CCN data from satellite retrievals and what can we do with them

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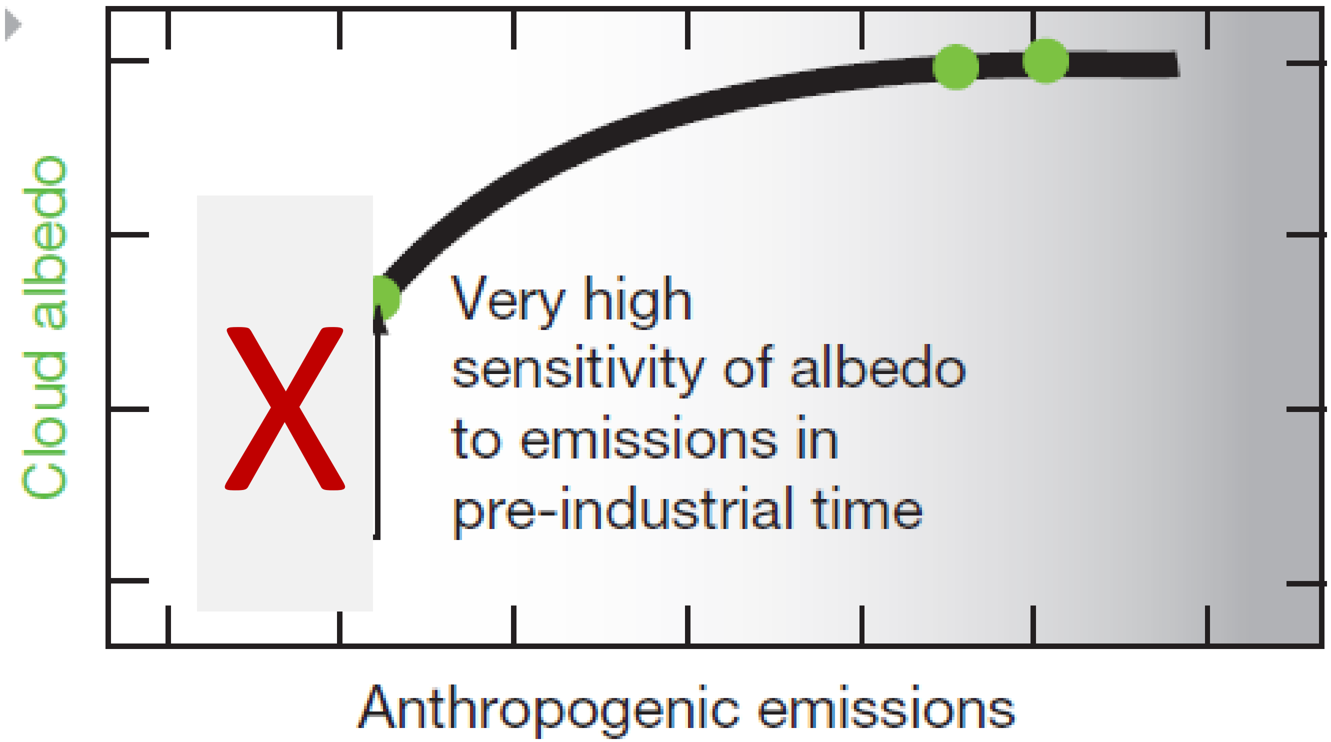
AEROSAT, Helsinki, 12 October2017

Motivation

2013 nature

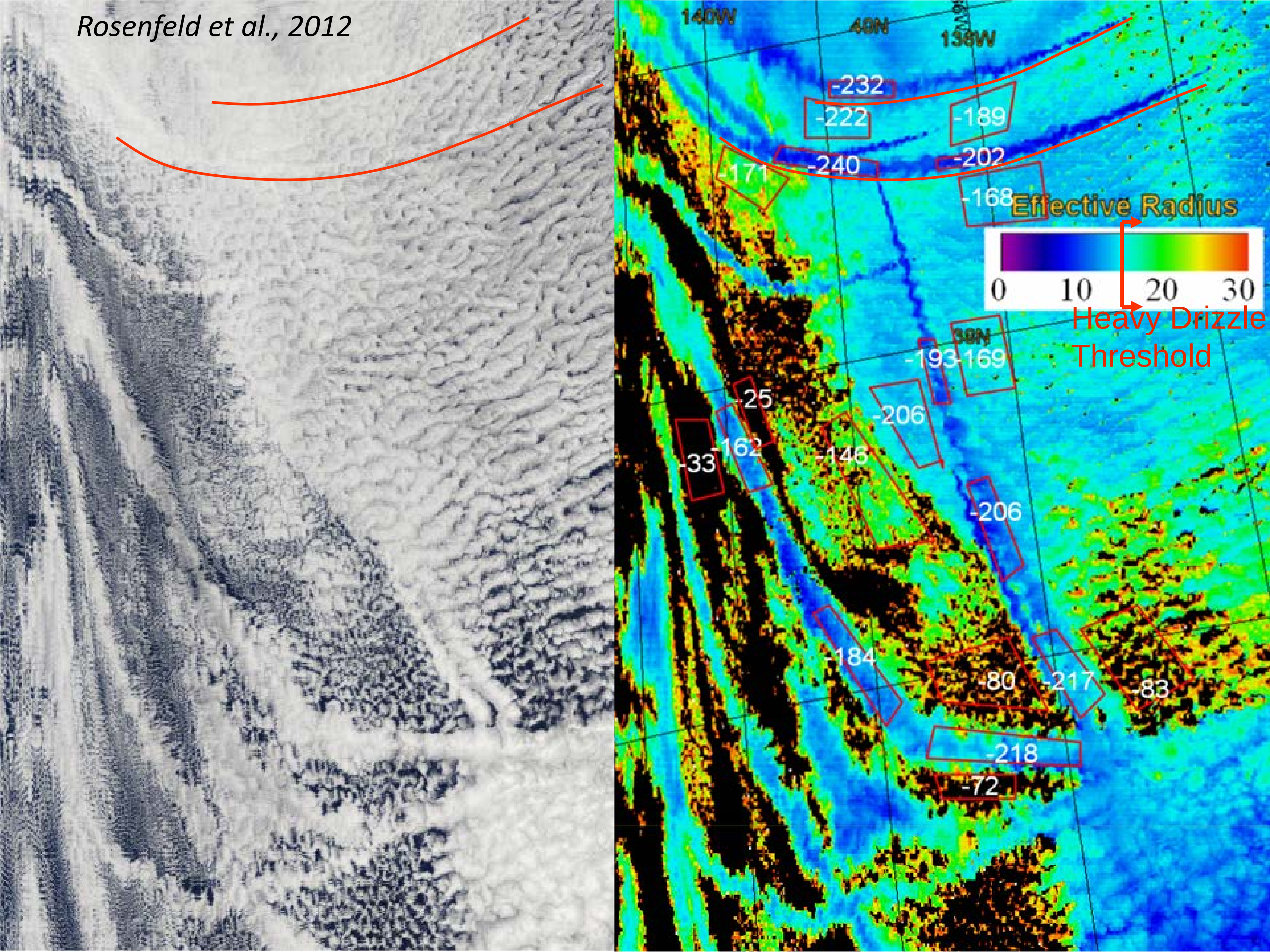
Large contribution of natural aerosols to uncertainty in indirect forcing

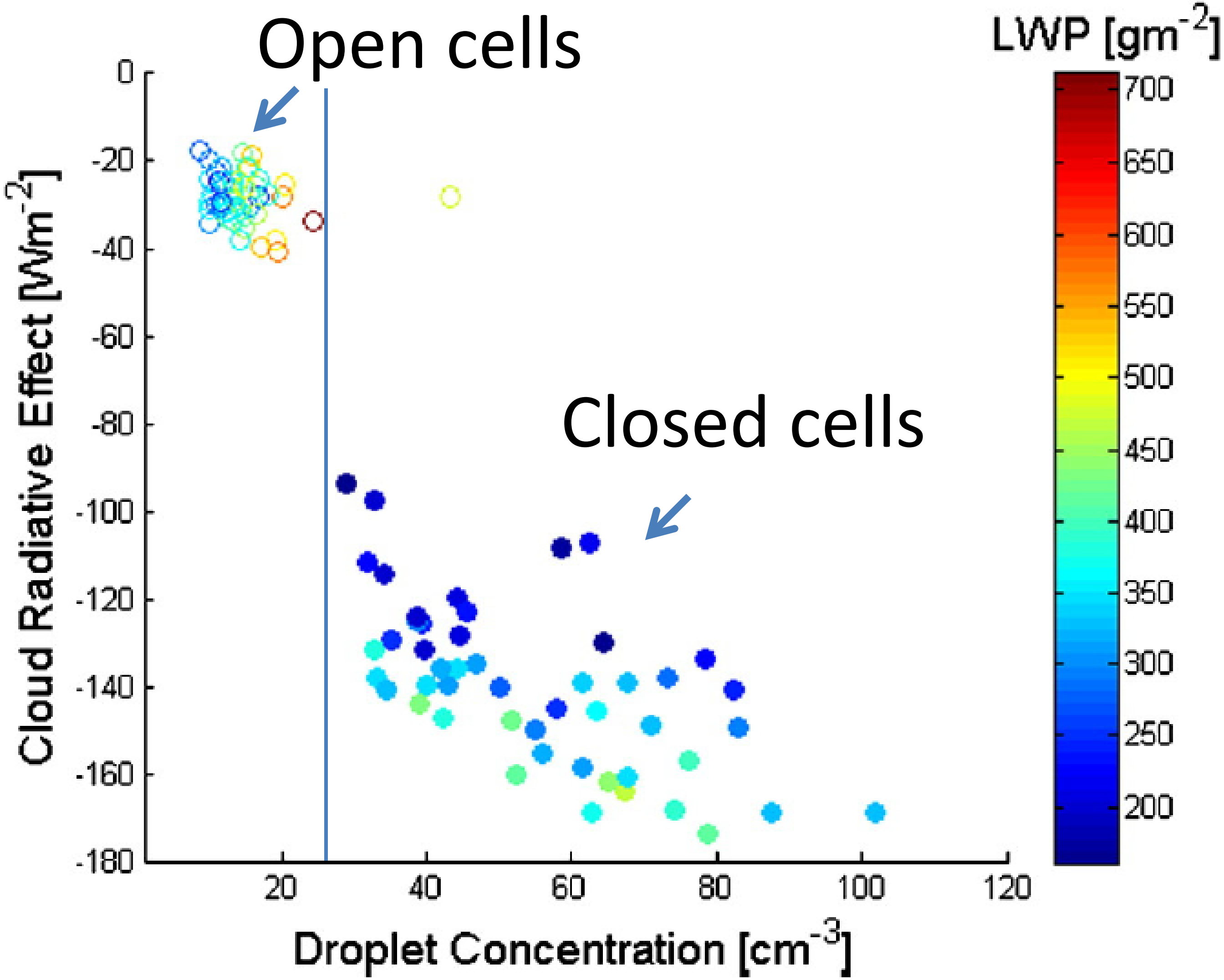
K. S. Carslaw[1], L. A. Lee[1], C. L. Reddington[1], K. J. Pringle[1], A. Rap[1], P. M. Forster[1], G. W. Mann[1,2], D. V. Spracklen[1], M. T. Woodhouse[1]†, L. A. Regayre[1] & J. R. Pierce[3]



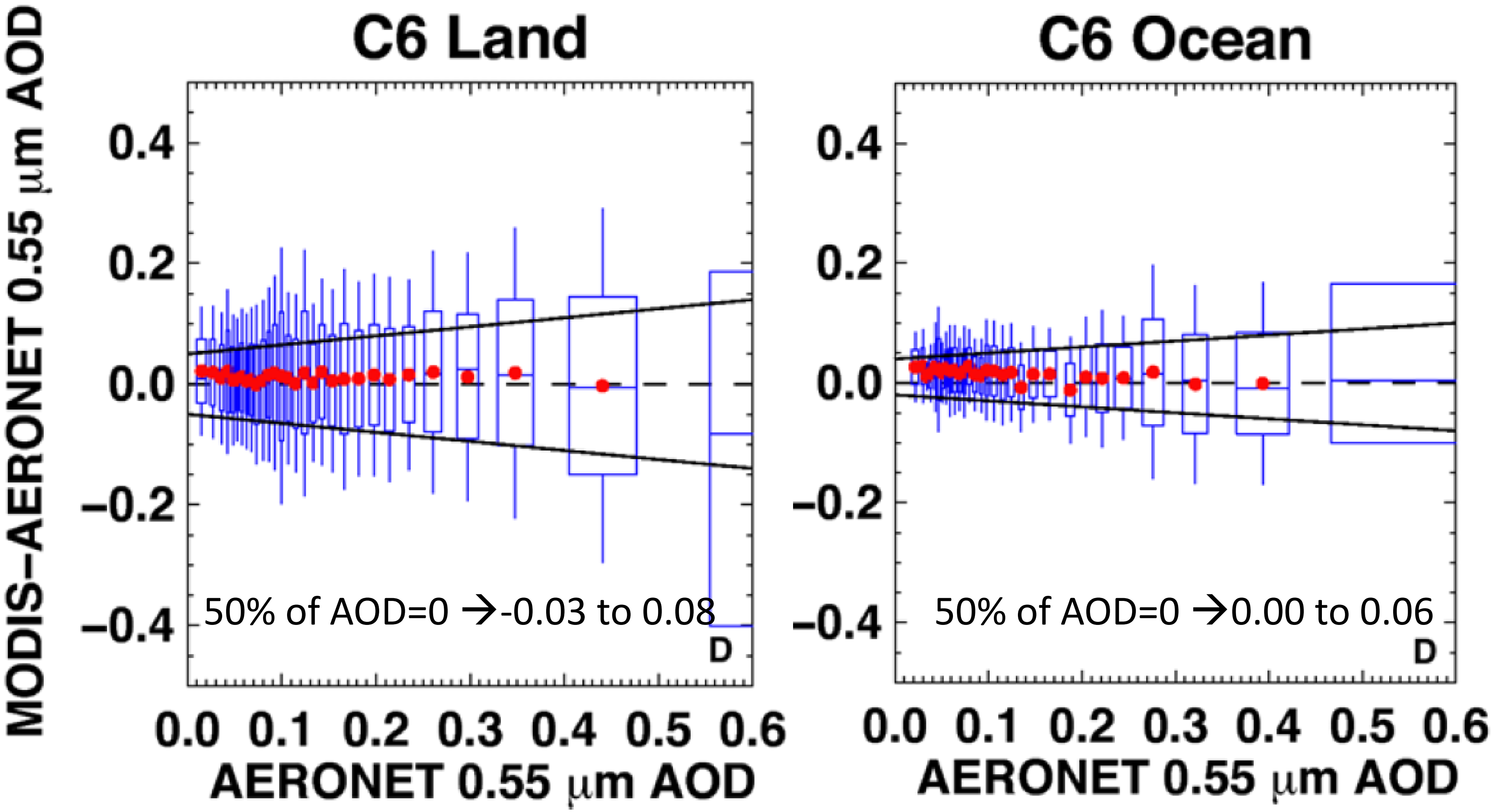
Aerosol forcing depends strongly on the reference background.

Limiting the sensitivity would limit the detectable forcing


Rosenfeld et al., 2012
140W
40N
138W
39N
-232
-222
-189
-240
-202
-171
-168
Effective Radius
0
10
20
30
Heavy Drizzle
Threshold
-193
-169
-25
-206
-162
-146
-33
-206
-184
-80
-217
-83
-218
-72



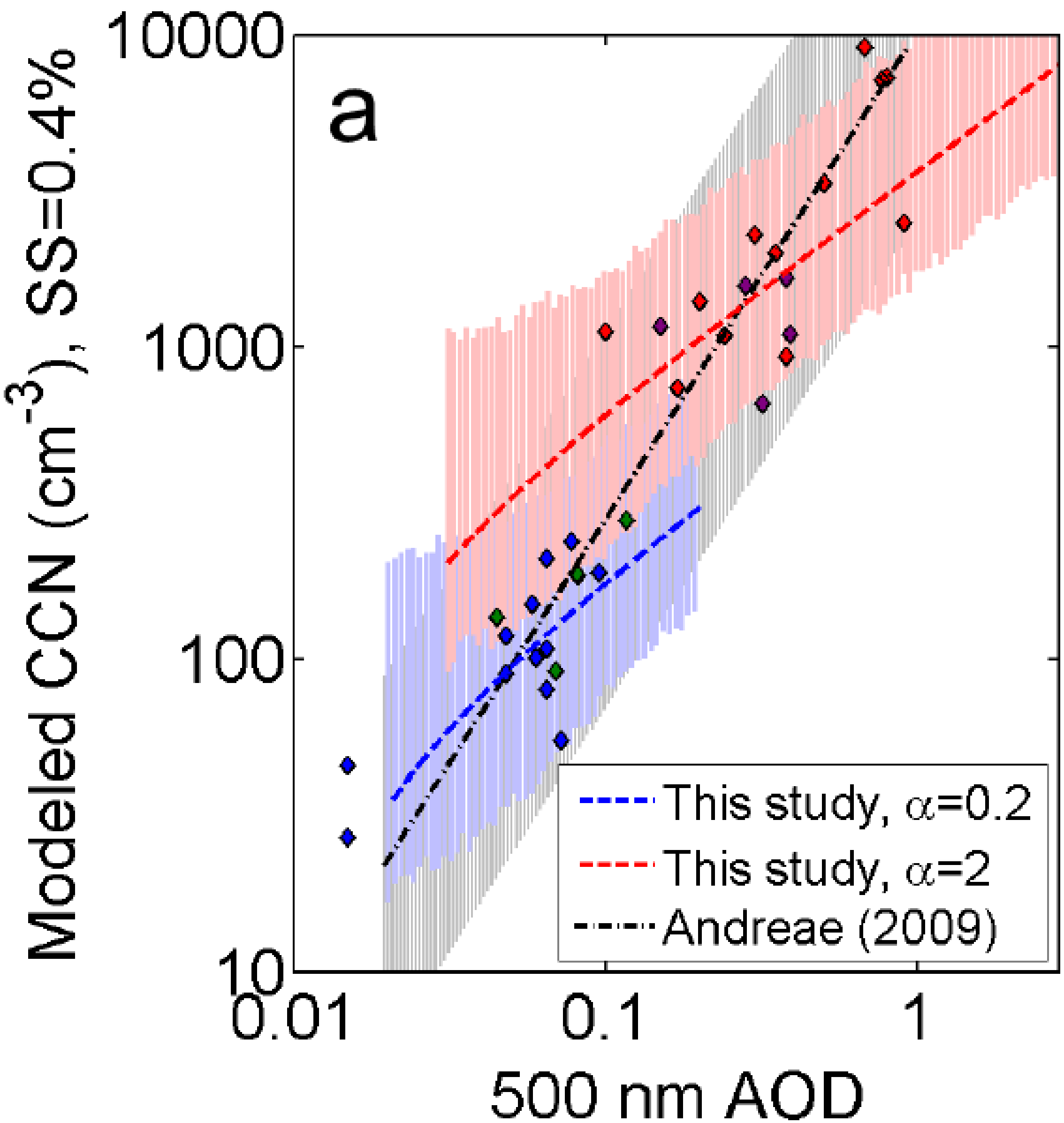
Goren and Rosenfeld, Atmos. Res., 2014



The Collection 6 MODIS aerosol products over land and ocean

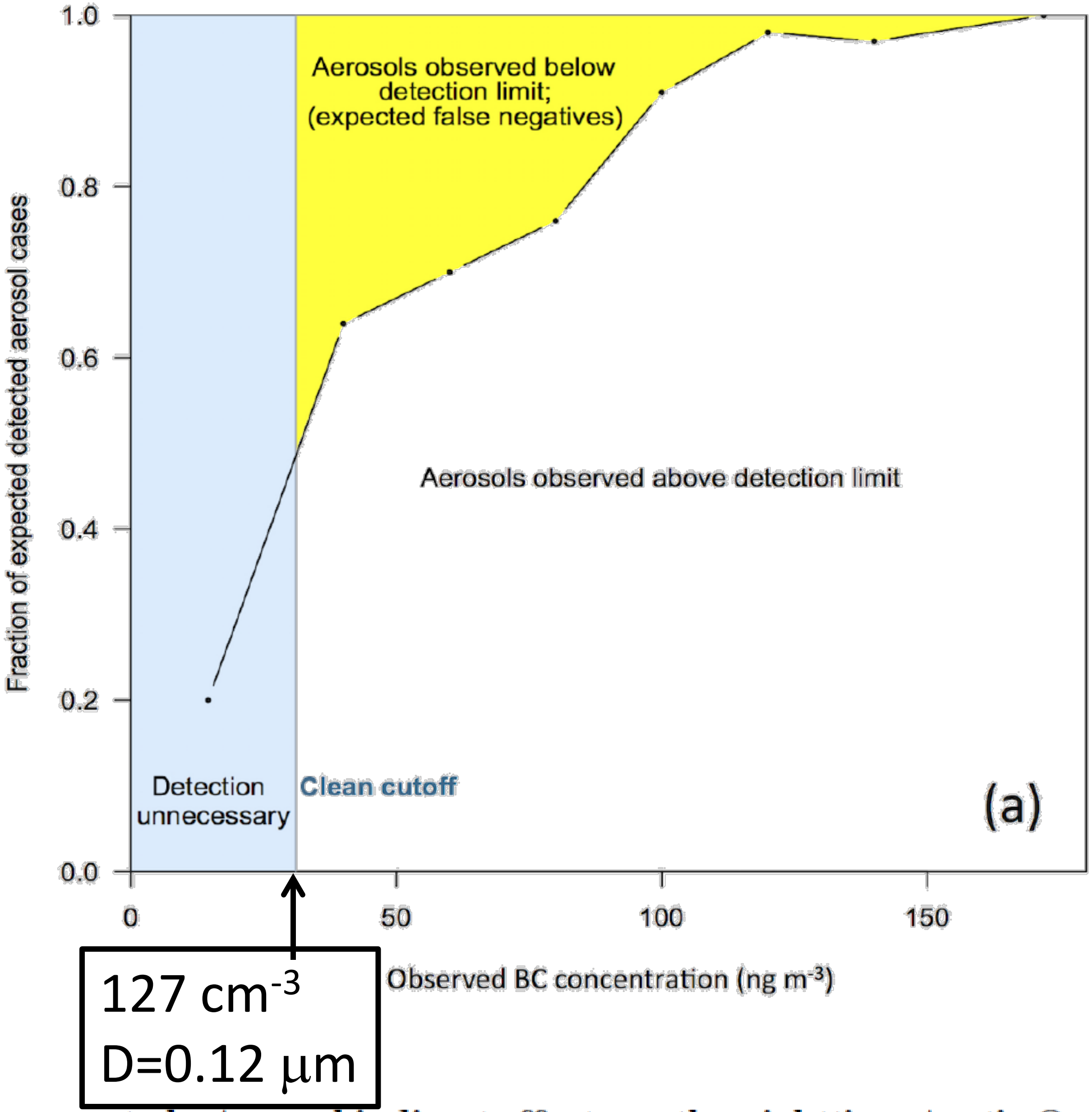
R. C. Levy[1], S. Mattoo[1,2], L. A. Munchak[1,2], L. A. Remer[3], A. M. Sayer[1,4], F. Patadia[1,5], and N. C. Hsu[1]

Atmos. Meas. Tech., 6, 2989–3034, 2013



Y. Shinozuka et al.: The relationship between CCN and dry extinction
Atmos. Chem. Phys., 15, 7585–7604, 2015

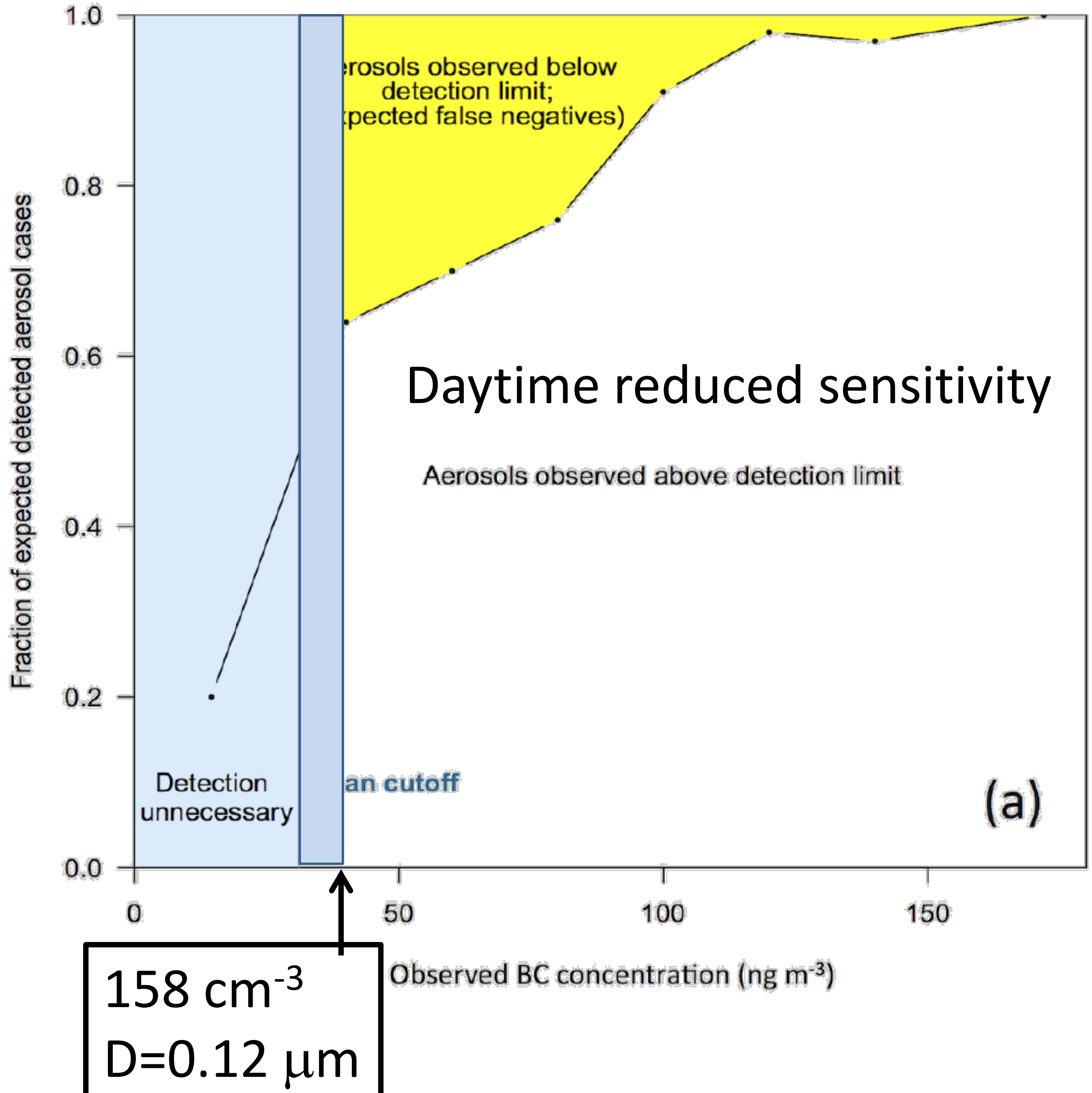
Sensitivity of CALIOP for aerosol detection



L. M. Zamora et al.: Aerosol indirect effects on the nighttime Arctic Ocean surface

Atmos. Chem. Phys., 17, 7311–7332, 2017

Sensitivity of CALIOP for aerosol detection

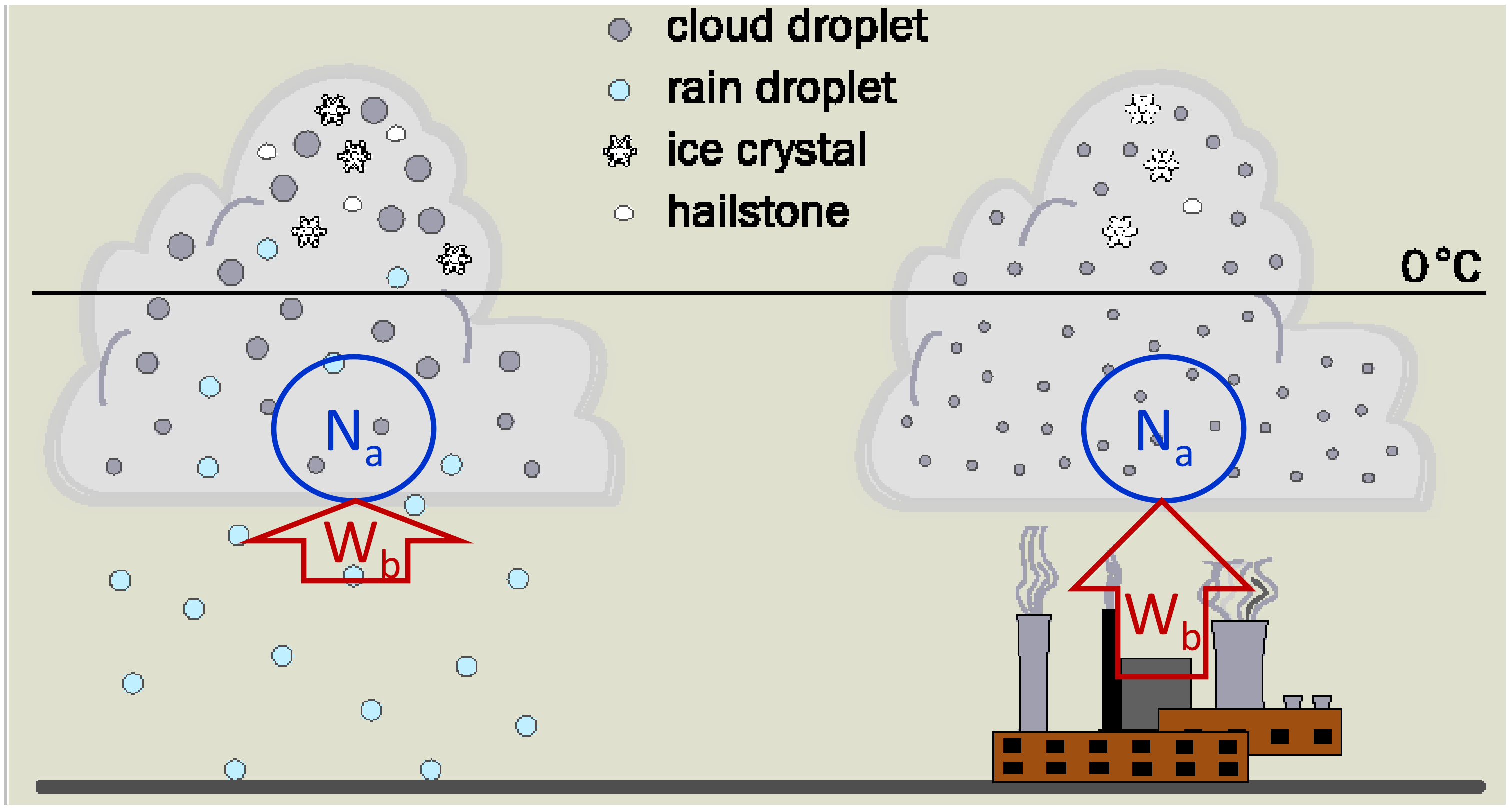


L. M. Zamora et al.: Aerosol indirect effects on the nighttime Arctic Ocean surface
Atmos. Chem. Phys., 17, 7311–7332, 2017

Satellite retrieval of cloud drop concentrations has no lower limit. So why won't we count them as proxy to CCN aerosols? Challenges:

Retrieving adiabatic drop concentrations, N_a

retrieving cloud base updraft, W_b



NPP: Building a Bridge to a New Era of Earth Observations

Solutions

Launched on 26/10/2011

Suomi/NPP
VIIRS Imager
375 m thermal resolution

This made it possible to retrieving N_a and W_b

CCN chambers measure the number of activated CCN (N_a) for a given super-saturation (S).

Measuring N_a and S in clouds can provide CCN(S):

S is calculated from the knowledge of N_a and W_b (Cloud base updraft). $S = C(T,P) W_b^{3/4} N_a^{-1/2}$

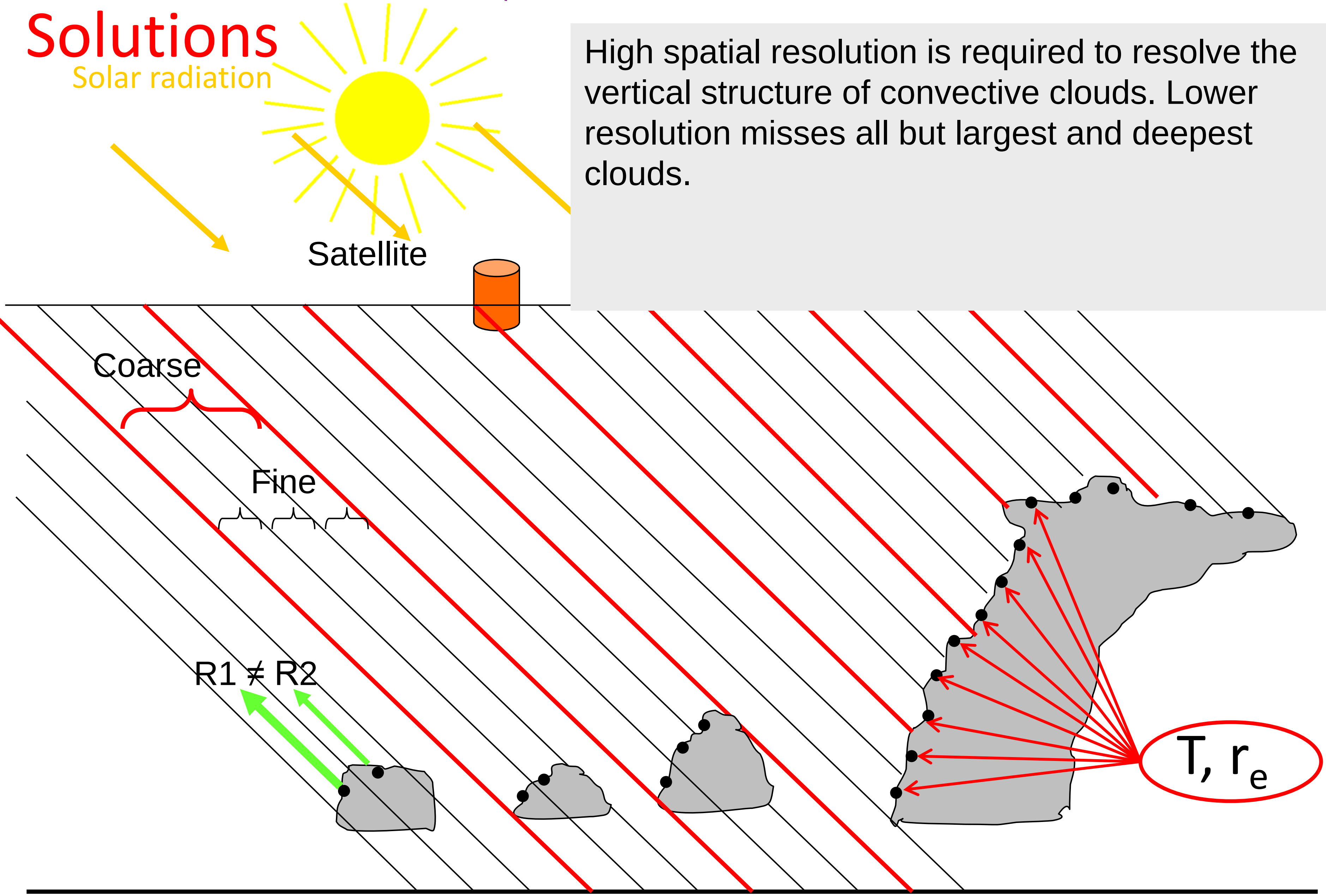
(*Pinsky et al., 2012)*

It is shown here that both N_a and W_b can be retrieved from high resolution (375 m) NPP/VIIRS satellite data.

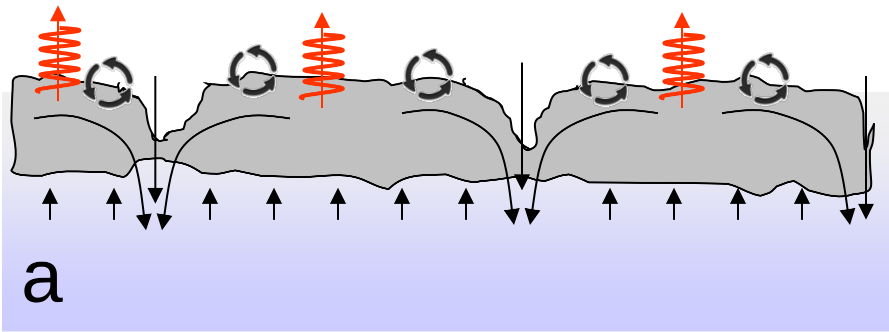
Satellite mapping of N_a, W_b and S → CCN(S), is becoming possible! *(Rosenfeld et al., PNAS 2016)*

Solutions

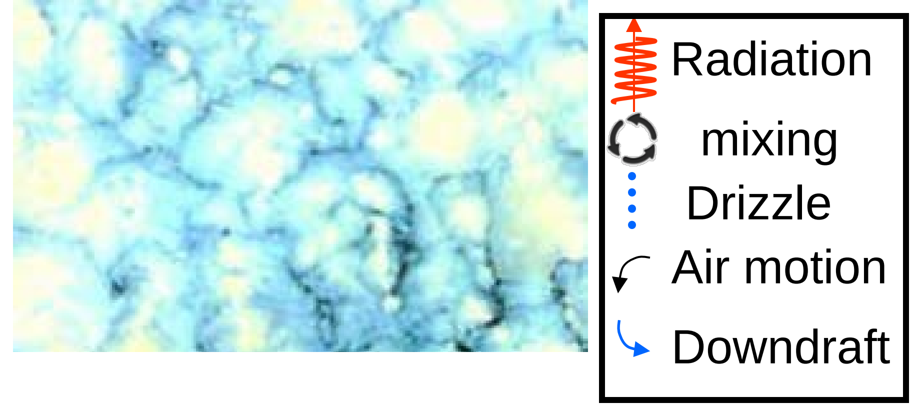
High spatial resolution is required to resolve the vertical structure of convective clouds. Lower resolution misses all but largest and deepest clouds.



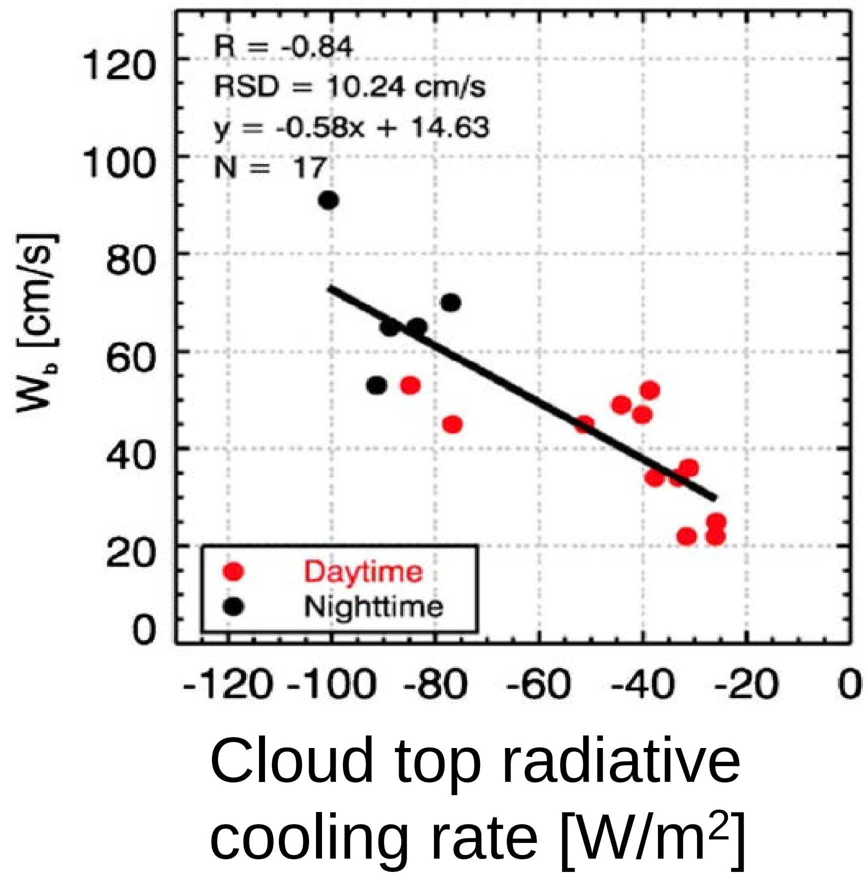
Measurement concept for T-r_e based CCN retrievals



Closed Benard Cells



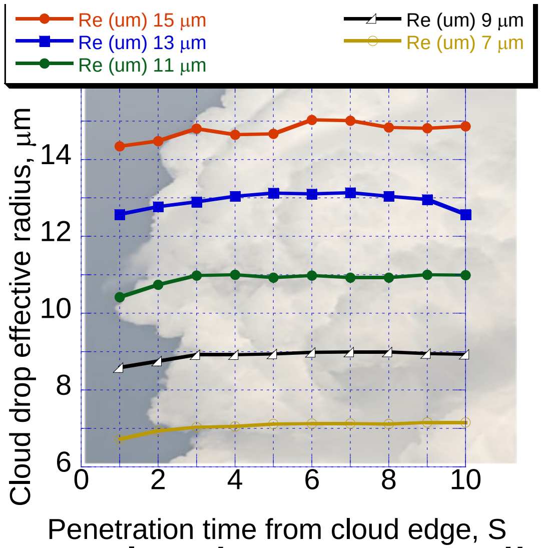
The dependence of W_b on cloud to radiative cooling rate in marine stratocumulus decks over the NE Pacific, as measured in the MAGIC ship campaign. W_b was measured by a vertically pointing Doppler cloud radar. The correlation coefficient (R), residual standard deviation (RSD), best fit regression equation, and case numbers (N) are provided. The red and black points stand for the daytime and nighttime cases, respectively (From Zheng and Rosenfeld, 2016).



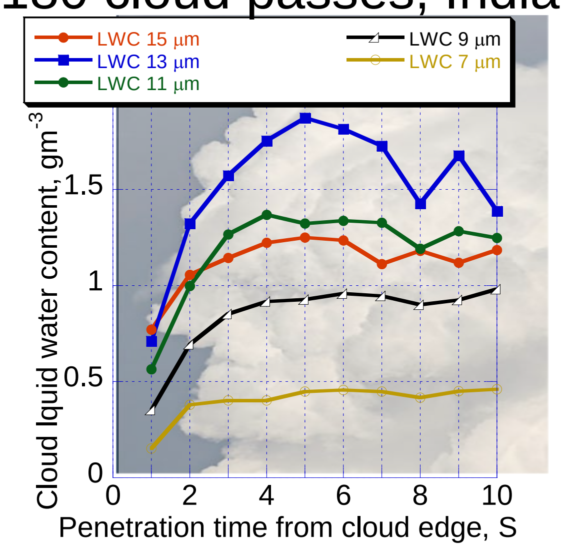
Zheng et al., GRL 2016

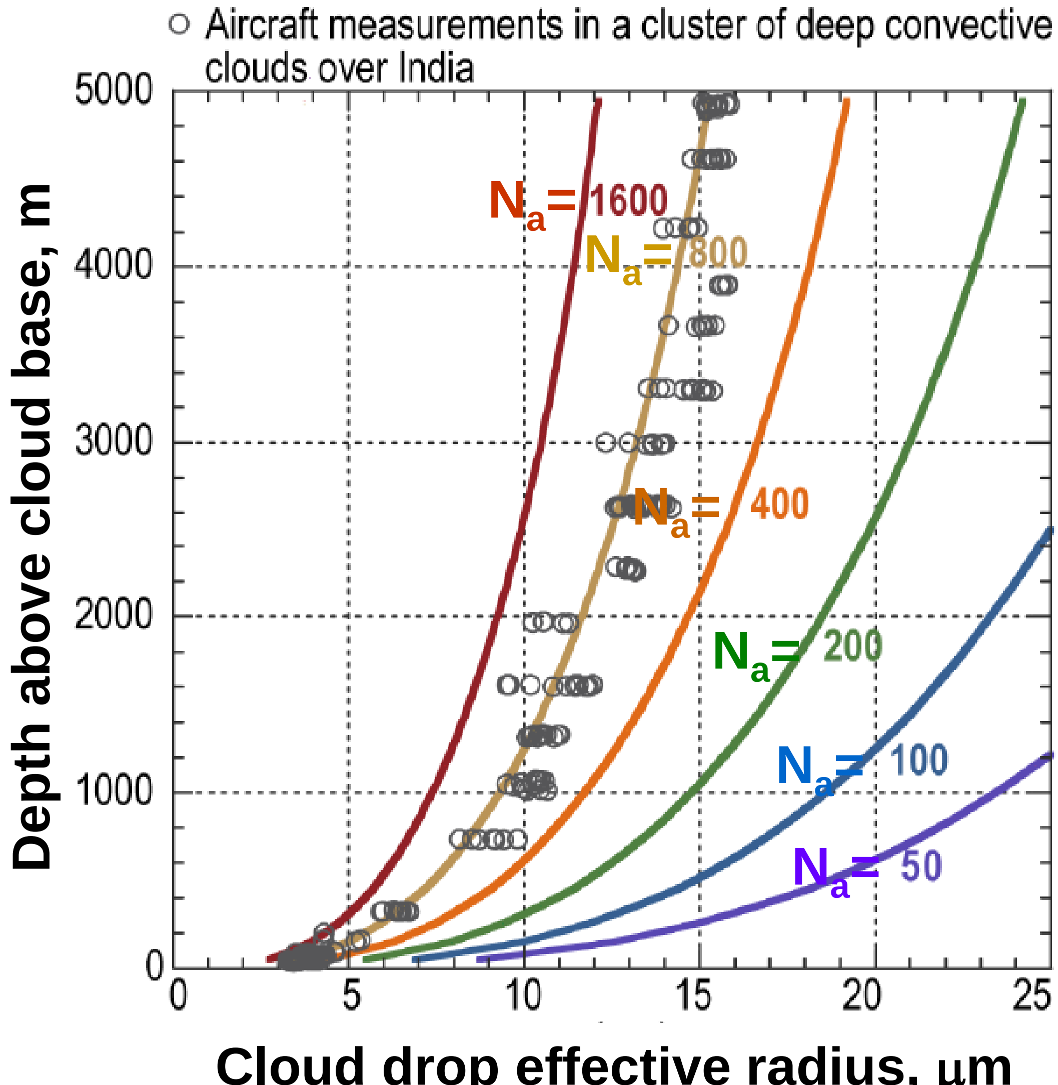
N_a is retrieved from the T-r_e (cloud top temperature – drop effective radius), due to nearly inhomogeneous cloud mixing, resulting in nearly adiabatic r_e.

MsC of Hagai Kousevittski at the Hebrew University



180 cloud passes, India



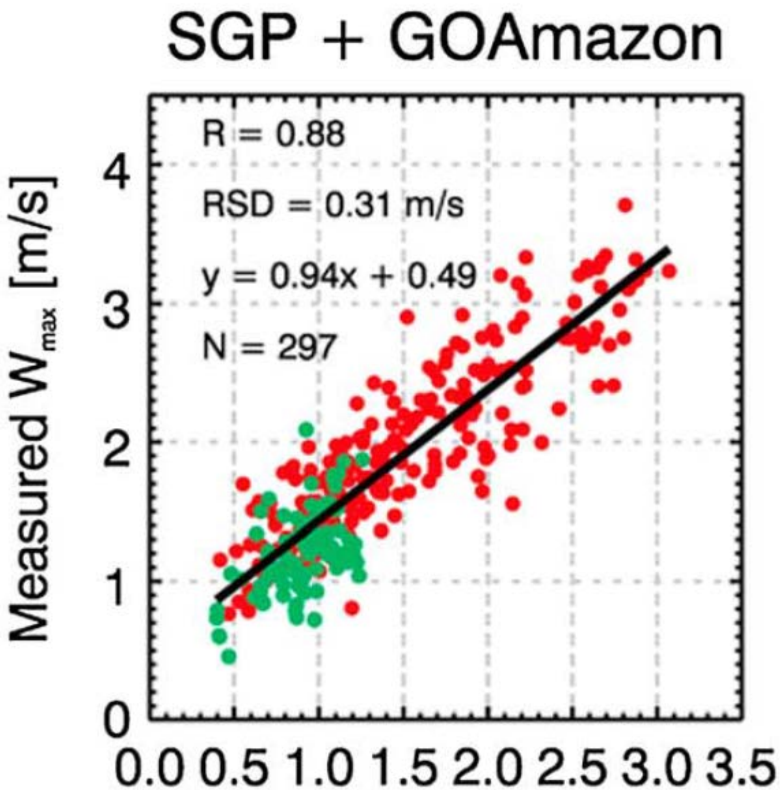


Retrieving cloud base updraft, W_b

Linear relation between convective cloud base height and updrafts and application to satellite retrievals

Youtong Zheng[1,2] and Daniel Rosenfeld[2]

Geophysical Research Letters 2015



Cloud base height [km]

Zheng and Rosenfeld., GRL 2015

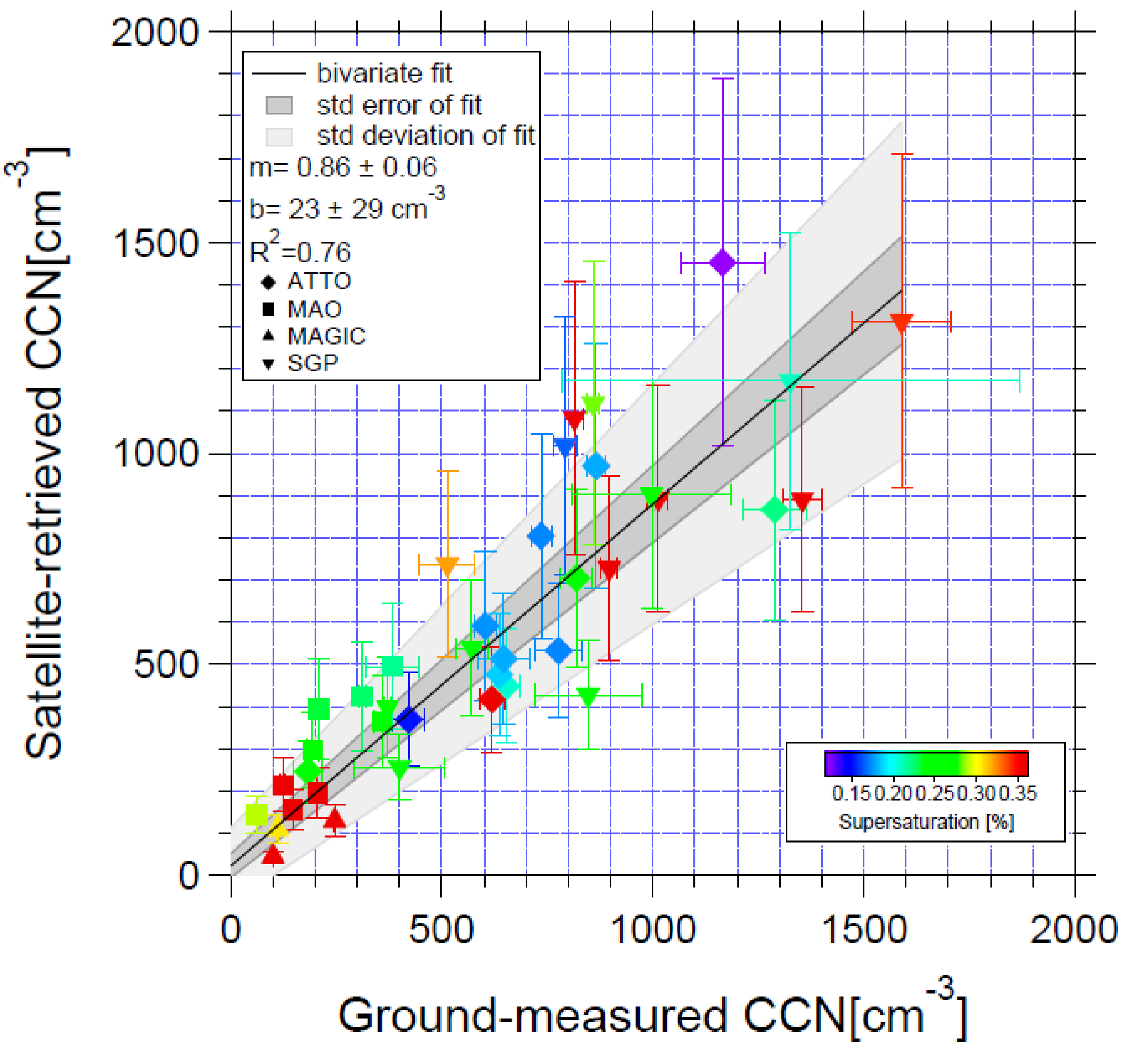
$S = C(T,P)W_b^{3/4}N_a^{-1/2}$

Satellite retrieval of cloud condensation nuclei concentrations by using clouds as CCN chambers

Daniel Rosenfeld[a,1], Youtong Zheng[b,c,d], Eyal Hashimshoni[a], Mira L. Pöhlker[e,f], Anne Jefferson[g], Christopher Pöhlker[e], Xing Yu[h], Yannian Zhu[d,h], Guihua Liu[h], Zhiguo Yue[h], Baruch Fischman[a], Zhanqing Li[b,c,d], David Giguzin[a], Tom Goren[a], Paulo Artaxo[i], Henrique M. J. Barbosa[i], Ulrich Pöschl[e,f], and Meinrat O. Andreae[e]

COLLOQUIUM PAPER

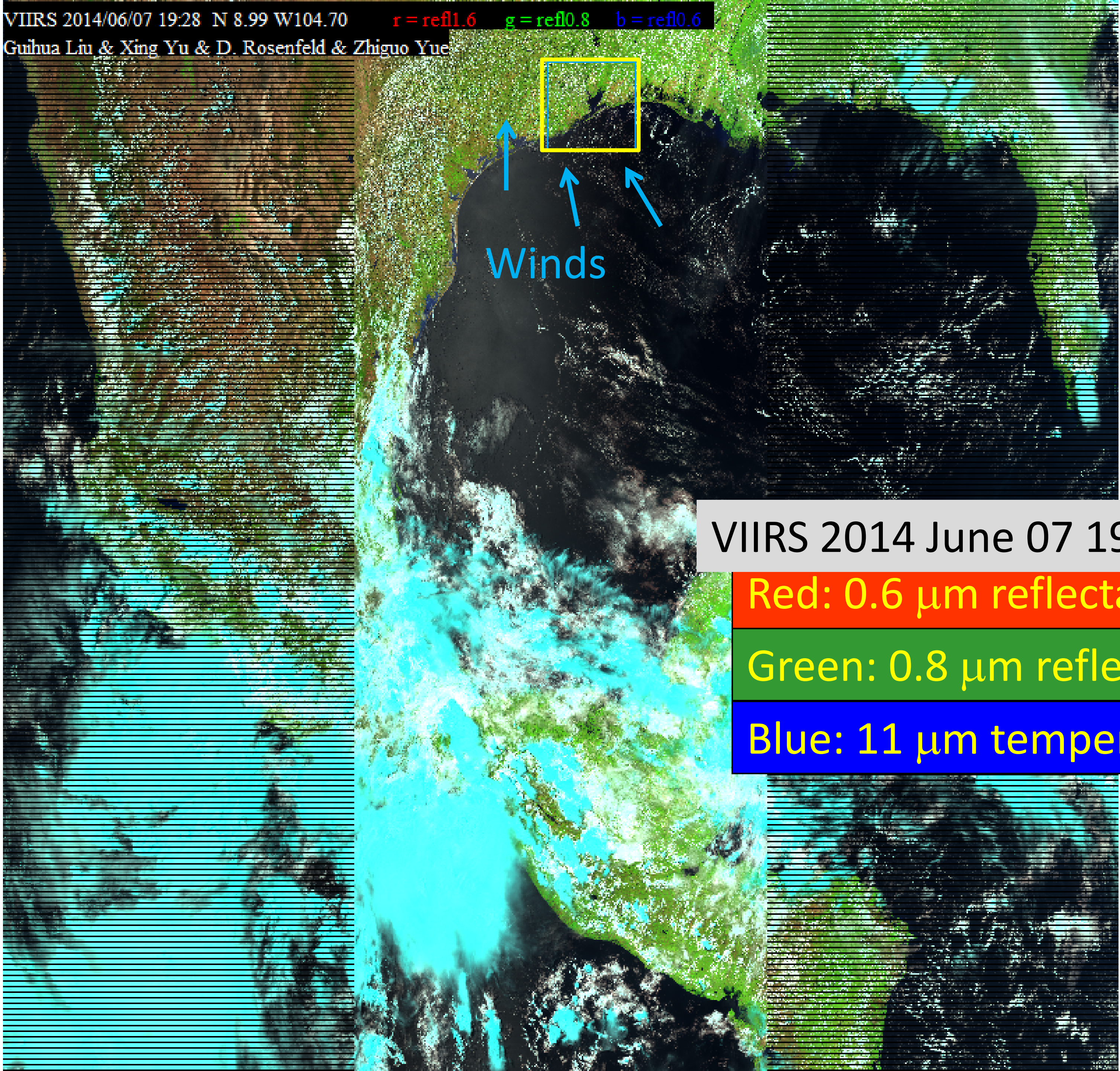
Validation



Applications

Houston

2014/06/07

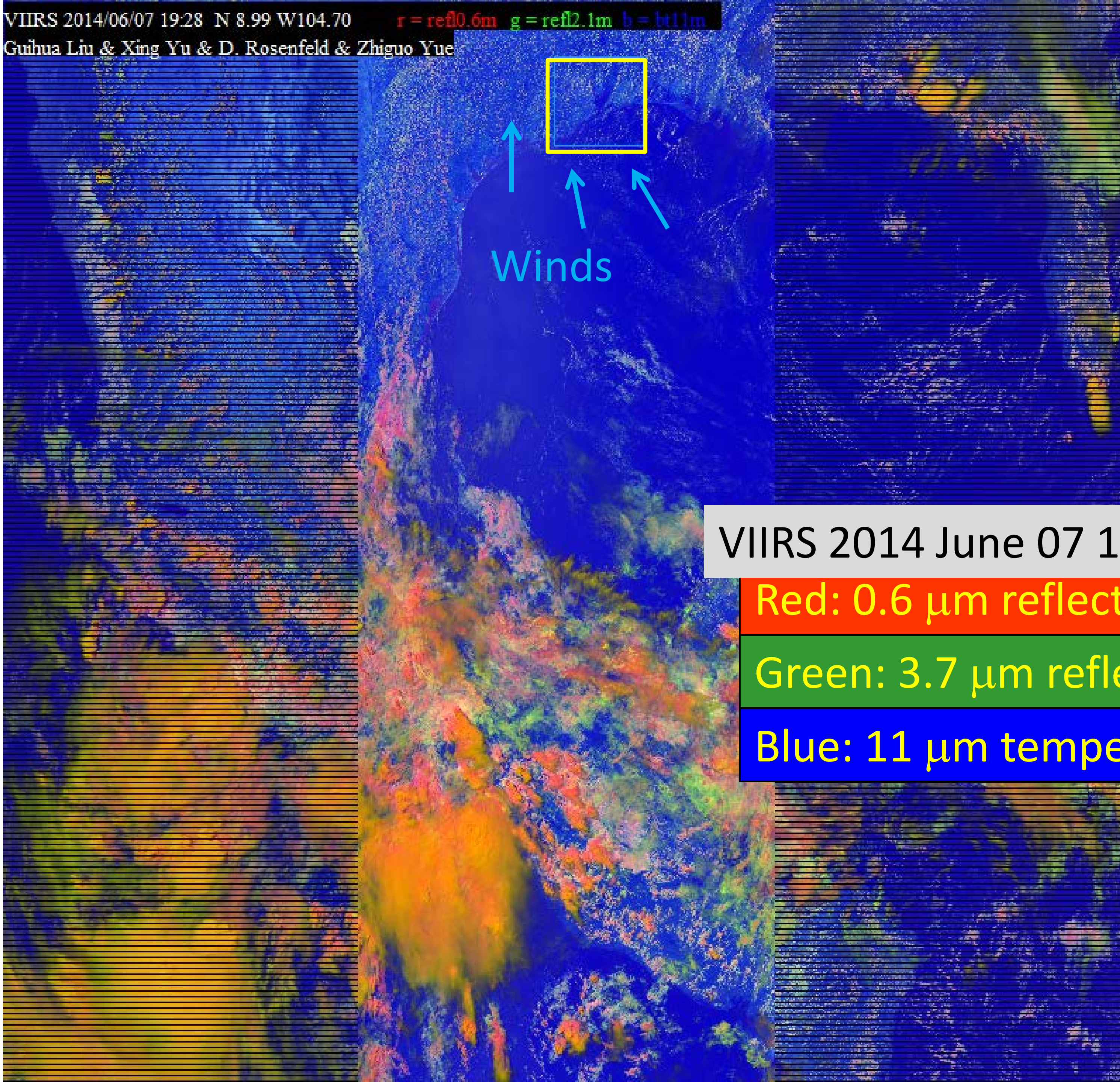


VIIRS 2014 June 07 19:28 UT

Red: 0.6 μm reflectance

Green: 0.8 μm reflectance

Blue: 11 μm temperature



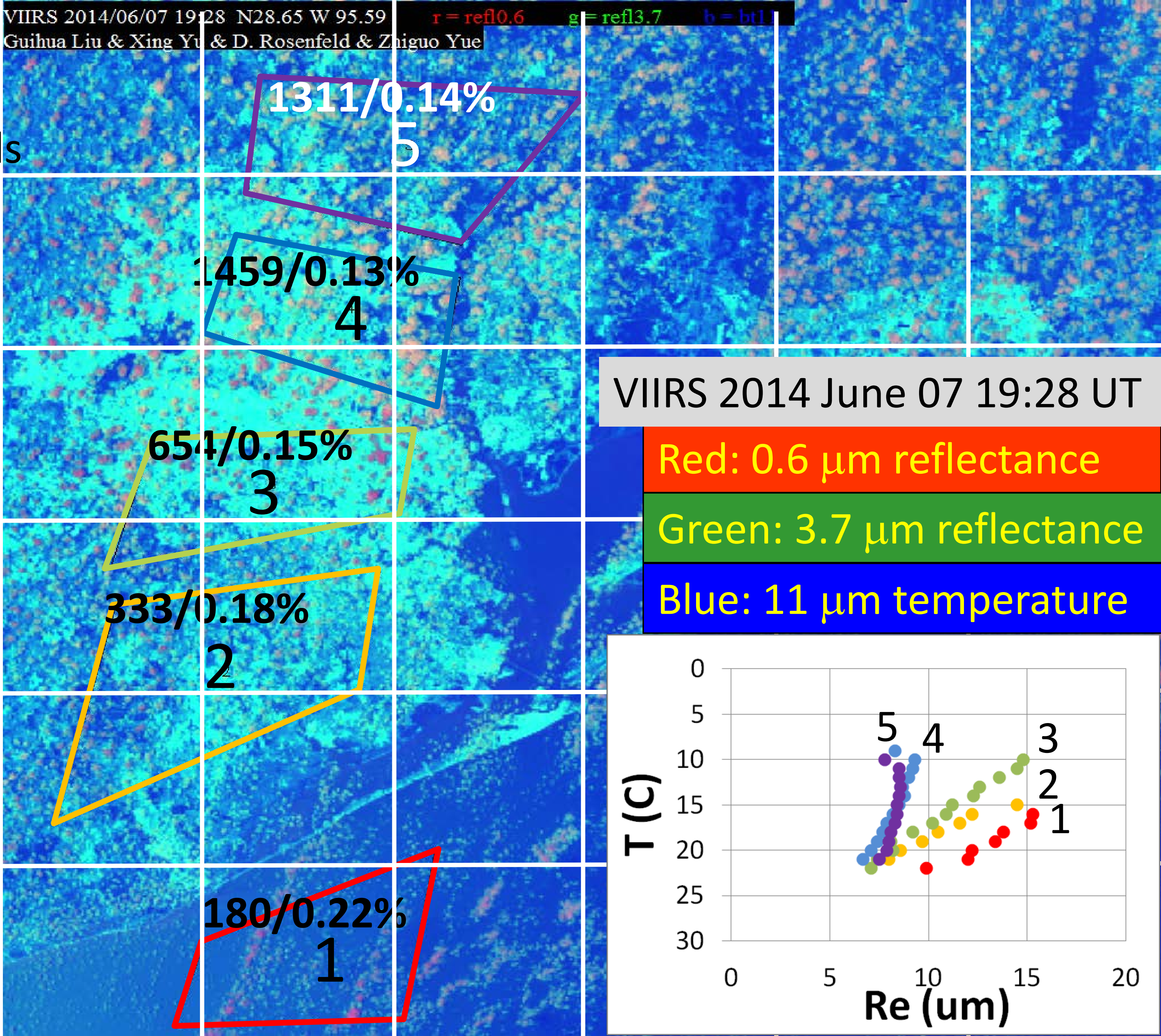
VIIRS 2014 June 07 19:28 UT

Red: 0.6 μm reflectance

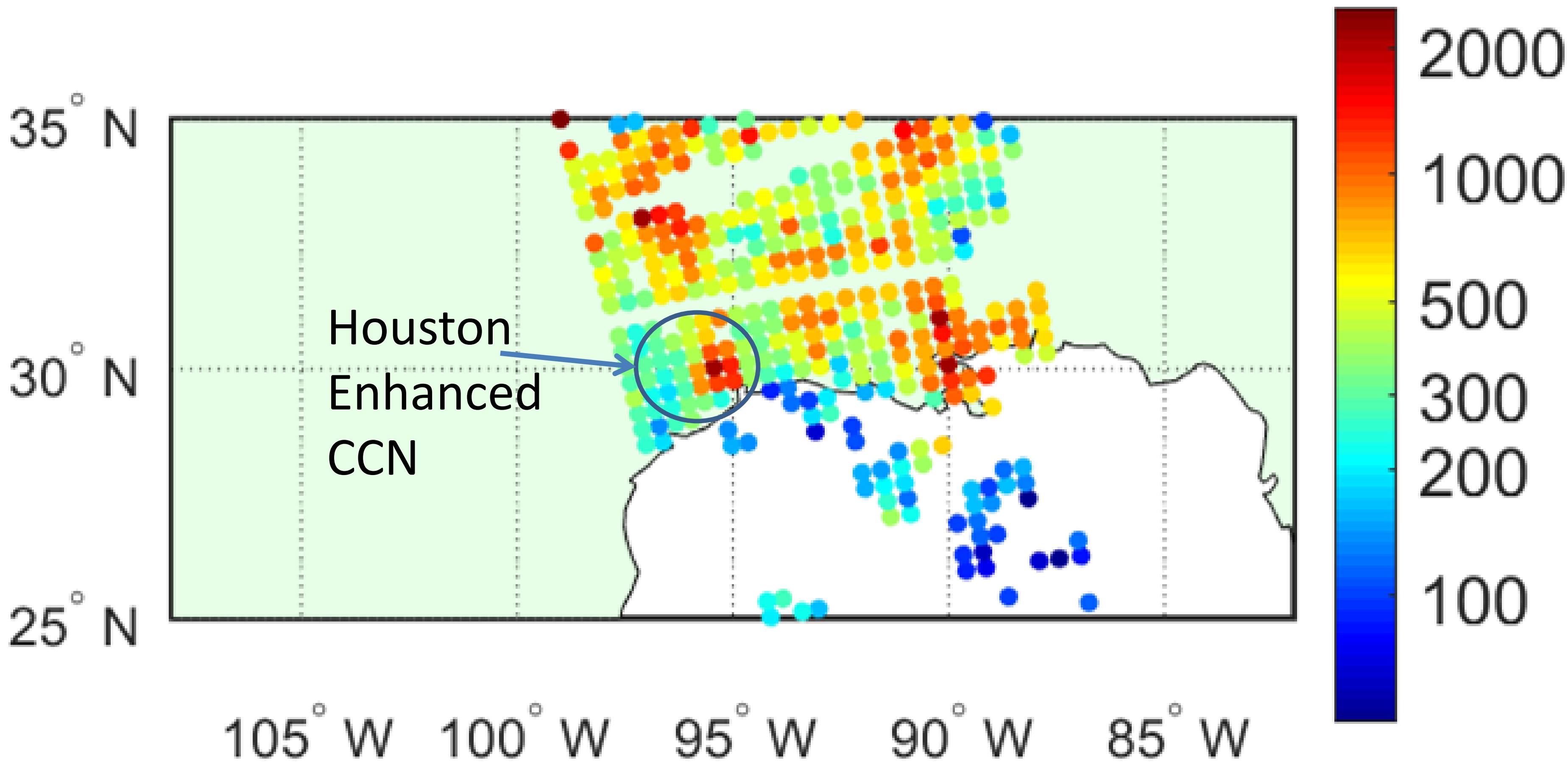
Green: 3.7 μm reflectance

Blue: 11 μm temperature

Grid of 80x80 pixels =30x30 km

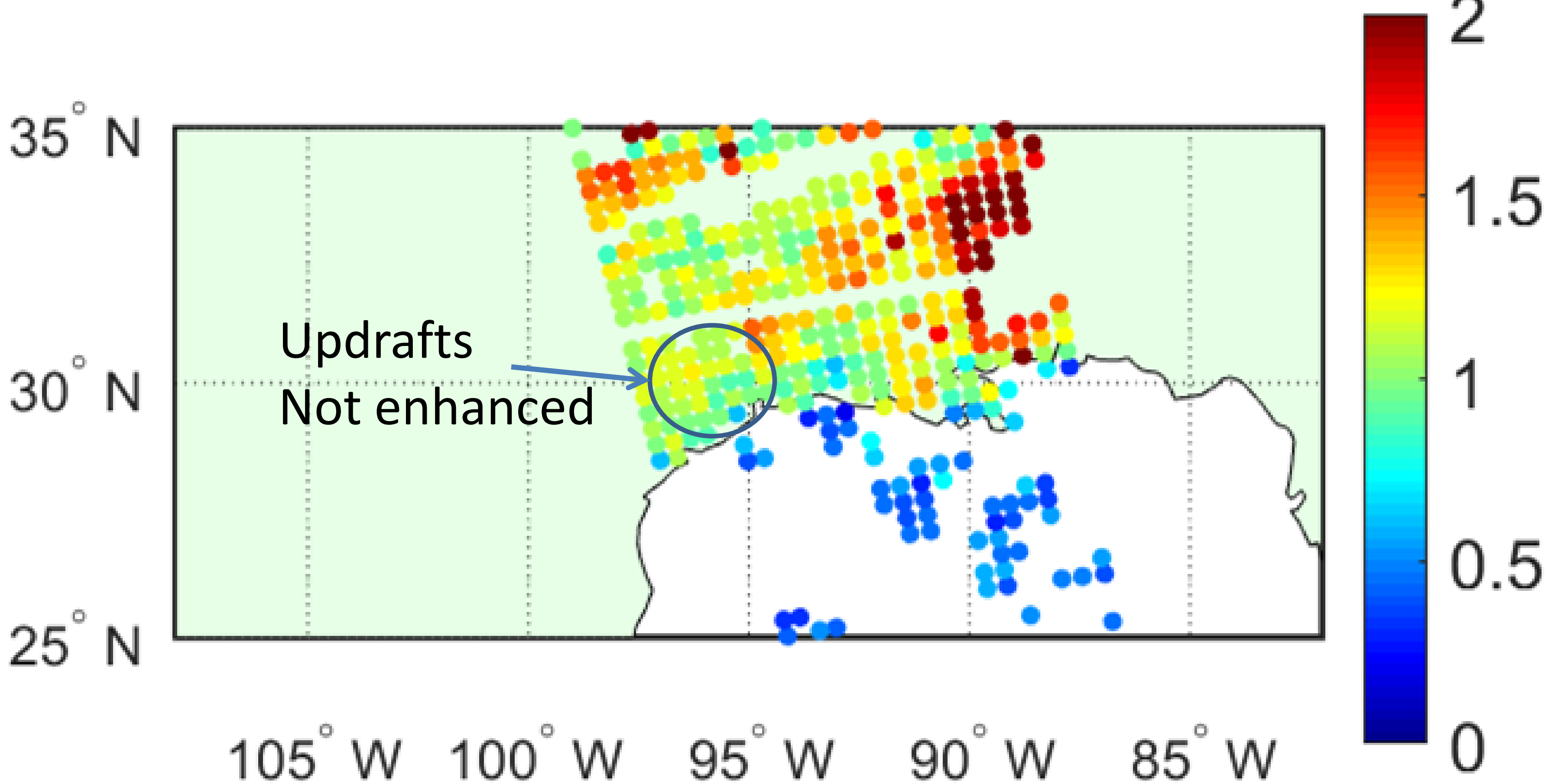


Satellite retrieved CCN [mg^{-1}]



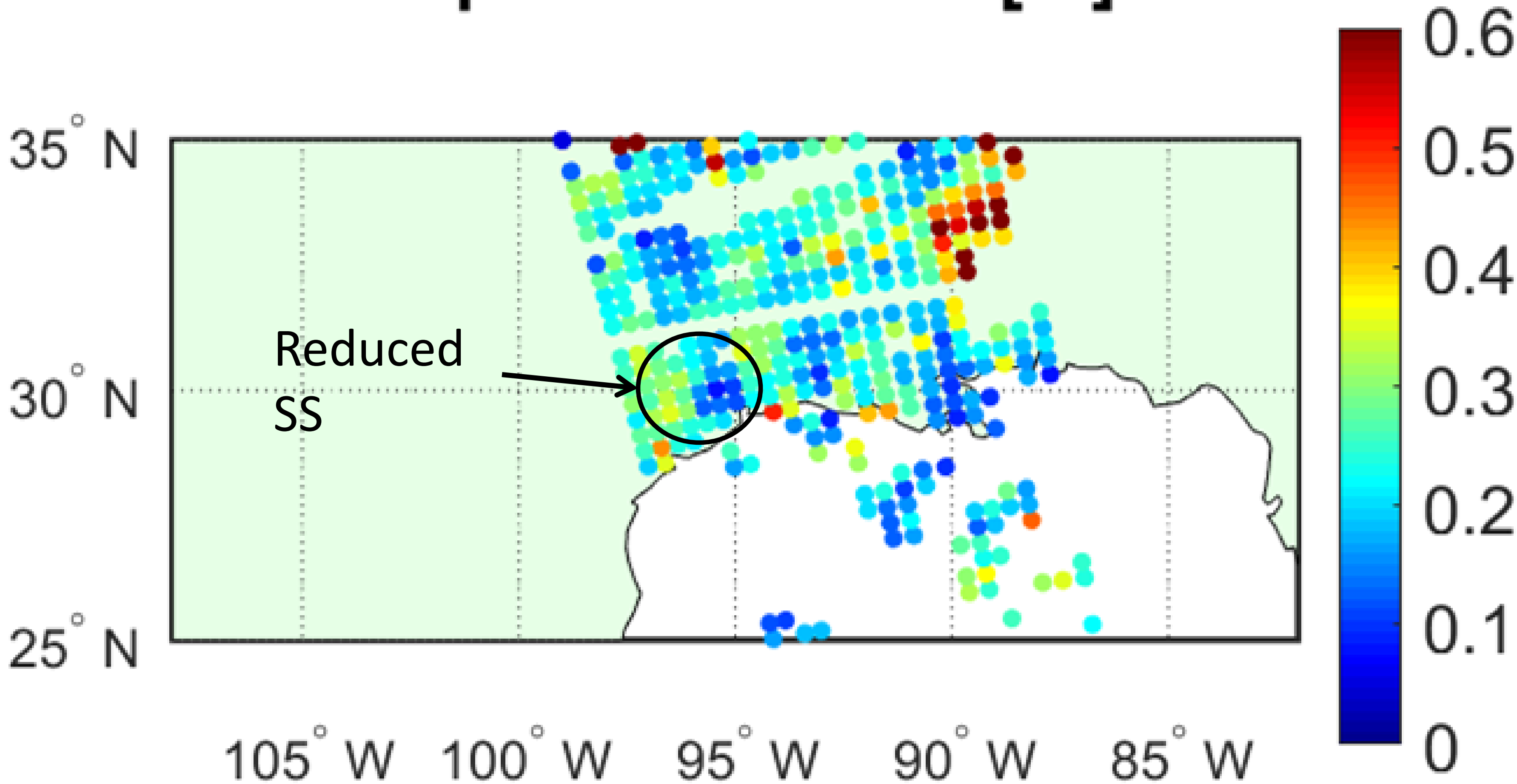
VIIRS 2014 June 07 19:28 UT

Cloud Base updrafts [m/s]



VIIRS 2014 June 07 19:28 UT

Super Saturation [%]



VIIRS 2014 June 07 19:28 UT

Model Description (Configuration)

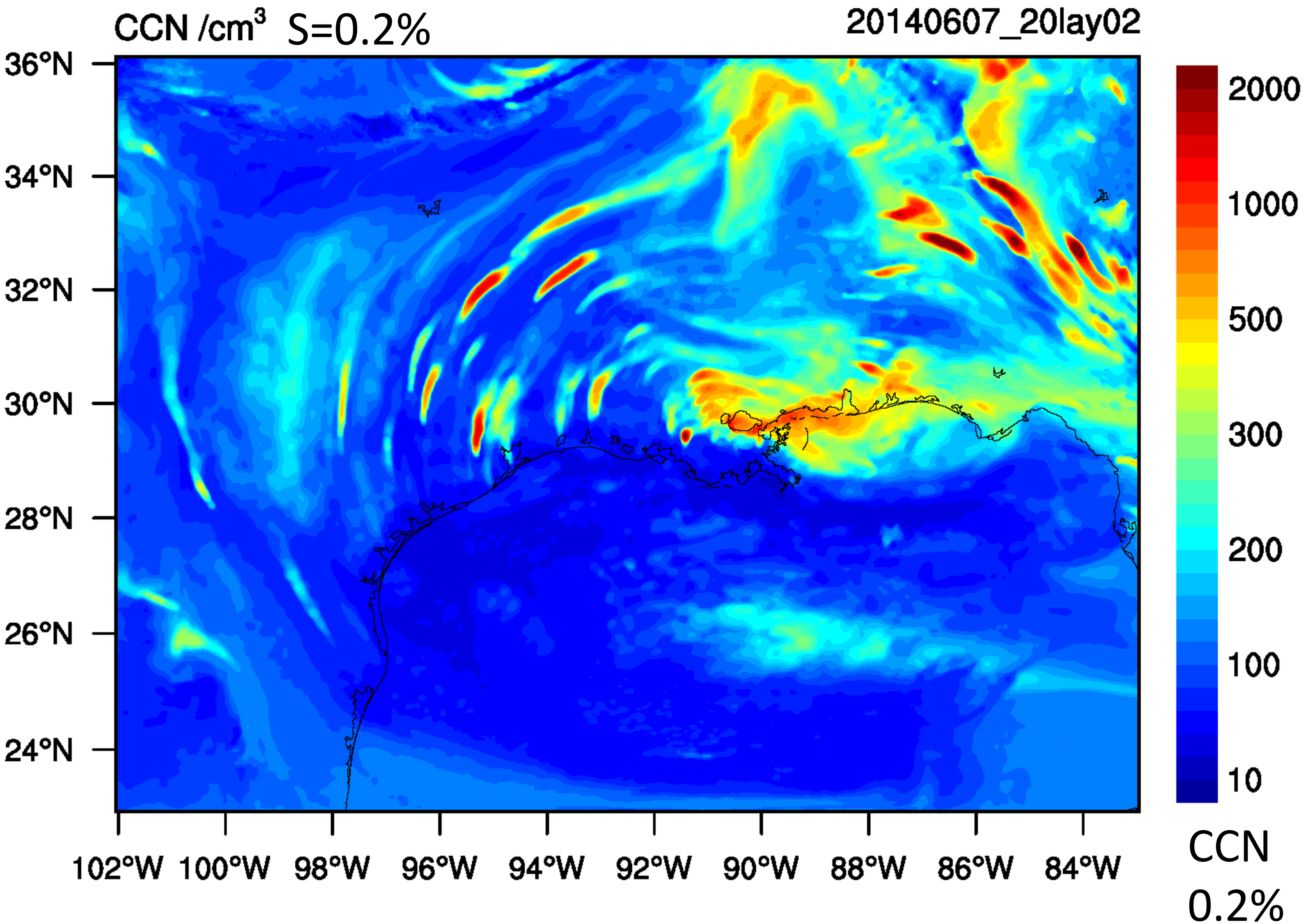
WRF, CMAQ models

Credit: Prof. Shaocai Yu
Zhejiang University, Hangzhou

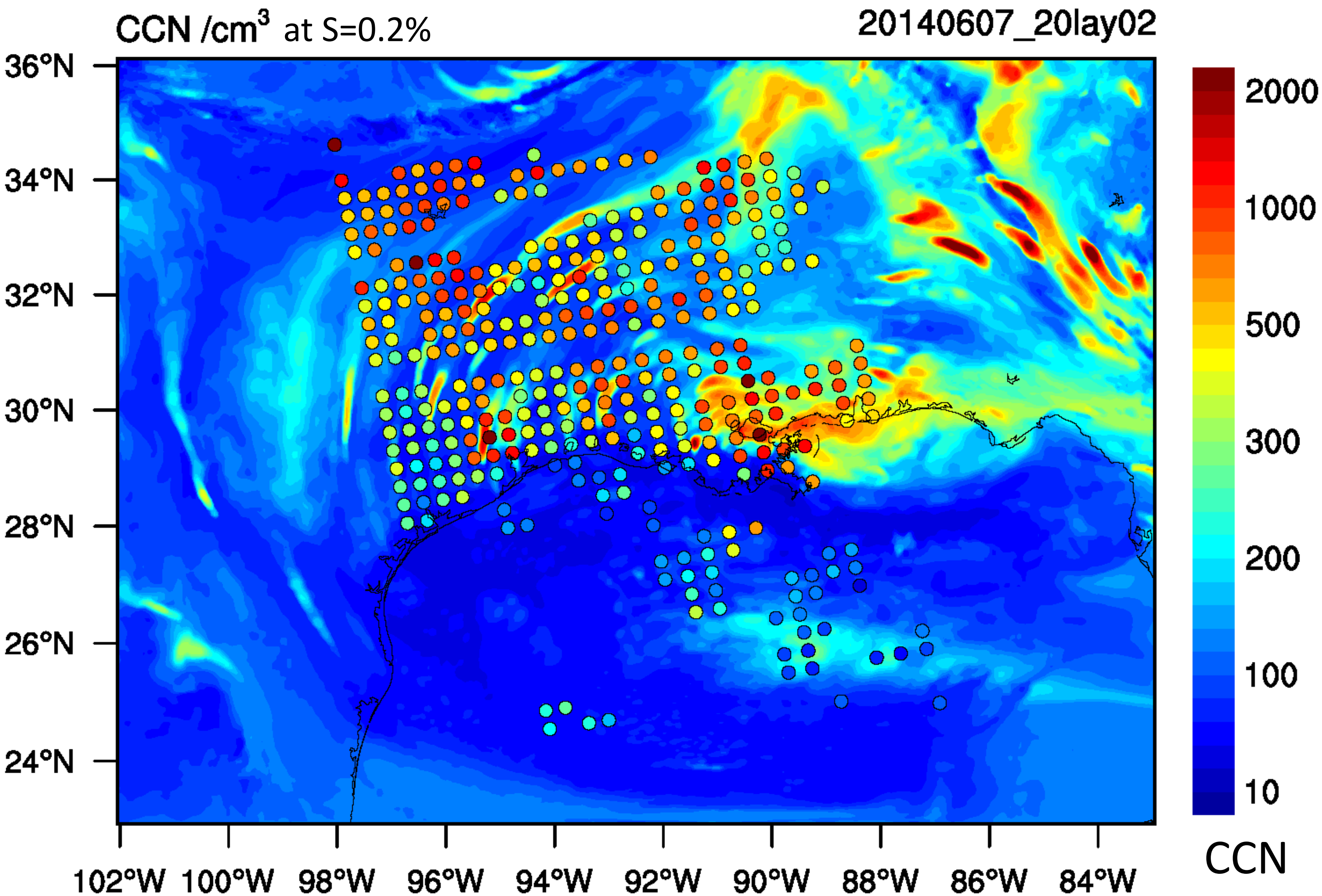
- **Weather Research Forecast (WRF3.4) model**
  - **Most popular meteorological model**
- **U.S. EPA CMAQ (5.01)**

  A widely-used air quality model

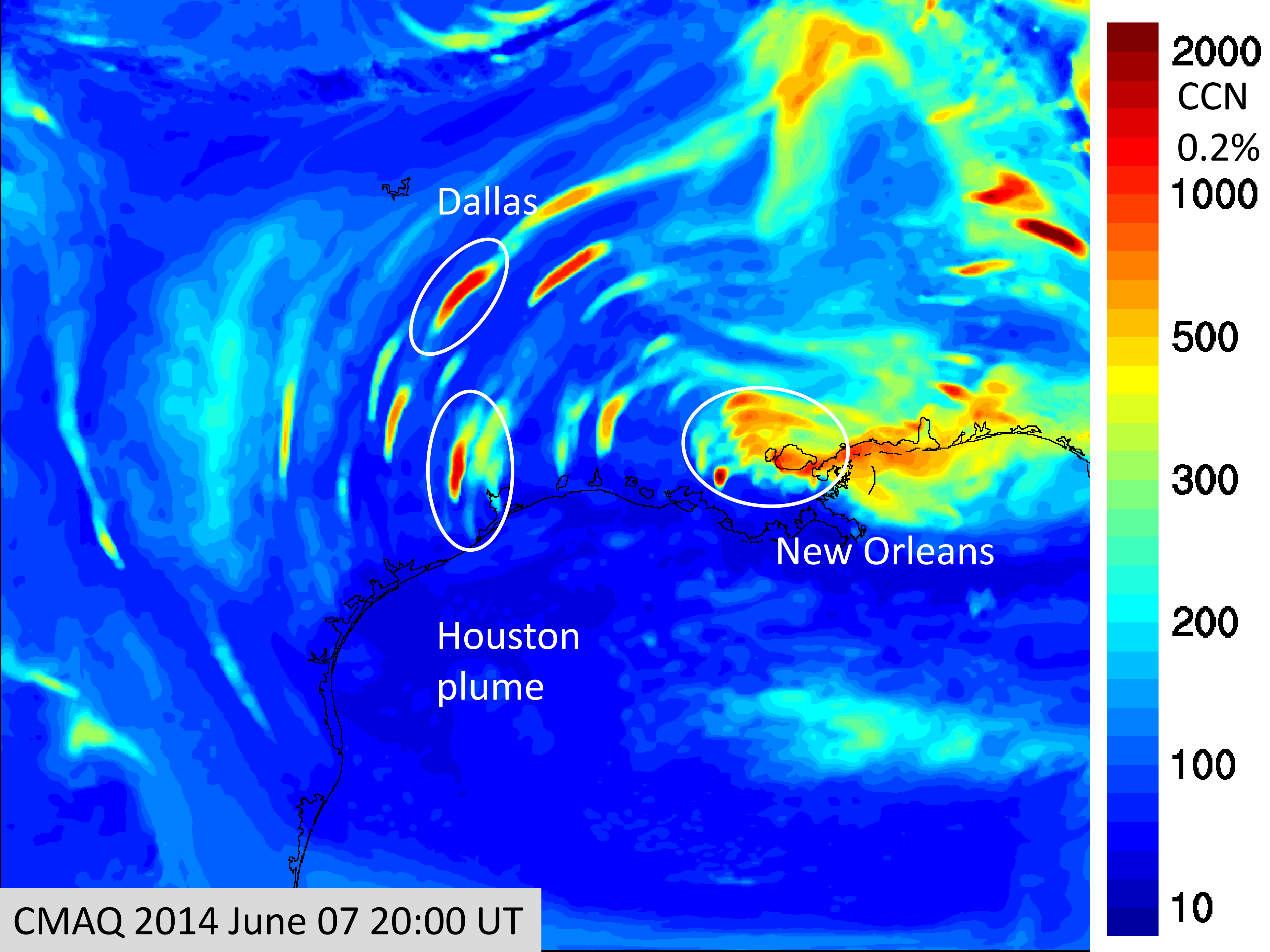
- **Aerosol indirect effects on grid-scale clouds have been implemented in the two-way coupled WRF-CMAQ model:**
  - **"Aerosol indirect effect on the grid-scale clouds in the two-way coupled WRF-CMAQ: model description, development, evaluation and regional analysis" by Yu et al., (ACP, 2014)**

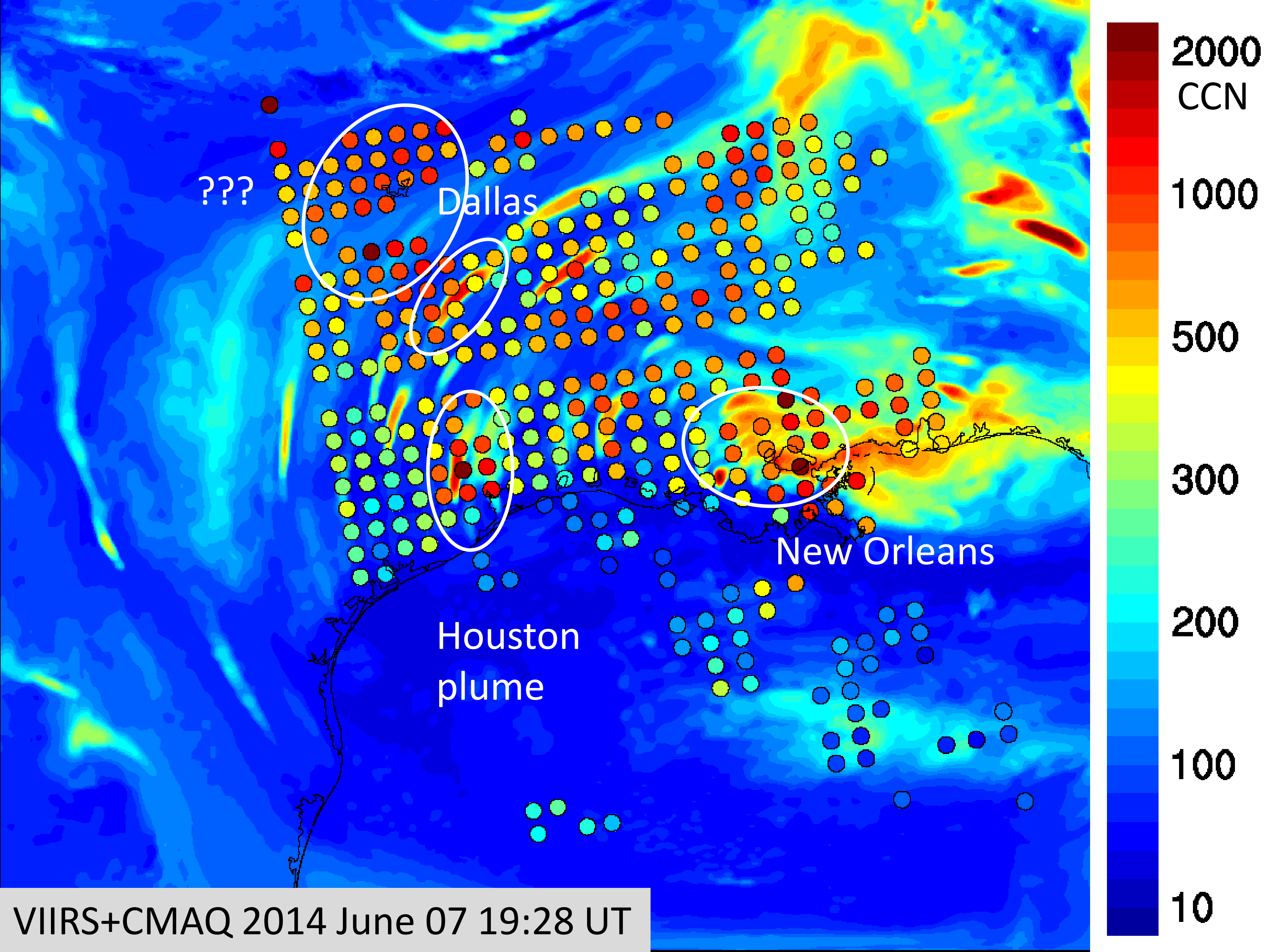


CMAQ 2014 June 07 20:00 UT



VIIRS+CMAQ 2014 June 07 19:28 UT


Dallas
Houston
plume
New Orleans
CMAQ 2014 June 07 20:00 UT
2000
CCN
0.2%
1000
500
300
200
100
10



???
Dallas
Houston
plume
New Orleans
2000
CCN
1000
500
300
200
100
10
VIIRS+CMAQ 2014 June 07 19:28 UT

Summary

- The first application of satellite mapping of CCN(S) reveals that cleanest continental areas found so far are pristine Amazon (Green Ocean) with background CCN of ~200 cm^{-3} at S=0.4%.
- Obviously large pollution sources are picked up well by both model and satellite.
- Minor emission sources that are not picked up by aerosol models appear to have substantial impacts with respect to pristine background.
- There is still much work before the CCN mapping can become operational reliably.