Hi all,

Friday map discussion for 1 March 2019 consisted of presentations by different individuals on a variety of topics of recent interest (http://www.atmos.albany.edu/mapdisco/20190301/). Following a brief overview of the Labrador anticyclonic uber jet case of 22 December 2013 by Lance, Andrew Winters presented the results of a Sawyer-Eliassen (S-E)equation diagnostic analysis of this uber jet event that also included a comparison with the cyclonic uber jet event of 20 Feb 2019. Daniel Keyser offered his perspective on Andrew's informative S-E equation diagnostics. Minghao Zhou followed with a discussion of TC Wutip. Tyler Leicht discussed the recent heat in northwestern Europe after which Matt Campbell discussed the recent heavy rains in California. Danny Reese discussed the expected weekend (2–3 Mar) storm and likely severe weather occurrence in the Southeast to conclude map discussion.

Background emails and imagery on the 22 Dec 2013 uber jet case are appended at the end of this post.

A. Anticyclonic and cyclonic uber jet cases of 22 December 2013 and 20 February 2019, respectively (Andrew Winters):

The "Uber jet" cases from December 2013 and February 2019 are accompanied by a remarkable consolidation of the pole-to-equator temperature gradient into a narrow zone of contrast. The across-front ageostrophic circulations that accompanied the development of these zones of strong, tropospheric-deep baroclinicity within each case were subsequently examined using the Sawyer (1956)–Eliassen (1962) Circulation Equation. A PowerPoint presentation to accompany the forthcoming discussion, including background information on the Sawyer–Eliassen (S-E) equation, is attached. A perspective by Daniel Keyser on the applicability of the S-E equation to jet circulation diagnostics to include testable scientific hypotheses for these two uber jets is also appended at the end of this section.

The December 2013 "Uber Jet" at 1200 UTC 22 December 2013 was embedded within a region of broad anticyclonic curvature and featured geostrophic cold-air (warm-air) advection on the cyclonic shear side of the jet within the jet-entrance (jet-exit) region. A solution of the Sawyer–Eliassen equation for the across-front ageostrophic circulation in the jet-entrance region featured a strong thermally-direct circulation that was centered on the tropospheric-deep polar front and was shifted slightly towards the equatorward side of the jet axis. The across-front ageostrophic circulation within the jet-exit region was thermally-indirect and shifted equatorward of the jet axis, such that ascent was positioned beneath the jet core. Both circulations are consistent with the "Shapiro effect", a phrase coined

by Rotunno et al. (1994) in reference to the work conducted by Shapiro (1981) that describes a "shift" in the location of across-front ageostrophic circulations relative to the jet axis based on the sign of the along-front geostrophic temperature advection.

In contrast to the December 2013 case, the February 2019 "Uber Jet" was embedded within a region of broad cyclonic curvature at 0000 UTC 20 February 2019. The jet also formed within a strongly confluent upper-tropospheric flow pattern over eastern North America, with a northwesterly air stream emanating from southern Canada, and a southwesterly air stream emanating from the southern U.S. A solution to the Sawyer–Eliassen equation for the across-front ageostrophic circulation within the jet-entrance region depicts a thermally-direct circulation centered squarely on the tropospheric-deep polar front, similar to the December 2013 case. A partition of the across-front ageostrophic circulation within the jet-entrance region into the components forced by geostrophic confluence and geostrophic horizontal shear, further indicates that the full across-front ageostrophic circulation was predominantly driven by the large-scale confluent flow pattern that characterized the jet-entrance region.

Finally, a distribution of 500-hPa psi vectors (Keyser et al. 1989) were calculated for the February 2019 case. The psi vector and its divergence field can be used to diagnose the full three-dimensional divergent circulation within a particular domain. In a general sense, the 500-hPa psi vectors qualitatively describe the horizontal component of the lower-tropospheric divergent wind field. In summary, the 500-hPa psi vectors are strongly convergent within the right entrance region of the February 2019 "Uber Jet", consistent with the diagnosis of a thermally-direct circulation from the Sawyer–Eliassen equation. However, the distribution of psi vectors also suggests that a substantial component of the upper-tropospheric divergent wind field was directed in the along-jet direction, which implies that a non-negligible fraction of the total wind associated with the February 2019 "Uber Jet" cannot be explained from a simple geostrophic balance. Therefore, given the likelihood that the assumption of semi-geostrophic balance may not always apply in these situations, caution must be applied when examining the character of across-front ageostrophic circulations in the vicinity of "Uber Jets" using the Sawyer–Eliassen equation. A holistic approach that employs the psi vector, as well as the Sawyer–Eliassen equation, is likely to illuminate the salient dynamical characteristics of these "Uber Jet" structures.

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Daniel Keyser's perspective on the applicability of the S–E equation to the two uber jet cases under discussion:

1) Irrotational flow in the entrance regions of the uber jets exhibits a substantial cross-isentrope component toward colder air on the DT and cross-contour component toward lower geopotential height on tropopause-level isobaric surfaces. This cross-contour irrotational flow appears to represent the upper horizontal branch of a thermodynamically direct vertical circulation in the entrance regions of the uber jets and is consistent with parcel speed accelerations in these jet entrance regions.

2) The configuration of the cross-isentrope/cross-contour irrotational flow takes the form of a quasi-linear, elongated strip that extends along the entrance regions of the uber jets. This configuration differs from the well-known star-burst pattern that is found on the DT and tropopause-level isobaric surfaces above the low-level baroclinic zones poleward and eastward of strong extratropical cyclones, This difference suggests the hypothesis that the irrotational flow in the entrance regions of the uber jets may be a manifestation of frontogenesis (i.e., dynamical forcing) rather than latent heating (i.e., diabatic forcing).

3) The hypothesis posed in item #2 could be tested in a quasi-geostrophic (QG) framework by solving the omega equation, partitioning the vertical motion between dynamical and diabatic forcing terms, and diagnosing the respective irrotational flows associated with the partitioned vertical motions.

4) An alternative approach to the methodology proposed in item #3 would be to represent the irrotational flow in terms of the psi vector introduced by Keyser et al. (1989), diagnosing the psi vector In a QG framework (where the psi vector is forced by the Q vector), and partitioning the psi vector into dynamically and diabatically forced contributions parallel to the approach based on the QG omega equation that is proposed in item #3.

5) The above discussion is restricted to the irrotational component of the flow given its routine
availability and conventional use in UAlbany map discussions, but it should be emphasized that a complete diagnosis of parcel speed accelerations/decelerations in jet entrance/exit regions, respectively, should include the contribution of the cross-isentrope/cross-contour nondivergent component of the flow.

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B. Minghao Zhou (TC Wutip):

Typhoon Wutip in the WNP reached Category 5 strength on 25 Feb based on satellite estimation and became the strongest TC observed in February in the NH (selected imagery can be found here under TC Wutip; http://www.atmos.albany.edu/mapdisco/20190301/). Minghao discussed how TC Wutip's genisis could be related to a westerly wind burst behind a convectively active eastward-propagating MJO, an equatorial Rossby wave, and low frequency ENSO signal (http://www.atmos.albany.edu/mapdisco/20190222/images/20190222summary.pdf). TC Wutip developed south of an anomalously strong subtropical ridge and a retracted subtropical jet in the WPAC, which had been persistent since almost the end of January. TC Wutip was able to develop within a broad area of "tropical" environment in a season that is typically not favorable for TC development, and reached Category 4 strength southwest of Guam where it slowed down and went through an eyewall replacement cycle (ERC as evidenced from an IR loop from Stu Ostro's twitter post https://twitter.com/StuOstro/status/1100134519846383618). Meanwhile, a quasi zonal upper-level flow impinging on the northern flank of TC Wutip opened up an elongated poleward outflow jet which lasted for more than 2 days (http://www.atmos.albany.edu/mapdisco/20190301/images/WIND.gif). After the ERC, TC Wutip's upper-level anticyclonic outflow expanded again toward its western quadrants and the vertical wind shear decreased from ~15 kt to below 10 kt around the TC (http://www.atmos.albany.edu/mapdisco/20190301/images/SHEAR.gif). This decrease in vertical wind shear allowed TC Wutip to reintensify over relatively low OHC (< 35 J・m-2) and become a rare February Category 5 storm. Subsequently, TC Wutip quickly weakened as it approached the exit region of another jet streak and was sheared apart before being able to undergo an extratropical transition. However, evidence of TC Wutip's indirect influence on midlatitude circulation can be found from Alicia Bentley's 300-200 hPa irrotational wind loops where negative PV advection by the irrotational wind associated with TC Wutip facilitated the tightening of the meridional PV gradient and the associated active North Pacific storm track (http://www.atmos.albany.edu/student/abentley/realtime/standard.php?domain=pacific&variable=irro_wind). Midlatitude cyclongenisis east of Japan on 23 and 26 Feb seemed to be

partially linked with the diabatic outflow directed from TC Wutip and benefited from tropical moisture brought by TC Wutip as seen from the PW field as well as mid-level IVT fields from Tomer Burg's
maps http://www.atmos.albany.edu/student/tburg/analysis/loop.php?model=gfs&prod=iv700_300&proj=pac&archive=1 (although not particularly evident from the low-level IVT field (http://www.atmos.albany.edu/student/tburg/analysis/loop.php?model=gfs&prod=ivt&proj=pac&archive=1). These active extratropical cyclones that developed in the exit region of a retracted subtropical jet turned north-northeastward and contributed to the persistence of discontinuous downstream ridge building over the Gulf of Alaska. The southeastern portions of progressive upper-level troughs associated with these extratropical cyclones sheared away from the main trough in a region of strong deformation, undercut the aforementioned Rex block, and resulted in the formation of a quasi-continuous cutoff cyclones in the eastern Pacific north of Hawaii. These cutoff cyclones north of Hawaii served as a source of IVT from the subtropical and tropical EPAC directed toward the US west coast.

VIS loop of Typhoon Wutip from Feb. 21st to Feb. 27th retrieved from CIRA RAMMB:
http://rammb.cira.colostate.edu/ramsdis/online/loop_timestamp.asp?data_folder=himawari-8%2Fhimawari-8_band_03_sector_03&width=1020&height=720&ending_image=himawari-8_band_03_sector_03_20190227090000.gif&starting_image=himawari-8_band_03_sector_03_20190221080000.gif

Science hypothesis #1: TC Wutip's interaction with a midlatutude trough between 23–26 Feb fit in the bin of "good" TC-trough interaction where eddy momentum forcing acting on the lower inertial stability TC outflow layer contributed to radial acceleration and a poleward outflow jet development. Enhanced upper level divergence in this case outperformed the negative factor of increasing shear brought by the trough and aided TC Wutip in sustaining its intensity over relatively low OHC.

Science hypothesis #2: The ERC of TC Wutip resulted in a broadened TC circulation and a wider area of higher inertial stability near the TC core which subsequently reduced ambient vertical wind shear and allowed for an extra day of reintensification.

Science hypothesis #3: Diabatic outflow from TC Wutip helped to enhance the WPAC subtropical jet due to negative PV advection by the irrotational wind and facilitated multiple midlatitude cyclonegenesis in the downstream poleward jet-exit region. The presence of TC Wutip also opened up the persistently strong subtropical ridge in WPAC, providing a tropical moisture fetch for these midlatitude cyclones. Given a retracted subtropical jet, the increasing amplitude and shortening wavelength of the upper-level disturbances associated with these extratropical cyclones was more likely to yield a “Rex block” pattern over the Gulf of Alaska with frequent cutoff cyclone formation north of Hawaii.

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C. Tyler Leicht (Heat wave in the UK and parts of northwestern Europe):

Tyler discussed the structure and evolution of the large-scale flow that permitted a warm Omega block to develop over the UK and northwestern Europe. He built his discussion from a class-related forecast of this event that he prepared with Alex Mitchell. Media stories on the impact of the hear…..which set all-time February maximum temperature records in the UK and triggered wild fires in many locations ….can be found here: (https://www.nytimes.com/2019/02/26/world/europe/climate-change-hottest-day-uk.html and https://www.cnn.com/2019/02/27/uk/fires-uk-record-temperature-february-intl-scli-gbr/index.html and https://www.euronews.com/2019/03/01/wildfires-spike-across-europe-amid-record-hot-temperatures-in-february). Alicia Bentley's loops for this event (they will age off) can be found here: https://www.euronews.com/2019/03/01/wildfires-spike-across-europe-amid-record-hot-temperatures-in-february. A key takeaway from Alicia's loops is that a persistent time-mean trough anchored just inland from the west Coast favored a time-mean ridge over the eastern CONUS with a subsequent time-mean downstream trough over the west-central Atlantic. A series of progressive disturbances that crested the eastern CONUS ridge and dropped into the west-central Atlantic trough subsequently lifted northeastward and kept rebuilding the UK ridge in conjunction with discontinuous ridge retrogression.

Science hypothesis: A progressive flow pattern from the Gulf of Alaska to the western CONUS that favors a time-mean trough position near 120 W in conjunction with a time-mean low-amplitude ridge over the eastern CONUS is a necessary condition for a downstream trough over the west central Atlantic. Disturbances of Pacific origin that reach the western CONUS and lift northeastward toward the eastern CONUS ridge are able to tap Gulf of Mexico moisture and contribute to repeated eastern CONUS ridge building episodes due to diabatically driven negative PV advection by the irrotational wind. Disturbances that crest this eastern CONUS ridge amplify as they approach the west-central Atlantic time-mean trough before they turn north-northeastward and keep rebuilding an Omega block over the UK and northwestern Europe in conjunction with discontinuous ridge retrogression.

D. Matt Campbell (California rains) and Danny Reese (weekend storm and severe weather outbreak):

Matt used Los Angeles (KLAX) as an example of just how wet it has been in California since December 2018. A time series of KLAX rainfall for the last year (source: CPC) can be found here: (https://www.cpc.ncep.noaa.gov/products/global_monitoring/precipitation/sn72295_1yr.gif. The cumulative rainfall anomaly is ~125 mm…..a big number for KLAX. Matt used the NOAA HYSPLIT trajectory model to show how the subtropical southeastern Pacific has served as an important moisture source for the CA rains this year.

Danny Reese discussed a number of the forecast uncertainties (mostly arising from storm track and intensity) associated with the weekend (2–3 March) storm in the Northeast. Significant discrepancies between many of the global models were readily apparent until 48–72 h in advance with the GFS being too weak and too far south initially and the ECMWF being too bullish and too far north initially. Danny also discussed the potential for a significant severe weather outbreak in the Southeast over the weekend. He rightly noted that the SPC was already on top of the significant severe weather threat.

Severe weather-related news stories of interest (thanks to Steve Weiss for making me aware of the Forbes story) are appended below.

New York Times story (A Tornado Warning Gave Alabamians 12 Minutes to Prepare. 23 People Died Anyway) from 5 March 2019: https://www.nytimes.com/2019/03/05/us/alabama-tornado-victims.html?action=click&module=RelatedCoverage&pgtype=Article&region=Footer&login=email&auth=login-email

Washington Post Capital Weather Gang story (Inside the Southeast tornado swarm that devastated Alabama on Sunday) from 4 March 2019: https://www.washingtonpost.com/weather/2019/03/04/inside-southeast-tornado-swarm-that-devastated-alabama-sunday/?utm_term=.d1daace4c236

Forbes article (Four Forecast And Messaging Takeaways From The Southern Tornado Outbreak) by Dr. Marshall Shepherd from 5 March 2019 (https://www.forbes.com/sites/marshallshepherd/2019/03/05/four-forecast-and-messaging-takeaways-from-the-southern-tornado-outbreak/#43b792d238f8)

Lance