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SUMMER SEASON CONVECTIVE INITIATION – STUDENTS AS INDEPENDENT RESEARCHERS

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1. INTRODUCTION

Convective activity occurs more commonly and frequently across the United States during the spring and summer (nominally, the period of May through September). While distribution of the activity has been examined both temporally (time of maximum activity and severity) and spatially (e.g., nationally as well as regional variations) to depict its characteristic time of occurrence and pattern, very limited improvements in its operational prediction have occurred (other than model parameterizations) in the 24 to 48 hour period versus during "nowcast" (e.g., less than 12 hours) or severe storms.

This practical knowledge is often integrated with typical coursework in atmospheric science (e.g., via thermodynamics and other introductory and upper division courses) but with little guidance to the more comprehensive nature of the convective process and its modalities. While strides have been made in this regard (e.g., COMET modules online, textbooks and web resources, visualization techniques), little has been done in an operational environment in terms of anticipatory, initiation, ongoing, and reduction of convection with time. These offer students a more realistic view of the phenomena and thus are important to emulate for their synthesis of material and in-depth understanding of interacting processes.

Regardless, in spite of a substantial amount of knowledge about thunderstorms and the processes involved, whether occurring as simple air mass or organized convection, the ability to accurately specify the occurrence of storms in time and space remains elusive – as does the ability to properly prepare students to witness and skillfully examine and predict their occurrence, behaviors, and characteristics. In addition, although typical thermodynamic and dynamic profiles of the atmosphere are well established for various convective modes, their operational prediction through various forecast approaches and application of numerical modeling have shown little improvement in skill over time.

1.1 Morphology as Instruction

The prediction of summer season convective activity is complicated by the fact that it is often discontinuous in space across a region (e.g., linear, isolated, clustered, scattered, widespread), and sporadic in time (diurnal versus any time of day). It is difficult to predict precisely in most areas of the United States (e.g., a forecast of a 30% chance across forecast zones) and remains a high priority item on the National Weather Service's priority list for study. The lack of skill is evident in poor verification (for zone or point forecasts) and as convection is not explicitly forecast for operational grids. It is also illustrative for students to identify with the high degree of spatial and temporal discontinuity that arises with convective activity.

At times summer season convective activity may also be supportive of convective interactions and the occurrence of pulse or organized severe weather, both of which demand better understanding to improve forecasts. Operationally, these create great difficulties in predicting thunderstorm activity during 24 hour and short term forecast periods (i.e. 0-6 hours). While convective climatologies based upon surface observations, radar, and satellite may be helpful, they are limited as a diagnostic tool – and may simply aid in 'trend' forecasts of activity. For students, acceptance of these difficulties requires their dismissal of synoptic scale models in favor of mesoscale considerations, boundary layer dynamics, and the ability to ascertain parcel behavior which is not explicitly modeled or observed.

These difficulties are often confounded due to the many factors responsible for the initiation of convection, and their interactions in a highly complex physiographic region that modulates convective activity. These often interact with the very nature of storm structure and thus can elicit feedback responses as well. These responses may support or diminish changes in the convective activity, its modality, and its intensity or severity. When considered in the context of physiographic features, students must then determine the relative importance of physical features in the region – the importance of which varies day-to-

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day and from one synoptic or mesoscale regime to the next. Rather than simply identify these as being "learned by experience" (or local "rules of thumb"), students must examine how best to identify, interrogate, analyze, depict, and relate these to storm initiation, behavior, and processes.

Therefore, even while knowledge of the atmosphere's production of convective modes is good (from both thermodynamic and dynamic perspectives, including severe thunderstorms), the current ability to predict precise timing, location, duration, and coverage of thunderstorms is lacking – even with application of numerical guidance. Since in many instances this lack of precision is due to local interactions, students must determine how these local factors enhance or diminish activity. While the use of mesoscale models has provided valuable insight, these are limited by how well they represent the true physical environment and how well they have been initialized to present the true atmospheric conditions locally. Each of these represents situational and operational learning opportunities for students.

1.2 Students as Independent Researchers

Summer season convective activity is of significant concern to a variety of interests (e.g., aviation forecasts; surface transportation; port operations) given its panorama of effects which can include: cloud base and ceilings, lightning, heavy rainfall, flash flooding, hail, gusty winds, and on occasion pulse severity (i.e. causing property damage or becoming life threatening). These impacts are often exacerbated in an urban setting such as the New York Metropolitan area.

Thunderstorm activity is also a concern and hazard to recreational activities (e.g., boating, fishing, beach, public swimming), construction and maintenance operations (e.g., site preparation, clearing, road work, landscaping), emergency management (including police, fire, public works), and agricultural and commercial interests (e.g., growers, irrigation, nurseries, department stores, outdoor events).

These impacts include significant economic and safety issues that require improved operational depiction and forecast of convective activity – particularly on a local scale. They also represent a wealth of opportunities for students to apply their knowledge to multifaceted problems that require unique solutions. These are generated from the same basis knowledge or content base but then must be molded to conform to the given situation and needs of a select user community. Therefore, students require a research experience that provides a conduit for their use of practical information and theory to solve real problems in a realistic environment.

Students were therefore enrolled to serve as independent researchers to examine the complexities of convective activity. This was accomplished through a variety of programs at Kean University and included: Students Partnering with Faculty (SpF), COMET (NWS/UCAR), Independent Study, and Honors Seminar. The first two programs provided the students with stipend support to work over two summers and during the subsequent academic years whereas the latter two allowed additional students an opportunity to participate. As part of their experience students were also responsible for project reporting and the preparation and delivery of abstracts, papers, reports, posters, and oral presentations at conferences and in other situations as needed.

In tandem, these provided real professional experiences, the use of various pedagogy methods, and the further establishment of the Kean University Meteorology Research Team. Their work included data collection, parsing, and analysis; and they were responsible for direct interaction with one another as well as National Weather Service (NWS) and other peers in meteorology. Much of the project work involved both query and search of relevant literature, data sources, and the manipulation and development of databases. The extensive data and metadata collection in this project required multimedia integration and skills as well as coordination among research team members.

Throughout the project, students made use of content and skills developed in their courses such as thermodynamics, dynamics, and synoptic meteorology. The synthesis of this material, in the context of convective activity, gave the students a structure to frame the work for an operational setting. Meetings and discussion sessions focused not only on data, analysis, and results but also on the literature, outcomes, and applications. Exploring each of these in the context of product delivery, and the eventual development of a conceptual model, were paramount to the student experience of the research process.

1.3 Research Process as Learning

Therefore, in order to better cope with and be prepared for the impacts associated with convective activity, this study focused on select aspects of summer season (June through August) convective activity in and around New Jersey: (i) convective initiation, (ii) differentiation of these from “contaminated” convection, (iii) subsequent convective evolution as related to synoptic, mesoscale, and physiographic features; and (iv) consideration of how the distribution of the convective population family may be used in forecast and verification. Each of these provides a subtopic for investigation by student research.

The intent was to identify convective initiation patterns on the mesoscale as a function of sea breeze and other local circulations as they interact with unique combinations of synoptic scale forcing and local physiographic features. These varying modalities represent an operational analysis of variance to identify relevant features and parameters that would provide definition of a conceptual model of convective activity and behaviors. Students were involved in all aspects of the project, including the development of the proposed research, data collection and methods, and the intended outcomes.

As the local summer convective cycle is most often driven by the diurnal cycle in the northern Mid-Atlantic region, the focus was only on activity occurring from 1200 through 0000 UTC. However, distinction would be made according to whether that day’s convection was “contaminated” by cells on-going or moving into the study region during the morning hours – more typically the convective minimum time of day. If no morning activity was observed, the day’s convection would be considered an “event” for study and compared with “contaminate” activity.

The ultimate pattern of evolution and coverage of all daytime convection was considered in order to better understand the spatial and temporal distributions of the activity. These provide insight to the interaction between local features and the prevailing synoptic and mesoscale flows. Each of these has relevance to the location, timing, coverage, and potential severity of convection. This provides greater insight to the characteristic nature of these events, their associated attributes and patterns, and provides guidance to forecasters in order to better recognize the potential for convective activity in advance and operationally.

This approach also assists in identification of what other work may be necessary, and what other tools or techniques may be needed, in order to improve prediction of thunderstorms across such a major metropolitan region. The study region included some of the CWA of both the Philadelphia/Mount Holly (PHI) and Upton (OKX) NWS Forecast Offices. In addition, the study provides verification relative to the timing and location of convective activity. This is important to an identification of what ‘works’ and where improvements are needed – and how to approach these problems.

2. DATA METHODOLOGY

During the summers of 2006 and 2007 synoptic and local data was gathered to characterize the environment in which convection was occurring (or not) in New Jersey and nearby areas (Figure 1). The study region consists of a large variation in both topographic features and land use (Figure 2) and covers varying climatic zones. Students from the local area were also able to provide some unique insights of specific features and observed convection.

Each day of the summer season (June through August inclusive) was examined through radar interrogation to designate the day as an *event* when convection initiated at any time after 1500 and before 0000 UTC, a *contaminated event* when pre-existing or developing activity occurred within the study region from 1200 to 1500 UTC, and a *null event* when no activity was observed from 1200 through 0000 UTC that day. The selection of the morning start time (1200 UTC) was made to consider the “first” convective forecast for the day that the majority of the impact-community would receive.

2.1 Data Collection

Data collection included both surface and upper air synoptic and mesoscale information as well as collection of radar and satellite imagery, animations; and numerical weather prediction output from the Kean University real-time WRF model (http://hurri.kean.edu/~nwpmodel). The latter would assist in following the evolution of convection with time (i.e. location, timing, movement, duration, and coverage). The data set also incorporated derived parameters (e.g., Skew-T indices, satellite-derived quantitites), local mesonet data (courtesy of the Office of the New Jersey State Climatologist website) as well as ocean and marine information.

The data were collected at 1200 UTC to depict the convective environment (and boundary layer) at the beginning of each day. Evolution of the environment was monitored by collecting similar data at 1500, 1800, 2100, and 0000 UTC. These were collected in order to analyze features of any convective initiates and of the local thermodynamic and dynamic environment as related to synoptic and mesoscale processes as they interacted with (or were potentially forced by) any of the regional physiography. They also avoided any short-lived activity that may have been spurious or representative of only very localized forcing on a time scale of less than three hours. However, weather conditions were monitored between collection times to note any significant changes or the occurrence of any activity.

Additional data included the Daily Weather Map Series in order to identify specific synoptic and mesoscale analyses needed to interpret the observed convective patterns in time and space. Archived and real-time lightning data were also reviewed through a collaborative effort with the PHI NWS in order to examine convective activity from an alternative perspective, as compared to radar, and were also used to examine the characteristics of initiates and convective activity for any given day. Information was also obtained from both the PHI NWS and the Storm Prediction Center (http://www.spc.noaa.gov) to identify any severe weather occurrences.

Given the extensive data collection effort, the data were obtained via internet bookmarks and archived for both retrieval and analysis. This process was developed and modified by the students as part of the research process. File naming conventions (not shown) were identified in order to maintain the mix of observational and derived data as well as imagery and animations. Archive data was also accessed to begin the development of a convective database for prior year activity (i.e. 2000 – 2005). Missing data (e.g., radar maintenance or failure) were replaced when possible by accessing other local radars nearby (e.g., OKX, DOV, and BGM).

2.2 Data Summary

For the three months examined during 2006 and 2007 (June, July, and August) 39 events and 22 contaminated events were identified (Tables 1 and 2) for the two summer period. All other days were classified as either "no data collected" or null events. All days from both seasons were entered into a summary spreadsheet to generate simple statistics (not shown) for comparison of events, contaminated events, and null events. This also allowed for data interrogation through histogram, graphical, and other analyses. Each of these provided an internal check for data consistency and verification of missing or incomplete information. These were pertinent to portray thermodynamic and dynamic environments and afforded the students greater insight to observed variations that would be encountered operationally.

In addition, to portray spatial and temporal features and trends of the convective activity, radar (and when necessary satellite and/or lightning) data was used to depict convection. The activity for each *event* and *contaminated event* were plotted (outlined) on a map of the study region based upon radar and radar animations. Plotting involved drawing an envelope of 30 dbz (and higher with 50 dbz highlighted) to capture any initial activity (and time) and to portray its distribution and characteristics (i.e. location and mode: cells, areas, clustered, linear, or isolated) and evolution with time. Cell evolution between data collection times was examined through animations to ensure continuity. These provided students with an overview of storm structure and evolution in real-time.

Each of the daily plots were then annotated and categorized according to the synoptic surface regime present at 1200 UTC and the base state flows at the surface (as defined by surface weather map features and isobaric configurations) and at the standard upper air pressure levels (i.e. 925, 850, 700, 500, 300, and 200 mb) according to contour analysis for the same initial conditions. The division of events and contaminated events by base state flows and synoptic regime is provided in Tables 3 and 4 (for 500 mb) and reveals a limited amount of variability in terms of preferred flow regimes associated with convective activity. For a southwesterly flow at 500mb (the most common) there were 14 events versus 6 contaminate events. Other flows were as follows: north 2 and 0; south 0 and 2; west 20 and 9; northwest 0 and 3. The majority of convective activity then is generated with the prevailing flow (west and southwest) of the region.

Although a limited sample size, the data do provide some insight to features associated with the family of convective activity occurring in the summer season in and around the study area. The two summer seasons collected capture a sampling of the statistical "family" (of the true population) of convective activity and are thus useful in application to any summer season. This provides information which may be used in better understanding the attributes of convective activity that may be employed in the prediction and operational environment. Students then are witness to interannual and intra-annual variations that may occur.

3. ANALYSIS OF EVENTS

Inspection of the collected data focused on the location of initiates for *contaminates* and *events* with regard to the observed base state flows and synoptic regimes. Once the data were parsed, the resultant motion and coverage of convection was examined collectively (within select flow directions) and individually (features of specific cases).

This allowed for comparisons of events with comparable *contaminates* to identify observed similarities and differences. Once identified, these were considered with regard to local physiographic features and local circulations (e.g., sea breeze, mountain-valley). A preliminary overview of all flow regimes (at various levels) and the attendant surface synoptic pattern revealed several characteristics. These preliminary insights are important to continuing the research process and helping students to understand the proper questions to ask.

For example, for events initiates had a similar location of origin to contaminate activity but mostly developed outside New Jersey. Most total activity was found as isolated clusters or cells and was less "focused" in comparison to contaminate activity. When the time of the season was considered it was found that just over half of the event initiates have an origin in the southern half of the study region as compared to very little in those locations during the early summer. In general the activity was highly variable, but limited, in time-placement-coverage versus contaminates that tended to cluster.

In the case of contaminate activity alone, it was observed that contaminate cells do not preclude further activity. The contaminate cells were also more 'focused' with a westerly flow at 500 mb. In the case of south and southwesterly flow they were found to be more often in southern New Jersey and nearby coastal regions. During the progression of the season their region of origin appeared to diminish in the higher terrain of northeastern Pennsylvania and northwestern New Jersey. The total activity for contaminate cells was highly variable.

In this paper, a brief review and comparison is offered for two of the 500 mb flow regimes to illustrate student involvement in the research process (Figure 3). A comparison of initiate events for west and southwest flow indicate that the initial convective activity appears preferentially clustered in the westerly flow cases with much greater variability under the southwest regime. In fact, the majority of activity is found in the interior sections with virtually none observed elsewhere. In the southwest cases the activity did occur over a larger area and extended to the coastal regions. Both exhibited linear features of cells with some variations in size and shape and the maximum intensities inside.

When compared with the contaminate activity (Figure 4) the westerly flow regime was much more productive than for initiate events in terms of location and coverage. In fact there was a greater occurrence of activity towards the coastal regions than inland. The opposite was true for the southwesterly cases in that activity was reduced but apparently of greater intensity. The location of origin appeared to be between higher elevation regions and the coastal plain. In west and southwest contaminate events the cells and/or lines tended to be oriented from southwest to northeast more so than events.

4. NEXT STEPS

In addition to the first investigation of the distribution and behavior of cells, the students will complete a full analysis including surface and upper air data and variables obtained previously. Simple compositing will be prepared to explore the convective environment and the inter-relationships among the family of convective modes in the study region. These will help in both verification of activity and the creation of a predictive methodology to diagnose convective activity in terms of timing, location, duration, and coverage.

Following these analyses, the initiation, evolution, and coverage patterns can be studied with regard to the physiographic features present (e.g., coastal plain, barrier islands, peninsula effects, hills, Pine Barrens, tidal rivers, lakes, and mountains) in which soil and flora vary considerably and that may generate local circulations. Land surface interactions and modeling studies support the significance of local physiographic features in determining the convective state of the atmosphere.

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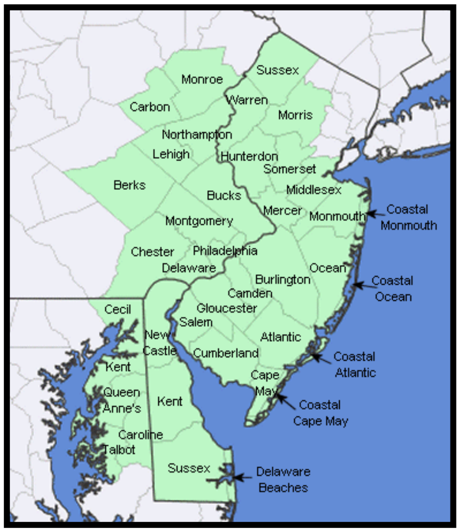

Figure 1. Study region includes the PHI (Philadelphia/Mount Holly) County Warning Area as well as nearby portions of New York, Connecticut, and Pennsylvania.

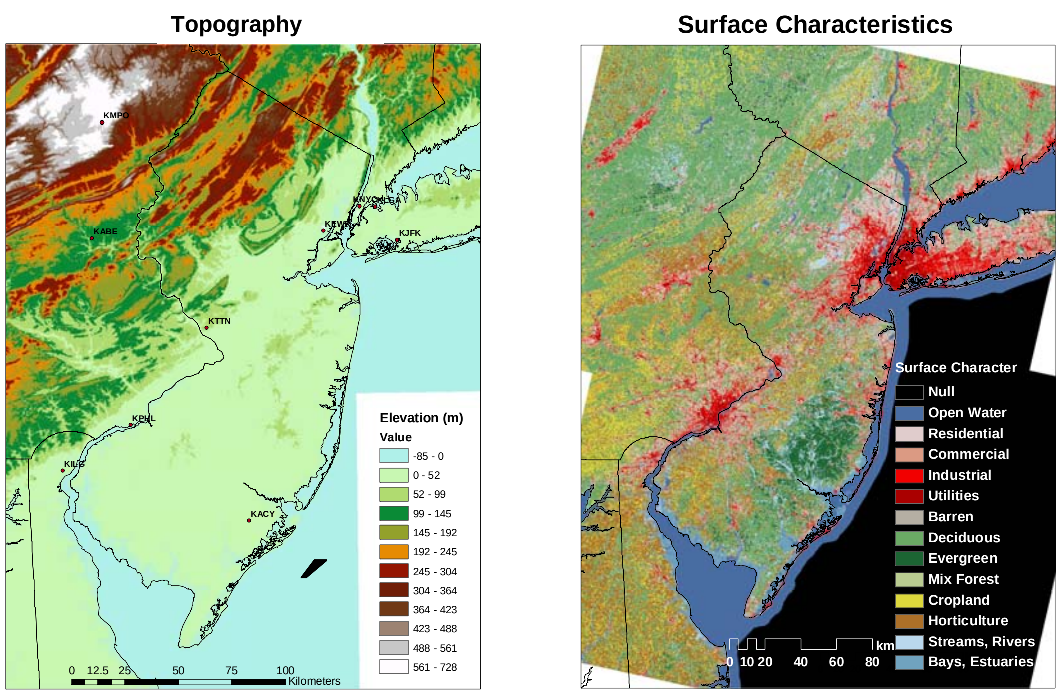

Figure 2. Study region local topographic variations and land use characteristics.

Frequency Distribution				2006
	June	July	August	Total
Event	4	7	2	13
Contaminated	4	3	2	9
Total	8	10	4	22

Frequency Distribution				2007
	June	July	August	Total
Event	9	10	7	26
Contaminated	4	5	4	13
Total	13	15	11	39

Tables 1 and 2. Number and type of events collected during the summer seasons of 2006 and 2007.

Base State Flow at 500mb								
Event/Contaminated	**N**	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
June	0,0	0,0	0,0	0,0	0,1	4,1	0,1	0,1
July	0,0	0,0	0,0	0,0	0,0	1,1	6,2	0,0
August	0,0	0,0	0,0	0,0	0,0	0,0	2,2	0,0
Total					0,1	5,2	8,5	0,1

Base State Flow at 500mb								
Event/Contaminated	**N**	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
June	2,0	0,0	0,0	0,0	0,1	1,1	4,1	0,0
July	0,0	0,0	0,0	0,0	0,0	7,4	2,0	0,1
August	0,0	0,0	0,0	0,0	0,0	1,0	6,3	0,1
Total	2,0	0,0	0,0	0,0	0,1	9,5	12,4	0,2

Tables 3 and 4. Distribution of events and contaminate events by 500 mb flow regime by month for 2006 and 2007.

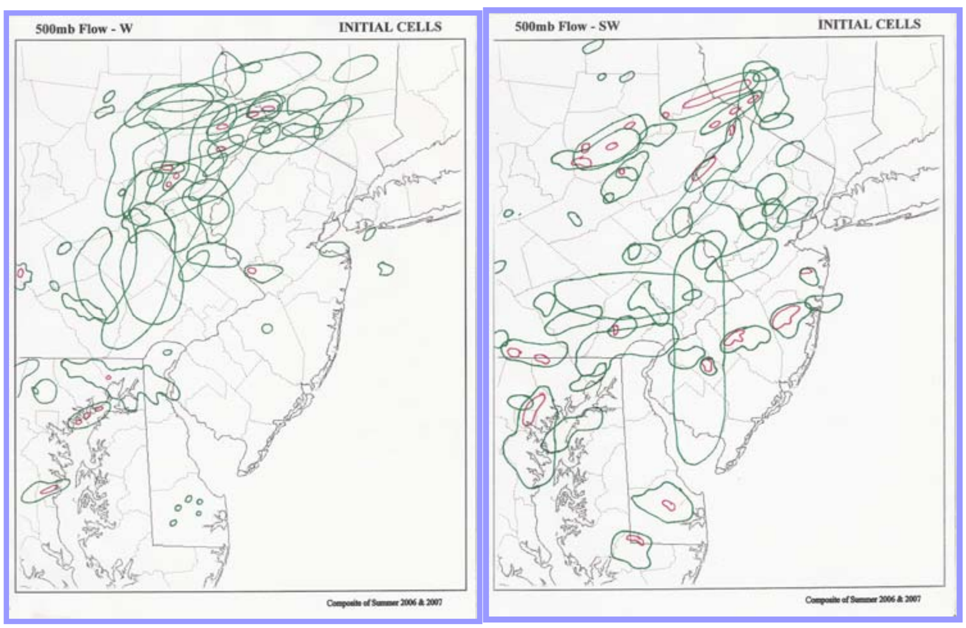

Figure 3. Initial cell activity and location for west and southwest flow at 500 mb.

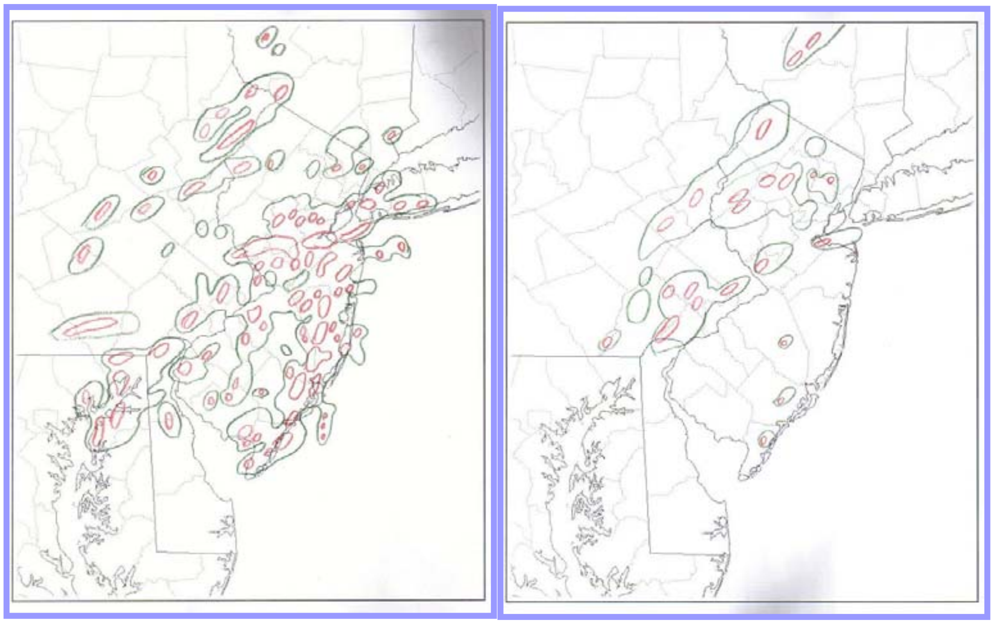

Figure 4. Same as Fig. 3 but for contaminate activity.