Quantifying factors determining thermals and cloud base updraft speeds over the land and ocean

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

[1] Department of Atmospheric and Oceanic Science, University of Maryland, College Park, Maryland, 20742, USA.

[2] Institute of Earth Sciences, The Hebrew University of Jerusalem, Jerusalem, 91904, Israel.

Why is updraft speed so important?

(1) In convective boundary layer, updrafts carry out the mixing of heat, moisture, momentum, aerosols, and gaseous pollution.

(2) Updrafts play a central role in the formation of convective clouds and precipitation.

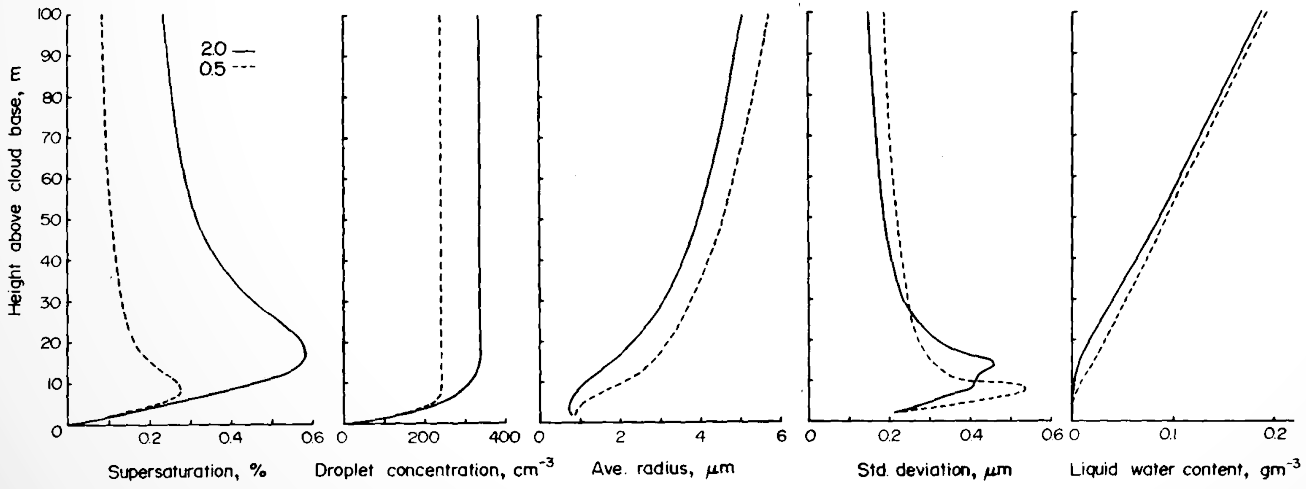
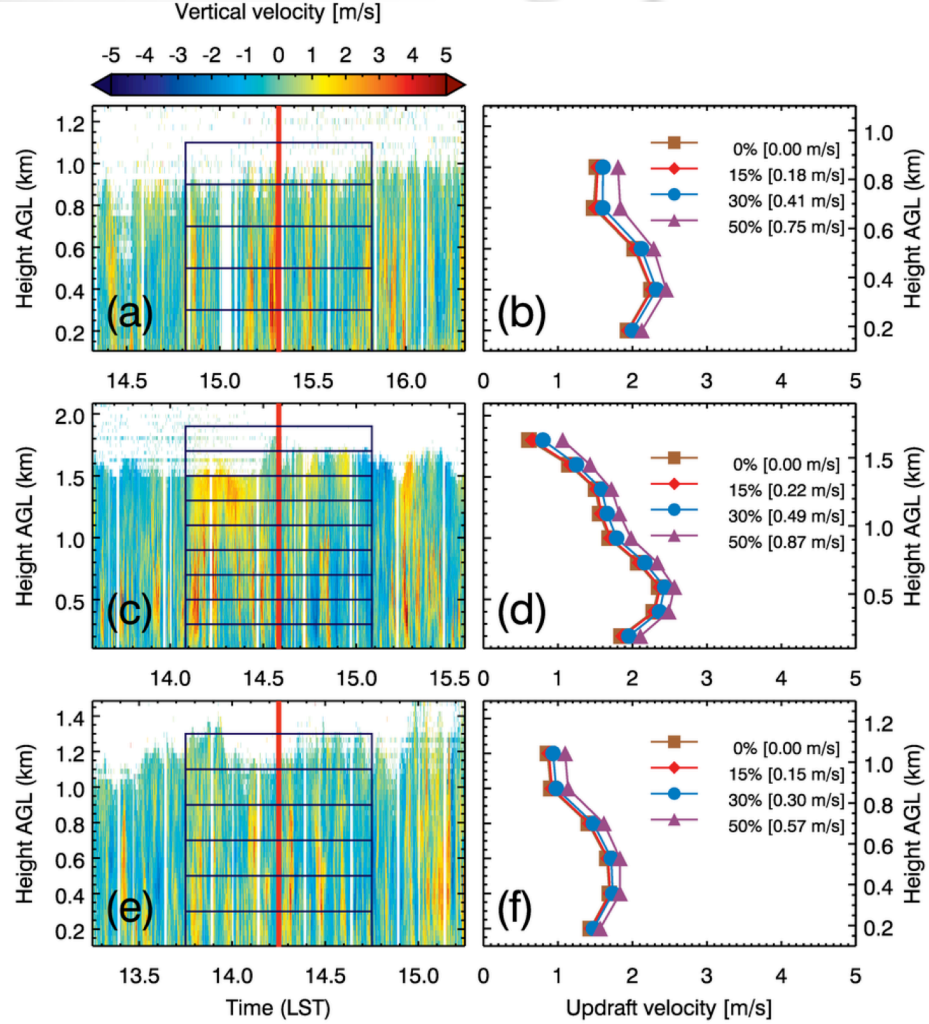


FIG. 7.4. Early development of cloud properties in air ascending at constant velocity of 0.5 m/s or 2 m/s.

From Rogers, 1989

Two methods of quantifying factors determining updraft speeds (W_{max} and W_b)



Zheng et al, 2015, JAS

W_b – Cloud base updrafts
W_{max}- Maximum updrafts

Method 1:

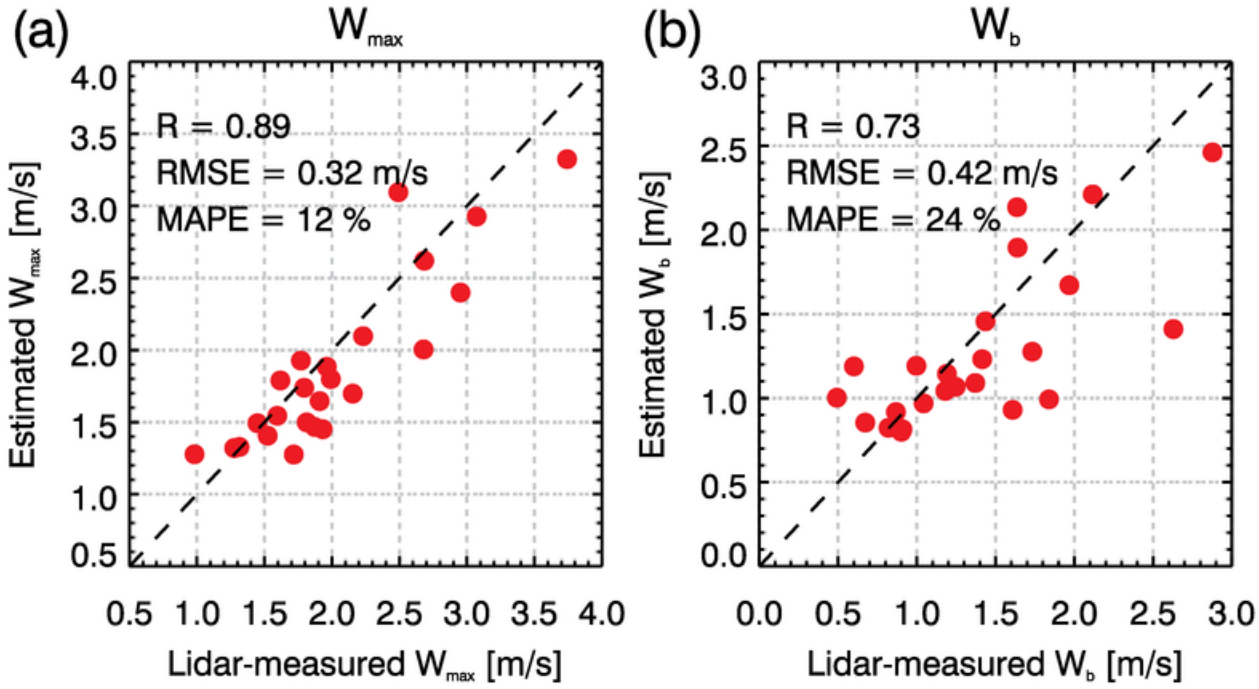
- *Zheng et al, 2015, JAS*
- Region: SGP

Method 2 :

- *Zheng and Rosenfeld, 2015, submitted to GRL*
- Region: SGP and MAGIC

METHOD 1

$$W_{est}=C_1[H_b(1+0.25V)(T_s-T_a)]^{1/2}+C_2$$

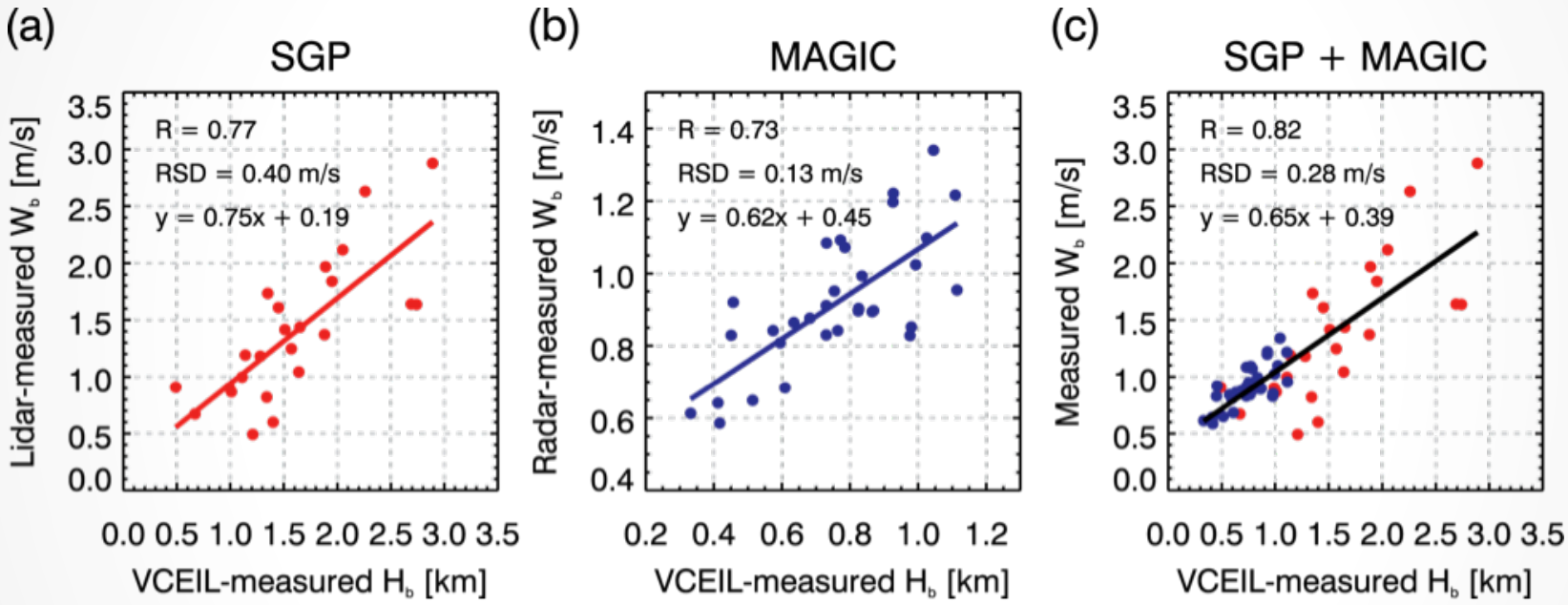


H_b – Cloud base height
V – Surface wind speed
T_s – Surface skin temp.
T_a – Surface air temp.

Variation of lidar-measured thermals and convective cloud base updrafts as a function of ground-air temperature difference (Ts-Ta), cloud base height (H_b) and surface wind speed (V). (*Zheng et al., JAS, 2015*)

METHOD 2

$$W_{est}=C_3H_b+C_4$$



H_b – Cloud base height
W_b- Cloud base updrafts

Linear relationship between cloud base updrafts and cloud base hieght . (*Zheng and Rosenfeld, 2015, submitted to GRL*)

METHOD 2: Data

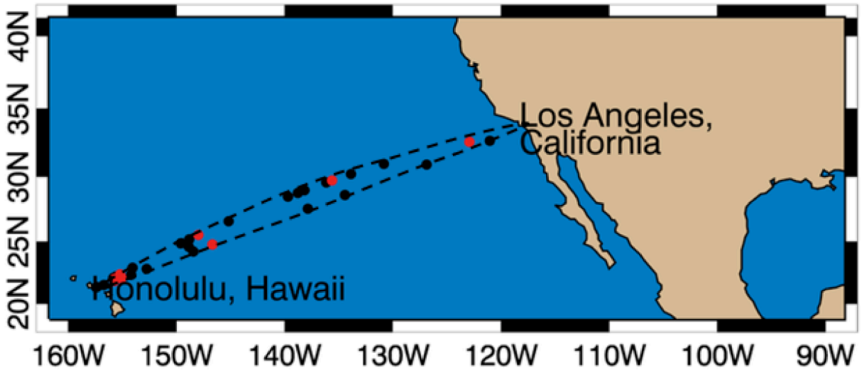
1. ARM Ground-based data:

- SGP site (continent)

The SGP CF site (36.6N, 97.5W) is located in the southeast of Lamont, Oklahoma. The land cover is consisted of cattle pasture and crop fields.

- MAGIC field campaign (ocean)

The recent MAGIC field campaign lasted from October 2012 through September 2013. The second ARM Mobile Facility (AMF2) was deployed on a container ship, named *Horizontal Spirit*, that completed 20 round trips between Los Angeles, California, and Honolulu, Howaii.

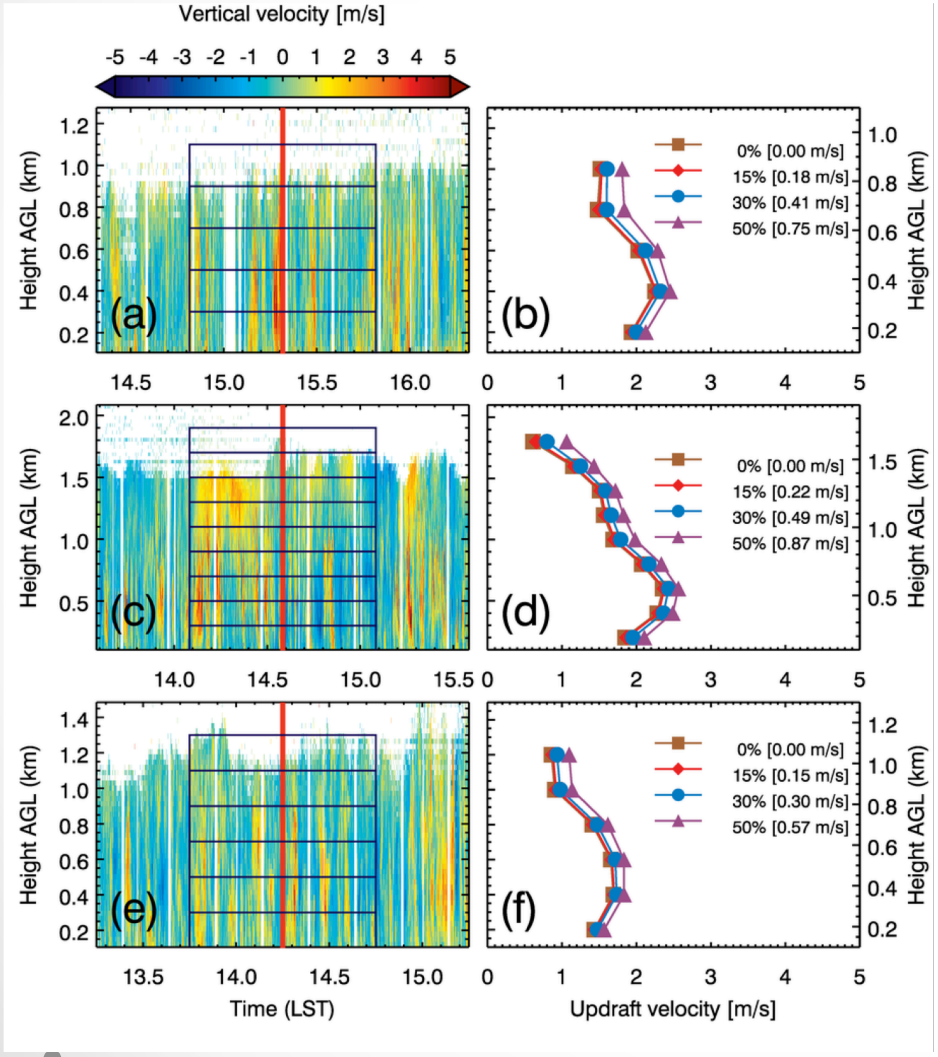


2. Satellite and reanalysis data:

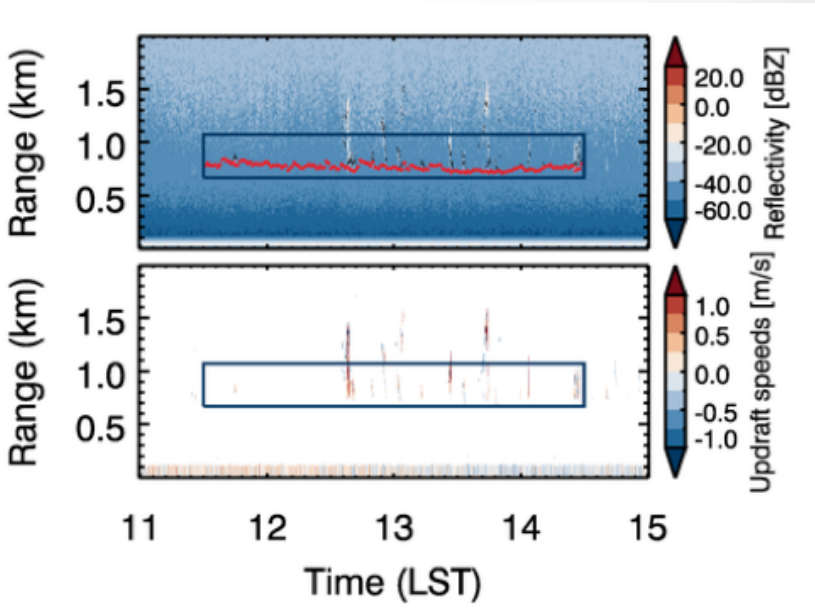
- Satellite: VIIRS (Visible Infrared Imaging Radiometer Suite) onboard the Suomi NPP (National Polar-orbiting Partnership)
- Reanalysis: ECMWF

Methodology

- SGP site: Doppler Lidar retrieval of updrafts

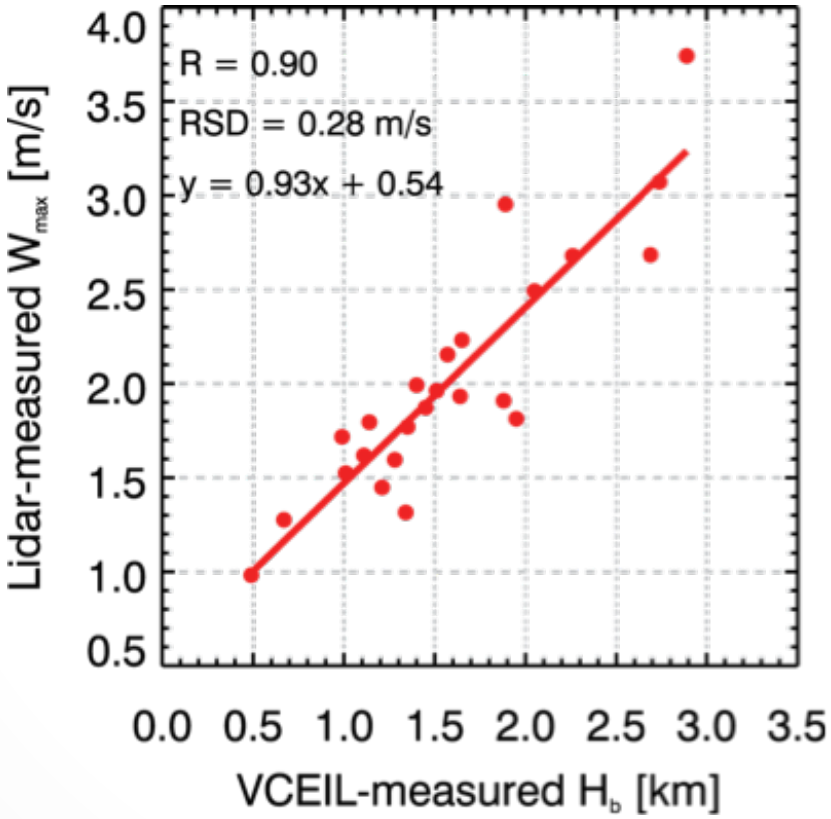


- MAGIC: Marine W-band Cloud Radar retrieval of updrafts



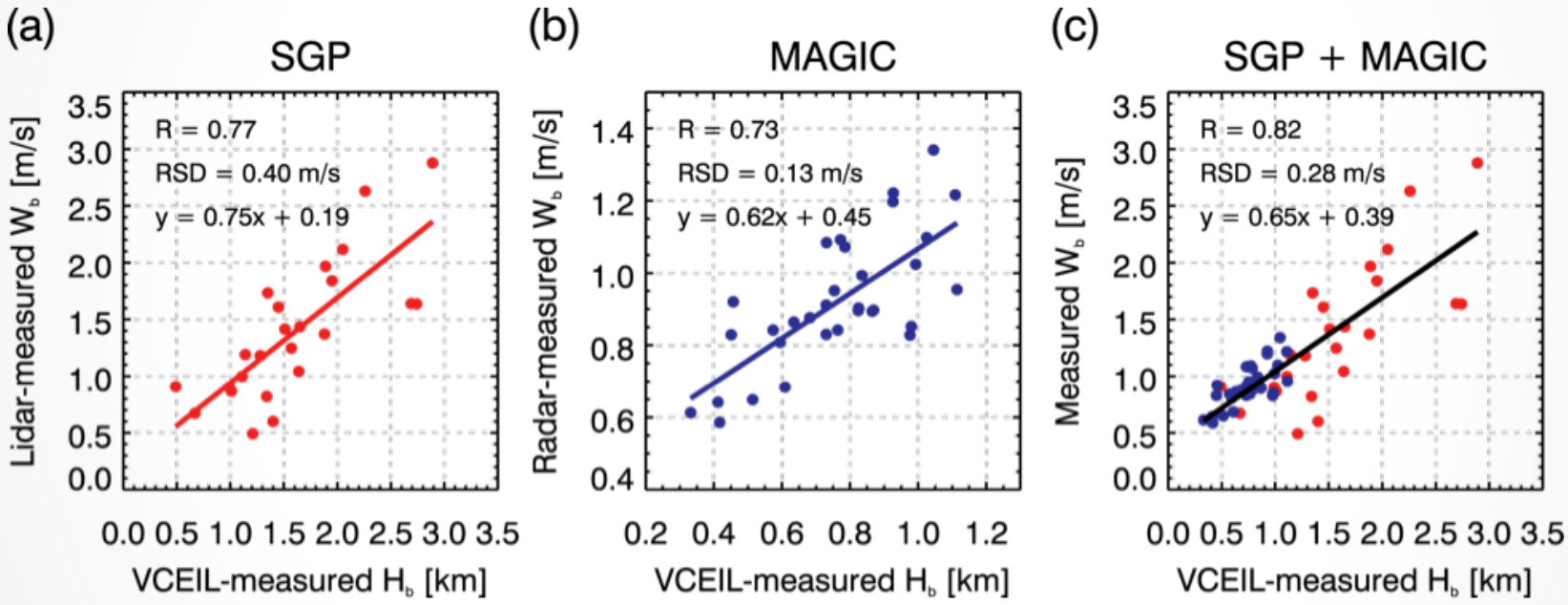
$$W = \left. \frac{\sum N_i W_i^2}{\sum N_i W_i} \right|_{W_i > 0}$$

Results: Linear relation between H_b and W_{max} over SGP



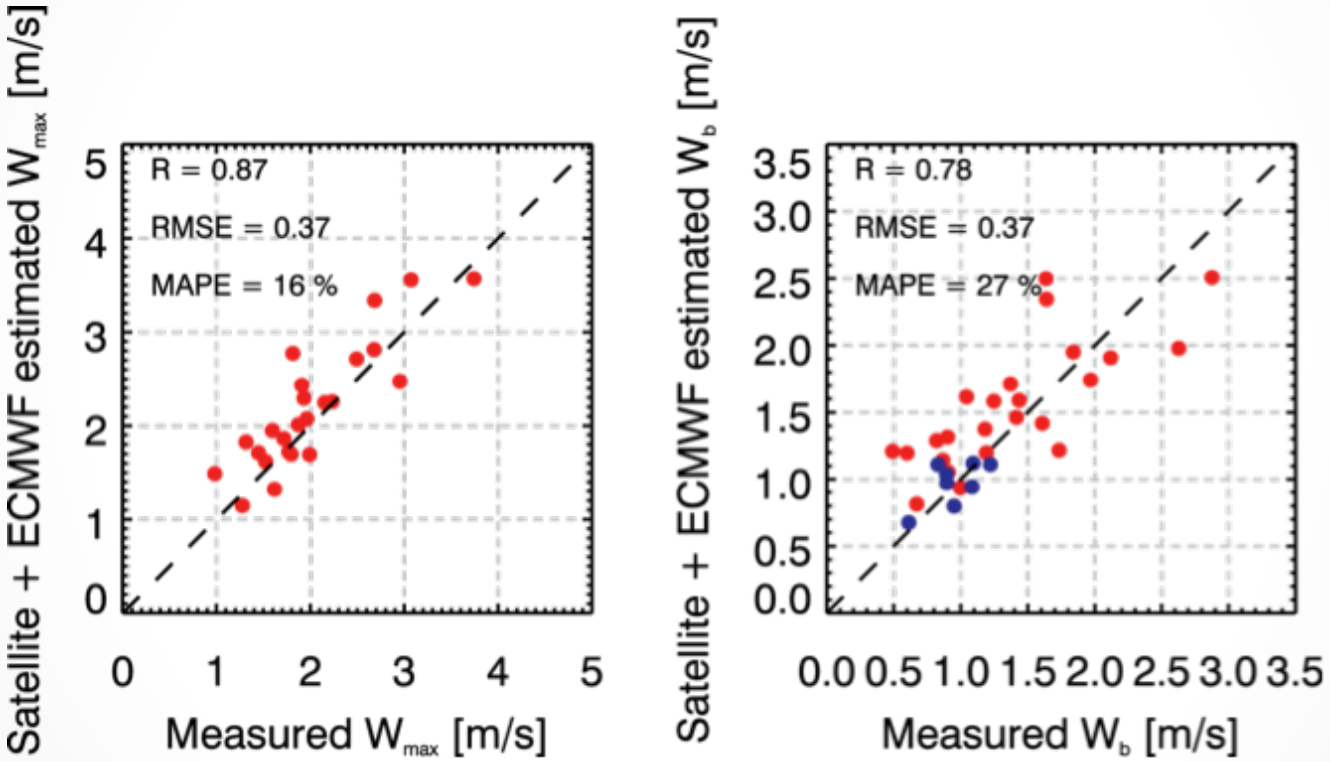
H_b – Cloud base height
W_{max}- Maximum updrafts

Results: Linear relation between H_b and W_b over SGP and MAGIC



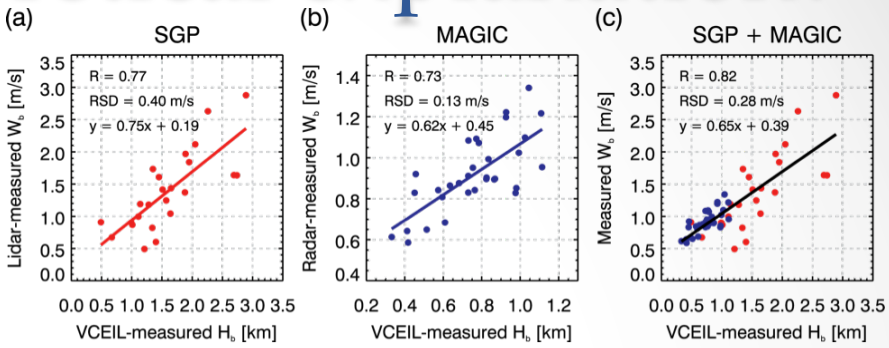
H_b – Cloud base height
W_b- Cloud base updrafts

Results: Satellite retrieval of W_{max} and W_b over SGP and MAGIC



$$W_{max} = 0.93H_b + 0.54$$
$$W_b = 0.65H_b + 0.39$$

How about the theoretical explanation?

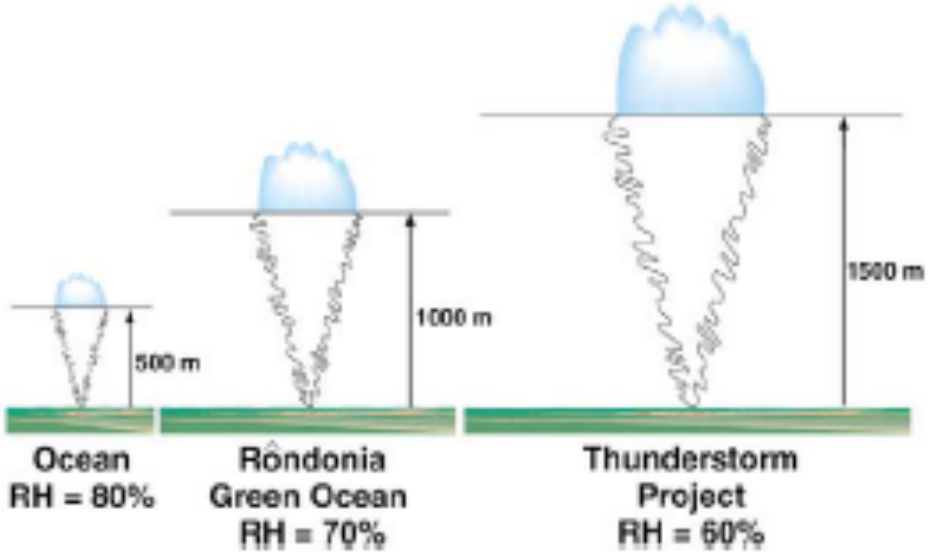


Higher cloud base

-> Drier PBL

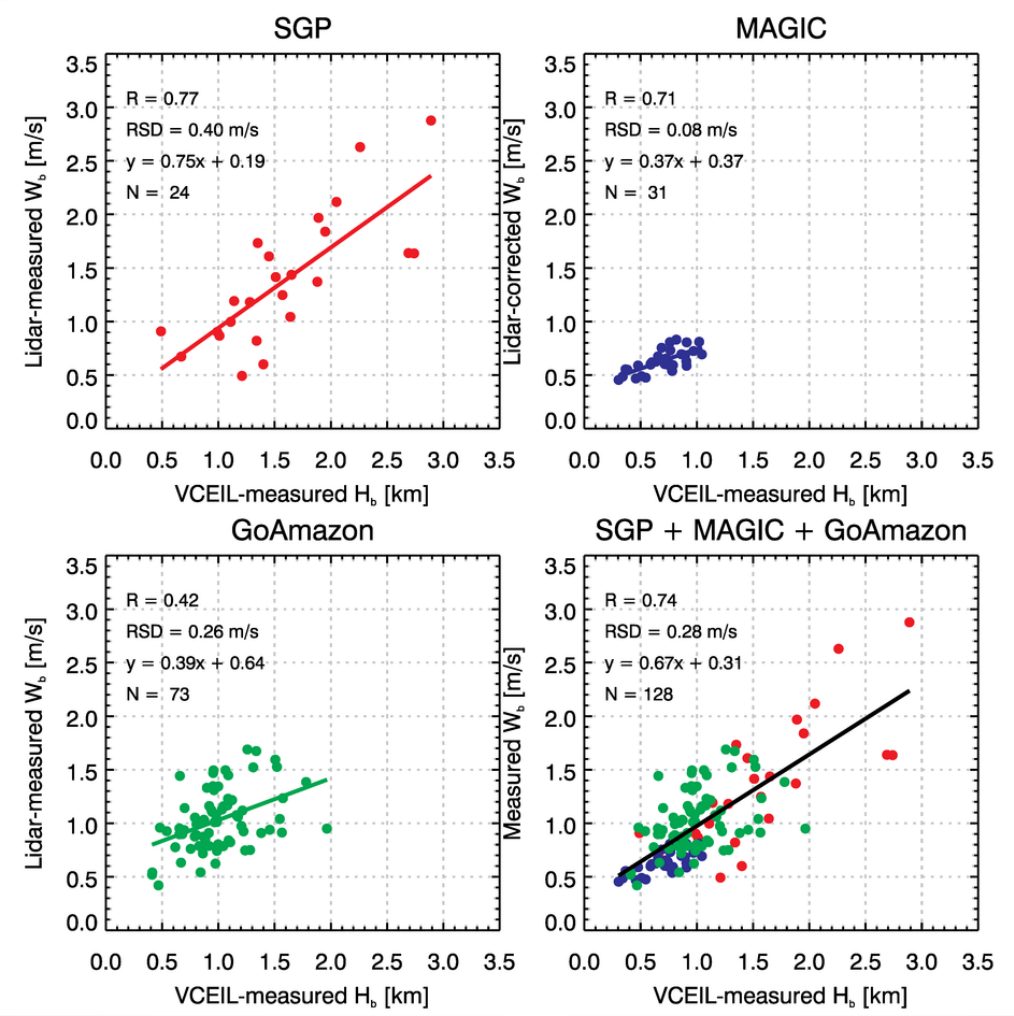
-> Less sunlight is invested in evaporation

-> more energy available for accelerating thermals



Williams, E., and S. Stanfill , 2002

Ongoing studies: Linear relation between H_b and W_b over SGP and MAGIC and GoAmazon



Conclusion

- Two methods of quantifying the factors determining updrafts were introduced.
- The first method is based on the dependence of updrafts on surface and PBL parameters (such as ground-air temperature difference, cloud base height and surface wind).
- The second method is based on a simple linear relation between H_b and updrafts (both W_{max} and W_b). This works for both SGP and MAGIC, indicating a possible universal relationship. The cases from GoAmazon fit this relation very well.
- Based on the linear relationship, a method of satellite retrieval of updrafts was proposed with MAPE of 16% and 27% for W_{max} and W_b respectively.
- A possible explanation for this linear relationship was given. But a well-established theory that quantitatively explains the linear relation is still lacking.
- It would be very useful if we have Doppler lidar in MAGIC-2.

Reference

- Zheng Y. and D. Rosenfeld, 2015: Linear relation between convective cloud base height and updrafts and application to satellite retrievals.. In revision, GRL

- Zheng, Y., D. Rosenfeld, and Z. Li, 2015: Satellite inference of thermals and cloud base updraft speeds based on retrieved surface and cloud base temperatures. J. Atmos. Sci. doi:10.1175/JAS-D-14-0283.1, in press.

- Williams, E., and S. Stanfill , 2002, The physical origin of the land–ocean contrast in lightning activity, *Comptes Rendus Physique*, *3*(10), 1277-1292.


THANKS