Comments on 2018 Atm. Chem. Phys. Discussions, paper #667:

We note that you define the entrainment and non-entrainment zone as the regions within 20-m above and below the height of maximum LWC in the VOCALS Sc, respectively; and you use these for describing the behavior of the droplet spectra and aerosol in the two zones. We also have been involved in an aircraft Sc field study (POST; 2008 off the CA coast) using the CIRPAS Twin Otter. The VOCALS and POST Sc should be quite similar given solid cloud cover and large temperature jumps above cloud top for both studies. Thus, it is of interest to do some initial comparisons here related to your comments on "entrainment in stratocumulus."

You suggest dry and warm air entrained in VOCALS Sc dilutes Nd and LWC but leaves droplet sizes relatively unaffected, thus resembling extreme inhomogenous entrainment/mixing. Also, you note that it is still unclear whether inhomogeneous or homogenous mixing dominates, and that previous studies favor inhomogenous mixing.

These suggestions are not far from what we found for the entrainment-mixing process in POST Sc; however, there are differences resulting from our look at the POST Sc using a different approach. We use a different vertical description in characterizing the region near Sc top (see Malinowski et al., 2013): "Cloud top" is defined as the maximum height of unbroken cloud. And above this cloud top the turbulent EIL (entrainment interface layer) extends up to the unaffected free atmosphere. Part of the EIL contains cloud filaments that are evaporating and where mixing can be termed extreme inhomogenous. Cloud and sensible heat detraining from cloud top are key in reducing buoyancy in the EIL. Radiative cooling is centered at cloud top causing the generation of negative buoyancy.

Then, what is entrained into the unbroken Sc below our cloud top, is it homogeneous or inhomogeneous? An answer is suggested by Fig. 1 which shows a 2-s (~100 m) data sample of LWC and Re (effective radius) collected on POST flight TO6.

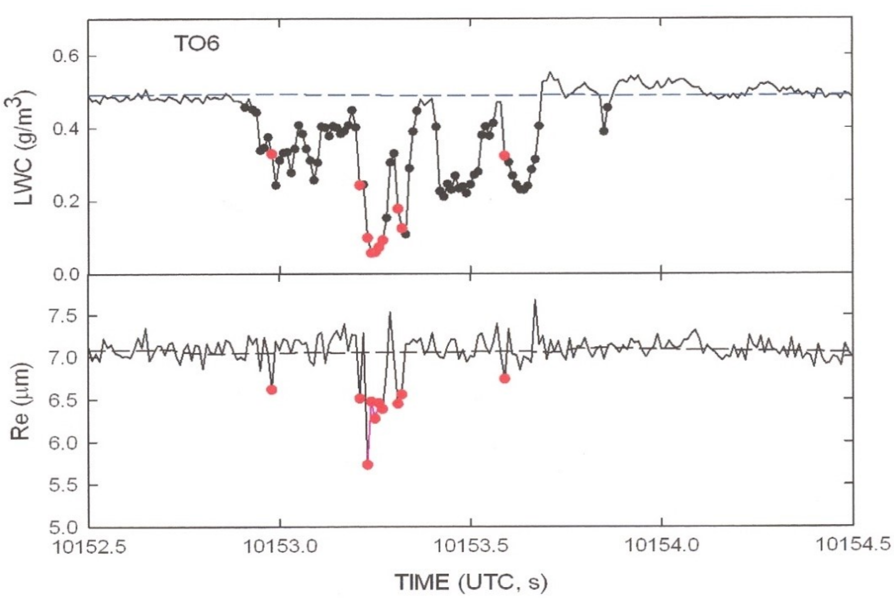

Fig. 1 – LWC and Re (effective radius) 20-cm horizontal resolution Sc data collected just below cloud top from POST flight TO6. Data points indicate the location of a descending entrained cloud parcel. The red data points indicate where both LWC and Re have decreased.

The LWC and Re data records in Fig. 1 both show relatively unchanging background values except for the location of the entrained parcel. Some Re values (red) show reduced values from the background indicating a change in the droplet size distribution and the probable presence of homogeneous mixing. However, most data points (black) only show a decrease in LWC. That sure looks again like extreme inhomogeneous mixing, but the black data more likely show a simple dilution of the cloud by air that has nearly the same buoyancy and moisture as cloud top, and that also preserves the value of Re. Gerber et al. (2016) give more details to support this conclusion including showing the independence of temperature reduction in entrained parcels from reduced LWC in the parcels (see Fig. 5 in that paper), and showing similar behavior of POST Sc with and without predicted buoyancy reversal using mixing fraction analysis.

Thus entrainment/mixing for the POST Sc, and likely also for the VOCALS Sc, is not simply extreme inhomogeneous mixing with warmer and dryer air causing the reduction of LWC and Nd in the Sc, but is a bit more complex with both extreme inhomogeneous mixing and homogenous mixing playing a role in the entrainment process. Yes, air entrained through Sc cloud top can change the droplet size spectrum as Fig. 1 suggests by the reduction of Re, but that appears secondary in most POST Sc in comparison to the dilution process that preserves the relative shape of the spectrum.

It would be interesting to know how your choice of entrainment and non-entrainment zones apply to the vertical-layer partitioning according to Malinowski et al. (2013), including your findings about droplet spectra and aerosol.

Malinowski, S.P., and Coauthors: Physics of Stratocumulus Top (POST): Turbulent mixing across capping inversion. Atmos. Chem. Phys., 13, 15233-15269, doi:10.5194/acpd-13-15223-2013, 2013.

Gerber, H., Malinowski, S.P., and Jonsson, H.: Evaporative and radiative cooling in POST stratocumulus. J. Atmos. Sci., 73, 3877-3884, doi:10.1175/JAS-D-16-0023.1, 2016.