Stormscope & Radar
A Comparative Analysis At The Next Level Of Detail

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Personal Experience.

I have been flying with a Stormscope (SS) since approximately 1995. I left a spot in the panel of the Glasair I built but, shame on me, I did not install the box until I had had two electromagnetic events that damaged my radio. I sold the Glasair in 2003 and, with a partner, bought a Cirrus SR-22 Centennial Edition. The SR-22 has a WX-500 Stormscope displayed on the Garmin 430s and the Avidyne Multi-Function Display (MFD). Thus, all my personal sferics experience is with the Stormscope. From Wikipedia:

> A radio atmospheric signal or Sferic (sometimes also spelled "Spheric") is a broadband electromagnetic impulse that occurs as a result of natural atmospheric lightning discharges. Sferics may propagate from their lightning source without major attenuation in the Earth-Ionosphere waveguide, and can be received thousands of kilometers from their source.

Since I have no reason to believe other sferics devices don't have a similar capability, I'll use "Stormscope" the same way my Mom used "Frigidaire", that is, as a generic term for a category of sferics "boxes."

Right off, I believe the SS gives much more helpful thunderstorm avoidance information than either airborne radar or Nexrad. I admit that my airborne radar experience is very dated – that is, from the late '50's and early '60's in C-118's, the Air Force's version of the DC-6. My Nexrad experience in my SR-22 comes from the handheld Garmin 496 with XM weather. My perception is that the overwhelming majority of operational information and magazine articles generally available to pilots is focused on the Nexrad. Thus, I decided to do a comparative analysis of Nexrad and SS to see if my bias was justified.

To set the stage, here are a few personal SS stories. Ten years ago I was going from Huntsville, AL, to Atlanta, GA, in classic warm front conditions: light to moderate rain but a smooth ride. Huntsville Approach was being very helpful and advised of Level 2 to 4 (the terminology then) ahead of us and offered vectors around it. The SS was clear so we pressed on through the rain and continued to have a smooth ride. On another occasion I was heading east on an early morning flight and there were buildups all around. There was one right in front of me that was black as the ace of spades with the sun directly behind the cumulus but the SS was clear. I kept going and had one small bump as I went through it. More recently, I was going from New Orleans, LA, to Dothan, AL, and there was a weak tropical disturbance over the Gulf that had generated thunderstorms and rain all along the Gulf coast and for some distance inland. As I approached Mobile, Mobile Approach advised me that there was moderate to heavy thunderstorm activity at my 12 o'clock and suggested deviating north or south. The SS was clear ahead but showed a little activity to the north and south so I advised Approach I would proceed straight ahead. He really got insistent and at one point asserted that my SS was broken. We encountered light to moderate rain and a smooth ride except for one moderate bump.

Obviously, operating here in the southeast US, I have had many opportunities to see the SS be very active. With its 200 nm range, I use the SS's capability to make strategic decisions on whether to go left or right - or land and wait. When I compare the SS with Nexrad I see a lot more of what I'd call "false positives" with the Nexrad. Notwithstanding the fact that there is the well known several minute delay in getting the Nexrad displayed in the cockpit, there just seems to be a lot of yellow and even red that doesn't correlate well with the SS and Mark-One Eyeball.

Technical Points

Stormscope

I believe the physics of the situation favors the SS for thunderstorm avoidance. It obtains all its raw data via a simple low frequency receiver and then applies clever on-board processing. The old Automatic Direction Finder (ADF) low frequency radios typically pointed to the biggest thunderstorm (lightning strike) around. So, knowing the direction of the strikes was the easy part. The cleverness was needed to determine how far away the strike occurred. Each lightning strike puts out a tremendous amount of electromagnetic energy. If one could determine the energy given off by the "average" strike, one could make an estimate of how far away that strike was by measuring the energy received at the airplane's antenna. I apologize to Paul Ryan and Nicholas Spitzer who patented the Stormscope in 1976 for my gross simplification of their work. Over the years since '76, electrical and computer engineers have greatly improved on the original box but the principles remain the same. Today's WX-500 ". . . detects the electric and magnetic fields generated by intra-cloud, inter-cloud, or cloud-to-ground electrical discharges that occur within a 200 nm radius of the aircraft and sends the resulting 'discharge signals' to the processor."[1] The operating handbook recommends using the cell mode instead of strike because the cell mode employs an algorithm that aids in identifying the locations of storm cells rather than individual strikes.

By definition, then, if there are no lightning strikes, there is no thunderstorm. Perhaps almost as important, where there is no lightning there is also little significant turbulence. The up and down drafts within the cumulus are what stirs up the electrons that then produce an electrical discharge. Thus, if there are no up and down drafts, there will be no turbulence – within reason. Those of us who fly in hot and humid places know that even without thunderstorms it will probably be bumpy when you are below the haze level or below "fair weather cumulus."

Airborne Radar

Radar must "see" reflected energy. Radar sends a radio signal out, receives a reflected reply, and then computes the range and direction (RAdio Direction And Ranging = RADAR). To see stuff far away, a radar needs to send out big packets of energy in order to get anything back. To see small stuff, it needs to use a highly focused, narrow beam. The longer the distance you want to see and the smaller the stuff you want to see the bigger the antenna needs to be and the bigger the packets of energy need to be. Single engine airplanes and many light twins do not have good places to put big forward looking antennas. Thus, from a practical standpoint, effective airborne weather radars are a tough engineering problem for light General Aviation (GA) aircraft and they are fraught with many compromises that result in limited operational performance for the cost incurred.

Nexrad In The Cockpit

Nexrad in the cockpit is the relatively new kid on the block and in some form or another is probably in a very large percentage of light GA aircraft. The Nexrad ground based equipment consists of a vast array of powerful radars with very large antennas and lots of computational power to make sense out of the huge quantities of raw data produced. The results of this effort are the products we see on TV, computers, and on the boxes in our aircraft. This ground-based infrastructure gives us impressive tools but their use carries some caveats. First of all is the well-publicized latency of the data that may mean upwards of 20 minutes delay before being available in the cockpit.

Other, perhaps esoteric, aspects of Nexrad are related to the manner in which the huge amounts of Nexrad data are collected, integrated, and ultimately displayed to end users. Dr David Strahle[2] makes the following points that should aid users of this product:

1. Nexrad sees smaller raindrops better than larger; warm front drizzle shows up brighter than cold front or thunderstorm raindrops. Thus, with today's long legged traveling GA planes, a pilot is apt to see both warm and cold front weather in a single flight. That means we need to know the kind of cloud that is producing the precipitation in order to make an accurate interpretation of Nexrad's colors.
2. The end user (pilot) is better served if the vendor (there are several) provides a "mosaic" of all of Nexrad's "composite" views from the individual sites. The composite picture from an individual site melds 0.9^{o} beam slices through the storm at various elevations and rates depending on storm activity. The "base" reflectivity is the lowest sweep of the pencil beam and may sweep below the height of the storm base and thus show no activity even though a storm is building at a higher altitude.
3. The number of slices made by the beam and the scan rate depends on the observed activity. If no storm activity is seen, the radar scans at 5 elevations once every 10 minutes; when activity begins to be seen, it scans at 9 elevations every 6 minutes; when it finds a thunderstorm, it scans at 14 elevations every 4 minutes.
4. XM is the only vendor providing Nexrad in the cockpit that is composed of a mosaic of composite views, not just the Base Composite.
5. Nexrad reports radar return energy in dBz. Its computer translates this energy into discrete bands and color codes the bands.

Our capability to compare ground available information with that available in the cockpit is made more difficult because the color-coding of radar returns has not yet become standard within our industry. The readily available Nexrad information found on the Internet, e.g. ADDS (14 colors), and the XM Nexrad information available on my Garmin 496 (7 colors) are at variance to one another. I have attempted to reconcile these differences with the table below. The definition of the Intensity levels with respect to dBz comes from the AIM Para 7-1-14 a. 2. The ADDS and 496 colors come from their in situ legends.

dBz	ADDS Color	XM 496 Color	Intensity	Note*
<30	Blues thru Light Green	Light and Dark Green	Light	Usually OK
30 to 40	Dark Green and Yellow	Yellow	Moderate	Maybe OK
>40 to 50	Dark Yellow and Orange	Orange and Pink	Heavy	10 Miles Away
>50	Red thru Violet	Red thru Brown	Extreme	20 Miles Away

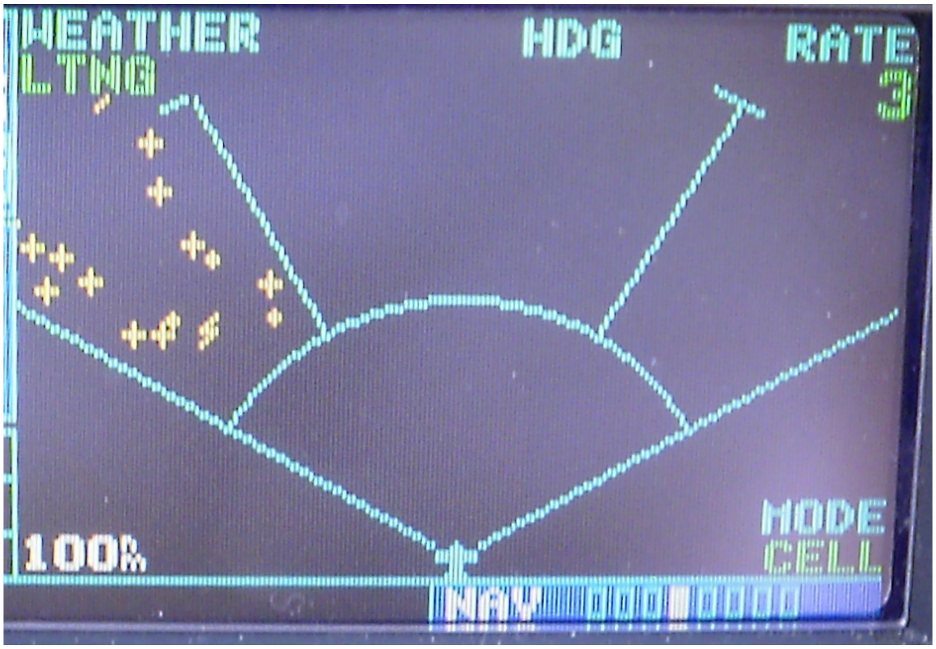
* Distances are from the edge of the Green, recommended by Dr. Strahle.

Graphic Comparisons

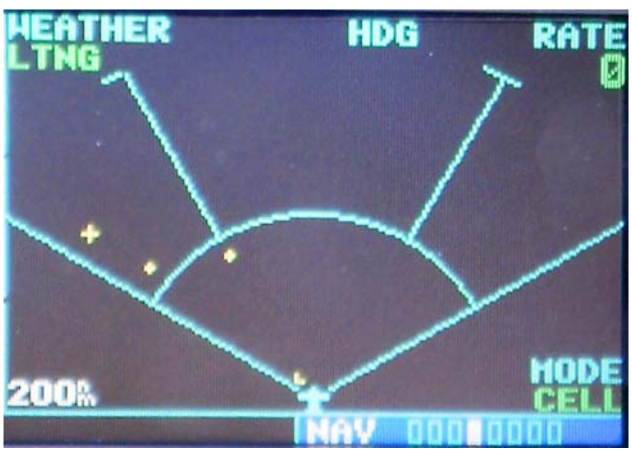
The following pairs of pictures were taken nearly simultaneously so they are helpful in making direct comparisons of the SS and Nexrad systems. I found it convenient to generate the following table in order to use the 496's heading ring as a pseudo range marker. For each of the Ranges selected using the "Out" and "In" buttons on the 496, the table shows the range from the little airplane icon to the heading ring. Thus when I display the 200 nm range on the SS, I generally select the 50-mile range on the 496 and the heading ring is about 208 nm from the airplane icon. When I have the SS on 100 nm range, I generally have the 496 on either the 20 or 30 nm range and the heading ring will be at either 83 nm or 125 nm respectively.

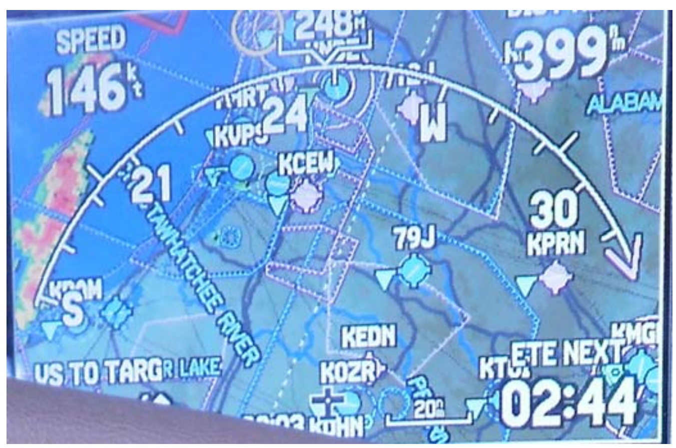
Range Set to:	Distance to Heading Ring
8	33
12	50
20	83
30	125
50	208
80	333
120	500

The following image shows the three symbols denoting the age of the strikes on the SS. The "S" lightening bolt is the first symbol displayed; after a minute it changes to a bold "**+**"; a minute later it changes to a subdued "+". Thus the last three minutes of activity are displayed.

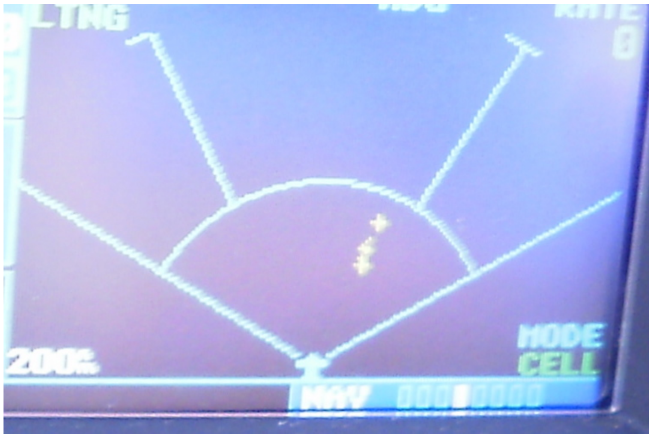


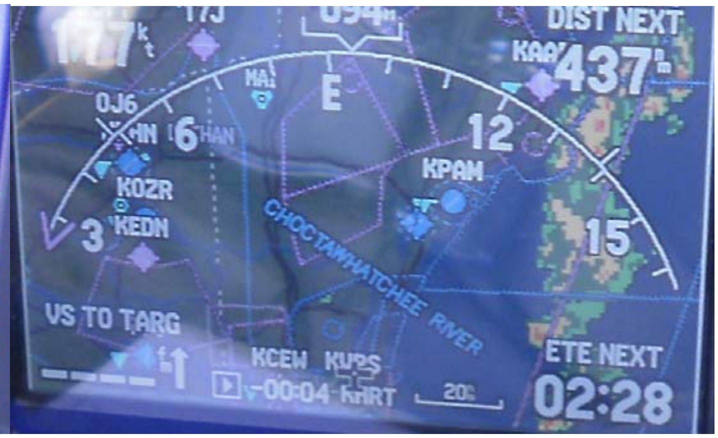
The Rate is displayed in the top right corner and is the number of strikes detected in the last minute. I find this a helpful metric in confirming how serious the activity is. My own personal feeling is that a rate of 0 to 9 is usually fairly benign, a rate of 10 to 19 deserves attention, and anything over 19 needs to be given a very wide berth indeed.



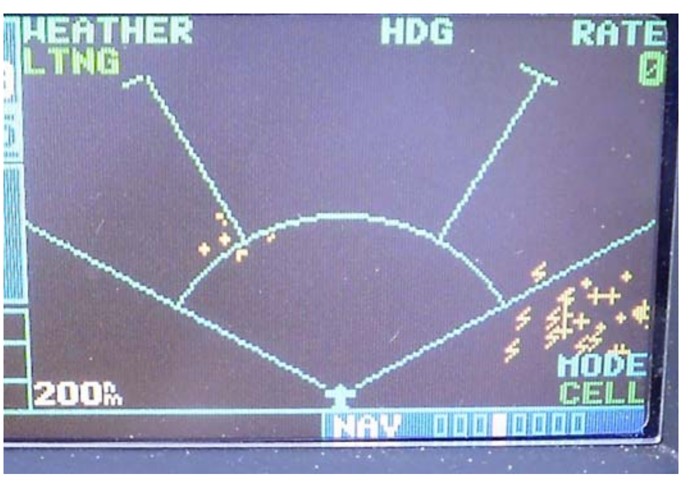


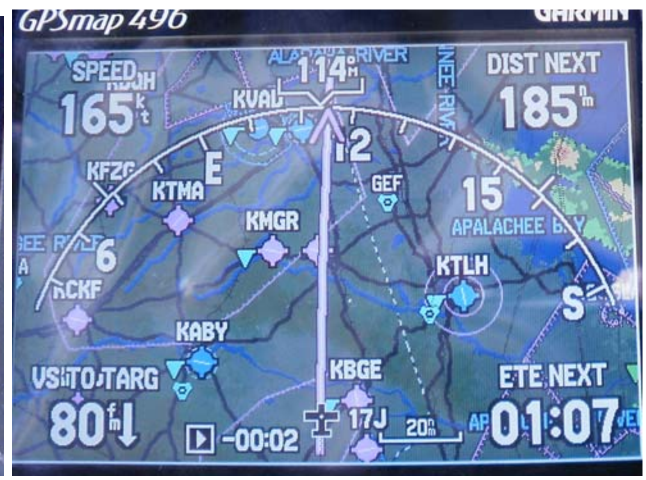
The above pair of pictures was taken at about 7:20 AM, CDT, on Sunday, Jul 11, 2010. I was enroute from Headland, AL, (0J6) to Pensacola, FL, (PNS) and thence to Tallahassee, FL (TLH). Shower activity on the Nexrad off the coast south of Panama City correlates well with respect to location with the weak activity shown on the SS. With the 20 nm scale on the 496, the heading ring is about 83 miles out. However, the yellow to brown (indicating moderate to extreme rain rates) does not correlate well with the relatively benign SS. The latter is showing only three activity spots that are between one and three minutes old and the rate is zero, indicating no strikes in the past minute. Notice that the Nexrad display indicates the image was received 3 minutes ago and with the ground processing and transmission delays the image is at least 8 minutes old.



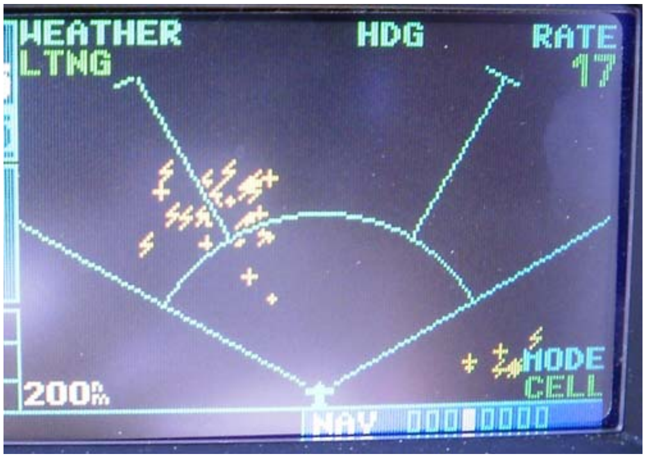


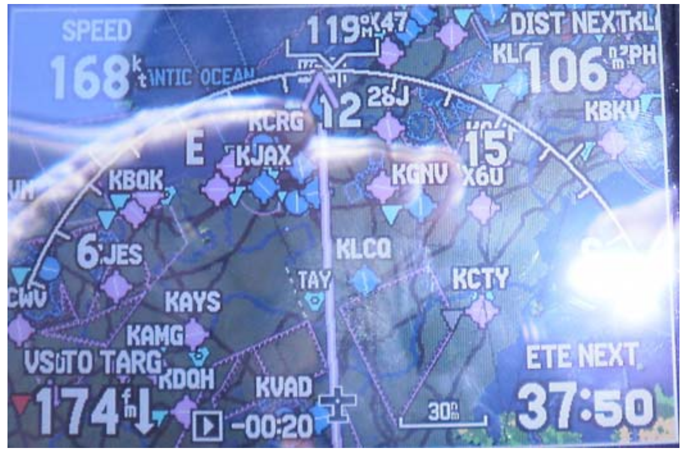
Later the same morning, I could see the same activity from the perspective of going from PNS to TLH. Again there is good positional correlation between the SS and the 496. This time though, there is also good correlation between the two with respect to activity: both show relatively low activity. However, the SS shows a cluster along a line from about 60 to 90 miles out at roughly 1 O'clock while the 496 shows that area as almost a "green hole" that might be tempting to fly through. Personally, if I wanted to go south, I'd go with the SS indication and either turn south now or wait until I got another 100 miles down the road.



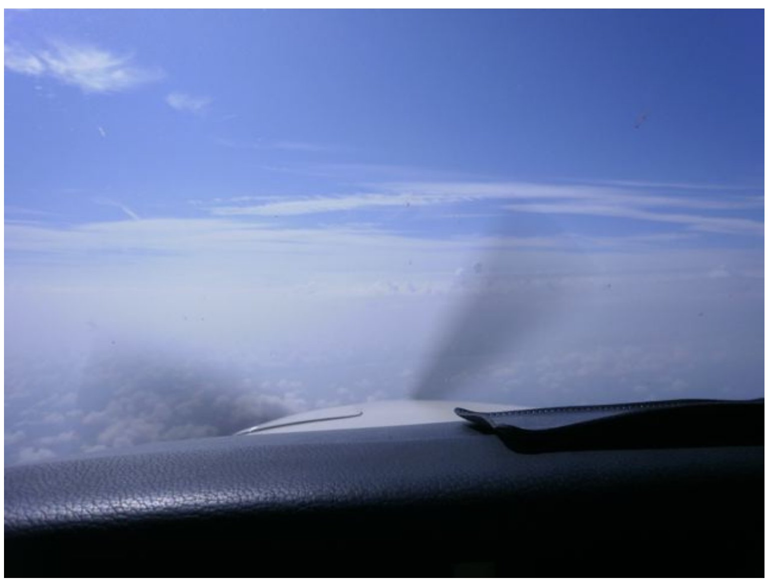


The above were taken about 8:40 AM CDT July 15, 2010, enroute from 0J6 to St Augustine, FL (SGJ). The location of the shower activity off the coast correlates fairly well with the SS. The SS picture also shows an instance of the SS showing a little activity at about 10 O'clock and 95 to 110 miles that is not showing up on the Nexrad. Notice that the Nexrad image was received 2 minutes ago and thus is at least 7 minutes old. The SS activity at 10 O'clock is between 1 and 3 minutes old based on the symbols so the real time SS is demonstrably better at showing the newly developing activity.



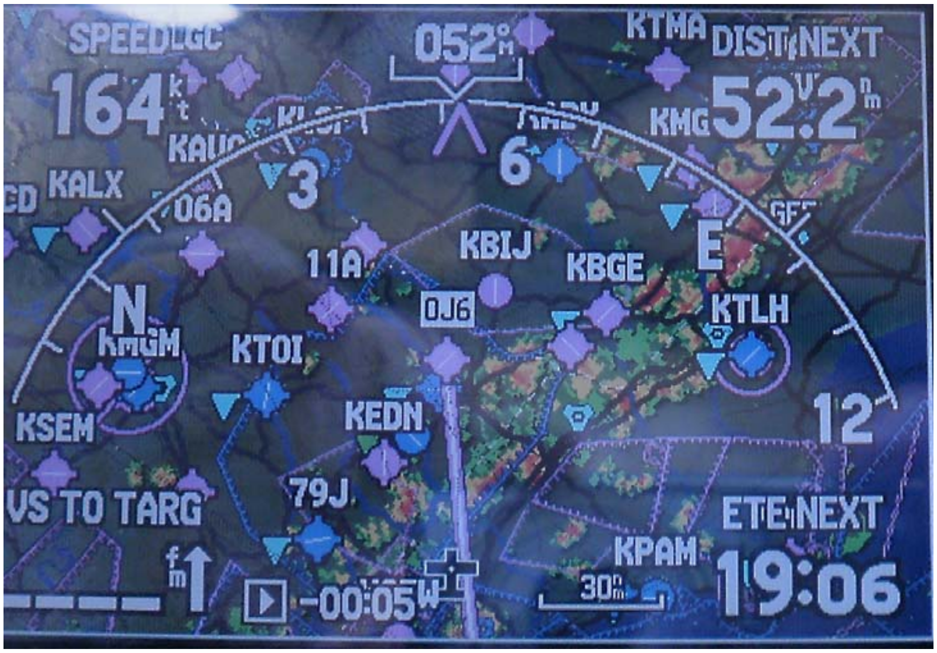


About 30 minutes later, the SS is showing fairly energetic activity at about 80 to 140 nm and about 11 O'clock with the rate now up to 17, a level that needs to be taken seriously. The 30 nm range on the 496 puts the heading ring at about 125 nm. Nexrad should be showing some of that 11 O'clock activity but since the age shows that the image was received 20 minutes ago, it is well behind the real time SS data that is between 0 and 3 minutes old. This illustrates that the latency of Nexrad can pose a serious error.

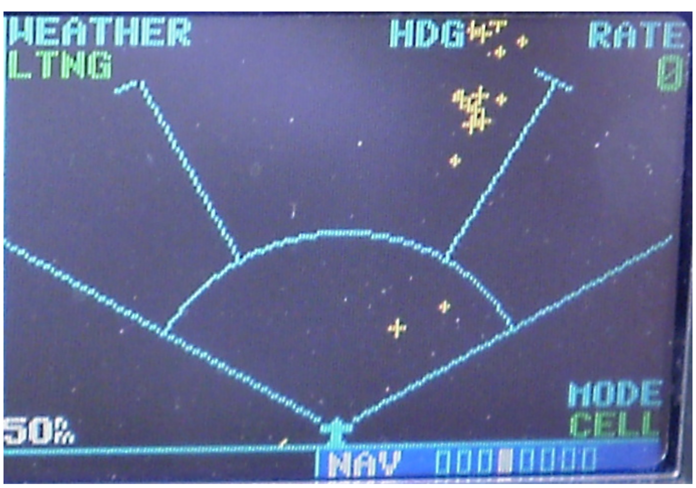


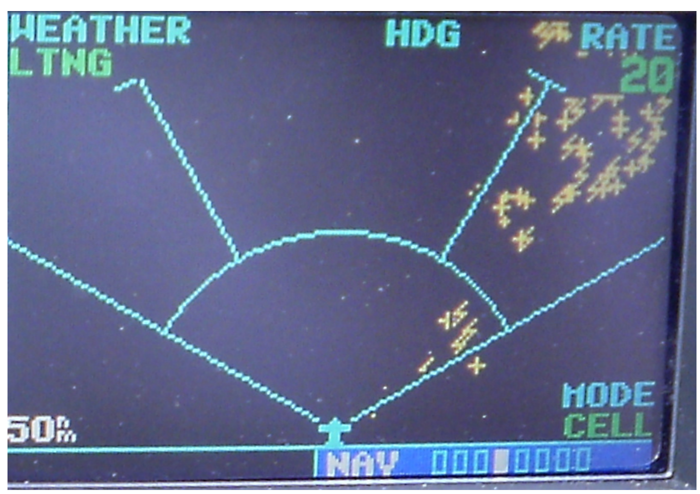
Interestingly, the view out the windshield looked just fine.

Another recent flight offered more comparisons of SS and Nexrad as well as FSS's interpretation. I was going from Destin, FL (DTS) back to Headland on the afternoon of Aug 7, 2010. I filed over the phone with FSS and the briefer was quite concerned that I wanted to make that trip in the face of the Nexrad picture he had in front of him. I reassured him that I had plenty of gas and thus had the option of going a long way around or returning to Destin. His briefing was based on this radar view:



This is an interesting view. With the scale set on 30 nmi, the heading ring is about 125 miles out so the activity extends along I-10 well past Tallahassee and shows lots of yellow, red and some brown. The corresponding SS pictures show, I think, a more definitive story:

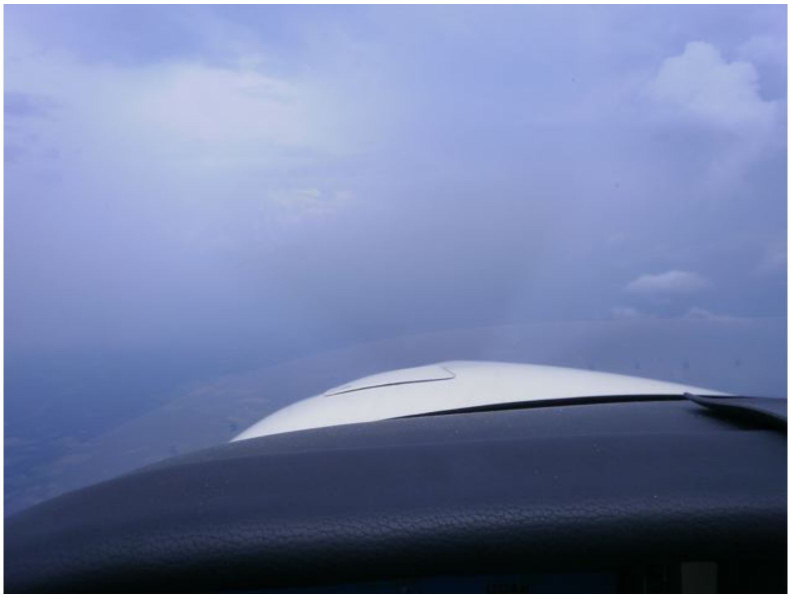




The one on the left was taken within a minute of the Nexrad picture; the one on the right was taken about four minutes later. In both, the path ahead is clear and the interesting activity is confined to a region extending from about 15 miles to beyond 50 miles (the range set on the SS at the time) at about 1 to 3 O'clock. Eglin Approach was being very helpful and offered headings based on what he was seeing on his radar – moderate to heavy precip. I declined his kind offer and requested on course to Headland and he cleared me on course. When I was in the middle of his depicted heavy precip, he asked me my flight conditions. I told him I had light rain and light, occasionally moderate, turbulence. I have found this to be a not uncommon reaction from ATC when I elect to use the SS for guidance instead of their friendly recommendations.

The SS picture on the right above is also instructive in that in just a short four minutes of time the activity has stepped up quite a bit. Notice the rate is now 20 and, consistent with that, there are a lot more "S" lightning bolts and bold "**+**'s". Again, this is real time actionable information. It is very clear which direction is OK and where it would not be fun to go – that is, all this activity remains in the 1 to 2 O'clock area.

A few minutes later, this was the view out the windshield as I'm breaking out on the north side of the line:



Concluding Thoughts

Thunderstorms can hurt you and/or your airplane. Like Texas, don't mess with them! I would like to believe that all instrument pilots are a bit timid. If you are like me, I nibbled at cloud flying a little at a time and over the years have become comfortable with flying in most (but not all) types of weather. I tell folks that I don't do ice and I don't do lightning! The fact that I live and fly in the Southeast US means that I have had the "opportunity" to see a lot of convective activity. I was also blessed to have a great flying buddy and mentor, Mike Scroggins, who provided me with a lot of Stormscope practical in-flight knowledge. I reflect from time to time about the fact that in the "olden days" unpressurized DC-3s and DC-4s of Delta and Eastern Airlines plied these same skies at the same altitudes I do on a regular basis. Back then, the common greeting when you went to pick someone up at the airport was, "How was the flight?" The expectation was that it had been bumpy to a greater or lesser extent – but safe. The guys up front had no Stormscope, no Nexrad, and no ATC guidance, but they knew the weather, how to read weather reports and forecasts, and how to go around the worst of it. But "bumpy" was sort of expected. My thinking now is that if you want to stay out of precipitation bumps, then stay out of Nexrad's Green; if you want to stay out of thunderstorms, but don't mind a few bumps and rain, make sure you are using the Stormscope information. To get used to precipitation bumps, plan to fly at least a part of your next hot humid flight below the haze line and/or below the fair weather cumulus. You'll certainly get bumps there, and no rain or thunderstorms!

References.

1. *Pilot's Guide for the Stormscope*, L-3 Communications Avionics Systems, Inc, Copyright 2004.

2. Dr David Strahle, dstrahle@rmipc.net, "Thunderstorm Avoidance Using Aircraft NEXRAD Radar", Presented at EAA AirVenture, July 31, 2010.

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Folks who have been kind enough to offer comments on this essay:

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