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The Multi-Scale Dynamics of the Complex Wind Oscillations Associated with the Yarnell Hill Fire in Arizona

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Abstract Text:

The Yarnell Hill Fire was a wildfire near Yarnell, Arizona. It was ignited by lightning on June 28, 2013. On June 30, it overran and killed 19 City of Prescott firefighters who were members of the Granite Mountain Hotshots. It was one of the deadliest wildfires in U. S. history (https://www.weather.gov/fgz/YarnellFire2013). In this presentation, we will compare numerous observations to high resolution numerical simulations to diagnose processes that organized the erratic winds leading to a shift in fire motion.

June 2013 was a remarkable weather month in Arizona, the fourth hottest June on record. This also represented a period of prolonged drought in the southwest U. S. The last week of June was the hottest week of the very hot summer with numerous daily high temperature records set for the 30th, e.g., 102ºF, at Prescott approximately 50 km northeast of Yarnell while temperatures approached and/or exceeded 100ºF at two Remote Atmospheric Weather Station (RAWS) stations (Stanton and Peeples Valley) only a few kilometers from Yarnell (https://d3dqsm2futmewz.cloudfront.net/docs/azclimate/MonthlyClimateSummaries/AzClimSumJuly2013.pdf).

Approximately 72 hours prior to ~2300 UTC on the 30$^{th}$, when the erratic winds shifted the path of the wildfire trapping the Granite Mountain Hotshots, a jet streak entered the Pacific Northwest poleward of an already massive ridge and started the further synoptic amplification of the ridge over the southwestern U. S. This amplification represented a classic and rather massive Rossby Wave Breaking (RWB) event that both strengthened the southwest U.S. ridge and began rotating it anticyclonically, i.e., shifting its core iso-height orientation from west-east to south-north. Consistent with RWB, a weak secondary jet streak aloft accompanied the trough thinning process downstream from the axis of the break. This jet propagated around the interior of the ridge just east and north of Arizona. In response to the secondary jet motion and trough thinning east of the ridge axis, strong sinking and adiabatic compression of air parcels above the very dry elevated plateau over the four corners region created extremely hot air approaching 20ºC at 700 hPa (potential temperature ~325K) over Arizona and a deep (~400 hPa) adiabatic layer with substantial Downdraft Convective Available Potential Energy (DCAPE) at Flagstaff and Las Vegas (http://weather.uwyo.edu/upperair/sounding.html) by 0000 UTC 1 July. The sinking air was initially enhanced by a rightward-directed ageostrophic wind component in the mid-upper troposphere on the anticyclonic side of the ridge accompanying the secondary jet streak west of a thinning trough, thus enhancing a variation in mass flux divergence/convergence within the ridge interior. This convergence feature was initially oriented northwest-southeast across southern Utah into southeastern Arizona nearly coincident with the diurnal heating above the Mogollon Rim during the late morning to afternoon time frame. Between ~1200 UTC and 1800 UTC the elevated heating over the high plateau and background secondary jet shear zone interacted to change the convergence aloft to generate a NW-SE-oriented divergence zone from southern Utah to southeastern Arizona to the northeast of Yarnell. The ascending flow and adiabatic cooling after 1800 UTC at 500 hPa reflected the growing westward-directed ageostrophic flow over central Arizona relative to northerly ageostrophic flow over northern Arizona. The divergence zone, reflecting the variation from ageostrophic easterly to northerly flow was apparent in the hourly RUC analyses from the SPC mesoscale archives (https://www.spc.noaa.gov/exper/ma_archive/images_s4/20130630/). The heating above the terrain seemed to intensify this mass divergence aloft.

Soon thereafter (~1845 UTC), a broken line of thunderstorms developed over the Mogollon Rim (https://vortex.plymouth.edu/myo/rad/). The convection then propagated southwestward down the Mogollon Rim towards the Black Hills. The convection then reformed and propagated southwestward towards the Bradshaw Mountains. This was followed by motion directed towards the gap in the hills at Yarnell. The sequence of dual polarimetric radars from Flagstaff NWS (KFSX) as well as RAWS observations at nearby Stanton and Peeples Valley indicated in detail a complex probable sequence of interactions among convection and convective outflows or density currents leading to the erratic wind shift from west-southwest to east-northeast that may have shifted the direction of fire spread. Between ~1845 and 2015 UTC the KFSX dual-pol indicated an arcing weak return propagating away from the Black Hills. This had the geometry of an anticyclonic outflow. Soon thereafter, intense convective echoes approaching 50 dBz, which were triggered near to this density current #1 feature, occupied much of the region just southwest of the Black Hills and propagated towards the Bradshaw Mountains to the west-southwest. This new convective line then triggered another line of strong convection and a similar arcing low-level density current (#2) as it propagated down the Bradshaw Mountains between ~2200 and 2300 UTC. This low-level cool air perturbation then moved into the gap between the Yarnell Hills and the town of Yarnell and subsequently by ~2300 UTC shifted the winds at the Peeples Valley RAWS and then the Stanton RAWS from the west-southwest to the north-northwest and north-north-east, respectively accompanying a temperature drop and pressure rise. This wind shift was located within a terrain gap and very close to the ongoing fire. The temperature at Stanton dropped from 103ºF to 95ºF and the wind gusted from the north-northeast at 41 kt between ~2300 and 0000 UTC.

Numerical simulations performed with a very high-resolution version of the Weather Research and Forecasting (WRF) model will be described and be compared to the aforementioned observationally-based analyses. We will focus, in particular, on higher resolution convection/terrain interactions that could have radically shifted the motion of the fire-front.

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