Quantifying aerosol-cloud interactions over the western North Atlantic Ocean during the ACTIVATE field campaign

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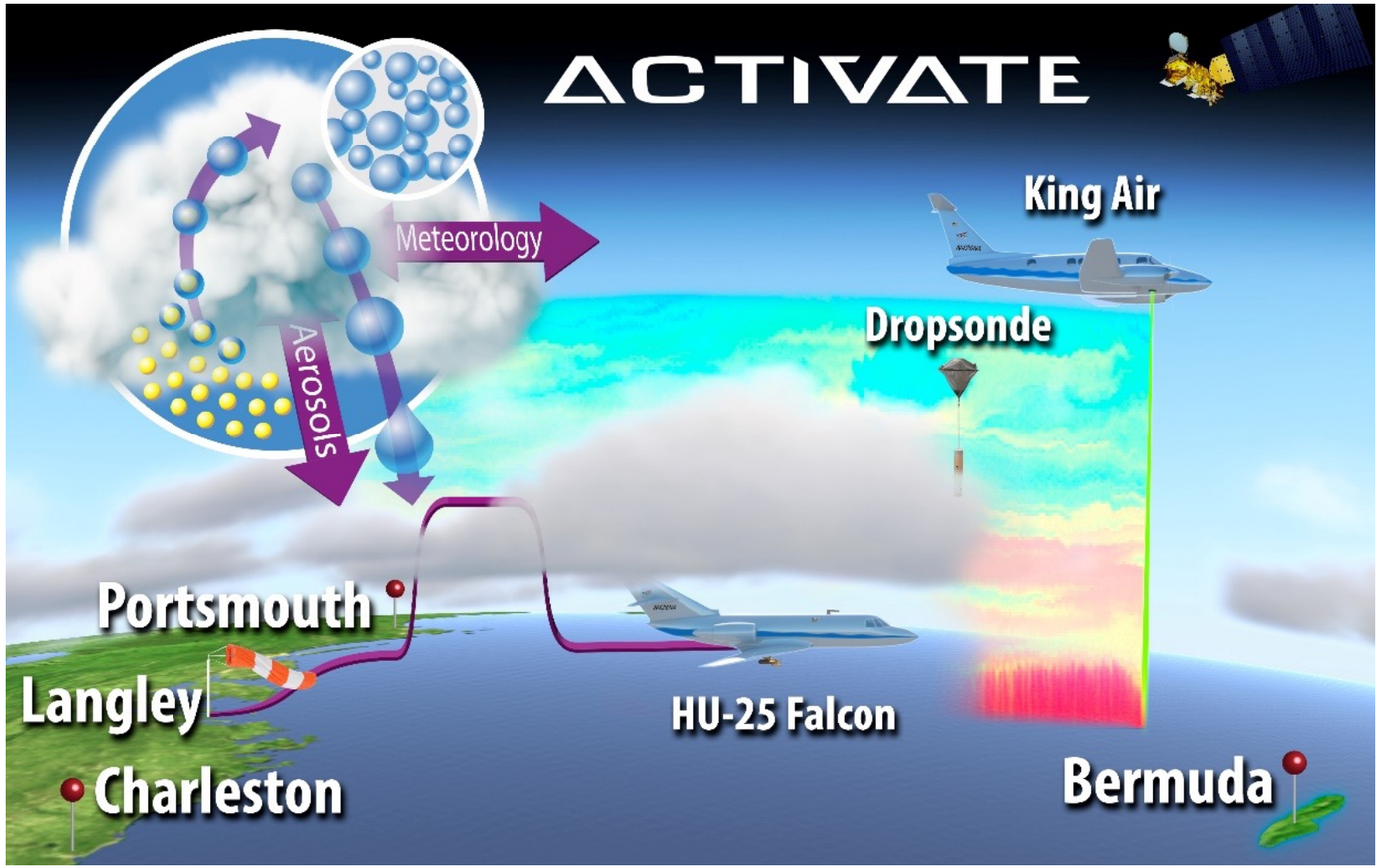
N_a-N_c relation

- ACI poses the largest uncertainty for climate projection
- Understand N_a-N_c relation and key physical processes

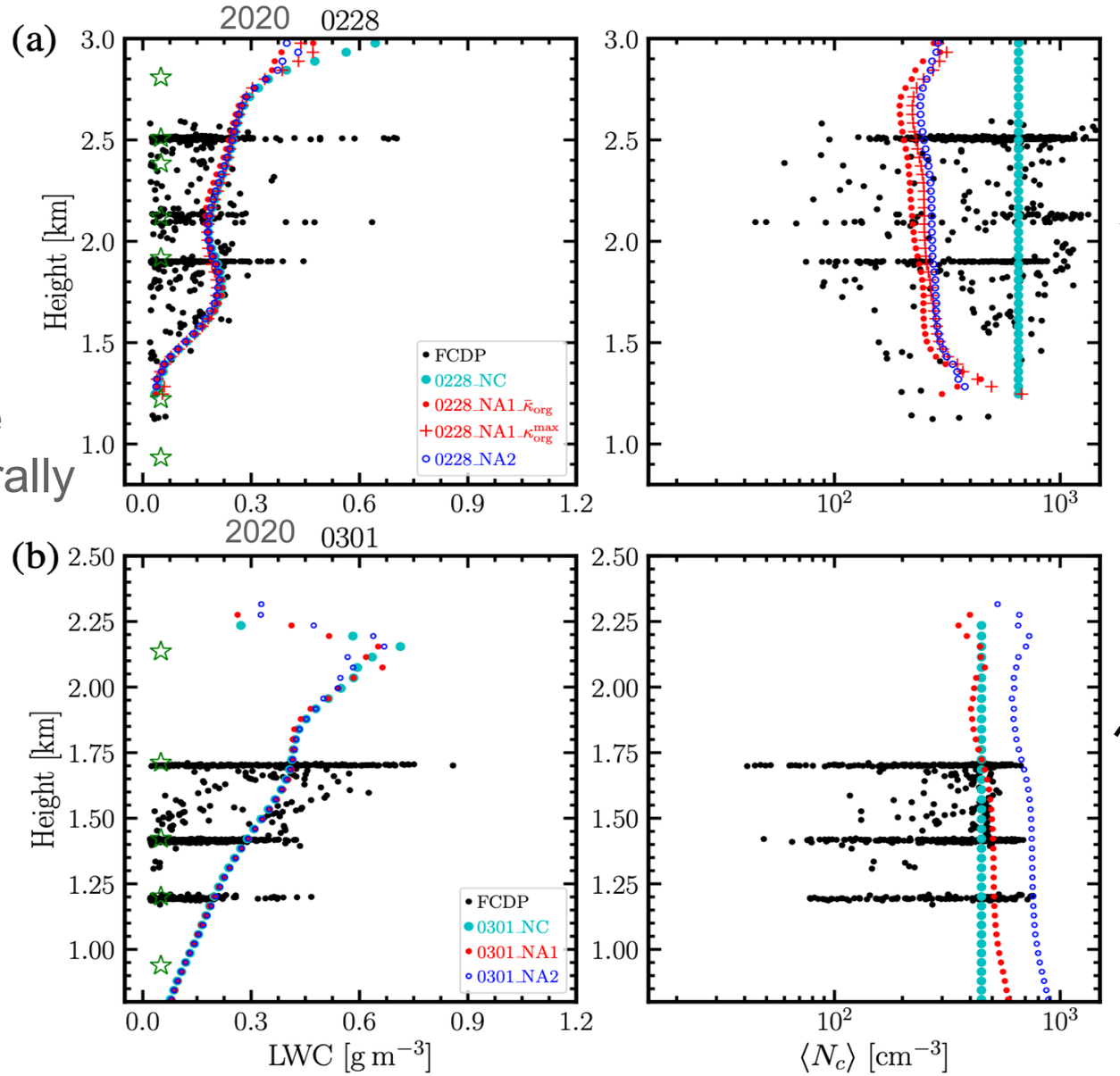


Science: Build **unprecedented dataset (~172 RFs)** to **better understand aerosol-cloud-meteorology interactions**, improve physical parameterizations for Earth system, ….

N_a-N_c: LES studies over the ACTIVATE region

Cold-air outbreak cases

NC: constant FCDP-N_c
NA: uniform aerosol size distribution spatiotemporally



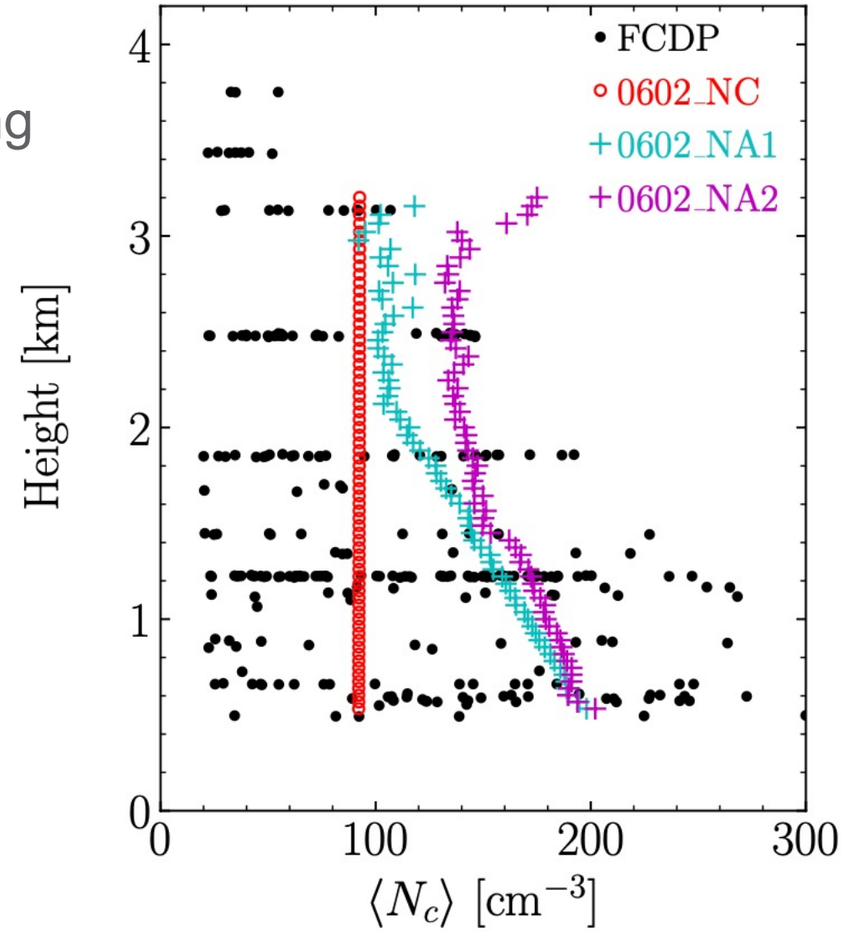
Challenging to reproduce FCDP-N_c

N_a-N_c: LES studies over the ACTIVATE region

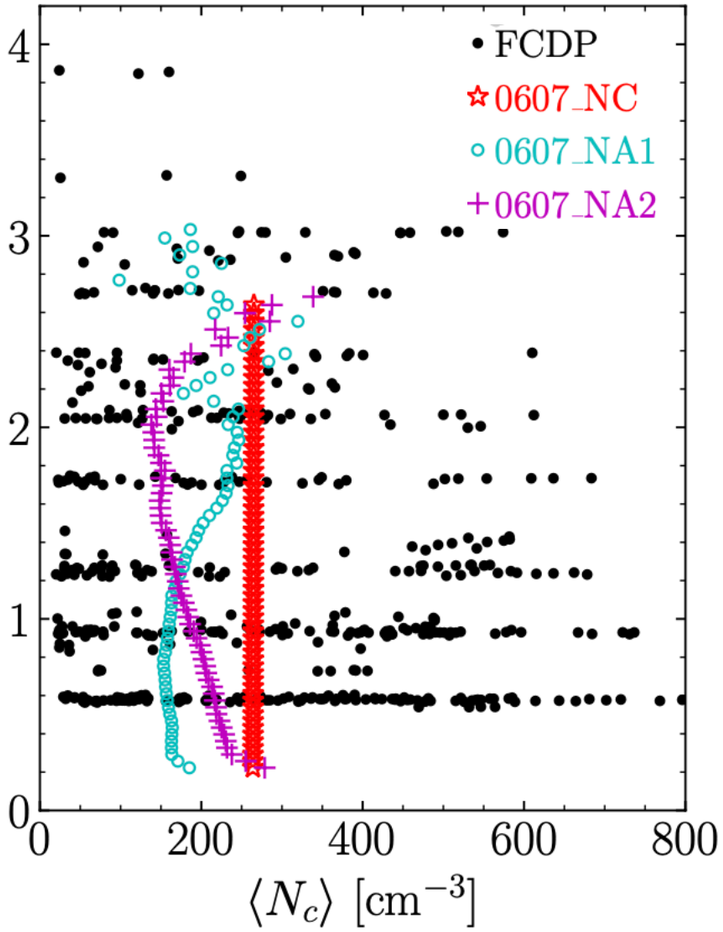
Summertime Precipitating Shallow Cumulus

Again, challenging to reproduce FCDP-N_c

2021-06-02

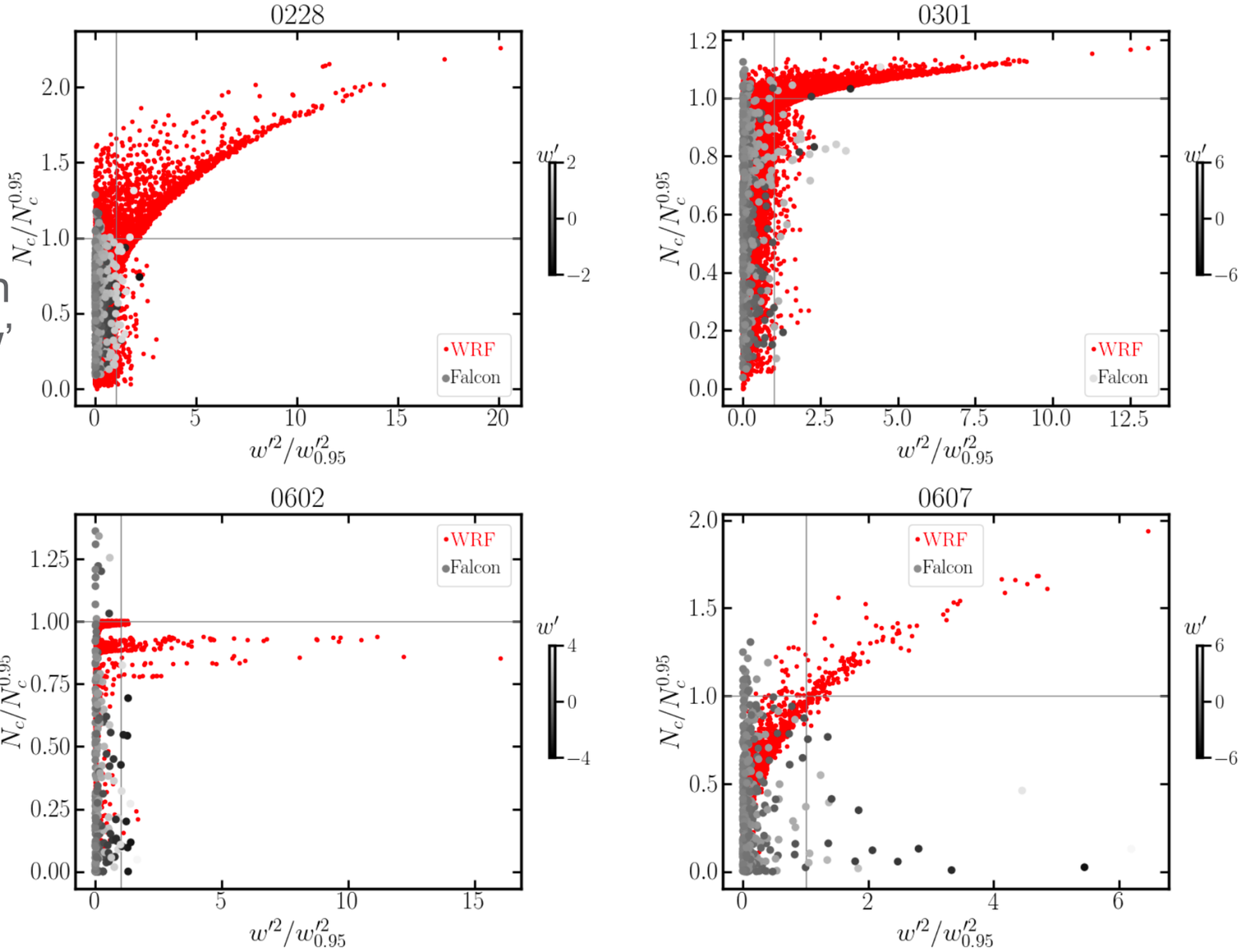


2021-06-07



N_a-N_c: correlation between N_c and w’

- Substantial difference between LES and observation in N_c – w’
- No clear N_c – w’ from the **154 cases** among 172 ACTIVATE flights



N_a-N_c: all ACTIVATE flights data

~172 ACTIVATE flights data represent different meteorology, cloud, and aerosol conditions. Can we get

$$N_c = G(X_{BCB}, N_{a,BCB}, w', u, v, T, q_v, \boldsymbol{x}, zenith, \ldots)?$$

X_{BCB}: chemical components of aerosols measured below cloud base (BCB)
$N_{a,BCB}$: # concentration of aerosols
w', u, v: measured velocity
T, q_v: measured temperature, water vapor mixing ratio
$\boldsymbol{x}$: lat, lon, alt

N_a-N_c: all ACTIVATE flights data

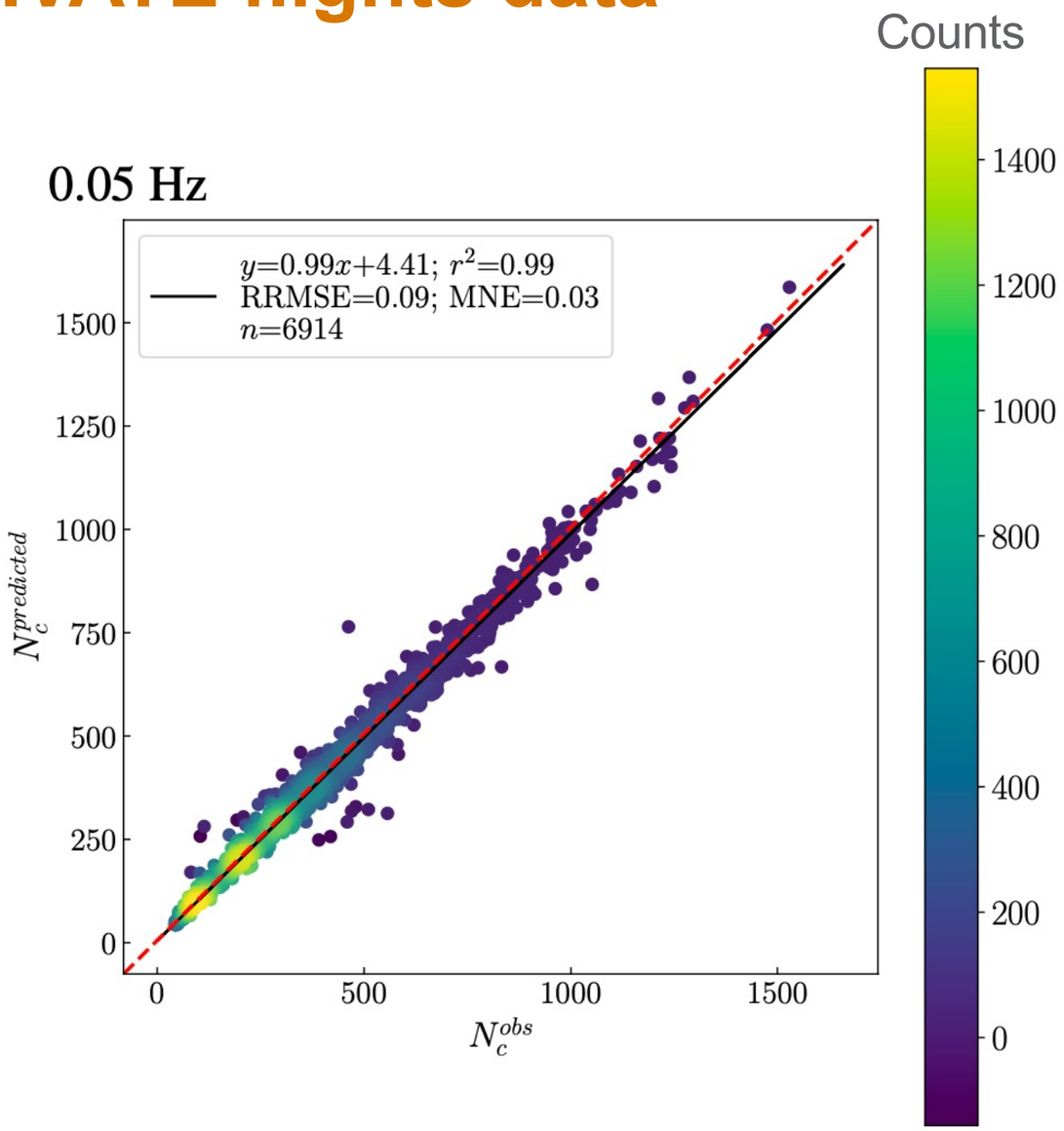
N_c = G(X_{BCB}, $N_{a,BCB}$, w', u, v, T, q_v, $\boldsymbol{x}$, $zenith$)

Methods:

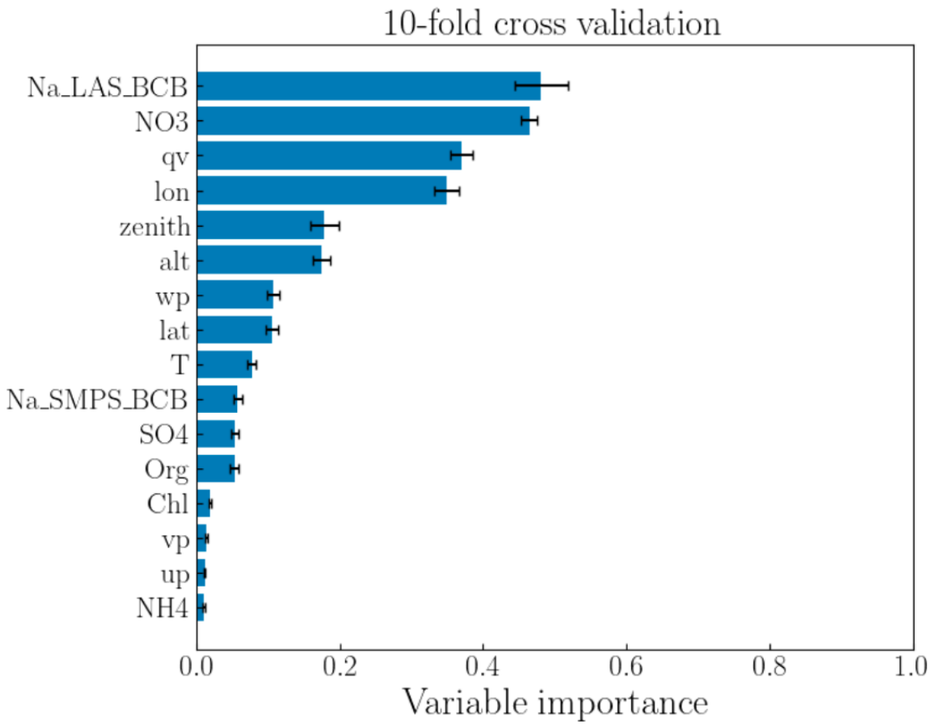
- Random forest model (RFM)
- ~172 ACTIVATE flights data

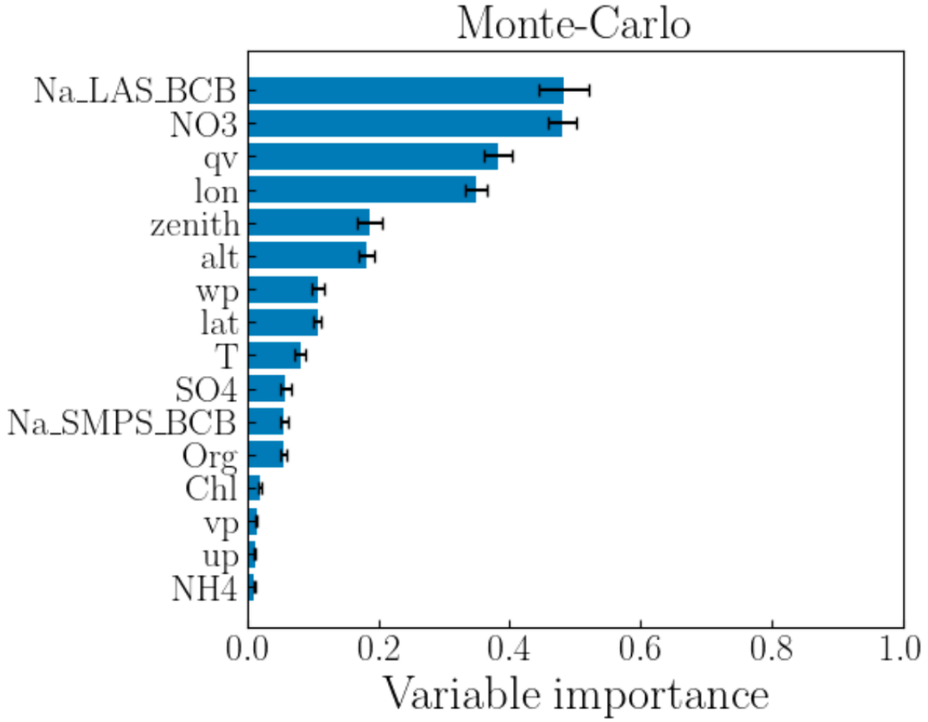
Results:

- RFM can successfully predict observed N_c even though the N_a-N_c relation is nonlinear and multiscale



N_a-N_c: variable importance

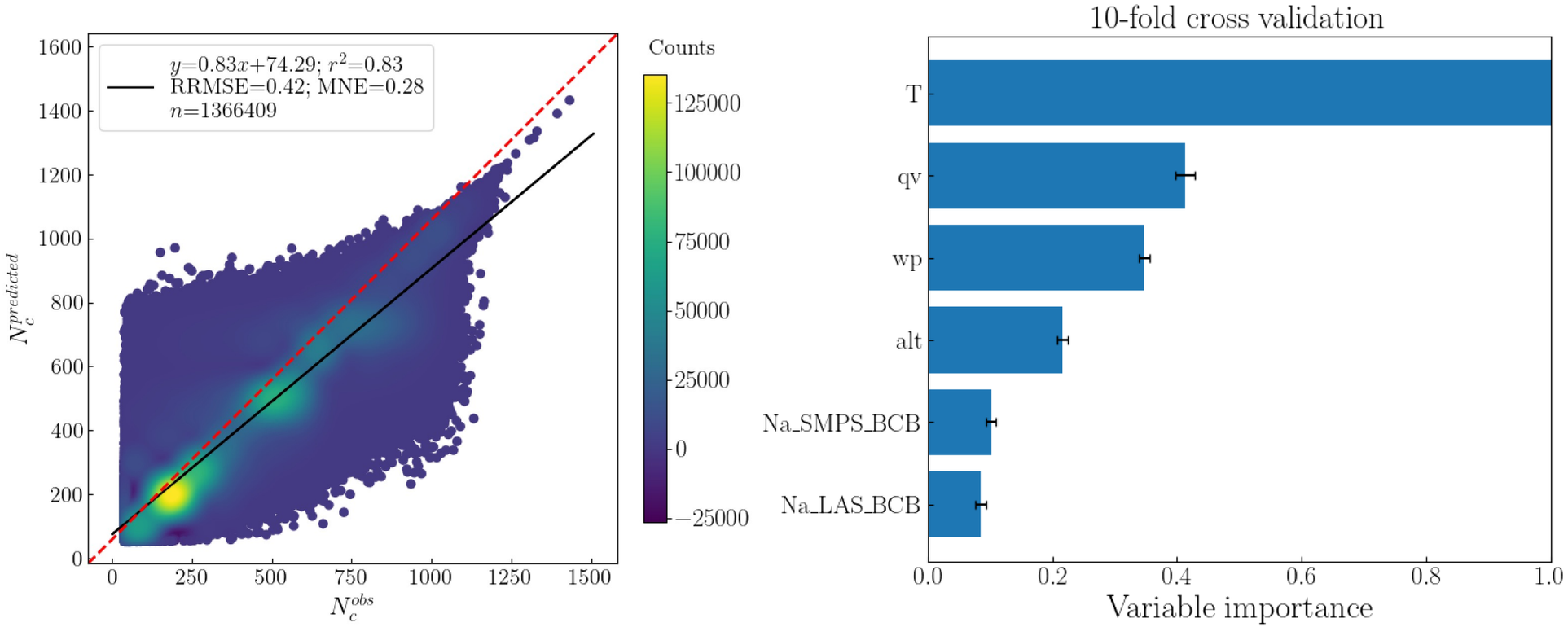




- Cross validations K-folds and Monte-Carlo yield almost the same variable importance
- The RFM captures the importance of the accumulation aerosol mode (Na_LAS_BCB)

N_a-N_c: predict LES-N_c

Training and validation data: LES simulation of cold-air outbreak cases (2020-03-01 and 2020-02-28) and summer-time cumulus cases (2021-06-02/07)



- The RFM predicts the LES-N_c reasonably well but cannot capture the **physical** variable importance
- Observation-driven model to train the LES

Take-home message

- With the **~172** ACTIVATE flight data as the training and validation data, the random forest model can **successfully predict observed N_c** and **capture the variable importance** even though the N_a-N_c relation is nonlinear and multiscale

- The RFM predicts the LES-N_c reasonably well but cannot capture the variable importance

- Observation-driven model to represent N_a-N_c relation for LES

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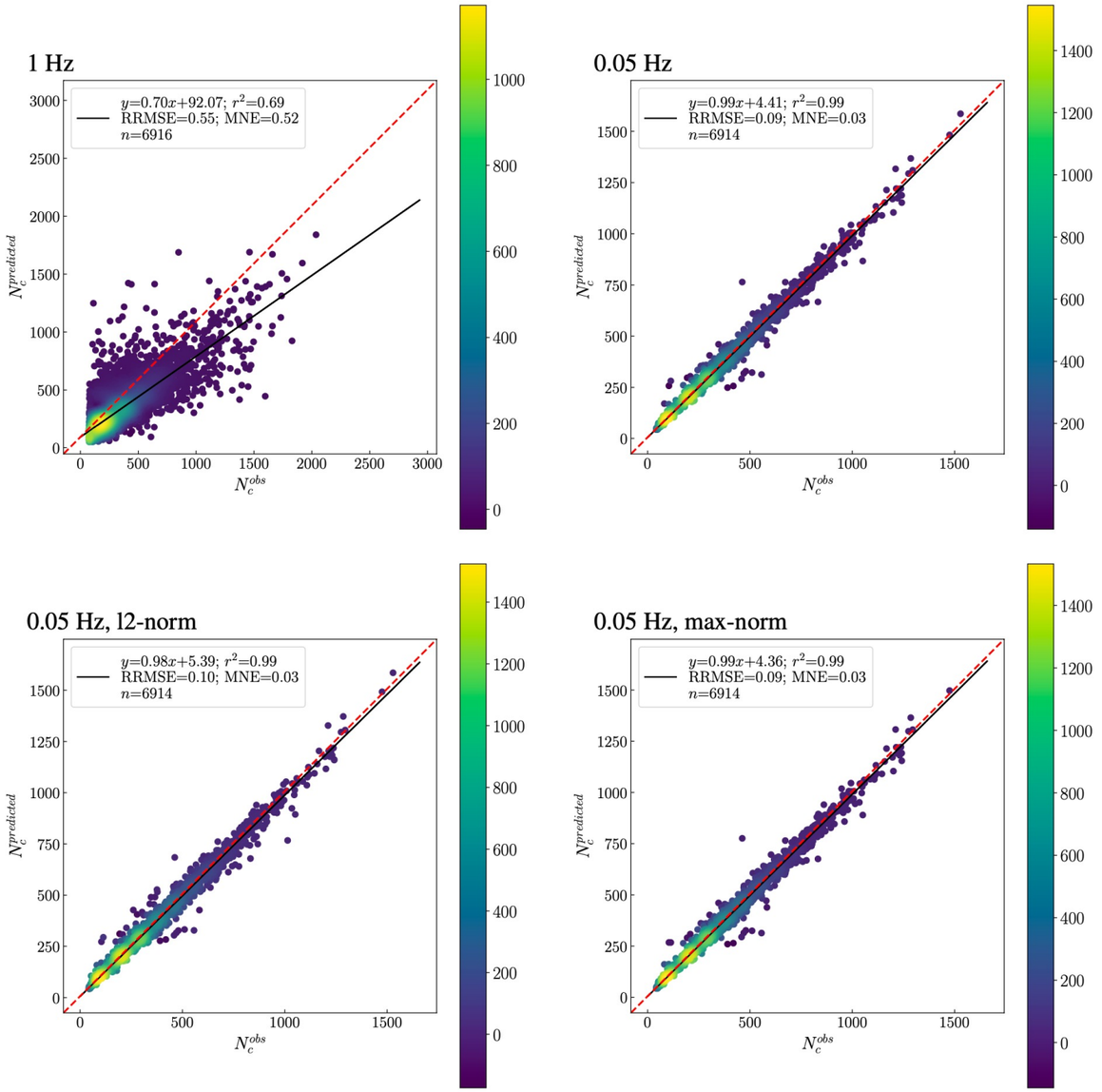
Appendices

Window size	R^2 training score	R^2 validation score	OOB score
1	0.95	0.69	0.68
2	0.97	0.81	0.80
5	0.99	0.93	0.93
10	1.00	0.98	0.98
20	1.00	0.99	0.99
50	1.00	1.00	1.00



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