Hi all,

Topics for Friday map discussion on 27 April included multiple North African dust surges into southern Europe during the second half of March 2018, flooding in the southern Israel desert on 25 April 2018, and flooding in Kauai that included an apparent all-time 24-h U.S. rainfall record on 14–15 April 2018. Links used during the discussion can be found here: http://www.atmos.albany.edu/mapdisco/20180427/. Eric Bunker and Tomer Burg assisted with the discussion.

1. Multiple North African Dust Surges into Southern Europe in March 2018:

Multiple dust outbreaks from North America toward southern Europe were fueled by an anomalously strong subtropical jet stream (STJ) that extended eastward from the Atlantic across northern Africa and the Mediterranean Sea. Dust imagery posted to Twitter can be scrutinized at the above link. Mean and anomaly NH maps for 1–29 March 2018 of 300-hPa geopotential height (http://www.atmos.albany.edu/mapdisco/20180427/images/300Zmean.gif and http://www.atmos.albany.edu/mapdisco/20180427/images/300Zanomaly.gif), 850-hPa temperature (http://www.atmos.albany.edu/mapdisco/20180427/images/850Tmean.gif and http://www.atmos.albany.edu/mapdisco/20180427/images/850Tanomaly.gif), SLP (http://www.atmos.albany.edu/mapdisco/20180427/images/SLP_NHmean.gif and http://www.atmos.albany.edu/mapdisco/20180427/images/SLPanomaly.gif), and anomaly 850-hPa geopotential height and 925-hPa vector wind composite anomaly (http://www.atmos.albany.edu/mapdisco/20180427/images/850Zanomaly.gif and http://www.atmos.albany.edu/mapdisco/20180427/images/925Wanomaly.gif) tell a big picture story of anomalously strong flow across northern Africa and the Mediterranean Sea in conjunction with an anomalous meridional temperature gradient that exceeded 10 C between northern Europe and northern Africa. The combination of an equatorward-shifted, anomalously strong STJ in conjunction with anomalously strong westerly flow in the storm track across North Africa and the Mediterranean Sea ensured that African dust raised in well-mixed surface-based layers in the warm sector of these cyclones would be drawn northeastward across the Mediterranean into southern Europe.

Science issue: Test the hypothesis that North African dust outbreaks into southern and southeastern Europe during the cool season are more frequent, prolonged, and intense during periods when an anomalously strong, equatorward-shifted STJ is present across North Africa and the Mediterranean Sea.

2. Israel Desert Flash Flooding on 25 April 2018:

Flash flooding in parts of the Negev Desert on 25–26 April 2018 have claimed at least nine lives (https://www.garda.com/crisis24/news-alerts/113691/israel-eilat-airport-closed-amid-flooding-april-26-update-1). This flash-flooding event is of

meteorological interest because the moisture source was not from the Mediterranean Sea as was evident from an Israeli radar loop that we examined during map discussion and that has, alas, since aged off the host computers. Kahana et al. (2002) published a paper on the synoptic climatology of major floods in the Negev Desert (https://rmets.onlinelibrary.wiley.com/doi/pdf/10.1002/joc.766) in which they showed that the primary water vapor source for Negev Desert flooding was the Mediterranean Sea..

Alicia Bentley's real-time maps (choose the Europe, Africa, and Asia projections to get the best perspective) show that the flooding was associated with a progressive "bowling ball" trough that tracked southeastward across the southern Mediterranean toward southern Israel (http://www.atmos.albany.edu/student/abentley/realtime/standard.php?domain=europe&variable=mslp_jet). Alicia's maps also show that the antecedent upper-level environment featured anticyclonic wave breaking over western Europe on 17–18 April, the subsequent formation of a Rex block over the western Europe and the southern Mediterranean on 19–20 April, and the aforementioned "bowling ball" trough forming as an innocuous-looking feature underneath the ridge member of the Rex block after which this trough moved ESE toward southern Israel on 22–25 April.

Alicia's maps also show the passage of a leading and relatively strong upper-level trough across Israel on 22 April. This leading trough originated from a strip of 500-hPa shear vorticity over northwestern Europe on 19 April. It subsequently deepened southeastward toward the eastern Mediterranean on the eastern side of the aforementioned Rex block and formed a cutoff cyclone by 0600 UTC 25 April as it reached Israel and the northern Red Sea. To see the antecedent impact of this leading 500-hPa trough, switch Alicia's maps to the Africa projection and choose 700-hPa heights/PW. As this leading 500-hPa trough crossed the Arabian peninsula on 22–23 April, PW values in the 35–40 mm range were drawn poleward from the ITCZ to the central and eastern Arabian Peninsula and the northern Arabian Sea. The approach of the aforementioned "bowling ball" trough on 25 April enabled higher PW values over the Arabian Peninsular and adjacent Ref Sea to be pulled poleward and and westward across the Negev Desert on the northern side of this trough as it reached the northwestern part of Saudi Arabia. A loop of soundings from Ben Gurion Airport (source: University of Wyoming) shows the the presence of deep southeasterly flow at 0000 and 1200 UTC 25 April above a very shallow northwesterly onshore flow from the southeastern Mediterranean Sea (http://weather.uwyo.edu/cgi-bin/sounding?region=africa&TYPE=GIF:SKEWT&YEAR=2018&MONTH=04&FROM=2500&TO=2700&STNM=40179). During this 12 h period ending 1200 UTC 25 April, CAPE values increased from to 499 to 779 J/kg and the PW increased from 26.1 mm to 29.8 mm, indicative of a quite moist and unstable air mass for this part of the world.

Science Issue: Test the hypothesis that the rare flash flooding in the Negev Desert absent any obvious eastward-directed moisture transport from the Mediterranean Sea was the result of a two-stage cyclogenesis process in which a strong leading trough first enabled moisture from the African ITCZ to be pulled poleward across the southern and central Arabian Peninsular and northern Red Sea, after which this moisture was pulled northwestward into southern Israel on the poleward side of the aforementioned southeastward-moving trailing bowling ball disturbance.

3. Kauai Deluge and Possible New U.S 24-h Rainfall Record from 14–15 April 2018:

We closed map discussion with an overview of what may be a new U.S. all-time 24-h rainfall record. Waipa, located on the north coast of Kauai, measured 49.69" (1.62 m) of rain between 14–15 April. According to the NWS, this rainfall measurement may be a new U.S. all-time 24-h rainfall record (http://www.prh.noaa.gov/hnl/pages/rer.php). We used Alicia Bentley's loops to assess how the large-scale flow pattern may have contributed to this epic rainfall event. Although her loops have aged off our computers, representative maps for 1200 UTC 15 April found here (http://www.prh.noaa.gov/hnl/pages/rer.php) provide a good overview of the large-scale flow pattern at a time when extremely heavy rain was falling at Waipa. These images reveal that: (1) the atmosphere across the subtropical central Pacific was relative baroclinic as evidenced by: (1) the 570-dam 1000–500-hPa thickness contour lying to the south of 20 N, (2) the location of Hawaii in the poleward exit region of an anomalously strong 40–50 m/s subtropical jet stream, a region known to be favorable for cyclogenesis, (3) a strong 1036+ anticyclone centered near 40 N and 155 W that ensured a relatively strong east-northeasterly flow would prevail across Hawaii in conjunction with warm-air advection based upon the orientation of the SLP isobars and 1000–500-hPa thickness contours, (4) CAPE values >1000 J/kg in the presence of warm-air advection at 850 hPa present across Hawaii supportive of deep convection, (5) a fractured PV anomaly located just to the northwest of Hawaii at the end of a weak PV streamer conducive to upward motion across Hawaii in conjunction with a band of 925–850-hPa relative vorticity across the region, (6) PW values in the 40–50 mm range across Hawaii in conjunction with narrow northwest-southeast corridor of integrated water vapor transport > 500 kg/m/s, and (7) a surface-to-dynamic tropopause (DT) vertical wind shear > 40 kt is supportive of organized deep convection across Hawaii.

Heather Archambault's archived DT map loops (http://www.atmos.albany.edu/student/heathera/dt/pac/7_to_22_apr18.html) nicely illustrate how anticyclonic wave breaking (AWB) at higher latitudes over the central Pacific on 12–13 April resulted in the formation of a PV streamer that extended southwestward to just northwest of Hawaii by 13–14 April. This PV streamer birthed the aforementioned fractured PV anomaly that provided a source for focused ascent over Hawaii. Heather Archambault's loop of 250-hPa wind speed, 250-hPa potential

vorticity, 250-hPa % relative humidity, 600–400-hPa layer mean ascent, and 300–200-hPa layer-averaged irrotational wind vectors (http://www.atmos.albany.edu/student/heathera/irrwind/pac/7_to_22_apr18.html) nicely shows the evolution of this fractured PV anomaly between 13–15 April and its interaction with convectively driven outflow over Hawaii on 14–15 April. Finally, Heather Archambault's loop of SLP, 1000–500-hPa thickness, 250-hPa wind speeds, and precipitable water (PW) shows how antecedent cold-air advection behind a leading trough ahead of the upstream region of AWB help to establish a region of strong baroclinicity over and poleward of Hawaii by 14 April (http://www.atmos.albany.edu/student/heathera/slp_thick/pac/7_to_22_apr18.html) . Note also how trough development in the surface easterly flow (SLP field) over and west of Hawaii on 14–15 April can be linked with a longitudinally confined poleward surge of higher PW air. The location of this SLP trough and high PW corridor just to the east of the aforementioned fractured PV is consistent with the interpretation that this PV anomaly and its associated unusually deep supper-level trough located unusually far to the south for the time of year is providing ideal larger-scale flow conditions supportive of an important rain event over Hawaii. At issue is the connection between the synoptic-scale forcing and the mesoscale and orographic processes that combined to create a record rainstorm on the north coast of Kauai. A sounding loop from station 91165 (Lihue, courtesy of the University of Wyoming) nicely shows the moistening and deep warm-air advection that developed in a moderately sheared environment between 1200 UTC 13–15 April. PW values reached 40 mm (high, but not extraordinarily so as noted separately by Sheldon Kusselson), CAPE values exceed 500 J/kg, 500-hPa temperatures cooled to as low as -12 C, and the 1000–500-hPa thickness values reached as low as 564 dam, values that collectively are indicative of midlatitude meteorological mischief making (http://weather.uwyo.edu/cgi-bin/sounding?region=naconf&TYPE=GIF:SKEWT&YEAR=2018&MONTH=04&FROM=1212&TO=1612&STNM=91165).

Science issue: Test the hypothesis that AWB and the subsequent formation of a fractured PV anomaly just to the northwest of Hawaii in an unusually baroclinic environment was a necessary condition for an epic mesoscale rainstorm in that the PV anomaly acted to generate an area of low-level warm-air advection across Hawaii in the presence of strong northeasterly surface flow, resulting in strong and persistent orographic upslope flow on the north shore of Kauai.

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Further information on this event can be found on this nice blog post to map earlier by Cliff Mass (https://cliffmass.blogspot.com/2018/04/kauai-experiences-us-24-h-precipitation.html). I especially liked his lightning map that shows strong clustering on the north and northeast side of Kauai….wow!

Dan Lindsey's just posted satellite loop clearly shows the importance of orographic forcing on the north shore of Kauai (http://rammb.cira.colostate.edu/templates/loop_directory.asp?data_folder=dev/lind

sey/loops/15apr18&loop_speed_ms=100). Additional excellent satellite imagery of this event can be found in a CIMSS blog (http://rammb.cira.colostate.edu/templates/loop_directory.asp?data_folder=dev/lindsey/loops/15apr18&loop_speed_ms=100) and the NESDIS Operational Blended TPW Products provided separately by Sheldon Kusselson (http://www.ospo.noaa.gov/Products/bTPW/TPW_Animation.html?fromDate=20180414&fromHour=21&endDate=20180415&endHour=23&product=EAST_PACIFIC_PCT&interval=hourly).

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