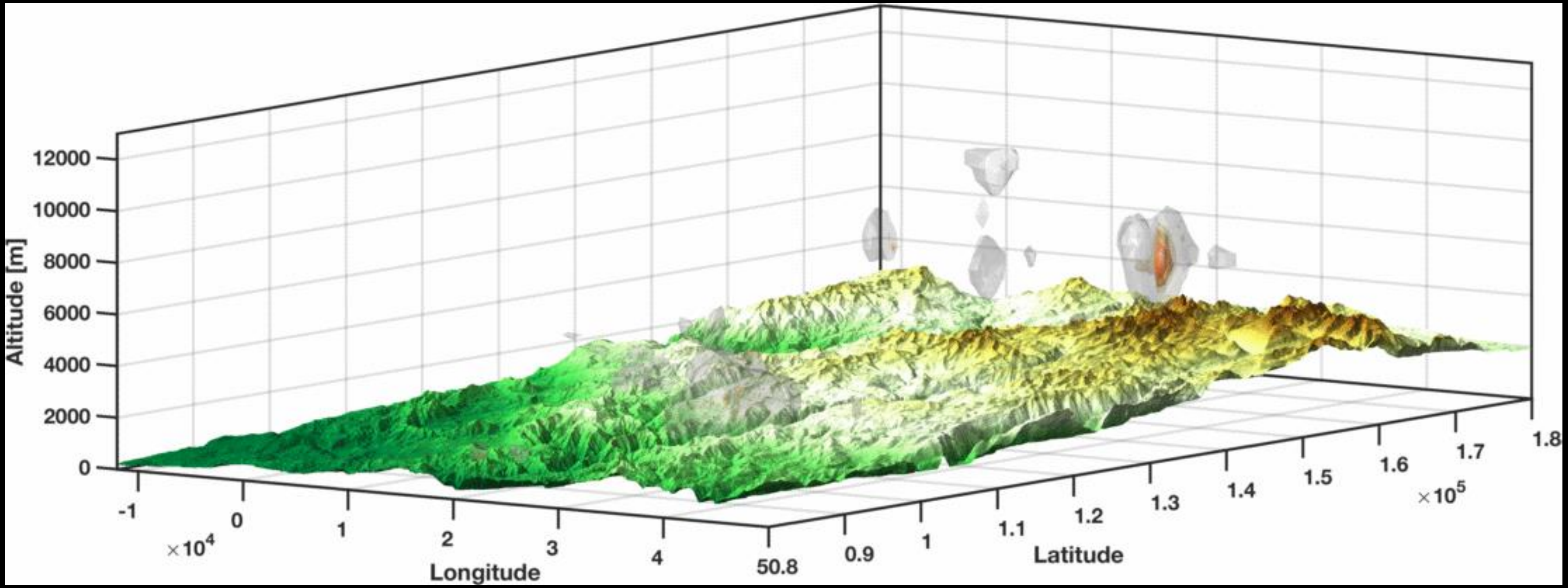
13 Feb 2024

Radar Observations of Wildfire Plume Dynamics



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Radars observe wildfire plume process:

- Fire-generated winds (vortices)
- Plume Structure/Evolution
- PyroCu/Cb processes
- And more…

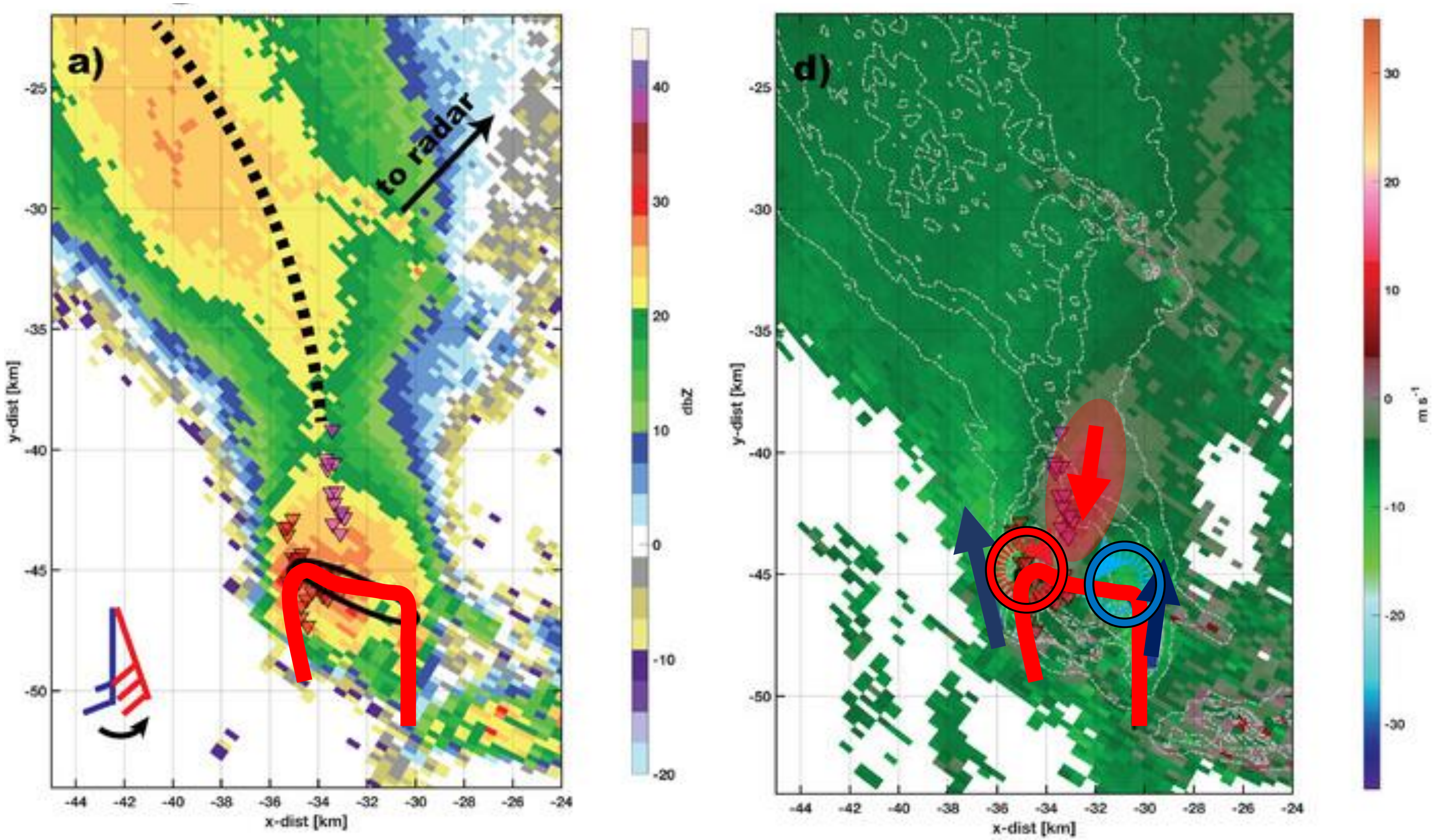
See Lareau et al. 2018 (GRL)

Fire generated winds: Counter Rotating Vortex Pair (CVP)

River Fire near Grass Valley, CA

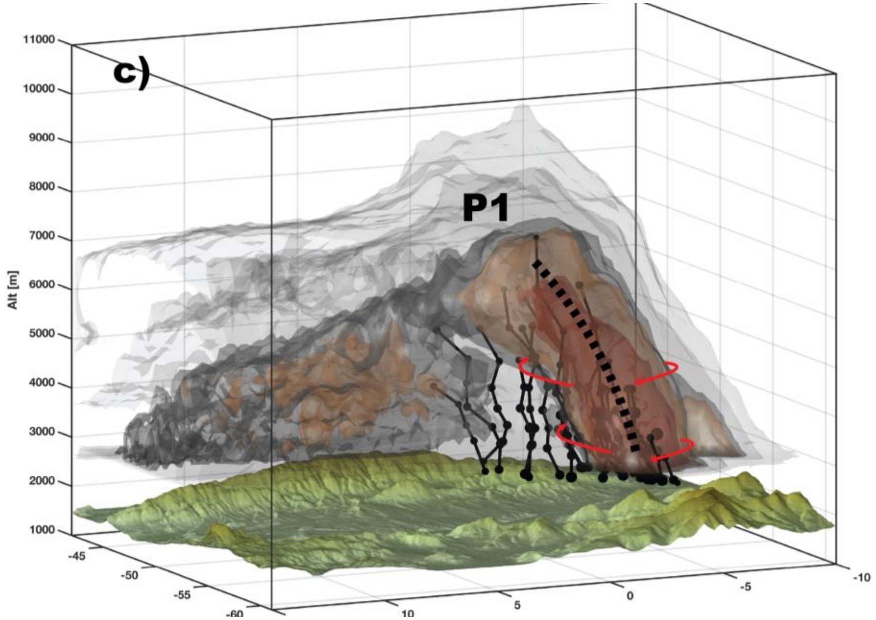
Loyalton Fire near Reno, NV

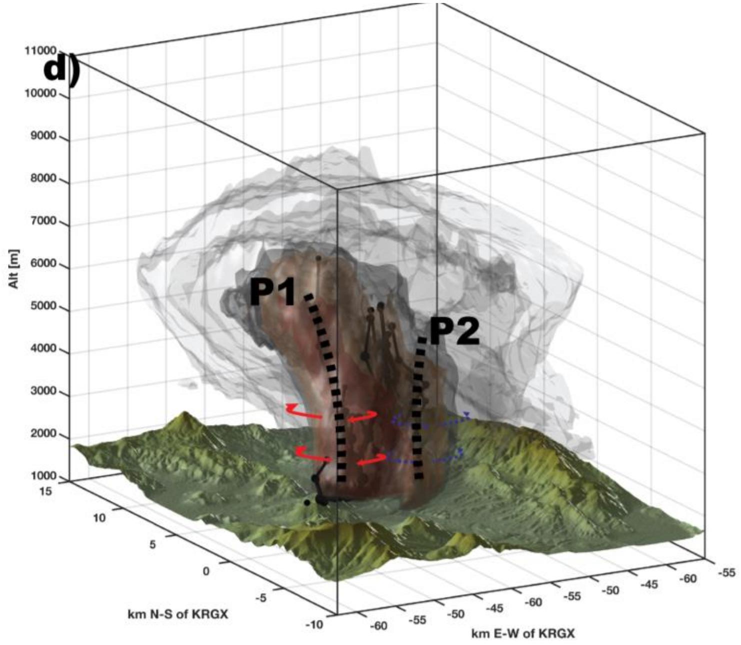
Radar Reveals Plume Structures Linked to CVPs

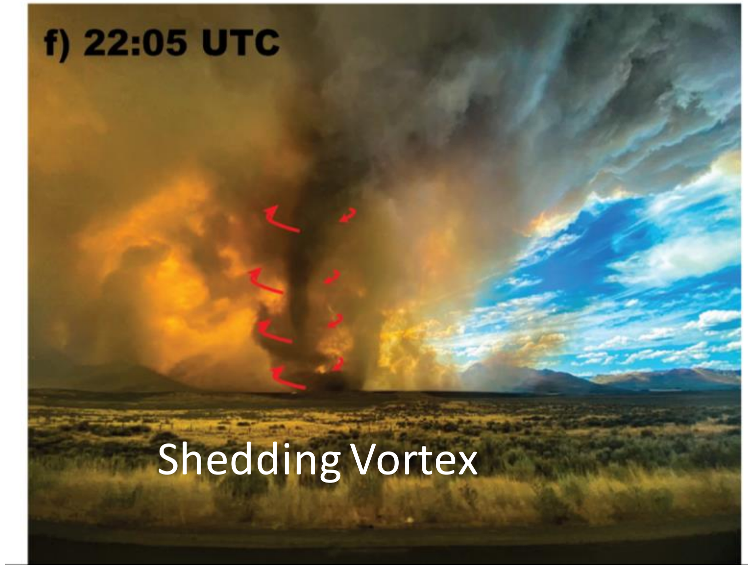


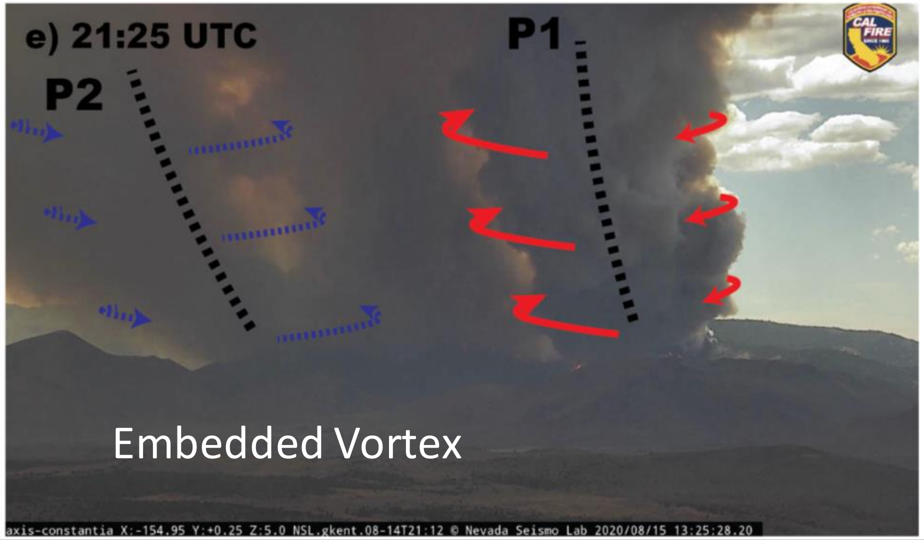
Lareau et al. 2021 (BAMS)

Radar Reveals Plume Structures Linked to CVPs

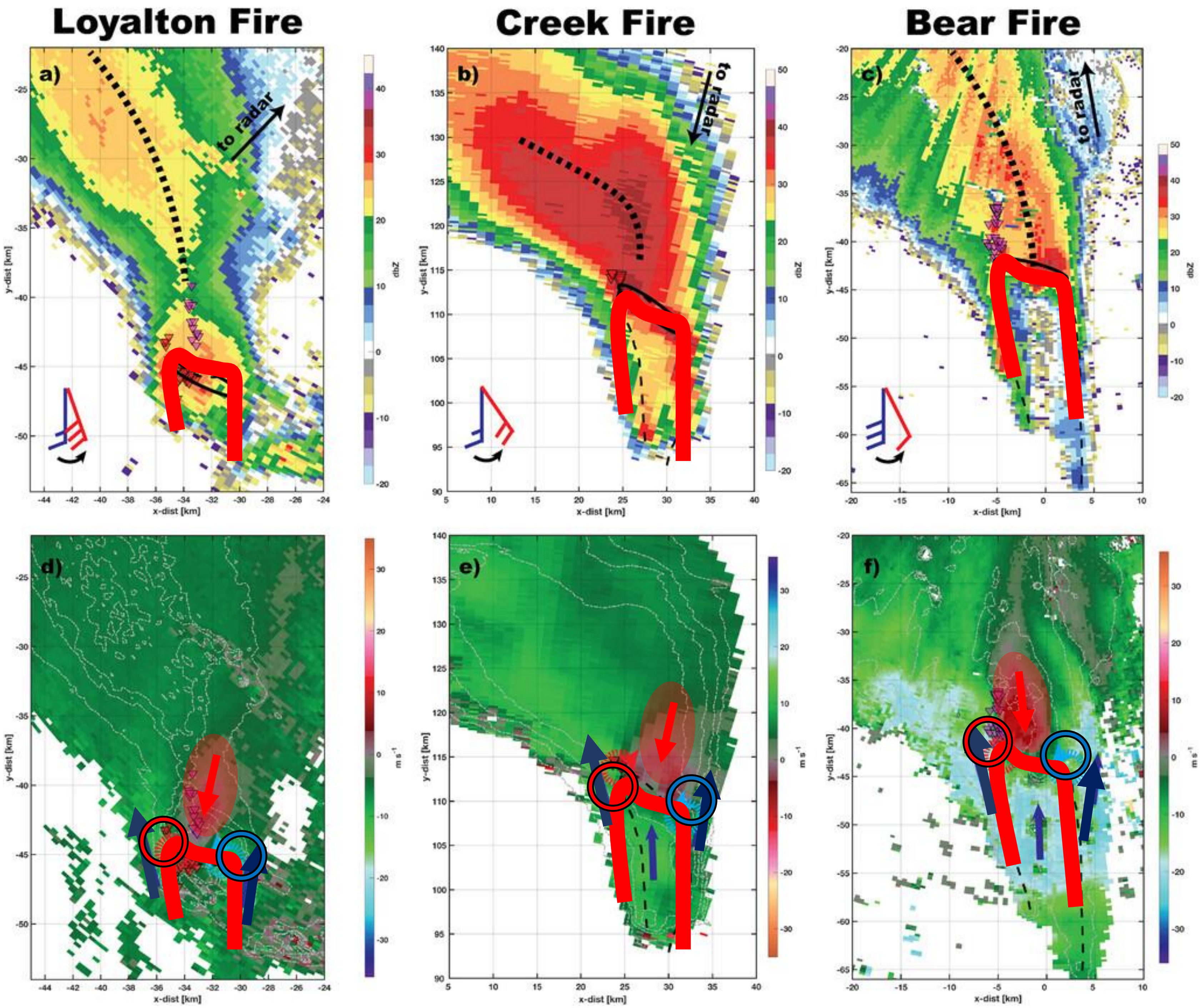








Lareau et al.
2021 (BAMS)

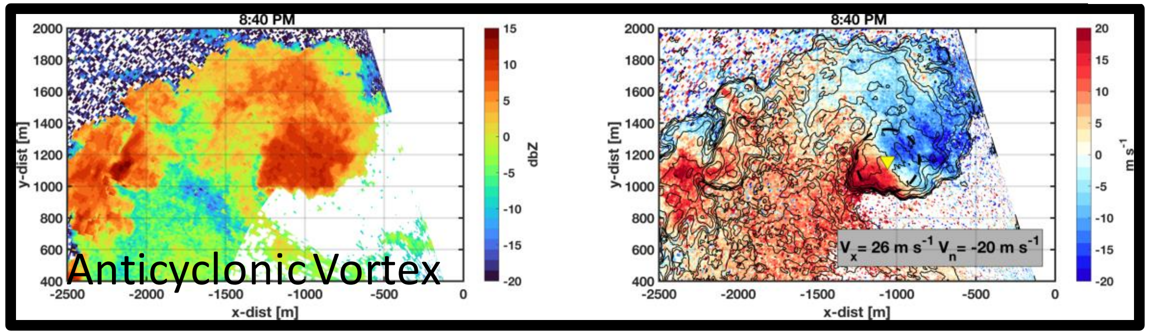


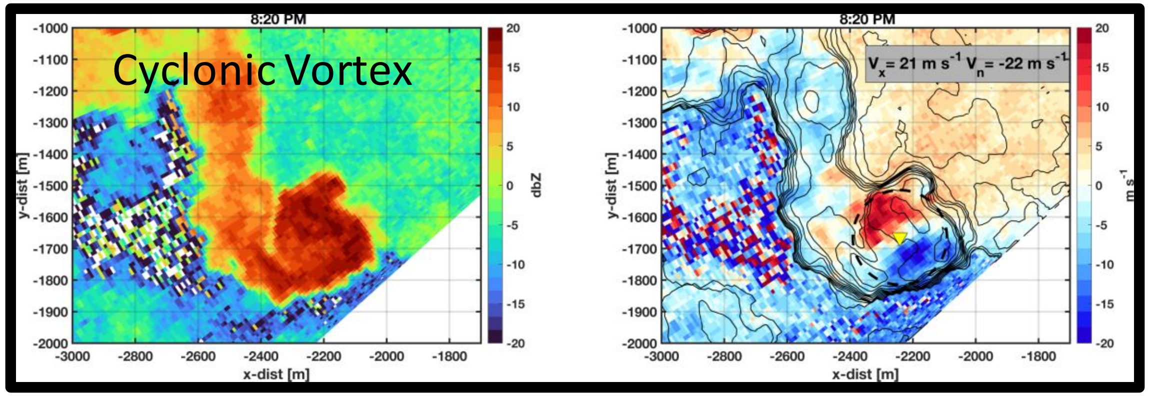
Common features:

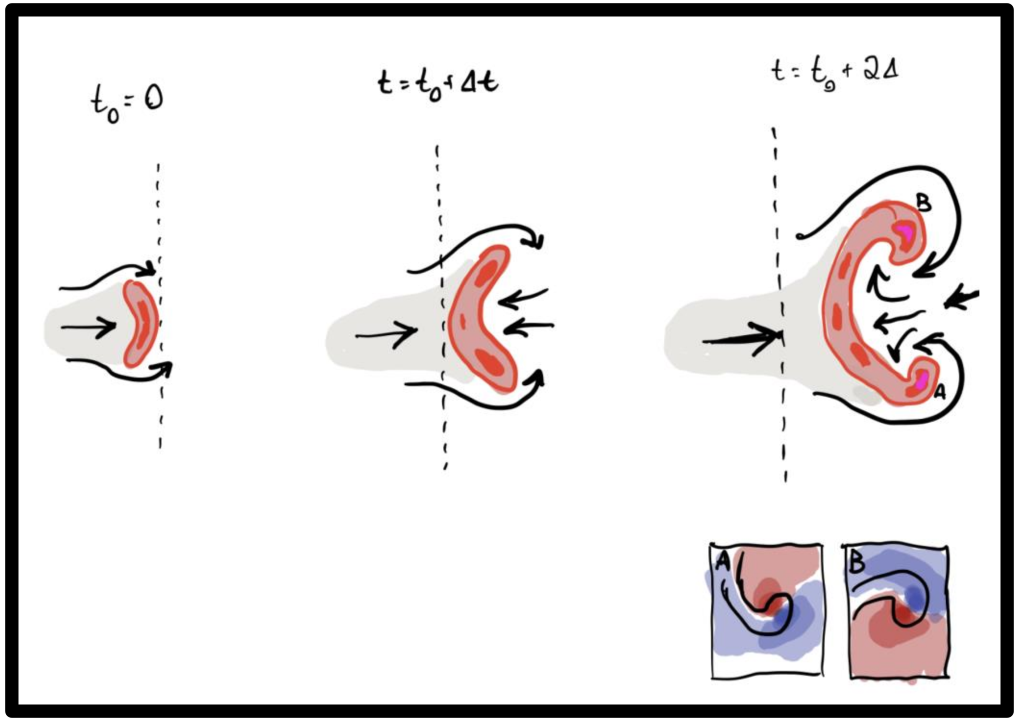
1. Meso-scale flow splitting and reversal
2. CVP on flanks of the head fire
3. Tornadic vortices embedded within and trailing from the anticyclonic CVP
4. PyroCb (more later)

Lareau et al. 2021 (BAMS)

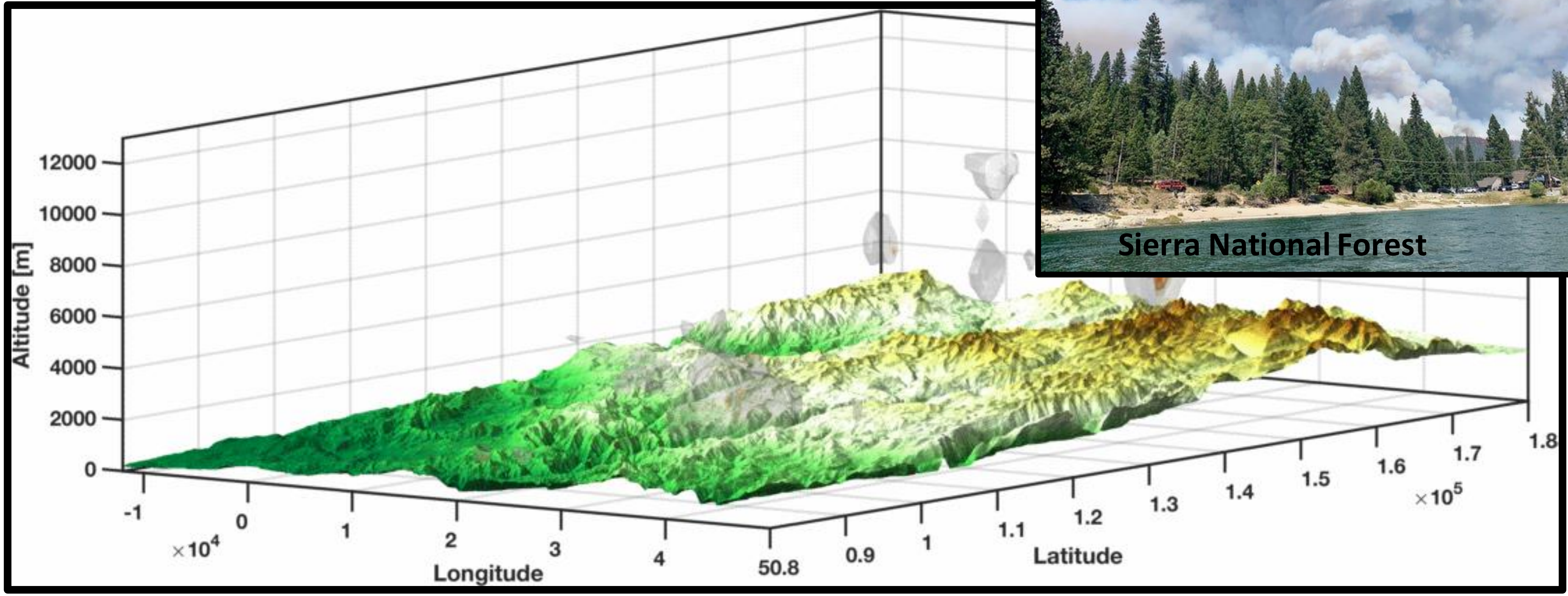
CVP Development during the Dixie Fire





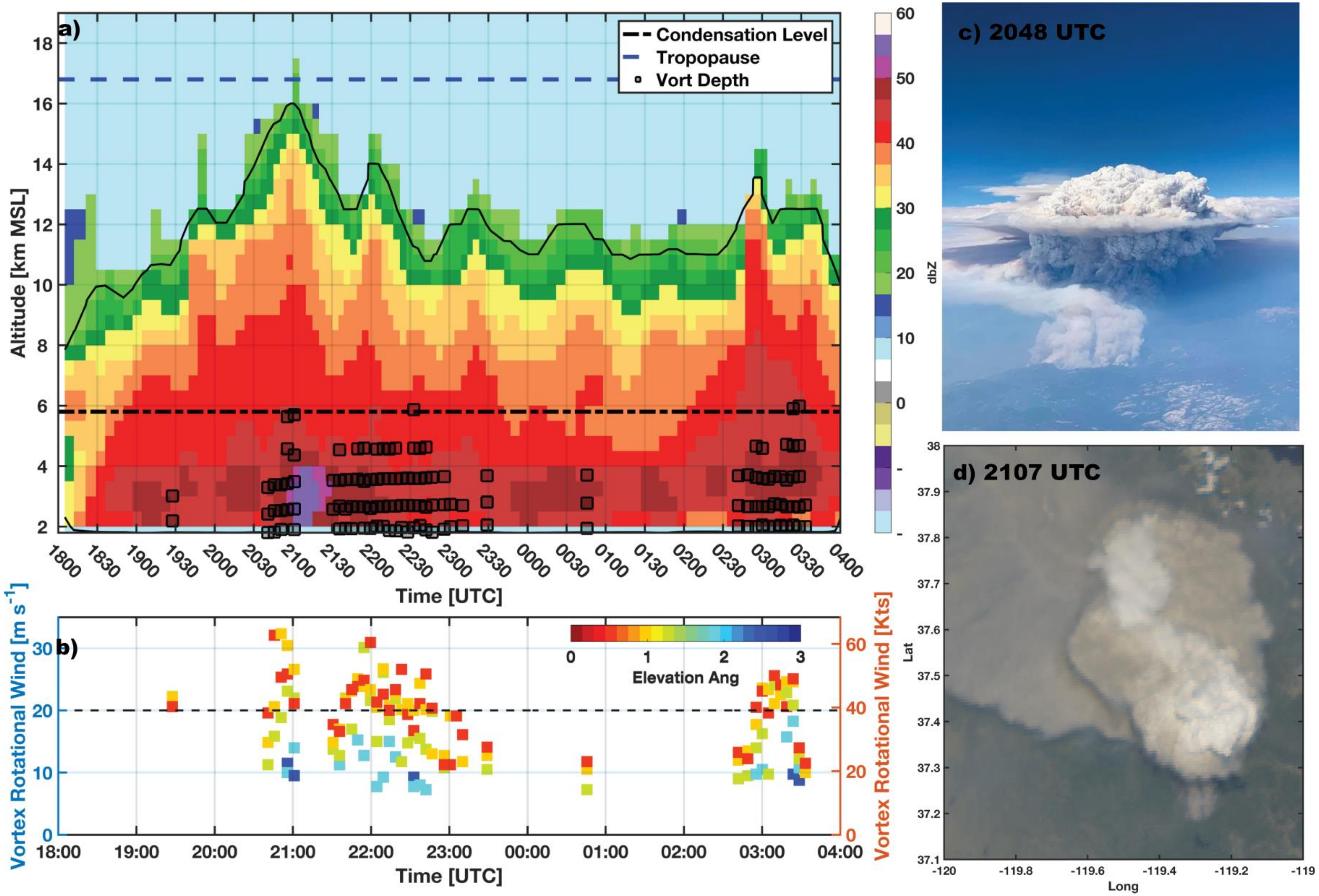


PyroCb Development



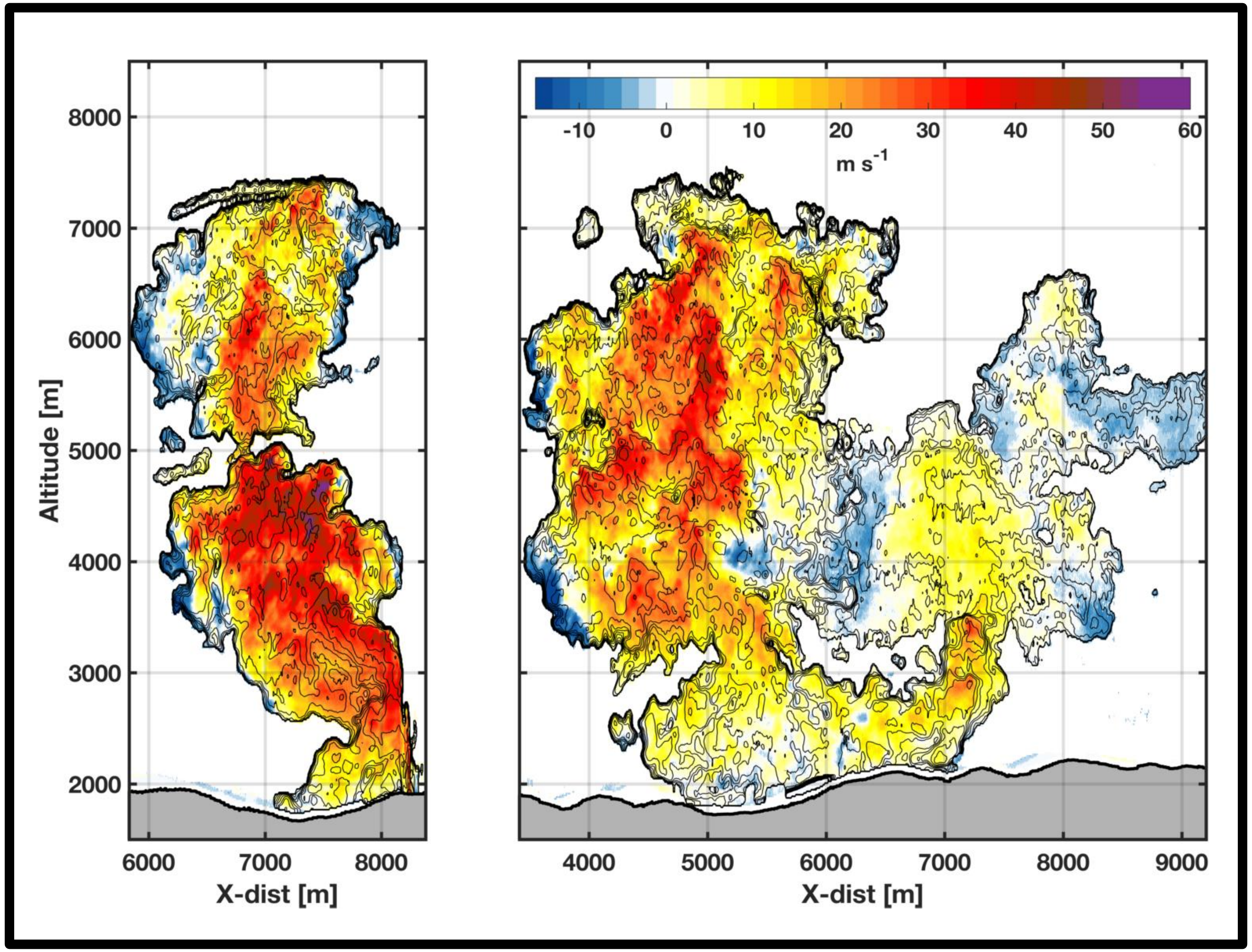
Creek Fire, California 9/5/2020

PyroCb Development and FGTVs



Lareau et al. 2021 (BAMS)

How strong are pyroCb updrafts? (Extreme, *From Pioneer Fire*)



Radar Velocity:

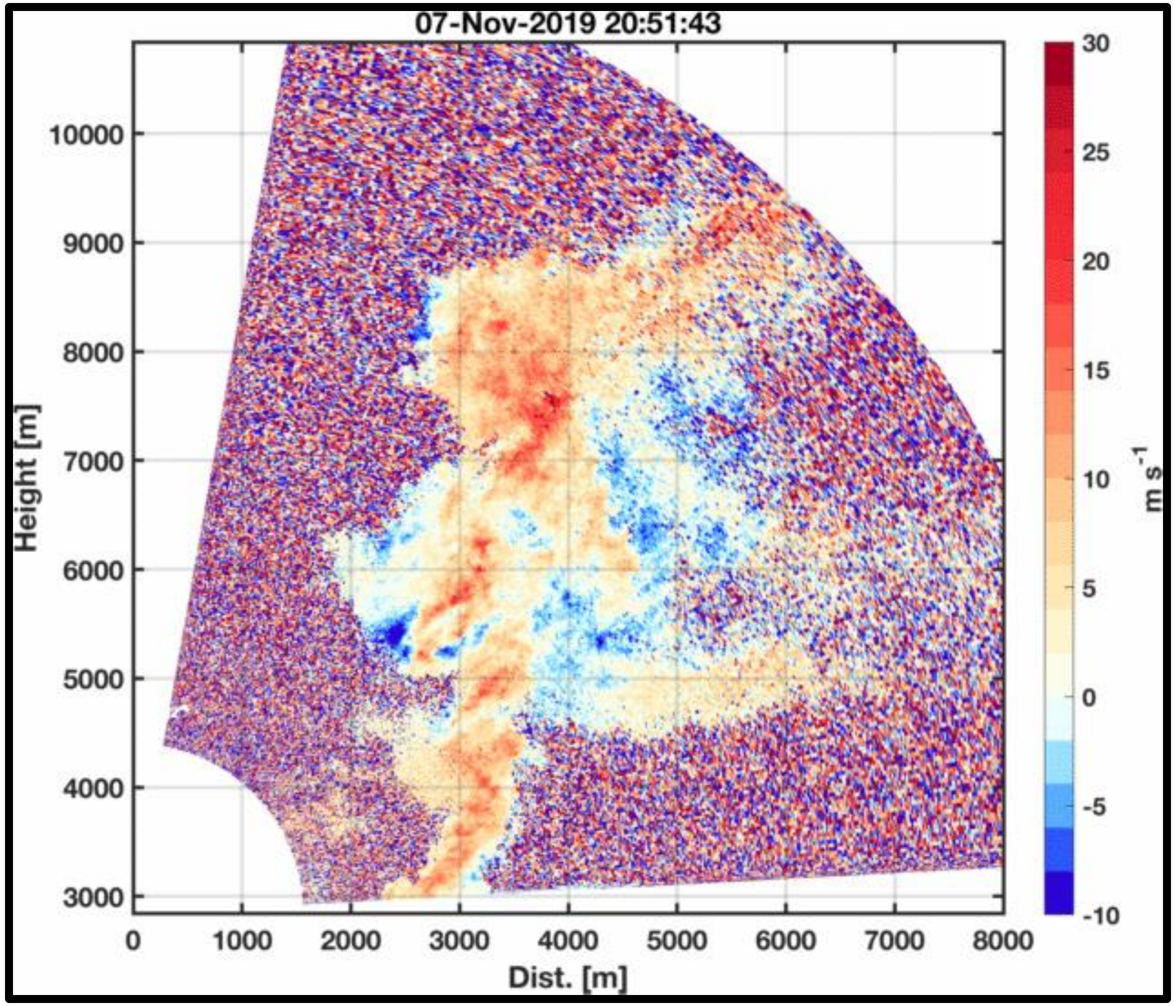
Max updraft: 58.1 m s^{-1} (130 mph)

Max downdraft: ~-30 m s^{-1}

W-band Doppler Velocity (unfolded), Wyoming Cloud Radar

Rodriguez et al. (2020 GRL)

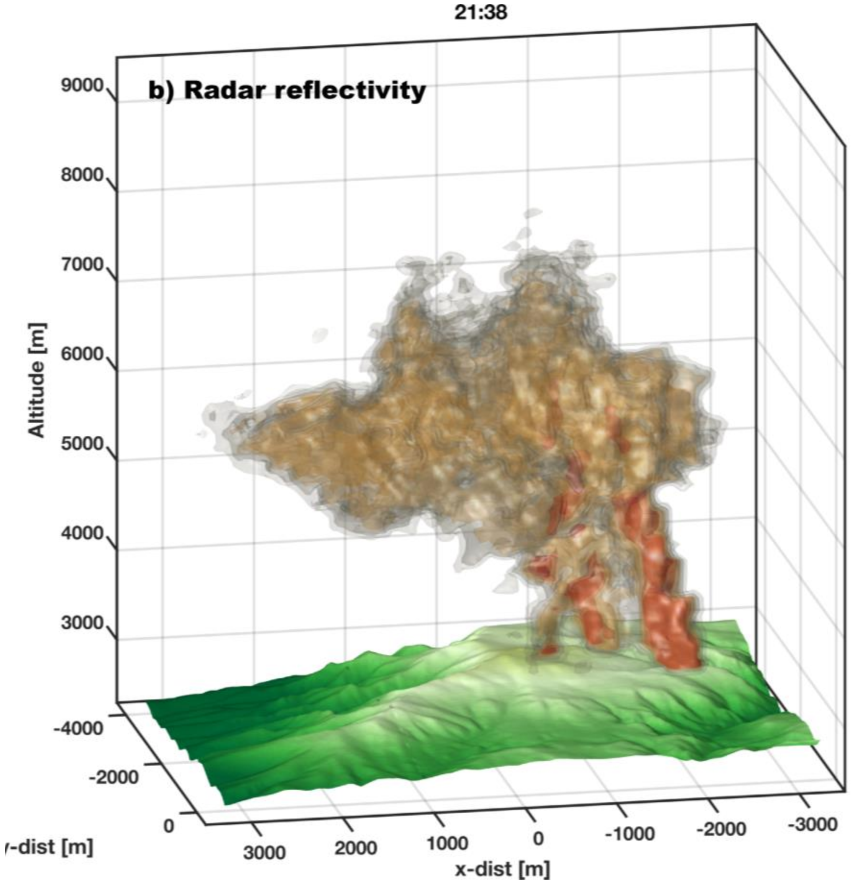
Chains of thermals

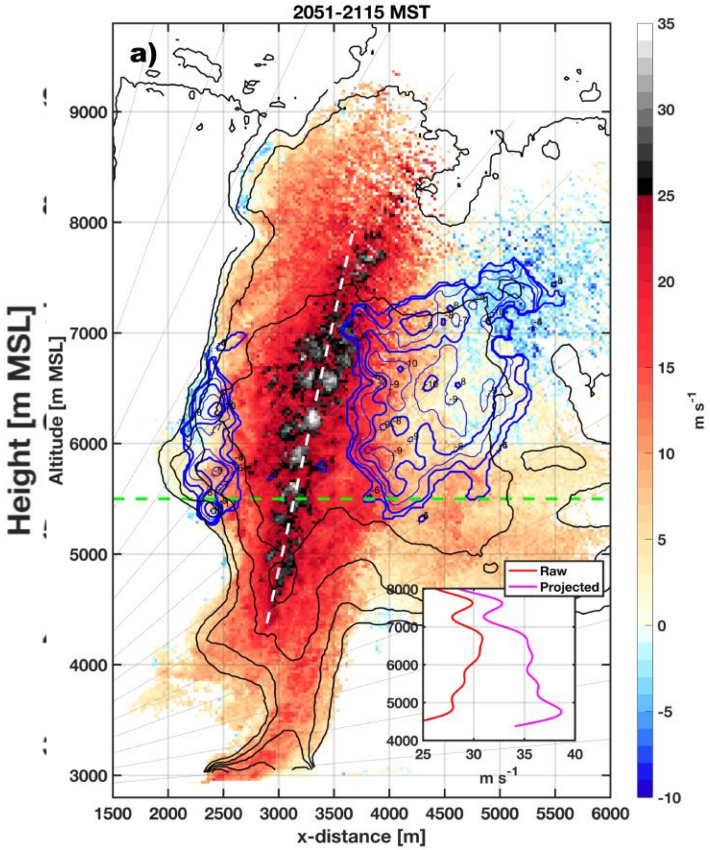


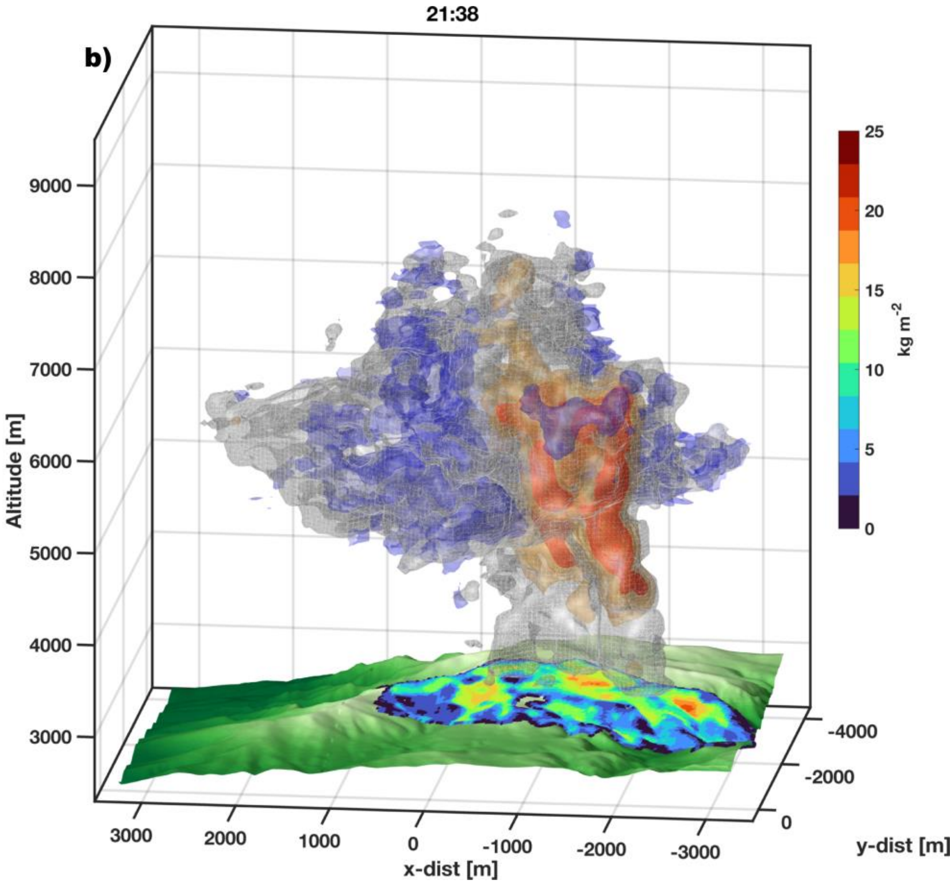
Parcels in the updraft continue to accelerate
Mechanically forced downdrafts and (maybe) ash fall out?

Photo Courtesy of Roger Ottmar

More Evidence for Extreme Updrafts



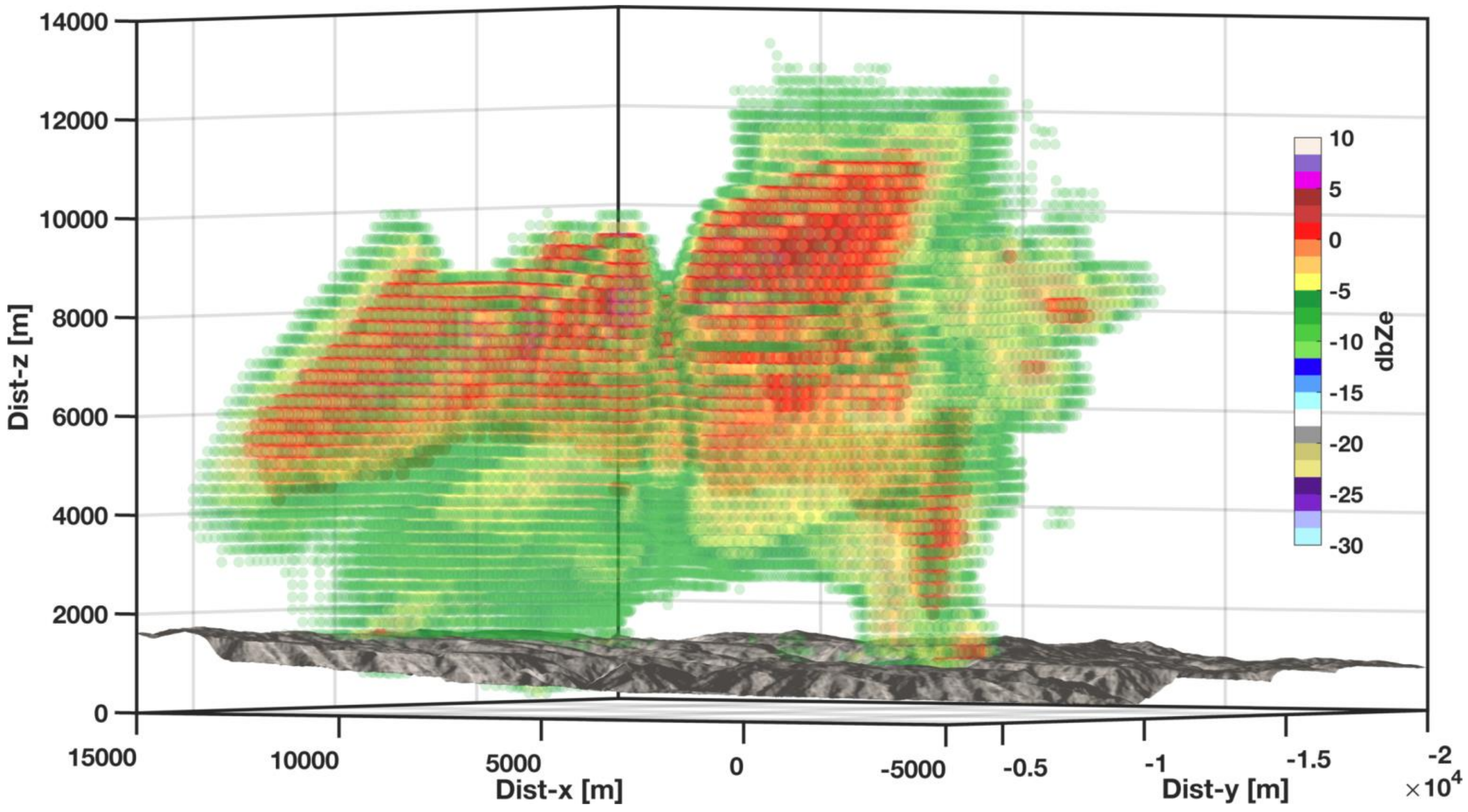




Lareau et al. 2024 (IJWF)

- High Reflectivity Updraft Cores
- Chain-of-thermals within the updraft (>35 m/s)
- Flanking downdrafts

PyroCb Microphysical Processes

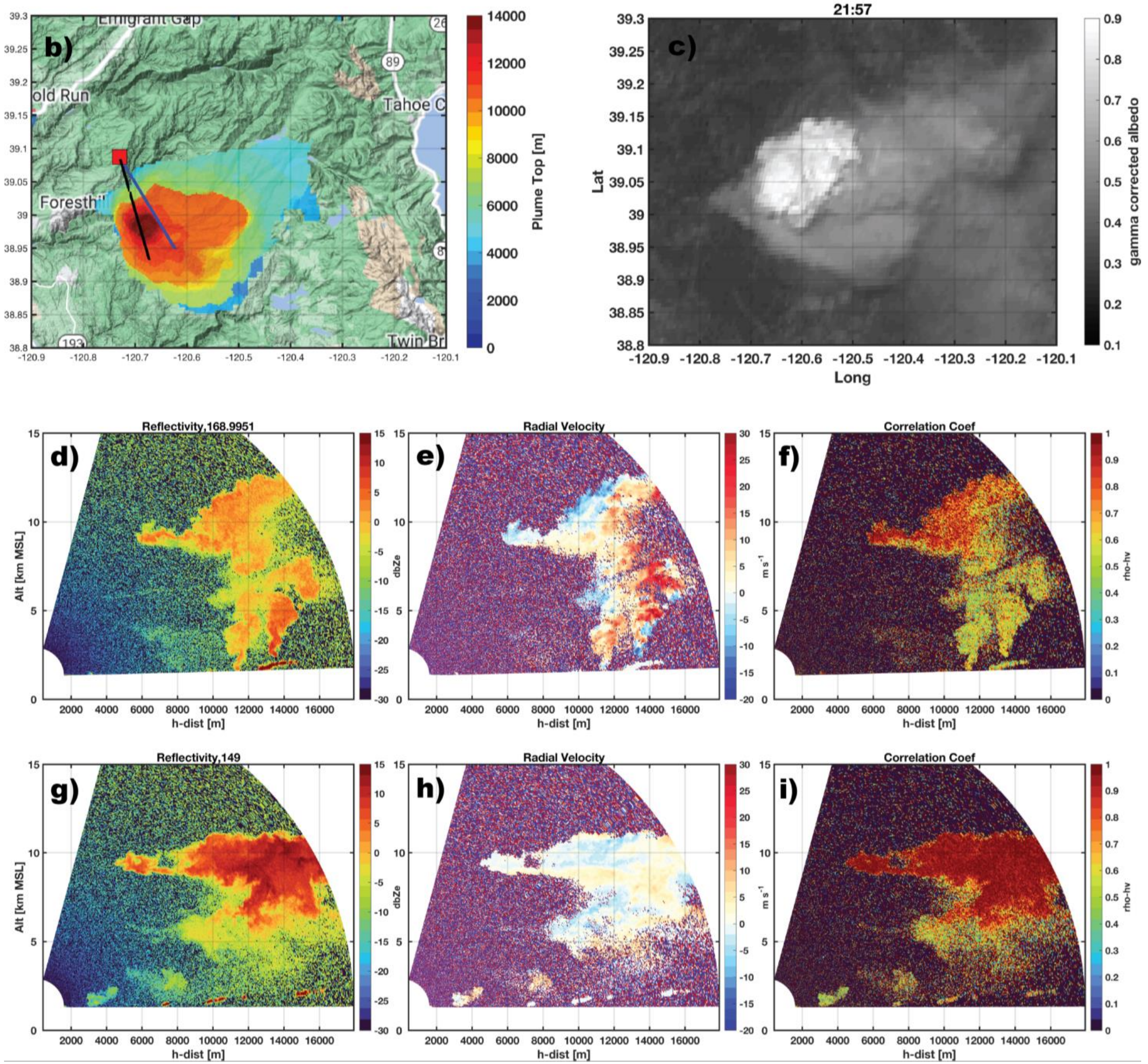


SJSU Ka-Band Radar Observations of Mosquito Fire's deep pyroCb on 9/8/2022

Data collected during the California Fire Dynamics Experiment (CALFIDE, NOAA)

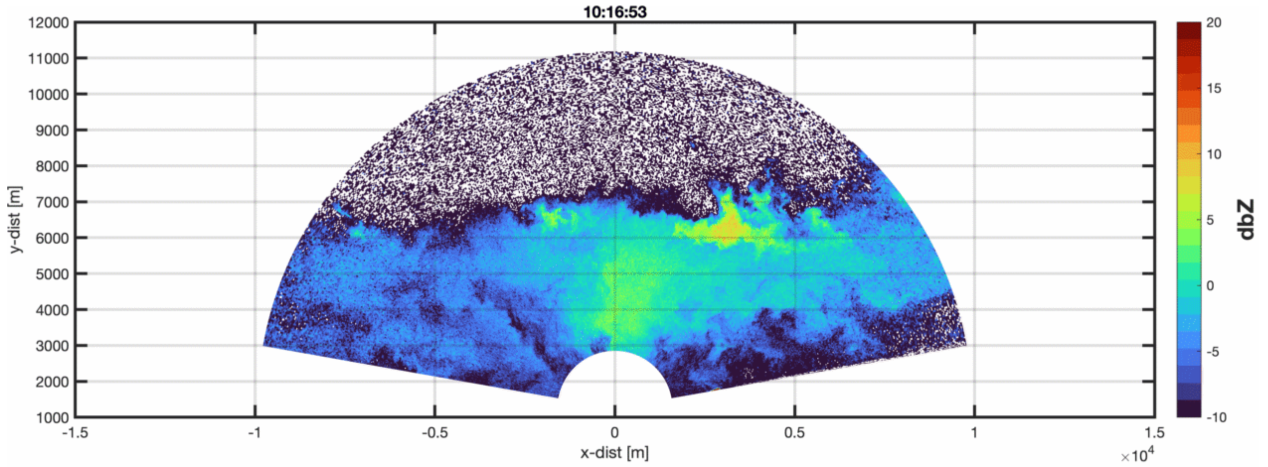
Carro;l et al. 2024 (BAMS)

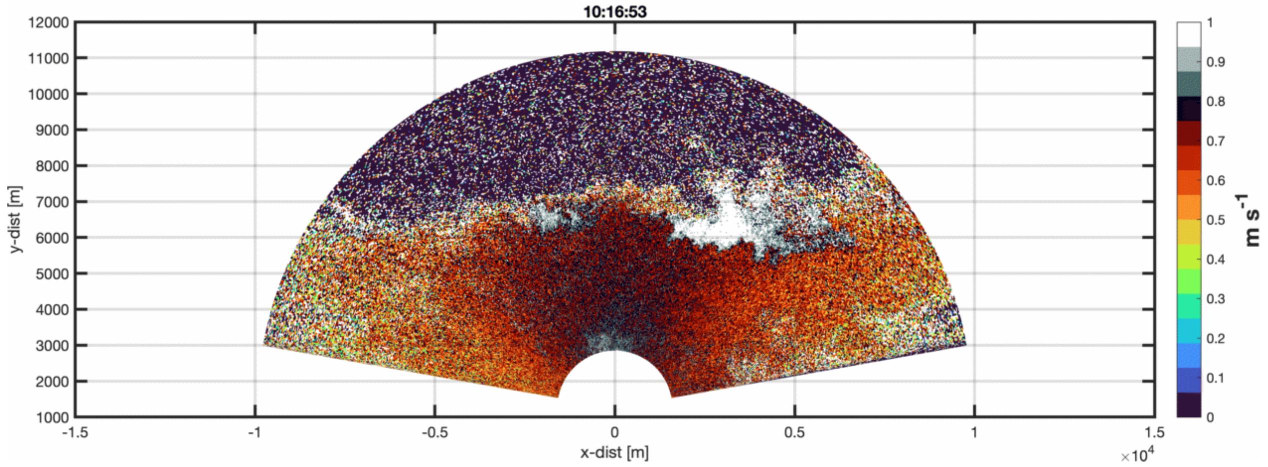
PyroCb Processes



Carro;l et al. 2024 (BAMS)

PyroCb Micro-Physical Processes

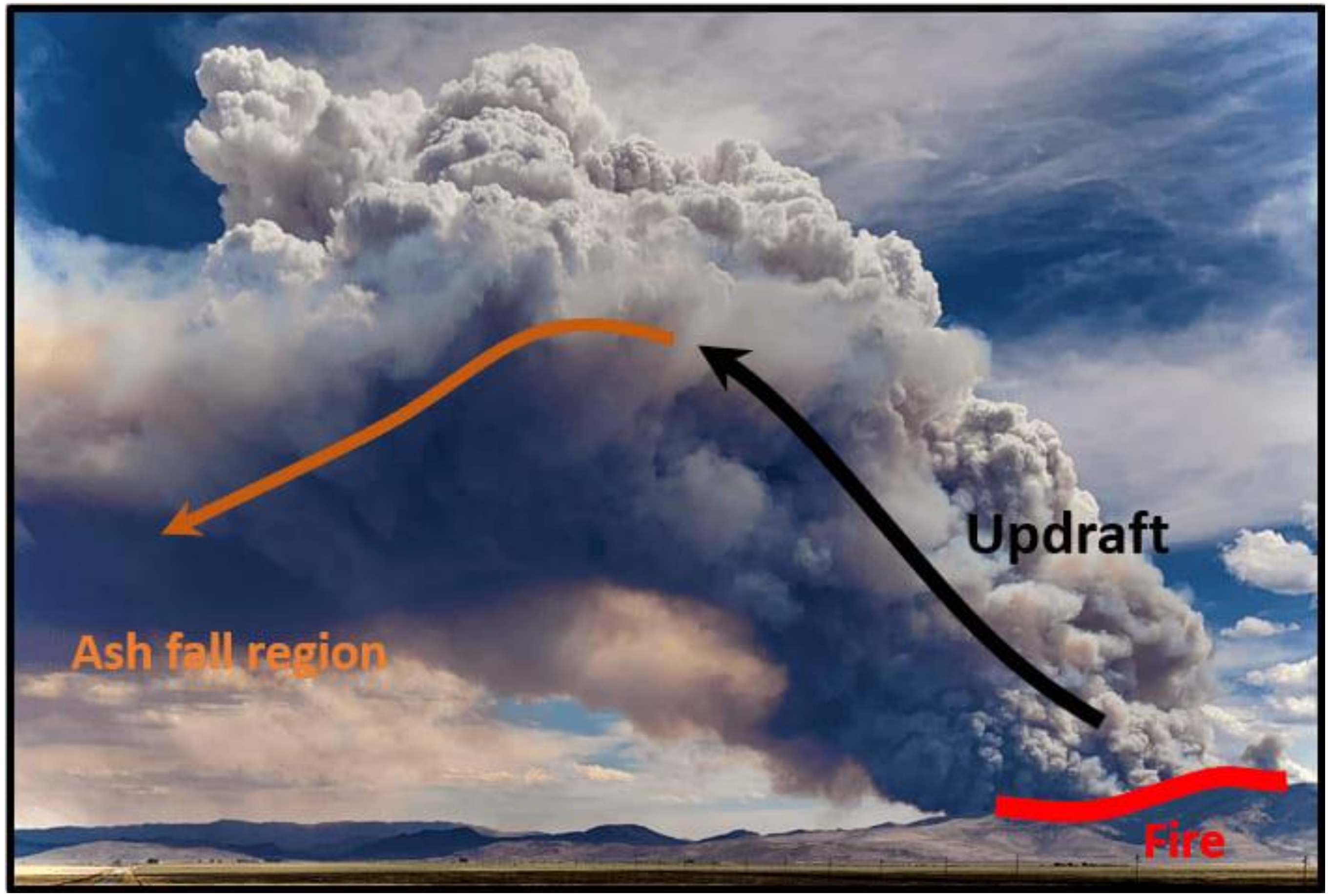




Dixie Fire 8/16/2021

- High reflectivity pyroCu/Cb features aloft
- High correlation coefficient indicates hydrometeor returns
- Some clouds evaporate (pyromammatus?)

Plume Structures Linked to Long-Range Spotting



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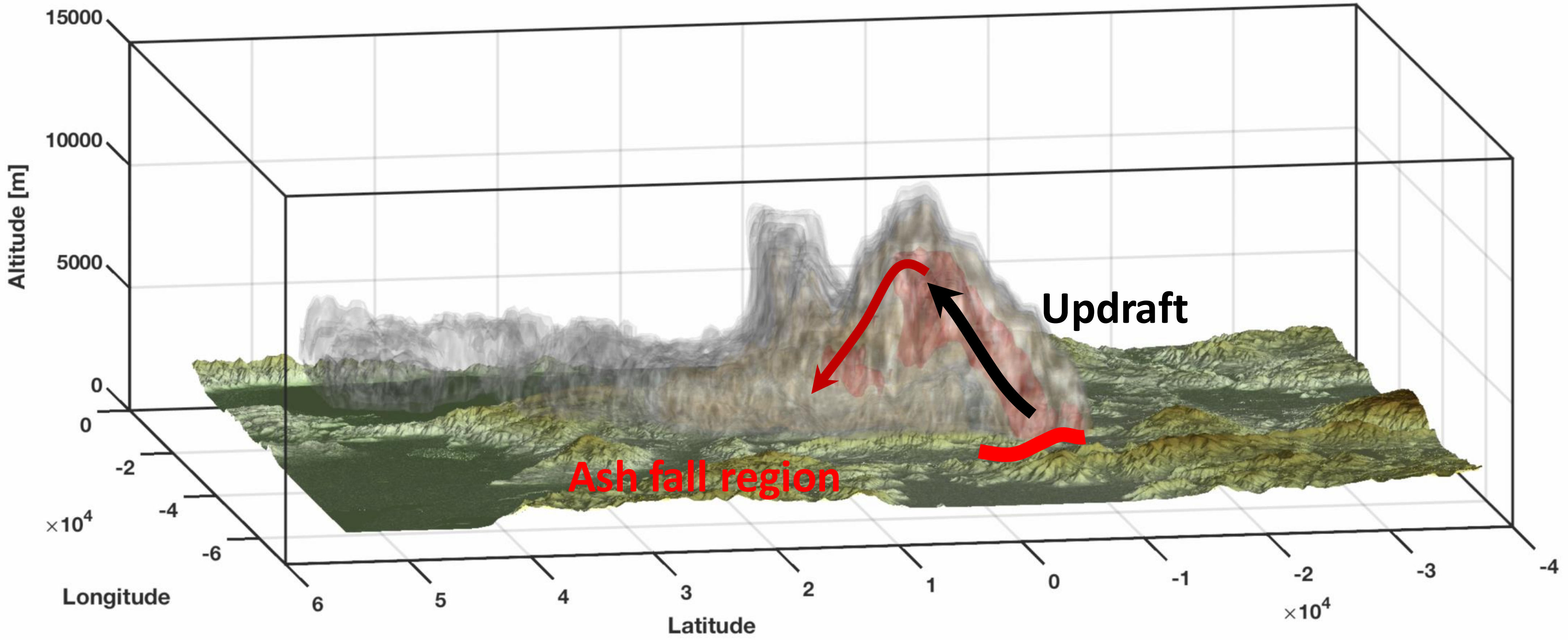
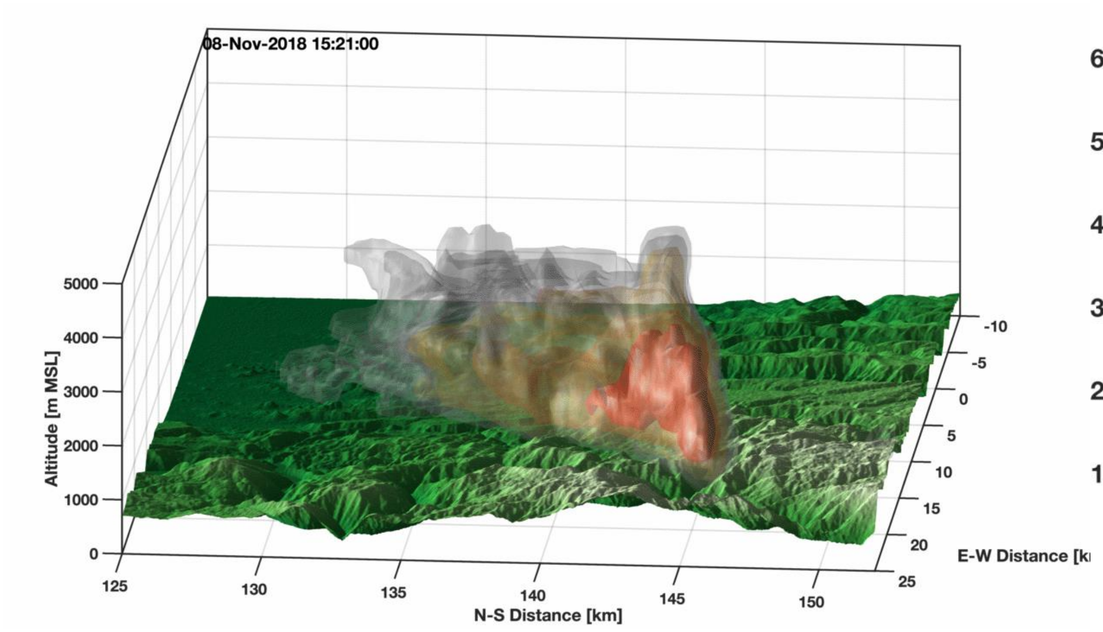
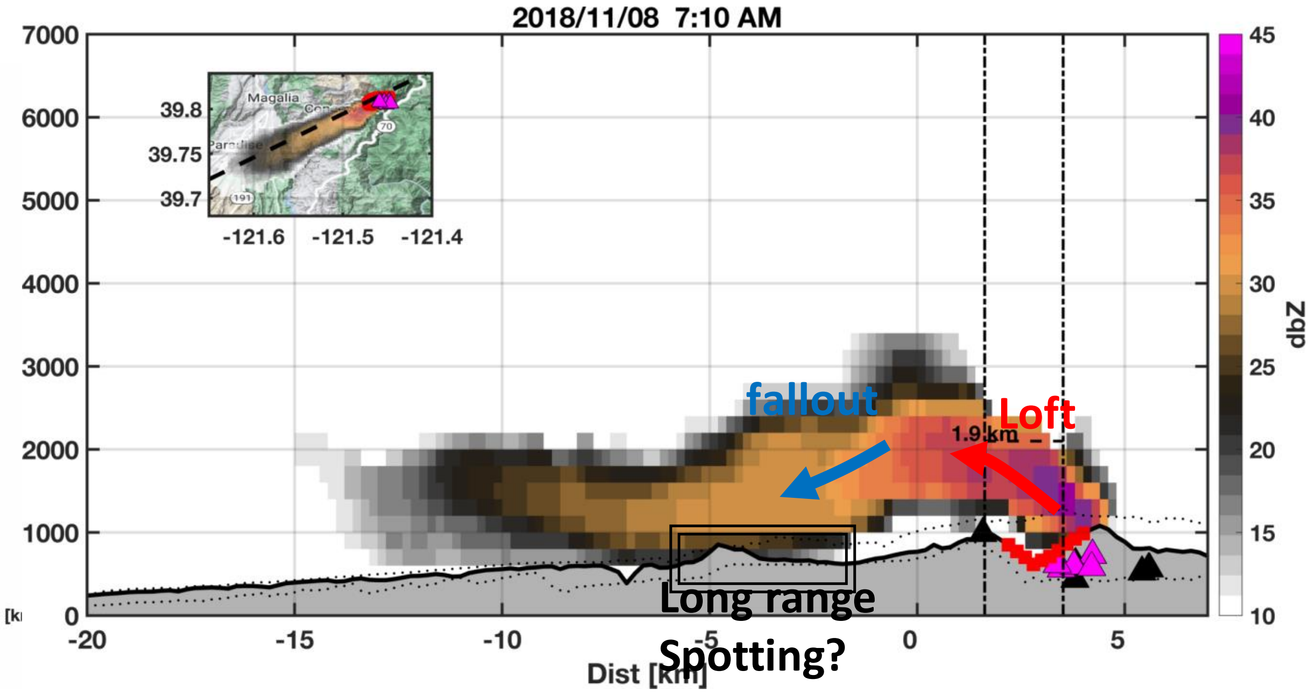


Ash/Debris Lofting and Fall Out

Radar Volume of Camp Fire



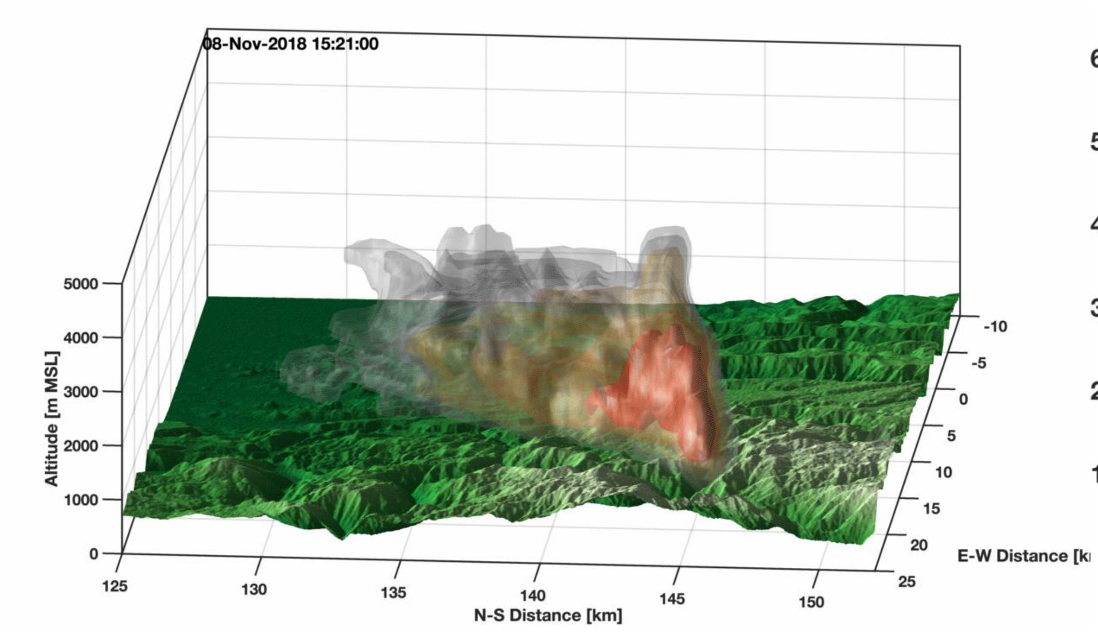
Camp Fire Plume Cross Section



Spot Fire Data from Maranghides et al. 2021

Ash/Debris Lofting and Fall Out

Radar Volume of Camp Fire



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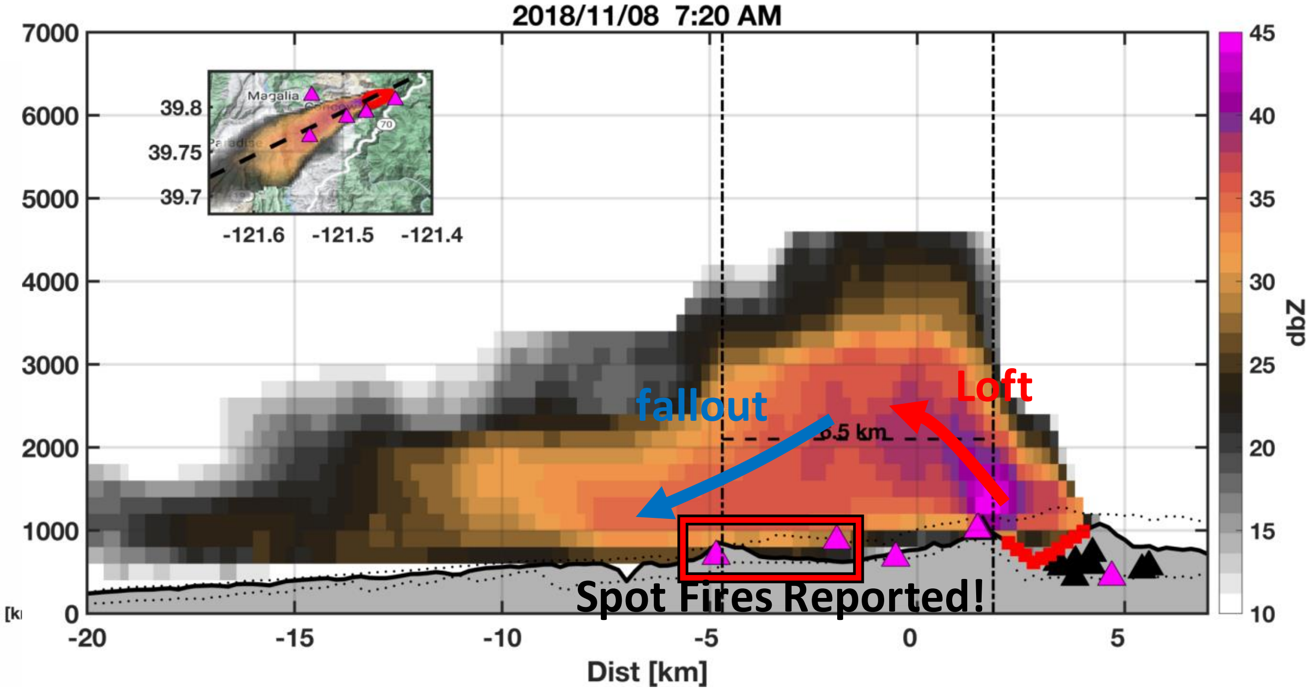

Spot Fire Data from Maranghides et al. 2021

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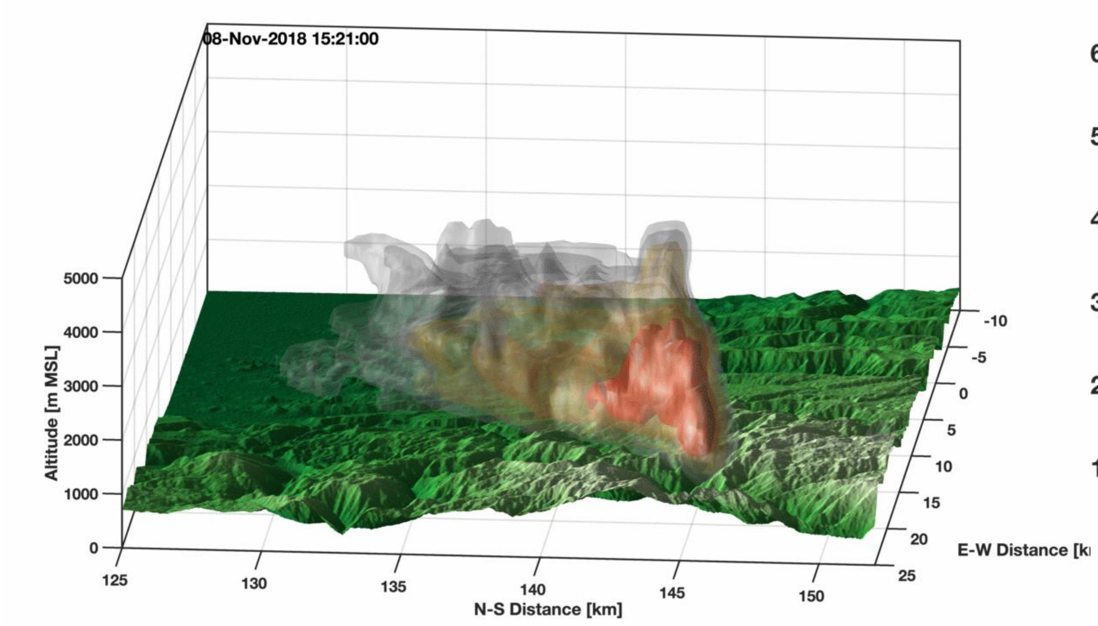

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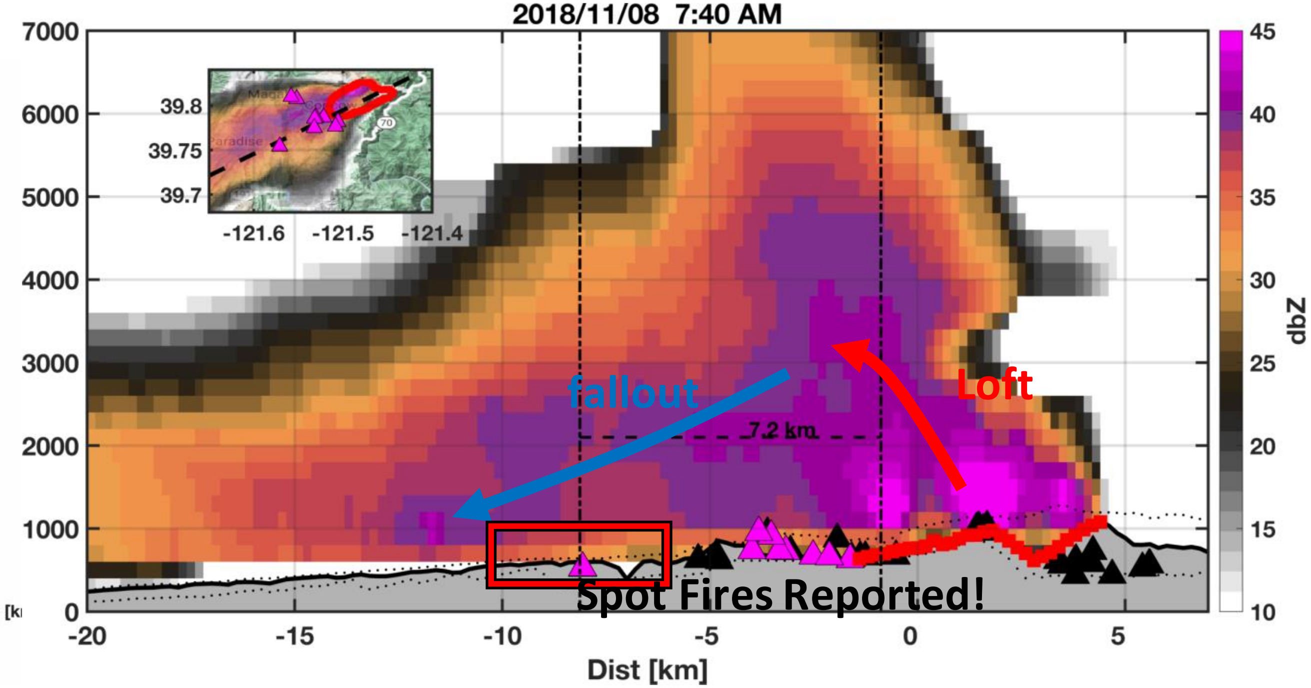
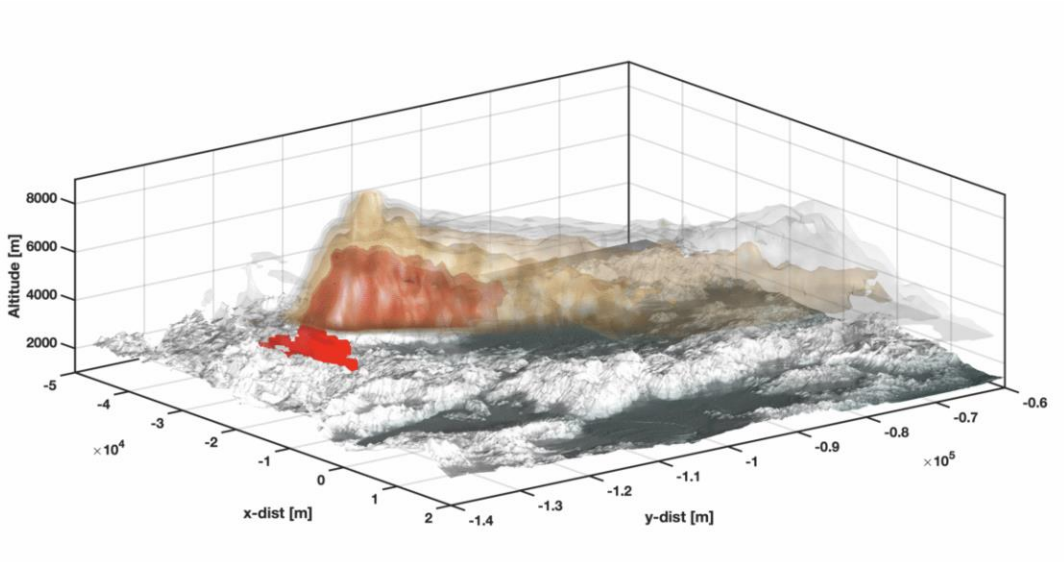
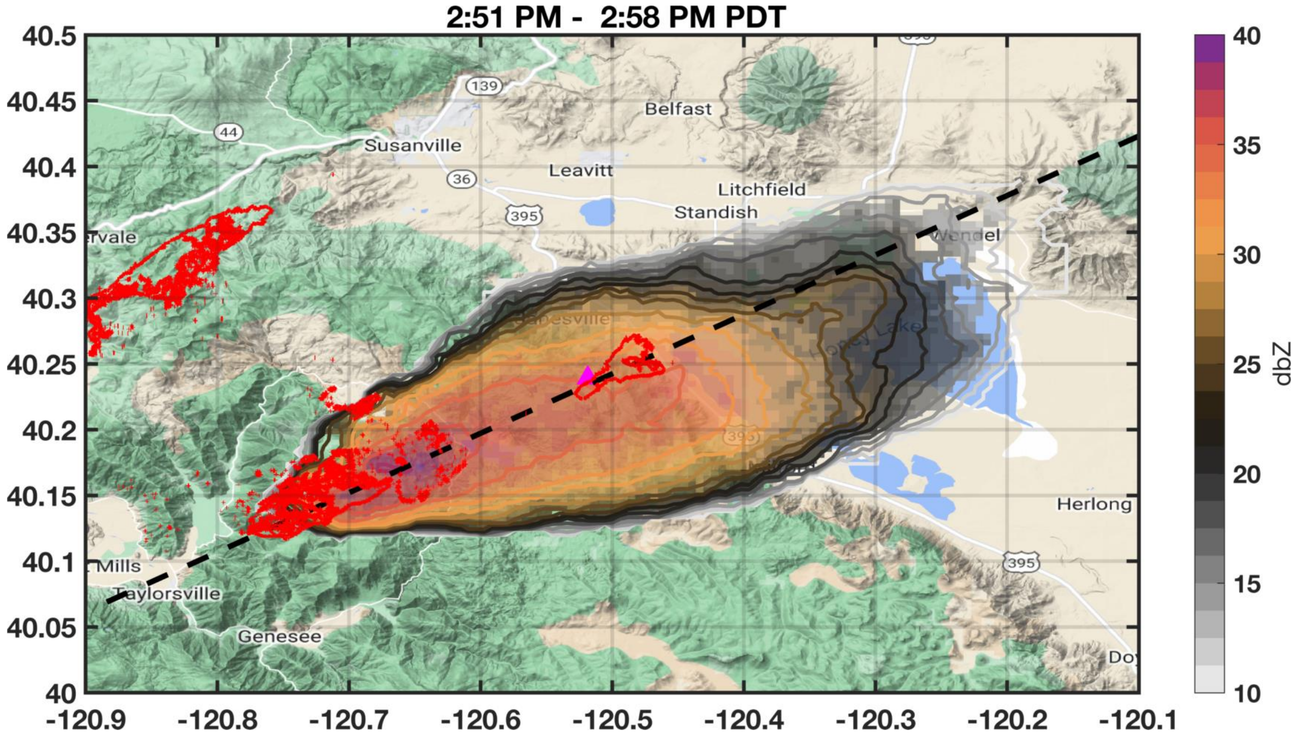


Spot Fire Data from Maranghides et al. 2021

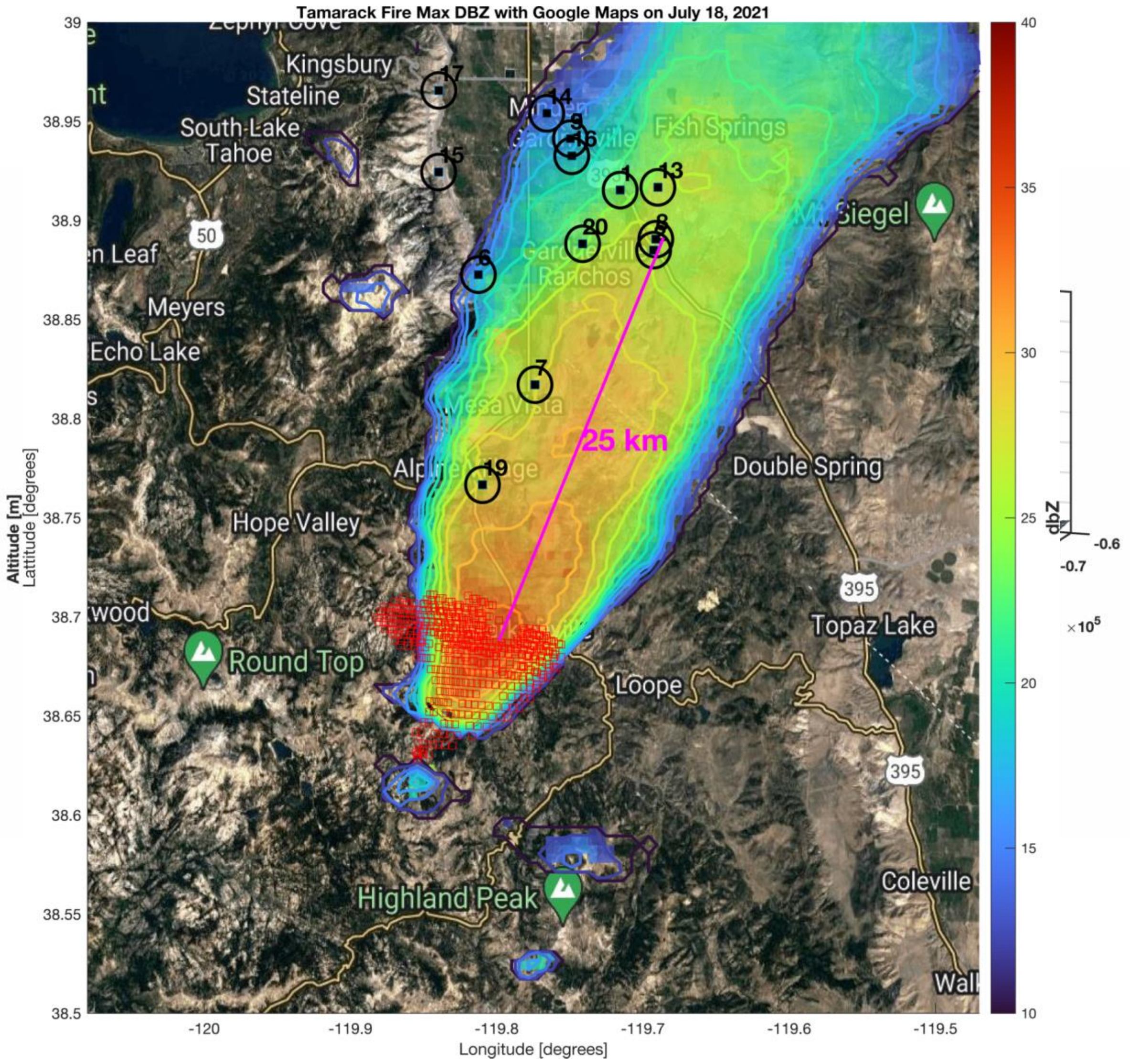
This plume structure is common:



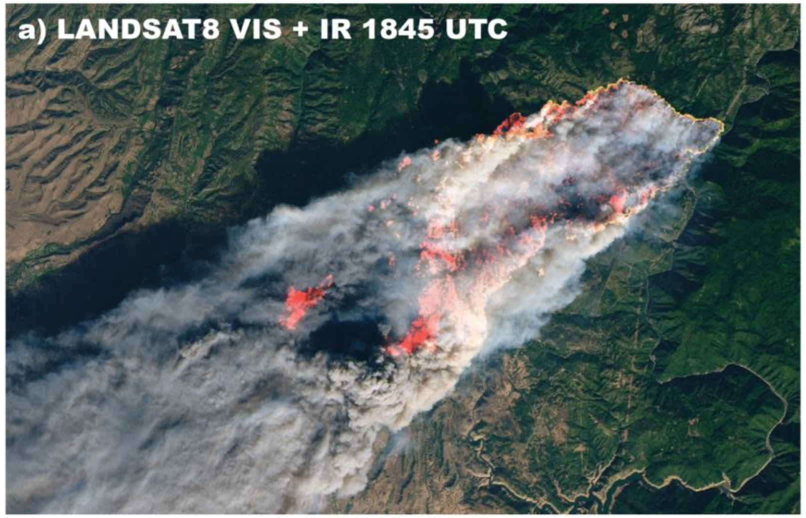
Tamarack Fire near Markleeville, CA

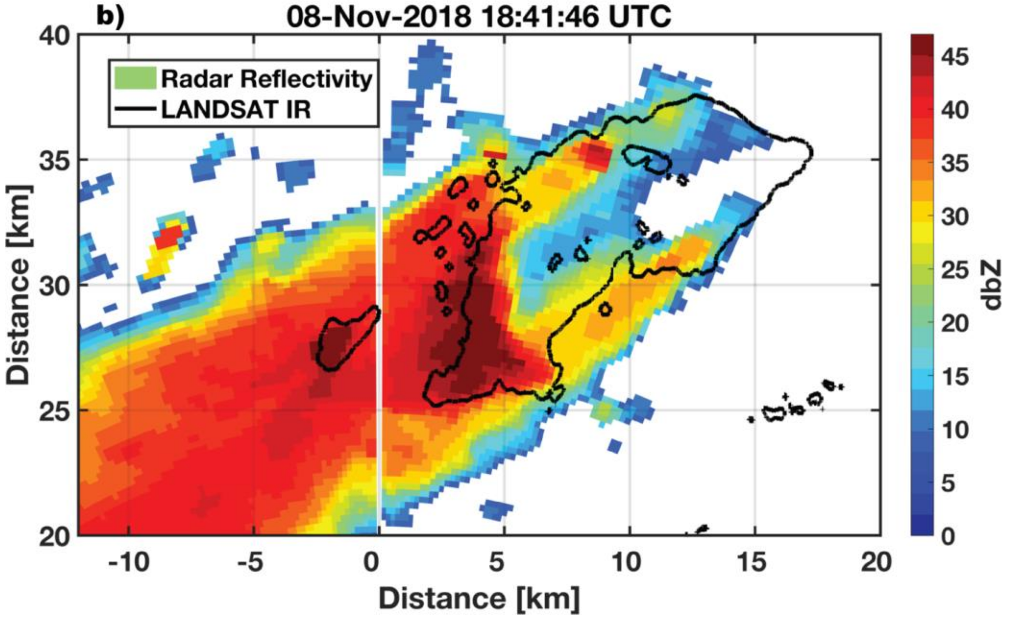


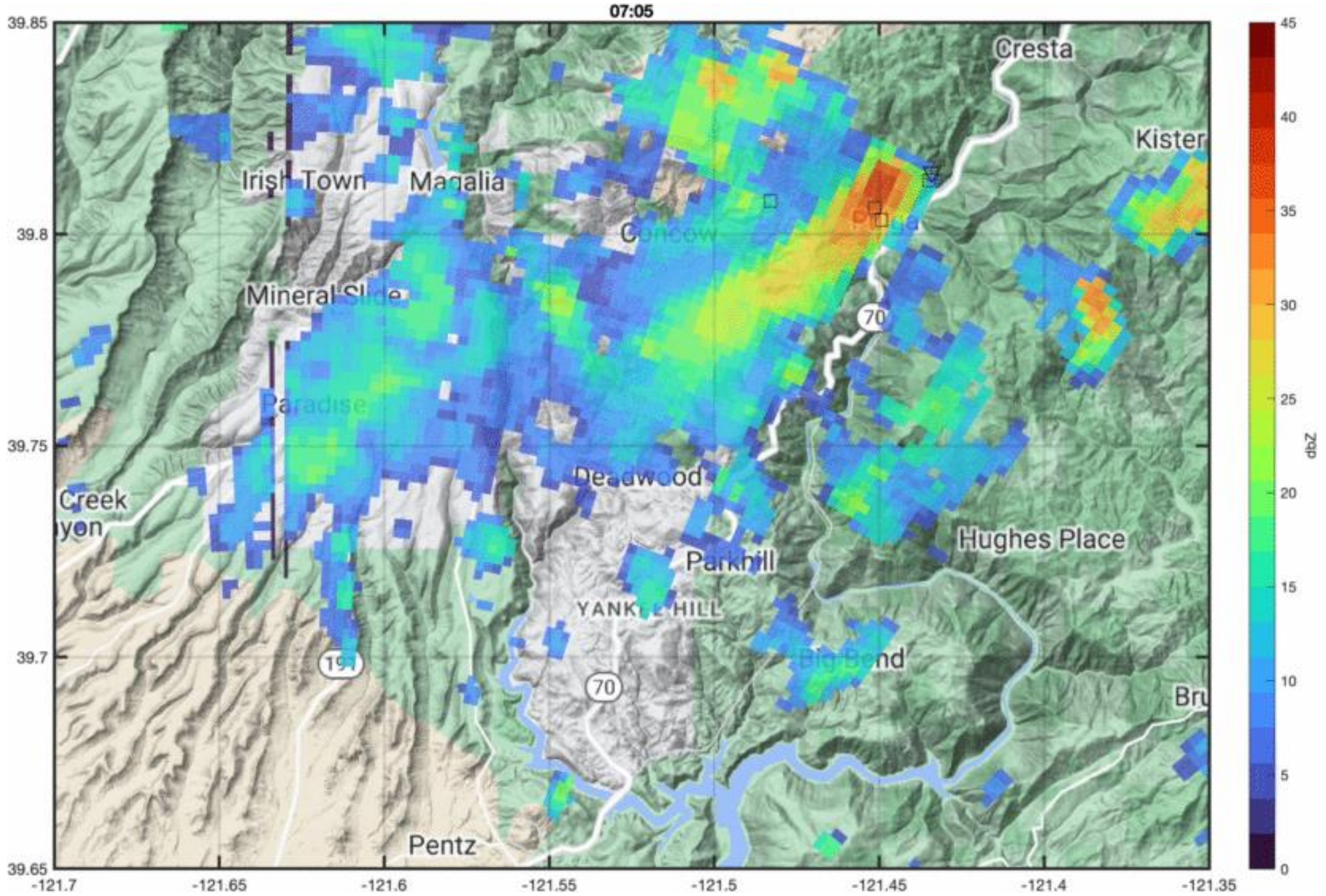
What is Falling out of the Plume?



Using Radar To Understand Fire Progression







Based on Lareau et al. 2022 JGRA

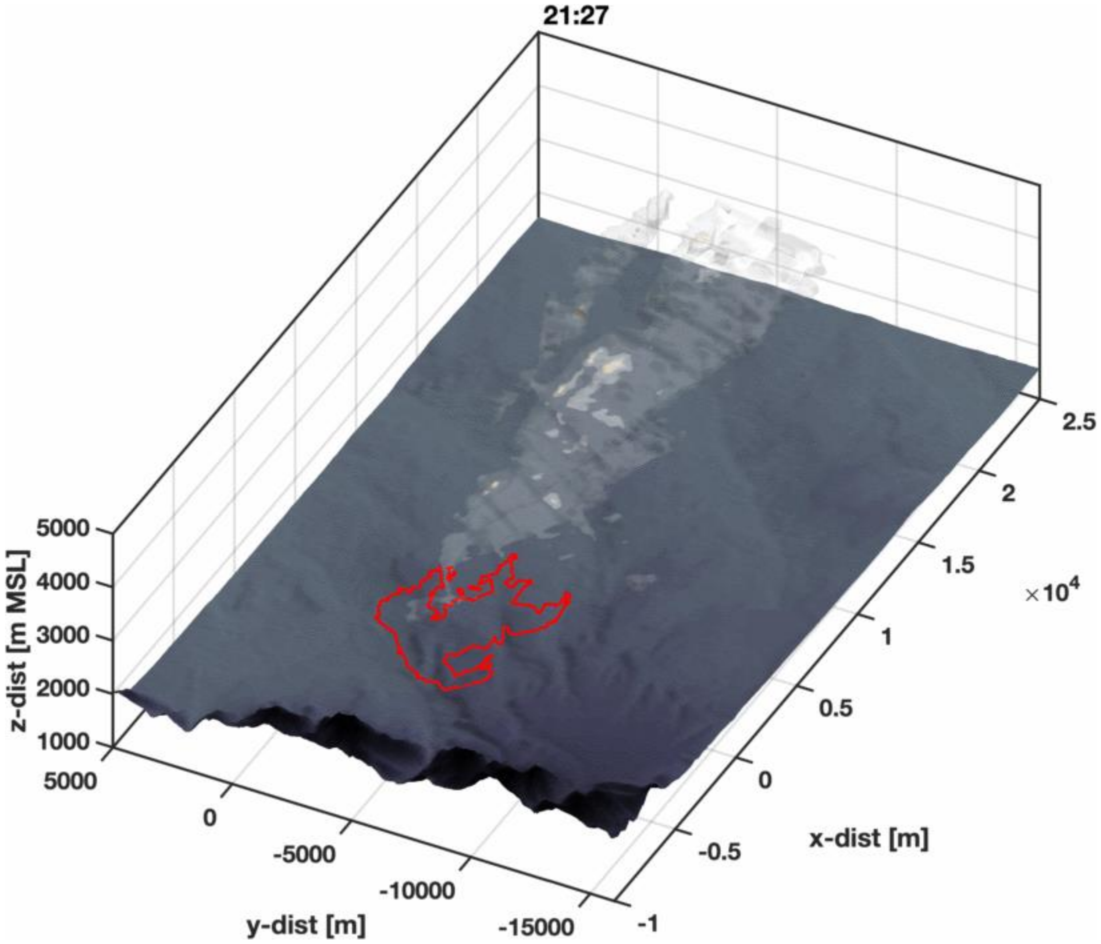
Spot fire data from NIST

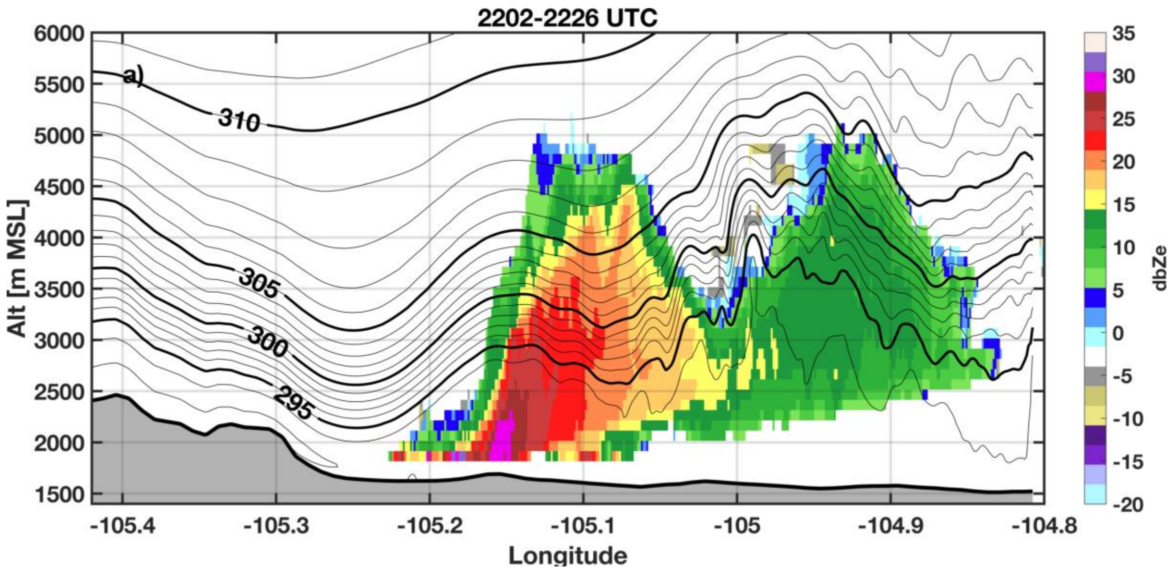
Conclusions

- Weather radars observe wildfire plume dynamics
- Vortex structure and evolution
- PyroCb updrafts/initiation
- Plume structures linked to long range spotting

What now?
We need a large field campaign that can:
(a) Quantify the coupled fire-atmosphere dynamics of landscape scale fires (not Rx)
(b) Contemporaneous fire and plume observations sufficient for model validation (again not Rx!)

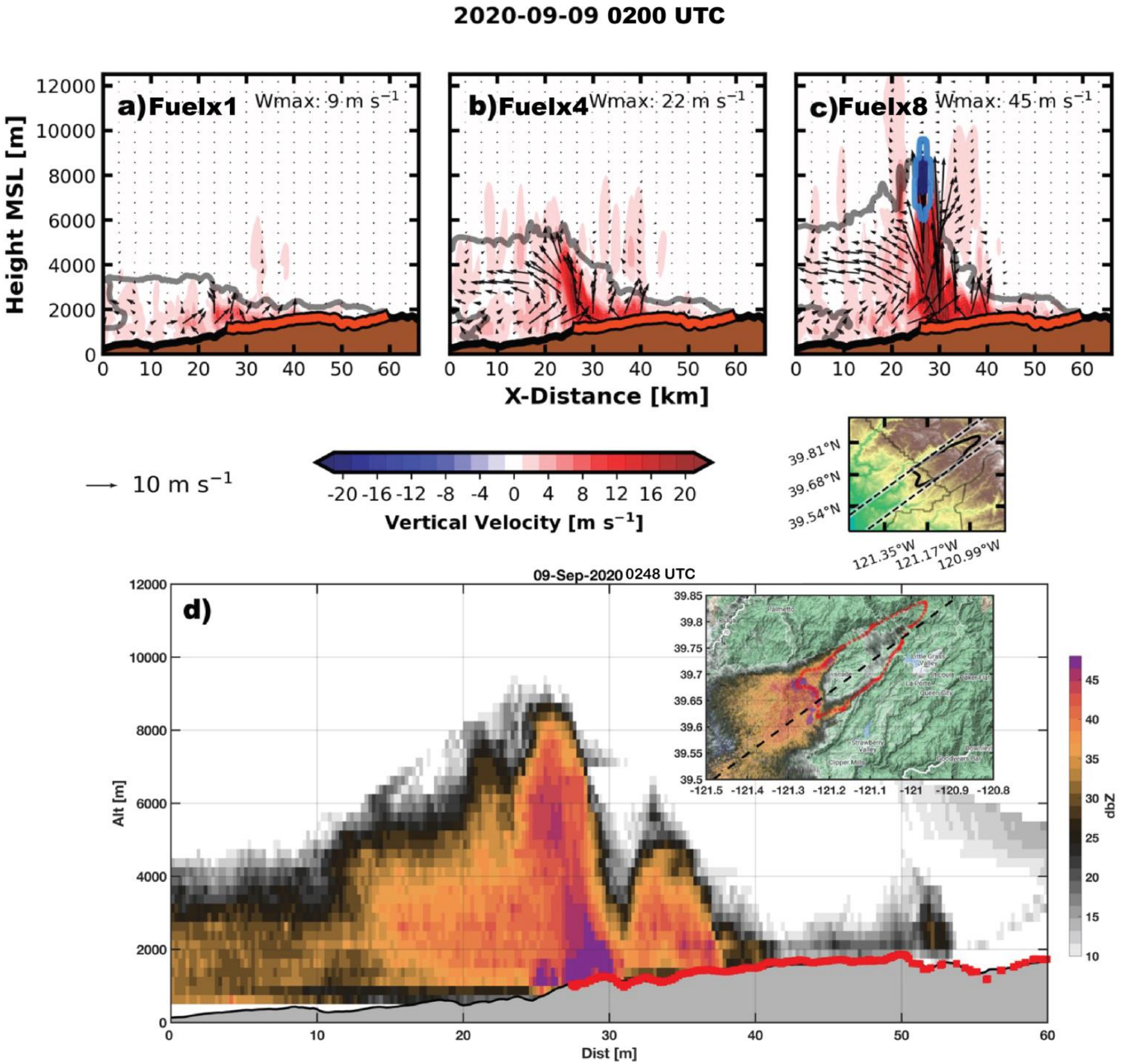
X-band Radar: Marshall Fire





- Multiple fire fingers
- Spotting processes
- Downslope winds and mountain wave structure
- Model validation (WRF-FIRE)

Juliano et al. 2023 GRL

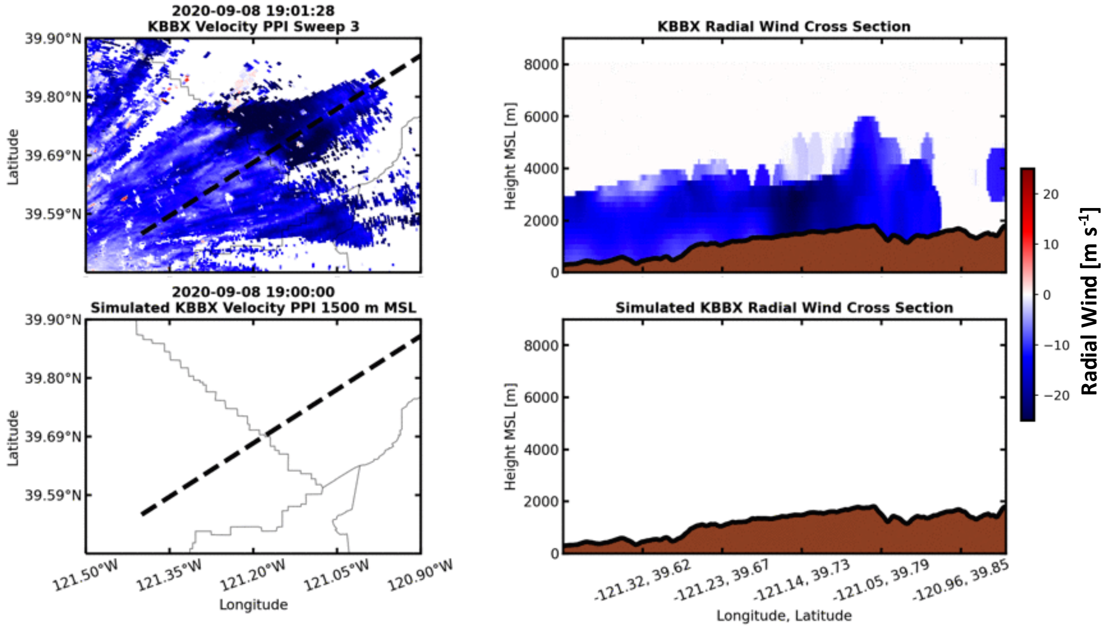


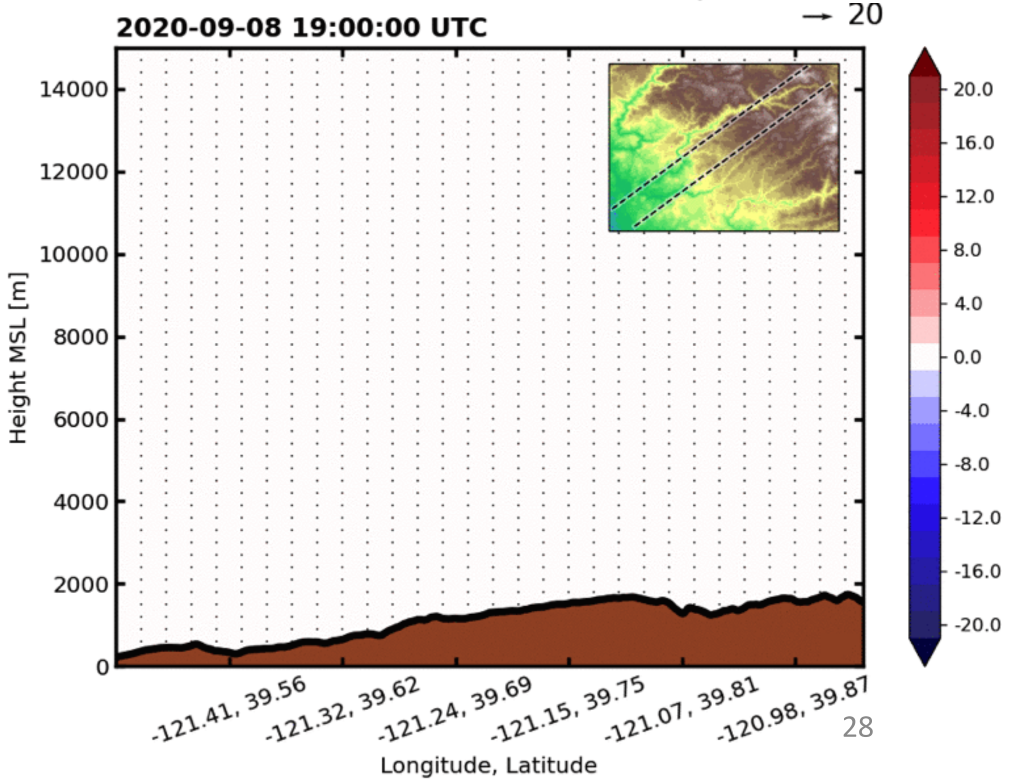
2020-09-09 0200 UTC
a)Fuelx1 Wmax: 9 m s^{-1}
b)Fuelx4 Wmax: 22 m s^{-1}
c)Fuelx8 Wmax: 45 m s^{-1}
Height MSL [m]
X-Distance [km]
10 m s^{-1}
Vertical Velocity [m s^{-1}]
39.81°N
39.68°N
39.54°N
121.35°W
121.17°W
120.99°W
09-Sep-2020 0248 UTC
d)
Alt [m]
Dist [m]
dbZ

Summary

Increasing fuel loads results in better atmospheric coupling in WRF-Fire for landscape-scale wildfires

- Realistic fuels (~20 kg m^{-2}, fuel x8) produces more realistic plumes
  - Deep plume with fire-generated circulations
  - Leeside flow reversal





Future Work

- Changes needed in physical representation of fire processes
  - Post fire-front smoldering and mass fire
  - Long range spotting
- Changes in WRF-Fire fuel representation
  - Including canopy fuels
  - Machine learning for better fuel representation

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