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Subject: Synopsis of Friday map discussion for 21 Nov 2014
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Hi all,

Friday map discussion for 21 Nov 2014 focused on the downstream impacts of the ET of North Pacific STY Nuri (see: http://agora.ex.nii.ac.jp/digital-typhoon/summary/wnp/s/201420.html.en for a documentation of the tropical portion of the storm's lifecycle) and its subsequent explosive reintensfication as an extratropical cyclone (EC). We focused on: 1) multiple downstream ridge building events that triggered several surges of arctic air into the CONUS, 2) stratospheric-tropospheric interactions (courtesy of Andrea Lang and Hannah Attard) associated with the aforementioned ridge building, 3) predictability issues (courtesy of Alan Brammer) associated with the downstream impacts of the STY Nuri ET/EC, and 4) and the remarkable lake-effect snow band that impacted areas just south of Buffalo, NY, that occurred in response to the passage of multiple arctic PV anomalies across the eastern Great Lakes. We concluded with a brief current weather discussion led by Ross Lazear. Nick Schiraldi, Alicia Bentley, and Philippe Papin assisted with map discussion. Links and images used during map discussion can be found here (http://www.atmos.albany.edu/mapdisco/). Choose "20141121" under "select a discussion" to access the map discussion links and images.

Lance, Nick, Alan, Alicia, Ross, Andrea, Hannah, and Philippe

Downstream Ridge Building:

The evolution of STY Yuri through ET, explosive redevelopment as an EC, and the subsequent downstream flow evolution across the North Pacific and North America can be examined from Alicia Bentley's assorted (seven-panel) loops (http://www.atmos.albany.edu/student/abentley/realtime.html). After the EC that originated from Yuri reached maximum intensity (924 hPa; http://www.atmos.albany.edu/mapdisco/20141121/images/NPAC_Bomb_06Z8Nov14.gif) at 0600 UTC 8 Nov 2014 and began to grow upscale, it triggered downstream flow amplification that included three high-latitude ridge-building sequences over the eastern North Pacific, Alaska, and western North America. These ridge-building sequences can be seen on Alicia's DT loops on 8-9 Nov (over the eastern Pacific and western North America), 10-12 Nov (high-latitude omega block over eastern Alaska and northwestern Canada, and 17-19 Nov (ridge reamplification near the west coast of North America). These three sequential ridge-building episodes enabled repeated surges of arctic air to plunge well southward east of the Rockies, and they occurred downstream of the upscaled cyclonic wave breaking (CWB) event that marked the Yuri ET and and its subsequent explosive redevelopment as an EC. As smaller-scale disturbances rotated cyclonically around the upscaled CWB disturbance, cyclogenesis, warm-air advection, and latent heat release ahead of these progressive smaller-scale disturbances further contributed to dynamically and diabatically forced ridge-building in the upper troposphere downstream over Alaska, western Canada, and the western CONUS. Given that this event was well forecast by the operational global models (see below), the complex spatiotemporal interactions between the relevant dynamical and thermodynamical processes can be investigated from the available operational simulations to include sensitivity assessments from the available ensemble distributions.

STY Nuri-Related Stratospheric-Troposheric Interactions:

Andrea Lang and Hannah Attard led this part of map discussion. See their loops of 925/500/10 hPa geopotential heights and temperatures (http://www.atmos.albany.edu/facstaff/andrea/webmaps/Nov14loop.html), 10 hPa analyses of 10 hPa geopotential heights, 200 hPa geopotential heights, and 850 hPa relative vorticity going back to 1 Oct (http://www.atmos.albany.edu/student/hattard/plots/mapdisco/112414/NH_analysis.html), and forecasts of stratosphere-troposphere maps for 500 hPa, 100 hPa, 50 hPa, and 10 hPa (http://www.atmos.albany.edu/student/hattard/realtime.php).

The Lang/Attard loops show that the post-STY Yuri ET, explosive reintensification as an EC, and downstream high-latitude ridge building also impacted the stratospheric circulation. Their loops suggested that a sudden stratospheric warming (SSW) event could occur toward the end of the month. A SSW event is very rare in November when the radiatively driven stratospheric polar vortex is rapidly strengthening. The 100, 50, and 10 hPa geopotential height and wind forecasts suggest that the stratospheric polar vortex could split into two off-pole vortices at 100 and 50 hPa before the end of the month, and continue growing upward to10 hPa, by 1 December 2014 (http://www.atmos.albany.edu/student/hattard/realtime/nh_strat/10_nh.html). If this forecast polar vortex-splitting forecast verifies, it would be a remarkable example of a very rare event with implications for the large scale circulation in the upper troposphere and lower stratosphere in the first half of the upcoming NH winter.

As remarked upon by Andrea and Hannah, the Yuri-induced ET/EC and the subsequent episodes of high-latitude ridge building have served to disrupt the seasonally strengthening polar vortex. As the poleward ends of these induced high-latitude ridges impinge upon the polar vortex the associated deformation processes can act to disrupt the approximate zonal wave number zero polar vortex centered on the North Pole in the lower stratosphere. As this vortex is disrupted and displaced off the North Pole, a wave number two flow regime can arise. If the amplitude of this wave number two pattern increases sufficiently then the polar vortex may split, which is what is forecast to happen before the end of the month at 100 and 50 hPa, and may happen at 10 hPa as well as vortex disruption proceeds upward from the lower troposphere.

A vertical cross section time series of normalized NH geopotential height anomalies for 65-90 N (http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/hgt.shtml) produced by NCEP-CPC indicates that the normalized height anomaly between 65-90 N has recently reached +2 and +1 standardized anomalies at 200 and 100 hPa, respectively. These standardized height anomalies are consistent both with a weakened lower stratospheric polar vortex and observed upward propagation polar vortex-splitting tendency. They are also consistent with the current negative phase of the arctic oscillation (AO) that began ~10 days ago. The GFS-based ensemble AO forecasts suggest that this index will soon become positive (between +1 and +2 standardized anomalies). If instead, the polar vortex does split then all bets may be off on the extended forecast for the early winter until the polar vortex recovers. As pointed out by Andrea, the ET of STY Dale over the western Pacific in November 1996 and the storm's subsequent explosive reintensification as a high latitude EC induced major high-latitude ridge building which weakened and disrupted the polar vortex (it took until late December 1996 for the stratospheric portion of the polar vortex to recover from the disruption induced by the ET/EC of former STY Dale). An anomalously weak lower stratospheric NH polar vortex in early winter may often be associated with relatively cold conditions over the CONUS east of the Rockies as one of the two lobes arising from the split polar vortex extends southward across Canada. We'll have to wait and see what will happen this year. Like Dale (1996), the Yuri (2014)-induced downstream NH circulation disruptions provides another excellent opportunity to study the dynamics and thermodynamics of tropospheric-stratospheric interaction processes and the implications of these interactions on the NH winter large-scale circulation.

Predictability:

The STY Nuri ET and its subsequent explosive reintensification as an EC as viewed from Alicia Bentley's real-time GFS maps (http://www.atmos.albany.edu/student/abentley/realtime.html) can also be viewed through the lens of downstream predictability by means of d(prog/dt) loops of ECMWF forecasts of 200 hPa ensemble mean geopotential height and ensemble standard deviation out to 10 days. These ECMWF d(prog)/dt lloops (source: Alan Brammer), initialized 6 days, 3 days, and the day of the most intense phase of the STY Nuri ET/EC, provide representative snapshots of atmospheric predictability associated with a large-scale high-impact weather event. Representative examples of these forecasts verifying 0000 UTC 12 Nov (amplification of an omega block over western North America; initial surge of arctic air into the CONUS), verifying 0000 UTC 15 Nov (reinforcing second surge of arctic air reaches the Northern Plains), and verifying 0000 UTC 18 Nov (snowing to "beat the band" in Buffalo; reinforcing third surge of arctic reaches the upper Midwest and Great Lakes) can be found at the following links.

ECMWF d(prog/dt) (Alan Brammer) verifying 0000 UTC 12 Nov 2014:
http://www.atmos.albany.edu/student/abrammer/graphics/typhoon_nuri/dprog.php?date=2720

ECMWF d(prog/dt) (Alan Brammer) verifying 0000 UTC 15 Nov 2014:
http://www.atmos.albany.edu/student/abrammer/graphics/typhoon_nuri/dprog.php?date=2732

ECMWF d(prog/dt) (Alan Brammer) verifying 0000 UTC 18 Nov 2014:
http://www.atmos.albany.edu/student/abrammer/graphics/typhoon_nuri/dprog.php?date=2744

These d(prog)/dt loops of 200 hPa ensemble mean geopotential heights and ensemble standard deviation are indicative of the rapid progress in the skill of modern numerical weather prediction (the advances in numerical weather prediction that I have seen in my lifetime are nothing short of extraordinary). Visually, the information content of the 200 hPa ensemble mean potential height forecasts, even from the 240 h forecasts, is significant.

Although the forecast amplitude of the long range troughs and ridges are underdone at these ranges, the positions of these features are mostly correct and can provide useful guidance to forecasters. I should add that similar useful forecast guidance was seen in the GFS ensembles, but we didn't have ready access to them in similar useful formats in time for for map discussion.

The Yuri-triggered large-scale NH circulation rearrangement and subsequent multiple cold surges over North America east of the Rockies also jeopardized the CPC monthly temperature forecast for Nov that was issued on 31 Oct. This CPC temperature forecast (http://www.atmos.albany.edu/mapdisco/20141121/images/NPAC_Bomb_06Z8Nov14.gif) called for a higher probability of above normal temperatures along the northern tier of states, consistent with the anticipation of a possible moderate El Nino event. In reality, the 925 hPa temperature anomaly for 1-17 Nov derived from NOAA/ESRL/PSD (http://www.atmos.albany.edu/mapdisco/20141121/images/nov.comp.gif) shows negative temperature anomalies almost everywhere over the CONUS east of the Rockies (the negative anomaly extent is even greater in an update through 19 Nov, not shown).

The hazards of extended range temperature prediction when an unanticipated large-scale, high-impact weather event occurs ….and the money to be made from correctly anticipating which side of the temperature pdf to hedge one's bets….were fully on display for this event. A science issue is how can we better understand under what circumstances the occurrence of a large-scale extreme weather event will be associated with a disruptive large-scale flow reconfiguration and how can we better determine what are the critical dynamical and thermodynamical processes that govern these large-scale flow regime changes and leverage this understanding into improving forecasts of temperature and rainfall probability density functions in week two (and week three farther down the road).

Buffalo Lake-Effect Snowstorm:

The huge mega-foot snow-dump on the south side of the Buffalo area on 18-19 Nov was remarkable. A satellite-based CIMSS blog discussion of this event can be found here (http://cimss.ssec.wisc.edu/goes/blog/archives/17196). Media pictures of this event can be found here (http://www.wkbw.com/homepage-gallery/photos-lake-effect-snow-buries-parts-of-wny). The CIRA-NWS lake-effect VISIT chat discussion of this event can be found here (http://rammb.cira.colostate.edu/training/visit/satellite_chat/20141119/; the discussion lasts ~30 min but is well worth viewing. It also contains radar loops for this event). Regional radar loops can also be viewed through the UCAR/NCAR image archive at: http://www.mmm.ucar.edu/imagearchive/. Philippe Papin has prepared an extended radar reflectivity loop from the NCAR/UCAR image archive (http://www.atmos.albany.edu/student/ppapin/lb13_img/special/20141118/radar.php). This radar loop runs from just before 0000 UTC 18 Nov to 0900 UTC 20 Nov (users can manually advance or reverse the loop with the arrow keys at the top). This extended radar reflectivity loop demonstrates: 1) the persistence of the snow bands, 2) the sharp northern edge to the bands where the largest reflectivity values are found, and 3) the more diffuse nature of the southern edge of the band. This radar imagery is also consistent with the aforementioned media video perspectives on the event.

A large-scale overview of the Buffalo snow dump can be obtained from Alicia Bentley's real-time GFS analysis loops (http://www.atmos.albany.edu/student/abentley/realtime.html). Kyle Meier's completed M.S. thesis on thundersnow has shown (along with the research of others) that major lake-effect snow events downwind of Lake's Erie and Ontario, especially early in the season, are usually associated with significant sub-synoptic scale forcing arising from the passage of progressive arctic PV anomalies on the dynamic tropopause (DT). As discussed in this forum eight years ago, a major lake-effect snowstorm on 13 October 2006 was triggered by the passage of an arctic PV anomaly across Lake Erie. Alicia Bentley's GFS-based DT analysis loop (http://www.atmos.albany.edu/student/abentley/realtime.html; choose the North America option) shows that the first arctic PV anomaly starts to overspread the Buffalo area after 0000 UTC 18 Nov. Potential temperatures on the DT decrease to < 288 K between 0600-1200 with the passage of this first arctic PV anomaly. Given that lake-water temperatures are as high as 12 C over the eastern end of Lake Erie, deep tropospheric instability is indicated over Lake Erie. Lightning activity detected during this snow event can be found here (http://www.atmos.albany.edu/mapdisco/20141121/images/nldn/; source: Kevin Tyle)

Also of interest is that the core of this initial arctic PV anomaly passes across Illinois and Indiana before it turns northeastward toward western New York. The air mass associated with this arctic PV anomaly is well represented by a backward trajectory that ends at KDKK at 2100 UTC 18 Nov (http://www.atmos.albany.edu/mapdisco/20141121/images/back_traj_KDKK.pdf; source: NOAA HYSPLT trajectory model) and provides an additional reason why the airmass on the south side of Lake Erie is warmer than the air mass on the north side of the lake. A second arctic PV anomaly with pockets of potential temperature on the DT < 282 K reaches western New York by 0000 UTC 19 Nov. The third, and final, arctic PV anomaly in the series crosses western New York near 0000 UTC 21 Nov. The sequential passage of these three arctic PV anomalies was sufficient to provide a favorable environment for the formation and maintenance of well-defined and persistent lake-effect snow bands.

Maps with plotted surface observations for 0000 and 2100 UTC 18 Nov can be found here (http://www.atmos.albany.edu/mapdisco/20141121/images/RAL_sfcplot_0000.gif) and here (http://www.atmos.albany.edu/mapdisco/20141121/images/stn_plot.gif). A take-home message from these maps is that on the scale of Lake Erie there is broad confluence over the eastern half of the lake associated with mostly westerly flow on the north side of the lake and mostly southwesterly flow on the south side of the lake. The plotted surface observations for 2100 UTC 18 Nov include a mid-lake station near the eastern end of Lake Erie. The reported NW wind at this station suggests that the along-lake axis of dilatation that marks the primary band-related confluence zone is located close to the southern shore of Lake Erie. The temperature differences across Lake Erie are also of interest. The observations clearly indicate that the coldest surface air is found south of Lake Erie while the warmest air is located over Lake Erie. A 36 h backward trajectory analysis using the NOAA HYSPLT trajectory model gridded datasets for air parcels arriving at 250, 500, and 750 m over Port Colborne (CWPC), Ontario, and Dunkirk (KDKK), New York at 2100 UTC 18 NOV shows that colder air parcels arriving over KDKK at 2100 UTC do not pass over relatively warmer waters of the Great Lakes whereas warmer air parcels arriving at CWPC traverse the northern side of Lake Erie and graze the southern end of Lake Michigan before they reach CWPC (see http://www.atmos.albany.edu/mapdisco/20141121/images/back_traj_KDKK.pdf and http://www.atmos.albany.edu/mapdisco/20141121/images/back_traj_CWPC.pdf).

A science issue arising from these observations is that the well-defined snow band over Lake Erie may be associated with meso-beta scale frontogenetical forcing in which relatively warmer air north of Lake Erie and over the northern half of the lake was likely forced to ascend over the colder air located to the south of the aforementioned along-lake surface confluence band along with low-level convergence was likely occurring. This inferred convergence band is likely reinforced by frictionally backed winds along the southern short of Lake Erie and, possibly, cold pools associated with shallow convection near the northern edge of the band (Justin Minder has addressed the possibility of cold pool dynamics at work here in separate offline discussions with me). The implication is that we have confluent frontogenetical forcing in play from multiple sources and on multiple scales thanks to the previous history of the air parcels (the air parcels arriving over KDKK do not traverse a warmer lake) in conjunction with the forced lifting of warmer air over the northern half of the lake above cooler air from a colder continental source over the southern half of the lake along the aforementioned convergence band. Given the observed strength of the sub-synopticscale and mesoscale arctic PV anomalies that crossed Lake Erie, it's quite likely that we have the juxtaposition of favorable sub-synoptic scale and mesoscale environments that collectively act to focus mesoscale ascent, an inference that can be tested by direct numerical simulation. Offline, Jim Steenburgh referred me to a paper by Wright et al. (2013; http://journals.ametsoc.org/doi/full/10.1175/MWR-D-12-00038.1) where some of these ideas and inferences are tested by means of numerical simulations. I will leave it to readers to decide whether Wright et al. (2013) have the "wright" stuff.

The presence of lake water temperatures that are as high as ~12 C over the eastern end of Lake Erie (see: http://rammb.cira.colostate.edu/training/visit/satellite_chat/20141119/) suggest that air parcels entrained in the ascent region of the snow band over the eastern end of Lake Erie were likely able to realize low-level CAPE inferred from the environmental conditions. Jim Steenburgh remarked to me offline that "The in-up-and-out conceptual model of midlake bands is clearly an overidealization in great need of modification. For example, there often appears to be warm air from one side of the lake rising over colder low-level air. This could be the result of the two land-breezes having a different density, or diabatic effects, or both. Take a look at the attached from the first Lake Erie monster band. Most of the stations in southern Ontario are 20F or greater. Most near Lake Erie in Ohio and Pennsylvania are in the teens. I'm not sure if this is due to solar heating or upstream modification by Lakes Michigan, Huron and St. Clair, but it would support the view that the lake breeze from the northern shore may have been marginally warmer than from the south side. Thus, when looking at those videos of the Buffalo band, even though the flow is primarily along the band, I suspect there is a component toward the band that rises over the low-level cold pool. The entrainment of some of that cold pool air and snowfall into the updraft might explain the apparent rising motion." Jim's inferences suggest that a way forward is through careful numerical experimentation and by thinking of how to incorporate applicable cold-pool dynamics issues associated with warm season severe convection into our thinking about convectively influenced lake-effect snow bands.

A word about the forecasts. The epic Buffalo area lake-effect snowstorm had all the hallmarks of a black swan event. this was a 1 in a 100 (and likely much longer) event. The storm was locally devastating because the snow band was very persistent and moved very little which means that a few areas received prodigious amounts of snow while many other areas received highly significant but far less impressive snowfall amounts more comparable to the typical 1-2 feet that can fall in the bigger lake-effect snow events. Tom Niziol on the Weather Channel discussed the Buffalo forecast situation this morning in response to a question about the timeliness and usefulness of the NWS forecasts. Tom made the excellent point that two days in advance the NWS warned that snowfall rates of 3-5 inches per hour along with blowing and drifting snow and snowfall accumulations measured in feet were going to make for a very dangerous situation. These kinds of conditions will shutdown any major metropolitan area, even those accustomed to dealing with lots of winter snow. When the social scientists get done with this heaven-sent research opportunity I suspect that we will learn that there were lots of communications breakdowns everywhere for a black swan event that stressed the system in ways that had not been previously anticipated. The heaviest snow was very localized. Our current knowledge, forecast skill, and state of numerical forecast modeling skill does not permit making definitive forecasts of snow or rain amounts on the scale of specific neighborhoods two days in advance. This would be a challenge even a few hours ahead of time. How do we get better? A legitimate research question is to what extent more numerous and better observations on smaller scales along with advances in computer technology and mesoscale numerical weather prediction will allow us to move closer toward "neighborhood scale" modeling and weather forecasting. When will these anticipated forecast advances happen? I don't know. It will depend on lots of things including investment in the future and political will, things in short supply across the political spectrum.

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