Hi all,

The opening Friday map discussion of the spring semester on 25 Jan focused on: (1) the NH sudden stratospheric warming (SSW) event of late December and early January and the subsequent and ongoing impacts of this SSW event on the troposphere, and (2) the challenging to predict mixed precipitation event of 19–20 Jan over the Northeast. Massey Bartolini, Matt Campbell, Danny Reese, and Minghao Zhou contributed to the discussion. Map discussion links can be found here: http://www.atmos.albany.edu/mapdisco/20190125/

1. SSW Warming Event (Andrea Lang):

Andrea showed Hannah Attard's time series of 10-hPa zonal mean zonal wind for 60 N (http://www.atmos.albany.edu/student/hattard/realtime/u_60N_10hpa.png) to indicate that the zonal mean wind became negative in late December 2018 (the definition of a major SSW event) and remained negative until only recently. Andrea showed a loop of daily-averaged PV at 10-hPa for the period 16 Oct 2018 – 20 Jan 2019 (http://www.atmos.albany.edu/facstaff/andrea/webmaps/mapdisc/PV20182019.html). This loop nicely showed the polar vortex that characterized this major SSW warming event. Andrea next showed time series loops of forecast anomalous eddy meridional heat flux [an approximation of upward wave activity flux (WAF)] between 40–80 N from 1000–10 hPa from 1 Oct 2018 to present, and standardized polar cap height from 1000–10 hPa (http://www.atmos.albany.edu/facstaff/andrea/webmaps/ND2018WAF.gif and http://www.atmos.albany.edu/facstaff/andrea/webmaps/NDJ2018polarcap.gif). These forecast loops showed the considerable challenge of correctly forecasting the WAF from the troposphere into the stratosphere beyond days 10–15.

There are to be two general categories of SSW events: 1) displacement of the polar vortex so that it shifts off the North Pole, and (2) and a split of the polar vortex into two separate smaller polar vortices that move equatorward separately toward higher middle latitudes. There can be fairly large spatial and temporal variability in the polar vortex location and morphology in each of the two aforementioned categories. The present SSW event has been characterized by a split polar vortex. A distinguishing feature of the stratospheric polar vortex is that one of the split polar vortices has moved equatorward across central North America where it has coupled vertically with a deep and cold 500-hPa baroclinic trough (http://www.atmos.albany.edu/student/hattard/realtime/dt_500/DT_500.php) with a resulting equivalent barotropic structure (http://www.atmos.albany.edu/facstaff/andrea/webmaps/waveUT.gif). This vertically coupled equivalent barotropic vortex has been a source of tropopause polar vortices (TPVs) that have dropped equatorward from the Arctic toward southern Canada. The most recent TPV that will be associated with -40 C air at 850-hPa over the Upper Midwest on Tu-Wed is currently dropping southward in this cold vertically coupled trough per Alicia Bentley's realtime maps (http://www.atmos.albany.edu/student/abentley/realtime/standard.php?domain=northamer&variable=dt_2pvu). The impact of this split stratospheric polar vortex on temperatures at 10-hPa, 50-hPa, and 100-hPa can be seen here (http://www.atmos.albany.edu/student/hattard/realtime/nh_strat/nh_temp.php) and on temperatures at these same levels can be seen here (http://www.atmos.albany.edu/student/hattard/realtime/nh_strat/nh_stanom.php).

2. Review of the rain, freezing rain, sleet, and snow predictability challenges with the storm of 19–20 Jan 2019:

We revisited this event that was first discussed in a special map discussion on Friday afternoon 18 Jan. At issue in the previous discussion was whether the 0 C isotherm at 850-hPa would reach Albany and cause a temporary changeover to IP (a deep, cold, and stable PBL would prevent ZR in Albany). This worry was justified after the fact because the maximum 1000–500-hPa thickness from the 06Z/19 NAM run peaked at ~540 dam while the peak thickness in the 12Z/19 run was at least 543 dam (a 3 dam thickness increase equates to a 1.5 C mean temperature increase in the column).

A d(prog)/dt analysis of the 12 km NAM forecast SLP/500-hPa height analyses verifying 06Z/20 showed that the trough across the Ohio Valley was deeper than earlier forecast. The dynamical consequences of this deeper trough were a deeper and more poleward-shifted primary cyclone west of the Appalachians (e.g. 993 hPa on the WV/OH border in the 12Z/19 NAM 18 h forecast verifying 06Z/20 versus 1000 hPa on the western NC/SC border in the 84 h forecast verifying the same time. The northern trough was also shifted more westward in the 18 h forecast relative to the 84 forecast verifying 06Z/20. The consequence of this westward shift was that the downstream confluence zone was farther north, stronger, and had a greater southerly component of the flow. The change in the configuration of this confluence zone also favored a stronger and more poleward-shifted primary cyclone which enabled warmer air east of the Appalachians to surge farther north (see the assorted d(prog/dt) loops for selected forecast maps, GFS and NAM KALB soundings, and GFS and NAM 2-m temperatures http://www.atmos.albany.edu/mapdisco/20190125/ nicely prepared and presented by Minghao Zhou for the details). Nick Bassill used maps from the NYS mesonet to provide a very nice overview of the relentless equatorward penetration of shallow Arctic air down the Hudson Valley and east of the Berkshires into southern New England (http://www.atmos.albany.edu/mapdisco/20190125/images/T2_COMPARISON.pdf).

Science issue #1: What was the source of the uncertainty that resulted in the greater forecast sensitivity to progressively warmer solutions associated with a stronger, deeper, and westward-shifted cyclone along the Appalachians? A testable hypothesis would be that the stronger and westward-shifted northern trough enabled the initial cyclone to move poleward farther west and remain stronger than initially forecast with a resultant transport of warm, moist air farther inland and poleward east of the Appalachians.

Science issue #2: What was the source of the flip in the observed HRRR forecast 2-m temperature bias for KALB from cold at 1200 UTC 19 Jan to warm at 1800 UTC 19 Jan as shown nicely by Massey Bartolini? A testable hypothesis would be that the pre-Arctic front warm surge was stronger than forecast due to the aforementioned strengthening northern trough while the subsequent warm bias was due to the well known inability of even the higher resolution mesoscale models to maintain the intensity of shallow cold PBL air masses and advect them far enough south behind Arctic fronts (a model mixing problem).

3. Upcoming CONUS Arctic air outbreaks east of the Rockies:

The upcoming multiple Arctic air outbreaks this week are associated with strong equatorward-propagatiing tropopause polar vortices (TPVs) of high-latitude origin based on Alicia Bentley's dynamic tropopause (DT) loops for the North Pacific (http://www.atmos.albany.edu/student/abentley/realtime/standard.php?)domain=pacific&variable=dt_2pvu) and for North America (http://www.atmos.albany.edu/student/abentley/realtime/standard.php?domain=northamer&variable=dt_2pvu). These DT maps reveal that a series of upper-level discontinuous ridge retrogressions in conjunction with cyclonic wave breaking (CWB) over the WPAC–CPAC enables a corridor of integrated water vapor (IVT) to be first advected eastward from the equatorial and subtropical far western Pacific and second to be advected poleward east of the Dateline. A series of eastward-propagating cyclonic disturbances in the exit region of the North Pacific jet (NPJ) enables these IVT corridors to be directed toward Alaska as surface cyclones deepen in the equatorward exit region of the NPJ and turn northward toward the Gulf of Alaska. As these cyclones turn toward Alaska and tap into these IVT corridors the resulting increase in precipitation-caused diabatically driven outflow and negative PV advection by the irrotational wind in conjunction with upstream CWB and a poleward-shifted NPJ (as summarized in the Andrew Winters NPJ phase diagram; not shown) results in serial discontinuous ridge retrogression across the NPAC.

The outcome of this serial discontinuous ridge retrogression process is ridge maintenance over Alaska and extreme northwestern Canada during 21–31 Jan 2019 in conjunction with downstream troughing and severe cold over central and eastern North America. The latitudinally extensive NNW flow between the aforementioned Alaskan ridge and a deep trough over central North America permits TPVs that form over extreme northern Canada and Alaska and over the Arctic Ocean to plunge southward toward the northern CONUS. A first intense Arctic TPV that neared the northwestern Great Lakes on 27 Jan and a second intense TPV that is forecast to reach the upper Midwest on 30 Jan, respectively, look to have been associated with subsynoptic-scale CWB (at least in part). The leading intense TPV formed in a cold pool over northern Canada on ~20 Jan. The trailing intense TPV formed in a mesoscale cold pool north of northeastern Russia on 19–20 Jan in conjunction with subsynoptic-scale CWB.

Science Issue #3: What role does a strong WPAC and CPAC subtropical jet (STJ) that is associated with a series of CWB events play in subsequent persistent downstream ridging over Alaska and far western North America? A testable hypothesis is that a sequence of progressive disturbances embedded in a strong WPAC/CPAC NPJ enables tropical moisture from the WPAC to flow eastward along atmospheric rivers that turn northward east of the Dateline toward Alaska such that diabatically driven upper-level negative PV advection by the irrotational wind further amplifies and "locks-in" high-latitude ridges over Alaska and far northwestern Canada.

Science Issue #4: What role do sequential East Asian cold surges play in helping to anchor a strong WPAC and CPAC STJ west of the Dateline? A testable hypothesis is that sequential East Asian cold surges favor downstream CWB such that zonally oriented IVT corridors (ARs) across the WPAC and CPAC on the anticyclonic shear side of the STJ can turn poleward east of the Dateline in conjunction with CWB-driven cyclogenesis, the associated poleward-directed transport of deep tropical moisture along ARs, and diabatically driven upper-level ridging.