Maximum Supersaturation in the Marine Boundary Layer Clouds Over the Eastern North Atlantic

Xianda Gong[1], Yang Wang[1], Hua Xie[2], Jiaoshi Zhang[1], Zheng Lu[2], Frank Stratmann[3], Heike Wex[3], Xiaohong Liu[2], Jian Wang[1,*] | [1]Department of Energy, Environmental and Chemical Engineering, Washington University in St. Louis, MO, USA. [2]Department of Atmospheric Sciences, Texas A&M University, College Station, TX, USA. [3]Leibniz Institute for Tropospheric Research, Leipzig, Germany.

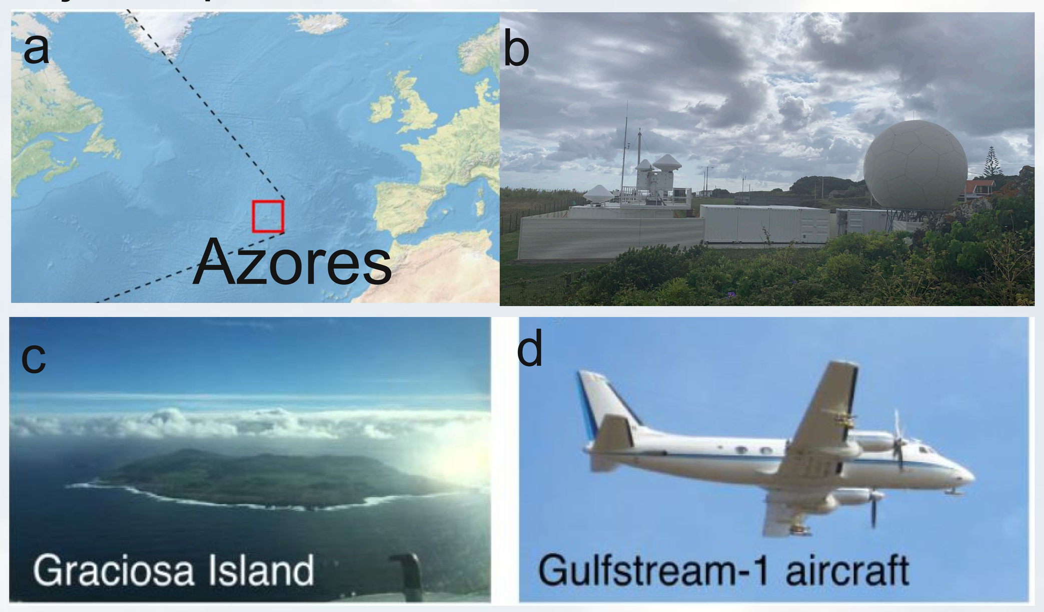
ASR Atmospheric System Research

1. Introduction

The maximum supersaturation (SS_{max}) inside clouds is a key parameter affecting the cloud's microphysical and radiative properties. However, SS_{max} inside the cloud is very difficult to measure directly.

During the ACE-ENA campaign, measurements are carried out continuously at the ENA observatory, which was set up in late 2013 on Graciosa Island in the Azores, Portugal[1].

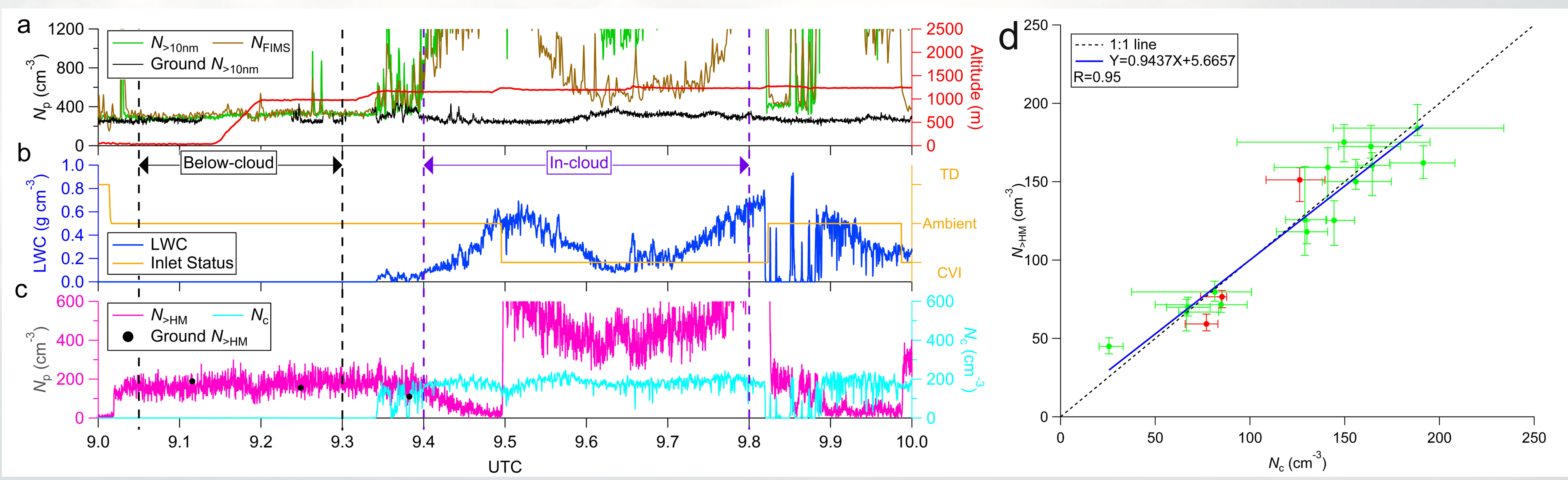
Additionally, a total of 39 flights were conducted in the vicinity of Azores, out of the Lajes airport on Terceira Island.



(a) The general geographic location of the sampling area. (b-d) A photo of ENA ground measurement site; the vicinity of the ENA site on Graciosa Island; and the G-1 aircraft[1].

2. Hoppel Minimum (HM) and Cloud Droplet Concentration

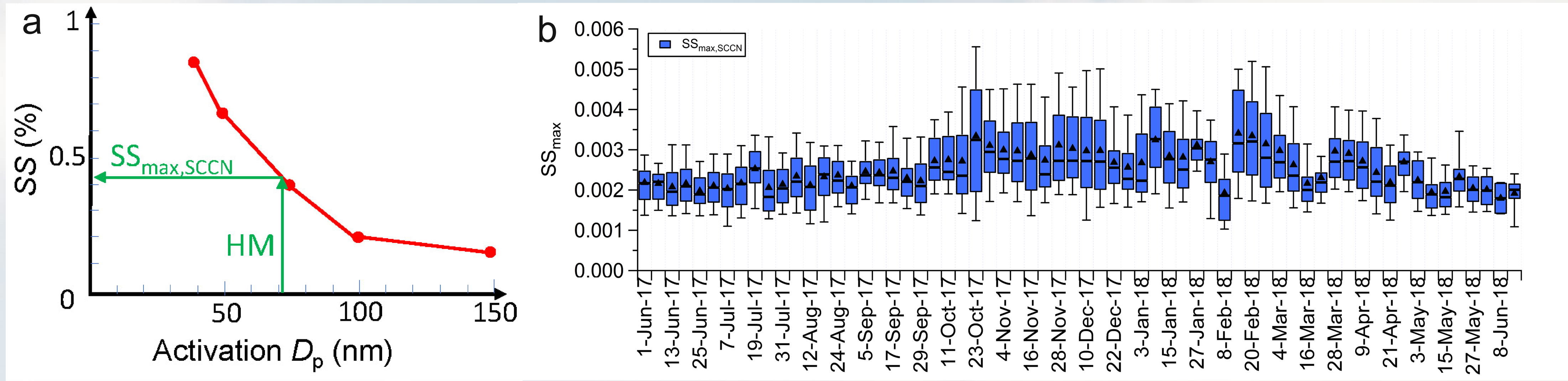
A good agreement between the number concentration of particles larger than HM out-of-cloud and cloud droplet concentration in-cloud was observed, indicating that HM represents the smallest size at which particles are activated into cloud droplets[2].



(a-c) Measurements onboard G-1 aircraft on 13 July 2017. (d) Scatter plot of number concentration of particles larger than Hoppel Minimum and cloud droplet concentration.

3. Derivation of Maximum Supersaturation (SS_{max})

- SS_{max} derived by interpolating size-resolved CCN measurements
- Higher SS_{max} values and a larger variability in winter
- Mean SS_{max} values: 0.25% in winter and 0.20% in summer



(a) Method to derive SS_{max}. (b) Seasonal variation of SS_{max}.

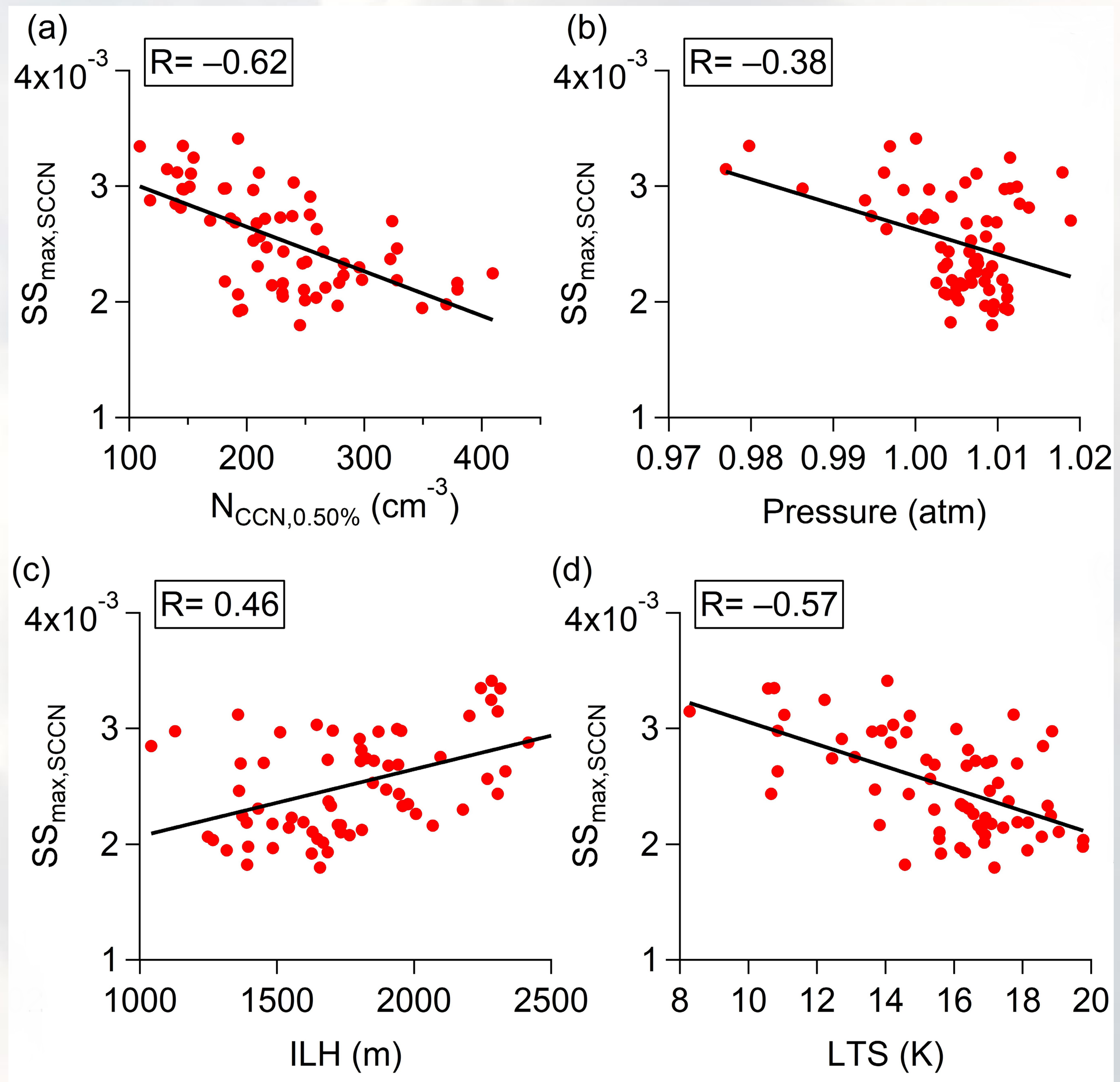
4. Relationships Between SS_{max} and CCN population or Synoptic Conditions

(a) Suppression of SS_{max} by increased condensation sink of water vapor at high N_{CCN}.

(b) Stronger convection and increased SS_{max} as cold air advects over warm ocean following the passage of fronts (i.e., low pressure).

(c & d) A weak lower tropospheric stability (LTS) leads to deeper boundary layer and thicker clouds. Thicker clouds tend to have stronger radiative cooling at cloud top and more latent heat release, both of which lead to stronger turbulence and thus higher updraft velocity and increased SS_{max}.

A multi-linear regression model based on $N_{CCN,0.50\%}$, pressure, LTS, ILH, and inversion strength (IS) can explain 57.0% of the variation in SS_{max}.

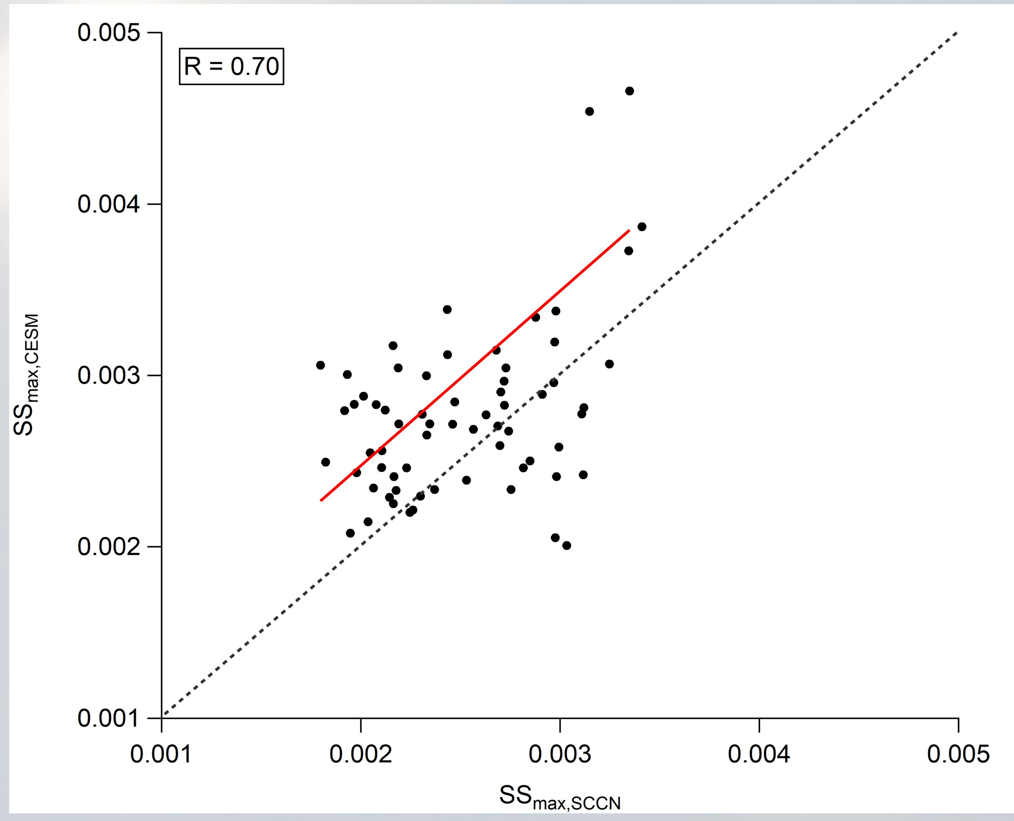


Scatter plot of SS_{max} against the $N_{CCN,0.50\%}$ (a), pressure (b), inversion layer height (ILH)(c), lower troposphere stability (LTS) (d).

5. Comparison Between Measured and Simulated SS_{max}

We used the global Community Earth System Model (CESM) to simulate SS_{max} values in the Azores.

$SS_{max,CESM}$ values broadly agree with those derived from the measurements ($SS_{max,SCCN}$, R=0.70), but they also show some positive biases.



Scatter plot of $SS_{max,SCCN}$ against $SS_{max,CESM}$.

References

1 Wang, J. et al. (2021). Aerosol and Cloud Experiments in the Eastern North Atlantic (ACE-ENA). Bulletin of the American Meteorological Society.

2 Hoppel, W. A. et al. (1986), Effect of nonprecipitating clouds on the aerosol size distribution in the marine boundary layer. Geophysical Research Letters.

3 Gong, X. et al (2022), in preparation.

Acknowledgments

We acknowledge funding support from Atmospheric System Research (ASR) and Atmospheric Radiation Measurement (ARM) programs.

Contact Information

• Jian Wang, jian@wustl.edu
• Xianda Gong, x.gong@wustl.edu

U.S. DEPARTMENT OF ENERGY | Office of Science