Hi all,

Friday map discussion for 16 Nov 2018 opened with a discussion of the large-scale NH flow pattern between 1–14 Nov 2018 that enabled the occurrence of: (1) Diablo/Santa Ana wind conditions in California and the subsequent almost unimaginable deadly wildfires, (2) an anomalous and impactful early-season cold-air outbreak in the Southern Plains and Midwest, and (3) an extraordinarily high-impact and calamitous nor'easter notable for its very meteorological ordinariness. Tomer Burg, Will Flamholtz, Tyler Leicht, and Danny Reese provided important analyses and insightful commentary during map discussion. Links used during map discussion can be found here: http://www.atmos.albany.edu/mapdisco/20181116/

1. Overview of the large-scale Northern Hemisphere (NH) flow pattern between 1–14 November 2018:

Mean and anomaly NH analyses of 300-hPa geopotential height and 850-hPa temperature for 1–14 Nov along with a 2-m temperature anomaly map for North America for 1–16 Nov (source: WeatherBell) can be found here: http://www.atmos.albany.edu/mapdisco/20181116/images/coldpattern.pdf. Key takeaways are: (1) a stable wave #4 NH flow regime with prominent cold troughs near 90 E and 90 W is present, (2) a high-latitude blocking ridge is present over northwestern Europe, and (3) prominent ridging is present over the EPAC and along the west coast of North America. The combined meteorological impact of this stable flow pattern is to enable: (1) very cold air to reach the lower latitudes of central Asia, (2) terrain-channeled cold air to surge well equatorward to the east of the Rockies, (3) the formation of a strong baroclinic zone along the east coast of North America, and (4) anomalously warm conditions to prevail across much of northwestern Europe, the adjacent Arctic, and much of northeastern Asia eastward to the west coast of North America (where a high wild fire threat would exist).

2. Onset of Diablo/Santa Ana conditions in California and subsequent wildfires:

Heather Archambault's dynamic tropopause loop for 1–15 Nov 2018 shows that a series of anticyclonic wave breaking (AWB) events occurred over the eastern Pacific and western North America during this period (http://www.atmos.albany.edu/student/heathera/dt/nam/1_to_15_nov18.html). This persistent AWB regime precluded any significant troughs and associated Pacific disturbances from reaching California. Instead, Pacific troughs moved eastward farther poleward around the periphery of the AWB region and then dropped southeastward across the Great Basin, prominent examples of which occurred between 8–9 Nov and 11–12 Nov. Cold-air advection over the Great Basin behind the aforementioned troughs drove significant sea level pressure (SLP) rises across the Great Basin east of the Sierras relative to coastal California (http://www.atmos.albany.edu/student/heathera/slp_thick/nam/1_to_15_nov18.html). Observed SLP differences between SLC–SFO and SLC-SAN SLP reached as large as 15 hPa, more than sufficient to drive strong Diablo/Santa Ana winds toward the coast across much of central and southern California. Tomer Burg's standardized SLP anomaly map loops show the aforementioned Diablo/Santa Ana wind signal nicely (http://www.atmos.albany.edu/student/tburg/analysis/loop.php?model=gfs&prod=500hght_std;mslp_std;850temp;850temp_std;1000temp_std;pwat;700pwat_std;&curid=1&proj=us&archive=1&run=2018111812). Caveat: the start of the loop period is 6 Nov and the loops will slowly age off.

Given the late start to the rainy season in California this year, any wildfires that ignited for whatever reason would be able to feed on tinder dry vegetation and be guaranteed to spread and grow rapidly as was observed with the Camp Fire in central California and the Woolsey Fire in southern California. More details and a much more in depth meteorological analysis of the Camp and Woolsey Fires that includes a discussion of the widespread impacts of extended poor air quality in much of California can be found in an excellent blog on this subject by Cliff Mass (http://cliffmass.blogspot.com/2018/11/the-air-quality-health-crisis-from.html). The New York Times has also constructed a detailed analysis of the wildfire that destroyed much of Paradise, CA ('Hell on Earth': The First 12 Hours of California's Deadliest Wildfire (https://www.nytimes.com/interactive/2018/11/18/us/california-camp-fire-paradise.html).

Science hypothesis: Eastern Pacific anticyclonic wave breaking may be a necessary but insufficient condition for an increased likelihood of the occurrence of Diablo/Santa Ana wind conditions in California.

3. A recipe for Southern Plains cold:

Tomer Burg has a web page that contains loops of standardized anomalies of assorted fields. His standardized anomaly loops that are most relevant to the understanding Southern Plains cold are as follows (caveat: these loops will age off with time):

SLP standardized anomalies (shaded) plus SLP contours and winds: http://www.atmos.albany.edu/student/tburg/analysis/loop.php?model=gfs&prod=500hght_std;mslp_std;850temp;850temp_std;1000temp_std;pwat;700pwat_std;&curid=1&proj=na&archive=1&run=2018111812

500-hPa standardized geopotential height anomalies (shaded) plus geopotential height contours and winds: http://www.atmos.albany.edu/student/tburg/analysis/loop.php?model=gfs&prod=500hght_std;mslp_std;850temp;850temp_std;1000temp_std;pwat;700pwat_std;&curid=3&proj=na&archive=1&run=2018111812

850-hPa standardized temperature anomalies (shaded) plus temperature contours and winds: http://www.atmos.albany.edu/student/tburg/analysis/loop.php?model=gfs&prod=500hght_std;mslp_std;850temp;850temp_std;1000temp_std;pwat;700pwat_std;&curid=3&proj=na&archive=1&run=2018111812

1000-hPa standardized temperature anomalies (shaded) plus temperature contours and winds: http://www.atmos.albany.edu/student/tburg/analysis/loop.php?model=gfs&prod=500hght_std;mslp_std;850temp;850temp_std;1000temp_std;pwat;700pwat_std;&curid=4&proj=na&archive=1&run=2018111812

Positively tilted western North American ridges in conjunction with “hang back” positively troughs over the Southwest are especially effectively at enabling low-level terrain-channeled cold air to move well equatorward east of the Rockies as evidenced by examples from 8–9 Nov and 12–13 Nov. These terrain channeled cold-air surges are facilitated by anomalously low SLP values over the Southern Plains ahead of a "hang-back” positively tilted trough and anomalously high SLP values over the Northern Plains and adjacent Canada ahead of a positively tilted ridge. For example, at 0000 8 Nov, standardized SLP anomalies are between -1 and -2 sigma over AZ/NM relative to standardized SLP anomalies between +1 and +2 sigma over MT in the cold anticyclone pushing southward east of the Rockies. By 1200 UTC 9 Nov, standardized SLP are between -0.5 and -1.0 over South TX and between +2.5 and +3.0 over the Northern Plains. Cold air has no place to go except equatorward under4 these conditions (1000-hPa standardized temperature anomalies are between -2.5 and -3.0 sigma at 1200 UTC 9 Nov).

In the stronger terrain-channeled cold-air surge of 12–13 Nov, standardized 1000-hPa temperatures anomalies reach -5 (and beyond) sigma in the lower Rio Grande Valley region (standardized SLP anomalies in the same region reach +4 sigma). Strongly positive standardized SLP anomalies are concentrated near and west of a deep, positively tilted southern stream trough at 1200 UTC 13 Nov. Similarly, standardized 500-hPa height anomalies in the highly amplified, positively tilted western North American ridge exceed +2 sigma over parts of southwestern Canada and the Pacific Northwest at 1200 UTC 13 Nov. These positive standardized 500-hPa height anomalies support a 1040 hPa anticyclone over part of interior western North America. Strong low-level northerly flow to the east of this anticyclone drives very cold air southward across Mexico and Central America and across the Chivela Pass into the Gulf of Tehuantepec.

Science hypothesis: Terrain-channeled cold surges east of the Rockies and exceptional cold periods in the Southern Plains and lower rio Grande Valley occur disproportionately in conjunction with positively tilted ridges west of the Rockies and positively tilted troughs east of the Rockies.

4. High-impact calamitous Nor’easter:

A rather ordinary early season nor'easter produced an epic extraordinary afternoon and evening transportation disaster (transpocalypse) in the NYC metro area on Thursday 15 November 2018. The gory details can be found in the following four links to storm-related stories in the New York Times:

NYT: The New York Area Was Nearly Paralyzed by 6 Inches of Snow. What Went Wrong? https://www.nytimes.com/2018/11/16/nyregion/snowstorm-total-delays-commute.html?action=click&module=Top Stories&pgtype=Homepage

NYT: New York Today: Snow Storm Causes Delays and Chaos for Trains, Buses, Schools https://www.nytimes.com/2018/11/16/nyregion/newyorktoday/port-authority-nj-transit-snow-commute-nyc.html?rref=collection/sectioncollection/nyregion&action=click&contentCollection=nyregion&region=stream&module=stream_unit&version=latest&contentPlacement=7&pgtype=sectionfront

NYT: 'Not a Soul Taking Control': How a Storm in the New York Area Upended the Night

https://www.nytimes.com/2018/11/16/nyregion/nyc-snowstorm-traffic-commute.html?rref=collection/sectioncollection/nyregion&action=click&contentCollection=nyregion&region=stream&module=stream_unit&version=latest&contentPlacement=1&pgtype=sectionfront

NYT: New York Today: Why Politicians Fear Snowstorms Even More Than You Do

https://www.nytimes.com/2018/11/19/nyregion/newyorktoday/new-york-today-politicians-storms.html?em_pos=large&emc=edit_ur_20181119&nl=new-york-today&nlid=54201803edit_ur_20181119&ref=headline&te=1

The question we wrestled with in map discussion was how could a run-of-the-mill ordinary Nor'easter that was reasonably well predicted and well advertised by the available numerical guidance produce such a disproportionate high-impact disastrous transportation debacle (aka transpocalyse) response (http://www.atmos.albany.edu/mapdisco/20181116/images/NY.png)?

Twas the week before Thanksgiving and not a vehicle was moving. A traffic map of the NYC metro area valid ~2100 UTC on 15 Nov: http://www.atmos.albany.edu/mapdisco/20181116/images/NY.png

A snowfall accumulation map through 1900 UTC 16 Nov (courtesy of Tomer Burg): http://www.atmos.albany.edu/student/tburg/mapdisco_20181116/map.png

The existing NWP models clearly advertised that a plowable snow was possible in the NYC metro area, western Long Island, and points north along the coast a couple of days in advance of the event as typified by the ECMWF total snowfall forecast map from 1800 UTC 13 Nov: http://www.atmos.albany.edu/mapdisco/20181116/images/1318Euro.png

So what went wrong? For openers, many public and private forecasts downplayed the potential for accumulating snow sufficient to disrupt the evening rush hour until it was too late as summarized in an internal email I sent on Friday (http://www.atmos.albany.edu/mapdisco/20181116/images/lance_email.pdf). The expected snowfall forecast issued by the NYC NWS office at 1153 UTC on 15 Nov showed the potential for accumulating snow on the western and northern sides of the metro area with maximum amounts of 1–2” in Manhattan and no snow on Long Island (http://www.atmos.albany.edu/mapdisco/20181116/images/NWS_official_forecast_20181115_12z.jpg). The NWS NYC 1735 UTC forecast update pretty much doubled the earlier forecast snowfall totals and now included significant accumulating snow over western Long Island and Manhattan. The problem, alas, was that most people had gone to work with the expectation that any snow would not be a big deal.

The Central Park (KNYC) observations below show that S- began at 1836 UTC, 61 min after the aforementioned NWS forecast update, transitioned to moderate snow (S) at 1859 (23 min after snow began), and further transitioned to heavy snow (S+) by 1943 UTC, 67 min after starting. Note that the transition to S+ produced liquid water equivalents of 0.15”, 0.25”, 0.18” and 0.15” in the hours ending 2051, 2151, 2251, and 2351 UTC, respectively. These precipitation rates suggest hourly snowfall rates of 1–3” per hour, more than enough to disrupt and disable transportation and produce widespread gridlock. The transpocalypse was compounded by a quasi-simultaneous mass exodus for home by millions of people, given that nearly everyone panicked once the snow started and quickly reached S, and then S+, levels. People then got stuck in their cars as the snow piled up which made it near impossible for the good folks who treat and plow the roads to do their jobs….a perfect recipe for widespread gridlock. This lemming-like behavior occurs time and time again in sudden-onset snow events. Perhaps social scientists can explain why our pavlovian response to head for the exits once snow begins in earnest meets the classic definition of insanity: doing something over and over again and expecting a different outcome.

KNYC 152351Z AUTO 3/4SM -SN BR M02/M02 A3023 RMK AO2 SLP230 P0015 60079 T10171022 10022 21022 56035 FZRANO $

KNYC 152251Z AUTO 3/4SM -SN BR M02/M03 A3025 RMK AO2 SLP236 P0018 T10221028 FZRANO $
KNYC 152151Z AUTO 1/4SM +SN FZFG M02/M02 A3027 RMK AO2 PRESFR SLP244 P0025 T10171022 FZRANO $
KNYC 152051Z AUTO 1/4SM +SN FG 00/M01 A3033 RMK AO2 SLP265 P0015 60021 T00001006 55037 FZRANO $
KNYC 152037Z AUTO M1/4SM +SN FG 00/M01 A3033 RMK AO2 PRESRR P0010 T00001006 FZRANO $
KNYC 152015Z AUTO 1/4SM +SN FG VV004 01/M01 A3030 RMK AO2 P0004 T00061006 FZRANO $
KNYC 151951Z AUTO 1/4SM +SN FG VV005 01/M01 A3032 RMK AO2 SLP261 P0006 T00061006 FZRANO $
KNYC 151943Z AUTO 1/4SM +SN FG OVC005 01/M01 A3032 RMK AO2 P0005 T00061006 FZRANO $
KNYC 151924Z AUTO 1/4SM SN FG BKN004 OVC010 01/M01 A3035 RMK AO2 PRESFR P0002 T00061006 FZRANO $
KNYC 151917Z AUTO 1/4SM SN FG SCT006 OVC012 01/M01 A3036 RMK AO2 PRESFR P0001 T00061011 FZRANO $
KNYC 151910Z AUTO 1/4SM SN FG SCT009 BKN016 OVC024 01/M01 A3038 RMK AO2 PRESFR P0001 T00061011 FZRANO $
KNYC 151859Z AUTO 1/2SM SN OVC021 01/M02 A3040 RMK AO2 PRESFR P0000 T00111022 FZRANO $
KNYC 151851Z AUTO 1SM -SN BKN025 OVC032 02/M03 A3041 RMK AO2 SNB36 SLP290 P0000 T00171028 FZRANO $
KNYC 151844Z AUTO 2 1/2SM -SN BKN027 OVC034 02/M04 A3041 RMK AO2 SNB36 P0000 T00171039 FZRANO $

KNYC 151751Z AUTO 10SM OVC031 02/M05 A3044 RMK AO2 SLP301 T00171050 10017 21006 56027 FZRANO $

The “transpocalypse" forecast debacle in the NYC area on Thursday afternoon evening 15 Nov appears to be more due to human-related forecasting issues, to communication problems, to failure to pay sufficient attention to the observations, and to misinterpreting and/or disbelieving numerical model guidance as opposed to significant problems with the available numerical guidance. The NAM and ECMWF, among other numerical guidance, clearly signaled that there would be significant accumulating snow in the NYC metro area. Most people get their weather forecast information today from automated statistics-based cell phone apps that by design leave little opportunity to convey nuance and forecast uncertainty. But what happens when statistics-based, post-processing runs amok and dispenses automated forecast nonsense as it did in the NYC area last Thursday and not enough people were minding the store (paying attention) until it was too late? What happens when a critical forecast requires more nuance and understanding than can be conveyed by a single icon on an app? As Alfred E. Newman of Mad Magazine famously said: "What, Me Worry?” The ongoing national debate about increasing automation is mostly about expected job losses. Much less discussed is how to keep humans in the loop to prevent automated systems from running amok. I'll take automated cars on icy roads for $2K, Alex......

And now for a little storm-related meteorology.....

A radar loop from Penn State shows the northward precipitation march on 15 Nov (http://www.atmos.albany.edu/student/tburg/mapdisco_20181116/radar2.php). Noteworthy is an east-west oriented band of heavy snow that organized along the PA/MD border near 1800 UTC. This heavy snow band moved into the NYC area by ~1930 UTC. Tomer Burg's loop of the potential temperature and winds on the dynamic tropopause (DT), and 850-hPa relative vorticity shows that a band of vorticity can be associated with the aforementioned radar loop at the leading edge of a DT disturbance (http://www.atmos.albany.edu/student/tburg/analysis/loop.php?model=gfs&prod=300wind;700rh;850temp;qpf6;tmp2m;700qvect;850tmpadv;dt_theta;&curid=7&proj=us&archive=1&run=2018111818). Additionally, Tomer Burg's loop of 700-hPa heights, temperatures, winds, Q-vectors, and Q-vector convergence shows a notable increase in the intensity of Q-vector convergence between 1800 UTC 15 Nov and 0000 UTC 16 Nov as an area of forcing for ascent crosses the Appalachians in the presence of frontogenetical forcing as evidenced by the orientation of the Q-vectors that point across the isotherms toward warmer air (http://www.atmos.albany.edu/student/tburg/analysis/loop.php?model=gfs&prod=300wind;700rh;850temp;qpf6;tmp2m;700qvect;&curid=5&proj=us&archive=1&run=2018111818).

These Q-vector maps and radar images were further linked by Tyler Leicht who observed that the SPC 850–700-hPa layer-mean mesoscale frontogenesis analysis coincided nicely with the heavier precipitation bands seen on radar and the observed Q-vectopr convergence (https://www.spc.noaa.gov/exper/ma_archive/action-html5.php?BASICPARAM=857f.gif&STARTYEAR=2018&STARTMONTH=11&STARTDAY=16&STARTTIME=18&INC=-48). Note the formation of an east-west oriented band of 850–700-hPa frontogenesis between 1000–1200 UTC near the NC-VA border. This frontogenesis region remained mostly east-west oriented as it expanded northward, becoming quite intense as it passed the PHL area near 2100 UTC before rolling across the western Long Island-NYC metro area between 2200–0200 UTC. Note also the reformation of a frontogenesis band, this time oriented more north-south from NC to PA after 0400 UTC ahead of the main upper-level disturbance. This secondary frontogenesis band produced a secondary band of snow in the Albany area near dawn on 16 Nov and was also associated with an area of heavy rain that moved offshore of Delmarva. A north-south oriented cross section of frontogenesis computed from a 5 h forecast from the NAM 3-km model initialized at 1800 UTC 15 Nov and valid 2300 UTC 15 Nov shows a band of frontogenesis near 900 hPa at 38 N that slopes upward to above 500 hPa poleward of 43 N (http://www.atmos.albany.edu/student/tburg/mapdisco_20181116/cross.png).

A critical aspect of the forecast problem was the relative contributions of strong ascent in a stable atmosphere and horizontal temperature advection to local temperature change in the thermodynamic equation. A series of nine sounding observed soundings between 1200 UTC 15–16 Nov 2018 ALB, OKX, IAD, GYX, and PWM all show that a very strong surface-based stable layer initially evolves into a deep quasi-isothermal layer near 0 C subsequently (http://www.atmos.albany.edu/mapdisco/20181116/images/soundings.pdf). We hypothesize that existing statistics-based forecast algorithms that rely heavily on the forecast 1000–500-hPa thickness relative to the forecast 1000–500-hPa planetary boundary thickness may have underestimated the probability of snow and sleet relative to rain and freezing rain based on observed 1000–500-hPa and 1000-850-hPa thicknesses near 548 dam and below 129 dam, respectively, in the heavy snow region. We further hypothesize that vigorous ascent in the aforementioned east-west oriented heavy snowband as evidenced by the above Penn State radar loop likely contributed disproportionately to cooling in a very stable boundary layer and that this cooling was sufficient to retard the northward advance of the 0 C isotherm due to horizontal warm-air advection, thus delaying the changeover to rain in the heavy snow band. Evidence for and against this hypothesis needs to be sought in a quantitative analysis of various numerical model solutions. We also wonder to what extent existing statistical post-processing schemes are able to fully represent the various contributions from the individual terms in the thermodynamical equation. We also note in closing that a NOAA HYSPLIT backward trajectory analysis performed by Tyler Leicht and Lance Bosart provides ample evidence that PBL air parcels that reached DCA, NYC, and ALB all originated near and west of Hudson Bay where temperatures have been anomalously cold for weeks. These air parcels moved SSE toward locations in the Northeast from the continental interior and resulted in cold and strong statically stable PBL across much of the Northeast prior to the outbreak of precipitation in last Thursday's storm.

Finally, we note that confluent jet-entrance region dynamics on 15 Nov likely contributed to an equatorward-directed surge of low-level Canadian cold air into the Northeast prior to Thursday's storm. The attached NCAR-RAL 250-hPa analysis for 0000 UTC 15 Nov 2018 shows the existence of very strong cross-contour ageostrophic flow directed toward lower heights in a strongly confluent jet region over eastern Canada in which wind speeds exceed 200 kt. A map of the subsequent GFS-derived 300–200-hPa layer-mean PV and irrotational wind vectors, layer-mean 600-hPa ascent, 250-hPa winds, and PW for 0600 UTC 15 Nov (source Alicia Bentley) shows that irrotational wind outflow from the developing cyclone over the central Appalachians is acting to produce negative PV advection by the irrotational wind on the equatorward side of the entrance region of the aforementioned 100+ m/s jet stream. Meanwhile, positive PV by the irrotational wind is occurring on the poleward side of this jet entrance region. The end result of PV advection by the irrotational wind is a strengthening of the PV gradient by in the confluent jet-entrance region over eastern Canada. The associated forced thermally direct vertical circulation implied by this pattern of PV advection by the irrotational wind would favor a low-level transport of cold air from Canada into the Northeast, as can be seen in Heather Archambault's appended map of SLP, 1000–500-hPa thickness, and 250-hPa winds for 0600 UTC 15 Nov 2018.

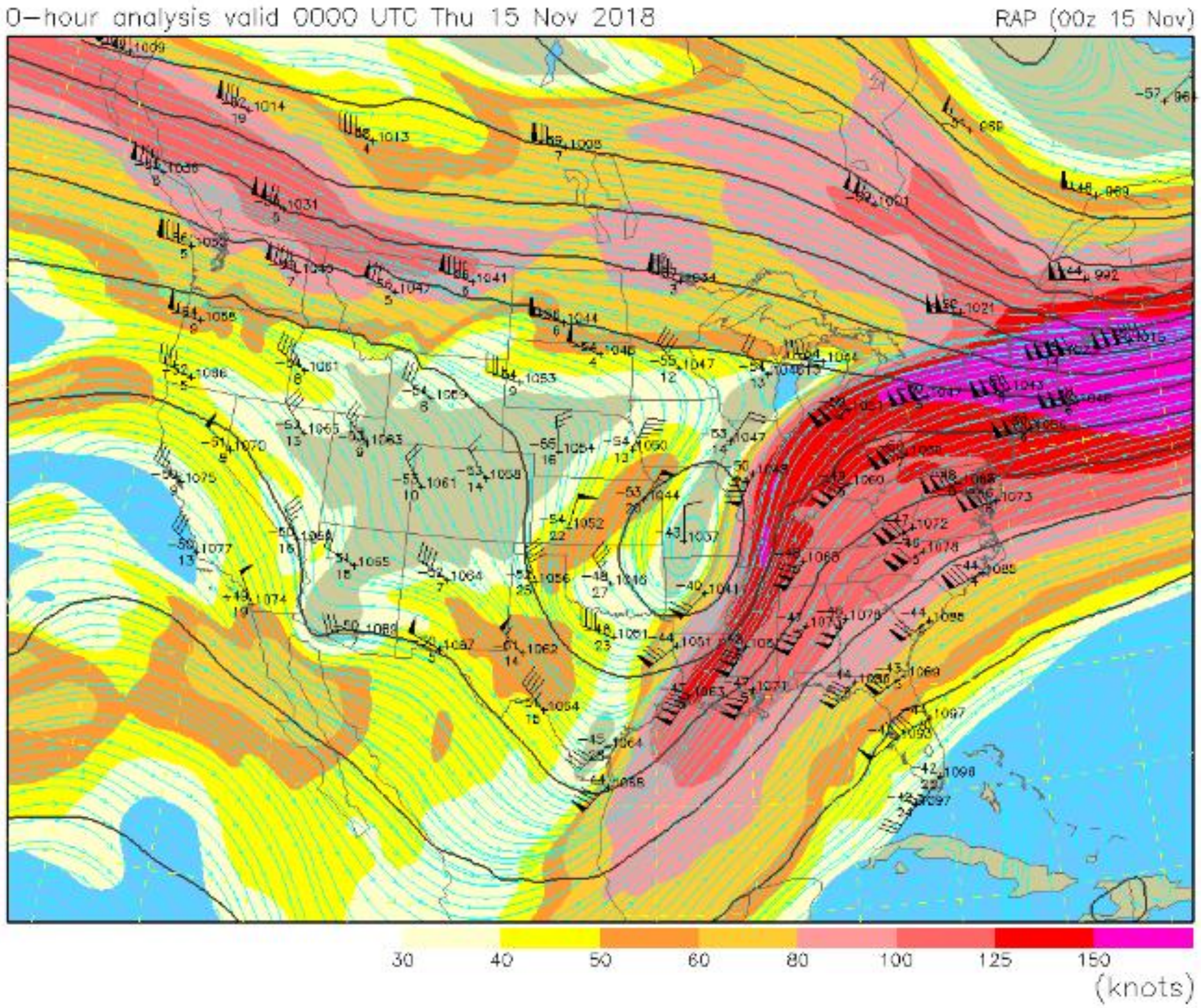
Science hypothesis #1: Existing statistics-based forecast algorithms that rely heavily on forecast 1000–500-hPa thickness values for precipitation type forecasts may fail to predict high enough probabilities of snow and sleet relative to rain and freezing rain when the forecast 1000–500-hPa thickness is relatively high and the forecast 1000–850-hPa planetary boundary thickness is relatively low relative to climatology.

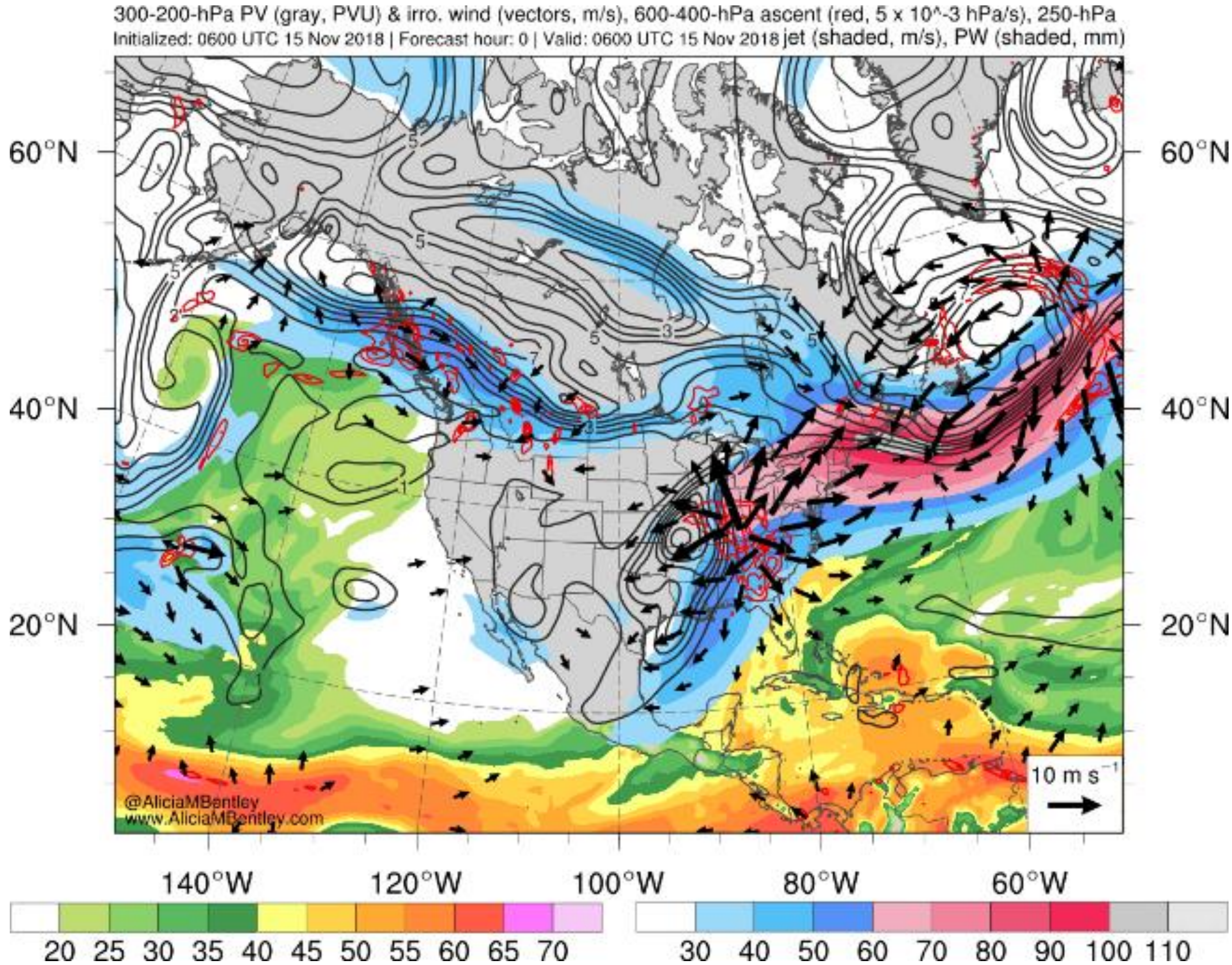
Science hypothesis #2: Vigorous ascent in an east-west oriented heavy snowband contributed disproportionately to cooling in a very stable boundary layer that was sufficient to retard the northward advance of the 0 C isotherm due to horizontal warm-air advection, thus delaying the changeover to rain in the heavy snow band.

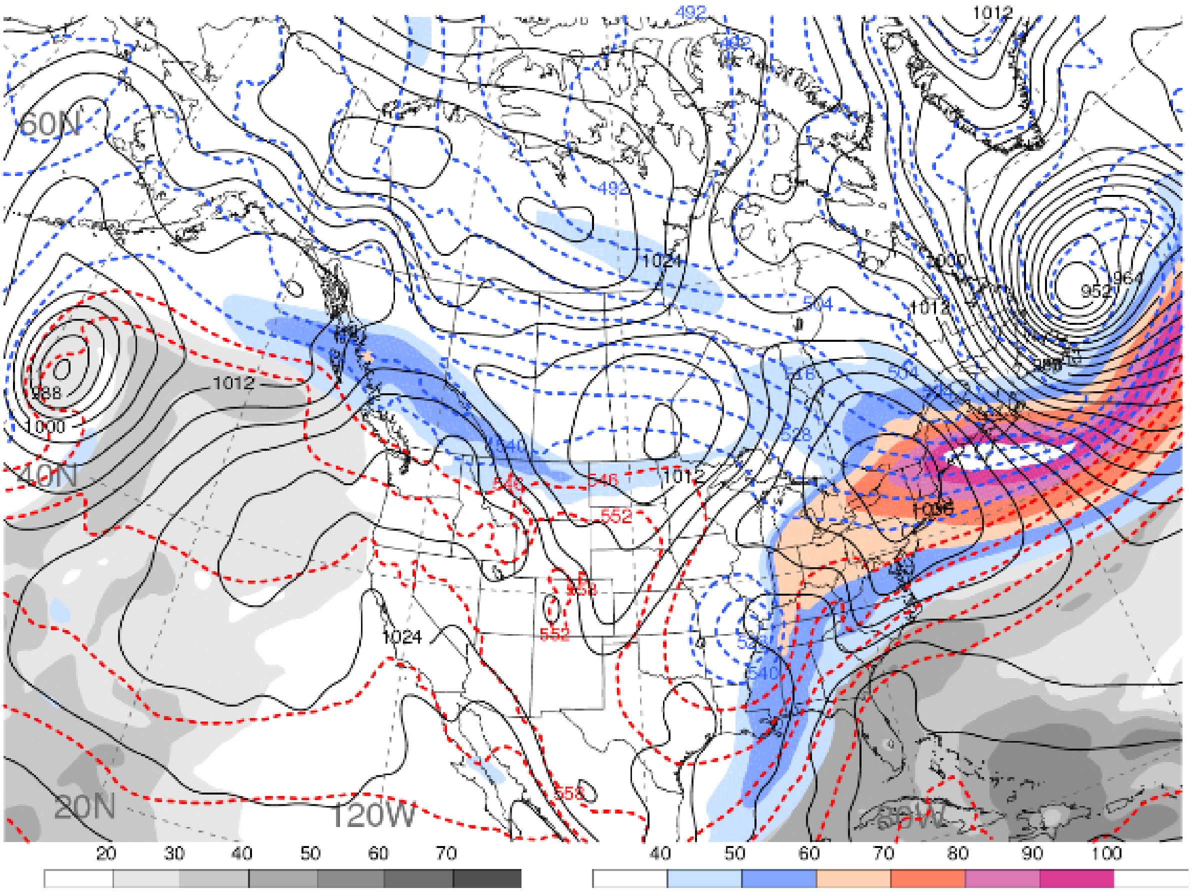
Science hypothesis #3: A strong thermally direct circulation in the entrance region of a 100+ m/s jet streak over eastern Canada facilitated the low-level equatorward transport of shallow low-level cold Canadian air into the Northeast instrumental in snowband-related frontogenetical forcing.

250 mb rawinsonde data 00z Thu 15 Nov 2018

250 mb Heights (dm) / Isotachs (knots)




300-200-hPa PV (gray, PVU) & irro. wind (vectors, m/s), 600-400-hPa ascent (red, 5 x 10^-3 hPa/s), 250-hPa
Initialized: 0600 UTC 15 Nov 2018 | Forecast hour: 0 | Valid: 0600 UTC 15 Nov 2018 jet (shaded, m/s), PW (shaded, mm)
60°N
40°N
20°N
140°W
120°W
100°W
80°W
60°W
10 m s^-1
@AliciaMBentley
www.AliciaMBentley.com
20 25 30 35 40 45 50 55 60 65 70
30 40 50 60 70 80 90 100 110



1000−500 hPa Thick, PW, SLP, 250 hPa Wnd at 181115/0600