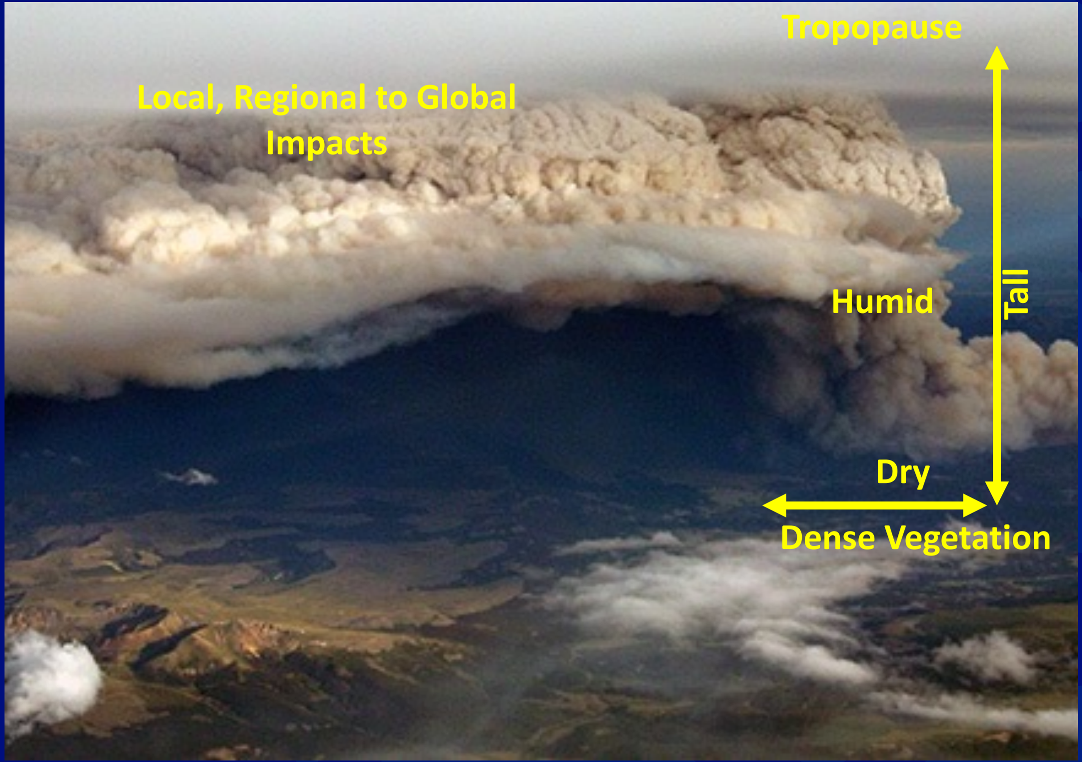
Large SOA Formation by Vapor Condensation in PyroCb outflow in LES Simulations and *in situ* Airborne Data

Manvendra Dubey, Kyle Gorkowski, Jon Reisner, Katherine Benedict, Alex Josephson and Eunmo Koo.



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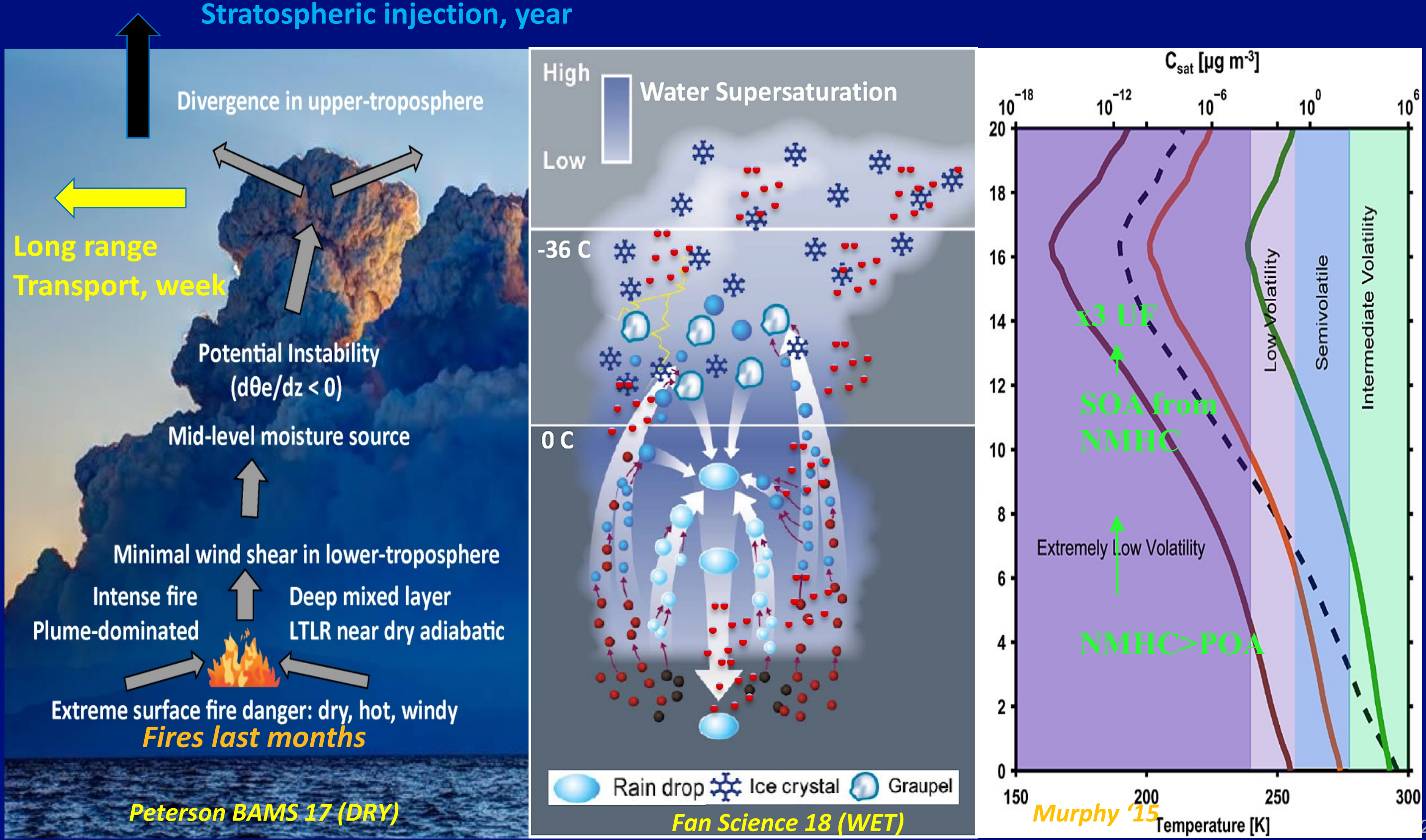
LA-UR-21-25802 dubey@lanl.gov

Conceptual PyroCumulomimbus (PyroCb) LES Models

- Intense fire & aerosols
- Dry Thunderstorm
- Inverted V sounding
- Dry-unstable low atm.
- Moist middle atm.
- Fast updrafts
- Ultrafine aerosols
- Delay precipitation
- Intensify convection
- Ice formation, lightning
- Aerosol Scavenging
- Aerosol Production
- Long-range pollution
- Stratospheric source
- More IN – cirrus clouds

PyroCb: Dynamics | Aerosol Microphysics | Chemistry



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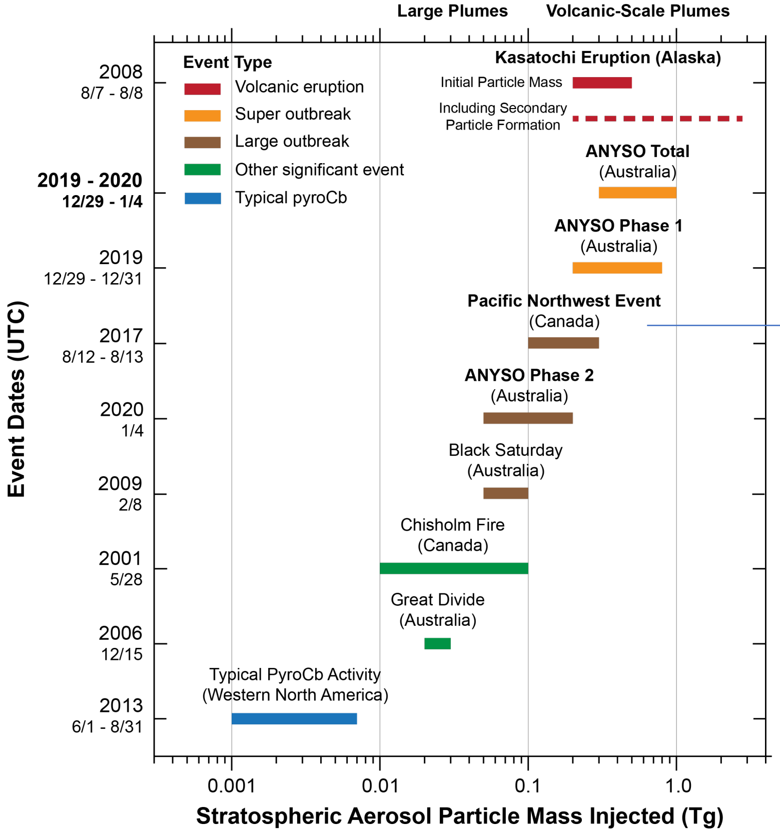
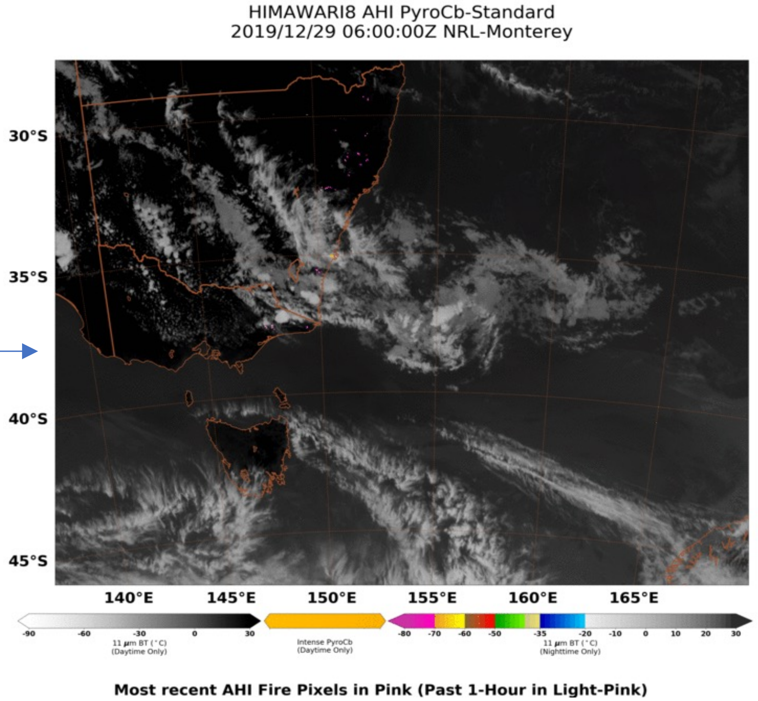
PyroCb Stratospheric Smoke Observation Provide New Constraints





British Columbia fires created 4-5 PyroCbs on August 12, 2017 (BC17) that injected about 0.2 Tg smoke into the lower stratosphere in 5 hours

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Peterson AGU '20

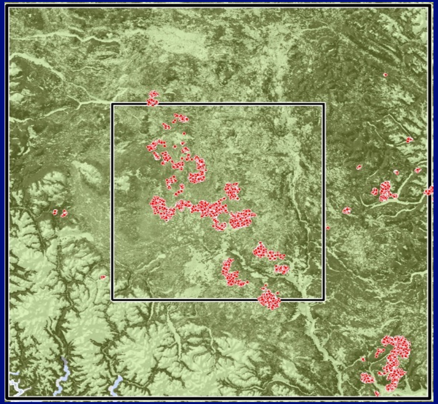
Simulate BC17 Observations: Challenges and Closure

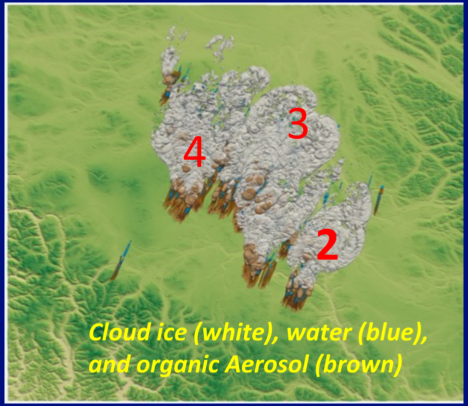
- 2017 PyroCb data show stratospheric penetration and large mass injection (0.2 Tg) over British Columbia (BC17) in hours. The dynamical, micro-physical and chemical mechanisms of the BC17 injection are unclear.
  - How was PyroCb smoke lofted into stratosphere so fast (direct versus self-lofting)?
  - Why was smoke mass higher than expected from fuel loads?

•Slash Pile **•PyroCb** **•Smoke-cloud (water/ice)** **•SOA-VOC**

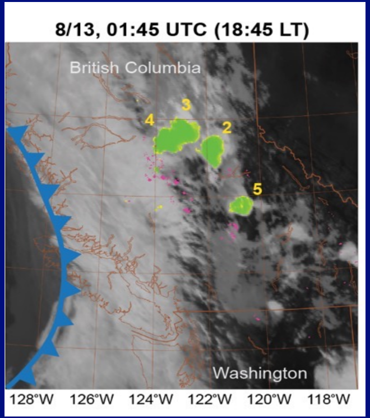
Hot spot data for 400 km x 400 km domain (outer box); Ones in 200 km x 200 km were used in simulations; heat, aerosol, and gases are emitted in hot spots (red patches). HIGRAD-LES PyroCb simulation at 100m with heat flux and aerosol and VOC emissions

Slash pile and forest mix due to logging and beetle kill were missed

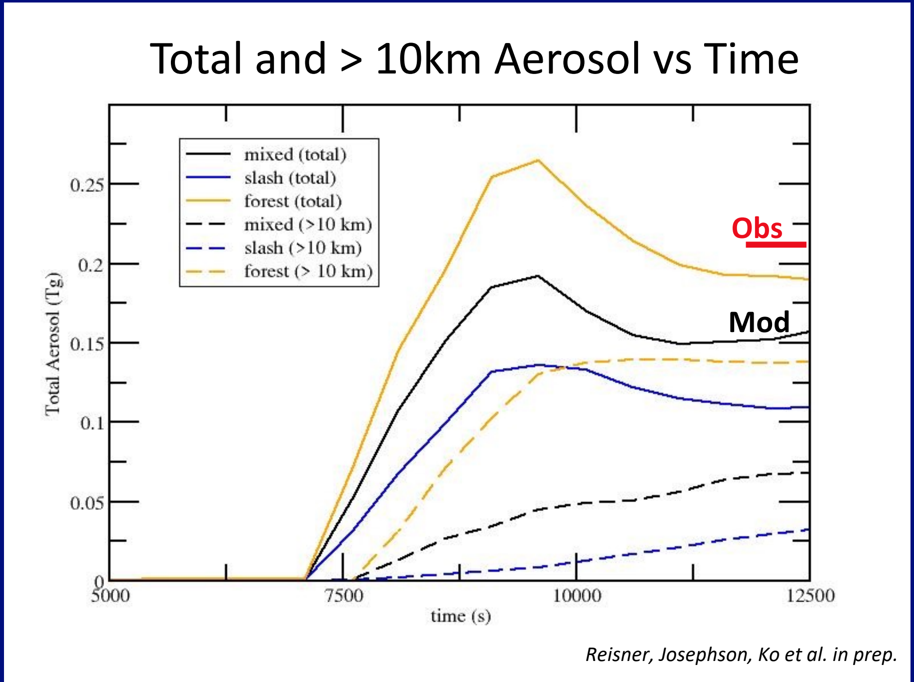




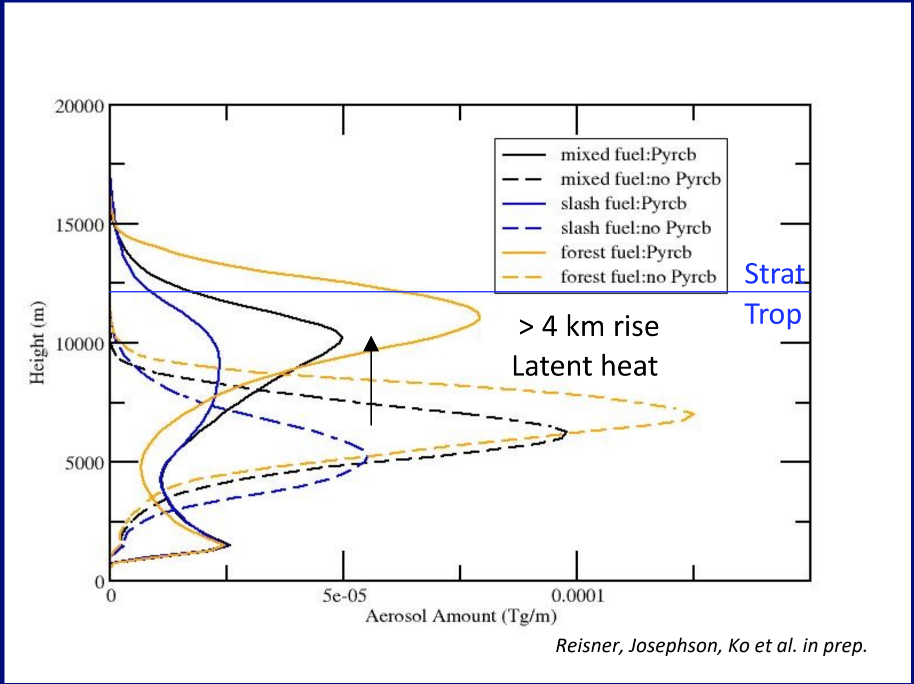
Cloud ice (white), water (blue), and organic Aerosol (brown)



Mixed Fuel Load with Aerosol-Cloud Inetactions Enhances Smoke Lofting into the UT/LS: But Simulations < Observations



Total (solid) and UT aerosols (dash) vs. time. Mixed simulation best represent observed fuel load predict about half of the observed UT/LS aerosols (0.2 Tg)



Vertical OA + soot profiles (3.5 hours) with solid) & without (dash) aerosol-cloud interactions. Forests burns hotter than mixed/slash piles an latent heat lifts the aerosols by > 4 km

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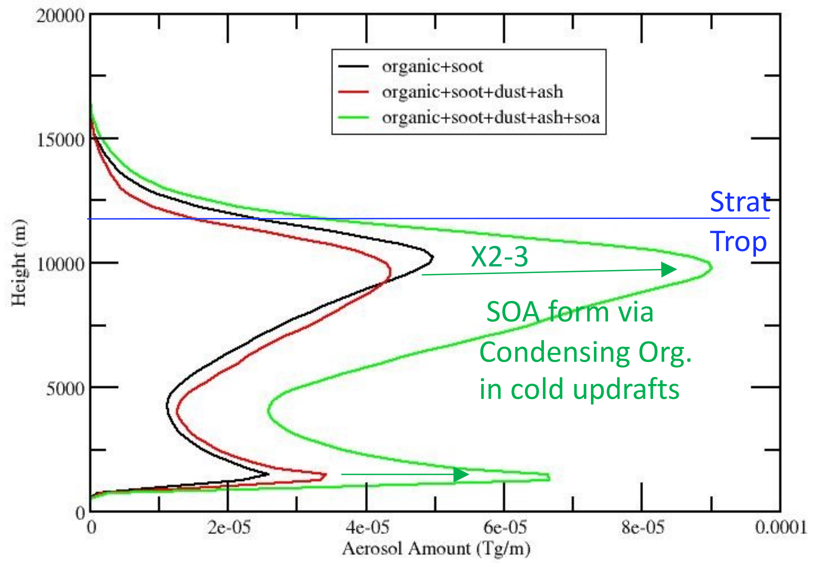
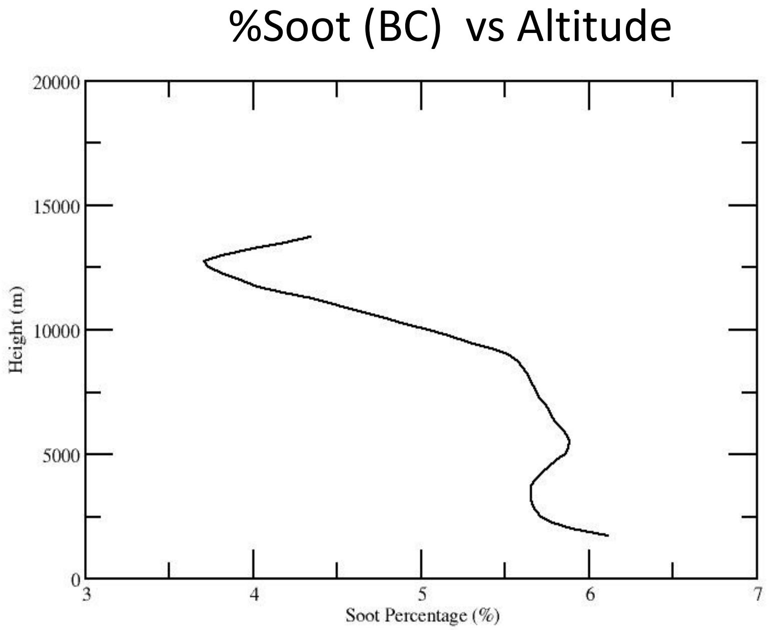
SOA from primary organic vapor condensation increase UT/LS aerosols by x2-3 and reduces %BC to match data

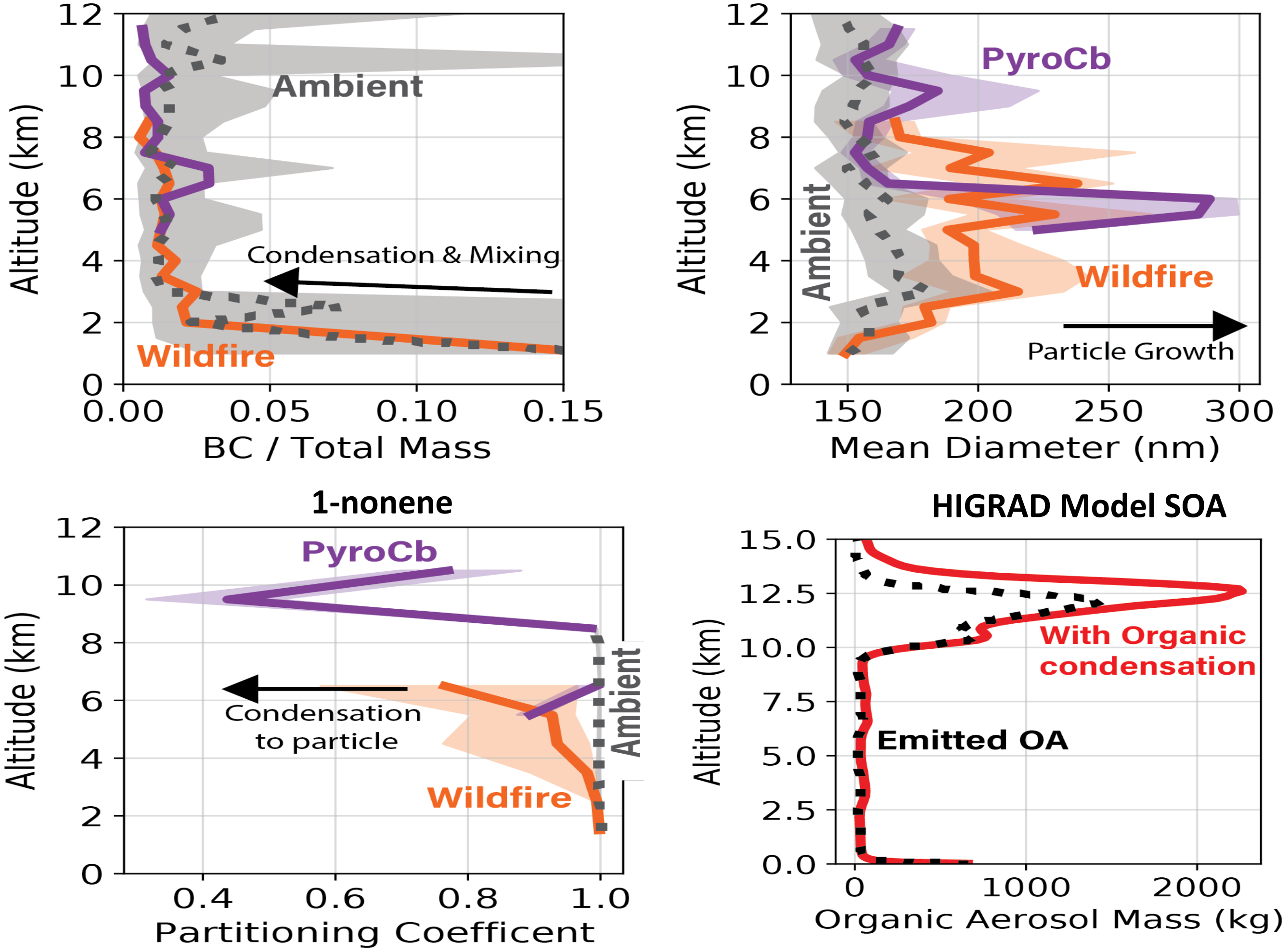


Reisner, Gorkowski et al. in prep.



Reisner, Gorkowski et al. in prep.

In situ synthesis of FIREX-AQ observation: BC falls, SOA and coatings grow in updrafts



Gorkowski, Benedict et al. in prep.

Fires CO > 10 ppb and PyroCbs from Williams Flats fire on August 8, 2019

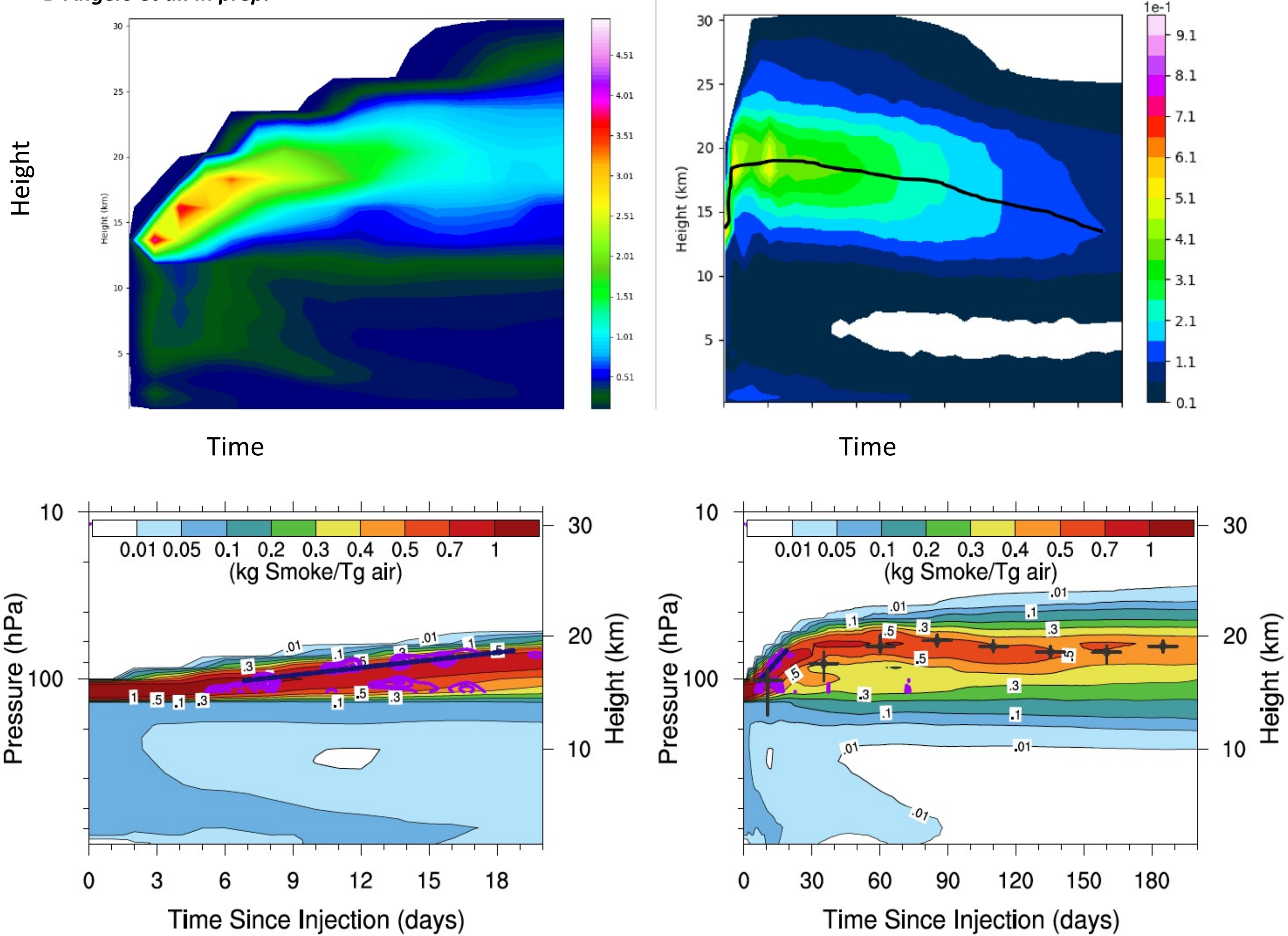
Global Data and Simulations

Top: GEOS plume self lofting and settling

Bottom: same with CESM/CARMA

Stratospheric Lifetime 5 months

D'Angelo et al. in prep.



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Conclusions

•PyroCbs significantly enhance aerosols in the UT/LS. These processes are missing in current climate models and will bias forcing and feedbacks.

•LES with mixed fuel, dry boundary layer, moist mid-troposphere create PyroCbs with warm/ice clouds that loft smoke and match observations.

•SOA formation via organic vapor condensation in the cold updraft is the dominant process that increases UT/LS smoke mass by x2-3.

•Smoke self lofting (*Malone effect, Science, '85*) by solar heating that depends on BC amount explains the observed BC17 smoke rise rate and lifetime.

•Unlike deep wet convection that efficiently scavenge aerosols dry PyroCb events do and and will loft BC into the UT/LS.

•The lifetime of BC17 smoke in the stratosphere is 5 months.