Response to Referee #3

Overall Response: We would like to thank the referee for the constructive comments. The detailed response is provided below following the reviewer's specific comments.

The authors have conducted a suite of month-long WRF–Chem simulations taking place during the VOCALS–Rex field campaign. The methodology is sound, the paper is well written, and the figures are nicely constructed. The results are not validated by observations, but the work has value as a sensitivity study looking at the interactive behavior of aerosol–cloud interactions in a mesoscale modeling framework. The paper notes rather subtle differences in cloud MBL macrophysical properties (zb, D_cld, LWP), with large differences only accompanying huge aerosol perturbations. Stronger effects are noted in radiatively-important quantities (re, COD). The most dramatic effect on the radiation budget for the realistic cases (i.e., non-ScaledEmis cases) appears to be confined to effects on the SW radiation budget in region P. The 5x emission experiment (ScaledEmis) unsurprisingly exhibits drastic differences.

Comments:
Abstract. Lines 17–21 of the abstract were terribly unclear on my first reading. After having read the paper, I understand it now. However, I would suggest rewording it to make it more understandable to a reader looking at it for the first time.

Response: This sentence and the sentence above it have been revised to improve clarity. The sentences have been revised to: "Under a scenario of five-fold increase in regional anthropogenic emissions, this relatively clean region shows large cloud responses, for example, a 13% increase in cloud-top height and a 9% increase in surface albedo in response to a moderate increase (25% of the reference case) in cloud condensation nuclei (CCN) concentration."

Page 14625, lines 25–9. Lines 6–9 correctly describe some effects of giant sea salt, but the previous part of the paragraph applies only to large sea salt aerosol. Sea salt particles in the submicron size range, however, act quite similarly to sulfate aerosols, so it is not completely proper to say "The effect of anthropogenic aerosols is counteracted by that of large sea-salt particles." See Kogan et al. (JAS, 2012) for how different size ranges of sea-salt particles influence MBL clouds. Also, "The effect of anthropogenic aerosols is counteracted by that of large sea-salt particles" is not completely consistent with framing the problem in the context of anthropogenic AIEs. The sea-salt component represents part of the background base state, which is perturbed by anthropogenic aerosols.

Response: In response to the referee's comment, Lines 25-26 on Page 14625 have been revised to “Over the ocean, aerosols from natural emissions (e.g. sea salt and sulfate from DMS oxidation) play a critical role in determining cloud properties and the perturbations to clouds and precipitation by anthropogenic aerosols.” A sentence has also been added in the related discussion: “In addition, sea-salt particles in different size ranges can impact clouds differently (Kogan et al., 2012).”

Page 14629, line 6. The purpose of the phrase “full online interactions” is to describe the fully interactive nature of the processes represented in WRF–Chem, but the “full online” part sounds bit strange to my ear.

Response: In response to the referee’s comment, the word ‘full’ has been deleted from the sentence.

Page 14635, line 4. The authors should note at this point (as they do later in the manuscript) that this quantity is a “susceptibility” in principle similar to precipitation susceptibility the discuss later in the manuscript.

Response: As suggested by the referee, we have added a sentence to point this out. “The ACI sensitivity factor is in principle similar to the precipitation susceptibility that is discussed later in Sect 3.4”.

Page 14637, lines 18–30. Two mechanisms may explain the increase of entrainment with increasing droplet concentrations.: 1. The potential buoyancy argument of Stevens et al. (1998), which focuses on drizzle-induced asymmetry in the boundary-layer circulation; and 2. The cloud droplet sedimentation formulated by Bretherton et al. (2007). I would argue that mechanism #2 is more subtle than #1 (i.e., it took many years of people running LES to identify mechanism #2), but in any case it is not exactly clear which mechanism is operating here. The authors should address both or provide evidence that the cloud sedimentation mechanism is the only one operating.

Response: We thank the referee for pointing this out. We mentioned the potential buoyancy argument slightly later, but use different references. “In addition, over the clean region, reduced precipitation (~65% reduction in cloud-base and near-surface rain rate) due to enhanced anthropogenic emissions (ScaledEmis) leads to a reduction of both below-cloud evaporative cooling and in-cloud latent heat release, resulting in stronger turbulence and thus an increase in the kinetic energy available for the cloud-top entrainment (Lu and Seinfeld, 2005; Wood, 2007).” In response to the referee's comment, we have moved the discussion forward and also provided additional discussion related to Stevens et al. (1998). Please see the revised manuscript Page 18 Line 23- Page 19 Line 5.

Page 14643, line 10. Does the "wet scavenging" in WRF–Chem represent the effects of coalescence processing (i.e., droplet coalescence and evaporation or fallout ultimately reducing the CCN field), or does it represent something else? Ideally, this quantity should be proportional to R*N_d (see Wood, JGR, 2006).

Response: In WRF-Chem, "wet scavenging" refers the removal of aerosol (both cloud-borne/activated and interstitial/unactivated, although the cloud-borne aerosol wet scavenging dominates) by precipitation. The cloud-borne aerosol wet-scavenging rate is assumed equal to the normalized rate at which cloud water is converted to precipitation (s^{-1}), and includes contributions from cloud water autoconversion and collection by rain in the Morrison microphysics. This is similar to the parameterization proposed by Wood (2006). In WRF-Chem, evaporation of cloud droplets in dry air resuspends cloud-borne aerosol back to the interstitial state. The complete evaporation of a raindrop will also resuspend the rain-borne particulate matter as a single (and relatively large) particle, but this process is not treated in our WRF simulations. This resuspension by evaporating raindrops would have little impact on the simulated CCN concentration (at s = 0.1%), as a raindrop is typically composed of hundreds to thousands of cloud droplets (and activated CCN), but the evaporation releases a single large CCN. Discussion of this has been added to the model description section to clarify.

Page 14662, Fig. 1. Please exponentiate the color table label: "1.E-2" looks bad.

Response: Changed as suggested.

References:

Kogan, Y. L., Mechem, D. B., Choi, K., Effects of sea-salt aerosols on precipitation in siumulations of shallow cumulus, J. Atmos. Sci, 69, 463-483, doi:10.1175/JAS-D-11-031.1, 2012.

Lu, M. L., and Seinfeld, J. H.: Study of the aerosol indirect effect by large-eddy simulation of marine stratocumulus, J Atmos Sci, 62, 3909-3932, 2005.
Stevens, B., Cotton, W. R., Feingold, G, Moeng C.-H.: Large-Eddy simulations of strongly precipitating, shallow, stratocumulus-topped boundary layers, J. Atmos. Sci., 55, 3616-3638, 1998.
Wood, R.: Cancellation of aerosol indirect effects in marine stratocumulus through cloud thinning, J Atmos Sci, 64, 2657-2669, Doi 10.1175/Jas3942.1, 2007.
Wood, R.: Rate of loss of cloud droplets by coalesence in warm clouds, J. Geophys. Res., 111, D21205, doi:10.1029/2006JD007553, 2006.