Pacific Northwest
NATIONAL LABORATORY

Assessment of vertical CCN retrieval methods against in-situ CCN measurements

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Poster session 2 #88

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U.S. DEPARTMENT OF ENERGY BATTELLE

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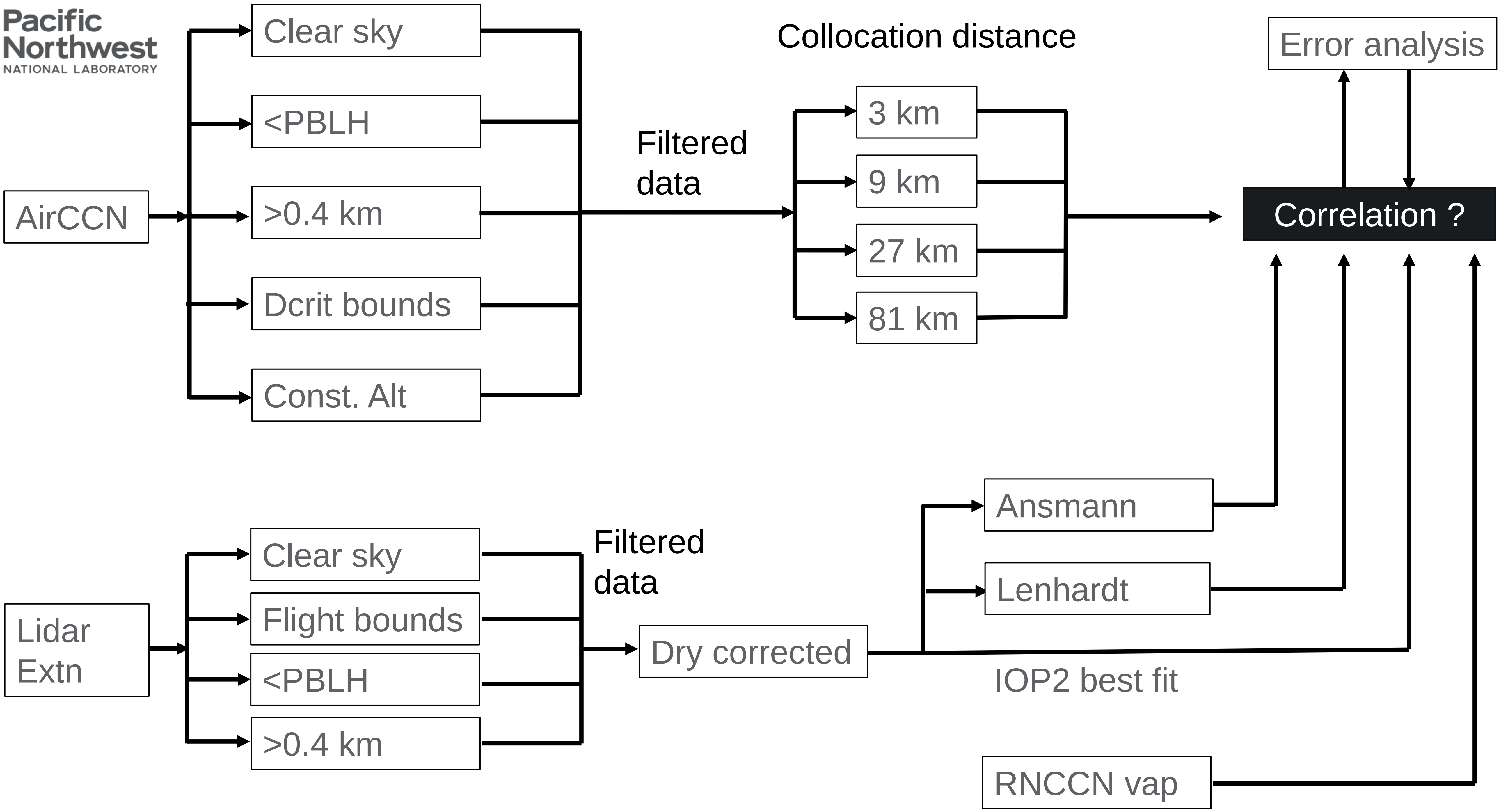
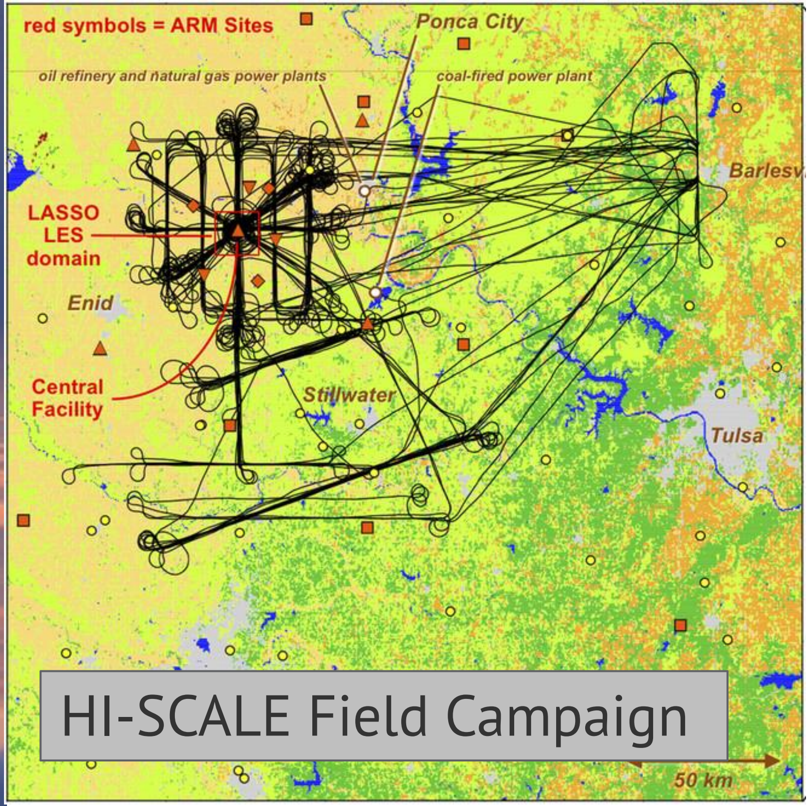
Objective:
Assessment of vertical CCN retrieval methods against in-situ CCN observations.
How measured CCN agree with the retrieved CCN?

Data:
HI-SCALE observations; Ground – RL, PBL, CCN, Aerosol, Met data; RNCCN ARM vap; CCN retrieval methods

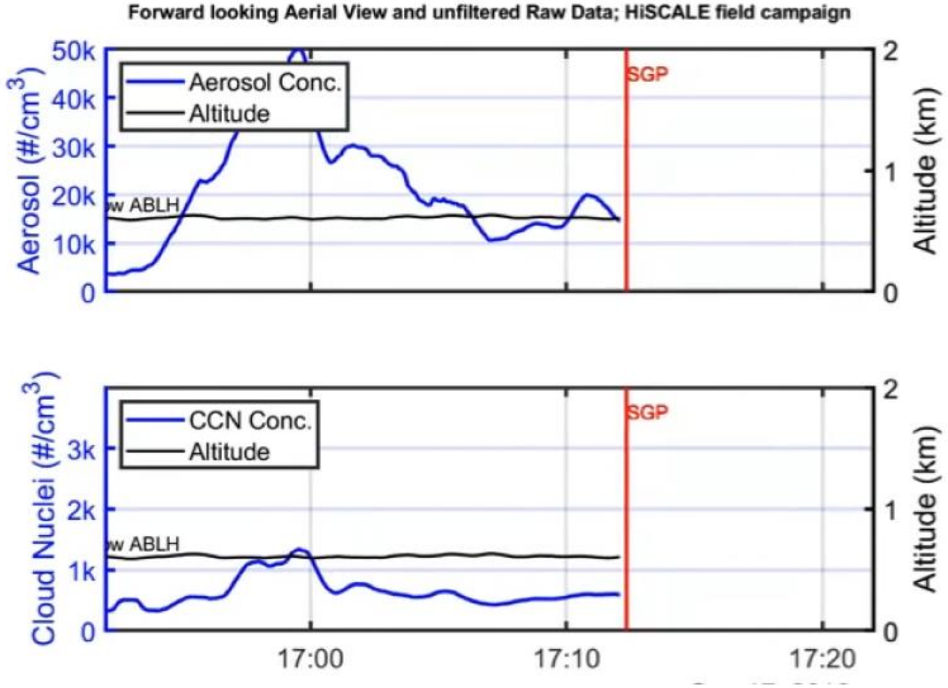
Implications:
This work will help us *to routinely calculate vertically resolved CCN to study ACI processes*. Construct a CCN climatology to better quantify ACI effects.
It should be noted that estimating CCN budget at the base of a liquid cloud remains highly uncertain.

Assessment Methodology





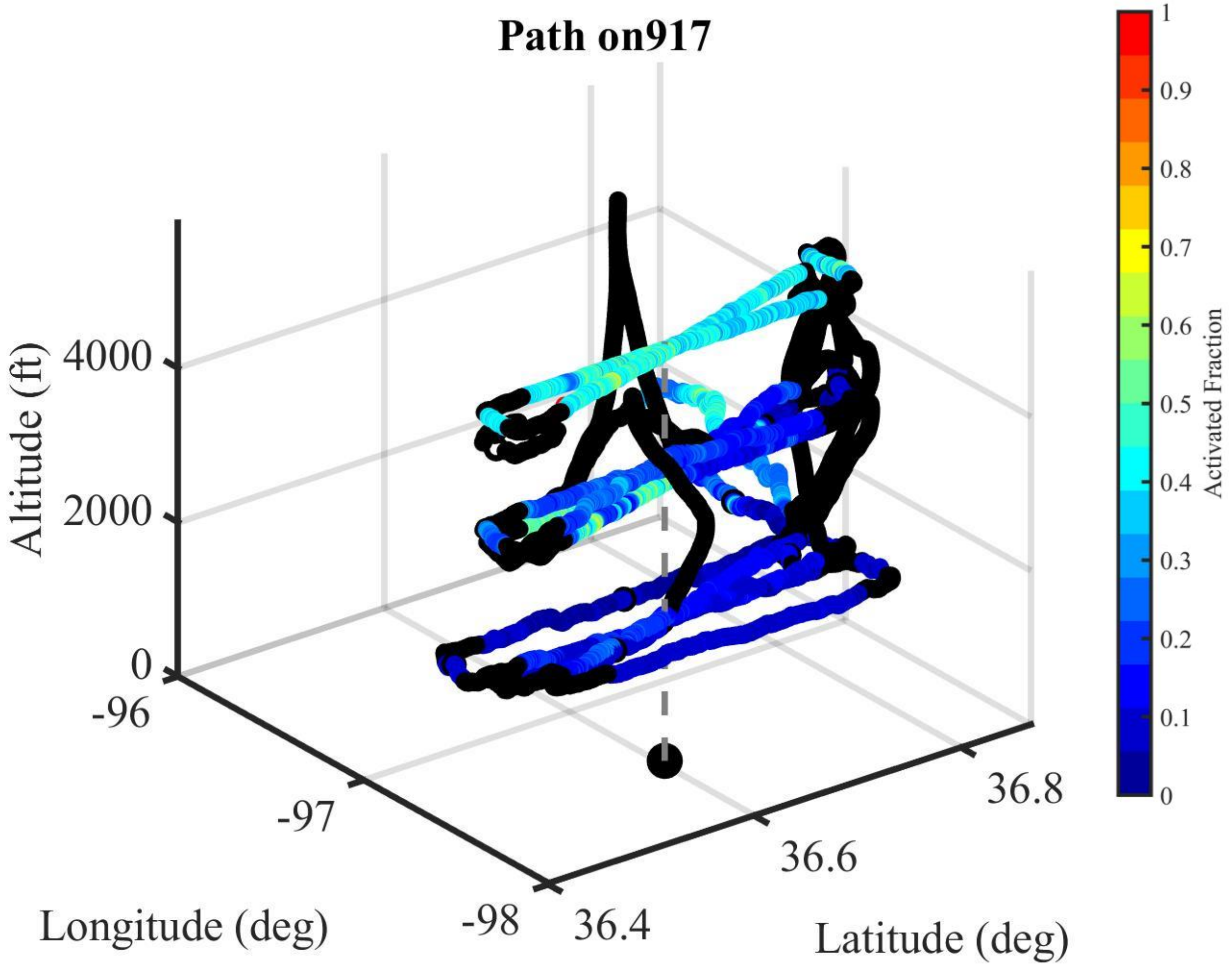
Fast et al. 2019



Forward looking aircraft movie; Supplementary, Kulkarni et al. 2023

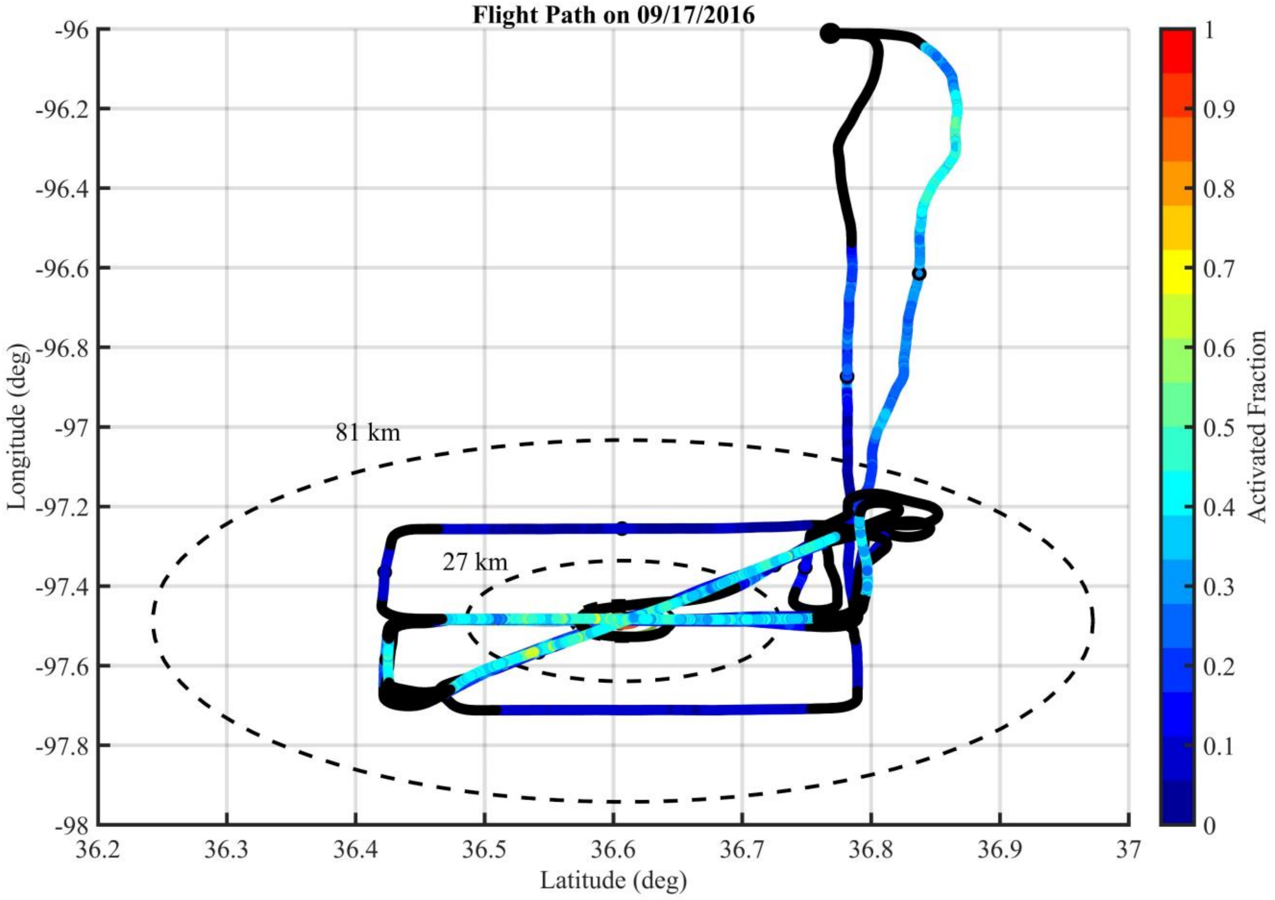
We have time series of airborne Aerosol and CCN data + air met data

IOP2 flights (#16):
Aug30a, 30b ;
Sept 1, 3, 4a, 4b, 6, 7a, 7b, 9, 10, 11, 13, 15a, 15b, **17**



Assessment at constant altitude within ± 100 m vertical distance.

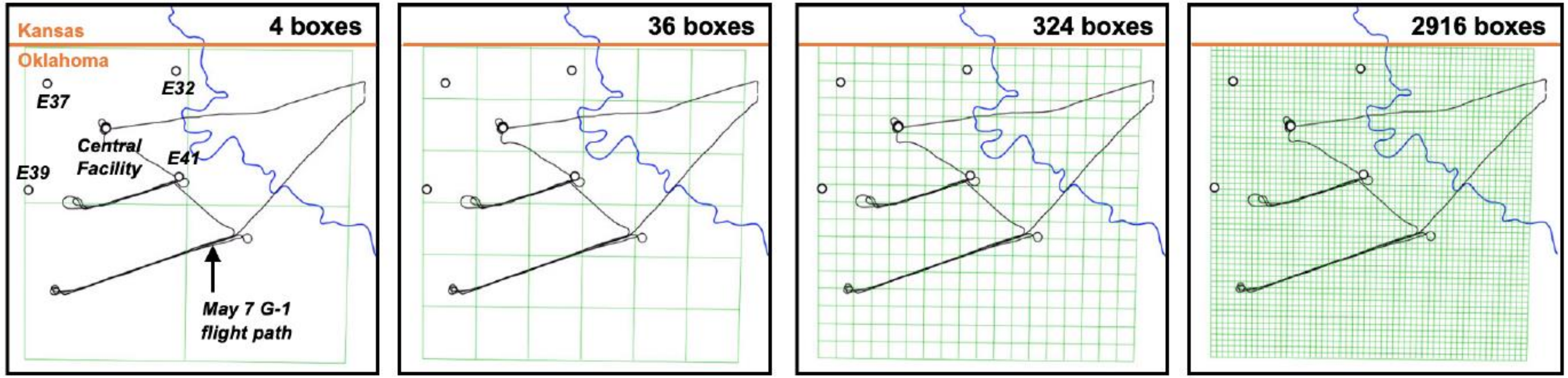
CCN data from multiple legs (#27) but that are at constant altitude are binned and averaged.



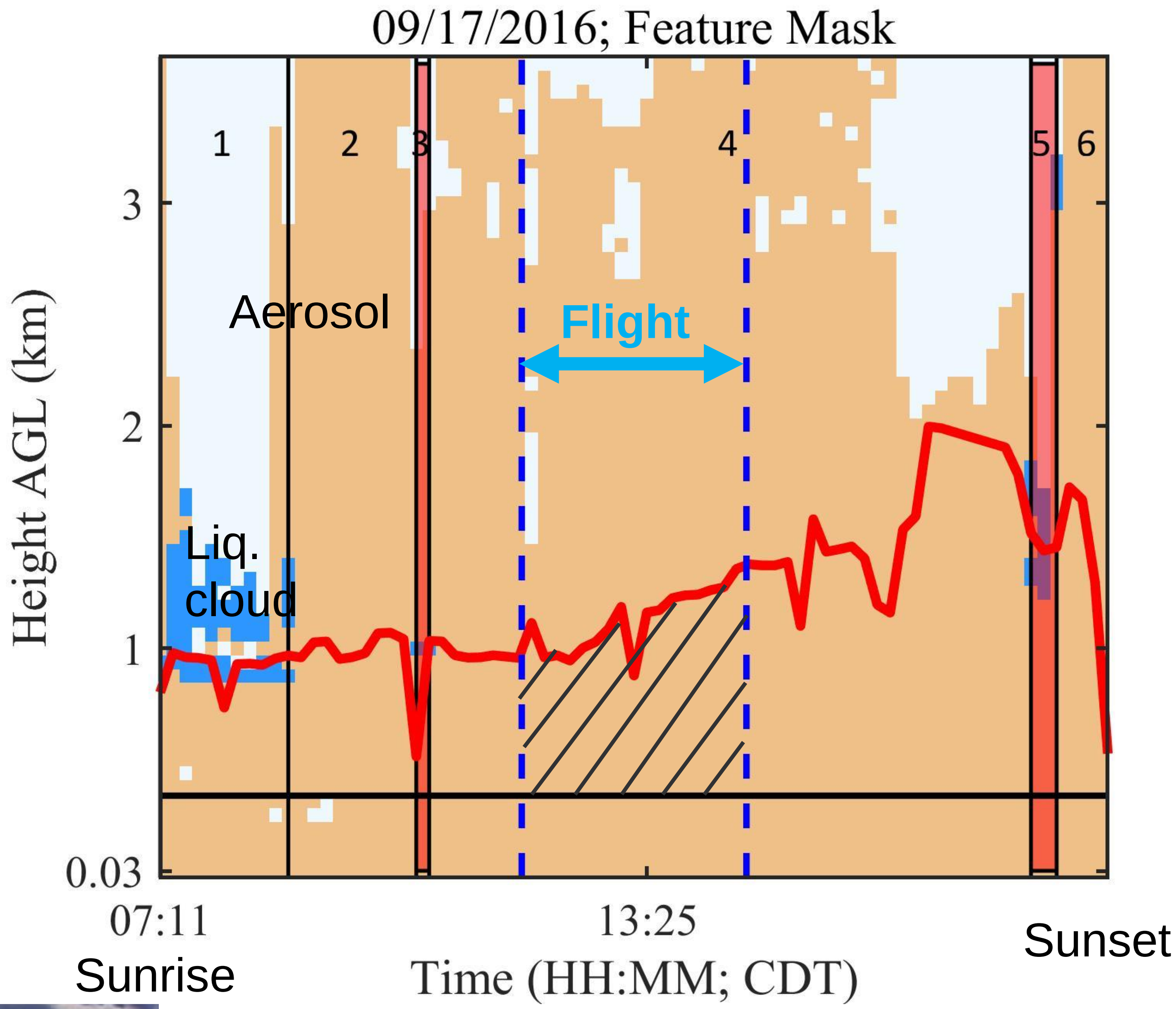
Collocation distance window: 3, 9, 27, and 81 km horizontal distance away from the site.

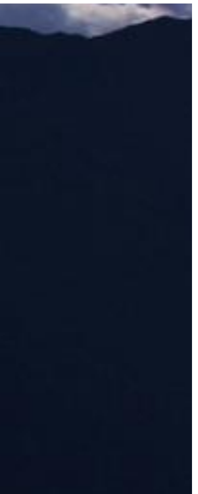
Data is screened based on the distance away from the site.

Fast et al. 2022



(a) Δx = 81 km boxes ~ current climate models
(b) Δx = 27 km boxes ~ near-future climate models
(c) Δx = 9 km boxes ~ current global forecast models
(d) Δx = 3 km boxes "cloud-system resolving" model





Time-Height display of feature mask

RL product provides feature mask:

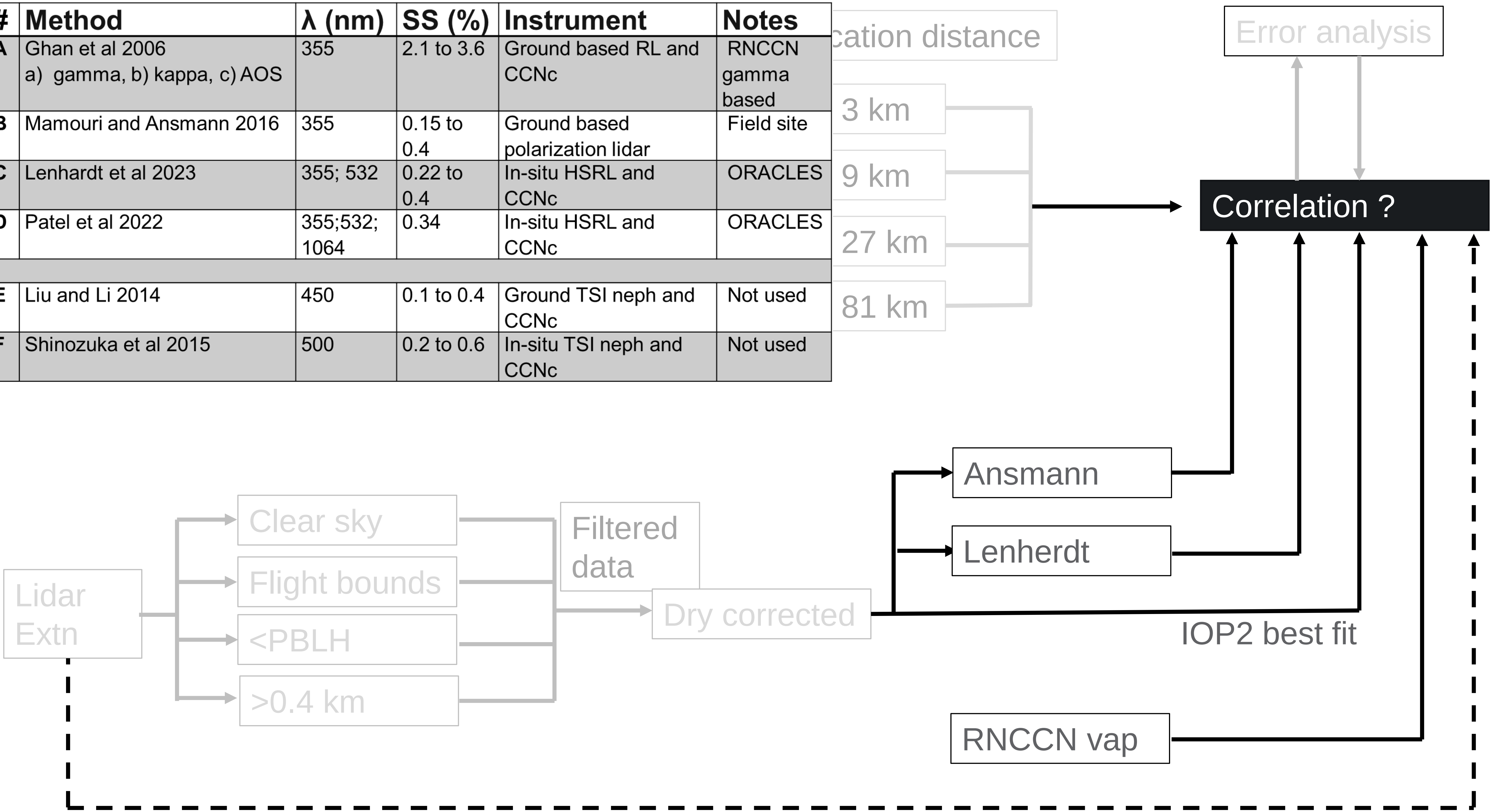
Aerosol,
rain,
liq_cloud,
ice_cloud

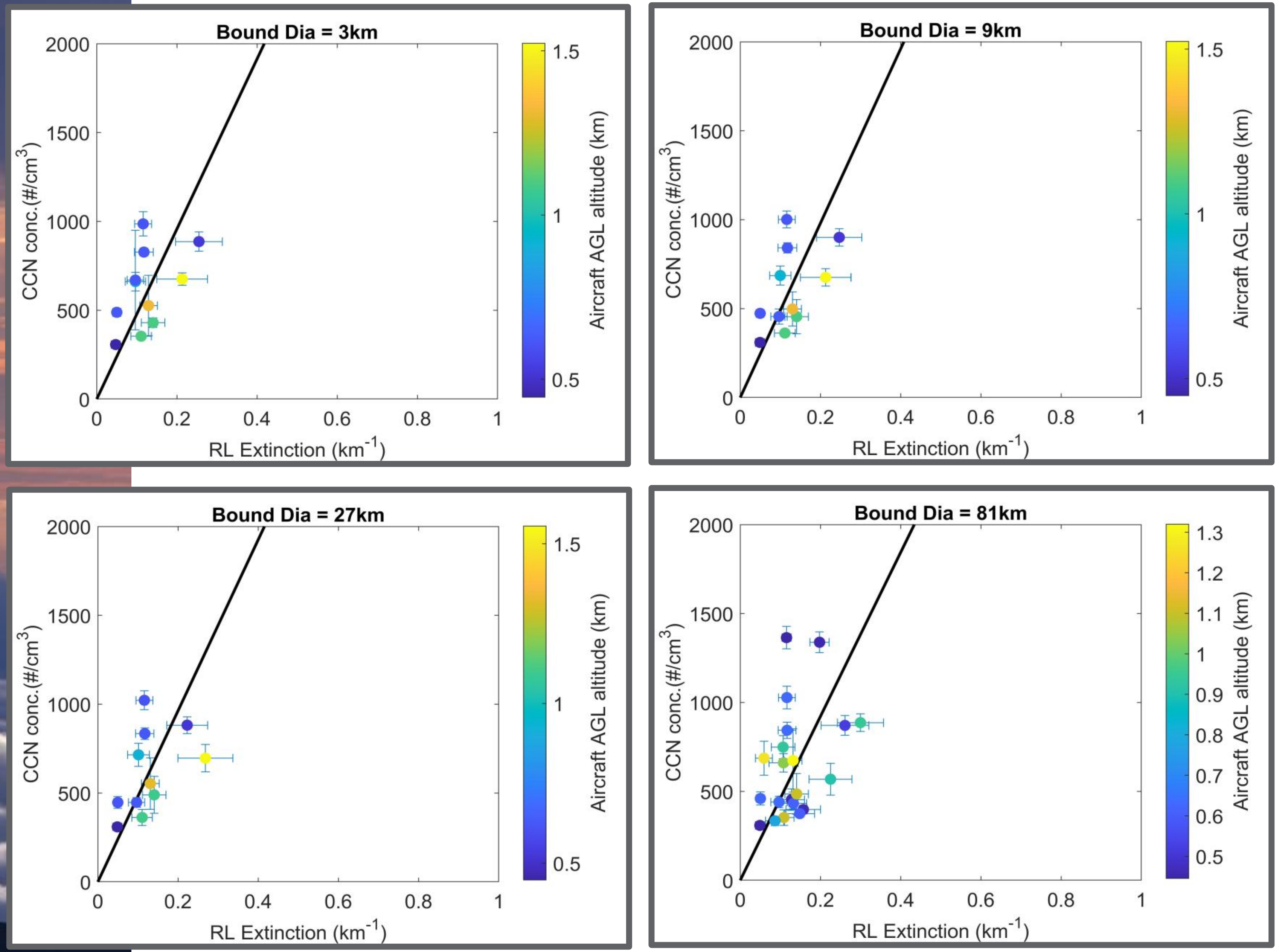
Clear sky days are used in this analysis.

Extn values that overlap with flight periods are used.

Literature Methods

#	Method	λ (nm)	SS (%)	Instrument	Notes
A	Ghan et al 2006 a) gamma, b) kappa, c) AOS	355	2.1 to 3.6	Ground based RL and CCNc	RNCCN gamma based
B	Mamouri and Ansmann 2016	355	0.15 to 0.4	Ground based polarization lidar	Field site
C	Lenhardt et al 2023	355; 532	0.22 to 0.4	In-situ HSRL and CCNc	ORACLES
D	Patel et al 2022	355;532; 1064	0.34	In-situ HSRL and CCNc	ORACLES
E	Liu and Li 2014	450	0.1 to 0.4	Ground TSI neph and CCNc	Not used
F	Shinozuka et al 2015	500	0.2 to 0.6	In-situ TSI neph and CCNc	Not used



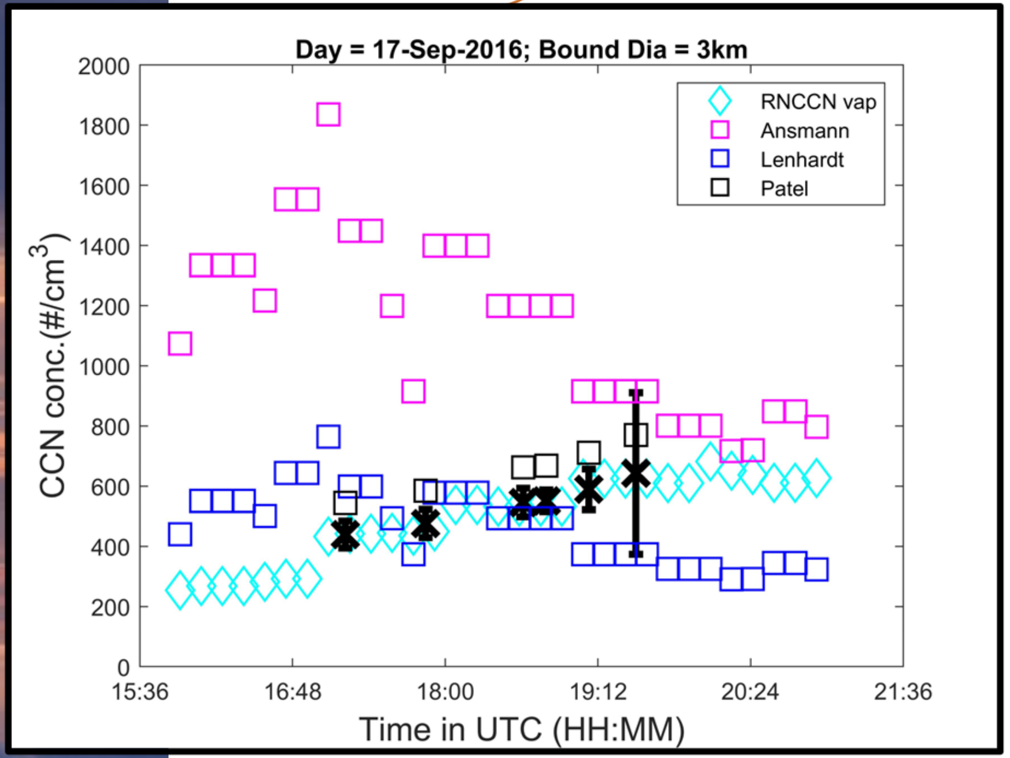


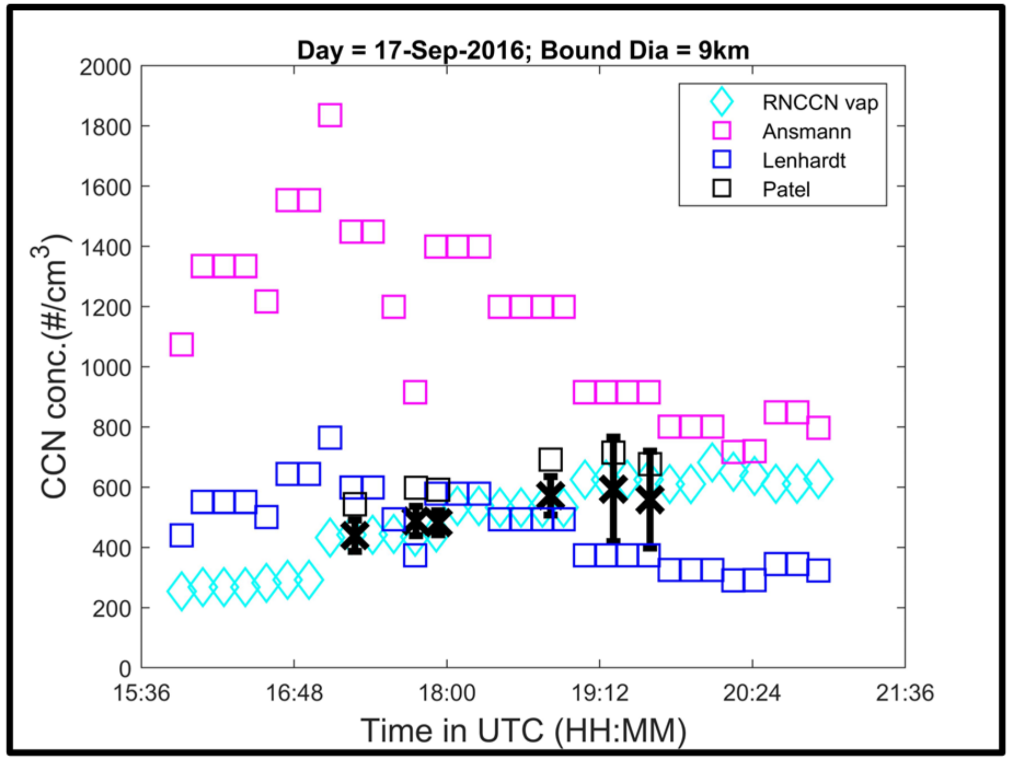
R is better when distance is short.

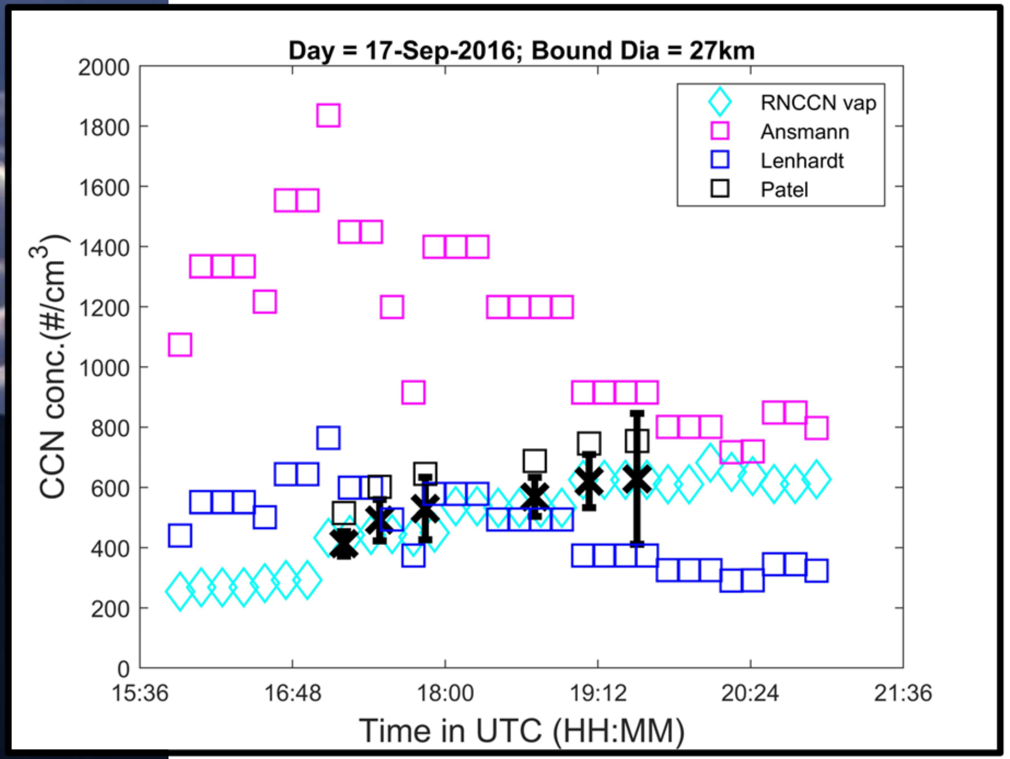
Z transformation (measure of 95% CI in the R) shows wide range.

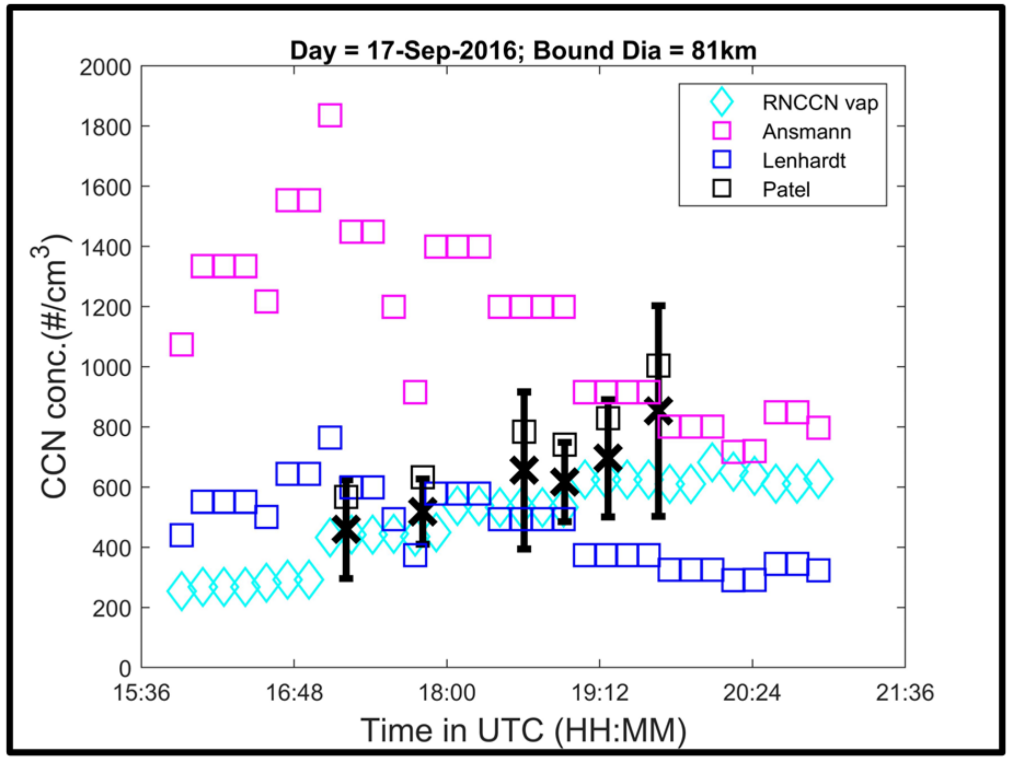
One can derive best fit slope (with intercept = 0) and compare against previous methods.

Grid (km)	R^2	Z_r; 95% CI	RMSE ($\#/cm^3$)	Best fit slope
3	0.55	0.27-0.94	170	4785
9	0.6	0.31-0.93	159	4902
27	0.52	0.21-0.92	187	4813
81	0.35	0.21-0.81	253	4609







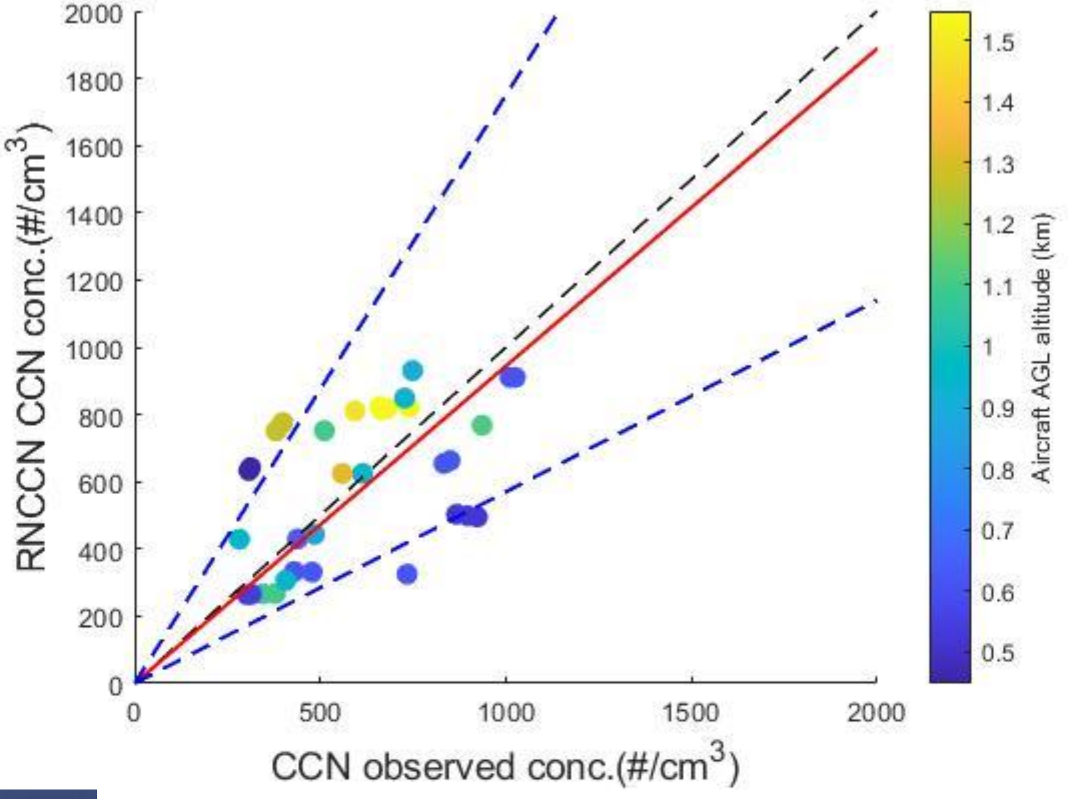


Mean (x) and range (1SD) of airCCN from the constant altitude legs were compared with the retrieved CCN.

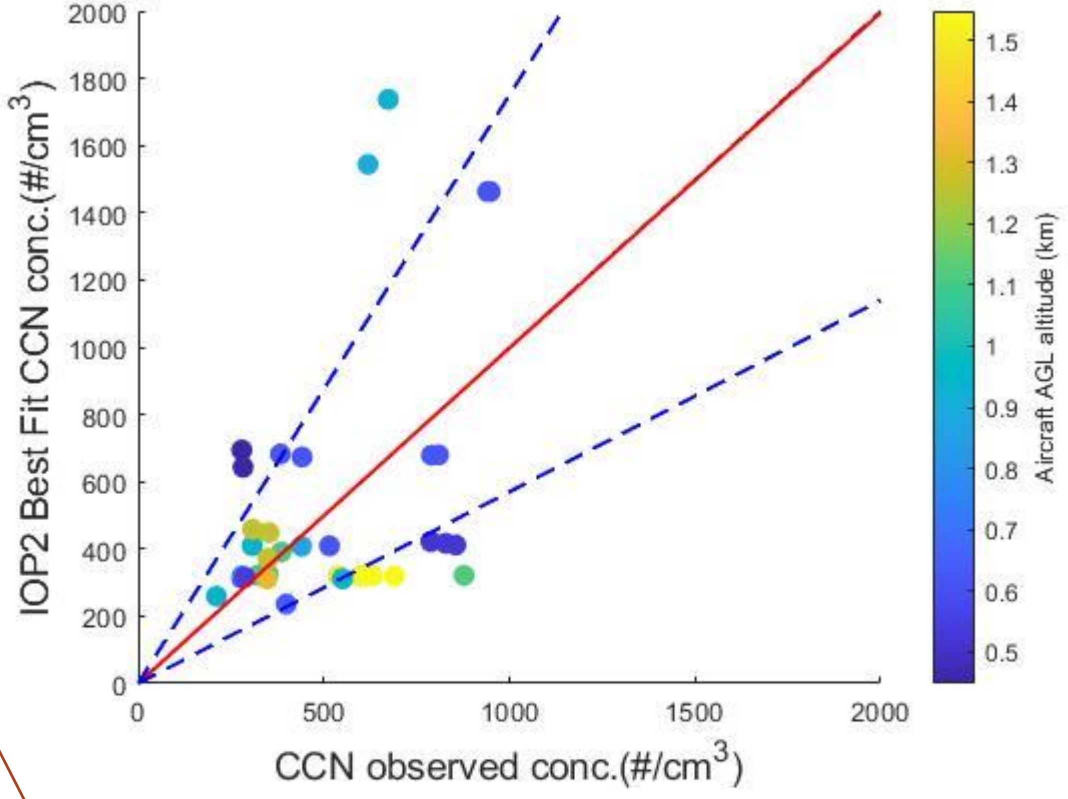
In-situ retrieval methods (Lenhardt and Patel) and RNCCN vap show agreement within one order of magnitude.

Ansmann method which is developed in a region dominated by dust shows poor agreement.

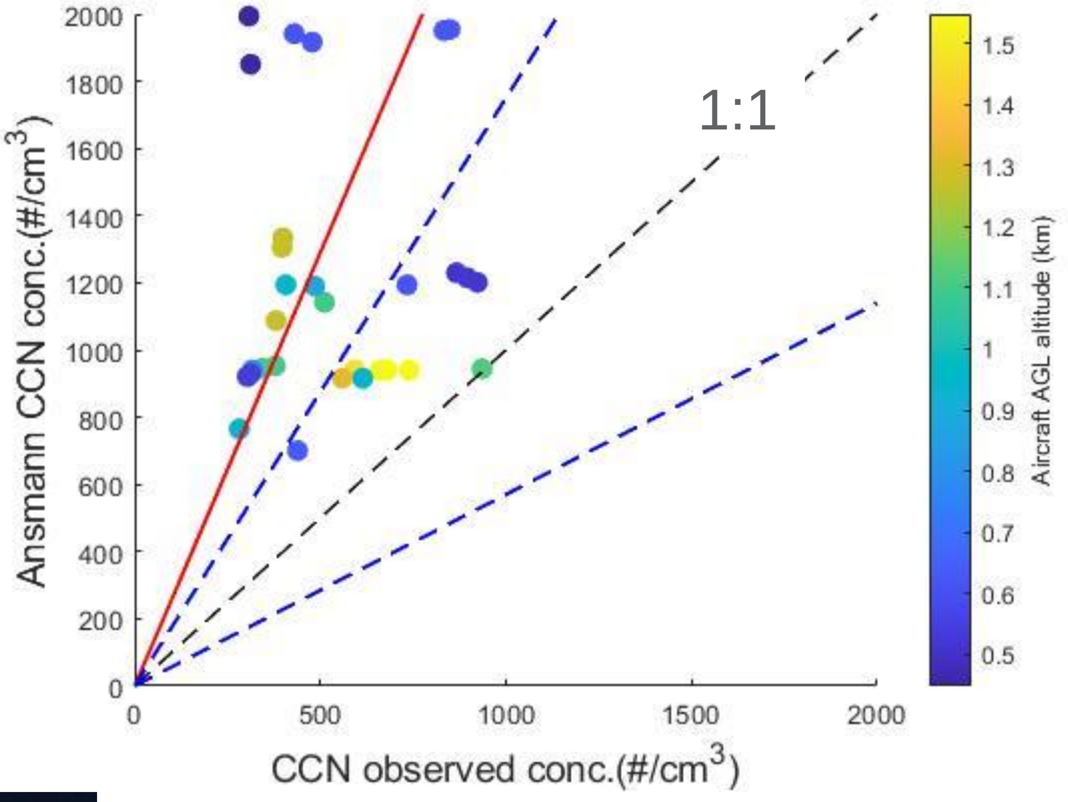
At 81km, the airCCN range (1SD) increases. Retrieval methods do not capture spatial variability.

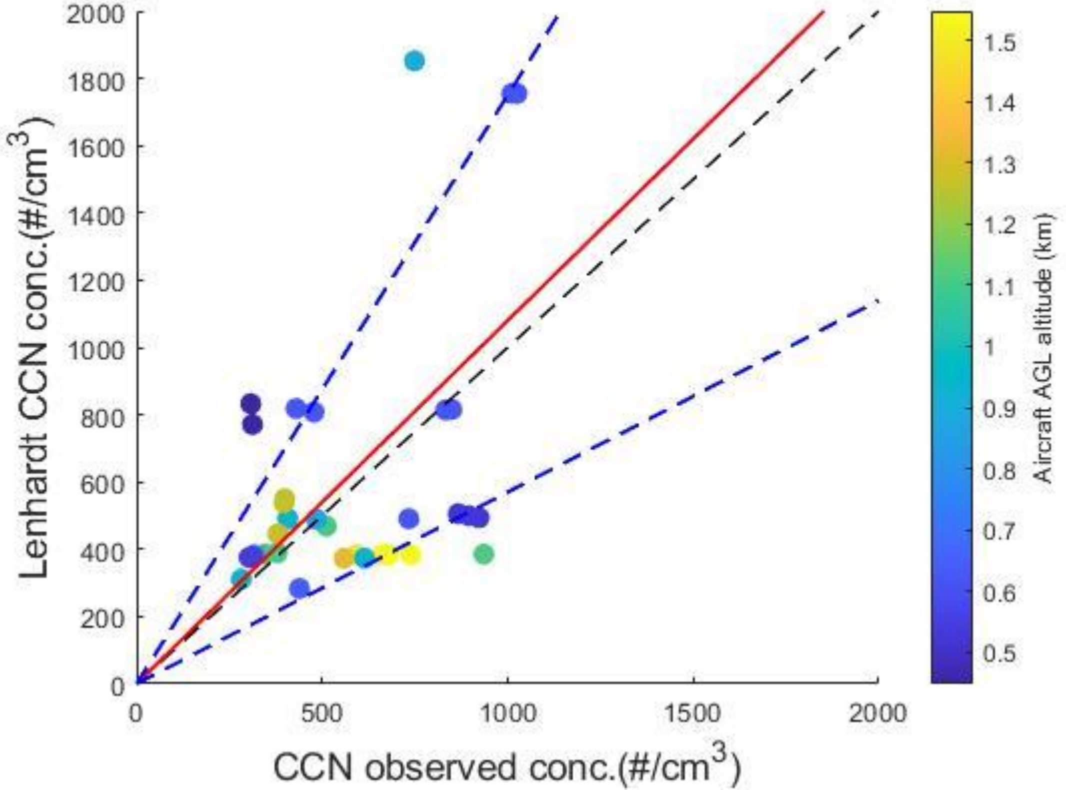


Agreement within ±75% uncertainty.



Summary of all IOP2 days





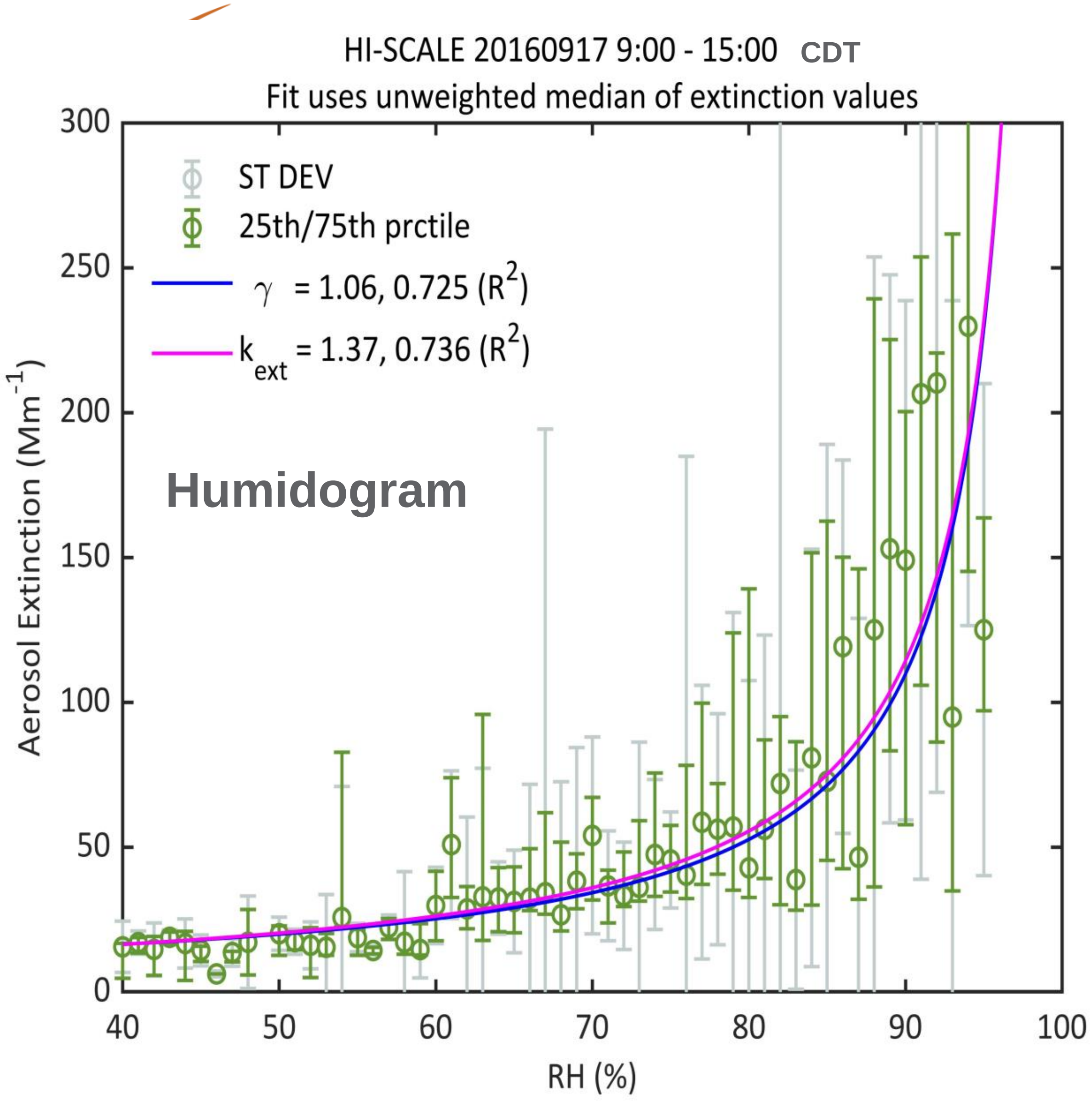
9 km collocation distance

Summary

Preliminary analysis show:

- Estimating vertical CCN budget is still challenging. Under well mixed boundary layer conditions, certain existing retrieval methods show agreement within order of magnitude.
- Correlation between airCCN and just extinction can be obtained with $R^2 = 0.5$.
- For certain days, the airCCN data shows broader range when using 81km distance window indicating presence of broader range of aerosol properties. Sensitivity to the sampling region.
- For all IOP2 days, certain methods agree within one order of magnitude.

Thank you

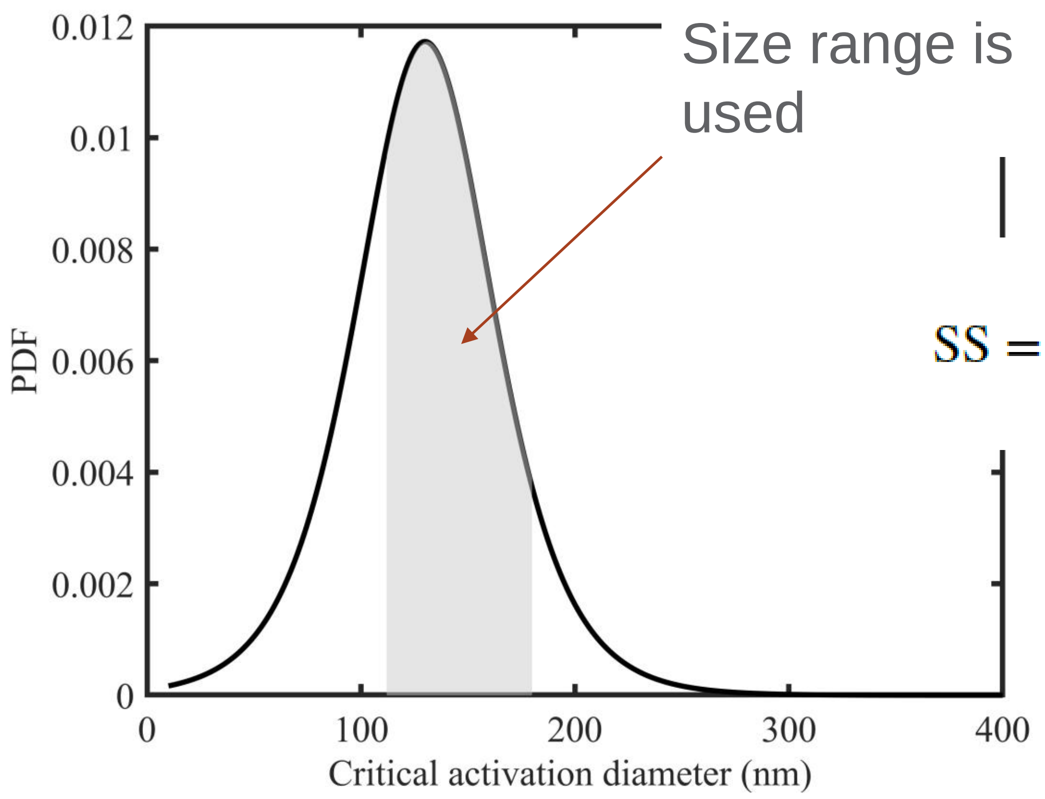


$$f(RH) \cong \frac{\alpha}{\alpha_0} = C_1(1-\mathrm{RH_f})^{-\gamma}$$

$$C_1 = (1 - \mathrm{RH_{f,0}})^{\gamma}.$$

Humidification enhancement factor is used for water-uptake corrections.

Ambient extinction profiles are corrected to dry extinction using fRH constant.

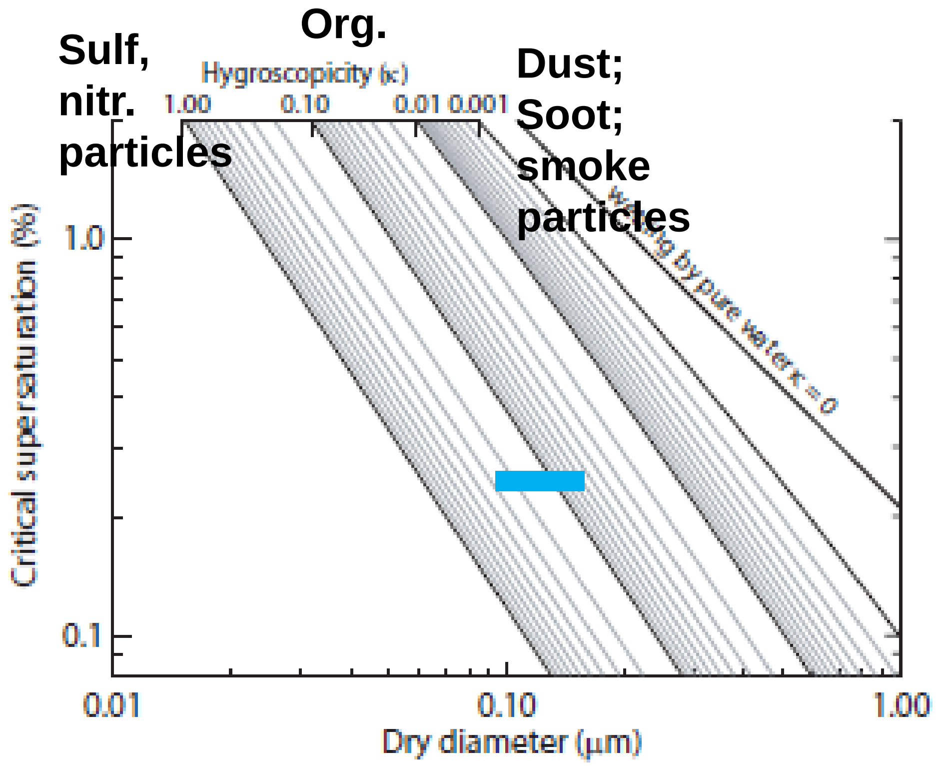


$$SS = \frac{D^3 - D_d^3}{D^3 - D_d^3(1-\kappa)} \exp\left(\frac{4\sigma_w M_w}{RT\rho_w D}\right)$$

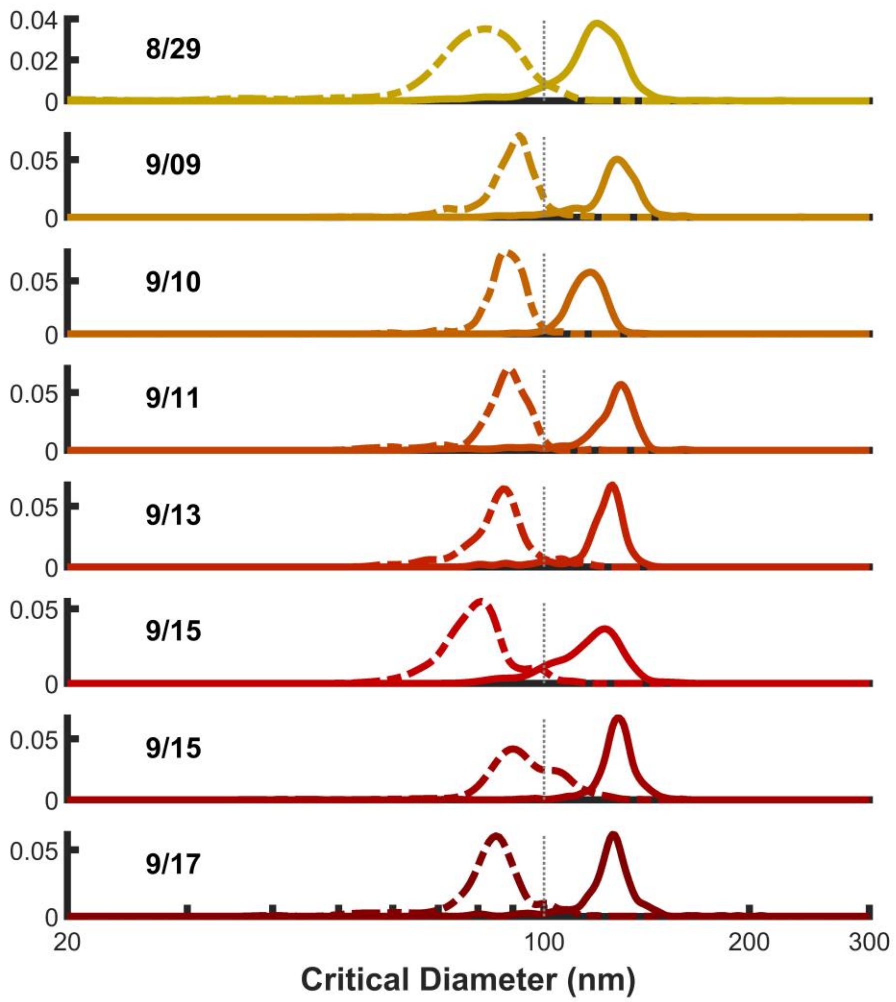
Kappa between 0.04 and 0.17 is used to constrain the chemical composition of aerosol.

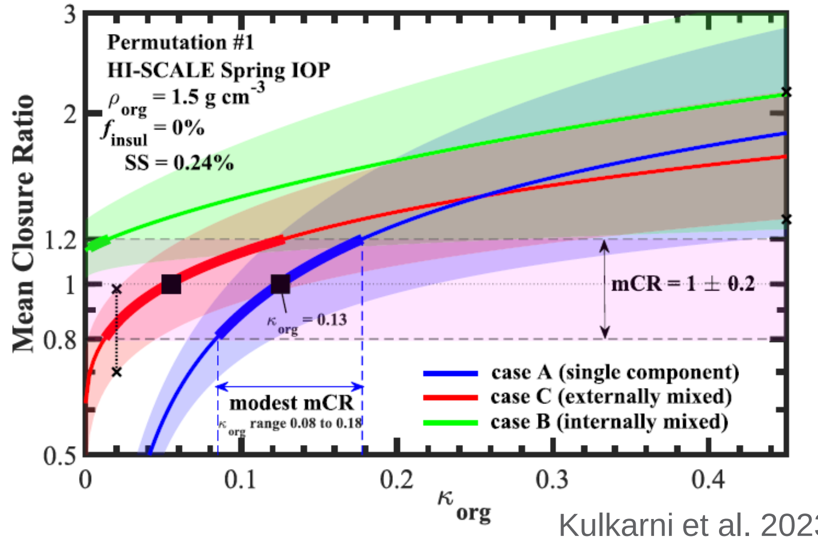
At constant SS, the bounds of dry diameter are calculated.

For analysis, time stamps that has dry dia between these bounds are used.



Petters et al 2007





Kulkarni et al. 2023