Satellite measurements of CCN and cloud properties at the cloudy boundary layer: The Holy Grail – is it achievable?

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Atmospheric Measurement Techniques

The scientific basis for a satellite mission to retrieve CCN concentrations and their impacts on convective clouds

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CHASER

An Innovative Satellite Mission Concept to Measure the Effects of Aerosols on Clouds and Climate

BY NILTON O. RENNÓ, EARLE WILLIAMS, DANIEL ROSENFELD, DAVID G. FISCHER, JÜRGEN FISCHER, TIBOR KREMIC, ARUN AGRAWAL, MEINRAT O. ANDREAE, ROSINA BIERBAUM, RICHARD BLAKESLEE, ANKO BOERNER, NEIL BOWLES, HUGH CHRISTIAN, ANN COX, JASON DUNION, AKOS HORVATH, XIANGLEI HUANG, ALEXANDER KHAIN, STEFAN KINNE, MARIA C. LEMOS, JOYCE E. PENNER, ULRICH PÖSCHL, JOHANNES QUAAS, ELENA SERAN, BJORN STEVENS, THOMAS WALATI, AND THOMAS WAGNER

CHASER proposes to revolutionize our understanding of the interactions of aerosols with clouds by making the first global survey of the fundamental physical entity linking them: activated cloud condensation nuclei.
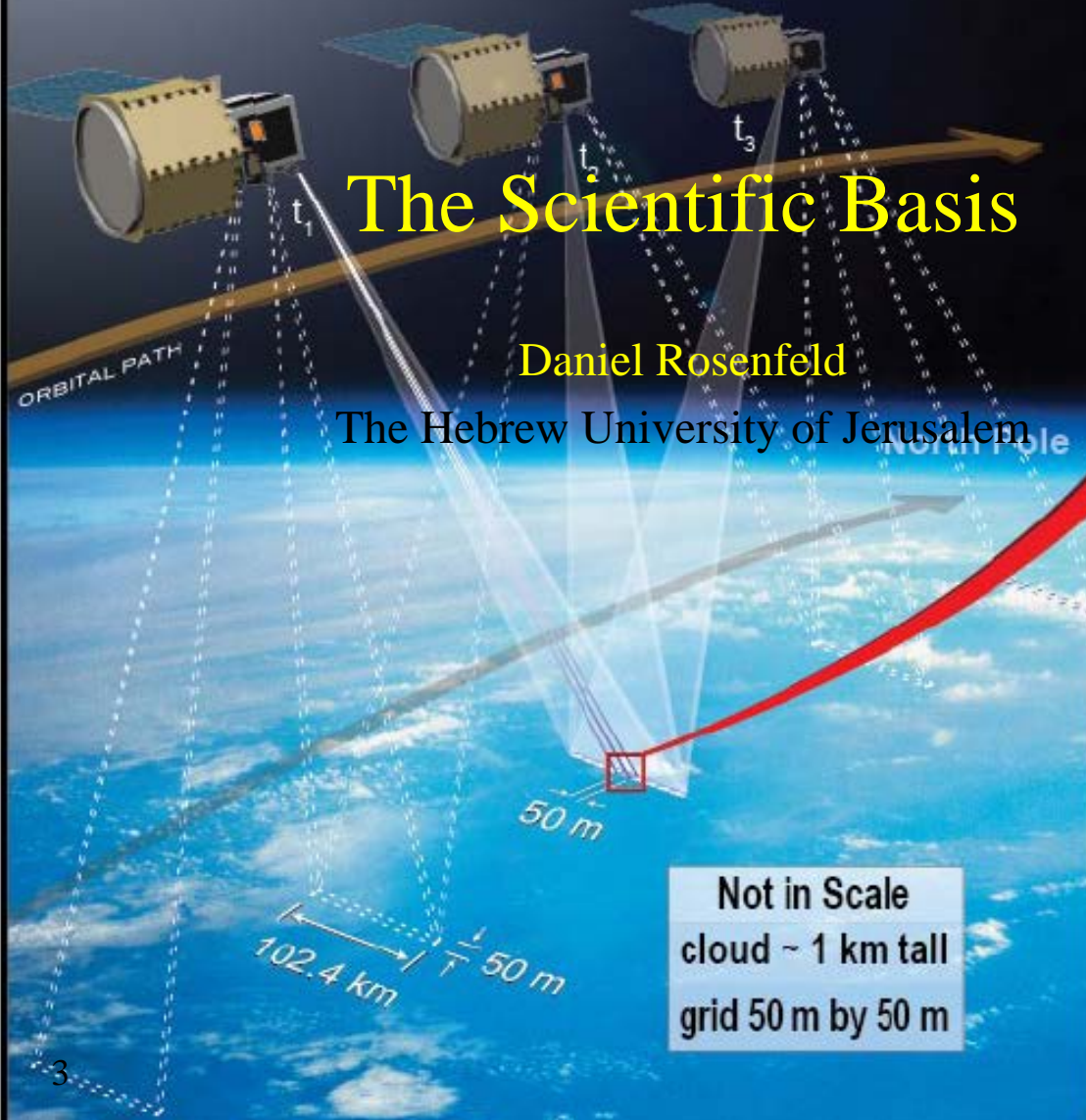
CHASER

The Scientific Basis
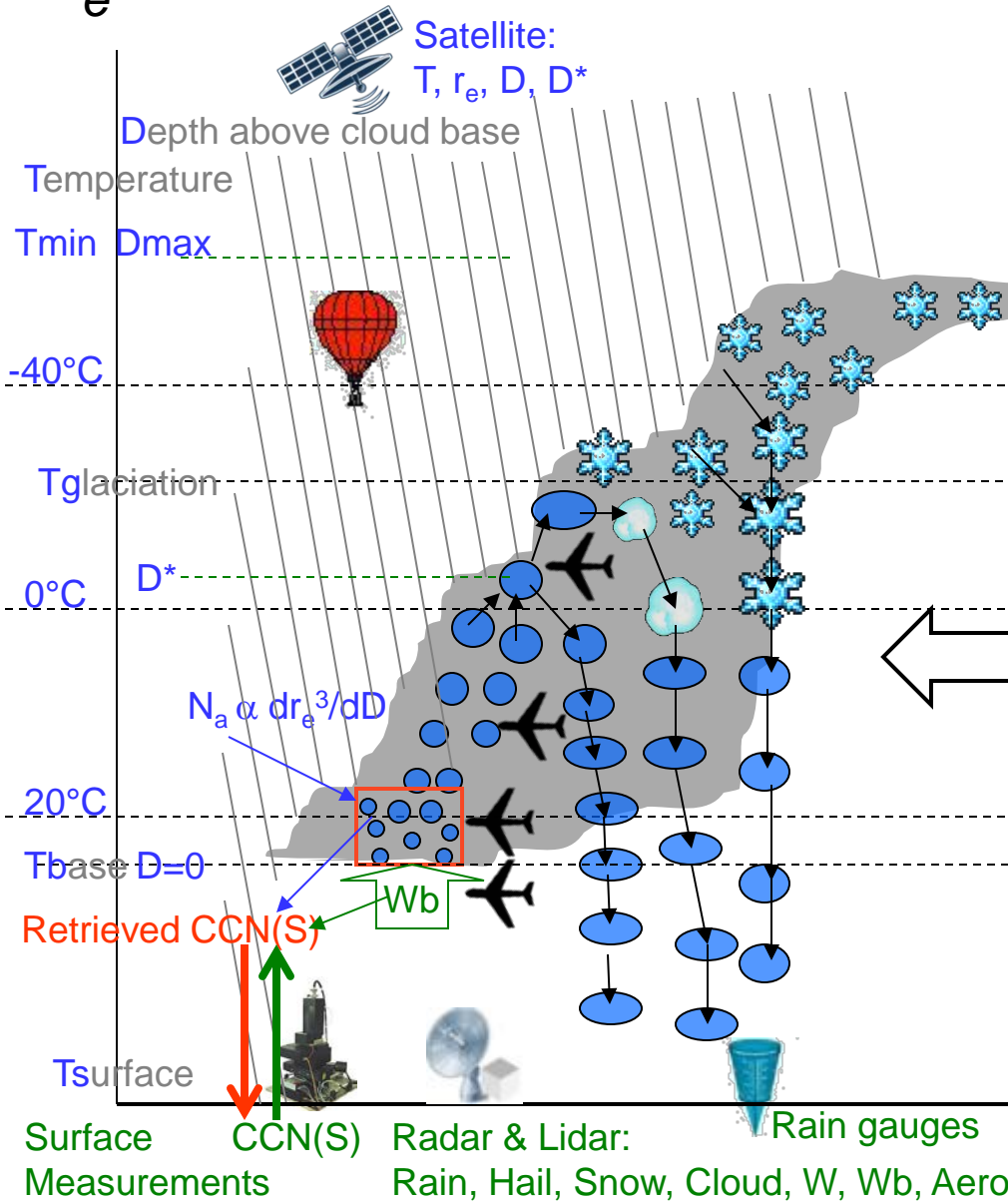
Daniel Rosenfeld
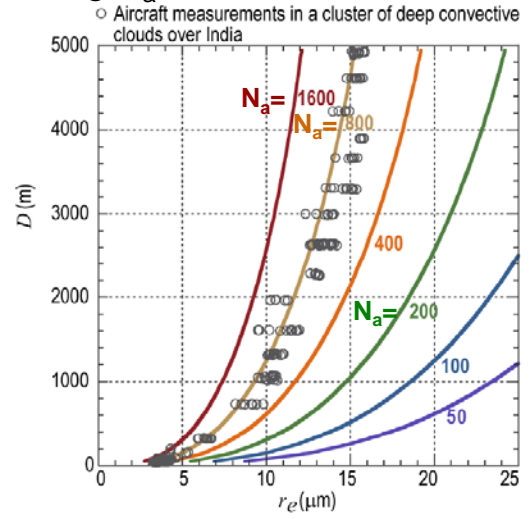
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Retrieving CCN from satellite-measured T-r_e relations of convective clouds

האוניברסיטה העברית בירושלים
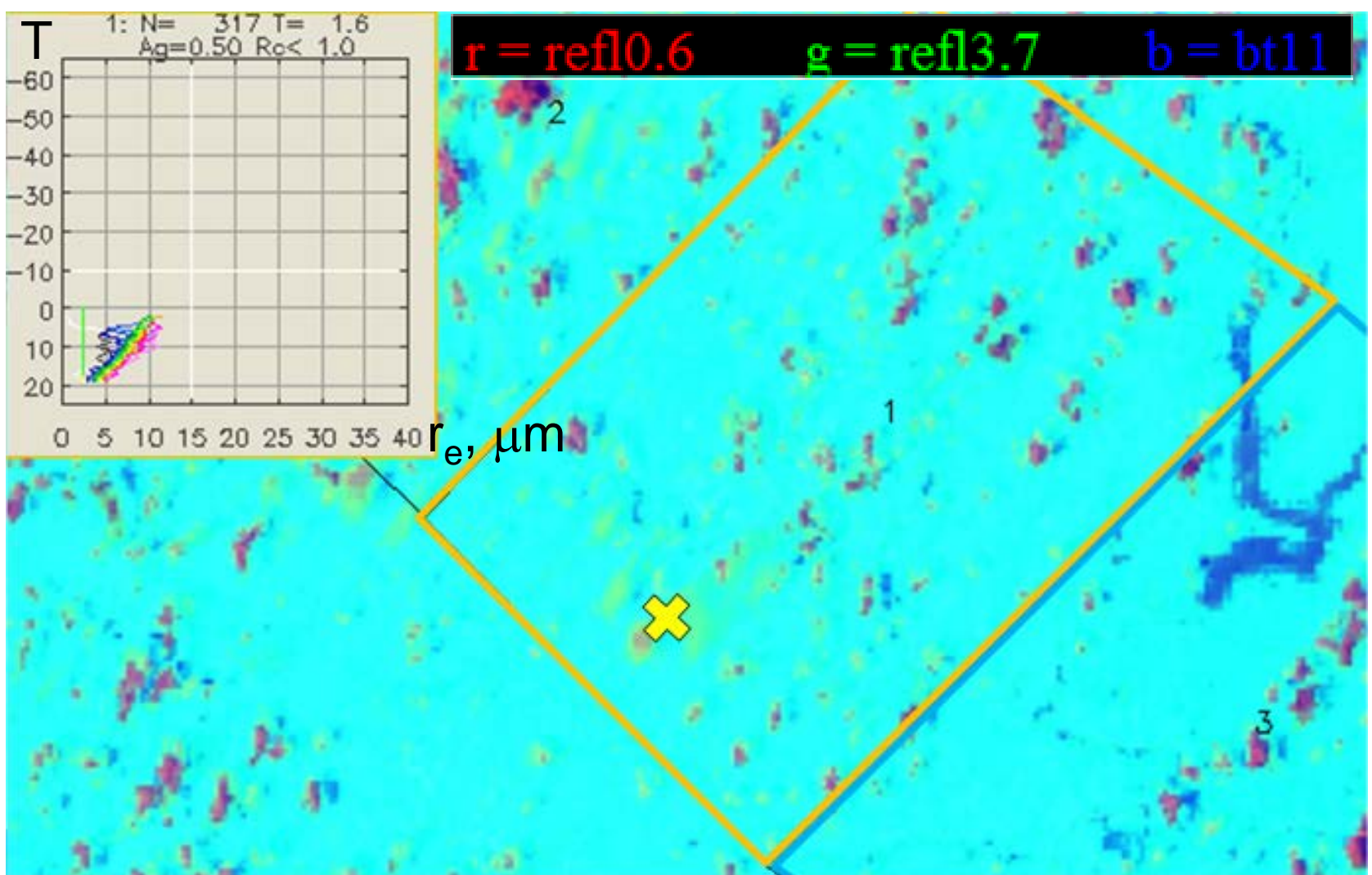The Hebrew University of Jerusalem

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Satellite: T, r_e, D, D*

Depth above cloud base

Temperature

Tmin Dmax

-40°C

Tglaciation

D*

0°C

$N_a \propto dr_e^3/dD$

20°C

Tbase D=0

Wb

Retrieved CCN(S)

Tsurface

Surface Measurements   CCN(S)   Radar & Lidar:
Rain, Hail, Snow, Cloud, W, Wb, Aerosols   Rain gauges
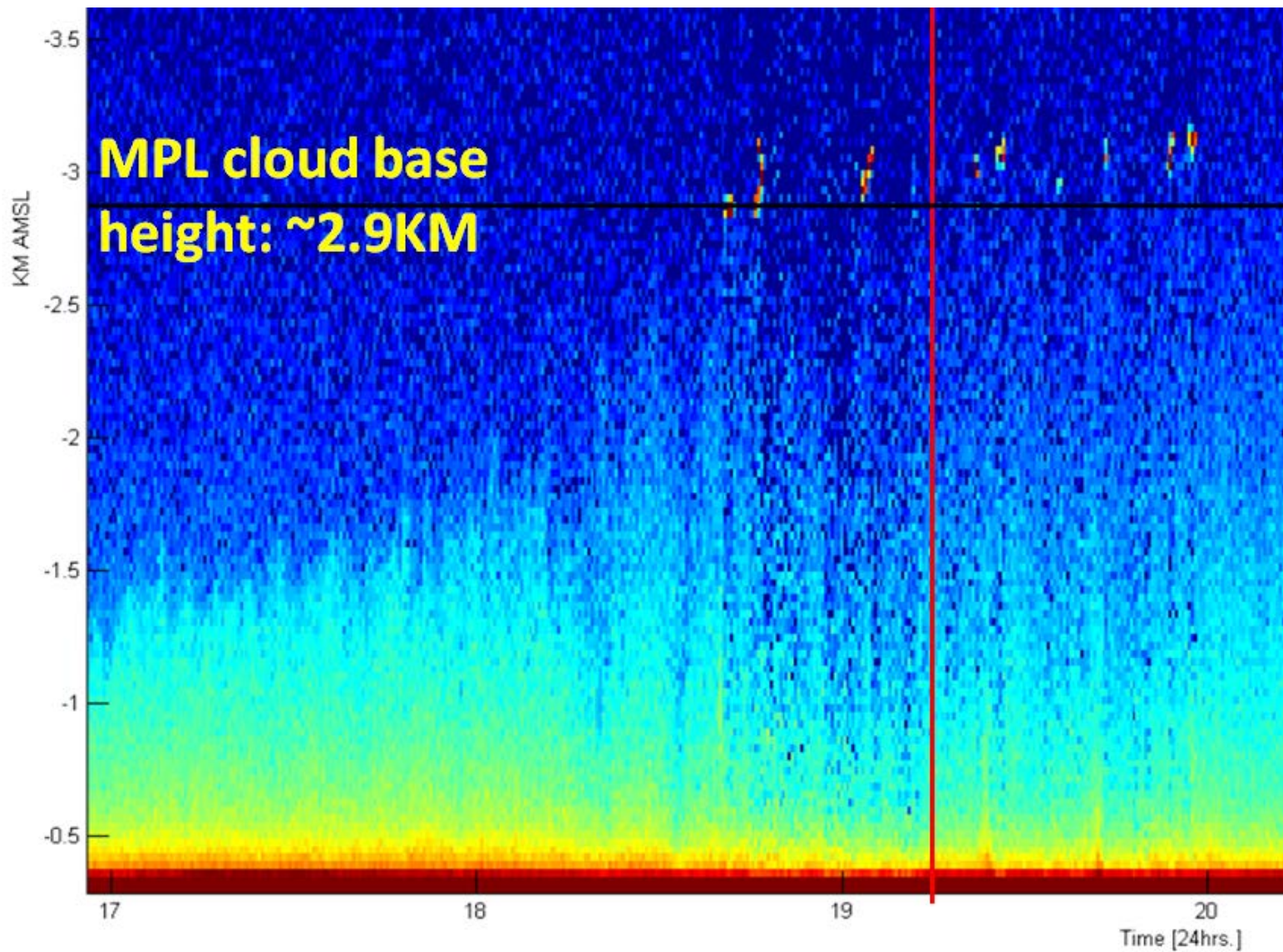
Calculating N_a from observed D- or T-r_e

Validation of the retrieved CCN over SGP
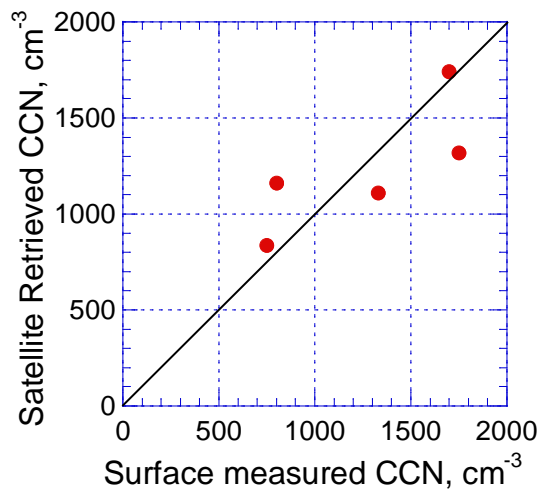
A VIIRS/NPP image of the convective clouds and T-r_e relations in an area over the ARM/SGP site at 25 July 2012 19:14 UT. The color scheme is RGB microphysics. The imager data is at a resolution of 375 m.
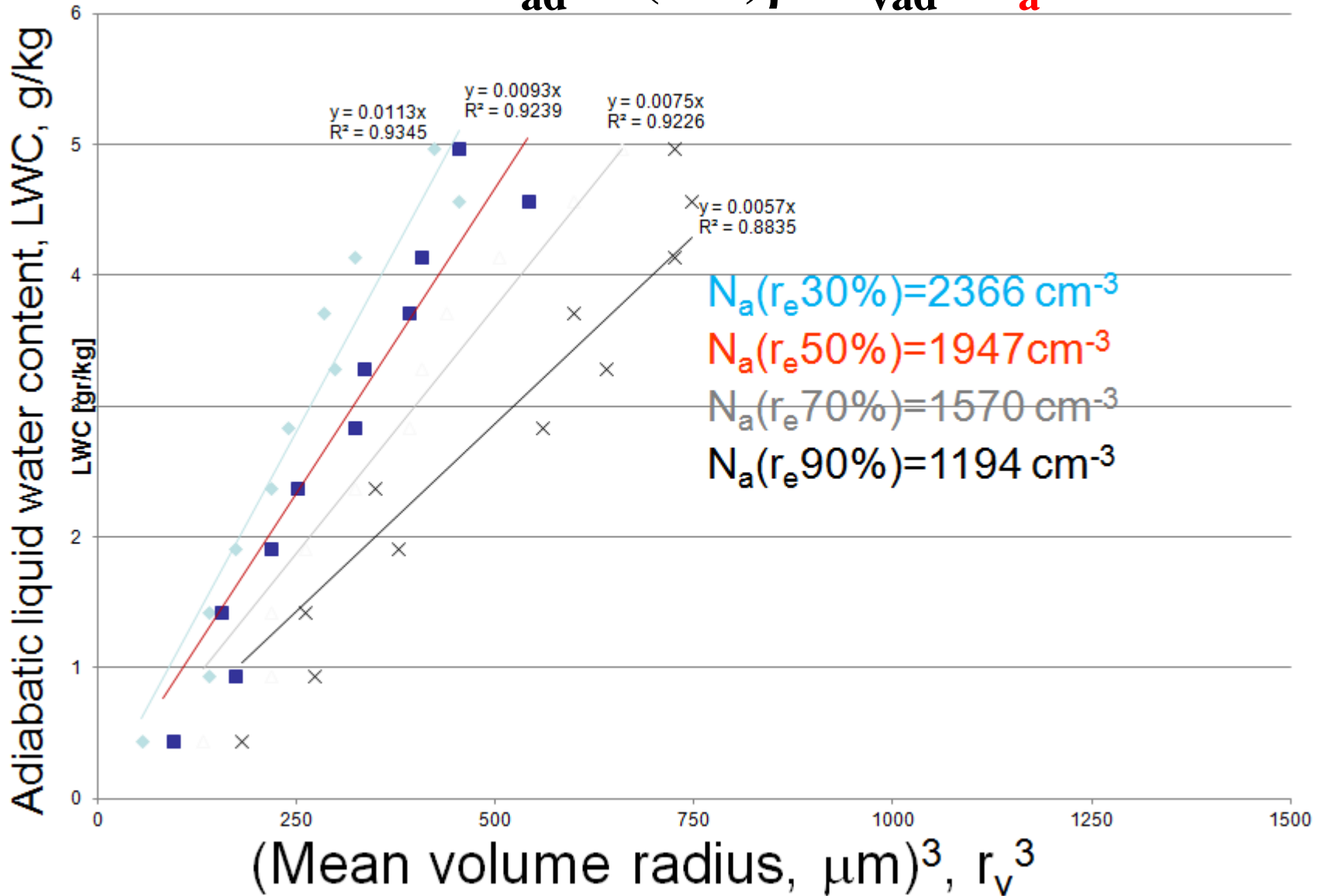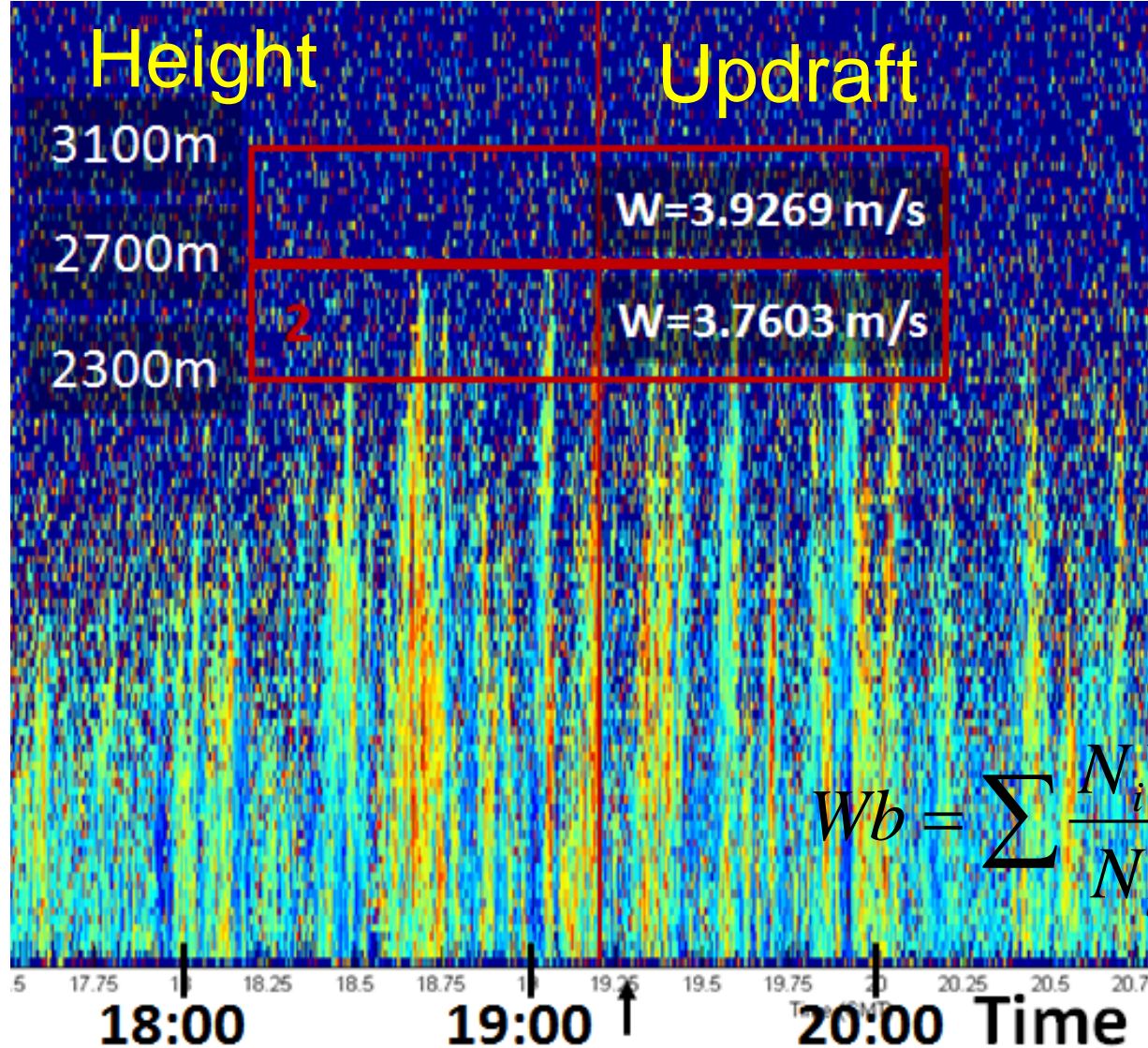
The MPL lidar backscatter vertical profile at the SGP, showing cloud base height at ~2.9 km msl. The vertical line denotes the overpass time.
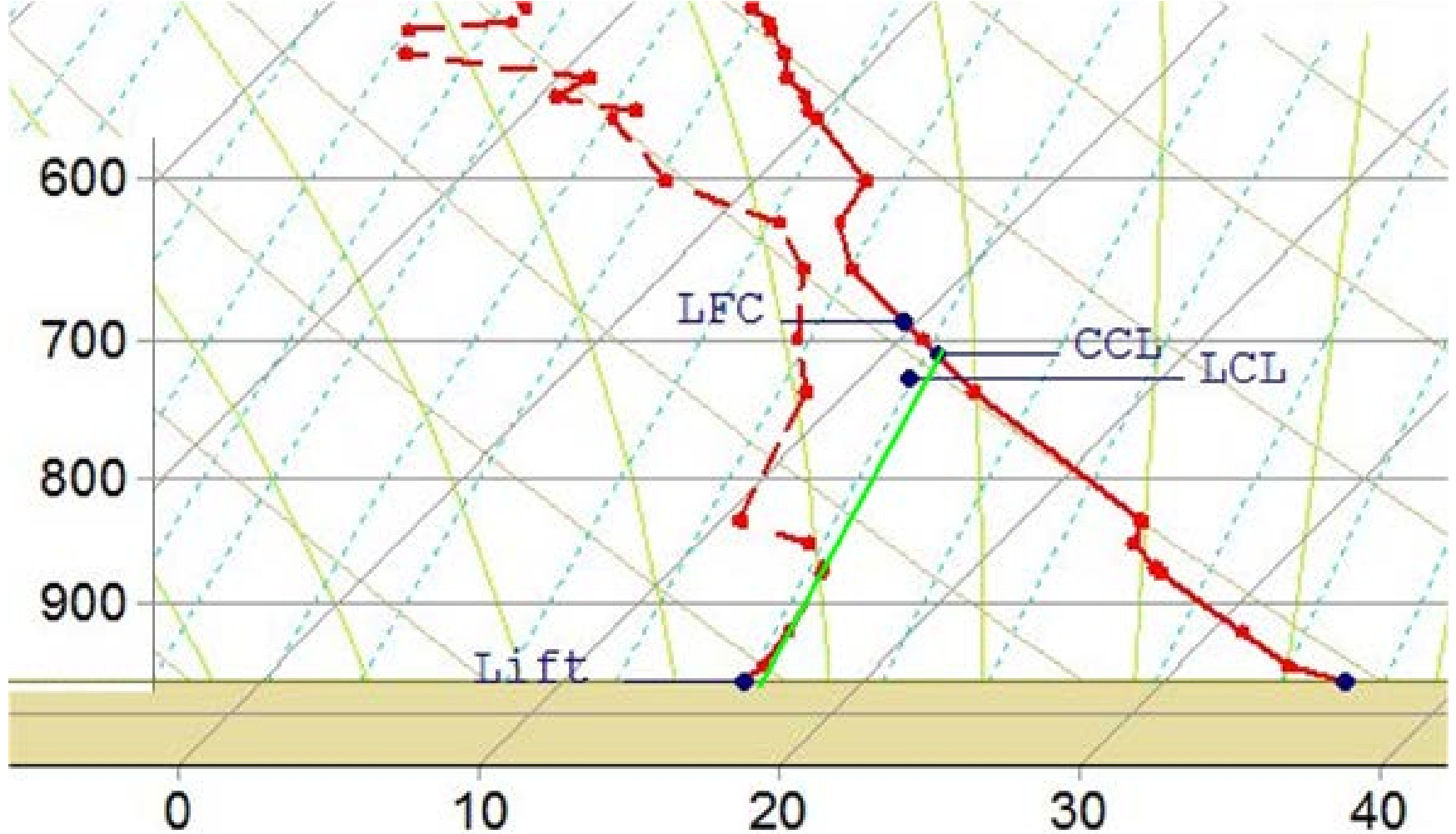
The SGP sounding of 25 July 2012 17:30 UT.
Temperature at cloud base height is about 13°C.
However, warmest satellite cloudy pixel is at 17°C.

$\text{LWC}_{ad} = (4/3)\rho\pi r_{vad}^3 \textcolor{red}{N_a}$

Adiabatic liquid water content, LWC, g/kg

LWC [gr/kg]

$y = 0.0113x$
$R^2 = 0.9345$

$y = 0.0093x$
$R^2 = 0.9239$

$y = 0.0075x$
$R^2 = 0.9226$

$y = 0.0057x$
$R^2 = 0.8835$

$N_a(r_e30\%)=2366 \text{ cm}^{-3}$

$N_a(r_e50\%)=1947 \text{cm}^{-3}$

$N_a(r_e70\%)=1570 \text{ cm}^{-3}$

$N_a(r_e90\%)=1194 \text{ cm}^{-3}$

(Mean volume radius, μm)^3, r_v^3

Height Updraft

3100m

W=3.9269 m/s

2700m

2 W=3.7603 m/s

2300m

$$Wb = \sum \frac{N_i W_i^2}{N_i W_i} \Big| W_i > 0$$
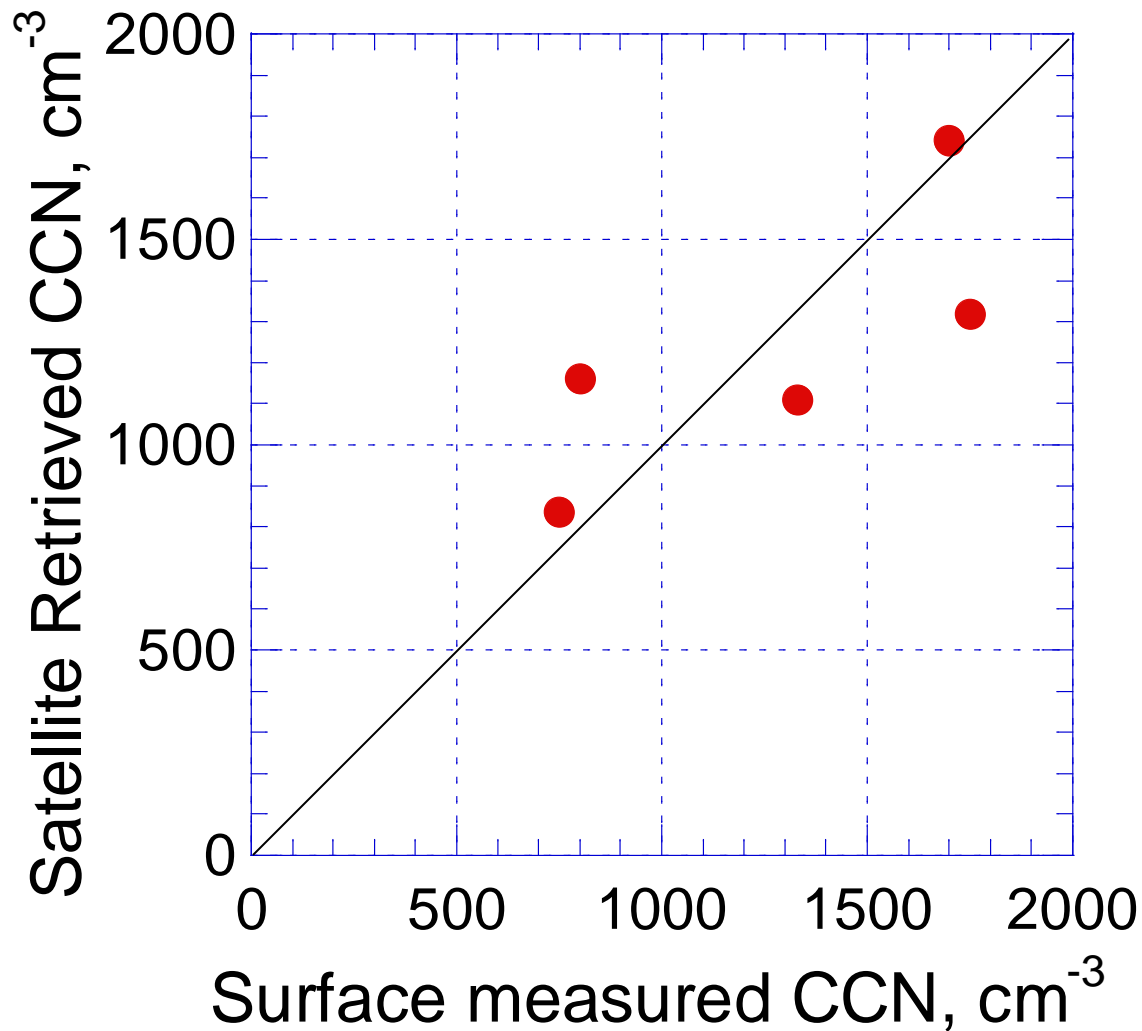
18:00   19:00   20:00 Time

Thermals in the well mixed boundary layer, as seen by the vertically pointing Doppler radar at the SGP site. The retrieved cloud base updraft speeds are denoted. The vertical line denotes the overpass time.
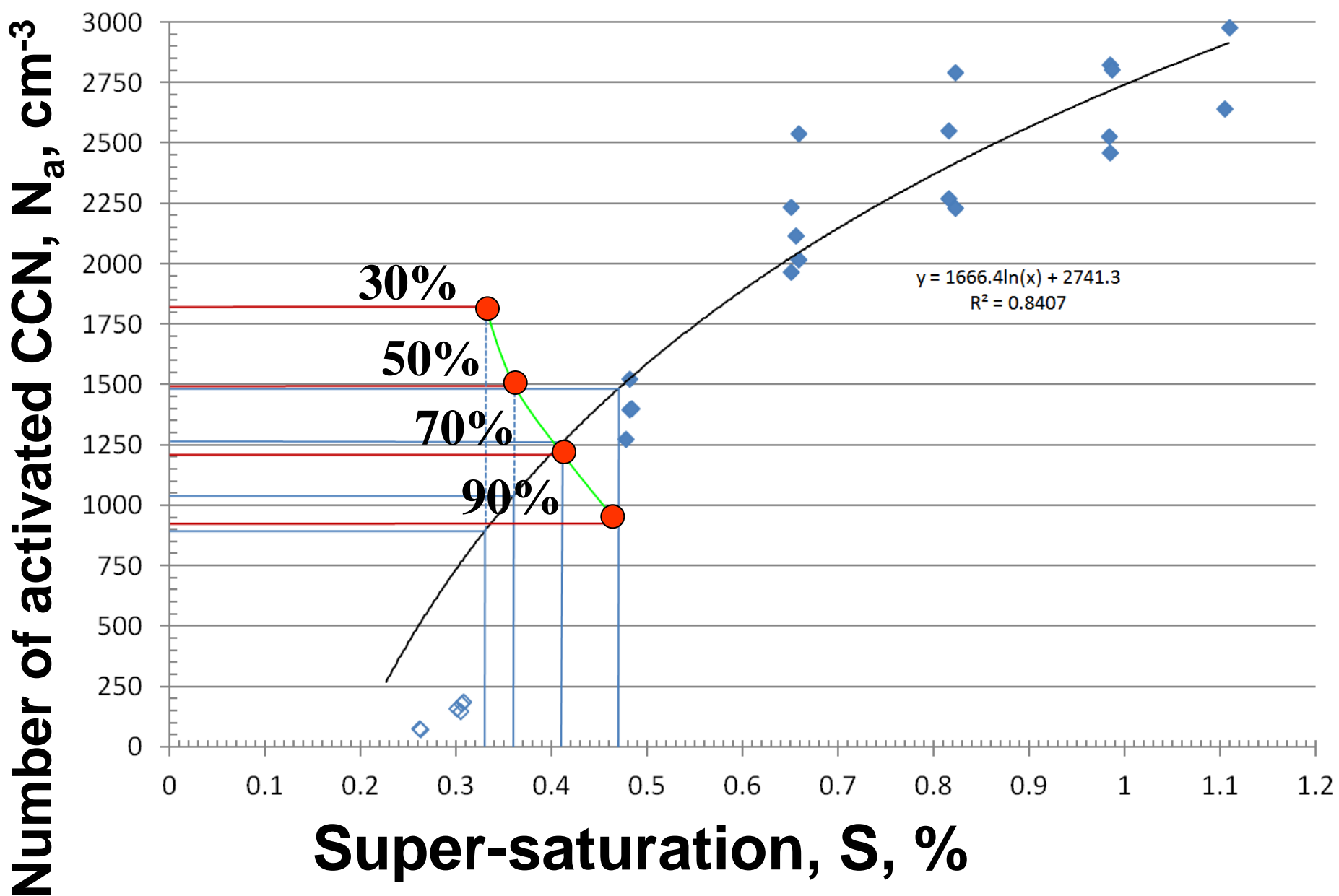
Validation of the retrieved CCN by surface measurements.

Validation of the satellite-retrieved CCN by surface measurements at the SGP for the 9, 13, 19, 24 and 25 of July 2012. The median r_e for a given T was used.

Description of work:

- Number of activated CCN at cloud base (N_a) can be obtained from satellite retrieved relations between temperature (T) and drop effective radius (r_e) of convective clouds.

- Cloud base updraft (w_b) is measured by vertically pointing cloud radar at the ARM/SGP site.

- Therefore, the supersaturation (S) at cloud base can be calculated based on N_a and w_b. Having N_a and S constitutes measuring the CCN(S).

- The retrieved CCN(S) at cloud base is validated by surface measurements of CCN(S) during times of well mixed boundary layer.

Ongoing and future plans:

- Improve the accuracy of surface CCN measurements at low supersaturations.

- Improve the accuracy of satellite measurements of cloud base temperatures.

- Add case studies for locations with accurate measurements of CCN and cloud base updrafts.

- Develop a methodology for assessing cloud base updraft from satellite measurements.