Observational analysis of Stratocumulus-to-cumulus Transition over North Pacific Ocean

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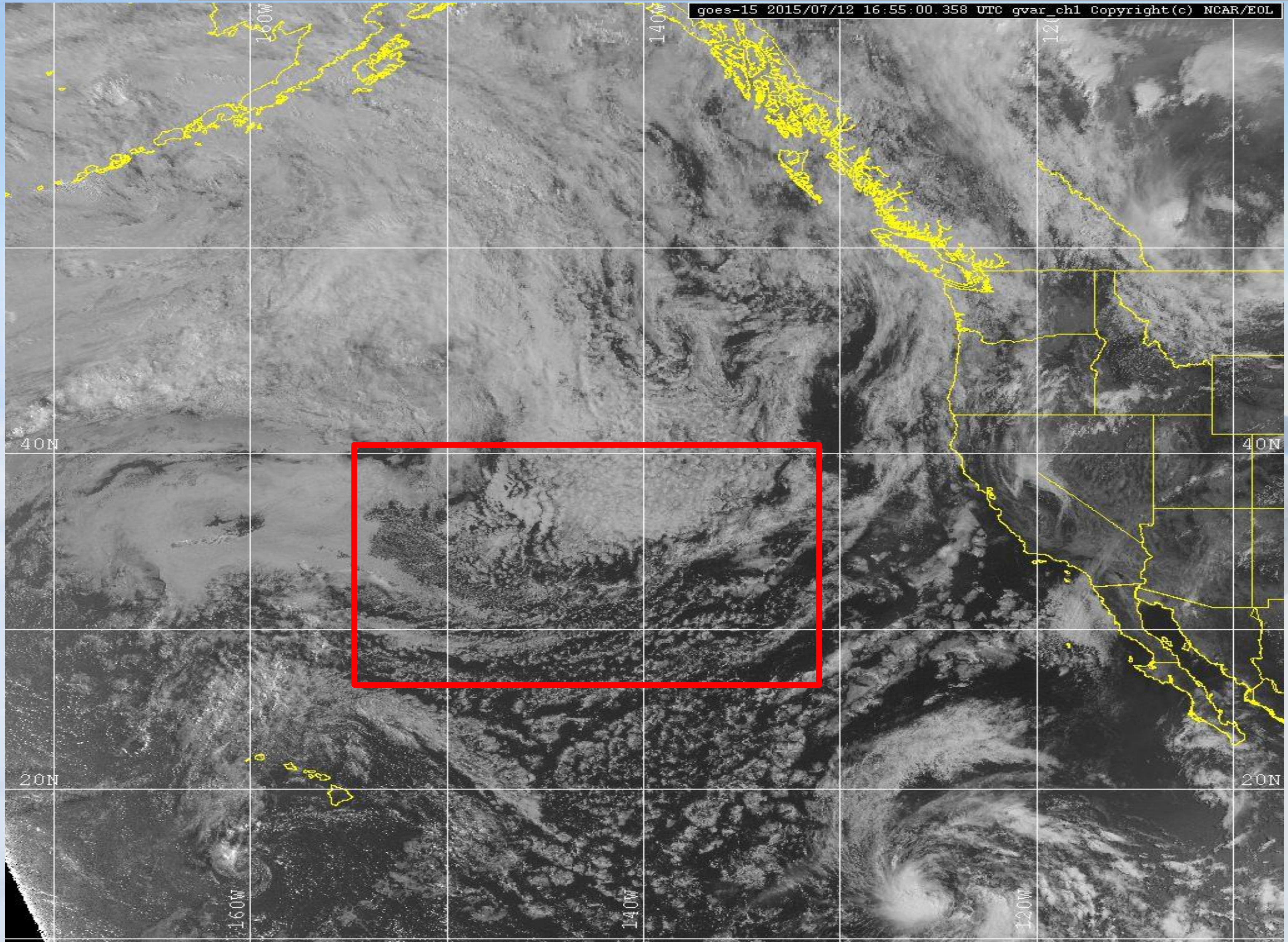
Cloud System Evolution in the Trades
CSET

Stratocumulus-to-cumulus transition



A striking feature of the global cloud climatology is the transition from unbroken sheets of stratocumulus to fields of scattered cumulus as boundary-layer air masses advect equatorward in the trades

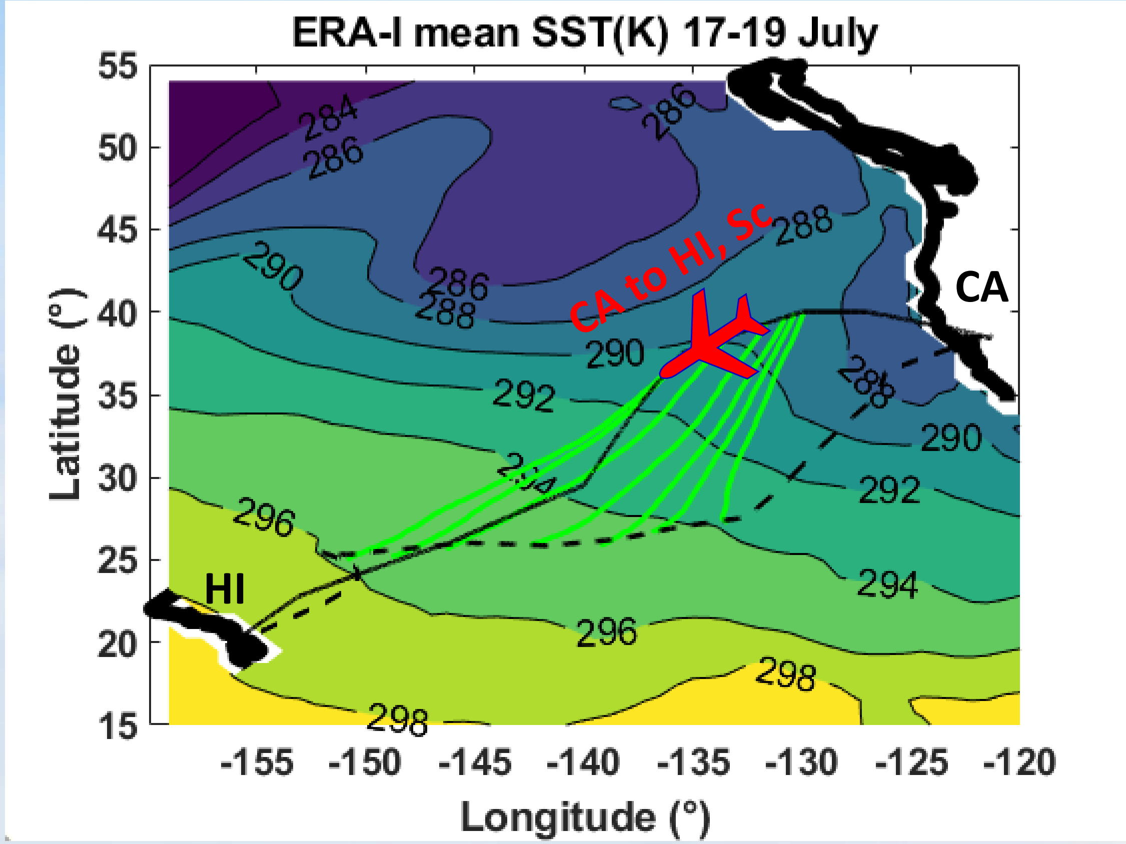
- Decrease in the local albedo **has significant global radiative impacts**.
- Models have difficulty in capturing this transition.

CLOUD SYSTEM EVOLUTION IN THE TRADES (CSET) MISSION

See Albrecht et al., 2019, BAMS for CSET overview

- CSET experiment studied Sc-Cu transition between California and Hawaii (1 July-15 August 2015).
- Air parcels were sampled while moving from CA to HI and then re-sampled two days later while returning from HI to CA.
- NSF/NCAR Gulfstream V conducted 15 research flights. Collected comprehensive in-situ and remote sensing (lidar, radar) datasets in this remote region.

Typical CSET flight-pair



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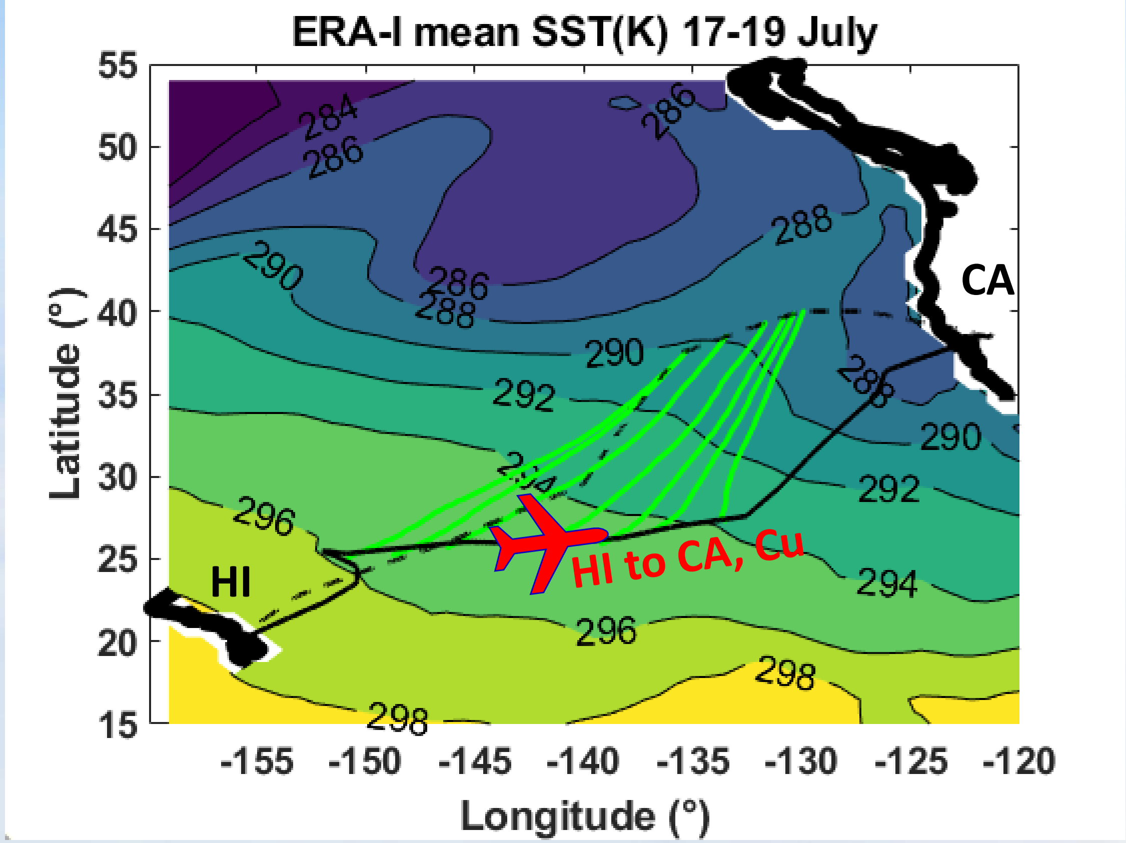

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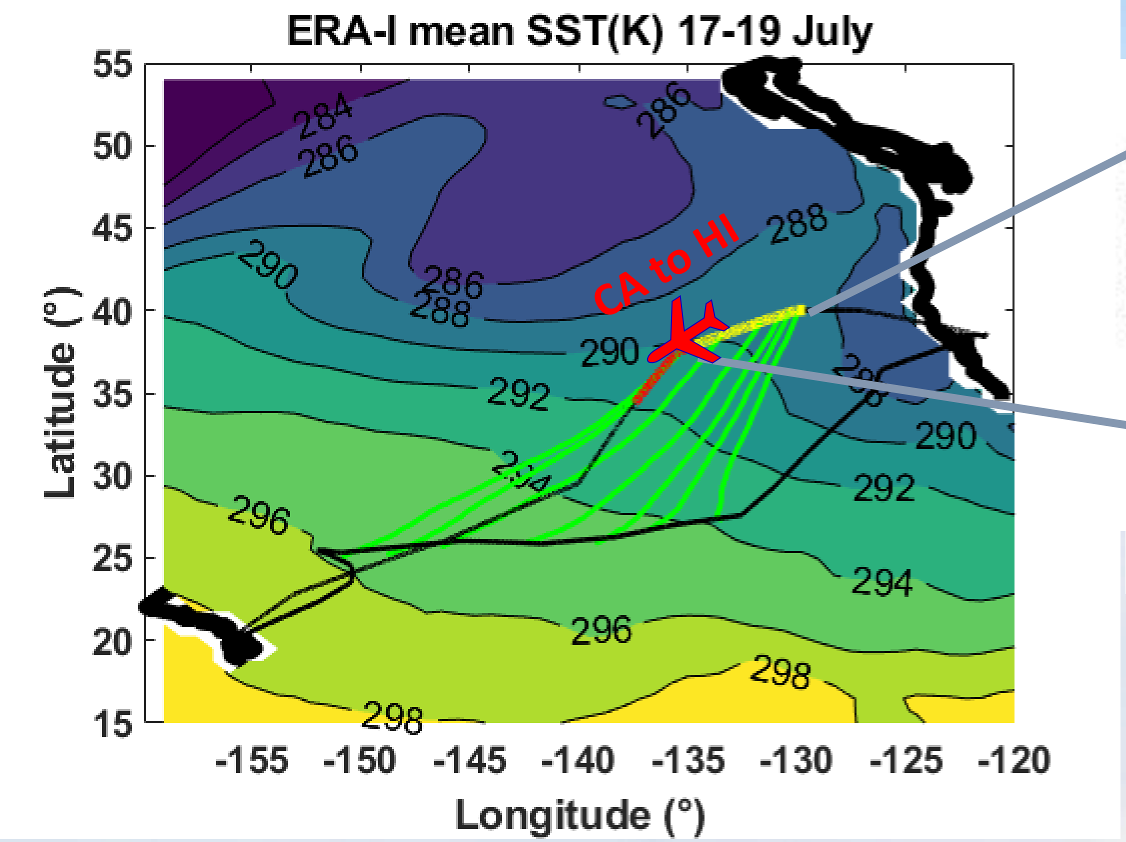


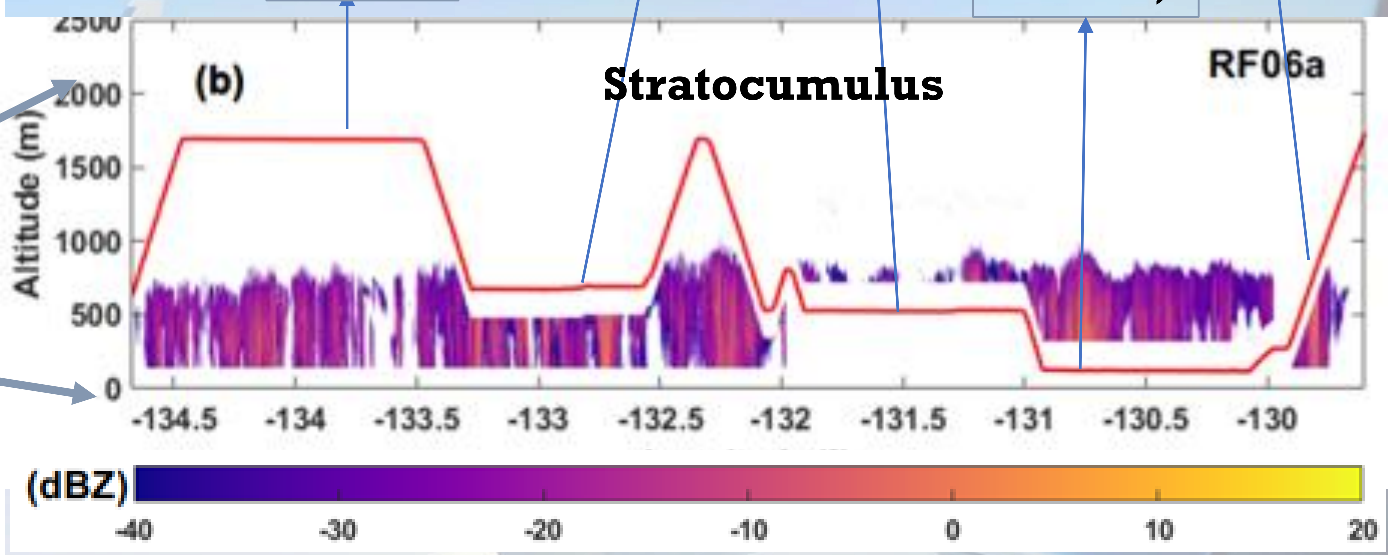
Typical CSET module

Above cloud

In-cloud

150m (near-surface)

Vertical



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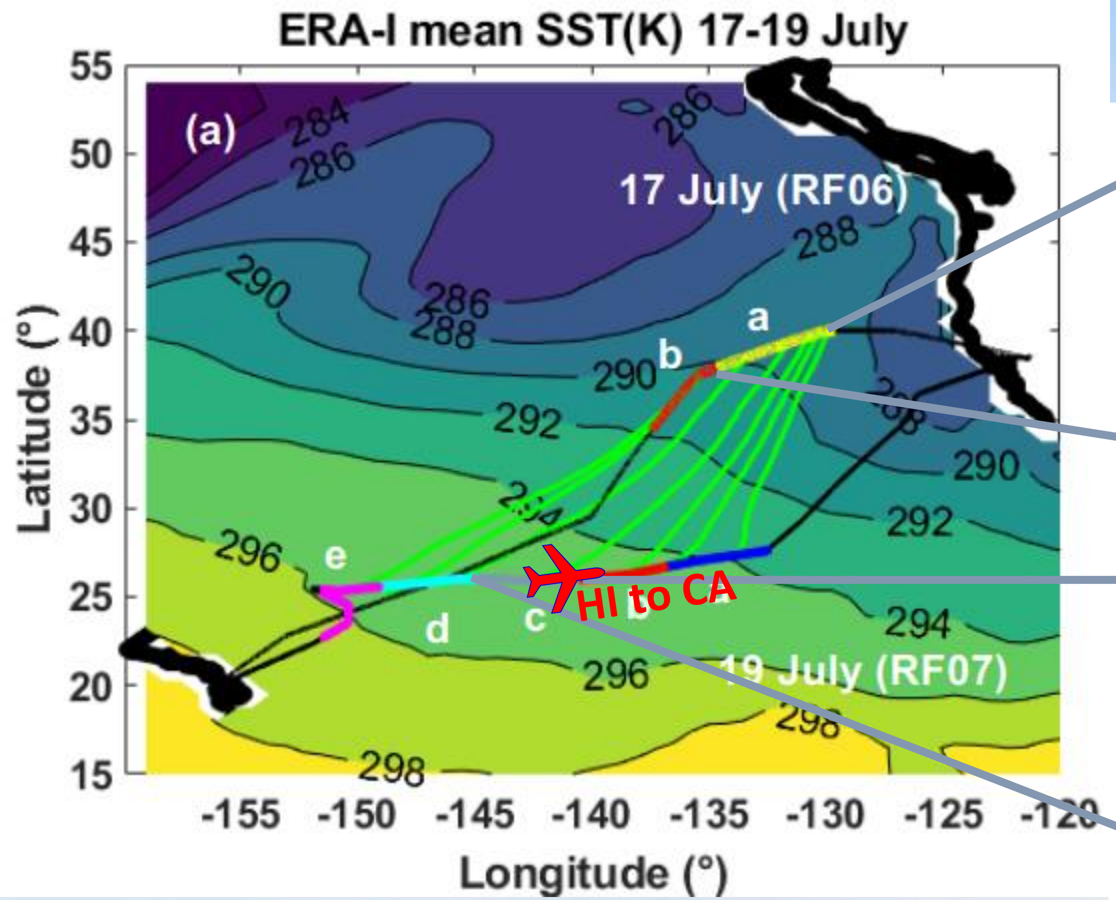
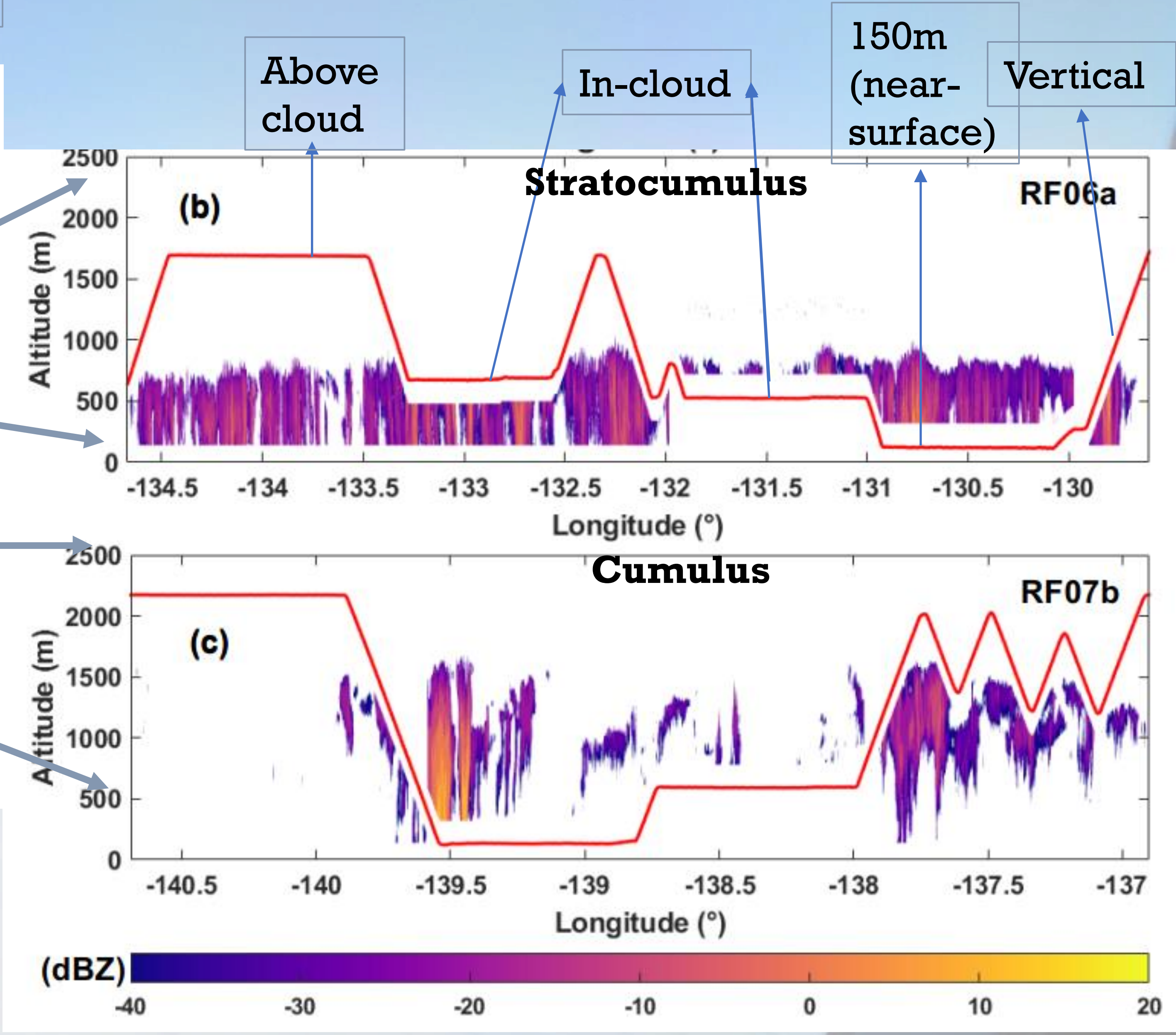
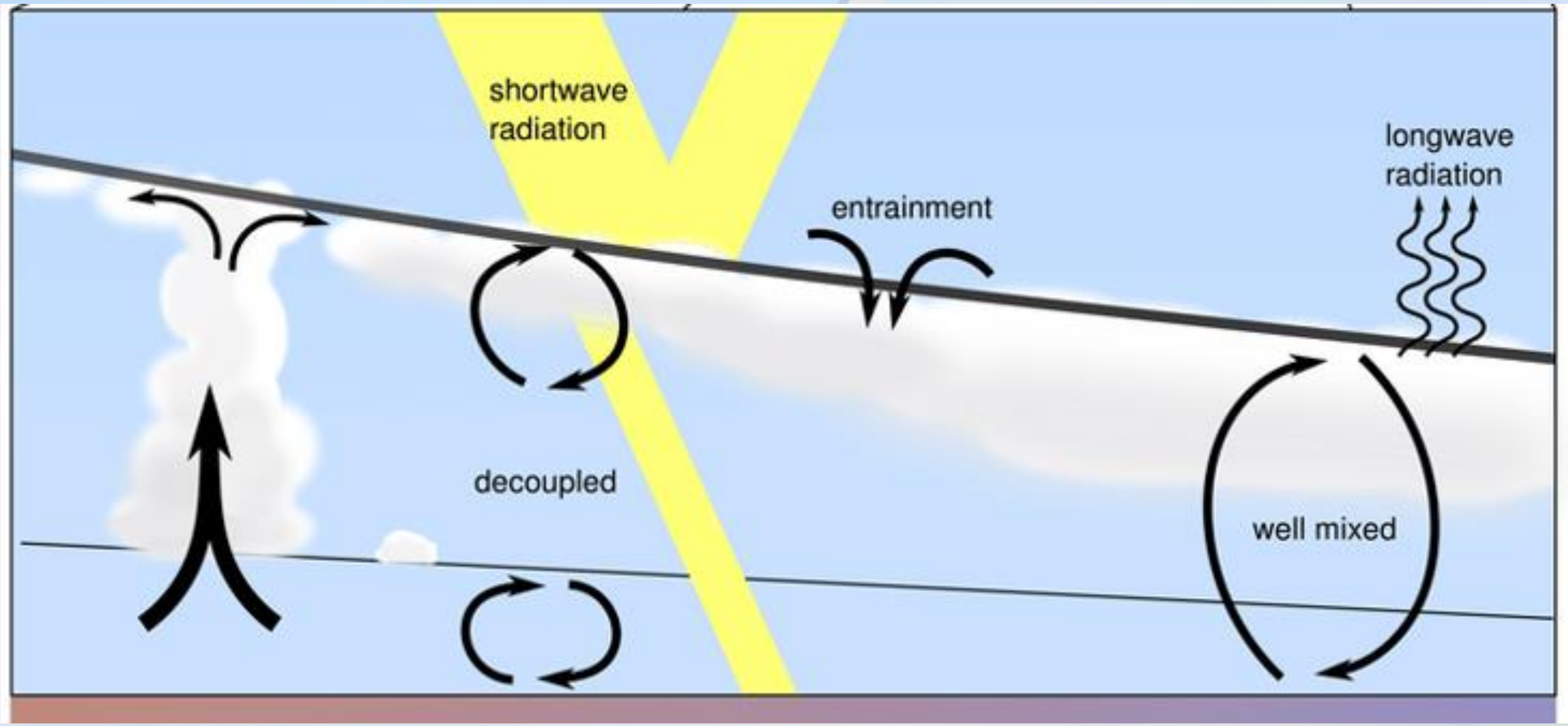


Typical CSET module



LITTLE FOCUS ON RAIN IN EARLY STUDIES

e.g., Krueger et al., (1995); Bretherton and Wyant, (1997), Wyant et al., (1997)



Source: van der Dussen et al. (2016)

Other modeling/observational work suggests **precipitation can hasten the transition**

Paluch&Lenschow, 1991: sub-cloud thermodynamic cooling & moistening from evaporation stabilizes layer w.r.t. cloud layer, discouraging transport of surface moisture to cloud layer.

Yamaguchi et al., 2017; O et al., 2018: microphysical depletion of stratiform layer.

Can the new observations help us understand if and how precipitation influences the pace of the stratocumulus to cumulus transition?

(Sarkar et al. 2020)

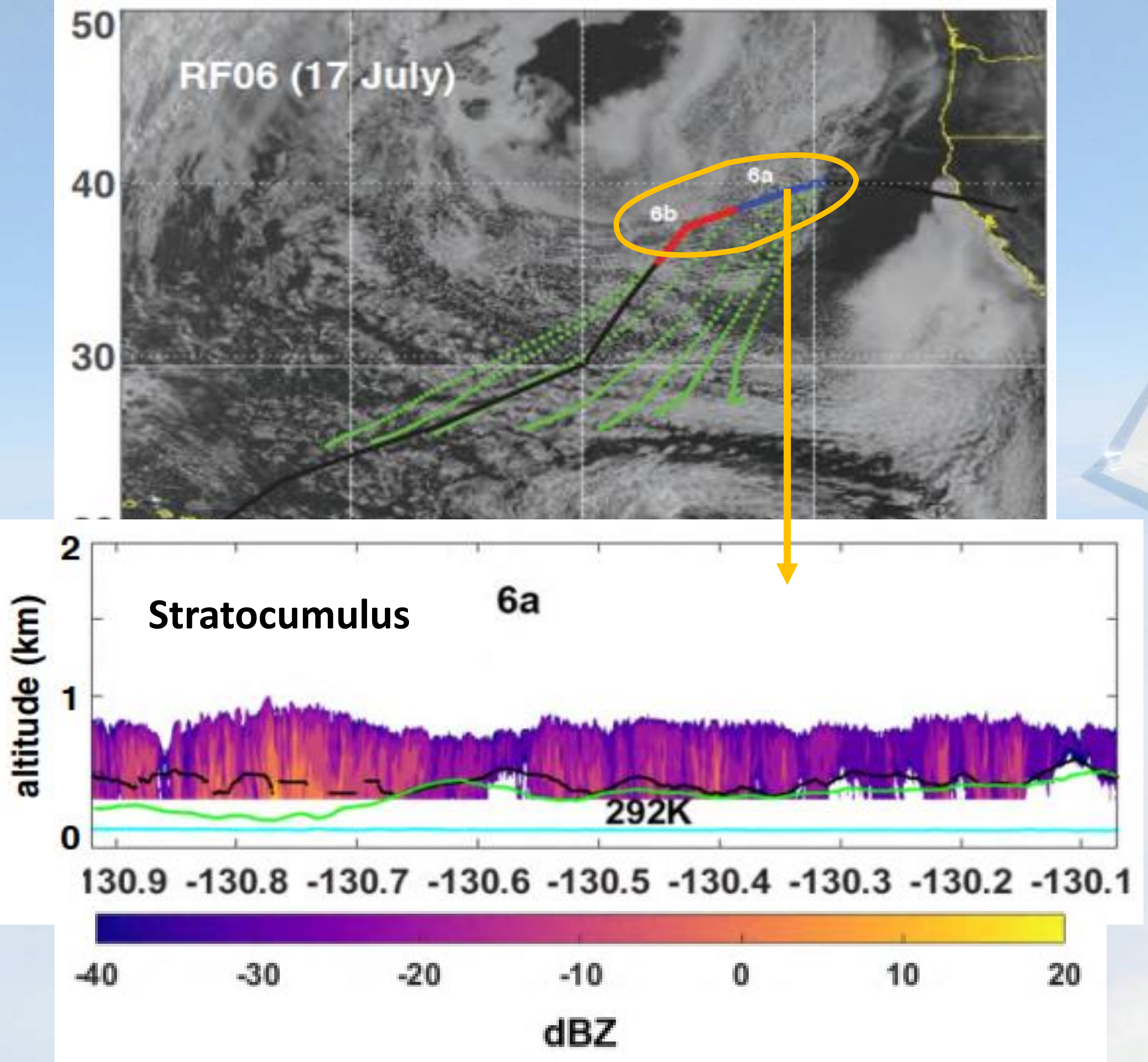
APPROACH

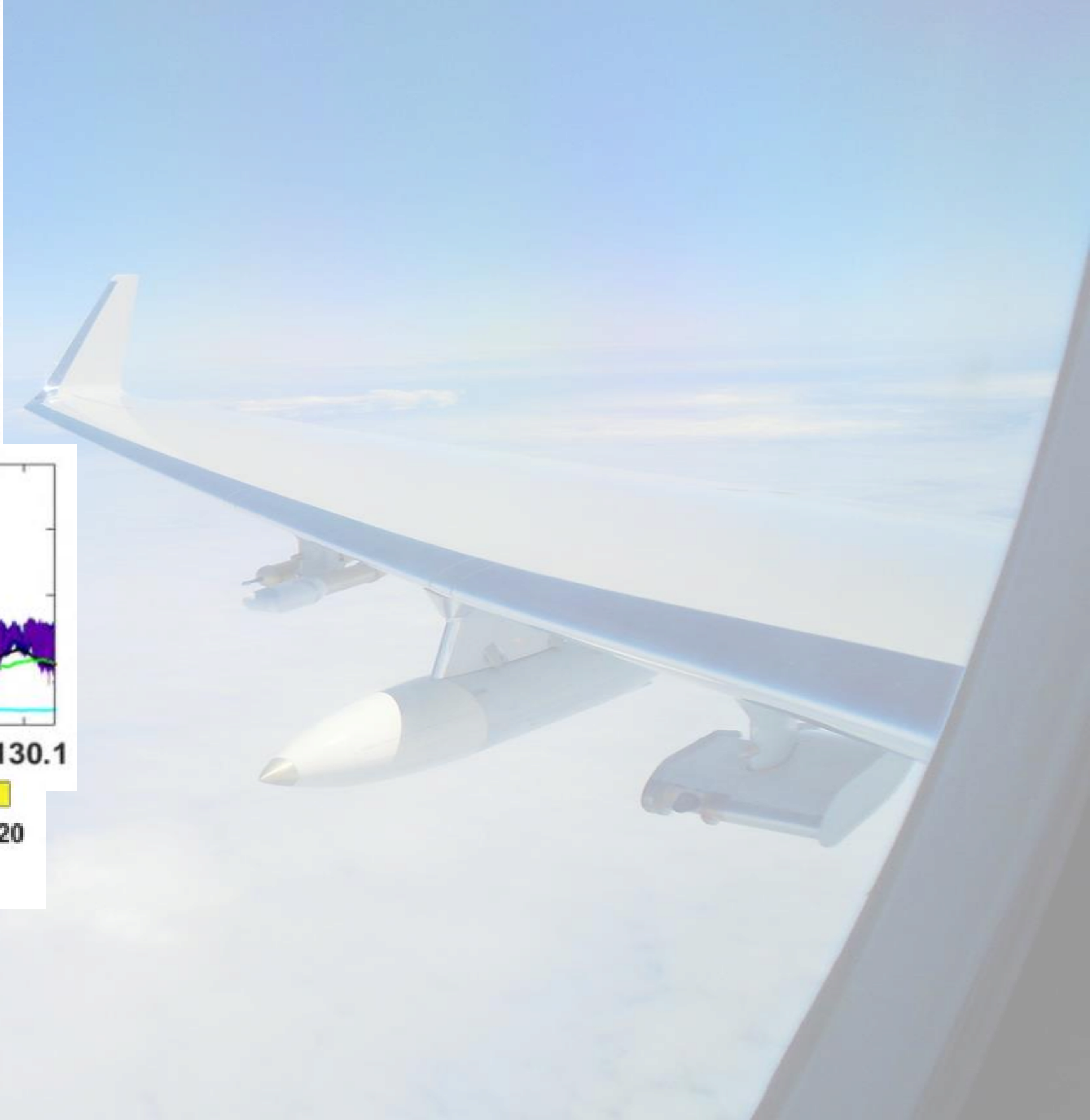
- Only select true stratocumulus-to-cumulus transitions (3 flight pairs only).

- *In-situ* two-dimensional optical array cloud probe (2DC) measurements indicate the microphysical changes.

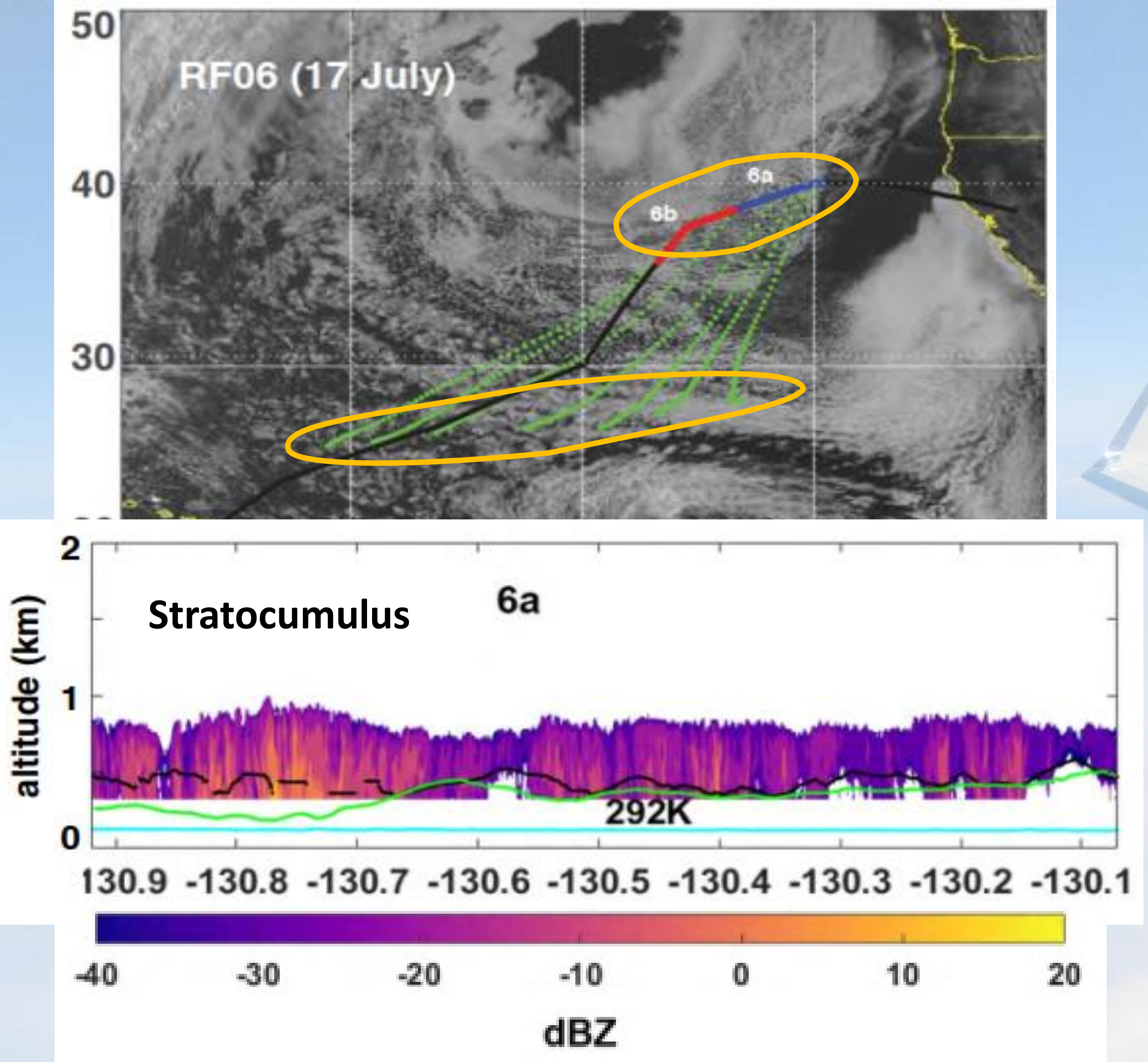
- Identify cloud transition from hourly GOES-15 infrared data

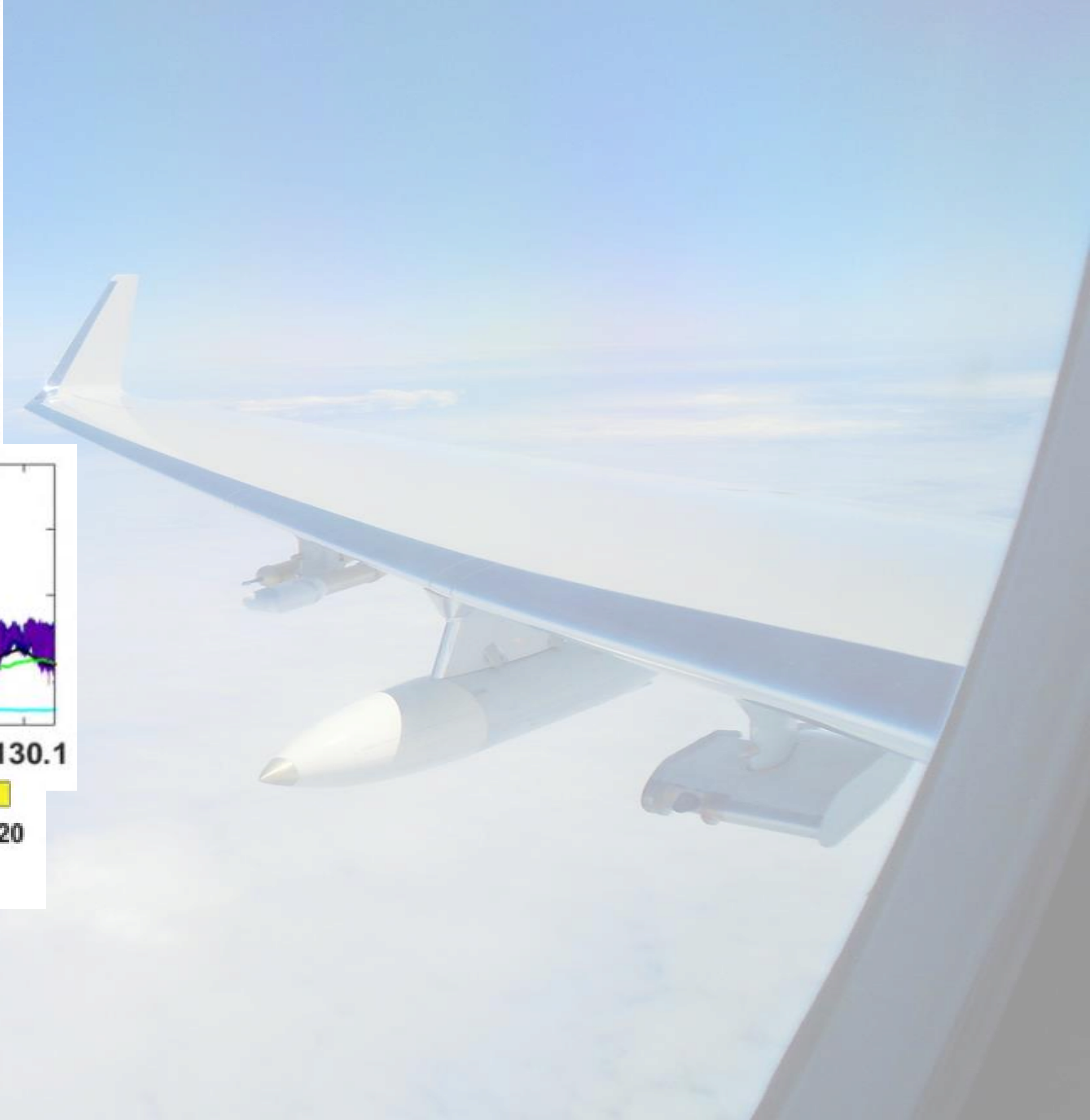
=> transition assigned at the beginning of a 5-hr period with cloud fractions below 0.5.





Stratocumulus reaching 800 m in height
Pristine (N_d of ~22 cm^{-3}),
strongly precipitating
(surface rain rate: 1.2 mm/hr)





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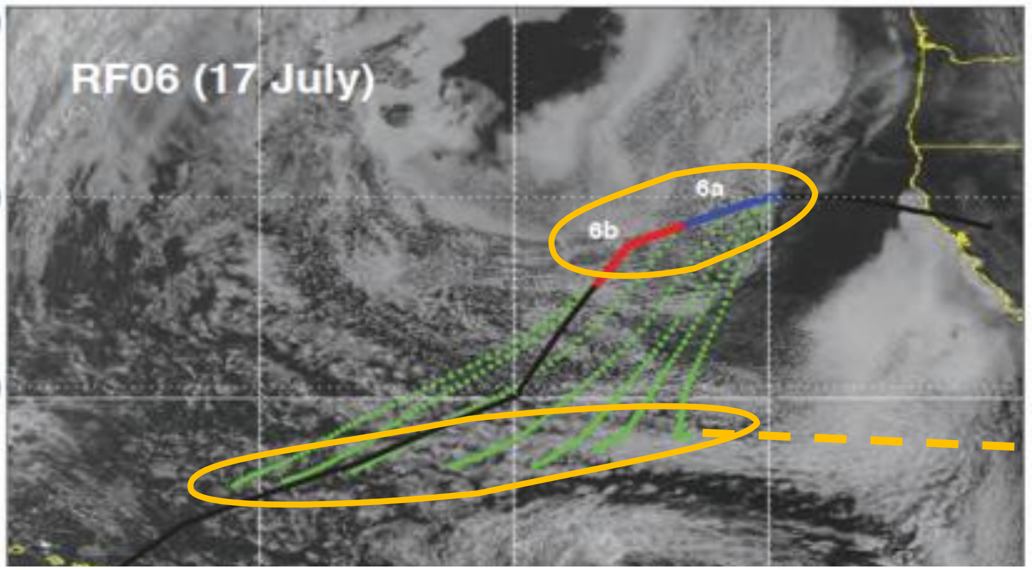

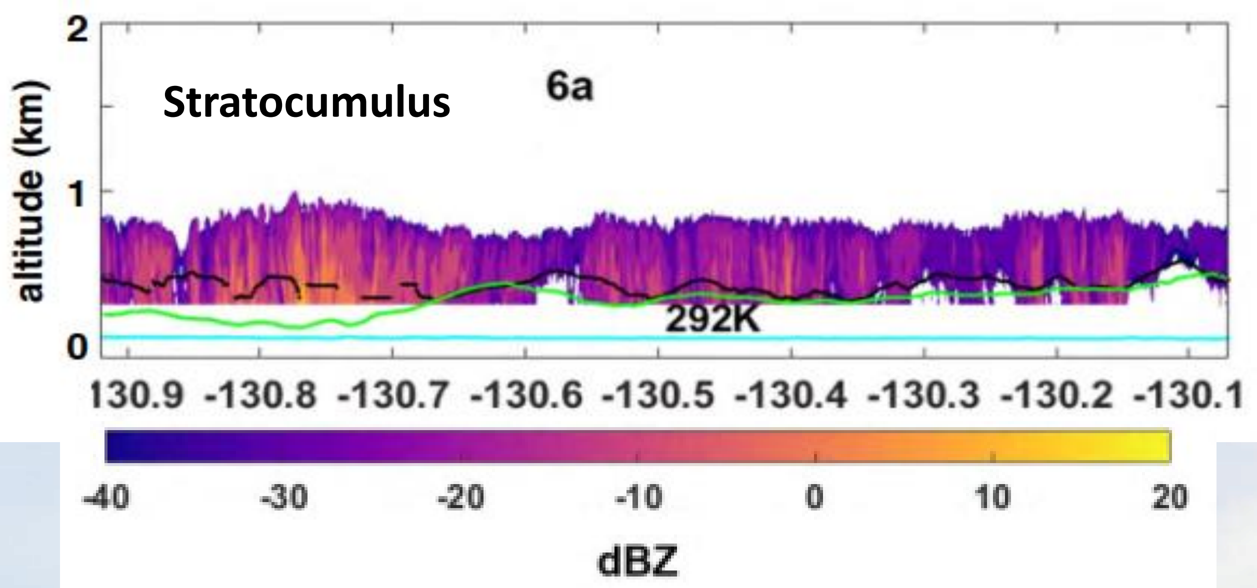

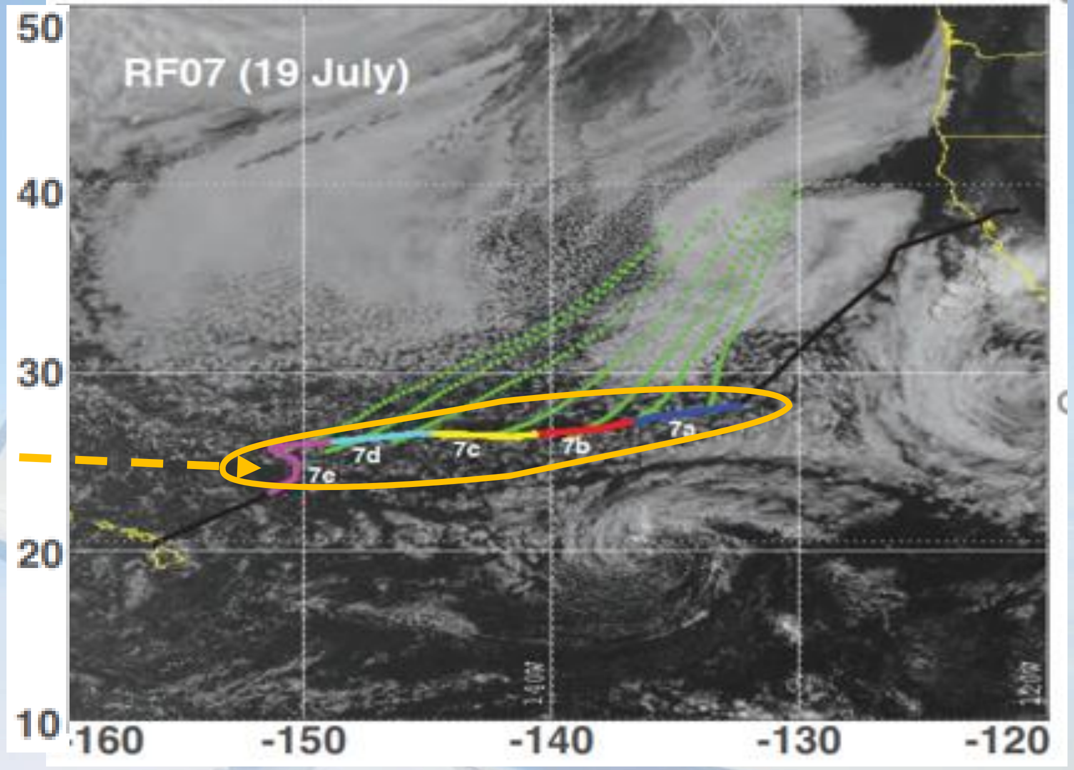

Transitions under strongly-divergent flow into 5 boundary layer modules spanning ~2000 km

Stratocumulus reaching 800 m in height
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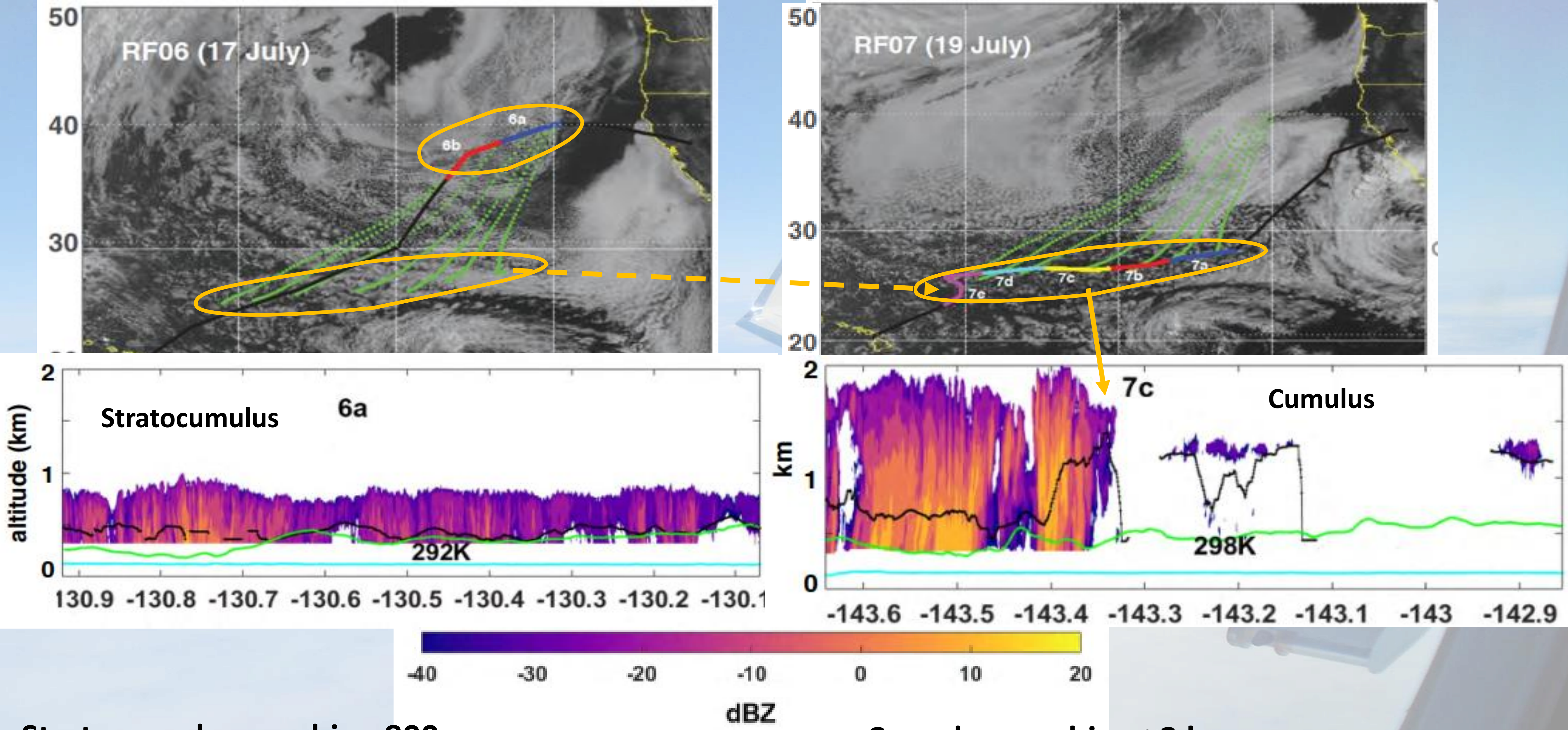
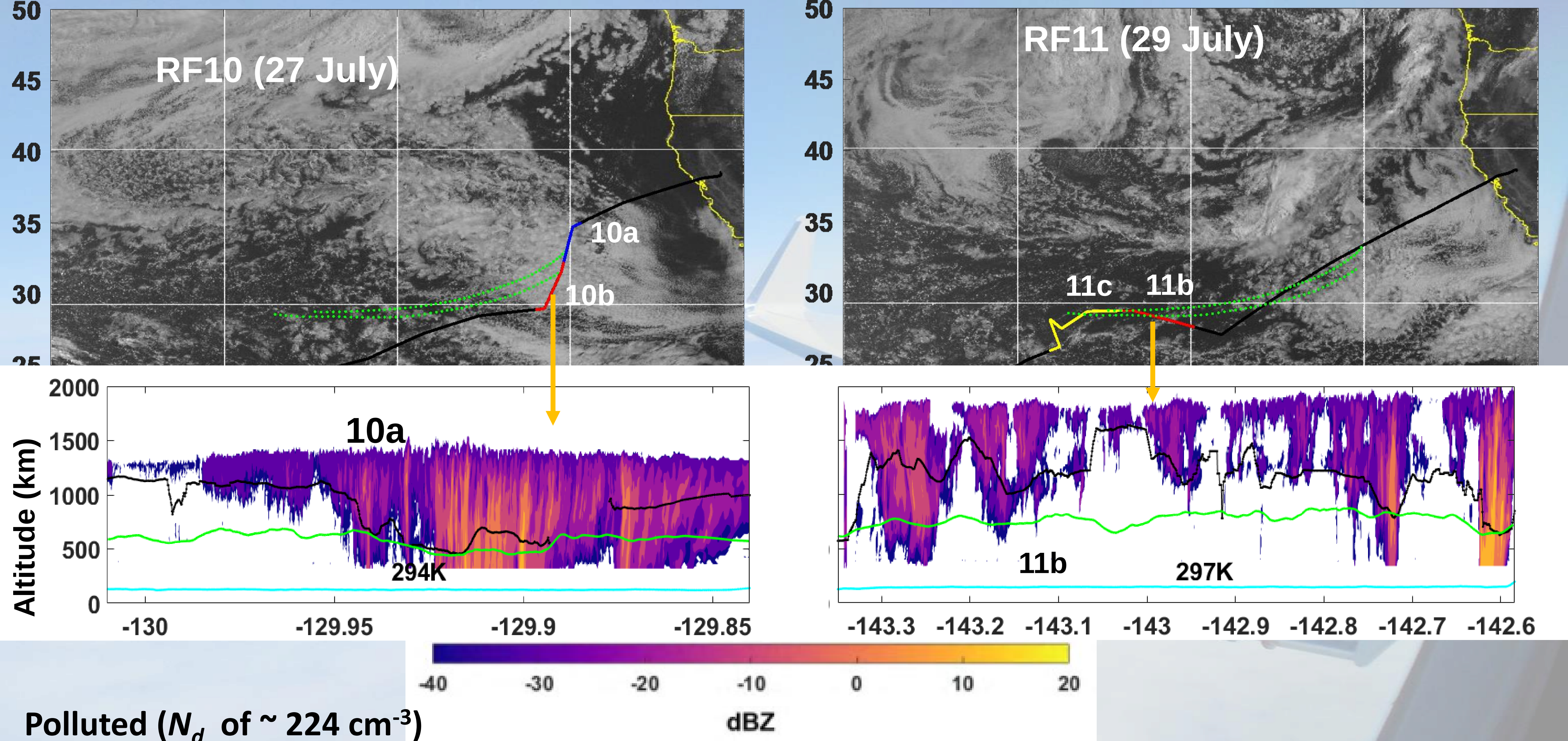
strongly precipitating
(Surface rain rate: 1.2 mm/hr)



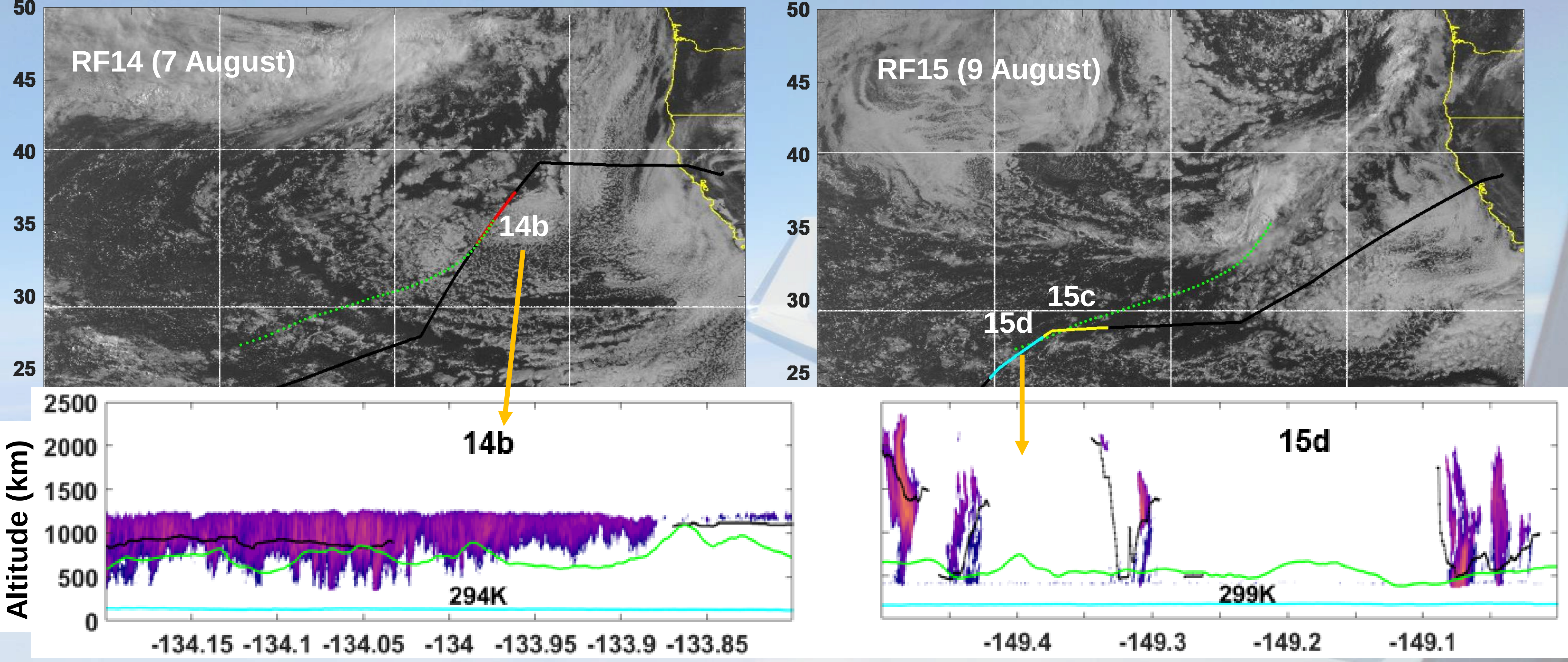
Stratocumulus reaching 800 m
Pristine (N_d of ~22 cm^{-3}),
strongly precipitating
(rain rate: 1.2 mm hr^{-1})

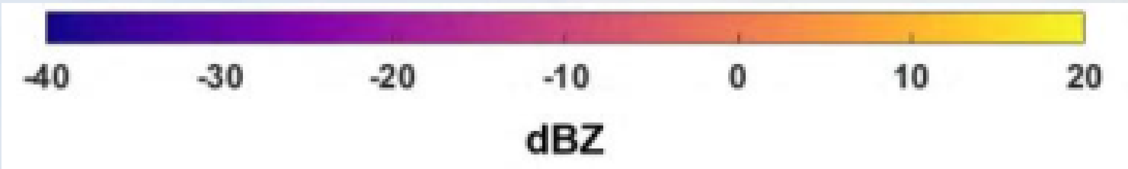
Cumulus reaching ~2 km
'ultra-clean' N_d of ~ 1 cm^{-3} within veil clouds
(see Wood et al., 2018).
more intense surface precipitation



Polluted (N_d of ~ 224 cm^{-3})
-forest fires in Oregon
lighter precipitation (0.6 mm hr^{-1})
Cloud tops: 1200 m

Clean (N_d of ~ 22 cm^{-3})
Increase in rain rate
Cloud top: 1800 m



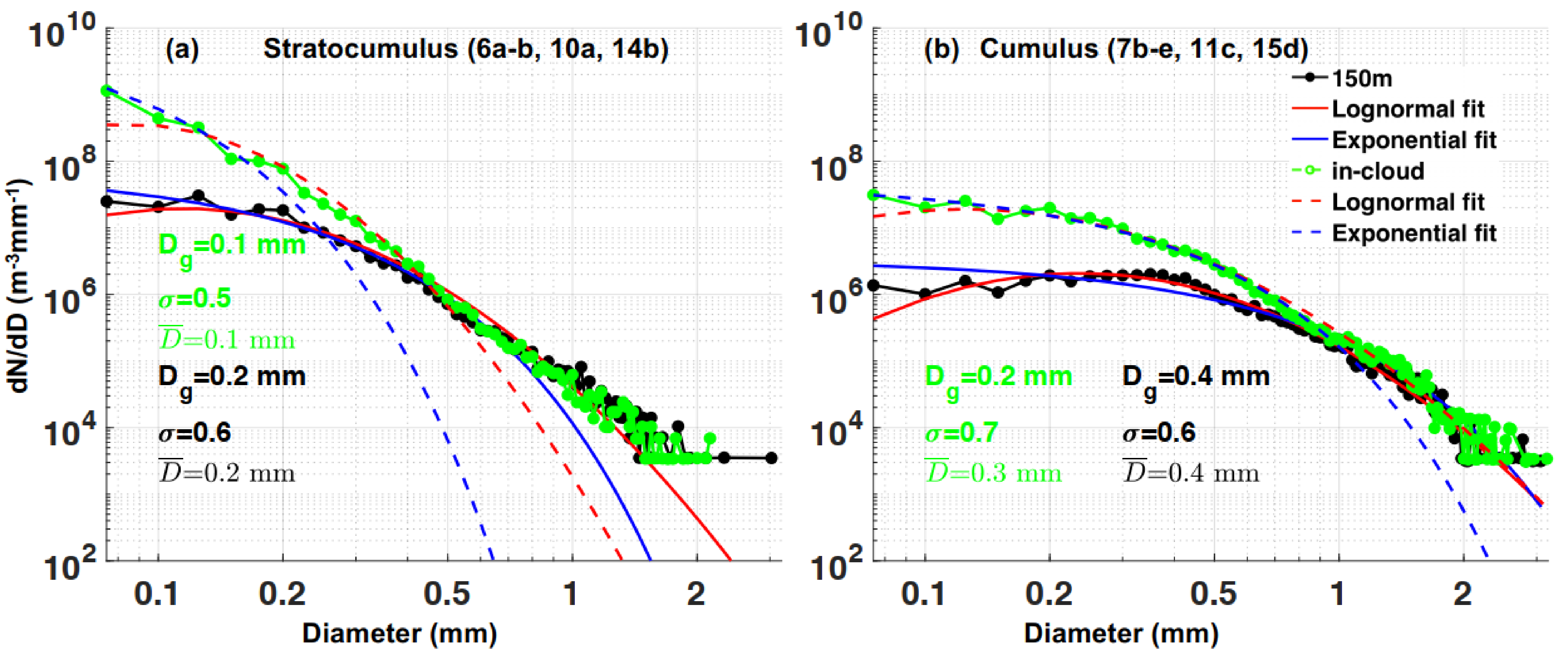


Pristine (N_d of ~ 22 cm^{-3})
Precipitation: NOT reaching surface
Clouds reaching 1200 m

→

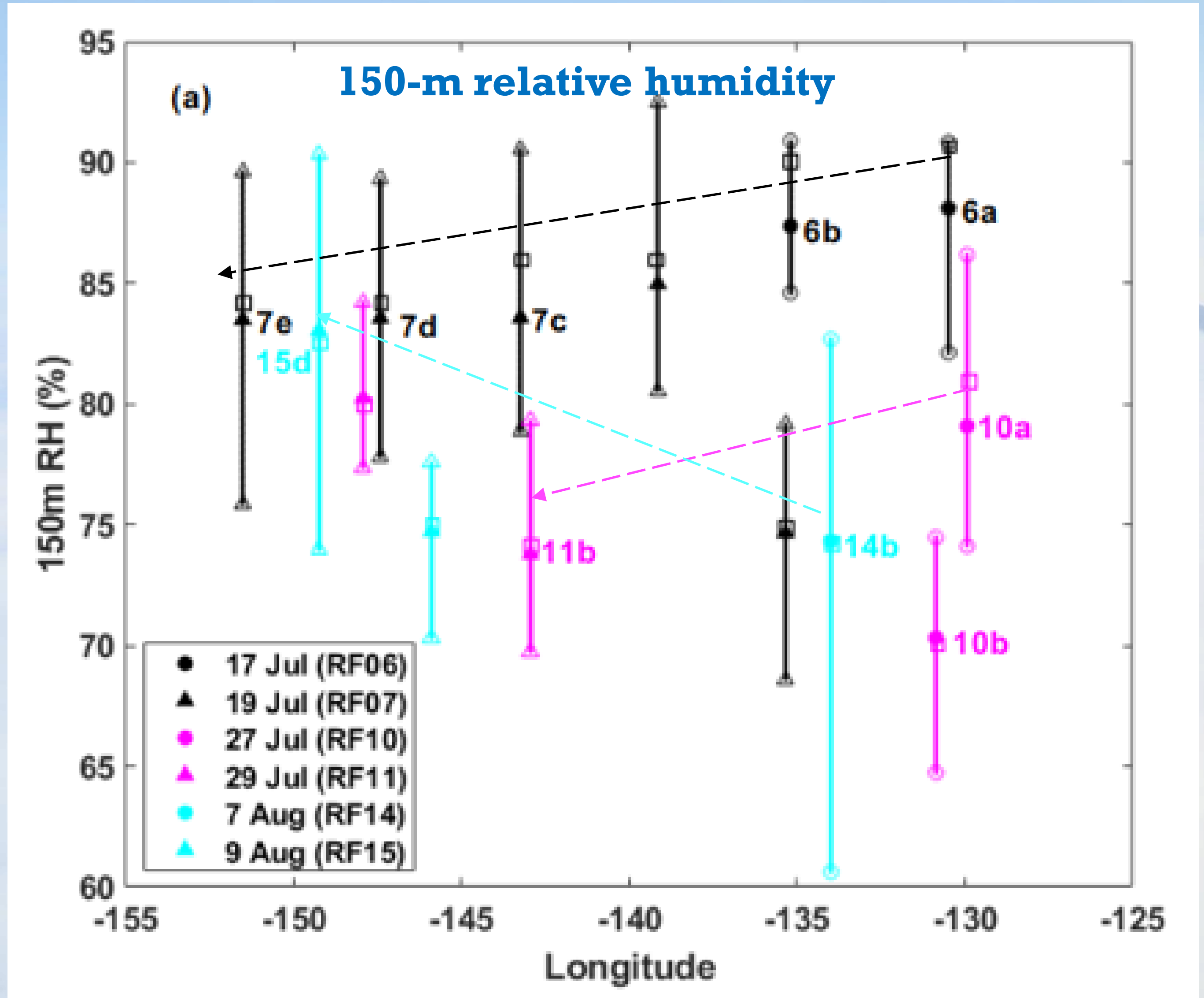
Unchanged N_d of ~ 21 cm^{-3}
Precipitating: not reaching surface
Clouds reaching 1800 m

Role of Microphysics in causing transition



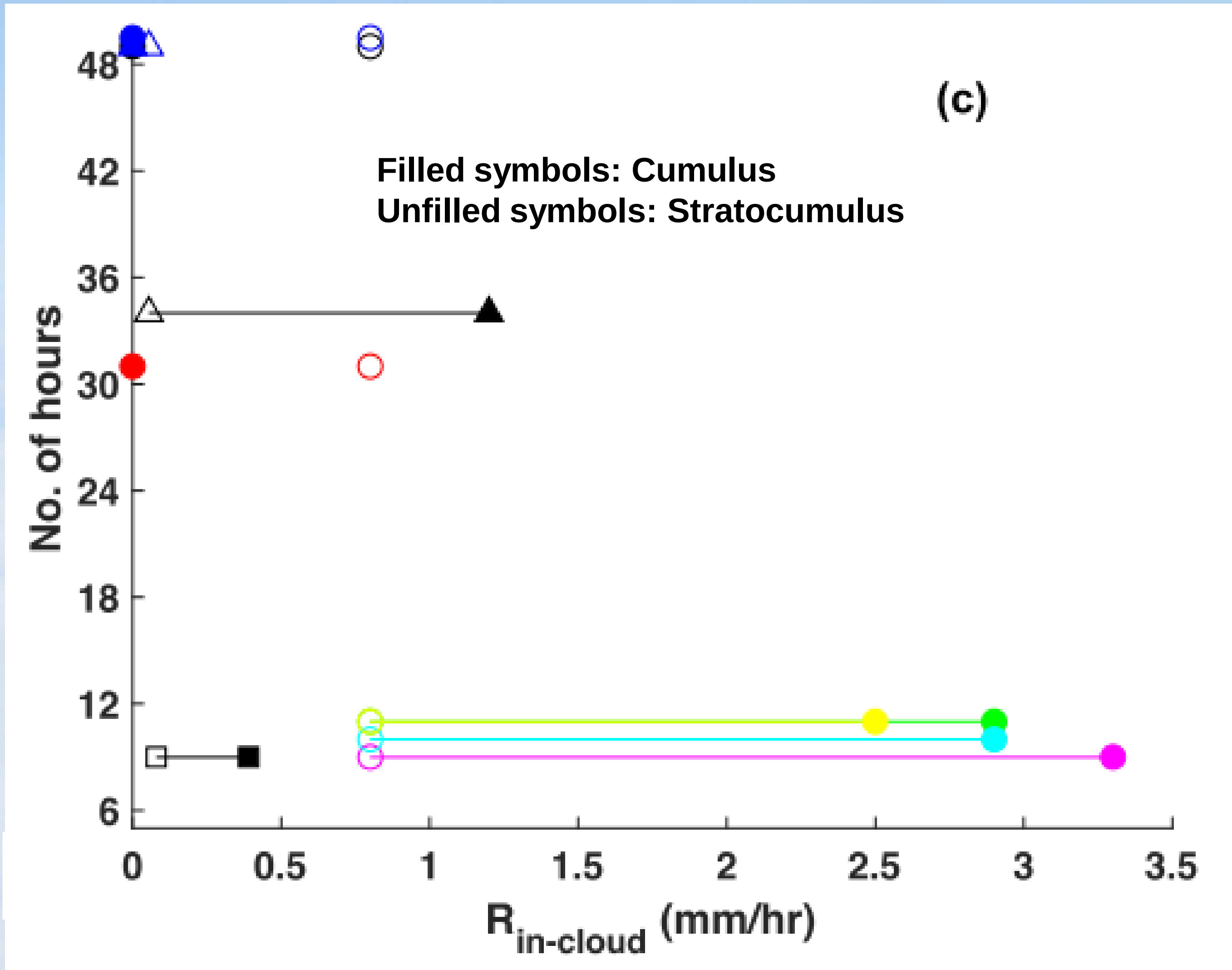
- 2DC **drop size distributions shift towards larger drop sizes along cloud transition** as clouds deepen (collision-coalescence).
- Lognormal distribution fits better than exponential distribution.
- Two of the three flight pairs show **precipitation** ↑, $\mathbf{N_d}$ ↓ => Precipitation cleansing the cloud layer.

Changes to the sub-cloud layer



- Near-surface (150 m) relative humidity most commonly decreases along the transition.
- Confirmed by higher lidar-perceived cloud bases.
- Consistent with more entrainment at cloud-top.
- 1-D evaporation model initialized by in-situ data indicates **sub-cloud evaporation increases**, with maxima closer to surface, during transition

Does precipitation hasten the transition*?



* no. of hours to transition=when IR-derived cloud fractions<0.5 for 5 subsequent hours

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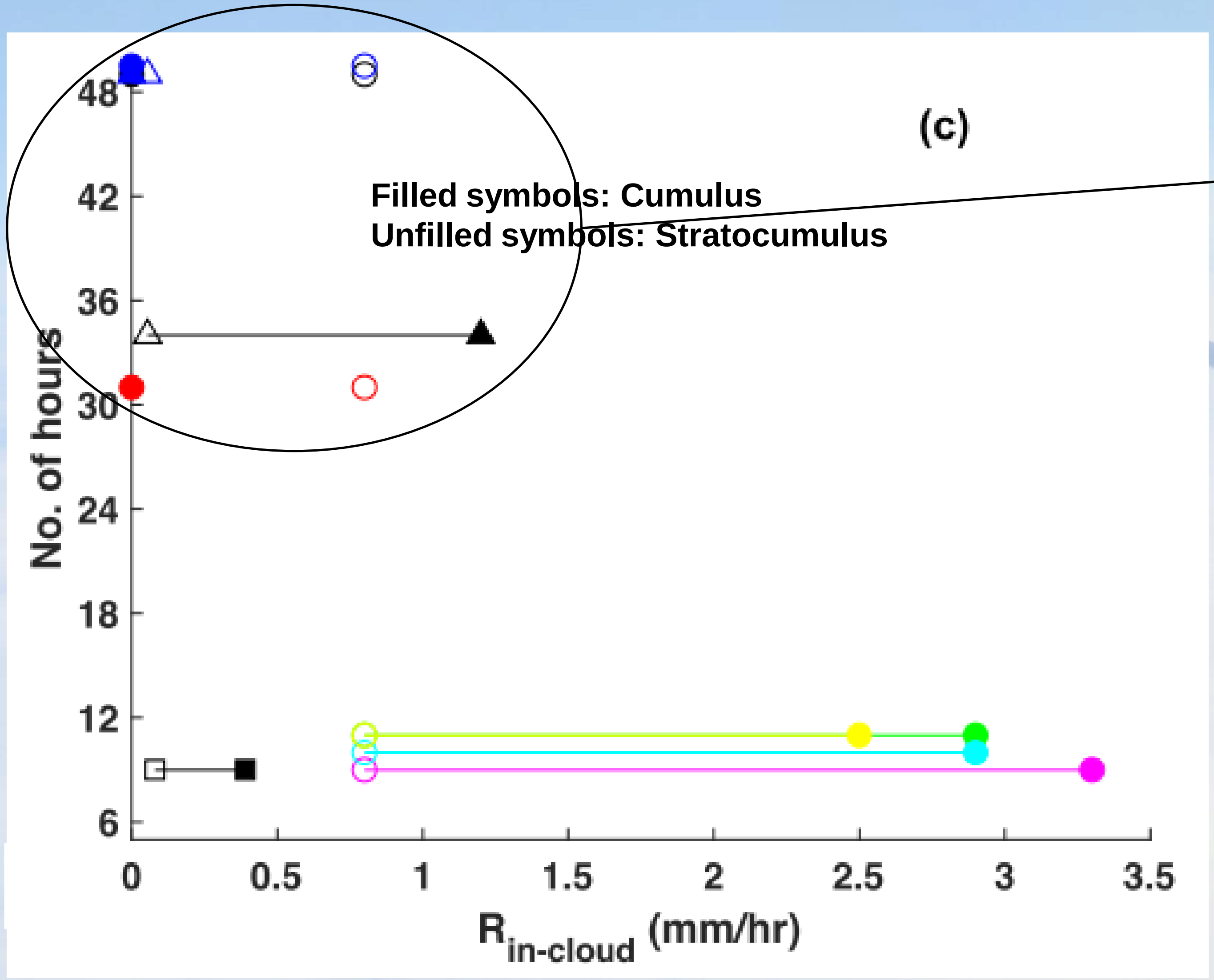

Cases with little increase in rain rate transition slowly

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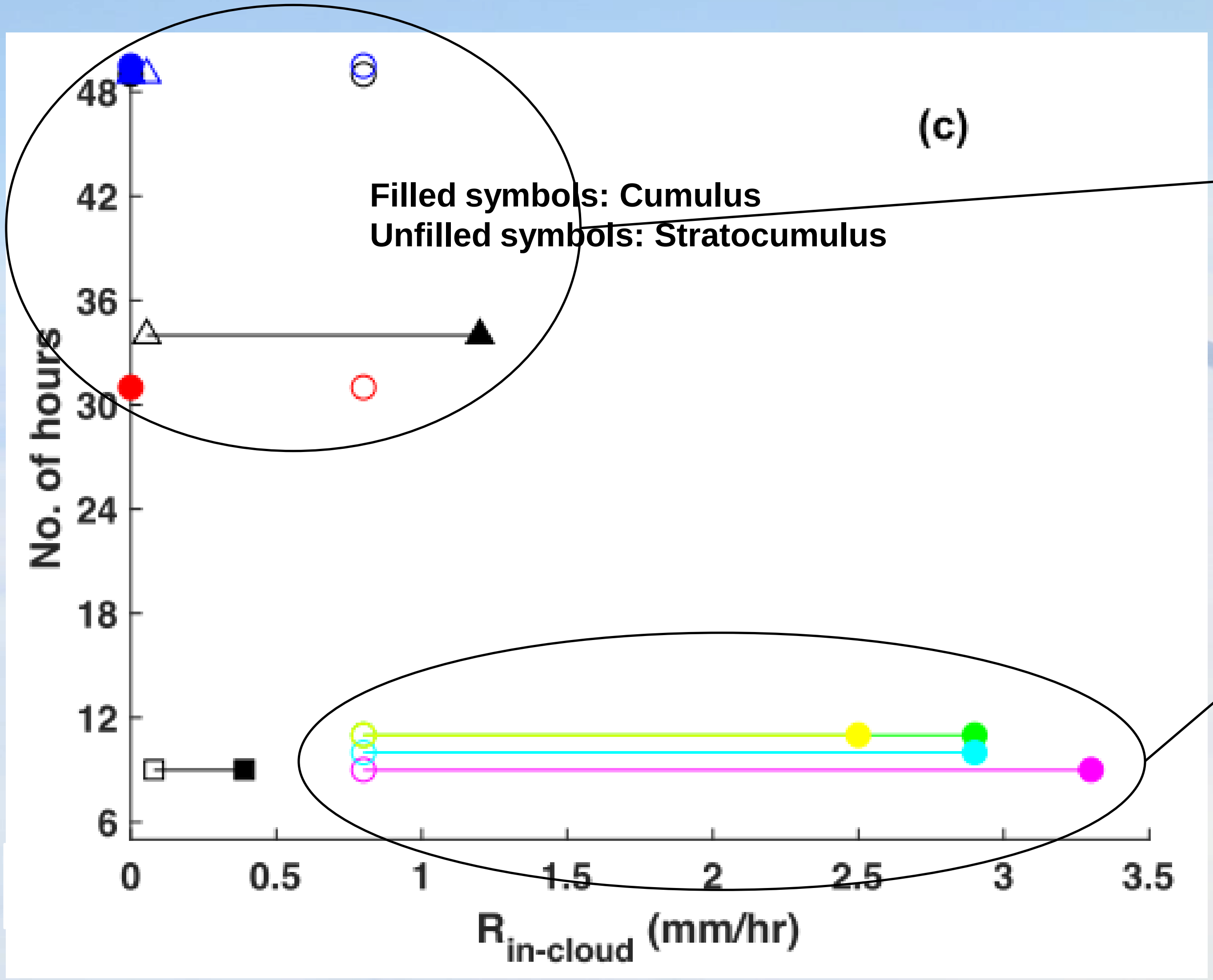

Cases with little increase in rain rate transition slowly

Cases with largest increase in rain rate transition faster.

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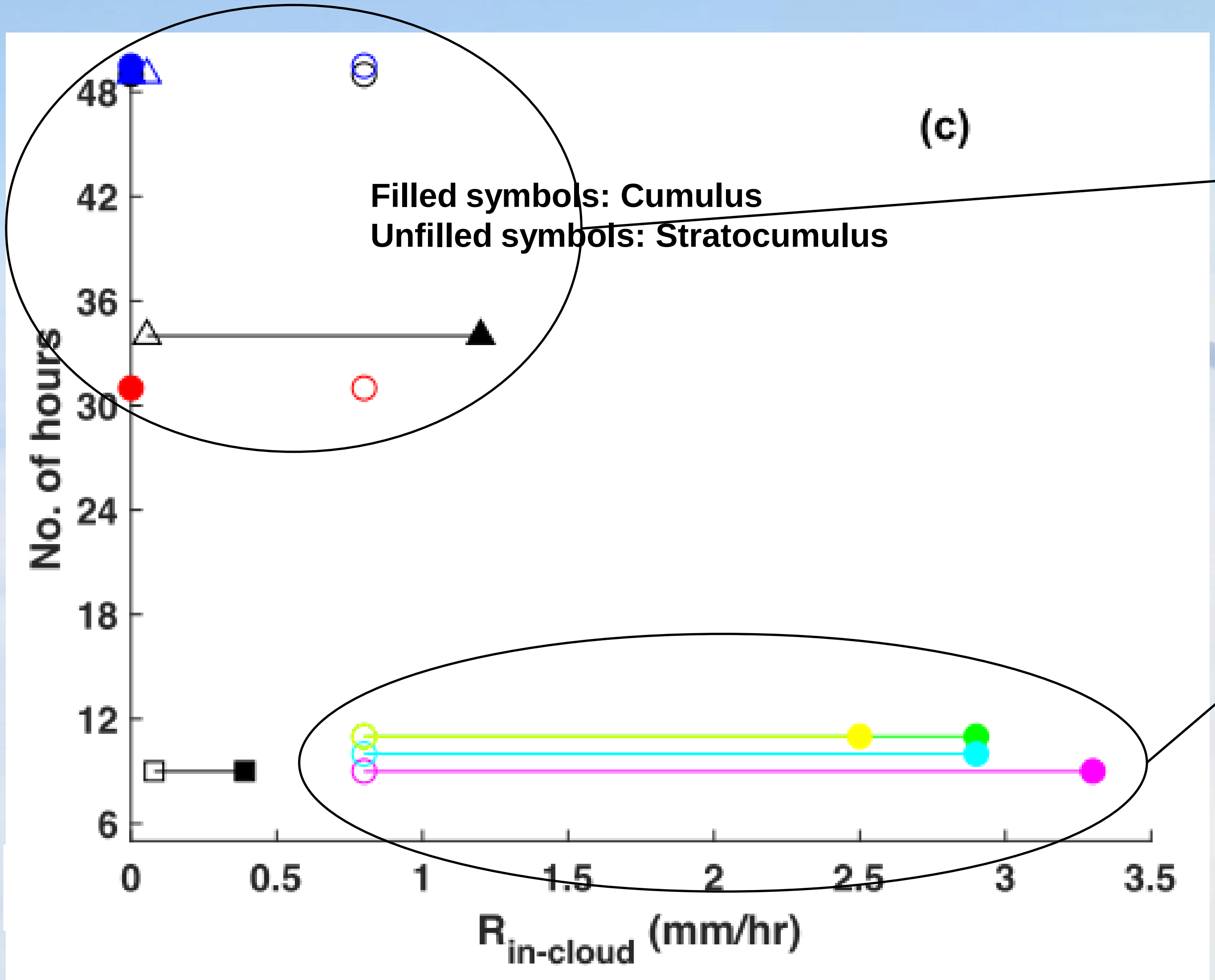

Cases with little increase in rain rate transition slowly

Cases with largest increase in rain rate transition faster.

But the precipitation also correlates with boundary layer depth; we can't discern an independent influence from precipitation.

* no. of hours to transition=when IR-derived cloud fractions<0.5 for 5 subsequent hours

WHAT DO WE TAKE AWAY FROM THIS?

- CSET observations are consistent with the view that: Precipitation, through a quick adjustment to the boundary layer depth, facilitates a hastening of the transition through both thermodynamic and microphysical processes
- The 3 flight pairs with true stratocumulus-to-cumulus transitions sampled a range of aerosol concentration and boundary layer depths, lending themselves well to assessment & initialization of further modeling studies
- Noteworthy are the high in-situ rain rates. Current work is reconciling radar-lidar rain rate retrievals with in-situ information.

See Sarkar et al., 2020, *Mon. Wea. Rev.* *https://doi.org/10.1175/MWR-D-19-0235.1*

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POSTDOC POSITIONS?

See Sarkar et al., 2020, *Mon. Wea. Rev.* https://doi.org/10.1175/MWR-D-19-0235.1

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