paper draft: supersat

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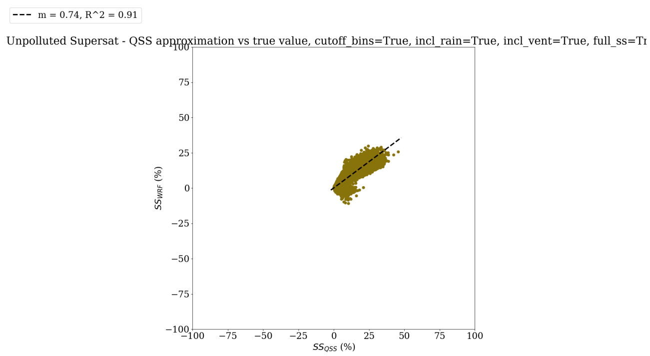
1 Introduction

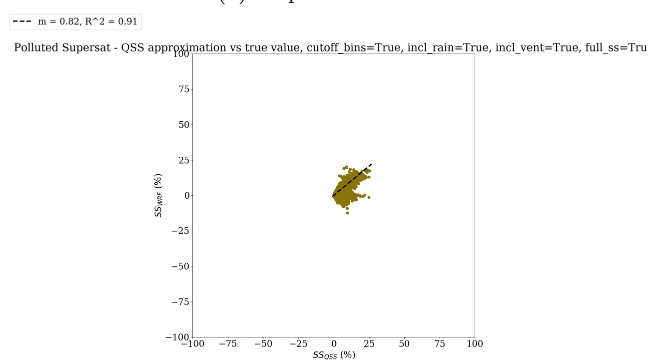
introductory notes.

2 Theory + Simulation

- brief statement of quasi steady state formula
- we see agreement between actual and QSS supersaturation under the conditions (see fig 1):
  - T >273K (we're not including ice in the theory)
  - w >2 m/s (reasonably strong updrafts)
  - cloud LWC >1e-4 g/g (in the convection core)
  - including rain droplets and ventillation corrections
- upon applying above filters, the distributions of SS_{QSS}, LWC (cloud only) and w, are shown in figs 2, 4, and 3.

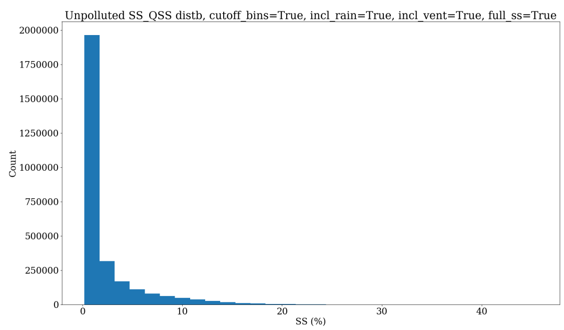


(a) Unpolluted case.



(b) Polluted case.

Figure 1: Actual (SS_{WRF}) vs predicted (SS_{QSS}) supersaturation.



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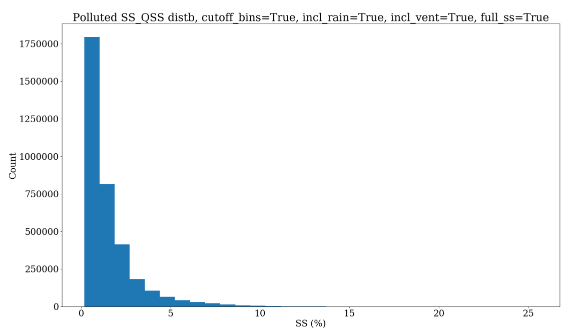
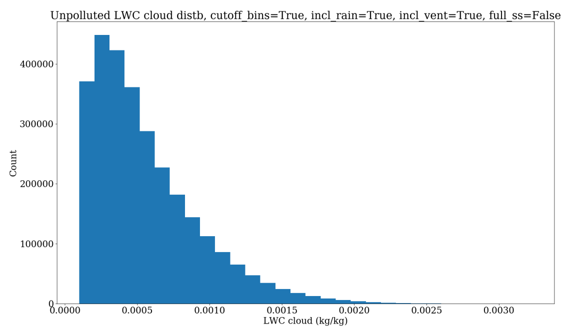


(b) Polluted case.

Figure 2: SS_{WRF} distribution in WRF simulation using filtering criteria described in the text.



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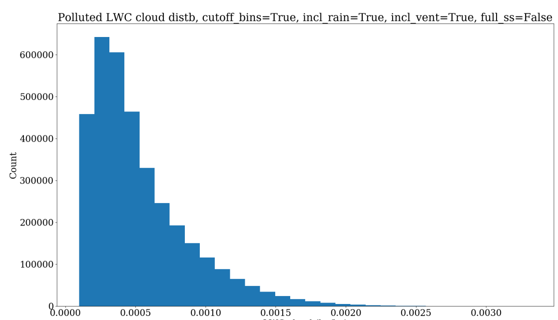
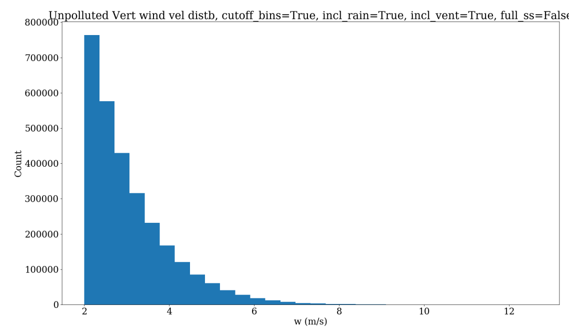


(b) Polluted case.

Figure 3: Cloud LWC distribution in WRF simulation using filtering criteria described in the text.



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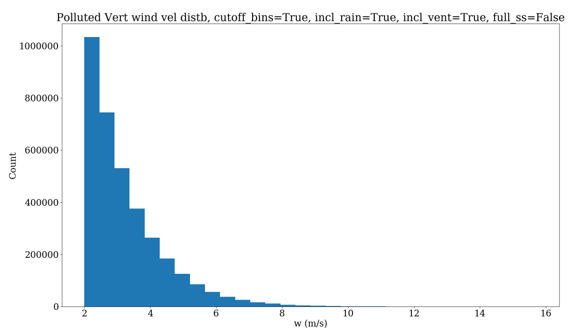


(b) Polluted case.

Figure 4: Vertical wind velocity distribution in WRF simulation using filtering criteria described in the text.

3 Experimental data

- using criteria from second bullet point of section 2, SS_{QSS} distributions from HALO and CAIPEEX campaigns look like figs 5 and 6, respectively (note: currently don't have raindrop data for CAIPEEX...).
- using same criteria, cloud LWC distributions are given in figs 7 and 8.
- using same criteria, vertical wind velocity distributions are given in figs 9 and 10.

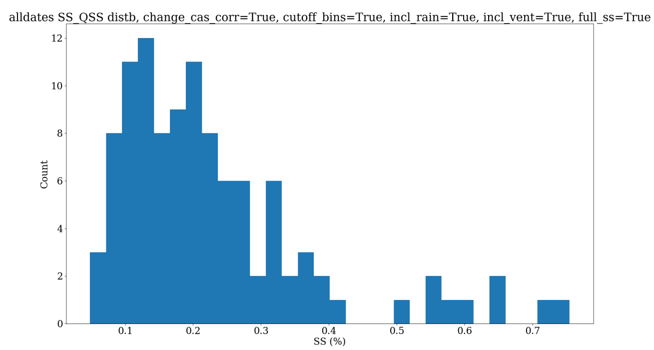


Figure 5: Predicted (SS_{QSS}) supersaturation distribution from HALO field campaign (all flight dates). Using filtering criteria outlined in section 2.

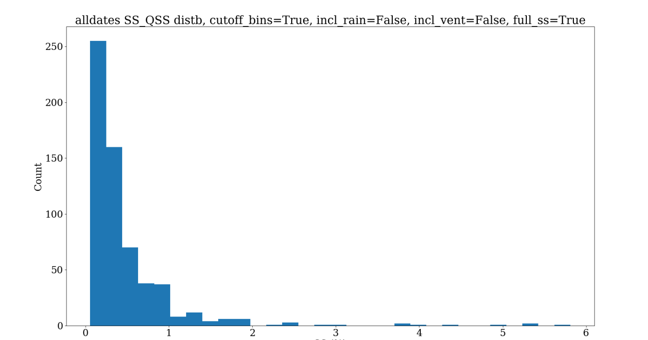


Figure 6: Predicted (SS_{QSS}) supersaturation distribution from CAIPEEX field campaign (all flight dates). Using filtering criteria outlined in section 2, but not including rain drops or ventilation corrections due to lack of data.

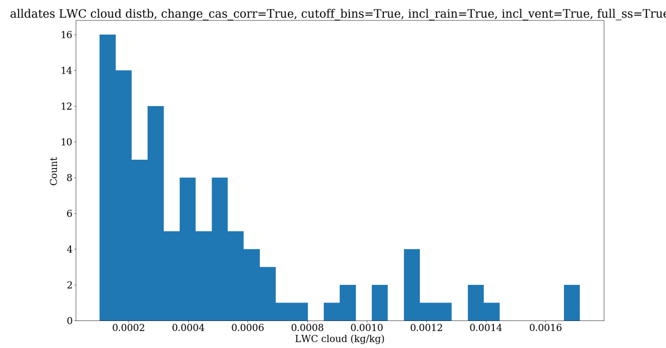


Figure 7: Cloud LWC distribution from HALO field campaign (all flight dates). Using filtering criteria outlined in section 2.

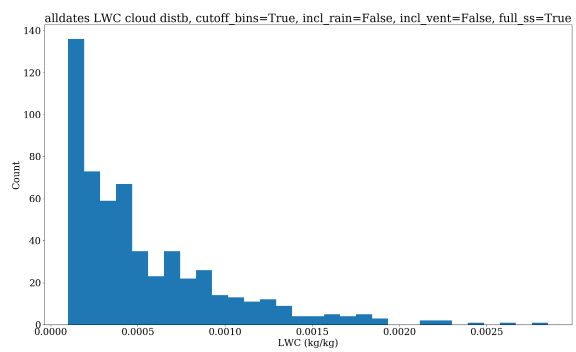


Figure 8: Cloud LWC distribution from CAIPEEX field campaign (all flight dates). Using filtering criteria outlined in section 2, but not including rain drops or ventilation corrections due to lack of data.

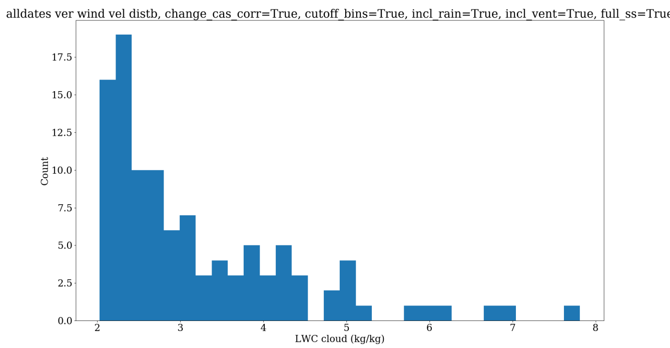


Figure 9: Vertical wind velocity distribution from HALO field campaign (all flight dates). Using filtering criteria outlined in section 2.

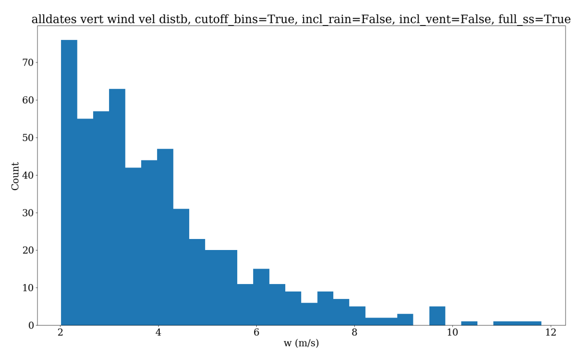


Figure 10: Vertical wind velocity distribution from CAIPEEX field campaign (all flight dates). Using filtering criteria outlined in section 2, but not including rain drops or ventilation corrections due to lack of data.

4 Line of argument

4.1 CLAIM

Figures 5 and 6 demonstrate that we don't observe the same high supersaturations seen in LES simulations (i.e. WRF data)

4.2 POSSIBLE COUNTERARGUMENTS

1. Experimental sites were too polluted to observe the high supersaturations
2. Something must be wrong because SS_{QSS} distributions are so different between HALO and CAIPPEX.
3. (more philosophical I guess) If you don't trust WRF to give you realistic supersaturation values then why do you trust it to give you the reasonable regime of validity for the QSS approximation?

4.3 POSSIBLE COUNTERARGUMENTS TO THE POSSIBLE COUNTERARGUMENTS

1. Compare experiment vs simulation for **mystery kernel** integrated over aerosol distribution. For now I am setting mystery kernel = 1 (i.e. final integrated quantity is just the number concentration) and plotting distributions for HALO in fig 11, and for WRF in fig 12. CAIPEEX figure is pending data from Thara. Right now the disparities in form of distributions is due to different diameter ranges (discuss w/ David).
2. Ideally the figures referenced in above point will also address this concern, but hard to say right now w/o CAIPEEX aerosol data. Also not sure if we'll have the necessary info based on literature (also a point to discuss)
3. Not sure yet...

4.4 Statistical analysis of supersaturation distributions

4.4.1 Null hypothesis

Quasi-steady-state supersaturation values at selected sample of points from field campaigns are drawn from a "true" distribution like one of the ones from WRF.

4.4.2 Test

Reduced chi-squared

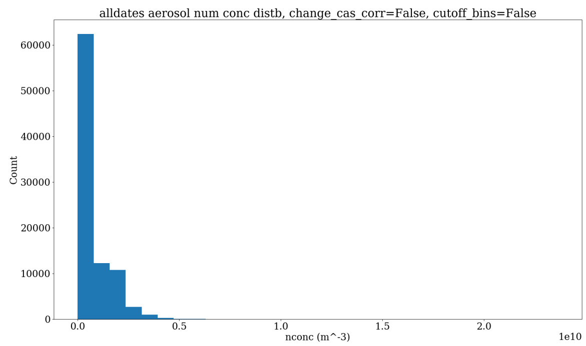


Figure 11: Aerosol number concentration distribution for particles 0.1-3.0um in HALO field campaign. All points below the freezing level and have cloud LWC less than 1e-5.

4.4.3 Details

Since altitude shows non-negligible correlation with SS_{QSS} in WRF data (Figure **??**), we actually need to compare the experimental SS_{QSS} distribution to an adjusted simulated distribution, to account for the differences in altitude distributions for sampled points in both datasets. Specifically:

$$\tilde{\chi}^2 = \frac{1}{d}\Big(\sum_k \frac{(\mathcal{O}_k - E_k)^2}{E_k}\Big), \tag{1}$$

where k labels discrete bins into which we group supersaturation values and,

$\mathcal{O}_k =$ of measurements observed in bin k (for all flight dates combined)

$E_k =$ of measurements observed in bin k (under adjusted SS_{QSS} distribution $P'_{sim}(SS_k)$)

The adjusted distribution is given by:

$$P'_{sim}(SS_k) = \sum_j P'_{sim}(z_j, SS_k), \tag{2}$$

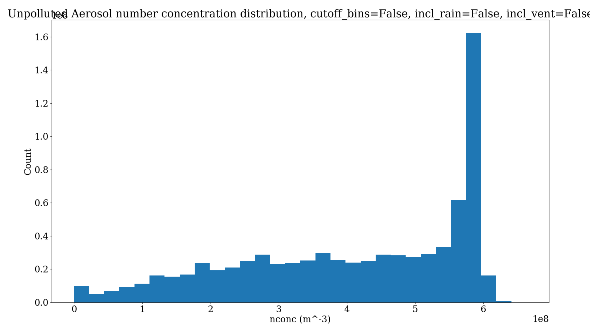
where,

$$P'_{sim}(z_j, SS_k) = \sum_{k''} \frac{P_{exp}(z_j, SS_{k''})P_{sim}(z_j, SS_k)}{\sum_{k'} P_{sim}(z_j, SS_{k'})} \tag{3}$$

In this analysis, we had to use unequal bin sizes (i.e., group bins in the tail of the SS_{QSS} distributions) in order to ensure $E'_k \geq 5$ and $n_{bins} \geq 4$ (the standard criteria for this statistical test). We set $d = n_{bins} - 2$ to account for the two choices of number of bins in the bivariate probability distributions $P(z_j, SS_k)$.

4.4.4 Results

4.4.5 Comments



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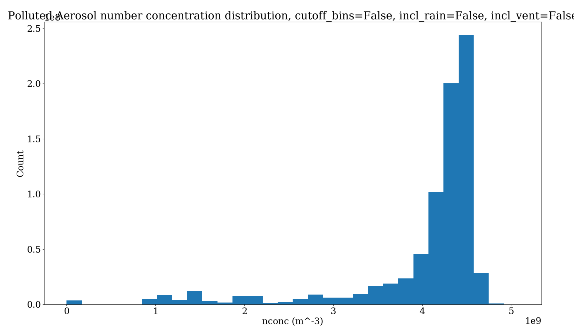

(b) Polluted case.

Figure 12: Aerosol (unknown diam range ?!?) number concentration distribution in WRF simulation, in clear sky regions (cloud LWC less than 1e-5) and below freezing level.

# SS bins	**# z bins**	$\tilde{\chi}^2$ **(Polluted)**	$\tilde{\chi}^2$ **(Unpolluted)**	$\tilde{\chi}^2_{0.990}$
4	10	37.24	25.01	4.61
4	20	42.75	28.13	4.61
4	30	44.58	32.28	4.61
6	10	41.53	21.90	3.32
6	20	51.20	25.77	3.32
6	30	55.74	26.89	3.32
8	10	45.96	17.46	2.80
8	20	58.37	21.07	2.80
8 / 7	30	64.83	26.44	2.80 / 3.10

Table 1

5 Figures to include in supplementary info

- all figures without lower bin cutoffs
- all figures without corrections from including raindrops / ventilation factors

6 TODO / remaining questions

- in code: optimize HALO instrument time offsets
- error analysis for experimental data
- look into commensurate binning in simulation / experiment comparisons?
- analytical justification for why actual and QSS supersaturation is still in linear relation
- expt vs model cloud/rain droplet size boundary

This is a reference [1].

References

[1] J. Fan, D. Rosenfeld, Y. Zhang, S. E. Giangrande, Z. Li, L. A. T. Machado, S. T. Martin, Y. Yang, J. Wang, P. Artaxo, H. M. J. Barbosa, R. C. Braga, J. M. Comstock, Z. Feng, W. Gao, H. B. Gomes, F. Mei, C. Pöhlker, M. L. Pöhlker, U. Pöschl, and R. A. F. de Souza, "Substantial convection and precipitation enhancements by ultrafine aerosol particles," *Science*, vol. 359, pp. 411–418, 1 2018.