Disentangling Diurnal and Lagrangian Influences on the Evolution of Trade-Wind Mesoscale Morphologies

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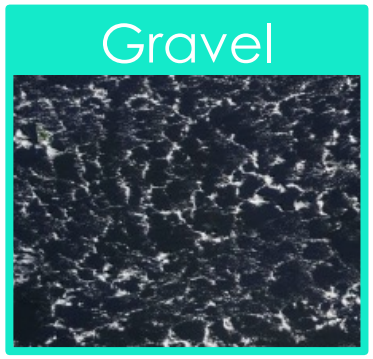
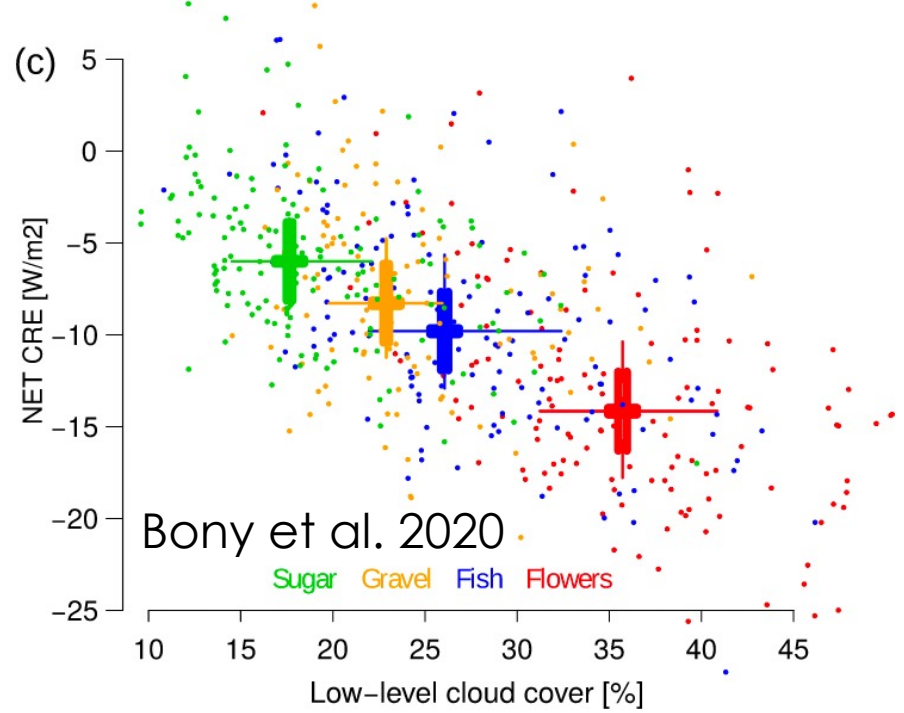
Motivation



C³ONTEXT ID, Schulz 2022

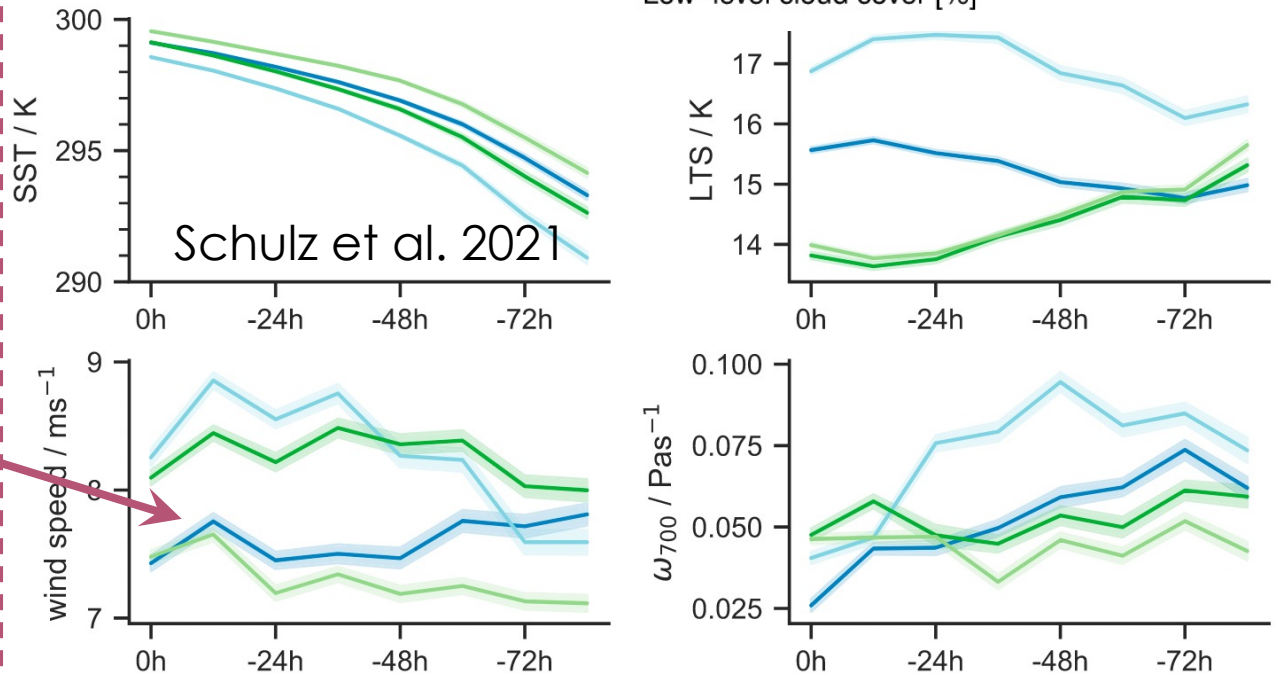


Mesoscale morphologies have distinct radiative properties (Bony et al. 2020) and Lagrangian evolution (Schulz et al. 2021).

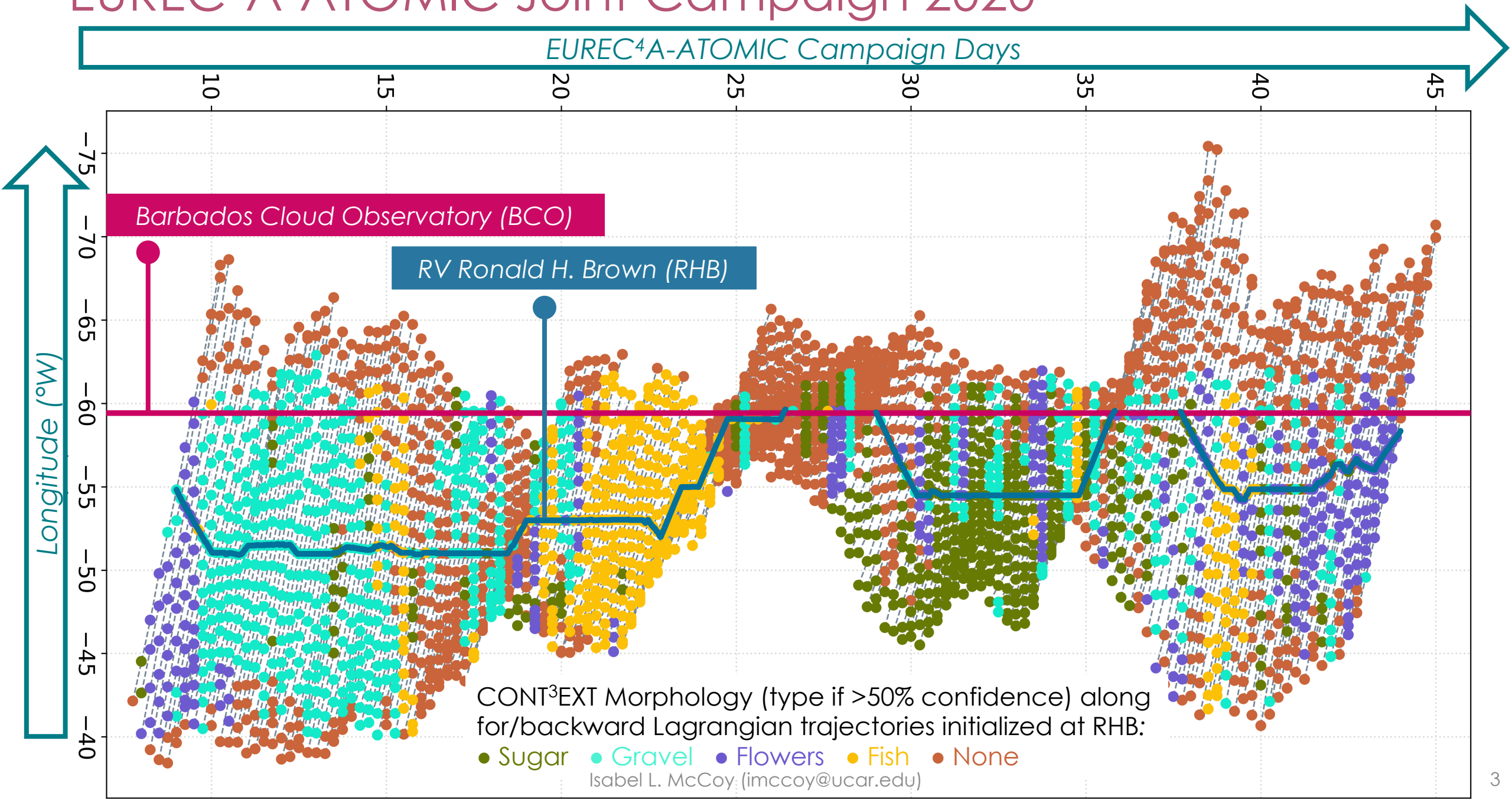
EUREC⁴A was designed to investigate the controls on convective mass flux and mesoscale organization, among other things (Bony et al. 2017).

Motivating questions:

- How do diurnal cycles assist morphology transitions and morphology persistence?
- Does mass flux differ between morphologies?
- Does mass flux change under Lagrangian and diurnal evolution?



EUREC^{4}A-ATOMIC Joint Campaign 2020



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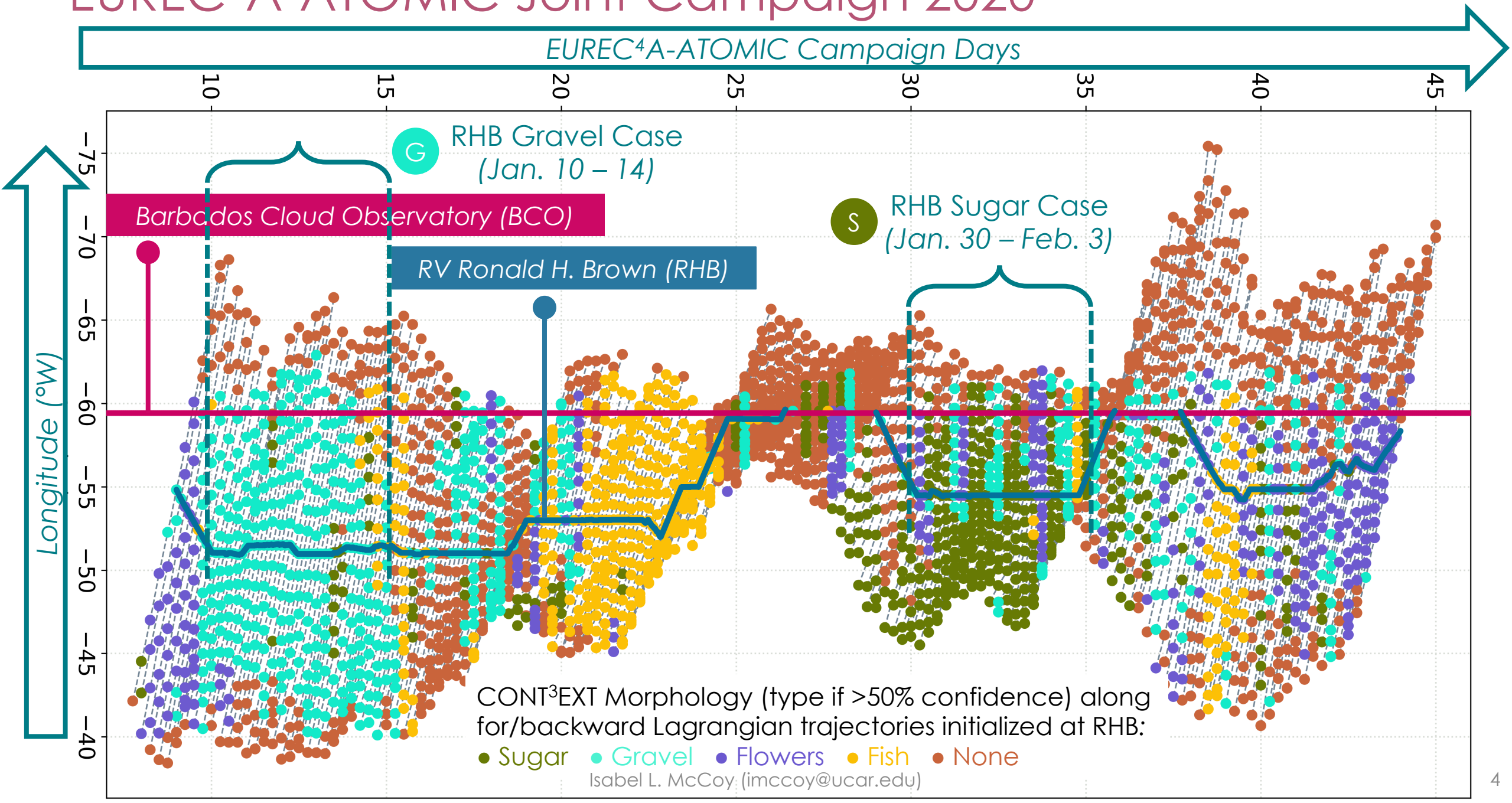
EUREC⁴A-ATOMIC Joint Campaign 2020



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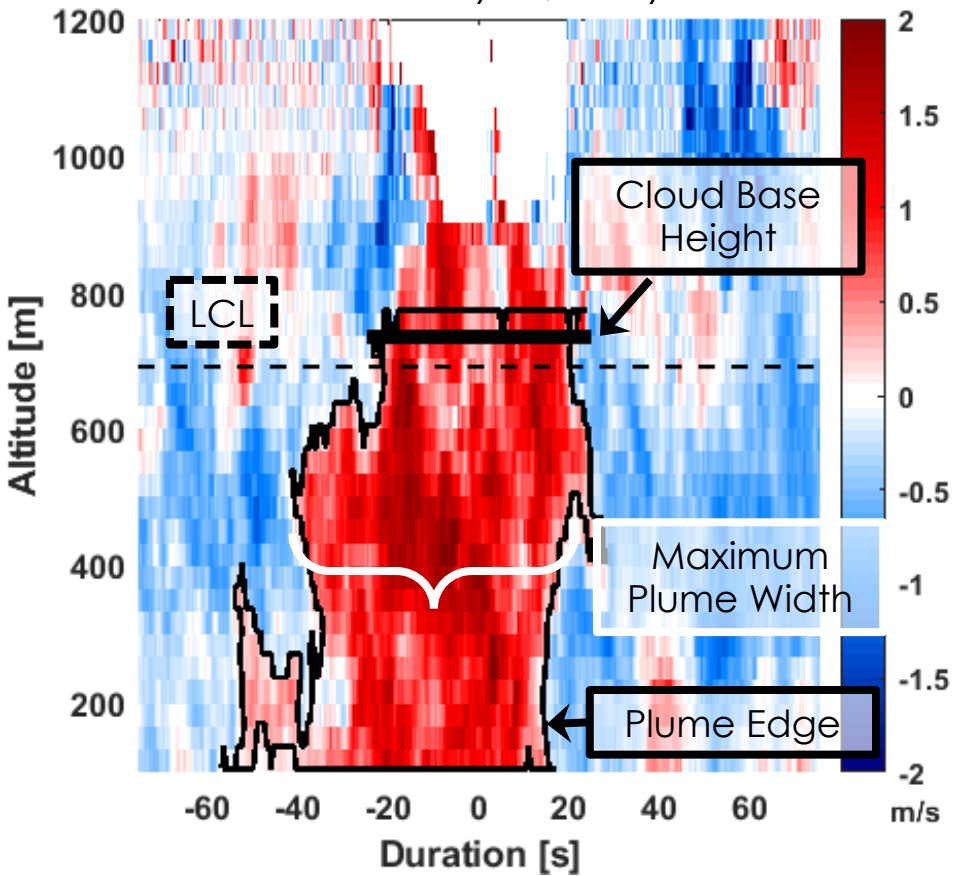
Similar Platform Observations

BCO and RHB have a (stabilized) Doppler-lidar, facilitating Lagrangian evolution comparisons of vertical velocity (w), cloud fraction (CF), and convective mass flux (M). Measurements taken on the RHB near the BCO (Jan. 24) compared favorably (BCO CF slightly lower).

Individual cloud identified at RHB (Gravel, February 11, 2020)



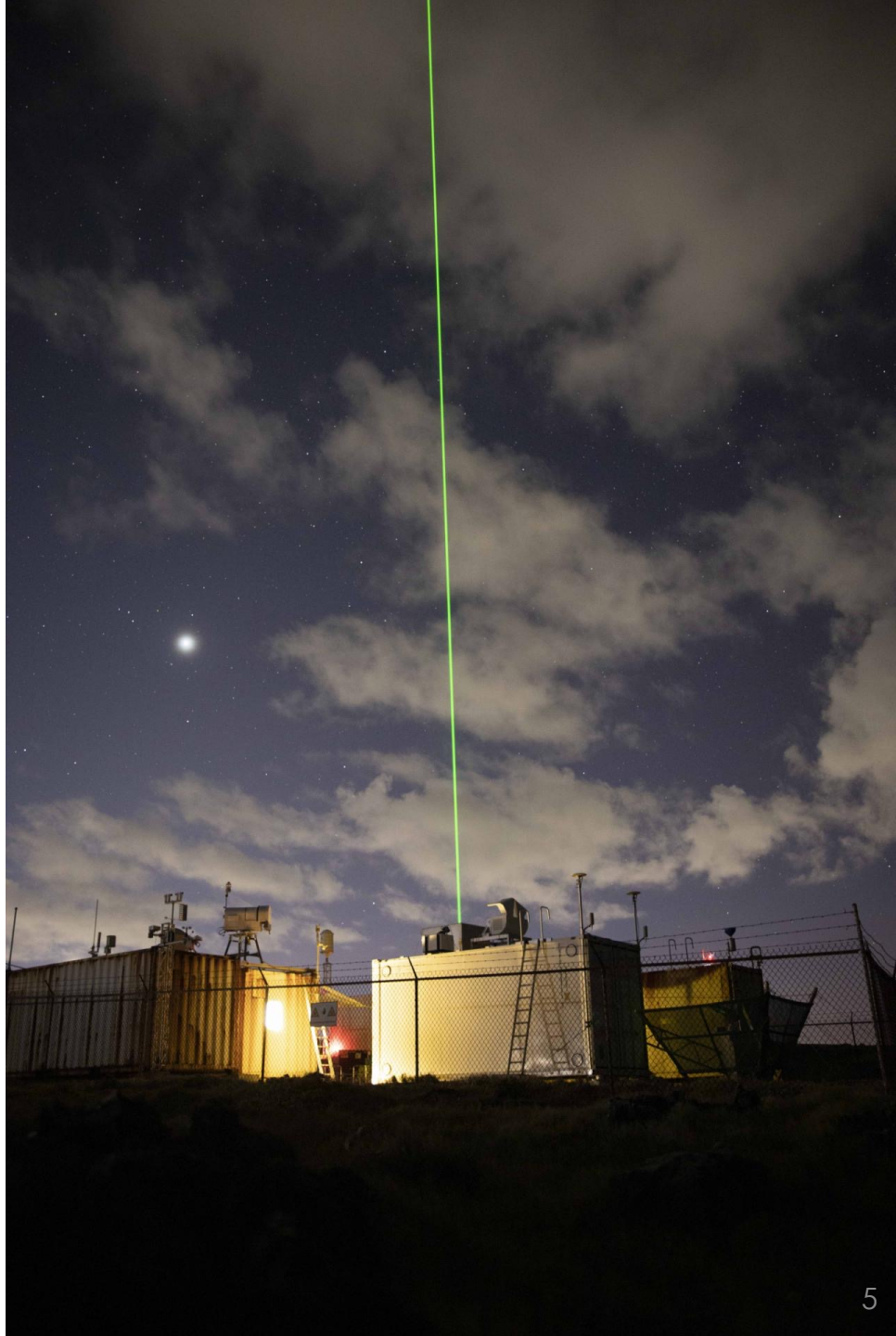
Hourly mass fluxes (computed following Arakawa 2004):

$$M = \sum_{i=1}^{N} \rho . w_i . \sigma_i$$

w_i is the mean cloud base vertical velocity of the ith cloud, σ_i is the fractional cloud cover over an hour

$$\sigma_i = \frac{L_i}{3600.s} = \frac{d_i}{3600}$$

L_i is cloud chord length, d_i is duration, s is speed.



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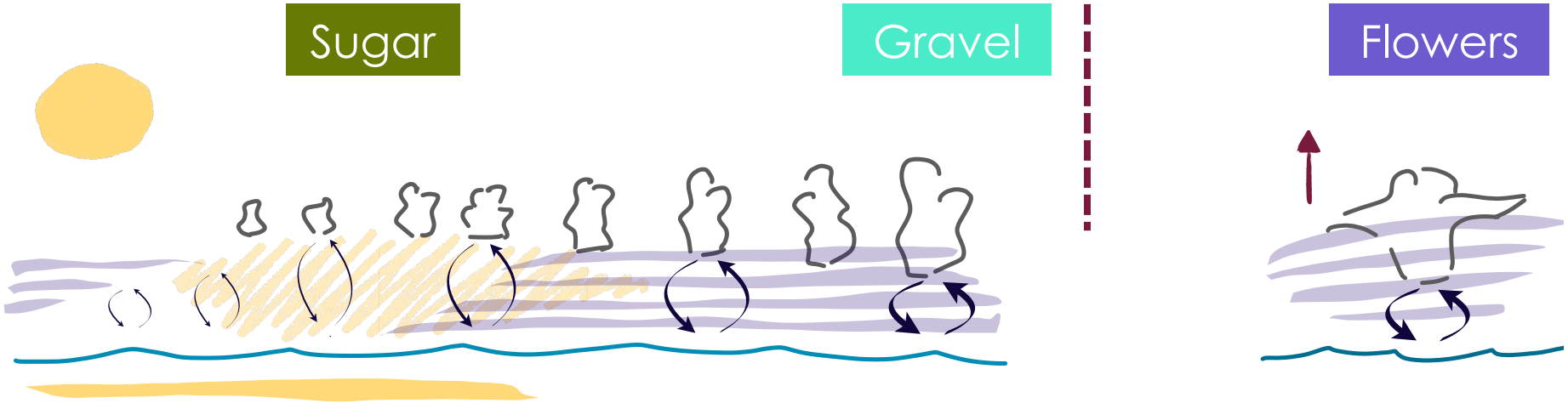
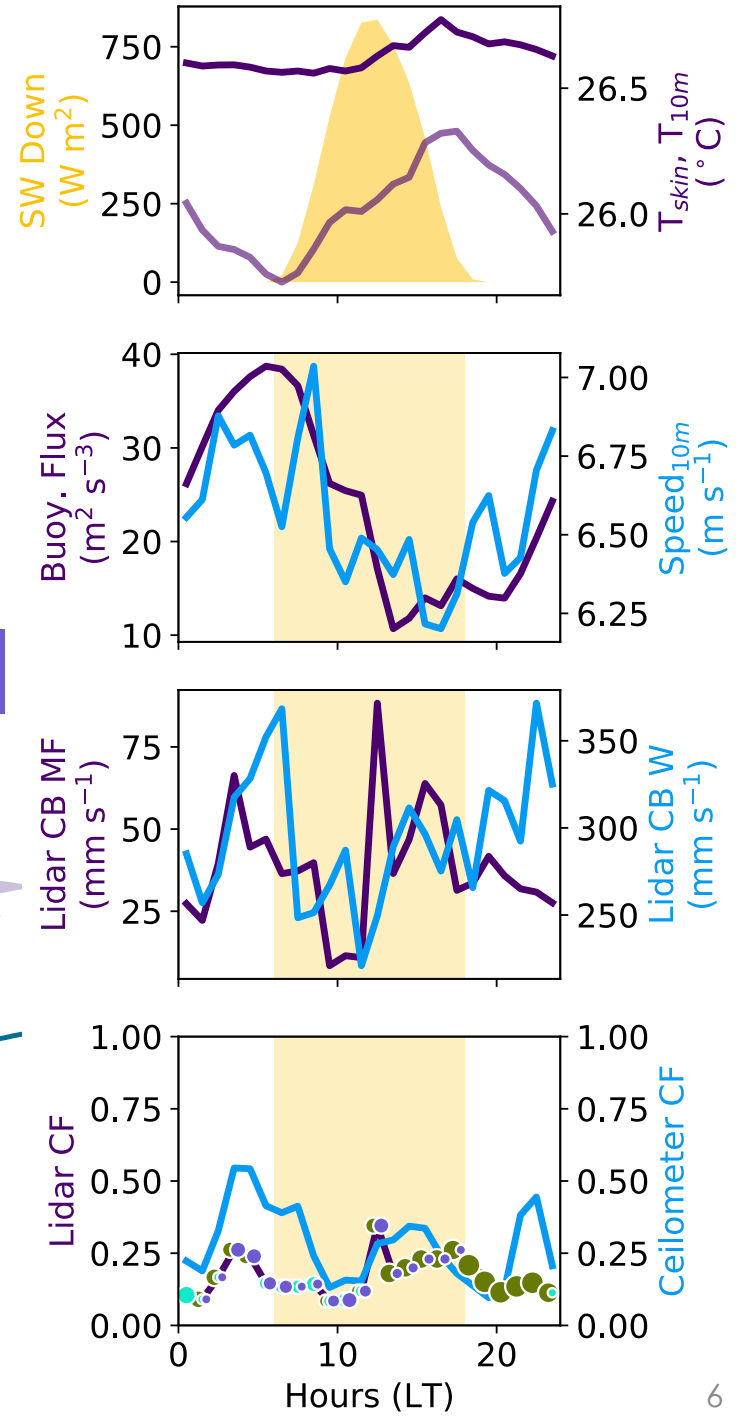
Diurnal Cloud Evolution

- Diurnal atmospheric heating observed at the RHB may help Sugar transition to Gravel/Flowers.





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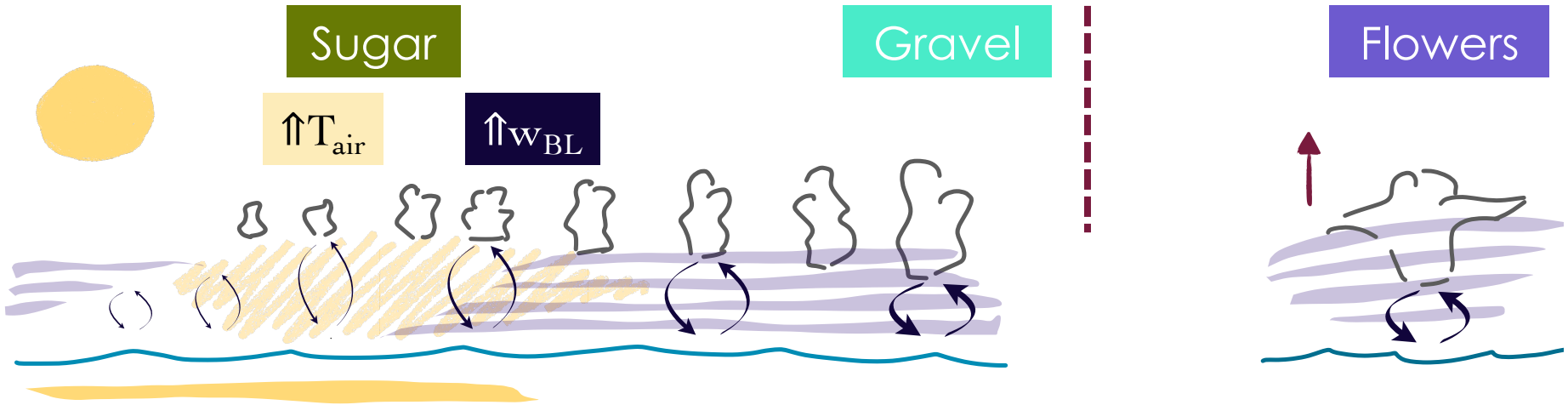
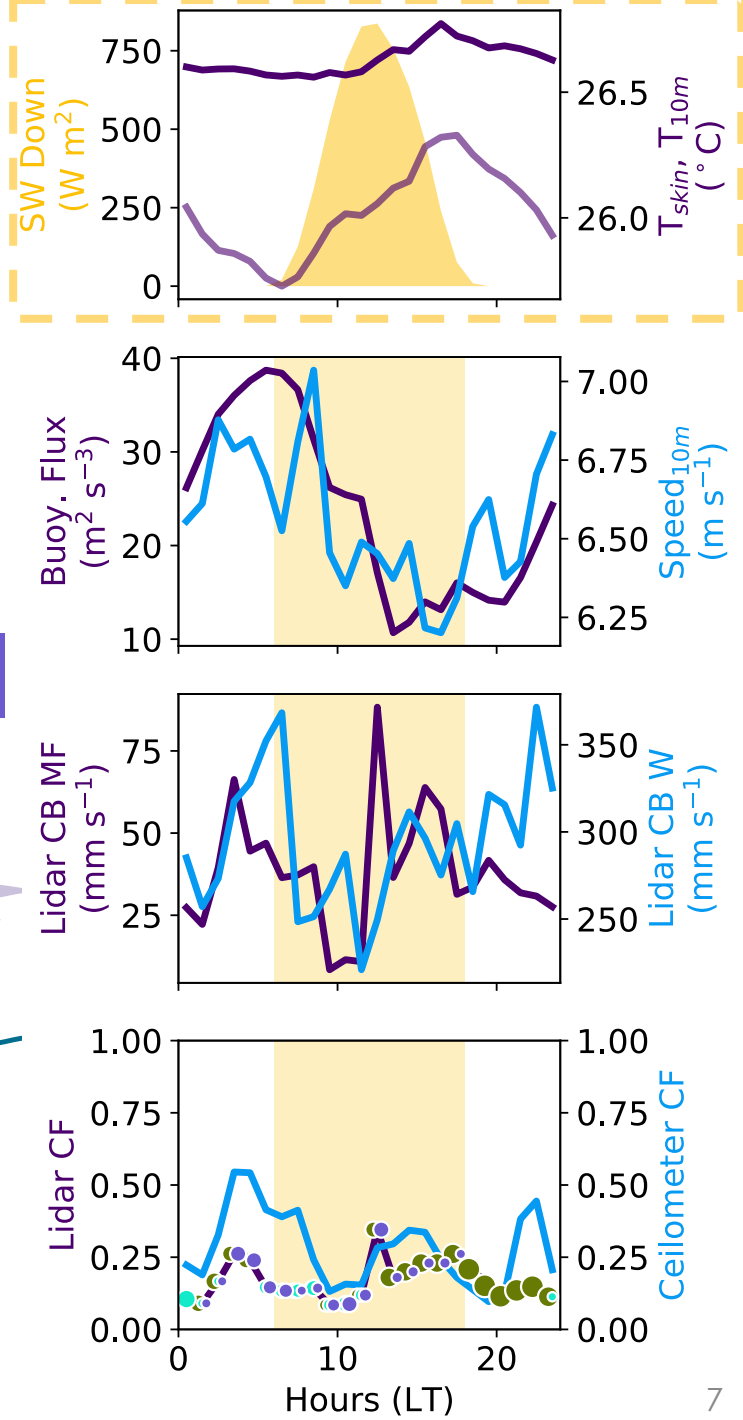
Atmospheric heating helps afternoon cloud development.





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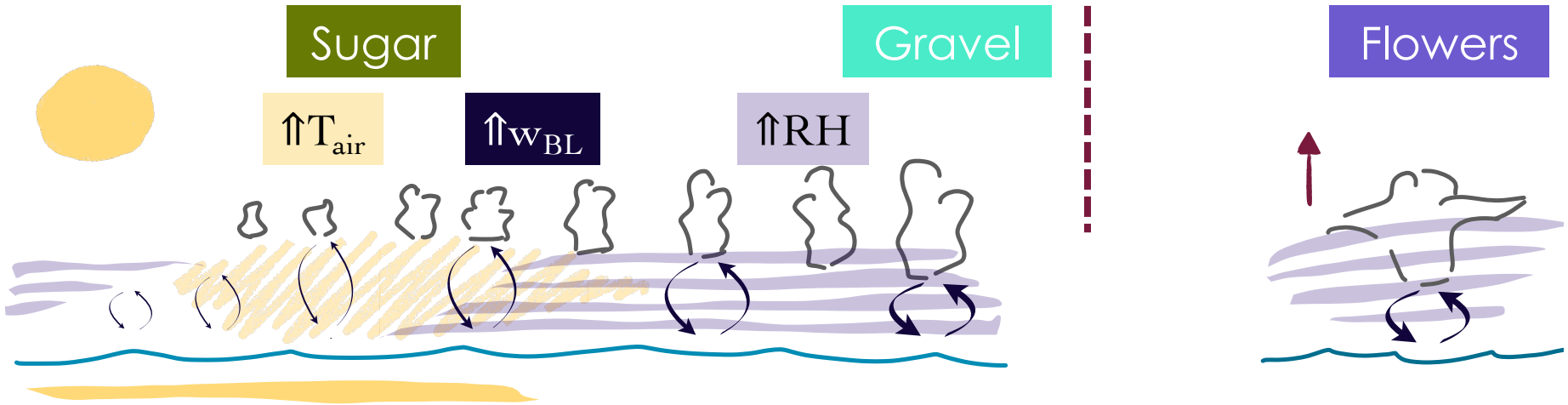
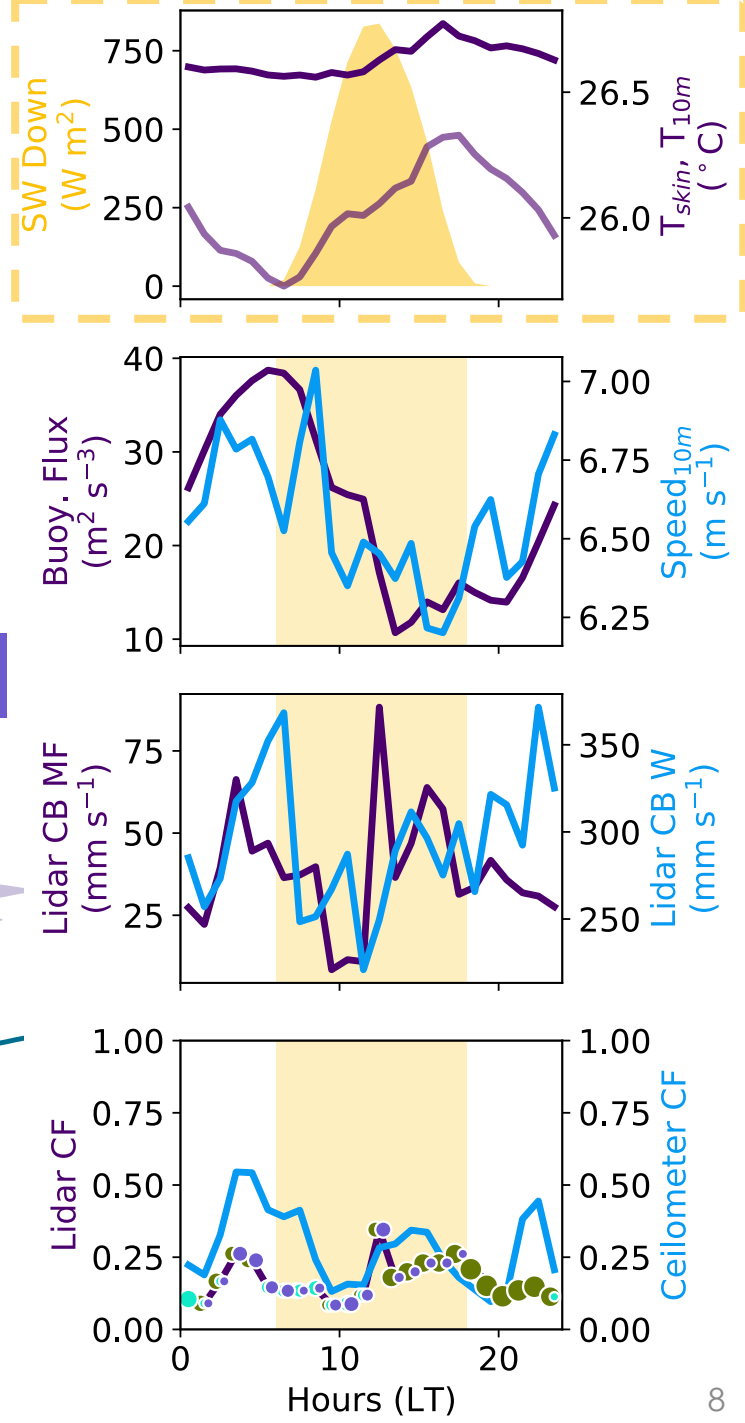
Atmospheric heating helps afternoon cloud development.

Moist layer development during transition potentially aids cloud recovery.





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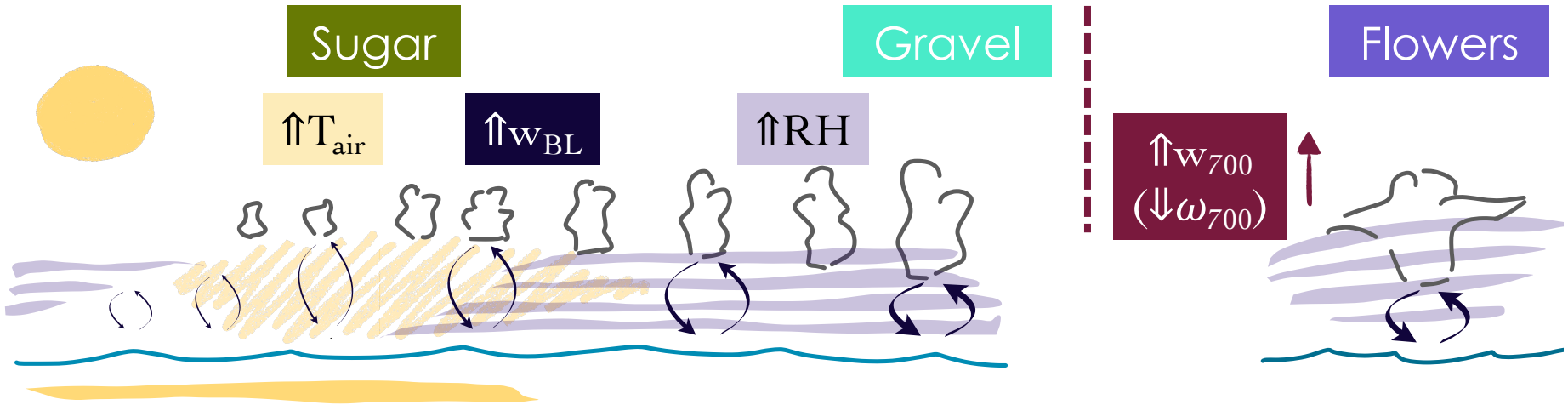
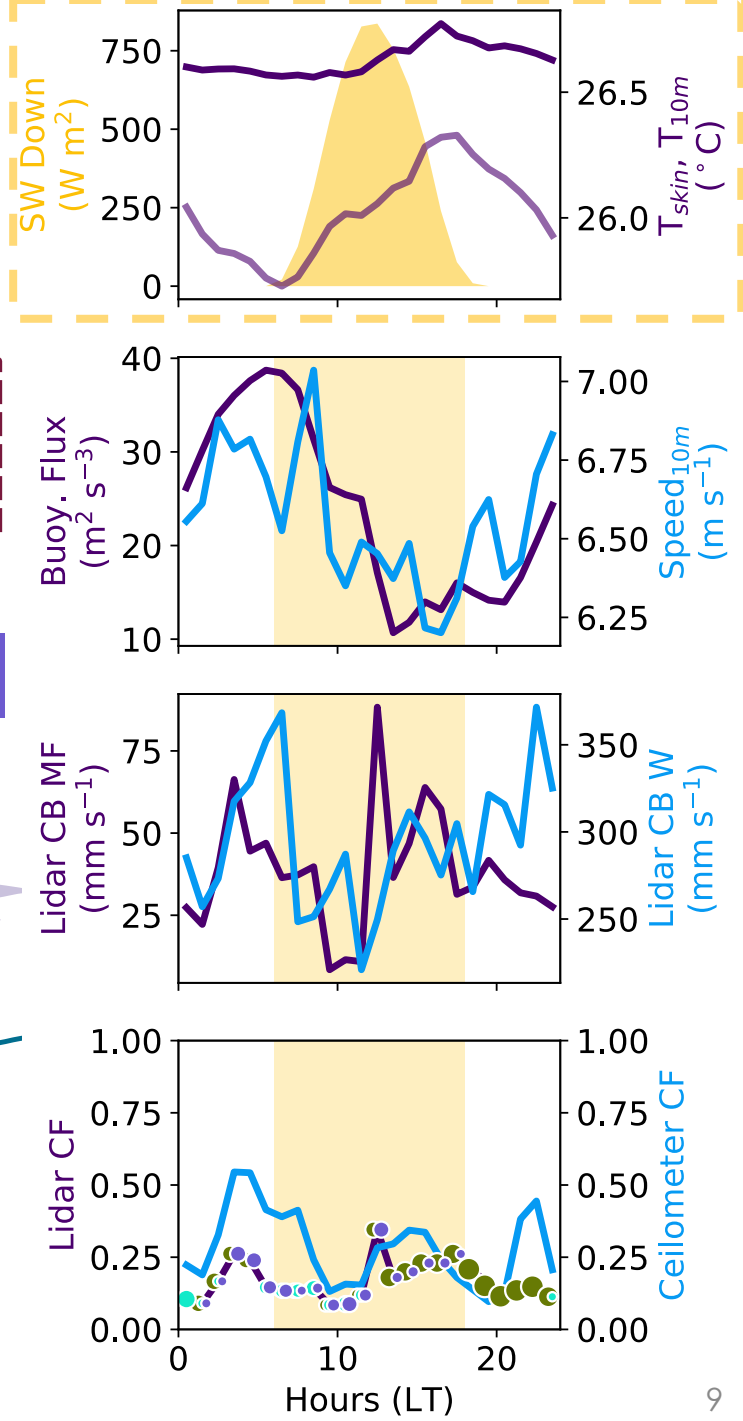
Under large-scale ascent, afternoon clouds can deepen further into Flowers.

Narenpitak et al. 2021, 2022





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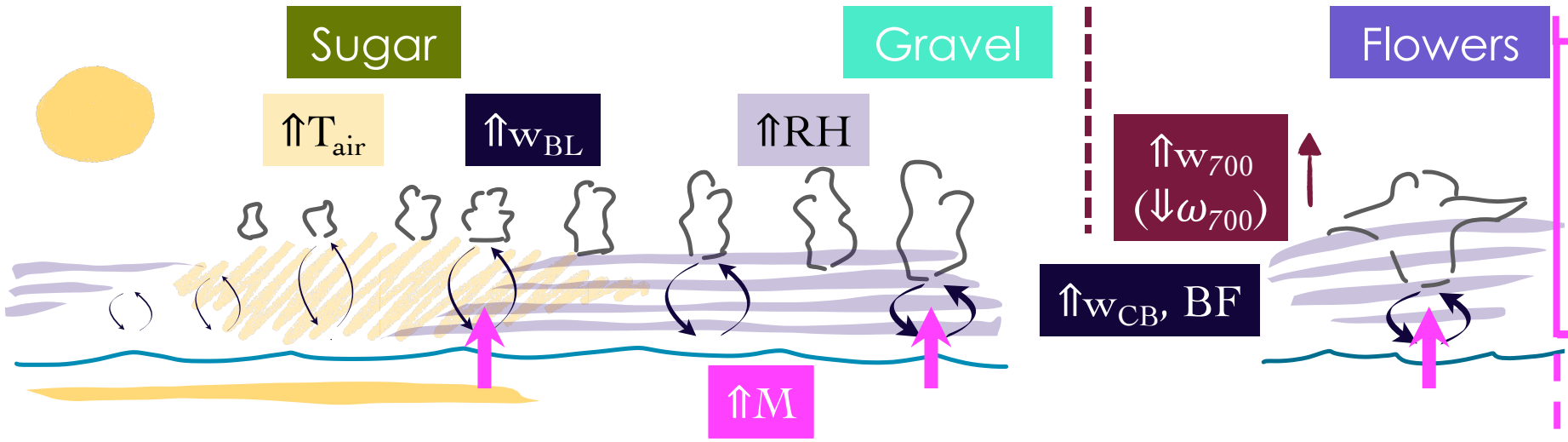
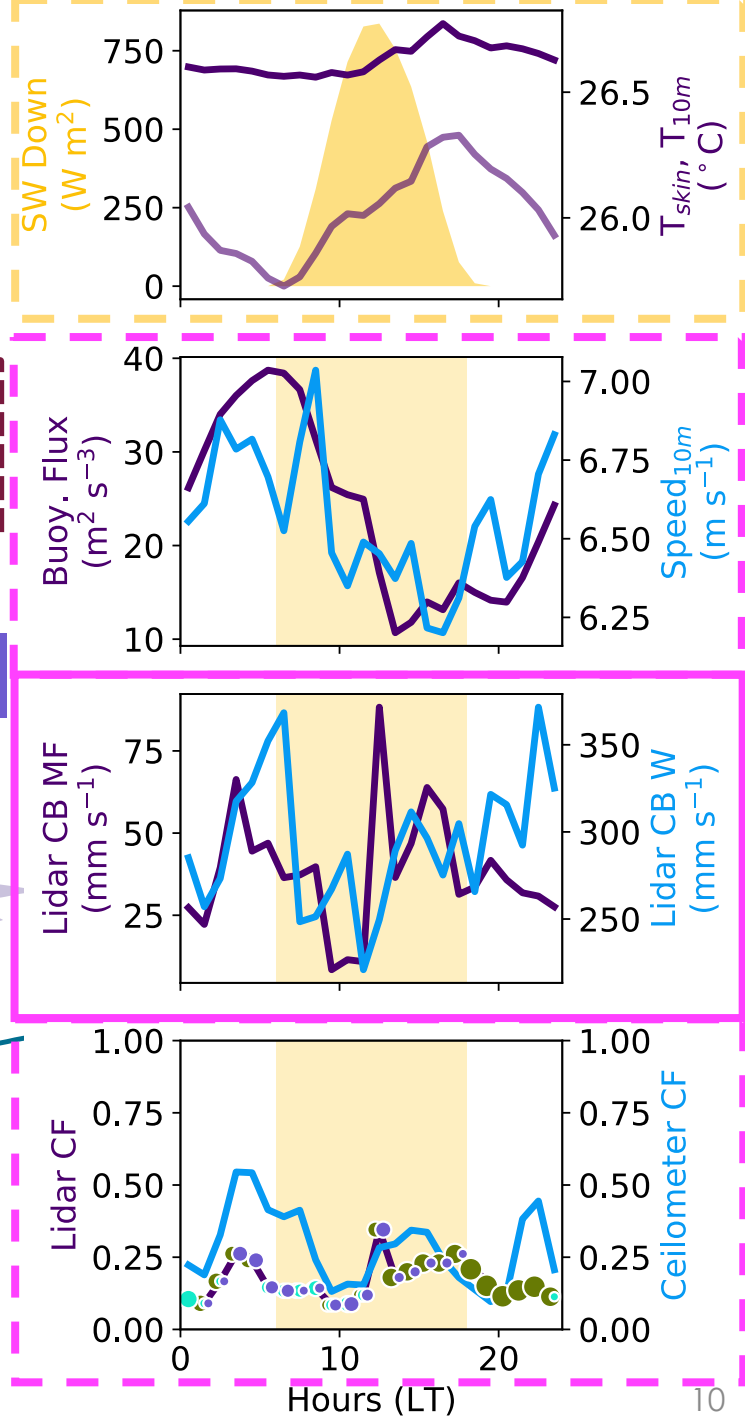


Mass flux exhibits two peaks, suggesting two cycles may be present associated with smaller afternoon (amount driven) and larger night time clouds (buoyancy/updraft driven).



Lagrangian Cloud Evolution from RHB to BCO

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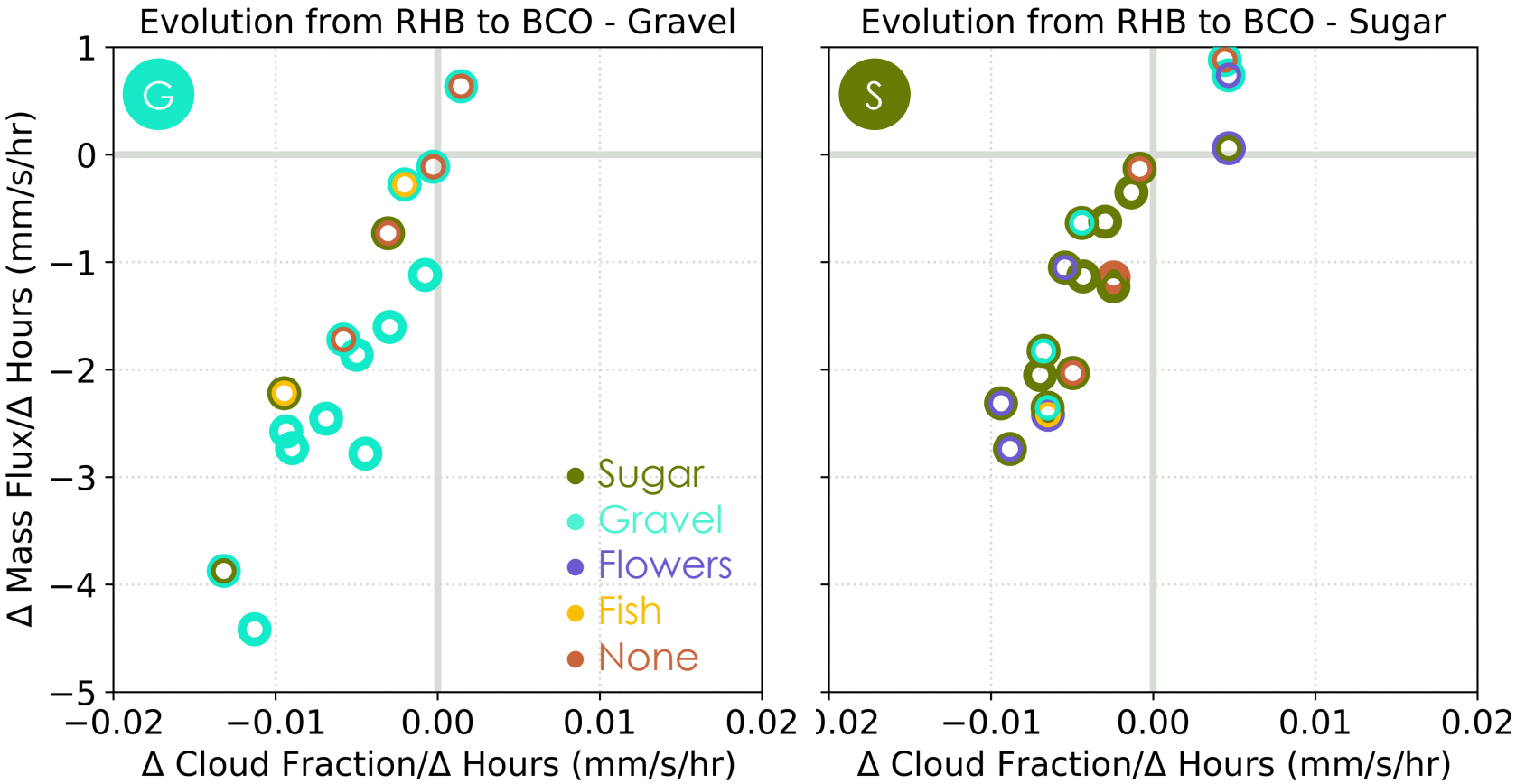
From RHB to BCO, CF and M decrease for both the Sugar and Gravel cases.
No clear difference between types of morphology transitions.



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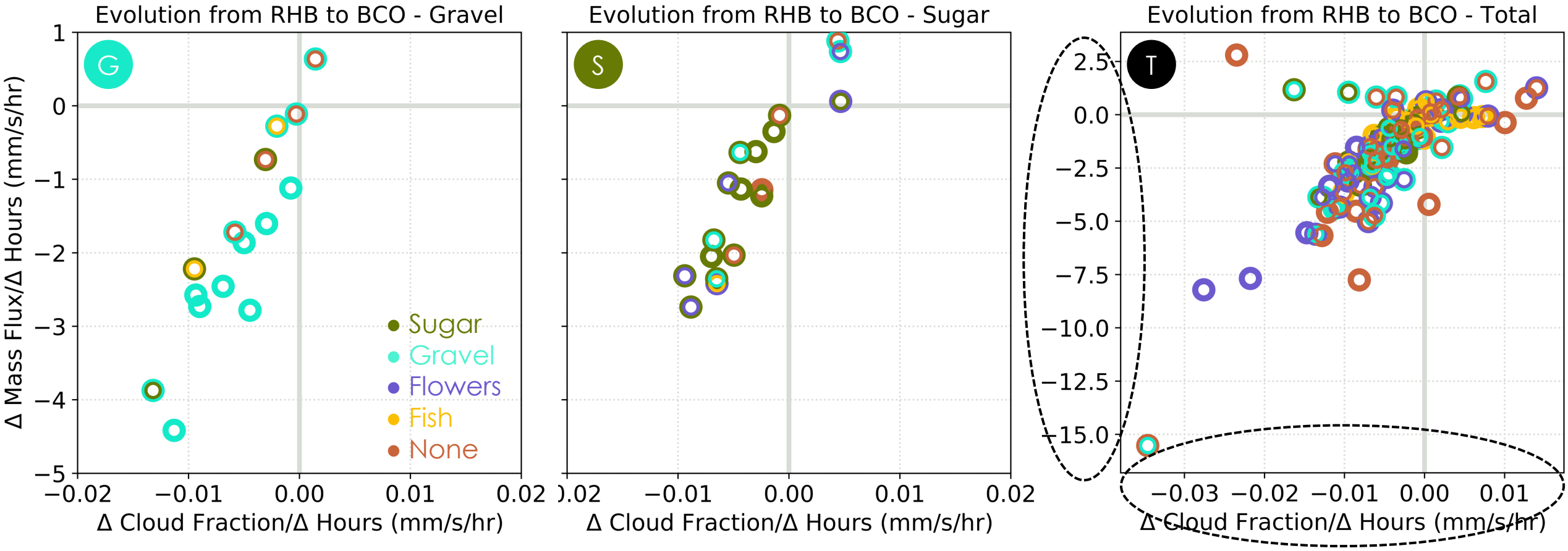
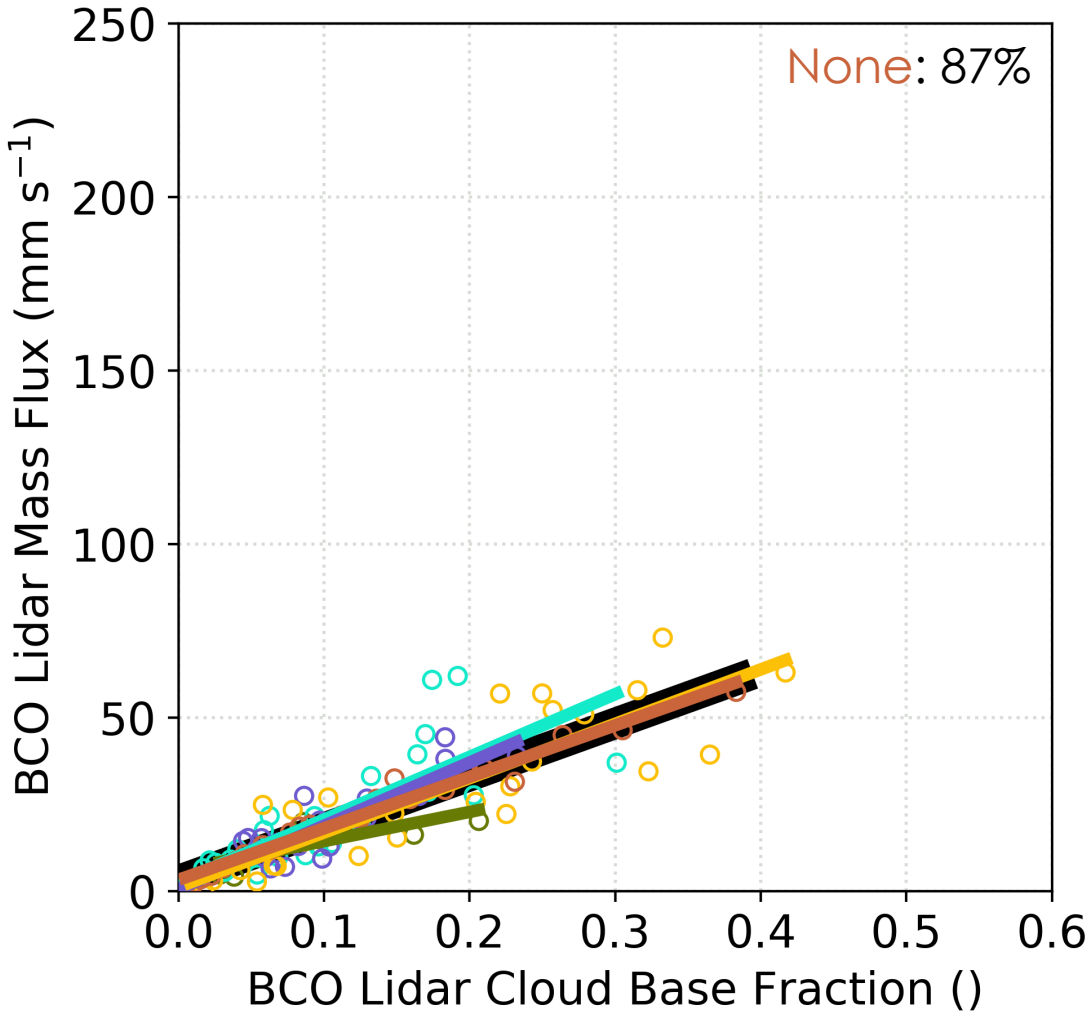
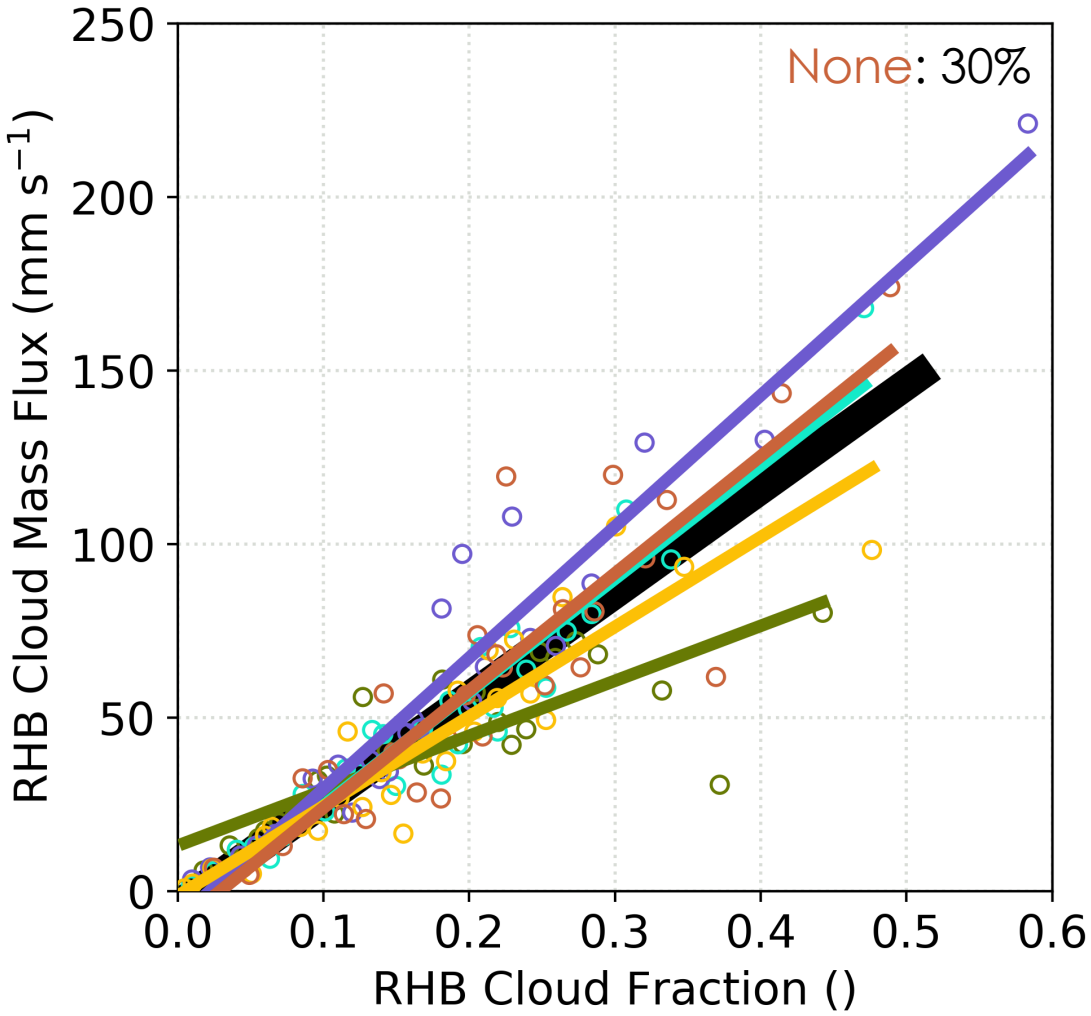


M Dependence at RHB vs. BCO

RHB has higher CF and larger M than at BCO. More morphologies are identified at RHB than BCO.





● Sugar ● Gravel ● Flowers ● Fish ● None

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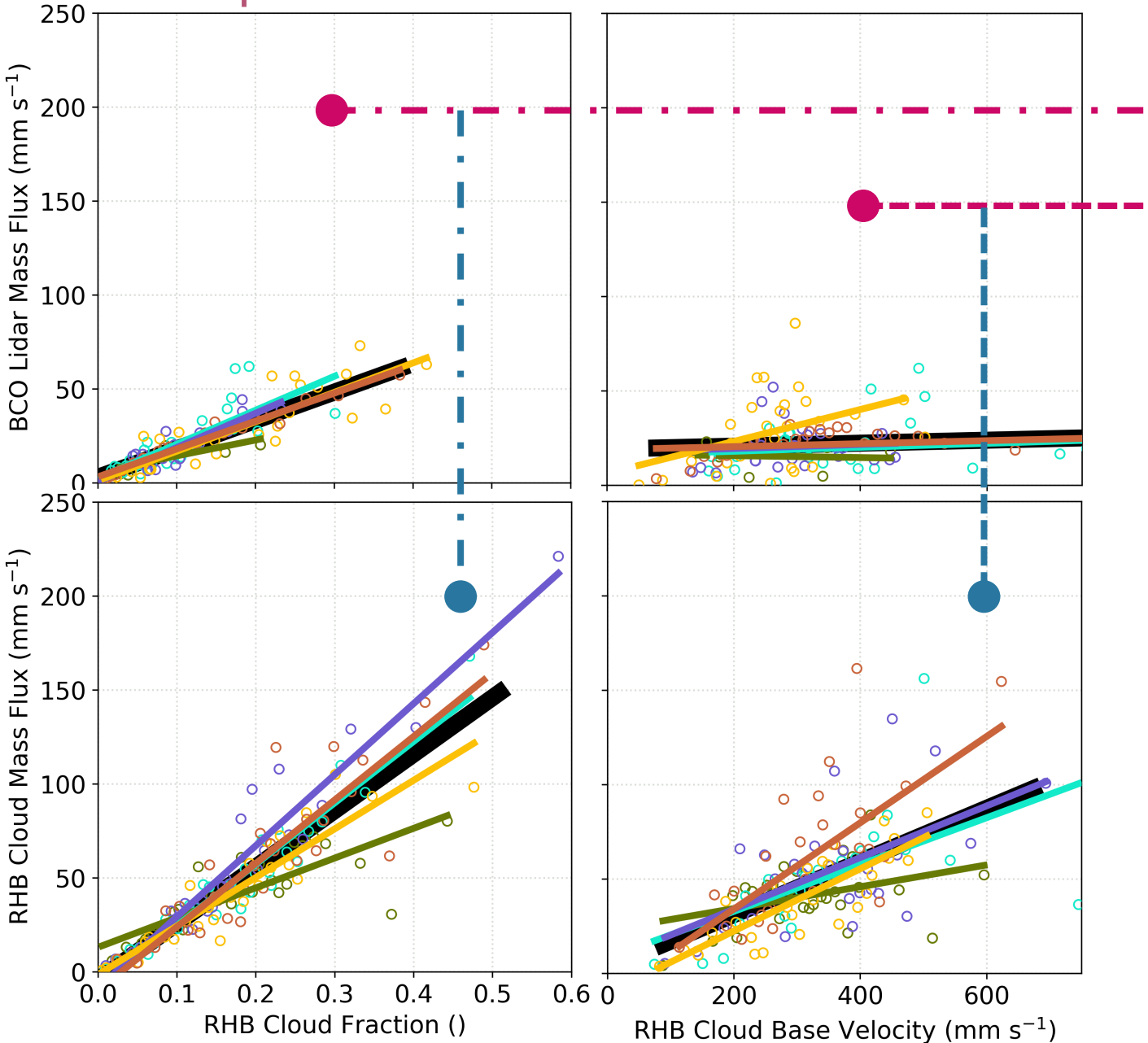
M Dependence at RHB vs. BCO



RHB has a stronger M dependence on CF

$R^2_{BCO\ CF} < R^2_{RHB\ CF}$

and on w

$R^2_{BCO\ w} < R^2_{RHB\ w}$

than at BCO (BCO behavior is similar to Klingebiel et al. 2021).

M relationships differ by morphology at RHB:

$R^2_{RHB\ CF}$, $R^2_{RHB\ w}$ for G, F > S

● Sugar ● Gravel ● Flowers ● Fish ● None

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Summary

- Diurnal cycle of atmospheric heating during Sugar occurrence may assist transitions to Gravel (and Flowers under large-scale ascent).
- Lower cloud amount and mass flux at BCO vs. RHB during the EUREC^{4}A-ATOMIC campaign. Fewer morphology identifications at BCO.
- Mass flux variance is most explained by cloud amount.
- Vertical velocity contributes to mass flux at RHB, more for larger cloud types (Gravel, Flowers vs. Sugar).

Open Questions

- Is Gravel more persistent when the large scale environment assists in its development vs. when it transitions from Sugar?
- What are the implications of this in a future climate where we expect Sugar to be more favored than Gravel (higher SST, higher EIS, e.g., Bony et al. 2020)?

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Thank you! Questions?
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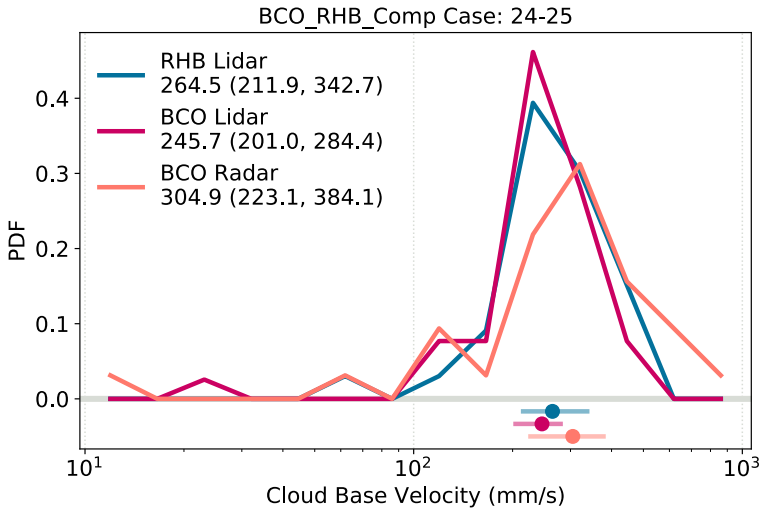
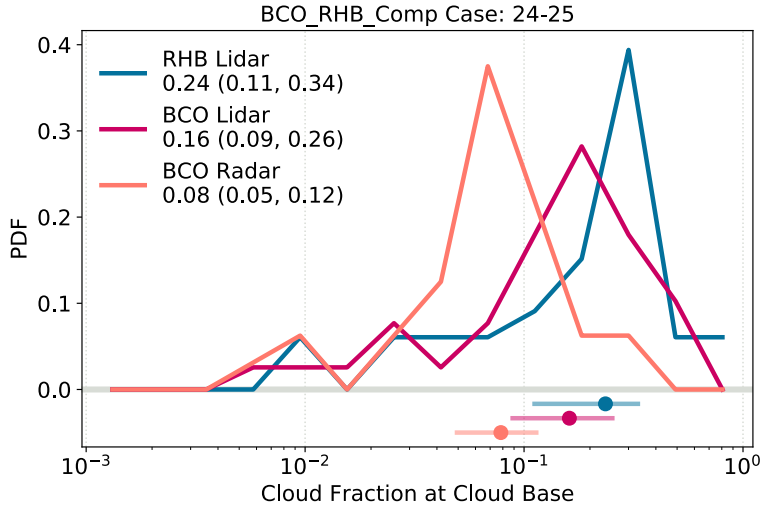
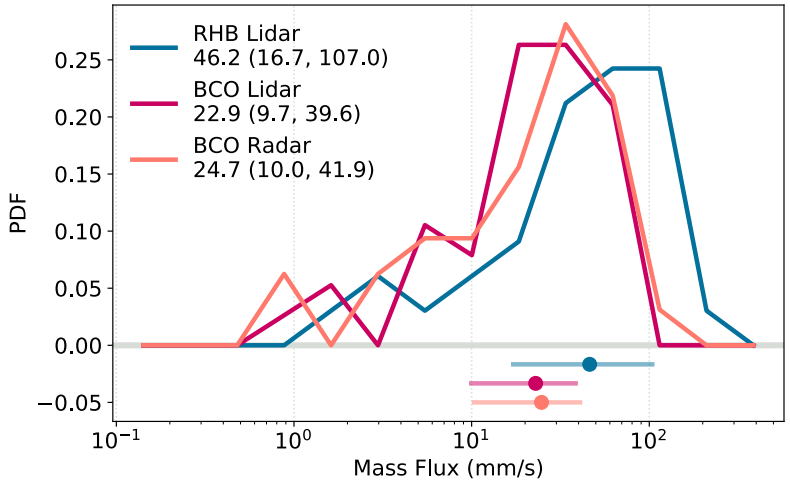
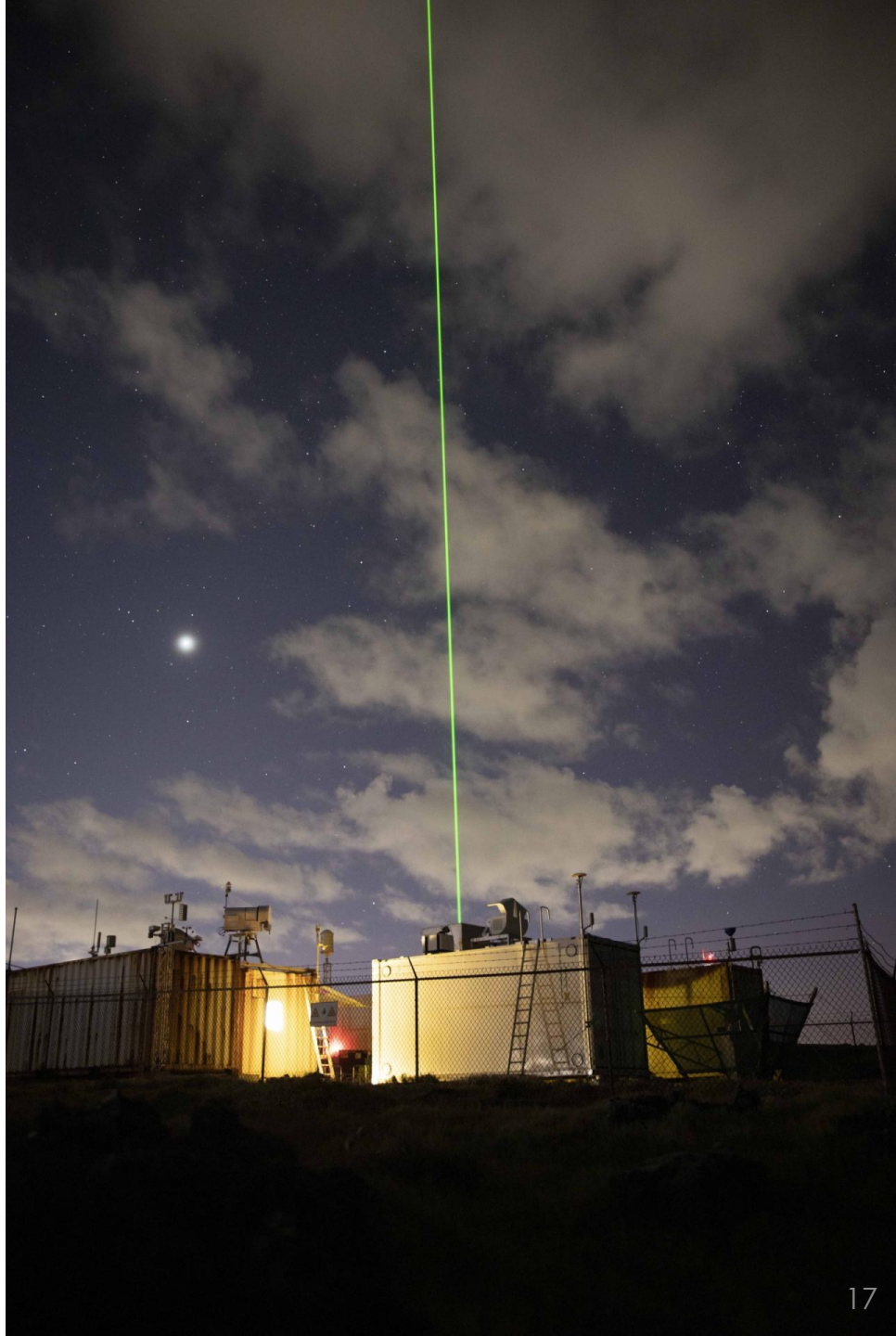
Matched Platform Observations

BCO (Lidar, Radar) and RHB (Lidar) sampled nearby clouds on January 24th. Results were broadly similar, although CF (and thus M) was a little lower at BCO.









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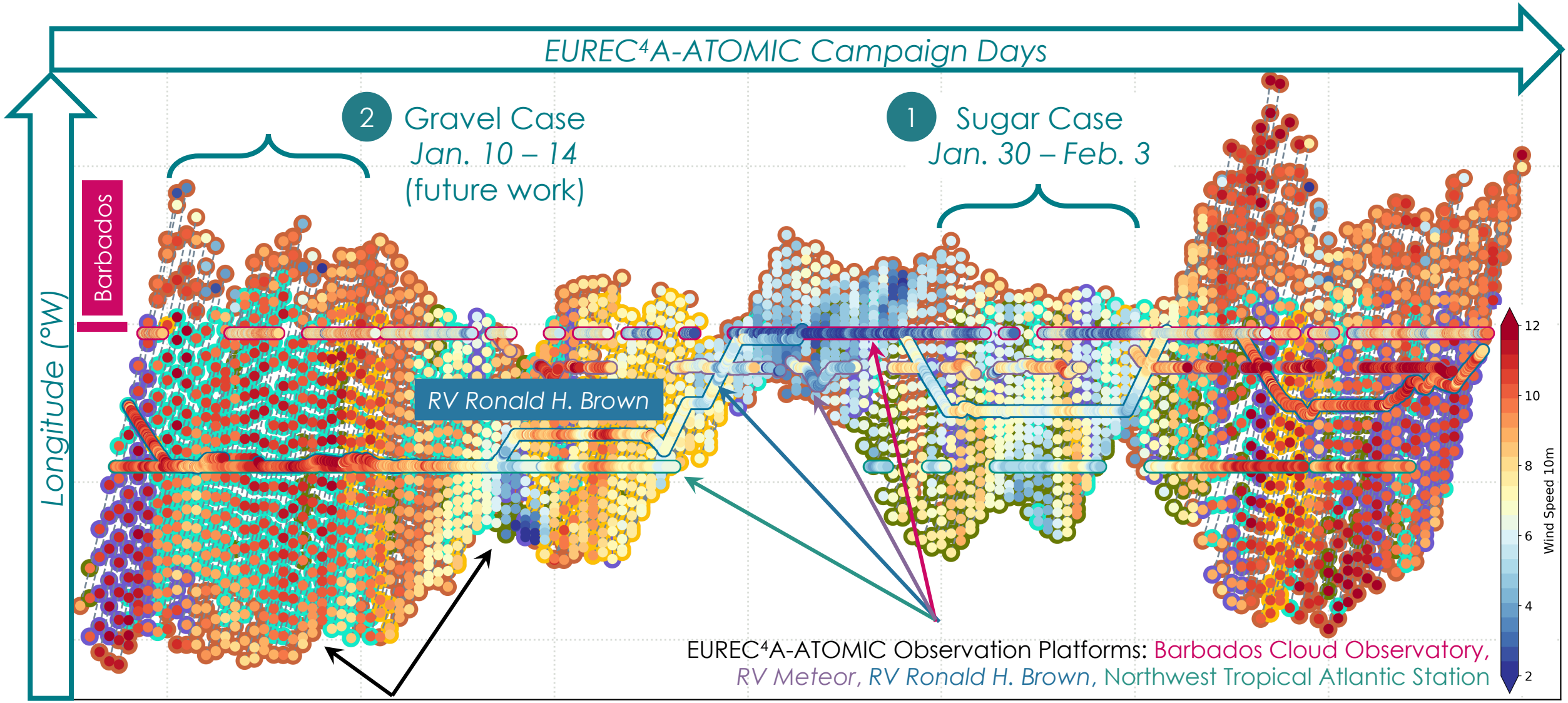
What are the differences between conditions during: (1) a transition from Sugar to Gravel/Flower clouds, and (2) an extended period of Gravel clouds?



CONT³EXT Morphology (along ERA5 for/backward Lagrangian trajectories initialized at the *RV Ronald H. Brown*):

● Sugar ● Gravel ● Flowers ● Fish ● None

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