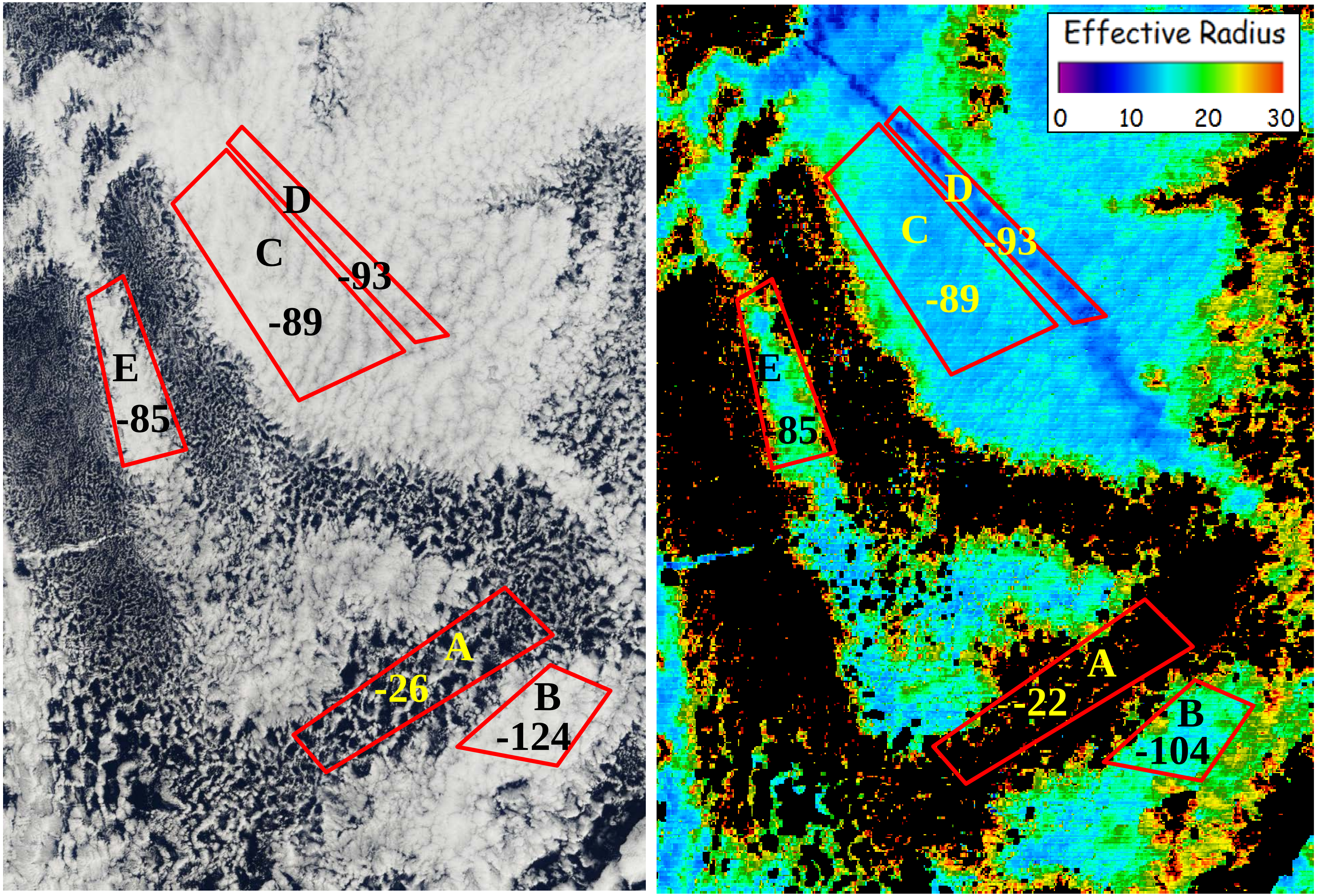
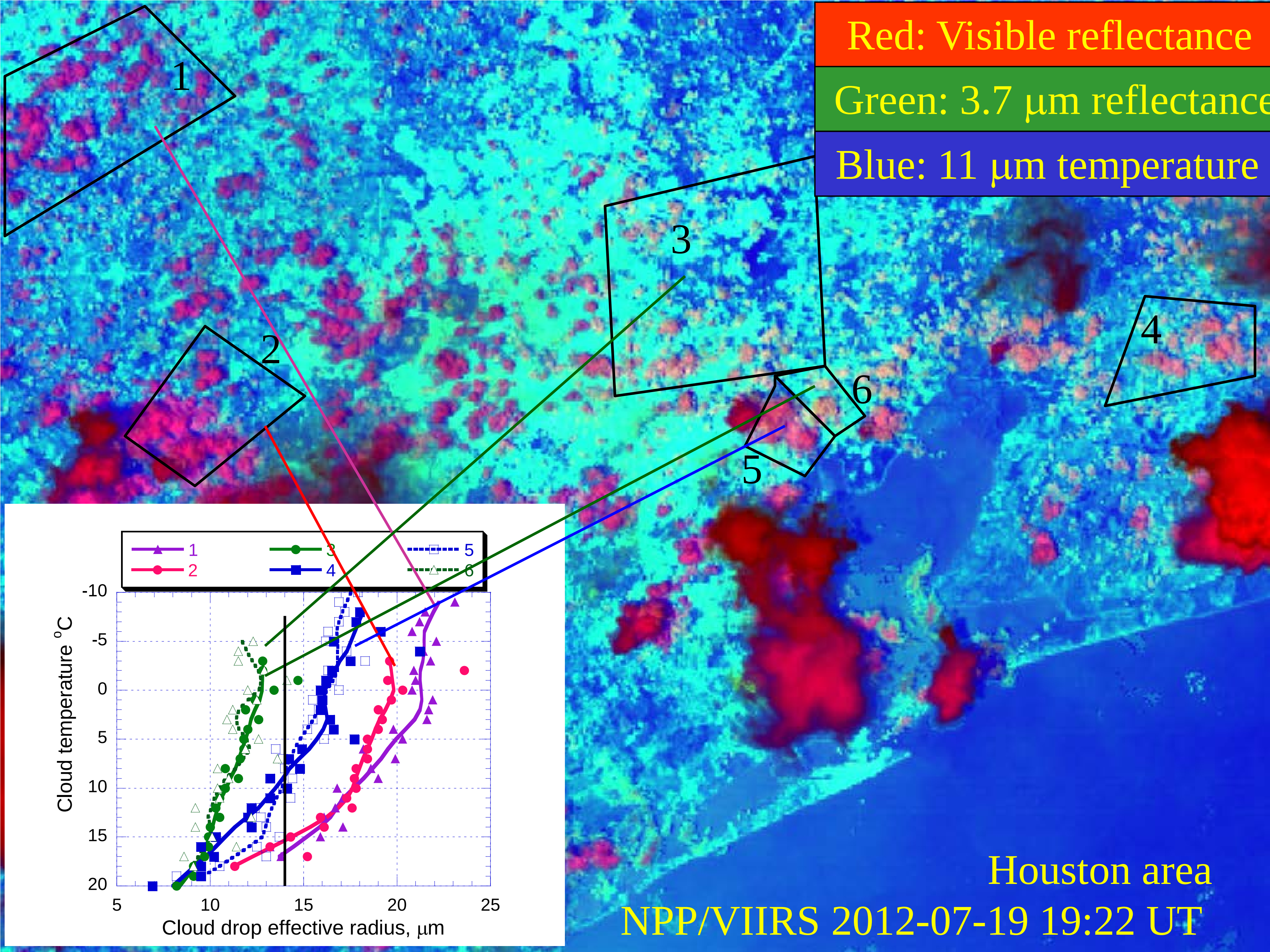
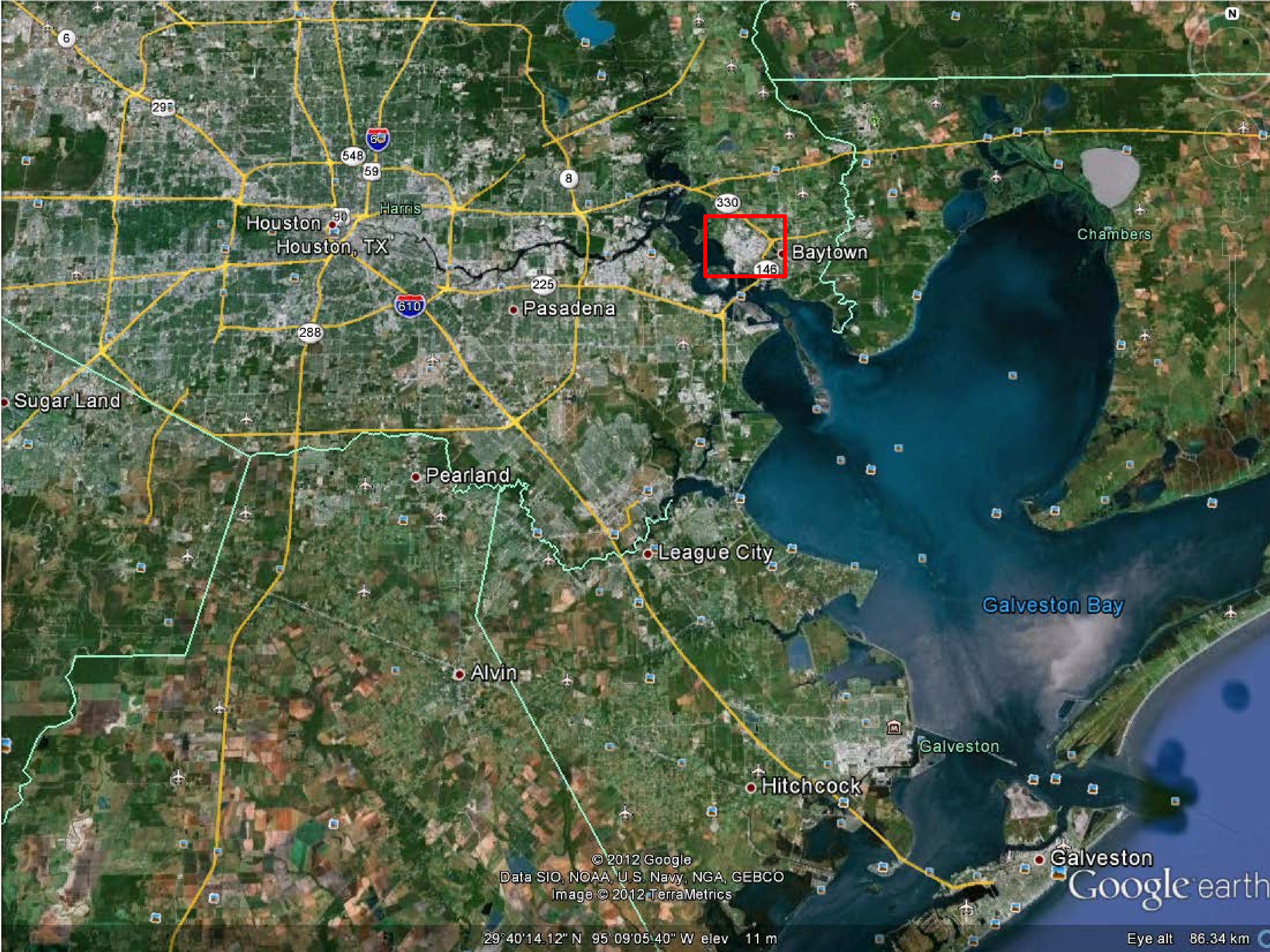
Satellite measurements of CCN and cloud properties at the cloudy boundary layer: The Holy Grail – is it achievable?

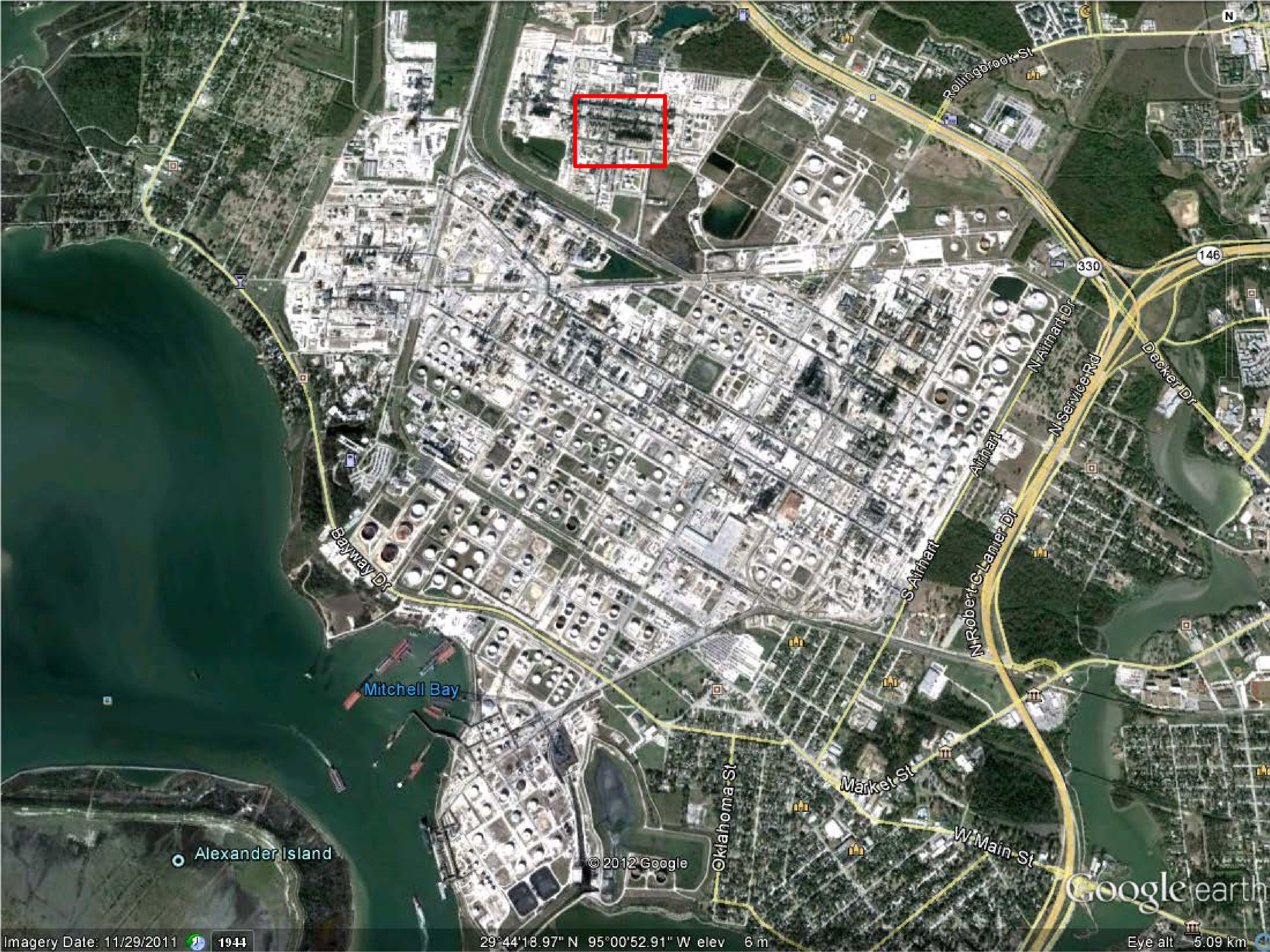
Daniel Rosenfeld, The Hebrew University of Jerusalem


D
C
-93
-89
E
-85
A
-26
B
-124
Effective Radius
0
10
20
30
D
C
-93
-89
E
85
A
-22
B
-104

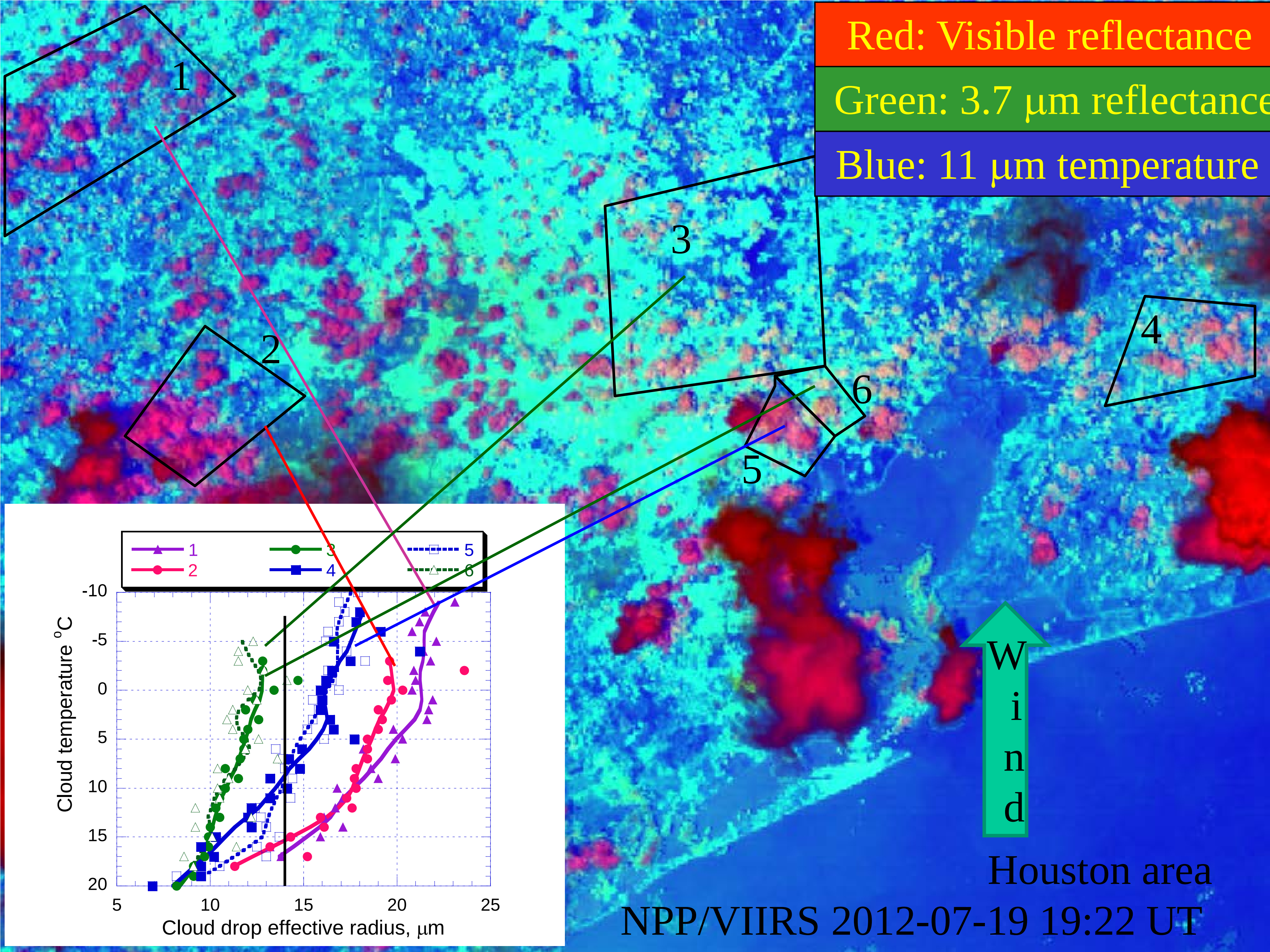


Red: Visible reflectance
Green: 3.7 μm reflectance
Blue: 11 μm temperature
1
2
3
4
5
6
1
2
3
4
5
6
Cloud temperature °C
-10
-5
0
5
10
15
20
5
10
15
20
25
Cloud drop effective radius, μm
Houston area
NPP/VIIRS 2012-07-19 19:22 UT


6
290
610
548
59
8
330
Harris
Houston
90
Houston, TX
Baytown
146
225
Chambers
Pasadena
610
288
Sugar Land
Pearland
League City
Galveston Bay
Alvin
Galveston
Hitchcock
Galveston
© 2012 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2012 TerraMetrics
Google earth
29°40'14.12" N 95°09'05.40" W elev 11 m
Eye alt 86.34 km


Rollingbrook St
330
146
N Airhart Dr
N Service Rd
Decker Dr
Airhart
N Robert C Lanier Dr
S Airhart
Bayway Dr
Mitchell Bay
Market St
W Main St
Oklahoma St
Alexander Island
© 2012 Google
Google earth
Imagery Date: 11/29/2011
1944
29°44'18.97" N 95°00'52.91" W elev 6 m
Eye alt 5.09 km


N
© 2012 Google
Google earth
Imagery Date: 11/29/2011
1978
29°45'20.86" N 95°00'45.75" W elev 7 m
Eye alt 384 m


Red: Visible reflectance
Green: 3.7 μm reflectance
Blue: 11 μm temperature
1
2
3
4
5
6
Wind
Houston area
NPP/VIIRS 2012-07-19 19:22 UT
Cloud temperature °C
Cloud drop effective radius, μm
-10
-5
0
5
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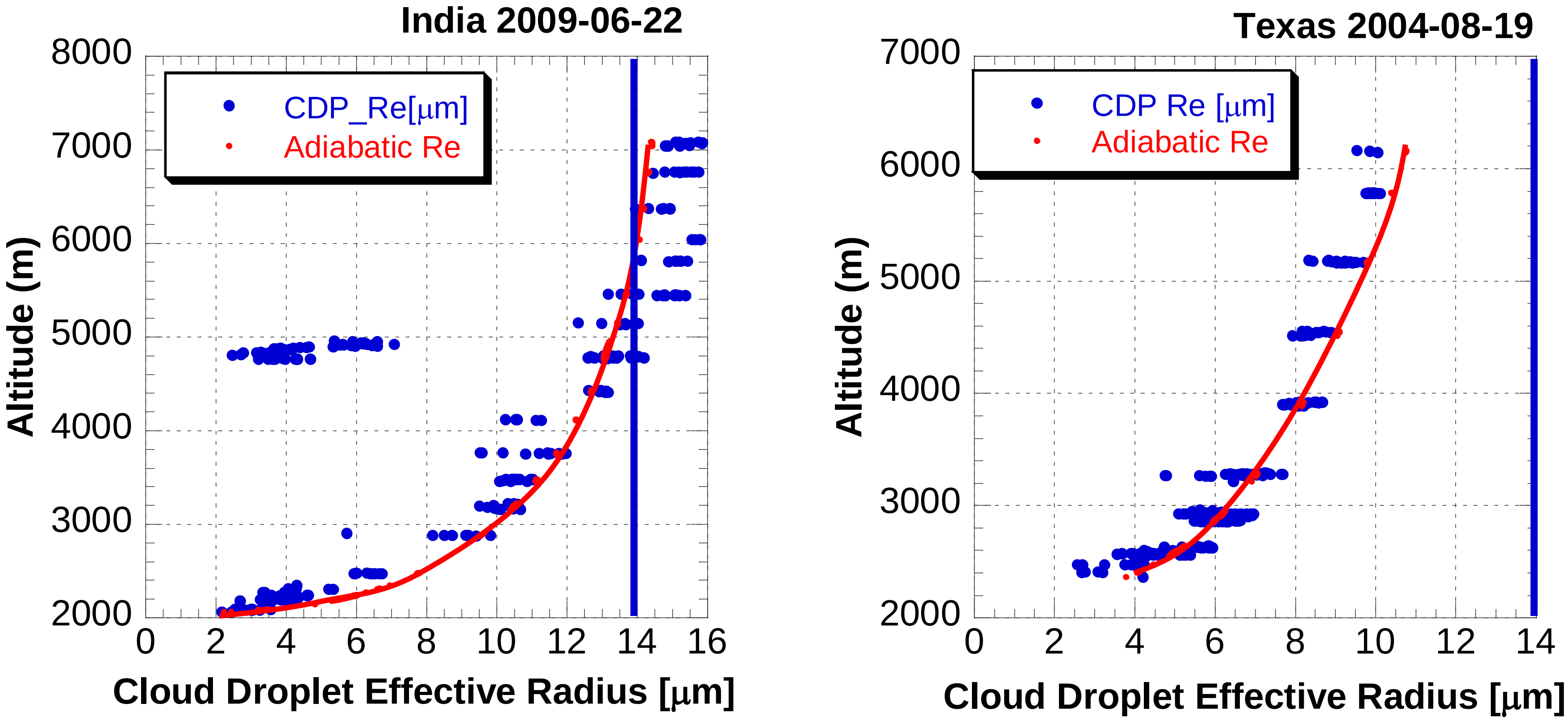


$r_e = 1.08R_V$

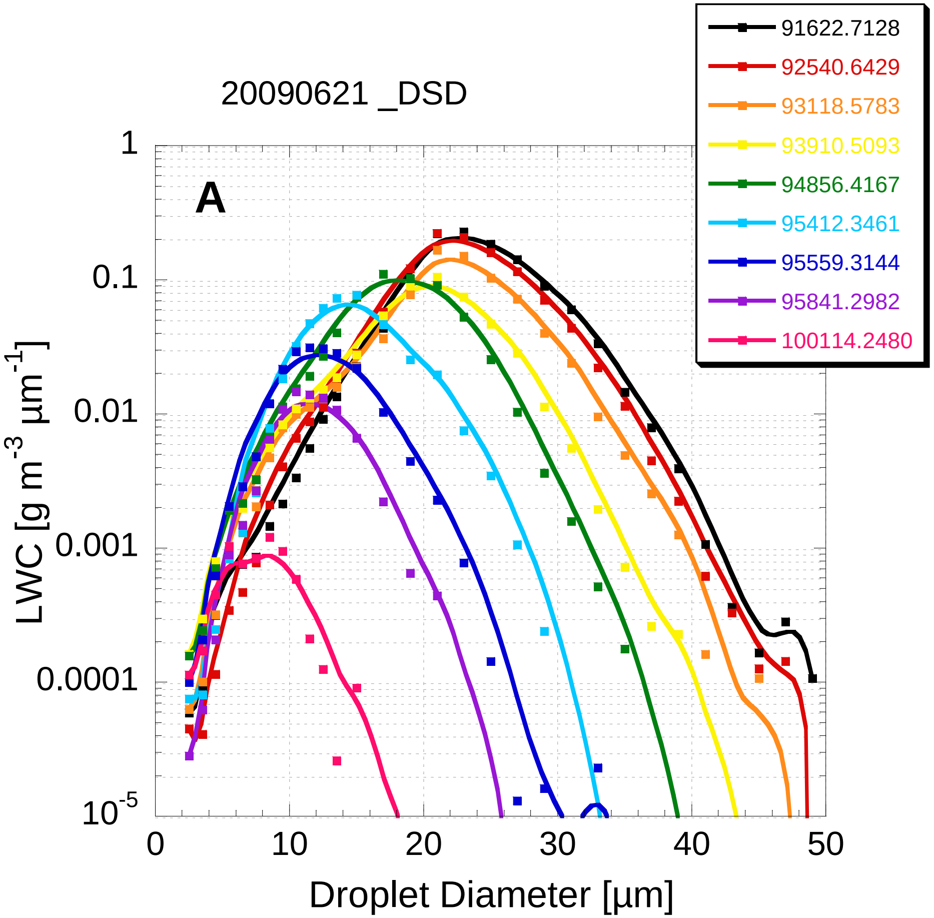
The cloud is dominated by inhomogeneous mixing.

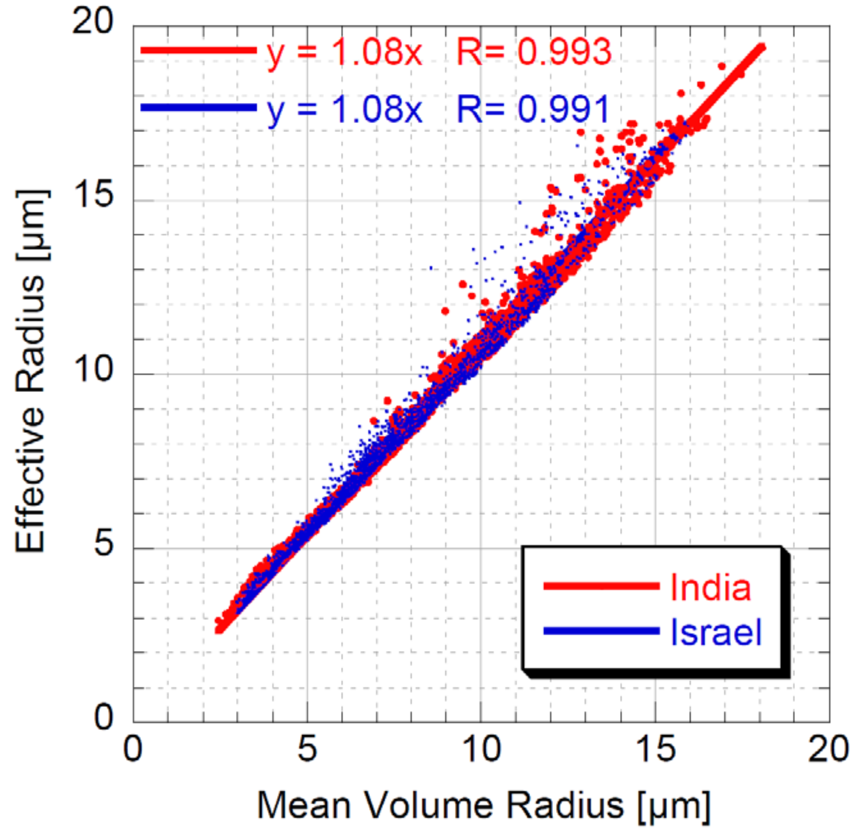
Therefore cloud drop size behaves almost as adiabatic cloud.

This explains the tight relations between Re and height or D.

Therefore, a well defined depth for rain initiation should exist, which depends on the nucleated cloud drop concentration.

Giant CCN can initiate raindrops at smaller r_e.



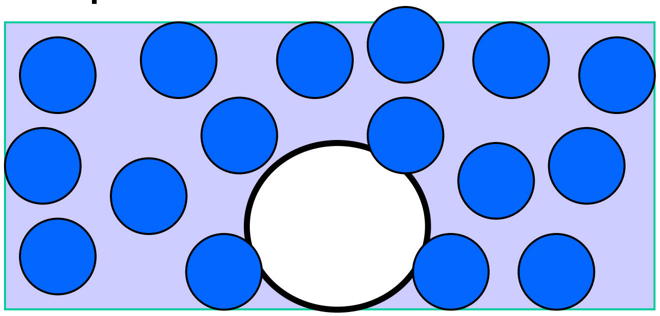


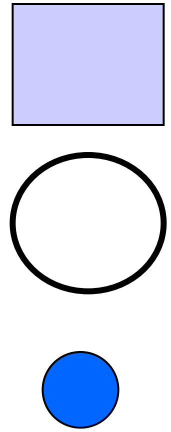
$r_e = 1.08\ r_v$

The self similarity of convective DSDs causes a similarity and a fixed relation between r_v and r_e.

Extreme inhomogeneous mixing

1. Dry air penetrates



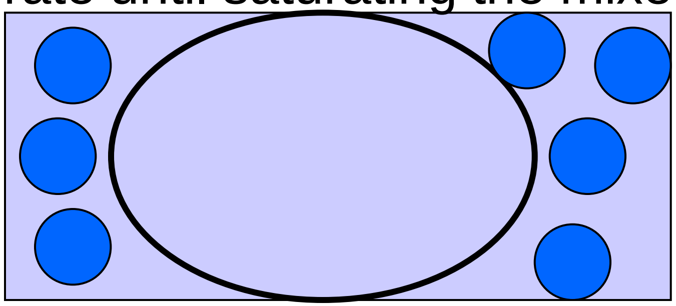


Saturated cloudy air parcel

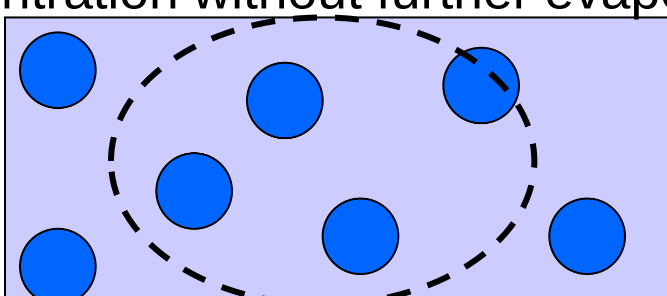
Dry entrained air parcel

Cloud drop

2. Drops at the border of the dry parcel completely evaporate until saturating the mixed parcel.



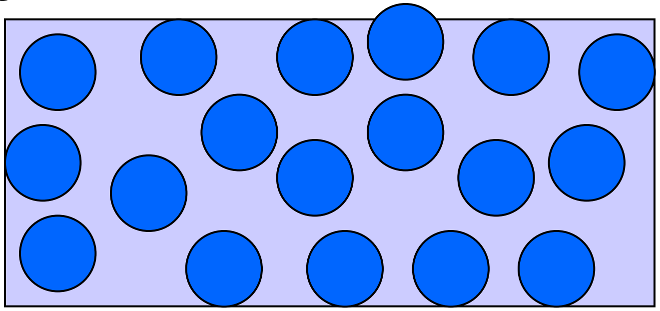
3. The saturated parcel mixes and dilutes the drop concentration without further evaporating them.

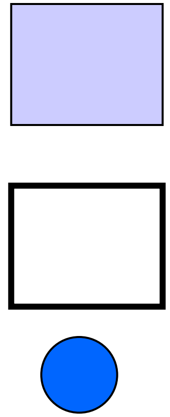


Results:
Drop concentration decreased
Drop size conserved

Extreme _homogeneous mixing

1. Original unmixed cloud



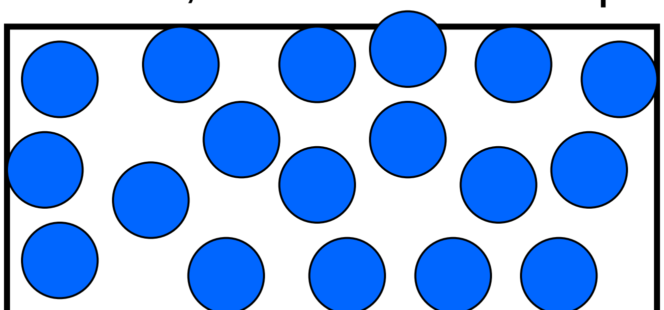


Saturated cloudy air parcel

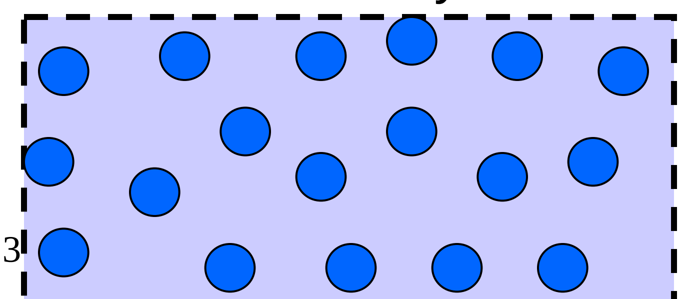
Sub-saturated mix of cloud with entrained air

Cloud drop

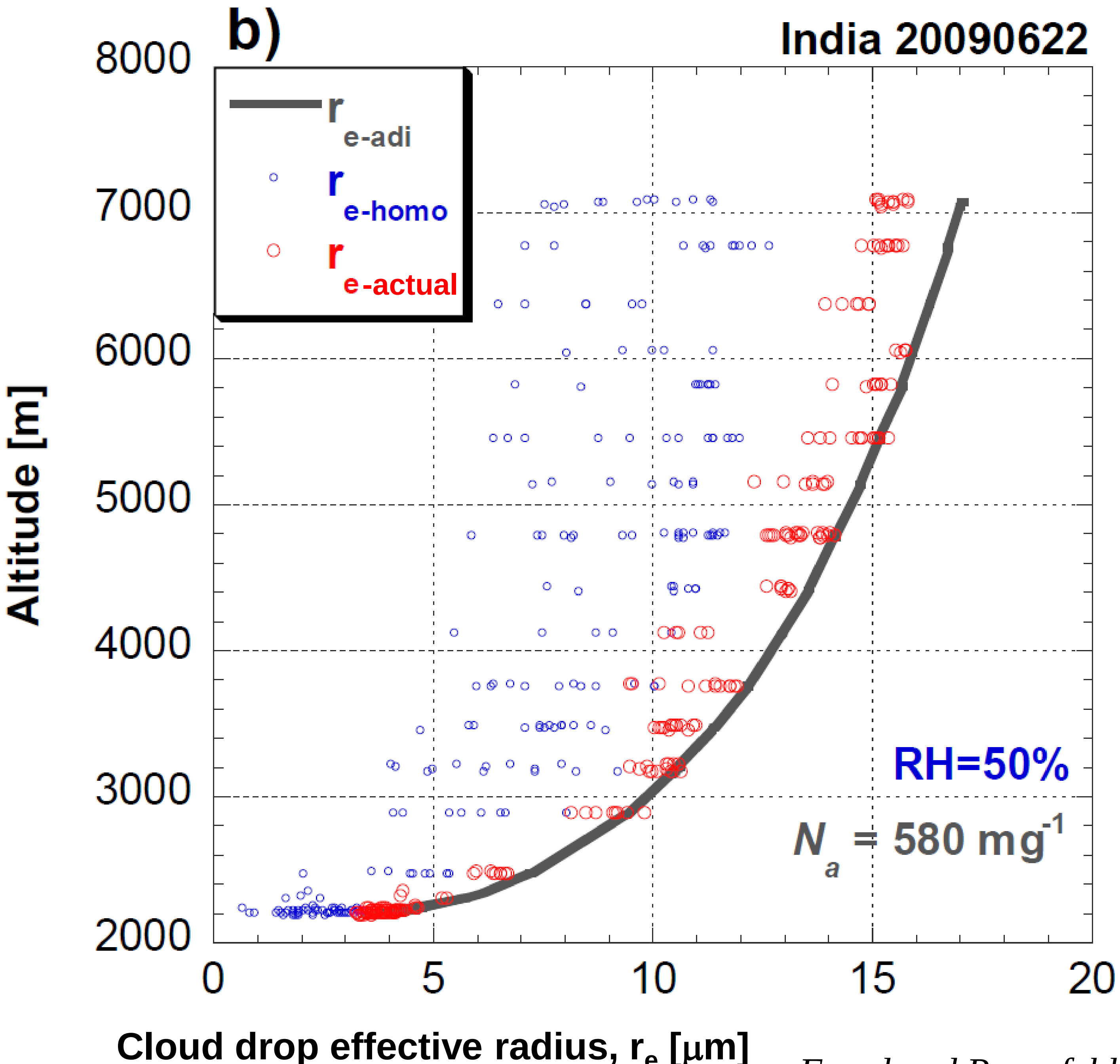
2. The cloud mixes homogeneously with dry air and becomes sub saturated, before cloud drops had time to evaporate.



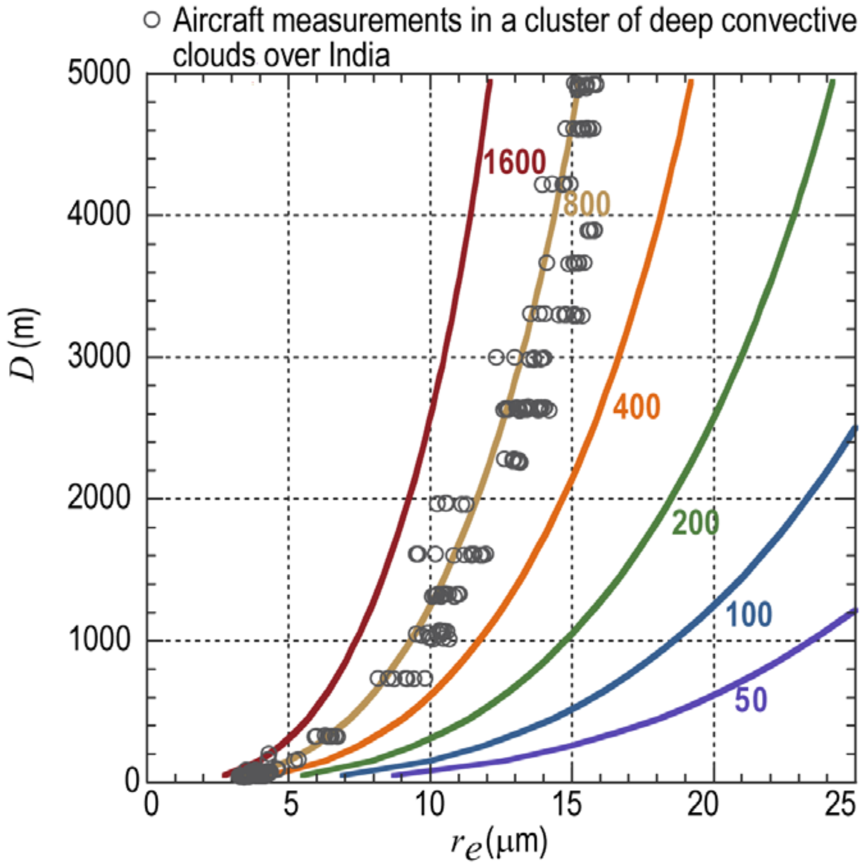
3. The cloud drops evaporate partially and reduce their size until the cloudy air saturates again.



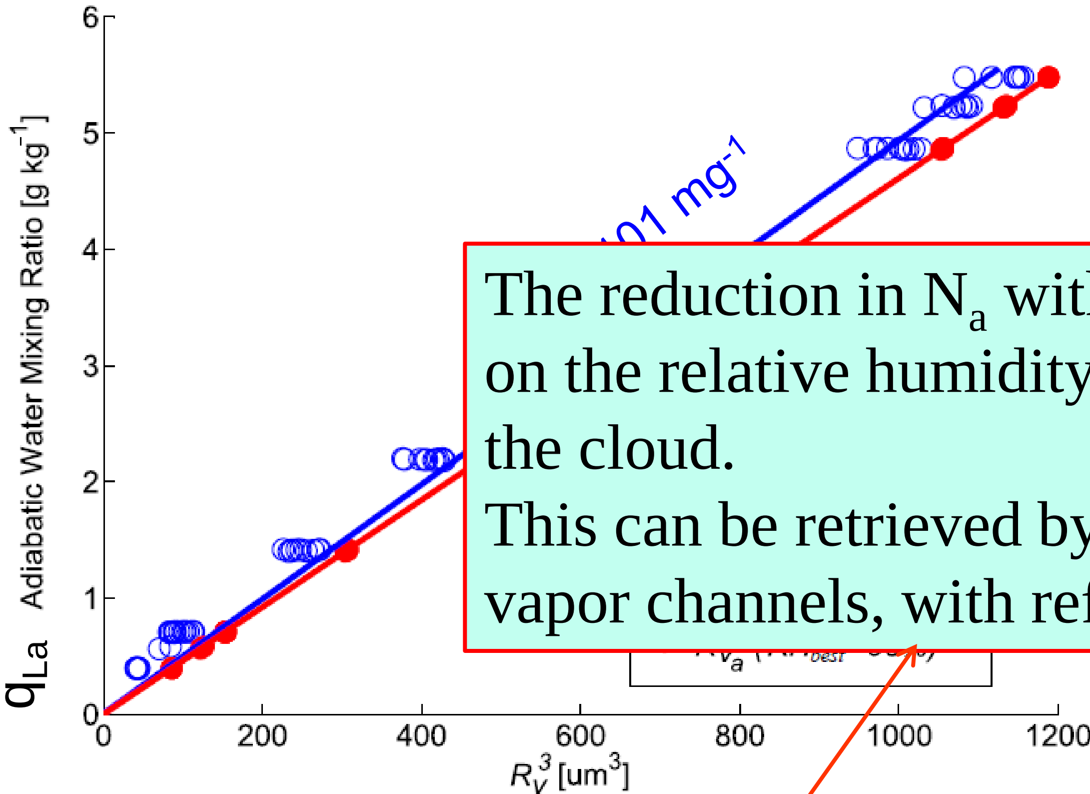
Results:
Drop concentration preserved
Drop size decreased



Freud and Rosenfeld, submitted.



The number of activated CCN at cloud base will be obtained from the microphysical vertical profiles of the convective clouds (T-r_e relations)



$$r_v = (3q_L/4\pi\rho_w N)^{1/3}$$

Where

The reduction in N_a with respect to adiabatic depends on the relative humidity of the air that is mixed with the cloud.
This can be retrieved by the thermal T and NIR water vapor channels, with reference to the cloud surfaces.

$$r_e = 1.08\ r_v$$

If T-r_e is so tight, it means that mixing with ambient dry air does not change much r_e, and it is similar to r_e of an unmixed (adiabatic) cloud.

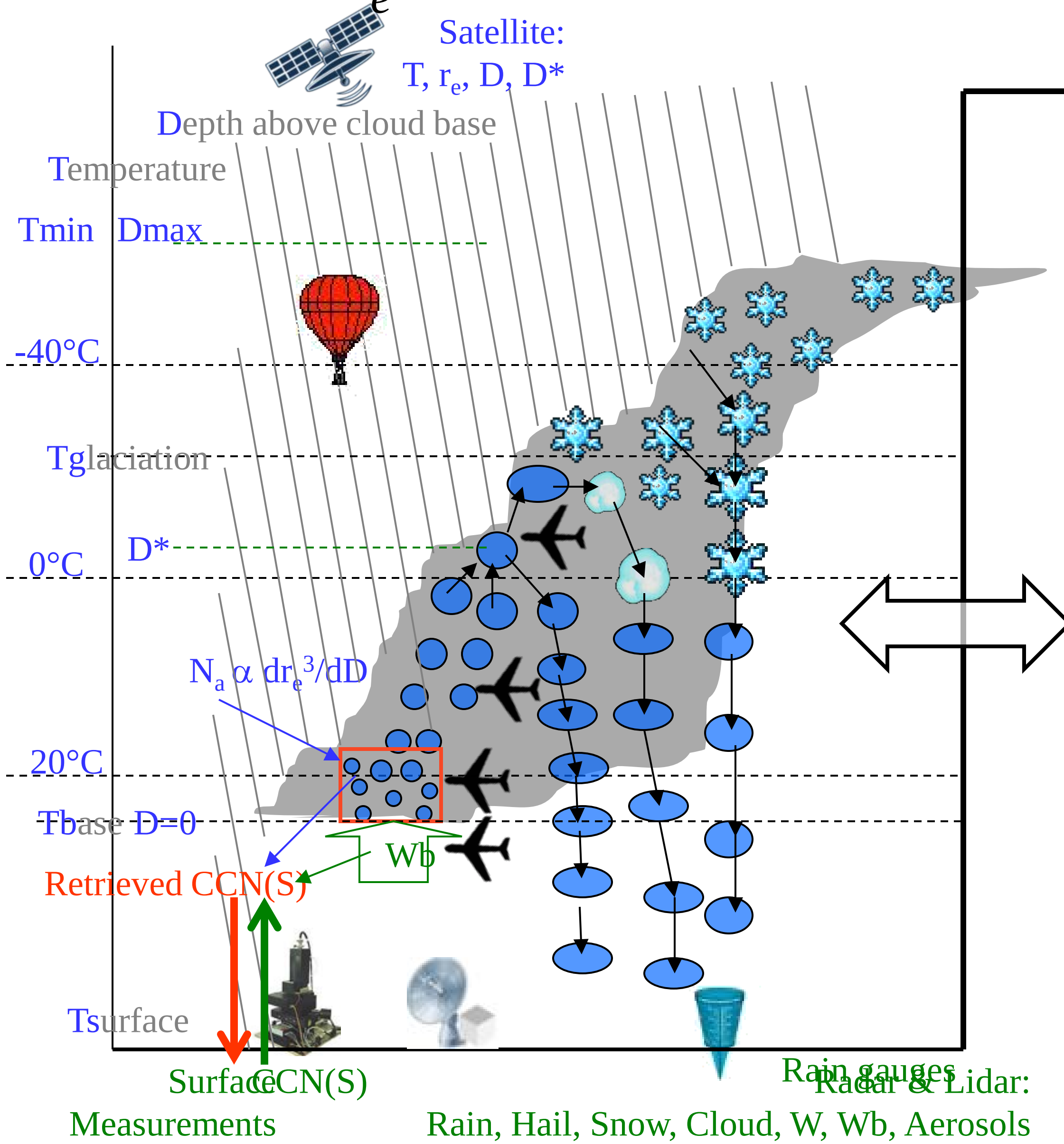
If r_e is adiabatic, we can calculate N adiabatic, or N_a, the number of activated drops at cloud base, N_a, as shown above.

We can correct the aircraft measured r_e to adiabatic r_{ea} according to the scheme of Freud and Rosenfeld, ACP 2012.
On average N_a ~ 0.77N_a adiabatic.

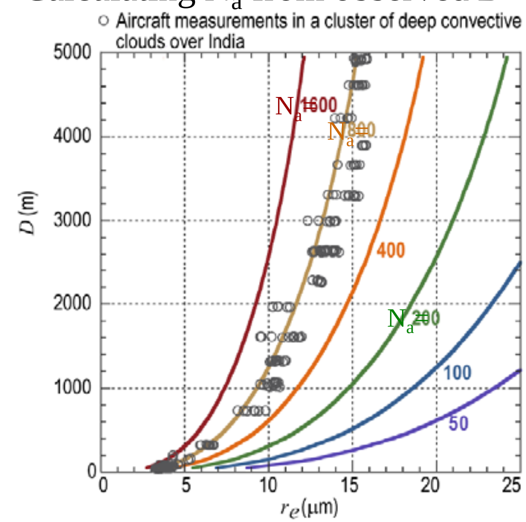
Retrieving CCN from satellite-measured *T*-r_e relations of convective clouds

האוניברסיטה העברית בירושלים
The Hebrew University of Jerusalem

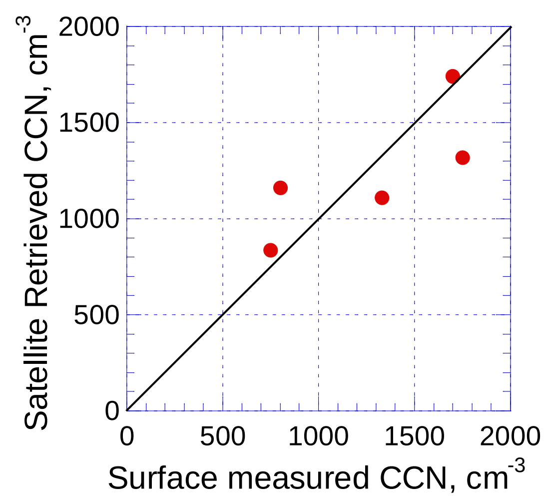
Daniel Rosenfeld



Calculating N_a from observed D- or T-r_e



Validation of the retrieved CCN over SGP



Atmos. Meas. Tech., 5, 2039–2055, 2012
www.atmos-meas-tech.net/5/2039/2012/
doi:10.5194/amt-5-2039-2012

Atmospheric Measurement Techniques

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

D. Rosenfeld[1], E. Williams[2], M. O. Andreae[3], E. Freud[1], U. Pöschl[3], and N. O. Rennó[4]

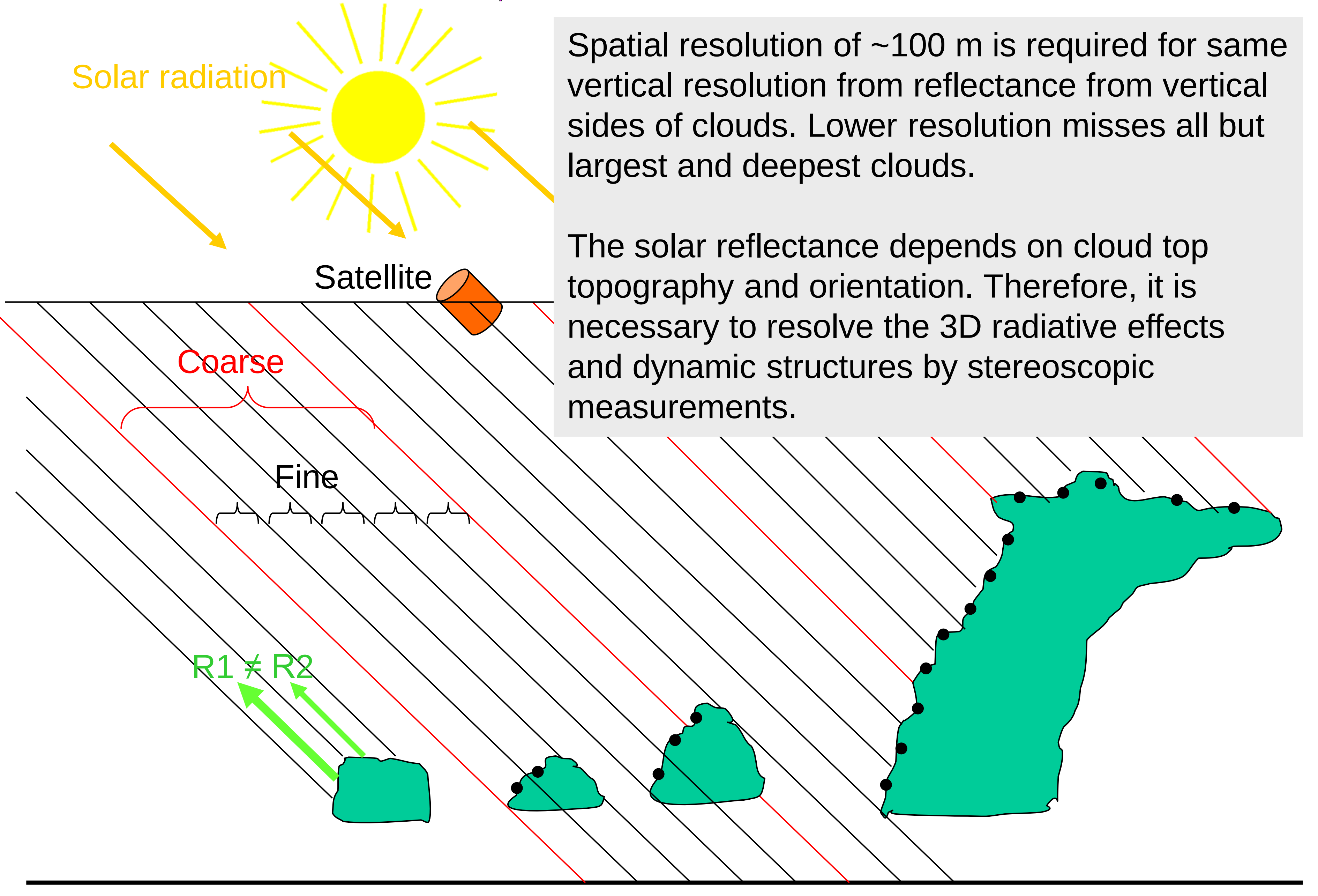
Bull. Amer. Met. Soc.

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.



Spatial resolution of ~100 m is required for same vertical resolution from reflectance from vertical sides of clouds. Lower resolution misses all but largest and deepest clouds.

The solar reflectance depends on cloud top topography and orientation. Therefore, it is necessary to resolve the 3D radiative effects and dynamic structures by stereoscopic measurements.

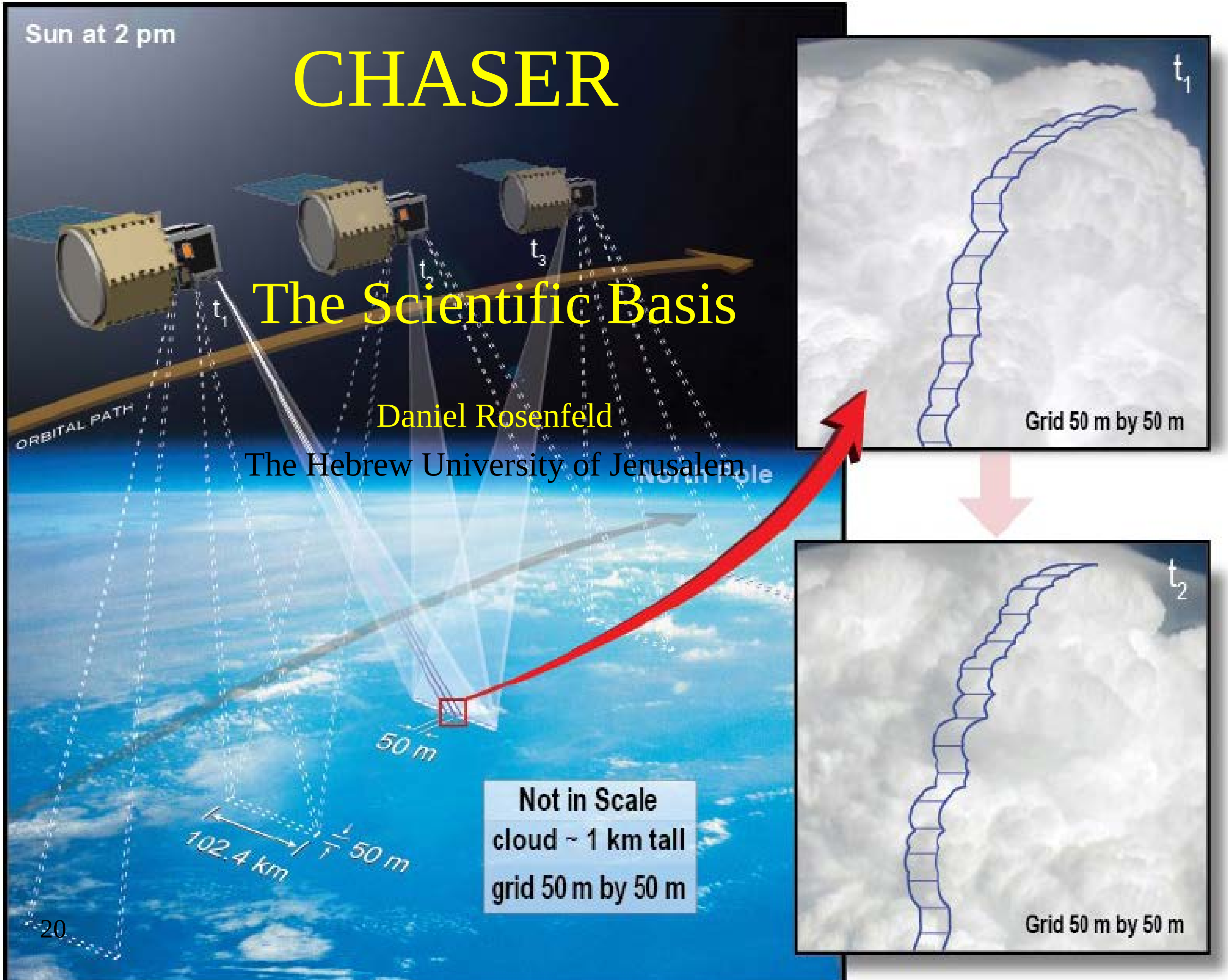
Measurement concept for T-r_e based CCN retrievals

CHASER

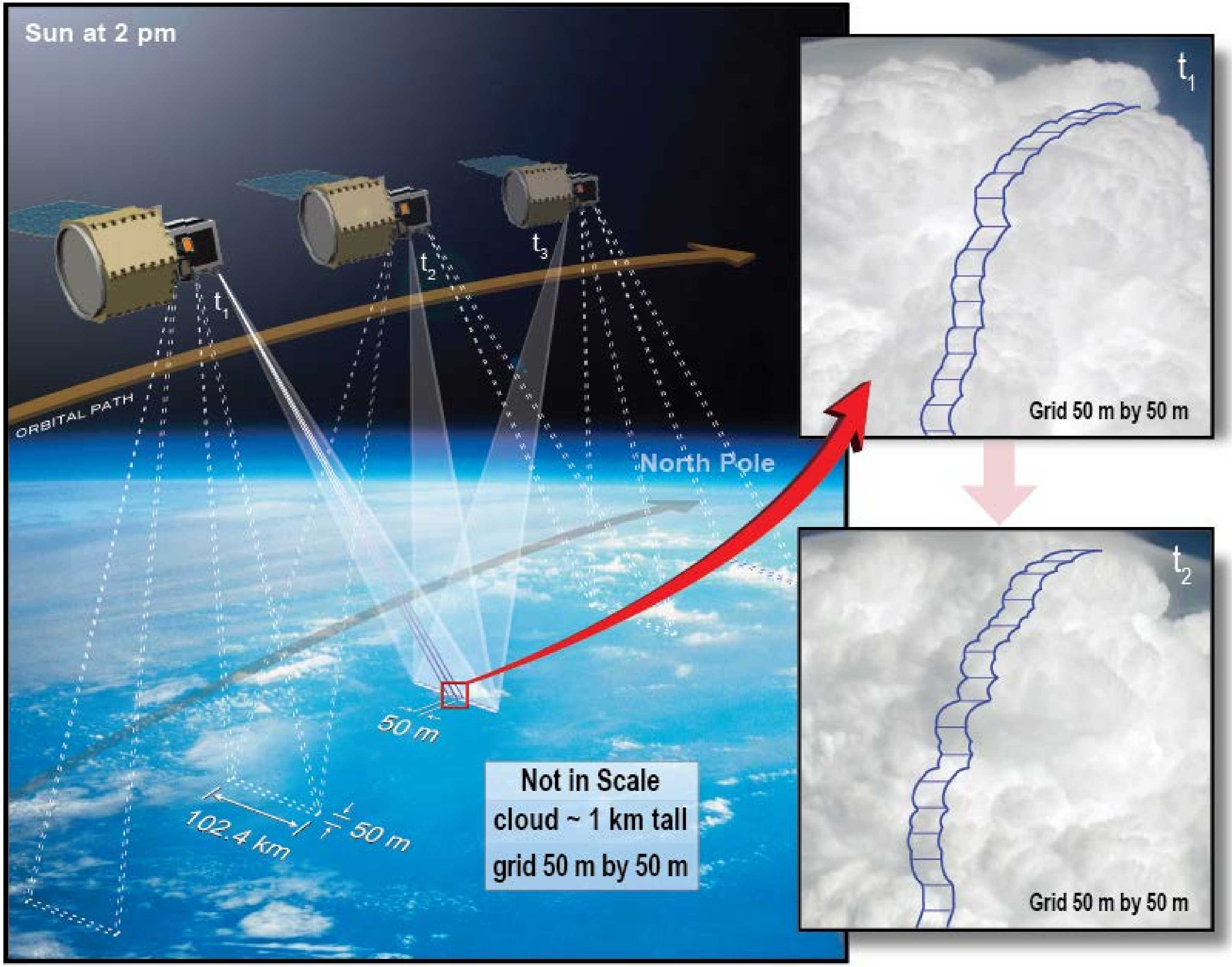
The Scientific Basis

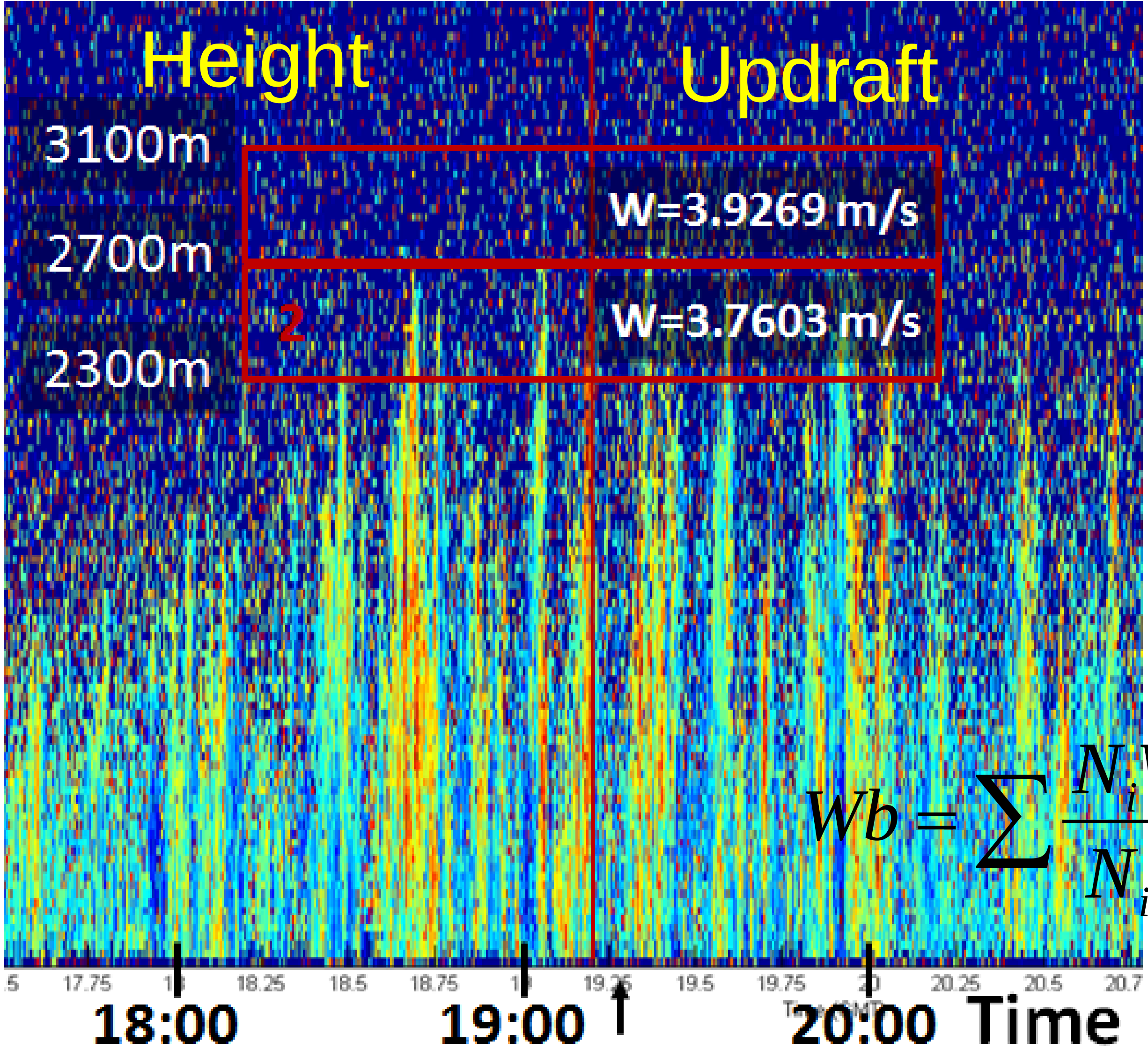
Daniel Rosenfeld

The Hebrew University of Jerusalem



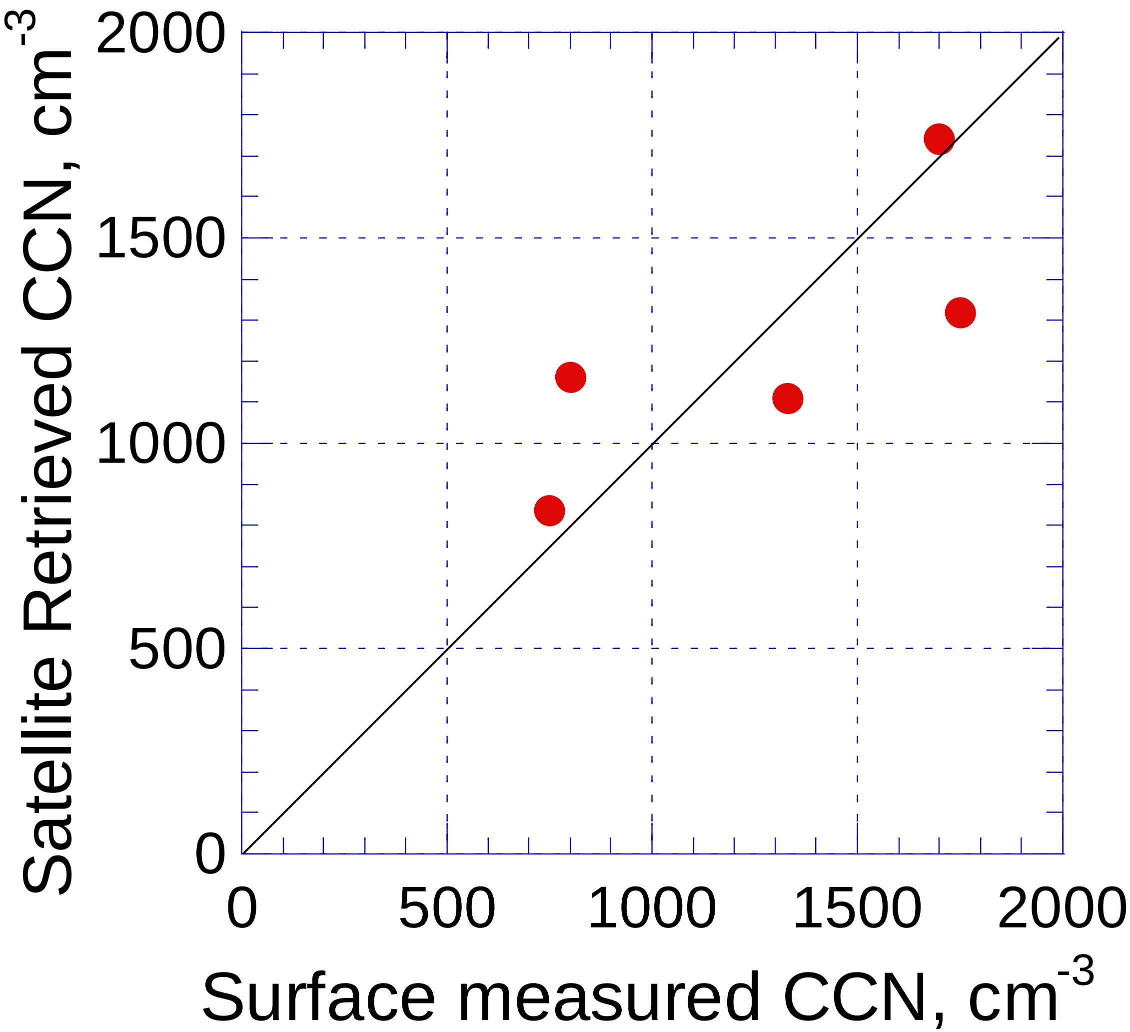
Nilton O. Rennó, Earle Williams, Daniel Rosenfeld et al., 2013: **CHASER: An Innovative Satellite Mission Concept to Measure the Effects of Aerosols on Clouds and Climate. BAMS,** May 201





$$Wb=\sum \frac{N_i W_i^2}{N_i W_i} \Big| W_i > 0$$

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 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.

Yes, it might be possible