ATM 400: Synoptic Meteorology I
Research Project Overview

For your ATM 400 research project, you may research any meteorological event that interests you **from a synoptic perspective**. Keep in mind, however, that this is a paper that is due at the end of the semester, so you should choose a topic that you can discuss in eight to 10 pages and complete in one to two months.

To help you stay on track, you will need to complete various parts of the project by the following **due dates**:

Topic: September 17
Proposal: September 24
Outline: November 6
Paper: December 9 *(by 5 PM)*
Presentation: December 16 8–10 AM *(University-scheduled final exam time)*

Topic:
The topic of your case study needs to be discussed with me before you progress to the proposal stage. Please see me, or email me, to finalize your topic by September 17.

Proposal:
Your proposal should consist of a one-page summary of your case study and is due on September 24. The proposal is worth 15% of the project grade and will be graded based on whether you've addressed the following questions regarding your chosen event:

~ Scientific motivation: What makes this event worth studying?

~ Societal motivation: Who was impacted by this event?

~ Geography: When/where did this event occur?

~ Methodology: How will you analyze this event, i.e., which data sources and weather maps will you plot and use?

~ Anticipated results: What synoptic features were key to the event? What dynamic principles are relevant?

Outline:
Your outline is the skeleton of what your paper will look like. The goal of the outline is to get you thinking about how you want to structure and organize your paper. The components of your outline (and paper) should include an Abstract, Introduction, Data & Methodology, Results, Discussion/Conclusions, and References. For each of the questions detailed above, your outline should expand on the ideas presented in your proposal. The outline is worth 15% of your grade and is due November 6.

Paper:
Your paper should include:

1. Abstract (100 to 200 words summarizing your main findings)

2. Introduction
3. Data sources & methodology
4. Results
5. Discussion and conclusions
6. References

The body of the paper (Introduction through Conclusions) should be eight to 10 pages. You should include a title page with your paper title, your name, and the abstract. It is also important that you use figures to demonstrate your motivation, results, and conclusions. You should include a minimum of five figures in your paper and no more than ten. One of your figures is **required to be a schematic** that graphically summarizes your case study, whether hand drawn or computer generated. The paper is due on, or before, December 9 @ 5 PM.

The written paper is worth 60% of your research project grade divided between the three categories below.

1. Writing format/style

~ Cover page

Does the paper have a cover page with the title of the project, the name of the author, and an abstract of 100–200 words?

~ Sections

Does the paper contain an Introduction, a Data & Methodology section, Results, a Discussion, and/or Conclusions?

~ References

Does the paper contain references that adhere to AMS format? Are the references properly cited in the text?

~ Coherence

Is the paper written in complete sentences? Are there typos? Was the paper spellchecked and proofread?

~ Length

Does the manuscript adhere to the page limit? (Note: The page limit does not apply to the cover page and figure captions.)

2. Original research

~ Motivation

Does the Introduction provide both scientific and societal motivation? Does the author provide enough information to answer the questions what, when, where, and who?

~ Data and methodology

Are the data sources and methodology appropriate for the case study? Does the author use their data sources effectively? Are the reasons for the specific data sources and methodology clearly explained?

~ Results

Does the author provide sufficient results to demonstrate why their case occurred where and when it did? If the author could not determine why, do they offer plausible hypotheses?

~ Summarizing discussion

Does the author summarize their results in a conclusions section? If the author was not able to determine why their event occurred, do they offer suggestions on how, if they had additional time, resources, knowledge/skill, etc., they might determine why?

3. <u>Figures</u>

~ Figure quality and purpose

Does the author provide at least five, but no more than ten, figures? Does the author reference each figure in the text? Does each figure contain a descriptive caption?

~ Summary/schematic figure

Does the author provide one figure that concisely summarizes their study?

<u>Presentations</u>:

The oral presentation should be a five-slide, 8-minute overview of your main findings: (1) What was the event, (2) why did you study this event (i.e., motivation), (3) what did you do to study the event, and (4) what were your primary results? Presentations will occur during the Final Exam period, on Tuesday, December 16, 8–10 AM, and are worth 10% of your grade.

The evolution of and role of ageostrophy in the 3-5 February 1998 Ice Storm

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ABSTRACT

The storm of 3-5 February 1998 was seen as another miss to snow lovers in the Northeast during the so called "non-winter" of 1997-1998. But while the storm was another disappointment to much of New England, the southeastern and mid-Atlantic states were hit with a powerful wind and rain event that produced up to 25 m/s winds along the North Carolina, Virginia and New Jersey coasts with over 80 mm of rain. Further north, sections of Maryland and Pennsylvania were hit with an ice storm of moderate intensity that left 50-80 mm of sleet on the ground.

While the storm's initial development and track was erratic, a second major period of deepening occurred between 00 UTC and 12 UTC on 4 February. Cyclogenesis began in connection with a short wave in the northern stream coming into phase with the southern flow trough associated with initiating the sea level cyclone. As these troughs approached the Carolina coastline they interacted with a coastal front present due to significant onshore flow and warm air advection. This deepening and large increase in the pressure gradient caused the isallobaric component of the ageostrophic wind to contribute significantly to the horizontal wind. The flow was in a northerly direction at low levels of the atmosphere pulling cold air down, under the strong warm air advection at 850 hPa to produce the sleet and ice storm of 5 February 1998.

Abstract should have at least one sentence stating the purpose of the paper.

1. Introduction

The development of the storm began late on 2 February as an upper level trough swung east into the Gulf of Mexico over a pre-existing frontal boundary at the surface. The track and estimated central pressure in 6 h intervals in Figure 1 reveal that cyclogenesis initially proceeded at

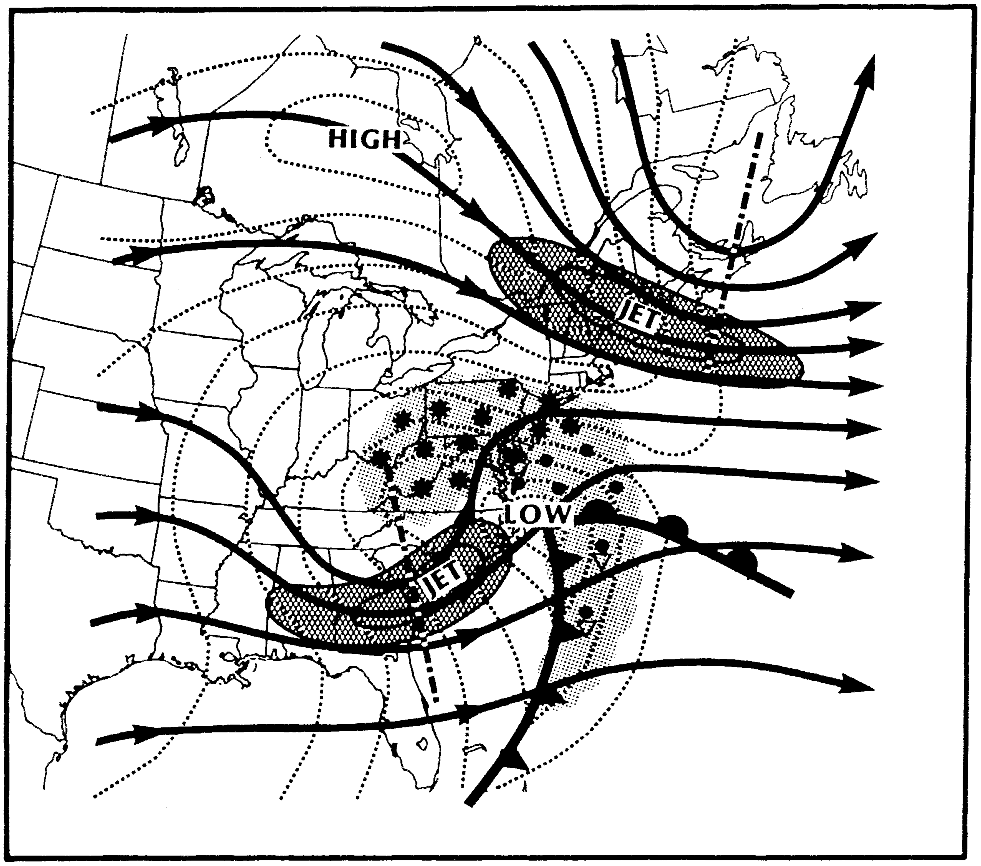

FIG. 1. Schematic of surface cold and warm fronts, high and low pressure centers, sea level isobars (dotted), precipitation (shading—asterisks represent snowfall; dots represent rain), upper-level flow (arrows), upper-level trough axes (dot-dashed), and jet streaks (cross-hatched shading) associated with a "typical" heavy snow event along the East Coast.

from the 1986/87 winter season. A brief review of the patterns of divergence, ageostrophic flow, and descriptions of vertical circulations associated with upper-level troughs and jet streaks is presented in section 2. Brief synoptic analyses and two-dimensional descriptions of vertical circulations are then described in section 3 for eight snowstorms, to provide evidence that the interaction of jet streak circulation patterns characterizes many heavy snow events along the East Coast. In addition, the ease and difficulties of isolating these patterns with the 12-h operational database are also illustrated. The results of the study are summarized in section 4.

2. Ageostrophic wind, divergence, and circulation patterns associated with trough-ridge systems and jet streaks

A net reduction in mass is required for surface cyclones to develop, whereby upper-tropospheric mass divergence exceeds low-level convergence. Bjerknes and Holmboe (1944), and more recently Newton and Trevisan (1984), relate the structure of troughs and ridges within upper-level waves and associated "longitudinal" (or alongstream) ageostrophic wind components to a pattern of upper-level divergence (convergence) downwind (upwind) of a trough axis that is conducive to surface cyclogenesis (anticyclogenesis), as illustrated in Fig. 2. Bjerknes and Holmboe also emphasize that decreasing wavelength, increasing wind with height, and diffluence (confluence) in the streamlines all act to enhance the divergence (convergence) aloft. Given the problem of diagnosing the divergence with the early radiosonde network, these processes have been inferred through the use of the vorticity and thermodynamic equations, forming the basis of the Sutcliffe (1947) and Petterssen (1956) development equations and the quasi-geostrophic geopotential tendency and omega equations (described by Holton, 1979, Chapter 7). Within these frameworks, the divergence in the upper levels is approximated by the vorticity advection fields, with cyclonic or positive (anticyclonic or negative) vorticity advections associated with divergence (convergence) (see also Palmen and Newton, 1969, pp. 318-319).

In addition to the contribution of the longitudinal or alongstream ageostrophic components to divergence within

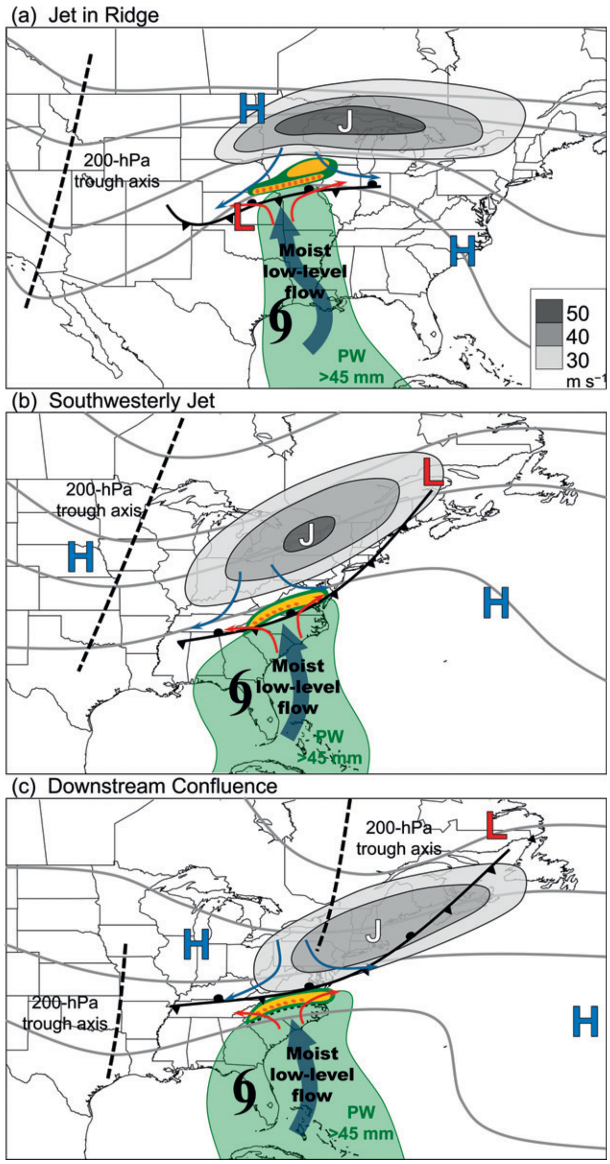

FIG. 20. Conceptual model of the key synoptic-scale features and processes for (a) JR, (b) SJ, and (c) DC category PREs. The gray contours denote the 200-hPa geopotential height field, with the thick dashed black line marking the primary trough axis. The gray shaded regions represent 200-hPa wind speed [m s^{-1}; gray shade bar in (a)] and the "J" marks the 200-hPa wind speed maximum. The thin red and blue arrows represent 925-hPa streamlines associated with regions of warm and cold advection, respectively. The position of the surface front is shown in standard frontal notation, and the positions of the SLP maxima and minima are marked by the "H" and the "L" symbols, respectively. The light green shading indicates the region with PW values >45 mm. The thick blue arrow represents a corridor of moist low-level flow. The dark green, gold, and orange shaded regions represent radar reflectivity thresholds of 20, 35, and 50 d*BZ*, respectively, associated with the PRE. The TC location is indicated by the tropical storm symbol.

The JR category, in contrast to the SJ and DC categories, represents a scenario in which a TC plays an indirect role in PRE development, with the TC primarily acting as a source region of water vapor that is "tapped" and transported by an LLJ into a distant region of frontogenetically forced ascent. The JR composites indicate that this tapping of water vapor occurs when the TC becomes embedded in a synoptic-scale flow pattern resembling the Maddox et al. (1979) frontal type flash-flood pattern. Typically, as demonstrated in the JR composites, lifting in the vicinity of JR PREs is not directly influenced by the cyclonic circulation or by the upper-level outflow of the TC. This lack of direct influence on the part of the TC can result when the TC circulation and upper-level outflow are relatively weak or small-scale and/or when the TC and PRE are separated by a large distance. As posited by GBS10 for the TC Erin (2007) PRE, it is plausible that for many JR PREs rainfall would occur even in the absence of the TC, but the presence of additional water vapor from the TC serves to enhance rainfall accumulations. Consistent with this interpretation, numerical model simulations of the TC Erin (2007) PRE by Schumacher et al. (2011), in which the moisture plume associated with TC Erin was removed, showed a 25% reduction in area-integrated rainfall and a 50% reduction in the maximum rainfall total for the PRE.

It is acknowledged that PREs are not limited to occurring within the three categories described in the current study. Accordingly, a so-called unclassifiable (UC) category was included, containing events that did not fit into any of the three categories. UC PREs were not examined in the current study and therefore represent a possible avenue for future research. Furthermore, PREs occurring in the United States east of the Rockies in association with Atlantic basin TCs have only been considered here. PREs or PRE-like events can occur in other parts of the world, such as the southwestern United States in association with east Pacific TCs (e.g., Corbosiero et al. 2009) and eastern Asia in association with western North Pacific TCs (e.g., Wang et al. 2009; Meng and Zhang 2012; Byun and Lee 2012), involving other unique synoptic-scale flow patterns. It is also acknowledged that there exist other methods of classification and composite analysis for examining the environments of PREs; we have presented only one possible approach. The results of the PRE classification and composite analysis presented in the current study can help improve identification and prediction of PREs in short- and medium-range forecasts. To supplement these results, future work could include a comprehensive assessment of operational numerical model performance in predicting PREs on short- and medium-range time scales.

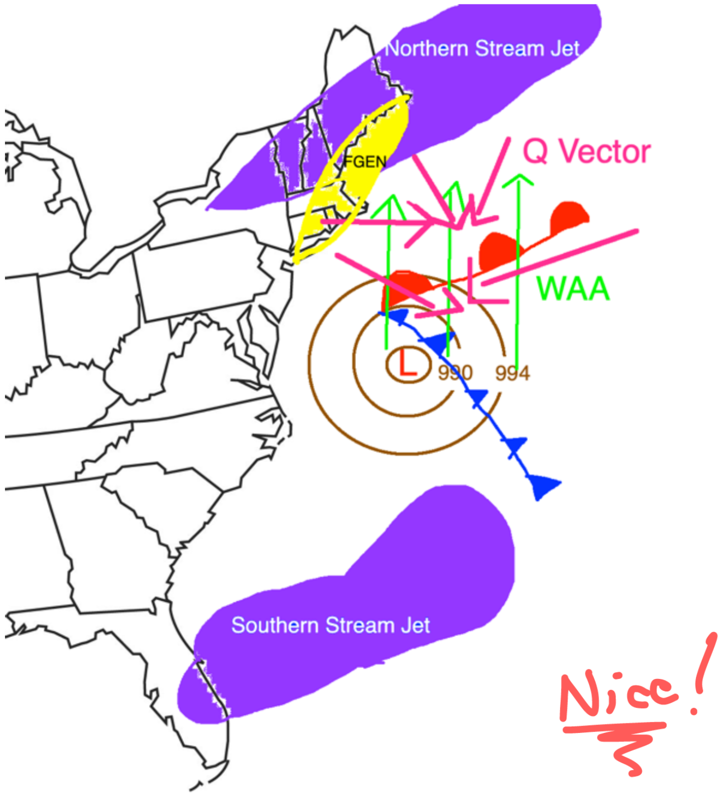

Figure 8: Hand-drawn schematic featuring the key synoptic features resulting in the development of the blizzard. Jet streaks (purple), cold front (blue), warm front (red), warm air advection (green arrows), Q vectors (pink), sea-level pressure (contours), frontogenesis (yellow).

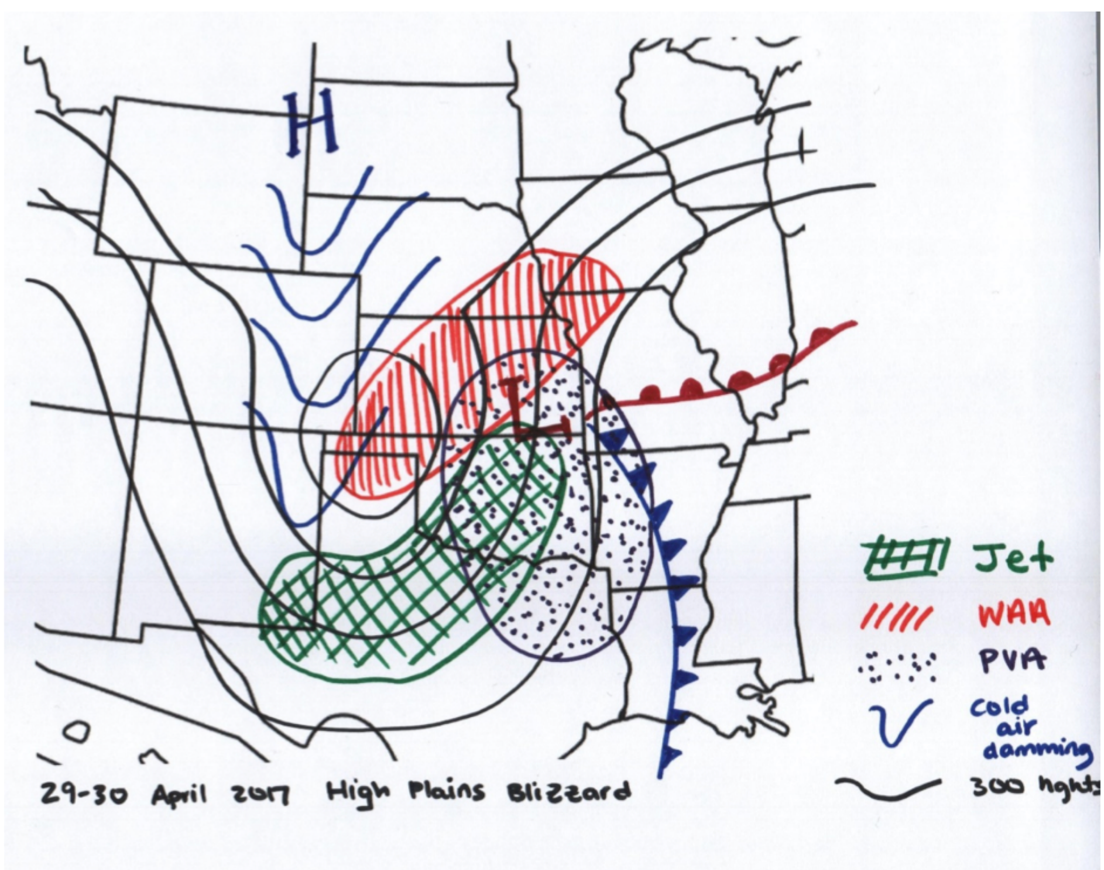

Figure 8: Schematic of 29–30 April 2017 High Plains blizzard. Black contours: 300-hPa heights, blue contours: surface pressure bowing from cold air damming, green: 300-hPa jet, orange: 700-hPa WAA, purple: 500-hPa PVA.

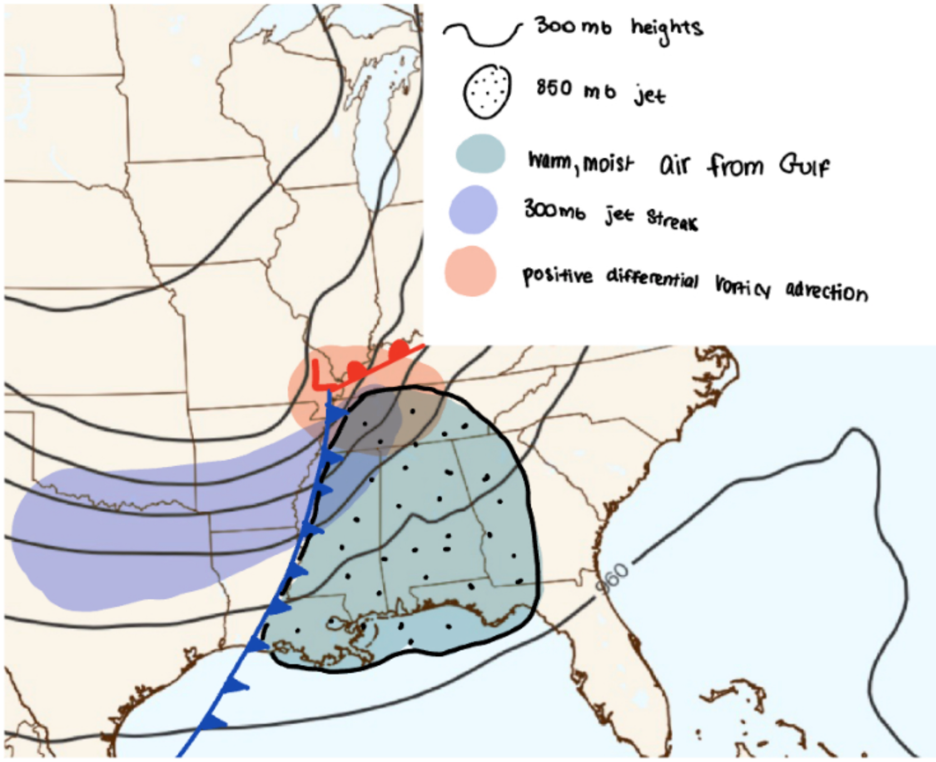

Figure 10: Schematic valid 2200 UTC 27 April 2011: 300-hPa heights (black contours), 850-hPa jet (dots), warm, moist air indicated by teal shading, 300-hPa jet streak indicated by purple shading, positive differential vorticity advection indicated by red shading, warm and cold fronts indicated by red and blue lines.

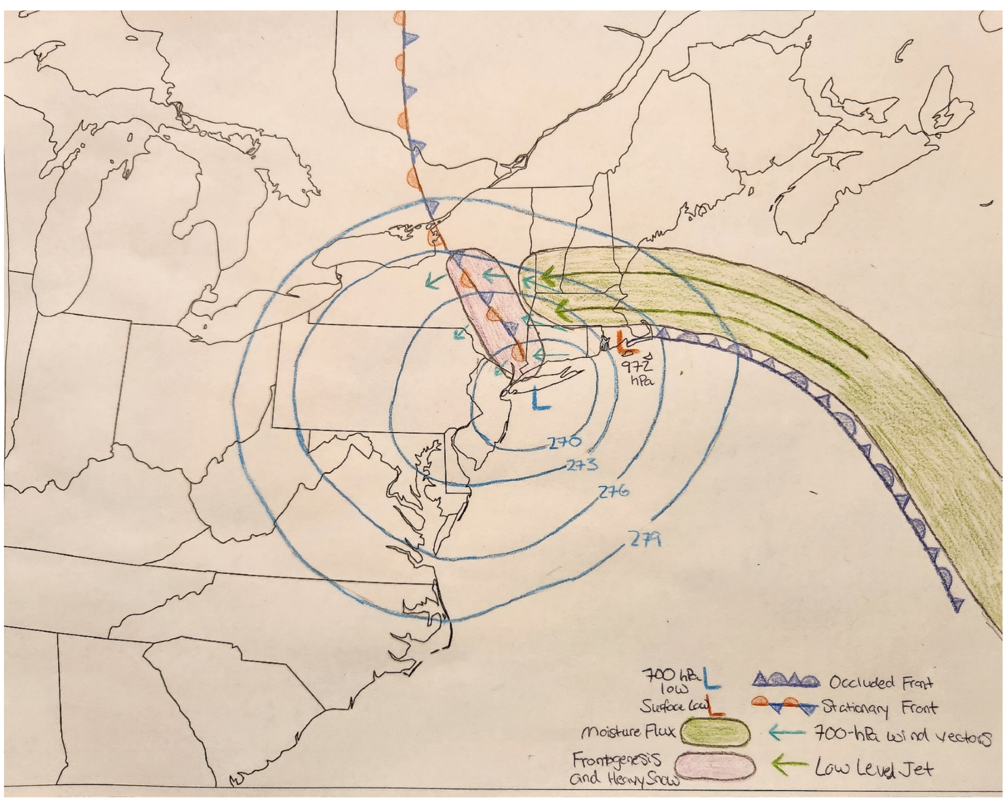

FIG. 10. Schematic of the nor'easter at peak intensity 0300 UTC 26 February 2010. Surface low (red L) and 700-hPa low (blue L) are shown. 700-hPa contours, & 700-hPa wind vectors (light blue), low level jet (green streamlines), moisture flux (green fill) & frontogenesis (pink fill). The occluded and stationary fronts are also shown.