Closure between HALO measured CCN (S), cloud base updraft and cloud droplets concentration

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Closure

Definition: Closure study is a set of analysis which combines in-situ measurements and model simulations in order to generate the understanding of physical processes.

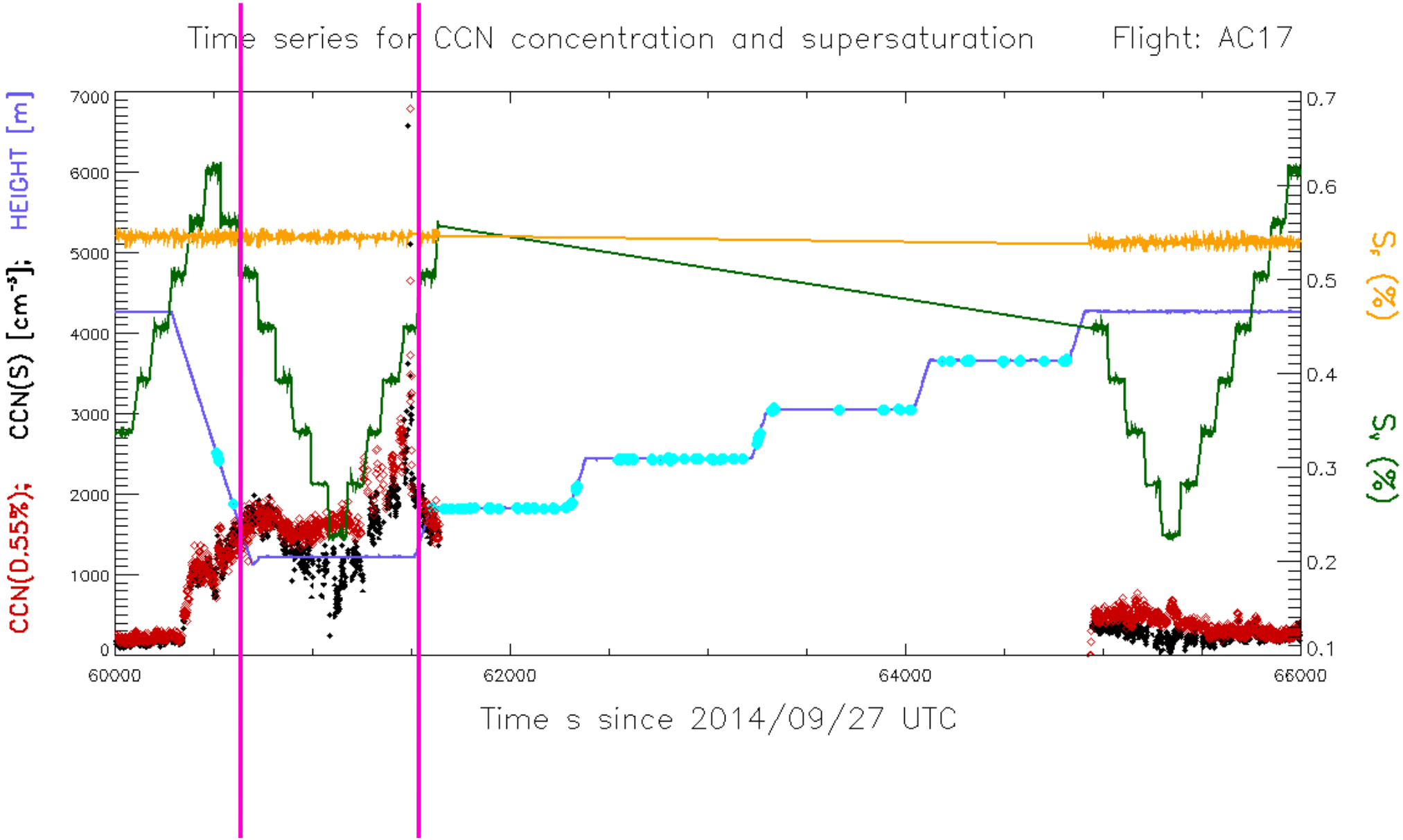
Importance: The learnings from closures provide the capability to reproduce it for larger coverage in time and space via simulation but not measured.

- Cloud base –> objective: understand what determines the number of cloud droplets concentration (Nd).

Aerosol + Updrafts

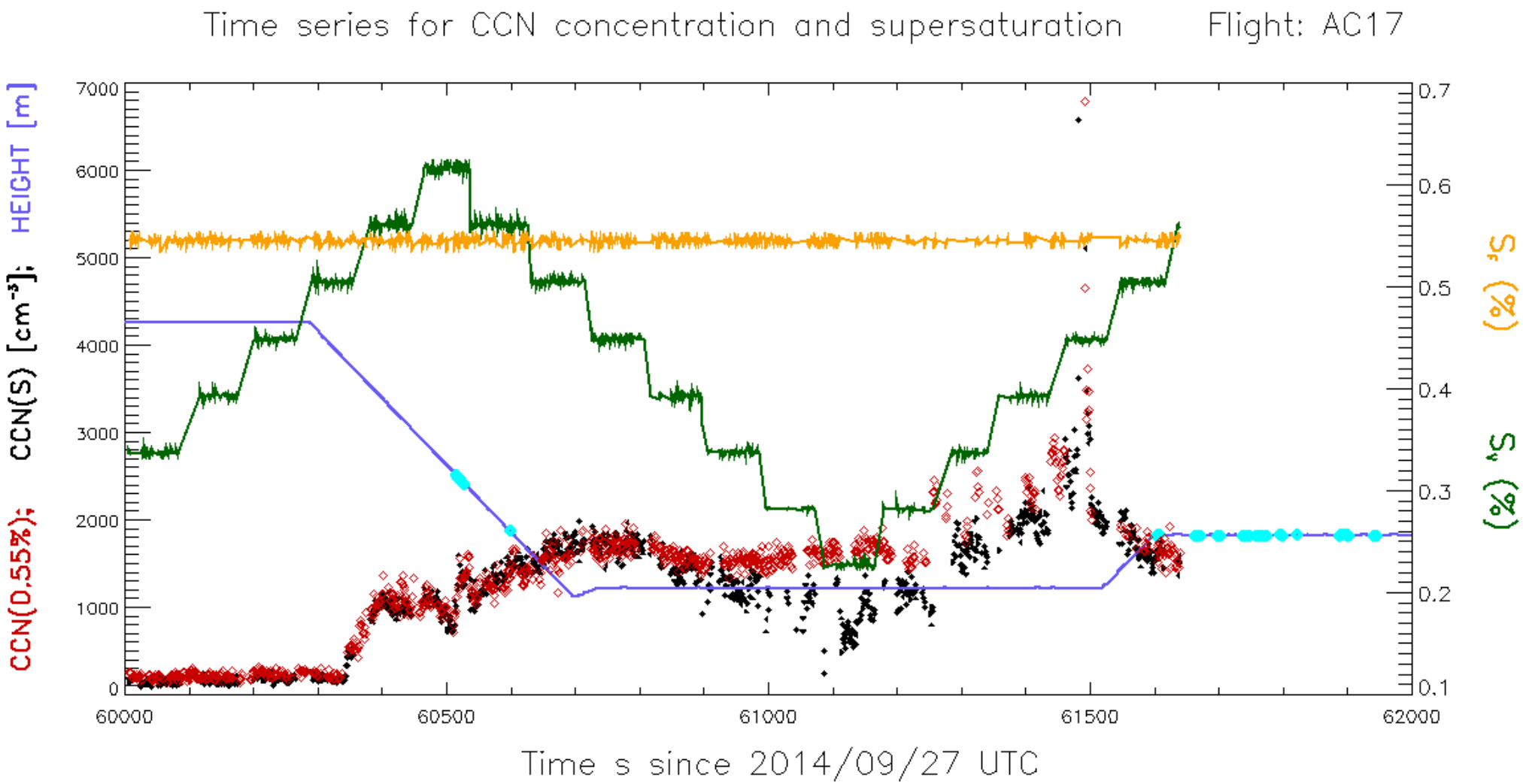
Pristine **Polluted**

CLOUD MICROPHYSICS MEASUREMENTS WITH HALO AIRCRAFT ON FLIGHT AC17



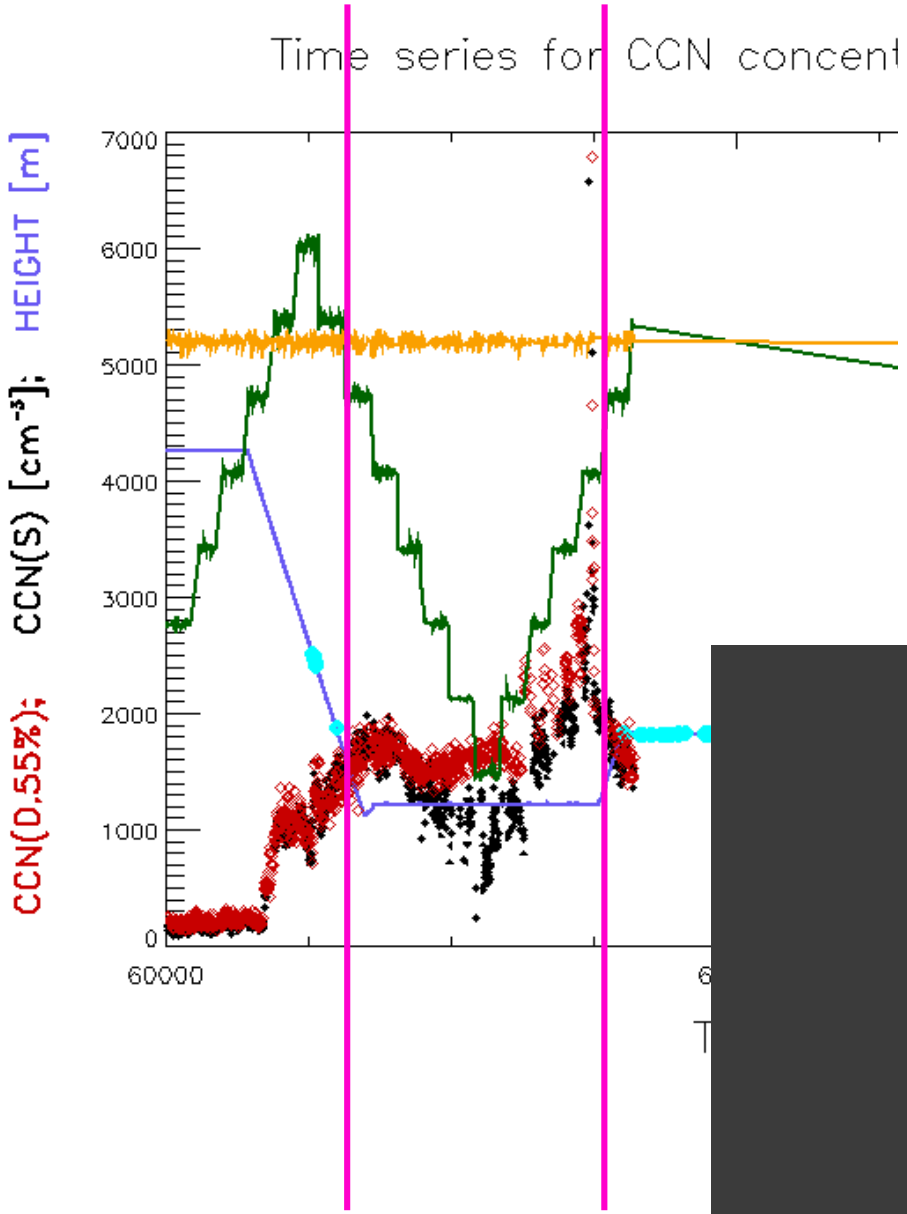
UNDER CLOUD BASE

CCN measurements under the cloud base



CCN measurements with fixed SS (%) and variable SS (%)

CLOUD MICROPHYSI
HALO AIRCRAF

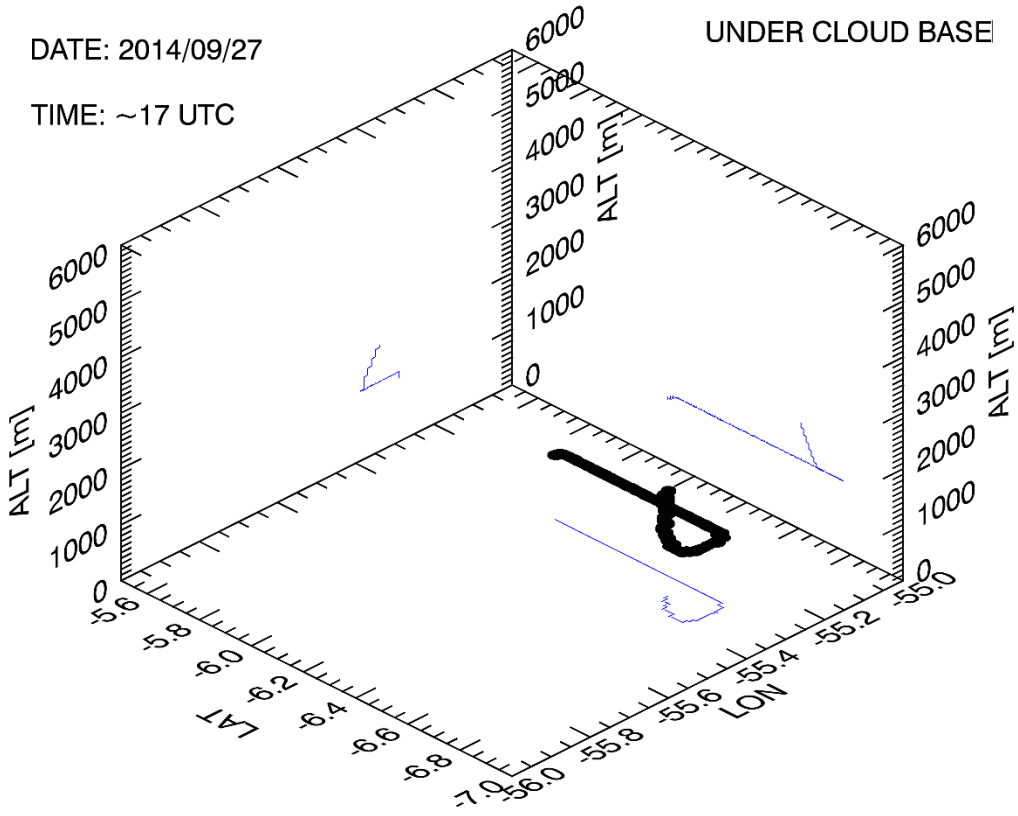


UNDER CLOUD BAS

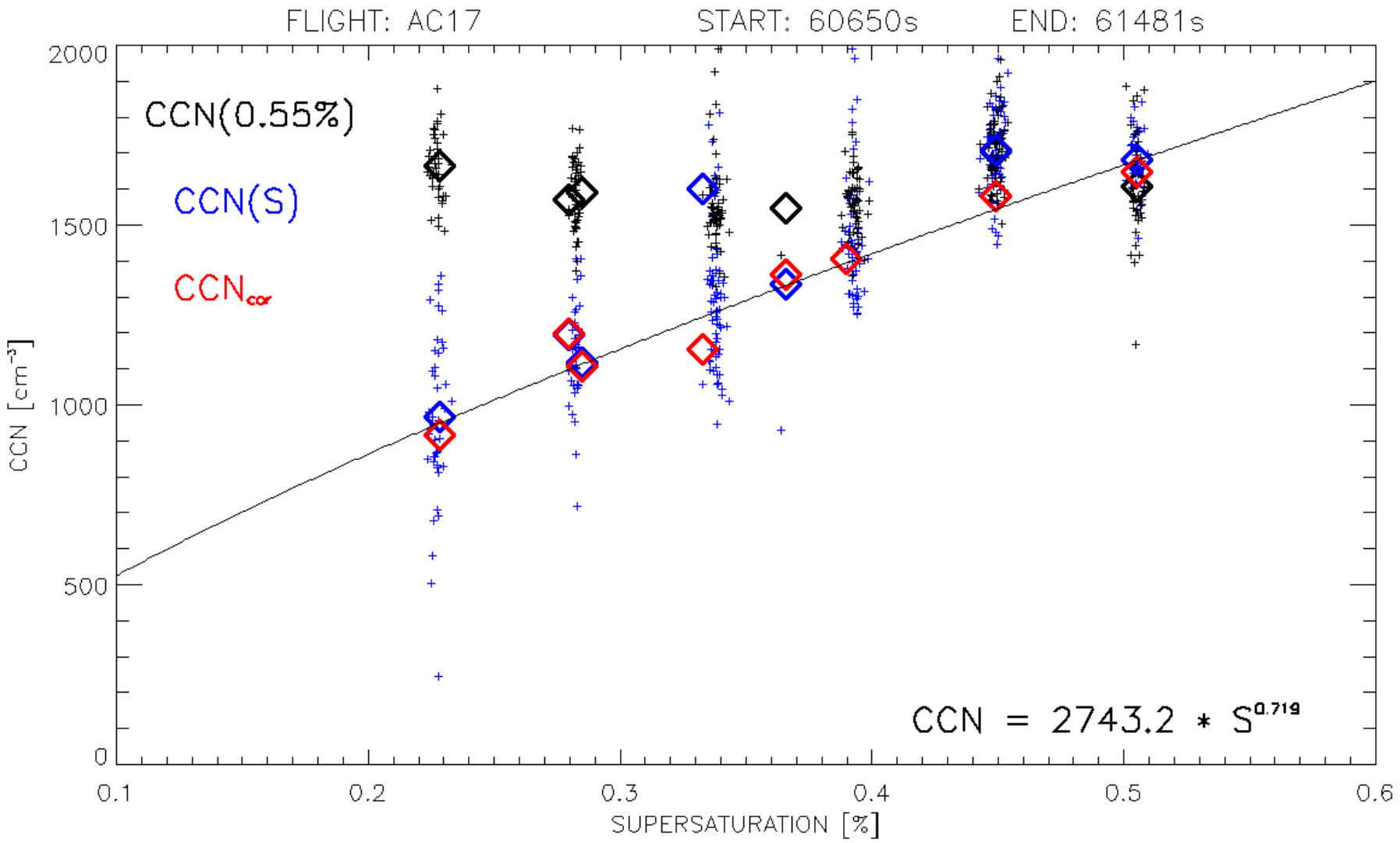
AC17

DATE: 2014/09/27

TIME: ~17 UTC

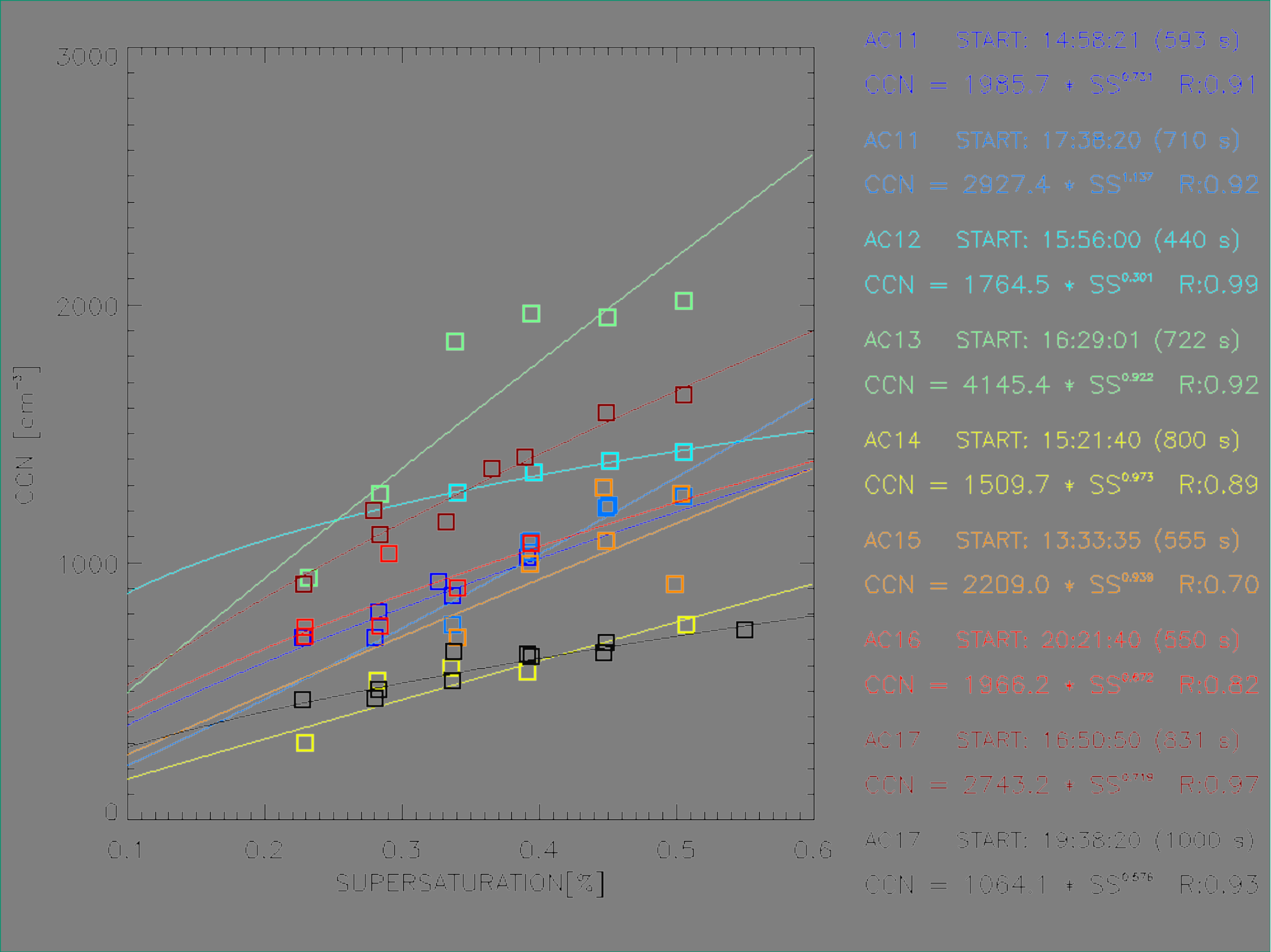


CCN measurements under the cloud base

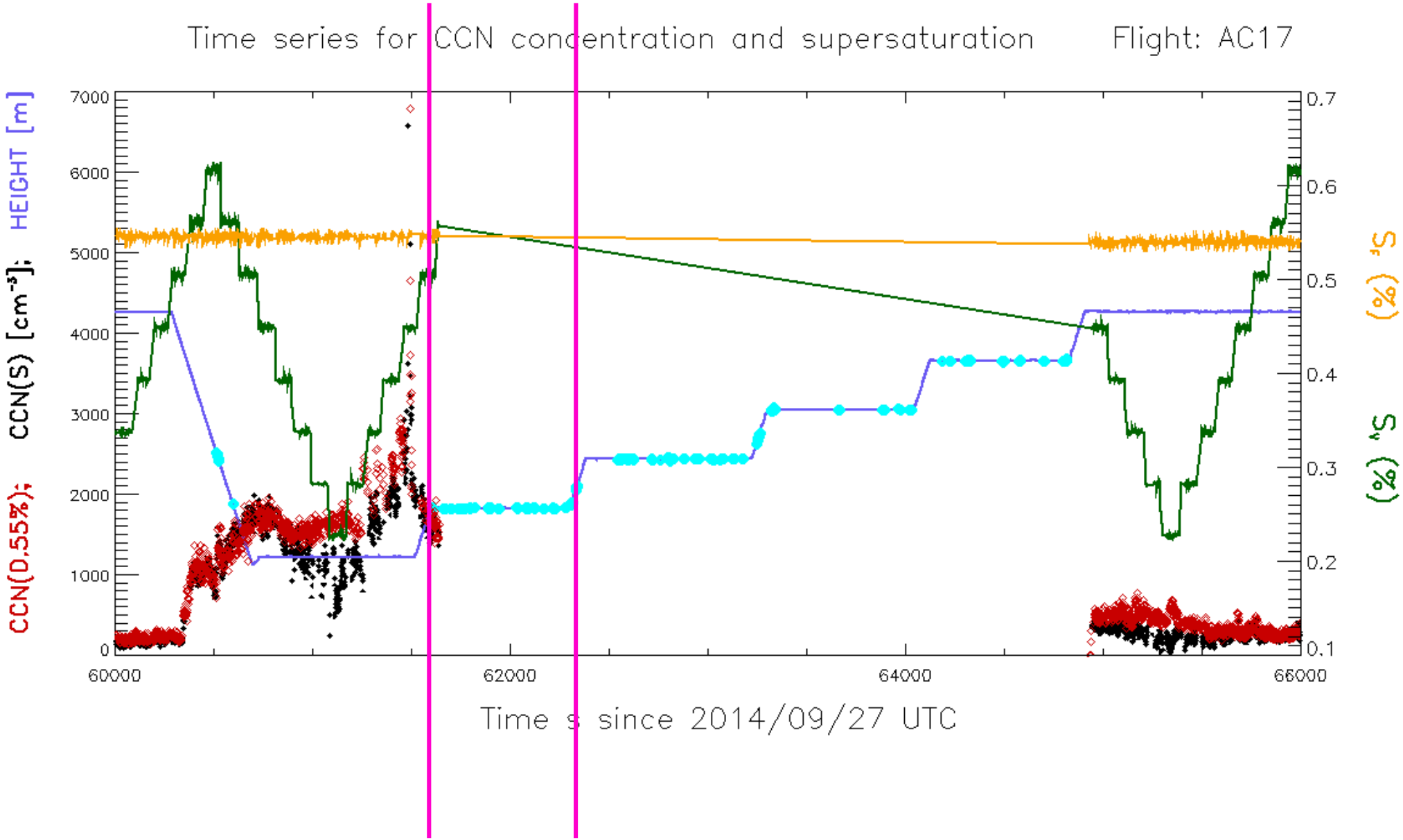


Procedure of normalization based with fixed SS(%)

CCNcor = CCN(S) * [CCN(S) / CCN(0.55%)]

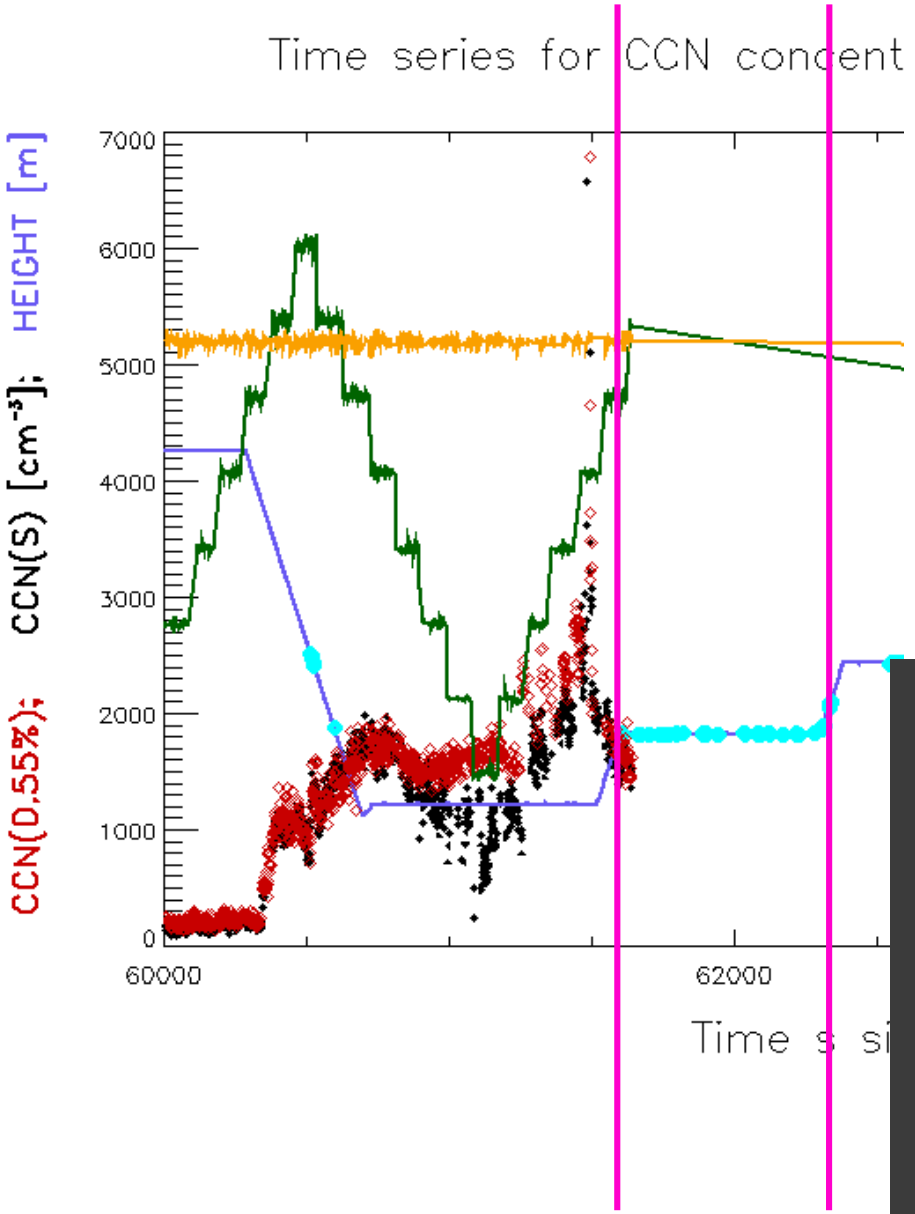

3000
2000
1000
0
CCN [cm^{-3}]
0.1
0.2
0.3
0.4
0.5
0.6
SUPERSATURATION[%]
AC11 START: 14:58:21 (593 s)
CCN = 1985.7 * SS$^{0.731}$ R:0.91
AC11 START: 17:38:20 (710 s)
CCN = 2927.4 * SS$^{1.137}$ R:0.92
AC12 START: 15:56:00 (440 s)
CCN = 1764.5 * SS$^{0.301}$ R:0.99
AC13 START: 16:29:01 (722 s)
CCN = 4145.4 * SS$^{0.922}$ R:0.92
AC14 START: 15:21:40 (800 s)
CCN = 1509.7 * SS$^{0.973}$ R:0.89
AC15 START: 13:33:35 (555 s)
CCN = 2209.0 * SS$^{0.939}$ R:0.70
AC16 START: 20:21:40 (550 s)
CCN = 1966.2 * SS$^{0.672}$ R:0.82
AC17 START: 16:50:50 (831 s)
CCN = 2743.2 * SS$^{0.719}$ R:0.97
AC17 START: 19:38:20 (1000 s)
CCN = 1064.1 * SS$^{0.576}$ R:0.93

CLOUD MICROPHYSICS MEASUREMENTS WITH HALO AIRCRAFT ON FLIGHT AC17

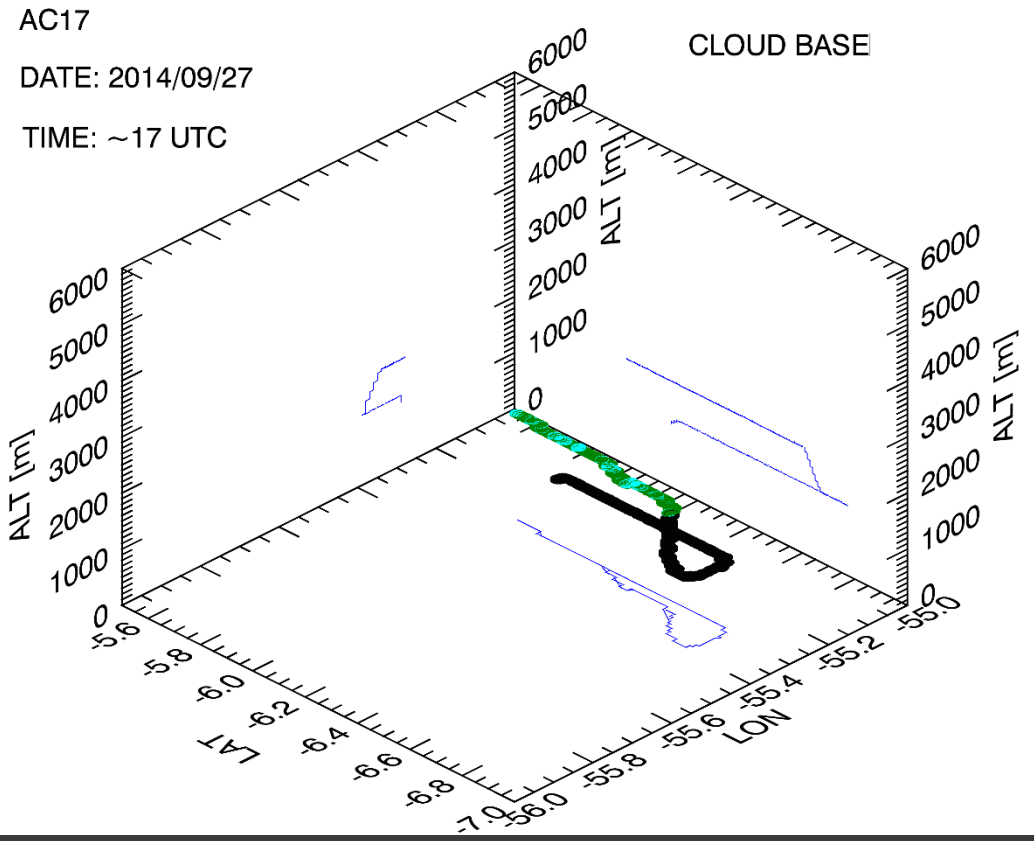


CLOUD BASE

CLOUD MICROPHYSIC
HALO AIRCRAF



CLOUD BASE

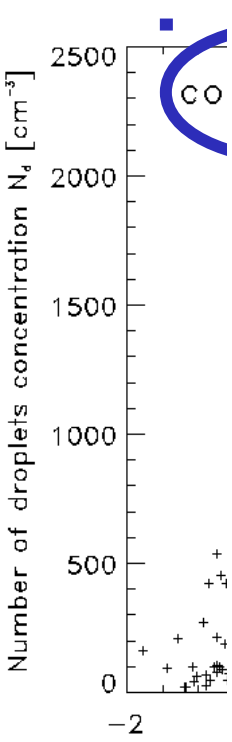


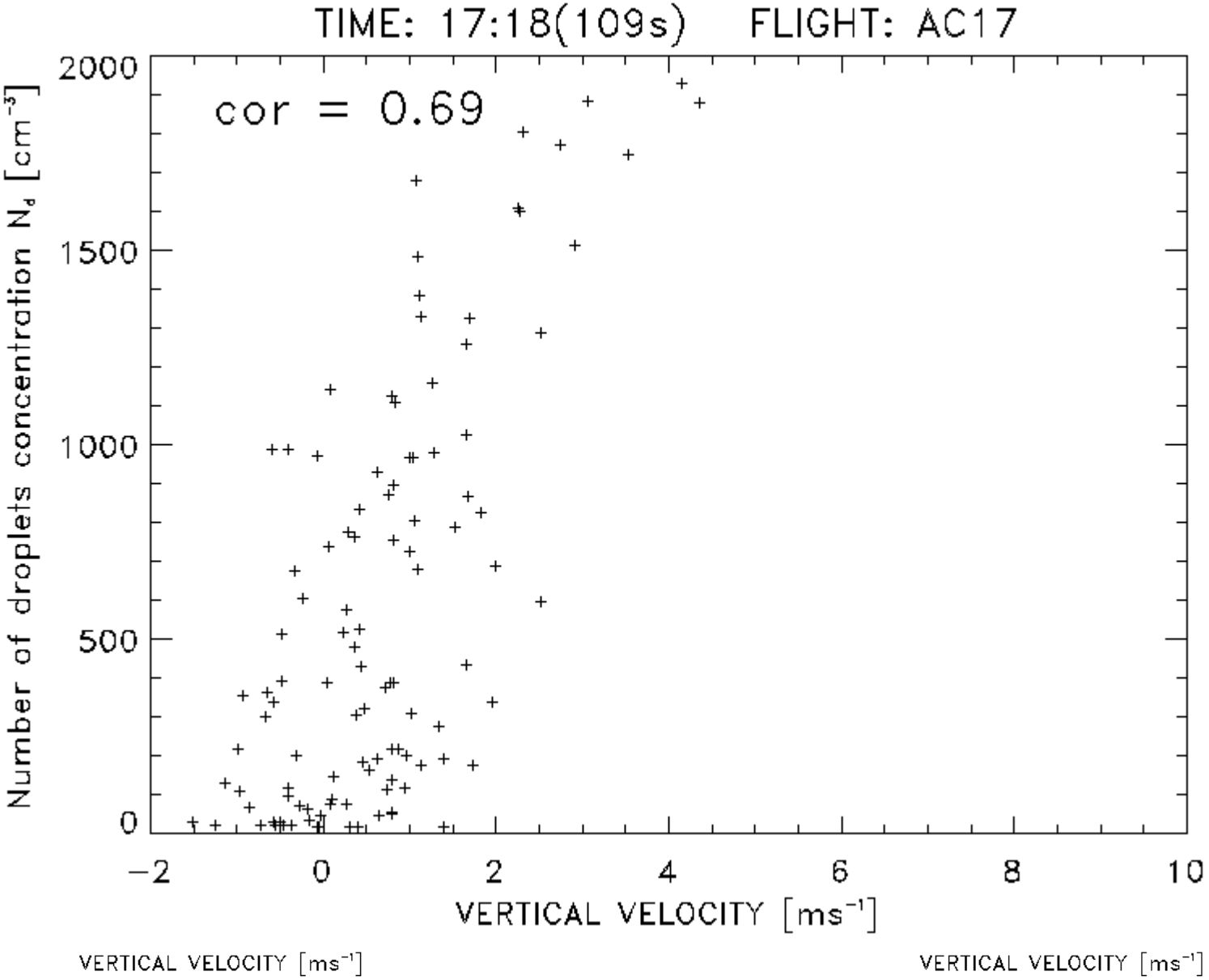
Cloud base updrafts + aerosol concentration ∞ Number of droplets in the cloud base

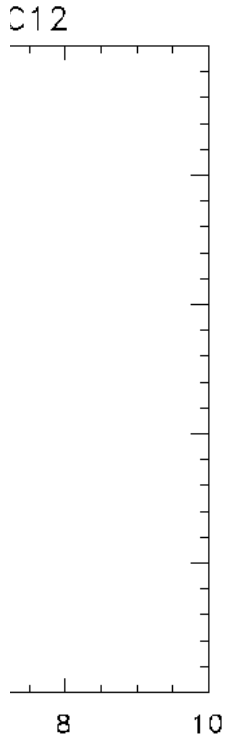
N_{dT} =

S_{max} = (

omey, 1959)



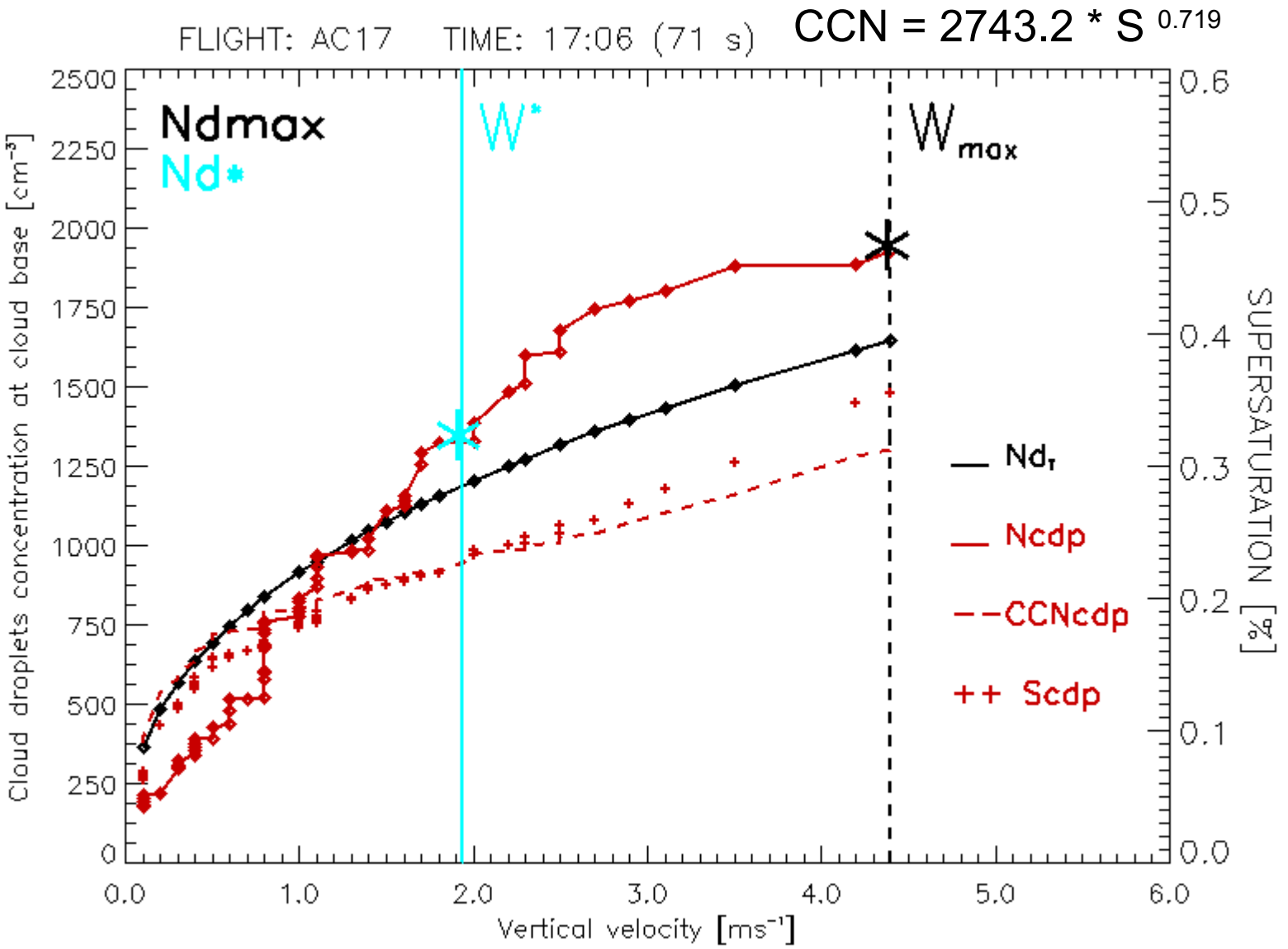




Generally the direct correlation between Nd and W is not high. The solution is to apply the probability match.

Probability match → the same percentiles of updrafts matchs the same percentiles of N_{db}

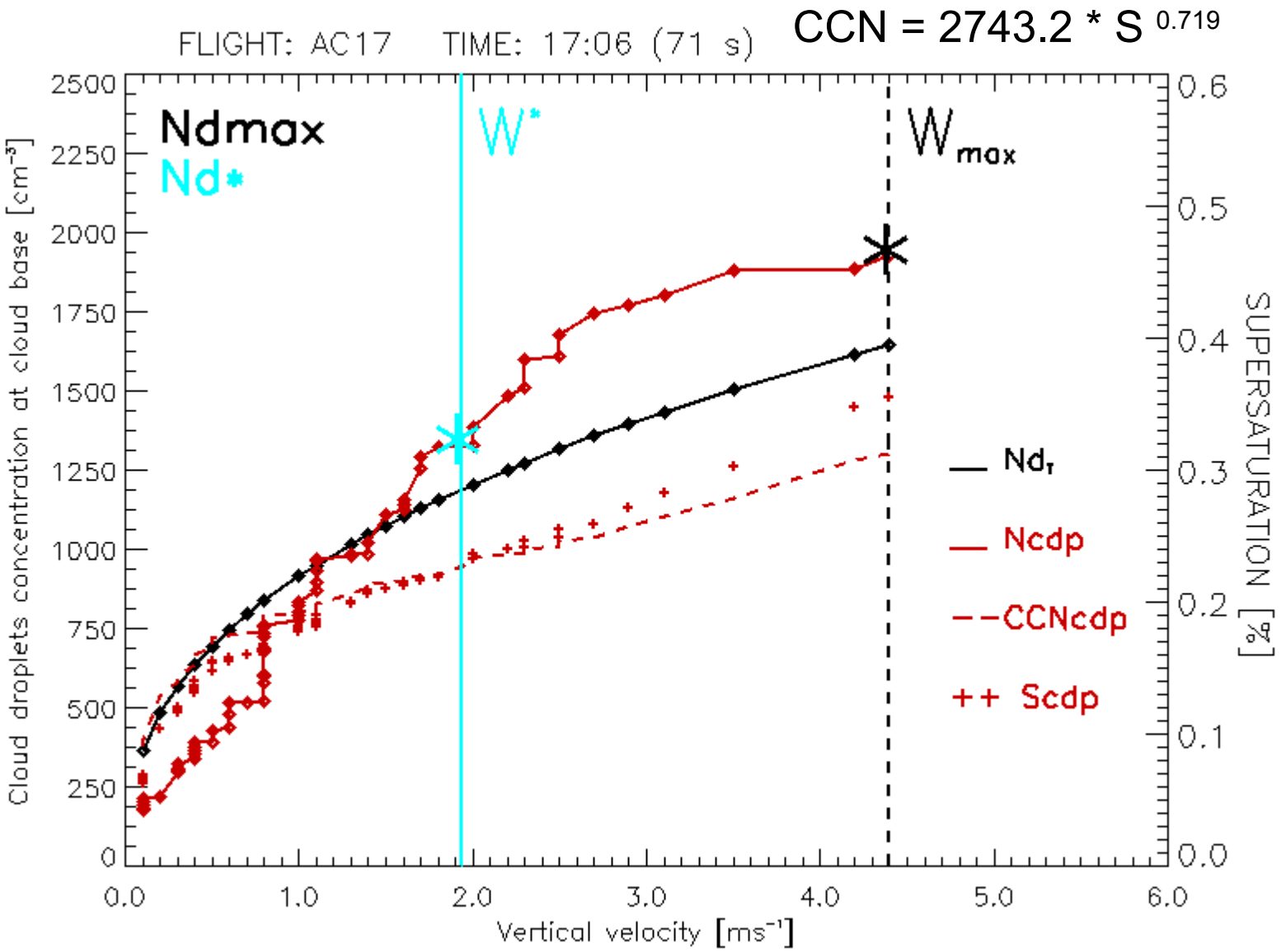
CDP



$$N_{dT} = 0.88 * N_0^{(2/k+2)} * [0.07 * (W_b^{1.5})]^{(k/k+2)}$$

Probability match → the same percentiles of updrafts matchs the same percentiles of N_{db}

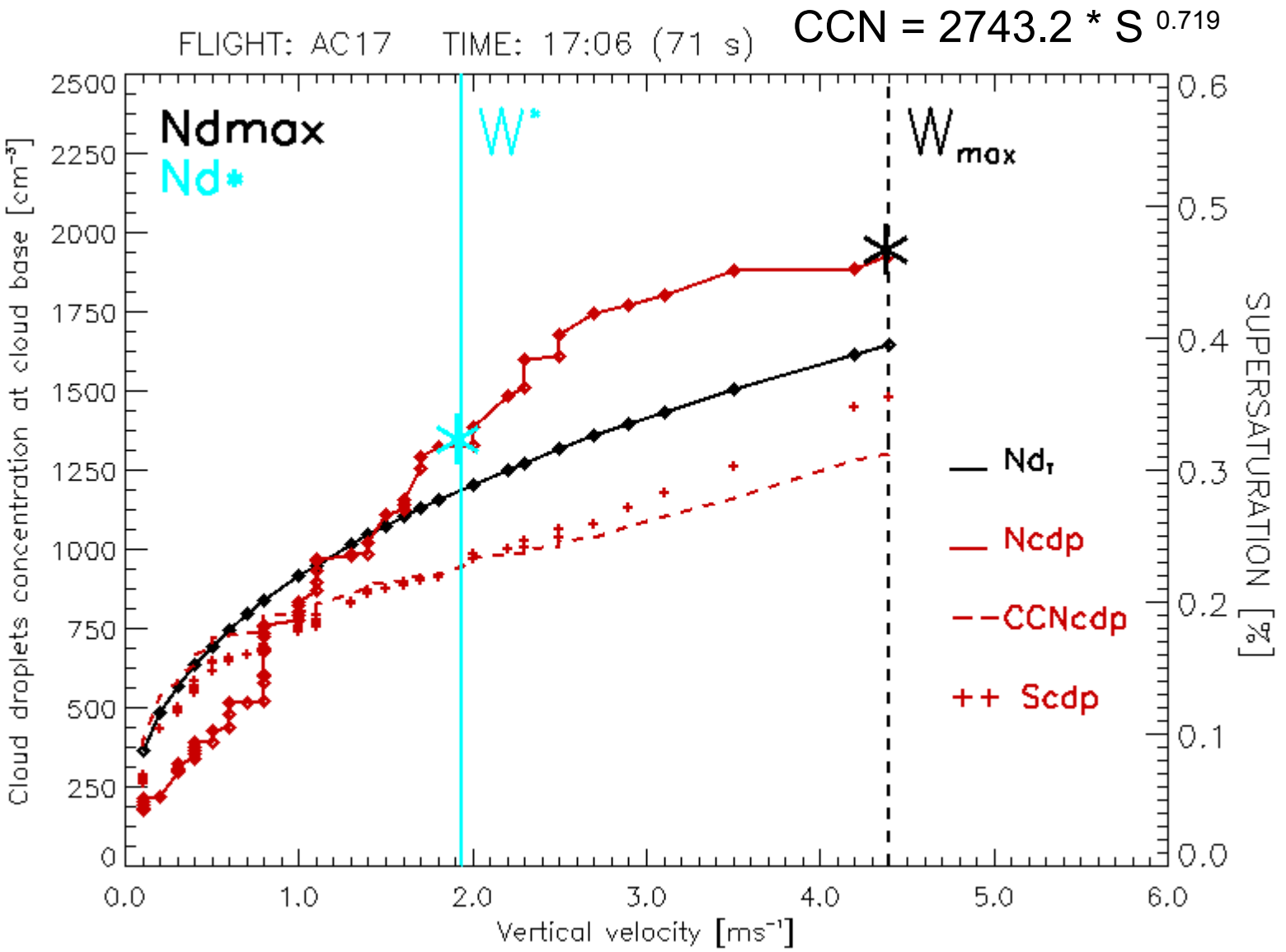
CDP



$S_{max} = C(T,P) * W_b^{3/4} * N_d^{-1/2}$ CCN = 2743.2 * S 0.719

Probability match → the same percentiles of updrafts matchs the same percentiles of N_{db}

CDP



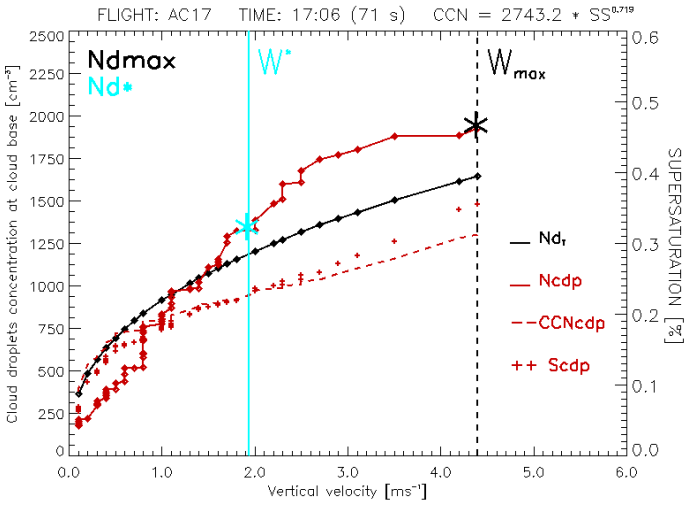
Cyan line indicate the cloud volume created by updrafts at the cloud base.

$$W^* = \int W_j^2 / \int W_j \text{ ; for } W_j > 0$$

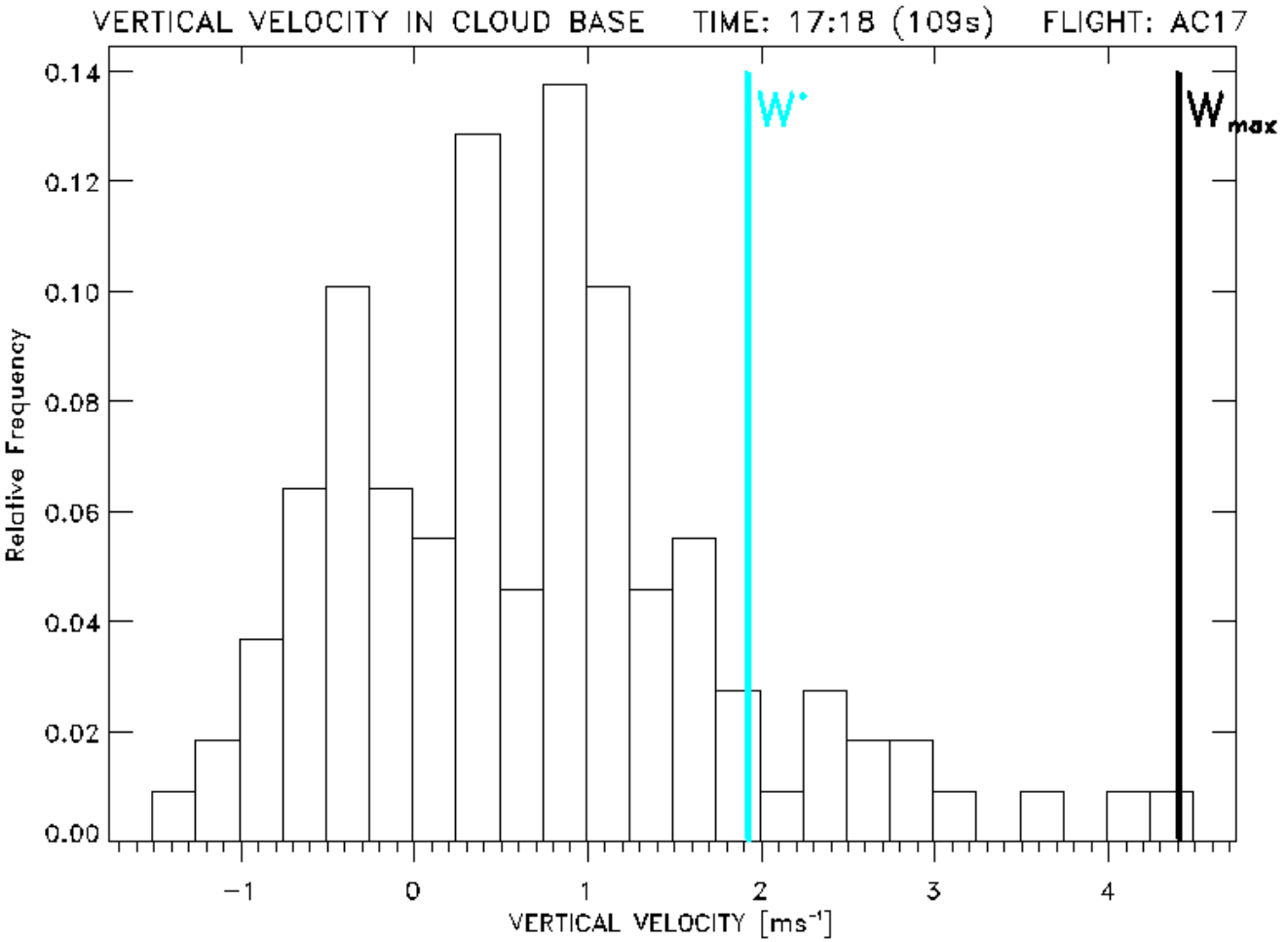
Nd* = Nd (Perc W*)

Probability match → the same percentiles of updrafts matchs the same percentiles of N_{db}

CDP



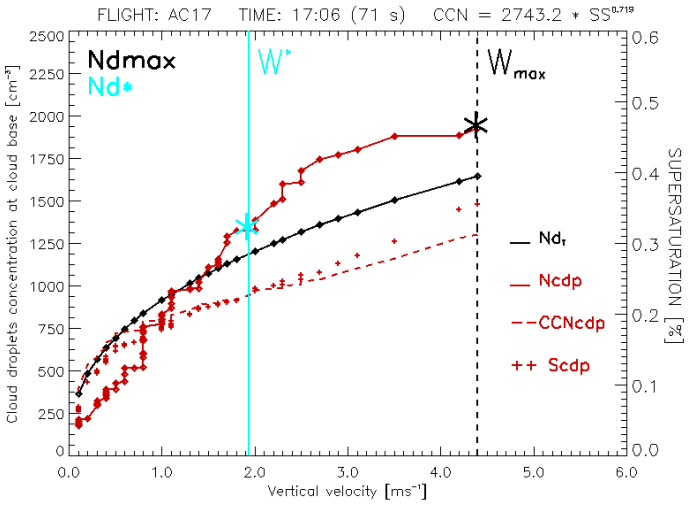
Cyan line indicate the cloud volume created by updrafts at the cloud base.



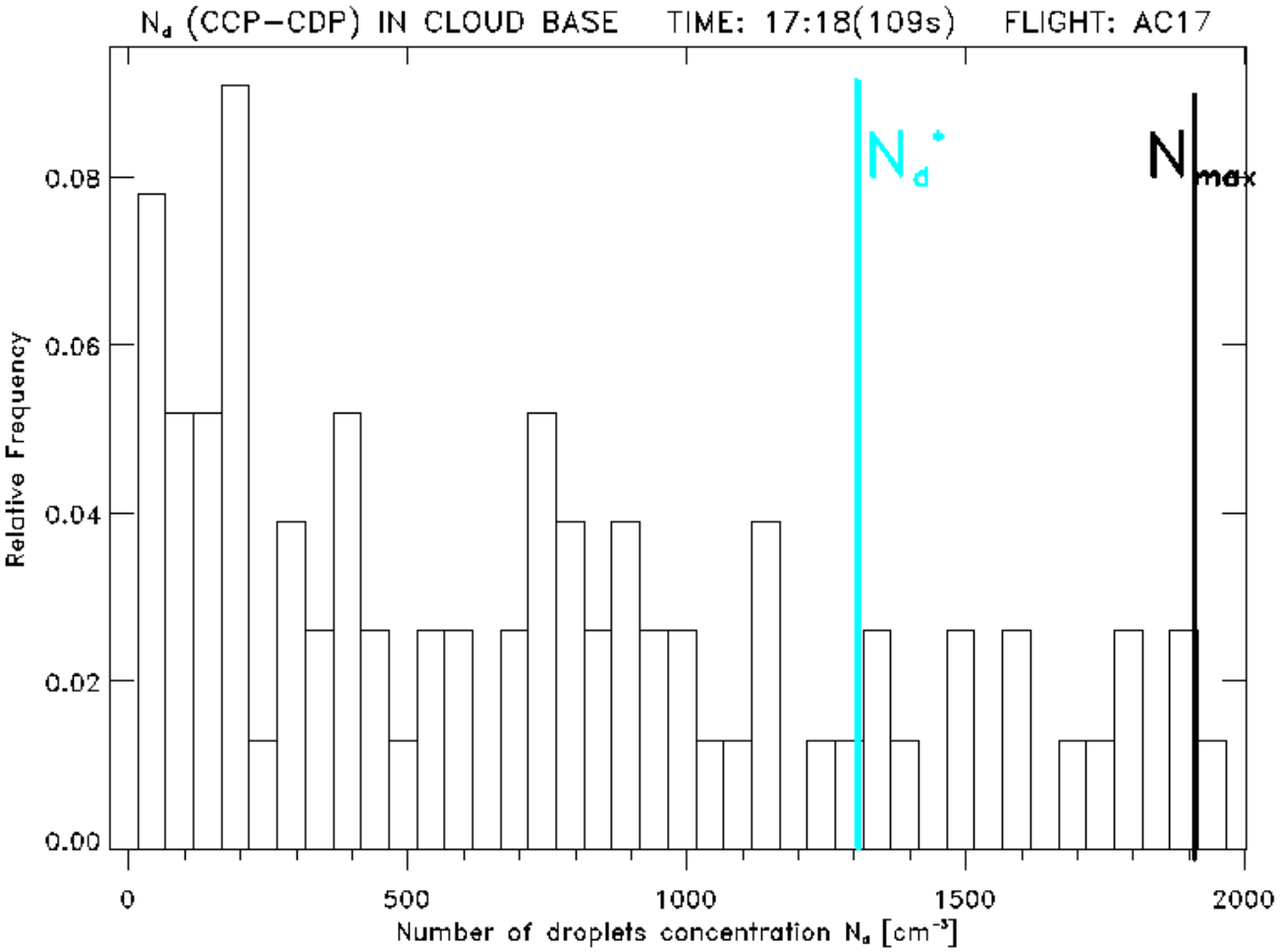
$$W^* = \int W_j^2 / \int W_j \text{ ; for } W_j > 0$$

Probability match → the same percentiles of updrafts matchs the same percentiles of N_{db}

CDP



Cyan line indicate the cloud volume created by updrafts at the cloud base.

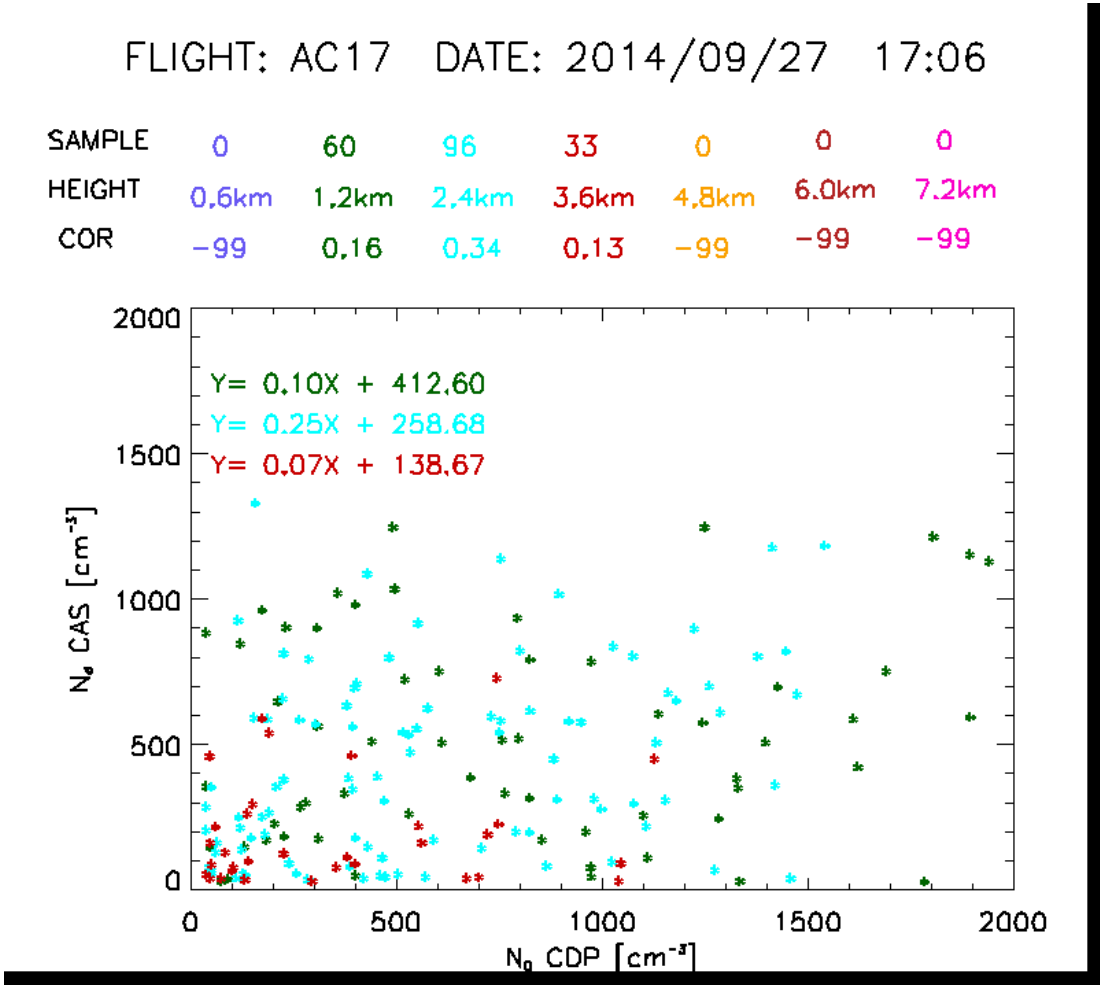


Nd* = Nd (percentile of W*)

Probability match → the same percentiles of updrafts matchs the same percentiles of N_{db}

PROBES CORRELATION

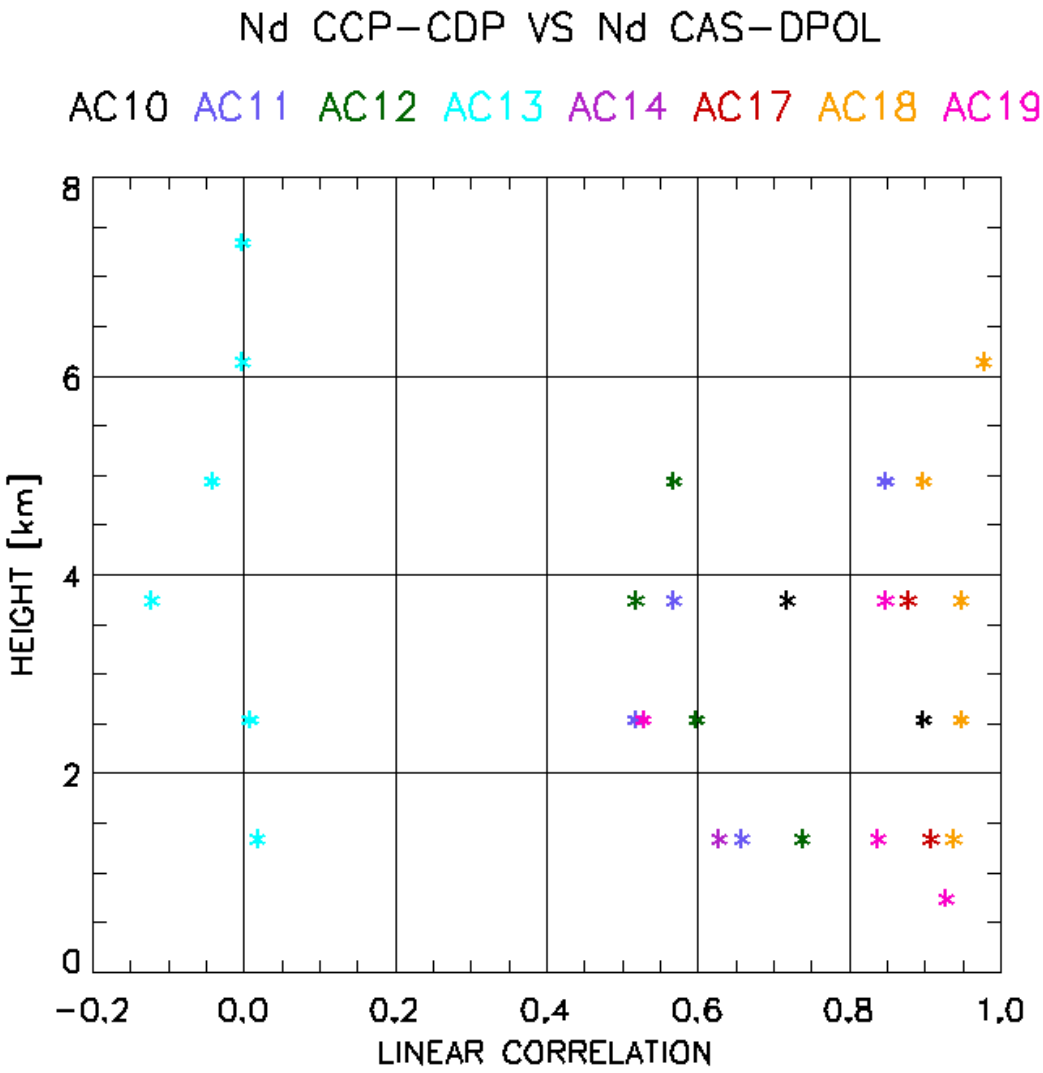
FLIGHT	Reference NIXE-CAPS	Delay in sec CAS-DPOL	Delay in sec CCP-CDP
AC07	ref	nodata	-1
AC08	ref	nodata	-1
AC09	ref	-1	-2
AC10	ref	0	-3
AC11	ref	0	-1
AC12	ref	0	-1
AC13	ref	-1	-2
AC14	ref	-1	-1
AC15	ref	0	nodata
AC16	ref	0	nodata
AC17	ref	0	-3
AC18	ref	0	-1
AC19	ref	0	-2
AC20	ref	nodata	-2

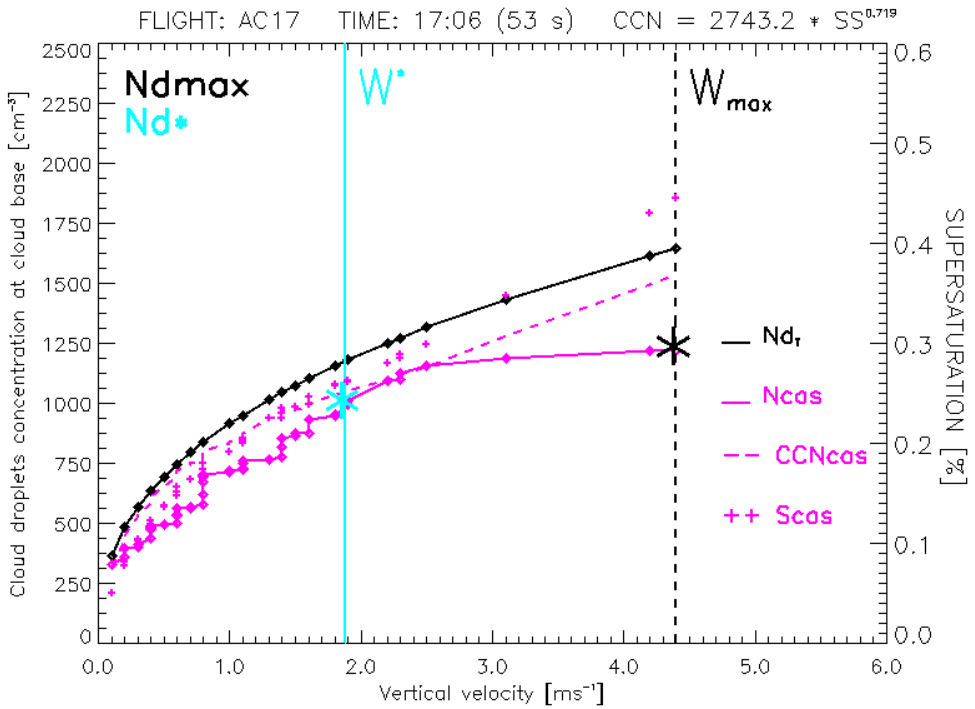


Probability match → the same percentiles of updrafts matchs the same percentiles of N_{db}

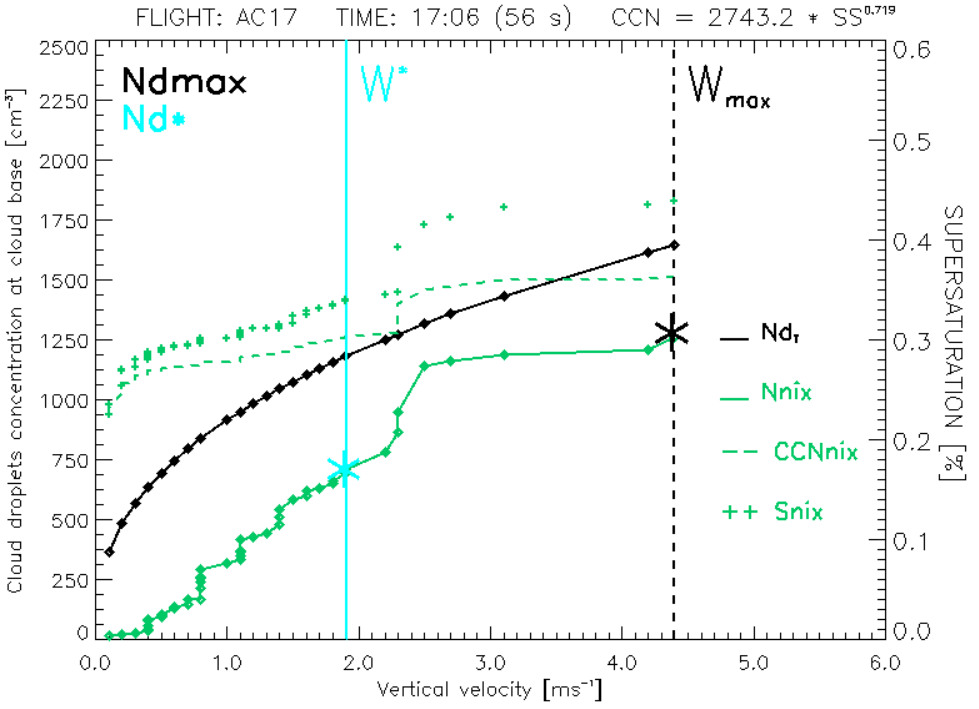
PROBES CORRELATION

FLIGHT	Reference NIXE-CAPS	Delay in sec CAS-DPOL	Delay in sec CCP-CDP
AC07	ref	nodata	-1
AC08	ref	nodata	-1
AC09	ref	-1	-2
AC10	ref	0	-3
AC11	ref	0	-1
AC12	ref	0	-1
AC13	ref	-1	-2
AC14	ref	-1	-1
AC15	ref	0	nodata
AC16	ref	0	nodata
AC17	ref	0	-3
AC18	ref	0	-1
AC19	ref	0	-2
AC20	ref	nodata	-2

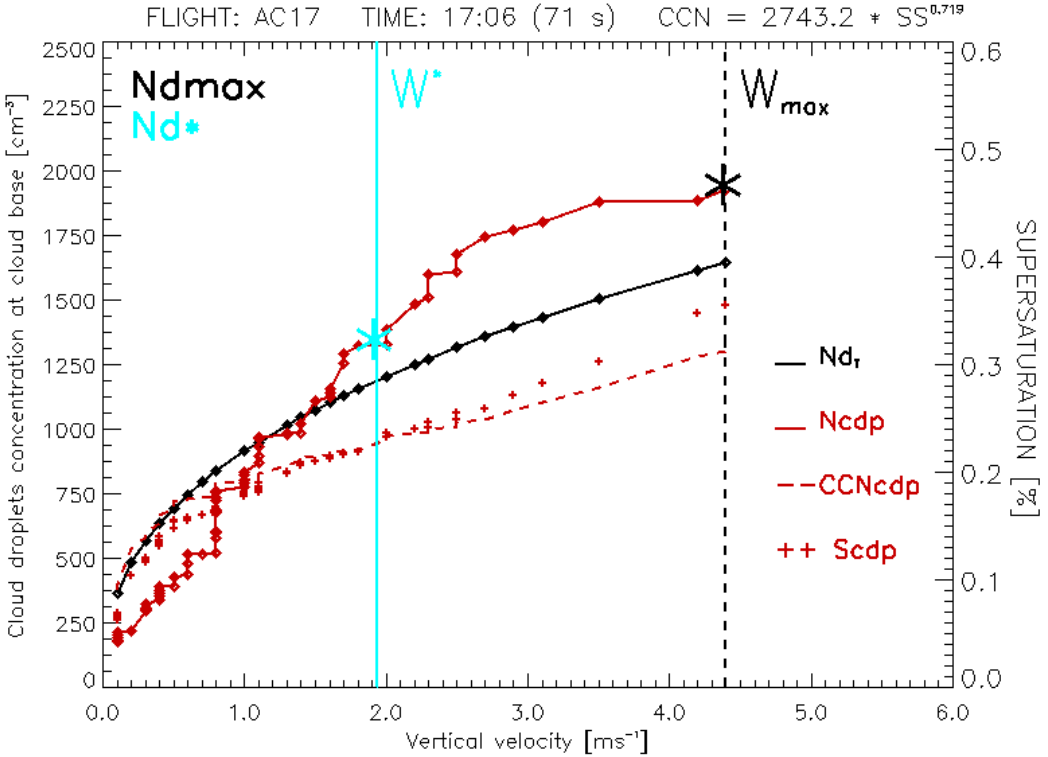



FLIGHT: AC17 TIME: 17:06 (53 s) CCN = 2743.2 * SS^0.719
Ndmax
Nd*
W*
Wmax
Ndt
Ncas
CCNcas
Scas
Cloud droplets concentration at cloud base [cm-3]
SUPERSATURATION [%]
Vertical velocity [ms-1]

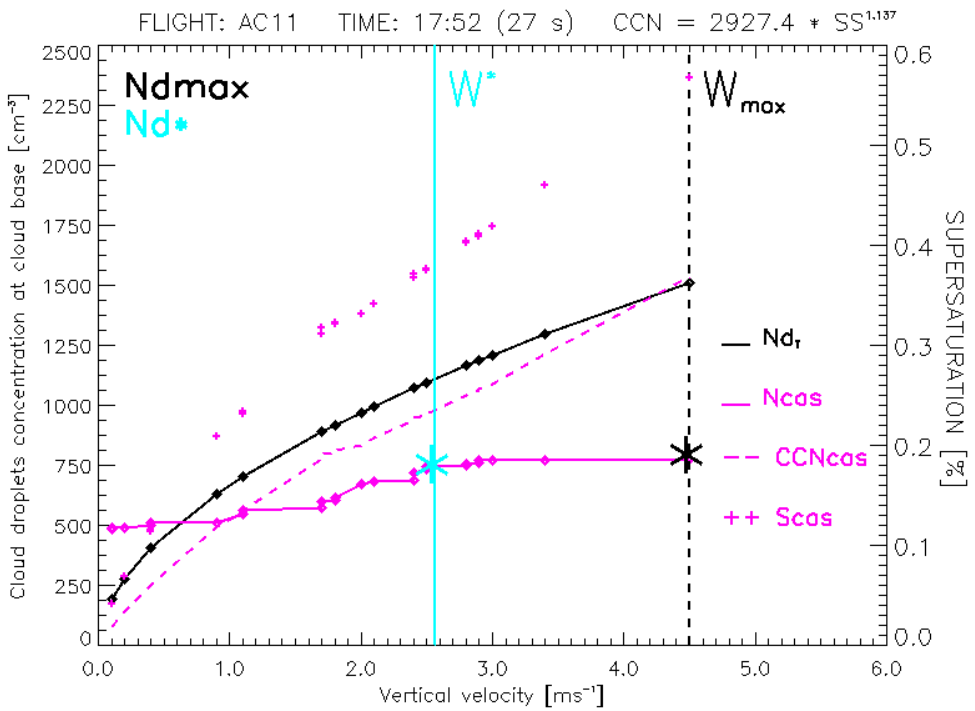
CAS


FLIGHT: AC17 TIME: 17:06 (56 s) CCN = 2743.2 * SS^0.719
Ndmax
Nd*
W*
Wmax
Ndt
Nnix
CCNnix
Snix
Cloud droplets concentration at cloud base [cm-3]
SUPERSATURATION [%]
Vertical velocity [ms-1]

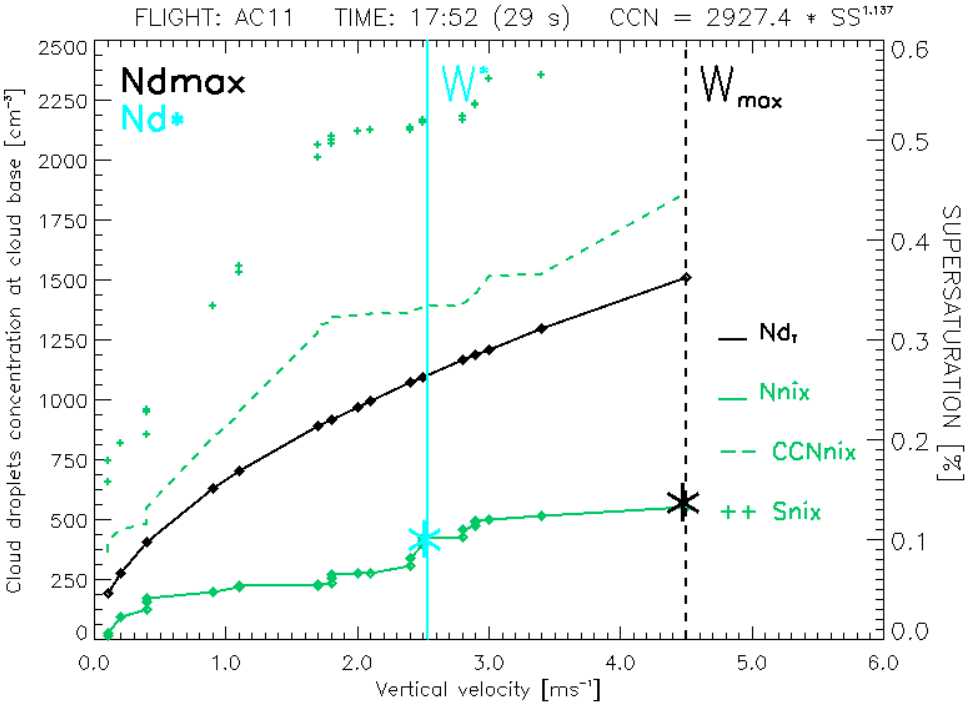
NIXE


FLIGHT: AC17 TIME: 17:06 (71 s) CCN = 2743.2 * SS^0.719
Ndmax
Nd*
W*
Wmax
Ndt
Ncdp
CCNcdp
Scdp
Cloud droplets concentration at cloud base [cm-3]
SUPERSATURATION [%]
Vertical velocity [ms-1]

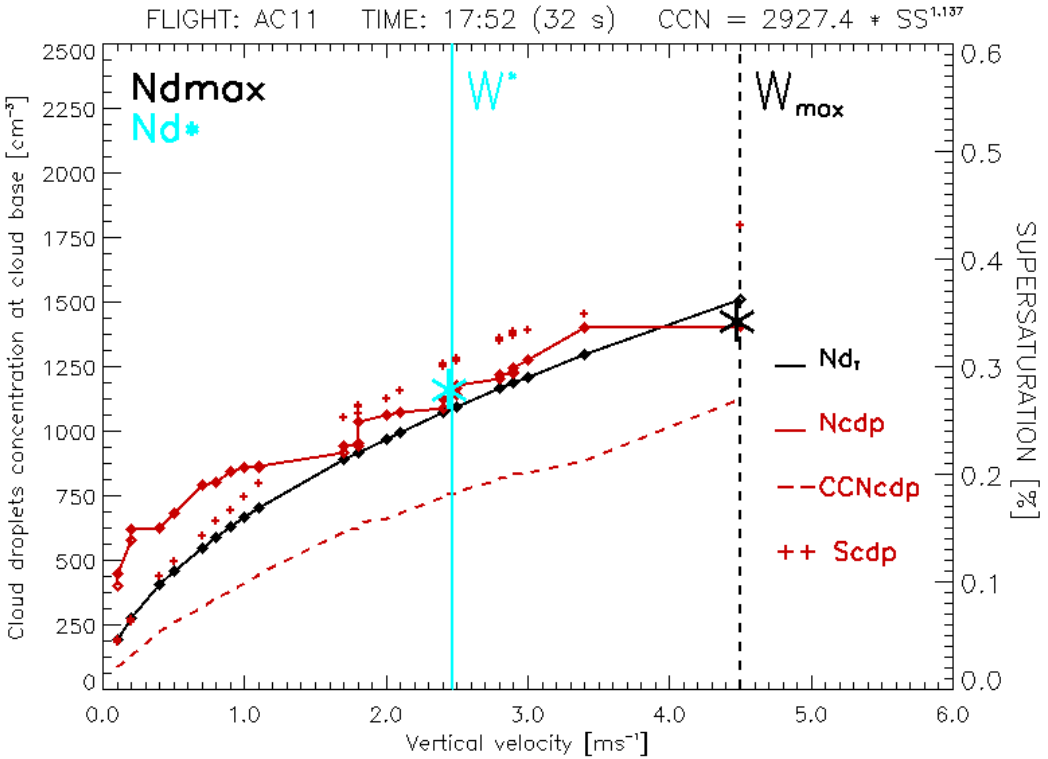
CDP


FLIGHT: AC11 TIME: 17:52 (27 s) CCN = 2927.4 * SS^1.137
Ndmax
Nd*
W*
W max
Nd_T
Ncas
CCNcas
Scas
Cloud droplets concentration at cloud base [cm^-3]
SUPERSATURATION [%]
Vertical velocity [ms^-1]

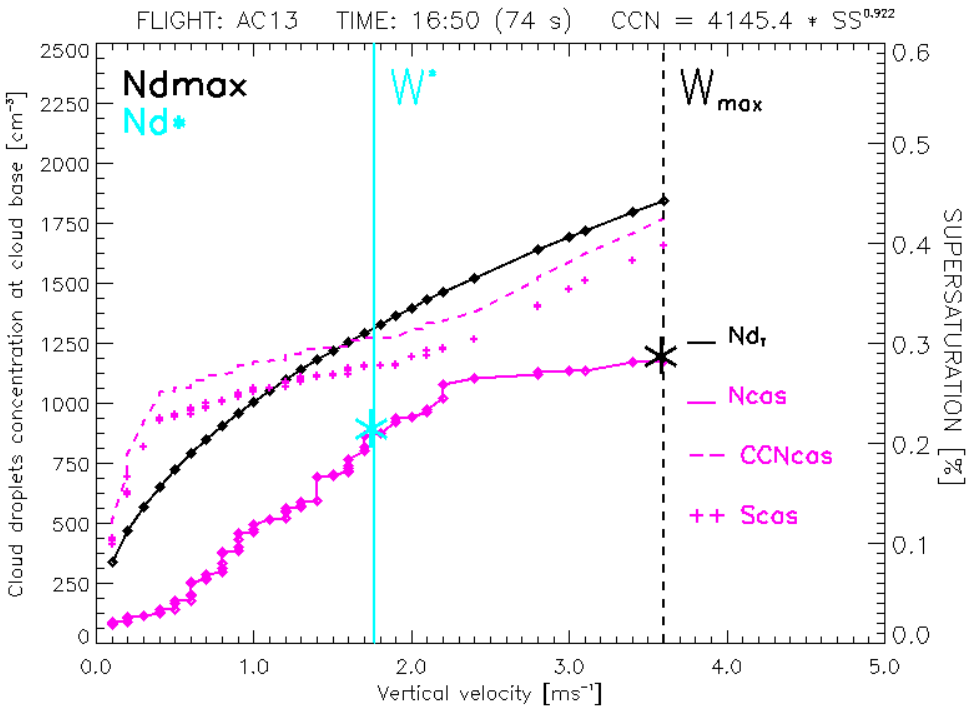
CAS


FLIGHT: AC11 TIME: 17:52 (29 s) CCN = 2927.4 * SS^1.137
Ndmax
Nd*
W*
W max
Nd_T
Nnix
CCNnix
Snix
Cloud droplets concentration at cloud base [cm^-3]
SUPERSATURATION [%]
Vertical velocity [ms^-1]

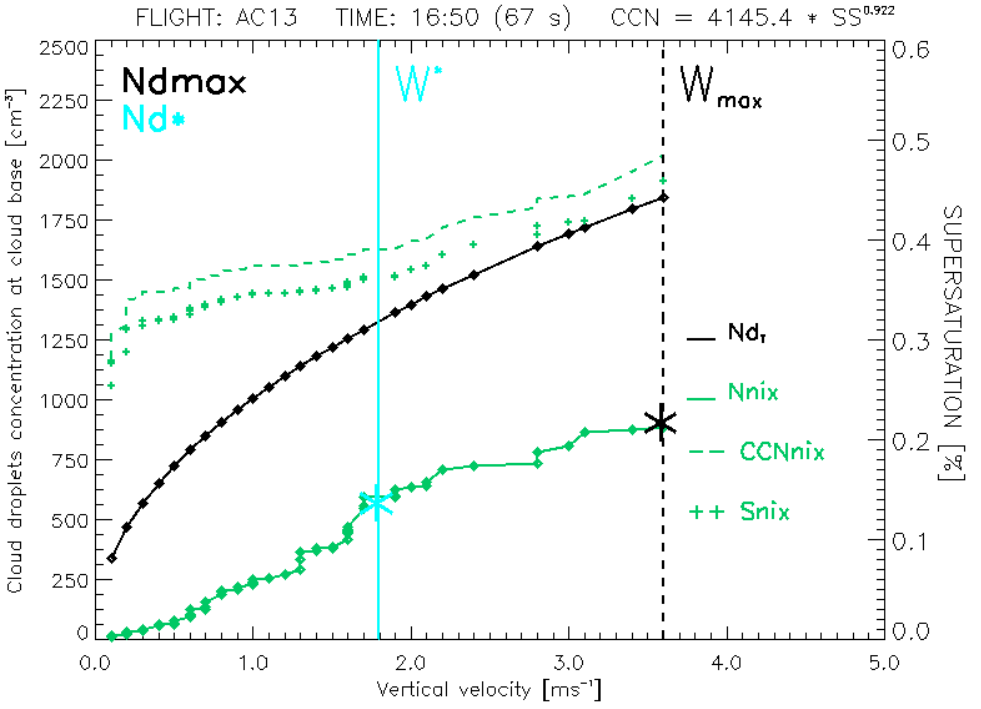
NIXE


FLIGHT: AC11 TIME: 17:52 (32 s) CCN = 2927.4 * SS^1.137
Ndmax
Nd*
W*
W max
Nd_T
Ncdp
CCNcdp
Scdp
Cloud droplets concentration at cloud base [cm^-3]
SUPERSATURATION [%]
Vertical velocity [ms^-1]

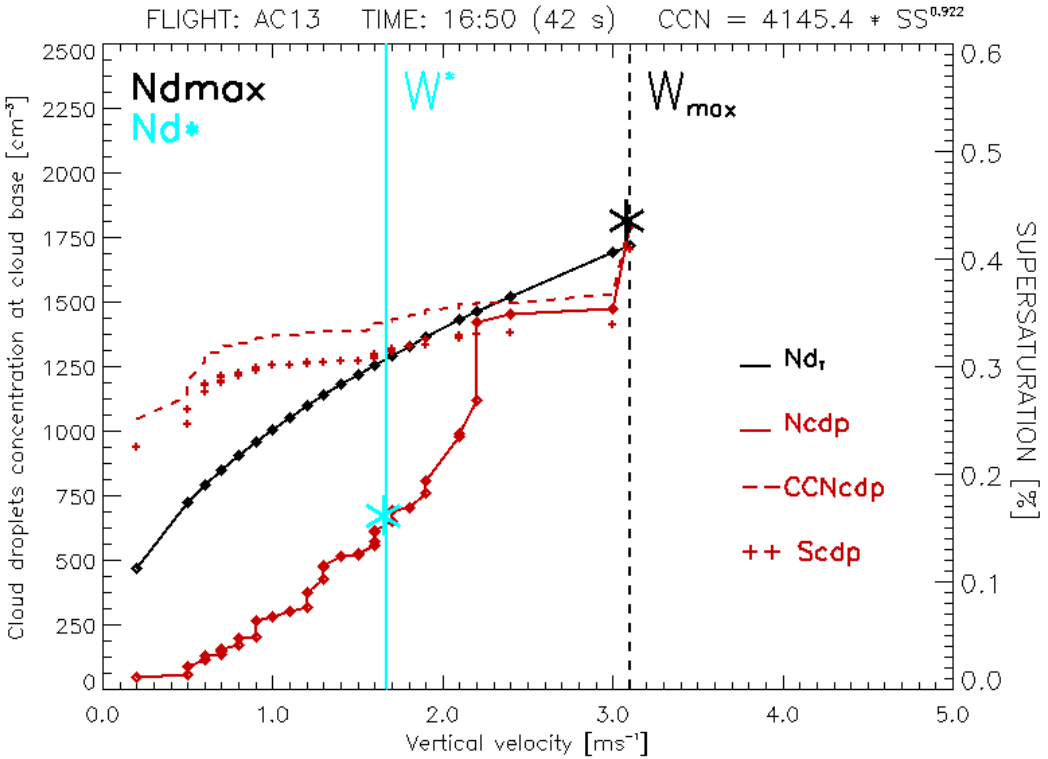
CDP


FLIGHT: AC13 TIME: 16:50 (74 s) CCN = 4145.4 * SS^0.922
Ndmax
Nd*
W*
Wmax
Ndt
Ncas
CCNcas
Scas
Cloud droplets concentration at cloud base [cm-3]
SUPERSATURATION [%]
Vertical velocity [ms-1]

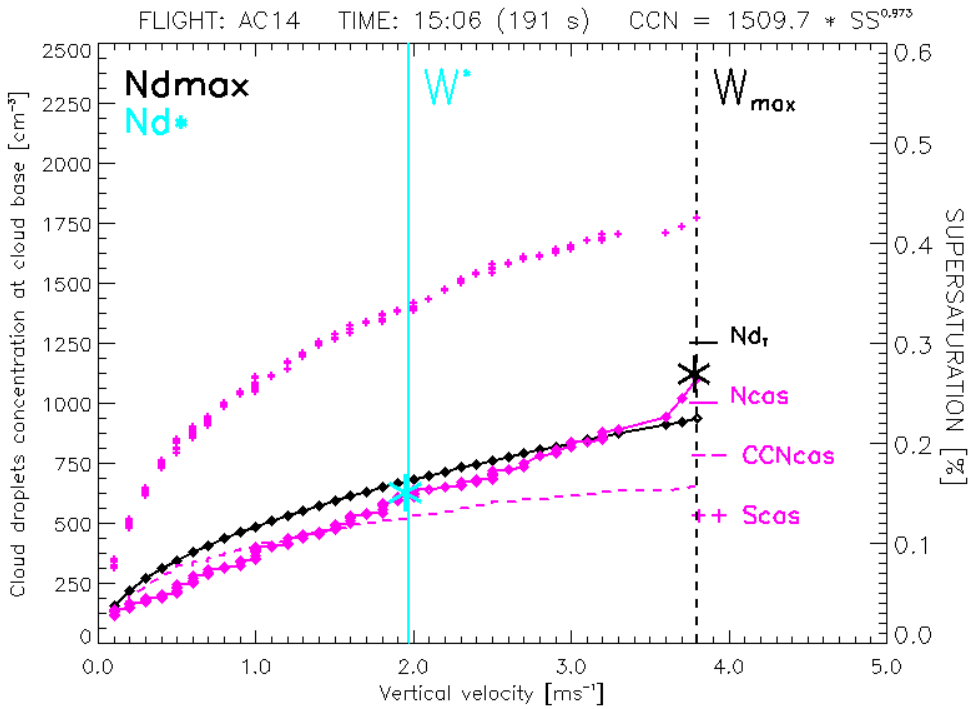
CAS


FLIGHT: AC13 TIME: 16:50 (67 s) CCN = 4145.4 * SS^0.922
Ndmax
Nd*
W*
Wmax
Ndt
Nnix
CCNnix
Snix
Cloud droplets concentration at cloud base [cm-3]
SUPERSATURATION [%]
Vertical velocity [ms-1]

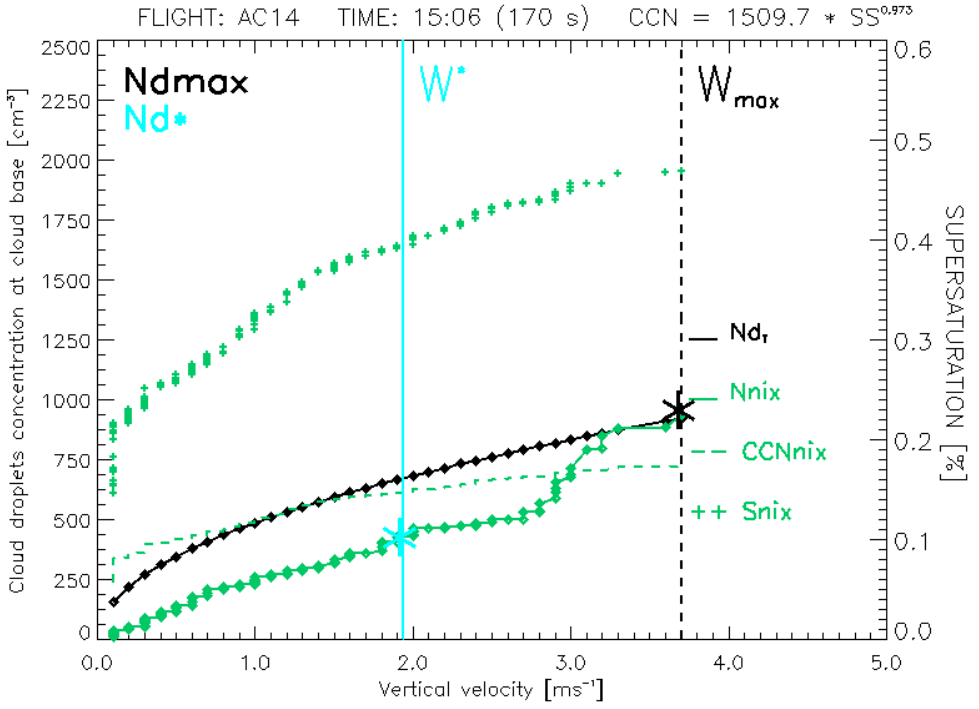
NIXE


FLIGHT: AC13 TIME: 16:50 (42 s) CCN = 4145.4 * SS^0.922
Ndmax
Nd*
W*
Wmax
Ndt
Ncdp
CCNcdp
Scdp
Cloud droplets concentration at cloud base [cm-3]
SUPERSATURATION [%]
Vertical velocity [ms-1]

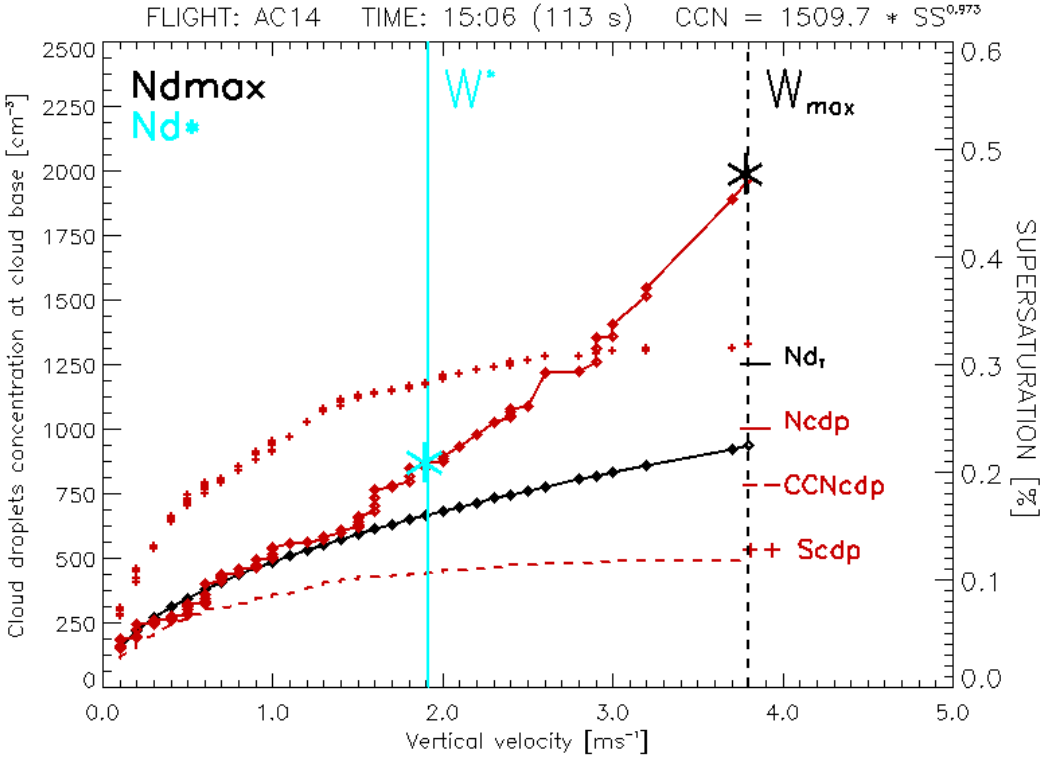
CDP


FLIGHT: AC14 TIME: 15:06 (191 s) CCN = 1509.7 * SS^0.973
Ndmax
Nd*
W*
W max
Ndr
Ncas
CCNcas
Scas
Cloud droplets concentration at cloud base [cm-3]
SUPERSATURATION [%]
Vertical velocity [ms-1]

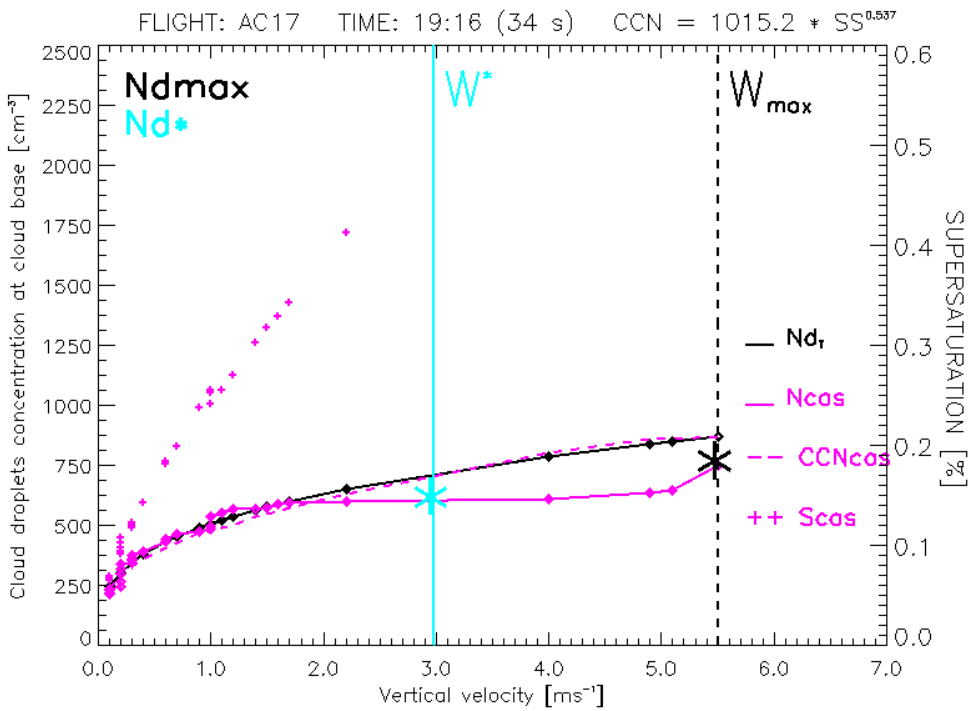
CAS


FLIGHT: AC14 TIME: 15:06 (170 s) CCN = 1509.7 * SS^0.973
Ndmax
Nd*
W*
W max
Ndr
Nnix
CCNnix
Snix
Cloud droplets concentration at cloud base [cm-3]
SUPERSATURATION [%]
Vertical velocity [ms-1]

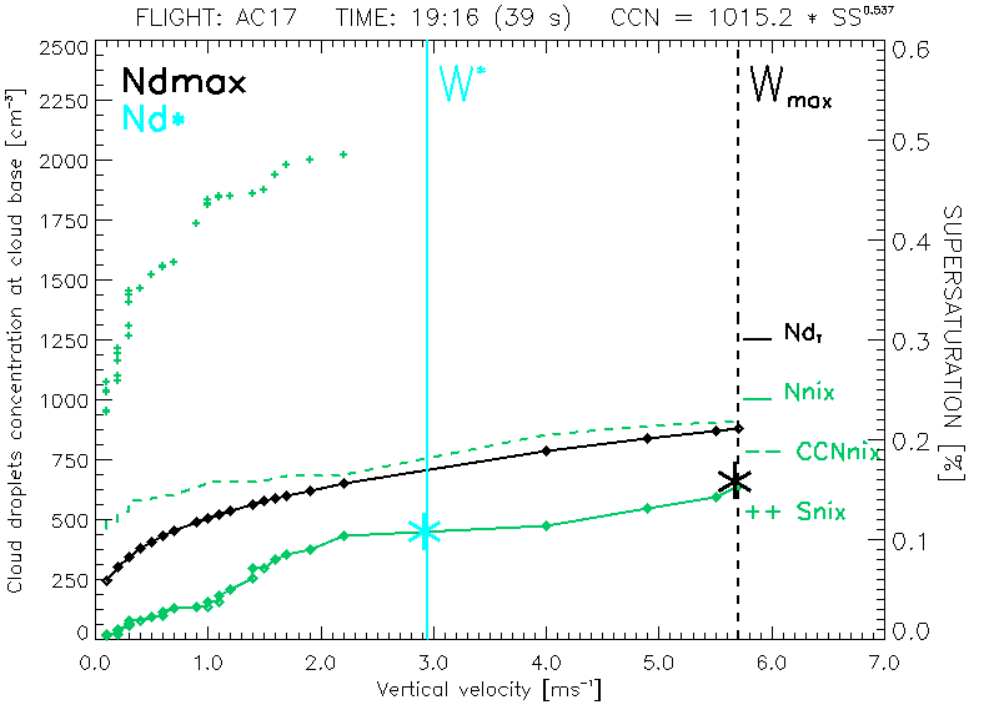
NIXE


FLIGHT: AC14 TIME: 15:06 (113 s) CCN = 1509.7 * SS^0.973
Ndmax
Nd*
W*
W max
Ndr
Ncdp
CCNcdp
Scdp
Cloud droplets concentration at cloud base [cm-3]
SUPERSATURATION [%]
Vertical velocity [ms-1]

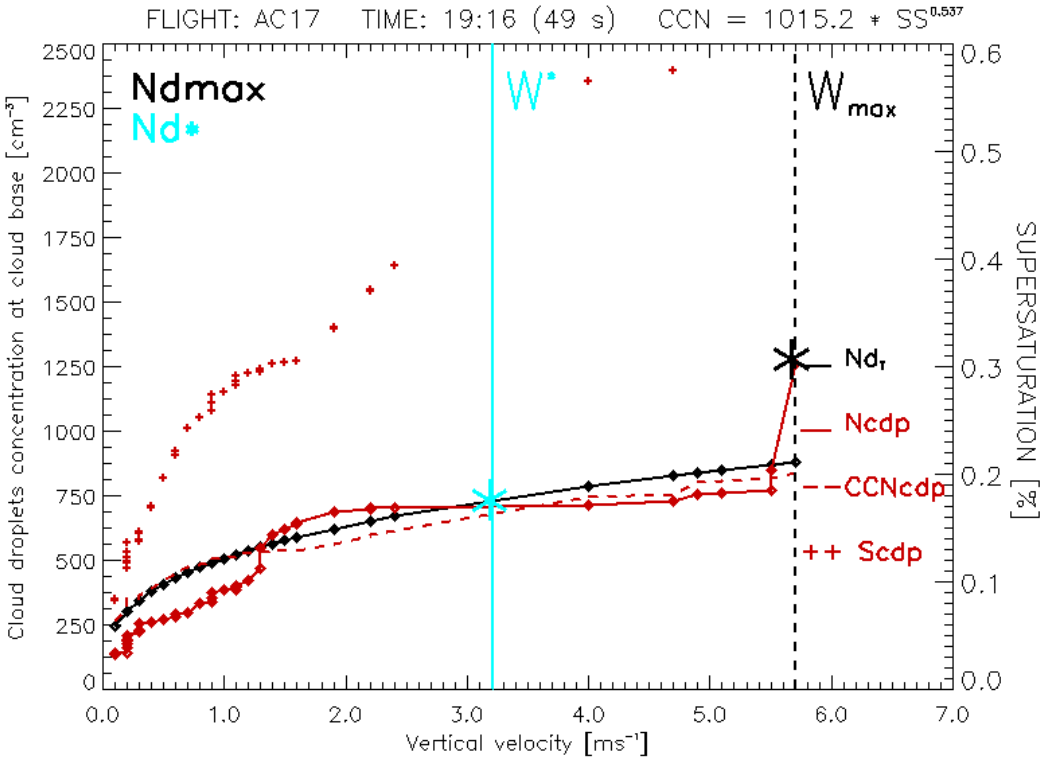
CDP


FLIGHT: AC17 TIME: 19:16 (34 s) CCN = 1015.2 * SS^0.537
Ndmax
Nd*
W*
W max
Nd_T
Ncas
CCNcas
++ Scas
Cloud droplets concentration at cloud base [cm^-3]
SUPERSATURATION [%]
Vertical velocity [ms^-1]

CAS


FLIGHT: AC17 TIME: 19:16 (39 s) CCN = 1015.2 * SS^0.537
Ndmax
Nd*
W*
W max
Nd_T
Nnix
CCNnix
++ Snix
Cloud droplets concentration at cloud base [cm^-3]
SUPERSATURATION [%]
Vertical velocity [ms^-1]

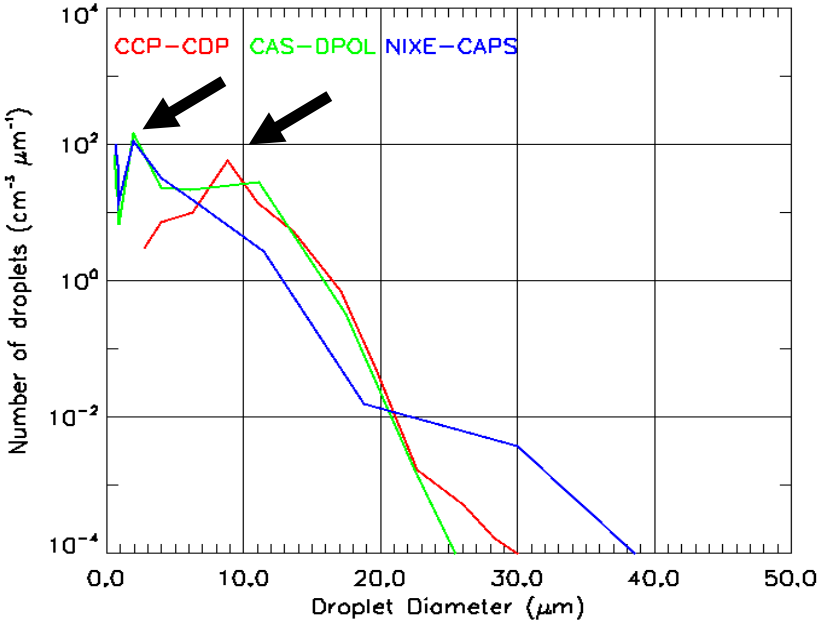
NIXE


FLIGHT: AC17 TIME: 19:16 (49 s) CCN = 1015.2 * SS^0.537
Ndmax
Nd*
W*
W max
Nd_T
Ncdp
CCNcdp
++ Scdp
Cloud droplets concentration at cloud base [cm^-3]
SUPERSATURATION [%]
Vertical velocity [ms^-1]

CDP

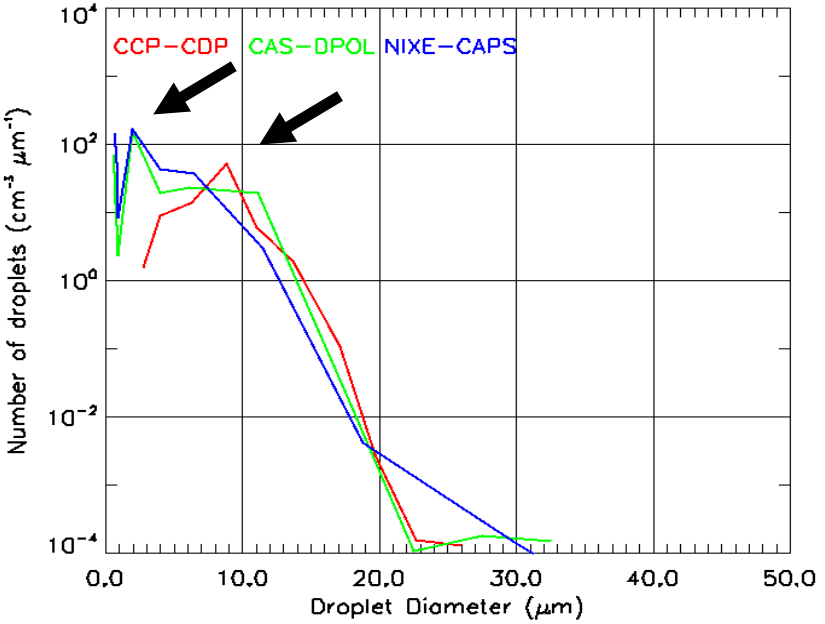
FLIGHT: AC11 DATE: 2014/09/16 17:52

MEAN CLOUD BASE MEASUREMENTS



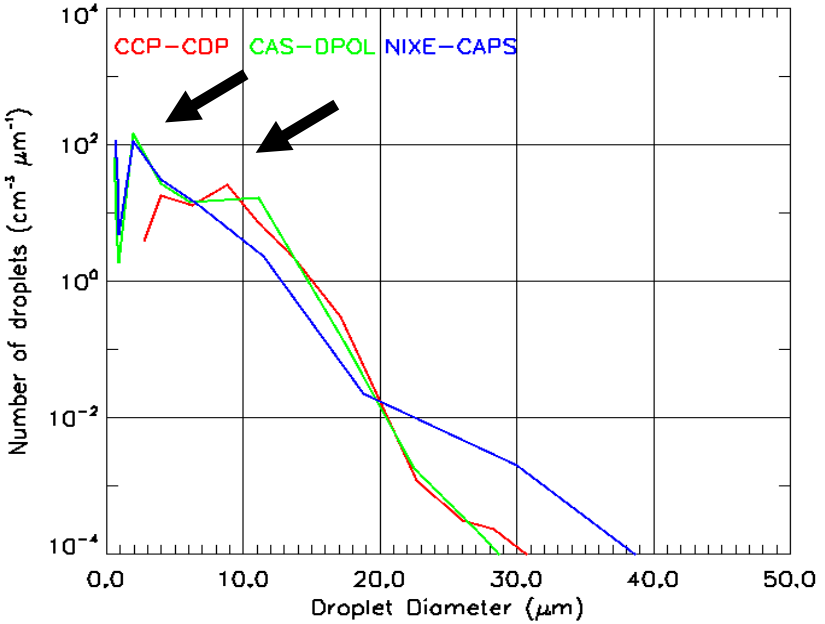
FLIGHT: AC12 DATE: 2014/09/18 15:55

MEAN CLOUD BASE MEASUREMENTS



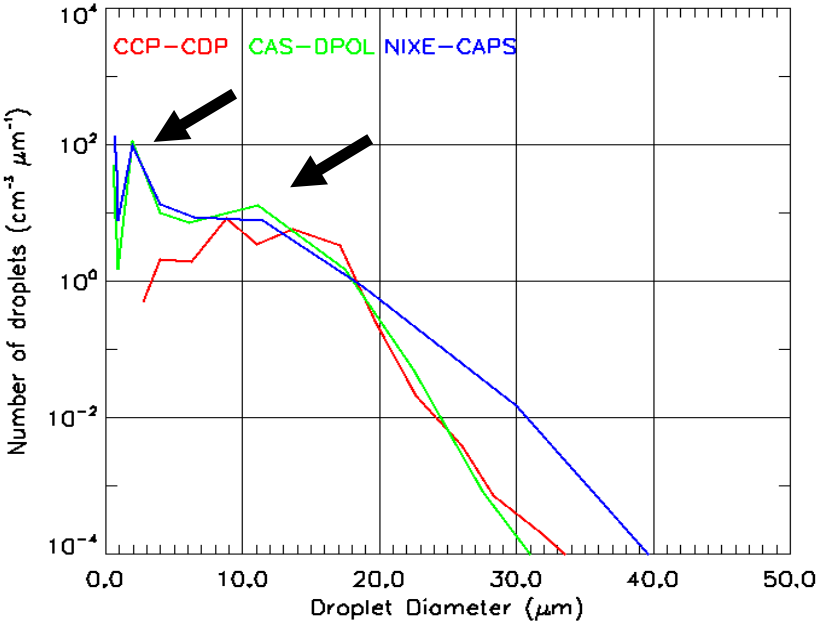
FLIGHT: AC14 DATE: 2014/09/21 15:06

MEAN CLOUD BASE MEASUREMENTS

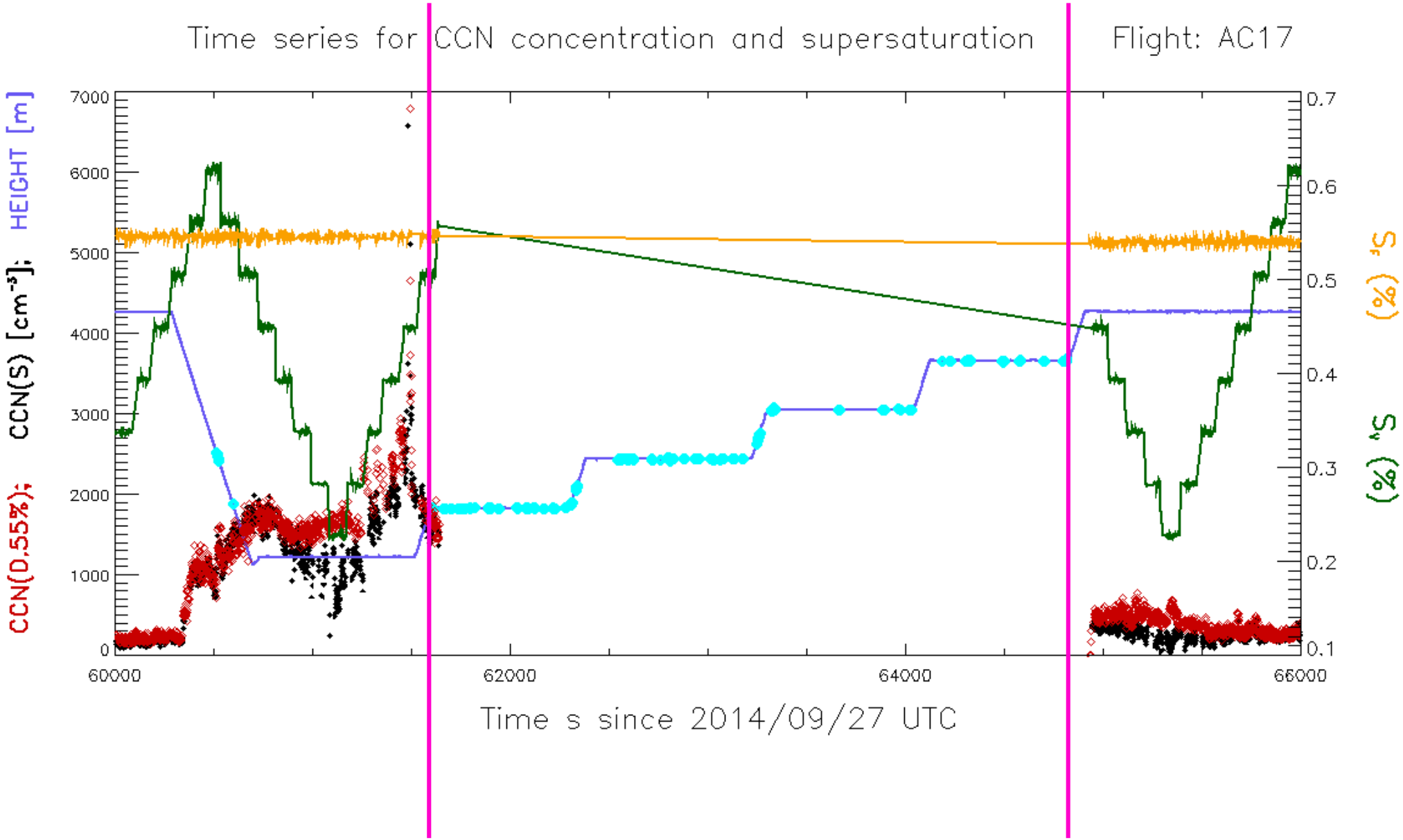


FLIGHT: AC17 DATE: 2014/09/27 19:17

MEAN CLOUD BASE MEASUREMENTS

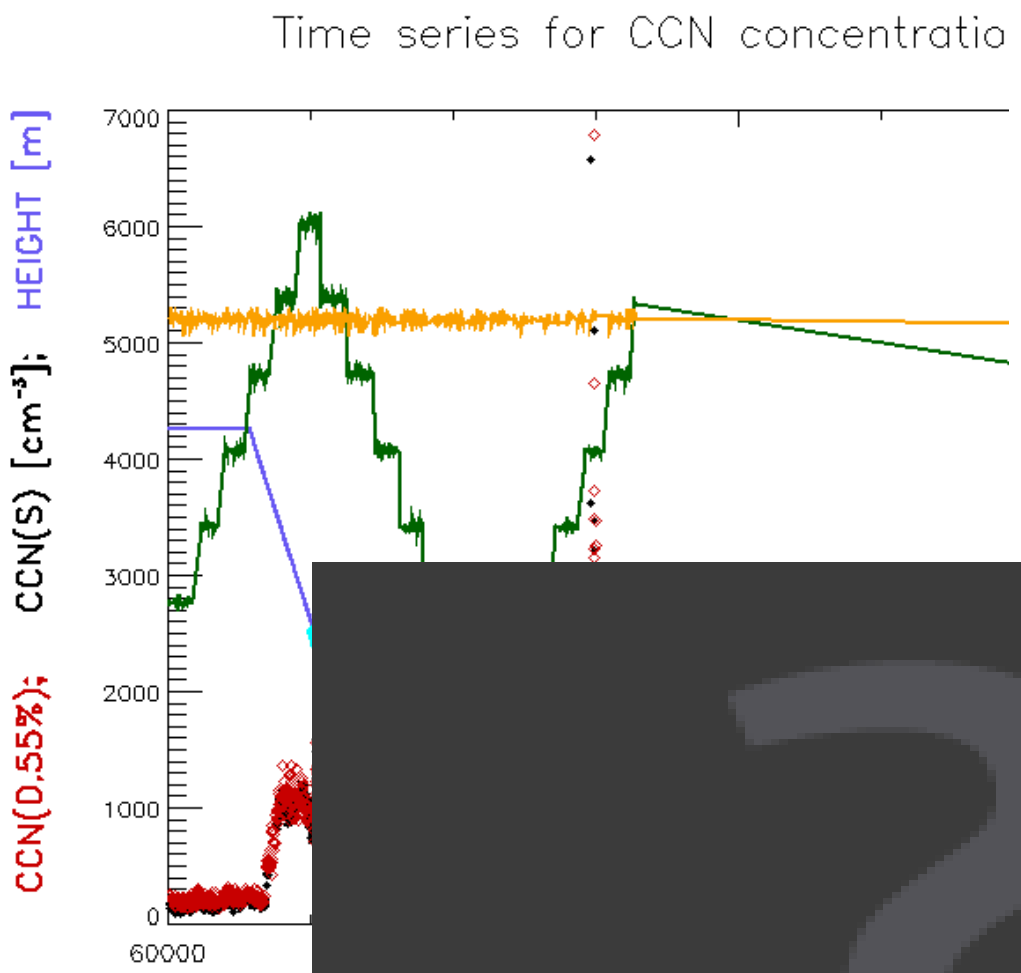


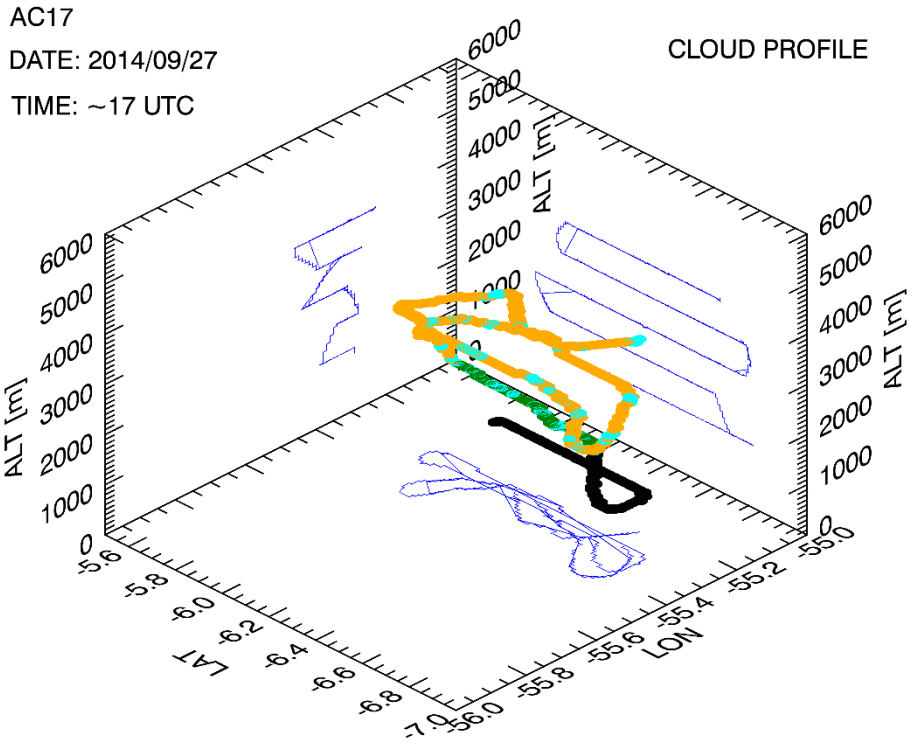
Next Steps – Cloud profile closure

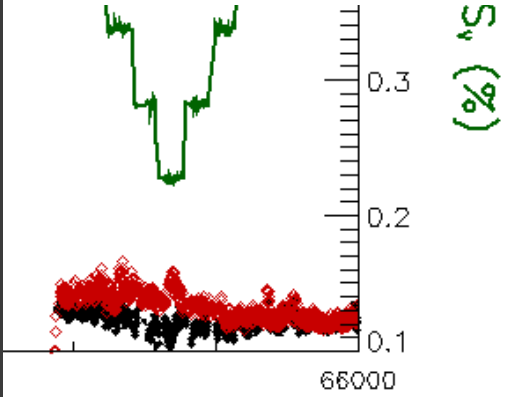


Cloud Profile

Next Steps – Cloud profile







Closure of cloud profiles using parcel model (Pinsky and Khain, 2002)

Input:

- Atmospheric sounding (BAHAMAS file);
- Estimated updrafts based on HALO measurements (BAHAMAS).
- 3 aerosol modal function (PCASP/UHSAS);

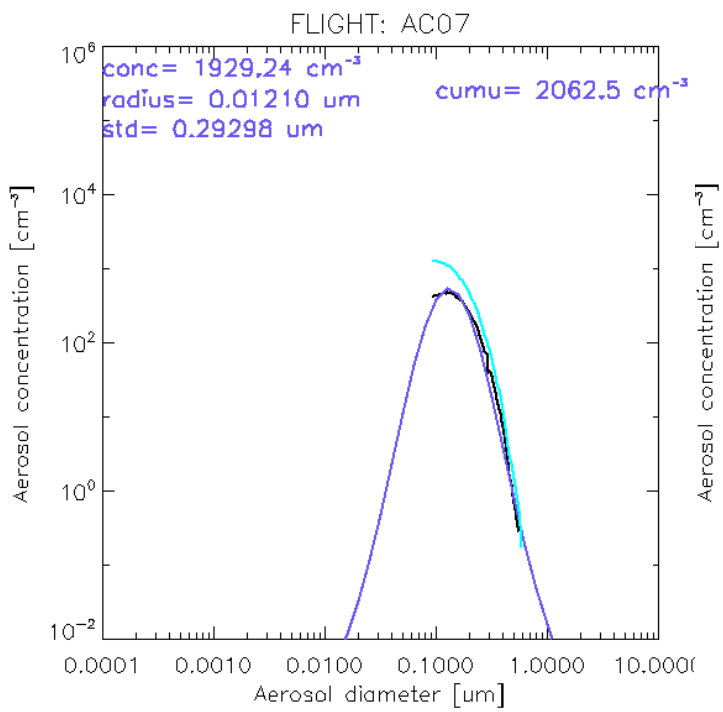
Output:

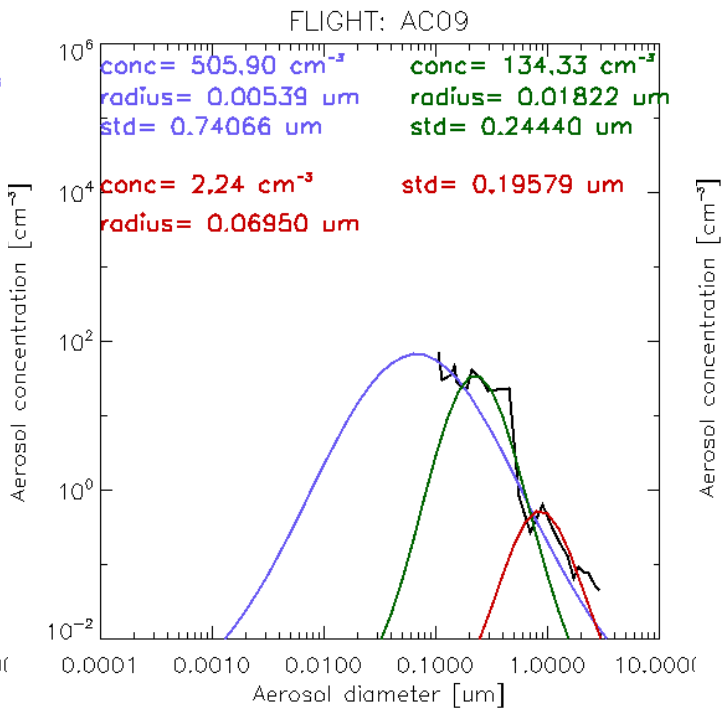
- Vertical profile of cloud microphysics properties (e.g. Nd, LWC, Re etc.)

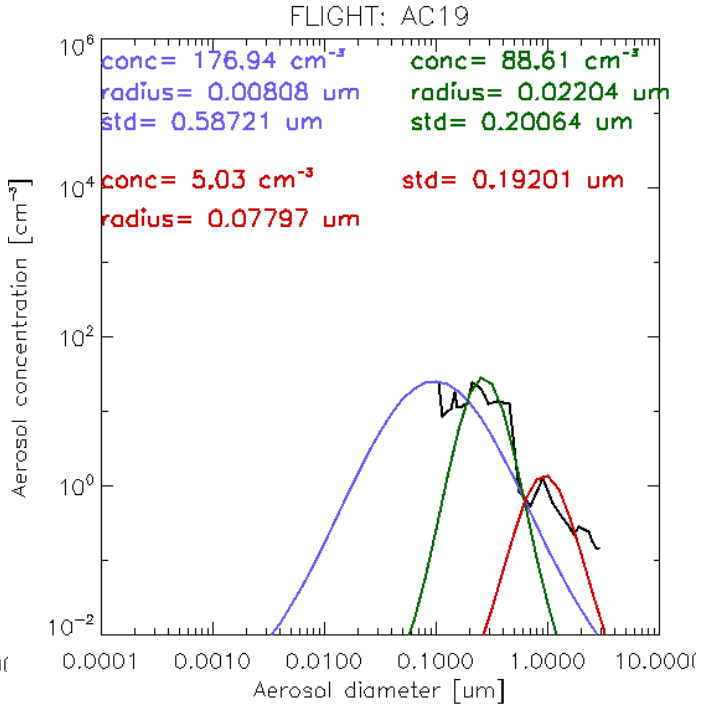
Closure of cloud profiles using parcel model (Pinsky and Khain, 2002)

Input:

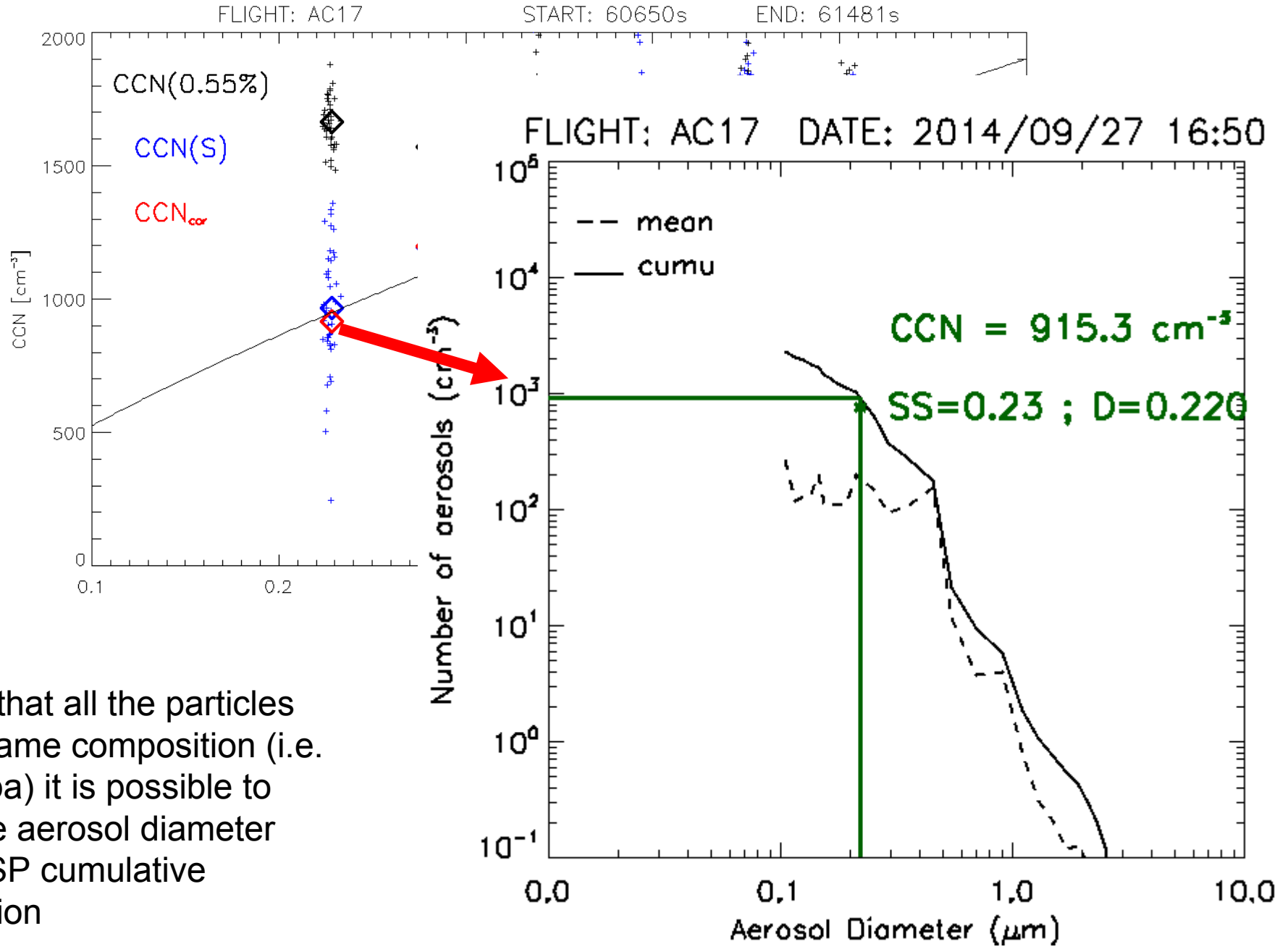
- 3 aerosol modal function (PCASP/UHSAS);





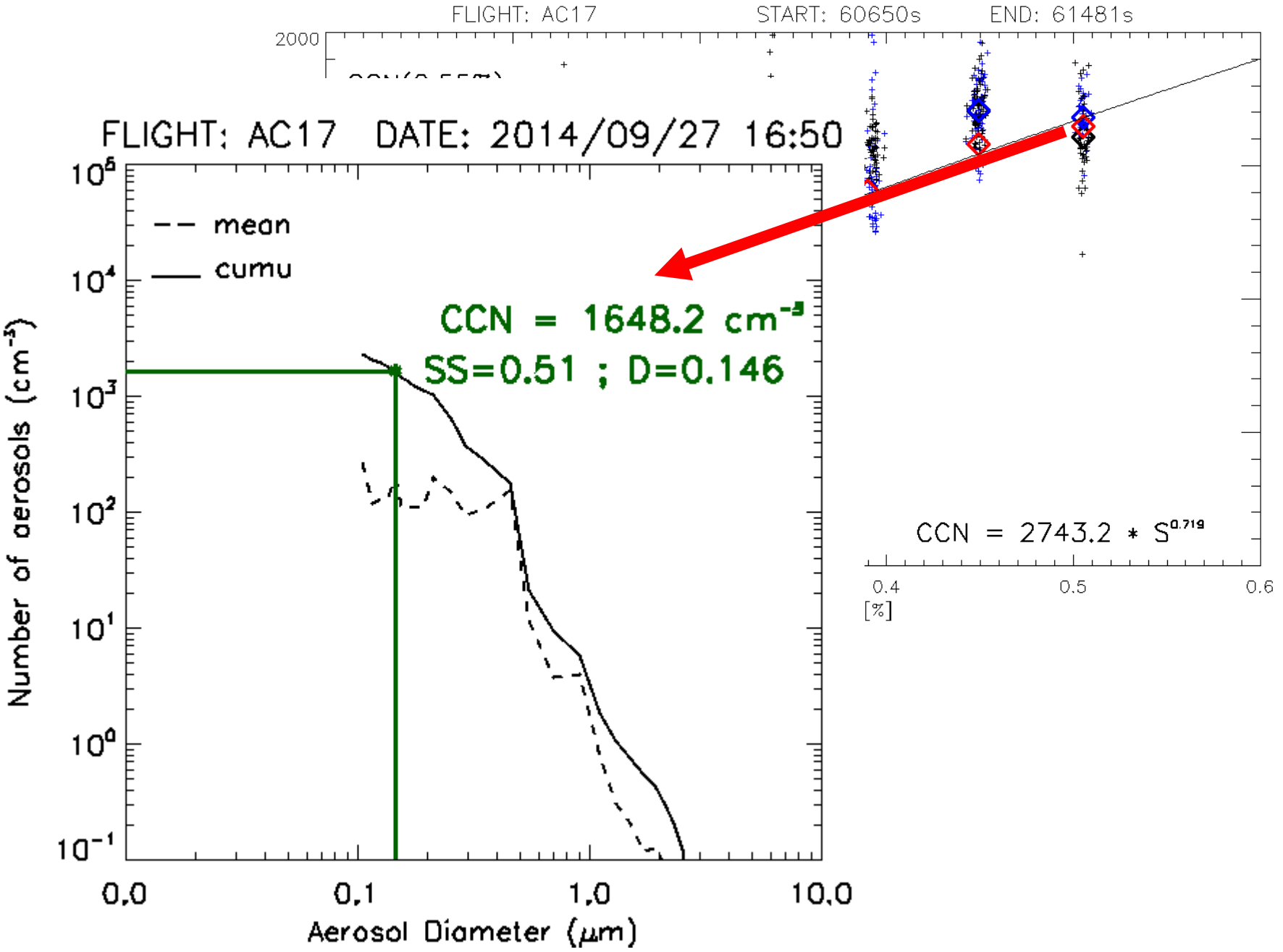


Calculate Kappa to fit parcel model aerosol input (NaCl)



Assuming that all the particles have the same composition (i.e. same kappa) it is possible to retrieve the aerosol diameter from PCASP cumulative concentration

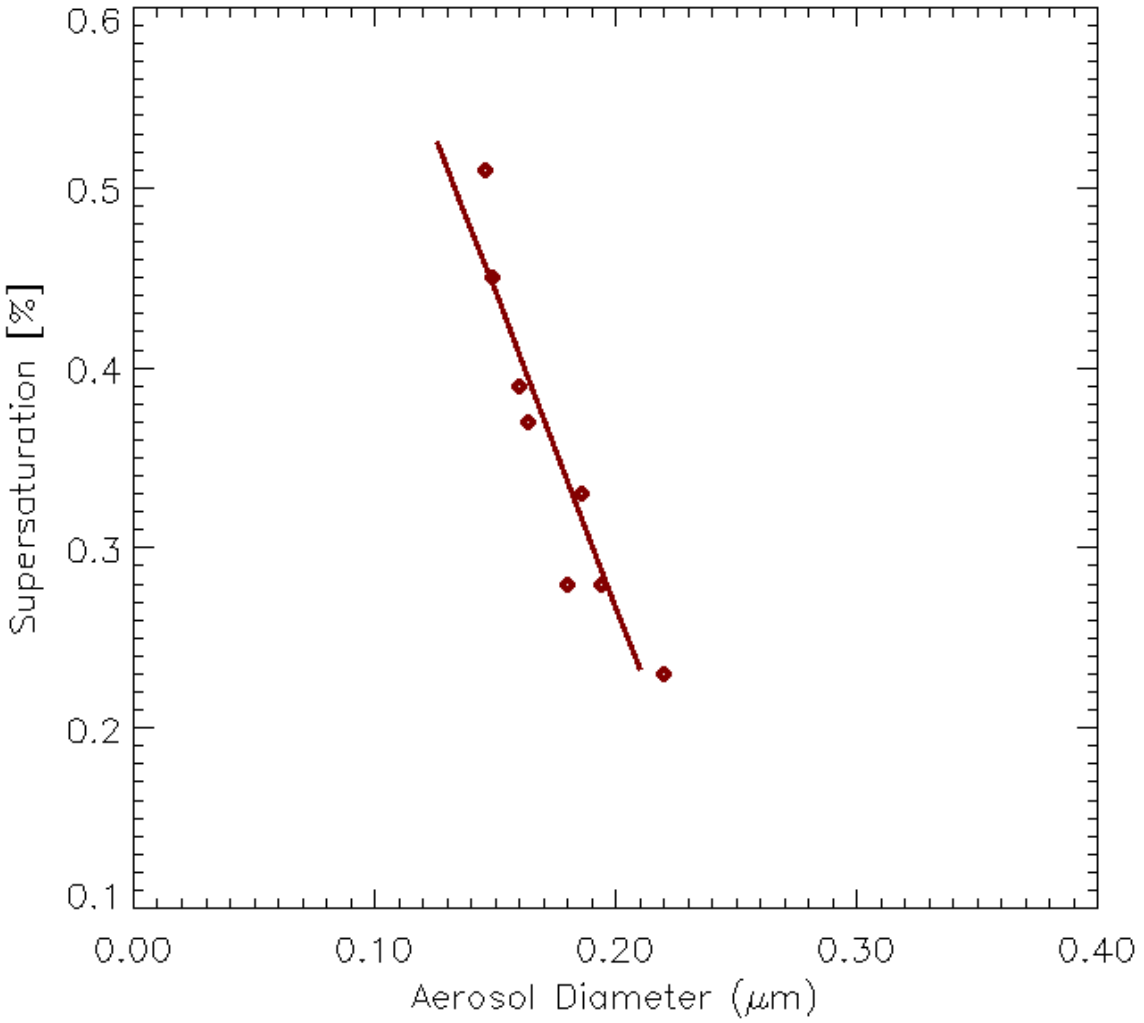
Calculate Kappa to fit parcel model aerosol input (NaCl)



Closure of cloud profiles using parcel model (Pinsky and Khain, 2002)

Input:

- 3 aerosol modal function (PCASP/UHSAS);

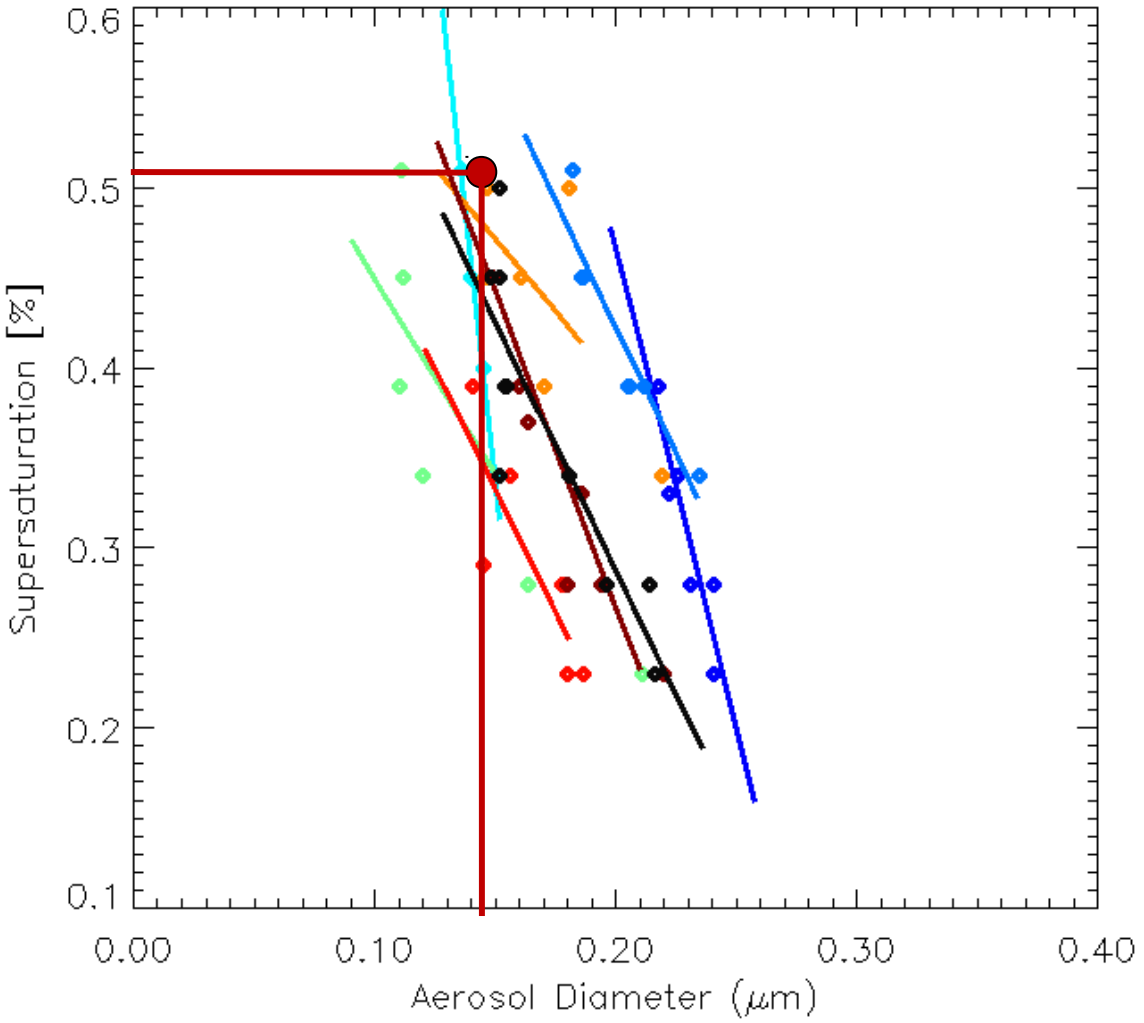


AC17 DATE: 2014/09/27 16:50

Closure of cloud profiles using parcel model (Pinsky and Khain, 2002)

Input:

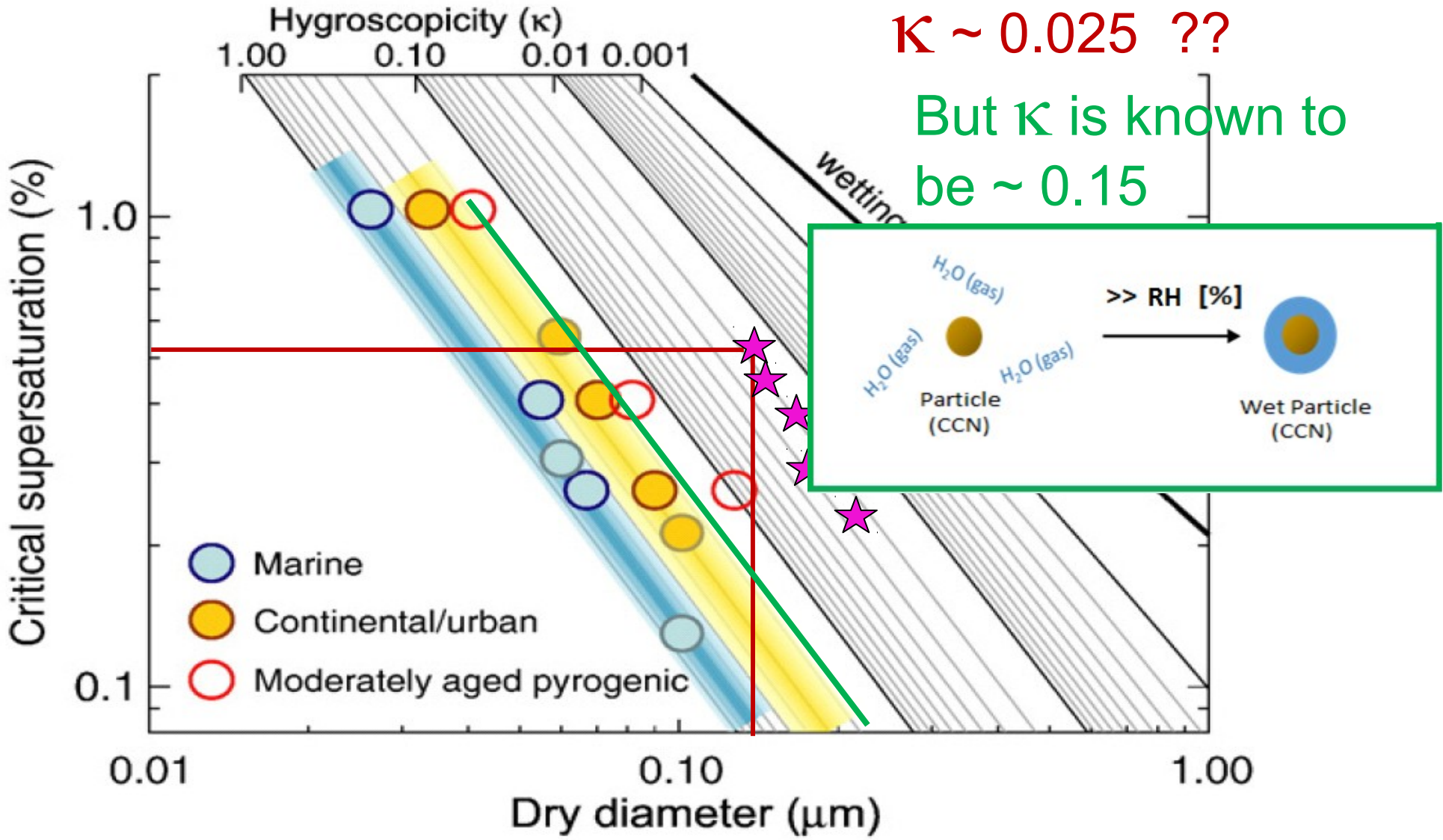
- 3 aerosol modal function (PCASP/UHSAS);



?

	KAPPA
AC11 DATE: 2014/09/16 14:58	0,015
AC11 DATE: 2014/09/16 17:38	0,010
AC12 DATE: 2014/09/18 15:56	0,035
AC13 DATE: 2014/09/19 16:29	0,050
AC15 DATE: 2014/09/23 13:33	0,015
AC16 DATE: 2014/09/25 20:21	0,050
AC17 DATE: 2014/09/27 16:50	0,025
AC17 DATE: 2014/09/27 19:38	0,030

We hypothesize that the aircraft measures swollen particles under cloud base. When ascribing it erroneously as dry particle causes large underestimate of kappa.
Paradoxially, larger real kappa shows as smaller indicated kappa.



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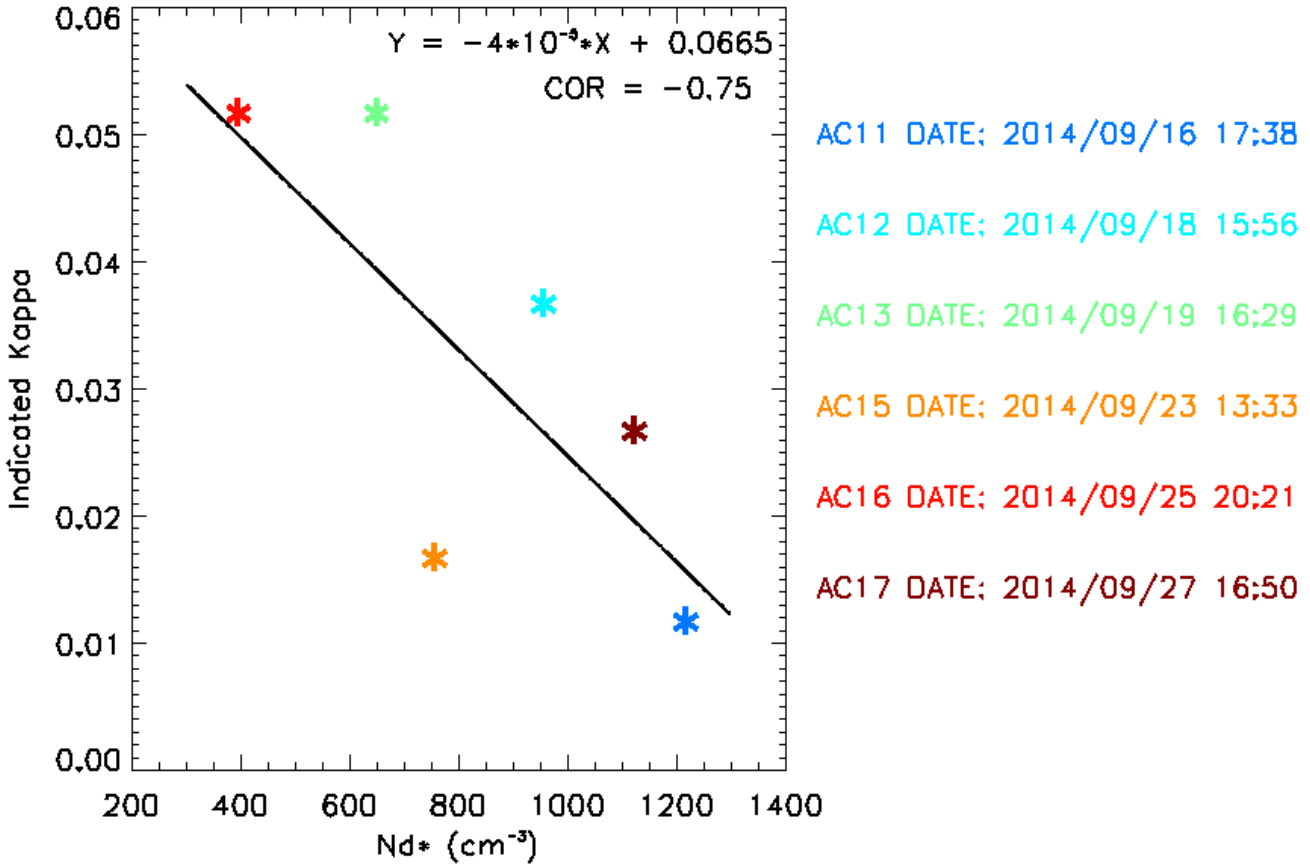

We observe smaller indicated κ → larger real κ, for aerosols under clouds with larger Nd
Is this real?
If so, what can be the reason?

Summary

1. A closure was sought by comparing the measured N_d to the calculated based on W_b and S.
2. Closure (i.e., good agreement) was achieved in most, but not all cases, specially for the CCP-CDP.
3. The closure was best for the CCP-CDP, and degraded for CAS-POL and even more for the NIXE-CAPS. Possible reasons are distortions of DSD by the CAS probes below 10 μm, possibly causing inaccuracies in the drop concentrations at the low end of the DSD.
4. Calculating Kappa for the PCASP and UHSAS measured under cloud base shows unreasonably low values, which is compatible with swelling of the aerosols by a large factor of up to more than 2.
5. Much more aerosol swelling occurred in days with larger N_d. The reason is still unknown.


Thank you