 is also found in these areas and corresponds to Image 1 which shows that cold spots also exist in these areas.