COLLEGE OF SCIENCE
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

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Particle Identification of Pyro-Convection from Wildfires

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Overview

- Climate change continues to cause more intense droughts and wildfires, making research the utmost necessity.
- Pyrocumulus (PyroCu) and pyrocumulonimbus (PyroCb) like **Figure 1**, formed by fires and containing mixtures of smoke and ash, allude to the presence of ice, which can trigger lightning, compounding the danger of firefighting.

Figure 1: Creek Fire PyroCb on 5 Sep 2020
Credit: Thalia Dockery via Twitter

- Ice identification in PyroCu/Cb could give insight into processes driving the events.
- Past research like LaRoche and Lang (2017) provided realistic results but lacked completeness, using rigid techniques like binary logic.

Methodology

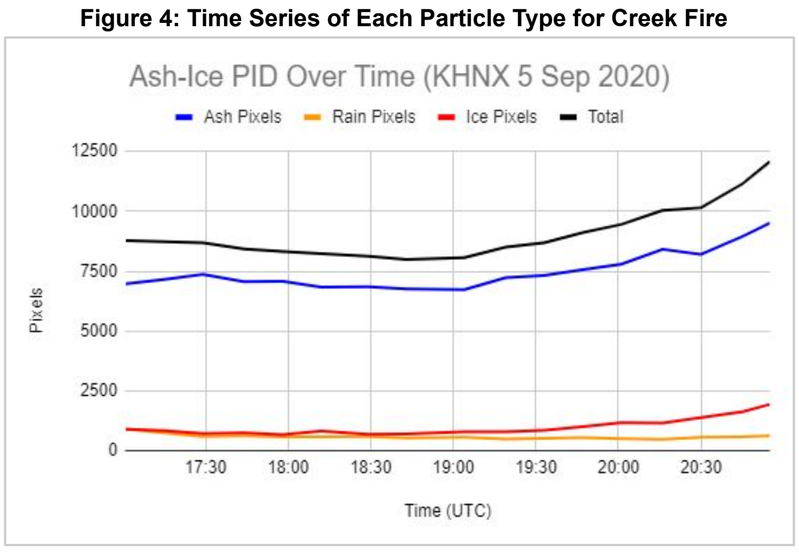
- Modified Colorado State University (CSU) particle identification (PID) algorithm used Level II NEXRAD radar data and nearby sounding data as well as a mathematical technique called fuzzy logic to determine the *most prominent* particle type in each grid.
- Fuzzy membership functions (MBFs) like **Figure 2** were built for each variable and particle type: Horizontal Reflectivity (Zh, dBZ), Differential Reflectivity (Zdr, dB), Correlation Coefficient (CC, %), and Heights/Temperatures (km or °C).
- Zdr is a ratio of returned power in the horizontal and vertical, which provides info about particle size, shape, and orientation. Higher Zdr alludes to non-spherical shape (blue curve for ash in **Figure 2**).
- CC reflects the variability of particle properties (shape, orientation, and dielectric) in each grid. Lower CC indicates more particle variability (as in ash plumes).
- Height/temperature data was used to reduce ice frequency well below the 0 °C and condensation levels (CCL).

Figure 2: Fuzzy Membership Function: Differential Reflectivity

Conclusions / Future Work

- Over all tested events, PID provided consistent and plausible results, like **Figure 3**, verified from past (though more limited) research like LaRoche and Lang (2017) etc.
- Shifted from binary to fuzzy PID, allowing more complexity and flexibility from increased weighting of important variables (Zdr and CC).

Figure 4: Time Series of Each Particle Type for Creek Fire

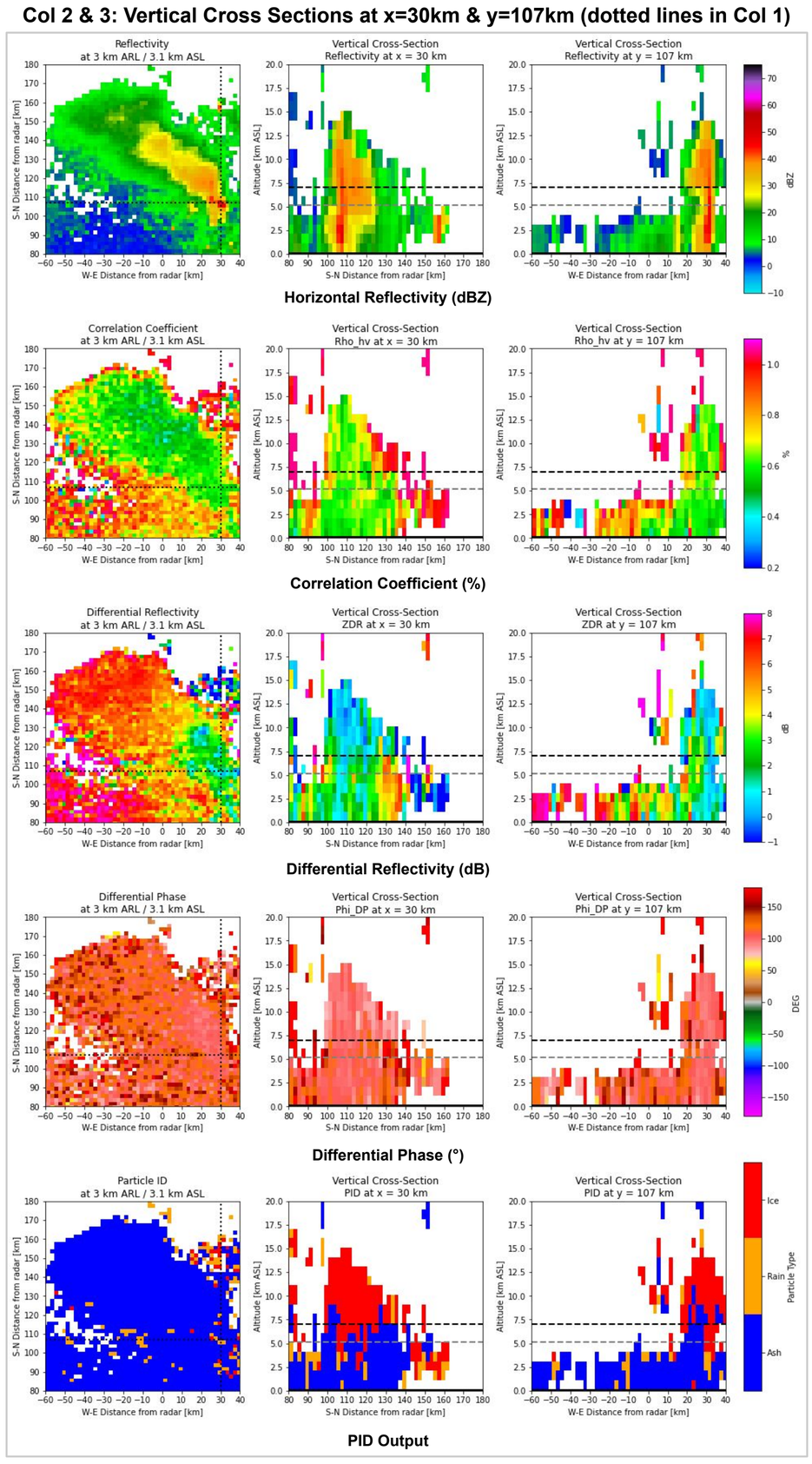


- Ash showed larger variability than in LaRoche and Lang (2017). CC rose >80%, while Zdr lowered to 1 dB near fire, but higher further away.
- Height data was useful, but lack of nearby sounding data led to errors in CCL level and PID outputs.
- Made use of differential phase for qualitative texture analysis. Future studies might add the variance to further differentiate ash and ice.
- In the future, radar particle modeling could improve MBFs and allow for reintegration into original CSU PID.

Key Findings

- Pyro-convection reached up to 15 km in the tested events. **Figure 3** shows widespread upper level ice development, consistent across events.
- Zdr and CC were highly weighted since characteristics varied widely between particle types. Ice showed high CC with near zero Zdr, while ash was characterized by higher Zdr and low CC likely because of the oblate shape and highly variable orientation of ash within the plumes.
- Rain created by melting ice falling from the upper levels of the pyro-convection occurred in multiple events. While ice formation varied between aggregation and possible riming, the surrounding environment already seemed to support non-pyro-convection.
- **Figure 4** displays a time series, showing ash volumes rising first, then ice later, creating the PyroCb (**Figure 1**).

Figure 3: PID Output for Creek Fire 5 Sep 2020 at 2055 UTC
Col 1: Horizontal Cross Sections at 3km ARL
Col 2 & 3: Vertical Cross Sections at x=30km & y=107km (dotted lines in Col 1)



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Key References

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