

Taken from : Washington-Baltimore Climate Review, March 2004
Written by: Steve Flood (NOAA/NCEP)

Preferred Thunderstorm patterns over the DC-Baltimore area

Ever watch summer storms and notice that they prefer to pass to your S or N, and wonder why? There are reasons! While summertime convection across the DC/Baltimore area is **highly complex** and can vary markedly from year to year, the patterns of storm development and propagation are **not random**. They are more predictable than you might think!

After **37 years** of watching thunderstorms in the DC area, I have attempted to document my impressions in this brief report. The **five basic convective patterns** that I have drawn up are based on years of watching **radar, upper air, and surface data**, along with **precipitation data** from many past **WBCR** (Washington-Baltimore Climate Review) issues. Of course there will be events that do **not fit** any of these patterns such as storms drifting or propagating from NE to SW. But **about 70%** of summer convective events should roughly fit one of these five patterns. Observers with long histories will be able to peruse thru past WBCR issues, and see how these five basic thunderstorm patterns tend to **repeat** themselves with some **regularity**. But I caution the user that these patterns are **approximations**, and we need a **denser**, high quality data base to be dogmatic about them. Each year's storm patterns are somewhat **unique** and different. It is likely that a few areas I have depicted as favored will in fact turn out to be unfavored the summer of 2004, and vice versa. Also, someone may come up with a **better way** of classifying types of storm patterns than I have here.

A number of **mesoscale, geographic, climatological, and synoptic scale factors** play significant roles thunderstorm development and propagation in this area.

Seasonal Climatology . July is normally the month with the most thunderstorm days for DC, 7. June has second place with 6 days, while May and August are tied for third place with 5. April and September normally see about 2 or 3 thunderstorm days.

Geographic Factors:

1) **The Blue Ridge Mountains**. These can either break up storms moving eastward out of the Appalachians or initiate them when they might never have formed otherwise. E of the Blue Ridge, there is a **gradual** trend for increasing elevation from SE to NW to the W of Washington-Baltimore. **Upslope** and **downslope** components have an important effect on **all** precipitation, including convective precipitation.

2) **The Potomac River and Chesapeake Bay**. During the warm time of day, surface winds tend to blow from the cooler water towards the heated land areas. Where the breeze off the Bay or Potomac River is **opposite** the **prevailing** low level wind direction, a **convergence zone** is set up which can trigger thunderstorms under the right conditions.

3) Urban heat islands.

Congestion of buildings, traffic and asphalt in urban areas create **bubbles of hot air** that may be several degrees hotter than the surrounding countryside. This hot air rises and tends to draw in a converging flow of air from cooler surroundings. If the thermal over the urban area can **sustain itself** and gain **vertical momentum** as cumulus clouds form...a “**heat island thunderstorm**” can develop.

Synoptic factors:

During the cold season October through April, large-scale synoptic and geographic features usually overwhelm the smaller scale features so that **precipitation tends to maximize near areas of favorable synoptic scale forcing or orographic lift**. With the onset of warm-sector convective precipitation from May into September, **smaller scale features** become increasingly important, especially in July and August. In summer months, strong synoptic scale forcing or **organized outflow boundaries** can still **mask** the pattern favored by the prevailing thunderstorm cell movement or propagation.

Some of these synoptic factors are:

1) **Fronts**- Large scale forcing and lift along airmass boundaries.

2) **Outflow boundaries**. These are **windshift lines** formed by rain-cooled air blowing away from a mature thunderstorm into air that has not yet been worked over by convection. This undisturbed, relatively unstable air frequently moves at right angles to ...or in opposition to...the movement of the cold outflow. Where the two meet and converge...new convection frequently forms.

3) **Differential Heating caused by clouds and/or precipitation**

Areas that receive rain on one day will tend to be several degrees cooler the next afternoon than surrounding nearby areas that did not receive rain. **Other things being equal...there will a net flow from the cooler areas towards the warmer ones**. A convergence zone tends to set up on the warm side of a rain-cooled boundary in areas that missed the previous days convection. This is one reason why a **particular area is seldom hit two consecutive days** with torrential air-mass thunderstorm rainfall.

Another favored area for storms to form is just on the sunny side of thick middle or high cloud decks....sometimes lower cloud decks as well. We see this frequently in visual satellite imagery. Areas getting **good solar heating** during the morning become **much warmer** by afternoon than cloudy areas. This sets up a tendency for winds to blow from the cooler cloudy areas towards the warm clear areas. Here is a **hypothetical example**. Suppose in weak morning surface SW flow...there is a thick middle cloud deck NW of a IAD-BWI line. SE of that line..there is sunny...rapidly warming conditions. Assume that the edge of the thick middle cloud layer stays in roughly the same area all morning. Under such circumstances... the light SW surface flow over the entire Washington-Baltimore area during the morning will become NW by early afternoon over

the NW half of the area. SE of the edge of the thick middle clouds along the **convergence zone** between NW winds blowing from the cloudy areas and SW flow deeper in the sun-warmed air... **thunderstorms** are favored to form.

4) The Appalachian Lee Trough

When westerly flow crosses a mountain range...a windshift line tends to develop to the lee of the mountain ranges along a surface pressure trough. This "Appalachian lee trough" sometimes helps focus/enhance thunderstorm development in the DC area. Generally, the stronger the westerly flow, and the more perpendicular it is to the mountains... the farther away from the mountains the lee trough will form.

5) Persistence.

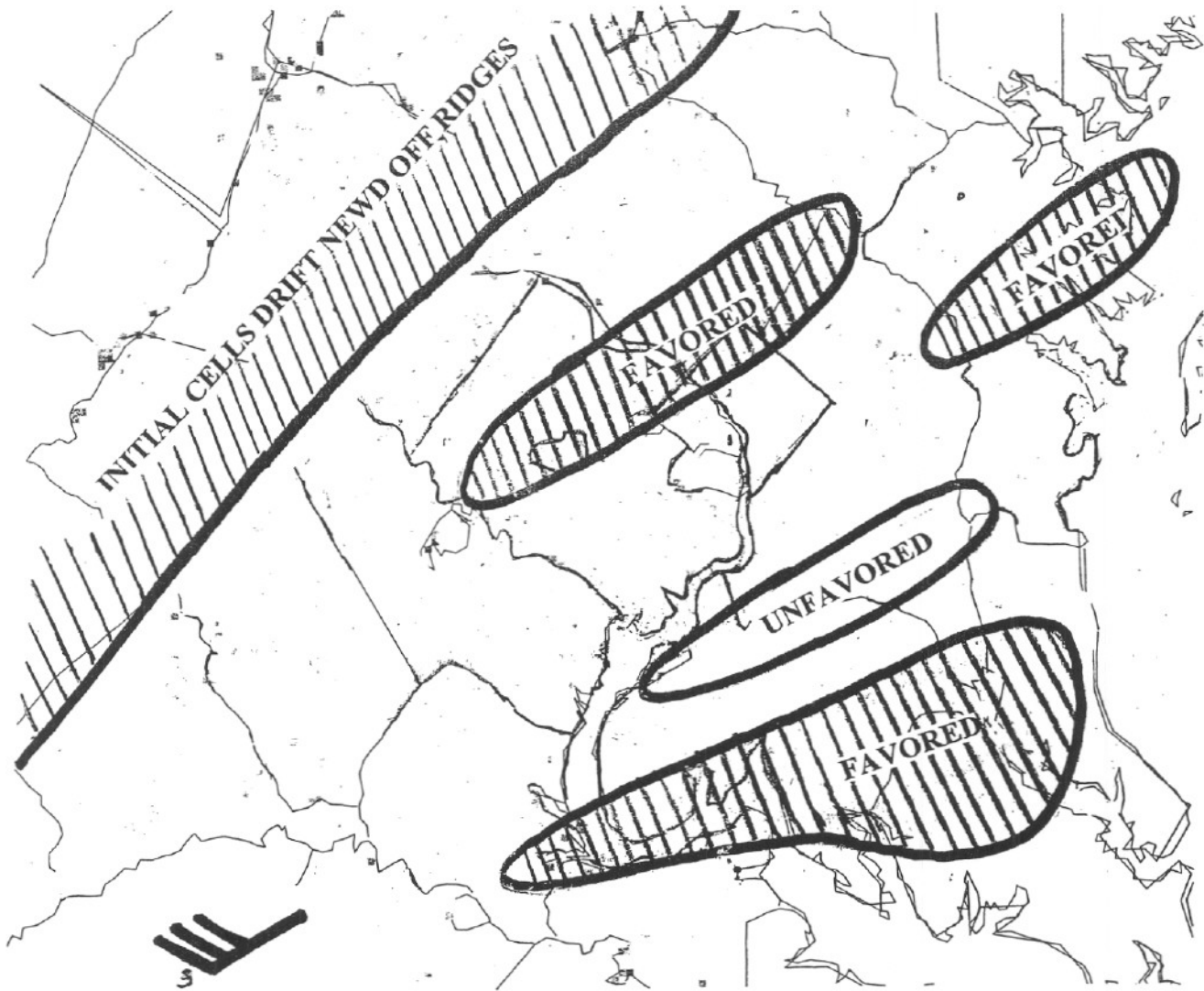
Droughts tend to perpetuate themselves. Lack of soil moisture keeps surface dewpoints several degrees lower than they might be otherwise. Also...dry ground heats up much more quickly than wet ground. Between the lower dewpoints and higher temperatures...the relative humidity is significantly lower...making it harder to pop airmass convection.

Last year (2003) the opposite occurred. The ground across the whole area was wet from frequent heavy precipitation events May-July which kept surface dewpoints high. When August came...the warmest of the 3 summer months ...we had above normal surface moisture and slightly above normal temps. The **high temperature-dewpoint combinations maximized instability** and contributed to 12-15 thunderstorm days in the DC Baltimore area for August 2003. This is a near record with even more occurrences of thunder than June or July.

6) Diurnal considerations

Of course there is the well known **primary** late afternoon and early evening convective maximum related to peak solar heating. What seems more evident in recent years is a **secondary** pre-dawn convective maximum, approximately 3-7AM EDT. This is especially true with approaching warm fronts. Decoupling of the lower layers at night seems to create a better lifting zone for **elevated convection** above a lower stable layer with an **approaching warm front**. Though most common in the Central Plains in association with a low level jet....the pre-dawn thunderstorm maximum can show up in the Washington-Baltimore area as well.

Five major Thunderstorm Patterns affecting the DC-Baltimore (WBCR) area.

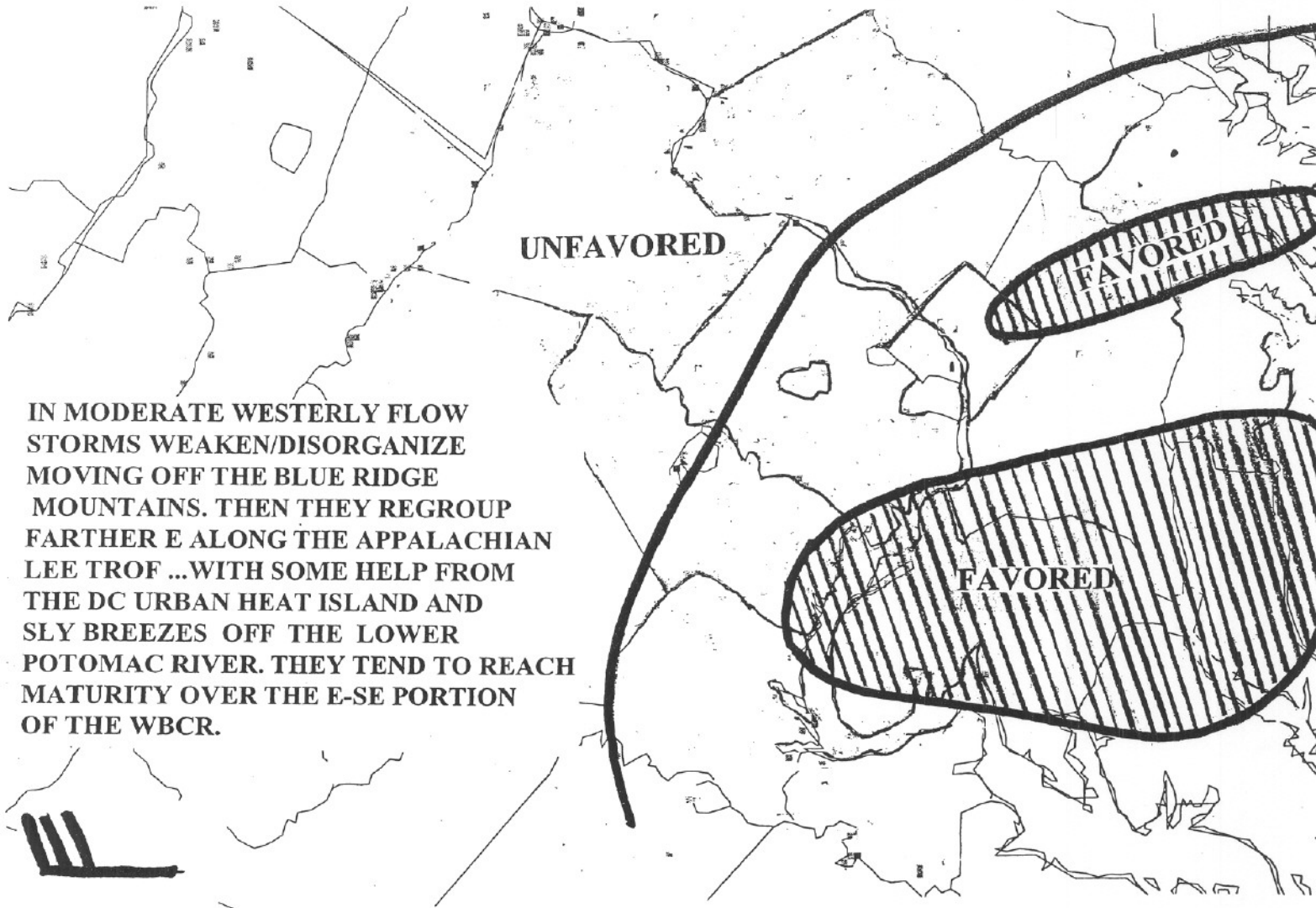


1. General WSW-SW Warm-sector Upper Flow (movement or Propagation Vector from 220-250 degrees).

This pattern is quite common in warm sector air-mass convection a day or two preceding a summer cold frontal passage. Broken lines of convection form along the Appalachians of WV/VA during the early to mid afternoon and drift off the mountains towards the lower elevations. The W-N suburbs are highly favored during the early stages of this flow regime. Later in the afternoon...another favored maximum seems to develop from Wm Fairfax County ENE towards Silver Spring, as well as from NW of IAD to the N of Gaithersburg in Nrn Montgomery County. Still another favored area for convection seems to develop downwind of the DC urban heat island extending towards Annapolis, MD.

Still later on this type of convective day...usually 6-9pm...another favored area for thunder seems to lie from Srn Stafford County across the lower Potomac River into Srn Charles, Nrn St Mary's, and central/Srn Calvert Counties. These storms can develop quite a bit of lightning and seem to get a boost from convergence along the Lower Potomac River and the Chesapeake Bay.

Of course...given this pattern type or any other...other convective systems and their outflow boundaries nearby can upset this regime. A classic case of this occurred on May 31, 2003. That day started out as a WSW Flow case...with the Waldorf area in the expected convective minimum in Nrn Charles County. Then some right-moving training cells developed on the tail end of activity farther N and moved ESE across Srn Waldorf giving over 2 inches of rain!

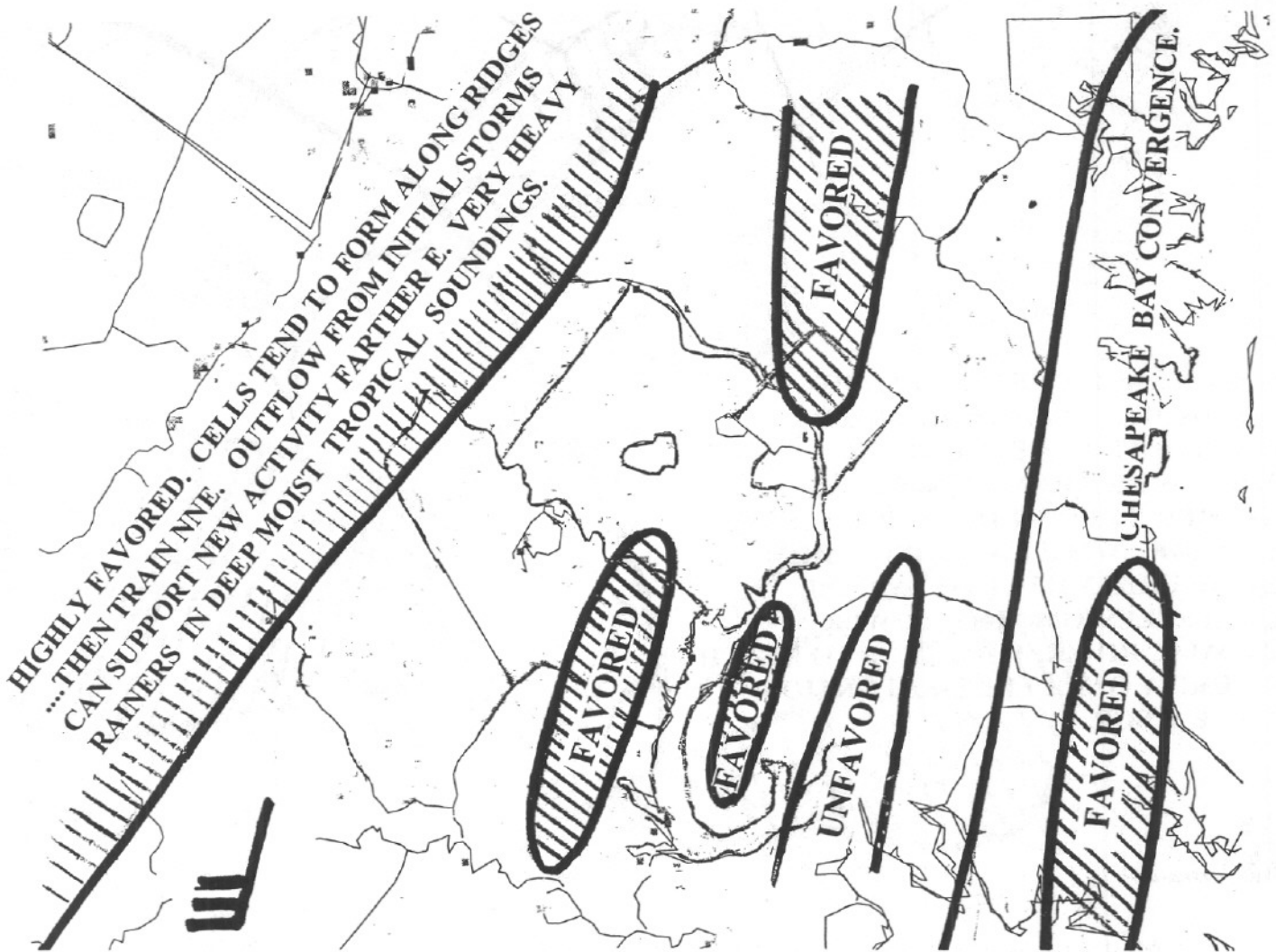


IN MODERATE WESTERLY FLOW STORMS WEAKEN/DISORGANIZE MOVING OFF THE BLUE RIDGE MOUNTAINS. THEN THEY REGROUP FARTHER E ALONG THE APPALACHIAN LEE TROF ...WITH SOME HELP FROM THE DC URBAN HEAT ISLAND AND SLY BREEZES OFF THE LOWER POTOMAC RIVER. THEY TEND TO REACH MATURITY OVER THE E-SE PORTION OF THE WBCR.

2. Moderate Westerly Flow (Movement or Propagation Vector from 250-290) .

This pattern is most apt to occur on a hot day with deep layered W or WNW flow, when we think that downslope E of the Blue Ridge will suppress thunderstorms. June, July and August are favored. On this type of day, the WBCR region is under the influence of a westward-extended Bermuda High over the southeastern states...with upper level shortwaves tracking across the upper Oh Valley into the mid-Atlantic/Srn New England areas. Surface winds are often from a W or even NW direction during the morning and early afternoon. There is a 10-15 mph breeze from a Wly component. The surface air is not stagnant but heats up rather quickly into the upper 80's to low 90's by early afternoon, with dewpoints staying in the mid 60's or higher.

A weak upper shortwave approaching during the late afternoon, combined with a diurnal pres fall maximum just E of the Blue ridge mountains, is sometimes enough to back the low level winds to light Sly during the late afternoon at DCA, DAA, and NYG. Meanwhile surface winds remain from a W or NW direction at IAD and MRB.. In this type of pattern storms can suddenly fire into a broken SW-NE line just E of a Warrenton-Manassas-Dulles-Rockville line. Or, scattered straggler storms moving out of the Blue Ridge area in unfavorable downslope flow can regroup/reorganize/redevelop in that same general area. In either case...the retrogression of the lee of the Appalachian surface trof to W of the Potomac River during the late afternoon helps focus moisture convergence along the windshift line...allowing storms to develop if other parameters are right. Surface dewpoints will often jump 5 degrees or more during the late afternoon of this type of day at DCA, DAA, and NYG as surface winds back from W-NW to S. Some of this dewpoint increase is from the Potomac River...but there is synoptic scale moisture convergence also.



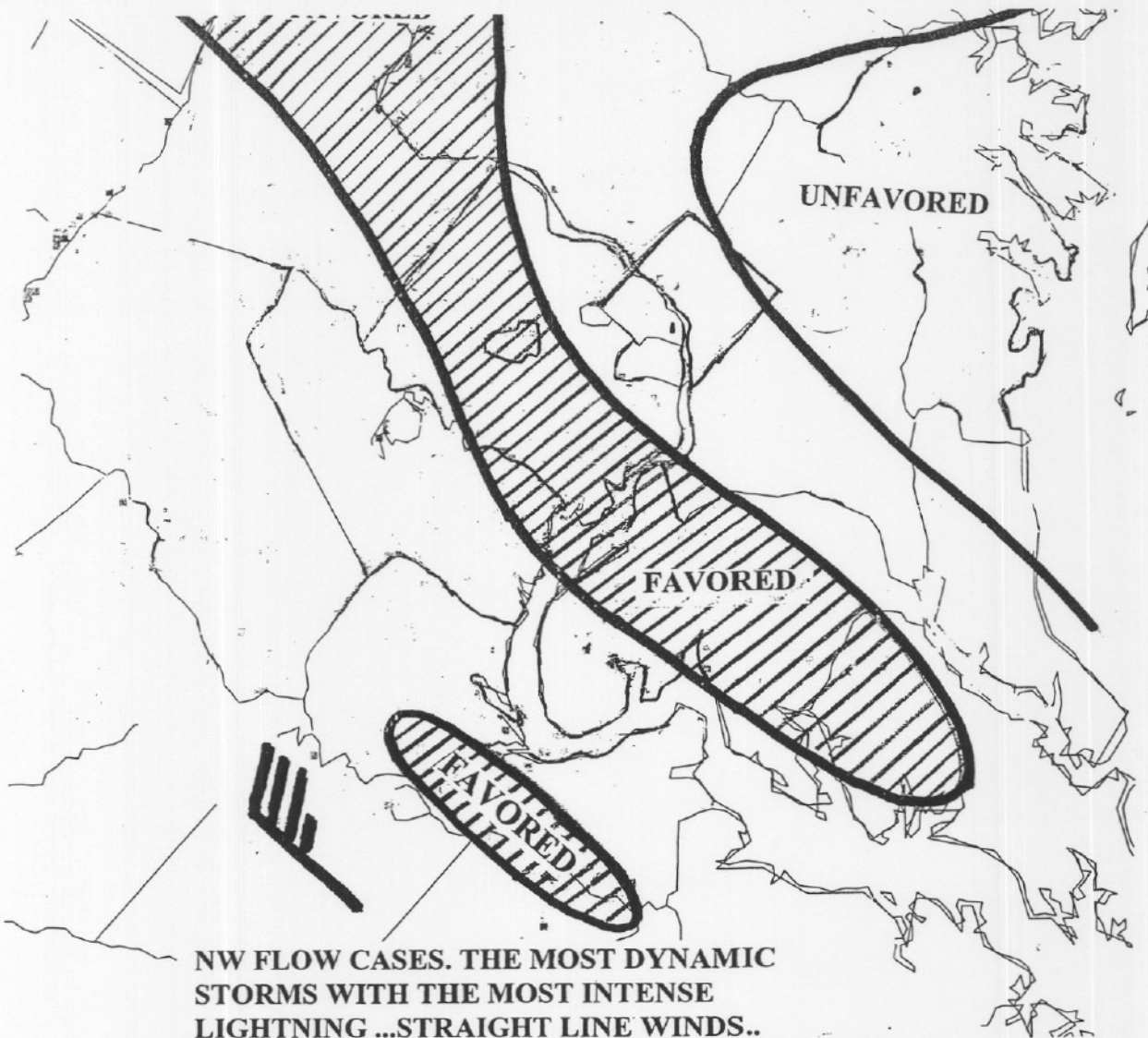
3. Deep Moist Sly Flow (Movement or Propagation Vector from 170-210).

This type of deep moist atmosphere most commonly occurs in August, when 500 millibar westerly components have retreated well to the N. The Appalachian Mountains and convergence along the W shores of the Chesapeake Bay become the main focal points for convective initiation.

Secondary convective maxima occur vicinity of the bend of the Lower Potomac River in SW Charles County, and a few miles W of the Potomac River thru Ern portions of Stafford, Prince William, and sometimes Fairfax County. Another important maxima seems to occur from the DC urban heat island Nwd thru Silver Spring into Howard County. Storms spawned by DC heat are sustained by upslope as they drift N thru Ern Montgomery to Howard County.

Deep moist Sly storms are primarily heavy rain producers and do not produce as much electrical activity as storms coming in from a more westerly direction. Perhaps this is because deep Sly flow is most apt to occur in areas of large wet synoptic-scale lift where lapse rates are close to moist adiabatic...with CAPE values generally 1000g/kg or less.. Still...if they happen to train over you, as sometimes happens over the Blue Ridge...you'll know it! Outflow boundaries from initial developments can focus new convection E or W of the convective initiation point.

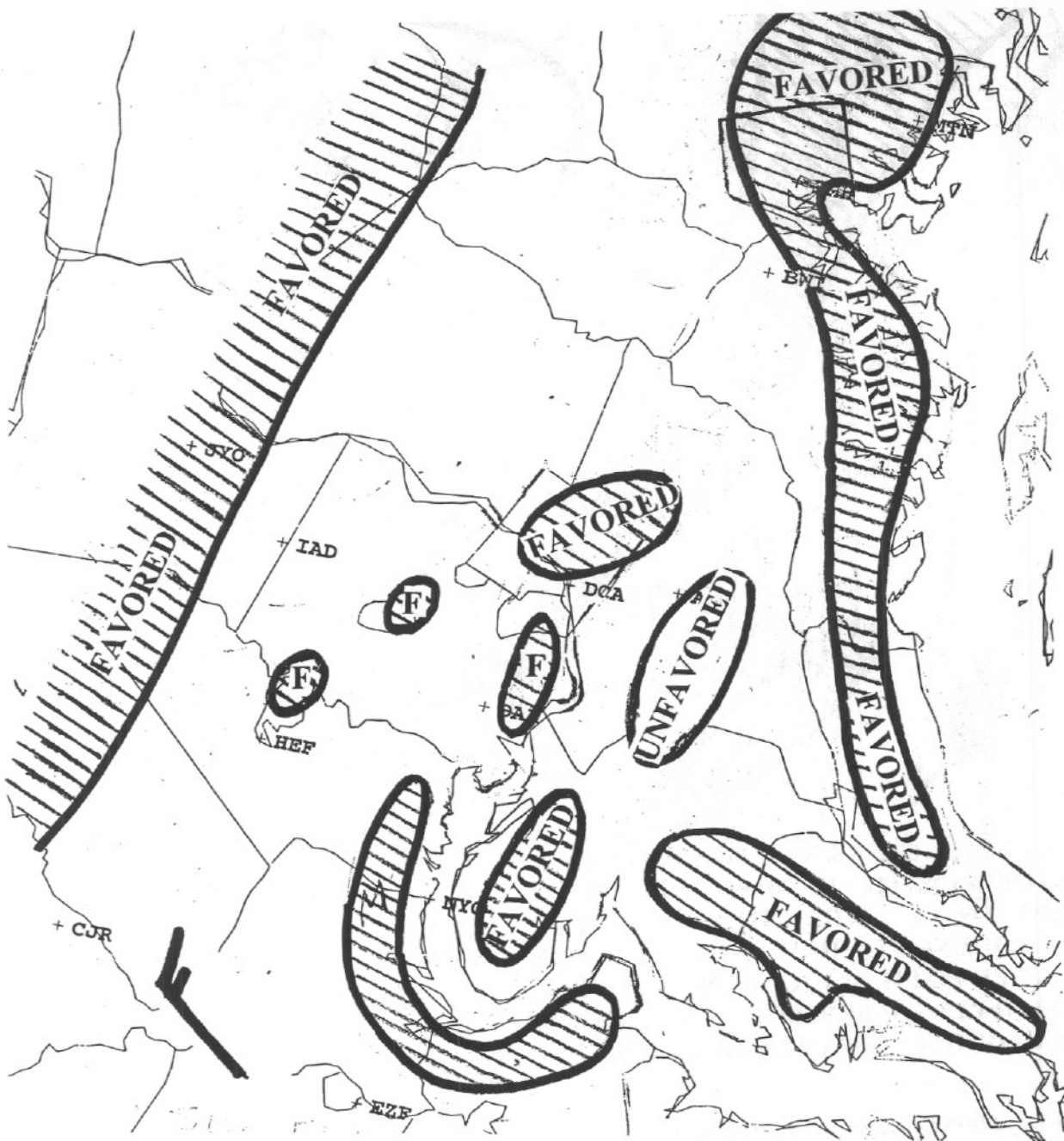
A recent case from last summer is August 9-10, 2003. Cells moving almost straight N developed in Nrn Calvert County late Friday evening into Saturday morning. These drifted N into Anne Arundel County during the pre-dawn hours Saturday with over 4 inches of rain occurring at Sparrows Point. Another less dramatic case occurred on August 3rd 2003 when a line of cells formed along the W shores of the Chesapeake Bay ...near the Bay Breeze convergence zone... and propagated W all the way to the Potomac River.



NW FLOW CASES. THE MOST DYNAMIC STORMS WITH THE MOST INTENSE LIGHTNING ...STRAIGHT LINE WINDS.. FREQUENCY OF HAIL. THEY FORM OVER THE UPPER POTMAC HIGHLANDS AND RACE SE WITH LESS DOWNSLOPE THAN STORMS COMING IN DIRECTLY FROM THE W.

4. NW Flow (Movement or Propagation Vector from 290-330)

These storms can produce the **most intense lightning** and move SE from the Potomac Highlands on a path that encounters **less downslope** than activity coming in more directly from the W. Unlike the deep moist Sly storms, conditions just before the storms hit typically feature surface SW-W flow, winds veering with height...and drier air at the 700-500 millibar level. The lower levels are apt to be fairly hot if the storms fire during the late afternoon or early evening...with steeper lapse rates in the lower troposphere than the deep moist Sly thunderstorms. **The steeper lapse rates and drier air aloft favor more lightning, hail, and momentum transfer to the ground with straight-line wind damage.** Two outstanding NW flow cases occurred June 26 and 27, 1978. In the first case, IAD had a micro-burst with 1 inch hail and 40 MPH gusts. The next evening an MCS raced SE from Wrn PA at 60 knots into the WBCR area with tremendous straight line winds, blinding rains, and vivid lightning. Harold Hess, a forecaster at that time, noted "clouds moving in with high speed from the W " from the World Weather Building 6/27/78. Other memorable NW flow cases occurred July 1, 1990, several in June 1998, July 14 2000, August 16th-17th 2003, and August 26th-27th 2003. **NW flow cases can generate the most spectacular nighttime lightning of all when they roll SE thru the areaespecially near the peak of a wave on a NW-SE oriented warm front during the pre-dawn hours.**



5. Light and Variable (Dog Day) airmass thunderstorms.

We all remember the “dog days” (we had relatively few last year) . Typically we see a suffocating temperature and dewpoint combination like 95/70. It’s usually hazy and smoggy, with lots of mosquitoes and gnats, and light and variable winds mainly in July or August. Often there is a warm mid-tropospheric cap that does not allow any storms to fire at all. When showers are able to form, elevated areas, land-water boundaries, and heat sources determine the favored areas of convective initiation. These areas include the Blue Ridge, the W shore of the Chesapeake Bay, just to either side of the Potomac River, the major urban heat islands of Washington DC and Baltimore, and minor heat islands near other built-up areas. **Any area hotter than its environment will be prone to draw in cooler air from its surroundings and set up a rising thermal in its vicinity.** If conditions are right, these thermals can become small air-mass thunderstorms. These airmass storms are likely to be small cells a few miles in diameter that sometimes amalgamate into clusters. They tend to be **short lived**, weakening after 20- 30 minutes or so of life, due to the lack of upper dynamics. **Rain-cooled air** spreads out from the parent storms and **kills** them, while sometimes initiating new small cells. Once formed, cells drift with the prevailing steering currents, typically from a W to N direction.