Entrainment and mixing of biomass burning aerosol into the Namibian stratocumulus cloud deck

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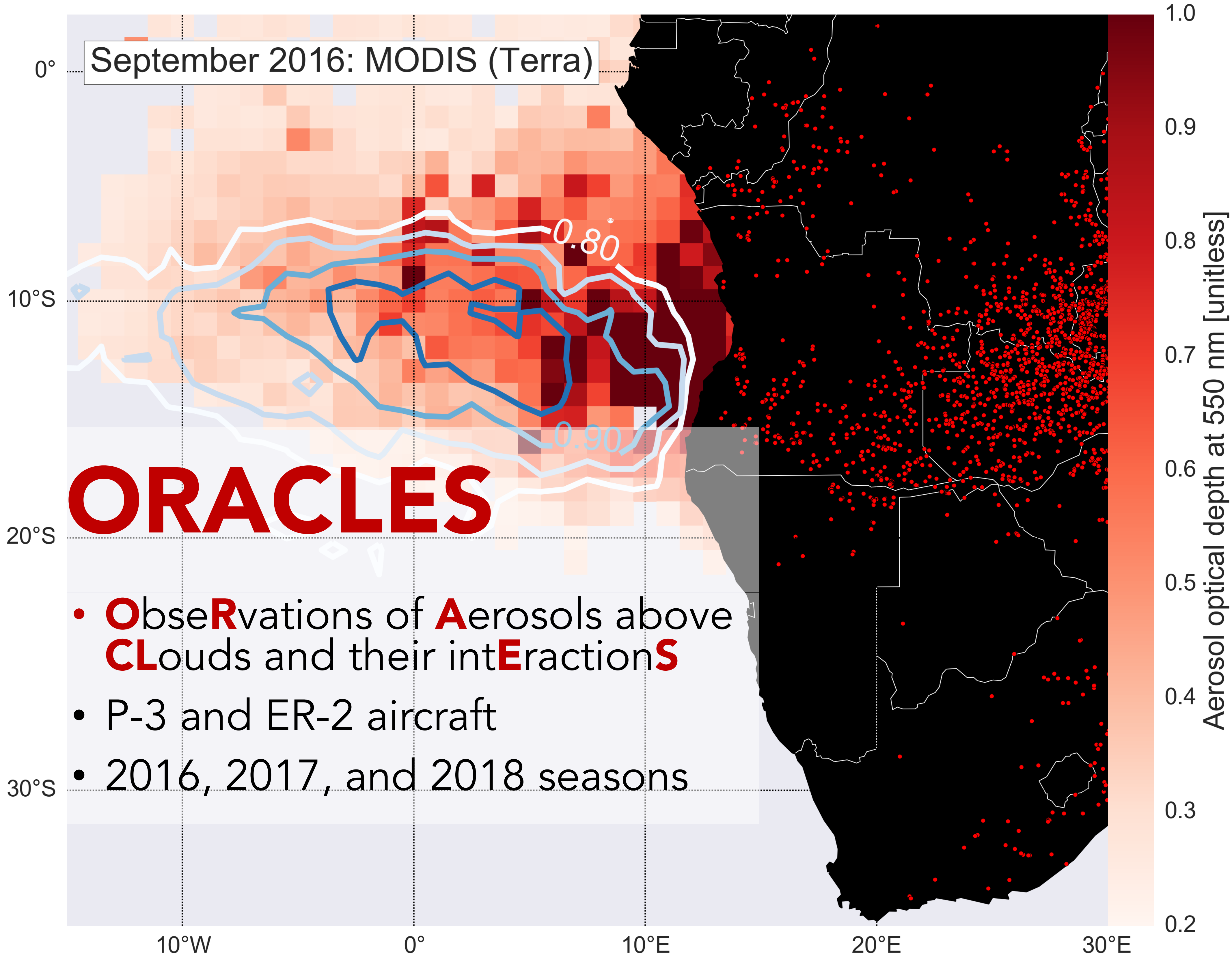
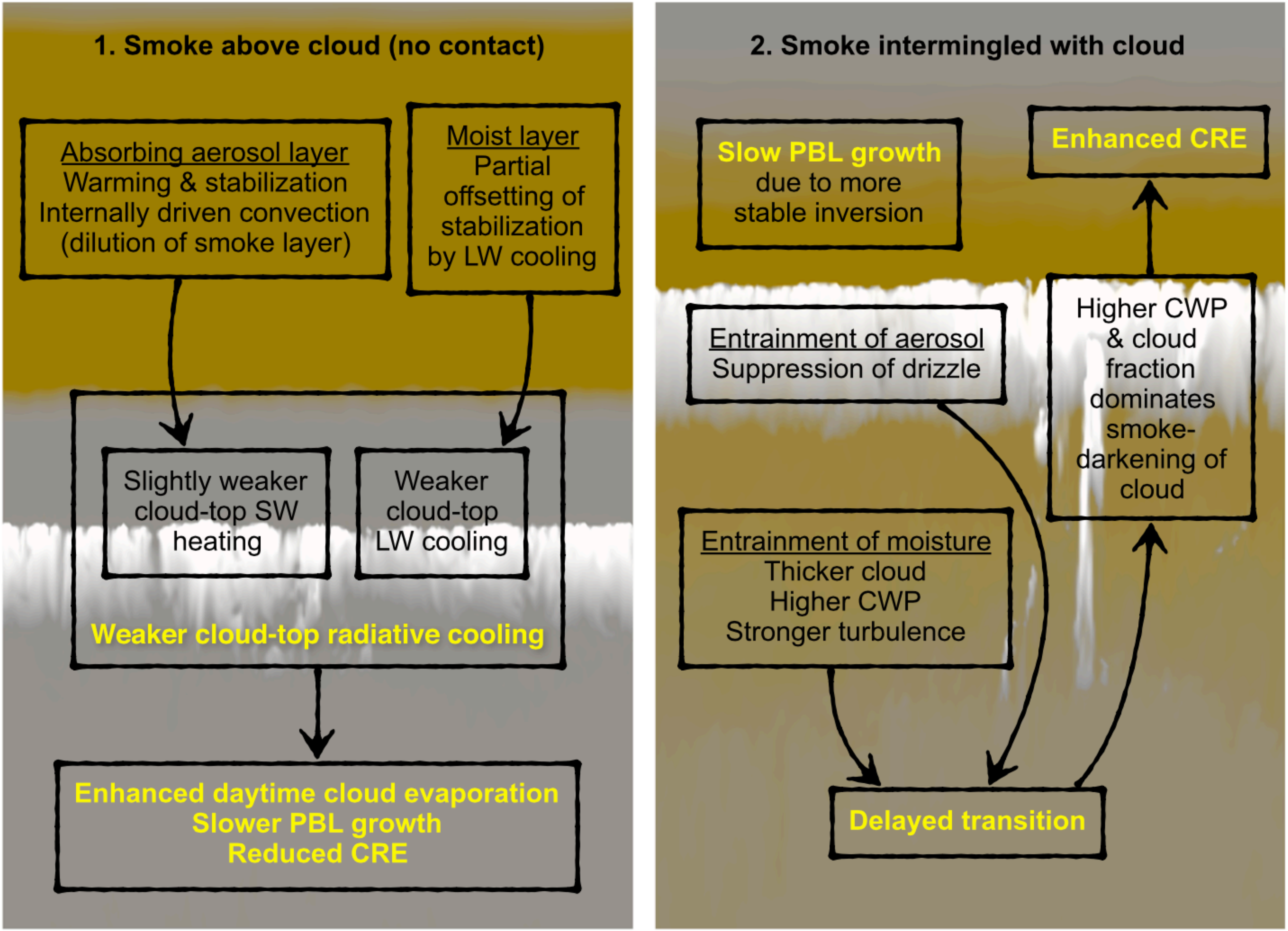

September 2016: MODIS (Terra)
0°
10°S
20°S
30°S
10°W
0°
10°E
20°E
30°E
0.80
0.90
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Aerosol optical depth at 550 nm [unitless]
ORACLES
• ObseRvations of Aerosols above CLouds and their intEractionS
• P-3 and ER-2 aircraft
• 2016, 2017, and 2018 seasons

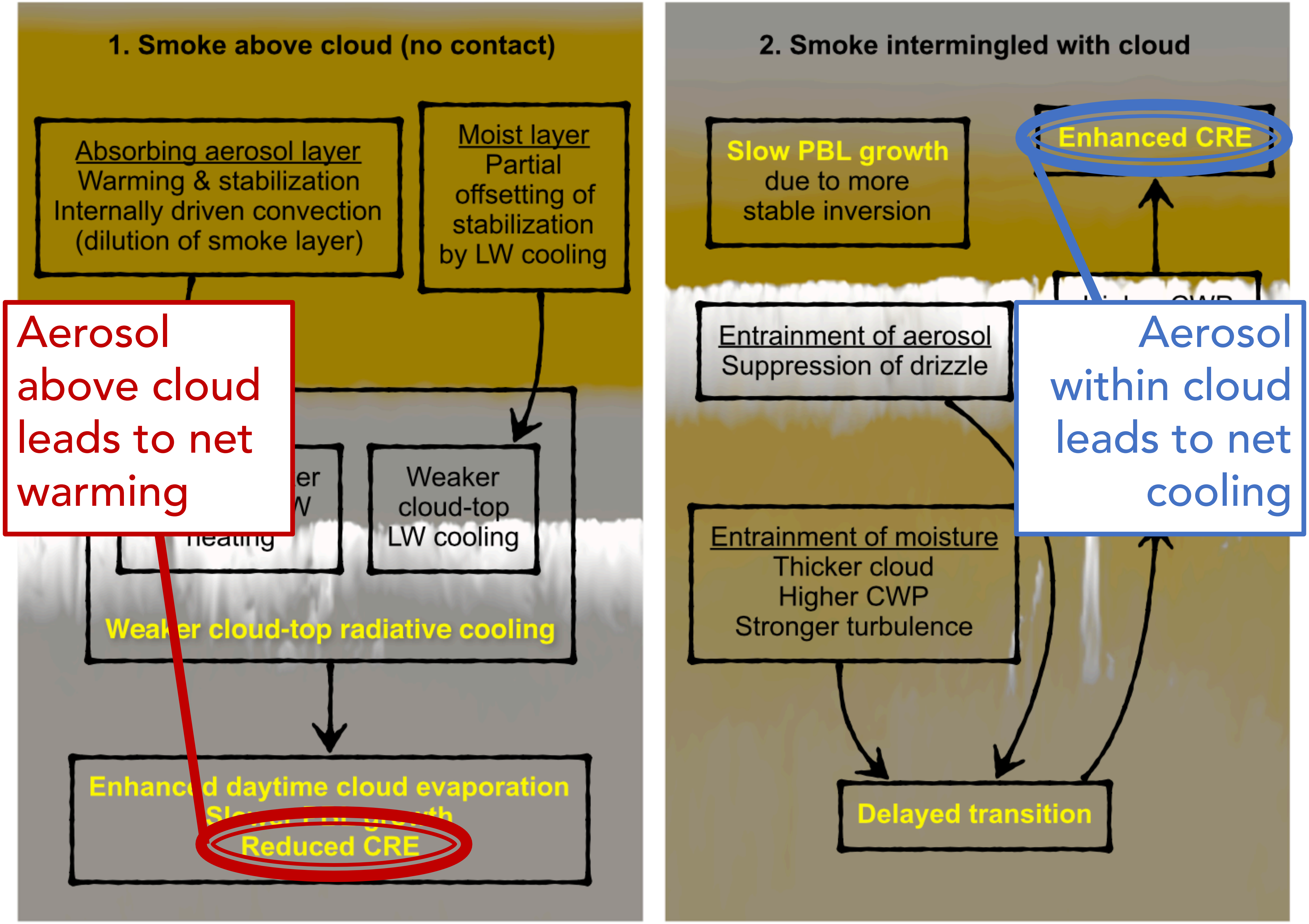
Motivating question:

How often and over what spatial extent are biomass burning (BB) aerosols mixing into the Namibian stratocumulus (Sc) cloud deck?

- **Why do we care?**
  - Large eddy simulations show net cooling due to BB aerosol in the southeast Atlantic, largely due to aerosol-cloud interactions
  - However, lidar measurements from the CALIPSO satellite show that the aerosol and cloud layers are rarely in direct contact



Yamaguchi, Feingold, et al. (2015), GRL

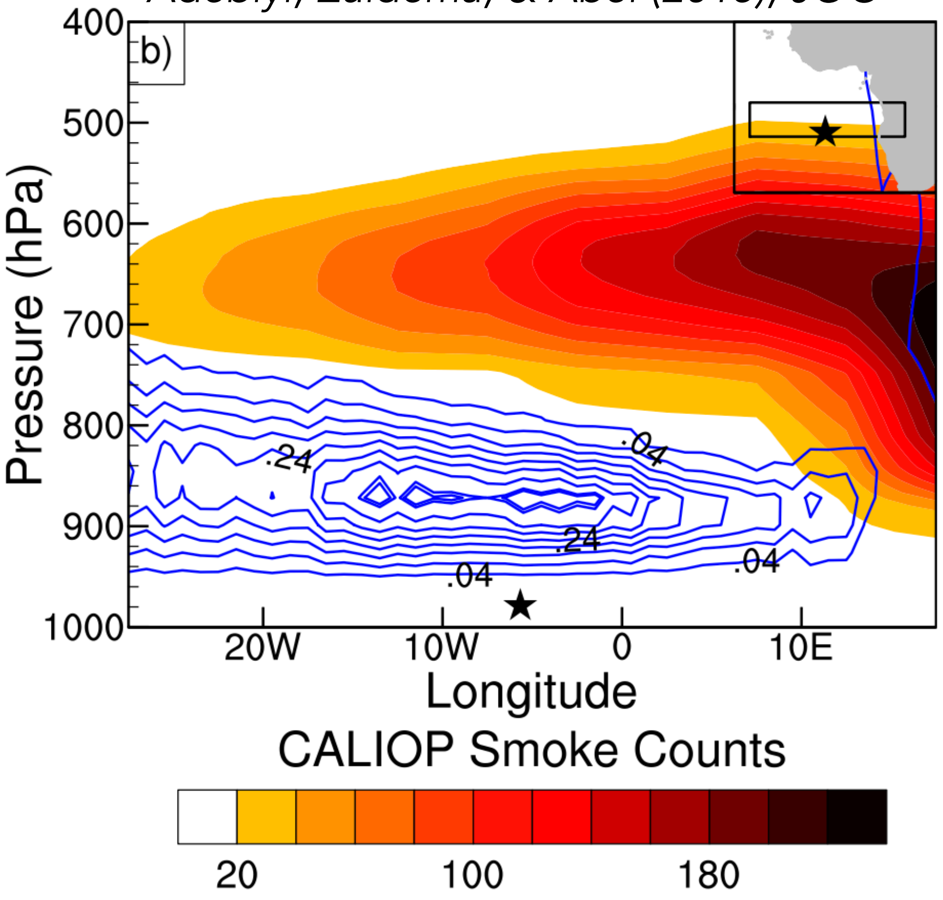


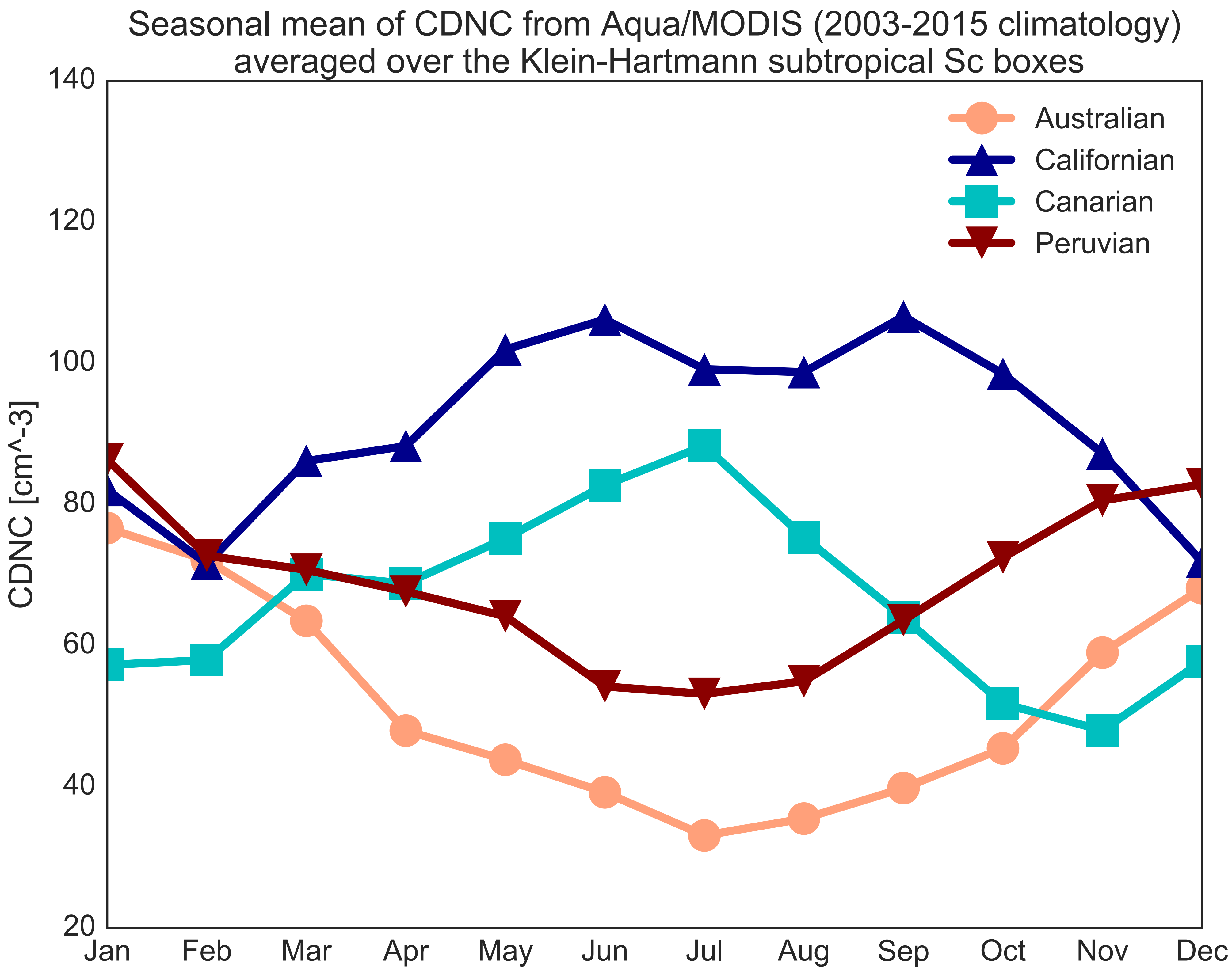
Yamaguchi, Feingold, et al. (2015), GRL

Frequency of smoke-cloud contact

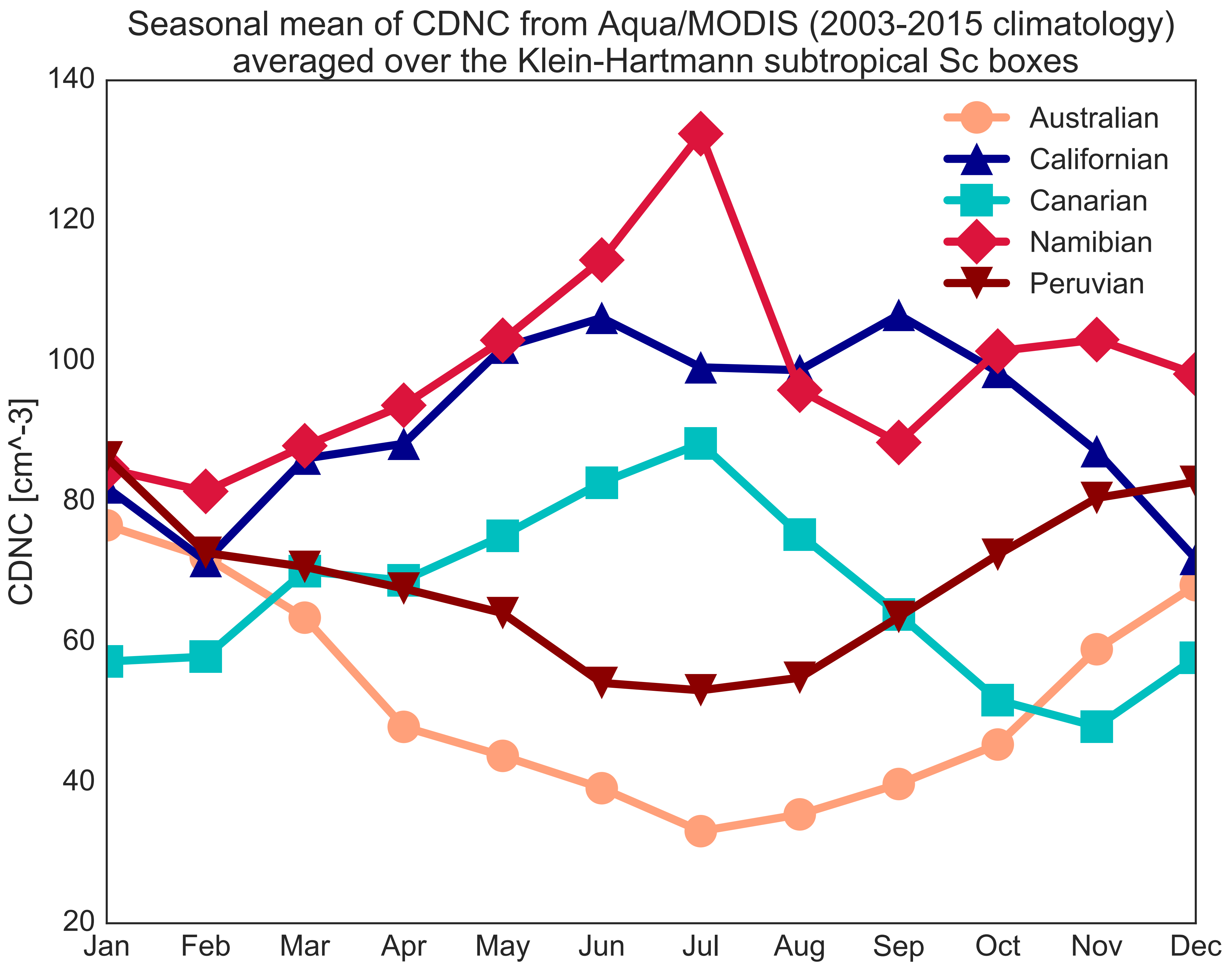
- *Constantino & Breón (2010), GRL:*
  - 83% well-separated, 17% mixed
- *Constantino & Breón (2013), ACP:*
  - 56% well-separated, 44% "close" or mixed
- *Painemal, Kato, & Minnis (2014), JGR:*
  - "the frequency of direct contact between the cloud and aerosol layers is not sufficient to explain" results, maybe because lidar signal is "substantially attenuated by thick smoke layers"

Adebiyi, Zuidema, & Abel (2015), JOC





Data: Bennartz & Rausch (2017), ACP, https://doi.org/10.15695/vudata.ees.1



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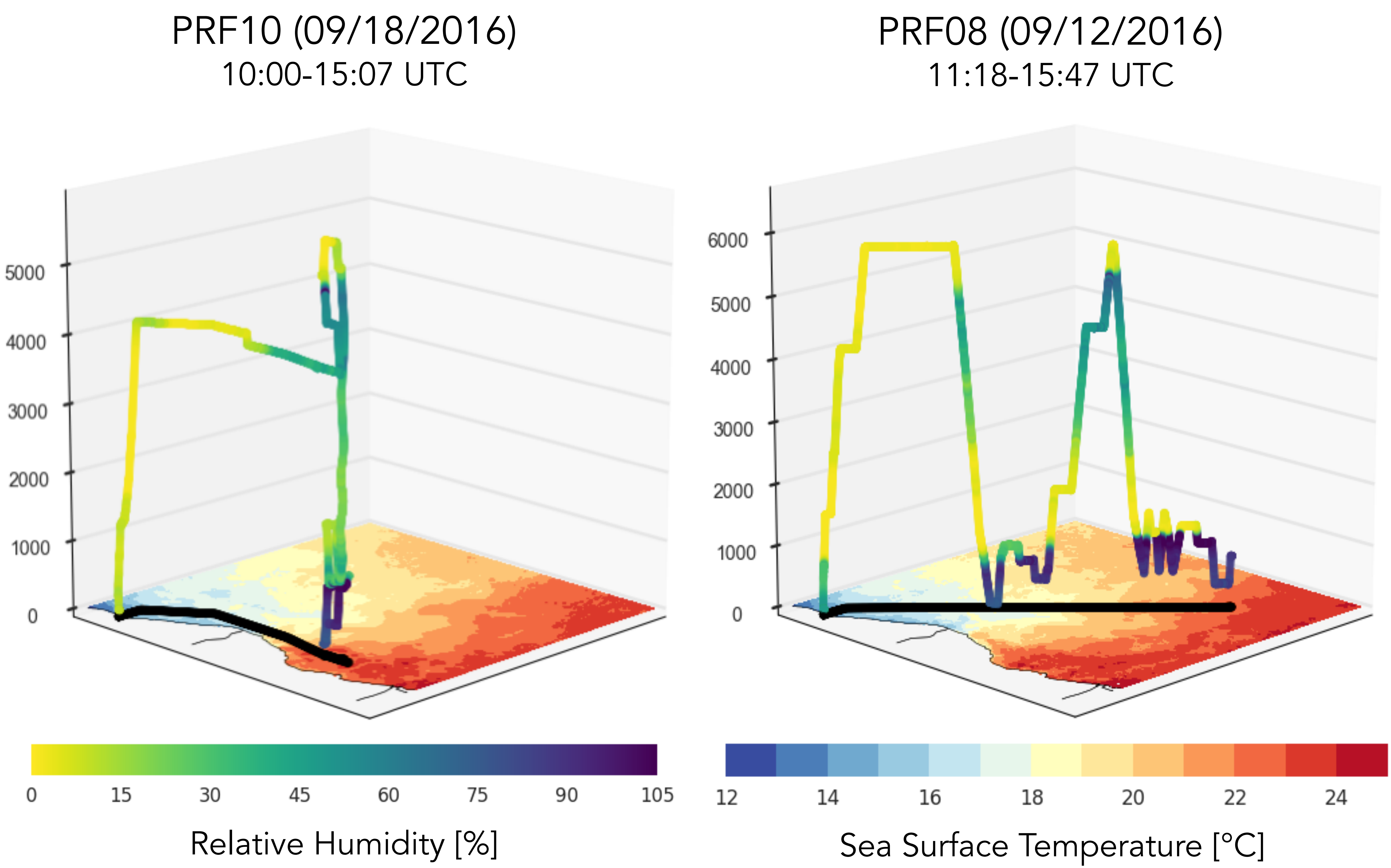
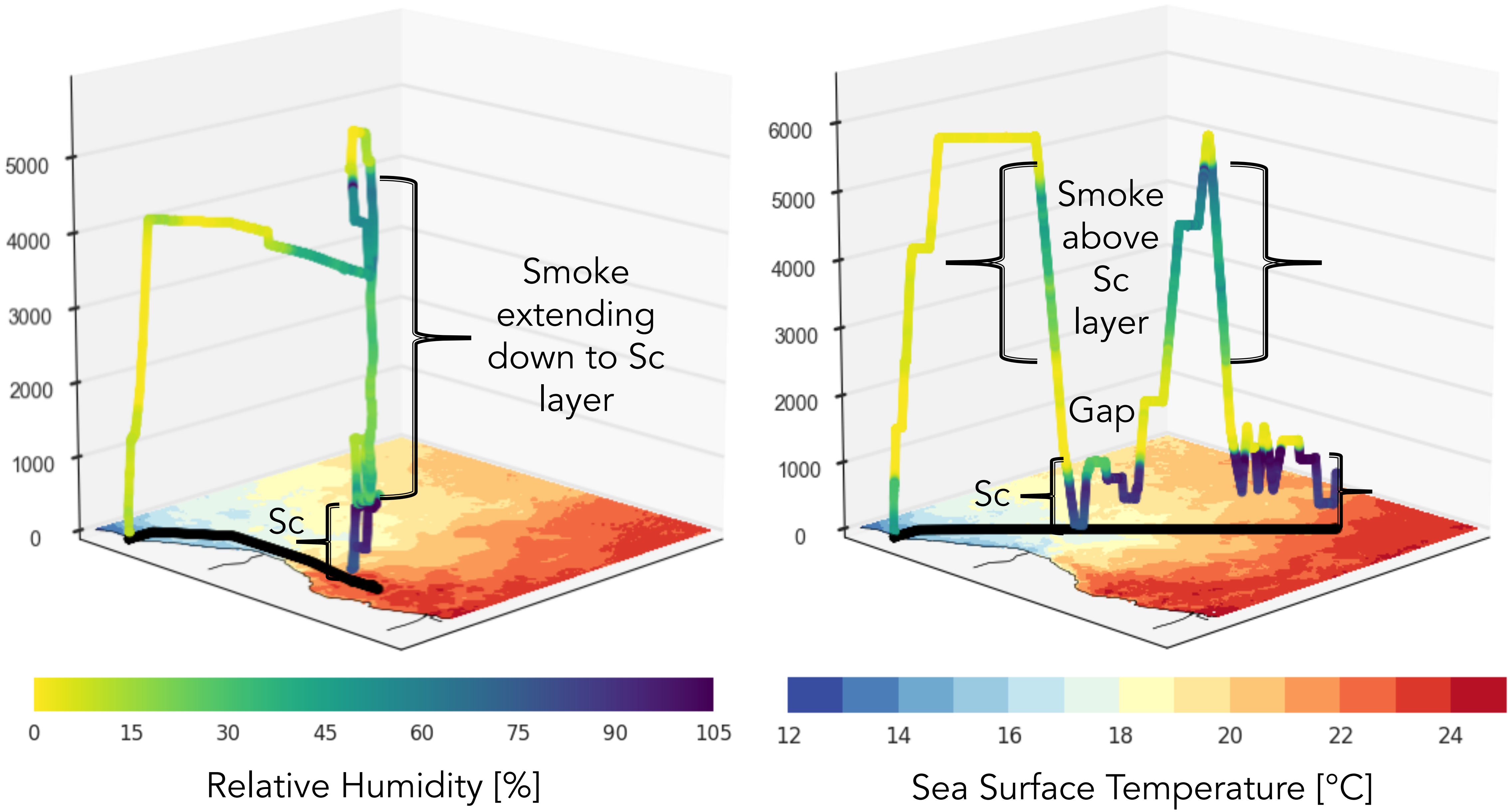


Aircraft data: asp-archive.arc.nasa.gov/Oracles/N426NA/; SST data: G1SST, ourocean.jpl.nasa.gov/SST

PRF10 (09/18/2016)
10:00-15:07 UTC

PRF08 (09/12/2016)
11:18-15:47 UTC



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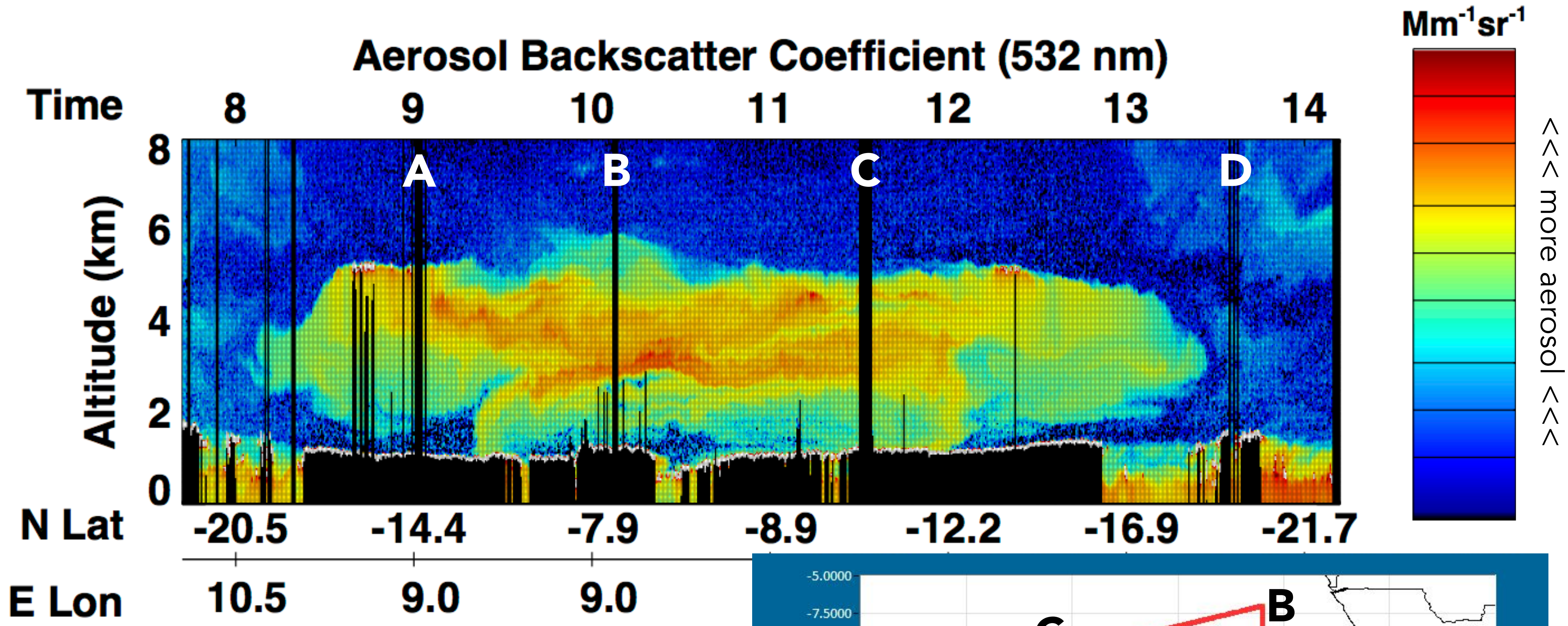
ERF04 (09/16/2016)



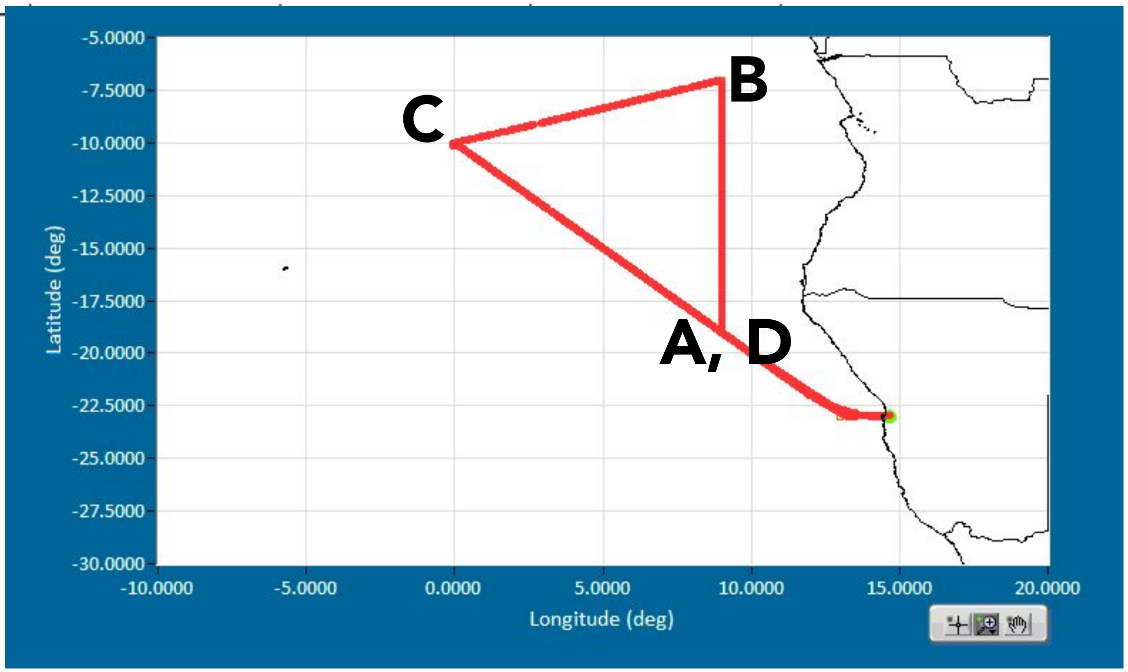


Image: Courtesy of Sharon Burton and the HSRL-2 Team

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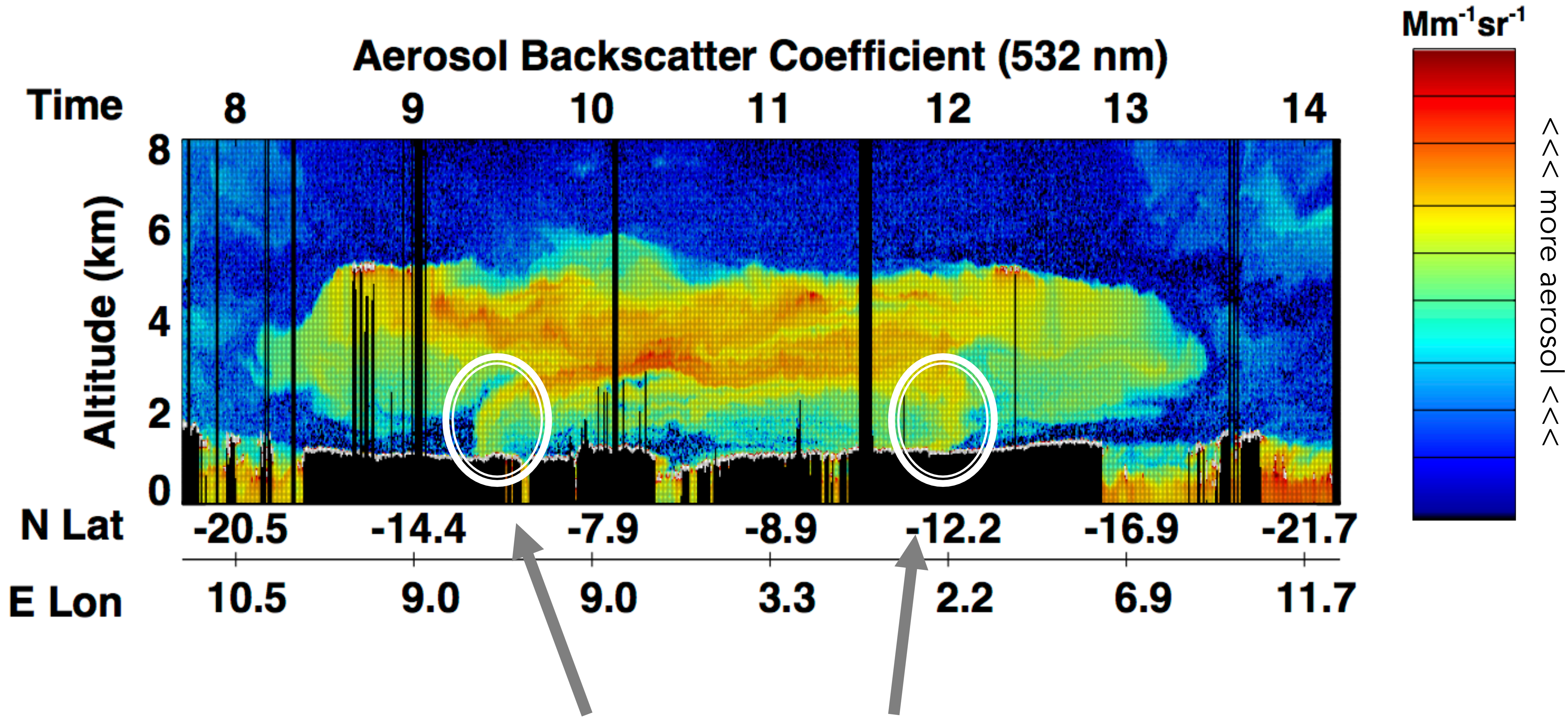
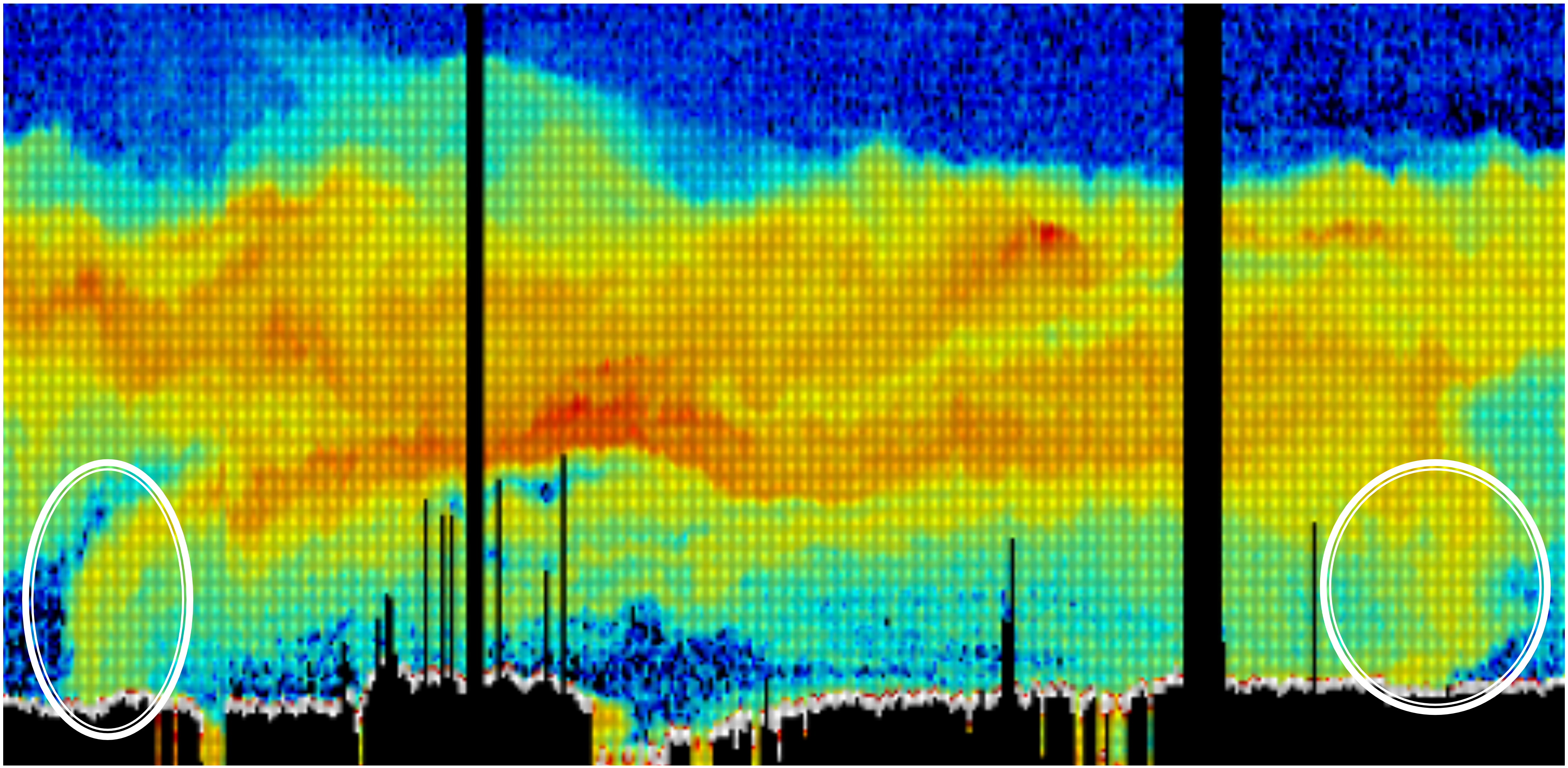


Aerosol mixing into cloud deck
around 12 °S?

Image: Courtesy of Sharon Burton and the HSRL-2 Team

ERF04 (09/16/2016)



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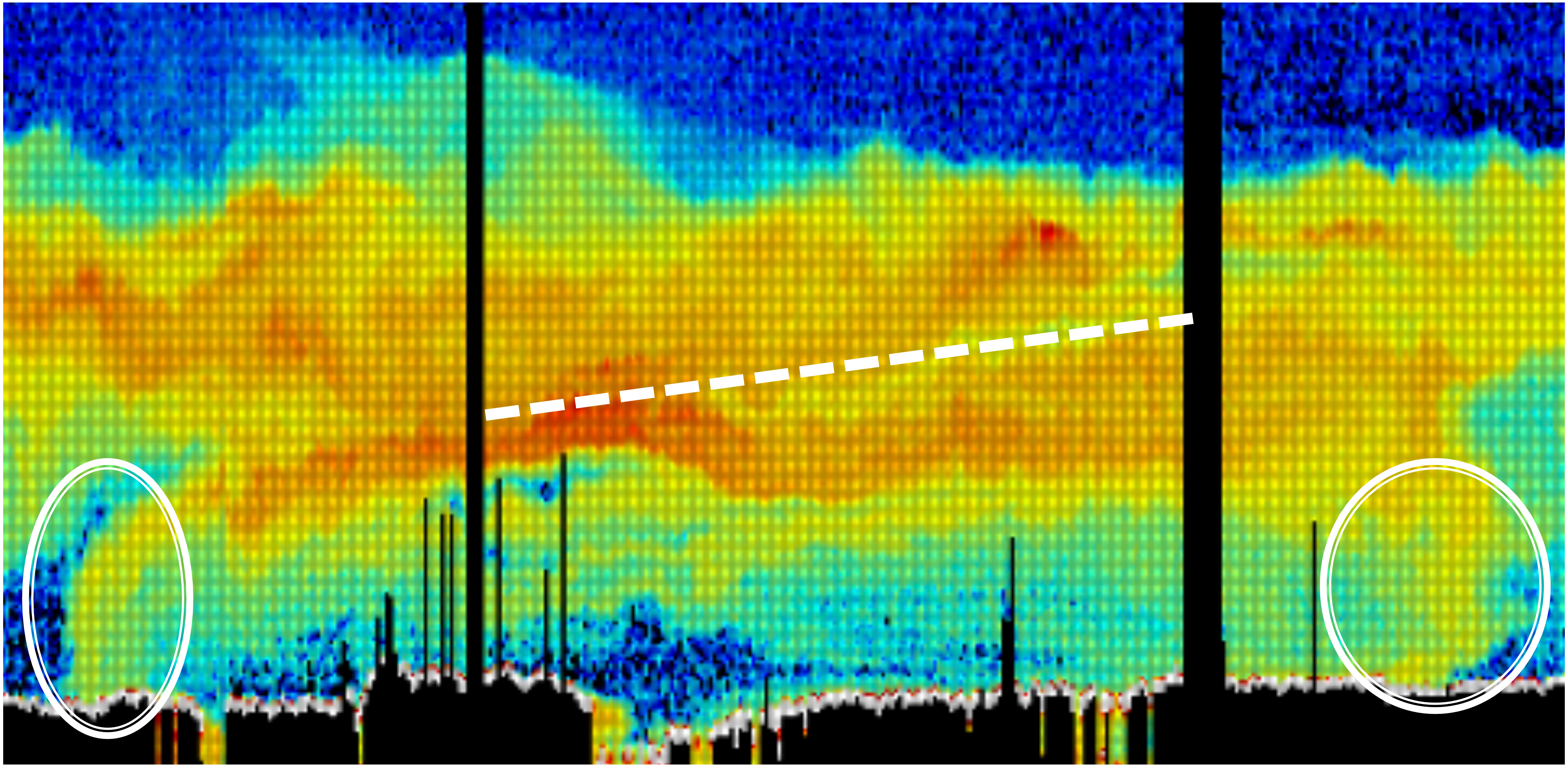
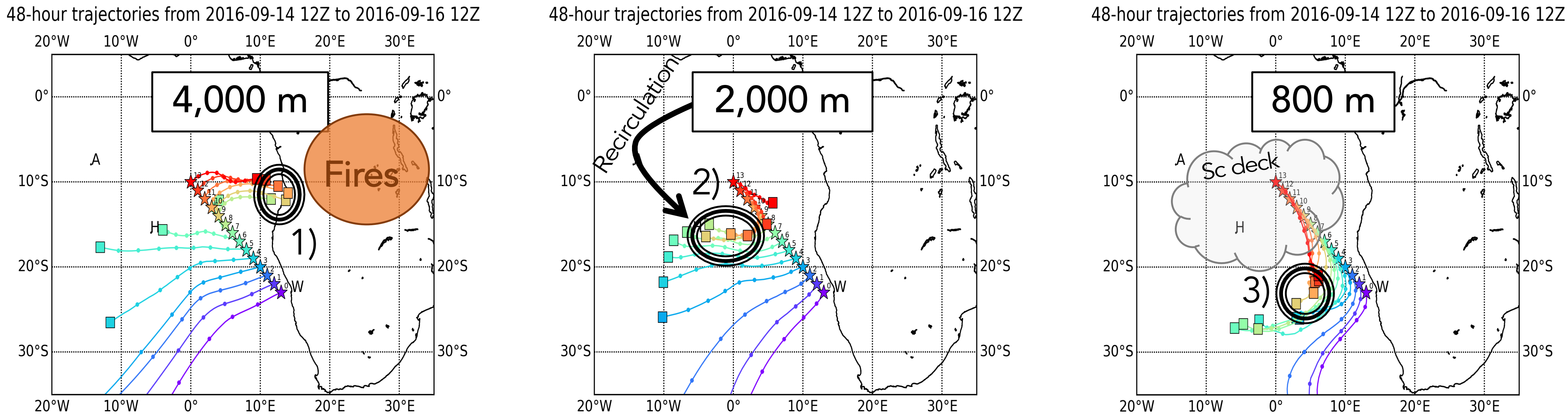


Image: Courtesy of Sharon Burton and the HSRL-2 Team

48 hour back trajectories initialized on 09/16/2016

(09/14/2016 to 09/16/2016)



Hypothesis: BB aerosol reaches the MBL through 1) westward transport from land to over the Atlantic Ocean, 2) recirculation and subsidence from the tropical Atlantic southward, and 3) further subsidence and northward transport for a subset of air parcels.

Data: Trajectories run by Hans Mohrmann, available at: http://atmos.uw.edu/~jkcm/ORACLES_plots/

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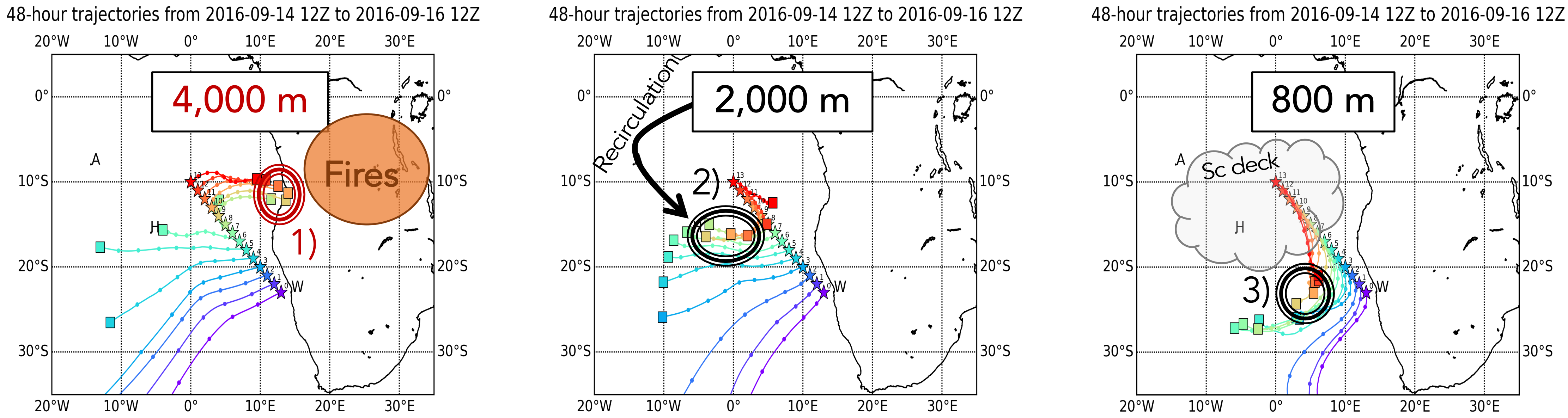

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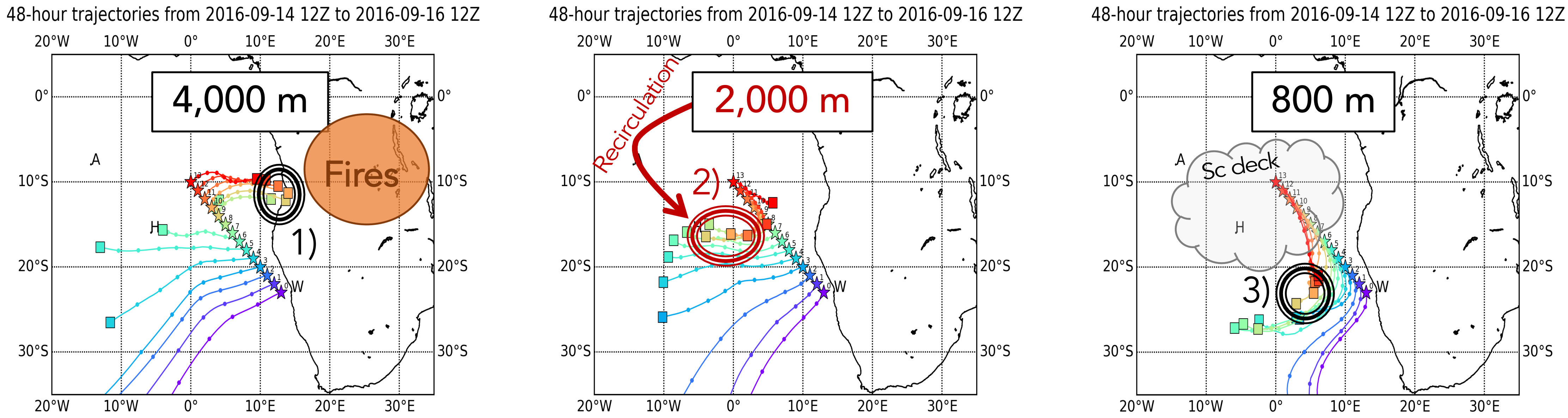

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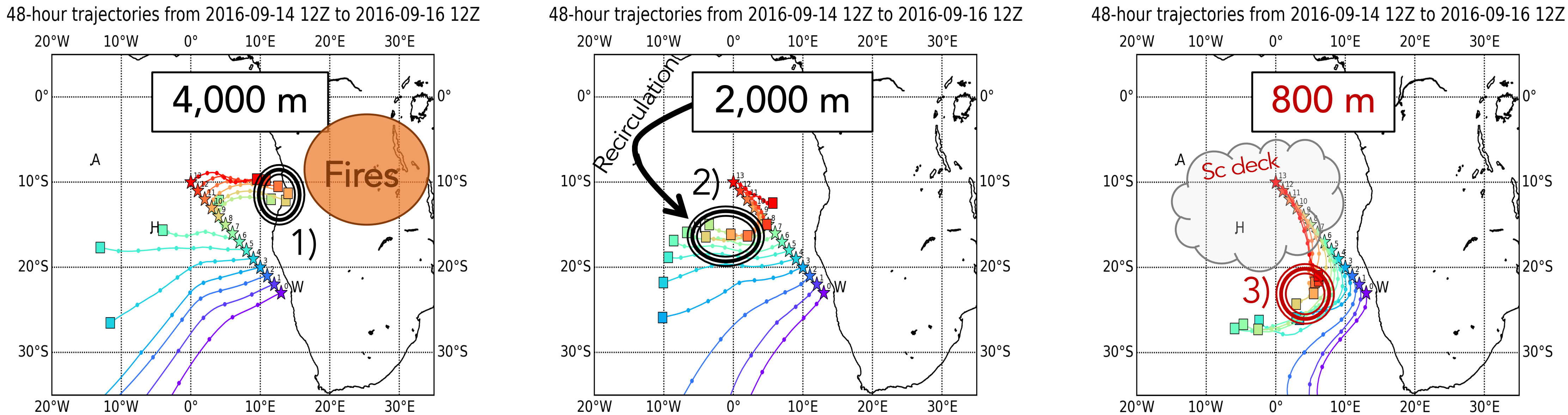

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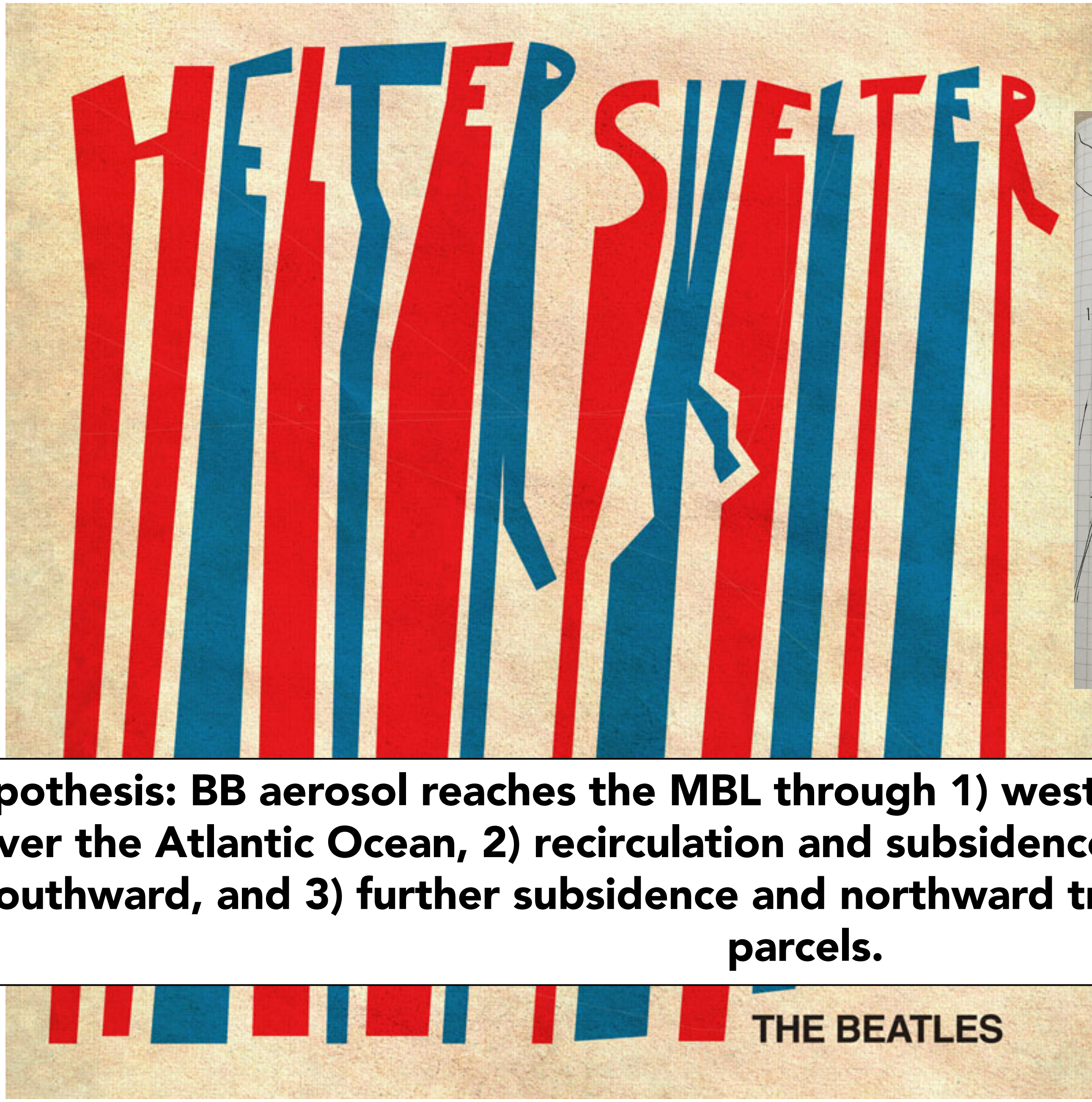

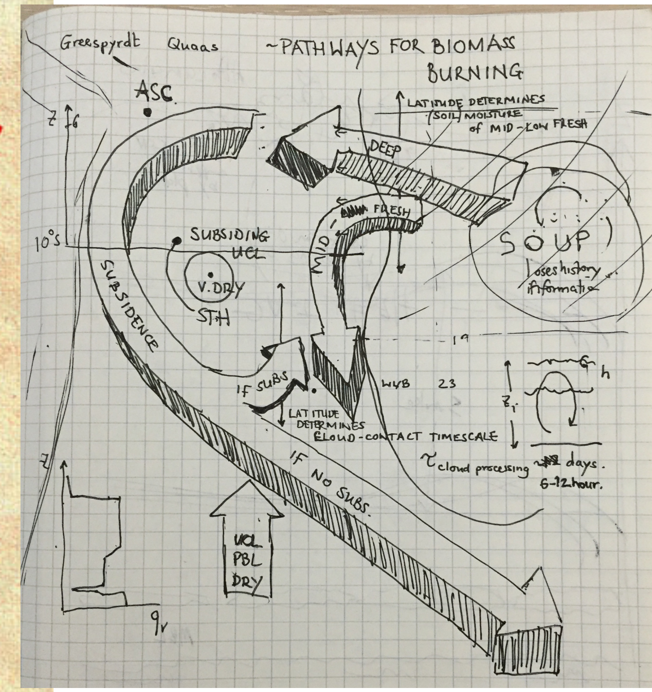

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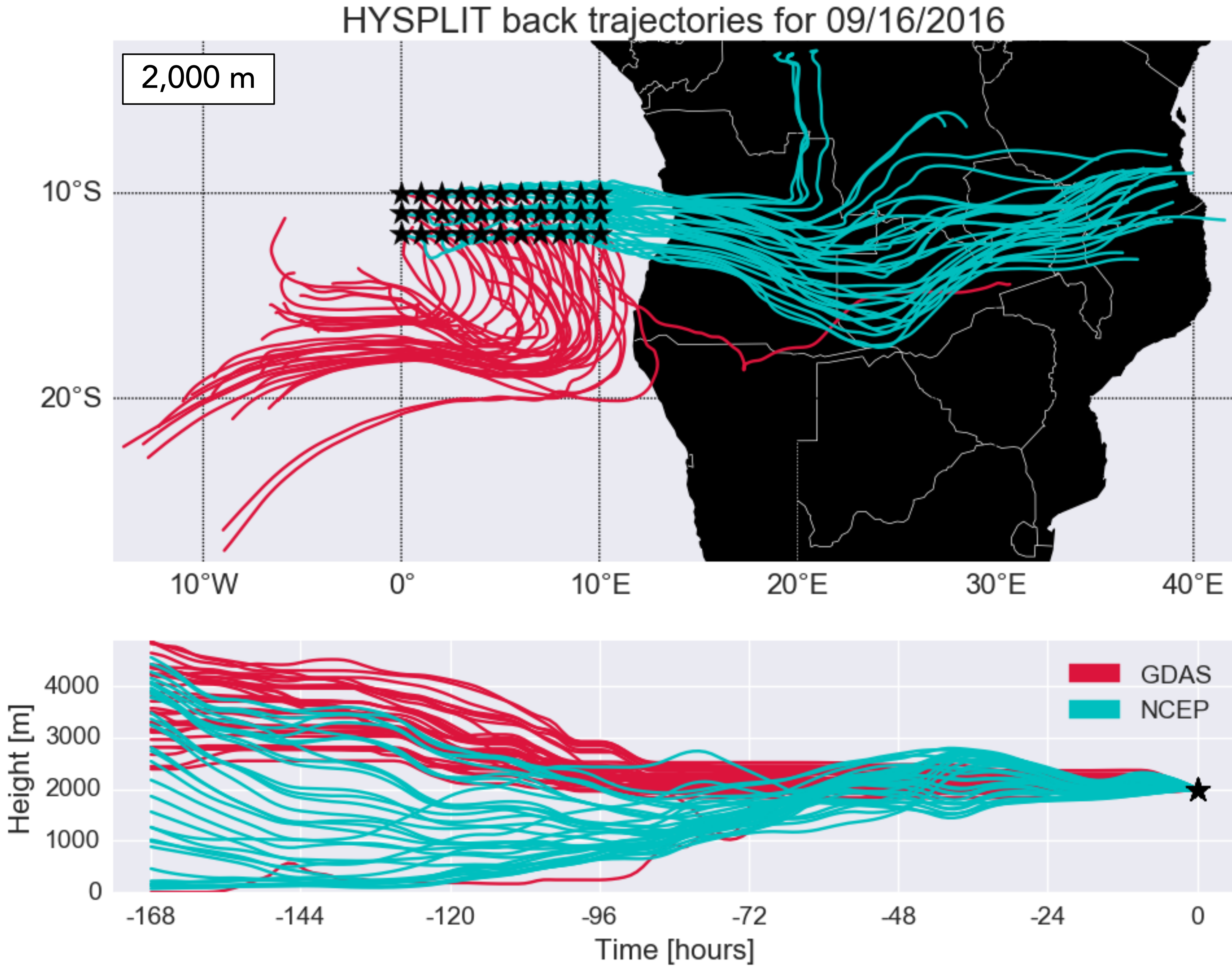
HYSPLIT back trajectories for 09/16/2016
2,000 m
10°S
20°S
10°W
0°
10°E
20°E
30°E
40°E
GDAS
NCEP
Height [m]
4000
3000
2000
1000
0
-168
-144
-120
-96
-72
-48
-24
0
Time [hours]

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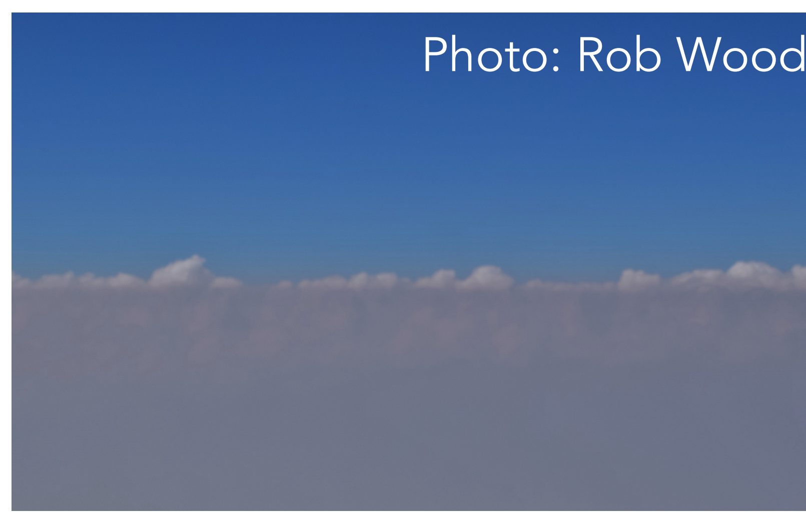
HELP!

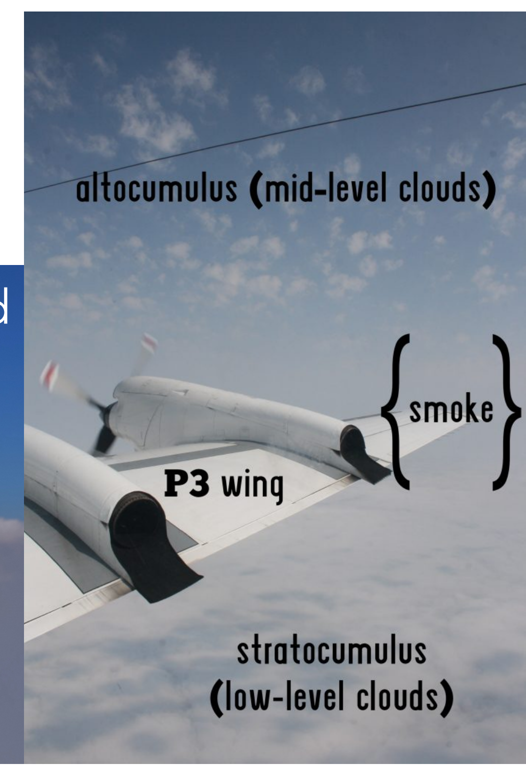
What to do:

- FLEXible PARTicle dispersion model (FLEXPART)
  - Configured to work with WRF-Chem output from 2016 ORACLES field season
  - Lagrangian particle tracking/dispersion modeling
  - Release particles **where ORACLES observations agree well with WRF-Chem aerosol concentrations**
    - Extend analysis to the LASIC ARM site on Ascension Island
- HYSPLIT
  - Generate transport statistics in free troposphere
  - Look for **systematic differences between models**

Further observational needs:

- Field measurements of the ORACLES region, but in:
    1. July (highest priority)
    2. Rest of year, to understand strange seasonality
- Composition of fuel burned and variation during BB season
    - More ground sites in south-central Africa?
- Mid-level cloud in ORACLES region





Summary

- LES modeling studies show net cooling due to smoke, largely due to aerosol indirect effects
- Remote sensing from the CALIOP and MODIS instruments show either (or both…):
  - Smoke and cloud layers rarely touch
  - Large biases due to aerosol absorption
- ORACLES will provide three years worth of observations of smoke and clouds in the southeast Atlantic
- Smoke transport pathways once over the Atlantic Ocean remain highly uncertain