The Diurnal Evolution of Controls on Trade Wind Mesoscale Morphologies

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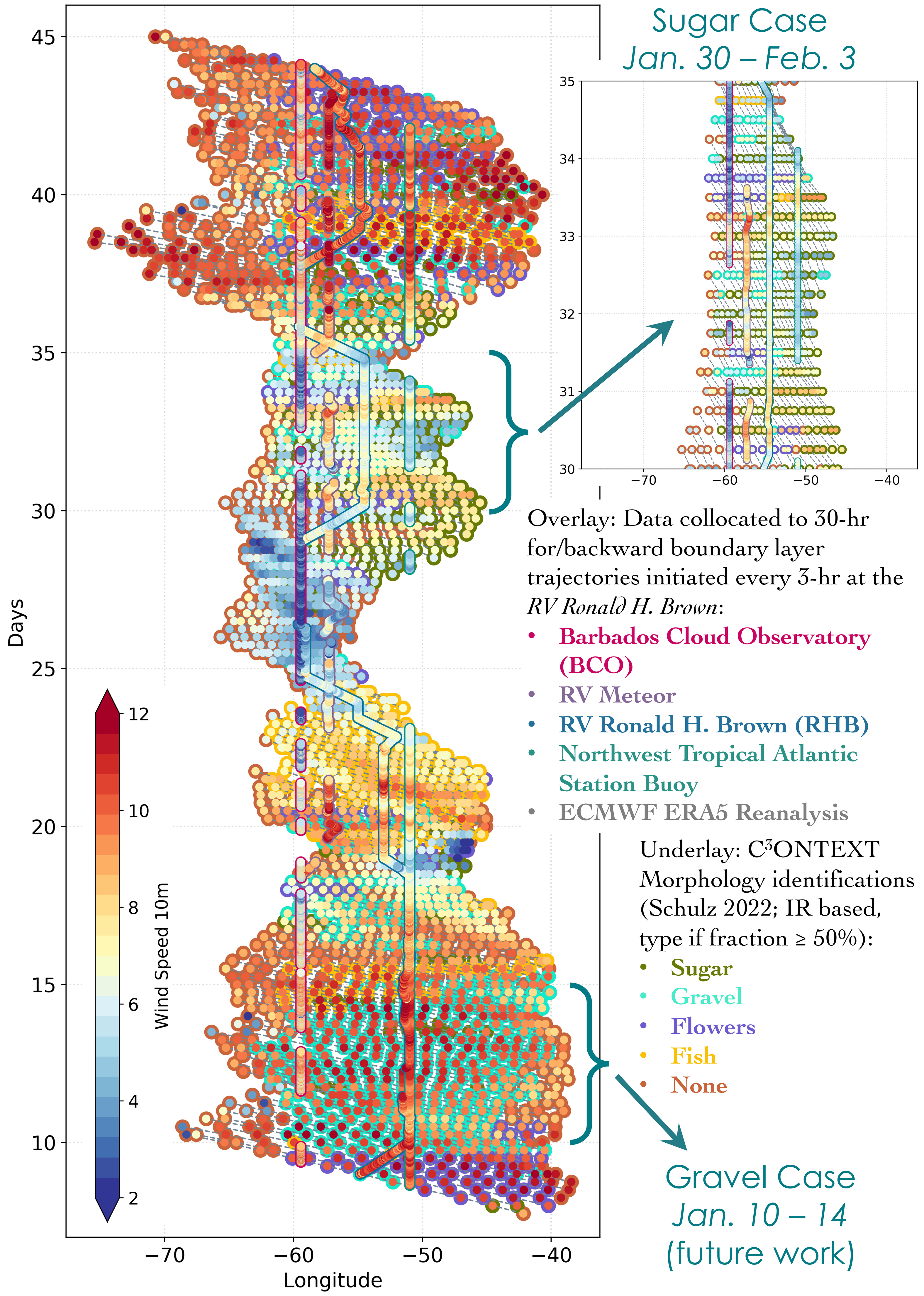


Overlay: Data collocated to 30-hr for/backward boundary layer trajectories initiated every 3-hr at the *RV Ronald H. Brown*:

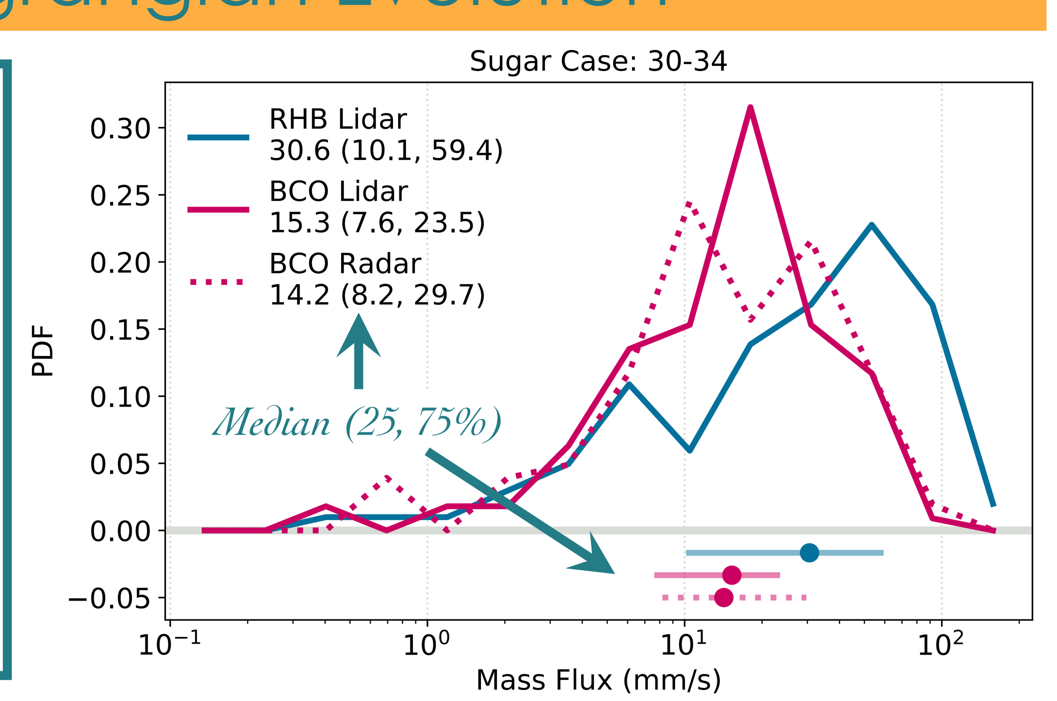
- Barbados Cloud Observatory (BCO)
- RV Meteor
- RV Ronald H. Brown (RHB)
- Northwest Tropical Atlantic Station Buoy
- ECMWF ERA5 Reanalysis

Underlay: C[3]ONTEXT Morphology identifications (Schulz 2022; IR based, type if fraction ≥ 50%):

- Sugar
- Gravel
- Flowers
- Fish
- None

Lagrangian Evolution

Preliminary Lagrangian evolution comparisons suggest mass flux is larger earlier in Sugar cloud transitions (RHB vs. downwind BCO cloud base positive mass flux).



In the non-precipitating Sugar case, hourly cloud-base mass flux estimates from radar (non-precipitating clouds, following Klingebiel et al. 2021) and Doppler-lidar (all clouds, this study) are similar at BCO. This suggests the Doppler-lidar mass flux calculation method is robust and comparable to earlier literature.

Motivation

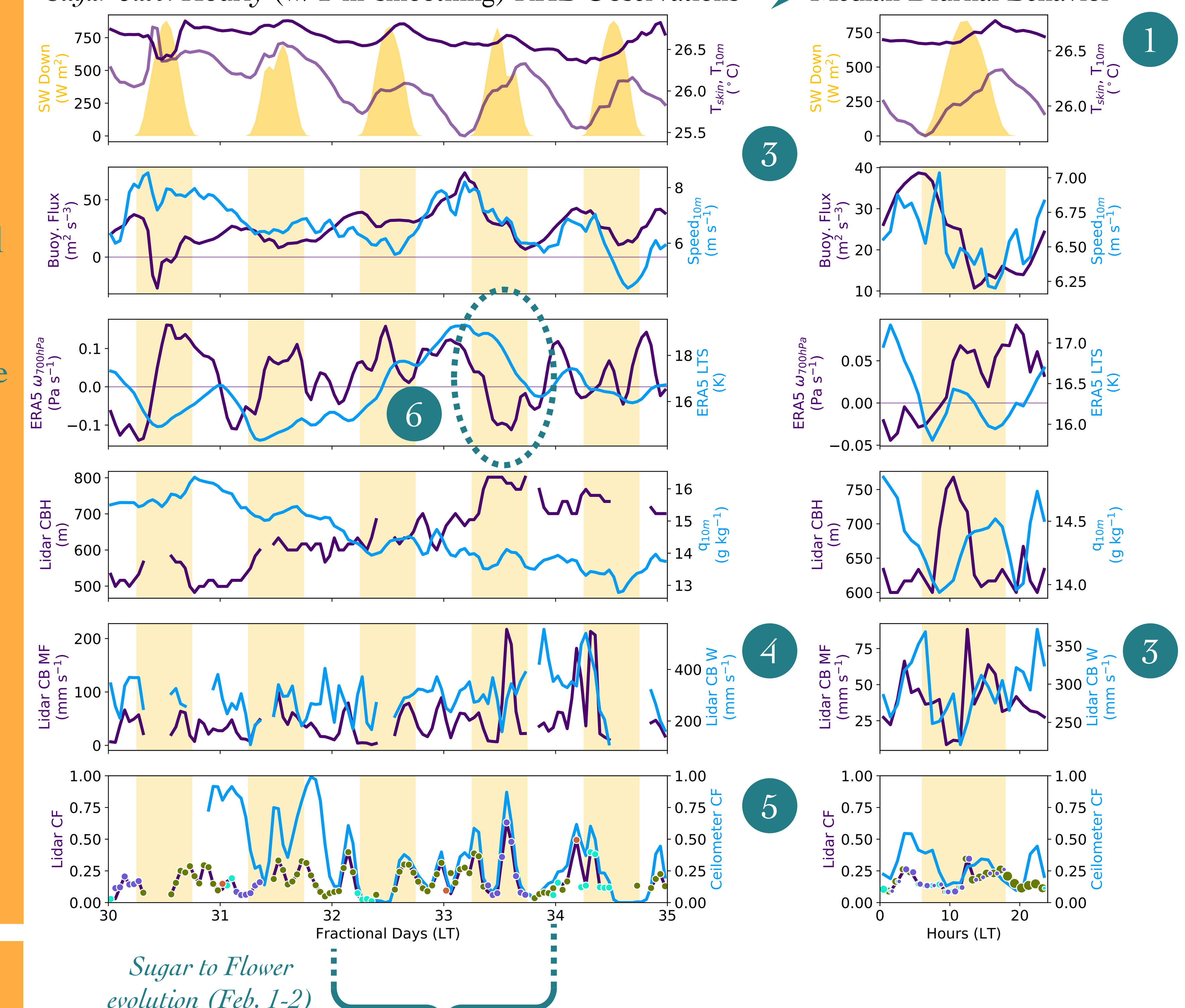
We utilize a synergistic, multi-platform observational dataset developed during the 2020 EUREC[4]A-ATOMIC joint campaign to investigate and disentangle the evolution of sub-cloud dynamics on diurnal and Lagrangian scales as a function of shallow convective organizational structures in the winter-time trade-winds. We will contrast cloud evolution mechanisms between two 5-day periods during which platforms were distributed in-parallel across the trade-wind alley: (*Jan. 30 - Feb. 3*) small, Sugar cloud evolution into larger, night-time cloud types (e.g. Gravel, Flowers), and (*Jan. 10-14*) persistent, wide-spread Gravel occurrence.

Questions

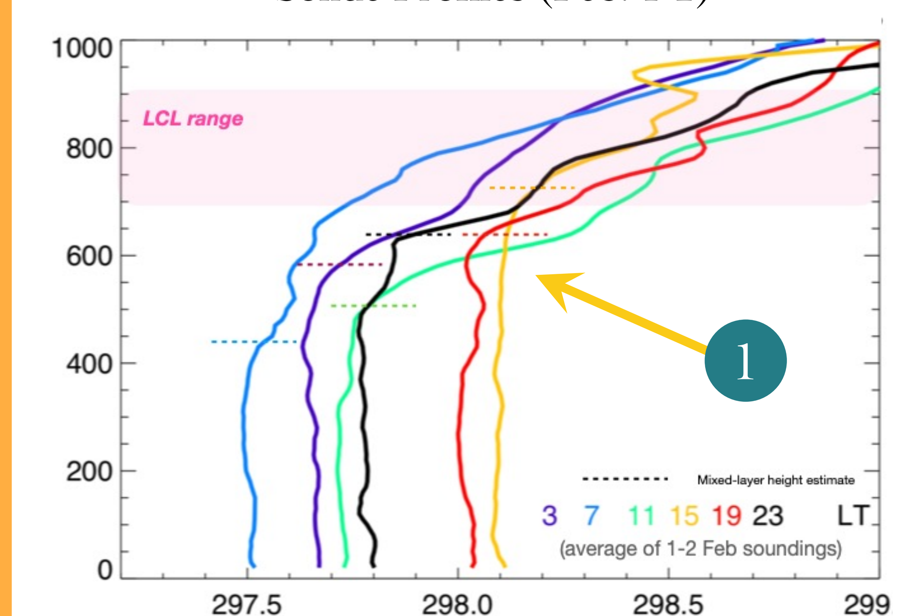
- *How do conditions differ between transitions from Sugar to Gravel/Flowers versus extended episodes dominated by Gravel alone?*
- *How important is the diurnal cycle in facilitating transitions to and maintenance of larger, more readily precipitating cloud organizational structures (i.e. Gravel, Flowers)?*
- *Are there competing diurnal cycles driving cloud organization (e.g. cloud fraction and cloud updrafts dominating different portions of the mass flux cycle)?*

Diurnal Evolution

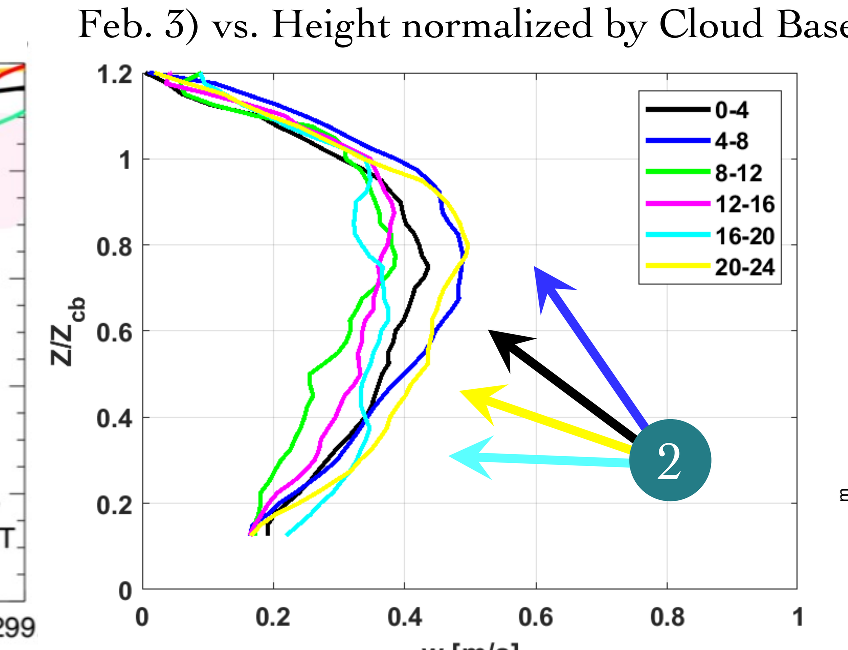
Sugar Case: Hourly (w/ 2-hr smoothing) RHB Observations ⇢ Median Diurnal Behavior



Diurnal Mean Potential Temperature RHB Sonde Profiles (Feb. 1-2)



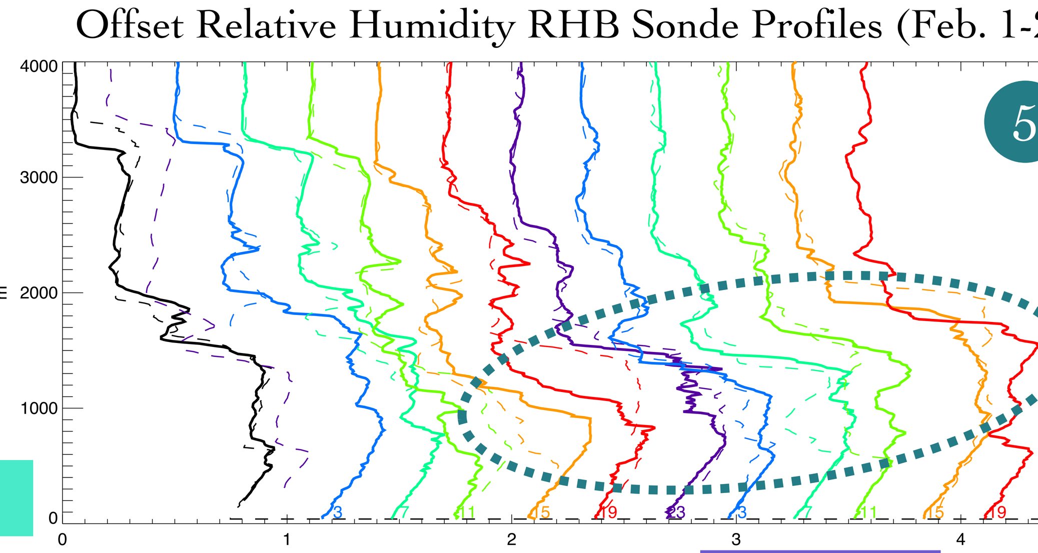
Diurnal Median RHB Doppler-lidar Vertical Velocity for Positive Mass Flux (Jan. 30-Feb. 3) vs. Height normalized by Cloud Base

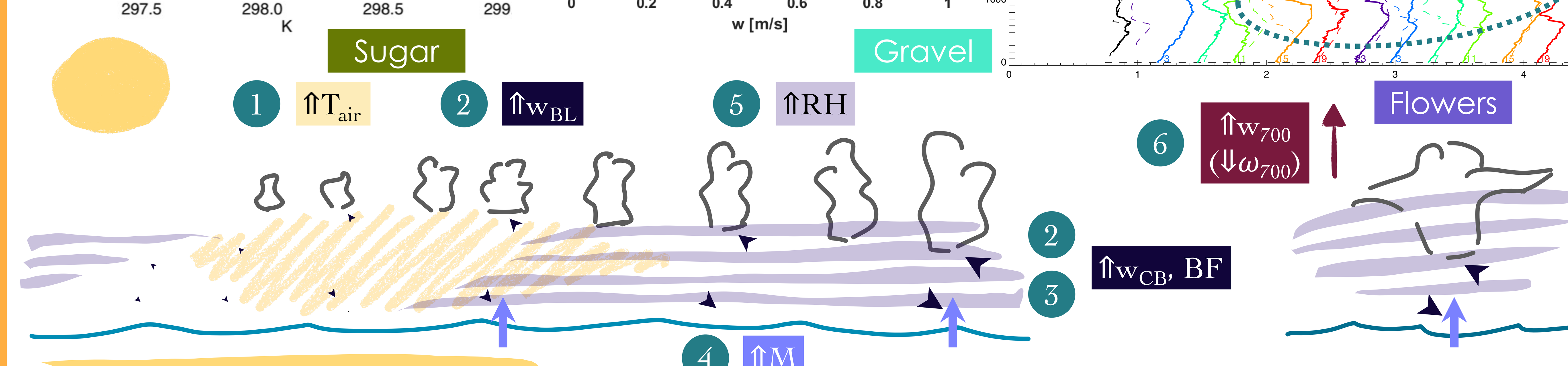


Hypothesized Diurnal Cycle Mechanism

1) Afternoon sub-cloud heating increases boundary layer depth to LCL (~3pm), allowing afternoon cloud development. *Warming of the atmosphere is more influential than SST (opposite from surface warming driven afternoon clouds, de Szoeke et al. 2021).*
2) Vertical velocity strength increases through depth of BL from the afternoon (connecting plumes to LCL) through the night (night-time peak at cloud-base).
3) Highest buoyancy flux at end of night (largest air-sea temperature difference, wind speeds), supports strongest cloud base updrafts and larger cloud structures.
4) Mass flux has two peaks diurnally: in the afternoon (cloud amount driven > Sugar) and at the end of the night (velocity driven > Gravel/Flowers)
5) Moist layer develops as Sugar transitions to Flowers/Gravel overnight and is maintained after morning cloud burn-off (~8-11am minimum cloud amount), potentially easing cloud recovery.
6) Decreases in large-scale subsidence (see Feb. 2-3 evolution in Narenpitak et al. 2021) allows afternoon clouds to deepen further into Flowers instead of Gravel.

Offset Relative Humidity RHB Sonde Profiles (Feb. 1-2)





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