Impact of cloud-top entrainment timescale on smoke-cloud interactions over the southeast Atlantic

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Grants: NNX-80NSSC17K0404 (MD) & NNX-15AF98G (EVS-2)











Prior "Eulerian" results: A-train studies



Costantino & Bréon [2010]

Painemal et al. [2014]

NASA P-3 Orion

Four-engine turboprop plane capable of both taking remote sensing observations and sampling smoke and clouds *in-situ* Data publicly available at: espoarchive.nasa.gov/archive/browse/oracles



P-3 landing in São Tomé. Credit: Jhony Zavaleta/NASA Earth Science Project Office

Flight maneuvers



Instruments and models

<u>Cloud droplet number concentration (N_d)</u>

 In-situ from an Artium Flight Phase Doppler Interferometer (PDI); remotely sensed from SEVIRI

Cloud condensation nuclei (CCN)

 In-situ at 0.3% supersaturation from a Droplet Measurement Technologies CCN-100 continuous-flow streamwise thermal-gradient CCN chamber

Refractory black carbon (rBC)

• In-situ number concentration from a DMT Single Particle Soot Photometer (SP2)

Carbon monoxide (CO)

• Modeled from WRF-AAM with assimilated fires (biomass-burning-tagged)















History of entrainment



Entrainment from the FT

$$\frac{\partial CCN_{MBL}}{\partial t} = \frac{w_e}{z_i} \left(CCN_{FT} - CCN_{MBL} \right)$$

- Highly idealized form: Assuming constant FT aerosol concentration, entrainment rate, boundary layer height, and no other source or sink terms
 - w_e = entrainment rate
 - $z_i = MBL$ height

Entrainment timescale: \mathbf{T}_{ent}

















Main implication

"Eulerian" studies (e.g., A-train) likely missing important details.

"Lagrangian" viewpoint will likely be needed for accurate accounting of radiative forcing due to ACI.

Summary

- ORACLES-2016 N_d and CCN are related as expected when comparing below-cloud values, but the relationship is much weaker using above-cloud values
 - Problem because above-cloud is analogous to prior A-train results
- August 31st and September 4th cases suggest history of smoke entrainment can help account for discrepancy
- Cloud-top entrainment mixes smoke into the MBL on a timescale of days, so instantaneous "snapshots" can mislead

Extra slides



Courtesy of Andrew Dzambo and the APR-3 team; RR = rain rate in mm/hour





Courtesy of Pablo Saide, https://acomstaff.acom.ucar.edu/saide/oracles/wrf_aam_2016-08-29/pmenu.html

